Barrel ECAL requirements for inclusive analyses

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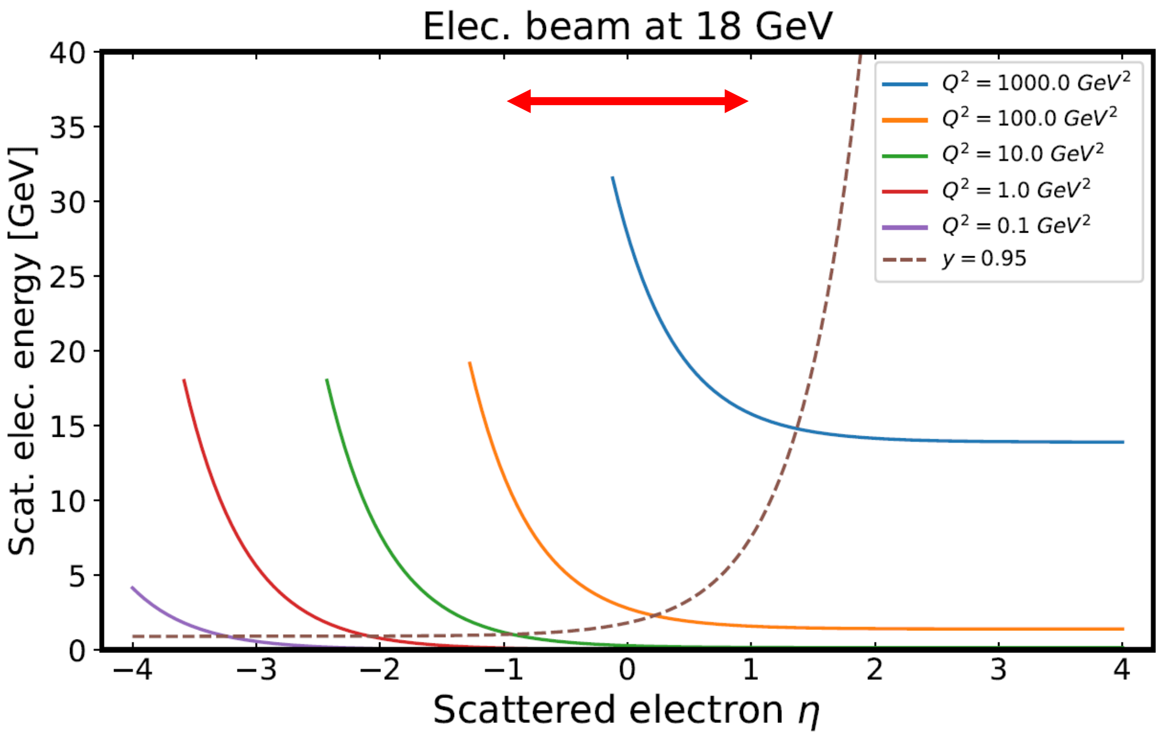
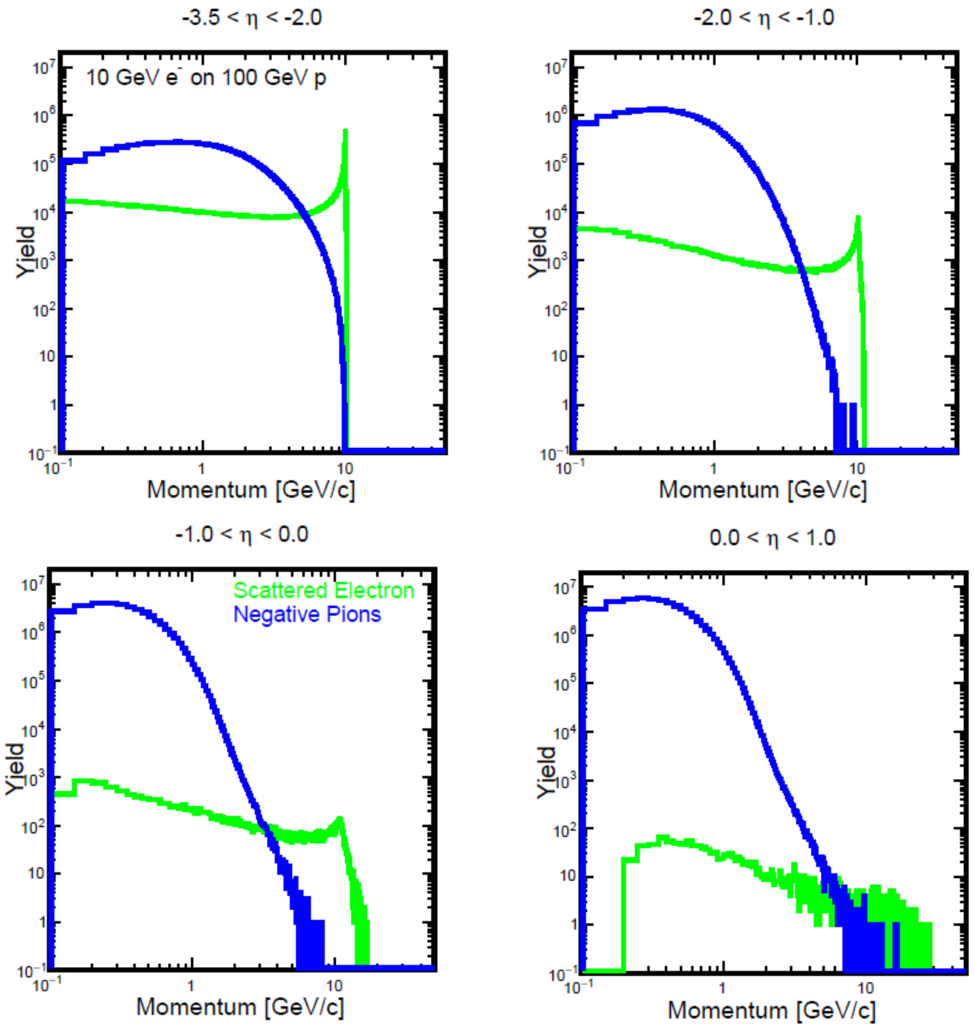
Importance of barrel ECAL

- In the barrel region, reconstruction of the scattered electron kinematic will rely on the tracking detector.



Importance of barrel ECAL

- In the barrel region, reconstruction of the scattered electron kinematic will rely on the tracking detector.
- For inclusive analyses, therefore, the primary role of the barrel ECAL will be the rejection of the negative pion background which originates largely from the low Q^2 part of the ep/A cross section.



