FEMC Minimal Energy: Reconsidering the Requirements

A.Bazilevsky

November 2025

YR: Detector Requirements

η	Nomenclature			Tracking				Electrons and Photons			π/K/p PID		HCAL		Muons
				Min p_T	Resolution	Allowed X/X_0	Si-Vertex	Min E	Resolution σ_E/E	PID	p-Range (GeV/c)	Separation	Min E	Resolution σ_E/E	
-6.9 — -5.8			low-Q^2 tagger		$\delta\theta/\theta < 1.5\%$; $10^{-6} < Q^2 < 10^{-2}$ GeV^2										
…	↓ p/A	Auxiliary Detectors													
-4.5 — -4.0			Instrumentation to separate charged particles from γ												
-4.0 — -3.5														~50%/√E+6%	
-3.5 — -3.0									2%/√E+(1-3)%						
-3.0 — -2.5			Backwards Detectors		σ_p/p ~ 0.1%×p+2.0%		σ_{xy}~30μm/p_T ⊕ 40μm								
-2.5 — -2.0														~45%/√E+6%	
-2.0 — -1.5					σ_p/p ~ 0.05%×p+1.0%		σ_{xy}~30μm/p_T ⊕ 20μm		7%/√E+(1-3)%	π suppression up to 1:10^4	≤ 7 GeV/c				
-1.5 — -1.0															
-1.0 — -0.5															
-0.5 — 0.0															
0.0 — 0.5		Central Detector	Barrel	100 MeV π 135 MeV K	σ_p/p ~ 0.05%×p+0.5%	~5% or less	σ_{xyz} ~ 20 μm, $d_0(z)$ ~ $d_0(r\varphi)$ ~ 20/p_T GeV μm + 5 μm	50 MeV			≤ 10 GeV/c	≥ 3σ	~500 MeV	~85%/√E+7%	Useful for bkg, improve resolution
0.5 — 1.0											≤ 15 GeV/c				
1.0 — 1.5									(10-12)%/√E+(1-3)%		≤ 30 GeV/c				
1.5 — 2.0			Forward Detectors		σ_p/p ~ 0.05%×p+1.0%		σ_{xy}~30μm/p_T ⊕ 20μm								
2.0 — 2.5										3σ e/π	≤ 50 GeV/c			~35%/√E	
2.5 — 3.0					σ_p/p ~ 0.1%×p+2.0%		σ_{xy}~30μm/p_T ⊕ 40μm				≤ 30 GeV/c				
3.0 — 3.5							σ_{xy}~30μm/p_T ⊕ 60μm				≤ 45 GeV/c				
3.5 — 4.0			Instrumentation to separate charged particles from γ												
4.0 — 4.5															
…	↑e	Auxiliary Detectors													
> 6.2			Proton Spectrometer		$\sigma_{intrinsic}(\lvert t\rvert)/\lvert t\rvert < 1\%$; Acceptance: $0.2 < p_T < 1.2$ GeV/c										

Section 8.2.5: $\Sigma \rightarrow \Lambda\gamma$

"We concluded that a requirement of γ detection with the nominal resolution in that region for Eγ > 200 MeV up to η=3.0 and Eγ > 400 MeV for 3.0 < η < 4.0 is sufficient to maintain a reasonable acceptance for Σ^0s."

Section 8.3.5: Jets

"… have assumed minimum energy thresholds of 200 MeV/c and see good jet energy scales and missing transverse energy resolutions."

Section 8.3.7: SIDIS

"An energy threshold of 100 MeV or better is also requested."

In Project:

"General, Functional, and Performance Requirements for the EIC Detector Systems"

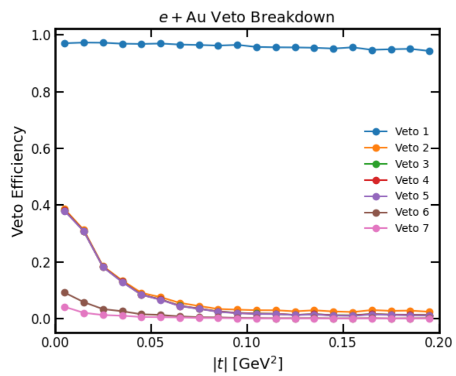
E_{min}=100 MeV is used

Keeping 100 MeV requirement in FEMC is a big challenge, which may require expensive design modification (if possible at all)

Can we accept higher threshold, e.g. 200 MeV for 1.4 < η < 3.0 and 400 MeV η > 3.0?

