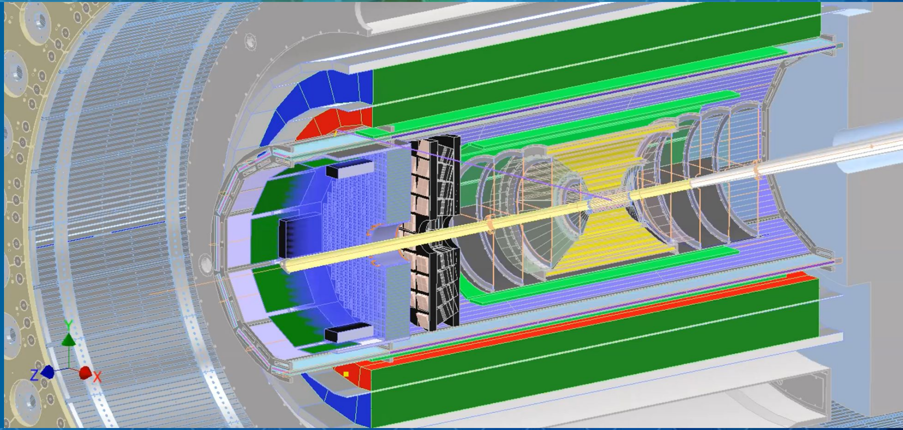
BIC Simulation Meeting

BIC Dynamic Range Simulation Updates + Layer Combination Studies



Maria Zurek

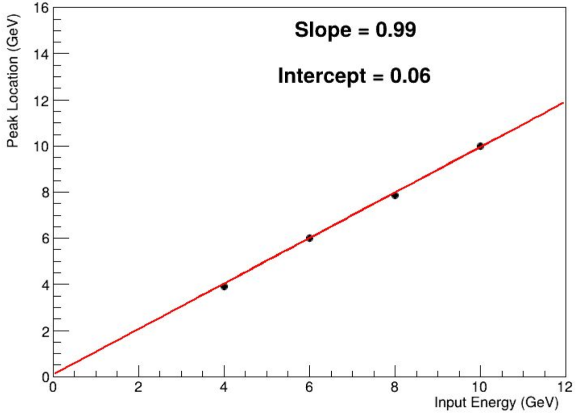
ePIC

SiPM Considerations - Dynamic Range

Estimate for review

- On the high energy side of the spectrum, we have F-DET-ECAL-BAR.2
  - *Shall provide photon measurements up to 10 GeV*
- SiPM readout consists of 57324 pixels per channel
  - When a pixel fires, it cannot register another signal for some time
  - Large signals can causes non-linearity due to multiple photons striking the same pixel
- 10 GeV photon will yield ~7700 p.e. at max per channel
  - Corresponds to ~14% of max occupancy
  - Slight non-linearity expected, can be corrected for
- Baby BCal beam tests showed no sign of saturation-induced non-linearity for 10 GeV electrons
  - This demonstrates linearity for BIC up to ~ 6 GeV, after scaling for different photon detection efficiency

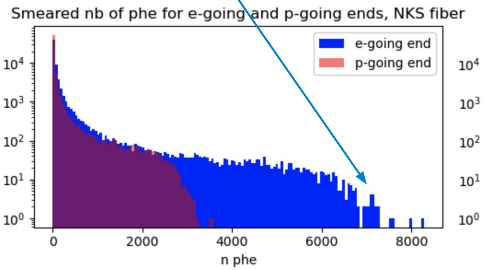
Baby BCal Test Beam (FNAL)

