CLAS collaboration meeting, JLAB

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SIDIS Pion Beam Spin Asymmetries with CLAS12 at 10.6 GeV based on the DNP data

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Overview and Introduction

- Physics motivation
- Analysis procedure
- First look on systematic effects
- Multidimensional binning
- Comparison to CLAS and HERMES

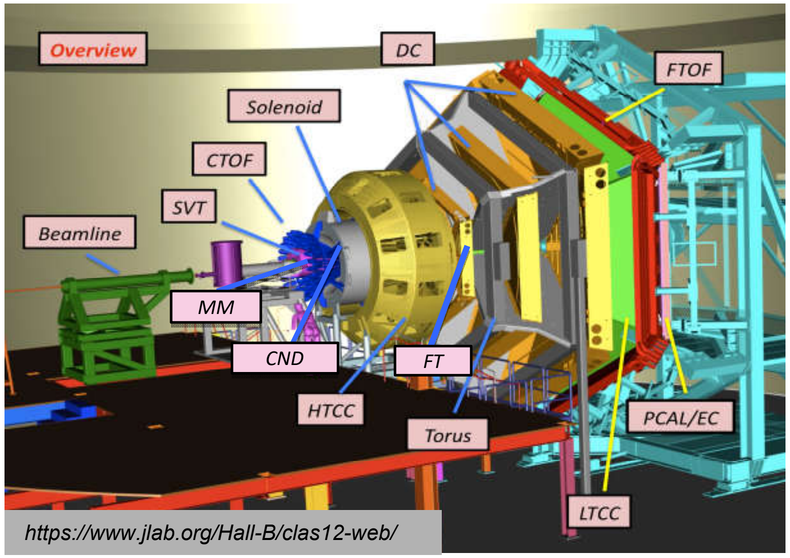
→ Data recorded with CLAS12 during spring of 2018

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

→ 10.6 GeV electron beam

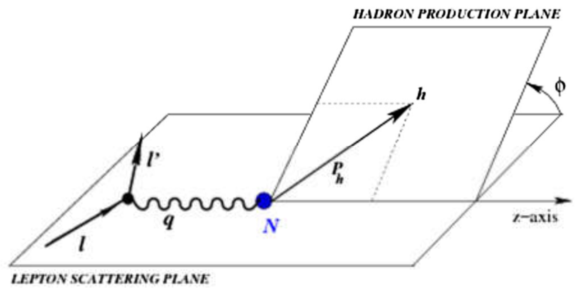
→ 85 % average longit. polarization

→ 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)

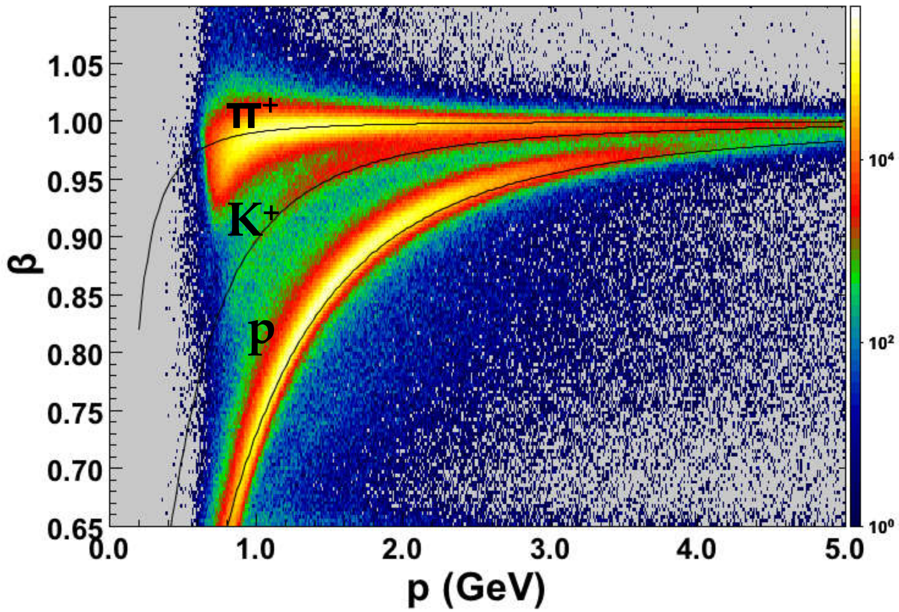
Particle ID

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**)



Event selection and kinematic cuts

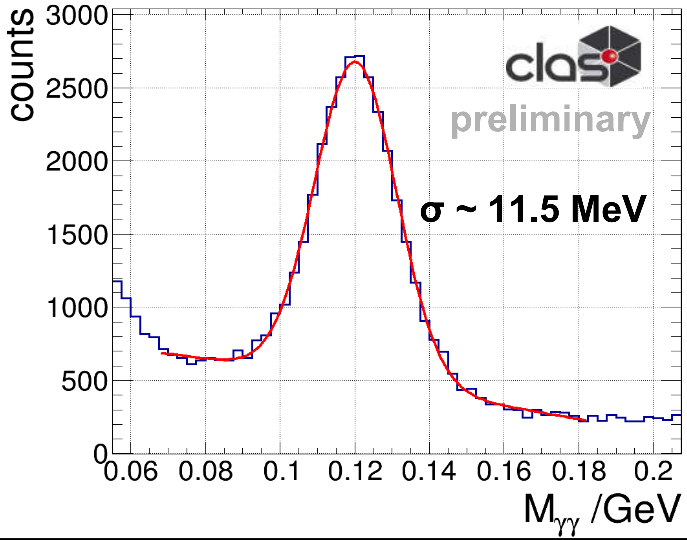
π^0 selection:

$E_\gamma > 0.6$ 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

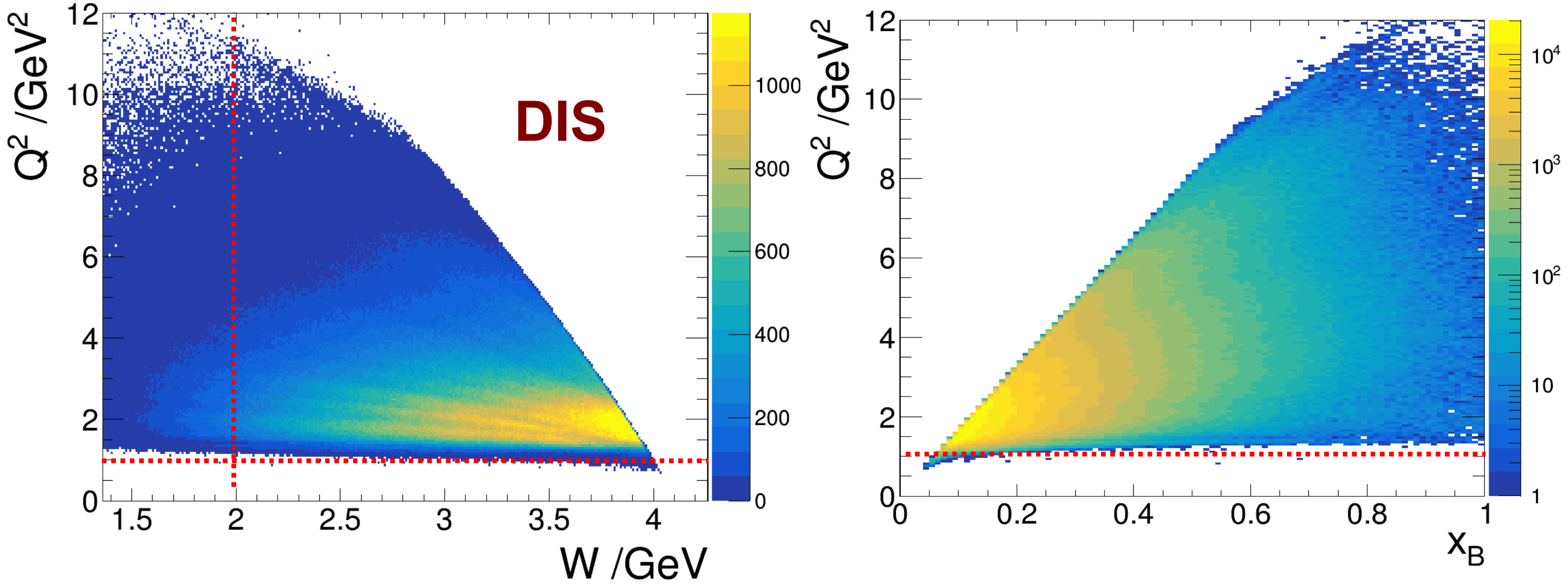
Additionally: Cut on the final state hadron momentum fraction z

$$0.3 < z < 0.7$$

→ $z > 0.3$ 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)

