US-FCC Calorimetry

Bob Hirosky
Michael Begel

17-Apr-2026

Calorimetry L2/L3 coordination

Community email list (us-hfcc-calorimetry@cern.ch)

Level 2 coordinators: Michael Begel, Bob Hirosky

Level 3 technology areas:

- Dual Readout: Grace Cummings
- Noble Liquid: Erich Varnes
- Si-W: Jim Brau
- Tile-Scint: Vishnu Zutshi

US FCC Calo - Recent talks given / planned

Given:

- **CPAD** October 2025, **DR** (Bob)
- **CPAD** Ocotber 2025, **DR** (Y. Feng)
- **CPAD** October 2025, **DR** (W. Jin)
- **CPAD** October 2025, **DR** (J. Wilson)
- **Lepton-Photon** August 2025, **DR, LAr, SiW (**Grace)
- **Argonne Physics (Nuclear) Division Seminar,** October 2025, **DR** (Grace)
- **Fermilab Wine & Cheese Seminar,** October 2025, **DR** (Grace)
- **Northwestern HEP Seminar,** November 2025, **DR** (Grace)
- **UIUC HEP Seminar**, November 2025, **DR** (Grace)
- **Yale NPA Seminar,** November 2025, **DR** (Grace)
- **Argonne HEP Seminar**, January 2026, **DR** (Grace)
- **Tufts Colloquium**, January 2026, **DR** (Grace)
- **Ohio State University Colloquim**, February 2026, **DR** (Grace)
- **MIT NUPAX Seminar**, February 2026, **DR** (Grace)
- **APS Global Physics Summit, Invited talk,** March 2026, **DR** (Grace)
- **APS Global Physics Summit,** March 2026**, DR** (Walker H.)
- **APS Global Physics Summit,** March 2026**, LAr** (Erich.)
- **APS Global Physics Summit,** March 2026**, SiW** (JBrau)

Currently planning talks for:

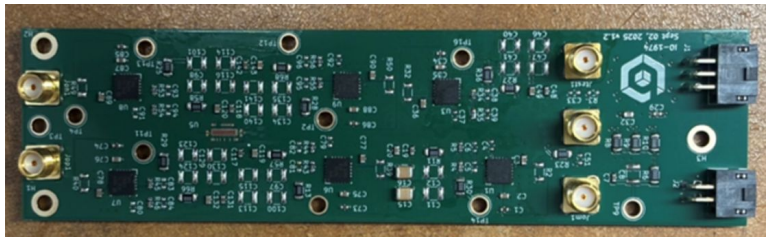
- **May 2026: CALOR Workshop**
- **June 2026: FCC Workshop**

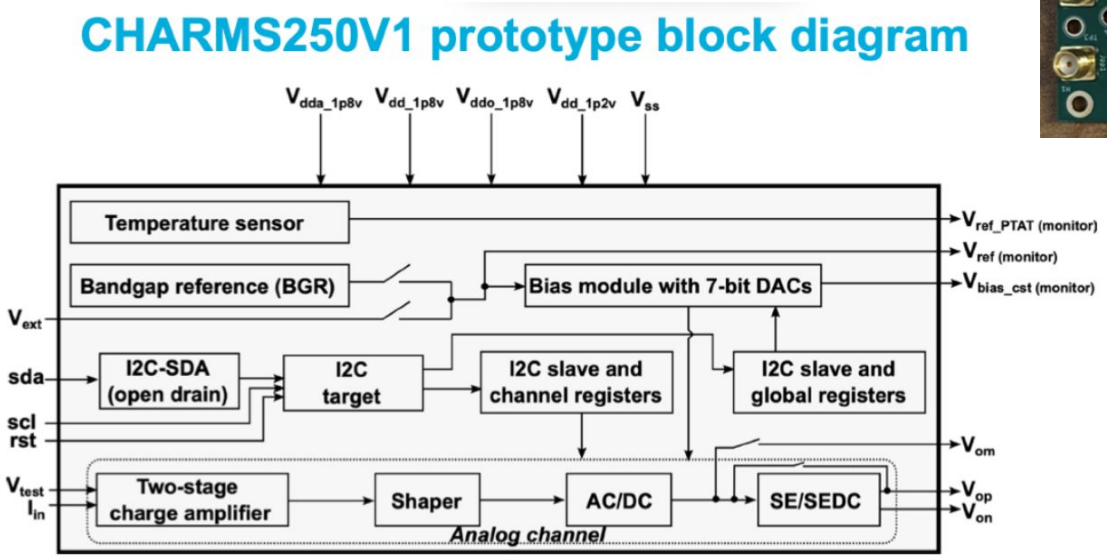
Apologies for any missed talks from USF CCC alo community Not counting overview talk on FCC, Full Detector concepts

