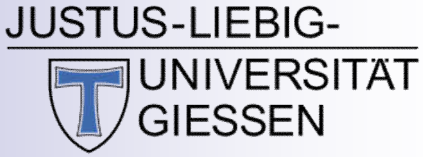
Backward-Angle (u-channel) Pysics Workshop

September 21, 2020

Large Angle Beam-Spin-Asymmetry of pions at CLAS



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Introduction

Focus of this talk:

Extraction of beam-spin asymmetries from the hard exclusive π^+ channel off protons in a wide range of kinematics

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accepted by PRL, available online soon

https://journals.aps.org/prl/accepted/9007fY83D271317096987c814a1b9bccbe706247e

https://arxiv.org/abs/2007.15677

- Outlook on opportunities with CLAS12

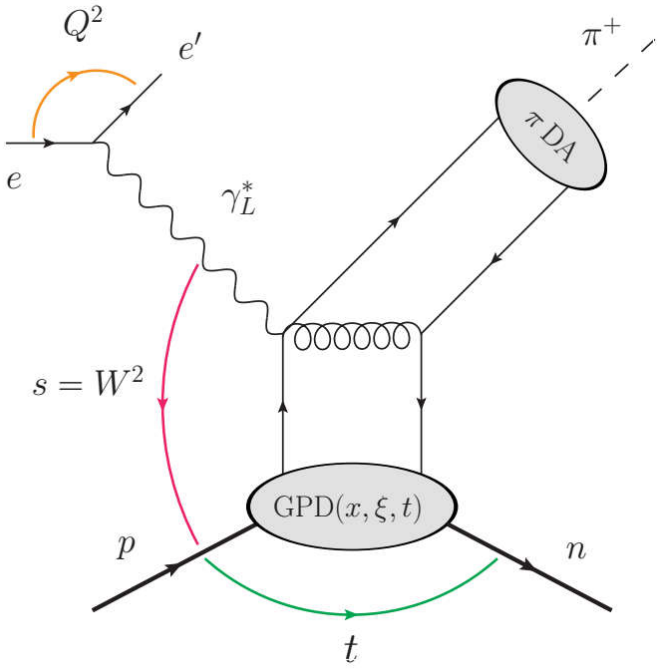
Theory collaborators: K. Semenov-Tian-Shansky, B. Pire, L. Szymanowski

