

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].

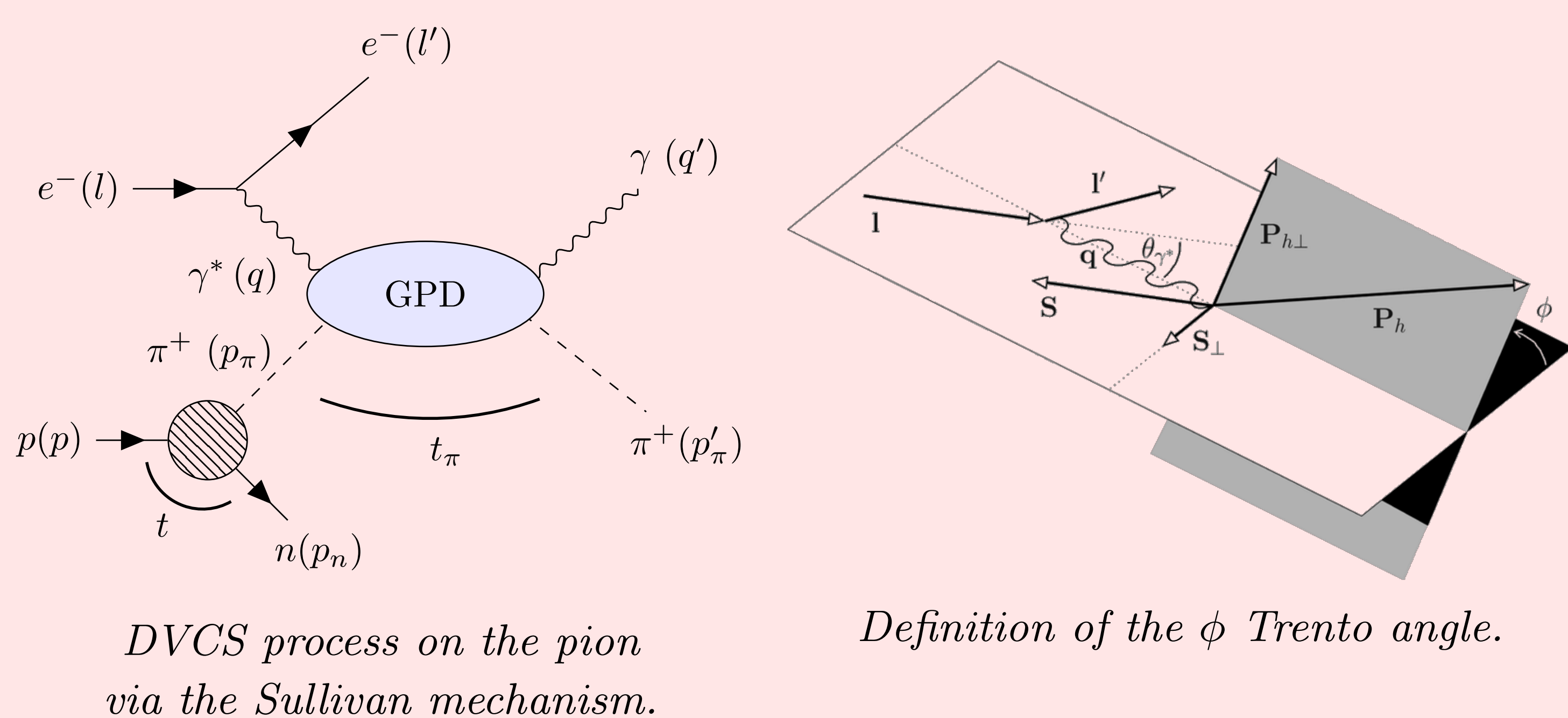
Experimental technique:

