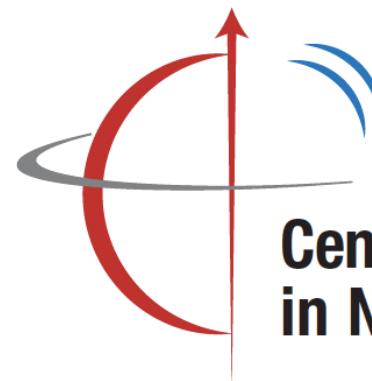


DVCS studies: From CLAS12 to ePIC

Igor Korover



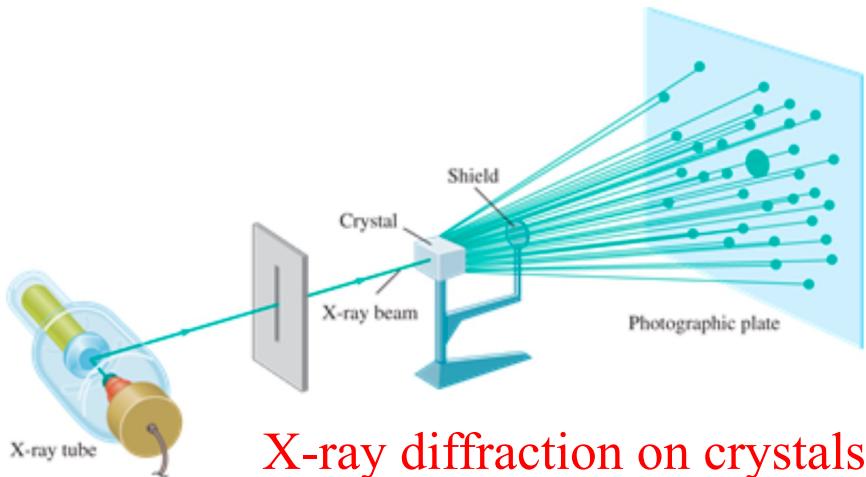
**Massachusetts
Institute of
Technology**



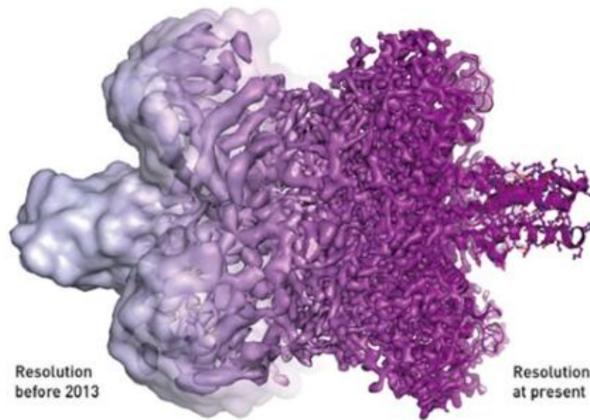
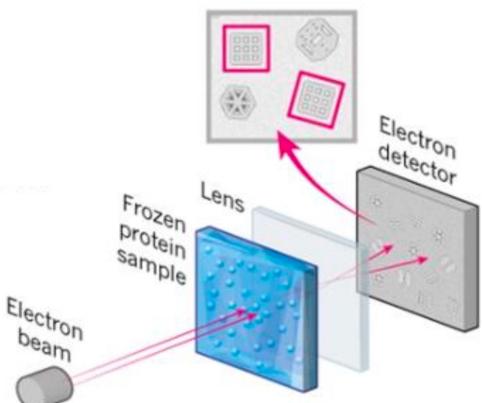
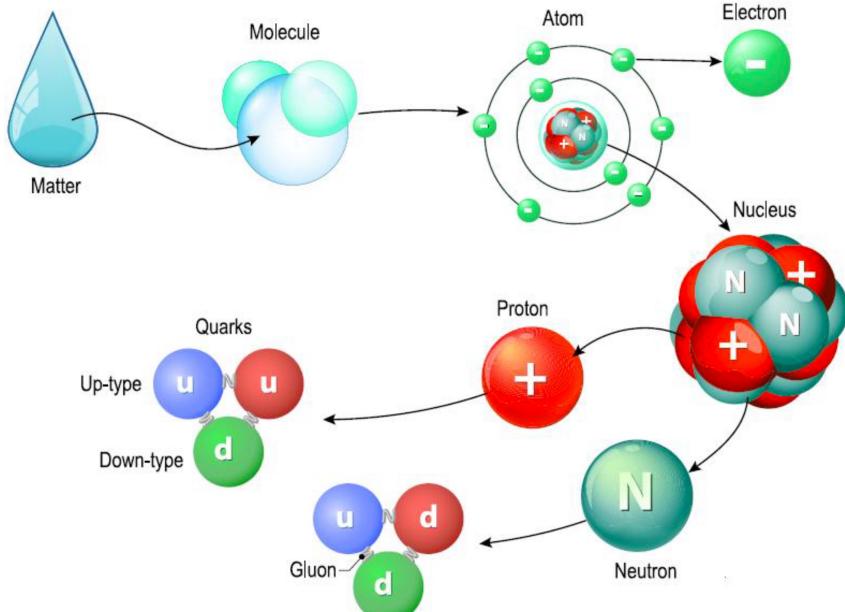
30 March 2023

The Quest to Understand the Fundamental Structure of Matter

Diffractive imaging

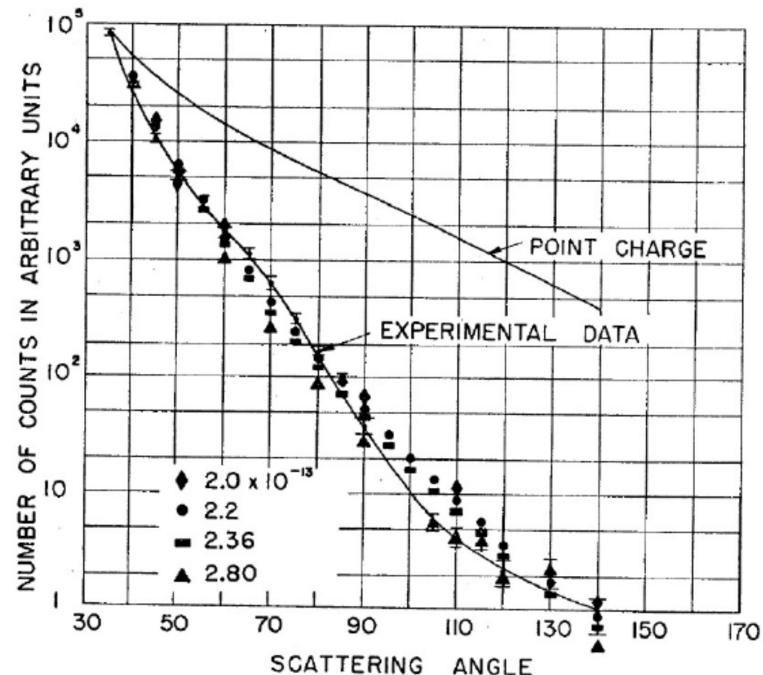
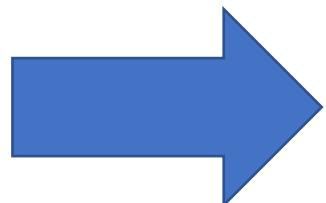
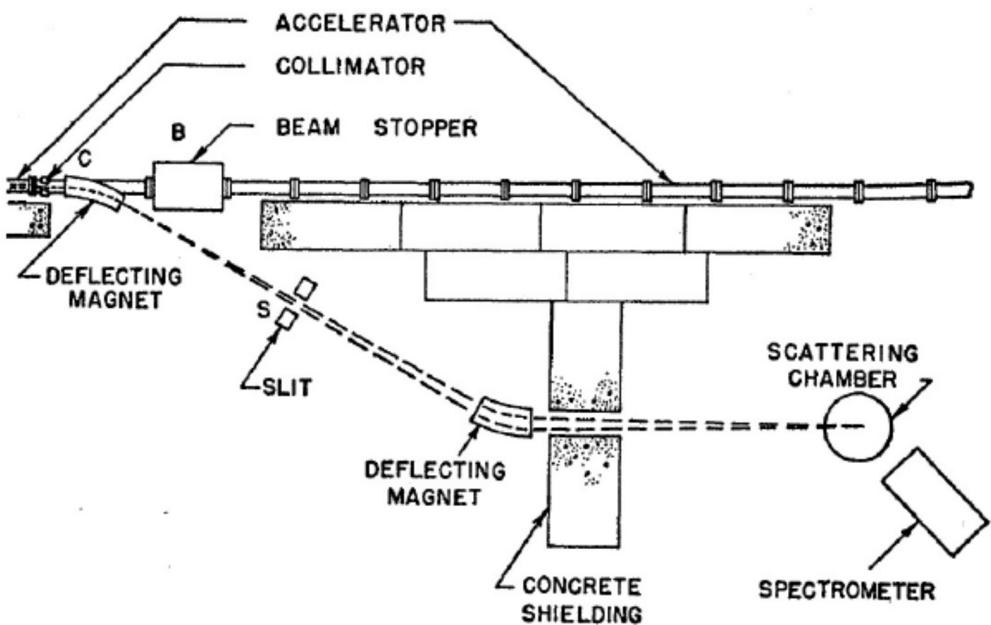


X-ray diffraction on crystals

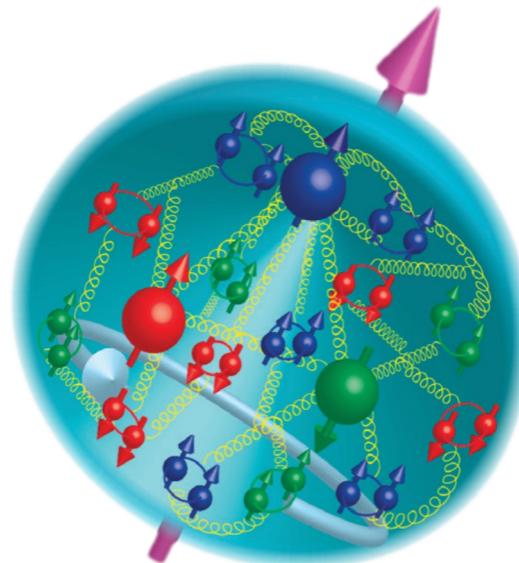


Electron diffraction on protein

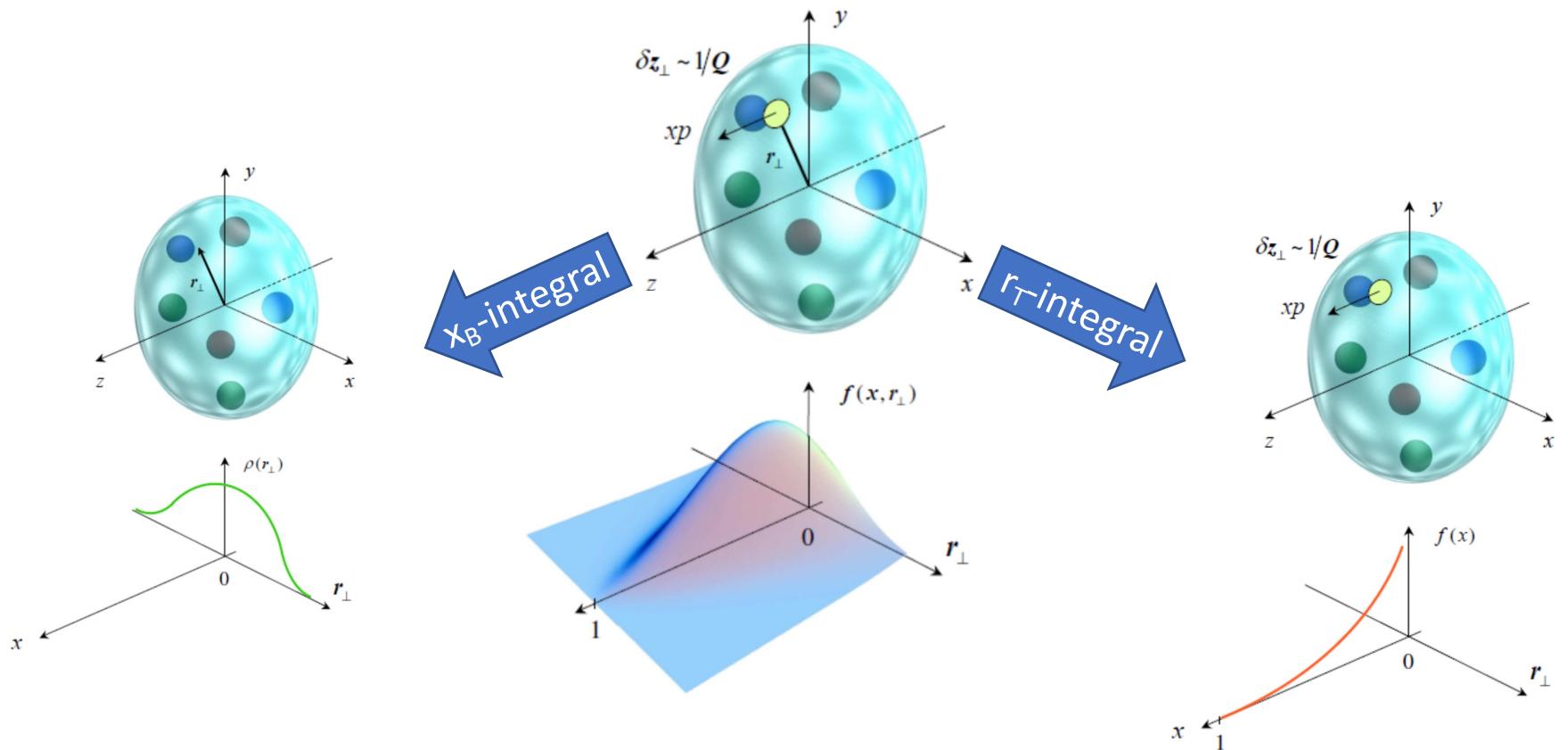
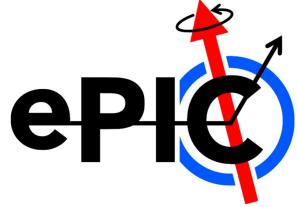
Electron diffraction on the proton



Hofstadter, R., et al., Phys. Rev. 92, 978 (1953).