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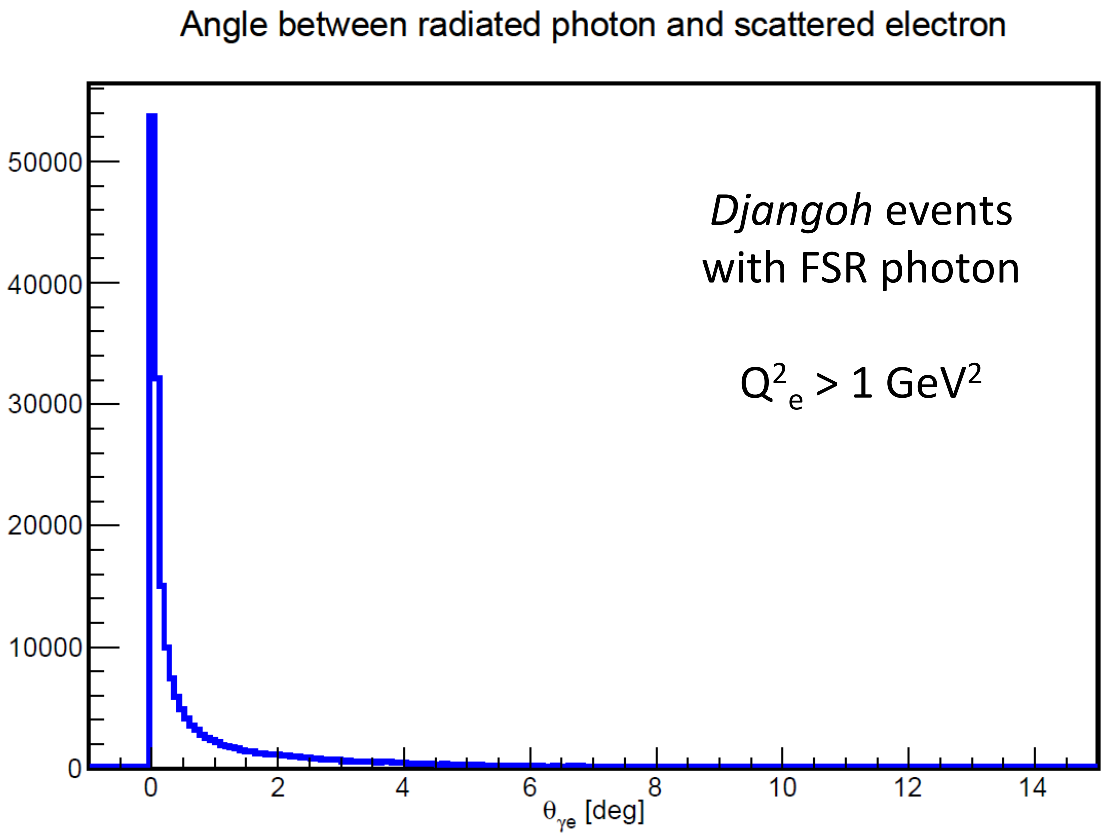
- In the barrel region, reconstruction of the scattered electron kinematic will rely on the tracking detector.
- For inclusive analyses, therefore, the primary role of the barrel ECAL will be the rejection of the negative pion background which originates largely from the low Q^2 part of the ep/A cross section.
- Secondary considerations are contributions to determination of total (and hadronic) $E\text{-}p_z$; and potential to distinguish any produced FSR photon from scattered electron.


Angle between radiated photon and scattered electron

Djangoh events with FSR photon

$Q^2_e > 1$ GeV^2

Impact of pion contamination on inclusive measurements

Unpolarized cross section

$$\left(\frac{\Delta\left(\sigma^{r,NC}\right)}{\sigma^{r,NC}}\right)_{\pi^-} = \Delta f_{\pi/e} \approx\ 0.1 f_{\pi/e}$$

Sensitivity to F_L at high y:

$$\sigma^{r,NC} = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

Inclusive asymmetry measurements

If contamination is small, can be treated as a dilution factor. Otherwise correct as:

$$A^e = \frac{1}{1-f_{\pi/e}}\left(A^e_{meas.} - f_{\pi/e}A^{\pi}\right)$$

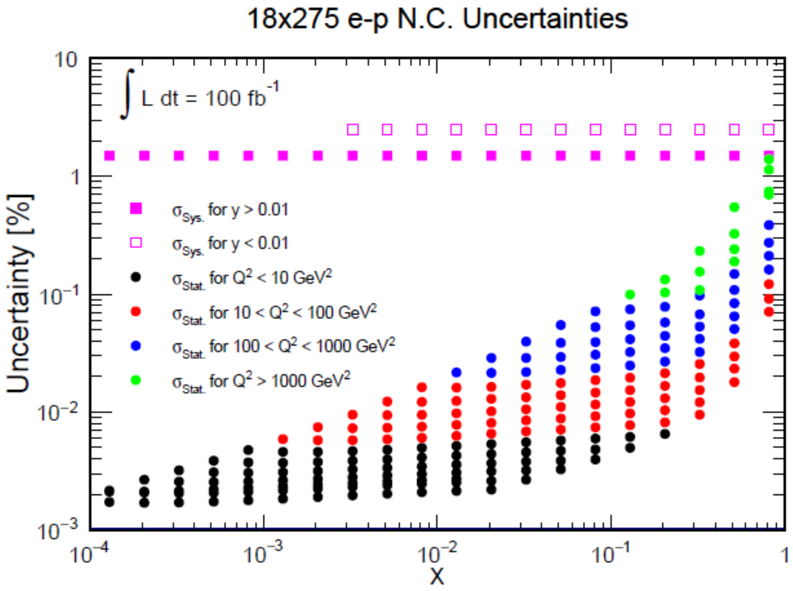
In either case, uncertainty is given as:

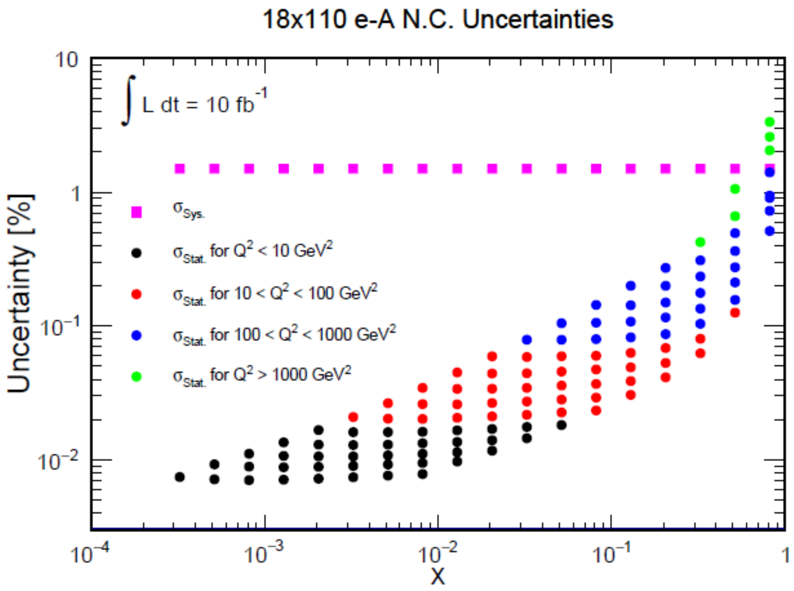
$$\left(\frac{\sigma_{A^e}}{A^e}\right)_{\pi^-} = \sqrt{(\Delta f_{\pi/e})^2 + \left(f_{\pi/e}\frac{|A^{\pi}| + \Delta A^{\pi}}{A^e}\right)^2}$$

$$\approx\ 0.1 \times f_{\pi/e} - 1 \times f_{\pi/e}$$

Unpolarized cross section requirement

- Statistical uncertainties for the unpolarized cross section will be small. Measurement will be systematics dominated.
- Pion contamination is generally treated as an uncorrelated (point-to-point) systematic uncertainty.
- A 90% scattered electron purity is needed to keep this uncertainty to the 1% level.





$$\frac{\Delta\left(\sigma^{r,NC}\right)_{stat.}}{\sigma^{r,NC}} = \frac{1}{\sqrt{N}}$$

Double-spin inclusive asymmetry requirement

- For asymmetry measurement, (fractional) statistical uncertainty can be large at smaller x and Q^2.
- In the barrel region, however, the statistical uncertainty can be below 1%. The asymmetry is also expected to be larger in this region.
- So, to keep the systematic uncertainty associated with the pion contamination to 1%, a 90% scattered electron purity is again needed.
- Better purity would allow the contamination to be treated as a dilution factor.

