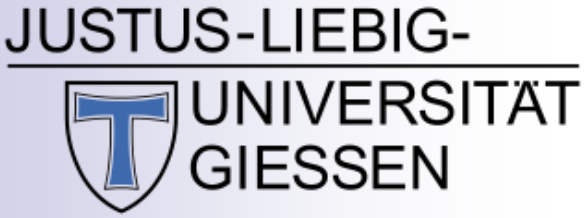
CLAS collaboration meeting, JLAB

November 07 - 10, 2023

Beam spin asymmetries from semi-inclusive pion electroproduction

- Impact of vector meson production -



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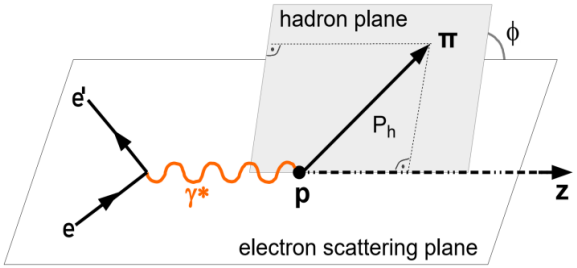
11/08/2023

Physics motivation

- The 3D nucleon structure in momentum space can be described by TMDs
- A way to acess these properties is semi inclusive deep inelastic scattering



SIDIS cross section for an unpolarized target:

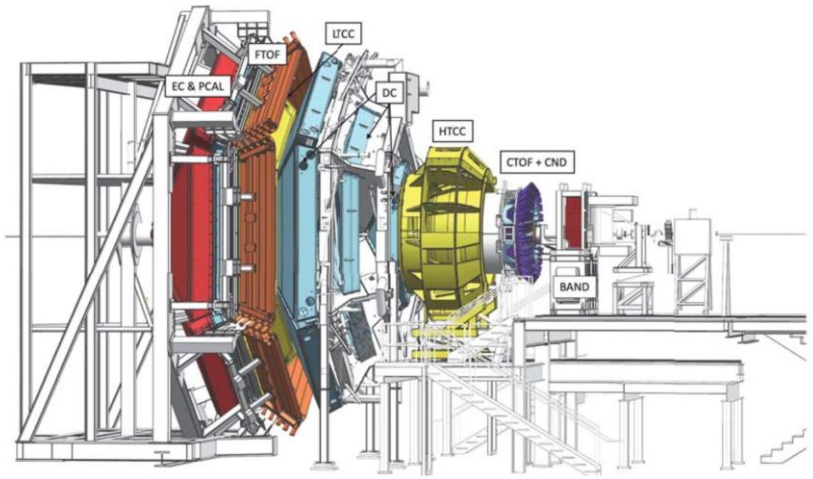
$$\frac{d\sigma}{dx_B\, dQ^2\, dz\, d\phi_h\, dp_{h\perp}^2} = K(x,y,Q^2)\Big\{F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\,\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon\cos(2\phi_h)F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\sin\phi_h F_{LU}^{\sin\phi_h}\Big\}$$

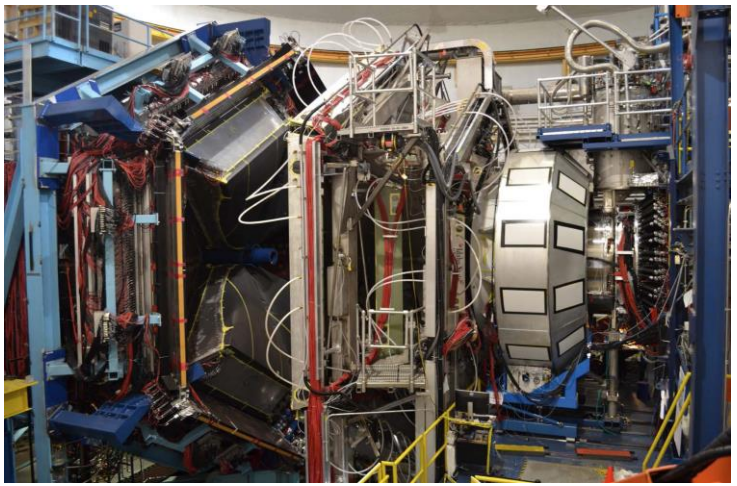
$$A_{LU}(x_B,Q^2,z,P_T,\phi) = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{\sqrt{2\epsilon(1-\epsilon)}\,\frac{F_{LU}^{\sin\phi}}{F_{UU}}\sin\phi}{1+\sqrt{2\epsilon(1+\epsilon)}\,\frac{F_{UU}^{\cos\phi}}{F_{UU}}\cos\phi+\epsilon\,\frac{F_{UU}^{\cos 2\phi}}{F_{UU}}\cos 2\phi}$$

$$F_{LU}^{\sin\phi_h} = \frac{2M}{Q}\zeta\left(-\frac{\hat{\mathbf{h}}\cdot\mathbf{k}_T}{M_h}\left(x\,e\,H_1^\perp + \frac{M_h}{M}f_1\,\frac{\widetilde{G}^\perp}{z}\right) + \frac{\hat{\mathbf{h}}\cdot\mathbf{p}_T}{M}\left(x\,g^\perp D_1 + \frac{M_h}{M}h_1^\perp\,\frac{\widetilde{E}}{z}\right)\right)$$

$$F_{UU,T} = \zeta[f_1 D_1], \qquad F_{UU,L} = 0, \qquad \textbf{(twist-3)}$$

Experimental setup and available dataset





RG-A data from fall 2018 and spring 2019 (pass 1 cooking):

➔ 10.6 GeV / 10.2 GeV electron beam ➔ ~87 % average polarization

➔ liquid H_2 target

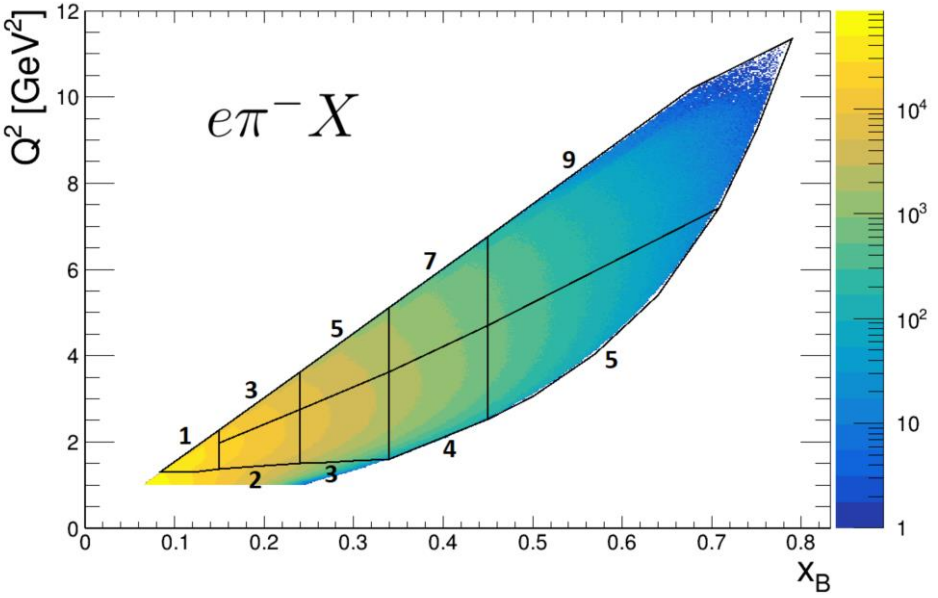
- **Common QA scheme „OKforAsymmetry“**
- **Fiducial cuts and PID refinements for electrons, pions and photons**
- **π^0 selection cuts and background subtraction for π^0 events**

