New results on SIDIS SSA from JLab

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- Physics Motivation
- Double spin asymmetries
- Single Spin Asymmetries
- Future measurements
- Summary

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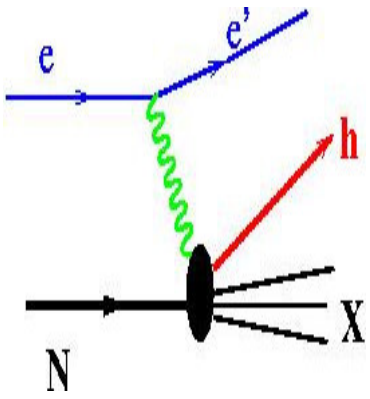
k_T-dependent parton distributions



Semi-Inclusive Deep Inelastic Scattering (SIDIS):

- Probes orbital motion of quarks through quark transverse momentum distribution
- Access to new PDFs not accessible in inclusive DIS.

Off-diagonal PDFs vanish if quarks only in s-state! In addition T-odd PDFs require FSI **(Brodsky et al., Collins, Ji et al. 2002)**

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

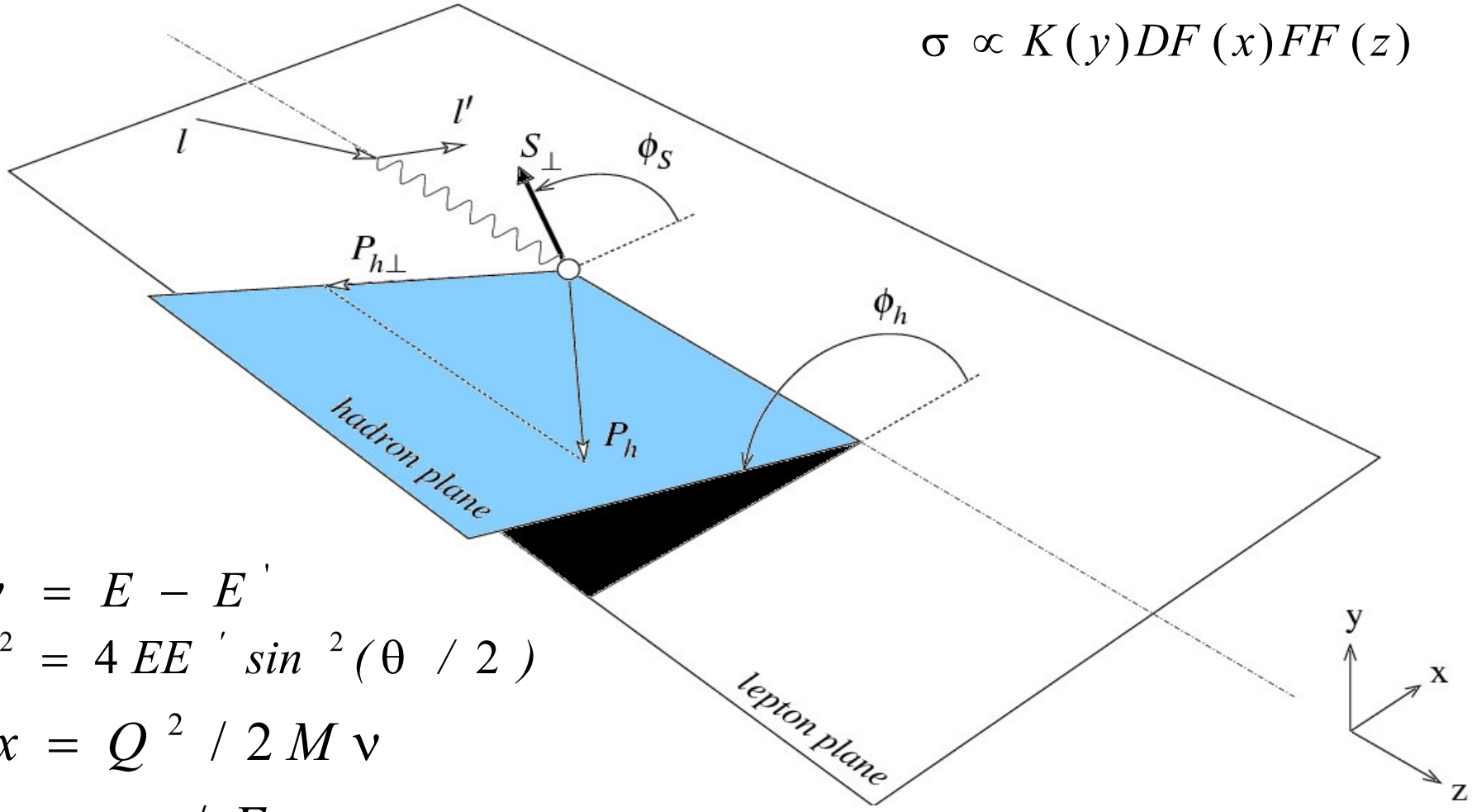
Sivers

transversity

- Factorization of k_T-dependent PDFs proven at low P_T of hadrons (Ji et al)
- Universality of k_T-dependent distribution and fragmentation functions proven (Collins,Mets…)

