Physics Working Group: overview and progress report

A. Dumitru, O. Evdokimov, A. Metz, C. Muñoz Camacho

(input from all physics working groups)

Physics WG subgroups conveners

- Inclusive
  - Th: Nobuo Sato (JLab)
  - Exp: Renee Fatemi (Kentucky), Barak Schmookler (Stony Brook)
- h SIDIS
  - Th: Alexey Vladimirov (Regensburg), Bowen Xiao (CCNU, China)
  - Exp: Ralf Seidl (RIKEN), Justin Stevens (W&M), Anselm Vossen (Duke)
- Jets, heavy quarks
  - Th: Frank Petriello (Argonne & Northwestern U.), Ivan Vitev (LANL)
  - Exp: Leticia Mendez (ORNL), Brian Page (BNL), Ernst Sichtermann (LBL)
- Exclusive
  - Th: Tuomas Lappi (Jyvaskyla), Barbara Pasquini (Pavia)
  - Exp: Raphaël Dupré (Orsay), Salvatore Fazio (BNL), Daria Sokhan (Glasgow)
- Diffractive & Tagging
  - Th: Wim Cosyn (Florida), Anna Stasto (PSU)
  - Exp: Or Hen (MIT), Doug Higinbotham (JLab), Spencer Klein (LBNL)

Charge for Pavia Workshop

Straw-man plan of attack:

a. Review previous existing work related to your subgroup.
b. Converge on a set of important and representative measurements for your subgroup.

Presented at the Temple meeting

c. Break-down physics deliverables into "physics objects" (PO) [electron, hadron (ID/noID), muon, jet]; map out kinematics for each PO.

d. Cross-check PO maps across physics subgroups to determine the most challenging constraints in terms of detector design; resolve overlaps [decide who runs what].

e. Focus on fast simulations for the most demanding measurements first; determine the optimal/acceptable detector performance; confirm/check resulting impact on the rest of the measurements

Simulation baseline parameters

Based on the current BNL design, we suggest, as a starting point for our physics simulations, to study one or several of the following beam energy combinations:

p-e	275 on 18 GeV	100 on 10 GeV	100 on 5 GeV	41 on 5 GeV
d/^{3}He/^{4}He-e	110 on 18 GeV	110 on 10 GeV		41 on 5 GeV
C/^{40}Ca/Cu-e	110 on 18 GeV	110 on 10 GeV		41 on 5 GeV
Au-e	110 on 18 GeV	110 on 10 GeV		41 on 5 GeV

(For nuclei the energy refers to the energy per nucleon)

Please assume integrated luminosities of 10 fb^{-1} and 100 fb^{-1}

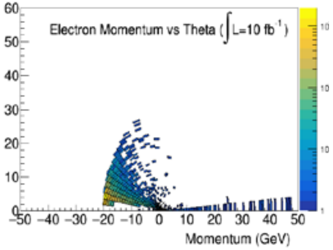
A polarization of 70% may be assumed for electrons and light ions

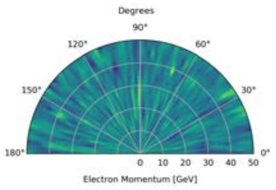
Simulation Tools and Information Flow

- To ensure reproducibility of YR studies and consistency across simulations for different processes/working group, the prefered solution is to converge on a single simulation tool (for each detector region): EIC-smear, EICRoot

- Coordination with Software team to establish versioning/ coherent implementation of Detector response parametrizations

- Have a common data-exchange format for kinematic maps https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Common#Standard_histogram_to_display_kinematic_coverage





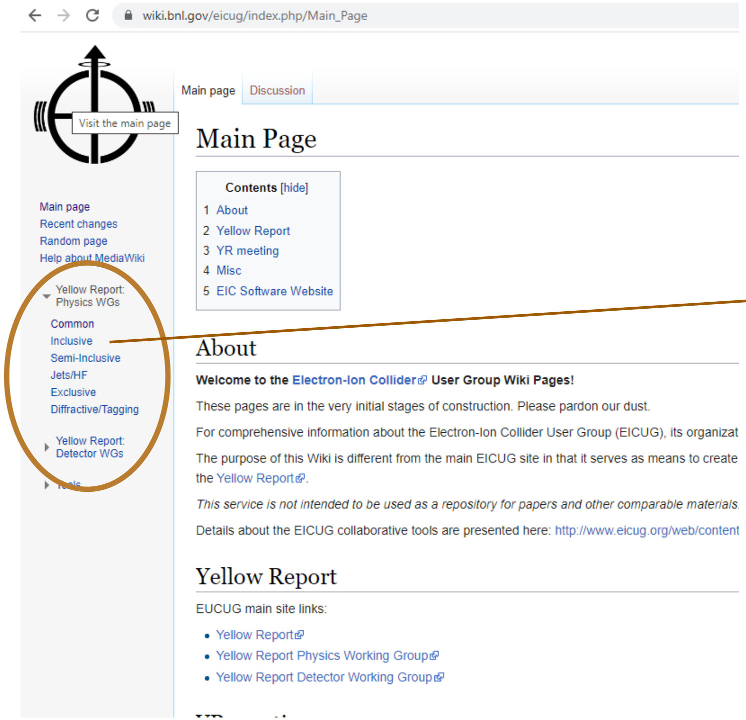
Exchanges with DWG

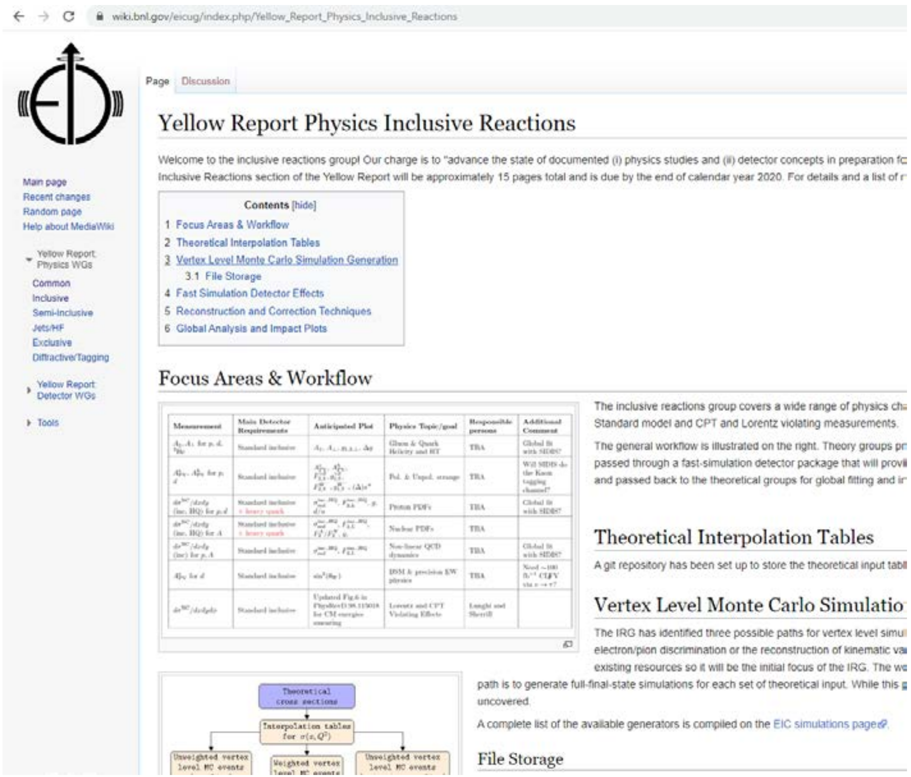
- ✔ Document studies/results in the wiki: https://wiki.bnl.gov/eicug/index.php
- ✔ Send information to the detector group in order to update the interactive detector matrix

η	Nomenclature			Tracking			Electrons		π/K/p		HCAL	Muons
				Resolution	Allowed X/X_0	Si-Vertex	Resolution σ_E/E	PID	p-Range (GeV/c)	Separation	Resolution σ_E/E	
-6.9 to -5.8		Auxiliary Detectors	low-Q2 tagger	σθ/θ < 1.5%; 10-6 < Q2 < 10-2 GeV2								
...	↓ p/A											
-4.5 to -4.0			Instrumentation to separate charged particles from photons									
-4.0 to -3.5							$2\%/\sqrt{E}$					
-3.5 to -3.0			Backward Detector	$\sigma_p/p \sim 0.1\% \oplus 0.5\%$								
-3.0 to -2.5												
-2.5 to -2.0				σ_p/p 0.1%⊕0.5%		TBD	$2\%/\sqrt{E}$		≤ 7 GeV/c		~50%/√E	
-2.0 to -1.5				σ_p/p 0.05%⊕0.5%			$7\%/\sqrt{E}$					
-1.5 to -1.0							$7\%/\sqrt{E}$	π suppression up to 1:10[4]				
-1.0 to -0.5			Barrel									
-0.5 to 0.0		Central Detector		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%			(10-12)%/√E					
2.0 to 2.5						TBD			≤ 20 GeV/c		~50%/√E	
2.5 to 3.0				σ_p/p ~ 0.1%×p+2.0%								
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												
...	↑ e		Neutron Detection									
> 6.2			Proton Spectrometer	$\sigma_{intrinsic}(\|t\|)/\|t\|$ < 1%; Acceptance: 0.2 < p_t < 1.2 GeV/c								

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

YR Wikipages





Inclusive physics working subgroup

Pavia YR Meeting

Barak Schmookler, Nobuo Sato, Renee Fatemi

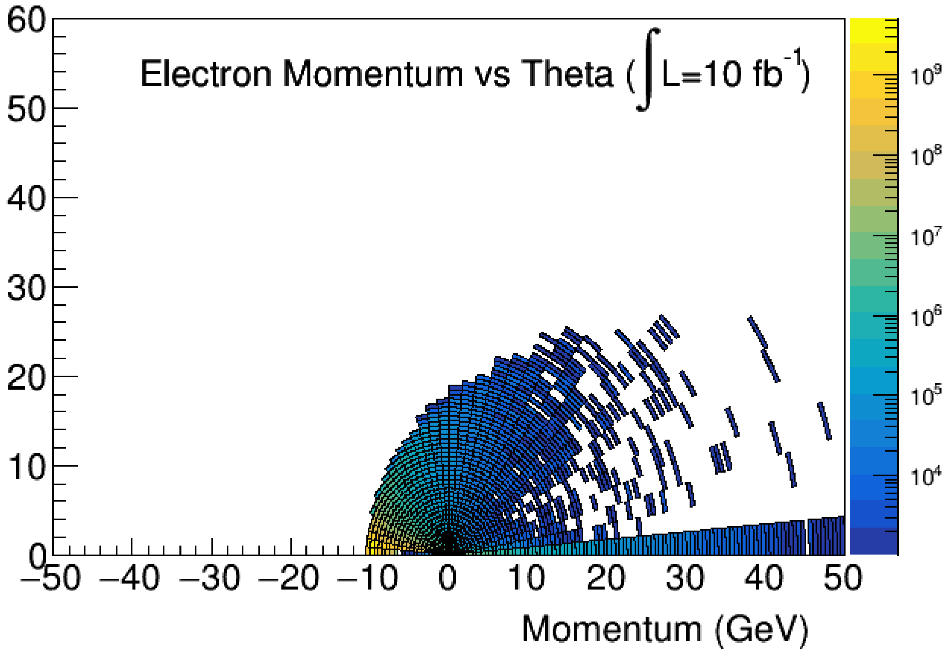
Summary of studied channels: kinematics

Note : Each kinematic map represents several physics channels

Measurement/ process	Main detector requirement	Expected YR plot	Physics goal/topic	Contact person	Comments
Neutral current e-p cross-sections and asymmetries	EMcal for e- energy, Tracker to reconstruct e- momentum and scattering angle, provide e/h discrimination (via E/p) and e+/e- separation	$A_{\|\|}$, $A_{\perp}$, A^{e}_{PV} $g_{1,2}$, $g^{\gamma Z}_{1,5}$ F_2, F_L, $F^{\gamma Z}_{2,3}$ Δg, g, Δs^{+}, s^{+} σ^{NC}_{red}, $\sin^2\theta_W$	Gluon and quark proton momentum & helicity PDFs. Non-linear QCD dynamics.	Barak Schmookler	✔ e-p 10-100 ▪ e-p 5-41 ▪ e-p 5-100 ▪ e-p 18-275 ? e+/pion maps? ? e-A?
Charged current e-p cross-sections and asymmetries	EMcal, HCal and tracker for E and p of hadronic recoil. Need low thresholds and as forward as possible.	A^{h}_{PV}, σ^{Cc}_{red}, $\Delta u/u$, $\Delta d/d$, high x sbar	Polarized and unpolarized sea quark asymmetries	Xiaoxuan Chu	✔ e-p 18-275

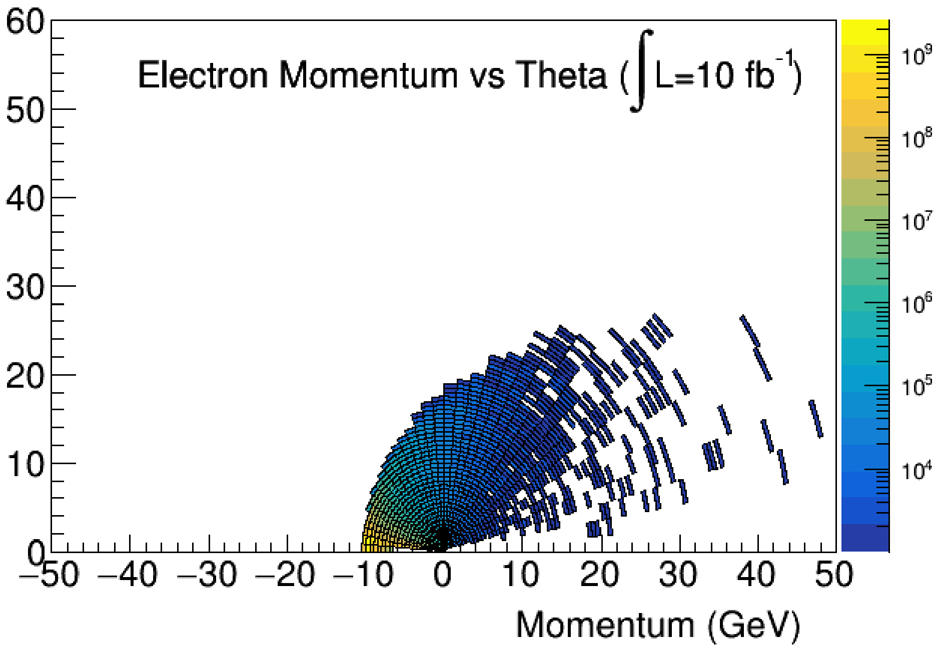
Neutral Current: kinematics 10x100

- PYTHIA6, no radiative effects. All electrons, scattered + decay
- **Largest yield is for electrons scattered backwards** (toward the electron beam-pipe)
- Highest momentum electrons scatter at mid to mid-forward rapidity.
- High momentum electrons at large angle original from meson decay.



Neutral Current: kinematics 10x100

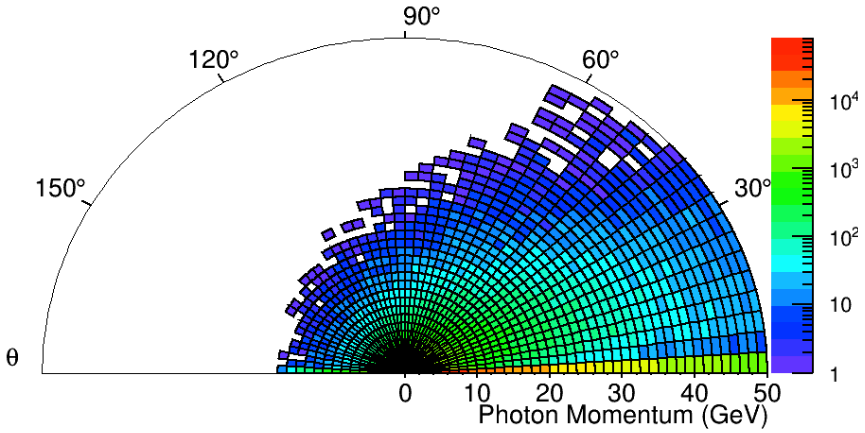
- PHYTHIA 6, no radiative effects. All electrons, scattered + decay
- **Largest yield is for electrons scattered backwards** (toward the electron beampipe)
- Highest momentum electrons scatter at mid to mid-forward rapidity.
- High momentum electrons at large angle original from meson decay. *These are removed when looking at only the scattered beam electrons.*

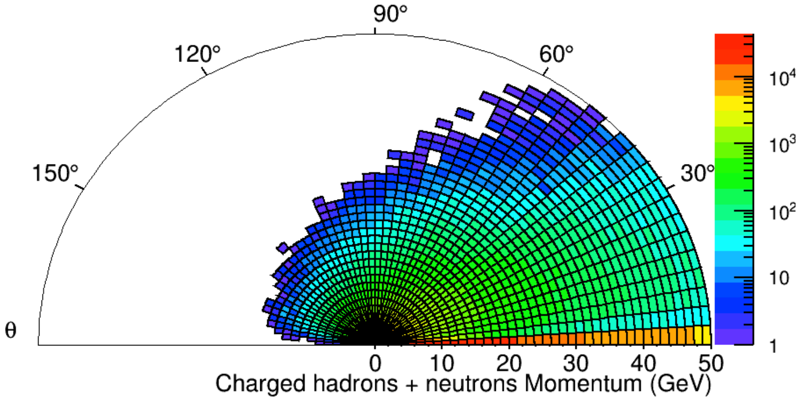


Charged Current: kinematics

- Highest momentum gamma go down the proton (+z) beamline
- Mid-range momentum photons from pion decay contribute in the forward (mid-forward eta) region.
- Peaked backward (-z) direction gamma come from e- radiation

- High momentum hadrons from the beam remnant go down the beampipe (+z)
- Fragmentation hadrons from scattered quark are produced at mid-range (mid-forward eta) region.
- **Need detector to be pushed as far forward as possible.**



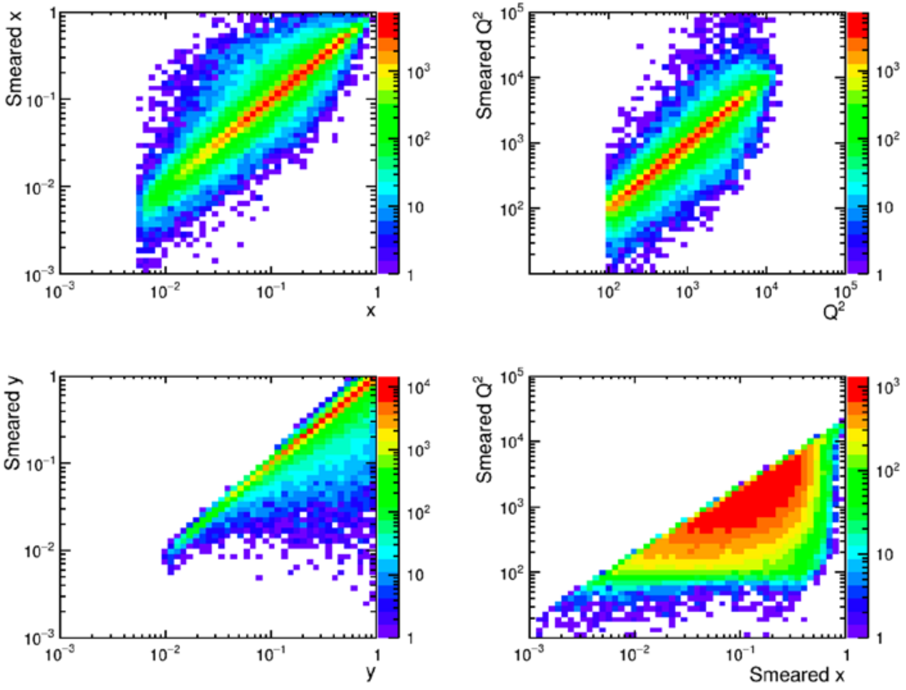


Summary of studied channels: fast simulations

Measurement /process	Main detector requirement	Expected YR Plot	Physics goal/topic	Contact person	Comments
Charged current e-p cross-section	EMcal, HCal and tracker for E_h and p_h of hadronic recoil. Need thresholds to be as low as possible and detectors extending as far forward as possible.	$\boldsymbol{\sigma}^{Cc}_{red}$, sbar	Sea quark distributions in the proton	Xiaoxuan Chu	Radiation, detector acceptance and PID effects studied. EIC smearing studies ongoing.
Neutral current e-p cross-section	EMcal for E_{e-} and tracker for p_{e-}, scattering angle, e/h discrimination (via E/p) and e+/e- separation	$\boldsymbol{\sigma}^{Nc}_{red}$, g, d/u	Proton PDFs	Xiaoxuan Chu Barak Schmookler	Generator level cross-section and EIC-smear studies ongoing.
g_2	Same at NC e-p cross-section	$g_2(x)$ vs Q^2	Quark and gluon helicity and higher Twist	Matt Posik	Generator level cross-section comparison to theory.
A^e_{PV}	Same as NC e-p cross-section	A^e_{PV}	Polarized and unpolarized strange PDFs	Hanjie Liu	Generator level PID studies.