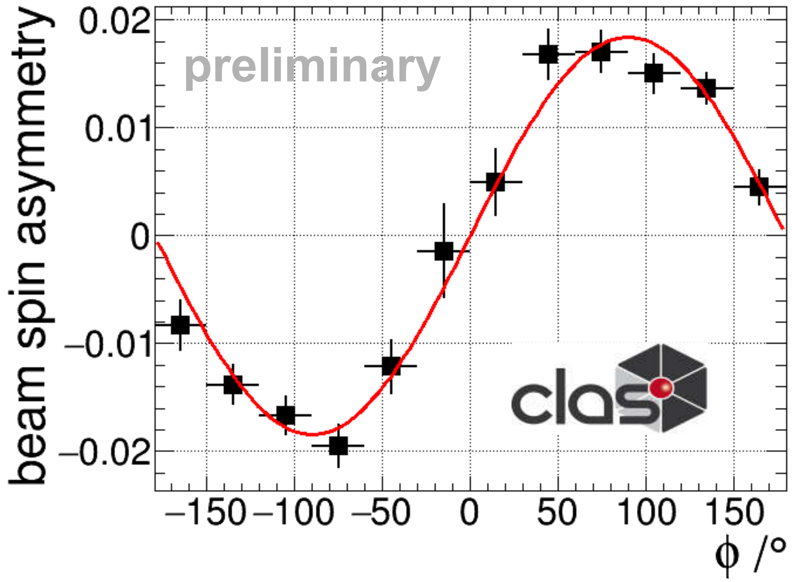


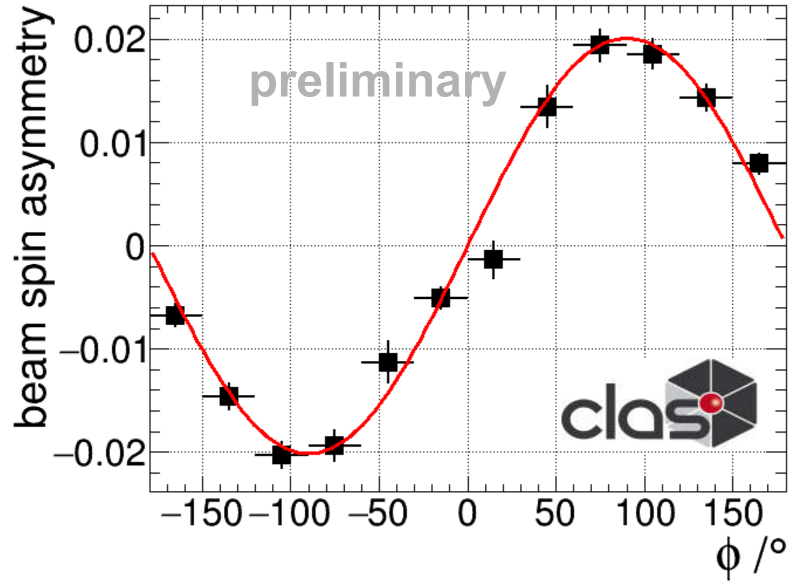
Integrated beam spin asymmetry

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

P_e = 85 % : average e^- beam polarisation

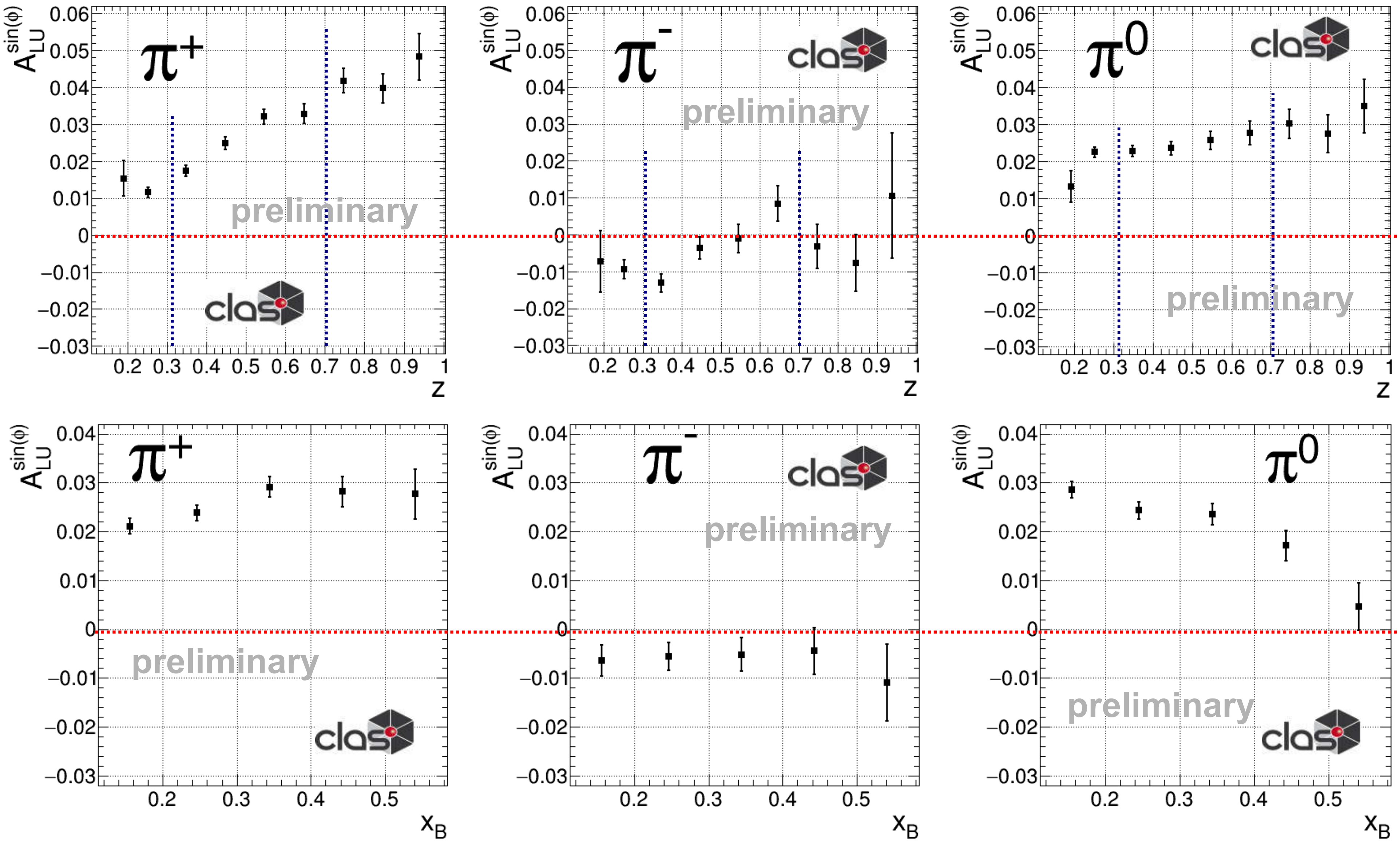
π^+ **π^0**



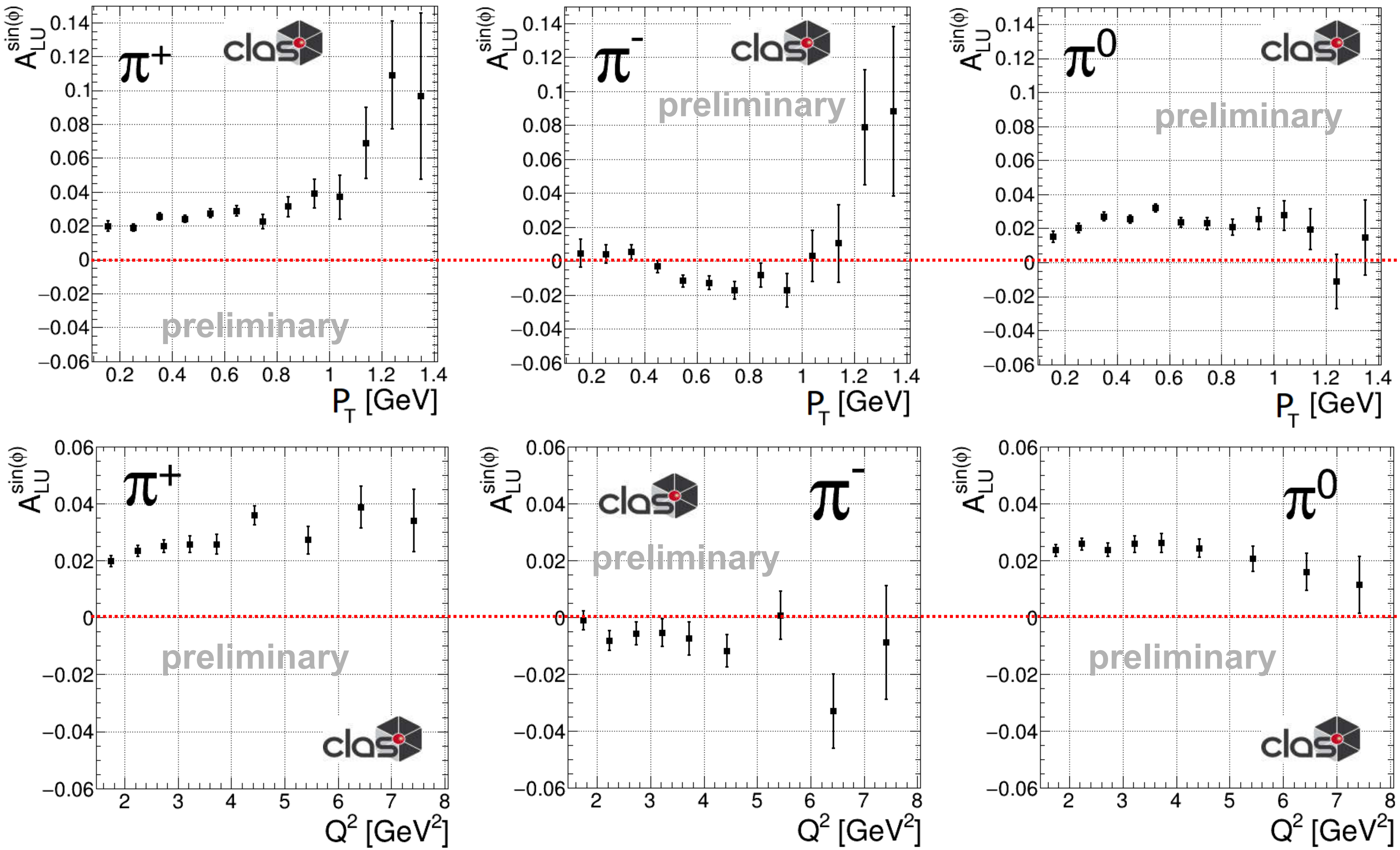


➔ Clear sinoid shape can be observed, according to $A_{LU}^{\sin\varphi} \sin\varphi$

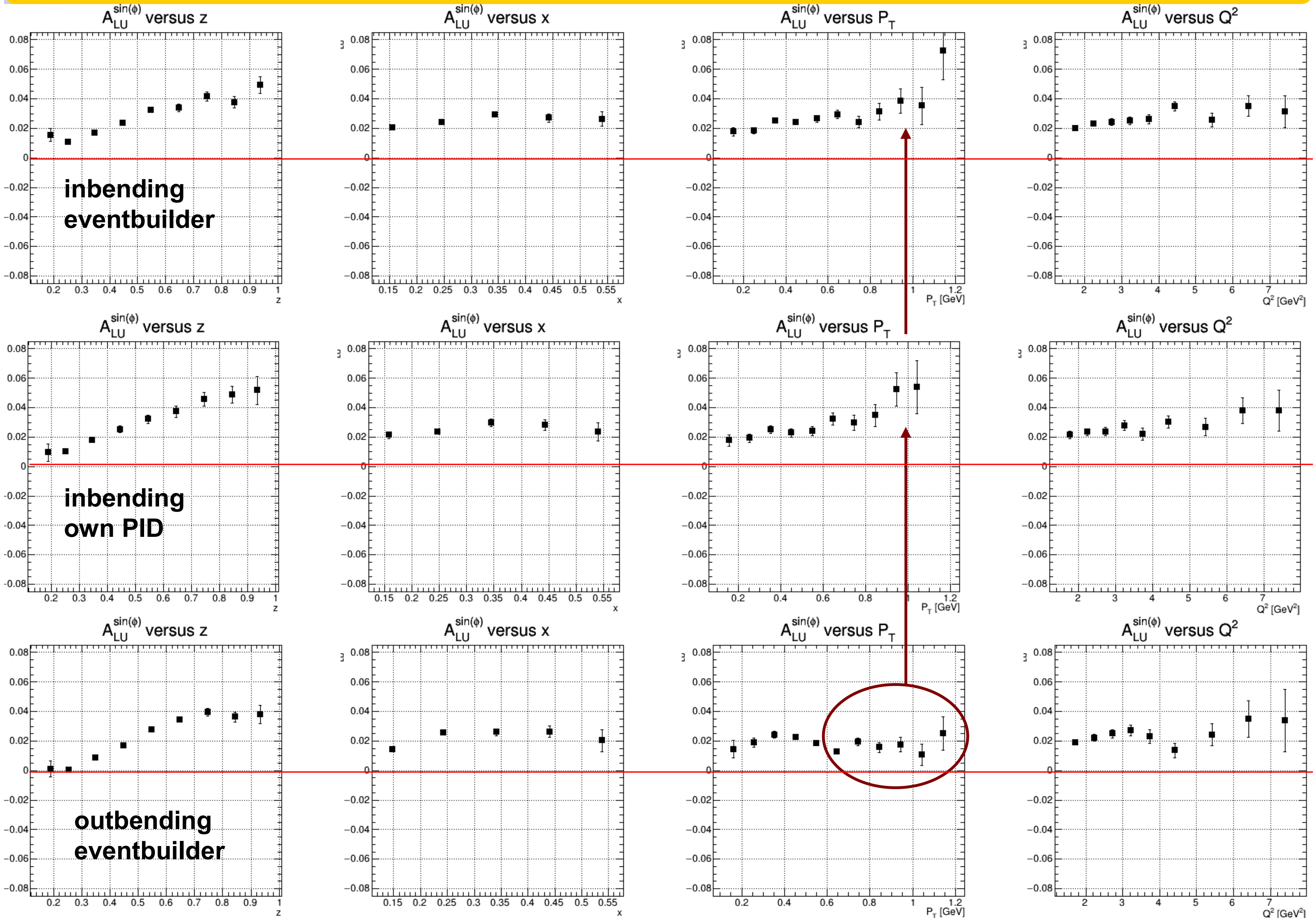
$A_{LU}^{\sin(\varphi)}$ for a **z** and **x_B** binning



