Spin Structure from JLab

Harut Avakian (JLab)

Correlations in Partonic and Hadronic Interactions (CPHI-2022)

7-12 March 2022, Duke University

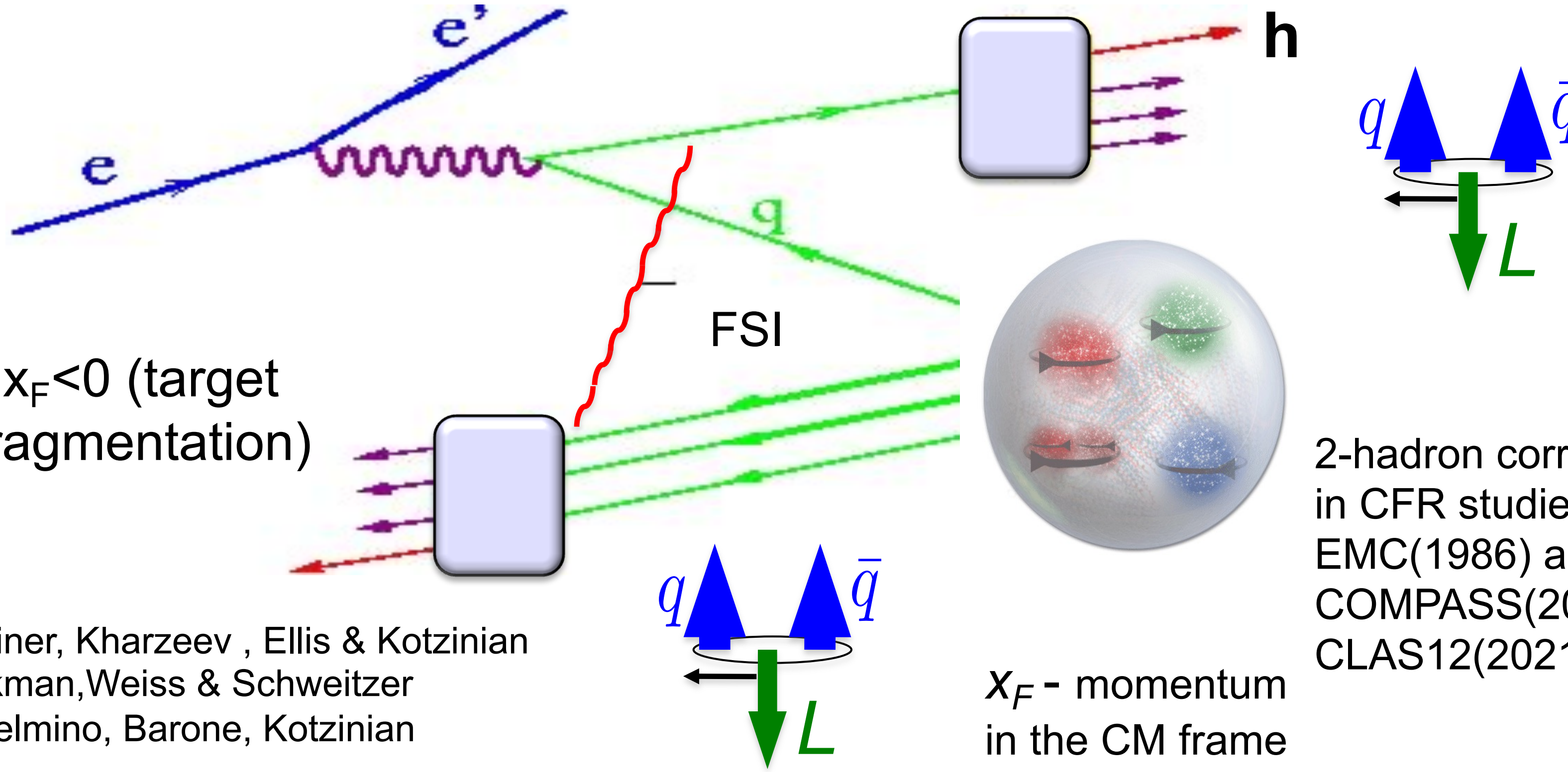
- Accessing spin-orbit correlations in SIDIS at JLab
- SIDIS observables in TFR and CFR
- Evolution and transverse momentum dependence of TMDs
- Measurements with polarized targets
- Complementarity of JLab12/24 and EIC
- Summary

Hadron production in hard scattering

x_F – fractional momentum in the CM frame

x_F>0 (current fragmentation)

X. Artru & Z. Belghobsi



x_F<0 (target fragmentation)

Karliner, Kharzeev , Ellis & Kotzinian
Strikman,Weiss & Schweitzer
Anselmino, Barone, Kotzinian

x_F - momentum in the CM frame

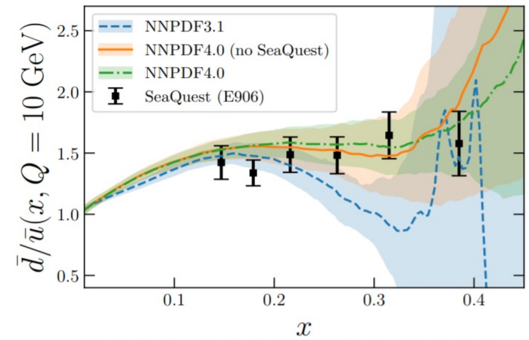
2-hadron correlations in CFR studied in EMC(1986) and COMPASS(2015) CLAS12(2021)

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

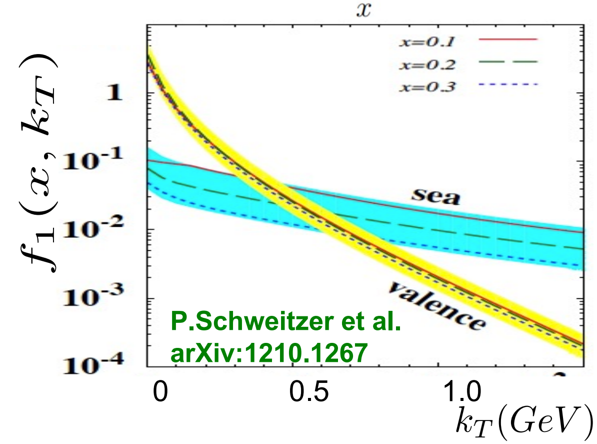
Non-perturbative contributions

Non-perturbative sea ("tornado"/$^3P_0$) in nucleon is a key to understand the nucleon structure

$\bar{d} > \bar{u}$

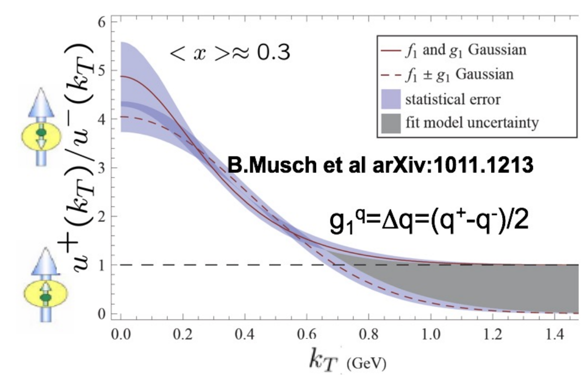


- Spin-Orbit correlations so far were shown (measurements and model calculations) to be significant in the region where non-perturbative effects dominate (x>0.02)
- Large transverse momenta of hadrons most relevant for understanding the non-perturbative QCD dynamics

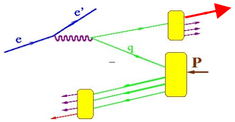


- Predictions from dynamical model of chiral symmetry breaking [Schweitzer, Strikman, Weiss JHEP 1301 (2013) 163]

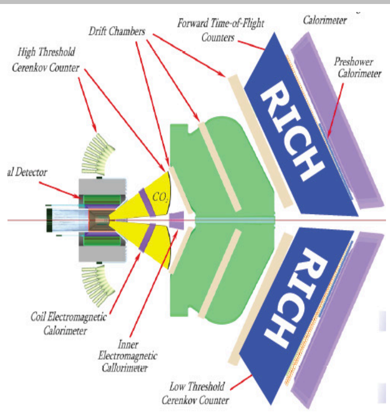
-- k_T (sea) >> k_T (valence)
-- short-range correlations between partons (small-size q-qbar pairs)
-- may be directly observable in P_T-dependence of hadrons in SIDIS



Understanding of the evolution of transverse momentum dependence most critical in validation of the theory



SIDIS at JLab12



Proton

Quark spin polarization (columns) / Nucleon polarization (rows)

N \ q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

CLAS12

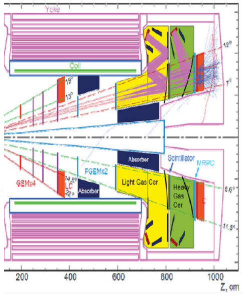
- E12-06-112: π^+,π^-,π^0 E12-09-008: K^+, K^-, K^0
- E12-07-107: π^+,π^-,π^0 E12-09-009: K^+, K^-, K^0
- C12-11-111: π^+,π^-,π^0 K^+, K^-

H_2, NH_3, HD

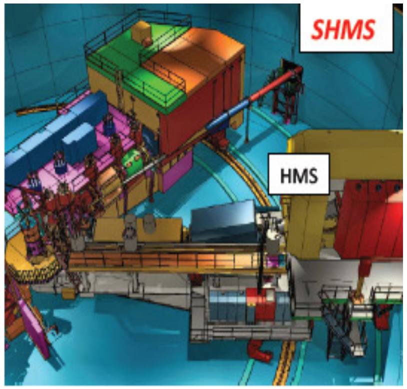
Hall C / Hall A

- E12-09-017: π^+,π^-, K^+,K^- C12-11-102: π^0 — HMS SHMS
- C12-11-108: π^+,π^- — Solid

H_2 NH_3



Coverage of large Q^2 and large P_T



D_2

Quark spin polarization (columns) / Nucleon polarization (rows)

N \ q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

CLAS12

- E09-008: π^+,π^-,π^0 K^+, K^-, K^0
- E07-107: π^+,π^-,π^0 E09-009: K^+, K^-, K^0

D_2, ND_3

Hall C

- E12-09-017: π^+,π^-, K^+,K^- C12-11-102: π^0 — HMS SHMS

D_2

^3He

Quark spin polarization (columns) / Nucleon polarization (rows)

N \ q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

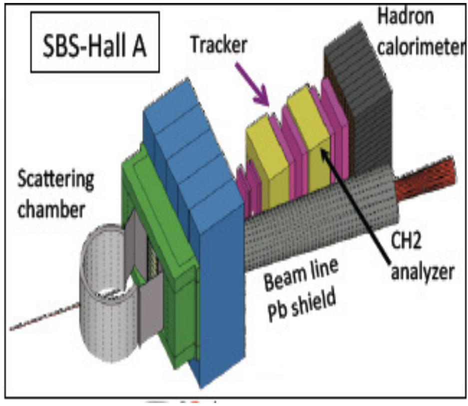
C12-20-002 π^+,π^-,π^0,K+

Hall A

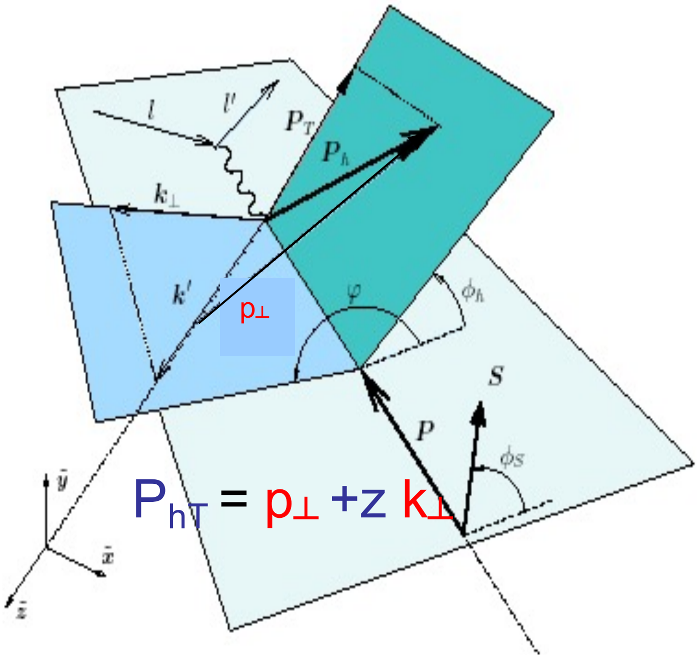
- E12-07-007: π^+,π^- — Solid
- E10-006: π^+,π^- E12-09-018: π^+,π^-, K^+,K^- — Solid, SBS

^3He

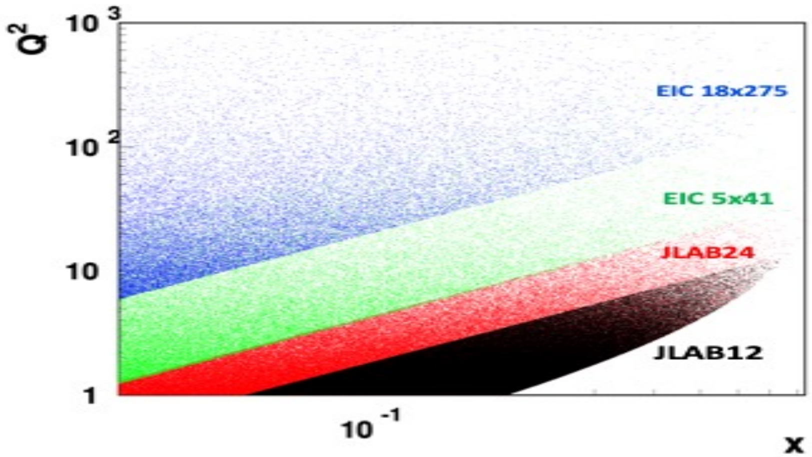
Precision measurements of all SFs in a wide range