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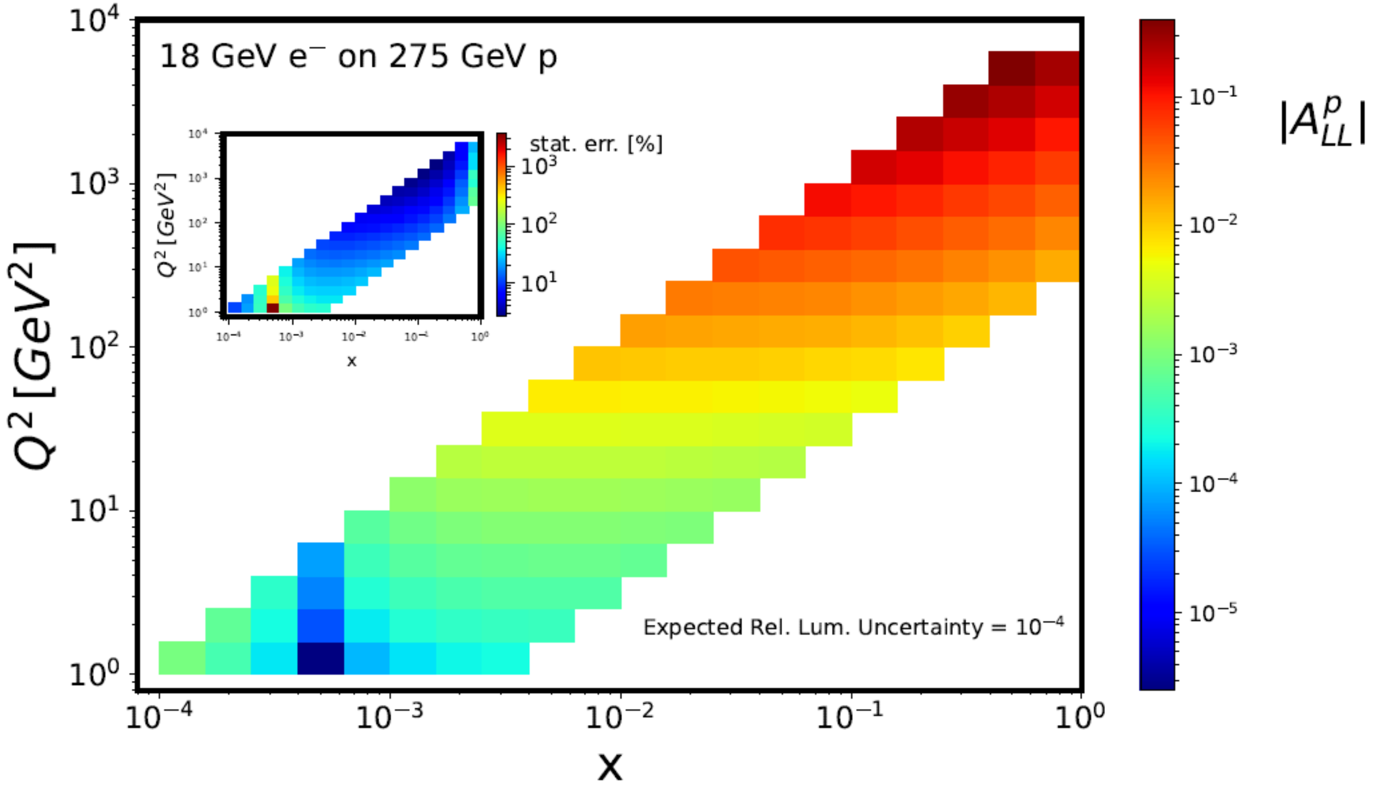
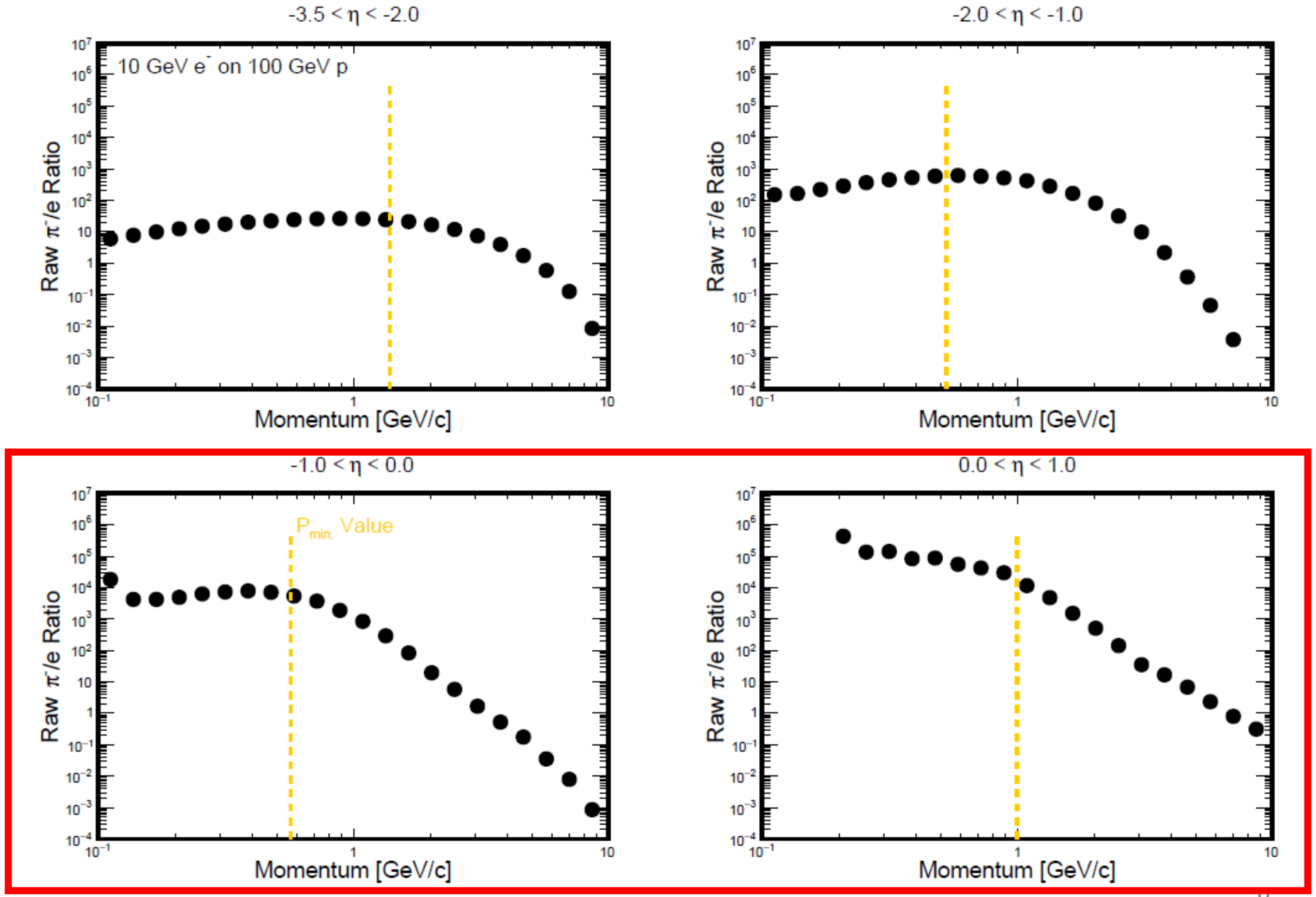


$$\sigma_{A_{LL}} = \frac{\sqrt{1 - A^2_{LL,meas}}}{P_e P_p \sqrt{N}} \approx \frac{1}{P_e P_p \sqrt{N}}$$

Raw negative pion to scattered electron ratios

- Plots to the right show the raw contamination as a function of momentum for different angular ranges. Most minimum bias events will not have a scattered electron in the main detector.
- The vertical orange line shows the minimum momentum satisfying a $Q^2 > 1$ GeV^2 and $y < 0.95$ cut on the electron candidate.
- As can be seen, the raw pion to electron ratio can approach 10^4 in the barrel region.