Generalized Parton Distributions



EM structure

Form factors, transverse
charge & current distributions

Nobel prize 1961-
Hofstadter

Quark-gluon structure
longitudinal momentum
& helicity distributions

Nobel prize 1990 -
Friedman, Kendall, Taylor

A world in a Function: Generalized Parton Distributions (GPDs)

- Nucleon Spin

$$J_q = \frac{1}{2} \Delta \Sigma + L_q = \frac{1}{2} [A_{q,g}(0) + B_{q,g}(0)]$$

$$\int_{-1}^1 dx x [H(x, \xi, \Delta^2) + E(x, \xi, \Delta^2)] = A(\Delta^2) + B(\Delta^2)$$

- 3D Tomography

$$q(x, \mathbf{b}_\perp) = \int \frac{d^2 \Delta_\perp}{(2\pi)^2} H_q(x, -\Delta_\perp^2) e^{-i \mathbf{b}_\perp \cdot \Delta_\perp}$$

- Origin of Visible Mass

- Nucleon Energy-Momentum Tensor (EMT)

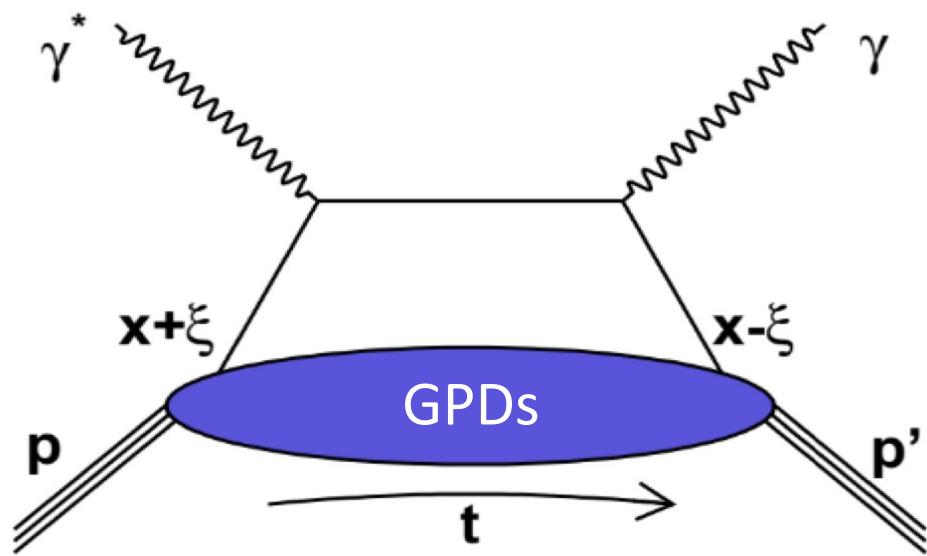
$$M_2^q(t) + \frac{4}{5} d_1(t) \xi^2 = \frac{1}{2} \int_{-1}^1 dx x H^q(x, \xi, t)$$



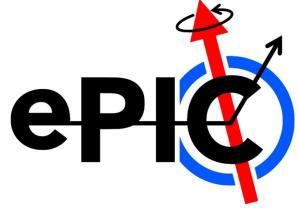
R. G. Milner and R. Ent,
Visualizing the Proton (2022)

GPDs Accessible via Exclusive Processes

[e.g. Deeply Virtual Compton Scattering (DVCS)]



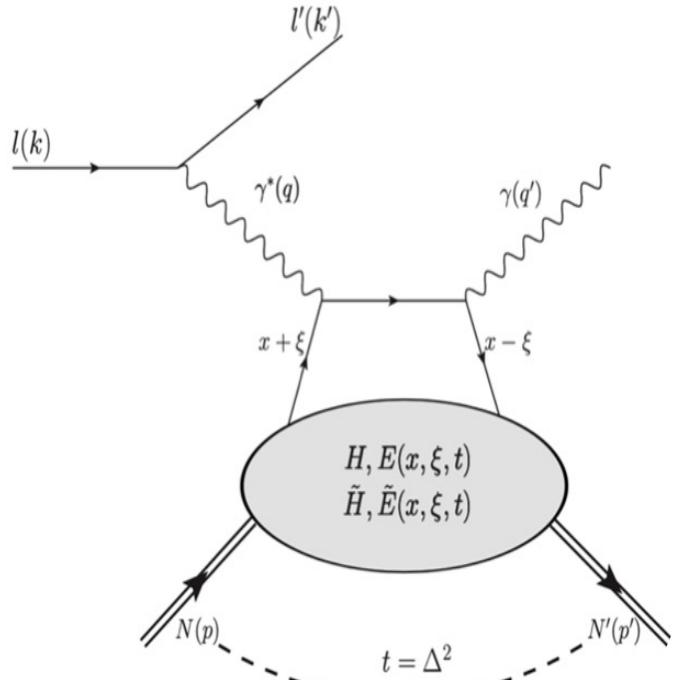
Deeply Virtual Compton Scattering



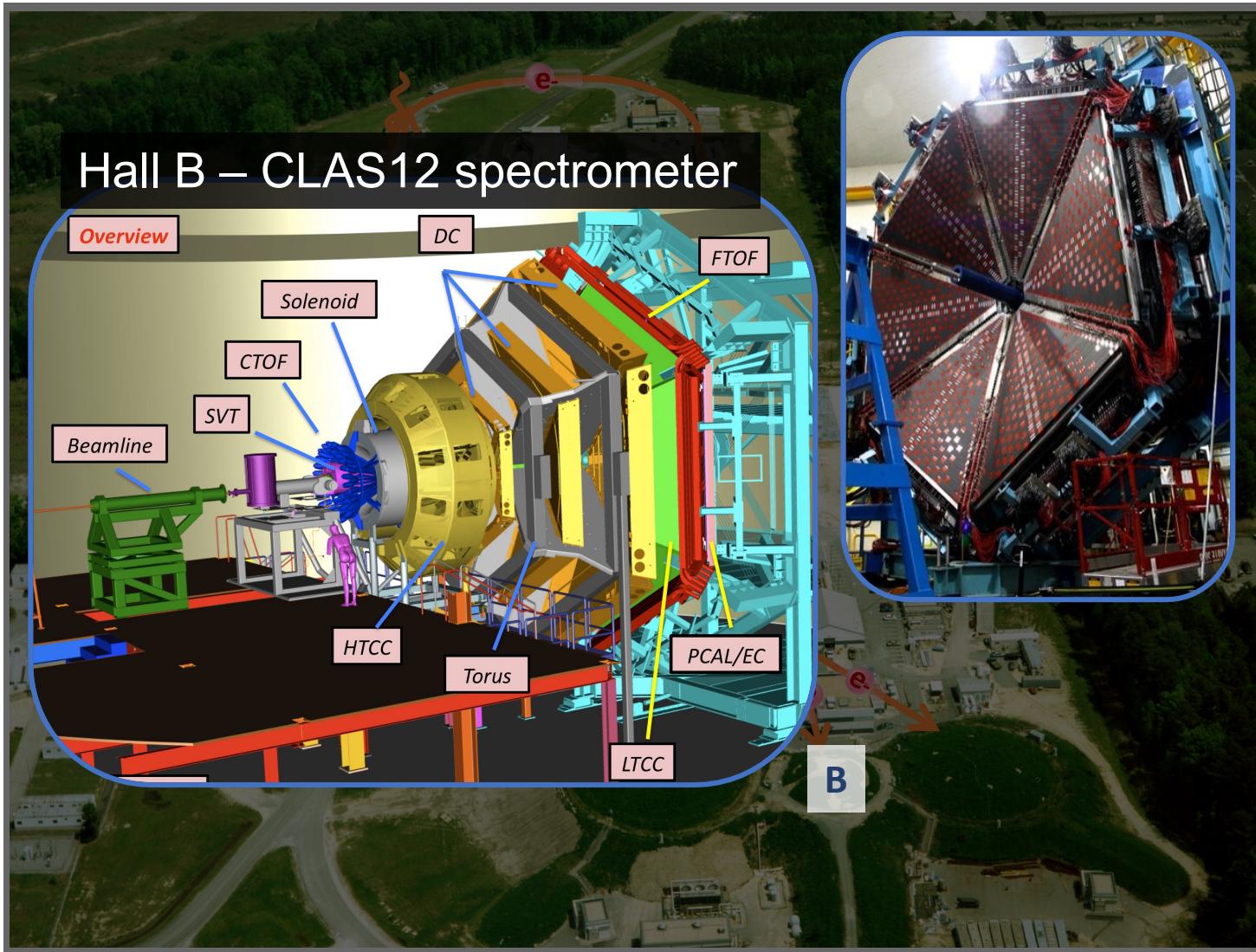
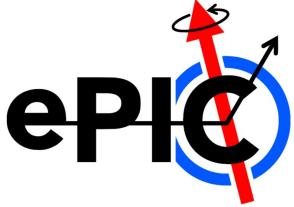
$$e + p \rightarrow e' + p' + \gamma$$

Simple reaction... but:

- Low cross-section
 - Large non-DVCS background
 - Exclusivity requirement
 - 4-dimentional extraction required
- ➔ Ideally suited for a high-luminosity, high-resolution, large acceptance experimental setups.

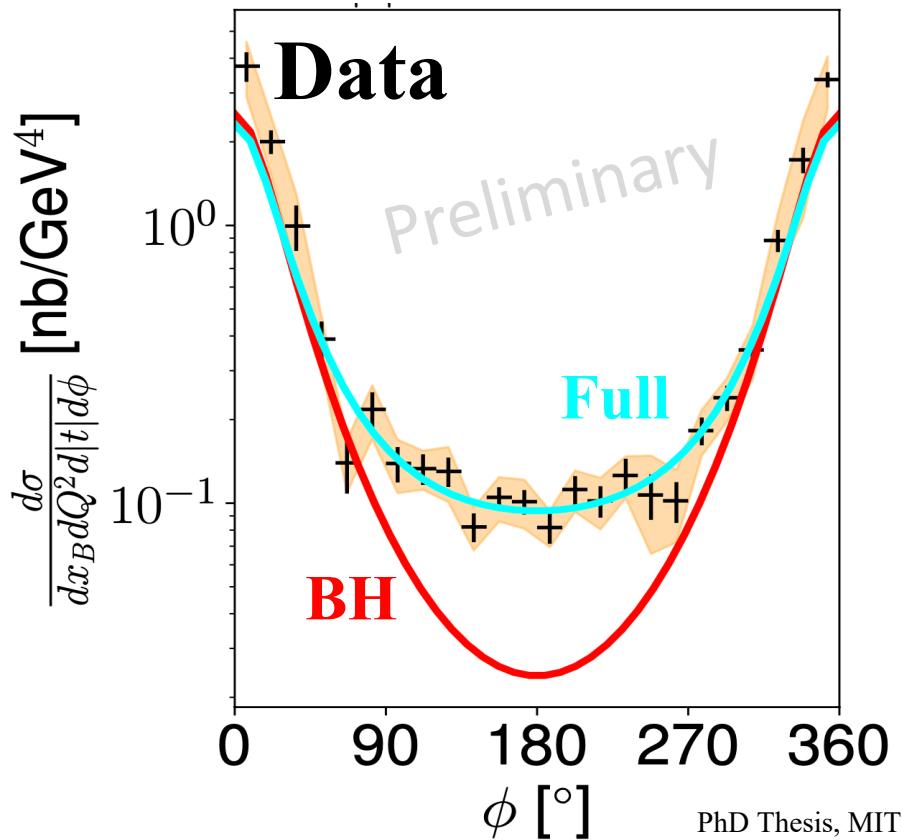
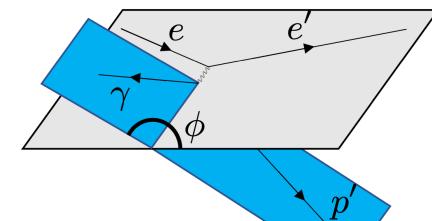


JLab CLAS12



CLAS12 4D Cross section Results

- DVCS dominate over BH (QED background) at central angles ($90^\circ - 270^\circ$)
- Good agreement with parametrization based on collider and JLab 6 GeV data
- Wide kinematic coverage required for multidimensional analysis



