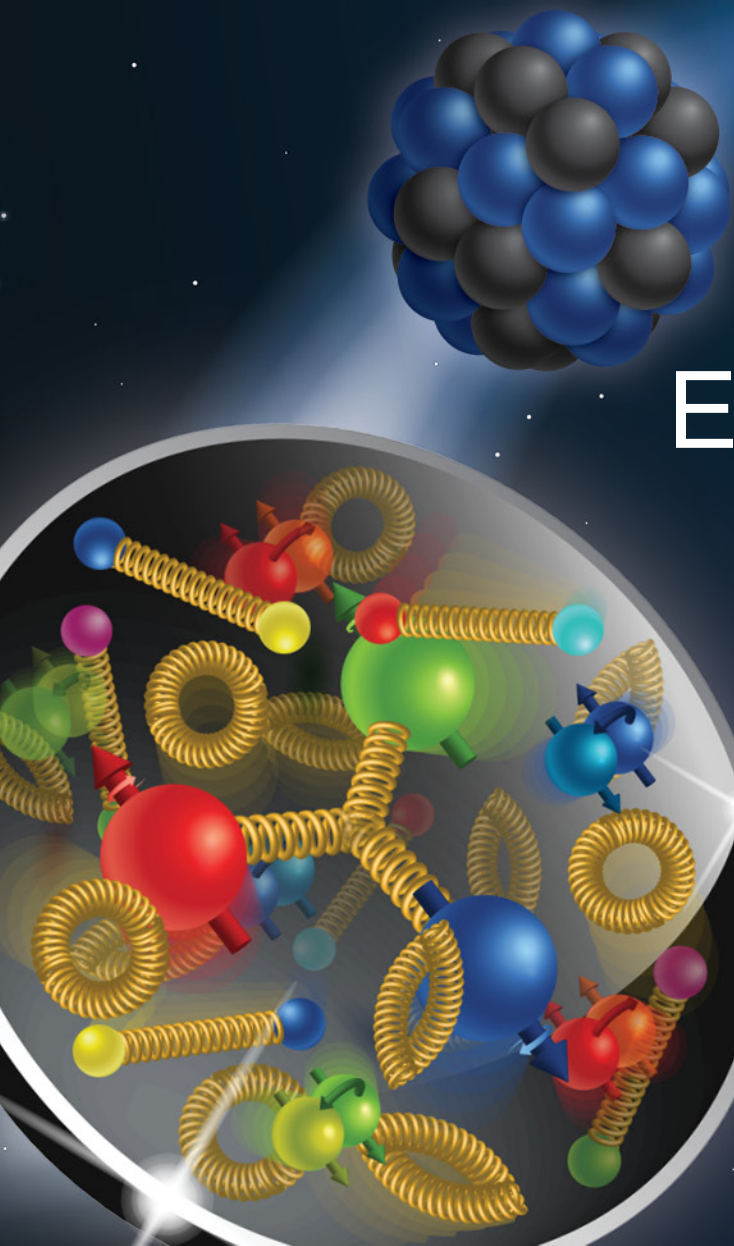


Exclusive and Diffractive Physics in the Far-Forward Region

Alex Jentsch, *Brookhaven National Lab*

2nd Yellow Report Meeting @ Pavia (remote)