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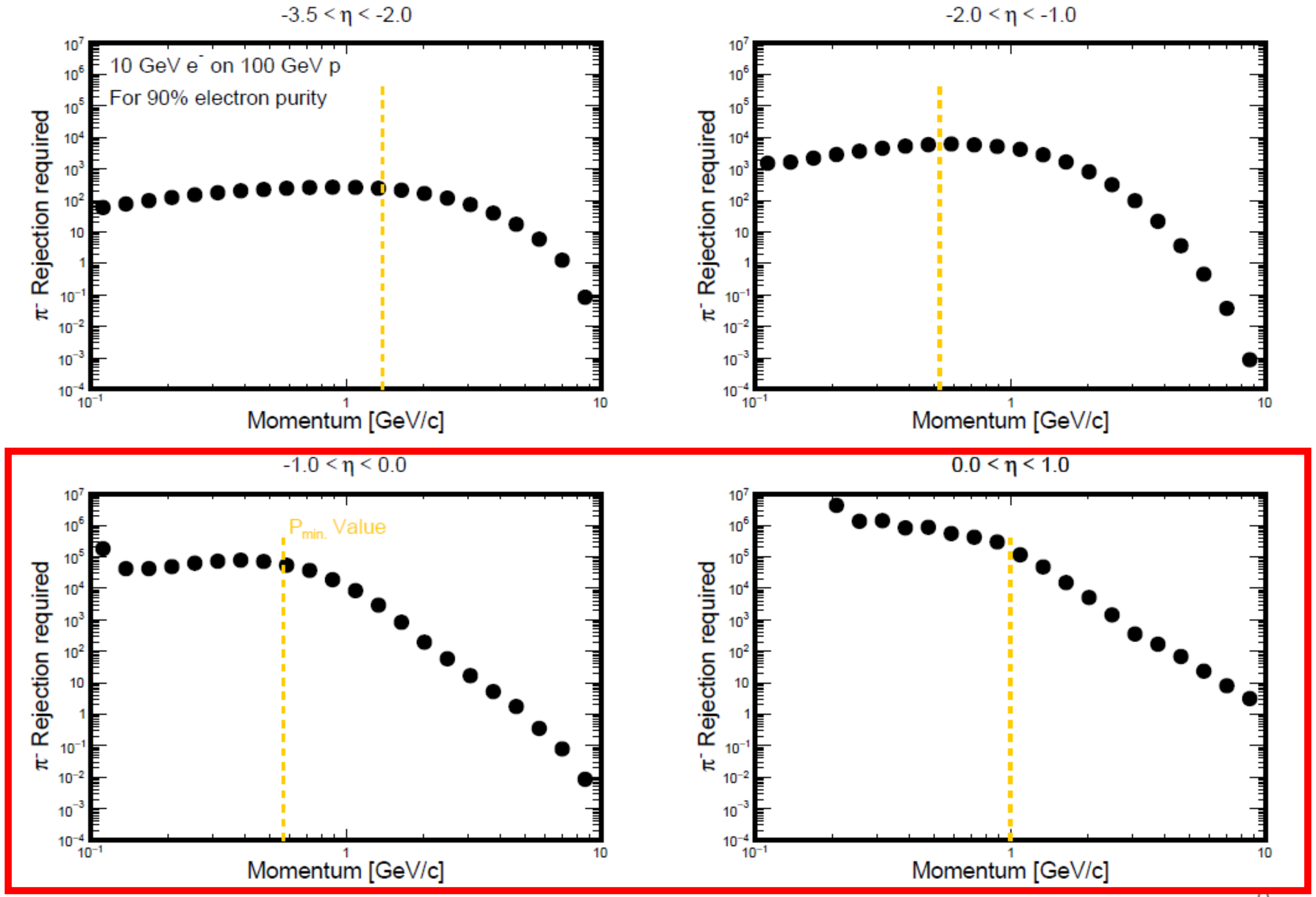
Pion rejection requirements

- To achieve the 90% final electron purity discussed above, a pion suppression up to 10^5 is needed above the minimum momentum threshold.
- 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.

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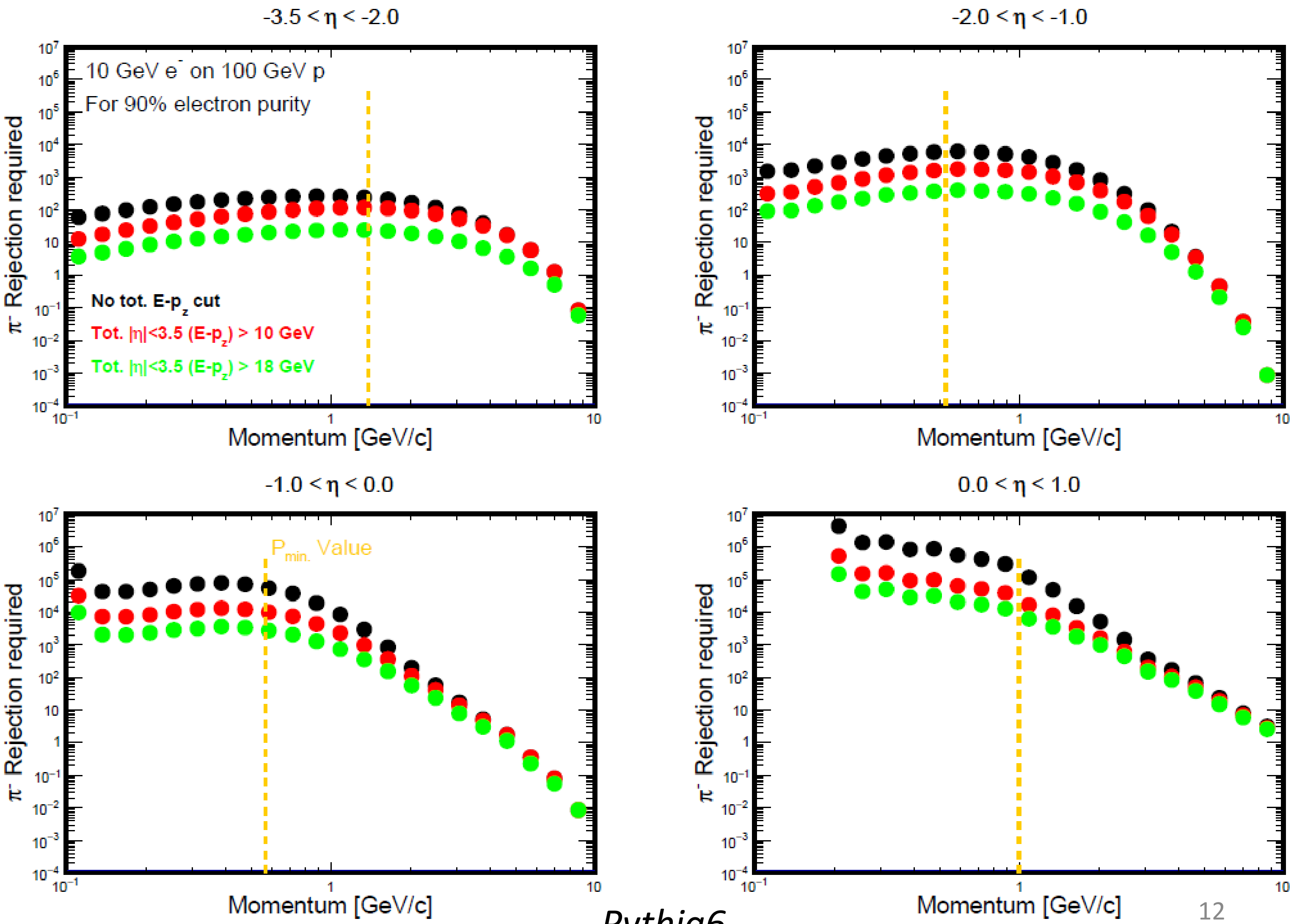
- In the detector proposals, parameterized approaches were taken to estimate the final scattered electron purity. These suggested >90% purity could be achieved.
- We need to repeat this work using the full *ePIC* simulation.
- This requires developing an electron finder that works on minimum bias data – not only for signal events.
- First steps have been taken. See Tyler’s talk.