➔ **Analysis note reviewed and approved!**

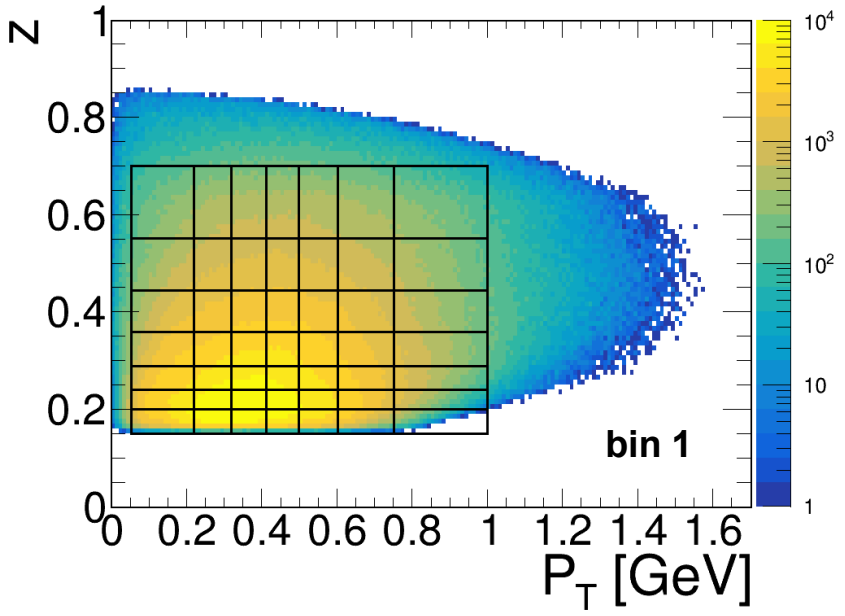
A fully multidimensional binning

Kinematic cuts: $Q^2 > 1$ GeV² $W > 2$ GeV $y < 0.75$

Cut to suppress exclusive N and N* DVMP: $M_{e\pi X} > 1.5$ GeV



9 bin in Q^2 - x_B

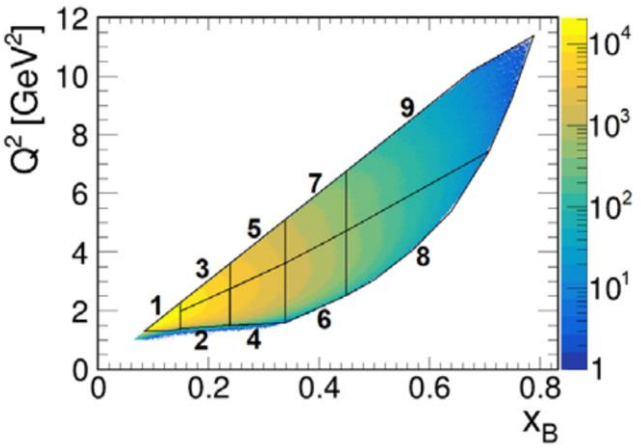


up to 7 x 7 bins in z - P_T
for each Q^2 - x_B bin

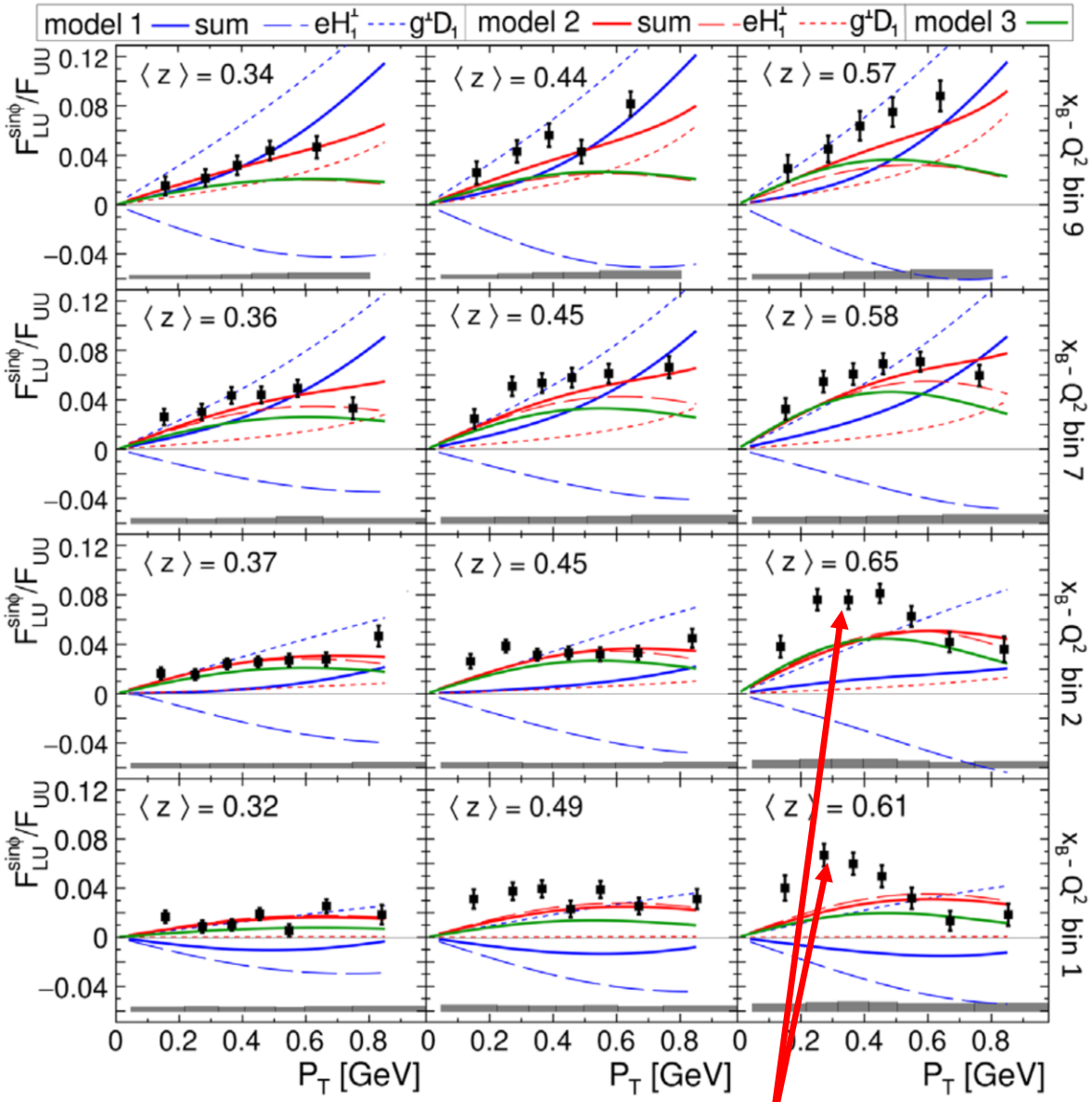
in total: 344 bins x 12 bins in Φ ~ 4130 BSA bins

π^+ SIDIS:

S. Diehl et al. (CLAS Collaboration), Phys. Rev. Lett. 128, 062005 (2022).



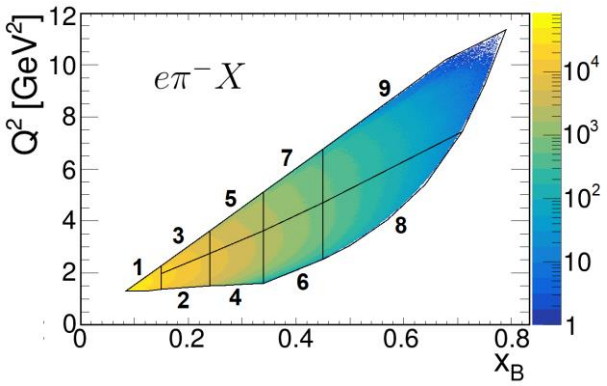
- model 1 $eH_1^\perp$
- model 1 $g^\perp D_1$
- model 1 sum
- model 2 $eH_1^\perp$
- model 2 $g^\perp D_1$
- model 2 sum
- model 3 $eH_1^\perp$



„bumps“ could not be explained by theory!

π SIDIS:

this work



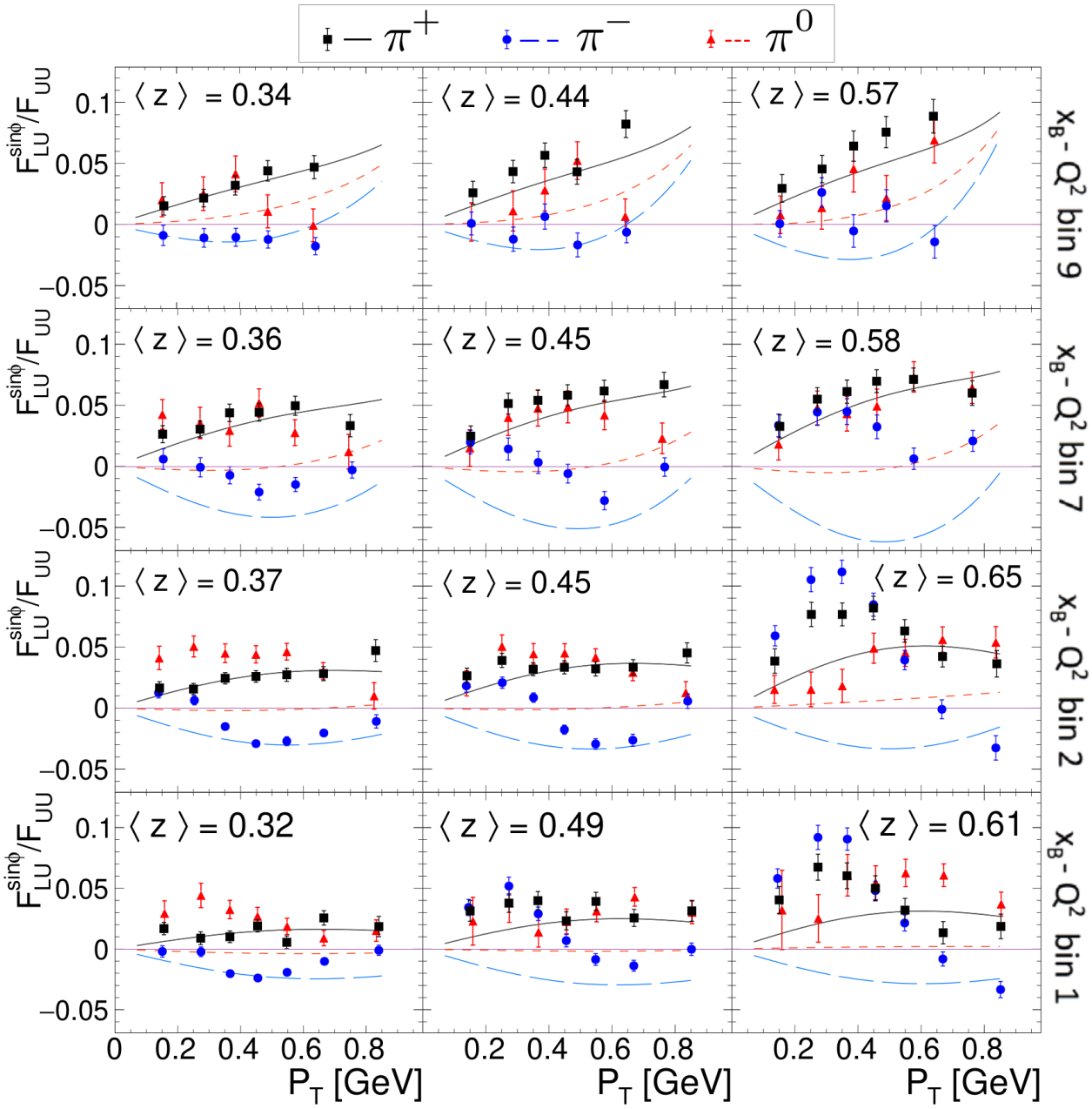
black: π^+

red: π^0

blue: π^-

lines: model 2

$eH_1^{\perp} + g^{\perp}D_1$



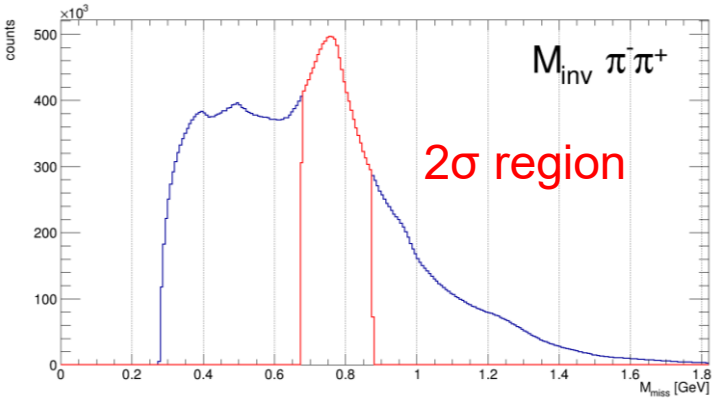
Where are the „bumps“ and the P_T dependent structures coming from?

