EMCal for eID

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For the EIC-YR-Detector-Calorimetry Group

Pavia Meeting

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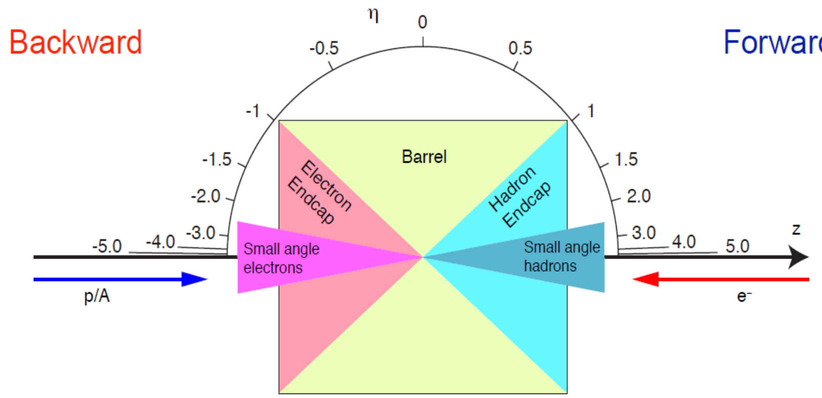
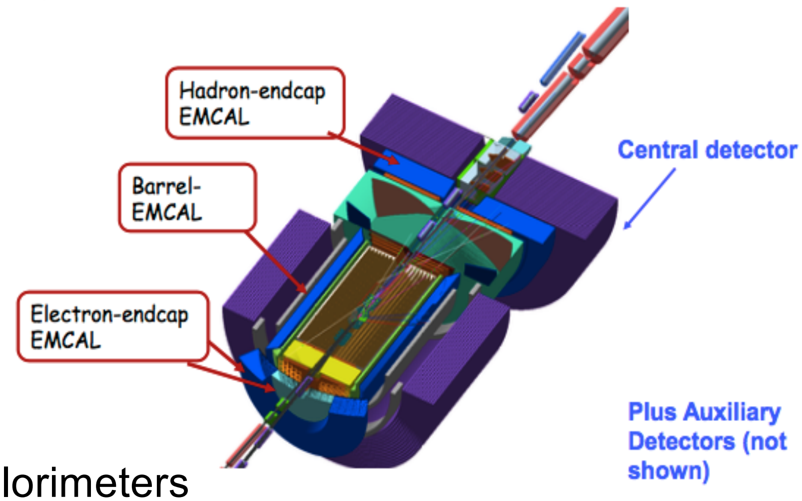
EIC Calorimetry overview



- Several options including crystals, glass, W/SciFi, Shashlyk, Pb/Sc, PbGl, etc.



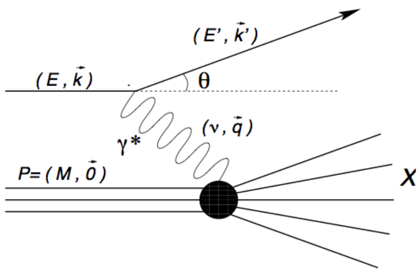
Detector Matrix for the calorimeters

η	Nomenclature	EmCal						HCal			
		Energy resolution %	Spatial resolution mm	Granularity cm^2	Min photon energy MeV	PID e/π πsuppression	Technology solution	Energy resolution %	Spatial resolution mm	Granularity cm^2	Technology solution
-3.5 : -2	backward	2/√E ⊕ 1	3/√E ⊕ 1	2x2	50	100	$PbWO_4$	50/√E⊕10	50/√E ⊕ 30	10x10	Fe/Sc
-2 : -1	backward	7/√E ⊕ 1.5	3(6)/√E ⊕ 1	2.5x2.5 (4x4)	100	100	DSB:Ce glass; Shashlik; Lead glass	50/√E⊕10	50/√E ⊕ 30	10x10	Fe/Sc
-1 : 1	barrel	(10-12) /√E ⊕ 2	3/√E ⊕ 1	2.5x2.5	100	100	W/ScFi	100/√E⊕ 10	50/√E ⊕ 30	10x10	Fe/Sc
1 : 3.5	forward	(10-12) /√E ⊕ 2	3/√E ⊕ 1	2.5x2.5 (4x4)	100	100	W/ScFi Shashlyk, glass	50/√E⊕ 10	50/√E ⊕ 30	10x10	Fe/Sc

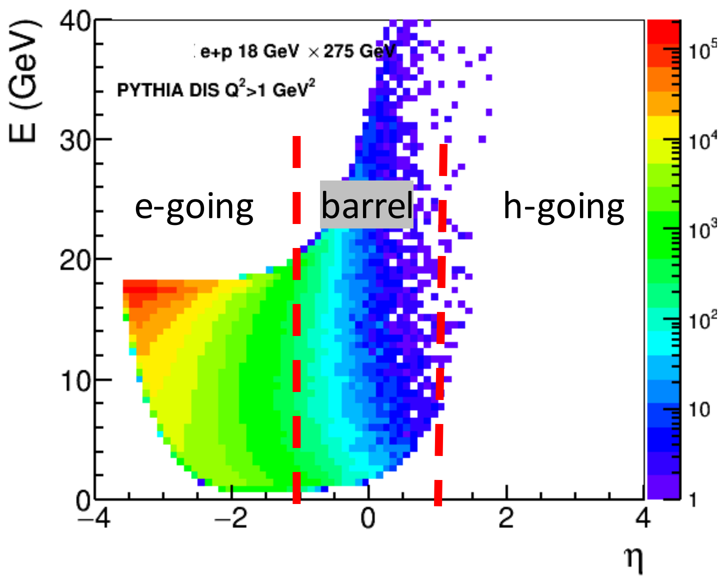
Technology selection depends on the space available
Several other technologies are under consideration
Material in front will affect the resolution

e/π: pion suppression depends on the energy, and the energy and momentum resolutions