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

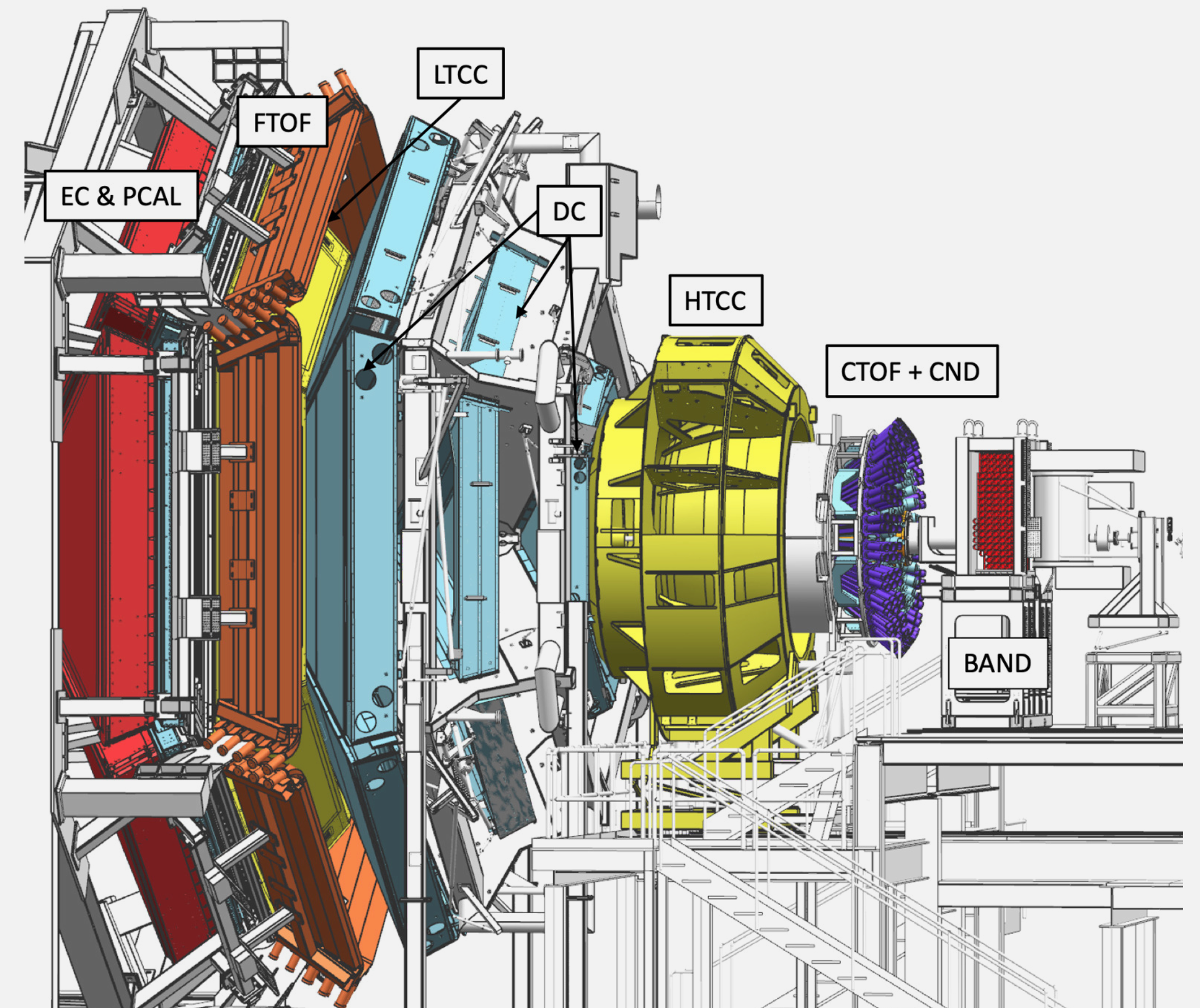
$$\gamma^* \pi^+ \rightarrow \gamma \pi^+$$

$$ep \rightarrow e' \gamma \pi^+ n$$

- 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.