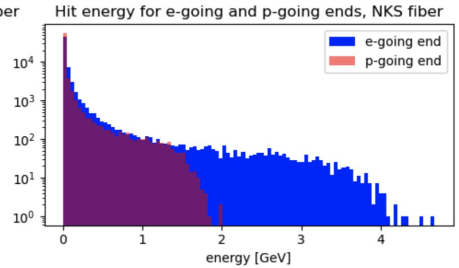


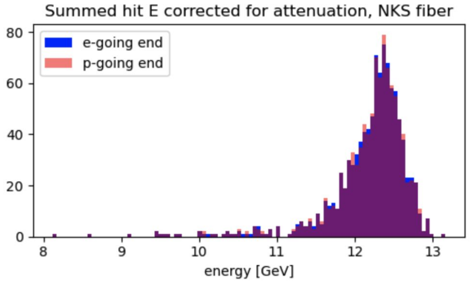
Max Number of Photoelectrons

Full simulations

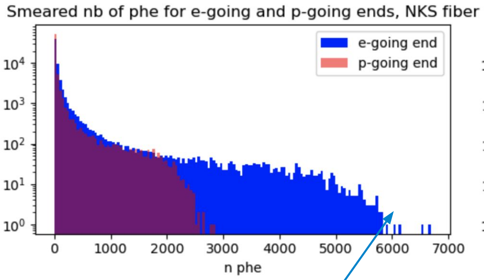
~7000 phe

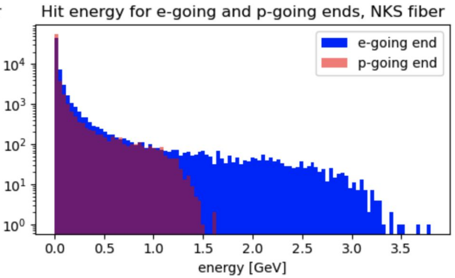


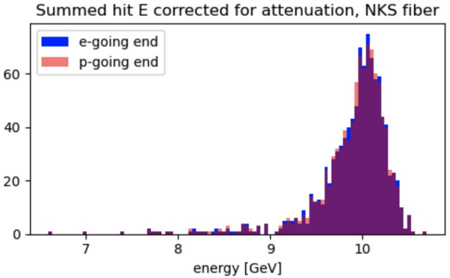




10 GeV photons at η ~ -1.7
fsam tuned to 5 GeV e⁻ at η = 0





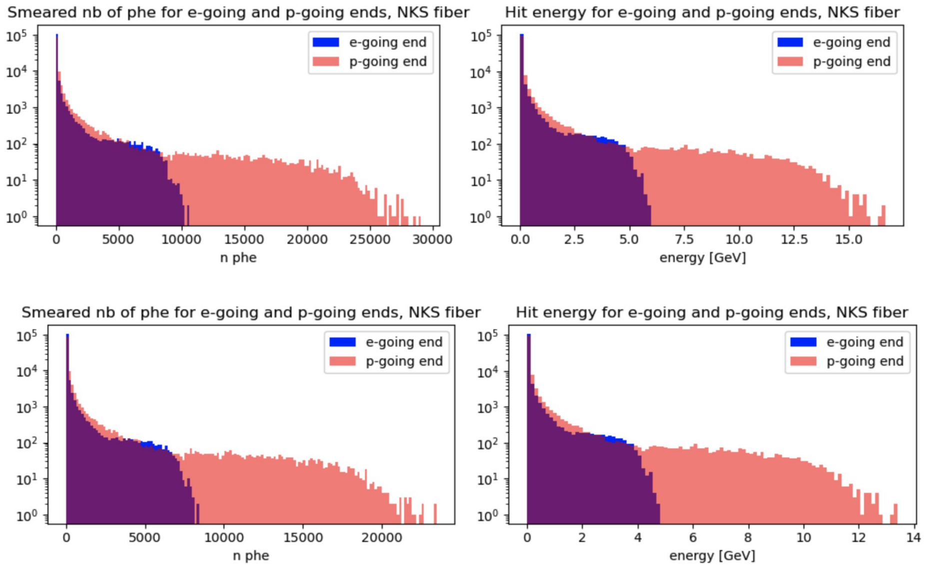


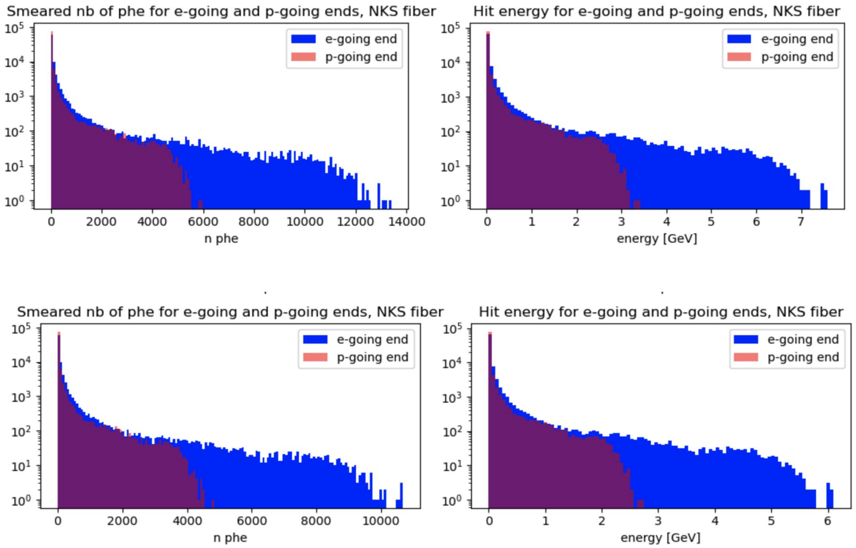
10 GeV photons at η ~ -1.7
fsam tuned to this sample

