Compton Polarimetry: Effect of Transverse beam smearing in Polarization Measurements at the Electron-Ion Collider

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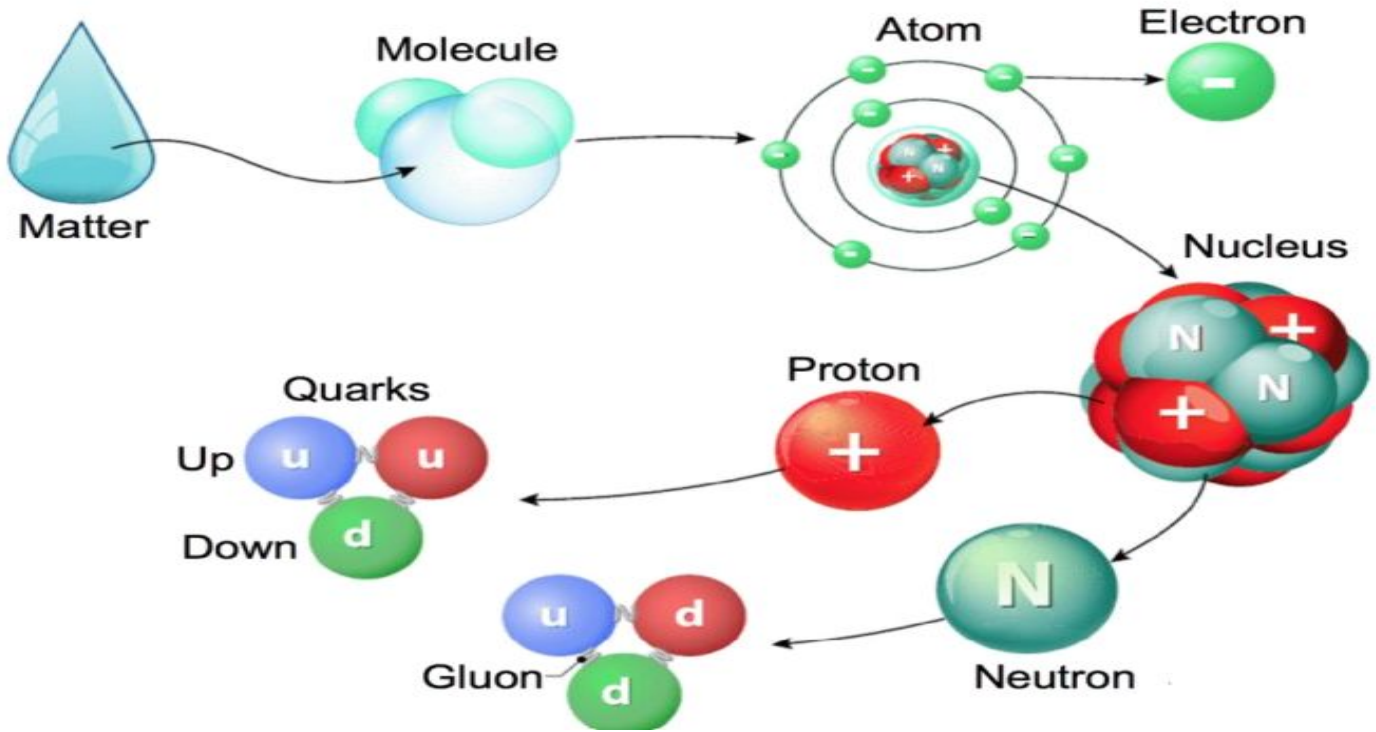


Figure Credit: Shutterstock

How the properties of matter originate from the fundamental constituents of QCD is the central motivation for polarized electron-proton and electron-ion collision at EIC.

- *How do nucleons acquire **mass**?*
- *How does the **spin** arise from its elementary quark and gluon constituents?*
- *What are the emergent* properties of dense systems of gluons?

