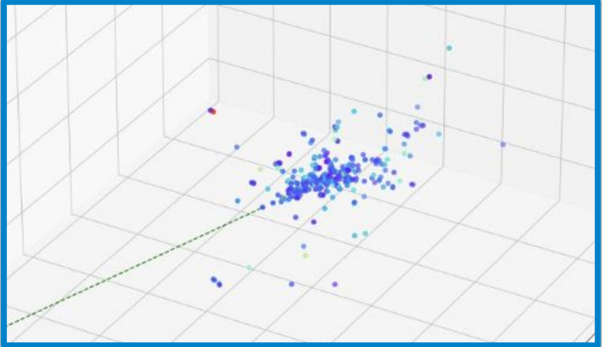
EIC Calorimetry WG Meeting

Argonne NATIONAL LABORATORY

Calorimetry Proposal Writeup



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U.S. DEPARTMENT OF ENERGY
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Writeup draft

- https://anl.box.com/s/now6irrwzs329kg0ai7iw89zt3740idx
- Placeholder e/pion separation plot
- Expected performance table

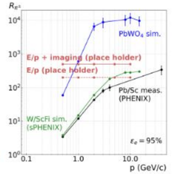
Barrel Electromagnetic Calorimeter

The main purpose of the barrel electromagnetic calorimeter is to detect scattered and secondary electrons and separate them from pions, to detect and reconstruct full kinematic information for photons, and to provide sufficient spatial resolution to identify neutral pions from $\pi^0 \rightarrow \gamma\gamma$ at high momenta.

The proposed design is a hybrid using light-collecting calorimetry using scintillating fibers (ScFi) embedded in Pb and imaging calorimetry based on monolithic silicon sensors. The imaging of particle showers is achieved by 9 layers of imaging Si sensors (AstroPix). (https://arxiv.org/abs/2101.02665) sandwiched with ScFi/Pb layers of up to 9 radiation lengths (X_0) and followed by about 11 X_0 of ScFi/Pb calorimeter.

Based on the EIC Yellow Report (YR) evaluations (https://arxiv.org/abs/2103.05419), the barrel calorimeter has to provide an energy resolution of approximately 10-12%/√E + 1-3%, excellent electron-pion separation up to 10^4 in pion suppression, a spatial resolution to separate gammas from π^0 decay with momentum up to about 15 GeV, and the capability of detecting gammas with energies down to 100 MeV.

This proposed hybrid design allows for precise measurement of energy and position of the incident particles' cascade in three-dimensional space. Utilizing machine-learning (ML) techniques for pattern recognition of the 3D image of particle showers, this calorimeter can provide a high pion-electron rejection power that is not achievable with traditional sampling calorimetry, especially at lower particle energies (< ~5 GeV). See Figure 1. The layers of ScFi/Pb sampling calorimeter improve the overall sampling fraction and hence the energy resolution of the calorimeter. Table 1 summarizes the expected detector performance based on simulations with realistic AstroPix sensor digitization and reconstruction algorithms for both 3D and 2D shower clustering.



The proposed technology for imaging layers is based on the off-the-shelf AstroPix sensor (https://arxiv.org/abs/2101.02665), the successor of the ATLASPix (https://arxiv.org/abs/2002.07253), a low-power pixel detector, developed for the ATLAS experiment, and further optimized for a NASA's AmegoX[1] mission. This family of sensors has demonstrated an excellent energy resolution at low energies (~7% at 30 keV) and does not have stringent power and cooling requirements. This technology was discussed in the YR as an alternative to light-collecting calorimeters. The YR suggested scintillating fibers embedded in an absorber as a main technology for the barrel ECAL. The proposed Pb/ScFi design is based on the existing GlueX Barrel Calorimeter (https://arxiv.org/abs/1801.03088) with 5%/√E + 1% energy resolution and 1 cm position resolution, scaled in length. A possible upgrade path for barrel ECAL includes a layer based on LGADs sensors replacing the first AstroPix layer (at r ~ 105 cm) to allow for PID based on Time-of-Flight measurements.

