CPAD & RDCs

Jonathan Asaadi & Jinlong Zhang

10th CPAD Workshop
10/07-10, 2025, University of Pennsylvania

Coordinating Panel for Advanced Detectors (CPAD)

- Mission and Goals
  - The Coordinating Panel for Advanced Detectors (CPAD), seeks to promote, coordinate and assist in the research and development of instrumentation and detectors for high energy physics experiments.
  - By helping to coordinate the development of both evolutionary and transformative detector instrumentation across the national laboratories and with the university community, CPAD works to ensure the future of high-energy physics experiments.
- Brief history
  - Formed in spring 2012 in response to an 18-month-long study by a task force appointed to address the organization of high-energy physics instrumentation.
  - Currently coordinated through the American Physics Society (APS) Division of Particles and Fields (DPF)

https://cpad-dpf.org/

CPAD 2025

JINLONG ZHANG
ARGONNE
CHAIR

JONATHAN ASAADI
UNIVERSITY OF TEXAS
VICE CHAIR

- Co-Chair 2025
  - Vice-chair: Jonathan Asaadi (UTA), Chair: Jinlong Zhang (ANL)
- Execute Committee (EC) 2025
  - Nural Akchurin (TTU), Amy Connolly (OSU), Sowjanya Gollapinni (LANL), Julia Gonski (SLAC), Sally Seidel (UNM), Peter Sorenson (LBNL), Ritoban Basu Thakur (Caltech), Laura di Vacri (PNNL), Sven Vahsen (Hawaii), Silvia Zorzetti (FNAL)
- CPAD EC 2026 Member Nomination
  - DPF inviting nominations to serve two-year terms on the CPAD
  - Particularly expertise in dark matter detection, neutrino detection, gaseous detectors, electronics and TDAQ
  - Please use the APS nomination form https://forms.aps.org/t/eCPhoo9ug7us

NURAL AKCHURIN
TEXAS TECH UNIVERSITY
CALORIMETRY

AMY CONNOLLY
THE OHIO STATE UNIVERSITY
NEUTRINOS

SOWJANYA GOLLAPINNI
LANL
NEUTRINOS, LIQUID ARGON DETECTORS

JULIA GONSKI
SLAC
FAST ML INTO ASICS/ FPGA

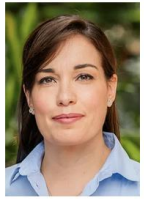
SALLY SEIDEL
UNIVERSITY OF NEW MEXICO
SILICON DETECTORS, RADIATION DAMAGE

PETER SORENSEN
LBNL
DARK MATTER AND NEUTRINOS

RITOBAN BASU THAKUR
CALTECH
DARK MATTER AND CMB

LAURA DI VACRI
PNNL
LOW BACKGROUND

SVEN VAHSEN
UNIVERSITY OF HAWAII
GAS DETECTORS



SILVIA ZORZETTI
FNAL
QUANTUM SENSORS

Highlights of CPAD Activities

- Annual Instrumentation Workshop
- DPF Instrumentation Award and DPF Instrumentation Early Career Award, Graduate Instrumentation Research Award (**GIRA**)
- Coordinating SBIR/STTR Input when requested by DOE
- Coordinating the generic R&Ds of US HEP instrumentation community
  - The formation of US detector R&D collaborations (**RDC**s) to address key technology areas that were identified in the 2019 Detector R&D BRN report (and beyond)
  - Interaction with CERN DRDs, Community input to ESPPU 2026
  - The annual process for proposal preparation for comparative review NOFOs and other funding opportunities
  - … …

Workshops

Welcome the 10th CPAD workshop

18-24 November 2024, University of Tennessee
https://indico.phy.ornl.gov/event/510

7-10 November 2023, SLAC
https://cpad-dpf.org/?page_id=1583

29 November - 2 December 2022, Stony Brook University
https://www.stonybrook.edu/cfns/cpad2022/index.html

18-22 March 2021, Stony Brook University (virtual)
https://www.stonybrook.edu/cfns/cpad2021/index.html

