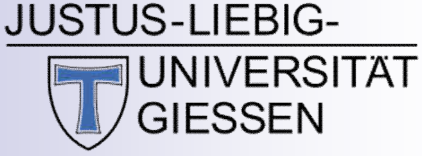
Prospects for extraction of GPDs
from global fits of current and future data

January 22 - 25, 2019

Beam spin asymmetry from hard exclsuive pion electro-production in the deeply virtual region with CLAS and CLAS12 at JLAB



Stefan Diehl

University of Connecticut

Justus Liebig University Giessen

Jefferson Loaboratory

Newport News

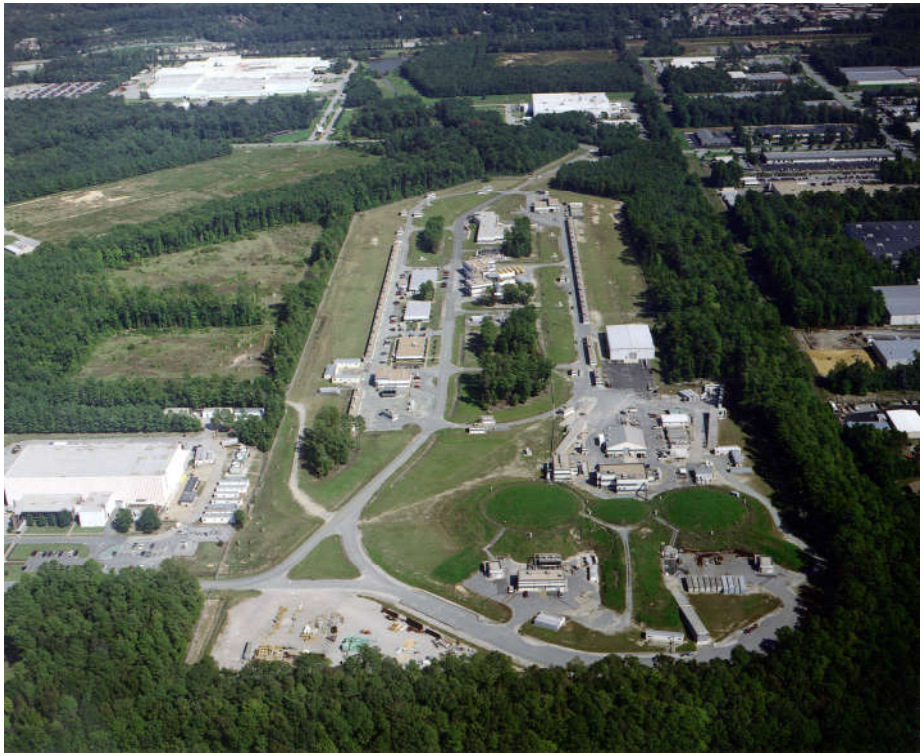
Virginia, USA

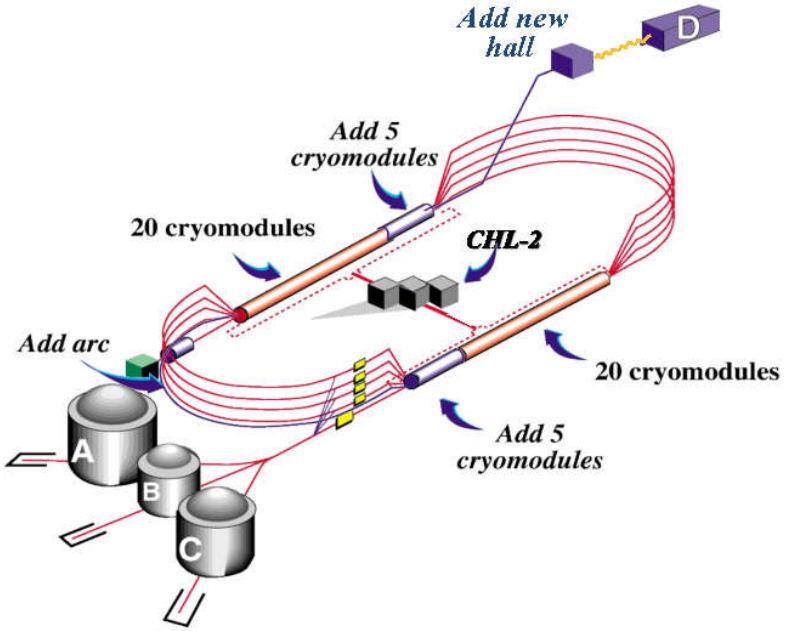
until 2014:

6 GeV polarized electron beam
3 experimental halls

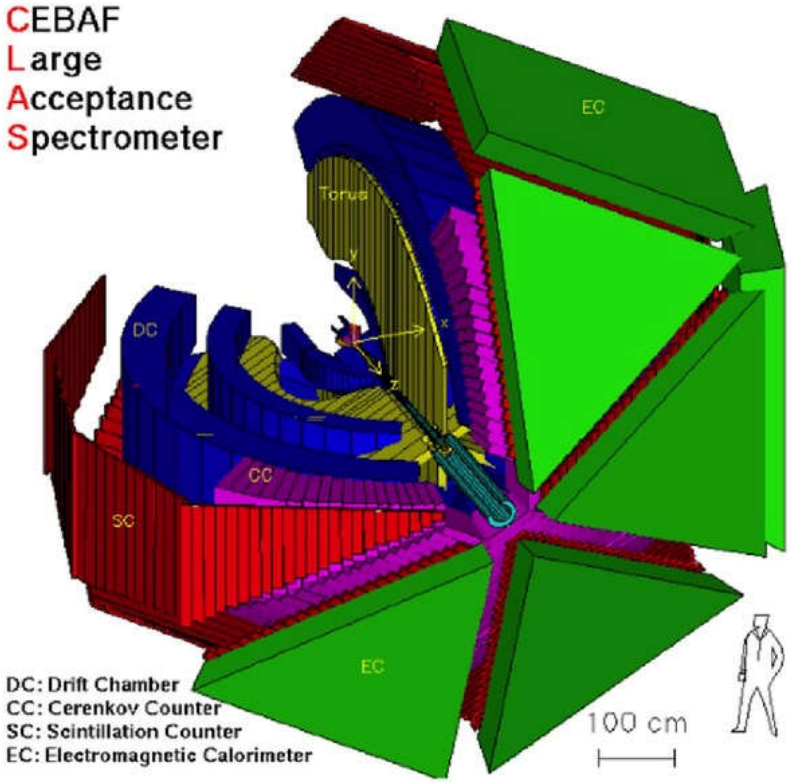
since 2017:

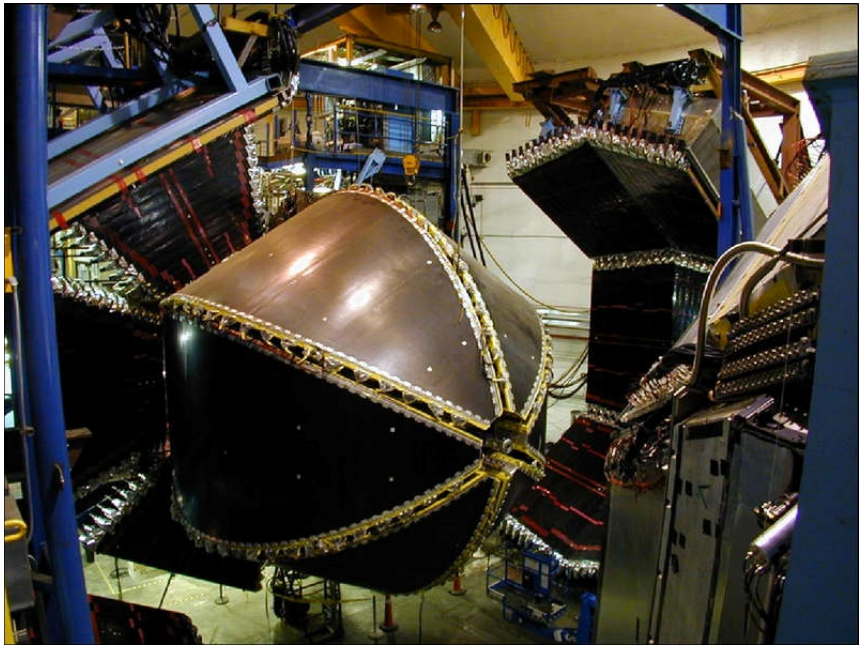
10.6 GeV polarized electron beam
4 experimental halls





Hall B until 2014: CLAS detector





Hall B since 2017: CLAS 12

(constructed 2014 – 2017)

Forward Detector:

- TORUS magnet
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter/ RICH detector
- Forward Time-of-Flight
- E.M. calorimeter

