Beam Background effects on the EEEMCal

TIC meeting

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12th April 2026

Overview

TC-office asks to investigate impact of beam backgrounds on subsystem performance

Slides from TIC meeting, 23-2-2026

Make use of what is at hand, namely the Feb. 2026 simulation campaign (10 x 100) and related simulation background (probably optimistic concerning beam-gas rates as vacuum after 10000 A-h of running is assumed)

- Events with background (10μm gold coating on the beampipe):
  /volatile/eic/EPIC/RECO/26.02.0/epic_craterlake/Bkg_Exact1S_2us/GoldCt/10um/DIS/NC/10x100/minQ2=1/
- *Events without background*:
  /volatile/eic/EPIC/RECO/26.02.0/epic_craterlake/DIS/NC/10x100/minQ2=1/

DIS Samples:
10 GeV e^+ x 100 GeV p

- **Obtain subsystem performance**(*) from DIS + the background
- **Compare the performance** with / without background

Suggested observables

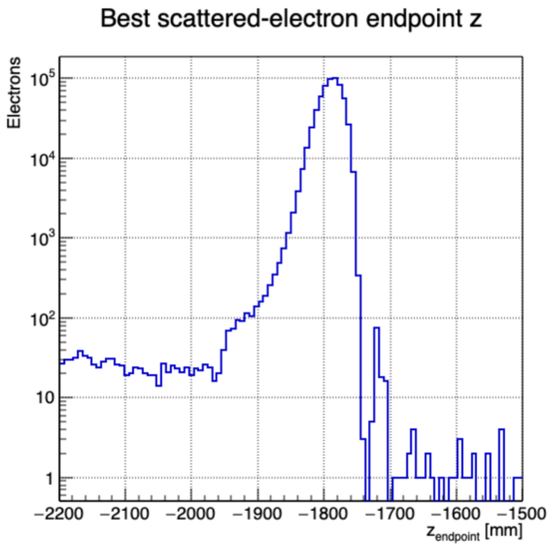
ECals

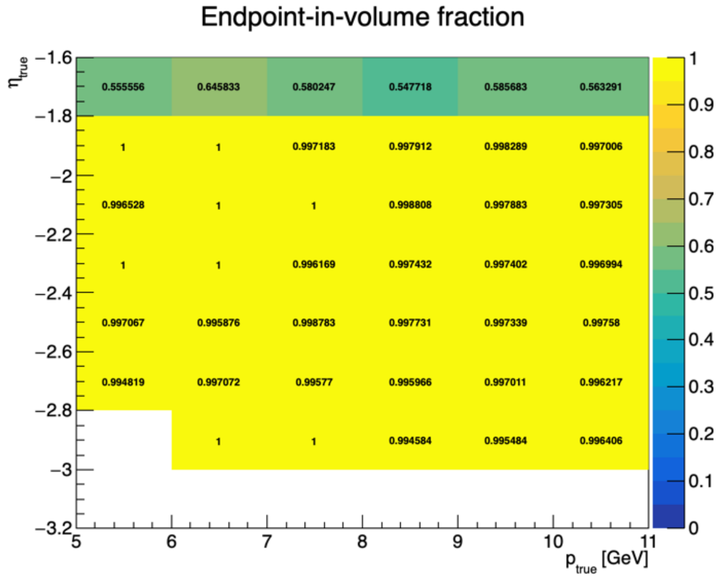
E-resolution (CD: vs p)
efficiency (CD: vs η, p)
π/e separation (CD only: vs p)
angular resolution (CD only)

Object selection: Truth scattered electron

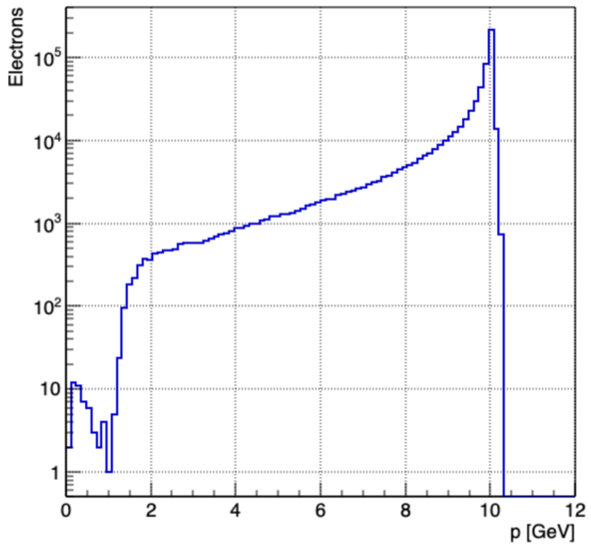
Tagged *e* selection available via `MCScatteredElectrons` collection
In 10% events two tagged e^-s, typically forward soft & backward hard
In this case, e^- with most negative p_z is chosen

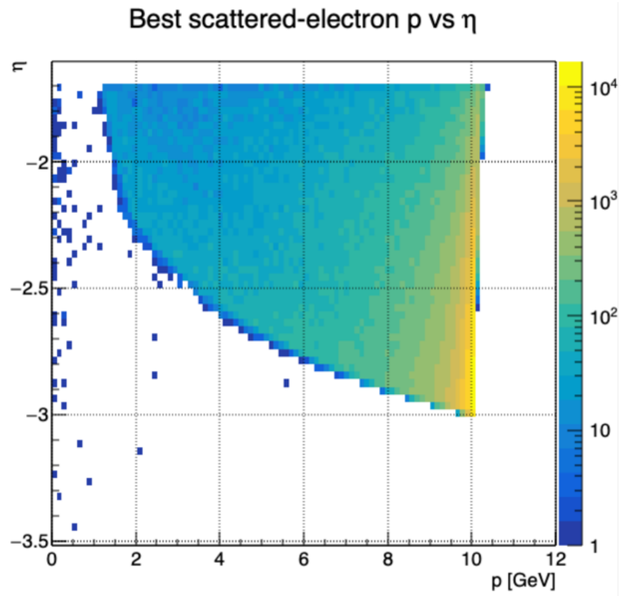
EEEMCal visible for scattered e^-s
stopping around -1950 < z_{end} < -1700





