Correlations in back-to-back hadron production in SIDIS

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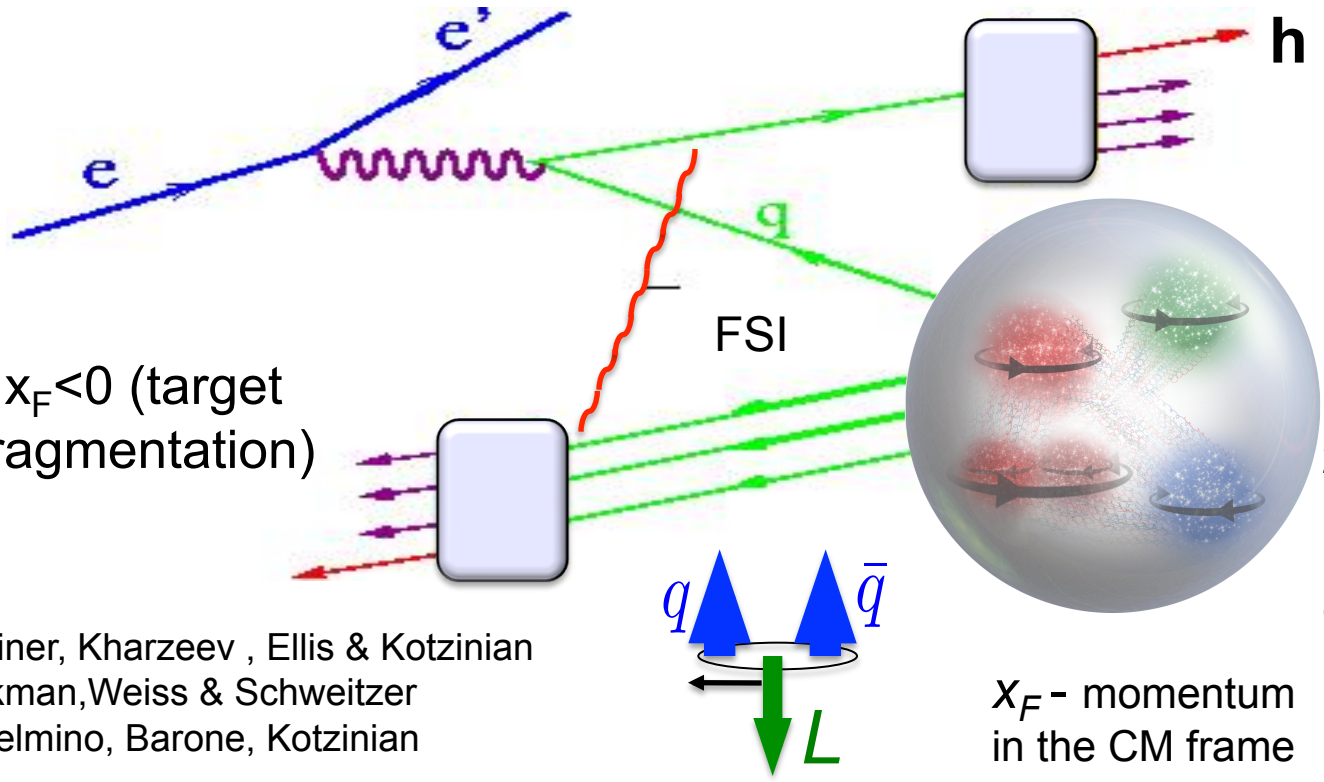
Outline

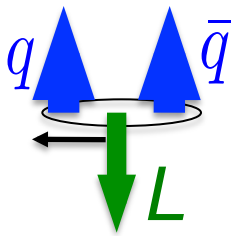
- Transverse Momentum in Hadron Production
- Non perturbative sea and k_T-distributions
- Accessing spin-orbit correlations in di-hadron production
- Back to back production of hadrons in SIDIS

Hadron production in hard scattering



x_F>0 (current fragmentation)

X. Artru & Z. Belghobsi



x_F<0 (target fragmentation)

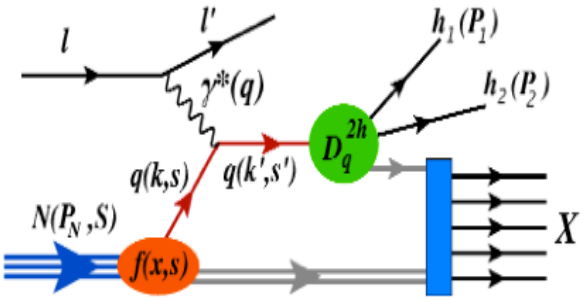
2-hadron correlations in CFR studied in EMC(1986) and COMPASS(2015)

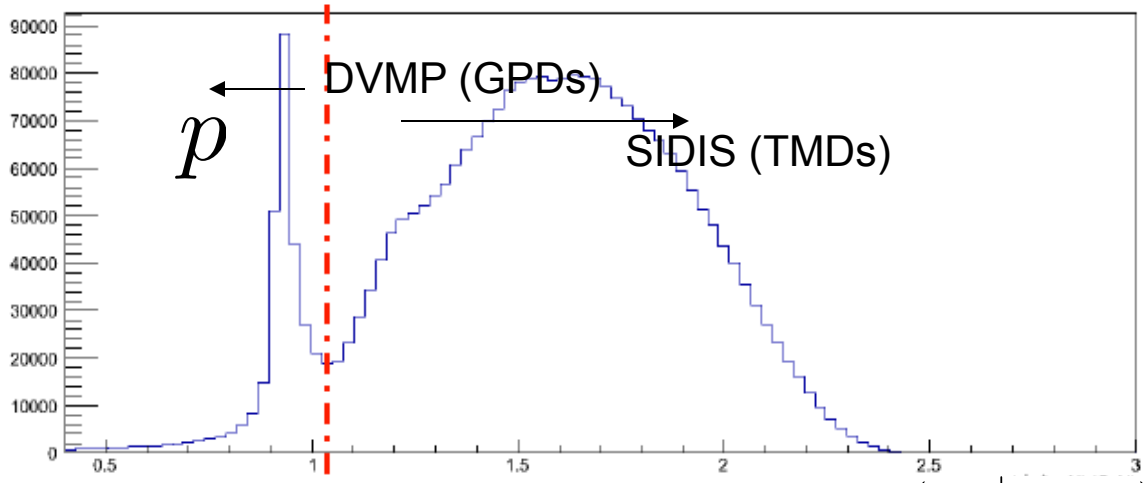
Karliner, Kharzeev , Ellis & Kotzinian
Strikman,Weiss & Schweitzer
Anselmino, Barone, Kotzinian

x_F - momentum in the CM frame

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

Dihadron asymmetries from CLAS





$$\frac{F_{LL}}{F_{UU}} \sim \frac{g_1(x)}{f_1(x)}$$

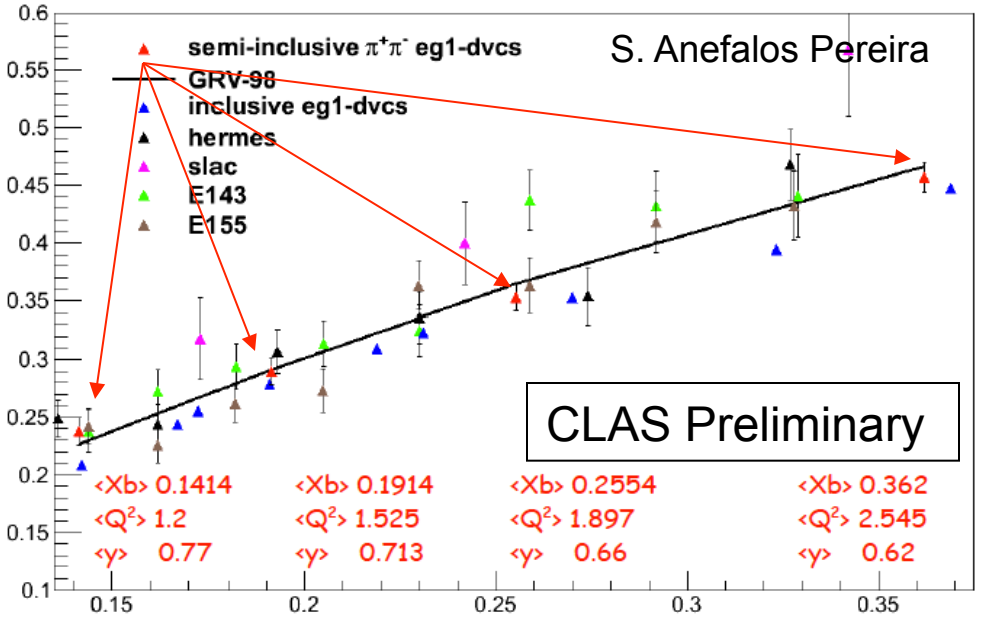
$$F_{UU,T} = x f_1^q(x)\, D_1^q\left(z, \cos\theta, M_h\right)$$

$$F_{LL} = x g_1^q(x)\, D_1^q\left(z, \cos\theta, M_h\right)$$

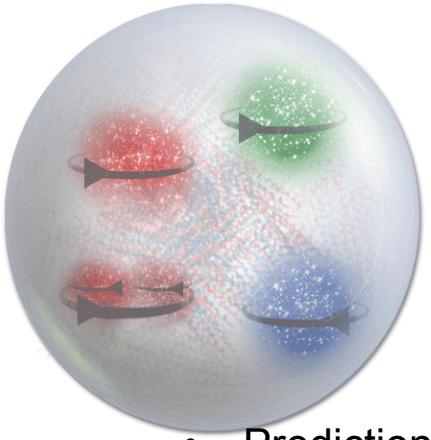
$$D_1^{u\to\pi+\pi-} \approx D_1^{d\to\pi+\pi-}$$

