SIDIS@Detector WG

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Summary of Physics program and basic kinematic region

- See SIDIS presentation by Ralf at today's conveners meeting for detailed kinematic maps (also in backup here)
- Exemplary Processes:
  - Single and di-hadron SIDIS for (TMD) PDFs, (n)FFs
    - Wide range in x, large Q2 reach to study evolution. Overlap with fixed target desired. Low and high z for FF measurements
  - Gluon Sivers and Gluon Saturation
    - Low Q2 (but large Q2 range desirable to study evolution) low x for gluon saturation, high x for Sivers
  - Spectroscopy
    - Low Q2 photoproduction
  - Lambda Production
    - For spin transfer similar x ranges as other spin measurements

Basic Detector Measurements

- Single and di-hadron SIDIS for (TMD) PDFs, (n)FFs
  - Scattered electron and hadrons over wide eta range to cover wide x, Q2 region (as was input to original detector design)
  - PID at high momenta (high z at high CME) might be limiting, p_T cutoff for low z
  - Hadron acceptance for CC events
- Gluon Sivers and Gluon Saturation
  - Track pT, eta and scattered electron, need high resolution for p imbalance measurements from 1-40 GeV and 2pi coverage. $\frac{\delta p}{p} \approx 2\%$ should be good enough
- Spectroscopy
  - Tracking resolution in the forward direction could be a limiting factor for mass resolution
- Lambda Production
  - Tracking resolution, displaced vertex and soft photon detection. Low p_T acceptance (not higher than 300 MeV)

For charged particles, how important is low p_T acceptance versus high p_T resolution

- Competing requirements →run at different field strengths?
- Single and di-hadron SIDIS for (TMD) PDFs, (n)FFs
  - Need low p_T acceptance for low z and di-hadron partial waves and high p_T resolution for high z
- Gluon Sivers and Gluon Saturation
  - For back-to-back hadrons/dijets p_T resolution more important
- Spectroscopy
  - High p_T resolution (in particular forward) needed for mass resolution
- Lambda Production
  - p_T acceptance critical. High p_T resolution needed for mass resolution to constrain feed-down

Importance of luminosity? Will you be systematic or statistics-limited? Which systematic sources are the most important?

- Single and di-hadron SIDIS for (TMD) PDFs, (n)FFs
  - Some differential channels will be statistics limited
- Gluon Sivers and Gluon Saturation
  - High luminosity required, in particular for unknown gluon Sivers
- Spectroscopy
  - Statistically limited
- Lambda Production
  - For given detector configuration statistically limited (systematics from feed-down will also go with lumi)

How important is polarisation to your physics program?

- Mainly hadron polarization needed, enters linearly
- Helicity measurements need electron polarization as well
  →overlapping reqs with DIS group

What beam energies are ideal for your physics aims (quantify if possible)?"

- Single and di-hadron SIDIS for (TMD) PDFs, (n)FFs
  - Probably wide range of energies to cover kinematic phase space
- Gluon Sivers and Gluon Saturation
  - Gluon saturation needs highes possible energies (at least 18*110 GeV for eA)
- Spectroscopy
  - Lower energies due to acceptance limitations at higher beam energies
- Lambda Production
  - Most studies currently with 10x100
  - Beam energy has little impact on soft pion
  - High beam energies push lambda more forward where tracking resolution is worse
  - →intermediate energies with high lumi

How important is the Interaction Region design for your physics observable and do you have criteria that might impact the design?

- Single and di-hadron SIDIS for (TMD) PDFs, (n)FFs
  - Current handbook outline seem adequate
- Gluon Sivers and Gluon Saturation
  - Current design (|eta| <4.5) is ok. For the collisional energy 18*275 GeV, the forward acceptance will impact the high x region.
- Spectroscopy
  - Reduced forward acceptance would be a show stopper for the exclusive spectroscopy measurements, but this will probably be elaborated by the exclusive WG
- Lambda Production
  - Preferable to choose CME such that Lambdas products are central, then IR design not too critical

Backup

Single hadron SIDIS for quark TMDs, helicities, (n)FFs, etc

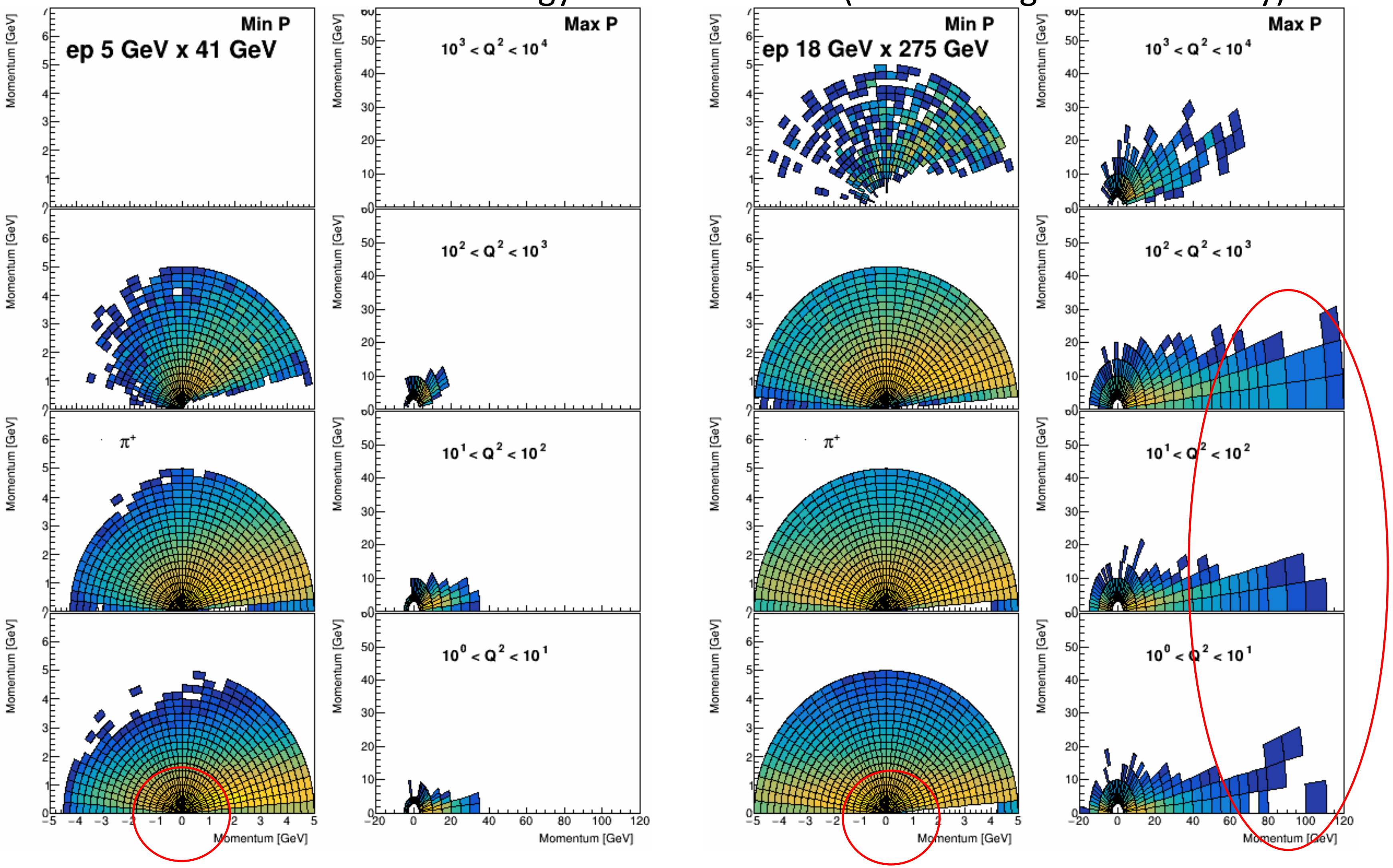
η	Nomenclature		Tracking Resolution	Allowed X/X_0	Si-Vertex	Electrons Resolution σ_E/E	PID	π/K/p p-Range (GeV/c)	Separation	HCAL Resolution σ_E/E	Muons
-6.9 to -5.8	Auxiliary Detectors	low-Q2 tagger									
...											
-4.5 to -4.0		Instrumentation to separate charged particles from photons									
-4.0 to -3.5											
-3.5 to -3.0	Central Detector	Backward Detector									
-3.0 to -2.5											
-2.5 to -2.0								≤ 7 GeV/c		~50%/√E	
-2.0 to -1.5							π suppression up to 1:10^4				
-1.5 to -1.0											
-1.0 to -0.5									≥ 3 σ		
-0.5 to 0.0		Barrel						≤ 5 GeV/c			TBD
0.0 to 0.5											
0.5 to 1.0											
1.0 to 1.5		Forward Detectors						≤ 8 GeV/c			
1.5 to 2.0											
2.0 to 2.5										~50%/√E	
2.5 to 3.0								≤ 20 GeV/c			
3.0 to 3.5								≤ 45 GeV/c			
3.5 to 4.0	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 to 4.5											
...		Neutron Detection									