Scattered e^-s highly
peaked at beam energy



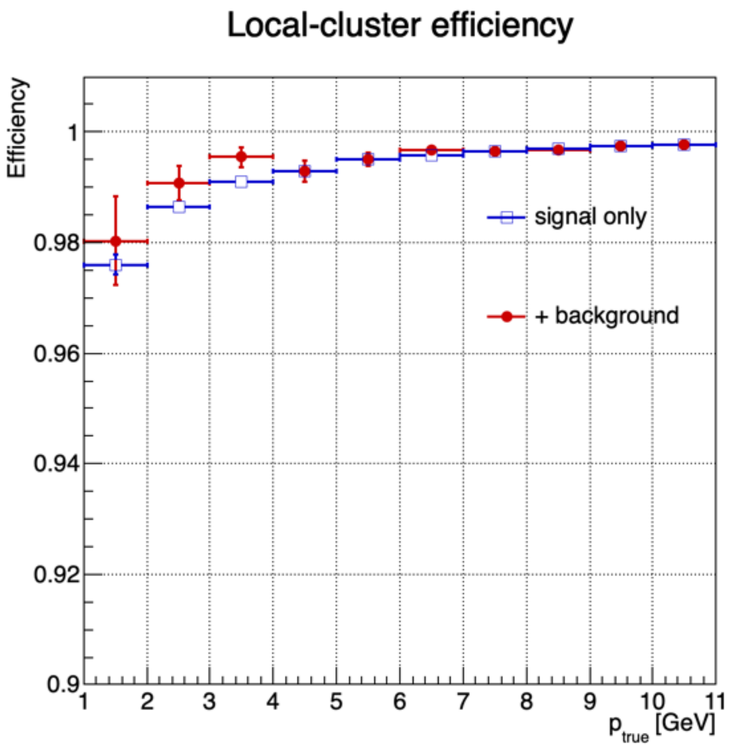


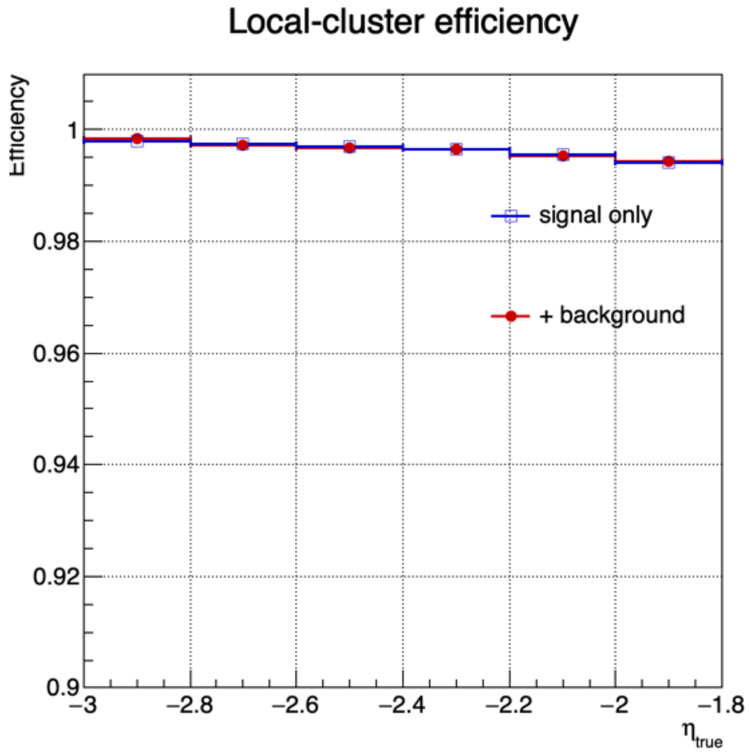
For this study use -3 < η < -1.8,
where ≈ 100% of e^-s stop in
EEEMCal & e^- shower is contained

No scattered e^-s with η < -3

Reconstructed electron selection & efficiency

- For each scattered e^- with -3 < η < -1.8, and having its endpoint in the calorimeter,
- I look for the local maximum in a 2x2 square crystal window around e^- endpoint
- Energy is reconstructed in a 5x5 window centered on the local maximum
- I consider the e^- reconstructed if matched E_{5x5} > 0.8 GeV





Cluster Position

Position of a 5x5 cluster built around seed determined with log weighting

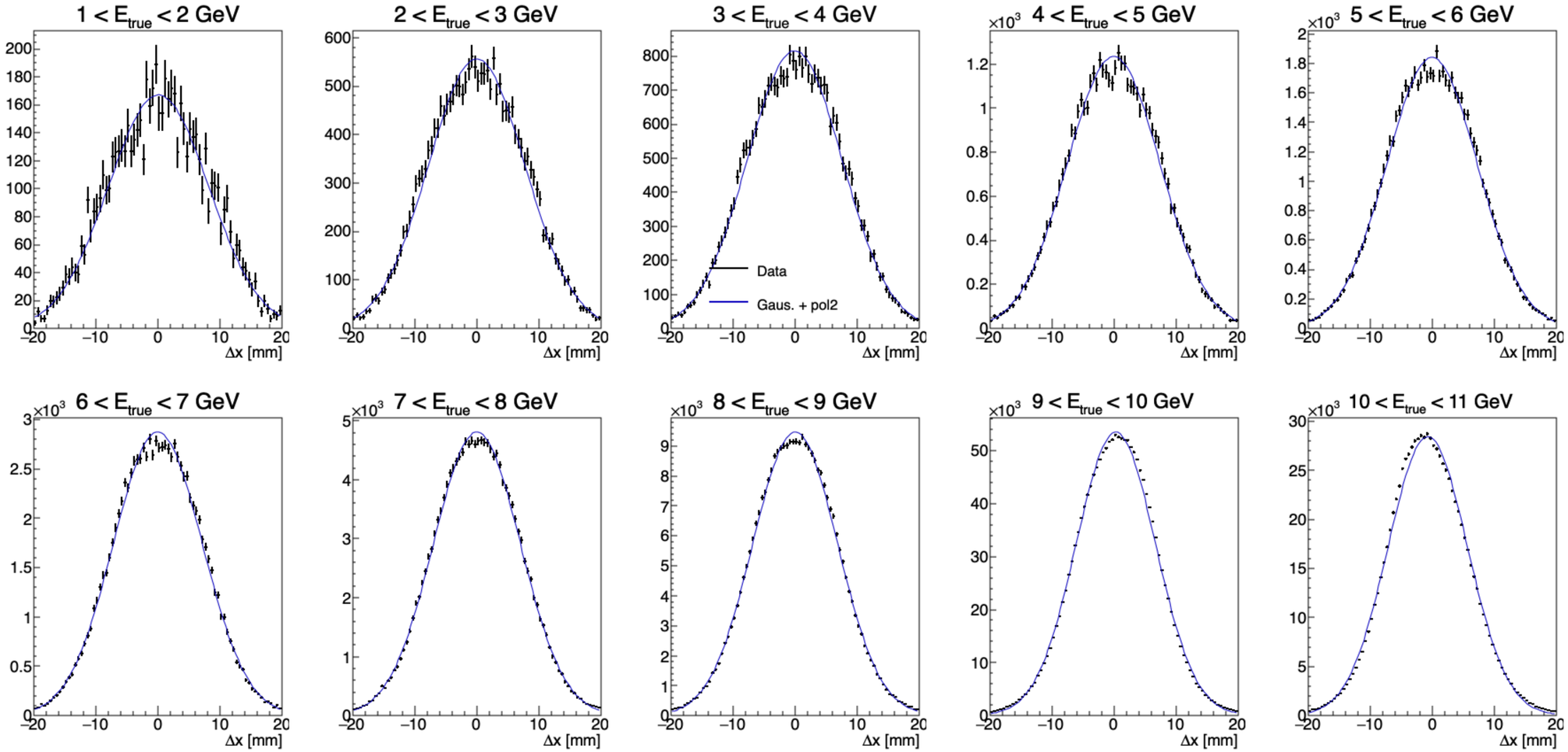
$$x_{\text{cluster}} = \frac{\sum_i w_i x_i}{\sum_i w_i} \qquad w_i = \max\left(0,\, w_0 + \ln \frac{E_i}{E_{\text{cluster}}}\right)$$

A rather typical value was chosen for weighting constant: $w_0 = 4$

The residual is defined w.r.t. the scattered *e* endpoint

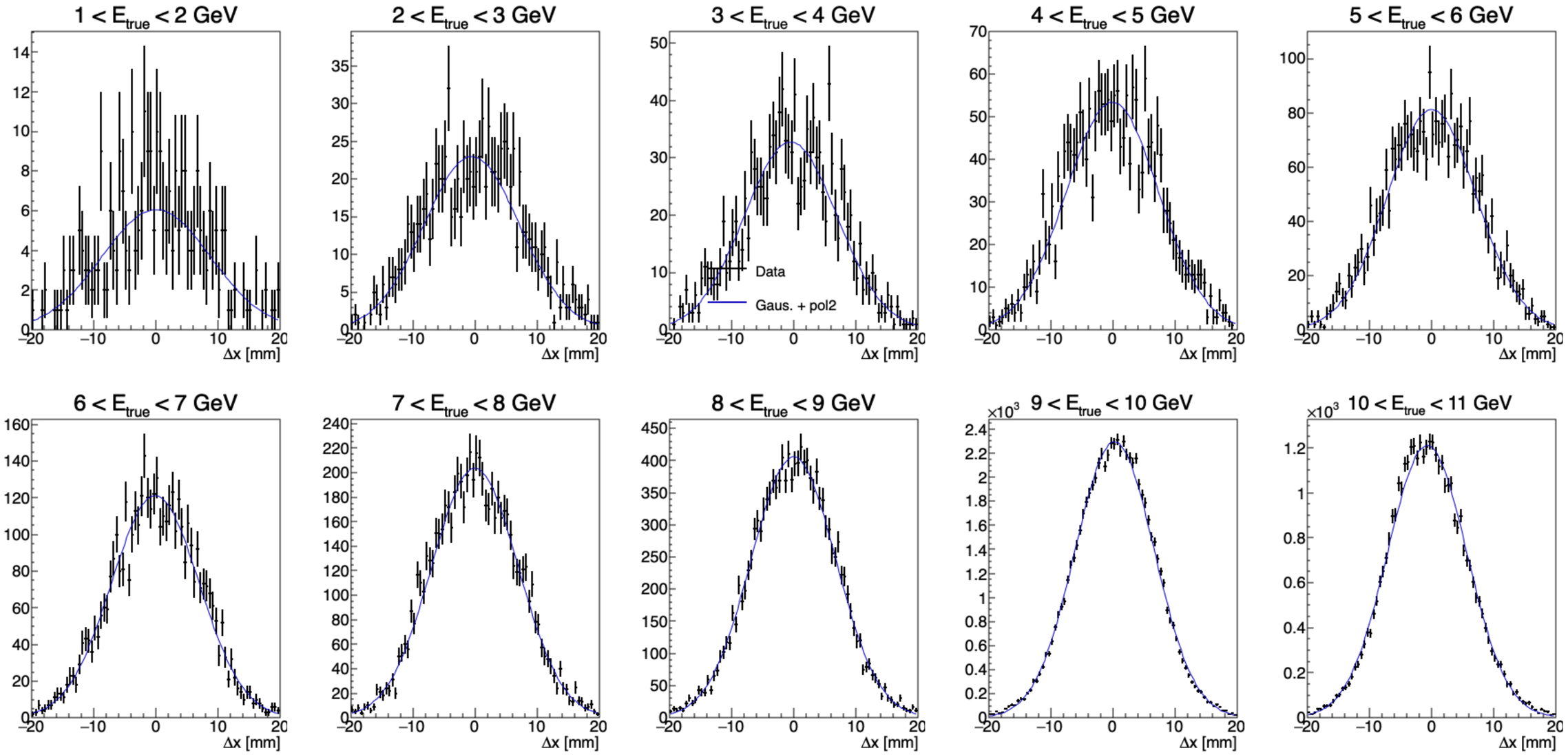
$$\Delta x = x_{\text{cluster}} - x_{\text{truth}}$$

