Back-to-back hadrons with unpol. and lonitudinal pol. targets

Harut Avakian (JLab)

Workshop on kaons and TFR, LNF, Dec 15, 2022

Introduction
- Locating the longitudinally polarized quarks in unpolarized protons
- Separating the kinematics of current and target fragmentation

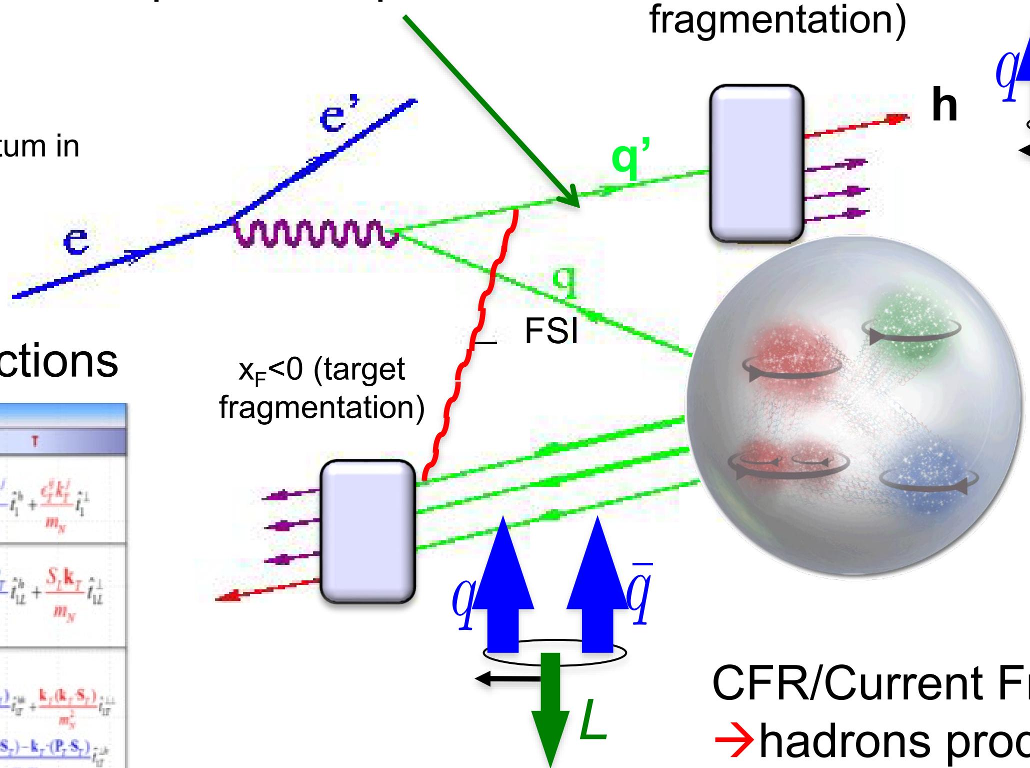
Test results with Longitudinally polarized protons (CLAS12 RGC)
- $ep \rightarrow e'pX$
- $ep \rightarrow e'p\pi^+X$

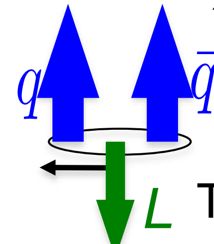
Summary

Hadron production in hard scattering

X. Artru & Z. Belghobsi

x_F – fractional momentum in the CM frame





TMD PDFs

Nucleon Polarization \ Quark polarization	U	L	T
U	$f_1^q(x,k_T^2)$	X	$\frac{\epsilon_T^{ij}k_T^j}{M}h_1^{\perp q}(x,k_T^2)$
L	X	$S_L g_{1L}^q(x,k_T^2)$	$S_L\frac{\mathbf{k}_T}{M}h_{1L}^{\perp q}(x,k_T^2)$
T	$\frac{[\mathbf{k}_T\times\mathbf{S}_T]_3}{M}f_{1T}^{\perp q}(x,k^2)$	$\frac{\mathbf{k}_T\cdot\mathbf{S}_T}{M}g_{1T}^{\perp q}(x,k_T^2)$	$\mathbf{S}_T h_{1T}^q(x,k_T^2)+\frac{\mathbf{k}_T}{M}\frac{(\mathbf{k}_T\cdot\mathbf{S}_T)}{M}h_{1T}^{\perp q}(x,k_T^2)$

Fracture Functions

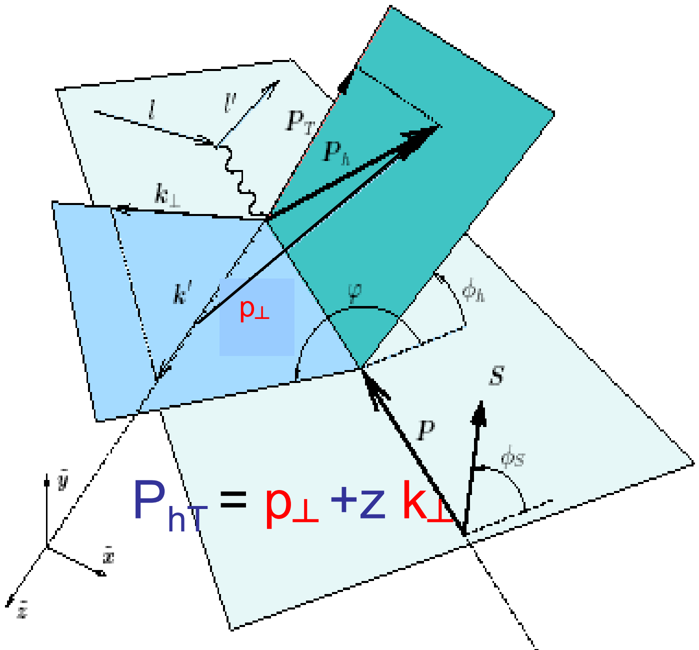
Nucleon Polarization \ Quark polarization	U	L	T
U	$\hat{u}_1$	$\frac{\mathbf{k}_T\times\mathbf{P}_T}{m_N m_h}\hat{l}_1^{\perp h}$	$\frac{\epsilon_T^{ij}P_T^j}{m_h}\hat{t}_1^h+\frac{\epsilon_T^{ij}k_T^j}{m_N}\hat{t}_1^{\perp}$
L	$\frac{S_L(\mathbf{k}_T\times\mathbf{P}_T)}{m_N m_h}\hat{u}_{1L}^{\perp h}$	$S_L\hat{l}_{1L}$	$\frac{S_L\mathbf{P}_T}{m_h}\hat{t}_{1L}^h+\frac{S_L\mathbf{k}_T}{m_N}\hat{t}_{1L}^{\perp}$
T	$\frac{\mathbf{P}_T\times\mathbf{S}_T}{m_h}\hat{u}_{1T}^h+\frac{\mathbf{k}_T\times\mathbf{S}_T}{m_N}\hat{u}_{1T}^{\perp}$	$\frac{\mathbf{P}_T\cdot\mathbf{S}_T}{m_h}\hat{l}_{1T}^h+\frac{\mathbf{k}_T\cdot\mathbf{S}_T}{m_N}\hat{l}_{1T}^{\perp}$	$\mathbf{S}_T\hat{t}_{1T}+\frac{\mathbf{P}_T(\mathbf{P}_T\cdot\mathbf{S}_T)}{m_h^2}\hat{t}_{1T}^{hh}+\frac{\mathbf{k}_T(\mathbf{k}_T\cdot\mathbf{S}_T)}{m_N^2}\hat{t}_{1T}^{\perp\perp}+\frac{\mathbf{P}_T(\mathbf{k}_T\cdot\mathbf{S}_T)-\mathbf{k}_T\cdot(\mathbf{P}_T\cdot\mathbf{S}_T)}{m_N m_h}\hat{t}_{1T}^{\perp h}$

Anselmino, Barone, Kotzinian

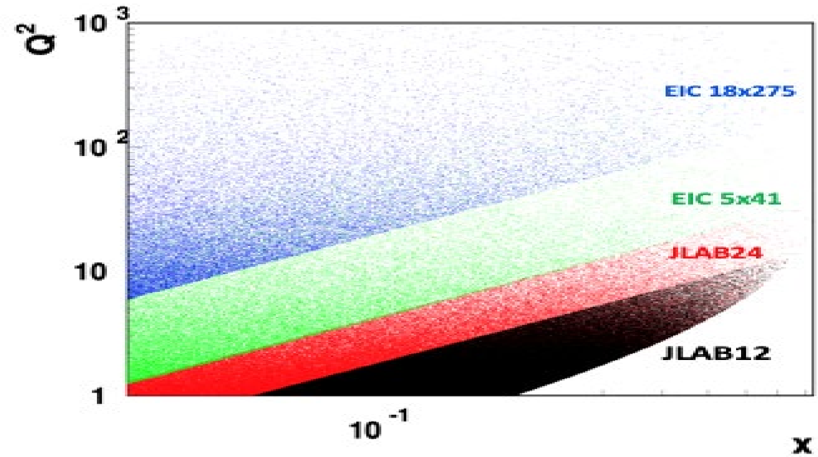
CFR/Current Fragmentation Region
→hadrons produced from struck quark
TFR/Target Fragmentation Region
→hadrons produced from remnant

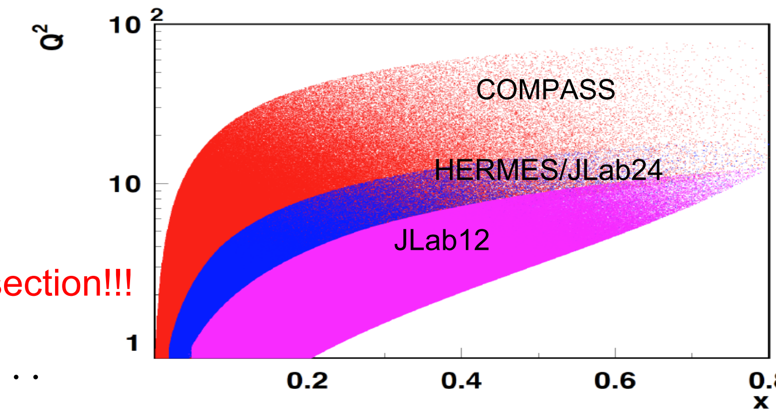
Correlations of the spin of the target or/and the momentum and the spin of quarks, combined with final state interactions define the azimuthal distributions of produced particles (different in CFR and TFR)

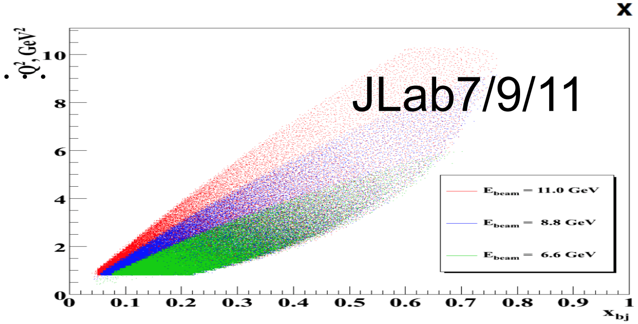
SIDIS kinematical coverage and observables



EIC







SIDIS experiments measure azimuthal dependence of the cross section!!!

$$\sigma \propto F_{UU} + P_b\sqrt{2\epsilon(1-\epsilon)}F_{LU}^{\sin\phi}\sin\phi + P_t\epsilon F_{UL}^{\sin 2\phi}\sin 2\phi + \ldots$$

$$+\epsilon F_{UU,L} + |S_\perp|[F_{UT}^{\sin\phi-\phi_S}\sin(\phi-\phi_S) + \sqrt{2\epsilon(1+\epsilon)}F_{UT}^{\sin\phi_S}\sin\phi_S] + \ldots$$

- Studies of azimuthal modulations give access to underlying 3D partonic distributions
- QCD predicts only the Q^2-dependence of 3D PDFs

WG3 hadronization and TMDs plan

3 hours of discussion: (15+5) = 8 talks + 20mins flash

1.Role of the JLab upgrade to address critical elements for interpretation of world SIDIS data

1. Role of F_UU,L
    1. theory perspective (Alessandro/Alexey)
    2. experimental perspective (Ed Kinney)
2. Role of VM decays and pT distributions (Albi)
3. Radiative Corrections in SIDIS (Jianwei/Nobuo)
4. Role of SIDIS regions (correlations between CFR/TFR/SFR..),
    1. Theory perspective (Prokudin/Sato?)

$$F_{UU,L} \sim P_T^2 z^2/Q^2$$

2.Opportunities of High luminosity JLab upgrade for precision TMD studies in valence region, the role of multidimensional binning

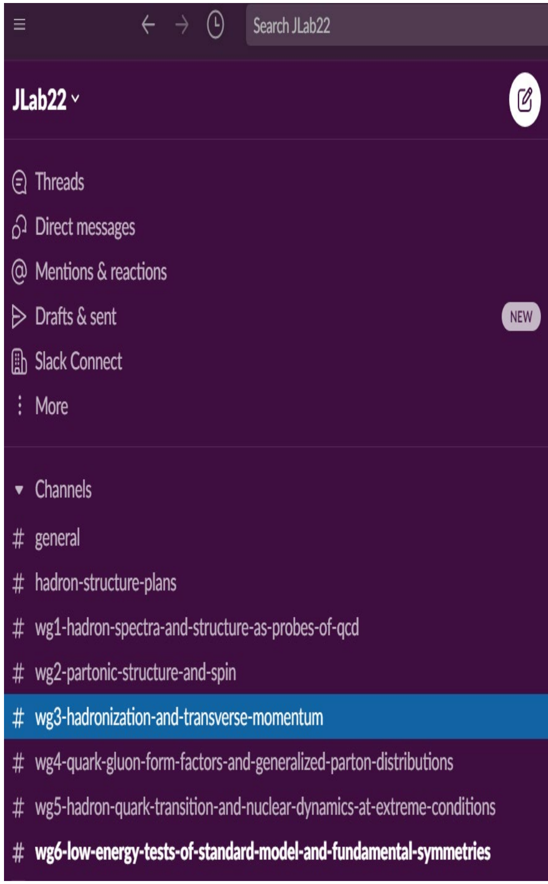
1. Experimental perspective (Bakur Parsamyan)
2. Theory perspective (Alexey Vladimirov)

3.Understanding hadronization [2 talks]

1. Independent fragmentation and role of charge symmetry (Whit Armstrong)
2. Correlations in Di-hadron production (Dilks)

4.Flash talks [5 talks] (3 mins)

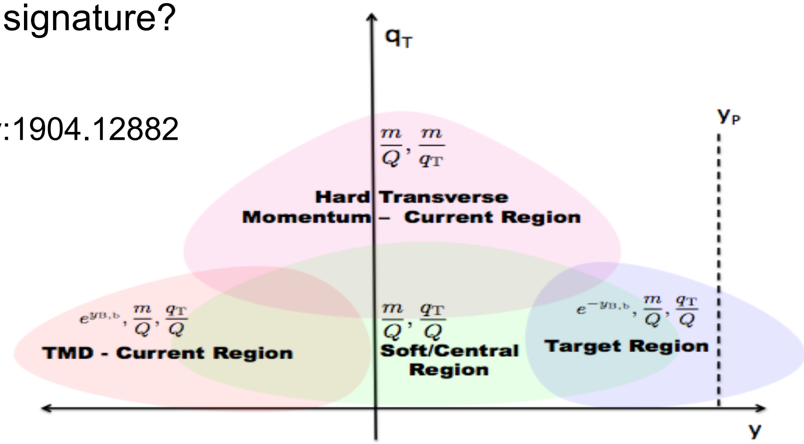
1. **Semi-exclusive processes: VM production (**Andrei Afanasev**)**
2. **Understanding the scale dependence of spin and azimuthal asymmetries**
    1. Cahn effect (Andrea Moretti)
    2. SSAs (Stefan Diehl)
    3. Evolution studies (Harut)
3. **Opportunities with Tagged SIDIS**
    1. Theory perspective
    2. Theory perspective (Wim Cosyn?)
4. **Role of SIDIS regions (correlations between CFR/TFR/SFR..), experimental perspective**(Timothy Hayward)

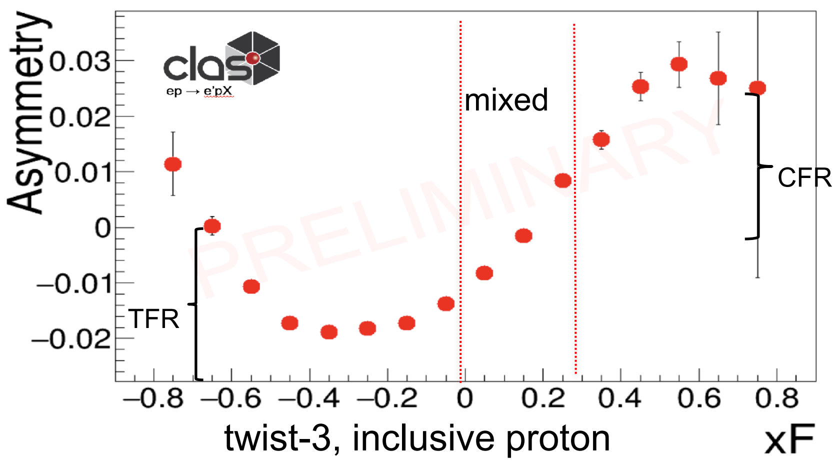


Beam SSAs: Where is the struck quark?

- Can we separate the CFR from TFR using the SSA as signature?

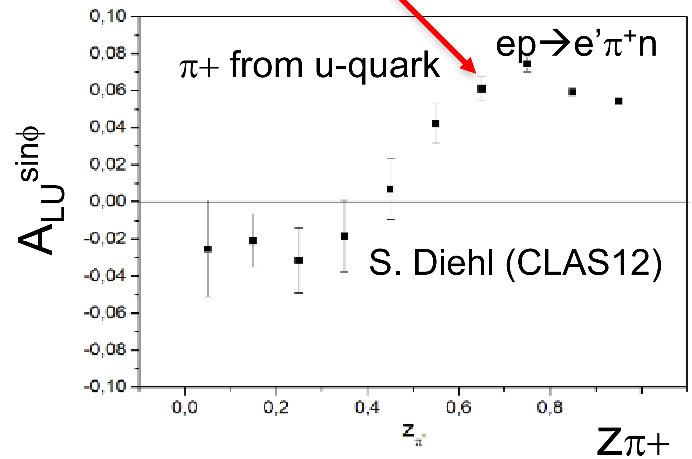
arXiv:1904.12882

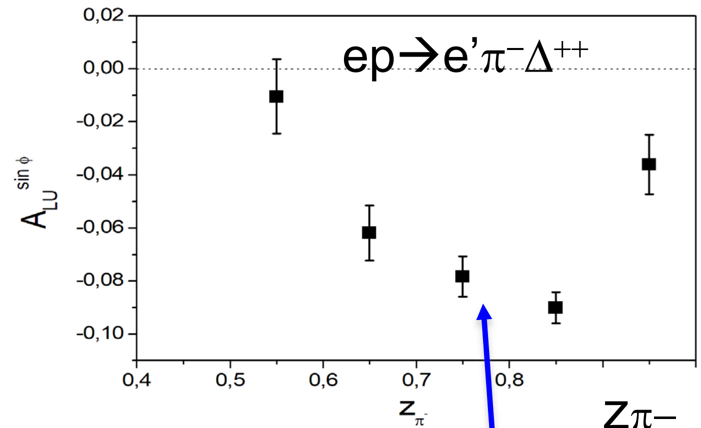




Negative sign of the SSA (plateau) defines the TFR dominance

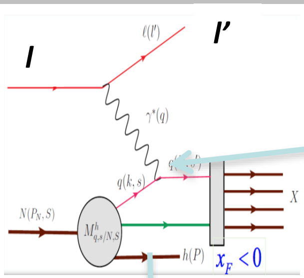
Polarized u-quark, dominates
→ SSA positive





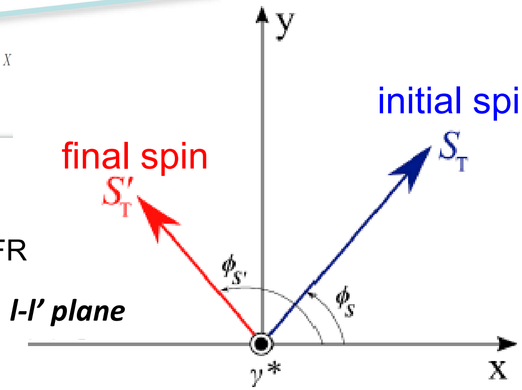
Polarized d-quark, is hard to locate, and one obvious process where we can guarantee it was hit, is the production of Δ++ (negative SSA)

Hadron production in TFR



opposite modulations in CFR and TFR

main difference between CFR and TFR → scattering



$$\phi_{s'} = \pi - \phi_s$$

Collins SSAs, sin(ϕ+ϕ$_S$),sin2ϕ

spin-flip causing Collins contributions in CFR

X. Tong (ECT* 2022)

$$F_{UU}^{\cos(\phi_h)} = -2\sum_a e_a^2\, x_B^2 \frac{|k_\perp|}{Q} u(x_B,\xi,k_\perp),$$

$$F_{LU}^{\sin(\phi_h)} = 2\sum_a e_a^2\, x_B^2 \frac{|k_\perp|}{Q} l(x_B,\xi,k_\perp)$$

$$F_{LL}^{\cos(\phi_h)} = -2\sum_a e_a^2\, x_B^2 \frac{|k_\perp|}{Q} l_L(x_B,\xi,k_\perp)$$

$$F_{UL}^{\sin(\phi_h)} = -2\sum_a e_a^2\, x_B^2 \frac{|k_\perp|}{Q} u_L(x_B,\xi,k_\perp)$$

Target fragmentation provides complementary information on proton structure and is simpler in interpretation (no Collins effect, both in leading and *subleading* contributions)

4 contributions for each in CFR!!!

