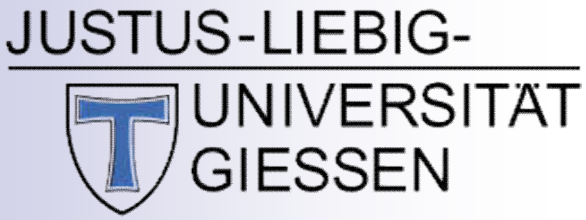
CLAS collaboration meeting

November 14, 2019, Newport News, VA

SIDIS Single Pion Beam Spin Asymmetry Measurements with CLAS 12



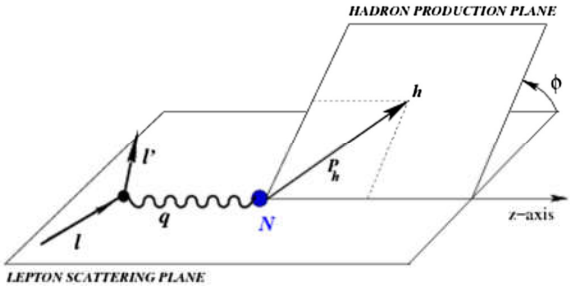
Stefan Diehl

Justus Liebig University Giessen

University of Connecticut

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

$$\frac{d\sigma}{dx_B\,dQ^2\,dz\,d\phi_h\,dp_{h\perp}^2} = K(x,y,Q^2)\Big\{F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\,\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon\cos(2\phi_h)F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\sin\phi_h F_{LU}^{\sin\phi_h}\Big\}$$

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

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

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

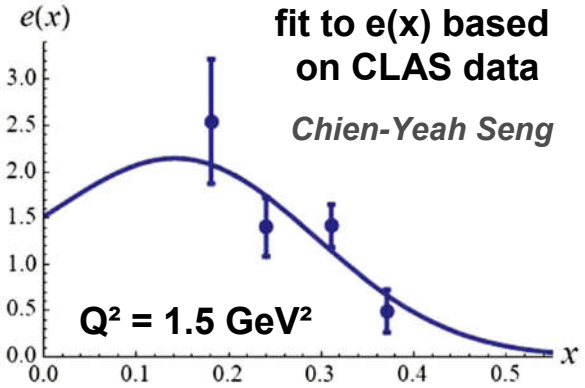
$$BSA = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{A_{LU}^{\sin\phi}\sin\phi}{1 + A_{UU}^{\cos\phi}\cos\phi + A_{UU}^{\cos(2\phi)}\cos(2\phi)}$$

Focus of this study: $A_{LU}^{\sin\phi} = \sqrt{2\varepsilon(1-\varepsilon)}\,\frac{F_{LU}^{\sin\phi}}{F_{UU}} \sim e(x)$

➔The chiral-odd, twist 3 distr. function ***e(x)*** is related to the nucleon sigma terms of the quark chromo magnetic dipole moment

→ Essential inputs for the CP-odd pion-nucleon couplings

→ Main contributors of long range CP-odd nuclear forces



fit to e(x) based on CLAS data

Chien-Yeah Seng

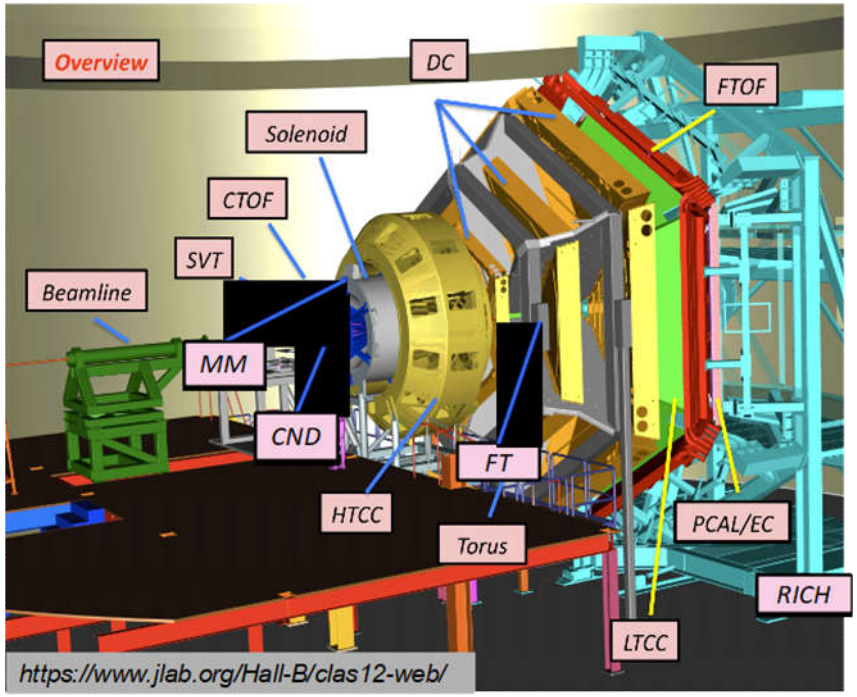
$$\sigma_c^0 = (0.08 - 0.34)GeV^2$$

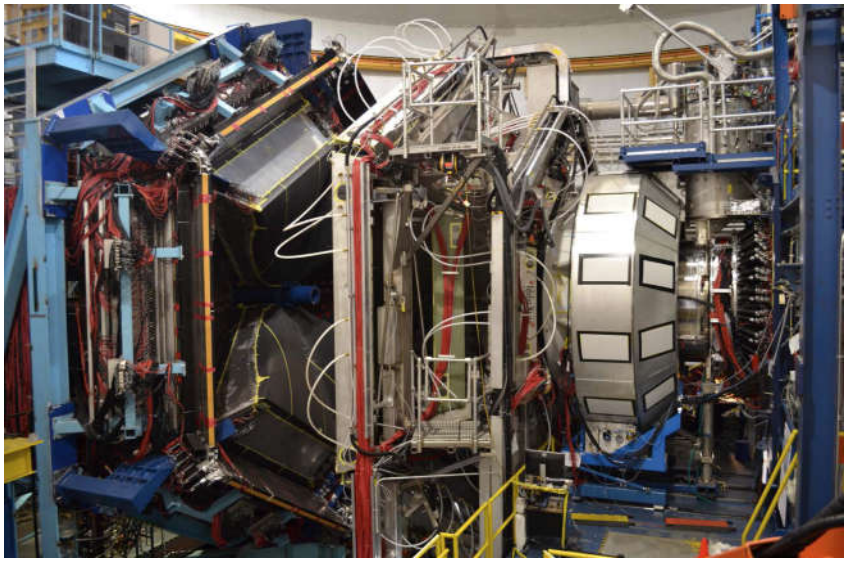
Past: Measurements have been performed with CLAS, HERMES and COMPASS

Advantages of CLAS12 → Significantly higher statistics

→ Extended kinematic coverage (Q^2, P_T)

Experimental Setup





➔ Data recorded with CLAS12 during fall of 2018

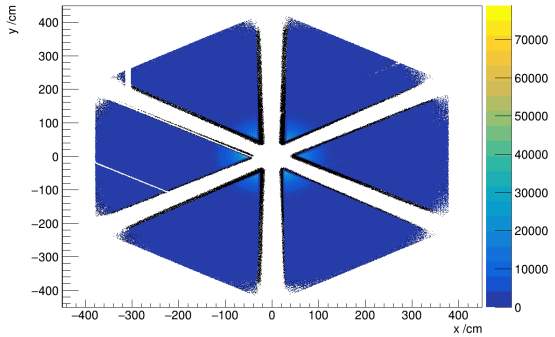
➔ 10.6 GeV electron beam ➔ 85 % average polarization ➔ liquid H_2 target

➔ Analysed data ~ 3 % of the approved RG-A beam time

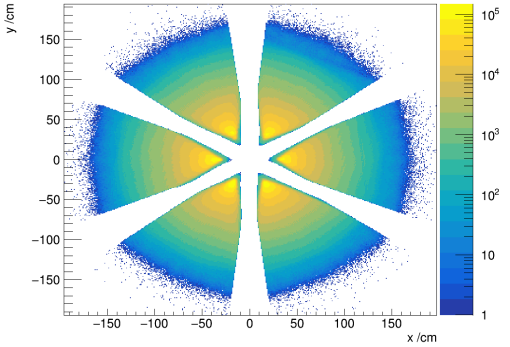
Electron ID

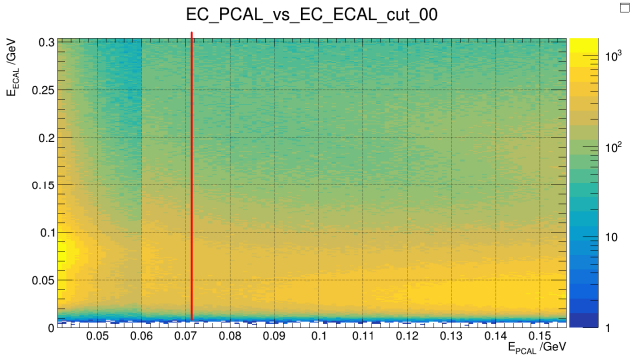
1. PCAL fiducial cuts
2. DC fiducial cuts for the 3 regions
3. PCAL energy deposition > 0.07 GeV
   eventbuilder: > 0.06 GeV
4. Calorimeter sampling fraction: 3 sigma region
5. p_e > 2.0 GeV
6. z-vertex cut [-11, +9]
   ➔ 2 % level of the maximum