Hadron momentum from as low as possible (magnet), lowest z reach

Slightly higher would be preferable

Single hadron SIDIS for quark TMDs, helicities, (n)FFs, etc

- Assume hadron fractional energy from 0.05 to 0.9 (current fragmentation only):



Polar angle in steps of 5 degrees

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Di-hadrons for Tensor charge/BM/Higher Twist

η	Nomenclature		Tracking Resolution	Allowed X/X_0	Si-Vertex	Electrons Resolution σ_E/E	PID	π/K/p p-Range (GeV/c)	Separation	HCAL Resolution σ_E/E	Muons
-6.9 to -5.8	Auxiliary Detectors	low-Q2 tagger									
...											
-4.5 to -4.0		Instrumentation to separate charged particles from photons									
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-3.0 to -2.5											
-2.5 to -2.0		Backward Detector						≤ 7 GeV/c		~50%/√E	
-2.0 to -1.5							π suppression up to 1:10^4				
-1.5 to -1.0											
-1.0 to -0.5	Central Detector								≥ 3 σ		
-0.5 to 0.0		Barrel						≤ 5 GeV/c			TBD
0.0 to 0.5											
0.5 to 1.0											
1.0 to 1.5								≤ 8 GeV/c			
1.5 to 2.0											
2.0 to 2.5		Forward Detectors								~50%/√E	
2.5 to 3.0								≤ 20 GeV/c			
3.0 to 3.5								≤ 45 GeV/c			
3.5 to 4.0	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 to 4.5											
...		Neutron Detection									