2. The CLAS12 Experiment



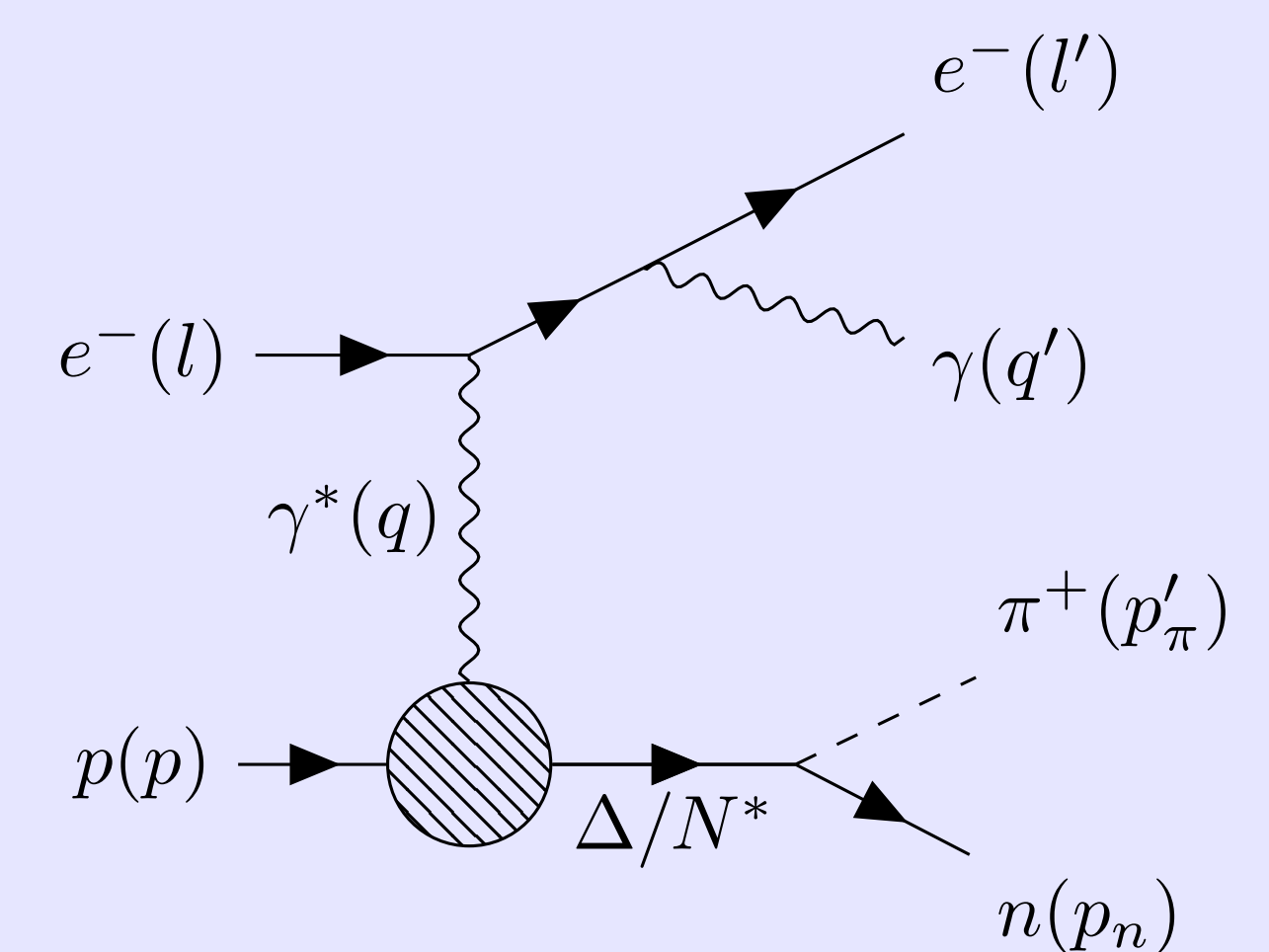
CLAS12 detector (Hall B, Jefferson Lab, USA).

- 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.