Comparison of t and u channel physics

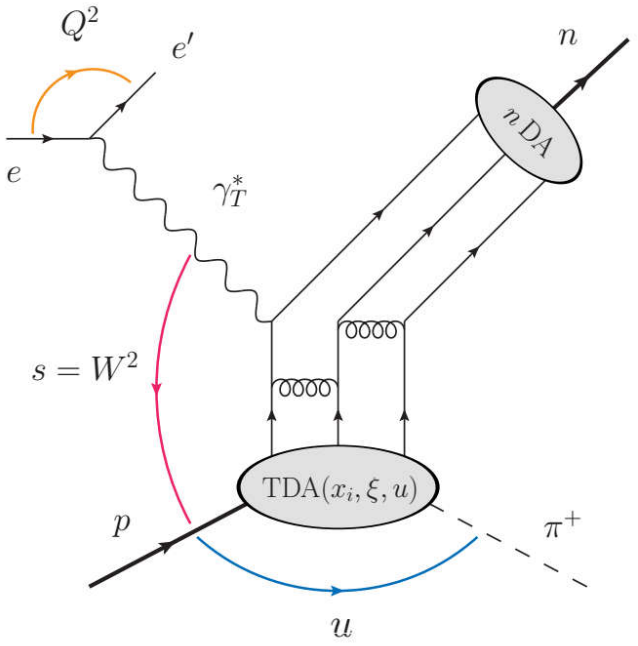
colinear factorization theorem

GPD based description
large Q^2 and s
small t channel contribution

TDA based description
large Q^2 and s
small u channel contribution

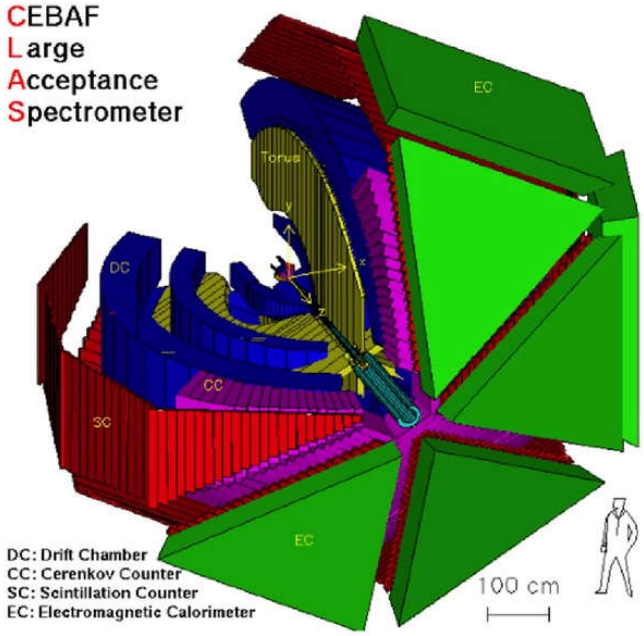


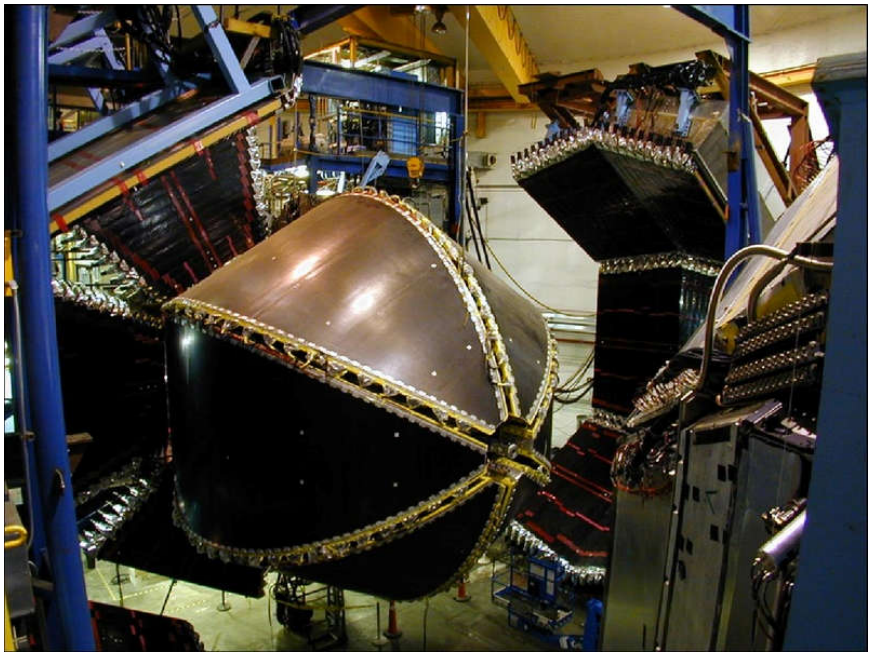
meson in forward region



meson in backward region

Backward π electroproduction with CLAS at JLAB





- CLAS (e16 + e1f run period)
- 5.5, 5.75 GeV longitudinally polarized electron beam
- unpolarized hydrogen target

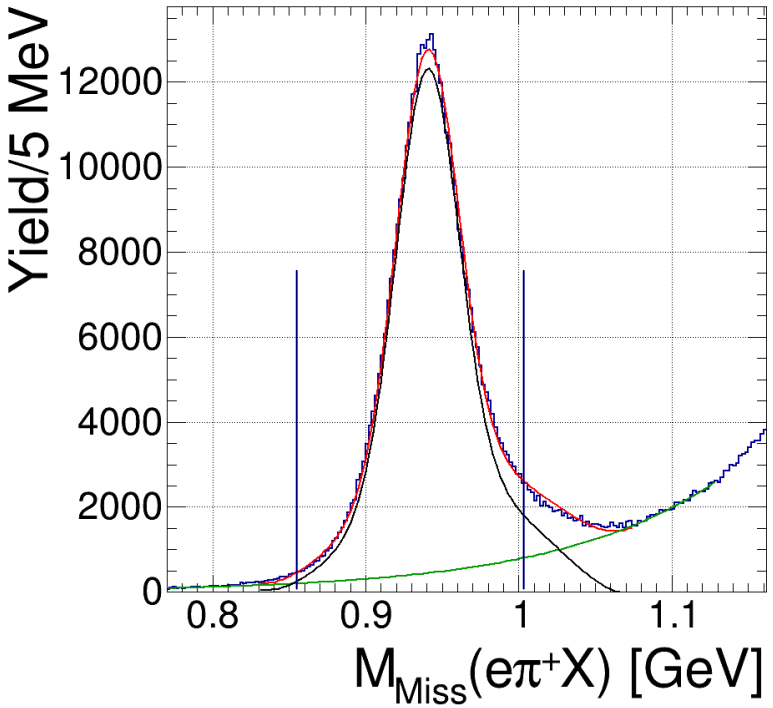
- **Electron ID** based on electromagnetic calorimeter and Cherenkov counters
- **π ID** based on a maximum likelyhood particle selection from TOF based β vs p correlation