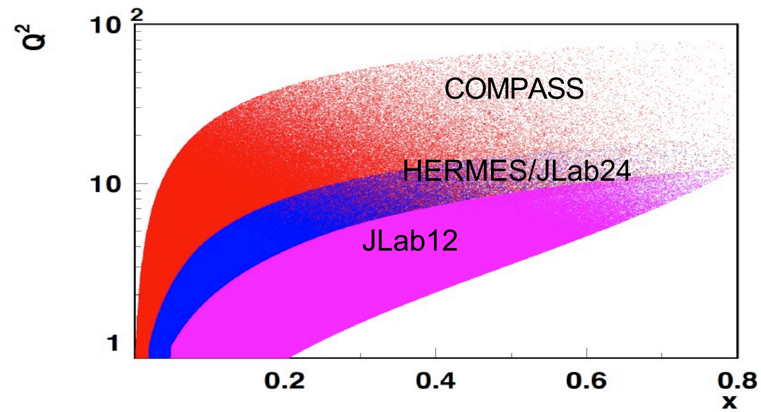


SIDIS kinematical coverage and observables

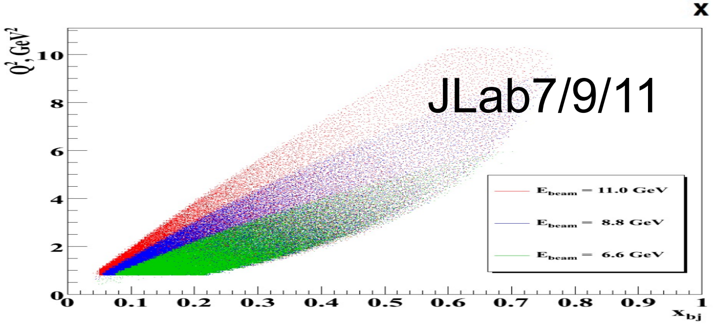


EIC



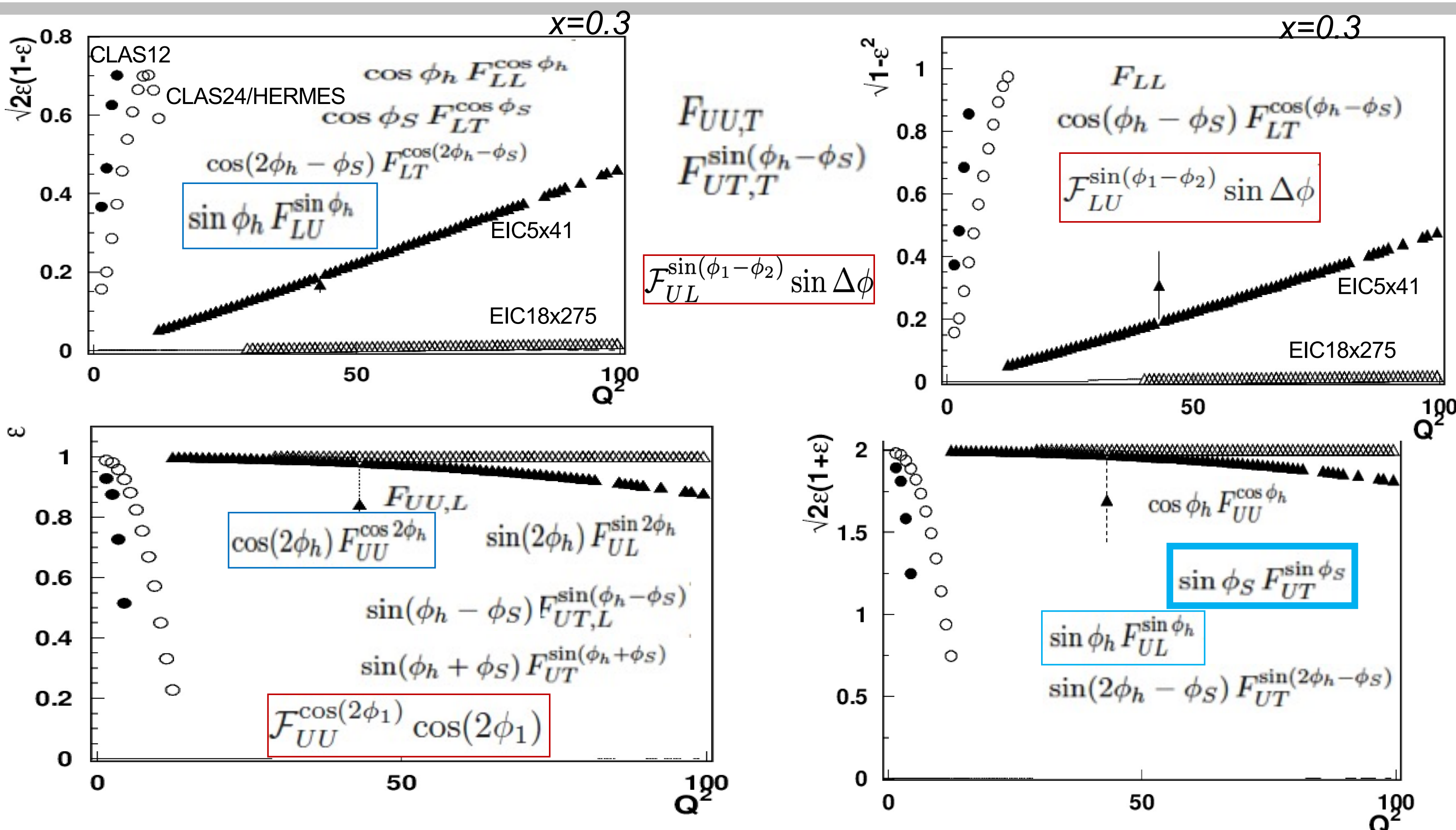


$$\sigma \propto F_{UU} + P_b\sqrt{2\epsilon(1-\epsilon)}F_{LU}^{\sin\phi}\sin\phi + P_t\epsilon F_{UL}^{\sin 2\phi}\sin 2\phi + \ldots$$



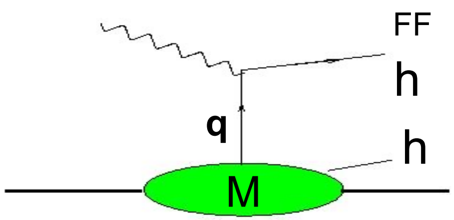
- Studies of azimuthal modulations give access to underlying 3D partonic distributions
- QCD predicts only the Q^2-dependence of 3D PDFs

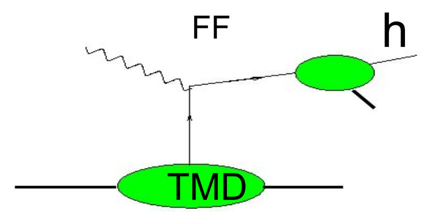
Kinematic factors at large x



- Fixed target experiments are sensitive to all SSAs
- For EIC, observables surviving the $\varepsilon \rightarrow 1$ limit could be used

Extending 1D PDFs: Leading Twist





-1 Fracture Functions (target fragmentation xF<0) | 0 TMDs (current fragmentation x_F>) x_F

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	$\hat{u}_{1T}^h, \hat{u}_{1T}^{\perp}$	$\hat{l}_{1T}^h, \hat{l}_{1T}^{\perp}$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$

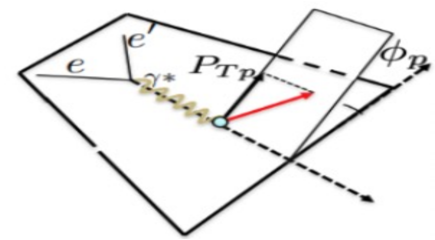
N/q	U	L	T
U	f_1	X	$h_1^{\perp}$
L	X	g_{1L}	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	g_{1T}	$h_1, h_{1T}^{\perp}$

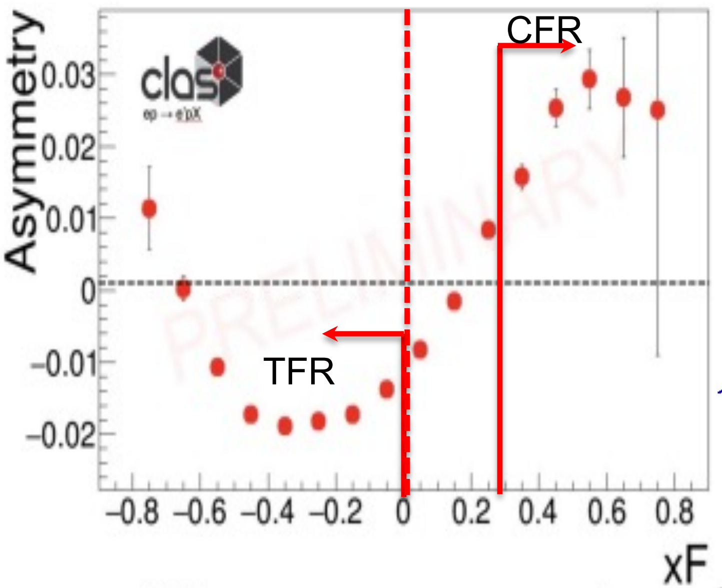
TFR studies provide a unique access to longitudinally polarized quarks in the unpolarized nucleons, and unpolarized quarks in the longitudinally polarized nucleons.

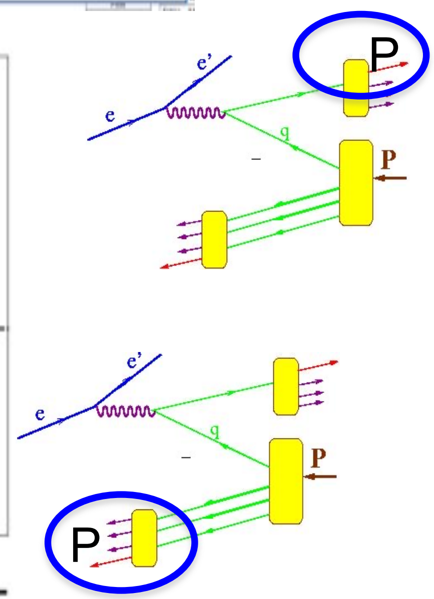
SSA in ep→e'pX production

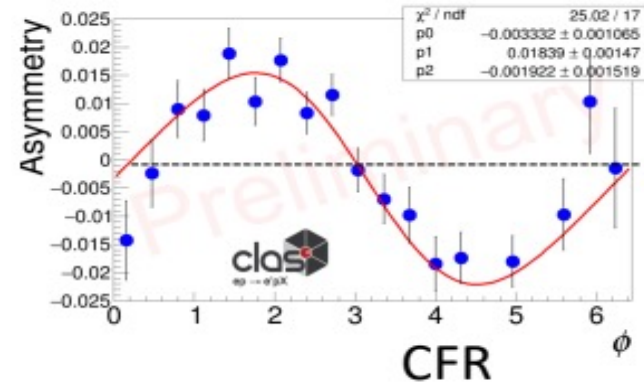
Talk by F. Benmokhtar

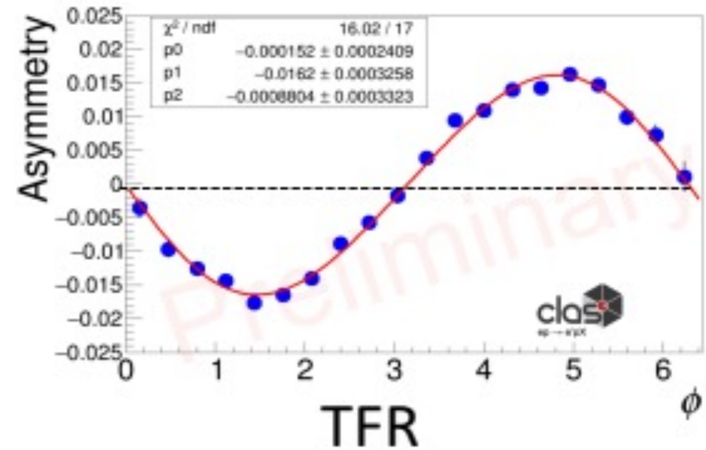
$$A(\phi)_{LU} = \frac{1}{p}\left(\frac{N^+ - N^-}{N^+ + N^-}\right) \rightarrow F_{LU}^{\sin\phi_h} = \frac{A(\phi)_{LU}}{\sqrt{2\varepsilon(1-\varepsilon)}}$$











- The SSA, clearly changing the sign, may be used to define separation of TFR and CFR regions
- More baryons in the TFR, mesons in the CFR

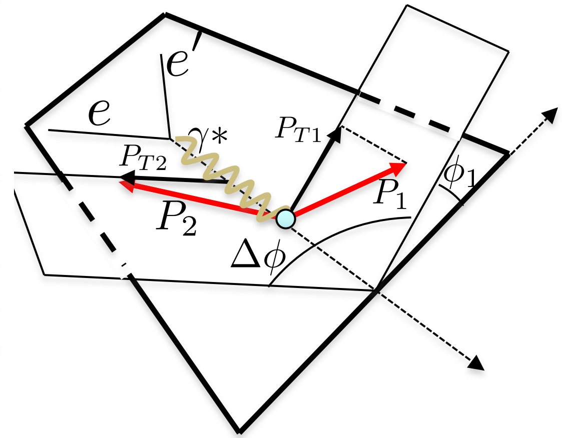
Correlations in 2 hadron production

Talk by T. Hayward

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

$$\mathcal{A}_{LU} = -\sqrt{1-\epsilon^2}\,\frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}}\sin\Delta\phi$$

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	$\hat{u}_{1T}^h, \hat{u}_{1T}^\perp$	$\hat{l}_{1T}^h, \hat{l}_{1T}^\perp$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$



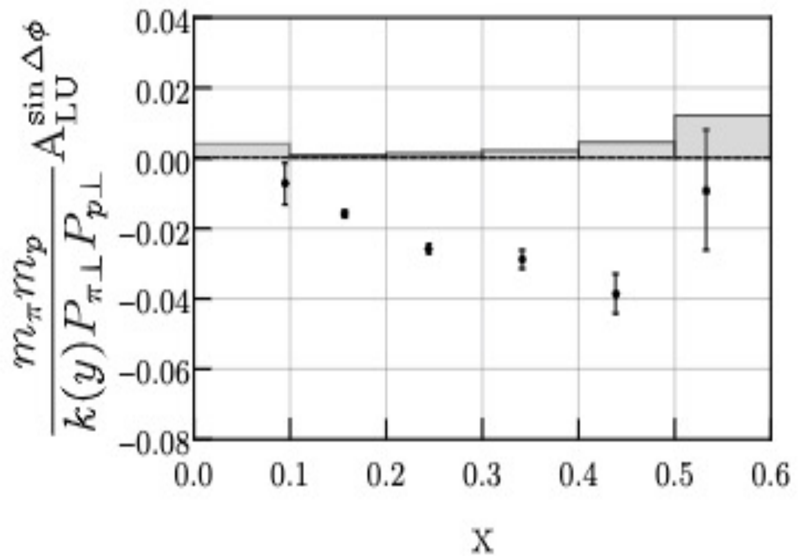
- Depolarization goes to 0 at high energies of EIC

$$\mathcal{A}_{LU} = -\frac{y\left(1-\frac{y}{2}\right)}{\left(1-y+\frac{y^2}{2}\right)}\frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}}\sin\Delta\phi$$

$$= -\frac{|\mathbf{P}_{1\perp}||\mathbf{P}_{2\perp}|}{m_N m_2}\,\frac{y\left(1-\frac{y}{2}\right)}{\left(1-y+\frac{y^2}{2}\right)} \times \frac{\mathcal{C}[w_5\,\hat{l}_1^{\perp h} D_1]}{\mathcal{C}[\hat{u}_1 D_1]}\sin\Delta\phi,$$

correlation

modulation

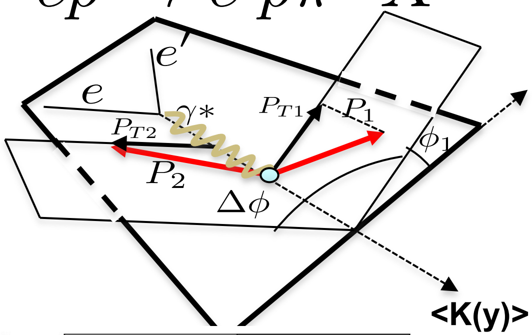


The correlation is most significant at large x, where the valence quarks most significant