Table with performance

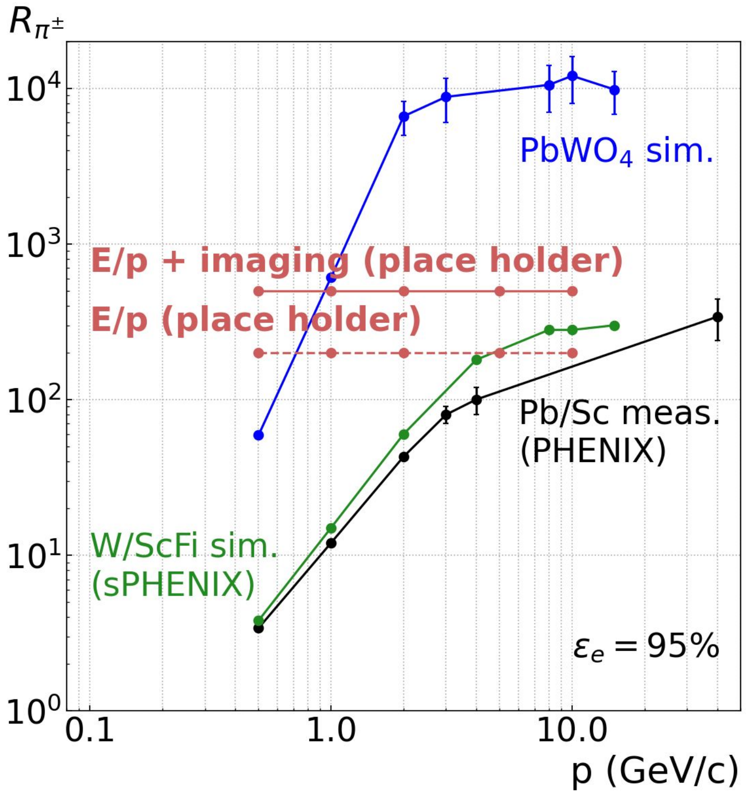
E resolution	e/π separation	$E_{\gamma,min}$	Spatial resolution	$\pi^0 \to \gamma\,\gamma$
5.4%/sqrt(E) + 0.2%	98% pion rejection with 99% electron efficiency	~ 100 MeV		For 20 GeV π^0 θ_{min} ~ $(2m_{\pi 0})/p_{\pi 0}$ = 0.018 For 105 cm Barrel radius this gives ~ 14 mm separation (28 pixels)
- Based on electron/photon simulations with eta=(-1,1). - Constant term do not include calibration effects. - Approx. readout, no light propagation, attenuation effects.	currently ML method tends to optimize 99% electron efficiency	- The cluster reco optimization is in progress. - Depends also on the material in front of the calorimeter.		

Performance plots

e/pi separation

Combined imaging shower identification and scfi E/p

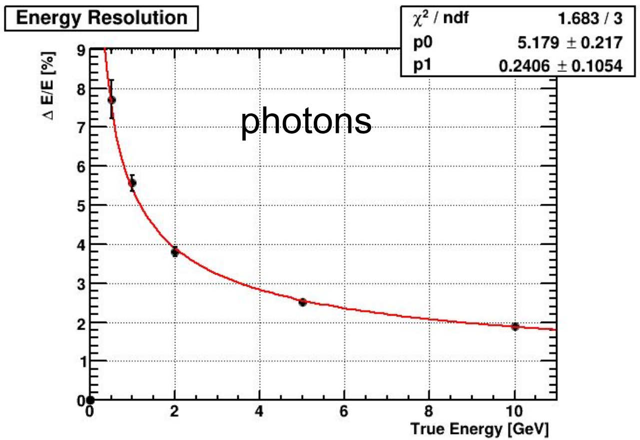
With/without material in front of the calo