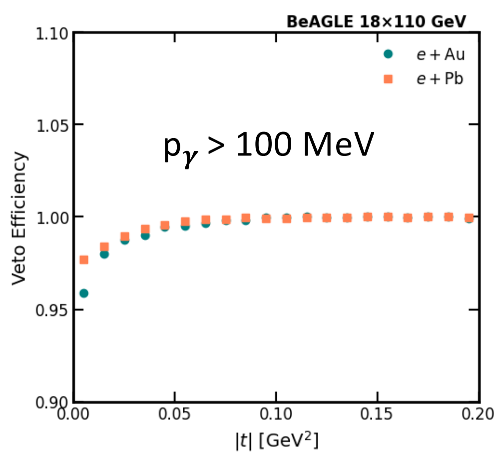
Tagging incoherent vector-meson production

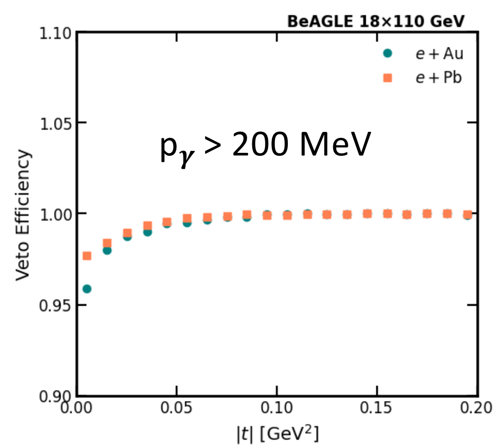
- Veto.1: no activity other than e^- and J/ψ in the main detector ($|\eta| < 4.0$ and $p_T > 100$ MeV/c) ;
- Veto.2: Veto.1 and no neutron in ZDC;
- Veto.3: Veto.2 and no proton in RP;
- Veto.4: Veto.3 and no proton in OMDs;
- Veto.5: Veto.4 and no proton in B0;
- Veto.6: Veto.5 and no photon in B0;
- Veto.7: Veto.6 and no photon with $E > 50$ MeV in ZDC.

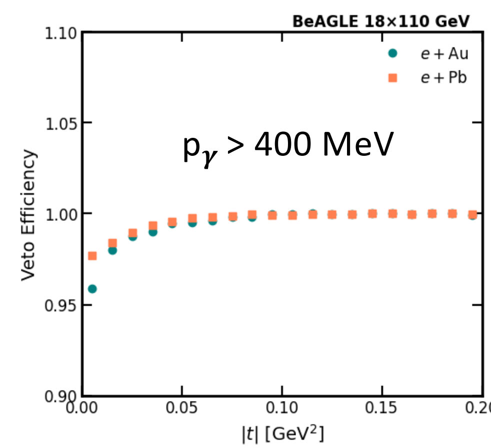


Mathias Labonté
Exclusive, Diffraction, & Tagging Meeting
June 30, 2025

Measuring photons coming from nuclear de-excitations can serve as a means of tagging incoherent events





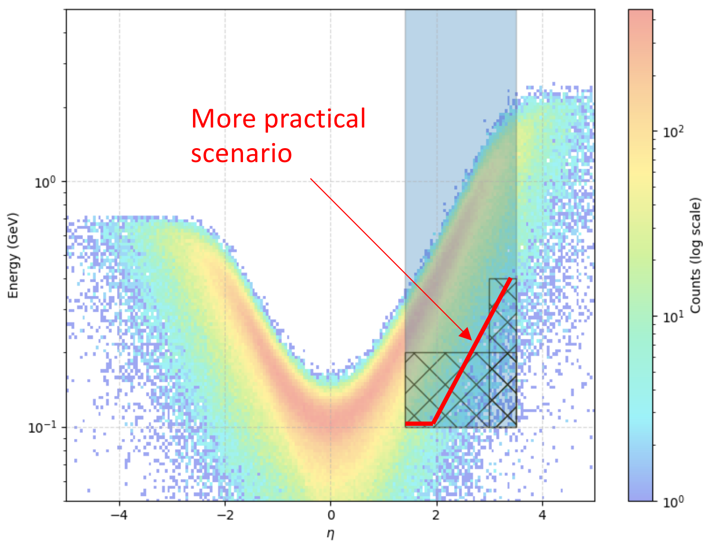


No impact, because all photons are very forward and are tagged by B0 and ZDC

Charmonium radiative decays

Minjun Kim
Exclusive, Diffraction, & Tagging Meeting
June 30, 2025

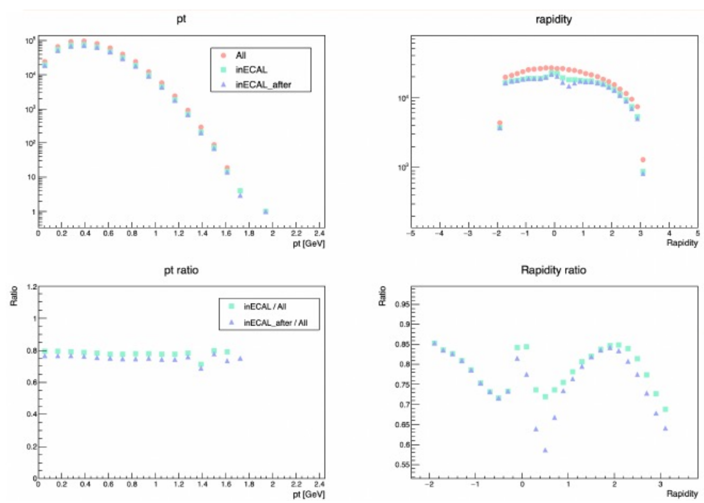
Photons from $J/\psi \rightarrow \eta_c + \gamma$ in ep 10x130 GeV