To address these questions, one needs high energy in order to achieve the needed resolution, which in turn requires colliding a beam of electrons with a counter-moving beam of protons or nuclei in an Electron-Ion Collider (EIC).

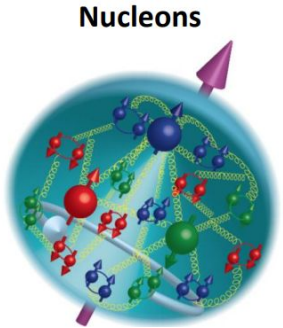


Figure Credit:Z.-E. Meziani.

The Electron-Ion Collider (EIC) would consist of two intersecting accelerators, producing an intense beam of electrons and other beam of either protons or heavier atomic nuclei, which then undergo head-on collisions.

The EIC machine designs are aimed at achieving:

- center-of-mass energies E_{CM} from 20 to 140 GeV
- Highly polarized electron, proton.
- High collision luminosity :10^{33} to 10^{34} cm^{-2} $sec^{-1.}$
- Ion beams from deuteron to the heaviest nuclei (uranium or lead)
- Possibilities of having more than one interaction region
- **First beam by 2029!**

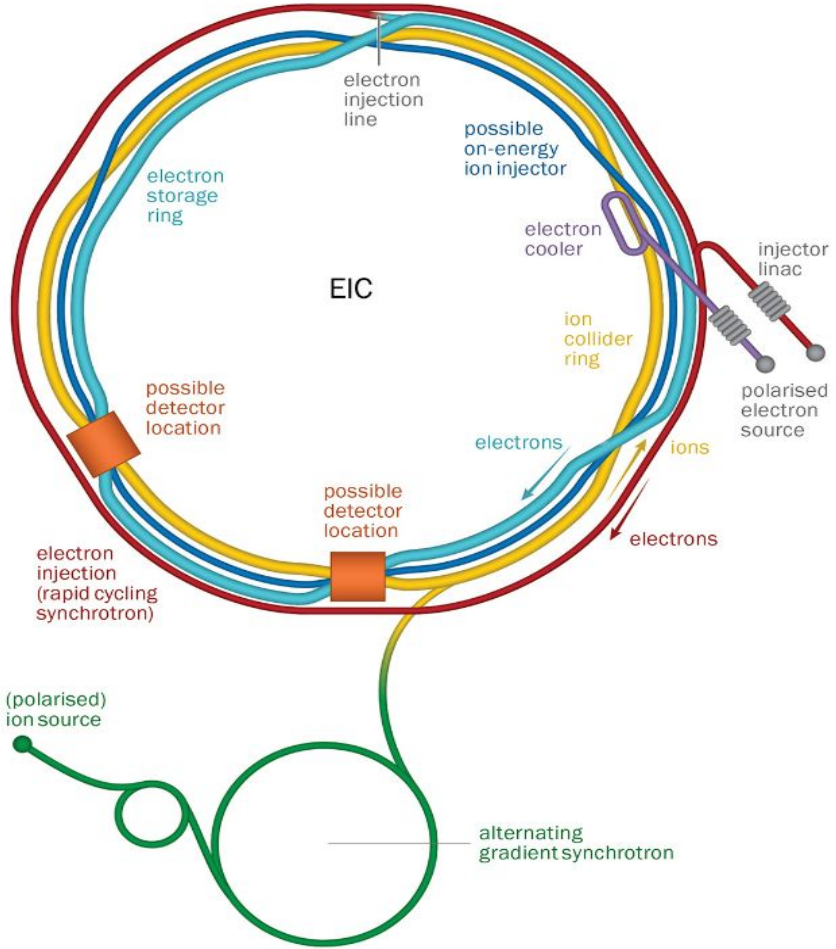


Figure credit: BNL

Compton Polarimetry -can used to measure both longitudinal and transverse electron beam polarization.

-Longitudinal polarization measured via counting asymmetry vs. energy.

