EMCal for eID

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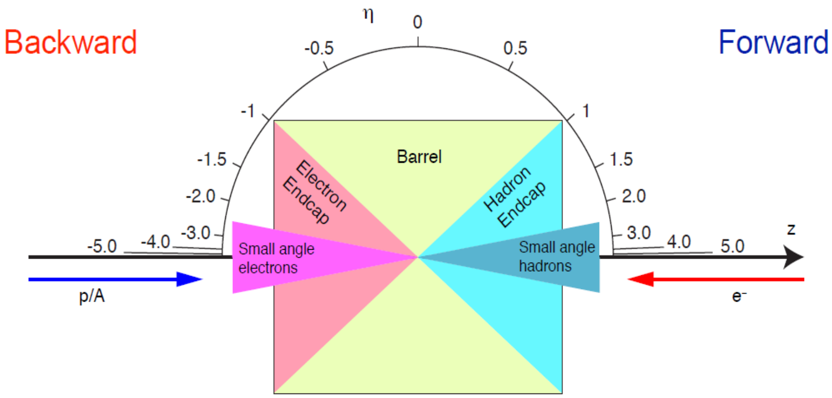
For the EIC-YR-Detector-Calorimetry Group

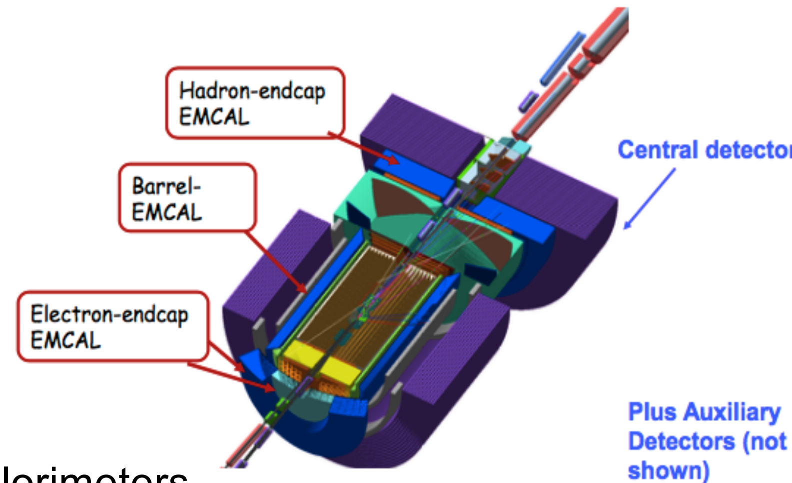
EIC-YR-Inclusive DIS Meeting

June 2, 2020

EIC Calorimetry overview



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



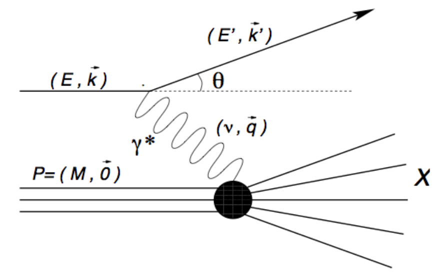
Detector Matrix for the calorimeters

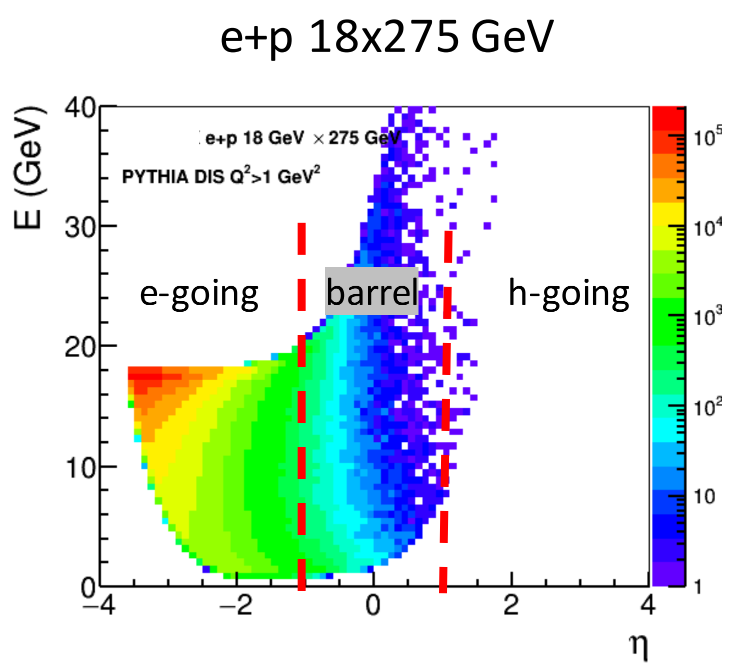
η	Nomenclature	EmCal						HCal			
		Energy resolution %	Spatial resolution mm	Granularity cm^2	Min photon energy MeV	PID e/π πsuppression	Technology solution	Energy resolution %	Spatial resolution mm	Granularity cm^2	Technology solution
-3.5 : -2	backward	2/√E ⊕ 1	3/√E ⊕ 1	2x2	50	100	$PbWO_4$	50/√E⊕10	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

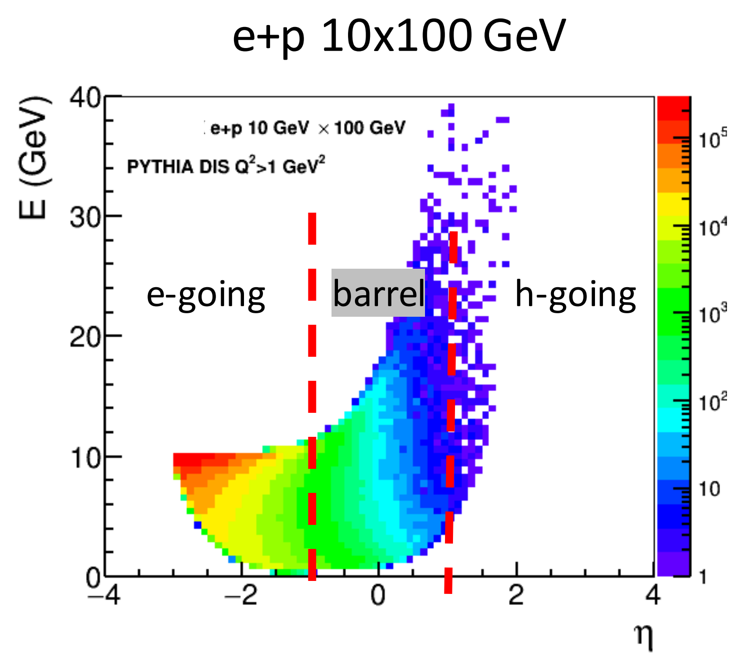
Technology selection depends on the space available
Several other technologies are under consideration
Material in front will affect the resolution