Charged Current Cross-section: smeared kinematics

- Work of Xiaoxuan Chu - https://indico.bnl.gov/event/8389/
- Django e+p = 18 + 275 GeV, $\sqrt{s}$ = 141 GeV
- Radiative effects turned on.
- L = 10 fb^{-1}, 0.01 < y < 0.95, 100 < Q^2 < 10^5 GeV^2.
- EIC Smear input:
  - Device SmearThetaHadronic(Smear::kTheta, "0.001");
  - HCAL -3.5 < η < -1.0 : sigma_E/E ~ 0.45/sqrt(E)+0.06
  - HCAL -1.0 < η < 1.0 : sigma_E/E ~ 0.85/sqrt(E)+0.07
  - HCAL 1.0 < η < 3.5 : sigma_E/E ~ 0.45/sqrt(E)+0.06
  - TRACKER -3.5 < η < -2.5 : sigma_p/p ~ 0.1% p+2.0%
  - TRACKER -2.5 < η < -1.0 : sigma_p/p ~ 0.05% p+1.0%
  - TRACKER -1.0 < η < 1.0 : sigma_p/p ~ 0.05% p+0.5%
  - TRACKER 1.0 < η < 2.5 : sigma_p/p ~ 0.05% p+1.0%
  - TRACKER 2.5 < η < 3.5 : sigma_p/p ~ 0.1% p+2.0%
- Reduced cross-section extracted using Jacquet-Blondel (JB) kinematic reconstruction



$$x_{JB} = \frac{Q^2_{JB}}{s y_{JB}}; \quad y_{JB} = \frac{(E - p_z)_h}{2E_e}; \quad Q^2_{JB} = \frac{p^2_{t,h}}{1 - y_{JB}}$$

Semi-inclusive physics working subgroup

Pavia YR Meeting

Ralf Seidl (RIKEN), Justin Stevens (William & Mary), Alexey Vladimirov (Regensburg), Anselm Vossen (Duke), Bowen Xiao (Central Normal University)

Summary of studied channels: simulations

Measurement /process	Main detector requirement	Expected plot for the YR	Physics goal/topic	Contact person
Single hadron SIDIS	η acceptance for hadrons • angular resolution • granularity of the detector (-1 <η< 4), • π/K/p identification • PID, Tracking, Δp/p, min p	pseudo-3D Sivers function vs (x,kt) • Value of Tensor charge uncertainties, h1 vs x • Q2 dependence of Sivers function or Collins at fixed x	3D (x, kT) Sivers Function, TMD Evolution, test of Sivers at inter. x, Tensor charge via Collins	Alexey Vladimirov
Comments: 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 impact studies for unpol.TMD and TMD evolution.				
Di-hadron correlations in eA	backward hadron acceptance, sufficiently high resolution for the momentum (mainly high pT) and azimuthal angle (need 2\pi coverage).	decorrelation plot as in white paper	low x, Probe onset of saturation phenomena	Bowen Xiao

Comments: Continuation of work based on **arXiv:1403.2413** with extension to jets with different algorithms using

Summary of studied channels: simulations

Measurement/ process	Main detector requirement	Expected plot for the YR	Physics goal/topic	Contact person
Dijets and di-hadrons for Gluon Sivers	resolution for the momentum (mainly high pT) and azimuthal angle (2\pi coverage)	Size of the asymmetry as a function of x	Probing the size of the gluon Sivers function	Bowen Xiao
Comments: 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 parameterizations of gluon Sivers function inputs from Pavia				
Spectroscopy	• leptons from J/ψ • displaced vertex and π/K separation for open charm	Kinematic map of decay particles; mass resolution and sensitivity for J/ψπ, DD* final states	Representative spectroscopy channels : X, Y, J/ψππ, DD*	Justin Stevens
Comments: Custom generators with theory input, eic-smear for mass resolution etc., Pythia background estimation				

Summary of studied channels: simulations

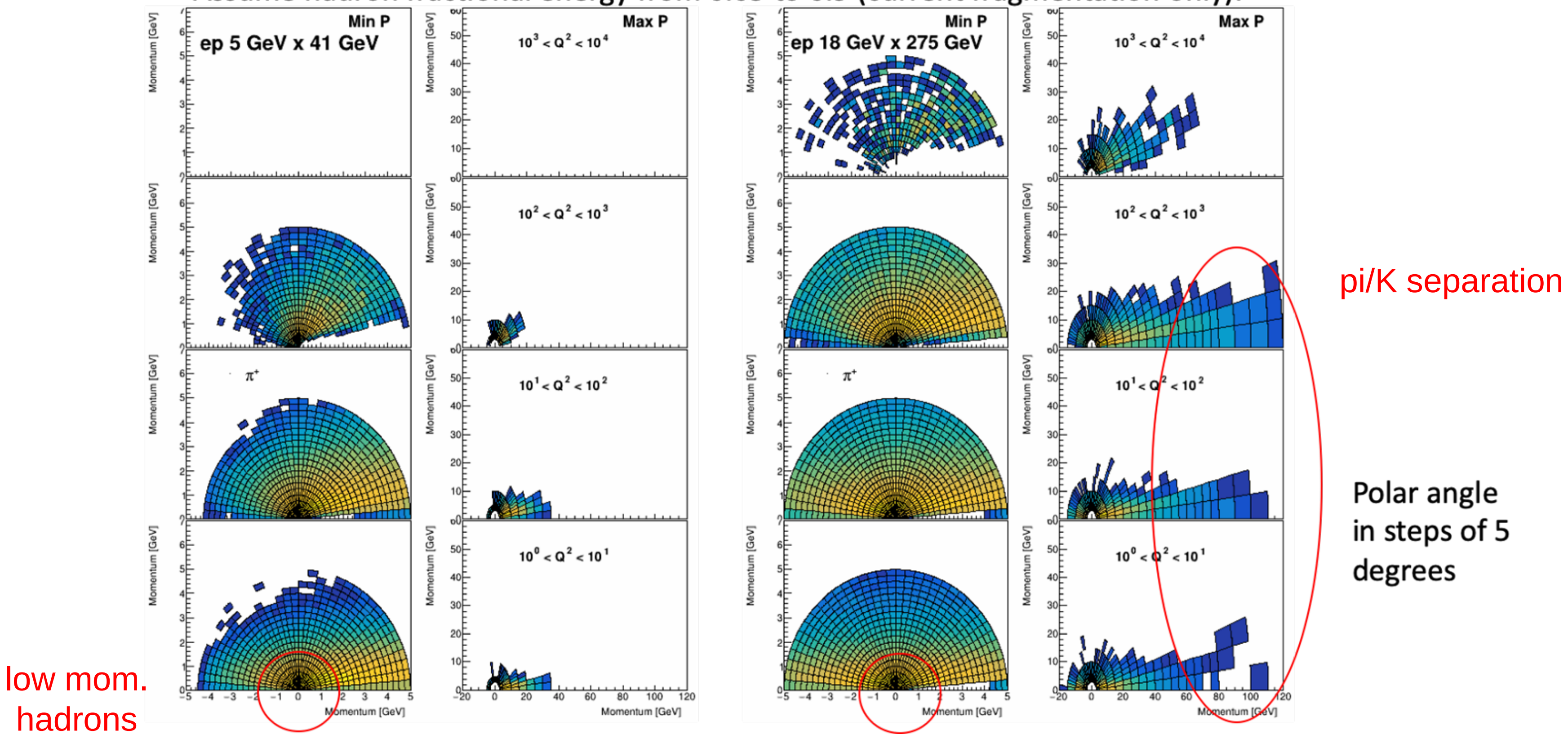
Measurement/ process	Main detector requirement	Expected plot for the YR	Physics goal/topic	Contact person
Sea quark helicity measurements	hadron momentum and energy resolution in forward direction ($2 < \eta < 4$) for CC events	Update of previous sea quark helicity PDF uncertainty plots	flavor separated (anti)quark helicity distributions over wide range of x	Ralf Seidl

Comments: 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 $D/3He$.

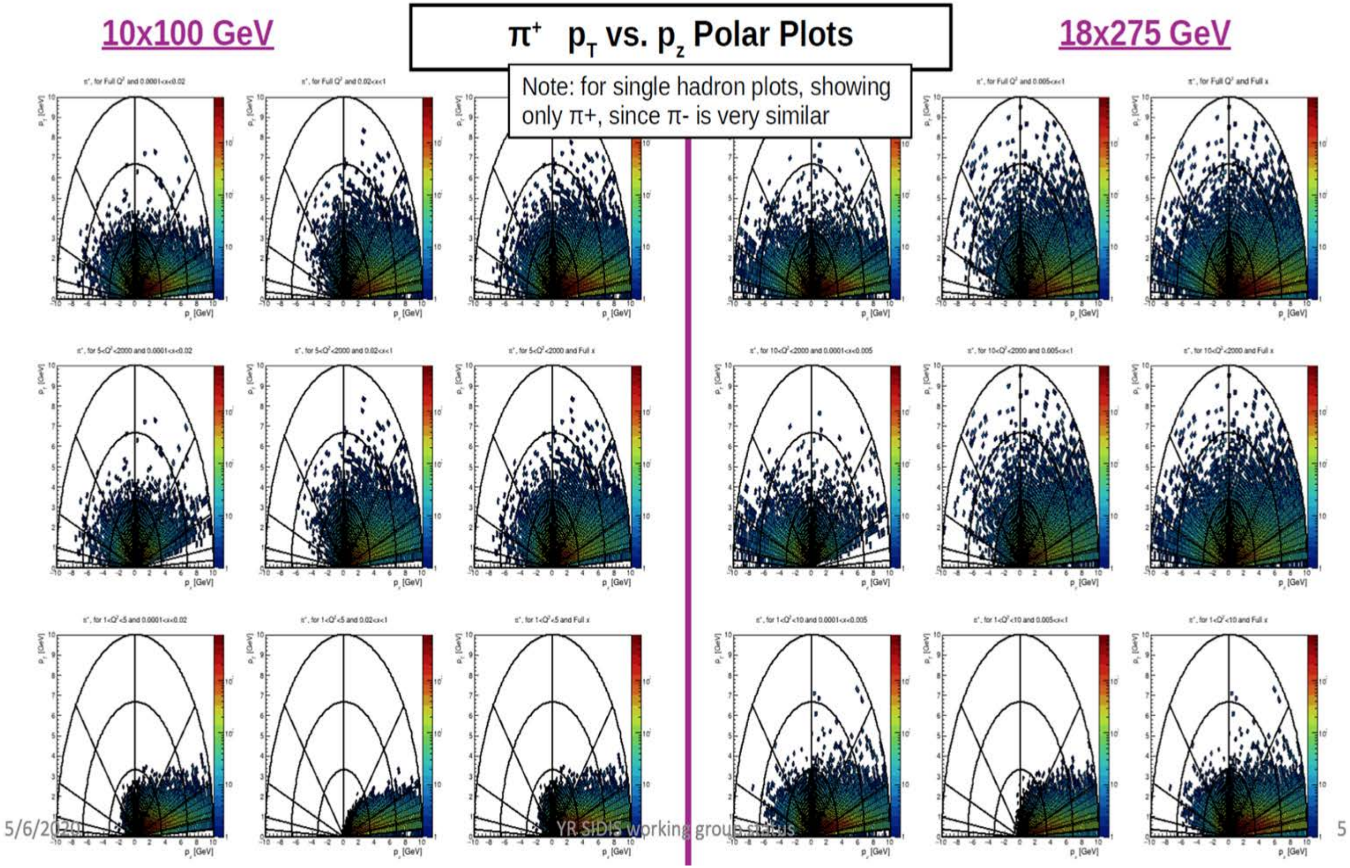
Results for Single hadron SIDIS: kinematics

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

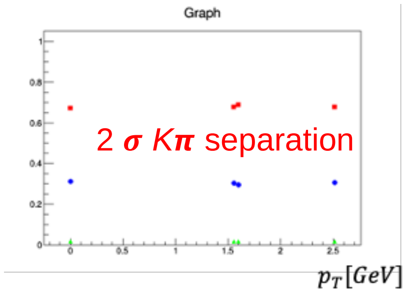


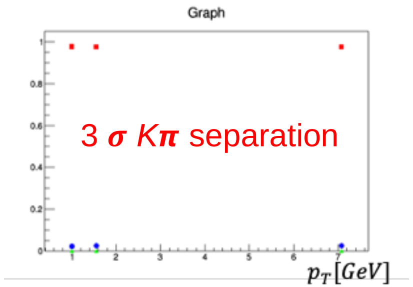
Polar angle in steps of 5 degrees

Results for Di-hadron Correlations: kinematics



PID Study of $K\pi$ Purities





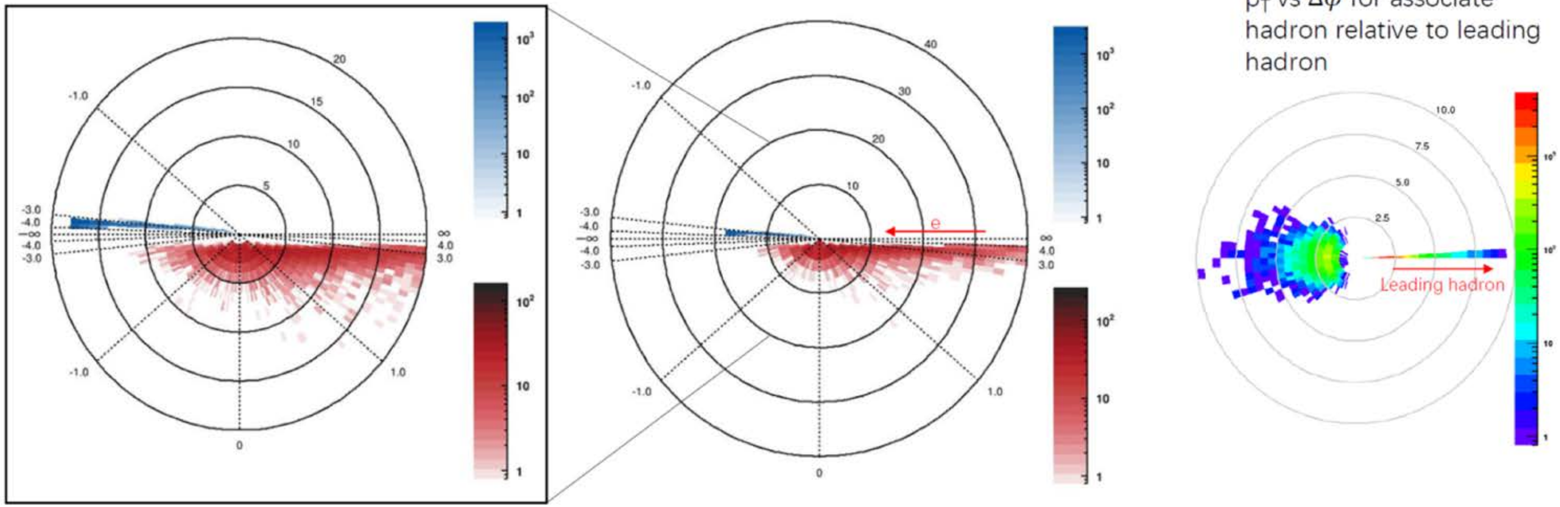
Results for Gluon Sivers: kinematics

Gluon Sivers measurement requirement from charged dihadron channel

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 $\gamma^*\mathbf{p}$ 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



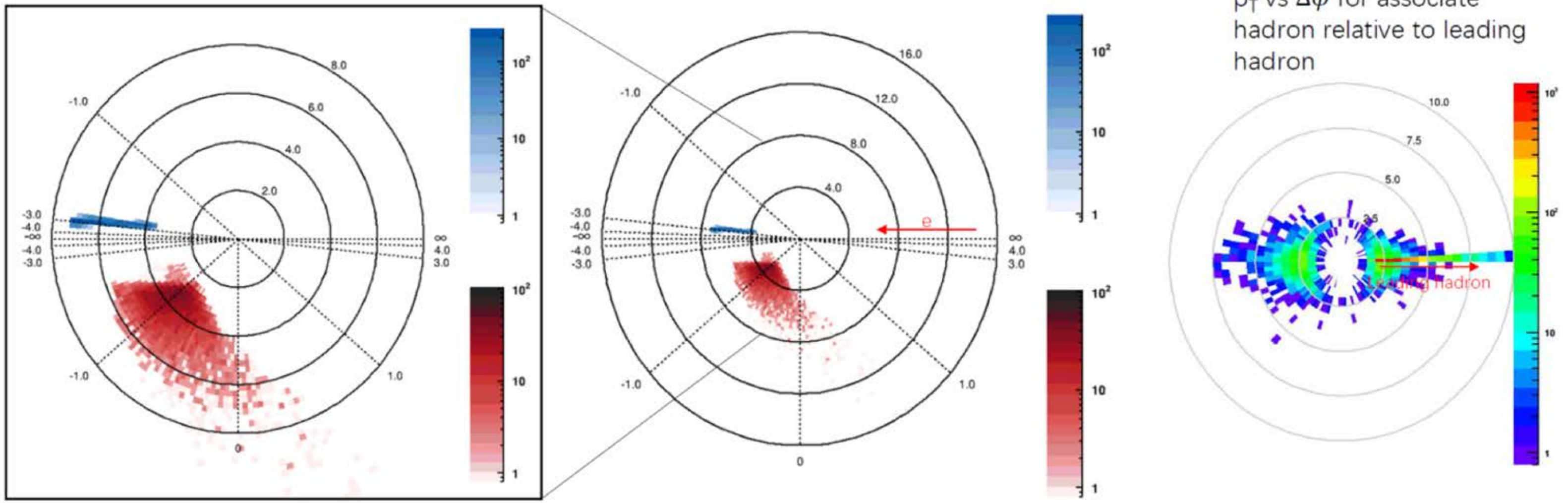
Results for Gluon Saturation: kinematics

