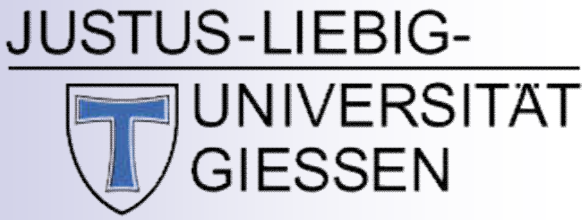
CLAS collaboration meeting, JLAB

July 22, 2020

SIDIS Single Pion Beam Spin Asymmetry Measurements with CLAS 12



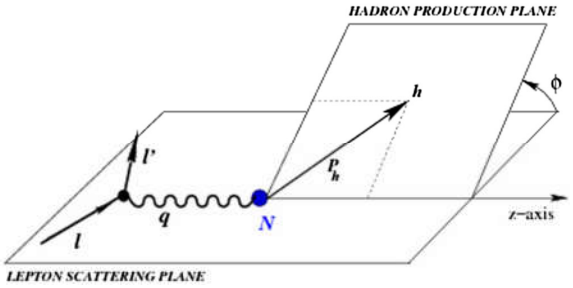
Stefan Diehl

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



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

➔ A convolution of 4 TMDs and 4 fragmentation functions

➔ The results can be used in a global fit to constrain the TMDs and FF

Physics Motivation

Goal of this study: Extract $F_{LU}^{\sin\phi} / F_{UU}$ from single π^+, π^- and π^0 BSA

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

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

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

$$A_{LU}^{\sin\phi} = \sqrt{2\varepsilon(1-\varepsilon)} \frac{F_{LU}^{\sin\phi}}{F_{UU}}$$

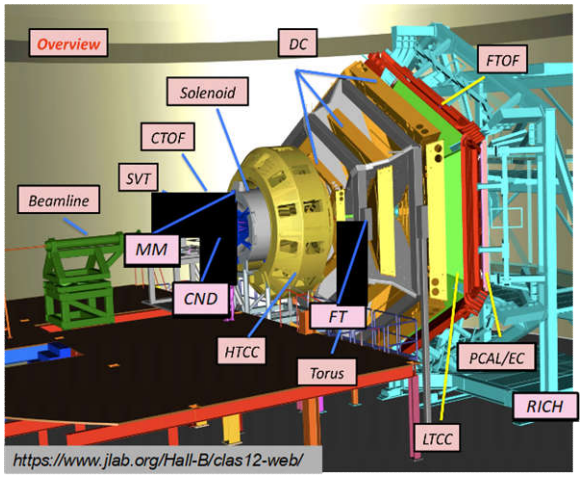
Past: Measurements have been performed with CLAS, HERMES and COMPASS

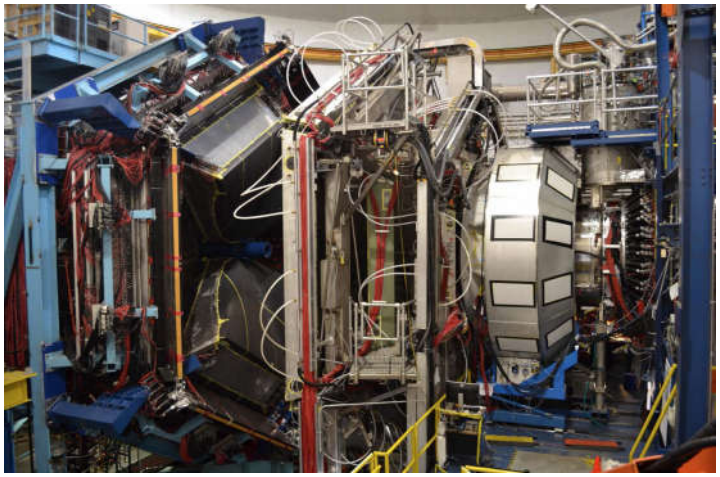
Advantages of CLAS12 → Significantly higher statistics

→ Extended kinematic coverage (Q^2, P_T)

First publication with CLAS12: A multidimensional study in Q^2, x_B, z and P_T

Experimental Setup and Available Dataset





RG-A data from fall 2018 (pass 1 cooking):

➔ 10.6 GeV electron beam ➔ 86.3 % / 89.2 % average polarization

➔ liquid H_2 target ➔ Available SIDIS single pion events:

	inb. pid + QA	outb. evb. no QA
π^+	$5 * 10^7$	$1 * 10^8$
π^-	$2 * 10^7$	$1 * 10^8$
π^0	$1 * 10^7$	$4 * 10^7$