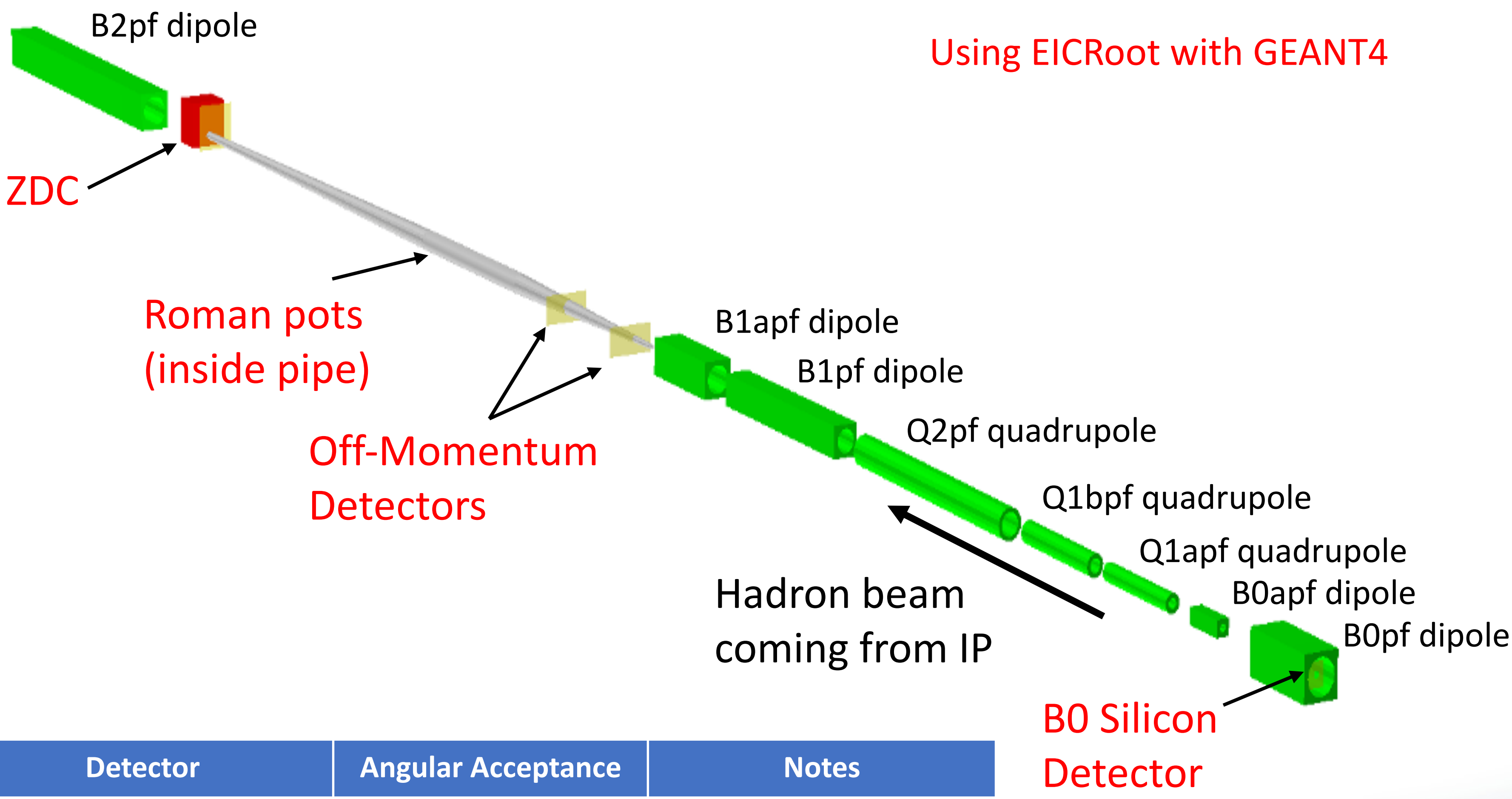
May 20th-22nd, 2020

Electron Ion Collider

BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY | Office of Science

Far-Forward Region Layout



Using EICRoot with GEANT4

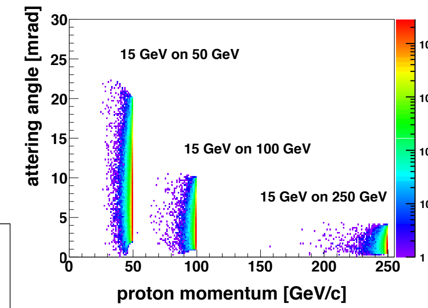
Detector	Angular Acceptance	Notes
ZDC	$\boldsymbol{\theta} < 5.5$ mrad	About 4.0 mrad at φ ~ π
Roman Pots	$0.0 < \boldsymbol{\theta} < 5.0$ mrad	Need 10σ cut.
Off-Momentum Detectors	$0.0 < \boldsymbol{\theta} < 5.0$ mrad	Roughly $.4 < x_L < .6$
B0 Sensors	$5.5 < \boldsymbol{\theta} < 20.0$ mrad	Still need to optimize.