- Two with unpolarized target; Two with longitudinally polarized target;

Proton polarization: x-sections

Semi-Inclusive:

Lepton helicity→ "+1" along the beam

$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{ F_{UU,T} + \varepsilon F_{UU,L} + \lambda_e \sqrt{2\varepsilon(1-\varepsilon)}\,\sin\phi_h\, F_{LU}^{\sin\phi_h}$$

$$+ S_{\|}\left[\sqrt{2\varepsilon(1+\varepsilon)}\,\sin\phi_h\, F_{UL}^{\sin\phi_h} + \varepsilon\sin(2\phi_h)\, F_{UL}^{\sin 2\phi_h}\right] + S_{\|}\lambda_e\sqrt{1-\varepsilon^2}\, F_{LL}\Big\}$$

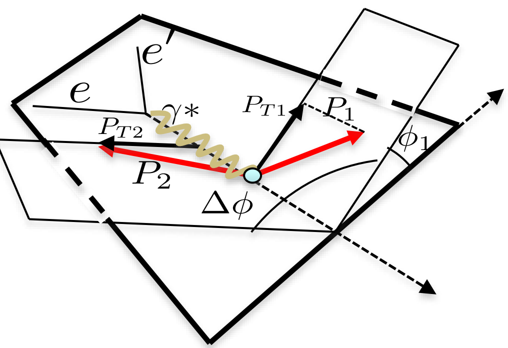
Proton helicity→ "+1" opposite to the beam

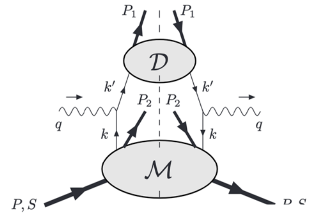
NH3 – 14 runs from latest RGC run group with beam energy 10.55 GeV used for tests, first preliminary results, to be released using pass0 RGC processing in January

Double polarized experiments allow studies of single beam-spin, single target-spin and double spin asymmetries

Correlations in back-to-back 2 hadron production

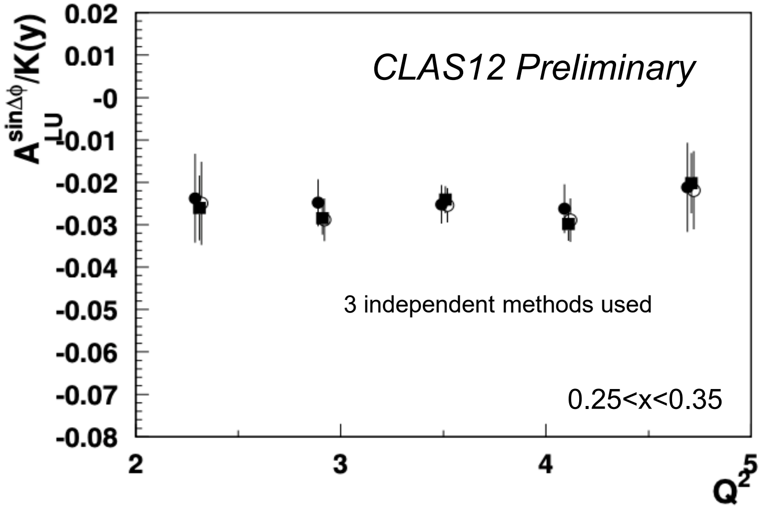
M. Anselmino, V. Barone and A. Kotzinian, Physics Letters B 713 (2012)





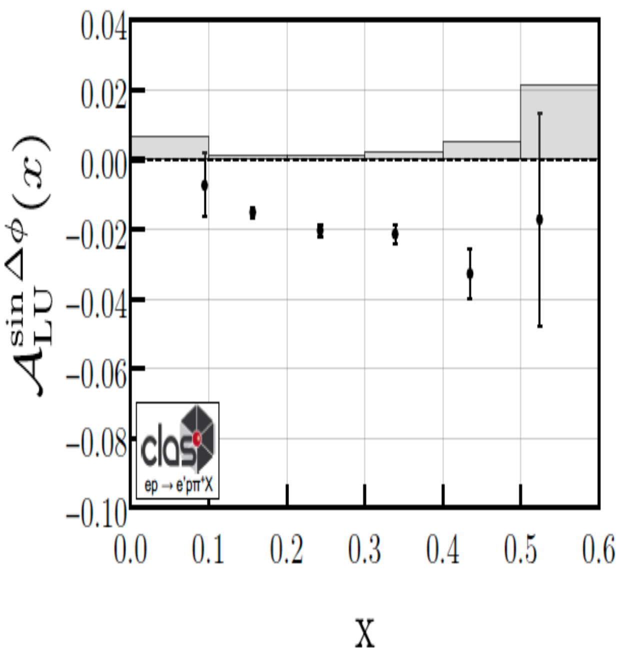
$$A_{LU} \propto \frac{\mathcal{C}[w_5\, \hat{l}_1^{\perp h} D_1]}{\mathcal{C}[\hat{u}_1 D_1]} \sin \Delta\phi$$

arXiv: 2208.05086
PRL



Twist-2 table
(Fracture Functions)

N/q	U	L	T
U	$\hat{u}_1$	$\hat{l}_1^{\perp h}$	$\hat{t}_1^h, \hat{t}_1^\perp$
L	$\hat{u}_{1L}^{\perp h}$	$\hat{l}_{1L}$	$\hat{t}_{1L}^h, \hat{t}_{1L}^\perp$
T	$\hat{u}_{1T}^h, \hat{u}_{1T}^\perp$	$\hat{l}_{1T}, \hat{l}_{1T}^\perp$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$



- SSA significant at large x, where the valence quarks (non-perturbative sea) dominate?
- Correlation asymmetry is linked to Leading Twist(LT) distributions of longitudinally polarized quarks
- First indication in large x SIDIS of a LT observable
- Correlation between the struck quark and the remnant produces correlation between hadrons (entanglement)
- Multidimensional measurements crucial for evolution studies

B2B correlations with long. Pol. Target

N/q	U	L	T
U	$\hat{u}_1$	$\hat{l}_1^{\perp h}$	$\hat{t}_1^h, \hat{t}_1^\perp$
L	$\hat{u}_{1L}^{\perp h}$	$\hat{l}_{1L}$	$\hat{t}_{1L}^h, \hat{t}_{1L}^\perp$
T	$\hat{u}_{1T}^h, \hat{u}_{1T}^\perp$	$\hat{l}_{1T}^h, \hat{l}_{1T}^\perp$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$

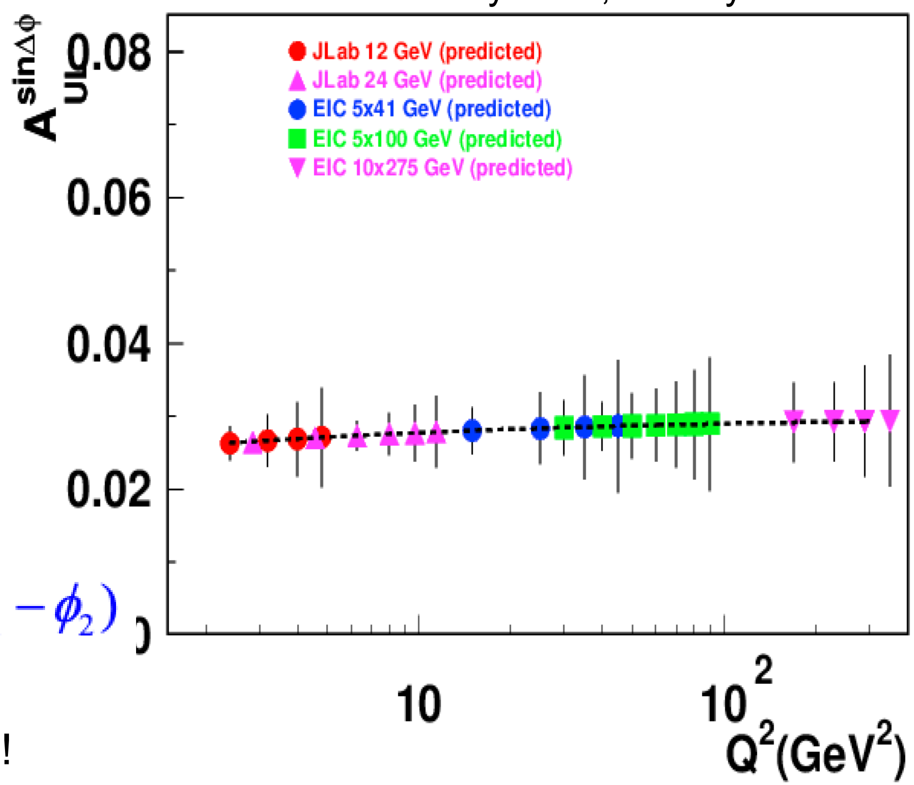
A. Kotzinian, arXiv:1107.2292

$$\sigma_{UU} = F_0^{\hat{u}\cdot D_1}$$

$$\sigma_{UL} = -\frac{P_{T1}P_{T2}}{m_2 m_N} F_{k1}^{\hat{u}_{1L}^{\perp h}\cdot D_1} \sin(\phi_1 - \phi_2)$$

No depolarization, like Sivers!

Lumi: JLab 10^{35}, EIC4x51/5x100/10x275 0.044,0.6,1x10^{34})
y>0.05,100 days



CLAS12 proposals

NH3/ND3
E12-09-009

E12-07-107
E12-09-007A

^{3}He
C12-20-002

^{7}LiD

E12-14-001

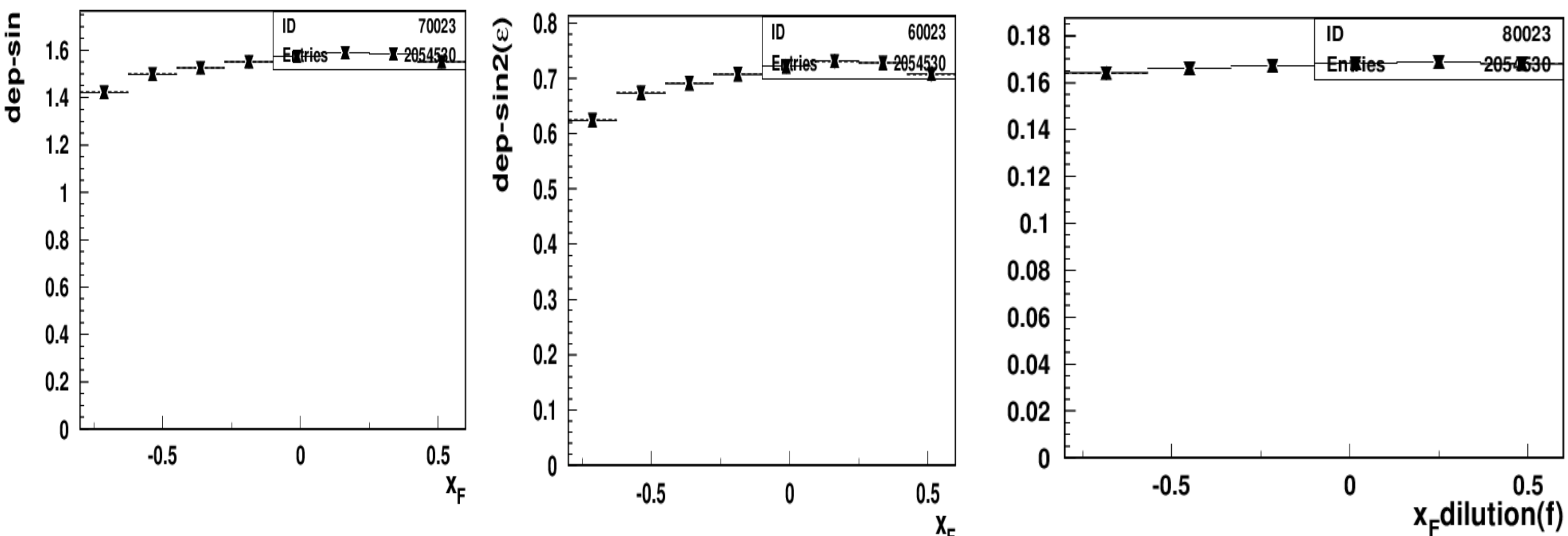
- Target SSA can be measured in the full Q^2 range, combining different facilities
- Advantages: Higher Lumi for JLab, less suppression at high Q^2 for EIC
- JLab24 will be crucial to bridge the studies of FFs between JLab12 and EIC in the valence region

Proton polarization: Double spin asymmetries

Semi-Inclusive:

$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Bigg\{ F_{UU,T}+\varepsilon F_{UU,L} + \lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{LU}^{\sin\phi_h}$$

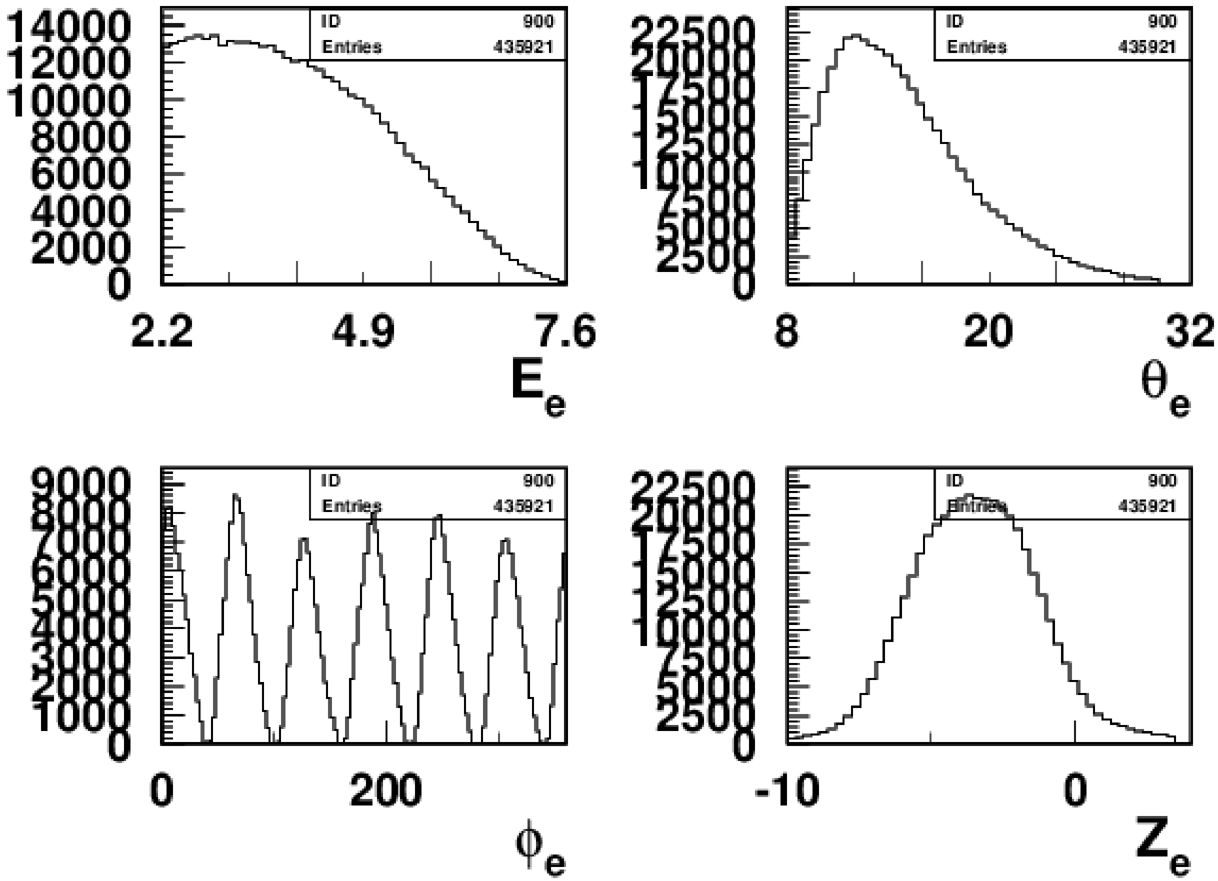
$$+ S_\parallel\left[\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_h\,F_{UL}^{\sin\phi_h} + \varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\right] + S_\parallel\lambda_e\,\sqrt{1-\varepsilon^2}\,F_{LL}\Bigg\}$$



The sinϕ modulation is enhanced compared to al other by a factor of ~2

RGC NH3: ep→e'pX

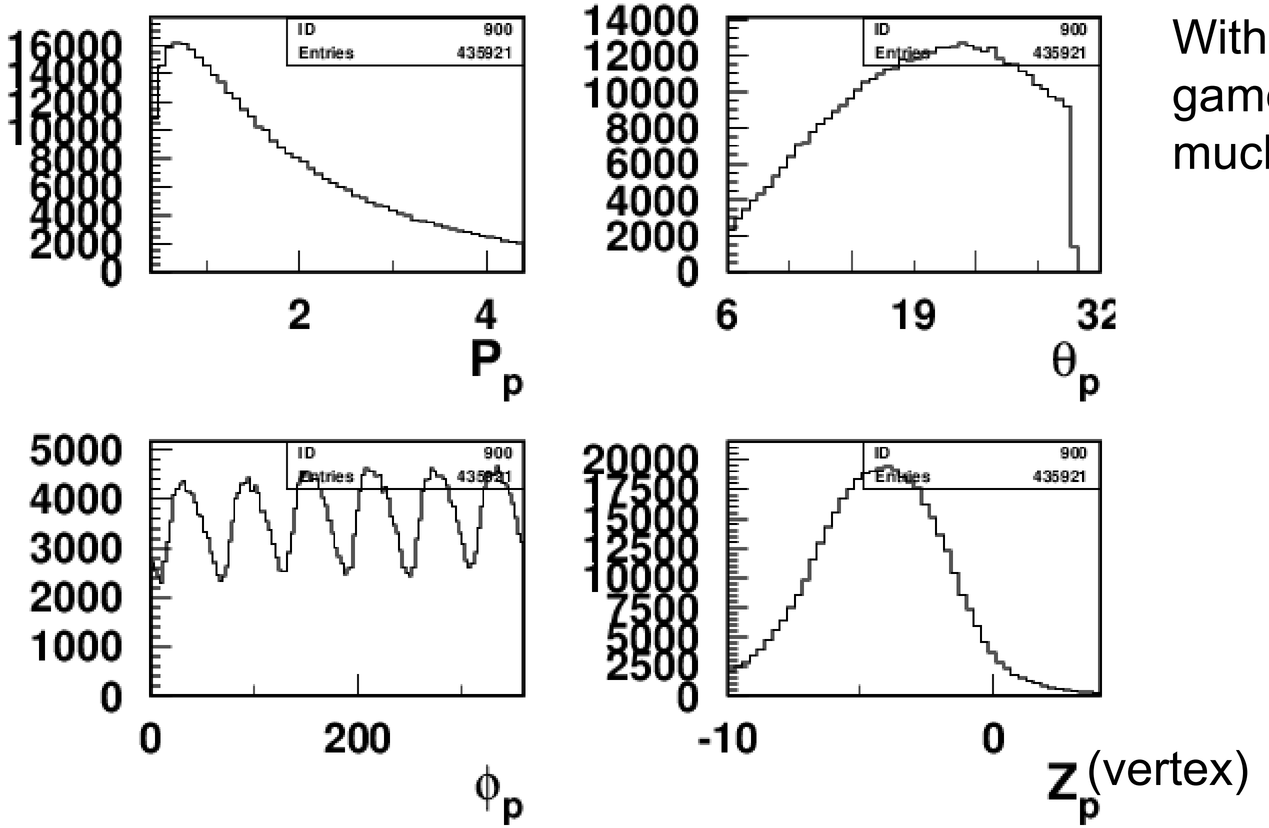
Kinematical distributions in epX: electrons



