Proton endcap ElectroMagnetic Calorimeter Design and Simulations

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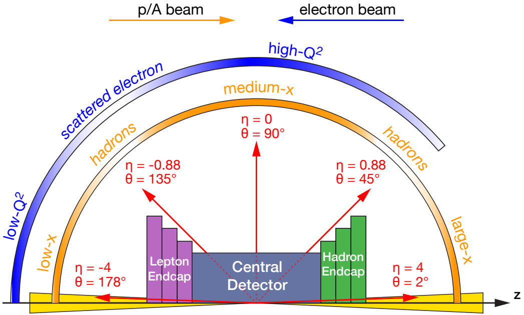
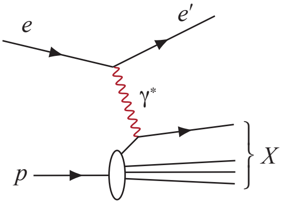
Outline

1. Physics requirements
2. Comparison of designs
3. Energy resolution
4. e/h ratio
5. $\pi^0 \to \gamma\gamma$ separation
6. Summary

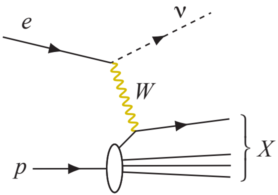
EIC physics

- Red particles are measured.
- Lepton endcap is important to reconstruct the kinematics of the scattered electron.
- Hadron endcap is important to measure hadrons in SIDIS and exclusive DIS.

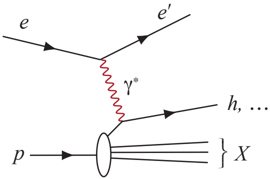




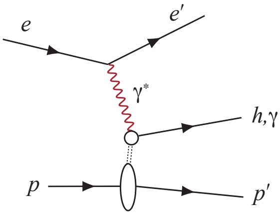
NC DIS: $e + p/A \longrightarrow e' + X$



CC DIS: $e + p/A \longrightarrow \nu + X$

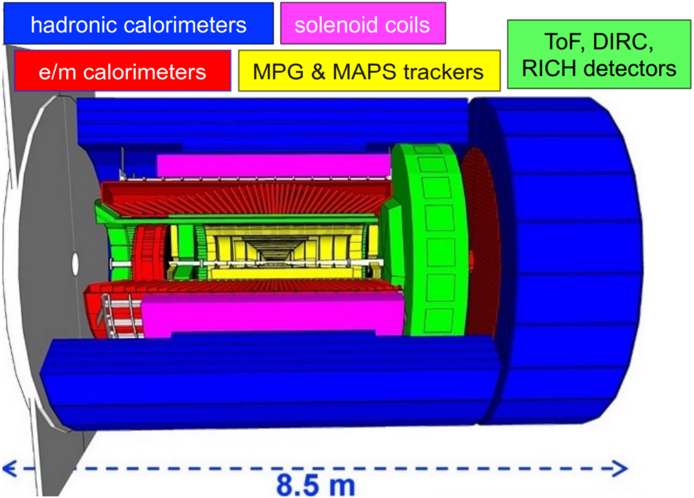


SIDIS:
$e + p/A \longrightarrow e' + h^{\pm,0} + X$



Exclusive DIS: $e + p/A \longrightarrow$
$e' + p'/A' + \gamma/h^{\pm,0}/VM$

Electron Proton Ion Collider (EPIC) Detector



Comparison of ECal designs

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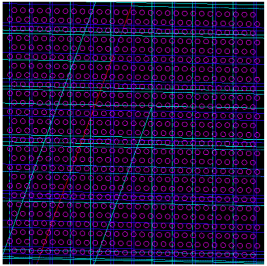
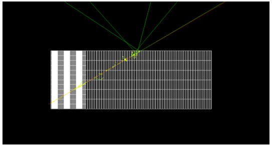
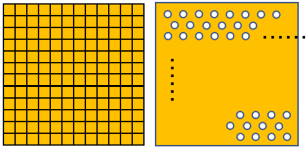
- Homogeneous ECal:
  - Reconstruct the scattered electron at the backward region.
  - Excellent energy resolution $[(2\text{–}7)\%/\sqrt{E} + (1\text{–}3)\%]$.
- Sampling ECal:
  - Measure photons and hadrons at the forward region.
  - Good energy resolution $[(10\text{–}12)\%/\sqrt{E} + (1\text{–}3)\%]$.
- Two designs of sampling ECal: W/ScFi (upper) and Shashlyc (lower).
- ECal: W/ScFi *vs* Shashlyc:
  - Both have good energy resolution.
  - W/ScFi has e/h ratio closer to 1.
  - W/ScFi has smaller radiation length.
- Readout will use SiPM.



