UC RIVERSIDE

CALIFORNIA EIC CONSORTIUM

New member of EIC UCR team

Prof. Owen Long

Summary of what we've done in 2022

New detector idea: our consortium conceived a new high-granularity insert **(HG-CALI)**

Laid the foundations of simulation work for Detector-1 forward calorimeters
Together with UCLA, we completed the entire forward calorimeter system in DD4Hep.
Full analysis chain working smoothly. Validated DD4Hep models against data.
*** with MRPI support for Ryan (UCLA, starting this summer at UCR), Sean, and Barak.**
+ DOE-NP AI grant support for Bishnu (postdoc)

CAD work for HG-CALI
Sketchup model and CAD model, to be used by engineer from Project for integration, flux-return and mechanical stability calculations
*** with MRPI support for Sebouh (postdoc)**

Lab work to support HG-CALI project:
SiPM-on-tile characterization
*** with MRPI support for Sean + NP-training grant support for Luis & Jay**

Completed first-round of HERA-4-EIC papers
Lepton-jet correlations PRL + 2 AI-methods spinoffs *** to be deployed in Sean's thesis**
Outreach:
Completed Virtual-reality event display. *** with MRPI support for Sean**

Leveraging

CALIFORNIA EIC
CONSORTIUM

“This proposal will expand our existing fruitful partnerships between NP researchers and computer scientists at LLNL ***to include other researchers from the California EIC consortium, which is a leading group in EIC R&D for tracking and calorimetry”***

DOE-AI grant (Soltz, Angerami, Nachman, Barish, Arratia)

Leveraging CALIFORNIA EIC CONSORTIUM

*“**The California EIC consortium has become a recognized entity in the nascent EIC community…***
*We can offer traineeship opportunities within a large research project that involves **a team of several undergraduate students, graduate students, postdocs, faculty members and staff scientists.** We have experience working together and also a well-defined plan for the next few years. In this context,*
***the trainees will become part of the California EIC consortium community**, from which they will be in an excellent position to …”*

DOE-NP Traineeship (Soltz, Sichtermann, Kang, Rudolph, Arratia)

Leveraging CALIFORNIA EIC CONSORTIUM

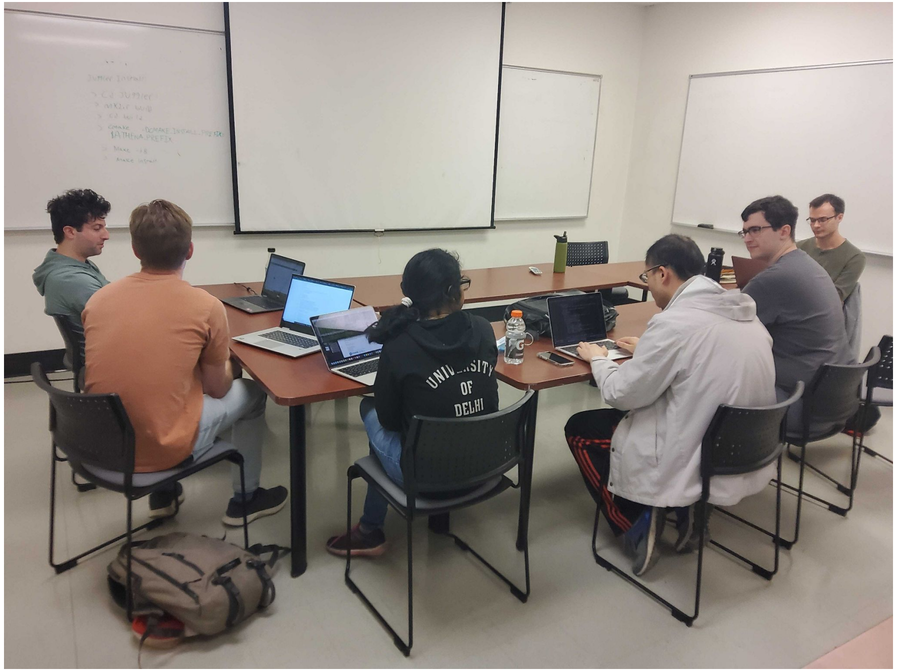
"We have established a UC southern hub for the EIC physics - through a synergy between theory and experiment…"
Seed funding abstract (Kang, Huang, Arratia, da Silva, Morreale, Soltz, Angerami, Vogt)

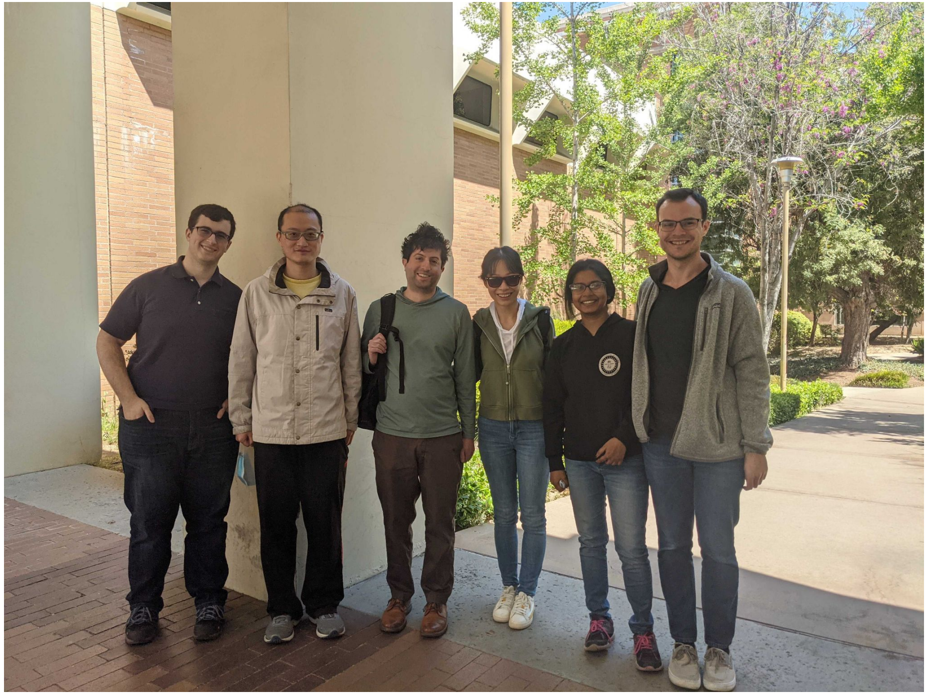
"…to collaborate on the design and R&D of the Forward Calorimeters at the Hadron Endcap for the designated EIC detector.
The UC Southern Hub will likely play an important role in the construction of the Forward Calorimeters."