8-10 December 2019, University of Wisconsin, Madison
https://physics.wisc.edu/cpad2019/

9-11 December 2018, Brown University
https://www.brown.edu/Conference/CPAD2018/
2018 Workshop Report

12-14 October 2017, University of New Mexico, Albuquerque
http://physics.unm.edu/CPAD2017/

8-10 October 2016, Caltech
http://hep.caltech.edu/cpad2016/

5-7 October 2015, University of Texas, Arlington
https://indico.fnal.gov/event/25025p

DPF Instrumentation Award and GIRA

- Award information
  - https://cpad-dpf.org/?page_id=750
  - DPF Instrumentation Award since 2015, Graduate Instrumentation Research Award (GIRA) since 2018
- 2025 Instrumentation Award & Early Career Award
  - To be announced in the near future
  - Ceremony session at a DPF meeting (TBD)
- GIRA Award Ceremony session on Friday
  - Thanks to the committee: Samantha Lewis (Wellesley - Chair), Alvaro Chavarria (UW), Daniel Baxter (Fermilab), Masahiro Morii (Harvard), and Elizabeth Worcester (BNL)

P5 Recommendations on Detector R&D

Generic

Area Recommendation 6: Increase the budget for generic Detector R&D by at least $20 million per year in 2023 dollars. This should be supplemented by additional funds for the collider R&D program.

Area Recommendation 7: The detector R&D program should continue to leverage national initiatives such as QIS, microelectronics, and AI/ML.

Targeted

Area Recommendation 10: To enable targeted R&D before specific collider projects are established in the US, an investment in collider detector R&D funding at the level of $20M per year and collider accelerator R&D at the level of $35M per year in 2023 dollars is warranted.

In the 2023 P5 Report

The particle physics community has identified the need for stronger coordination between the different groups carrying out detector R&D in the US. We strongly support the R&D Collaborations (RDCs) that are being established and will be stewarded by CPAD, the Coordinating Panel for Advanced Detectors, overseen by the APS/DPF. The RDCs are organized along specific technology directions or common challenges, and aim to define and follow roadmaps to achieve specific R&D goals. This coordination will help to achieve a more coherent detector instrumentation program in the US, and will help to avoid duplication while addressing common challenges. International collaboration is also crucial, especially in cases where we want to have technological leadership roles. Involvement in the newly established Detector R&D Groups at CERN is encouraged, as are contributions to the design and planning for the next generation of international or global projects. Targeted future collider detector R&D in particular, such as for Higgs factories or a muon collider, is covered in Section 6.5.

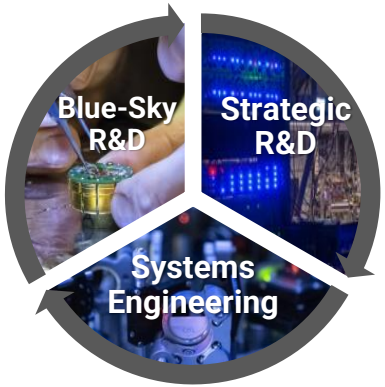
The RDCs are in the P5 report as is participation in the CERN based Detector R&D (DRDs)

U.S. RDCs Established

- Detector R&D efforts in many different technology areas are essential to realize the planned future experiments spanning all frontiers in High Energy Physics (HEP) / Nuclear Physics (NP)
- Much of the efforts needed require **collaboration** and **coordination** in order to realize the technologies required
  - **Collaboration**: The required expertise/resources/new ideas often live within multiple people, institutions, labs and only by bringing these pieces together can we hope to realize the technological challenges
  - **Coordination**: In a resource limited environment we need cohere efforts, minimize duplication, and build off progresses happening elsewhere
- Note that future projects likely have established R&D organizations (targeted R&Ds)
  - RDCs are created with generic R&D focus, are working closely the targeted R&Ds to optimize the resources and promote the work being done
  - There are ongoing R&D projects/activities that comprise both generic and targeted aspects, and RDCs are working with those for smooth evolvement and transition as appropriate
- Continuously enhancing communication with CERN DRDs, each having the scope of a US RDC and all relevant project specific R&Ds (though DRDs and RDCs don't have 1-to-1 match)

