Scattered electron reconstruction in *ePIC*

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Outline

- ❑ Requirements on the scattered electron at the EIC
- ❑ Track projection implementation
- ❑ Plans for Inclusive physics

Detection and identification of the scattered electron at the EIC

- Given the universal importance of accurately identifying and reconstructing the scattered electron for NC measurements at the EIC, it is important to carefully consider the requirements for electron reconstruction.
- These requirements are divided into three categories: angular and momentum acceptance; momentum (energy) resolution; and electron purity.

Scattered Electron kinematics

- For the beam energies that will be used at the EIC and considering scattered electrons in the pseudo-rapidity range of $-4 < \eta < 4$ (where $Q^2 \gg m_e^2$), we can relate the inclusive kinematic variables to the scattered electron angles and energies as

$$y_e = 1 - \frac{E'_e}{2E_e}(1 - \cos\theta_e) \ ,$$

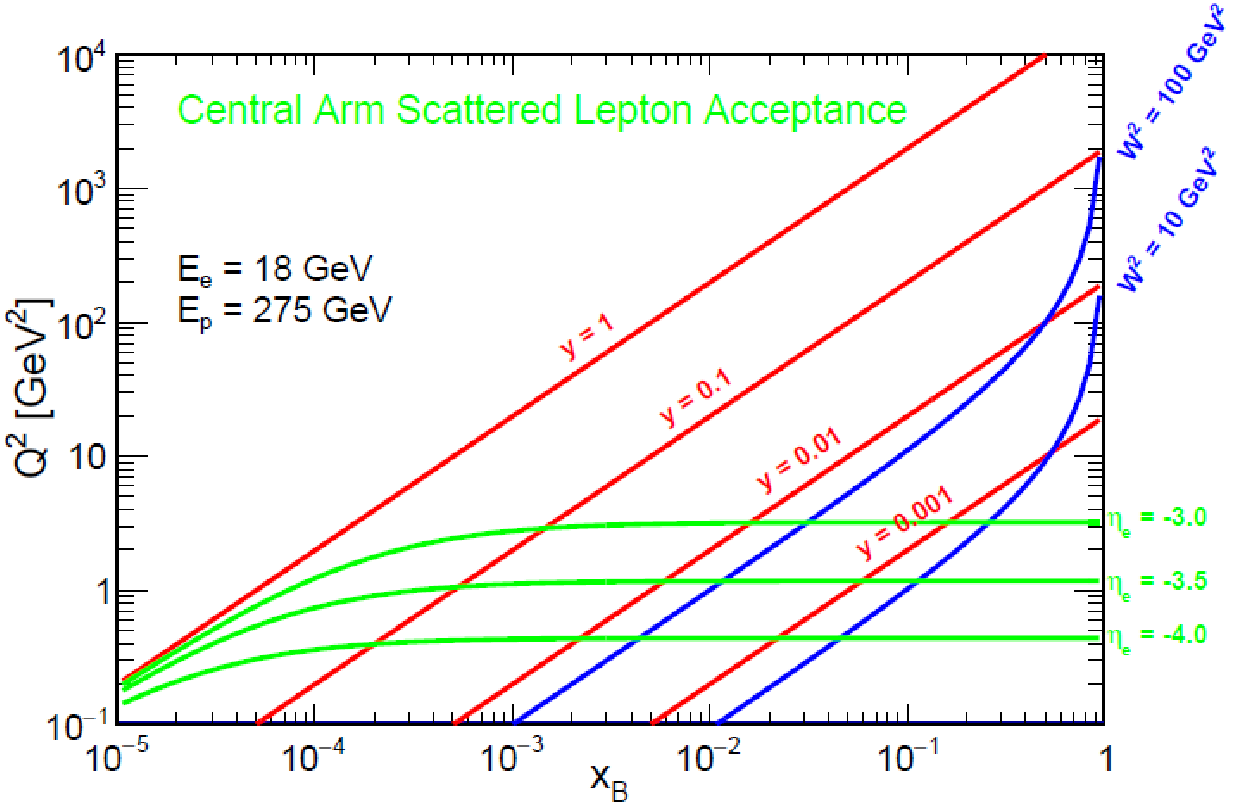
$$Q^2_e = 4E_eE'_e\cos^2(\theta_e/2) \ ,$$

$$x_e = \frac{Q^2_e}{sy_e} \ .$$

- Note how neither Q^2 nor y depend explicitly on the proton beam energy.

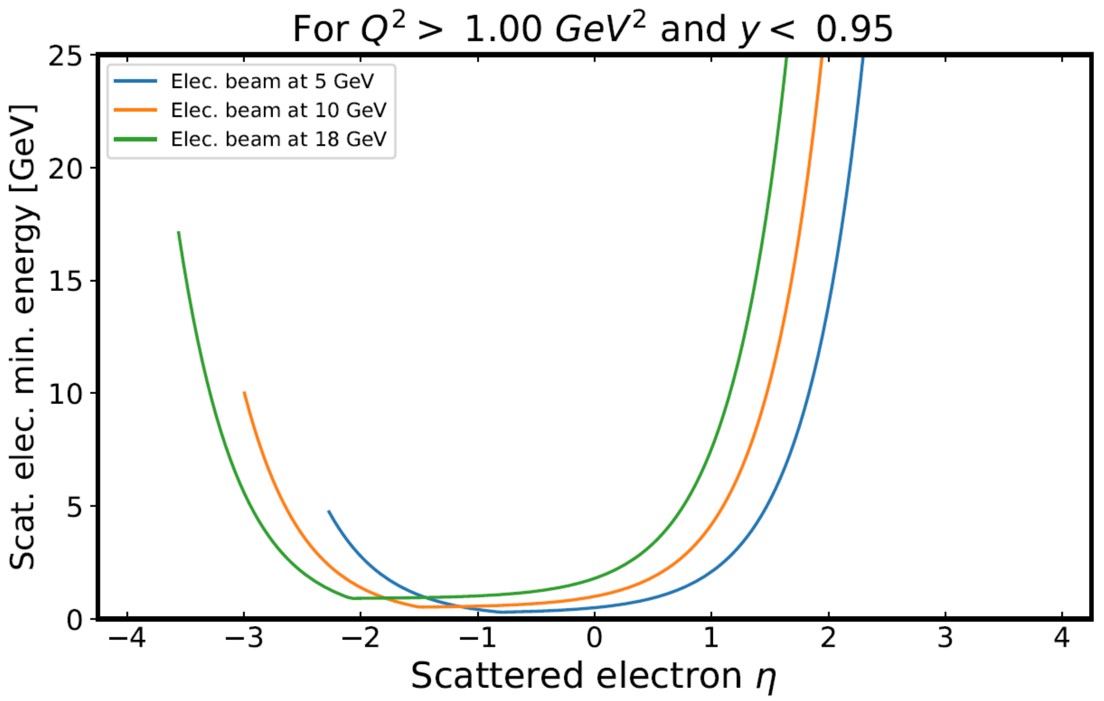
Electron Angular Acceptance

- For many EIC physics processes which have a requirement that $Q^2 > 1\ \text{GeV}^2$, an angular acceptance of $\eta \gtrapprox -3.6$ will allow full coverage at the highest EIC beam energy setting. At lower energies, this same acceptance coverage would allow access to lower values of Q^2 (see next slide).
- Any processes which require $Q^2 < 1\ \text{GeV}^2$ at the highest energy setting will need an extended acceptance below $\eta \approx -3.6$.
- For inclusive physics, coverage below $Q^2 = 1\ \text{GeV}^2$ has strong motivations.

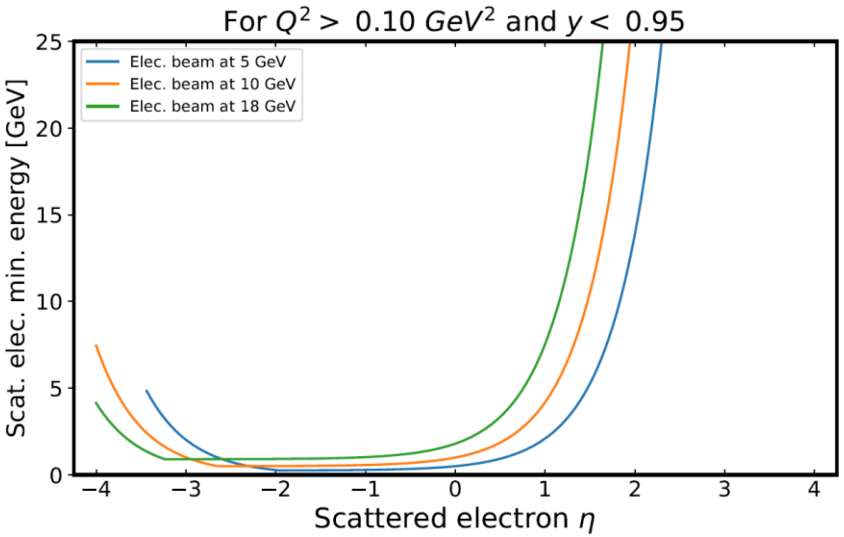


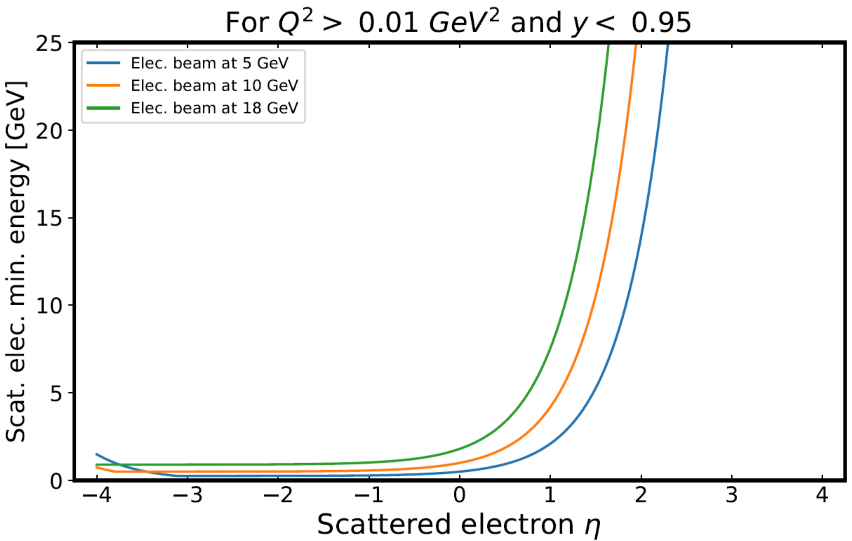
Electron Minimum momentum (energy)