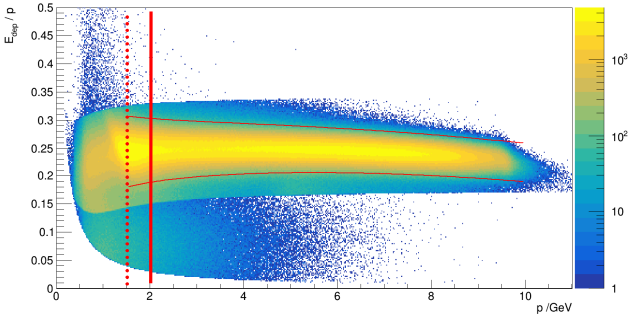
PCAL

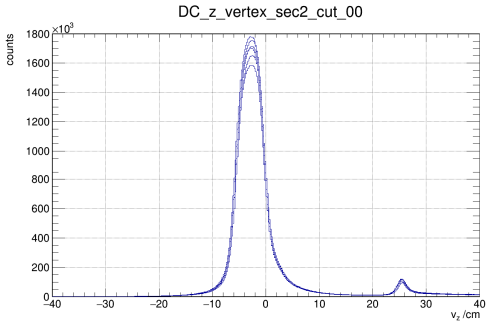


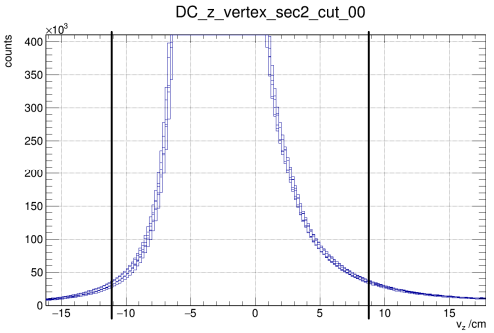
DC region 1











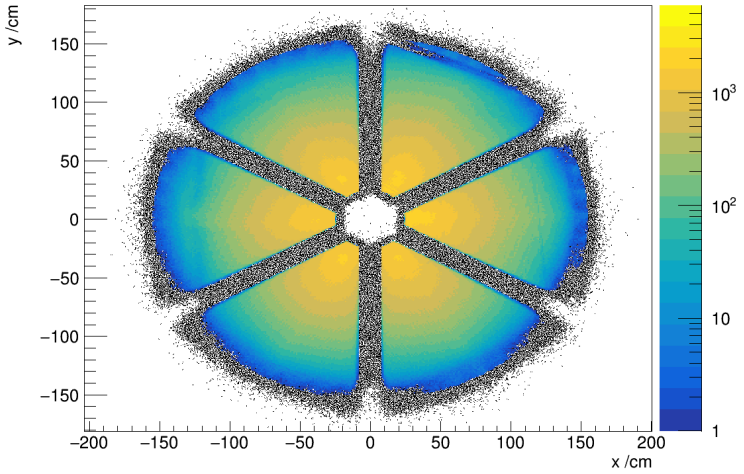
Hadron ID

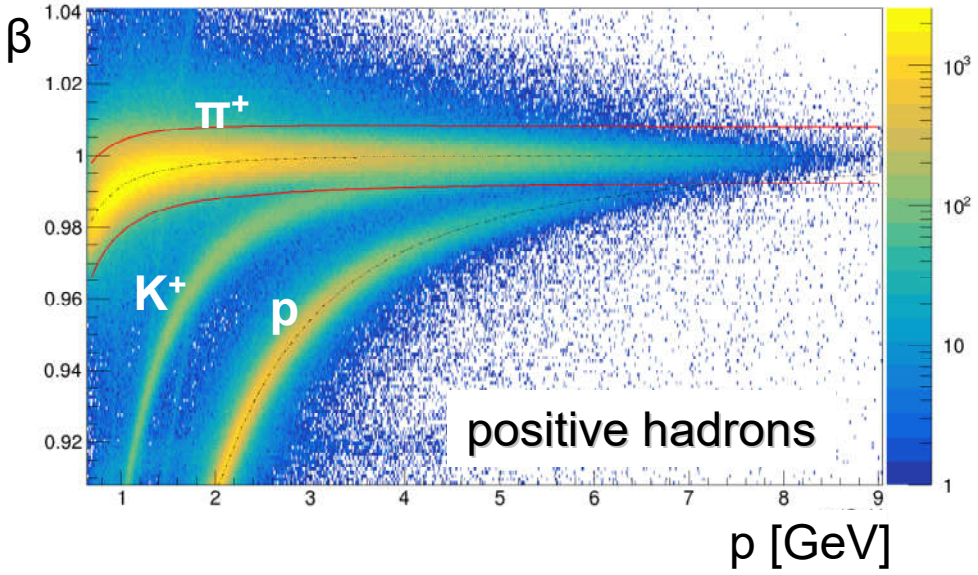
1. DC fiducial cuts for the 3 regions

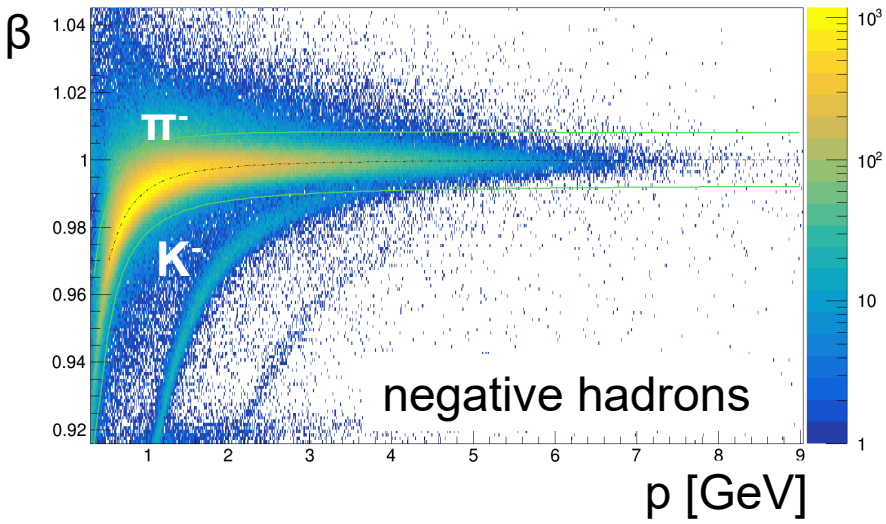
2. Final selection based on TOF

→ Maximum likelyhood PID from eventbuilder with $\chi^2 < 3.0$

→ Provides similar results as a custom maximum likelyhood PID without event weighting

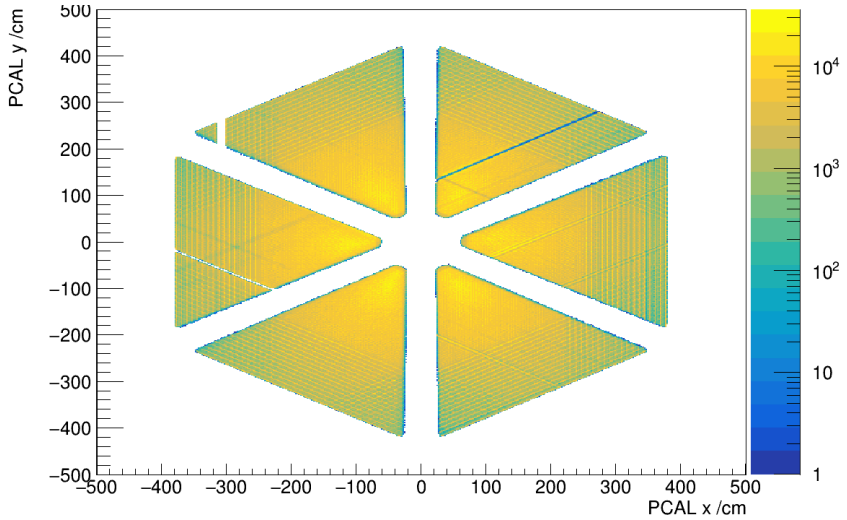




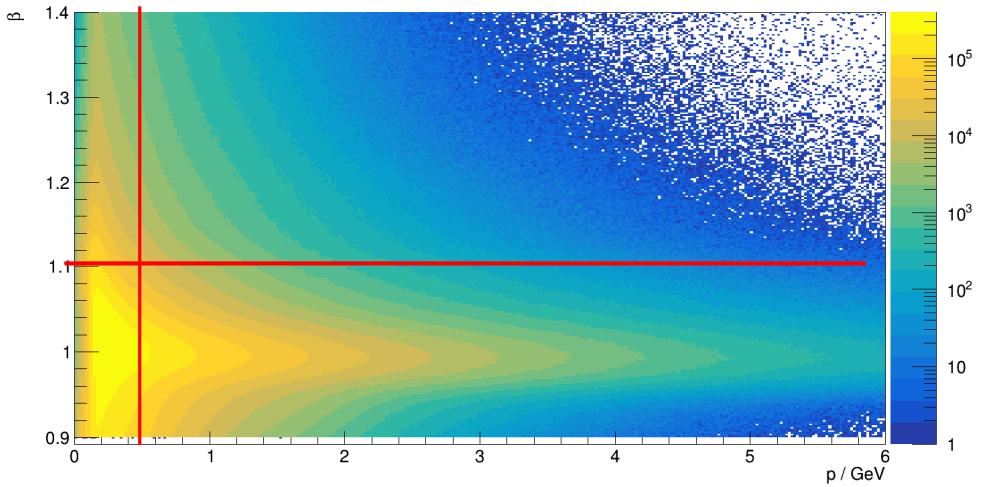


Photon ID

1. PCAL fiducial cuts



2. Cut on the β vs p distribution from PCAL



- Upper cut to reject accidentials from following beam bunch

  → expected at β = 1.2

→ Lower cut set to 3 sigma region

Event selection and kinematic cuts

π^0 selection:

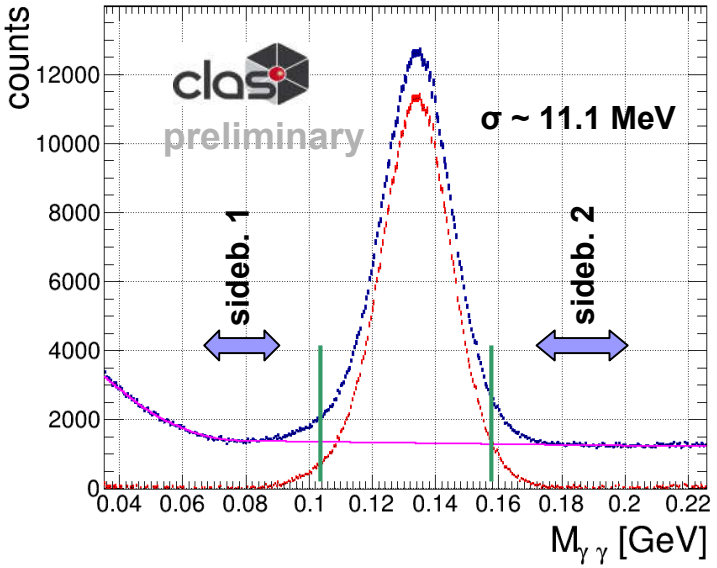
$E_\gamma > 0.6$ GeV $\alpha(e\gamma) > 8°$

all 2γ pairs

→ 2.2 σ cut around the peak positions

→ sidebands are used to estimate the asymmetry of the background

→ A sideband subtraction has been done



Kinematic cuts for all pions:

minimal electron energy: 2.0 GeV minimal pion energy: 1.25 GeV

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

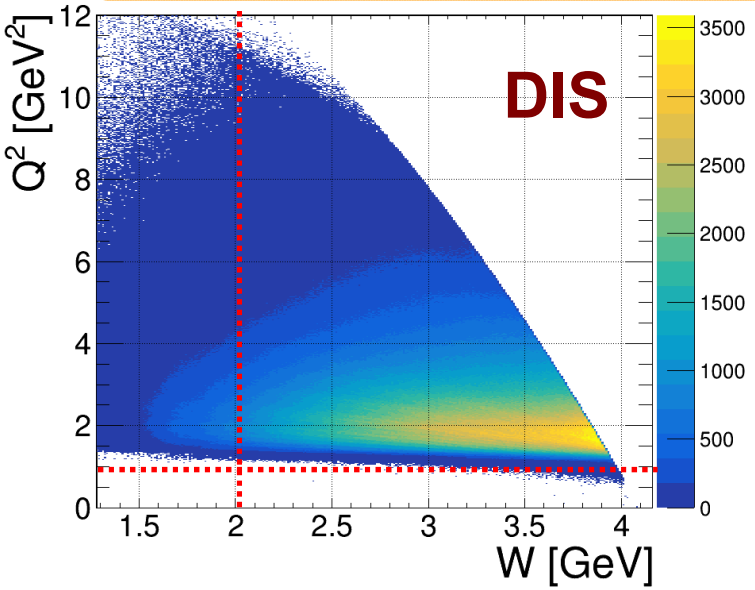
Additionally: Cut on the final state hadron momentum fraction z

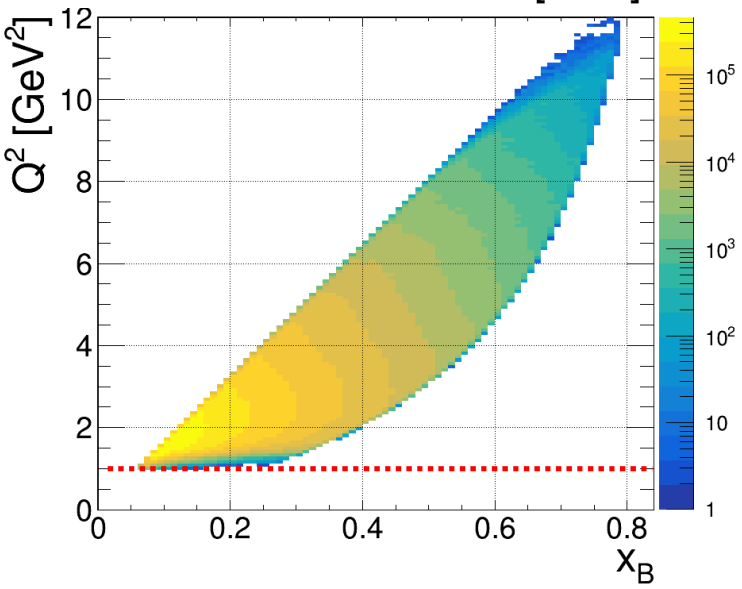
$$0.3 < z < 0.7$$

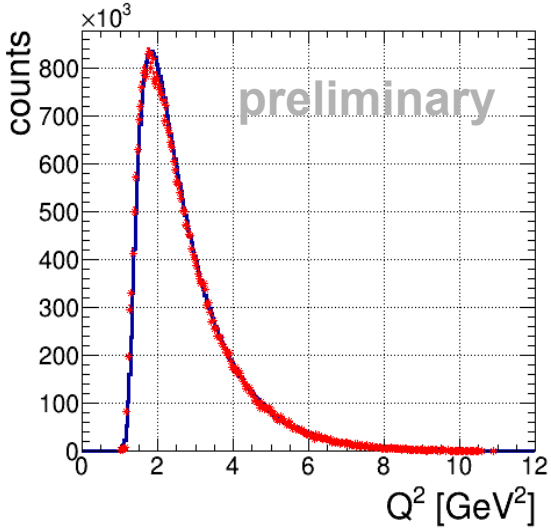
→ $z > 0.3$ removes the "target fragmentation region"

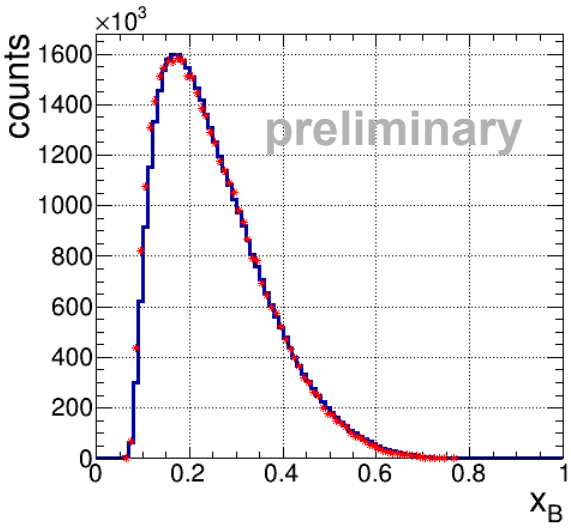
→ $z < 0.7$ removes contamination by pions from exclusive channels

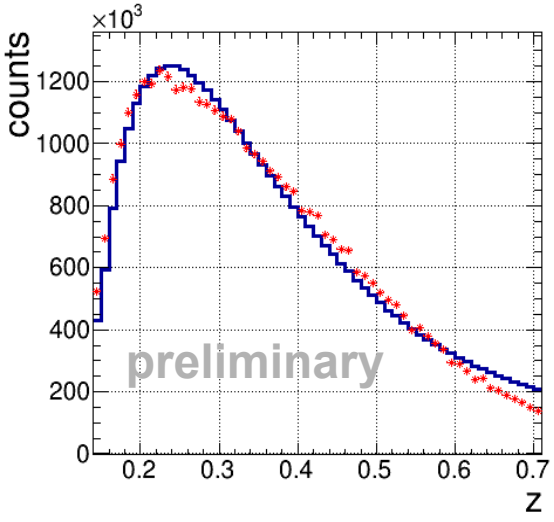
Kinematic coverage for π^+ (similar for π^- and π^0)