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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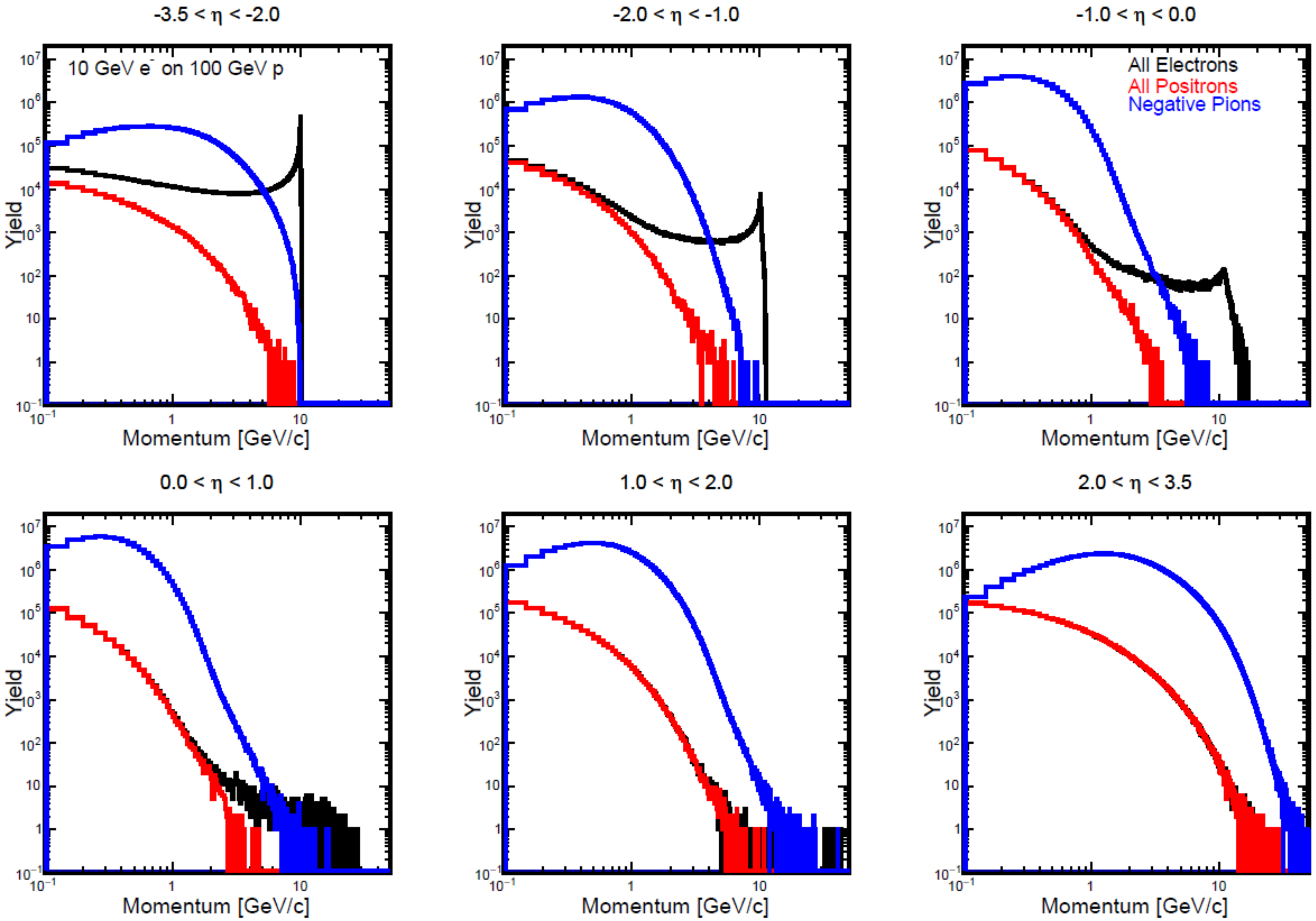
Conclusions

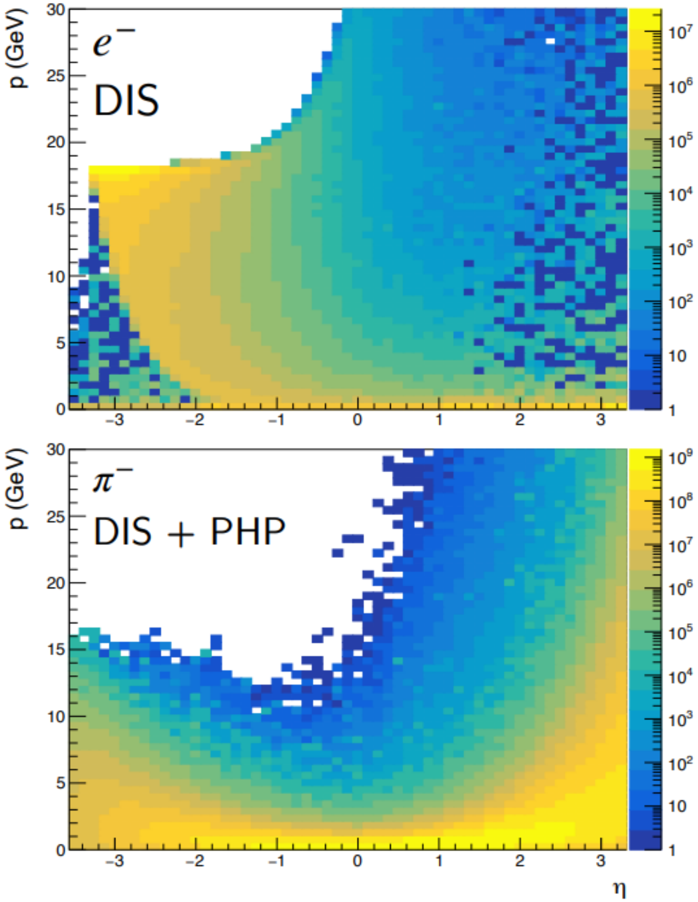
- Large pion contamination in the barrel is a challenge for high y electron identification.
- Pion rejection will require both detector-level and kinematic-level cuts.
- This makes it difficult to provide specific requirements on the barrel ECAL without full minimum-bias simulations. But a parameterized approach can be taken in the short term, as was done in the proposals.
- Some progress has been made towards developing an electron finder.