Cuts on electrons: E>2.6, W>2, Q2>1.0, remove edges in phi

RGC NH3: ep→e'pX

Kinematical distributions in epX: protons

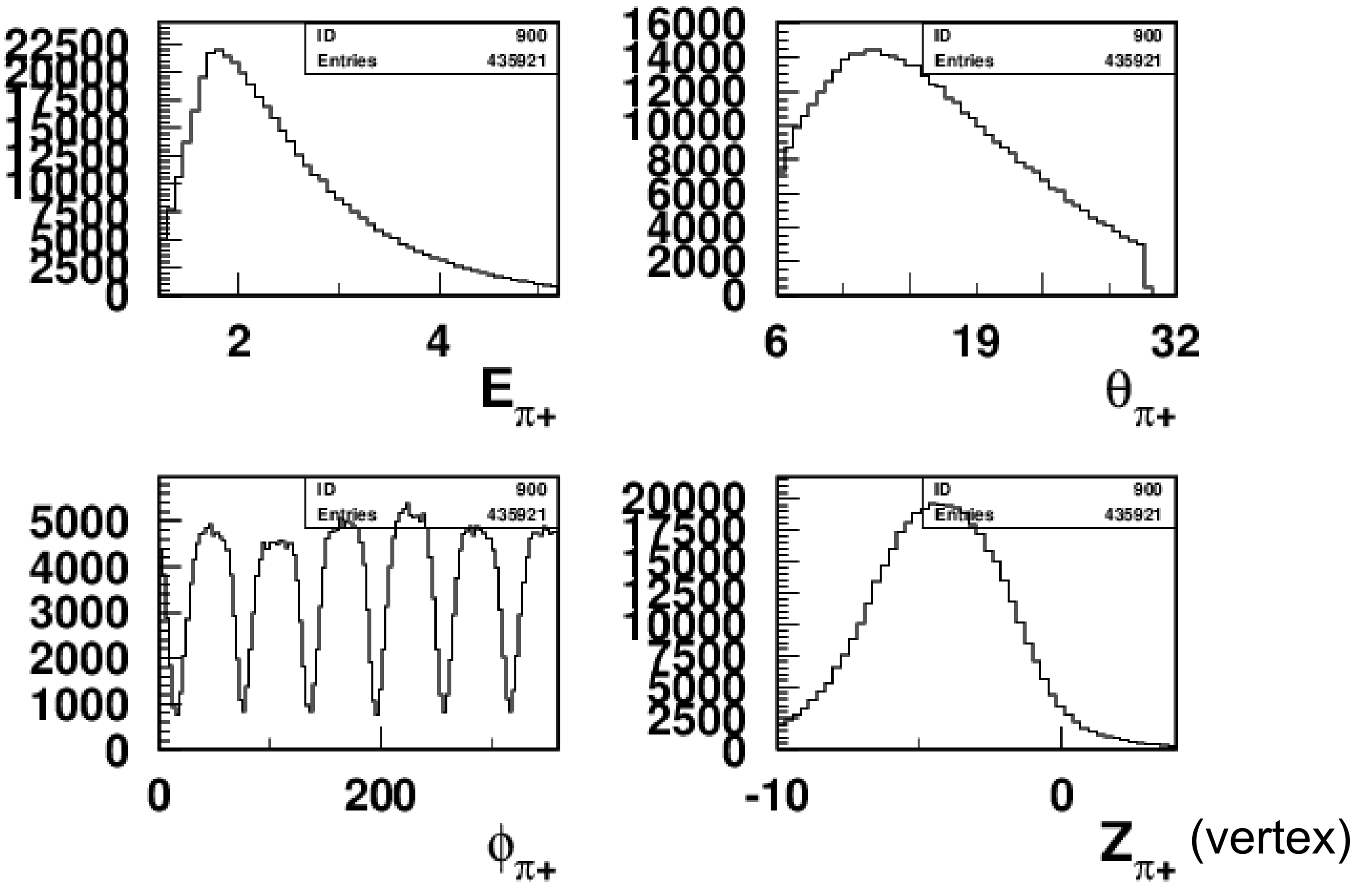


With CVT in the game will have much more

Cuts on electrons: P>0.5,ID=2212, only FD,|chi2|<5, |ΔVz|<7

RGC NH3: ep→e'pπ+X

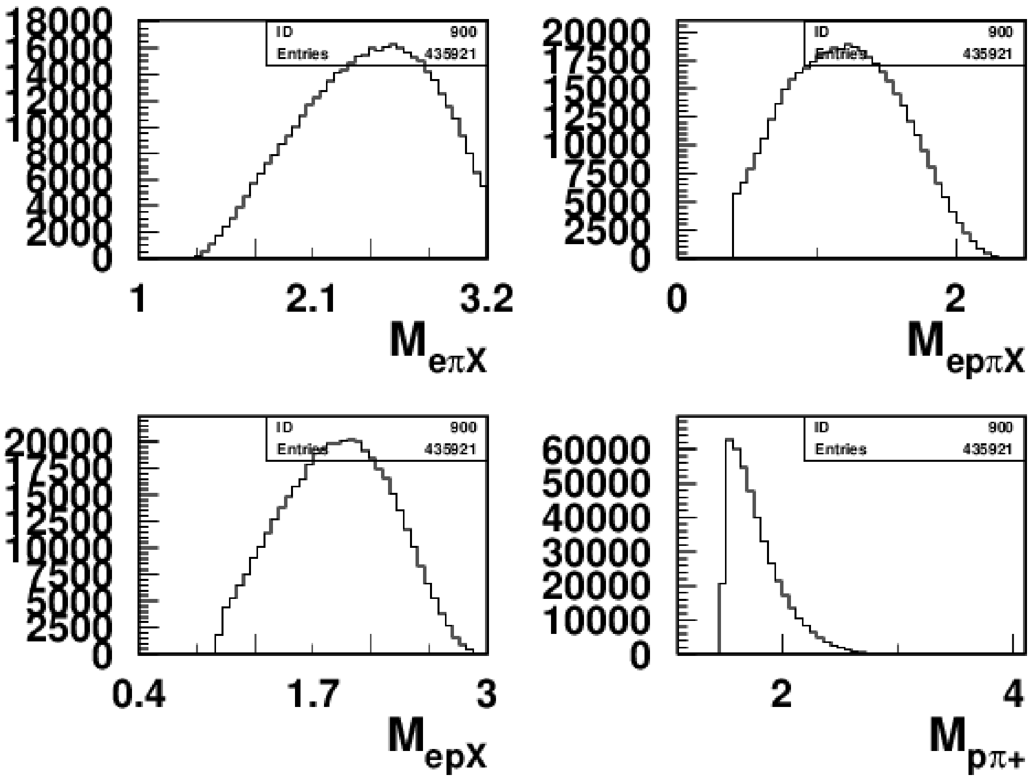
Kinematical distributions in epπX: pions



Cuts on electrons: P>1.2,ID=211, only FD,|chi2|<5, |ΔVz|<7

RGC NH3: ep→e'pπ+X

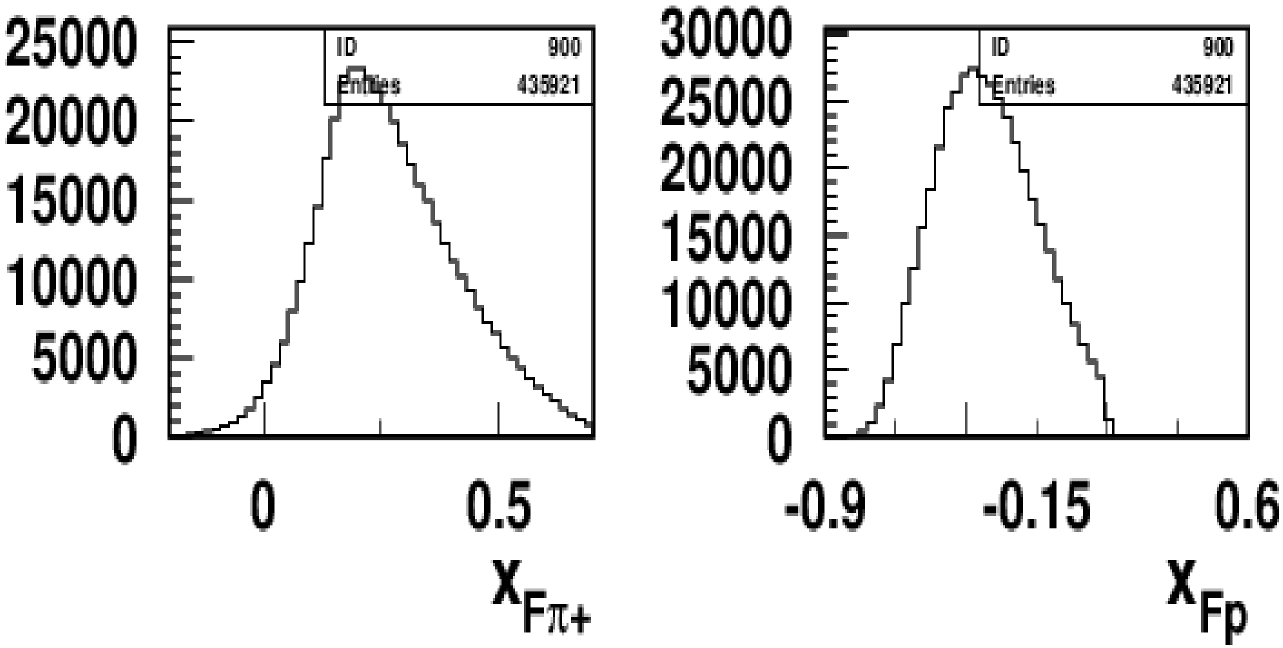
Kinematical distributions in epπX: missing masses

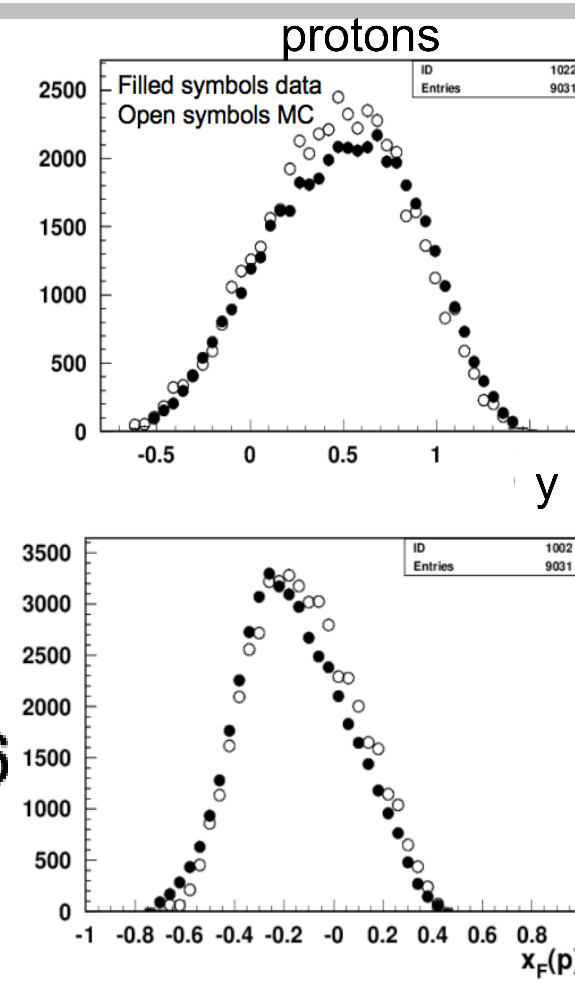


So far using cuts on missing masses to exclude exclusive states
Missing mass dependences will be extracted to understand the origin

RGC NH3: ep→e'pπ+X

Kinematical distributions in epπX: x_F-distributions

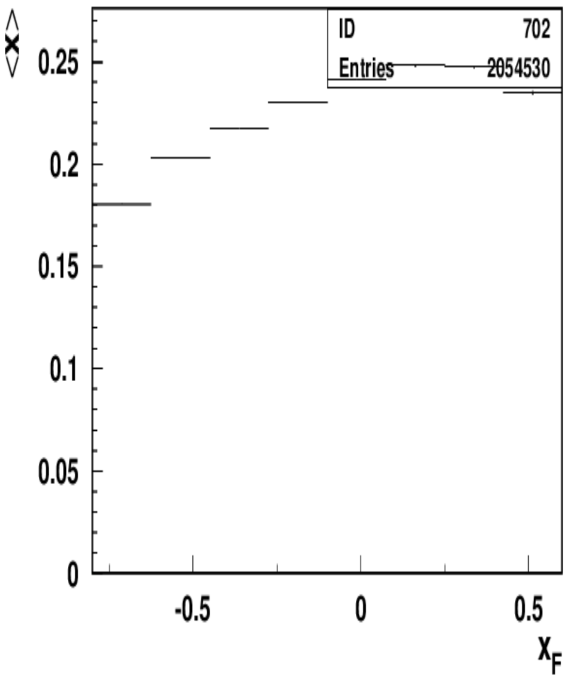


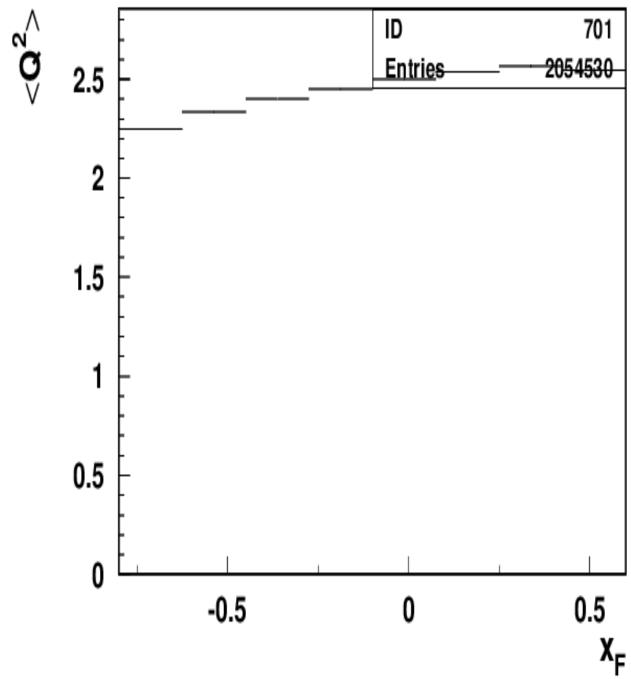


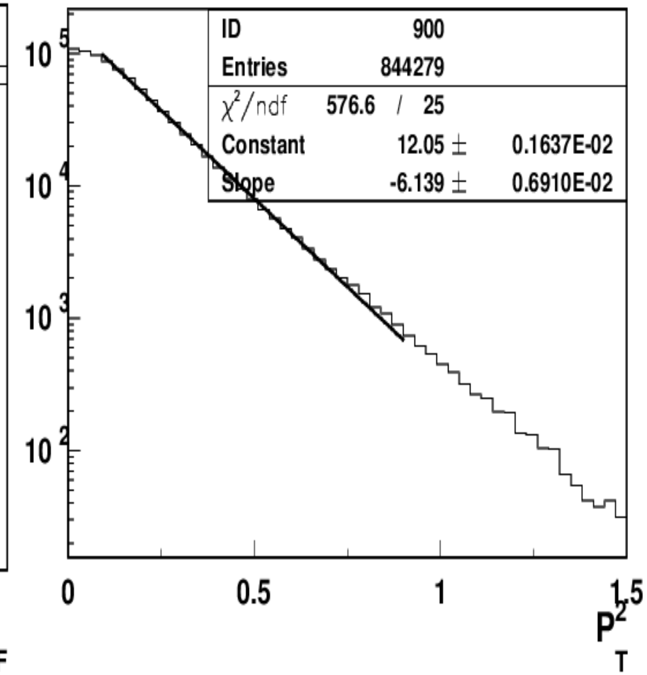
Protons in the negative hemisphere (TFR) pions in the positive (CFR)
Distributions in xF and rapidity (y) in good agreement with MC

RGC NH3: ep→e'pX

Kinematical correlations of variables for epX





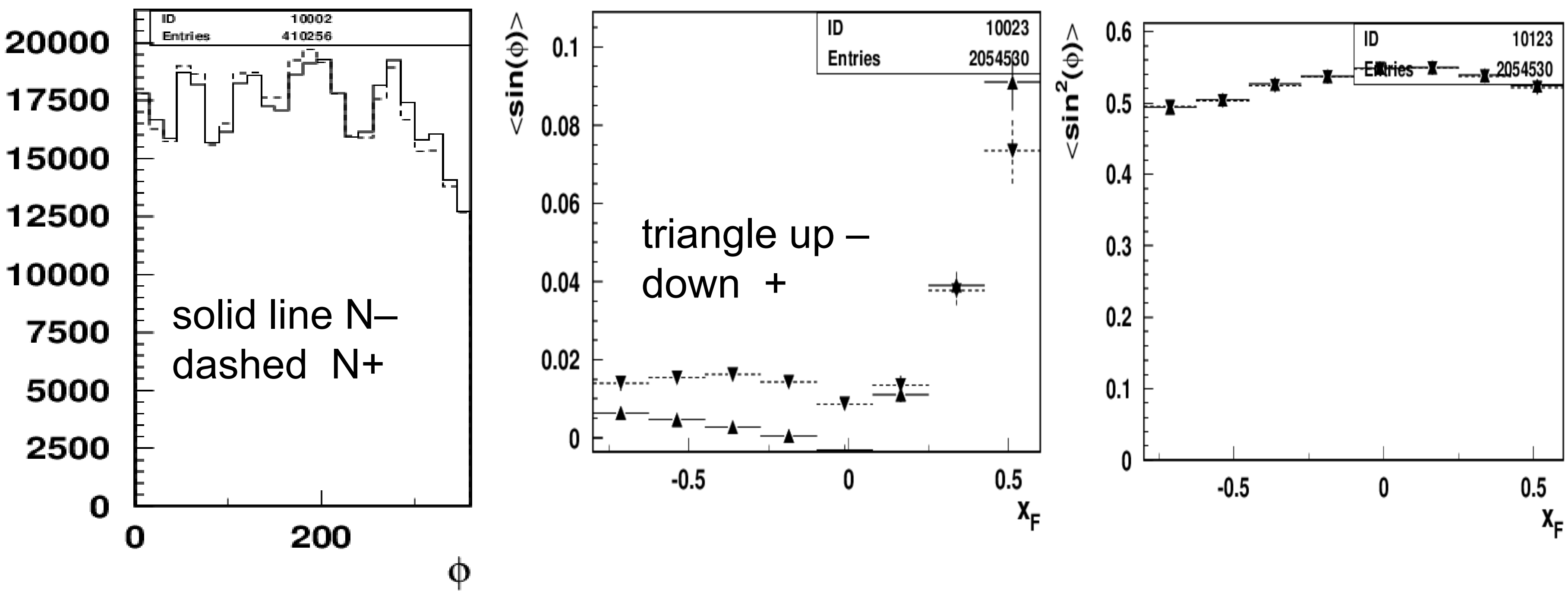


No significant variations of the electron kinematics for different bins in x_F

Proton distributions in transverse momentum close to gaussian

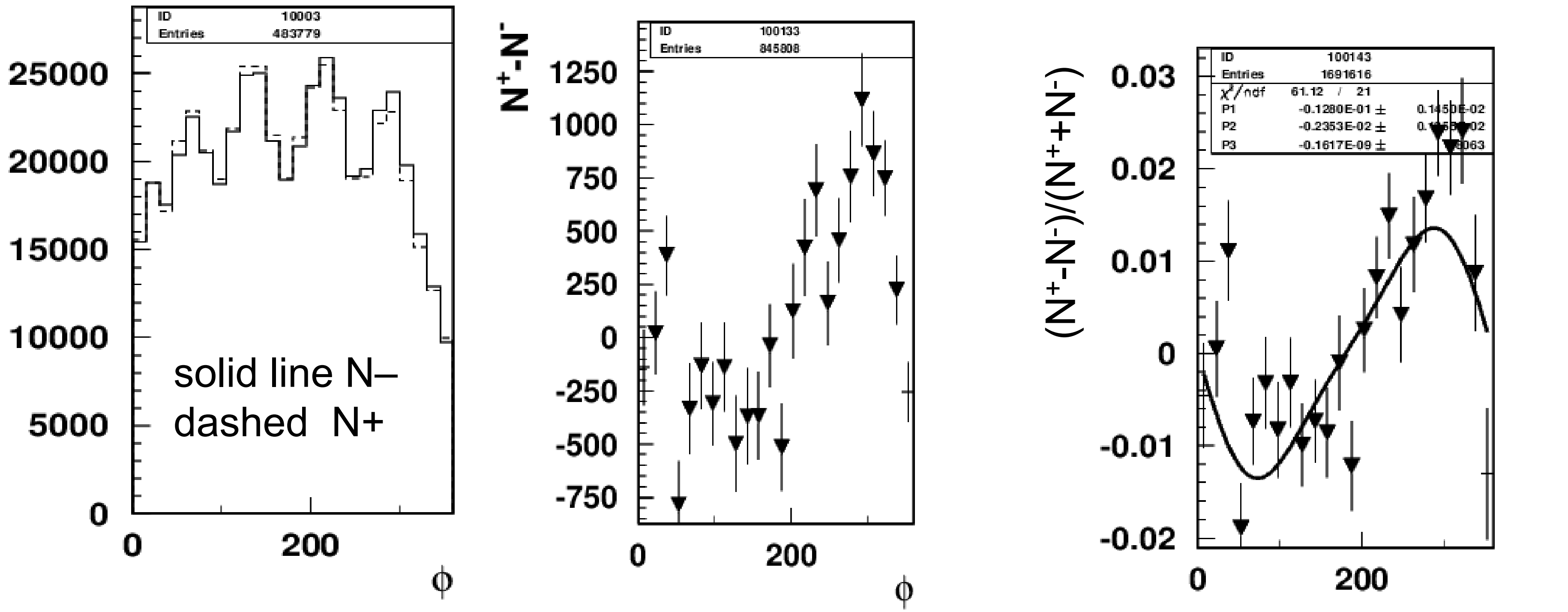
RGC NH3: azimuthal modulations ep→e'pX

$$\frac{F_{UL}}{F_{UU}} = 1/f/D(y)/P_T \times \frac{< \sin\phi >}{< sin^2\phi >}$$



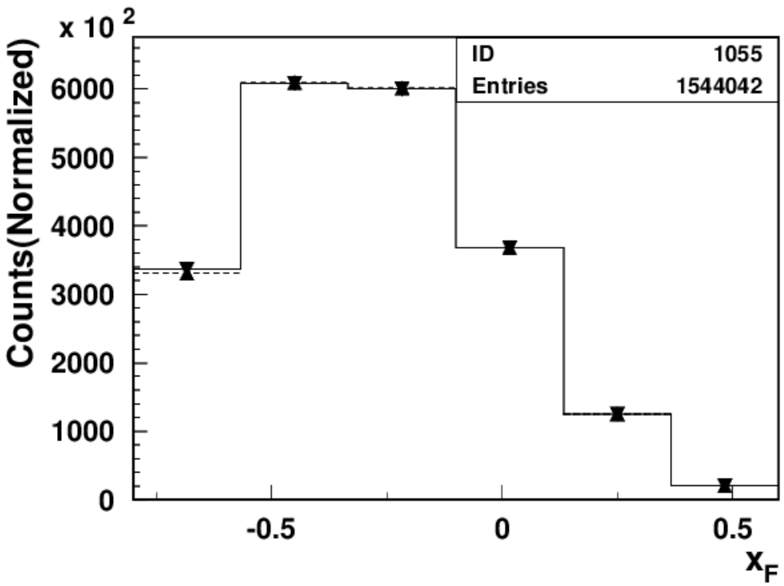
While azimuthal distributions complex, need both polarizations to define the A_{UL}