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

Inclusive DIS: scattered electron

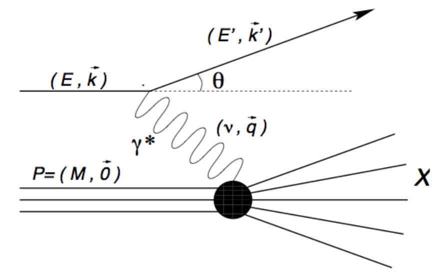


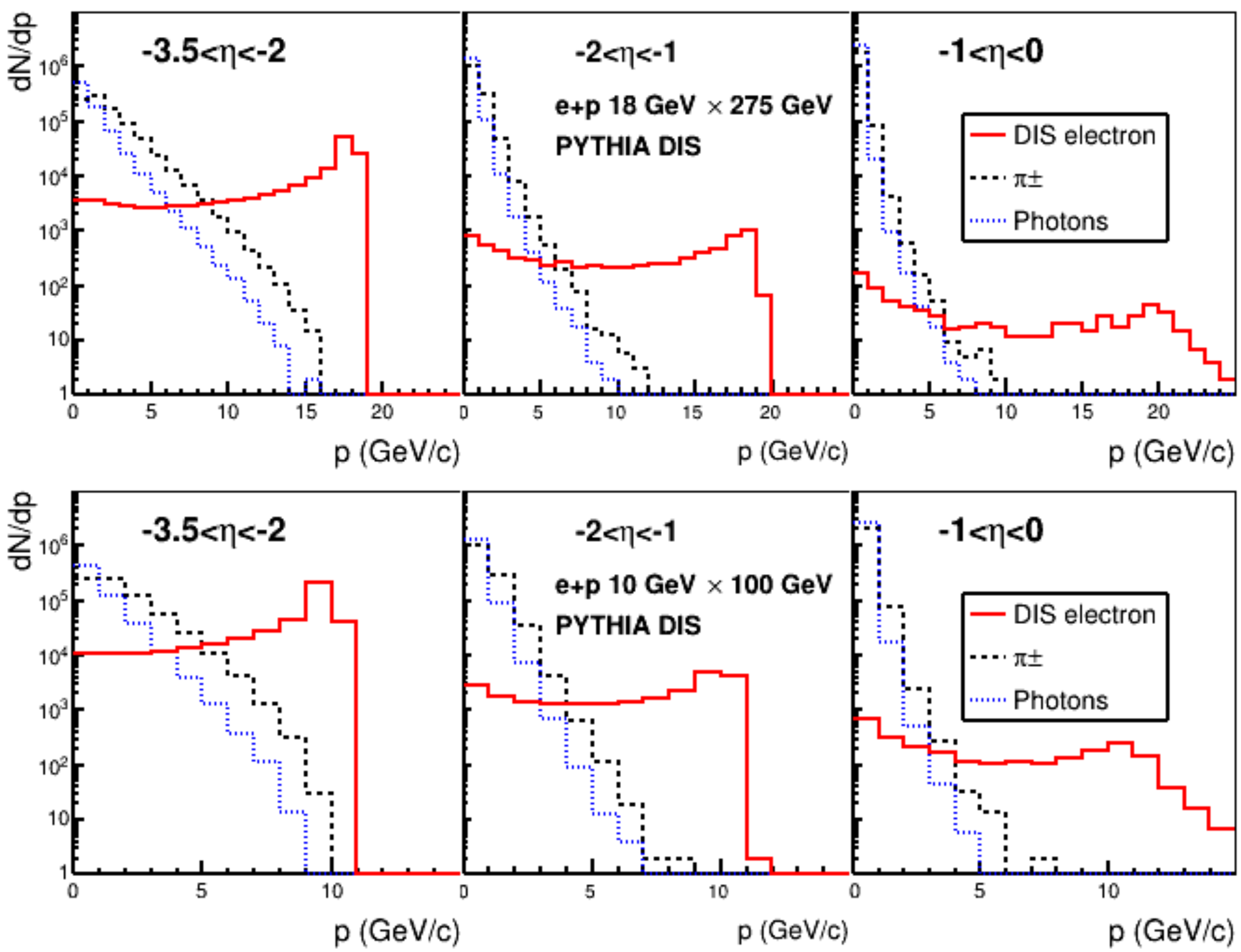




Mostly scattered in backward (e-going) and barrel
Electron energy varies from 0 to e-beam energy in backward (e-going)
And to higher energy in barrel and h-going region

Inclusive DIS: background





18x275 GeV

10x100 GeV

Clean measurements at higher momenta
Huge background at lower momenta

Background suppression tools

EMCal+Tracking

Different EMCal response to electrons and charged hadrons => E/p cut
Different transverse profile of hadronic and EM showers in EMCal

HCal:

Different long. shower profile of hadronic and EM showers => energy back leak of the EMCal (strongly correlated with with the tools above)

Other detectors:

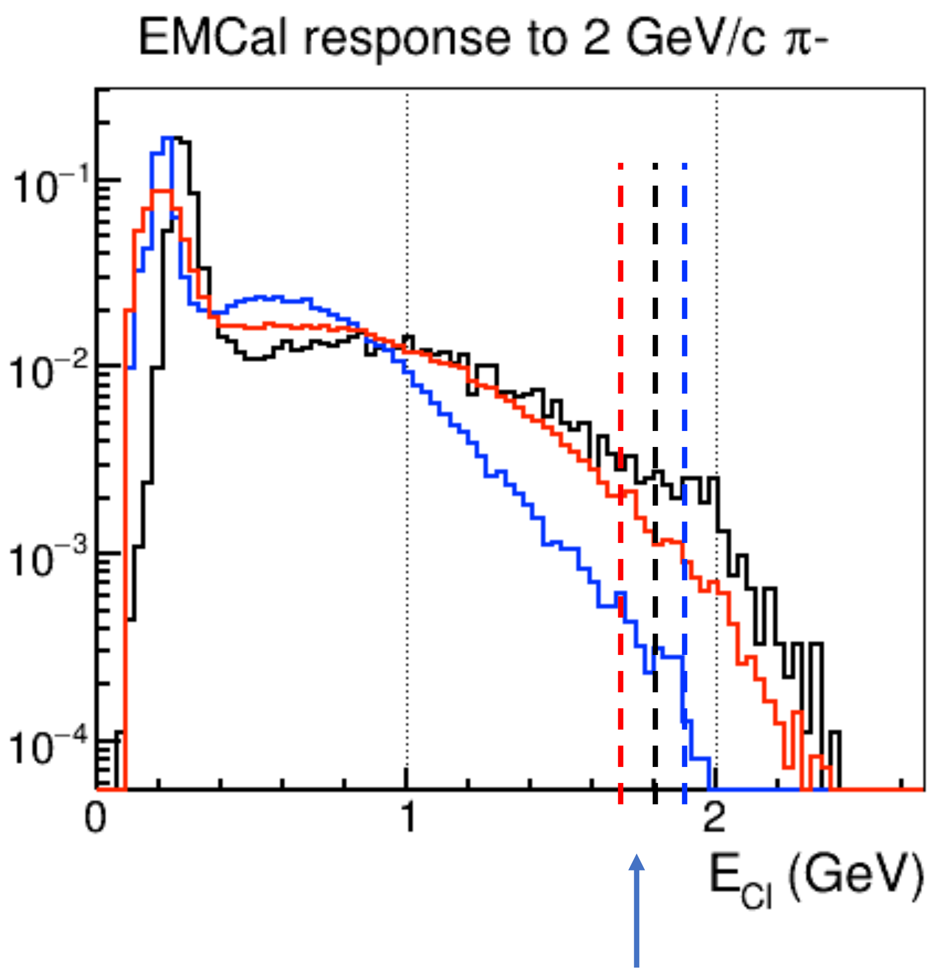
Preshower
ToF, mRICH, etc (for lower momenta)

EMCal response to electrons and charged hadrons => E/p cut

h± response in EMCal

Ideal case:

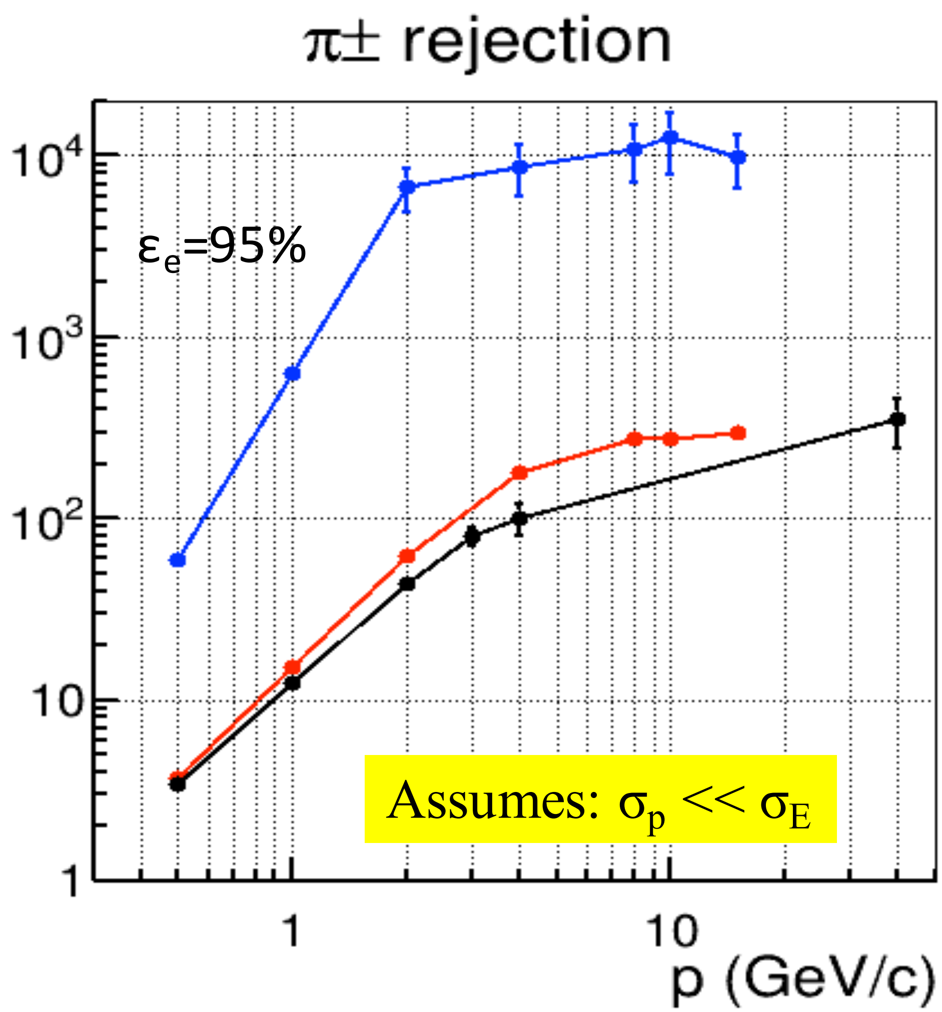
- No material on the way to EMCal
- Perfect EMCal (no gaps/cracks)
- Gaussian response to electron



	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

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

π± rejection with E/p cut



Ideal case:

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	$PbWO_4$ Crystal (GEANT)	**W/SciFi** (sPHENIX, GEANT)	**PbSc** (PHENIX, data)
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Depth, λ_I	0.87	~0.83	0.85
e/h	>2		<1.3

