

January 23, 2023

GD/I WG Meeting

GD/I WG: barrel ECAL review preparation

Imaging BCal

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U.S. Department of Energy laboratory
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1946–2021

ePIC Barrel ECAL Review Charge

EPIC Barrel ECAL review Request for information from the proponents

GD/I conveners, 12/12/2022

It is asked that the proponents address the following questions:

1. Reminder of the proposed **detector configuration** for the use in the ePIC detector.
2. **Input information:**
 - a. **R&D, prototypes and their tests:** done so far, ongoing effort, future planning (with timelines); results from prototypes and their tests
 - b. Pertinent **information on similar technology/design** that is used by other experiments or R&D efforts (example reference could be literature, and/or conference talks).
 - c. **Simulation studies:** already performed, ongoing and planned (with timelines); results from the simulations; particular care in (i) showing how realistic the parameters used in simulations are and (ii) reporting what is missing for a fully realistic simulation (backward, specific event categories, ...)
 - d. Does the simulation take into account the **realistic light collection uniformity, response of the selected photosensors and related FEE?**
3. **Performances:**

Please use the official simulation framework. Please tag all software (sim., reco., and analysis) used in these studies.

 - a. Key plots to be shown:
 - i. Photon and electron energy resolution σ/E as a function of E (0-18 GeV) at $\eta=0, 0.5, 1$. Consider a minimum energy of 50 MeV.
 1. For each point, please extract FWHM and percentage of gammas/electrons within a cut window of $|E/p-1| < 1 \times \text{FWHM}$. Please provide the E/p lineshape in the backup material.
 - ii. Photon angular resolution (ϕ, η) as a function of E (0-18 GeV) at $\eta=0, 0.5, 1$
 - iii. Pion rejection as a function of p (0-18 GeV/c) at 95% e-efficiency at $\eta=0, 0.5, 1$
 - iv. Pion rejection versus e-efficiency at $p = 1, 5, 10$ GeV/c at $\eta=0, 0.5, 1$
 - v. Separation of gamma from π^0 decay: separation probability as a function of p at $\eta=0, 0.5, 1$
 - vi. Measured cluster energy response to $E = 8$ GeV single electron vs η & ϕ in the full acceptance
 - b. Comparison of the **present assessment of the detector performance compared with the YR requirements?**

- c. In coordination with the inclusive PWG, show the performance of key high-level physics observables, g_1 and F_2 (possibly F_L), on both statistical reach and systematic uncertainty.
- d. Performance perspectives **beyond the YR requirements, if any?**
4. **Sensors and FEE:**
 - a. Status of **sensor selection** (a single consolidated option, more options under consideration) and photosensor characteristics?
 - b. **Status of the sensor** validation for the specific application and related potential issues?
 - c. **Perspectives of sensor mass production** and timelines for the production period?
 - d. Status of **FEE selection** (a single consolidated option, more options under consideration)?
 - e. **Characteristics of the FEEs** considered?
 - f. Status of the **FEE development** and related potential issues?
 - g. Perspectives of **FEE mass production** and timelines for the production period?
5. **Mechanical Design and Integration:**
 - a. **Status of the proposed detector integration** into the current baseline detector?
 - b. Status of the **design of the electrical/electronic infrastructure** (channels, power supplies, heat, rate)?
 - c. **Cooling strategies?**
6. **Workforce:**
 - a. **List of groups** engaged in the proposed detectors and of other groups potentially interested;
 - b. **Workforce needed with timelines and qualification of the required professional profiles;** please, include also physicists needed for dedicated simulation studies;
 - c. **Available workforce** (specifying: granted, expected, possible) by the groups proposing the detector;
7. **Cost and schedule:**
 - a. up-to-date cost estimate for the different components and expenditure categories;
 - b. In-kind contributions (specifying: granted, expected, possible).
 - c. Outline the path towards and schedule for the full scale production
 - d. If a baseline detector can be replaced by the proposed EMCal (e.g. last layer of MPGD), please use project cost for cost saving. And please work with the corresponding working group (e.g. tracking) to ensure the performance remains the same or better.
8. **Envisioned risk and risk mitigation strategy**

Question 3 - Performances

Barrel ECAL EPIC Review - Feb 2023

3. Performances:

Please use the official simulation framework. Please tag all software (sim., reco., and analysis) used in these studies.