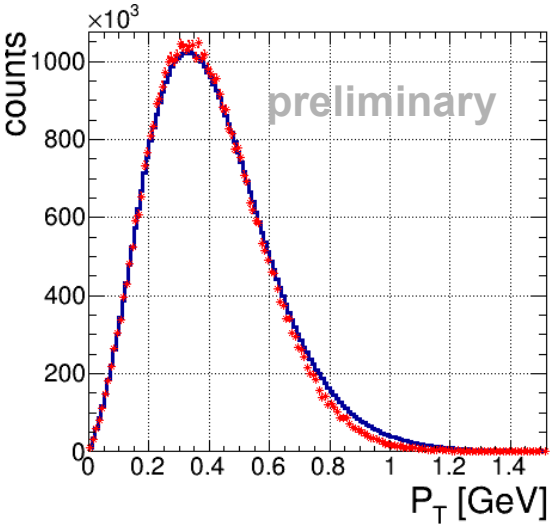












Experimental ✳ GEANT based Monte Carlo

Beam spin asymmetry

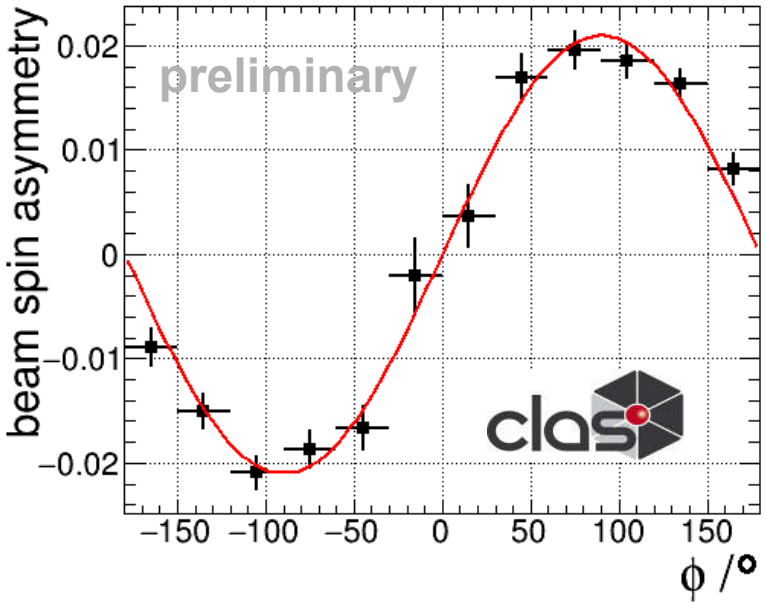
$$BSA_i = \frac{1}{P_e} \cdot \frac{N_i^+ - N_i^-}{N_i^+ + N_i^-}$$