QA: Common QA scheme „good for BSA“

Electron ID

Basis: eventbuilder

1. PCAL fiducial cuts (v, w > 9 cm)

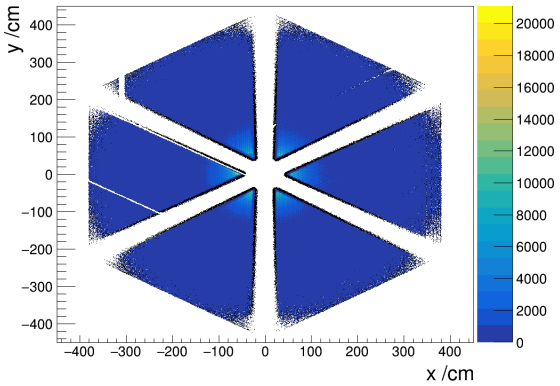
2. DC fiducial cuts for the 3 regions

3. Calorimeter sampling fraction: E/p > 0.17

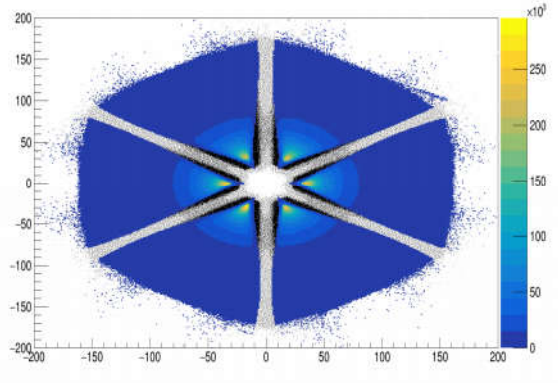
4. PCAL energy deposition > 0.07 GeV

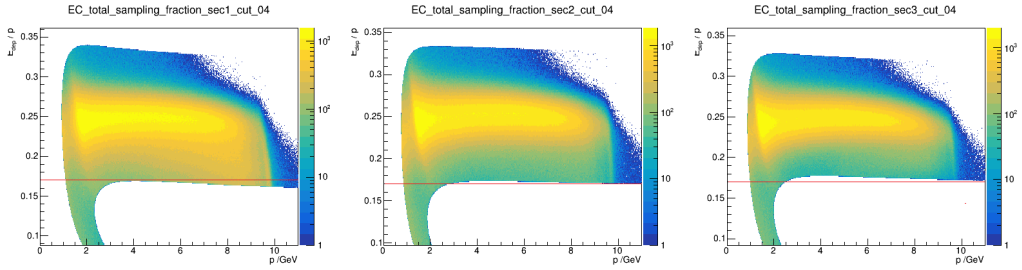
5. z-vertex cut

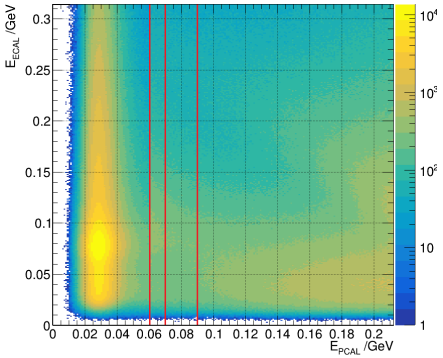
PCAL

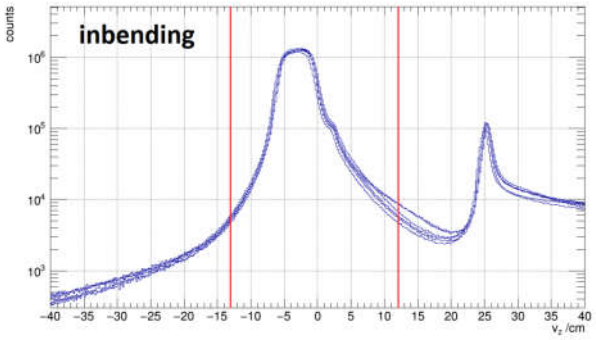


DC region 1



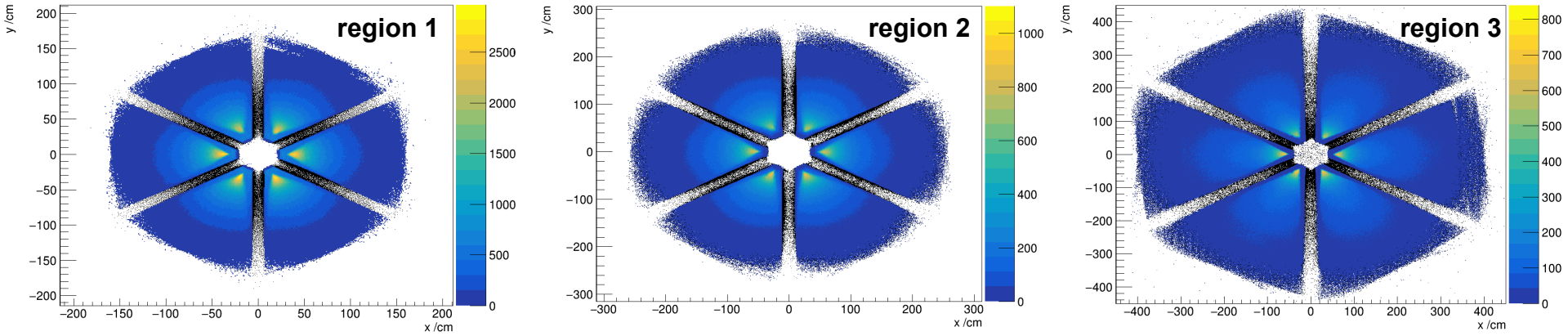




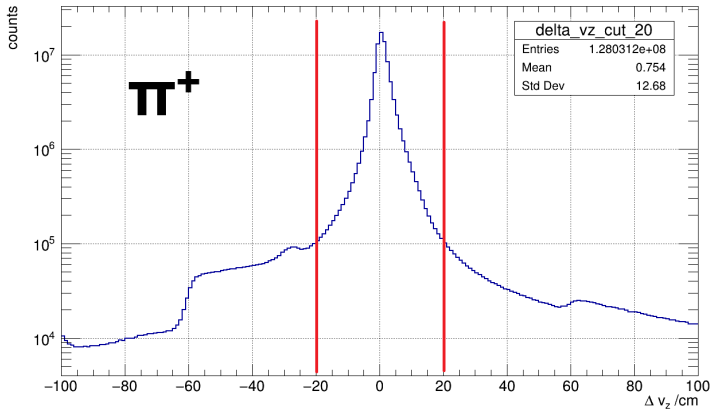


Hadron ID

1. DC fiducial cuts for the 3 regions

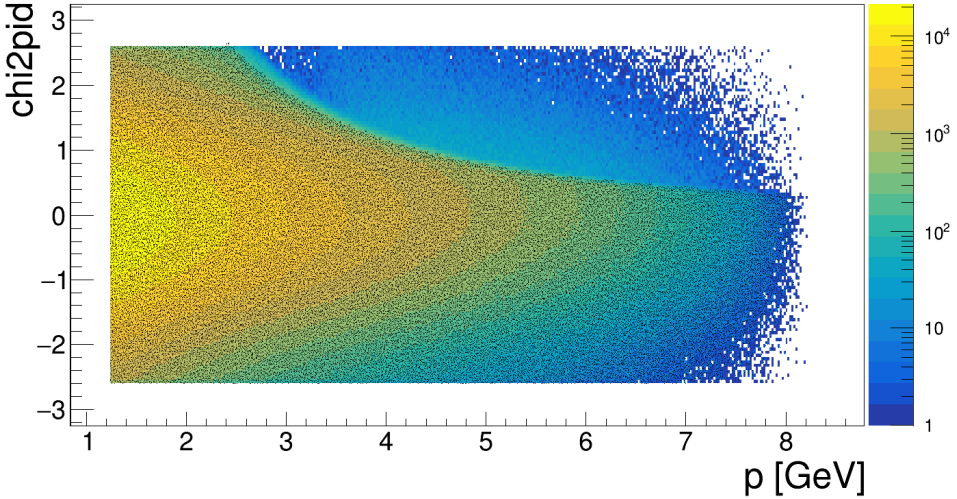


2. z-vertex difference cut



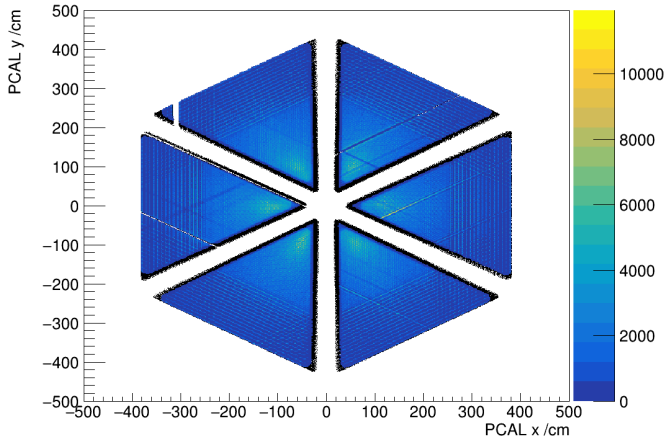
$$|v_z(ele) - v_z(had)| < 20cm$$

3. Cut on TOF based chi2PID

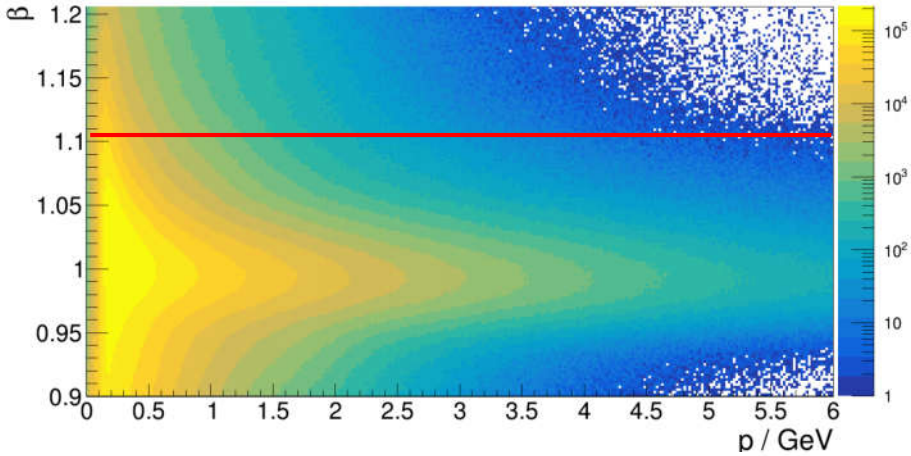


Photon ID and π^0 Selection

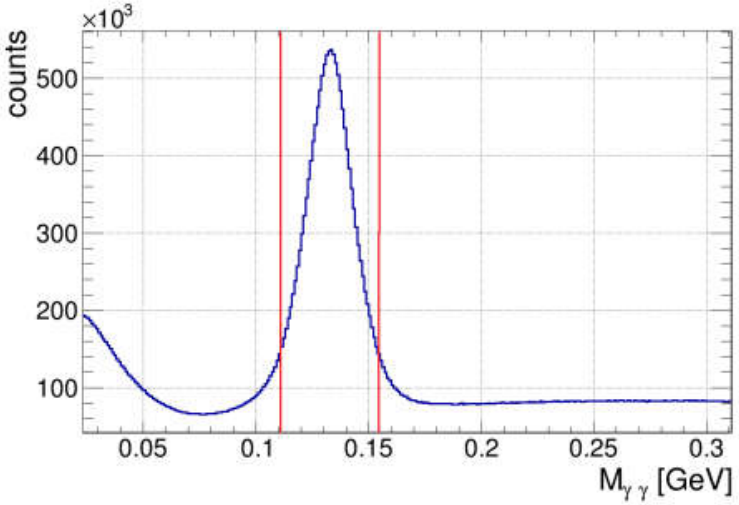
1. PCAL fiducial cut (v,w > 9 cm)



2. Cut on beta $\beta > 0.9$ $\beta < 1.1$



- **FD only**
- **E_γ > 600 MeV**
- **$\alpha(e^-,\gamma)$ > 8°**
- **all photon pairs**
- **2.2σ cut on π^0 mass**



Kinematic Cuts

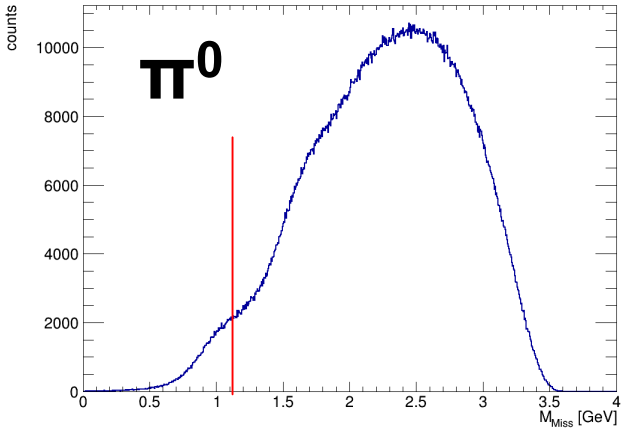
DIS cut: $Q^2 > 1\ GeV^2$ $W > 2\ GeV$

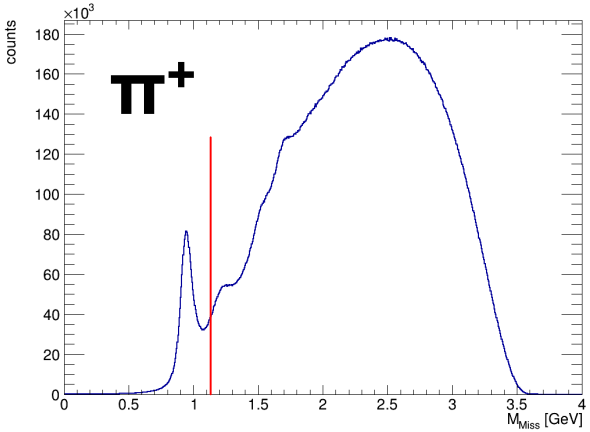
$y < 0.8$ ➔ $P_{min}(e^-) = 2.1\ GeV$ $P_{min}(\pi^+) = 1.25\ GeV$

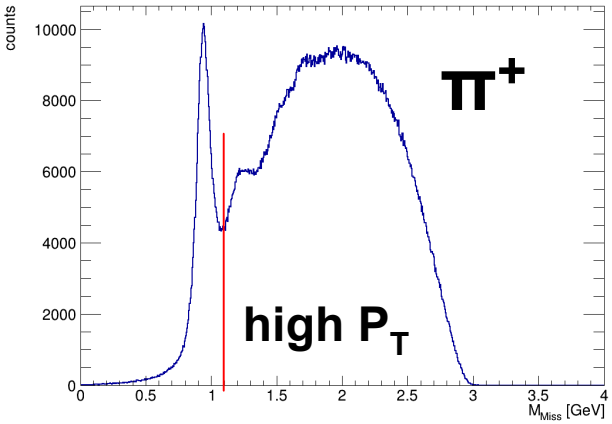
1 D plots: Cut on the final state hadron momentum fraction z

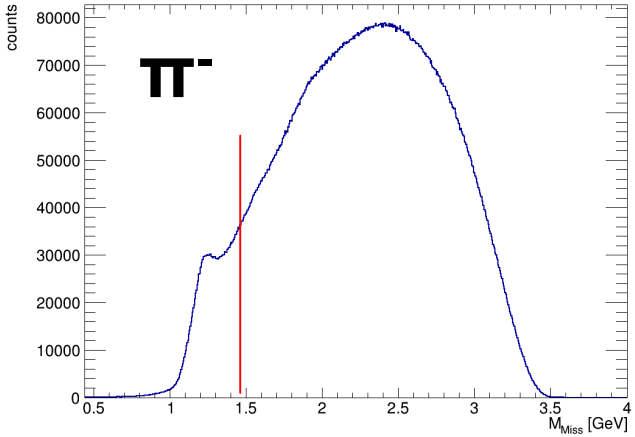
→ $z > 0.3$ removes the "target fragmentation region"

Cut to remove / suppress the contribution from exclusive channels:



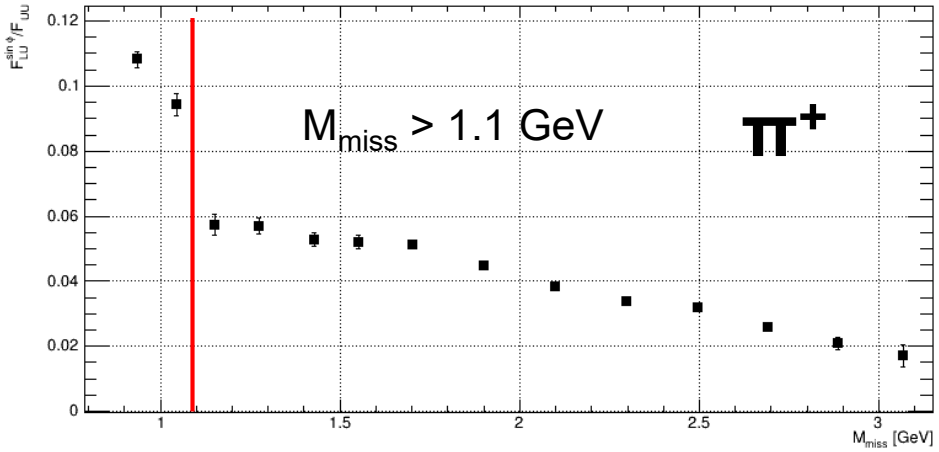


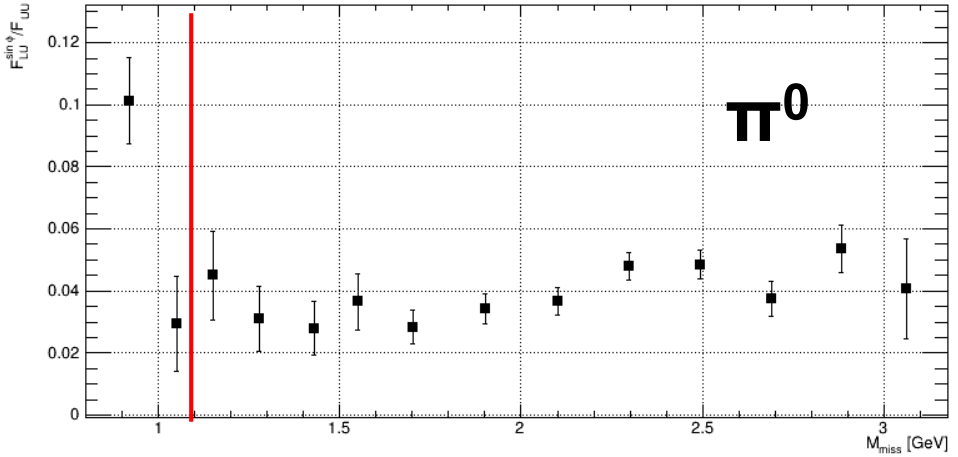




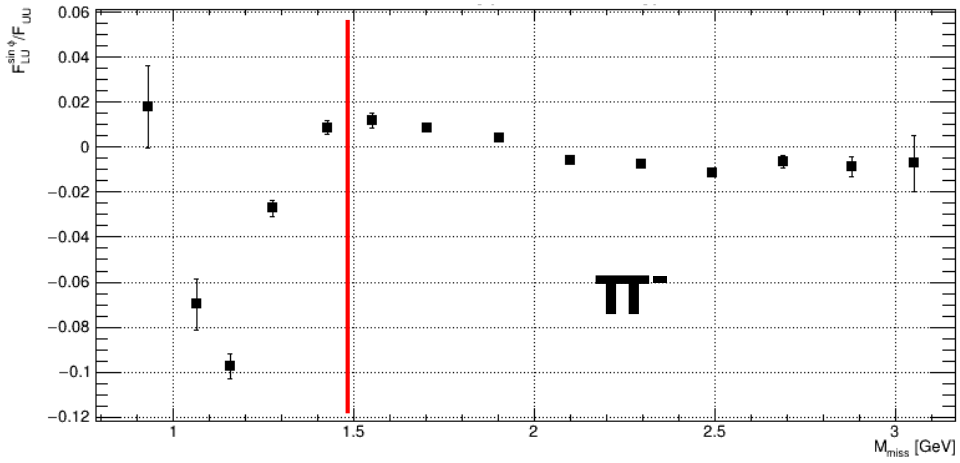
Kinematic Cuts

cut on the eπX missing mass

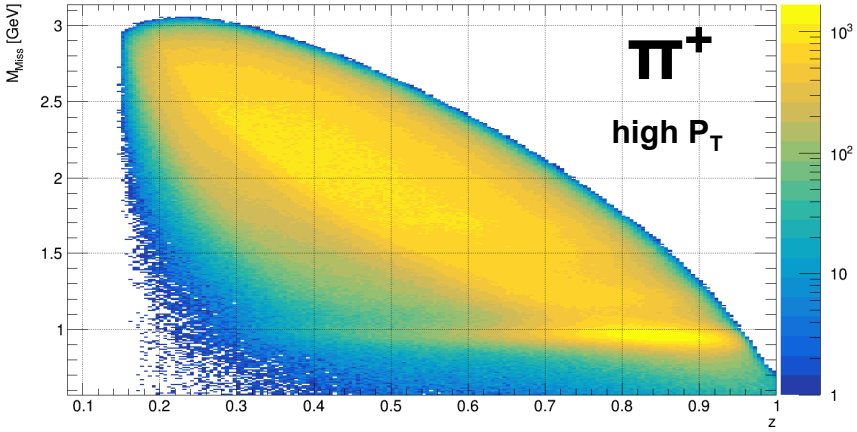




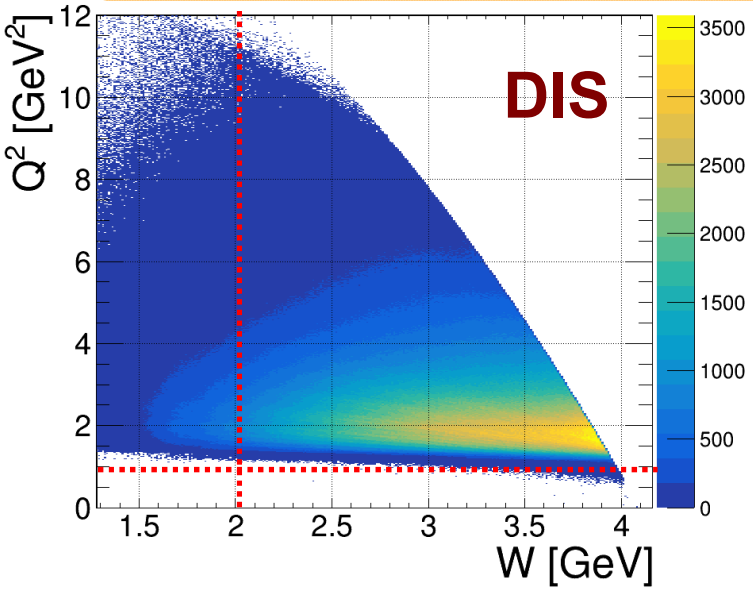
M_{miss} > 1.1 GeV

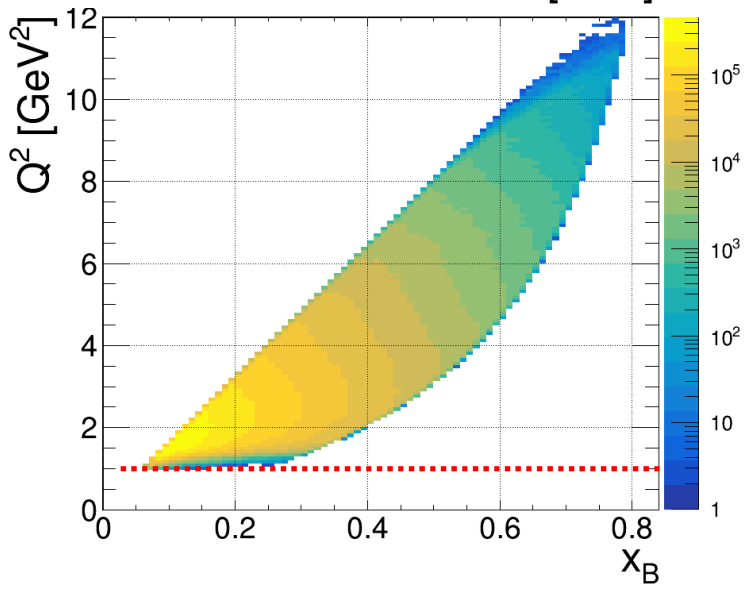


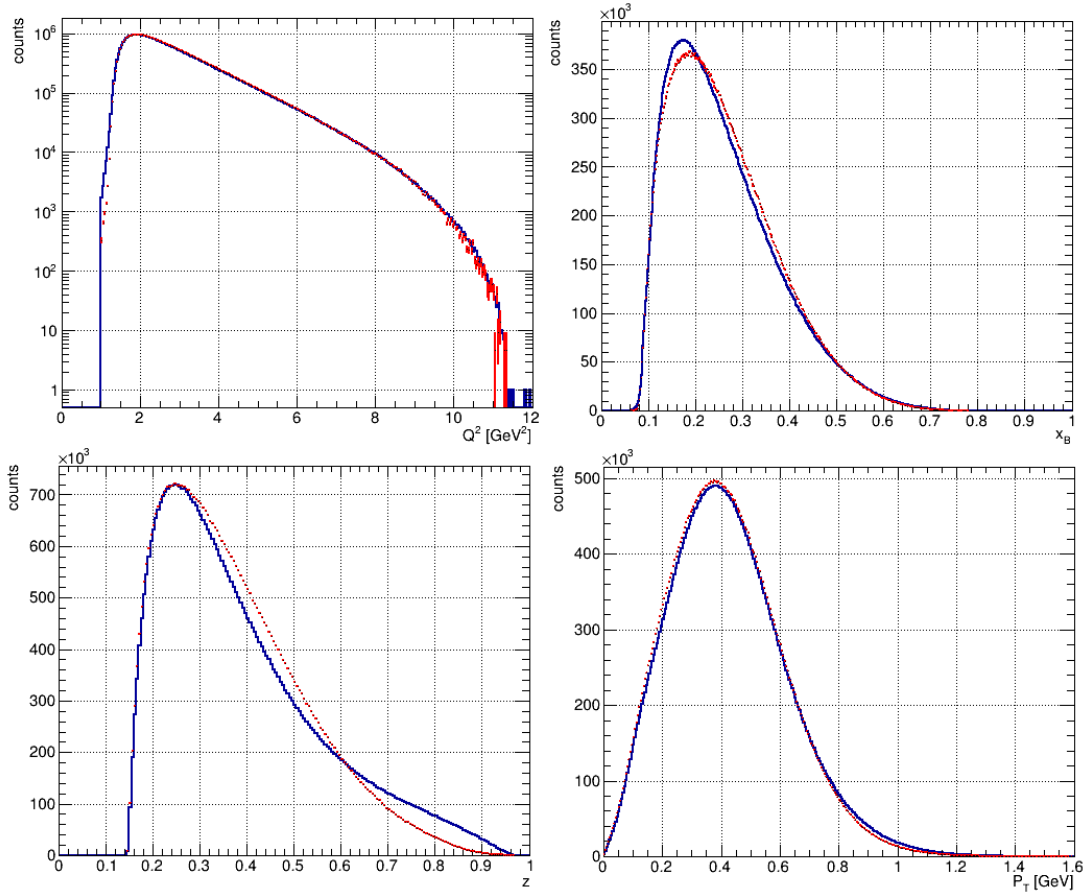
M_{miss} > 1.5 GeV



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







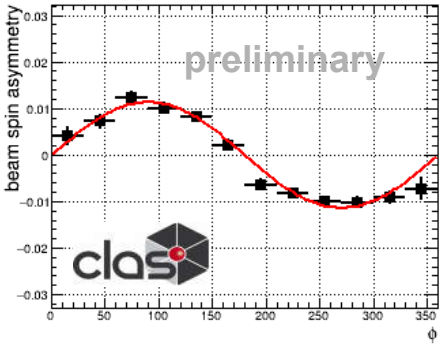
Experimental CLAS-DIS MC data

Beam Spin Asymmetry

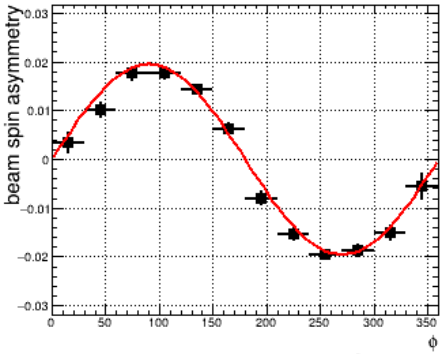
π^+

z binning:

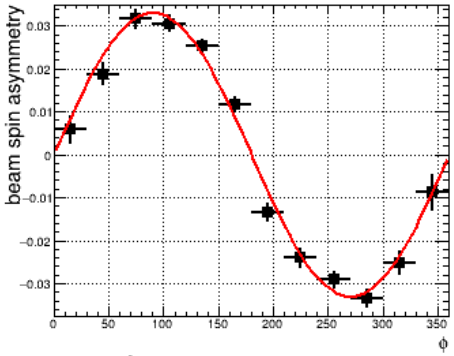
z = 0.27



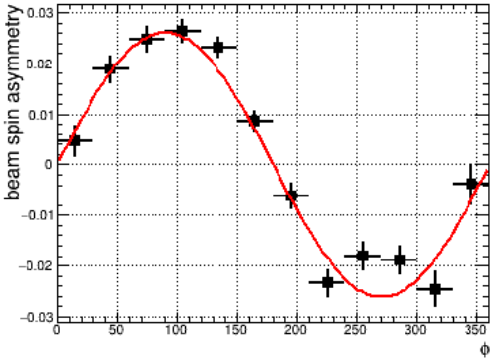
z = 0.34



z = 0.66

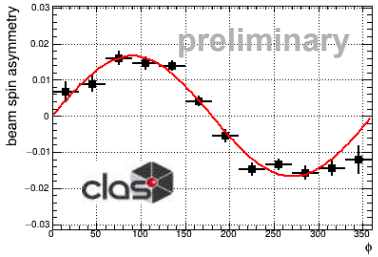


z = 0.85

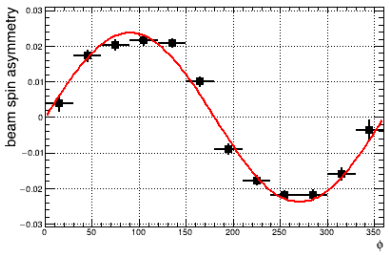


Q^2 binning:

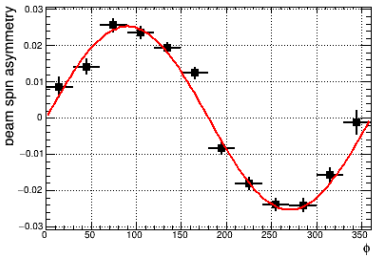
Q^2 = 1.8 GeV²



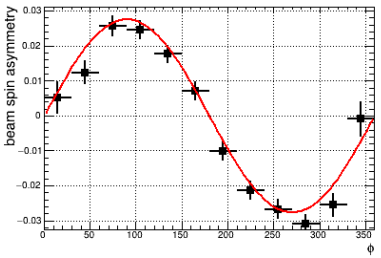
Q^2 = 2.8 GeV²



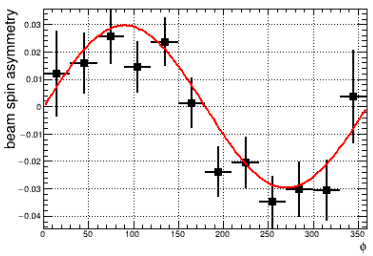
Q^2 = 3.8 GeV²



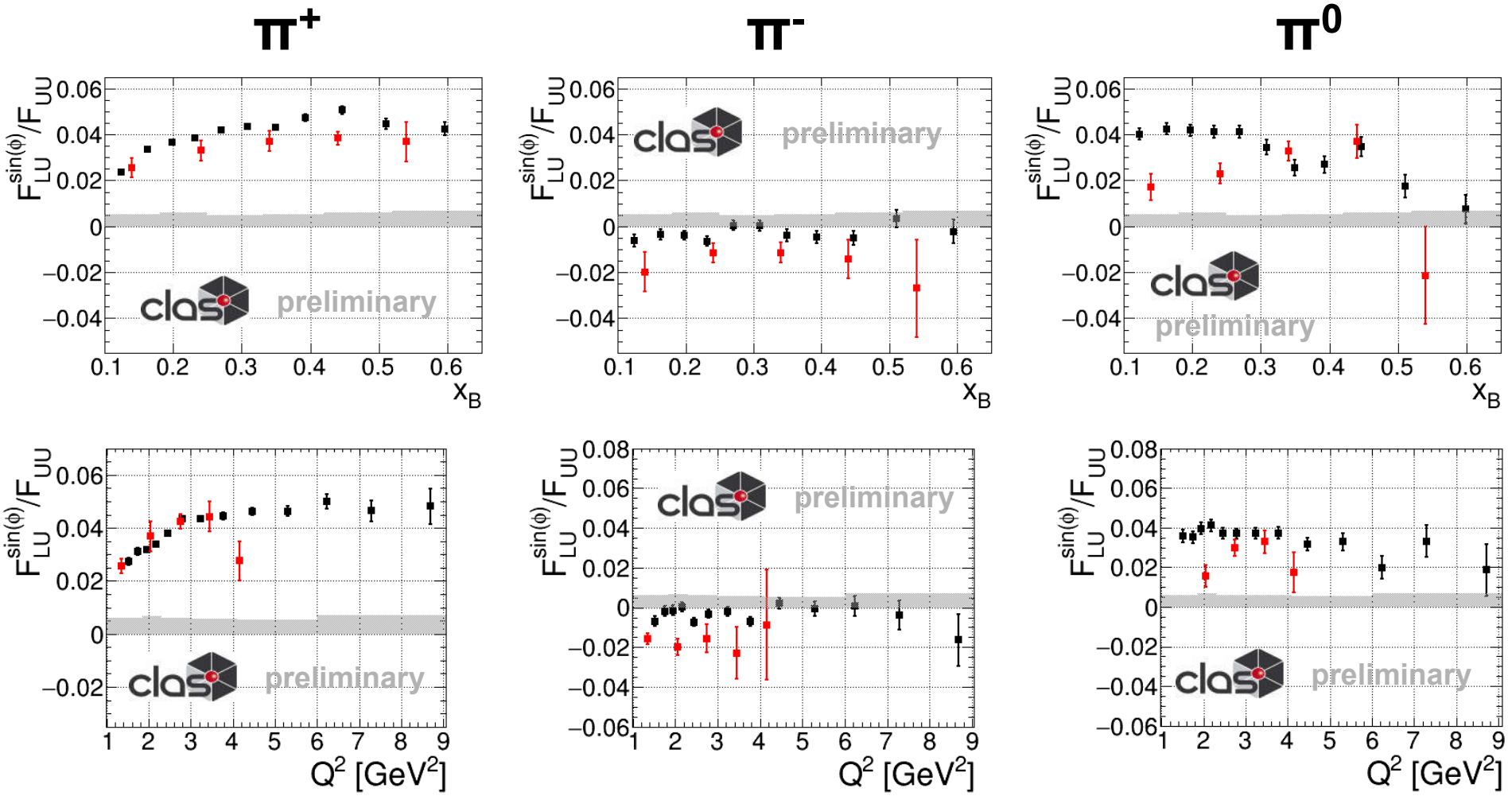
Q^2 = 5.3 GeV²



Q^2 = 8.7 GeV²

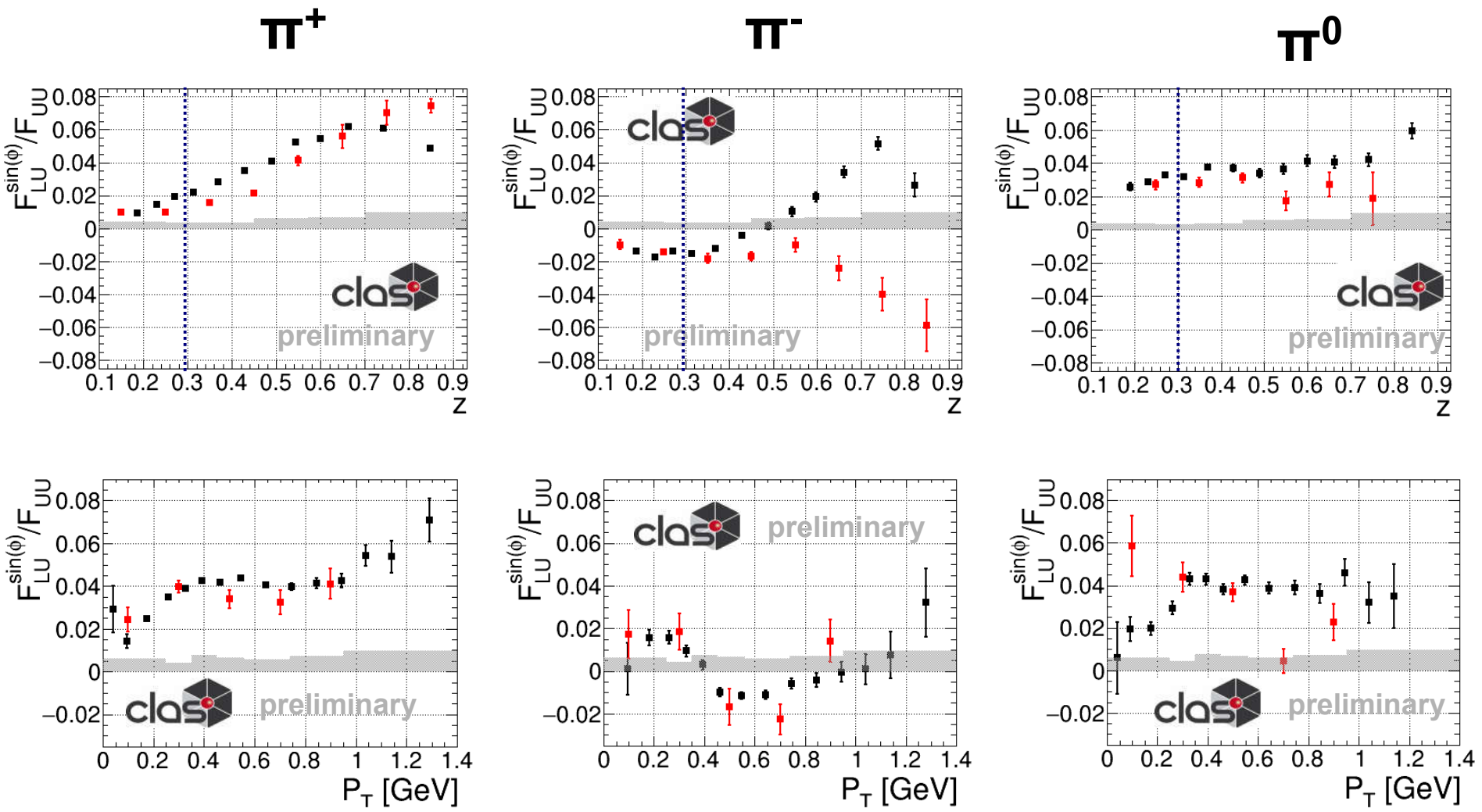


$F_{LU}^{\sin\phi} / F_{UU}$ for a x_B and Q^2 binning



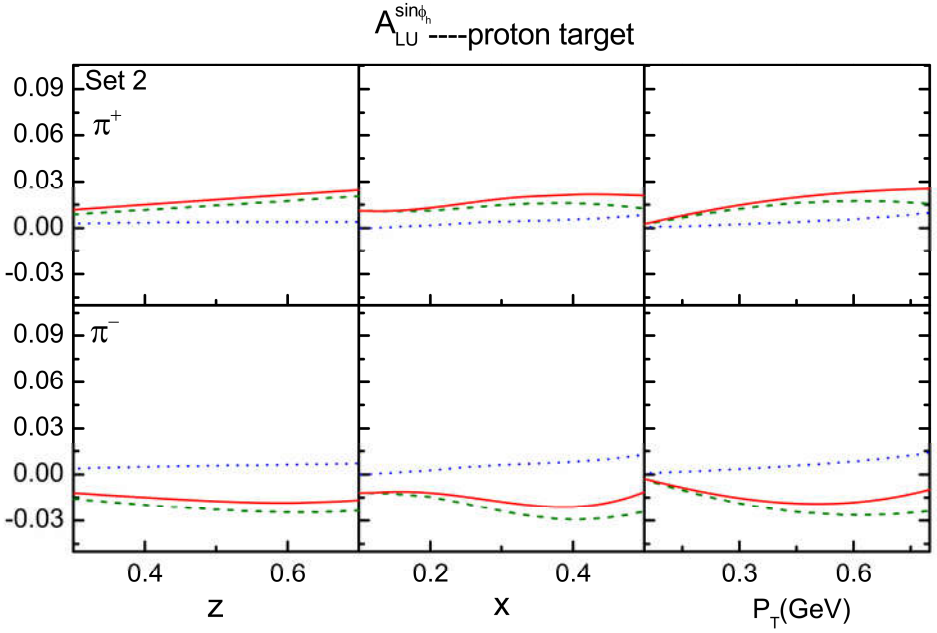
■ CLAS12 ■ CLAS [W. Gohn.et al. PRD 98 (2014)]

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



Comparison to Theoretical Predictions

Predictions for the 12 GeV JLAB data:



Wenjuan Mao, Zhun Lu

Eur. Phys. J. C (2014) 74:2910
DOI 10.1140/epjc/s10052-014-2910-7

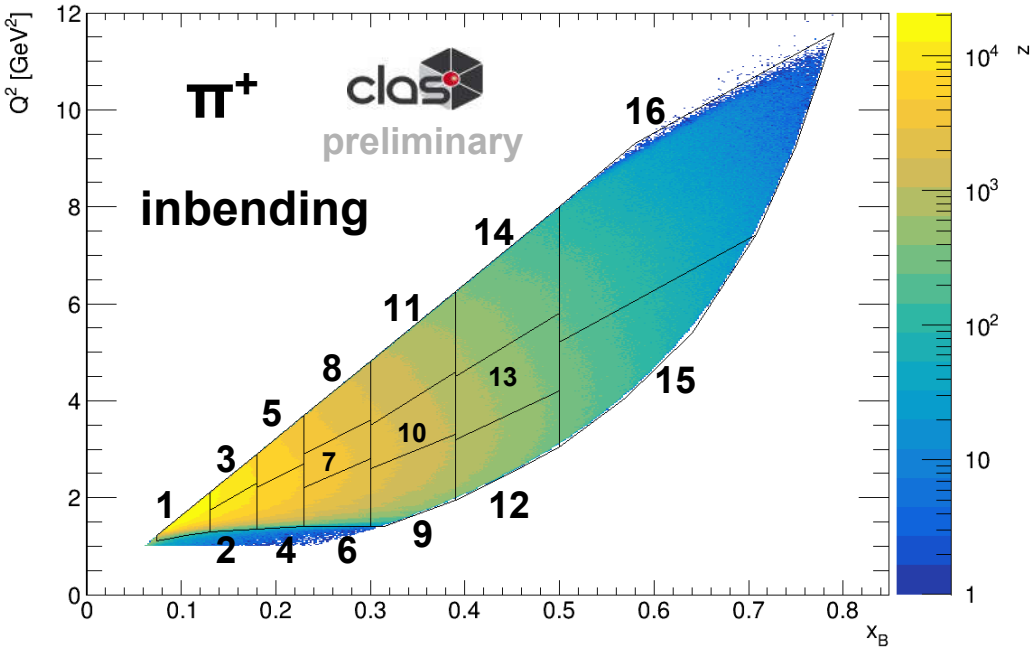
➔ Prediction reproduces several characteristics of our results

➔ Updated calculations from different collaborators are in progress

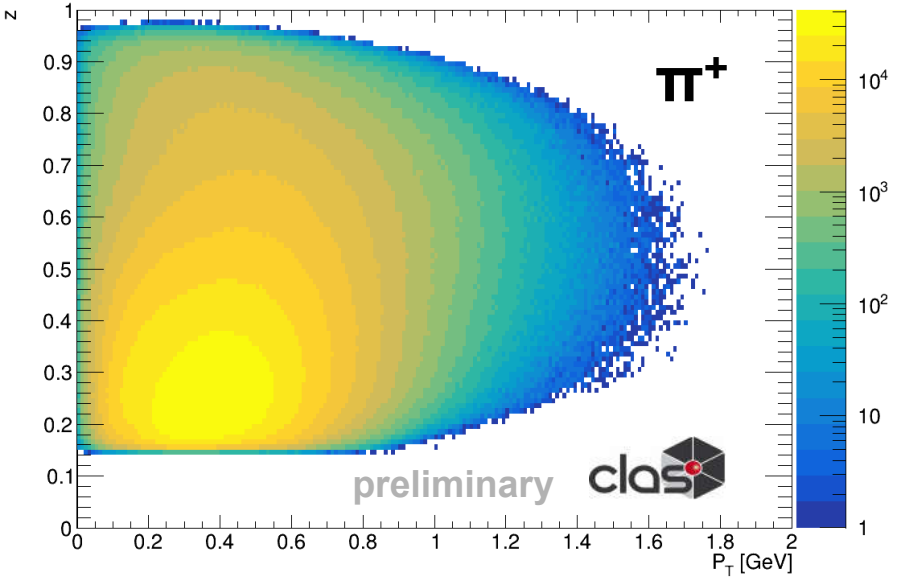
➔ A multidimensional binning will enable a much better comparability with the calculations

A Fully Multidimensional Binning

- With the available statistics, a fully multidimensional binning in Q^2, x_B, z and P_T becomes possible for the first time



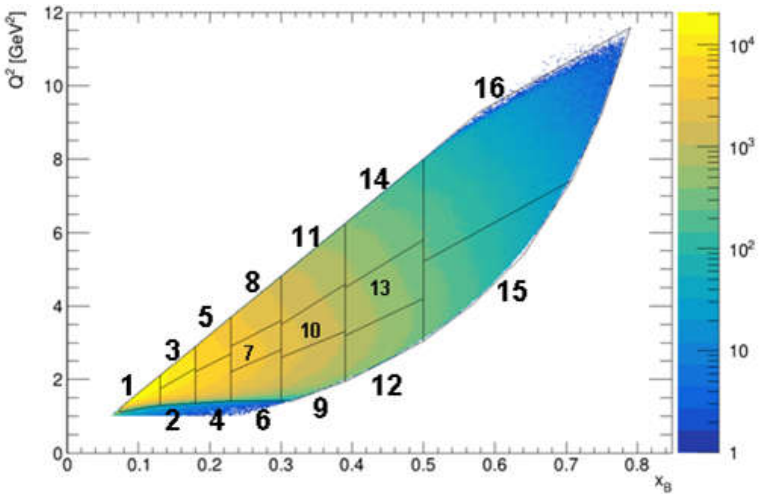
16 bin in Q^2 - x_B

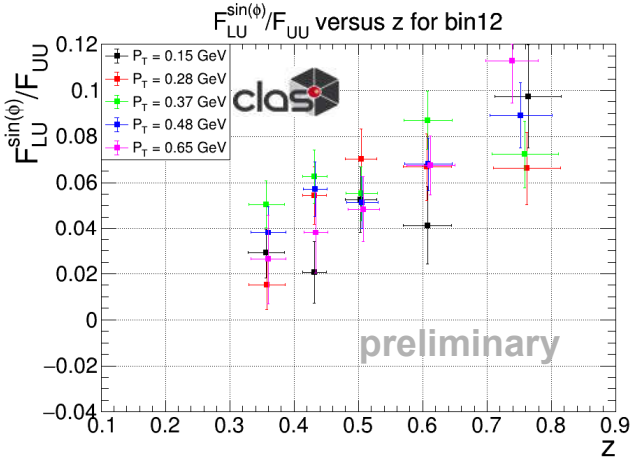


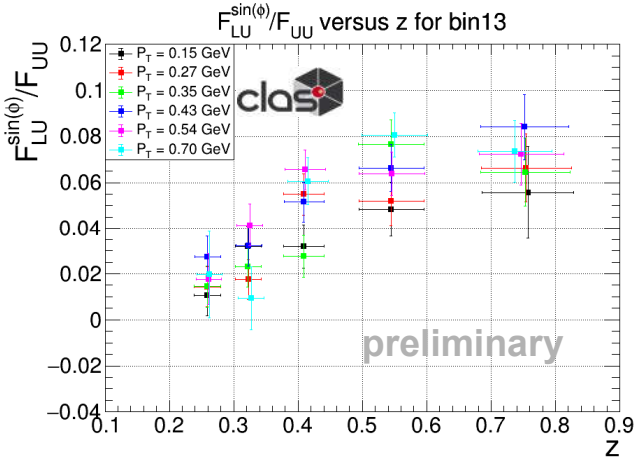
up to 7 x 7 bins in z - P_T
for each Q^2 - x_B bin

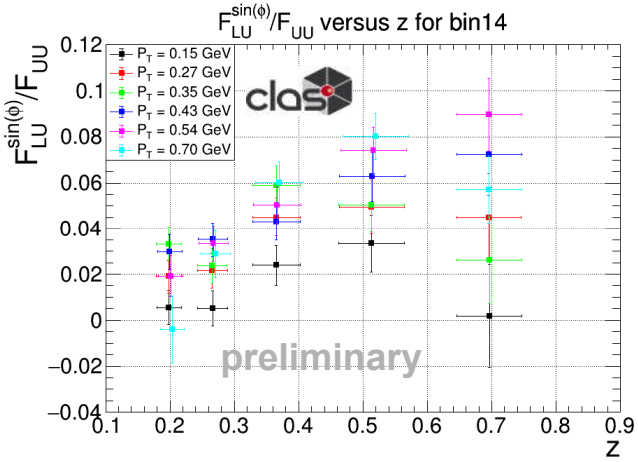
in total: 583 bins x 12 bins in Φ ~ 7000 BSA bins

