Workshop on Novel Probes of the Nucleon Structure in SIDIS, e^+e^- and pp (FF2019), Duke University

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SIDIS Pion Beam Spin Asymmetries with CLAS12 at 10.6 GeV

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Overview and Introduction

- Physics motivation
- Analysis procedure
- Multidimensional binning
- Comparison to CLAS and HERMES

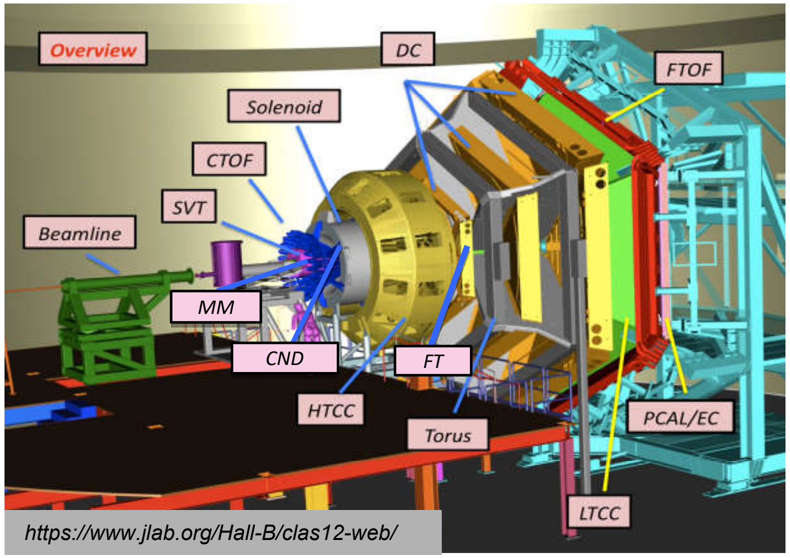
➔ Data recorded with CLAS12 during spring of 2018

➔ Analysed data < 2 % of approved RG-A beamtime

➔ 10.6 GeV electron beam

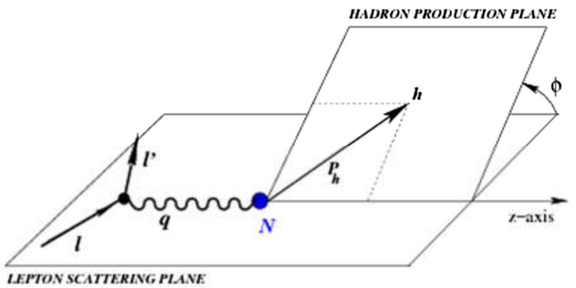
➔ 85 % average longit. polarization

➔ liquid hydrogen target



Physics Motivation

- The 3D nucleon structure in momentum space can be described by TMDs
- A way to acess these properties is the semi inclusive deep inelastic scattering



The SIDIS cross section for an unpolarized target:

→ Contains model independent structure functions

$$\frac{d\sigma}{dx_B\, dQ^2\, dz\, d\phi_h\, dp_{h\perp}^2} = K(x,y,Q^2)\Big\{F_{UU,T} + \varepsilon F_{UU,L}$$

$$+\sqrt{2\,\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon\cos(2\phi_h) F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\sin\phi_h \underline{F_{LU}^{\sin\phi_h}}\Big\}$$

$$F_{LU}^{\sin\phi} = \frac{2M}{Q}\mathcal{C}\left(-\frac{\hat{\mathbf{h}}\cdot\mathbf{k_T}}{M_h}\left(xeH_1^\perp + \frac{M_h}{M} f_1 \frac{\tilde{G}^\perp}{z}\right) + \frac{\hat{\mathbf{h}}\cdot\mathbf{p_T}}{M}\left(xg^\perp D_1 + \frac{M_h}{M} h_1^\perp \frac{\tilde{E}}{z}\right)\right)$$

twist-3 pdf

Collins FF

unpolarized dist. function

twist-3 FF

twist-3 t-odd dist. funcion

Boer-Mulders

twist-3 FF

⇨ **Twist 3 component in every term**

Physics Motivation

In a simplified way, it can be expressed as:

$$d\sigma = d\sigma_0 (1 + A_{UU}^{\cos\phi} \cos\phi + A_{UU}^{\cos 2\phi} \cos 2\phi + \lambda_e A_{LU}^{\sin\phi} \sin\phi)$$

where the moments $A_{UU}^{\cos\phi}$, $A_{UU}^{\cos 2\phi}$, $A_{LU}^{\sin\phi}$ are directly related to the structure functions of the cross section