~6000 phe

Max Number of Photoelectrons

Full simulations





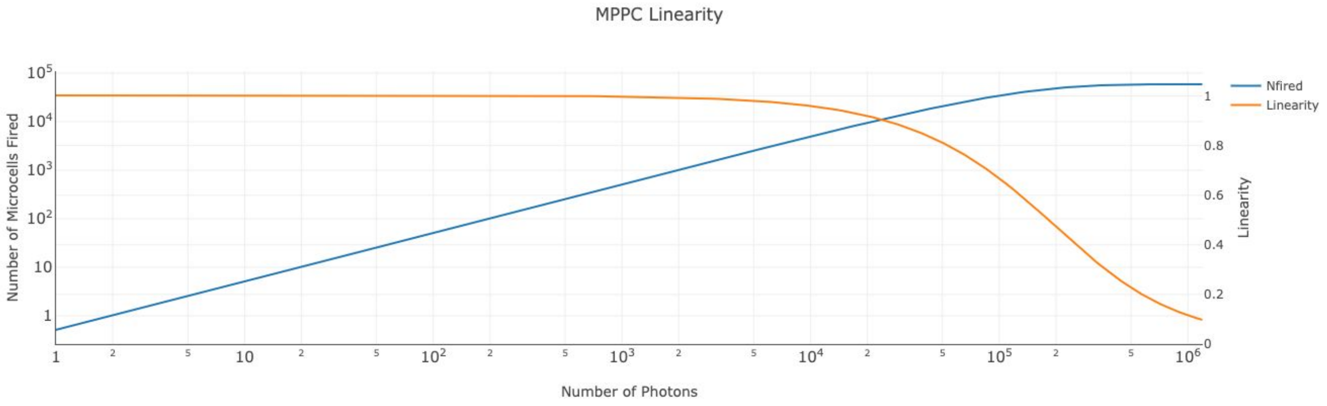
50 GeV electrons at η ~ 1.4

- **top: fsam tuned to 5 GeV e^- at η = 0**
- **bottom: fsam tuned to this sample**

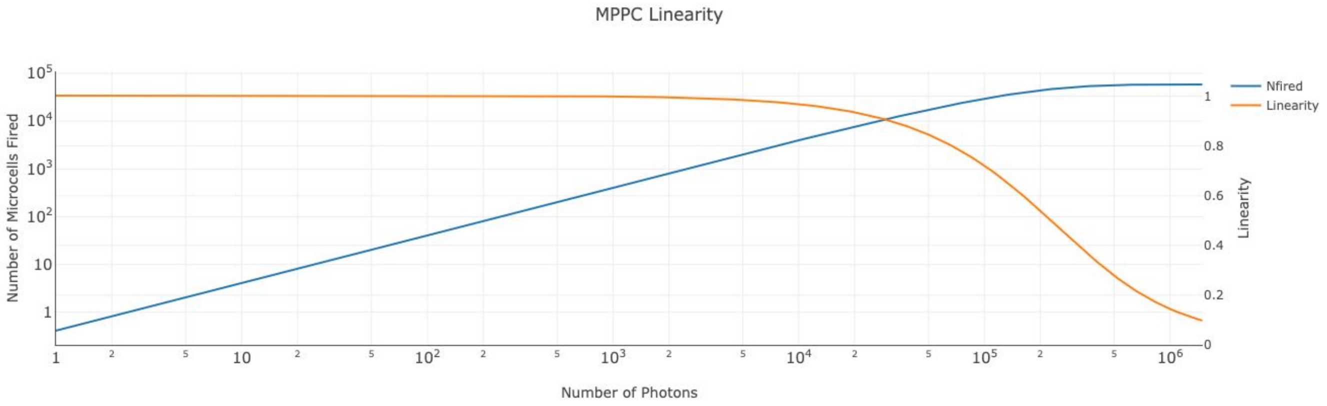
19 GeV electrons at η ~ -1.7

- **top: fsam tuned to 5 GeV e^- at η = 0**
- **bottom: fsam tuned to this sample**

Nonlinearity



50% PDE folded in (S14 Family)



40% PDE folded in (S13 Family)

