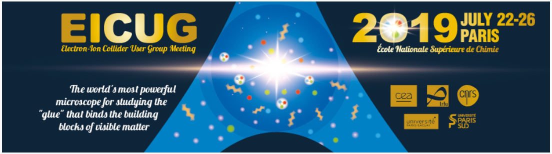

Double Deeply Virtual Compton Scattering (DDVCS) at Electron-Ion Collider

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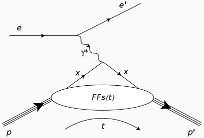
Generalized Parton Distributions (GPDs)

elastic scattering $ep \to ep$

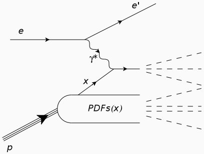


R. Hofstadter, Nobel Prize 1961

Form Factors (FFs)

$\to$ transverse position space.

DIS $ep \to eX$

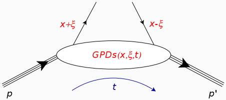


Friedman, Kendall, Taylor, Nobel Prize 1990

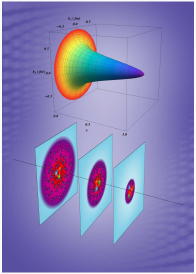
Parton Distribution Functions (PDFs)

$\to$ longitudinal momentum.

exclusive inelastic scattering

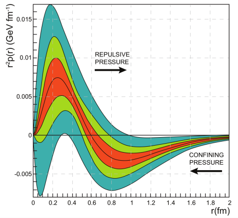


GPDs: $H^q, E^q, \widetilde{H}^q, \widetilde{E}^q(x, \xi, t)$ describe the non-perturbative quark (gluon) structure of the nucleon.



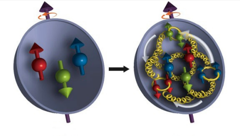
Dupré, Guidal, Niccolai, Vanderhaeghen 2017

$\to$ nucleon tomography from the correlation between transverse position and longitudinal momentum



Burkert, Elouadrhiri, Girod 2018

$\to$ internal pressure distribution



Ji 1997

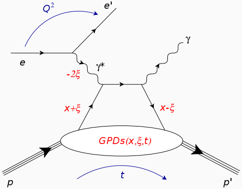
$\to$ quark angular momentum

$\int dx x\, [H^q(x, \xi, 0) + E^q(x, \xi, 0)]$

GPDs Measurements

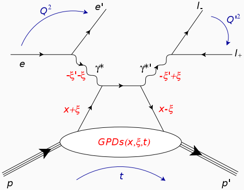
DVCS and DDVCS [1-4] are two golden processes for direct measurements of GPDs

$ep \to ep\gamma$



Deeply Virtual Compton Scattering (DVCS)

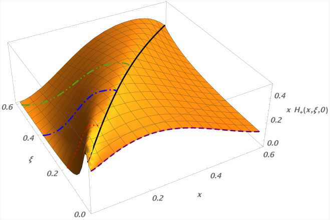
$ep \to epl^- l^+$



Double DVCS (DDVCS)

$$\mathcal{H}(\xi,\xi,t) = \sum_q e_q^2 \Big\{ \mathcal{P}\int_{-1}^{1} dx\, H^q(x,\xi,t) \left[\frac{1}{x-\xi} + \frac{1}{x+\xi}\right] - i\pi \left[H^q(\xi,\xi,t) - H^q(-\xi,\xi,t)\right] \Big\}$$

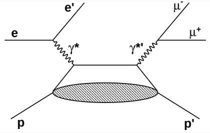
$$\mathcal{H}(\xi',\xi,t) = \sum_q e_q^2 \Big\{ \mathcal{P}\int_{-1}^{1} dx\, H^q(x,\xi,t) \left[\frac{1}{x-\xi'} + \frac{1}{x+\xi'}\right] - i\pi \left[H^q(\xi',\xi,t) - H^q(-\xi',\xi,t)\right] \Big\}$$

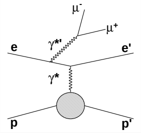


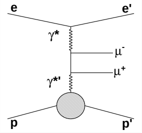
- DVCS can access GPDs only at $x = \pm\xi$;
- DDVCS allows one to measure the GPDs for each x, ξ, t values independently ($|\xi'| < \xi$).

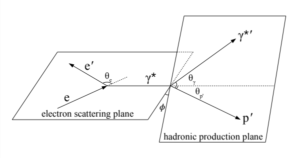
[1] M. Guidal and M. Vanderhaeghen, Phys. Rev. Lett. **90** 012001 (2003).
[2] A. V. Belitsky and D. Müller, Phys. Rev. Lett. **90** 022001 (2003).
[3] I. V. Anikin, *et al.*, Acta Phys. Pol. B **49** 741 (2018).
[4] S. Zhao, arXiv:1904.09335.