Generic vs Targeted

- A balanced, integrated instrumentation community pursuing both aspects
- Generic, blue-sky R&Ds as RDC focus
- Targeted R&Ds aiming to tackle known challenges and requirements, and system aspects of the future projects
- Future projects have established R&D organizations (targeted R&Ds), such as
  - US HFCC
  - US MUC
  - … …



HFCC-PED: FY25

SLAC

- Continued bottom-up prioritization of R&D efforts led by the HFCC L2/L3's
- Continued support for tracking related detector R&D efforts in FY25.
- Furthermore, discussions at the SLAC HFCC meeting (12/2024) identified support for software/simulation as critical and cross-cutting, required for further activities in all L2 areas.
- Limited funding could only allow support for a few focused low budget activities.

Simulation and Analysis Tools support	Princeton
Key4HEP support/development	LBNL
Software workshops, training events	FNAL
Prototype Straw tracker development Michigan 60	Michigan
Engineering design for analog FE for Dual R crystal matrix	FNAL
Endcap design work on LAr turbine structure associated PCB	Arizona

Additional funding to support travel and workshops

Srini Rajagopalan 28

DPF Community Meeting

US MUC FUNDING

ALFRED P. SLOAN FOUNDATION · THE KAVLI FOUNDATION · U.S. DEPARTMENT OF ENERGY Office of Science · SIMONS FOUNDATION · RESEARCH CORPORATION for SCIENCE ADVANCEMENT

At labs

- Fermila emonstrator (LDRD)
- Fermila e collider software (LDRD)
- Brookhaven collider R&D - RCS and cooling cell (LDRD)
- LBNL future collider detectors (LDRD)
- SLAC high-field RF test stand (GARD)

At the universities

- Princeton/Chicago/Tennessee Acc+Exp for MuC (Simons Foundation)
- Tennessee Fellowships (Cottrell x2, Sloan)
- UCSB/Princeton/Northeastern/UTK Interdisciplinary Seminar Series (Kavli Foundation)
- + start-ups, internal funding, and fractions of base grants/ECAs/CAREERs

also at labs

constrained by lack of significant R&D funding from gov't agencies

Tova Holmes, University of Tennessee 33

CERN DRD

DRDs should cover Strategic R&D

European Strategy for Particle Physics

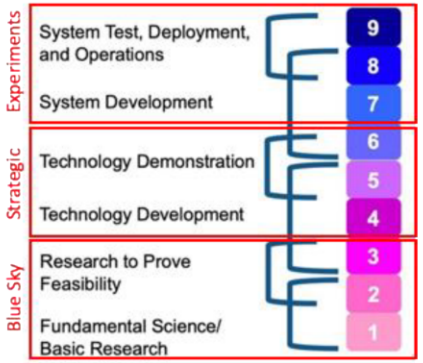
T. Bergauer

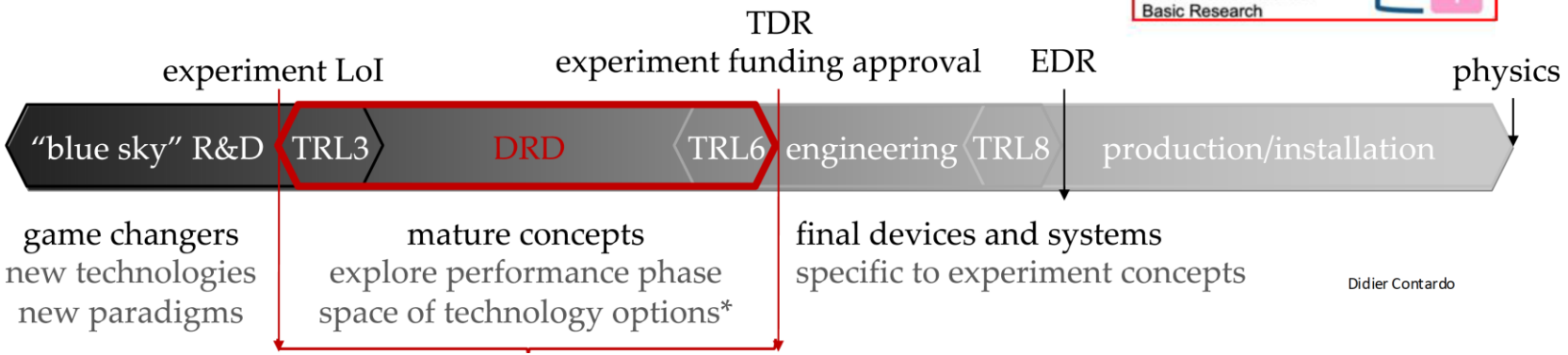
Strategic R&D bridges the gap between the idea ("**blue sky research**", low TRLs) and the **deployment and use in a HEP experiment** (TRL 8-9)

