First DVCS measurements with CLAS12

CLAS collaboration

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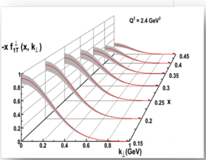
A set of distributions encoding the nucleon structure

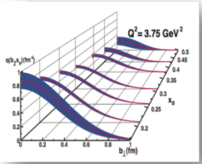
TMDs: Fraction of longitudinal momentum x et transverse momentum k

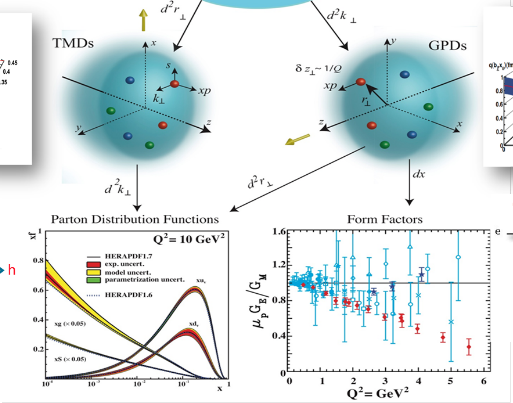
Scan in momentum

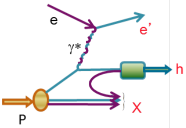


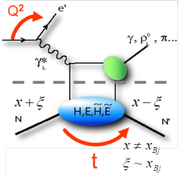
GPDs: Fraction of longitudinal momentum x et transverse position b

Scan in position

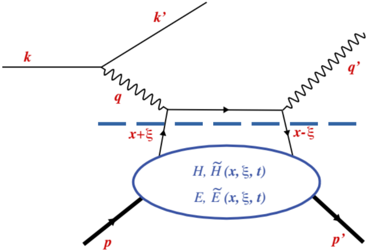








DVCS and GPDs



- $Q^2 = -q^2 = -(k - k')^2$.
- $x_B = \frac{Q^2}{2p \cdot q}$
- x longitudinal momentum fraction carried by the active quark.
- $\xi \sim \frac{x_B}{2-x_B}$ the longitudinal momentum transfer.
- $t = (p' - p)^2$ squared momentum transfer to the nucleon.

The GPDs enter the DVCS amplitude through a complex integral. This integral is called a *Compton form factor* (CFF).

$$\mathcal{H}_{++}(\xi, t) = \int_{-1}^{1} H(x, \xi, t) \left(\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon} \right) dx \, .$$

The generalized parton distributions and the nucleon

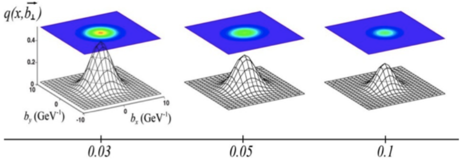
At leading twist there are 8 GPDs:

- 4 chiral-even GPDs: H, E, $\widetilde{H}$ and $\widetilde{E}$.
- 4 chiral-odd GPDs: H_T, E_T, $\widetilde{H}_T$ and $\widetilde{E}_T$.

Using the GPDs, we can determine the total angular momentum of quarks in the nucleon.

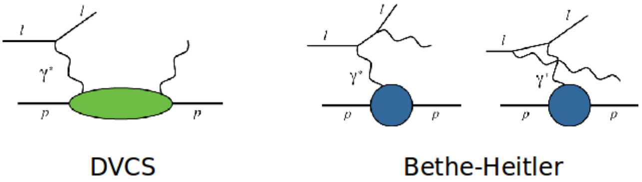
$$\int_{-1}^{1} x \left[H^f(x,\xi,0) + E^f(x,\xi,0) \right] dx = J^f \qquad \forall \xi \ .$$

By Fourier transform of the GPD H at ξ=0 (need extrapolation), we obtain the distribution in the transverse plane of the partons as a function of their longitudinal momentum.

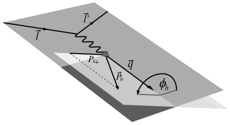


Photon electroproduction

We use leptons beam to generate the γ^* in the initial state... not without consequences.
Indeed, experimentally we measure the cross section of the process $ep \to ep\gamma$ and not strictly $\gamma^* p \to \gamma p$.



$$\frac{d^4\sigma(\lambda, \pm e)}{dQ^2 dx_B dt d\phi} = \frac{d^2\sigma_0}{dQ^2 dx_B}\frac{2\pi}{e^6} \times \left[\left|\mathcal{T}^{BH}\right|^2 + \left|\mathcal{T}^{DVCS}\right|^2 \mp \mathcal{I} \right] ,$$



Photon electroproduction and GPDs

The interference term allows to access the phase of the DVCS amplitude, *i.e* allows to isolate imaginary and real parts of CFFs.