Highlights related to Task 1 & 2
(design and simulation)

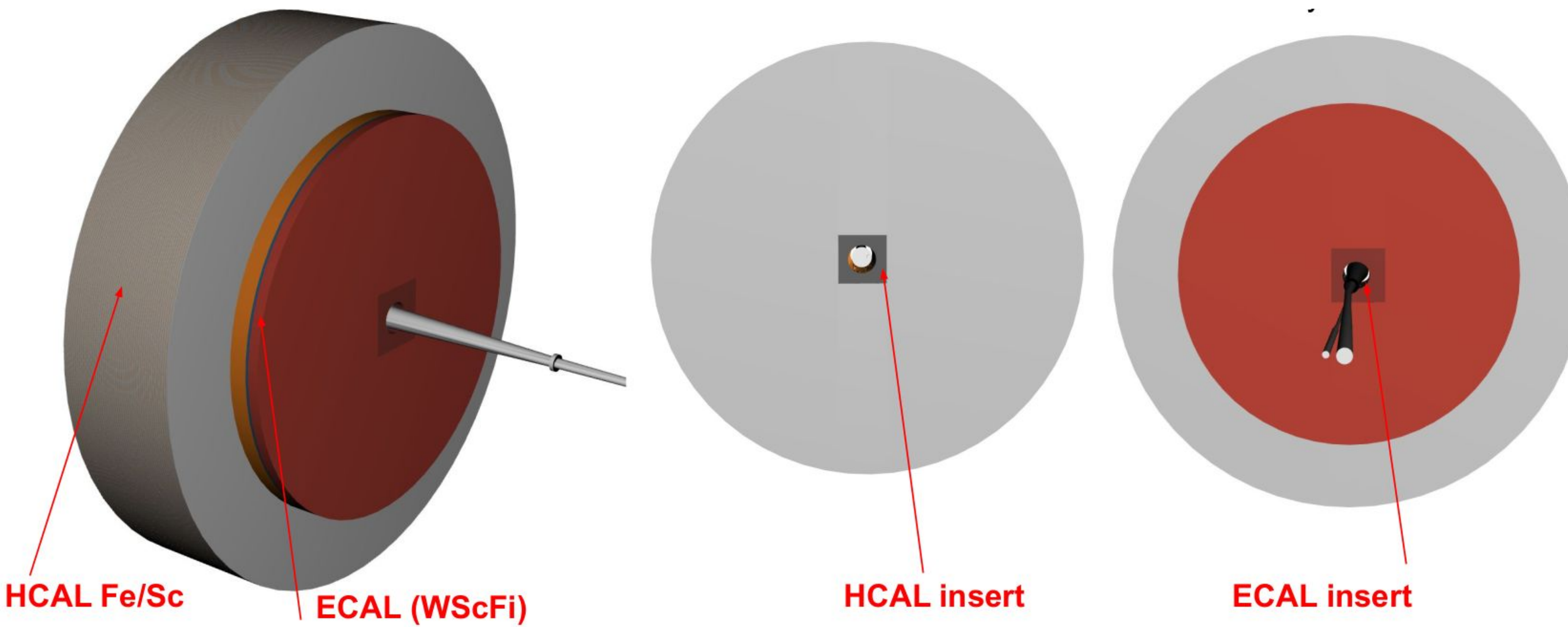
Task 1: Develop a conceptual design of silicon pixel tracking detector and calorimeter systems to measure jets, heavy flavor, and quarkonium produced in e+p and e+nucleus collisions. (UCB, UCLA, UCR, UCD, LBNL, LANL)
Task 2: Simulations to quantify technical and physics performance of tracker and calorimeter conceptual designs. (UCB, UCLA, UCR, UCD, LBNL, LANL, LLNL)

UCR-UCLA workshops, led by Barak



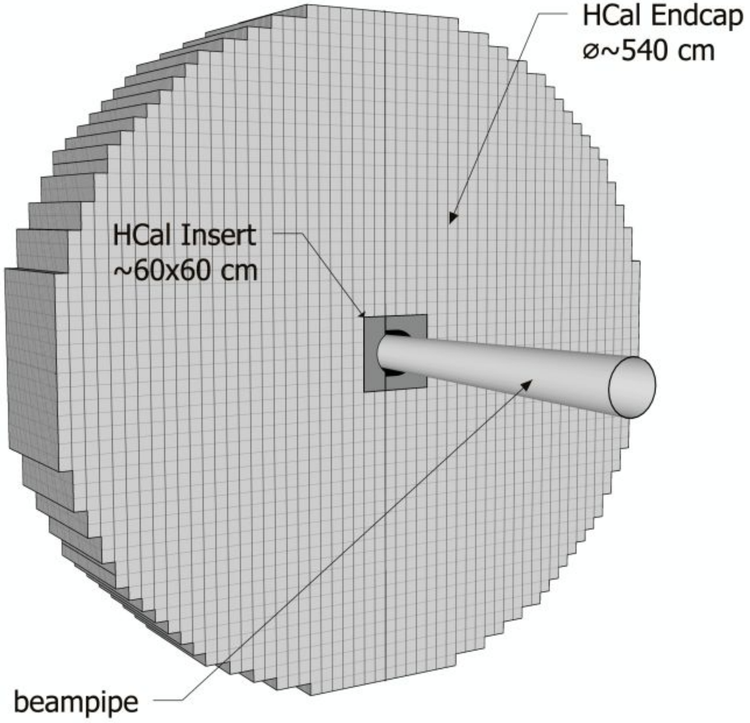


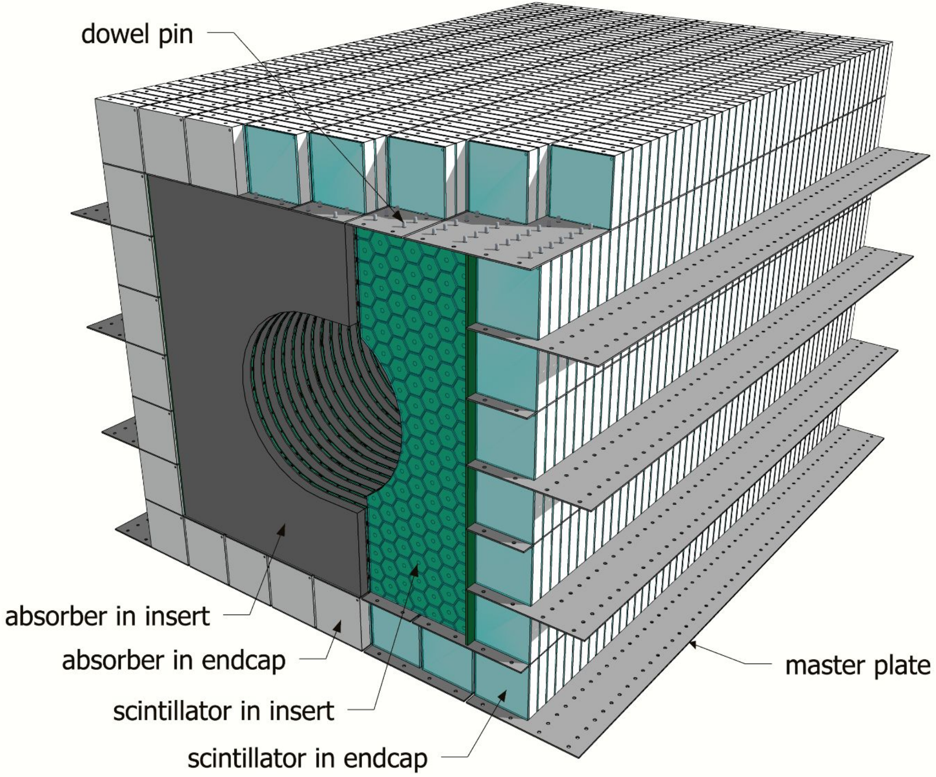
Direct result of those workshops is a complete DD4Hep model of all forward calorimeter systems