Position residuals: signal only

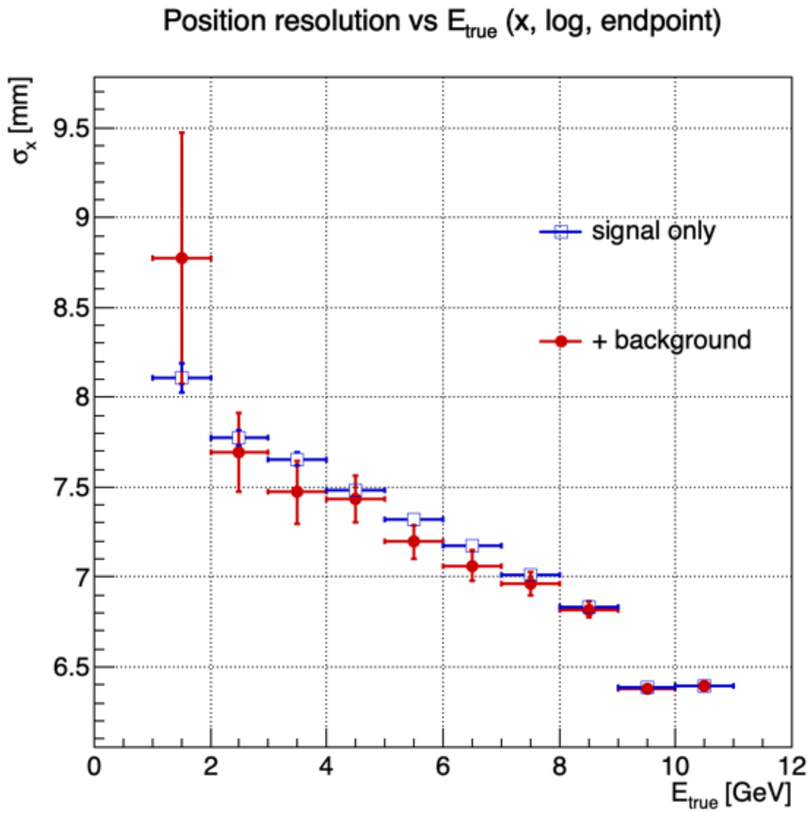


- Instead of using truth clusters I evaluate residual w.r.t. the scattered e^- endpoint
- This definition gives some intrinsic smearing w.r.t. the shower maximum