Back to back SSAs in ep→e'pπ+X

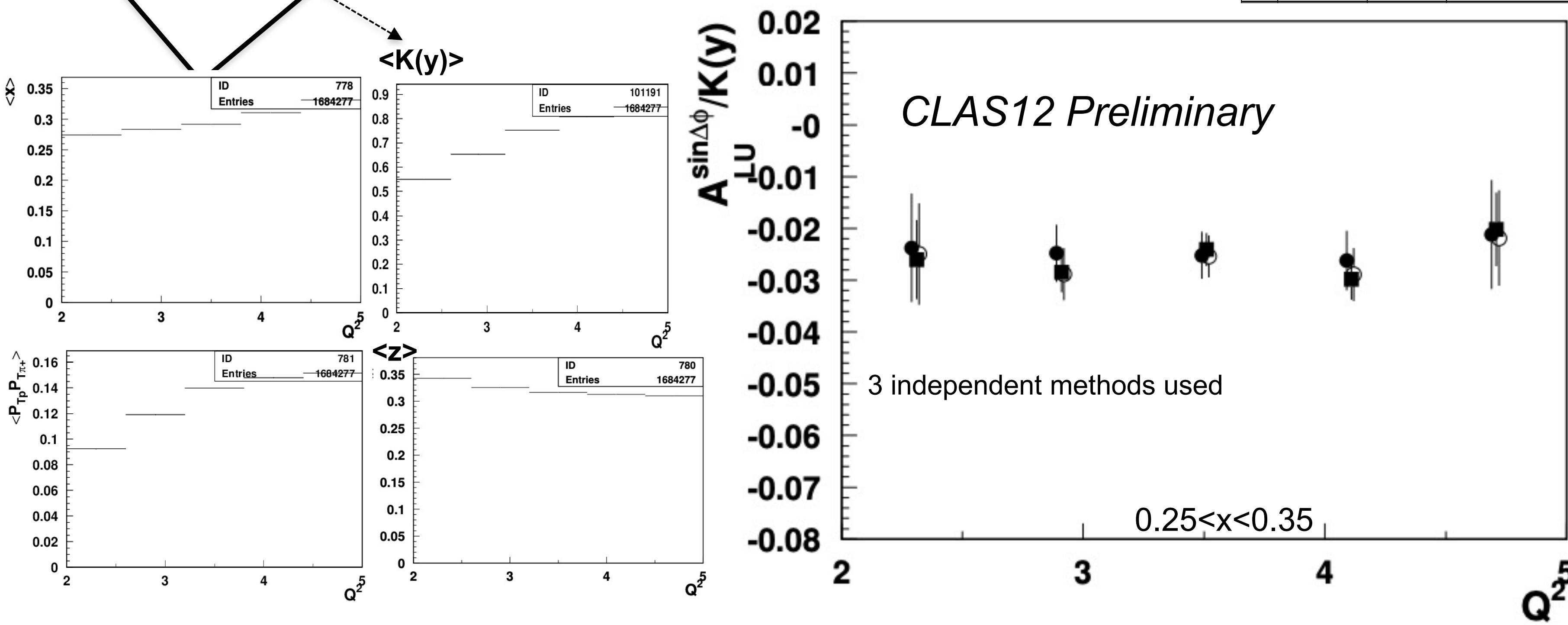
Talk by T. Hayward

$$ep \to e' p \pi^+ X$$



$$\mathcal{A}_{LU}^{\sin(\phi_1-\phi_2)} \propto \frac{\mathcal{C}[w_5\, \hat{l}_1^{\perp h} D_1]}{\mathcal{C}[\hat{u}_1 D_1]}$$

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	$\hat{u}_{1T}^h, \hat{u}_{1T}^\perp$	$\hat{l}_{1T}^h, \hat{l}_{1T}^\perp$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$

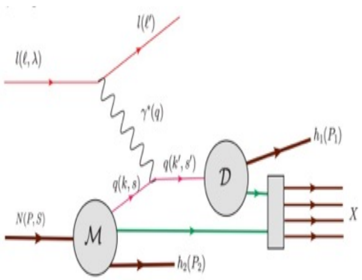


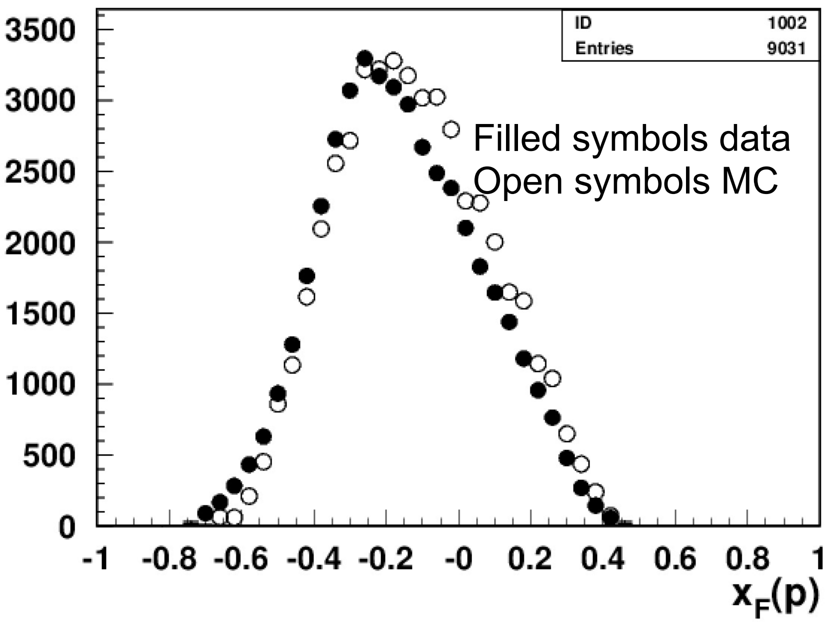
No significant Q^2-dependence observed for B2B A_{LU}

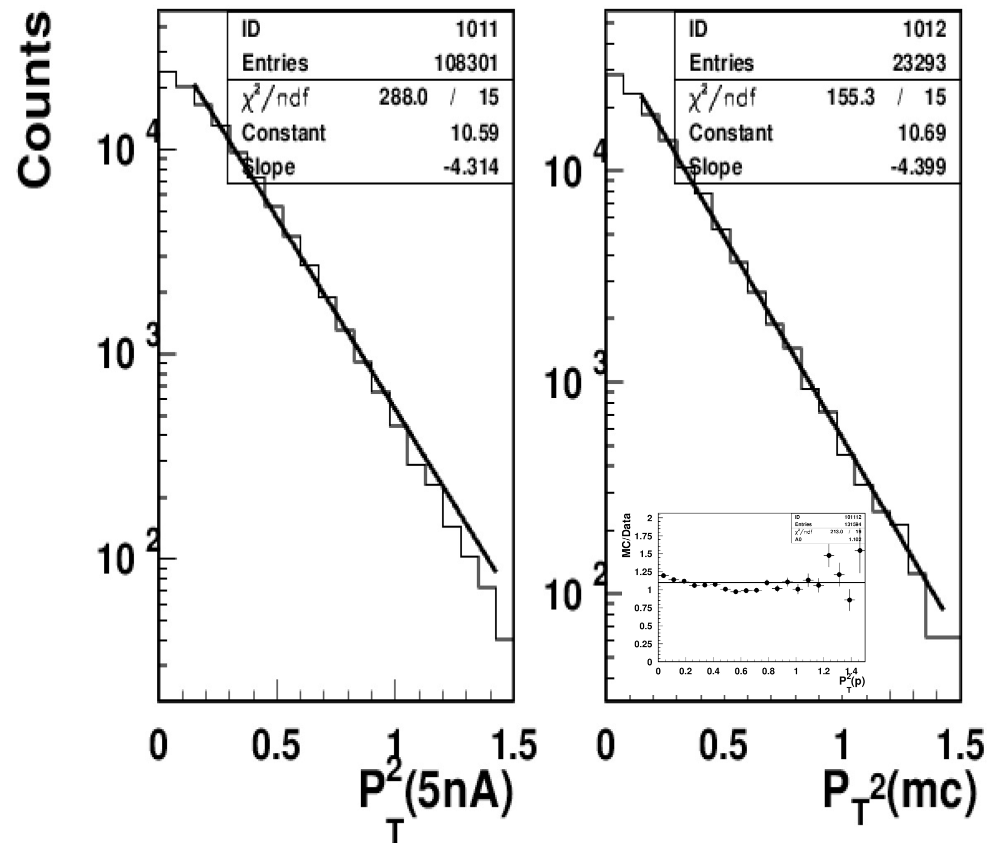
- First indication in large x SIDIS of a LT observable
- Multidimensional measurements crucial for evolution studies

CLAS12 Studies: Data vs MC

Using PEPSI (LUND) generator



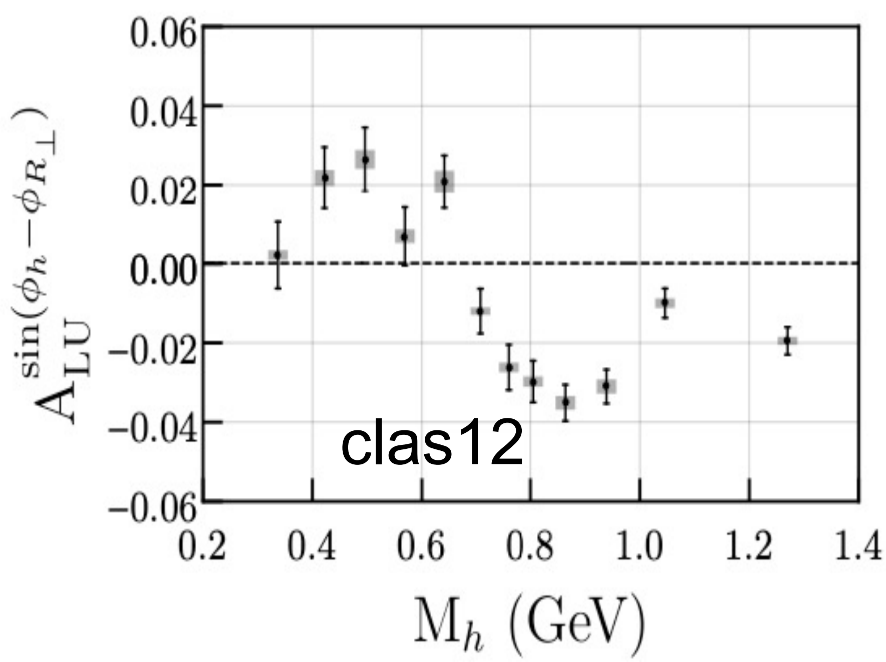




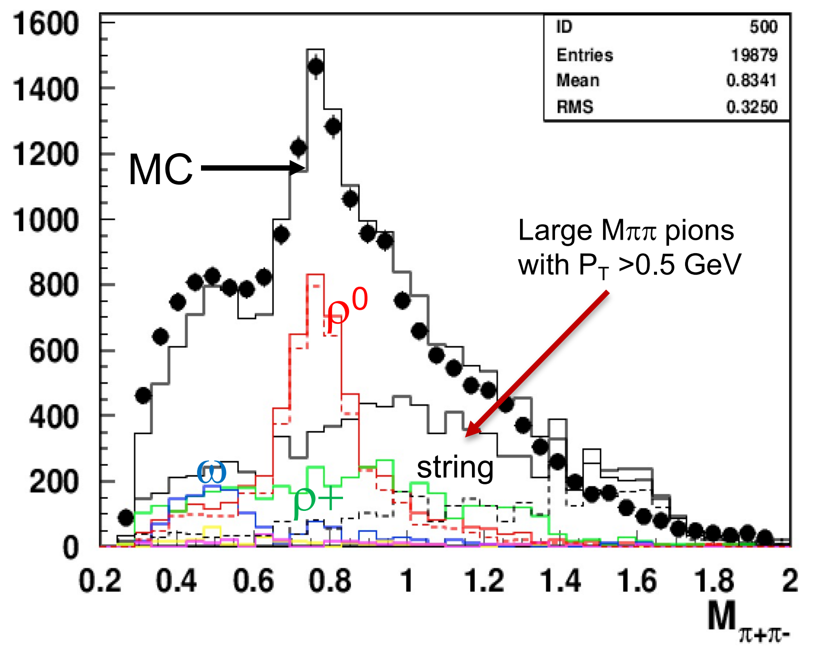
- Kinematic distributions, z, x_F, P_T-distributions of protons, and widths are in good agreement with LEPTO
- TFR may be a valuable source for studies of widths in hadronization
- Expect significantly better separation of TFR and CFR at JLab24

Talk by C. Dilks

T. Hayward et al. Phys. Rev. Lett. 126, 152501 (2021)

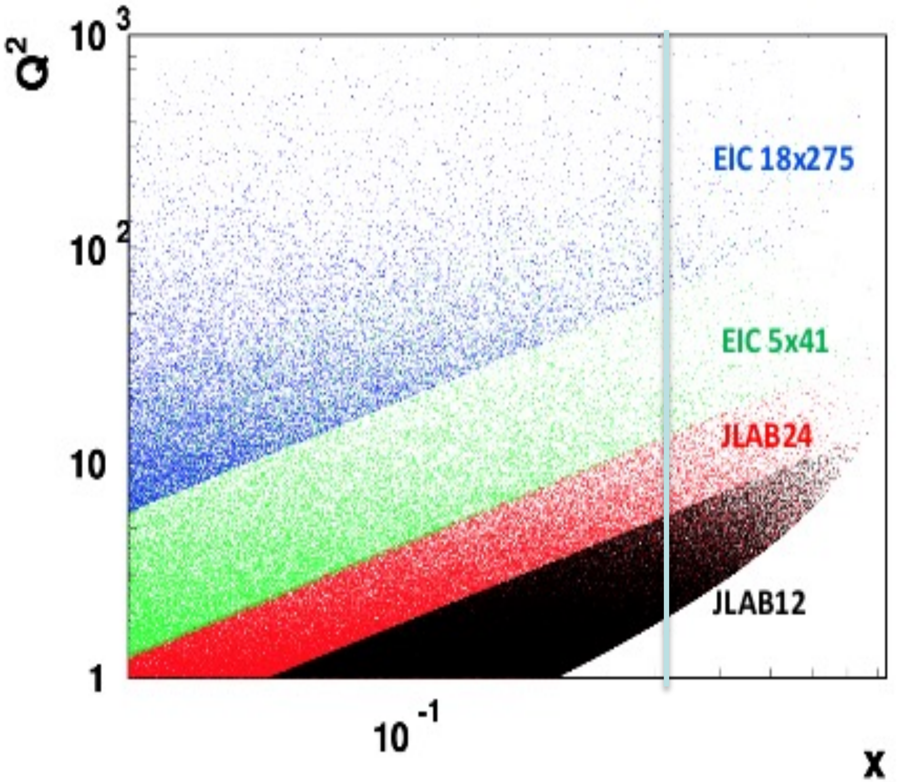


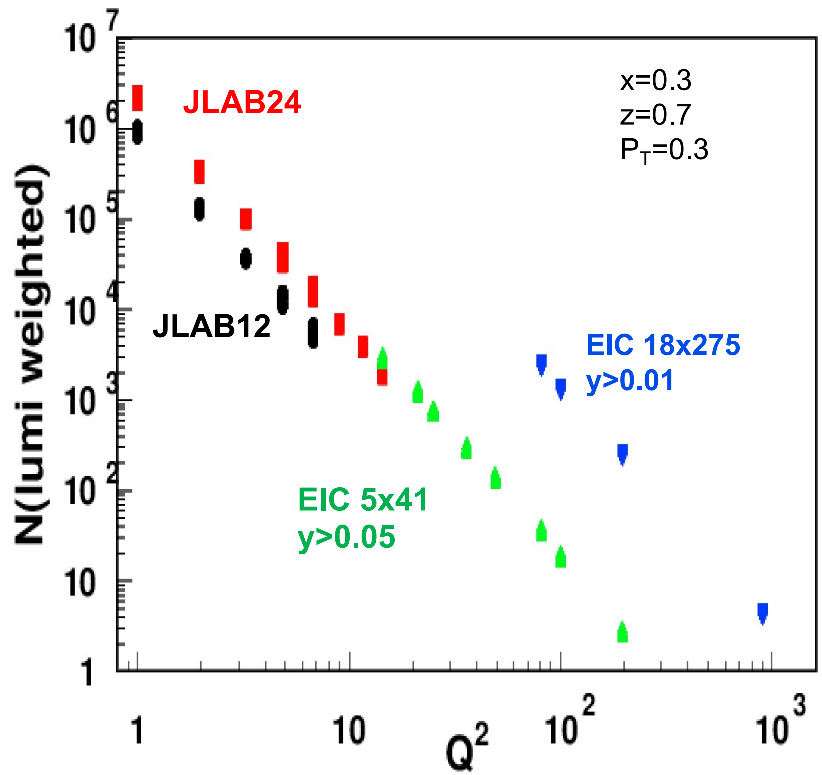
Contributions to π^+ in e'$\pi^+\pi^-$X sample from different channels