RGC NH3: azimuthal modulations ep→e’pX

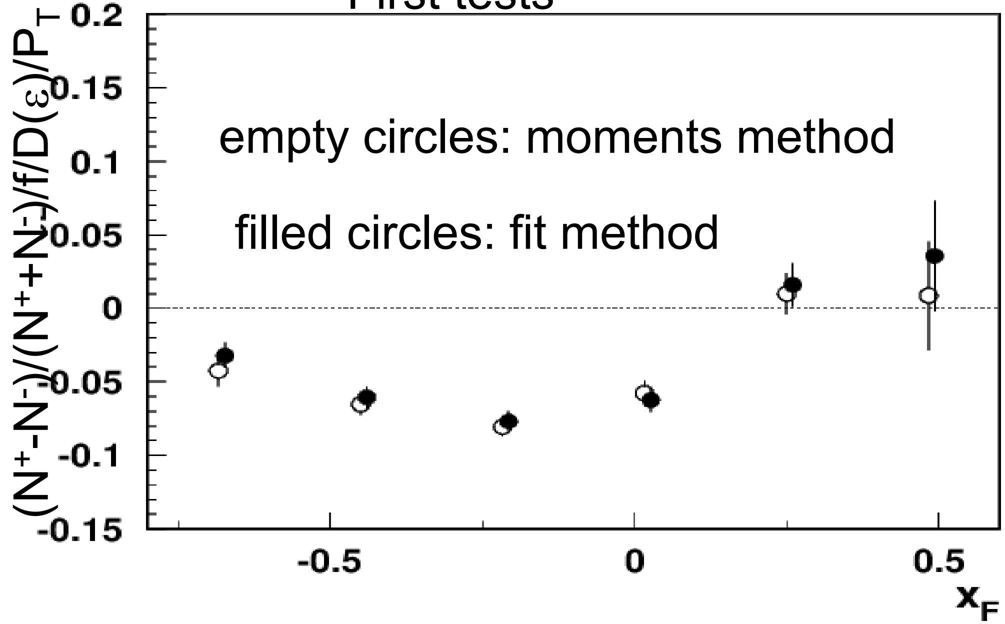


While azimuthal distributions complex, differences look like sinusoids

RGC NH3: azimuthal modulations ep→e'pX

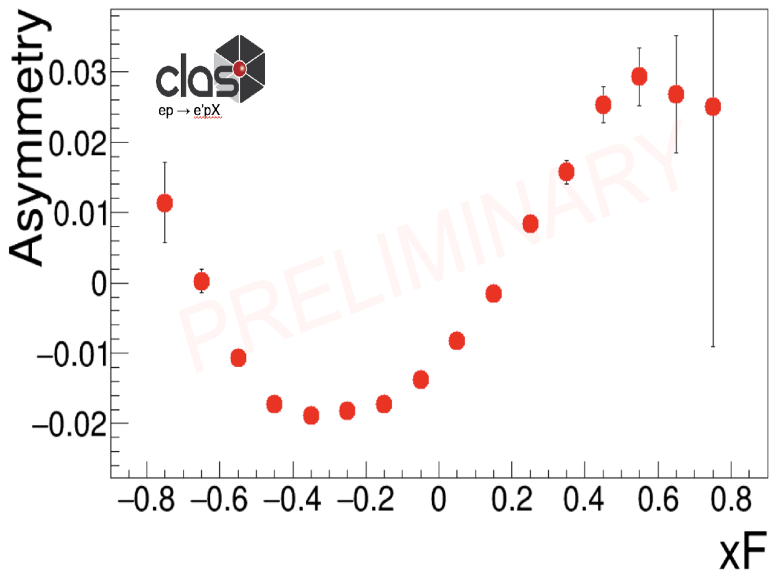


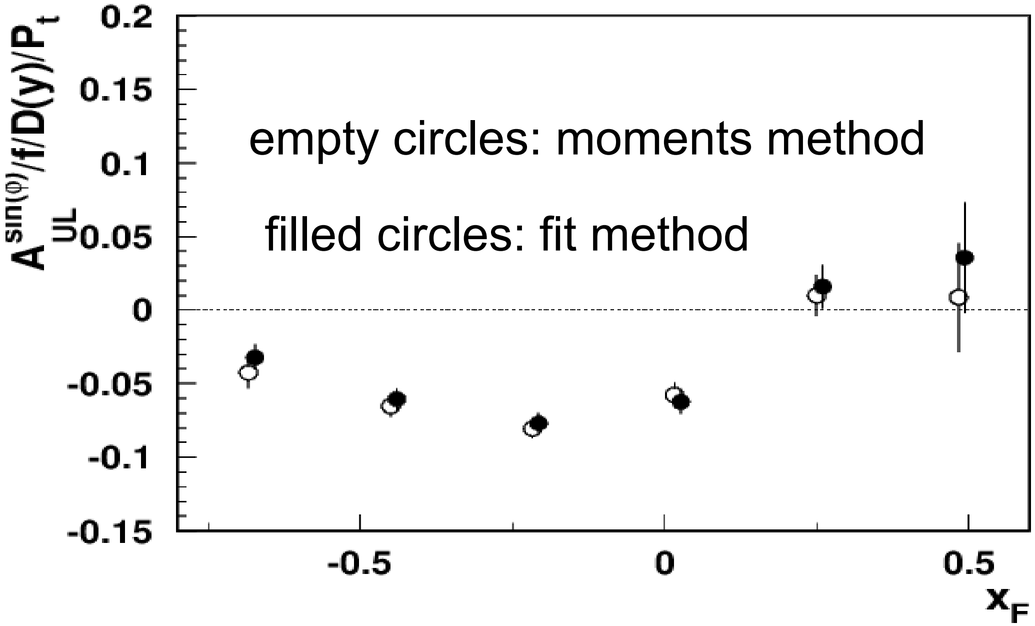
First tests



Test results: Both extraction methods agree indicating a huge SSA

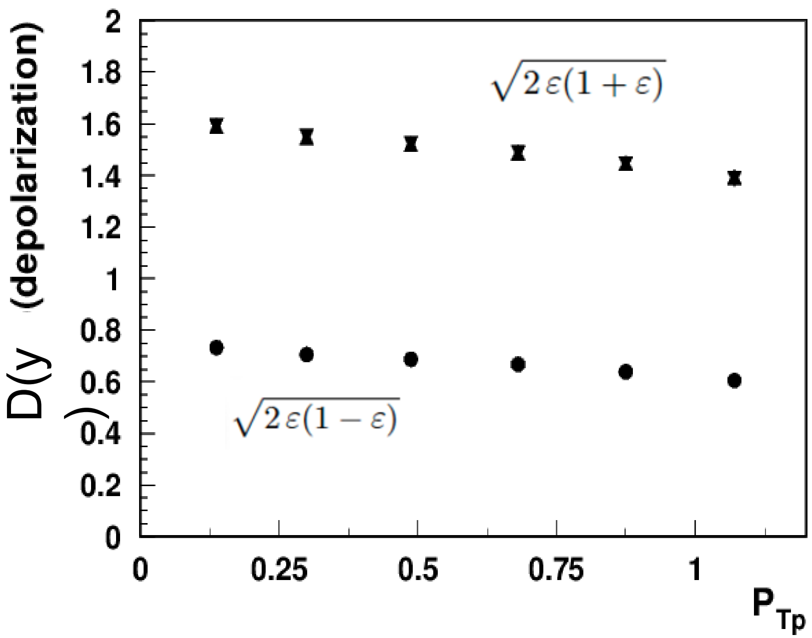
RGC NH3: azimuthal modulations ep→e'pX

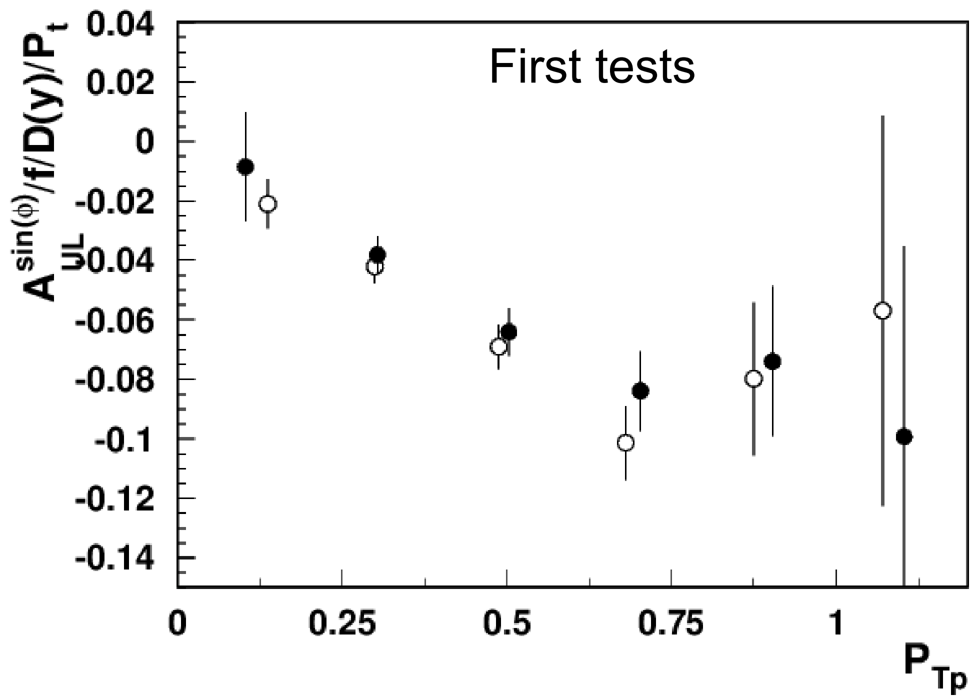




- Beam and target sinusoidal modulations most likely related to longitudinally polarized quarks
- SSAs indicate that protons up to xF~0.3 come mostly mostly from target fragmentation

RGC NH3: azimuthal modulations ep→e'pX





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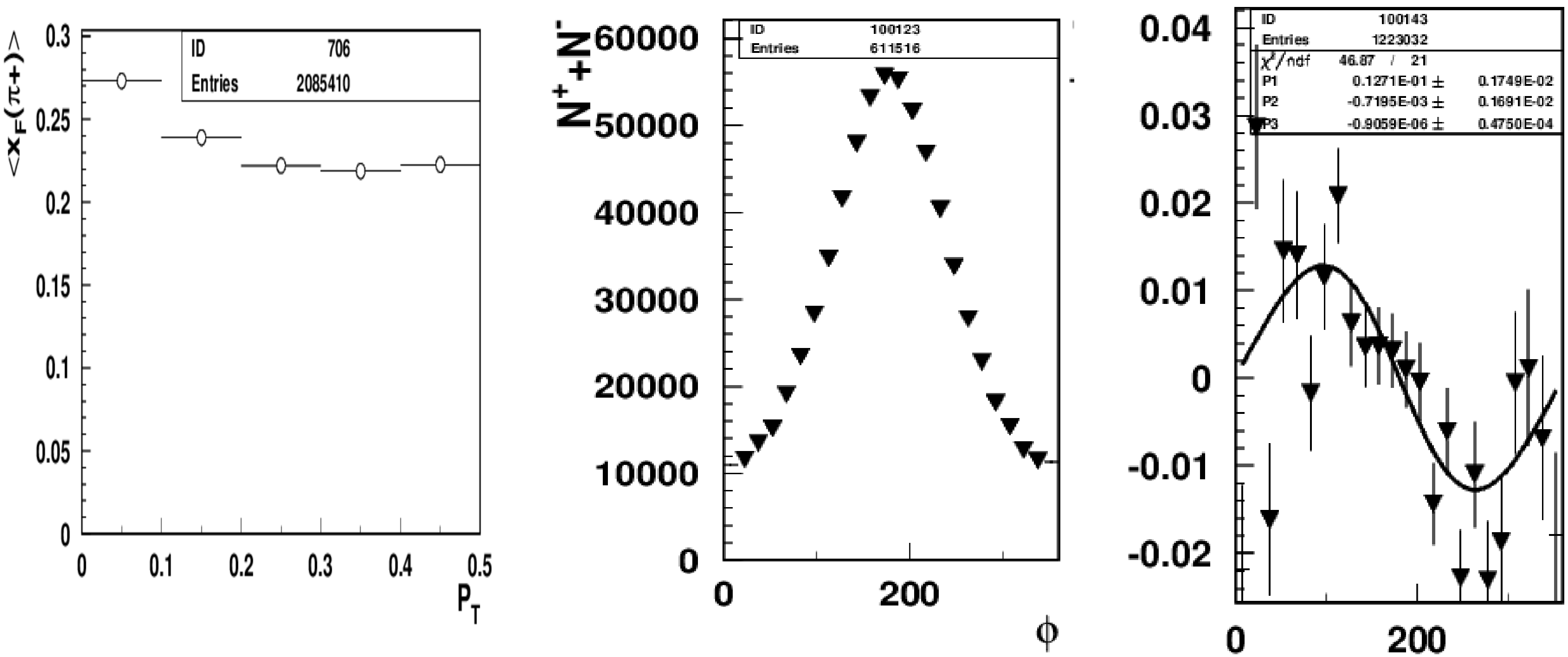
RGC NH3: azimuthal modulations ep→e'pπ+X



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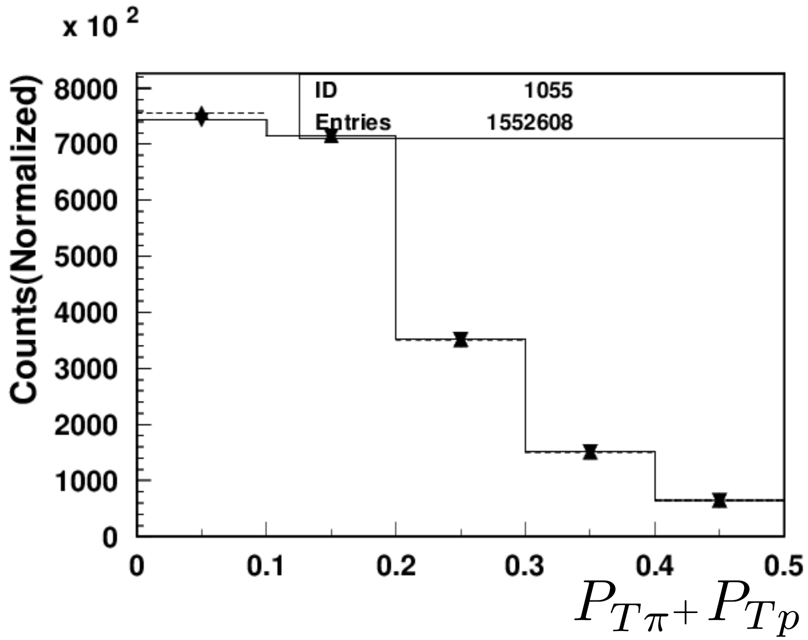
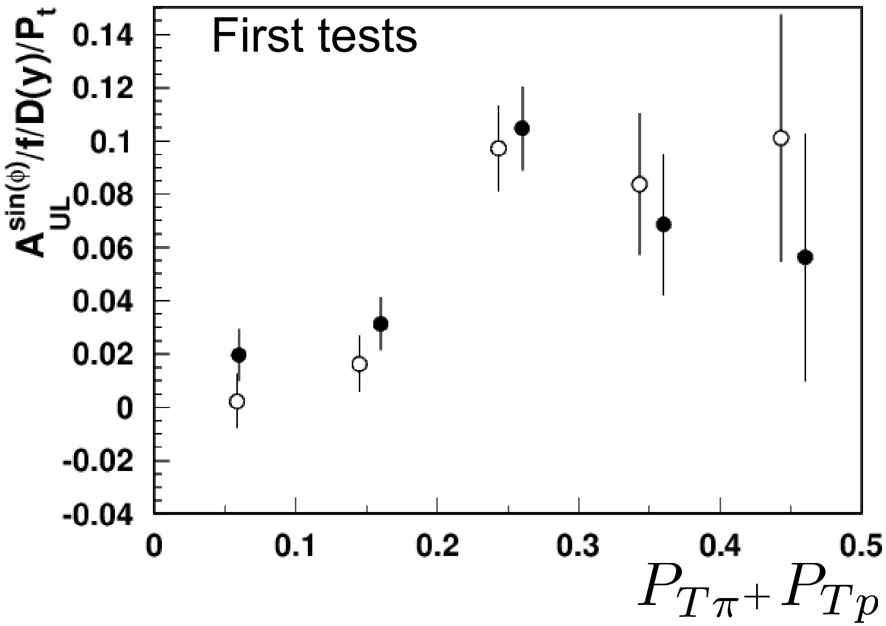
- SSAs indicate that protons up to xF~0.3 come mostly mostly from target fragmentation

RGC NH3: azimuthal modulations ep→e'pπ+X





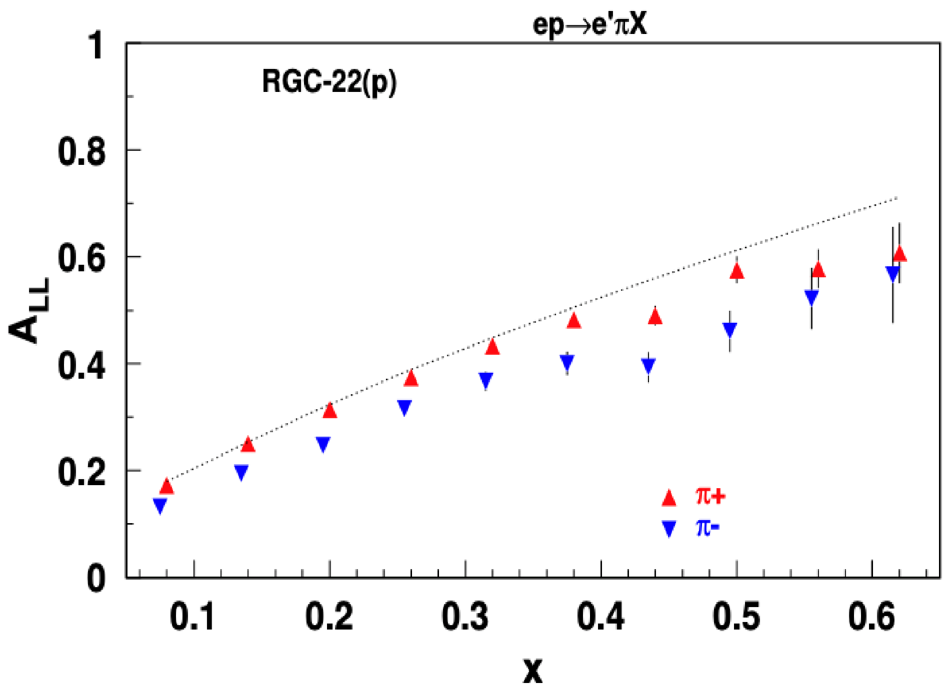
$$\sigma_{UU} = F_0^{\hat{u}\cdot D_1}$$

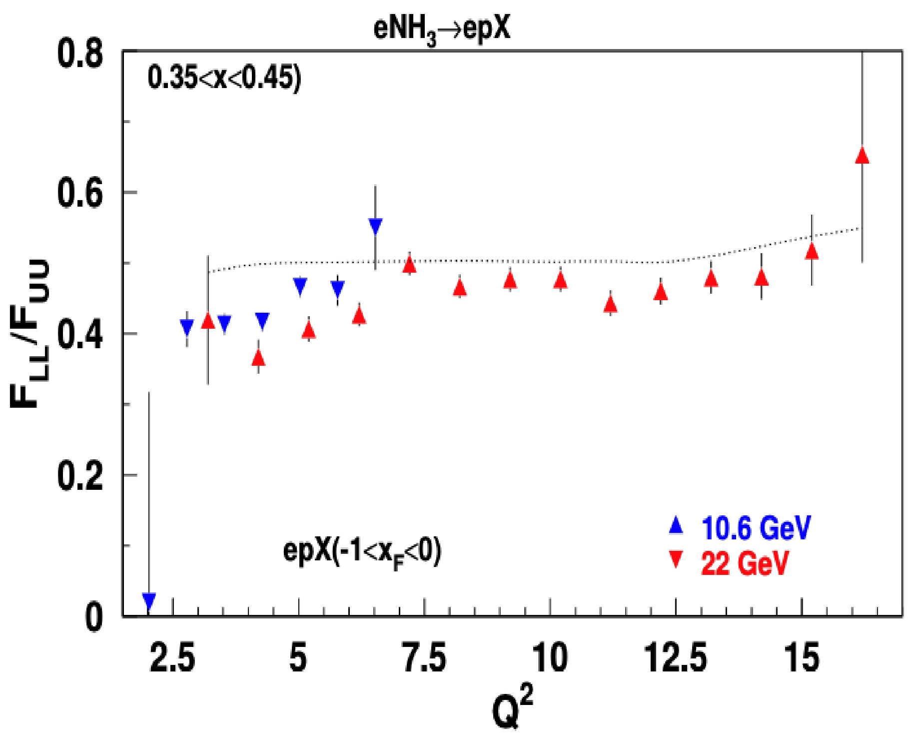
$$\sigma_{UL} = -\frac{P_{T1}P_{T2}}{m_2 m_N} F_{k1}^{\hat{u}_{1L}^{\perp h}\cdot D_1} \sin(\phi_1 - \phi_2)$$