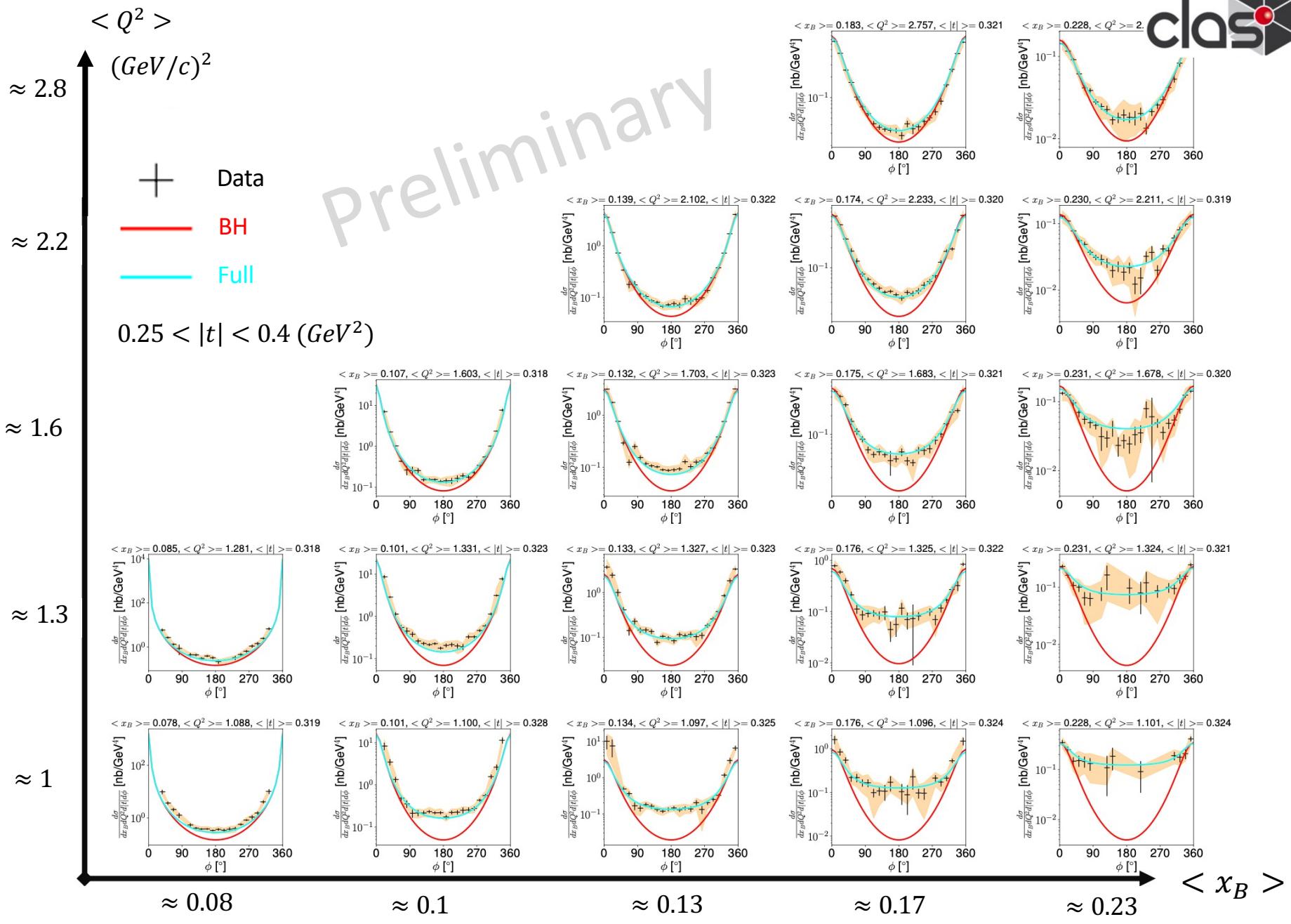
PhD Thesis, MIT
Sangbaek Lee

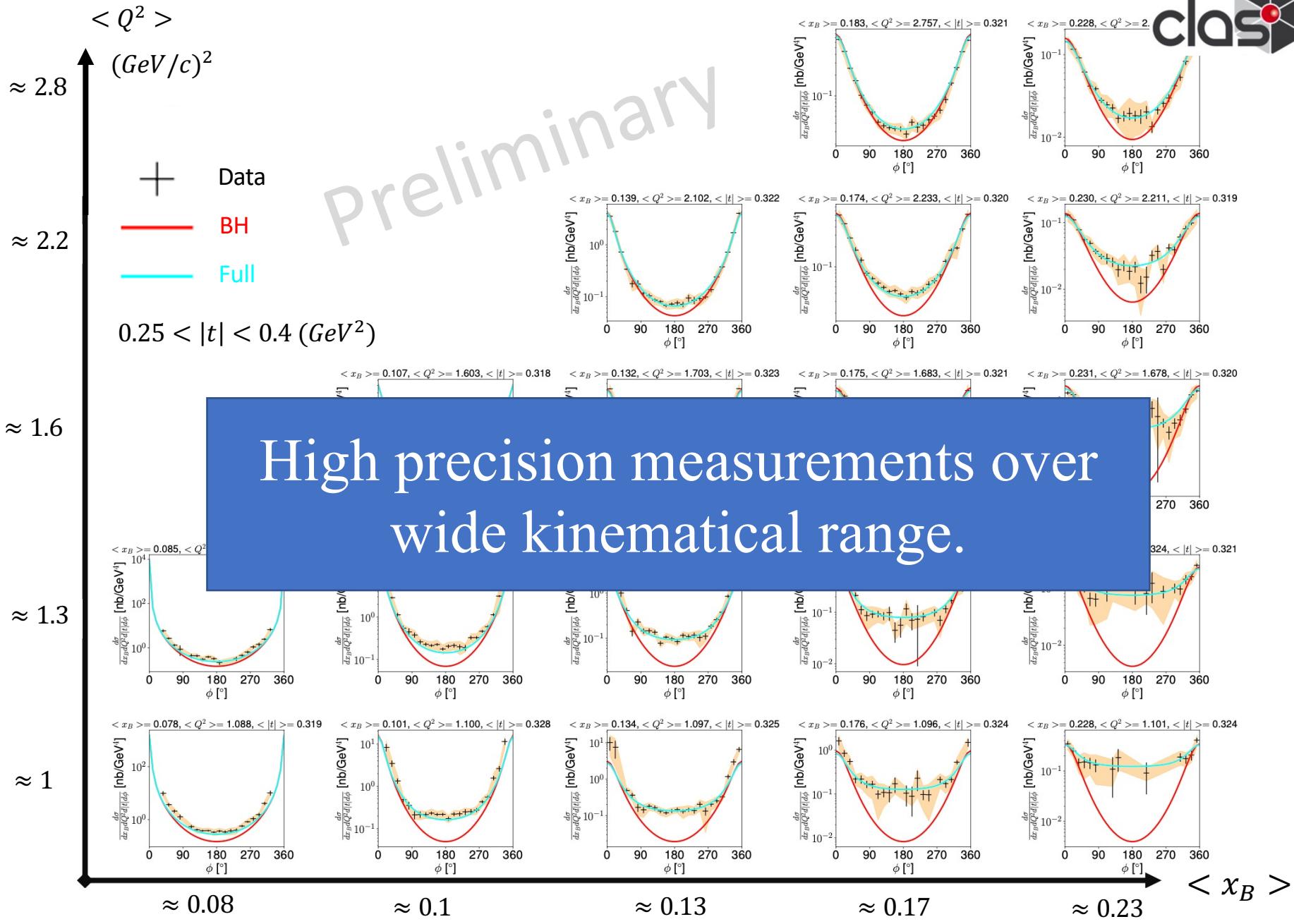
$$\langle x_B \rangle \approx 0.13$$

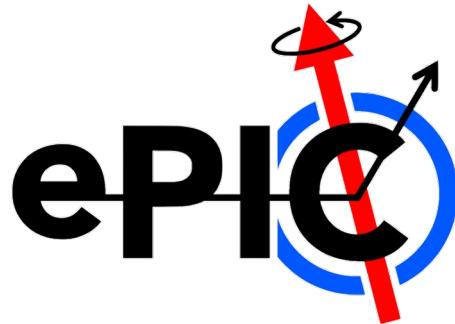
$$\langle Q^2 \rangle \approx 1.3 \left(\frac{GeV}{c}\right)^2$$

$$\langle |t| \rangle \approx 0.3 \text{ GeV}^2$$









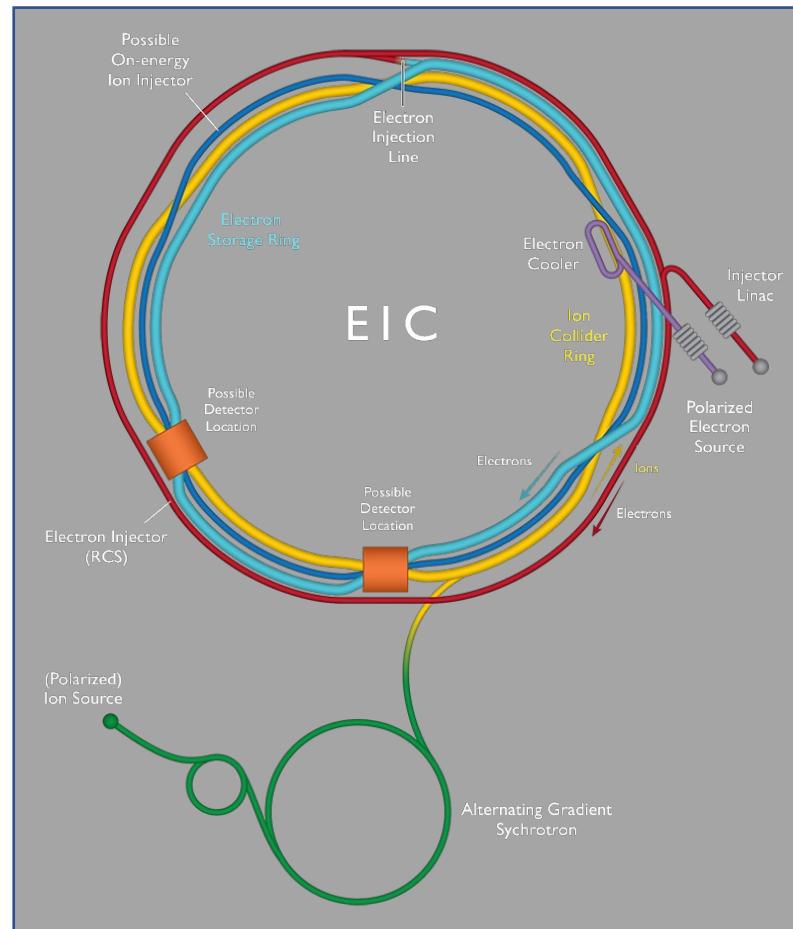
EIC: Polarized ep (eA) collider at Brookhaven National Lab

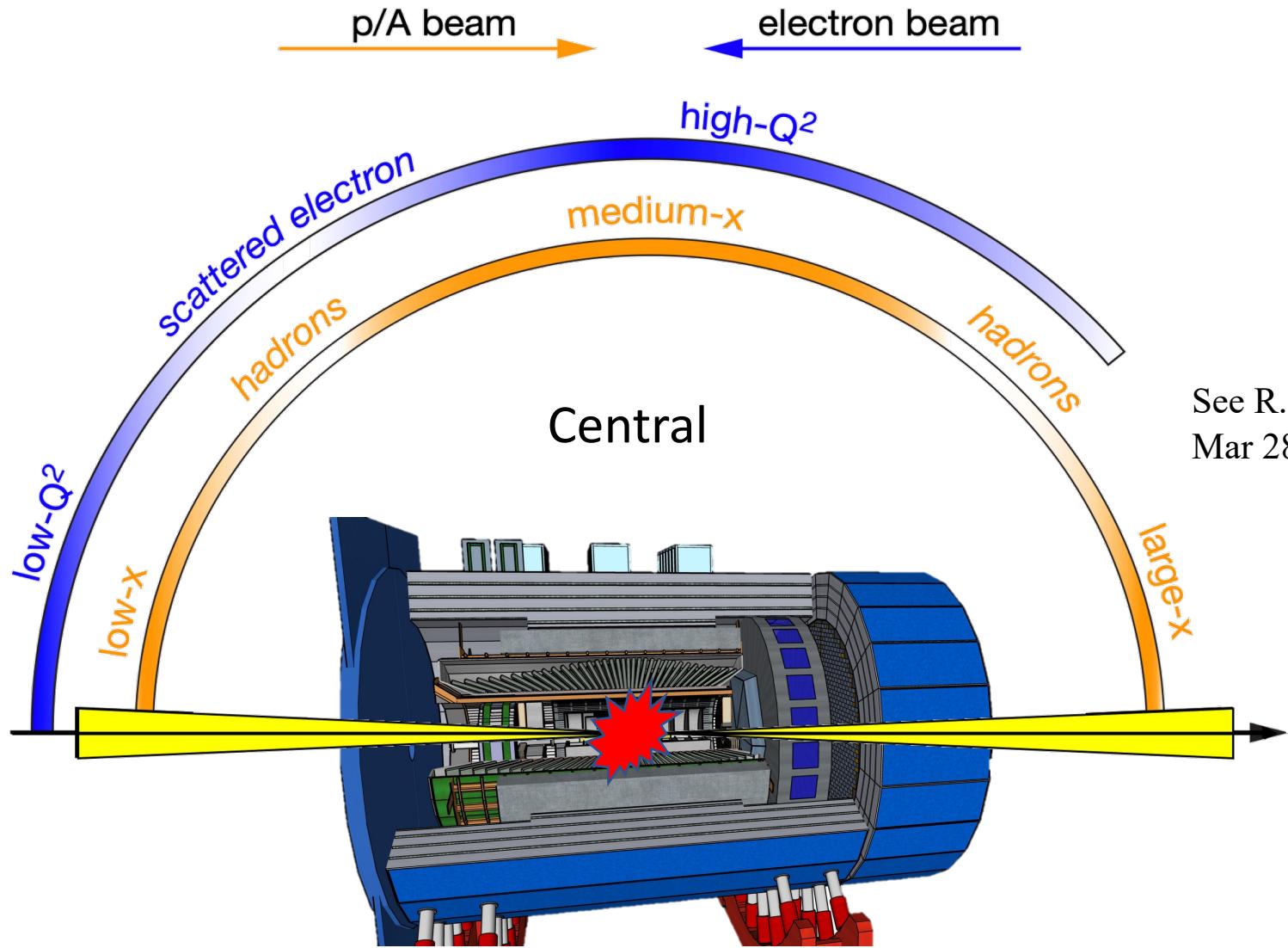
DOE project, set to revolutionize our understanding of QCD