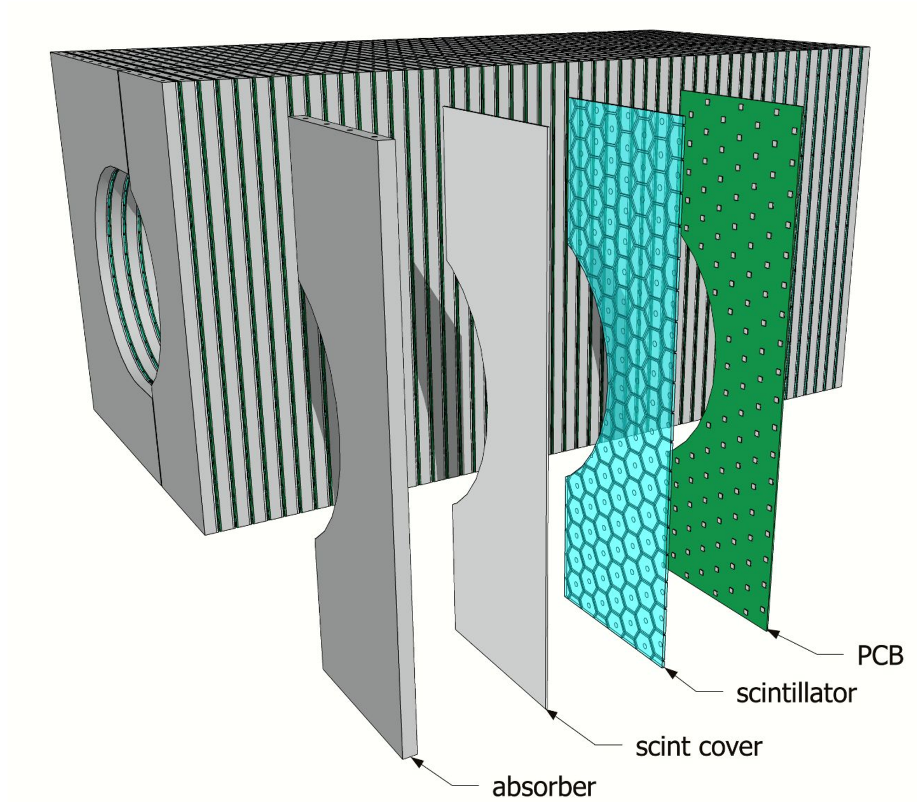
The high-granularity calorimeter insert (HG-CALI)

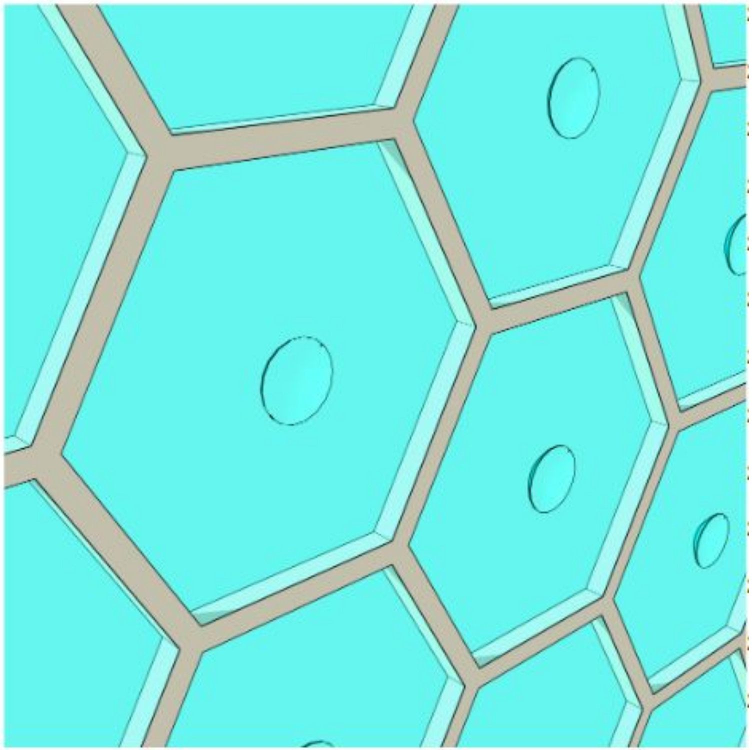
"It maximizes coverage close to the beampipe, while solving challenges arising from the beam-crossing angle and mechanical integration."





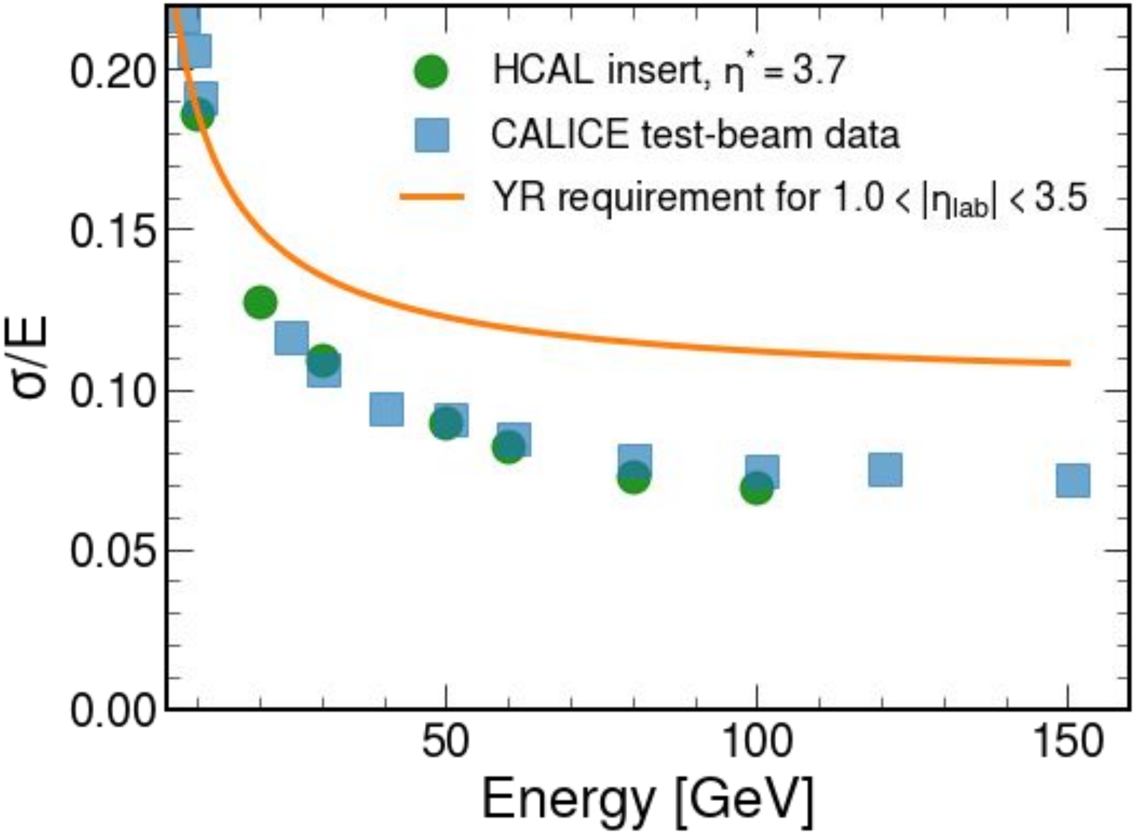
Sampling calorimeter with scintillator tiles directly coupled to SiPMs (similar to CALICE & CMS HCAL)