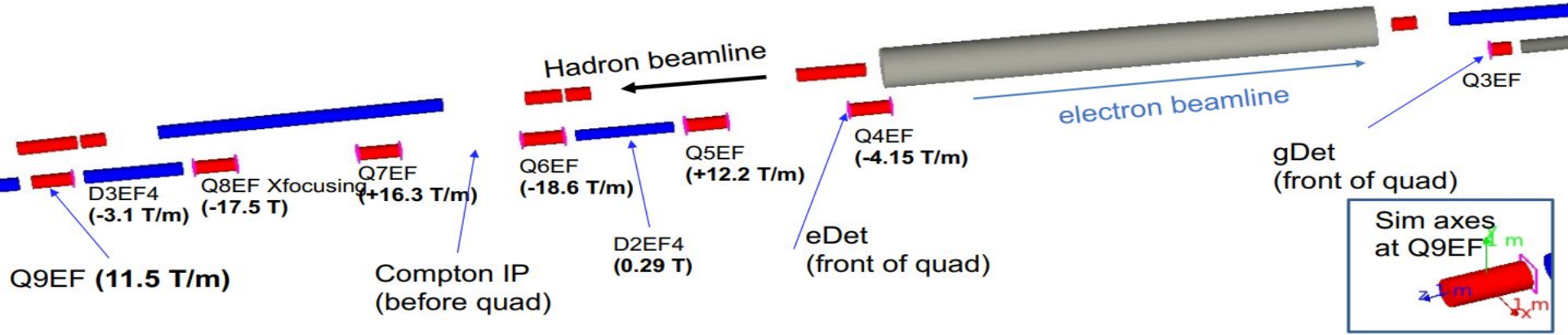
-Transverse polarization typically measured via spatial dependence (up-down) of asymmetry.

$$A_{EXP} \equiv \frac{N^+ - N^-}{N^+ + N^-} = \boldsymbol{P_e} * P_\gamma * A_{QED}(E_e, k_\gamma, k_{\gamma'})$$

Measured asymmetry

Polarization of the photons (measurable)

Asymmetry computed using QED

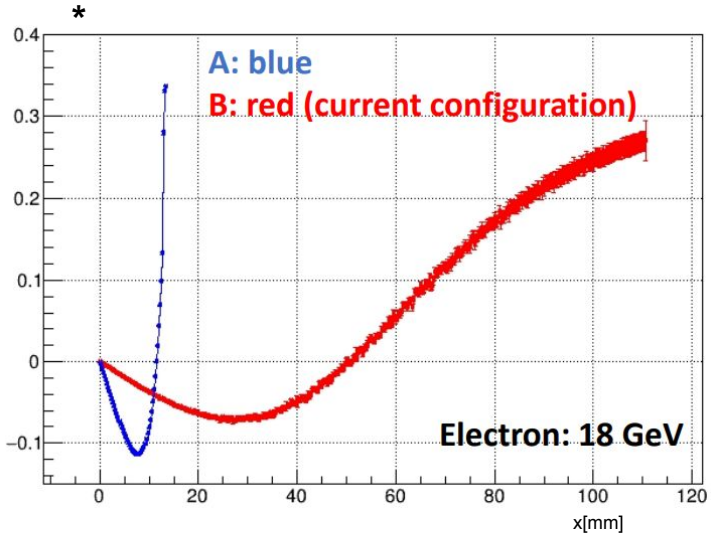


IP Location : middle of quad Q9EF

- Q8EF is Focusing in X. It worked against the spread that dipole D3EF4 produces.
- This gives a squeezed distribution for scattered electron signal.