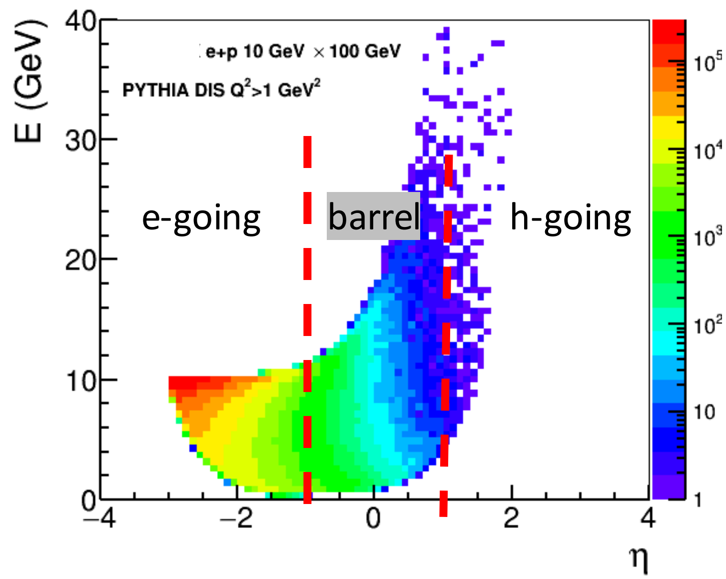
Inclusive DIS: scattered electron



e+p 18x275 GeV

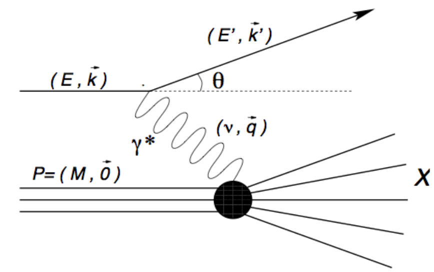


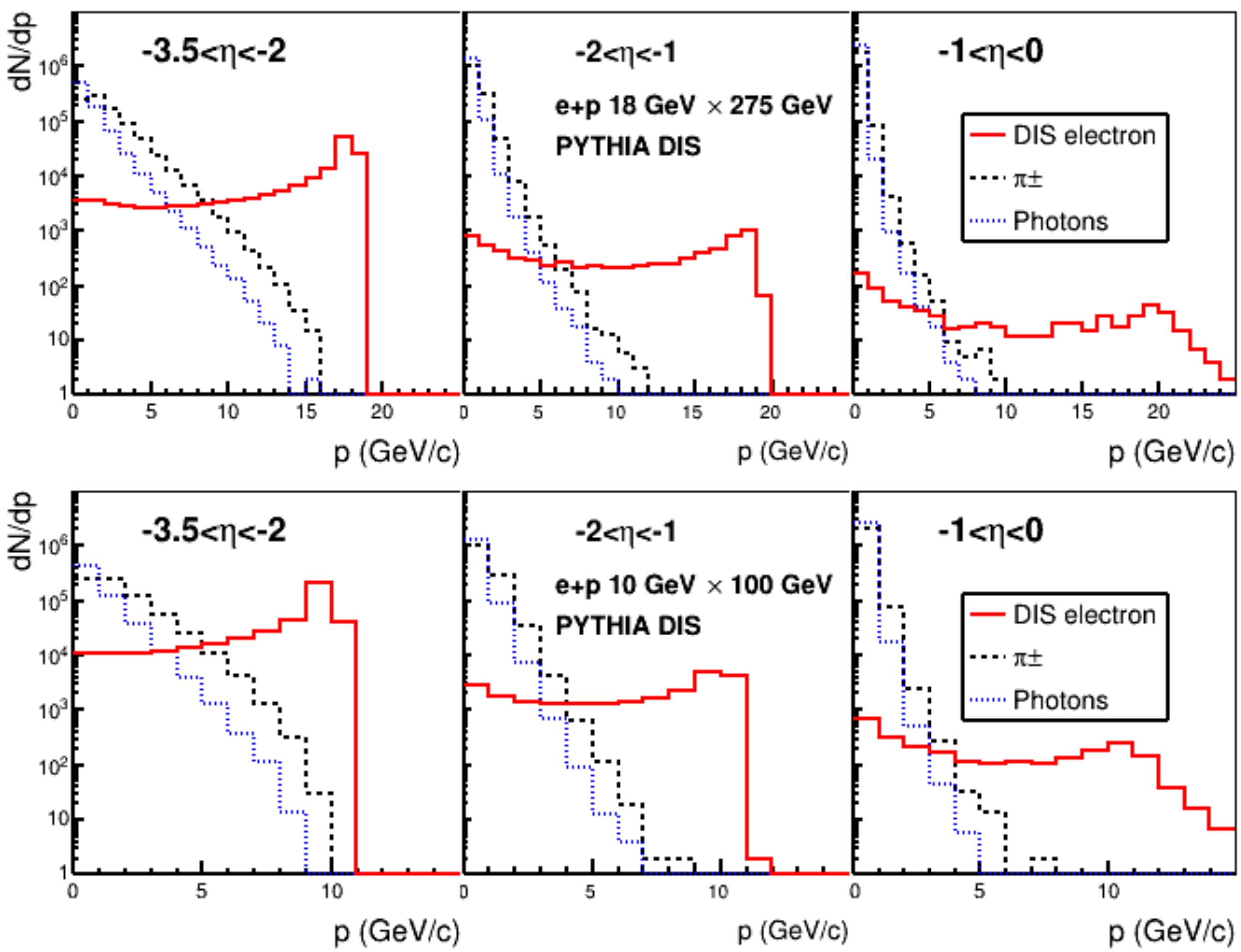
e+p 10x100 GeV



Mostly scattered in backward (e-going) and barrel
Electron energy varies from 0 to e-beam energy in backward (e-going)
And to higher energy in barrel and h-going region