Noble Liquid Updates and Plans

Recent NL Accomplishments

BNL (funded via LDRD, not HFCC)
– Cold electronics (amplifier/shaper) [talk]





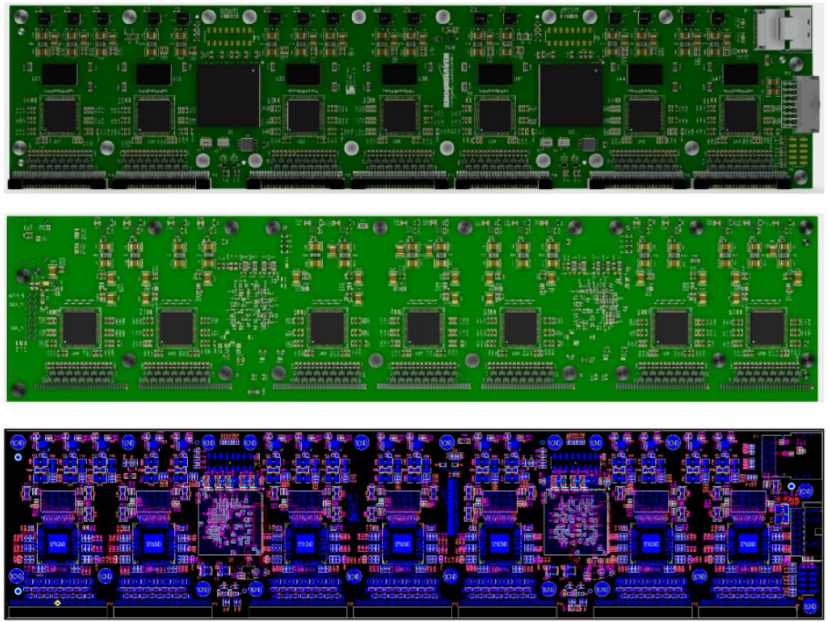
Noble Liquid Updates and Plans

Recent NL Accomplishments

BNL (funded via LDRD, not HFCC)
– Front-end board [talk]

CFEB Layout

- PCB design
  - 22 Layers
    - 12 signal layers 10 power planes
  - Board Dimensions
    - 350mm x 80mm x 2.5mm
- Board Status
  - Currently out for fabrication
    - Expected by 05/28/2026