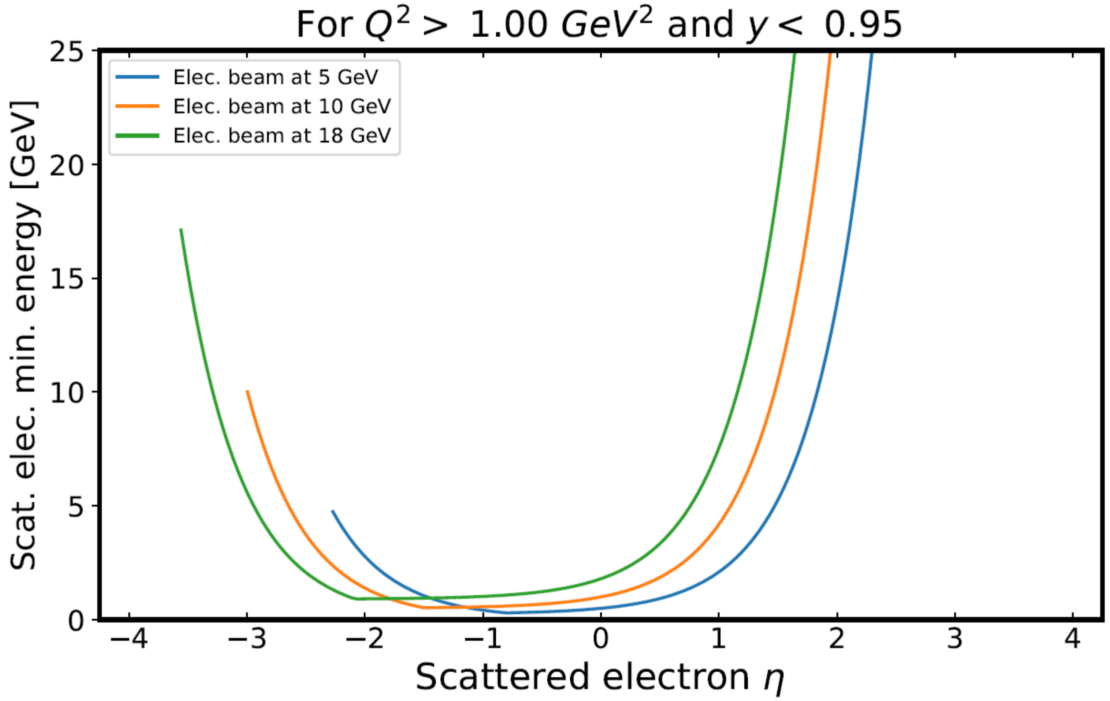
- The plot on the right shows as a function of η the minimum electron energy that satisfies both a $Q^2 > 1$ GeV^2 requirement and a $y < 0.95$ requirement.
- There are a few important features of this plot:
  1. The curves do not extend to the lowest possible values of pseudo-rapidities. Events with $Q^2 = 1$ GeV^2 can not be produced at the most backwards angles.
  2. For the left part of the curve, the minimum energy is exactly at the $Q^2 = 1$ GeV^2 limit (while still satisfying the $y < 0.95$ requirement). Once the curve begins to increase towards more positive values of η, the minimum energy of the scattered electron is at the $y = 0.95$ limit (while still satisfying the $Q^2 > 1$ GeV^2 requirement).



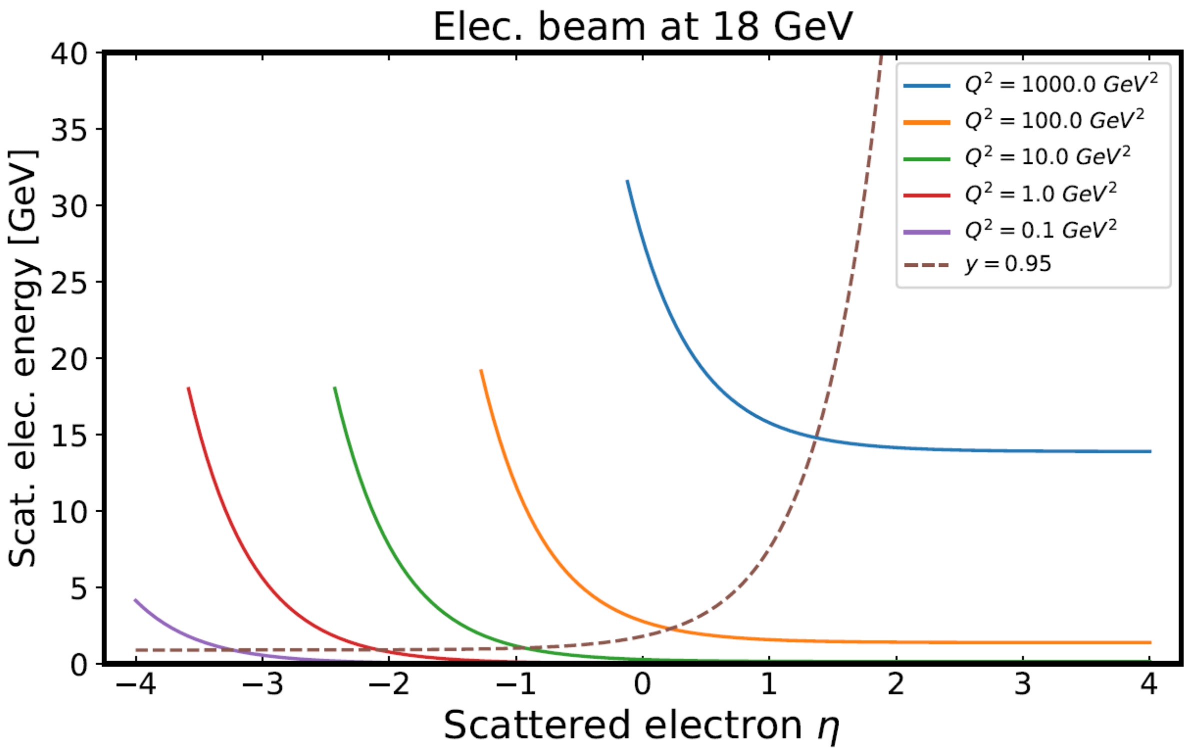
Scattered electron energy in backwards direction is quite large unless at very low Q^2