Possible source: Pions originating from exclusive VM (ρ) production

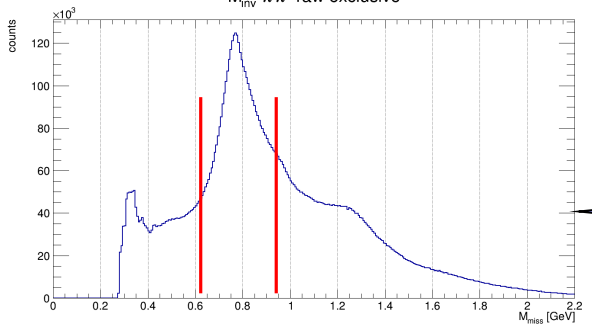
➔ Can not be rejected in single pion SIDIS (2 missing particles!)

➔ CLAS12 can study the properties of these events!

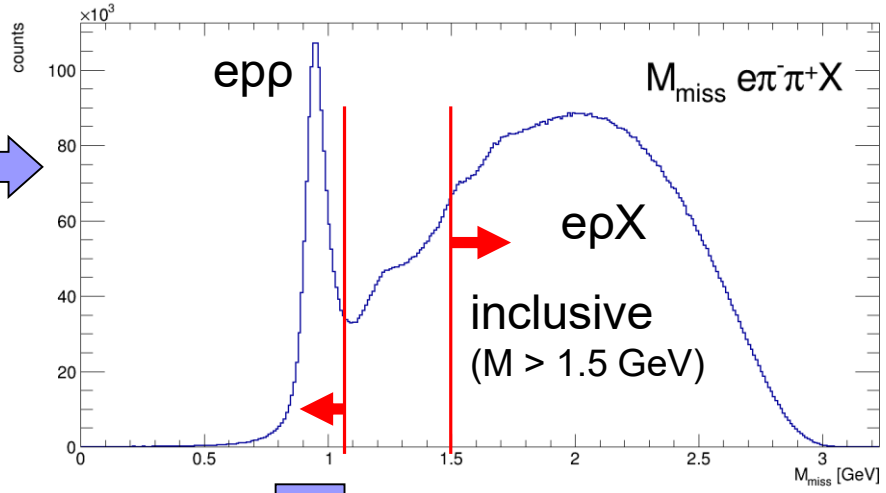
- Select events with e π^+ π^- X $Q^2 > 1.5$ GeV² W > 2 GeV y < 0.75
- Pions: FD only for SIDIS π and FD + CD for secondary π (acceptance)



M_{inv} $\pi^-\pi^+$ raw exclusive



- $M_{e\pi X}$ > 1.5 GeV for SIDIS π



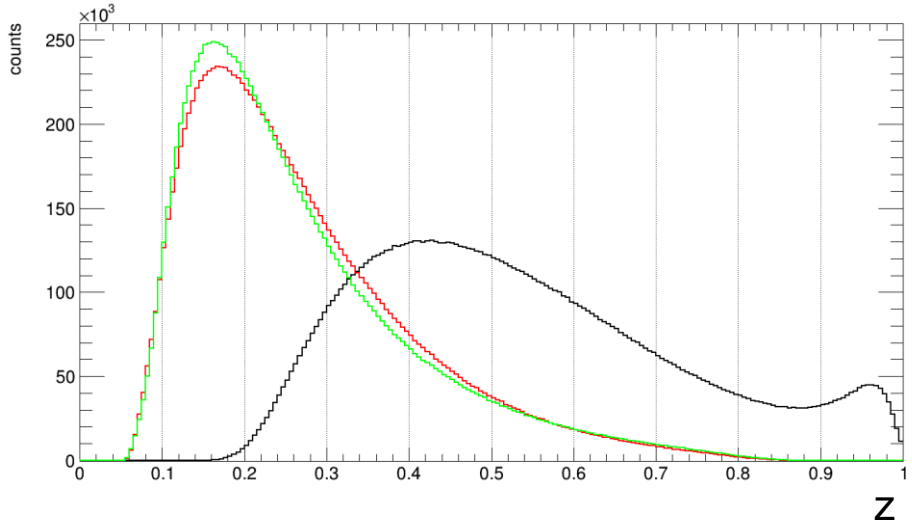
exclusive (M_{miss} < 1.05 GeV)

Kinematics of pions from ρ decays

➔ Use individual z, P_T and ϕ for π^+, π^- and ρ

$e\pi^+\pi^-X$

with $M(\pi\pi) \sim \rho$

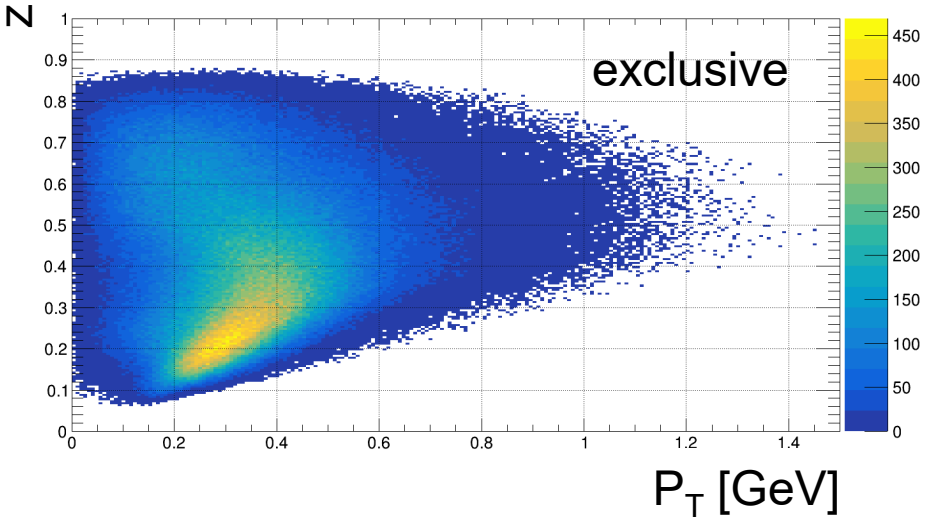


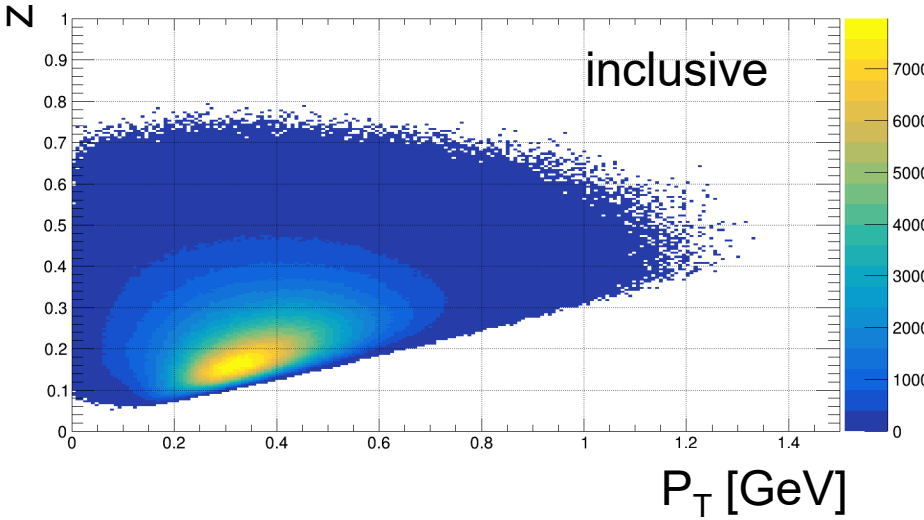
$\rho = \pi^+ + \pi^-$

π^+

π^-

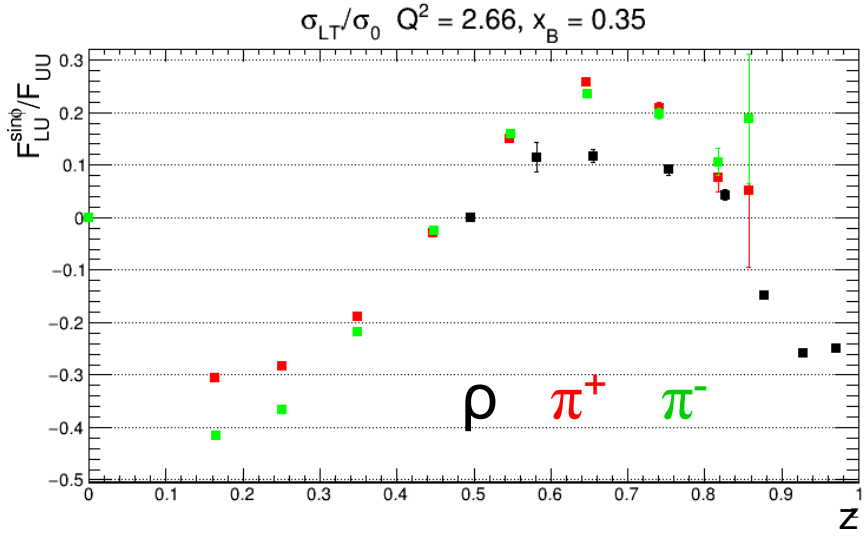
Pions:

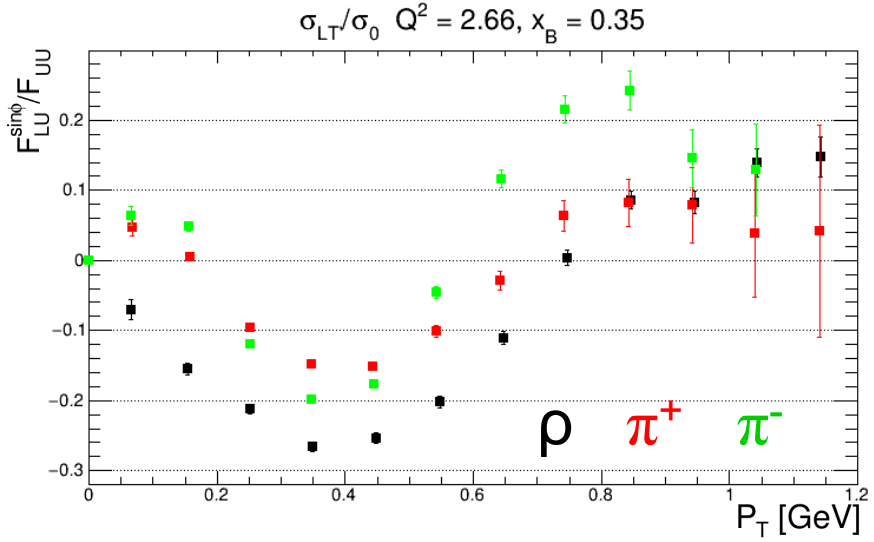




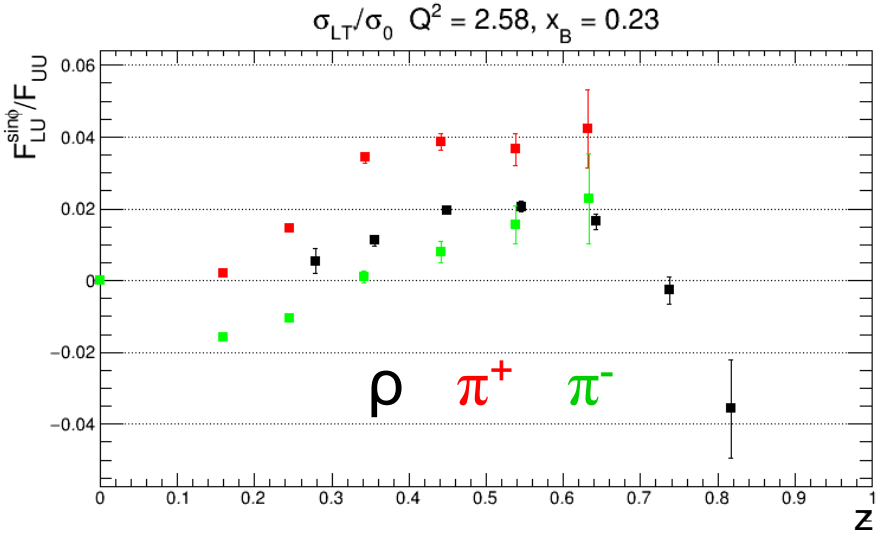
1D study: Asymmtries of pions from ρ decays

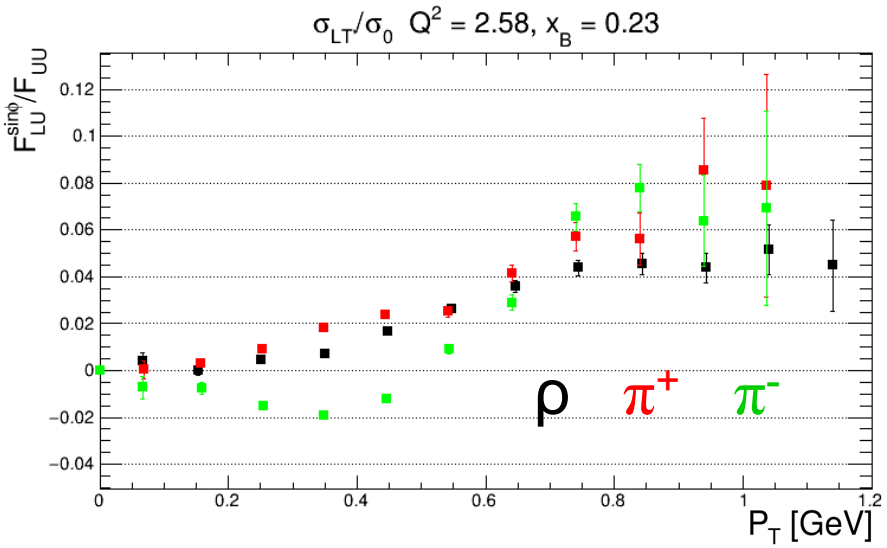
Exclusive ρ:





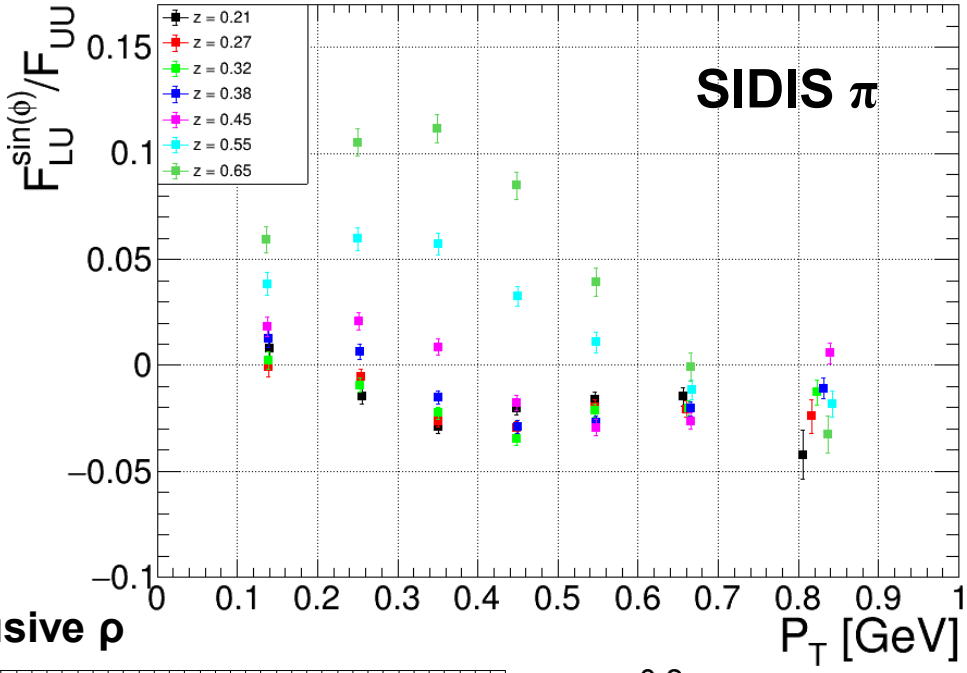
Inclusive ρ:

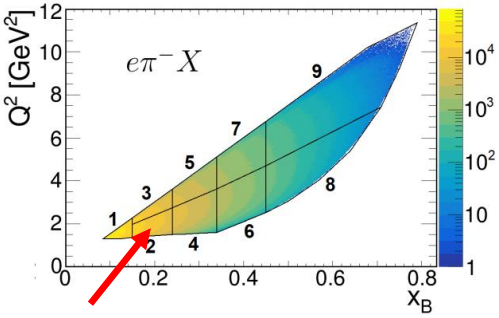




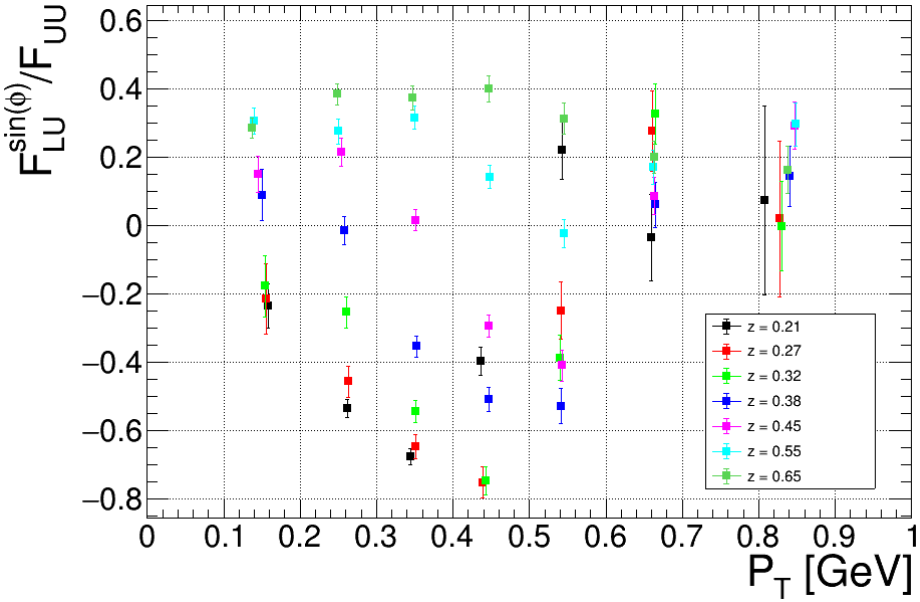
π^- SIDIS:

Q^2-x_B bin 2:

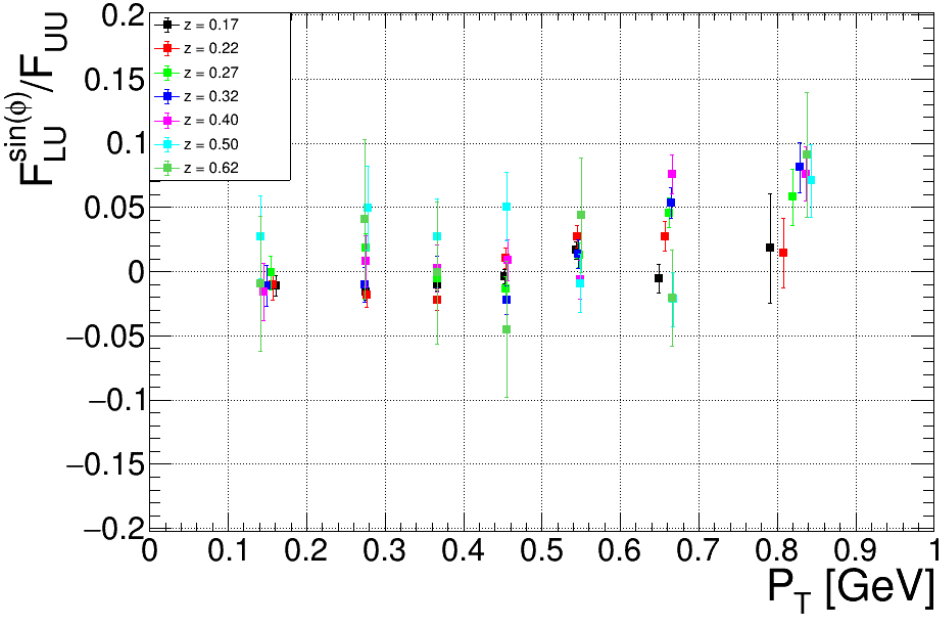




π from exclusive ρ

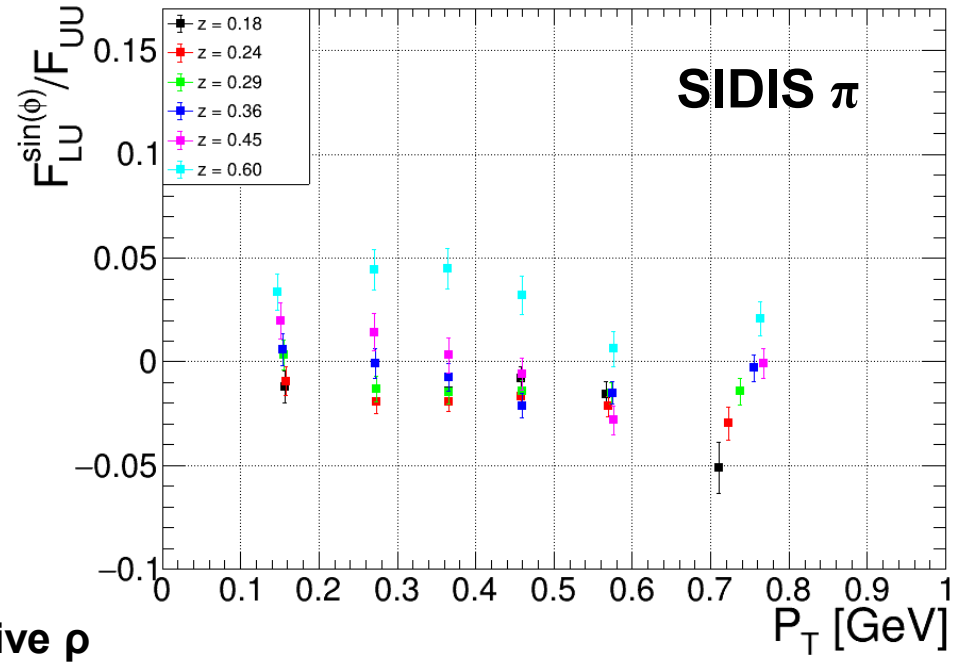


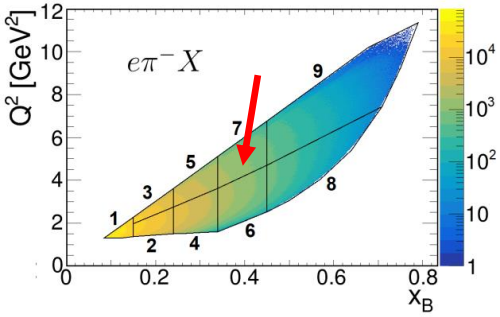
π from inclusive ρ



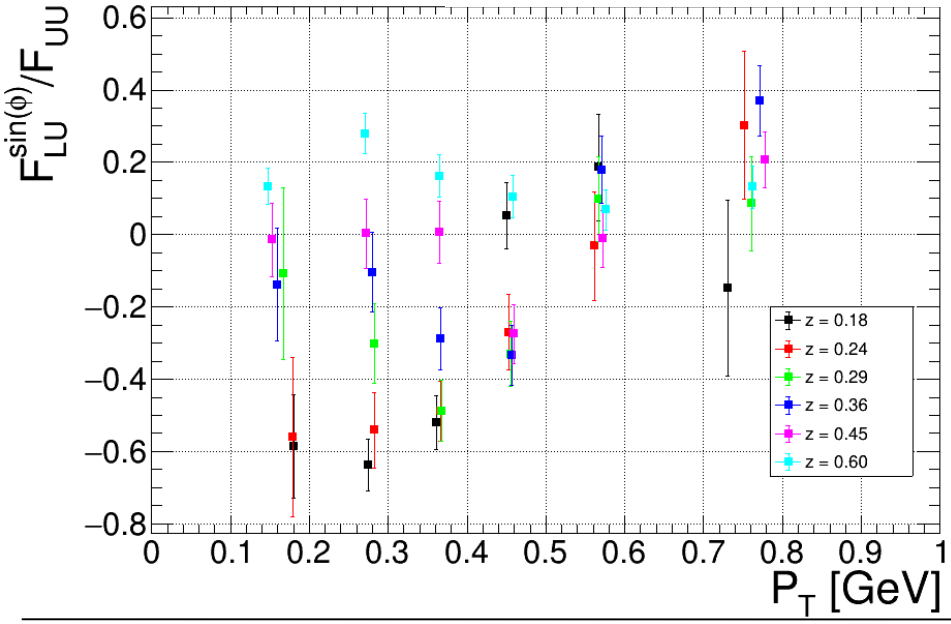
π^- SIDIS:

Q^2-x_B bin 7:

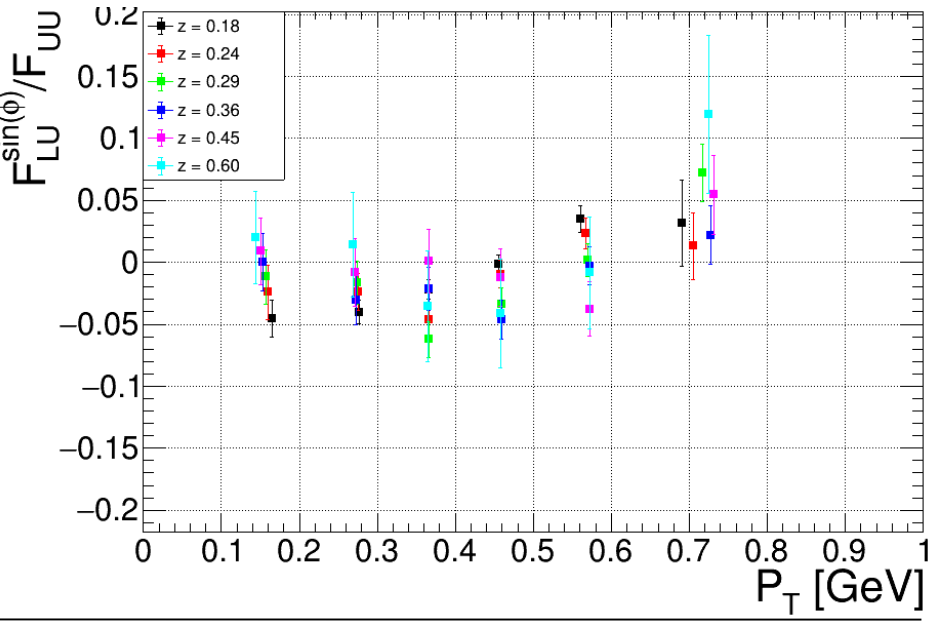




π from exclusive ρ



π from inclusive ρ



Asymmetries of pions from ρ decays

- Large „bumps“ can only originate from pions produced in **exclusive** ρ production
- Pions originating from inclusive ρ show similar characteristics as SIDIS pions

But: Exclusive ρ contamination in the SIDIS MC is small

+ Not reliable for a multidimensional study

➔ Determine the exclusive rho contamination from CLAS12 data

Contamination estimate based on 2 samples:

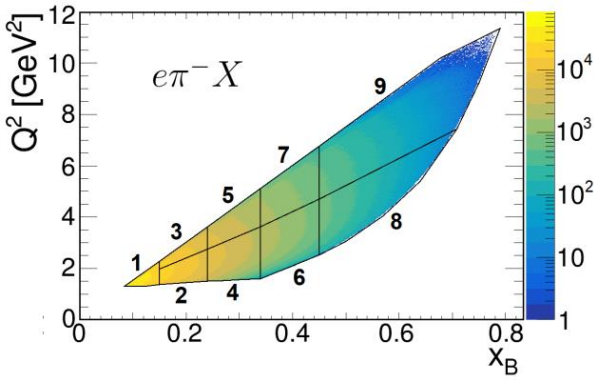
1. **e π^- X** SIDIS sample
2. **e $\pi^+\pi^-$ X** with 2σ cut on ρ mass and cut on missing proton mass

➔ MC based acc. correction for both samples!