BACKUP

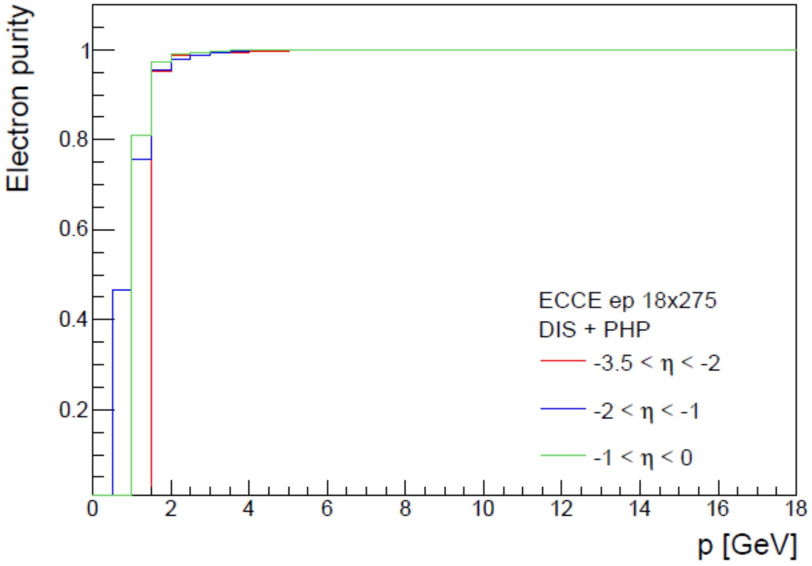
Raw backgrounds

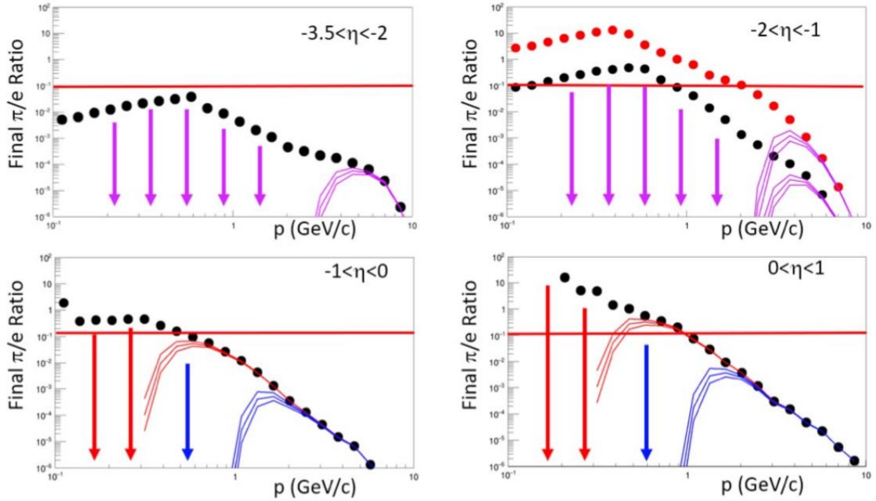


Proposal studies – Electron purity

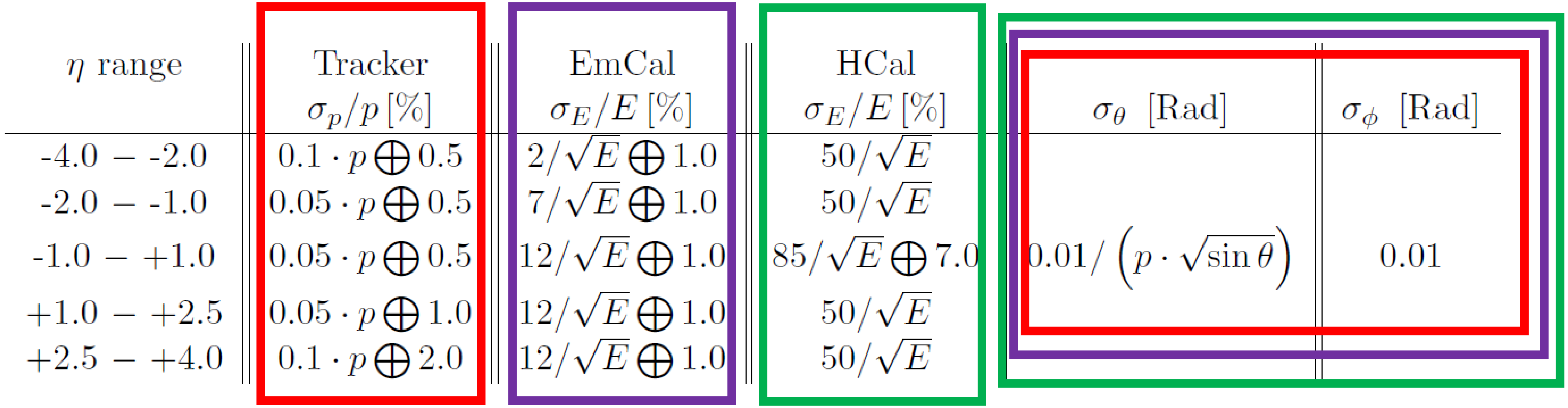


- Studies done using raw pion-to-electron ratios and applying parameterizations of calorimeter and PID detector responses.





Fast simulation for reconstruction of total E-p_z



η range	Tracker σ_p/p [%]	EmCal σ_E/E [%]	HCal σ_E/E [%]	σ_θ [Rad]	σ_ϕ [Rad]
-4.0 – -2.0	$0.1 \cdot p \bigoplus 0.5$	$2/\sqrt{E} \bigoplus 1.0$	$50/\sqrt{E}$	$0.01/\left(p \cdot \sqrt{\sin\theta}\right)$	0.01
-2.0 – -1.0	$0.05 \cdot p \bigoplus 0.5$	$7/\sqrt{E} \bigoplus 1.0$	$50/\sqrt{E}$		
-1.0 – +1.0	$0.05 \cdot p \bigoplus 0.5$	$12/\sqrt{E} \bigoplus 1.0$	$85/\sqrt{E} \bigoplus 7.0$		
+1.0 – +2.5	$0.05 \cdot p \bigoplus 1.0$	$12/\sqrt{E} \bigoplus 1.0$	$50/\sqrt{E}$		
+2.5 – +4.0	$0.1 \cdot p \bigoplus 2.0$	$12/\sqrt{E} \bigoplus 1.0$	$50/\sqrt{E}$		

Charged particles

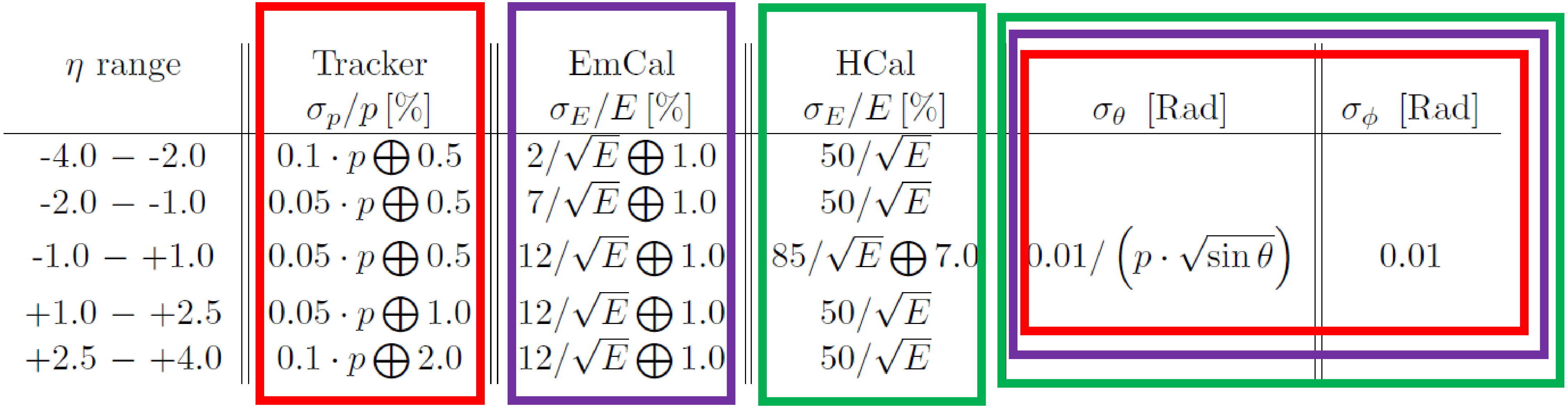
Photons

Neutral hadrons

General comments:

1. Parameterization based on Yellow Report detector matrix, with minor changes.
2. We only study events where the scattered electron is reconstructed.
3. We use the tracker to reconstruct the momentum (energy) of the scattered electron for this study.
4. When the radiated photon is within the detector acceptance, we assume it is separated from the scattered electron and can be treated as any other photon.
5. For all particles, we use a minimum P_t acceptance of $P_t > 0.25$ GeV/c.