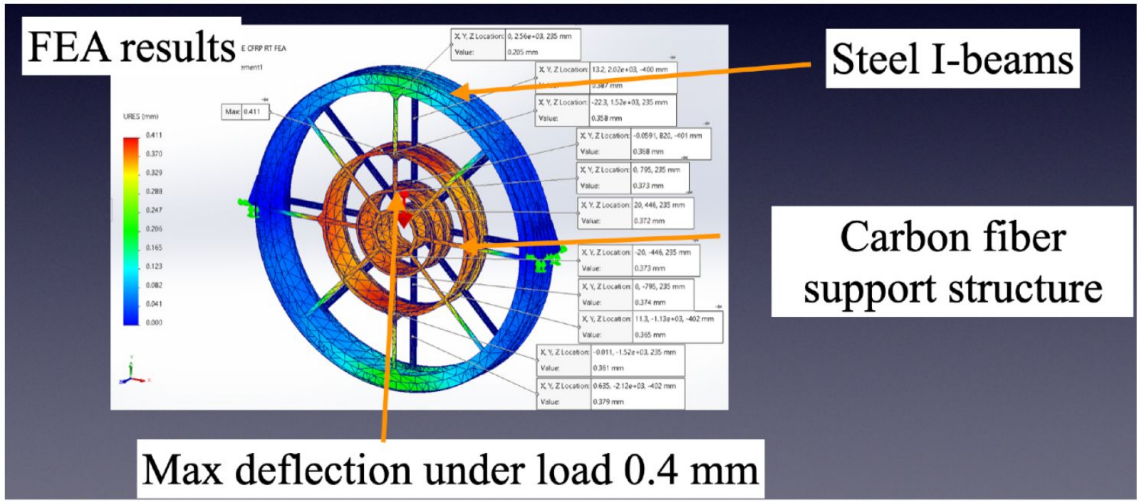


Noble Liquid Updates and Plans

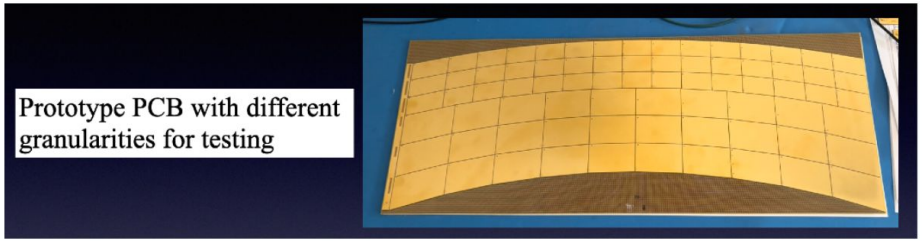
Recent NL Accomplishments

Arizona

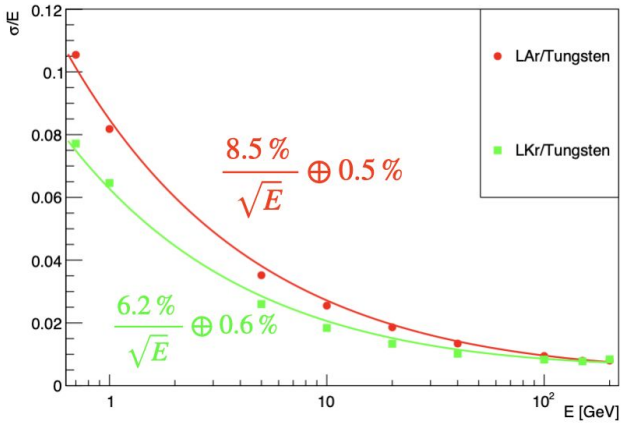
– Mechanical design of endcap ECal



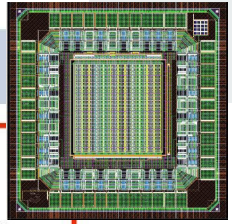
– Prototype readout board:



– Geant4 simulations



Si-W Calorimetry for Higgs Factory



Si-W Calorimetry

PROPOSED ACTIVITY

- Digital ECal based on Monolithic Active Pixel Sensors (MAPS)
  - Jim Brau (Oregon)
  - Caterina Vernieri (SLAC)
- Reimagining Si-W based e+e- collider precision luminosity measurements
  - Graham Wilson (Kansas)

Reimagining Si-W based e+e- collider precision luminosity measurements

Working on a **new approach** to the design of the **luminosity calorimetry** for future e+e- colliders. Emphasis on simulation and design studies.
The detector technology is likely to be **Si-W**.
Exploring an analog approach and plan to look at digital.
Simulations achieve 3.7%/sqrt(E) using **thick silicon layers (750 um) with high sampling frequency**, and expect significantly better than 100 um resolution in radius and and r dphi for modest cell sizes (the much better sampling also improves position resolution - it is not all about Moliere radius).

This started from the premise of trying to evaluate how feasible it is to extend the acceptance for the e+e- -> gamma gamma process into the LumiCal acceptance, where one will need excellent Bhabha rejection.
The ultra-high granularity opens up new directions in shower reconstruction but also in being able to resolve individual showers that will aid in a more exclusive measurement that can probe the details of the process modeling (for both Bhabhas and gamma gamma).

Resource request:
- o Some travel support.
- o Some GS support (even just summer).
- o Some M&S funds for detector components for effective positron lifetime measurements.

Digital ECal based on MAPS

Builds on and complements the sensor development for tracking

- Sensor needs to first satisfy the requirement for Higgs factory tracking, then adaptation for calorimetry will be implemented
- Prototyping steps achieved in collaboration w/ CERN (@SLAC) along with detailed Higgs factory shower reconstruction simulation studies

Design and prototyping needed to optimize Higgs factory performance
- power consumption (10 mW/cm2 / lower?)
- cooling design/power dissipation
- potential for multiple thresholds
- bit depth requirement for calorimetry
- stitching to make 2000 m^2 feasible
- basic mechanical design
- absorber with minimized sampling gaps
  - maintain Moilere radius
- passive cooling / power pulsing

Simulation studies demonstrate needed Higgs factory performance
- for electromagnetic shower resolution
- for shower containment
- for separation of showers within jets
- for particle flow reconstruction

Simulations continue optimization
- sampling frequency
- pixel sizes
- other choices

Common interests/coordination with DRD6 collaborators
- Utrecht University (T. Peitzmann)
- University of Birmingham (N. Watson)
- others (FOCAL for ALICE)

Other collaborators interested:
- Brown(Gouskos), Stony Brook(Dao, Piacquadio)

SUPPORT NEEDED URGENTLY
- Partial grad student research assistant
- Travel to collaborative meetings and workshops