Photon in EMC acceptance |eta| < 3.5 & E > 100 MeV	78.56%
Photon in FEMC acceptance 1.4 < eta < 3.5 & E > 100 MeV	22.75%
Fraction of photon rejected due to new threshold (hashed area)	2.62%

Using the $J/\psi \rightarrow \eta_c + \gamma$ channel as a benchmark
Represents a general case for studies of charmonium radiative decays, as many of these processes emit photons in a similar energy range.

Acceptance as a function of J/ψ momentum and rapidity



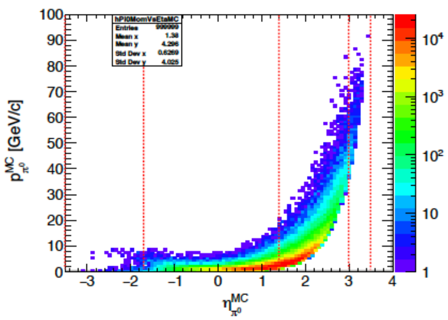
New minimum energy threshold in FEMC rusults in 2-3% reduction in acceptance overall, with some rapidity dependence

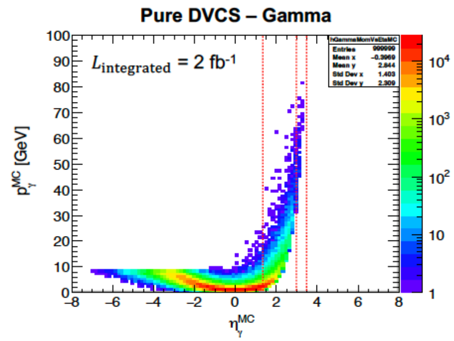
The impact is expected to be significantly smaller for smooth $E_{min}(\eta)$

Exclusive $\pi 0$ and DVCS γ

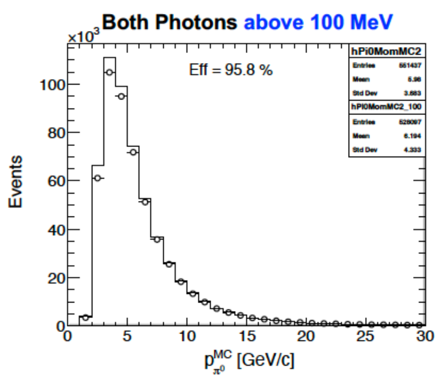
Jihee Kim
Exclusive, Diffraction, & Tagging Meeting
June 16, 2025

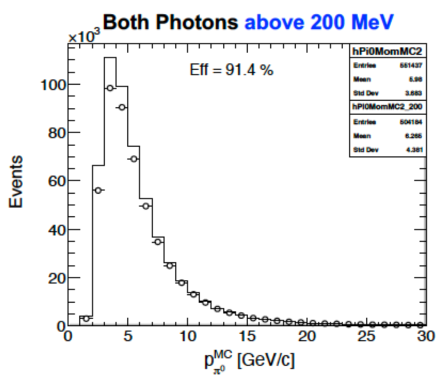
ep 10x130 GeV





$1.4<\eta<3.0$





$1.4<\eta<3.0$, E_{min}=100 MeV → 200 MeV: 4.4% decrease in eff
$3.0<\eta<3.5$, E_{min}=100 MeV → 400 MeV: 1.6% decrease in eff

Background to DVCS (upper bound)
(*E.Aschenauer et al, PRD 112, 036010 (2025)*):

<1% for 5x41 GeV
<0.5% for 10x100 GeV
<0.05% for 18x275 GeV

A factor of x2 increase (upper bound) may be expected due to new proposed threshold