Pixel Size and Number of Pixels

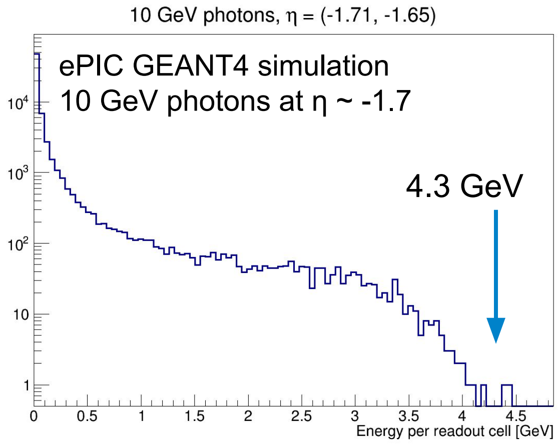
FDR simulations

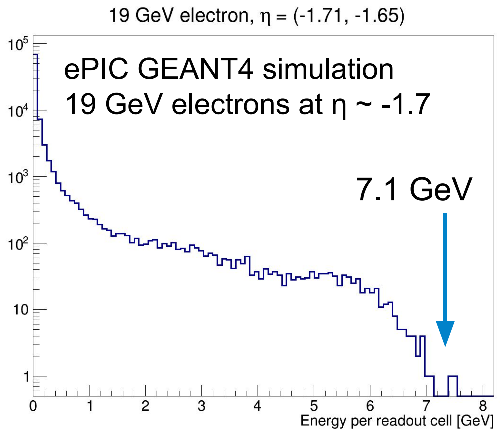
Defined by photoelectron statistics and energy range to be measured

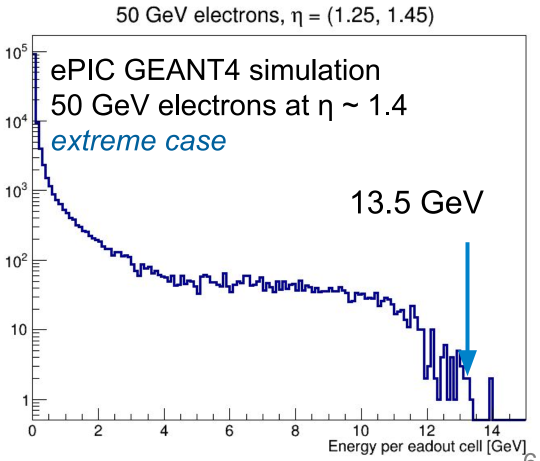
Energy measurement ranges in BECal:

- *Shall provide photon measurements up to 10 GeV* (F-DET-ECAL-BAR.2) *and down to 100 MeV* (F-DET-ECAL.9)
- *Shall provide electron ID up to 50 GeV and down to 1 GeV and below* (F-DET-ECAL-BAR.1)
  - Electron energy measurement needed for e/π separation only (straightforward at high energies)
- Reasonable performance for MIPs needed for calibration and for muon ID

Largest energy deposit occurs for particles at large η (steep angle) where the pathlength in a cell is maximal and the attenuation is minimal.







Photoelectron statistics

From our 2023 Hall D tests using GlueX SiPMs and double-clad Kuraray fibers: **1000 phe/GeV** per side for showers at the center of the Baby BCAL prototype

- Corrected for attenuation: **1077 phe/GeV*** per side

We can scale these results for the **ePIC Barrel ECal*:**

- x 1.5 factor improvement in **SiPM photon detection efficiency**
- x 1.16 factor to account for **better optical coupling**
- x 0.69 reduction accounting for **single-clad** Kuraray fibers

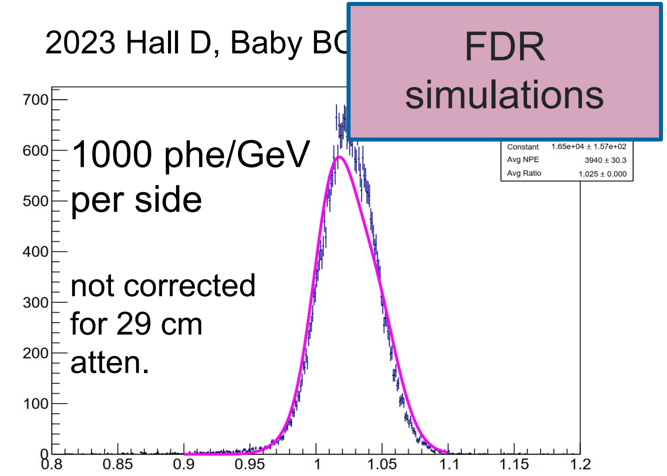
This gives ~ **1239 phe/GeV** per side (fully corrected for attenuation)

- **10 GeV ɣ at η ~ -1.7:** 5560 phe → **9.8 % max SiPM occupancy**
- **19 GeV e^- at η ~ -1.7:** 9181 phe → **16.1 % max SiPM occupancy**
- **50 GeV e^- at η ~ 1.4 (most extreme case):** 17456 phe → **30.1% max SiPM occupancy**

Well below the region where large nonlinearities in the SiPM response are expected in almost all cases.