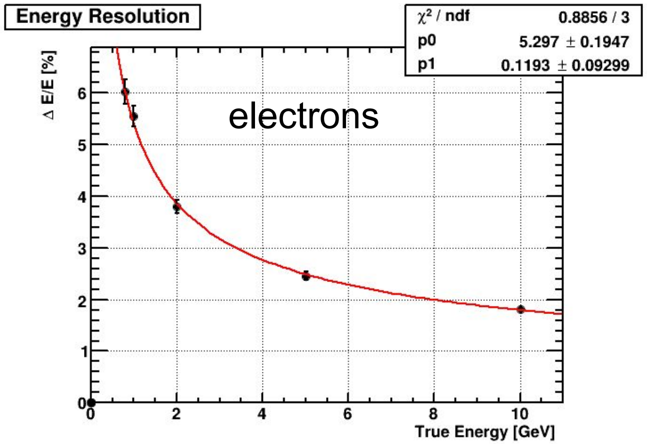


Performance plots

dE resolution to be included in the performance table

5-6% √E + 1%





Min gamma energy
Studies of J. Kim

Using 0.1 – 5.0 GeV γ dataset

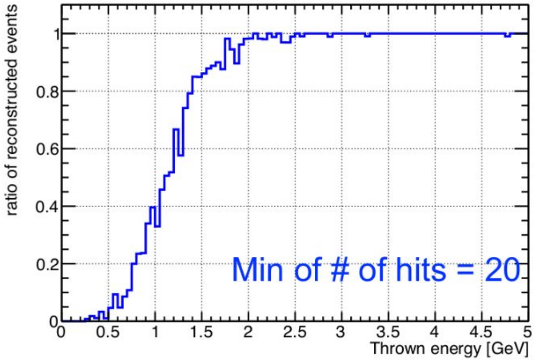
Using only imaging layers

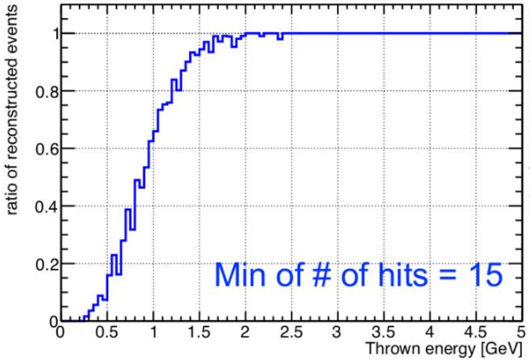
THRESHOLD ENERGY
All events reconstructed in em barrel

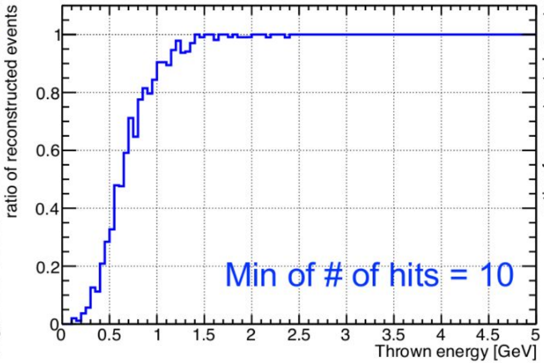
Histograms of $\dfrac{\#\ of\ reconstructed\ event}{\#\ of\ thrown\ event}$

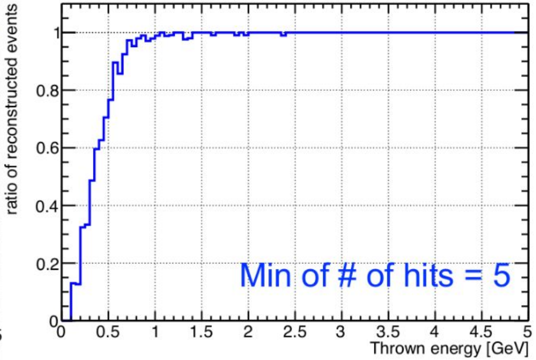
with different cuts on min of #hits

Min of cluster edep = 0.5 MeV









Min gamma energy

Studies of J. Kim

Using only imaging layers

NUMBER OF CLUSTERS

How many clusters reconstructed

With different cuts on min of #hits
Min of cluster edep = 0.5 MeV

Using 0.1 – 5.0 GeV γ dataset