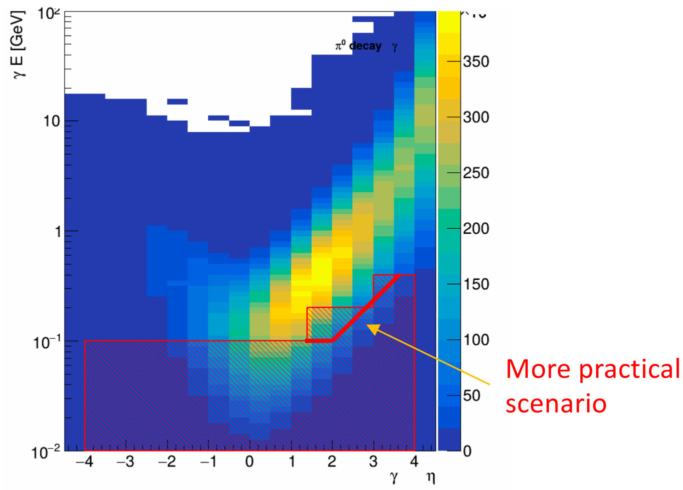
Only minor effect

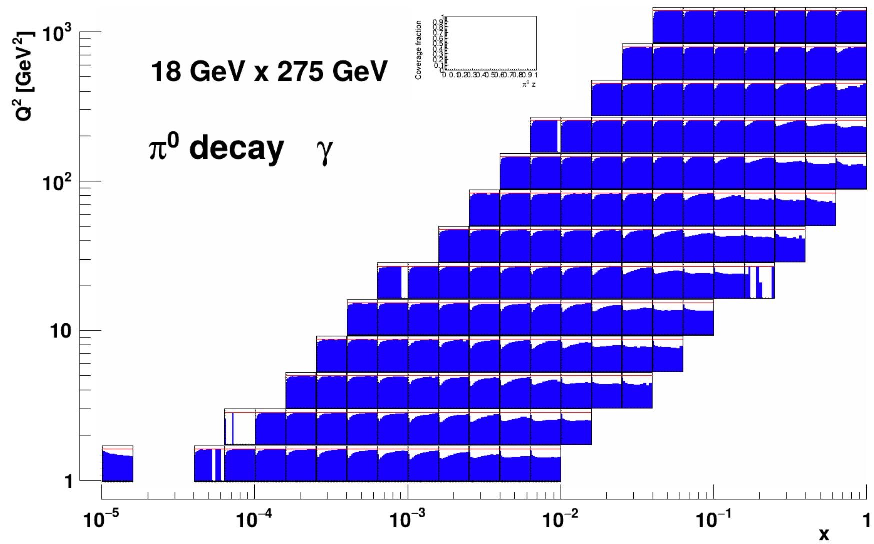
The impact is expected to be significantly smaller for smooth $E_{min}(\eta)$

Ralf Seidl
SIDIS Meeting
July 8, 2025

SIDIS: pi0

Not a primary channel, serves mainly as a cross check for charged pion probes (for flavor separation)



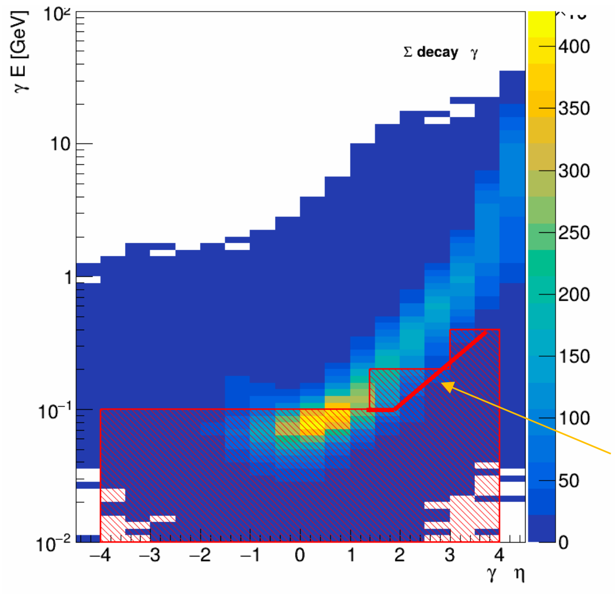


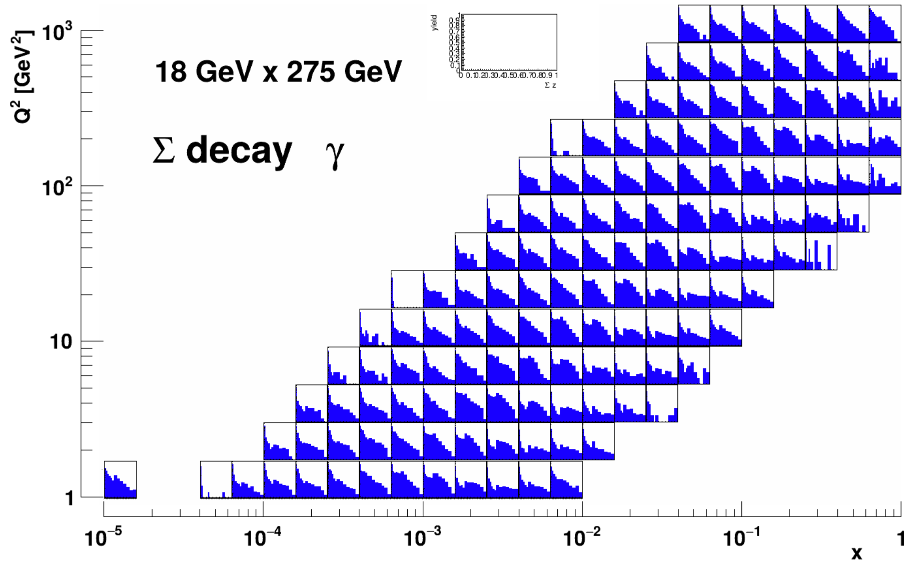
Some minor losses, no phase space reduction

The impact is expected to be significantly smaller for smooth $E_{min}(\eta)$

SIDIS: $\Sigma \to \Lambda\gamma$

Ralf Seidl
SIDIS Meeting
July 8, 2025





YR Section 8.2.5: $\Sigma \to \Lambda\gamma$

"We concluded that a requirement of γ detection with the nominal resolution in that region for Eγ > 200 MeV up to η=3.0 and Eγ > 400 MeV for 3.0 < η < 4.0 is sufficient to maintain a reasonable acceptance for Σ^0s."