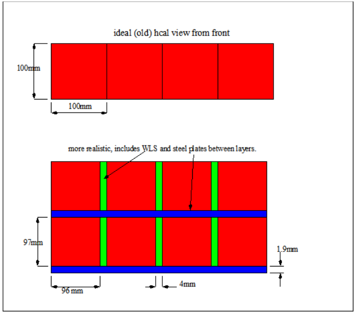


ECal and HCal configurations

- W/ScFi ECal:
  - Beehive with fibers of radius 0.235 mm.
  - Absorber: 97% Tungsten + 3% polystyrene.
  - Fiber: 100% polystyrene.
- Shashlyc ECal:
  - Sandwich with 66 layers.
  - Absorber of each layer: 1.5 mm Pb.
  - Active material of each layer: 4 mm polystyrene.
- Both ECal: 2.5×2.5 cm^2 tower of total 60×60 cm^2.
- HCal:
  - Sandwich structure: tested 36, 41, and 46 layers.
  - Absorbing material is 15/20 mm Fe.
  - Active material is 3 mm polystyrene.
  - 10×10 cm^2 tower of total 6×6 towers.
- Geant4 physics list: FTFP_BERT_HP.

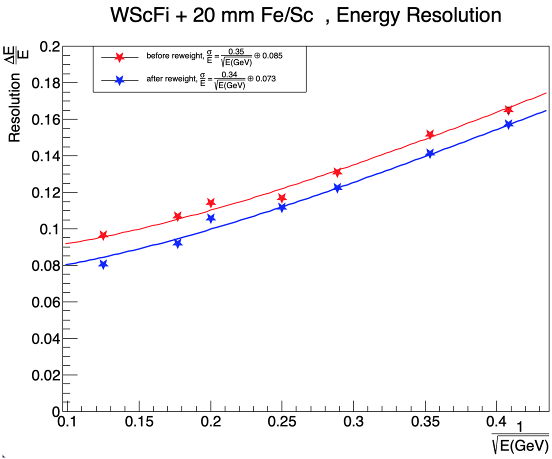


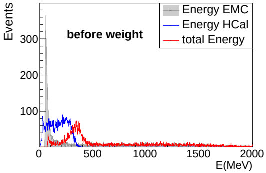
Shashlyk (front) W/ScFi (front)

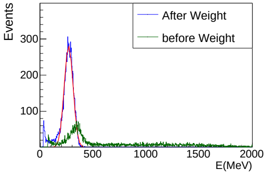


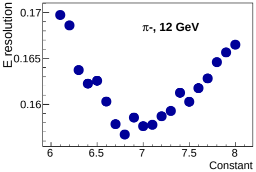
Energy weighting

- Weight energy by: $E_{tot} = E_{ECal}/C + E_{HCal}$.



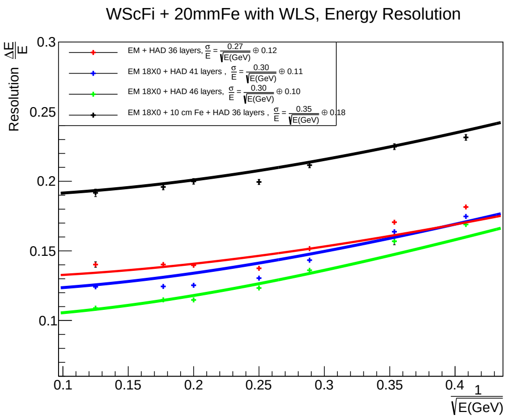




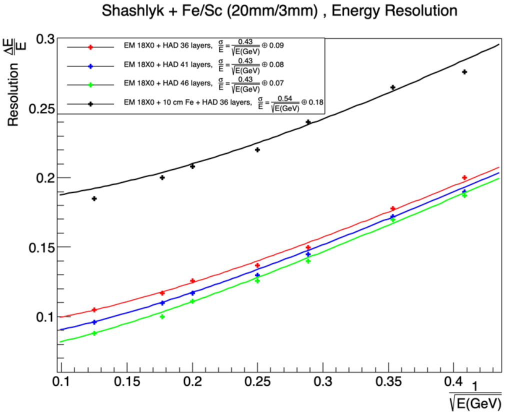


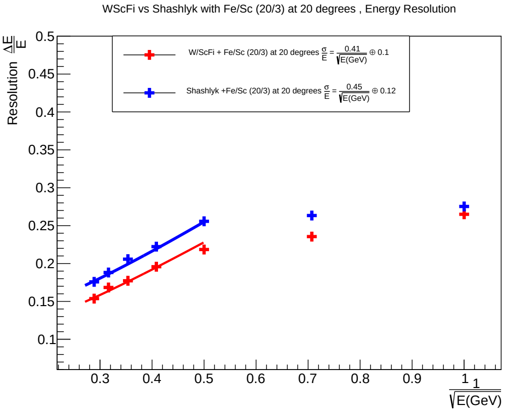
Energy resolution: W/ScFi + HCal

- W/ScFi ECal: 17 cm ($\sim 1.1\lambda_{int}$).
- Shashlyc ECal: 36.3 cm.
- 4 HCal configurations:
  - 36 layers: $\sim 4.4\lambda_{int}$.
  - 41 layers: $\sim 5.0\lambda_{int}$.
  - 46 layers: $\sim 5.6\lambda_{int}$.
  - 36 layers + 10 cm dead layer of Fe.
- Use optimal weight.