$$x_L = \frac{p_{z,nucleon}}{p_{z,beam}}$$

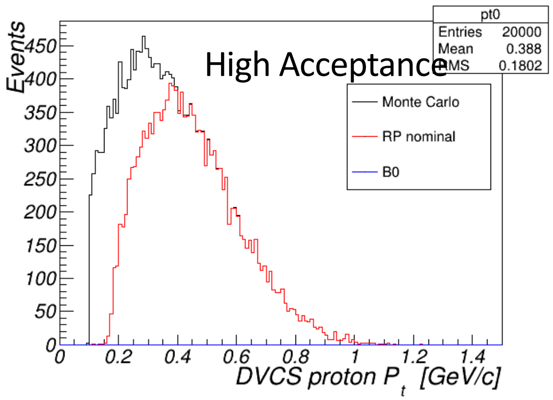
What has been studied?

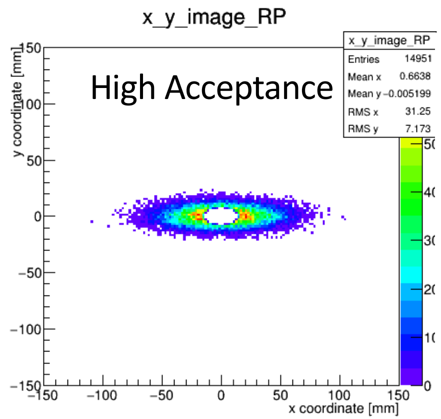
- DVCS proton measurements (using MILOU).
  - Acceptances of protons in Roman Pots and B0.
  - Pt resolution and measurement of t-distribution.
  - All effects included (e.g. angular divergence, detector reconstruction, etc.).
  - Three energies (5x41 GeV, 10x100 GeV, 18x275 GeV).
- Spectator tagging of e+D nuclear breakup with BeAGLE (paper soon to be on arXiv).
  - Acceptance and resolutions for all 4 detectors.
  - All effects included.
  - Two energies (18x110 GeV, 18x135 GeV).