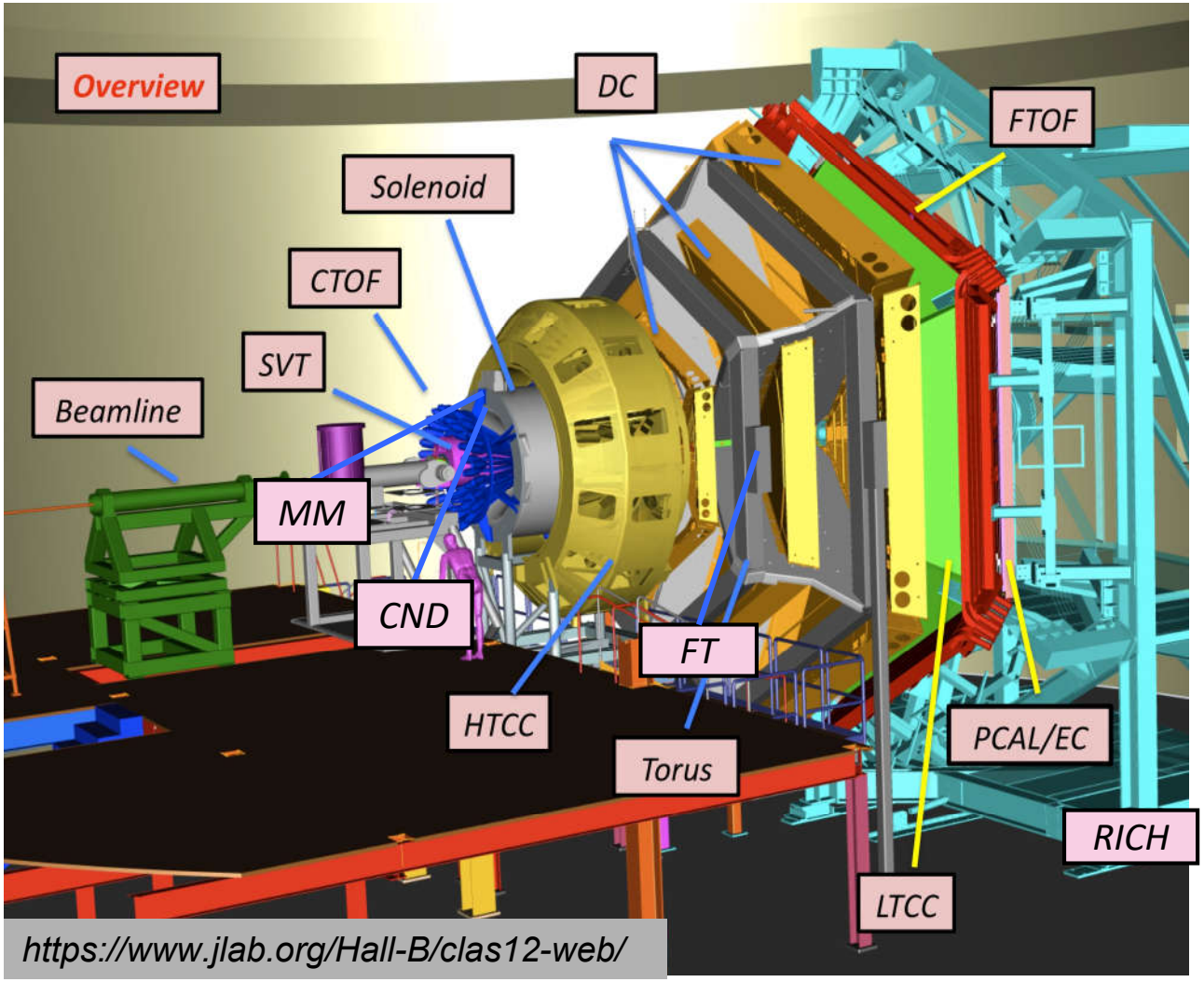
Central Detector:

- SOLENOID magnet
- Micromegas Tracker
- Barrel Silicon Tracker
- Central Time-of-Flight
- Neutron detector

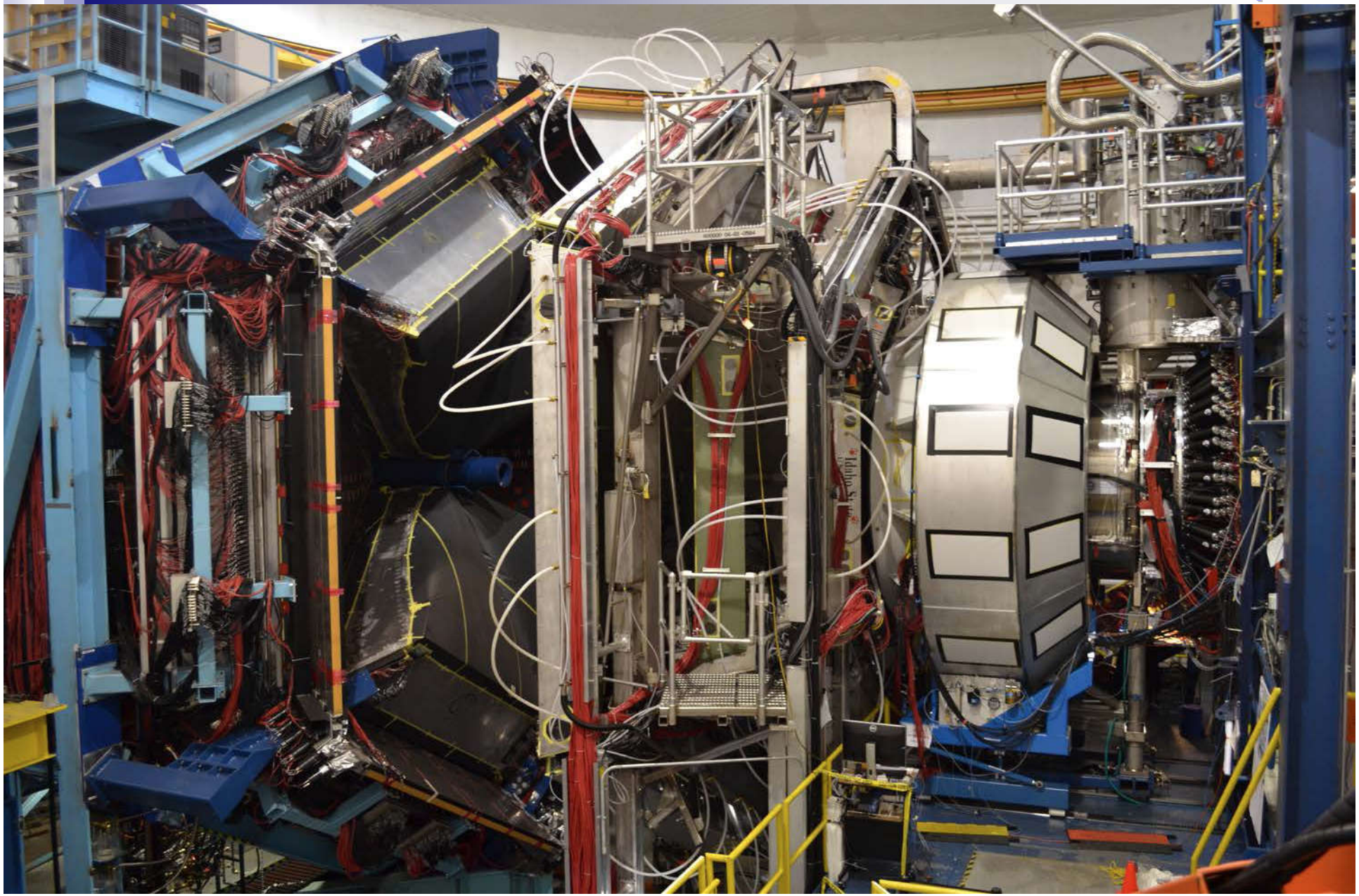
Extended Setup:

- Forward Tagger

~100,000 readout channels



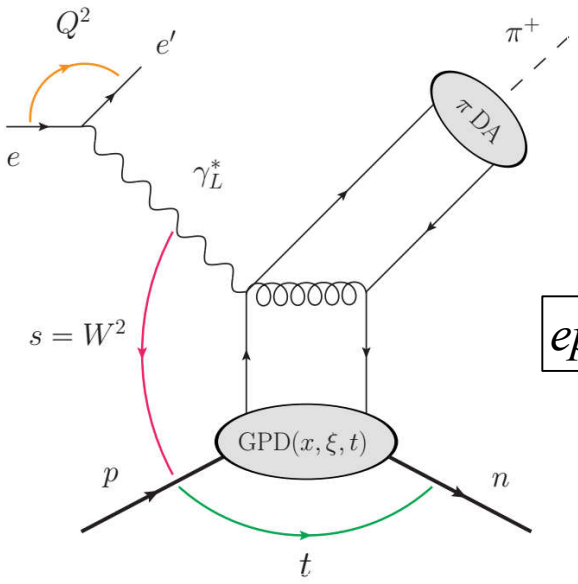
https://www.jlab.org/Hall-B/clas12-web/



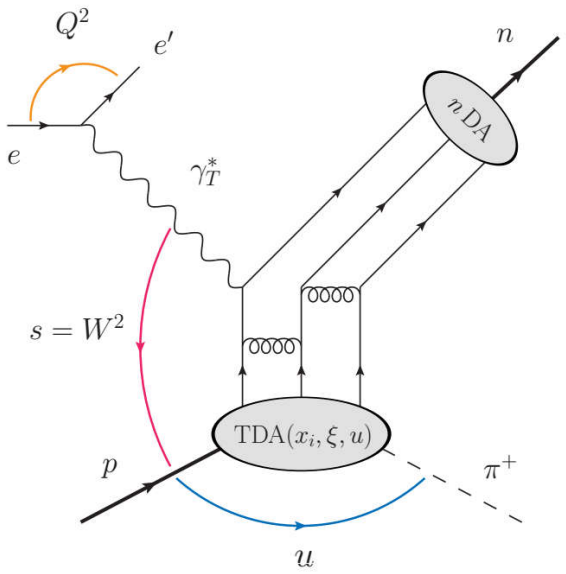
Extraction of $A_{LU}^{\sin(\varphi)}$ from the hard exclusive π^+ channel

- CLAS at 5.5 GeV (e1f run period)
- longitudinally polarized electron beam
- unpolarized hydrogen target

Physics motivation



$ep \rightarrow en\pi^+$



forward region

small t / large u channel contribution

backward region

small u / large t channel contribution

Theory: Common features between baryon to meson TDAs, nucleon DAs and GPDs

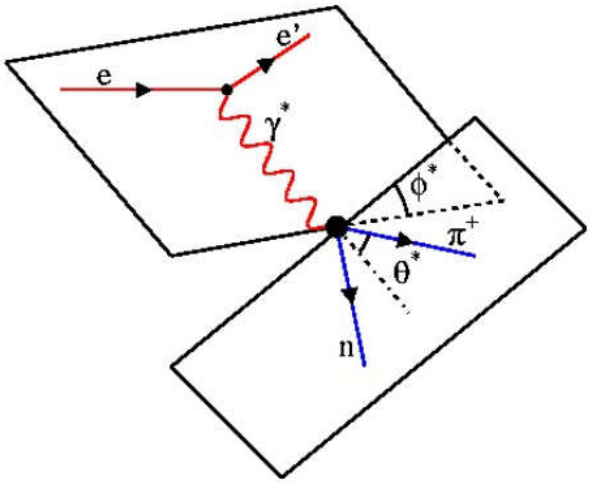
→ Partonic correlations inside a nucleon with the momentum distribution of the nucleon's baryon density

→ Similar to GPDs, a Fourier transformed TDA ($\Delta_T \rightarrow \mathbf{b}$) allows an impact-parameter interpretation for TDAs in the transverse plane