4. Background Studies

Bethe-Heitler process on nucleon resonance

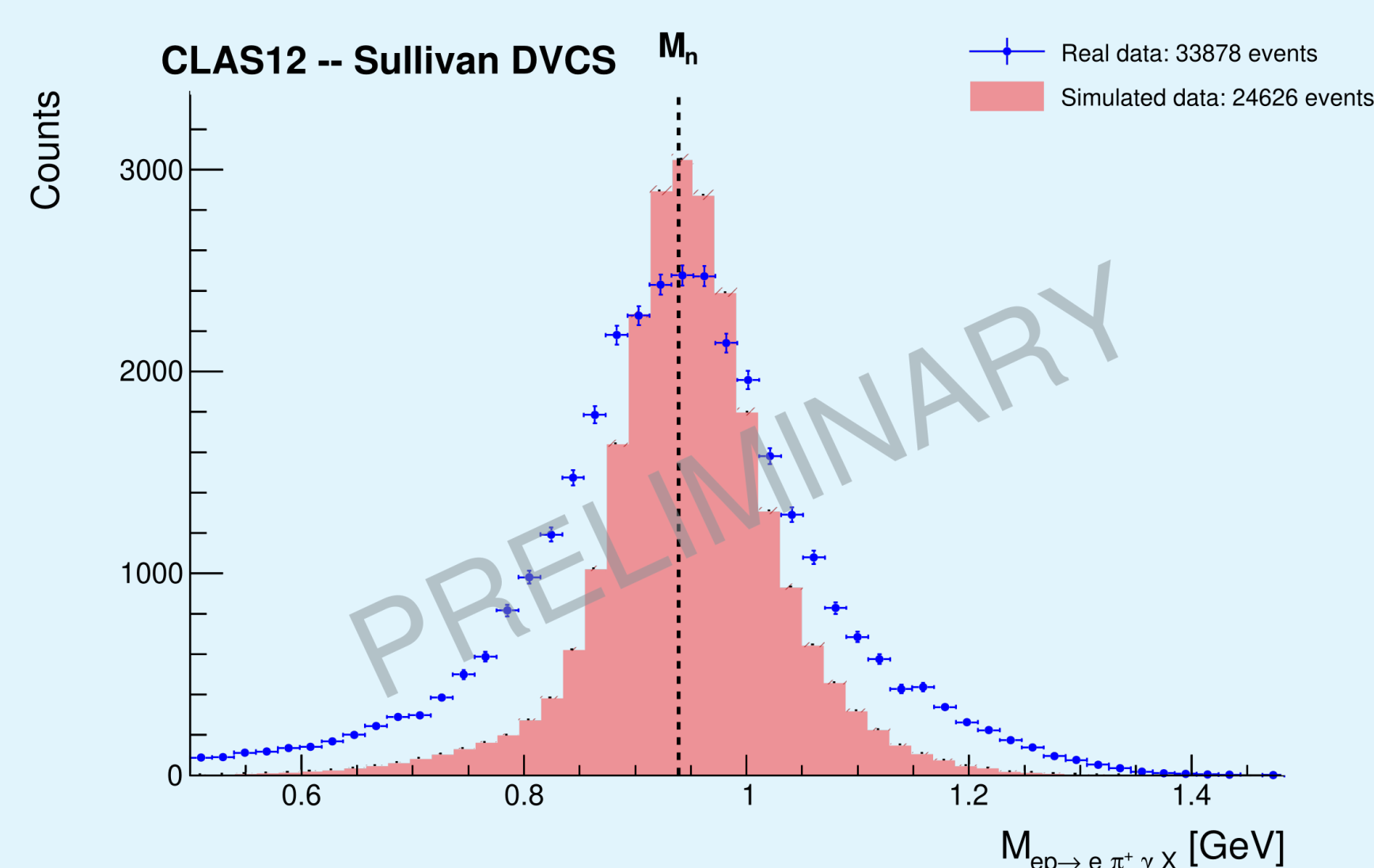
- Competing channels:
 $ep \rightarrow e' \gamma \Delta^+ / N^* \rightarrow e' \gamma \pi^+ n$
- Same final state and kinematic domain as Sullivan process.



Bethe-Heitler process on nucleon resonance.