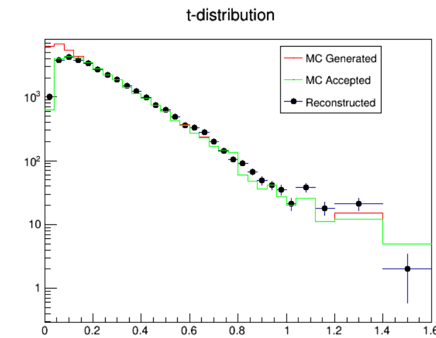
Review of DVCS results



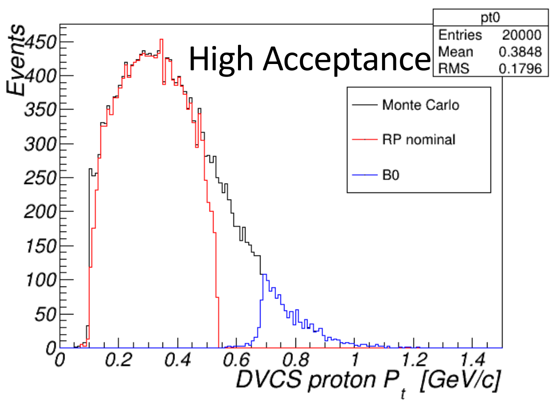
18x275 GeV

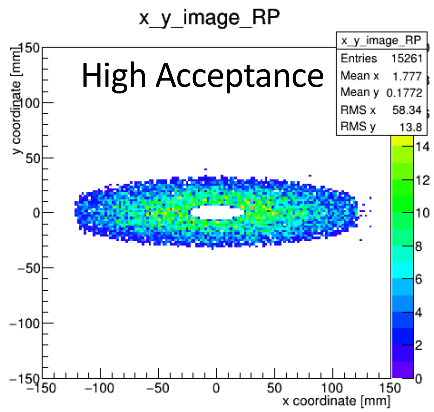


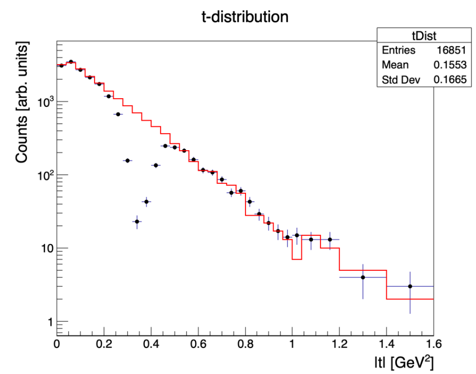




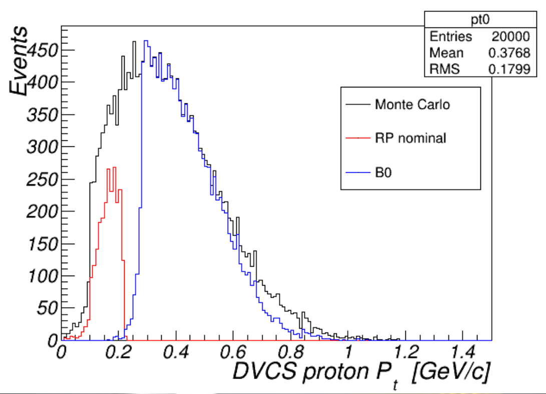
10x100 GeV

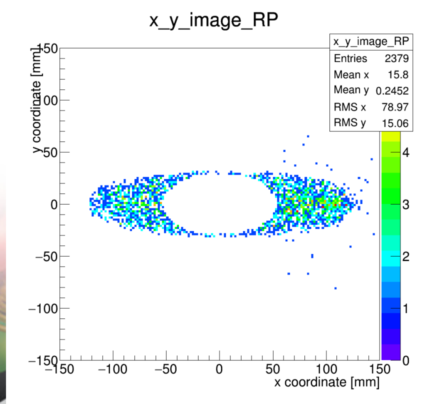


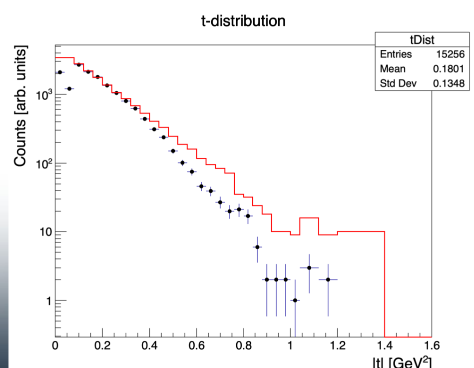




5x41 GeV







Review of DVCS results

$$\Delta p_{t,total} = \sqrt{(\Delta p_{t,AD})^2 + (\Delta p_{t,CC})^2 + (\Delta p_{t,pxl})^2}$$