P_e = 85 % : average e^- beam polarisation

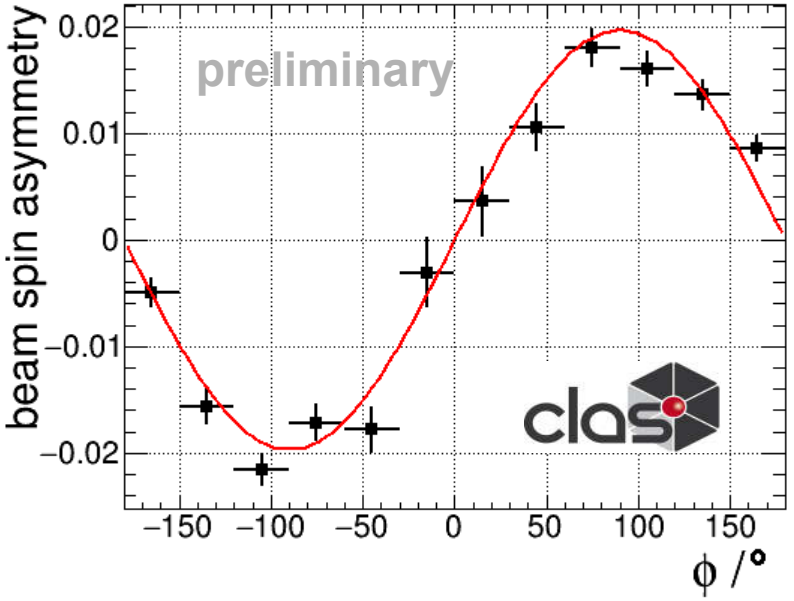
Φ dependence without kinematic bins

<Q^2> ~ 3.0 GeV² <x_B> ~ 0.27 <z> ~ 0.42 <P_T> ~ 0.45

π^+

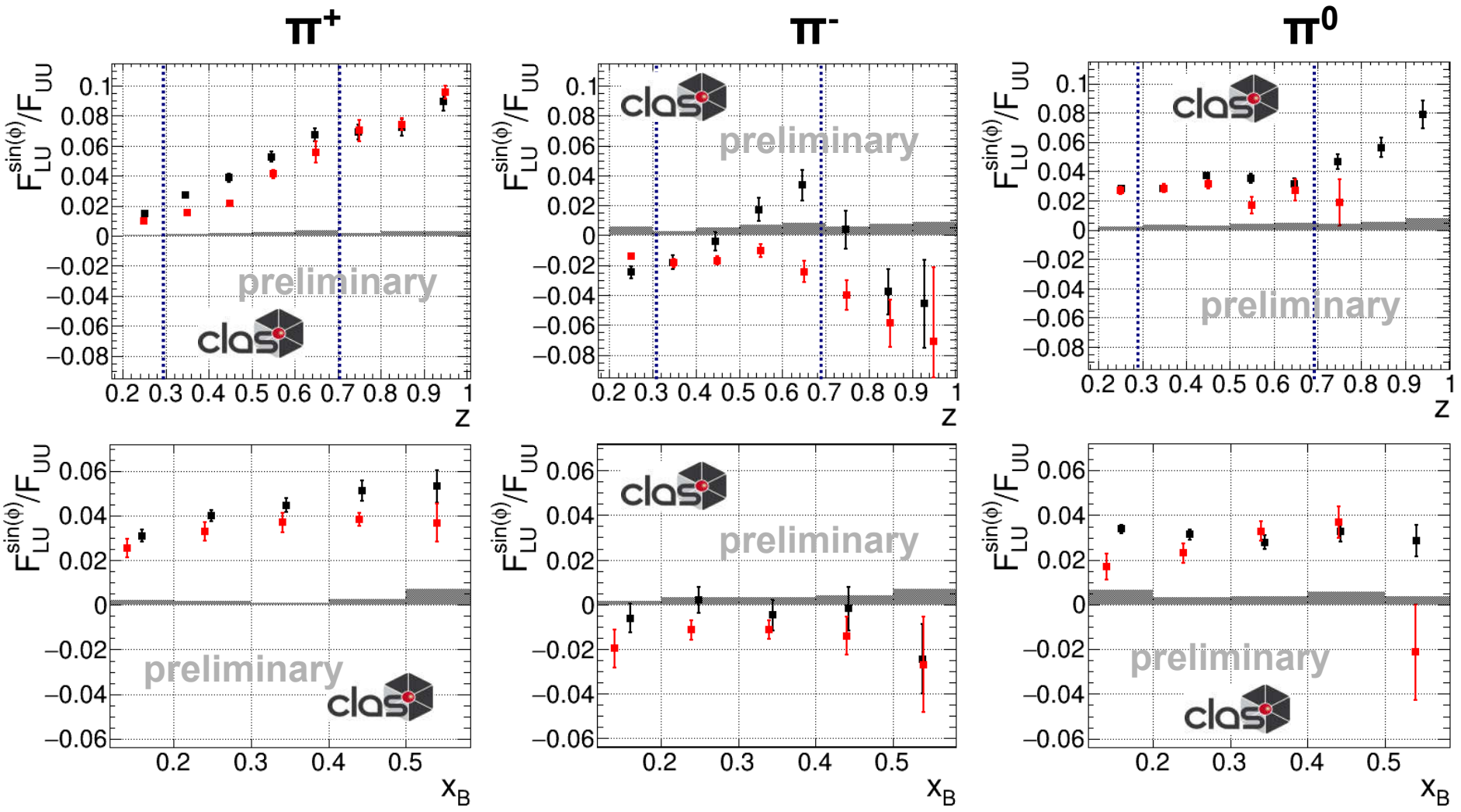


π^0



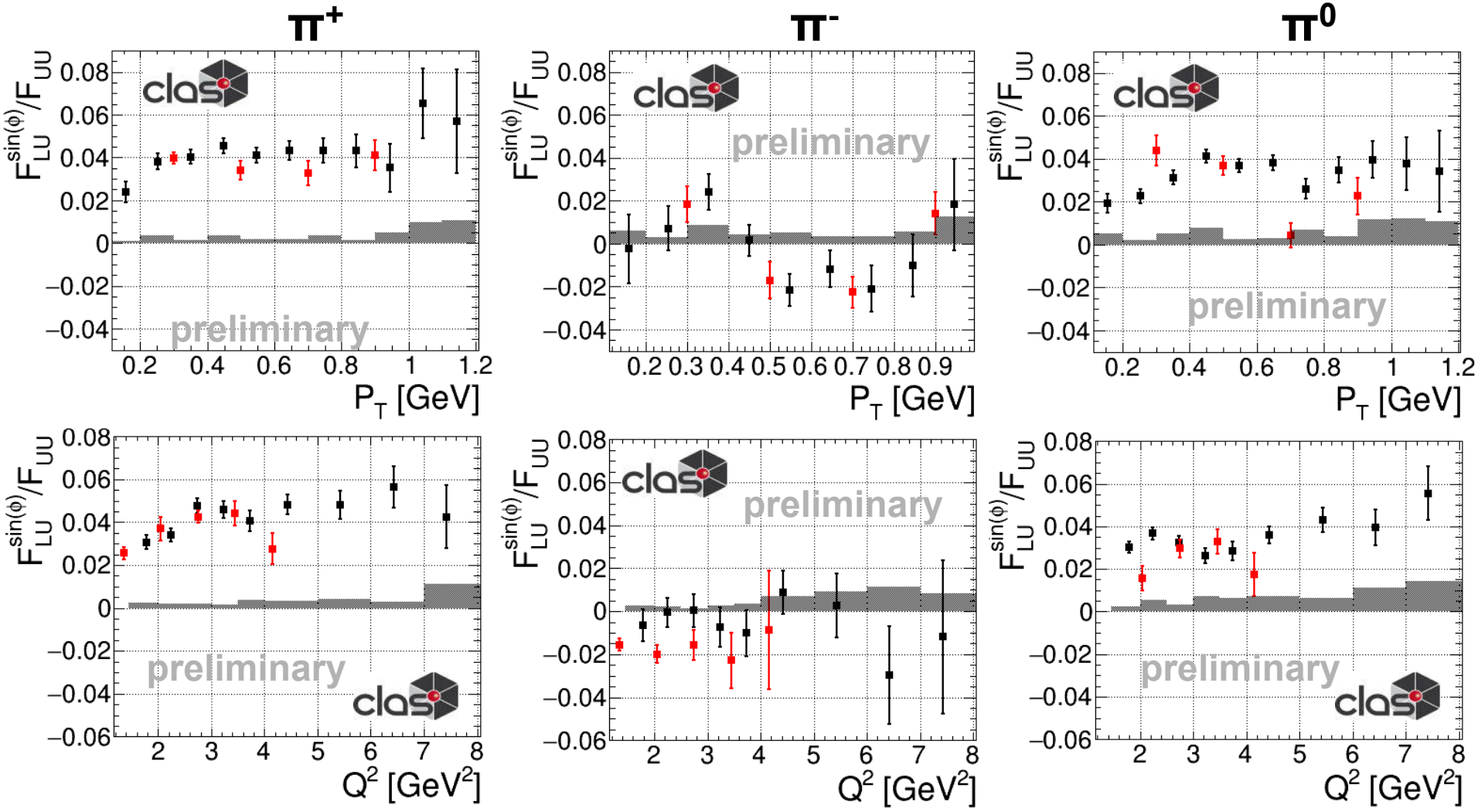
➔ Clear sinoid shape can be observed

$F_{LU}^{\sin\phi} / F_{UU}$ for a **z** and $\mathbf{x_B}$ binning

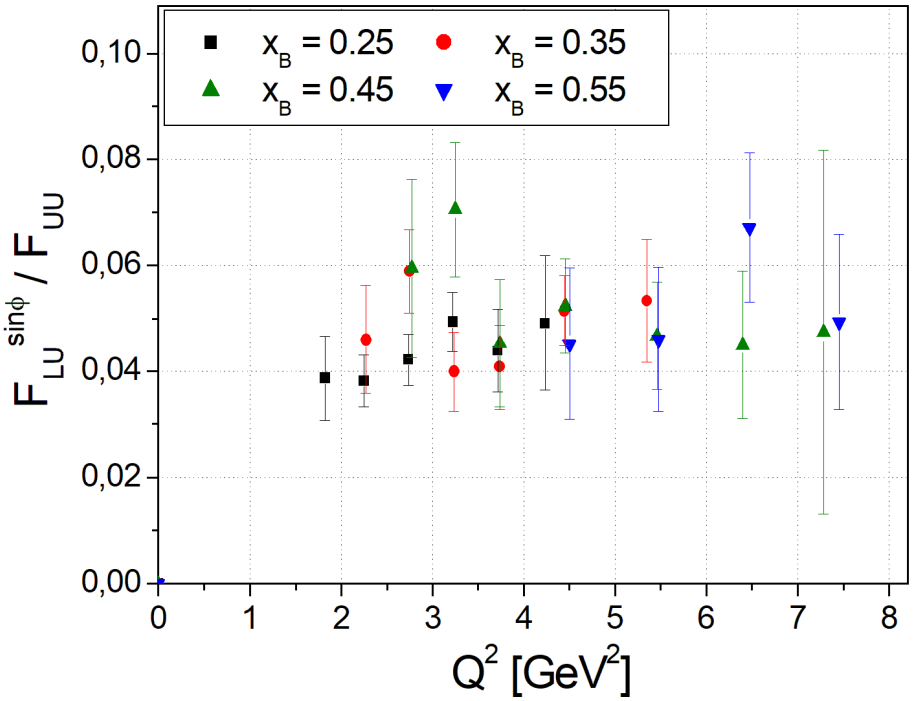


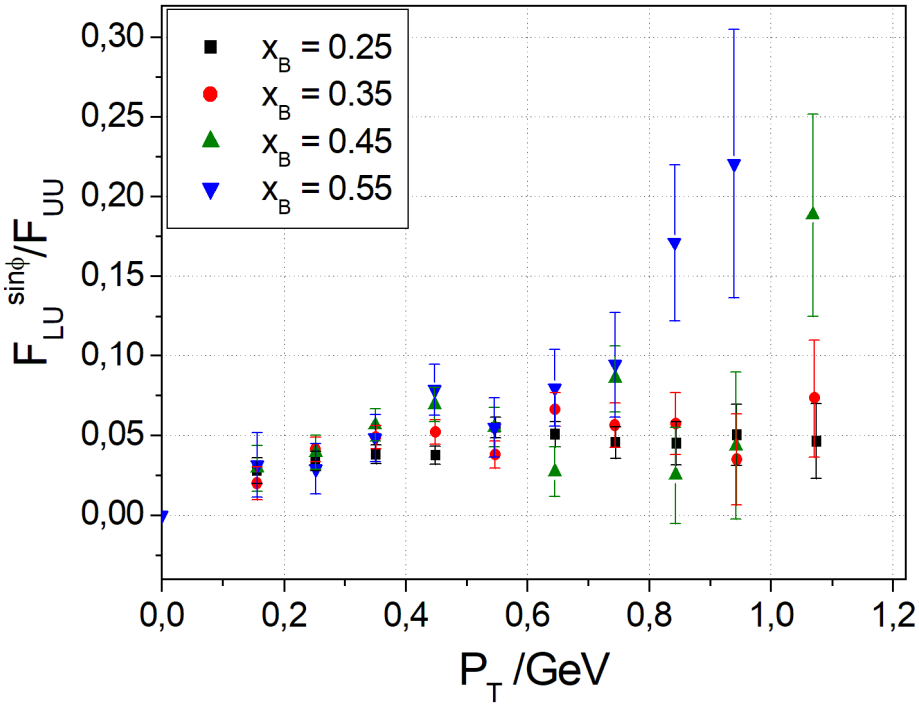
■ CLAS12 ■ CLAS [W. Gohn.et al. PRD 98 (2014)]