Dihadron double spin asymmetry measured at 6 GeV consistent with DIS

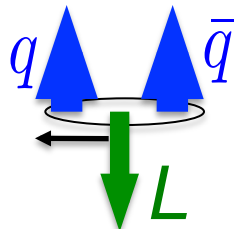
$\frac{g_1(x)}{f_1(x)}$



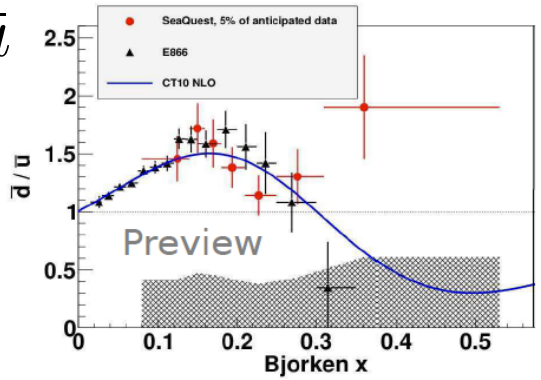
Features of partonic 3D non-perturbative distributions



Non-perturbative sea in nucleon is a key to understand the nucleon structure



Large flavor asymmetry as evidence $\bar{d} > \bar{u}$

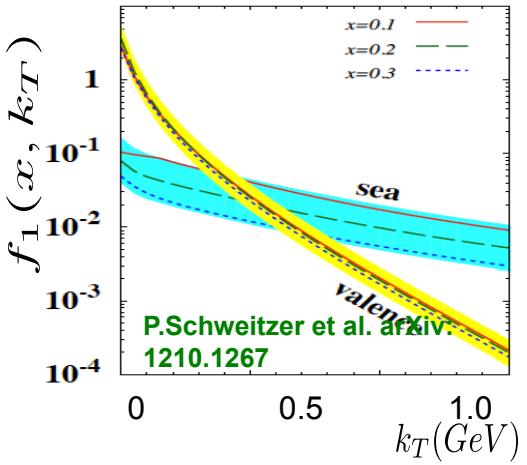


- Predictions from dynamical model of chiral symmetry breaking [Schweitzer, Strikman, Weiss JHEP 1301 (2013) 163]

  -- k_T (sea) >> k_T (valence)

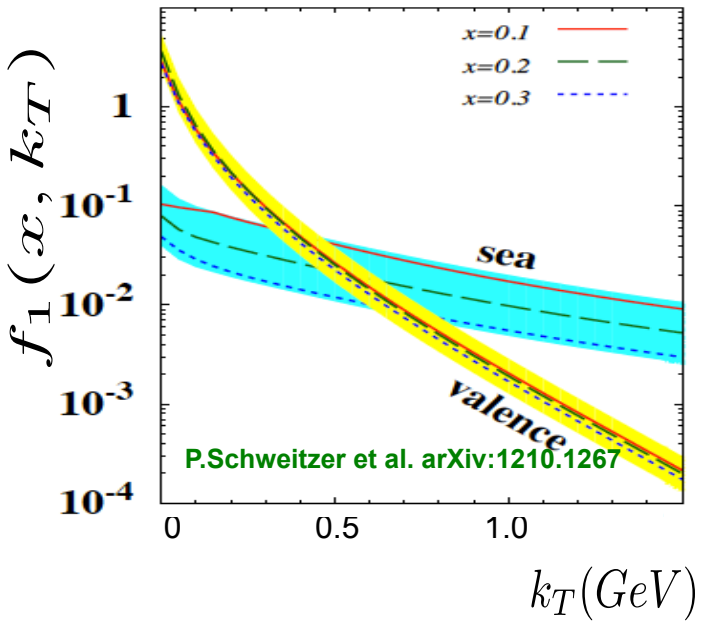
  -- short-range correlations between partons (small-size q-qbar pairs)

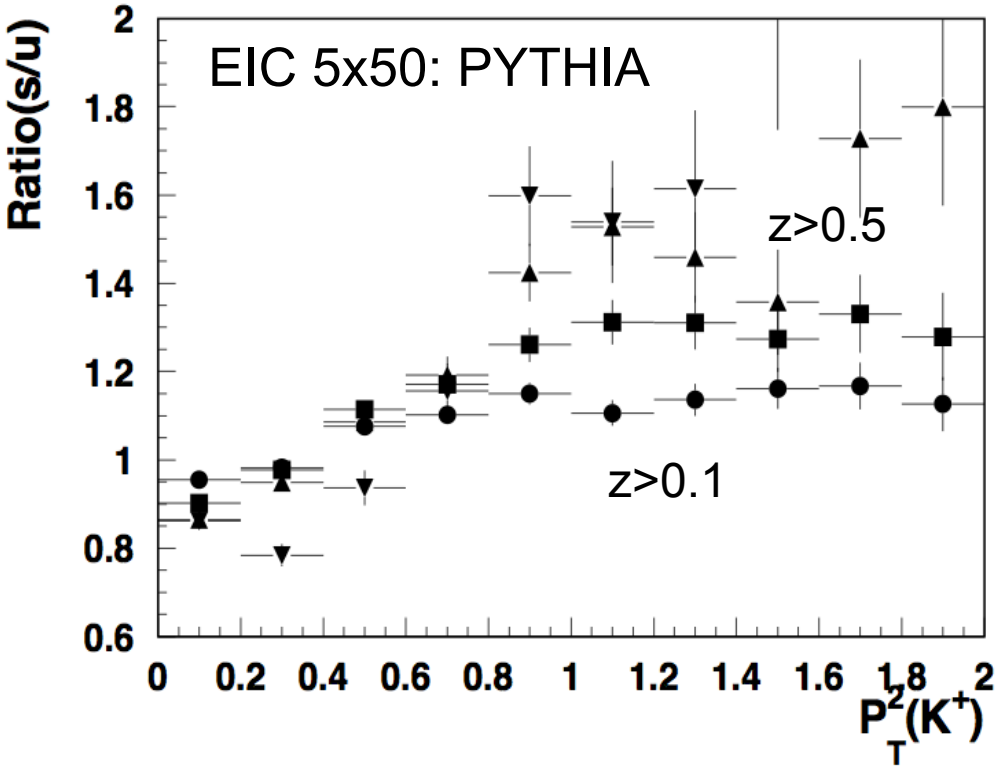
  -- directly observable in P_T-dependence of hadrons in SIDIS



- spin and momentum of struck quarks are correlated with remnant
- correlations of spins of q-q-bar with valence quark spin and transverse momentum will lead to observable effects

P_T-distributions of Kaons from s and u quarks



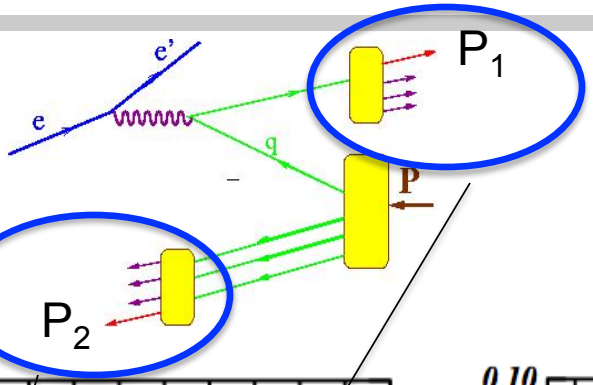


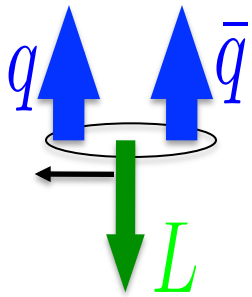
Increase the $<k_T>$ in PYTHIA
(no orbital effects accounted)

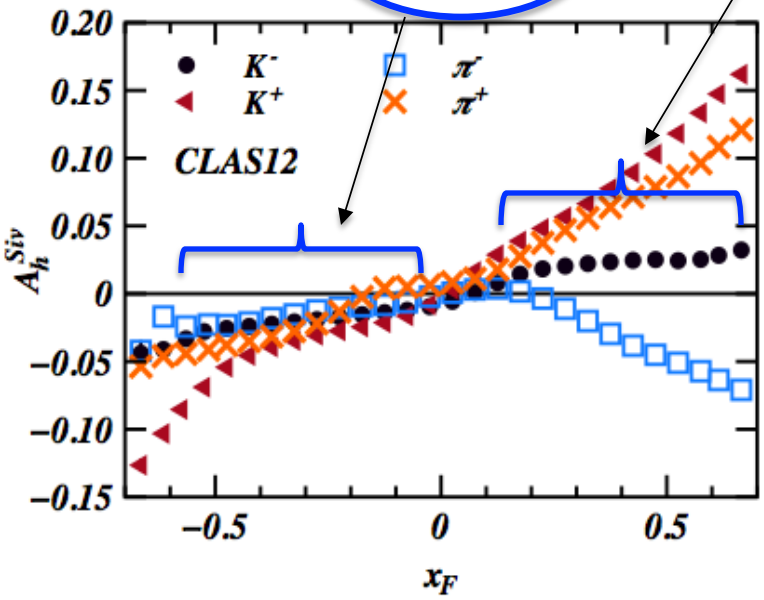
- At relatively large x (x>0.01), where non perturbative sea start to dominate significant fraction of Kaons may come from s-quarks
- Additional control possible by detection of target fragments