Focus of this study: $A_{LU}^{\sin\phi}$

→ Only moment which depends on the beam helicity

→ Helicity dependence arises from the asymmetric part of the leptonic tensor and its coupling to the hadronic tensor

→ Directly correlated with the structure function $F_{LU}^{\sin\phi}$

➔ Provides information about the quark gluon correlations in the proton

Physics Motivation and Extraction

- BSA is a good tool to extract $A_{LU}^{\sin\phi}$

$$BSA = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{A_{LU}^{\sin\phi}\sin\phi}{1 + A_{UU}^{\cos\phi}\cos\phi + A_{UU}^{\cos(2\phi)}\cos(2\phi)}$$

➔ Helicity independent acceptance terms cancel out in the ratio!

Past: Measurements have been performed with CLAS, HERMES and COMPASS

Advantages of CLAS12:

➔ Significantly higher statistics

➔ Extended kinematic coverage (Q^2, P_T)

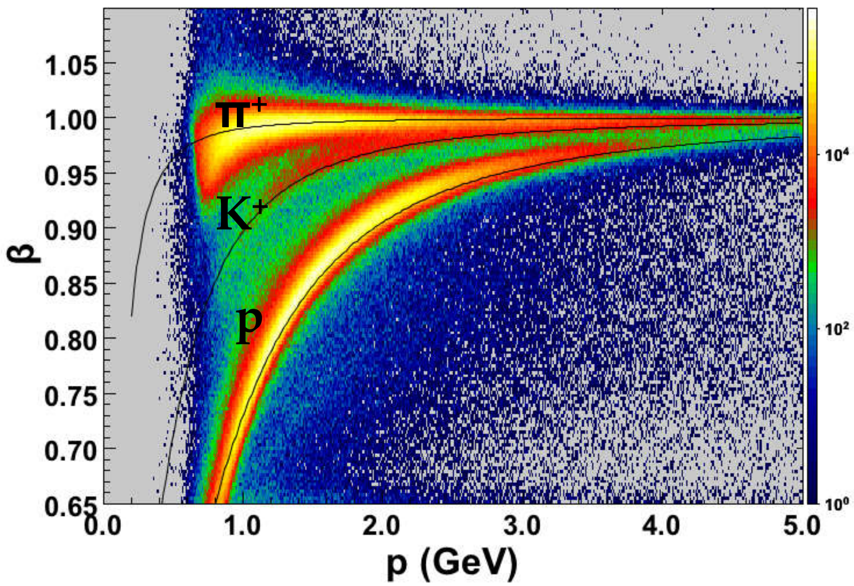
Particle ID

Electron ID → Based on the electromagnetic calorimeter and the cherenkov counters

Hadron ID → Charge corresponding to the selected hadron

→ Fiducial cuts on the hit position in the drift chambers

→ Particle selection based on β vs p correlation



→ **Maximum likelihood particle ID**

$$P(\beta) = \frac{1}{\sqrt{2\pi}\sigma} \cdot \exp\left(-\frac{1}{2} \left(\frac{\beta - \mu}{\sigma} \right)^2 \right)$$