Official productions: issue with EICrecon cluster reconstructions (IslandClustering and ImagingClustering)

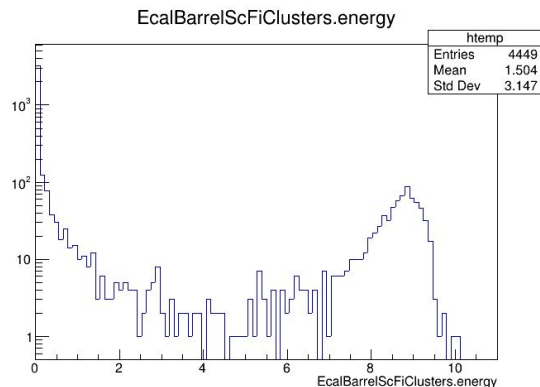
- dd4hep units vs edm4hep units

1. Issue with SciFi/Pb clustering (Island) - too many low energy clusters

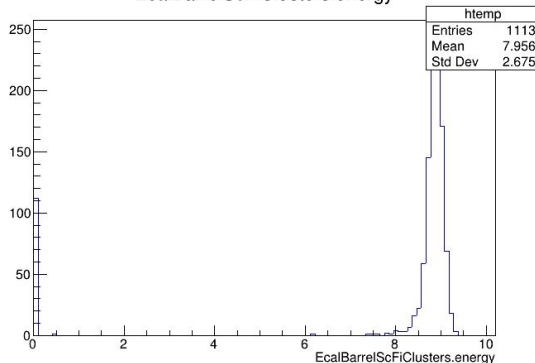
<https://github.com/eic/EICrecon/pull/444>

Plots below are made with 1000 simulated photons at $\eta=0$ (same simu file, different reconstruction)

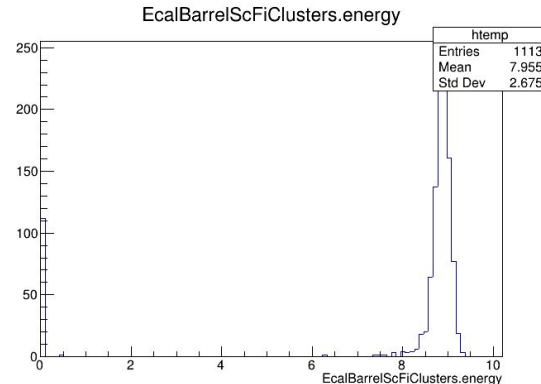
Official EICrecon production



Private Juggler reco
(with exactly same parameters)
EcalBarrelScFiClusters.energy



EICrecon after fix



Barrel ECAL EPIC Review - Feb 2023

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In the EICrecon `m_sectorDist=5.0 * dd4hep::cm` in

https://github.com/eic/EICrecon/blob/main/src/detectors/BEMC/ProtoCluster_factory_EcalBarrelSciFiProtoClusters.h#L37 is translated to `["BEMC:ecalbarrelscfiprotoclusters:sectorDist", "5", "5", ""]` (**dd4hep units: cm = 1**).

The sector distance is used here: <https://github.com/eic/EICrecon/blob/main/src/algorithms/calorimetry/CalorimeterIslandCluster.h#L144> to compare to the hit position magnitude with is in **edm4eic units of mm = 1**.

Barrel ECAL EPIC Review - Feb 2023

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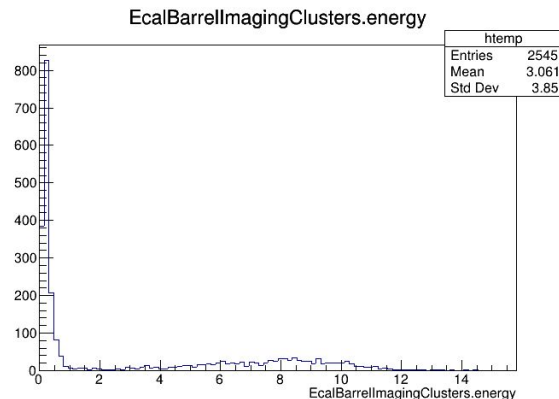
- dd4hep units vs edm4hep units

