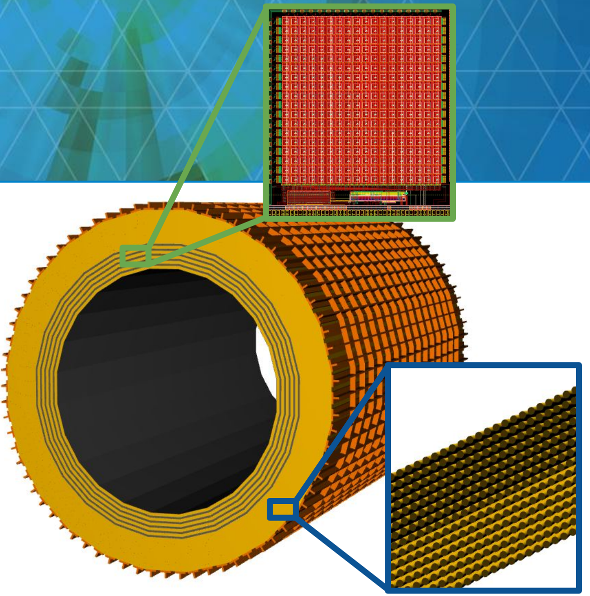
ePIC Calorimetery Meeting,
August 9th, 2023

Low Energy Threshold



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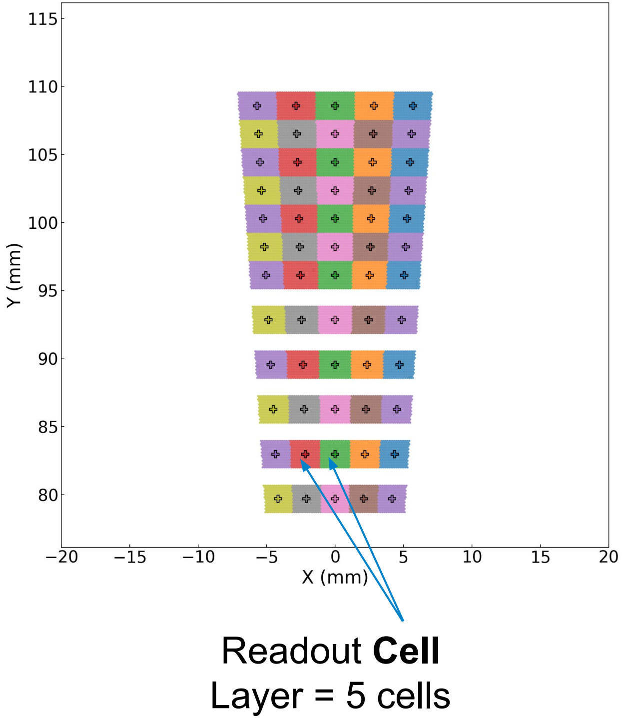
SciFi/Pb Readout Channels

- 12 readout layers on each sector end
- 5 readout cells per layer
- We plan to use one 1.2x1.2 cm2 SiPM array in each channel, as in GlueX (4 x 4 array of 3x3 mm2 SiPMs)

- Total number of SiPM is:
  - 12 (layers) * 5 (cells/layer) * 2 (ends) * 48 (sectors) = 5760 readout cells
  - 5760 (cells) * 1 (SiPM array/cell) = **5760 SiPM arrays**

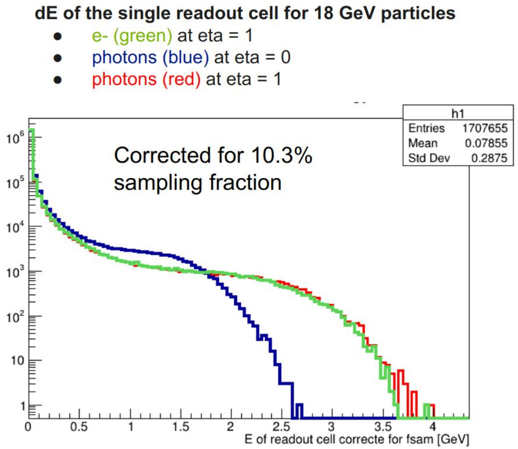
Sector End View
(x-y plane view)