π^+: z Dependence for Increasing Q^2 and Fixed x_B



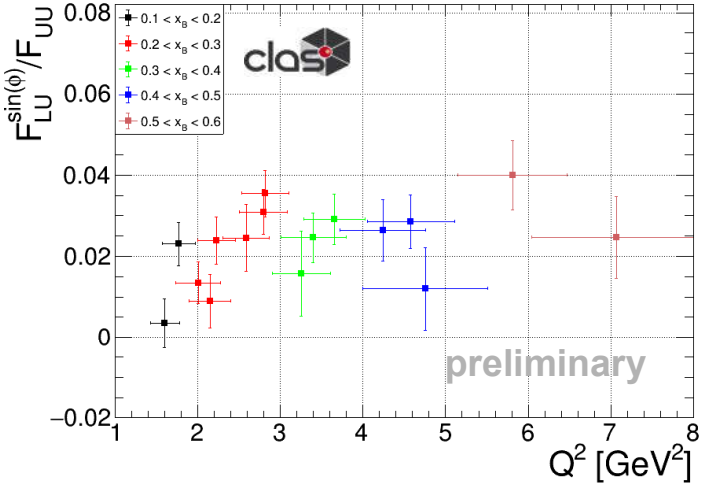




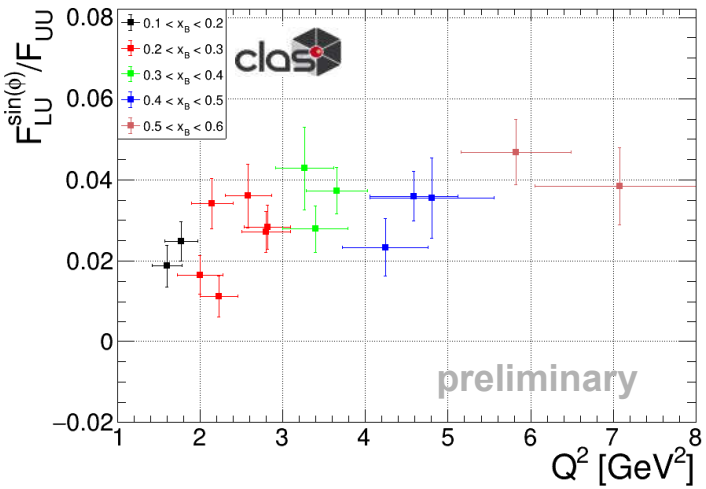


π^+: Q^2 Dependence ($0.3 < z < 0.4$, x_B fixed)

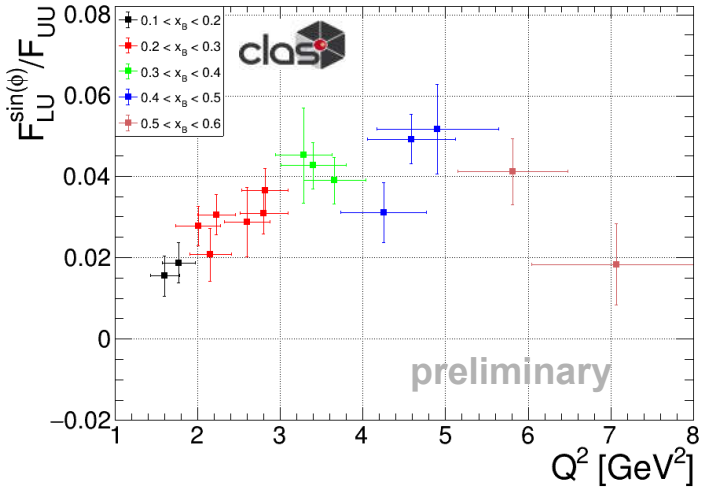
0.2 GeV < P_T < 0.3 GeV



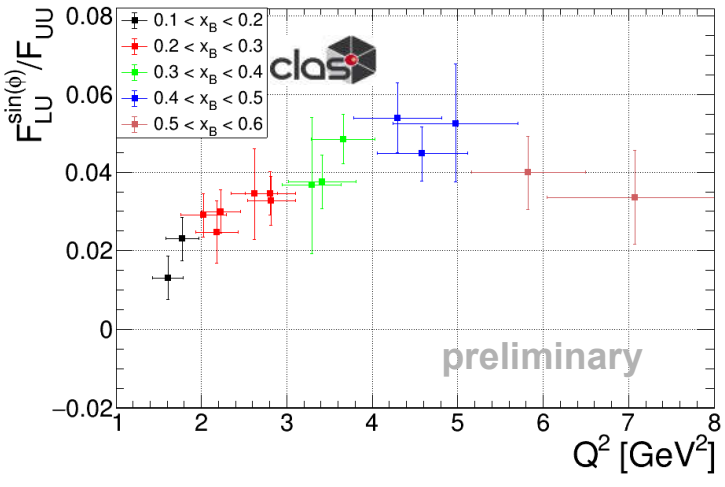
0.3 GeV < P_T < 0.4 GeV



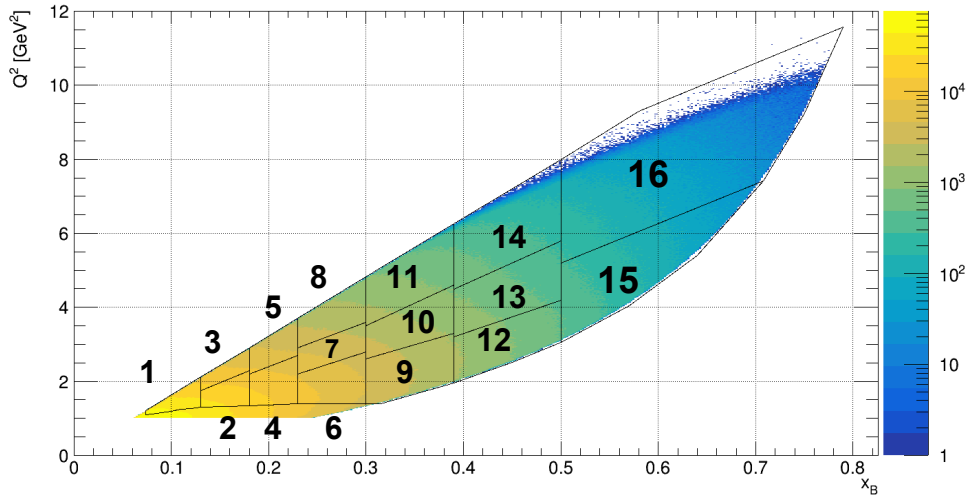
0.4 GeV < P_T < 0.5 GeV

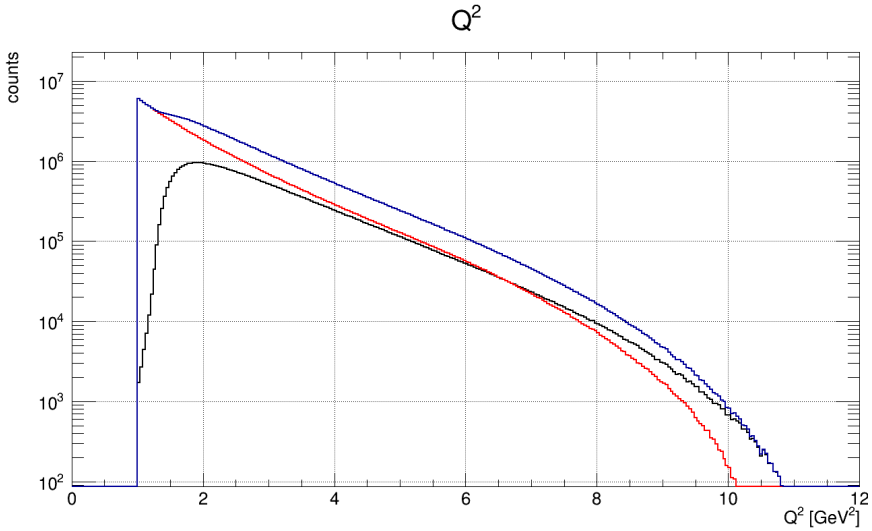


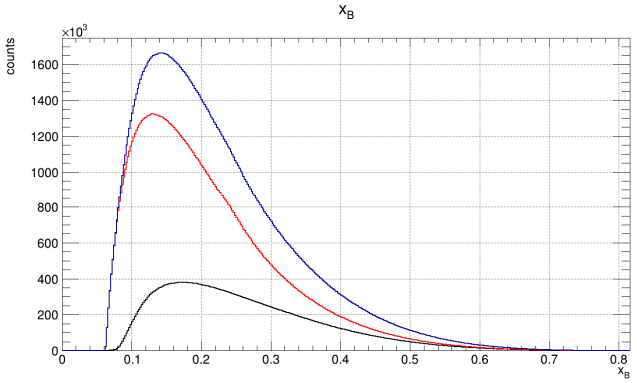
0.5 GeV < P_T < 0.6 GeV

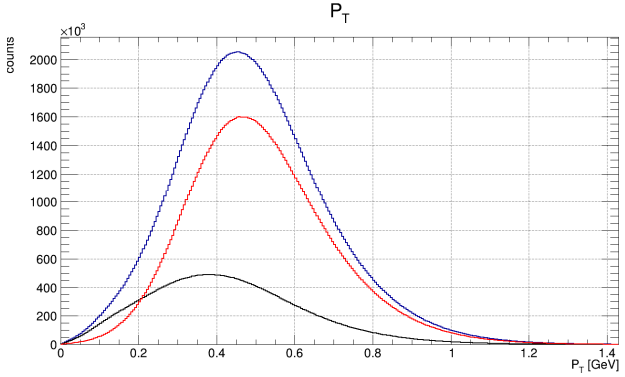


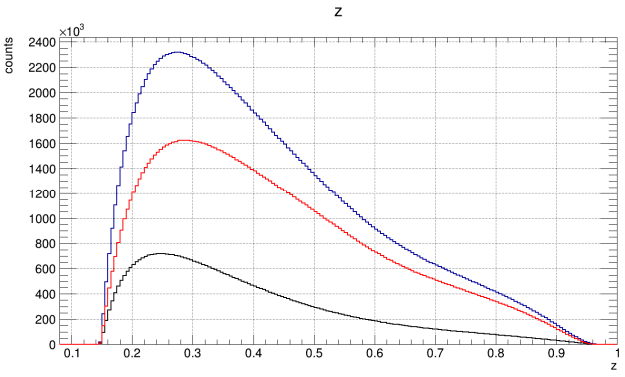
Comparison to the Outbending Data (π^+)







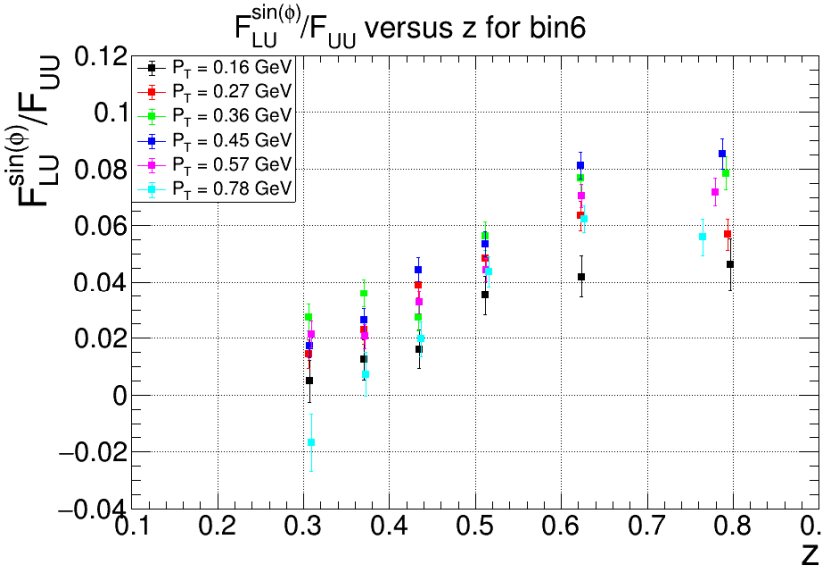


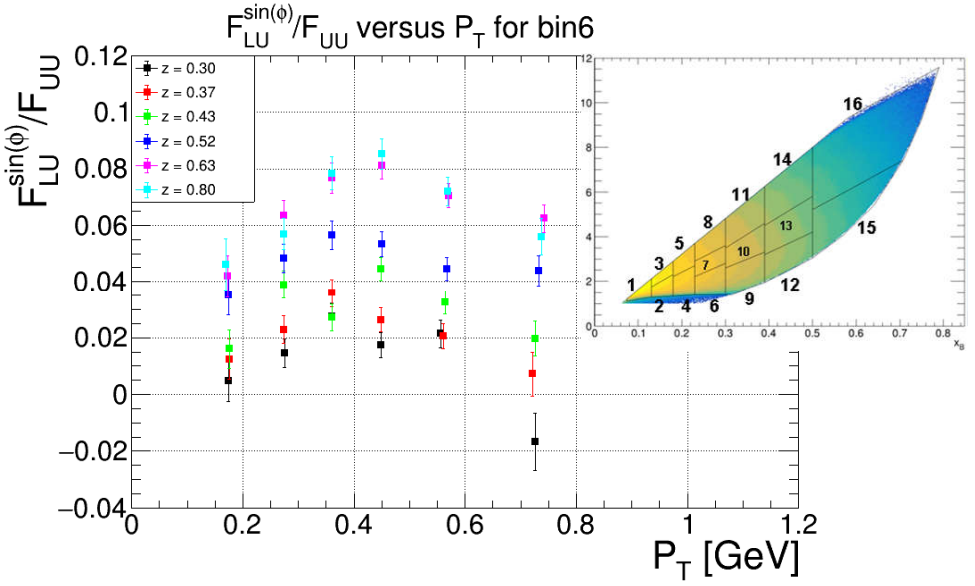


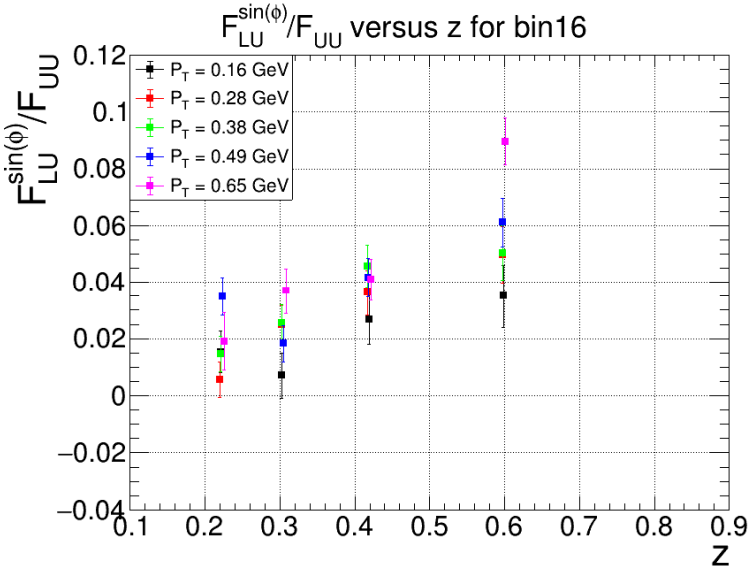
➔ **Increase of statistics even more significant for π^-**