p: 41 – 275 GeV

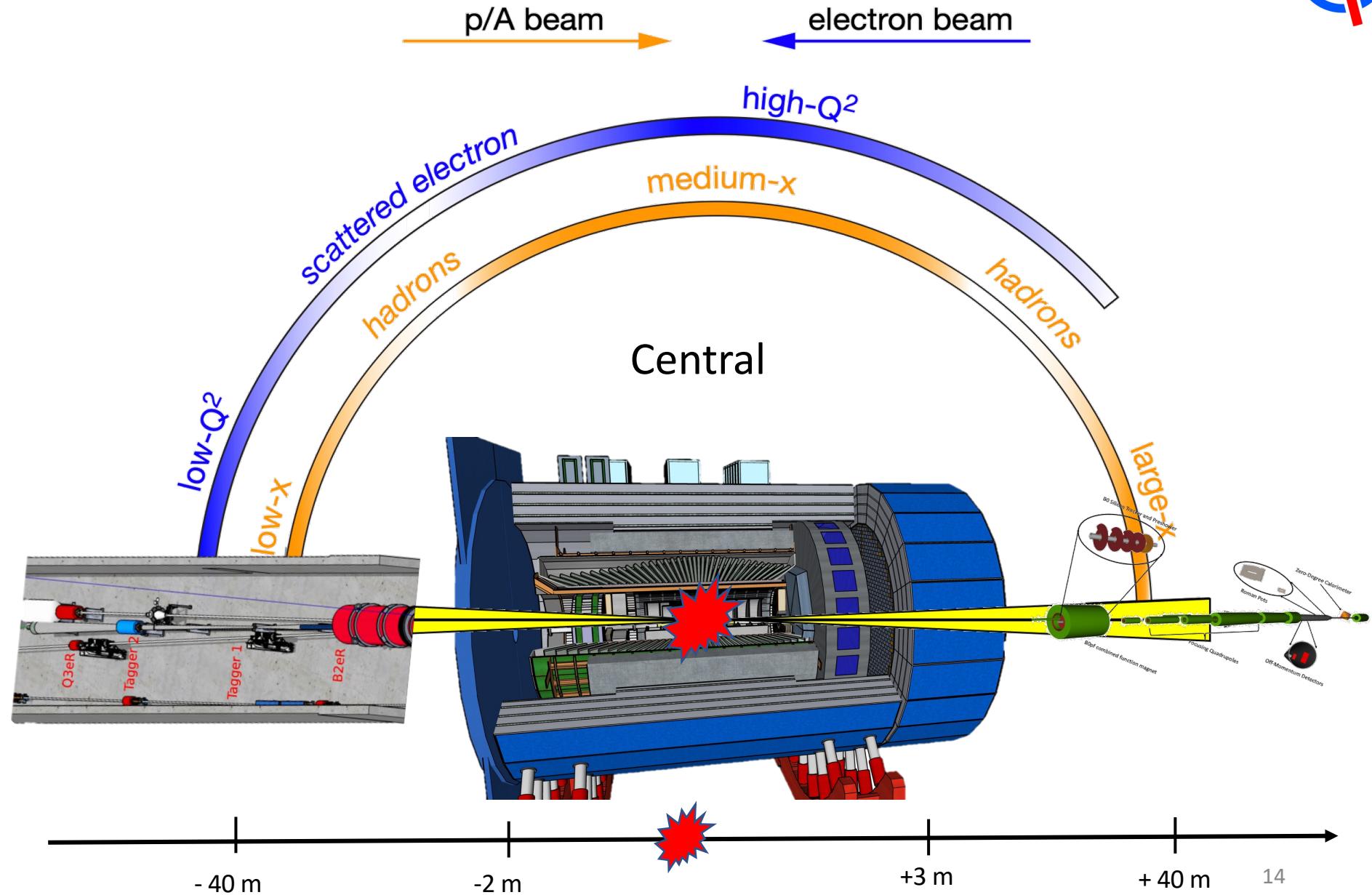
e: 5 – 18 GeV

Data taking starting 2031/32

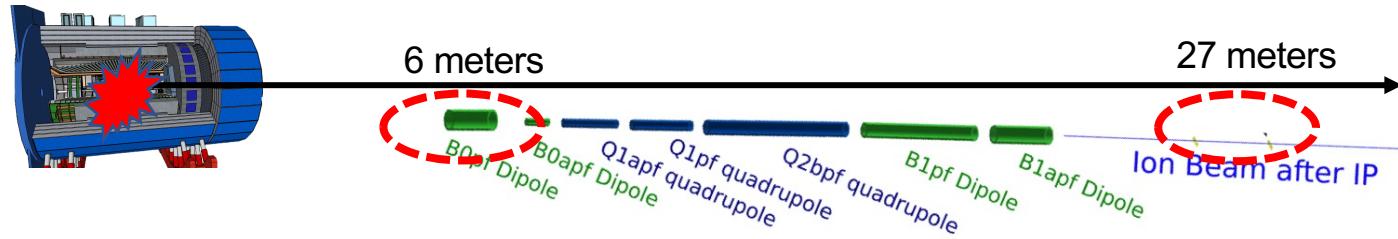




See R. Milner
Mar 28, 9 am

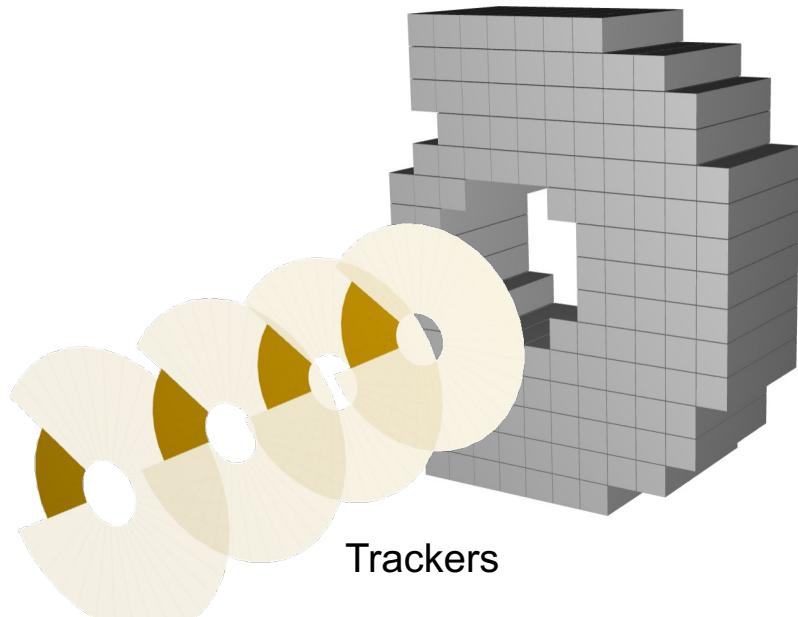


Far-Forward Detectors Enable Exclusive Physics

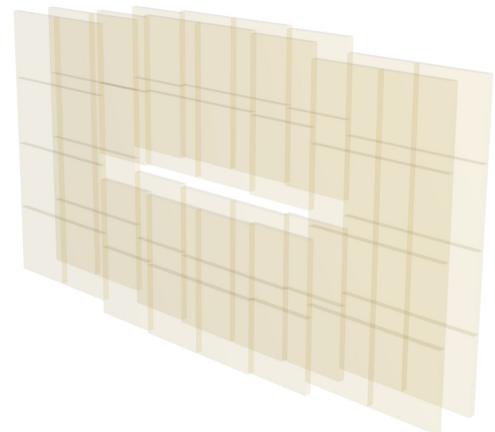


B0 spectrometer

Calorimeter

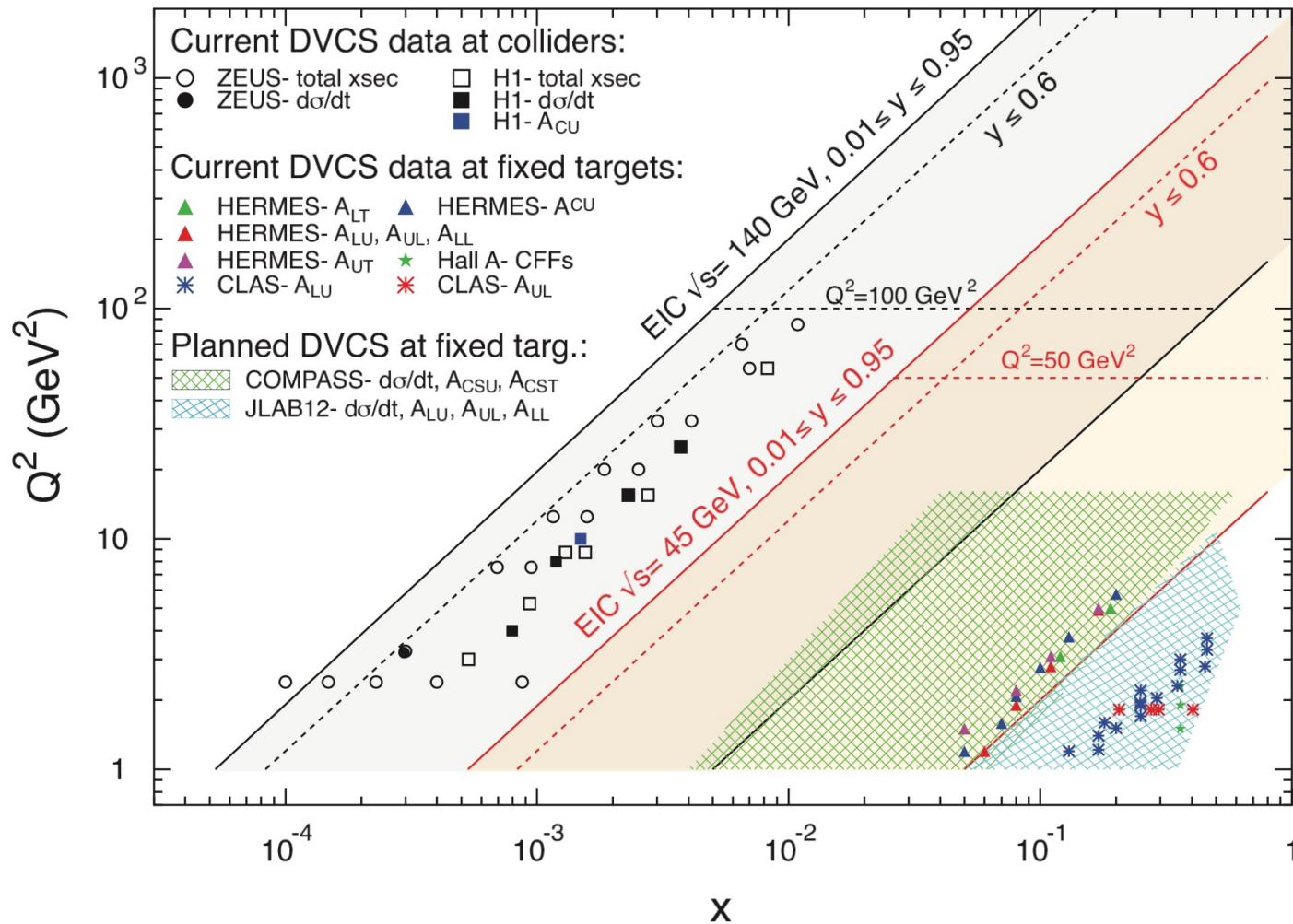


Roman Pots

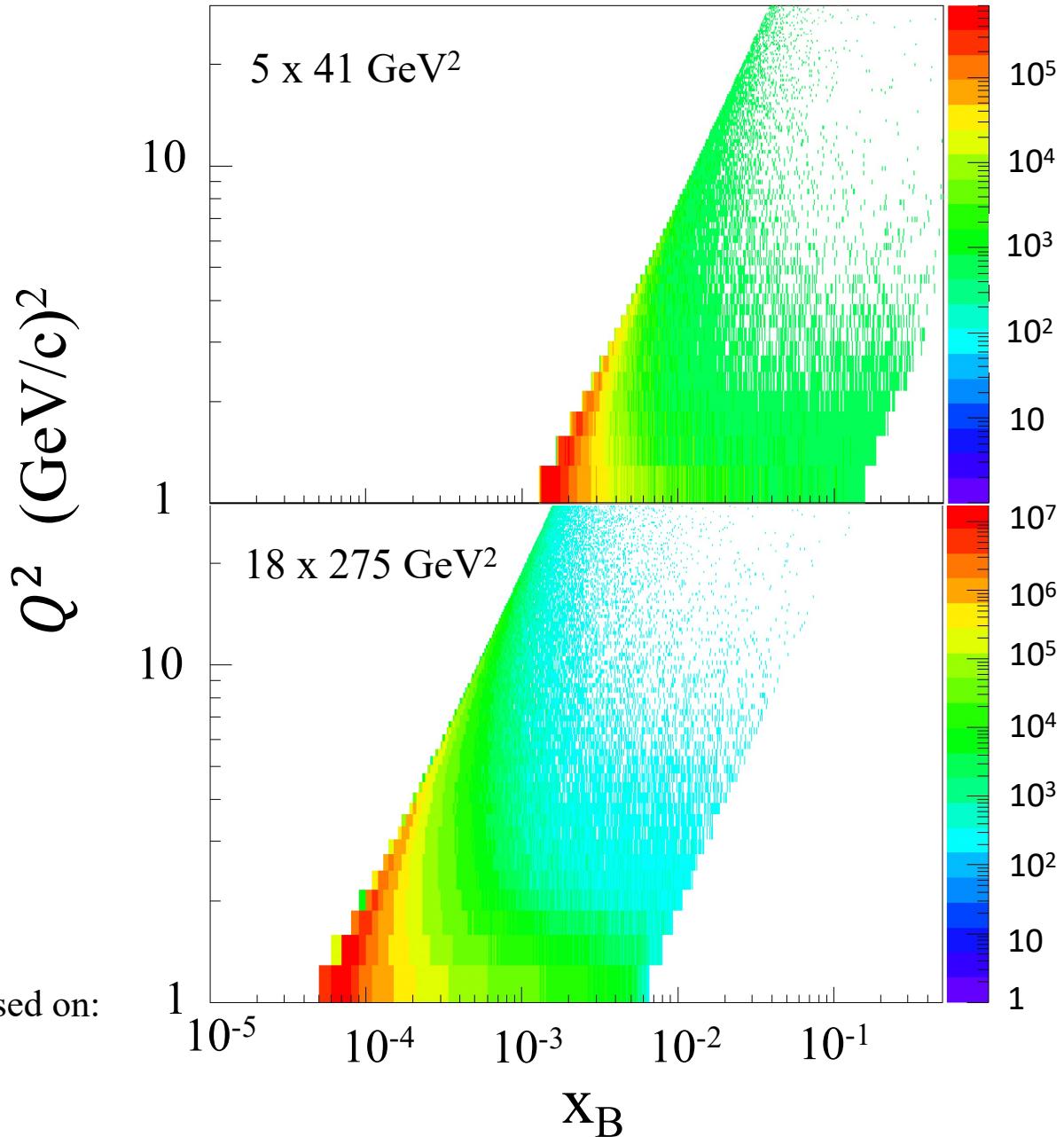


See. A. Jentsch's talk
(Mar 28, 2023, 5:50 PM)