CLAS π^+ study

$$ep \rightarrow en\pi^+$$

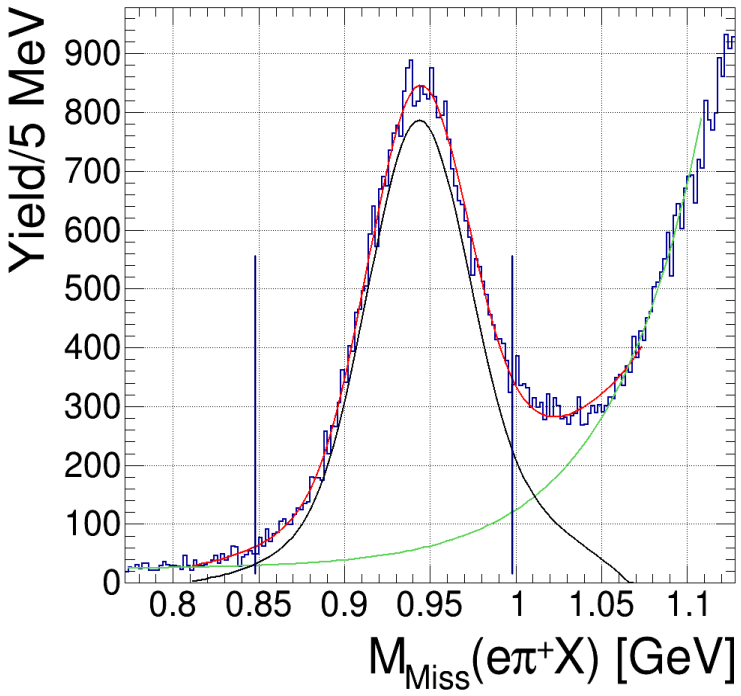
forward

-t < 1.5 GeV² cos(θ) > 0

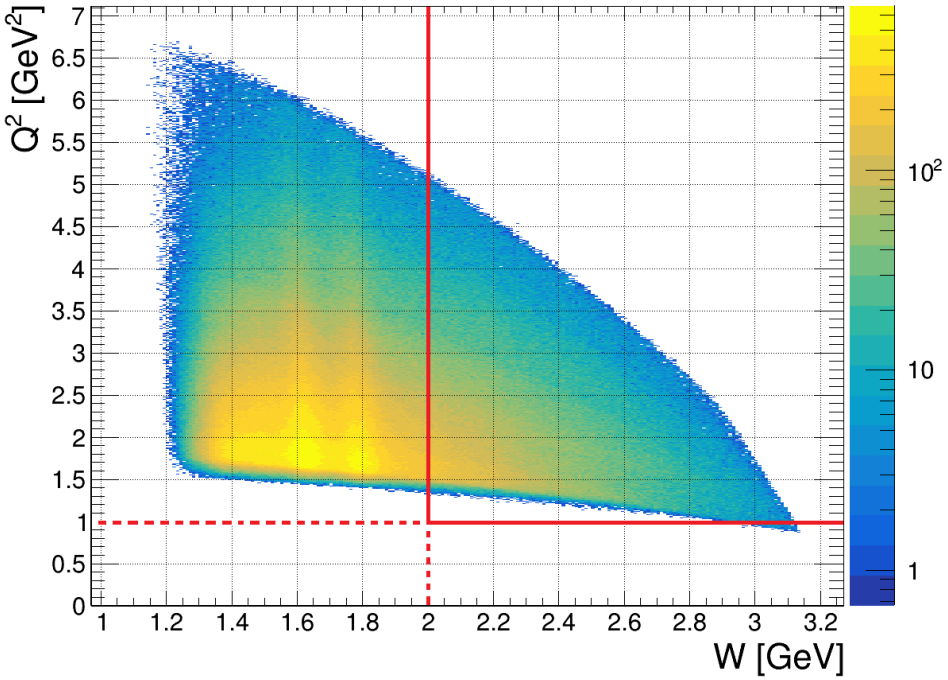


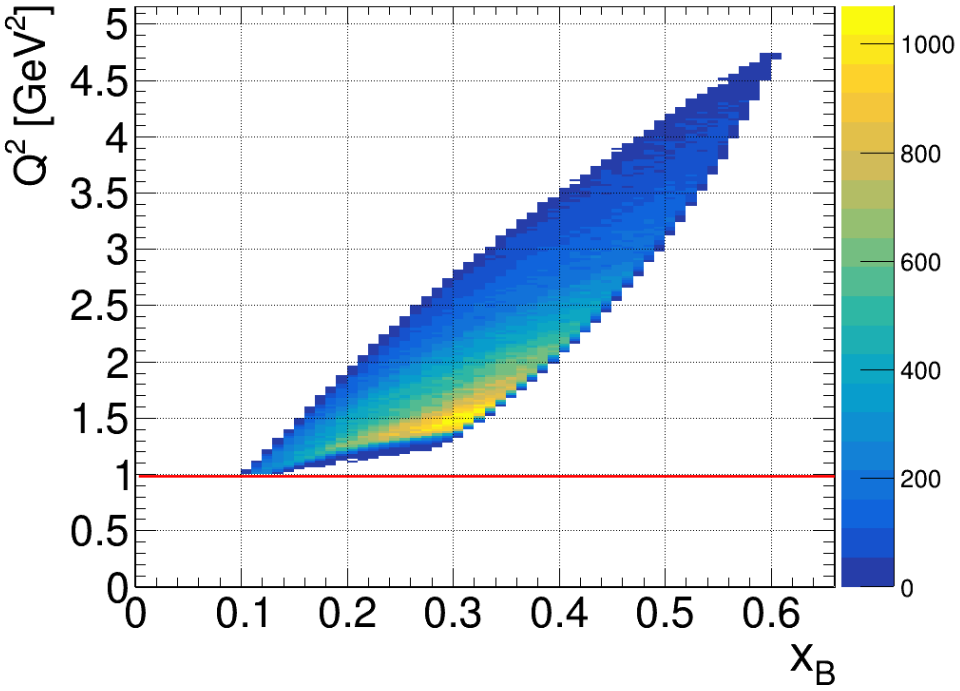
backward

-u < 2.0 GeV² cos(θ) < 0



Kinematics accessible with CLAS (E_b = 5.5 GeV)

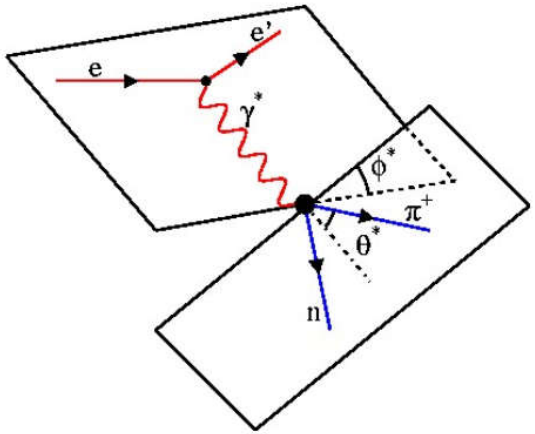




DIS cuts: W > 2 GeV $Q^2 > 1$ GeV^2

Beam spin asymmetry in forward and backward direction

$$ep \rightarrow en\pi^+$$



Cross section **(longitudinally pol. beam and unpol. target):**

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

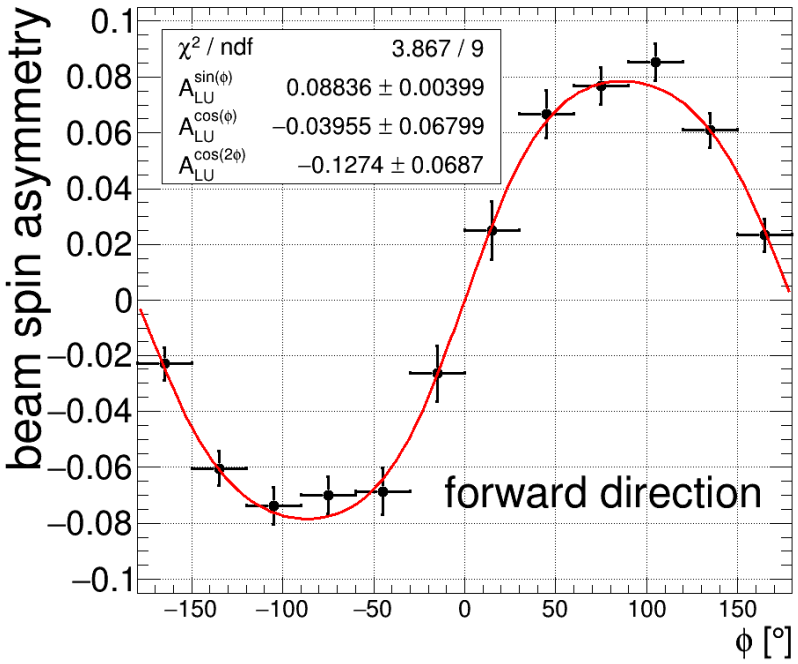
$$BSA(t,\phi,x_B,Q^2) = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{A_{LU}^{\sin\phi}\sin\phi}{1 + A_{UU}^{\cos\phi}\cos\phi + A_{UU}^{\cos 2\phi}\cos 2\phi}$$

