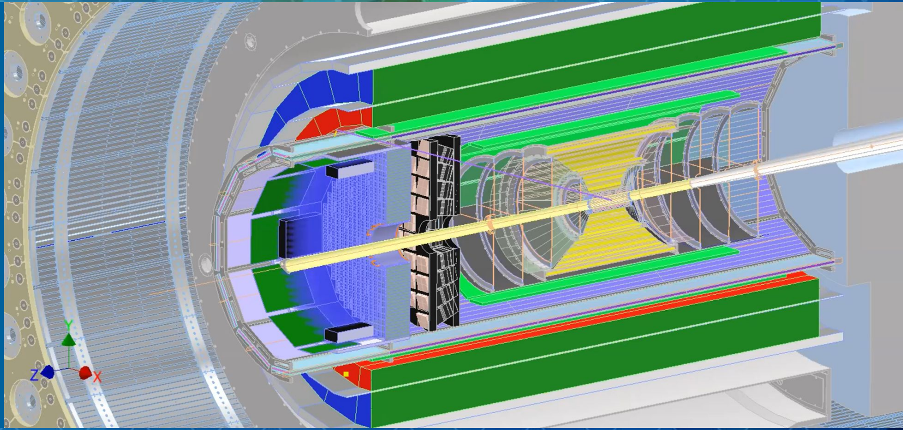
BECal Meeting

# Barrel Electromagnetic Calorimeter

## Geometry Optimization

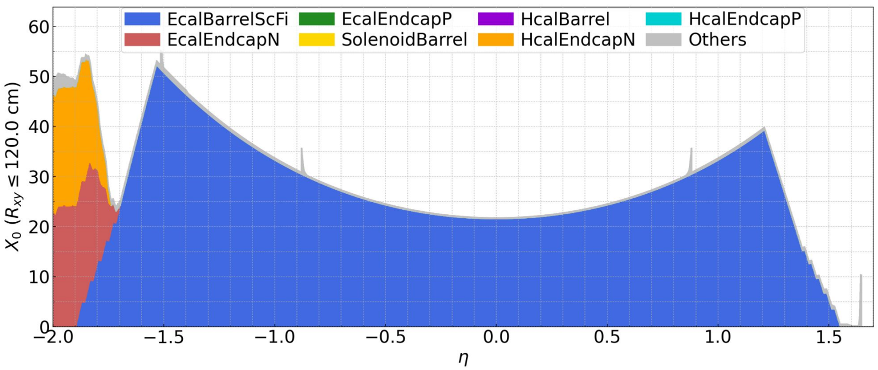


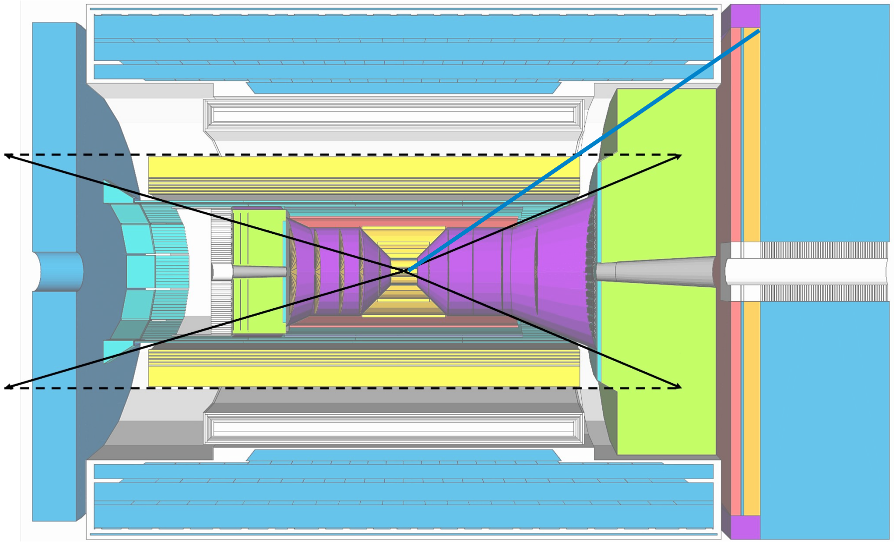
05/02/2023

# Question: Can we make the calorimeter less deep?

- **Barrel ECal is currently ~21 $X_0$ deep**
  - Driven mostly by the high-energy electron response (up to ~ 40 GeV)
  - Plus: Deeper calo ⟶ more interaction length (inner HCal)

- **Can we make it less deep?**
  - We could gain in lower weight and price. How much?