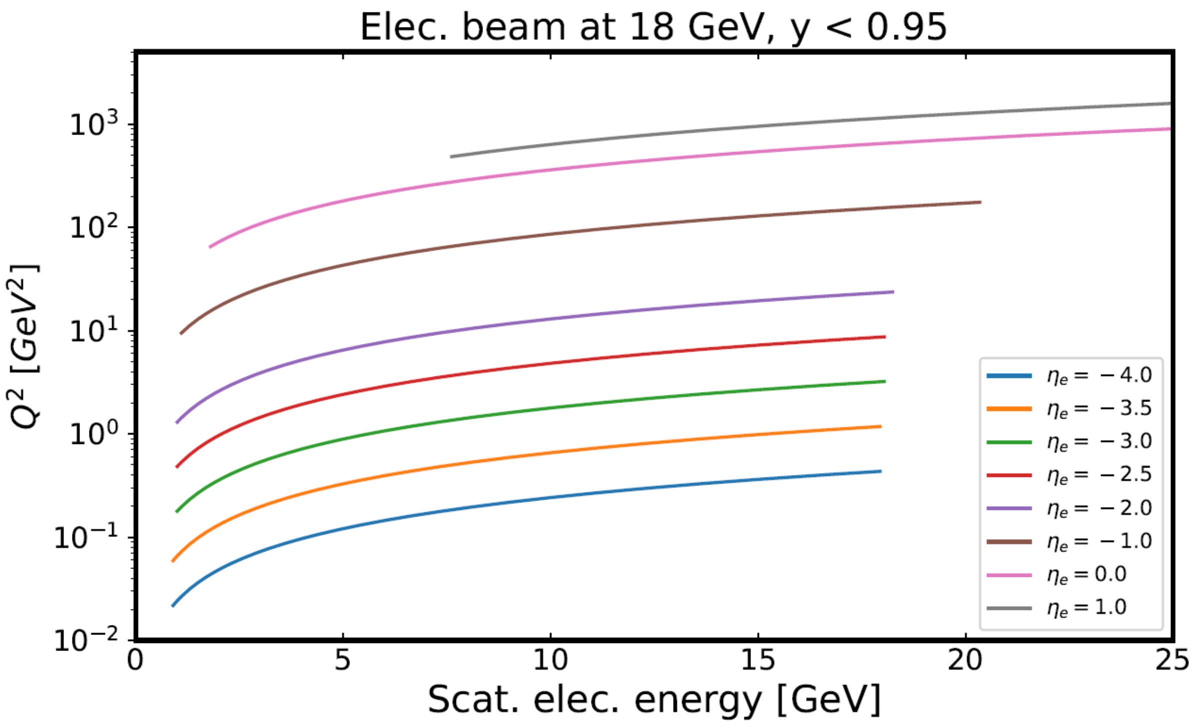




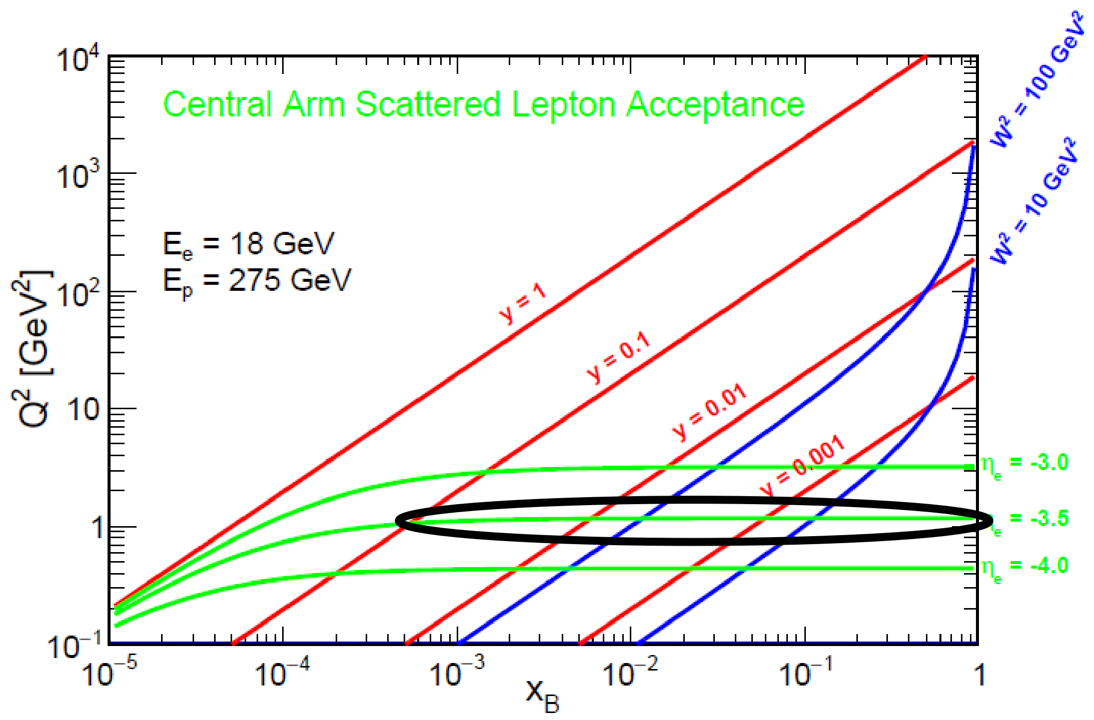


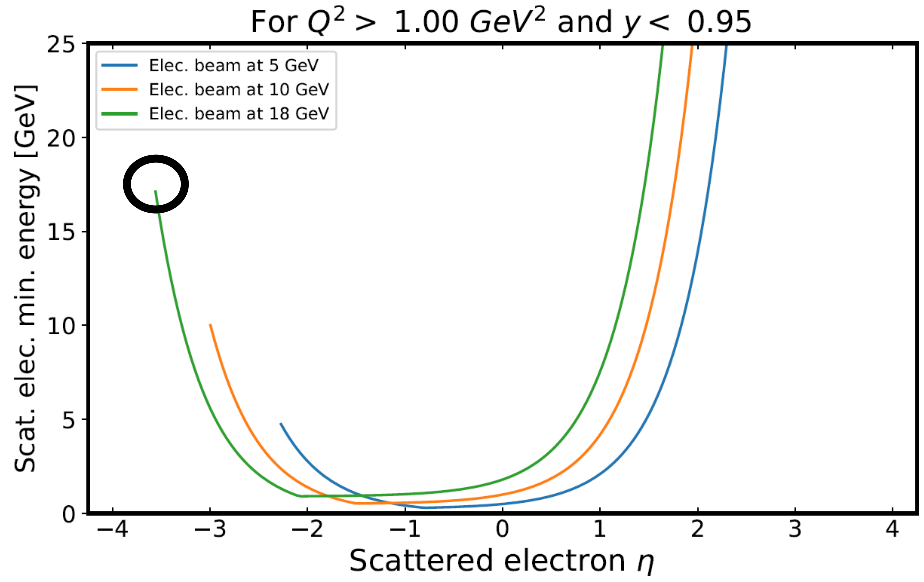
y < 0.95 cut sets Q2 lower limit

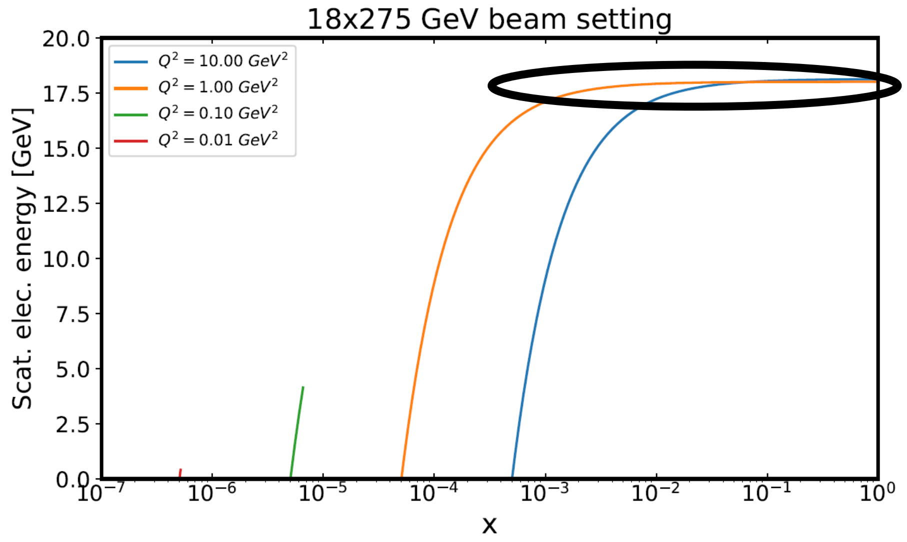




xB dependence on scattered electron kinematics



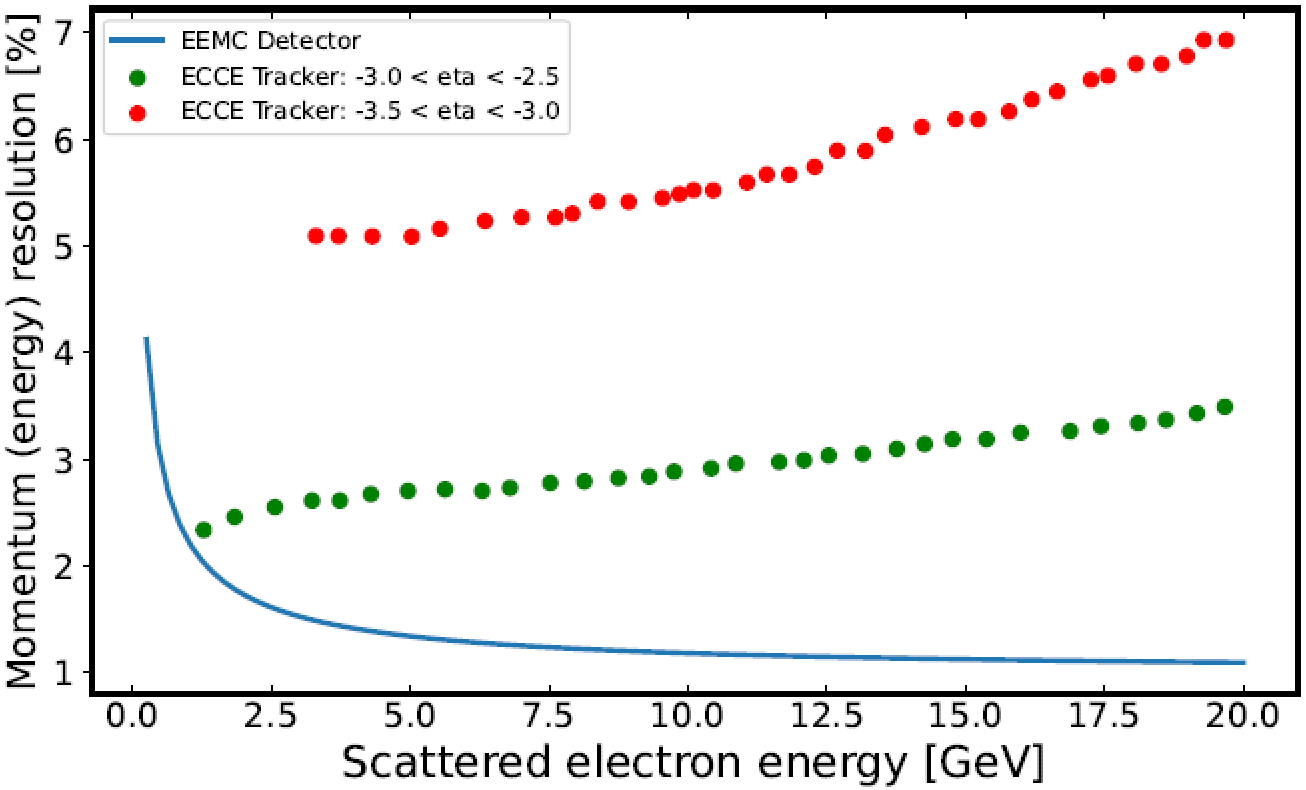




- For Q^2 = 1 GeV^2, the scattered electron energy is at almost a fixed energy for a large range of x. Reconstruction of x using the scattered electron is impossible here.
- Note how more central rapidities correspond to lower x at a fixed Q^2.