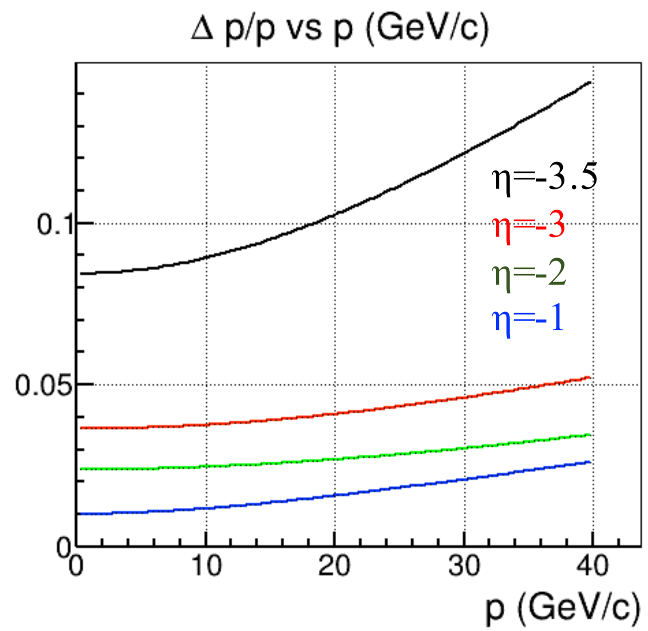
E/p > 1 - 1.6 · σ_{EMC} to keep ε_e=95%

Including momentum resolution

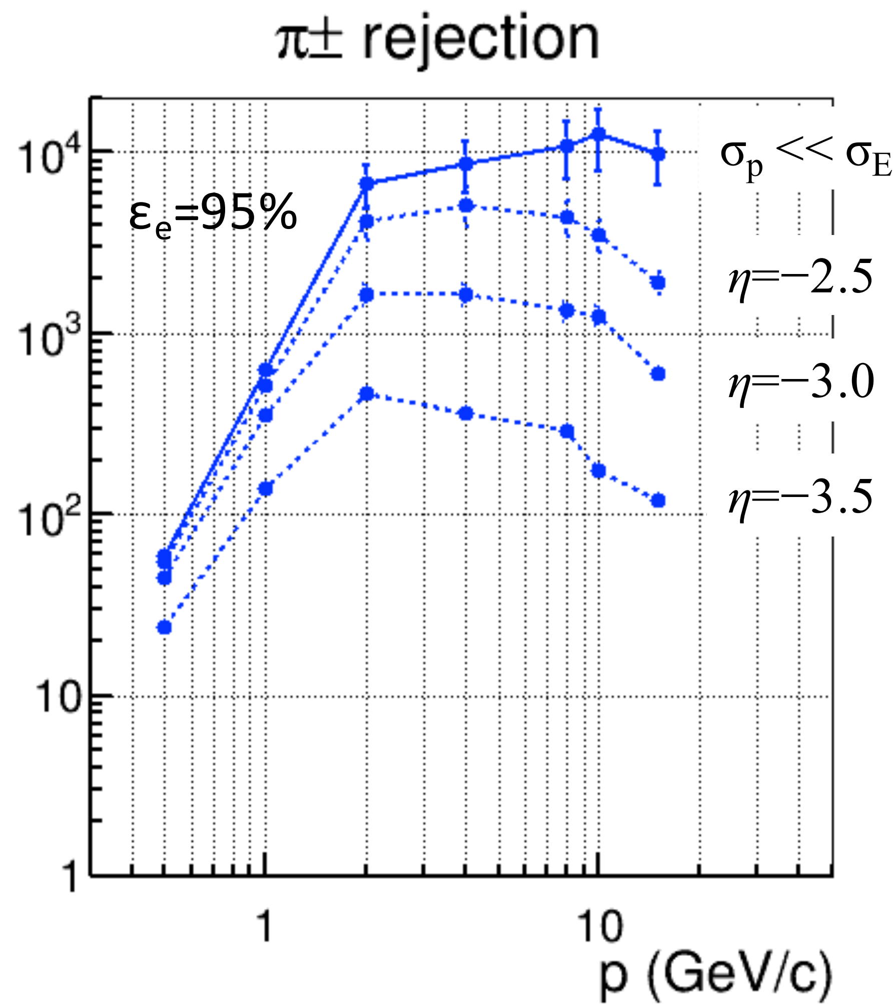
$PbWO_4$ Crystal (GEANT)

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

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



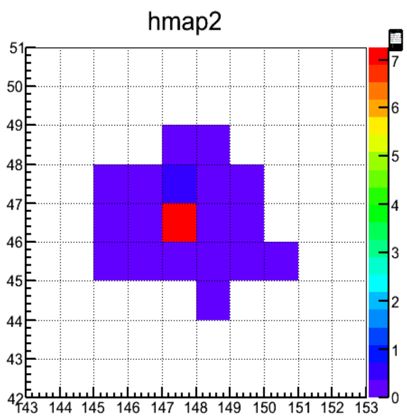
$E/p > 1 - 1.6 \cdot \sqrt{\sigma_{EMC}^2 + \sigma_p^2}$ to keep $\boldsymbol{\varepsilon}_e$=95%



Transverse profile of hadronic and EM showers in EMCal

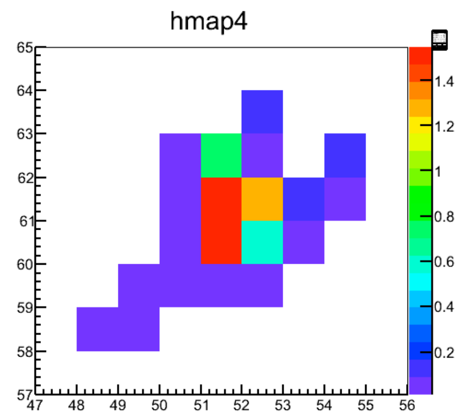
Evaluating shower profile

Electron

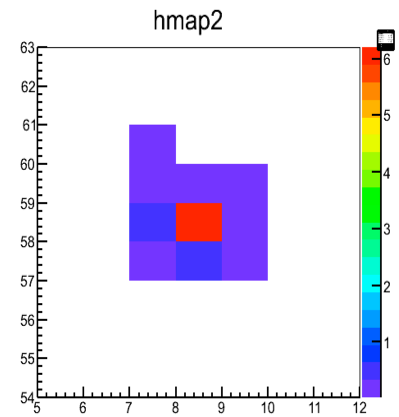


Well defined shower shape

π-



Broader shape



Very similar to electron shower shape

$$\chi^2 = \sum \frac{(E_i^{meas} - E_i^{pred})^2}{\sigma_i^2}$$

E_i^{meas} – measured energy in a tower

$E_i^{pred} = E(x_i\text{-}x_{CG}, y_i\text{-}y_{CG})$ – predicted energy in a tower from electron shower parameterization

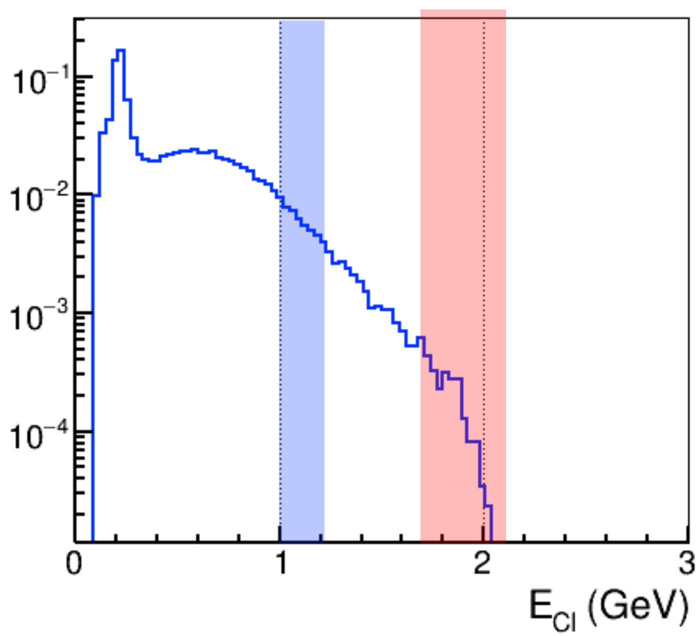
$\sigma_i = \sigma(x_i\text{-}x_{CG}, y_i\text{-}y_{CG})$ – fluctuations in a tower from electron shower parameterization