Inclusive DIS: background





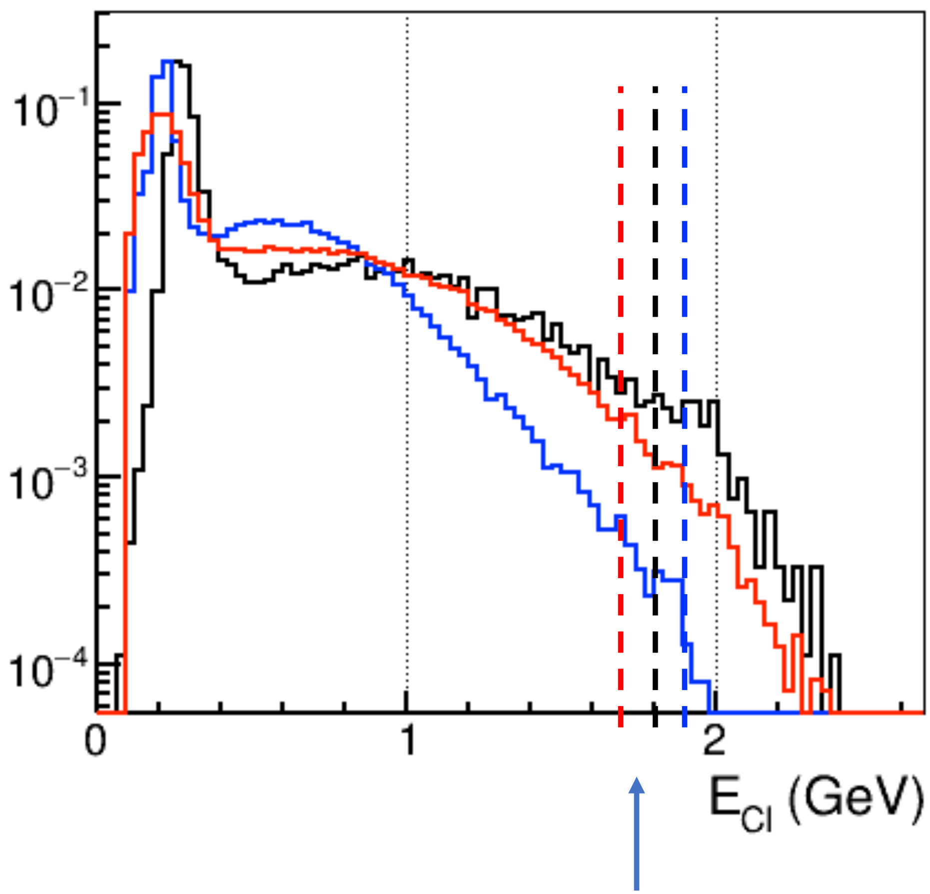
18x275 GeV

10x100 GeV

Clean measurements at higher momenta
Huge background at lower momenta

h± response in EMCal

Ideal case:
- No material on the way to EMCal
- Perfect EMCal (no gaps/cracks)
- Gaussian response to electron



E/p > 1 - 1.6 · σ_{EMC} to keep ε_e=95%

	$PbWO_4$ Crystal (GEANT)	**W/SciFi** (sPHENIX, GEANT)	**PbSc** (PHENIX, data)
Depth, X_0	20	~20	18
$\frac{\sigma_E}{E}$	$\frac{2.5\%}{\sqrt{E}} \oplus 1\%$	$\frac{13\%}{\sqrt{E}} \oplus 3\%$	$\frac{8\%}{\sqrt{E}} \oplus 2\%$
Depth, λ_I	0.87	~0.83	0.85
e/h	>2		<1.3

π± rejection with E/p cut

Ideal case:
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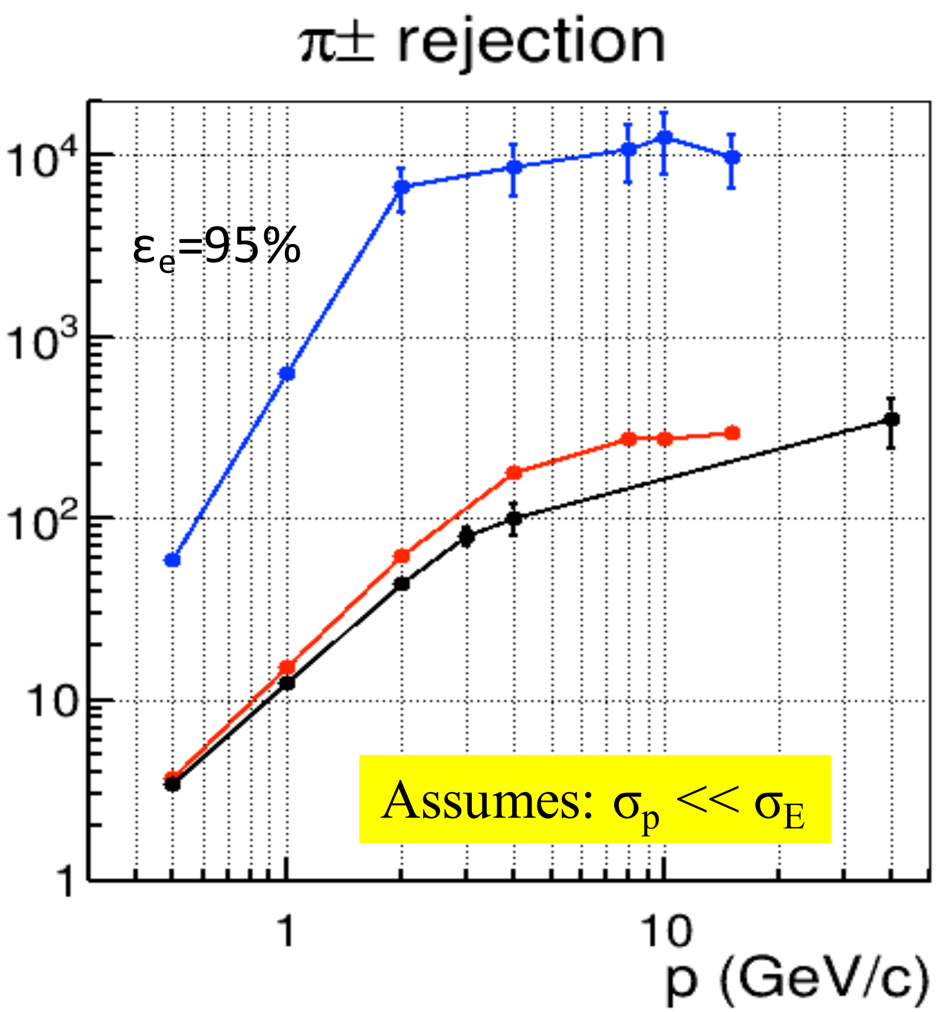

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Depth, λ_I	0.87	~0.83	0.85
e/h	>2		<1.3

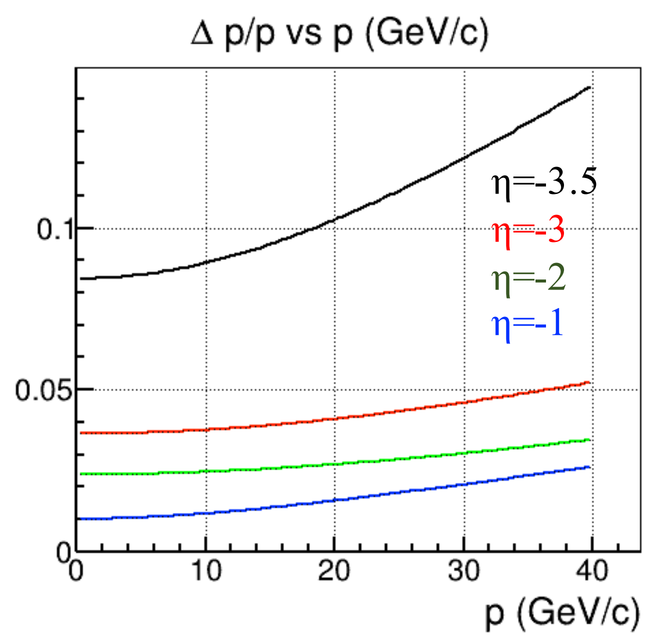
E/p > 1 - 1.6 · σ_{EMC} to keep $\boldsymbol{\varepsilon}_e$=95%

