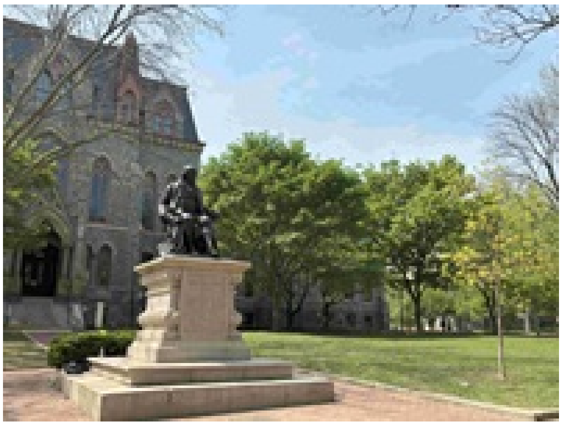
CPAD 2025 at Penn

Tuesday 7 October 2025 - Friday 10 October 2025

Inn at Penn, University of Pennsylvania



Book of Abstracts

Contents

RDC 3 Solid State Tracking / 3

Evidence for mitigated thermal stress with interposers in extended thermocycling of ATLAS ITk strip modules

Author: Jesse Liu[1]

[1] *New York University*

Corresponding Author: jesse.liu@cern.ch

The ATLAS Inner Tracker (ITk) project saw unexpected sensor fracturing when thermocycling strip modules during pre-production. This critical mechanical failure delayed production worldwide, motivating an innovative test-to-destruction study for diagnosis. Five pre-production modules are thermocycled at progressively wider temperatures, raising sensor bow by 146 ± 27 μm after cycling between +40C and −35C. Thermal stress fractures four such modules after lowering to −44C. To solve this problem, interposers comprising Kapton and stress-mitigating silicone are prototyped onto three modules. Negligible sensor bow change of 1 ± 10 μm and no sensor fractures are observed after extended thermocyling. This significant reduction in sensor deformation provides evidence that interposers mitigate thermal stress. This reopens the path to production, while highlighting important lessons for future collider detector development. Based on recent paper: https://arxiv.org/abs/2507.12586

RDC 2 Photodectors / 4

Innovative Back-Side Illuminated SiPMs (BSI-SiPMs): first results from the IBIS project

Authors: Alessandro Montanari[1]; Edoardo Rovati[1]; Elisabetta Montagna[2]; Elisabetta Montagna[3]; Gabriele Sirri[4]; Giulia Fadini[1]; Laura Patrizii[None]; Luigi Pio Rignanese[5]; Nicolò Tosi[1]; Pietro Antonioli[2]; Riccardo Ricci[1]; Roberto Preghenella[5]; Rosario Nania[2]

[1] *INFN Bologna*

[2] *Universita e INFN, Bologna (IT)*

[3] *INFN - Bologna*

[4] *INFN*

[5] *INFN, Bologna (IT)*

Corresponding Authors: elisabetta.montagna@cern.ch, emontagn@bo.infn.it, laura.patrizii@bo.infn.it, pietro.antonioli@cern.ch, rosario.nania@bo.infn.it, luigipio.rignanese@bo.infn.it, roberto.preghenella@bo.infn.it, riccardo.ricci@cern.ch, gabriele.sirri@bo.infn.it

INFN, in collaboration with FBK (Fondazione Bruno Kessler), is developing a novel type of Silicon Photomultiplier (SiPM) — the Back-Side Illuminated (BSI) SiPM — within the framework of the IBIS and IBIS_NEXT projects (Innovative Back-Side Illuminated SiPMs). This new sensor architecture introduces a clear separation between the charge collection and multiplication regions of the device, enabling the implementation of a charge-focusing mechanism. This approach offers several key advantages: a near-100% fill factor even for devices with small microcells, significantly enhanced sensitivity down to vacuum ultraviolet (VUV) wavelengths through optimised surface treatments, improved radiation hardness thanks to a reduced high-field region, and simplified integration with readout electronics via bump bonding, as all electrical contacts are located on the same side of the sensor.

The BSI SiPM technology is particularly well suited for experiments employing the Cherenkov technique — such as the ePIC experiment at the EIC — and for future upgrades of ALICE 3 and LHCb. It is also highly promising for noble liquid detectors — such as DUNE — and paves the way towards high resolution imaging with SiPMs in several other applications.

We present the first results from characterisation studies of prototype sensors from the IBIS RUN 1, fabricated by FBK with single-photon avalanche diode (SPAD) pitches ranging from 15 µm to 35 µm. Detailed measurements of key performance parameters — carried out in dark conditions, within a climatic chamber, and at cryogenic temperatures (77 K) — will be reported.

SHARED SESSION / 5

Performance of AC-LGADs for ePIC and beyond

Authors: Abraham Seiden[1]; Bruce Andrew Schumm[1]; Hartmut Sadrozinski[1]; Simone Michele Mazza[1]

[1] *University of California,Santa Cruz (US)*

Corresponding Authors: hartmut@ucsc.edu, baschumm@ucsc.edu, abraham.seiden@cern.ch, simone.michele.mazza@cern.ch

Low Gain Avalanche Detectors (LGADs) are characterized by a fast rise time (˜500ps) and extremely good time resolution (down to 17ps), and potential for a very high repetition rate with ˜1 ns full charge collection. For the application of this technology to near future experiments such as e+e- Higgs factories (FCC-ee), the ePIC detector at the Electron-Ion Collider, or smaller experiments (e.g., the PIONEER experiment), the intrinsic low granularity of LGADs and the large power consumption of readout chips for precise timing is problematic. AC-coupled LGADs, where the readout metal is AC-coupled through an insulating oxide layer, could solve both issues at the same time thanks to the 100% fill factor and charge-sharing capabilities. Charge sharing between electrodes allows a hit position resolution well below the pitch/sqrt(12) of standard segmented detectors. At the same time, it relaxes the channel density and power consumption requirement of readout chips. Extensive characterization of AC-LGAD devices from the first full size (up to 3x4 cm) production from HPK for ePIC will be shown in this contribution. We will present the first results on AC-LGADs irradiated with 1 MeV reactor neutrons and protons as well. We'll also present a look into the future development of AC-LGADs for the improvement of production yield and performance.

Poster / 6

Exploring Axion Dark Matter with Optical Quantum Sensors

Author: Young Jin Kim[1]

Co-authors: David Tanner [2]; Igor Savukov [1]; Leanne Duffy [1]; Neil Sullivan [3]

[1] *Los Alamos National Laboratory*

[2] *University of Florida*

[3] *Univeristy of Florida*

Corresponding Author: youngjin@lanl.gov

We recently started a project to develop a new pathfinding experiment with a new detection concept [1] to explore ultralight axion dark matter in a completely unexplored mass range near 10 neV. Our detection concept is based on a superconducting resonant inductor-capacitor (LC) circuit with an optical quantum sensor (OQS). The target signal we seek to detect is a minute axion-induced magnetic field oscillating at an angular frequency equal to axion mass. The OQS is the most sensitive non-cryogenic magnetic-field sensor, which manipulates atomic spins for sensitive magnetic sensing using alkali-metal vapor cells and lasers (for optical pumping and spin-state probing). The OQS operates at ambient temperatures without the need for expensive cryogens and complicated cryogenic infrastructure. We anticipate that the experiment would improve current sensitivities to the axion signal strength by 5-6 orders of magnitude in the project's target parameter space. Further, the experiment would create a competitive advantage in the development of new quantum sensing

probes to search for axion dark matter. In this talk, we present our LC circuit-OQS axion detection concept and the projected axion sensitivity.

[1] Y. J. Kim, L. Duffy, I. Savukov, and P.-H. Chu, "Sensitivity of ultralight axion dark matter search with optical quantum sensors,"Physical Review D 108, 052007 (2023).

SHARED SESSION II / 8

Aligning data to better than one picosecond.

Authors: Roger Rusack[1]; Rohith Saradhy[2]

Co-authors: Emily Vadnais [2]; Erich Frahm [2]; Yahya Tousi [2]

[1] *University of Minnesota (US)*

[2] *The University of Minnesota*

Corresponding Authors: roger.rusack@cern.ch, rsaradhy@umn.edu, ymtousi@umn.edu, frah0014@umn.edu

Of the many items that need to be considered in a push towards one -picosecond timing for particle detectors, we have focused on one essential component: the distribution of references clock with an inter-channel precision of 100 femtoseconds (fs) or less. Our program has been to develop the tools to measure a reference clock to this level of precision using a digital dual mixer time difference (DDMTD) circuit and to adjust the phase of a clock in steps of 200 fsec with a custom ASIC the DCPS for digitally controlled phase shifter. Our original DDMTD was built with discrete high-speed flip flops, readout with an FPGA. With this we have achieved a single measurement precision of 400 fs or better, and with multiple measurements made over a period of 10 seconds we have achieved a resolution of 100 fs. Based on this experience we have designed new circuity to manage better the metastability of the flip flops so as to achieve an improvement of approximately a factor 10 in the precision. We have used our improved DDMTD and the DCPS to stabilize a reference clock at the end of a 1 km mono-mode optical fiber to a precision of 100 fs over a period of two days.

In the next step in our program we are designing an ASIC that includes the DDMTD circuit and the new logic. The DDMTD circuit has been designed with CML logic in the TSMC65LP process and the first version with the DDMTD and test logic has been received and is under test. The next variation of this ASIC will include the logic to manage the metastability that we have demonstrated with discretes. We will also design it to be radiation tolerant so that it can be installed on-detector, which is essential to achieving sub-picosecond timing precision across large scale systems.

RDC 1 Noble Element Detectors / 9

LAr Scintillating Bubble Chambers for Rare Event Searches

Author: Daniel Pyda[1]

[1] *Drexel University*

Corresponding Author: dpyda14@gmail.com

The Scintillating Bubble Chamber (SBC) collaboration is developing liquid-noble bubble chambers to detect sub-keV nuclear recoils, allowing the search for low-mass (GeV-scale) dark matter and coherent elastic neutrino-nucleus scattering from low-energy (MeV-scale) neutrinos. The scintillating bubble chamber detectors benefit from the energy reconstruction that the scintillation signal gives in addition to the superior electron-recoil insensitivity that bubble chambers naturally provide. The high level of superheat achievable in noble liquids while being electron-recoil insensitive allows for lower nuclear recoil thresholds than in existing freon-based bubble chambers, potentially reaching the 100 eV threshold desired for reactor CEvNS measurements. To validate this lower threshold, the

SBC collaboration is constructing two 10 kg detectors that are functionally identical. The SBC-LAr10, which is currently being commissioned at Fermilab, is intended for engineering and calibration research and has additional possibilities in assessing coherent elastic neutrino-nucleus scattering in argon. SBC-SNOLAB, the second detector for a low-background dark matter search, will be run at SNOLAB underground. The status of SBC-LAr10 commissioning will be discussed, along with an overview of the SBC experiment.

Poster / 10

High-Rate Picosecond Photodetectors (HRPPDs) for Particle Identification Subsystems

Author: Yifan Jin[1]

[1] *Brookhaven National Laboratory (US)*

Corresponding Author: yjin1@bnl.gov

High-Rate Picosecond Photodetectors (HRPPDs) are micro-channel plate (MCP)-based, DC-coupled photosensors recently developed by Incom, Inc. These sensors offer an active area of 104 mm × 104 mm, a pixel pitch of 3.25 mm, peak quantum efficiency exceeding 30%, low dark count rates, and a timing resolution of approximately 20 ps for single-photon detection. These features make HRPPDs highly suitable for use in Ring Imaging Cherenkov (RICH) detectors with high-precision timing capabilities, and they are being considered as upgrade options for the LHCb and Belle II experiments. A set of newly produced HRPPDs has recently been characterized at Brookhaven National Lab, Jefferson Lab as well as INFN Trieste and Genova. In addition to a systematic evaluation of their key properties such as timing resolution, gain and quantum efficiency uniformities, this talk reports, for the first time, measurements of the absolute photon detection efficiency of these photosensors. Preliminary results on HRPPDs' resilience to magnetic fields up to 2 T and degradation due to aging effects caused by excessive light exposure will also be discussed.

SHARED SESSION / 11

Response of AC-LGADs to Ionizing and Non-ionizing Radiation Damage

Authors: Alessandro Tricoli[1]; Gabriele D'Amen[1]; Gabriele Giacomini[1]; Jiahe Si[2]; Martin Hoeferkamp[3]; Mohamed Hijas Mohamed Farook[3]; Sally Seidel[3]

[1] *Brookhaven National Laboratory (US)*

[2] *University of New Mexico*

[3] *University of New Mexico (US)*

Corresponding Authors: martin@phys.unm.edu, gabriele.d'amen@cern.ch, giacomini@bnl.gov, sally.seidel@cern.ch, hijas.farook@cern.ch, jsi@unm.edu, alessandro.tricoli@cern.ch

Low gain avalanche detectors with DC- and AC-coupled readout were exposed to ionizing and non-ionizing radiation at levels relevant to future experiments in particle, nuclear, and medical physics, and to astrophysics. Damage-related change in their acceptor removal constants and in the resistivity of the region between the guard ring and the active array are reported, as is change in the leakage current of the active volumes.

RDC 1 Noble Element Detectors / 12

Properties and mitigation strategies of high-voltage phenomena measured at the Stanford Liquid Xenon High-Voltage Observatory

Author: Lin Si[1]

[1] *Stanford University*

Corresponding Author: linsi@stanford.edu

No large-scale, noble-liquid element experiment has ever reached its design electric field configuration without first encountering high-voltage phenomena (HVPs) that either require special procedures to address, or ultimately limit the ability of the experiment to measure properties of the universe. Noble-liquid detectors will only encounter harsher high-voltage challenges as they scale in mass and physics sensitivity. This presentation will discuss the results of a 10 kg liquid xenon experiment at Stanford that has observed a variety of HVPs using multiple pairs of solid, polished, electrodes with 15 cmˆ2 area oriented in a plane-to-plane geometry with the ability to explore fields up to 60 kV/cm. The emphasis of the experiment is to explore the impact on HVP mitigation from depositing thin films of metals and insulators onto the surfaces of electrodes. A comparison of the performance of bare stainless steel, platinum, and magnesium-fluoride-coated electrodes will be presented.

RDC 9 Calorimetry / 13

Development of the FEB2 Readout Electronics for the ATLAS Liquid Argon Calorimeter HL-LHC Upgrade

Author: Brian Kirby[1]

[1] *Columbia*

Coping with the higher collision rates of the High-Luminosity Large Hadron Collider (HL-LHC) requires the development of new ATLAS Liquid Argon (LAr) Calorimeter readout electronics. The HL-LHC LAr frontend (FE) readout is implemented on the Frontend Board 2 (FEB2), and is designed to read out the full granularity of the calorimeter with full precision over the 16-bit dynamic range at the bunch crossing frequency of 40 MHz, while withstanding the high radiation levels anticipated. Each 128-channel FEB2 board integrates a number of custom-designed radiation-tolerant ASICs to amplify, shape, digitize and transmit the calorimeter signals off the detector. This presentation will summarize the FEB2 design and development process, along with recent prototype performance and integration testing results. Plans will also be reviewed for final production and installation in the ATLAS cavern of the 1524 FEB2 boards required to read out the almost 200k LAr calorimeter channels.

RDC 9 Calorimetry / 14

Operation and performance of the new ATLAS LAr Calorimeter Trigger

Authors: Gabriel Pinheiro Matos[1]; atlas-larg-speakers[None]

[1] *Columbia*

Corresponding Author: atlas-larg-speakers@cern.ch

The Liquid Argon Calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region |eta| < 3.2, and for hadronic and forward calorimetry in the region from |eta| = 1.5 to |eta| = 4.9.
They also provide inputs to the first level of the ATLAS trigger. In 2022 the LHC started its Run-3 period with an increase in luminosity and pile-up of up to 60 interactions per bunch crossing.

To cope with these harsher conditions, a new trigger readout path has been installed. This new path significantly improved the triggering performances on electromagnetic objects with lower pT thresholds, but also lower rates.
This was achieved by increasing the granularity of the objects available at trigger level by up to a factor of ten.

The installation of this new trigger readout chain also required the update of the legacy system. More than 1500 boards of the precision readout have been extracted from the ATLAS cavern, refurbished and re-installed. The legacy analog trigger readout that will remain during the LHC Run-3 as a backup of the new digital trigger system has also been updated.

For the new system, 124 new on-detector boards have been added. Those boards that are operating in a radioctive environment are digitizing the calorimeter trigger signals at 40MHz. The digital signal is sent to the off-detector system and processed online to provide the measured energy value for each unit of readout. In total up to 31Tbps are analyzed by the processing system and more than 62Tbps are generated for downstream reconstruction. To minimize the triggering latency the processing system had to be installed underground.
The limited available space imposed a very compact hardware structure. To achieve a compact system, large FPGAs with high throughput have been mounted on ATCA mezzanine cards. In total no more than 3 ATCA shelves are used to process the signal from approximately 34000 channels.

Given that modern technologies have been used compared to the previous system, all the monitoring and control infrastructure is being adapted and commissioned as well.

This contribution presents the commissioning challenges, operational experience, performance results, and the remaining milestones toward full deployment of the new digital trigger system.

SHARED SESSION / 15

Quartz fluorescence backgrounds in liquid xenon TPCs

Author: Peter Sorensen[1]

[1] *LBL / Berkeley Lab*

Corresponding Author: pfsorensen@lbl.gov

Searches for 1-10 GeV dark matter particles with liquid xenon TPCs such as LZ, XENONnT and PandaX-4T are presently limited by instrumental backgrounds consisting of accidental photon coincidence. We have investigated this pathology and conclude that the dominant source of the photons, which follow each particle interaction, is fluorescence of the quartz windows of the photomultiplier tubes. Recent results and next steps will be discussed.

RDC 3 Solid State Tracking / 16

Thin Film Detectors

Authors: Earl Almazan[None]; Jason Nielsen[1]; Jennifer Ott[1]; Jessica Metcalfe[2]; Mike Hance[3]; Shiva Abbaszadeh[None]; Sungjoon Kim[None]; Tony Affolder[1]; Vitaliy Fadeyev[1]

[1] *University of California,Santa Cruz (US)*

[2] *Argonne National Laboratory (US)*

[3] *UC Santa Cruz*

Corresponding Authors: jessica.metcalfe@cern.ch, sabbasza@ucsc.edu, jnielsen@ucsc.edu, jeott@ucsc.edu, michael.hance@cern.ch, affolder@ucsc.edu, fadeyev@ucsc.edu

Thin Film particle detectors represent a new generation of particle detectors that can be made with scalable fabrication techniques with the aim of a printable design. These fabrication techniques also enable a wider variety of potential detector materials that can achieve high performance through better charge collection properties or faster electron mobilities for better timing. A set of InP detectors were fabricated as a first step toward demonstrating this concept. The charge collection properties were studied after irradiation and in test beam environments. The overall concept and challenges as well as the recent results will be presented.

Cross-Cutting Topics / 17

The Noble Liquid Test Facility at Fermilab

Author: Flor de Maria Blaszczyk[1]

[1] *Fermilab*

Corresponding Author: fblaszcz@fnal.gov

The **Noble Liquid Test Facility (NLTF)** at Fermilab is a liquid argon detector R&D facility open to the national and international HEP community. The facility consists of 4 permanent cryostats, ranging from 250L up to 3000L, open space for small open dewar testing and an optical test stand facility capable of measuring the optical properties of materials and characterizing photon detectors. NLTF's strongest advantage is its capability to provide ultra-pure LAr in a reliable manner. Its inline filters are capable of filtering all of the three biggest contaminants for standard LAr detectors, O2 and H2O down to < 1ppb and N2 < 1ppm. This is critical for the users of the test stands as small levels of impurities can dramatically change the efficiency of LArTPCs for the collection of charge and light. The smallest cryostat is mainly used for material testing, a service provided to the international HEP community interested in understanding how the introduction of a specific material might affect the electron lifetime in LAr. The test stands can be equipped with a purity monitor, which allows measuring the electron lifetime in real time, as well as gas sampling and analyzing, and in the near future, local recirculation and filtering.

The facility has hosted many successful R&D projects, which have published their results in well-known journals and talks. A few examples of such projects are the NIR light production in LAr and GAr, the characterization of VUV metalenses, the testing of new filter media capable of filtering N2 from LAr, high voltage studies and direct charge amplification in LAr, and various doping studies.

SHARED SESSION / 18

5D tracking active target development for the PIONEER experiment

Authors: Adam Molnar[None]; Bruce Andrew Schumm[1]; Jennifer Ott[1]; Simone Michele Mazza[1]

[1] *University of California,Santa Cruz (US)*

Corresponding Authors: azmolnar@ucsc.edu, simone.michele.mazza@cern.ch, jeott@ucsc.edu, baschumm@ucsc.edu

PIONEER is a next-generation experiment to measure the charged-pion branching ratio to electrons vs. muons and the pion beta decay with an order of magnitude improvement in precision. A high-granularity active target (ATAR) is being designed to provide detailed 4D tracking information, allowing the separation of the energy deposits of the pion decay products in both position and time. The chosen technology for the ATAR is Low Gain Avalanche Detectors (LGAD). These are thin silicon detectors with moderate internal signal amplification. To achieve a ˜100% active region, Trench Insulated LGADs (TI-LGADs) without a support wafer (total thickness ˜120um) are considered. Since a range of deposited charge from Minimum Ionizing Particle (MIP, a few 10s of KeV) from positrons to several MeV from the stopping pions/muons is expected, the detection and separation of close-by hits in such a wide dynamic range will be the main challenge. Furthermore, the compactness and the requirement of low inactive material of the ATAR present challenges for the readout system, forcing the amplification chip and digitization to be positioned away from the active region. The contribution will start with a brief introduction to the LGAD active target idea for PIONEER, then go into the details of sensor, readout, and mechanics R&D. We'll present results on devices thinned to 60um total thickness with an active thickness of 55um.

RDC 3 Solid State Tracking / 19

Time Resolution Studies of 4H-SiC LGADs for Fast Timing Applications

Author: Tao Yang[1]

Co-authors: Ben Sekely [2]; Yashas Satapathy [2]; Abraham Tishelman Charny [3]; Greg Allion [2]; Gil Atar [2]; Philip Barletta [2]; Carl Haber [1]; Steve Holland [1]; John Muth [2]; Spyridon Pavlidis [2]; Stefania Stucci [3]

[1] *Lawrence Berkeley National Laboratory*

[2] *North Carolina State University*

[3] *Brookhaven National Laboratory*

Corresponding Authors: grallion@ncsu.edu, bjsekely@ncsu.edu, abraham.tishelman.charny@cern.ch, muth@ncsu.edu, gatar@ncsu.edu, spavlidis@ncsu.edu, pbarlet@ncsu.edu, stucci@bnl.gov, seholland@lbl.gov, tao.yang@lbl.gov, ysatapa@ncsu.edu, chhaber@lbl.gov

We report on the development and timing performance evaluation of 4H-SiC Low Gain Avalanche Detectors (LGADs), motivated by their potential for enhanced radiation hardness and fast signal response. The devices were fabricated on custom multi-layer epitaxial 4H-SiC wafers and feature etched termination and field plate designs to improve edge breakdown performance. Using UV-TCT, β-particle, and 40 MeV electron beam measurements, we systematically characterized the timing resolution of 4H-SiC LGADs. These results demonstrate the strong potential of SiC LGADs as a robust platform for precision timing in future 4D tracking detectors.

RDC 2 Photodectors / 20

A Directional Skipper CCD Detector for MeV Scale Dark Matter

Author: Nora Hoch[1]

[1] *MIT*

Corresponding Author: nhoch@mit.edu

The search for sub-GeV dark matter requires novel experimental design due to the small expected ionization signal and large backgrounds, many of which still need to be modeled or calibrated. One

way to unambiguously detect dark matter is to measure the directionality of the incoming particles so that the daily modulation of the rate can be used to confirm a dark matter signal. This can be accomplished by combining anisotropic scintillating crystals, such as trans-Stilbene, as a detector target, with an optically-sensitive Skipper CCD as a readout. I will present progress over the past six months developing the first prototype of this detector, including optical testing of the trans-Stilbene, designing the detector, and initial characterization of the CCD. This work will lead to the deployment of the first prototype later this year.

RDC 7 Low-Background Detectors / 21

Dual-sided Skipper-CCDs for sub-GeV dark matter searches

Author: Sho Uemura[1]

[1] *Fermilab*

Corresponding Author: suemura@fnal.gov

Skipper-CCDs - finely segmented silicon detectors with the ability to count single charges - have been used by SENSEI and DAMIC-M for sub-GeV dark matter searches with world-leading sensitivity.

I will present the concept and projected performance of the dual-sided Skipper-CCD, a proposed detector that simultaneously reads out electrons and holes from the two sides of the device.
This will greatly improve background rejection for future large-scale CCD experiments such as Oscura.

RDC 7 Low-Background Detectors / 22

Measuring the optical scattering in n-type GaAs that could explain its high cryogenic scintillation luminosity

Author: Cecilia Ferrari[1]

[1] *MIT*

Corresponding Author: ferraric@mit.edu

N-type GaAs crystals doped with Silicon and Boron have recently attracted attention due to their high brightness at cryogenic temperatures, a property of particular relevance to light dark matter detection and other low-background experiments. However, this behavior appears inconsistent with the material's high refractive index and narrow-beam absorption, which should strongly suppress photon extraction from the crystal bulk.

A possible explanation for the high light output observed in n-type GaAs at low temperatures is that much of the narrow-beam absorption is a previously unmeasured volumetric elastic scattering process that randomizes photon directions within the crystal.

We investigate this hypothesis by illuminating a 4 mm thick n-type GaAs crystal with an infrared laser at cryogenic temperatures and, to reduce systematic uncertainties, simultaneously and independently measure both its narrow beam transmission and bulk scattering intensity. To interpret the observations, we employ Monte Carlo simulations of photon transport that incorporate both elastic scattering and absolute absorption coefficients. Comparison between simulation and experimental data provides insight into this new internal scattering mechanism of n-type GaAs under cryogenic conditions.

Poster / **23**

Design and Performance of a Cryogenic THz Calibration System for Ultra-Sensitive Detectors

Author: Emily Perry[1]

[1] *Lawrence Berkeley National Laboratory (LBNL)*

Corresponding Author: eaperry@lbl.gov

The calibration of ultra-sensitive THz/meV detectors in cryogenic environments is a significant challenge, as standard fiber optics absorb THz radiation and tunable sources are limited. A system is being developed using a photomixer and hollow circular waveguides to deliver tunable frequency THz photons to cryogenic sensors. This work is motivated by the need to calibrate superconducting quasiparticle-amplifying transmons (SQUATs), which are sensitive to single THz photons and meV phonons, and are utilized in searches for axion and other low-mass dark matter candidates and neutrinos.

This poster reports on the progress of a calibration setup to validate photomixer performance and test waveguide transmission. Initial room-temperature bench testing focused on characterizing capillary waveguides, alignment, and noise mitigation. We also report on the progress of our first cryogenic tests, a crucial milestone, as the long-term goal is to use this calibration system as a reliable THz source for the calibration of SQUATs in a dilution refrigerator. This work will additionally allow the full calibration of the Broadband Reflector Experiment for Axion Detection (BREAD).

Poster / **24**

Advancements in Power-over-Fiber technology for the DUNE Far Detector 3

Author: David Martinez[1]

[1] *South Dakota School of Mines and Technology*

Corresponding Author: damartin83@gmail.com

The Deep Underground Neutrino Experiment (DUNE) is a next generation long-baseline neutrino experiment that will study neutrino oscillations using a high-intensity neutrino beam produced by the Long-Baseline Neutrino Facility at Fermilab. The beam will pass through two detector complexes: a near detector complex at Fermilab and a far detector complex located ~1.5 km underground at the Sanford Underground Research Facility in South Dakota.
The DUNE far detector photon detection system (PDS) requires a reliable power supply system capable of operating under cryogenic temperatures and in high-voltage environments. To address these challenges, the power-over-fiber (PoF) technology has emerged as a reliable solution.
PoF is a power-supply technology that generates electrical power by transmitting light from a laser diode through an optical fiber to a photovoltaic power converter. PoF was successfully deployed and operated at CERN for the PDS of the DUNE FD prototype of the vertical drift liquid argon TPC, representing the first successful application in a high-energy physics experiment.
Ongoing efforts aim to further develop this technology to enable power supply delivery to the innovative large-area photon detectors integrated into the TPC field cage, with the goal of increasing the photon detection coverage and improving the energy thresholds, time resolution, and energy resolution of the DUNE Far Detector 3 (FD3). This talk will present the recent advances in PoF and its integration in the proposed PDS for DUNE Phase II FD3.

Poster / **25**

Network intelligence for fault tolerance and data load balancing

Author: Maurice Garcia-Sciveres[1]

[1] *Lawrence Berkeley National Lab. (US)*

Corresponding Author: mgarcia-sciveres@lbl.gov

This project will use on-chip machine learning algorithms to produce intelligent networks. Both conventional digital logic and spike-based neuromorphic implementations will be explored. Two network scales will be prototyped: a multi-chip network, where each element is a complex functionality sensor and many sensors are integrated on a circuit board to form the network (suitable for DUNE or other detectors of similar scale), and a network-on-chip, where the individual pixels of a sensor are the network elements (suitable for collider pixel detectors). Both these cases are 2-dimensional, regular geometry networks, where each element has exactly 4 neighbors. A third case, corresponding to an ad-hoc wireless network in 3-dimensional space, relevant for proposed smart dust detector systems, will be investigated with theory and simulation.

RDC 8 Quantum & Superconducting Sensors / 26

Superconducting Hafnium films for detectors

Authors: Kaja Rotermund[1]; Xinran Li[2]; Aritoki Suzuki[3]; Aidar Kemelbay[1]; Robin Cantor[4]

[1] *LBNL*

[2] *Lawrence Berkeley national laboratory*

[3] *Lawrence Berkeley National Laboratory*

[4] *Starcryo*

Corresponding Authors: krotermund@lbl.gov, akemelbay@lbl.gov, xinranli@lbl.gov, asuzuki@lbl.gov, rcantor@starcryo.com

Hafnium (Hf) is a superconducting material that has been gaining popularity among the superconducting detector community –for e.g. TES bolometers (Rotermund et al. in prep), TES calorimeters (Lita et al. 2009, Safonova et al. 2024), optical and near-IR MKIDs (Zobrist et al. 2019, Coiffard et al. 2020), phonon-sensitive MKIDs (Li et al. in prep), STJ (STAR Cryoelectronics SBIR awarded 2022), and QPDs (Ramanathan et al. 2024). Hf is an attractive superconducting film for many reasons, including that its bulk critical temperature (Tc) is near 128 mK, the London penetration depth is estimated to be 20 nm [Kraft et al. 1998], and the surface kinetic inductance is high at around 15-20 pH/□ for a 125 nm film [Coiffard et al. 2020], thus making it well-matched to needs across many experiments.

One key difference between past Hf detector efforts and our own, is our use of a heated sputter deposition. The heated sputter deposition has 2-fold consequences 1) it enables us to precisely tune Tc to our desired target value due to its linear dependence on deposition temperature and 2) it ensures that the Tc is robust against subsequent exposure to heat as long as the initial deposition temperature is not exceeded.

Here we further develope our study of hafnium's material properties that lends itself to being a good superconductor across many detector efforts. We considered film properties such as the phases present through XRD measurements and how they are affected by deposition temperature. XPS measurements reveal the native oxide that grows on the film making it challenging to make good electrical contact with the hafnium. We identify NbN as an alloy that makes reliable electrical contact with high yield.

As an example of a hafnium-based detector, we have successfully fabricated a TES bolometer integrated into a full-stack cosmic microwave background dichroic detector with polarization sensitivity.

RDC 1 Noble Element Detectors / 27

Calibrating the LUX-ZEPLIN (LZ) Dark Matter Detector

Author: Jack Genovesi[1]

[1] *Pennsylvania State University*

Corresponding Author: jgg27@psu.edu

The LUX-ZEPLIN (LZ) experiment is a direct detection dark matter experiment located 4,850 feet underground at the Sanford Underground Research Facility in South Dakota. The core of the detector is a dual-phase Time Projection Chamber that utilizes 7 tonnes of active liquid xenon as its target medium to search for dark matter interactions. The primary candidate of interest is the Weakly Interacting Massive Particle, but other Beyond the Standard Model (BSM) candidates can be probed as well. A detailed understanding of detector response to particle interactions and microphysics modeling are essential for accurately identifying potential BSM signals. This talk will highlight LZ' s advanced high- and low-energy calibration techniques that enable LZ's world-leading sensitivity and results.

SHARED SESSION II / 28

SparsePixels: Efficient Convolution for Sparse Data on FPGAs

Authors: Ho Fung Tsoi[1]; Dylan Sheldon Rankin[1]; Vladimir Loncar[2]; Philip Coleman Harris[3]

[1] *University of Pennsylvania (US)*

[2] *CERN*

[3] *Massachusetts Inst. of Technology (US)*

Corresponding Authors: philip.coleman.harris@cern.ch, dylan.sheldon.rankin@cern.ch, vladimir.loncar@cern.ch, ho.fung.tsoi@cern.ch

Inference of standard convolutional neural networks (CNNs) on FPGAs often incurs high latency and long initiation intervals due to the nested loops required to slide filters across the full input, especially when the input dimensions are large. However, in some datasets, meaningful signals may occupy only a small fraction of the input, say sometimes just a few percent of the total pixels or even less. In such cases, most computations are wasted on regions containing no useful information. In this work, we introduce SparsePixels, a framework for efficient convolution for sparsely populated input data on FPGAs operating under tight resource and low-latency constraints. Our approach implements a special class of CNNs where only active pixels (non-zero or above a threshold) are retained and processed at runtime, while the inactive ones are discarded and ignored.
We show that our framework can achieve performance comparable to standard CNNs in some target datasets while significantly reducing both latency and resource usage on FPGAs. This also demonstrates its potential for efficient readout in next-generation detectors, where inputs are massive but signals could be sparse. Custom kernels for training and the HLS implementation are developed to support sparse convolution operations.

RDC 1 Noble Element Detectors / 29

Optimizing Dual-phase LArTPCs for Sub-keV siignals

Author: Shawn Westerdale[None]

Corresponding Author: shawn.westerdale@ucr.edu

Dual-phase liquid argon time projection chambers (LArTPCs) have a proven track record measuring keV-scale signals from light dark matter through the electron-counting ("S2-only") channel. Enhancing their design can open the door for new, optimized searches for light dark matter, coherent elastic neutrino-nucleus scattering measurements at nuclear reactors, searches for new forces in beam dump experiments, and other topics. This talk will discuss ongoing R&D studying the possibility of using hydrogenous, photo-sensitive dopants to lower the threshold of dual-phase LArTPCs, as well as other ongoing efforts to optimize their design for S2-only analyses and to understand the origins of spurious electron backgrounds that limit sensitivity to their lowest accessible energies.

RDC 7 Low-Background Detectors / 30

Ultra-Pure Nickel for Structural Components of Low-Radioactivity Instruments

Author: Tyler Schlieder[1]

[1] *Pacific Northwest National Lab*

Corresponding Author: tyler.schlieder@pnnl.gov

We report an evaluation of nickel produced via chemical vapor deposition (CVD) for potential use as a general structural material in future, large-scale, low-radioactivity rare-event search experiments in nuclear and particle physics. In particular, this work is focused on assessing both mechanical strength and radiopurity (i.e., concentration of primordial radionuclides ^{232}Th, ^{238}U, and ^{40}K) of CVD Ni, two critical considerations for use as a structural material in future experiments. Nickel can have tensile strengths significantly exceeding that of ultra-pure copper, a material frequently used within low-radioactivity instruments. Pull tests of the manufacturer-supplied CVD Ni showed tensile strengths of ˜600 MPa. However, initial welding tests produced welds of reduced strength (˜160-315 MPa) more similar to the strength of commercially available (annealed) Ni plate (˜370-400 MPa). This behavior may be related to the observed porosity of CVD Ni and/or thermal annealing. Material assay results determined via ICP-MS showed the bulk of the CVD Ni had concentrations of ^{232}Th, ^{238}U, and ^{nat}K on the order of ˜70 fg·g^{-1} (˜0.3 µBq·kg^{-1}), ≤100 fg·g^{-1} (≤1.24 µBq·kg^{-1}), and ˜900 pg·g^{-1} (˜27.5 µBq·kg^{-1}), respectively. In addition to bulk radiopurity results, an evaluation of radio-contaminant distribution with depth into CVD Ni is also presented. Notably the exterior surfaces of the CVD nickel showed elevated levels of these radioactive elements. New data are compared to results from SNO, the one other well documented usage of CVD Ni in a low radioactive background physics research experiment. In summary, CVD Ni presents a promising option for use as a low-radioactive structural material.