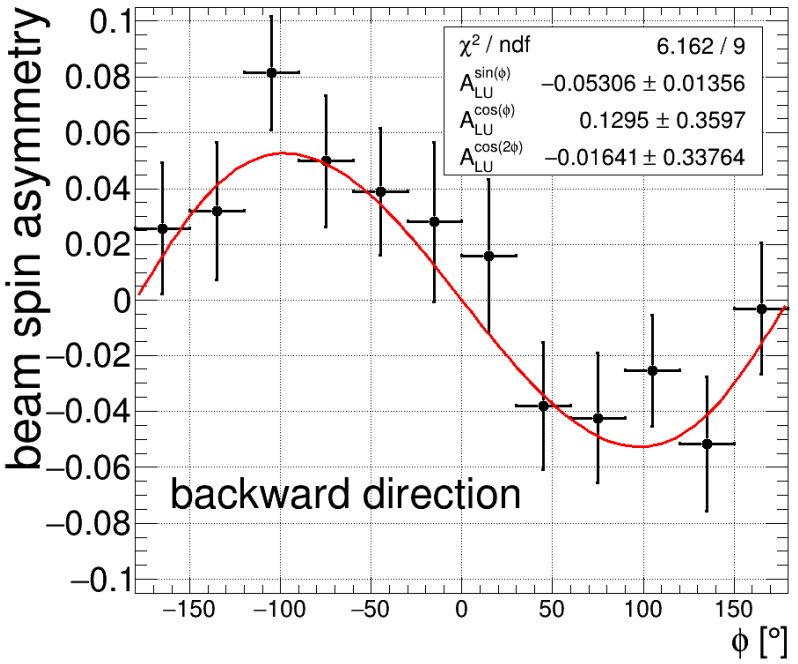
$$A_{LU}^{\sin\phi} = \frac{\sqrt{2\epsilon(1-\epsilon)}\,\sigma_{LT'}}{\sigma_T + \epsilon\sigma_L}$$

Beam spin asymmetry in forward and backward direction

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

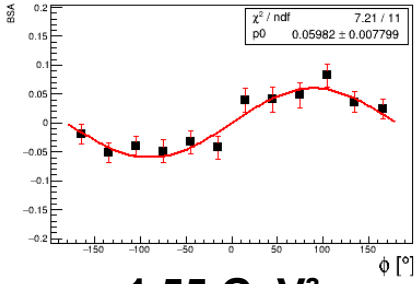
P_e = 75 % : average e^- beam polarisation