Including momentum resolution

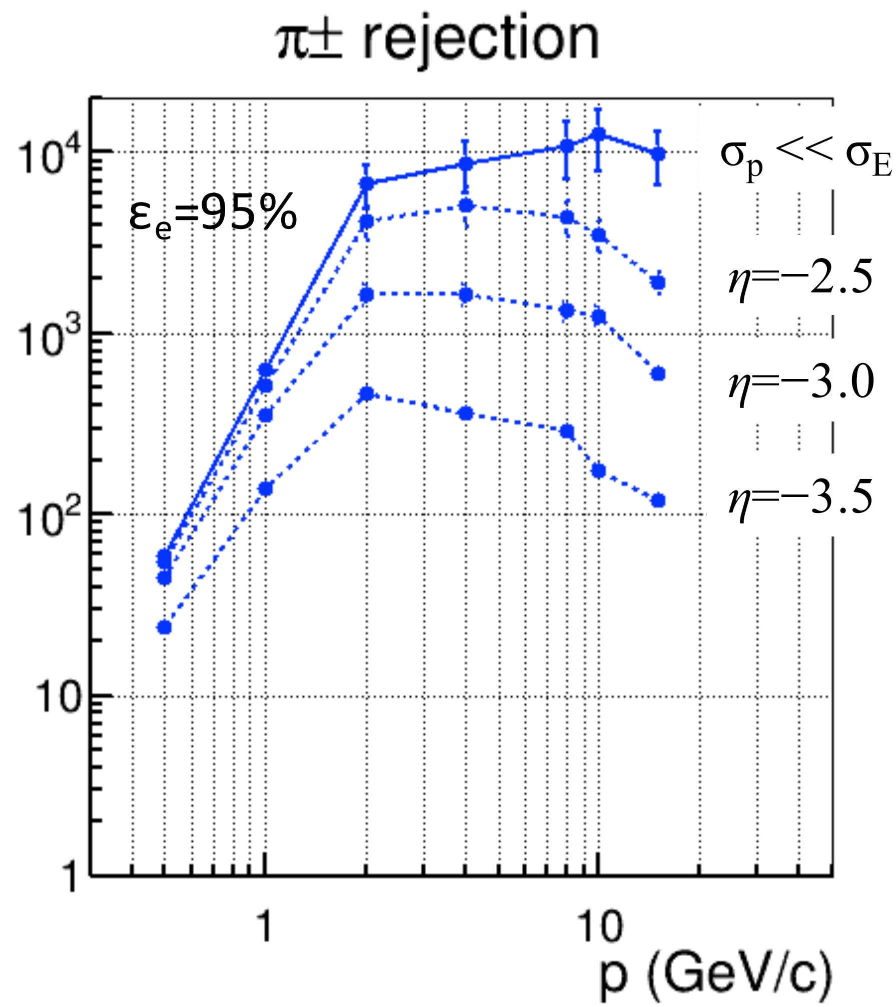
PbWO$_4$ Crystal (GEANT)

$$\frac{\sigma_E}{E} = \frac{2.5\%}{\sqrt{E}} \oplus 1\%$$

BaBar-based Tracking model:
TPC (barrel), Si +GEM (forw)
(Fun4All-GEANT4 simulation)



E/p > 1 - 1.6 · $\sqrt{\sigma_{EMC}^2 + \sigma_p^2}$ to keep ε_e=95%



DIS: Hadronic Background Suppression

PbWO$_4$ Crystal (GEANT)

$$\frac{\sigma_E}{E} = \frac{2.5\%}{\sqrt{E}} \oplus 1\%$$

BaBar-based Tracking model:
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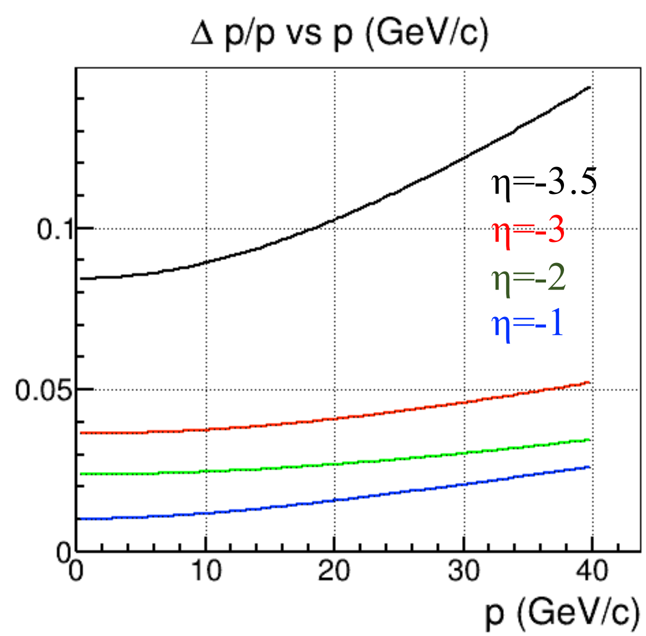
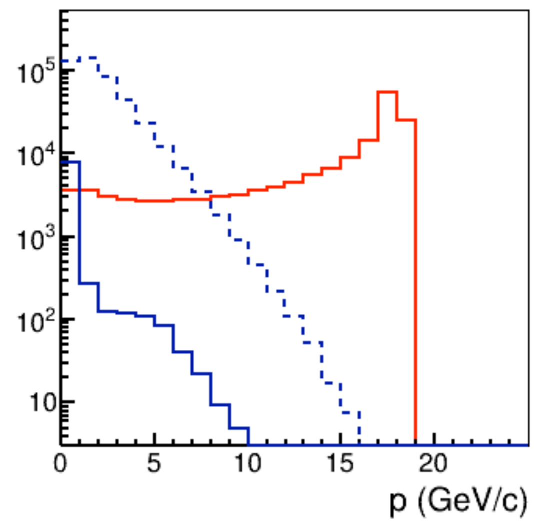
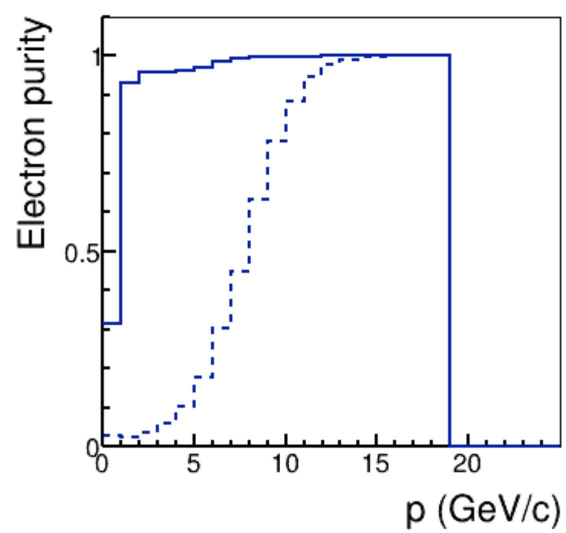