Phase space not sacrificed
Losses, mainly from 100 MeV threshold in barrel.
Minimal effect from FEMC threshold

Inclusive DIS

Tyler Kutz, Stephen Maple
Inclusive DIS
Private communication

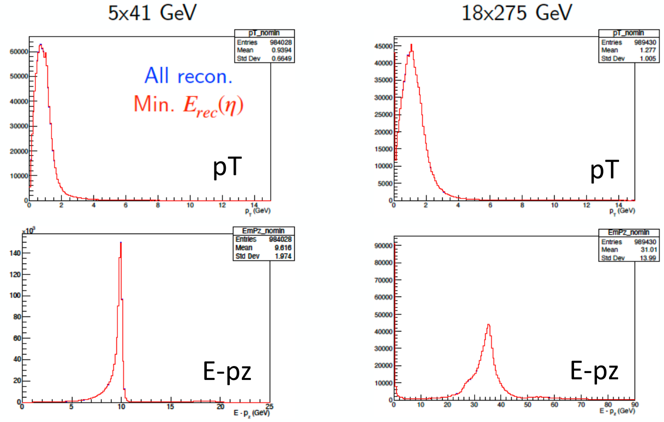
Inclusive kinematics reco with hadronic final state (JB, DA, …)

$$\sum_i (E_i - p_{z,i})$$

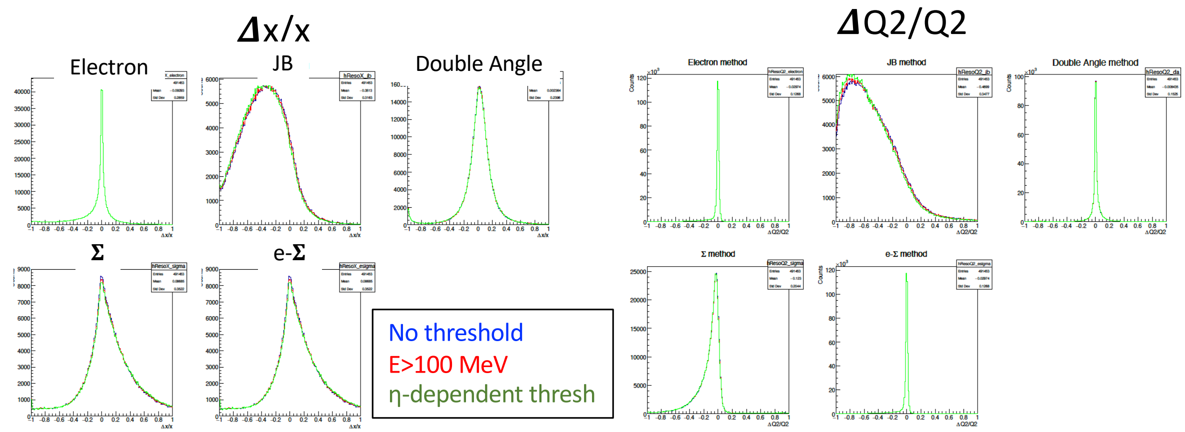
$$P_T = \sqrt{(\sum_i p_{x,i})^2 + (\sum_i p_{y,i})^2}$$

-3.5<η<1.4: E>0.1GeV
1.4<η<3.0: E>0.2GeV
3.0<η<3.5: E>0.4GeV

5x41 GeV 18x275 GeV



18x275 GeV, 100<Q^2<1000 GeV^2



Also checked for 5x41 GeV and different Q2 bins

No impact from increased energy threshold in FEMC

Suggestion

Minimal Energy Requirements change in FEMC:

From: 100 MeV

To: **100-400 MeV from low to high pseudo-rapidity**

Big Thanks to all physics groups for quick responses and studies performed

Backup

YR

Table 3.1: This matrix summarizes the high level performance of the different subdetectors and a 3 T Solenoid. The interactive version of this matrix can be obtained through the Yellow Report Detector Working Group (https://physdiv.jlab.org/DetectorMatrix/).