DVCS kinematic Reach @

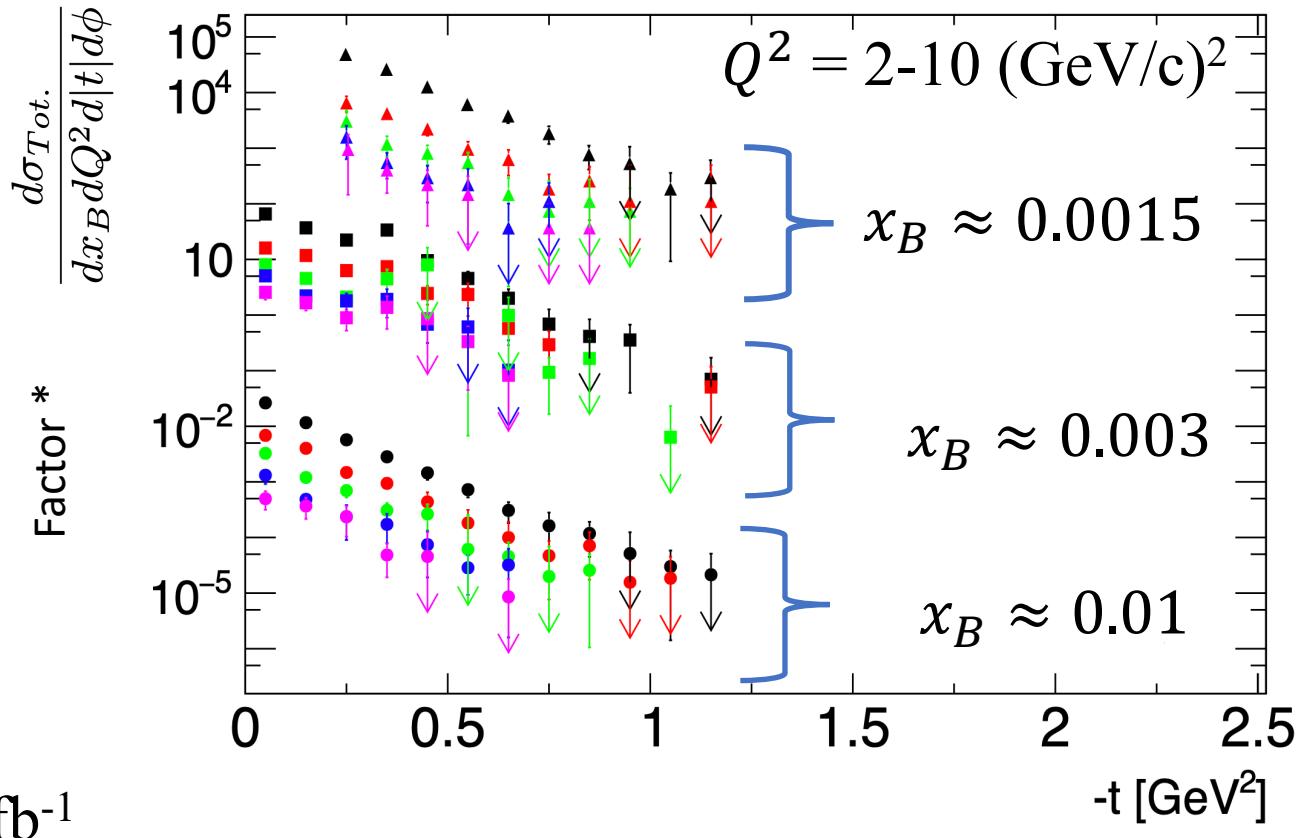


Weighted DVCS Phase Space @



EpIC Generator based on:
[Eur. Phys. J. C
82, 819 \(2022\)](https://doi.org/10.1140/epjc/s10050-022-10200-0)

Projected cross-sections



$\mathcal{L} = 10 \text{ fb}^{-1}$

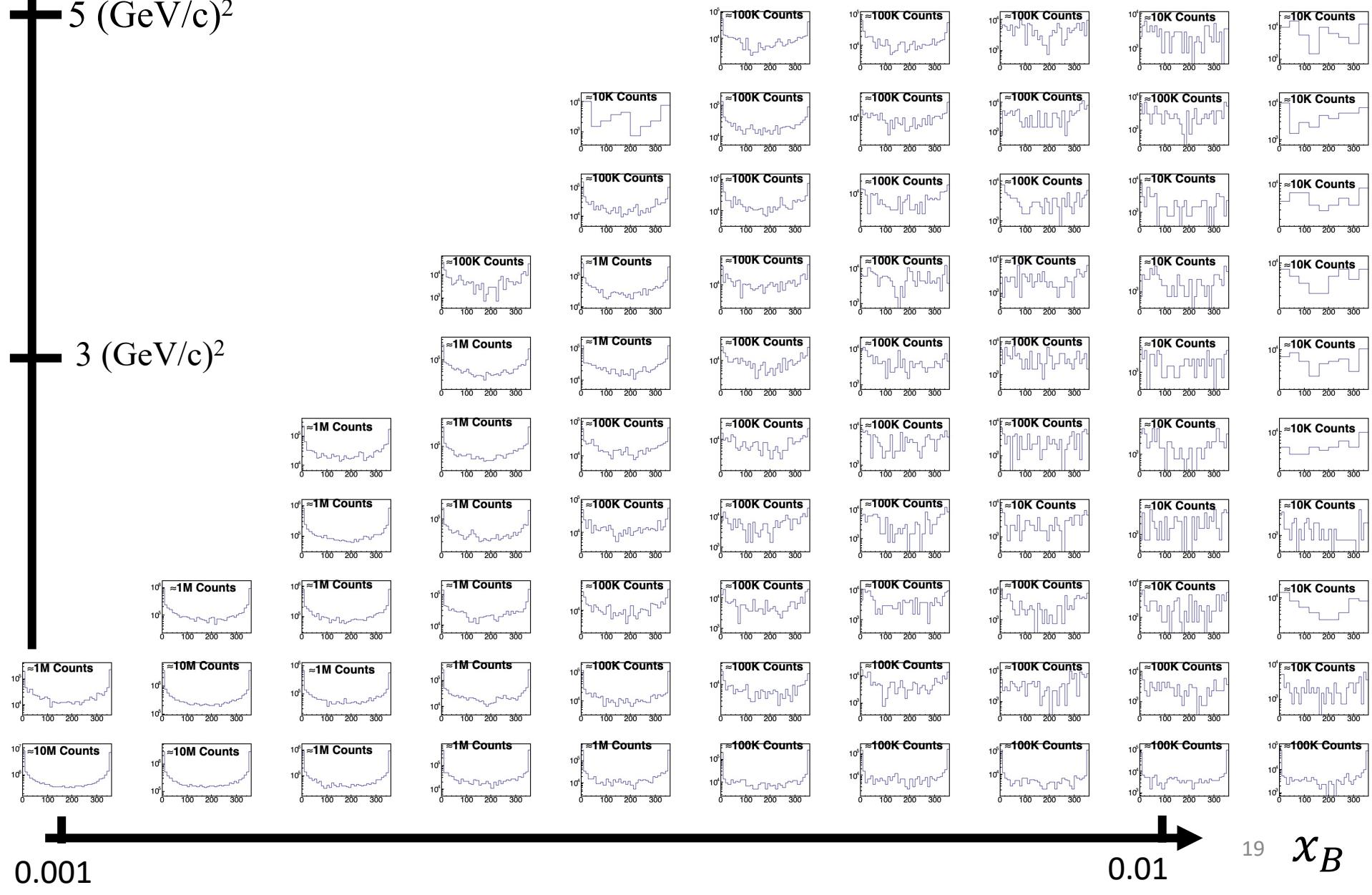
- ECCE Simulation
- ▲ e+p 18+275 GeV
- e+p 10+100 GeV
- e+p 5+41 GeV

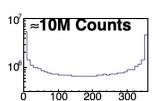
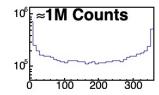
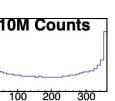
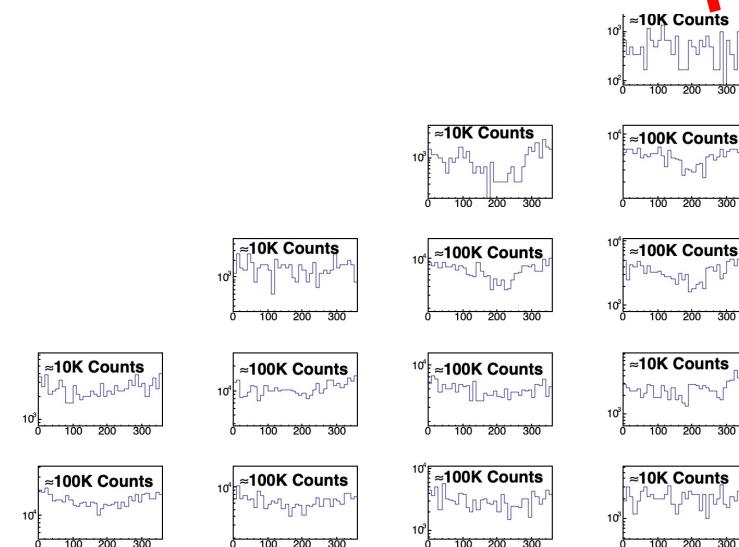
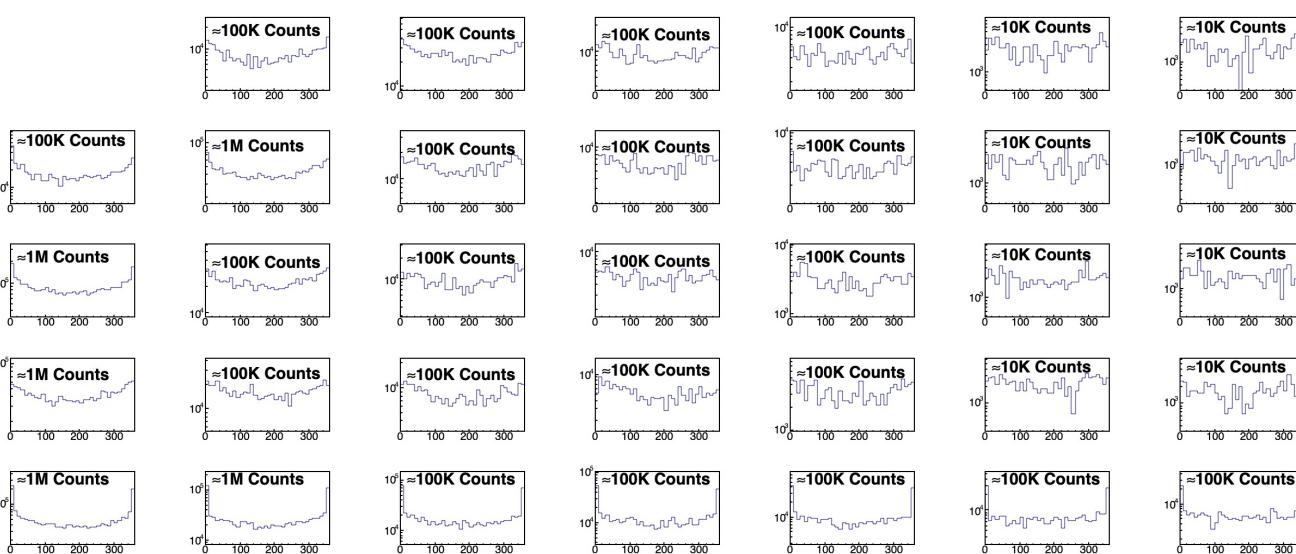
Q^2

5x41 GeV²

The logo for ePIC, featuring the letters "ePIC" in a bold, black, sans-serif font. To the right of the "C" is a circular emblem composed of a blue outer ring and a red inner ring. A thick red arrow points diagonally upwards from the bottom right towards the top left, crossing through the center of the circle.

$$5 \text{ (GeV/c)}^2$$

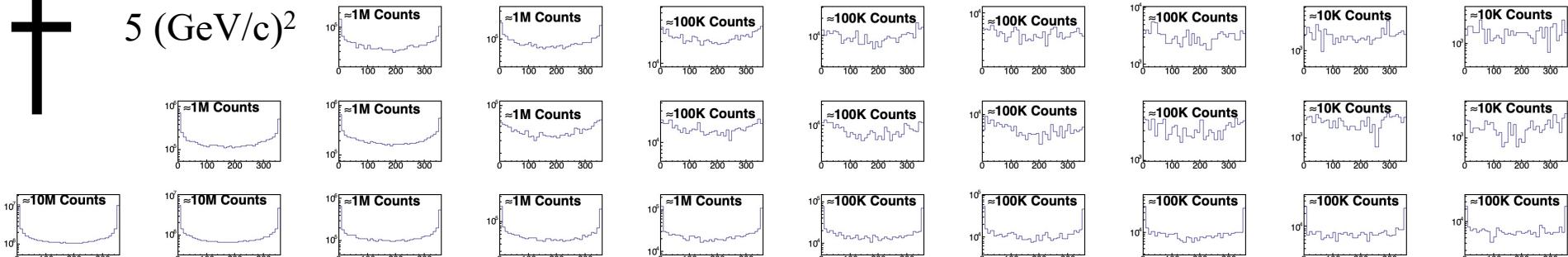


Q^2 $18 \times 275 \text{ GeV}^2$  $20 (\text{GeV}/c)^2$ $10 (\text{GeV}/c)^2$ $5 (\text{GeV}/c)^2$  $1e^{-5}$ $1e^{-4}$ χ_B 20 $1e^{-3}$ 