$F_{LU}^{\sin\phi} / F_{UU}$ for a P_T and Q^2 binning



2 dimensional analysis



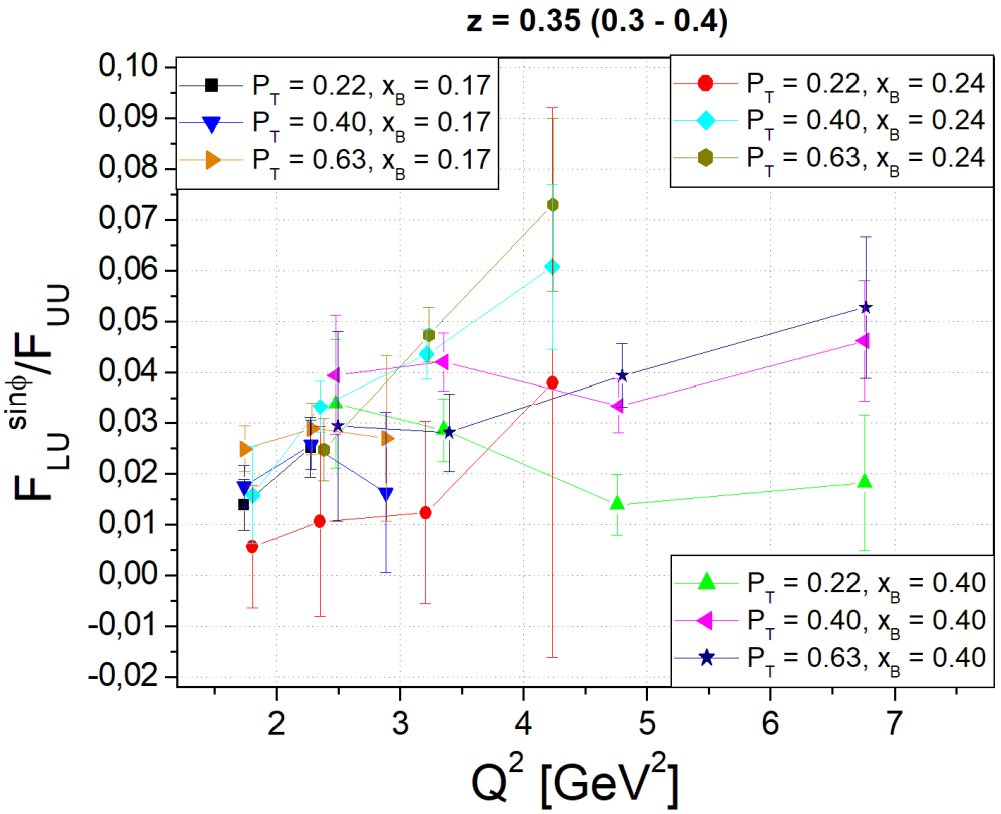


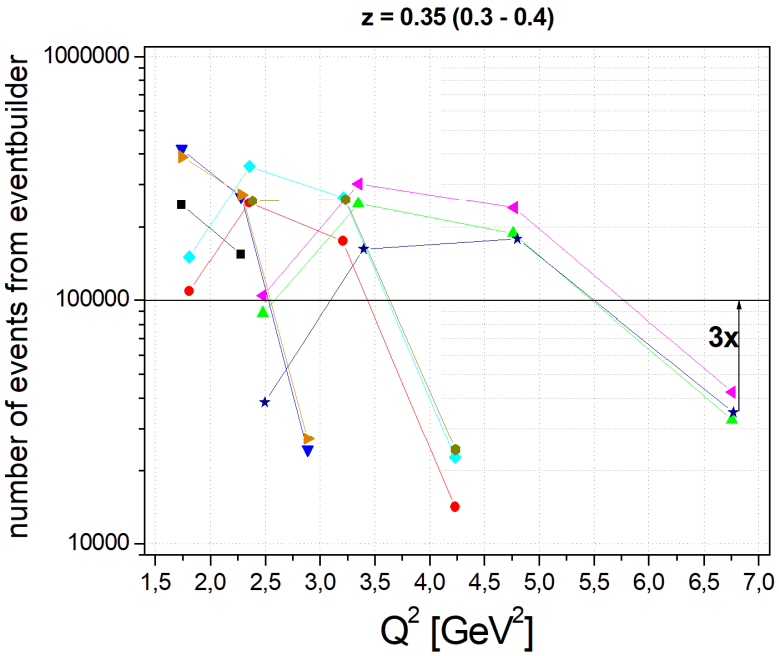
➔ Nearly flat Q² dependence at high Q²

➔ Increase for large P_T and large x_B

multidimensional analysis

5 bins in $\mathbf{Q^2}$, 3 bins in $\mathbf{x_B}$ and $\mathbf{P_T}$, 1 bin in $\mathbf{z}$

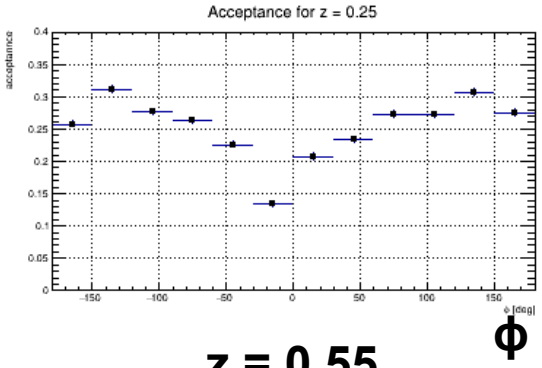




Systematics: Acceptance effects

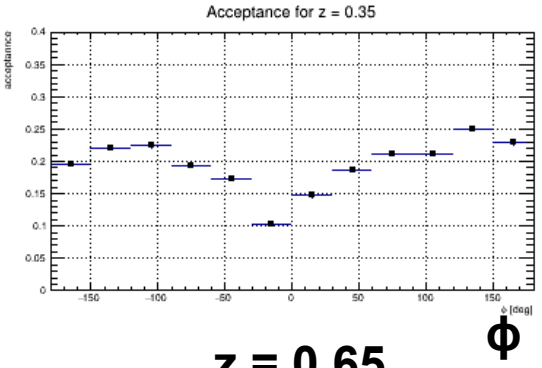
π^+ ϕ acceptance

z = 0.25



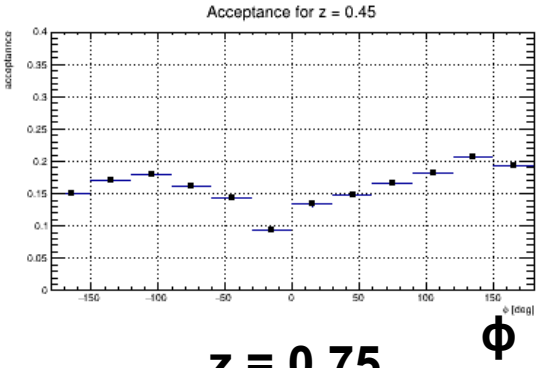
ϕ

z = 0.35



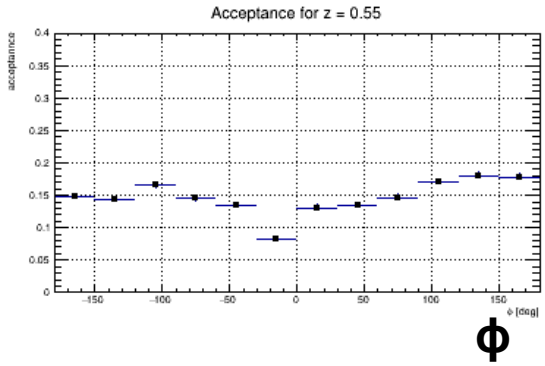
ϕ

z = 0.45



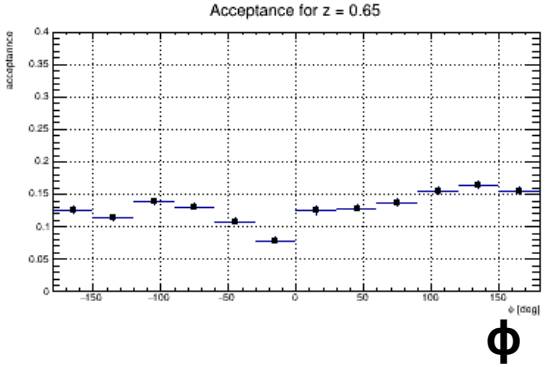
ϕ

z = 0.55



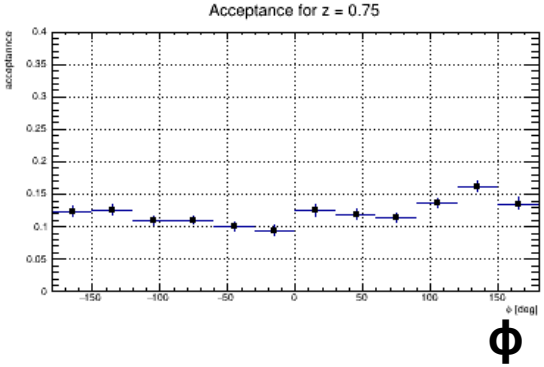
ϕ

z = 0.65



ϕ

z = 0.75



ϕ

- Smooth acceptance curves
- If they exist, acceptance effects due to the finite bin size only around $\phi = 0$

Systematics: acceptance effects

MC for π^+:

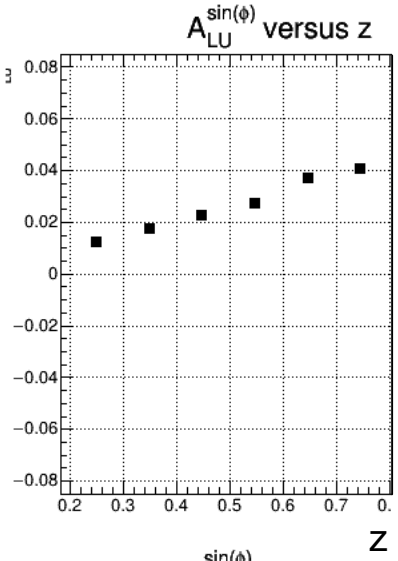
genearated

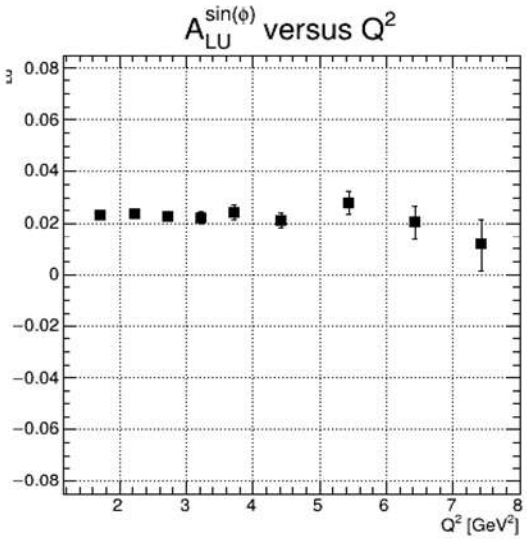
(with experimental BSA)

implemented:

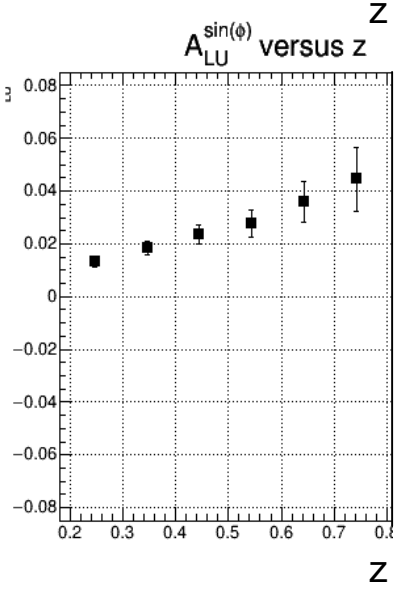
→ fit to exp. Result

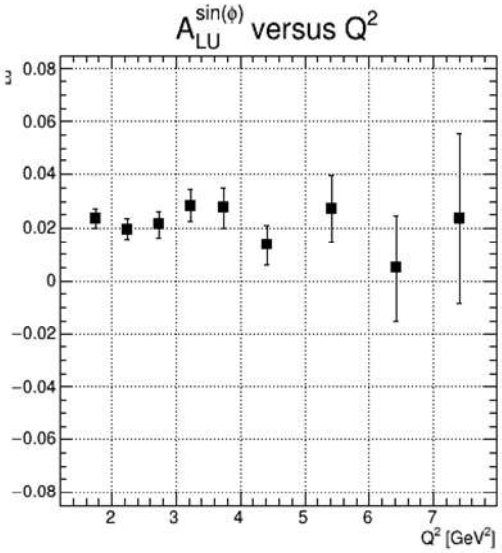
$A_{LU}^{\sin\phi} = -0.00285 + 0.05787 * z_{gen}$





reconstructed



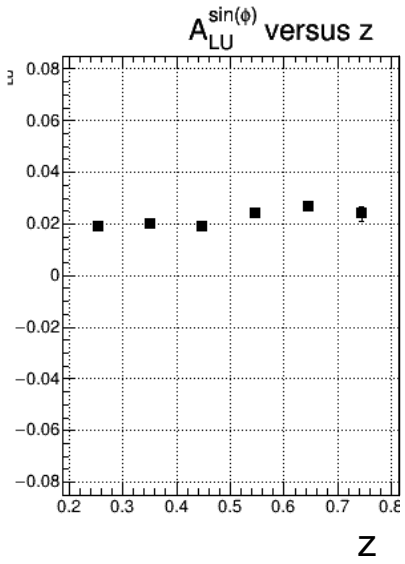


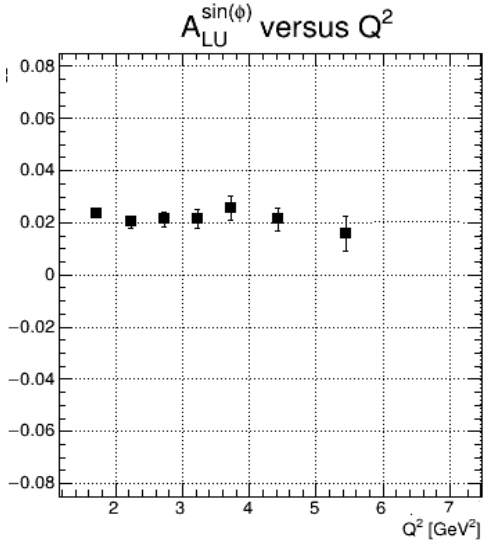
Systematics: Acceptance effects

MC for π^0:

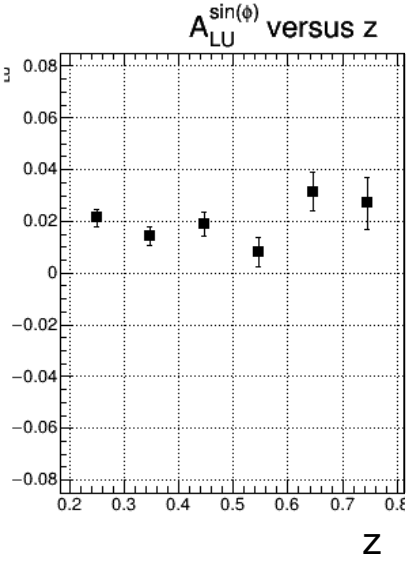
genearated

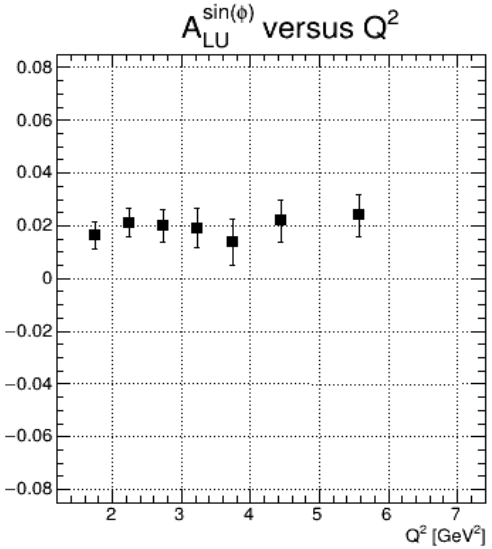
(with experimental BSA)





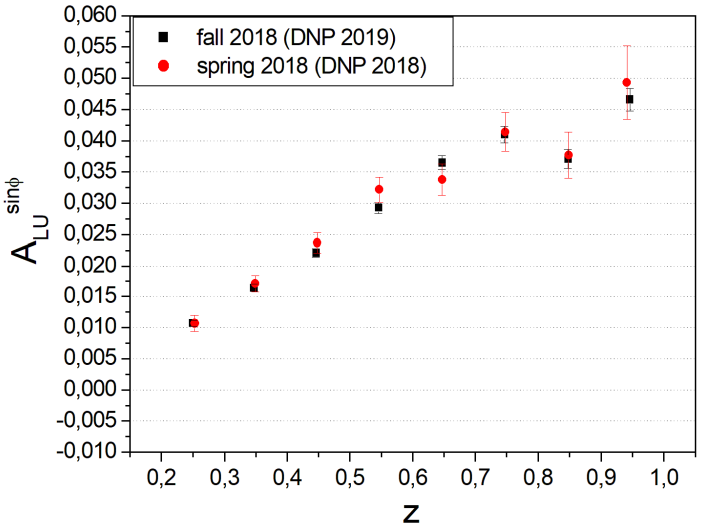
reconstructed

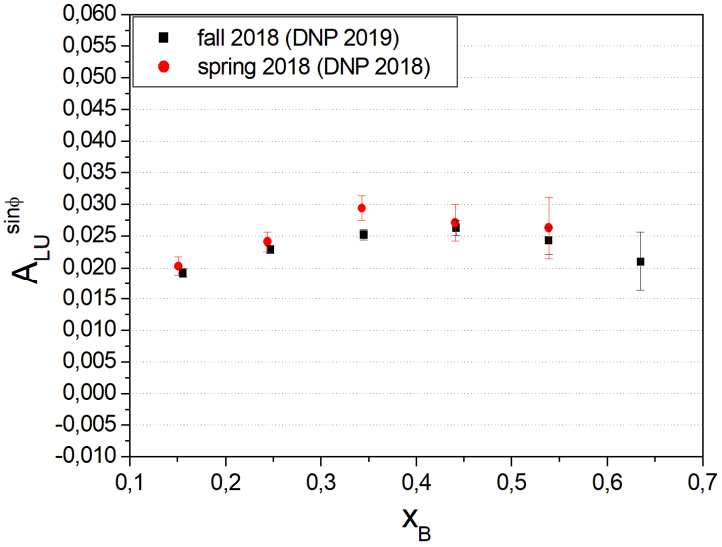


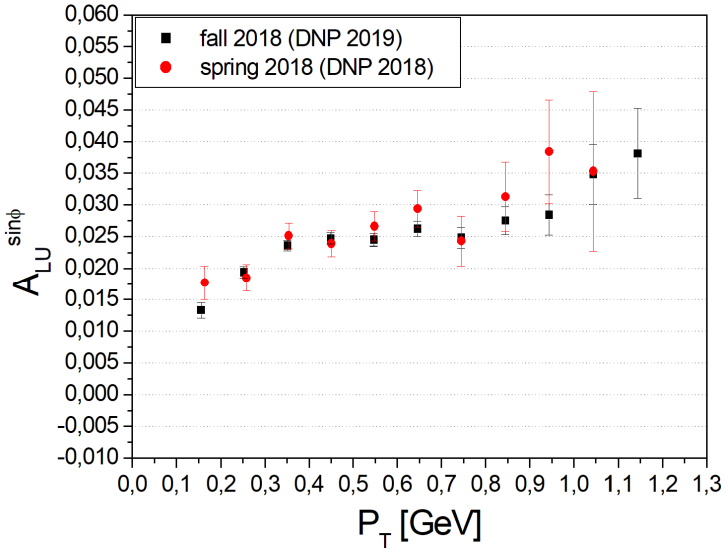


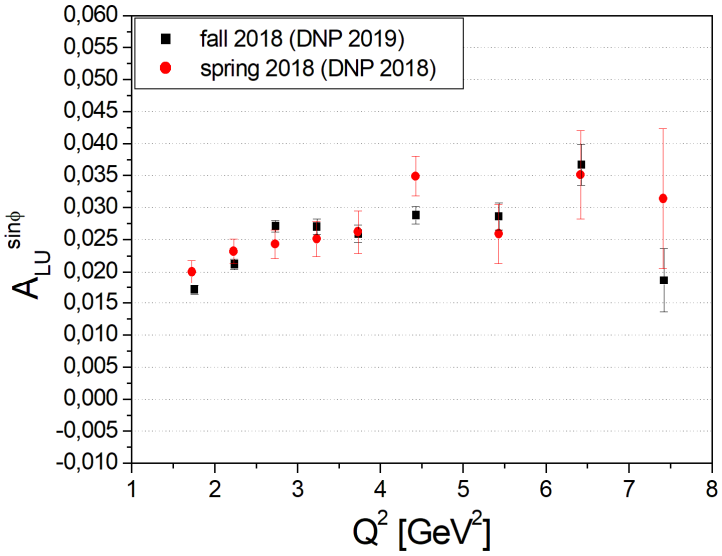
Systematics: Dependence of the result on the data quality