- Significant correlations observed in b2b pion production with longitudinally polarized NH3
- Order of magnitude more statistics already available
- Q^2-dependence will be studied (like for beam SSA)

CLAS12 at 22 GeV with longitudinally polarized target

Full simulations using LUND-based generator and full CLAS12 reconstruction chain





- Studies of evolution of observed double spin asymmetries will be a critical task in validating the QCD predictions $g_1(x,k_T)$-studies CLAS12
- Asymmetries measured with input polarized and unpolarized PDFs, can be used to test the flavor decomposition capabilities
- Kinematical correlations, even for small bins relevant (multidimensional bins critical)

summary

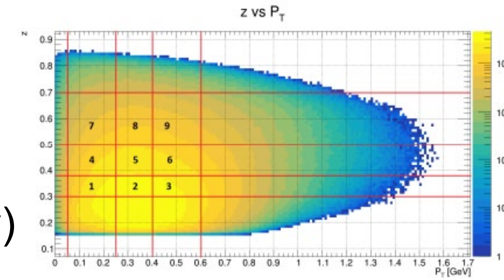
- Sinusoidal modulations of the hadronic cross sections observed with unpolarized and longitudinally polarized targets, provide direct access to correlation of orbital momentum and longitudinal polarization of quarks
- Test results indicate significant single target spin asymmetries in epX and b2b epπX SSAs from RGC longitudinally polarized target data
- SSAs can be used in separation of kinematical regions TFR/Soft/CFR
- Kinematical dependence of SSA of TFR protons with longitudinally polarized target support the origin of beam/target SSAs related to longitudinally polarized quarks.
- Full RGC data set would allow studies P_T and Q^2 dependence of single and double spin asymmetries

TODO list

- Precision measurements for dilution factors for all relevant processes will be required for more precise measurements of all observables (cross checked by MC), systematics from target polarization
- Define the role of correlations in CFR SSAs

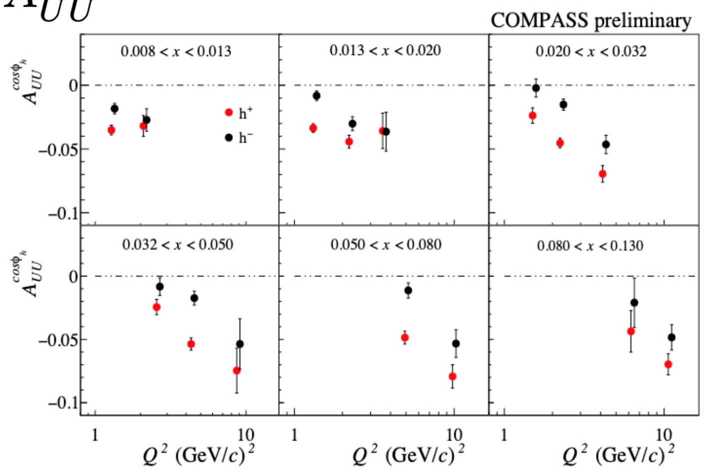
support

Attempts to understand Q^2-dependence of HT



CLAS12(preliminary)

$A_{UU}^{\cos\phi}$ COMPASS



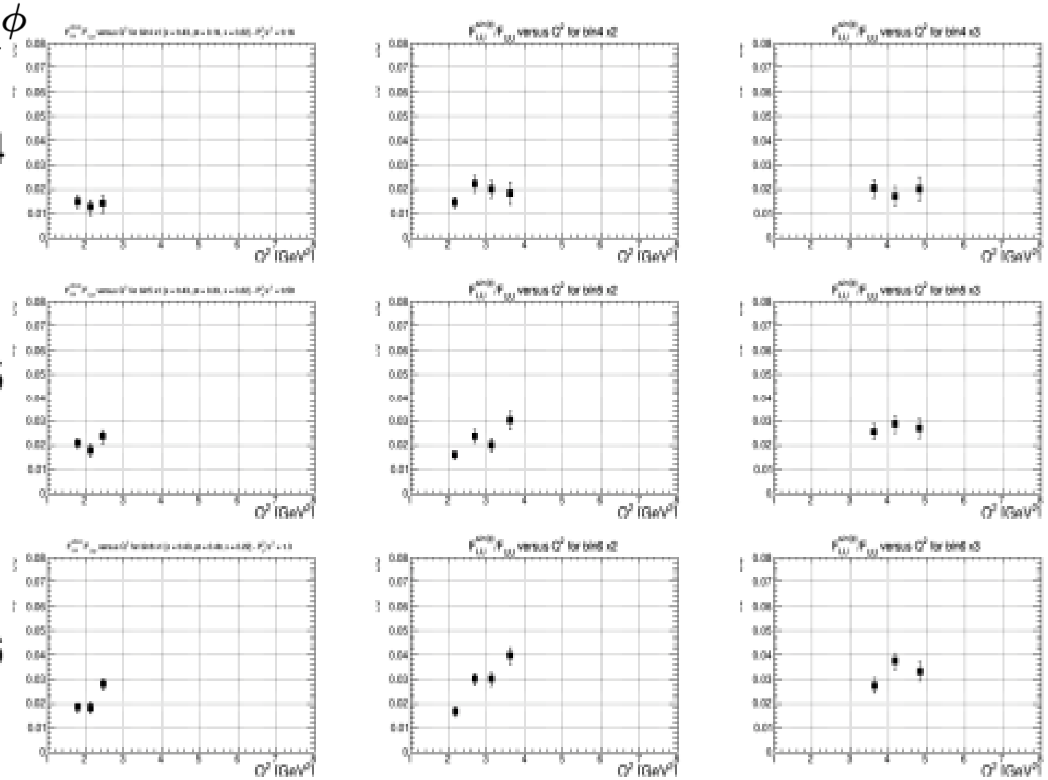
$A_{LU}^{\sin\phi}$

0.18 < x < 0.26 | 0.26 < x < 0.35 | 0.35 < x < 0.5

bin4

bin5

bin6



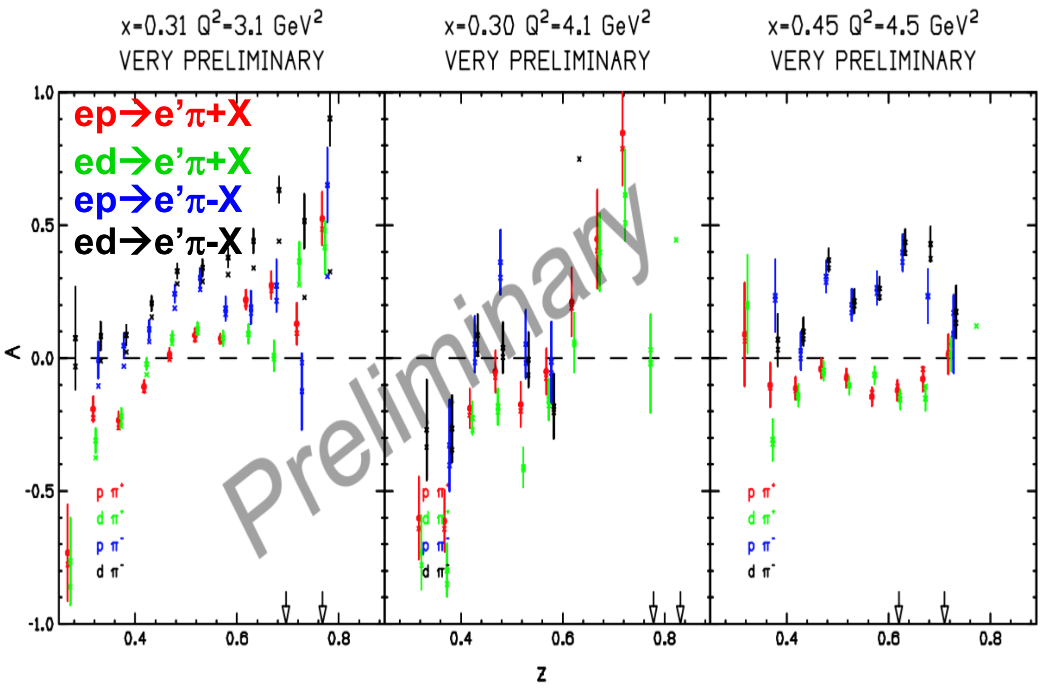
- We always measure ratio to

$$F_{UU,T} + \varepsilon F_{UU,L}$$

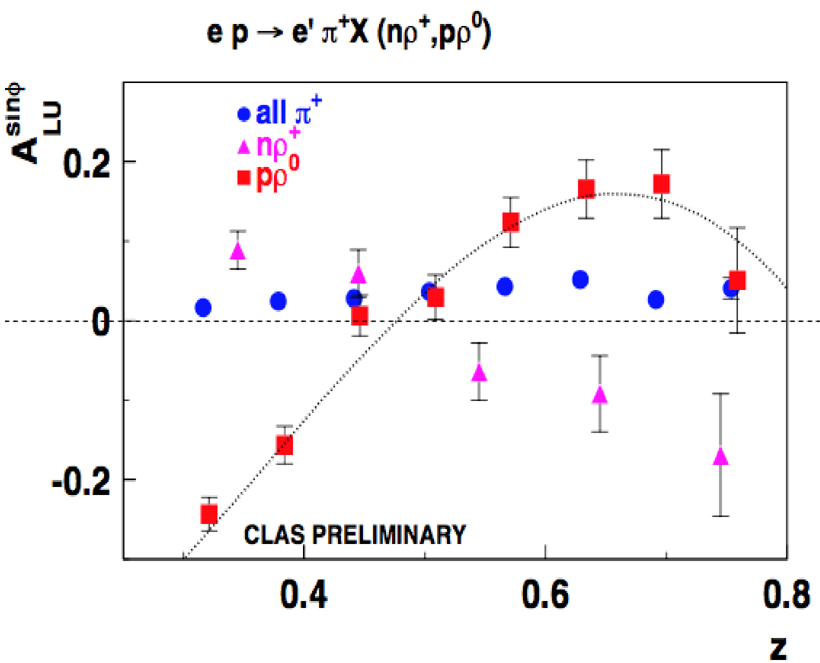
- The moments defined as a ratio to ϕ-independent x-section(to $F_{UU,T}$), are not decreasing with Q!!!
- The HT observables, don't look much like HT observables, something missing in understanding
- **Understanding of these behavior can be a key to understanding of other inconsistencies**
- Checking the Q^2 and P_T-dependences of the $F_{UU,L}$ may provide crucial input for validation

sin and cos azimuthal modulations from JLab

P. Bosted et al → Hall-C (ECT*-2022)



H.A. → Hall-B (GDH-2004)



$$y = M_0 b e^{-b p_T^2}(1 + A p_T \cos\phi)$$

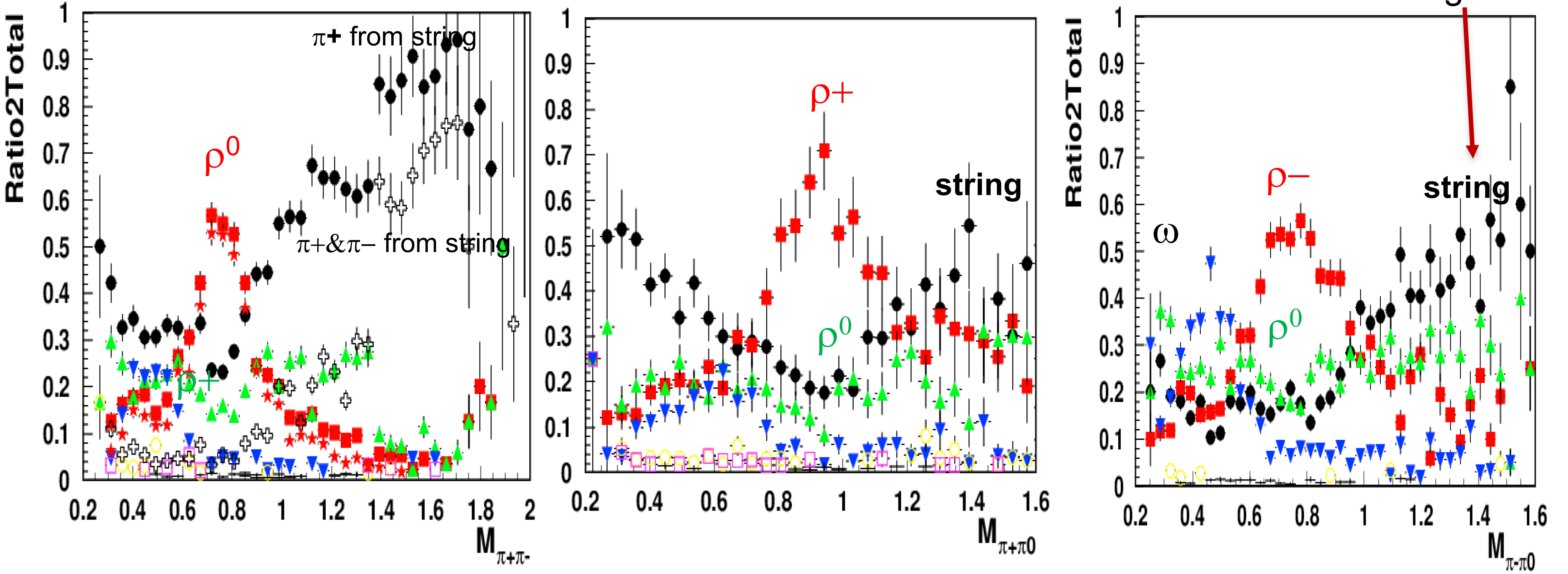
- "A"(cosine modulation) generally close to zero or positive.
- Cahn effect should give negative cosine

rho decay pions produce pions with SSA flipping the sign ~z=0.5)

- Indication of dominant rho contributions, in particular for pions at low P_T, specially for pi-,
- Understanding of the production mechanism is critical in understanding of QCD dynamics

Sources of inclusive pions: CLAS12 MC

Detection of π^0s allows also studies of $\rho^{\pm}$



Dominant fraction of 2 pion combinations come from VM decays

All measured 2 pion combinations are dominated by VM decays, indicate that all inclusive pions are dominated by VM decays at small P_Ts, and in particular at lower z!!!

Target A_{LL} in ep→e'X (RGC)

NH3 - FTout: 16983, 16990, 16992, 17001, 17015, 17019, 17076, 17088, 17092

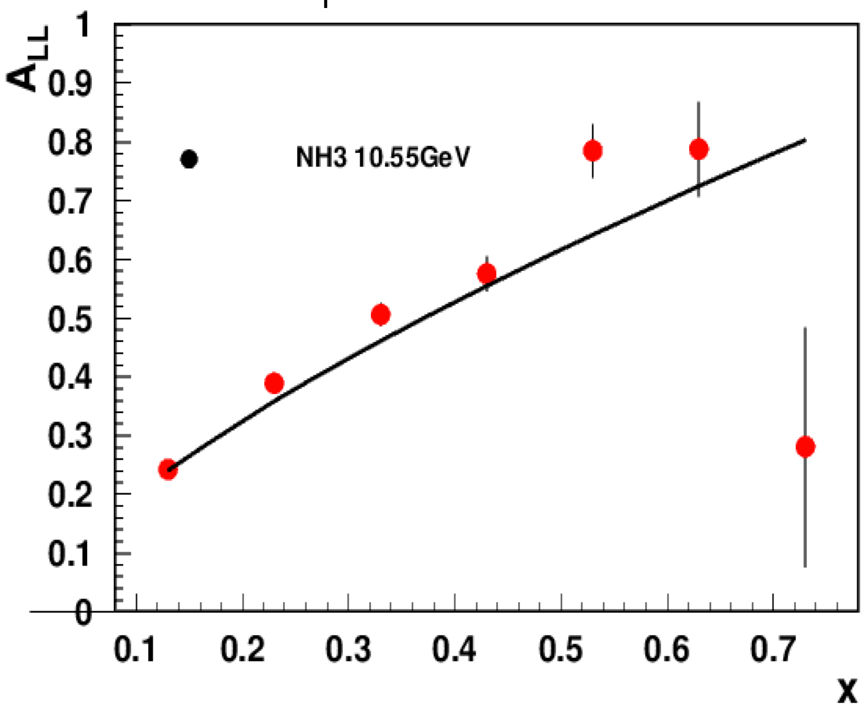
Positive

negative

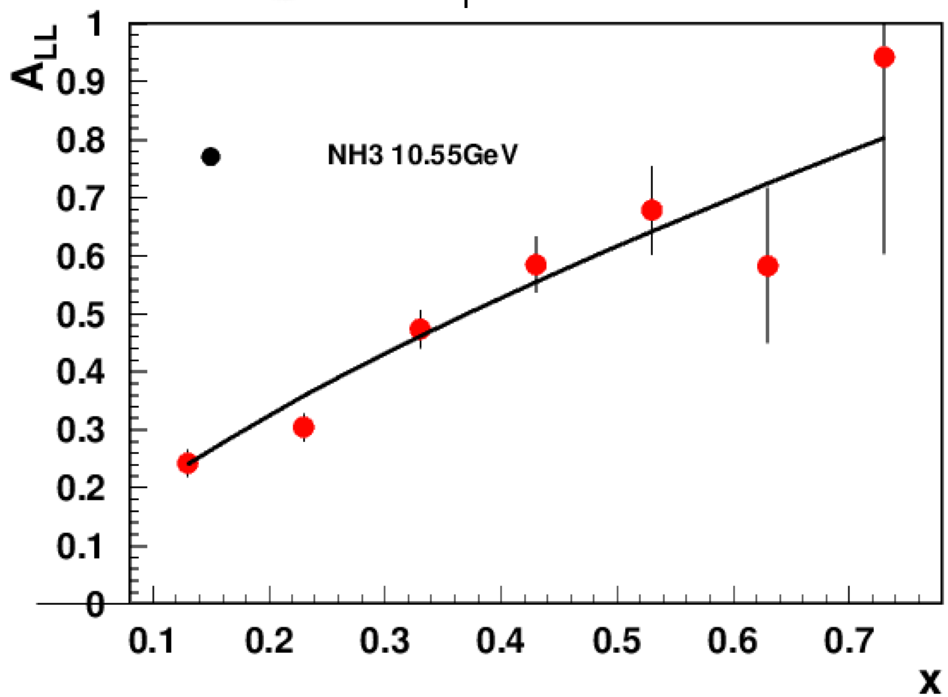
positive

$A_{LL}=A_1/D(y)/f/P_B/P_T$

$P_T=0.77$



$P_T=-0.7$

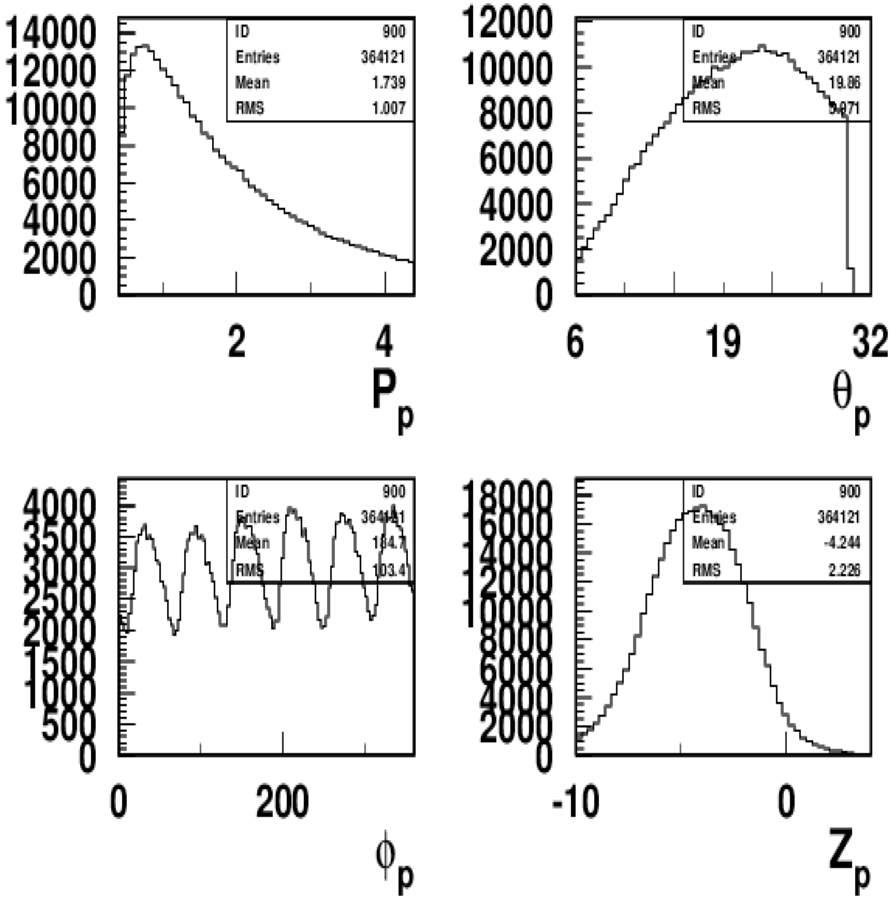


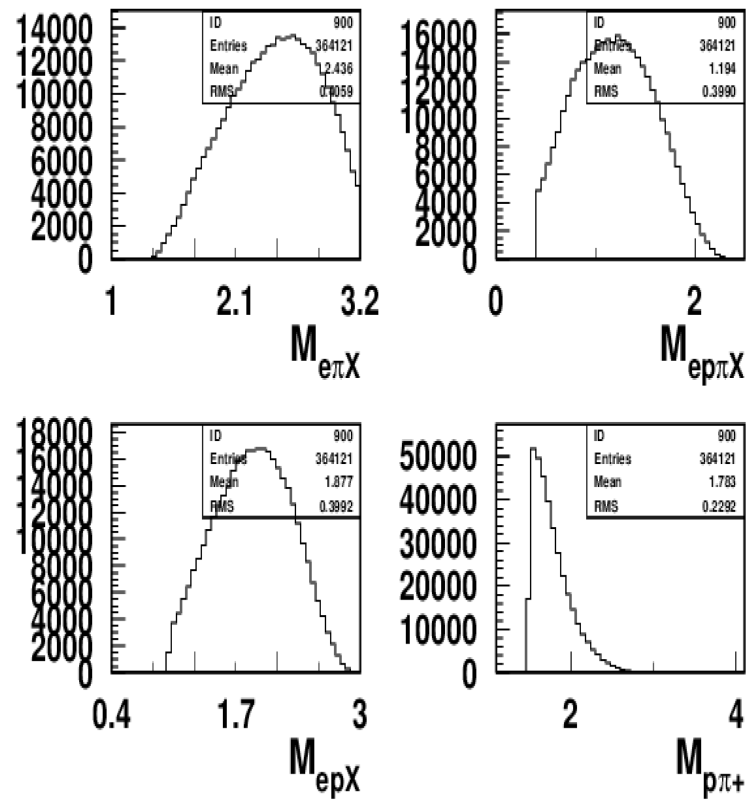
Pb=0.83, f=0.15+0.075*x (from MC), the line x^0.7