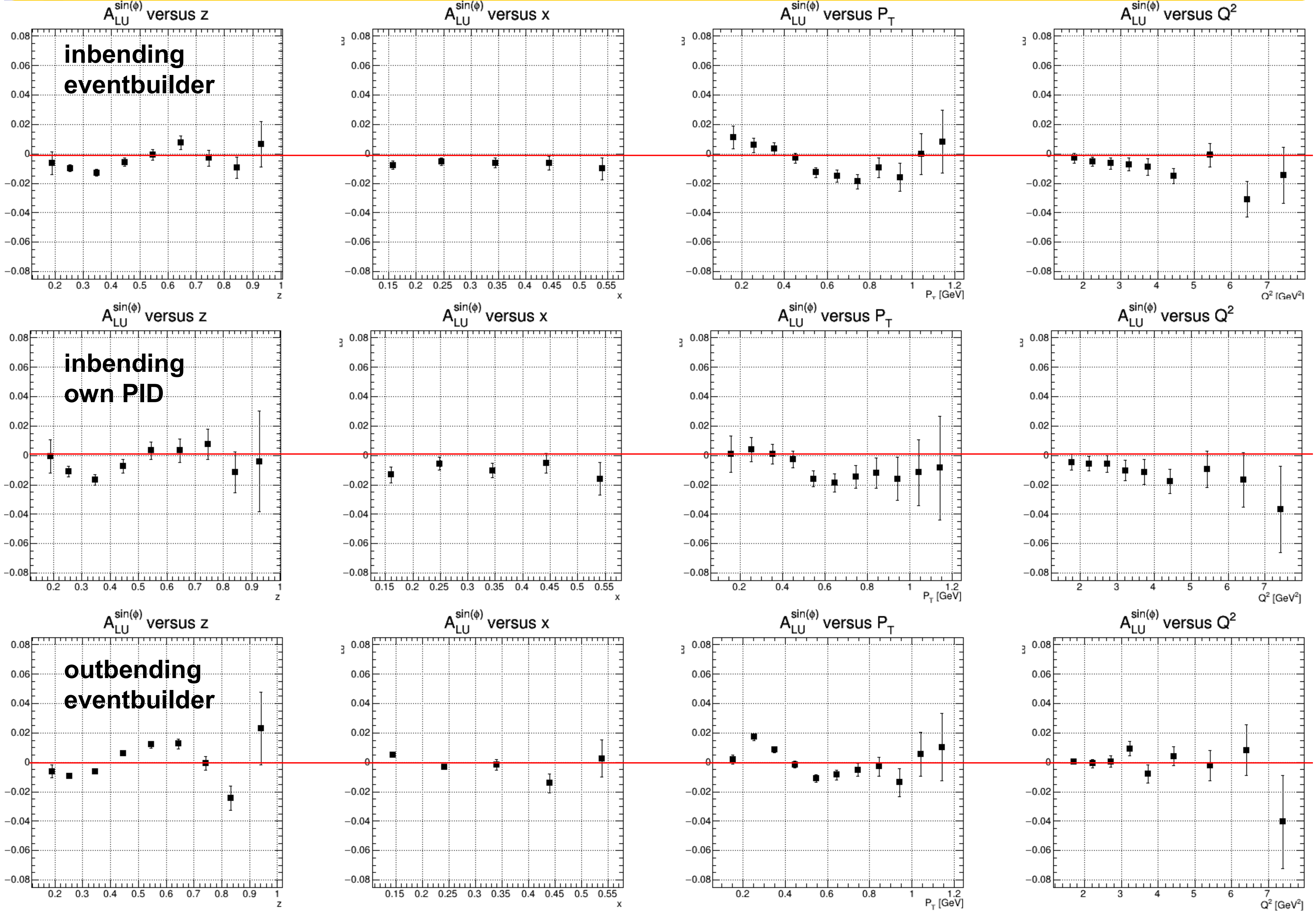
$A_{LU}^{\sin(\varphi)}$ for a $\mathbf{p_T}$ and $\mathbf{Q^2}$ binning