Small non-linear effects possible for some ultra-high energy electrons, which is acceptable (e-π separation straightforward).

* See backup slide for the attenuation length measurement and extraction of those factors



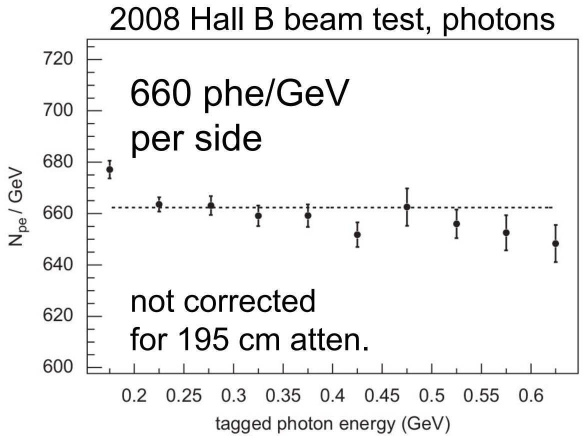


Fig. 16. The number of photoelectrons per GeV per end of the BCAL module is shown as a function of energy. A one parameter fit is plotted (dashed line). For more details see the text.

Layer Configuration

AstroPix Layer Placement

Layer Placement (1-3-4-6): General Motivation

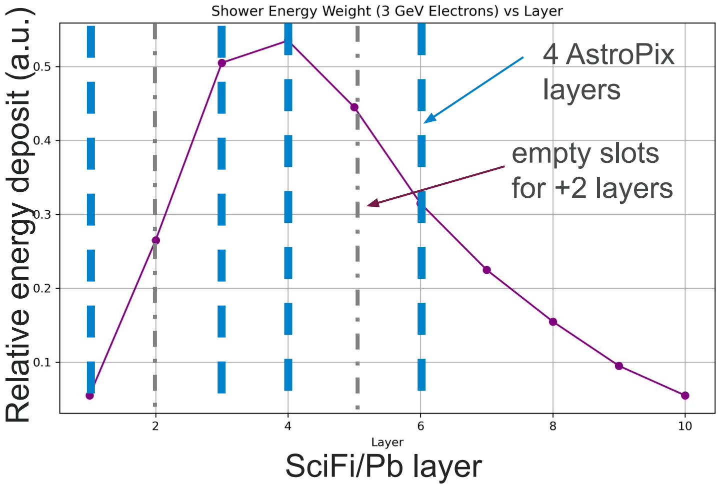
6 imaging layers separated by $1.45X_0$ at η = 0 of Pb/ScFi

All layers important for the e/π separation for mid energy particles <5 GeV and overall sampling of shower energy for SciFi/Pb close shower energy splitting