Gluon Saturation from charged dihadron channel

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 $\gamma^{*}p$ 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



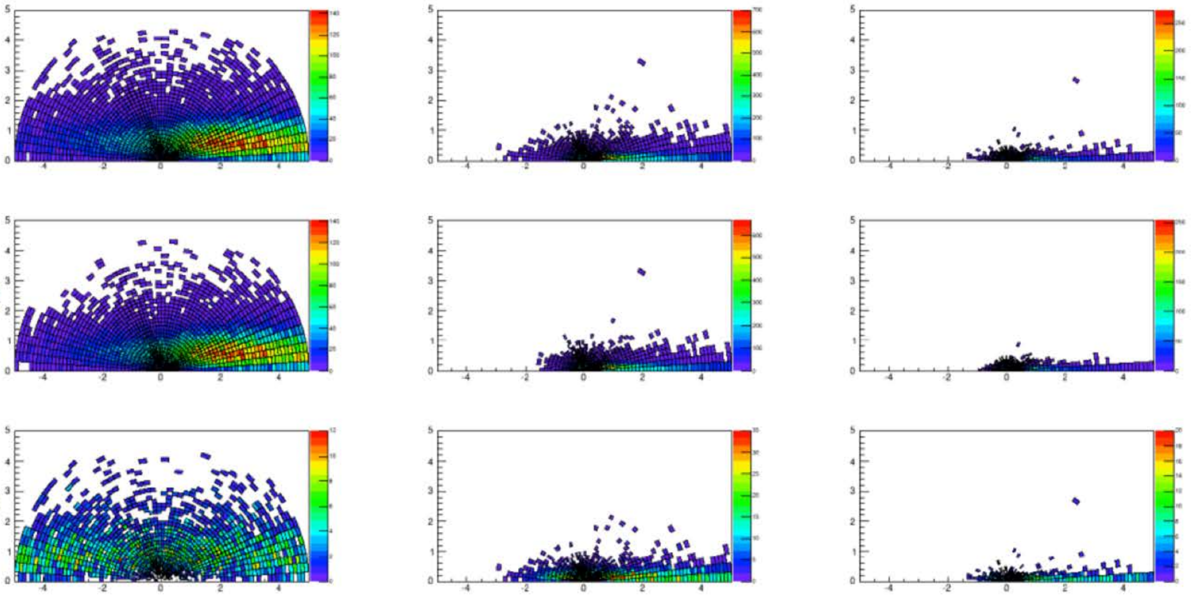
Results for Hyperons: kinematics + smearing

Proton from Lambda | Pion from Lambda | Gamma from Sigma0

All

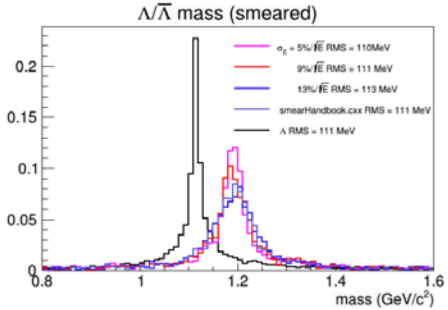
z_h < 0.4

z_h > 0.4



Angle for theta, radius for momentum/energy

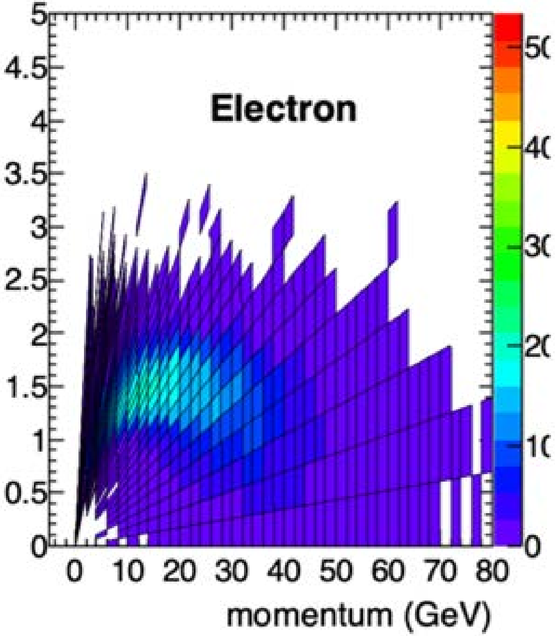
Λ mass resolution and $\Sigma \rightarrow \Lambda\gamma$ feeddown

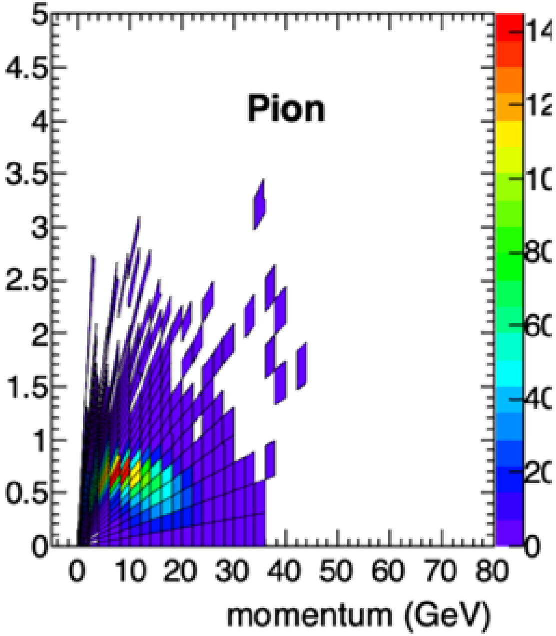


- In addition to the tracking smearing (handbook)
- Handbook setup push mass to larger side
- Lambda and sigma peak start merging at 3%/√E

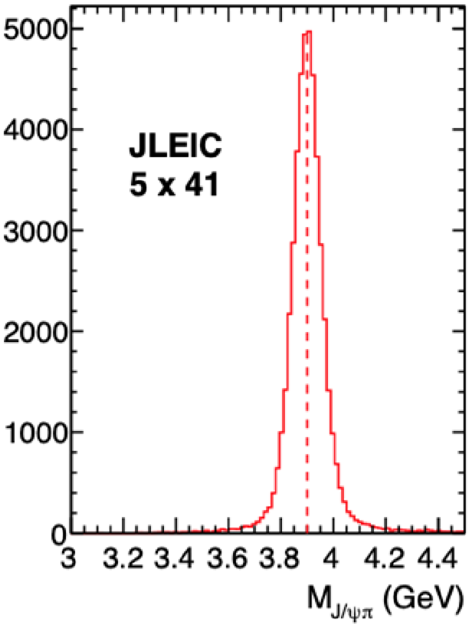
Results for Spectroscopy: kinematics + smearing

$$\gamma p \to Z_c^+ n \quad Z_c^+ \to J/\psi \pi^+$$





Smeared mass resolution



Jets and Heavy Flavor physics working subgroup

Pavia YR Meeting

Leticia Cunqueiro, Brian Page, Frank Petriello, Ernst Sichtermann, Ivan Vitev

Summary of studied channels: simulations

Measurement /process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Open heavy flavor - Mesons - Λ_c - Leptons - Displaced tracks	Momentum resolutions dp/p over 2-3% or better for invariant mass reconstruction; challenging B.dl in very forward region; Currently ideal PID assumed, to be investigated further; Several displaced vertex resolution studies ongoing (implications for pixel size)	Heavy meson modification vs fragmentation fraction z, Structure functions, e.g. F2-charm	Heavy flavor production, energy loss, hadronization Gluon content of the nucleon and nuclei	Prior JLab and BNL work, X. Li, X. Dong,	Nearing completion
Quarkonia / Exotics	Tracking performance consistent or better than the EIC handbook requirement. Good electron ID, muon ID	Quarkonium suppression vs p_T, rapidity	Quarkonium interactions in matter Threshold production	M. Durham	Nearing completion
Jet Angularity (Photoproduction)	High efficiency and resolution tracking. Calorimeter spatial resolution requirements need to be investigated	Shift in angularity spectrum for different detector configs	Cold nuclear matter effects; access to NP shape function; detailed Monte Carlo tuning	B. Page	Nearing completion

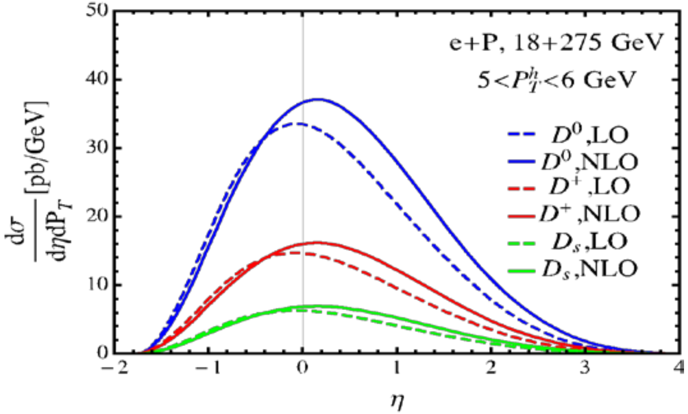
Results for open heavy flavor: kinematics

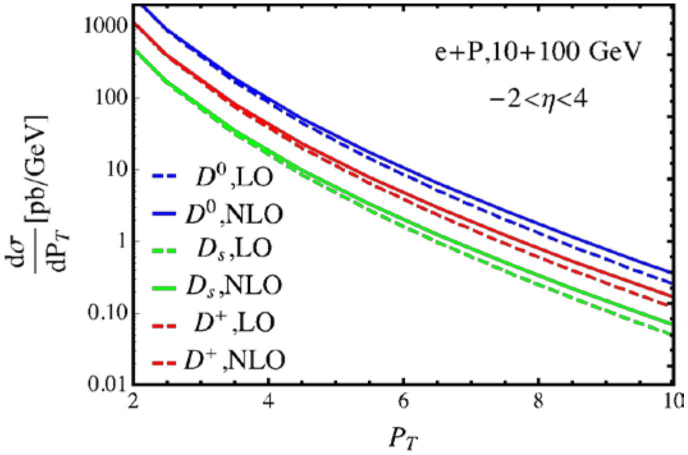
Kinematic distributions up to NLO where possible

Mid rapidity to forward coverage. For this measurement - moderate to high momenta

$$\theta = 2\arctan[\exp(-\eta)] \qquad p_T = \frac{p}{\cosh(\eta)}$$

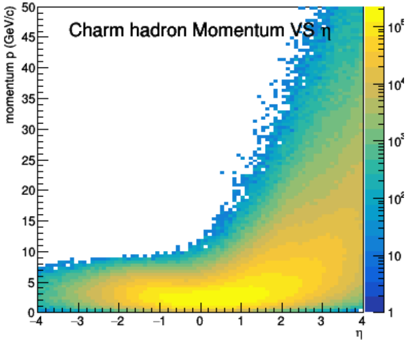
eta	theta [deg]	pT for p=10 [GeV]
0	90	10
1	40.4	6.5
2	15.4	2.7
3	5.7	1
4	2.1	0.4



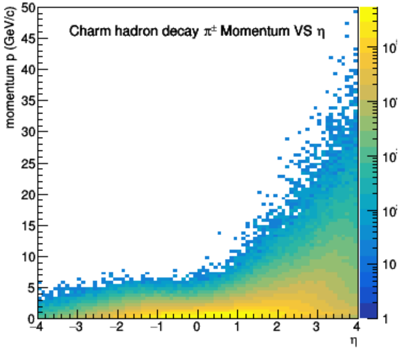


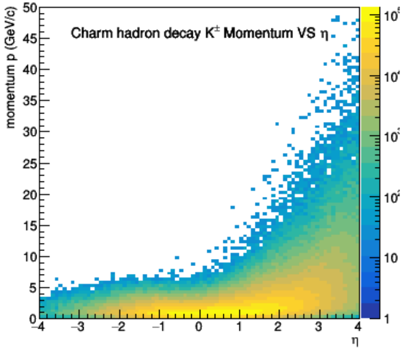
Results for open heavy flavor: kinematics

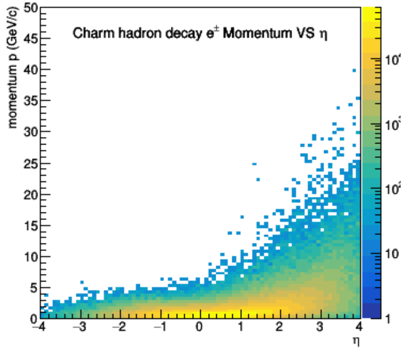
Example: Charm mesons through various decay channels (K, pi, semileptonic): 10 GeV electron + 100 GeV proton with integrated luminosity at 10 fb^{-1}. Minimum Q^2 = 10 $(GeV/c)^2$



Charm hadrons



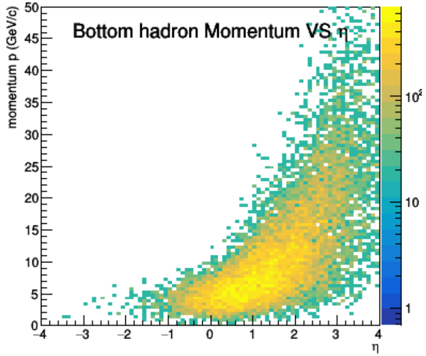




Decay products: pi, K, e

Have maps for various energy combinations. , also B mesons

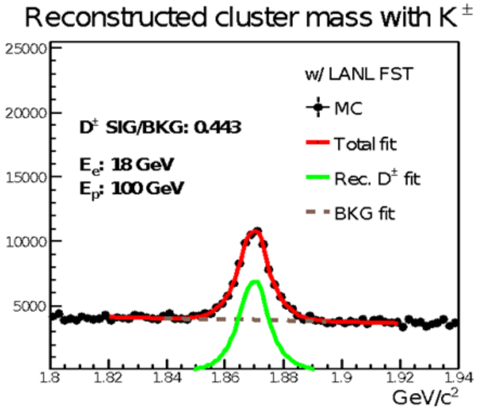
Mid rapidity to forward coverage. Moderate momenta going to high at forward angles

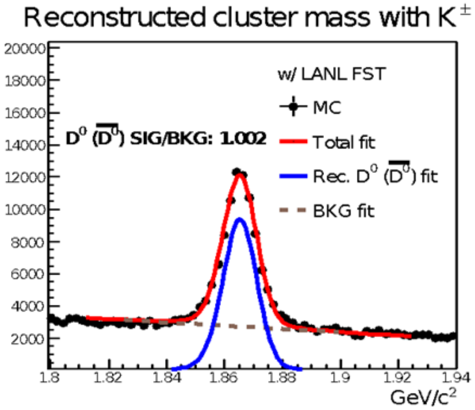


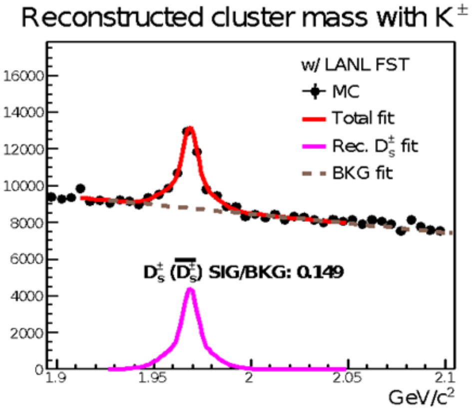
Bottom hadrons

Results for D, B mesons: fast simulation

Example: in fast simulation 18 GeV electron + 100 GeV proton int. luminosity at 10 fb^{-1}.
Track pseudorapdity cut: 1 to 3.

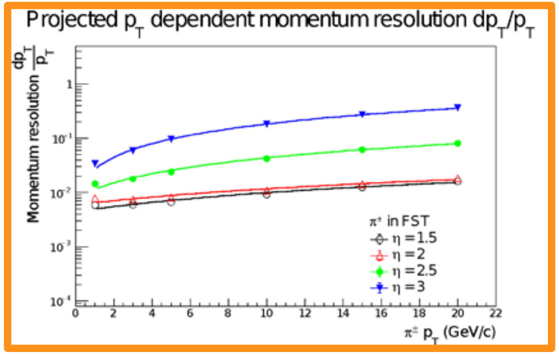






Assumption a hybrid design of MAPS (0.4%X_0) and HV-MAPs (0.8%X_0) – forward tracker

- Vertex spatial resolution smeared.
- Pseudorapidity dependent tracking momentum and spatial resolution smeared.
- 95% tracking efficiency.
- 100% PID identification.

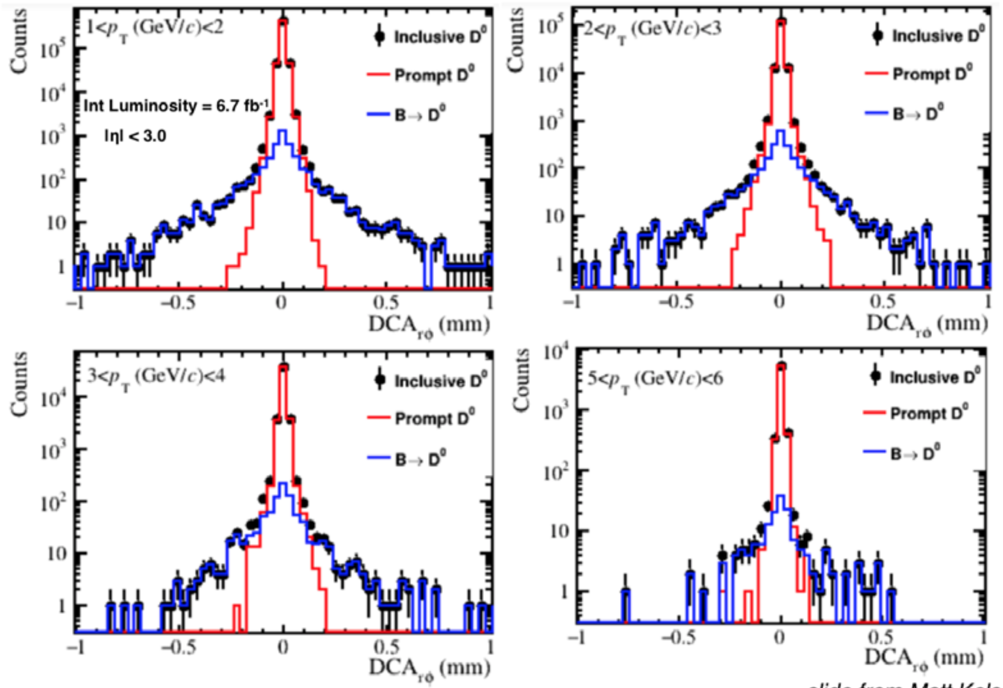


Results for B reconstruction with vertexing

Example: D0 → k,pi:

20 GeV electron + 100 GeV proton with integrated luminosity 10 fb^{-1}. Minimum Q^2 = 1 $(GeV/c)^2$

Momentum resolutions taken from Detector Matrix

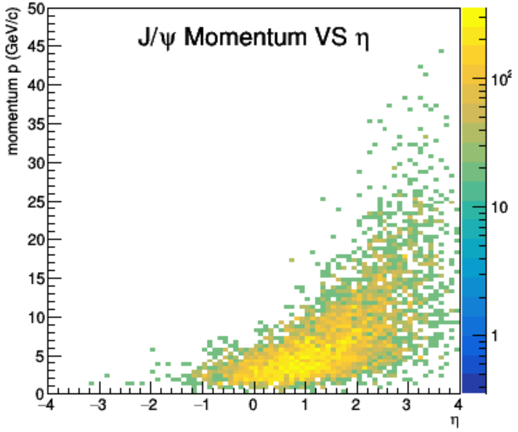


- Good separation between prompt and non-prompt D^0

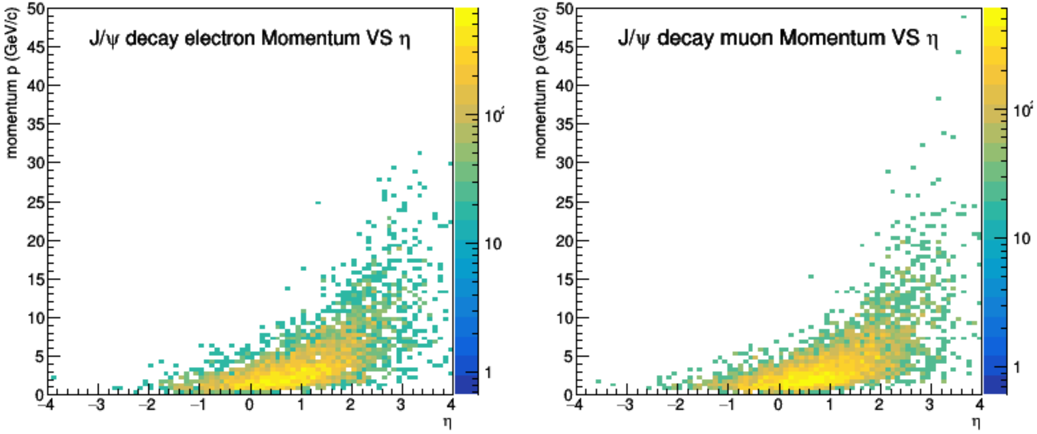
slide from Matt Kelsey

Results for quarkonia: kinematics

Example Charm through various decay channels (k,pi,semileptonic): 18 GeV electron + 275 GeV proton with integrated luminosity at 10 fb^{-1}. Minimum Q^2 = 10 $(GeV/c)^2$



J/psi



Decay products: electrons, muons

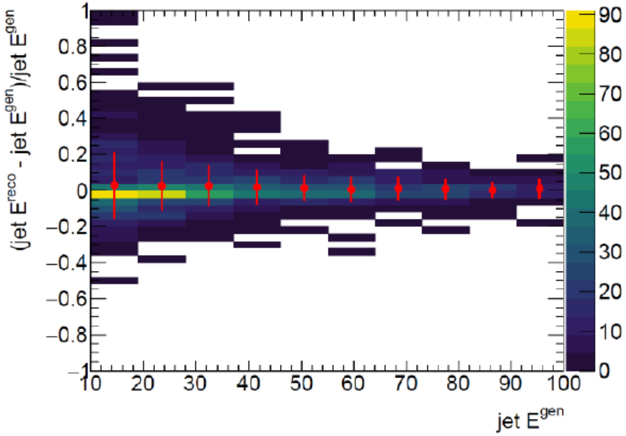
Similar mid to forward rapidity distribution. Upsilon counts are much fewer

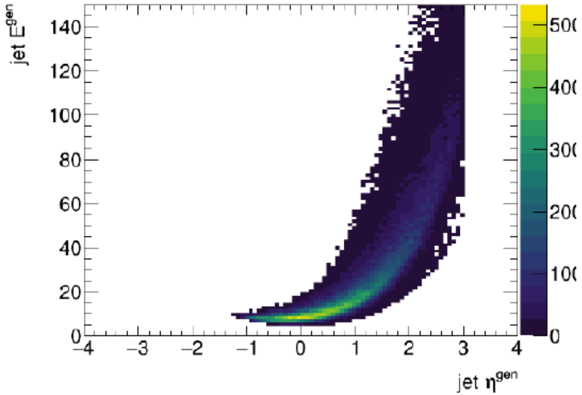
For this measurement - somewhat smaller energies/pT coverage than charm

Jets for 3D imaging

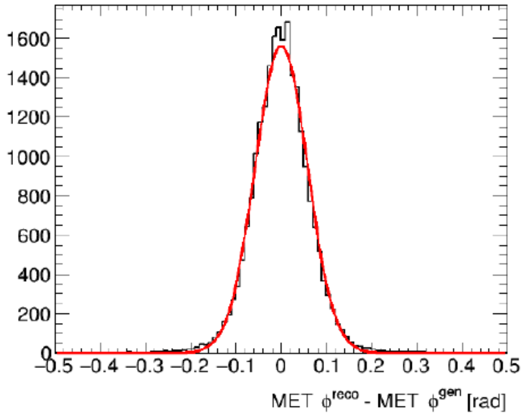
Jet performance

anti-kT R=1.0, particle-flow





Neutrino φ-angle



~20% at 10 GeV, ~10% at 50 GeV

4

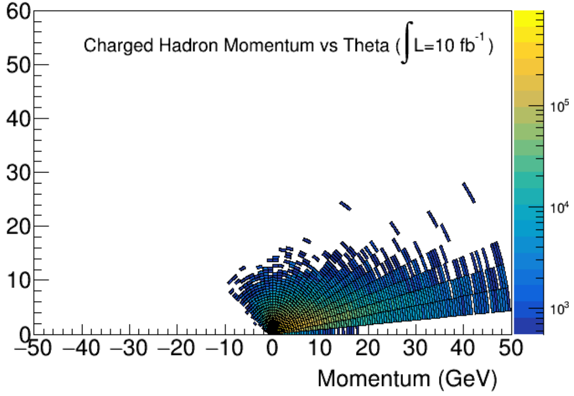
~ 0.10 rad at 10 GeV, ~0.05 rad at 30 GeV

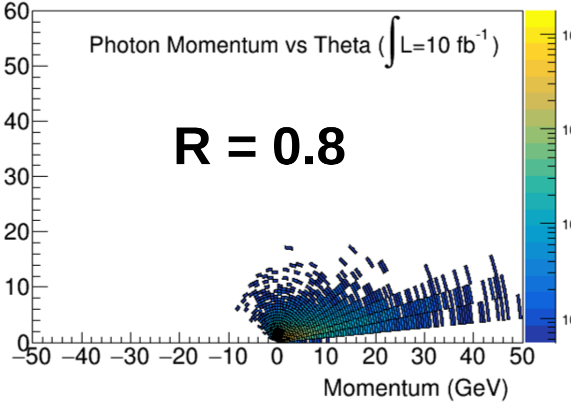
Results for Jet Angularity: Cuts

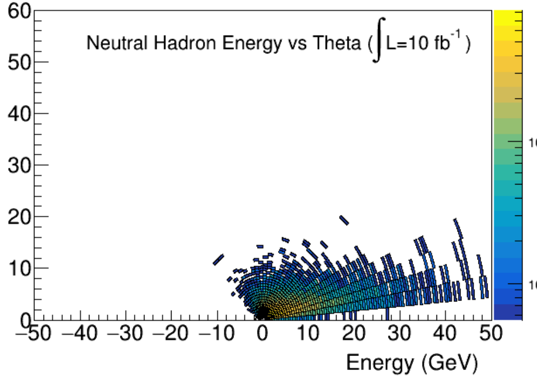
- Photoproduction Region: $10^{-5} < Q^2 < 1$ ($0.01 < y < 0.95$)
- Cluster all stable particles with $|eta| < 3.5$ (excluding scattered electron)
- Find jets using Anti-k_T with R=0.8 and R=0.4; Only consider jets with $p_T > 10$ GeV and $|eta| < 3.5 - R$

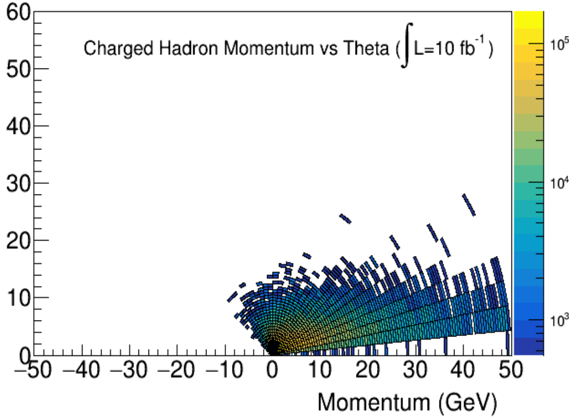
- Note:
  - Low Q^2 only, higher Q^2 -> higher momentum particles
  - No cuts on minimum particle p_T or energy
  - Lowering jet p_T cut will enhance numbers of low momentum particles and extend range in negative eta
- Plot momentum (energy) vs theta for all charged hadrons, photons, and neutral hadrons in jets

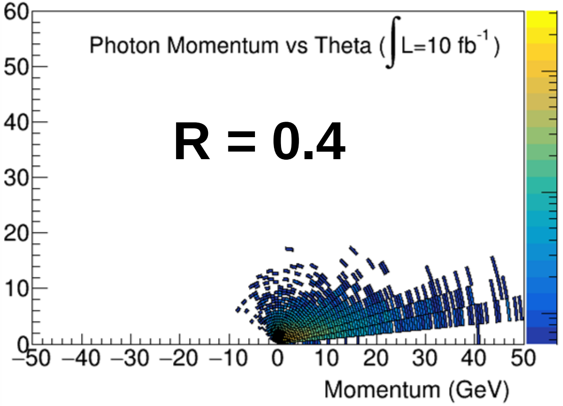
Results for Jet Angularity: Kinematic Plots

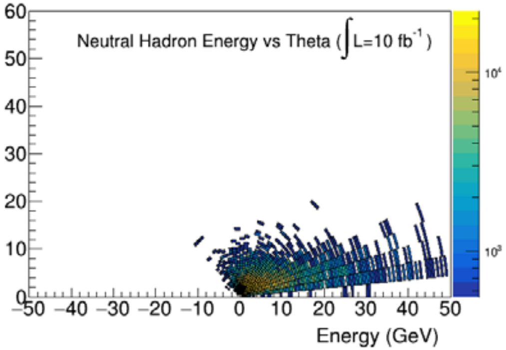












Other channels

Measurement /process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Heavy flavor jets		Heavy flavor jet cross sections /substructure	Heavy vs light flavor	P. Wong	Initial cross section simulations

Exclusive physics working subgroup

Pavia YR Meeting

Raphael Dupré, Salvatore Fazio, Tuomas Lappi,
Barbara Pasquini, Daria Sokhan

Summary of studied channels: kinematics

Kinematic distributions have been studied and required coverages are available

Measurement/ process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
DVCS	Low *t* reach, forward h detection, full ϕ hermeticity, EM Calorimeter cluster resolution for π^0 subtraction	A_{UT}	3D imaging, Ji's sum rule, GPDs	M. Defurne, F.-X. Girod, S. Fazio	Study in progress
J/Ψ and other VMs in eA	p_T resolution for $e^{\pm}$, $\mu^{\pm}$, hermiticity (rapidity gap), incoherent background suppression via forward instrumentation	dσ/dt	Saturation and shadowing, nGPDs	T. Ullrich	Study close to completion
Diffractive dijets	Jet p_T resolution	dσ/dϕ for different *t*, jet p_T	Elliptic gluon Wigner distribution	Z. Zhang	Study close to completion

Summary of studied channels: kinematics

Kinematic distributions have been studied and required coverages are available

Measurement/ process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Coherent DVCS on D, ^{3}He, ^{4}He	*t* acceptance in forward spectrometers	$d\sigma/dt$	Nuclear GPDs	R. Dupré, S. Fucini, S. Scopetta	Study ongoing
DVCS on neutron: double-tagging on d	ZDC acceptance, *t* resolution, spectator detection	$d\sigma/dt$	Neutron GPDs, flavour separation	A. Jentsch, B. Z. (Kong) Tu	Study close to completion
TCS and J/Ψ in ep	Lepton pair momentum resolution and acceptance in forward detectors	$d\sigma/dt$	GPDs, proton mass / trace anomaly	Y. Furletova, S. Joosten, J. Wagner (PARTONS)	Study close to completion

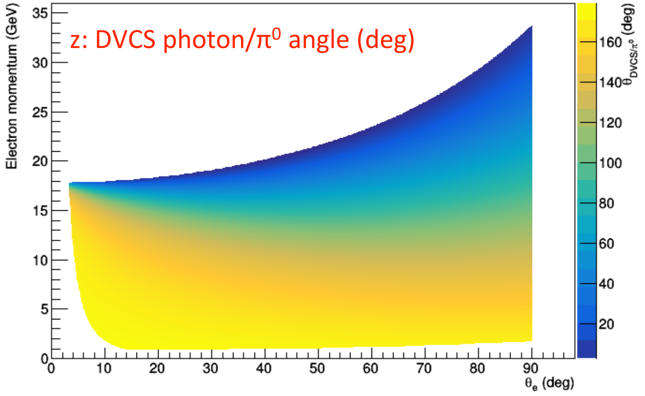
Summary of studied channels: kinematics

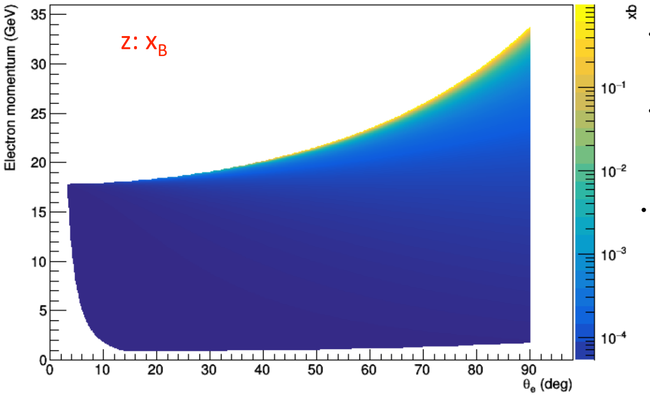
Kinematic distributions have been studied and required coverages are available

Measurement/ process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Exclusive π^0 and π^+	PID, EM Calorimeter resolution, cluster separation for photons	$d\sigma/dt$	GPDs (chiral-odd and chiral-even), TDAs.	M. Defurne, F.-X. Girod, K. Tezgin (PARTONS), L. (Bill) Wenliang	Study ongoing
Charged current pion production	Actually a semi-inclusive process	$d\sigma/dt$	GPDs	M. Siddikov, I. Schmidt	Study near completion

DVSC/π0 production: electron kinematics

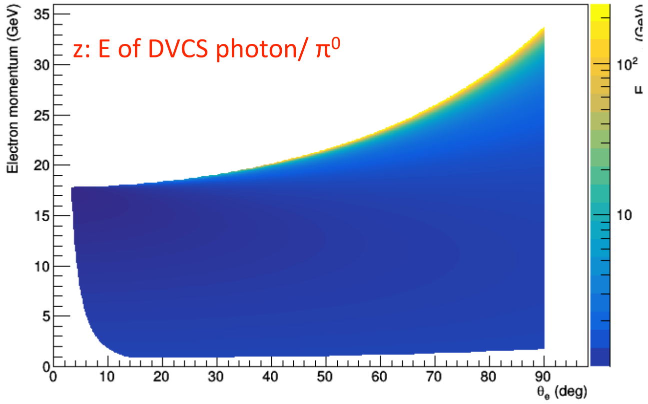
Maxime Defurne (CEA Saclay)

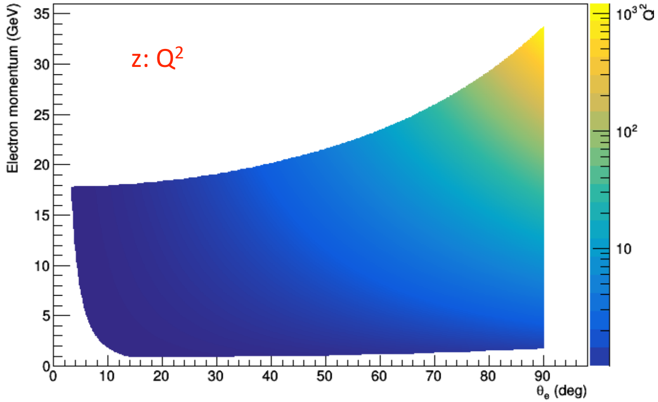


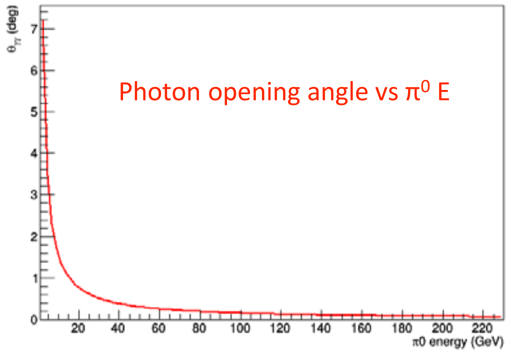


- Each 2D plot shows electron momentum vs scattering angle.
- Cross-section falls as Q^2 rises.

- Detection of both decay photons constrained by **energy threshold** (assume ~ 300 MeV min) in calorimeter and **angular resolution between clusters**.