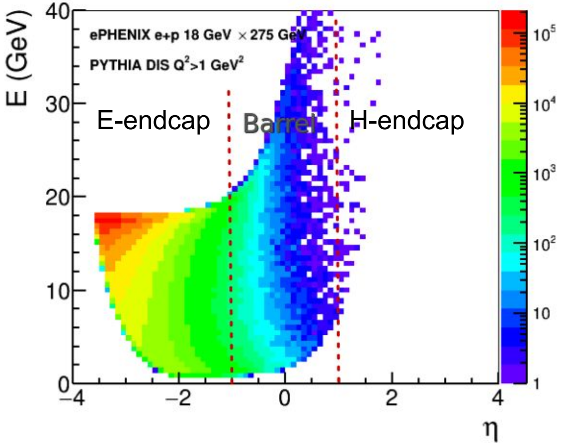


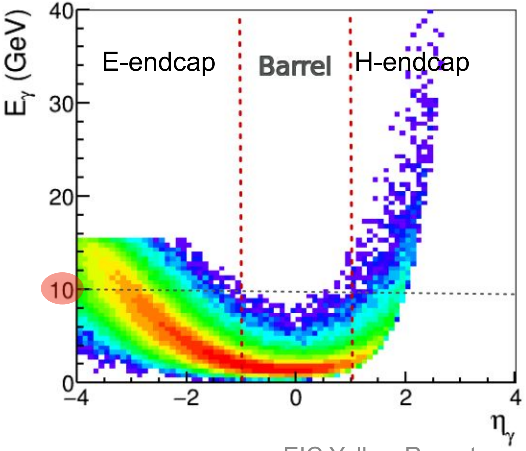
# EIC Calorimetry Requirements

EIC Yellow Report

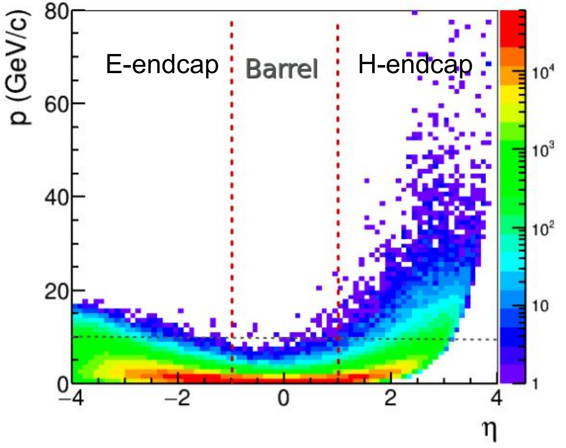
DIS electrons



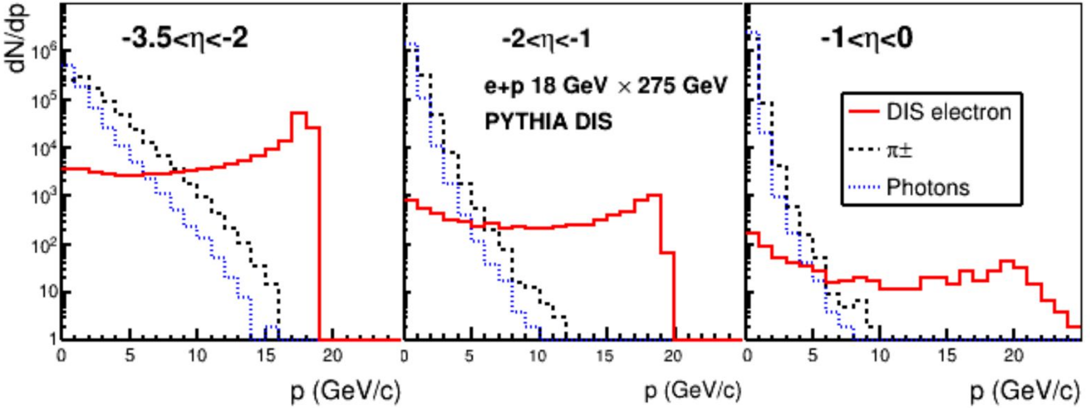

DVCS photons




SIDIS $\pi^0$




EIC Yellow Report



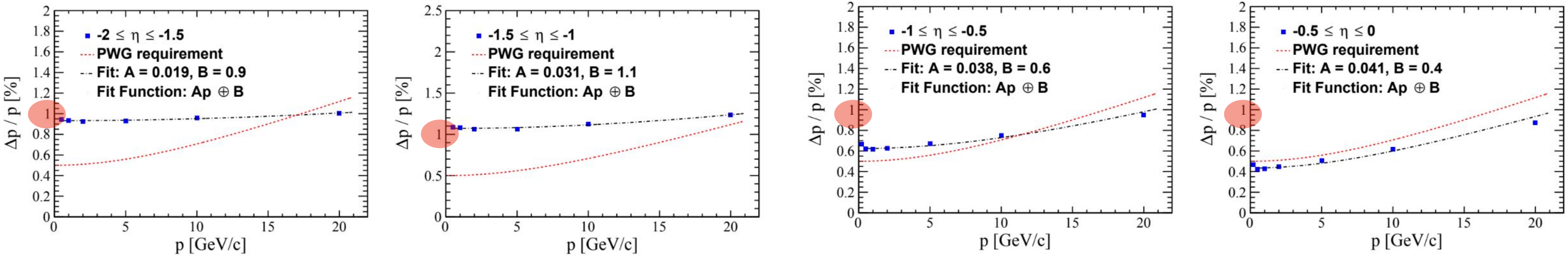

e/π separation:

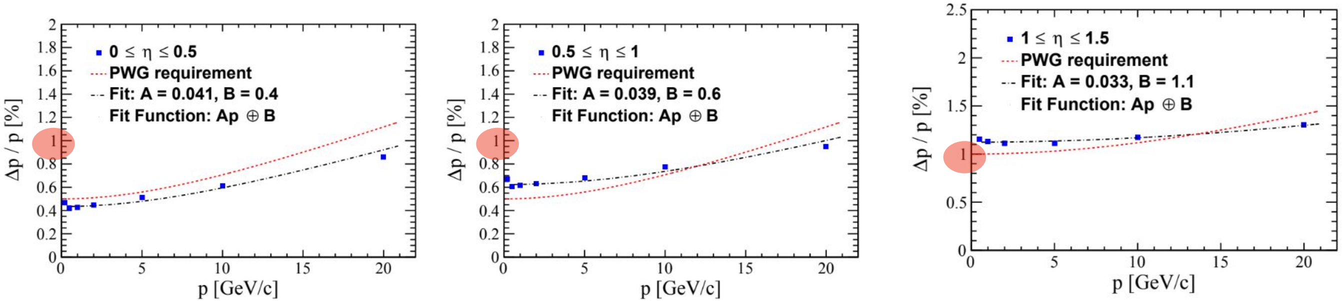
- Depends on momentum and η
- Tightest constrain from parity violating asymmetries $10^{-4}$
- ΔG requires ~ $10^{-3}$

# Electron momentum determination

- Will electron momentum will be measured by tracking with superior resolution?