The area 1 light guide is attached

Pixel Size

- Defined by **photoelectron statistics** and **maximal energy** to be measured
  - Maximal fraction of the total shower energy deposited in a longitudinal layer of **~1.5 X0 size** (approximately the readout layer depth) will be **~15%** (from longitudinal shower profile) **at $\eta = 0$**
  - With a steeper impact angle, the effective thickness of one SciFi/Pb layer will be longer, so the energy deposit per layer will be larger.
  - The most extreme case for us would be **50 GeV electrons at +1.31** (30 deg impact)
  - Assuming that we have ~30% (15%/sin(30 deg)) of max deposit for 50 GeV electrons at eta = 1.31 this gives us **~15 GeV**



dE in single readout cell
Example for 18 GeV photons at $\eta = 0$ and $\eta = 1$ (~41 deg impact)

- Max dE at $\eta = 0$: ~2.7 GeV (18 GeV * 15%)
- Max dE at $\eta = 1$: ~4.1 GeV (18 GeV * 15%/sin(41 deg))

Pixel Size

- Defined by **photoelectron statistics** and **maximal energy** to be measured
  - GlueX reports ~660 phe/GeV (with PMTs)
  - Assuming that we will get 1000 phe/GeV **TBC in measurements** (assuming ~1.5 larger SiPM phe efficiency):
    - 15 GeV * 1000 phe/GeV = 15000 phe
  - We have 57600 pixels in 1 SiPM array with 50um pixel:
    - 15000/57600 = ~26% (max ratio)

- 4 x 4 array of 3x3 mm2 SiPMs 50 um pixel per should be just right: HPK S14160-3050-04

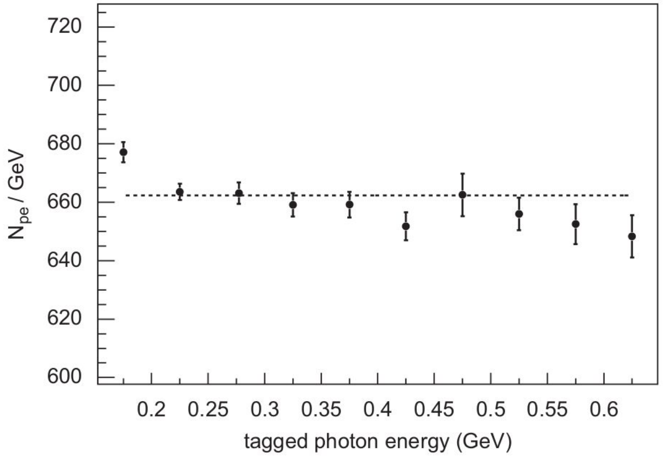


Fig. 16. The number of photoelectrons per GeV per end of the BCAL module is shown as a function of energy. A one parameter fit is plotted (dashed line). For more details see the text.

RDO Questions:
https://docs.google.com/document/d/1rCLd582q-gBkBymc2C5VDufSeJYM_qjqMS07oYsVG54/edit

Scintillating Fibers

- **Review:** Show that we understand the requirements for the fibers: attenuation and light yield
- The most challenging requirement: **capability to measure low energy photons down to 100 MeV***
- GlueX did show that they can measure 50 MeV showers

* YR newer explains the reason for this threshold

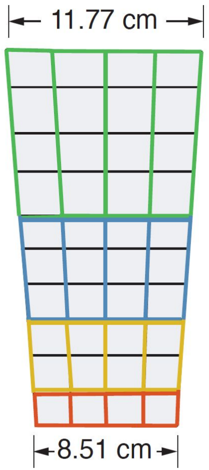
- **Goal:** demonstrate that we'll perform not worse than the GlueX: e.g. the amount of light we will get with the proposed fibers (accounting for SiPMs and the SiPM-PbSciFi coupling) will be equal or larger than in GlueX (and preferably with single-clad)