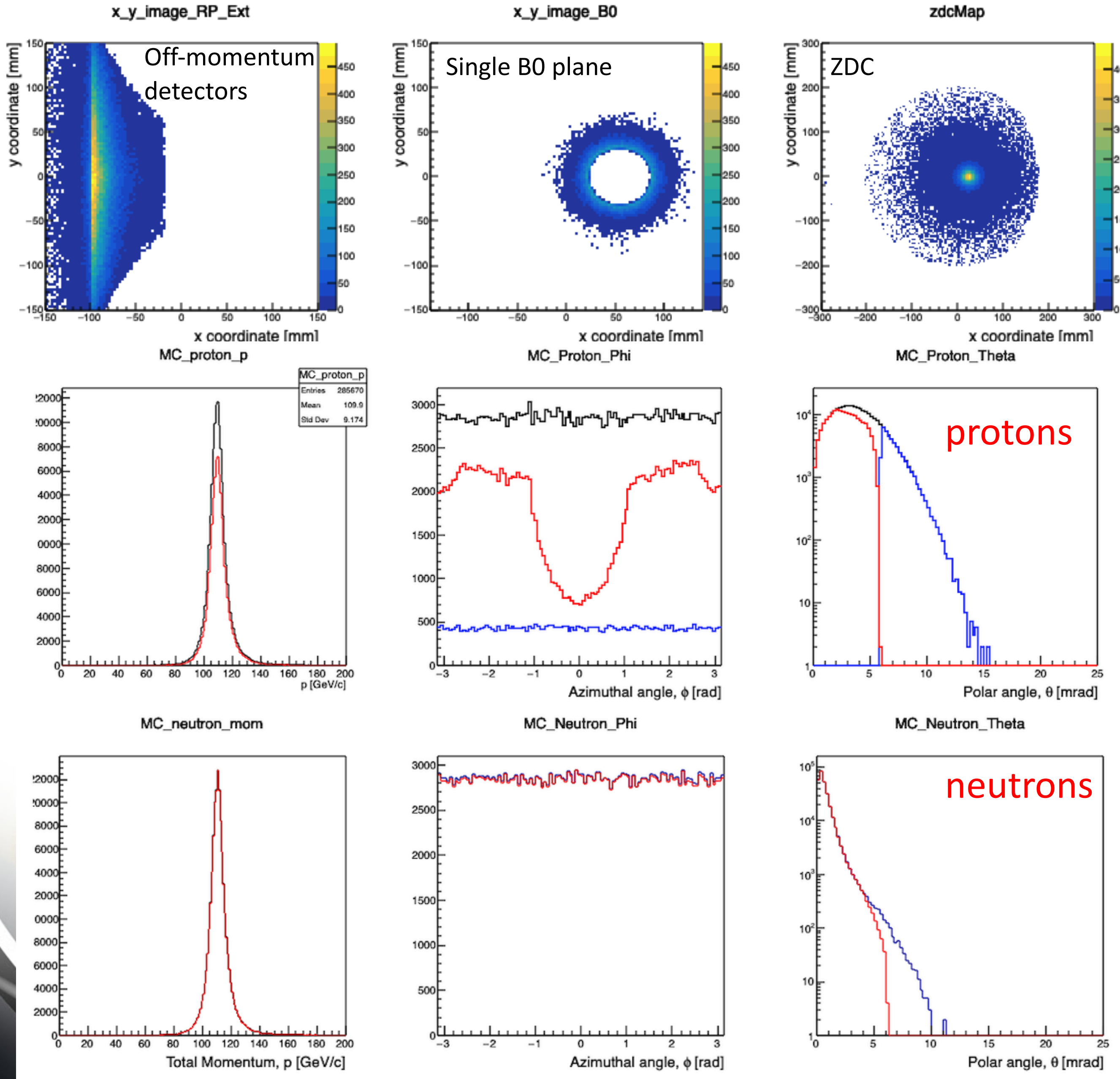
- $(\Delta p_{t,AD})^2$: Angular divergence
- $(\Delta p_{t,CC})^2$: Primary vertex smearing from crab cavity rotation.
- $(\Delta p_{t,pxl})^2$: Smearing from finite pixel size.

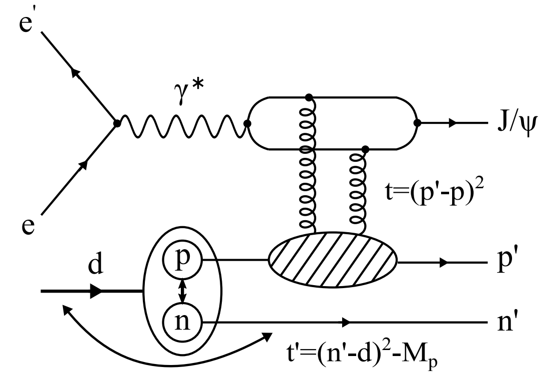
Detector	Angular Acceptance	Notes
Roman Pots	$0.0 < \theta < 5.0$ mrad	Need 10σ cut.
B0 Sensors	$5.5 < \theta < 20.0$ mrad	Still need to optimize.

	Ang Div. (HD)	Ang Div. (HA)	Vtx Smear	250um pxl	500um pxl	1.3mm pxl
$\Delta p_{t,total}$ [MeV/c] - 275 GeV	40	28	20	6	11	26
$\Delta p_{t,total}$ [MeV/c] - 100 GeV	22	11	9	9	11	16
$\Delta p_{t,total}$ [MeV/c] - 41 GeV	14	-	10	9	10	12

- **Beam angular divergence**
  - Beam property, can't correct for it – sets the lower bound of smearing.
  - Subject to change (i.e. get better) – beam parameters not yet set in stone
- **Vertex smearing from crab rotation**
  - Correctable with good timing (~35ps)
- **Finite pixel size on sensor**
  - 500um seems like the best compromise between potential cost and smearing