  - Barrel ECal covers region η = (-1.7, 1.2)

Brycecanyon 22.11.2 single pion, truth seeding with no smearing




ECal Energy resolution

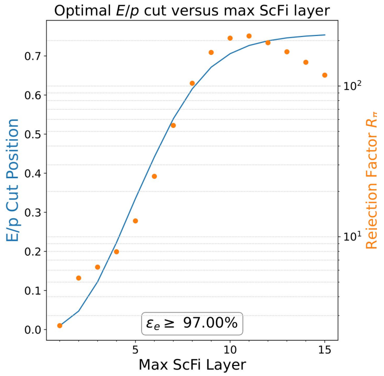
σ = ~5.2% /√$E$ ⊕ 1% at $21X_0$

# Electron/pion separation

Leans on the AstroPix layers response and E/p cut at different depth of the calorimeter from SciFi/Pb

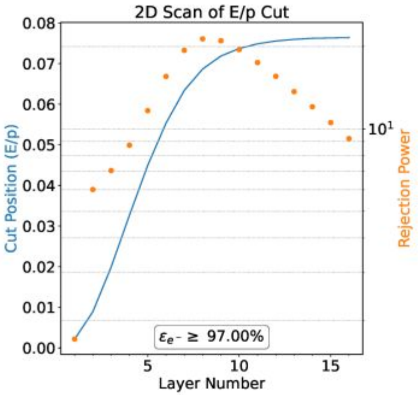
- Side SiPM readout of SciFi/Pb on at different depths (SciFi/Pb layers)
- One layer = 17 rows of fiber (~2 cm) - lightguide surface attached to the calo (2x2 $cm^2$)