Position residuals: + background

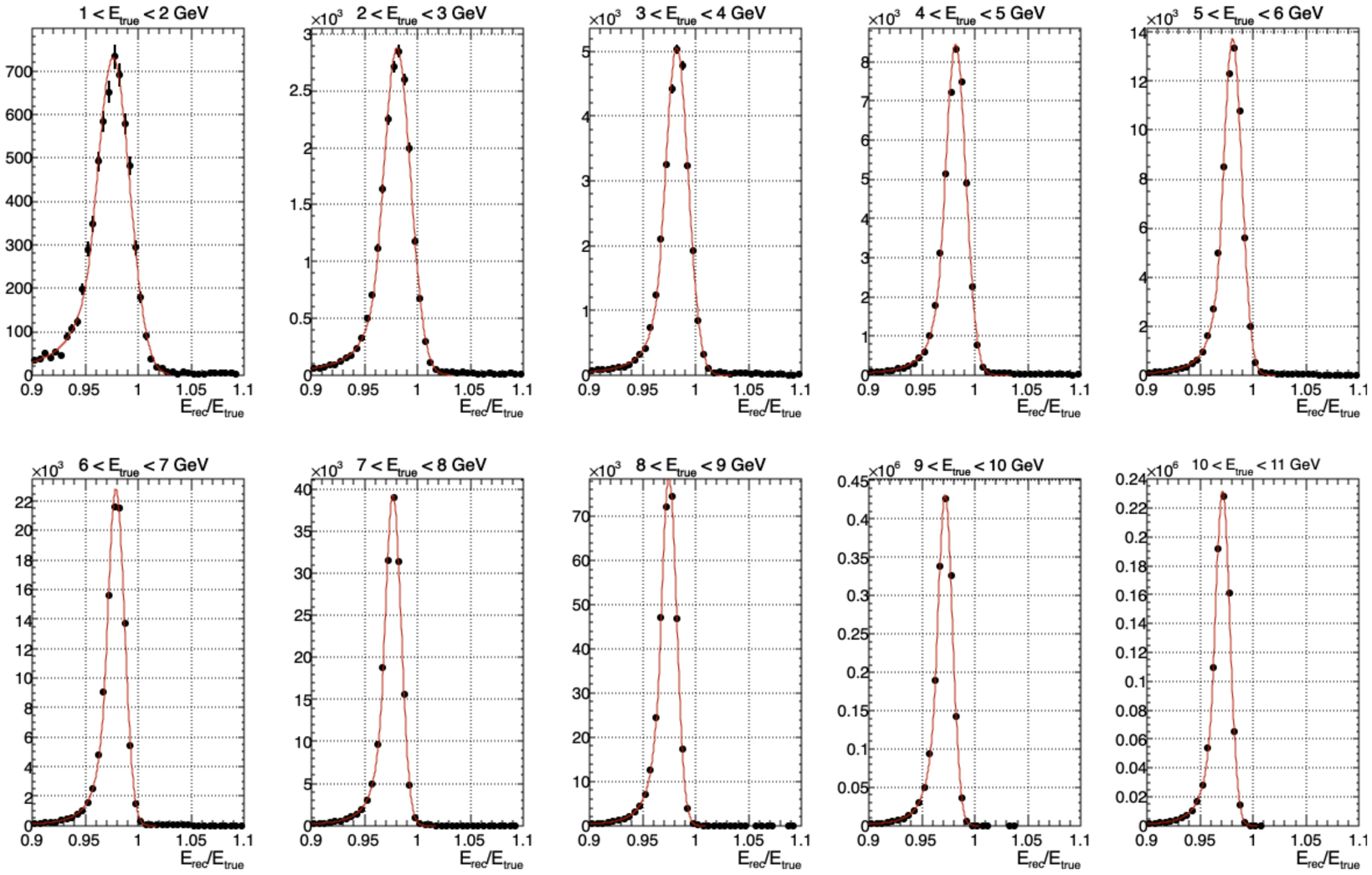


Position resolution from scattered e^- endpoint



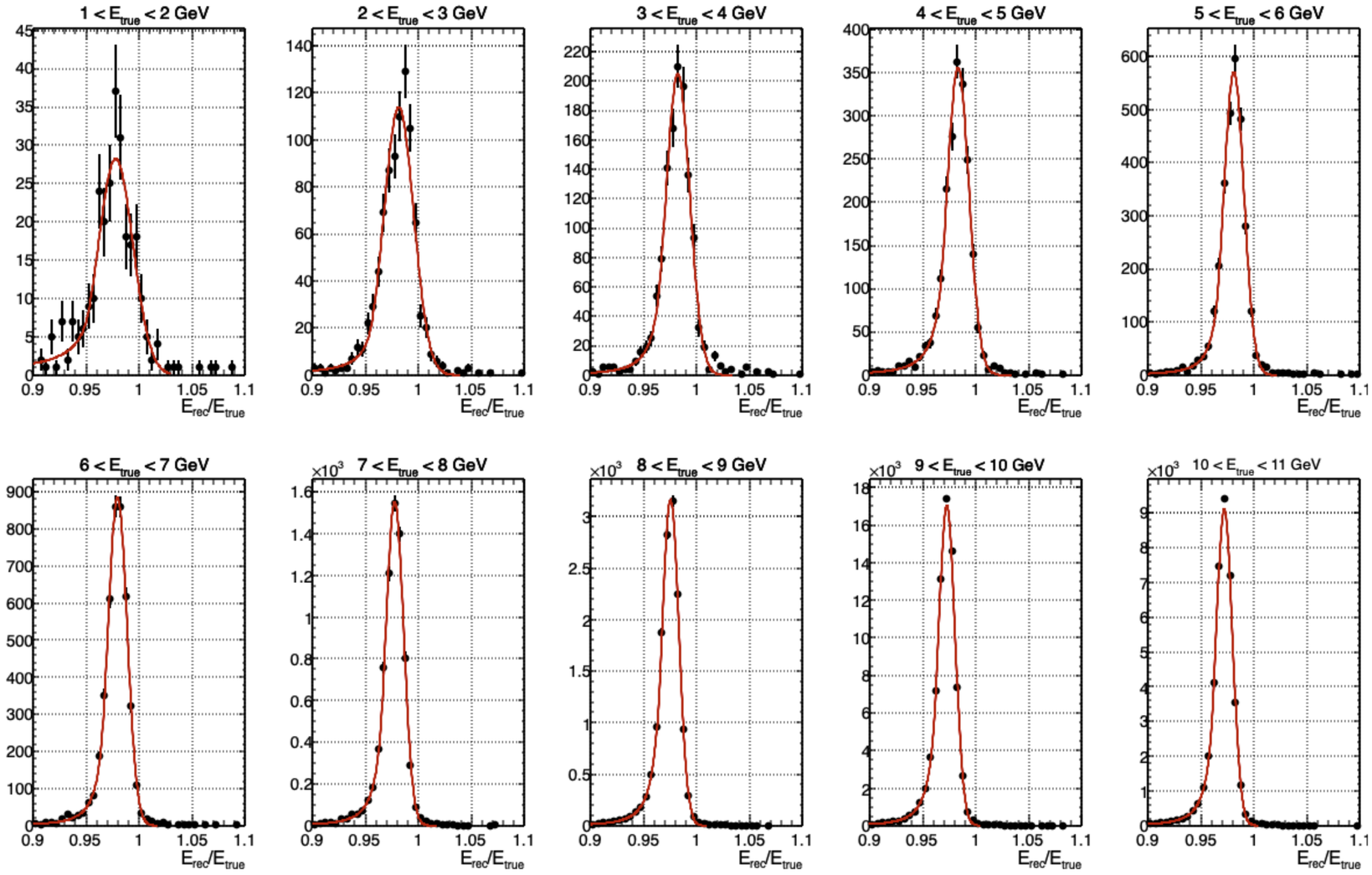
- Beam background has no effect on position resolution, *within precision of current test*
- For a more standard definition of position resolution using truth clusters, see backup