SHARED SESSION / 31

Development of pTP Coatings for Wavelength Shifter with Industrial Scale in LAr Detectors

Author: Yichen Li[None]

Co-authors: Jay Hyun Jo [1]; Milind Vaman Diwan [2]; Yimin Hu [3]; Aleksey Bolotnikov [1]; Babak Azmoun [1]; Steven Linden ; Chao Zhang [1]; Craig Woody [2]; Thomas Tsang [1]; Xin Qian [1]

[1] *Brookhaven National Laboratory*

[2] *Brookhaven National Laboratory (US)*

[3] *LaserFiberOptics.LLC*

Corresponding Authors: czhang@bnl.gov, jjo@bnl.gov, xqian@bnl.gov, tsang@bnl.gov, woody@bnl.gov, slinden1@bnl.gov, azmoun@bnl.gov, yichen@bnl.gov, bolotnik@gmail.com, yhu@laserfiberoptics.com, diwan@bnl.gov

The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline neutrino oscillation experiment that seeks to address fundamental questions in particle physics, including neutrino mass ordering and the possible CP violation in the lepton sector that can provide information on the matter–antimatter asymmetry of the universe. A critical challenge in DUNE is the detection of scintillation light from neutrino interactions in LAr emitted at 127 nm, outside the sensitivity range of conventional photodetectors. To enable detection, this vacuum ultraviolet (VUV) light must be wavelength-shifted to the visible range (~420 nm) using materials such as para-Terphenyl (pTP). The proposed photon detection System (PDS) of DUNE Phase-II Far Detector (FD3) requires ~2000 m² of wavelength-shifting filter coverage to achieve a mean light yield of 180 PE/MeV. This corresponds to a production requirement of ~100k pieces of filter plates, each with the current PDS dimensions of 143.5 mm x 143.5 mm. We aim to develop and validate a scalable, cost-effective wavelength shifter coating technology in collaboration with industry. This study investigates the use of industrial vacuum vapor deposition to produce high-quality, uniform pTP coatings with improved process control. The samples produced have been characterized using a UV monochromator and synchrotron light source at NSLS-II with measurements of emission spectra and light yield, while the coating thickness was measured by profilometer. Preliminary results show promising consistency and performance improvements over lab-scale coatings. Furthermore, the pTP-coated filters are planned to be cold-tested in the 260-L LAr test stand at BNL to demonstrate reliable performance under cryogenic conditions, offering a scalable coating solution for FD3. This work advances the development of robust photon detection systems for all noble-element detectors and contributes to detector R&D aligned with DOE scientific missions.

RDC 1 Noble Element Detectors / **32**

Initial Results of Liquid Argon Doping Studies with TinyTPC

Authors: Hannah McCright[1]; Joseph Zennamo[None]

[1] *University of Maryland, College Park*

Corresponding Authors: jaz8600@fnal.gov, hmccrigh@terpmail.umd.edu

TinyTPC is a compact Liquid Argon Time Projection Chamber (LArTPC) with a pixelated LArPix readout, used for R&D on improving energy reconstruction for low-energy events through enhanced ionization charge creation. We investigate the use of isobutylene, a photosensitive dopant with an ionization energy well-matched to argon scintillation light. Since scintillation light in LArTPCs is typically collected with much lower efficiency (<1%) than ionization charge (~100%), converting scintillation photons into additional ionization could increase the total detectable signal and improve energy resolution. In our first doping run, we introduced isobutylene at the 4 ppm level and observed a 5% increase in total collected charge compared to pure argon. I will present our experimental setup, data analysis methods, and results from this initial test.

Plenary / **34**

Characterization of Low Gain Avalanche Diodes Using Diverse Particle Beams

Authors: Alessandro Tricoli[1]; Enrico Rossi[2]; Gabriele D'Amen[1]; Gabriele Giacomini[1]; Giovanni Pinaroli[2]; Mohamed Hijas Mohamed Farook[3]; Sally Seidel[3]

[1] *Brookhaven National Laboratory (US)*

[2] *Brookhaven National Laboratory*

[3] *University of New Mexico (US)*

Corresponding Authors: hijas.farook@cern.ch, gabriele.d'amen@cern.ch, alessandro.tricoli@cern.ch, giacomini@bnl.gov, erossi@bnl.gov, gpinaroli@bnl.gov, sally.seidel@cern.ch

Low Gain Avalanche Diodes (LGADs) are silicon sensors renowned for their ability to deliver fast timing, especially in high energy and nuclear physics. They achieve a timing resolution of 20-30 picoseconds through an internal multiplication process that creates a controlled avalanche of charge carriers, producing a gain of 10-100. Some variants of LGADs can also track particle trajectories with great precision. While most research has focused on how LGADs respond to energetic charged particles, this work expands the study to include non-minimum-ionizing particles like low-energy protons, alpha particles, X-rays, and gamma-rays. This is crucial for future applications in fields like biology and medical physics. The study compares the LGAD's response, including its gain, to these different particle beams with results from TCAD simulations.

Acknowledgement
The authors wish to thank their colleagues at Brookhaven National Laboratory: Don Pinelli, Antonio Verderosa, Joe Pinz and Tim Kersten for sensor mounting. This material is based upon work supported by the U.S. Department of Energy under grants DE-SC0012704, DE-SC443363, DE-SC426496 and DE-SC0020255.

SHARED SESSION / 35

Optimization of Ultrafast Silicon Detectors for Timing Applications in Future High Luminosity Collider Experiments

Author: Bridget Mack[1]

Co-author: Marina Artuso [1]

[1] *Syracuse University (US)*

Corresponding Authors: bridget.mack@cern.ch, marina.artuso@cern.ch

There is a high priority in particle physics for research and development into instrumentation motivated by the physics goals of the next generation of experiments. Several challenges need to be addressed, including high pile-up, as future hadron and muon colliders will feature both high in- and out-of-time backgrounds. A time resolution of the order or below ten picoseconds allows for the mitigation of these backgrounds while also providing time-of-flight measurements that can be used to distinguish between different hadron species in a broad momentum range. Ultrafast silicon detectors, in combination with other detector technologies, must be tailored to be able to provide the measurements needed for specific applications, and we have started exploration focusing on the optimization of their design parameters. We present our ongoing efforts to study signal formation and timing resolution in low gain avalanche diodes (LGADs) of different areas, thicknesses, and gains, with the goal of optimizing cell sizes and fabrication parameters for large scale timing applications.

SHARED SESSION / 36

Suppressing high energy events in superconducting devices in a shallow underground laboratory

Author: Jacob Bargemann[1]

[1] *Pacific Northwest National Lab*

Corresponding Author: jack.bargemann@pnnl.gov

In pursuit of a quantum computer, there have been many proposals of qubits that take advantage of quantum systems, from solid-state systems to trapped ions. A particularly promising candidate is the transmon, a qubit based on a superconducting resonator with a Josephson Junction and optimized to have reduced sensitivity to charge noise. It is well-known that these types of qubits suffer from decoherence via quasiparticle poisoning sources that originate from, e.g., environmental radioactivity, interfacial solid-state physics, and more. Importantly, some sources (such as environmental radioactivity) can induce correlated errors among multiple qubits, which can be catastrophic for error-correction schemes in quantum computers.

At PNNL, we are investigating the contribution of cosmogenic radiation to qubit errors. To do so, we utilize microwave kinetic inductance detectors [MKIDs]. Like transmon qubits, MKIDs consist of a superconducting resonator patterned onto a substrate (often silicon or sapphire), but with the added benefit of spectroscopic capabilities. With MKIDS, we measure the background spectra a qubit would see, from both our shallow underground lab and from the surface. Our Low Background Cryogenic Facility is located underground with a ˜30-meter water-equivalent overburden, which suppresses the cosmogenic muon flux suppressed by a factor of ˜6 and the cosmogenic proton and neutron fluxes by a factor of >100. We hypothesize that the residual catastrophic correlated error rate observed in gap-engineered qubits is due to high energy interactions with cosmic-ray-produced neutrons and protons. By comparing spectra acquired in our surface and shallow underground labs, we test the effectiveness of a shallow overburden to attenuate the highest energy events.

RDC 4 Readout & ASICs / 37

Power conversion for HEP using piezoelectric elements

Author: Adrian Nikolica[1]

[1] *University of Pennsylvania (US)*

Corresponding Author: nikolica@hep.upenn.edu

Efficient power conversion and distribution is an important consideration for advanced detectors as power requirements and channel density increase. Future detectors will have unique requirements such as very low mass, and ability to operate in environments with high magnetic fields or radiation. Switched power converters using inductive elements are difficult to miniaturize, generate electromagnetic interference, and are not inherently magnetic field tolerant. They suffer from inefficiency and reduced power density as the size of the magnetic elements are reduced. Switched capacitor converters can achieve higher power densities, but cannot achieve continuously variable voltage regulation with only capacitors as the energy storage element. Power conversion using piezoelectric materials as the energy storage element presents exciting possibilities for front end detector mounted converters. Piezoelectric resonators can achieve very high quality factors as compared to inductors. When used in power converters, they can achieve a degree of voltage regulation with potential to be used for biasing in pixel and silicon photomultiplier detectors. This talk will present an overview of the physics of operation of piezoelectric boost and buck converters, and discuss power converter work at the University of Pennsylvania. Topics included will be: proof of concept results and lessons learned; switch design using a bipolar-CMOS-DMOS (BCD) process and comparisons to other processes; resonator design using promising materials such as lithium niobate, which can achieve very high Q factors; and comments on future work including constraints on mounting and packaging, alternate resonator geometries and electrode design, and regulation control at high frequencies.

RDC 4 Readout & ASICs / 38

The Analog Photon Processor ASIC

Author: Adrian Nikolica[1]

[1] *University of Pennsylvania (US)*

Corresponding Author: nikolica@hep.upenn.edu

Waveform digitization remains the baseline method for reading out large scale neutrino detectors consisting of thousands of channels of photomultiplier tubes (PMTs). Because events in these detectors happen relatively infrequently, this method results is high cost, high power, and extremely high data volumes. The problems are compounded when considering that modern PMTs with very fast risetimes require ever higher bandwidth to meet the Nyquist rate and ensure proper reconstruction of the waveforms. Analog sampling techniques that capture key parameters of the waveform – such as peak amplitude, leading and trailing edge times, and total integrated charge – present an interesting alternative that can drastically mitigate problems inherent in full digitization. This talk will describe the Analog Photon Processor (APP) integrated circuit, being designed in a 65nm process at the University of Pennsylvania, to be used for photon feature extraction in next generation detectors

RDC 7 Low-Background Detectors / 39

LEGEND: Search for neutrinoless double beta decay in high-purity 76Ge-enriched detectors

Author: Louis Varriano[1]

[1] *University of Washington*

Corresponding Author: varriano@uw.edu

The LEGEND experiment searches for neutrinoless double beta decay in ^{76}Ge-enriched high-purity germanium detectors operating in liquid argon, whose scintillation acts as an active veto against external background events. Using specialized detector geometries, pulse shape discrimination is performed to further veto background events. LEGEND-200 has completed about one year of stable physics data-taking at Laboratori Nazionali del Gran Sasso (LNGS) in Italy, with the first data recently unblinded and analyzed. With a planned ultimate exposure of 1 ton·yr and a target background index of 2×10^{-4} cts/(keV·kg·yr) at $Q_{\beta\beta}$ = 2039 keV, LEGEND-200 is expected to reach a 3σ discovery sensitivity of 10^{27} years half-life. The next generation experiment, LEGEND-1000, will operate 1000 kg of detectors and reach an expected discovery sensitivity of 10^{28} years half-life, covering the inverted neutrino mass hierarchy. In this talk, an overview of LEGEND will be presented with some focus on detector performance.

This work is supported by the U.S. DOE, and the NSF, the LANL, ORNL and LBNL LDRD programs; the European ERC and Horizon programs; the German DFG, BMBF, and MPG; the Italian INFN; the Polish NCN and MNiSW; the Czech MEYS; the Slovak RDA; the Swiss SNF; the UK STFC; the Canadian NSERC and CFI; the LNGS and SURF facilities.

RDC 4 Readout & ASICs / 40

CMS HGCAL ECON-D ASIC : Impact of CMOS fabrication process tuning on performance and radiation tolerance

Authors: Chinar Syal[1]; Clara Ramon Alvarez[2]; Danny Noonan[1]; Danny Noonan[3]; Danny Noonan[1]; Davide Ceresa[4]; Grace Cummings[3]; Honor Hare[5]; Jim Hirschauer[3]; Jinglu Wang[6]; Marko Stamenkovic[7]; Ramneet Kaur[8]; Yulun Miao[9]

[1] *Fermilab*

[2] *University of Virginia (US)*

[3] *Fermi National Accelerator Lab. (US)*

[4] *CERN*

[5] *Rochester*

[6] *Northwestern University (US)*

[7] *Brown University (US)*

[8] *Alabama*

[9] *Northwestern*

Corresponding Authors: dnoonan@fnal.gov, daniel.christopher.noonan@cern.ch, james.francis.hirschauer@cern.ch, gcumming@fnal.gov, jinglu.wang@cern.ch, marko.stamenkovic@cern.ch, clara.ramon.alvarez@cern.ch

The CMS experiment's High Granularity Calorimeter (HGCAL) upgrade will replace CMS's existing endcap calorimeters in preparation for the High Luminosity LHC. To effectively use over 6 million channels of this "imaging"calorimeter, CMS has developed two novel Endcap Concentrator (ECON) ASICs to perform data compression/selection on detector. The ECON-D ASIC operates on the 750kHz data path, and the ECON-T ASIC on the 40MHz trigger path. These 65 nm CMOS ASICs are radiation tolerant to 200 Mrad and low power, operating at less than 2.5 mW/channel.

The first full-functionality prototype ECONs were produced and characterized in 2021-23, and an initial engineering run was performed in 2024. ECON-D radiation testing for the engineering run revealed that the chip's internal SRAMs produce intermittent read errors for a non-negligible fraction of chips. Further investigation indicated that the SRAM performance is highly sensitive to the exact parameters of the CMOS fabrication process. To both study this process sensitivity and mitigate SRAM performance issues, twenty ECON wafers were produced in 2025 with a range of doping concentrations designed to tune the underlying transistor threshold voltage by 0%, 5%, 10%, and 15% from nominal. This talk will present first measurements of ECON-D performance, power consumption, and radiation tolerance for these four variations of CMOS process.

SHARED SESSION / 41

Development of an Ultrasensitive ICP-MS Assay Method for the Determination of Uranium, Thorium and Potassium in Gadolinium Used in Scintillator Materials

Author: Isaac Arnquist[1]

Co-authors: Lawrence Horkley [1]; Maria Laura di Vacri [1]; Scott Haselschwardt ; Tyler Schlieder [2]

[1] *Pacific Northwest National Laboratory*

[2] *Pacific Northwest National Lab*

Corresponding Authors: lawrence.horkley@pnnl.gov, haselsco@umich.edu, tyler.schlieder@pnnl.gov, marialaura.divacri@pnnl.gov, isaac.arnquist@pnnl.gov

The development of ultra-low background gadolinium-loaded liquid scintillator (Gd-LS) is critical for current and next-generation experiments in neutrino and rare-event physics, including supernova neutrino detection, reactor monitoring, and as a neutron veto in dark matter searches. The presence of trace radioactive contaminants such as 238U, 232Th, and 40K can introduce backgrounds that severely limit sensitivity. In this work, we present a novel, highly sensitive inductively coupled plasma mass spectrometry (ICP-MS) assay method capable of quantifying 238U, 235U, 232Th, and 40K at microBq/kg levels in complex gadolinium compounds used in scintillator production. The developed method incorporates an ultra-clean dry ashing and separation procedure that minimizes contaminant introduction during sample processing as well as spectral interferences and matrix effects during mass spectrometric analysis. The method has been successfully applied to the organic-based Gd(TMHA)3 material used in the LUX-ZEPLIN (LZ) experiment's Gd-LS neutron veto, enabling a better understanding of the background contributions and ultimate sensitivity reach of the detector. This method provides a foundation for quality assurance in future low-background experiments utilizing Gd-LS and offers a high-throughput approach capable of processing batches of scintillator precursor compounds within days at sensitivities not achievable using other techniques.

SHARED SESSION II / 42

Generic Hardware Platform for future high-bandwidth detector readout

Authors: Shaochun Tang[1]; Hao Xu[1]

[1] *Brookhaven National Laboratory (US)*

Corresponding Authors: shaochun.tang@cern.ch, hao.xu@cern.ch

In the High Energy Physics (HEP) and Nuclear Physics (NP) experiments, there is always a wish to readout all the detector data to improve efficiency and avoid losing potential useful information. This requirement motivates the development of technologies such as the on-detector processing, high speed data links and powerful back-end electronics. The Front-End Link eXchange (FELIX) system is an interface between the detector and trigger readout electronics and commodity switched networks for the ATLAS experiment at CERN. The FELIX approach takes advantage of modern FPGAs and commodity computing to reduce the system complexity and effort needed to support data acquisition systems in comparison to previous designs. FELIX Phase-I hardware (FLX-712) is based on the generic PCIe form factor with Kintex Ultrascale FPGA with support of PCIe Gen3. It has been widely adopted by other HEP and NP experiments - sPHENIX at RHIC, ProtoDUNE-SP at CERN, CBM/RE21 at FAIR, test beam experiments at Fermilab and CERN. The Phase-II design FLX-182 and FLX-155 are based on the AMD Versal FPGA with support of PCIe Gen4/5 and 25Gb/s optical links. It has been and is going to be tested by several HEP and NP experiments - ePIC at EIC, sPHENIX at RHIC, LHCb at CERN, ALICE at CERN, CBM/RE21 at FAIR. In addition, CERN DRD7 (Electronics) collaboration has it as a hardware platform for adaptation from Front-End to Back-End with 100+ GbE in one of Work Packages. This rapid improvement in the back-end electronics is a paradigm shift and enables triggerless readout of the future particle experiments that maximize their discovery potential. The design and test results of Versal FPGA based FELIX development will be presented in this contribution.

RDC 2 Photodectors / 43

Development of UV-Sensitive GaN Single Photon Geiger-Mode avalanche diodes

Authors: Alexandra Dolgashev[None]; Davide Balzerani[None]; Nepomuk Otte[1]; Russel Dupuis[None]; Theeradetch Detchprohm[None]

[1] *Georgia Institute of Technology*

Corresponding Author: otte@gatech.edu

Silicon photomultipliers (SiPMs) have had a transformative impact on experiments in high-energy physics and astrophysics. However, SiPMs face intrinsic limitations in their response to wavelengths below 300 nm, which is crucial for liquid noble scintillation detectors. In this study, we explore AlGaN and GaN semiconductors, which feature a tunable band gap and improved sensitivity in the ultraviolet (UV) range. With the availability of sufficiently clean substrates, we successfully fabricated single GaN photodiodes and demonstrated their UV sensitivity and Geiger-mode operation. I will provide a status update and present the results from our latest devices fabricated this year.

Poster / 44

On the way to design fast beam loss monitor for Machine-Detector Protection at EIC: Test results at RHIC

Authors: Aleksey Bolotnikov[1]; Andrii Natochii[1]; Bela Urbschat[2]; Erik Muller[1]; Evgeny Shulga[1]; Thomas Tsang[1]

[1] *Brookhaven National Laboratory*

[2] *Nagoya University*

Corresponding Authors: urbsch@hepl.phys.nagoya-u.ac.jp, eshulga@bnl.gov, bolotnik@gmail.com, tsang@bnl.gov, emuller@bnl.gov, anatochii2@bnl.gov

Rapid detection of beam losses is essential at large-scale HEP/NP facilities to protect sensitive components from the damaging effects of unstable high-energy beams. To address this for the EIC, we deployed a prototype beam loss monitoring (BLM) system at Relativistic Heavy Ion Collider (RHIC), designed to test fast abort capabilities with response times on the order of a single beam revolution.

We will present results of beam loss measurements at the 2025 RHIC run utilizing scintillating light and CVD diamond detectors. Since July 16, 2025, the system has operated stably, recording bunch-by-bunch loss data consistent with expectations and independently measured profiles from C-AD BLMs. Preliminary results show strong correlation with nominal beam conditions, with peak loss rates up to kHz level. The talk will include details of signal processing, time structure analysis, and detector response characterization under both single-beam and collision conditions.

RDC 9 Calorimetry / 45

Simulation of the CalVision crystal dual-readout calorimeter test-beam array

Authors: Bob Hirosky[1]; John Paul Chou[2]; Jon Wilson[3]; Kenichi Hatakeyama[3]; Sarah Eno[4]

[1] *University of Virginia (US)*

[2] *Rutgers State Univ. of New Jersey (US)*

[3] *Baylor University (US)*

[4] *University of Maryland (US)*

Corresponding Authors: sarah.eno@cern.ch, jsw@fnal.gov, john.paul.chou@cern.ch, kenichi.hatakeyama@cern.ch, bob.hirosky@cern.ch

The CalVision collaboration is developing a dual-readout calorimeter that can be used for precision electromagnetic and hadronic energy resolution, meeting the requirements of future e+e- colliders. The calorimeter will consist of a homogeneous dual-readout crystal electronic calorimeter in front of a dual-readout fiber hadron calorimeter. In order to understand the data recorded from crystal test beam runs, optimize the plans for future test beam runs, and explore design variations, we have developed a Geant4 simulation of the crystal array. We will present some preliminary results from the simulation, including energy-resolution estimates.

RDC 7 Low-Background Detectors / 46

Cosmogenic tritium in silicon: measurement, mitigation, and removal

Author: Richard Saldanha[None]

Co-authors: Alvaro Chavarria [1]; Ben Loer [2]; Dave Reading [3]; Luca Pagani [4]; Paolo Privitera [5]; Phillip Warwick [3]; Pitam Mitra [1]

[1] *University of Washington*

[2] *Pacific Northwest National Laboratory*

[3] *University of Southampton*

[4] *UC Davis*

[5] *University of Chicago*

Corresponding Authors: pitamm@uw.edu, ben.loer@pnnl.gov, lpagani@ucdavis.edu, chavarri@uw.edu, priviter@uchicago.edu, richard.saldanha@pnnl.gov

Long-lived radioactive isotopes produced by cosmogenic activation can be a major source of background for rare event searches such as dark matter and neutrinoless double beta decay. In this talk I will present efforts to measure and mitigate cosmogenic tritium production in silicon devices, focusing on a recent demonstration of a technique to efficiently remove cosmogenic tritium from high purity silicon.

RDC 8 Quantum & Superconducting Sensors / 47

A quantum-enhanced two-cavity Haloscope for high-mass QCD axion detection

Author: Christian Boutan[1]

[1] *Pacific Northwest National Laboratory*

Corresponding Author: christian.boutan@pnnl.gov

The nature of dark matter is one of the most perplexing open questions in physics today. A particularly compelling dark matter candidate called the QCD axion, if discovered, could simultaneously solve the Strong CP Problem of quantum chromodynamics and account for the missing mass in our universe. The "axion haloscope" is an established detection technique, designed to resonantly convert μeV axions into detectable microwave photons in a tunable, high-Q, resonant cavity permeated by a strong static magnetic field. These detectors, used by collaborations like the Axion Dark Matter eXperiment (ADMX), HAYSTAC, CAPP, and ORGAN, are well suited for the 0.5–10 GHz frequency range. However, future detectors designed to leverage these traditional haloscope techniques to search the rest of this frequency range will face significant challenges. The loss in sensitivity, due to decreased detector volume and the increase in quantum noise, will conspire to make axion detection near-impossible without compatible strategies to both boost signal and reduce noise at these higher frequencies. Furthermore, proposed solutions such as multi-cavity or quantum sensing approaches improve detector sensitivity at the cost of increased complexity; this complexity that may not be tractable without advanced automated detector controls at high frequencies. Our research takes a broad view to treat both detector compatibility and complexity problems as a single entangled challenge, aiming to address both with the help of a new two-cavity R&D platform. This pathfinder, the ADMX-SIDETRAC, will be built to set new limits in the 5.8-6 GHz range. The platform will also provide a training ground where promising techniques can be stress tested together in realistic data-taking conditions and synthesized for broad use in HEP. In this talk, I will motivate this pathfinder, give a status update on construction, and seek CPAD community involvement.

RDC 6 Gaseous Detectors / 48

A High-Pressure Gaseous-Argon TPC R&D Effort for Neutrinos and Rare Events: Simulation Studies

Author: Brenna McConnell[1]

[1] *Indiana University Bloomington*

Corresponding Author: bremcco@iu.edu

High pressure gaseous argon time projection chambers (HPgTPCs) are crucial for many applications, including neutrino oscillation analyses, rare event searches such as coherent elastic neutrino-nucleus scattering (CEvNS), and low-energy nuclear recoil detection. Current R&D efforts are focused on testing gas electron multipliers (GEMs) in high-pressure environments, which is critical for optimizing the performance and reliability of HPgTPC systems. Results may be particularly applicable for DUNE Phase II, where the HPgTPC's low detection threshold will be used in the near detector complex to address one of the significant sources of uncertainty in neutrino oscillation analysis: nuclear effects in argon at the neutrino interaction vertex. This talk will provide an overview of the GEM simulation studies using Garfield++, which aim to benchmark and guide experimental optimizations.

RDC 1 Noble Element Detectors / 49

CrystaLiZe: Towards a neutrino-limited dark matter search with Crystal Xenon

Authors: Chloe O'Brien[1]; Dan Hunt[1]; Gregory Sehr[1]; Scott Kravitz[1]

[1] *University of Texas at Austin*

Corresponding Authors: dan.hunt@utexas.edu, skravitz@utexas.edu, sehr@utexas.edu, clobrien@utexas.edu

We present the Crystal Xenon Time Projection Chamber (CXe TPC), a novel particle detector technology as a proposed upgrade to existing LXe TPCs, or as a standalone next-generation particle detector. The dominant background in current LXe dark matter searches is beta decays from radon contamination, which has proven to be ubiquitous, long-lived, and extremely soluble in liquid xenon. Foundational tests at the sub-kg scale have shown that CXe offers a factor 500x mitigation of Rn progeny, allowing for a dark matter search with neutrino interactions as the leading background, while preserving the benefits of LXe as a detection medium. This presentation will provide an overview of the operating principles of a CXe TPC and current work to demonstrate the scalability of this technology, including results from a 10kg-scale crystal Xe detector.

Poster / 50

Cold readout electronics for liquid argon TPCs in the DUNE far detector

Authors: Shanshan Gao[None]; Xuyang Ning[1]

[1] *Brookhaven National Laboratory (US)*

Corresponding Authors: xning@bnl.gov, sgao@bnl.gov

The DUNE far detector phase I consists of two 10-kt fiducial mass Liquid Argon Time Projection Chambers (LArTPCs), FD-HD (Horizontal Design) and FD-VD (Vertical Design), providing 20-kt of active volume for high-precision neutrino detection and rare event searches. There are 384,000 electrodes over 150 detector units called Anode Plane Arrays (APAs) in FD-HD, and 245,760 electrodes over 80 detector units called Charge Readout Planes (CRPs) in FD-VD, total over 600,000 channels to be read out by cold electronics submerged in liquid argon. Cold readout electronics offer significant advantages: much lower noise through integrated front-end electronics and CMOS technology in liquid argon, and substantially fewer cryostat penetrations by enabling signal processing inside the cryostat, reducing cables and feed-through connections. During the verification phase, ProtoDUNE located in CERN neutrino platform has demonstrated excellent physics performance due to high yield, low noise, and good stability of cold electronics, validating cold electronics as the optimal technology for DUNE LArTPC. This talk will cover the readout solution for the DUNE single phase

TPCs and the quality control (QC) strategies towards batch production and detector instrumentation.

RDC 7 Low-Background Detectors / 51

Development of Carbon-based Dark Matter Detectors with Magnetic Phonon Sensors

Author: Geon-Bo Kim[1]

Co-authors: William Matava [2]; Inwook Kim [1]; Nathan Hines [1]; Luke Emmert [3]; STP Boyd [3]; Noah Kurinsky [4]; Harris Kagan [5]

[1] *Lawrence Livermore National Laboratory*

[2] *University of California, Berkeley*

[3] *University of New Mexico*

[4] *SLAC*

[5] *Ohio State University*

Corresponding Authors: stpboyd@unm.edu, kim90@llnl.gov, wmatava@berkeley.edu, kim124@llnl.gov, kagan.1@osu.edu, hines24@llnl.gov, kurinsky@slac.stanford.edu, lemming@unm.edu

We present a novel approach for the detection of sub-GeV dark matter using carbon-based crystals integrated with paramagnetic phonon sensors for low-threshold, low-background athermal phonon sensing. The paramagnetic phonon sensors, consisting of Er-doped Ag metallic films, are directly deposited onto the surfaces of target crystals. Athermal phonons generated by dark matter interactions in the crystal are absorbed by the magnetic films, inducing spin flips that are precisely read out using DC-SQUID (Superconducting Quantum Interference Device) magnetometers. This technique offers strong versatility, enabling reliable integration of magnetic sensing films with a wide range of single-crystal detector materials, including diamond and SiC. It features fast timing resolution (<100 ns) for athermal phonon arrival, enabling precise phonon-pulse shape discrimination (P-PSD) to suppress non-nuclear recoil backgrounds and electronic noise events. Additionally, the method is highly scalable, requiring no complex superconducting circuit fabrication on the detector substrate and relying only on Ag:Er film deposition, which is broadly compatible with many crystal types. We report recent progress from our experimental development, including characterization of diamond and SiC detectors and comparison with sapphire detectors, along with preliminary studies of $PbWO_4$ crystals for potential neutrino detection applications.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This work was supported by the Laboratory Directed Research and Development program of LLNL (22-FS-011) and DOE Office of Science HEP Advanced Detector R&D program.

Poster / 52

Characterization of Microwave SQUID Multiplexers for the RICOCHET Experiment

Author: Jiatong Yang[1]

Co-authors: Wouter van de Pontseele [2]; Patrick Harrington [3]; H. Douglas Pinckney [1]; Mingyu Li [1]; Faith Reyes [1]; Bethany M. Niedzielski [4]; Steve Weber [4]; Hannah Stickler [4]; Cyrus Hirjibehedin [4]; William D. Oliver [5]; Joseph Formaggio [1]

[1] *Department of Physics, MIT*

[2] *Department of Physics, Colorado School of Mines*

[3] *HRL Laboratories, LLC*

[4] *MIT Lincoln Laboratory*

[5] *Department of Electrical Engineering and Computer Science, MIT*

Corresponding Author: jiatongy@mit.edu

The RICOCHET experiment measures the spectrum of coherent elastic neutrino-nuclear scattering (CEνNS) of reactor neutrinos to search for physics beyond the Standard Model. In RICOCHET's Q-Array detector, recoil energy deposited in an array of superconducting crystals is transferred to transition-edge sensors (TES). TESes convert the heat signals into current signals, which then get amplified and read out through a microwave SQUID multiplexer (μMUX). Compared to more traditional multiplexing techniques such as time and code division multiplexing, a frequency-division multiplexer made with high Q superconducting resonators allows for faster pulse response, higher multiplexing factor, and lower power dissipation.

Together with Lincoln Laboratory, we designed, fabricated, and characterized the aluminum μMUX. In this poster, we present the characterization results of a 6-channel device. When flux biased at the sensitive point, the μMUX is limited by 1/f noise at low frequencies and the amplifier noise at high frequencies. The amplifier noise from the HEMT is around 1-2 $\mu\Phi_0\sqrt{\text{Hz}}$. Adding a travelling wave parametric amplifier (TWPA) before the HEMT lowers the amplifier noise floor by a factor of 2-3. Flux ramping modulation reduces the amount of 1/f noise from the resonators. At high frequencies, it's mainly limited by amplifier noise, which we measure to be around 3-4 $\mu\Phi_0\sqrt{\text{Hz}}$.

RDC 2 Photodectors / 53

Fabrication and characterization of selenium alloys by co-deposition for application specific

Authors: Kaitlin Hellier[1]; Shiva Abbaszadeh[None]

[1] *University of California, Santa Cruz*

Corresponding Authors: khellier@ucsc.edu, sabbasza@ucsc.edu

Amorphous selenium (a-Se) has become of high interest in detectors for high-energy physics due to its versatility in application. It exhibits a number of ideal properties, including a low threshold field for impact ionization (<70 Vμm), high photoconversion efficiency over a broad range of frequencies, and the capability for uniform large area fabrication. A-Se can be fabricated on a variety of substrates and readout systems with minimal pos-fabrication processing, and can be integrated onto CMOS chips as a hybrid detector, which will allow for large area camera development by tiling. Many of the optical and electrical properties of a-Se can be tuned through alloying and doping, providing even greater control over the detector for specific applications. The Radiological Instrumentation Laboratory has recently reported on our investigations of alloying with type IV and VI semiconductors, demonstrating improved sensitivity in green to near-infrared wavelengths. However, precise control of the alloy composition and the inclusion of elements that have significantly different melting points requires the co-deposition of materials from multiple sources during thermal evaporation. In this work, we present our first studies on films fabricated from our newly installed co-deposition system and discuss how we can continue to tune the photoconversion layer to improve detector properties.

RDC 9 Calorimetry / 54

Results of Dual Readout single crystal test beam at Jefferson Lab and matrix test plans for CalVision

Author: Grace Cummings[1]

Co-author: Bob Hirosky [2]

[1] *Fermi National Accelerator Lab. (US)*

[2] *University of Virginia (US)*

Corresponding Authors: bob.hirosky@cern.ch, gcumming@fnal.gov

Homogeneous inorganic scintillator-based calorimeters are the gold standard for electromagnetic energy resolution, but often degrade the hadronic energy resolution achievable at colliders. By incorporating the dual readout technique, we seek to improve the hadronic energy resolution of these calorimeters through the measurement and separation of the scintillation and Cherenkov light in hadronic showers. Recently, CalVision ran in parallel with the GlueX experiment at the Thomas Jefferson National Accelerator Facility using electrons from conversions of their primary photon beam to test samples of BGO, PWO, BSO and PbF2 with new fast-shaping electronics for improved pulse shape discrimination for Cherenkov and scintillation light. These new results precede the construction of a BGO matrix for electromagnetic containment to demonstrate if precision electromagnetic resolution can be obtained while allowing for the dual readout technique.