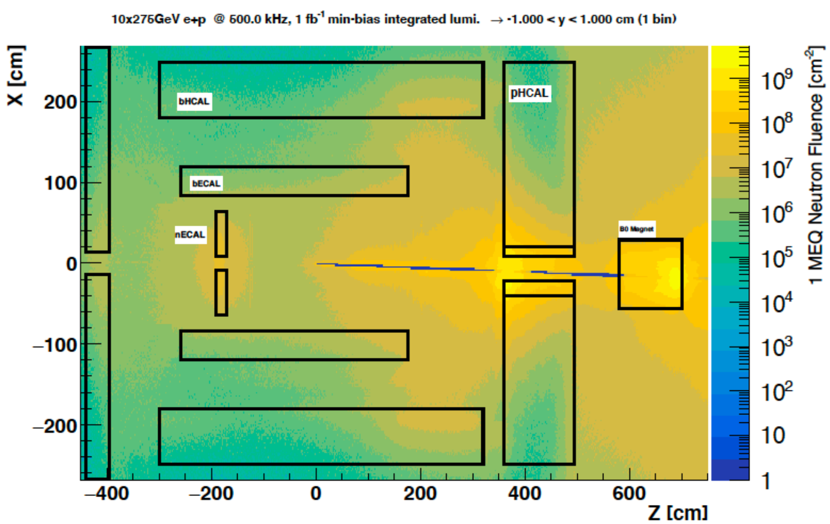
η	Nomenclature	Tracking: Resolution	Tracking: Relative Momentum	Tracking: Allowed X/X_0	Tracking: Minimum-p_T (MeV/c)	Tracking: Transverse Pointing Res.	Tracking: Longitudinal Pointing Res.	Electrons and Photons: Resolution σ_E/E	Electrons and Photons: PID	Electrons and Photons: Min E Photon	π/K/p: p-Range	π/K/p: Separation	HCAL: Resolution σ_E/E	HCAL: Energy	Muons
< -4.6	Low-Q2 tagger														
-4.6 to -4.0		Not Accessible													
-4.0 to -3.5		Reduced Performance													
-3.5 to -3.0	Backward Detector		σ_p/p ~ 0.1%×p⊕2%	~5% or less	150-300			1%/E ⊕ 2.5%/√E ⊕ 1%	π suppression up to 1:10⁴	20 MeV	≤ 10 GeV/c		50%/√E ⊕ 10%		Muons useful for background suppression and improved resolution
-3.0 to -2.5															
-2.5 to -2.0			σ_p/p ~ 0.02% × p ⊕ 1%												
-2.0 to -1.5						dca(xy) ~ 40/p_T μm ⊕ 10 μm	dca(z) ~ 100/p_T μm ⊕ 20 μm	2%/E ⊕ (4-8)%/√E ⊕ 2%	π suppression up to 1:(10³-10²)	50 MeV					
-1.5 to -1.0															
-1.0 to -0.5	Barrel		σ_p/p ~ 0.02% × p ⊕ 5%		400	dca(xy) ~ 30/p_T μm ⊕ 5 μm	dca(z) ~ 30/p_T μm ⊕ 5 μm	2%/E ⊕ (12-14)%/√E ⊕ (2-3)%	π suppression up to 1:10²	100 MeV	≤ 6 GeV/c	≥ 3σ	100%/√E ⊕ 10%	~500MeV	
-0.5 to 0.0															
0.0 to 0.5															
0.5 to 1.0															
1.0 to 1.5	Forward Detectors		σ_p/p ~ 0.02% × p ⊕ 1%		150-300	dca(xy) ~ 40/p_T μm ⊕ 10 μm	dca(z) ~ 100/p_T μm ⊕ 20 μm	2%/E ⊕ (4*-12)%/√E ⊕ 2%	3σ e/π up to 15 GeV/c	50 MeV	≤ 50 GeV/c		50%/√E ⊕ 10%		
1.5 to 2.0															
2.0 to 2.5															
2.5 to 3.0			σ_p/p ~ 0.1%×p⊕2%												
3.0 to 3.5															
3.5 to 4.0	Instrumentation to separate charged particles from photons	Reduced Performance													
4.0 to 4.5		Not Accessible													
> 4.6	Proton Spectrometer; Zero Degree Neutral Detection														

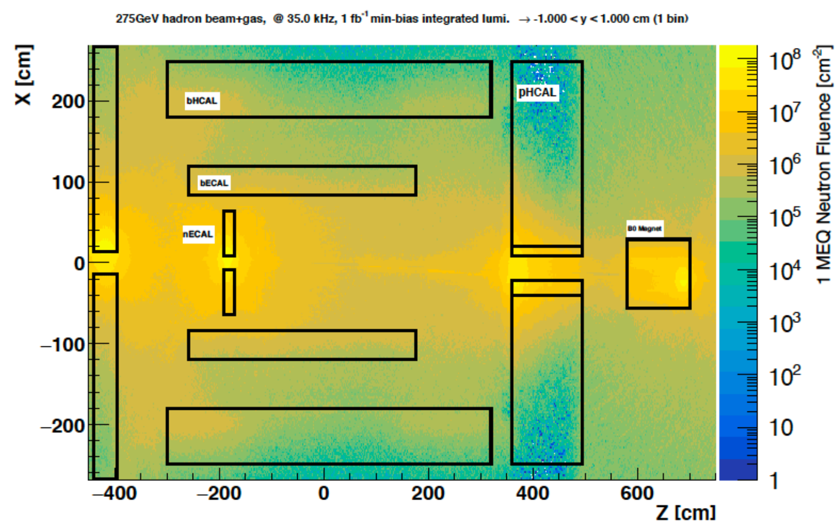
Table 11.50: This matrix summarizes the high level performance of the different subdetectors and a 3 T Solenoid. The interactive version of this matrix can be obtained through the Yellow Report Detector Working Group (https://physdiv.jlab.org/DetectorMatrix/).