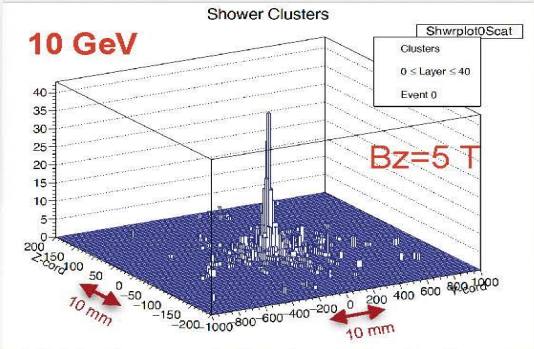
EM CALORIMETER PERFORMANCE
Shower energy & transverse position measurement

EM ENERGY RESOLUTION (single bit digital)

HITS	$16.4\,\%/\sqrt{E} \oplus 2.0\,\%$
CLUSTERS	$12.2\,\%/\sqrt{E} \oplus 1.4\,\%$
IDEAL - MIPS	$8.8\,\%/\sqrt{E} \oplus 0.2\,\%$

EM resolution goal set by particle flow.

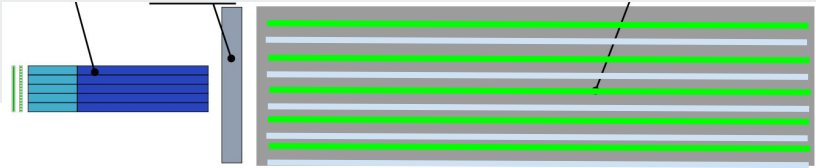
SiD ECal = 27 X_0 (20 thin +10 thick layers)



	Shower spread (mm-rms)		Shower position measurement (mm)					
			all clusters		within 4 mm & 1st 20 Layers		within 3 mm & 1st 15 Layers	
Eγ (GeV)	Y	Z	δY	δZ	δY	δZ	δY	δZ
1	4.7	4.2	1.19	1.06	0.41	0.40	0.33	0.33
10	4.8	4.3	0.43	0.37	0.14	0.14	0.12	0.11
50	5.1	4.6	0.21	0.19	0.07	0.07	0.06	0.06

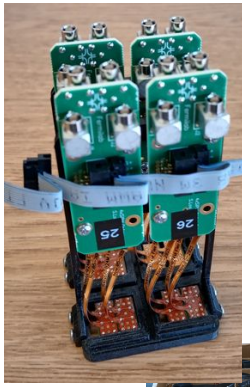
- This precision can be improved:
  - - naive, simple selections.
- Important for jet particle flow measurements

DR Calo Updates and Plans

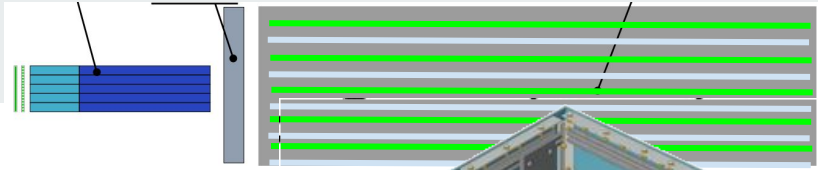


EM Matrix status

- **Preparing for EM-shower matrix testing staring end of August**
- **Still waiting on remaining crytals.**
  - **If the Chinese government doesn't release remaining xtals in ~30 days, we will proceed w/ 80% of rear matrix to study S/C collection and MC-corrected resolution studies.**
  - **Planning for additional studies in 2027 in any case.**
- **Electronics produced for rear matrix (FNAL)**
- **Readout interface designed for front, producing now (FNAL)**