Momentum (energy) resolution

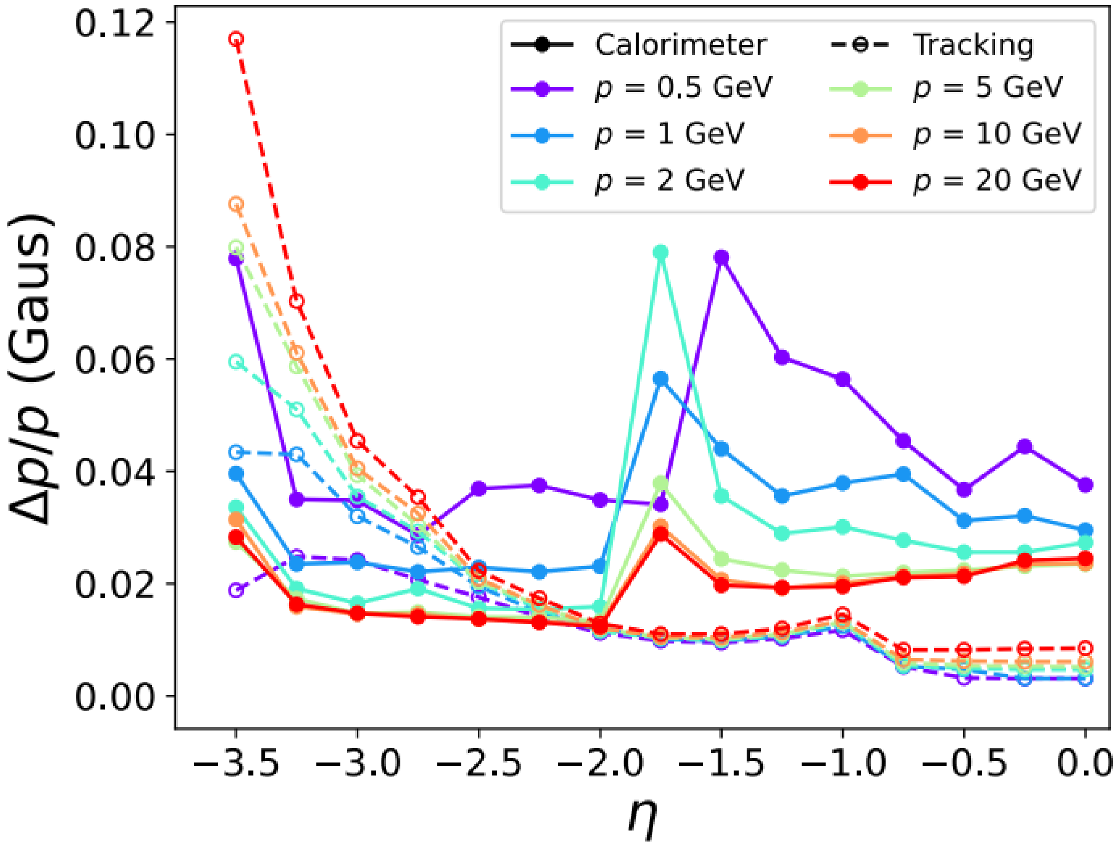
- The momentum (energy) resolution requirements for the scattered electron given in the yellow report are sufficient for all inclusive measurements.
- One important consideration is how best to perform the momentum (energy) reconstruction for the scattered electron in the electron endcap.
- We saw above that for processes with $Q^2 > 1$ GeV^2, we only need to measure scattered electrons with energy greater than 5 GeV for $\eta < -3.0$.
- The higher Q^2 electron momentum reconstruction at these backwards angles will therefore rely on the EEMC detector, as can be seen in the right plot.



The tracking resolution curves shown above come from figure 2.7 in the ECCE proposal. The EEMC resolution is drawn assuming a 2% stochastic term and a 1% constant term.

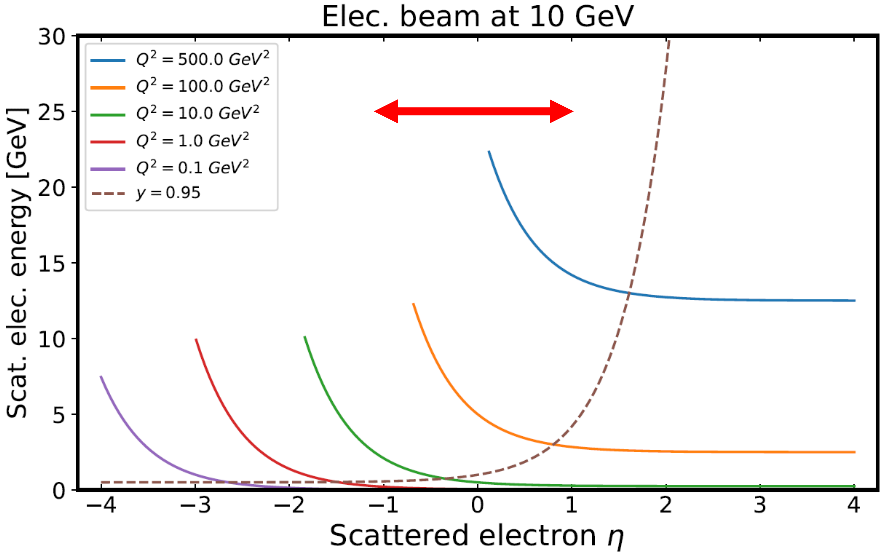
Calorimeter and tracker electron resolutions in *ePIC* simulation

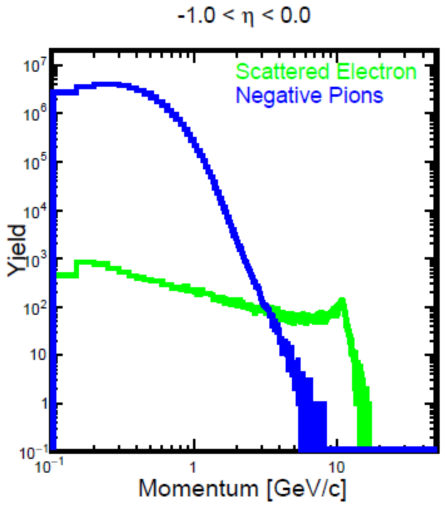
- Plot based on single-particle simulations with full *ePIC* detector implemented.
- Better performance for calorimeter for η < 2.
- Poor calorimeter performance at endcap / barrel boundary (η ~ 1.8).
- Better tracker performance in barrel.

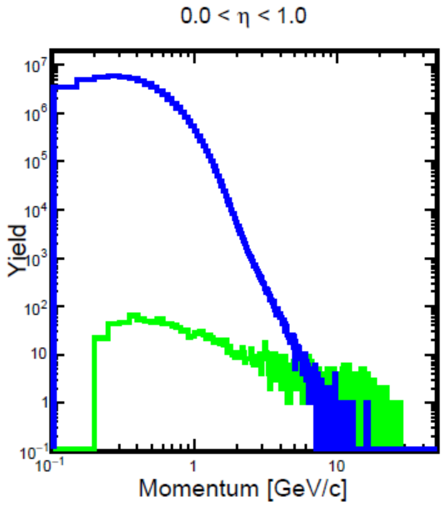


Importance of barrel ECAL

- Requirements on the scattered electron purity were determined by the inclusive working group during the yellow report. The requirement is given as 99% electron purity over the entire detector. This requirement is quite stringent and can be relaxed to 90% for the ‘golden’ inclusive measurements.
- In any case, there is a large raw pion background that originates from the low Q^2 part of the ep/A cross section.
- Primary role of barrel ECal for scattered electron reconstruction is pion rejection.