Readout SciFi/Pb - GlueX

GlueX scheme

- **2-side SiPM readout**
- **Lightguides** attached to the stave sides
  - inner surface ~2×2 cm^2
  - output face 1.3×1.3 cm^2
- **Summing scheme**
  - Following the preamp stage, outputs summed by columns (see picture)
- ~17 MeV threshold on one channel (corrected for f_{sam})
  - summing 1 - 4 channels together

GlueX
1/48th of the barrel
side view



Hamamatsu S12045(X)
4×4 array of 3×3 mm^2
50×50μm^2 pixels

16 FADC per side
12 TDC per side

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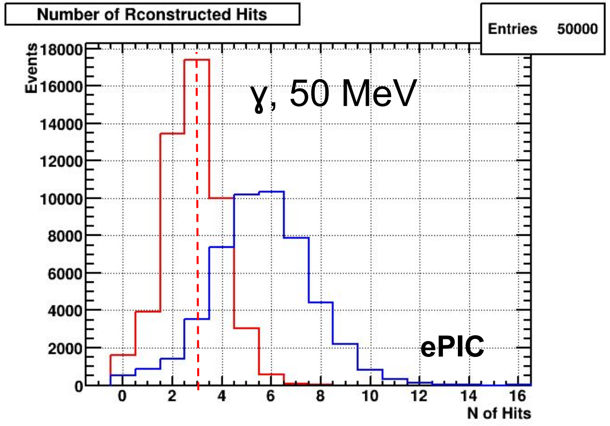
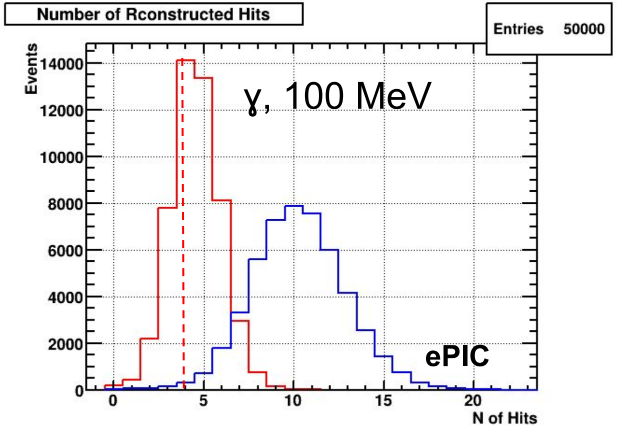
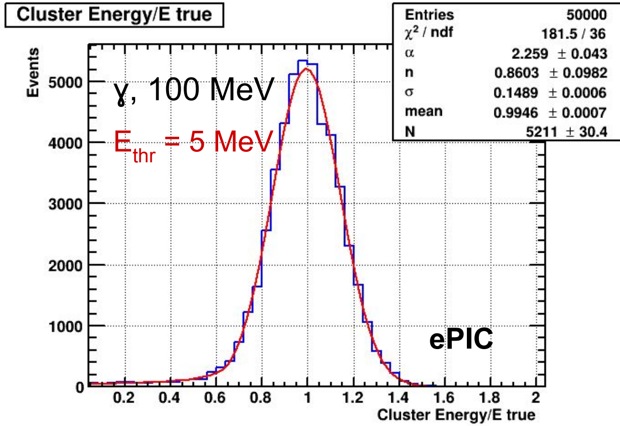
Low Energy Particles

Threshold corrected for f_{sam}
E_{thr} = 0.5 MeV
E_{thr} = 5 MeV

- For electrons: cut out because of the 1.7 T field to reach the calorimeter (p < ~408 MeV)
- For photons shown number of fired readout cells with different thresholds at η = 0