RGC NH3, Ftout: ep→e'pπ+X (RGC)

NH3 - FTout: 16983, 16990, 16992, 17001, 17015, 17019, 17076, 17088, 17092

Positive negative positive

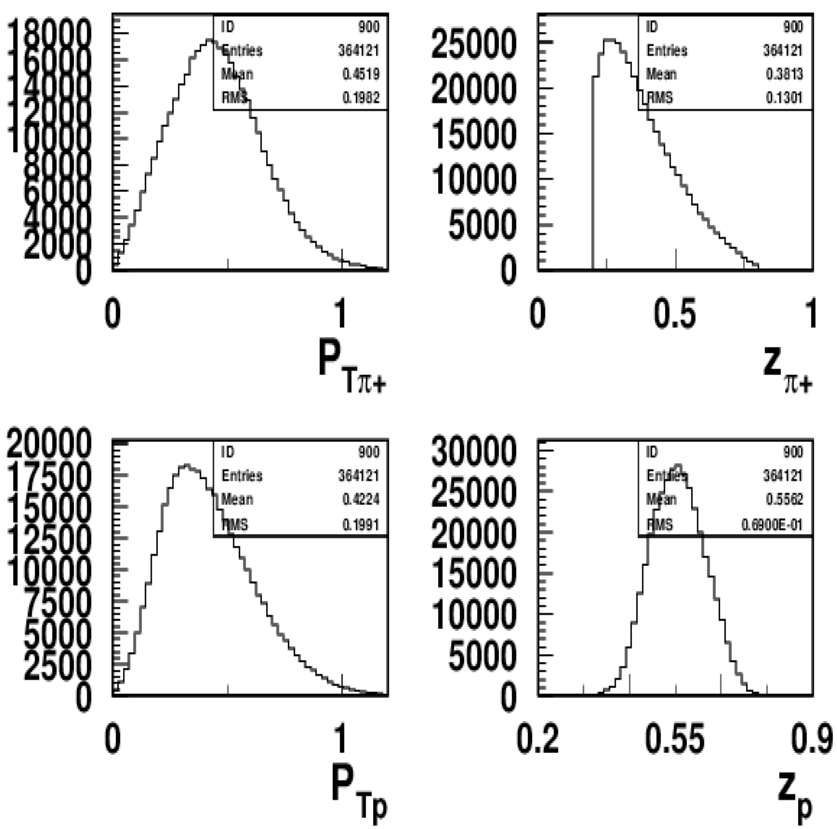


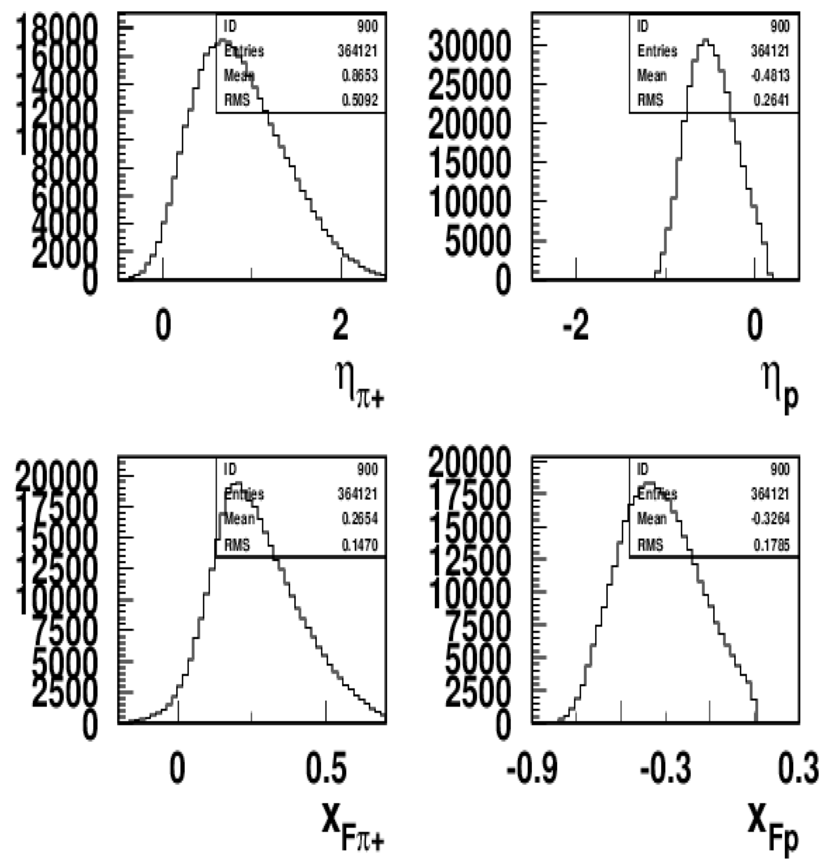


RGC NH3, Ftout: ep→e'pπ+X (RGC)

NH3 - FTout: 16983, 16990, 16992, 17001, 17015, 17019, 17076, 17088, 17092

Positive negative positive

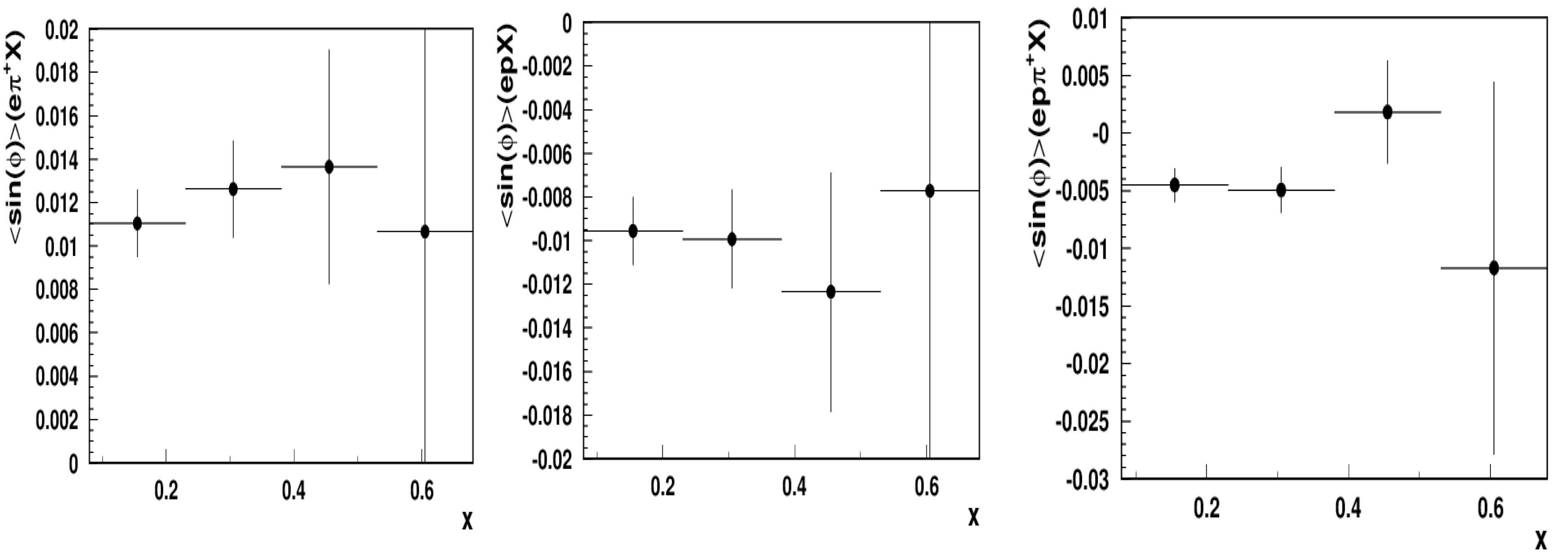




Beam SSAs in ep→e'pπ+X (RGC)

NH3 - FTout: 16983, 16990, 16992, 17001, 17015, 17019, 17076, 17088, 17092

Positive negative positive



Helicity of the lepton is correct, reproducing signs of all observed beam SSAs

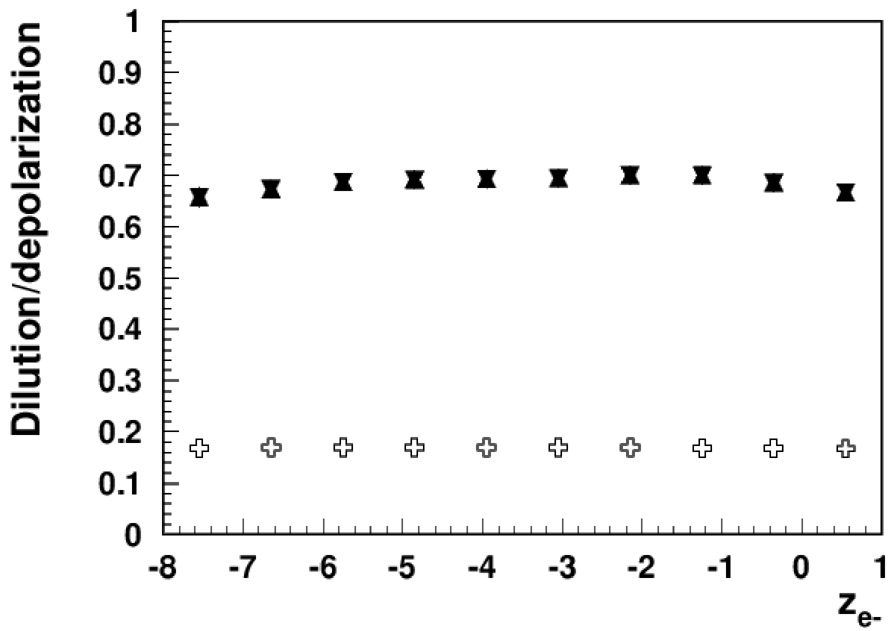
Target A_{LL} in ep→e'X (RGC)

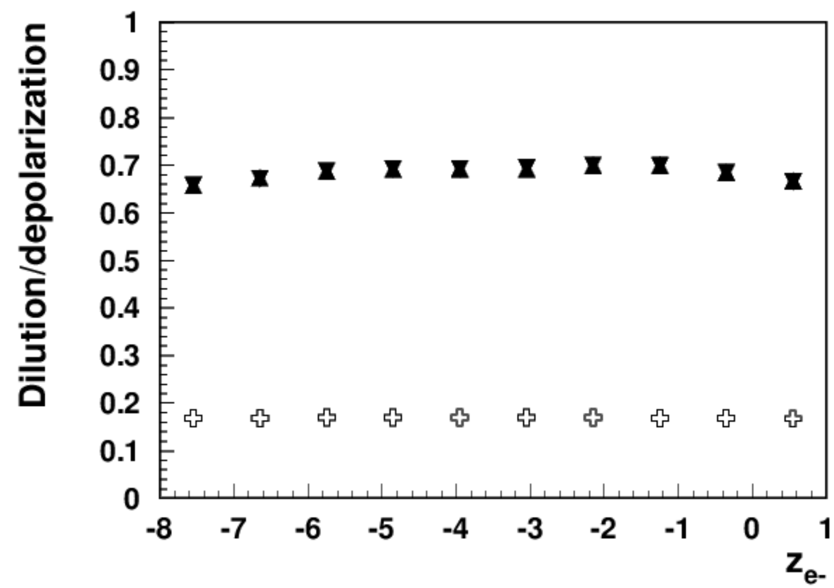
NH3 - FTout: 16983, 16990, 16992, 17001, 17015, 17019, 17076, 17088, 17092

Positive negative positive

$A_{LL}=A_1/D(y)/f/P_B/P_T$

$P_T=0.77$ $P_T=-0.7$





Pb=0.83, f=0.15+0.075*x (from MC), the line x^0.7

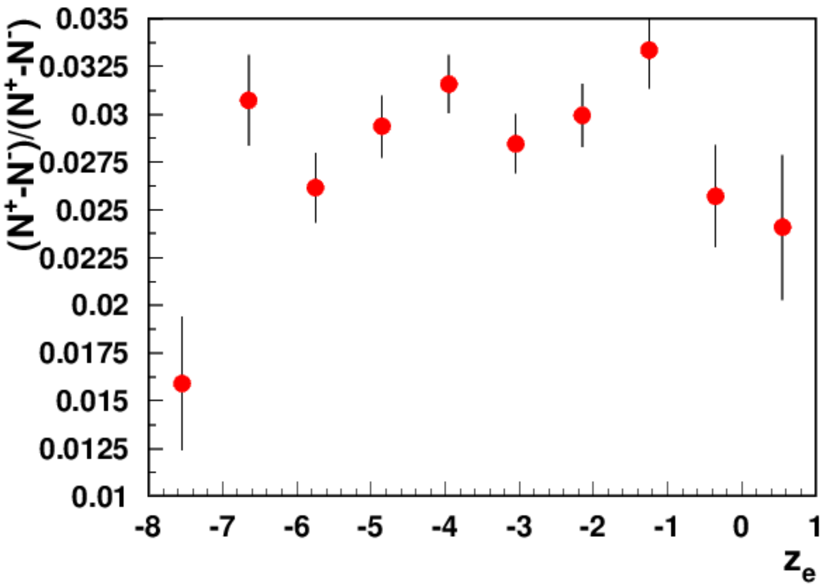
Target A_{LL} in ep→e'X (RGC)

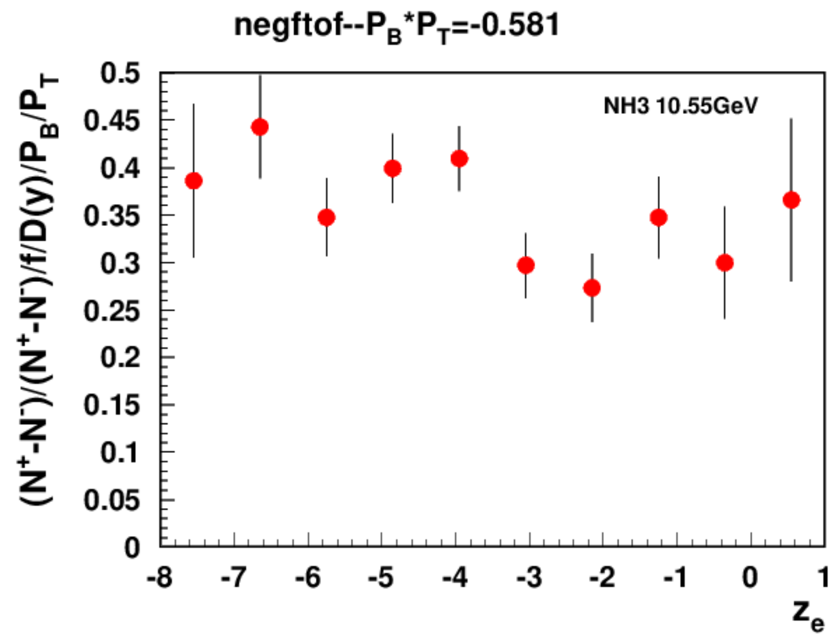
NH3 - FTout: 16983, 16990, 16992, 17001, 17015, 17019, 17076, 17088, 17092

Positive   negative   positive

$A_{LL}=A_1/D(y)/f/P_B/P_T$

$P_T=0.77$ $P_T=-0.7$





Pb=0.83, f=0.15+0.075*x (from MC), the line x^0.7

Target A_{LL} in ep→e'X (RGC)

NH3 - FTin: 16681 16683 16717 16720 16768 16770 16772 16726 16728 16741 16746 16750 16759 16762

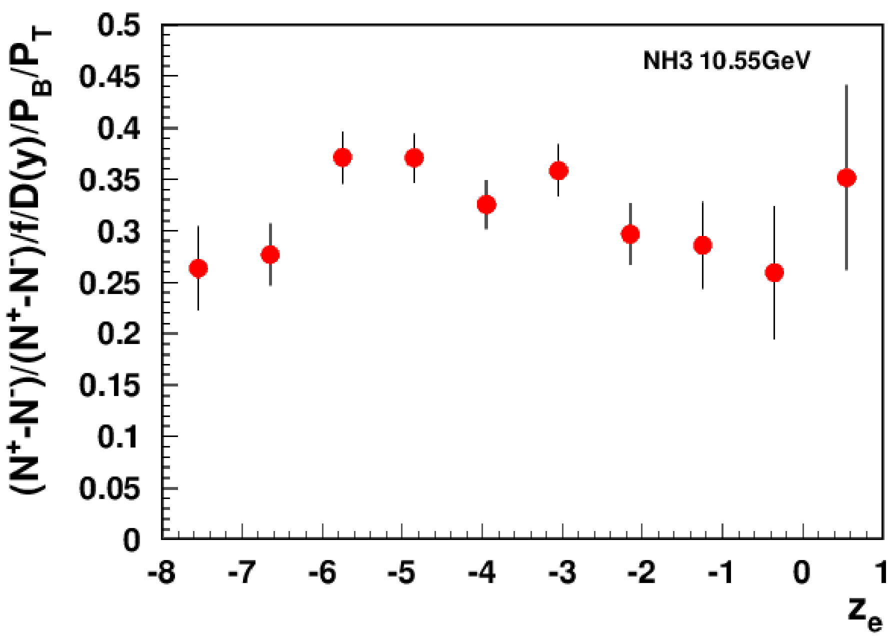
Positive

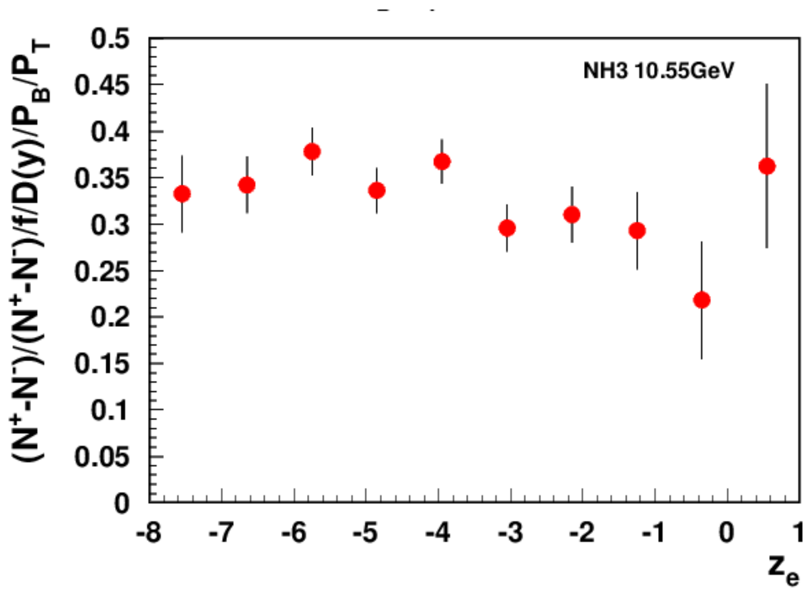
negative

$A_{LL}=A_1/D(y)/f/P_B/P_T$

$P_T=0.77$

$P_T=-0.7$





Pb=0.83, f=0.15+0.075*x (from MC), the line x^0.7

Kinematics

MC files with SIDIS events

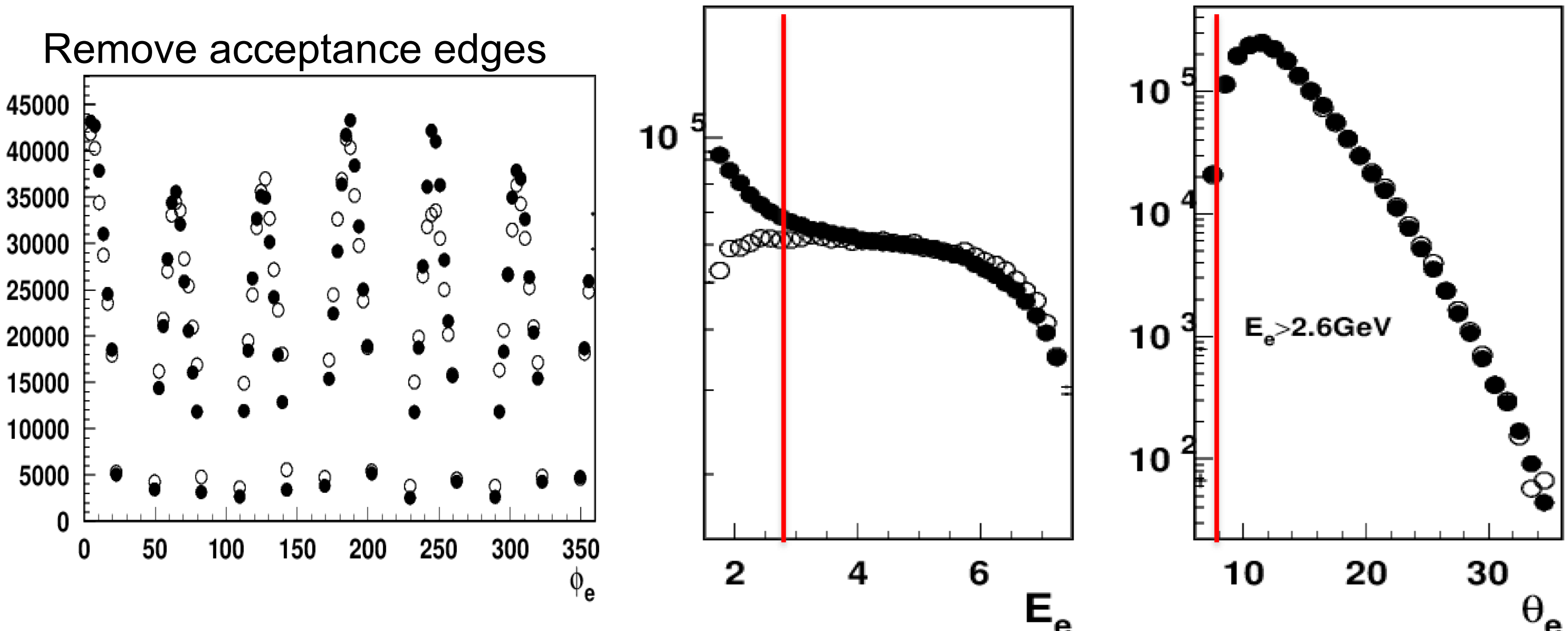
/work/cebaf24gev/sidis/reconstructed/polarized-plus-10.5GeV-neutron/hipo/
/work/cebaf24gev/sidis/reconstructed/polarized-minus-10.5GeV-neutron/hipo/
/work/cebaf24gev/sidis/reconstructed/polarized-plus-10.5GeV-proton/hipo/
/work/cebaf24gev/sidis/reconstructed/polarized-minus-10.5GeV-proton/hipo/