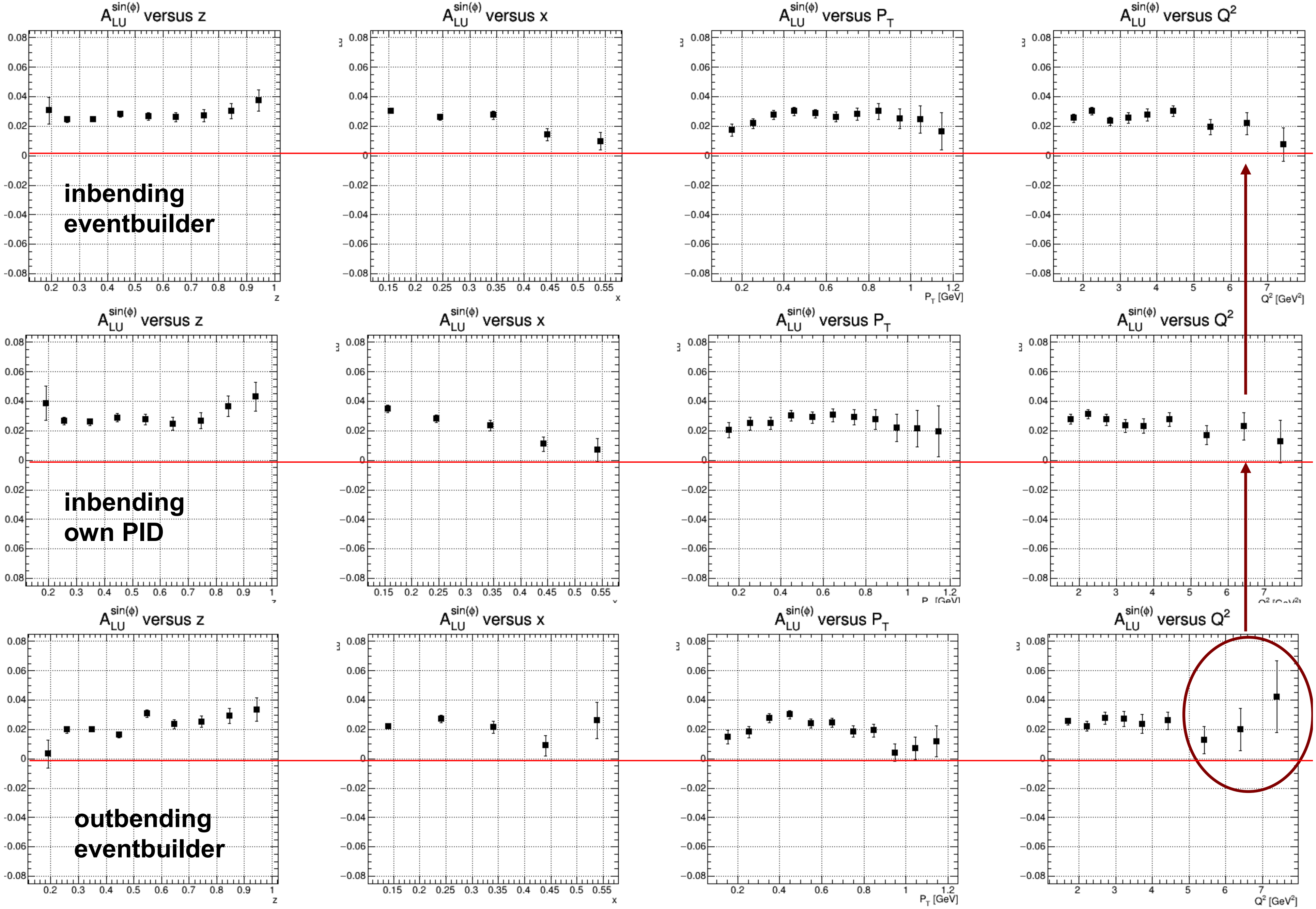
π^+ - first look on systematic effects



π⁻ - first look on systematic effects



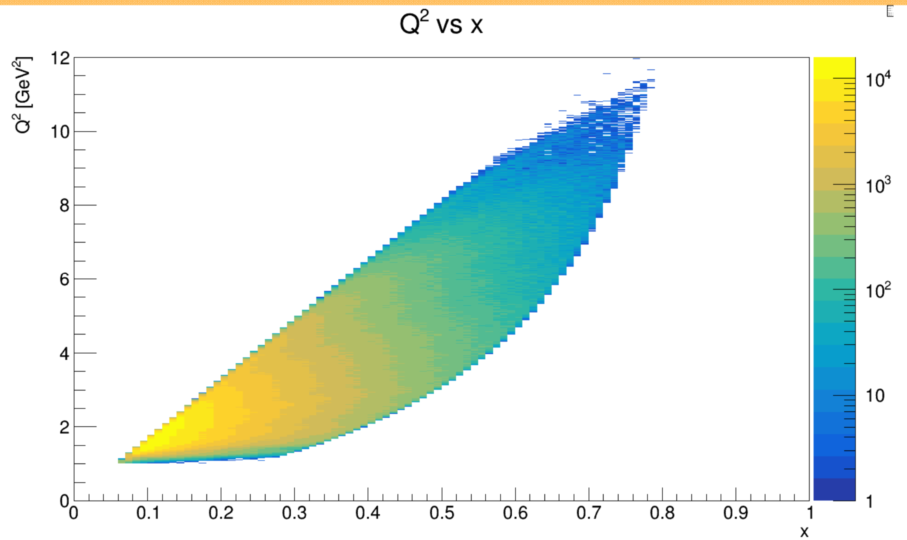
π^0 - first look on systematic effects

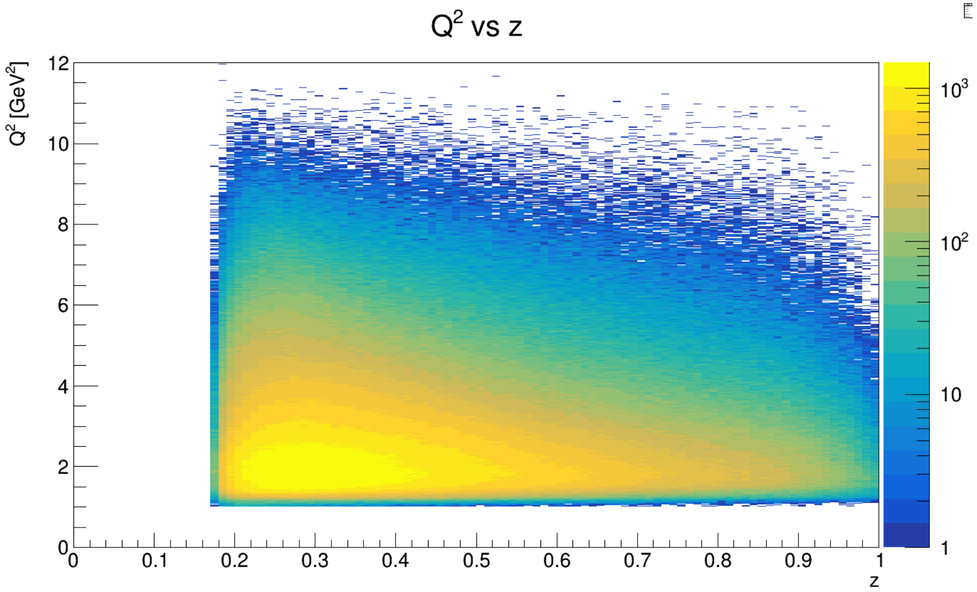


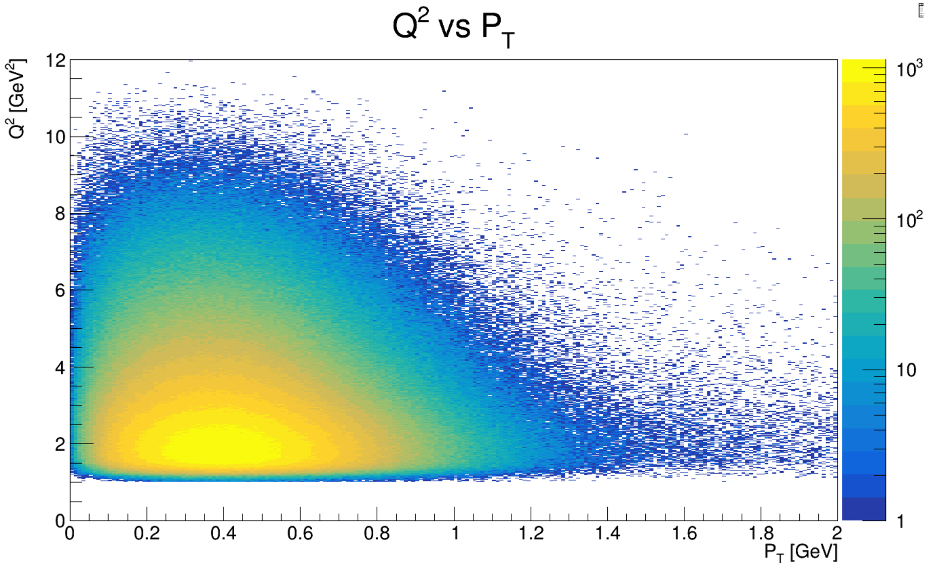
First studies on a multidimensional binning with CLAS 12

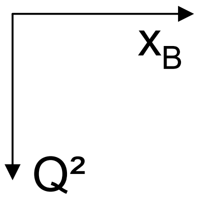
- Statistics of the full spring run (10% of RGA) will be sufficient for a multidimensional binning
- **Up to now:** 10 % of the spring run already work well, but cause incresed error bars for high Q^2 and / or P_T bins
- Study has been done for all combinations of bins, but following slides will focus on Q^2 and P_T dependence for different sencondary bins

π^+ kinematic coverage (similar for π^-, π^0)