e+p 18x275
-3.5<η<-2



e
Dashed: π-
solid: π-, after E/p

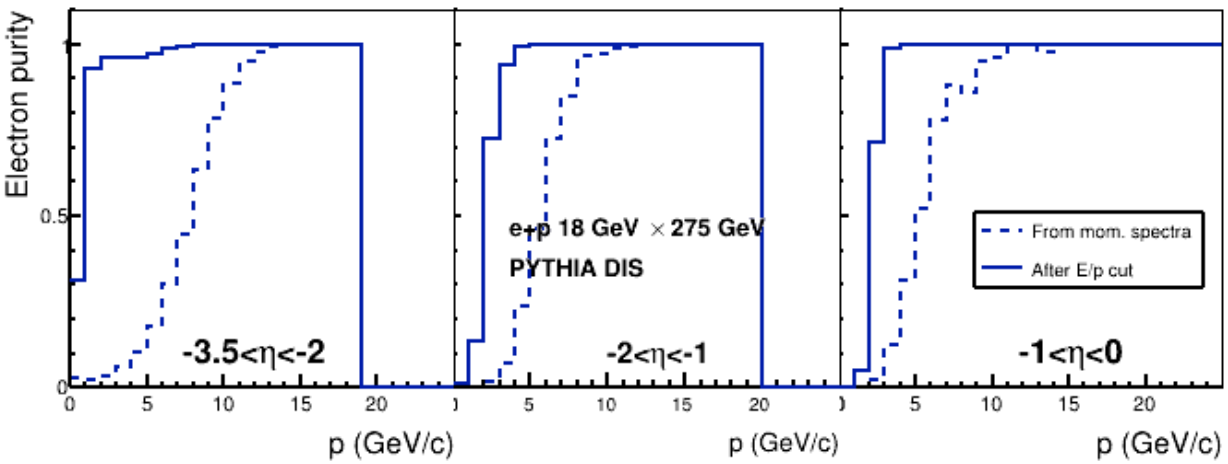


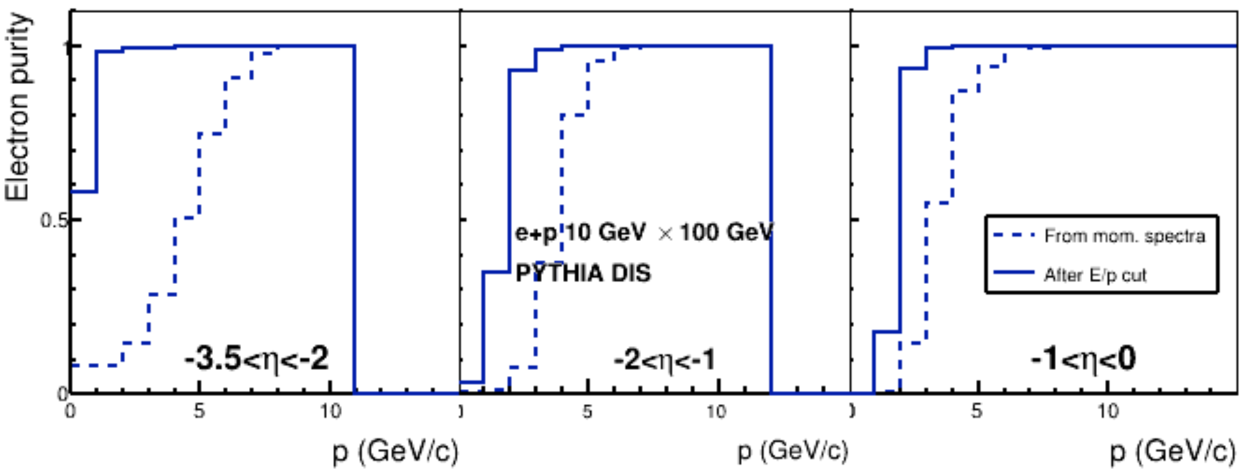
Purity = e / (e+π)

Dashed: Before E/p
Solid: After E/p

DIS scattered electron purity

-3.5<η<-2	-2<η<-1	-1<η<1
$\frac{\sigma_E}{E} = \frac{2.5\%}{\sqrt{E}} \oplus 1\%$	$\frac{\sigma_E}{E} = \frac{7\%}{\sqrt{E}} \oplus 2\%$	$\frac{\sigma_E}{E} = \frac{12\%}{\sqrt{E}} \oplus 2\%$





Ideal case:

- No material on the way to EMCal
- Perfect EMCal (no gaps/cracks)
- Gaussian response to electron

Purity = e / (e+h)

18 GeV × 275 GeV:

Clean eID at >4 GeV/c

10 GeV × 100 GeV:

Clean eID at >2-3 GeV/c

Need additional eID capabilities at p<4 GeV/c

Summary

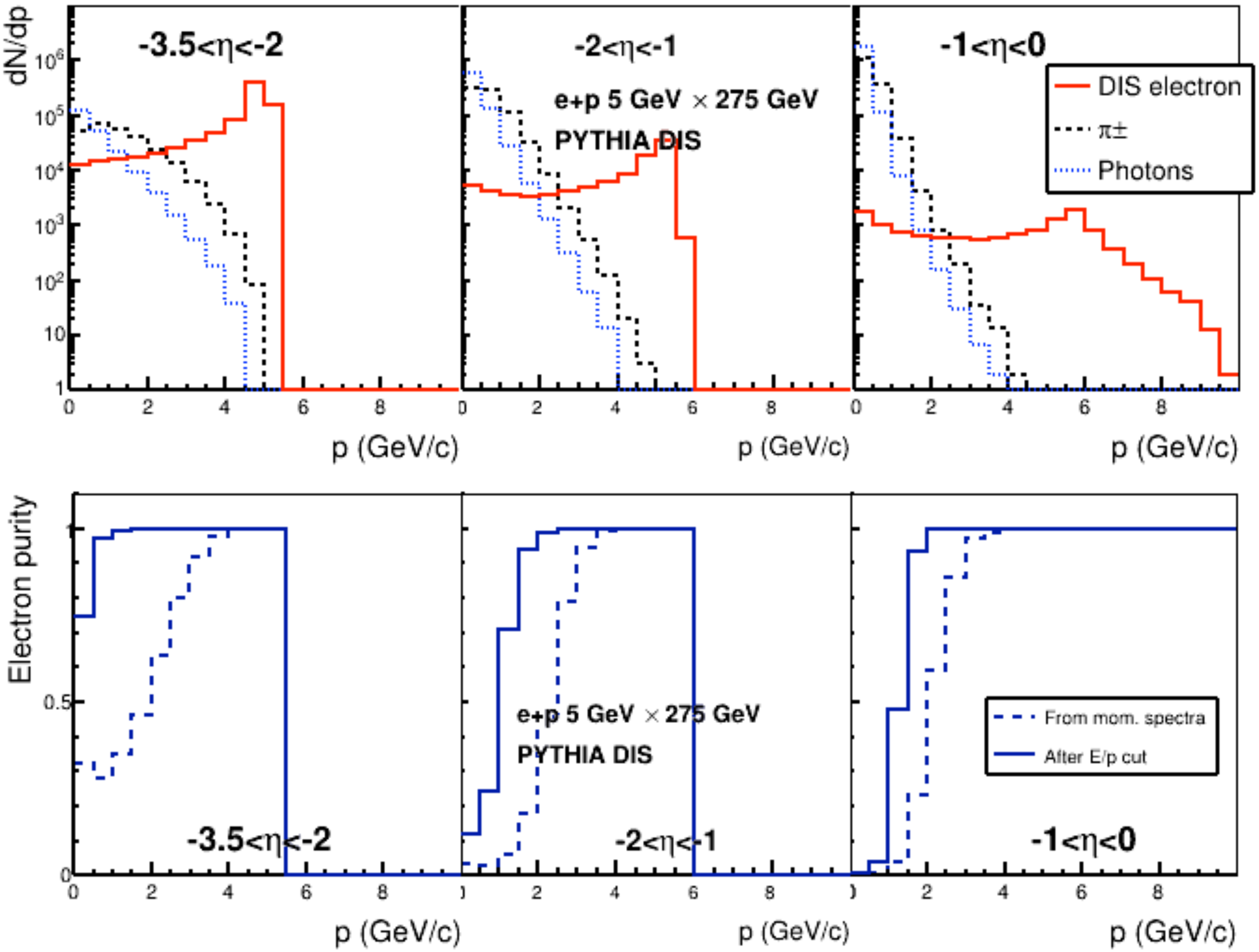
- We are at initial stage in evaluation of EMCal eID capability
  - Calculations done for “nearly ideal” detector and environment
  - Need to explore world wide experimental experience with similar EMCals
  - Need to take and evaluate test beam data for each EMCal prototype (ongoing R&D)