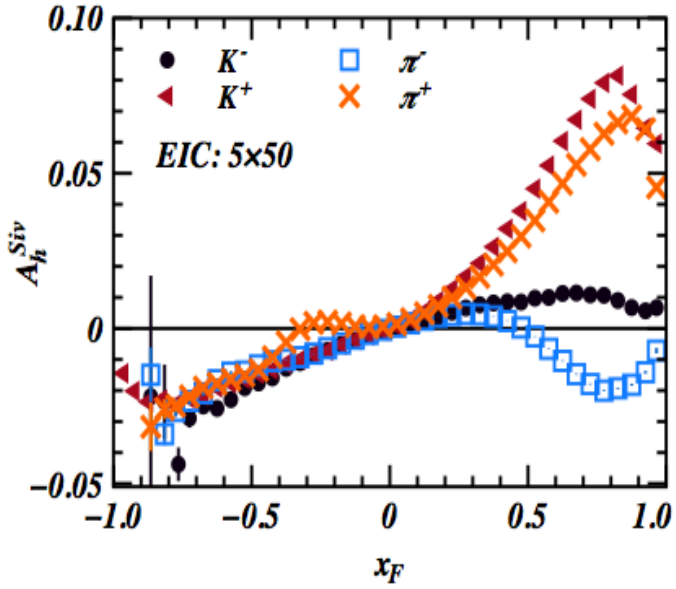
Target fragmentation: Sivers effect

H. Matevosyan et al.
arXiv:1502.02669



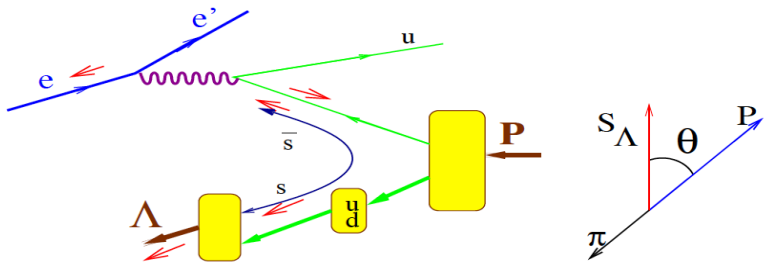


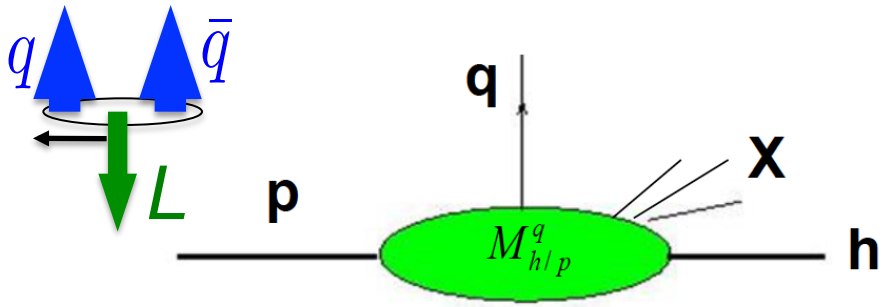




Wide coverage of CLAS12 and EIC will allow studies of kinematic dependences of the Sivers effect, both in current and target fragmentation regions

Target fragmentation region: Λ production





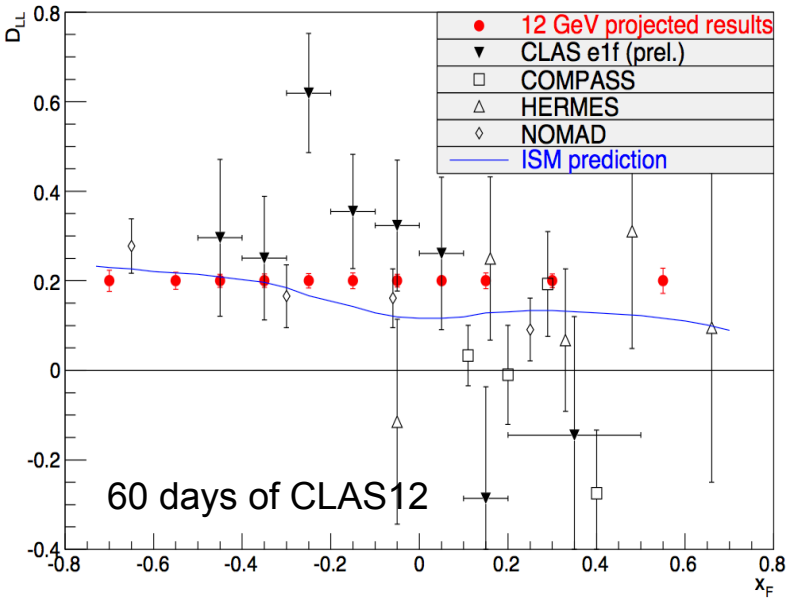
probability to produce the hadron h when a quark q is struck in a proton target

Measurements of fracture functions opens a new avenue in studies of the structure of the nucleon in general and correlations between current and target fragmentation in particular

$$A_{LUL}^{TFR} = hS_{\parallel}\frac{y\left(1-\frac{y}{2}\right)\sum_a e_a^2 \Delta M^L}{\left(1-y+\frac{y^2}{2}\right)\sum_a e_a^2 M}$$

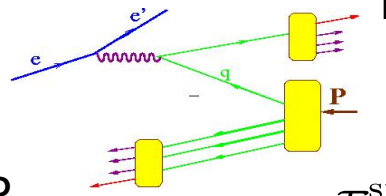
$$D^{LL} = \frac{\sum_a e_a^2 \Delta M^L}{\sum_a e_a^2 M}$$

polarization transfer coefficient



- Large acceptance of CLAS12 and EIC provide a unique possibility to study the nucleon structure in target fragmentation region
- First measurements already performed using the CLAS data at 6 GeV.

Back-to-back hadron (b2b) production in SIDIS



P_1

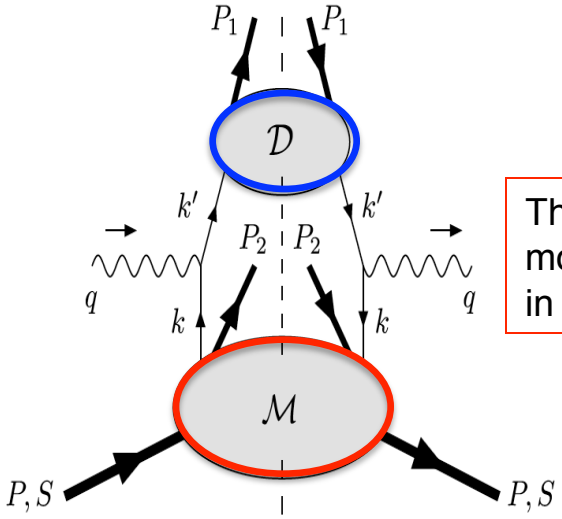
P_2

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

$$\mathcal{F}_{LU}^{\sin(\phi_1-\phi_2)} = \frac{|\vec{P}_{1\perp}\vec{P}_{2\perp}|}{m_N m_2}\mathcal{C}[w_5 M_L^{\perp,h} D_1]$$

Leading Twist

	U	L	T
U	M	$M_L^{\perp,h}$	$M_T^h, M_T^\perp$
L	$\Delta M^{\perp,h}$	ΔM_L	$\Delta M_T^h, \Delta M_T^\perp$
T	$\Delta_T M_T^h, \Delta_T M_T^\perp$	$\Delta_T M_L^h$ $\Delta_T M_L^\perp$	$\Delta_T M_T, \Delta_T M_T^{hh}$ $\Delta_T M_T^{\perp\perp}, \Delta_T M_T^{\perp h}$



The beam–spin asymmetry appears, at leading twist and low transverse momenta, in the deep inelastic inclusive lepto-production of two hadrons, one in the target fragmentation region and one in the current fragmentation region.

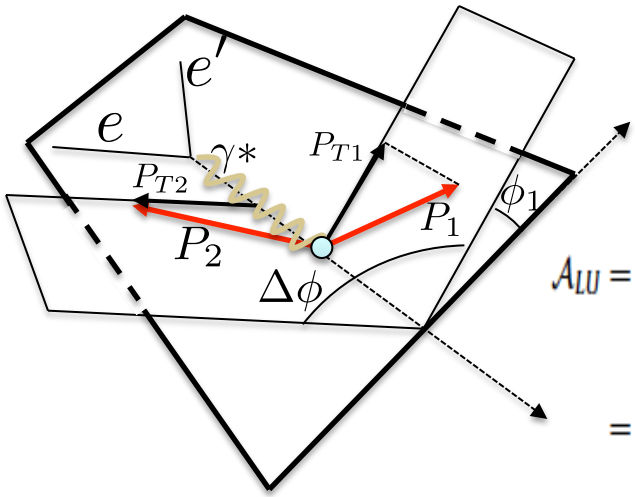
$$A_{LU} = -\frac{y\left(1-\frac{y}{2}\right)}{\left(1-y+\frac{y^2}{2}\right)}\frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}}\sin\Delta\phi$$

Back-to-back hadron production in SIDIS would allow:
- study SSAs not accessible in SIDIS at leading twist
- measure fracture functions
- control the flavor content of the final state hadron in current fragmentation (detecting the target hadron)
- study entanglement in correlations in target vs current
- access quark short-range correlations and χSB (Schweitzer et al)
- ...