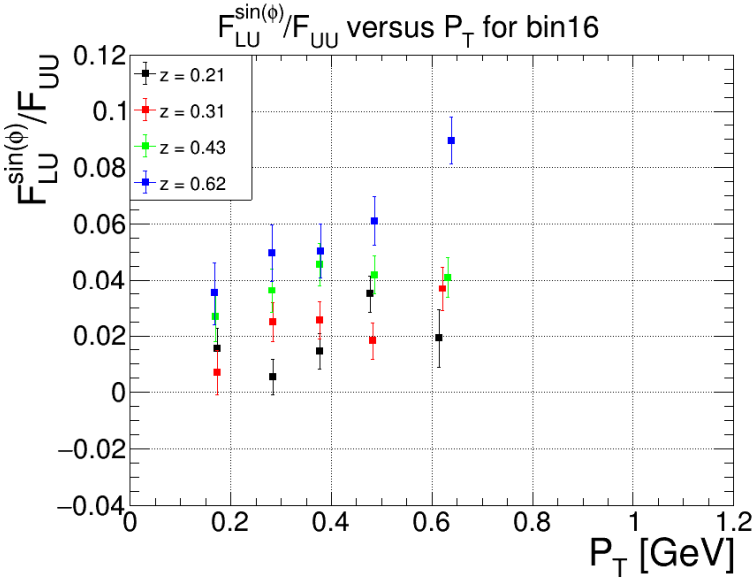
➔ **Factor 3 - 5**

Combined Inbending and Outbending Data (π^+)



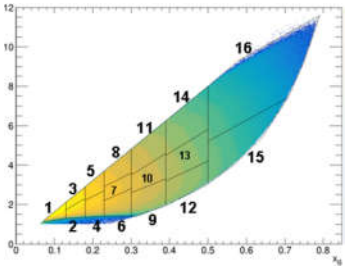


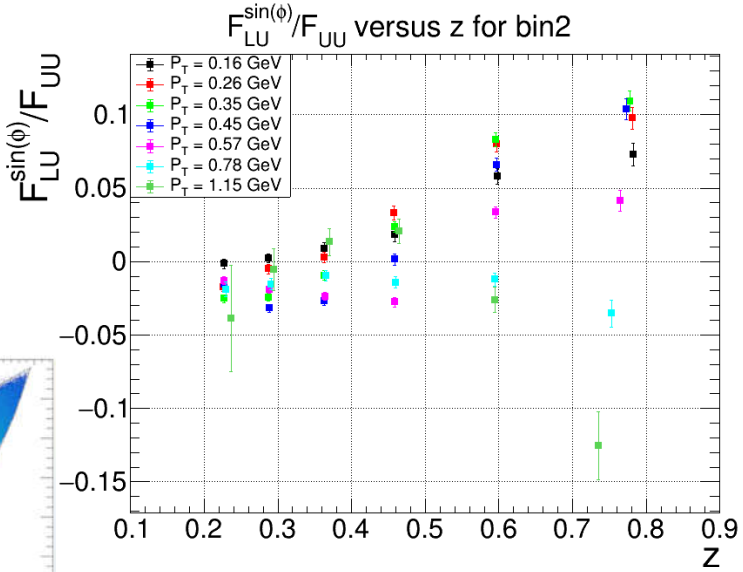


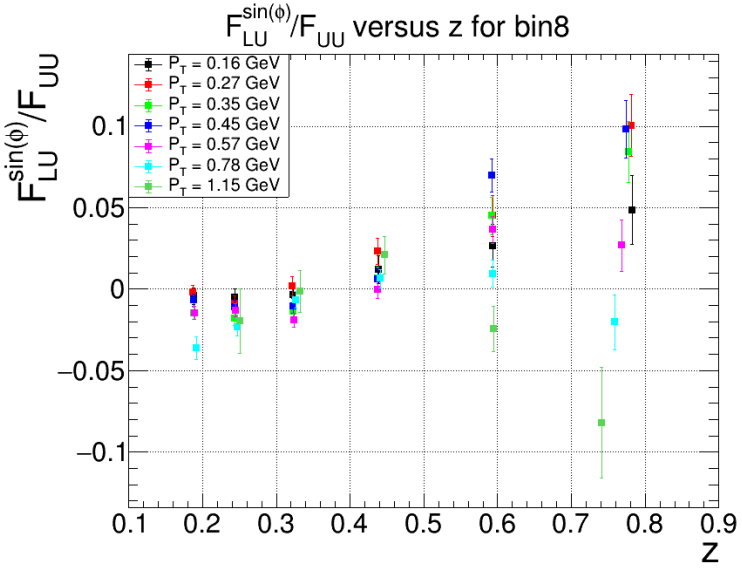


Combined Inbending and Outbending Data

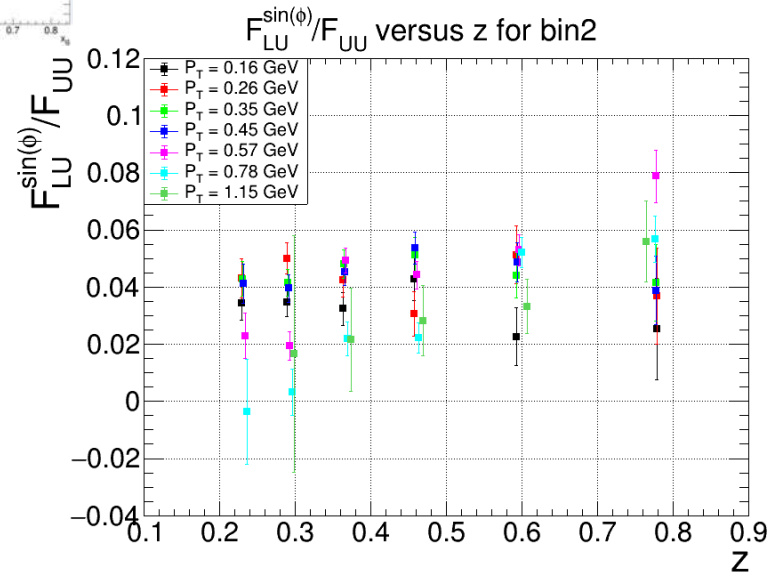
π^-

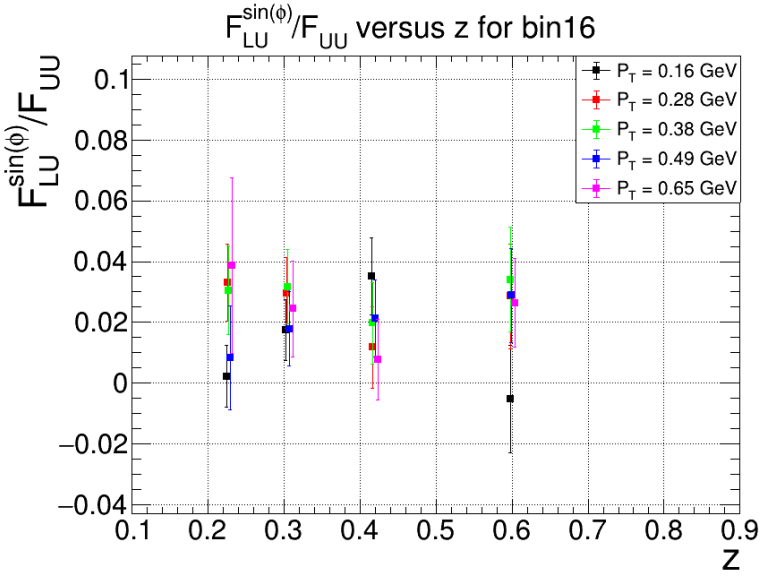






π^0





Sources of Systematic Uncertainty

→ Uncertainty of the beam polarisation

→ Fiducial cuts and particle ID refinements
(strictness of the PID / contamination in the pion sample)

→ Acceptance Effects

→ Extraction method and higher order moments

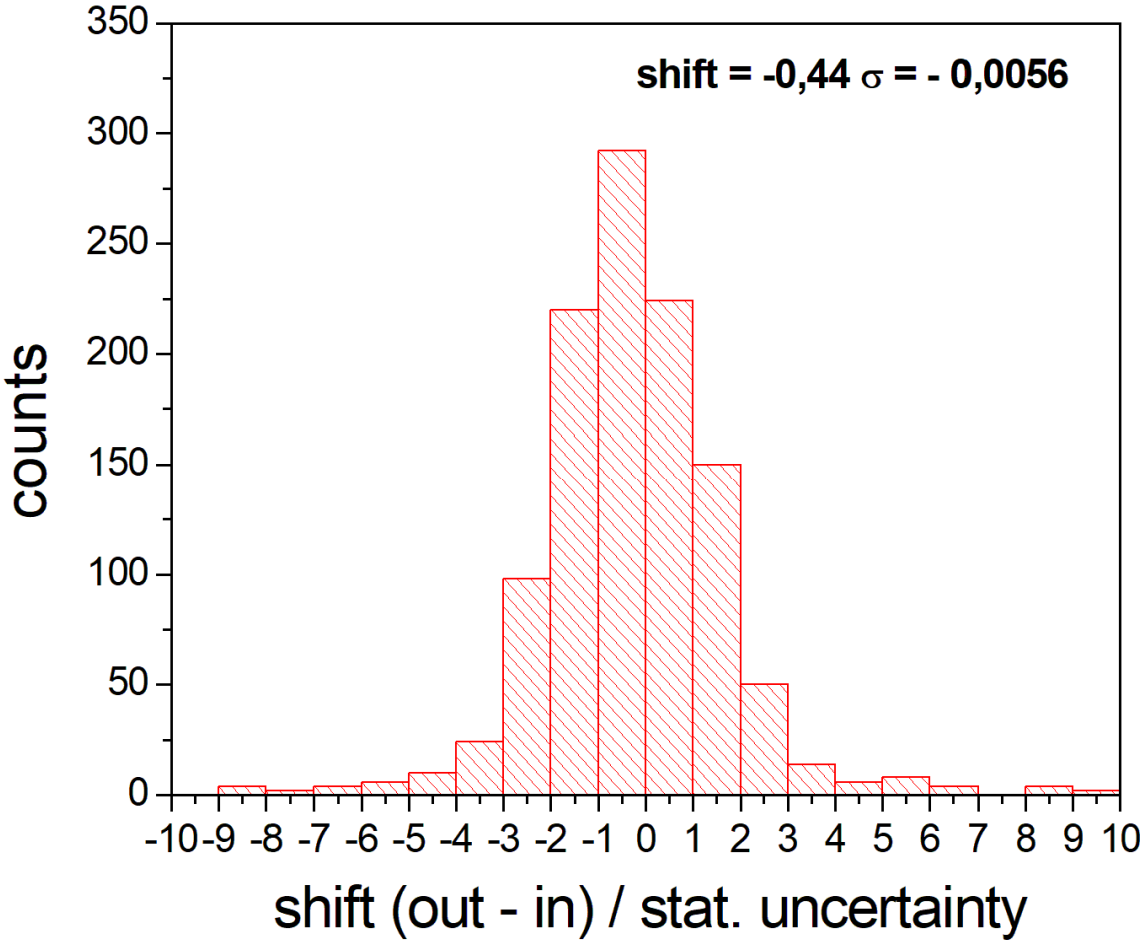
→ Detector inefficiencies / sector dependence

→ Radiative effects

→ Binning / resolution effects

➔ **Studys are ready or currently finalized**

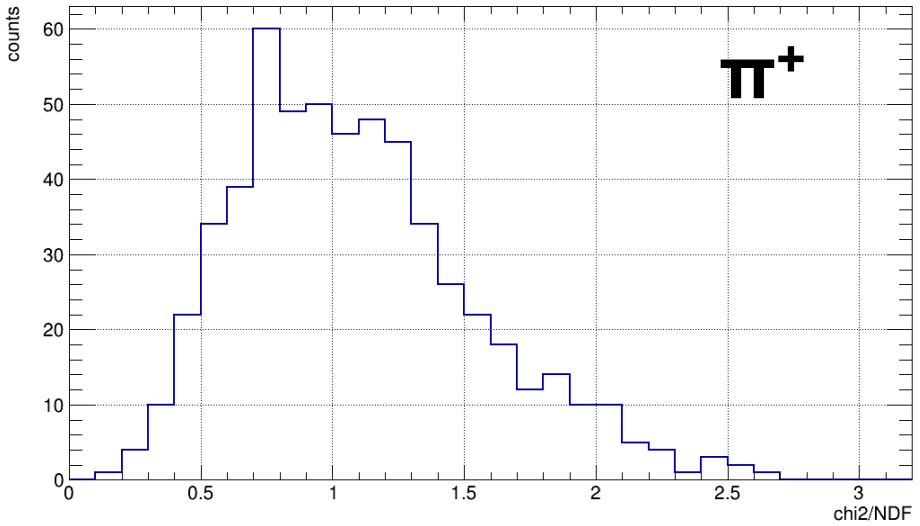
Comparison Between Inbending and Outbending (π^+)