- Tracking momentum resolution effect is dominant in EMCal+Tracking eID capabilities in the region covered by high resolution EMCal ($-3.5<\eta<-2$)

- EMCal+Tracking eID provides high electron purity at p>4-5 GeV/c at the highest beam energy configuration
  - Need additional eID capabilities at p<4-5 GeV/c

Backup

ep 5x275

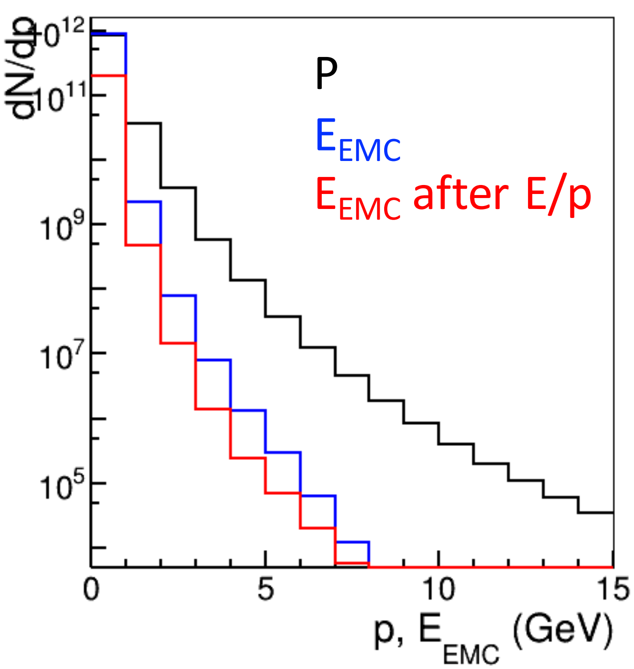


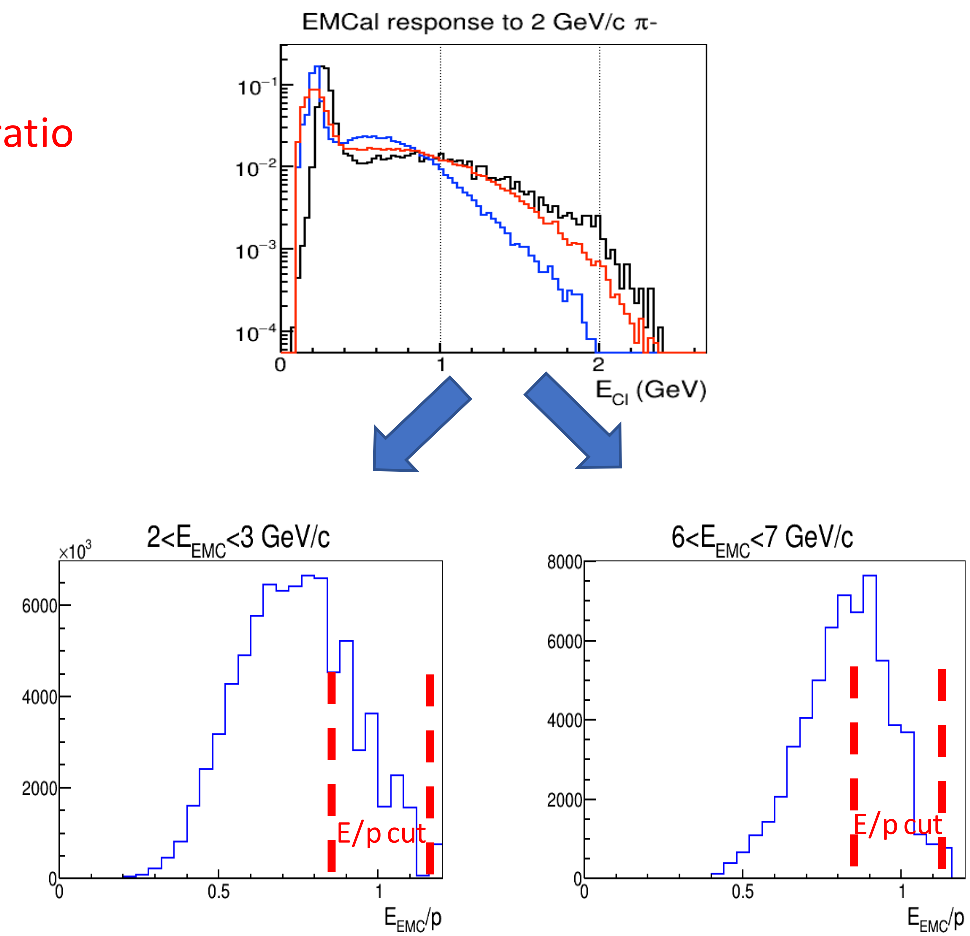
Clean eID
at p>2 GeV/c

Inclusive DIS: Background Suppression

Use $\boldsymbol{E_{EMC}}$ to measure electron candidate momentum
Use $\boldsymbol{p}$ for E/p cut