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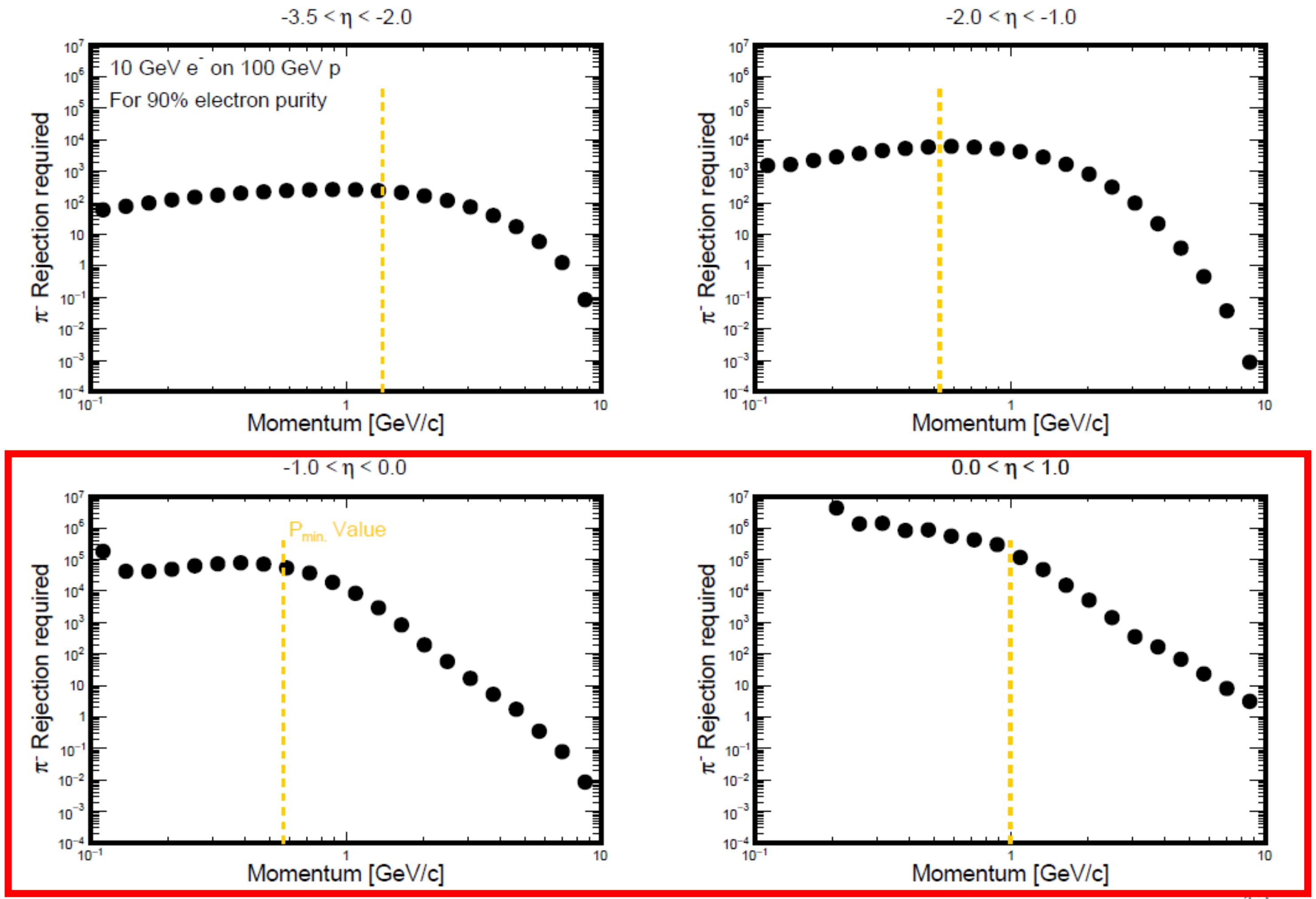
Pion rejection requirements

- To achieve 90% final electron purity , a pion suppression up to 10^5 is needed above the minimum momentum threshold (y < 0.95 in barrel region).
- Including imperfect electron efficiency would adjust this slightly.



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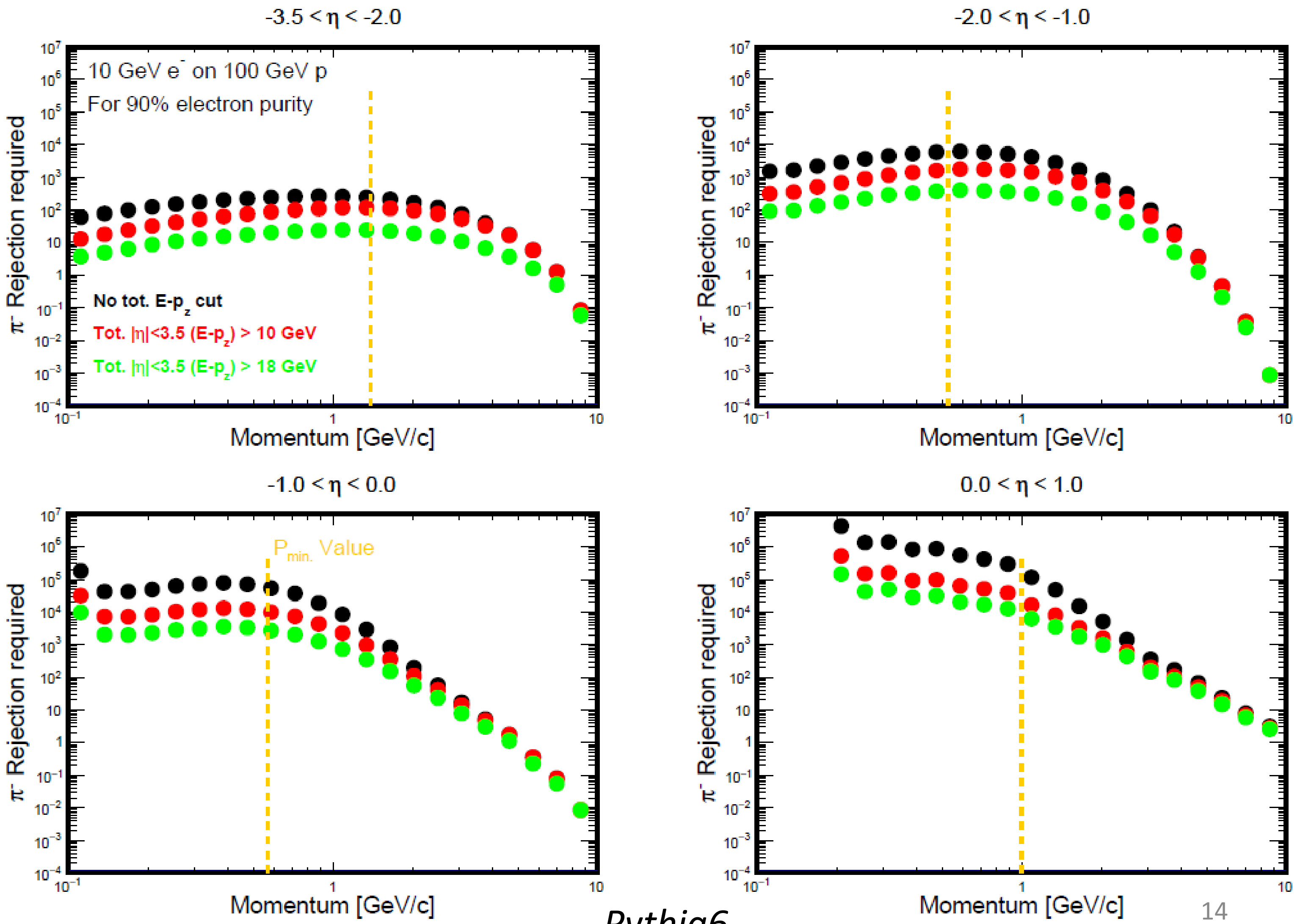
How to achieve high scattered electron purity

- There are several methods to suppress the raw backgrounds for the scattered electron.
  1. EMCal and PID detector responses for each electron candidate.
  2. Event-level requirement on the total measured E-p_z.
  3. Isolation cuts on electron candidates.
  4. Veto on far-backwards electron tagger.
  5. Reconstruction of positron spectrum to subtract decay/dalitz electrons.

- In the detector proposals, parameterized approaches were taken to estimate the final scattered electron purity. These suggested >90% purity could be achieved.
- We need to repeat this work using the full *ePIC* simulation.
- More realistic studies require developing an electron finder that works on minimum bias data – not only for signal events.

Example: sensitivity to total E-p_z determination

- Plots to the right show the rejection factor after applying certain cuts on total E-p_z. The sum is over generated particles within the main detector acceptance.
- The effect of this cut is more pronounced at lower momentum, as expected.
- This shows that the final requirement on the detector performance will depend on the total E-p_z resolution of the detector.