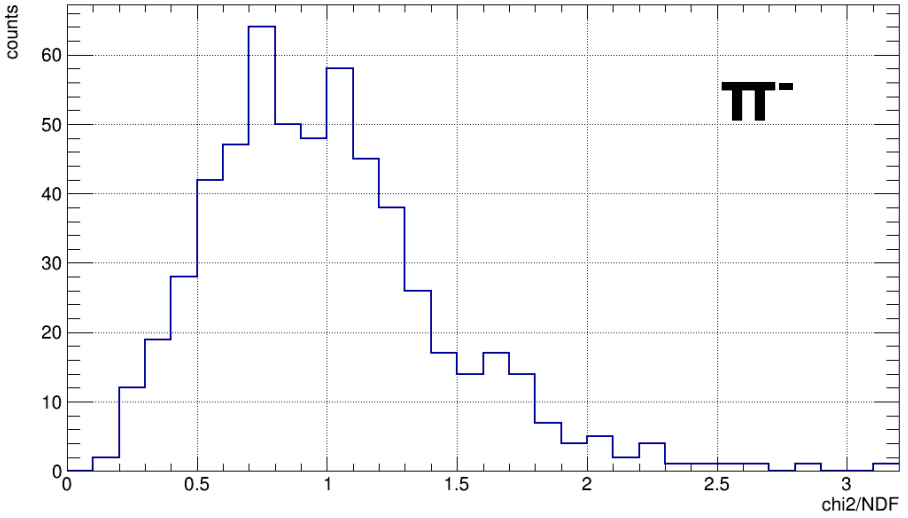


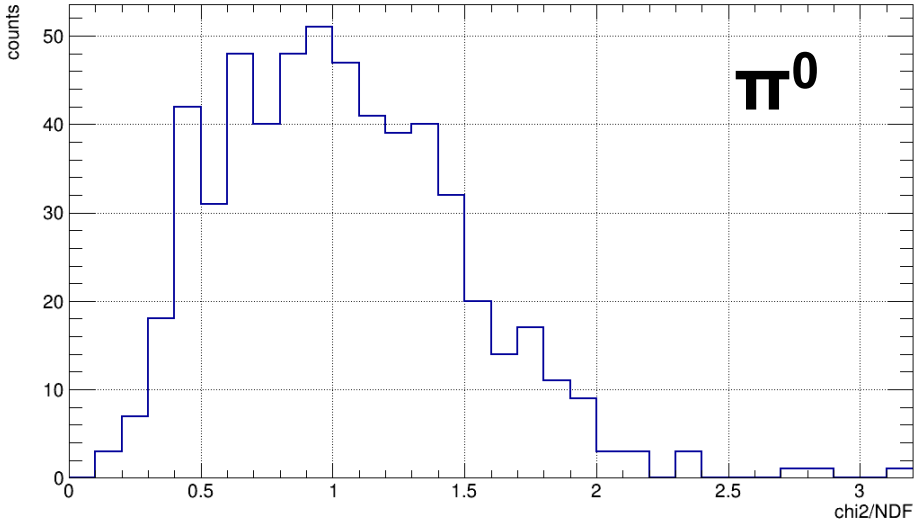
small offset between the two field configurations due to diffferent slope of the kinematic variables

10 – 15 %

Quality of the Fit and Extraction Method

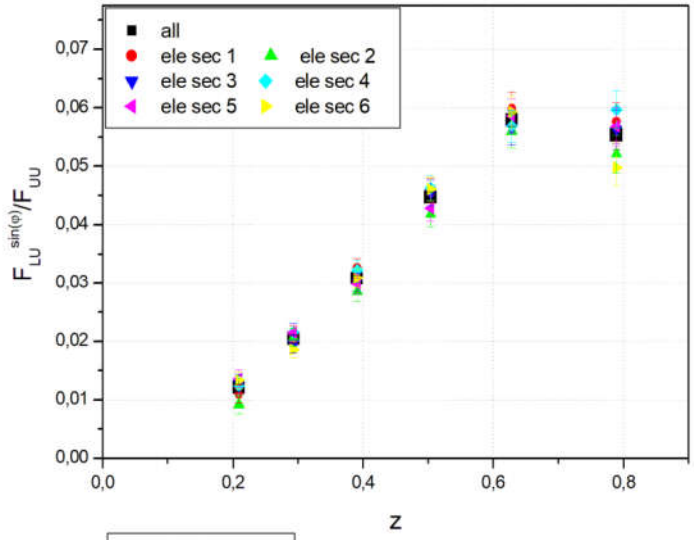


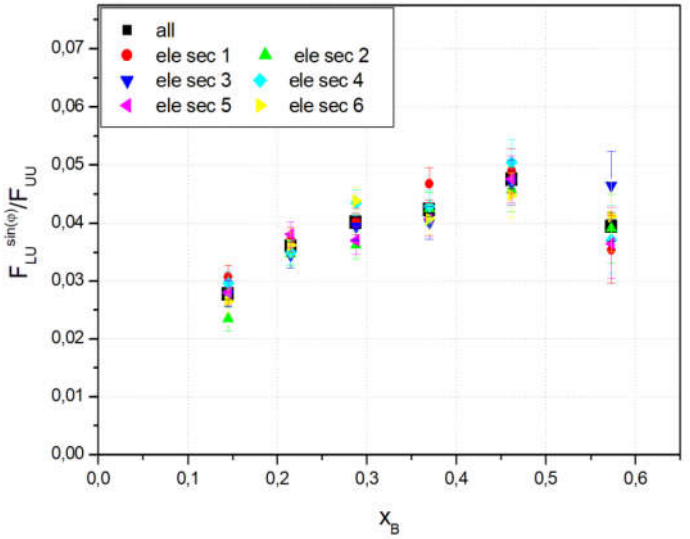


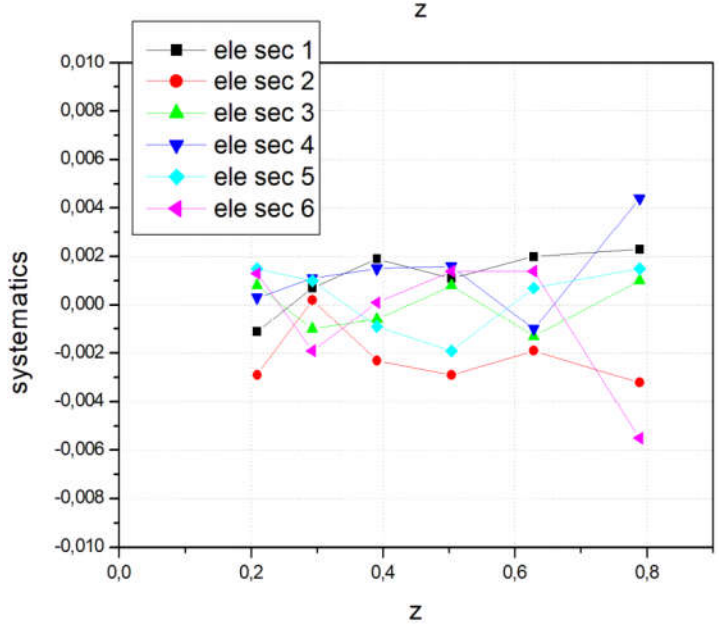


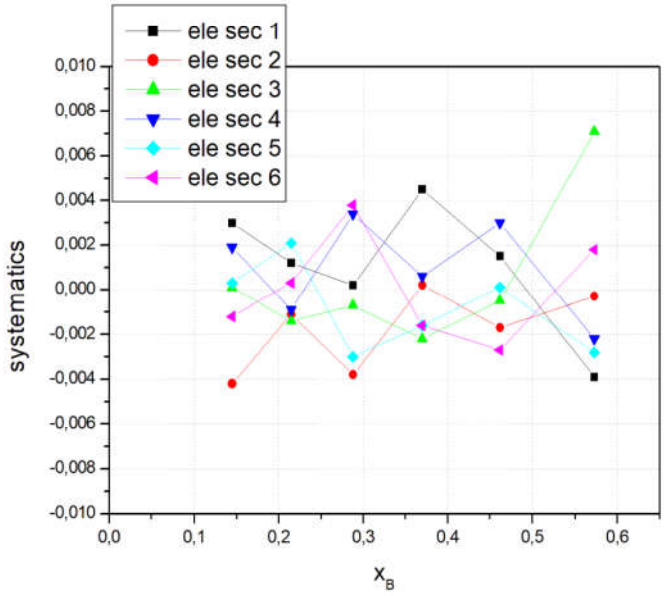
- **Each of the fits in the 583 bins provides a chi2/NDF**
  - ➔ **Can be used to check the quality of the fit**
  - ➔ **chi2/NDF will be provided in the output table to allow a weighting in a global fit**

Dependence on the Electron Sector









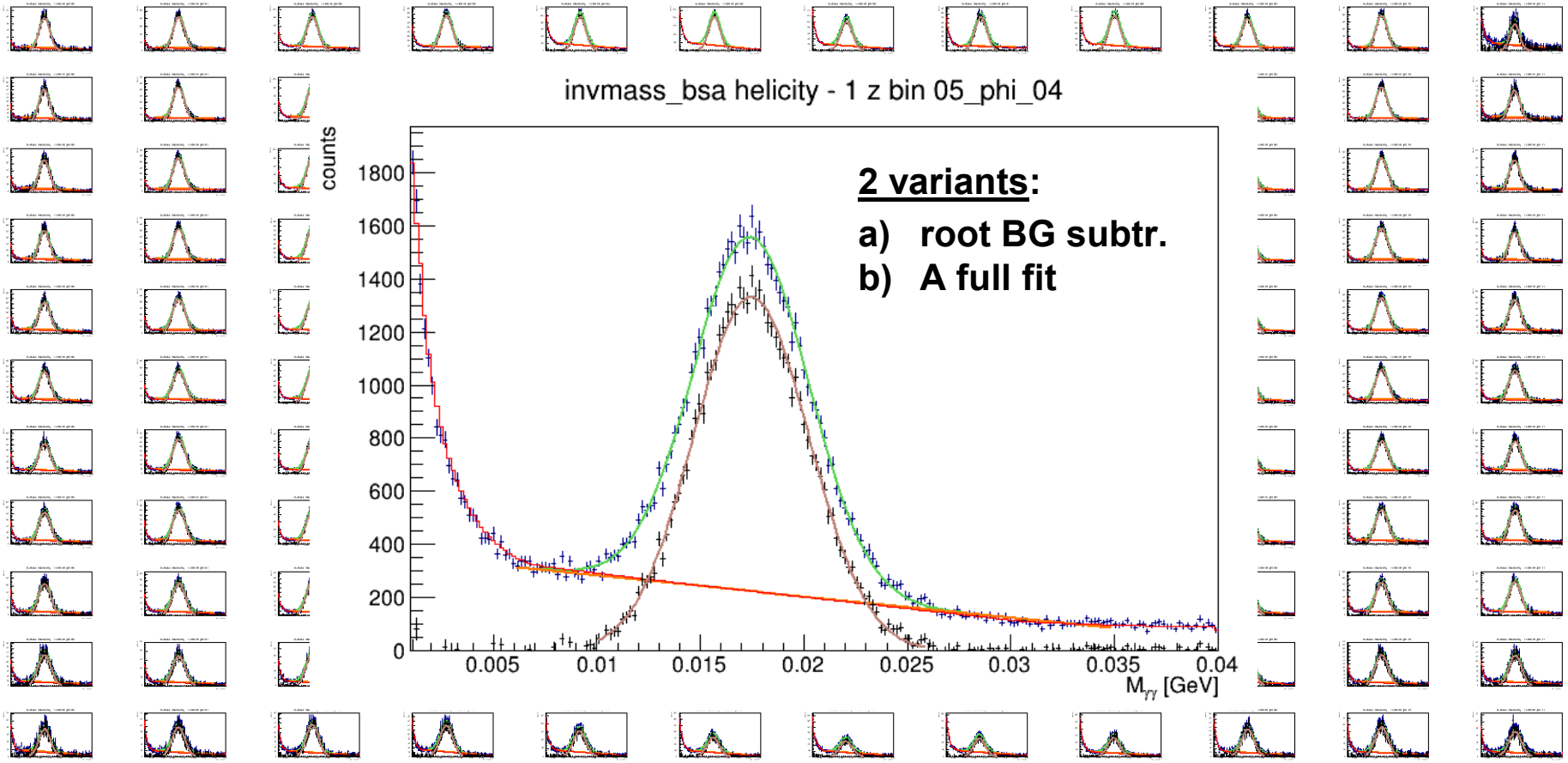
Summary of Systematic Uncertainties

Systematic uncertainty for the different electron sectors:	0.002 – 0.003	**5 – 8 %**
Same study has been done for the pion sector:	0.002 – 0.003	**5 – 8 %**
Hadron ID:	0.001 – 0.002	**3 – 5 %**
Fiducial cuts:	0.002 – 0.003	**5 – 8 %**
Extraction method:	0.001 – 0.005	**5 – 8 %**
Radiative effects:		**3 %**