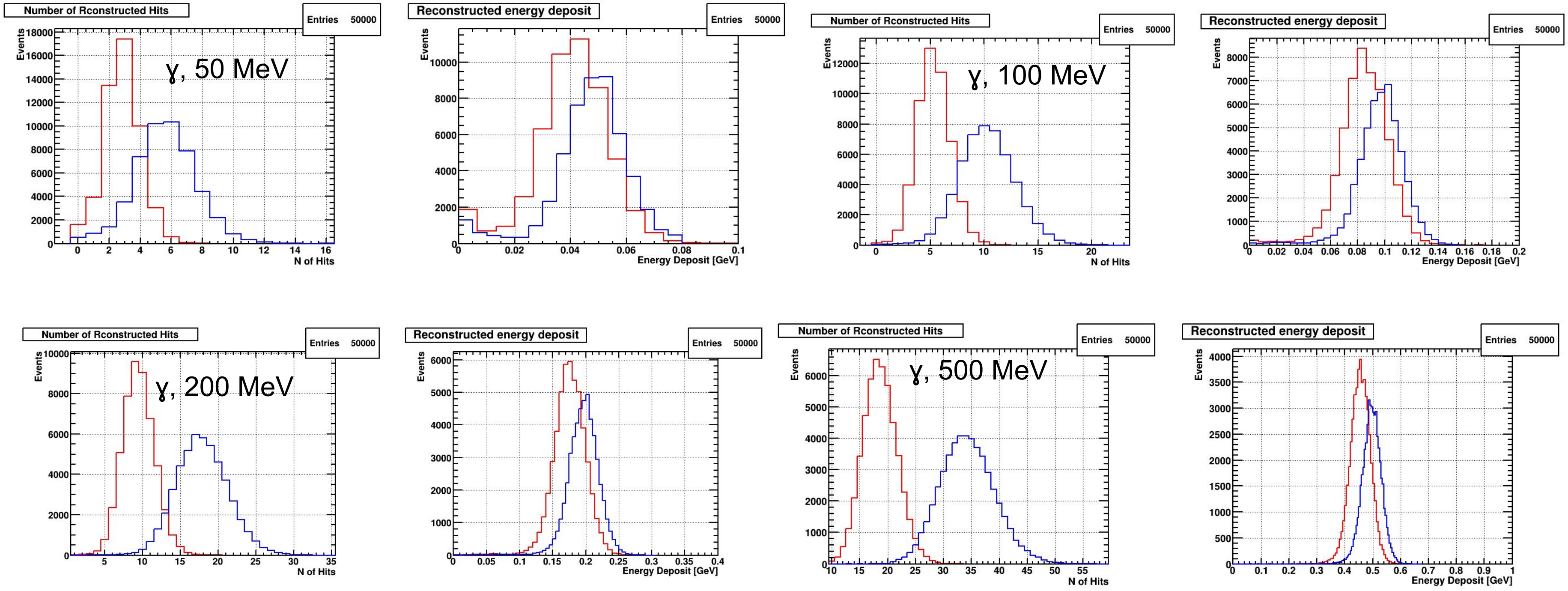


Blue threshold very low just to illustrate the distribution shape

- **From GlueX** studies: cluster/shower threshold is 100 MeV nominal (down to 50 MeV for some analyses, with mostly two cells per event only). Low energy detection threshold studied also with Michel electrons. (NIM, A 896 (2018) 24-42)