Hadron momentum from as low as possible (magnet), partial wave extraction

Important for pi-K pairs from Mis-ID pion pairs

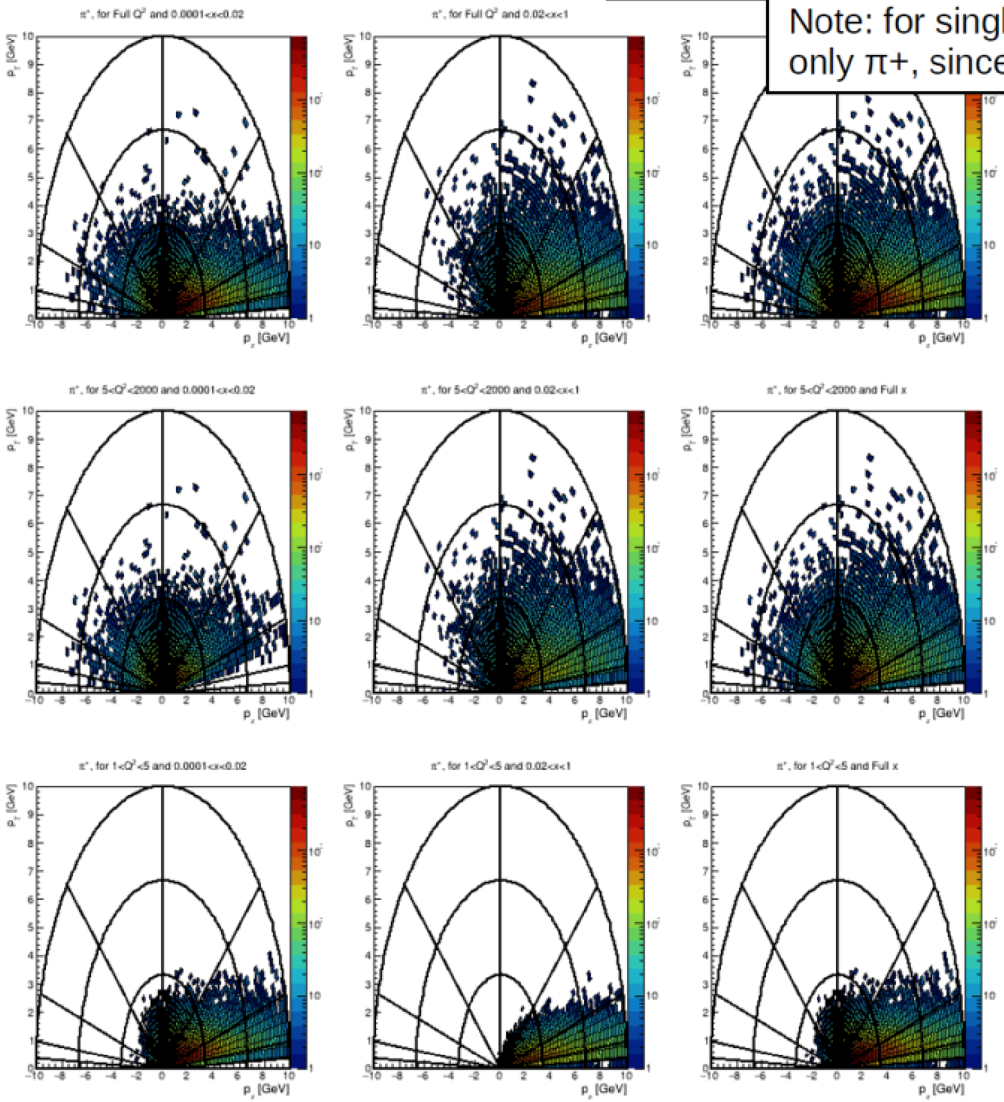
Chris Dilks, et. al

Di-hadrons for Tensor charge/BM/Higher Twist

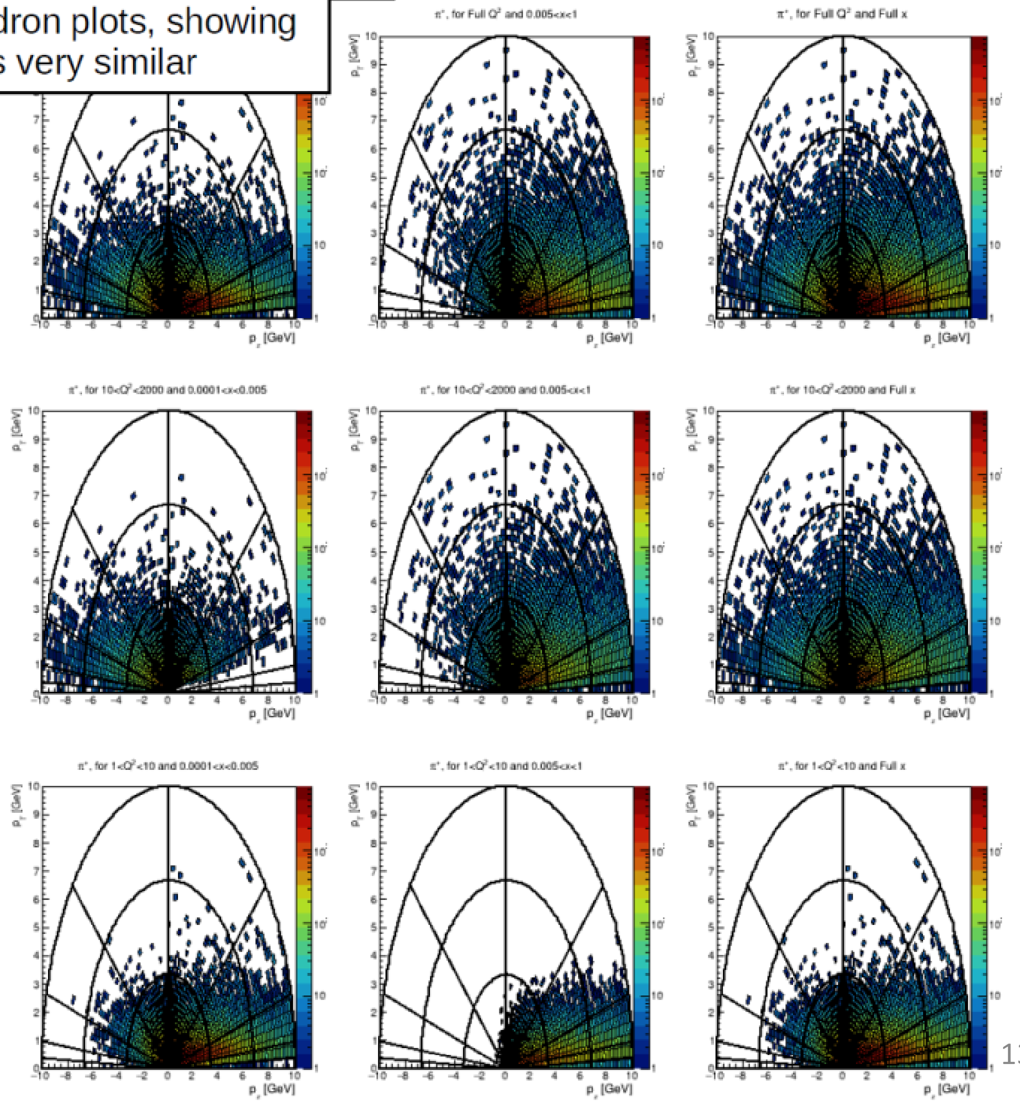
π^+ p_T vs. p_z Polar Plots

Note: for single hadron plots, showing only π+, since π- is very similar

10x100 GeV



18x275 GeV



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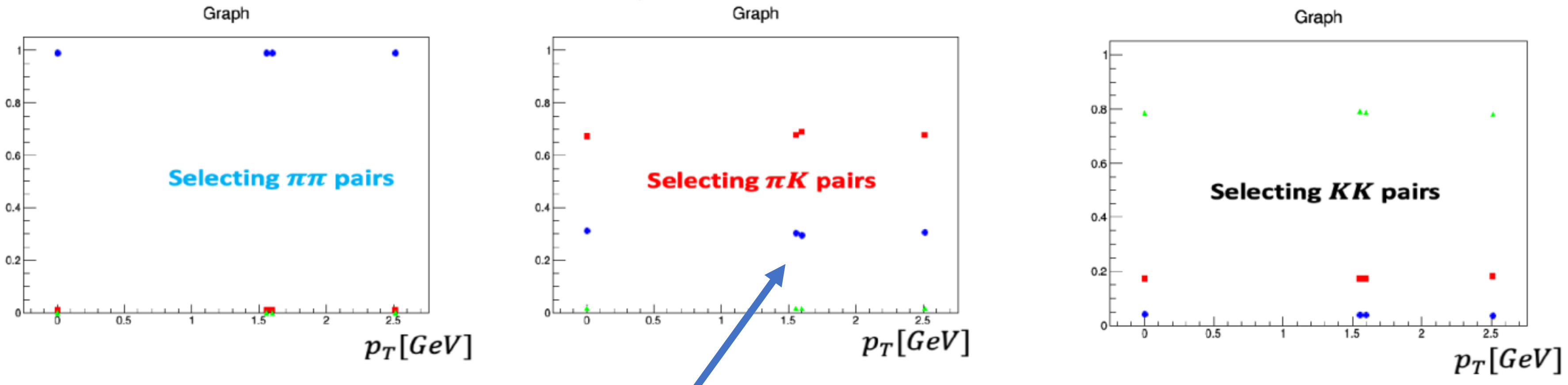
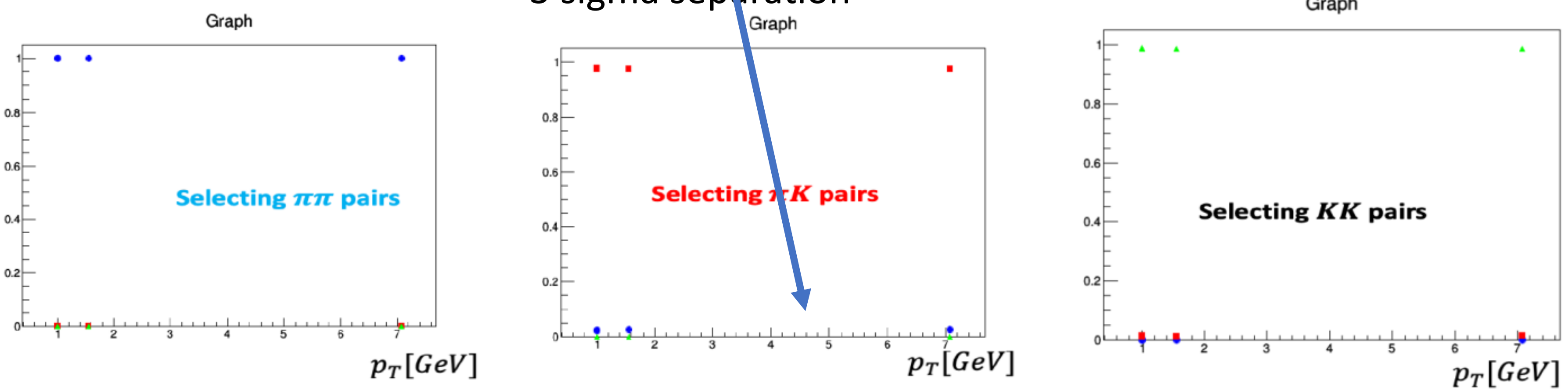
2 sigma separation



- Fraction of reconstructed $\pi\pi$ pairs
- Fraction of reconstructed πK pairs
- Fraction of reconstructed KK pairs