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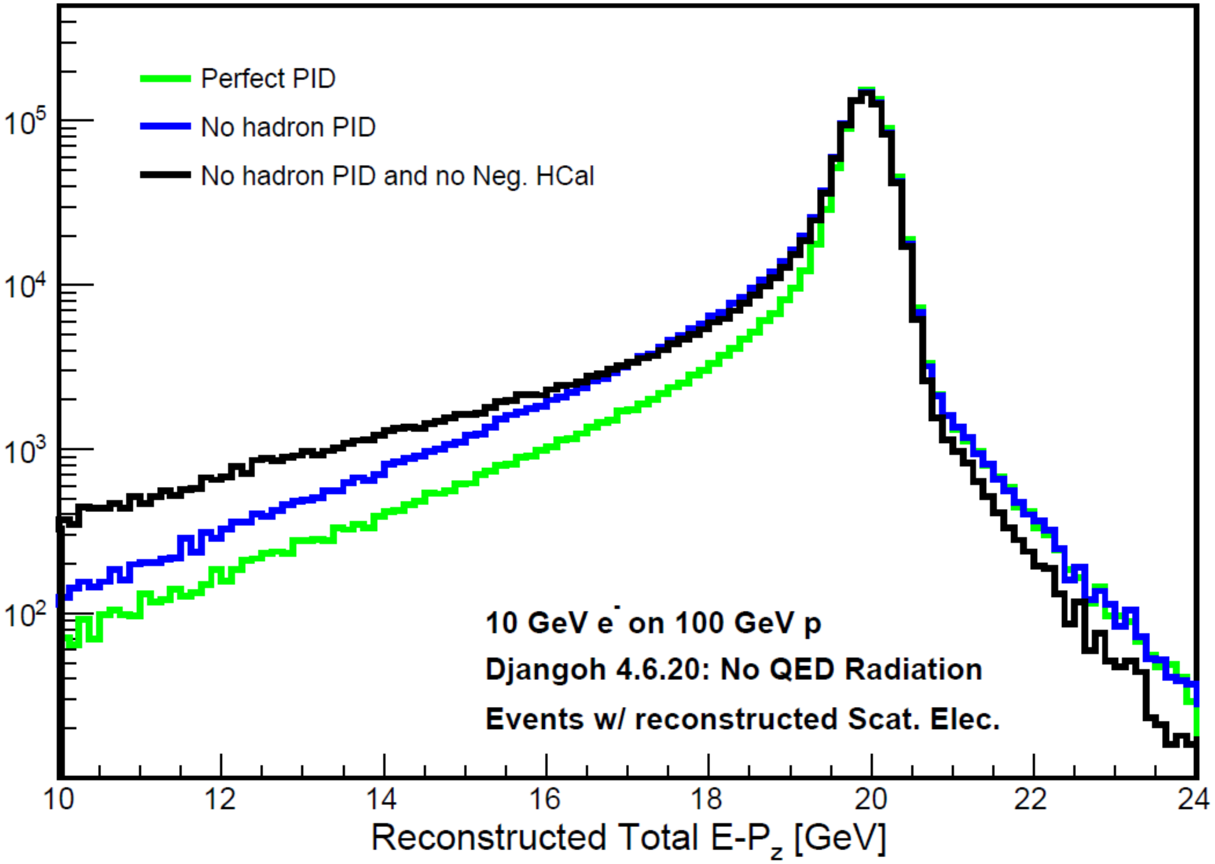
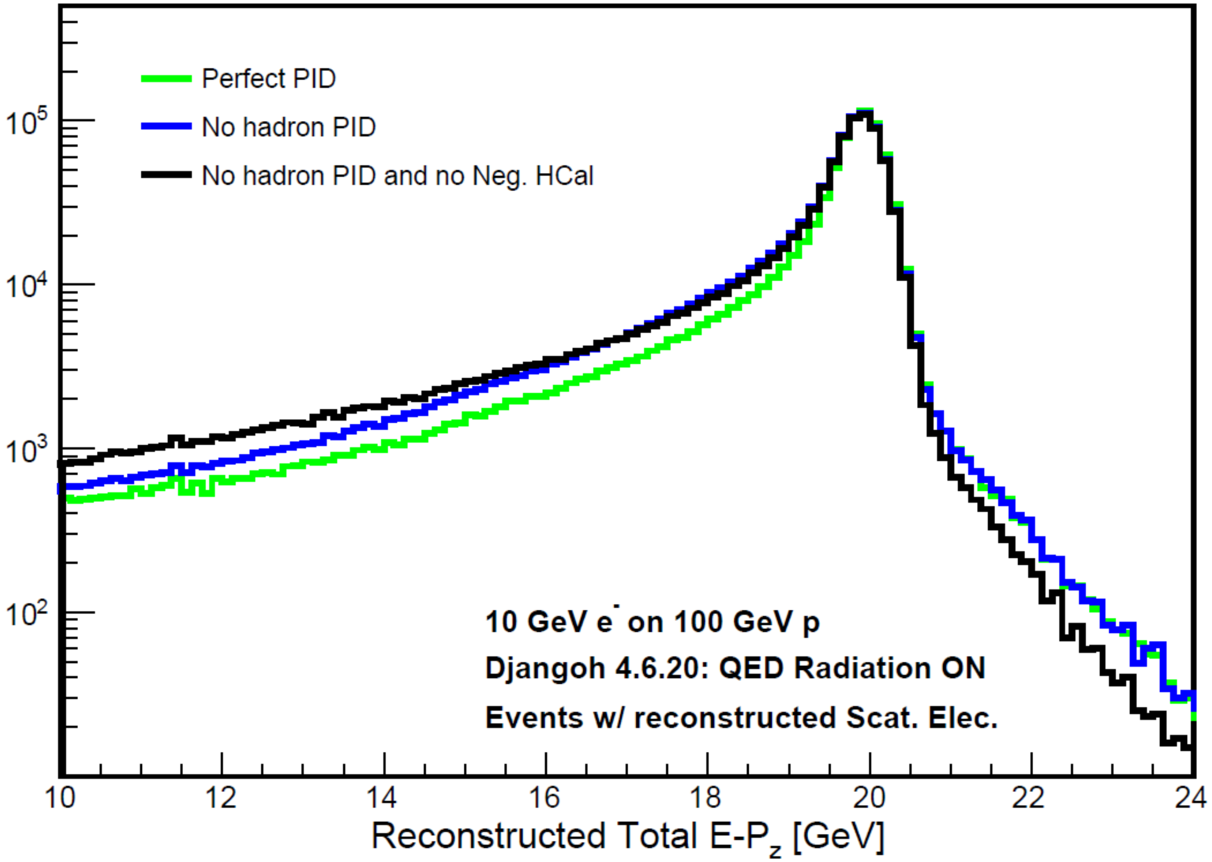
Fast simulation E-p_z resolution: Yellow Report reference detector

No QED effects included

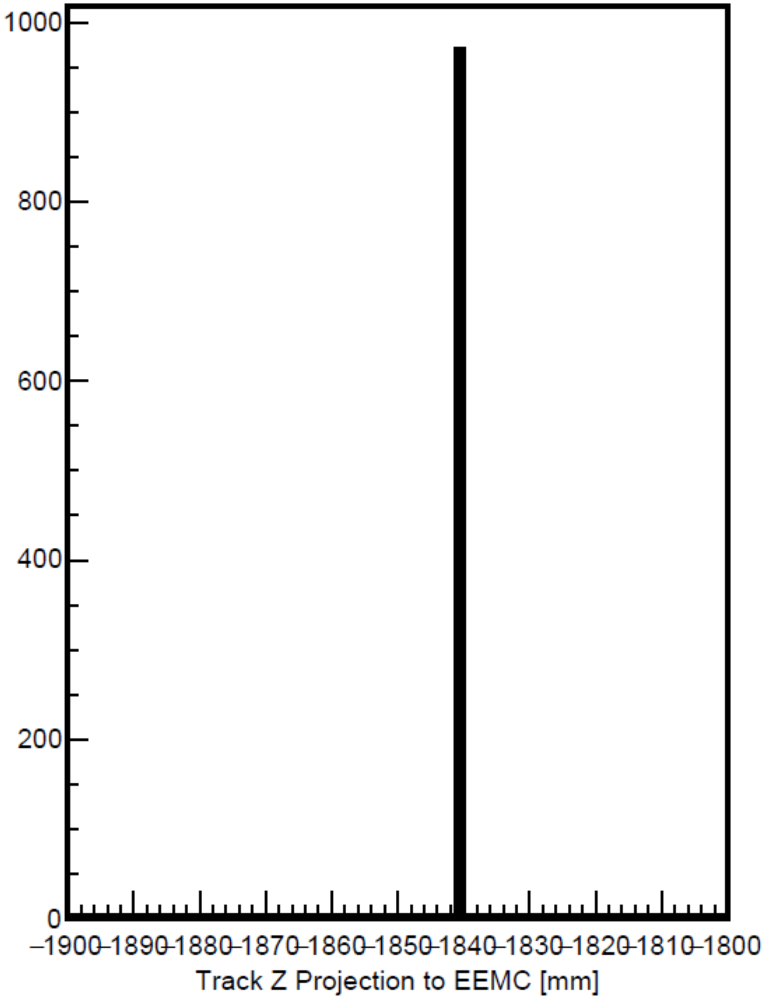


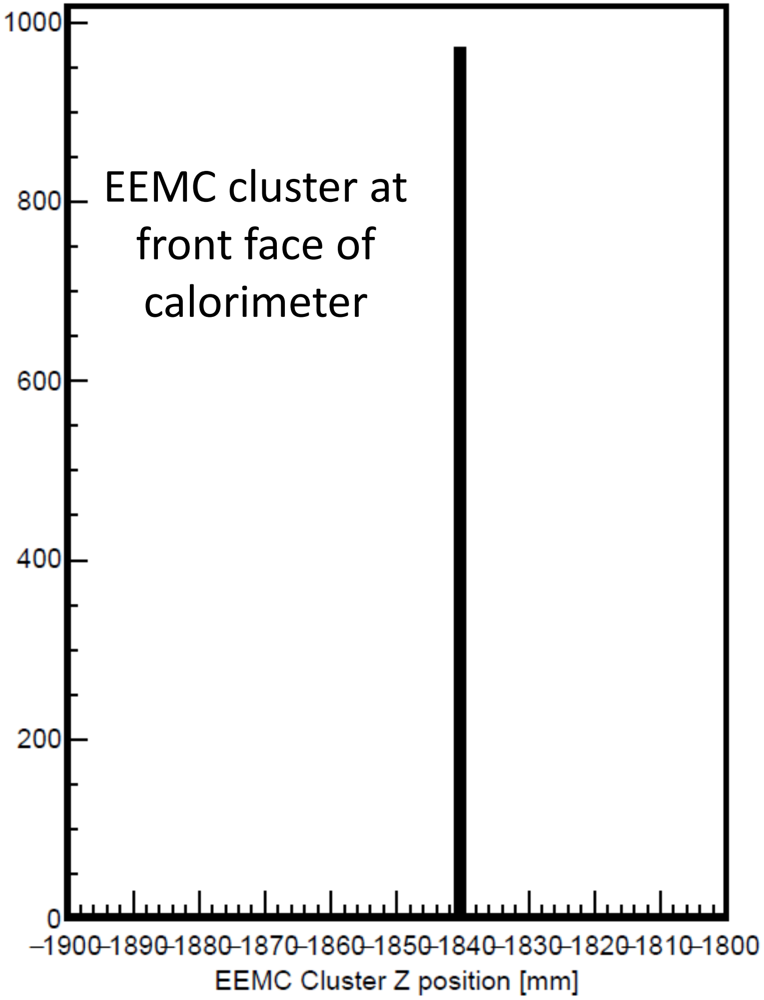
QED effects turned ON



Towards scattered electron reconstruction (electron finder) – Track projection

Single Electrons generated:
1 GeV < E < 20 GeV
$160^\circ < \theta < 170^\circ$, $0^\circ < \phi < 360^\circ$