Covers the **development and maturing of technologies**, e.g.

- Iterating through different options
- Improving radiation hardness
- Scaling up challenges: detector area, number of channels, layers,..
- …

„NASA" TRL levels:





DRD Status

The DRD Collaborations

T. Bergauer

Eight DRD collaborations have been approved for an initial period of 3 years (extendable) with different histories and "maturity":

- Based on previous R&D collaborations:
  - **DRD1: Gaseous detectors** (based on RD51): *161 institutes, 700++ people*
  - **DRD3: Semiconductor Detectors** (previously RD42, RD50): *145 institutions / 700++ people*
  - **DRD6: Calorimetry** (CALICE, other proto-experiment collabs.): *135 institutes*
- Completely new: (community building, building trust, and finding benefit of being "CERN hosted")
  - **DRD2: Liquid Detectors:** *86 institutes, 205 members*
  - **DRD4: Photodetectors & PID:** *74 institutes*
  - **DRD5: Quantum Sensors and emerging technologies:** *112 involved groups*
- Transversal activities: no service provider, but with genuine R&D interest (TF9 → ECFA Training Panel)
  - **DRD7: Electronics:** *67 Institutes*
  - **DRD8: Mechanics & Integration:** *38 institutes*

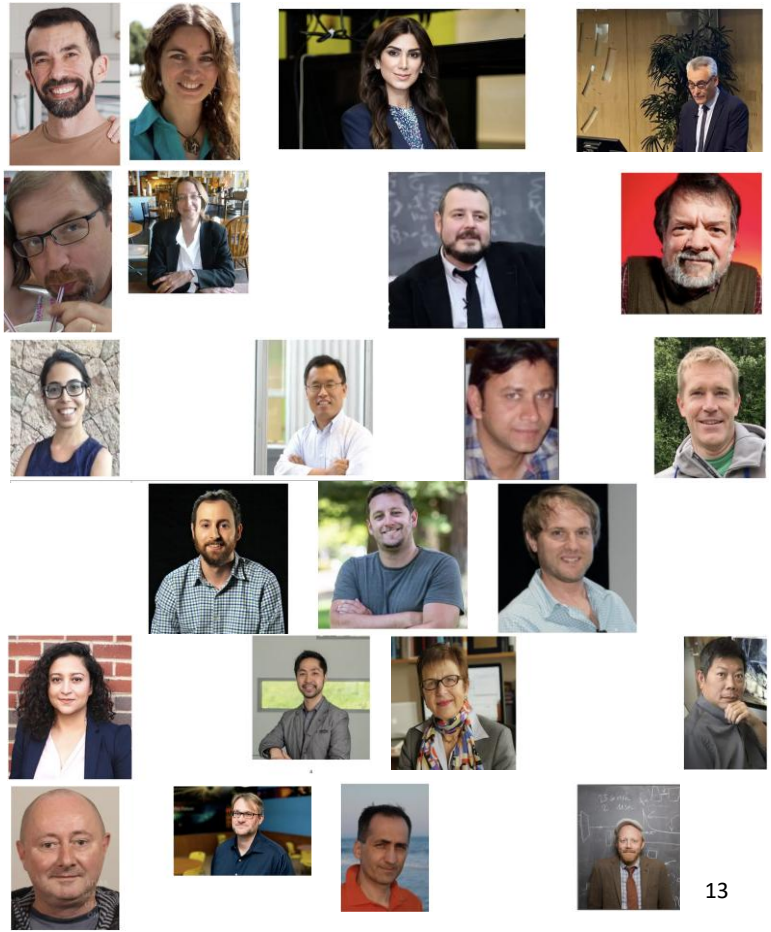
Input to European Strategy for Particle Physics Update