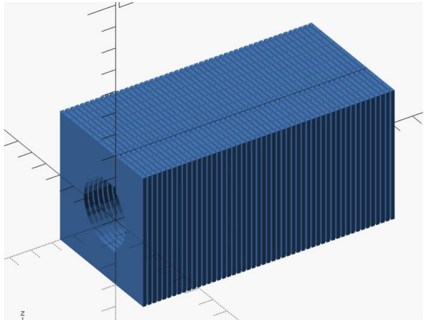


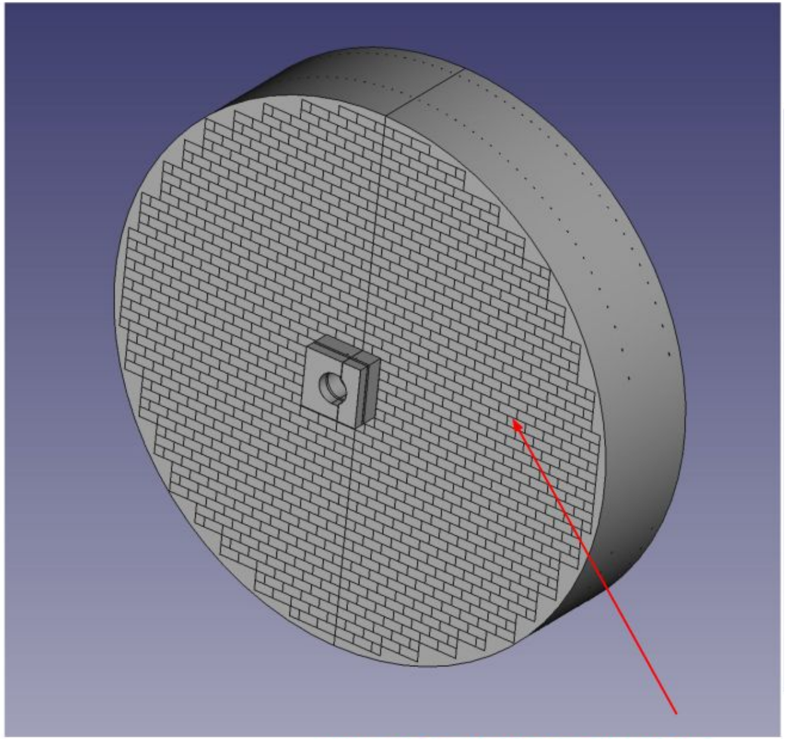
Performance of HG-CALI

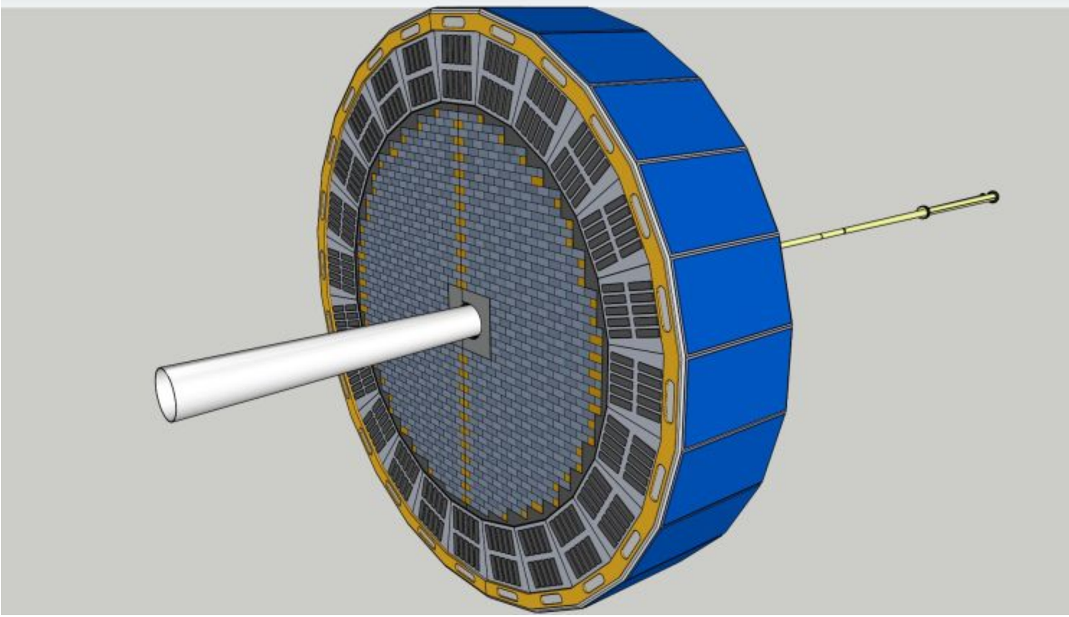
(with rudimentary algorithm)



CAD with HG-CALI







Modified ECCE HCAL

We're drafting HG-CALI paper

- Design
- Performance
- AI potential
- R&D plans

A high-granularity calorimeter insert based on SiPM-on-tile technology at the future Electron-Ion Collider

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[a]*Department of Physics and Astronomy University of California Riverside CA 92521 USA*
[b]*Department of Physics and Astronomy University of California Los Angeles CA 90095 USA*
[c]*Physics Division Lawrence Berkeley National Laboratory Berkeley CA 94720 USA*
[d]*Berkeley Institute for Data Science University of California Berkeley CA 94720 USA*
[e]*Lawrence Livermore National Laboratory Livermore CA USA*

Abstract

We present a design for a high-granularity calorimeter insert for the forward region of the future EIC detector. The sampling-calorimeter design uses scintillator tiles directly coupled to silicon photomultipliers. It maximizes coverage close to the beampipe, while solving challenges arising from the beam-crossing angle and mechanical integration. It has a transverse area of about 60×60 cm^2 and covers the pseudorapidity range $3 < \eta < 4$. Simulation studies based on GEANT4 show a compensated response ($e/h \approx 1$) that is linear over the energy range of interest for the EIC. The single-pion energy resolution meets the requirements set in the EIC yellow report even with a basic reconstruction algorithm. Moreover, this detector will provide 5D shower information (position, energy, and time), which can be exploited with modern machine-learning techniques. We conclude by describing R&D plans to incorporate this design in the EIC project detector from day one.