Aim: Study the transition from the GPD to the TDA formalism

Hard exclusive π^+ electroproduction

$$ep \to en\pi^+$$



Cross section:

$$\frac{d^4\sigma}{dQ^2 dx_B d\phi dt} \sim \sigma_T + \varepsilon_L \sigma_L + \varepsilon \cdot \sigma_{TT} \cdot \cos(2\phi) + \sqrt{2 \cdot \varepsilon_L \cdot (1+\varepsilon)} \cdot \sigma_{LT} \cdot \cos(\phi) + h \cdot \sqrt{2 \cdot \varepsilon_L \cdot (1-\varepsilon)} \cdot \sigma_{LT'} \cdot \sin(\phi)$$

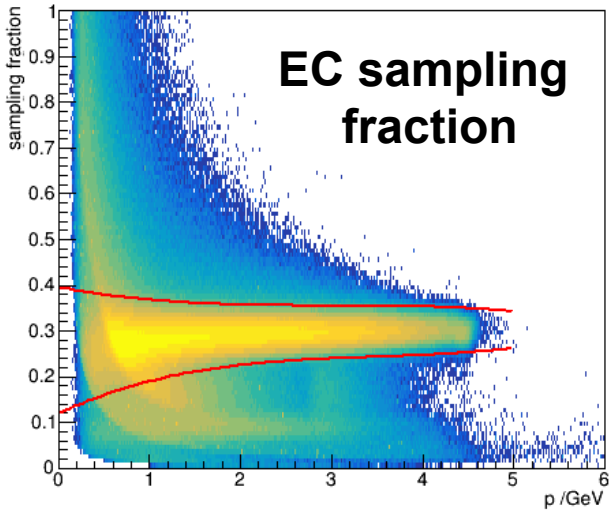
$$\Rightarrow \quad d\sigma = d\sigma_0 (1 + A_{UU}^{\cos\phi} \cos\phi + A_{UU}^{\cos 2\phi} \cos 2\phi + \lambda_e A_{LU}^{\sin\phi} \sin\phi)$$