$ep \to ep\mu^-\mu^+$ (avoid antisymmetrization)









$$\sigma \propto \mathcal{T}^2 = |\mathcal{T}_{\text{ddvcs}}|^2 + |\mathcal{T}_{\text{BH}_1} + \mathcal{T}_{\text{BH}_2}|^2 + \mathcal{I} \text{ (linear in Compton form factors)}$$

polarized electron, unpolarized proton

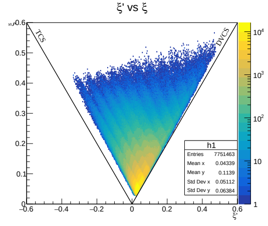
$$\Delta\sigma_{\text{LU}} \sim \Im\text{m}\left\{F_1\mathcal{H} + \xi'(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}\right\}\sin\phi$$

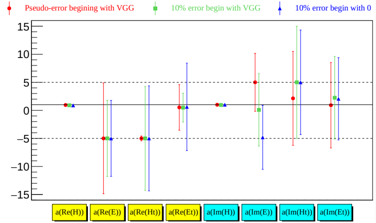
electron and positron, unpolarized proton

$$\Delta\sigma_{\text{C}} \sim \Re\text{e}\left\{F_1\mathcal{H} + \xi'(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}\right\}\cos\phi$$

Ongoing feasibility study of DDVCS at JLab12:

- events generation
- pseudo-data analysis
- CFF extraction





DDVCS Observables II

EIC provides the opportunity for measuring the observables of polarized proton.

unpolarized electron, longitudinally polarized proton

$$\Delta\sigma_{\mathrm{UL}} \sim \Im\mathrm{m}\left\{F_1\widetilde{\mathcal{H}} + \xi'(F_1 + F_2)(\mathcal{H} + \frac{\xi}{1+\xi}\mathcal{E}) + \cdots\right\}\sin\phi$$

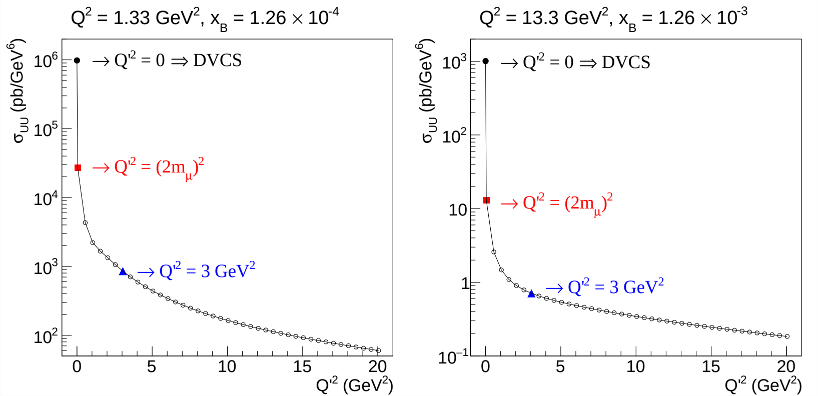
unpolarized electron, transversely polarized proton

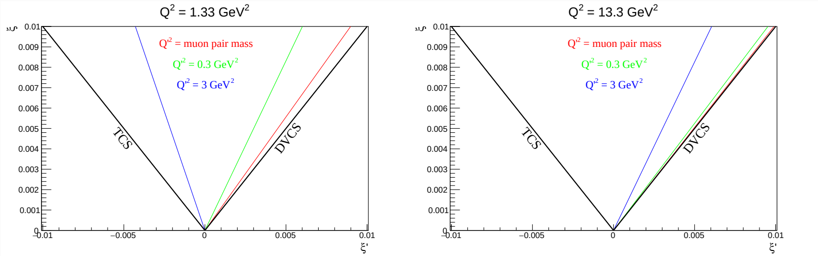
$$\Delta\sigma_{\mathrm{UT}} \sim \Im\mathrm{m}\left\{\xi^2 F_1(\mathcal{H} + \mathcal{E}) - \frac{t}{4M^2}(F_2\mathcal{H} - F_1\mathcal{E}) + \cdots\right\}\sin\phi$$

VGG model [4] is the only one having DDVCS cross section calculation. In the following, all the projections are predicted with it.

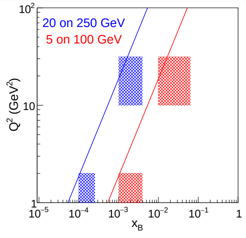
[4] I. V. M. Vanderhaeghen, P. A. M. Guichon and M. Guidal, Phys. Rev D, **60**, 094017 (1999).