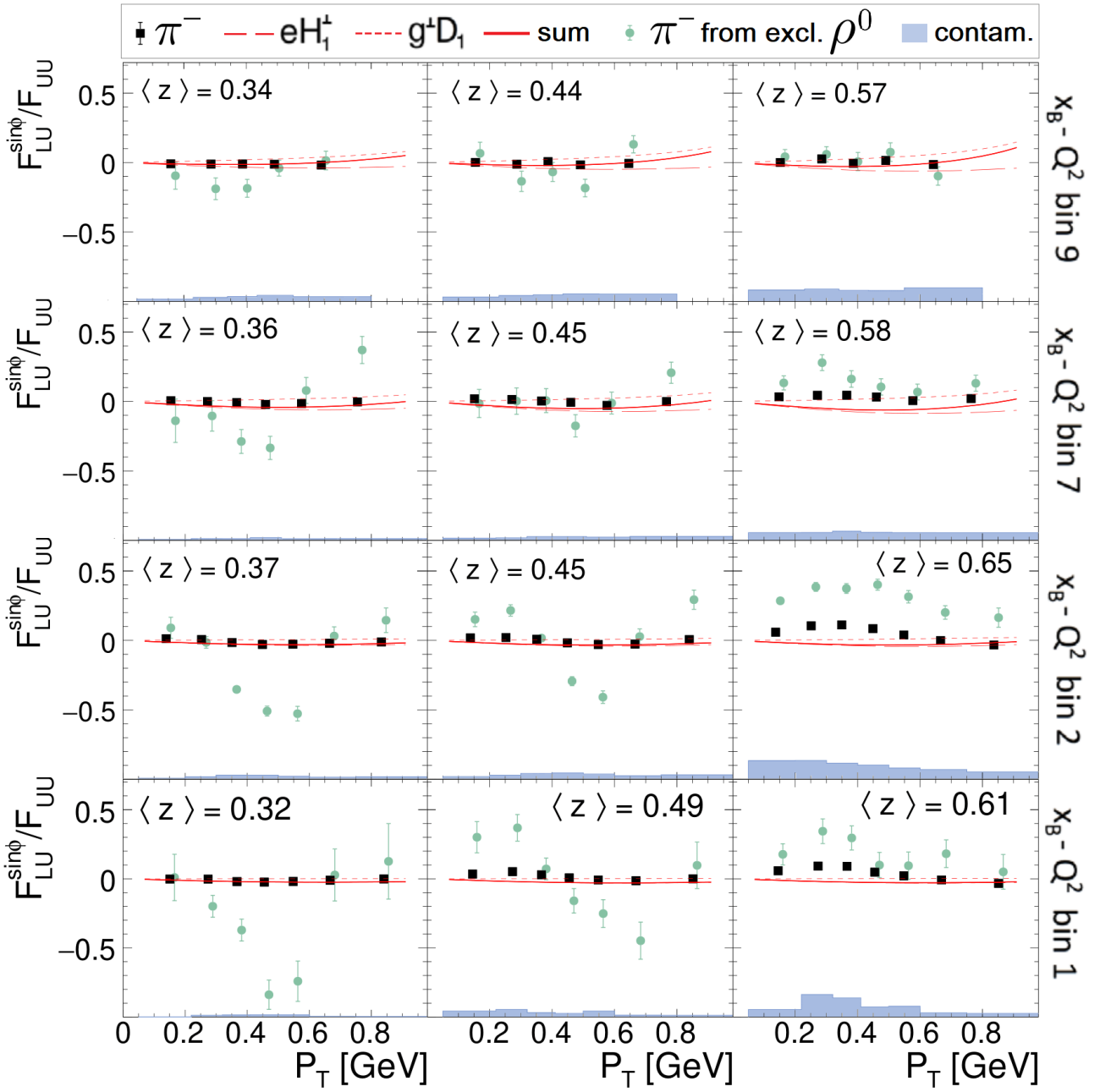
➔ Ratio of sample 2 and sample 1 gives a contamination estimate

π^- SIDIS:

P_T dependence (fullscale)

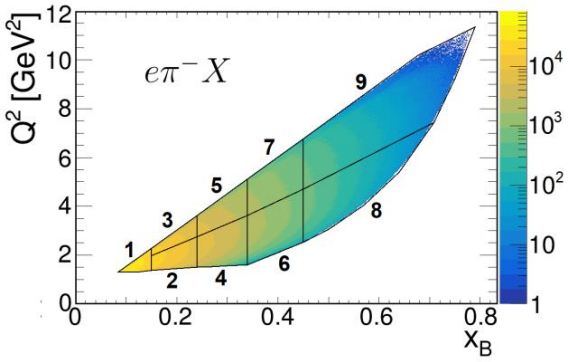


- SIDIS π^-
- π^- from excl. $ep\pi^+\pi^-$ events in the ρ region

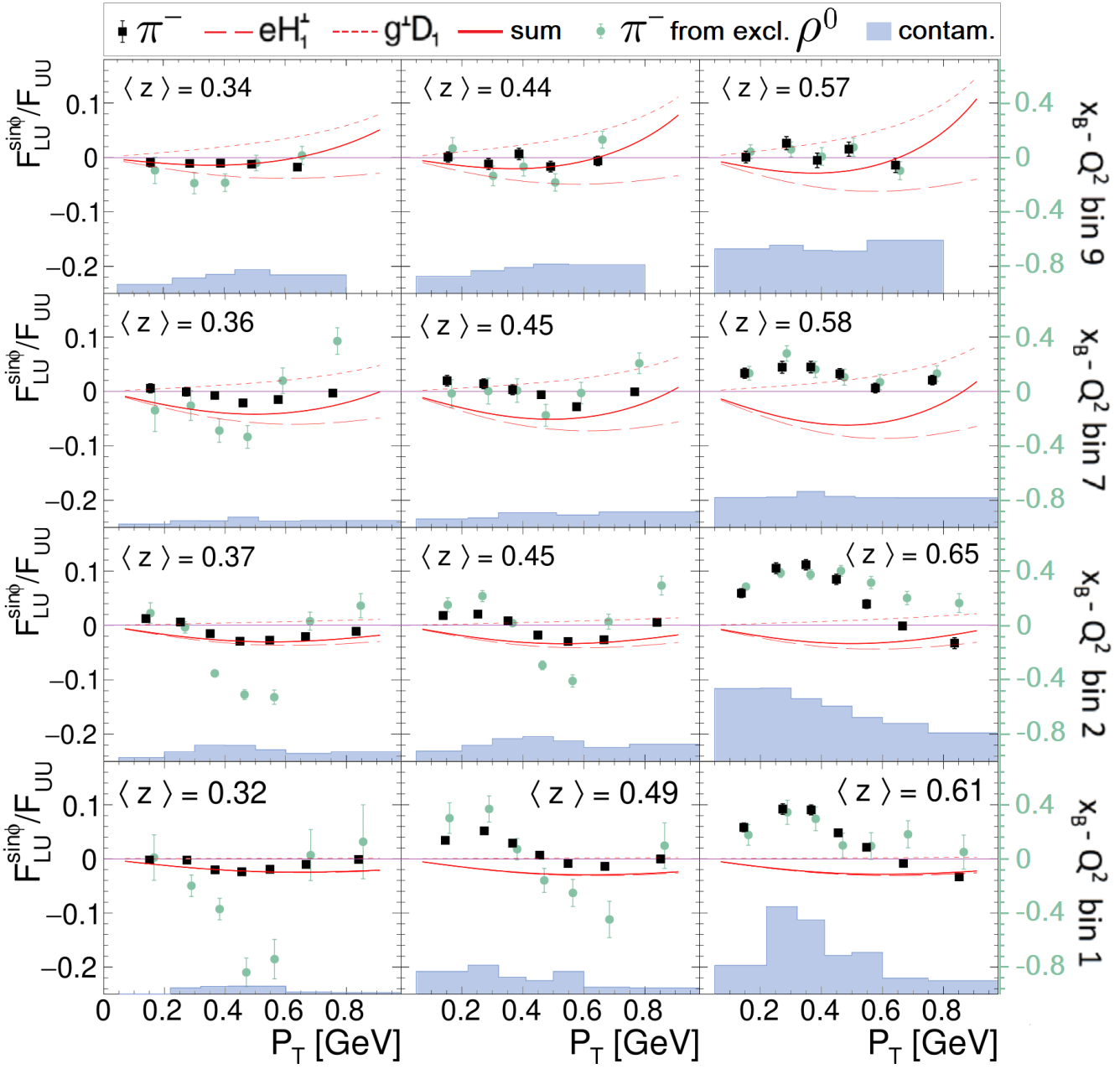


π^- SIDIS:

P_T dependence (scaled)