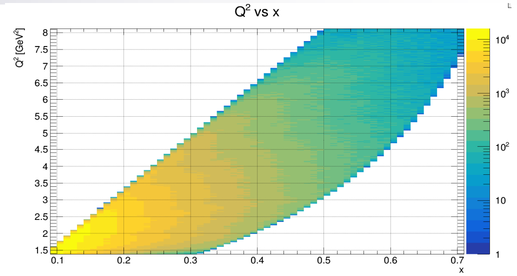


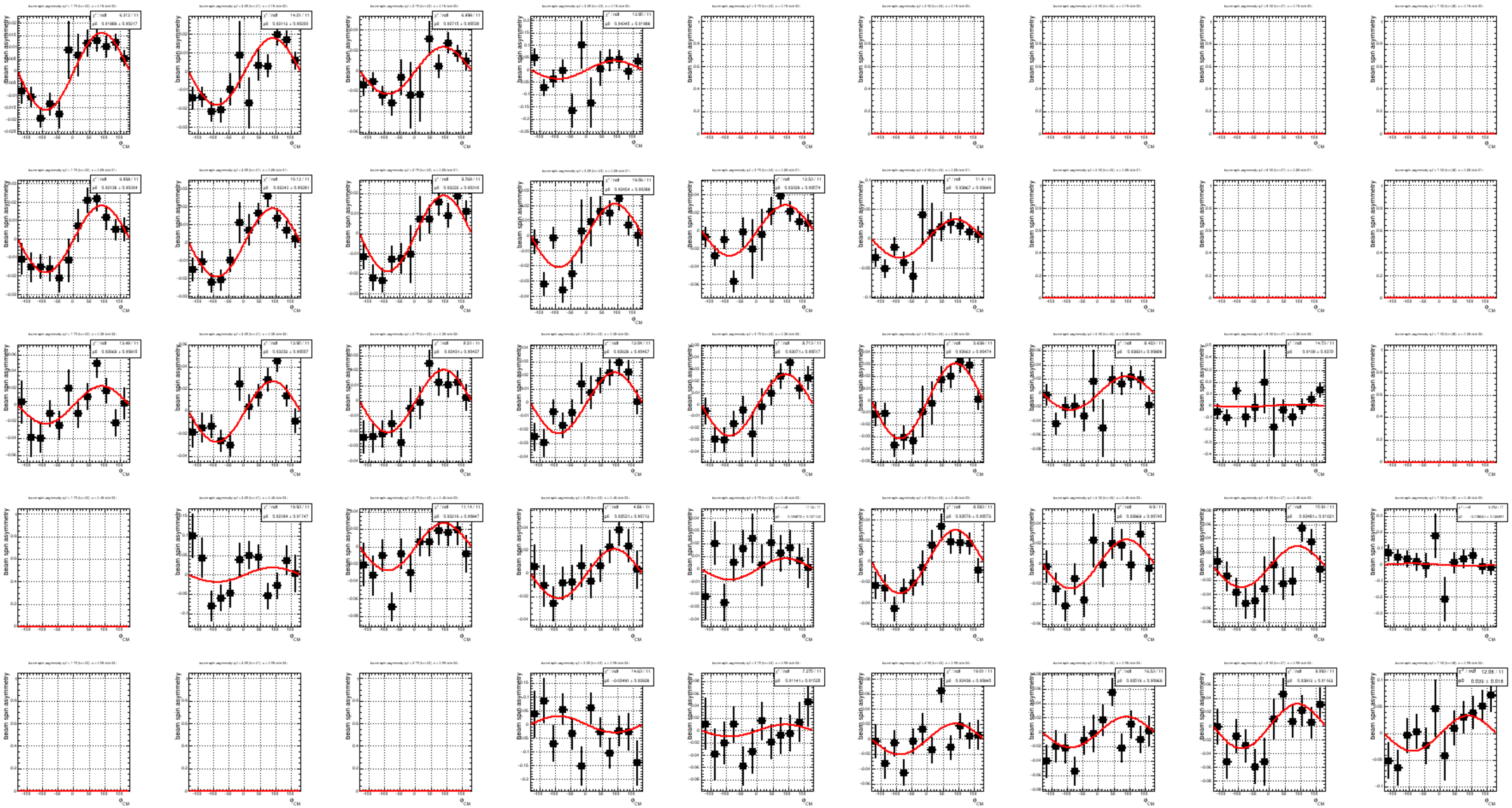






BSA for π^+ Q^2 vs x_B

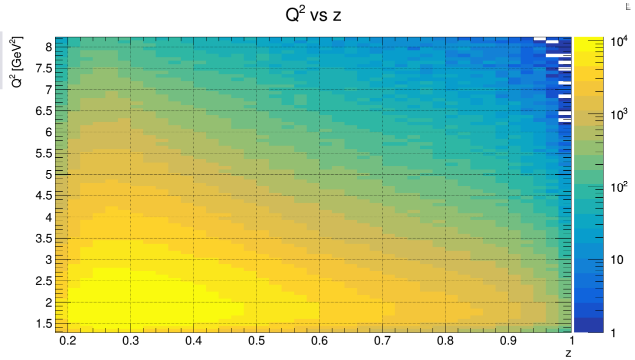


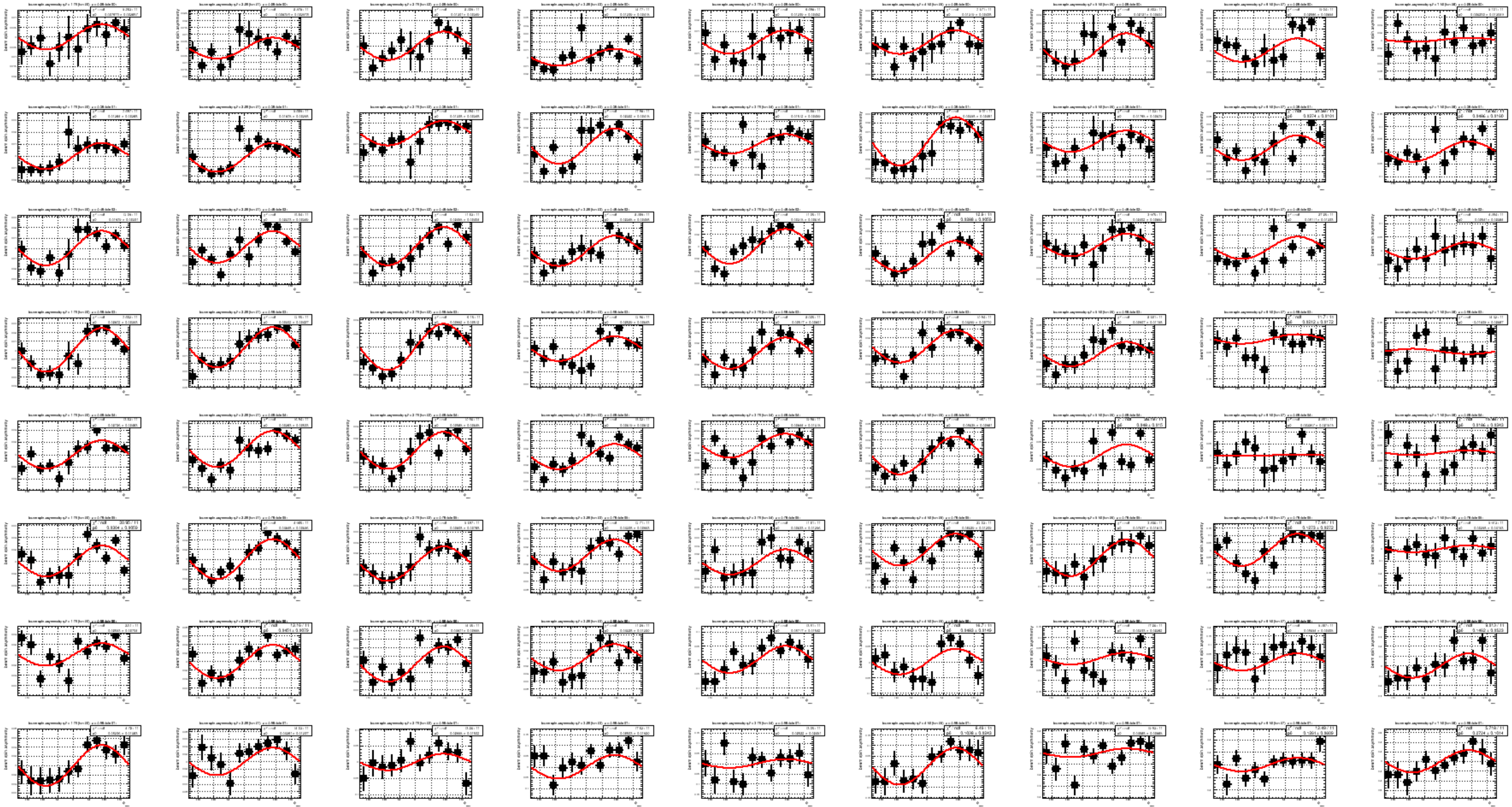


z

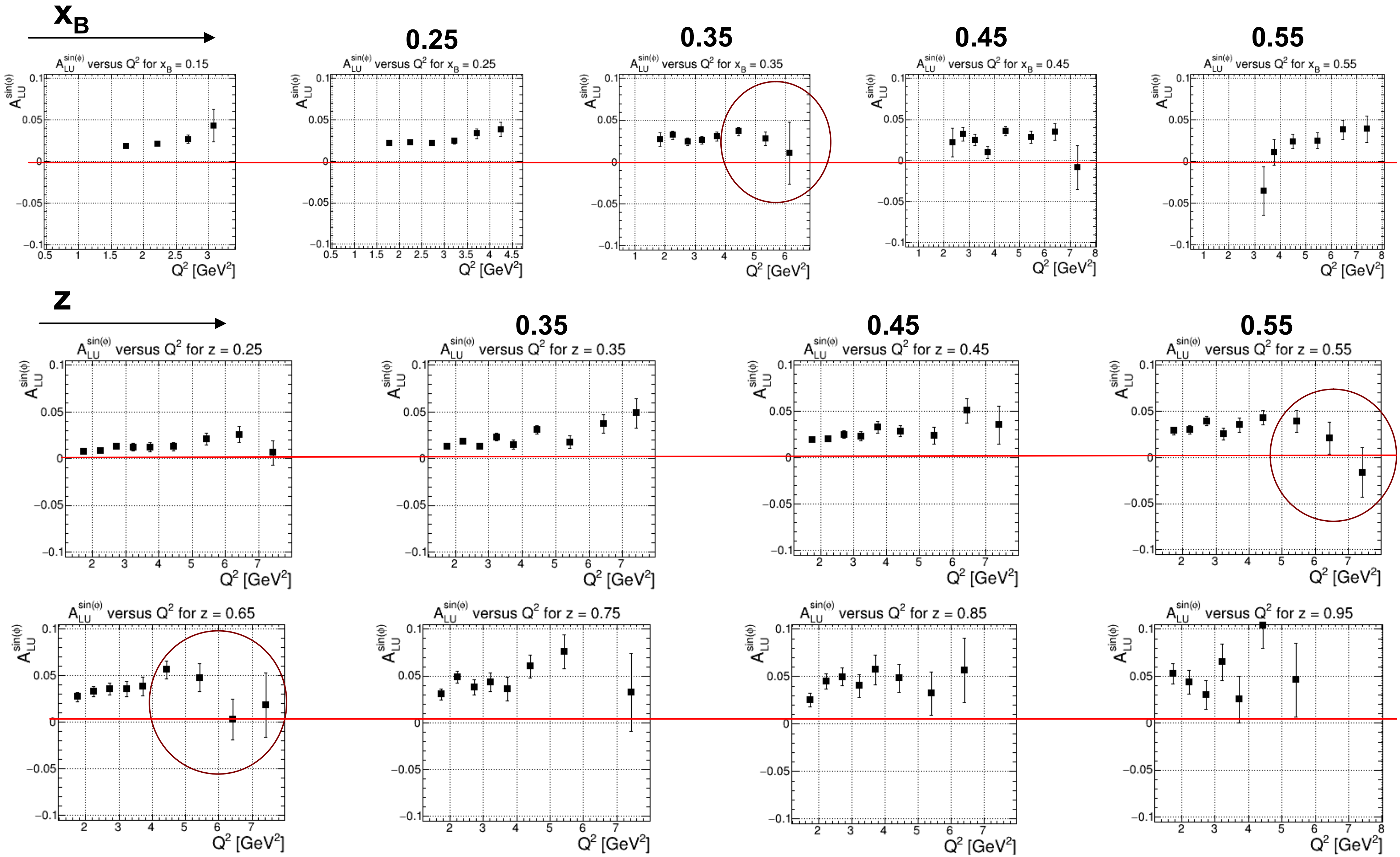
Q^2

BSA for π^+ Q^2 vs z



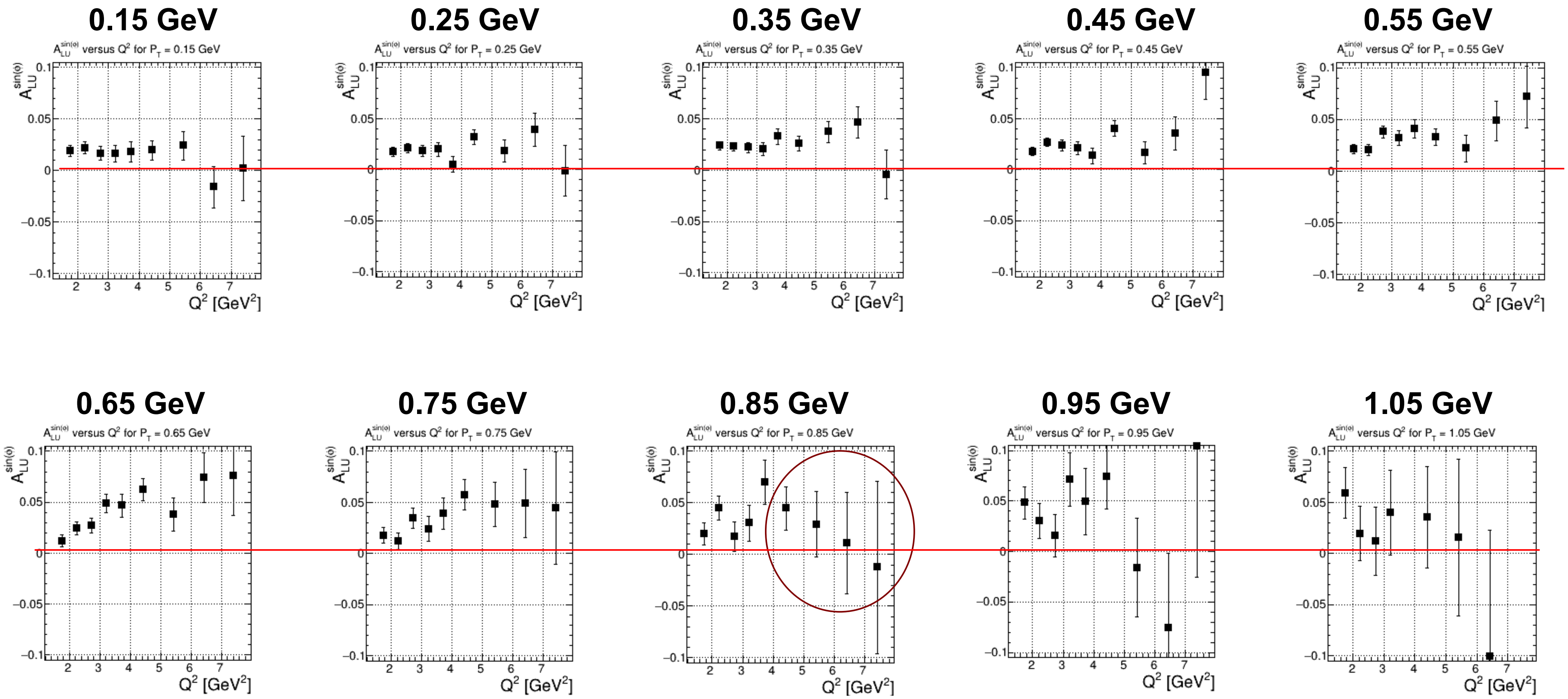