- After consulting with DPF and community workshop, CPAD submitted a whitepaper (ID 93) for detector R&D on behalf of the instrumentation community, by
  - Reiterating key messages related to instrumentation in Snowmass IF report and 2023 P5 report, connecting to ESPPU
  - Emphasizing the need of continuous strong support for instrumentation, both targeted and generic (identified by ECFA roadmap and Snowmass process)
    - For targeted, stated briefly and referred the proposed project whitepapers
    - For generic, summarized the latest RDC developments and connections to relevant DRDs
      - Work packages for R&D priorities
      - Highlights for technology progresses
    - For broad and cross-cutting matters, used Snowmass Report and ECFA Roadmap information
  - Strengthening broader collaboration with DRDs

RDCs

RDC	Topic	Coordinators
1	Noble Element Detectors	Jonathan Asaadi, Carmen Carmona
2	Photodetectors	Shiva Abbaszadeh, Flavio Cavanna
3	Solid State Tracking	Sally Seidel, Tony Affolder
4	Readout and ASICs	Angelo Dragone, Mitch Newcomer
5	Trigger and DAQ	Jinlong Zhang, Zeynep Demiragli
6	Gaseous Detectors	Prakhar Garg, Sven Vahsen
7	Low-Background Detectors	Noah Kurinsky, Guillermo Fernandez-Moroni, Daniel Baxter
8	Quantum and Superconducting Detectors	Aritoki Suzuki, Rakshya Khatiwada
9	Calorimetry	Marina Artuso, Minfang Yeh
10	Detector Mechanics	Andy Jung, Eric Anderssen
11	Fast Timing	Gabriele Giacomini, Matt Wetstein

Broad, cross-cutting topics, such as workforce development and facilities, currently reside in different RDCs.



Process for Proposal Preparation in 2024

- Over the summer months of 2024, through the whitepaper process, the RDCs worked with the community on both fostering new collaborations and drawing attention to existing R&D efforts
  - The community was largely supportive, open, welcoming and vocal
  - The process was very agile to accommodate new efforts, new coordination strategies, and new information
- >30 whitepapers were received from the community
  - These whitepapers were made available on the CPAD website
  - A community workshop was organized with a subset of these whitepapers (15) on their proposed R&Ds presented
- CPAD Executive Committee and the RDC coordinators ranked the whitepapers with predefined rubrics
  - The outcome was announced to the community
  - RDCs worked with proponents of the high-ranked (and other) whitepapers (subject to 2024 constraints) on submitting proposals to the DOE Comparative Review FOA

2024 Outcome in Brief

- Three whitepapers in the top rankings across the various categories

1. Smart Dust for Particle Tracking (RDC 4: Readout & ASICS) **(No proposal submitted)**
2. An exploration of high resistivity sub-kelvin Tc superconductors for particle astrophysics and cosmology detectors (RDC 8: Quantum)
3. Development of Ultrafast Timing Detectors Using Wide Band Gap Semiconductor Materials (RDC 3: Solid State Tracking) **(Awarded)**

- Two additional white papers in the majority of the top rankings

4. Development of Radiation Hard Ga2O3 Detectors for High Energy Physics (RDC 3: Solid State Tracking)
5. Characterizing the Performance of Novel Charge Readout Structures in High-Pressure Gaseous TPCs (RDC 6: Gas Detectors)

Process for Proposal Preparation in 2025

- Based on the feedback for 2024 process, a different approach without ranking is being taken for 2025, i.e., a mini BRN process
- Each RDC articulates the R&D priorities with the associated community, produces a list of handful priorities in a consistent format, like
  - Label: RDC1-WP1
  - Definition: New modalities for signal detection
  - Dictionary in brief: Going beyond the current paradigm just collecting electrons and photons (e.g. Meta-stable fluids, micron-scale tracking, combined multimodal sensors)
- A document combining all RDC priorities will be made available to the community and posted for reference
  - To encourage the proposals to cite the priority document and highlight the scope consistency with the individual priorities
  - To prepare collaboration letters as needed