Energy resolution: Comparison with Shashlyc





e/h ratios

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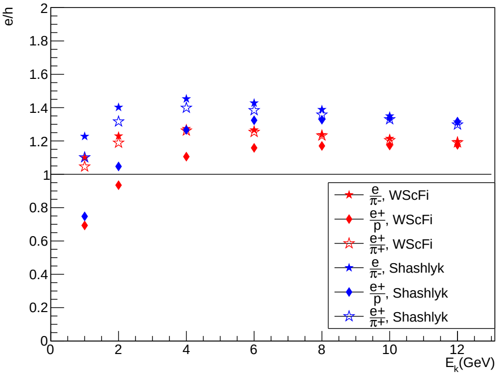
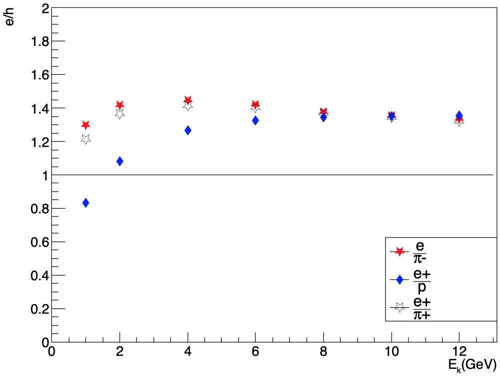
- Sandwich: $\lambda_{eff} = \dfrac{1}{\frac{x_i}{x_{tot}}\frac{1}{\lambda_i} + \frac{x_j}{x_{tot}}\frac{1}{\lambda_j}}$.
- Beehive: $\lambda_{eff} \dfrac{1}{\frac{A_i}{A_{tot}}\frac{1}{\lambda_i} + \frac{A_j}{A_{tot}}\frac{1}{\lambda_j}}$.
- Use detector length: $9\lambda_{eff}$.
- λ_{eff} (in mm) $=$ 153 (W/ScFi), 398 (Shashlyc), 187 (HCal).

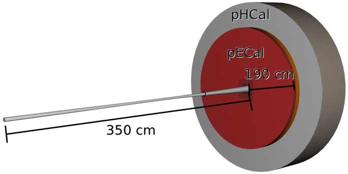
e/h for WScFi vs Shashlyk at 20 degree



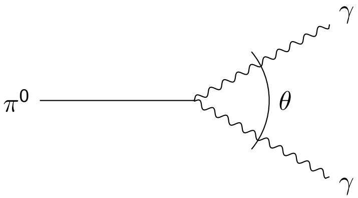
e/h for Fe/Sc at 20 degree



$\pi^0 \to \gamma\gamma$ separation



- "Usual" criteria: $\pi^0 \to \gamma\gamma$ distinguished if photons are separated by one tower size.
- pECal: 2.5×2.5 cm at z = 350 cm.
- $\theta_{min} = \frac{2.5\ cm}{350\ cm} = 0.007 \Rightarrow E_{\pi^0} = 38\ GeV$.



$$\theta_{min} = \frac{2m_{\pi^0}}{E_{\pi^0}}$$

Shower profile *vs* neural networks

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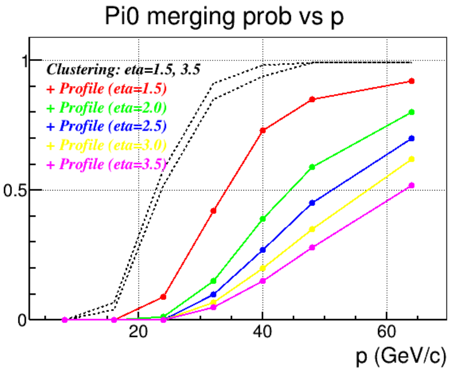
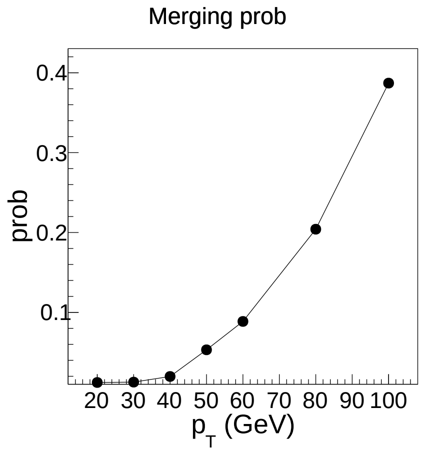
- Shower profile: $\chi^2 = \sum_i \left(\frac{E_i^{meas} - E_i^{pred}}{\sigma_i} \right)^2$
- EIC YR Fig. 11.46: pECal with granularity $\sim$0.008 (2.5×2.5 cm^2 at z=3m).



- Neural networks input ($\eta = 2$): 5×5 central tower energies; pECal x and y positions.



Summary

- Forward ECal is important to measure the photons and hadrons.
- Sampling ECal has good energy resolution and is most suitable for pECal.
- Both W/ScFi and Shashlyc designs have good energy resolution.
- W/ScFi has e/h ratio closer to 1 and less interaction length than Shashlyc design.
- Neural networks give better $\pi^0 \rightarrow \gamma\gamma$ separation than the shower profile analysis.