**2 GeV/c e/π**



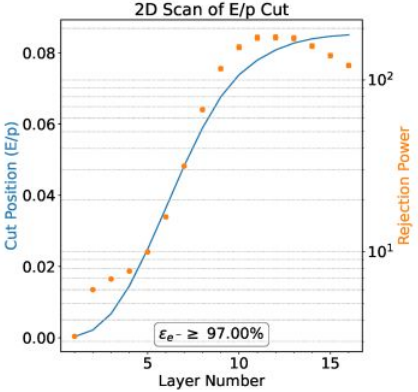

Optimal cut at 15.73 $X_0$ (layer 11)

**0.6-0.8 GeV/c**



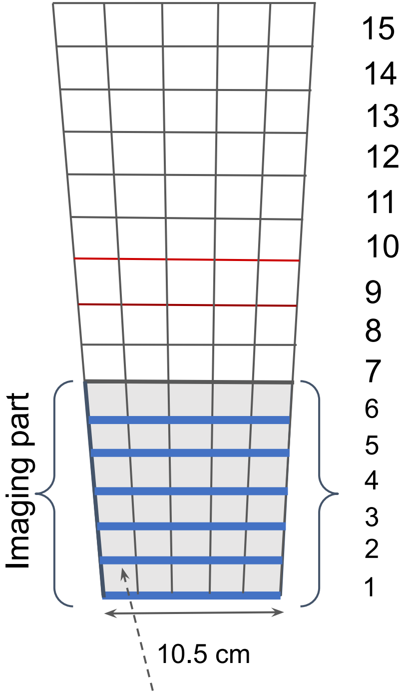

Optimal cut at 15.77 $X_0$ (layer 8)

**9.9-10.1 GeV/c**




Optimal cut at 16.15 $X_0$ (layer 12)

**EPIC**
1/48th of the barrel
side view

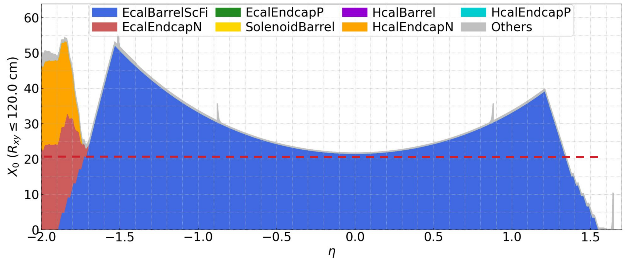



**Imaging layers**
(not to scale)

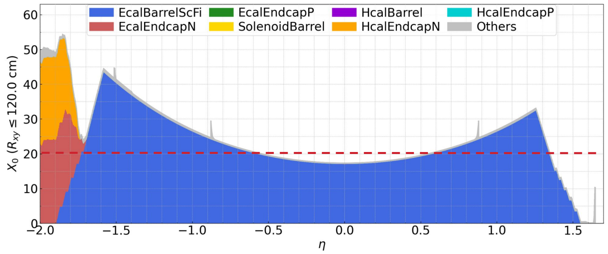
Plots at $\eta = 0$

# Let's try to drop 2 SciFi/Pb layers

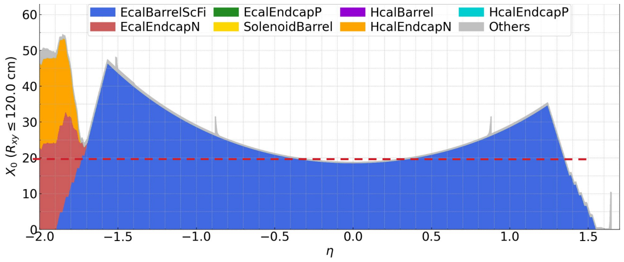
- Currently 15 layers x 17 fibers = 15 x 2.074 cm (SciFi/Pb only) = 15 x 1.43 $X_0$ = ~21.45 $X_0$