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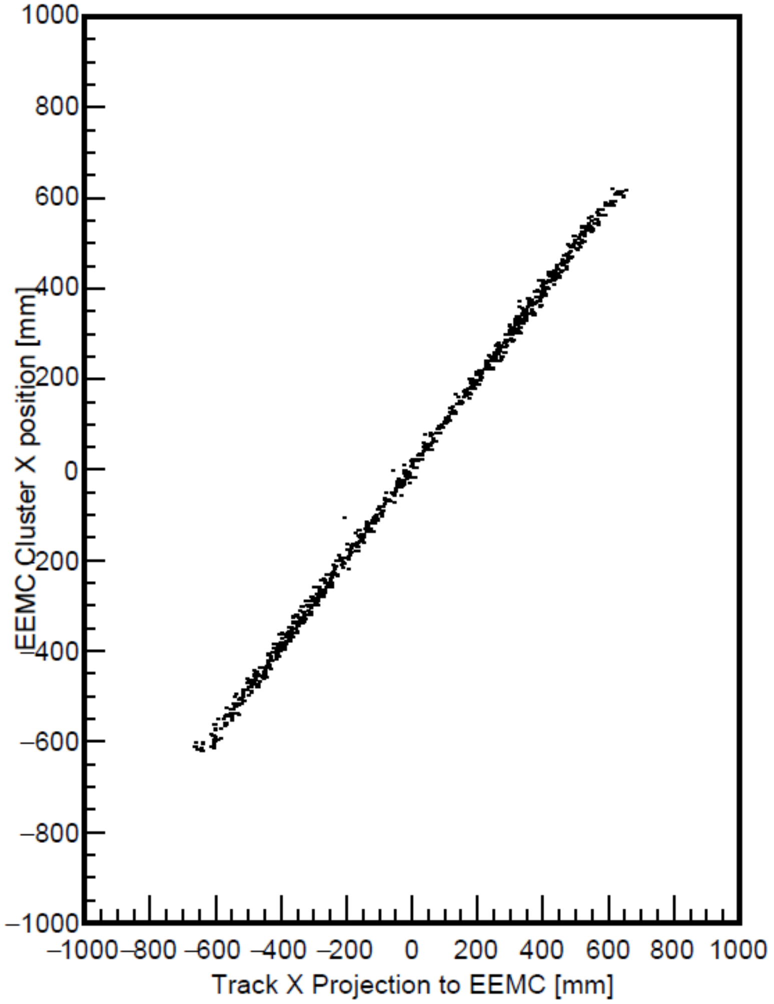

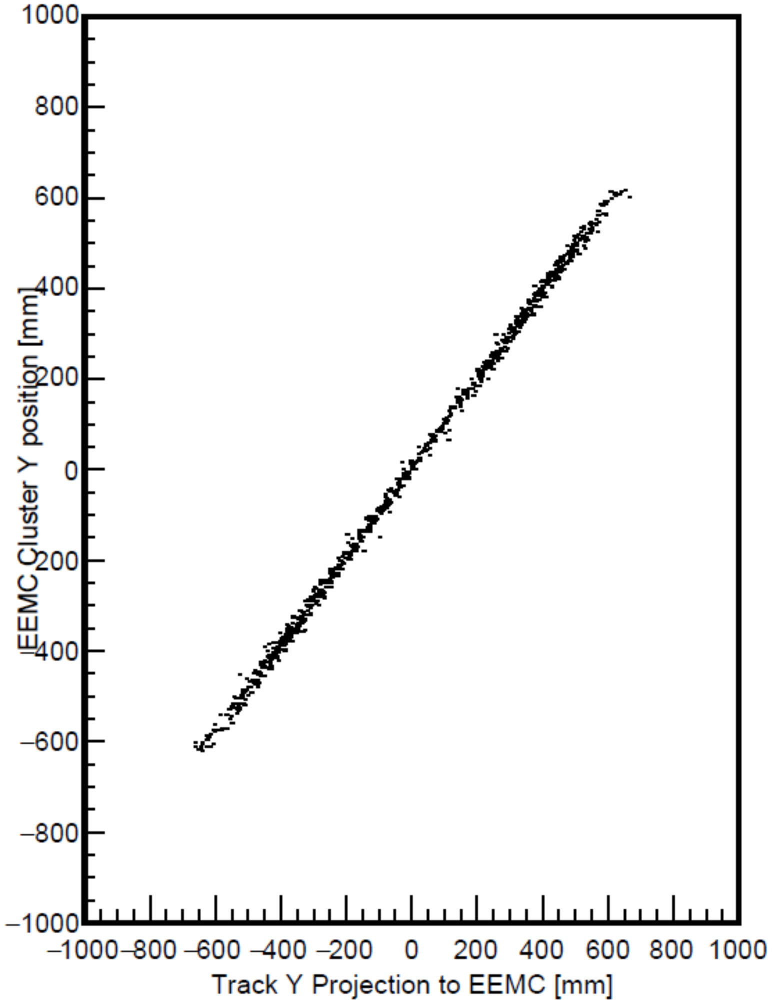

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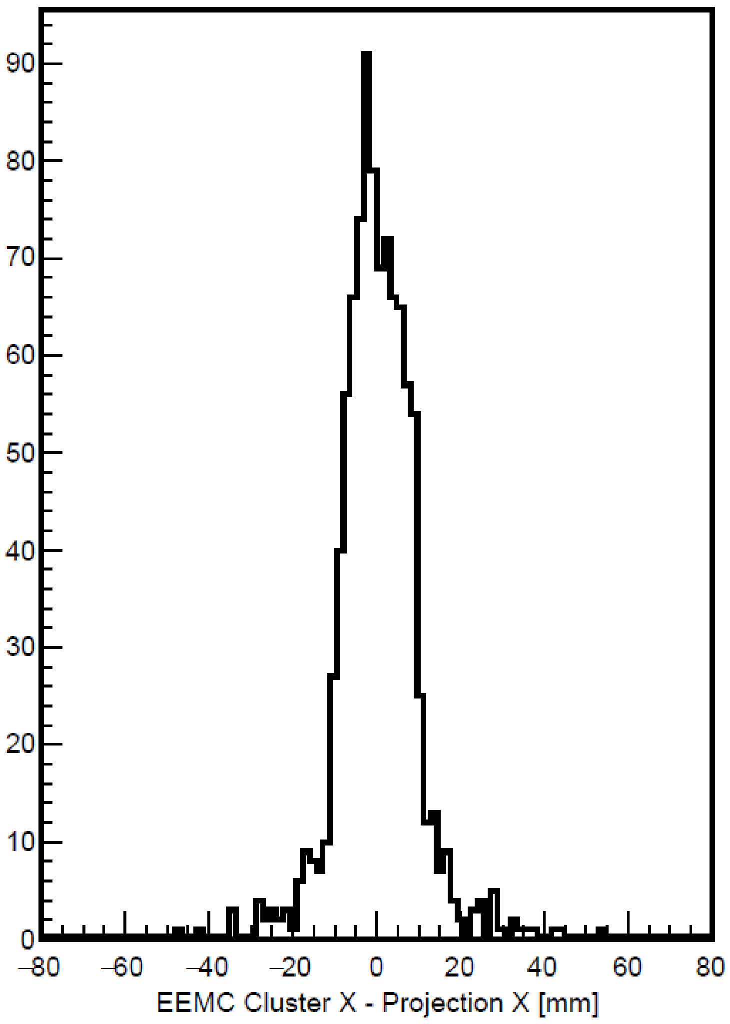