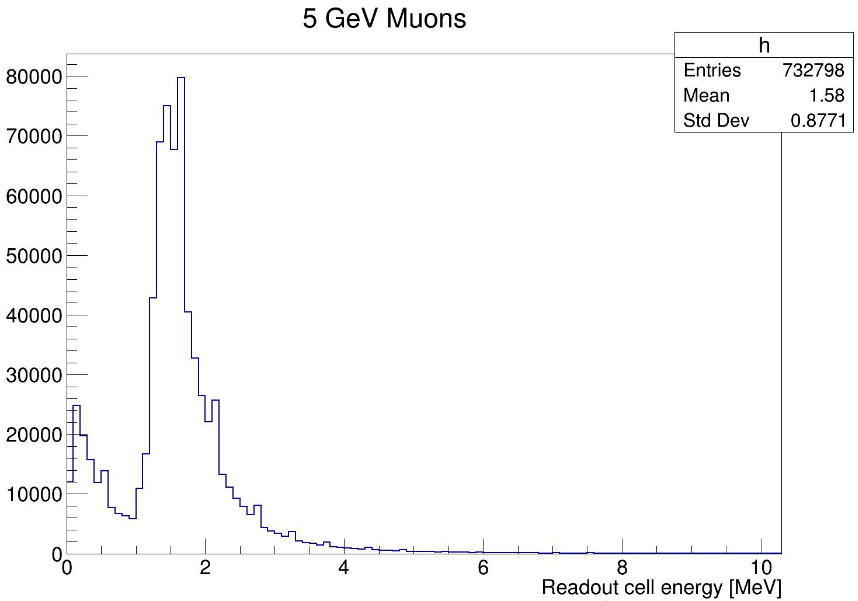
Low Energy - Gammas

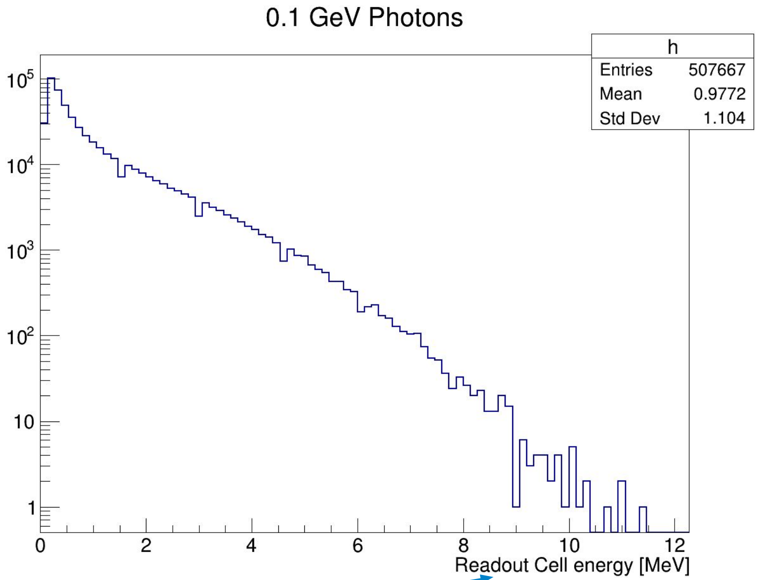
Threshold corrected for f_{sam}
E_{thr} = 0.5 MeV
E_{thr} = 5 MeV



N of Hits: Number of cells above the threshold
Energy Deposit: Energy deposited with particular threshold