- With 15 layers: ~21.45 X0

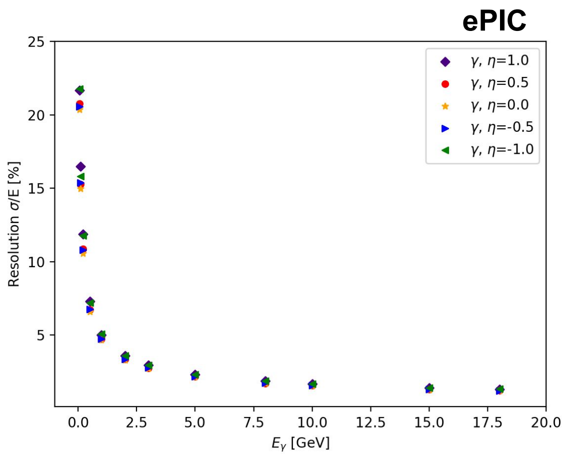


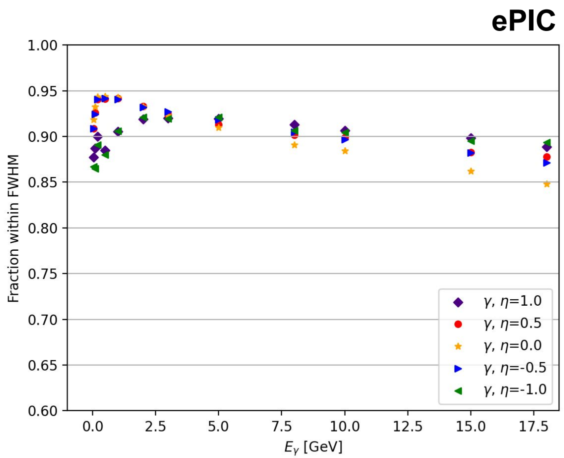

- With 12 layers: ~17.1 X0

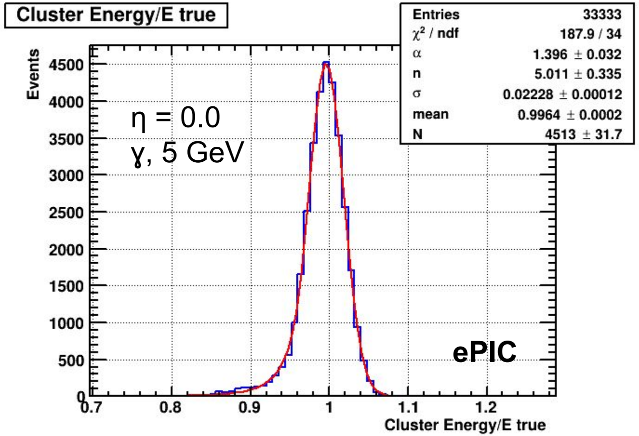



- With 13 layers: ~18.5 X0

# Energy Resolution - Photons - 21 $X_0$




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) |

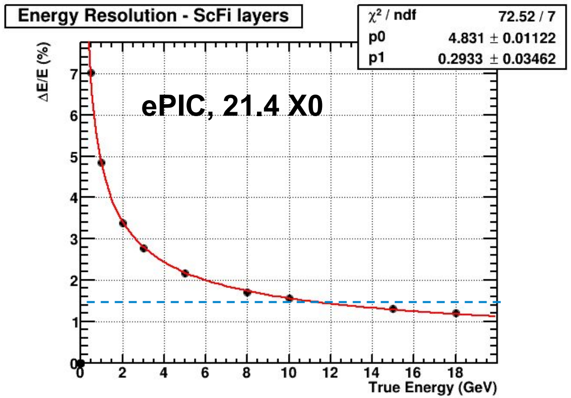
- Based of Pb/ScFi part of the calorimeter
- Resolution extracted from a Crystal Ball fit σ

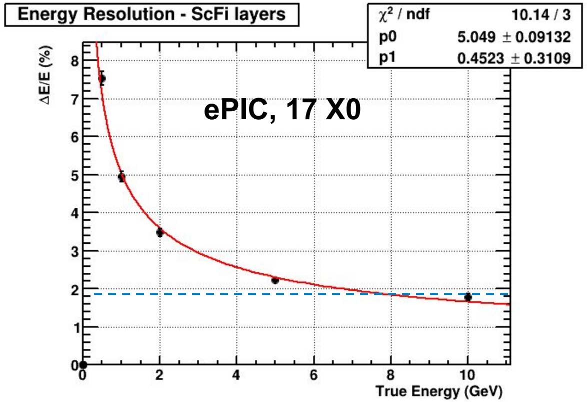
**GlueX Pb/ScFi ECal:** $\sigma = 5.2\% / \sqrt{E} \oplus 3.6\%$ NIM, A 896 (2018) 24-42