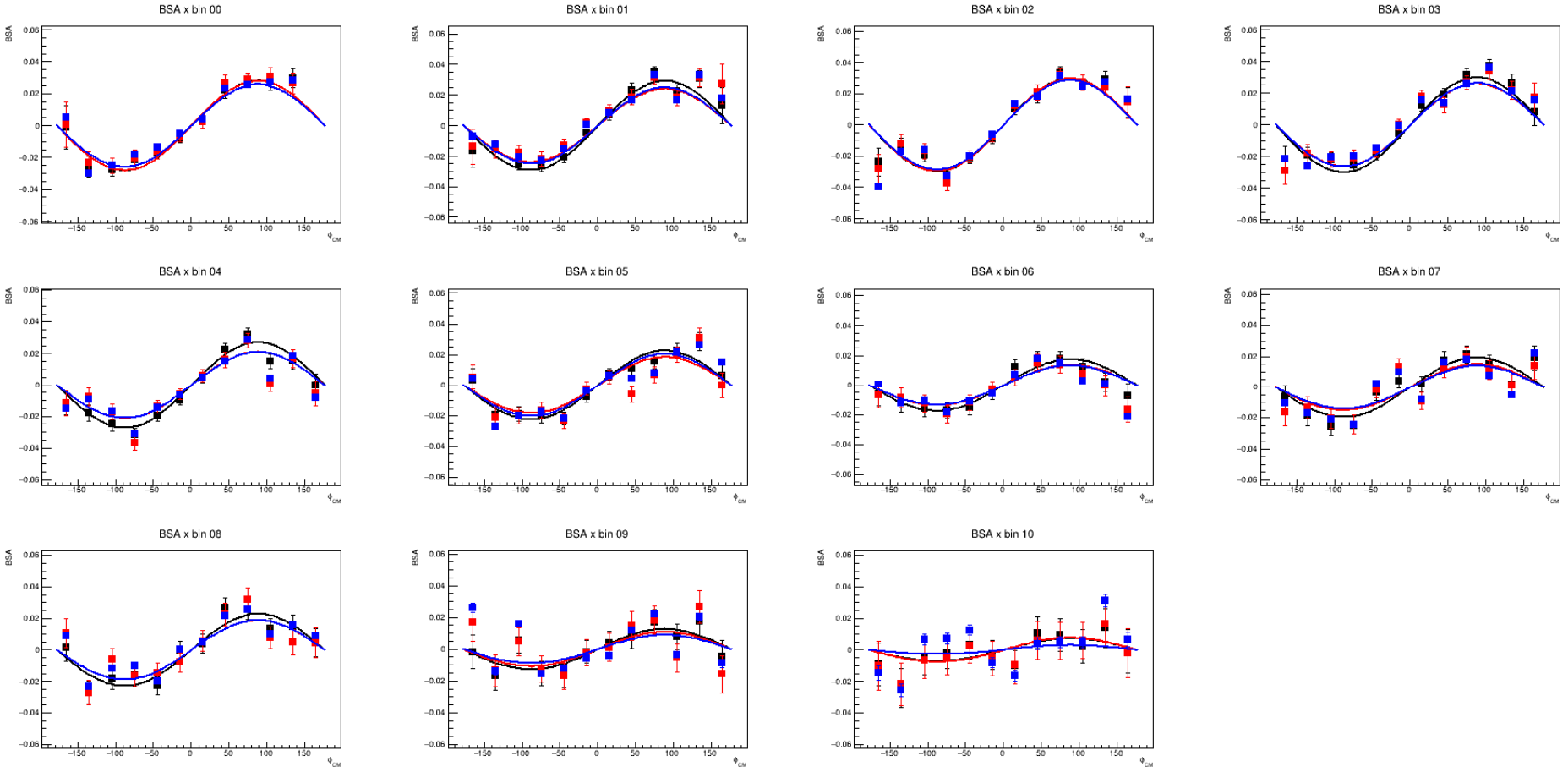
Total systematic uncertainty: ~ 10 %

Background Below the π^0 Peak

Method 1: A fit of $M_{\gamma\gamma}$ in each kinematic bin



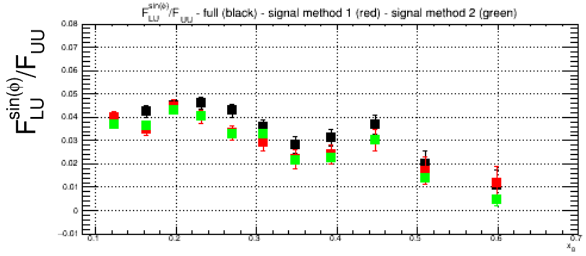
Background Below the π^0 Peak

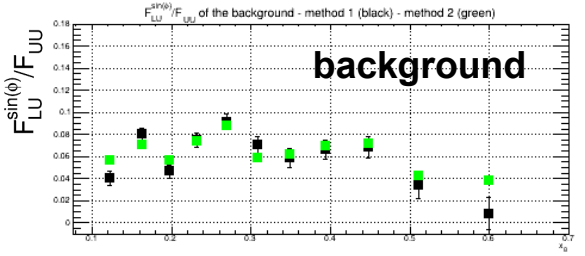


black: no bg subtraction **red: root BG subtraction** **blue: full fit with lin. BG**

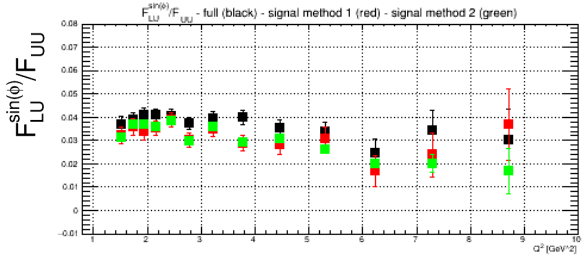
Background Below the π^0 Peak

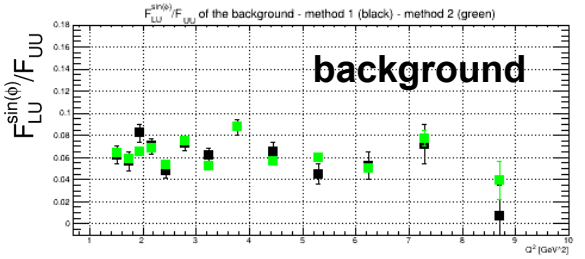
x_B



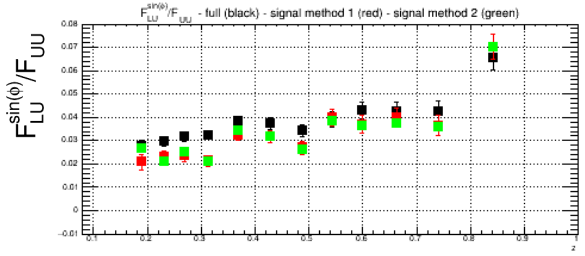


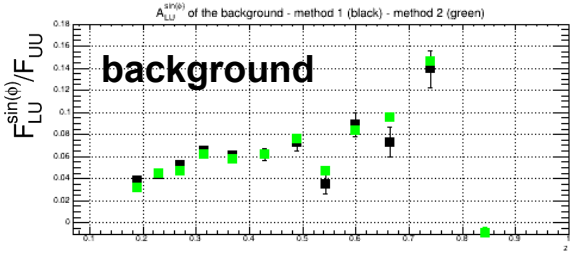
Q^2



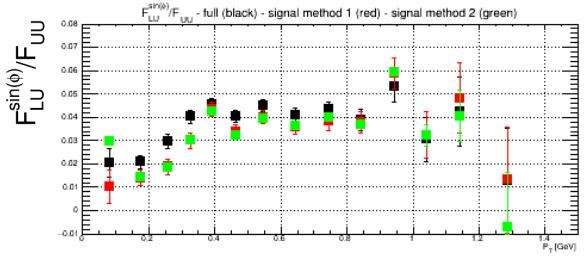


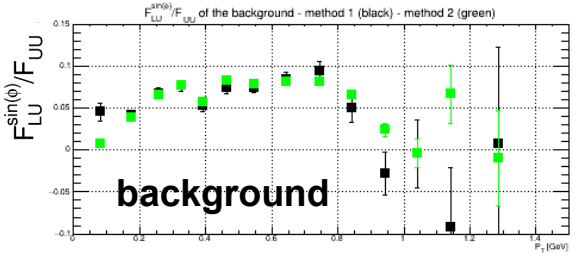
z





P_T



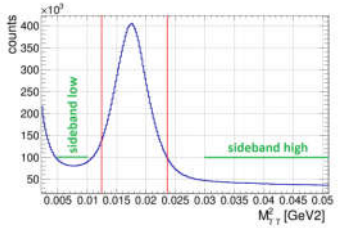


black: no bg subtraction **red: root BG subtraction** **green: full fit with lin. BG**

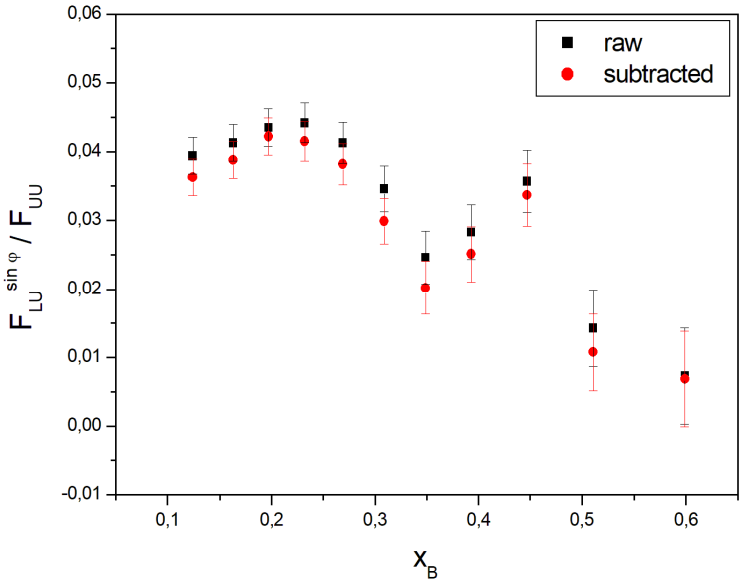
Background Below the π^0 Peak

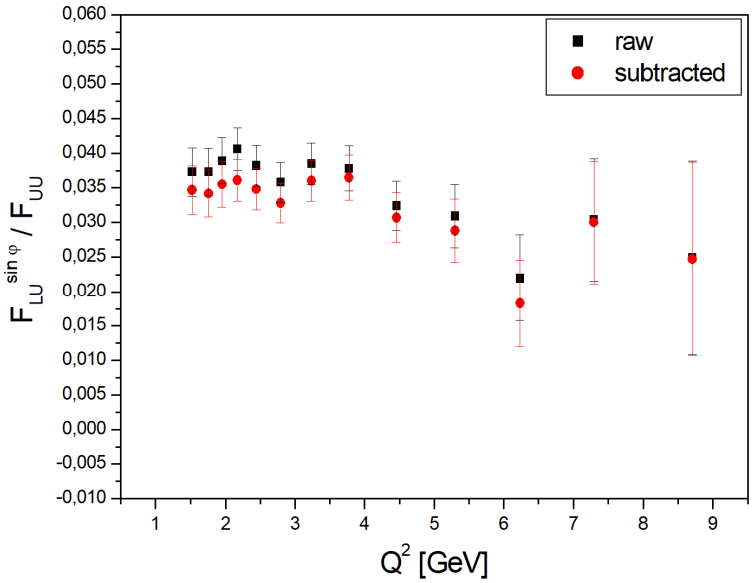
Method 2:

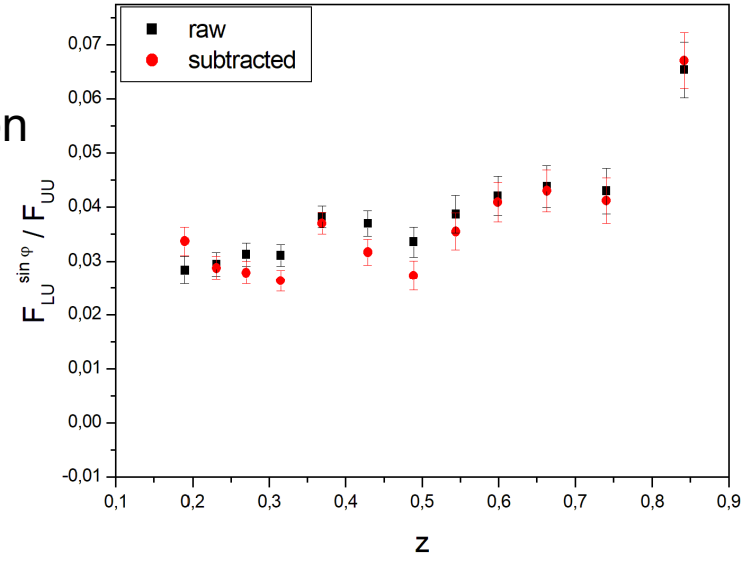
sideband subtraction

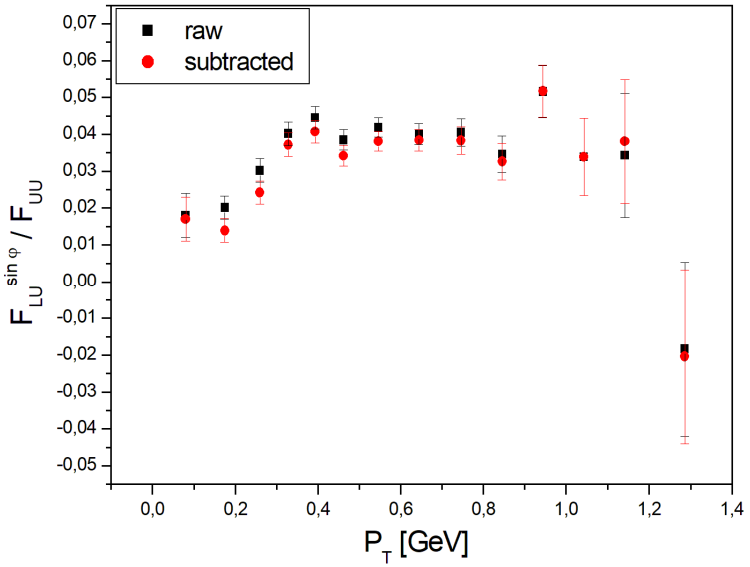


- consistent result
- typically 10 % or less reduction
- << stat. uncer-tainty in 4D
- Assign as systematic uncertainty in 4D









Conclusion and Outlook

- Inbending and outbending datasets from fall 2018 are available.
- PID refinements and fiducial cuts have been finalized and are currently under dicussion.
- Common SIDIS MC production for pass 1 data is well in progress for the inbending and has started for the outbending dataset.
- The goal for the first publication is to show a multidimensional binning.
  → Available for the first time and very important for global TMD fits.
- The statistics of the inbending dataset is sufficient for a multidimensional binning, but adding the outbending dataset can significantly reduce the statistical uncertainty.
- The analysis note in coordination with the common RG-A analysis note is well in progress.

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

UNIVERSITY OF CONNECTICUT 1881

clas