Fast simulation for reconstruction of total E-p_z



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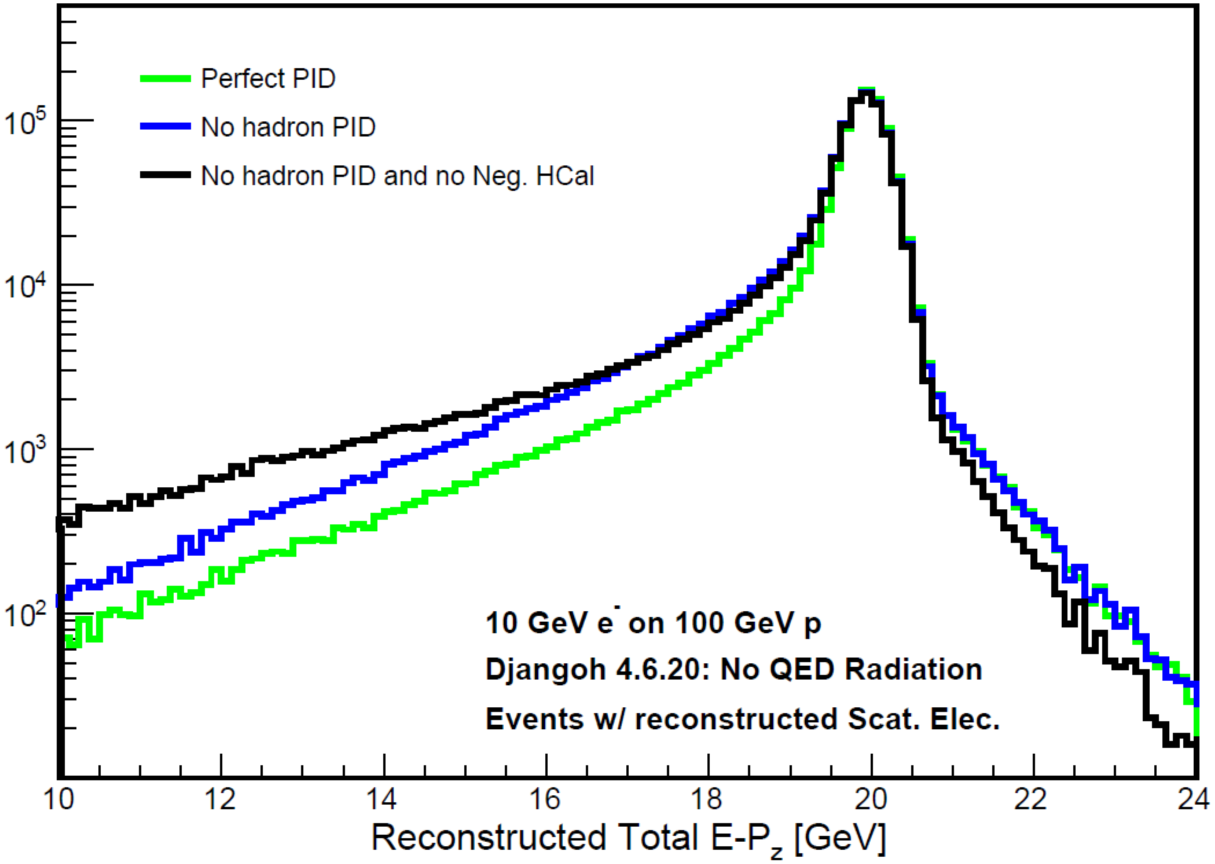
Charged particles
Photons
Neutral hadrons

We studied three different detector settings within the above detector configuration:

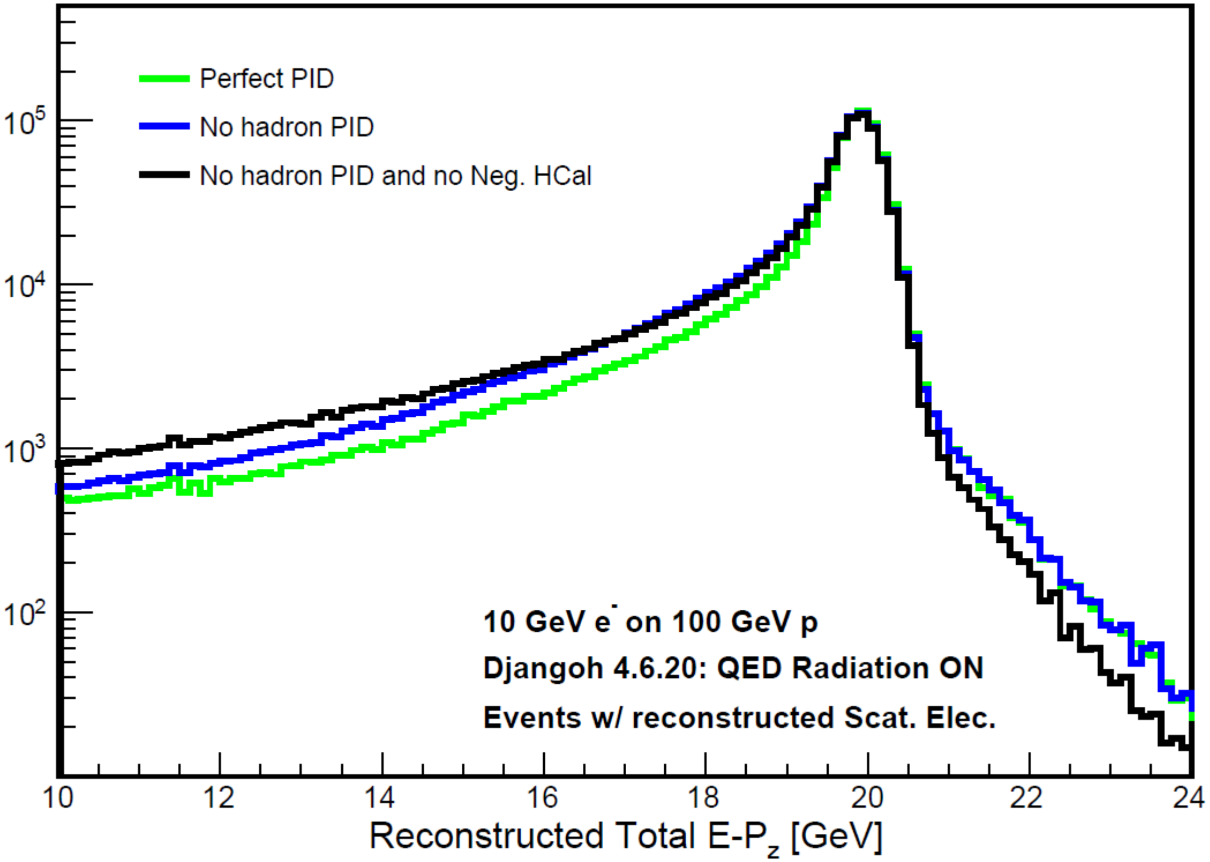
1. Perfect PID for all reconstructed particles.
2. No hadronic PID: for charged particles other than electrons and positrons, reconstruct particle using charged pion mass; for neutral hadrons, reconstruct using zero mass.
3. No hadronic PID and no backwards HCal: same as setting 2, with HCal from -4 < eta < -1 removed.