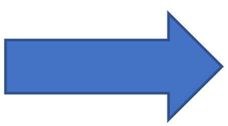
Profile χ^2 : electron vs π-

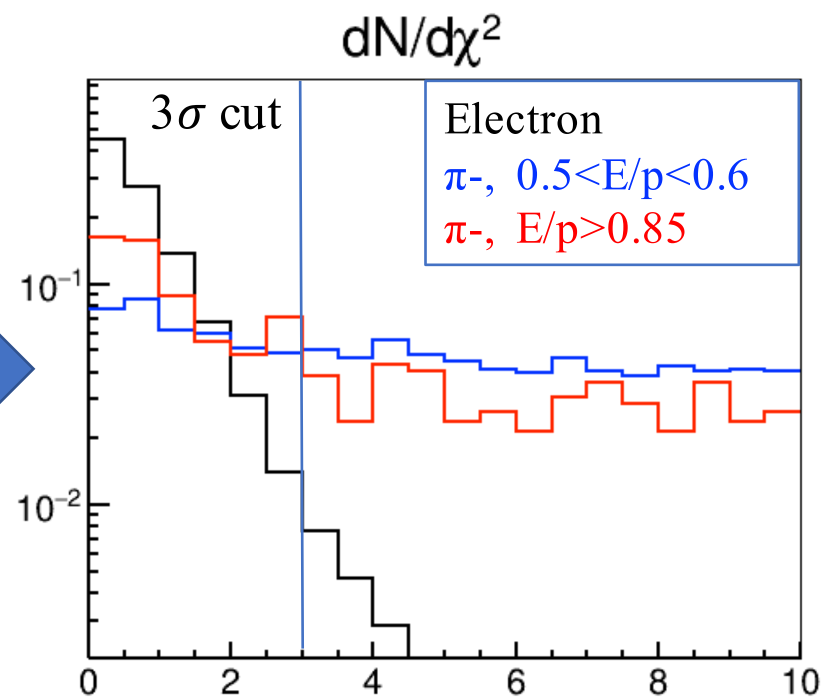
PbWO$_4$ Crystal (GEANT)

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

EMCal response to 2 GeV/c π-



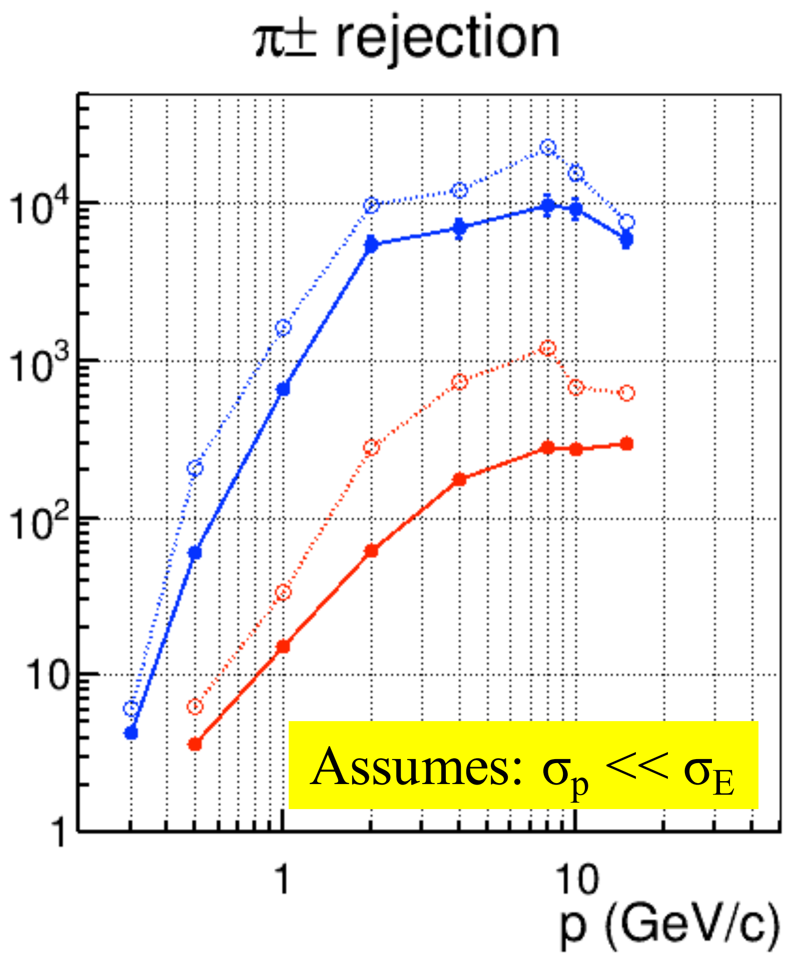




Rejection ~10

Rejection ~4

π± rejection: E/p and profile



Solid: E/p, ε_e=95%
Dashed: E/p+Prof, ε_e=92%

Ideal case:

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

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

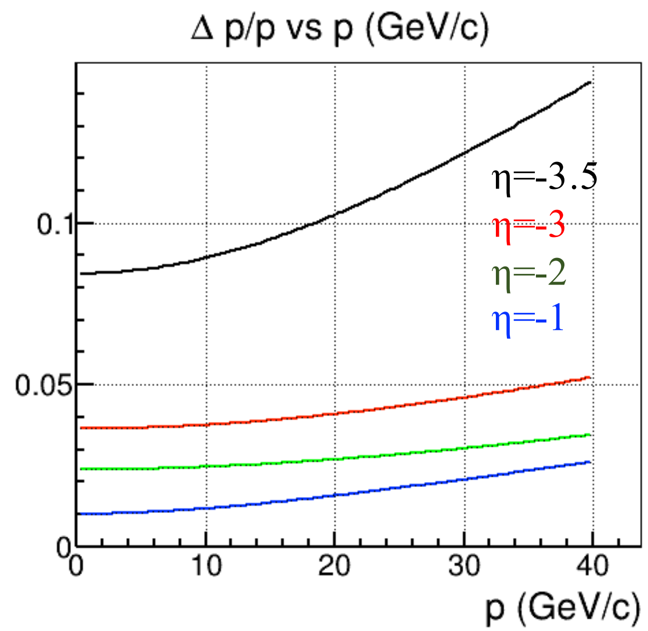
So, profile cut provides additional hadron suppression factor of 2-4