DR Calo Updates and Plans



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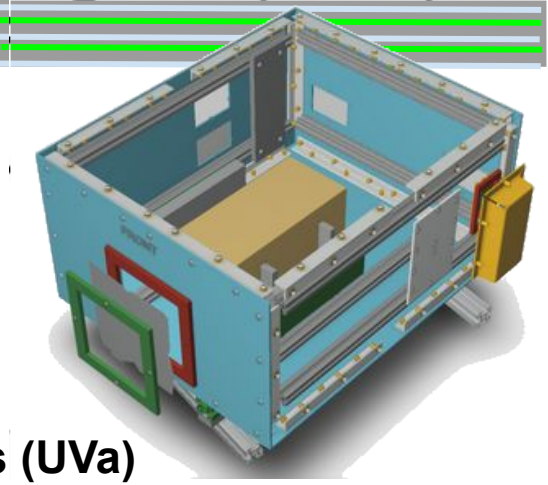
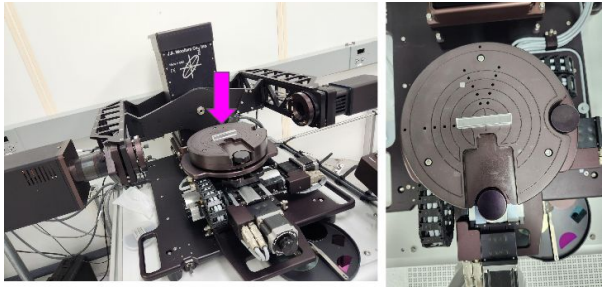
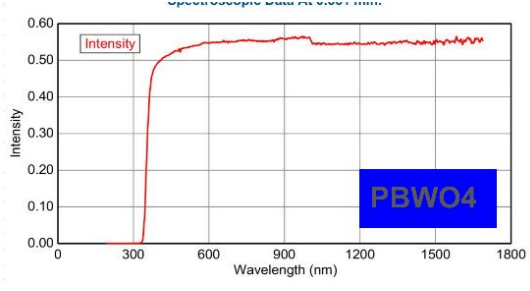
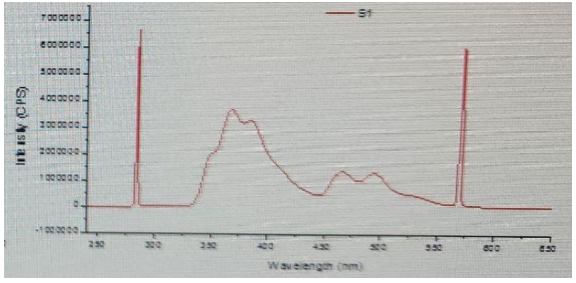


- **Matrix mechanics and assembly understood (UVa, Purdue, FNAL)**
  - **Start assembly by the end of the month (UVA)**
  - **Improved optical matching scheme**
- **New testbeam dark box designed, production in progress (UVa)**
- **New DAQ based on EUDAQ being developend (UMI)**
  - **Commissioing by team effort (UVa, UMD, UMI, FNAL)**
- **New crystal test facilities (UMD,CUA)**







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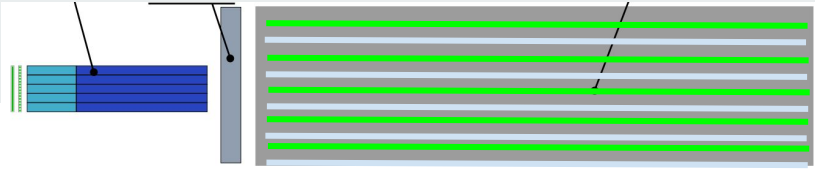
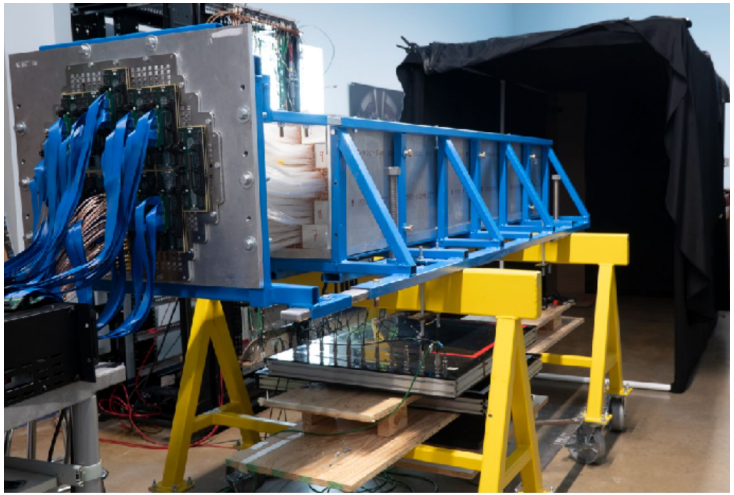
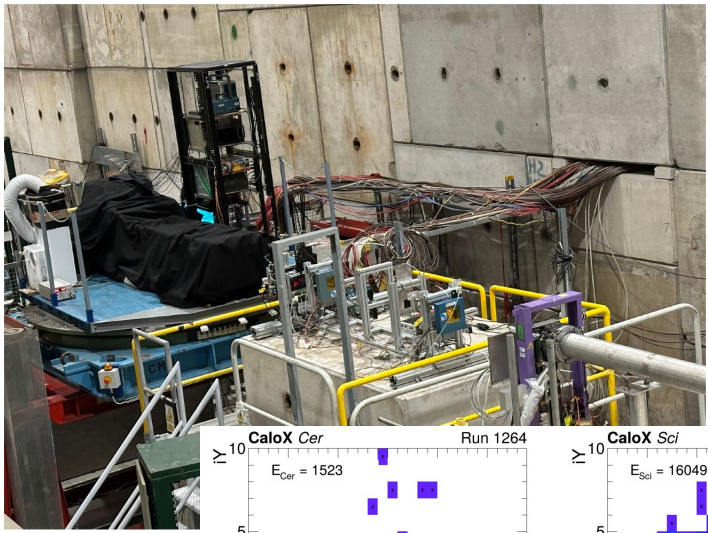