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

Particle identification

Electron ID

→ Based on the electromagnetic calorimeter and the cherenkov counters

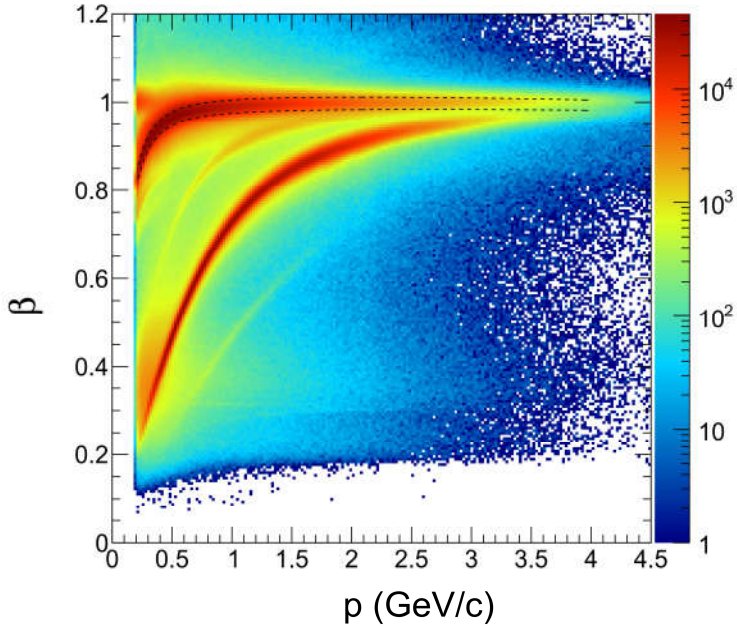


π^+ ID

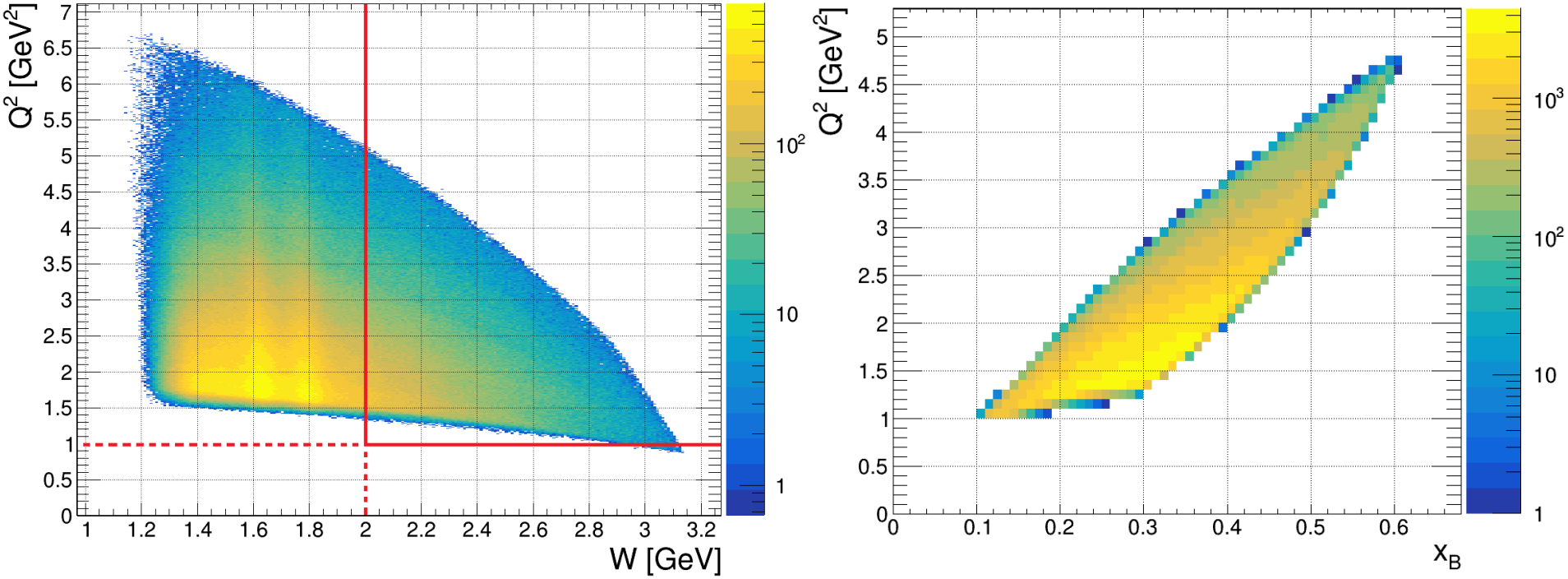
→ Positive charge

→ Fiducial cuts on the hit position in the drift chambers

→ Particle selection based on β vs p correlation



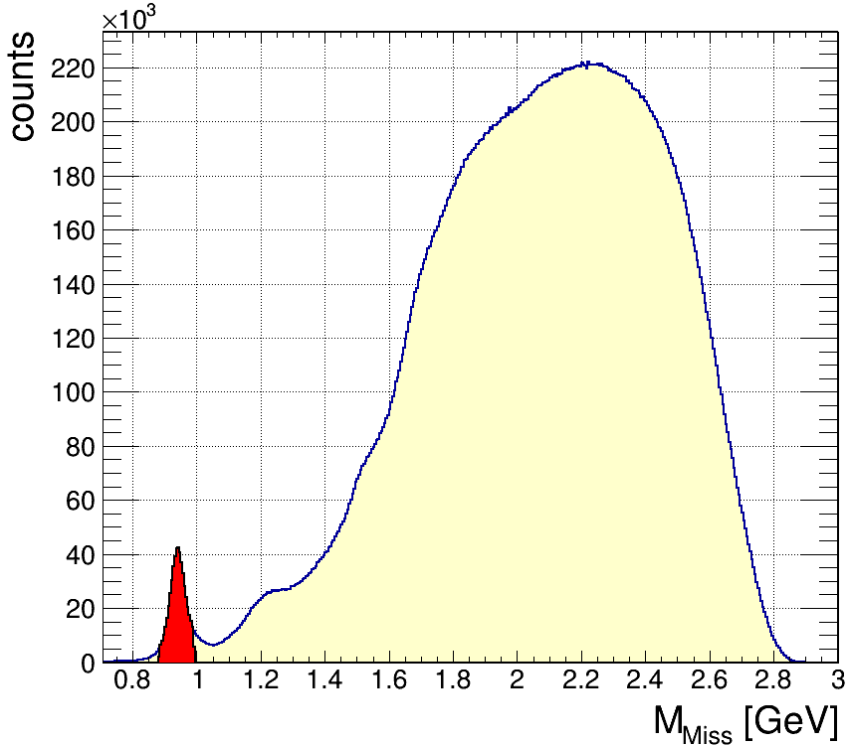
Kinematic coverage and cuts

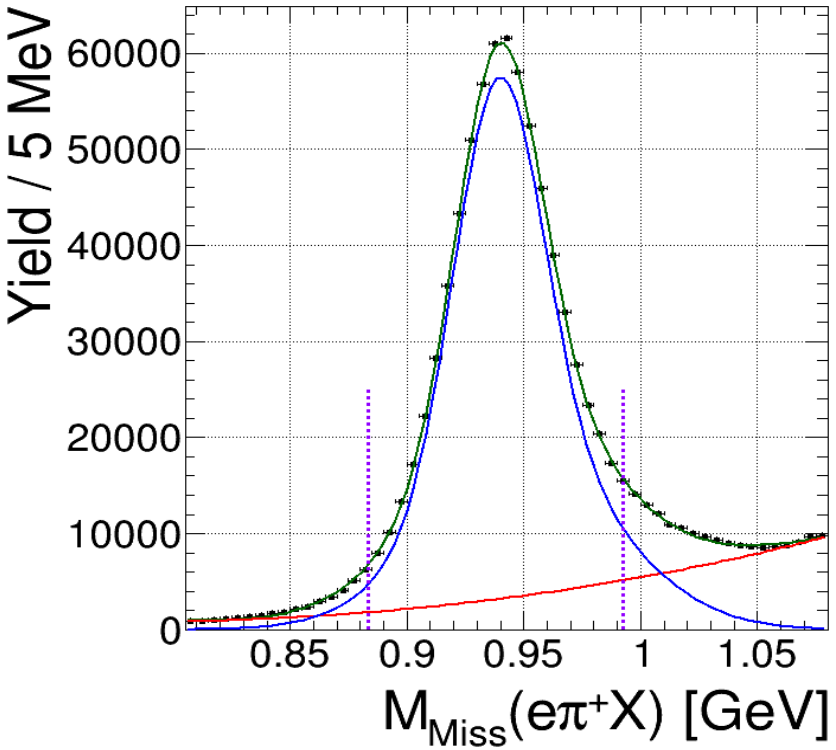


DIS cut: W > 2 GeV Q^2 > 1 GeV^2

Selection of exclusive events

e π⁺ X

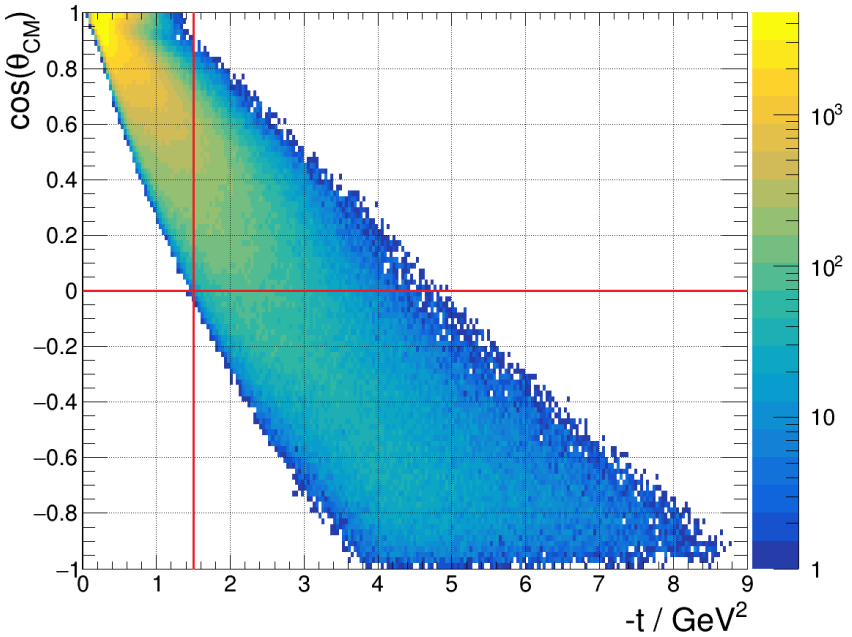




- 3 σ cut on the missing neutron peak
- ≤ 10% background

Separation of forward and backward region

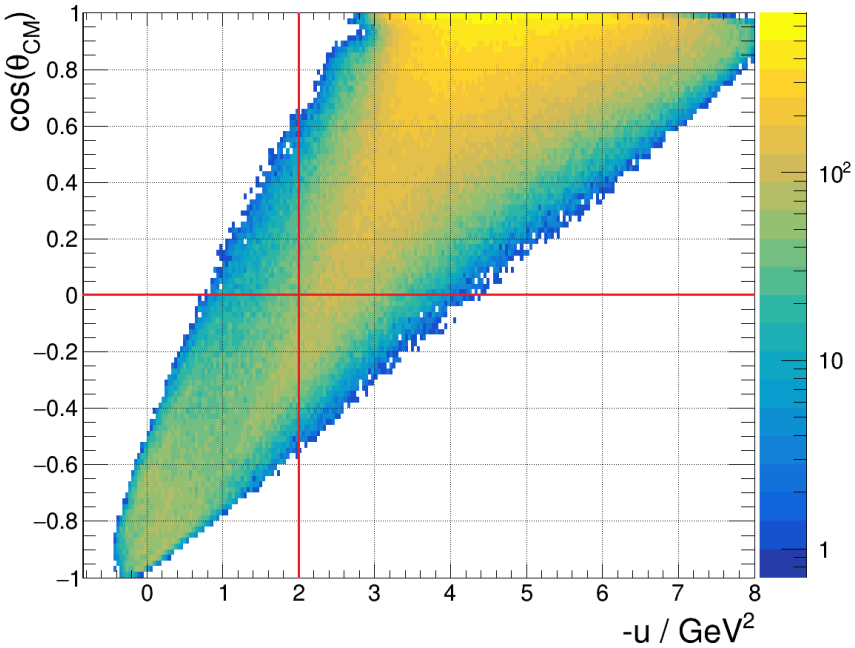
forward region „small t“



-t < 1.5 GeV²

cos(θ) > 0

backward region „small u“



-u < 2.0 GeV²

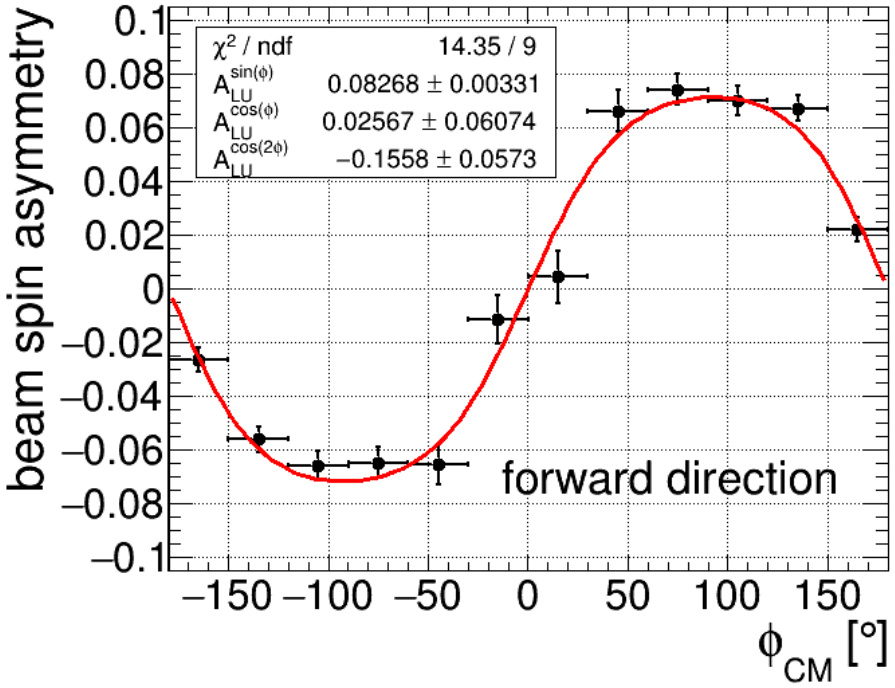
cos(θ) < 0

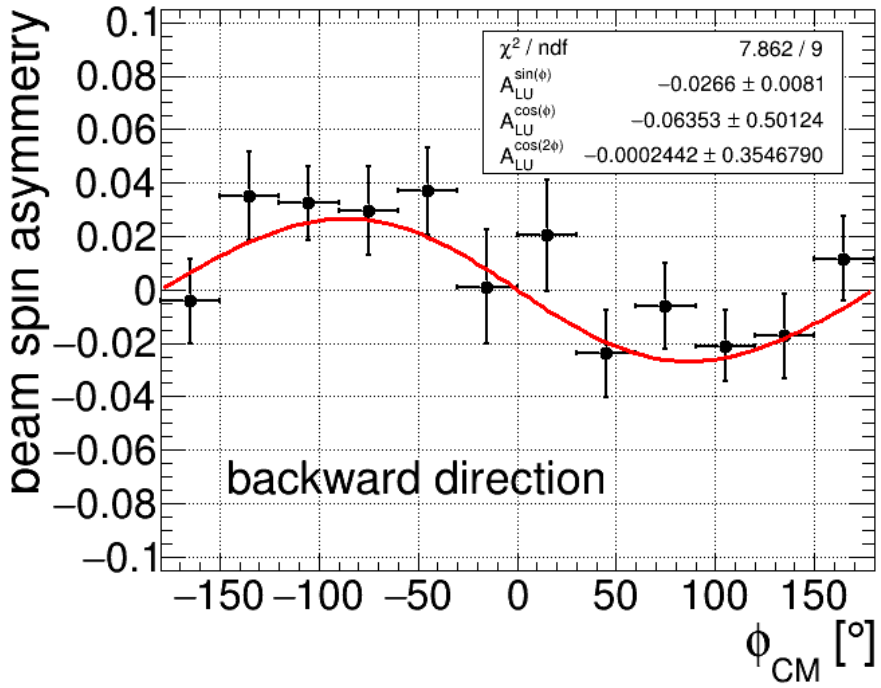
Beam spin asymmetry

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

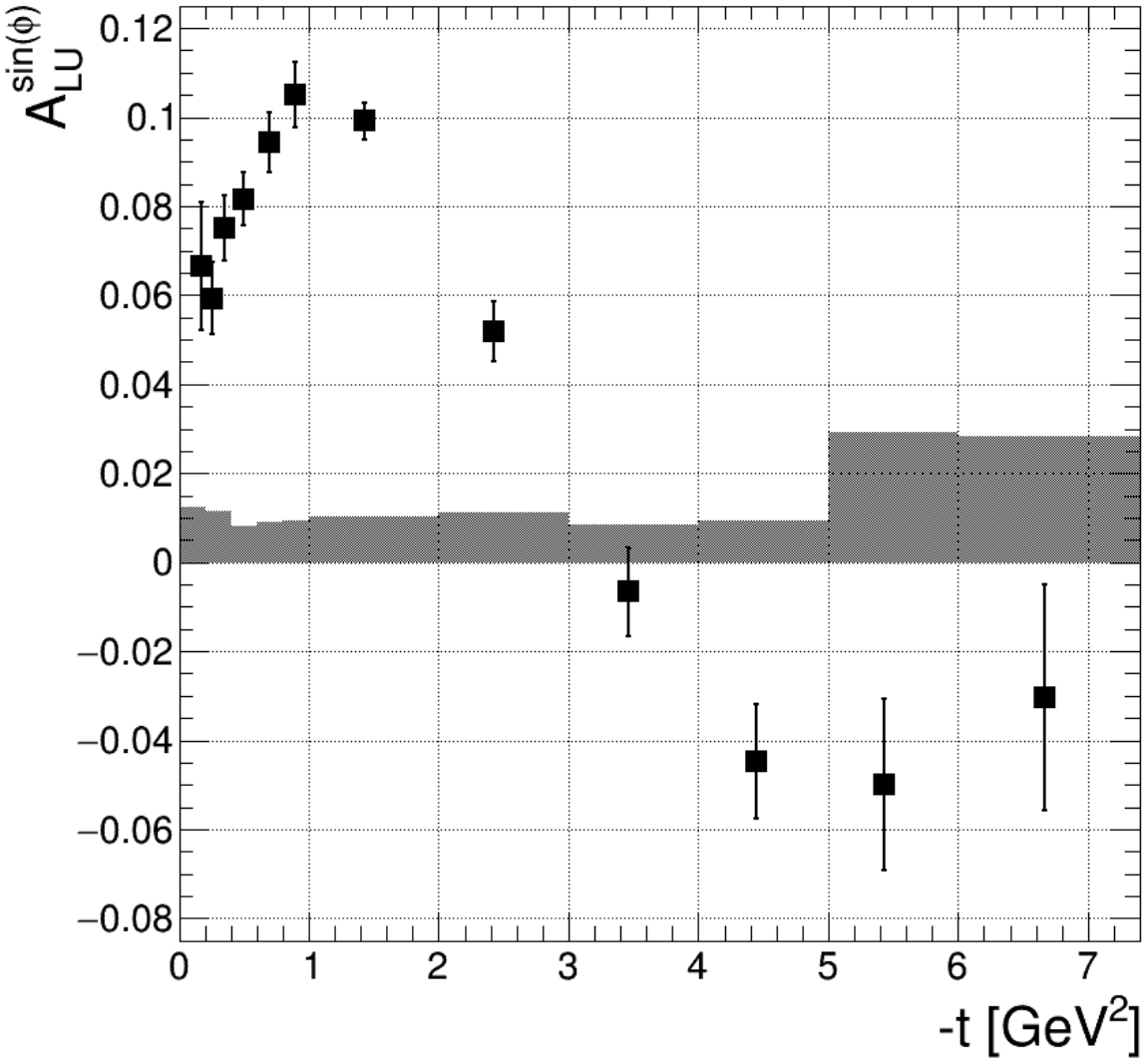
P_e = 75 % : average e^- beam polarisation