B2B hadron production in SIDIS: First measurements

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

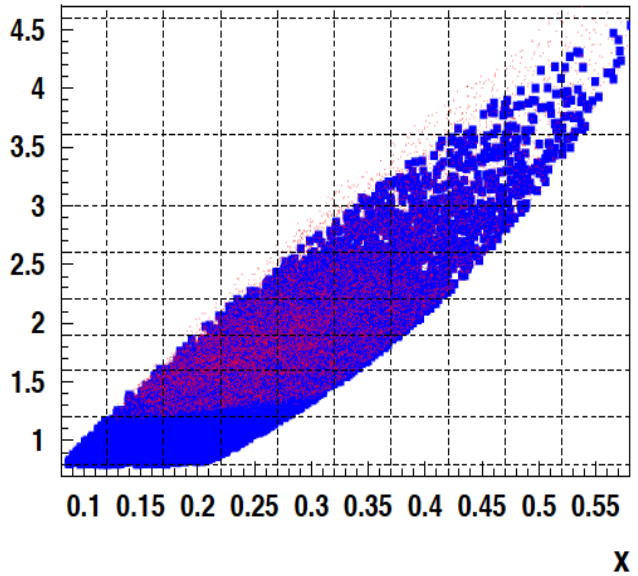
$$ep \rightarrow e' p \pi^+ X$$

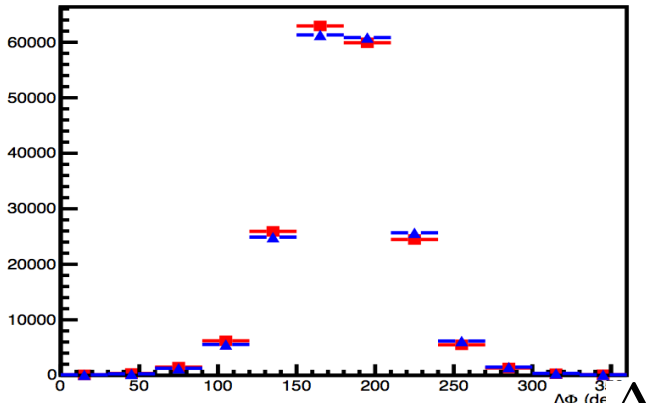


$$A_{LU} = -\frac{y(1-\frac{y}{2})}{(1-y+\frac{y^2}{2})}\frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}}\sin\Delta\phi$$

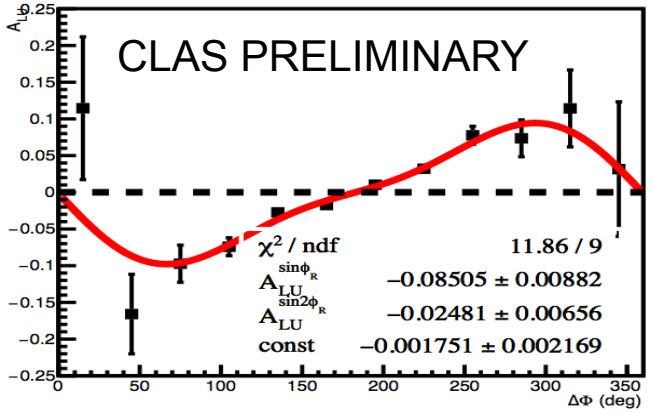
$$= -\frac{|\boldsymbol{P}_{1\perp}||\boldsymbol{P}_{2\perp}|}{m_N m_2}\frac{y(1-\frac{y}{2})}{(1-y+\frac{y^2}{2})}\frac{\mathcal{C}[w_5 M_L^{\perp,h} D_1]}{\mathcal{C}[M D_1]}$$

CLAS e16 and e1f data sets





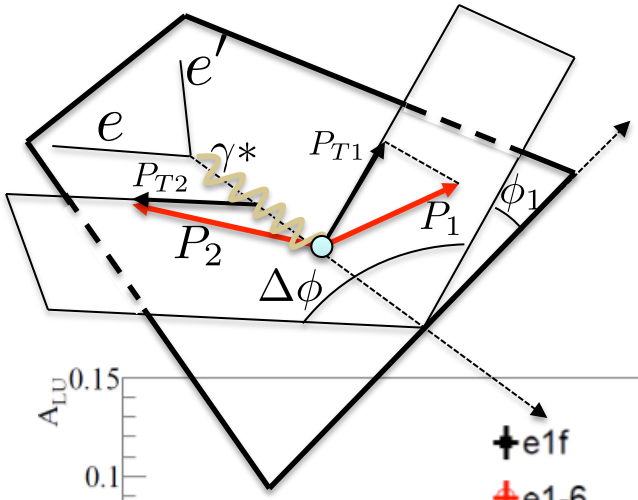
$\Delta\phi$

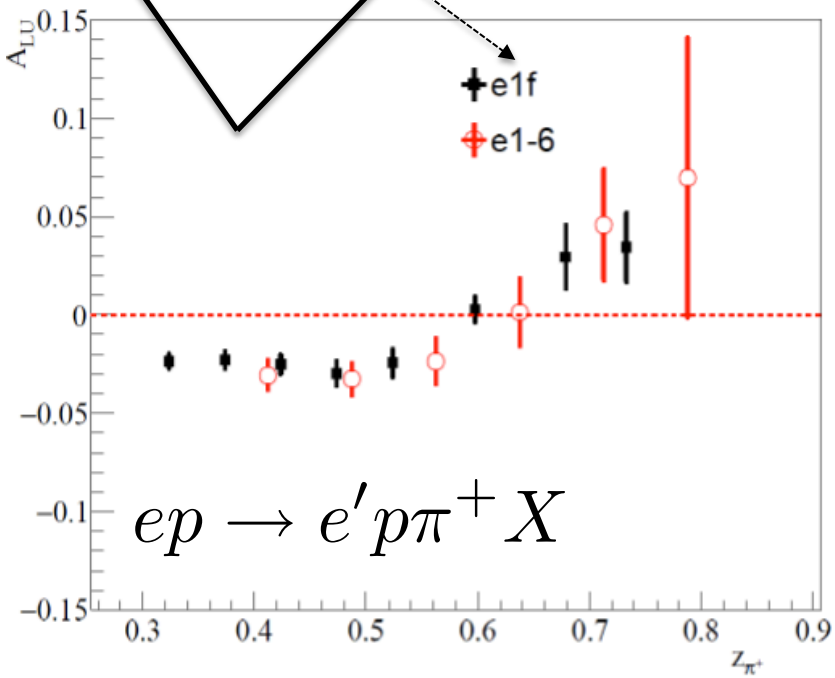


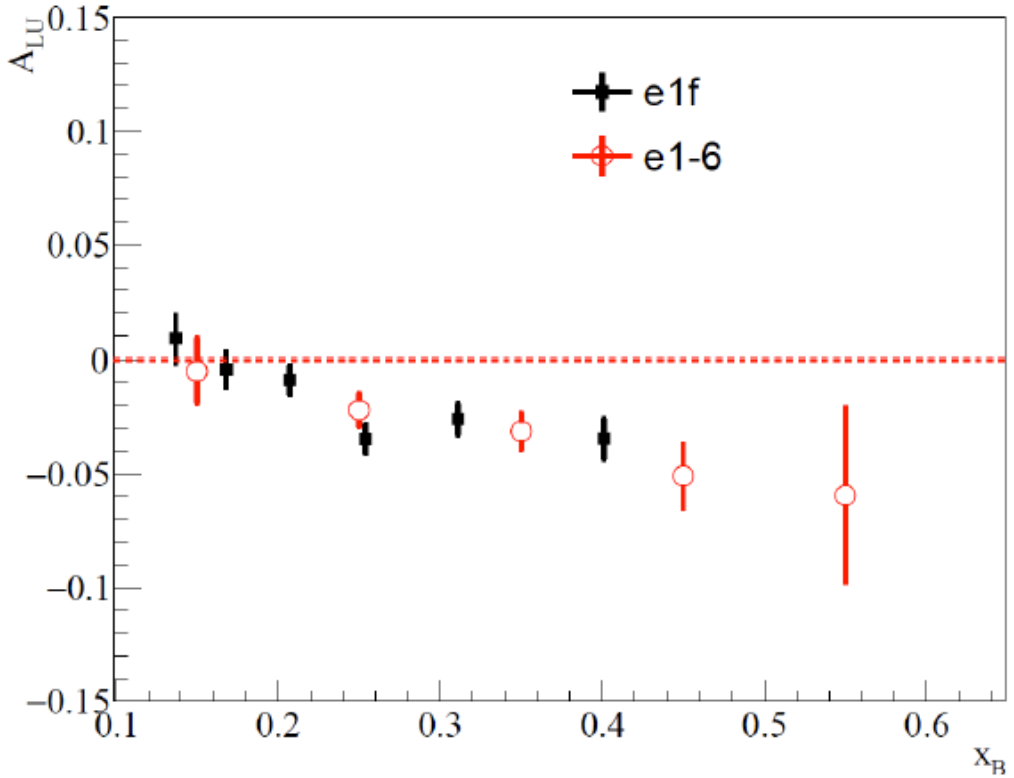
$\Delta\phi$

Significant asymmetries observed by CLAS at 6 GeV

A_{LU} comparing CLAS data sets e16 and e1f





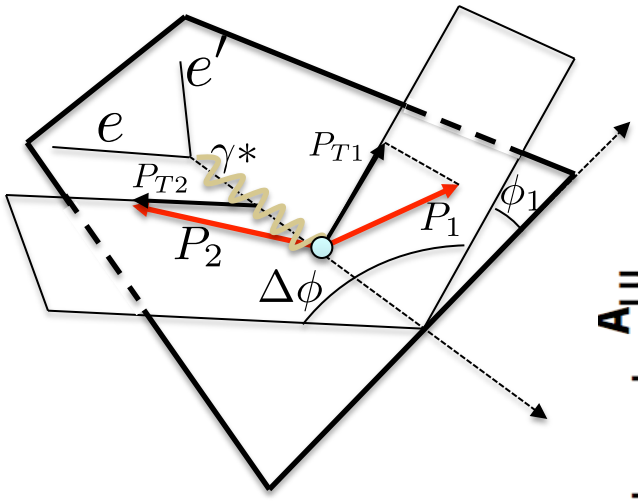


e1f: weaker field, lower Q^2 and x
e16: higher field, higher average Q^2

- Asymmetries may change the sign in the exclusive limit
- Asymmetries are large in the large x-region