Contents

1. Introduction

One of the key requirements for detectors at the future Electron-Ion Collider (EIC) is to have tracking and full calorimetry with 2π azimuthal acceptance over a large range in pseudorapidity – nominally $|\eta| < 4.0$ [1]. This would ensure a "4π, general purpose detector" that could be used to pursue the original EIC scientific goals [2] and much beyond.

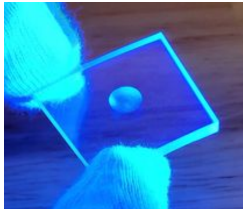
While both the ATHENA and ECCE [3] detector designs contemplate coverage with full calorimetry up to $\eta = 4.0$, nominally, the specifics on how to implement it remain undefined. Accomplishing large coverage in the region $3 < |\eta| < 4$ is rather challenging due to the EIC beam-crossing angle, which is 25 mrad [1]. As illustrated in Fig. 1, the beam pipe envelope crosses the region where the forward hadronic calorimeter (HCal) would be located at an angle that is neither in the proton nor in the electron direction, but rather 24.3 mrad. Any detector covering this region needs to simultaneously fill a complex volume and keep clearance to the beampipe, while fitting the other calorimeters without the need of additional support structures.

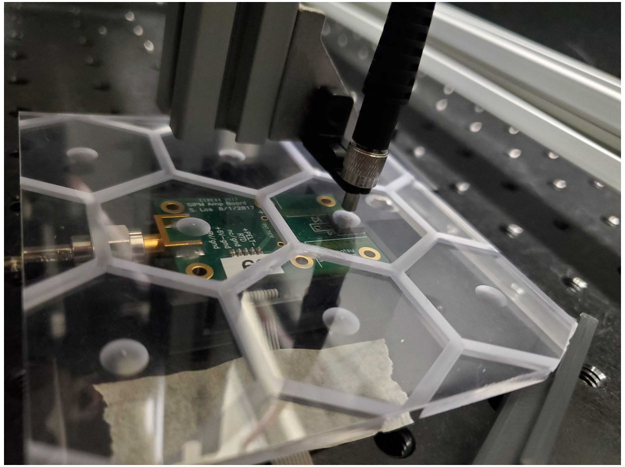
In addition, the detector in the $3 < \eta < 4$ region needs to be well matched to the particle densities and energies expected at the EIC. At the highest energy setting of 18 GeV electron beam and 275 GeV proton beam, jets can reach close to the proton-beam energy with a high rate at nominal luminosity [1]. Furthermore, single-particle measurements up to 60 GeV are considered a requirement [1]. Hadronic calorimetry in this region is of highlighted importance since the magnet envisioned for the EIC detector is solenoidal and thus leads to poor tracking

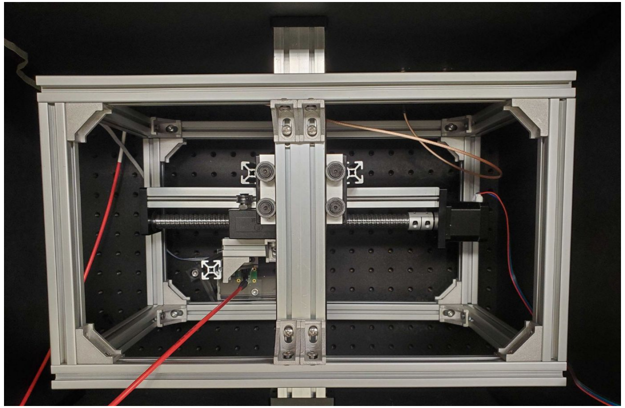
Highlights related to Task 4
(R&D and prototypes)

Task 4: R&D and prototype construction of silicon pixel and calorimeter technologies. (UCB, LBNL, LANL, UCLA, UCR)

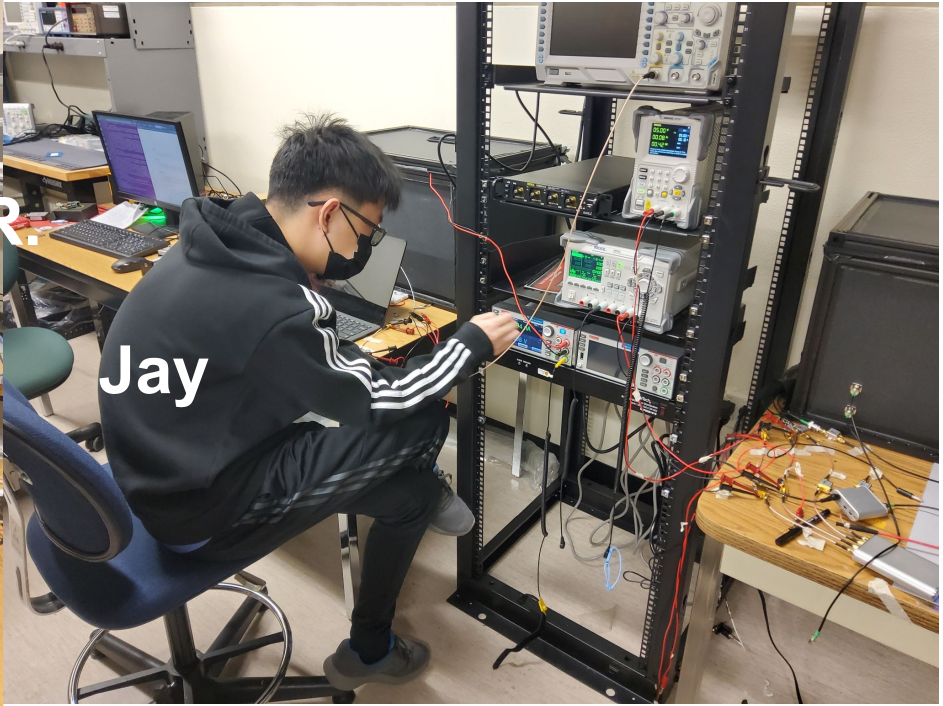
SiPM-on-tile uniformity and light-yield tests at UCR