Results from e+D nuclear breakup

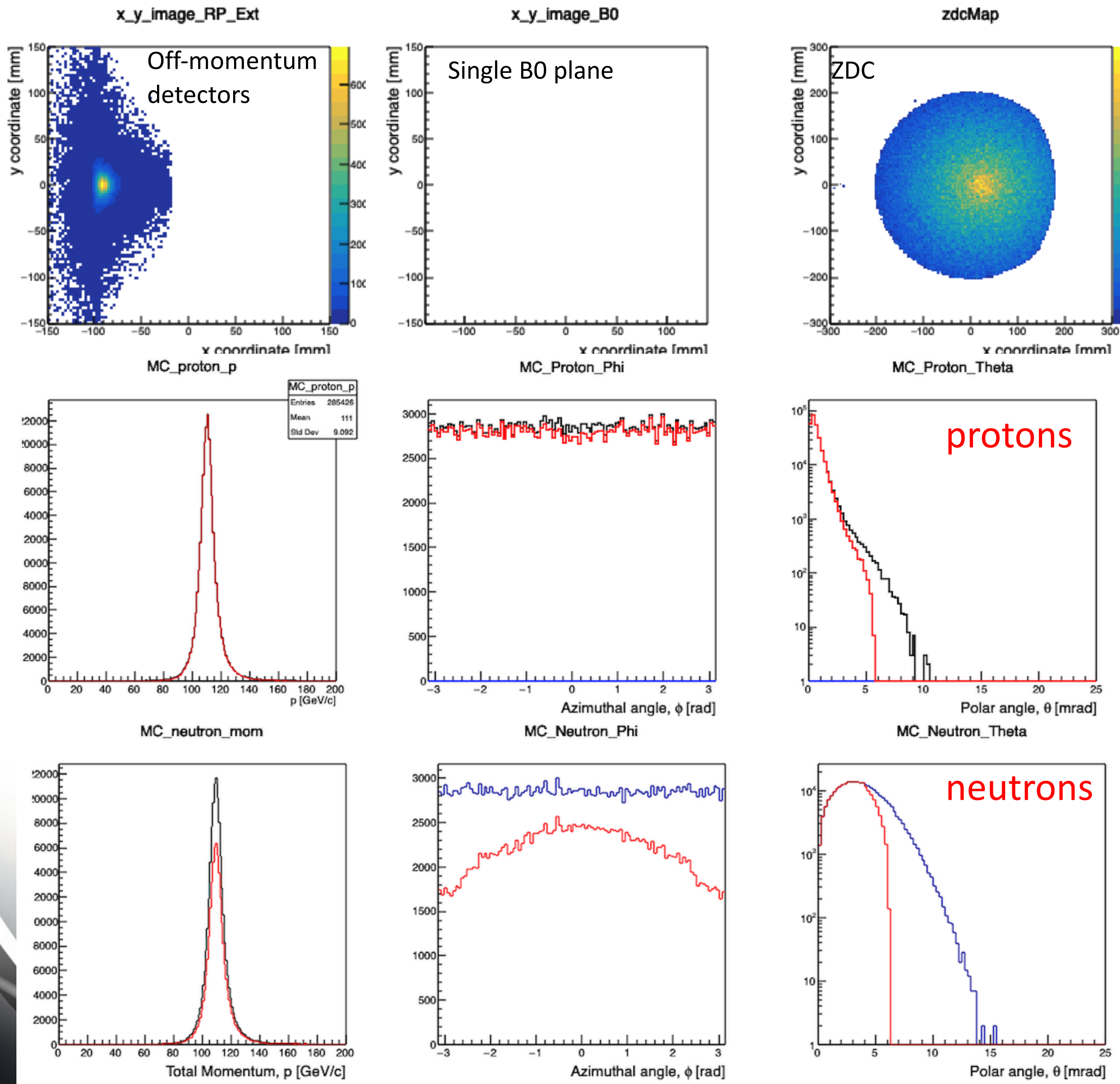


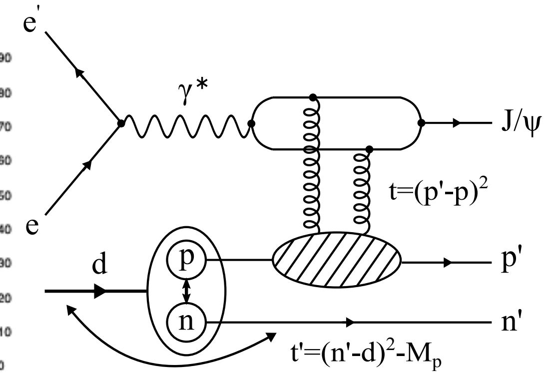


Particular process in BeAGLE: incoherent diffractive J/psi production off bounded nucleons.