Integrated over all kinematic variables in forward / backward region:



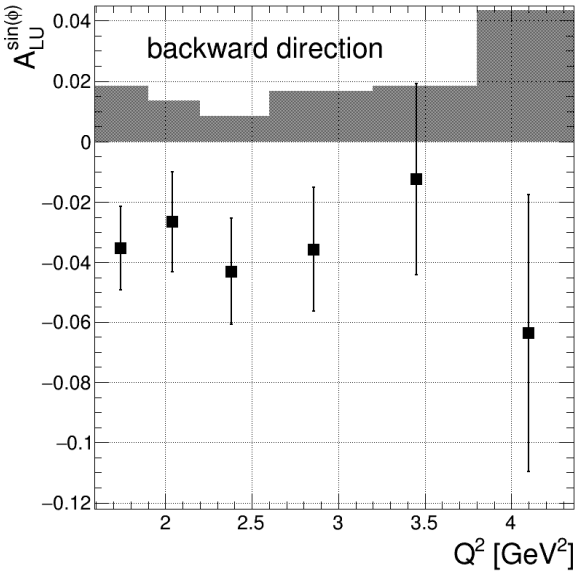


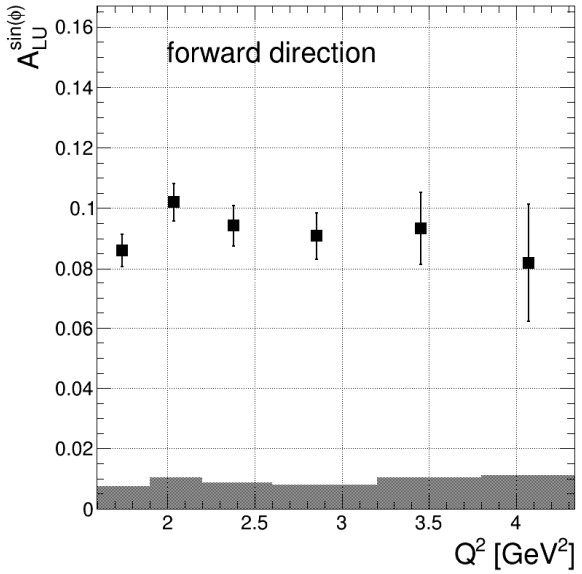
Results


$A_{LU}^{\sin(\phi)}$
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
0
1
2
3
4
5
6
7
-t [GeV^2]

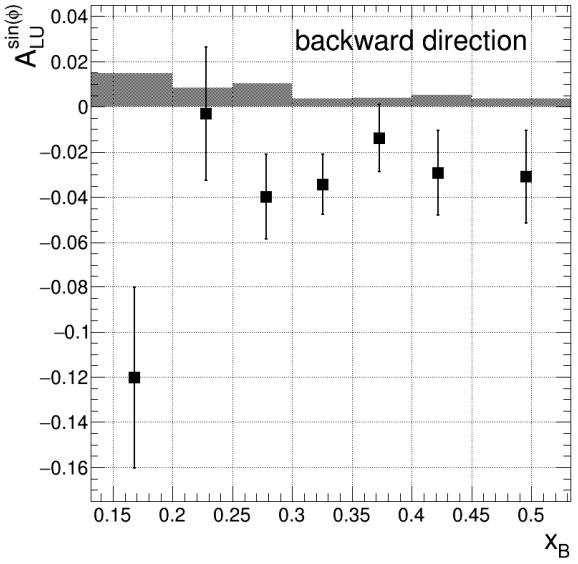
Results

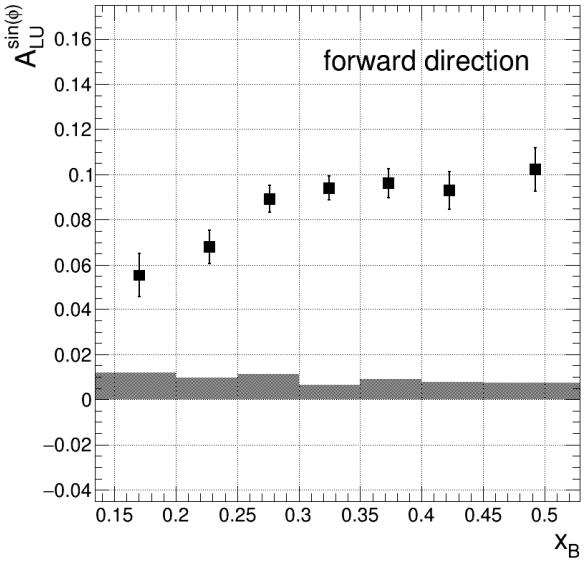
Q^2





x_B



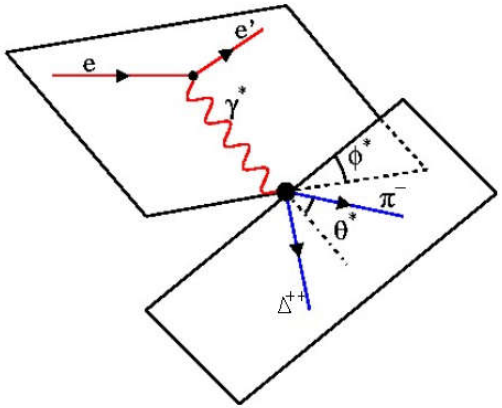


Application of the analysis to the hard exclusive π^- and π^0 channel

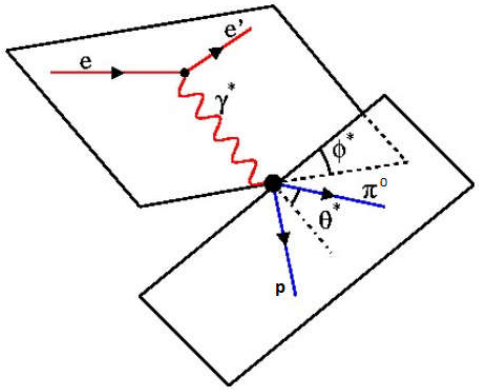
- CLAS at 5.5 GeV (e1f run period)
- longitudinally polarized electron beam
- unpolarized hydrogen target