η	θ	Nomenclature	Tracking: Resolution	Tracking: Relative Momentum	Tracking: Allowed X/X_0	Tracking: Minimum-pT	Tracking: Transverse Pointing Res.	Tracking: Longitudinal Pointing Res.	Electrons and Photons: Resolution σE/E	Electrons and Photons: PID	Electrons and Photons: Min E Photon	π/K/p: p-Range (GeV/c)	π/K/p: Separation	HCAL: Resolution σE/E	HCAL: Energy	Muons
< -4.6		↓ p/A; Far Backward Detectors; low-Q2 tagger														
-4.6 to -4.0			Not Accessible													
-4.0 to -3.5				Reduced Performance												
-3.5 to -3.0		Central Detector; Backward Detector		σp/p ~0.2%×p⊕5%	~5% or less X	70-150 MeV/c (B=1.5 T)			1%/E ⊕ 2.5%/√E ⊕ 1%	π suppression up to 1(E-4	20 MeV	≤10 GeV/c		50%/√E⊕10%		Muons useful for bkg, improve resolution
-3.0 to -2.5																
-2.5 to -2.0				σp/p: 0.04%×p⊕2%												
-2.0 to -1.5							dca(xy) ~ 40/pT μm ⊕ 10 μm	dca(z) ~ 100/pT μm ⊕ 20 μm	2%/E ⊕ (4-8)%/√E ⊕ 2%	π suppression up to 1(E-3 - E-2)	50 MeV					
-1.5 to -1.0																
-1.0 to -0.5		Barrel		σp/p ~0.04%×p⊕1%		200 MeV/c	dca(xy) ~ 30/pT μm ⊕ 5 μm	dca(z) ~ 30/pT μm ⊕ 5 μm	2%/E ⊕ (12-14)%/√E ⊕ (2-3)%	π suppression up to 1(E-2	100 MeV	≤ 6 GeV/c	≥ 3 σ	100%/√E+10%	~500MeV	
-0.5 to 0.0																
0.0 to 0.5																
0.5 to 1.0																
1.0 to 1.5		Forward Detectors		σp/p ~0.04%×p⊕2%		70 - 150 MeV/c (B = 1.5 T)	dca(xy) ~ 40/pT μm ⊕ 10 μm	dca(z) ~ 100/pT μm ⊕ 20 μm	2%/E ⊕ (4*-12)%/√E ⊕ 2%	3σ e/π up to 15 GeV/c	50 MeV	≤ 50 GeV/c		50%/√E+10%		
1.5 to 2.0																
2.0 to 2.5																
2.5 to 3.0																
3.0 to 3.5				σp/p ~0.2%×p⊕5%												
3.5 to 4.0		↑ e; Instrumentation to separate charged particles from photons		Reduced Performance												
4.0 to 4.5			Not Accessible													
> 4.6		Far Forward Detectors; Proton Spectrometer; Zero Degree Neutral Detection														

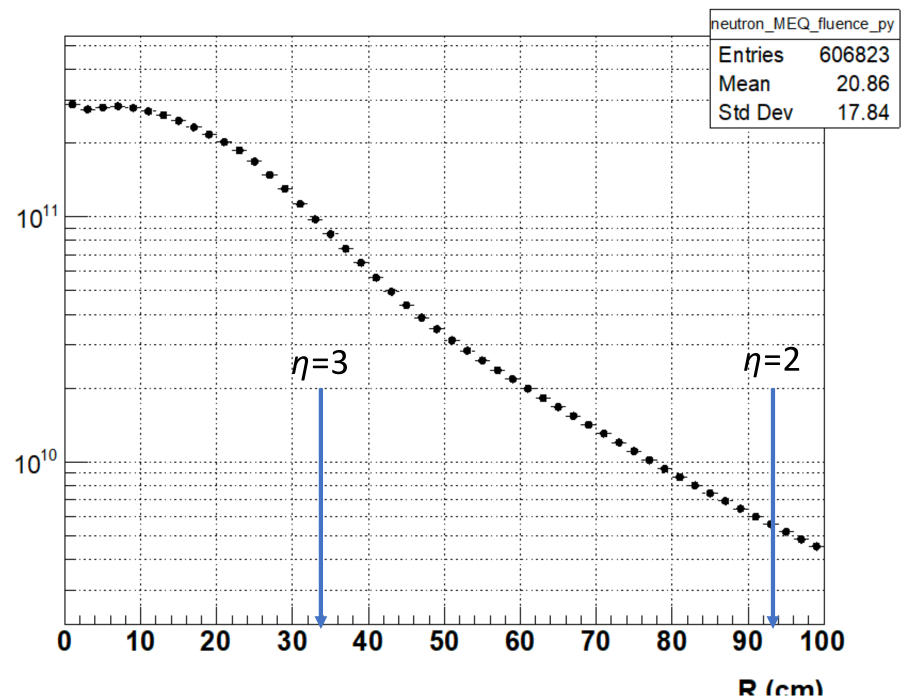
Table 10.6: This matrix summarizes the high level requirements for the detector performance. The interactive version of this matrix can be obtained through the Yellow Report Physics Working Group WIKI page (https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Common).