- Spin-azimuthal correlations in hadron pair production are very significant
- Hadron pairs in SIDIS (true from JLab to LHC) are dominated by VM decays (therefore single hadron channel too)
- Direct pions dominate only at relatively high P_T, (P_T >0.6-0.7 GeV)

From JLab to EIC: complementarity

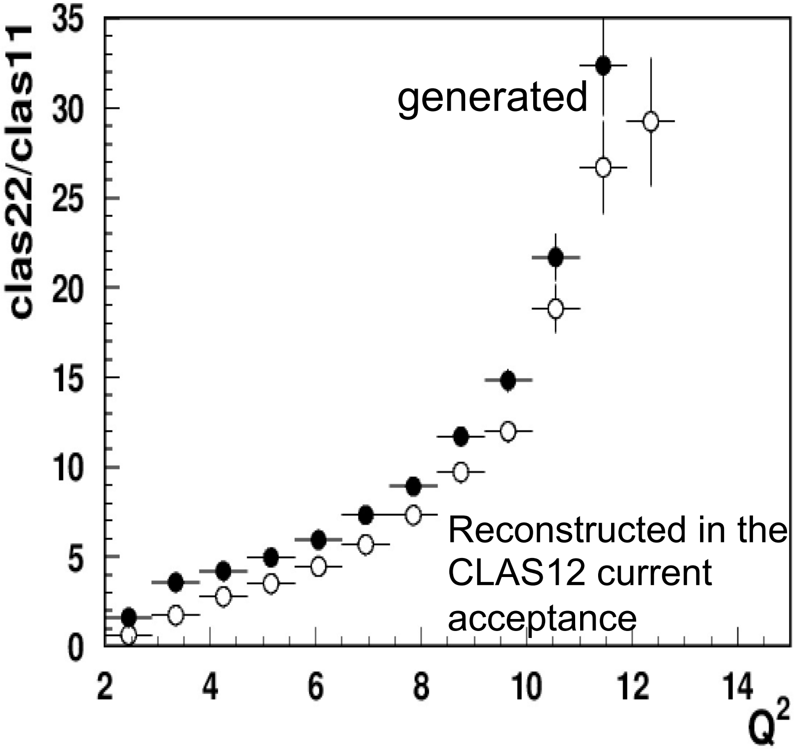




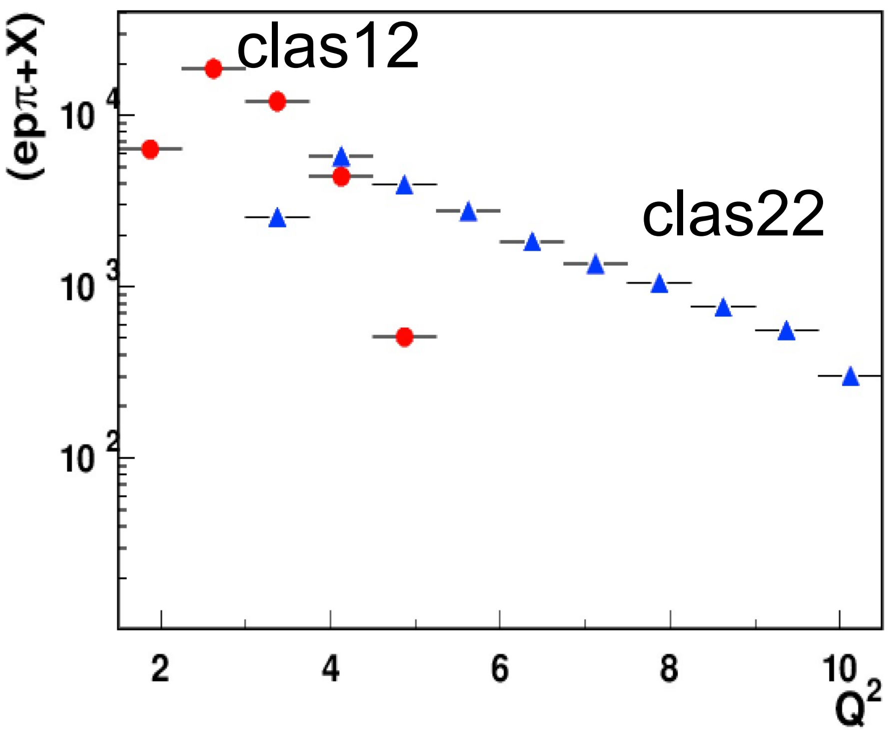
- The counts in a given bin, and the size of the effect will define the expected sensitivity.
- Proper evaluation of systematics, will require definition of fiducial kinematics, and the impact of the multidimensionality
- JLab at 24 GeV will provide critical input in evolution studies of TMDs, increase the P_T coverage
- Higher Q^2-coverage of “Low s” EIC running will provide validation of evolution studies at JLab at large x (will require high luminosity)

Q^2-dependence of the counts: CLAS12 vs CLAS22

Inclusive electrons



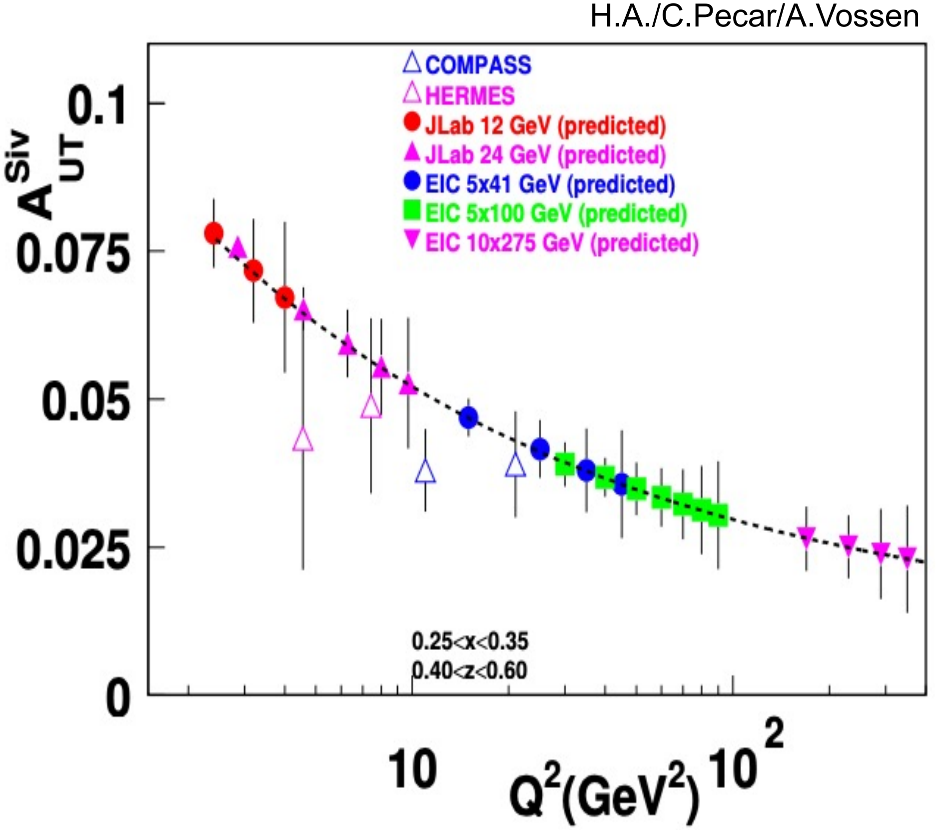
Events reconstructed using the current CLAS12 gemc-coatjava chain

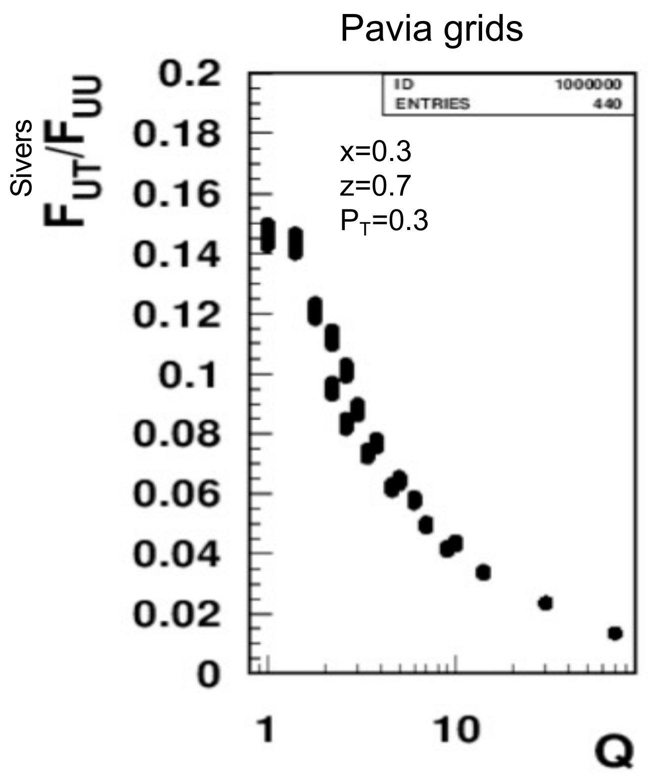


- Measurements of Q^2-dependence of SSAs will be crucial in validation of the theory
- JLab24 will be crucial to provide evolution studies in a wide range

Contributions for 3D structure studies: Sivers

y>0.05,100 days (corrected for EIC official lumi)





- Measurements of Q^2-dependence of SSAs will be crucial in validation of the theory
- JLab24 will be crucial to bridge the TMD studies between JLab12 and EIC in the valence region

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	$\hat{u}_{1T}^h, \hat{u}_{1T}^{\perp}$	$\hat{l}_{1T}^h, \hat{l}_{1T}^{\perp}$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$

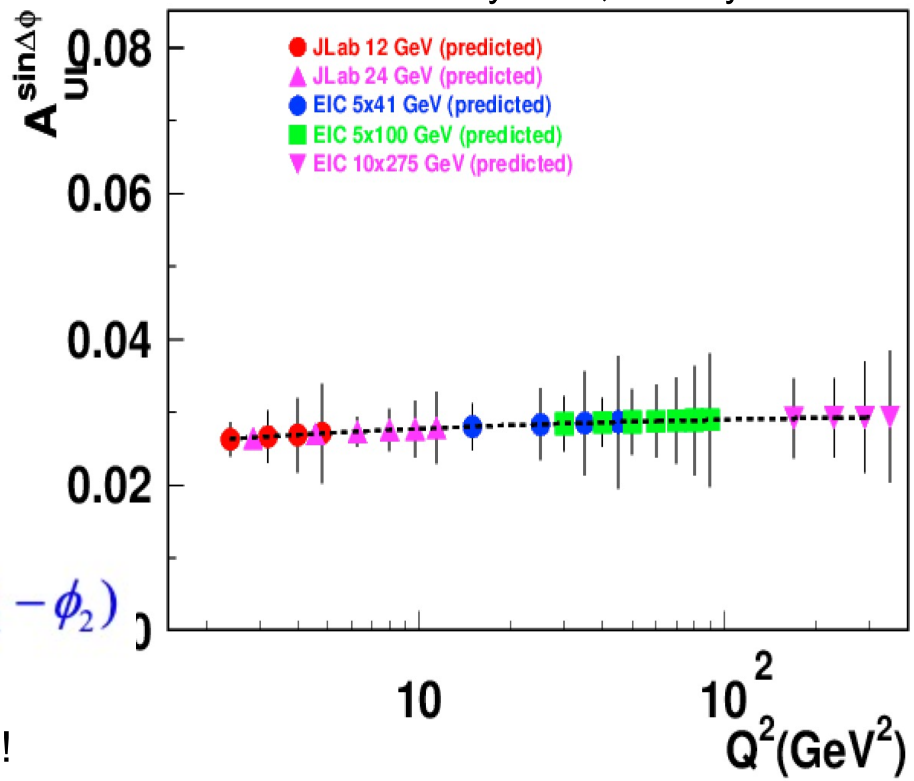
A. Kotzinian, arXiv:1107.2292

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

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

No depolarization, like Sivers!

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



CL AS12 proposals

NH3/ND3
E12-09-009

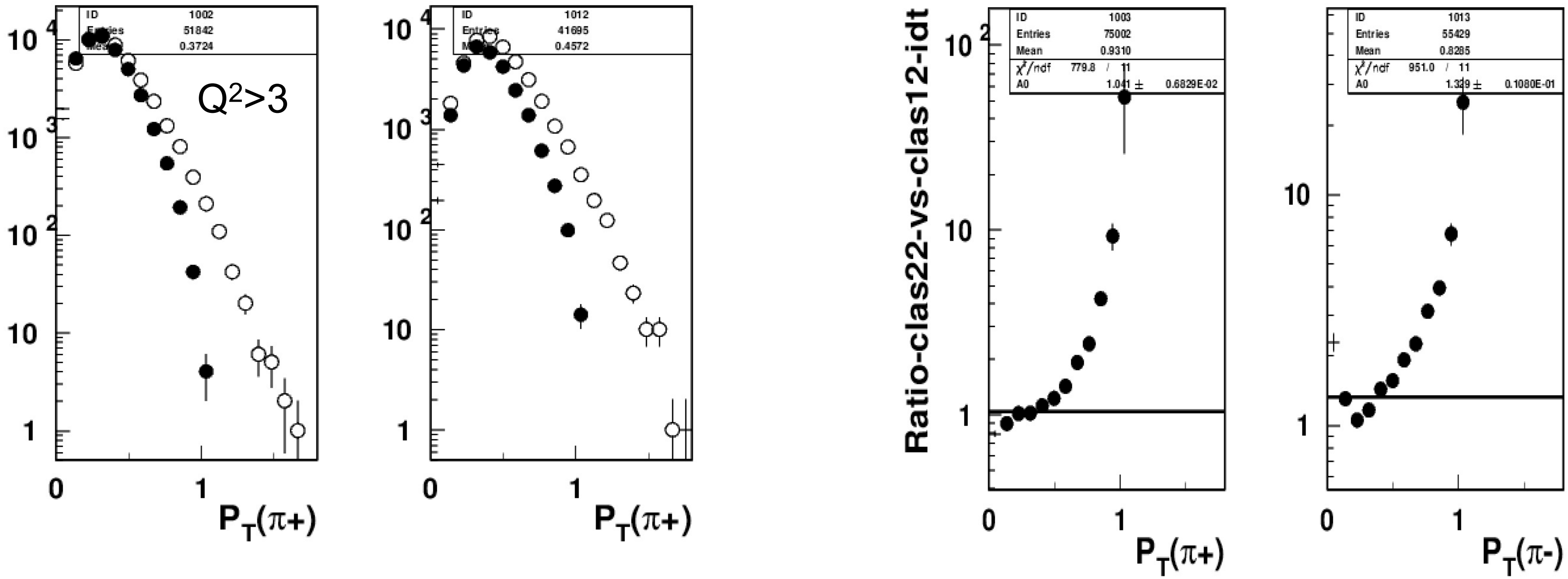
E12-07-107
E12-09-007A

^{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

P_T-dependences: JLab11 vs JLab22



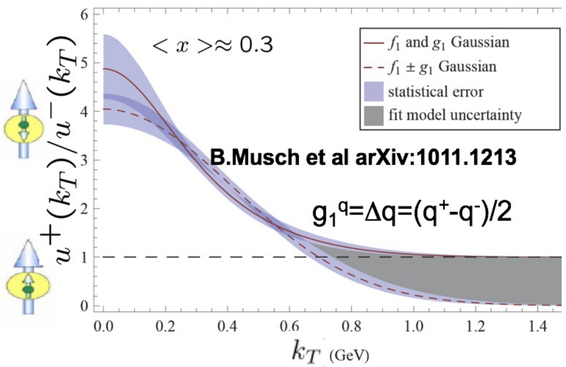
- Large transverse momentum coverage (P_T>0.8)critical for TMD studies
- The same lumi, with e- π+ and π- reconstructed and properly identified in the current CLAS12 detector
- Higher energy provides significant improvements in P_T-coverage