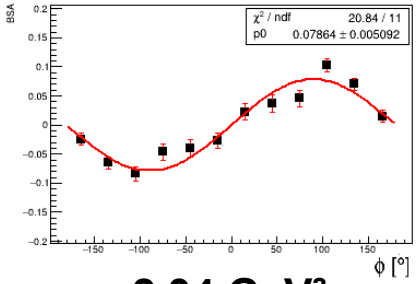


BSA for different -t bins

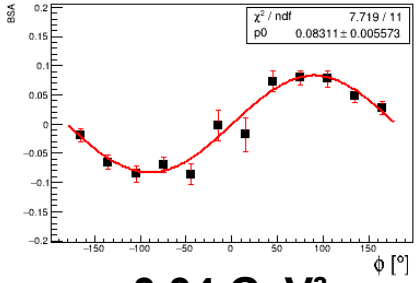
0.11 GeV²



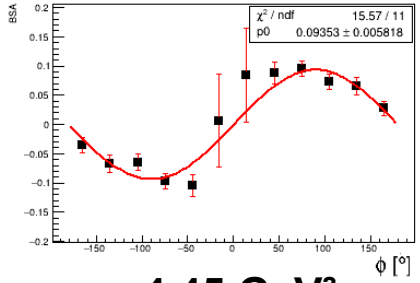
0.26 GeV²



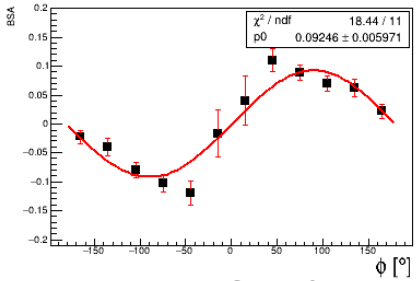
0.56 GeV²



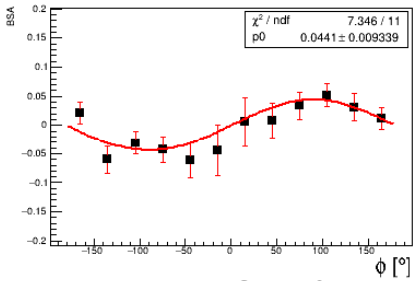
0.96 GeV²



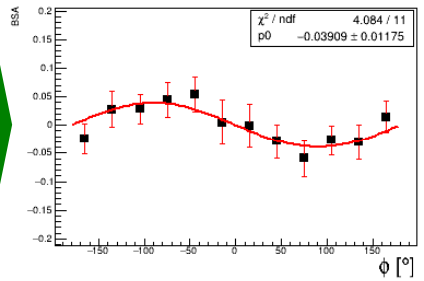
1.55 GeV²



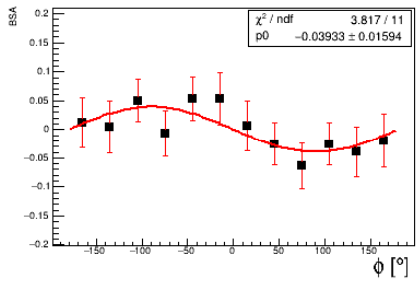
2.34 GeV²



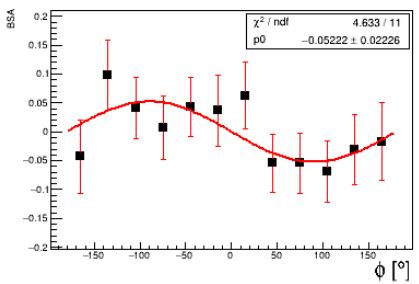