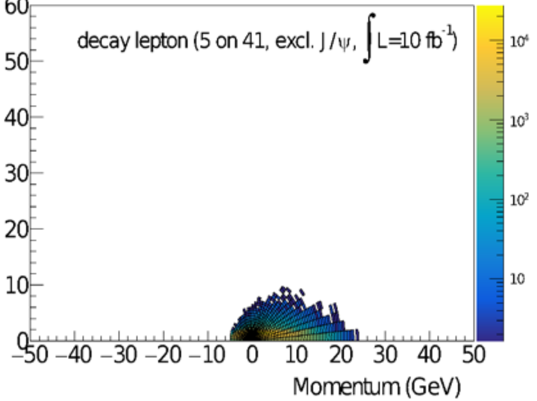


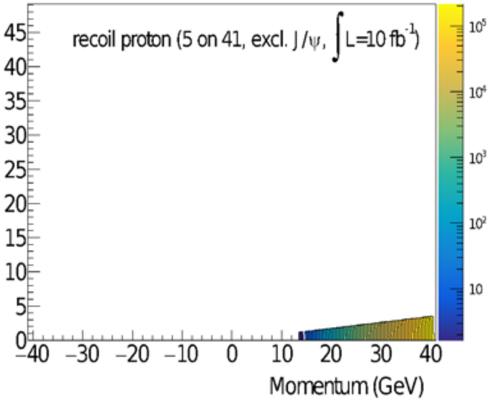


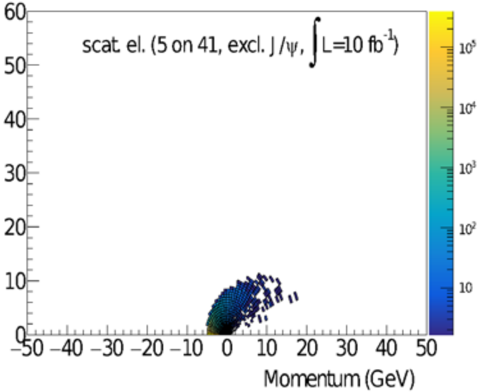
J/ψ production in e+p

Sylvester Joosten (ANL)

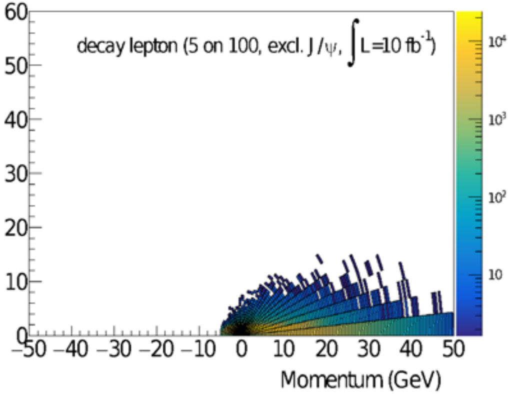
- 5 x 41 GeV

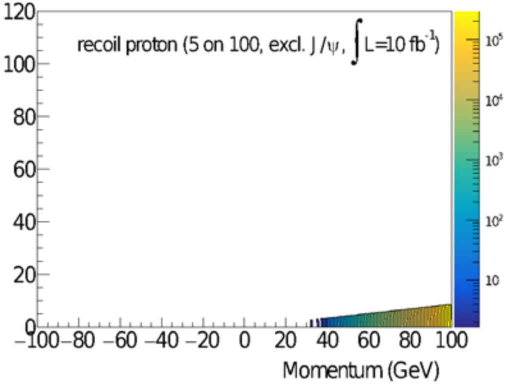


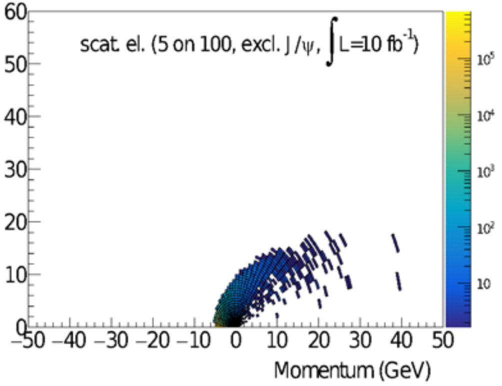




- 5 x 100 GeV



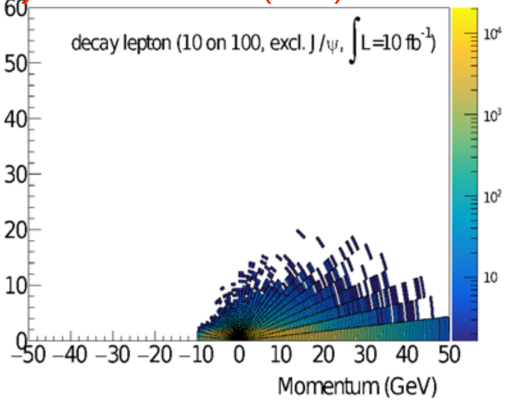


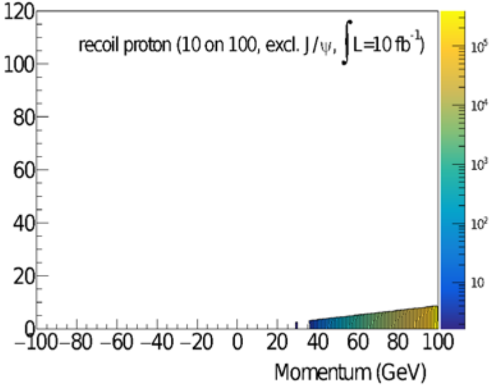


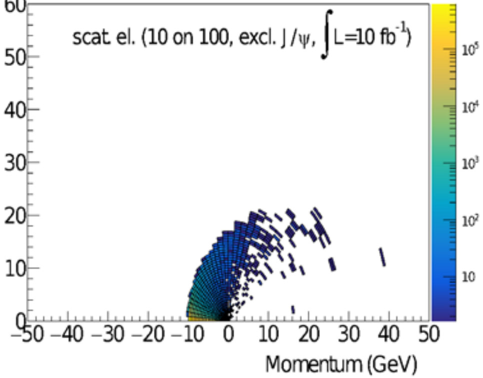
J/ψ production in e+p

Sylvester Joosten (ANL)

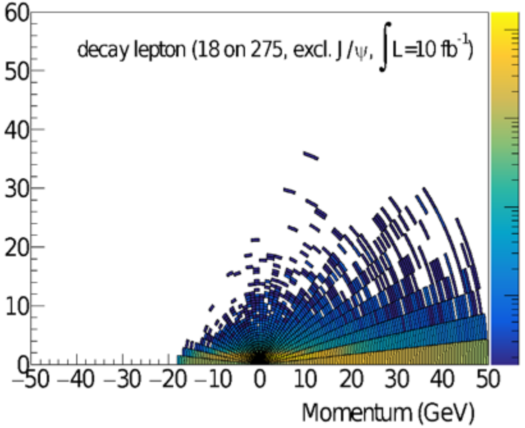
- 10 x 100 GeV

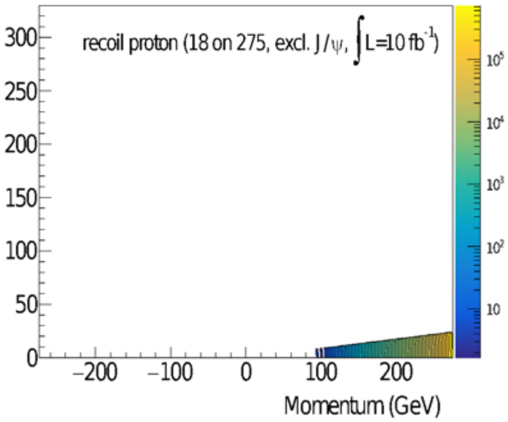


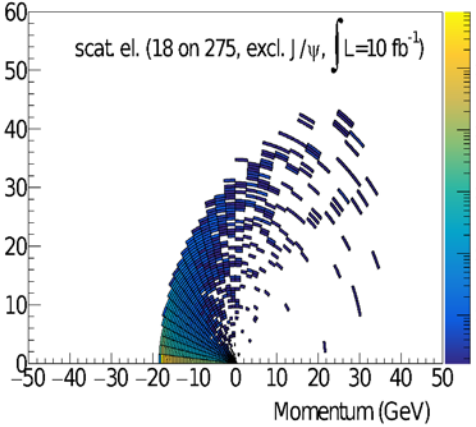




- 18 x 275 GeV



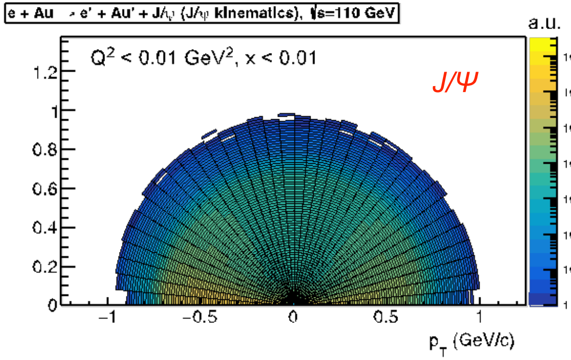


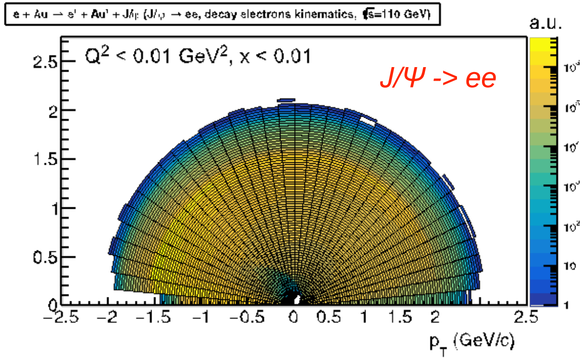


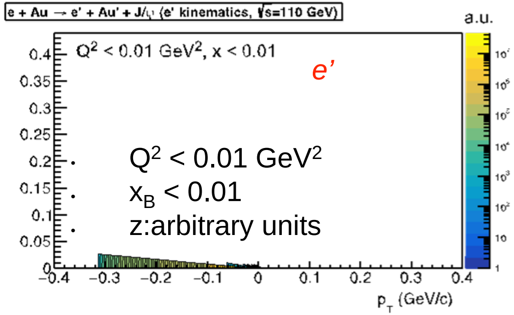
J/ψ production in e+Au

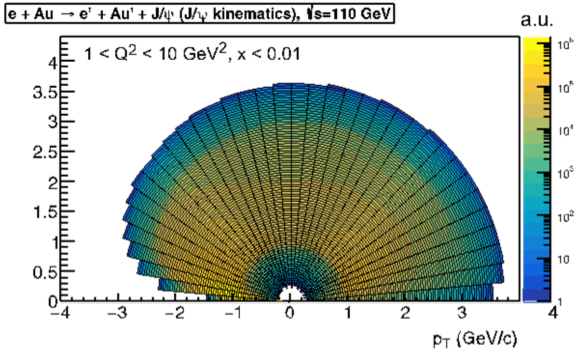
Thomas Ullrich (BNL)

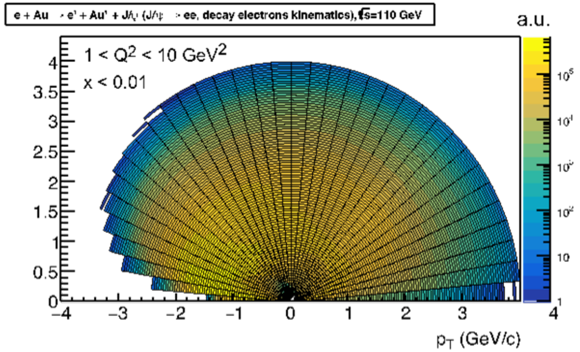
$\sqrt{s} =$ 90 GeV

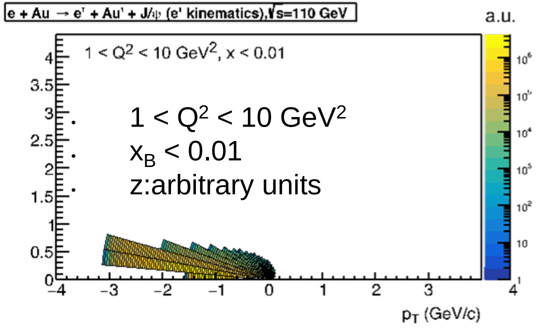








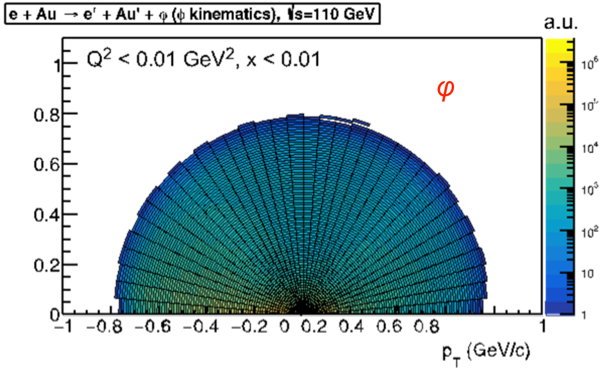


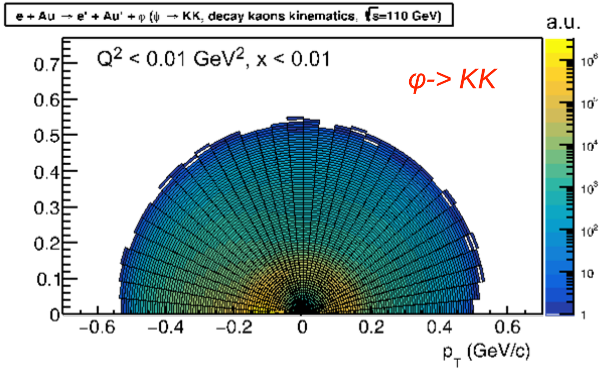


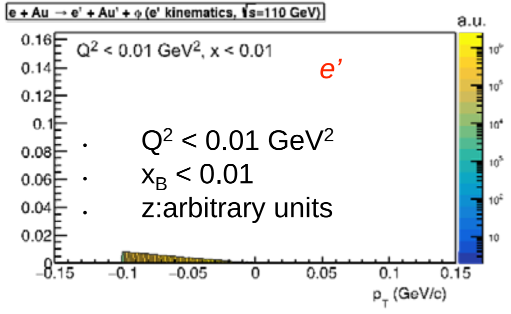
φ production in e+Au

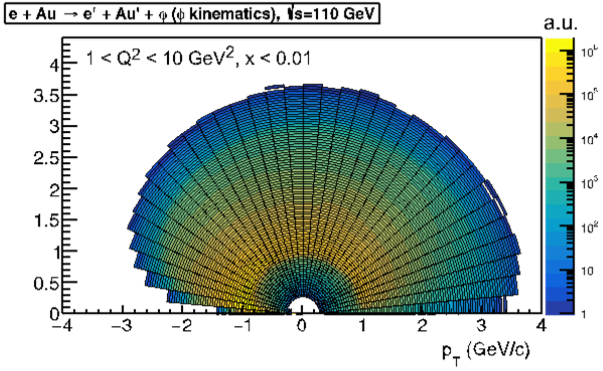
Thomas Ullrich (BNL)

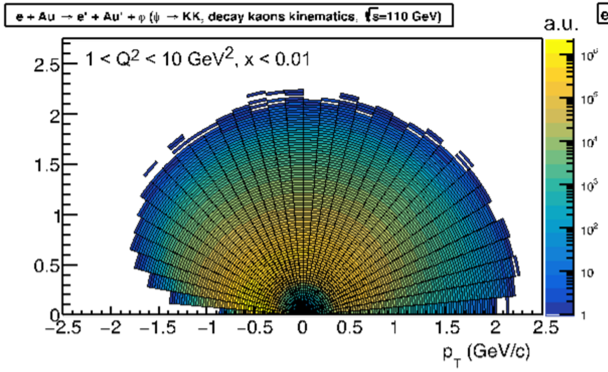
$\sqrt{s} =$ 90 GeV

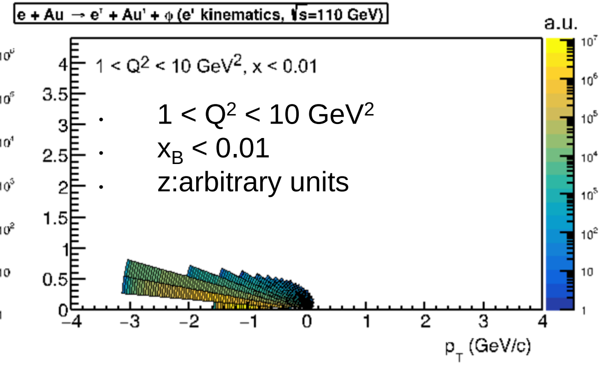








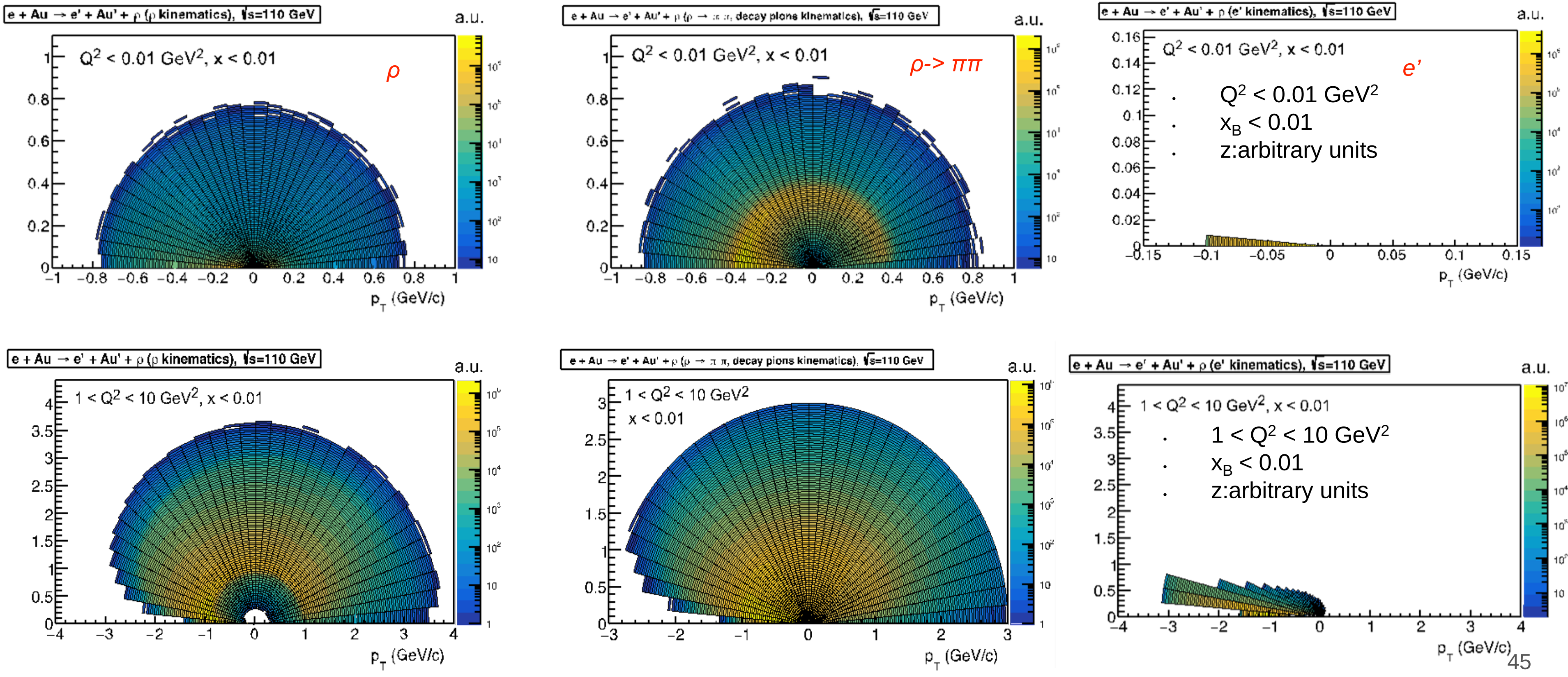




ρ production in e+Au

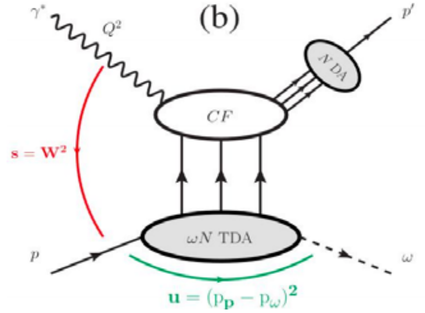
Thomas Ullrich (BNL)

