Probing the Pion Structure with the CLAS12 Experiment

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1. Probing the Internal Structure of the Pion

Why?

- The pion, the lightest and simplest bound state of a quark and an antiquark, is a key system to study Quantum Chromodynamics (QCD) and hadron structure.

How?

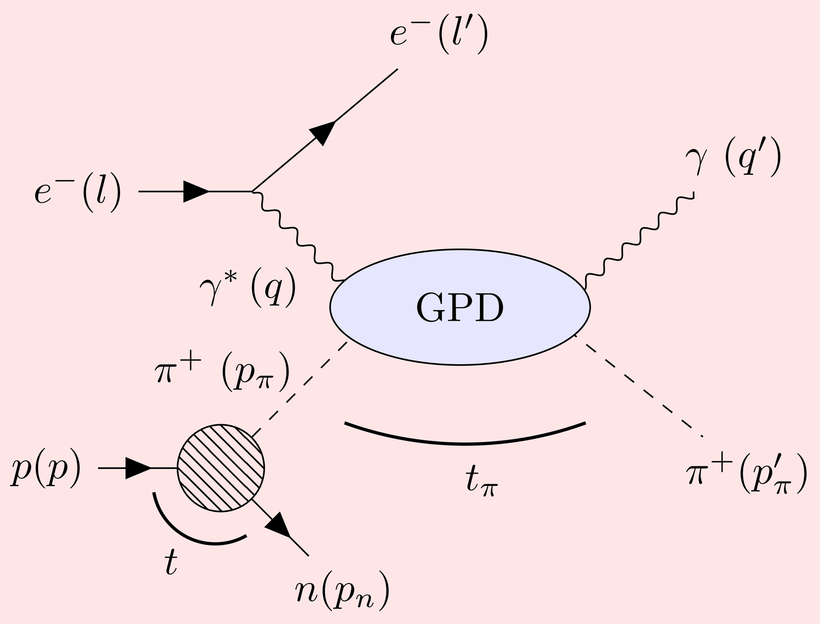
- **The Sullivan Process:** Use the nucleon's meson cloud as an effective target of quasi-real pion [1].

Experimental technique:

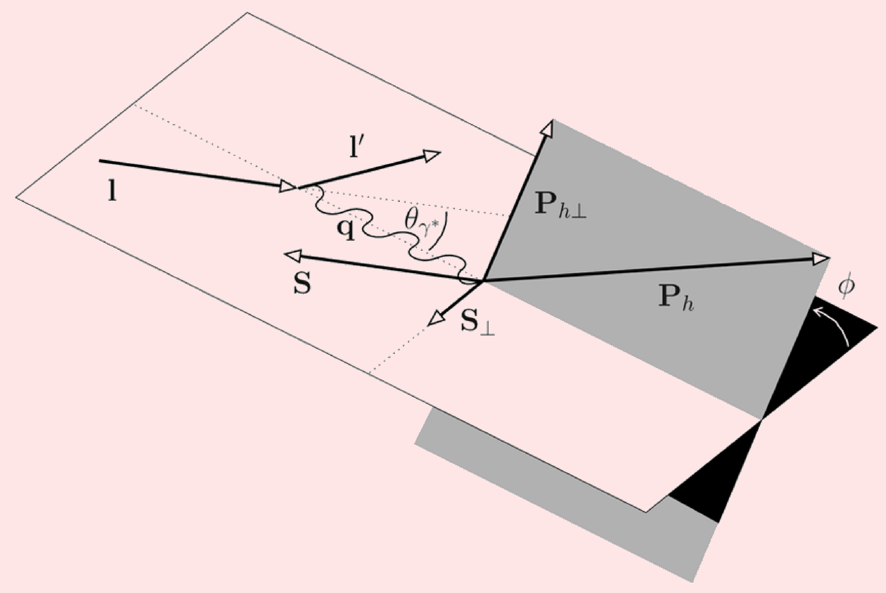
- We measure the **Deeply Virtual Compton Scattering (DVCS)** on virtual pion target [2]:

$$\gamma^* \pi^+ \to \gamma \pi^+$$
$$ep \to e' \gamma \pi^+ n$$

- The amplitude of this reaction is parameterized by the **Compton Form Factors (CFFs)** $\mathcal{H}_\pi$, which are related to the **Generalized Parton Distributions (GPDs)** [3], describing the correlation between parton momentum and spatial distributions inside the pion.