SIDIS kinematic plane and relevant variables

$$\sigma \propto K(y)DF(x)FF(z)$$



$$\nu = E - E'$$

$$Q^2 = 4EE' \sin^2(\theta/2)$$

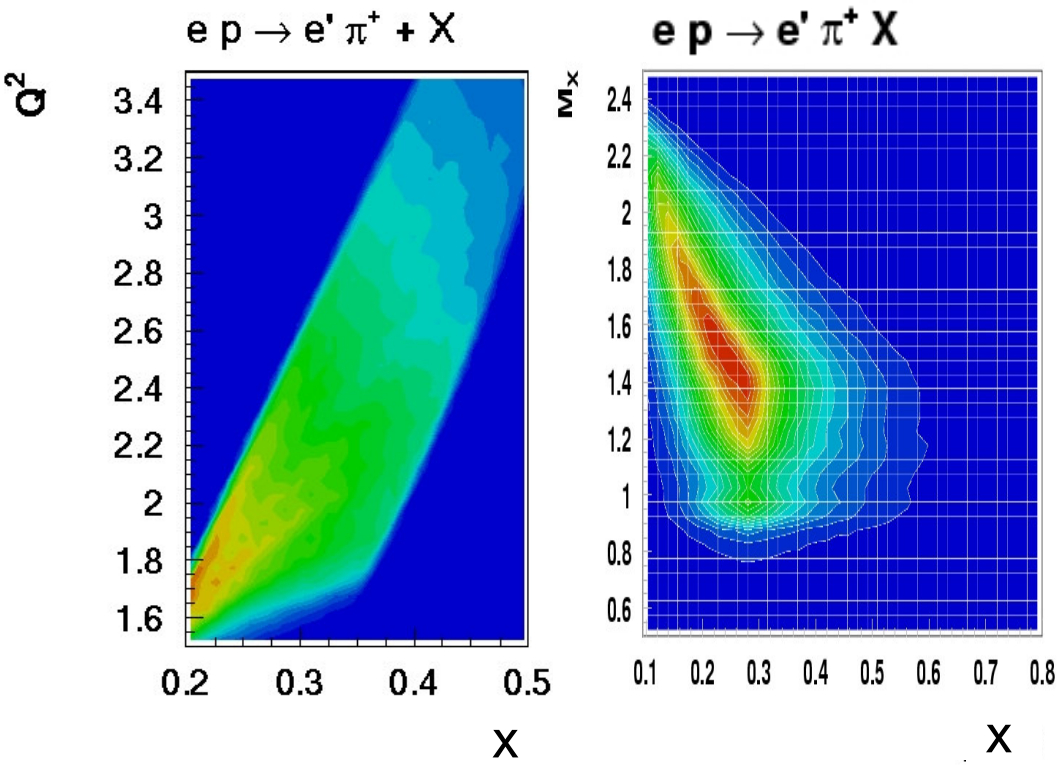
$$x = Q^2 / 2M\nu$$

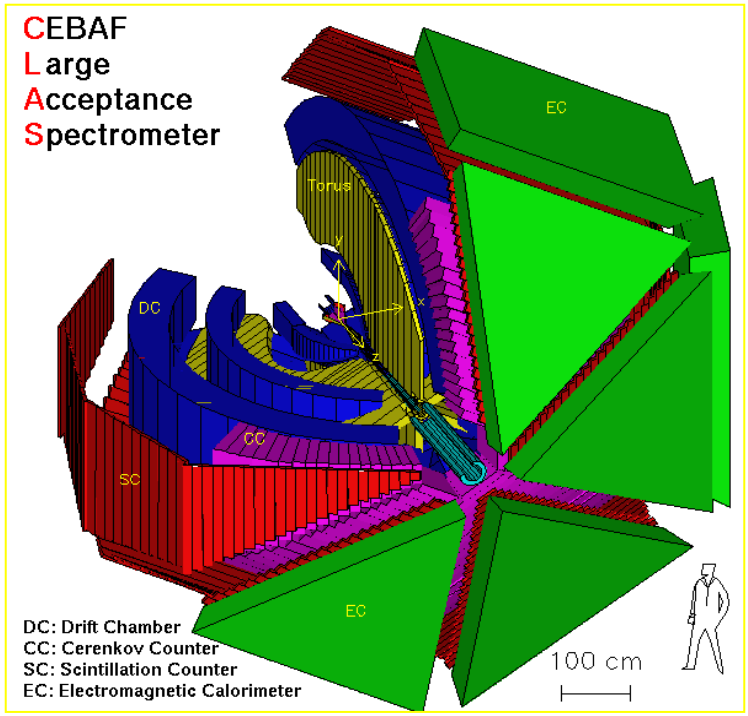
$$y = \nu / E$$

$$z = E_h / \nu$$

The CLAS Detector