Low Energy Particles - Energy per readout cell

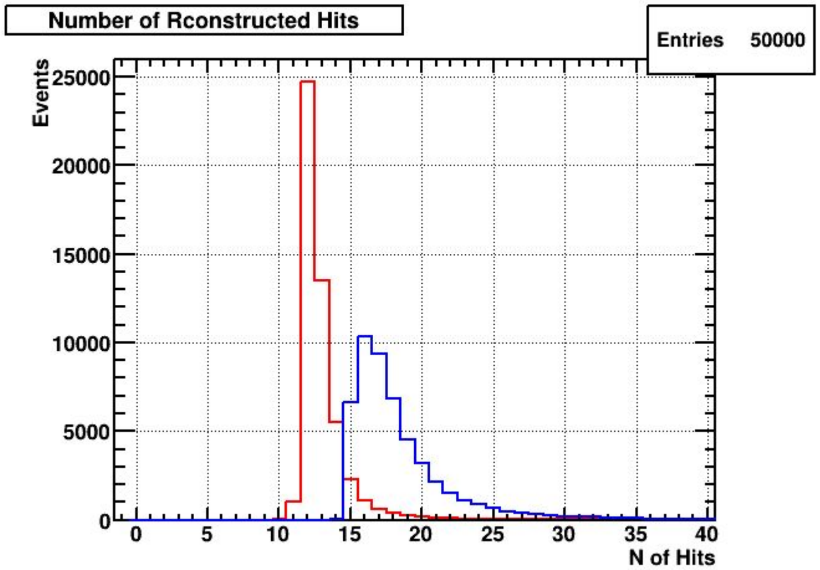


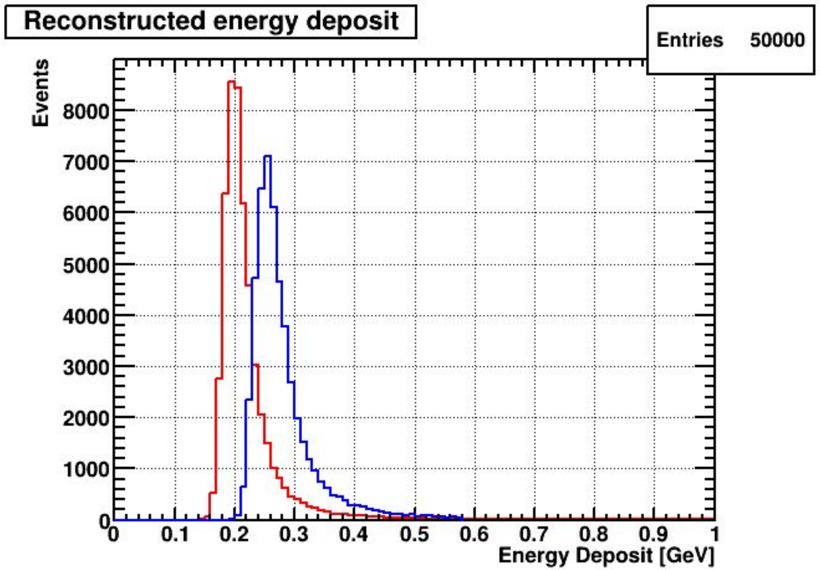


- Energy not corrected for 10% sampling fraction in readout cells
- Studies at η = 0 to look at the lowest dE
- Threshold set very low = 0.05 MeV to study the energy distribution of readout cells

Low Energy Particles - MIPs

Threshold corrected for f_{sam}
E_{thr} = 0.5 MeV
E_{thr} = 5 MeV





- 5 GeV Muons
- Studies at $\eta = 0$ to look at the lowest dE
- Threshold set very low = 0.05 MeV to study the energy distribution of readout cells

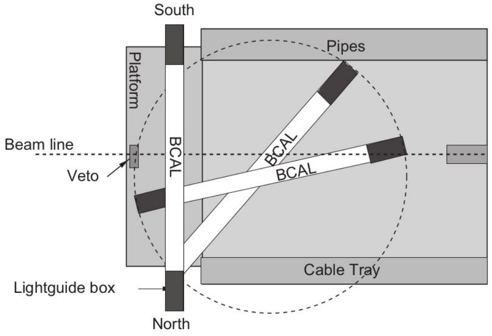
Summary

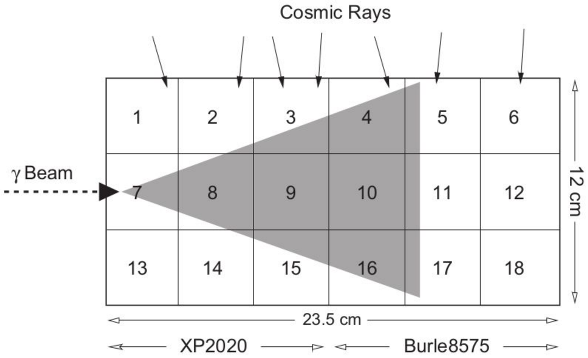
- Low energy threshold for gammas not clear from the Yellow Report
- GlueX can measure MIPs and gammas down to 50 MeV (2 cells fired in average) with 17 MeV threshold on readout cell (1.7 MeV not corrected for f_{sam}), but Gluex sums up the channels
- For barrel ECal to register 100 MeV gammas and MIPs we would need to set ~5 MeV threshold on single cell (0.5 MeV not corrected for f_{sam})
  - Seems reasonable but noise needs to be further studied

Comparison with GlueX prototype data

Test at JLab Hall B with **full size one stave prototype**, secondary **photon beam**, **~0.15-0.6 GeV**, **90º angle**

NIM, 596 (2008) 327–337, Performance of the prototype module of the GlueX electromagnetic barrel calorimeter