Undergraduate researchers



Highlights related to Task 6
(HERA-4-EIC)

Task 6: Analysis of data from HERA (the previous electron-proton collider) to study tomography with jets and develop analysis approaches for EIC. (UCR)

Our flagship paper is now published

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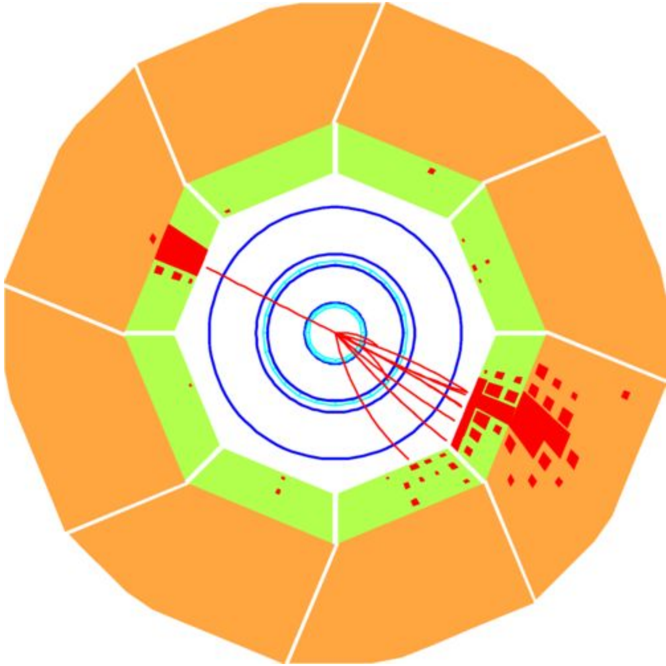
Measurement of Lepton-Jet Correlation in Deep-Inelastic Scattering with the H1 Detector Using Machine Learning for Unfolding

V. Andreev *et al.* (H1 Collaboration)

Phys. Rev. Lett. **128**, 132002 – Published 31 March 2022



Sean and I are co-authors

New: two EIC-inspired, AI-methods papers

(using simulation from **H1@HERA** and EIC fast sims)

ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 1025, 11 February 2022, 166164

Reconstructing the kinematics of deep inelastic scattering with deep learning

Miguel Arratia [a, b], Daniel Britzger [c], Owen Long [a], Benjamin Nachman [d, e]

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Journal of Instrumentation

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Optimizing observables with machine learning for better unfolding

Miguel Arratia[1,2], Daniel Britzger[3], Owen Long[1] and Benjamin Nachman[4,5]

Published 5 July 2022 • © 2022 The Author(s)

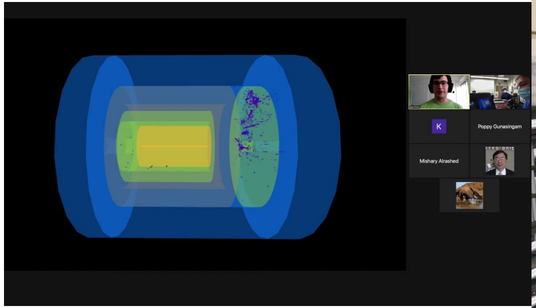
Journal of Instrumentation, Volume 17, July 2022

Citation Miguel Arratia *et al* 2022 *JINST* **17** P07009

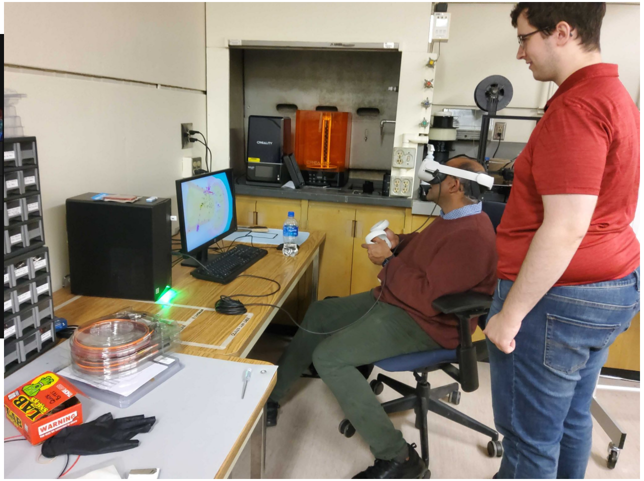
Methods will be deployed to real H1@HERA data by Sean as part of his thesis, supported by MRPI

