

Physics Working Group Requirements Overview

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Miami->DC-> Berkeley: Collaboration with DWG

- ✓ Document studies/results in the wiki: <https://wiki.bnl.gov/eicug/index.php>
- ✓ Prepare updates for the detector matrix!

1	Nomenclature		Tracking			Electrons		HVL		HOL		Misc	
			Resolution	Alumel/KV ₀	Si-Vertex	Resolution _{xy} E	FD	p-Range (GeV)	Separation	Resolution _{xy} E			
-4.9e-18	1.9k	Auxiliary Detectors	Ion-51 Stage	6.0E-17 0.04E-03									
-													
-4.0e-18													
-4.0e-18													
-3.9e-18	1.9k	Auxiliary Detectors	Ion-51 Stage	6.0E-17 0.04E-03									
-3.0e-18													
-2.0e-18													
-2.0e-18													
-2.0e-18													
-2.0e-18													
-2.0e-18													
-2.0e-18													
-2.0e-18													
-2.0e-18													
-2.0e-18	1.9k	Central Detectors	Beam	6.0E-17 0.04E-03	300								
0.0e+00													
0.0e+00													
0.0e+00													
0.0e+00													
0.0e+00													
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0.0e+00													
0.0e+00	1.9k	Auxiliary Detectors	Beam	6.0E-17 0.04E-03	300								
0.0e+00													
0.0e+00													
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To summarize emerging requirements from each group: update (excel) table.

The “color-coding”/updating scheme is as follows:

- Unchanged cell -- only if this parameter has not yet been considered but it may have an impact on your processes
- Fill **green** -- if listed performance is sufficient and/or will have no impact on your processes. If known, add an updated performance quantifier of what your measurements could “tolerate” without loss of physics
- Fill **red** & update the cell -- if improvements are shown necessary

<https://physdiv.jlab.org/DetectorMatrix/>

Summary of PWG Detector Requirements @ DC

Documentation:

https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Common

- [Inclusive Reactions](#) (Renee Fatemi, Nobuo Sato, Barak Schmookler)
- [Semi-inclusive Reactions](#) (Ralf Seidl, Justin Stevens, Alexey Vladimirov, Anselm Vossen, Bowen Xiao)
- [Jets, Heavy Quarks](#) (Leticia Mendez, Brian Page, Frank Petriello, Ernst Sichtermann, Ivan Vitev)
- [Exclusive Reactions](#) (Raphaël Dupré, Salvatore Fazio, Tuomas Lappi, Barbara Pasquini, Daria Sokhan)
- [Diffractive Reactions & Tagging](#) (Wim Cosyn, Or Hen, Doug Higinbotham, Spencer Klein, Anna Stasto)

Summary of PWG Detector Requirements @ DC

Documentation: https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Common

Tracking resolution p_T^{min} HCAL PID resolution

η	Nomenclature		Resolution	Tracking	Electrons and Photons	$\pi/K/p$	HCAL	Muons			
			Allowed	Minimum p_T	SI-Vertex	Resolution	Resolution σ_z/E	Energy			
6.9 to 5.8	1 pA	Auxiliary Detectors	low-Q2 Jagger								
5.0 to 4.5				300 MeV pions							
4.5 to 4.0				300 MeV pions	2% \pm (E) \pm 1-3%	50 MeV					
4.0 to 3.5	Central Detector	Backward Detector		<100MeV pions, 135MeV kaons							
3.5 to 3.0				<100MeV pions, 135MeV kaons		50 MeV		\sim 50% \pm E \pm 6%			
3.0 to 2.5			ppp \sim 0.1% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 40 μ m	50 MeV	\leq 7 GeV/c		muons useful for bkg. improve resolution		
2.5 to 2.0			ppp \sim 0.1% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 20 μ m	50 MeV	2% \pm (E) \pm 1-3%			\sim 45% \pm E \pm 6%	
2.0 to 1.5			ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 20 μ m	50 MeV	7% \pm (E) \pm 1-3%				
1.5 to 1.0				<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 20 μ m	50 MeV	7% \pm (E) \pm 1-3%				
1.0 to 0.5			Stamp	ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xyz} \sim$ 20 μ m, $\phi(z) \sim$ $\phi(0) \cdot e^{- z /\lambda}$ \sim 20 μ m \pm 5 μ m	50 MeV	π suppresses soon up to 1:1E-4			
0.5 to 0.0				ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons		50 MeV	\geq 3 σ		\sim 85% \pm E \pm 7%	
0.0 to 0.5				ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons		50 MeV			\sim 85% \pm E \pm 7%	
0.5 to 1.0				ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons		50 MeV			\sim 85% \pm E \pm 7%	
1.0 to 1.5		ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 20 μ m	50 MeV						
1.5 to 2.0		ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 20 μ m	50 MeV						
2.0 to 2.5		ppp \sim 0.05% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 20 μ m	50 MeV						
2.5 to 3.0		ppp \sim 0.1% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 40 μ m	50 MeV	3 σ \pm 1E-4					
3.0 to 3.5		ppp \sim 0.1% \pm 0.5%	<100MeV pions, 135MeV kaons	$\sigma_{xy} \sim$ 30 μ m \pm 60 μ m	50 MeV	(10-12)% \pm (E) \pm 1-3%					
3.5 to 4.0	1 μ	Auxiliary Detectors		<100MeV pions, 135MeV kaons							
4.0 to 4.5				300 MeV pions		50 MeV					
4.5 to 5.0				300 MeV pions		50 MeV					
> 8.2		Proton Spectrometer	$\sigma_{transverse}/ p \sim$ 1%; Acceptance: 0.2 \leq p_T \leq 1.2 GeV/c								