3 sigma separation



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Di-hadrons(jets,HF) for low-x and gluon Sivers

η	Nomenclature		Tracking Resolution	Tracking Allowed X/X_0	Tracking Si-Vertex	Electrons Resolution σ_E/E	Electrons PID	π/K/p p-Range (GeV/c)	π/K/p Separation	HCAL Resolution σ_E/E	Muons
-6.9 to -5.8	Auxiliary Detectors	low-Q2 tagger	σθ/θ < 1.5%; 10-6 < Q2 < 10-2 GeV2								
...											
-4.5 to -4.0		Instrumentation to separate charged particles from photons									
-4.0 to -3.5						2%/√E					
-3.5 to -3.0	Central Detector	Backward Detector	σ_p/p ~ 0.1%⊕0.5%								
-3.0 to -2.5											
-2.5 to -2.0			σ_p/p								
-2.0 to -1.5			σ_p/p 0.05								
-1.5 to -1.0											
-1.0 to -0.5		Barrel									
-0.5 to 0.0			σ_p/p ~0.0								
0.0 to 0.5											
0.5 to 1.0											
1.0 to 1.5		Forward Detectors									
1.5 to 2.0			σ_p/p ~0.0								
2.0 to 2.5											
2.5 to 3.0			σ_p/p 0.1%								
3.0 to 3.5											
3.5 to 4.0	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 to 4.5											
...		Neutron Detection									
> 6.2		Proton Spectrometer	σ_{intri} 1%; Acceptance: 0.2 < p_t < 1.2 GeV/c								

Generally similar to single hadron measurements:
gluon Sivers: forward region (higher x)
Saturation: central/backward region (low x)

- High tracking resolution needed at higher momenta
- full azimuthal coverage for azimuthal correlation needed

Gluon Sivers measurement requirement from charged dihadron channel

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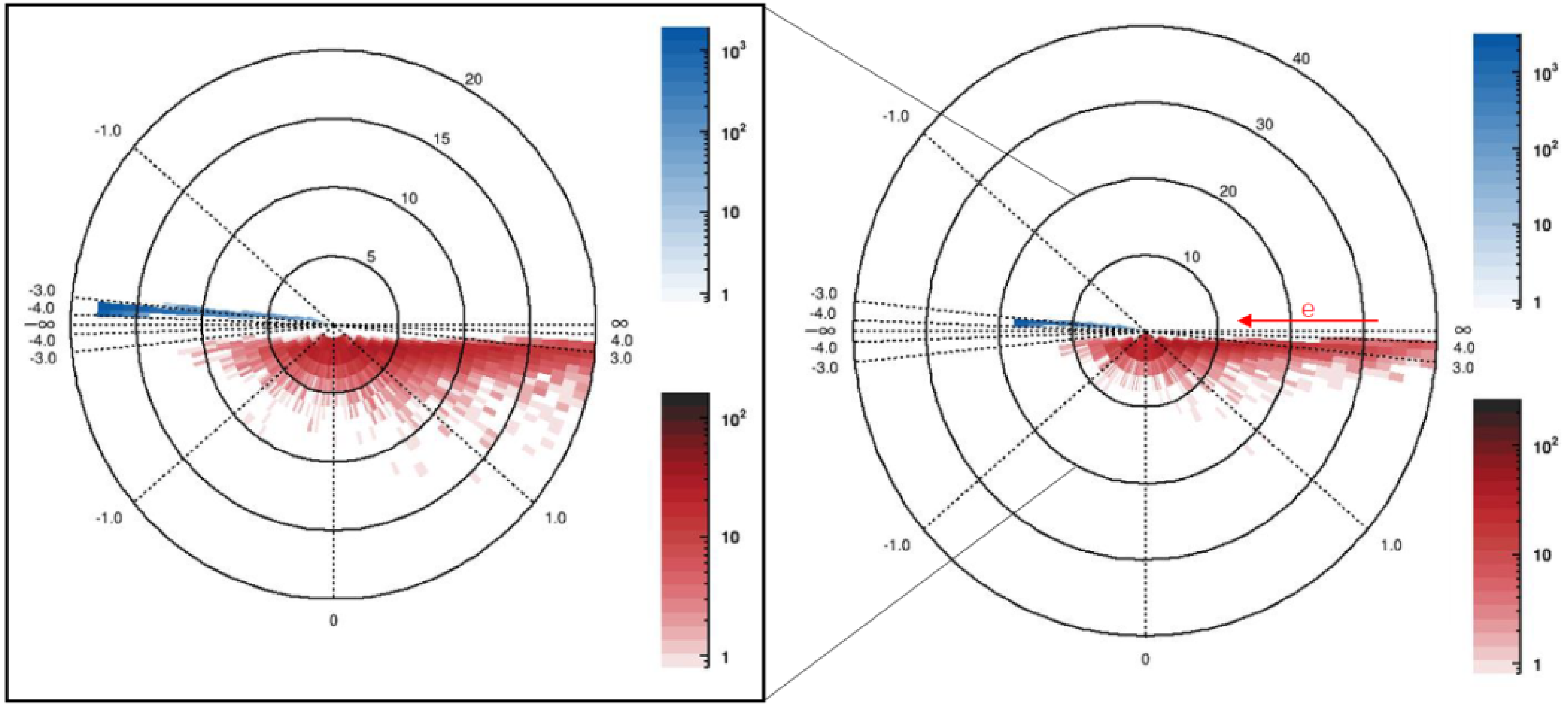
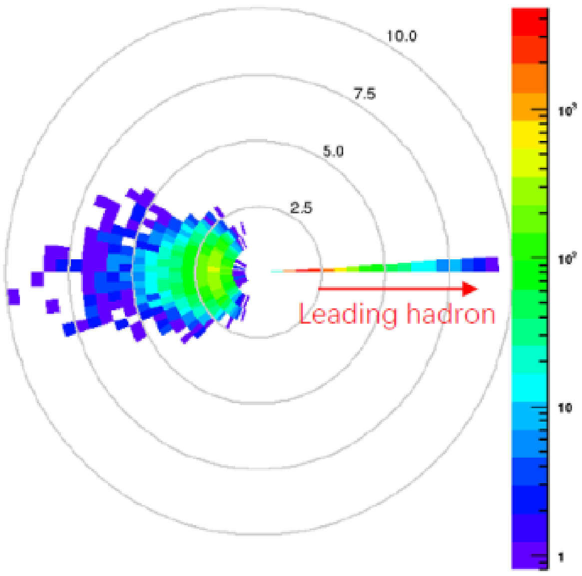
ep 18x275 GeV
0.01<y<0.95, $1<Q^2<2$ GeV^2
charged hadron, $|\eta|<4.5$, $p_T^*>1.4$ GeV, $z_h>0.1$,
$k^*_T/P^*_T<0.7$, * indicates γ^*p c.m.s frame