Energy residuals: signal only



Fit model: Single-sided Crystal Ball

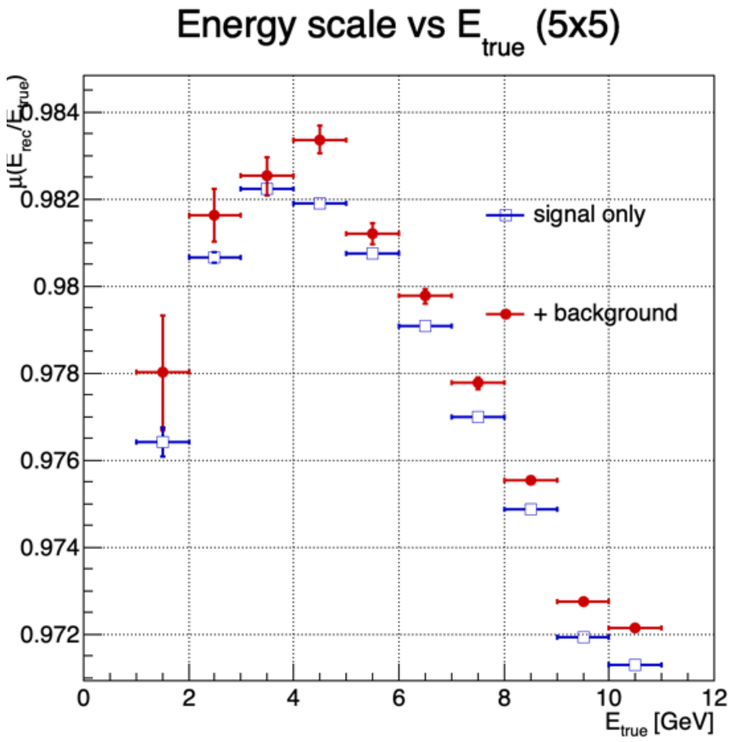
Energy residuals: + background

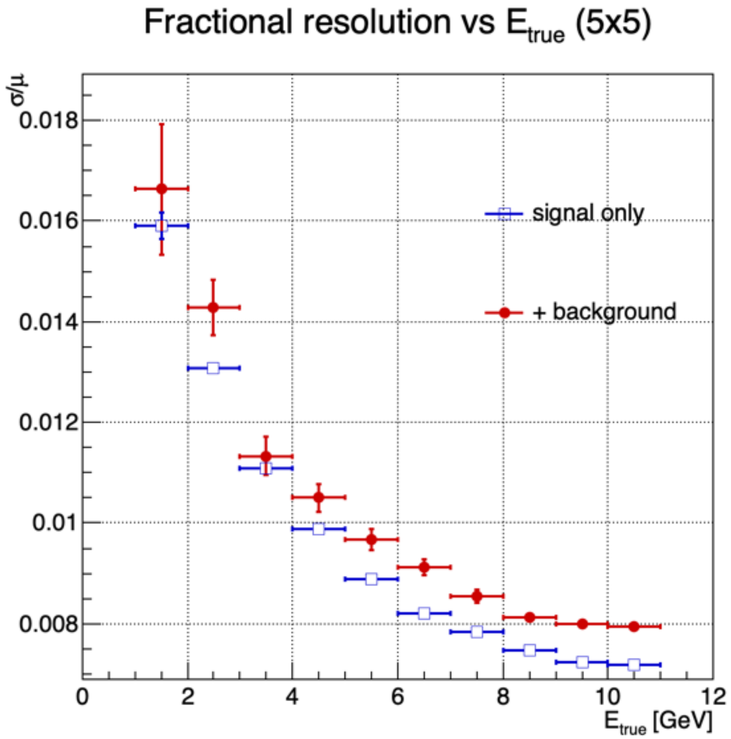


Fit model: Single-sided Crystal Ball

Energy scale & resolution

Tiny increase in energy scale, ≈ 0.1%





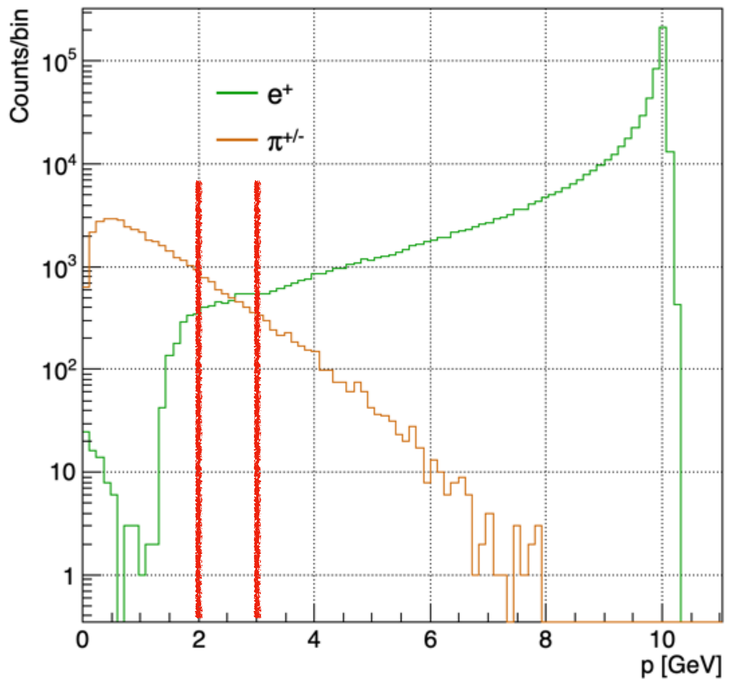
Energy resolution degrades a bit, < 10%

Note: No reconstructed hit thresholds are applied for this study

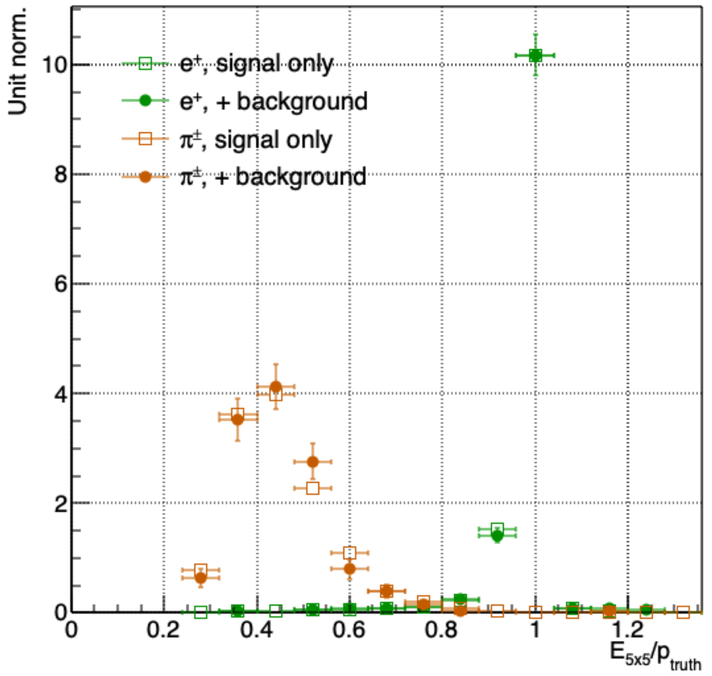
Pion rejection

In DIS events very few pions at large momenta, where the scattered e^- lives

→not optimal for evaluating $\pi^{\pm}$ contamination

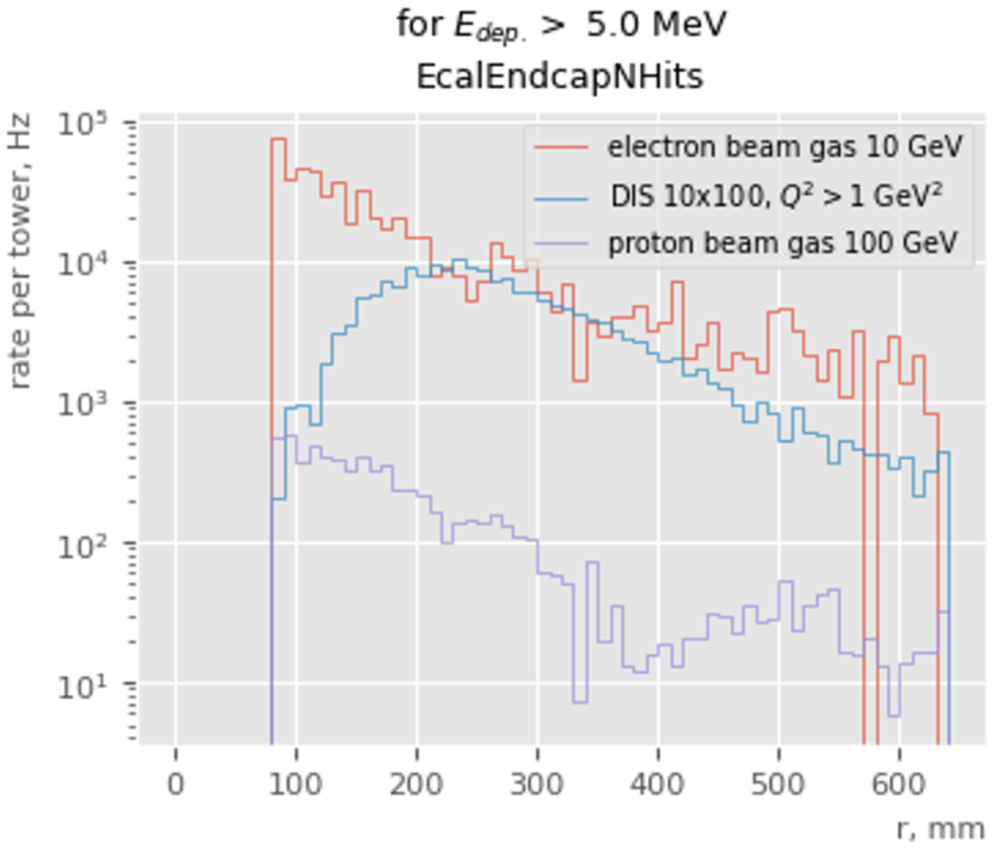


$2 < p_{truth} < 3$ GeV



In the momentum range with best overlap ($2 < p_{truth} < 3$ GeV) no significant change to E/p for either e^- or $\pi^{\pm}$

Background rates



ePIC latest simulation campaign:
EEEMCal benchmark plot

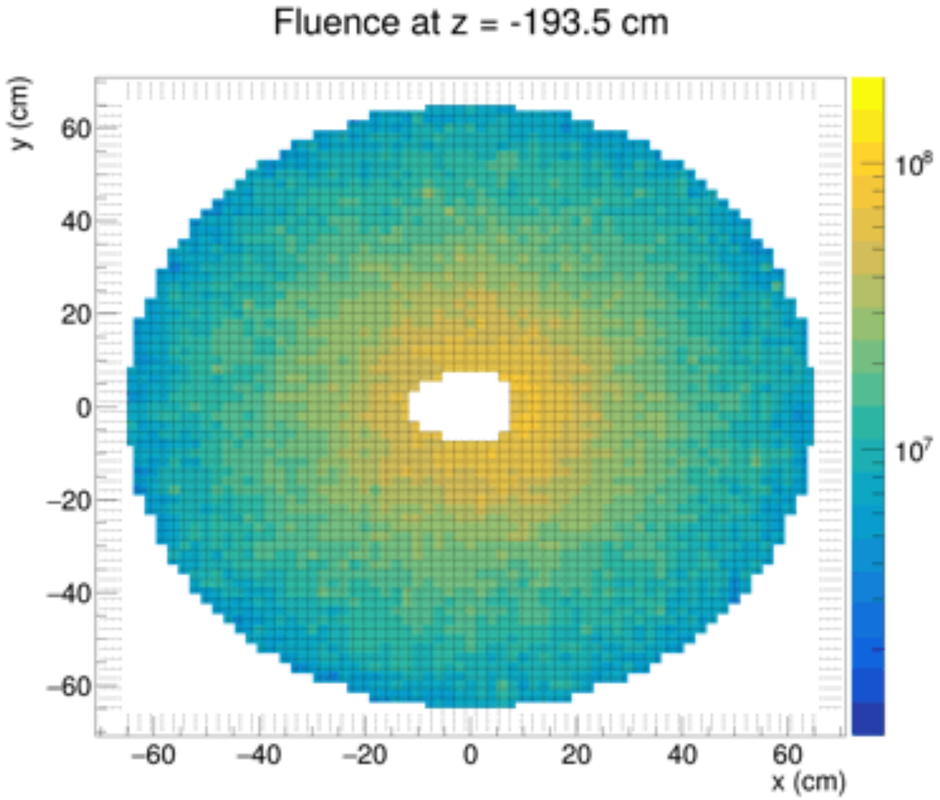
Rates per crystal above 5 MeV
(expected energy threshold)