2. Issue with SciFi/Pb clustering (Island) - too many low energy clusters

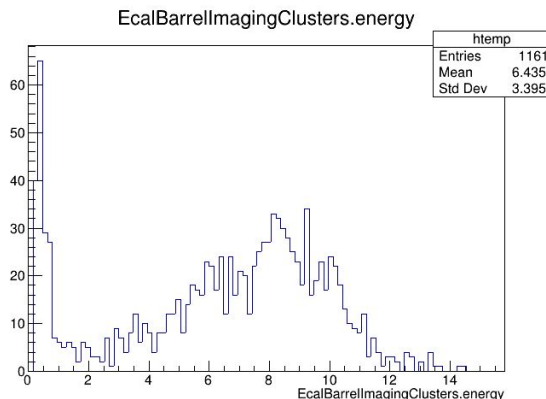
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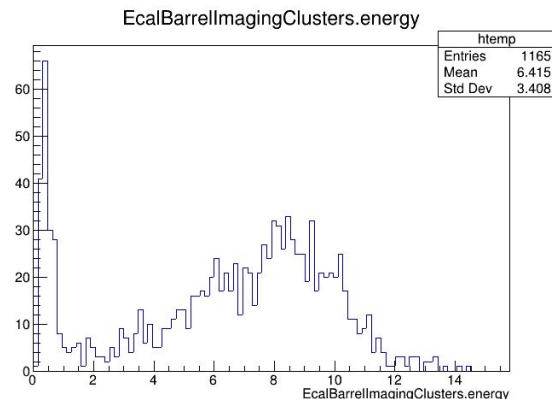
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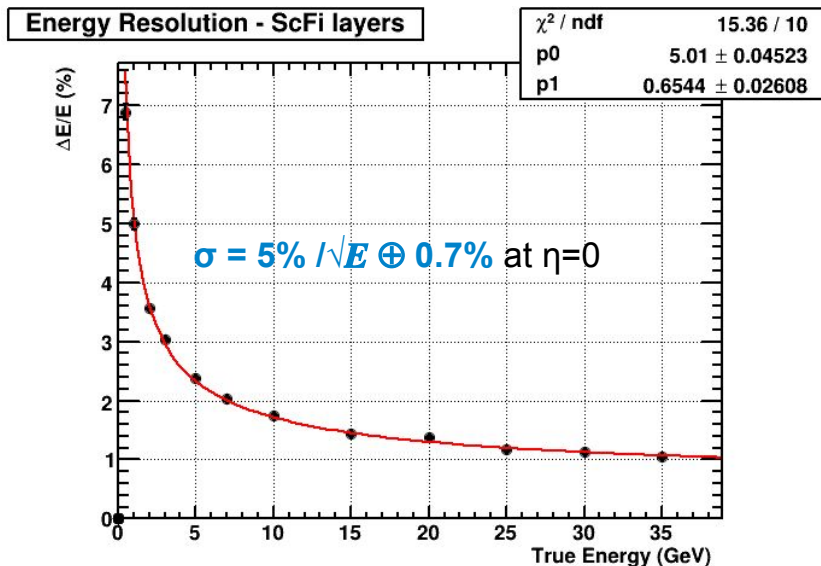
- <https://github.com/eic/EICrecon/pull/445>

Parameters `m_minClusterEdep, m_minClusterCenterEdep, m_minClusterHitEdep`, weren't assigned in https://github.com/eic/EICrecon/blob/main/src/detectors/BEMC/ProtoCluster_factory_EcalBarrelImagingProtoClusters.h

and the default variables from the algorithm <https://github.com/eic/EICrecon/blob/main/src/algorithms/calorimetry/ImagingTopoCluster.h> has been used in the reconstruction.

Performance Study

Energy resolution from SciFi/Pb layers - Private Production



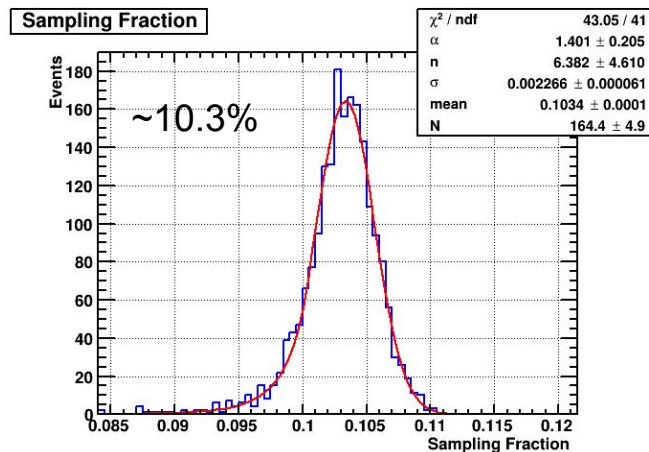
GlueX SciFi/Pb ECal

$\sigma = 5.2\% / \sqrt{E} \oplus 3.6\%$ (NIM, A 896 (2018) 24-42)