Intensive discussions with the DWG

Tension points/emerging constraints:

- 1) Central detectors optimal on $|\eta| < 3.5$
- 2) PID in $|\eta| < 1$ (K and π) up to 6 GeV
- 3) HCAL only $\frac{50\%}{\sqrt{E}} + 10\%$ for $1 < \eta < 3.5$

Inclusive Reactions

DISCUSSION POINTS	η	Nomenclature	Tracking		Electrons		n/K/p		HCAL Resolution σ_E/E	Muons
			Resolution	Allowed X/Y0	SI-Vertex	Resolution σ_E/E	PID	p-Range (GeV/c)		
	-6.9 to -5.8	low-Q2 tagger	$\sigma_{\theta/B} < 1.5\%$; $10^{-6} < Q^2 < 10^{-2} \text{ GeV}^2$							
1) Forward coverage in tracking and calorimeters for JB reconstruction	-4.5 to -4.0	Auxiliary Detectors ↓ p/A Instrumentation to separate charged particles from photons				2%/VE				
2) Hadronic Calorimeter resolution for JB purity and stability	-4.0 to -3.5 -3.5 to -3.0 -3.0 to -2.5 -2.5 to -2.0 -2.0 to -1.5 -1.5 to -1.0	Backward Detector	$\sigma_{p/p} \sim 0.1\% \oplus 0.5\%$ $\sigma_{p/p} \sim 0.1\% \oplus 0.5\%$ $\sigma_{p/p} \sim 0.05\% \oplus 0.5\%$	$\sim 5\%$ or less X cannot evaluate without full detector simulations Critical that this is minimized to reduce pair symmetric correction	TBD	2%/VE 7%/VE 7%/VE	suppression up to 1:104 cannot evaluate without full detector simulations and PID algorithms see e/pion	$\leq 7 \text{ GeV/c}$	$\sim 45\% \text{ VE} \oplus 6\%$	
3) Pion suppression at midish-rapidity $-2 < \eta < 1$	-1.0 to -0.5 -0.5 to 0.0 0.0 to 0.5 0.5 to 1.0 1.0 to 1.5 1.5 to 2.0 2.0 to 2.5 2.5 to 3.0 3.0 to 3.5	Central Detector Barrel Pion suppression	$\sigma_{p/p} \sim 0.05\% \oplus 0.5\%$ $\sigma_{p/p} \sim 0.05\% \oplus 1.0\%$ $\sigma_{p/p} \sim 0.1\% \oplus 2.0\%$	$\sigma_{\text{sys}} \sim 20 \mu\text{m}$ $\sigma(\Delta z) \sim 80 \text{ fwhm}$ $\sim 20 \text{ p/GeV}$ $\Delta z \sim 5 \mu\text{m}$				$\leq 5 \text{ GeV/c}$ $\geq 3 \sigma$	$\sim 85\% \text{ VE} \oplus 7\%$ $\sim 85\% \text{ VE} \oplus 7\%$ $\sim 85\% \text{ VE} \oplus 7\%$	TBD
4) Minimize material to reduce pair-symmetric background.	3.5 to 4.0 4.0 to 4.5 ... > 6.2	Auxiliary Detectors ↑ e Instrumentation to separate charged particles from photons Neutron Detection Proton Spectrometer	Forward coverage critical for JB reconstruction $\sigma_{\text{int}} \sim 1\%$ Acceptance: $0.2 < p_t < 1.2 \text{ GeV/c}$			110-120%/VE		$\leq 20 \text{ GeV/c}$ $\leq 45 \text{ GeV/c}$	$\sim 45\% \text{ VE} \oplus 6\%$ Forward coverage critical for JB reconstruction	