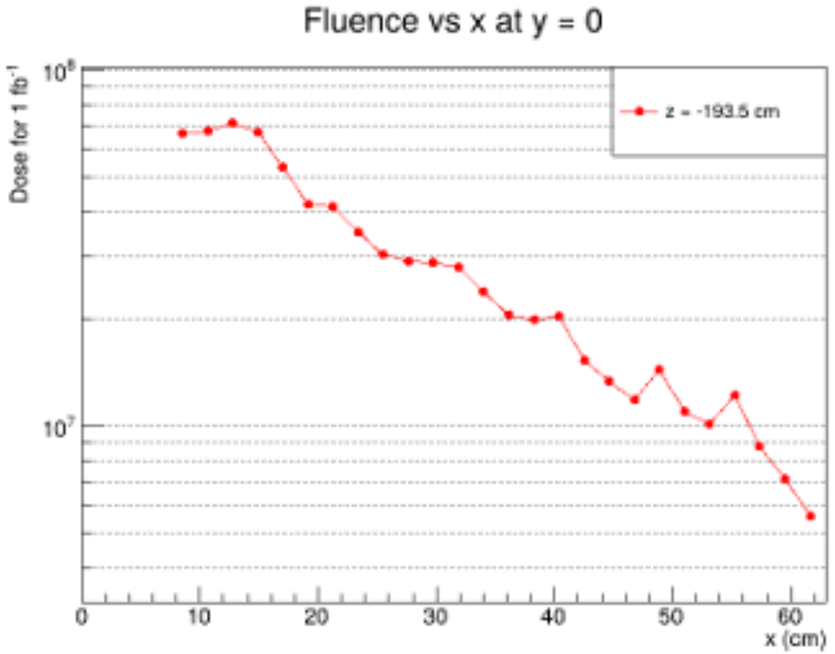
- 10-100 kHz in crystals at high rapidity
  (electron beam gas dominated)
- 1-10 kHz for most of the crystals

EEEMCal rates dominated by background,
but still within DAQ expected capabilities

Radiation dose

- EEEMCal **SiPMs** are located at z = -194 cm
- Plots show neutron fluence for 1 fb^{-1} with latest files at https://wiki.bnl.gov/EPIC/index.php?title=Radiation_Doses





At 150 fb^{-1}: ~ $8 \cdot 10^8$ – $1 \cdot 10^{10}$ depending on the crystal

Source: https://www.dropbox.com/scl/fi/e8ajjxnziye0xtye8zm0f/summed_1_MEQ_protons_and_neutrons_Feb_2026.root?rlkey=s6nckwgl4gqjryrrjel5p72zk&dl=0

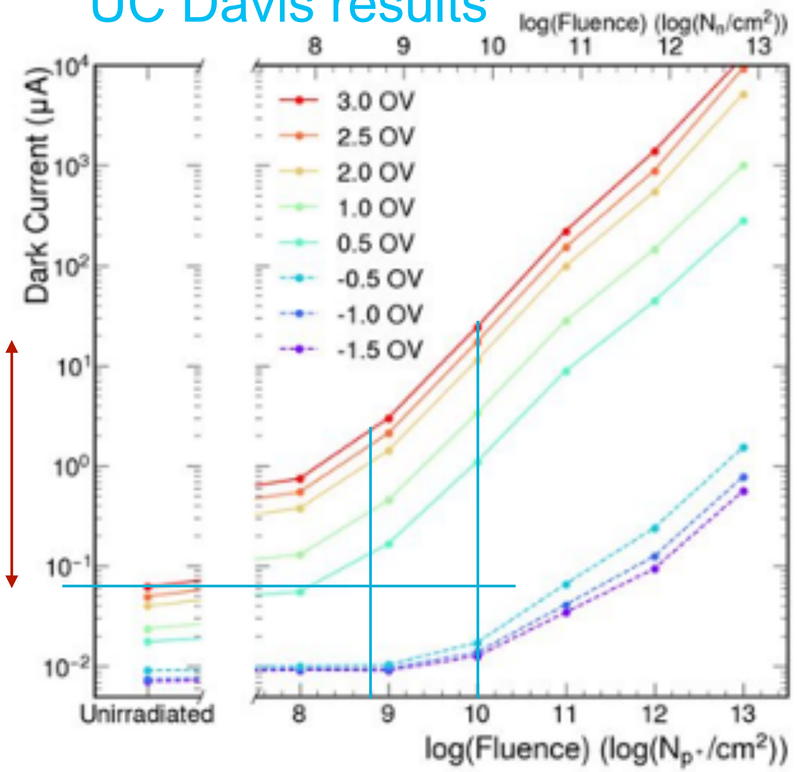
Effects on SiPMs

Expected dark current levels for S14160-3015PS:

1.7 ± 0.4 Mcps (measurement before irradiation, at Vop (Vbr+4V)

~ ×30–300 after irradiation (equivalent to 150 fb^{-1})

UC Davis results



×30–300 at 3.0 OV
(2–20/6.5·10^{-2})

Noise contribution to energy resolution:

- Before irradiation: 1.7 Mcps x 100 ns = 0.17 → Noise : √ 0.17 = 0.41
- After 150 fb-1: 0.41 ×√30–0.41 √300=2–7 pixels (0.28-1 MeV) per SiPM (x4 for 16 SiPM: 1.1–3.9 MeV)

(LY: 7225 pixels/GeV)

Results compatible with the ones reported on June 25 (2025), done at 100 fb^{-1} (instead of 150 fb^{-1} now)

- Noise levels below threshold for most of the channels after 150 fb^{-1}
- Some channels near the beampipe may need higher threshold (or be replaced) before reaching 150 fb^{-1}