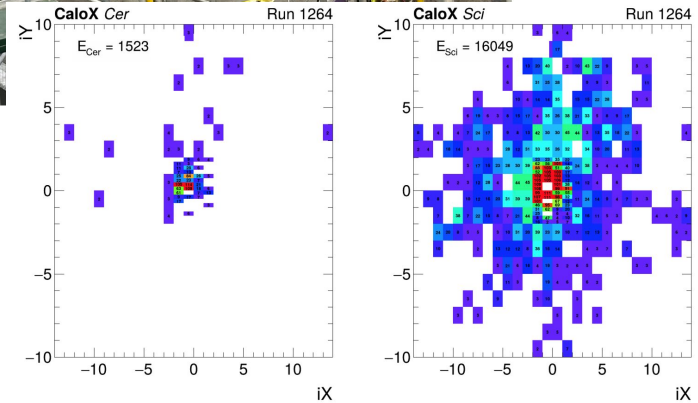
HG-DREAM → fiber sampling DR

- **high-granularity, precision timing with fast SiPMs, , integration of NNs, and exploration of new fibers/materials**
- **Two test beams at CERN last year**
- **First time with refurbished DREAM module**

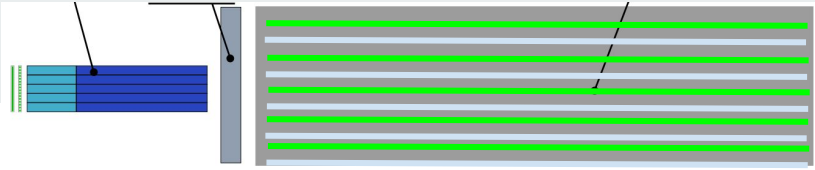




W. Jin, CPAD 2025
Y. Feng, CPAD 2025



DR Calo Updates and Plans



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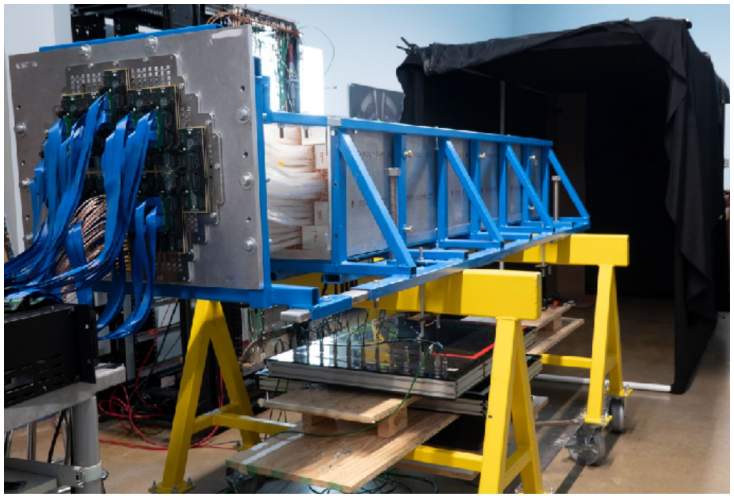
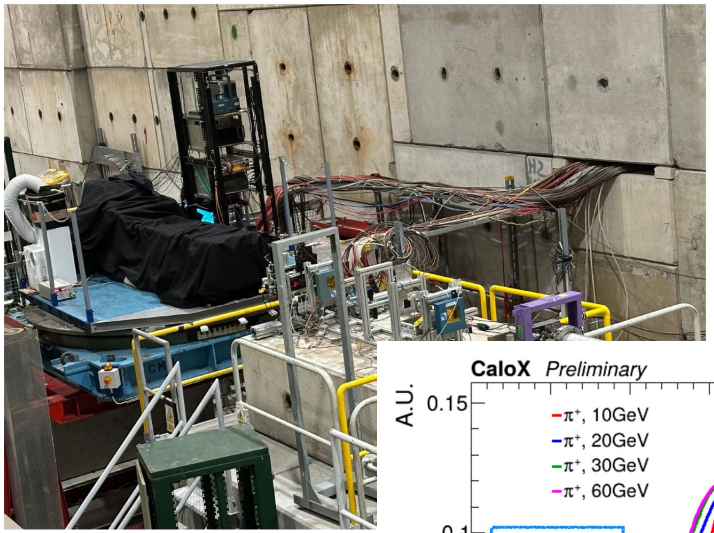
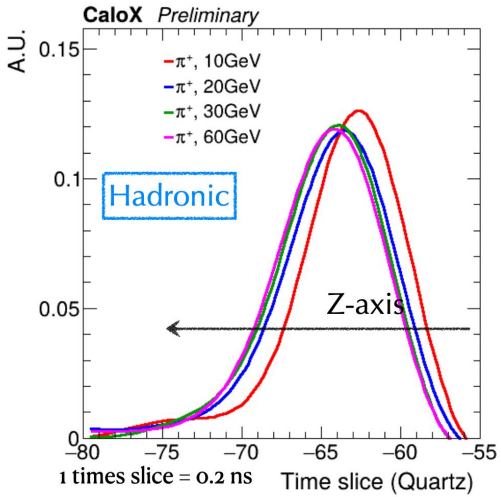