Reconstruction results – all

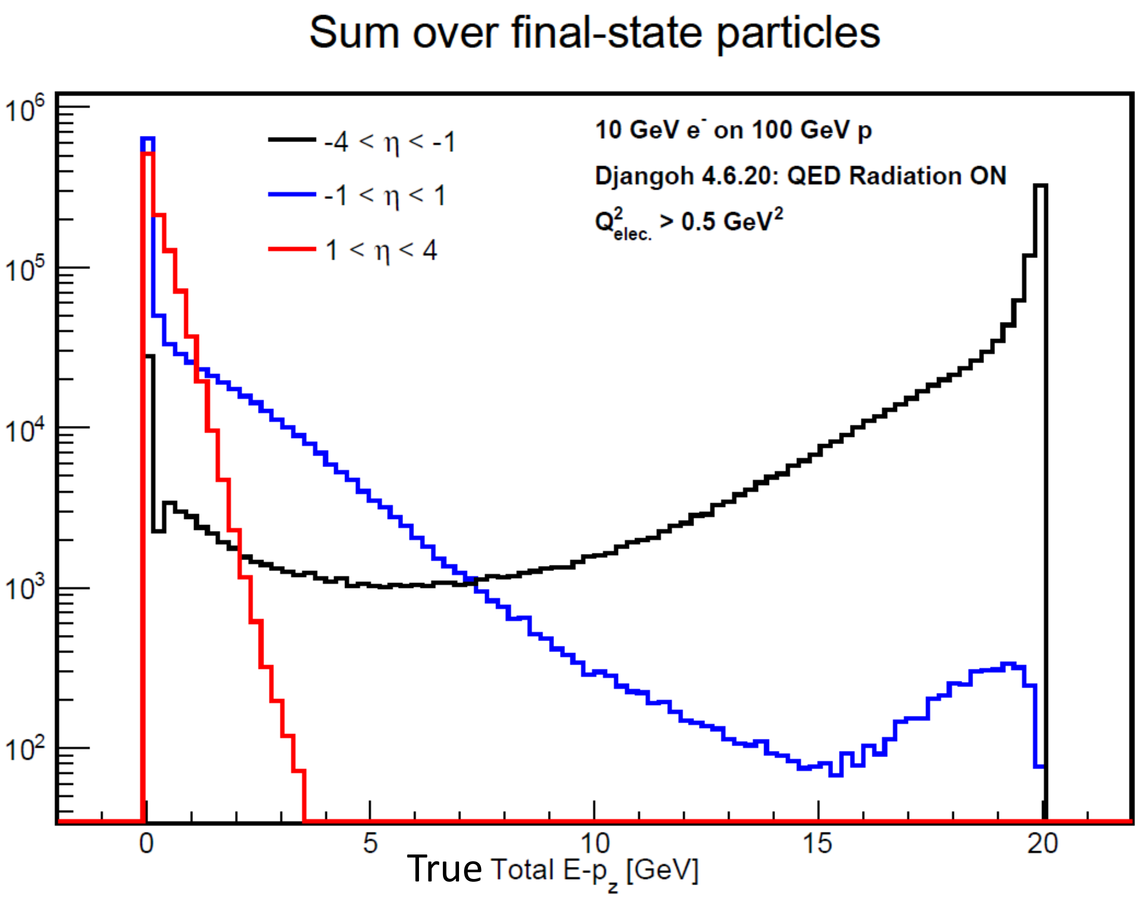
No QED effects included

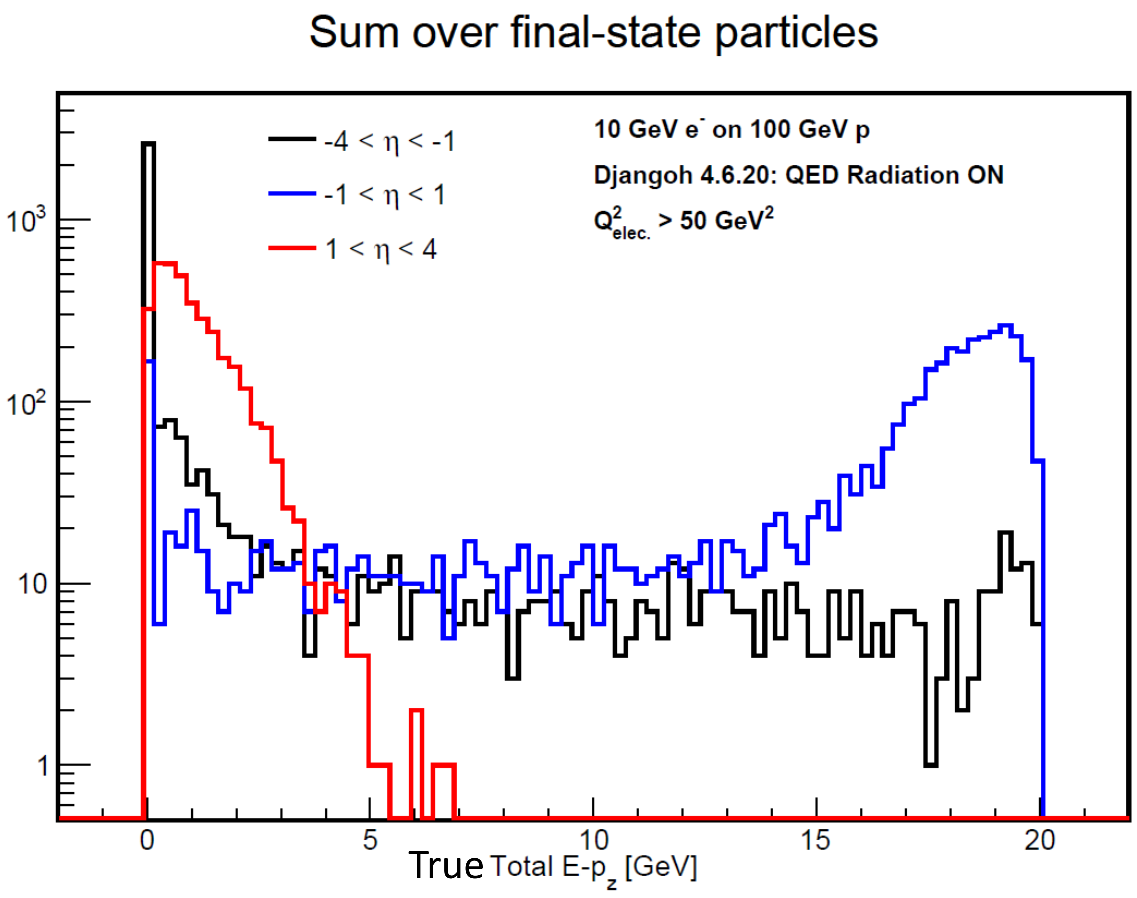


QED effects turned ON



Where in the detector does most of the total E-p_z go?





Distribution of the total E-p_z in the detector depends strongly on the scattered electron kinematics.

Hadronic final-state (HFS) distribution and total E-p_z

- The HFS will carry a total E-p_z approximately equal to the inelasticity times twice the electron beam energy $(2yE_e)$.
- The HFS will go into the hadron endcap at lower values of y – this is, when is carries a small amount of the total E-p_z. The exception may be at very high x and Q^2 for the high beam energy setting.