p vs η for scattered electron and charged hadron pairs



p_T vs $\Delta\phi$ for associate hadron relative to leading hadron



Gluon Saturation from charged dihadron channel

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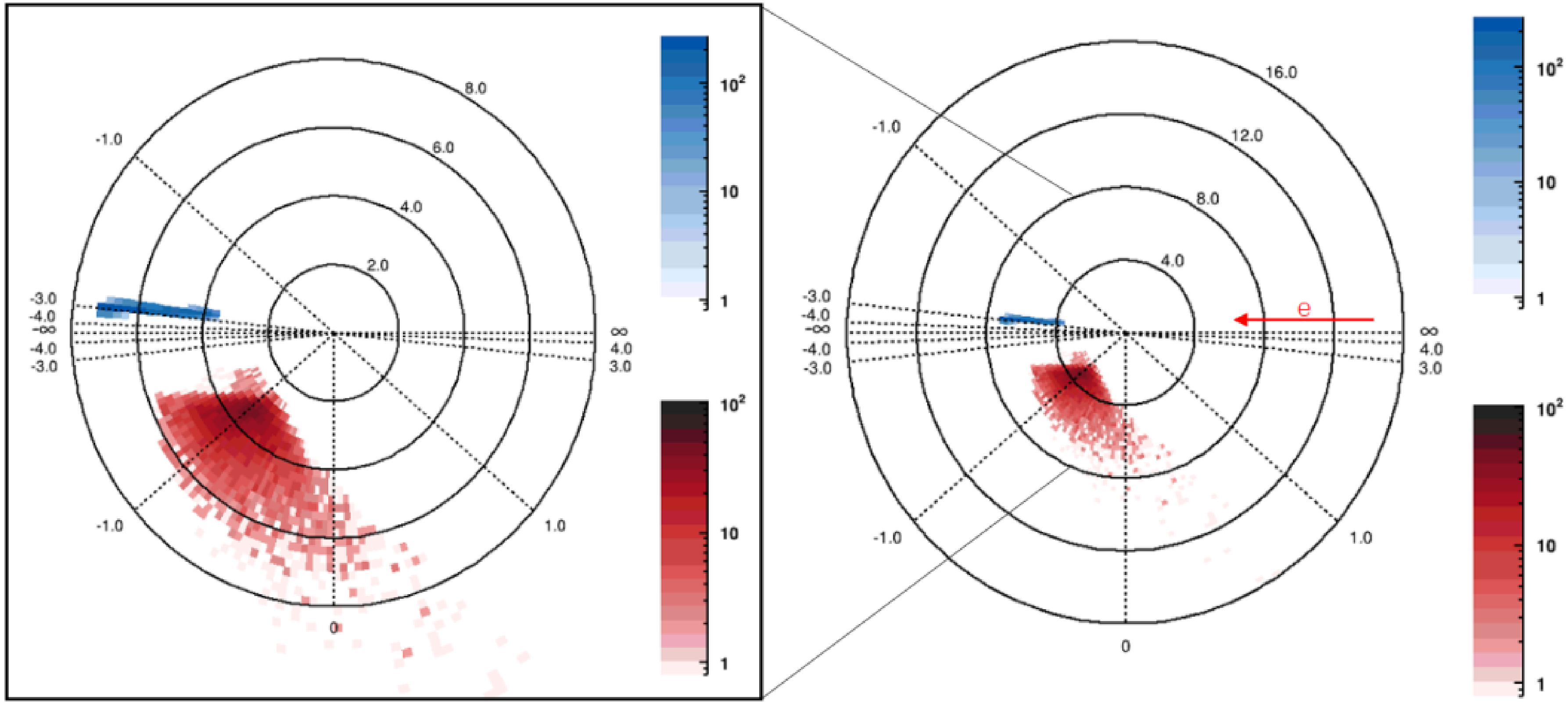
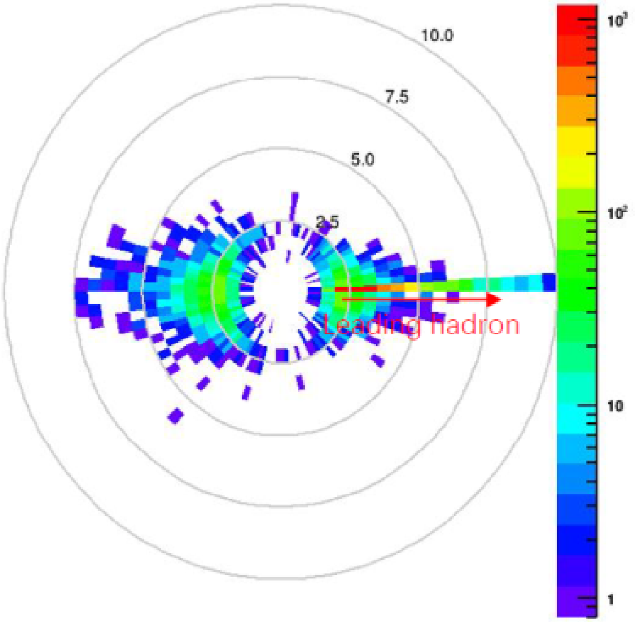
ep 18x110 GeV
$0.6<y<0.8$, $1<Q^2<2$ GeV^2
charged hadron, $|\eta|<4.5$, $p_{T\ trig}^*>2$ GeV, $p_{T\ assc}^*>1$ GeV,
$0.2<z_h<0.4$, * indicates γ^*p c.m.s frame

p vs η for scattered electron and charged hadron pairs



p_T vs $\Delta\phi$ for associate hadron relative to leading hadron



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Lambda measurements

η	Nomenclature		Tracking Resolution	Allowed X/X_0	Si-Vertex	Electrons Resolution σ_E/E	PID	π/K/p p-Range (GeV/c)	Separation	HCAL Resolution σ_E/E	Muons
-6.9 to -5.8	Auxiliary Detectors	low-Q2 tagger									
...											
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-3.5 to -3.0	Central Detector	Backward Detector									
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-2.5 to -2.0								≤ 7 GeV/c		~50%/√E	
-2.0 to -1.5											
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-1.0 to -0.5									≥ 3 σ		
-0.5 to 0.0		Barrel						≤ 5 GeV/c			TBD
0.0 to 0.5											
0.5 to 1.0											
1.0 to 1.5		Forward Detectors						≤ 8 GeV/c			
1.5 to 2.0											
2.0 to 2.5								≤ 20 GeV/c		~50%/√E	
2.5 to 3.0											
3.0 to 3.5								≤ 45 GeV/c			
3.5 to 4.0	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 to 4.5											
...		Neutron Detection									

Slow decay pion determines Λ statistics. Mass resolution via tracking and vertex resolution