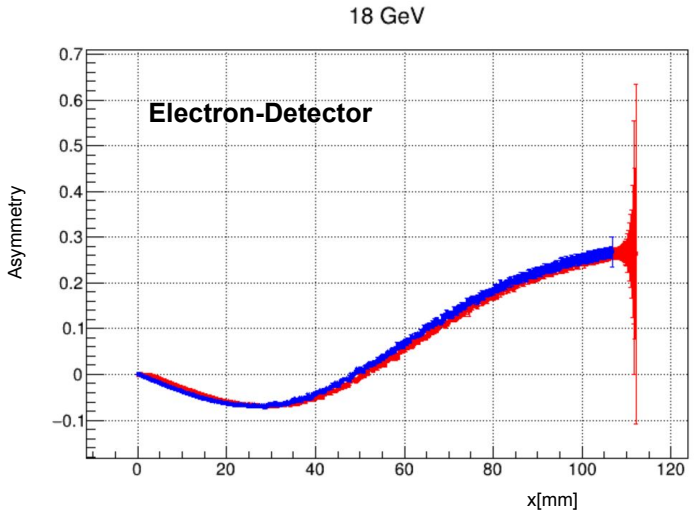
IP Location : before quad Q6EF

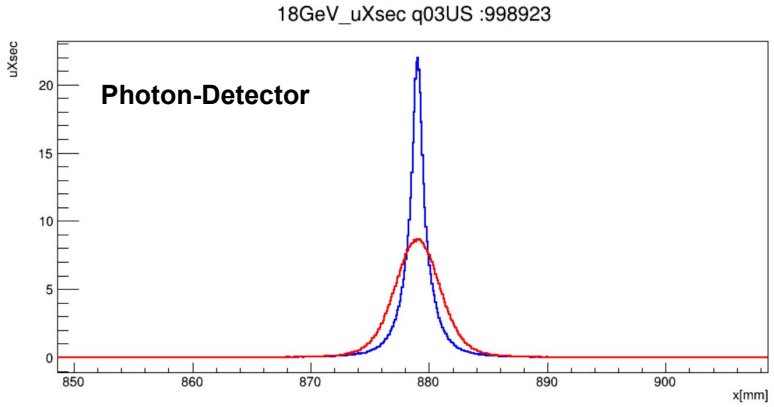
- Q5EF is horizontally defocusing.
- This gives a broaden spread in distribution for scattered electron signal which is similar to compton spectrum.



*Dr.Ciprian Gal

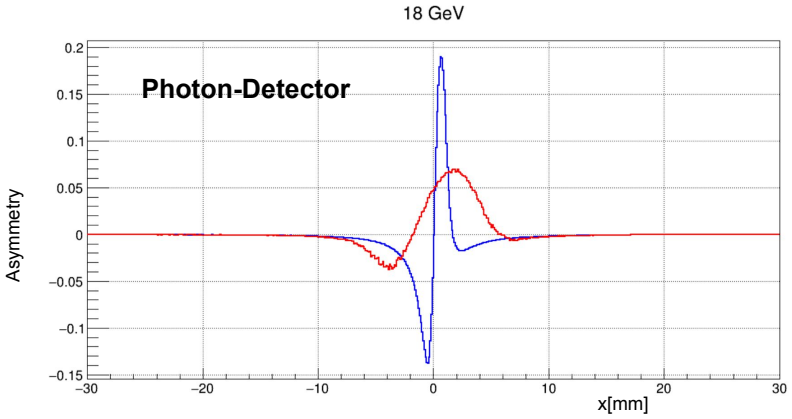
Transverse Beam Smearing





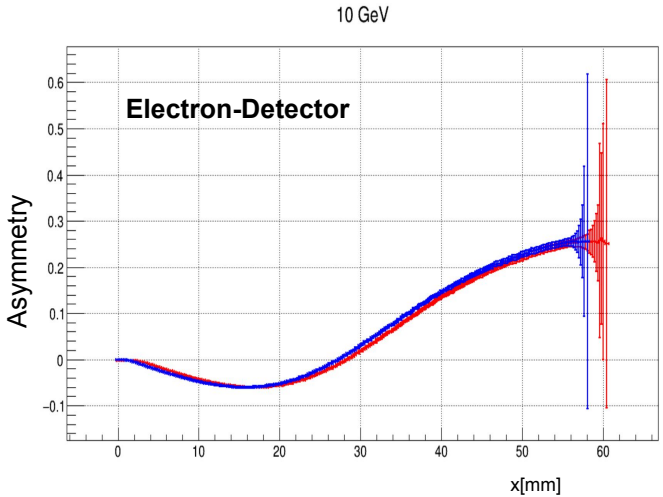
The distribution at the photon detector sees some significant broadening