Front layers important for γ/π^0 separation and position resolution

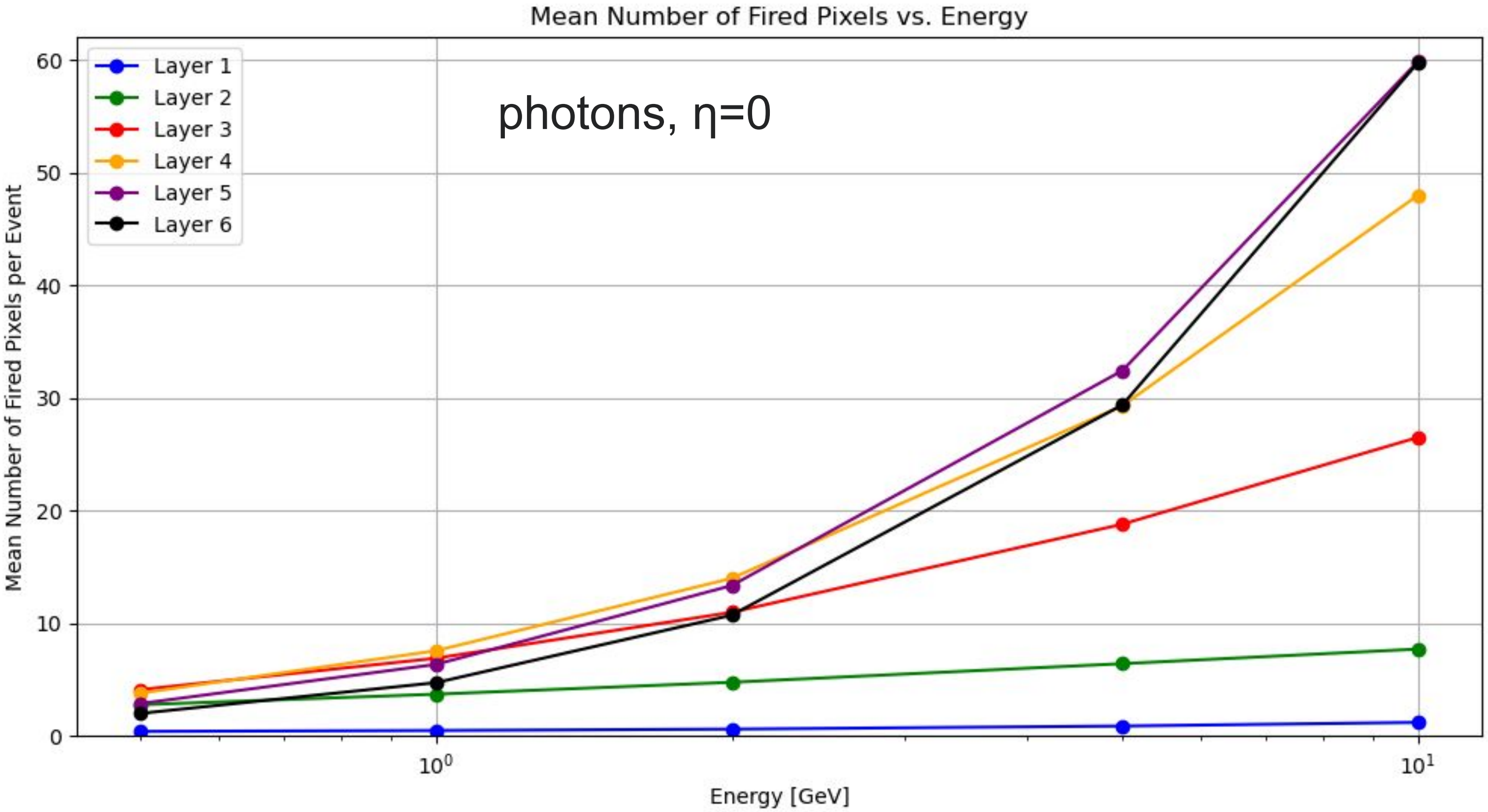
- 1st layer in front of the calorimeter: effectively a tracking layer for charged particles to support DIRC PID - very little "calorimetric" performance
- 1 pre-shower slot empty (impact on γ/π^0 separation and position resolution)
- 2 layers around shower max (sample much total of shower for energy reconstruction and shower separation and e/π separation)
- 1 post-shower slot empty (important sampling overall shower energy, e/π)
- 1 layer in tail (deeper in the tail for larger η to catch e/π separation and still sample important part of shower energy)