Neutron spectator case.

Results from e+D nuclear breakup



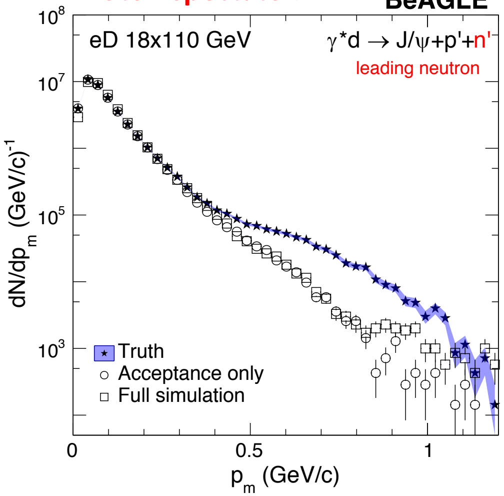


Particular process in BeAGLE: incoherent diffractive J/psi production off bounded nucleons.

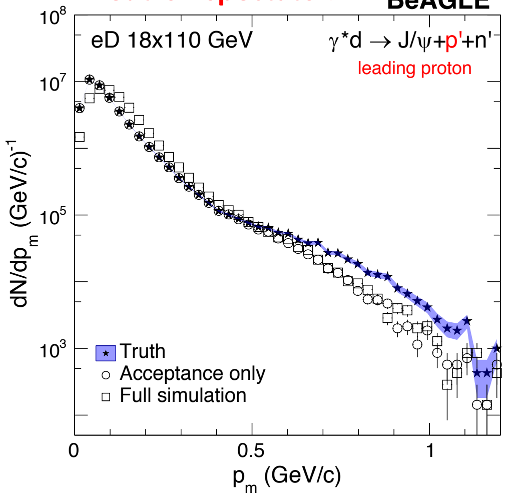
Proton spectator case.

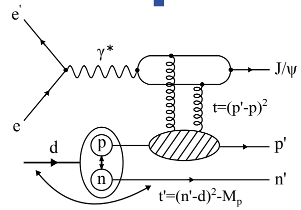
Results from e+D nuclear breakup

Proton spectator.

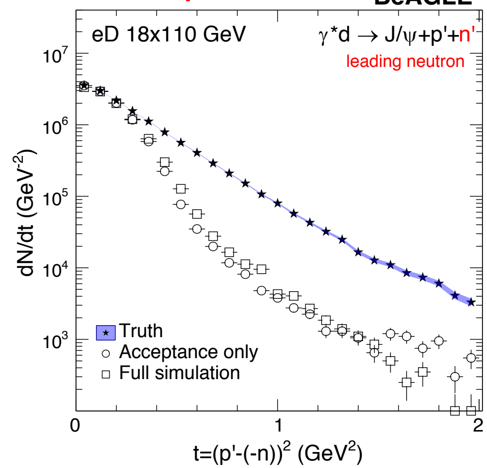


Neutron spectator.