Data from /volatile/clas12/rg-c/production/ana_data/dst/train/sidisdvcs/

Event selection

The same cuts applied to MC and data |z+3.5|<4, Ee>2.6, 35>θ>8

Remove acceptance edges



Within fiducial region MC and data are consistent

Target A_{LL} in eNH3→e'X (RGC-sol1)

NH3 : 17215 17191 17195

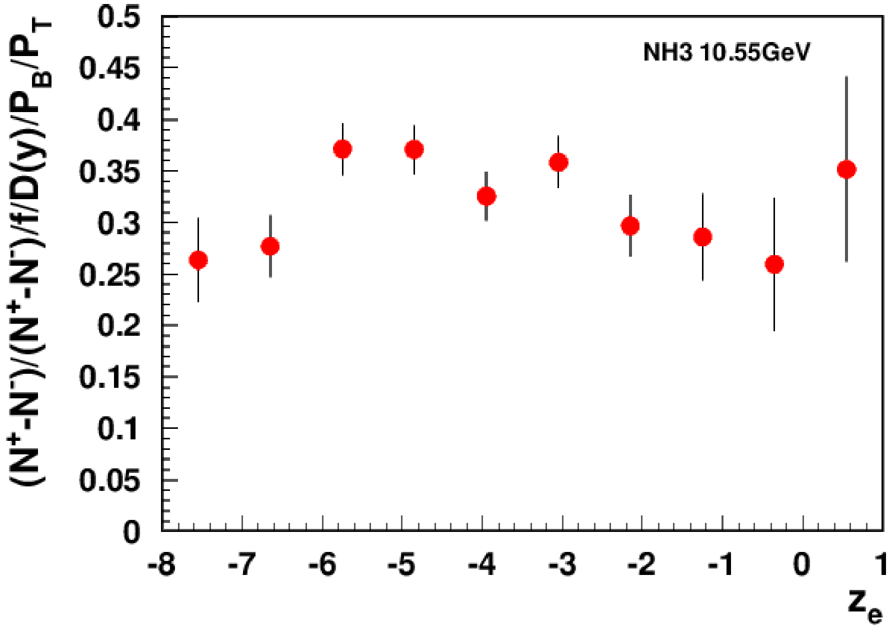
Positive

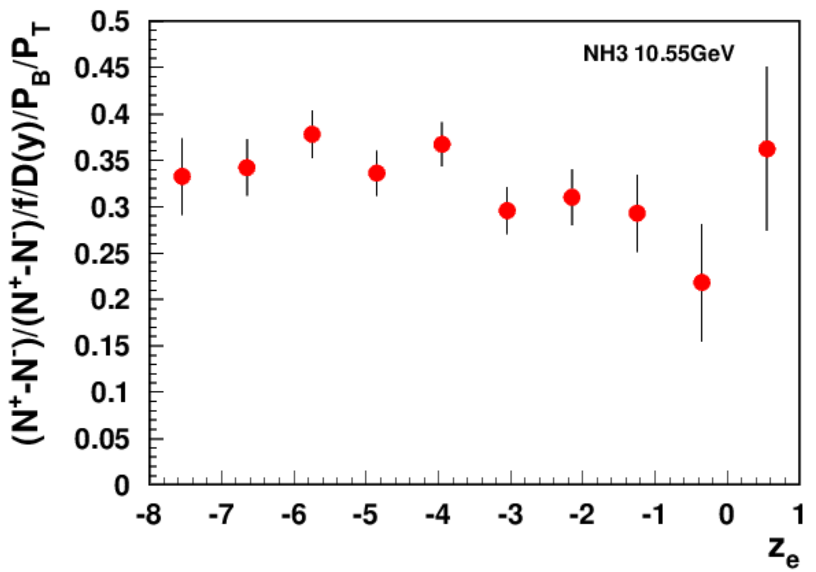
negative

$A_{LL}=A_1/D(y)/f/P_B/P_T$

P_T=0.77

P_T=-0.7





Pb=0.83, f=0.15+0.075*x (from MC), the line x^0.7

Target A_{LL} in eND3→e'X (RGC)

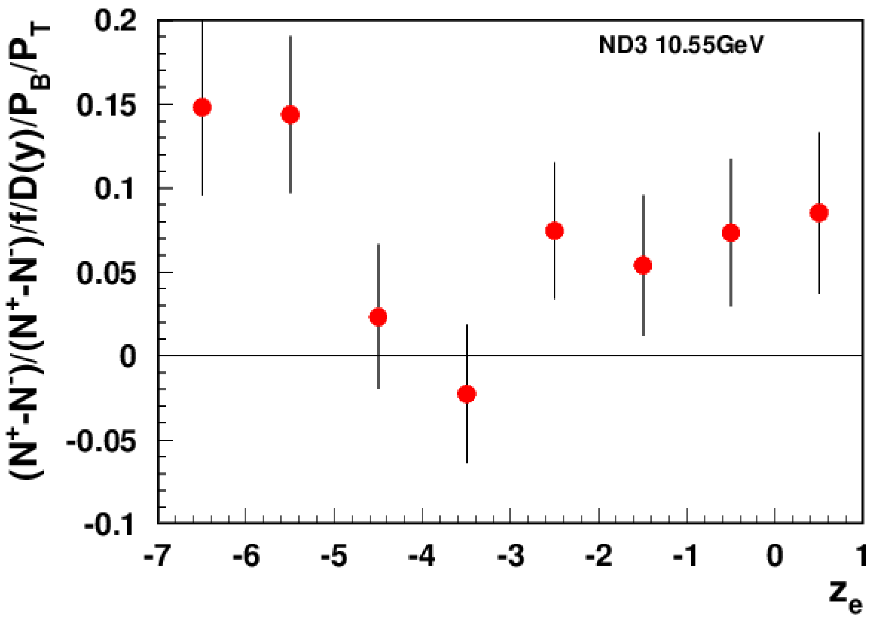
ND3: 17265 17269, 17273 17227 17237 17262

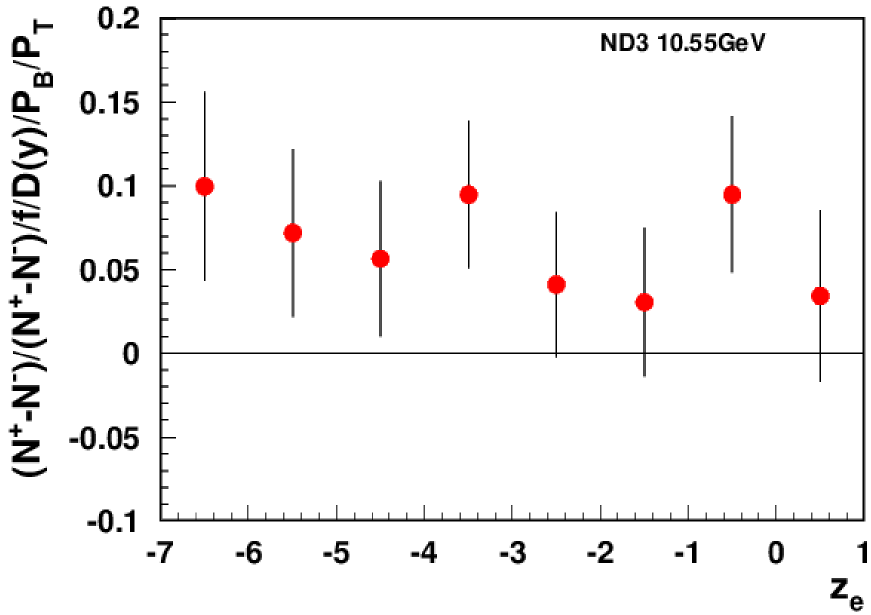
Positive negative

$A_{LL}=A_1/D(y)/f/P_B/P_T$

$P_T=0.3$

$P_T=-0.3$





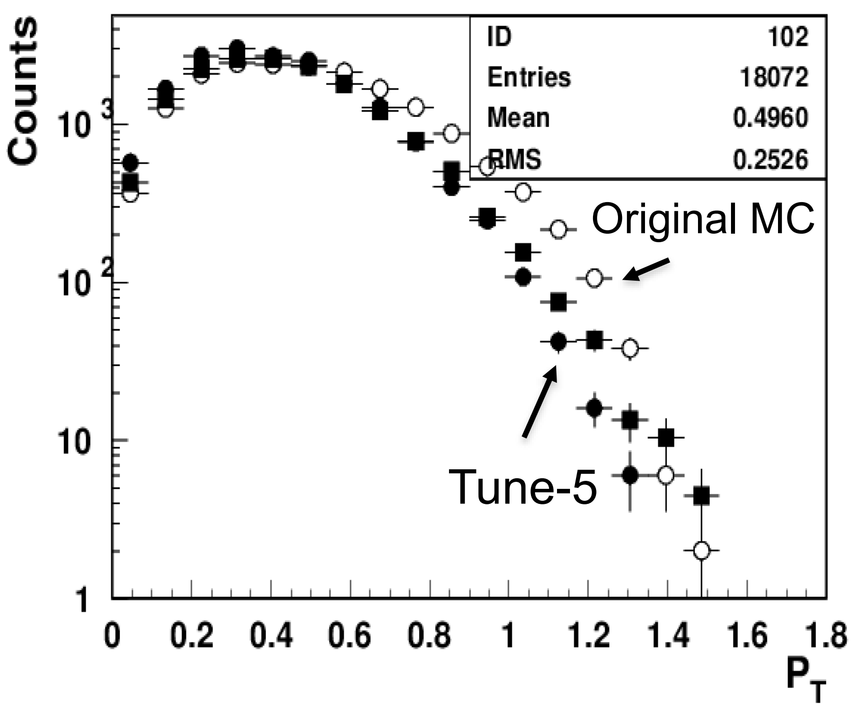
Pb=0.83, f=0.84*(0.305-0.01*x) (from MC)

Adding nuclear background

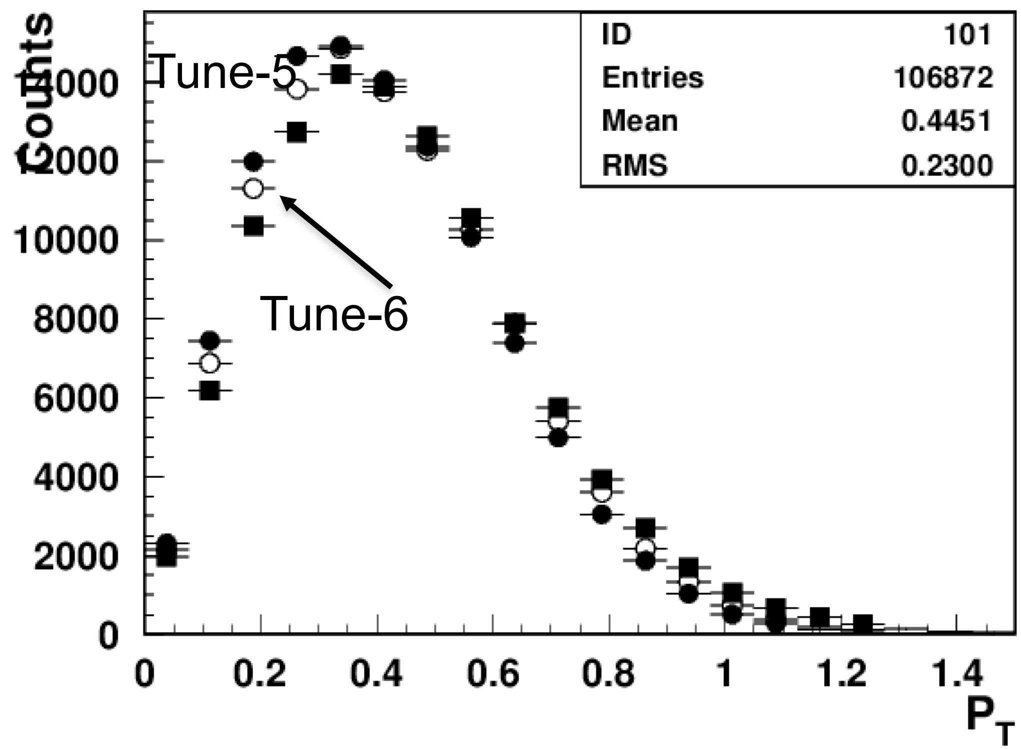
- Comparing nuclear MC (A. Alaoui/L. El Fassi) with RGC carbon

Squares RGC carbon run#16128

e’π+X

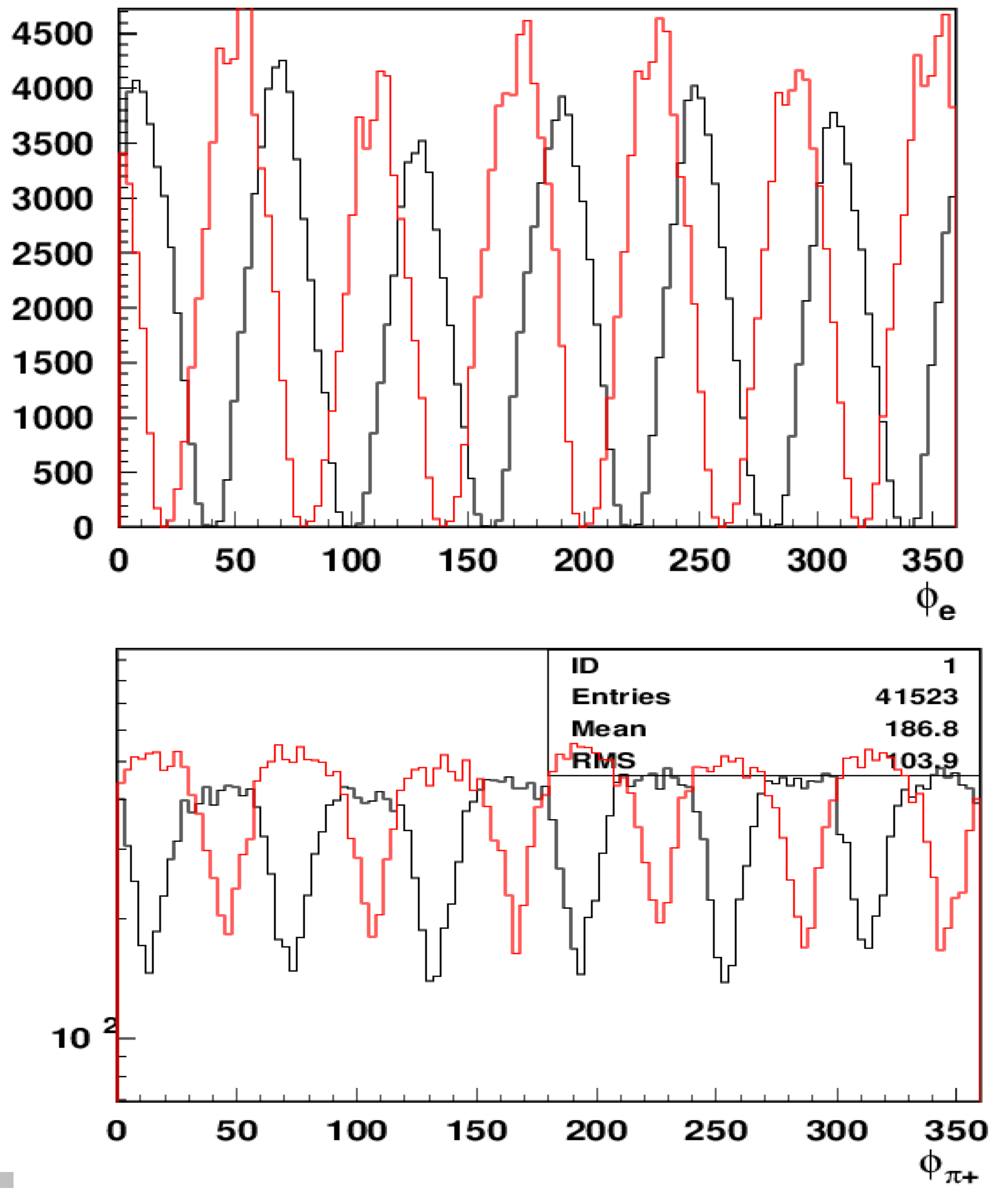


e’π+X



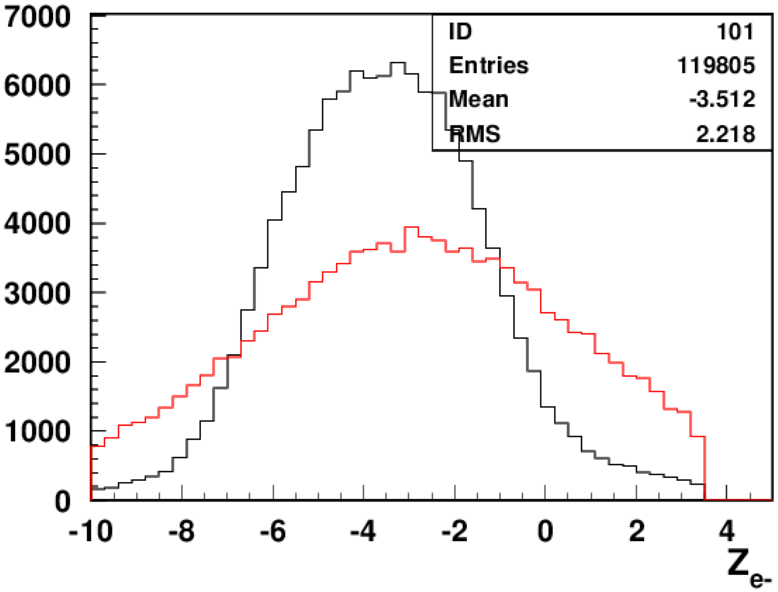
Nuclear MC (PYTHIA based) has been tuned in several iterations to get closer to RGC carbon data (main changes: use the same input as for clasdis with enhanced VM fractions)
Will need accounting of radiative corrections for fine tuning