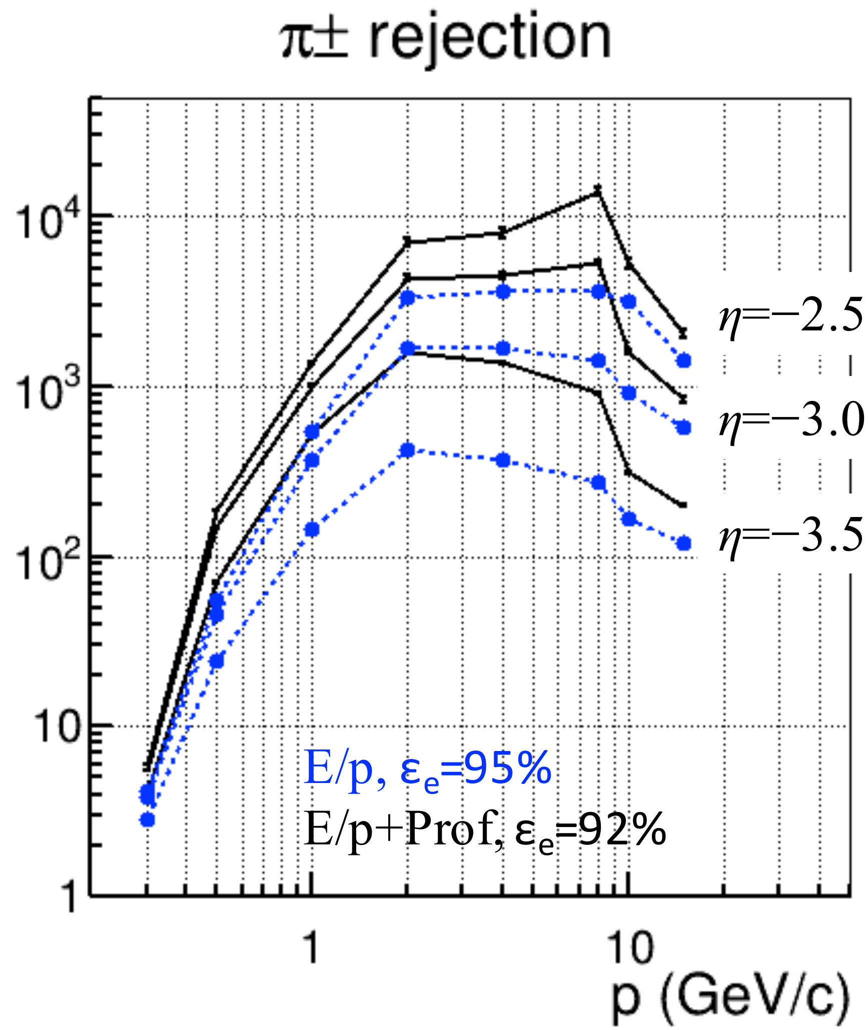
Including momentum resolution

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)





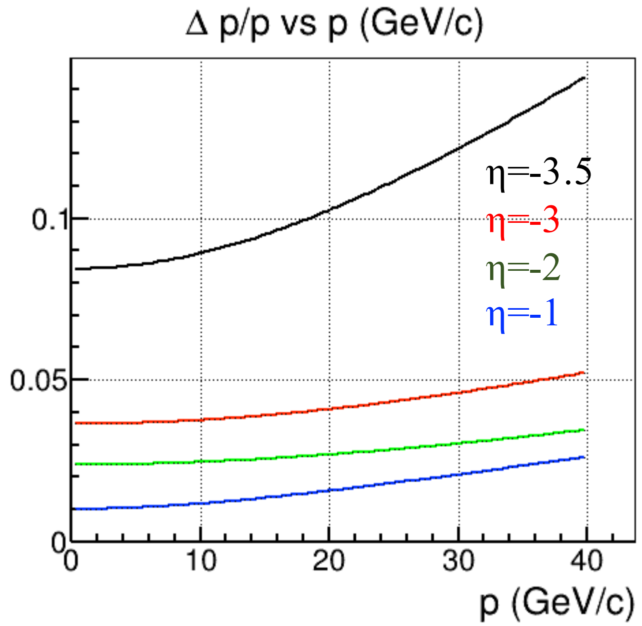
So, profile cut provides additional hadron suppression factor of 3-4

DIS: Hadronic Background Suppression

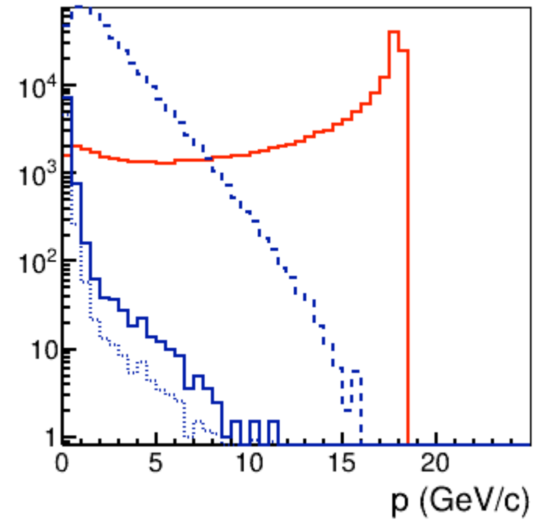
$PbWO_4$ Crystal (GEANT)