Scattering of 5.7 GeV polarized electrons off polarized NH_3

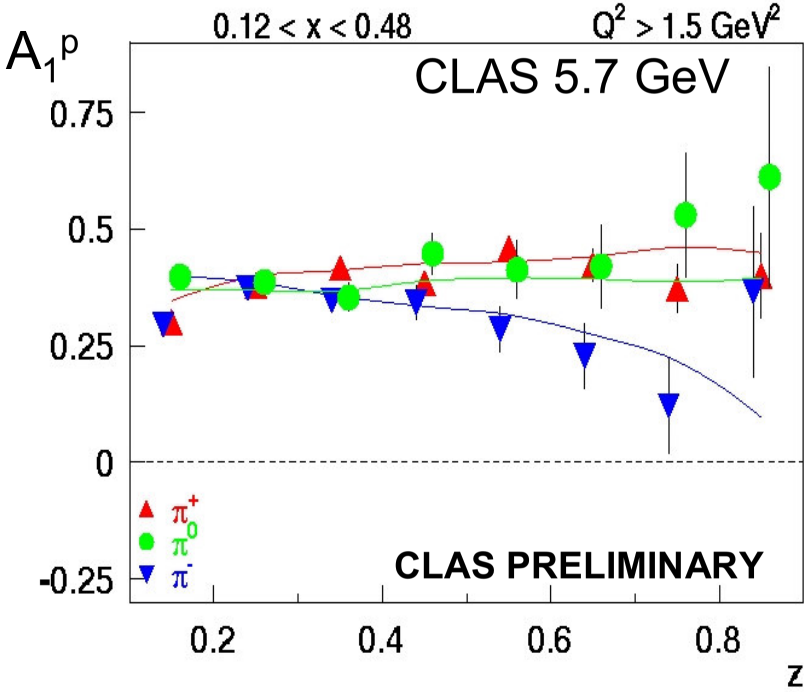


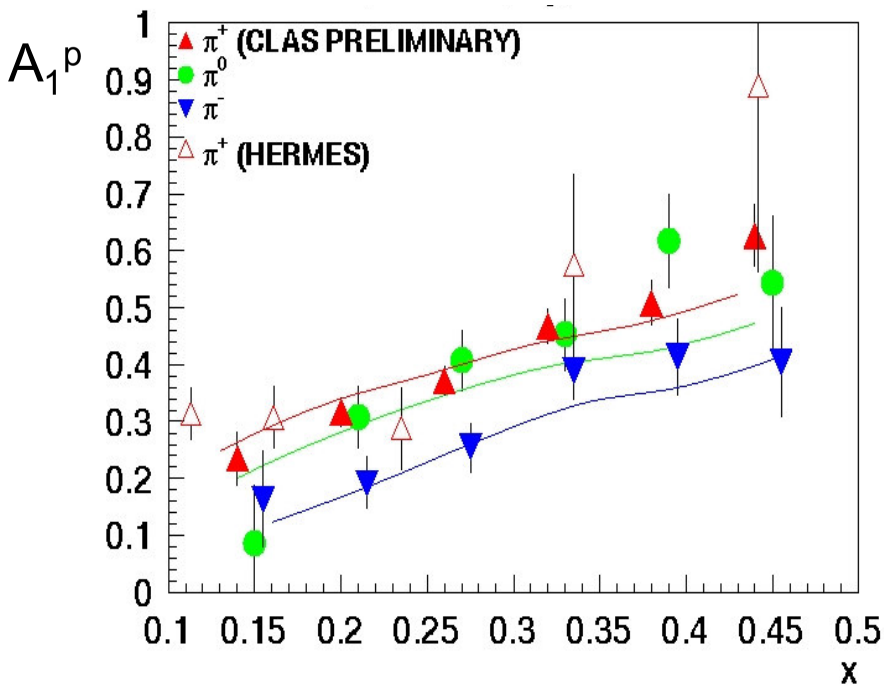


- **~8M π^+ in DIS kinematics,SIDIS $Q^2>1.1GeV^2$, $W^2>4GeV^2$, y<0.85,**
- **beam polarization 73%**
- **target polarization 72% (f=0.2)**