→ Assign particle to species with the highest probability

→ Check if particle is within a certain confidence level

➔ Provides a cleaner particle ID for inclusive measurements

Event selection and kinematic cuts

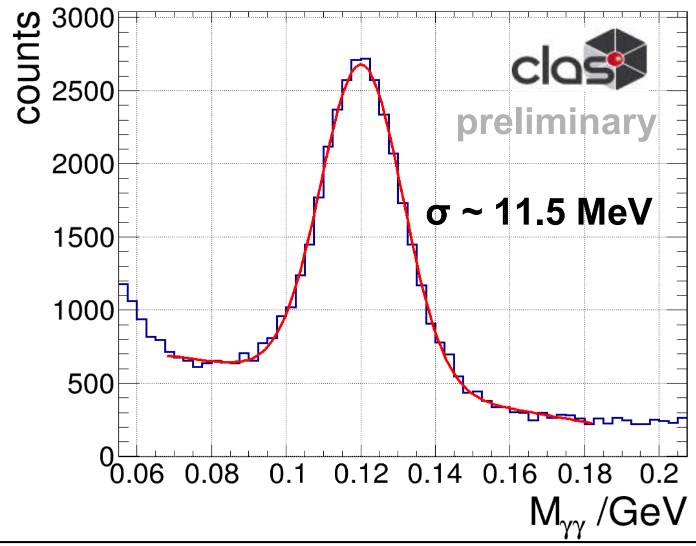
π^0 selection:

$E_\gamma > 0.6$ GeV, all 2γ pairs

SIDIS simulations show:

background dominated by SIDIS π^0

→ 3 σ cut around the peak positions



Kinematic cuts for all pions:

minimal electron energy: 2.0 GeV   minimal pion energy: 1.5 GeV

DIS cut: $Q^2 > 1$ GeV² $W > 2$ GeV

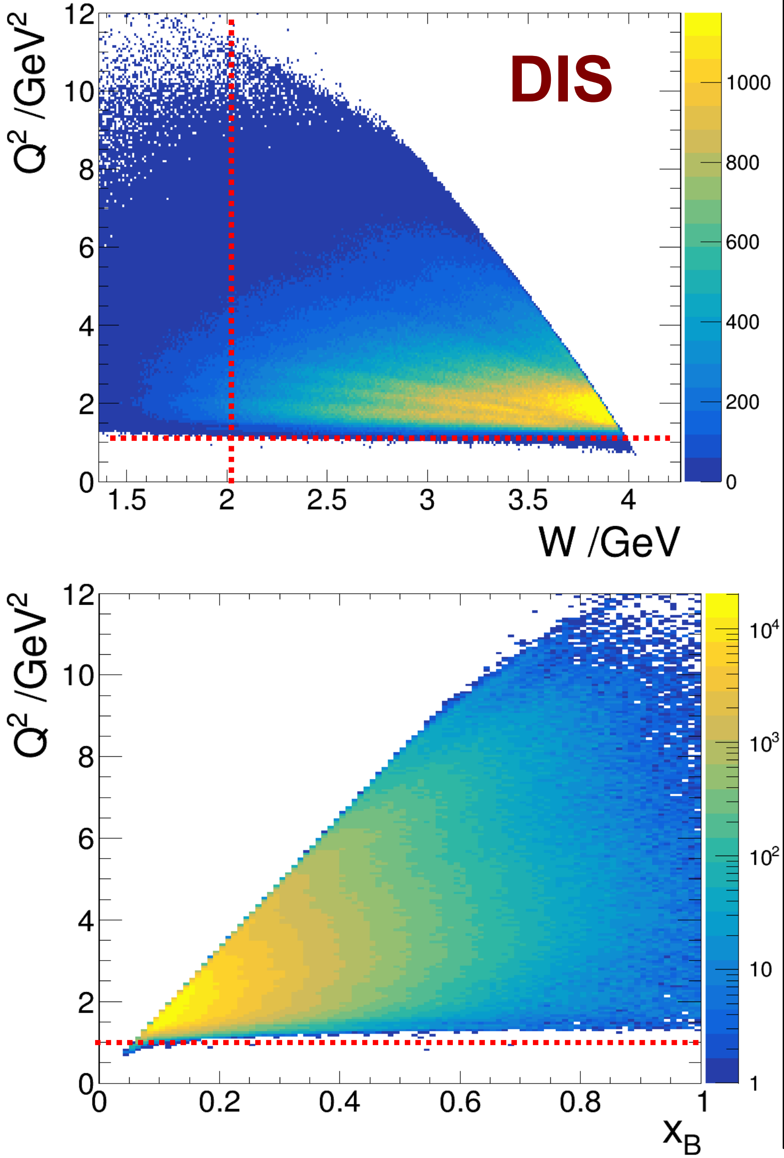
Additionally: Cut on the final state hadron momentum fraction z