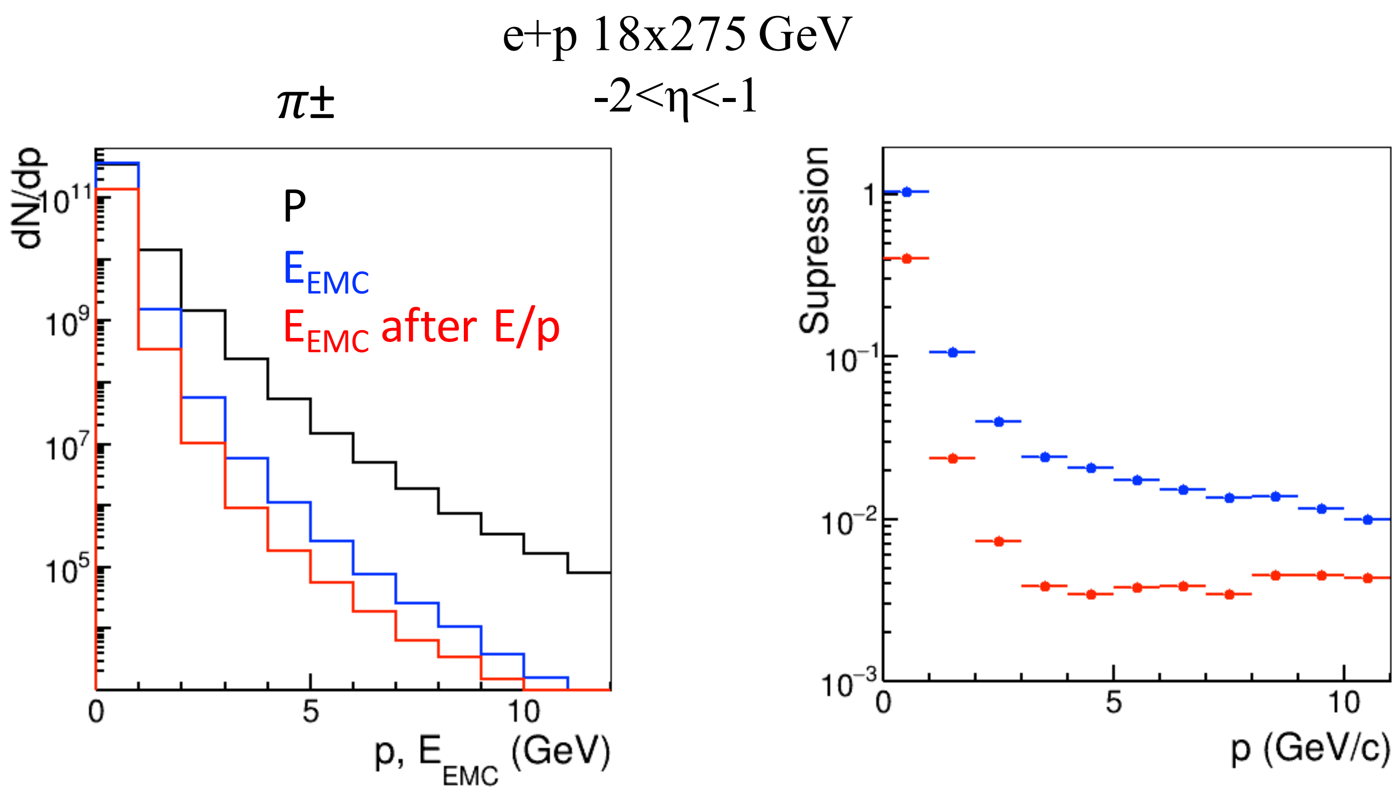
Effect of sharply falling spectrum:
Effectively selects hadrons with high E/p ratio