2025 Timeline

- CPAD EC and RDC coordinators disseminated the feedback and agreed on the new approach in Feb 2025
  - Collated the exiting RDC R&D priority descriptions presented during 2024 CPAD Workshop
  - Started engaging the associated community
    - To inform, improve, and agree on the RDC R&D priorities
- CPAD community meeting March 2025
- EC and RDC coordinators meetings in July and very earlier August
  - To finalize all the R&D priorities, update the full document and make it ready for public
  - To check and agree on the overall content
- Community meeting on August 7
  - To share the finalized document with the whole instrumentation community
  - To start prepare collaboration letters as needed for proposals to DOE Comparative Review NOFO

2025 RDC R&D Priority Document

https://docs.google.com/document/d/1sc-W2FbIbv8dmrXPkAvoElDRNFhTK7Xw/edit?usp=sharing&ouid=109289369655969416396&rtpof=true&sd=true

Coordinating Panel for Advanced Detectors

RDC R&D Priorities
CPAD 2025

Contacts: Jonathan Asaadi (CPAD vice-Chair), Jinlong Zhang (CPAD Chair)

Introduction

These generic detector R&D priorities were developed based on the key challenges identified by the 2021 Snowmass Instrumentation Frontier report [1], which concurred and broadened the Priority Research Directions in the 2019 DOE HEP Detector R&D Basic Research Needs (BRN) report [2]. The list was presented initially at CPAD Workshop 2024, synthesized for the Instrumentation Community Input to the European Strategy for Particle Physics (ESPP) 2026 Update [3].

US R&D Collaborations (RDCs) were established with generic R&D focus, and are organized along specific technology directions or common challenges, and aim to define and follow roadmaps to achieve specific R&D goals, as described in the 2023 P5 Report [4]. The RDC coordinators have been continuously articulating the R&D priorities by working with the community. Each priority item is described in this document as a work package (WP) with brief definition and concise dictionary text. A complete version of this document will be made available to the instrumentation community with a citable reference.

The proposals are encouraged to cite this document and highlight the scope consistency with the individual priorities. Collaboration letters will be prepared as needed.

Cross-RDCs Topics

- **cRDCs-WP1: Intelligence in the front-end electronics**
  Integration of artificial intelligence / machine learning (AI/ML) algorithms for on-chip triggering and/or data-reduction capabilities. Technologies include smart pixel technology, embedded Field Programmable Gate Arrays (eFPGA), anomaly detection systems, and unconventional computing methods. [RDC1, RDC3, RDC4, RDC5, RDC6, RDC9]
- **cRDCs-WP2: Timing distribution with picosecond synchronization**
  Precision timing protocols and distribution systems enabling sub-picosecond synchronization over large-scale detector networks for TDAQ applications (1 ps over 1 km). [RDC3, RDC4, RDC5, RDC6, RDC9, RDC11]
- **cRDCs-WP3: Monolithic Active Pixel Sensors**
  Novel Monolithic Active Pixel Sensors (MAPS) with a focus on improving timing (few ns and below) and spatial resolution (sub-10um). This includes exploring novel materials and technologies (CMOS and beyond) and novel readout approaches. [RDC3, RDC4, RDC9]
- **cRDCs-WP4: Pixelated detectors for 4D tracking**
  Development of readout ASIC for precise 4D tracking at future colliders, with sub-100um pixel pitch and sub-50 ps timing resolution. Developments include: fast analog front-ends, Time-to-Digital Converters (TDC), timing synchronization strategies, hybridization and 3D integration strategies. [RDC3, RDC4, RDC11]
- **cRDCs-WP5: Readout electronics for sub-10ps timing detectors**
  Developing advanced readout electronics specifically designed for sub-10ps timing detectors, to be used in calorimetry applications with sensors like SiPM, LAPPDs, LGADs, *etc.*. Technologies include high-speed analog/mixed-signal readout ASICs that can accurately measure and perform on-chip processing, the development of digital SiPMs. [RDC4, RDC6, RDC9, RDC11]