3.34 GeV²



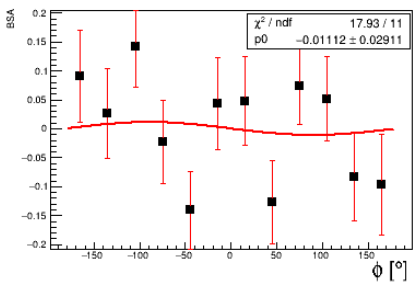
4.45 GeV²



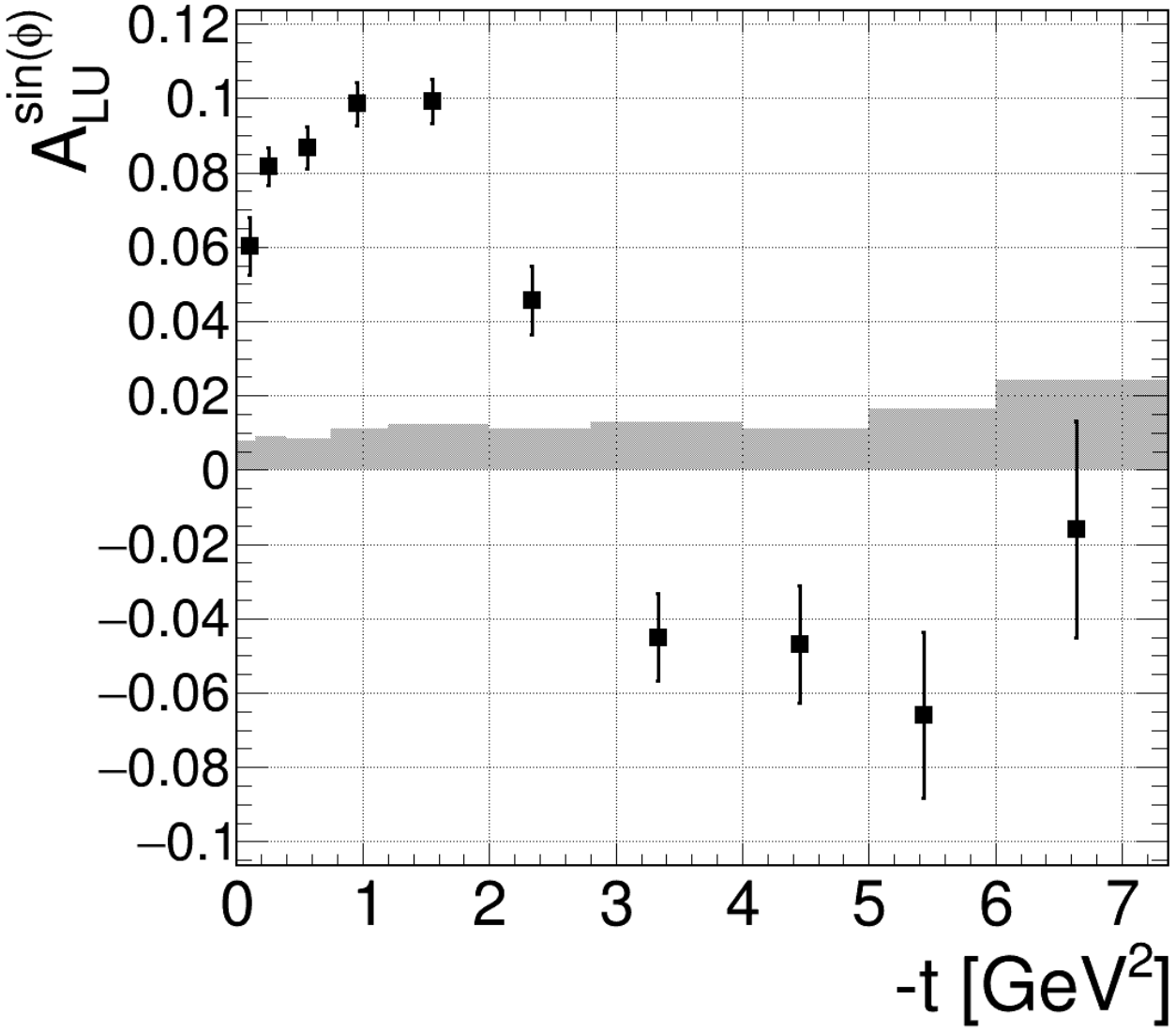
5.44 GeV²



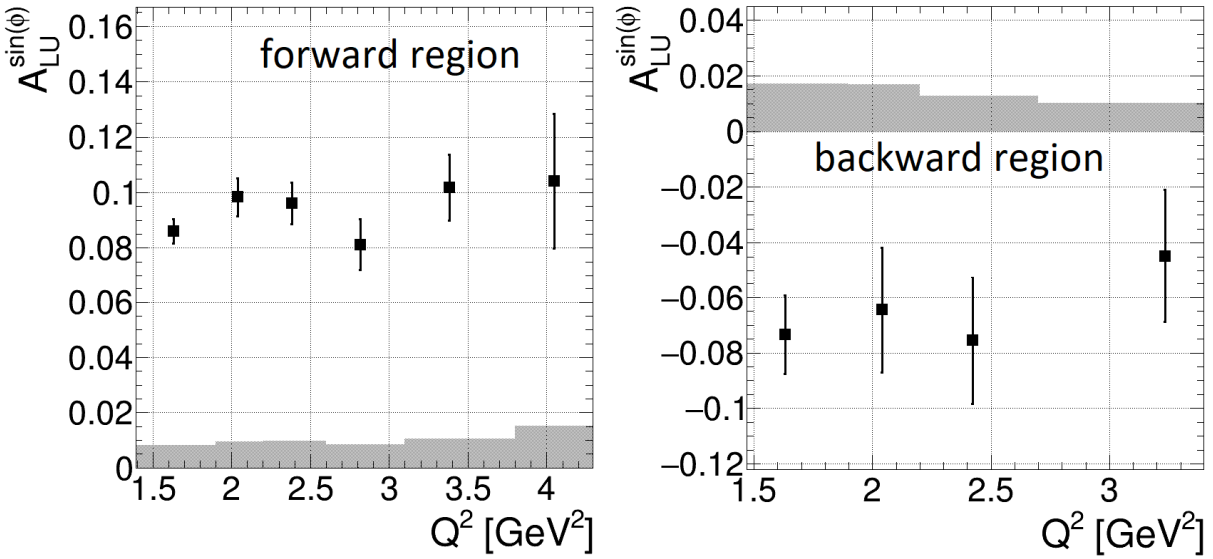
6.64 GeV²

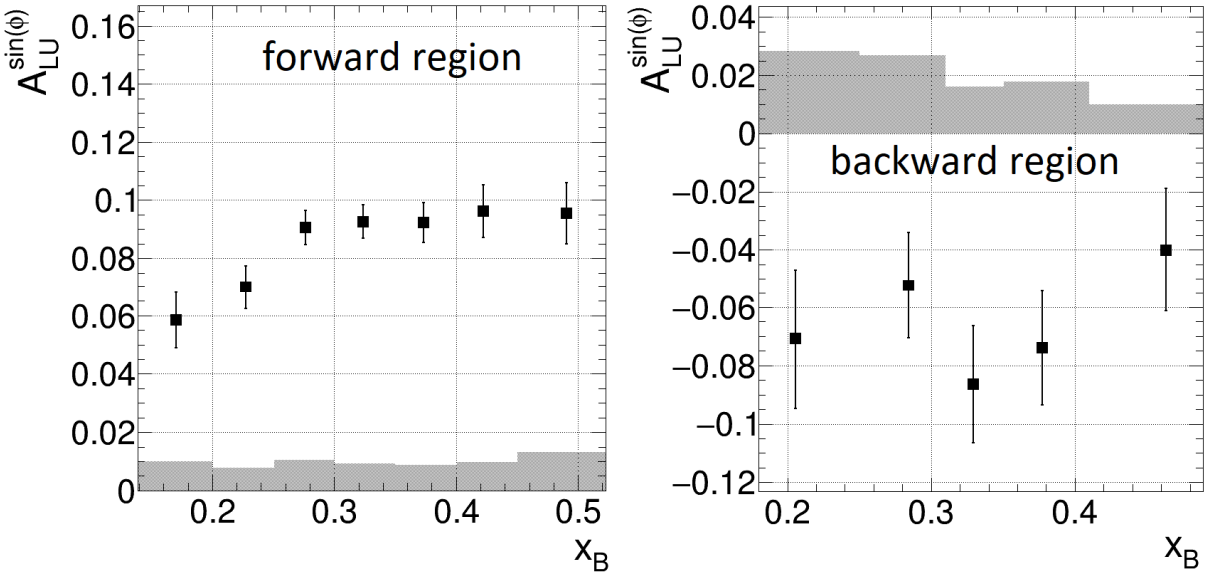


-t dependence of $A_{LU}^{\sin(\phi)}$



Q^2 and x_B dependence of $A_{LU}^{\sin(\phi)}$





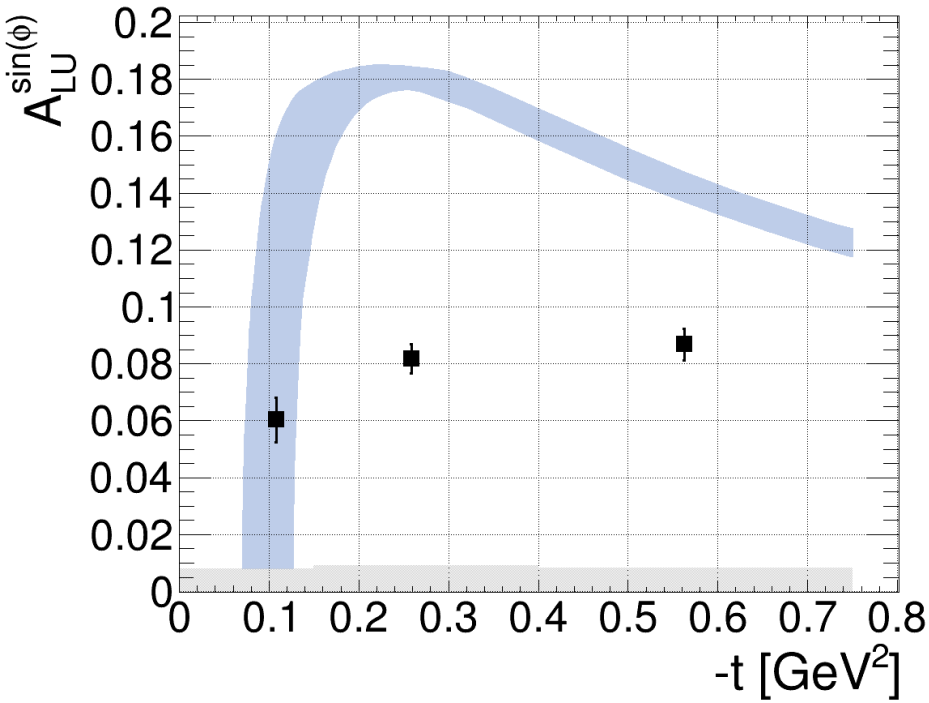
Theoretical description

Forward direction:

-t < 0.75 GeV² (-t/Q² ≈ 0.25)

➔ Leading twist GPD framework

• GPD-based model by Goloskokov and Kroll



$$A_{LU}^{\sin\phi} \sim \frac{\sigma_{LT'}}{\sigma_T + \varepsilon\sigma_L}$$

$$\sigma_{LT'} \sim Im\left[\langle\overline{E}_{T-eff}\rangle^*\langle\widetilde{H}_{eff}\rangle + \langle H_{T-eff}\rangle^*\langle\widetilde{E}_{eff}\rangle\right]$$

$$\widetilde{E}_{eff} = \widetilde{E} + pole\ term$$

$$\widetilde{H}_{eff} = \widetilde{H} + \frac{\xi^2}{1-\xi^2}\widetilde{E}_{eff}$$

➔ Discrepancy caused by the interplay between the pion pole term and the poorly known GPDs H_T and $\overline{E}_T$

Theoretical description

Backward direction:

$$\sigma_{LT'} \sim \mathrm{Im}\left[\langle H_i^{\mathrm{tw3}}\phi_j^{\mathrm{tw3}}\rangle\left(\langle H_i^{\mathrm{tw4}}\phi_j^{\mathrm{tw3}}\rangle + \langle H_i^{\mathrm{tw3}}\phi_j^{\mathrm{tw4}}\rangle\right)^*\right]$$

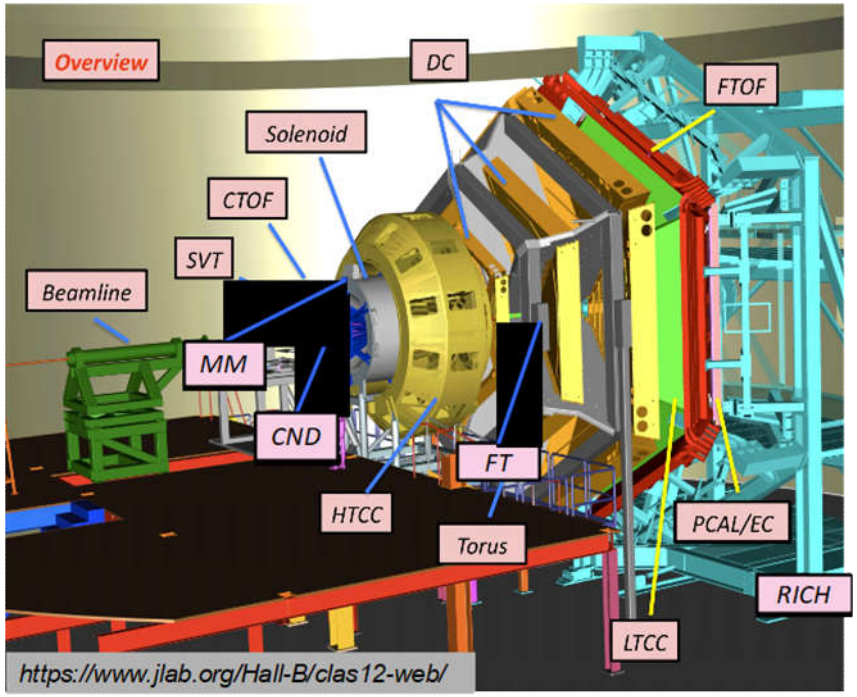
Interference between leading twist transverse amplitudes
→ twist-3 πN TDAs (H^{tw3}) and nucleon DAs (ϕ^{tw3})

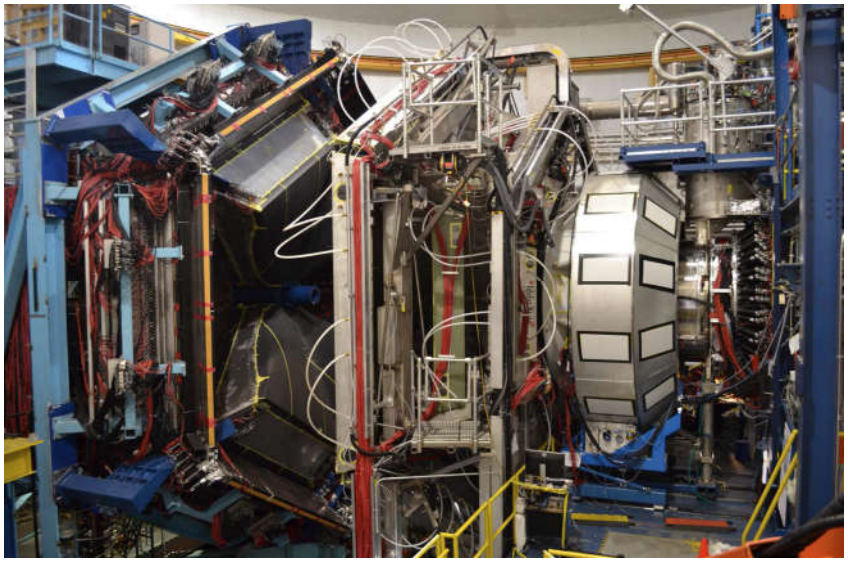
and next leading sub-process longitudinal amplitudes
→ twist-4 TDAs (H^{tw4}) and DAs (ϕ^{tw4})

➔ Complete theoretical study of the twist-4 longitudinal amplitudes not yet available

Open questions: Which particular twist-4 πN TDAs and DAs will contribute?
What kind of phenomenological models can be implemented?