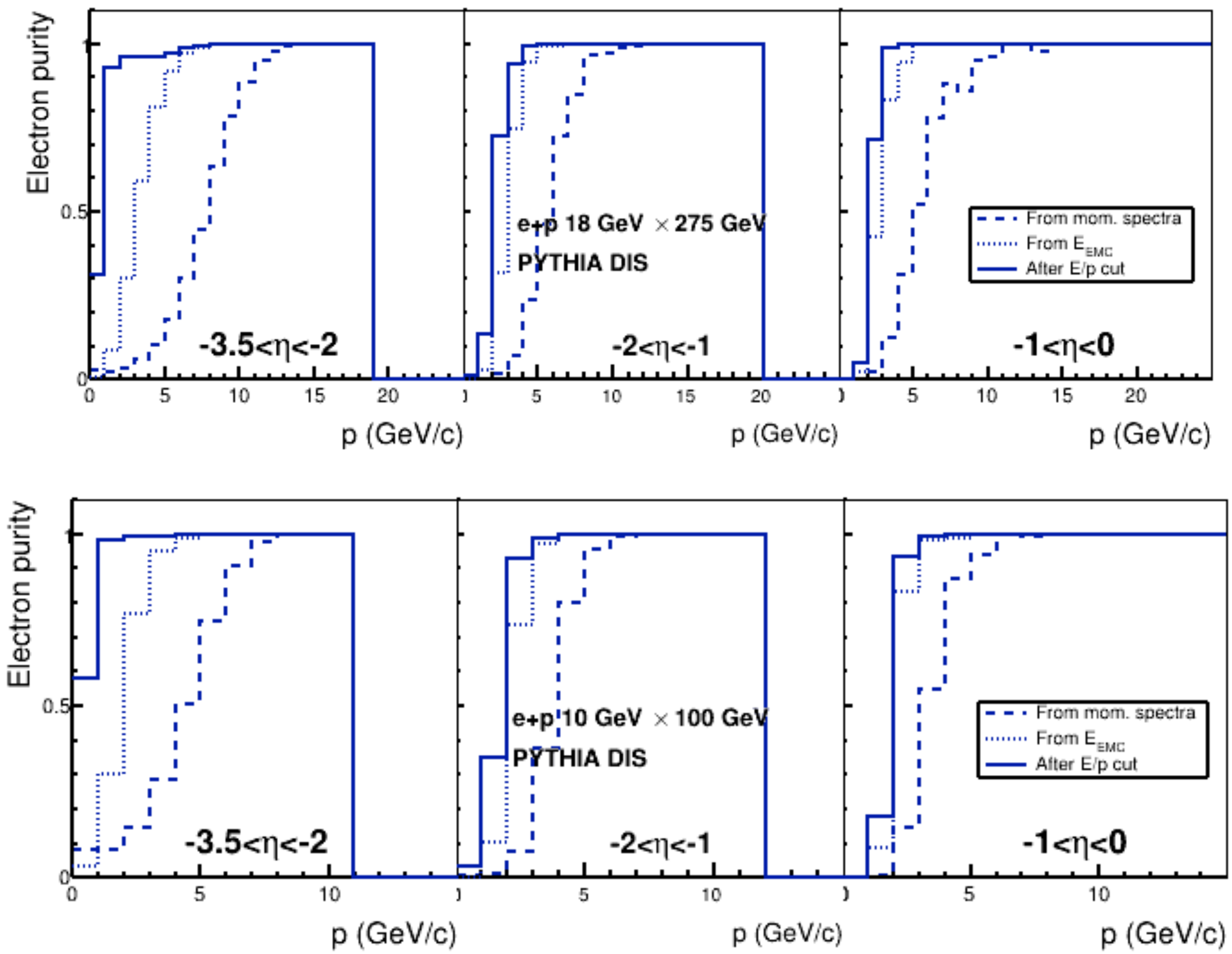


EMCal: Hadronic Background Suppression

Use $\boldsymbol{E_{EMC}}$ to measure electron candidate momentum
Use $\boldsymbol{p}$ for E/p cut



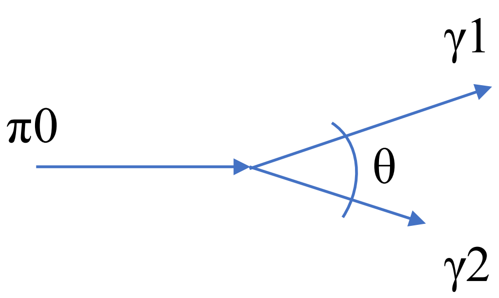
>50 charged hadron suppression at >4 GeV/c due to **EMCal response**
~300 charged hadron suppression at >3 GeV/c after **E/p cut**


Electron purity
e+p 18 GeV × 275 GeV
PYTHIA DIS
-3.5<η<-2
-2<η<-1
-1<η<0
From mom. spectra
From E_{EMC}
After E/p cut
p (GeV/c)
e+p 10 GeV × 100 GeV
PYTHIA DIS

Granularity and π0/γ discrimination in EMCal (alone)

"Usual" criteria:

$\pi \rightarrow \gamma\gamma$ distinguished if photons are separated by 1 tower size

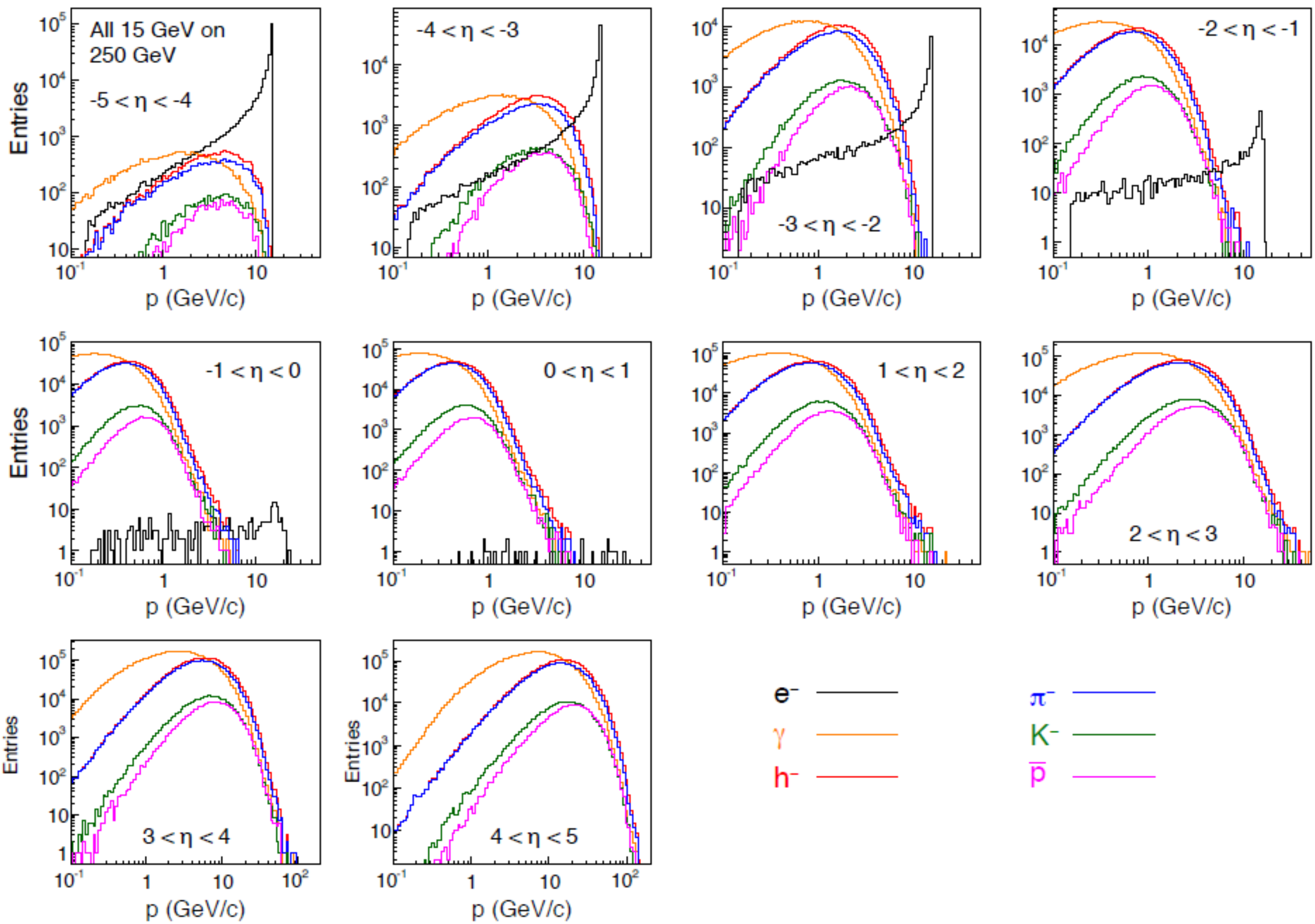


$$\theta = \frac{2m_{\pi 0}}{E_{\pi 0}\sqrt{1-\alpha^2}}$$

$$\alpha = \frac{E_{\gamma 1} - E_{\gamma 2}}{E_{\gamma 1} + E_{\gamma 2}}$$

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

Θ_{min}	$E_{\pi 0}$ GeV
0.005	54
0.01	27
0.02	13.5


All 15 GeV on
250 GeV
-5 < η < -4
-4 < η < -3
-3 < η < -2
-2 < η < -1
-1 < η < 0
0 < η < 1
1 < η < 2
2 < η < 3
3 < η < 4
4 < η < 5
Entries
p (GeV/c)
e⁻
γ
h⁻
π⁻
K⁻
p̄