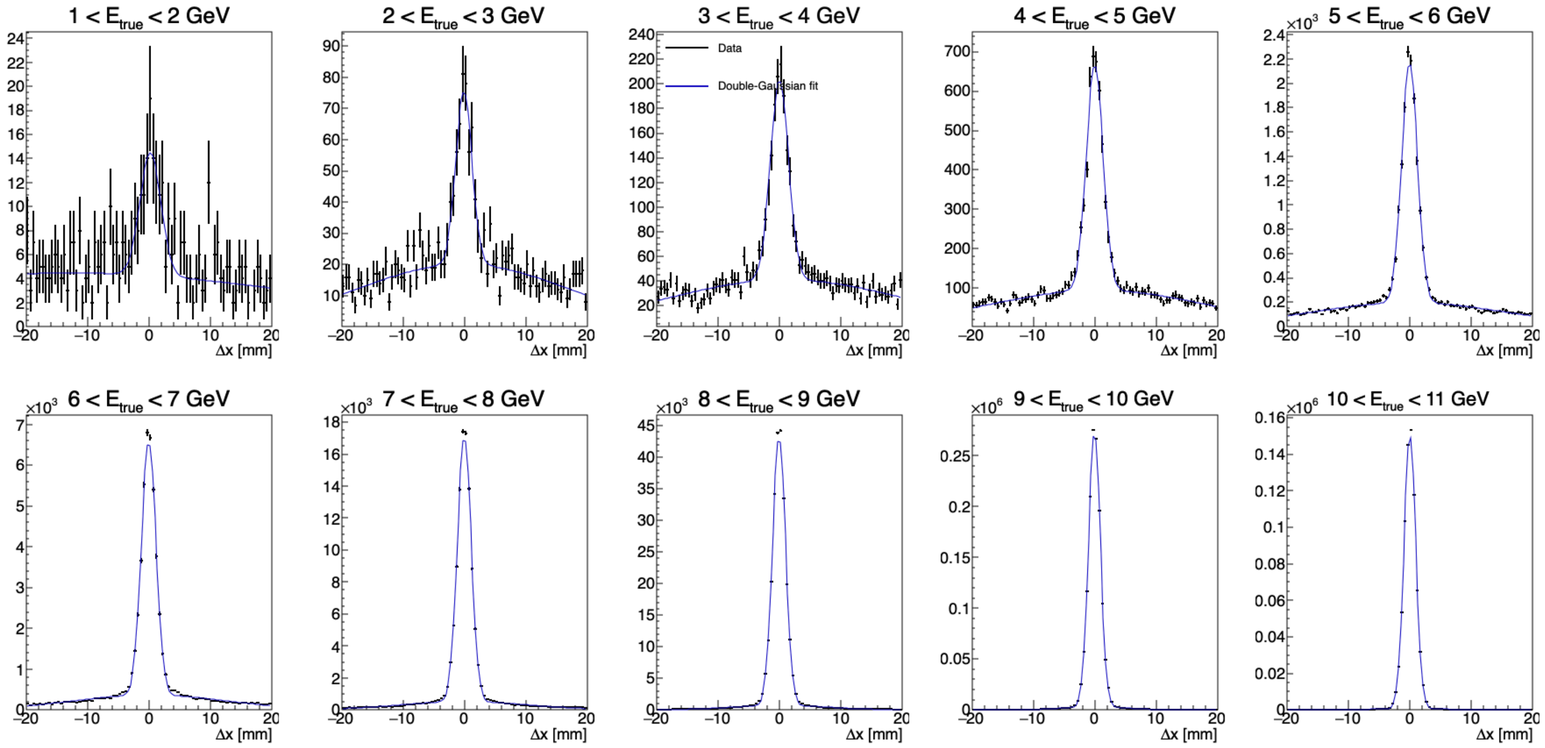
Conclusions

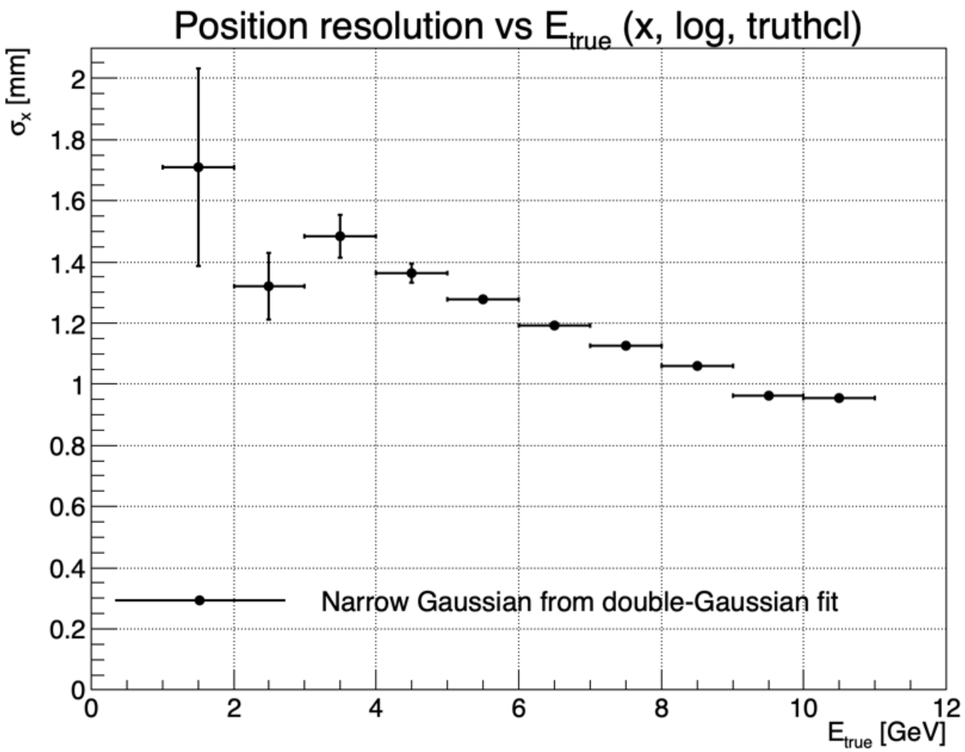
- Effect of beam background from by 10 μm foil on the EEEMCal was studied in DIS MC
  - effects are found to be modest to the extent they could be tested with these samples
- Background rates in simulation are compatible with DAQ limitations
- Neutron fluence was evaluated for 1 /fb of data
- Noise from dark current in SiPMs evaluated to be below expected threshold at 150 /fb

Backup

Position residuals w/ truth clusters: signal only

- Matching of truth cluster to scattered e^+ is provided in input
- I choose the highest energy among matched truth clusters

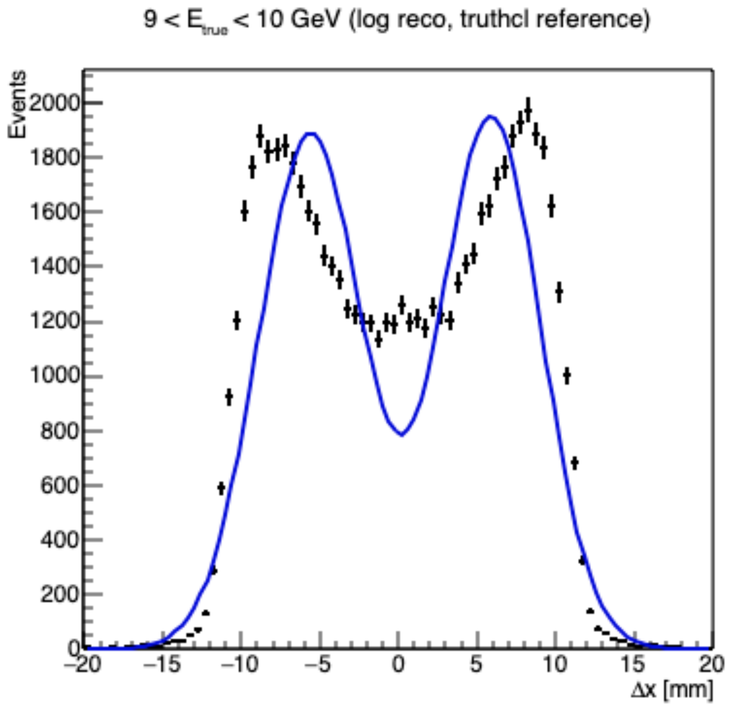




1D position resolution is of order 1mm

Position residuals w/ truth clusters: + background

In samples that include background matching to truth clusters gives a non-sensical result