$18 \times 275 \text{ GeV}^2$ Q^2 $20 (\text{GeV}/c)^2$

Expected: High precision data over wide kinematics range ($\sim 100K$ events)

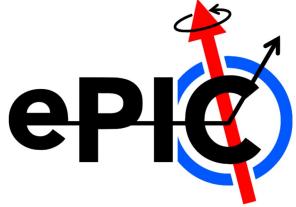
Especially at lowest x-Bjorken region ($\sim 1M$ events)

 $5 (\text{GeV}/c)^2$  $1e^{-5}$ $1e^{-4}$ χ_B

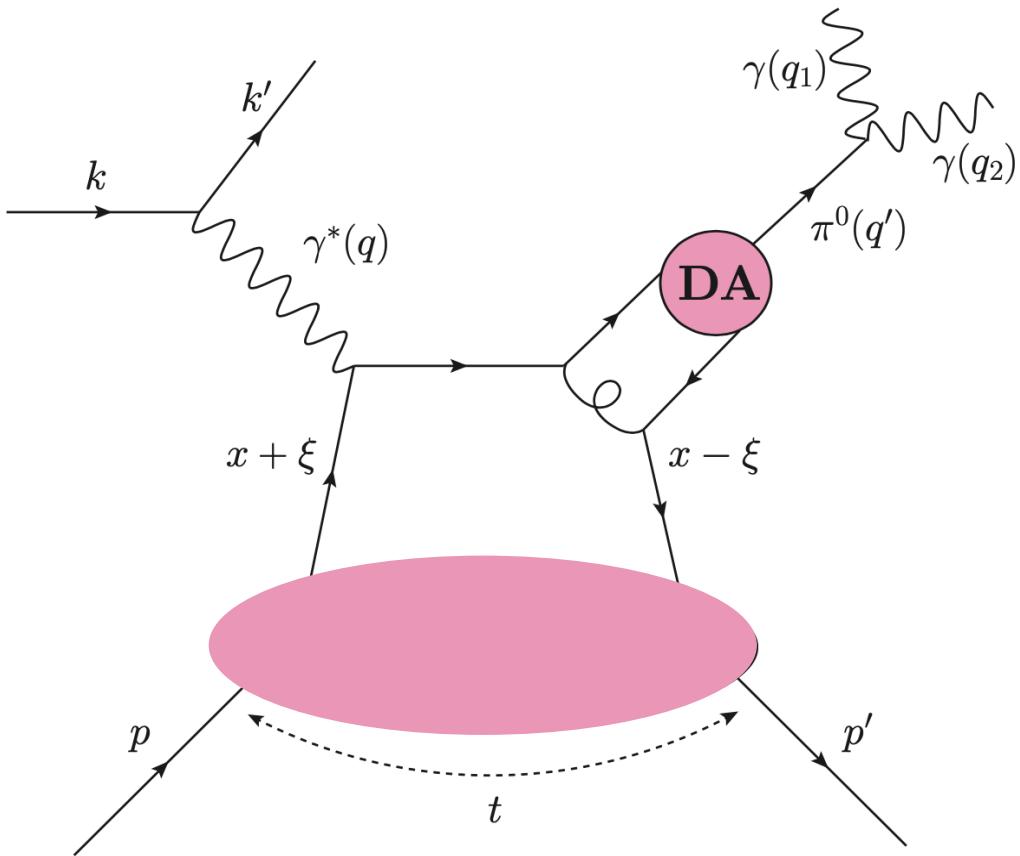
21

 $1e^{-3}$

π^0 Background

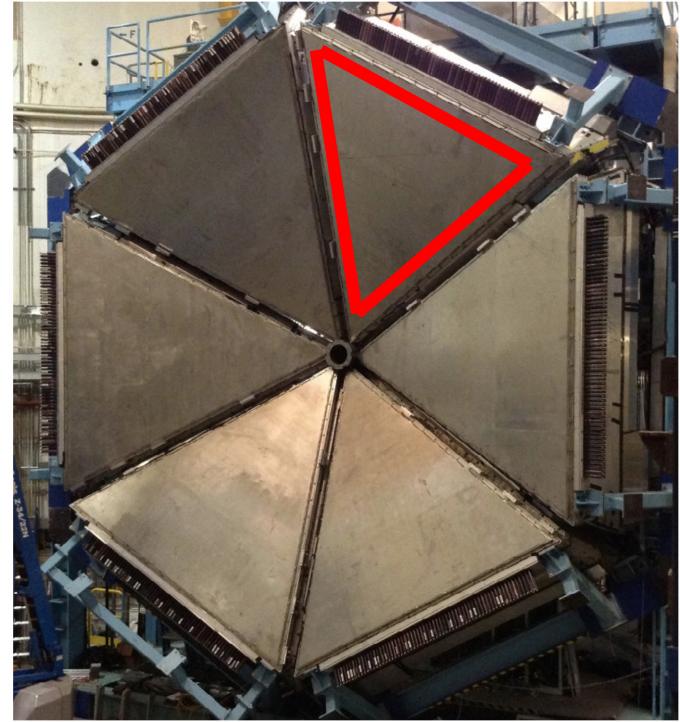
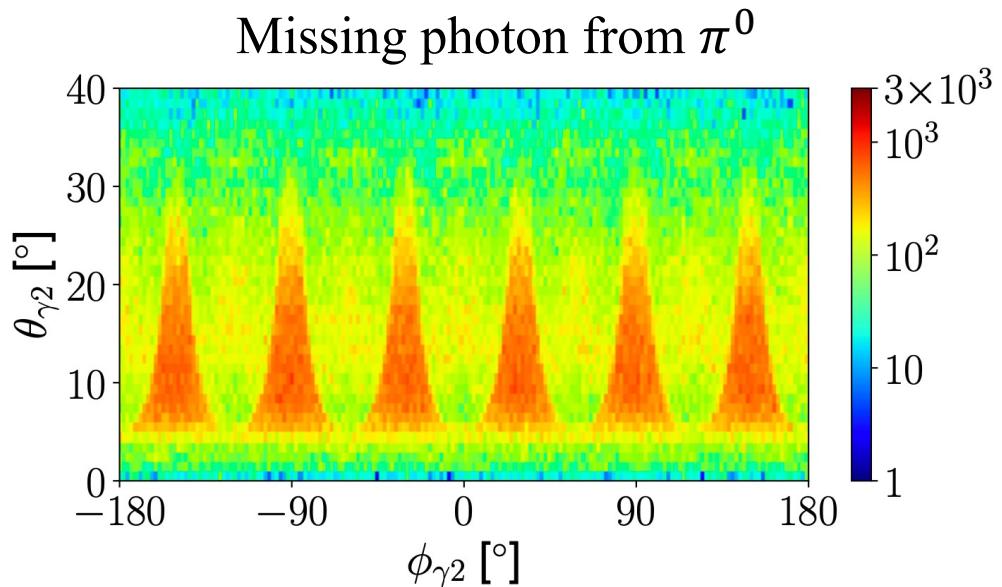


$$e + p \rightarrow e' + p' + \pi^0 (\gamma \cancel{\times})$$



Example from CLAS12

→ Contamination ratio can reach $\sim 30\%$



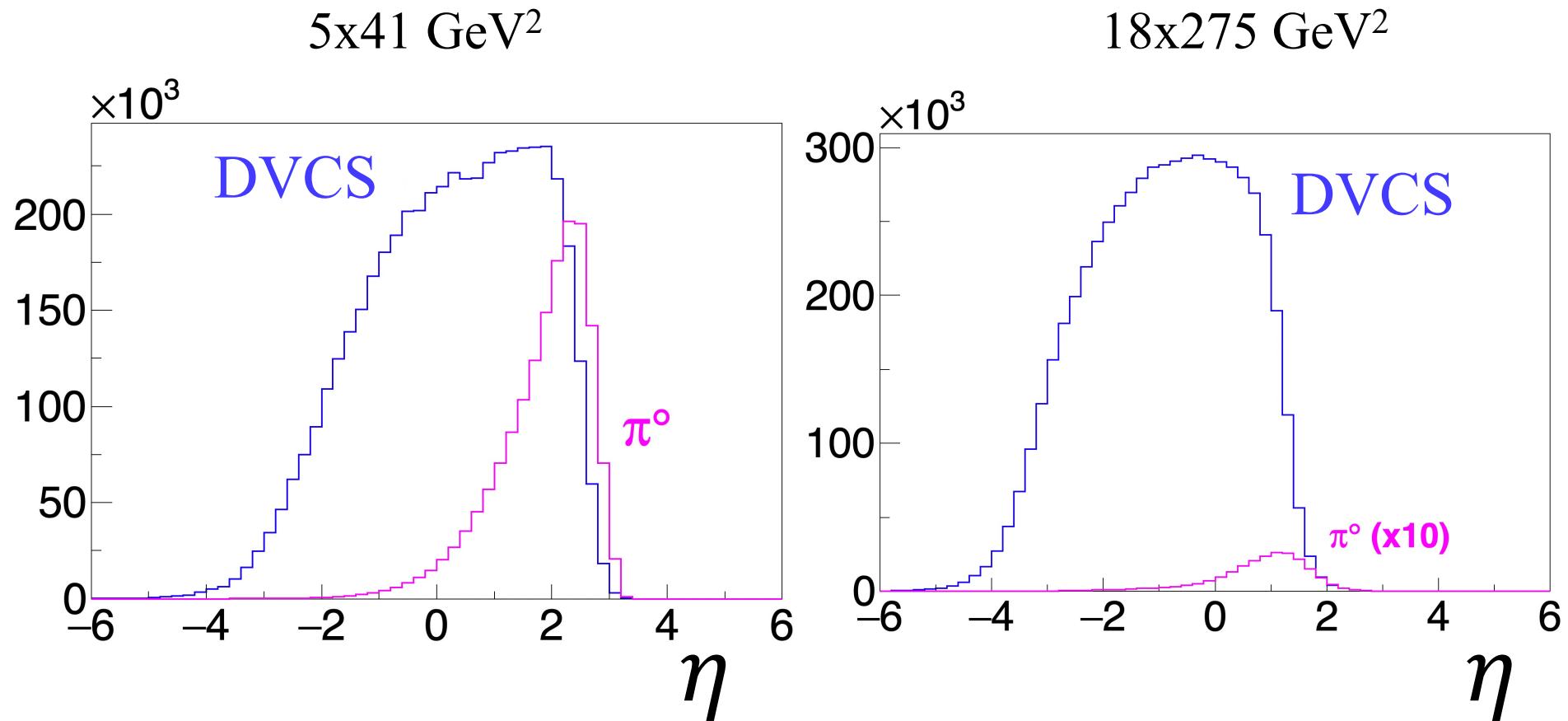
NIMA, 959, 163419 (2020)