$$c_{0,UU}^{DVCS} \sim \quad 4(1-x_B)\left(\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*\right),$$

$$c_{1,UU}^{\mathcal{I}} \sim \quad F_1\ Re\mathcal{H} + \xi(F_1+F_2)\ Re\widetilde{\mathcal{H}},$$

$$s_{1,LU}^{\mathcal{I}} \sim \quad F_1\ Im\mathcal{H} + \xi(F_1+F_2)\ Im\widetilde{\mathcal{H}},$$

$$s_{1,UL}^{\mathcal{I}} \sim \quad F_1\ Im\widetilde{\mathcal{H}} + \xi(F_1+F_2) Im\mathcal{H},$$

In the present talk, we will be interested in deriving the beam-spin asymetry defined as:

$$A = \frac{\Delta^4\sigma}{d^4\sigma} \tag{1}$$

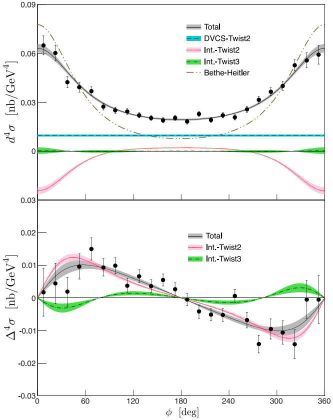
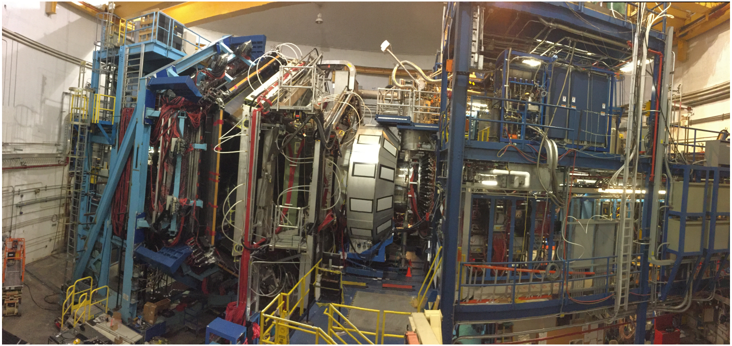
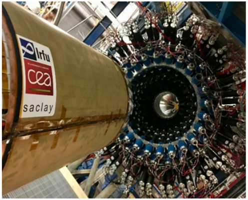
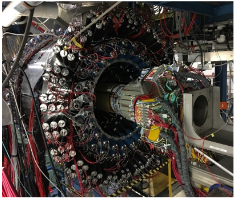


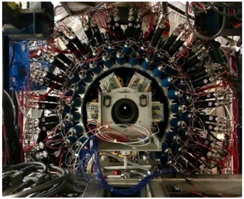
Figure: Unpolarized and beam-helicity cross sections at Q^2=2.3 GeV^2, x_B=0.36, t=-0.3 GeV^2 (Hall A).

Focus on CLAS12: Beam from right to left.





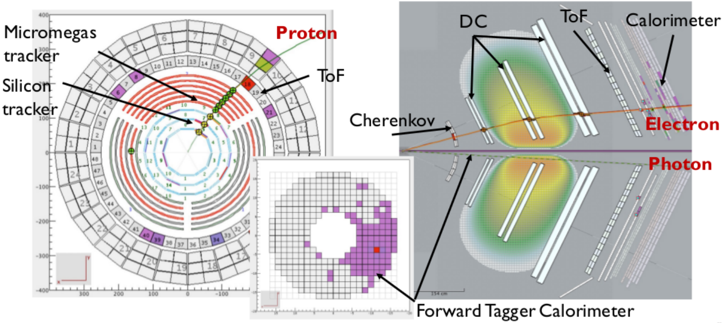




A typical DVCS event in CLAS12

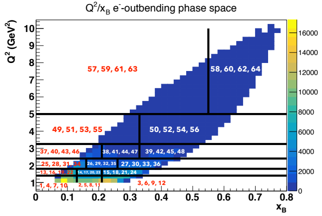
A 10.6-GeV electron beam scatters off a 5-cm LH_2 target. The beam is ∼85% longitudinally polarized. All CLAS12 detectors are necessary to reconstruct all particles of a DVCS final state:

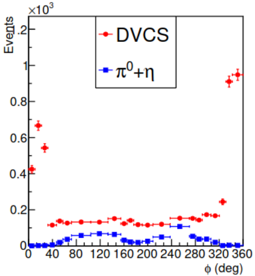
- The electron is going through Cerenkov detector, drift chambers and electromagnetic calorimeter.
- The photon is either detected in a sampling calorimeter or a small $PbWO_4$-calorimeter close to the beamline.
- The recoil proton goes in the Silicon and Micromegas detector.

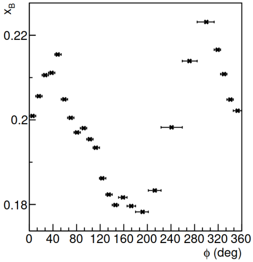


DVCS phase-space with CLAS12 @ 10.6 GeV

The binning has been chosen to accomodate for the main kinematical dependence of the BSA with the available statistics.