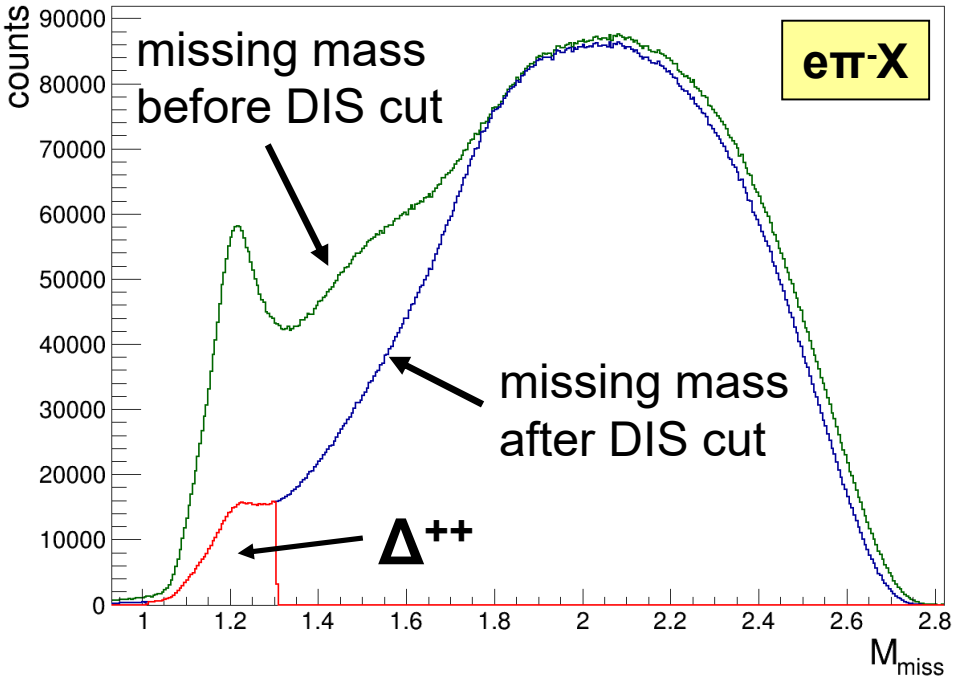
Event selection

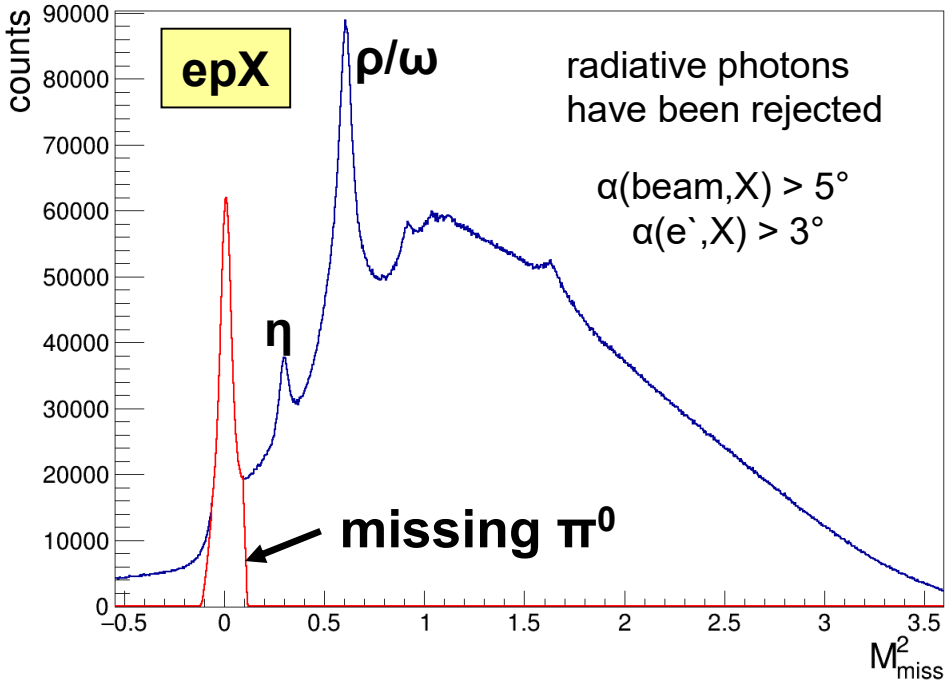
$ep \rightarrow e\Delta^{++}\pi^{-}$



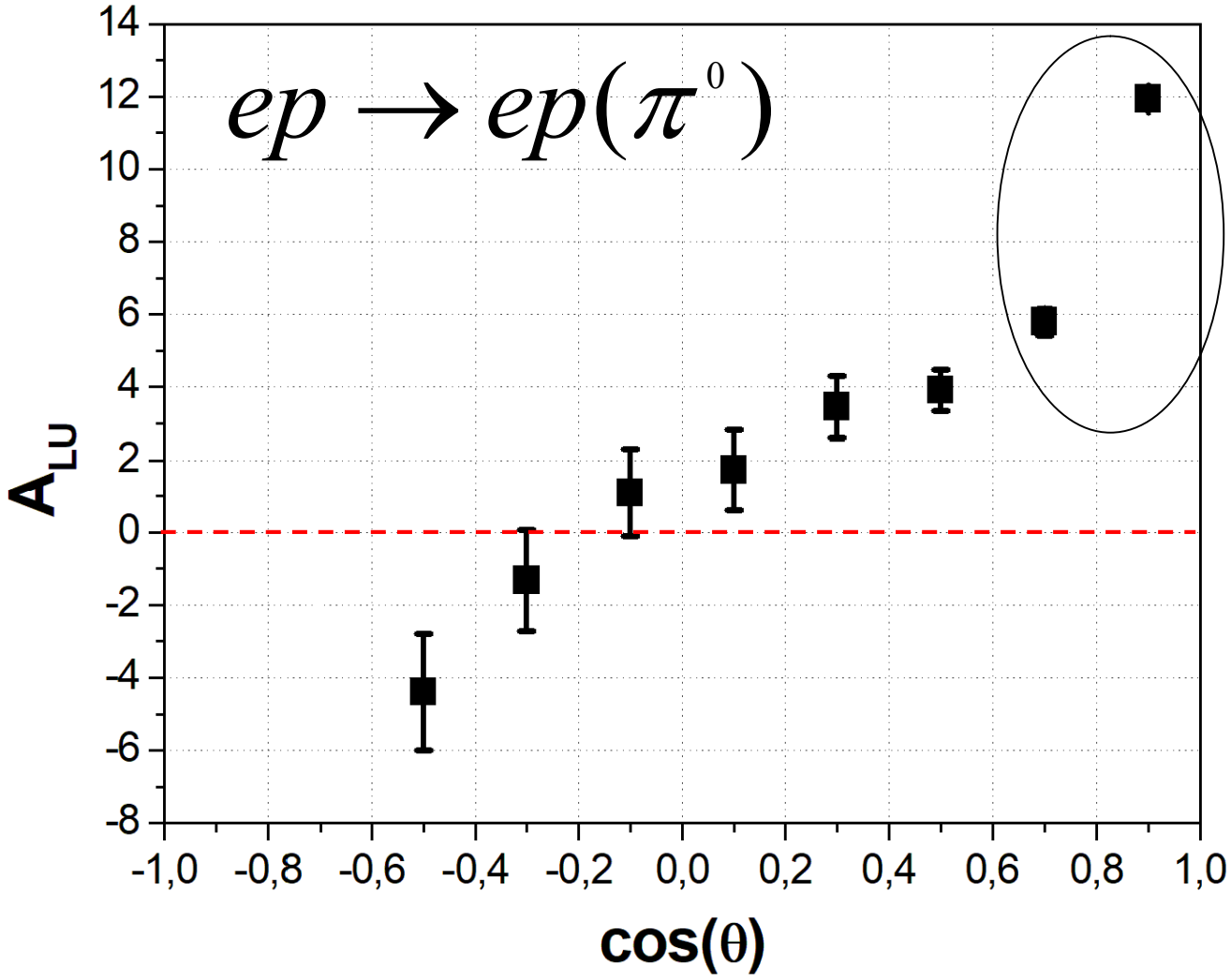
$ep \rightarrow ep\pi^{0}$







Results for π^0

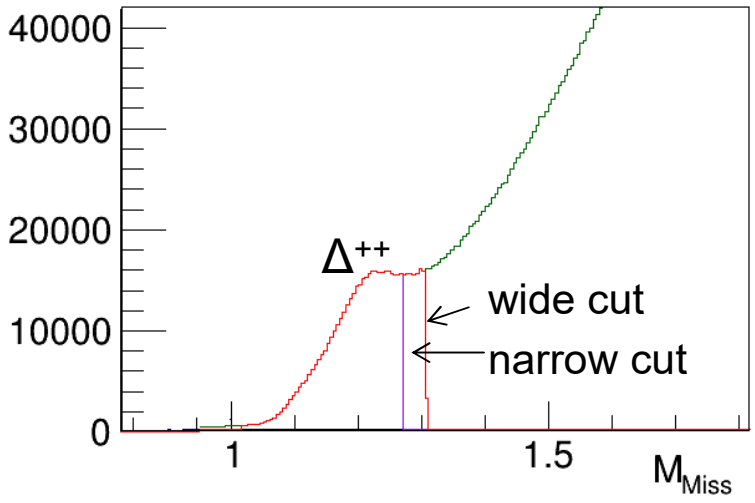


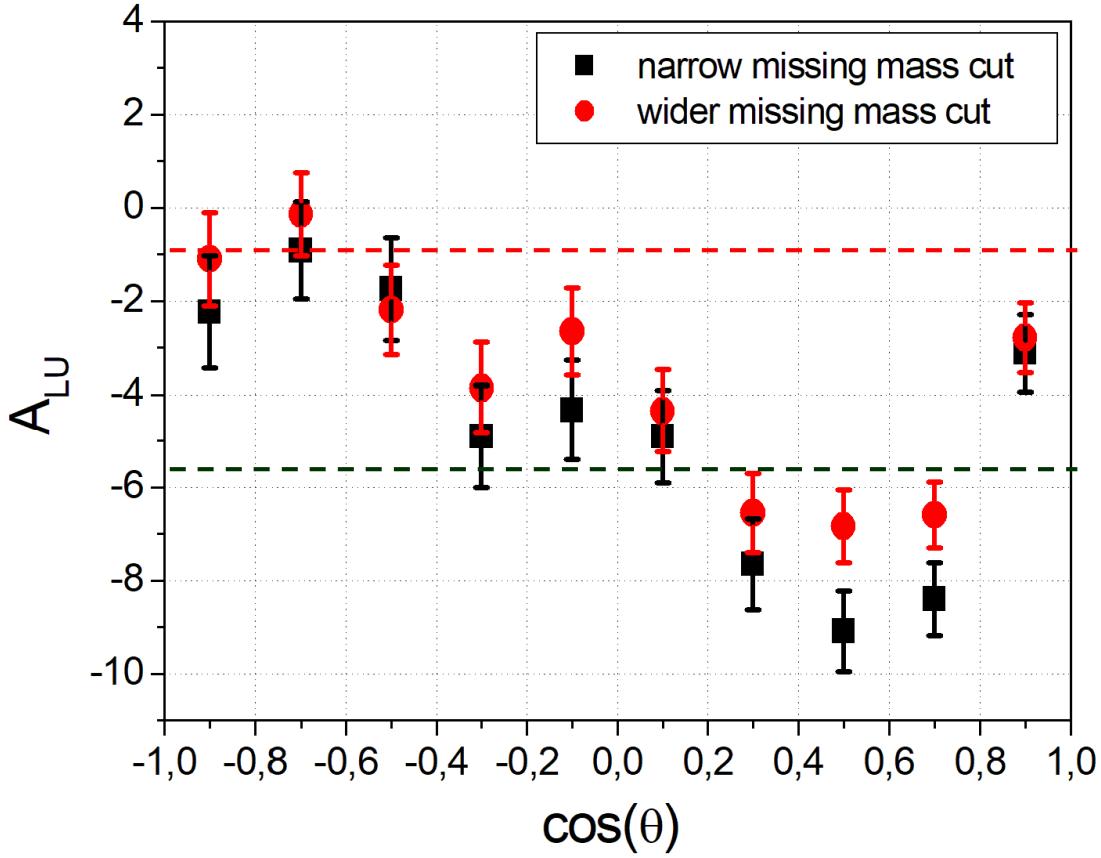
Contamination by DVCS photons ?!

Fully exclsuive channel has to be checked!