3 GeV electron shower profile at η = 0



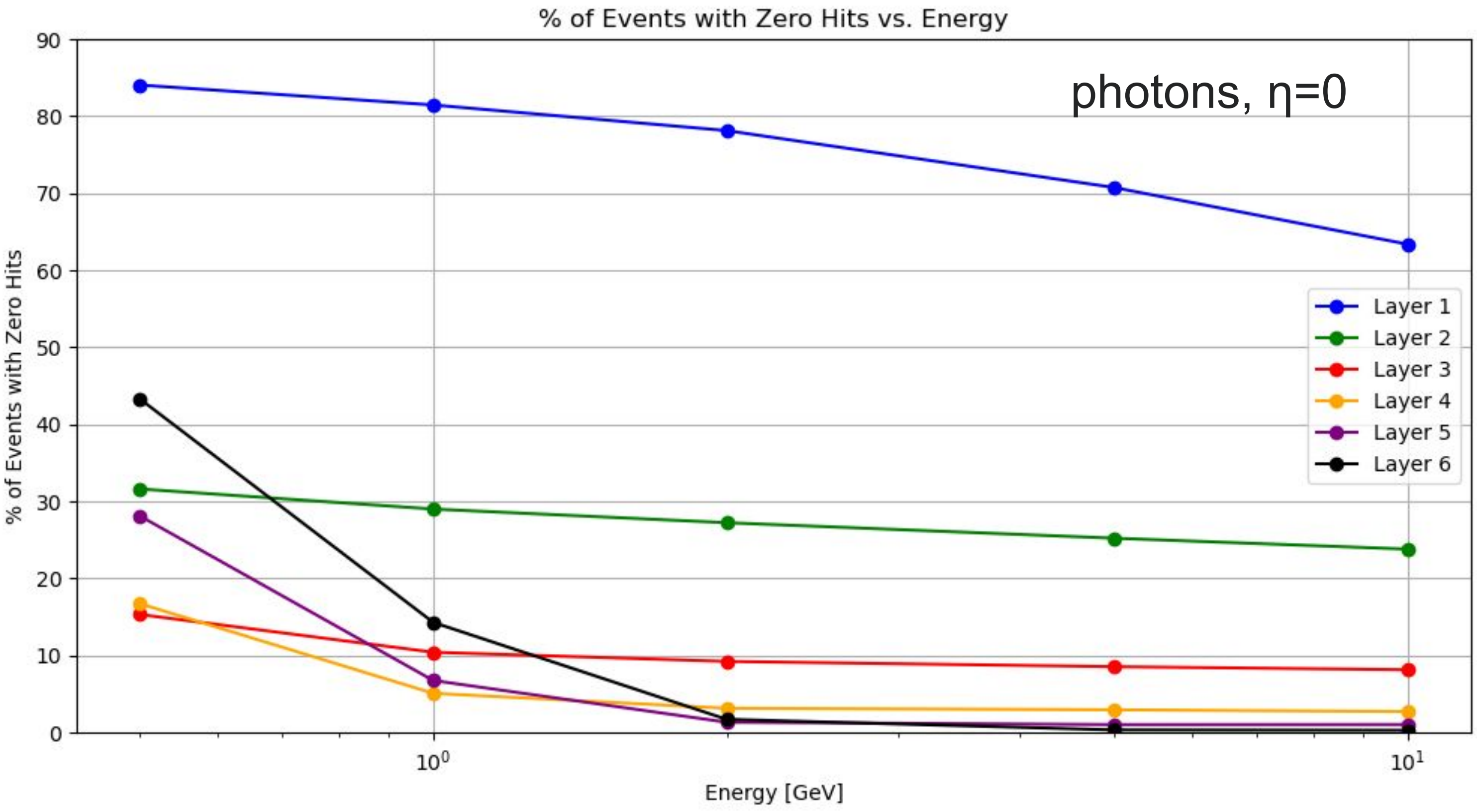
Optimized for preserving e/π separation for mid energy particles and max shower sampling for effective 3 calorimetric layers only

Mean hit multiplicity per AstroPix Layer vs Energy



Note that mean includes the cases when there is no hits at all

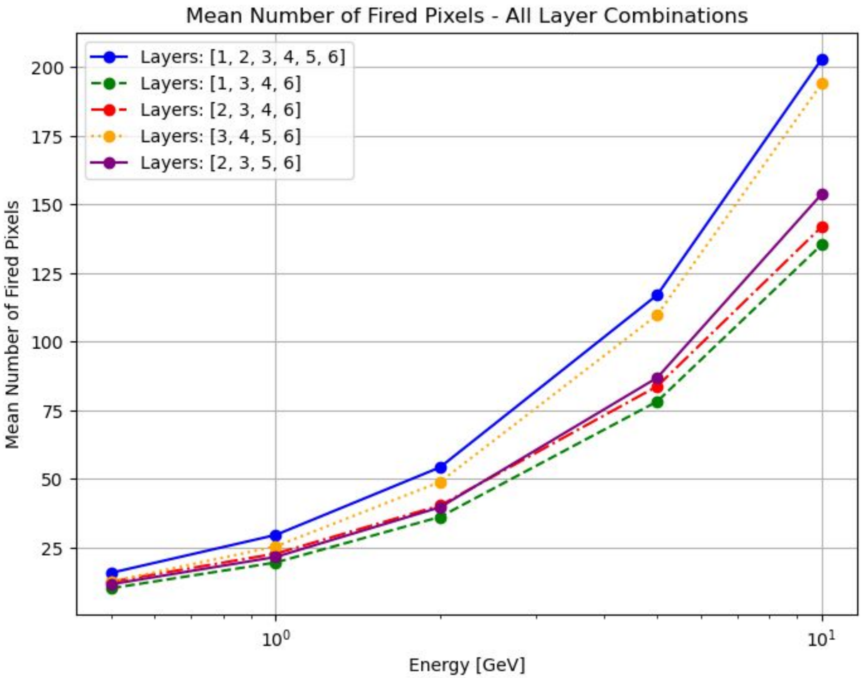
% of events with zero hits in the layers