From data

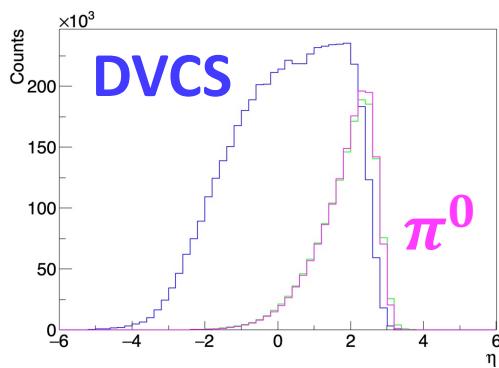
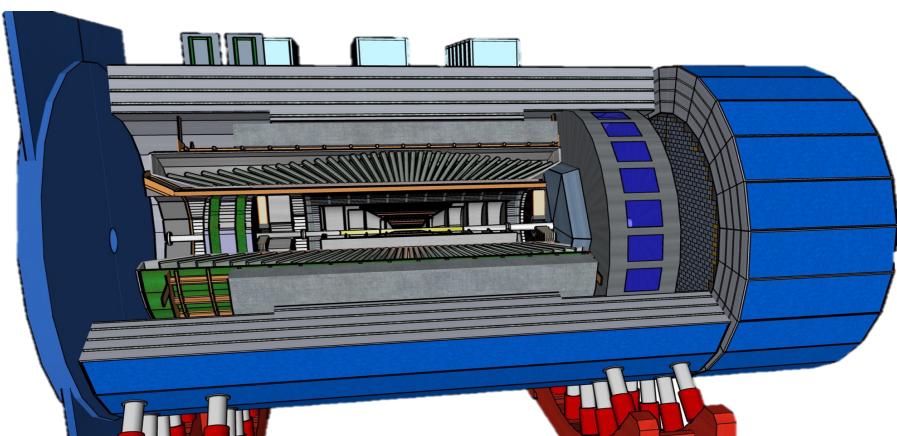
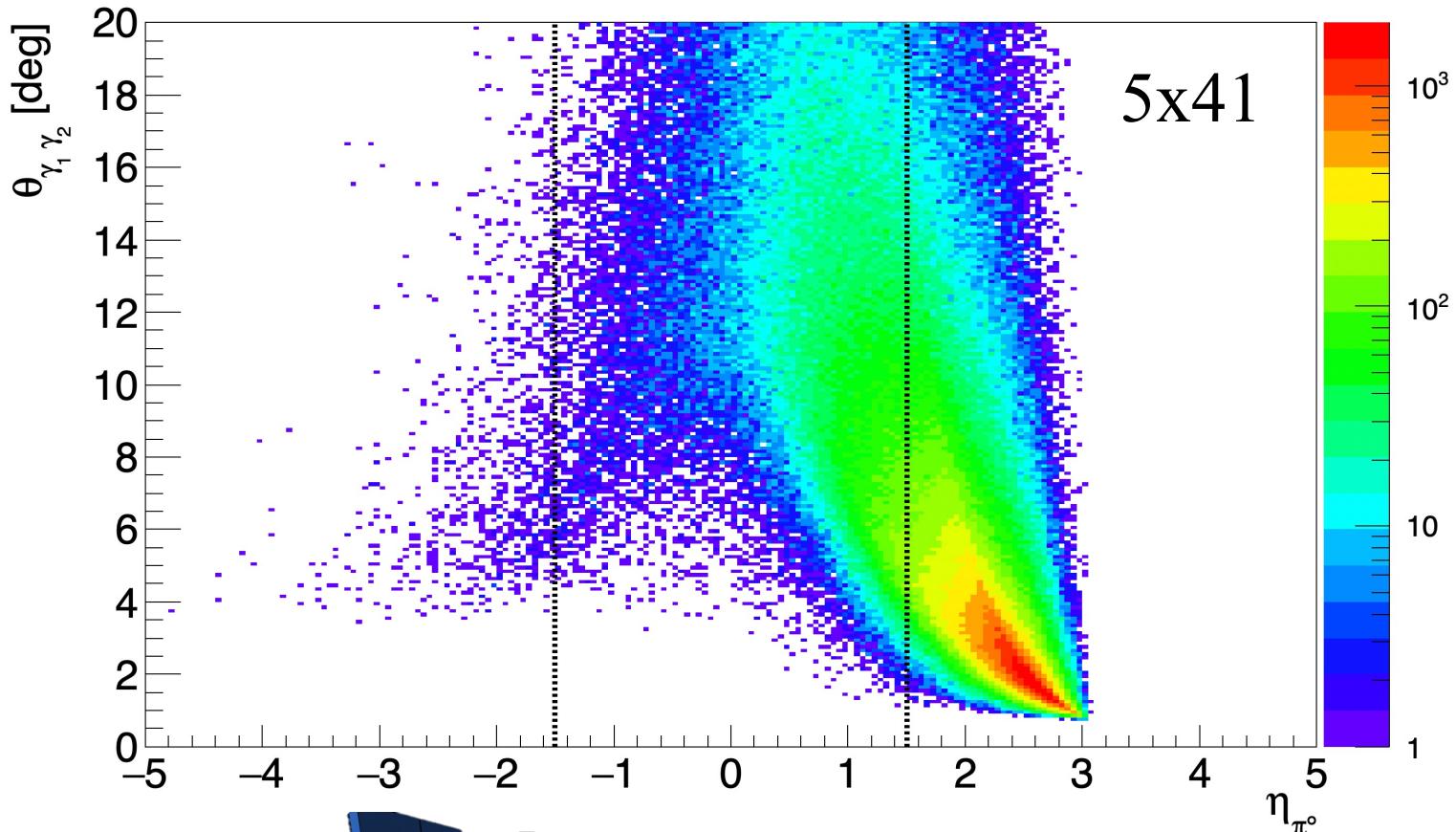
$$N_{ep \rightarrow e' p'(\pi^0 \rightarrow 1\gamma)} = N_{ep \rightarrow e' p'(\pi^0 \rightarrow 2\gamma)} \times \frac{N_{ep \rightarrow e' p'(\pi^0 \rightarrow 1\gamma)}}{N_{ep \rightarrow e' p'(\pi^0 \rightarrow 2\gamma)}}$$

From Simulation

π^0 contamination at EIC kinematics: Significant at low-energy and high pseudo-rapidity

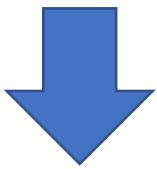


Normalized to $\mathcal{L} = 10 \text{ fb}^{-1}$



Photon detection

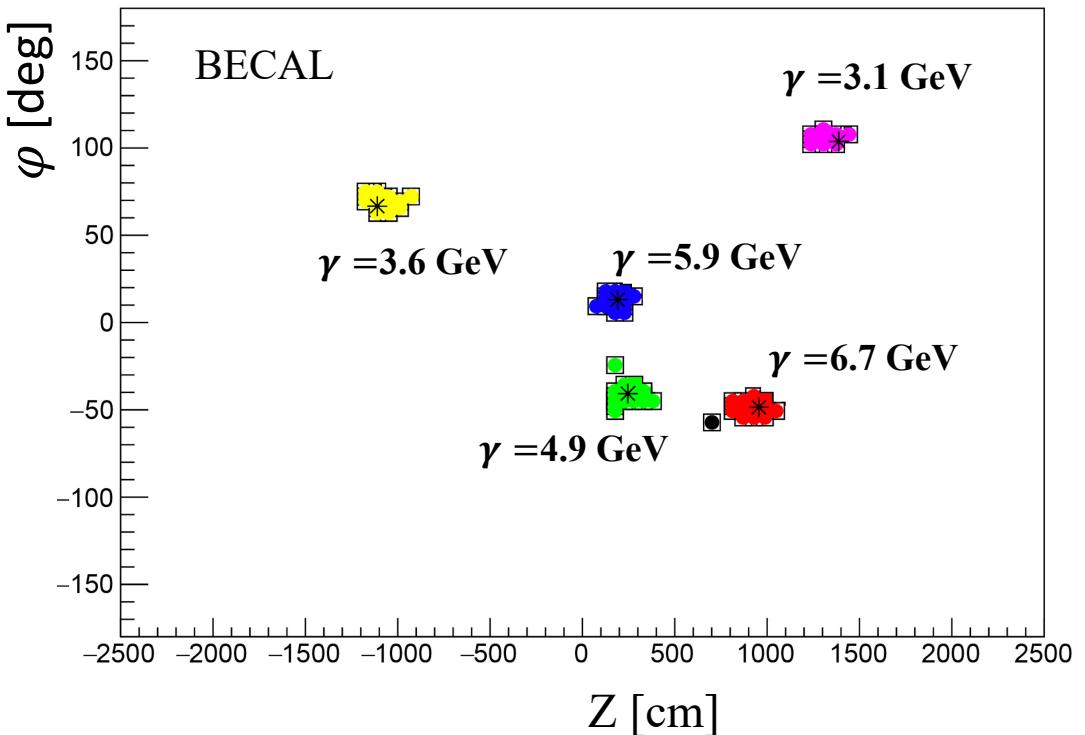
Generate photons



Detector Simulation

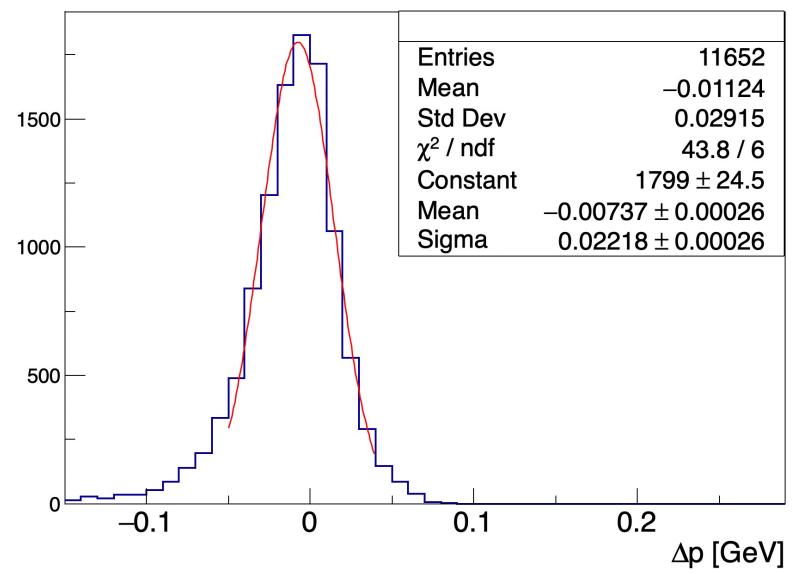
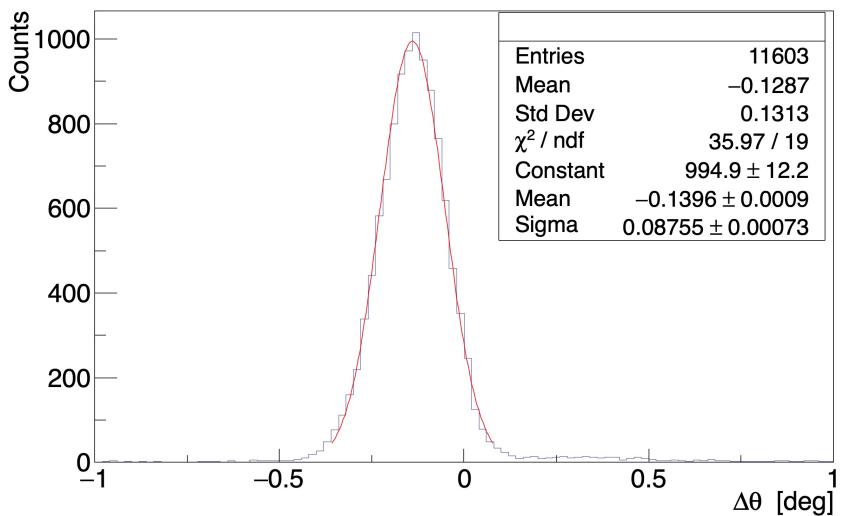
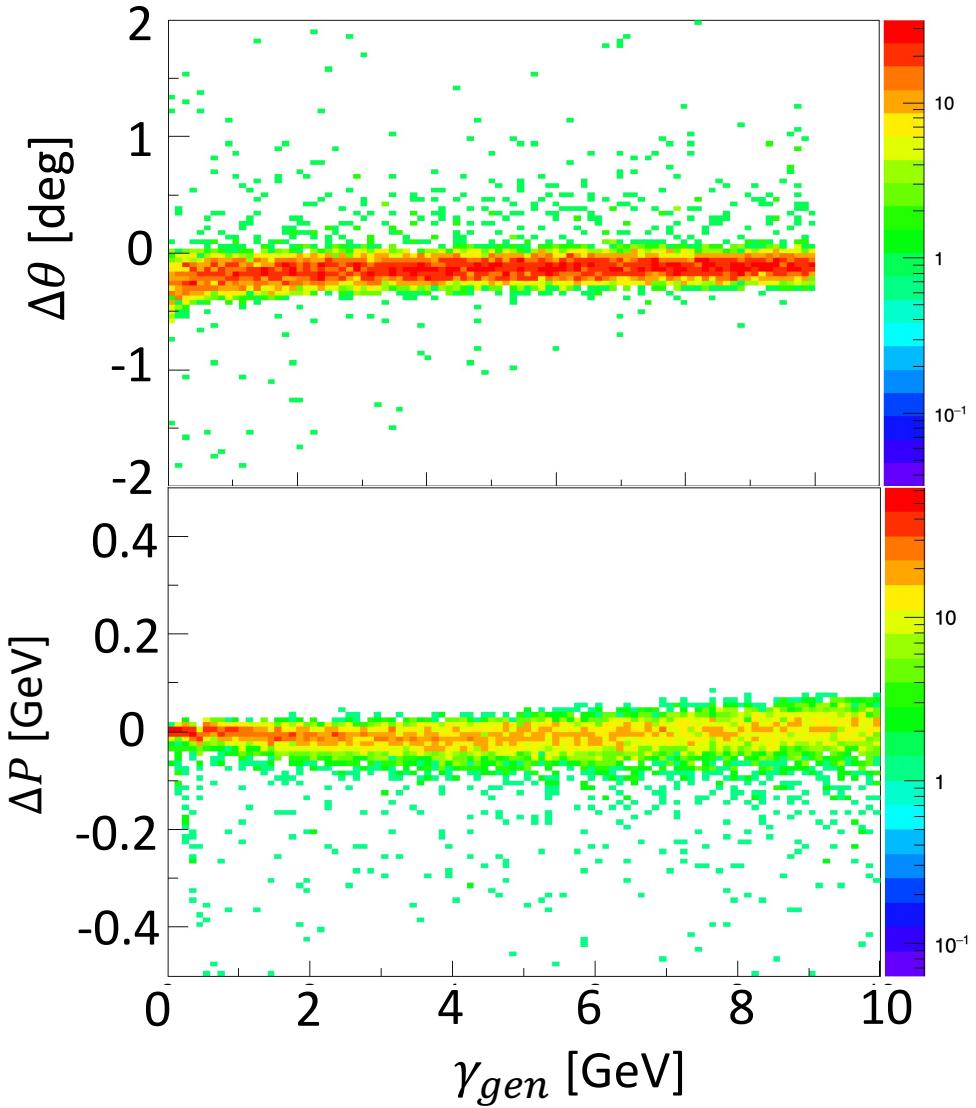


Clustering



- 1) Energy Resolution
- 2) Angular Resolution
- 3) Acceptance

Endcap Angular Resolution: ~ 0.1 [deg]