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

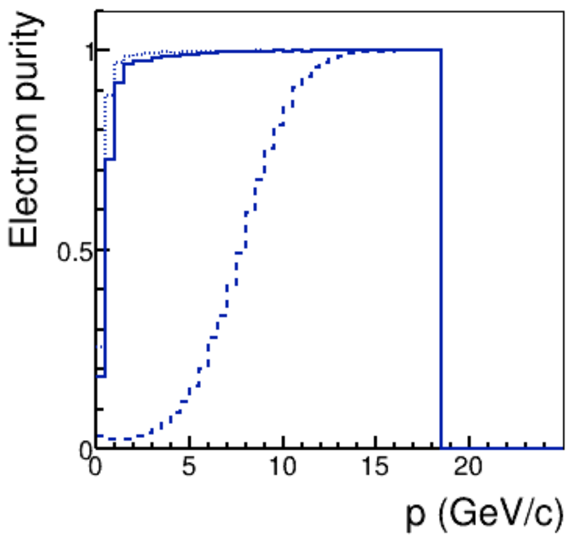
BaBar-based Tracking model:
TPC (barrel), Si +GEM (forw)
(Fun4All-GEANT4 simulation)



e+p 18x275
-3.5<η<-2



e
Dashed: π-
solid: π-, after E/p
Dotted: π-, after E/p+Prof

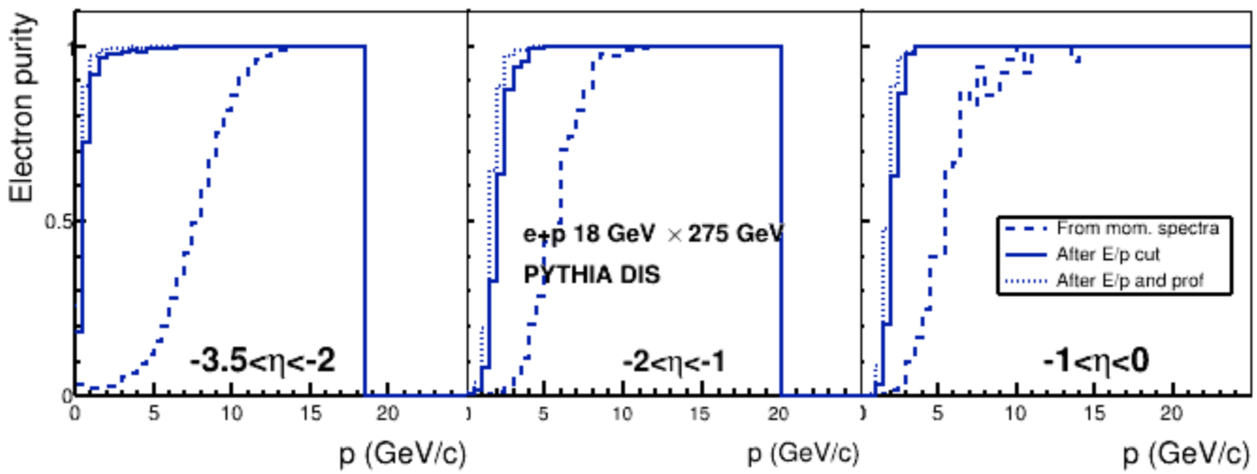


Purity = e / (e+π)

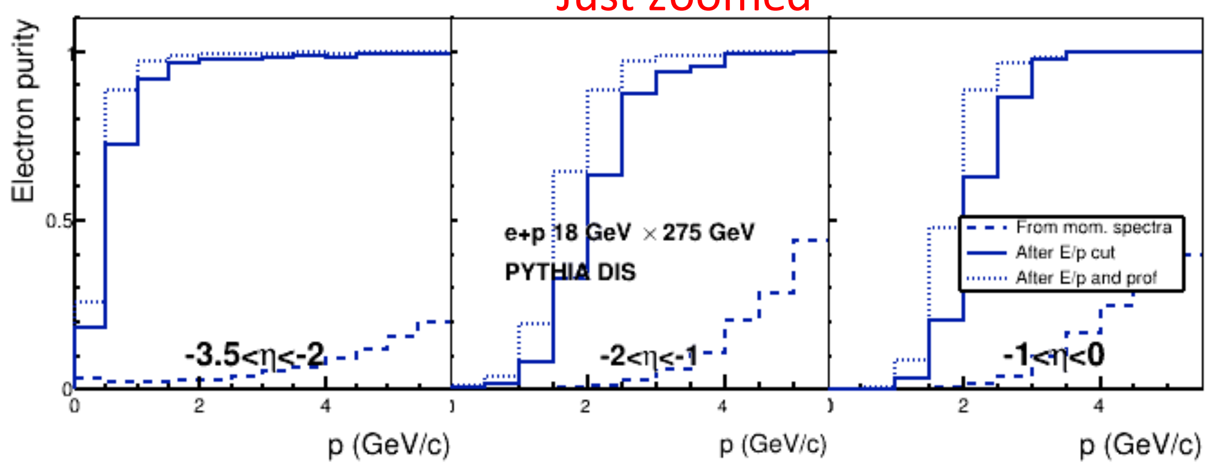
Dashed: Before eID
Solid: After E/p
Dotted: After E/p+Prof

DIS scattered electron purity

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



Just zoomed



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 >2.5 GeV/c

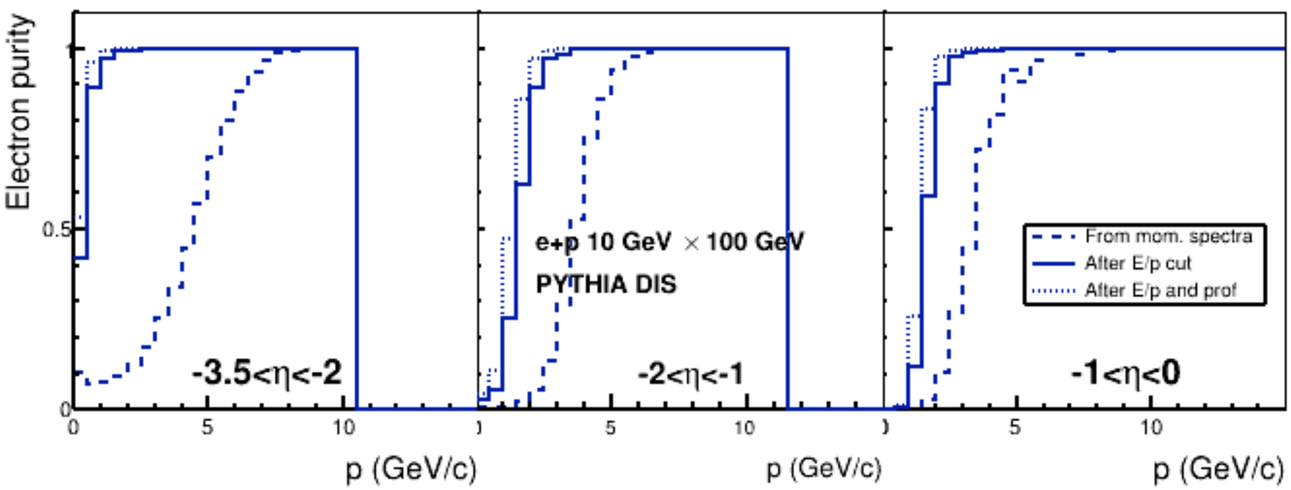
(purity > 96%)