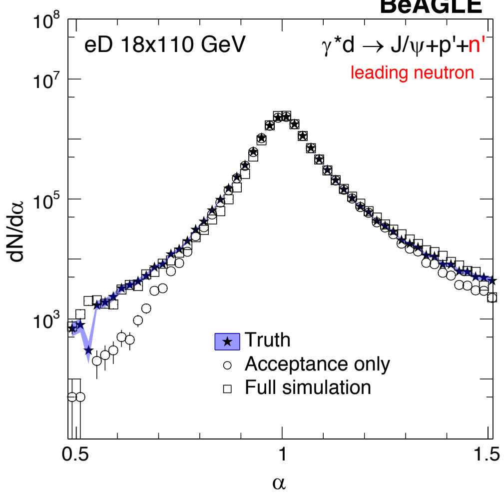




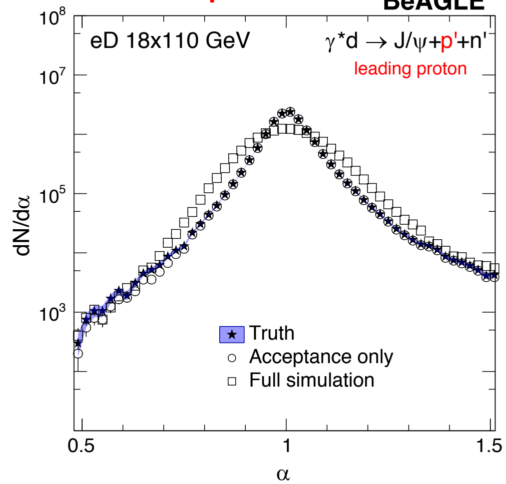
Proton spectator.



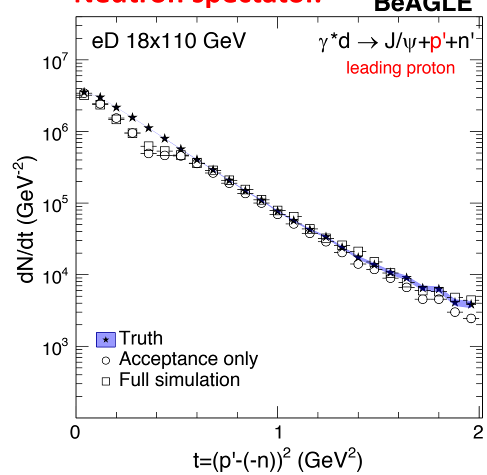
Proton spectator.



Neutron spectator.



Neutron spectator.



Results from e+D nuclear breakup

p_T Resolution	Proton		Neutron	
	%	MeV/c	%	MeV/c
$p_T < 140$ MeV/c	15	22	29	37
$140 < p_T < 350$ MeV/c	8	25	14	43
$350 < p_T < 630$ MeV/c	6	30	10	52
$p_T > 630$ MeV/c	4	26	9	70

E Resolution	Neutron	
	%	GeV/c
$50 < p < 80$ GeV/c	7.5	5.5
$80 < p < 110$ GeV/c	7	7
$110 < p < 130$ GeV/c	6.7	8.5
$p > 130$ GeV/c	6.2	11

Assumptions:

1) ZDC
   - energy resolution $\frac{\sigma_E}{E} = \frac{50\%}{\sqrt{E}} \oplus 5\%$
   - Angular resolution $\frac{3\ \mathrm{mrad}}{\sqrt{E}}$
2) Off-Momentum Detectors
   - 500 um x 500 um pixels
3) B0 Sensors
   - 50 um x 50 um pixels
4) Using angular divergence numbers from pCDR 18x100 GeV e+p with strong cooling.

Methods	Momentum transfer t (GeV^2)							
	0–0.05	0.05–0.11	0.11–0.17	0.17–0.25	0.25–0.35	0.35–0.49	0.49–0.69	0.69–1.20
1. $\delta t/t$ (%) with $t = (p' - p)^2$	-	-	-	-	-	-	-	-
2. $\delta t/t$ (%) with $t = (e - e' - V)^2$	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100
3. $\delta t/t$ (%) with $t \approx (p_{T,V} + p_{T,e'})^2$	20.3	7.8	5.8	4.8	3.9	3.4	3.0	2.5
4. $\delta t/t$ (%) with $t = (p' - (-n))^2$	49.6	41.6	36.2	31.6	28.2	24.4	17.9	16.0

Summary and takeaways

- The IR was designed with Roman Pots and a ZDC in mind.
  - The acceptances for DVCS are quite good across all energies, with low energy requiring some optimization.
- Measuring off-energy protons from nuclear breakup events is a challenge.
  - But this lattice allows for quite good acceptance, with most spectator protons being captured by the Off-momentum detectors.
- More processes using the far-forward region are under study (such as pions from lambda decay).
- Areas where the baseline IR leaves things to be desired drive the requirements for a second IR.

Discussion