RDC 8 Quantum & Superconducting Sensors / 55

Examining the effect of various radioactive sources on superconducting qubits protected through gap-engineering

Author: Doug Pinckney[1]

Co-authors: Alan Hunt [2]; Aranya Goswami [1]; Bethank Niedzielski [3]; Felipe Contipelli [3]; Hannah Binney [1]; Hannah Stickler [3]; Jeffrey Grover [1]; Jiatong Yang [4]; Joseph Formaggio [4]; Kate Azar [1]; Kevin Schultz [2]; Kyle Serniak [3]; Mallika Randeria [3]; Max Hays [1]; Mike Gingras [3]; Mollie Schwartz [3]; Patrick Harrington [5]; Renee DePencier Pinero [3]; Tom McJunkin [2]; William Oliver [1]; Wouter van de Pontseele [6]; Yenuel Jones-Alberty [2]

[1] *Massachusetts Institute of Technology*

[2] *Johns Hopkins Applied Physics Laboratory*

[3] *MIT Lincoln Laboratory*

[4] *Department of Physics, MIT*

[5] *HRL Laboratories, LLC*

[6] *Department of Physics, Colorado School of Mines*

Corresponding Authors: aranya@mit.edu, maxhays@mit.edu, alan.hunt@jhuapl.edu, jiatongy@mit.edu, kevin.schultz@jhuapl.edu, yenuel.jones-alberty@jhuapl.edu, bethany.huffman@ll.mit.edu, mallika.randeria@ll.mit.edu, hdpinck@mit.edu, felipe.contipelli@ll.mit.edu, kazar@mit.edu, mollie.schwartz@ll.mit.edu, wi18222@mit.edu, hannah.stickler@ll.mit.edu, serniak@mit.edu, tom.mcjunkin@jhuapl.edu, jagrover@mit.edu, hbinney@mit.edu, michael.gingras@ll.mit.edu, renee.depencierpinero@ll.mit.edu

Impacts from high-energy particles have been demonstrated to cause correlated errors in superconducting qubits by increasing the quasiparticle density in the Josephson junction (JJ) leads. These correlated errors are particularly harmful as they cannot be remedied via conventional error correcting codes. It was recently demonstrated that these correlated errors can be reduced or eliminated by engineering the difference in superconducting gap across the JJ to be larger than the qubit frequency. In order to test the efficacy of this strategy we have exposed arrays of this type of "gap-engineered" qubits to a variety of radioactive sources, scanning both particle type and energy deposited in the substrate. I will describe measurements utilizing an electron linear accelerator and an ^{241}Am alpha particle source and discuss their implications for the future of preventing correlated errors.

RDC 9 Calorimetry / 57

Simulation and Design of Liquid Argon Positron Emission Tomography

Author: Thomas Murphy[1]

Co-author: Mitchell Soderberg [2]

[1] *Fermi National Accelerator Lab*

[2] *Syracuse University*

Corresponding Authors: thmurphy@fnal.gov, msoderbe@syr.edu

Positron Emission Tomography (PET) scanners detect gamma rays resulting from a tracer chemical like fluorine-18.. These gamma rays have been detected in a pixelated Liquid Argon Time Projection Chamber (LArTPC) optimized for neutrino physics studies. These tests have in part motivated the optimization and design of a LArTPC for application in PET. This talk will present the simulations and designs for a liquid argon PET (LArPET) scanner.
An initial simulation was created to optimize for detector parameters like time projection chamber dimensions, channel size, and configurations of the readout electronics. This simulation characterizes the detector response and suggests that a pixelated LArTPC would detect the gamma rays emitted by the tracer with a higher spatial resolution than traditional scintillation crystals.
A second Monte Carlo simulated the scan of several sources of different sizes. Then the detector systematic models of both traditional and the LArPET scanners were applied to the datasets, and an image reconstruction algorithm was applied to each simulation with the LArPET scans generating clearer images.
These studies have informed the design and construction of a small scale LArPET scanner to be constructed at Syracuse University. Results of those tests could motivate the design and construction of a full scale detector. If validated, this could enhance the ability to screen for diseases like cancer and Alzheimer's.

RDC 9 Calorimetry / 58

Gamma Ray Detection in Liquid Argon Time Projection Chambers

Author: Thomas Murphy[1]

[1] *Fermi National Accelerator Lab*

Corresponding Author: thmurphy@fnal.gov

The future Deep Underground Neutrino Experiment (DUNE) experiment will require unprecedented levels of precision to reach its physics goals. To this end, efficient reconstruction of photons produced in neutrino-nucleus scattering will be essential. This talk will present a new Compton scattering gamma-ray reconstruction tool that can associate blip-like energy depositions with a primary interaction vertex. This would improve the reconstruction of both accelerator and supernova neutrino interactions.
To this end, efficient reconstruction of photons produced in inelastic neutrino-argon interactions in excess of 250 keV will be essential. This new reconstruction was tested with data collected by placing a radioactive fluorine-18 source next to a prototype of the liquid argon time projection chamber of the DUNE Near Detector. This test showed the ability to reconstruct the direction of sub-MeV photons within a 10 percent error, and provided strong support for applying this method to neutrino-nucleus interactions.
We aim to utilize this method to associate each blip-like energy deposit to its interaction vertex leaving behind just background hits, doing so would allow for studies like a millicharged particle analysis in a high rate detector like the DUNE Near Detector. Using this work, we have also developed a design for a liquid argon-based Positron Emission Tomography (PET) scanner. PET scanners

detect gamma rays emitted by a tracer chemical like fluorine-18 to help screen for diseases like cancer.

Poster / 59

FPGA-acceleration of image feature extraction for the ATLAS experiment at CERN at the Large Hadron Collider

Author: Tong Xu[1]

[1] *Argonne National Laboratory (US)*

Corresponding Author: tong.xu@cern.ch

Fast and efficient processing of data from the tracking detector of the ATLAS experiment is required for the high-luminosity program. The tracking detector is equipped with semiconductor sensors with high-segmentation of about 50 by 50 microns. A charged particle crossing a sensor ionizes a few pixels along its trajectory. Our firmware processes images from the sensors to calculate coordinates of particle crossings. The firmware groups pixels with non-negligible ionization into clusters and then estimates coordinates of the particle crossing by calculating cluster's centroid. The firmware is programmed into FPGAs that run as CPU co-processors. The FPGAs will receive collision data from the experiment at the rate of about 1 MHz. We benchmark the performance of the clustering firmware interfaces at Vitis kernel and compare it to a clustering algorithm for CPUs. The FPGAs in AMD Alveo U250 cards demonstrate faster processing and energy savings in comparison to the CPUs.

RDC 6 Gaseous Detectors / 60

Embedded ML Solutions for Real-time Processing in Future Drift Chamber Detectors

Authors: Charlie Young[1]; Christian Herwig[2]; Deniz Yilmaz[3]; Dylan Sheldon Rankin[4]; Julia Lynne Gonski[1]; Liangyu Wu[1]

[1] *SLAC National Accelerator Laboratory (US)*

[2] *University of Michigan (US)*

[3] *SLAC National Accelerator Laboratory (US)*

[4] *University of Pennsylvania (US)*

Corresponding Authors: t.herwig@cern.ch, julia.gonski@cern.ch, young@slac.stanford.edu, dylan.sheldon.rankin@cern.ch, liangyu5@stanford.edu, dyilmaz@slac.stanford.edu

Cluster counting (dN/dx) offers significant promise for enhanced particle identification (PID) resolution compared to traditional dE/dx methods by measuring the number of primary ionization acts per unit length. However, future detectors such as IDEA operating under high-speed digitization face unprecedented data transfer rate challenges. We are developing advanced ML algorithms that demonstrate superior performance over conventional derivative-based methods for cluster counting tasks. We further investigate optimizing these models to fit within estimated front-end resource constraints while achieving competitive latency performance. This ML-based front-end electronics approach enables real-time data reduction with substantial compression ratios. These capabilities address immediate bandwidth limitations and simultaneously open new possibilities for implementing intelligent real-time data acquisition in future collider experiments. In this presentation, I will discuss our progress in developing these ML-assisted data processing solutions, demonstrate performance comparisons with traditional methods, and discuss the implications of this data reduction capability for drift chamber applications at FCCee.

Poster / 61

Results from Testing of the Novel Optical Communication Scheme with the Clockless Q-Pix Charge Readout System in Gaseous Argon

Author: John Hunt[1]

[1] *University of Texas at Arlington*

Corresponding Author: jph1978@mavs.uta.edu

We present the results of testing the novel optical communication scheme for the Q-Pix charge readout in an Argon purity monitoring system. Q-Pix is a novel charge readout scheme which consists of a charge-integrate-replenishment circuit that provides replenishment pulses corresponding to the time when a particular amount of charge is collected. In our optical communication scheme, the replenishment data is transferred from the charge readout plane to the external environment optically instead of using a conventional data transfer. Here, the replenishment output of the Q-Pix is used to pulse an LED which is then read out using a SiPM spatially and electrically separated from the Q-Pix readout board. This is expected to reduce the noise injected from the environment into the charge readout plane and thus can achieve a better signal-to-noise ratio than wire-based communication. The purity monitoring system, in which this optical readout scheme is tested, has been built to determine the purity of Argon by measuring the transport efficiency of photoelectrons from the photocathode to the charge readout pixel on the anode. We first demonstrate the functionality of the optical readout scheme to effectively transfer the charge information from the anode. We aim to compare the signals collected using the optical readout scheme to those collected using the conventional readout.

Poster / 62

A Novel Optical Communication Scheme for a New Clock-less Q-Pix Detector Design (for Q-Pix Collaboration)

Author: Grace Gansle[1]

[1] *University of Texas at Arlington*

Corresponding Author: gmg2243@mavs.uta.edu

We present a novel optical communication system that can overcome the limitations of conventional wire-based readout. We have coupled this system to a novel clockless Q-Pix design built using Commercial Off-The-Shelf (COTS) components. In Q-Pix, charge is read out using a charge-integrate-replenishment circuit that provides replenishment pulses corresponding to the time when a particular amount of charge is collected. In standard Q-Pix schemes, the time at which the replenishment occurs is produced using a local clock. However, in the scheme presented here, we employ basic digital logic components to produce a time-delayed pulse that resembles a clock. This pulse determines the replenishment charge per pixel, as well as the timing circuitry. This pulse is used to control an LED which is then read out using a spatially and electrically separated SiPM and Schmitt Trigger. This is expected to reduce the noise injected from the environment into the charge readout plane and thus can achieve a better Signal-to-Noise Ratio (SNR) than wire-based communication. We present a general design outline and results of bench-testing that compares the wire-based communication scheme to our optical scheme. We will discuss the expected improvements in SNR in a large-scale pixel readout system that employs this optical scheme.

Poster / 63

ALFE2, a Large-Dynamic-Range, Low-Noise Front-End ASIC Designed for the ATLAS Liquid Argon Calorimeter High-Luminosity Large-Hadron Collider (HL-LHC) upgrade

Author: Tiankuan Liu[1]

Co-authors: Dimitrios Matakias [2]; Enrico Rossi [2]; Eric Buschmann [1]; Gabriella Carini ; George Chatzianastasiou [2]; Grzegorz Deptuch [1]; Hao Xu [1]; Hong Ma [1]; Hucheng Chen [1]; James Kierstead [1]; Laurent Duflot [3]; Marcos Oliveira [2]; Mauricio Feo [4]; Mayan Tamari [2]; Mietek Dabrowski [2]; Nicolas Morange [5]; Sergio Rescia [2]; Shaochun Tang [1]; Yuze Chen [6]

[1] *Brookhaven National Laboratory (US)*

[2] *Brookhaven National Laboratory*

[3] *CNRS (FR)*

[4] *CBPF - Brazilian Center for Physics Research (BR)*

[5] *Université Paris-Saclay (FR)*

[6] *Stony Brook University*

Corresponding Authors: nicolas.morange@cern.ch, grzegorz.wladyslaw.deptuch@cern.ch, m.feo@cern.ch, yuze.chen@stonybrook.edu, hucheng.chen@cern.ch, eric.buschmann@cern.ch, laurent.duflot@in2p3.fr, hong.ma@cern.ch, carini@bnl.gov, shaochun.tang@cern.ch, tiankuan.liu@cern.ch, erossi@bnl.gov, george.chatzianastasiou@cern.ch, kierstead@bnl.gov, hao.xu@cern.ch

ALFE2 is an ATLAS Liquid Argon Calorimeter (LAr) front-end ASIC designed for the High Luminosity-Large Hadron Collider (HL-LHC) upgrade. ALFE2 comprises four channels of Pre-Amplifiers (PAs) and CR-(RC)2 shapers (SH) with adjustable input impedance. Each shaper has a Low Gain (LG) output and a High Gain (HG) output. Both outputs can be simultaneously read out to cover a 16-bit dynamic range with optimum resolution. ALFE2 includes a CR-RC shaper for a layer-sum output with a switchable gain of 1 or 3. ALFE2 is manufactured in a TSMC 130 nm CMOS process.

ALFE2 is characterized by using an ALFE2 test board, a calibration pulser, and a Front-End Test Board (FETB). The ALFE2 test board hosts a BGA test socket and RF relays. The RF relays select one of two typical detector loads for tests with different input impedance configurations of 25 Ω or 50 Ω. The calibration pulse generator injects current calibration signals into the test board. The FETB is a high-speed data-acquisition platform based on a System-on-Module (SOM) Mercury+ XU1 from Enclustra. The SOM has a Xilinx Zynq UltraScale+ Multi-Processor System on a Chip (MPSoC) running Peta-Linux. The FETB uses two 8-channel 16-bit state-of-the-art ADCs ADS52J65 from Texas Instruments.

The ALFE2 test results demonstrate that ALFE2 fulfills or greatly exceeds all specifications for the ATLAS LAr Calorimeter. The measured Equivalent Noise Currents (ENIs) are 170 nA and 50 nA for 25 Ω and 50 Ω input impedances, respectively, about half of the specifications. The measured Integral Non-Linearities (INLs) of the HG and LG outputs are below 0.1% (specification 0.2%) and 0.5% (specification 5% in the full dynamic range), respectively. Excellent uniformity is measured with a yield of 97% and a large margin observed across 900 ASICs.

ALFE2 is tested for radiation tolerance. Thirty ALFE2 samples from 3 wafer lots (three extra reference samples without irradiation) were irradiated in Cobalt-60 gamma-rays from 2.2 kGy to 9.5 kGy. During the test, the changes in the baseline and the gain were within ±0.5% and ±0.1%, respectively. The power consumption, peaking time, INL, and ENI were stable. Four ALFE2 samples were tested with 226 MeV protons. The cross-section of the Single-Event Upsets (SEUs) is about 3.56E-15 cm2/bit at a 95% confidence level. The extrapolated error rate for the whole HL-LHC ATLAS LAr calorimeter is less than 7.3 errors per day at the 95% confidence level. The test results indicate that ALFE2 meets the radiation-tolerance requirements.

About 80,000 ALFE2 chips have been produced. Quality control tests are being performed at Brookhaven National Laboratory (BNL) and IJCLab. A custom-designed robotic test system was developed at IJCLab and duplicated at BNL. The preliminary analysis of about 5,000 chips that have been tested indicates an agreement between the two test systems. The commissioning of the robotic test system is being finalized, and the production QC tests will get started soon at both BNL and IJCLab.

Plenary / 64

Development of the novel 3D-projection opaque liquid scintillator calorimeter

Author: Guang Yang[1]

[1] *Brookhaven National Lab*

Corresponding Author: gyang1@bnl.gov

Since the entry to the precision era for the nuclear and high-energy physics communities, excellent particle detection capability is highly demanded for each part of the detection system. A homogeneous EM-Calorimeter could provide excellent energy resolution for electrons and photons in a wide dynamic range allowing rapidity coverage, particle containment and granularity. However, concerns of high cost and radiation hardness in a severe radiation environment are often raised for large (tens of tons) calorimeters planned in future collider experiments such as the Electron-Ion Collider (EIC).
We are developing a scalable 3D-projection calorimeter designed for multiple purposes in the High-Energy Physics and Nuclear Physics community. As a first step, a full 3D-projection readout system has been carried out at the Brookhaven National Lab, paving the road for the future stages developing a liquid-phase 3D-projection calorimeter with fine granularity, tunable high light yield, fast timing, excellent scalability, and cost efficiency. In this talk, the current development status will be presented for such a calorimeter.

RDC 8 Quantum & Superconducting Sensors / 65

Investigation of Low-Energy Event Detection through Meissner Screening probed by a Superconductor–NV Center ensemble

Authors: Pratyanik Sau[1]; Jacob Bogenschutz[1]; Jonathan Asaadi[1]; Yuan Mei[1]; V. A. Chirayath[1]

[1] *University of Texas at Arlington*

Corresponding Authors: chirayat@uta.edu, jhb0089@mavs.uta.edu, yuan.mei@uta.edu, jonathan.asaadi@uta.edu, pxs6807@mavs.uta.edu

We propose a new particle detection scheme that utilizes Nitrogen-Vacancy (NV) center magnetometry for probing variations in magnetic field exclusion through a superconductor as it undergoes a phase transition. We present exploratory simulation results of a Superconductor-NV center-based detector to probe the Meissner screening for low-energy event detection. A modular Python–COMSOL workflow developed in-house was used to model the detector geometry and simulate the superconducting-to-normal phase transition triggered by localized energy deposition. This phase transition alters the local magnetic field profile due to the collapse of the Meissner screening, which can be subsequently detected by the ensembles of NV centers in diamond. Simulation results show that an O(100) eV energy deposition can lead to a change in magnetic field of miliTeslas or less. Such a change in magnetic field can be detected in either the shift in the resonance frequency of the initialized NV qubit state, or the overall quenching of the fluorescence intensity. In parallel, we also describe experimental efforts towards realizing NV-based magnetometry. We present early-stage experimental efforts to achieve NV fluorescence spectroscopy by developing a cost-effective and modular optical setup along with custom-built software capabilities, capable of performing widefield and confocal fluorescence microscopy. This would eventually be used to perform NV-center-based quantum magneto-optical studies and characterize the performance of the detector.

RDC 9 Calorimetry / 66

Latest result from the BNL 1ton Water-based Liquid Scintillator detector development

Author: Adam Baldoni[1]

[1] *Penn State University*

Corresponding Author: baldonia@psu.edu

Three years have passed since the start of the 1ton Water-based Liquid Scintillator (WbLS) at Brookhaven National Lab. This detector is by-far the longest running tonne-scale WbLS detector in the world. Since it started, we have completed two phases and a paper has been published showing the initial performance. In the latest phase, phase-III, we initiated a multi-step WbLS injection from 0.3% to 1% with a step size of 0.1%. The environmental conditions and the readout systems have been carefully taken care of and calibrated throughout the phase-III run.
The WbLS material stability and performance is critically important for all other larger-scale WbLS experiments. In this talk, we will review the BNL 1ton detector design, development and current status. The data indicating the detector stability for almost a year will be shown.

RDC 9 Calorimetry / 67

Development and performance of the BNL 30-ton scale Water-based Liquid Scintillator detector

Author: Praveen Kumar[1]

[1] *University of Alabama*

Water-based Liquid Scintillator (WbLS) is an innovative material for constructing large-scale detectors in neutrino and dark matter research. The tunable light yield, enabled by an inline circulation system, allows for flexible detector optimization for different physics searches. With adequate photosensor coverage, detecting low-intensity light can reconstruct the momentum of energetic charged particles while enhancing sensitivity to low-energy events, thereby improving background suppression in kiloton-scale neutrino detectors. Adding metallic elements like Gadolinium further enhances WbLS as a candidate for outer detectors optimized for neutron background tagging. A 30-ton WbLS demonstrator has been constructed at Brookhaven National Laboratory (BNL) to assess its stability, optical properties, and circulation process, providing valuable insights for designing large-scale detectors. With almost a year of running, the 30-ton demonstrator has accumulated a substantial amount of high-quality data. A multi-step WbLS injection has been performed to understand the light production mechanism. Furthermore, the neutron deployment system along with the nanofilteration system and Gd system have been actively designed and tested. In this talk, current effort on all aforementioned developments will be discussed. Initial WbLS stability and performance results will be shown.

RDC 9 Calorimetry / 68

A novel AmBe neutron source design for future large-scale liquid detector

Author: Ryan Wang[1]

[1] *University of Alabama*

The Americium-Beryllium (AmBe) source is well-known for the use of gamma and neutron detection calibration in large-scale liquid detectors. At Brookhaven National Lab, we designed a new type of AmBe source combining with Lutetium–yttrium oxyorthosilicate (LYSO) crystal. By combining them, the single PE calibration for the PMTs in the liquid detector can be done with the intrinsic LYSO crystal activities. Meanwhile, the gamma from the AmBe source can provide us with a tag to look for the neutron signal that is captured in the liquid, either by hydrogen or Gd, afterward. In this talk, this new source design will be shown along with the preliminary test results from this source calibration system.

SHARED SESSION / 69

Calibrating Interactions in Low-Threshold, Phonon-Mediated Qubit Detectors

Author: Grace Bratrud[1]

[1] *Northwestern University*

Corresponding Author: gracebratrud2027@u.northwestern.edu

Recent work has shown that ionizing radiation incident on a superconducting qubit chip can cause phonon excitation and trapped charges. The phonons can generate non-equilibrium quasiparticles in the superconductor, which can tunnel across the junction and interact with the qubit energy. Trapped charges change the electric field environment in nearby qubits and are seen as charge noise in charge-sensitive qubits. High-energy interactions can cause these behaviors to manifest across multiple qubits on the same chip, correlated in space and time. We are studying these behaviors in various samples with different sensitivities: an array of weakly charge-sensitive aluminum qubits, an array of tantalum transmon qubits, and an array of SQUATs. These experiments are performed in our low background underground environment to study the effects of gamma radiation on these chips, specifically the NEXUS and QUIET underground testbeds at Fermilab. In this talk, we discuss how these studies can be used to calibrate the sensing potential of superconducting quantum sensors for particle detection.

Poster / 70

Characterization and modelling of three building block circuitry of the Q-Pix charge read out scheme implemented using the open-source Skywater 130nm MOSFETS for application in liquid Argon detectors.

Author: ASHISH RIMAL[1]

[1] *University of Texas at Arlington*

Corresponding Author: ashishrimal8@gmail.com

We report room-temperature and 77 K characterization and modeling of SkyWater 130 nm (Sky130) NMOS and PMOS transistors. Using a custom closed cycle cryostat we measured the I-V characteristics from multiple Sky130 MOSFETs. These MOSFETs were fabricated on a chip manufactured as a part of the Efabless Open Multi-Project Wafer program using the Sky130 CMOS technology node specifically to evaluate their performance under cryogenic conditions. Using the data taken at 77 K, we developed an NGSpice compatible model for Sky130 MOSFETS which was used to simulate three building blocks of the QPix charge read out scheme - the integrator, the comparator and the ring oscillator. We aim to compare these simulations with the measured performance of the three circuits at 77 K. Our results will provide the overall performance of the fabricated circuits using the open source Sky130 technology node and will enable us to make improvements to the design for its optimal functionality in liquid argon detectors.

RDC 8 Quantum & Superconducting Sensors / 71

Phonon sensitive kinetic inductance device with low-Tc hafnium for light dark matter search

Author: Xinran Li[1]

Co-authors: Aidar Kemelbay [2]; Aritoki Suzuki [3]; Kungang Li [1]; Maurice Garcia-Sciveres [4]; Michael Williams [3]; Yen-Yung Chang [5]

[1] *Lawrence Berkeley national laboratory*

[2] *LBNL*

[3] *Lawrence Berkeley National Laboratory*

[4] *Lawrence Berkeley National Lab. (US)*

[5] *University of California Berkeley*

Corresponding Authors: mgarcia-sciveres@lbl.gov, kungangli@lbl.gov, michaelwilliams@lbl.gov, akemelbay@lbl.gov, xinranli@lbl.gov, yychang@berkeley.edu, asuzuki@lbl.gov

Searching for light dark matter between 10keV and 100MeV requires noval sub-eV threshold detectors. Superconducting sensors that detects phonons from the crystal substrate is a promising direction. In addition to the mature transition edge sensors (TESs), kinetic inductance devices (KIDs) provide another option, which has the advantage of up-scaling with multiplexed readout.
We work on Low-Tc (200mK) Hafnium KID development for light dark matter search at LBL. With the internal quality factor exceeding 10^5, we demonstrated around 2eV internal energy resolution in Hf KIDs by optical photon and gamma ray calibrations. The resolution is amplifier noise dominated. Progress has been made to 1) improve amplifier noise with kinetic inductance traveling wave parametric amplifiers (KITWPA), and 2) improve phonon collection efficiency with MEMS fabrication techniques to translate the eV level internal resolution to the phonon signal resolution. These efforts provide a tangible path to a eV level threshold KID phonon detector.

SHARED SESSION / 72

Effect of Defect Formation on Low-Threshold Detector Physics

Authors: Alexander Biffl[1]; Anthony Villano[2]; Nader Mirabolfathi[1]

[1] *Texas A&M University*

[2] *UC Denver*

Corresponding Authors: ajbiffl3@tamu.edu, mirabolfathi@physics.tamu.edu, anthony.villano@ucdenver.edu

We propose and simulate a novel experiment to quantify the energy stored in stable crystal defects —such as Frenkel pairs—produced by nuclear recoils following neutron capture. These quantum defects can absorb part of the recoil energy, altering the apparent energy scale for nuclear recoils and impacting the interpretation of signals in low-threshold dark matter and coherent elastic neutrino-nucleus scattering (CEvNS) experiments. By simultaneously detecting the de-excitation gamma and the associated recoil nucleus from neutron capture, we aim to directly measure this missing energy. Simulations using a 1 mCi californium neutron source show that such a measurement is feasible with only 26.1 gram-days of exposure using existing detector technologies. This method not only improves low-energy calibration and opens the door to future single-defect energy measurements, but also enables investigation of defect annealing effects as a potential contributor to the low-energy excess observed in recent dark matter experiments.

RDC 2 Photodectors / 73

Novel optical readout scheme for UV photodetection in ZnO/noble-metal thin film devices using Surface Plasmon Resonance Spectroscopy

Author: Vivek Khichar[1]

Co-authors: Jonathan Asaadi [1]; V.A. Chirayath [1]; Nader Hozhabri [1]

[1] *UT Arlington*

Corresponding Authors: chirayat@uta.edu, vivek.khichar@uta.edu, jonathan.asaadi@uta.edu, nh@uta.edu

We present a novel UV photon detection method using ZnO/metal thin film architecture operated under surface plasmon resonance (SPR) conditions. Here, we couple a 633 nm probe light to the ZnO/metal thin film via the Kretschmann configuration to excite surface plasmons at the metal-dielectric interface. The reflectance of the probe light under SPR is utilized as the detection signal. The reflectance of the 633 nm probe light is expected to change due to the variations in the refractive index of the ZnO thin film as a result of the absorption of the UV photons and the subsequent creation of the photoinduced charge carriers. The reflectance is also expected to change due to the modulation of the SPR induced field at the metal-dielectric interface as result of the electric field screening by the creation and transport of the photoinduced charges. For the fabrication of the SPR-based detection devices, COMSOL Multiphysics simulations were utilized to optimize the film thicknesses of the ZnO/metal layers to produce the sharpest SPR curve for a 633 nm light with maximum loss in reflectivity at resonance. Preliminary results from our prototype detectors show that appreciable change in intensity of the reflected 633 nm from the metal-dielectric interface can be detected as the UV light is absorbed. We will discuss the utility of such an optical readout methodology for the detection of the scintillation VUV photons produced in liquid noble detectors.

SHARED SESSION / 74

Design and characterization of the FCFD chip for strip AC-LGAD readout

Authors: Artur Apresyan[1]; Cristián Peña[1]; Shuoxing Wu[2]; Si Xie[3]; Tom Zimmerman[2]

[1] *Fermi National Accelerator Lab. (US)*

[2] *Fermilab*

[3] *California Institute of Technology (US)*

Corresponding Authors: artur.apresyan@cern.ch, si.xie@cern.ch, shuoxing.wu@cern.ch, cristian.pena@cern.ch

We present the design and performance of the latest version of the Fermilab Constant Fraction Discriminator (FCFD) readout ASIC, FCFDv1.1. The chip was delivered in May 2025, and results were measured in testbedam in July 2025. We will also present the status of the development of the next version of FCFD readout chip. The FCFD will be used to readout the 1-cm long AC-LGAD strip sensors of the barrel TOF detector at ePIC, and is a candidate readout chip for several other subsystem at ePIC. The ASIC is the first to apply the CFD at the readout level for LGAD sensors, which significantly simplifies detector design and operation. We will show our new method of precise characterization of AC-LGAD RC-network parameters, as these parameters play a critical role in the design of the chip. We present measured performance of the FCFD v1.1 with multi-channel capability using LGAD signals from minimum-ionizing particles produced at the DESY test beam facility. We demonstrate excellent timing performance for 1-cm long AC-LGAD sensors, and characterize the performance of the sensor+readout system, demonstrating performance matching the ePIC bTOF detector specification.

RDC 9 Calorimetry / 75

Water results from Eos

Authors: Eos collaboration[None]; Gabriel Orebi Gann[1]; Tanner Kaptanoglu[2]

[1] *University of California, Berkeley / Lawrence Berkeley National Laboratory*

[2] *LBNL*

Corresponding Author: gorebigann@lbl.gov

Future kilotonne-scale neutrino detectors, such as Theia, aim to leverage new and emerging technologies to simultaneously measure Cherenkov and scintillation light, to enable rich science programs and nonproliferation efforts. To achieve these goals, these hybrid detectors will exploit fast timing photodetectors, novel liquid scintillators, and spectral sorting techniques.

This talk highlights a currently operating technical demonstrator, Eos, which is a novel detector with a fiducial target volume of approximately 4 tonnes, constructed at UC Berkeley and Lawrence Berkeley National Laboratory. Eos serves as a test bed for these emerging technologies required for hybrid Cherenkov/Scintillation detectors, and can accommodate a range of detector targets, including water-based liquid scintillators (WbLS), organic scintillators, and metal-loaded liquids.

Eos deploys an array of calibration sources to validate and improve scintillator and photon detector optical models, to facilitate extrapolation to kilotonne-scale detectors. This talk presents results from the water phase of Eos, with the data collected in 2024 and 2025.

RDC 9 Calorimetry / 76

WbLS results from Eos

Authors: Eos collaboration[None]; Gabriel Orebi Gann[1]; Leon Pickard[None]

[1] *University of California, Berkeley / Lawrence Berkeley National Laboratory*

Corresponding Author: gorebigann@lbl.gov

Hybrid neutrino detectors utilize both Cherenkov and scintillation light for event detection and reconstruction - leveraging the lower energy threshold of pure scintillation emission and the enhanced direction resolution afforded by water. The benefits of hybrid technologies provide for advancements in both fundamental physics research and in nuclear nonproliferation applications. Benchtop experiments have shown success in Cherenkov/scintillation separation. Now, a ton-scale demonstration of these technologies is needed to extrapolate the performance to larger detectors, such as Theia, with a fiducial volume of tens of kT.

Eos, constructed at UC Berkeley and Lawrence Berkeley National Laboratory, is a detector with an approximately 4-ton target fiducial volume. Featuring fast photomultiplier tubes (900 ps transit time spread), a novel water-based liquid scintillator (WbLS) target, and the first large-scale test of spectral sorting, will provide a test-bed for these emerging technologies.

This talk will present the first WbLS results of Eos, highlighting optical model verification, event detection and reconstruction capabilities. Furthermore, the extrapolation to kT-scale detectors and the adoption of these advanced techniques for nuclear non-proliferation and fundamental neutrino experiments will be discussed.

SHARED SESSION / 77

Mortality of ultra-thin LGADs from high energy deposition

Author: Abraham Tishelman-Charny[1]

Co-authors: Alessandro Tricoli [1]; Alexander Buzzi ; Dylan Ponman ; Enrico Rossi [2]; Gabriele D'Amen [1]; Gabriele Giacomini [1]; Jennifer Roloff [3]; Matthew Glenn Kurth [1]; Mohamed Hijas Mohamed Farook [4]; Stefania Stucci [2]

[1] *Brookhaven National Laboratory (US)*

[2] *Brookhaven National Laboratory*

[3] *Brown University (US)*

[4] *University of New Mexico (US)*

Corresponding Authors: alessandro.tricoli@cern.ch, alexander_buzzi@brown.edu, giacomini@bnl.gov, stucci@bnl.gov, abraham.tishelman.charny@cern.ch, hijas.farook@cern.ch, erossi@bnl.gov, gabriele.d'amen@cern.ch, matthew.glenn.kurth@cern.ch, dylan_ponman@brown.edu, jroloff2@gmail.com

Low Gain Avalanche Diodes (LGADs) are prime candidates for high-resolution timing applications in High Energy Physics, Nuclear science, and other fields. When used at hadron colliders, these sensors are required to withstand enormous amounts of radiation while maintaining acceptable performance. When particles interact with highly biased sensors in these high-radiation environments, this can produce irreversible damage to the sensors through a phenomenon known as Single Event Burnout (SEB).

SEB is one of the main limitations to the usage of silicon detectors in high-radiation environments, as it often results in the permanent destruction of the sensors. Recent studies conducted using minimum ionizing particles (MIPs) found that when LGADs are operated below a certain bias voltage threshold, the risk of SEB is greatly minimized. As LGADs would be exposed to a large energy range of radiation at hadron colliders, it is crucial to also understand this phenomenon, and the behavior of LGADs, at energy deposition levels greater than those of MIPs.

This was achieved by pre-irradiating 20, 30, and 50 µm LGADs and PiN diodes at the Rhode Island Nuclear Science Center up to $1.5\times10^{15}\ \frac{n_{eq}}{cm^2}$, and then exposing them to high intensity beams of protons and several species of heavy ions (C, O, Fe, Au) produced at the BNL Tandem Van de Graaff accelerator. This talk describes the results of the irradiations, including a showcasing and categorization of the different observed mortality modes of the sensors for different energies and species of heavy ions. This study furthers our understanding of SEB and permanent radiation damage of LGADs in high-radiation environments, crucial towards developing techniques to mitigate this issue and safely operate LGADs at future detectors.

SHARED SESSION / 78

Laboratory characterization of ARCADIA MAPS sensors, and status of future developments at Fermilab

Authors: Alessandro Tricoli[1]; Artur Apresyan[2]; Cristián Peña[2]; Koji Nakamura[3]; Nicola Bacchetta[4]; Ron Lipton[4]; Si Xie[5]; Zhenyu Ye[6]

[1] *Brookhaven National Laboratory (US)*

[2] *Fermi National Accelerator Lab. (US)*

[3] *KEK High Energy Accelerator Research Organization (JP)*

[4] *Fermilab*

[5] *California Institute of Technology (US)*

[6] *Lawrence Berkeley National Lab. (US)*

Corresponding Authors: si.xie@cern.ch, zhenyu.ye@cern.ch, alessandro.tricoli@cern.ch, cristian.pena@cern.ch, artur.apresyan@cern.ch, koji.nakamura@cern.ch

We will present the ongoing efforts on development of high precision low-power CMOS detectors for particle detection. Results of detailed characterization using IR-laser in Fermilab and techniques developed to scan the properties of the detector at few micron granularity level. We will present measurements of the performance of the ARCADIA main demonstrator performed in labs and in test beams, and the status of future developments of the chip. We will also present the status of

our developments and simulation work towards production of MAPS detectors with a commercial foundry in the US, which are pursued within our US-Japan consortium and we will present our current status.

SHARED SESSION / 79

Measuring Beta Particle Momentum with CMOS Sensors and Scintillating Detectors for Sterile Neutrino Detection

Author: Daniel Kodroff[1]

[1] *Lawrence Berkeley National Lab*

Corresponding Author: danielkodroff@lbl.gov

We describe the first experimental demonstration of the beta momentum detectors for the proposed QuIPs experiment. The Quantum Invisible Particle Sensor (QuIPS) experiment, introduced at CPAD in 2024, is an optomechanical laser trap surrounded by active pixel detectors searching for heavy sterile neutrino masses in the 10s of keV to few MeV regime via weak nuclear decays. The experimental setup uses CMOS sensors to measure the direction of a beta particle emitted from a trapped nanosphere, and a plastic scintillator detector to reconstruct its energy. When combined with the momentum impulse imparted to the trapped nanosphere, the full momenta of the beta decay products may be reconstructed. This talk will present the proof-of-principle experimental demonstration of reconstruction beta momentum using two CMOS sensors and a scintillator in coincidence. The plans for deployment and operation of this custom beta detector in an optomechanical trap will also be discussed.