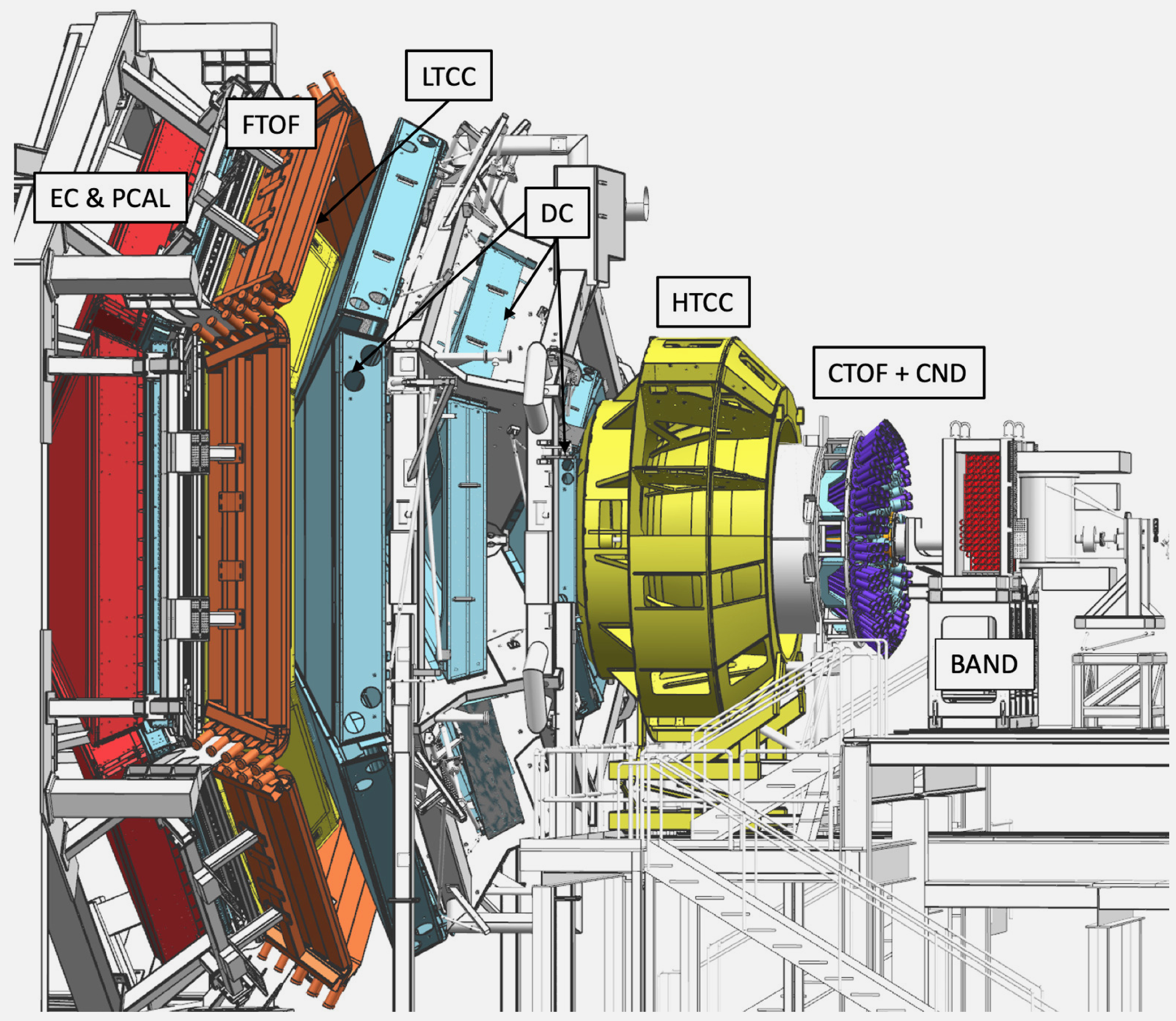


DVCS process on the pion via the Sullivan mechanism.