Results for π^-

$$ep \rightarrow e(\Delta^{++})\pi^-$$

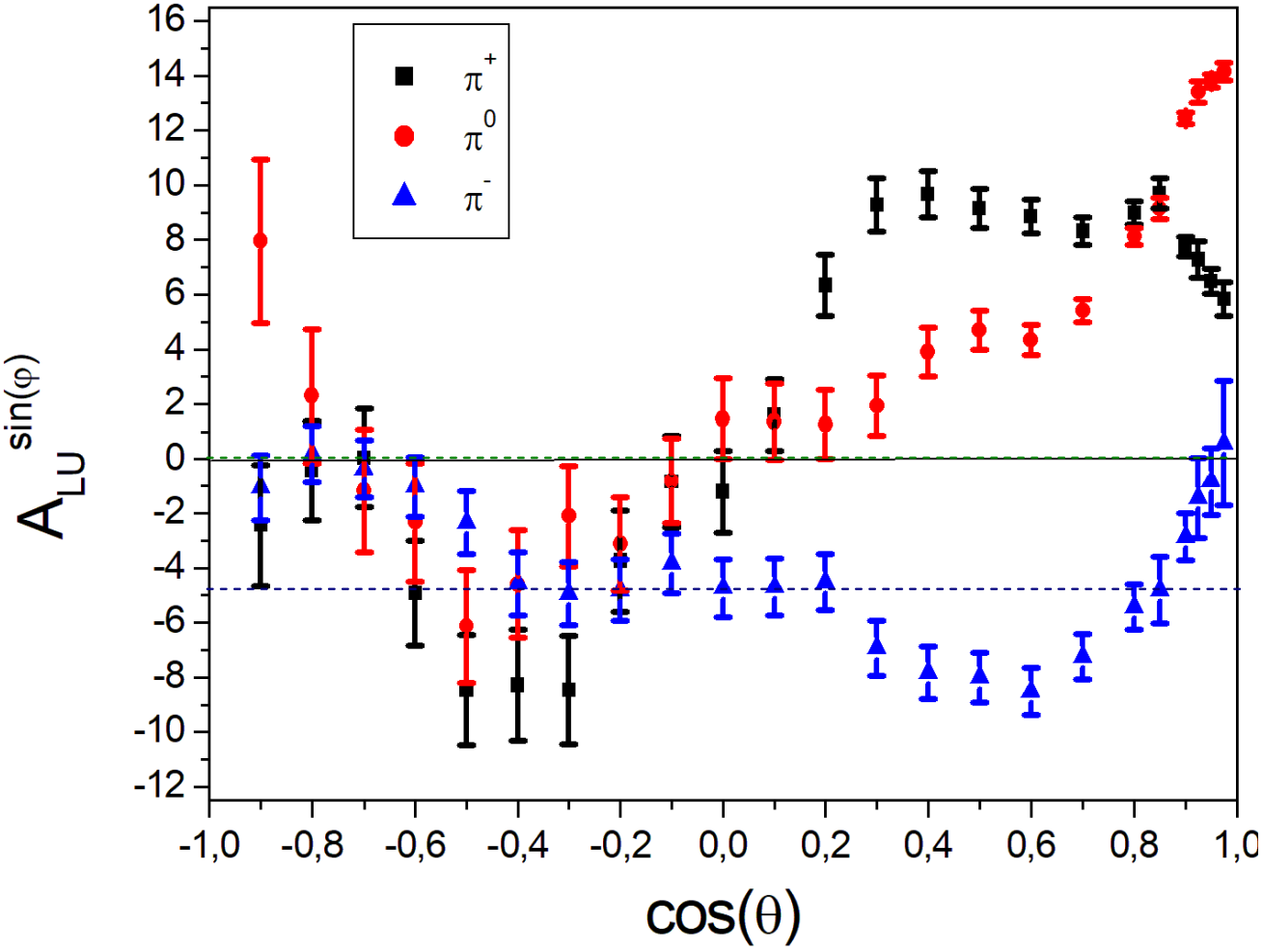




→ Negative offset (due to significant background?)

→ Turning point at ~ 90°

Comparison of A_{LU} for the three pions



A_{LU} of π^+ is positive in forward directions and negative in backward directions

→ sign changes at 90°

A_{LU} of π^- shows an opposite bahviour if the offset is considered

→ turning point at 90°

A_{LU} of π^0 is small in the central region, but increases in very forward directions

→ sign changes ~ 90°

First studies of exclusive pion production with CLAS12 at 10.6 GeV

Particle ID

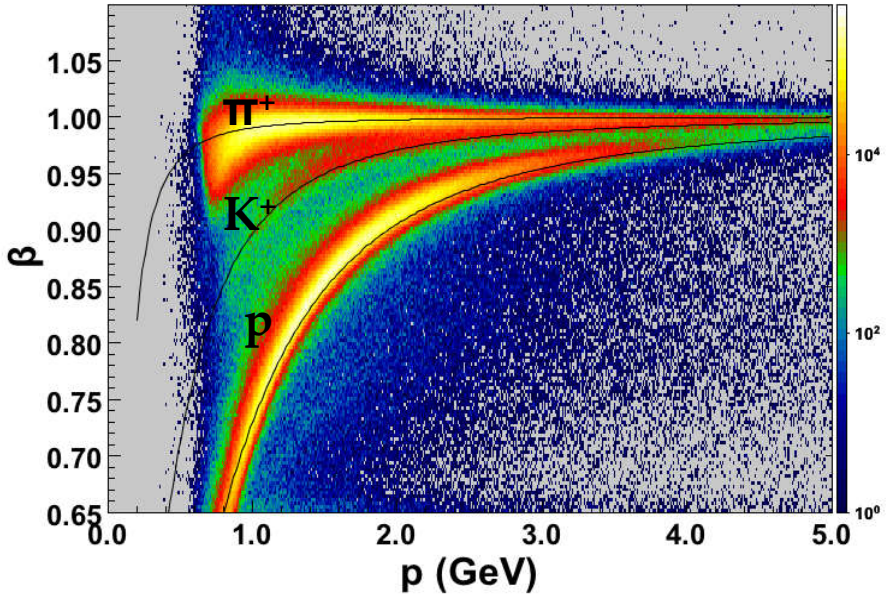
Electron ID → Based on the electromagnetic calorimeter and the cherenkov counters

Photon ID → Based on an electromagnetic calorimeter based β cut

Hadron ID → Charge corresponding to the selected hadron

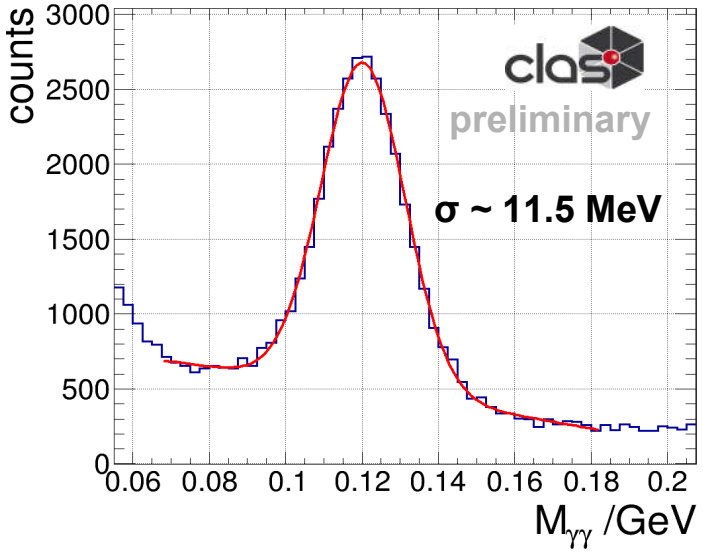
→ Fiducial cuts on the hit position in the drift chambers

→ Particle selection based on β vs p correlation

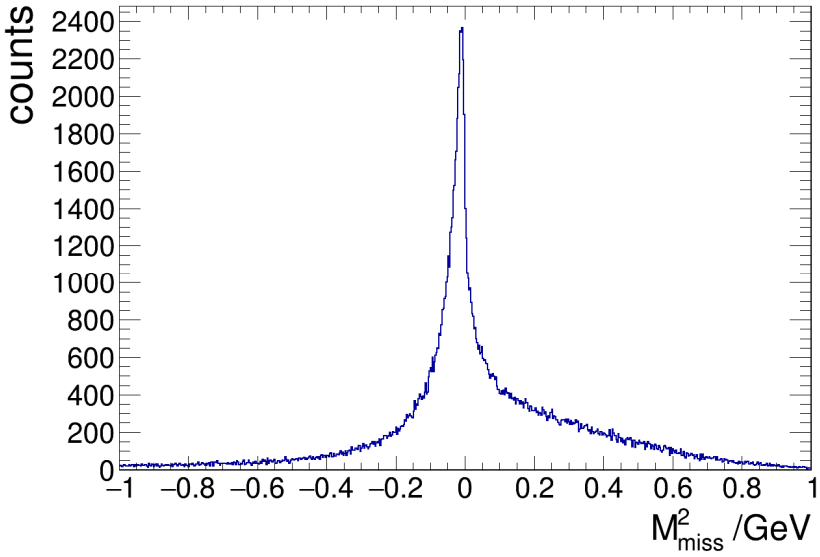


e p → e p π^0

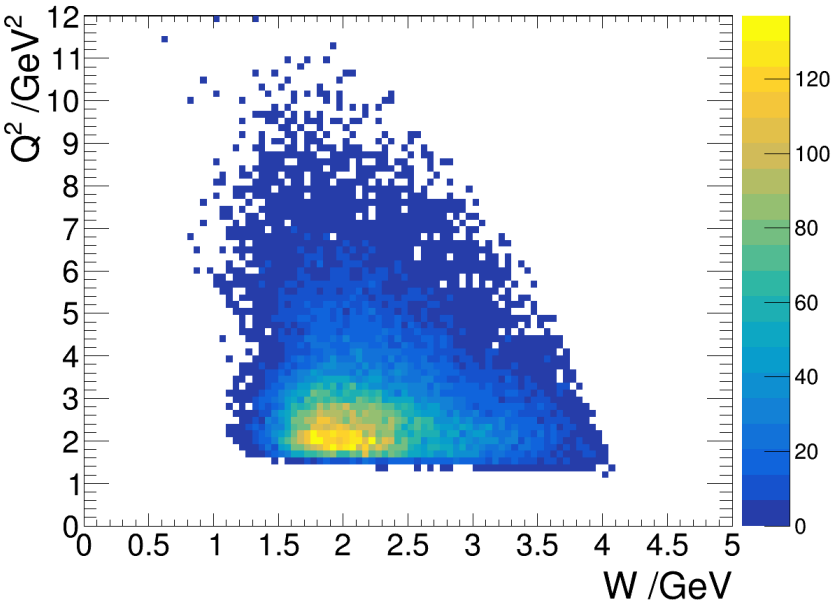
- π^0 is reconstructed from all permutations of 2 photons (each > 400 MeV)