RDC 2 Photodectors / 80

Power-over-Fiber Development for DUNE VD Photon Detection System

Author: Biswaranjan Behera[1]

[1] *South Dakota Mines, USA*

Corresponding Author: biswaranjan.behera@cern.ch

The Deep Underground Neutrino Experiment (DUNE) aims to answer fundamental questions about neutrinos, including CP violation, mass hierarchy, and proton decay searches, and to observe neutrinos from supernova bursts. To support these goals, DUNE will implement Power-over-Fiber (PoF) technology to safely deliver power to its Far Detector Vertical Drift (FD-VD) photon detection system. This system operates in a high-voltage environment (~300 kV), where traditional electrical cabling is not feasible. PoF enables optical power transmission through fibers, offering a reliable and scalable solution for supplying power to electronics located near the cathode. Following its successful deployment and operation in one of the DUNE prototypes at CERN, preparations are now underway for full-scale production and integration into the DUNE FD-VD module. This presentation will detail the development, performance, and integration strategy of the PoF system, emphasizing its novel implementation in large-scale neutrino detectors.

SHARED SESSION / 81

Design and characterization of 28nm readout ASICs for 3D-integrated LGAD sensors

Authors: Aseem Gupta[1]; Bojan Markovic[2]; Christos Bakalis[1]; Davide Braga[3]; Gang Liu[1]; Larry Ruckman[1]; Lorenzo Rota[4]; Troy England[3]

Co-authors: Angela Kok [1]; Anne Mayer Garafalo [5]; Ariel Gustavo Schwartzman [2]; Arthur Carpenter [5]; Artur Apresyan [3]; Christopher Kenney [1]; Cristian Pena [3]; Farah Fahim [6]; Julie Segal [1]; Ron Lipton [3]; Sergey Los [3]; Shuoxing Wu [3]; Si Xie [3]; Todd Zenger [3]

[1] *SLAC National Accelerator Laboratory (US)*

[2] *SLAC National Accelerator Laboratory (US)*

[3] *Fermi National Accelerator Lab. (US)*

[4] *SLAC National Laboratory*

[5] *Lawrence Livermore National Laboratory (USA)*

[6] *Fermilab*

Corresponding Authors: carpenter38@llnl.gov, ruckman@slac.stanford.edu, aseemg@slac.stanford.edu, los@fnal.gov, kenney@slac.stanford.edu, bojan.markovic@cern.ch, lipton@fnal.gov, dzenger@fnal.gov, swu1@fnal.gov, lorenzor@slac.stanford.edu, sxie@fnal.gov, liugang@slac.stanford.edu, garafalo1@llnl.gov, artur.apresyan@cern.ch, ariel.gustavo.schwartzr cmorgoth@fnal.gov, dbraga@fnal.com, tengland@fnal.gov, cbakalis@slac.stanford.edu, angiekok@slac.stanford.edu, jsegal@slac.stanford.edu

Highly granular precision timing detectors are required to achieve scientific breakthroughs across HEP, NP, BES, and FES applications, and their critical need was highlighted by DOE BRN, European Strategy for Particle Physics, and Snowmass. To enable the development of these detectors, 3D-intgration between advanced sensor wafers and scaled CMOS technology nodes is required but is currently cost-prohibitive for use in scientific applications and experiments. Closing this technology gap is the main objective of the joint SLAC, FNAL and LLNL effort "3D Integrated Sensing Solutions", supported by DOE's Accelerated Innovation in Emerging Technologies grant. In collaboration with leading semiconductor industry partner, this effort is pursuing development of LGAD structures compatible with fabrication in commercial 12-inch wafer processes that can be cost-effectively 3D-integrated with readout ASICs. In parallel with the LGAD development, a co-design effort in the development of high-performance readout ASICs is underway and will be the subject of this talk.
The first readout ASIC prototype has been fabricated and tested. It features a linear array of 40 pixels with 50 µm and 100 µm pitch, matched to LGAD cell variants. Each pixel integrates a low-jitter front-end, fast comparator, and a high-resolution in-pixel Time-to-Digital Converter (TDC). The system targets timing resolution below 20 ps with power consumption under 1 W/cm². Initial testing confirms ˜10 ps jitter for the in-pixel TDCs. The TDC employs a 2D Vernier ring oscillator architecture with an embedded sliding-scale technique, enabling simultaneous measurement of Time-of-Arrival (TOA) and Time-over-Threshold (TOT) with resolutions of 6.25 ps (11-bit) and 50 ps (8-bit), respectively. Power consumption scales with occupancy, averaging 51.1 µW at 10% and 6.2 µW at 1% occupancy per TDC.
The prototype has been characterized using on-chip charge injection and will be wire-bonded to LGAD sensors. Finally, we will present the design of the second-generation 10k-pixel ASIC scheduled for fabrication in September, to be bump bonded to designed LGAD sensors for testing and system validation.

RDC 2 Photodectors / 82

Dichroic Filter Characterization

Author: Amanda Bacon[1]

Co-authors: Benjamin Harris [2]; Joshua R Klein [2]

[1] *University of Pennsylvania*

[2] *University of Pennsylvania (US)*

Corresponding Authors: jrk@hep.upenn.edu, hbjamin@sas.upenn.edu, ajbacon@sas.upenn.edu

Dichroic filters, filters that selectively transmit and reflect specific wavelengths while minimizing absorption, are increasingly employed in nuclear and particle physics for photon-detection, including in EOS for Cherenkov and scintillation light separation. In this talk, I will present transmission and reflection measurements of several dichroic filters over a range of angles of incidence and in multiple media: air, water, and LAB-based liquid scintillator. These measurements reveal how the optical response shifts with environment and geometry, and demonstrate that a modified Bragg's Law provides a good model for the transmission edge. These results provide essential input for optical simulations and detector design, and support the development of wavelength-separation optical systems for next-generation hybrid Cherenkov/scintillator detectors.

SHARED SESSION II / 83

High Speed DAQ Solution for Small-scale Particle Physics Experiment

Authors: Brent Clelland[None]; Kyle Mo[None]; Pranava Surukuchi[None]; Sean Maloney[None]; Tae Min Hong[None]; Yuvaraj Elangovan[1]

[1] *University of Pittsburgh (US)*

Corresponding Author: yuvaraj.elangovan@cern.ch

We present a high-speed, modular Data Acquisition (DAQ) solution developed for Pitt-CoRTEx (Pitt-Cosmic Ray Tracker Experiment), a compact and scalable muon tracking detector designed for educational and small-scale particle physics applications. The detector consists of 128 extruded plastic scintillator bars, each embedded with a wavelength-shifting (WLS) optical fiber that guides light to Silicon Photomultipliers (SiPMs) upon energy deposition. To support real-time signal readout, a custom front-end DAQ system is developed using the CITIROC-1A ASIC for signal amplification, shaping and charge measurement. Each DAQ module integrates a 32-channel CITIROC ASIC and a Spartan-7 FPGA daughter card, providing local signal processing and scalability. Four such DAQ modules interface with the detector, with one acting as the master and others as slaves, enabling synchronized acquisition across all 128 channels. The master DAQ transmits the 128-bit muon trajectory data to a Raspberry Pi module, which in turn controls 128 LEDs mounted on the front panels of each detector layer, illuminating the corresponding LEDs along both the X and Y axes which provides a visual display of cosmic muon track. The DAQ modules include onboard SiPM biasing, ADCs for charge digitization, and FPGA resources for implementing real-time track fitting and timing measurement. The Pitt-CoRTEx system is portable, low-power, and well-suited for muon flux and angular distribution studies, undergraduate training, and public science outreach. And the DAQ solution proposed here is a plug-and-play architecture that makes it a viable solution for other SiPM-based particle detector applications.

Poster / 84

A GHz-Bandwidth Readout and Trigger System for the Eos Hybrid Neutrino Detector

Author: Benjamin Harris[1]

[1] *University of Pennsylvania (US)*

Corresponding Author: hbjamin@sas.upenn.edu

Eos is a hybrid neutrino detector constructed to demonstrate reconstruction techniques that leverage both Cherenkov and scintillation light. Eos is currently filled with 4-tons of water-based liquid scintillator, and employs 200 fast 8" PMTs (R14688-100) with transit time spreads of 1 ns (FWHM) and risetimes of 2.2 ns, as well as 12 spectral sorting dichroicon PMTs to isolate Cherenkov light. To preserve the integrity of these fast signals, a custom GHz bandwidth readout and trigger system was designed: 17 custom front end boards provide high voltage to PMTs and discriminate their signals; 3 custom analog summing boards provide further discrimination; and a custom trigger board with an FPGA performs synchronous trigger logic. This talk will provide an in depth overview of the Eos

readout and trigger system, which was primarily designed at the University of Pennsylvania and modeled after SNO+. An example michel electron trigger used in Eos will also be discussed.

RDC 7 Low-Background Detectors / 85

Imaging nuclear recoils with light sheet microscopy

Author: Sam Hedges[1]

Co-author: Patrick Huber

[1] *Virginia Tech*

Corresponding Authors: pahuber@vt.edu, schedges@vt.edu

Nuclear recoils can produce stable optically-active color centers in many common materials. Advances in light-sheet microscopy now allow rapid large-volume imaging of these materials with micrometer-scale resolution. We present the development of the mesoSPIM light sheet microscope at Virginia Tech, designed for imaging particle tracks relevant to nuclear and high-energy physics, including neutrino, dark matter, and neutron interactions. We discuss challenges and opportunities of this detection approach, and present commissioning data from the VT mesoSPIM.

SHARED SESSION / 86

Understanding the Origin of Non-Ionizing Phonon Bursts seen in Phonon Calorimeters and Superconducting QUBITs.

Author: Matt Pyle[1]

[1] *University of California Berkeley*

Corresponding Author: mpyle1@berkeley.edu

To date, all light mass dark matter calorimeters have measured a low energy, non-ionizing background whose rate decreases with time since cooldown. Such bursts have recently also been seen to be the dominant source of parity flipping in superconducting QUBITs. In this talk, we will summarize recent work to understand the source of this background where we correlated the measured burst rate to substrate thickness and to fast neutron exposure.

RDC 6 Gaseous Detectors / 87

Electronics testing and development for high-pressure argon-based detectors

Authors: Francisco Martínez López[1]; Tanaz Mohayai[1]

[1] *Indiana University*

Corresponding Authors: tanaz.angelina.mohayai@cern.ch, frmart@iu.edu

High-pressure gaseous TPCs (HPgTPCs) offer the tracking capabilities of gaseous detectors combined with an increased target density, making them particularly suitable for high-precision neutrino interaction measurements. However, developing readout electronics for these detectors poses

unique challenges distinct from collider-based systems. The low occupancy typical of neutrino detection requires lower channel density and power per channel, rendering conventional solutions unnecessarily complex and cost-prohibitive. This talk presents results from an FPGA-based readout system deployed at the TOAD pressure vessel at Fermilab, tested across a range of gas mixtures and pressures up to 4.5 barA. This experience helped identify critical areas for improvement, including the cooling scheme and noise mitigation strategies. Ongoing R&D efforts focus on adapting this electronics system to characterise gas electron multipliers (GEMs) under high-pressure conditions. This approach aims to support the optimisation of charge amplification structures, helping to establish scalable, cost-effective solutions for the next generation of HPgTPCs.

SHARED SESSION / 88

ML processing and compression of signal shared AC-LGADs

Authors: Gaetano Barone[1]; Jessica Tang[1]; Samantha Sunnarborg[1]

[1] *Brown University*

Corresponding Authors: jessica_h_tang@brown.edu, gaetano.barone@cern.ch

Resistive Silicon Devices (RSDs), particularly AC-coupled Low Gain Avalanche Diodes (AC-LGADs), open the path of pico-second level space and time (4D) tracking in high-energy physics (HEP) experiments such as those at the Large Hadron Collider (LHC), Electron-Ion Collider (EIC), and future (lepton) colliders facilities. These sensors combine the fine spatial resolution of segmented detectors with the excellent timing performance of LGADs, achieving nearly 100% fill factor. Unlike conventional detectors, typically structured as linear strip arrays (1D) or pixel matrices (2D), RSDs offer a highly flexible geometry for readout pads, allowing for optimization based on experimental demands.

When ionizing radiation interacts with these sensors, the generated charge spreads beyond adjacent pixels. This broad charge sharing, while beneficial for interpolation-based resolution enhancement, is complicated by reduced signal amplitudes and Landau fluctuations on pixels farther from the true hit location. To address these challenges, we study pixelated AC-LGADs fabricated at Brookhaven National Laboratory with different pad geometries, including square and triangular configurations with a 500 µm × 500 µm pitch, and analyze their impact on spatial resolution.

In contrast to previous studies, we leverage full-waveform information from each readout channel and utilize Recurrent Neural Networks (RNNs) to infer the full waveforms of the readout pads, given the hit's position and AC-LGAD structure, thereby reconstructing the hit position. The higher precision achieved by the classical charge-imbalance and geometry-based matrix inversion methods is leveraged by the amount of information processed by the networks, such as identifying optimal trade-offs between spatial granularity and data volume. Initial studies on Transient Current Techniques are used as inputs to further refine the algorithms with particle beams, where Landau fluctuations challenge the readout.

To support real-time applications and reduce computational load, we evaluate waveform rasterization techniques for compressing temporal signal data while preserving critical spatial information. These techniques are essential for future implementation on Field Programmable Gate Arrays (FPGAs) and other low-latency hardware platforms. Additionally, we conduct comparative studies of alternative geometric pad arrangements, assessing how shape and connectivity influence charge collection and algorithmic performance. These combined studies demonstrate the feasibility and scalability of using RSDs with flexible geometries, optimized readout configurations, and machine learning-enhanced reconstruction to meet the stringent resolution and speed requirements of next-generation high-energy physics (HEP) detectors.

SHARED SESSION / 89

Stress Tests on Low Gain Avalanche Diodes and AC-coupled Low Gain Avalanche Diodes

Authors: Gaetano Barone[1]; Lixing Wang[1]; Trevor Russell[1]

[1] *Brown University*

Corresponding Authors: trevor_russell@brown.edu, gaetano.barone@cern.ch, lixing_wang@brown.edu

Devices with internal gain, such as Low Gain Avalanche Diodes (LGADs), demonstrate O(30) ps timing resolution, and they play a crucial role in High Energy Physics (HEP) experiments, among other applications. Similarly, resistive silicon devices, such as AC-coupled Low Gain Avalanche Diodes (AC-LGADs) sensors, achieve a fine spatial resolution while maintaining the LGAD's timing resolution. However, their performance is strongly affected by environmental factors such as temperature, humidity, and storage conditions. The challenging operating conditions in space impose challenging constraints on the operational performance, against temperature fluctuations, for example. Therefore, devices with different depletion layers and implantation characteristics are tested. A systematic evaluation of the response of these sensors as a function of these environmental parameters is therefore of essential importance when accounting for any application. The precise characterization of resistive silicon devices is experimentally challenging because of the capacitively coupled correlated degrees of freedom involved in the readout. (AC-)LGAD sensors fabricated at the Brookhaven National Laboratory (BNL, US) are characterized at the Silicon Laboratories at BNL, at Brown University, and the RD50/DRD3 facilities at CERN. They are stress-tested against various operating conditions. Previous studies have focused primarily on the electrical characterization of LGAD; now, we focus on the environmental resilience of AC-LGADs and on the signal characterization when ionizing radiation hits those devices.

RDC 4 Readout & ASICs / 90

Cryogenic Modeling of Open-Source Skywater 130nm Process Design Kit at 77K for High Energy Physics

Author: Faith Beall[1]

[1] *The University of Texas at Arlington*

Corresponding Author: feb9528@mavs.uta.edu

We present a Berkeley Short-channel IGFET Model (BSIM4)-based cryogenic Process Design Kit (PDK) for the open-source Skywater 130nm transistor node for operation at 77 Kelvin. Reliable operation of read-out electronics at cryogenic temperatures is crucial for their use in liquid argon detectors that are ubiquitous in high energy physics (HEP) experiments. The open-source Skywater 130nm node is a viable option for large-scale detector read-out ASICs (application-specific integrated circuits) due to its cost effectiveness. However, ASIC designers require cryogenic models for HEP applications because cryogenic temperatures fall outside of the temperature range of the foundry-verified, room temperature PDK. For this reason, we sought to characterize and model the Skywater 130nm PDK at liquid nitrogen temperature (77K), a region previously unexplored. I-V curves were acquired at room temperature (300K) for model verification and at 77K for the generation of the cryogenic PDK for multiple single transistors. A physics-based parameter extraction strategy was implemented to adjust model parameters that reflect the change in transistor behavior in cold environments to achieve a better model fit. The cryogenic models can be incorporated into a SPICE-simulator framework to verify cryogenic performance of readout circuits commonly used in HEP applications using the Skywater 130nm node.

RDC 9 Calorimetry / 91

Cosmic Ray Muon Detection and Commissioning with a Highly Granular Dual-Readout Fiber Calorimeter (HG-DREAM)

Authors: Christopher Madrid[1]; Jordan Damgov[1]; Nural Akchurin[1]; Yongbin Feng[1]

[1] *Texas Tech University (US)*

Corresponding Authors: chris.madrid@ttu.edu, nural.akchurin@cern.ch, yongbin.feng@cern.ch, jordan.damgov@cern.ch

Calorimeters play a central role in high-energy physics experiments by enabling precise energy measurements and providing critical information for particle identification and event reconstruction. Advances in calorimeter technology are essential to meet the increasingly demanding requirements of future collider experiments—such as the FCC and muon colliders—as well as non-collider experiments in neutrino physics, dark matter searches, and astrophysical observations.

Building on the success of previous dual-readout calorimeter (DREAM) studies, we constructed the HG-DREAM calorimeter at Texas Tech University—a highly granular dual-readout fiber detector instrumented with 896 silicon photomultipliers (SiPMs). The readout system combines CAEN FERS 5202 and CAEN V1742 modules for charge integration and waveform digitization, respectively, with the latter operating at a 5 GHz sampling rate.

In this talk, we present results from the commissioning of HG-DREAM using cosmic ray muons. This initial testing phase allowed us to characterize system noise, single-photoelectron resolution, response linearity, light yield, and overall detector stability in preparation for high-energy test beam campaigns at CERN. We report intriguing observations from cosmic muon events—some exhibiting minimum ionizing particle (MIP)-like behavior, while others produce showers within the detector. These measurements are compared to GEANT4 simulations, and we highlight the use of muon-induced electromagnetic showers for system debugging and preliminary calibration.

RDC 7 Low-Background Detectors / 92

Characterizing single-electron backgrounds in Skipper-CCDs

Author: Yikai Wu[1]

[1] *Stony Brook University*

Corresponding Author: yikai.wu@stonybrook.edu

The Skipper Charge Coupled Device (CCD), used by the SENSEI and DAMIC-M experiments, is currently the leading technology for detecting sub-GeV dark matter due to its single-electron sensitivity and low background rate. Since the start of the SENSEI experiment, one of its main efforts has been on reducing the single-electron backgrounds. Two sources of single-electron backgrounds are dark current, generated through thermal excitations, and spurious charge, induced by clocking during readout. In this talk, we will present the recent measurements of the dark current in the SENSEI detector at SNOLAB, which we found to be as low as 10ˆ-5 e/pixel/day, as well as our current work on characterizing the spurious charge in Skipper-CCDs.

RDC 9 Calorimetry / 93

Performance of High Granularity Dual-Readout Fiber Calorimeter (HG-DREAM) with High Energy Particle Beams

Authors: Christopher Madrid[1]; Jordan Damgov[1]; Nural Akchurin[1]; Weijie Jin[2]; Yongbin Feng[1]

[1] *Texas Tech University (US)*

[2] *University of Zurich (CH)*

Corresponding Authors: weijie.jin@cern.ch, nural.akchurin@cern.ch, yongbin.feng@cern.ch, chris.madrid@ttu.edu, jordan.damgov@cern.ch

Calorimeters play a critical role in current and future high-energy physics experiments. Building on the success of earlier dual-readout calorimeter (DREAM) studies, we developed the HG-DREAM calorimeter at Texas Tech University—a highly granular dual-readout fiber detector instrumented with 896 silicon photomultipliers (SiPMs). Compared to the original DREAM module using photomultiplier tubes, HG-DREAM achieves a 24-fold increase in transverse segmentation enabled by SiPM technology. The readout system integrates CAEN FERS 5202 modules for charge integration and CAEN V1742 modules for waveform digitization, the latter operating at a 5 GHz sampling rate.

The performance of HG-DREAM is being evaluated using high-energy particle beams at the H8 beam line at CERN. The primary goals are to assess the impact of increased transverse granularity and to analyze Cherenkov and scintillation pulse shapes for improved energy and timing reconstruction. We further explore effective longitudinal segmentation via precision timing and investigate AI/ML techniques that leverage the fine shower structure for enhanced performance. While data analysis is ongoing, we present preliminary results and outline plans for future integration with a crystal-based electromagnetic calorimeter to form a unified dual-readout system.

RDC 9 Calorimetry / 94

Developing Digital Silicon Photomultiplier (dSiPM) Specifications for a High-Granularity Calorimeter with Simulations

Authors: Christopher Madrid[1]; Jordan Damgov[1]; Liangyu Wu[2]; Nural Akchurin[1]; Yongbin Feng[1]

[1] *Texas Tech University (US)*

[2] *Stanford/SLAC National Accelerator Laboratory (US)*

Corresponding Authors: liangyu5@stanford.edu, jordan.damgov@cern.ch, nural.akchurin@cern.ch, yongbin.feng@cern.ch, chris.madrid@ttu.edu

Calorimeters play a central role in high-energy physics experiments by enabling precise energy measurements and providing critical information for particle identification and event reconstruction. Advances in calorimeter technology are essential to meet the increasingly demanding requirements of future collider experiments, such as the FCC and muon collider, as well as non-collider experiments in neutrino physics, dark matter searches, and astrophysical observations.

One of the critical elements in calorimetry is photon detection. We investigate the performance potential of digital silicon photomultipliers (dSiPMs) for high-granularity dual-readout calorimetry, with a focus on timing resolution and photon-counting capabilities. Using detailed simulations, we develop optimized dSiPM specifications tailored for use in fiber calorimeters. These results inform design choices for future detector modules aimed at achieving enhanced time resolution, dynamic range, and reconstruction accuracy.

RDC 8 Quantum & Superconducting Sensors / 95

Axion Search with HAYSTAC Phase III Multi-Rod Cavity Upgrade

Author: Claire Laffan[1]

[1] *Yale University*

Corresponding Author: claire.laffan@yale.edu

QCD axions are doubly motivated due to their ability to comprise dark matter and solve the strong CP problem. This makes them one of the most promising dark matter candidates. Haloscopes are axion detection experiments that use tunable microwave cavities to resonantly enhance signals from the axion-photon coupling that occurs in the presence of a strong magnetic field. Because the haloscope cavity readout is quantum-limited, they are coupled to superconducting readout lines containing low-noise amplifiers. The Haloscope At Yale Sensitive To Axion CDM (HAYSTAC) is the first haloscope to use quantum squeezing to noiselessly amplify its cavity readout. This broadens the sensitivity bandwidth, allowing HAYSTAC to achieve a maximum scan-rate enhancement of 2x. HAYSTAC has placed exclusions on axion parameter space between 4.1 −5.8 GHz (16.96-24.0 μeV) using a cylindrical microwave cavity with a single tuning rod during data-taking Phases I & II. In preparation for Phase III, HAYSTAC is currently upgrading to a multi-rod cavity that can perform high-frequency searches with a high FOM, allowing searches between 5.5-7.3 GHz (22.75-30.19 μeV). This talk will provide an overview of HAYSTAC and the seven-rod cavity design, summarize the testing and commissioning of the new cavity at Yale, as well as discuss outlooks for HAYSTAC Phase III.

RDC 6 Gaseous Detectors / 96

Triple-GEM Characterization for High-Pressure Gas Argon-Based Operation

Author: Tanaz Mohayai[1]

[1] *Indiana University*

Corresponding Author: tmohayai@iu.edu

High-pressure gaseous TPCs provide increased target density while preserving fine charged-particle tracking. This combination can allow for low energy detection thresholds while maintaining event rates suitable for rare-event searches and neutrino experiments, from sub-MeV nuclear recoils to few-GeV neutrino interactions. In alignment with an RDC 6 priority—developing gas amplification structures for challenging environments—this talk presents experimental results from ongoing studies of triple-GEM performance in argon-based mixtures at the GORG (GEMs Over-pressured with Reference Gases) test stand at Fermilab. Measurements are being carried out over multiple gas admixtures and voltage configurations, with pressure scans taken in steps from 1 atm toward the upper range for which the test stand is rated, 10 atm. These measurements aim to help define viable design envelopes for charge amplification in conditions where higher voltages are required, and to inform future optimization of MPGDs in high-pressure gaseous detectors.

Poster / 97

LAr Purification and Purity Monitoring System at Wellesley College

Author: Wenzhao Wei[1]

Co-authors: I-see Warisa Jaidee [1]; James Battat [1]; Jonathan Asaadi [2]; Spencer Dockal [1]

[1] *Wellesley College*

[2] *The University of Texas at Arlington*

Corresponding Author: ww102@wellesley.edu

We report results from a 12-liter liquid argon test stand at Wellesley College. The system includes a single-pass liquid argon purifier, a double-gridded purity monitor to assess the electron lifetime, and a slow control and data acquisition system. This purifier will support ongoing detector R&D on charge and light readout technologies for future large-scale liquid argon time projection chambers (LArTPCs) such as Q-Pix and other cold electronics systems. We will present the design, construction, and operation of the test stand, along with initial performance results, including measured O2-equivalent impurity level of 0.4 ppb, corresponding to an electron lifetime of 800 us at a 500 V/cm drift field.

Poster / 98

CHARMS250: A Cryogenic Front-End ASIC for Low-Noise Readout of Charge or Light Signals

Author: Prashansa Mukim[1]

Co-authors: Chao Zhang [1]; Dominik Gorni [1]; Gabriella Carini ; Giovanni Pinaroli ; Grzegorz Deptuch [1]; Hucheng Chen [1]; Niccolo' Gallice [1]; Piotr Maj [1]; Sergio Rescia [1]; Shanshan Gao [1]; Soumyajit Mandal [1]

[1] *Brookhaven National Laboratory*

Corresponding Authors: pmaj@bnl.gov, gpinaroli@bnl.gov, smandal@bnl.gov, czhang@bnl.gov, carini@bnl.gov, dgorni@bnl.gov, ngallice@bnl.gov, gdeptuch@bnl.gov, rescia@bnl.gov, pmukim@bnl.gov, hucheng.chen@cern.ch, sgao@bnl.gov

In this talk, we will present CHARMS250V1, a cryogenic front-end application specific integrated circuit (ASIC) developed using a 65 nm process for low-noise readout of charge or light signals produced in noble liquid detectors. The design of CHARMS250V1 has evolved from the LArASIC chip, which was manufactured in a 180 nm process and has been selected as the first component in the 3-ASIC readout solution for Phase I of the Deep Underground Neutrino Experiment (DUNE). CHARMS250V1 is designed to operate at temperatures ranging from room temperature (RT) down to liquid nitrogen temperature (LNT), i.e., 77 K. It comprises of a single channel containing pre-amplification and pulse shaping stages that provide charge gain programmable in the range of ˜ 4–25 mV/fC, peaking time programmable between 250 ns and 2 μs, and programmable baseline of either 200 mV or 900 mV for processing of unipolar and bipolar signals, respectively. CHARMS250V1 is the first prototype of this design that has been submitted for fabrication, prior to the design of the full 16-channel ASIC.
CHARMS250V1 also features enhanced digital programmability of all bias voltages and currents through 7-bit digital-to-analog converters (DACs), improving its robustness for operation at a wide range of temperatures ranging between RT and LNT. Global and channel registers used to set operational conditions of CHARMS250V1 are programmed through a two-wire I2C interface. Applications for CHARMS250V1 include light/charge readout of the Far Detector (FD) 3/4 in Phase II of DUNE, charge readout in the future circular lepton collider (FCC-ee), light readout in nEXO, and the silicon-based active target and liquid xenon calorimeters in PIONEER.

RDC 4 Readout & ASICs / 99

A Smart Readout ASIC with Digital Signal Processing and Machine Learning Integrated into the Front-End

Author: Prashansa Mukim[1]

Co-authors: Dominik Gorni [1]; Grzegorz Deptuch [1]; Jack Fried [1]; Piotr Maj [1]; Shinjae Yoo [1]; Shubha Kharel ; Soumyajit Mandal [1]; Yihui Ren [1]

[1] *Brookhaven National Laboratory*

Corresponding Authors: jfried@bnl.gov, yren@bnl.gov, pmaj@bnl.gov, gdeptuch@bnl.gov, dgorni@bnl.gov, sjyoo@bnl.gov, smandal@bnl.gov, pmukim@bnl.gov

The explosive growth in data rates being seen by next-generation detectors calls for transformative solutions that integrate intelligence at the edge. In this talk, we will present a smart readout application specific integrated circuit (ASIC) that incorporates advanced digital signal processing (DSP) and artificial neural networks (ANNs) directly into the detector front-end. By leveraging high-level synthesis for the DSP circuitry and custom RTL design for the ANNs, we co-optimize multi-layer perceptrons (MLPs) for regression and classification tasks, including amplitude estimation and pulse shape discrimination. A stochastic rounding technique ensures convergence of training with quantized weights, enabling deployment of compact AI models on-chip. This tight integration of DSP and machine learning in front-end electronics opens the door to real-time feature extraction and low-latency edge processing, leading to improved energy-efficiency and reduction in data transmission rates to further data acquisition systems.

Poster / 100

Integrated Electro-Photonic Graph Neural Networks (GNNs) for Charged Particle Tracking

Author: Prashansa Mukim[1]

Co-authors: Fu-Wei Hong ; Gabriella Carini ; Grzegorz Deptuch [1]; James Ang [2]; Jesun Firoz [2]; Oceane Bel [2]; Piotr Maj [1]; Soumyajit Mandal [1]

[1] *Brookhaven National Laboratory*

[2] *Pacific Northwest National Laboratory*

Corresponding Authors: fhong@bnl.gov, gdeptuch@bnl.gov, pmukim@bnl.gov, smandal@bnl.gov, carini@bnl.gov, pmaj@bnl.gov

In this talk, we will present our on-going work on the co-design of integrated electro-photonic Graph Neural Networks (GNNs) for real-time charged particle tracking, as part of the El-Pho project within the MEERCAT microelectronics science research center (MSRC). GNNs are a natural fit for particle track reconstruction due to their ability to efficiently process the sparse and irregular data produced by tracking detectors. Our approach emphasizes a hardware-software co-design methodology, including novel techniques for optimal partitioning of hardware between electronic and photonic components, to exploit the low-latency, high-bandwidth and energy-efficiency of integrated photonics. We evaluate our GNN architectures using publicly available physics-based tracking datasets and benchmarks, laying the groundwork for next-generation intelligent detector systems for high-energy physics experiments.

RDC 2 Photodectors / 101

Recent Advances in Lead-free MCPs Functionalized by ALD for Photomultiplier Tubes

Author: Cole Hamel[1]

Co-authors: Alexey Lyashenko [1]; Anton Tremsin [2]; Jeffrey Elam [3]; Mark Popecki [1]; Matt Grden [1]; Melvin Aviles [1]; Michael Minot [1]; Oswald Siegmund [2]; Stefan Cwik [1]; Travis Curtis [2]

[1] *Incom. Inc.*

[2] *UC Berkeley, Space Science Laboratory*

[3] *Argonne National Laboratory*

Corresponding Authors: mjm@incomusa.com, astr@berkeley.edu, jelam@anl.gov, ossy@berkeley.edu, tcurtis@berkeley.edu, map@incomusa.com, chamel@incomusa.com, alyashenko@incomusa.com, scwik@incomusa.com

Microchannel Plates (MCPs) are utilized for applications ranging from image intensifier tubes and photomultiplier tubes to mass spectrometry and electron microscopy, offering ultra-fast timing and high gain. Conventional lead-glass MCPs have been the industry standard since the 1960s. The manufacturing process includes a hydrogen firing step to reduce the lead oxide surface in the pores, bringing the MCP to target resistance and generating the electron emission layer at the same time. This functionalization limits the adjustability of the MCP for target applications.

Incom, Inc. has commercialized ALD-GCA-MCP technology, applying Atomic Layer Deposition (ALD) technology from Argonne to Incom's Glass Capillary Arrays (GCAs) to produce MCPs. Incom's physically and chemically robust silicate glass allows the fabrication of large area GCAs up to 203 x 203 mm and even unconventional form factors such as curved MCPs (see image below). In addition, the high resistance of the GCAs enables functionalization with ALD, creating separate resistive and emissive layers. The tunable resistive layer defines most electrical characteristics of the MCP, serving as a strip layer to recharge the emissive layer. The emissive layer comprises a high secondary electron yield (SEY) material such as MgO or Al2O3 to provide maximum gain for intensifier applications.

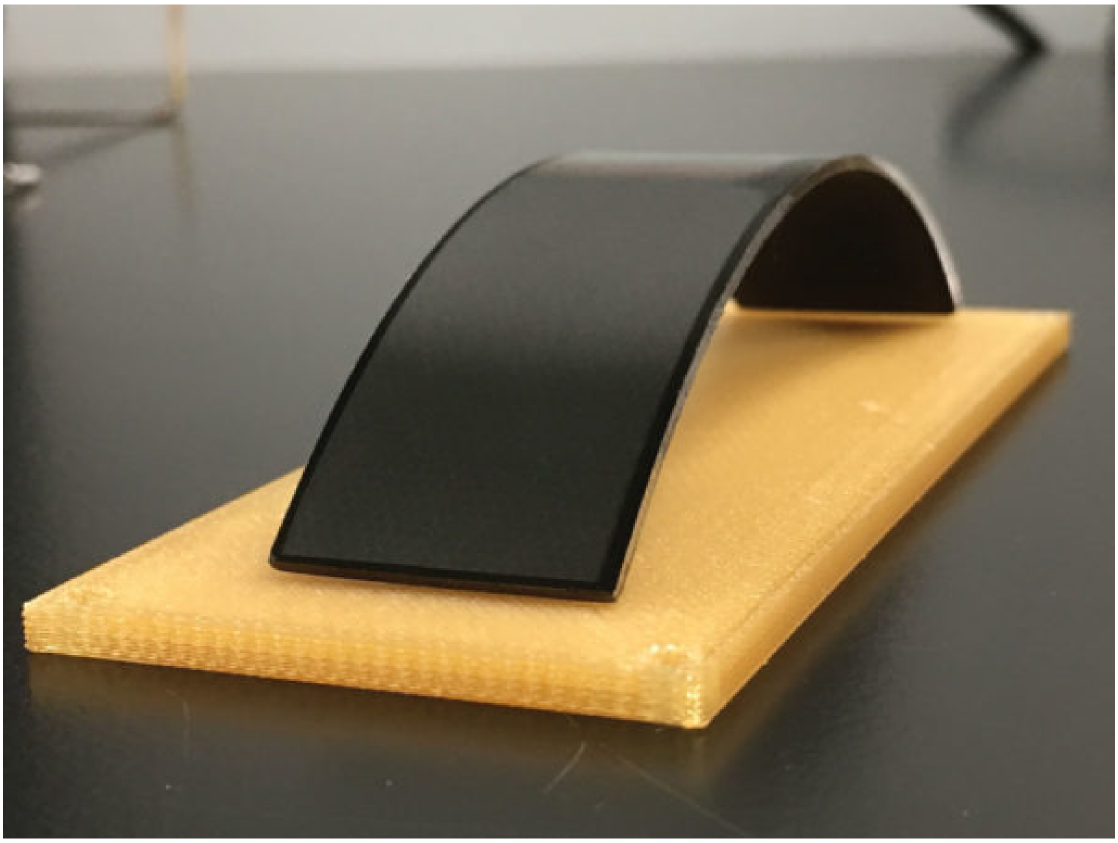


Figure 1: Curved ALD-GCA-MCP

Incom's 1st generation ALD-GCA-MCPs rely on the combination of Chem-1 and MgO, which provides high gain for both sealed PMTs and open MCP applications. While both the high gain and the durability of Chem1-MgO MCPs meet the standards of conventional MCPS and MCP-PMTs, further development work was needed to improve the thermal coefficient of resistance (TCR) and the after-pulse rate.