Definition of the ϕ Trento angle.

2. The CLAS12 Experiment

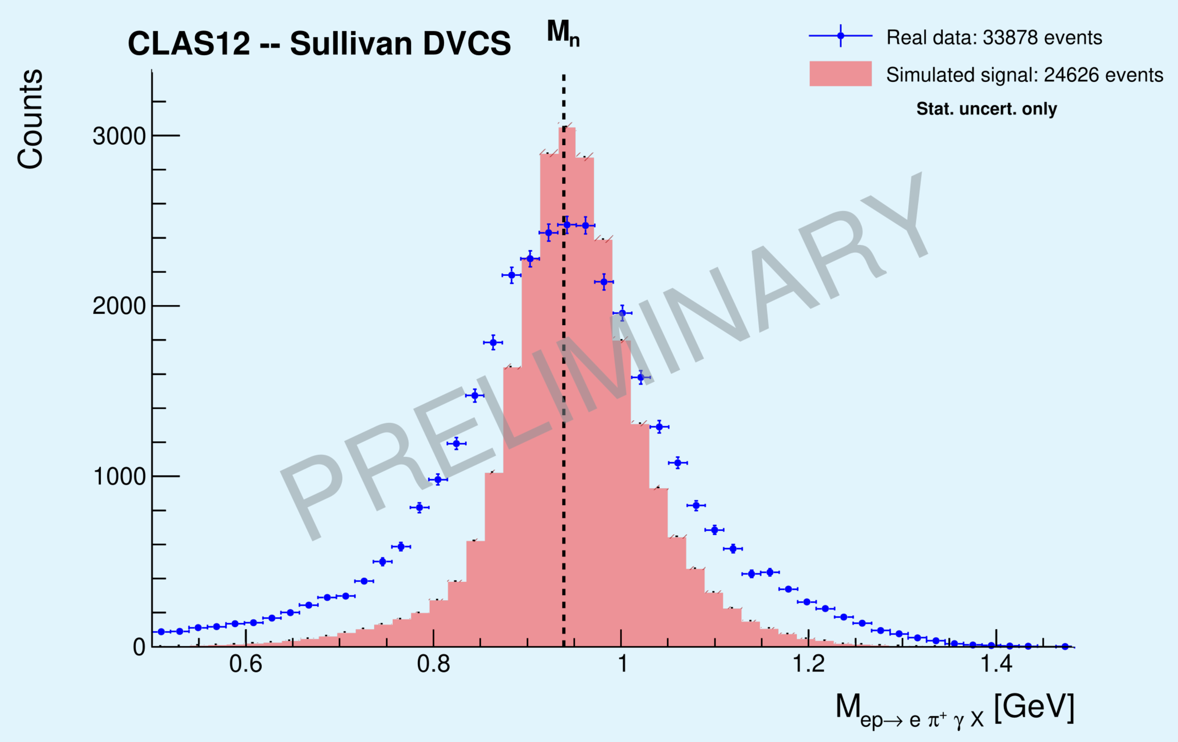


CLAS12 detector (Hall B, Jefferson Lab, USA).

- Electron beam: 10.6 GeV, longitudinal polarization.
- Target: liquid hydrogen.
- Fully equipped to detect final state particles: e', γ, π^+.
- Neutron identified using the missing mass technique.