W. Jin, CPAD 2025
Y. Feng, CPAD 202

Shower profiling w/ timing!



DR Testbeams

DR test beams for 2026

- **EM Matrix (late August/Early September)**
  - **CERN PS T10**
  - **DESY**

- **Fiber Calo**
  - **????**

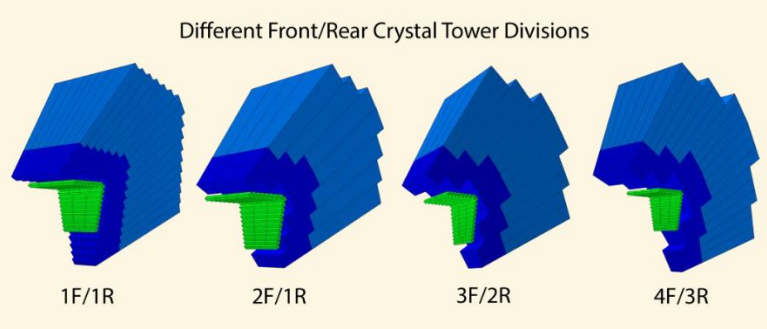
Opportunities for continued testing in 2027@ DESY, potentially SLAC (SLAC offers interesting opportunities for precision timing studies)

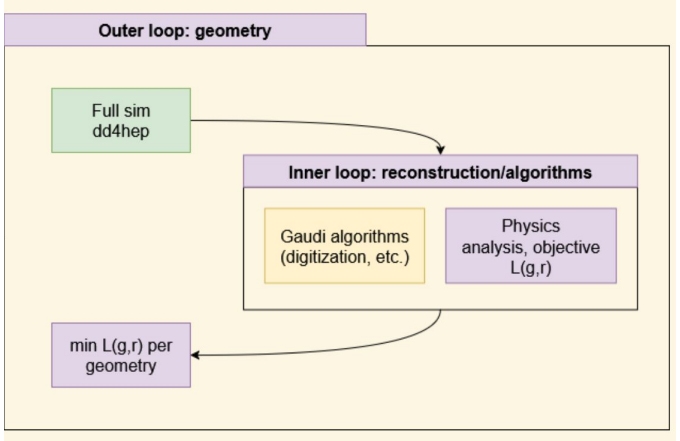
World test beam schedule
https://cernbox.cern.ch/external-ms365/public/wQdagv1LRXedAgW/InternationalTBplan-worldwide.xlsx

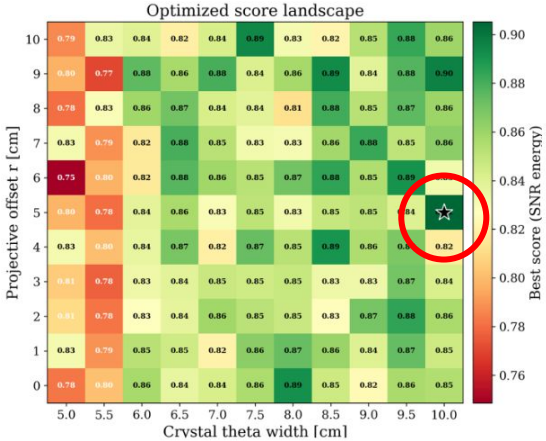
DR Simulations update

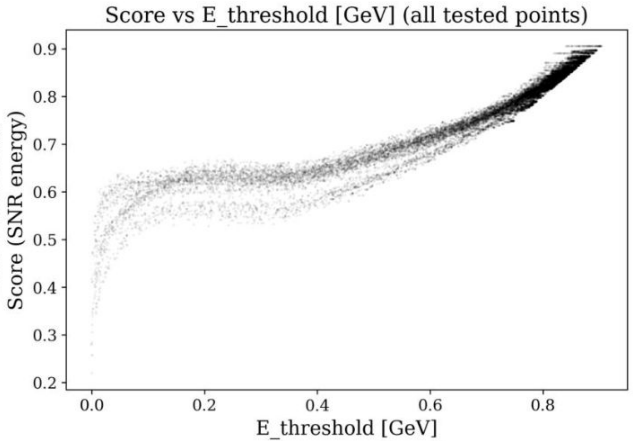
Wonyong Chung (crosscutting w/ computing/AIM)