Precise Photon energy measurement from Σ decays to separate Λ and Σ

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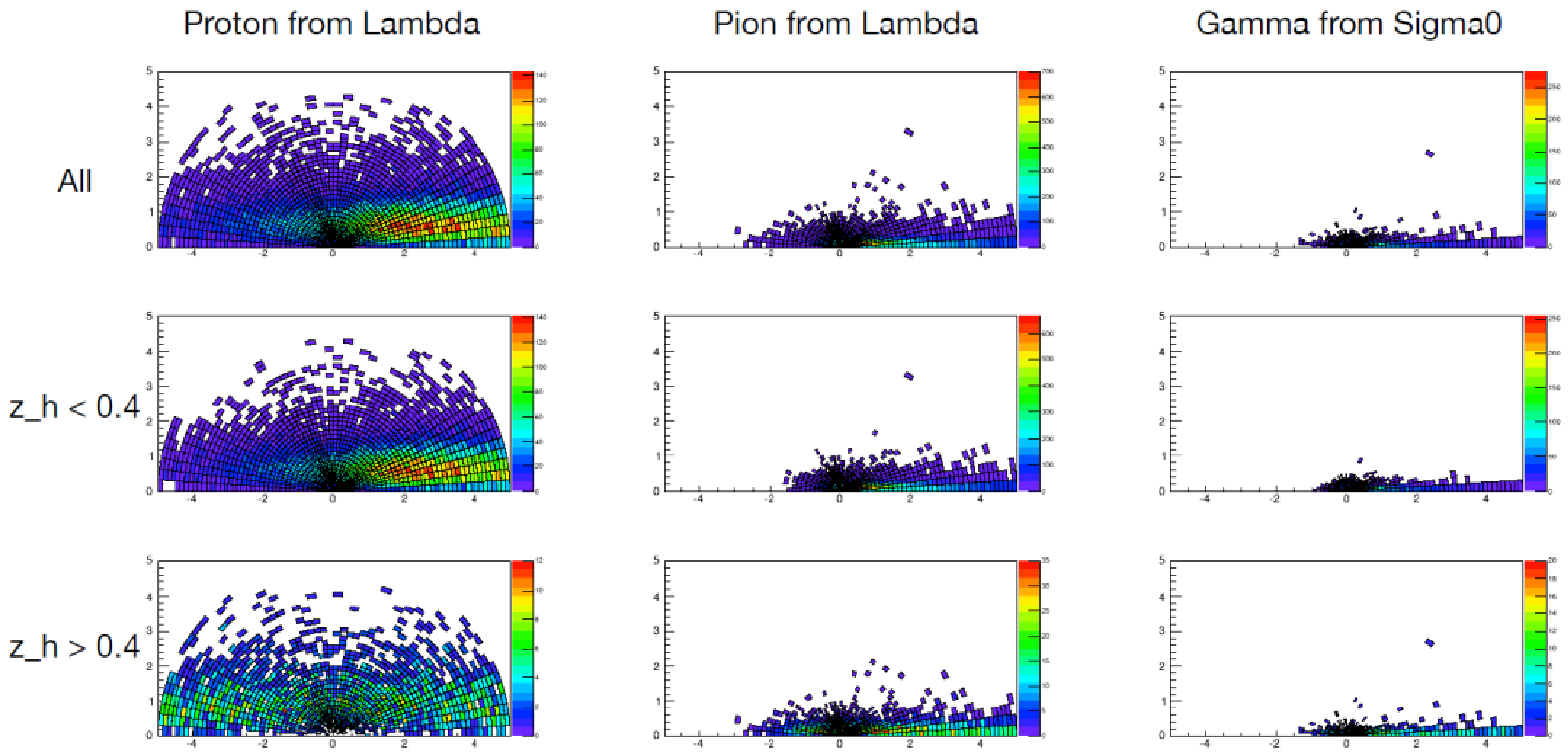
Momentum vs theta

275 GeV → ← 18 GeV



Angle for theta, radius for momentum/energy

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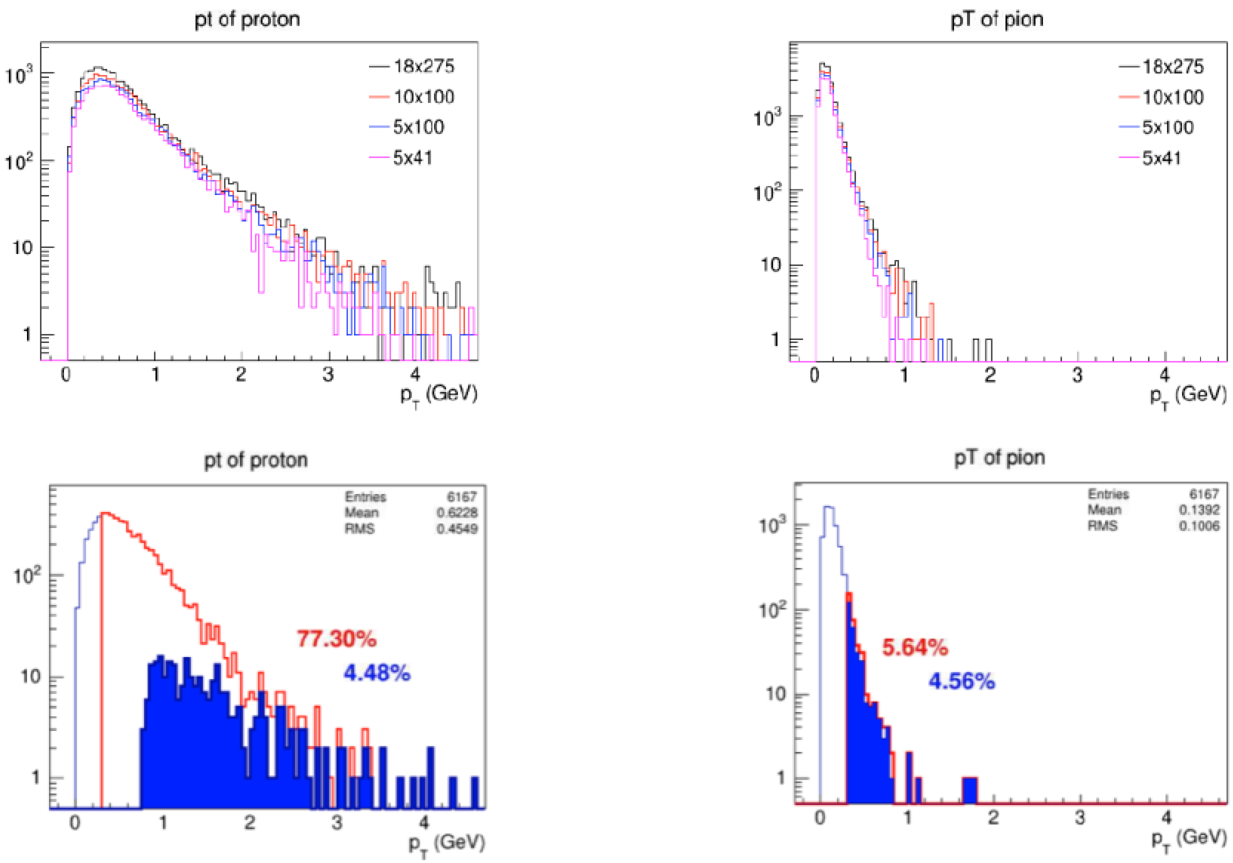
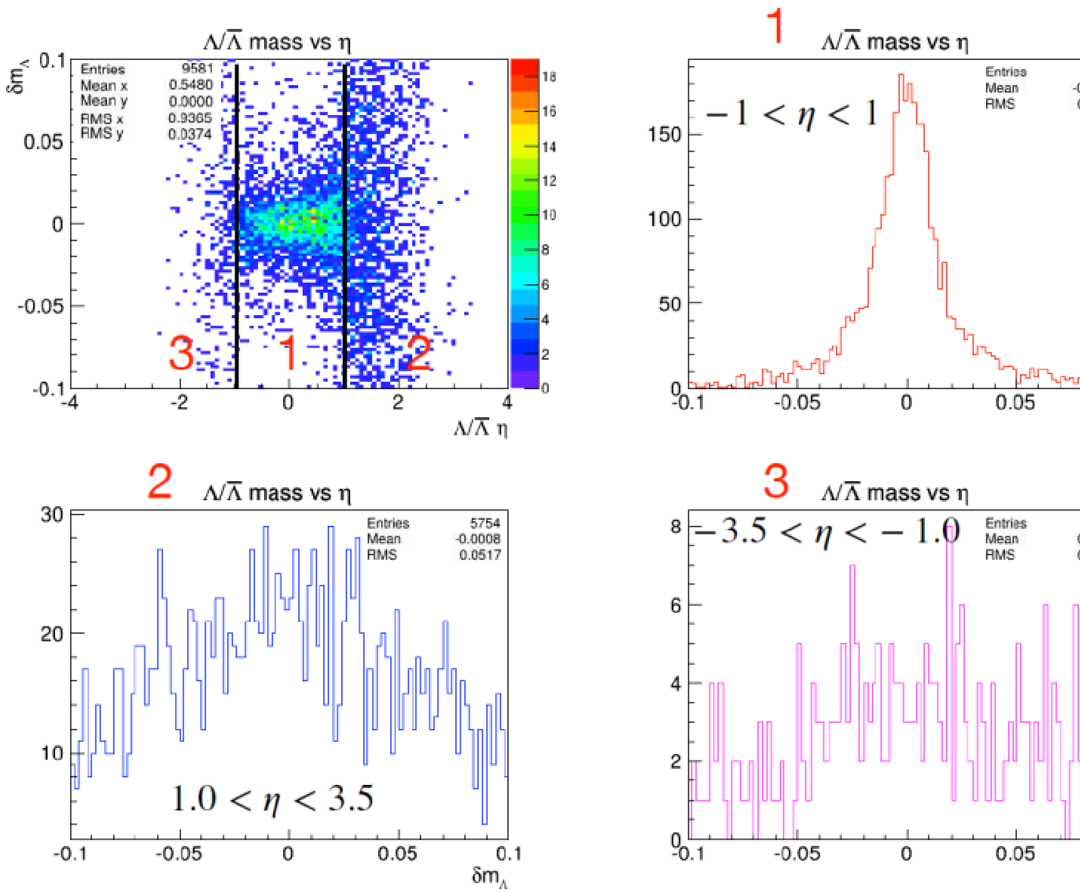
Final p_T limits