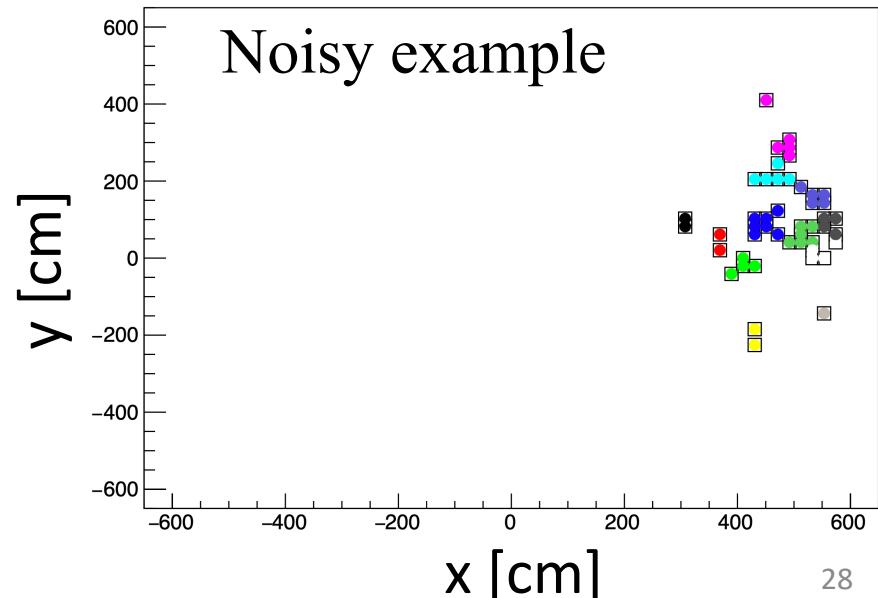
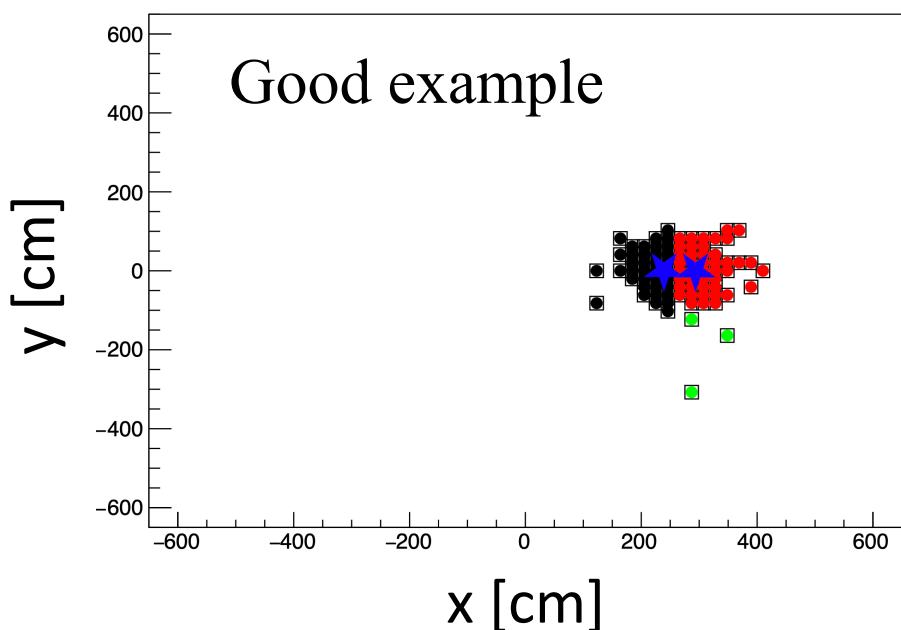
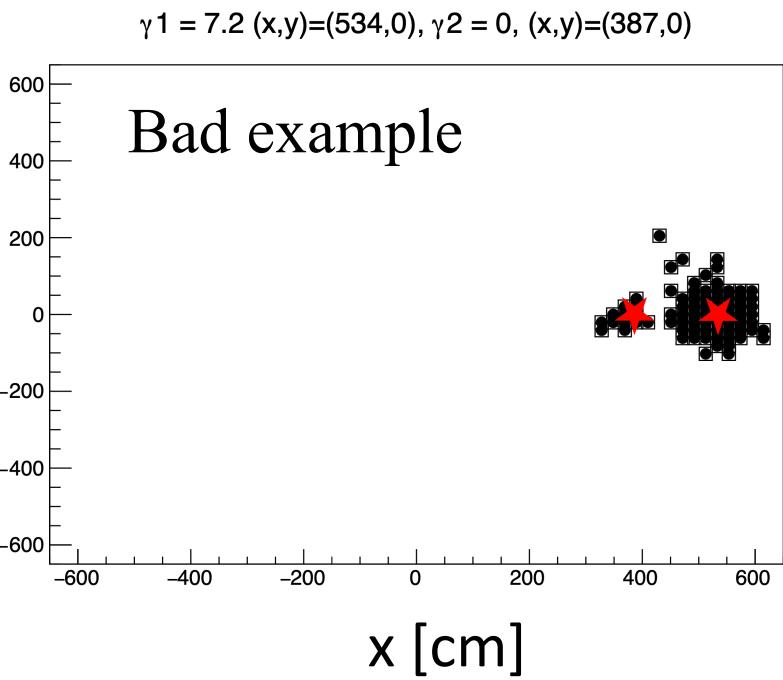


(not including vertex uncertainties etc.)

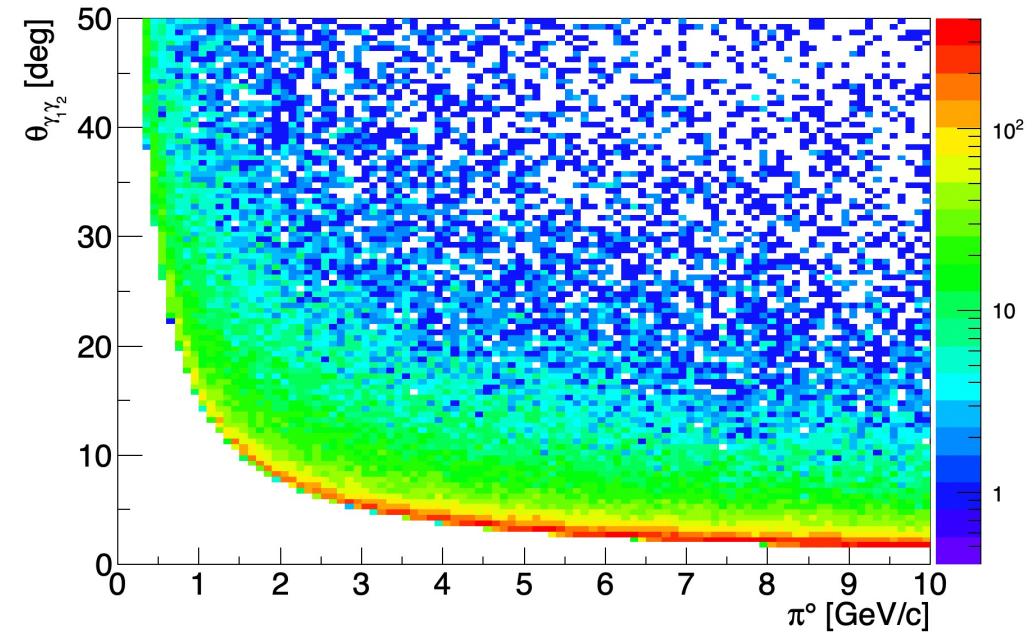
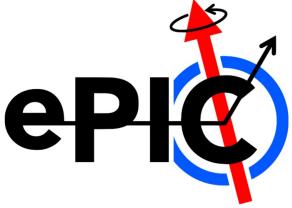


Clustering – pion examples (FEMC)

$\gamma 1 = 4.3$ ($x,y)=(294,0$), $\gamma 2 = 5$, ($x,y)=(240,0$)



Pion reconstruction including detector resolution



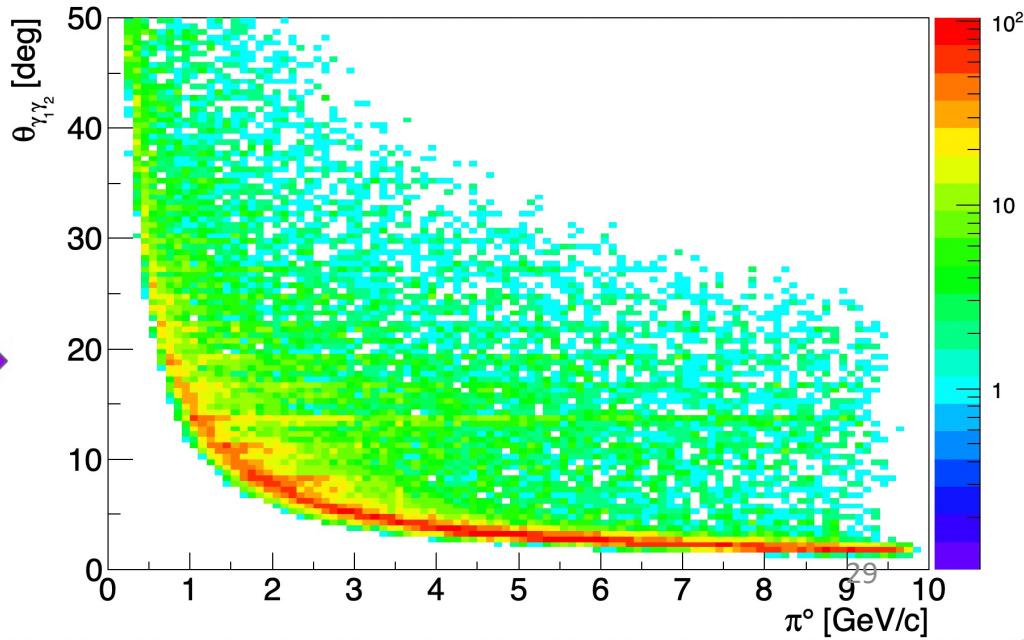
Simulated pions

Generated
events

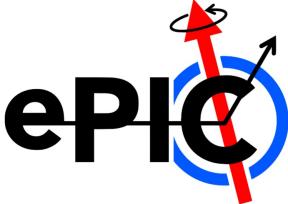
ddsim

podio file
(simulated data)

dd4hep
(geometry)



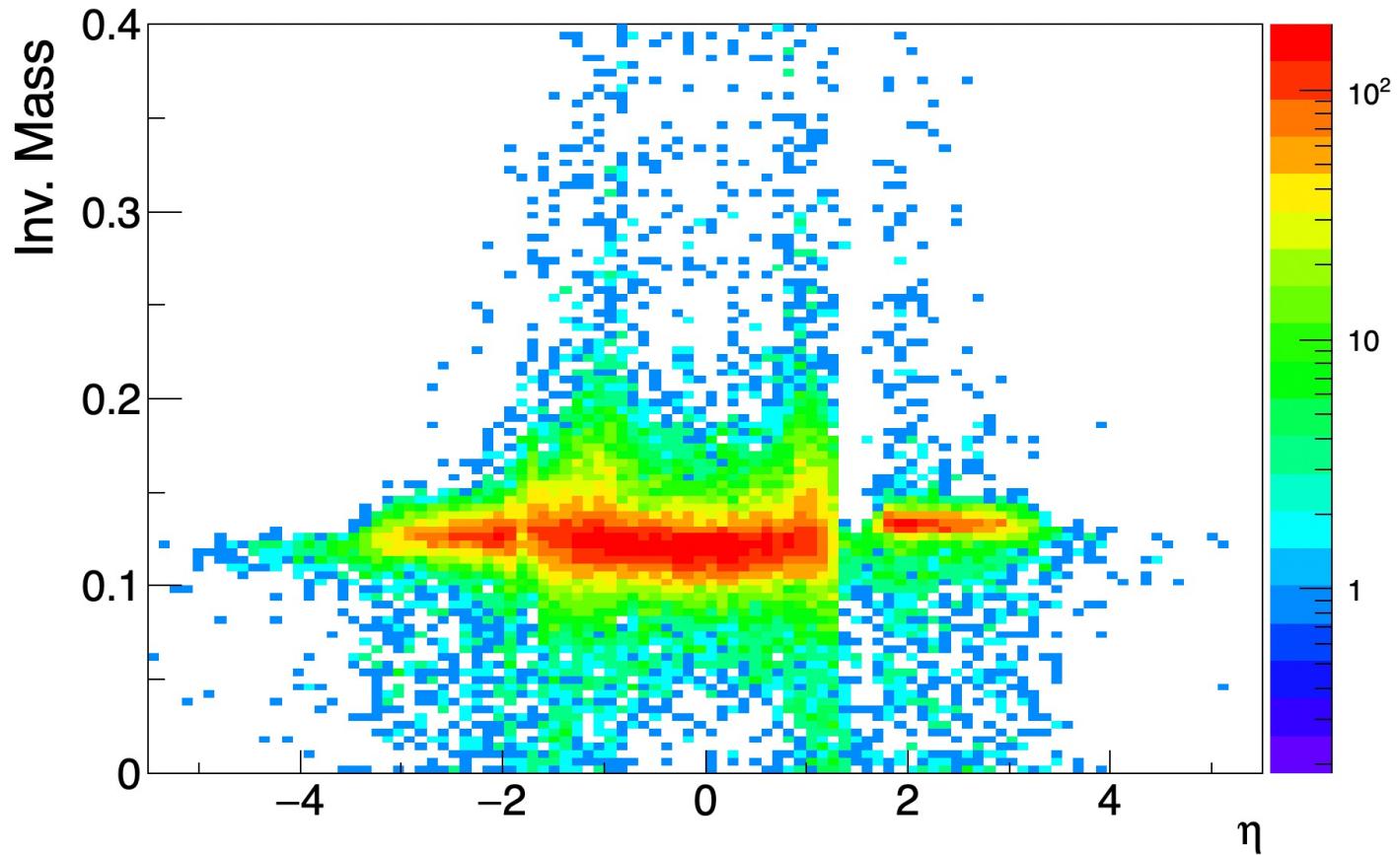
Invariant mass reconstruction



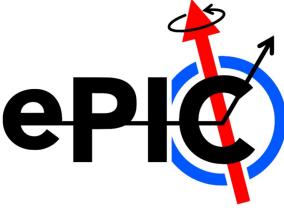
Generated pions: 0.01 – 10 GeV/c

Photon energy – energy deposition in cluster

Photon direction – weighted average of hits in cluster



Summary:



EIC will provide a wide phase space for DVCS study.

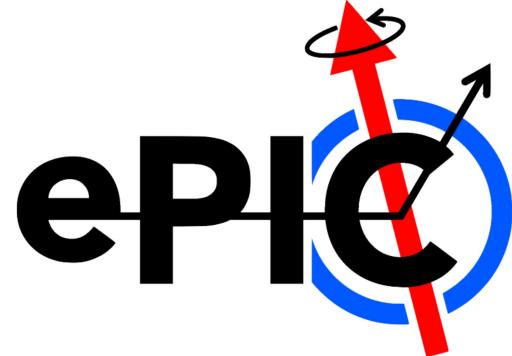
→ Probe low x-Bjorken sector

High precision data is expected over the wide kinematical range.

→ Crucial for multidimensional analysis

High acceptance and efficiency and resolution will enable removal of background.

→ Separate for competing processes



Thank you!