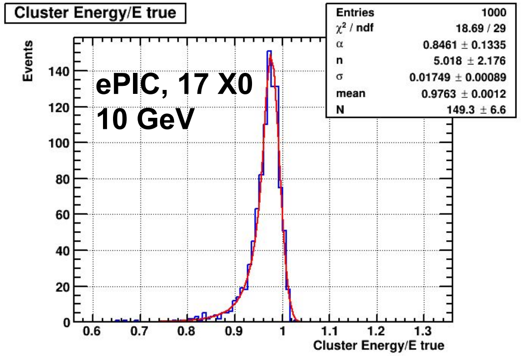
- 15.5 $X_0$, extracted for integrated range over the angular distributions for $\pi^0$ and η production at GlueX ($E_\gamma$ = 0.5 - 2.5 GeV)
- Measured energies not able to fully constrain the constant term

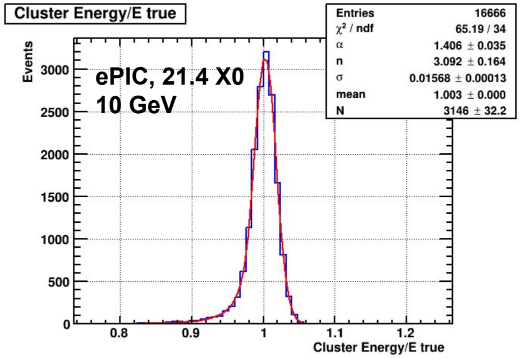
Simulations of **GlueX prototype** in ePIC environment agree with data at $E_\gamma$ < 0.5 NIM, 596 (2008) 327−337

# Energy Resolution - Photons - 17 vs 21 $X_0$




The fit parameters differ a bit from the previous page (I generate here less low energy points)

More statistics in progress, point at 10 GeV has decent statistics

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

**η = 0**

# What can we gain?

| | |
|---|---|
| r_min [cm] | 78.3 |
| nb of staves | 48 |
| length [cm] | 432.5 |

| | 15 SciFi/Pb layers | 13 SciFi/Pb layers | 12 SciFi/Pb layers |
|---|---|---|---|
| Air Space for AstroPix = 1 cm | | | |
| Total depth | 37.065 cm + 3 cm (Al back plate) | 33 cm + 3 cm (Al back plate) | 30.843 cm + 3 cm (Al back plate) |
| Weight of SciFi [kg] | 40800 | 34500 | 31500 |
| Nb of fibers | 1.25M | 1.04M | 0.94M |
| Air Space for AstroPix = 2 cm | | | |
| Total depth | 42 cm + 3 cm | 38 cm + 3 cm | 35.8 cm + 3 cm |
| Weight of SciFi [kg] | 42400 | 35900 | 32700 |
| Nb of fibers | 1.29M | 10.8M | 0.976M |

# What can we gain?

| | |
|---|---|
| r_min [cm] | 78.3 |
| nb of staves | 48 |
| length [cm] | 432.5 |

310000 × 4.325 m × 1.09 $/m = ~1.46M

| | 15 SciFi/Pb layers | 13 SciFi/Pb layers | 12 SciFi/Pb layers |
|---|---|---|---|
| Air Space for AstroPix = 1 cm | | | |
| Total depth | 37.065 cm + 3 cm (Al back plate) | 33 cm + 3 cm (Al back plate) | 30.843 cm + 3 cm (Al back plate) |
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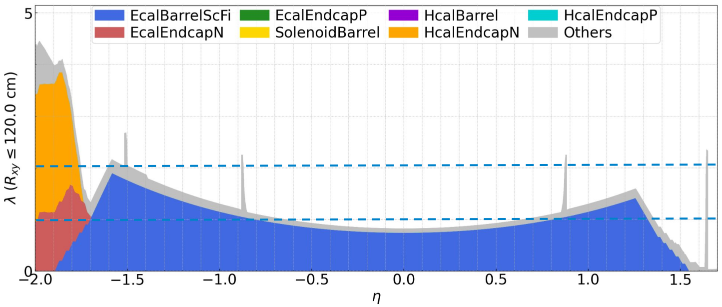
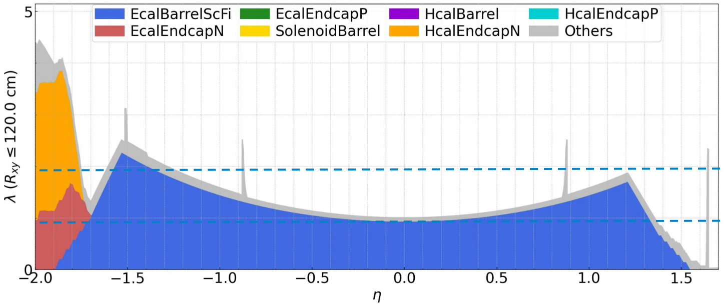
# Summary