Outreach events

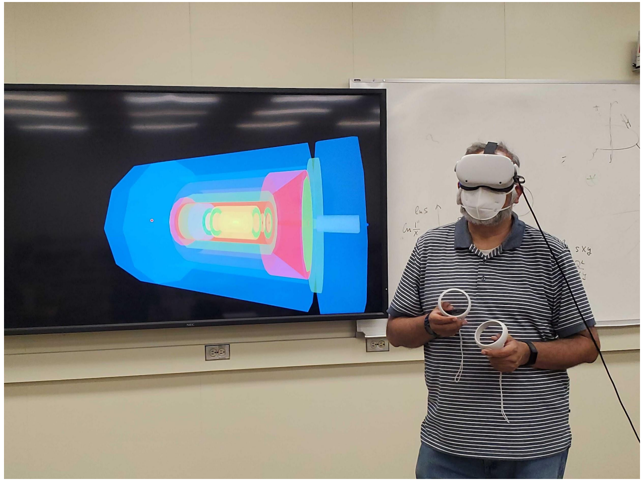
Virtual event with UCLA team



VIP visit at UCR



VIP demo at Stony Brook

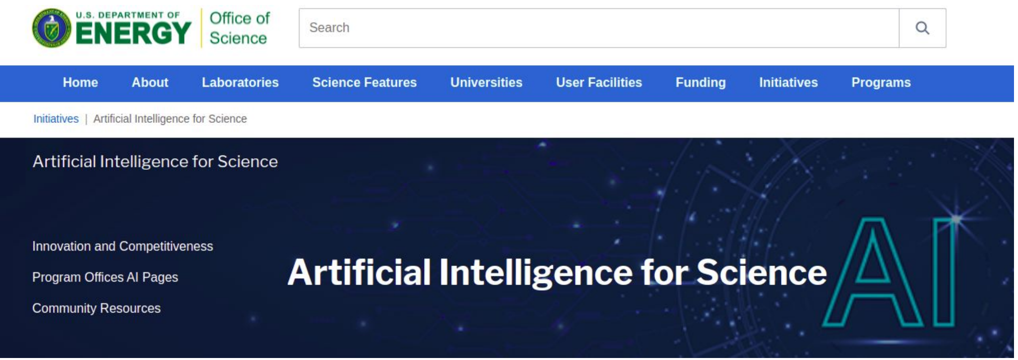


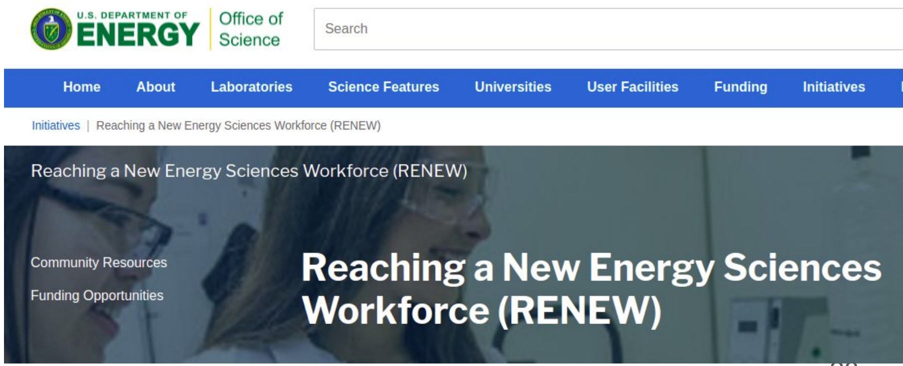
https://kang-research-group.physics.ucla.edu/content/exploring-your-universe-2021

Summary

- UCR team is 1 faculty stronger with addition of Owen
- New grants that allow us to strengthen connections with consortium partners.
  Total dollar amount for DOE-traineeship + DOE-AI 2-year grants
  is above 80% of the total 4-year MRPI.
  Next rounds of these pilots program are coming up
- Steady progress towards completing our MRPI tasks on all fronts

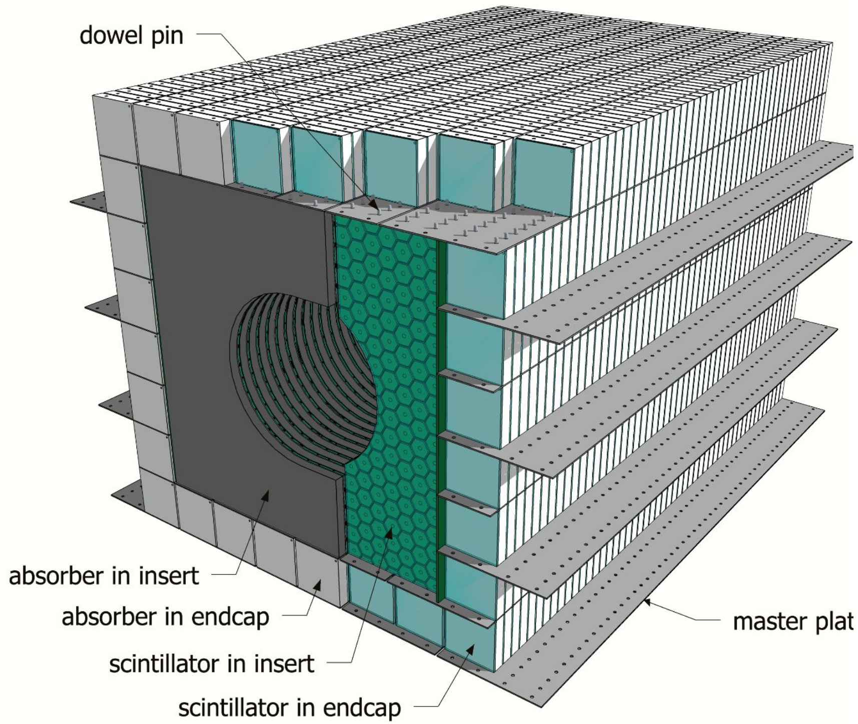
Next steps include to prepare for calls from:





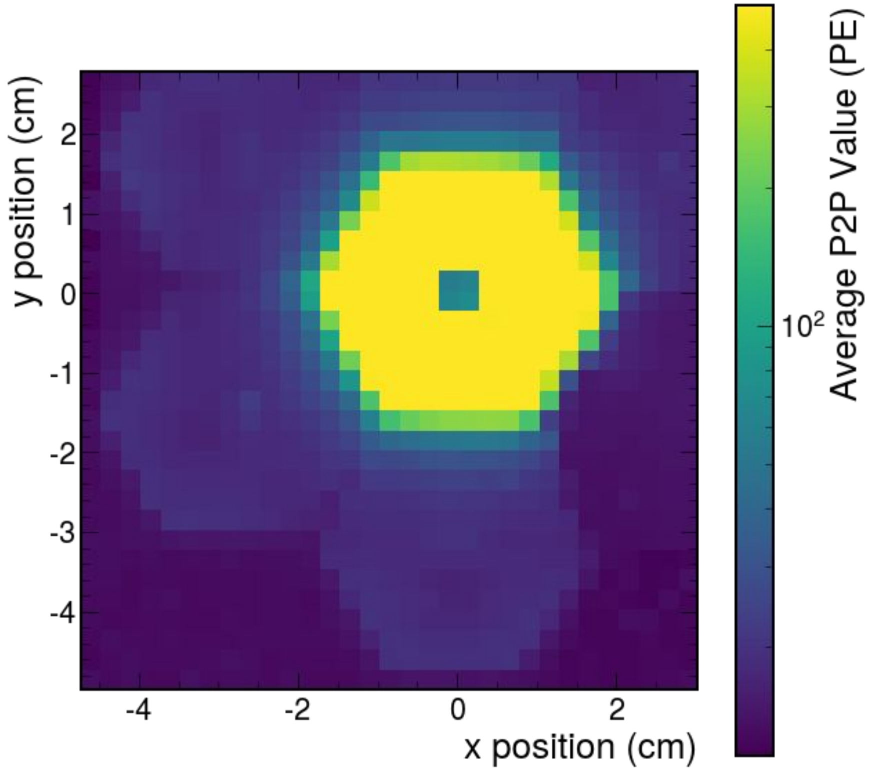
Postdoctoral position: STAR Cold QCD analysis and AI studies for high-granularity calorimeter for the EIC