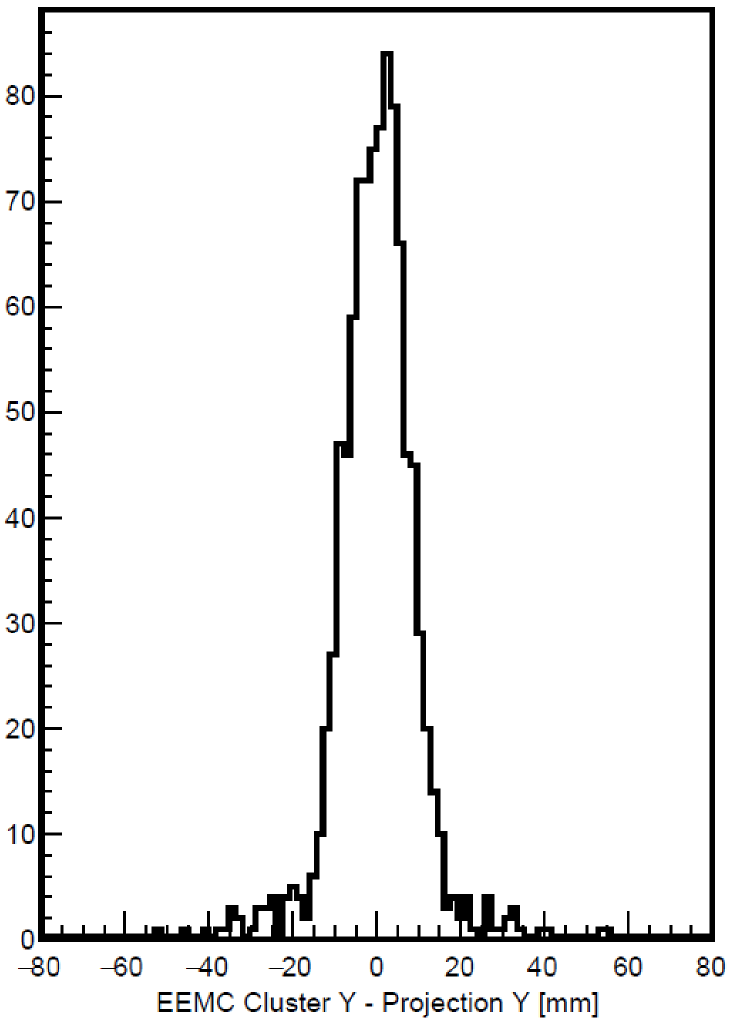

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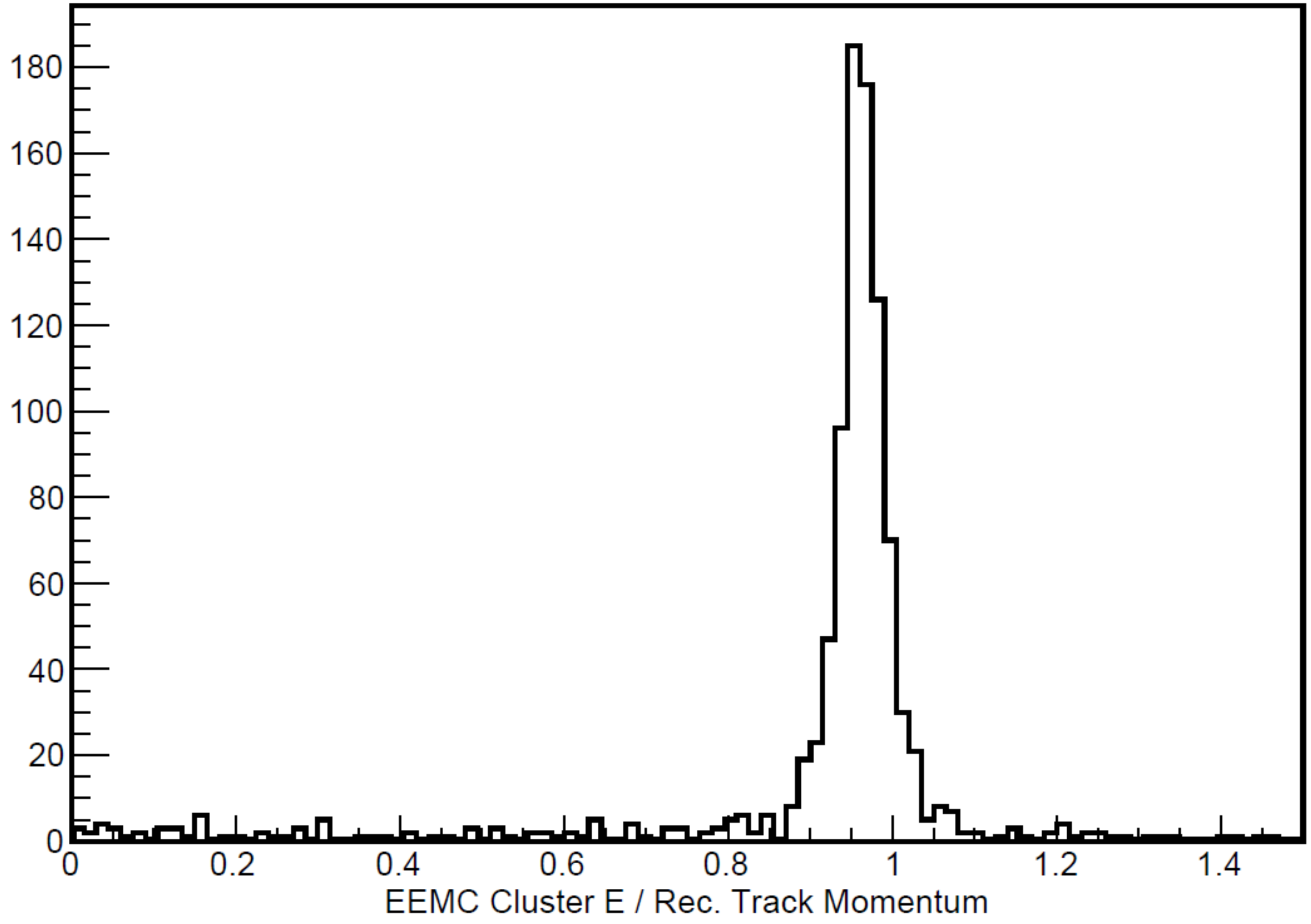
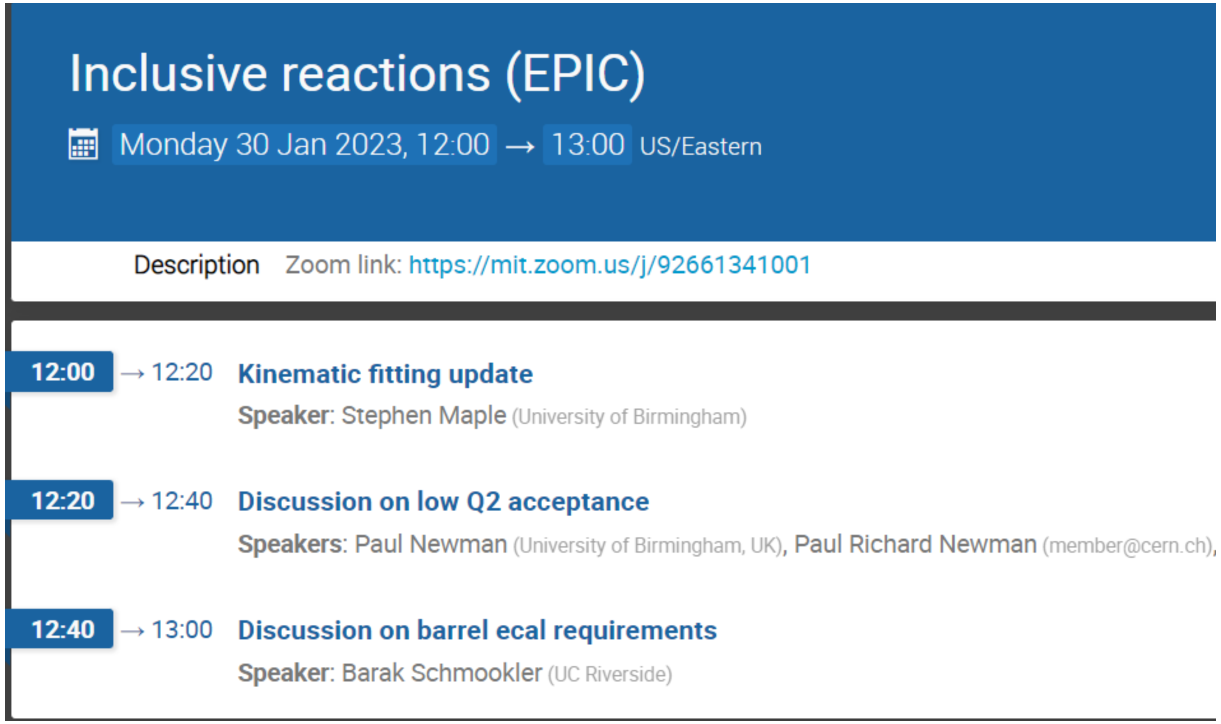


Ongoing work by the inclusive group

- Further studies of track projections for endcap calorimeters / PID detectors.
- Implementation of track projection to cylindrical surfaces.
- Testing PID detector response in *ePIC* full simulation.
- Development of simple electron finder algorithm
- Development of algorithm to mask track-associated clusters for neutral reconstruction.


Inclusive reactions (EPIC)

Monday 30 Jan 2023, 12:00 → 13:00 US/Eastern

Description Zoom link: https://mit.zoom.us/j/92661341001

12:00	→ 12:20	**Kinematic fitting update** Speaker: Stephen Maple (University of Birmingham)
12:20	→ 12:40	**Discussion on low Q2 acceptance** Speakers: Paul Newman (University of Birmingham, UK), Paul Richard Newman (member@cern.ch),
12:40	→ 13:00	**Discussion on barrel ecal requirements** Speaker: Barak Schmookler (UC Riverside)