- The photon energy resolution at 10 GeV tested with current simulation changes from ~1.4% - ~1.9%
- Energy resolution in the region η = (-1.7, 1.2) for electrons driven by tracker (per current simulations)
- Reduction in interaction length:

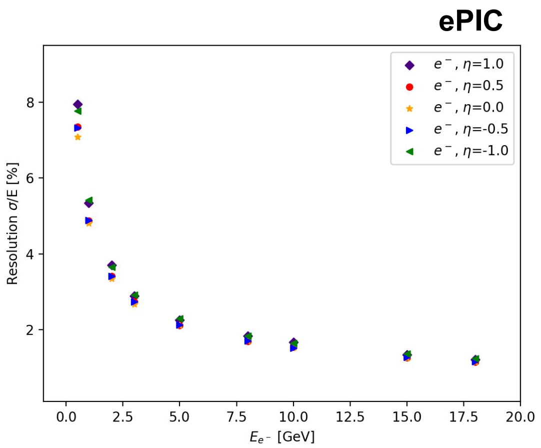
Less deep calo

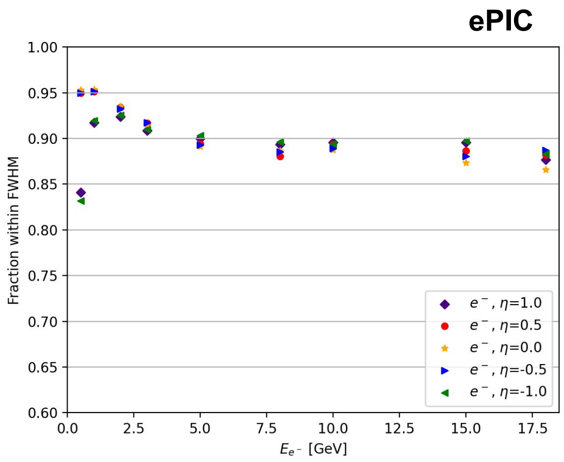


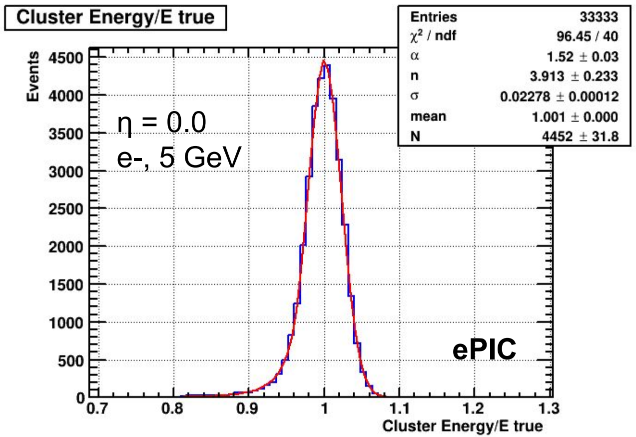



# Backup

# Energy Resolution - Electrons




Fit parameters

| η | a/√(E) [%] | b [%] |
|---|---|---|
| -1 | 5.22(0.02) | 0(0.08) |
| -0.5 | 4.88(0.01) | 0(0.04) |
| 0 | 4.81(0.01) | 0(0.08) |
| 0.5 | 4.88(0.01) | 0(0.04) |
| 1 | 5.19(0.01) | 0(0.06) |