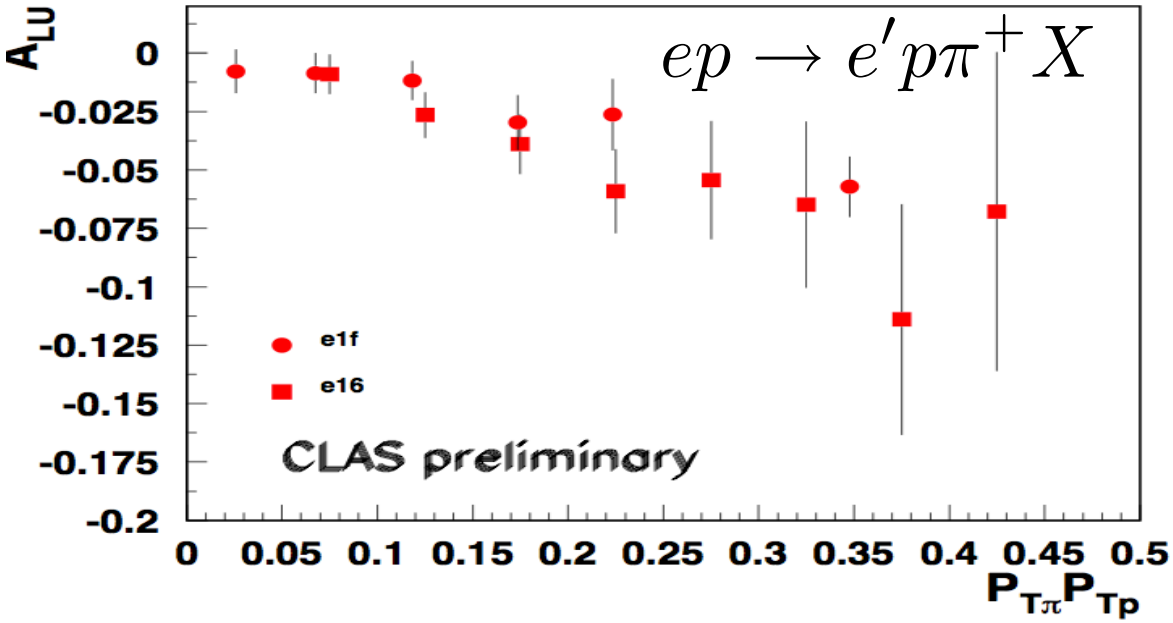
B2B hadron production in SIDIS: First measurements

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



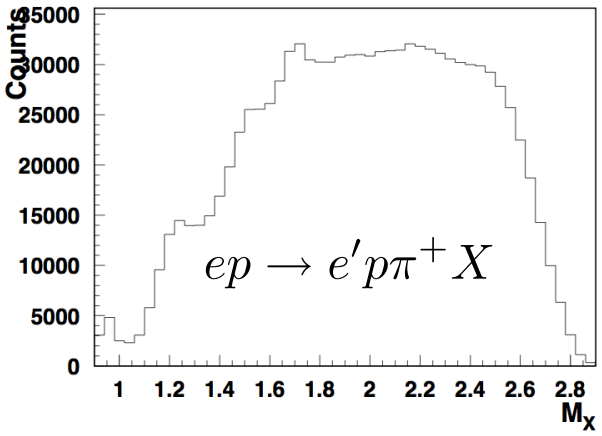
$$\mathcal{A}_{LU} = -\frac{y(1-\frac{y}{2})}{(1-y+\frac{y^2}{2})}\frac{\mathcal{F}_{LU}^{\sin\Delta\phi}}{\mathcal{F}_{UU}}\sin\Delta\phi$$

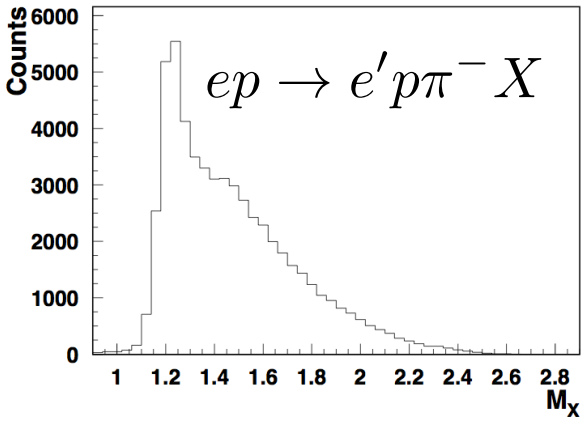
$$= -\frac{|\boldsymbol{P}_{1\perp}||\boldsymbol{P}_{2\perp}|}{m_N m_2}\frac{y(1-\frac{y}{2})}{(1-y+\frac{y^2}{2})}\frac{\mathcal{C}[w_5 M_L^{\perp,h} D_1]}{\mathcal{C}[M D_1]}\sin\Delta\phi$$

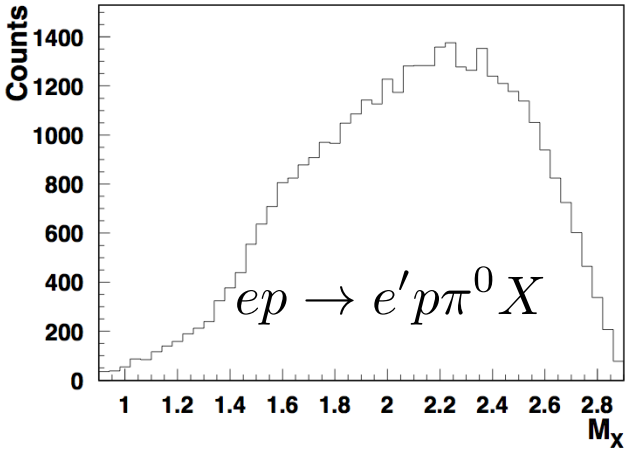


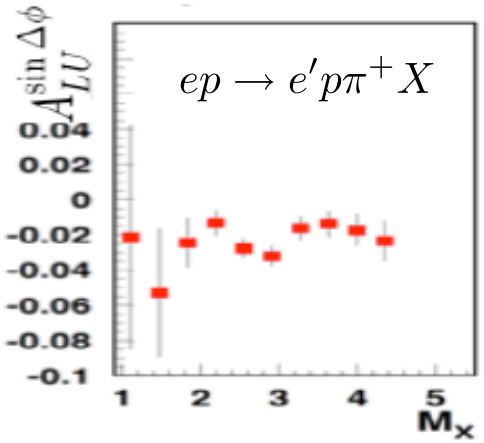
Asymmetry transverse momentum dependence consistent with theory prediction