$\sqrt{s} =$ 90 GeV

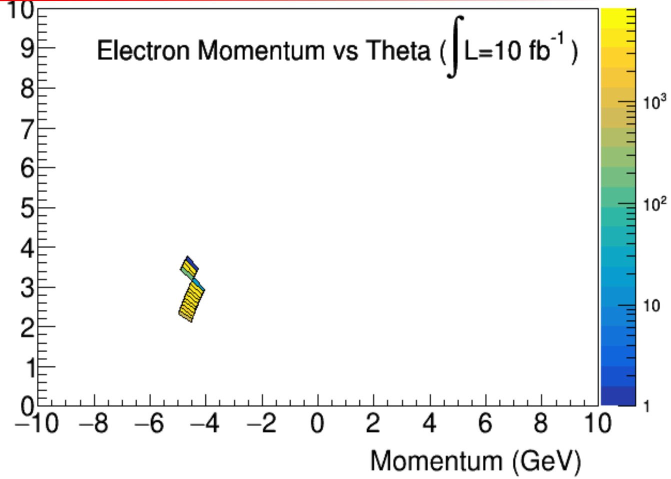


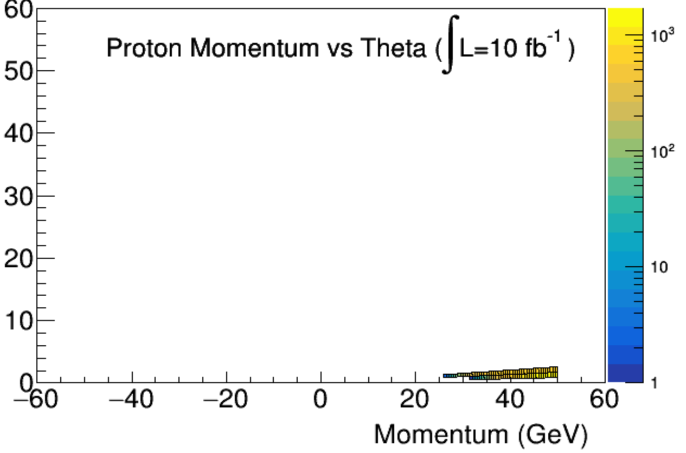
U-channel π0 production

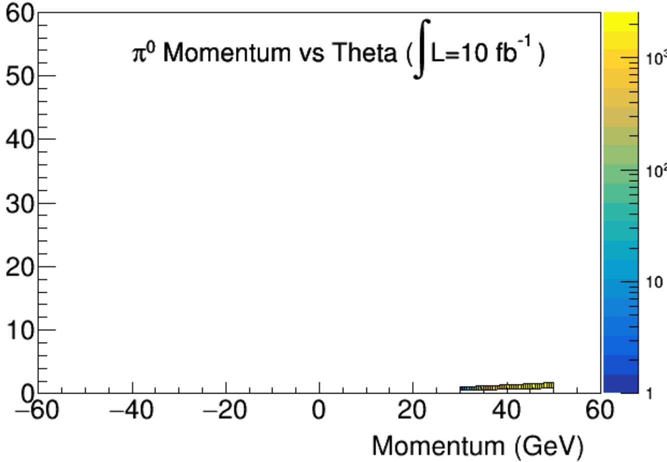
Li (Bill) Wenliang (BNL)

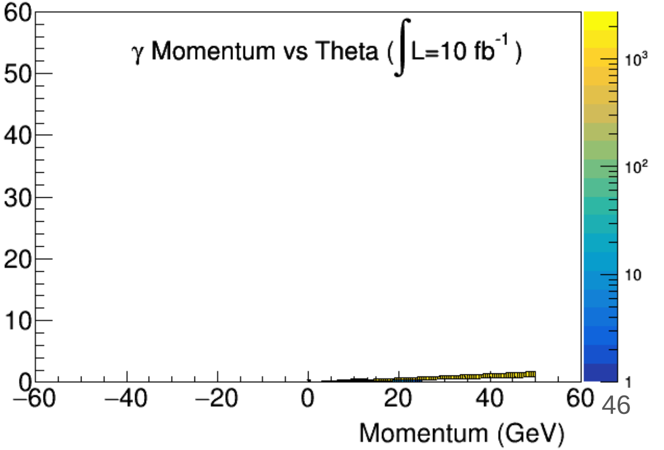


- Backward angle production of pi0 from proton: TDAs.
- π^0 mom: 20-50 GeV. π^0 angle from above 50 to below 35mrad. Photon opening angle 0.4-0.8 deg.
- Q^2 < 12 GeV, W~ 10 GeV







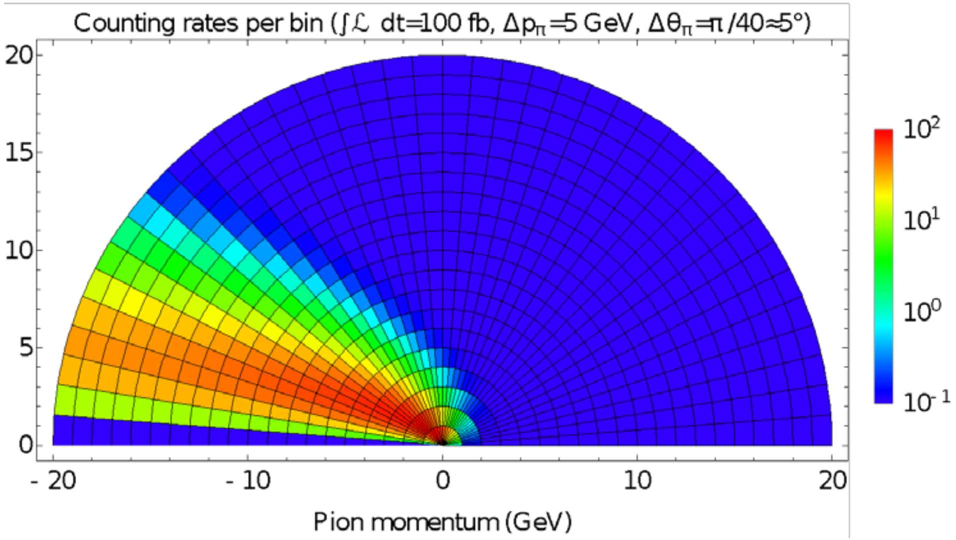


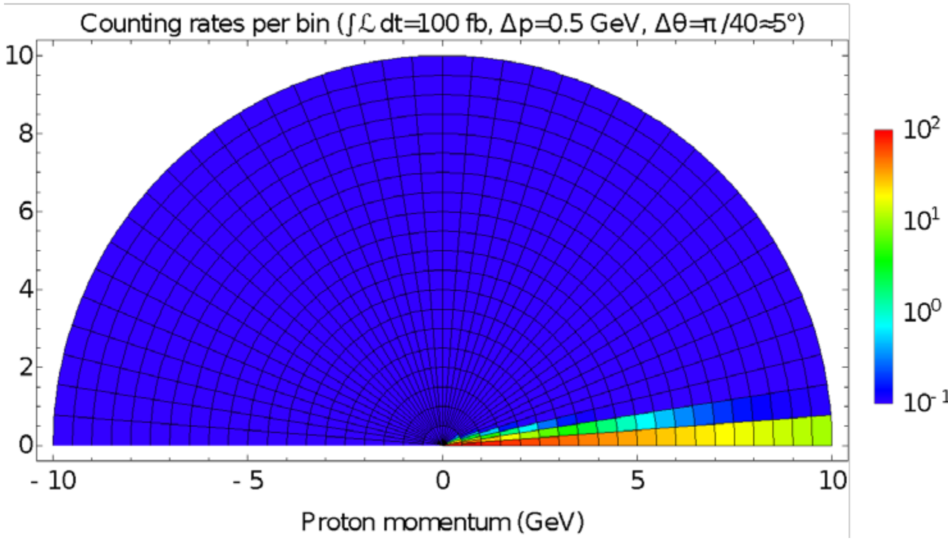
Charged current pion production

Marat Sidikov, (USM, Valparaiso, Chile)

- Process is suppressed in comparison to DVMP, integrated luminosity for the plots is 100 fb^{-1}

$$ep \to \nu_e \pi^- p$$





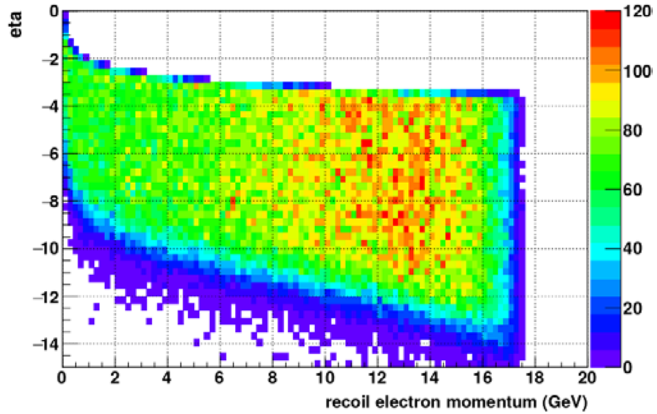
- **Kinematic studies have been carried out on more channels – see weekly meeting slides on Indico!**

Diffractive dijet production in e+p

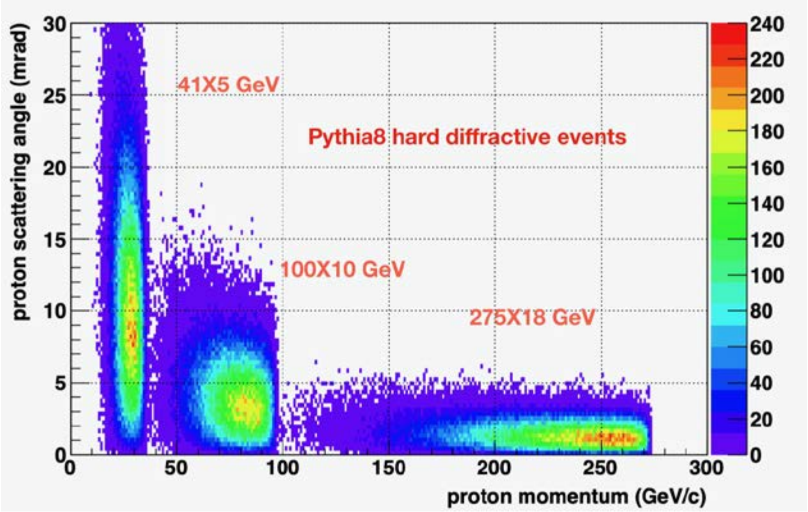
Zhengqiao Zhang (BNL)

(Pythia8 ,Q^2<1)

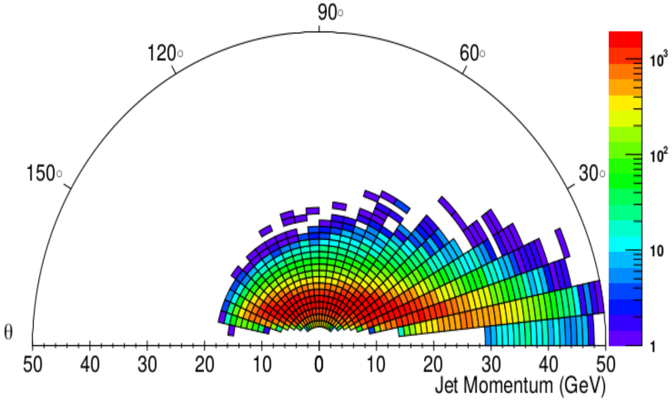
Electron



Proton



Jet



Other channels

Some of the channels which will be worked on but don't have kinematic distributions yet:

Measurement/ process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Exclusive ϕ and ρ in ep and eA	PID for hadronic decay channels	$d\sigma/dt$	GPDs, gluon saturation	F.-X. Girod,	
Exclusive production of meson-photon pair ($\rho\gamma$)	Far-forward detectors	$d\sigma/dt$	GPDs	D. Sokhan	

Diffraction and Tagging physics working subgroup

Pavia YR Meeting

Wim Cosyn, Or Hen, Douglas Higinbotham, Spencer Klein, Anna Stasto

May 20, 2020

Summary of studied channels: kinematics

Measurement/process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Sullivan process ep/d -> e + pi/K/X + nucleon	-detection of forward p/n -detection of forward decay products of Λ,Σ -hadronic calorimetry in forward region	-pion and kaon SF projections a la HERA proton structure function plots -pion form factor at large Q^2	Meson structure	T.Horn	fast simulations in progress
ep/A-> e + X+p/A	Roman pot for leading protons	Roman pot acceptance, diffractive kinematics, structure function pseudodata, diffractive PDFs	diffractive structure functions and PDFs in protons and nuclei	N.Armesto P.Newman,W.SlominskiA.Stasto	To do: PDFs in nuclei

Summary of studied channels: kinematics

Measurement/process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
ep/A-> e + VM+rapidity gap+Y inelastic diffraction of vector mesons	excellent acceptance for forward region for measurement of large rapidity gaps	cross section growth with rapidity gap size, dependence on t, angular vs pT acceptance	Pomeron trajectory, energy and t-dependence of the cross section on the rapidity gap size	M. Deak, M.Strikman, A.Stasto	To do: angular acceptance plots, simulations
Electro/Photo-production J/ψ Upsilon 1S, 2S, 3S	Central Detector Scattered Electron Forward Detector for nuclear fragments to separate coherent/incoherent	Gluon distributions as a function of x and $b_{\perp}$	Gluon Dist. 3D Gluon imaging	S. Klein S. Heppelmann	ep 18X100, 100x250 eA 18x100

Summary of studied channels: kinematics

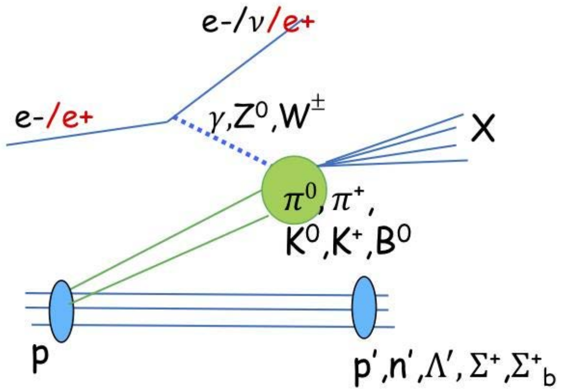
Measurement/process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Diffractive deuteron breakup in J/ψ production	deuteron internal momenta up to 0.8–1 GeV/c can be detected with good acceptances and excellent resolutions with current far forward design	number of events vs p_miss with p and n spectators	Various: study is proxy for processes with single and double nucleon tagging in deuteron	Kong Tu Alex Jentsch	arXiv imminent
eA QE 2N knockout	Acceptance for far forward nucleons		SRC studies	F. Hauenstein	
e-p/d elastic scattering	small angle scattered electron detection	FF projections as a function of Q^2	elastic FF	B.Schmookler	

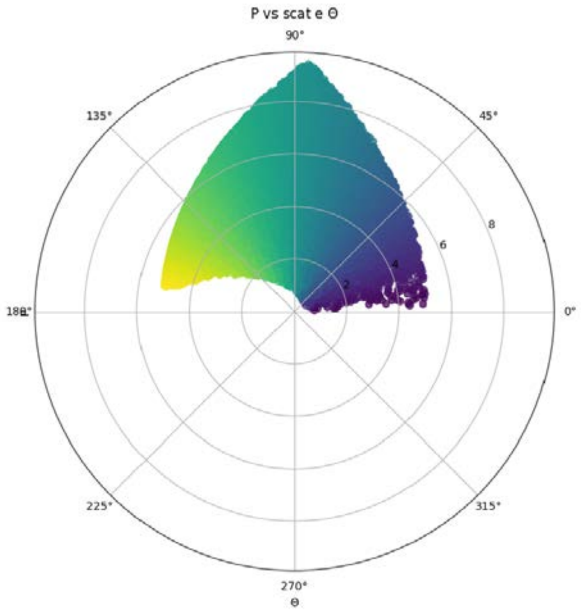
Summary of studied channels: fast simulations

Measurement/process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Electro/Photo-production J/ψ Upsilon 1S, 2S, 3S	Central Detector Scattered Electron Forward Detector for nuclear fragments to separate coherent/incoherent	Gluon distributions as a function of x and b⊥	Gluon Dist. 3D Gluon imaging	S. Klein S. Heppelmann	EICRoot Framework Detector Setups: • LBNL All-Si • BeAST
Diffractive deuteron breakup in J/ψ production	deuteron internal momenta up to 0.8–1 GeV/c can be detected with good acceptances and excellent resolutions with current design	number of events vs p_miss with p and n spectators	Various: study is proxy for processes with single and double nucleon tagging in deuteron	Kong Tu Alex Jentsch	arXiv imminent Beagle + current far forward detectors
eA QE 2N knockout	Acceptance for far forward nucleons		SRC studies	F. Hauenstein	Beagle + g4e

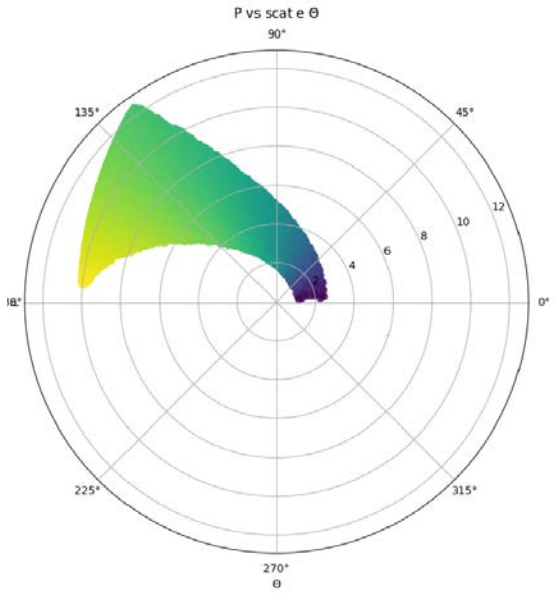
Meson Structure Functions – Scattered Electron

ep/d -> e +pi/K/X + nucleon





5 on 41

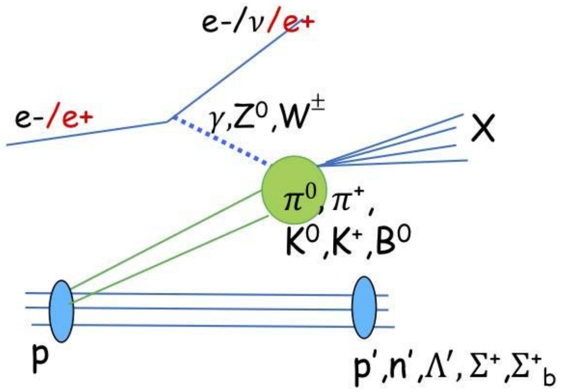


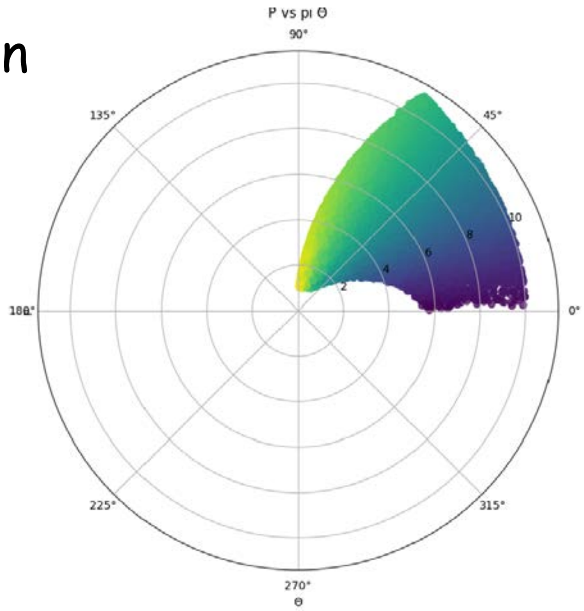
10 on 100
(12 on 135)