DIS scattered electron purity

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

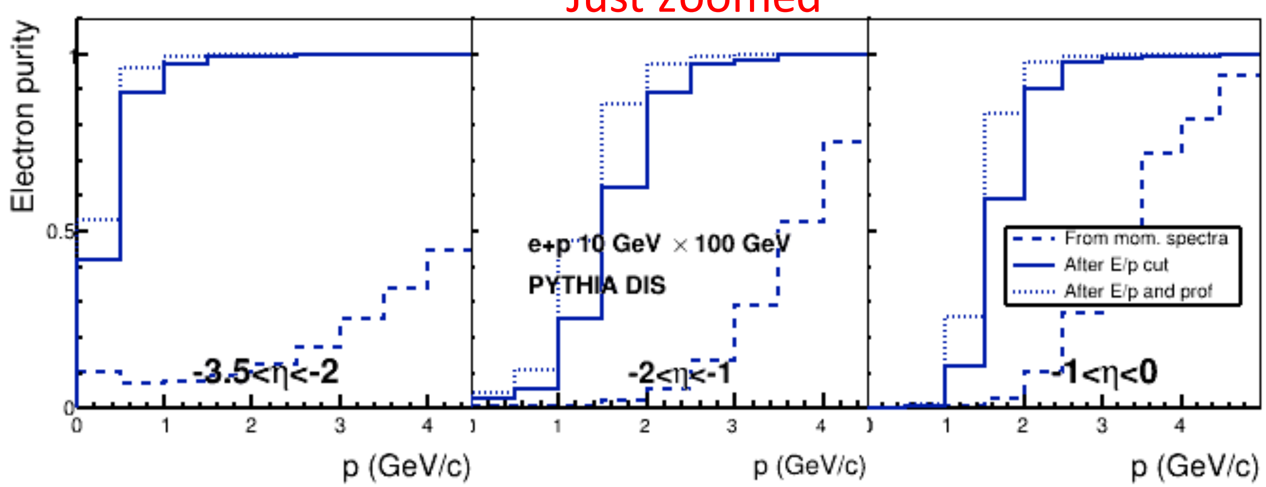
-3.5<η<-2	-2<η<-1	-1<η<1
$\frac{\sigma_E}{E} = \frac{2.5\%}{\sqrt{E}} \oplus 1\%$	$\frac{\sigma_E}{E} = \frac{7\%}{\sqrt{E}} \oplus 2\%$	$\frac{\sigma_E}{E} = \frac{12\%}{\sqrt{E}} \oplus 2\%$

Purity = e / (e+h)



10 GeV × 100 GeV:

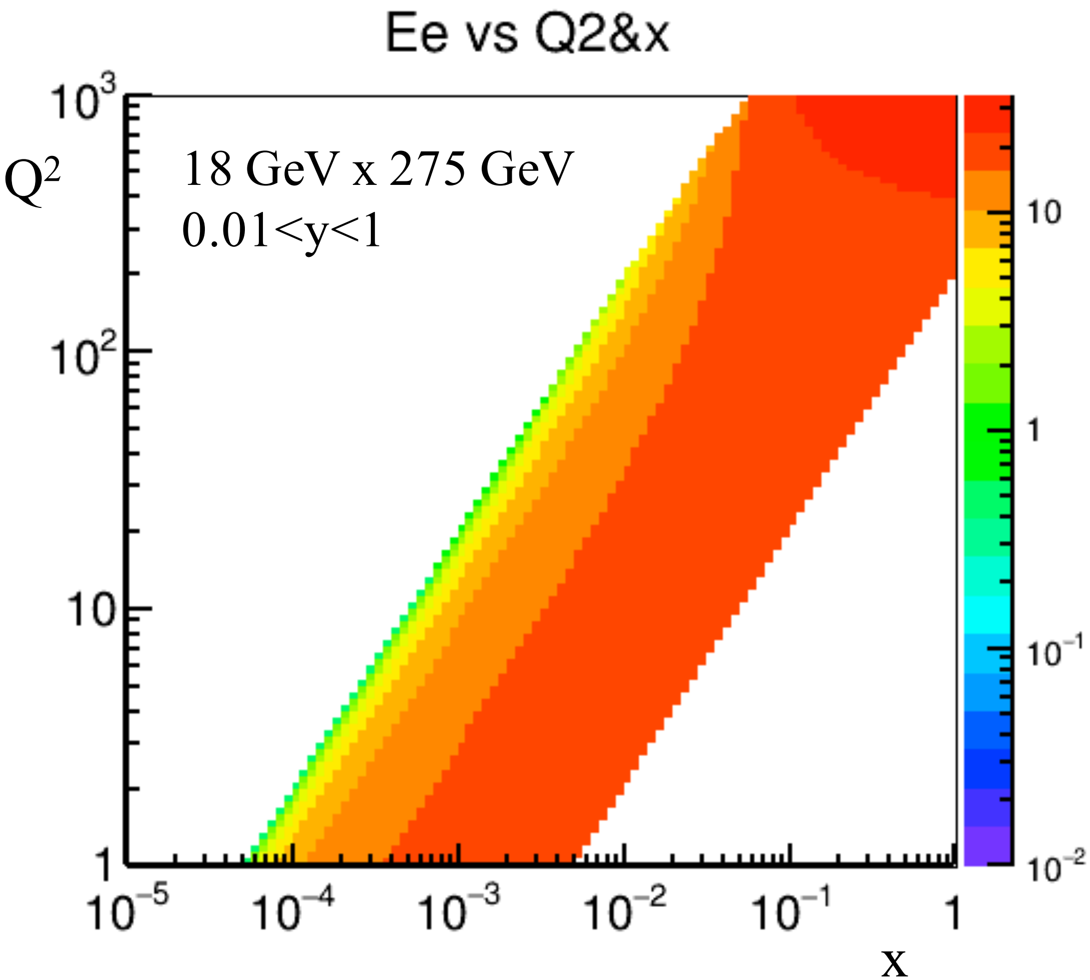
Just zoomed



Clean eID at >2GeV/c

(purity > 96%)

Scattered electron energy



DIS scattered electron energy (z-axis) vs (Q^2,x)

… Looks like not a big loss if we can not identify electrons at <3 GeV/c?

*Radiation correction will change it a bit

Backup