Looking Forward to 2026

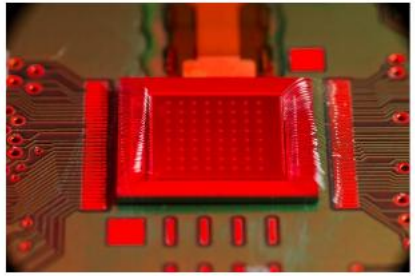
- RDC 2024 process for HEP University Comparative Review for FY2025
  - Multi-institutional (consortium) proposals were encouraged, two awarded
- RDC 2025 process for HEP University Comparative Review for FY 2026
  - FY26 pre-proposals by July 31, 2025
  - FY26 proposals to be considered in the Comparative Review by September 4, 2025
    - Multi-institutional team proposals discouraged
- (RDC 2026 process TBD for) HEP University Comparative Review for FY 2027 (FY26 SC Open Call DE-FOA-0003600)
  - FY27 pre-proposals by July 30, 2026
  - FY27 proposals to be considered in the Comparative Review by September 3, 2026
    - Multi-institutional team proposals discouraged

Targeted Review: Multi-institutional Team Applications for HEP Detector R&D

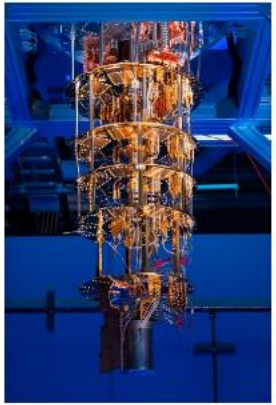
- A merit-review panel in June 2026 for multi-institutional team applications submitted to the topic, proposing high-risk, high-reward blue-sky research that address significant challenges beyond the scope of typical single-investigator awards.
- In the FY26 SC Open Call DE-FOA-0003600
  - Pre-proposals by February 27, 2026 (mandatory)
  - Encouragement / discouragement decisions by March 27, 2026
  - Encouraged proposals by May 1, 2026
- Additional details in the NOFO and the forthcoming Lab Call
  - The award ceiling is $500,000 per year in total across all institutions for a three-year award.
  - HEP expects to make at most three awards.

National Initiatives

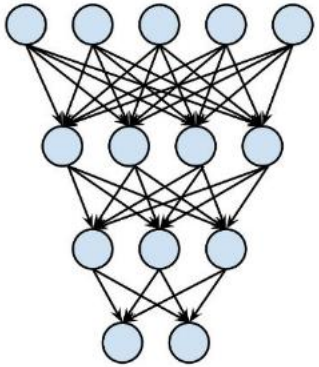
- Utilize effectively the national initiatives relevant to HEP instrumentation
  - Contribute with adequate resources and to planning matters
  - Play equal or major partners Shape and define the initiatives
  - Enhance connections to other programs, other offices/agencies, private foundations/commercial partners, and global collaborations



Microelectronics



Quantum Information Science



AI/ML

RDC Process for Other Opportunities/Initiatives

- QuantISED2.0 FOA
  - RDC8 acted on concurring the priorities and facilitating the collaborations
  - Communicated with PIs via RDC8 meetings and other methods
    - 1) Whether they lead or participate in proposal(s), if so, which high-priority RDC8 work package(s) will the proposal(s) be in line with or potentially benefit to
    - 2) Whether they need identify more collaborator(s)
  - Conducted diligently by RDC8 then
    - Assessed whether there is lack of proposal(s) for some RDC8 high-priority work packages so to encourage additional different proposals;
    - Communicated the information collection for 2) with relevant individuals/institutes (NOT in the large forum) and connected the relevant parties (but leave the detailed collaboration matters for themselves)
- Microelectronics call
  - RDC4 acted on concurring the priorities and facilitating the collaborations, with the same approach above
- Hardware-aware AI for HEP
  - RDCs didn't act on as it was a CompHEP call and was aware of CPSC being created
- Your feedback will be greatly appreciated for how to act on for future similar opportunities