Kinematics for meson structure functions

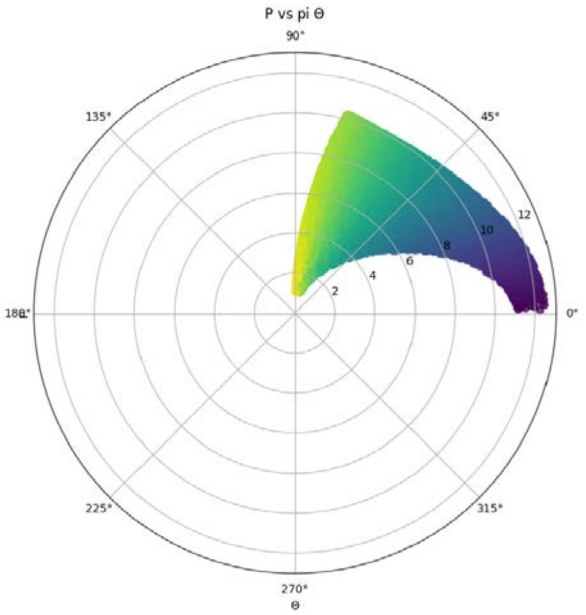
Meson Structure Functions – Scattered Meson

ep/d -> e +pi/K/X + nucleon





5 on 41

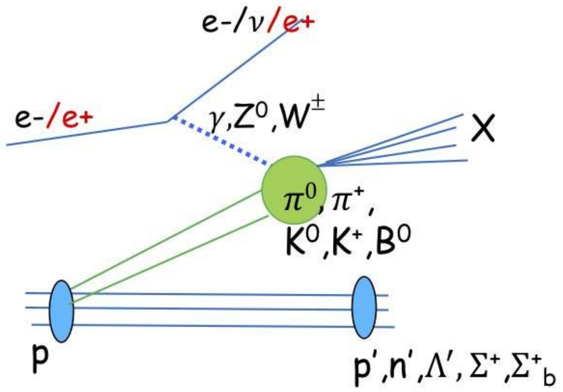


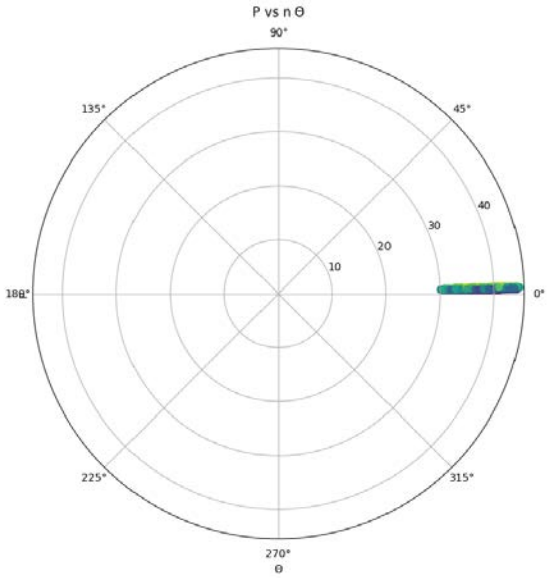
10 on 100
(12 on 135)

Kinematics for meson structure functions

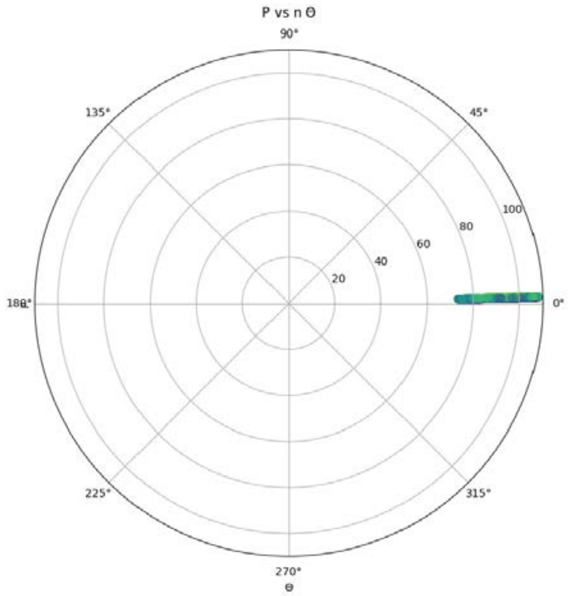
Meson Structure Functions – Forward Baryon

ep/d -> e +pi/K/X + nucleon





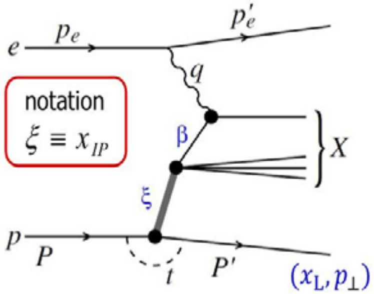
5 on 41

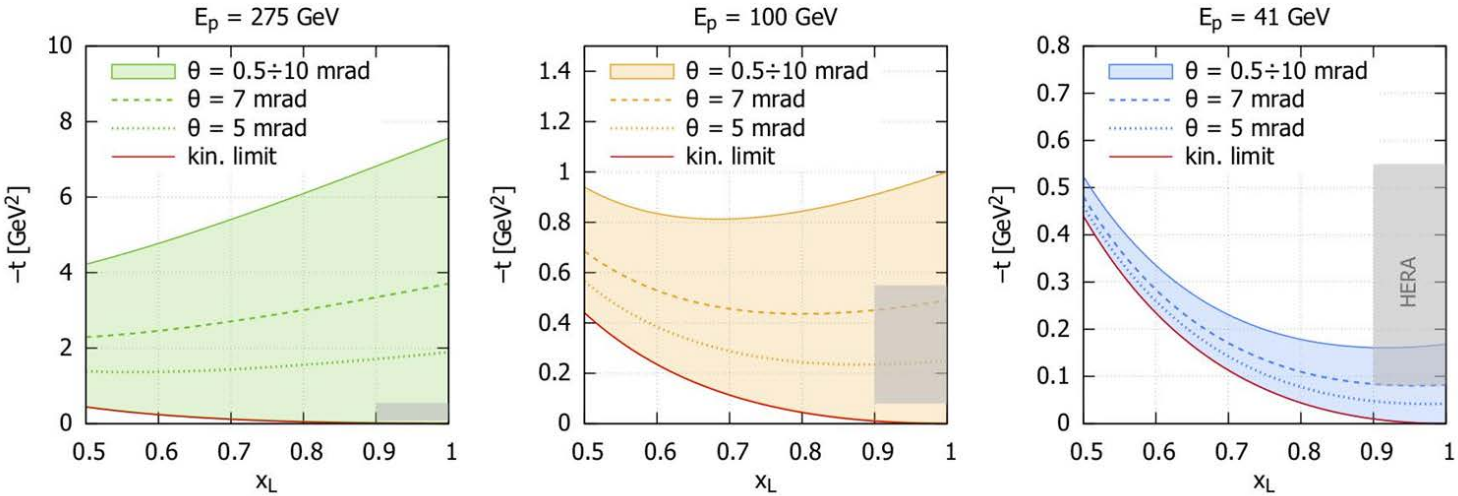


10 on 100
(12 on 135)

Kinematics for meson structure functions

Inclusive diffraction: Roman pots acceptance





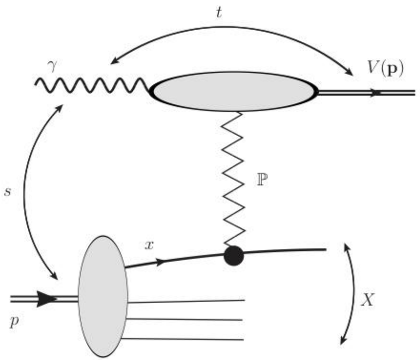
Outgoing proton momentum : (x_L,p_T) with $x_L P^+ = P'^+$

-t range up to 2 GeV^2 is necessary for reliable extraction of t-dependence of diffractive exchanges

Desired detector and machine features:

- Proton tagging angle: 0.5 to 7 mrad, for diffractive cross section measurement with t dependence
- Outgoing proton : $x_L<0.6$
- Additional intermediate energies needed for the precise longitudinal structure function measurement

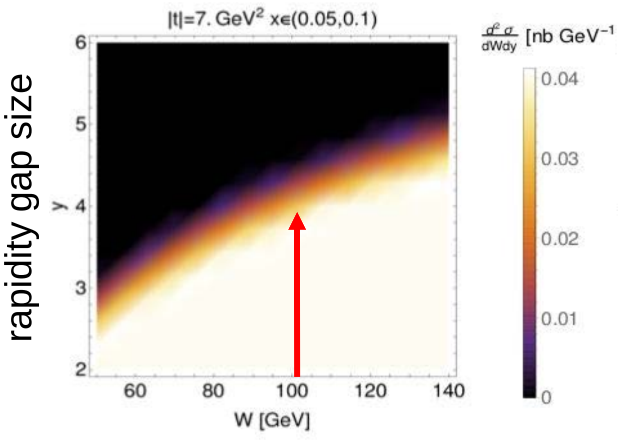
Inelastic diffraction of vector meson: J/ψ

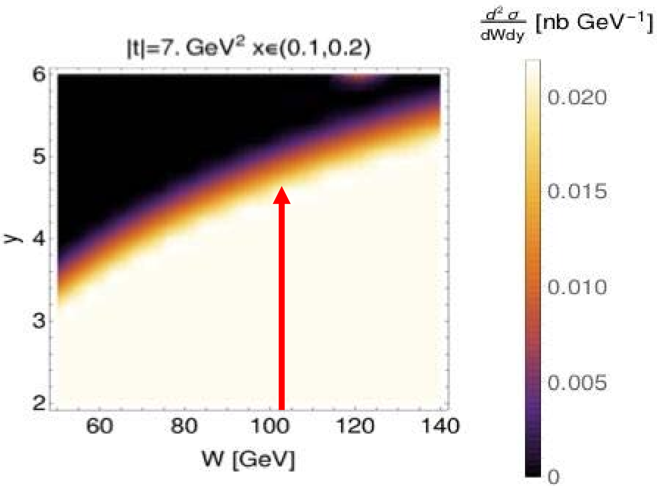


Need to access rapidity gaps between 2 to 4(4.5) to extract energy dependence and trajectory of Pomeron
Possible, if good angular acceptance in forward region.

Preliminary estimates on angle and p_T

- For p_T=2.6 GeV, Θ=11º for x=0.05, gap up to 3.5 units rapidity
- For p_T=2.6 GeV, Θ=5.5º for x=0.1
- For p_T=2.6 GeV, Θ=2.75º for x=0.2 , gap up to 4.5 units rapidity





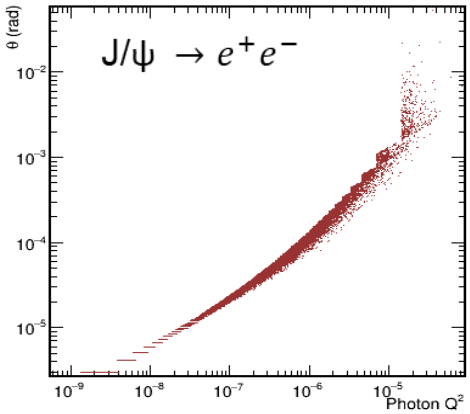
To do:
angular acceptance plots, with mapping of rapidity gaps

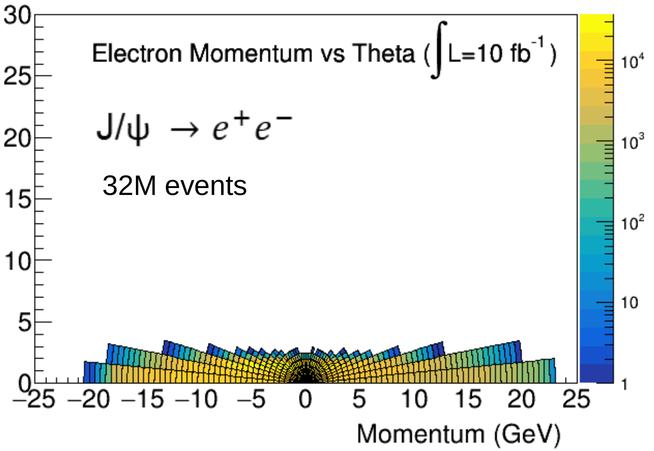
Vector Meson Photo/Electro-production: kinematics

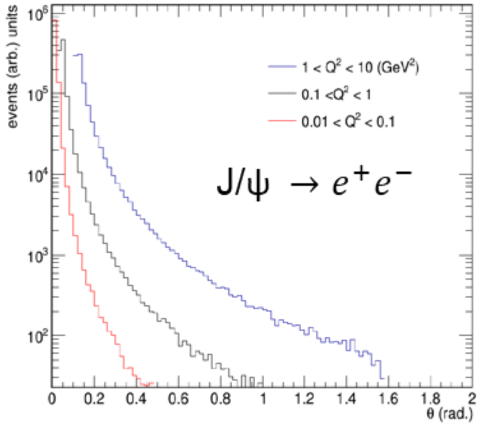
e + p

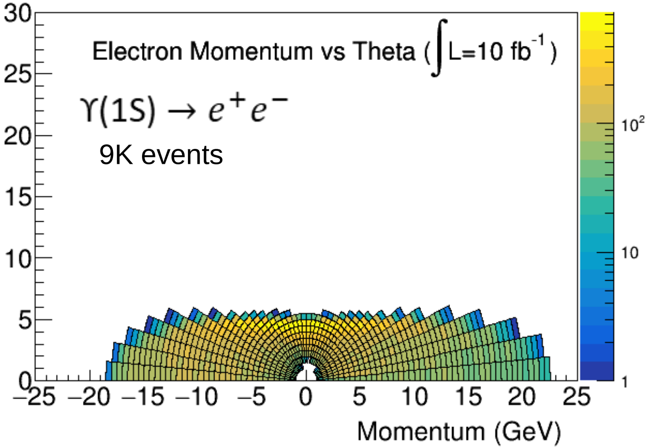
Outgoing electron deflection angle:

For photoproduction $(Q^2 < 1\ \mathrm{GeV}^2)$





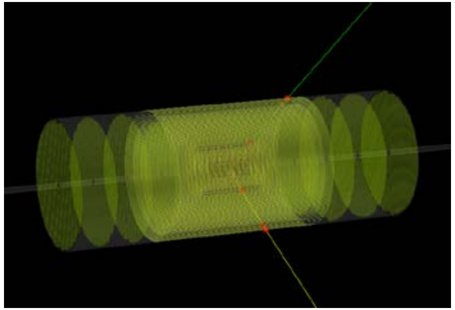


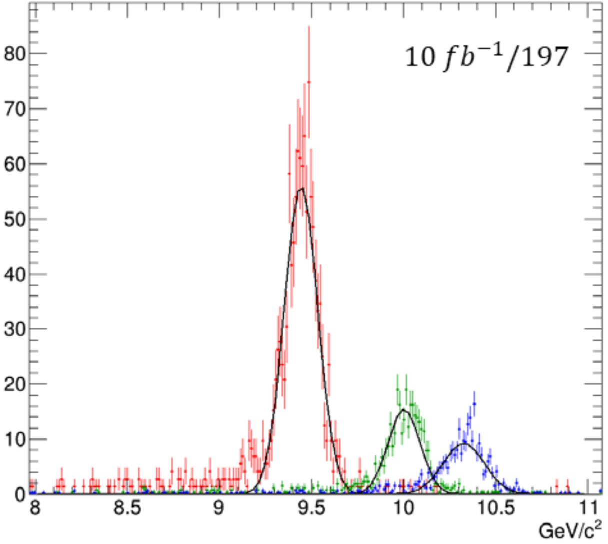


Upsilon Events in EICRoot All-Silicon Detector

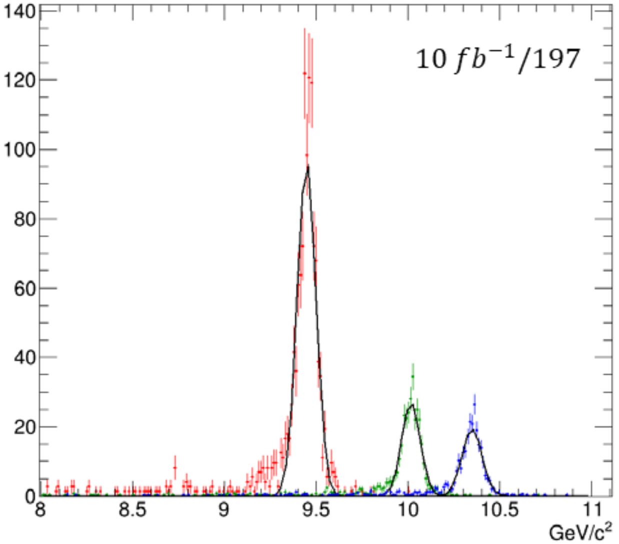
LBNL All-Silicon Detector
(Developed by LBNL's eRD16 generic EIC detector project)

- **Silicon Tracker**
  6 layers
- **Silicon Endcap Disks**
  6 disks





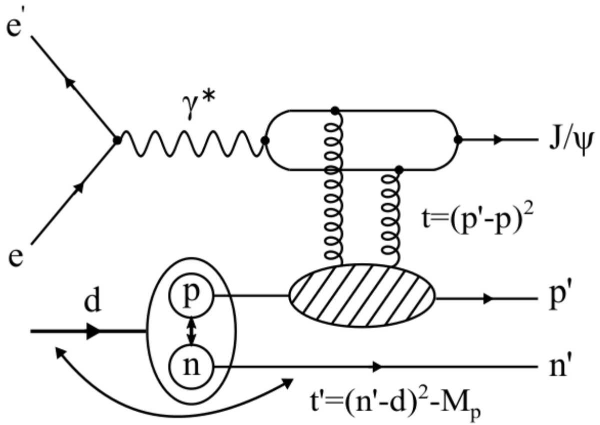
1.5 Tesla

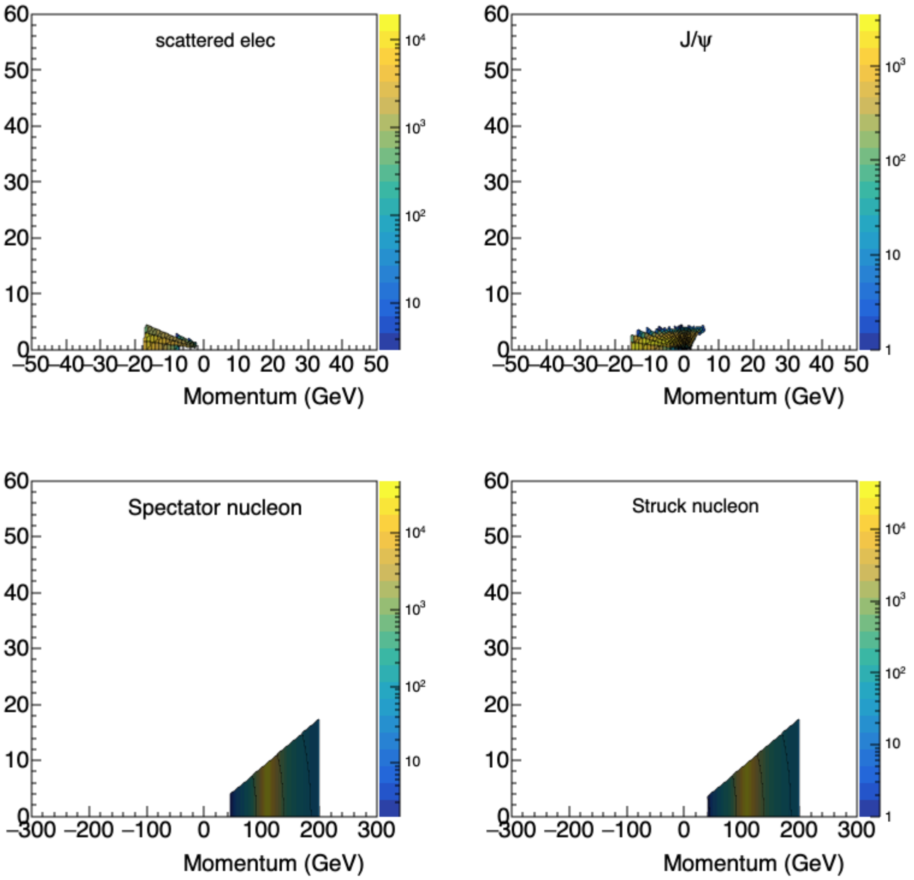


3.0 Tesla

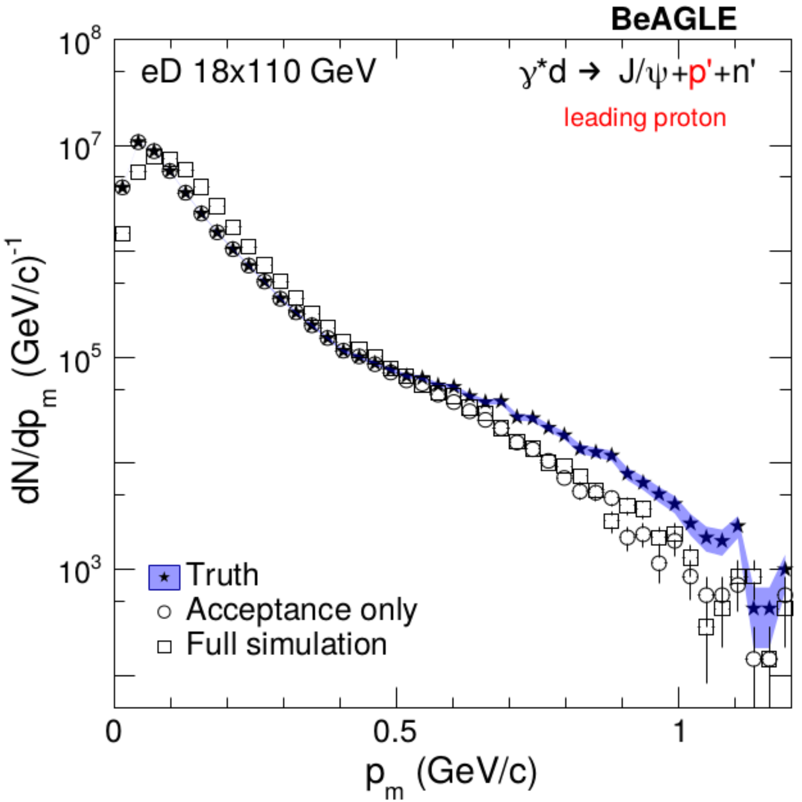
Upsilon peaks are still distinguishable with a lower B-Field