3. Preliminary Results

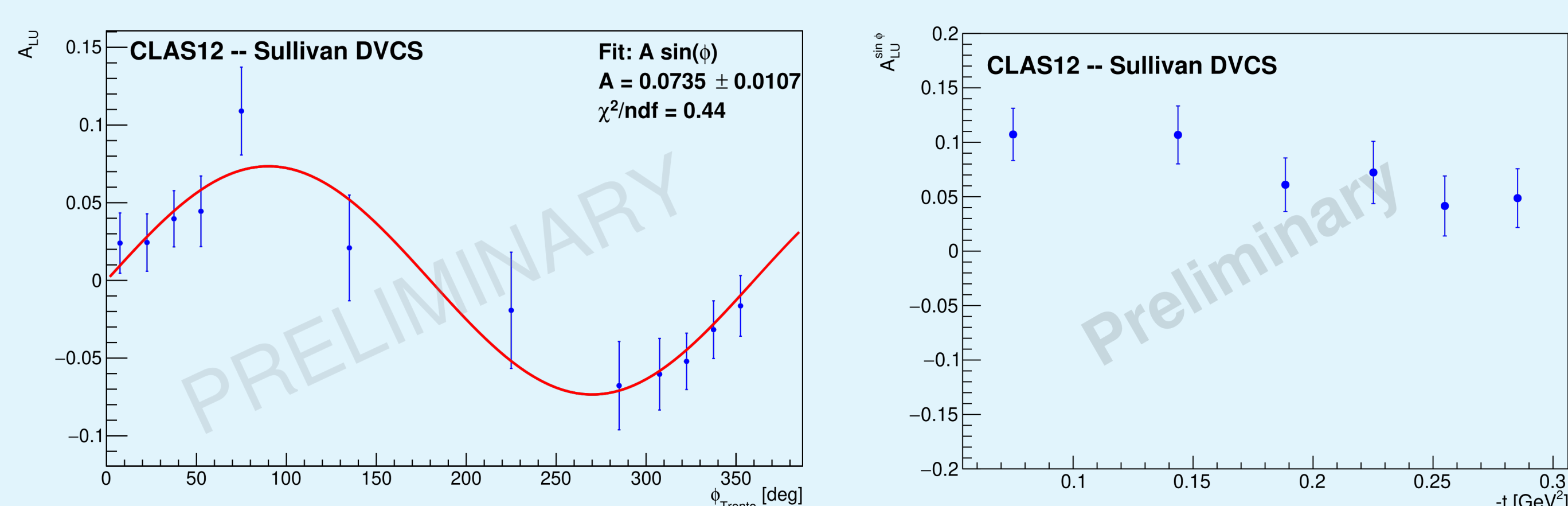
Exclusivity of the process



Reconstructed Missing Mass of the Neutron.

Beam Spin Asymmetry (BSA)

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

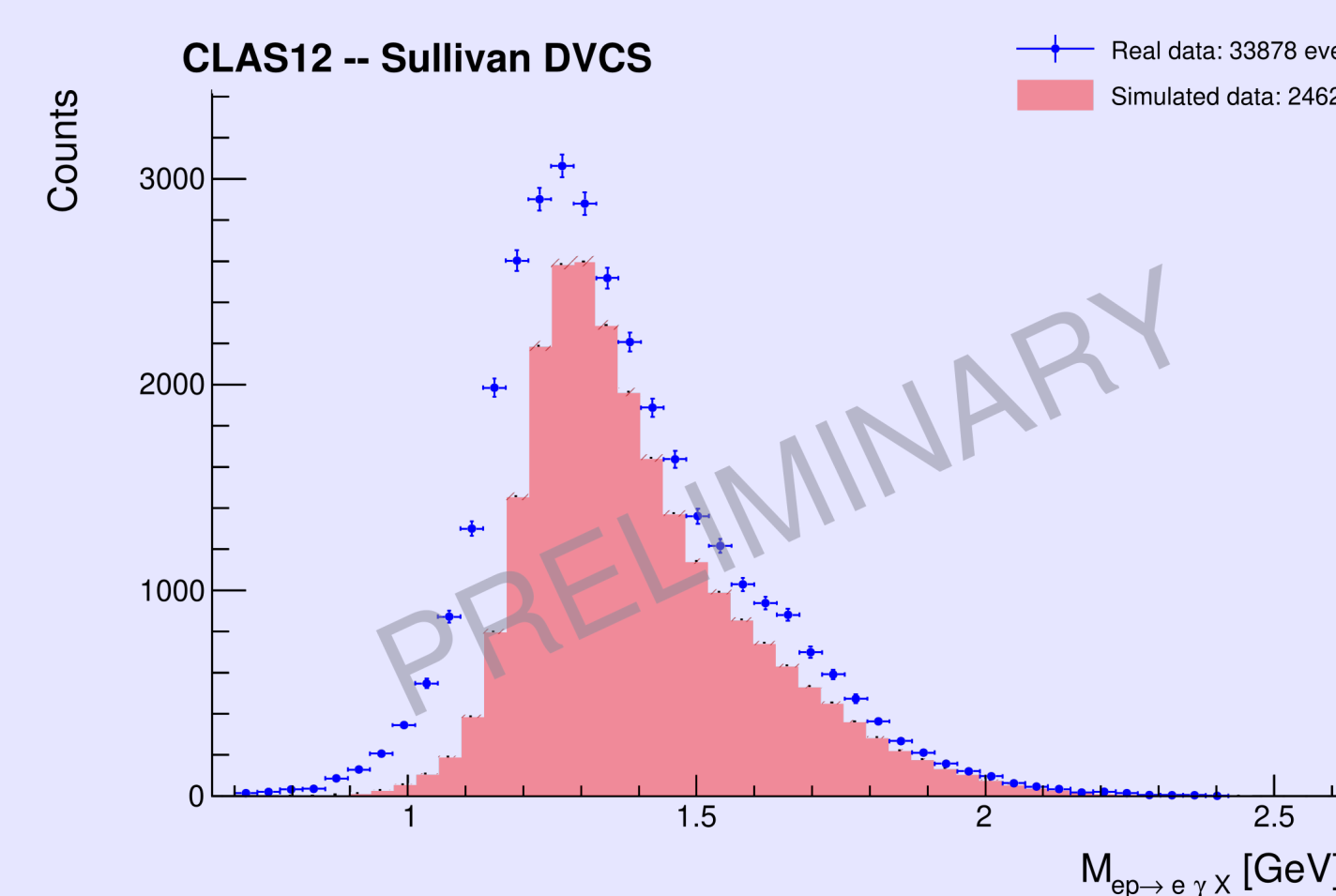


BSA fitted with $A \sin(\phi)$.