Unknown “known” f_1, g_1 TMDs

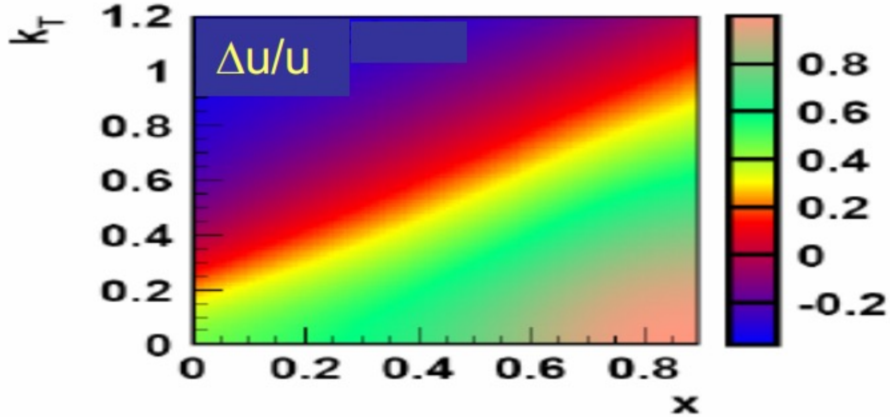
	U	L	T
U	f_1		$h_1^{\perp}$
L		g_{1L}	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	g_{1T}	$h_1, h_{1T}^{\perp}$

$$u^{+}(x,k_T) = f_1^u(x,k_T^2) + g_1^u(x,k_T^2)$$

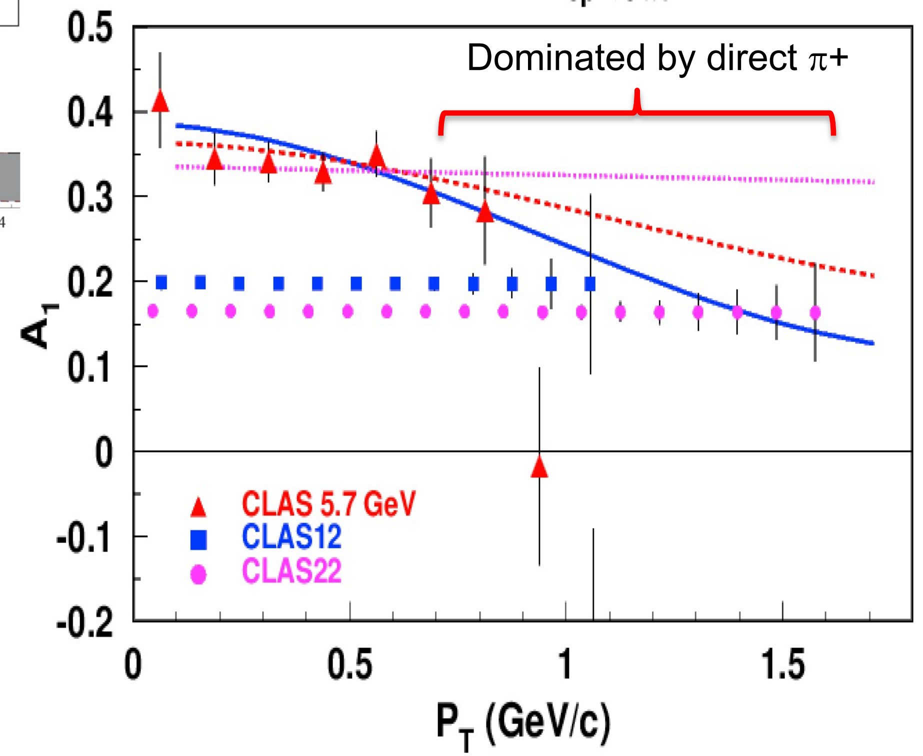
$$u^{-}(x,k_T) = f_1^u(x,k_T^2) - g_1^u(x,k_T^2)$$



(dipole formfactor), J.Ellis, D-S.Hwang, A.Kotzinian



0.25<x<0.35



- Models and lattice predict very significant spin and flavor dependence for TMDs
- Large transverse momenta are crucial to access the large k_T of quarks
- Several CLAS12 proposals dedicated to $g_1(x,k_T)$-studies CLAS12
- Understanding of k_T-dependence of g_1 will help in modeling of f_1

Summary

•Multidimensional measurements of Large Single Spin Asymmetries, performed by CLAS12 experiment, in proton pion production, indicate correlations between hadrons in CFR and TFR can be very significant

•Extending JLab measurements to a wider range in Q^2 and P_T with energy upgrade, will be crucial in studies of evolution properties of underlying PDFs, and separation of higher twist contributions, critical for understanding the QCD dynamics

•New single spin asymmetries sensitive to quark distributions in the longitudinally polarized nucleons at large *x,* have been proposed for studies at EIC and JLab24 (part of CLAS12 program), where the TFR/CFR separation is more clear

•Realistic projections have been performed using the existing CLAS12 software, with the existing CLAS12 acceptance.

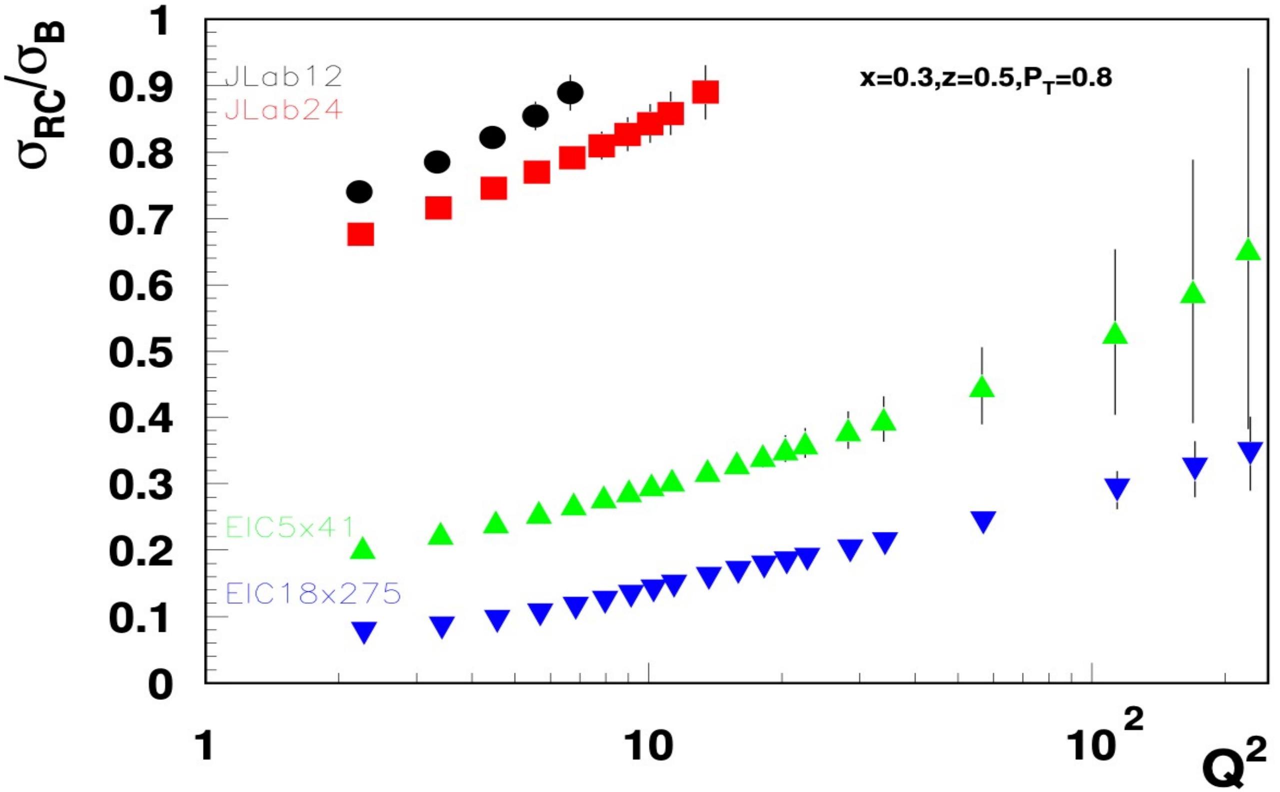
•Proposed measurements with upgraded JLab, will be the part of SIDIS studies in motivating the upgrade (in flagship list).

Support slides

From JLab to EIC: complementarity

The ratio of radiative cross (σ_{RC}) section to Born (σ_B) in SIDIS

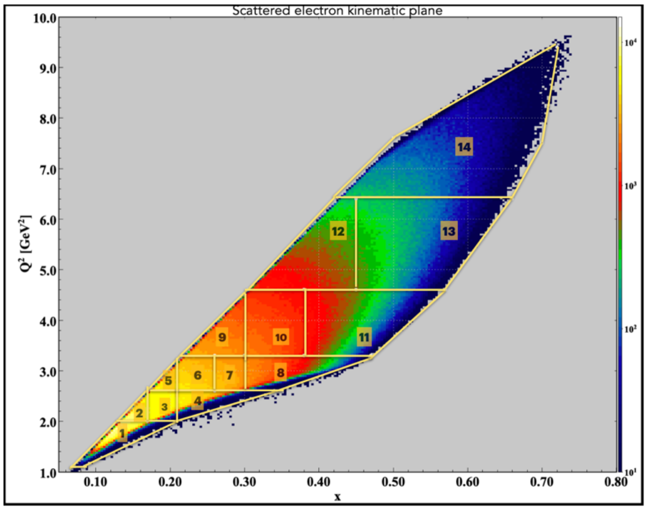
T. Liu et al
JHEP 11 (2021) 157
Gaussian F_{UU} (ϕ_h=0)



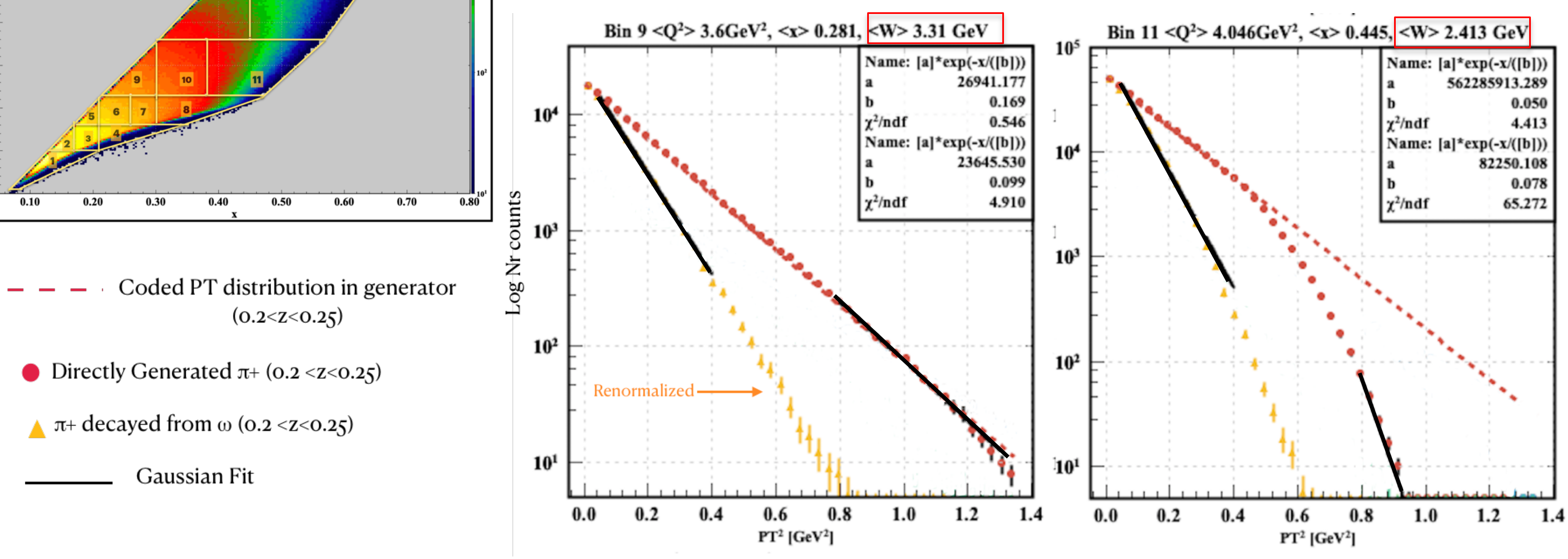
- The radiative effects in SIDIS may be very significant and measurements in multidimensional space at different facilities will be crucial for understanding the systematics in evolution studies.
- Most sensitive to RC will be all kind of azimuthal modulations sensitive to cosines

CLAS12 1h Multiplicities: high P_T & phase space

G.Angelini (Sardinia 2021)

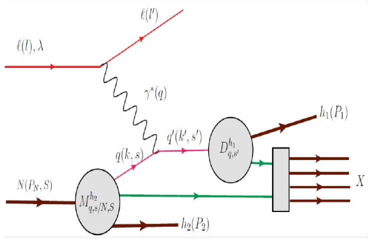


We binned the MC Phase space as for the CLAS12 multiplicity analysis, we used a single hadron generator with PDFs, FFs, and Gaussian Ansatz for transverse momentum and looked at the produced distribution.

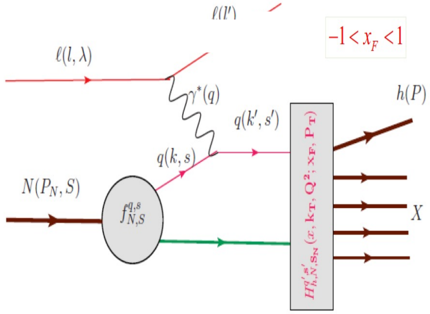


- Phase space limitations for direct pion production more significant at low W, and low z
- Decayed pions have a much steeper P_T distribution at the same z

Hard scattering in e'hX and e'hhX



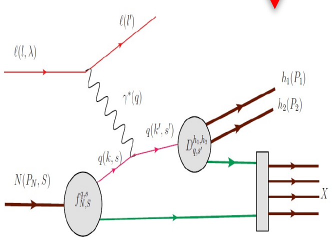
- A single-hadron MC with the SIDIS cross-section where widths of k_T-distributions of pions are extracted from the data is not reproducing well the data.
- LUND fragmentation based MCs were successfully used worldwide from JLab to LHC, showing good agreement with data.