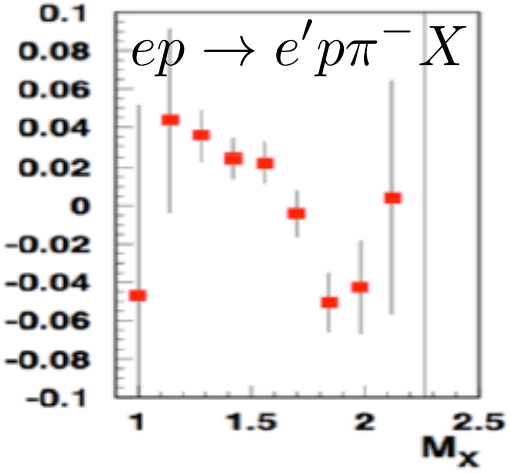
B2B in SIDIS: different pions

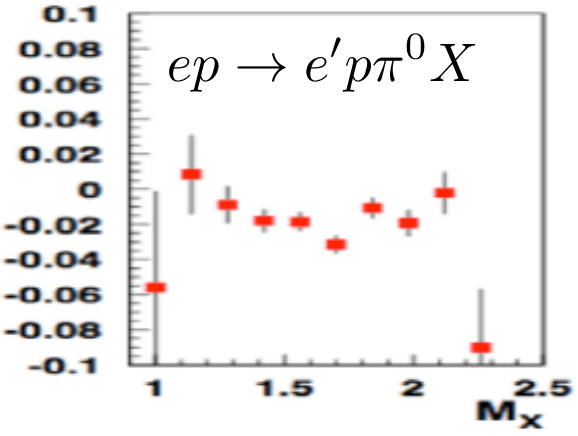










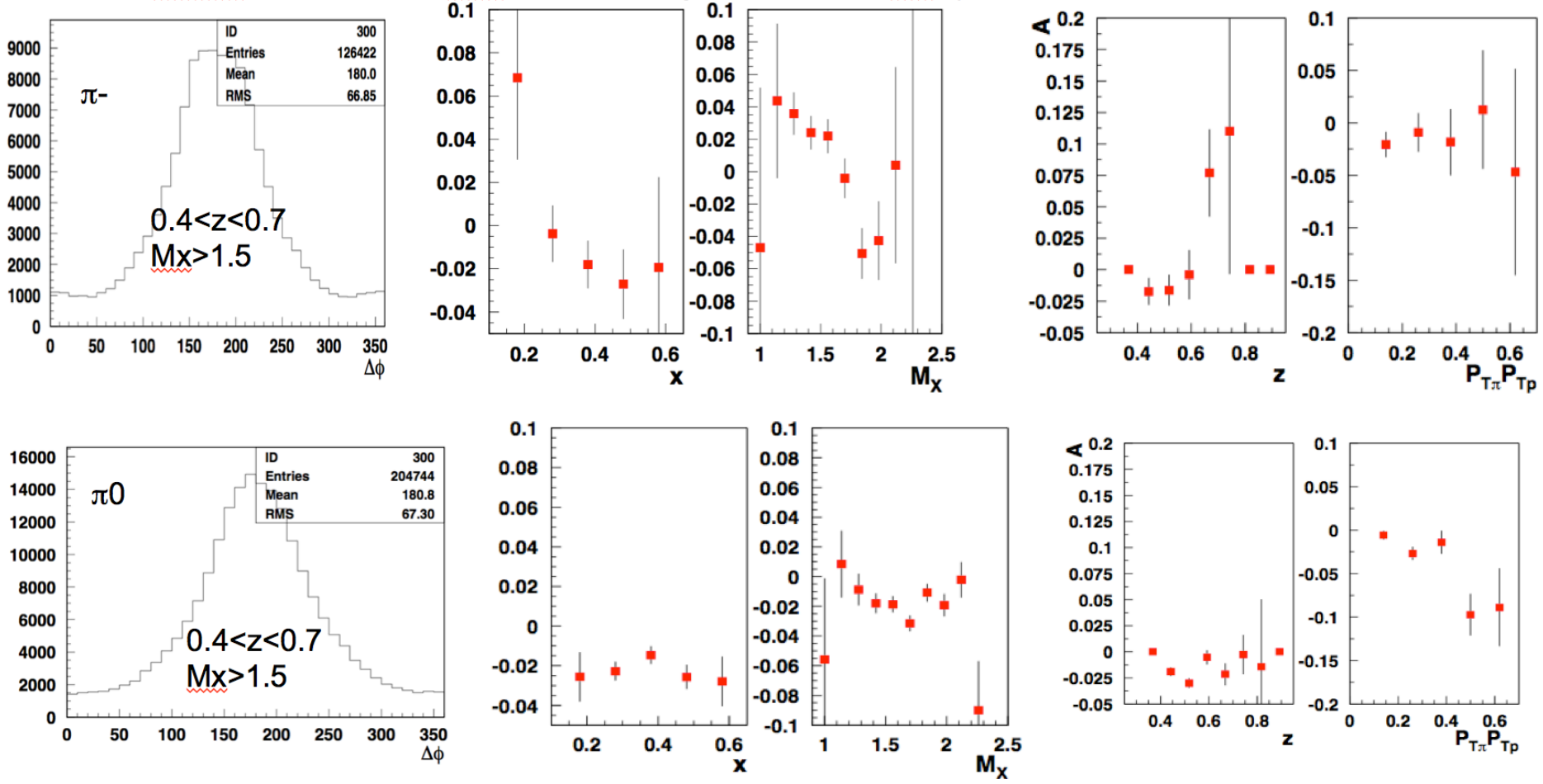


At large missing mass asymmetry consistent for all three pions.

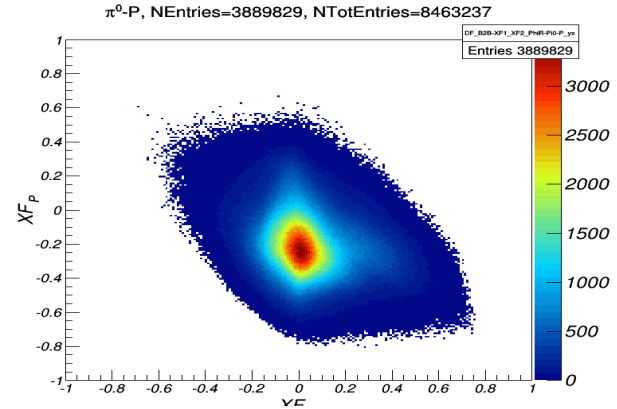
b2b SSAs

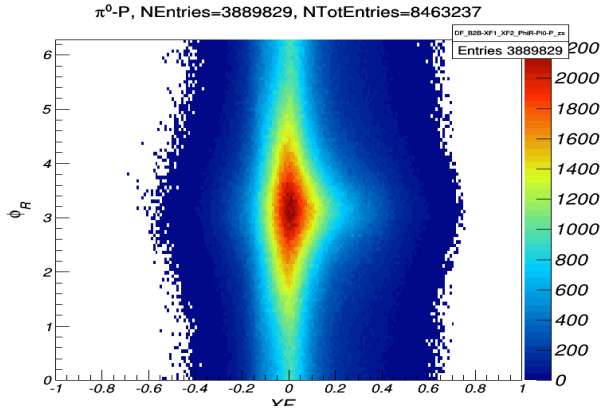
b2b SSA (ALU) for ep->e'pπX for e16 data set

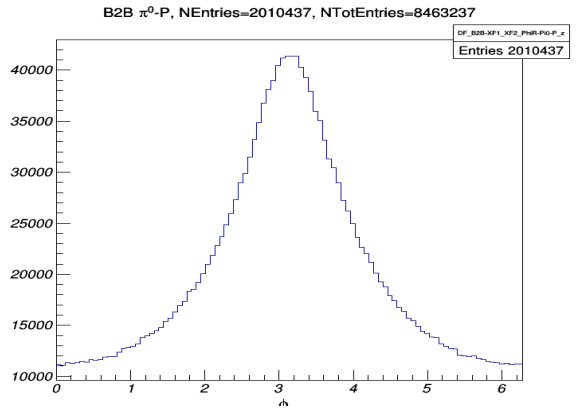
with fiducial electron cuts, M_x is the missing mas of the e'\piX system.

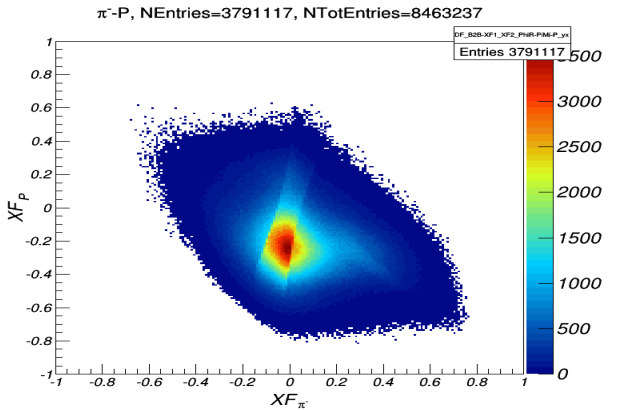


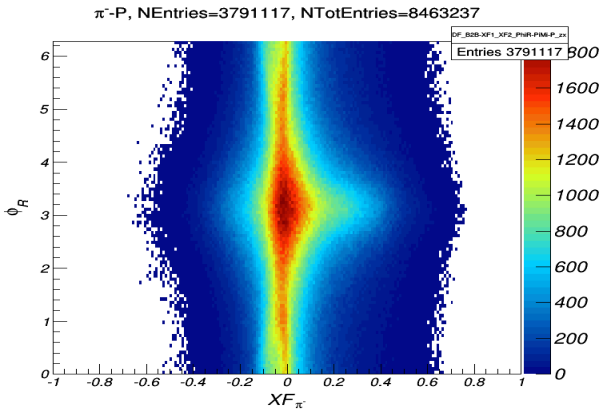
b2b distributions: CLAS12 (proton-pion)