To this end, Chem5, an alternative resistive layer, was transferred from Argonne to Incom to enable the fabrication of improved ALD-GCA-MCPs that were halide free and boasted superior performance. The optimization of Chem5-MgO MCPs enabled upscaling to 108x108mm format, used in Incom's 10 cm detector, the High Rate Picosecond Photodetector (HRPPD). The TCR of the current version of Chem5-MgO is -0.03 K-1, worse than the -0.02 K-1 achieve with Chem1-MgO. However, as a resistive coating, Chem5 revealed extraordinary current stability with over 1 mA of current measured for a chevron pair of 33 mm Chem5-MgO MCPs at 150 ℃ (0.8 MΩ in operation at 1 kV), exceeding the performance of both Chem1 and conventional MCPs. The high current stability reduces the risk of thermal runaway despite a higher TCR.

After-pulse rates of MCPs are related to molecules, most commonly water, adsorbed to the surface within the pores. Certain surface chemistries are more prone to this adsorption. Chem5-MgO has demonstrated high adsorption rates, but also the ability to desorb water through bakeout, yielding a more pure surface layer.

Chem5-MgO MCPs were integrated in HRPPDs to determine performance in a sealed environment. The end result was a significant improvement in gain, reducing the operational voltages from 850 V to 650 V per MCP. In 2025, Incom Inc. is transitioning the 203x203mm Large Area Picosecond Photodetector (LAPPD) to 2nd generation Chem5-MgO MCPs.

RDC 8 Quantum & Superconducting Sensors / 102

High Energy Particle Detection with Large Area Superconducting Microwire Array

Authors: Adi Bornheim[1]; Artur Apresyan[2]; Boris Korzh[None]; Christina Wenlu Wang[2]; Claudio Ariel San Martin Valenzuela[3]; Cristian Pena[2]; Emanuel Knehr[None]; Jamie Luskin[None]; Lautaro Narváez[None]; Maria Spiropulu[4]; Matias Barria[5]; Matthew Shaw[None]; Sahil Patel[None]; Si Xie[1]; Valentina Vega[None]

[1] *California Institute of Technology (US)*

[2] *Fermi National Accelerator Lab. (US)*

[3] *Federico Santa Maria Technical University (CL)*

[4] *California Institute of Technology*

[5] *Universidad Tecnica Fedirico Santa Maria*

Corresponding Authors: adolf.bornheim@cern.ch, christina.wenlu.wang@cern.ch, artur.apresyan@cern.ch, smaria@caltech.edu, mat.barrial@gmail.com, claudio.sanmartinval@gmail.com, si.xie@cern.ch, cmorgoth@fnal.gov

Superconducting Nanowire Single Photon Detectors (SNSPDs) are a leading detector technology for single-photon detection with diverse applications, due to their ultra-low energy threshold of below 0.04~eV, low dark counts of 10^-5~Hz, and pico-second level time resolution. Recent advancement in the fabrication of large area superconducting microwire single photon detectors (SMSPDs) make them an ideal photo sensor to detect single photons in dark matter detection experiments and a potential innovative detector technology for future accelerator-based experiments.

In this talk, we present the first detailed study of an 8-channel 2×2~mm^2 WSi SMSPD array exposed to 120~GeV proton beam and 8~GeV electron and pion beam at the Fermilab Test Beam Facility. The SMSPD detection efficiency was measured for the first time for protons, electrons, and pions, enabled by the use of a silicon tracking telescope that provided precise spatial resolution of 30~\um for 120~GeV protons and 130~\um for 8~GeV electrons and pions. Time resolution of 1.15~ns was measured for the first time for SMSPD with proton, electron, and pions, enabled by the use of an MCP-PMT which provided a ps-level reference time stamp.

We will also present our future plan to measure the SNSPD hit detection efficiency and beam-induced background more precisely by improving the SNSPD characterization system, to simulate the interactions between charged particles and SNSPD to refine the current physics models, and finally to optimize the SNSPD sensors for high energy particle detection.

RDC 3 Solid State Tracking / 103

InAs/GaAs Semiconductor Quantum Dot Scintillation Detector: Real and Projected Performance for 4D Tracking

Authors: Gyana Biswal[1]; Michael Hedges[2]; Michael Yakimov[1]; Pavel Murat[2]; Serge Oktyabrsky[1]

[1] *University at Albany*

[2] *Fermilab*

Corresponding Authors: mhedges@fnal.gov, soktyabrsky@albany.edu, gbiswal@albany.edu, murat@fnal.gov

The high speed and efficiency of the novel semiconductor InAs/GaAs quantum dot (QD) scintillator make it a promising alternative competitor to direct-ionization drift detectors for 3D tracking and other high-energy physics and medical applications. In this detector, self-assembled epitaxial QDs serve as artificial luminescent centers, converting the kinetic energy of incoming charged particles into photons, which are then collected by a monolithically integrated p-i-n photodiode. Starting with evaluating the expected performance of the scintillation tracking detector and comparing it to a prospective Si LGAD tracker, we identify key physical factors, such as device thickness, QD radiative efficiency and waveguiding losses, that govern the detector's time resolution.
Recent measurements on a 26-micron-thick scintillator demonstrated a yield of 34000 electrons/MeV (or 14% of the achievable maximum), an energy resolution of 4.4%, and decay time 270 ps, resulting in a time resolution of 20 ps for 4.5 MeV deposited energy. Timing performance can be improved in thicker detectors (unlike drift-based counterparts) and at higher efficiency. A recently observed hybrid response, where the ionization track is shared between the scintillator and a few-micron-thick photodiode, achieved over 60000 electrons/MeV yield and enabled detection of 60 keV photons. Consequently, the expected tracking performance under hybrid response was evaluated. Radiation hardness was assessed using a 1.5 MeV proton beam at 10^{14} protons/cm^2, corresponding to equivalent 1 Mev neutron fluence of 2×10^{15} cm^{-2}.

Poster / **104**

High-Voltage Phonon-Focusing Detector with Spectral Filtering for Sub-eV Nuclear Recoil Discrimination

Authors: Gerardo Gonzalez[1]; Nader Mirabolfathi[1]

[1] *Texas A&M University*

Corresponding Authors: mirabolfathi@physics.tamu.edu, gonzal23@tamu.edu

We present a new cryogenic detector concept that exploits anisotropic phonon focusing in high-purity Ge or Si crystals, combined with high-voltage Luke amplification and phonon spectral filtering, to achieve nuclear recoil (NR) and electronic recoil (ER) discrimination down to ~1 eV recoil energies. The detector is oriented so that ballistic longitudinal phonons from an event are concentrated by crystal anisotropy into a well-defined caustic on the surface, where a single, ultra-low-capacitance quasiparticle-trap-assisted TES (QET) with high-gap superconducting fins is placed to preferentially capture the high-frequency prompt phonons. The opposite face, instrumented with a conventional CDMS-style QET array using lower-gap fins, also serves as the high-voltage electrode and is optimized to absorb softer, late-arriving Luke phonons.

Nuclear recoils produce a larger fraction of prompt ballistic phonons collected at the focusing hot spot, while electronic recoils generate more late Luke phonons predominantly absorbed by the base. By combining spatial selectivity from phonon focusing with frequency selectivity from superconducting gap engineering, and exploiting the strong bias dependence of the ER Luke component, timing differences and spectral partition between the two faces provide robust NR/ER separation without ionization readout.

This concept directly addresses the challenge of achieving background discrimination at the eV scale, a critical threshold for detecting low-mass dark matter and coherent elastic neutrino-nucleus scattering (CEvNS). Simulations indicate that with <111> orientation, accurate sensor placement, and 50–150 V bias across a 1 cm crystal, discrimination is achievable for individual events. The approach builds on phonon-based detector technologies developed for CDMS but adds the new capability of phonon "color"discrimination and optimized geometry for focusing, representing a significant step toward single-electron sensitivity with phonon-only readout.

Poster / 105

ArCS: A Magnetized LArTPC in a Test Beam

Authors: Angela Fava[1]; Claudio Montanari[2]; Geoffrey Savage[2]; Giulia Cicogna[3]; Jiaoyang Li[2]; Marco Del Tutto[4]; Mônica Nunes[5]; Ornella Palamara[4]

[1] *Fermi National Accelerator Lab. (US)*

[2] *FNAL*

[3] *University of Bologna*

[4] *Fermilab*

[5] *UNICAMP*

Corresponding Authors: palamara@fnal.gov, mdeltutt@fnal.gov, savage@fnal.gov, claudio.montanari@cern.ch, monisnunes@gmail.com, giulia.cicogna@studio.unibo.it, jiaoyang@fnal.gov, angela.fava@cern.ch

Over the past few decades, Liquid Argon Time Projection Chambers (LArTPCs) have emerged as a central technology for rare-event detection, due to their calorimetric and imaging capabilities. Adding a magnetic field to LArTPCs would enable charge identification and momentum measurements via curvature. For neutrino experiments, this is crucial for wrong-sign neutrino rejection, electron/positron and electron/photon discrimination, and improved momentum reconstruction. The ArCS (Argon detector with Charge Separation) experiment at Fermilab's Test Beam Facility will place a $47\times40\times90$ cm³ LArTPC inside a 0.7 T magnet to: (i) establish charge sign discrimination for electrons and positrons, (ii) reconstruct particle momenta via curvature, and (iii) determine the minimal magnetic field needed for these measurements. This poster will present the project status, with updates on installation and simulations of expected performance.

RDC 4 Readout & ASICs / 106

LArPix Pixelated Charge Readout System

Author: Brooke Russell[1]

Co-authors: Armin Karcher [2]; Carl Grace [2]; Cecilia Ferrari [1]; Cynthia McNulty [2]; Daniel Dwyer [2]; Jaafar Chakrani [2]; Kevin Wood [2]; Matthew Senesky [2]; Panagiotis Zarkos [2]; Stephen Greenberg [2]; Tarun Prakash [2]

[1] *Massachusetts Institute of Technology*

[2] *Lawrence Berkeley National Laboratory*

Corresponding Authors: sgreenberg@lbl.gov, kwood@lbl.gov, crgrace@lbl.gov, tprakash@lbl.gov, russell3@mit.edu, arkarcher@lbl.gov, mksenesky@lbl.gov, dadwyer@lbl.gov, jchakrani@lbl.gov, panzark@lbl.gov, cmcnulty@lbl.gov, ferraric@mit.edu

LArPix is an end-to-end pixelated charge readout system for 3D imaging at the millimeter-scale in multi-tonne liquid argon time-projection chambers (LArTPCs). Leveraging large-scale commercial fabrication techniques, the system is designed to be highly scalable and robust, enabling low-cost quick-turn system production at industry standard. The system is based on the LArPix ASIC, a cryo-compatible, low-power detector system-on-a-chip composed of 64 input channels. The analog front-end on each channel includes an integrating charge-sensitive amplifier, a tunable discriminator, and a 10-bit successive approximation register analog-to-digital converter. A digital core is shared across all ASIC channels, time-stamping and buffering event data, as well as creating a configurable chip-to-chip network. LArPix performance using prototype detectors at the 10ˆ5 channel scale will be presented, and progress on design of 10ˆ7-10ˆ8 channel systems will be discussed.

RDC 8 Quantum & Superconducting Sensors / 107

Towards long-distance phase coherence for large-area quantum sensors.

Authors: Andrew Cameron[1]; Claire Ellison[2]; Prathwiraj Umesh[2]; Raju Valivarthi[2]; Michael Bregar[2]; Si Xie[3]; Cristian Pena[3]

[1] *Fermi National Accelerator Laboratory*

[2] *Caltech*

[3] *Fermi National Accelerator Lab. (US)*

Corresponding Authors: mbregar@caltech.edu, rajuval@caltech.edu, acameron@fnal.gov, cmorgoth@fnal.gov, ellison@caltech.edu, sxie@fnal.gov, pumesh@caltech.edu

Quantum sensors connected with optical fiber can effectively cover large areas and provide phase coherence between distant experiments by transmitting entangled photons through phase stable links. These sensors have applications in gravitational wave detection and km-long wavelength axion detection. Optical phase stability presents experimental challenges in deployed fibers where vibrations and temperature fluctuations are present and difficult to suppress. In this work, we present our recent efforts on phase instability analysis and phase stabilization through FPGA-run feedback loops across Fermilab campus.

RDC 8 Quantum & Superconducting Sensors / 108

On-Sky Demonstration of a Superconducting Filter Bank Spectrometer on SPT-SLIM

Authors: Cyndia Yu[1]; SPT-SLIM Collaboration[None]

[1] *UChicago/ANL*

Corresponding Author: cyndia.yu@anl.gov

We present initial on-sky observation data from superconducting mm-wave filter bank spectrometers on the South Pole Telescope Shirokoff Line Intensity Mapper (SPT-SLIM). The SPT-SLIM experiment is designed to measure redshifted carbon monoxide (CO) line emission from galaxies at $0.5 < z < 2$. It was first deployed during the 2024-2025 Antarctic summer for a commissioning and two-week observing campaign on the South Pole Telescope, a high-resolution platform for mm-wave observations. The on-chip spectrometer filter bank couples a superconducting microstrip bank of narrowband filters from 120-180 GHz to an array of microwave kinetic inductance detectors (MKIDs) for a compact design intended to scale to large-scale line-intensity mapping (LIM) experiments. We discuss the detector design, laboratory characterization, and preliminary performance from this initial campaign, and discuss prospects for future LIM observations with the compact filter bank spectrometer technique.

Cross-Cutting Topics / 109

Modern Electronics Education with AI/ML and FPGA

Author: Keisuke Yoshihara[1]

[1] *University of Hawaii at Manoa*

Corresponding Author: kyoshiha@hawaii.edu

PHYS476 at the University of Hawaiʻi at Mānoa is an upper-division course that teaches modern electronics through real-world applications in experimental physics. Students gain hands-on experience

with digital circuit design, FPGA programming, and AI/ML techniques for real-time data analysis, combining laboratory work with targeted lectures.

The course centers on project-based learning. Using the hls4ml framework and Vitis HLS, students design and optimize neural networks, then deploy them on FPGA hardware. For their final project, they choose between waveform signal processing or 2D fast tracking, both modeled after realistic use cases in particle and nuclear physics.

By testing their designs through simulation and FPGA hardware implementation, students develop skills in reproducibility, hardware–software integration, and real-time verification. This approach not only strengthens their preparation for academic research but also addresses workforce development needs in AI/ML hardware, equipping graduates with expertise that is increasingly in demand across science and technology sectors.

RDC 8 Quantum & Superconducting Sensors / 110

Quantum Charge Sensing with cCPT Amplifiers for Modular Rare-Event Detectors

Author: Caleb Fink[1]

Co-authors: Jadyn Anczarski [2]; Juliang Li [3]; Noah Kurinsky [4]; arran phipps [5]

[1] *Syracuse University*

[2] *Stanford University*

[3] *University of Chicago*

[4] *SLAC/Stanford*

[5] *CSU East Bay*

Corresponding Authors: arran.phipps@csueastbay.edu, kurinsky@slac.stanford.edu, janczar@stanford.edu, juliangli@uchicago.edu, cwfink@syr.edu

The development of quantum-limited charge amplifiers is enabling new classes of detectors for rare-event physics, with applications in low-mass dark matter and CEvNS. We report on recent progress in the development of a cavity-coupled Cooper pair transistor (cCPT) amplifier, designed to achieve sub single-electron sensitivity while remaining modular and detector-target agnostic. Building on joint work with SLAC, LANL, U Chicago, and Syracuse, our approach combines qubit-derived electrometers with high-impedance resonators, enabling integration with low-capacitance solid-state detectors. I will discuss the design, initial cryogenic testing, and projected coupling to narrow-bandgap semiconductors under development. This charge sensing platform can serve both as a standalone low-threshold ionization detector and as a flexible backend for hybrid charge/phonon devices. I will also briefly describe ongoing work on SQUATs, a transmon-based phonon sensor using a similar architecture, targeting single meV phonon sensitivity.

RDC 8 Quantum & Superconducting Sensors / 111

Accurate Phonon Transport Across Interfaces in G4CMP for sub-eV Detector Simulations in the BeEST Experiment

Author: Caitlyn Stone-whitehead[1]

[1] *Colorado School of Mines*

Corresponding Author: cstonewhitehead@mines.edu

The BeEST experiment searches for physics beyond the standard model (BSM) in the neutrino sector by measuring the recoiling daughter from the electron capture (EC) decay of 7Be. The 7Be is embedded in superconducting tunnel junction (STJ) sensors such that the low-energy (eV-scale) decay products are detected with sub-eV energy resolution. Modelling of low-energy backgrounds in the SiO2/Si substrate as well as phonon-mediated quasiparticle interactions in the STJs themselves is crucial to understanding potential physics beyond the Standard Model (BSM). In order to model these effects using the G4CMP toolkit, phonons transport across interfaces must be included. In this talk, recent development efforts to provide accurate phonon refraction across interfaces will be discussed as well as validation efforts. To ensure a low background environment for the BeEST, as well as other experiments utilizing low threshold detectors, the Colorado Underground Research Institute (CURIE) is a new shallow-underground laboratory located at the Edgar Experimental Mine. CURIE offers a testbed for the development of superconducting qubits and novel detector technologies, as well as for studying backgrounds relevant to rare-event searches, such as those for dark matter and neutrinoless double-beta decay. We welcome new collaborations and users for this facility.

The BeEST experiment is funded by the Gordon and Betty Moore Foundation (no. 10.37807/GBMF11571); the US Department of Energy, Office of Science, Office of Nuclear Physics, under award nos. DE-SC0021245 and SCW1758; the LLNL Laboratory Directed Research and Development program through grant nos. 19-FS-027 and 20-LW-006; the European Metrology Programme for Innovation and Research (EMPIR) project nos. 17FUN02 MetroMMC and 20FUN09 PrimA-LTD; the Natural Sciences and Engineering Research Council (NSERC) in Canada, and the FCT—Fundação para a Ciência e Tecnologia (Portugal)—through national funds in the framework of the project no. UID/04559/2020 (LIBPhys). TRIUMF receives federal funding through a contribution agreement with the National Research Council of Canada. This work was performed under the auspices of the US Department of Energy by LLNL under contract no. DE-AC52-07NA27344. F.P. is funded as part of the Open Call Initiative at Pacific Northwest National Laboratory and conducted under the Laboratory Directed Research and Development Program. Pacific Northwest National Laboratory is a multiprogram national laboratory operated by Battelle for the US Department of Energy.

Poster / 112

Advancements and future expansions of the Caribou DAQ system

Author: Eric Buschmann[1]

Co-authors: Changbum You [2]; Dominik Dannheim [3]; Hucheng Chen [1]; Ilias Kamoisis [4]; Mathieu Benoit [5]; Ryan St-Jean [2]; Shaochun Tang [1]; Simon Spannagel [6]; Thomas Koffas [2]; Tomas Vanat [6]; Younes Otarid [3]

[1] *Brookhaven National Laboratory (US)*

[2] *Carleton University (CA)*

[3] *CERN*

[4] *CERN and Aristotle University of Thessaloniki (GR)*

[5] *Oak Ridge National Laboratory (ORNL)*

[6] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: shaochun.tang@cern.ch, mathieu.benoit@cern.ch, ilias.kamoisis@cern.ch, ryanstjean@cmail.carleton.ca, thomas.koffas@cern.ch, eric.buschmann@cern.ch, changbumyou@cunet.carleton.ca, simon.spannagel@cern.ch, younes.otarid@cern.ch, tomas.vanat@cern.ch, dominik.dannheim@cern.ch, hucheng.chen@cern.ch

Caribou is a versatile data acquisition system used in multiple collaborative frameworks (CERN EP R&D, DRD3, AIDAinnova, Tangerine) for laboratory and test-beam qualification of novel silicon pixel detector prototypes. The system is built around a common hardware, firmware and software stack shared across different projects, thereby drastically reducing the development effort and cost. It consists of a custom Control and Readout (CaR) board and a commercial AMD Zynq System-on-Chip (SoC) platform. The SoC runs a Yocto distribution integrating the custom software framework (Peary) and custom FPGA firmware built within a common firmware infrastructure (Boreal). The CaR board provides a hardware environment providing various resources such as power supplies, slow control interfaces, and high-speed data links for the target detector prototype. Boreal and

Peary, in turn, offer firmware and software environments that enable seamless integration of control and readout for new detector prototypes. While the first version of the system used a SoC platform based on the ZC706 evaluation board, migration to Zynq UltraScale+ platforms is progressing with the finalized support of the ZCU102 and Mercury+ ST1 boards and the ultimate objective of integrating the SoC functionality directly into the CaR board, eliminating the need for separate evaluation boards. This talk describes the Caribou system, focusing on the latest project developments and showcasing progress and future plans across its hardware, firmware, and software components.

RDC 7 Low-Background Detectors / 113

Progress on the HeRALD Experiment

Author: Joanna Wuko[1]

[1] *UMass Amherst*

Corresponding Author: jkwuko@gmail.com

The TESSERACT experiment searches for sub-GeV dark matter with multiple cryogenic target materials and technologies. The HeRALD technology uses superfluid 4He as a target material for dark matter-nucleon scattering. Phonons produced by an atomic recoil trigger the evaporation of 4He atoms into the vacuum. These atoms are then detected calorimetrically using a Transition Edge Sensor (TES) array suspended above the 4He surface. This TES array has a multi-channel readout which allows for the rejection of heat-only events in the sensors themselves. In this talk I will summarize the R&D progress of the HeRALD experiment. Deployment at Modane Underground Laboratory will begin in 2028.

RDC 8 Quantum & Superconducting Sensors / 114

Development of microwave multiplexed readout for athermal phonon TES-based detectors

Authors: John Groh[1]; Rebecca Carney[1]; Tran Tsan[1]

[1] *Lawrence Berkeley National Laboratory*

Corresponding Authors: ttsan@lbl.gov, rcarney@lbl.gov, john.groh@lbl.gov

The scalability of sub-Kelvin superconducting sensors is generally limited by their associated superconducting readout electronics, motivating multiplexing schemes which reduce the system complexity, cost, and thermal load on the refrigerator. Microwave SQUID multiplexing, which inherently has access to ˜100x the operation bandwidth of alternative schemes, is a compelling candidate for future advanced readout. It combines the inherent frequency-division multiplexing capability of kinetic inductance detectors with the ability to independently optimize the sensor array, enabling broad compatibility with a variety of TES and MMC sensors. Here, we report on new work to develop a microwave SQUID multiplexer for sub-eV threshold TES calorimeters suitable for direct detection searches for keV - GeV dark matter. A unique challenge with any readout scheme of such sensors is the avoidance of sub-fW parasitic power dissipated in the TESs, which can saturate them. We describe efforts to model, measure, and mitigate the sources of parasitic leakage in microwave SQUID readout as a first step to developing a scaling path towards a future experiment with thousands of TES sensors.

RDC 8 Quantum & Superconducting Sensors / 115

Enhanced Phonon Collection Efficiency in Aluminum MKIDs with Phonon Reflective Coating

Author: Kungang Li[1]

Co-authors: Xinran Li [2]; Maurice Garcia-Sciveres [3]; Eric Gullikson [1]; Farhad Salmassi [1]; Alp Sipahigil [1]; Aritoki Suzuki [4]; Daniel Yohannes [5]; Zihuai Zhang [6]

[1] *Lawrence Berkeley National Lab*

[2] *Lawrence Berkeley national laboratory*

[3] *Lawrence Berkeley National Lab. (US)*

[4] *Lawrence Berkeley National Laboratory*

[5] *SEEQC*

[6] *UC Berkeley*

Corresponding Authors: kungangli@lbl.gov, asuzuki@lbl.gov, dyohannes@seeqc.com, zihuaiz@berkeley.edu, emgullikson@lbl.gov, mgarcia-sciveres@lbl.gov, fsalmassi@lbl.gov, alp@berkeley.edu, xinranli@lbl.gov

Phonon-sensitive Microwave Kinetic Inductance Detectors (MKIDs) are promising superconducting sensor candidates, offering scalability and lower energy resolution for fundamental physics experiments such as low-mass dark matter direct detection and neutrinoless double beta decay searches. Energy resolution of the sensor to phononic signal can be improved by improving phonon collection efficiency. We demonstrated a method to increase phonon reflectivity at the detector's boundaries by introducing a thin multilayer Si/Mo phonon reflection coating. We developed a microfabrication process to deposit 15 bi-layers of Si/Mo (350 nm thick) on the backside of the silicon substrates with Al MKID sensors. We tuned this reflective coating structure to be effective in the 100–225 GHz phonon frequency range. We did comparative measurements of phonon collection efficiencies between two MKID devices with identical front side MKID design, but one with the reflective coating and one without. We measured the coating's phonon reflectivity is approximately 60%. This presentation will cover the design and fabrication of the coated Al MKIDs and the details of the measurements.

RDC 3 Solid State Tracking / 116

Radiation-Hard Ga_2O_3 Solid-State Detectors for Extreme Environments in High-Energy Physics

Author: Ge Yang[1]

[1] *Department of Nuclear Engineering, North Carolina State University*

Corresponding Author: gyang9@ncsu.edu

The escalating radiation environment at next-generation colliders demands revolutionary advances in detector materials —and Ga_2O_3 emerges as a game-changing candidate poised to redefine innermost solid-state tracking through unparalleled radiation tolerance and thermal resilience. Future high-energy physics experiments will expose tracking layers to particle fluences exceeding 10^{15}–10^{16} n_eq/cm^2, multi-Mrad total ionizing doses, and stringent material budget constraints. Even the most advanced silicon detectors are nearing their fundamental performance limits under these extreme conditions, driving urgent exploration of alternative ultra-wide-bandgap semiconductors.

Ga_2O_3 combines an exceptional ultra-wide bandgap (˜4.9 eV), an extraordinarily high breakdown field (˜8 MV/cm), and intrinsic radiation hardness —enabling ultra-low leakage currents at elevated temperatures and the fabrication of ultra-thin, low-mass detector layers. These characteristics position Ga_2O_3 as an ideal platform for radiation-hard, long-lifetime solid-state tracking sensors capable of reliable operation with significantly reduced cooling demands in the harshest collider environments.

We report new experimental results from multiple Ga_2O_3 detector prototypes, featuring detailed electrical characterization, microstructural analysis, and rigorous ion irradiation testing. Our preliminary data reveal stable high-bias performance and robust structural integrity even after substantial radiation exposure, underscoring Ga_2O_3's potential as a radiation-immune detector material readily integrable with advanced low-noise readout electronics.

This work pioneers a new frontier for HEP tracking detectors, establishing Ga_2O_3 as a strong complement —and potential successor —to established wide-bandgap materials such as diamond and SiC. Our findings highlight the critical and timely need for coordinated R&D efforts to unlock Ga_2O_3's full potential and accelerate its path toward deployment in future collider tracking systems and other extreme-environment instrumentation.

Plenary / 117

Progress of the TESSERACT Dark Matter Experiment

Author: William Matava[1]

[1] *University of California at Berkeley*

Corresponding Author: wmatava@berkeley.edu

The TESSERACT experiment will deploy 3 unique detector modules based on a common transition edge sensor-based readout to search for sub-GeV dark matter. HeRALD will use sensors with silicon or sapphire substrates to image radiative and quasiparticle emission from a target of superfluid helium-4 . SPICE will use sensors fabricated on sapphire and gallium arsenide substrates sensitive to both scintillation and heat signals produced by dark matter scattering within the substrates. Finally, a third module will use silicon or germanium substrates with applied electric fields and simultaneous charge readout. I will give an overview of the status of TESSERACT as we move toward deploying these modules for extended dark matter searches in Modane Underground Laboratory in 2028.

RDC 2 Photodectors / 118

Is lamination the key to large-area, uniform multi-well amorphous Selenium detectors?

Authors: V. A. Chirayath[1]; Iakovos Tzoka[1]; Jonathan Asaadi[1]

[1] *University of Texas at Arlington*

Corresponding Authors: ixt6284@mavs.uta.edu, chirayat@uta.edu, jonathan.asaadi@uta.edu

We present an exploratory idea that allows effective fabrication of large-area amorphous selenium detectors with field shaping multiwell structure. Field shaping multi-well structures consists of well-regions produced by Frisch grids within the amorphous selenium vertical architecture. Such structures are usually produced using complex nanofabrication methods to create pillars on a substrate with metallic films on top of the pillars. The Frisch grids allow to concentrate the field lines within the well region thereby confining the avalanche multiplication process in the well, and thus improves the timing resolution and charge collection efficiency. Such a detector has the promise to reach picosecond timing resolution as shown by a few recent demonstrations. However, the depth over which the avalanche multiplication can occur within the well is limited since the conventional line-of-sight Se deposition clogs the well for depths exceeding ˜2 μm. We propose a laminated multi-well architecture that forms the wells by mating two plates rather than filling deep cavities. Each plate carries the Frisch grid metal electrodes on top edge and the high-k hole-blocking dielectric on all sides. After separate, uniform a-Se deposition on largely open surfaces, plates are aligned (≤±0.5 μm) and perimeter-bonded, if possible, at room temperature with precautions to keep adhesive out

of the active area. The bottom electrode is now grown, completing the multi-well structure. We believe such a laminated gap will yield fields necessary for avalanche and makes a large area multi-well avalanche detector a reality.

SHARED SESSION II / 119

On-sensor regression of particle kinematics

Author: Jennet Elizabeth Dickinson[1]

[1] *Cornell University (US)*

Corresponding Author: jdickins@cern.ch

Next-generation pixel sensors will be sufficiently fine-grained, both in space and time, to determine kinematic properties of a traversing particle by analyzing the resulting charge cluster in a single layer of silicon. Customized machine learning (ML) models based on mixture density networks are capable of extracting track angles and hit positions, as well as uncertainties on these quantities. We compare the performance of ML models of varying complexity and evaluate the promise of each for implementation in hardware. The minimal set of track parameters calculated on-ASIC is sufficiently small to send to the lowest-level hardware trigger of a collider experiment at 40 MHz, promising improvements in physics analyses that are currently limited by this trigger acceptance.

RDC 4 Readout & ASICs / 120

Smartpixels: Developing ASICs for high-energy particle detectors with on-chip neural networks in 28 nm CMOS

Authors: Adam Quinn[1]; Alice Bean[2]; Anthony Badea[3]; Arghya Ranjan Das[4]; Benjamin Parpillon[1]; Benjamin Weiss[5]; Chinar Syal[6]; Corrinne Mills[7]; Cristian Gingu[6]; Daniel Abadjiev[8]; Danush Shekar[9]; David Jiang[10]; Douglas Ryan Berry[1]; Eric You[8]; Farah Fahim[6]; Giuseppe Di Guglielmo[6]; Jennet Elizabeth Dickinson[11]; Jieun Yoo[7]; Karri DiPetrillo[8]; Lindsey Gray[1]; Mark Neubauer[12]; Miaoyuan Liu[13]; Mira Littmann[8]; Morris Swartz[14]; Nhan Tran[1]; Petar Maksimovic[15]; Tom Deline[1]

[1] *Fermi National Accelerator Lab. (US)*

[2] *The University of Kansas (US)*

[3] *University of Chicago (US)*

[4] *Purdue University West Lafayette*

[5] *Cornell University*

[6] *Fermilab*

[7] *University of Illinois Chicago*

[8] *University of Chicago*

[9] *University of Illinois Chicago (US)*

[10] *University of Illinois Urbana-Champaign*

[11] *Cornell University (US)*

[12] *Univ. Illinois at Urbana Champaign (US)*

[13] *Purdue University (US)*

[14] *Johns Hopkins University (JHU)*

[15] *Johns Hopkins University (US)*

Corresponding Authors: gdg@fnal.gov, gingu@fnal.gov, miaoyuan.liu@cern.ch, cmills10@uic.edu, mslittmann@uchicago.edu, danush.shekar@cern.ch, karri.folan.di.petrillo@cern.ch, douglas.ryan.berry@cern.ch, aquinn@fnal.gov, anthony.badea@cern.ch, bw539@cornell.edu, youeric@uchicago.edu, abean@ku.edu, petar.maksimovic@cern.ch, lindsey.gray@cern.ch, davidgj2@illinois.edu, jyoo49@uic.edu, jdickins@cern.ch, dabadjiev@uchicago.edu, morris.swartz@cern.ch, bparpill@fnal.gov, farah@fnal.gov, ntran@fnal.gov, msn@illinois.edu

Fine-granularity trackers have the potential to enhance high-priority physics in challenging environments of future high-energy experiments. This requires intelligent ways to overcome the strict bandwidth and power constraints of the detector. As part of the Smartpixels project, we have been developing and testing radiation-hard ASICs fabricated using a 28 nm CMOS process with on-chip neural networks, which can enable data-reduction using single-layer hit information. In particular, we have implemented a filtering neural network informed by prior simulation and algorithm development, capable of classifying the transverse momentum of incident particles based on the charge clusters they deposit in the sensors. Preliminary results of the ASIC characterization and the on-chip neural network performance will be presented. Ongoing studies will seed further algorithm and hardware development efforts, improving performance and validating this approach for future experiments.

RDC 7 Low-Background Detectors / 121

The KIPM Detector Consortium

Author: Dylan Temples[1]

[1] *Fermilab*

Corresponding Author: dtemples@fnal.gov

A Kinetic Inductance Phonon-Mediated (KIPM) Detector is a microcalorimeter that leverages kinetic inductance detectors (KID) to read out phonon signals from the device substrate. They are an attractive architecture for low-threshold rare-event searches. We have established a consortium comprising university and national lab groups dedicated to advancing the state of the art in these detectors. The ultimate goal of this consortium is to deploy a detector of kg-scale target mass and sub-eV energy threshold for direct detection of dark matter with masses below 10 MeV$/c^2$, necessitating meV-scale energy resolution. While these detectors have yet to achieve the resolution attained by transition-edge sensors (TES), our consortium has recently demonstrated a sensor resolution (*i.e.*, resolution in the quasiparticle channel) of 2.1 eV, the current record for such devices. The meV-scale energy resolution can be achieved in KIPM detectors by: (1) reducing the intrinsic detector noise including the two-level-system (TLS) noise, amplifier noise, and generation-recombination (GR) noise; and (2) improving total efficiency to $\approx 30\%$, as demonstrated with TES-based detectors, limited by the phonon pair breaking efficiency. Both low noise and high efficiency can be achieved by implementing quasiparticle trapping with aluminum absorbers and low-T_c inductors. Our consortium brings together experts in KID design, phonon and quasiparticle dynamics, and noise modeling, along with specialized fabrication facilities, test platforms, and unique calibration capabilities. In this talk, I will provide an overview of the consortium and its capabilities, discuss recent results from our member groups focusing on our observed pulse shapes and phonon dynamics, and present projections for realizing our goal.

Poster / 122

Event-Driven Readout: Key to Next-Generation Granular Detectors and AI-Integrated Processing in HEP and NP

Authors: Dominik Gorni[1]; Grzegorz Deptuch[2]; Piotr Maj[1]

[1] *Brookhaven National Laboratory*

[2] *Brookhaven National Laboratory (US)*

Corresponding Authors: pmaj@bnl.gov, grzegorz.wladyslaw.deptuch@cern.ch, dgorni@bnl.gov

Future high-energy physics (HEP) and nuclear physics (NP) experiments will depend on increasingly granular, low-mass tracking and vertex detectors to achieve unprecedented spatial and temporal resolution. This segmentation trend imposes strict requirements on readout integrated circuits (ROICs): amplification, filtering, amplitude and timing extraction, and higher-level feature analysis must fit within minimal silicon area, operate with ultra-low power dissipation, and minimize interference.

Traditional frame-based or polling-based readout architectures introduce dead time, waste bandwidth on empty or redundant data, and increase power consumption—limiting their scalability for next-generation systems. The also disallow intrinsic timing resolution that instead of nanoseconds is shifted into microseconds scale in the frame-based readout systems.

Event-Driven Readout (EDR) architectures address these challenges by transmitting only zero-suppressed, time-stamped event data when needed. This eliminates idle bandwidth use, prevents collisions through dynamic arbitration, and ensures latency-free operation. The concept mirrors the biological efficiency of the human eye, which transmits only essential encoded signals from the retina to the brain for parallel processing.