Azimuthal kicks

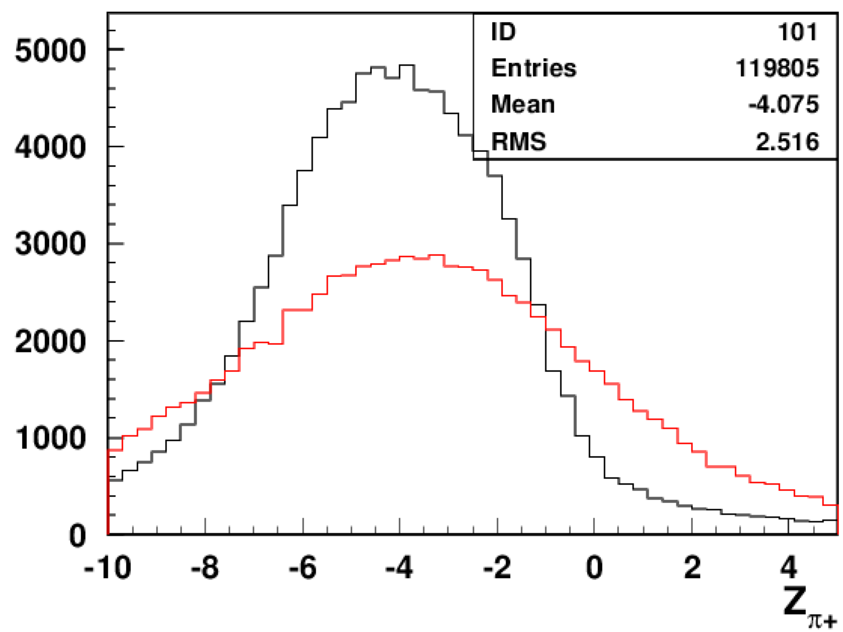


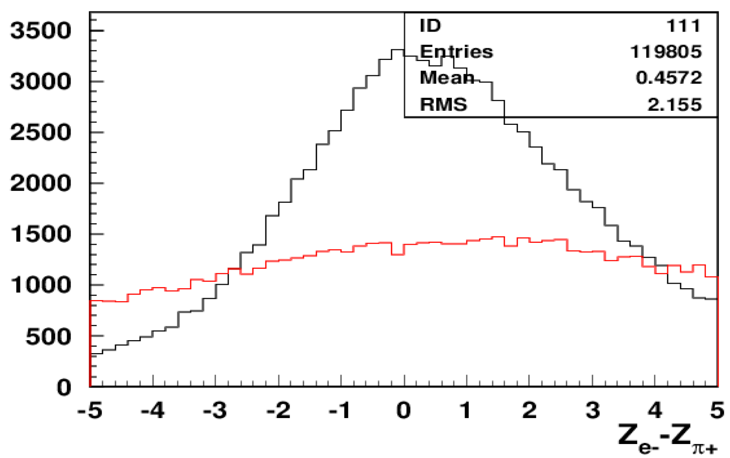
Red-inverted solenoid

Vertexes



Red-inverted solenoid

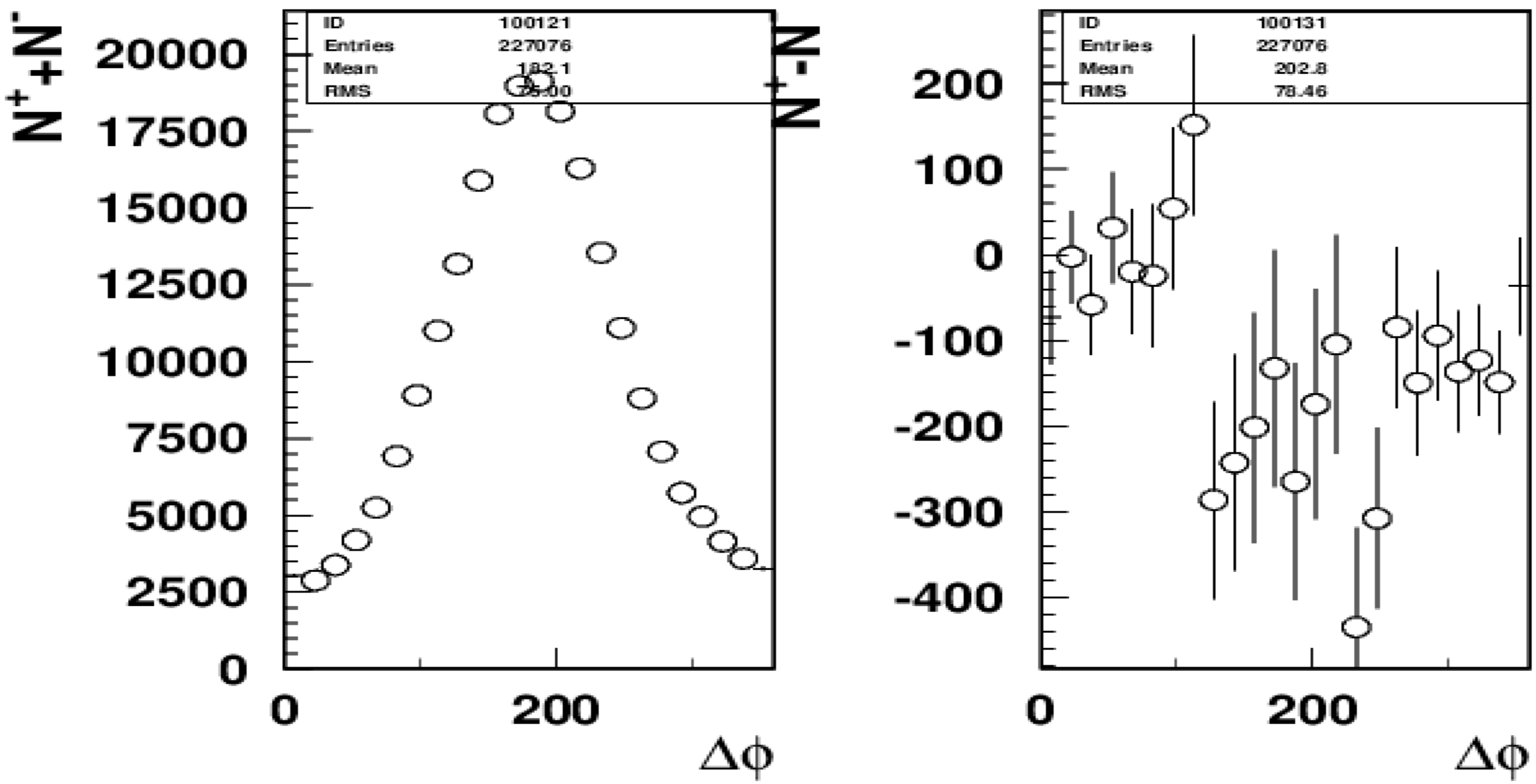




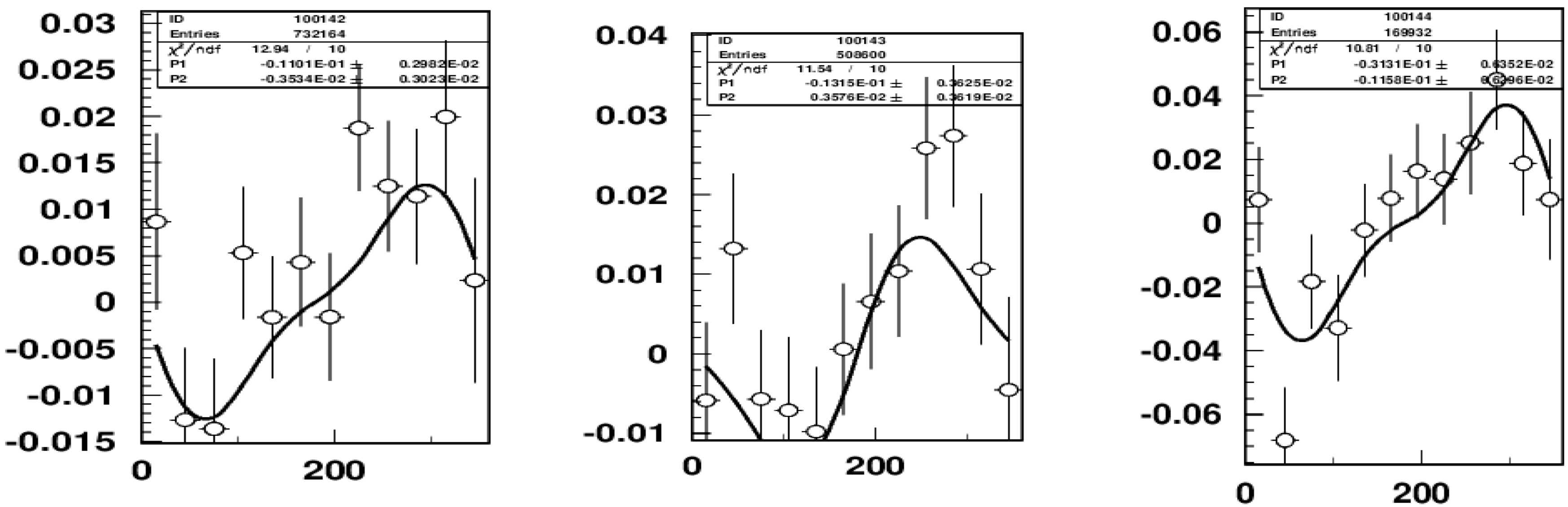
Bigger spread in z!
HBT vs TBT (will compare with full tracking)
May need calibration

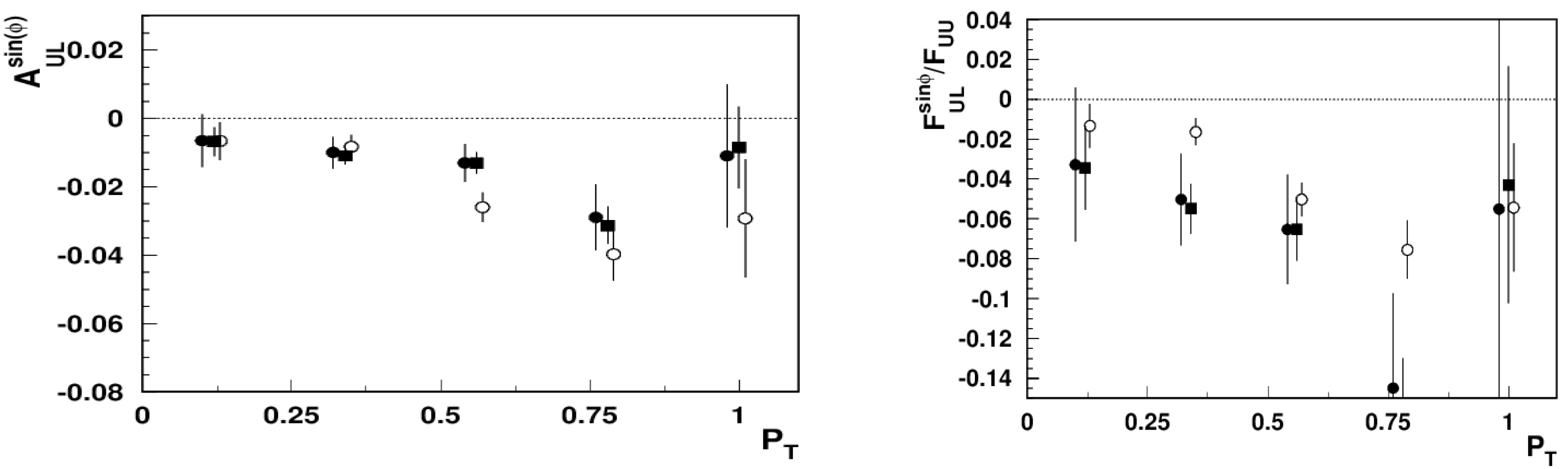
Beam SSA in ep→e'pπ+X

Significant disbalance in helicities, not critical for SSAs, but will be important for DSAs



Target SSA in ep→e'pπ+X

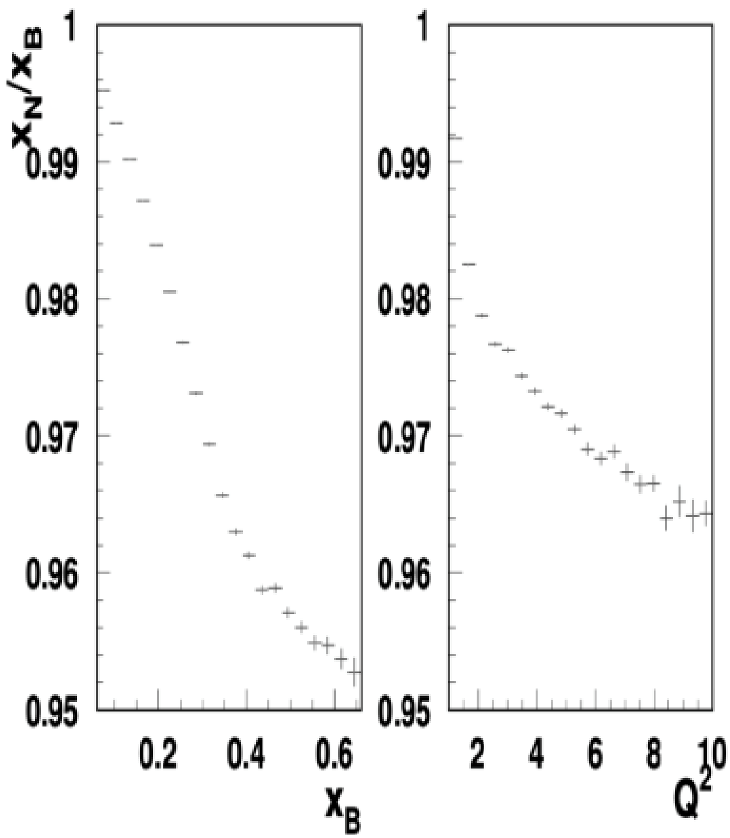


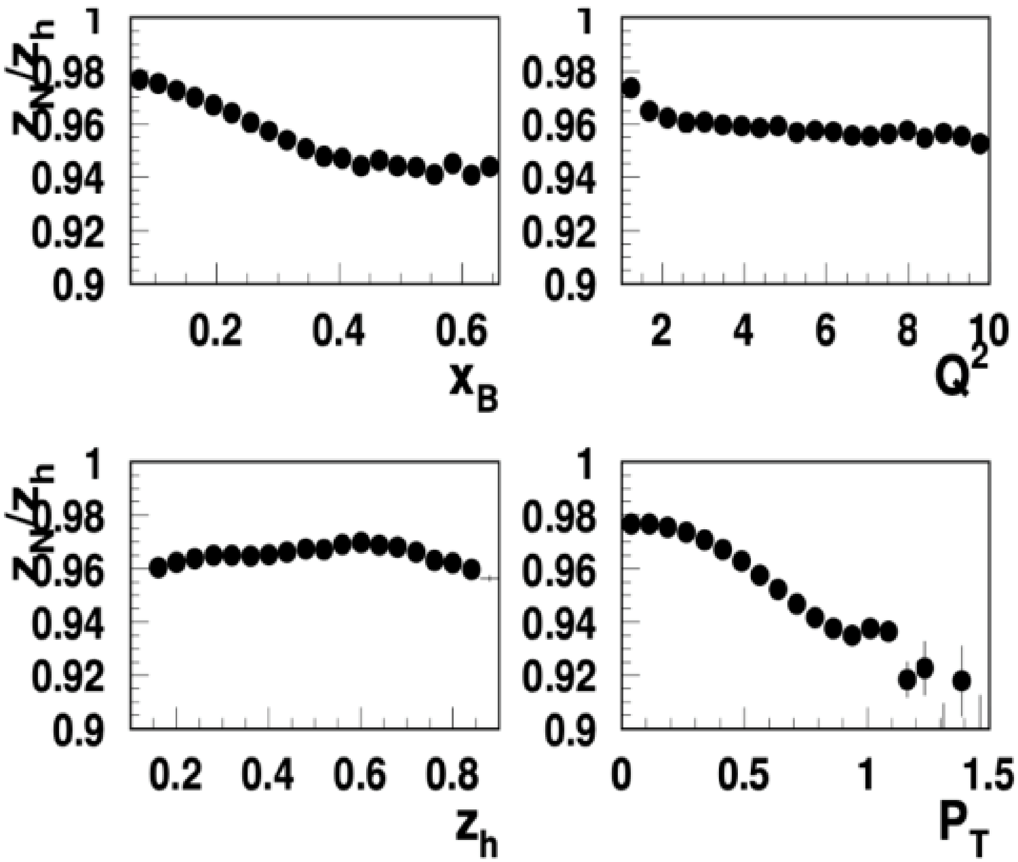


CLAS12: Mass corrections to x_B and z_h

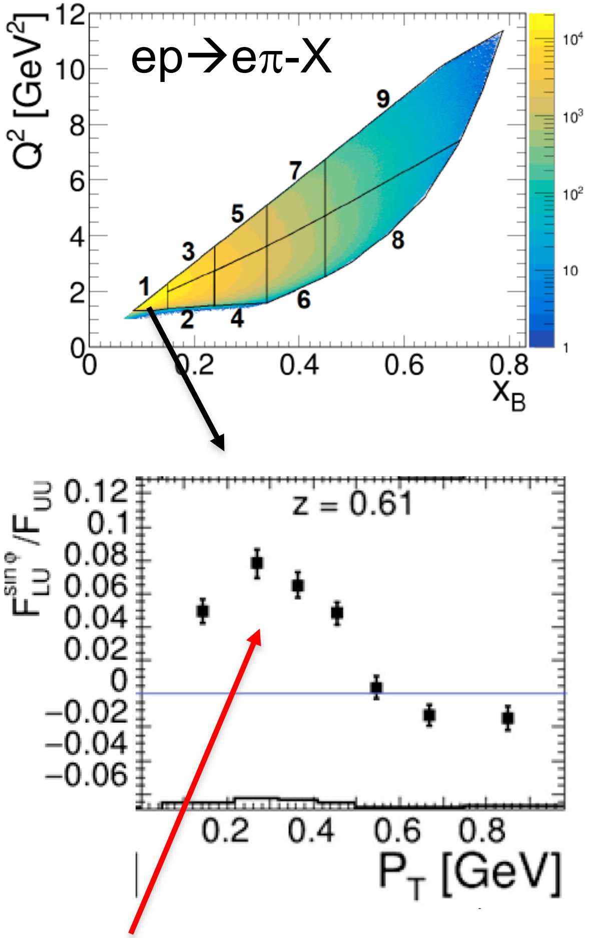
$$x_N = -\frac{q^+}{P^+} = \frac{2x_{Bj}}{1+\sqrt{1+\frac{4x_{Bj}^2 M^2}{Q^2}}}$$

$$z_N = \frac{Q^4 x_N z_h \left(1 \pm \sqrt{1 - \frac{4M^2 M_B^2 x_{Bj}^2 (Q^4 + x_N^2 M^2 \mathbf{q}_T^2)}{Q^8 z_h^2}}\right)}{2x_{Bj}(Q^4 + x_N^2 M^2 \mathbf{q}_T^2)}$$



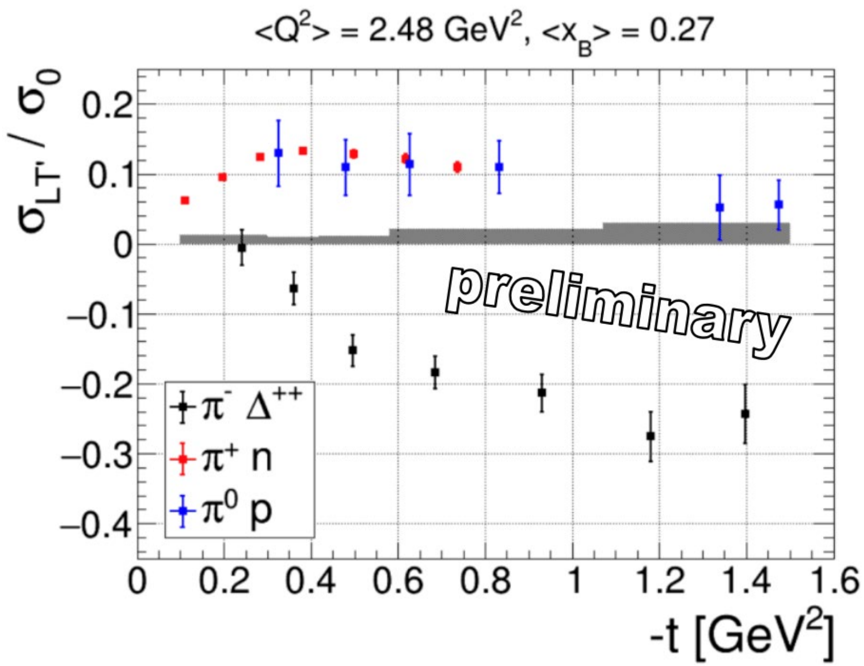


Multidimensional measurements



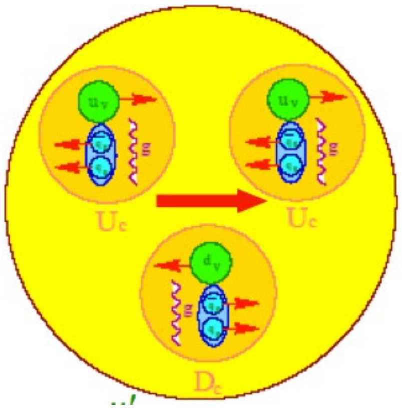
Low P_T dominated by VM decays from u-quarks

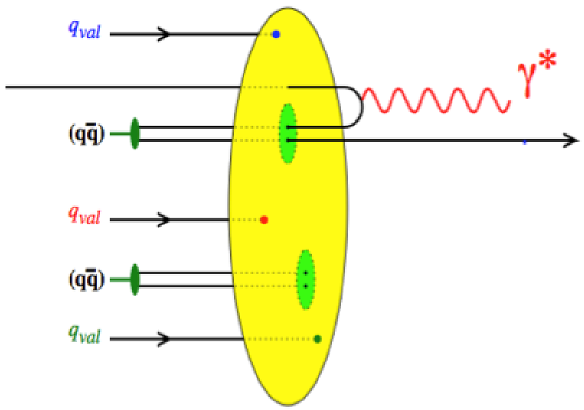
Beam SSAs as a tool to access the longitudinally polarized quarks

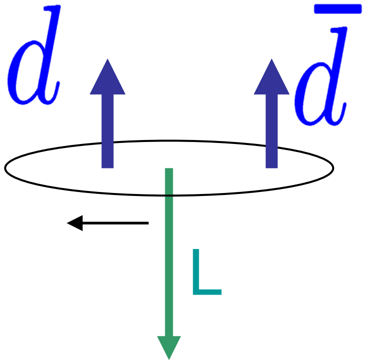


π- has sensitivity to polarized d-quarks, but require multidimensional measurements

Correlations between target and current







•how the remnant system dresses itself up to become a full-fledged hadron
•correlation with the spin of the target or/and the produced particles