- $15.5 X_0$, extracted for low energy photons $< \sim 1$ GeV
- Measured energies not able to fully constrain the constant term

Simulations of **single photons** at $\eta=0$ ($\sim 21 X_0$)

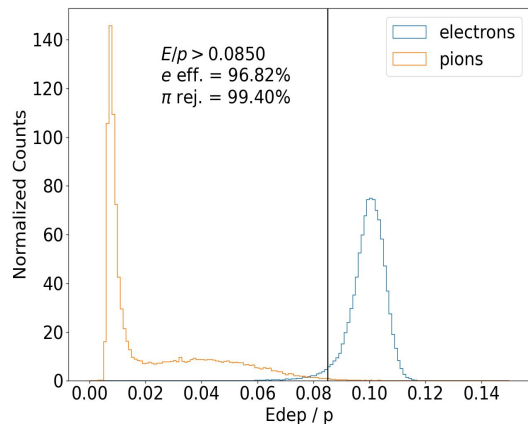
- **Realistic implementation of SciFi/Pb matrix** with glue and cladding
- Energy resolution takes into account **realistic signal digitization and reconstruction**



$$\text{Sampling fraction} = \Sigma E_{\text{fibers}} / E_{\text{thrown}}$$

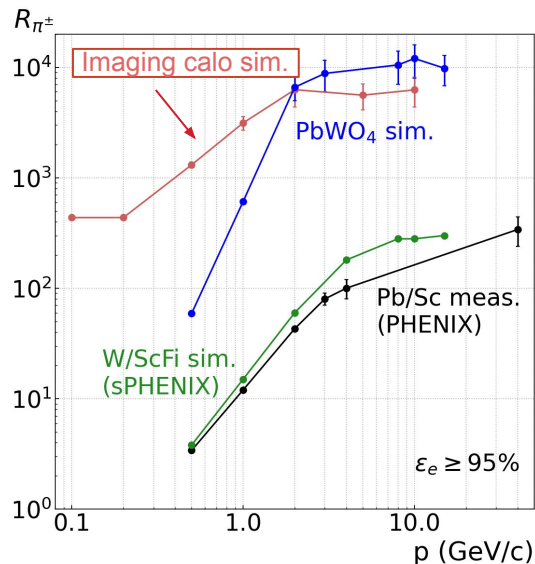
Performance Study

Electron Identification - Private Production

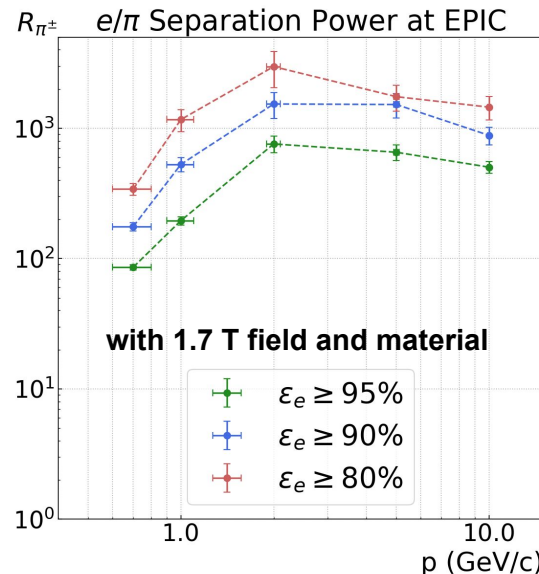


Initial cut on E/p from SciFi/Pb layers for $e-\pi$ separation

Standalone simulation



Realistic ePIC simulation



- For all the required data points need to switch to the “campaign” productions
- Particle ID studies with ML for many points and configurations require computing resources
 - work in progress to establish analysis resources to run ~5K samples

Question 5 - Mechanical Design and Integration

Integration

5. Mechanical Design and Integration:

- Status of the proposed detector integration into the current baseline detector?
- Status of the design of the electrical/electronic infrastructure (channels, power supplies, heat, rate)?
- Cooling strategies?