- p_T of pion and proton > 0.3 GeV
- Red is independent 0.3 GeV cut
- Blue filled is combined eta and pT cut

Lambda mass vs eta



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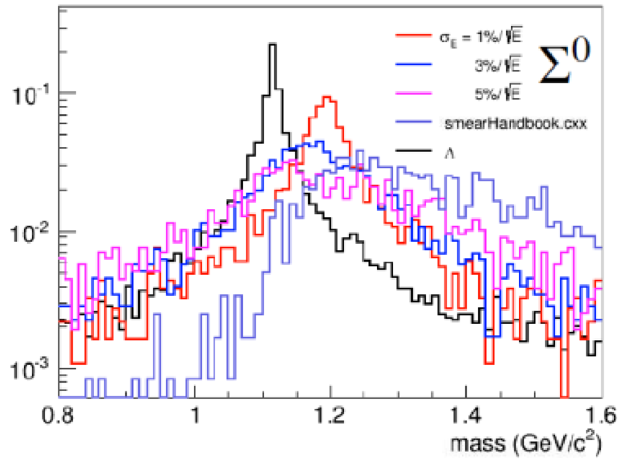
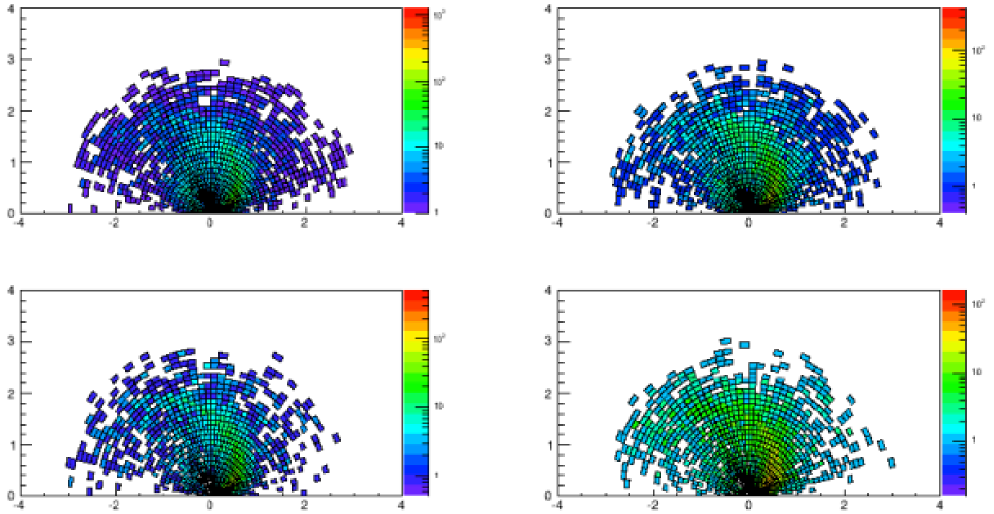
Smearing photon E for Sigma0

- In addition to the tracking smearing (handbook)
- Handbook setup push mass to larger side
- Lambda and sigma peak start merging at 3%/√E



Angle for theta, radius for open angle between lambda and photon



Spectroscopy measurements: **ep → Zc+n, Zc+ → J/ψπ+**

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η	Nomenclature		Tracking Resolution	Allowed X/X_0	Si-Vertex	Electrons Resolution σ_E/E	PID	π/K/p p-Range (GeV/c)	Separation	HCAL Resolution σ_E/E	Muons
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-4.5 to -4.0		Instrumentation to separate charged particles from photons									
-4.0 to -3.5						2%/√E					
-3.5 to -3.0		Backward Detector	σ_p/p ~ 0.1%⊕0.5%								
-3.0 to -2.5											
-2.5 to -2.0			σ_p/p 0.1%⊕0.5%		TBD	2%/√E		≤ 7 GeV/c		~50%/√E	
-2.0 to -1.5			σ_p/p 0.05%⊕0.5%			7%/√E	π suppression up to 1:10^4				
-1.5 to -1.0						7%/√E					
-1.0 to -0.5											
-0.5 to 0.0	Central Detector	Barrel	σ_p/p ~0.05%×p+0.5%	~5% or less X	σ_{xyz} ~ 20 μm, $d_0(z)$ ~$d_0(r\Phi)$ ~ 20/p_TGeV μm + 5 μm			≤ 5 GeV/c	≥ 3 σ		TBD
0.0 to 0.5											
0.5 to 1.0											
1.0 to 1.5		Forward Detectors						≤ 8 GeV/c			
1.5 to 2.0			σ_p/p ~0.05%×p+1.0%								
2.0 to 2.5					TBD	(10-12)%/√E				~50%/√E	
2.5 to 3.0			σ_p/p ~ 0.1%×p+2.0%								
3.0 to 3.5											
3.5 to 4.0	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 to 4.5											
...		Neutron Detection									
> 6.2		Proton Spectrometer	$\sigma_{intrinsic}(\|t\|)/\|t\|$ < 1%; Acceptance: 0.2 < p_t < 1.2 GeV/c								