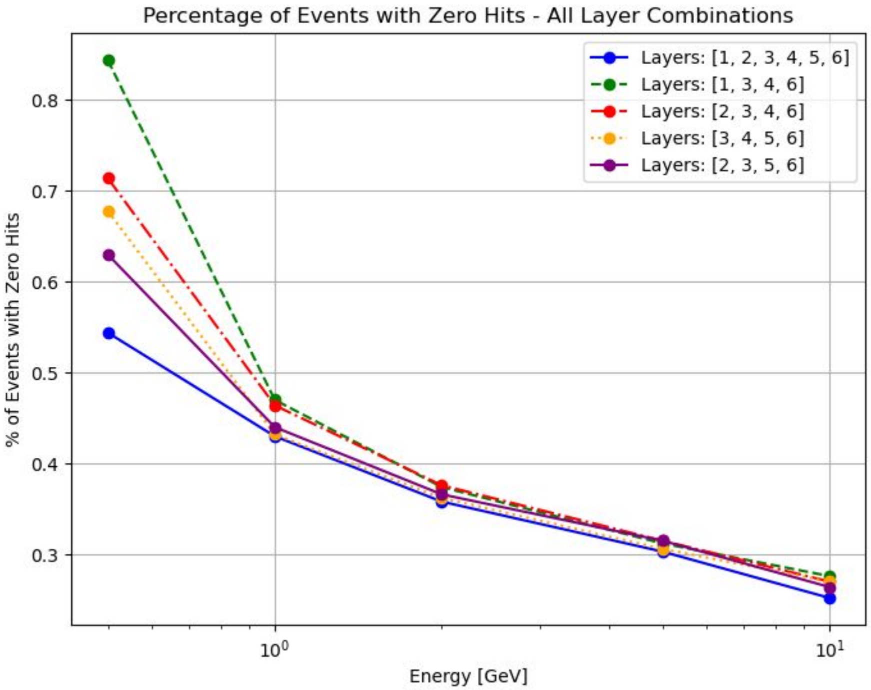


See backup for example distributions of nb of hits per layer

Mean hit multiplicity and % of zero hits in all AstroPix layers

Different layer configurations

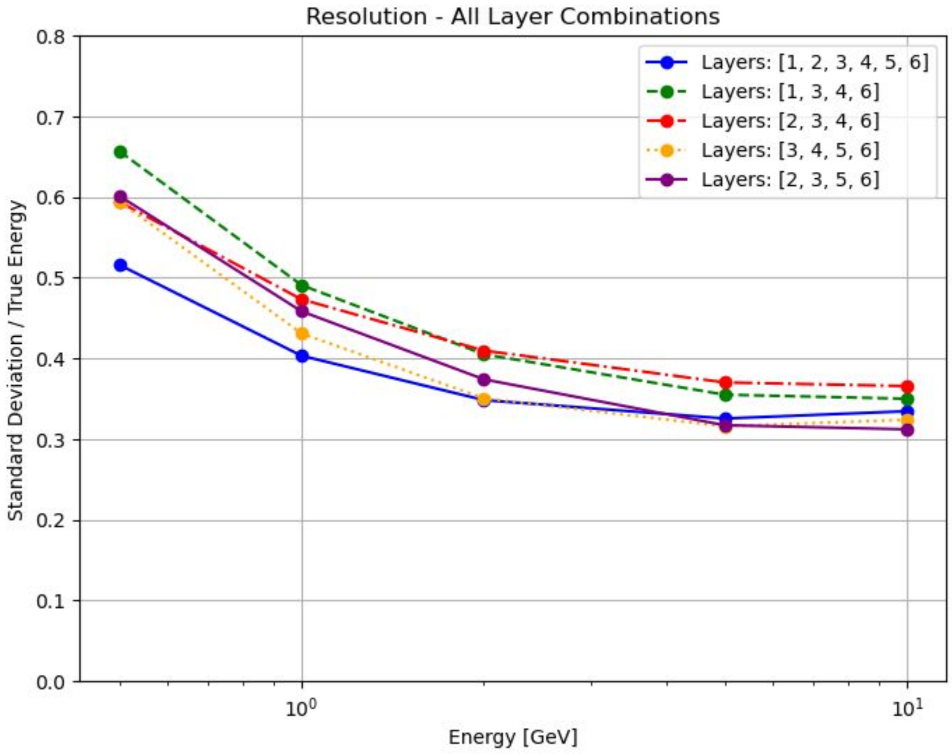




Note that this is for photons at η=0, different η will differ

Energy Resolution

Different layer configurations



Plot show Standard Deviation of energy deposit in AstroPix layers

Photons, η=0: for low energy response at this rapidity, 3-4-5-6, 2-3-5-6, 2-3-4-6 look preferable

For high energy, overall energy reconstruction affected by longitudinal shower (and it's shower max) fluctuations.

Extreme example for η=0, at larger η, more confinement