3. Preliminary Results

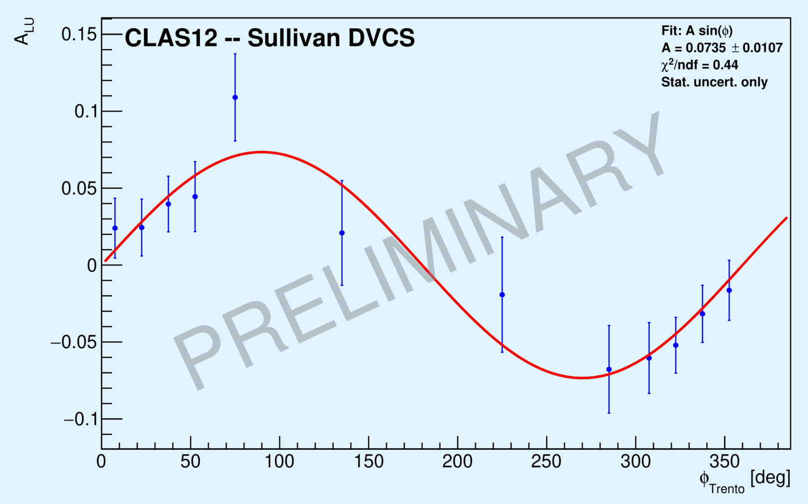
Exclusivity of the process



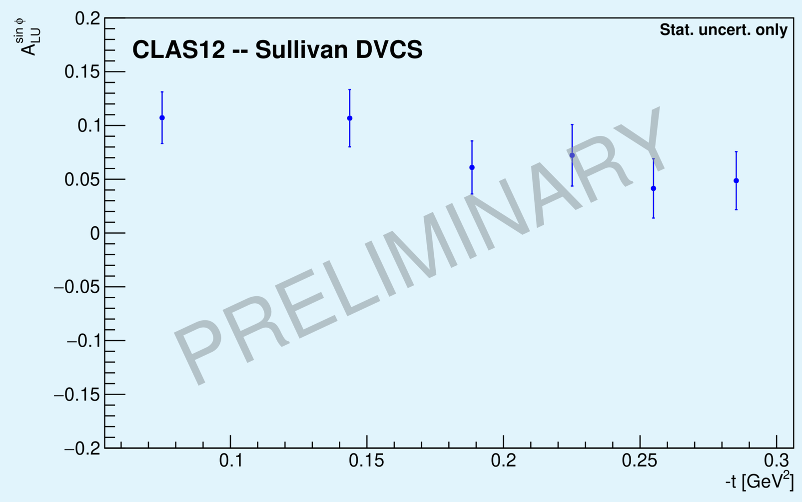
Reconstructed Missing Mass of the Neutron.

Beam Spin Asymmetry (BSA)

$$\mathcal{A}_{\text{LU}}(\phi) = \frac{d\sigma^+(\phi) - d\sigma^-(\phi)}{d\sigma^+(\phi) + d\sigma^-(\phi)} \propto \Im m\,(\mathcal{H}_\pi)\sin(\phi)$$



BSA fitted with $A\sin(\phi)$.



BSA amplitude as a function of the pion virtuality $-t$.

- BSA as a function of $-t \to$ test of the near-on-shell pion model.

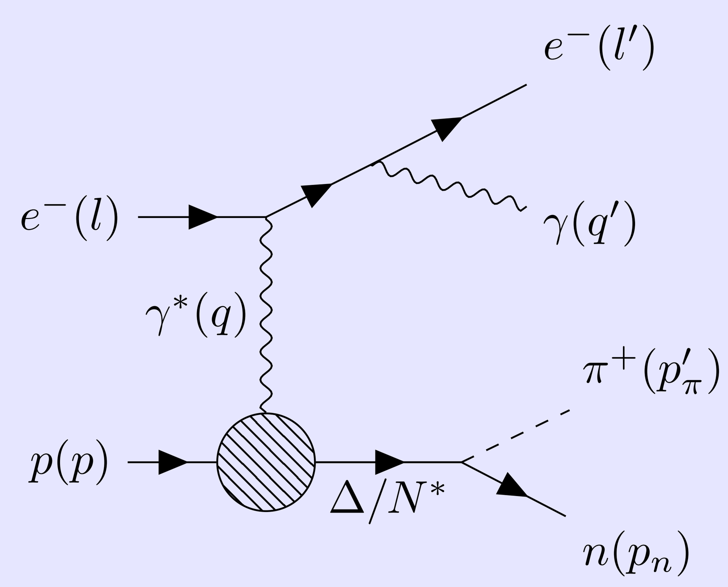
4. Background Studies

Bethe-Heitler process on nucleon resonance

- Competing channels:

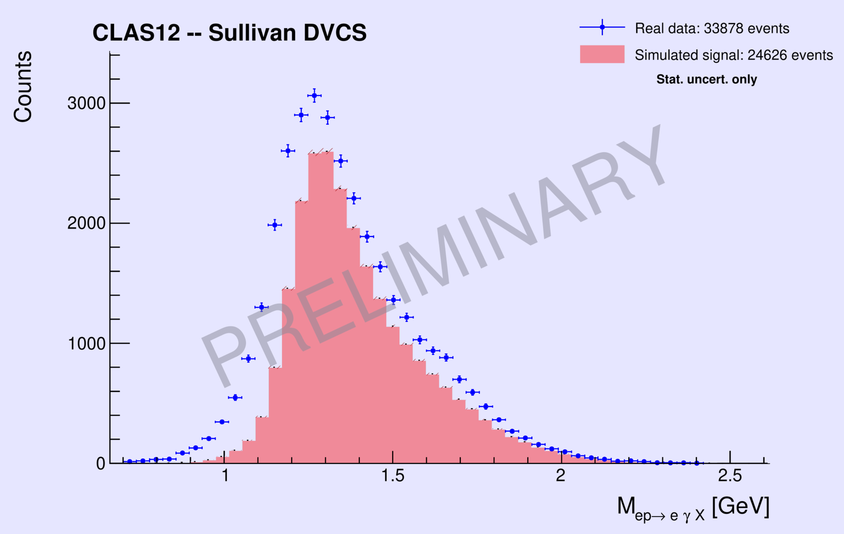
$$ep \to e'\,\gamma\,\Delta^+/N^* \to e'\,\gamma\,\pi^+\,n$$

- Same final state and kinematic domain as Sullivan process.

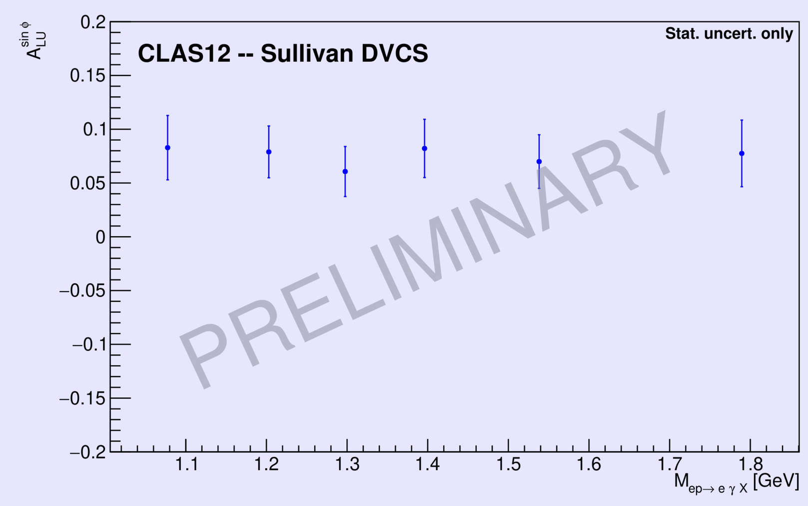


Bethe-Heitler process on nucleon resonance.

Impact on the BSA measurement



Invariant mass of the $\pi^+ n$ system.



BSA amplitude as a function of the $\pi^+ n$ invariant mass.

- No significant variation of the BSA amplitude across the pion-neutron invariant mass range $\to$ no conclusion can be drawn yet about the contribution of the resonance background.

5. Next Steps

- Remove π^0 contamination: $ep \to en\pi^+\pi^0 \to en\pi^+\gamma\gamma$.
- Develop a method to estimate the background from nucleon resonances.
- Compare the extracted BSA with predictions from existing pion GPD models.

References

[1] Sullivan, *Phys. Rev. D* 5, 1732 (1972)
[2] Amrath et al., *Eur. Phys. J. C* 58, 179 (2008)
[3] Chavez et al., *Phys. Rev. D* 105, 094012 (2022)