A_1^p -kinematic dependence for $\pi^{+/-/0}$

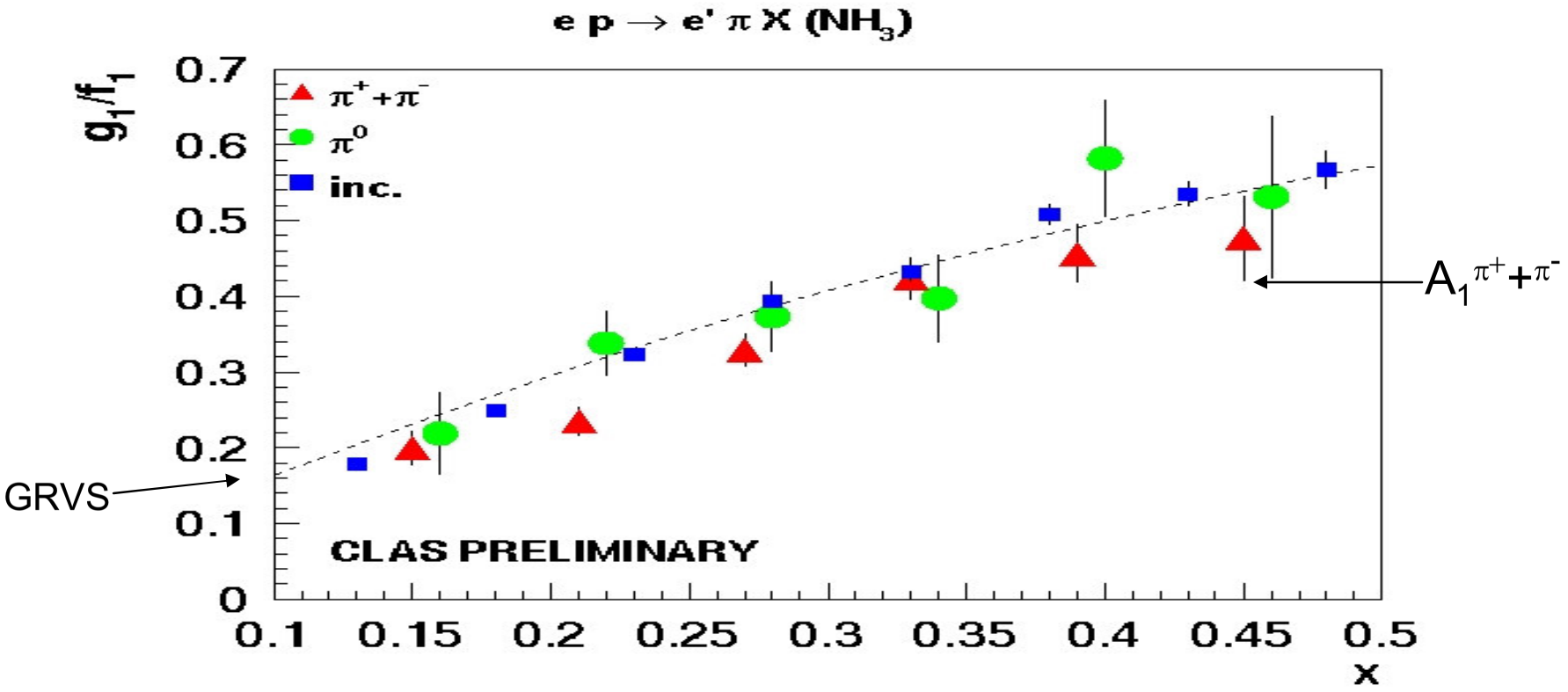
$$A_1^p \approx \frac{1}{P_B P_T f D_{LL}(y)} \frac{N^{+-} - N^{++}}{N^{+-} + N^{++}} \propto \frac{g_1}{f_1}$$





- No significant z-dependence of A_1 in the range $0.4<z<0.7$ ($\pi^+\pi^0$)
- **x** dependence of CLAS $\mathbf{A_1^p}$ ($A_\perp=0$) consistent with HERMES data at 3 times higher Q^2 and with PEPSI (LUND)MC.