tracking, PID, HCAL

- 1) **Central region constraints:** loss of phase-space coverage; some loss in resolution in the JB reconstruction method, but no loss of physics capabilities per se.
- 2) **PID cut-off at 6 GeV:** no major effect
- 3) **HCAL resolution:** loss in resolution in the JB reconstruction method, but no loss of physics.

Semi-Inclusive Reactions

η	Nomenclature	Resolution	Tracking		minimum-pT	Electrons		Photons		$\pi/K/p$	HCAL	Muons
			Allowed X/X0	SI-Vertex		Resolution $\sigma E/E$	PID	min E	p-Range (GeV/c)			
-6.9 to -5.8	Auxiliary Detectors ↓ p/A	low-Q2 tagger $\sigma Q^2 < 1.5\%$; $10^{-6} < Q^2 < 10^{-2} \text{ GeV}^2$										
...												
-4.5 to -4.0		Instrumentation to separate charged particles from photons					$2\%/E$					
-4.0 to -3.5	Central Detector	Backward Detector $\sigma p/p \sim 0.1\% \oplus 0.5\%$ $\sigma p/p \sim 0.1\% \oplus 0.5\%$ $\sigma p/p \sim 0.05\% \oplus 0.5\%$										
-3.5 to -3.0												
-3.0 to -2.5		TBD										
-2.5 to -2.0												
-2.0 to -1.5												
-1.5 to -1.0												
-1.0 to -0.5	Barrel	$\sigma p/p \sim 0.05\% \oplus 0.5\%$										
-0.5 to 0.0			$\sim 5\%$ or less X									
0.0 to 0.5												
0.5 to 1.0												
1.0 to 1.5												
1.5 to 2.0	Forward Detectors	$\sigma p/p \sim 0.05\% \oplus 1.0\%$										
2.0 to 2.5												
2.5 to 3.0												
3.0 to 3.5												
3.5 to 4.0												
3.5 to 4.0	Auxiliary Detectors ↑ e	Instrumentation to separate charged particles from photons										
4.0 to 4.5		Neutron Detection										
...												
> 6.2	Proton Spectrometer	$\sigma_{\text{intrinsic}}(t)/ t < 1\%$; Acceptance: $0.2 < p_t < 1.2 \text{ GeV}/c$										

minimum p_T threshold, PID

- 1) **Central region constraints:** loss of phase-space coverage (x-range for gluon Sivers); loss in resolution in the JB for charged current or Double Angle for neutral current; visible effects, but no dramatic loss of physics.
- 2) **PID cut-off at 6 GeV:** modest impact on TMD extraction (model dependent).
- 3) **HCAL resolution:** loss in resolution in the JB reconstruction method, but no loss of physics.