Outlook on opportunities with CLAS12





RG-A: Data recorded during 2018 and 2019

➔ 10.6 GeV polarized electron beam ➔ liquid H_2 target

➔ Other run groups with different beam energies, a deuterium target and polarized targets are currently taking data or are scheduled to take data

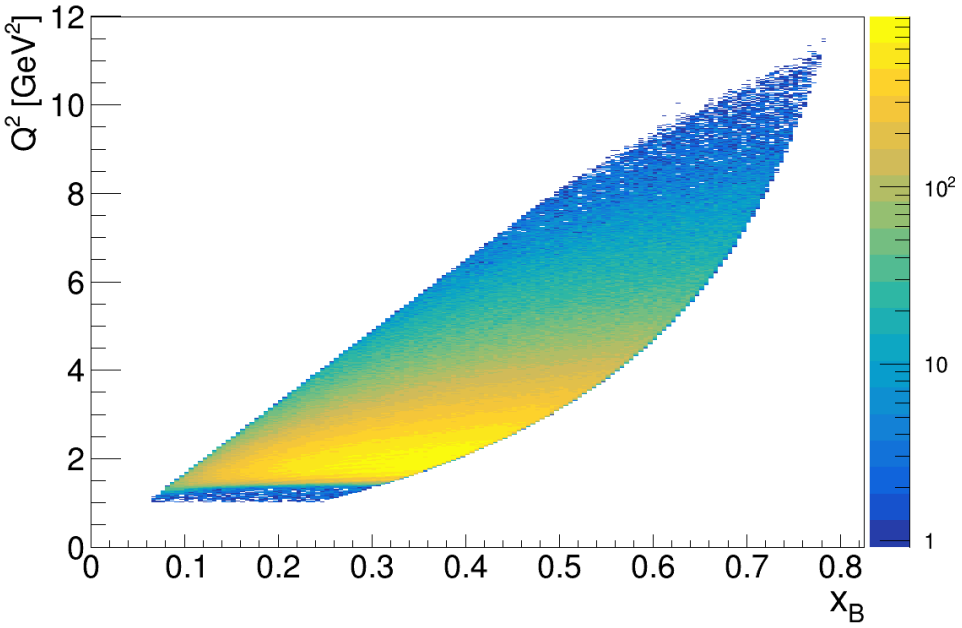
Opportunities with CLAS12

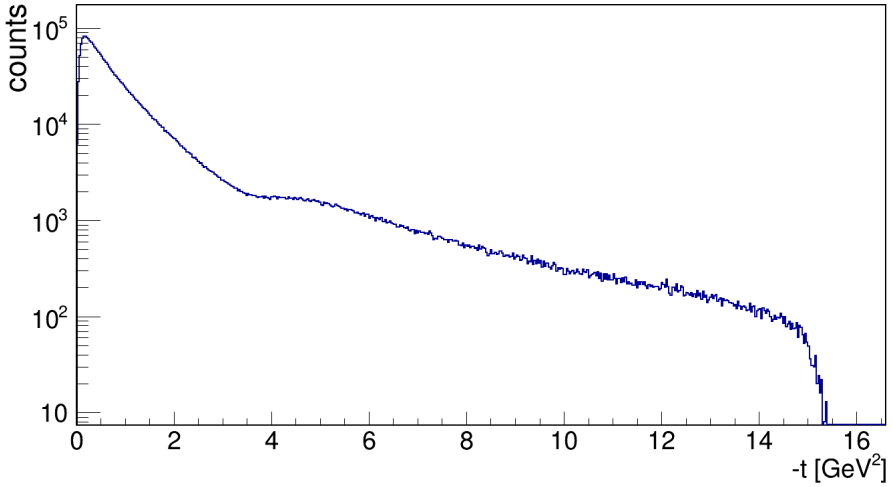
Examples for the feasability of exclsuive meson production
in the different kinematic regimes:

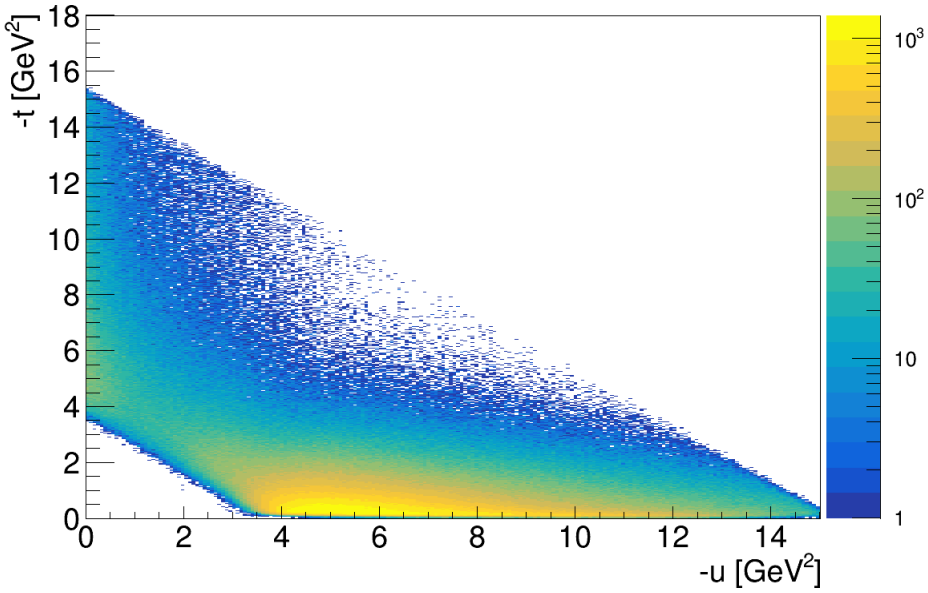
	forward	backward	
e p π^0	✓	○	only via missing mass
e p η	✓	○	only via missing mass
e n π^+	✓	✓	
e p ω/ρ	✓	✓	
e p ϕ	✓	[✓]	

CLAS12 coverage of the t and u channel

$$ep \rightarrow e'\pi^{+}(n)$$







Summary and Outlook

- $A_{LU}^{\sin(\phi)}$ moment from the hard exclusive π^+ channel has been extracted for the first time over a large range of kinematics with CLAS.

- The results show a clear sign change from forward to backward angles, which may indicate a transition from the GPD to the TDA regime.

- CLAS 12 enables the study of different hard exclusive channels over a wide range of kinematics.