Facilities

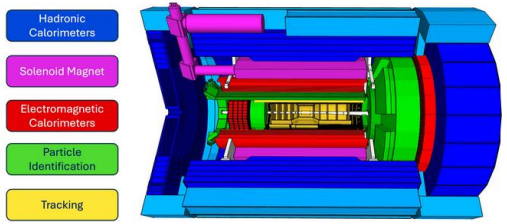
- Future experiments will operate in demanding environments: temperature, magnetic field, radiation, low-background, low-power, …
- It is vital to develop and maintain critical facilities, centers and capabilities for the sharing of common knowledge and tools

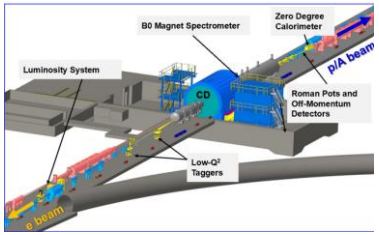
Test Beams	Irradiation	Magnet	Noble Liquid
Test beams with expanded capabilities	High-flux irradiation facilities using different particle types	General-purpose high-field magnet platform	Noble Liquid platform for neutrino and other cryogenic experiments

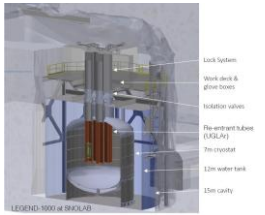
Quantum Systems	Low-Background	Characterization	Calibration
General-purpose platform for quantum sensors	Assay and low-background facilities	Platforms for fundamental properties studies	Platform for calibration and systems design

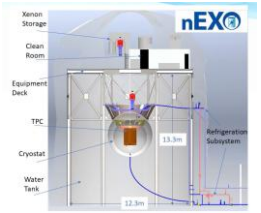
Synergies with NP

- Great synergies between HEP and NP in many technology areas
  - ePIC detector
    - Si based tracking
    - MPGD
    - Calorimetry
    - PID
    - Electronics
  - Ton-Scale 0νββ detectors
    - CUPID: bolometer with heat and light
    - nEXO: LXe TPC with ionization and light
    - LEGEND: HPGe detectors operated in liquid argon
  - … …



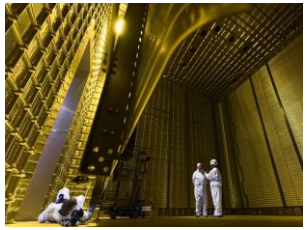


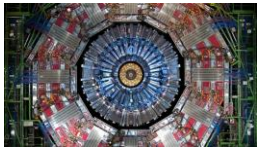




- Keys to the success of this enterprise are people, facilities and resources, and connections and collaborations
  - Advanced workforce and research collaborations
  - Unique facilities and capabilities
  - Connections to other programs, other offices/agencies, private foundations/commercial partners, and global collaborations

Workforce, Collaborations, Facilities & Partnerships





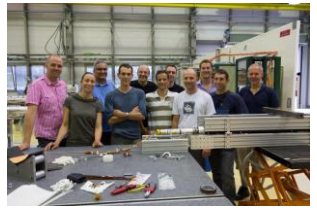
Workforce Development

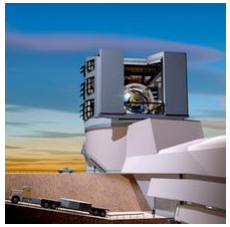
Research Collaborations

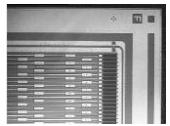
Advanced Detector Development

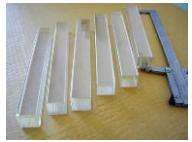
Facility Stewards

Industry Partnerships









Summary

- Much improved status of the instrumentation community
- CPAD RDCs are very active on R&D priorities and annual processes
- Please join CPAD and RDCs (this is the instrumentation community)

  CPAD@LISTSERV.FNAL.GOV

Enjoy the workshop!