π^+ - Q^2 dependence of $A_{LU}^{\sin(\varphi)}$

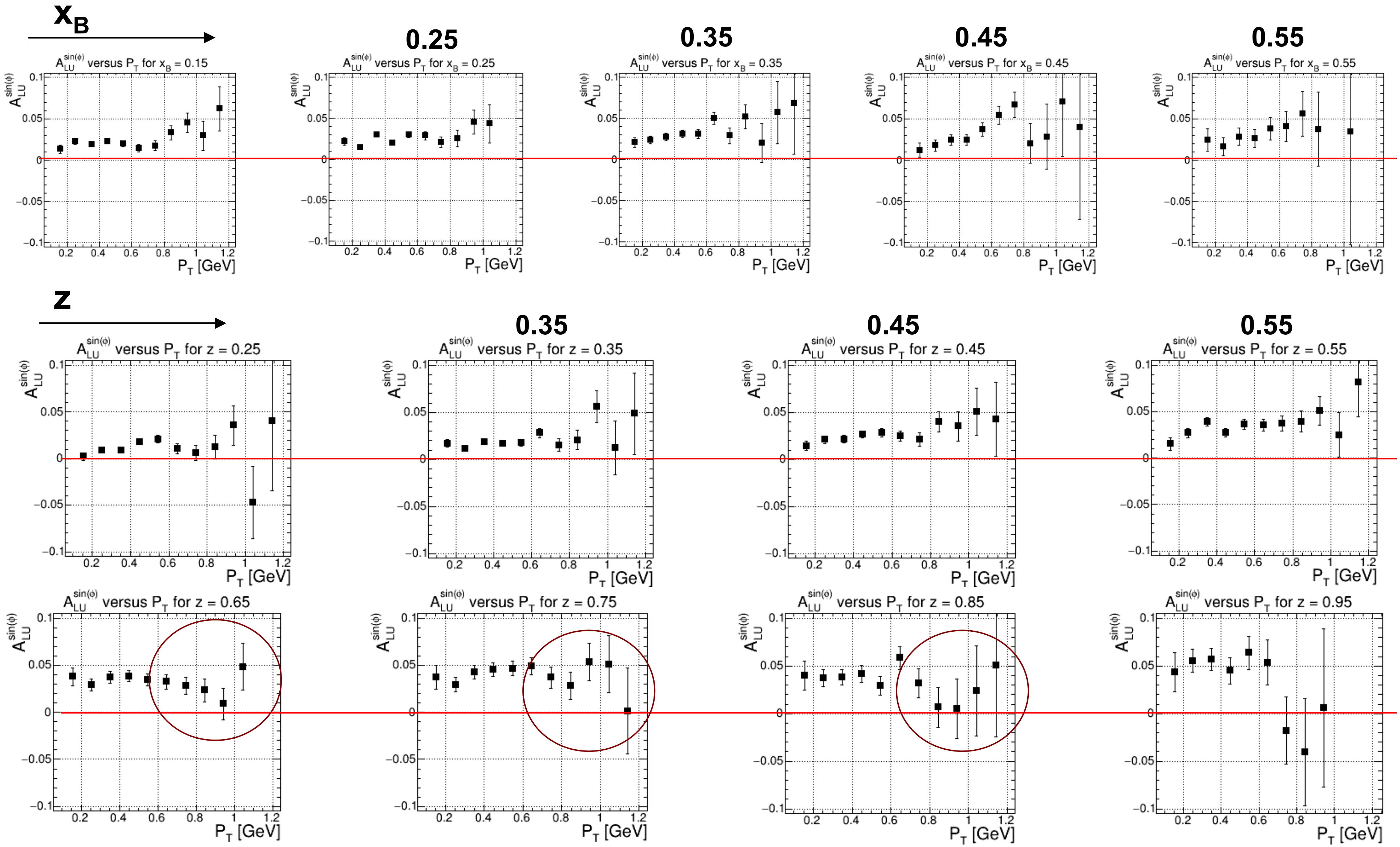


π⁺ - Q² dependence of $A_{LU}^{\sin(\varphi)}$

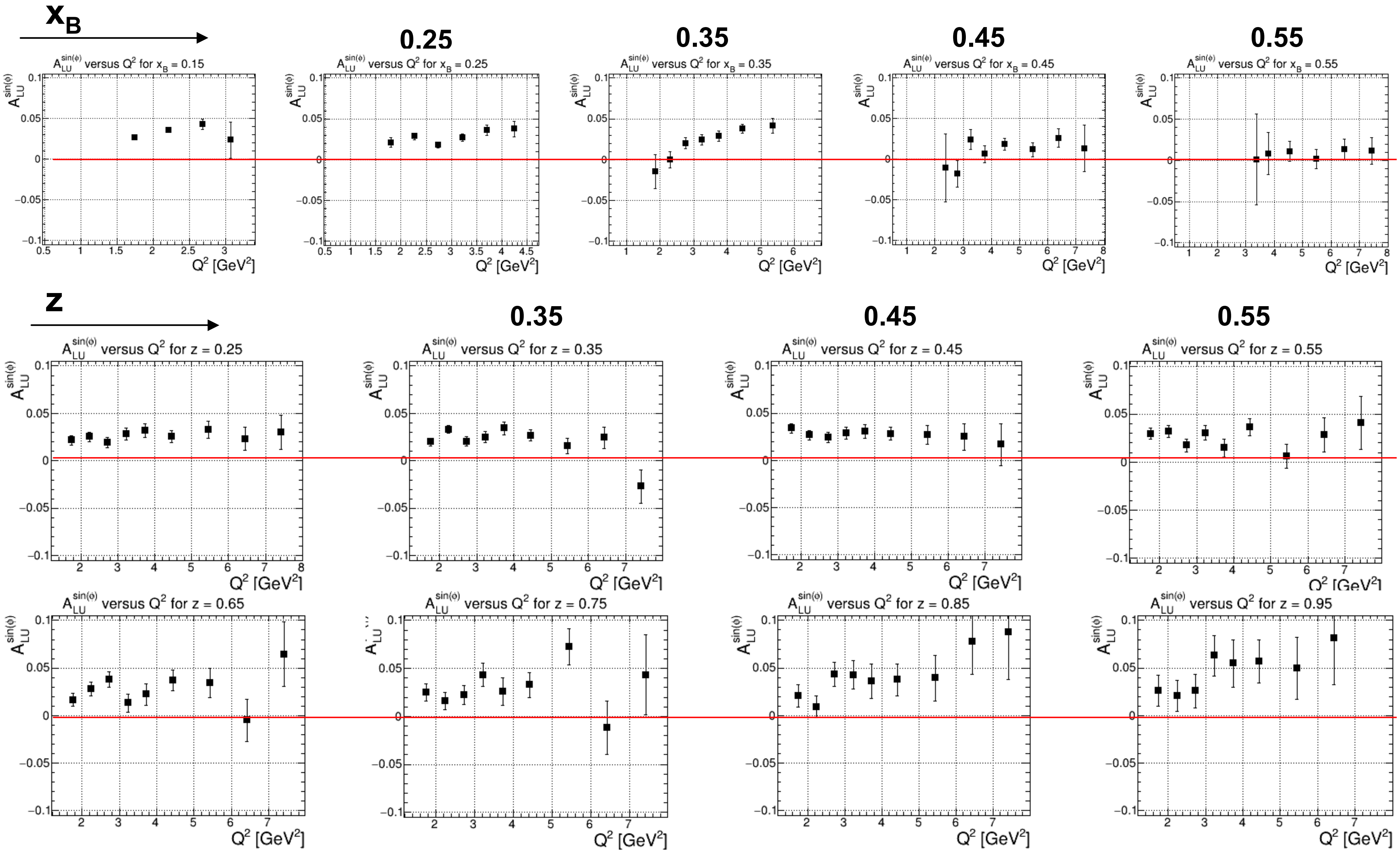
P_T →



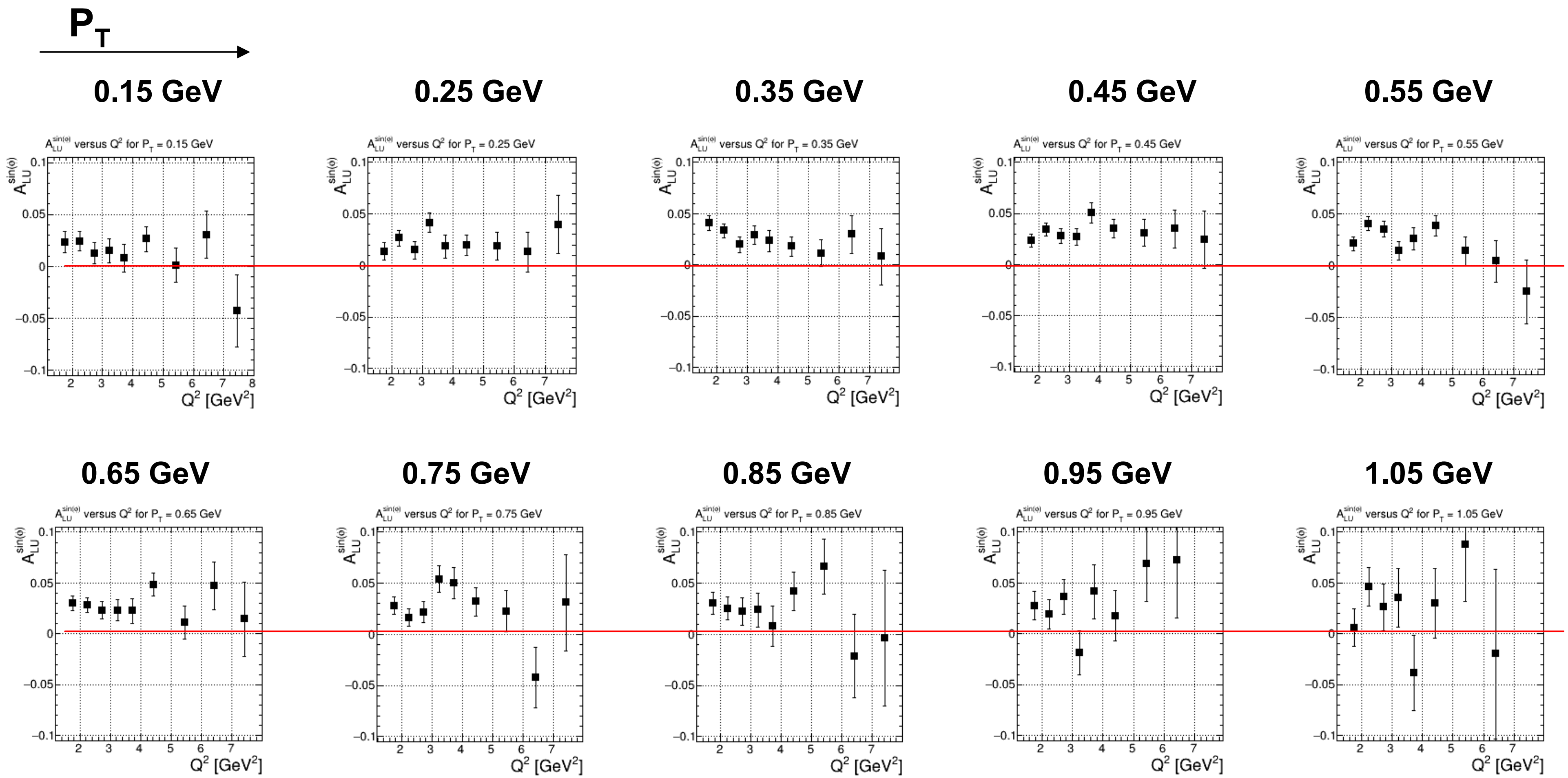
π⁺ - P_T dependence of $A_{LU}^{\sin(\varphi)}$