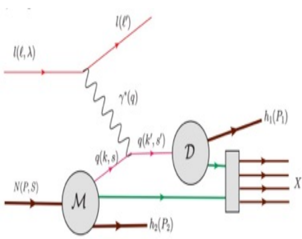


LUND-MCs are more successful in description of hard scattering processes, and SIDIS in the first place.

subsamples

- The hadronization into different hadrons, in particular Vector Mesons is accounted (full kinematics)
- Accessible phase space properly accounted
- The correlations between hadrons, as well a as target and current fragments accounted
- ….





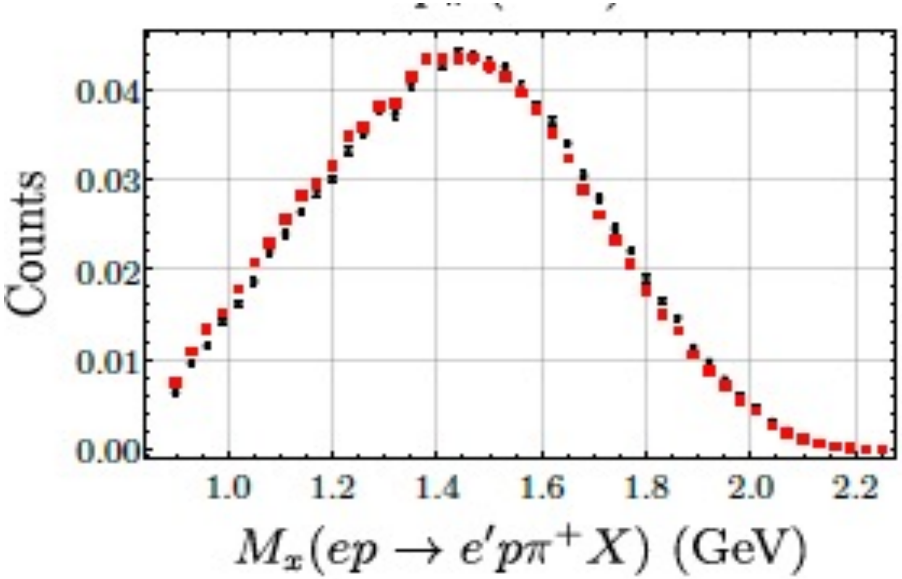
To understand the measurements we should be able to simulate, at least the basic features we are trying to study (P_T and Q^2,-dependences in particular)

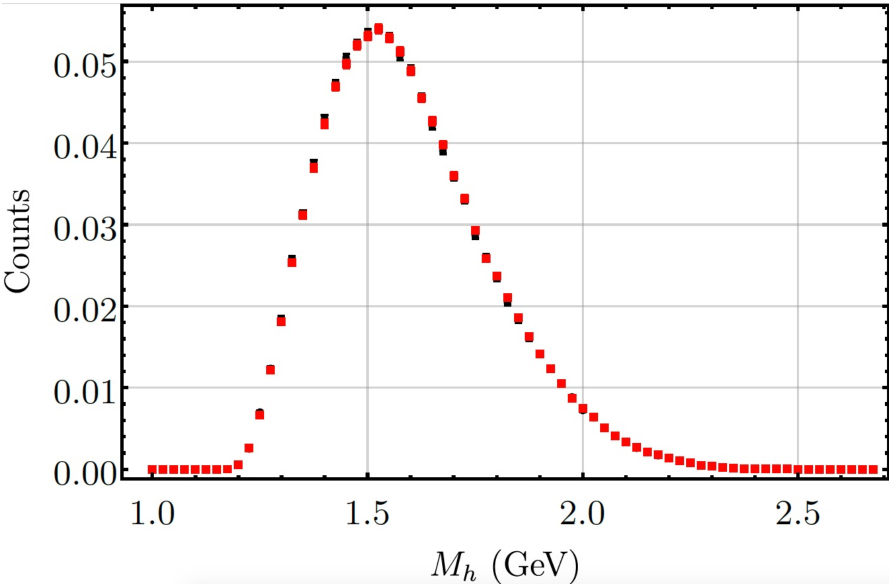
The studies of correlated hadron pairs in SIDIS may be a key for proper interpretation !!!

Protion-pion distributions from data

Missing mass of e’pπ+X

Invariant mass of pπ+system

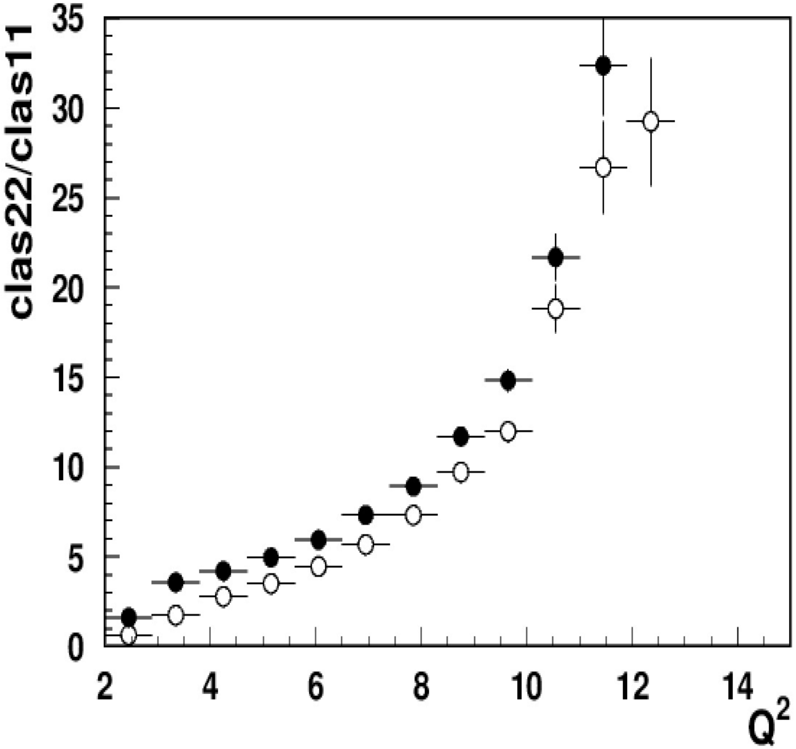




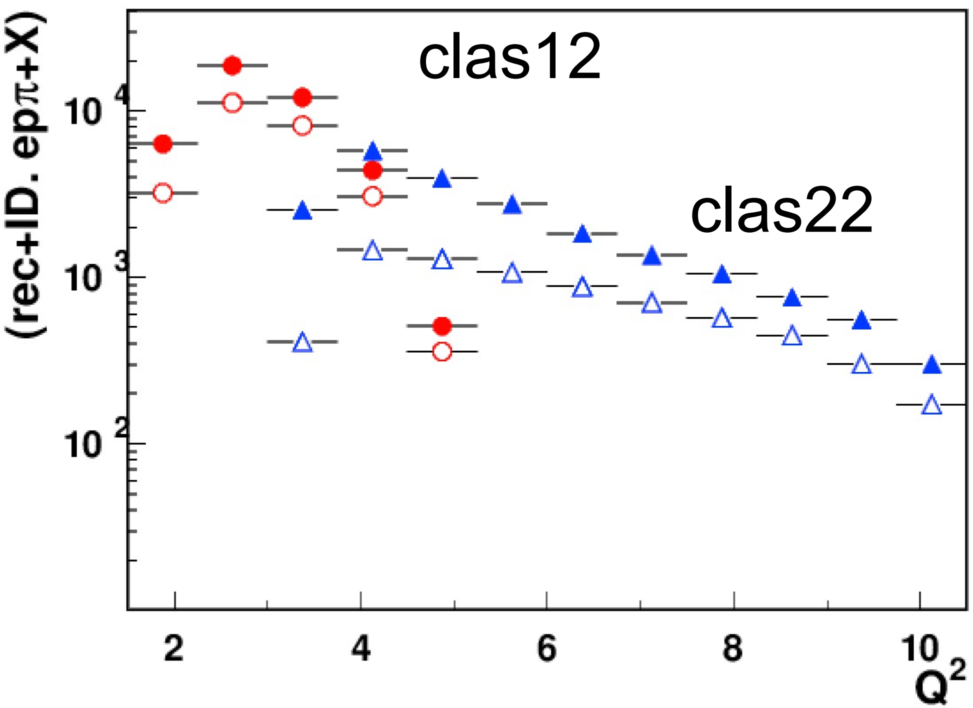
- Asymmetries were extracted in the full range of available missing masses, and invariant masses, and no significant variations were observed
- No indication of any specific channels (ex. Delta++) in the sample

Q^2-dependence of the counts

Inclusive electrons



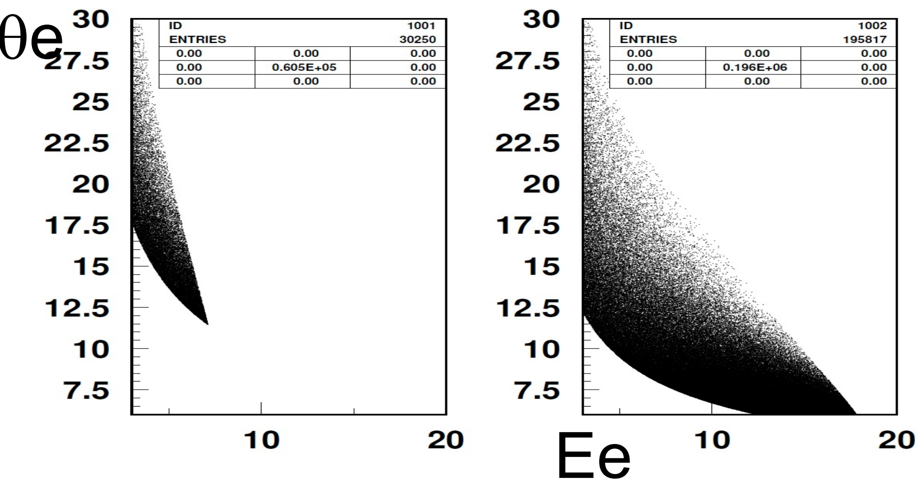
Events reconstructed using the current CLAS12 gemc-coatjava chain

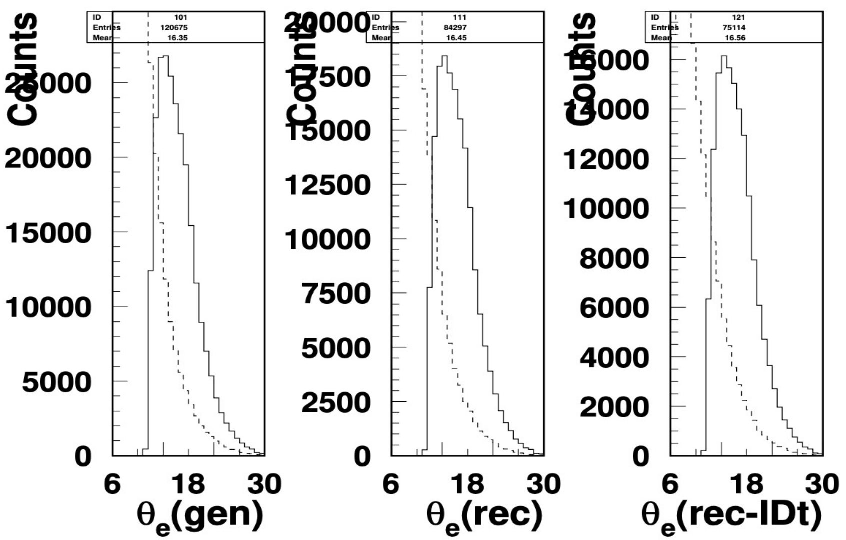


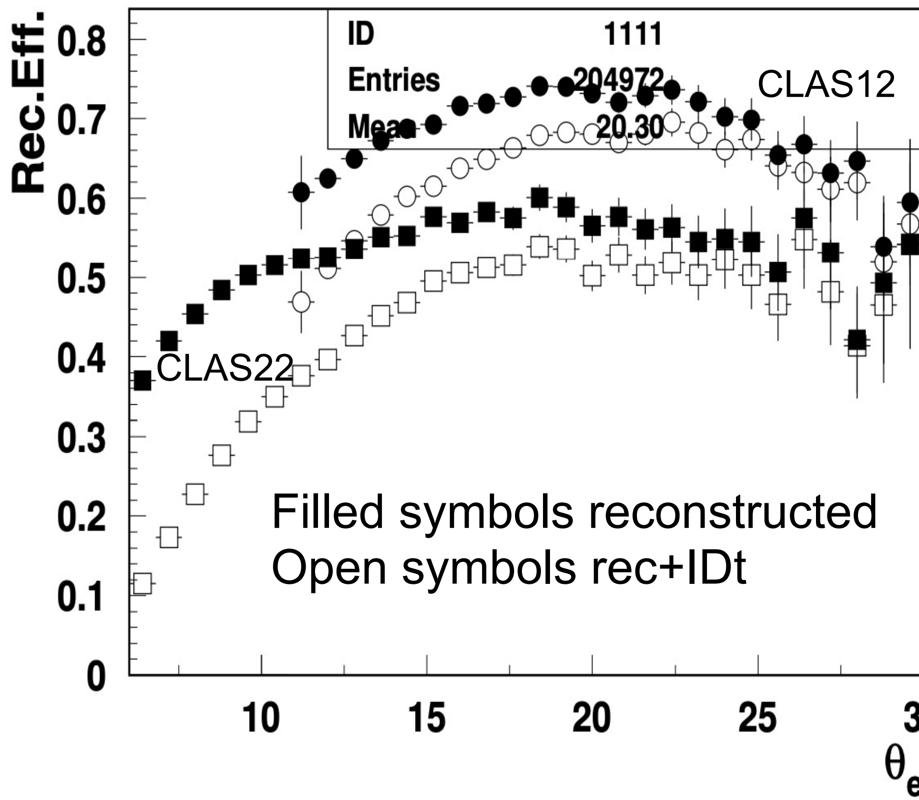
- Measurements of Q^2-dependence of SSAs will be crucial in validation of the theory
- JLab24 will be crucial to provide evolution studies in a wide range