Building on the Segmented, Ionizing Radiation with Event-Notified Acquisition (SIRENA) detector platform and its patented EDWARD (Event-Driven with Access and Reset Decoder) protocol, we present a scalable, collision-free architecture supporting both greedy and non-greedy arbitration schemes. EDWARD requires no pixel-level geo-priority, remains inactive in the absence of events, and preserves data integrity even under high hit rates. Its selective, on-demand readout substantially reduces the power–bandwidth footprint while enabling deployment in large-area detectors.

The architecture supports a range of Address-Event Representation (AER) schemes—from framed readouts to frameless, neuromorphic-inspired designs—allowing adaptation across collider detectors, spectroscopic X-ray systems, nuclear safeguards instrumentation, and distributed radiation monitoring.

We will trace the evolution of readout methods from early X–Y coordinate scanning and token-passing arbitration (e.g., token rings in current LHC detectors) to dynamic frameless implementations. The discussion will integrate lessons from photon science applications and Monolithic Active Pixel Sensor (MAPS)-based collider detectors, where scaling and efficiency demands mirror those of upcoming HEP and NP experiments.

Key advantages of this approach include:

Eliminated continuous clock or strobe distribution, activating readout only in response to actual radiation-induced events.

No built-in pixel-level geo-priority, and zero activity in the absence of events.

Simplified CAD/EDA integration, leveraging standard design flows and industry-proven tools.

Reduced infrastructure overhead, with minimized clock distribution and peripheral routing.

Compatibility with AI-driven, near-sensor processing, enabling real-time pattern recognition and adaptive data reduction.

These attributes make event-driven architectures a critical enabler for the DOE mission in HEP and NP. They also provide a technology transfer bridge to commercial applications in radiation detection, nuclear monitoring, and precision materials characterization. By aligning detector innovation with scalable, low-power electronics, EDR not only advances experimental capabilities but also accelerates the path from lab-developed intellectual property to industrial adoption.

The presentation will be illustrated by multiple animations allowing to absorb better the developed concept.

RDC 6 Gaseous Detectors / 123

Research and Development efforts towards a Carbon-Fiber Wire Drift Chamber

Author: Caden Glenn[1]

Co-authors: Andreas Werner Jung [1]; Ben Pulver [2]; Gino Daniels [2]; Sushrut Karmarkar [2]

[1] *Purdue University (US)*

[2] *Purdue University*

Corresponding Authors: glenn10@purdue.edu, andreas.werner.jung@cern.ch

The future of high energy physics is dependent on advancements in particle colliders, with lepton colliders being one of the more promising avenues. The FCC-ee is one of these options, providing higher luminosities at Higgs mass or top quark anti-top quark production threshold. However, one of the key challenges in FCC-ee detector design is reducing material budget causing adverse effects and improving tracking resolution, particularly in the vertex and tracking detectors. Compared to the current wire chamber standard, gold-coated tungsten, carbon fiber has significantly fewer protons, i.e. Z=6, resulting in a lower radiation length while maintaining thermal mechanical performance requirements. A lower radiation length is expected to improve performance of such a device due to the lower amount of material in the active sensing volume. This work details the initial prototype results, as well as early simulation results for the development of a carbon fiber wire chamber.

RDC 8 Quantum & Superconducting Sensors / 124

Geant4 Condensed Matter Physics Simulations of Kinetic Inductance Phonon-Mediated Detectors

Author: Selby Dang[1]

Co-authors: Zoë Smith [1]; Noah Kurinsky [2]; Ryan Linehan [3]; Dylan Temples [4]; Osmond Wen [5]

[1] *Stanford University/SLAC National Accelerator Laboratory*

[2] *SLAC/Stanford*

[3] *Fermi National Accelerator Laboratory*

[4] *Fermilab*

[5] *Stanford University*

Corresponding Authors: osmondw@stanford.edu, smithzj@stanford.edu, kurinsky@slac.stanford.edu, linehan3@fnal.gov, dtemples@fnal.gov, sqd@stanford.edu

Kinetic inductance phonon-mediated (KIPM) detectors are superconducting microcalorimeters that show promise in applications toward low-threshold rare-event searches. Despite an excellent sensor energy resolution, the overall energy resolution of KIPM detectors is limited by an observed single-percent phonon collection efficiency. Monte Carlo simulations of charge and phonon processes using the Geant4 Condensed Matter Physics (G4CMP) package provide a microphysical picture of KIPM detectors that is not directly accessible through experimental measurements. By comparing these simulations to position-dependent pulsed LED measurements of a KIPM detector, we illustrate the mechanisms of phonon loss that underpin our low phonon collection efficiency. In this talk, we will present simulation results of position-dependent phonon energy collection as well as phonon lifetimes. We will then compare these results to pulsed LED measurements, which were enabled by use of a micro-electro-mechanical system to steer the optical beam over the full footprint of the 2.2 cm $\times$ 2.2 cm silicon chip. We will also illustrate new developments in the G4CMP software package for state-of-the-art modeling of phonon-quasiparticle processes in superconducting thin films.

SHARED SESSION / 125

Q-Pix: Pixelated Charge Readout Design, Prototyping, & Simulation

Author: Kalindi Gosine[1]

[1] *University of Texas at Arlington*

Corresponding Author: kalindi.gosine@gmail.com

Future long baseline neutrino experiments such as the Deep Underground Neutrino Experiment (DUNE) call for the deployment of multiple multi-kiloton scale liquid argon time projection chambers (LArTPCs). Traditional wire-plane technologies present a set of challenges in the construction of the anode planes, the continuous readout of the system required to accomplish the physics goals of proton decay searches and supernova neutrino sensitivity, and the 2D projective reconstruction of complex neutrino topologies.
The Q-Pix concept (arXiv: 1809.10213) is a continuously integrating low-power charge-sensitive amplifier (CSA) viewed by a comparator. When the trigger threshold is met on a clock edge, the comparator initiates a 'reset'transition and returns the CSA circuitry to a stable baseline. This is the elementary Charge-Integrate / Reset (CIR) circuit. The instance of reset time is captured in a 32-bit clock value register, buffers the cycle and then begins again. What is exploited in this new architecture is the time difference between one clock capture and the next sequential capture, called the Reset Time Difference (RTD). The RTD measures the time to integrate a predefined integrated quantum of charge (Q). Waveforms are reconstructed without differentiation and an event is characterized by the sequence of RTDs. This technique easily distinguishes the background RTDs due to 39Ar decays (which also provide an automatic absolute charge calibration) and signal RTD sequences due to ionizing tracks. Q-Pix offers the ability to extract all track information providing very detailed track profiles and also utilizes a dynamically established network for DAQ for exceptional resilience against single point failures.
This talk will present the status of the charge readout design, introduce results from the first ASIC prototype and simulation, and discuss future planned tests.

SHARED SESSION / 127

Stored energy releases: material problem in dark matter search and quantum computing

Author: sergey pereverzev[1]

[1] *LLNL*

Corresponding Author: persev@gmail.com

In advanced detectors, we observe events of stored energy releases, as well as energy accumulation and delayed release dynamics. Spontaneous burst emission of phonons, photons, and quasiparticles produces excess backgrounds in dark matter detectors and correlated quantum errors and decoherence in quantum information devices- in the same way as external particles. These effects are now observed in all common materials used for detectors and qubits, presenting a fundamental condensed matter problem that has not been considered in research programs studying materials for quantum computers. Collaborative research program between HEP, material science, and QIS is required for these fundamental material effects affecting high-priority DOE projects in fundamental science and national security.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLLNL-ABS-2009789

Poster / 128

Delayed backgrounds and charged liquid surface effects in dual-phase detectors.

Author: sergey pereverzev[1]

[1] *LLNL*

Corresponding Author: persev@gmail.com

In advanced detectors, we observe events of stored energy releases, as well as energy accumulation and delayed release dynamics. Spontaneous burst emission of electrons, photons, phonons, and quasiparticles produces excess backgrounds in different dark matter detectors. Accumulation of unextracted charges on the liquid-gas interface in large dual-phase detectors can lead to surface instabilities and suppression of small electron signals extraction.
While we see evidence of surface instabilities, effects of small signal suppression were not checked out by low-energy calibration procedures, which can lead to significant systematic errors in recent papers claiming the detection of solar neutrinos in large dual-phase Xenon detectors.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-2009788

RDC 3 Solid State Tracking / 130

4D Pixel Detector Demonstrator Project

Authors: Ariel Gustavo Schwartzman[1]; Maurice Garcia-Sciveres[2]; Simone Pagan Griso[2]; Timon Heim[2]

[1] *SLAC National Accelerator Laboratory (US)*

[2] *Lawrence Berkeley National Lab. (US)*

Corresponding Authors: mgarcia-sciveres@lbl.gov, timon.heim@cern.ch, simone.pagan.griso@cern.ch, ariel.gustavo.schwartzman@cern.ch

High spatial and temporal resolution detectors will be critical to operate in the conditions created by future colliders. Based on the input from the 4D Tracking detector workshop at SLAC in September 2024 we have derived a proposal for a 4D Pixel detector demonstrator project. The project aims to coalesce multiple current R&D efforts in the US, better understand high precision timing systems holistically, and build a foundation for future targeted R&D to fork off from. The proposal outlines multiple work packages like sensors, front-end readout chip, and data acquisition among others, that when brought together enable the creation of a small scale 4D Pixel detector demonstrator system with the intention to operate as a telescope in a testbeam environment. The component specifications for the first stage are chosen such that the project can deliver a working prototype within the next 3-4 years, heavily leveraging already existing R&D in this area or using current ATLAS and CMS HL-LHC upgrades as a starting point. Initially the project will lean towards requirements set by the Muon collider detector environment, as they have a particular emphasis on 4D tracking, but the second stage of the proposal will encourage more specialized R&D thrusts to emerge from the foundation build during the first stage. A center piece of the project will be the front-end read out ASIC design in 28nm CMOS, for which a design framework shall be established that simplifies integration of new circuits in subsequent design iterations, such as reconfigurable data processing units, AI/ML enabled feature identification, or neuromorphic front-end designs. This presentation will outline the main points of our proposal in an effort to broadcast it to the community and potentially attract further collaborators.

RDC 8 Quantum & Superconducting Sensors / 131

Environmental Engineering of Qubit-Based Detectors

Author: Daniel Molenaar[1]

Co-authors: Arianna Colón Cesaní [2]; Rakshya Khatiwada [3]; Sara Sussman [4]

[1] *Illinois Institute of Technology*

[2] *Northwestern University*

[3] *Fermilab/Illinois Institute of Technology*

[4] *Fermilab*

Corresponding Authors: ariannacoloncesani2028@u.northwestern.edu, rkhatiw@fnal.gov, sarafs@princeton.edu, dmolenaar@hawk.iit.edu

Superconducting qubits offer a promising new platform for detectors as a result of their natural sensitivity to their environment. In recent years superconducting qubits have made huge strides in performance and quality. These devices have already demonstrated exceptional sensitivity for prototype dark matter searches due to their high sensitivity. As qubits achieve higher coherence times, the need for a low background environment becomes critical to realize their full potential as detectors. There is still significant room to optimize the local qubit environment. We have studied qubits in increasingly optimized configurations by monitoring our T1, T2, T2Echo, effective temperature, and single shot fidelity measurements as we've gradually improved our shielding, filtering and thermalization schemes. These general qubit parameters directly impact how intricate of measurement schemes can be deployed. It is through these measurements that qubits are able to perform as high quality sensors. A brief overview of how different backgrounds can effect such qubit devices will be provided followed by the improvements that we observed. We will further discuss the details of effective shielding and how to properly implement some of these important features.

Plenary / 132

Towards 6D Tracking: using fast-timing to determine track position, time, and angles

Author: Victor Turbiner[1]

Co-authors: Ariel Gustavo Schwartzman [1]; Christopher Kenney [2]; Elena Michelle Villhauer [3]; Julie Segal [2]

[1] *SLAC National Accelerator Laboratory (US)*

[2] *SLAC National Accelerator Laboratory (US)*

[3] *The University of Edinburgh (GB)*

Corresponding Authors: kenney@slac.stanford.edu, victur03@slac.stanford.edu, elena.michelle.villhauer@cern.ch, jsegal@slac.stanford.edu, ariel.gustavo.schwartzman@cern.ch

Current and future particle trackers are beginning to incorporate timing measurements as part of the readout electronics. The ATLAS HGTD and CMS MTD timing detectors for the HL-LHC are already capable of sub-50 picosecond-level resolution, and tracking detectors for future colliders such as the muon or 10 TeV hadron colliders will require similar or better levels of time resolution with pixel pitches in the tens of microns.

In this talk we show, using device-level simulations, that if an LGAD-based particle tracker can achieve O(10ps) hit time resolution with a pixel pitch in the tens of microns, we can use the timing information of neighboring pixels to calculate the angle at which the track crosses the detector. This would enable the determination of the angle of a particle track without needing a double-layer, just by using timing information. Furthermore, we show that when fast-timing information is used for track-hit clustering, it is important to be aware of the angle of the track, because it can change timing information by hundreds of picoseconds.

RDC 8 Quantum & Superconducting Sensors / 134

Progress of Qubit-based Sensors for meV Phonon Detection

Author: Brandon Sandoval[1]

Co-authors: Karthik Ramanathan ; Noah Kurinsky [2]; Sunil Golwala

[1] *Caltech*

[2] *SLAC/Stanford*

Corresponding Authors: kurinsky@slac.stanford.edu, karthikr@wustl.edu, golwala@caltech.edu, bsandova@caltech.edu

With decades of null results from direct detection experiments for dark matter with mass above ˜1 GeV, sub-GeV dark matter has become an increasingly compelling alternative. At such masses, we expect meV-scale nuclear recoil energies, where phonons are the dominant energy excitation. Superconducting charge qubits demonstrate sensitivity to single quasiparticle tunneling events, a property that can be exploited to sense phonons from sub-eV energy depositions. We present two qubit-based phonon sensors utilizing this phenomenon: Superconducting Quasiparticle Amplifying Transmons (SQUATs) and Quantum Parity Detectors (QPDs). In both designs, phonons generated from an interaction within the crystalline substrate break Cooper-pairs in the superconducting metal film, increasing the quasiparticle density near the qubit junction, hence increasing the measured tunneling rate across the junction. These devices benefit from inherent multiplexability, non-dissipative operation, and exponential suppression of thermal noise with temperature. Here, we present an overview of device theory and operation, results from the first generation of device testing, and a path towards meV-scale sensitivity.

RDC 8 Quantum & Superconducting Sensors / 135

Toward a meV Kinetic Inductance Phonon-Mediated (KIPM) detector for low mass dark matter searches

Author: Junwen Xiong[1]

[1] *Caltech*

Corresponding Author: xjw@caltech.edu

Dark matter candidates on the mass scale of $\mathcal{O}(10-10^4)\,\mathrm{keV}$ produce $\mathcal{O}(1-10^3)\,\mathrm{meV}$ phonon excitations. Probing these low-mass dark matter candidates requires quantum sensors with meV phonon energy resolution (σ_E). Transition edge sensors (TESs) have achieved the lowest energy threshold so far, with $\sigma_E \sim \mathcal{O}(100)\,\mathrm{meV}$. On the other hand, the kinetic inductance phonon-mediated (KIPM) detectors have demonstrated 2.1 eV absorbed energy resolution ($\sigma_{E_{abs}}$) with a $\mathcal{O}(1)\%$ phonon collection efficiency. This contribution presents a pathway toward building a $\sigma_E \sim \mathcal{O}(1)\,\mathrm{meV}$ phonon-absorber-assisted (PAA) KIPM detector. Specifically, the meV KIPM energy resolution can be achieved by (1) reducing the intrinsic detector noises including the two-level-system (TLS) noise, amplifier noise, and the generation-recombination (GR) noise and (2) improving total efficiency, including the phonon collection efficiency (η_{ph}) and quasiparticle trapping efficiency (η_{trap}), to $\mathcal{O}(30)\%$ limited by the phonon pair breaking efficiency (η_{pb}), as demonstrated in quasiparticle-trap-assisted electrothermal-feedback
transition-edge sensors (QETs). Achieving both low noise and high efficiency requires implementing quasiparticle trapping, using aluminum (Al) absorbers and low T_c inductors, to enable high active Al surface coverage and small inductor volume. Detailed noise studies and efficiency characterization are conducted to predict detector performance. This contribution briefly summarizes the latest PAA-KIPM design, expected detector performance, and fabrication and testing status.

RDC 8 Quantum & Superconducting Sensors / 136

Transmon-based single microwave photon detectors for QCD axion searches in the classical window

Author: Osmond Wen[1]

Co-author: Chaolin Kuo

[1] *Stanford University*

Corresponding Authors: osmondw@stanford.edu, clkuo@stanford.edu

The post-inflationary QCD axion is a sharp BSM theory target that spans a frequency range from 5 to 50 GHz known as the classical window. At these higher frequencies, linear amplifiers as cavity haloscope receivers are severely degraded in sensitivity by the standard quantum limit: $P_{\mathrm{bkgd}} = h\nu\Delta\nu$. For calorimetric measurements, this limit can be evaded through the use of direct photon counting. The background power from thermal photons is $P_{\mathrm{bkgd}} = \bar{n}_{\mathrm{th}} h\nu\Delta\nu = \frac{1}{1-e^{h\nu/kT}} h\nu\Delta\nu$, where $\bar{n}_{\mathrm{th}}$ is the thermal photon population. At mK temperatures, the occupation number can be suppressed by three to four orders of magnitude below 1, providing remarkable enhancement to QCD axion scan rates.

We present on our work to develop a tunable single microwave photon detector (SMPD) that could be used in a cavity haloscope experiment in the 6 to 7 GHz range. The detector architecture is modeled after an existing transmon-based design, initially developed by the Quantronics group at Paris-Saclay University. We describe the design's fundamental working principles, which include four-wave mixing, dispersive readout, and cyclic readout operation. We also detail the effort to make a tunable SMPD from 6 to 7 GHz, chosen to line up with existing high-volume cavity haloscopes (this work is a subproject of the ADMX-VERA R&D working group). Lastly, we report $T_1 = 1.2\,\mu s$ for a prototype device, hypothesize what it may be limited by, and project how this low T_1 will limit overall detector efficiency.

RDC 2 Photodectors / 137

Chemical Deposition of Wavelength Shifting Material p-Terphenyl for Photodetectors in DUNE Phase II FD APEX design

Author: Rado Fanantenana Razakamiandra[1]

Co-authors: Wei Shi [2]; Ciro Riccio [2]; Alex Heindel [1]; Chang Kee Jung [2]; Stone Chou [1]; Uladzislava Yevarouskaya [2]; Clark McGrew [1]; Flavio Cavanna [3]

[1] *Stony Brook University*

[2] *Stony Brook University (US)*

[3] *Fermi National Accelerator Lab. (US)*

Corresponding Authors: chang.jung@stonybrook.edu, wei.shi.1@stonybrook.edu, clark.mcgrew@stonybrook.edu, flavio.cavanna@cern.ch, uladzislava.yevarouskaya@cern.ch, ciro.riccio@cern.ch, radofanantenan.razakamiandra@stonybrook.edu

The Deep Underground Neutrino Experiment (DUNE) is a long baseline neutrino oscillation experiment with a near and far detector complex located ˜1300 km away from each other. DUNE is planned to have four far detectors modules to achieve its physics goals which includes the determination of neutrino mass hierarchy and the measurement of the CP-violating phase in neutrino oscillations.
During Phase I, two far detector modules will be installed, which have been developed by exploiting the ionization charge in a liquid argon time projection chamber (LArTPC) while using the prompt scintillation light for the determination of the t0 of the neutrino interaction in the LArTPC.
For Phase II, an optimization of the light detection system to cover up to 60% of the active volume of the LArTPC is proposed in APEX (Aluminum Profile with Embedded X-ARAPUCA). For this development, a mass production of the light detector modules is needed where the preparation of the first layer of those detectors would occupy most of the time. This layer converts the VUV scintillation light of liquid argon (128 nm) to higher wavelength (˜350 nm) using p-terphenyl or pTP. The pTP

chemical solution deposition presented in this work investigates the possibility of using it during mass production which has the advantage of fast production once automatized.

Poster / 138

Long-Term Performance of VUV-Sensitive Silicon Photomultipliers in Cryogenic Environments for nEXO

Author: Edryd van Bruggen[1]

Co-authors: Andrea Pocar [2]; Hannah Peltz Smalley [3]; Julia Pankowska [3]; Loick Marion [2]; Makayla Bobusia [3]; Marty Tsankov [3]; Nick Yazbek [3]; Noah Jenkins [3]; Priyanka Kachru [4]; Wesley Gillis [5]; Zihan Rao [3]

[1] *University of Massachusetts*

[2] *University of Massachusetts, Amherst*

[3] *University of Massachusetts Amherst*

[4] *Fondazione Bruno Kessler*

[5] *Bates College*

Corresponding Authors: priyanka.kachru@gssi.it, loick.marion@gmail.com, wgillis@bates.edu, mbobusia@umass.edu, pocar@umass.edu, mtsankov@umass.edu, njenkins@umass.edu, ed@edryd.org, nyazbek@umass.edu, zrao@umass.edu, heps1996@gmail.com, jpankowska@umass.edu

The nEXO experiment, a next-generation liquid xenon time-projection chamber enriched to 90% ^{136}Xe, will search for neutrinoless double-beta decay with a projected half-life sensitivity of 1.35×10^{28} years over a 10-year lifespan. Achieving this sensitivity requires high efficiency vacuum-ultraviolet (VUV) silicon photomultipliers (SiPMs) to detect xenon scintillation light at 175 nm, motivating a rigorous characterization of their long-term performance under cryogenic conditions. We present a multi-year study of a single Fondazione Bruno Kessler HD3 VUV SiPM in a kilogram-scale liquid xenon cryostat. This setup allows for the long term characterization of the SiPM through IV curves, detection of single photon events, and measurement of xenon scintillation light. This enables the characterization of SiPM properties such as gain, breakdown voltage, correlated avalanches, and photon detection efficiency across three mediums: vacuum, gaseous nitrogen, and liquid xenon. These conditions directly replicate the nEXO detector environment, providing essential validation of SiPM longevity and performance for the experiment's decade-scale lifetime.

SHARED SESSION / 139

Development of AC-LGAD Detectors for Electron-Ion Collider

Author: Yu Hu[1]

[1] *Lawrence Berkeley National Laboratory*

Corresponding Author: yuhu@lbl.gov

The Electron-Ion Collider (EIC) is a next-generation flagship facility being constructed at Brookhaven National Laboratory to explore the properties of nuclear matter and the strong interaction via electron-proton and electron-ion collisions. In this talk, we will present the latest designs of Time-of-Flight detector systems based on the silicon AC-coupled Low Gain Avalanche Diode (AC-LGAD) technology. Featuring a built-in gain layer and a uniform resistive layer with AC-coupled electrodes, this technology enables simultaneous precision timing (~20–35 ps) and spatial (~20–30 µm) measurements of charged particles. Results from the latest test beam campaigns on detector prototypes, the performance and readiness will be discussed.

RDC 8 Quantum & Superconducting Sensors / 140

Development of Iridium Platinum Bilayer-based Athermal Phonon Detectors

Author: Gensheng Wang[1]

Co-authors: Bruno Serfass [2]; Clarence Chang [1]; Maggie Reed [2]; Marharyta Lisovenko [1]; Matt Pyle [2]; Michael Williams [3]; Roger Ramoni [2]; Thomas Cecil [1]; Valentine Novosad [1]; Vetri Velan [3]; Volodymyr Yefremenko [1]

[1] *Argonne National Laboratory*

[2] *University of California at Berkeley*

[3] *Lawrence Berkeley National Laboratory*

Corresponding Authors: novosad@anl.gov, michaelwilliams@lbl.gov, clchang@anl.gov, mpyle1@berkeley.edu, mlisovenko@anl.gov, maggie_reed@berkeley.edu, gwang@anl.gov, cecil@anl.gov, yefremenko@anl.gov, serfass@berkeley.edu, vvelan@lbl.gov, rkromani@berkeley.edu

A large area superconducting Athermal Phonon Detector (APD), which consists of Aluminum phonon/photon collection fins and Transition-Edge Sensors (TESs), is an advanced particle detection technology which enables light dark matter searches with a sub-eV resolution. While it is well known that a lower transition temperature (Tc) in a TES enhances detection sensitivity, recent experimental data suggest the presence of intrinsic low energy excess background events, which may be associated with stress in the detectors. We have been developing an Ir/Pt bilayer TES and integrating it with Al fins as an ultra-sensitive low-stress APD. The Tc of an Ir/Pt bilayer is tunable down to 20 mK simply by changing the films'relative thicknesses. More importantly, its stress can be independently minimized by controlling film deposition parameters. By fabricating Ir/Pt TESs with varying control parameters, we have conducted experimental studies of the TESs with different film thicknesses, stresses, and transition temperatures. We also integrated Ir/Pt TESs with Al fins to create two types of functional APDs: One has Ir/Pt TESs directly connected to Al fins. Another uses Ir quasiparticle reservoirs between Ir/Pt TESs and Al fins to explore technical paths for increasing quasiparticle collection efficiency from Al fins. Our measurements include superconducting-to-resistive transition profiles, complex impedances for Ir/Pt TES dynamic parameters, I-V curves at a variety of bath temperatures for the thermal properties of Ir/Pt TES, thermal conductance optimization of APDs, stress-induced event counting, and preliminary measurements of APDs. We will report on the detailed fabrication processes and experimental results of the Ir/Pt TESs and the integrated APDs.

RDC 2 Photodectors / 142

Novel High-Performance Single-Photon Detectors for Next Generation HEP Applications

Author: Mst Shamim Ara Shawkat[1]

[1] *Florida International University*

Corresponding Author: mshawkat@fiu.edu

High energy physics (HEP) experiments require high-performance detectors to advance the energy, luminosity, and cosmology frontiers. Photomultiplier tubes (PMTs) have been extensively used to detect scintillation light. In recent years, silicon photomultipliers (SiPMs), an array of single photon avalanche diodes (SPADs), have become preferable as a solid-state alternative to PMTs due to their invulnerability to magnetic fields, compactness, low operating voltage, robustness, and lower cost. Furthermore, SiPMs implemented in a standard CMOS process, as opposed to a dedicated optical process, allow the optical sensor to be coupled on the same chip with the readout electronics. This results in a compact, low-cost, and low-bias voltage SiPM detector. However, SiPMs tend to rapidly degrade in high irradiation environments, making them unsuitable for some collider experiments, particularly given the trend towards higher luminosities and therefore higher irradiation levels. One of the major challenges of SiPM in such high-radiation environments is their noise performance. In addition, CMOS detectors have been developed for precision position (ps time resolution)

measurements in HEP due to their compactness and spatial granularity. The goal is to develop a new class of SiPM detectors that provides an order-of-magnitude improvement in key performance metrics, namely timing resolution and noise. High energy physics (HEP) experiments require high-performance detectors to advance the energy, luminosity, and cosmology frontiers. Photomultiplier tubes (PMTs) have been extensively used to detect scintillation light. In recent years, silicon photomultipliers (SiPMs), an array of single photon avalanche diodes (SPADs), have become preferable as a solid-state alternative to PMTs due to their invulnerability to magnetic fields, compactness, low operating voltage, robustness, and lower cost. Furthermore, SiPMs implemented in a standard CMOS process, as opposed to a dedicated optical process, allow the optical sensor to be coupled on the same chip with the readout electronics. This results in a compact, low-cost, and low-bias voltage SiPM detector. However, SiPMs tend to rapidly degrade in high irradiation environments, making them unsuitable for some collider experiments, particularly given the trend towards higher luminosities and therefore higher irradiation levels. One of the major challenges of SiPM in such high-radiation environments is their noise performance. In addition, CMOS detectors have been developed for precision position (ps time resolution) measurements in HEP due to their compactness and spatial granularity. The goal is to develop a new class of SiPM detectors that provides an order-of-magnitude improvement in key performance metrics, namely timing resolution and noise. This idea involves integrating field-modulating gates into SPADs within commercial CMOS processes to create perimeter-gated SPADs. Preliminary work has shown that the field modulating gate reduces the noise (dark count) of regular SPADs and SPAD-based SiPM detectors. To improve the timing resolution, we will design new front-end readout circuits at the pixel level.

SHARED SESSION / 143

MAPS with improved timing performance for low-duty cycle accelerators

Authors: Aiden Duncanson[1]; Angelo Dragone[1]; Bojan Markovic[2]; Caterina Vernieri[2]; Christos Bakalis[3]; Lorenzo Rota[1]; Martin Breidenbach[None]; Megan Zeng[1]; Victor Turbiner[2]

[1] *SLAC National Laboratory*

[2] *SLAC National Accelerator Laboratory (US)*

[3] *SLAC National Accelerator Laboratory (US)*

Corresponding Authors: caterina.vernieri@cern.ch, cbakalis@slac.stanford.edu, victur03@slac.stanford.edu, zengm@stanford.edu, bojan.markovic@cern.ch, lorenzor@slac.stanford.edu, mib@slac.stanford.edu, afdunc@stanford.edu

In low duty cycle machines, such as linear and muon colliders, collision happen only in a small fraction of the total operational time. Currently, most of the developments of Monolithic Active Pixel Sensor (MAPS) focus on circular colliders, with a continuous time analog front-end. In this contribution we propose a time-variant analog front-end, which, when operated synchronously with the accelerator, achieves a better timing performance/power metric. We report on the design, simulation and preliminary results obtained on a TPSCo 65 nm CMOS technology. We will also discuss system level issues and ongoing R&D efforts, in particular the development of a time-to-digital converter (TDC) to be integrated in the pixel matrix.

RDC 3 Solid State Tracking / 144

Machine-Detector Interface for the MAIA Detector at a 10 TeV Muon Collider

Authors: Benjamin John Rosser[1]; Kiley Elizabeth Kennedy[2]

[1] *University of Chicago (US)*

[2] *Princeton University (US)*

Corresponding Authors: kiley.elizabeth.kennedy@cern.ch, brosser@uchicago.edu

Muon colliders have emerged as an exciting option for enabling access to the 10 TeV energy scale in the post High Luminosity LHC era in a compact and power-efficient way compared to proton-proton alternatives. However, significant research and development is required to address the fundamental challenge that muons are unstable, and will decay continuously while moving through an accelerator complex. These challenges mean that careful optimization of the machine-detector interface (MDI) between the accelerator and any experiment is critically important in order to minimize beam-induced background (BIB) while maximizing luminosity. In this talk, I'll present some of the latest developments in MDI studies for a muon collider, describe their impact in the context of the proposed MAIA (Muon Accelerator Instrumented Apparatus) detector for a 10 TeV muon collider, and discuss some directions for future work on both MDI and on the detector design itself.

RDC 3 Solid State Tracking / 145

α, β pulse shape discrimination in silicon detectors

Authors: Isaac Kunen[1]; Christian Nave[1]; Forest Tschirhart[1]; Louis Varriano[1]

[1] *University of Washington*

Corresponding Author: varriano@uw.edu

The Beta-decay Paul Trap (BPT) at Argonne National Laboratory primarily studies the beta delayed-alpha decays of ^{8}Li and ^{8}B to measure the beta-neutrino angular correlation coefficient in these decays to search for a tensor contribution to the weak interaction. Additionally, the BPT is able to directly measure the ^{8}B unoscillated neutrino spectrum, an important input for current and next generation solar neutrino detectors. The BPT uses four, 1 mm thick double-sided silicon strip detectors for 25% solid angle coverage with angular resolution of $\sim 2°$, which sample the β energy due to their thickness. One present experimental limitation is the lack of discrimination between α and β particles below $\sim$ 1 MeV, a portion of the energy spectrum which has a large impact on the reconstruction of the ^{8}B neutrino spectrum. To overcome this limitation, we investigate using pulse shape discrimination to distinguish between α and β particles in thick silicon detectors, with promising performance under both simple approaches and more complex machine learning techniques.

RDC 8 Quantum & Superconducting Sensors / 146

Utilizing the Quantum Zeno Effect in superconducting qubit based particle sensors

Author: Olivia Seidel[None]

Corresponding Author: olivias@fnal.gov

Superconducting qubit sensors are a compelling option for detecting faint signals from dark matter or low energy neutrino interactions. Improving their reach calls for both signal amplification and background suppression. The Quantum Zeno Effect (QZE)–which governs how entanglement reshapes a quantum system's time evolution–addresses both needs. By quantifying these modified time dynamics, we can better predict a qubit's response to a genuine particle event while suppressing coherence dips from other local disturbances. We present a new QZE-based protocol that could mitigate a dominant source of coherence fluctuations from Two Level Systems, show initial measurements of the QZE in superconducting qubits, and discuss additional opportunities where understanding and exploiting the effect are critical for building robust, high-sensitivity qubit detectors.

RDC 8 Quantum & Superconducting Sensors / 147

Readout and Noise Sensing Schemes for Qubit-Based Detectors

Author: Kester Anyang[1]

Co-authors: Israel Hernández [2]; Rakshya Khatiwada [3]; Ryan Linehan [4]; Sara Sussman [5]

[1] *Illinois Institute of Technology*

[2] *Higher Institute of Technologies and Applied Sciences*

[3] *Fermilab/Illinois Institute of Technology*

[4] *Fermi National Accelerator Laboratory*

[5] *Fermilab*

Corresponding Authors: linehan3@fnal.gov, sarafs@princeton.edu, israelhernandezsehara@gmail.com, kanyang@hawk.iit.edu, rkhatiw@fnal.gov

Superconducting qubits are intrinsically sensitive to environmental fluctuations, making them promising platforms for sub-eV energy sensing. In this regime, qubits can operate as Cooper pair breaking detectors, where incident energy generates phonons in the substrate (eg; Sapphire) that subsequently break Cooper pairs in the qubit's superconducting film. The resulting quasiparticles tunnel across the Josephson junction, altering the qubit's charge parity and occasionally inducing energy relaxation. By monitoring charge parity switching, energy relaxation rates, and multi-level qubit spectroscopy, one can infer changes in quasiparticle density from energy depositions. We present a comparative study of readout sensitivities for multiple qubit based energy sensing schemes, along with recent qudit spectroscopy measurements of the charge environment in a sapphire substrate using a tantalum transmon.

RDC 4 Readout & ASICs / 148

Functional and Single Event Effects (SEE) Triplication Verification of the ATLAS ITk Strip Tracker HCCStar and AMACStar Front-end ASICs

Authors: Paul Keener[1]; Benjamin John Rosser[2]

[1] *University of Pennsylvania (US)*

[2] *University of Chicago (US)*

Corresponding Author: keener@hep.upenn.edu

With ASICs becoming more complex and traditional verification frameworks, such as UVM, requiring specialized knowledge, alternatives such at the cocotb python-based frameworks become attractive. In an academic environment, students who are already familiar with python can quickly be leveraged to write testbenches for complex ASICs. This talk will give a brief introduction to cocotb using our experience with the HCCStar and AMACStar designs as well as a detailed discussion of the extensive triplication implemented as SEE mitigation and the techniques used to verify the triplication.

Poster / 149

Machine Learning to Accelerate Qubit Designs for Quantum Sensing

Author: Olivia Seidel[None]

Corresponding Author: olivias@fnal.gov

Designing superconducting qubit sensors with high sensitivity to ultra-low energy particles requires engineering chips that realize precise quantum Hamiltonians. Traditionally, creating a chip that realizes a specific Hamiltonian requires a time-consuming, iterative loop of simulations and manual adjustments. In this work, we apply supervised machine learning to dramatically accelerate this process. Using the SQuADDs open source database of chip geometries and corresponding Hamiltonians, we train a multilayer perceptron to learn the inverse mapping from target Hamiltonians directly to chip designs. This approach achieves low prediction error and reduces the design loop to a single network pass. Our results highlight a promising direction toward automating and scaling superconducting qubit sensor development.