Bilevel Detector Optimization Pipeline (talk)









Complete framework to automate detector optimization studies:

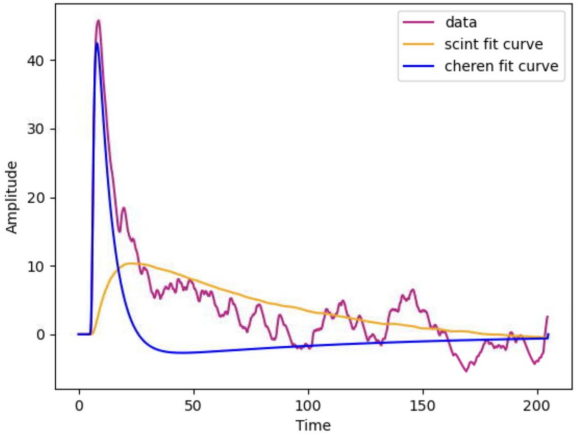
- Paramaterized geometry management
- Full detector sim
- Physics analysis and scoring
- Parameter variation+optimization

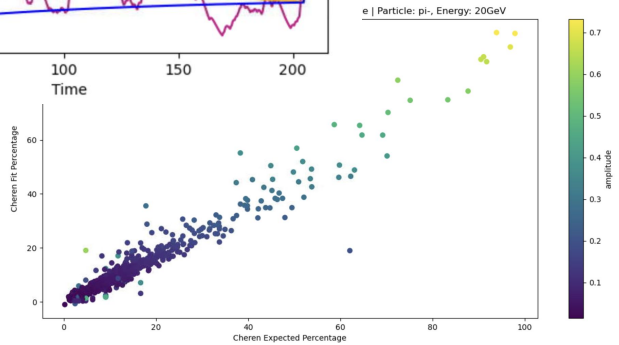
DR Simulations update

Module-level simulations (UMD, Baylor, UVa, Stonybrook, Rutgers, …)

Much progress in high fidelity optical simulations since BNL Hackathon last summer

- DD4HEP, Key4hep, Gaudi…
- Geometry improvements
- Analog waveforms
- Sim-Sipm library plugin
- …
- Multiple studies in progress





Optical Physics in Celeritas

(Hollenbeck UVa)

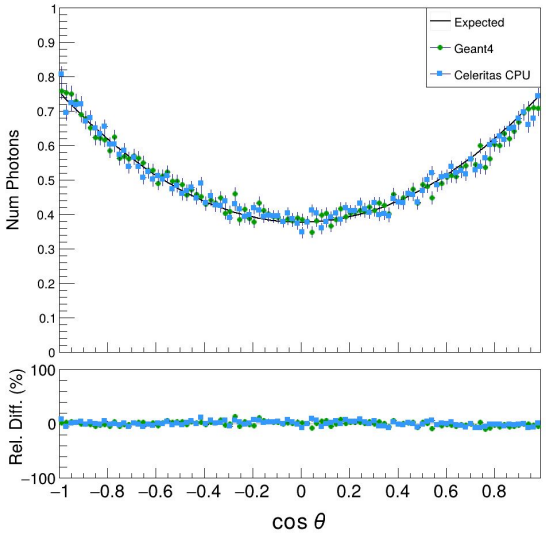
Celeritas: GPU-Accelerated Monte-Carlo Detector Simulation

- Geant4 integration support (geometry, physics data, etc)
- Separate optimized optical processing
- Efficient generation of photons from physical processes (Cherenkov, scintillation) or direct offloading
- Bulk and surface physics supported (including wavelength shifting)
- Adaptable framework for custom physics models

Currently working onintegrations with different experimental frameworks. Strong interest from Dune. We will push for FCC/DD4HEP integration as well.

Ongoing physics validation - validating directly against Geant4!

Rayleigh cos θ



FY27 Requests

We will finalize requests by the next meeting

The general convergence is:

- Test beam studies following up on initial commissioning and testing from 2026 by DR groups [TTU, FNAL, UMI, UMD, Baylor,...]
  - Precision timing, jet structure PID, resolutions, signal studies
  - Full simulation studies [Princeton, new groups,...]
- Engineering design for LAr [BNL, Arizona, …]
  - thermal simulation and cooling interface
  - EE/Mech design work leading to protptyope turbine calo
- Simulation for Si-W performance and sensor design requirements [UO, SLAC,...]