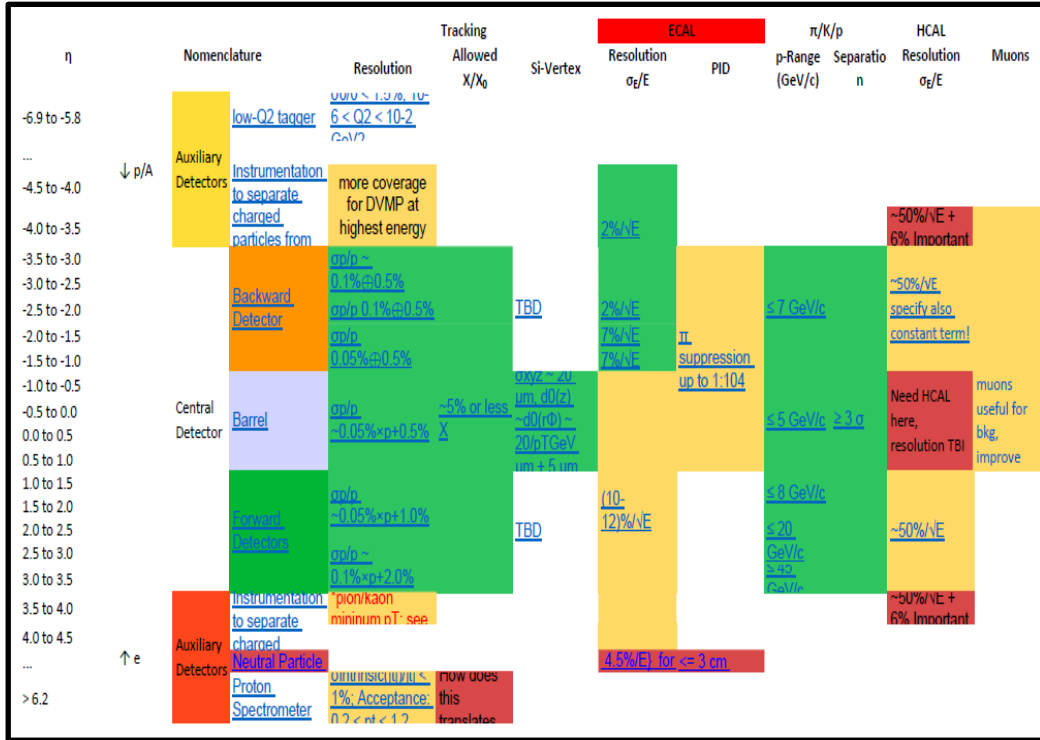
Jets and Heavy Quarks

η	Nomenclature	Tracking				Electrons (and Photons)			$\pi/K/p$		HCAL		Maxes
		Resolution	Minimum	Allowed	SI-Vertex	Resolutio	Energy	PID	p-Range (GeV/c)	Separation	Resolution $\sigma E/E$	Energy	
-6.9 to -5.8	Auxiliary Detectors	low-Q2 tagger	$\sigma_{\eta\theta} < 1.5\%$; 10-6 <										
4.5 to 4.0		instrumentation to separate charged particles from photons		Minimum p_T request informed by the need to detect soft particles	Vertex resolution informed by the need to reconstruct charmonium and bottomonium for R_{eA}	2% (E) (1-3.5%)		For Ecal and Hcal, would be good to understand sizes of any subpeak	PID requirements driven by mid to high z jet fragmentation function measurements and Collins asymmetry		Constant factor at highest eta driven by need for good energy resolution where tracking dies out. Extension to eta	For Hcal and Ecal, understanding minimum energy threshold would be helpful	
-4.0 to -3.5													
-3.5 to -3.0	Central Detector	Backward Detector	$\sigma_{\eta\theta} \sim 0.1\% \pm 0.2\%$										
-3.0 to -2.5			$\sigma_{\eta\theta} \sim 0.1\% \pm 0.2\%$			$\sigma_{xy} \sim 30/\mu\text{T} \mu\text{m} + 40$	2%/E			17 GeV/c		~50% (E) + 30%	
-2.5 to -2.0			$\sigma_{\eta\theta} \sim 0.02\% \pm 0.03\%$			$\sigma_{xy} \sim 30/\mu\text{T} \mu\text{m} + 20$	1%/E						
-2.0 to -1.5			$\sigma_{\eta\theta} \sim 0.02\% \pm 0.03\%$				1%/E						
-1.5 to -1.0		Barrel		100 M+V/c	~1% or less	$\sigma_{xy} \sim 20 \mu\text{m} \sqrt{p_T}$ (silicon) - 2000 GeV $\mu\text{m} + 5 \mu\text{m}$		~200 MeV	ii. suppress on up to 1-104				
-1.0 to -0.5										≤ 10 GeV/c	~3σ	~85 100%/E + 10%	TDQ
-0.5 to 0.0										≤ 15 GeV/c			
0.0 to 0.5	Forward Detectors								≤ 30 GeV/c				
0.5 to 1.0									≤ 30 GeV/c				
1.0 to 1.5									≤ 30 GeV/c				
1.5 to 2.0									≤ 30 GeV/c		~500 M+V		
2.0 to 2.5									≤ 30 GeV/c		~500%/E (+10%)		
2.5 to 3.0								≤ 30 GeV/c					
3.0 to 3.5								≤ 20 GeV/c					
3.5 to 4.0	Auxiliary Detectors	instrumentation to separate charged particles from photons	We would like clarification on what B field is assumed and for what particle momentum ranges the resolution parameterizations hold							3 sigma likely sufficient, but there was a question about feasibility of 4 sigma for p<10 GeV		~50%/E + 5%	
4.0 to 4.5		Neutron											
> 6.2		Proton	$\sigma_{\text{intrinsic}}(D)/D < 1\%$				Would like No	Several			As with Ecal,		