π^+

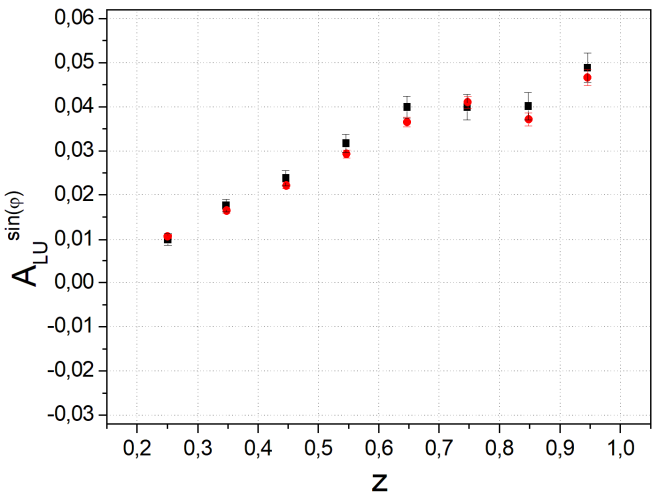


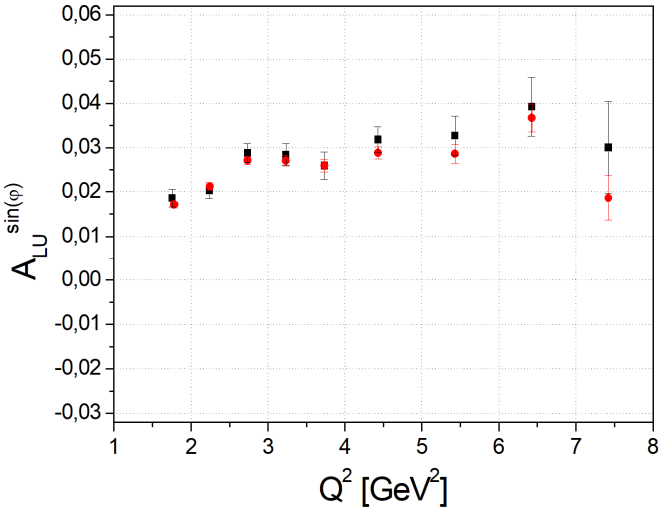


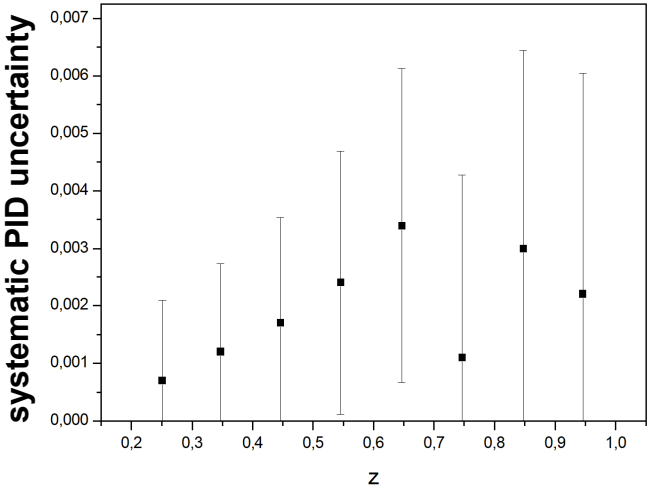


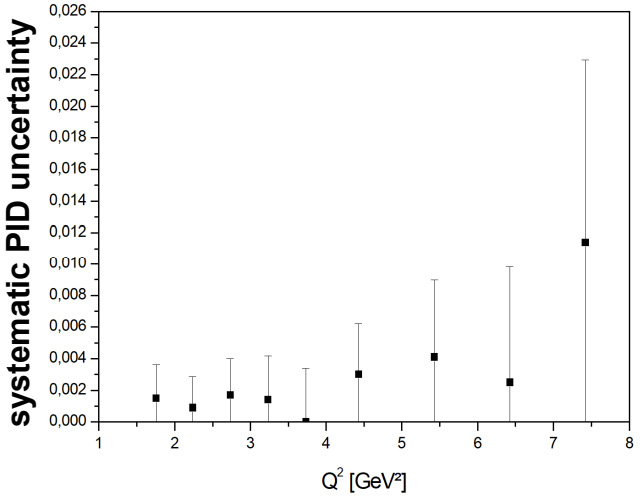


Systemtics: Uncertainty from the PID









red: eventbuilder
black: redefined PID

→ Small effect (requires final statistics for precise results)

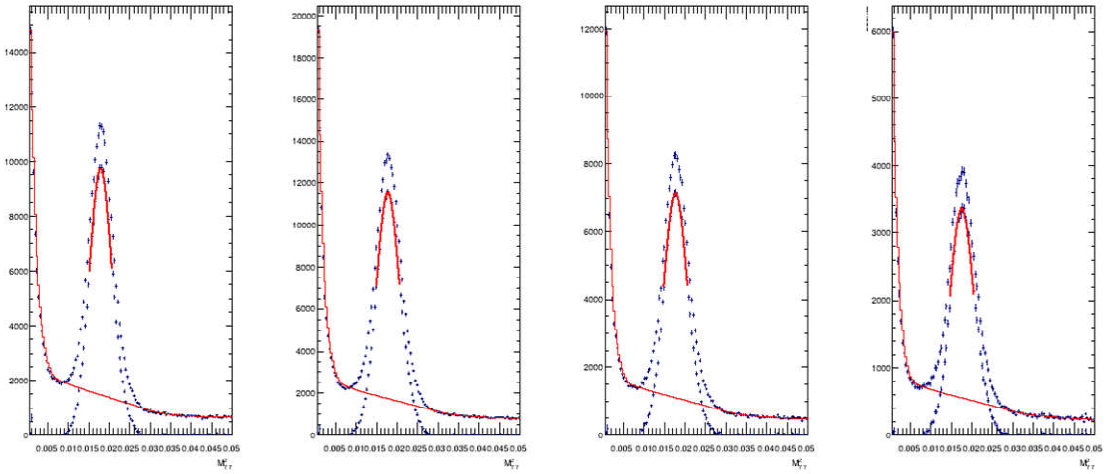
Systematics: Additional effects

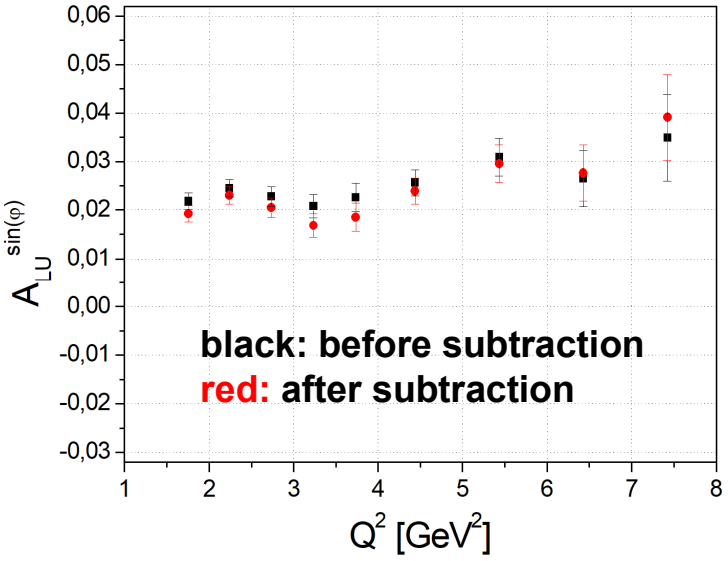
i) Systematics of the beam polarisation ~ 3 – 4 %

→ Can be easily calculated when final value for the statistical and systematic uncertainty of the polarisation measurement is available

ii) Subtraction of the background asymmetry for π^0

x_B = 0.15 **x_B = 0.25** **x_B = 0.35** **x_B = 0.45**





Conclusion and Outlook

- A scheme to refine the eventbuilder PID has been developed
- CLAS12 enables the extraction of SIDIS pion BSA moments with high accuracy in an extended kinematic range.
- $F_{LU}^{\sin\phi} / F_{UU}$ is positive for π^+ and π^0 and close to zero or slightly negative for π^-.
- Already with only 3 % of RGA we can achive a precision that is equal or better than CLAS6
- A multidimensional binning becomes possible for the first time with CLAS12
- The analysis is ongoing on the way to a first publication …