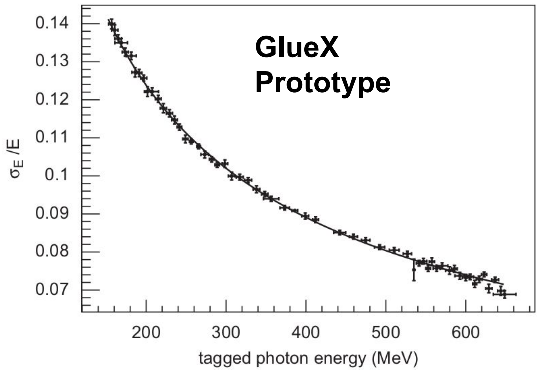


Fig. 11. Energy resolution vs. E_{BEAM} for photons for $\theta = 90^\circ$ and $z = 0$ cm. The fit gives $\sigma_E/E = 5.4\%/\sqrt{E(\text{GeV})} \oplus 2.3\%$. The fit of Fig. 10 corresponds to the 40th datum from the right (19th from the left) in this figure.

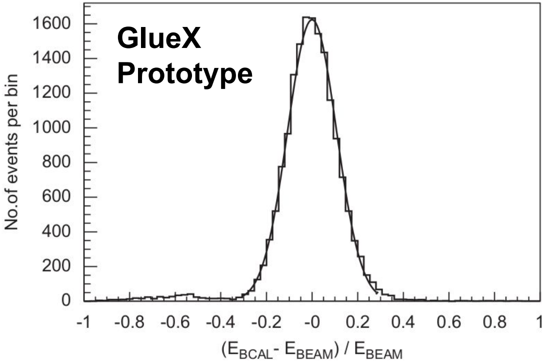
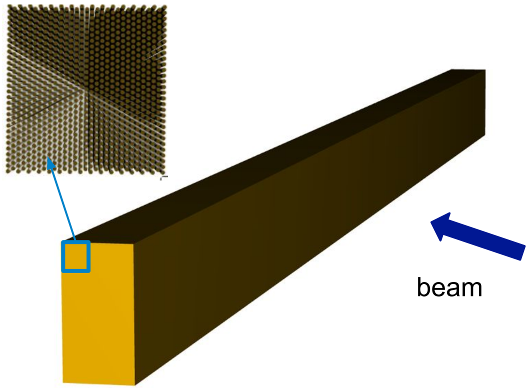
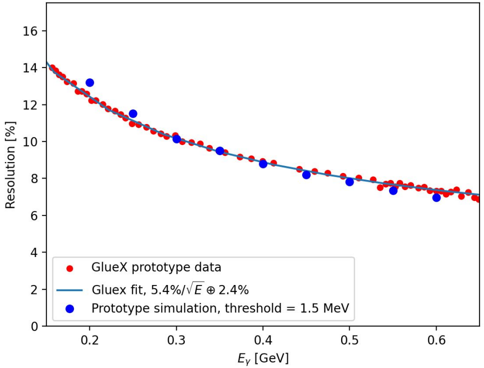


Fig. 10. The calibrated spectrum for D is shown for timing counter 40, corresponding to a beam energy of 273 MeV. The solid line is a Gaussian fit to the data.

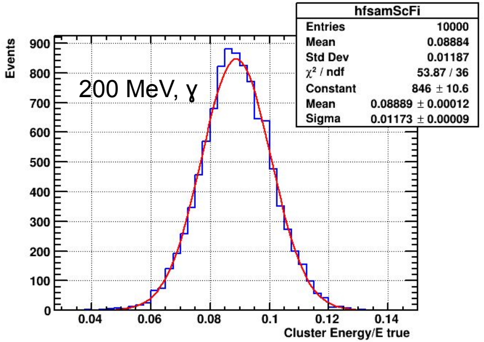
Comparison with GlueX prototype data

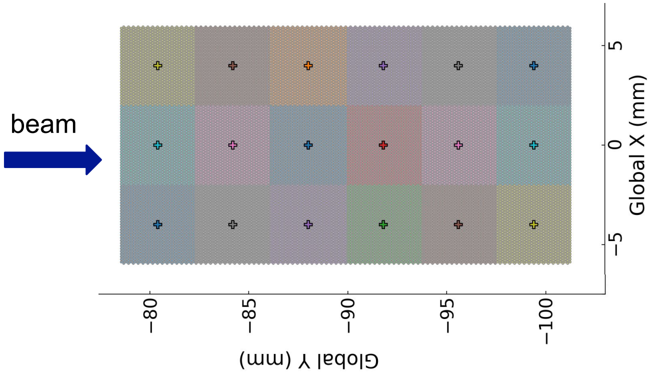
Simulation of GlueX prototype and readout scheme in **ePIC simulation environment**