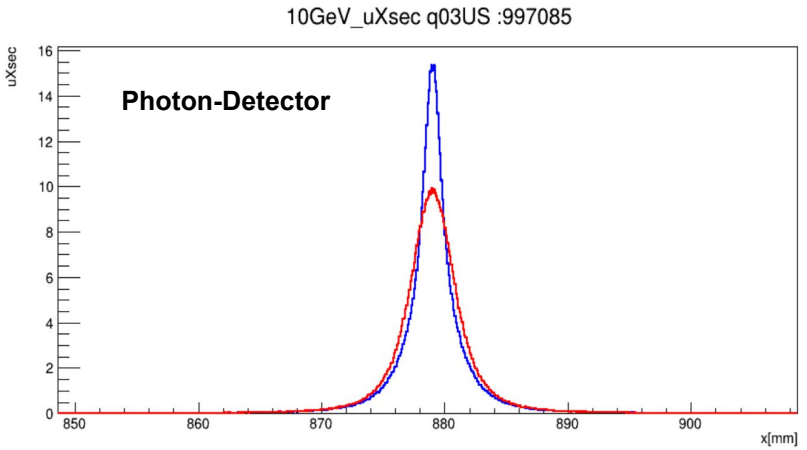
The positional distribution at the electron detector and the asymmetry see a very small effect due to the smearing as expected

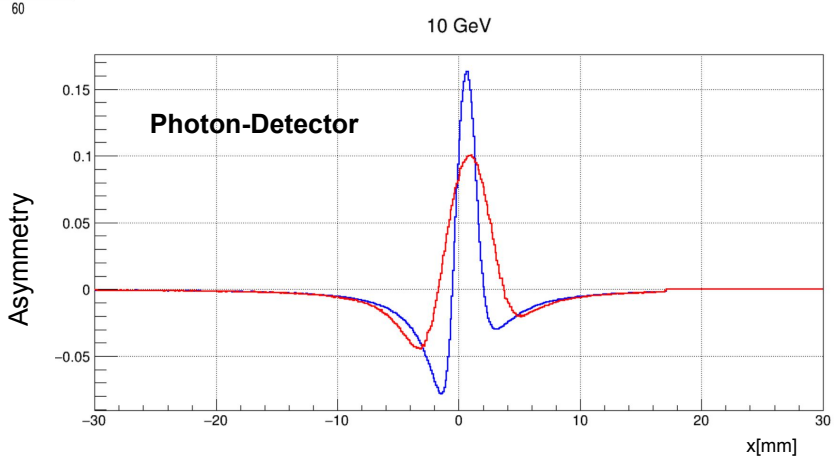


The transverse asymmetry sees a suppression making the measurement more challenging that it already was