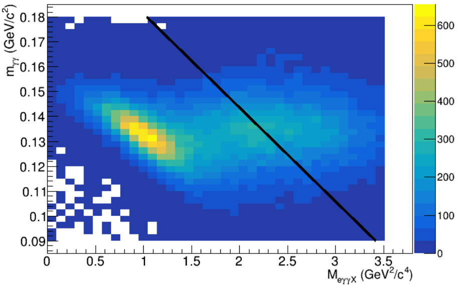


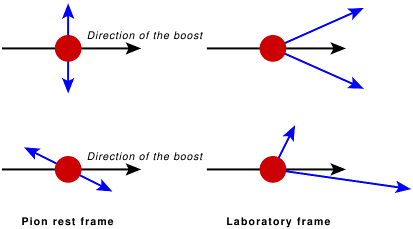


- For each Q^2/x_B, 4 bins in $t_{min} - t$ are defined.
- Regarding ϕ, a adaptative binning procedure was implemented to accomodate for the steep dependence of the cross section.
- $Q^2/x_B/t$-kinematics are *phi*-dependent.

π^0-contamination

After cutting on the exclusivity variables, SIDIS events are rejected but we still have a significant contamination from mostly exclusive π^0's events.





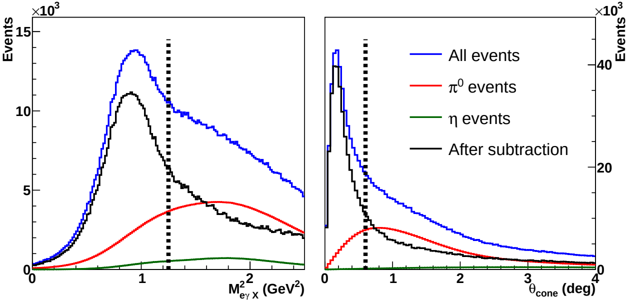
Being only due to unfortunate decays, the π^0-contamination is estimated by:

- Estimating the fraction of decays $r_{MC} = \frac{n_{1\gamma}^{cont}}{n_{2\gamma}}$ with a Monte-Carlo simulation.
- Normalizing by $n_{1\gamma}^{cont-Exp} = r_{MC} \times n_{2\gamma}^{Exp}$.

DVCS event selection

Exclusivity is enforced by cutting on 5 variables:

- The missing mass ep$\rightarrow$eγpX,
- The missing mass ep$\rightarrow$eγX,
- The missing energy,
- The missing transverse momentum,
- The cone angle (angle between detected photon and expected photon assuming exclusivity).



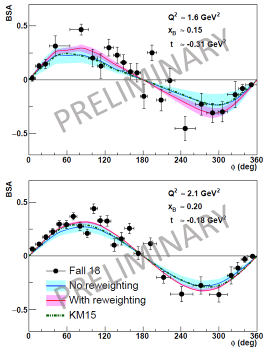
Results and comparison with fits/models

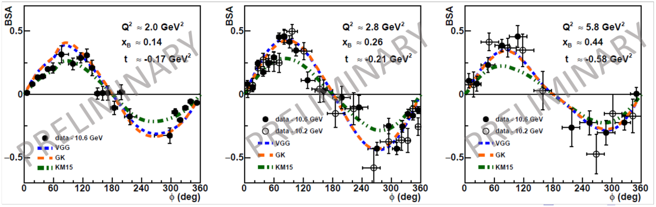
- Deriving the mean and standard deviation of a 100 ANN-predictions produced by a global fit, the new data are shown to be in good agreement. Called reweighting technique, a weight ω_k for the kth-ANN is computed:

$$\omega_k = \frac{1}{Z}\chi_k^{n-1} e^{-(\chi_k^2/2)} , \qquad (2)$$

  A weighted mean and standard deviation of the 100 ANNs show the impact of the newly collected data.

- Comparisons with KM15 and VGG/GK models are performed as well. (see last slide for references)





Conclusion

- The data shown represents approximately 25% of the beam time allocated to DVCS study with an unpolarized target. Another 25% is being calibrated and reconstructed. Finally the remaining 50% will be collected later.
- With the energy and the luminosity upgrade, CLAS12 reaches high-Q^2/high x_B region with excellent statistical accuracy.
- Through the reweighting technique, we have shown that the data are in reasonable agreement with 6-GeV data and greatly reduce the uncertainties.
- In many bins, data agrees with KM15 predictions except in some bins at large x_B where data agrees well with GK/VGG models.

- Many other DVCS analysis are on going with neutron target or lower beam energies for Rosenbluth separation.
- This June, data will be collected on longitudinally polarized target until March 2023.

References

- H. Moutarde, P. Sznajder, and J. Wagner, Eur. Phys. J. C 79, 614 (2019), arXiv:1905.02089 [hep-ph].
- Kumericki, Kresimir and M uller, Dieter, EPJ Web of Conferences 112, 01012 (2016).
- S. V. Goloskokov and P. Kroll, The European Physical Journal C 65, 10.1140/epjc/s10052-009-1178-9 (2009)
- M. Vanderhaeghen, P. A. Guichon, and M. Guidal, Phys.Rev. D60, 094017 (1999), arXiv:hep-ph/9905372 [hep-ph].