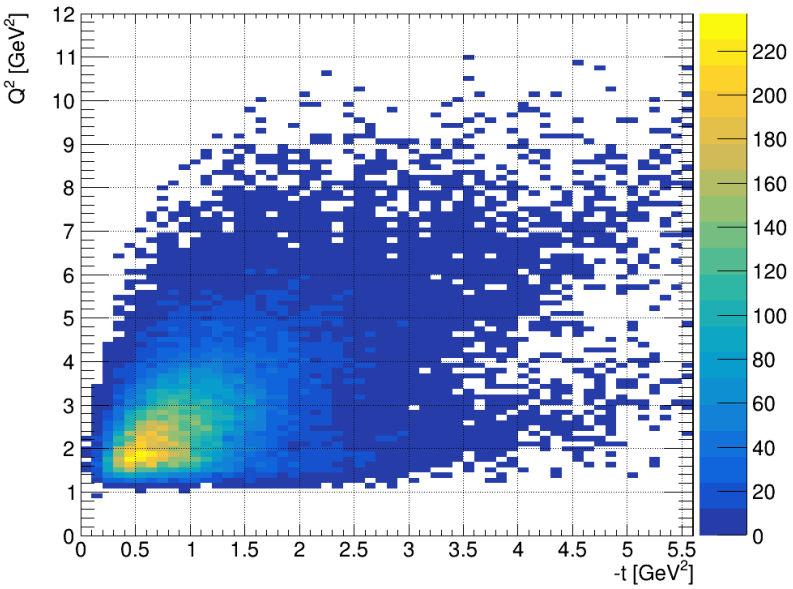


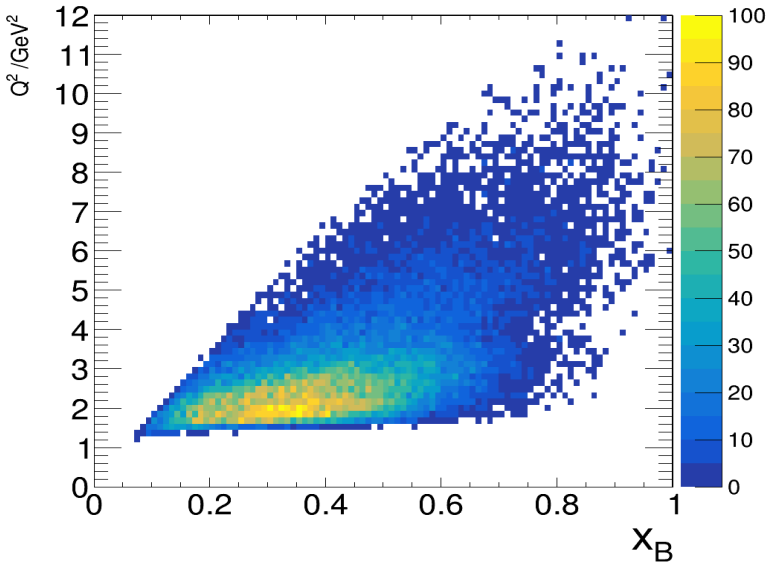
- Selection of fully exclusive events via 3 σ cuts on the missing energy and missing mass



e p → e p π^0 kinematic coverage

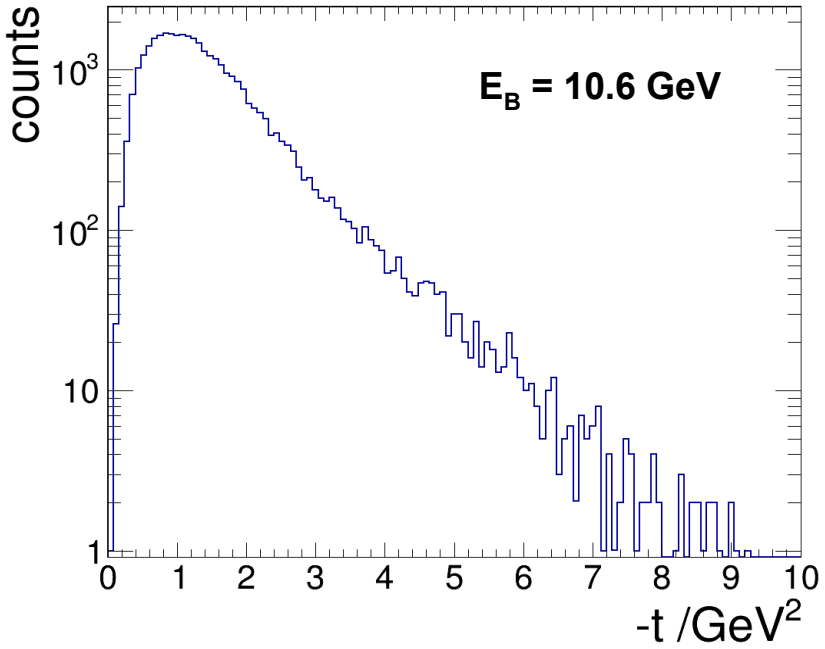


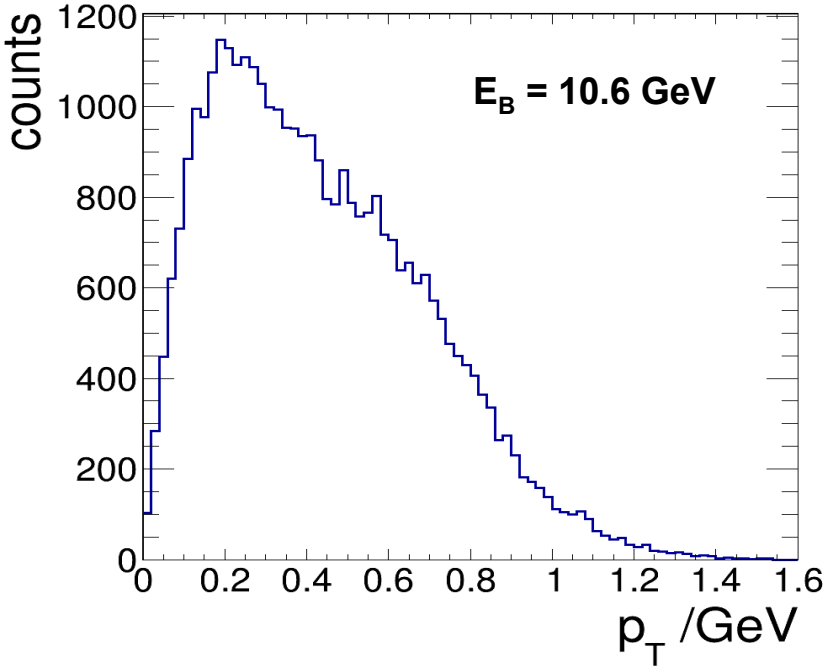




E_B = 10.6 GeV

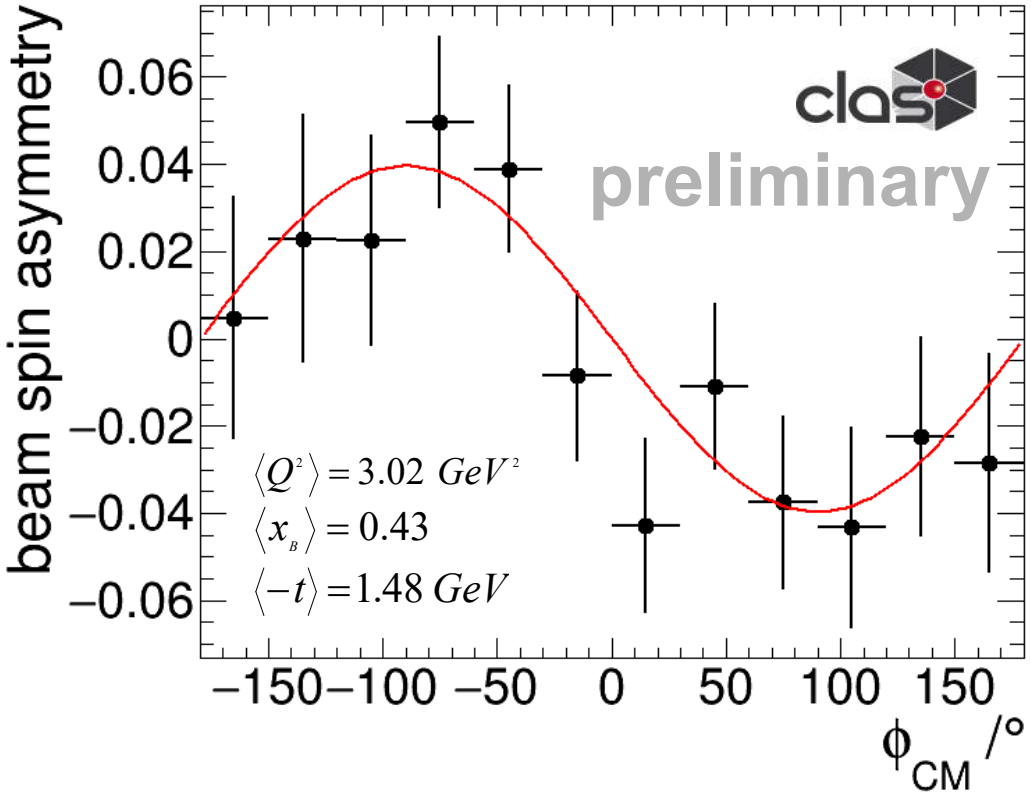
$e\ p \rightarrow e\ p\ \pi^0$ kinematic coverage





e p → e p π^0 beam spin asymmetry

- Integrated beam spin asymmetry of fully exclusive e p π^0 events
- Based on 1.8 % of the appoved beamtime



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

$$BSA \approx A \cdot \sin(\varphi)$$

Summary and Conclusion

- Based on CLAS data, the $A_{LU}^{\sin(\Phi)}$ moment from the hard exclusive π^+ channel above the resonance region has been measured for the first time with nearly full coverage from forward to backward angles
- The results show a clear sign change from forward angle to backward angle, which may indicate a transition from the GPD to the TDA regime.
- A similar effect can be observed for π^0 and π^-
- The exclusive e p π^0 channel provides promising results from CLAS12
- The presented CLAS12 analysis is based on only close to 2 % of the approved RG-A beamtime
- A kinematic fitter for CLAS12 is in preparation and will be used for a better event selection of the fully exclusive channels in the future