Comparing clas12 and clas22

Electrons for $Q^2>3$



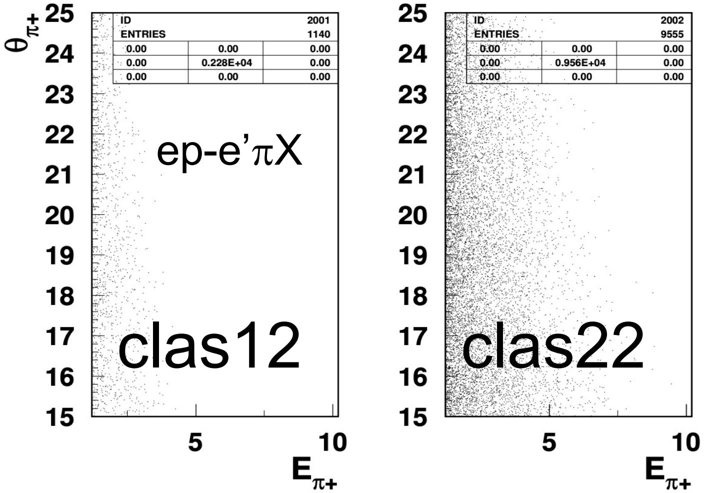


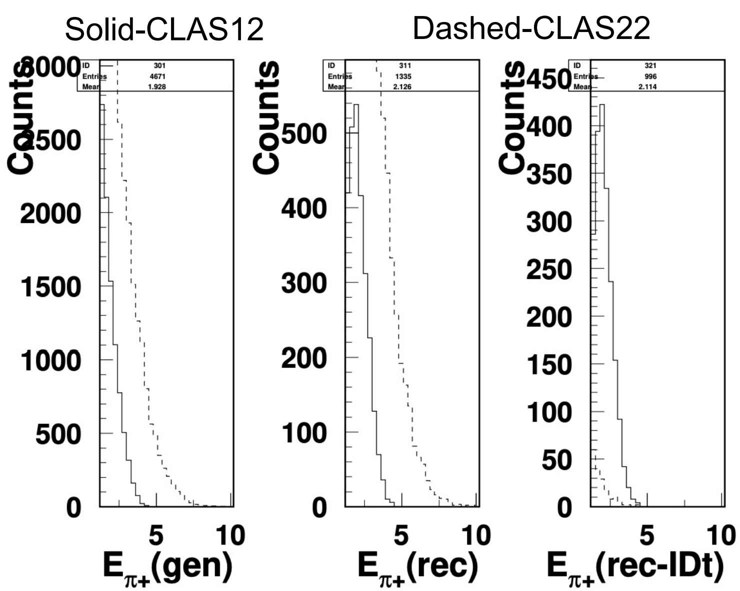


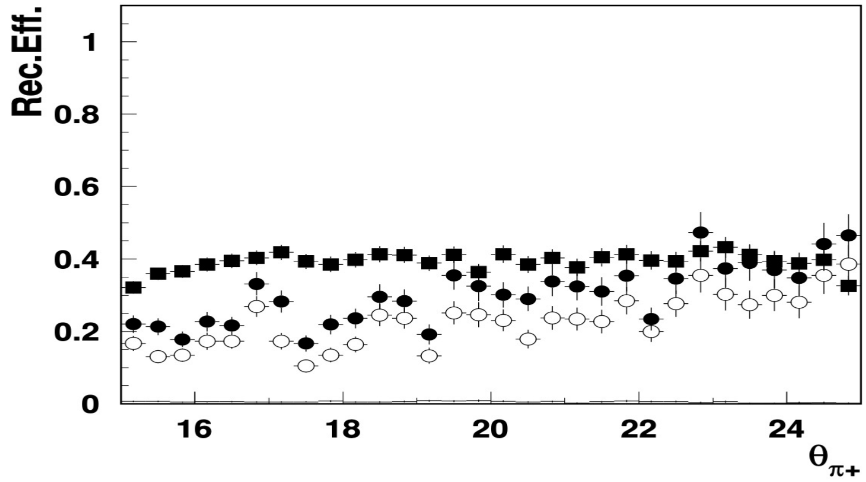
Most events at smaller angles,
Still rates much higher
Need to improve ID

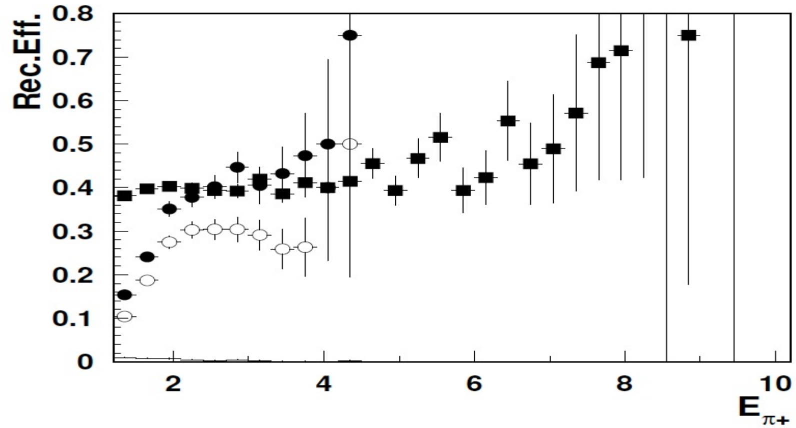
Comparing clas12 and clas22

ep-e'πX









Reconstructed events more in full angular and momentum range

Need to improve ID

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

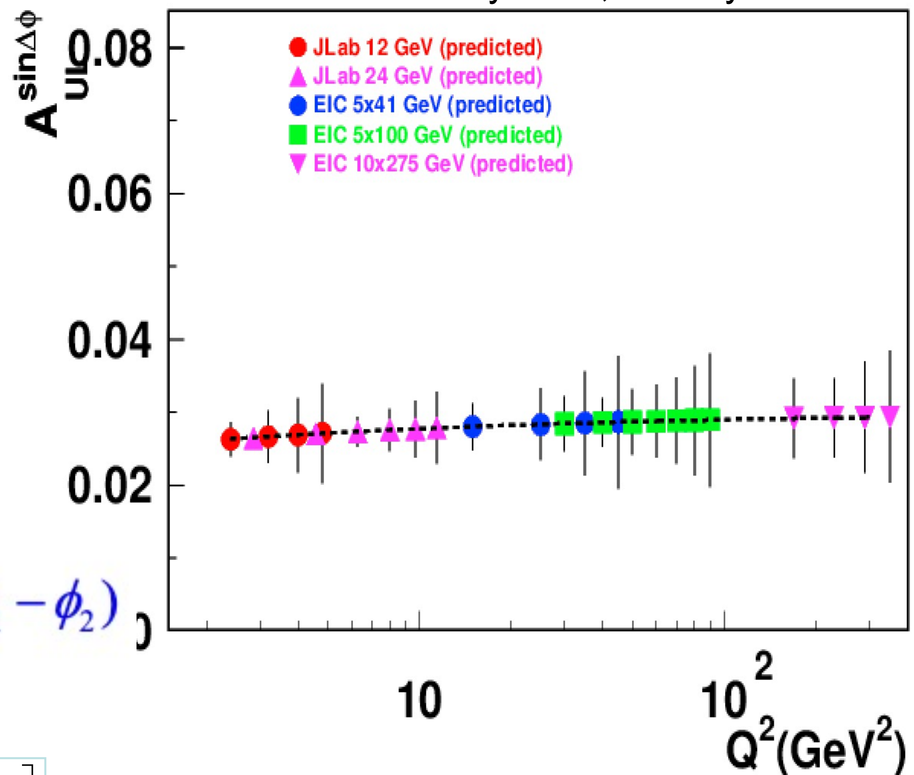
$$\sigma_{UU} = F_0^{\hat{u}\cdot D_1}$$

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

No depolarization, like Sivers!

$$F_{k1}^{\hat{M}\cdot D} = C\left[\hat{M}\cdot D\,\frac{(\mathbf{P}_{T1}\cdot\mathbf{P}_{T2})(\mathbf{P}_{T2}\cdot\mathbf{k}) - (\mathbf{P}_{T1}\cdot\mathbf{k})\mathbf{P}_{T2}^2}{(\mathbf{P}_{T1}\cdot\mathbf{P}_{T2})^2 - \mathbf{P}_{T1}^2\mathbf{P}_{T2}^2}\right]$$

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

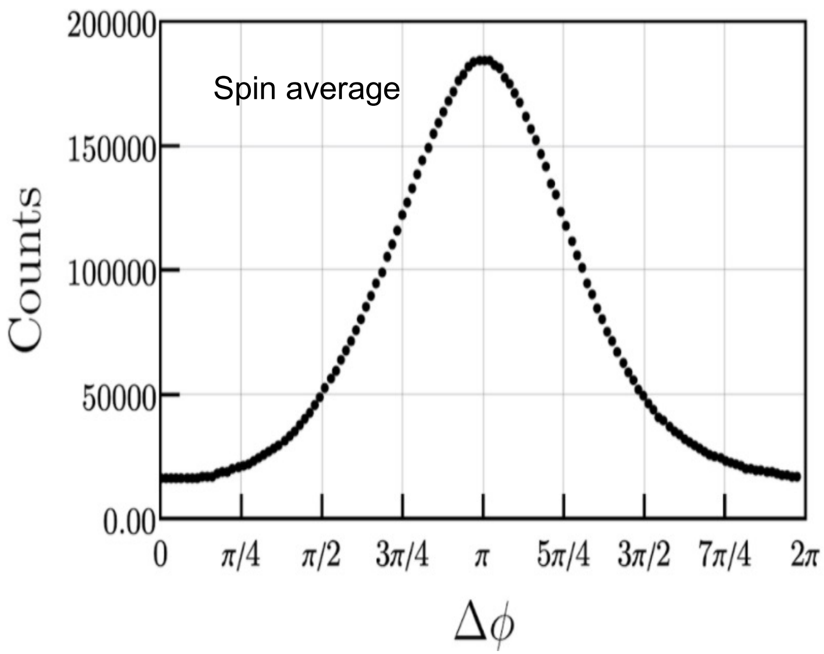
E12-14-001

- Target SSA can be measured in the full Q^2 range, combining different facilities
- JLab24 will be crucial to bridge the studies of FFs between JLab12 and EIC in the valence region

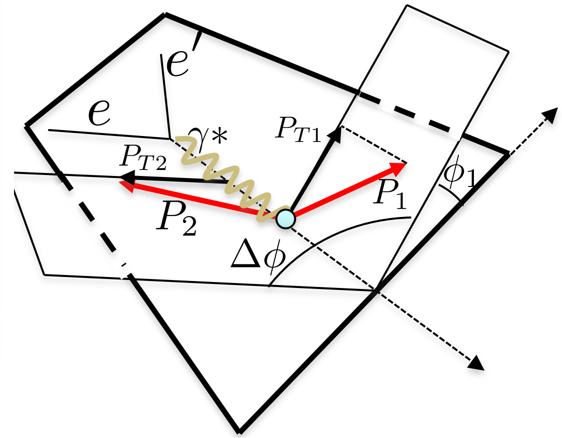
Correlations in 2 hadron production

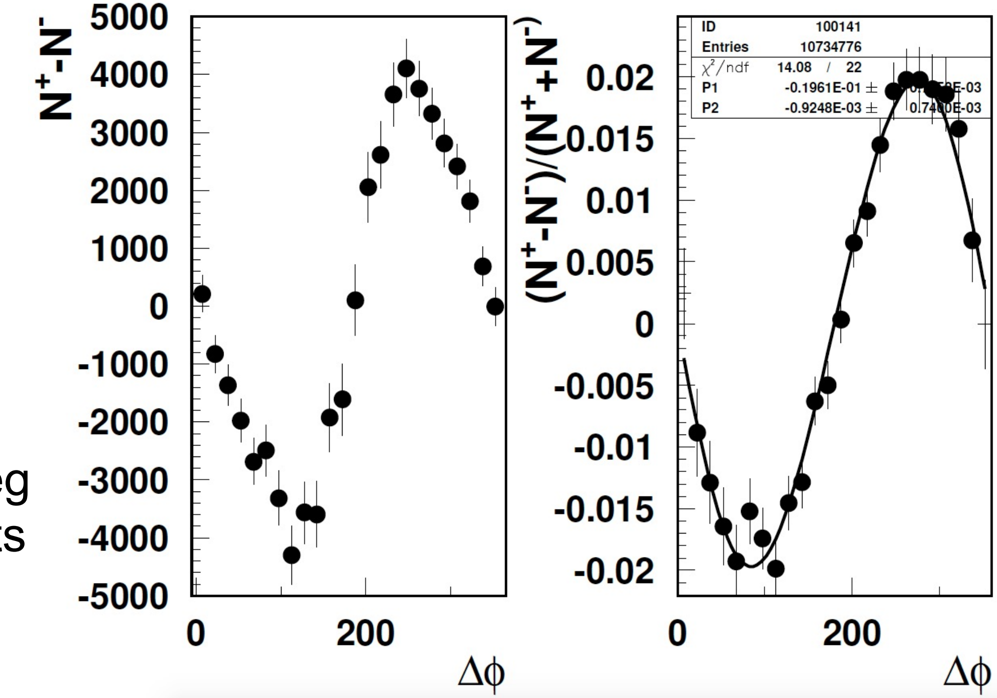
M. Anselmino, V. Barone and A. Kotzinian,
Physics Letters B 713 (2012)

$$\mathcal{A}_{LU} = -\sqrt{1-\epsilon^2}\,\frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}}\,\sin\Delta\phi$$



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	$\hat{u}_{1T}^h, \hat{u}_{1T}^\perp$	$\hat{l}_{1T}^h, \hat{l}_{1T}^\perp$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$

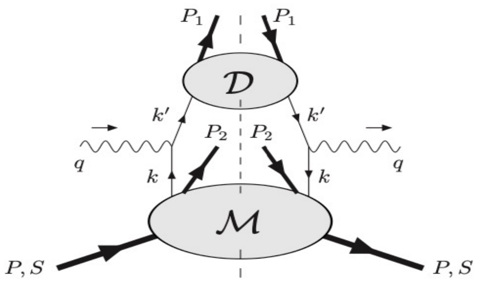


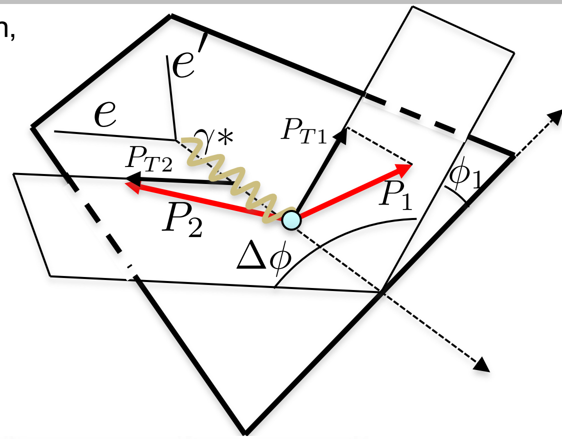


- Distributions in Δϕ peak around 180 deg
- Strong sinϕ and a minor sin2ϕ moments the full range of accessible transverse momenta