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 $\pi^0$ and η production at GlueX ($E_\gamma$ = 0.5 - 2.5 GeV)
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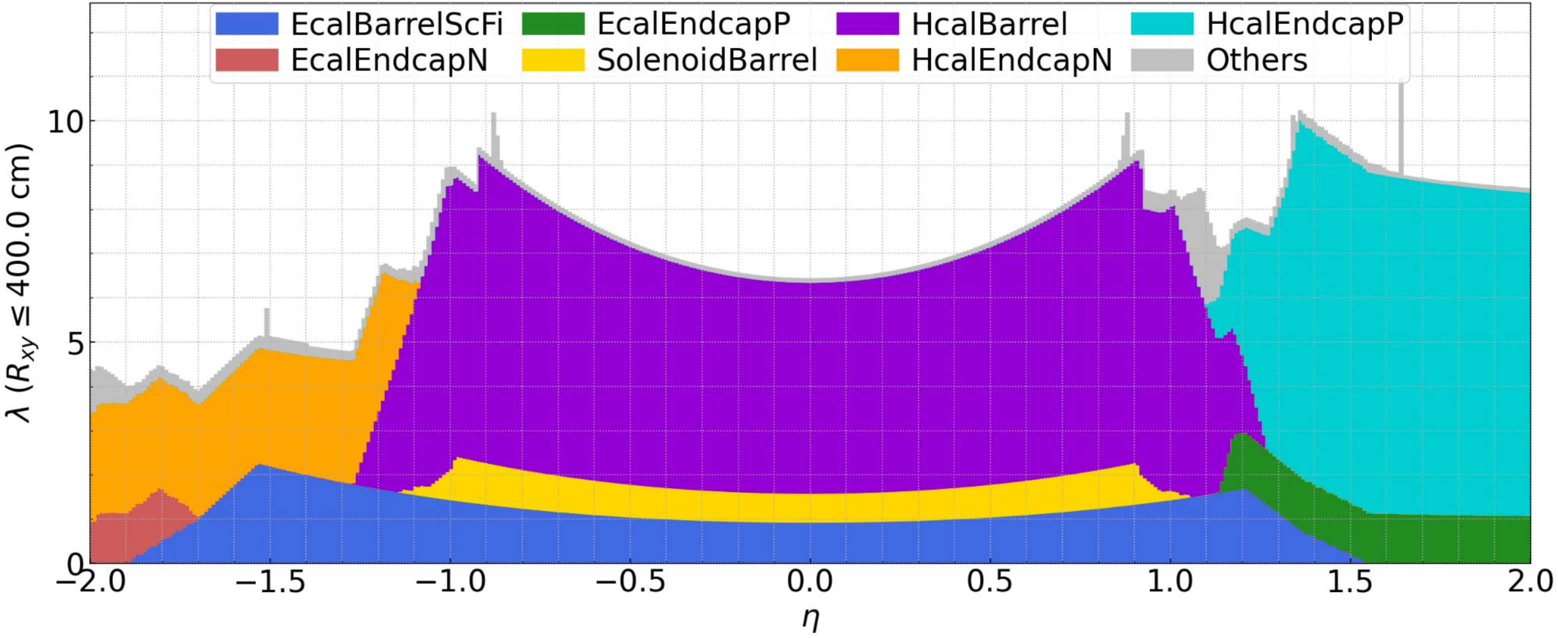
# Material Scan



# Crystal Ball Function

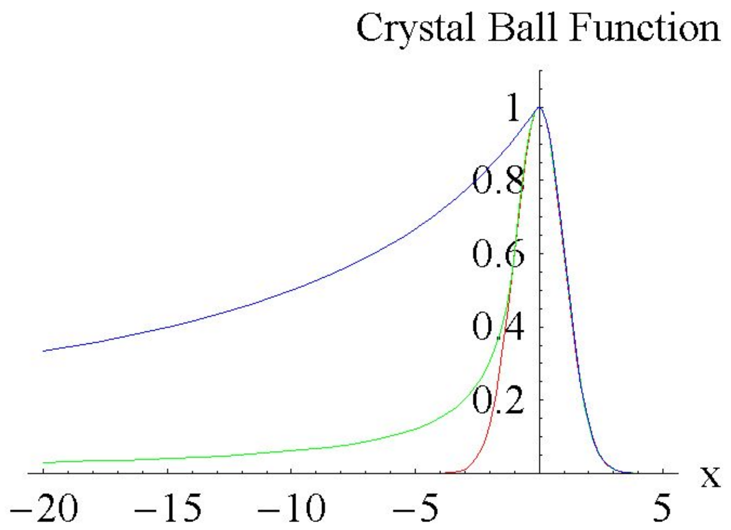
$$f(x;\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} \exp(-\frac{(x-\bar{x})^2}{2\sigma^2}), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot (B - \frac{x-\bar{x}}{\sigma})^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leqslant -\alpha \end{cases}$$

where

$$A = \left(\frac{n}{|\alpha|}\right)^n \cdot \exp\left(-\frac{|\alpha|^2}{2}\right)$$

$$B = \frac{n}{|\alpha|} - |\alpha|$$

**Examples of the Crystal Ball function.**




$\bar{x} = 0, \sigma = 1, N = 1$ Red: α = 10, Green: α = 1, Blue: α = 0.1.