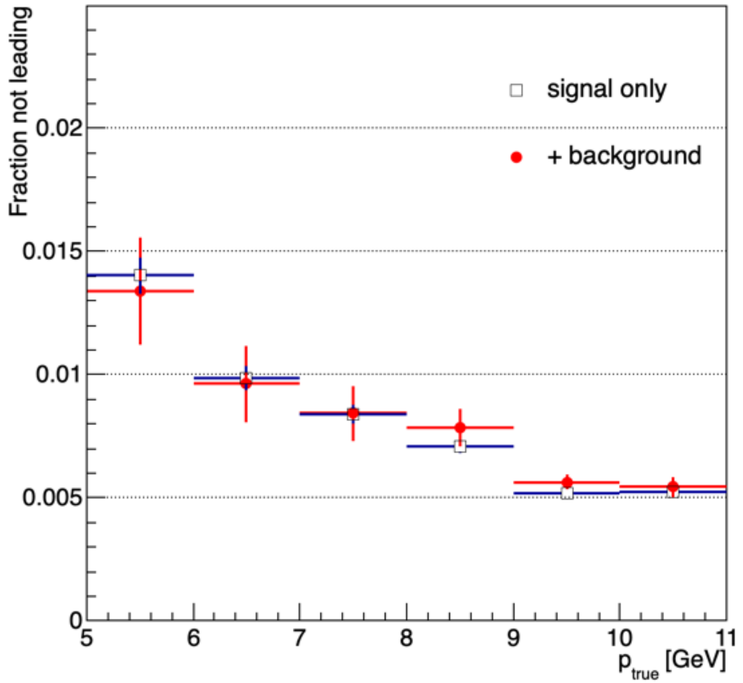


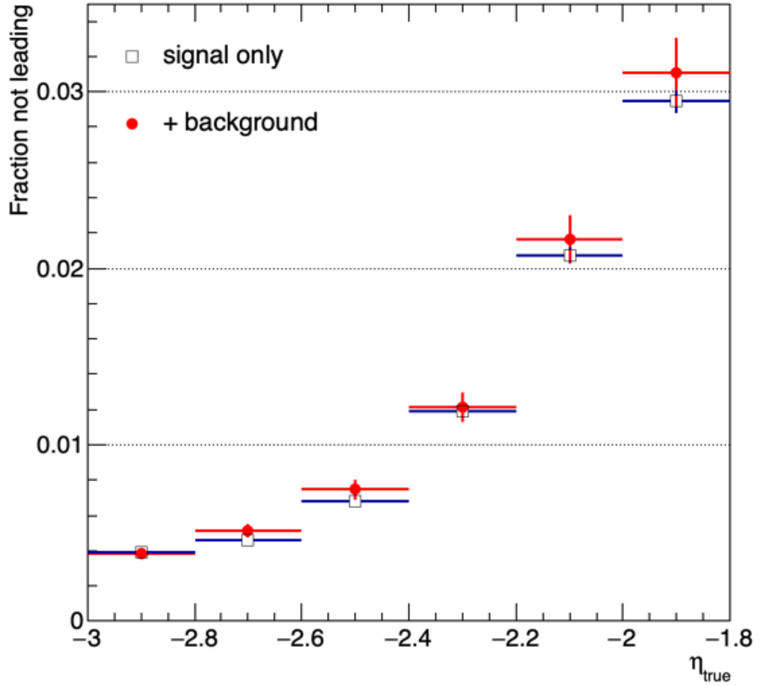

```
============================================================
Event 1  scattered electron idx=7  p=10.0074 GeV  eta=-2.94821
Endpoint = (185.575, 67.7876, -1809.56) mm
Reco max seed idx=7  seed pos=(191.34, 63.78, -1850.13) mm  seed E=4.89934  E5x5=9.76944 GeV
Reco cluster containing seed: idx=0  E=9.86354  pos=(181.749, 67.341, -1850.13)  nhits=33  assoc simID=7

Truth clusters associated to scattered electron (simID == best_idx):
  truthcl 0  E=0.00890096  pos=(148.82, 21.26, n/a)  recID=0  dr_to_seed=60.1324 mm
  truthcl 1  E=0.0101725  pos=(106.3, 42.52, n/a)  recID=1  dr_to_seed=87.6572 mm
  truthcl 2  E=0.00890096  pos=(106.3, 106.3, n/a)  recID=2  dr_to_seed=95.0776 mm
  truthcl 3  E=0.0432332  pos=(148.82, 63.78, n/a)  recID=3  dr_to_seed=42.52 mm
  truthcl 4  E=0.0432332  pos=(212.6, 42.52, n/a)  recID=4  dr_to_seed=30.0662 mm
  truthcl 5  E=0.0813802  pos=(212.6, 85.04, n/a)  recID=5  dr_to_seed=30.0662 mm
  truthcl 6  E=0.125885  pos=(191.34, 42.52, n/a)  recID=6  dr_to_seed=21.26 mm
  truthcl 7  E=4.89934  pos=(191.34, 63.78, n/a)  recID=7  dr_to_seed=3.8147e-06 mm
  truthcl 8  E=3.00598  pos=(170.08, 63.78, n/a)  recID=8  dr_to_seed=21.26 mm
  truthcl 9  E=0.492096  pos=(191.34, 85.04, n/a)  recID=9  dr_to_seed=21.26 mm
  truthcl 11  E=0.0254313  pos=(191.34, 21.26, n/a)  recID=10  dr_to_seed=42.52 mm
  truthcl 12  E=0.0165304  pos=(148.82, 42.52, n/a)  recID=11  dr_to_seed=47.5388 mm
  truthcl 13  E=0.0139872  pos=(212.6, 21.26, n/a)  recID=12  dr_to_seed=47.5388 mm
  truthcl 14  E=0.0228882  pos=(233.86, 85.04, n/a)  recID=13  dr_to_seed=47.5388 mm
  truthcl 16  E=0.0190735  pos=(170.08, 21.26, n/a)  recID=14  dr_to_seed=47.5388 mm
  truthcl 17  E=0.0114441  pos=(191.34, 127.56, n/a)  recID=15  dr_to_seed=63.78 mm
  truthcl 20  E=0.0127157  pos=(148.82, 127.56, n/a)  recID=16  dr_to_seed=76.654 mm
  truthcl 22  E=0.0114441  pos=(170.08, 127.56, n/a)  recID=17  dr_to_seed=67.23 mm
  truthcl 23  E=0.190735  pos=(212.6, 63.78, n/a)  recID=18  dr_to_seed=21.26 mm
  truthcl 24  E=0.0305176  pos=(148.82, 106.3, n/a)  recID=19  dr_to_seed=60.1324 mm
  truthcl 26  E=0.0228882  pos=(233.86, 42.52, n/a)  recID=20  dr_to_seed=47.5388 mm
  truthcl 28  E=0.0254313  pos=(127.56, 63.78, n/a)  recID=21  dr_to_seed=63.78 mm
  truthcl 31  E=0.0330607  pos=(212.6, 106.3, n/a)  recID=22  dr_to_seed=47.5388 mm
  truthcl 32  E=0.0457764  pos=(191.34, 106.3, n/a)  recID=23  dr_to_seed=42.52 mm
  truthcl 34  E=0.00508626  pos=(255.12, 63.78, n/a)  recID=24  dr_to_seed=63.78 mm
  truthcl 35  E=0.0127157  pos=(233.86, 106.3, n/a)  recID=25  dr_to_seed=60.1324 mm
--> nearest associated truth cluster = 7  E=4.89934  dr_to_seed=3.8147e-06 mm
```

In this sample cells are not being clustered effectively, such that energy end up in multiple truth clusters

Leading electron selection

As an alternative to geometrical matching, can simply select leading *e* in the event

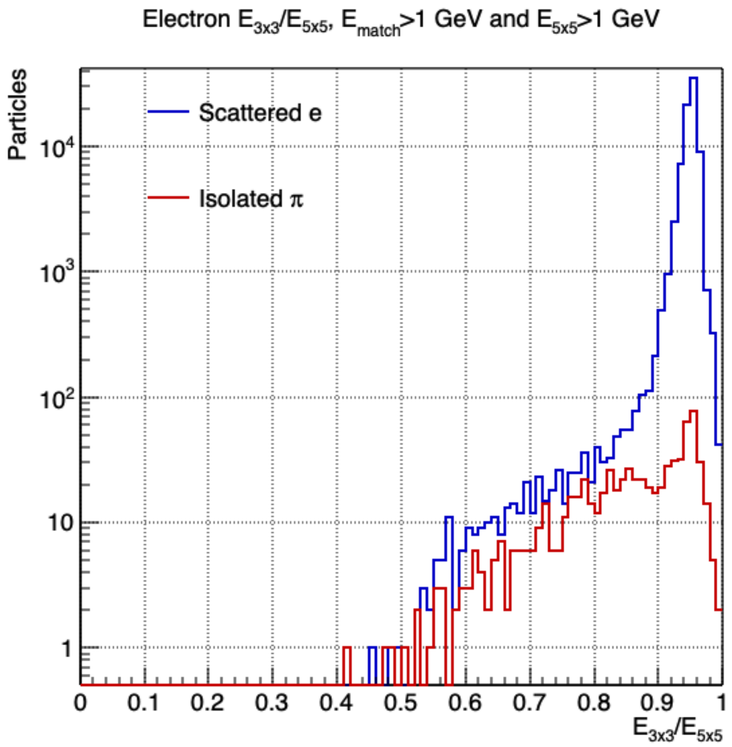


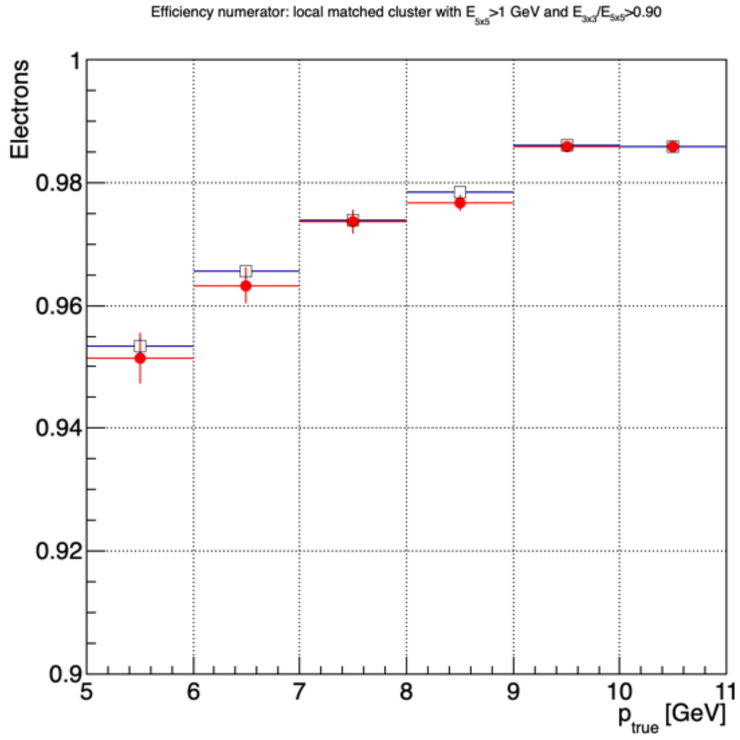


Scattered *e* can be detected but fail selection, however this is a percent-level effect

A shower shape variable

R_{35} = ratio of 3x3 to 5x5 energy





Electrons tend to leave nearly all their energy in central 3x3, while a good fraction of pions leave wider showers

→R_{35} discriminates against pions

R_{35} is quite robust against background

∴ pion rejection will be robust

E/p for electrons & pions