vertex, PID, HCAL

- 1) **Central region constraints:** loss of $x-Q^2$ coverage can be partially compensated by beam energy scan;
- 2) **PID cut-off at 6 GeV:** will severely cut into the $z-j_T$ phase-space for identified hadrons; degradation studies underway; larger impact expected for kaons
- 3) **HCAL resolution:** should suffice

Exclusive Reactions



- 1) **Central region constraints:** loss of exclusivity, impact on resolution/precision;
- 2) **PID cut-off at 6 GeV:** n/a
- 3) **HCAL resolution:** resolution? large coverage required for jets

neutral detection @ forward, π^0 and γ for DVCS, HCAL coverage

Diffractive Reactions & Tagging

η	Nomenclature	Resolution	Allowed	Tracking	Si-Vertex	Electrons	$\pi/K/p$	HCAL	Muons	Photons	
		$\frac{\Delta p_T}{p_T} \sim \frac{\Delta p}{p}$		Minimum p_T		Resolution	PID	Separati	Resoluti	Emitt	Resolution
6.9 to -5.8	low-Q2 tagger			300 MeV pions							
5.0 to -4.5	Auxiliary Detectors			300 MeV pions							
4.5 to -4.0	Instrumentation to separate charged particles from photons			300 MeV pions		2%/NE					
4.0 to -3.5	Central Detector	0.1% $x_F \pm 0.5%$	~5% or less	135 MeV/c kaons						50 MeV	
3.5 to -3.0				Backward Detector	TBD	2%/NE				50 MeV	
3.0 to -2.5						7%/NE	π suppression up to 1:104			50 MeV	
2.5 to -2.0						7%/NE		≤ 7 GeV/c	~50% \sqrt{E}	50 MeV	
2.0 to -1.5										50 MeV	
1.5 to -1.0				135 MeV/c kaons						50 MeV	
1.0 to -0.5	Barrel	-0.05% $x_F \pm 0.5%$		135 MeV/c kaons	xyz ~ 20 μm , dD(z)		≤ 5 GeV/c	$\geq 3\sigma$	TBD	50 MeV	
0.5 to 0.0				135 MeV/c kaons	~dD(z) ~ 20 μm TGeV					50 MeV	
0.0 to 0.5				135 MeV/c kaons	$\mu m + 5 \mu m$					50 MeV	
0.5 to 1.0				135 MeV/c kaons						50 MeV	
1.0 to 1.5	Forward Detectors	-0.05% $x_F \pm 1.0%$		135 MeV/c kaons			≤ 8 GeV/c		35% NE* (* for large-x processes need)	50 MeV	
1.5 to 2.0				135 MeV/c kaons			≤ 20 GeV/c			50 MeV	
2.0 to 2.5				135 MeV/c kaons	TBD	10-12%/NE	$\frac{\Delta p_T}{p_T} \sim \frac{\Delta p}{p}$			50 MeV	
2.5 to 3.0				135 MeV/c kaons						50 MeV	
3.0 to 3.5				135 MeV/c kaons						50 MeV	
3.5 to 4.0	Auxiliary Detectors			135 MeV/c kaons							
4.0 to 4.5	Instrumentation to separate charged particles from photons			300 MeV pions							
5.0 to -4.5				300 MeV pions							
> 6.2				300 MeV pions							

minimum p_T , HCAL

- 1) Central region constraints: forward losses limit high-x studies (near-threshold production, pentaquarks, high-x gluons); backward losses limit low-x studies (gluons).
- 1) PID cut-off at 6 GeV: n/a (PID required in soft sector)
- 2) HCAL resolution: acceptable