π^0 - Q^2 dependence of $A_{LU}^{\sin(\varphi)}$



π^0 - Q² dependence of $A_{LU}^{\sin(\varphi)}$



Comparison of $F_{LU}^{\sin(\Phi)}$ for π^+ π^- and π^0 and with other experiments

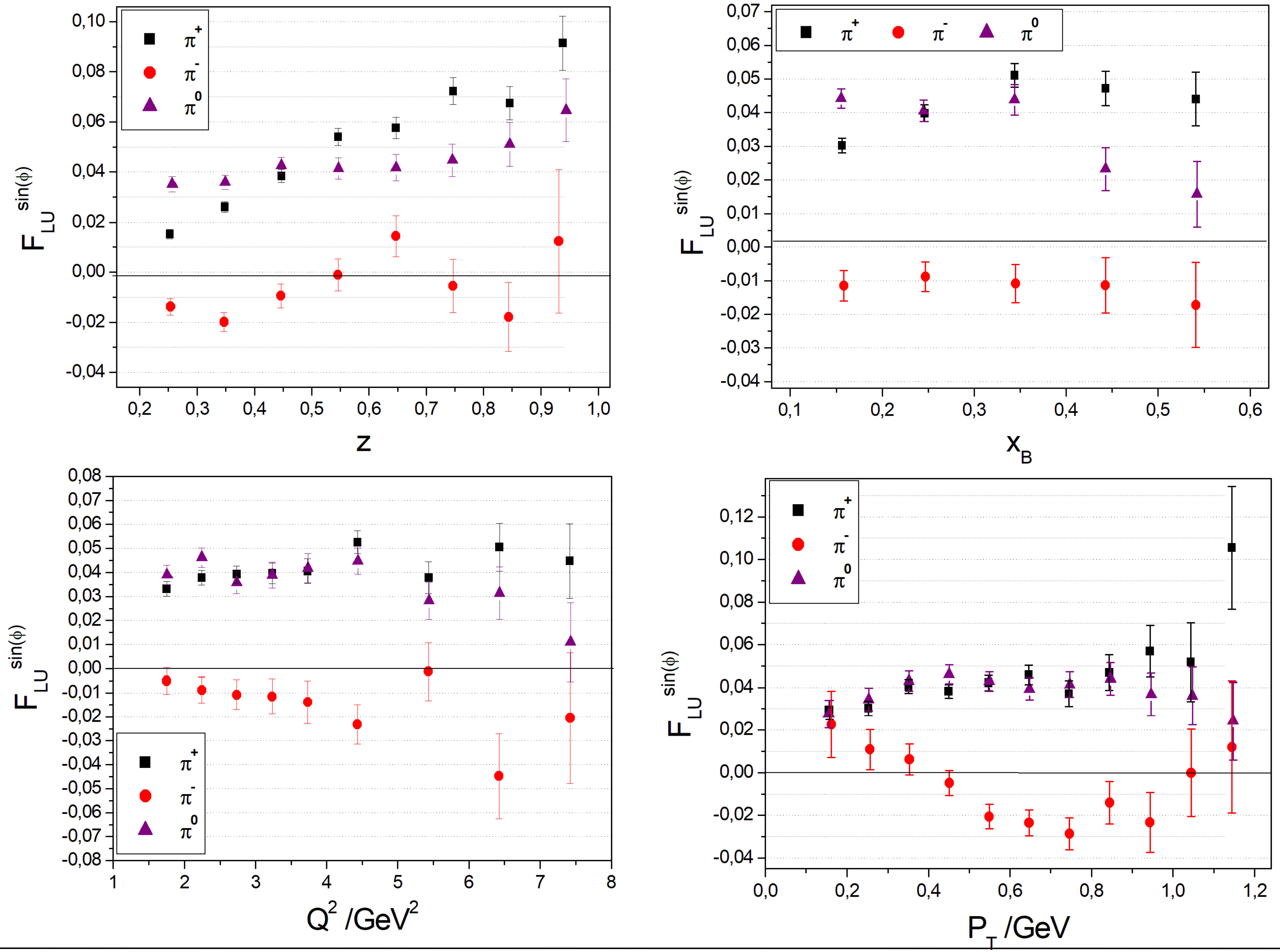
➔ **inbending configuration**

$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} \begin{cases} \sim \lambda_e A_{LU}^{\sin\phi} \sin\phi \\ \sim \lambda_e \sqrt{2\,\varepsilon(1-\varepsilon)}\, \sin\phi_h\, F_{LU}^{\sin\phi_h} \end{cases}$$

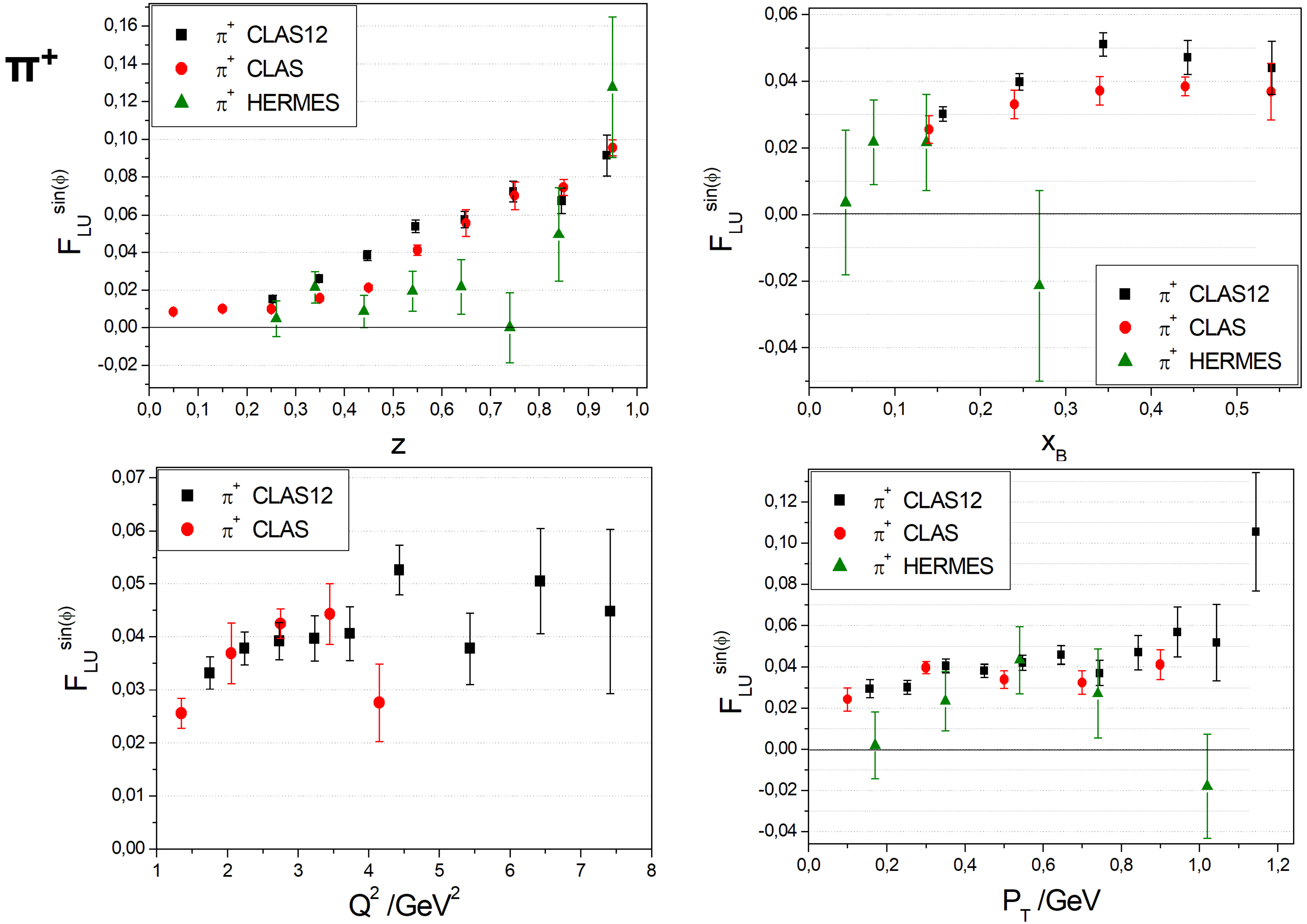
$$\varepsilon = \frac{1 - y - \frac{1}{4}\gamma^2 y^2}{1 - y + \frac{1}{2}y^2 + \frac{1}{4}\gamma^2 y^2} \qquad y = \frac{P\cdot q}{P\cdot l} \qquad \gamma = \frac{2Mx}{Q}$$