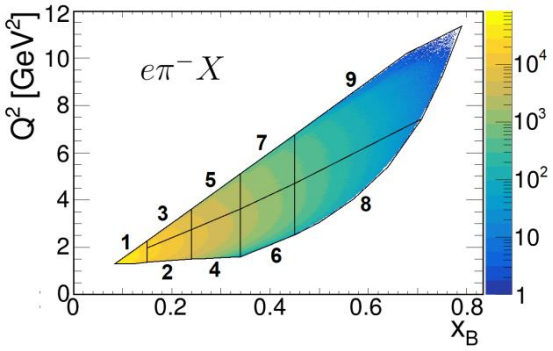


- SIDIS π^-
- π^- from excl. $ep\pi^+\pi^-$ events in the ρ region

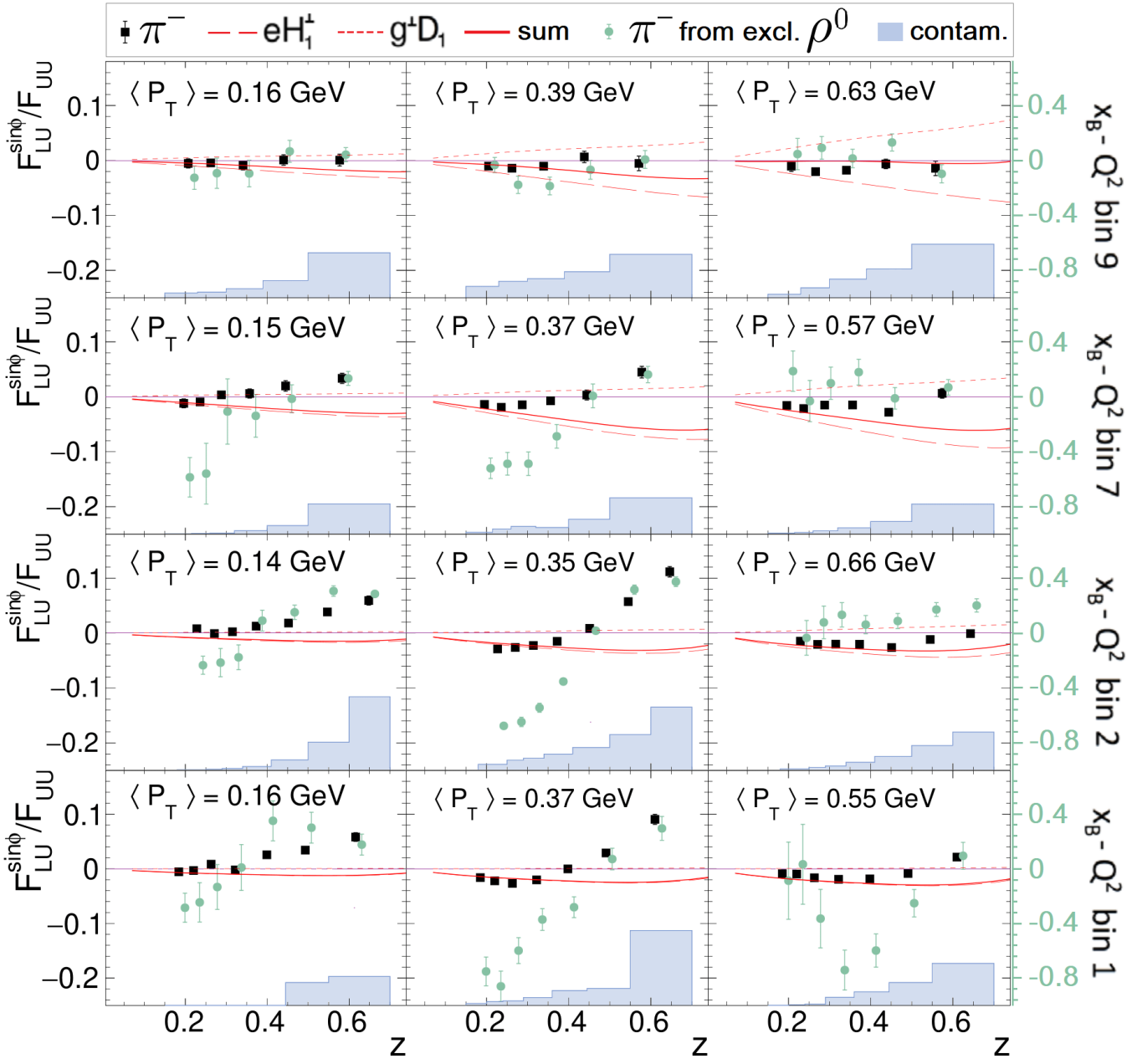


π^- SIDIS:

z dependence (scaled)



- SIDIS π^-
- π^- from excl. $ep\pi^+\pi^-$ events in the ρ region



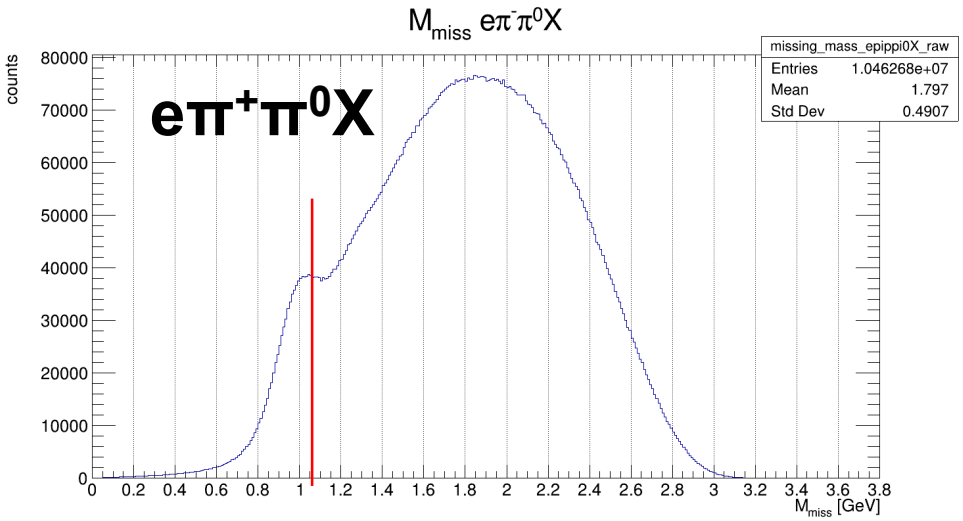
How does the asymmetry look like for pions from charged ρ?

$e\,p \rightarrow e\,p\,\rho^0 \rightarrow e\,p\,\pi^+\,\pi^-$

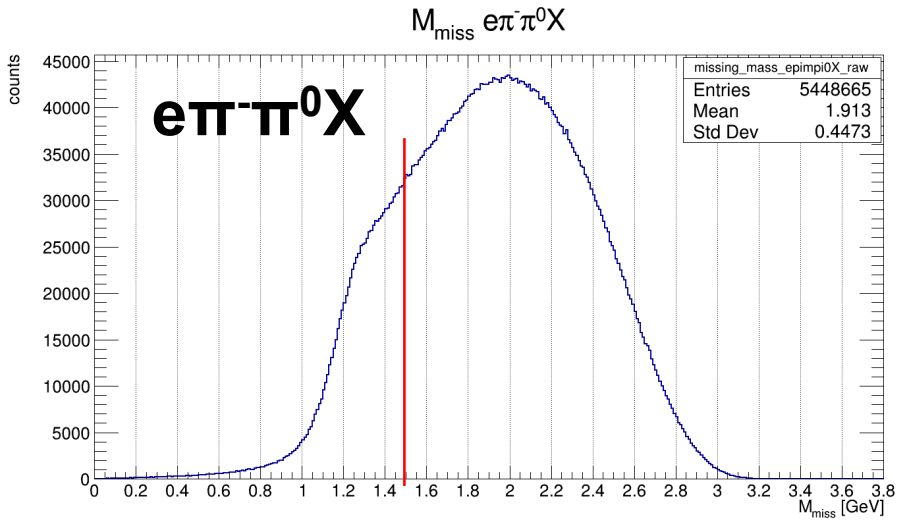
$e\,p \rightarrow e\,n\,\rho^+ \rightarrow e\,n\,\pi^+\,\pi^0$

$e\,p \rightarrow e\,\Delta^{++}\,\rho^- \rightarrow e\,\Delta^{++}\,\pi^-\,\pi^0 \rightarrow e\,p\,\pi^+\,\pi^-\,\pi^0$

$e\,p \rightarrow e\,n\,\rho^+ \rightarrow e\,n\,\pi^+\,\pi^0$

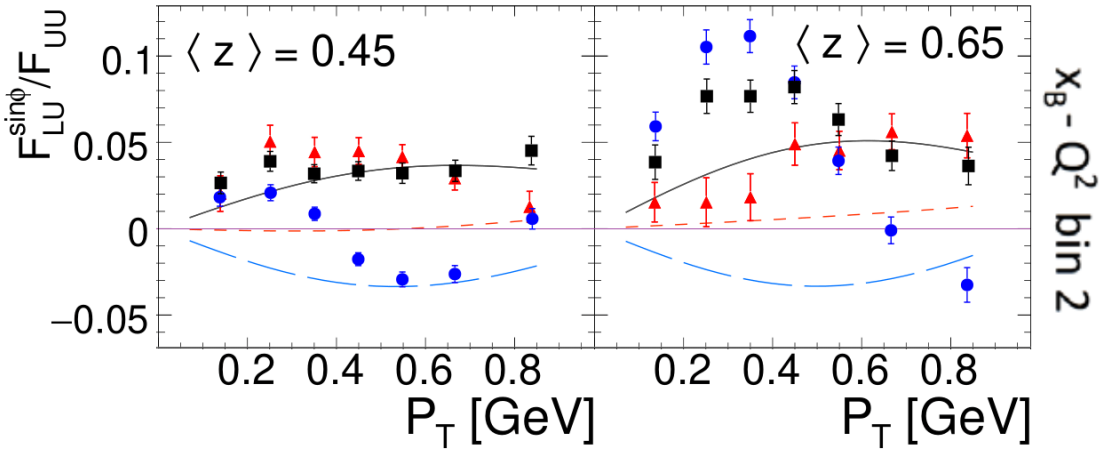


$e\,p \rightarrow e\,\Delta^{++}\,\rho^- \rightarrow e\,p\,\pi^+\,\pi^-\,\pi^0$



➔ Limitted by π^0 / γ resolution!