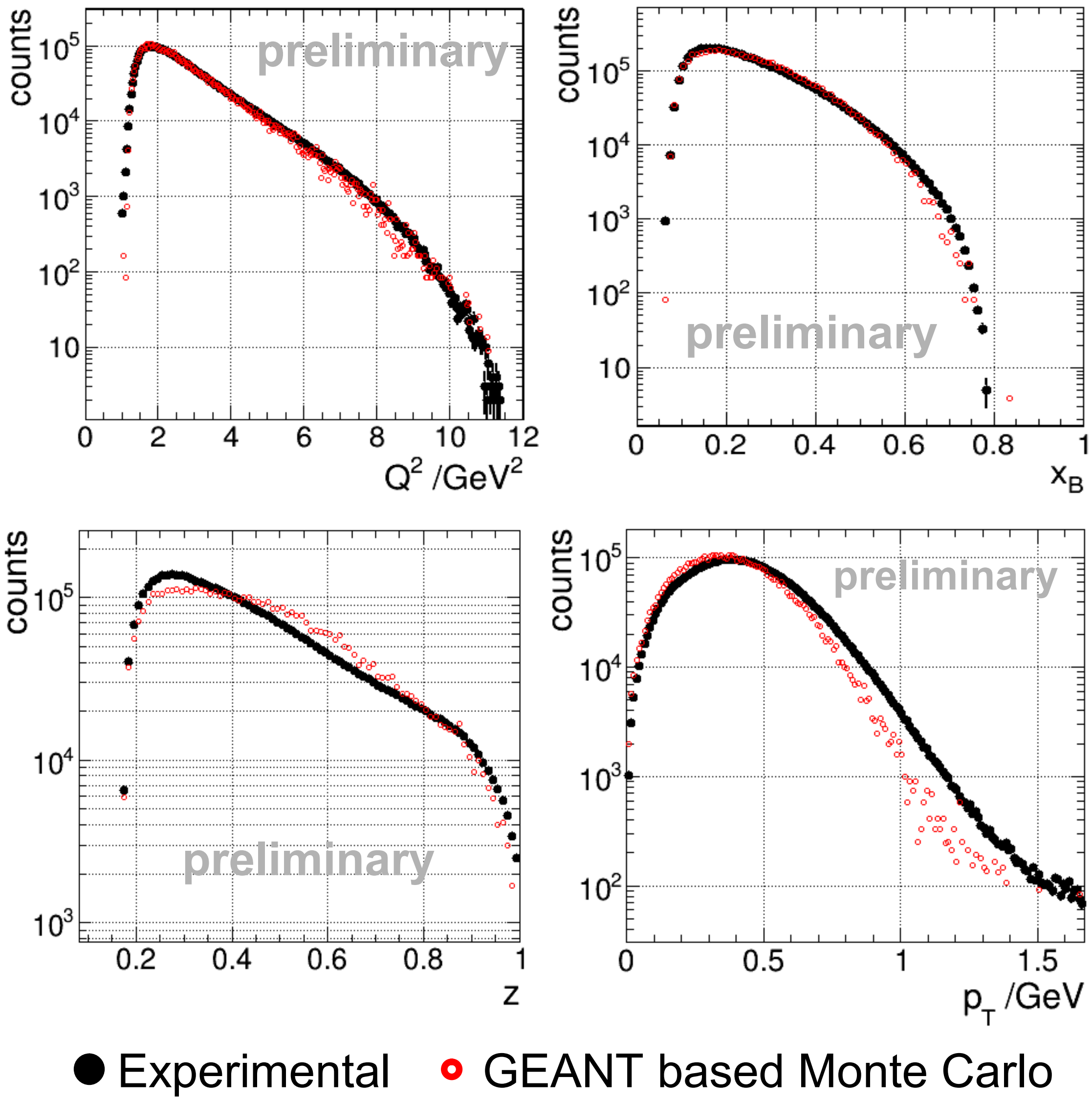
$$0.3 < z < 0.7$$

→ $z > 0.3$ removes the "target fragmentation region"