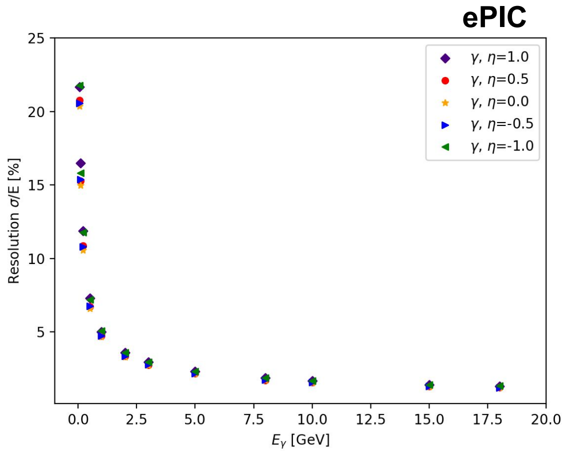
Reconstructed Energy/True energy

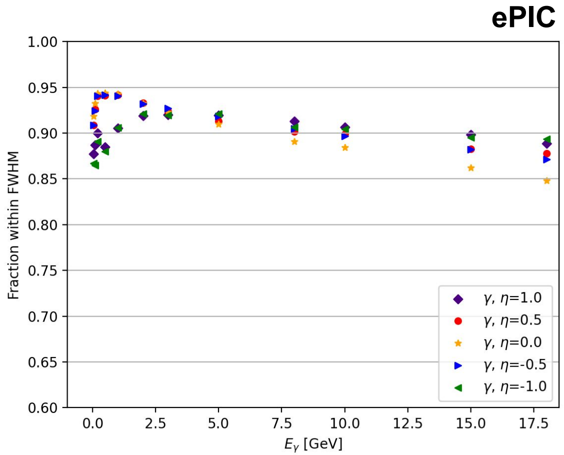


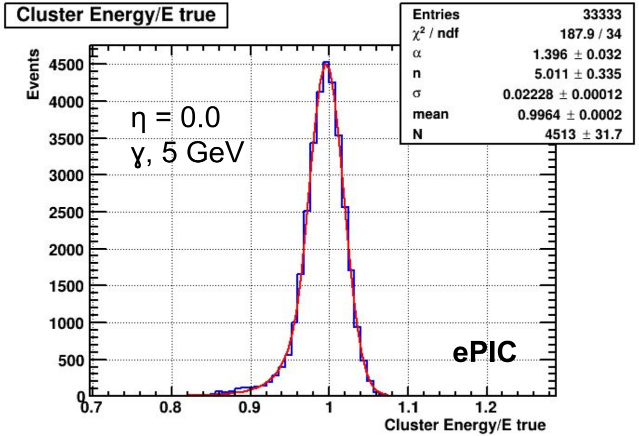


- Realistic geometry implementation and simulation of the prototype and readout
- Low energy data described quite well by the simulation
- Energies up to ~6 GeV tested in the ongoing test at Hall D

Energy Resolution - Photons







Fit parameters

η	a/√(E) [%]	b [%]
-1	5.1(0.01)	0.47(0.03)
-0.5	4.77(0.01)	0.38(0.02)
0	4.67(0.01)	0.40(0.02)
0.5	4.75(0.01)	0.39(0.02)
1	5.1(0.01)	0.41(0.02)

- Based of Pb/ScFi part of the calorimeter
- Resolution extracted from a Crystal Ball fit σ

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

- 15.5 X_0, extracted for integrated range over the angular distributions for π^0 and η production at GlueX (E_γ = 0.5 - 2.5 GeV)
- Measured energies not able to fully constrain the constant term

Simulations of **GlueX prototype** in ePIC environment agree with data at E_γ < 0.5 NIM, 596 (2008) 327−337