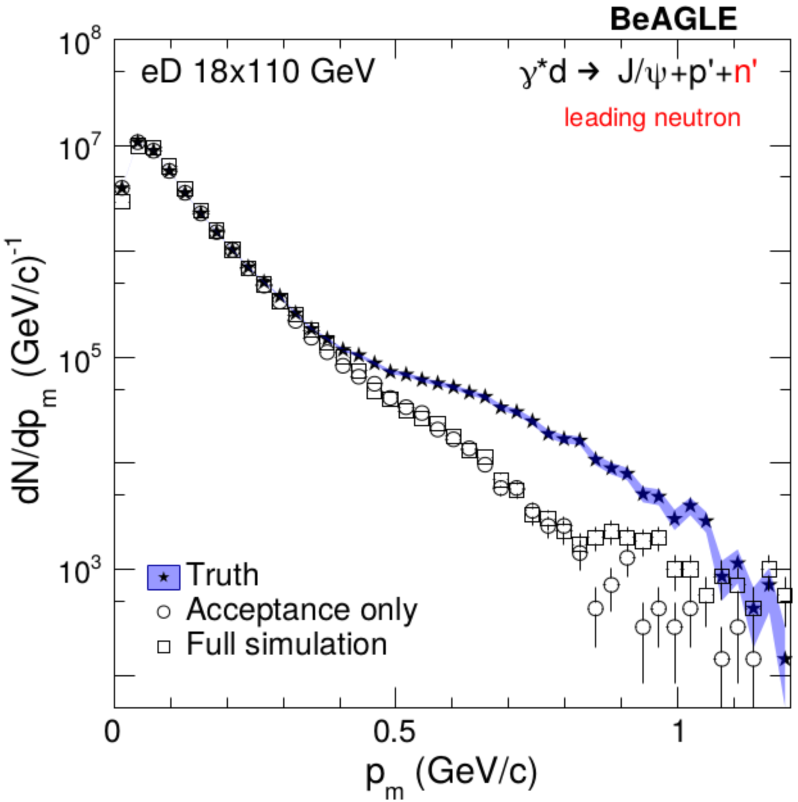
Diffractive deuteron breakup: e+d -> e' + J/ψ + p + n





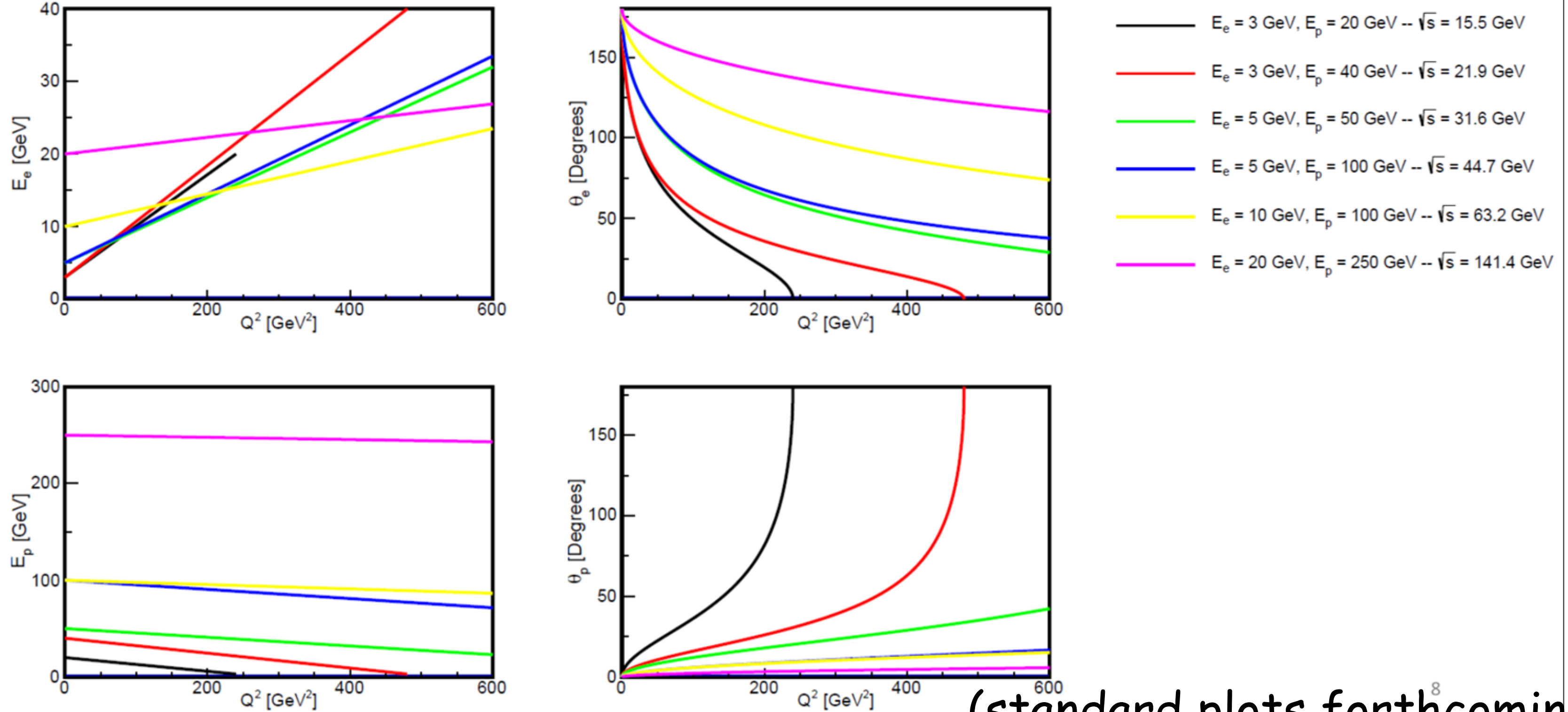
Beagle simulations





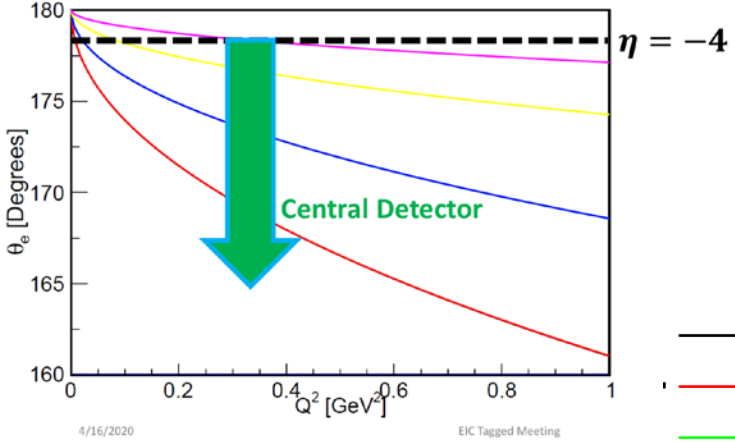
Elastic ep scattering

Kinematics

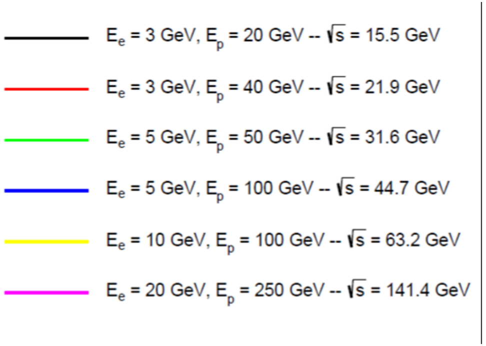


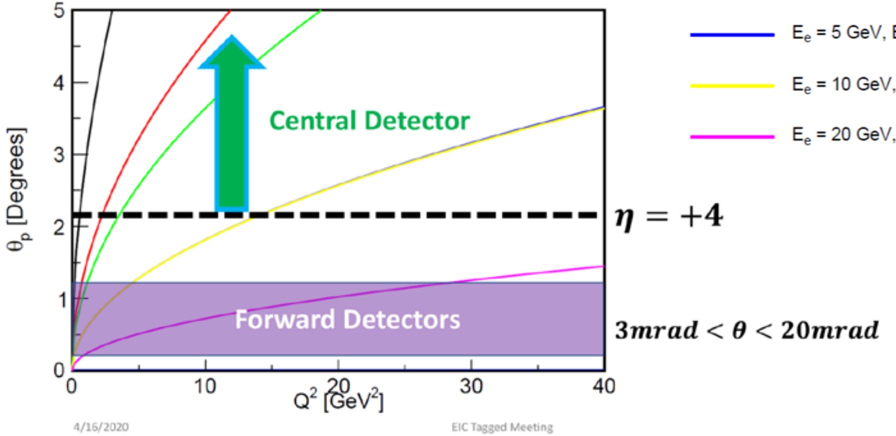
(standard plots forthcoming)

Elastic ep scattering



Kinematics:Low Q2 Electron Angle

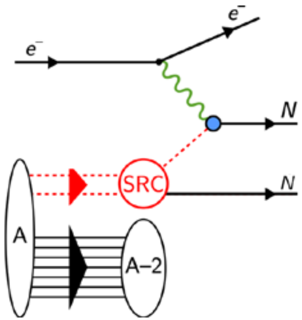




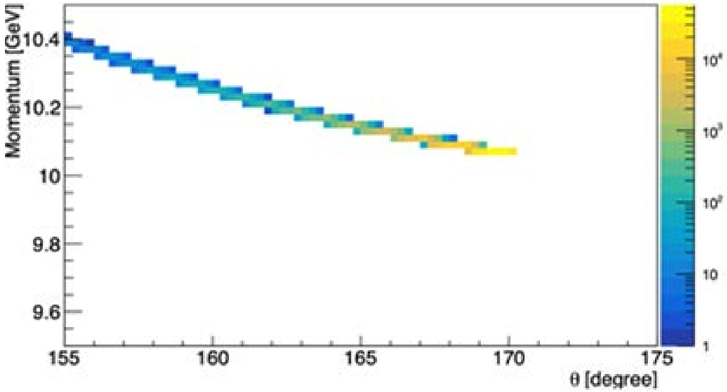
Kinematics: Proton Angle

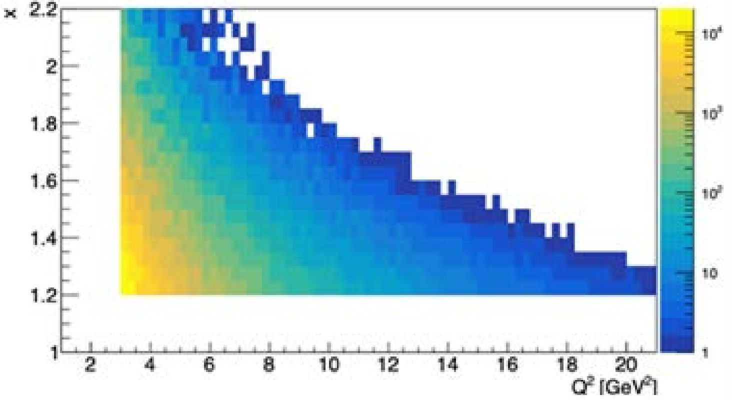
(standard plots forthcoming)

eA QE 2N knockout



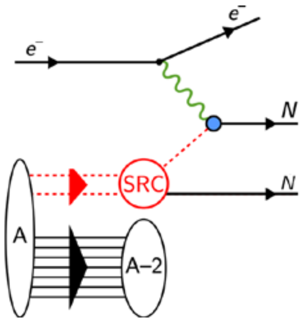
Electron Kinematics e+C 10x41/A





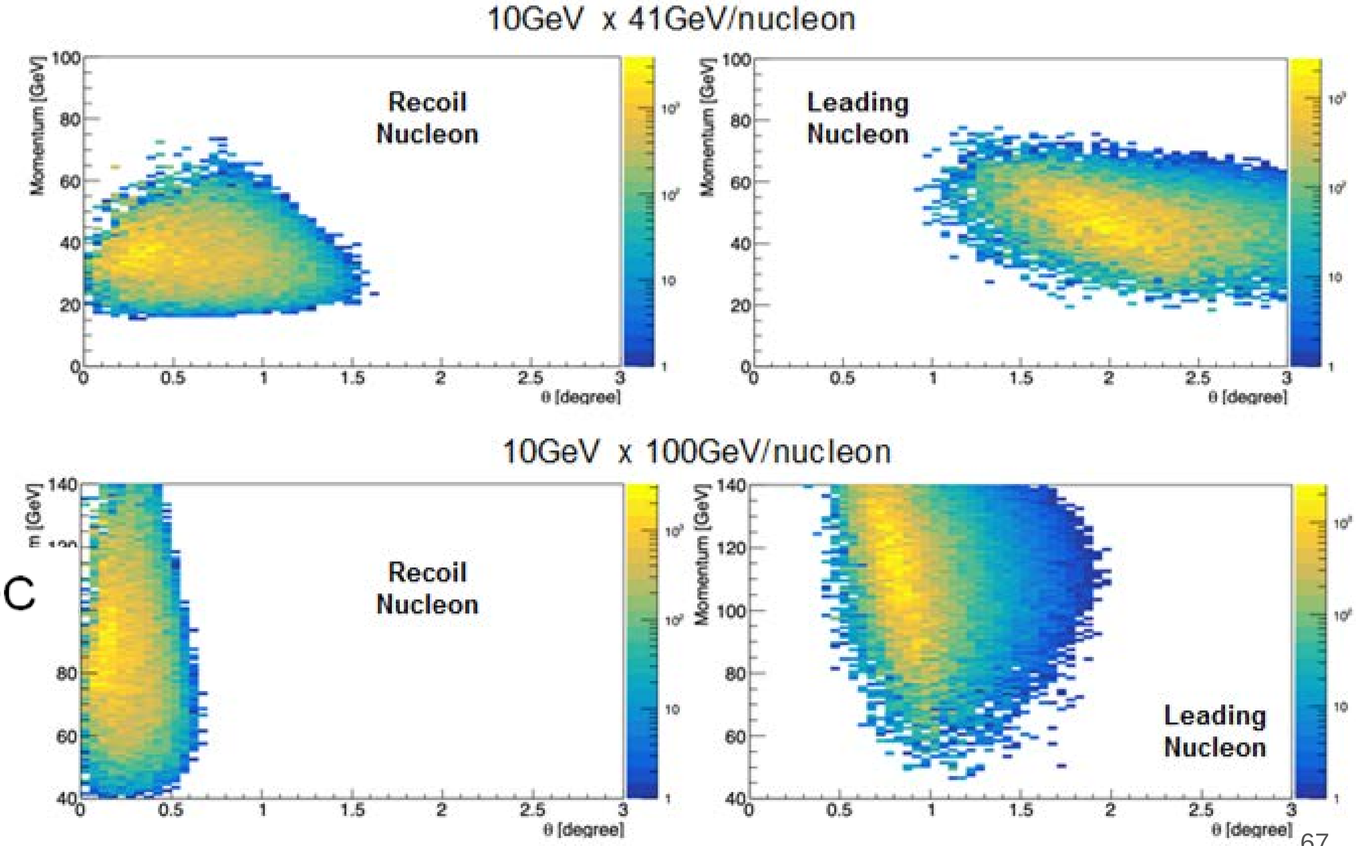
similar for e+C 10x100

eA QE 2N knockout



Hadron Kinematics:

Leading and Recoil for e+C



simulations without crossing angle, intra-nuclear cascading or FSI

Other channels

Measurement/process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
Hadron spectroscopy	central barrel tracking and calorimetry down to 100 MeV	Invariant mass distribution (state TBD)	exotic hadron spectroscopy (i. e. XYZ states)	TBD	
Bethe-Heidler	Acceptance for small-angle photons	elastic FF projections	(transition) FF measurements at variable energies exploiting initial state radiation	Ch. Hyde Ch. Weiss	kinematic plots forthcoming
Coherent production of VM in 4He scattering	$0.01 < -t < 0.5$ GeV^2	Evolution of t-dependence of VM production as a function of Q^2	Color transparency, rescattering, color opacity at various Q^2,	M. Strikman	

Other channels

Measurement/ process	Main detector requirement (if known/anticipated)	Expected plot for the YR	Physics goal/topic	Contact person	Comments
nucleon fragmentation e+p -> e+h(p,n,π)[TF]+X e+p ->e+h+π/dijet[CF]+X	Far forward: -p/n: x_L range down to 0.1; p_T range: 0 <p_T <0.7 GeV/c -Delta production: detection of pions with xL range from 0.3 to 0.1	leading hadron cross sections as a function of xL (normalized to inclusive)	fracture functions, multiparton nucleon structure, formation time	M. Strikman	Double tagging: detecting π, K, charm, dijet in the current fragmentation region to separate processes with u,d,g
ep/A-> e + 2 jets + X + Y	Roman pot for leading protons, forward neutron calorimeter for pion exchange, nuclei	Differential diffractive cross section for jet production, i.e. Figs. 5d, 6d; 8b and 9d from 2004.06972	diffractive PDFs in protons and nuclei, pion PDFs, nuclear excitation	M. Klasen V.Guzey	NLO calculations finished, must still optimise YR plot(s) Pass through simulations?

Summary

- Many channels are under study, progressing well
- Many kinematic maps for physics objects completed/near completion;
  cross-group cross-checks are next step (at/after Pavia)
- Fast simulations of many channels are well underway
- Initial constraints on detectors are starting to come out (and being communicated to the DWG)