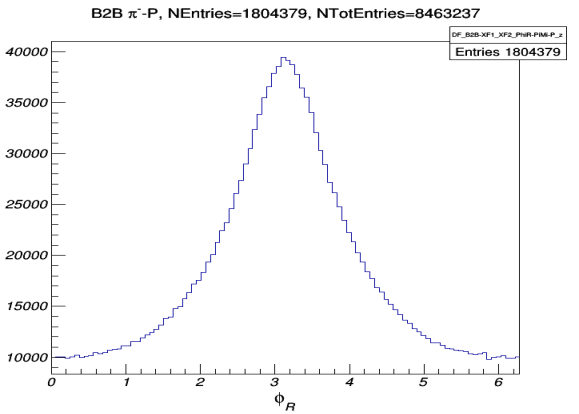


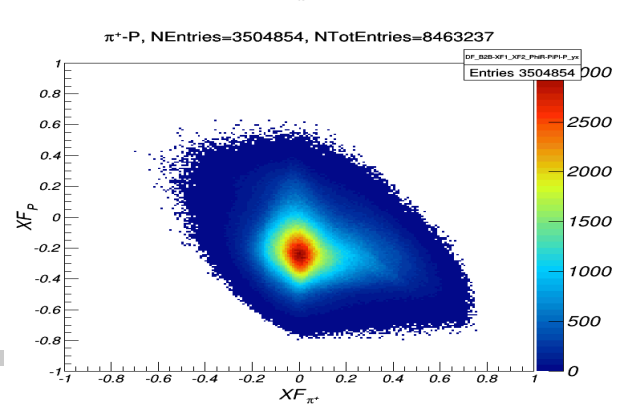


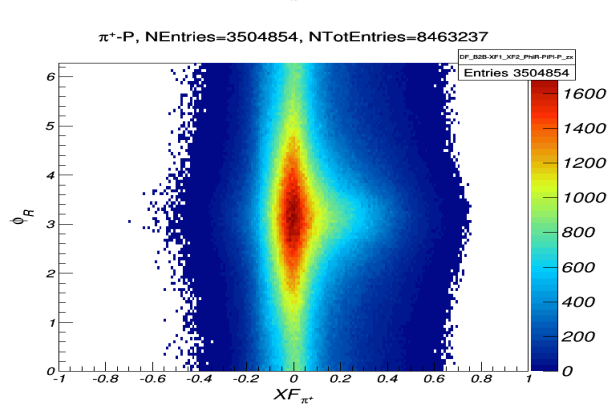


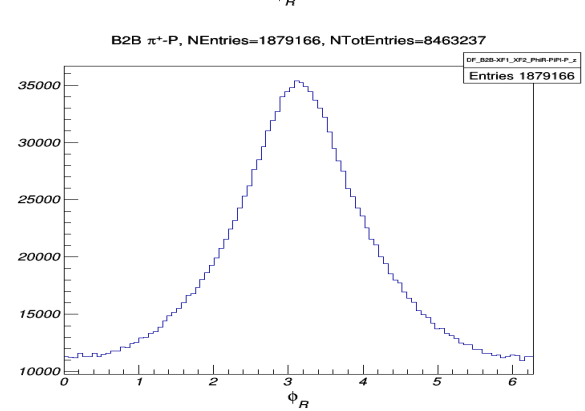




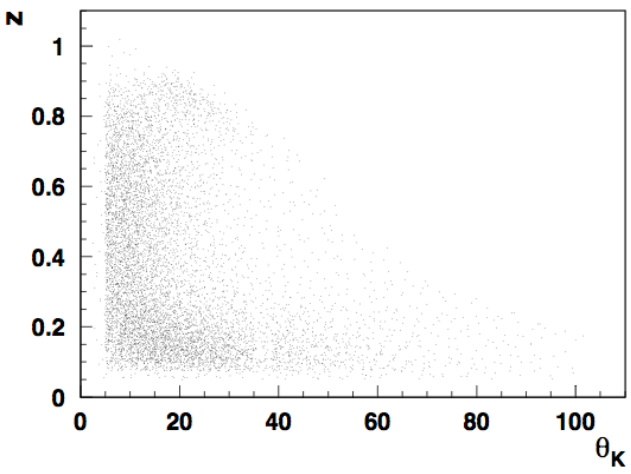


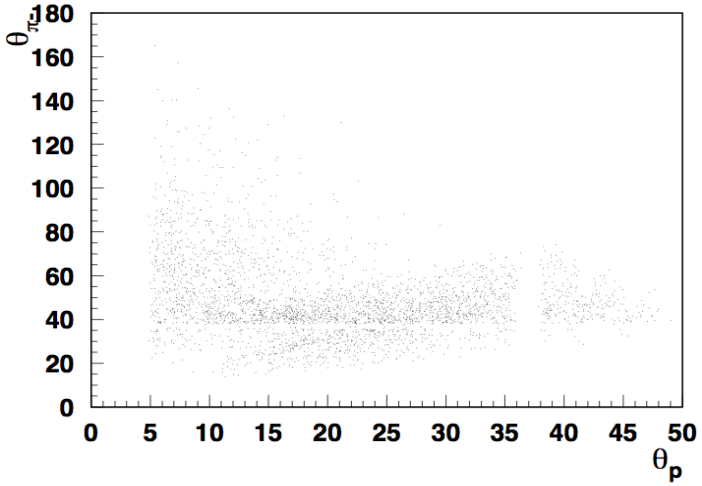


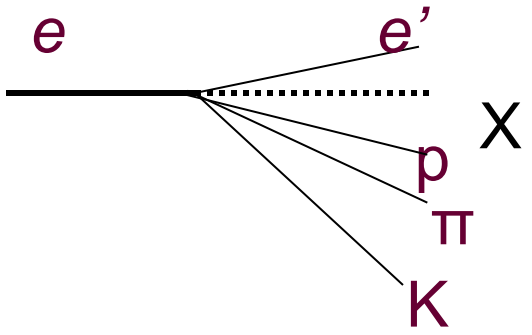




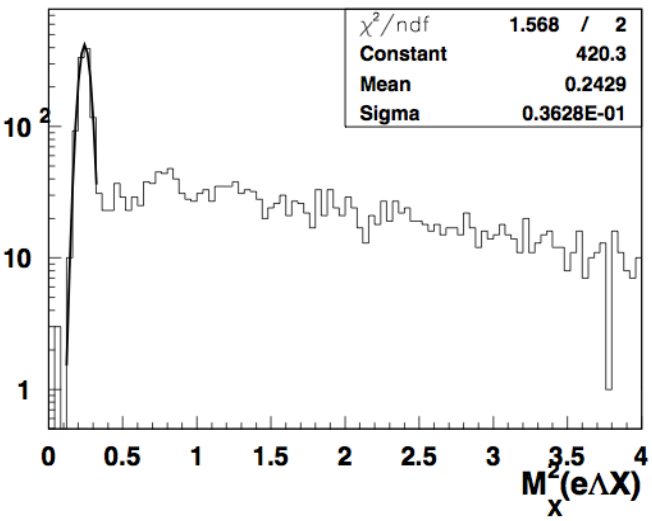
Lambda production at Jlab (CLAS12)

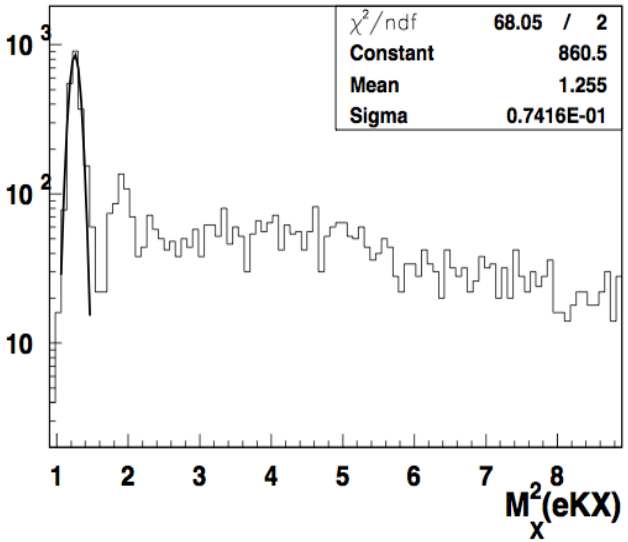


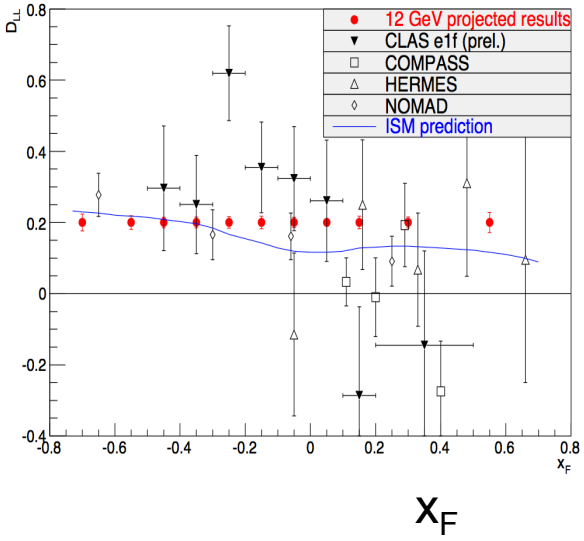




Controlling the flavor content with target-current correlations



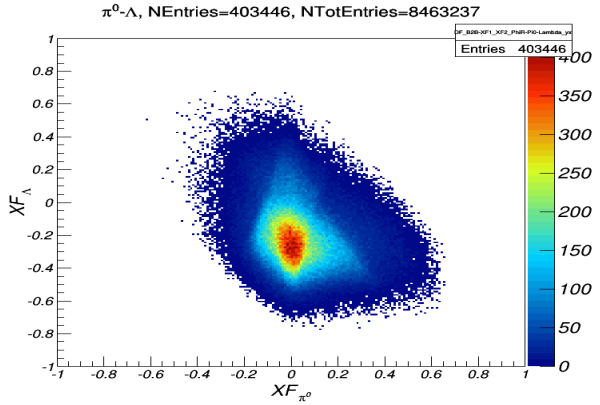


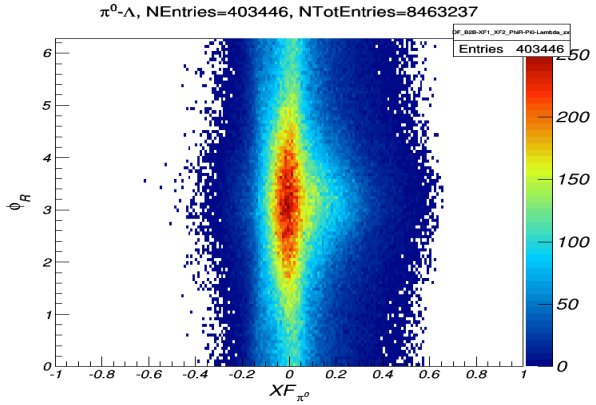


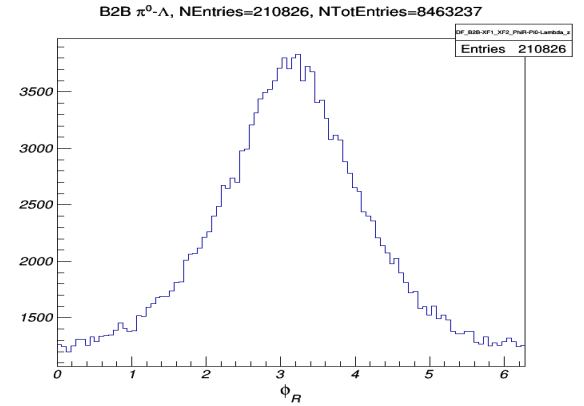
x_F

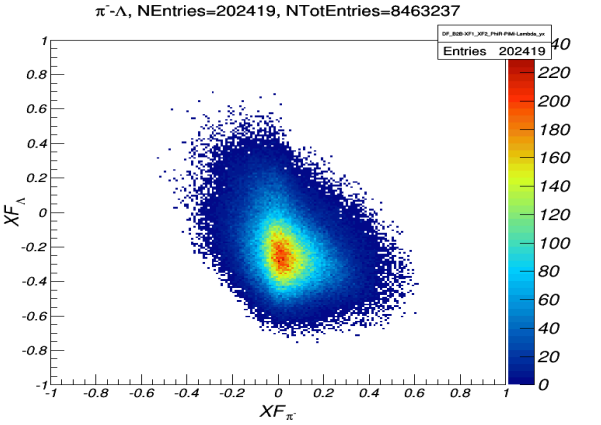
•Large acceptance of CLAS12 (and EIC) provide a unique possibility to detect simultaneously hadrons in the forward and backward regions