cross section at EIC I

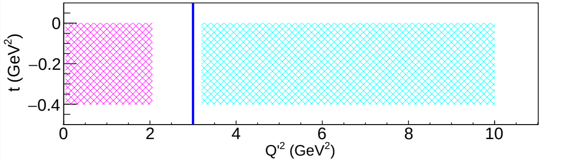




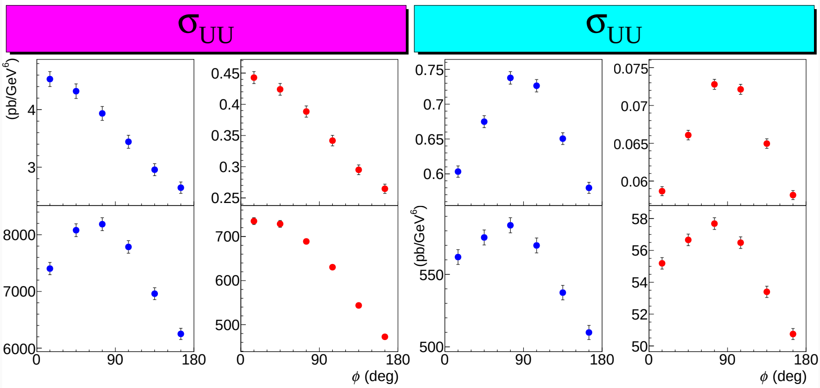
cross section at EIC II



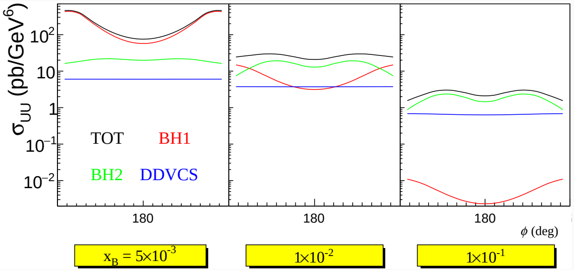
large bins



small Q'^2 - $\int \mathcal{L}dt = 10$ fb^{-1}, large Q'^2 - $\int \mathcal{L}dt = 100$ fb^{-1}

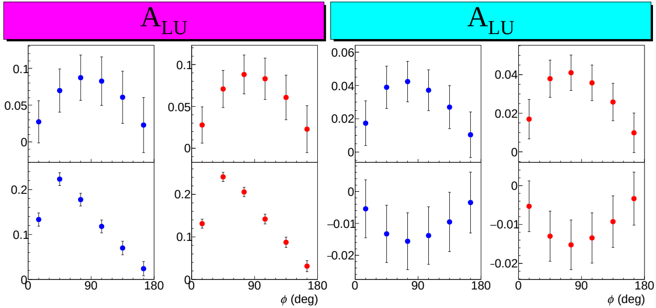


asymetries at EIC I



asymmetry: $A = \dfrac{\Delta\sigma}{\sigma_{UU}}$

additional BH2 increases the denominator

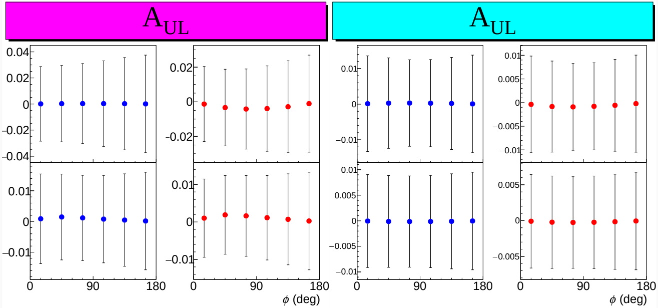


$$A_{LU} = \frac{\Delta\sigma_{LU}}{\sigma_{UU}}$$

$\rightarrow \mathcal{H}$

promising

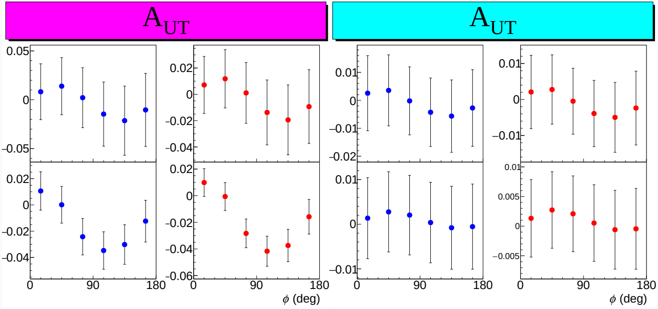
asymetries at EIC II



$$A_{\text{UL}} = \frac{\Delta\sigma_{\text{UL}}}{\sigma_{\text{UU}}}$$

$$\rightarrow \widetilde{\mathcal{H}}$$

difficult



$$A_{\text{UT}} = \frac{\Delta\sigma_{\text{UT}}}{\sigma_{\text{UU}}}$$

$$\rightarrow \mathcal{H}, \mathcal{E}$$

challenging

Conclusion and outlook

conclusion

- Based on this preliminary experimental projection of DDVCS at EIC, it is possible to obtain some DDVCS experiment observables with good precision.
- VGG model was designed mostly for the valence region, it may not give a satisfactory description in low x range.
- Muon detection capabilities are required for DDVCS.

outlook

- Continue and finish DDVCS phenomenological study at JLab12;
- DDVCS cross section calculation using appropriate GPDs model in low x range is needed for EIC.

Thank you!