η		Nomenclature		Tracking: Resolution	Tracking: Allowed	Tracking: minimum-pT	Tracking: Si-Vertex	Electrons and Photons: Resolution σE/E	Electrons and Photons: PID	Electrons and Photons: min E	π/K/p: p-Range	π/K/p: Separation	HCAL: Resolution σE/E	HCAL: Energy	Muons
-6.9 to -5.8	↓ p/A	Auxiliary Detectors	low-Q2 tagger	σθ/θ < 1.5%; 10-6 < Q2 < 10-2 GeV2											
-5.0 to -4.5						300 MeV pions									
-4.5 to -4.0			Instrumentation to separate charged particles from photons			300 MeV pions		2%/√E(+1-3%)		50 MeV					
-4.0 to -3.5										50 MeV			~50%/√E + 6%		
-3.5 to -3.0		Central Detector	Backward Detector		~5% or less X	<100MeV pions, 135MeV kaons			π suppression up to 1:1E-4	50 MeV	≤ 7 GeV/c	≥ 3 σ	~45%/√E+6%	~500 MeV	muons useful for bkg, improve resolution
-3.0 to -2.5				σpT/pT ~ 0.1%@0.5%			σ_xy ~ 30/pT μm + 40 μm			50 MeV					
-2.5 to -2.0				σpT/pT			σ_xy ~ 30/pT μm + 20 μm	2%/√E(+1-3%)		50 MeV					
-2.0 to -1.5				σpT/pT				7%/√E(+1-3%)		50 MeV					
-1.5 to -1.0				0.05%@0.5%				7%/√E(+1-3%)		50 MeV					
-1.0 to -0.5			Barrel	σpT/pT ~0.05%×pT+0.5%			σxyz ~ 20 μm, d0(z) ~d0(rΦ) ~ 20/pTGeV μm + 5 μm	(10-12)%/√E(+1-3%)		50 MeV	≤ 10 GeV/c		~85%/√E+7%		
-0.5 to 0.0										50 MeV			~85%/√E+7%		
0.0 to 0.5										50 MeV			~85%/√E+7%		
0.5 to 1.0										50 MeV	≤ 15 GeV/c		~85%/√E+7%		
1.0 to 1.5			Forward Detectors	σpT/pT ~0.05%×pT+1.0%			σ_xy ~ 30/pT μm + 20 μm		3σ e/π	50 MeV	≤ 30 GeV/c		35%/√E		
1.5 to 2.0										50 MeV	≤ 50 GeV/c				
2.0 to 2.5										50 MeV					
2.5 to 3.0				σpT/pT ~ 0.1%×pT+2.0%			σ_xy ~ 30/pT μm + 40 μm			50 MeV	≤ 30 GeV/c				
3.0 to 3.5							σ_xy ~ 30/pT μm + 60 μm			50 MeV	≤ 45 GeV/c				
3.5 to 4.0	↑ e	Auxiliary Detectors	Instrumentation to separate charged particles from photons	Tracking capabilities are desirable for forward tagging						50 MeV					
4.0 to 4.5										50 MeV			35%/√E (goal), <50%/√E (acceptable)*, 3mrad/√E (goal)		
4.5 to 5.0			Neutron Detection			300 MeV pions		4.5%/√E for photon energy > 20 GeV	<= 3 cm granularity	50 MeV					
> 6.2			Proton Spectrometer	σintrinsic(|t|)/|t| < 1%; Acceptance: 0.2 < pt < 1.2 GeV/c											


10x275GeV e+p @ 500.0 kHz, 1 fb-1 min-bias integrated lumi. → -1.000 < y < 1.000 cm (1 bin)
X [cm]
Z [cm]
bHCAL
bECAL
nECAL
pHCAL
B0 Magnet
1 MEQ Neutron Fluence [cm-2]


275GeV hadron beam+gas, @ 35.0 kHz, 1 fb-1 min-bias integrated lumi. → -1.000 < y < 1.000 cm (1 bin)
X [cm]
Z [cm]
bHCAL
bECAL
nECAL
pHCAL
B0 Magnet
1 MEQ Neutron Fluence [cm-2]

n_{eq}(R) flux in FEMC



Material in front of FEMC