Even more forward than SIDIS channels, requires higher momenta

+ forward neutron tagging

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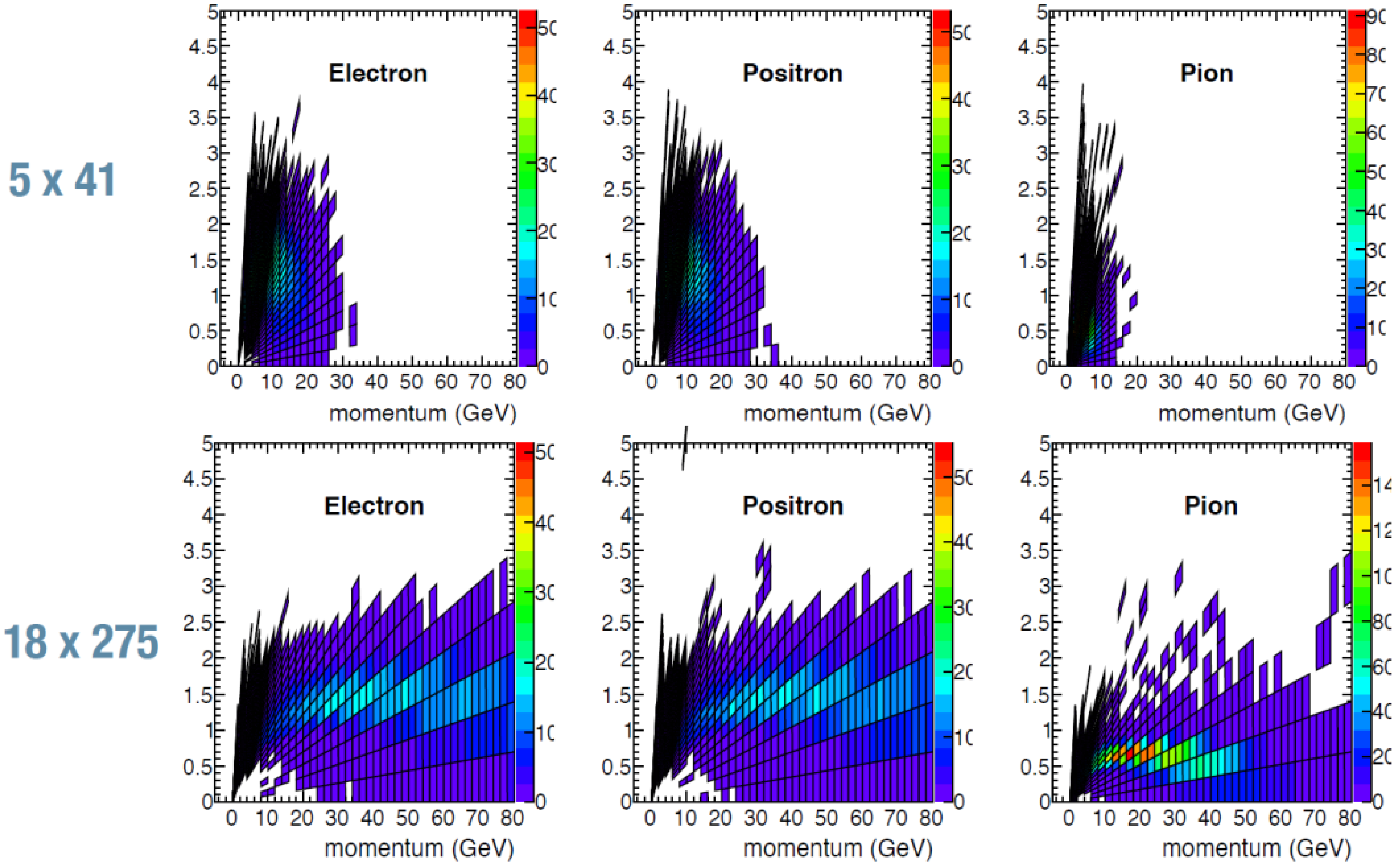
Polar detector maps



Overall status

- All channels are progressing well, all have produced some simulation data (mostly pythiaerhic+eicsmear, some dedicated generators and Pythia8)
- Application of latest smearing package (from Kolja’s mail) ongoing
- Some pseudo-data already with theorists for impact studies

- Requests for Pavia meeting: Maybe again joint SIDIS/HFjets session.

Golden channels I

Measurement/process	Main detector requirements	Anticipated plot	**Comments**
Quark Sivers, 3D momentum structure, TMD evolution from single hadrons →3D image (x, kT) of the Sivers Function, Evolution test of Sivers at intermediate x, Tensor charge via Collins Alexey Vladimirov	• η acceptance for hadrons • angular resolution • granularity of the detector (central to forward -1 to 4), • pi/K/p identification • Comments: PID↔Tracking, B −field, Δp/p, min p	• pseudo-3D Sivers function as a function kt for various x bins, • Value of Tensor charge uncertainties + plot vs x, • Q2 dependence of Sivers function or *A*$%at fixed x	• Use of existing simulations at Elke's group + smearing + weights originating from theorists, weights for Sivers asymmetries prepared • Work on common database ongoing, integrate in SW environment • Theory work on fits/parameterizations. First tests for unpol TMD data
Gluon Sivers via di-jets/dihadrons →Probing the size of the gluon Sivers function Bowen Xiao	acceptance for back-to-back Dihadrons	Size of the asymmetry as a function of x	• Continuation of study based on **arXiv:1805.05290** together with current EIC detector design • consideration of different jet algorithms Elke, Zheng, Lee and Yin • Possible different parametrizations of gluon Sivers function inputs from Pavia

Golden channels II

Measurement/process	Main detector requirements	Anticipated plot	**Comments**
Spectroscopy possibilities →Representative spectroscopy channel : X,Y → J/Ψππ, DD* Justin Stevens	• dilepton identification for J/psi • displaced vertex • pi/K separation for open charm • forward proton/neutron recoils from diffractive production (similar to DVCS reqs)	Kinematic coverage for decay particles in representative channels Possibly expected limits on coupling vs mass for J/Ψππ, DD* final states	Generator, EICsmear for mass resolution etc., bkgd. estimation

Silver channels I

Measurement/process	Main detector requirements	Anticipated plot	**Comments**
Sea quark helicity measurements →flavor separated (anti)quark helicity distributions over wide range of x Ralf Seidl	hadron momentum and energy resolution in forward direction ($2 < \eta < 4$) for CC events	Update of previous sea quark helicity PDF uncertainty plots	Work will follow ongoing sensitivity studies by Elke's group + Argentinian global fitters. • Implementation of detector smearing, etc needs to be added to existing studies. • Concentration on CC and $D/3He$.
FFs/nFFs/nPDFs via single hadron FF →Single hadron fragmentation functions for ep and eA for FFs, nFFs, nPDFs Ralf Seidl	See TMD SIDIS reqs	nPDF uncertainty expectation, (n)FF Expectation	Simulations prepared using official 4 ep and 3 eAu beam energy combinations, for smeared simulation BeAST resolutions were used in eicsmear. • reweighted eAu multiplicitis using nFFs from SSZ fit • Not implemented: magnetic field and PID (hadron, momentum, rapidity) impact.

Silver+New channels

Measurement/process	Main detector requirements	Anticipated plot	**Comments**
Di-hadron correlations in eA →low x →Probing the onset of saturation phenomenon Bowen Xiao	backward hadron acceptance, granularity	decorrelation plot as in white paper	Continuation of work based on **arXiv:1403.2413** with extension to jets with different algorithms using the new collisional energies at eRHIC.
Di-hadron FF for Tensor charge/Boer-Mulders Anselm Vossen	Single hadron reqs+min z for partial wave expansion	• Impact on tensor charge/transversity extraction • Projected BM asymmetries	Initial simulations prepared for kin. Ranges, Reweighting of asymmetries next
Lambda related spin measurements →L/T spin transfer, polarizing FFs (universality), jet structure Anselm Vossen	• Λ acceptance • Slow pion →low momentum cutoff, displaced vertex	• Precision of Λ polarization measurements	Detailed study of acceptances and momentum requirements