$$q = l - l'$$

Comparison of differently charged pions

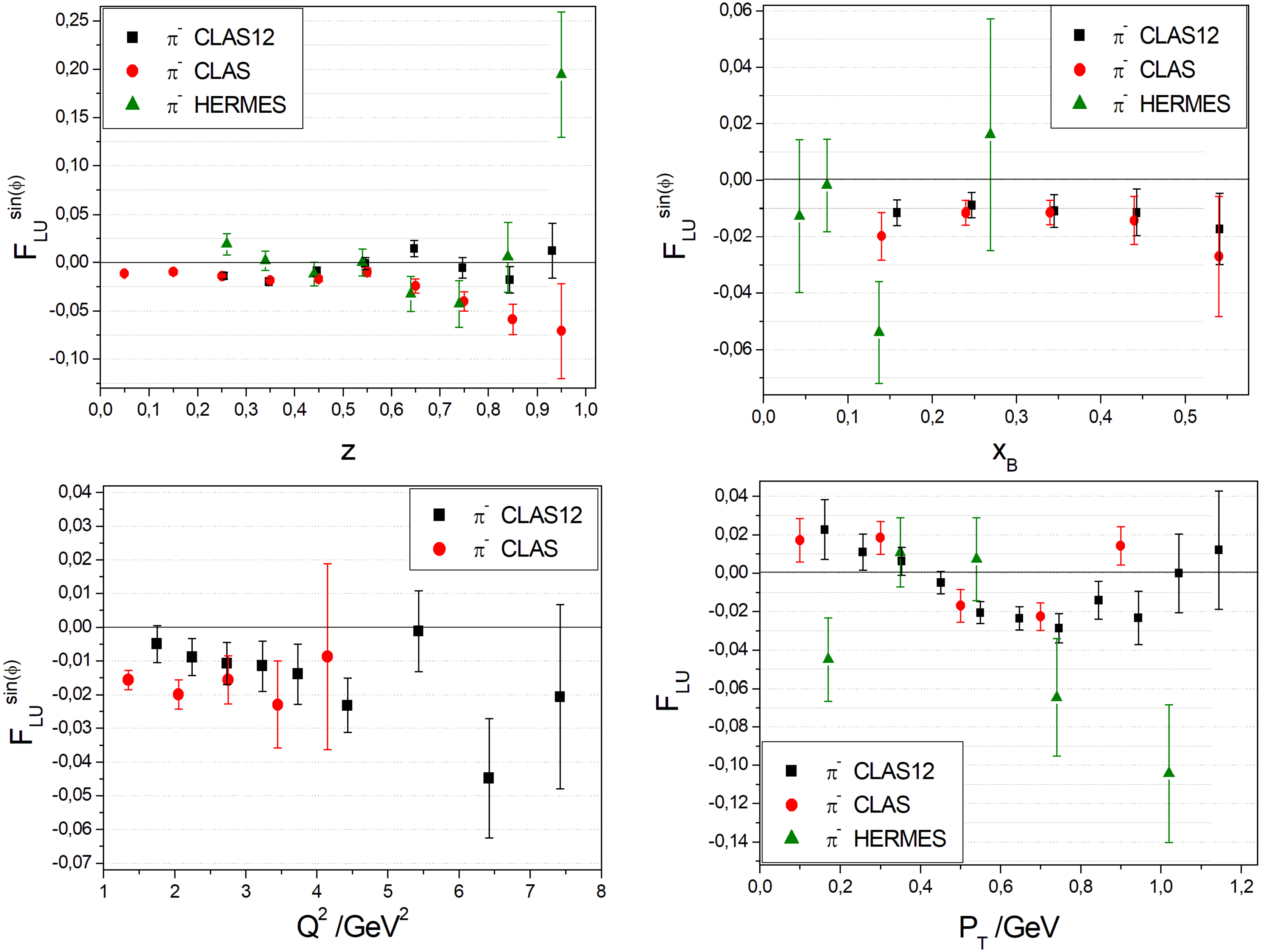


Comparison of π^+ results for CLAS12, CLAS and HERMES



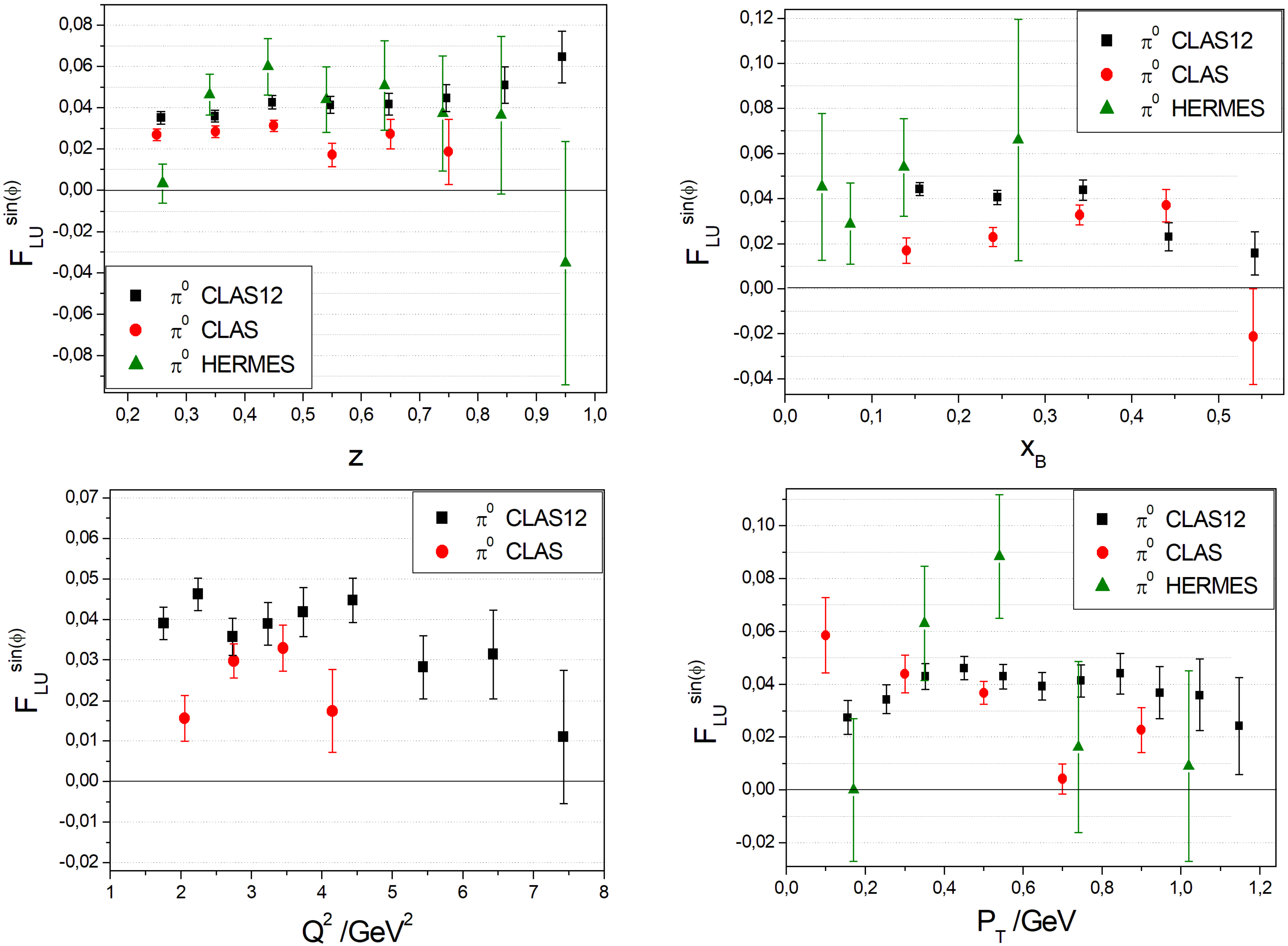
Comparison of π⁻ results for CLAS12, CLAS and HERMES

π⁻



Comparison of π^0 results for CLAS12, CLAS and HERMES

π^0



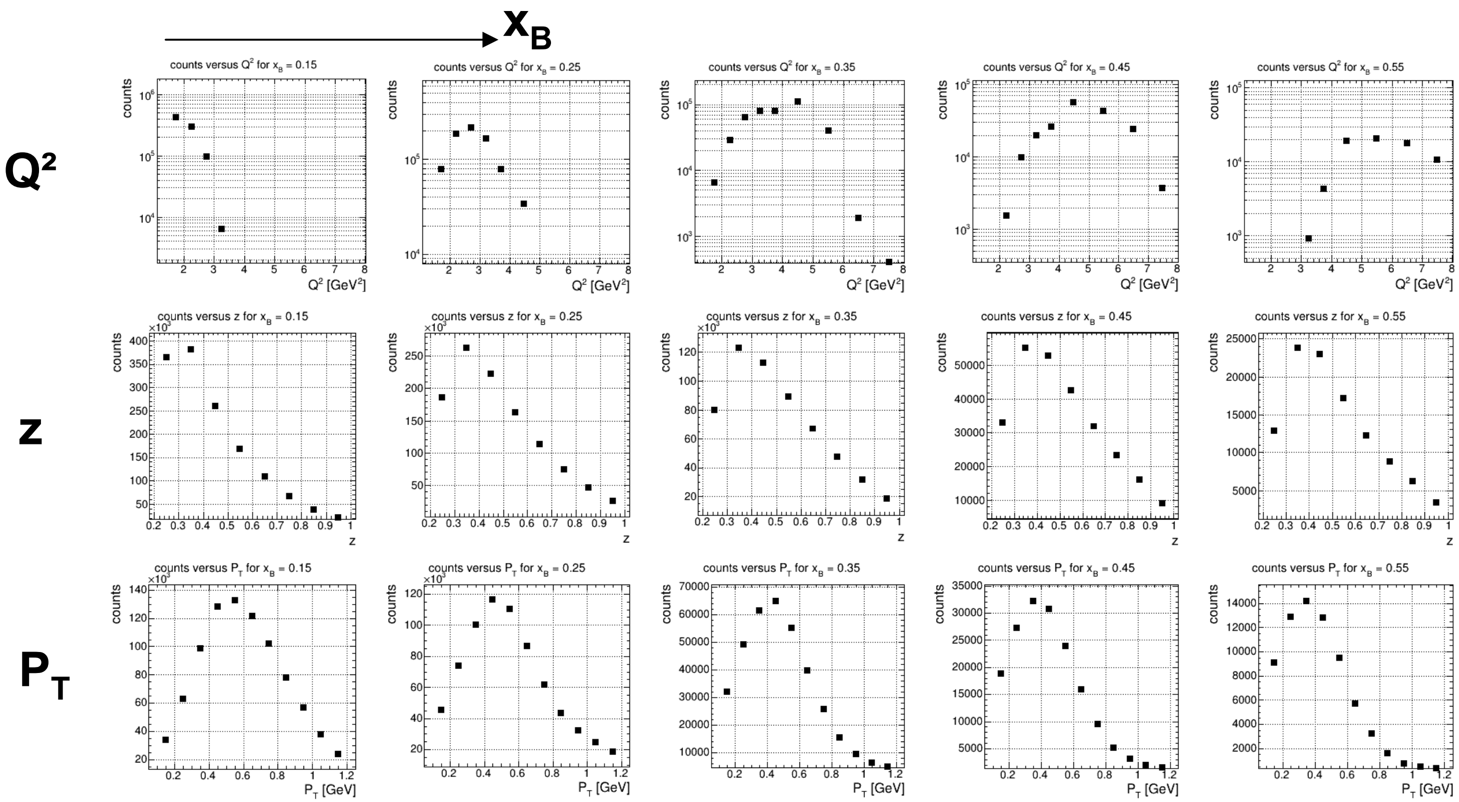
Estimate of the number of events for SIDIS MC

➔ For the full spring run a MC sample of **400M SIDIS events** is required

➔ Based on the available data, an estimate of the number of events in each bin (for a 1D and 2D binning) has been performed

➔ Can be used as input for a weighted MC generator (available from Harut)

Number of events for the different bins in x_B for the π^0 sample:



Conclusion and Outlook

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

- **Next steps:**
  - Repeat the studies with the full spring run data
  - Generate high statistics MC to study acceptance effects etc.
  - The behaviour at large Q^2 and p_T values will be studied in more detail
  - Systematic effects will be investigated