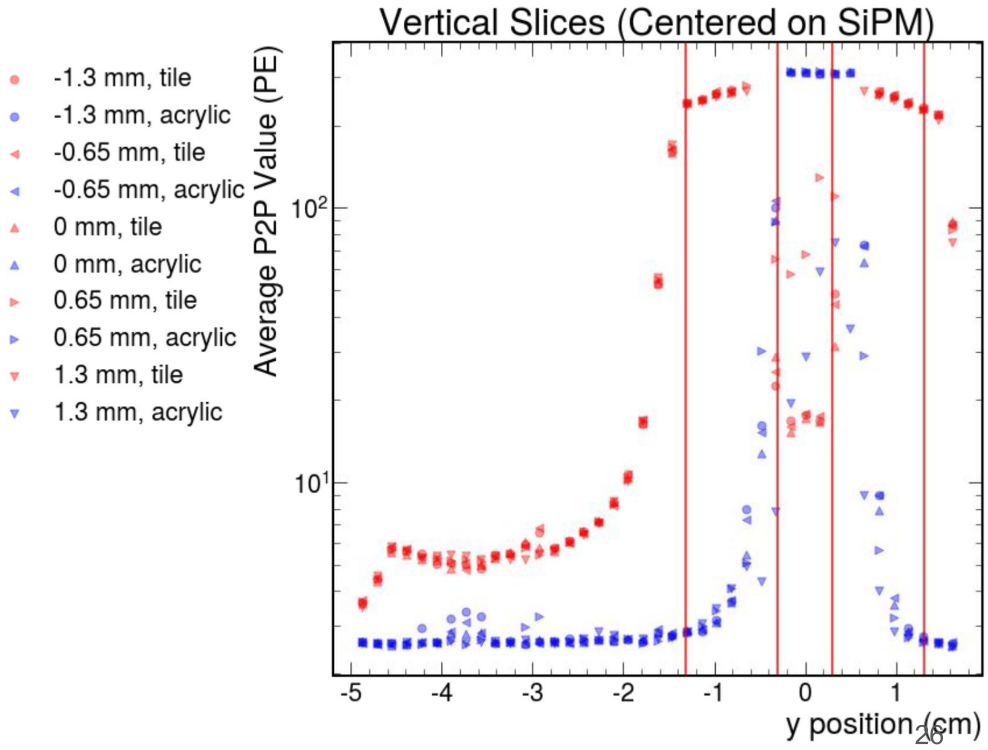
UC, Riverside (main) • North America



Backup

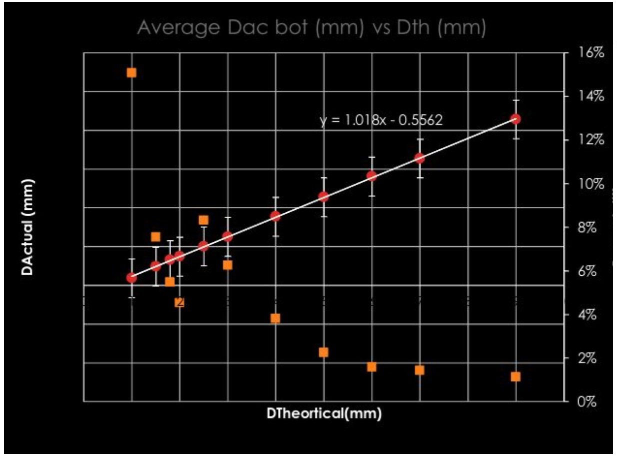
Uniformity and cross-talk studies ongoing





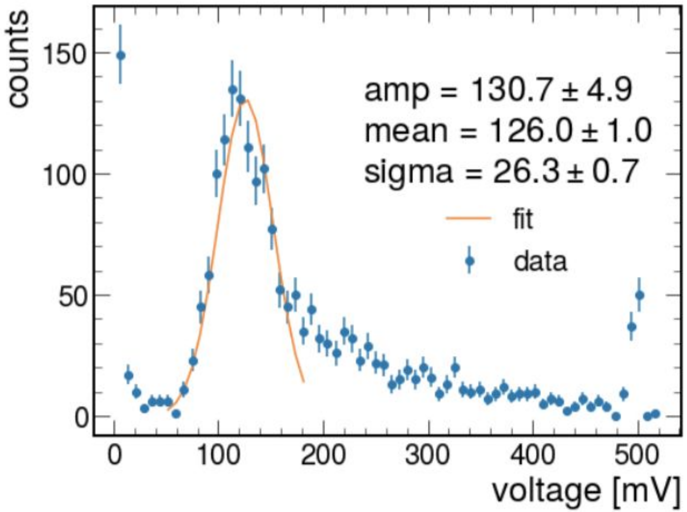
Undergraduate researchers

Luis



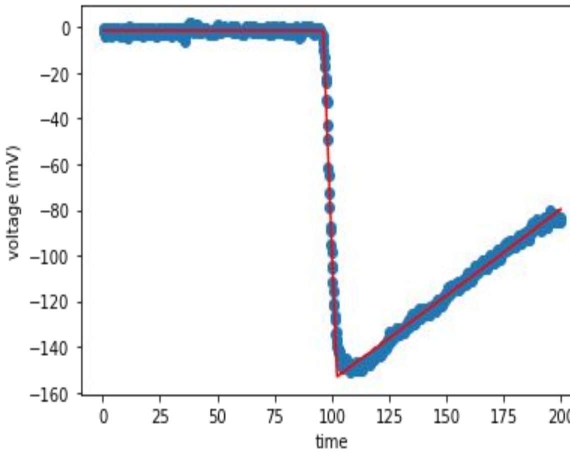
WLS fiber & fiber guide studies

Miguel R.

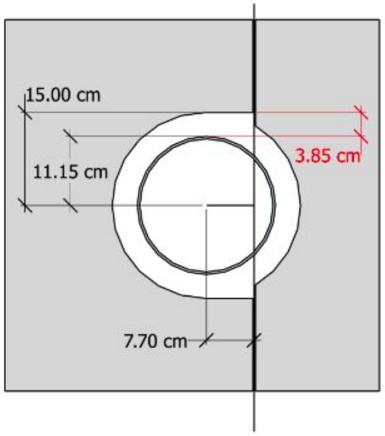


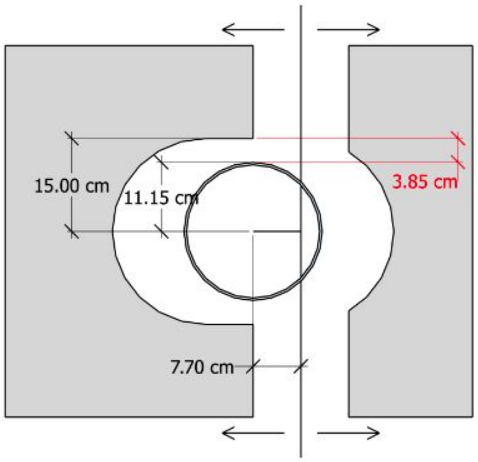
SiPM-on-tile
Light yield with cosmics

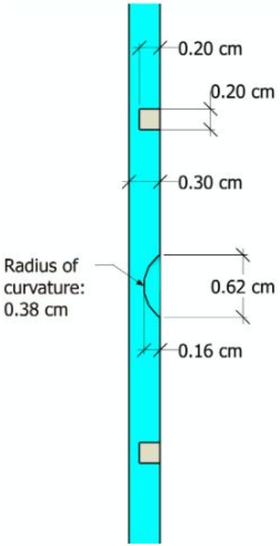
Jay



SiPM IV and
Waveform analyzes


15.00 cm
11.15 cm
3.85 cm
7.70 cm


15.00 cm
11.15 cm
3.85 cm
7.70 cm


0.20 cm
0.20 cm
0.30 cm
Radius of
curvature:
0.38 cm
0.62 cm
0.16 cm