→ $z < 0.7$ removes contamination by pions from exclusive channels

Kinematic coverage for π^+ (similar for π^- and π^0)



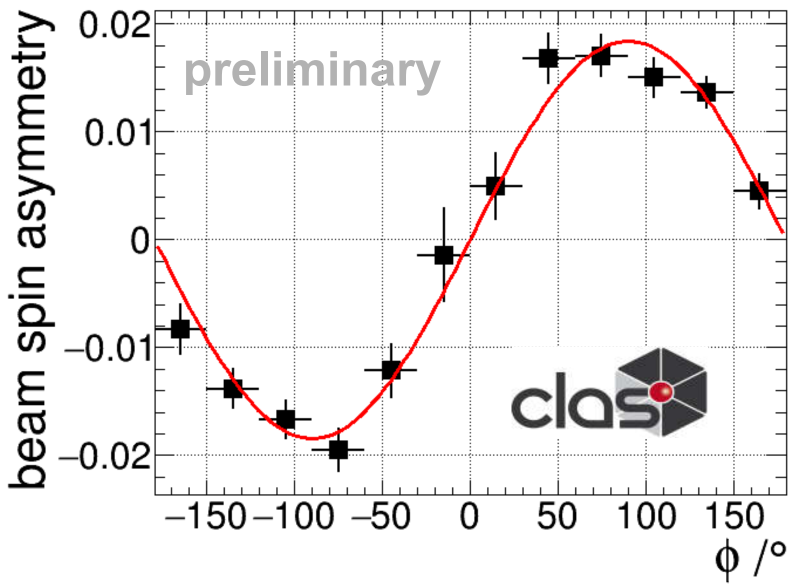


Integrated beam spin asymmetry

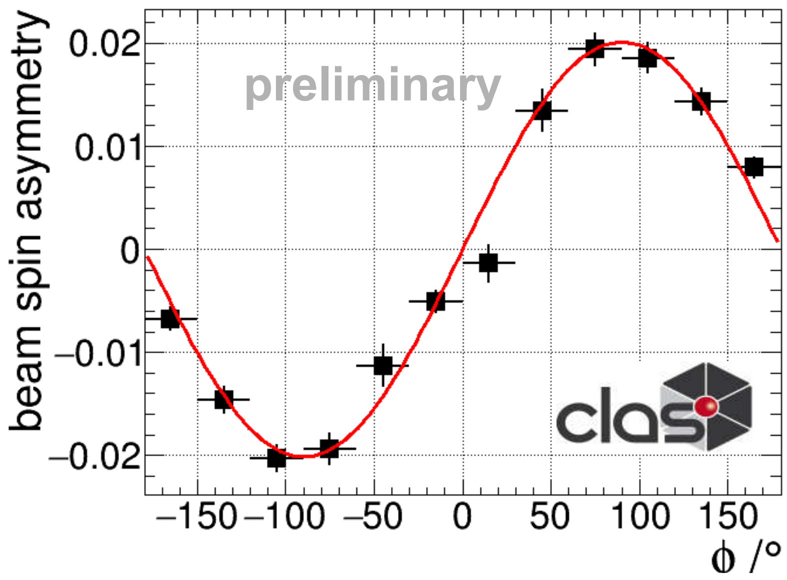
$$BSA_i = \frac{1}{P_e} \cdot \frac{N_i^+ - N_i^-}{N_i^+ + N_i^-}$$