$e\,p \rightarrow e\,n\,\rho^+$
$\rightarrow e\,n\,\pi^+\,\pi^0$



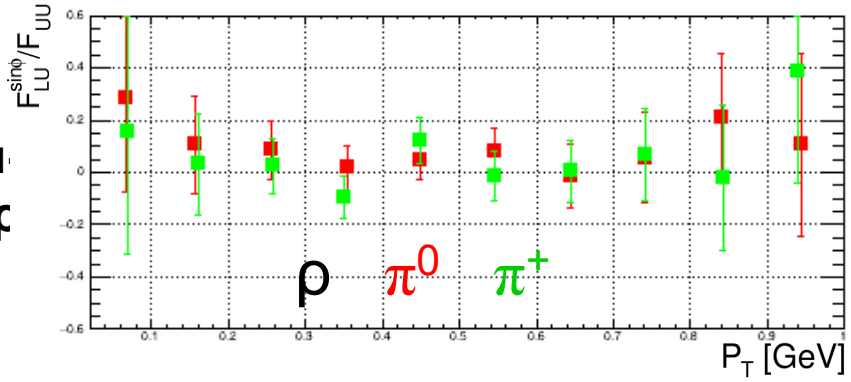
SIDIS

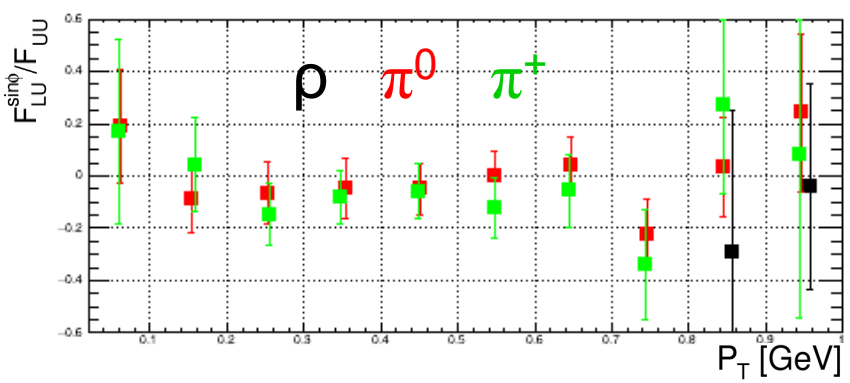
π^+

π^0

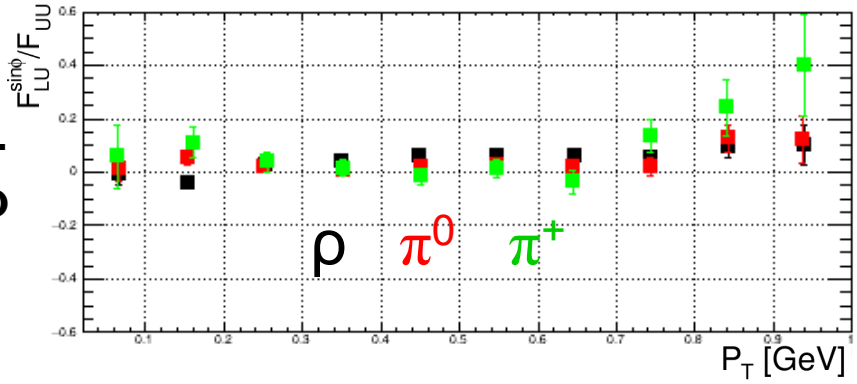
π^-

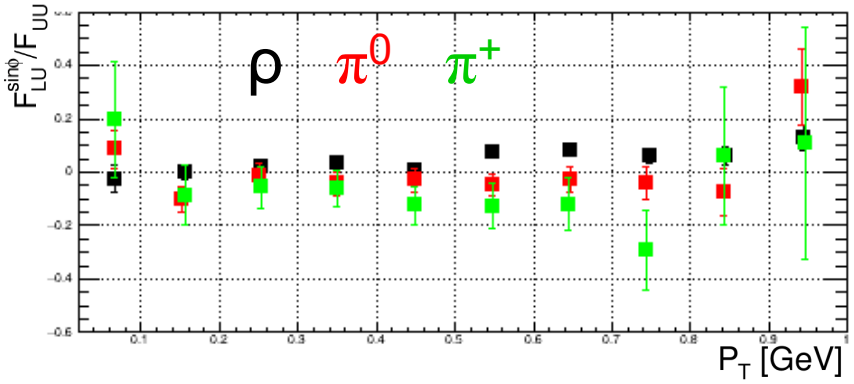
„exclusive“ ρ



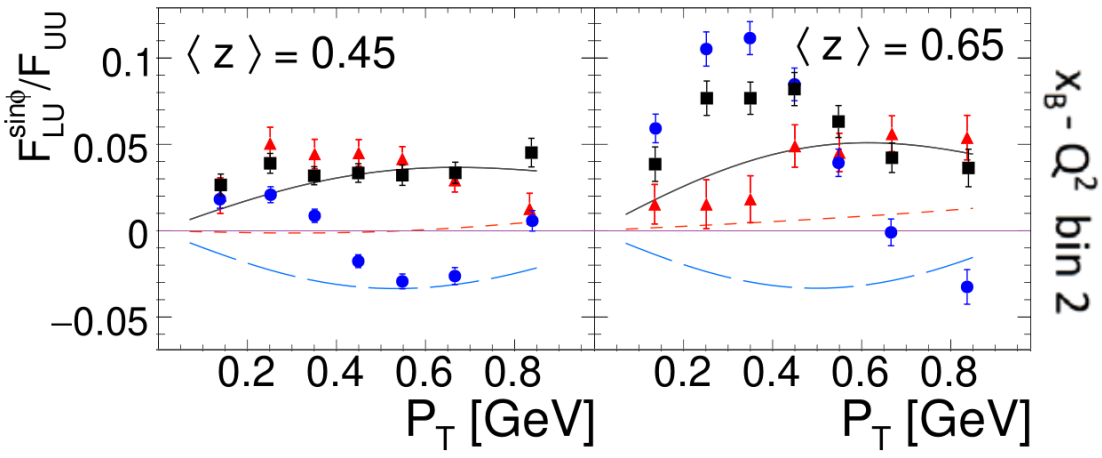


inclusive ρ





$e\ p \rightarrow e\ \Delta^{++}\ \rho^{-}$
$\rightarrow e\ p\ \pi^{+}\ \pi^{-}\ \pi^{0}$



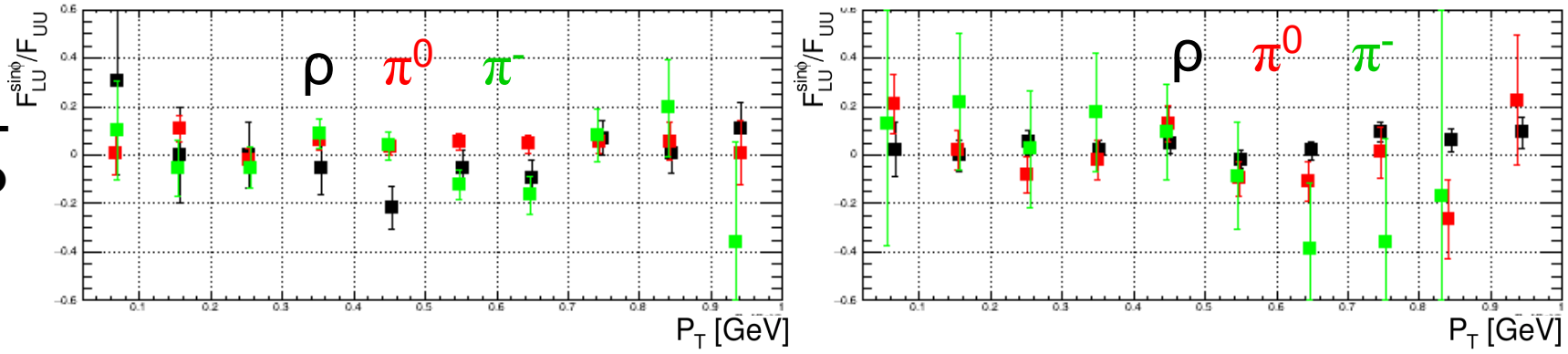
SIDIS

π^{+}

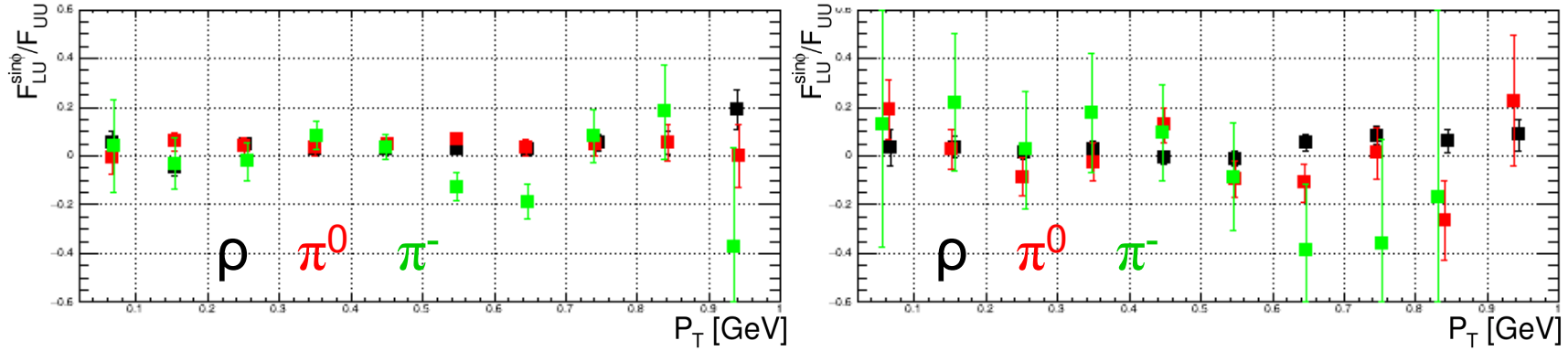
π^{0}

π^{-}

„exclu-sive“ ρ



inclu-sive ρ



Conclusion

- P_T dependent structures and „bumps“ in the SIDIS data of charged pions are dominated by exclusive $\rho^0 \rightarrow \pi^+ \pi^-$.
- Structures are similar for positive and negative pions.

  ➔ Effect more dominant for π^- due to small intrinsic asymmetry.
- π^0 SIDIS shows a more smoth behaviour.

  ➔ Consistent with the fact, that π^0 from charged ρ decays show mostly flat asymmetries without dominant structures.

  But: Statistics and resolution are not sufficient for a final multidim. conclusion
- At high Q^2 structures disappear (higher twist effect?) and contaminations are at a reasonable level ➔ **More direct access to TMD physics for $Q^2 > 5$ GeV²**

➔ Kinematic effects and discrepancy between data and theory are understood

➔ A correction can not be performed for the present publication due to the existing uncertainties.