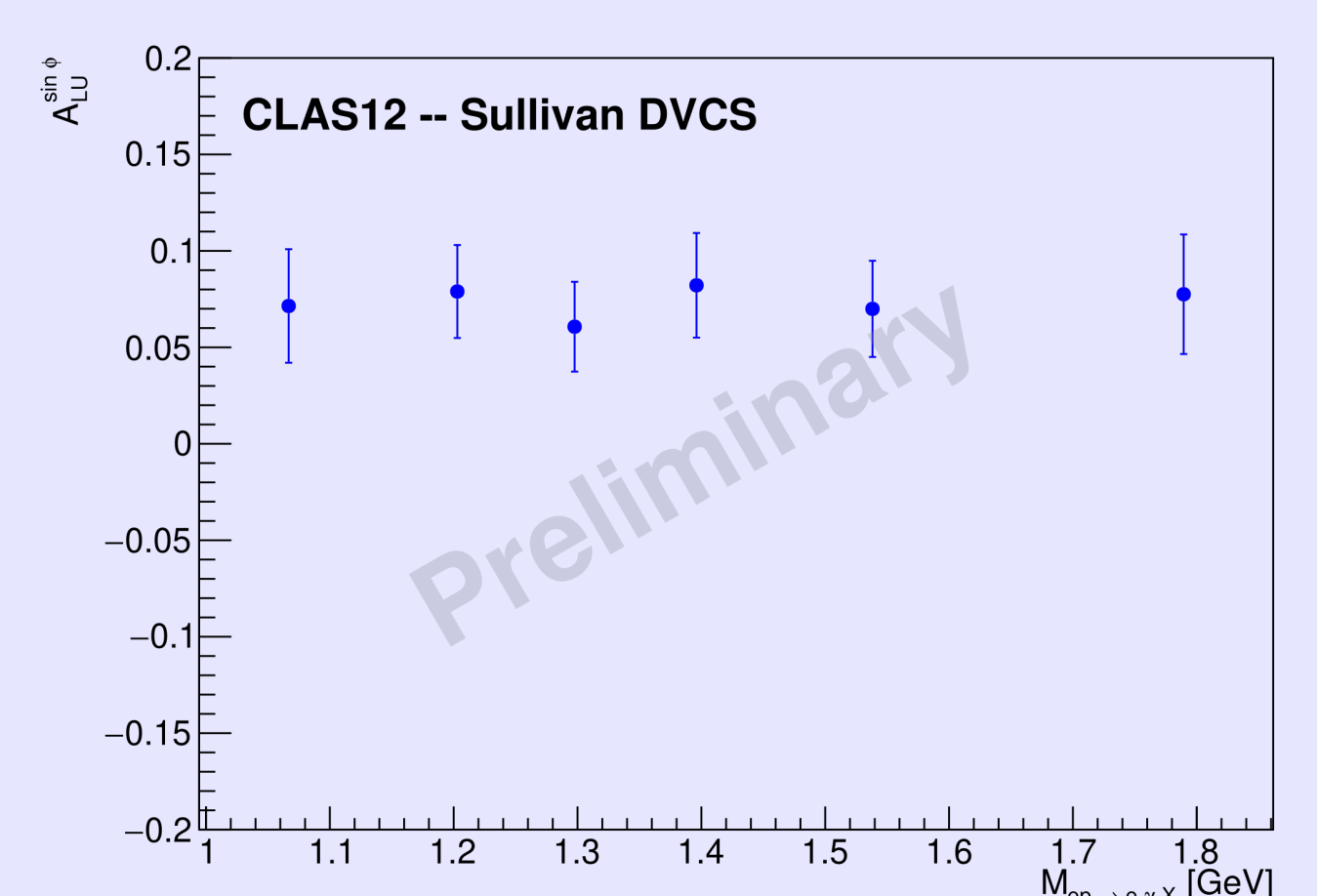
BSA amplitude as a function of the pion virtuality $-t$.

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

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 $\rightarrow$ no conclusion can be drawn yet about the contribution of the resonance background.

5. Next Steps

- Remove π^0 contamination: $ep \rightarrow en \pi^+ \pi^0 \rightarrow en \pi^+ \gamma \gamma$.
- 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)