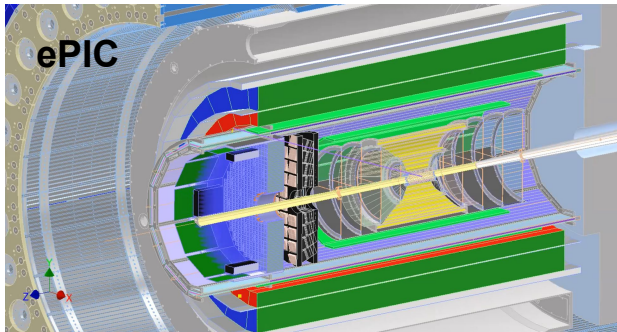
Following GlueX Barrel design

- Self-supporting structure, each sector attached to its neighbour
- Entire ECAL has to be slid into the detector

Imaging layer support structure and cooling under development

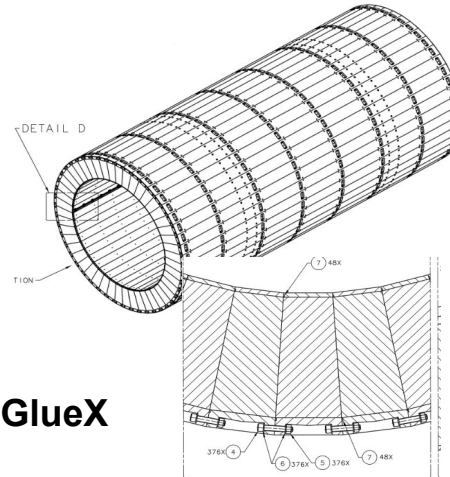
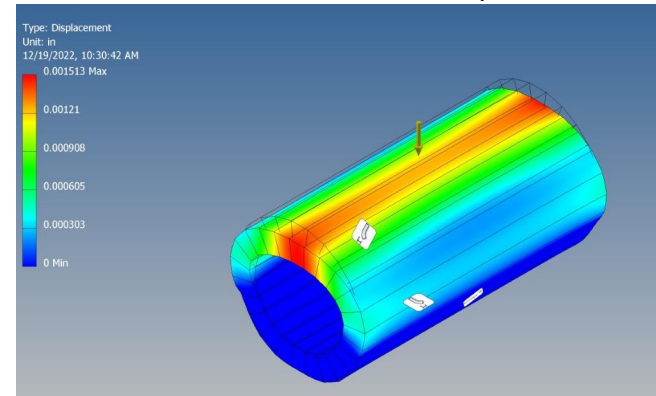
- “Si tracker layer” structure
- First imaging layer - outer tracker for DIRC

Ongoing work on integration w/ Argonne PHY and HEP engineers

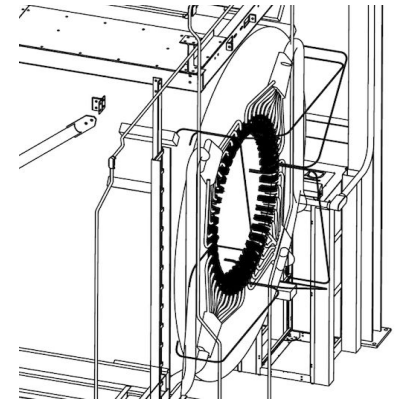


Status of CAD/Engineering Efforts on BEMC, R. Wimmer,
EPIC GD/I WG Meeting, Sep 12, 2022

First studies on EIC barrel displacement



GlueX



GlueX self-supporting structure

Question 1 - Input Information and R&D

R&D

2. Input information:

- R&D, prototypes and their tests:** done so far, ongoing effort, future planning (with timelines); results from prototypes and their tests
- Pertinent **information on similar technology/design** that is used by other experiments or R&D efforts (example reference could be literature, and or conference talks).

SciFi/Pb tested extensively in for energies $E_\gamma < 2.5$ GeV

- At EIC energies up to ~ 10 GeV for photons and ~ 50 GeV for electrons
- Higher-energy data** important to constrain the constant term of energy resolution