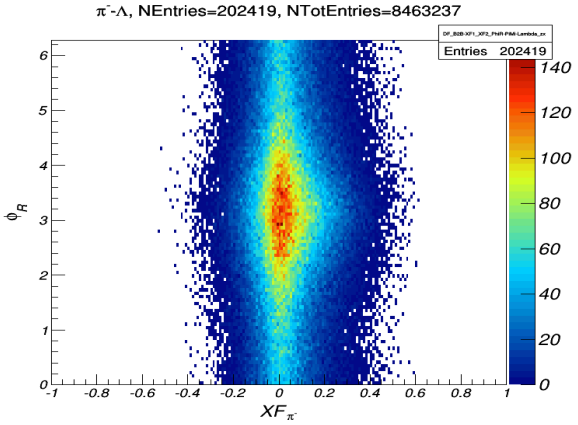
b2b distributions: CLAS12(Lambda-pion)

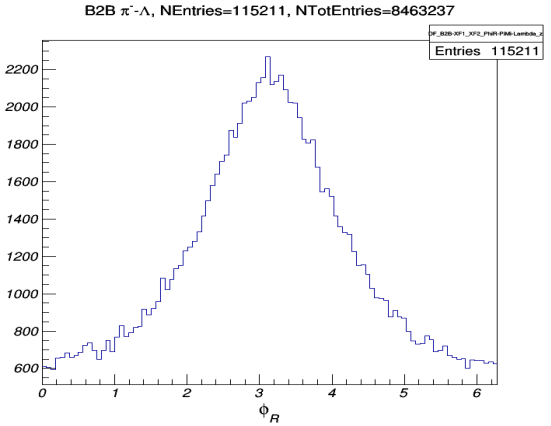


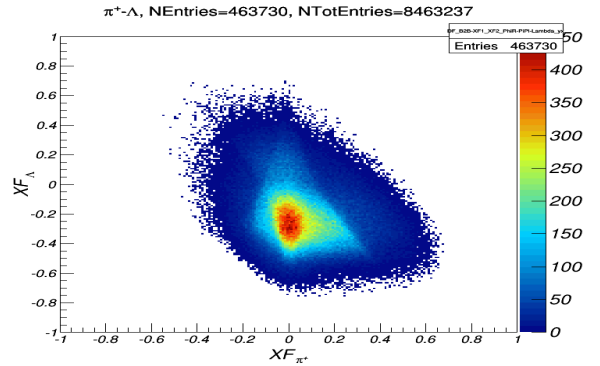


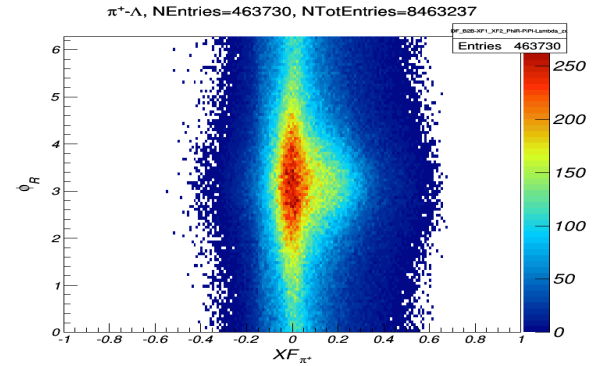


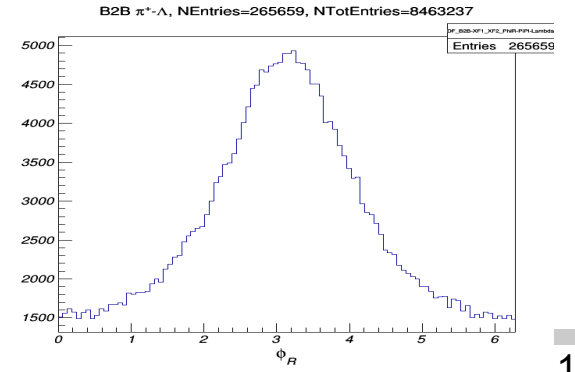












Summary

•Significant SSA in b2b SIDIS have been measured at JLab for the first time for proton pion final states

•Flavor and spin content changes with transverse momentum and z, opening new possibilities for multi-dimensional analysis

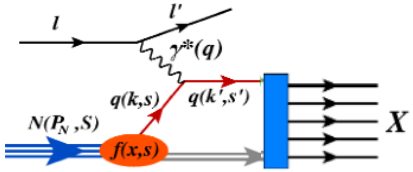
•Studies of the nucleon structure beyond the traditional current fragmentation, provides qualitatively new tool to study the nucleon structure.

•Large acceptance of the CLAS12 combined with better separation of target and current fragmentation regions provide a unique possibility to study the nucleon structure in target fragmentation region and correlations of target and current fragmentation regions

Support slides

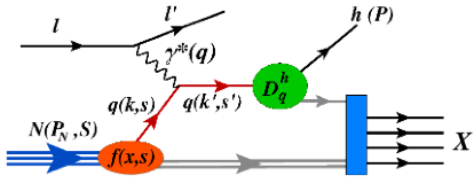
QCD: from testing to understanding

0h DIS



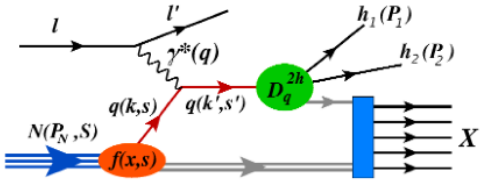
Testing stage:
pQCD predictions, observables in the kinematics where theory predictions are easier to get (higher energies, 1D picture, leading twist, current fragmentation, IMF)

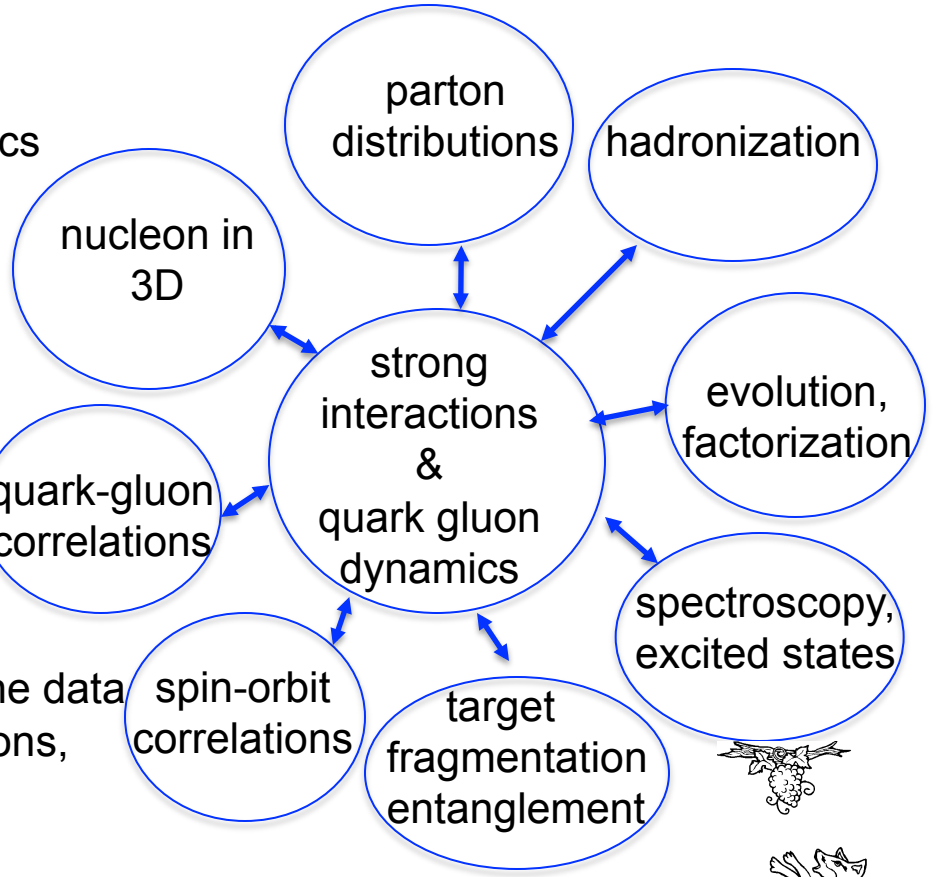
1h SIDIS/DVMP

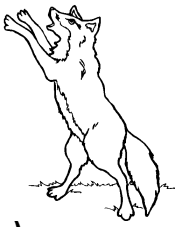


Understanding stage:
non-perturbative QCD, strong interactions, observables in the kinematics where most of the data is available (all energies, quark-gluon correlations, orbital motion)

2h SIDIS/DVMP







production in SIDIS provides access to correlations inaccessible in simple SIDIS (BEC,dihadron fragmentation , correlations of target and current regions, entanglement....)

CLAS6 kinematics