RDC 4 Readout & ASICs / 150

Cryogenic Testing of CRYO ASIC for Photon Readout

Author: Liang Yang[1]

Co-authors: Aldo Pena-Perez [2]; Zepeng Li [3]

[1] *UC San Diego*

[2] *SLAC*

[3] *University of Hawaii*

Corresponding Authors: liyang@physics.ucsd.edu, zepengli@hawaii.edu, aldopp@slac.stanford.edu

Integrating cryogenic readout electronics directly into large noble liquid detectors offers reduced front-end noise and minimized detector backgrounds, thus enhancing sensitivity for rare event searches. The CRYO ASIC is a compact 7 mm × 9 mm System-on-Chip (SoC) waveform digitizer and serializer specifically designed for cryogenic operation. The ASIC interfaces directly with signals from time projection chambers (TPCs) and transmits digitized data to the data acquisition (DAQ) system with low power dissipation. While primarily designed for charge readout, the CRYO ASIC can be used for cryogenic readout for large area silicon photomultipliers (SiPMs). In this talk, we present characterization results of SiPM readout using the CRYO ASIC. These results demonstrate that the ASIC can support scalable and low-noise photon detection for next-generation rare event search experiments.

RDC 4 Readout & ASICs / 151

Amplitude Walk in Fast Timing: The Role of Dual Thresholds

Author: Sebastian White[1]

[1] *University of Virginia (US)*

Corresponding Author: sebastian.white@cern.ch

In preparation for HL-LHC operation, a number of new detector systems are being constructed with timing precision on physics objects of ≤50 picoseconds. These time stamps will reduce the level of pileup induced backgrounds as the number of interactions per crossing will reach of order 100-200.
In this report we note that this high pileup level will necessitate a new approach to calibration of these large timing arrays (typically with several ×105 channels) since a single t0 reference is hard to come by in regular data taking.
We demonstrate that enhancing the usual pair of timing ASIC data (ie threshold time and amplitude

or time-over-threshold) with a 2nd threshold time greatly simplifies the analysis of amplitude walk. Since slope at threshold is directly relevant for amplitude walk, day-1 walk calibration can often have an analytical solution.

RDC 7 Low-Background Detectors / 152

SPLENDOR's Modular Detector System Designed for meV Charge Signals with Novel Semiconductors

Authors: Aditi Pradeep[None]; Betty Young[1]; Caleb Fink[2]; Jadyn Anczarski[3]; Noah Kurinsky[4]; Taylor Aralis[None]; arran phipps[5]

[1] *Santa Clara University*

[2] *Syracuse University*

[3] *Stanford/SLAC/KIPAC*

[4] *SLAC/Stanford*

[5] *CSU East Bay*

Corresponding Authors: arran.phipps@csueastbay.edu, cwfink@syr.edu, kurinsky@slac.stanford.edu, tbaralis@gmail.com, janczar@stanford.edu, aditi.pradeep@slac.stanford.edu, byoung@scu.edu

SPLENDOR is a cross-discipline collaboration—involving theorists, condensed matter physicists, and low energy-threshold instrumentation specialists—focused on developing narrow-gap semiconductors to search for Sub-MeV dark matter. SPLENDOR has developed a novel modular detector system that offers adaptability to incorporate newly developed semiconducting materials into an experimental package with two-stage HEMT charge readout technology. Recently, SPLENDOR published projected dark matter search sensitivity that has the potential to probe athermal relic dark matter. The projection is based on using a 800 mg crystalline, ˜ 60 meV bandgap sample of $Eu_5In_2Sb_6$ synthesized by SPLENDOR collaborators at Los Alamos National Laboratory. In parallel with synthesizing this narrow-gap semiconductor, SPLENDOR developed a world-leading cryogenic charge amplifier with a resolution of 20 ± 7 electrons that should achieve single electron energy resolution in the coming year. This talk will provide the CPAD community with an update on SPLENDOR's recent progress, highlighting our efforts in amplifier calibration and outlining the next steps and future technologies.

RDC 6 Gaseous Detectors / 153

Design and production of GEM modules for the MOLLER experiment

Authors: Abhay Deshpande[1]; James Shirk[2]; Jaydeep Datta[None]; Zuhal Seyma Demiroglu[2]; brynna Moran[2]

[1] *CFNS, Stony Brook University*

[2] *Stony Brook University*

Corresponding Authors: brynna.moran@stonybrook.edu, abhay.deshpande@stonybrook.edu, james.shirk@stonybrook.edu, zuhal.demiroglu@stonybrook.edu, jaydeep.datta@stonybrook.edu

The upcoming MOLLER experiment at Jefferson Lab (JLab) will measure the parity-violating asymmetry by scattering longitudinally polarized electrons off unpolarized electrons with high precision in a liquid Hydrogen target. The high precision will enable a search for new physics beyond the standard model.

Twenty-eight large area triple Gas Electron Multiplier (GEM) detector-packages will be utilized for spectrometer calibration and background measurements. Stony Brook University was responsible

for construction of 16 of the 28, which have now been completed and delivered to JLab. In this talk, we will present the design considerations of the GEM detectors, the fabrication process, and present preliminary results of characterization studies undertaken at SBU and JLab.

Poster / 154

Measurement of the Qpix analog front end for track reconstruction in a Pixelated Liquid Argon TPC

Author: Alex Kramer[1]

Co-author: Mitchell Franck Newcomer [2]

[1] *University of Pennsylvania*

[2] *University of Pennsylvania (US)*

Corresponding Authors: alexanderkramer2024@gmail.com, mitch@hep.upenn.edu

The Qpix ASIC implements a novel idea for reconstruction of tracks by measuring ionization currents as a time correlated collection of unit charges with a programmable unit charge between ½ and 2fC and a minimum time marking interval of 2X the clock (external or internal). Measurement results of bench tests of a 16 channel ASIC at room temperature and at liquid nitrogen temperature with the two different approaches to a very low power (<50uW/channel) low noise front end will be presented and novel techniques allowing leakage current to be tracked down to the sub pico-amp level will be presented.

RDC 2 Photodectors / 155

Develop the new generation DELTA photodetector

Author: Wei Shi[1]

[1] *Stony Brook University (US)*

Corresponding Author: wei.shi.1@stonybrook.edu

In this talk, I present a proposal for the next generation of fully packaged digital photodetectors based on a light-trapping mechanism called DELTA, Digital End-to-end Light Trap Assembly. The end-to-end development covers incident photons up to the digital signals saved to disk. Main topics of R&D for the DELTA detector include large-area photo-collectors that trap light inside, small-area photosensors optically coupled to photocollectors, on-board fast signal processing and digitization, and finally, laser photonics for power & signal transmission. The goal is to prototype this next-generation DELTA photodetector using the resources available under CPAD RDC2 working packages (WP1 and WP2).

The DELTA photodetector has final target applications in future noble liquid dark matter and neutrino experiments, as well as VUV light detection in astro-particle physics, astronomy, nuclear particle physics, medical physics, and national security where compact light detectors, large scale deployment, or harsh environment such as cryogenics, high voltage, and radio purity are called for. This proposal is motivated by emerging technologies in many fields, including microelectronics, laser photonics, and material science.

Preliminary light detection simulation performance, ongoing detector R&D, and future development interests will be presented.

Poster / 156

FELIX: the transition of the ATLAS readout system from LHC Run 3 to Run 4

Author: Haotian Cao[1]

[1] *Argonne National Laboratory (US)*

Corresponding Author: haotian.cao@cern.ch

After being successfully deployed to readout a subset of the ATLAS subdectors during LHC Run 3 (2022-2026), the FELIX will serve all
ATLAS subdectors in LHC Run 4 (2030-2033). FELIX is a router between custom serial links from front-end ASICs and FPGAs to data collection and processing components via a commodity switched network. FELIX is also responsible for forwarding the LHC clock, fixed latency trigger accepts, and resets received from the TTC (Timing, Trigger and Control) system to front-end electronics. FELIX uses FPGA-based PCIe I/O cards installed in commodity servers. To cope with the increased data rate expected after the major upgrade to the LHC and the detector in between runs, the FLX712 Run 3 PCIe Gen3x16 card, based on an AMD Kintex Ultrascale XCKU115 FPGA, will be replaced with the FLX155, a bifurcated 2x PCIe Gen5x8 card equipped with an AMD Versal Premium VP1552 FPGA/SoC. Firmware installed on the FPGA and software running on the FELIX server are also being upgraded to handle the increased data.

RDC 8 Quantum & Superconducting Sensors / 157

Phonon and Quasiparticle Transport in Superconductors and novel materials

Authors: Israel Hernandez[1]; Kester Anyang[1]; Rakshya Khatiwada[2]; Ryan Linehan[3]

[1] *Illinois Institute of Technology*

[2] *Fermilab/Illinois Institute of Technology*

[3] *Fermi National Accelerator Laboratory*

Corresponding Authors: ihernandez6@hawk.iit.edu, linehan3@fnal.gov, rkhatiw@fnal.gov, kanyang@hawk.iit.edu

Understanding phonon and charge propagation in superconducting devices is essential for low-threshold dark matter and neutrino searches. In this work, we extend G4CMP capabilities to model phonon propagation in novel superconducting materials, including Aluminum, Tantalum, and Niobium. Furthermore, we enable phonon–quasiparticle transport in the interface of superconducting thin film and the substrate and evaluate the performance of the devices. Finally, we investigate strategies to enhance phonon collection efficiency for various qubit designs.

RDC 10 Detector Mechanics / 159

Production of Vessel and Mirrors for the pfRICH Detector at the EIC

Author: Charles Joseph Naim[1]

[1] *Stony Brook University (CFNS)*

Corresponding Author: charlesjoseph.naim@stonybrook.edu

We will present an overview of the proximity-focusing Ring Imaging Cherenkov (pfRICH) detector developed for the ePIC experiment at the Electron-Ion Collider (EIC) at Brookhaven National Laboratory (BNL). Serving as a key particle identification (PID) subsystem in the backward pseudorapidity

region -3.5
$lesssim\eta$
$lesssim - 1.5$, the pfRICH provides at least 3σ PID separation for pions, kaons, and protons up to 7 GeV/c —capabilities crucial for Semi-Inclusive Deep Inelastic Scattering (SIDIS) measurements.
In this presentation, we will focus on two critical components: the vessel and the mirrors. The vessel, constructed from a robust carbon fiber composite plastic (CFRP) with an aramid honeycomb core, supports all detector components, ensures gas and light containment, and minimizes the material budget by employing construction techniques adapted from the sPHENIX TPC field cages. The mirrors, fabricated using evaporative coating methods, achieve high reflectivity (up to 90 \%) and precisely redirect a fraction of the Cherenkov photons produced in the aerogel radiator toward the photon sensors, enhancing ring imaging performance.

We will discuss the design, fabrication, and assembly of these components at Stony Brook University, in collaboration with Purdue University and BNL, highlighting their essential roles in the overall performance of the pfRICH detector for the upcoming EIC.

RDC 6 Gaseous Detectors / 160

Plans for EIC generic R&D based on MPGD technology

Author: Sourav Tarafdar[1]

[1] *On behalf of MPGD EIC generic R&D consortium*

Corresponding Author: stara@jlab.org

The versatility of MPGD technology has drawn tremendous interest in both Nuclear and High Energy Physics communities to use as particle detector in experiments. Particle tracking detectors are integral part of Nuclear Physics experiment and MPGDs has established themselves as reliable tracking detectors due to their moderate material budget, low cost, moderate spatial resolution and relatively easier fabrication as large size detector. Many Nuclear and High Energy experiments including ePIC at EIC has incorporated multiple MPGD technologies as tracking detectors and there is possibility of utilizing same technology either as possible second EIC detector or any future Nuclear and High Energy Physics experiment.
Apart from its role as tracking detector, MPGD technology has also demonstrated excellent timing performance with timing resolution of a few tens of picoseconds. Even it is in early stage of R&D, MPGDs has potential for being an alternate for currently existing technologies for Time-of-Flight Particle Identification Detectors in Nuclear and High Energy Physics experiments. Over the past decade significant progress has been made on this front in terms of optimizing the amplification structure, optimizing gas mixture, improving longevity of photocathode and increasing the active area of the detector itself.
The EIC generic R&D program is focused on advancing cutting edge detector technologies for Nuclear Physics experiment and currently there are focus on advancement of MPGD technology both as tracking detectors and picosecond timing detectors in Nuclear and High Energy Physics experiments. This presentation will focus on overview of various ongoing R&Ds using MPGD technology under EIC generic R&D program.

RDC 10 Detector Mechanics / 161

Relieving Thermal Stress in ATLAS ITk Strip Modules

Author: Anne Winifred Fortman[1]

[1] *Lawrence Berkeley National Lab. (US)*

Corresponding Author: anne.winifred.fortman@cern.ch

A new all-silicon tracking detector known as the Inner Tracker (ITk) will replace the current Inner Detector system of the ATLAS experiment in preparation for the High Luminosity LHC. The outermost layers of the ITk will be tiled with ITk Strip modules, where each module is composed of front-end electronics glued to a silicon microstrip sensor. During module pre-production, a critical problem emerged: silicon sensors cracked due to thermal stresses when mounted to local support structures and brought to cold operating temperatures. The primary mitigation strategy involved redesigning the modules to include a new layer of soft glue between the front-end electronics and the silicon sensor to absorb thermal stresses. This redesign necessitated a new R&D phase of the project, including material testing of the added components, developing new processes to integrate the added layers into the module assembly chain, and design validation testing of prototype modules. This presentation will also discuss the key lessons learned to avoid similar failures in future detectors.

RDC 8 Quantum & Superconducting Sensors / 162

Radiation-Induced Correlated Events in Layered Superconducting Detectors

Author: Samuel Watkins[1]

[1] *Pacific Northwest National Laboratory, USA*

Corresponding Author: samuel.watkins@pnnl.gov

Here, we present the LLNL Cosmic Sandwich, a detector consisting of three cm2-scale sapphire substrates layered in close vertical proximity. The middle section of the Sandwich comprises an array of transmons patterned on the surface, and the top and bottom substrates each have grids of microwave kinetic inductance detectors (MKIDs). This detector package enables tagging of events that are coincident among multiple sensors (or qubits) on the same substrate, as well as across different substrates within the Sandwich. Through these coincidence events, we can tag which types of radiation (gammas, alphas, muons, etc.) are the most problematic for causing events correlated among the sensors.

At PNNL, we have the capability to install a variety of known radioactive sources close to the Sandwich and observe the extent of the observed correlated events. In this contribution, we will review the design of the LLNL Cosmic Sandwich, as well as its constituent sensors. We will further show preliminary results of these studies in various irradiated conditions and connect these observations to the priorities of the superconducting qubit community.

RDC 2 Photodectors / 163

Measurements of Spectral Photon Sorting Using Dichroicons in Large Optical Neutrino Detectors

Author: Jieran Shen[1]

[1] *University of Pennsylvania (US)*

Corresponding Author: jierans@upenn.edu

Many neutrino detectors use photons as their primary event detection method, typically through photon counting and determining their arrival times. Photons also carry information about an event through their wavelength, polarization, and direction, but often little to none of this information is utilized. The "dichroicon," a Winston-style light concentrator comprised of dichroic filters, allows detectors to use the wavelength information encoded in photons. This talk will discuss measurements of the performance of the dichroicon in the CHESS detector, focusing on the dichroicon's scintillation and Cherenkov photon detection and sorting efficiency. The results will include measurements from two types of dichroicons paired with water based and liquid scintillators exposed to radioactive and cosmogenic sources. In addition to the benchtop results, the talk will discuss the deployment of dichroicons in Eos, a 20-ton hybrid Cherenkov-scintillation detector. The Eos detector is a demonstrator for very large scale neutrino detectors, including Theia, and features the first deployment of 12 large-scale monolithic dichroicons. The talk will dicuss the ongoing measurements of the performance of dichroicons at Eos, as well as priliminary results that have so far shwon good data/MC agreement. The talk will also include predictions of the performance of dichroicons in future detectors like Theia. These results will include studies of the collection efficiency and discrimination between Cherenkov and scintillation light, new handles on particle ID, and novel reconstruction techniques that leverage the advantages of both Cherenkov and scintillation light.

RDC 8 Quantum & Superconducting Sensors / 164

Event reconstruction analysis on radiation-induced correlated errors in superconducting qubits

Author: Emanuela Celi[1]

[1] *Northwestern University*

Corresponding Author: emanuela.celi@northwestern.edu

When an ionizing particle interacts with the substrate of a superconducting qubit chip, it generates athermal phonons that propagate through the material, breaking Cooper pairs in the superconducting film and inducing quasiparticle poisoning. This process increases correlated error rates, posing a significant challenge for the development of fault-tolerant quantum computing. Additionally, the sensitivity of superconducting qubits to Cooper pair breaking makes them promising detectors for dark matter searches and coherent elastic neutrino nucleus scattering, given the meV-scale energy required for quasiparticle generation in most superconductors. In recent years, this field has gained significant interest, leading to extensive experimental studies on the response of superconducting qubits to ionizing radiation. Concurrently, theoretical models have been developed to describe the dynamics of ballistic phonons in the qubit substrate and their impact on quasiparticle relaxation, aiming to establish connections between these processes and qubit design. In this work, I present an advanced analysis aimed at validating these theoretical models using real experimental data. By refining our understanding of phonon and quasiparticle dynamics, this study provides deeper insights into their influence on qubit performance, with implications for both quantum computing and particle detection applications.

SHARED SESSION / 168

Toward a general-purpose ultra-low-external interference quantum device holder

Authors: Yashwanth Balaji[1]; Daniel Baxter[2]; Rebecca Carney[1]; Yen-Yung Chang[3]; Maurice Garcia-Sciveres[1]; Sunil Golwala[4]; Scott Hertel[5]; Rakshya Khatiwada[6]; Holden Kowitt[7]; Noah Kurinsky[8]; Xinran Li[1]; Daniel Molenaar[6]; Matt Pyle[3]; Karthik Ramanathan[9]; Shilin Ray[4]; Yann Sadou[4]; Chiara Salemi[3]; Brandon Sandoval[4]; Adam Schwartzberg[1]; Sidney Stevens[10]; Aritoki Suzuki[1]; Ronald Vaughn[5]; Junwen Xiong[4]

[1] *Lawrence Berkeley National Laboratory*

[2] *Department of Physics and Astronomy, Northwestern University, Quantum Division, Fermi National Accelerator Laboratory*

[3] *Lawrence Berkeley National Laboratory, Department of Physics, University of California, Berkeley*

[4] *Department of Physics, California Institute of Technology*

[5] *Department of Physics, University of Massachusetts-Amherst*

[6] *Illinois Institute of Technology, Quantum Division, Fermi National Accelerator Laboratory*

[7] *Department of Physics, University of California, Berkeley*

[8] *SLAC National Accelerator Laboratory, Kavli Institute for Particle Astrophysics and Cosmology, Stanford University*

[9] *Department of Physics, Washington University in St.~Louis*

[10] *SLAC National Accelerator Laboratory*

Corresponding Authors: xjw@caltech.edu, ybalaji@lbl.gov, salemi@berkeley.edu, hkowitt@berkeley.edu, asuzuki@lbl.gov, karthikr@wustl.edu, kurinsky@slac.stanford.edu, sray@caltech.edu, ysadou@caltech.edu, mgarcia-sciveres@lbl.gov, danielbaxter2013@u.northwestern.edu, rcarney@lbl.gov, golwala@caltech.edu, mpyle1@berkeley.edu, rvaughn@umass.edu, xinranli@lbl.gov, yychang@berkeley.edu, rkhatiw@fnal.gov, amschwartzberg@lbl.gov, bsandova@caltech.edu, dmolenaar@hawk.iit.edu, shertel@umass.edu, sidneyas@stanford.edu

We have produced a general-purpose ultra-low-external interference quantum device holder suitable for various qubit and quantum sensor platforms. It is a continuation of UCB/LBNL's blackbody radiation (BBR) stub filter flange (SFF) study, in collaboration with nine US institutes to obtain the best available techniques in attempt to optimize every aspect possible. In this presentation, we first introduce the concept of SFF. We explain its theory, working principle, and its criticality that distinguishes our device performance from others. Next, we introduce our approach to integrate SFF with advanced features and techniques available in the collaboration for optimizing magnetism, vibration, quantum platform compatibility, production cost, and cryogenic engineering practicality. Finally, we present preliminary data from various qubit and quantum sensor platforms to demonstrate the promising results of the project.

RDC 10 Detector Mechanics / 169

Global Mechanics Challenges for Materials and Structures in Future Collider Detectors

Authors: Giorgio Vallone[1]; Todd Claybaugh[1]; Thomas Johnson[1]; Nicholas Payne[1]; Joseph Silber[1]; Eric Anderssen[1]

[1] *Lawrence Berkeley National Laboratory*

Corresponding Authors: jhsilber@lbl.gov, tmclaybaugh@lbl.gov, gvallone@lbl.gov, tajohnson@lbl.gov, ecanderssen@lbl.gov, npayne@lbl.gov

Future particle detectors will present unprecedented global mechanics challenges in multiple disciplines. For example, FCC detectors are expected to be substantially larger than the current ATLAS and CMS detectors, with structures approximately twice the diameter and two to three times the active area. Furthermore, they will face similarly stringent requirements with other detectors —for example, ePIC for the EIC —on the overall mass budget, which will require novel design solutions and construction technologies. In general, detectors are expected to employ a wide range of technologies, such as strips, hybrid pixels, or MAPS. A major goal is reducing mass, with lower sensing, support, and service material budgets. Here we present the most promising technologies to achieve these goals: MAPS sensing for low mass, carbon conductors for lighter services, thermoformed polyimide for very low mass structures, and multi-functional components to combine portions of the material budget. Some of these technologies are already under development at certain institutions; others are currently being developed in different fields (e.g., aerospace, automotive) and may be ready for implementation in future detectors. We highlight the most promising of these technologies that are worth exploring, along with the key areas where further development is needed for practical implementation. In this context, we also emphasize the importance of proper characterization of materials —such as elastomers used to support silicon —to ensure correct early design choices. These studies should be carried out within the community to evaluate performance in the unique high-radiation environments in which future detectors will operate.

RDC 6 Gaseous Detectors / 170

Development of Thin Gap GEM-μRWELL Hybrid Detectors at Jefferson Lab

Author: Kondo Gnanvo[1]

[1] *Southeastern Universities Research Association, Inc. (US)*

Corresponding Author: kagnanvo@jlab.org

Over the past few decades, Micro Pattern Gaseous Detector (MPGD) technologies have been increasingly adopted as tracking detector options in High Energy and Nuclear Physics experiments thanks to their good spatial resolution, high-rate capability, stability and more importantly their ability for large area coverage at a relatively low cost compared to the alternative. The thin gap GEM-μRWELL hybrid detector is the latest addition to the MPGD family, that was introduced to vastly improve the spatial resolution capability of gaseous trackers when deployed in the barrel region to cover large angular acceptance of the central tracker in a collider experiment.
In this talk, I will re-introduce the concept and motivation for the development of thin gap GEM-μRWELL hybrid technology with an emphasis on the initial studies that establish the proof-of-concept of the technology. I will then discuss the more recent results from latest beam test campaign at Jefferson Lab in May 2025 to study detector efficiency performance with various gas mixtures. I will also briefly present the ongoing activities to develop large area thin gap GEM-μRWELL tracking detectors for the ePIC experiment of the future Electron Ion Collider as well as the exploration of the technology to provide large area tracking options to the muon system of experiments at a future Higgs Factory Collider such as the FCC-ee for example. Finally, I will conclude with some perspectives on new ideas under exploration to develop the next generation of thin gap MPGD technologies with enhanced timing and spatial resolution capabilities.

RDC 7 Low-Background Detectors / 171

Advancing TES-Based Detectors for Sub-GeV Dark Matter Detection

Author: Aditi Pradeep[1]

Co-authors: Taylor Aralis ; Hope Fu [2]; Noah Kurinsky [1]; Brian Lenardo [3]; James Ryan ; Aviv Simchony [2]; Kelly Stifter [4]; Qihua Wang [2]; Betty Young [5]

[1] *SLAC/Stanford*

[2] *Stanford University*

[3] *SLAC National Accelerator Laboratory*

[4] *Fermilab*

[5] *Santa Clara University*

Corresponding Authors: qihuaw@slac.stanford.edu, hopefu@slac.stanford.edu, kstifter@fnal.gov, simchony@slac.stanford.edu, jlryan@stanford.edu, kurinsky@slac.stanford.edu, blenardo@slac.stanford.edu, taralis@caltech.edu, aditi.pradeep@slac.stanford.edu, byoung@scu.edu

The search for sub-GeV dark matter has pushed for the development of detectors with sub-eV energy resolution. Superconducting sensors have emerged as leading candidates in this effort. A central challenge in this field is achieving lower detector thresholds while minimizing background levels to maximize sensitivity to low-mass dark matter. At SLAC, the DMQIS group is addressing this challenge through several avenues: investigating novel materials that require minimal excitation energy, developing ultra-low noise cryogenic readout systems to enhance resolution, and deploying high-precision cryogenic calibration tools to better understand and mitigate detector backgrounds. This talk will focus on developments on the TES-based detectors we fabricate in-house at SLAC. We will present recent progress on detectors incorporating substrates with low band gaps and light nuclei (e.g. SiC, diamond) which broaden sensitivity to lower mass dark matter models. As experiments begin exploring the sub-GeV dark matter space, backgrounds like the Low Energy Excess pose a strong barrier to further enhancements in detector sensitivity. We will describe the group's efforts to precisely characterize the LEE in our TES detectors using a custom-built cryogenic MEMS-based calibration source with fine beam-steering capability. These measurements are critical for informing the design of next-generation, ultra-low background detectors. We also will describe progress on a new effort working with the BeEST collaboration to perform a precision nuclear recoil calibration of TES-based dark matter detectors by measuring the radioactive decay of ion-implanted 7Be. These results should enable further refinement of detector response models.

RDC 2 Photodectors / 172

High performance RICH detector concept with HRPPD sensors for EIC Generic R&D

Author: Laura Brittany Havener[1]

Co-author: Prakhar Garg [2]

[1] *Yale University (US)*

[2] *Yale University*

Corresponding Authors: prakhar.garg@yale.edu, laura.brittany.havener@cern.ch

The Yellow Report for the EIC sets the stage for designing detectors that can best meet its science goals, noting the importance of having two complementary detectors and interaction regions. The first detector, ePIC at IP6, is already well into development, while new technologies could be refined for a second detector at IP8. In this talk, I will discuss the proposed research program, which is focused on the development of the High Performance Ring Imaging Cherenkov Detector (hpRICH) for the second detector. Key features of such a device are a wide momentum coverage for PID due to the choice of radiator medium and fast timing capabilities due to the choice of photosensors, enabling time-of-flight measurements, especially for low-momentum particles.

RDC 6 Gaseous Detectors / 173

A High-Precision, Fast, Robust, and Cost-Effective Muon Detector for the FCC-ee

Author: Linnuo Zhang[1]

Co-author: Jianming Qian [1]

[1] *University of Michigan (US)*

Corresponding Authors: linnuo.zhang@cern.ch, qianj@umich.edu

We propose a high-precision, fast, robust and cost-effective muon detector concept for an FCC-ee experiment. This design combines precision drift tubes with fast plastic scintillator strips to enable both spatial and timing measurements. The drift tubes deliver two-dimensional position measurements perpendicular to the tubes with a resolution around 100~μm. Meanwhile, the scintillator strips, read out with the wavelength-shifting fibers and silicon photomultipliers (SiPMs), provide fast timing information with a precision of 200~ps or better and measure the third coordinate along the tubes with a resolution of about 1~mm.

SHARED SESSION / 174

Testing of the CRYO ASIC for in-liquid-xenon ionization readout

Author: Brian Lenardo[1]

[1] *SLAC National Accelerator Laboratory*

Corresponding Author: blenardo@slac.stanford.edu

Liquid xenon (LXe) time projection chambers (TPCs) are powerful tools in the search for neutrinoless double beta decay (NDBD), offering a scalable, ultra-low-background technology with excellent energy resolution in the MeV energy range. An important aspect of these detectors is their 3D imaging capability, which enables powerful signal/background discrimination based on the position and topology of each event. Here we describe the CRYO ASIC –a LXe-compatible ionization readout solution developed for the nEXO experiment. nEXO is a proposed next-generation TPC that is designed to achieve sensitivity to NDBD at half-lives beyond 10ˆ28 years. CRYO is a system-on-chip designed in 130 nm CMOS technology that provides configurable front-end amplification and shaping as well as 2 MSPS digitization and serialization for up to 64 channels directly in the liquid xenon, reducing both noise and cabling requirements for high-resolution and low-background applications. I will discuss results from the nEXO collaboration's testing of the CRYO ASIC both at room temperature and at cryogenic temperature, including preliminary tests of performance in liquid xenon. The talk will also touch on R&D towards high-speed digital signal transmission for in-LXe electronics.

SHARED SESSION / 175

AstroPix: Low power high voltage CMOS active pixel sensors for future space and collider experiments

Author: Manoj Jadhav[None]

Corresponding Author: mjadhav@anl.gov

AstroPix is a novel monolithic high-voltage CMOS (HV-CMOS) active pixel sensor and has the advantages of a fully monolithic structure with low power consumption, low manufacturing cost, low material budget, fast charge collection, and high radiation tolerance. AstroPix is inspired by ATLASPix3 and MuPix (for High-Luminosity Large Hadron Collider) and is designed using a 180 nm CMOS process for future space-based applications, specifically gamma-ray astrophysics missions.
To ensure high precision and sensitivity, a next-generation Pair/Compton telescopes targeting a medium-energy (MeV) γ-ray from extreme explosions and accelerators requires detectors with good energy and position resolution in three dimensions with a low energy threshold. AstroPix provides low-power operation with large sensitive areas, low noise, wide dynamic range, and good energy/spatial resolution. At the ComPair2 tracker prototype, 10 tracking layers with a total area of 10 m^2 are designed with AstroPix sensors. The speaker will describe the integration of the AstroPix MAPS sensor in the ComPair2, a tracker prototype. Considering the features of the AstroPix sensor, it is selected as a baseline silicon sensor for the imaging part in the barrel electromagnetic calorimeter (BIC) for the Electron-Proton/Ion Collider (ePIC) experiment at the Electron-Ion Collider (EIC). The presentation will provide an overview of Astropix, highlighting the characterization and performance evaluation results, and describe the application of AstroPix in ComPair2 and BIC-ePIC detectors.

RDC 4 Readout & ASICs / 176

A readout ASIC on CMOS 28 nm for SiPM/PMT readout at cryogenic temperatures

Authors: Llorenc Fanals-i-Batllori[None]; Hugo Hernandez-Herrera[None]

Co-authors: Aldo Pena-Perez ; Lorenzo Rota ; Gang Liu ; Aseem Gupta ; Bojan Markovic ; Henry Shi ; Victor Turbiner ; Kevin K. Boateng ; Mike Hammer ; Ann M. Wang ; Steffen Luitz ; Tom Shutt ; Brian Lenardo ; Zepeng Li ; Marissa Hsu [1]

[1] *SLAC National Laboratory*

Corresponding Authors: markovic@slac.stanford.edu, liugang@slac.stanford.edu, fanals@slac.stanford.edu, zepengli@hawaii.edu, lorenzor@slac.stanford.edu, shim@anl.gov, blenardo@slac.stanford.edu, hdhernan@slac.stanford.edu, aseemg@slac.stanford.edu, awang5@stanford.edu, kevinkb@slac.stanford.edu, victur03@slac.stanford.edu, aldopp@slac.stanford.edu, mhammer@anl.gov, tshutt@slac.stanford.edu, luitz@slac.stanford.edu

Light readout systems with single-photon resolution are essential for next-generation HEP experiments, including dark matter searches, neutrino detectors, and noble liquid experiments. Technologies such as silicon photomultipliers (SiPMs) and photomultiplier tubes (PMTs) offer low noise and scalability, making them well-suited for large-area detector arrays.

This work presents a cryogenic R&D ASIC prototype, fabricated in 28 nm CMOS technology, designed to mitigate signal degradation and reduce background noise in large-scale light readout systems. The ASIC integrates multiple IP blocks, including a front-end readout channel with programmable gain transimpedance amplification, semi gaussian pulse shapers, waveform digitization, and a digital back end with high-speed CML output buffers. The analog front-end features three pulse shaping stages with selectable shaping times (30ns/60ns), offset and bias current trimming, each followed by a 12-bit, 100 MS/s ADC. On-chip, high-speed digitization at cryogenic temperature can simplify system-level design, minimize noise pickup, and improve signal quality, offering significant benefits for future experiments such as XLZD and others. Additionally, the ASIC incorporates on-chip supply regulation with bandgap reference circuits and cap-less LDO regulators, eliminating the need for bulky external decoupling capacitors. This design could not only fulfill the stringent radiopurity requirements of rare-event research but also establishes a path towards scalable, high-performance light readout solutions in future HEP detectors. We describe the design of the first prototype, together with possible future developments targeting cryogenic applications, as well as room temperature applications (e.g., calorimetry).

RDC 1 Noble Element Detectors / 177

Calibration and Performance of the ICARUS Detector at Fermilab

Author: Matteo Vicenzi[1]

[1] *Brookhaven National Laboratory (US)*

Corresponding Author: mvicenzi@bnl.gov

ICARUS is the largest Liquid Argon Time Projection Chamber (LArTPC) in operation and serves as the Far Detector of the Short Baseline Neutrino (SBN) program at Fermilab. Precise detector calibration is essential for reliable energy reconstruction and for maximizing the physics reach of the experiment. In this talk, I will describe the energy and timing calibration procedures developed at ICARUS. Thanks to the abundant flux of cosmic ray muons at the surface, the TPC response to ionization charge has been equalized across the detector, removing non-uniformities and in-transparency effects. A novel data-driven procedure has been used to tune the simulation of ionization signals and electronics noise yielding close agreement between Monte Carlo and data with minimal residual bias in reconstructed charge. In addition, the light detection system has been calibrated to sub-nanosecond timing resolution. This precision enables efficient cosmic background rejection and accurate synchronization of neutrino interactions with the time structure of both the Booster Neutrino Beam (BNB) and Neutrinos at the Main Injector (NuMI) beam. Together, these efforts demonstrate the robust performance of the detector and provide critical experience for future large LArTPCs, such as DUNE.

RDC 4 Readout & ASICs / 178

Possible new iterations of the VMM chip for MPGD readout

Author: Alexandre Camsonne[None]

Co-author: Gianluigi De Geronimo [1]

[1] *University of Michigan, Stony Brook University, dgcircuits.com*

Corresponding Authors: gianluigi.de.geronimo@cern.ch, camsonne@jlab.org

The JLab SoLID experiment is assessing the VMM ASIC family for GEM tracker readout in high-rate environments. The current VMM3a falls short of requirements. We propose a VMM3b revision with optimized gain and shaping time for high-rate GEM and uRWell operation. Additionally, we are considering a VMM4 version, migrating to TSMC 65nm, with redesigned ADCs, digital core, and new features to serve broader MPGD community applications.

RDC 6 Gaseous Detectors / 179

A straw tracker for FCC-ee experiments

Author: Linnuo Zhang[1]

Co-author: Junjie Zhu [1]

[1] *University of Michigan (US)*

Corresponding Authors: linnuo.zhang@cern.ch, junjie.zhu@cern.ch

We propose to build a straw tracker for FCC-ee experiments. The straw tracker offers the advantage of a low material, a crucial factor in minimizing overall inner detector material budget. With the capability to achieve a single-hit resolution of approximately 100 microns per layer, and the potential for up to 100 layers, the straw tracker will play a pivotal role in momentum measurement, pattern recognition, and particle identification. We will present performance studies based on GEANT simulations and cosmic ray data, along with preliminary results on particle identification using the primary cluster counting method (dN/dX).

RDC 6 Gaseous Detectors / 180

Improvements on directional nuclear recoil measurements with BEAST TPCs

Authors: Jeffrey Schueler[1]; Shashank Jayakumar[2]; Sven Vahsen[3]

[1] *The University of New Mexico*

[2] *University of Hawaiʻi at Mānoa*

[3] *University of Hawaii (US)*

Corresponding Authors: shayjayakumar@gmail.com, sevahsen@hawaii.edu, jschueler1@unm.edu

We report on the performance of compact, high definition Time Projection Chambers (TPCs) with pixel chip readout as part of the BEAST II beam background measurement project at SuperKEKB. The TPCs detect fast neutrons by measuring the three dimensional (3D) ionization distribution of nuclear recoils in ^{4}He:CO_2 gas at atmospheric pressure. We use these detectors to characterize the fast-neutron flux near the Belle II detector at the SuperKEKB electron–positron collider in Tsukuba, Japan.