Correlations in 2 hadron production

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

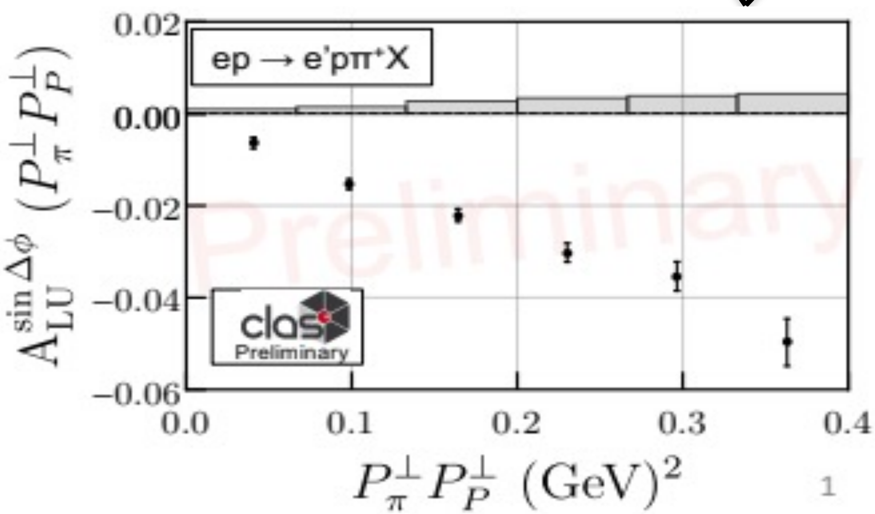


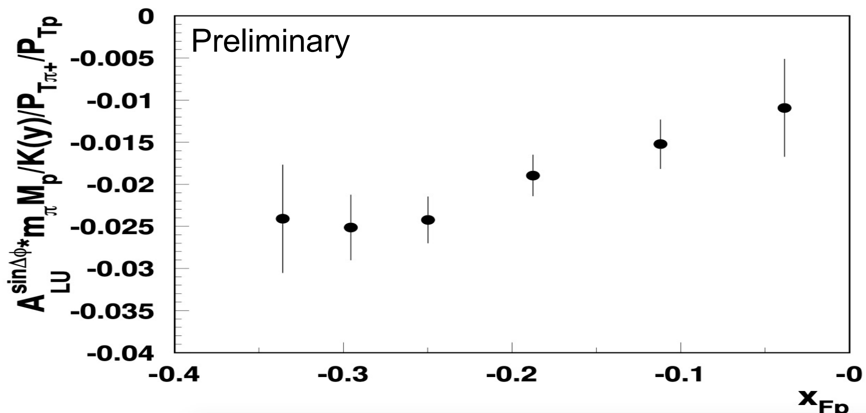


$$A_{LU} = -\frac{y\left(1-\frac{y}{2}\right)}{\left(1-y+\frac{y^2}{2}\right)} \frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}} \sin\Delta\phi$$

$$= -\frac{|\mathbf{P}_{1\perp}||\mathbf{P}_{2\perp}|}{m_N m_2} \frac{y\left(1-\frac{y}{2}\right)}{\left(1-y+\frac{y^2}{2}\right)}$$

correlation $\times \frac{\mathcal{C}[w_5\, \hat{l}_1^{\perp h} D_1]}{\mathcal{C}[\hat{u}_1 D_1]} \sin\Delta\phi,$ modulation





SSA increasing in TFR

- Spin-azimuthal correlations in hadron pair production in CFR and TFR are very significant
- The correlation is most significant at large x, where the valence quarks most significant
- The beam SSA is suppressed at small y, and will be challenging in EIC kinematics
- Phase space accessible at JLab24 would allow the coverage in much wider PT, and rapidity

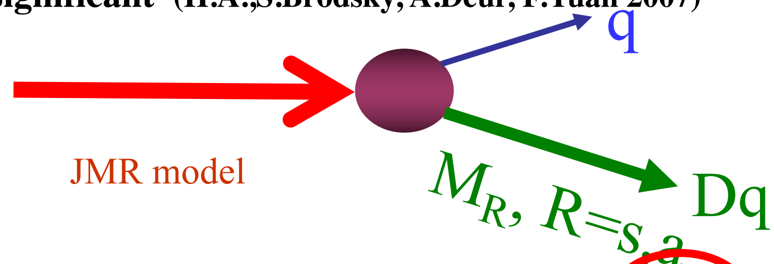
Unknown “known” f_1, g_1 TMDs

$u^{+}(x,k_T) = f_1^u(x,k_T^2) + g_1^u(x,k_T^2)$

$u^{-}(x,k_T) = f_1^u(x,k_T^2) - g_1^u(x,k_T^2)$

	U	L	T
U	f_1		$h_1^\perp$
L		g_{1L}	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$h_1, h_{1T}^\perp$

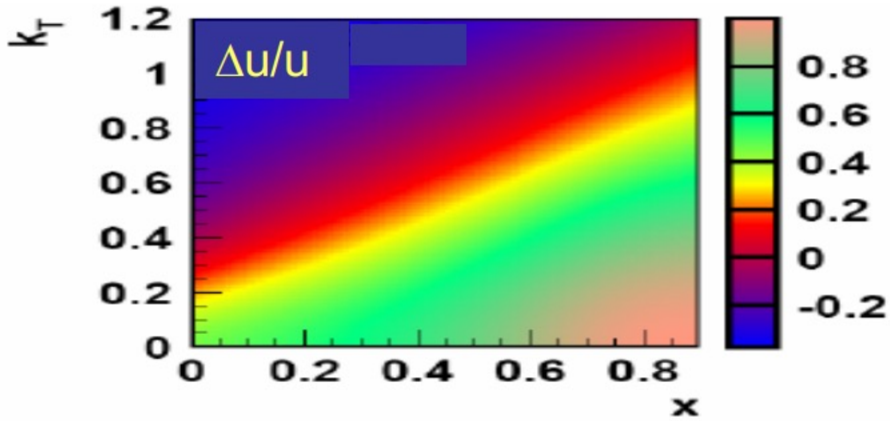
Effect of the orbital motion on the q- may be significant (H.A.,S.Brodsky, A.Deur, F.Yuan 2007)

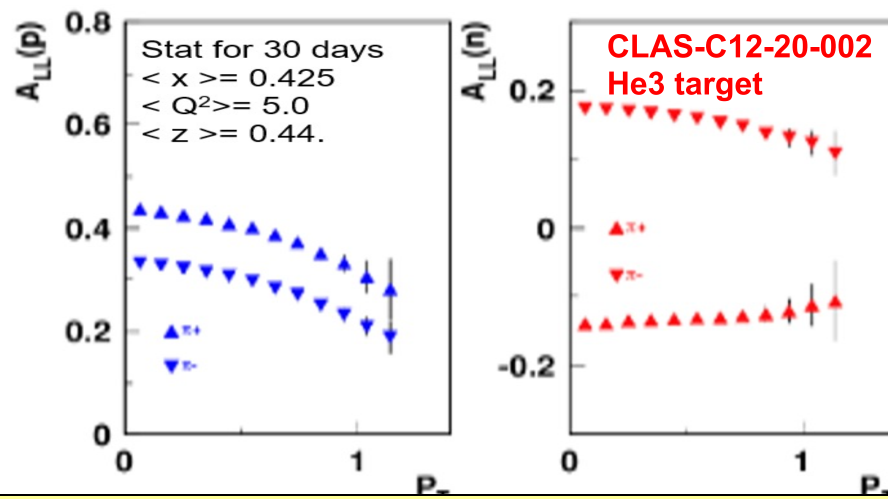


$$f_1(x, \mathbf{k}_T^2) = A \frac{(xM+m)^2 + \mathbf{k}_T^2}{(\mathbf{k}_T^2 + \lambda_R^2)^{2\alpha}},$$

$$g_1(x, \mathbf{k}_T^2) = A \frac{(xM+m)^2 - \mathbf{k}_T^2}{(\mathbf{k}_T^2 + \lambda_R^2)^{2\alpha}},$$

(dipole formfactor), J.Ellis, D-S.Hwang, A.Kotzinian





Models and lattice predict very significant spin and flavor dependence for TMDs
Large transverse momenta are crucial to access the large k_T of quarks
A dedicated to g1(x,k_T)-studies CLAS12 proposal with He3 target approved by PAC

CLAS12 Studies: Data vs MC

T.Hayward

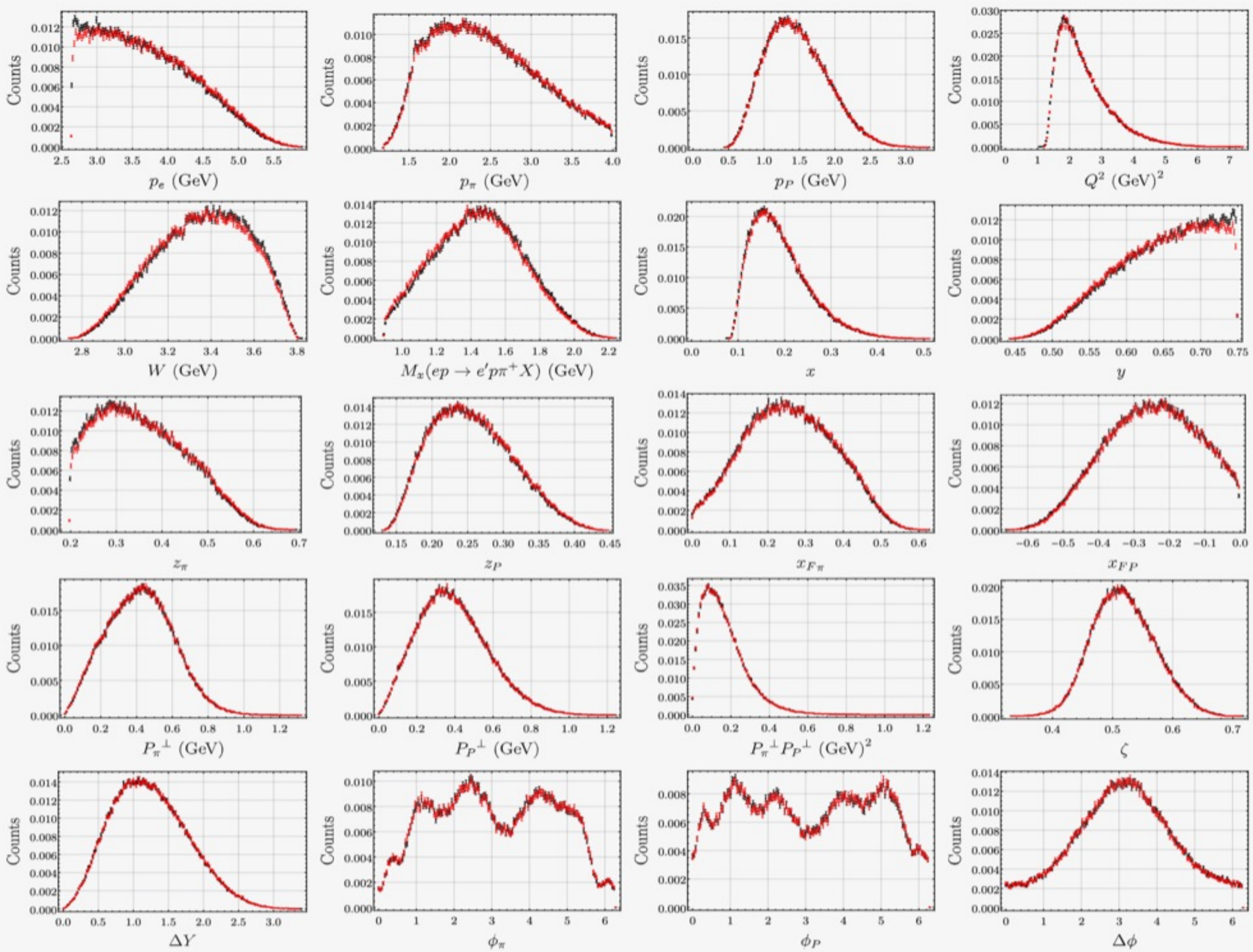


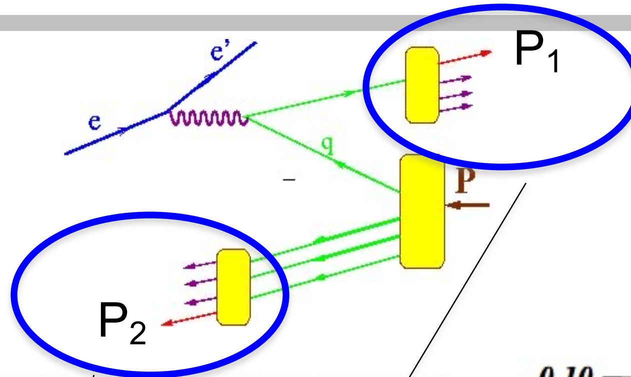
FIG. 41: Comparison between the Monte Carlo (red) and data (black). From left to right and top to bottom they are p_e, p_π, p_P, Q^2, W, M_x, x, y, z_π, z_P, $x_{F\pi}$, x_{FP}, $P_\pi^\perp$, $P_P^\perp$, $P_\pi^\perp P_P^\perp$, ζ, ΔY, ϕ_π, ϕ_P, $\Delta\phi$.

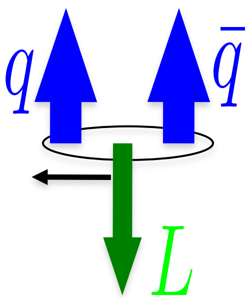
Good agreement for all relevant kinematical variables for

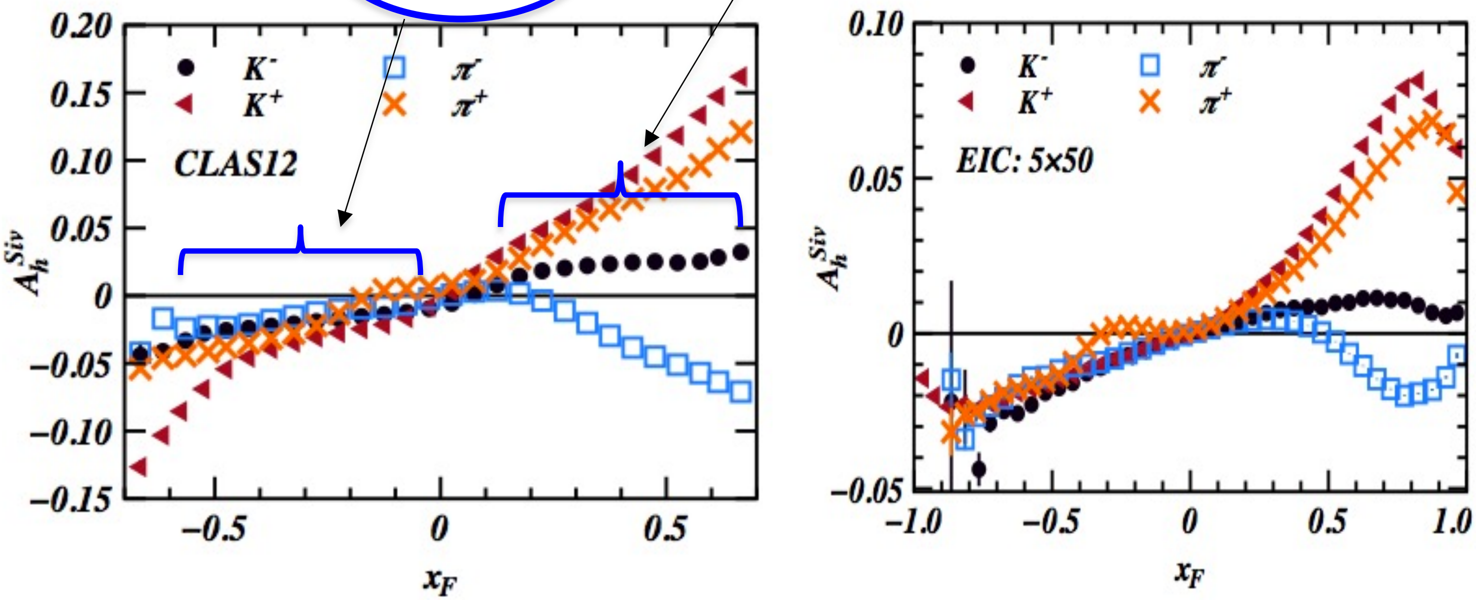
ep→e'pπX

Target fragmentation: Sivers effect

H. Matevosyan et al.
arXiv:1502.02669







Wide coverage of CLAS12/24 and EIC will allow studies of kinematic dependences of the Sivers effect, both in current and target fragmentation regions