10 GeV

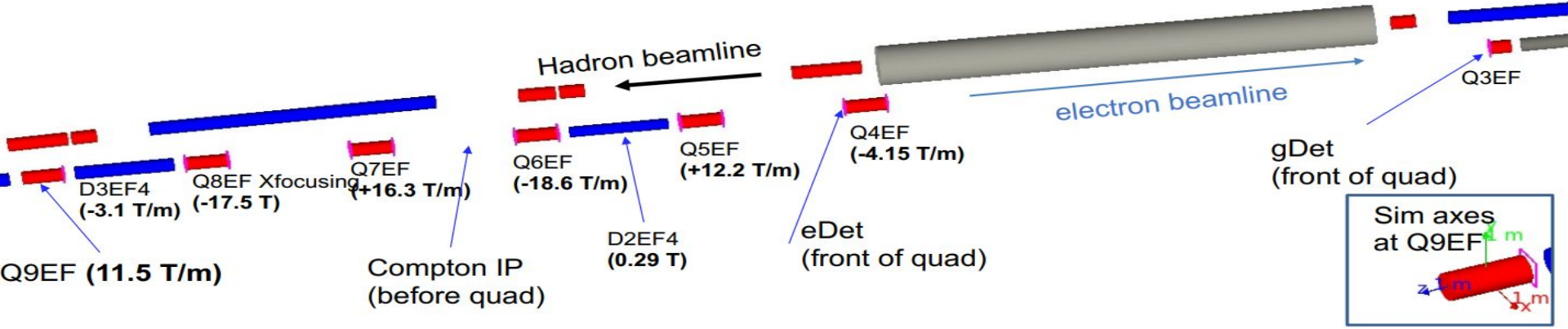

10 GeV
Electron-Detector
Asymmetry
x[mm]


No Smearing
Smearing
10GeV_uXsec q03US :997085
Photon-Detector
uXsec
x[mm]


10 GeV
Photon-Detector
Asymmetry
x[mm]

Beam Parameters used:

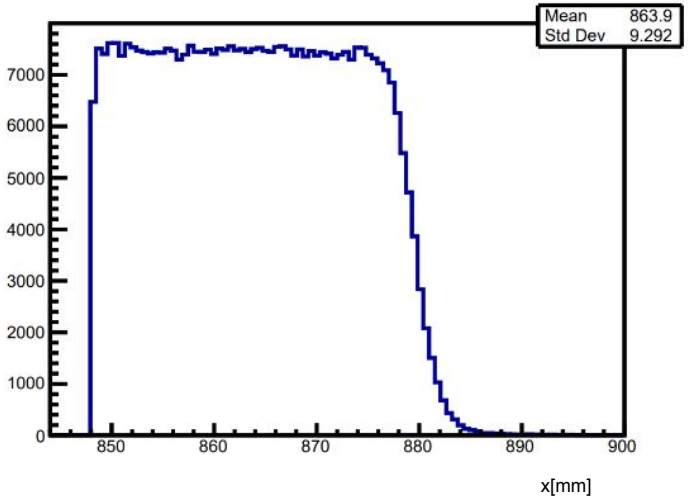
Energy	18 GeV	10 GeV
beta_x	**10.1229**	**17.8739**
beta_y	**4.9255**	**1.3152**
alpha_x	**-2.1912**	**-4.3747**
alpha_y	**1.5356**	**0.3008**
For high divergence configuration:		
Emit_x	**24 nm**	**20 nm**
Emit_y	**2.0 nm**	**1.3nm**



Synchrotron Radiation: Photon Detector

There are two sources of Synchrotron Radiation

- the scattered Compton electron
- the beam electrons



Conclusion:

- The transverse beam smearing seems to have a significant effect on our ability to extract the transverse component of the polarization.

- We can see the Synchrotron Radiation from the Compton electrons is a small fraction of the photons reaching the photon detector plane.

Thank You

Back up

$$A_{\text{long}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}(1-\rho(1+a))\left[1-\frac{1}{(1-\rho(1-a))^2}\right]$$

$$A_{\text{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}\cos\phi\left[\rho(1-a)\frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))}\right]$$

Reference:

- Bardin, G., et al. "**Conceptual design report of a Compton polarimeter for CEBAF Hall A**." (1996).
- Willeke, Ferdinand, and J. Beebe-Wang. ***Electron Ion Collider Conceptual Design Report 2021***. No. BNL-221006-2021-FORE. Brookhaven National Lab.(BNL), Upton, NY (United States); Thomas Jefferson National Accelerator Facility (TJNAF), Newport News, VA (United States), 2021.
- Accardi, A., et al. "**Electron-Ion Collider: The next QCD frontier: Understanding the glue that binds us all.**" *The European Physical Journal A* 52 (2016): 1-100.