The results highlight the mobility of the TPCs by measuring the fast-neutron flux at new locations. We also showcase new machine learning techniques that can provide accurate head-tail assignment even at low energies, significantly improving directional capabilities. Scaled-up detectors based on the detection principle demonstrated here may be suitable for directional dark matter searches, measurements of coherent neutrino–nucleus scattering, and other experiments requiring precise detection of neutrons or nuclear recoils.

RDC 1 Noble Element Detectors / 181

Simulation of Noble Element Detectors with NEST

Author: Kian Trengove[1]

Co-authors: Cecilia Levy [1]; Matthew Szydagis [1]

[1] *University at Albany, SUNY*

Corresponding Authors: ktrengove@albany.edu, levycec@gmail.com, mszydagis@albany.edu

Noble element detectors are currently one of the most attractive technologies for rare-event search experiments, such as searches for WIMP dark matter. NEST (Noble Element Simulation Technique) is a software toolkit used to model the microphysics of xenon and argon in both gases and liquids. NEST can be used across a large range of applications, from table-top setups to multi-tonne experiments, such as LZ, XENONnT, and PandaX. NEST models light and charge production along with final pulse areas with high accuracy across different particle types, energies, and electric fields, all based on experimental data and simple, empirical formulae. This enables efficient computational scaling, with millions of simulated events able to be processed in only tens of seconds with off-the-shelf computers. I present here an overview of NEST and its applications, along with recent updates that have continued to improve the accuracy of NEST.

RDC 9 Calorimetry / 182

LFHCal for ePIC Detector at EIC

Author: Prakhar Garg[1]

[1] *Yale University*

Corresponding Author: prakhar.garg@yale.edu

The Longitudinally-segmented Forward Hadronic Calorimeter (LFHCal) will be a part of the ePIC detector at the future Electron Ion Collider (EIC). The ePIC forward LFHCal is a steel-plastic scintillator sampling calorimeter, read out in transverse and longitudinally separated segments. The design is based on the SiPM-on-tile concept introduced by CALICE collaboration. In this talk, I will present the current status, test beam results and future preparations for LFHCal.

RDC 4 Readout & ASICs / 183

Development of a 28 nm Cryogenic PDK for Next-Generation HEP Detectors

Authors: Panagiotis Zarkos[None]; Aldo Pena-Perez[None]; Timon Heim[None]; Brian Lenardo[None]

Co-authors: Aikaterini Papadopoulou ; Lorenzo Rota ; Carl Grace ; Valeria Zarco ; Maurice Garcia-Sciveres ; Kevin K. Boateng ; Bryan Kwe ; Chase R. Parker ; Victor Turbiner ; Will Johnson ; Ariella Atencio ; Marissa Hsu [1]; Michael Lu [1]

[1] *SLAC National Laboratory*

Corresponding Authors: mlu@slac.stanford.edu, hsuma@stanford.edu, blenardo@slac.stanford.edu, panzark@lbl.gov, katerina@lbl.gov, aatencio@slac.stanford.edu, victur03@slac.stanford.edu, theim@lbl.gov, willreid@stanford.edu, brkwe@lbl.gov, crgrace@lbl.gov, lorenzor@slac.stanford.edu, mgarcia-sciveres@lbl.gov, aldopp@slac.stanford.edu, valeriazarco@my.smccd.edu, crparker@stanford.edu, kevinkb@slac.stanford.edu

Advances in high-energy physics (HEP) increasingly rely on ASICs operating at cryogenic temperatures. While modern 28 nm CMOS offers superior speed, power efficiency, and integration density, its behavior under deep cryogenic conditions deviates significantly from nominal operation. Threshold voltage shifts, mobility enhancement, mismatch, noise, and reliability mechanisms all change substantially, making standard room-temperature models inadequate. A dedicated cryogenic process design kit (cryo-PDK) in 28 nm is therefore essential for accurate modeling, simulation, and design. Such a PDK, validated down to 4 K, reduces design risk, enables first-pass silicon success, and establishes a framework for ASIC development in extreme environments.

This work describes the ongoing collaboration between LBNL and SLAC in four R&D directions: (1) the design of a 28 nm mini-ASIC with test structures covering all device flavors; (2) the development of a cryogenic test setup for characterization at 165 K, 77 K, and 4 K; (3) a model extraction and data-fitting platform for cryo-PDK development; and (4) radiation-hardness analysis. By capturing cryogenic device physics and closing the loop between measurement, modeling, and design, the cryo-PDK will enable next-generation low-noise, low-power, and radiation-tolerant readout systems for HEP detectors, quantum technologies, and space instrumentation.

RDC 6 Gaseous Detectors / 184

Development of an Ideal Gaseous TPC Detector

Author: Tanner Polischuk[1]

[1] *University of Hawaii at Manoa*

Corresponding Author: tannerjpolischuk@gmail.com

The Flexible, Ideal MPGD system (FIMS) is a collaborative effort to realize a detector whose performance is not limited by technology, but by the fundamental physics of particles interacting with matter. Designed to have applications spanning the extremes of gaseous TPC use-cases, the objective is to achieve ideal performance based on the metrics of: 3D spatial resolution, detection efficiency, and ion backflow. I will review the progress from the first year of this project, with particular attention to the design of the MPGD amplification structure to minimize the ion backflow.

RDC 6 Gaseous Detectors / 185

Development of a scaleable 40L gaseous TPC module with micromegas strip readout for directional reconstruction of low-energy nuclear recoils

Author: Michael Litke[1]

[1] *University of Hawaii at Manoa*

Corresponding Author: mlitke@hawaii.edu

The directions of low energy nuclear recoils open windows into previously unprobed areas of physics. Specifically, directional detection of coherent elastic neutrino nucleus scattering (CEνNS) would probe for new, beyond-the-standard-model (BSM) gauge bosons involved in that interaction as well as provide a tool for distinguishing between dark matter and neutrino scattering. This talk presents work from the development, construction, and first commissioning results of a 40L prototype gaseous TPC for directional detection of low energy nuclear recoils, as well as the prospects for scaling our TPCs up to active volumes of order 1m^3, which is necessary for both directional CEνNS measurements and for dark matter searches.

Poster / 186

Low-Latency Graph Neural Network Implementation for Charged Track Reconstruction

Authors: Amilqar Karam[None]; Philip Chang[1]; Tae Min Hong[2]

[1] *University of Florida (US)*

[2] *University of Pittsburgh (US)*

Corresponding Authors: tae.min.hong@cern.ch, philip.chang@cern.ch, amilqar.karam@ufl.edu

Graph Neural Networks (GNNs) have proven effective for edge classification in particle track reconstruction at the LHC. In this context, our GNN is trained in PyTorch to identify edge candidates—line segments connecting pairs of detector hits originating from ionizing particles. We present an FPGA-based emulator of such a GNN that achieves, to our knowledge, the fastest reported clock speed for this task, 290 MHz. Our approach replaces the original NN engines with boosted decision trees (BDTs) that regress the outputs of its three constituent models (two relational networks and one object network). These models are then mapped onto the FPGA fabric using the software package fwXMachina, enabling a design that uniquely uses no digital signal processors (DSPs). Along with its resource efficiency, the emulator is predicted to reproduce the GNN's edge-classification AUC to within three decimal places. Looking ahead, this 290 MHz design can be integrated with optimized HDL architectures to significantly reduce trigger-level latency in particle track reconstruction for the LHC, paving the way for real-time deployment of ML-based tracking algorithms.

RDC 9 Calorimetry / 187

The RADiCAL Platform: A Modular Development Testbed for Fast-Timing Calorimetry and Beyond

Author: James William Wetzel[1]

[1] *University of Iowa (US)*

Corresponding Author: james.william.wetzel@cern.ch

The next generation of collider experiments will require electromagnetic calorimetry with unprecedented precision in both timing and energy resolution, alongside robust radiation hardness. The RADiCAL (RADiation-hard Innovative CALorimeter) prototype has been developed to address these challenges, thus far achieving sub-20 ps timing performance and excellent EM energy resolution in recent beam tests.

While conceived as a calorimeter module, RADiCAL is now evolving into a flexible development platform. Its modular design enables integration and evaluation of new ideas in front-end electronics, photodetectors, fast-timing readout, scintillators, and radiation-hard crystals, providing a

unifying testbed where multiple R&D directions can converge. This approach positions RADiCAL not only as a pathfinder for future collider calorimetry, but also as an infrastructure to accelerate community-driven detector innovation.

At CPAD, we will present our plans to expand RADiCAL as a shared platform: advancing underlying calorimeter technology while offering an adaptable environment for the broader community to explore novel concepts in timing, materials, and readout. This inclusive framework strengthens the synergy between calorimetry (RDC 9 and DRD6-CALO) and fast-timing detector development (RDC 11), and others (DRD4-Photosensors), ensuring that critical R&D efforts are integrated, validated, and scalable toward future collider applications.

RDC 2 Photodectors / 188

LightPix-v3: Improvements in scalable readout for silicon photomultipliers in cryogenic environments

Author: Brooke Russell[1]

Co-authors: Amy Flather [2]; Armin Karcher [2]; Carl Grace [2]; Cecilia Ferrari [3]; Daniel Dwyer [2]; Jaafar Chakrani [2]; Panagiotis Zarkos [2]; Stephen Greenberg [2]; Tarun Prakash [2]

[1] *Massachusetts Institute of Technology*

[2] *Lawrence Berkeley National Laboratory*

[3] *MIT*

Corresponding Authors: tprakash@lbl.gov, panzark@lbl.gov, aflather@lbl.gov, arkarcher@lbl.gov, crgrace@lbl.gov, dadwyer@lbl.gov, ferraric@mit.edu, sgreenberg@lbl.gov, jchakrani@lbl.gov, russell3@mit.edu

The LightPix application-specific integrated circuit (ASIC) is designed for amplification, triggering, digitization, and multiplexed readout of high-channel count silicon photomultiplier (SiPM) systems, particularly within cryogenic environments. Here we report on performance measurements using LightPix-v3 which includes a variety of enhancements relative to the previous version. A new custom very-low-power (O[100]-uW) front-end amplifier enables use of larger-area (>10 mm2) SiPMs and delivers sufficient bandwidth to a TDC with O1-ns precision. This version also adds an 8-bit SAR ADC to each input channel, for better calorimetric performance in higher-occupancy applications. The LightPix system leverages the scalable readout techniques and digital back-end components from the related LArPix effort, which has been demonstrated in multiple liquid argon detectors with >10ˆ5 channels. LightPix also features programmable multi-channel hit-coincidence logic to mitigate high dark count rates, facilitating use in non-cryogenic detectors.

Cross-Cutting Topics / 189

Optical Characterization of Low-Gain Avalanche Diodes

Authors: Gabriele Giacomini[1]; Mohamed Boukhicha[2]; Thomas Tsang[2]

[1] *Brookhaven National Laboratory (US)*

[2] *Brookhaven National Laboratory*

Corresponding Authors: mboukhicha@bnl.gov, giacomini@bnl.gov, tsang@bnl.gov

We characterized a type of Low-Gain Avalanche Diode (LGAD) fabricated at the Brookhaven National Laboratory. LGADs are a type of silicon avalanche photodiodes originally developed for the fast detection of minimum ionizing particles for high-energy particle detectors. We study its detection capability on different types of ionization particles, such as X-rays, gamma-rays, alphas, and examine its intrinsic quantum efficiency with non-ionization optical photons. Here, using near infrared photon pulses, we demonstrated LGAD can accurately measure a nearly 1-MIP equivalent minimum ionizing particles with picosecond timing resolution. Furthermore, we perform some tests at cryogenic temperatures too.

RDC 2 Photodectors / 190

Development, Characterization and Quality Control of Silicon Photomultipliers for the CMS Barrel Timing Layer

Authors: Anton Karneyeu[1]; Arjan Heering[None]; Mitch Wayne[2]; Yuri Musienko[1]

[1] *University of Notre Dame (US)*

[2] *Notre Dame*

Corresponding Authors: adriaan.heering@cern.ch, mwayne@nd.edu, anton.karneyeu@cern.ch, iouri.musienko@cern.ch

The CMS experiment at CERN is adding a new timing detector, the Barrel Timing Layer (BTL), as part of the Phase II upgrade of the detector in preparation for high luminosity running at the LHC. The detector is comprised of more than 160,000 LYSO crystals, each read out at both ends by a Silicon Photomultiplier (SiPM). Our group led the development of the BTL SiPMs and their packaging, including the implementation of small thermoelectric coolers (TEC) to cool the SiPMs during operation and heat them during downtimes to anneal away radiation damage. We were also responsible for the quality control of 50% of the production SiPMs . Results will be shown for more than 180,000 SiPM channels illustrating excellent yield and uniformity of performance across the production, as well as results from radiation and long-term aging studies of a smaller sample of SiPMs.

Plenary / 191

Migration of feature extraction from firmware to software for the Belle II TOP detector

Author: Harsh Purwar[1]

[1] *University of Hawaii at Mānoa, Honolulu, HI, USA*

Corresponding Author: purwar@hawaii.edu

As SuperKEKB approaches its target instantaneous luminosity of 6×10^{35} cm^{-2} s^{-1}, its only particle detector, Belle II comprised of several subdetectors*, is also undergoing constant upgrades and changes. Closer to its target luminosity, the Belle II detector expects to receive very large data samples that have much higher background and radiation levels. Single event upsets (SEU) due to neutrons and charged particles have been known to lock up the Time of Propagation (TOP) subdetector's on-chip processing system (PS), a part of the Xilinx Zync SoC. By migrating the existing functionality of the PS to the readout servers for the TOP subdetector, we will prevent PS lockups from stopping Belle II data acquisition (DAQ), as the readout servers at Belle II are in a radiation-safe zone, close to the detector. In addition, this opens new pathways for using more advanced data-processing techniques, including AI/ML-based feature extraction in the future.

The current functionalities of the PS include feature extraction (features like pulse height, width, position, rise and fall times, etc.), data reduction, and re-formatting. Feature extraction in the PS currently utilizes the Constant Fraction Discrimination (CFD) method to extract these features from the raw waveforms. After migrating these functionalities to the readout servers, the role of PS in data-taking is completely removed, thus avoiding any downtime during DAQ due to PS lockups. Further improvements by replacing the CFD method with a trained machine learning (ML) model to extract these features more precisely, e.g., using template fitting, etc., can be made. Similarly, ML models trained on these waveform features may be used to classify events and thus reduce noise. I

will report on the status and compare performance post-migration of these functionalities from PS to the readout servers for the TOP detector at the workshop.

*https://www.belle2.org/research/detector/

RDC 2 Photodectors / 193

ProtoDUNE Vertical Drift (NP02) Photon Detection System Status

Author: Wei Shi[1]

[1] *Stony Brook University (US)*

Corresponding Author: wei.shi.1@stonybrook.edu

The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline neutrino oscillation experiment in the US. It will have four liquid argon time projection chamber (LArTPC) far detector (FD) modules, each holding 17 kilotons of liquid argon. These modules sit 1,500 meters underground and 1,300 kilometers from the near detector complex. The Vertical Drift (VD) FD module, the first of the four FD modules to be installed at Sanford Underground Research Facility, features X-ARAPUCA photodetectors installed on the LArTPC cathode plane and the cryostat membrane. The VD photon detection system (PDS) will provide timing for non-beam events, calorimetric energy measurement for neutrino events from MeV to GeV, and efficient light-charge association for improved event reconstruction.
To validate the VD technology, a large-scale prototype, ProtoDUNE-VD with a total LAr mass of 770 tons, has been constructed at CERN. The first hadron beam data was taken from July to September 2025. Key features of the X-ARAPUCA photodetector have been successfully demonstrated, for example the first-ever watt-level laser power delivery over optical fibers (PoF) to front-end electronics referenced to a -154kV high-voltage surface, and analog signal transmission over optical fibers (SoF) in a cryogenic environment. During this talk, I will review the ProtoDUNE-VD PDS design, its installation, commissioning, and operation. I will present preliminary PDS data analysis results from its first beam data. Other non-beam physics programs, such as the pulsed neutron source program, xenon doping, and future analysis plans, will also be presented.

Poster / 194

hls4ml - a tool for machine learning hardware-software co-design for HEP detector applications

Authors: Jan-Frederik Schulte[1]; Miaoyuan Liu[1]

[1] *Purdue University (US)*

Corresponding Authors: miaoyuan.liu@cern.ch, jan-frederik.schulte@cern.ch

The tight integration of machine learning (ML) models into detector readout and trigger systems will allow future HEP detectors to move complex reconstruction tasks much closer to the detector compared to the current implementations. This will enable these detectors to cope with much higher data rates and perform more complex and better targeted event selection at trigger level. ML algorithms have to be designed from the beginning with the tight latency and computing resource constraints in mind, a process called co-design. This is often challenging and the integration of ML models into FPGAs or ASICs requires significant technical know-how. ML We present hls4ml, an open-source tool that translates ML models from standard tools like keras or pytorch into high level synthesis (HLS) code for integration into either FPGA or ASICs. hls4ml supports a large variety of common ML operations, recently adding support for transformer architectures. It generates HLS code targeting a variety of vendors, such as Xilinx/AMD, Intel/Altera, or Siemens EDA. Hardware-software co-design is enabled with native solutions, such as pruning techniques that specifically optimize the model for FPGA resource usage, or thanks to the tight integration of hls4ml into a wider eco-system of model pruning and quantization tools. These include established tools such as QKeras or QONNX, but also many advanced open-source tools that are developed by the HEP community. These include PQuant and HGQ2, support for which have recently been added to hsl4ml. hls4ml is already widely used in the HEP community to integrate ML models into existing trigger systems and its capabilities in accelerating ASIC design for detector readout has been demonstrated.

RDC 8 Quantum & Superconducting Sensors / 195

Searching for Axions with Magnetic Resonance Force Microscopes

Authors: Elham Kashi[1]; Muhammad Hani Zaheer[1]; Ryan Petery[1]; Swati Singh[1]

[1] *University of Delaware*

Corresponding Authors: rpetery@udel.edu, swatis@udel.edu, hani@udel.edu, elkashi@udel.edu

We propose a magnetic resonance force microscopy (MRFM) search for axion dark matter around $m_a \sim \mathrm{GeV}$. The experiment leverages the axion's derivative coupling to electrons, which induces an effective A.C. magnetic field on a sample of electron spins polarized by a D.C. magnetic field and a micromagnet. A second pump field at a nearby frequency enhances the signal, and the detuning is matched to the resonant frequency of a magnet-loaded mechanical oscillator. The resulting spin-dependent force is detected with high sensitivity via optical interferometry. Accounting for the relevant noise sources, we show that current technology can be used to put constraints competitive with those from laboratory experiments with just a minute of integration time. Furthermore, varying the D.C. magnetic field and pump field frequency allows one to scan the axion mass. Finally, we explore this setup's capability to put constraints on other axion- Standard Model couplings.

Plenary / 196

The QUAntum LImited PHotons In the Dark Experiment

Authors: Andrew Bear[1]; Christopher Albert[2]; Evelyn Jean Thomson[3]; Peter Day[4]; Ritoban Basu Thakur[None]

Co-authors: Karthik Ramanathan ; Lanqing Yuan [1]

[1] *WUSTL*

[2] *Caltech*

[3] *University of Pennsylvania (US)*

[4] *JPL*

Corresponding Authors: evelyn.thomson@cern.ch, a.bear@wustl.edu, karthikr@wustl.edu, ritoban@caltech.edu, peter.k.day@jpl.nasa.gov, yuan.l@wustl.edu, calbert@caltech.edu

QUAntum LImited PHotons In the Dark Experiment (QUALIPHIDE) searches for Hidden Photons (HP) as dark matter. Quantum sensing techniques, such as photon counting, enable exploring new phase space for both HPs and axion like particles as candidates for dark matter. We have fielded a deeper than standard quantum limit search with single photon resolving MKIDs. This newest version of QUALIPHIDE operates in 4-16 THz (˜50 meV hidden photon masses), with expected sensitivity of kinetic mixing $< 10^{-12}$. The talk will outline detector technologies being explored, and our plans to pursue such dark matter searches with THz MKIDs.

SHARED SESSION II / 197

PQuant: Streamlining ML Model Compression to Deployment for Next-Gen Detector Systems

Author: Roope Oskari Niemi[None]

Co-authors: Chang Sun [1]; Anastasiia Petrovych [2]; Dimitrios Danopoulos [2]; Enrico Lupi [3]; Arghya Ranjan Das [4]; Sebastian Dittmeier [5]; Michael Kagan [6]; Miaoyuan Liu [4]; Vladimir Loncar [2]

[1] *California Institute of Technology (US)*
[2] *CERN*
[3] *CERN, INFN Padova (IT)*
[4] *Purdue University (US)*
[5] *Ruprecht-Karls-Universitaet Heidelberg (DE)*
[6] *SLAC National Accelerator Laboratory (US)*

Corresponding Authors: das214@purdue.edu, vladimir.loncar@cern.ch, miaoyuan.liu@cern.ch, michael.aaron.kagan@cern.ch

Real-time machine learning is emerging as a key tool for next-generation detector systems, where strict latency and hardware constraints require highly efficient models. We present PQuant, a backend-agnostic Python library designed to unify and streamline pruning and quantization techniques for hardware deployment, supporting both PyTorch and TensorFlow. PQuant provides a comprehensive suite of methods, including unstructured pruning, structured pruning (PDP and ActivationPruning), and hardware-aware resource (DSP/BRAM) optimization, pattern compression for convolutional kernels, in FPGAs/ASICSs, through MDMM framework. PQuant also provides flexible quantization options, ranging from fixed-point to high-granularity schemes, with per-layer or per-weight bit control. Integration with hls4ml is ongoing, enabling compressed models to be deployed directly to FPGAs/ASICs. PQuant bridges advanced compression methods with implementation directly translating to resource optimization, providing a practical path to low-latency ML in triggers, DAQ, and online reconstruction for high-energy physics experiments.

RDC 3 Solid State Tracking / 198

MAIA: A Detector Concept for a 10 TeV Muon Collider

Author: Rose Powers[1]

[1] *Princeton University (US)*

Corresponding Author: rp7916@princeton.edu

The prospect of a muon collider has fueled remarkable research and development efforts across physics frontiers. As the high-energy physics community continues to make strides towards the feasibility of a 10 TeV-scale muon collider, both the International and US Muon Collider Collaborations (IMCC and USMCC) have achieved significant progress in detector R&D, producing two potential detector designs currently under study. This talk will focus on one such concept, MAIA (Muon Accelerator Instrumented Apparatus). We will discuss the detector design, the strategies we employ to mitigate beam-induced background, and the latest results of performance studies. Finally, we will address some of the exciting opportunities the MAIA effort's remaining challenges provide for cutting-edge R&D.

Poster / 201

Characterization of the MetaRock prototype TDC for future HEP experiments

Authors: Amanda Krieger[1]; Carl Grace[None]; Josef Daniel Sorenson[2]; Kennedy Caisley[3]; Maurice Garcia-Sciveres[4]; Timon Heim[None]; Zhicai Zhang[5]

[1] *Berkeley Lab*

[2] *University of New Mexico (US)*

[3] *University of Bonn*

[4] *Lawrence Berkeley National Lab. (US)*

[5] *Tsinghua University (CN)*

Corresponding Authors: theim@lbl.gov, mgarcia-sciveres@lbl.gov, kcaisley@uni-bonn.de, akrieger@lbl.gov, sorensonj@unm.edu, crgrace@lbl.gov, zhicai.zhang@cern.ch

Detectors at future colliders will require timing precision on the order of 10 ps. Towards this goal, we've developed a low-power, high-speed prototype ASIC in 28nm CMOS named MetaRock. MetaRock is an evolution of the Pebbles ASIC. As compared to its predecessor, MetaRock includes a prototype low-power TDC based on a time stretching circuit. An on chip test bench consisting of a charge injection circuit and a second high-resolution (20 ps LSB) TDC are used for evaluating the performance of the low-power TDC. We will present the low-power TDC and testbed architecture and summarize the test results of the prototype. In addition, a characteristic study of the FE architecture, motivated by the MetaRock performance, is presented with lessons learned for future prototype structures.

Poster / 202

Beam Test Results of SiPM-on-Tile Calorimeter Prototypes Toward the ePIC Forward Calorimeter

Author: Weibin Zhang[None]

Corresponding Author: weibinz@ucr.edu

The SiPM-on-Tile technology has been adopted in several calorimeter subsystems of ePIC, including the forward and backward hadronic calorimeters ($1.5 < \eta < 3.0$), the high-granularity insert ($3.0 < \eta < 4.0$), and the Zero-Degree Calorimeter (ZDC, $\eta > 6.0$). To validate the design and assess detector performance, we developed prototypes for both the insert and the ZDC. These prototypes were tested in beam campaigns at the STAR hall and at the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Lab (BNL). At the STAR hall, the prototypes were exposed to particles from 200 GeV Au+Au collisions, providing measurements of detector response in a realistic collision environment. At NSRL, we performed a systematic study of SiPM response to different levels of irradiation, evaluating pedestal stability and MIP calibration. Together, these tests provide comprehensive validation of the SiPM-on-Tile technology for ePIC calorimetry.

SHARED SESSION / 203

Performance of HPSoCv2: measurements on a very high Channel Density Waveform Digitizer with sub-10ps resolution

Authors: Christopher Chock[1]; Greg Uehara[1]; Isar Mostafanezhad[1]; Jennifer Ott[2]; Luca Macchiarulo[1]; Simone Michele Mazza[2]

[1] *Nalu Scientific, LLC*

[2] *University of California,Santa Cruz (US)*

Corresponding Authors: isar@naluscientific.com, chris@naluscientific.com, greg@naluscientific.com, jeott@ucsc.edu, simone.michele.mazza@cern.ch, luca@naluscientific.com

In recent years, the introduction of very fast optical sensors with extremely low pitches (e.g. Low Gain Avalanche detectors -LGADs) has enabled high-density designs for high energy and nuclear physics detectors offering excellent spatial and timing precision; to harness the extreme spatial and timing resolution achievable with such devices, novel high performance/high channel density readout systems are required. For this reason we studied and designed the architecture of the HPSoC, a customized multi-channel waveform digitizing readout that is capable of directly interfacing with state-of-the-art sensor arrays, can self trigger and extract relevant information from the waveform derived from each pixel and internally distill such information in a compact digital format, with timing precision at the few picoseconds level and capable of sub-pixel spatial precisions at a few tens of micrometers or less.
In order to demonstrate the feasibility of the design and test some of its critical components, a staged approach was followed, and we will report on the various measurements on the performance of the second revision of the chip, the HPSoCv2, a 4 channel device with direct interfacing to LGAD sensor array, sampling speed in excess of 10 Gsps and demonstrated timing resolution below 10 ps. In particular, we will discuss the various measurements on the input front end, composed of a sensitive TransImpedance Amplifier designed to capture the salient timing and energy features of a typical LGAD detector, both on pixels and strips. We then discuss the characterization and performance of the fast digitizer (10-14Gsps) with input calibration signals, discussing the timing resolution achievable and potential feature extraction mechanisms. We finally show some initial test of readout of pulses that are acquired using the entire chain (LGAD, TIA, digitizer).

We will conclude with a discussion on the improvements and additional features that have been added to the third revision of the chip (HPSoCv3), for which testing is imminent.

RDC 6 Gaseous Detectors / 204

Large-area MPGDs for Physics Experiments at Jefferson Lab

Author: Huong Nguyen[1]

Co-author: Nilanga Liyanage [1]

[1] *University of Virginia*

Corresponding Authors: nl8n@virginia.edu, htn3r.uva@gmail.com

Large-area Micro-Pattern Gas Detectors (MPGDs) have become key components in the tracking systems of many major ongoing and future electron scattering experiments at Jefferson Lab (JLab). Various large-area Gas Electron Multiplier (GEM) trackers have been recently developed and constructed for three highly ranked experimental programs at JLab: the Super Bigbite Spectrometer (SBS), PRad-II, and MOLLER. GEM trackers are also considered the primary choice for the future SoLID physics program at JLab. Due to their excellent position resolution, low material budget, and simple mechanical construction, large-area Micro-Resistive Well (μRWELL) detectors have emerged as highly promising candidates for upgrading the CLAS12 forward tracking system to support operations at luminosities as high as $2 \times 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ in Hall B. By combining high-granularity tracking with transition radiation capabilities for particle identification, the GEM-based Transition Radiation Detector (GEM-TRD) has been proposed as a key component for improving electron-pion separation in the GlueX experiment in Hall D at JLab. This talk will discuss the challenges in the design, fabrication, and operation of large-area GEM trackers for high-luminosity experiments at JLab, as well as ongoing R&D efforts on large-area μRWELL and GEM-TRD technologies for future JLab experiments.

RDC 8 Quantum & Superconducting Sensors / 205

The SuperCDMS-HVeV Program: Results and New Directions

Author: Enectali Figueroa-Feliciano[1]

[1] *Northwestern University*

Corresponding Author: enectali@northwestern.edu

The SuperCDMS-HVeV (High-Voltage with eV resolution) program is an R&D project focused on developing detectors with low energy resolution to search for low-mass dark matter (⊠ 1 GeV/c2), study charge-transport in cryogenically-cooled crystals, and probe unclassified backgrounds at low energy. The program utilizes gram-scale silicon detectors instrumented with TES (transition-edge sensor)-based phonon sensors. A high-voltage bias can be applied to the crystal to amplify phonon signals from ionizing interactions via the Neganov-Trofimov-Luke effect. Utilizing these tools, HVeV detectors have recently achieved sub-eV baseline energy resolutions and demonstrated competitive sensitivities to electron-recoil dark matter at masses below 1 MeV/c2. This talk will provide an overview of the latest developments in the HVeV program. This includes the results from a dark matter search conducted at the NEXUS underground facility which featured a new detector housing design to reduce backgrounds from dielectric materials used in previous designs. Preliminary results from the most recent data taking campaign at the SNOLAB deep underground laboratory will also be shown which employed new strategies for reducing the rate of single electron-hole pair events. Finally, I will preview new directions being explored for this technology that will enable new science capabilities for both the dark matter and neutrino coherent scattering fields.

Plenary / 206

National AI Initiatives and Opportunities in HEP Instrumentation

Author: Shih-Chieh Hsu[1]

[1] *University of Washington Seattle (US)*

Corresponding Author: schsu@uw.edu

This talk presents an overview of the major national AI initiatives driving today's scientific breakthroughs, focusing on the Department of Energy's AI for Science efforts, including the FASST and hardware-aware AI programs, and the National Science Foundation's AI research institutes and AI2 ecosystem. The presentation highlights how these initiatives foster foundational AI model development, infrastructure, workforce training, and domain-specific research accelerators. Emphasis is placed on the current technical status and emerging opportunities at the intersection of AI and High Energy Physics (HEP) detector instrumentation, including AI-enhanced data acquisition, calibration, real-time processing, and digital twins of accelerator systems. Attendees will gain insight into how AI is revolutionizing detector performance and experimental workflows, opening new frontiers for discovery.

RDC 10 Detector Mechanics / 207

Temperature dependent thermal conductivity measurements and their effects on the thermal management predictions for Silicon Detector Support Structures

Authors: Andreas Werner Jung[1]; Pau Simpson[None]

[1] *Purdue University (US)*

Corresponding Authors: simps128@purdue.edu, andreas.werner.jung@cern.ch

We present measurements of the temperature dependent thermal conductivities for carbon composite laminates, thermal interface material, carbon foam and adhesives used for the construction of the Tracker Forward Pixel detector support structures as designed for the HL-LHC CMS upgrade project. The simulation set up for thermal performance using temperature dependent properties is described and comparative simulation results are presented to highlight the effects of temperature dependent material properties. First efforts to measure the thermal contact resistance using Laser Flash Analysis method are presented for co-cured facesheet to carbon foam interface and titanium pipe glued to carbon foam interface.

RDC 8 Quantum & Superconducting Sensors / 208

A Dark Photon Dark Matter Search with a Widely-Tunable SRF Cavity

Author: Raphael Cervantes[None]

Corresponding Author: raphaelc@fnal.gov

The SERAPH (SupERconducting Axion and Paraphoton Haloscope) experiment is a family of superconducting haloscopes being developed by the Superconducting Quantum Materials and Systems (SQMS) Center to search for wavelike dark matter. This presentation will focus on preliminary results from our dark photon dark matter search using a widely-tunable SRF cavity operating between 4-7 GHz, nicknamed the "plunger cavity."

I will present the cavity design and characterization, analyze the impact of microphonics on system performance and haloscope sensitivity, and describe our tuning methodology for this Q˜10ˆ8 cavity. The presentation will cover our haloscope analysis approach and discuss sensitivity limits achieved within this frequency range. Finally, I will outline lessons learned from this first search, implications for future axion searches, and proposed improvements for subsequent SERAPH experiments.

Plenary / 209

ESPPU and DRDs

Corresponding Author: thomas.bergauer@cern.ch

Plenary / 210

DOE Remarks

Corresponding Author: helmut.marsiske@science.doe.gov

Plenary / 211

Q&A

Plenary / 212

Welcome from Dean of the School of Arts & Sciences at the University of Pennsylvania

Corresponding Author: trodden@physics.upenn.edu

Plenary / 213

Guest 2

Plenary / 214

Welcome from Local Organizing Committee

Corresponding Author: evelyn.thomson@cern.ch

Plenary / 215

CPAD Introduction and Updates

Corresponding Authors: jinlong.zhang@cern.ch, jonathan.asaadi@uta.edu

Plenary / 216

National Initiatives: Microelectronics

Corresponding Author: mgarcia-sciveres@lbl.gov

Plenary / 217

National Initiatives: QIS

Corresponding Author: zorzetti@fnal.gov

Plenary / 218

HEP Instrumentation at U Penn

Corresponding Authors: williams@hep.upenn.edu, williams@physics.upenn.edu

Plenary / 219

US HFCC PED

Corresponding Author: elizabeth.brost@cern.ch

Plenary / 220

DUNE Phase-2 Detector R&D

Corresponding Author: russell3@mit.edu

Plenary / 221

Muon Collider PED R&D

Corresponding Author: isabel.rose.ojalvo@cern.ch

Plenary / 222

ePIC

Corresponding Author: hartbricho@ornl.gov

Plenary / 223

HEP Facility Status and Needs

Corresponding Author: carini@bnl.gov

RDC 9 Calorimetry / 224

Opening remarks

Corresponding Authors: marina.artuso@cern.ch, yeh@bnl.gov

RDC 9 Calorimetry / 225

Round table discussion

Corresponding Authors: yeh@bnl.gov, marina.artuso@cern.ch

Plenary / 226

NSF Remarks

RDC 8 Quantum & Superconducting Sensors / 227

Introduction

RDC 8 Quantum & Superconducting Sensors / 228

Discussion on RF amplifiers, simulation, test infrastructure

Corresponding Authors: rkhatiw@fnal.gov, asuzuki@lbl.gov

RDC 8 Quantum & Superconducting Sensors / 229

Discussion on material R&D, test infrastructure

Corresponding Authors: rkhatiw@fnal.gov, asuzuki@lbl.gov

Plenary / 231

GIRA Award: Olivia Seidel

Corresponding Author: olivias@fnal.gov

Plenary / 232

Poster Award / RDC Highlights / Closeout

Plenary / 233

Closeout

Plenary / 234

GIRA Award: Earl Almazan

Corresponding Author: earl.russell.almazan@cern.ch

235

Conference Photo Information

Corresponding Author: jonathan.asaadi@uta.edu

Plenary / **236**

Photo before 2pm and banquet at 6:30pm

Corresponding Authors: jonathan.asaadi@uta.edu, jinlong.zhang@cern.ch, evelyn.thomson@cern.ch