P_e = 85 % : average e^- beam polarisation

π^+



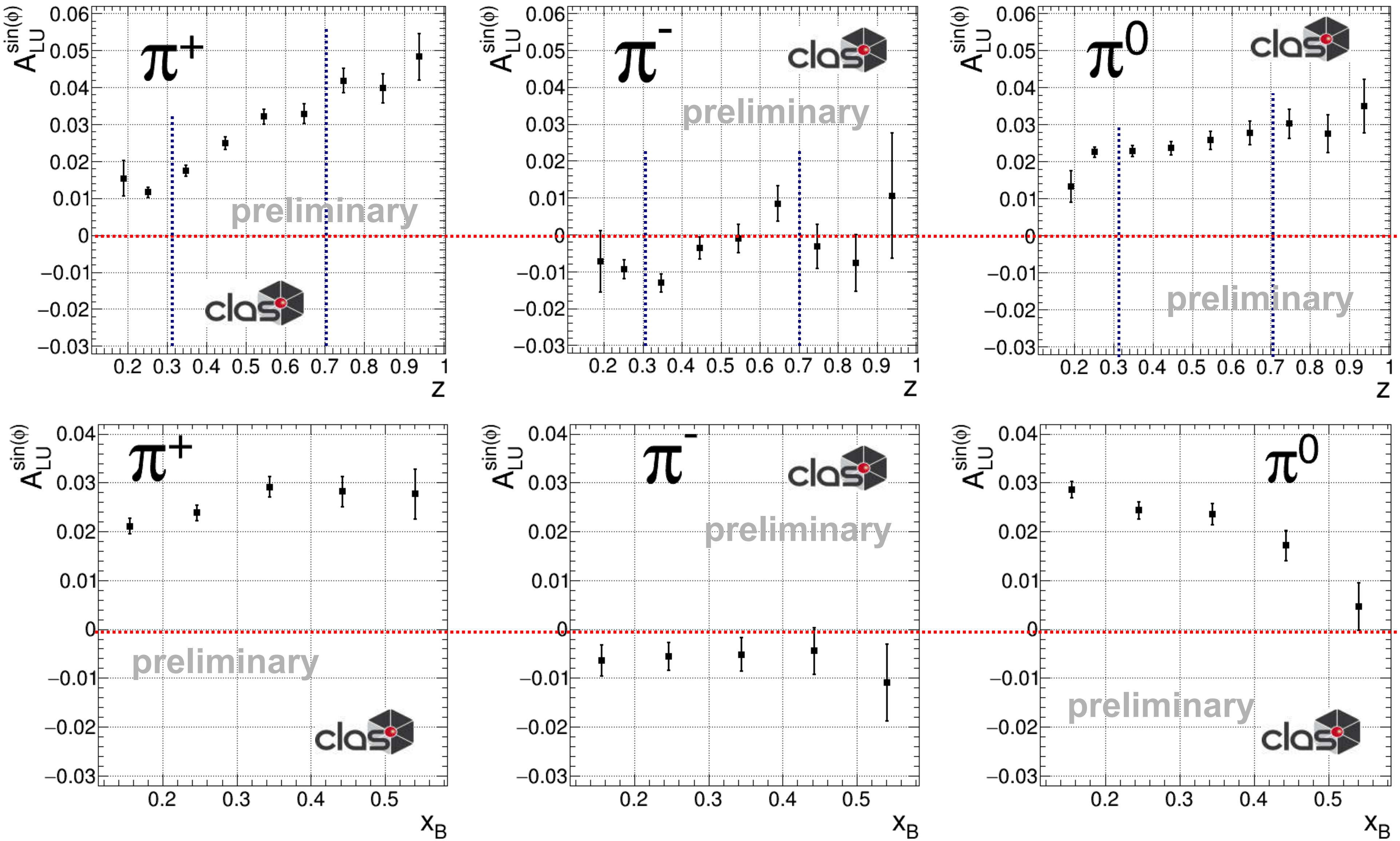
π^0



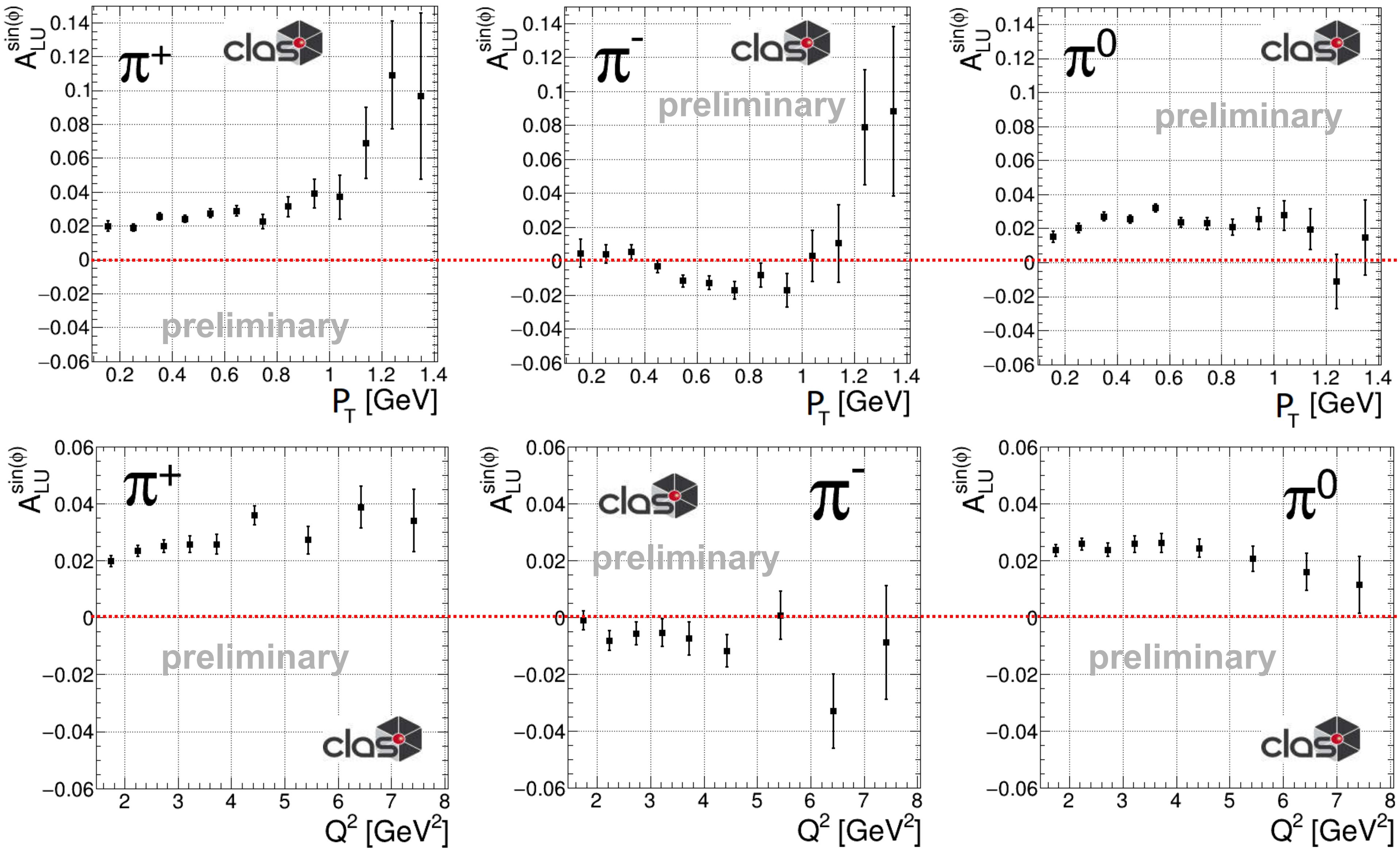
→ Clear sinoid shape can be observed, according to $A_{LU}^{\sin\varphi} \sin\varphi$

→ No systematics, no kinematic binning

$A_{LU}^{\sin(\varphi)}$ for a **z** and $\mathbf{x_B}$ binning



$A_{LU}^{\sin(\varphi)}$ for a $\mathbf{p_T}$ and $\mathbf{Q^2}$ binning



The figures on multidimensional binning and the comparison to other experiments (slides 11 -23) are not officially approved by the collaboration yet, and therefore not available online.

Conclusion and Outlook

- CLAS12 enables the extraction of SIDIS pion BSA moments with high accuracy in an extended kinematic range
- Qualitative agreement with previous experiments
- The presented analysis is based on only close to 2 % of the approved RG-A beamtime
- 20 % of RG-A will be available in a few month

  → The behaviour at large Q^2 and P_T values will be studied

  → Systematic effects will be investigated

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