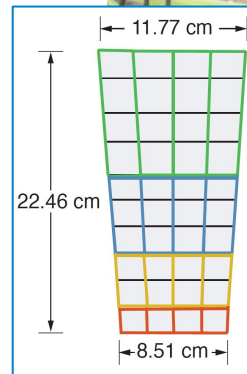
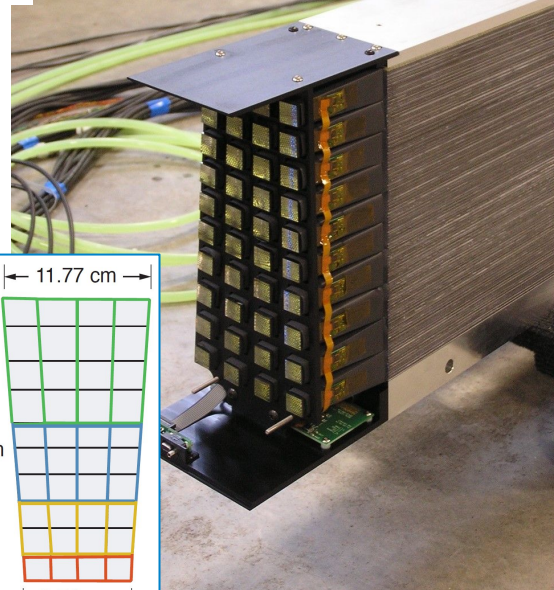
R&D goals with GlueX prototype

- Obtain **responses to electromagnetic and hadronic showers** to benchmark simulations and provide input to realistic **waveform analysis**
- This will be further used to optimize the detector design

Beam tests plans

- Hall D, electrons** (energies up to ~ 5 GeV)
- FY23 - beginning of March 2023

GlueX prototype $\sim 15.5 X_0$



- 60-cm long prototype
- 40 light guides on either side
- 40 SiPMs per side

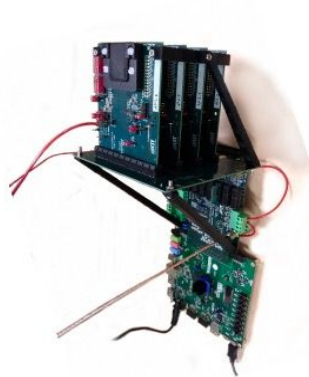
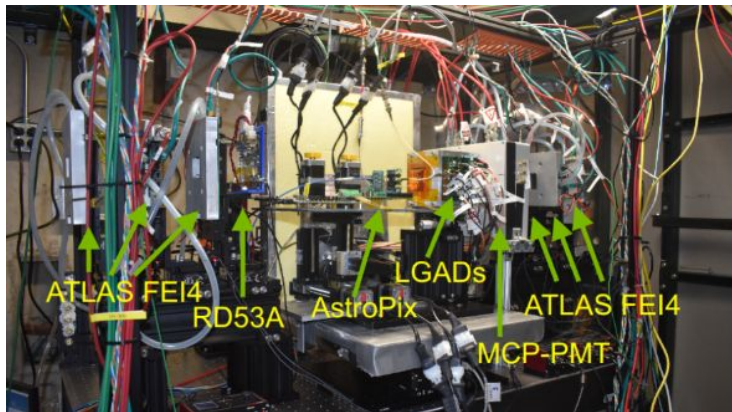
R&D

2. Input information:

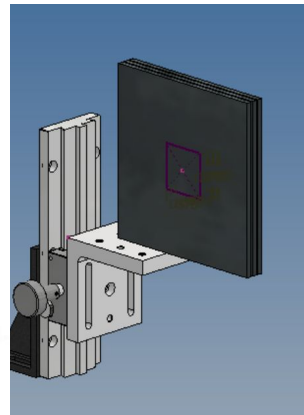
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R&D program towards prototyping the generic imaging calorimetry for EIC in FY23

- Tests of **AstroPix v2/v3 sensor** in the EM calorimetry environment
 - **Multilayer chip tests** in FNAL with protons, pions and electrons, tests with tungsten radiator, readout aspects (ANL LDRD grant)
 - **Beam tests in February (14-28) and May 2023**
 - **Irradiation test** in the FNAL ITA Facility (ANL LDRD grant)
 - Readout of multilayer chips with the **Felix board** (activities within the ANL HEP and NASA community)



v2 multilayer
chip boards



W radiator holder

Summary

Simulation studies ongoing

- Issues found in clustering algorithms affecting produced campaign samples
- In parallel, studies done on private productions (energy resolution, e/π)
- But moving forward we will need to test many samples in many detector configurations - we need support from simQA with official samples
- Development of ML training and testing procedure with Argonne computing resources (~5K samples to run)

Work on **mechanical design** with Argonne PHY and HEP engineers ongoing

- Studies on displacements and mechanical structure of imaging layers

Preparation to **upcoming R&D programs**

- AstroPix test in FNAL beam test - 02/14 - 02/28
- SciFi/Pb test in Hall D - beginning of March