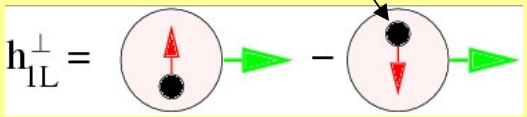
SIDIS: factorization studies



- A_1 inclusive, from $\pi^+\pi^-$ sum and π^0 are consistent (in range 0.4<z<0.7)
- A_1^p dependence can serve an important check of HT effects and applicability of simple partonic description.
- There is an indication that A_1^p of $\pi^+ + \pi^-$ is lower than inclusive at large z.

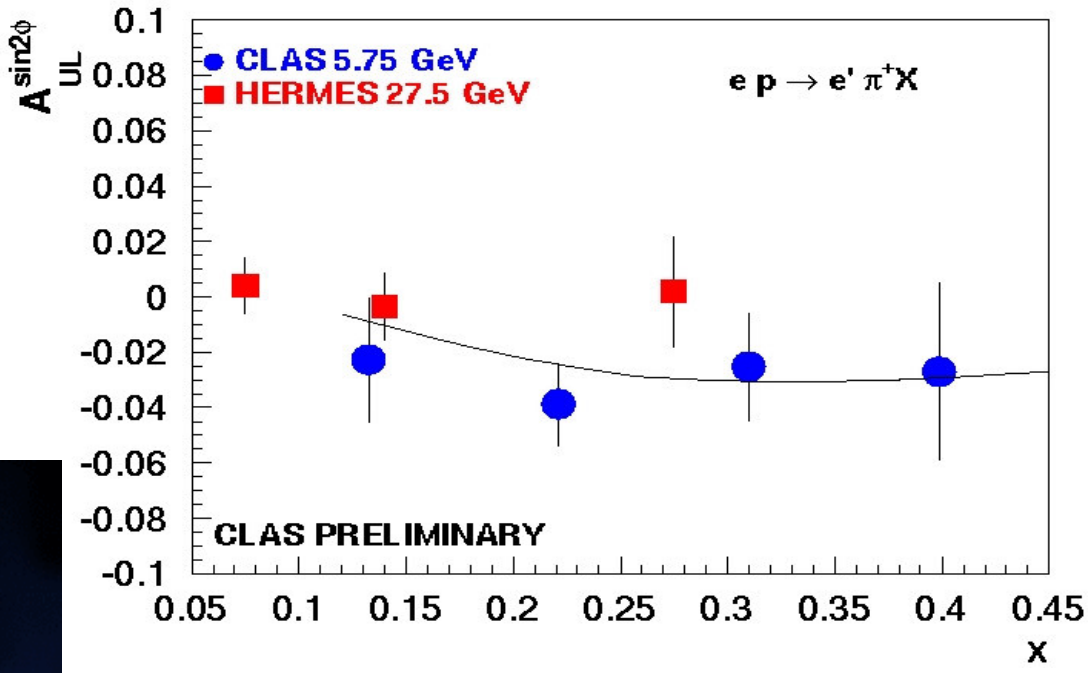
Longitudinally polarized Target SSA

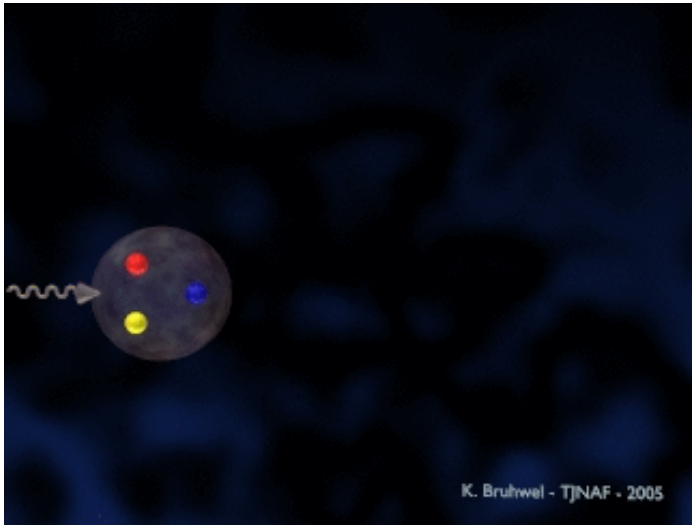
N \ q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

$h_{1L}^\perp$ = 

Real part of interference of wave functions with L=0 and L=1

$$\sigma_{UL}^{KM} \sim (1-y) h_{1L}^\perp H_1^\perp$$





Measure the k_T dependent twist-2 distribution and provides an independent test of the Collins fragmentation.

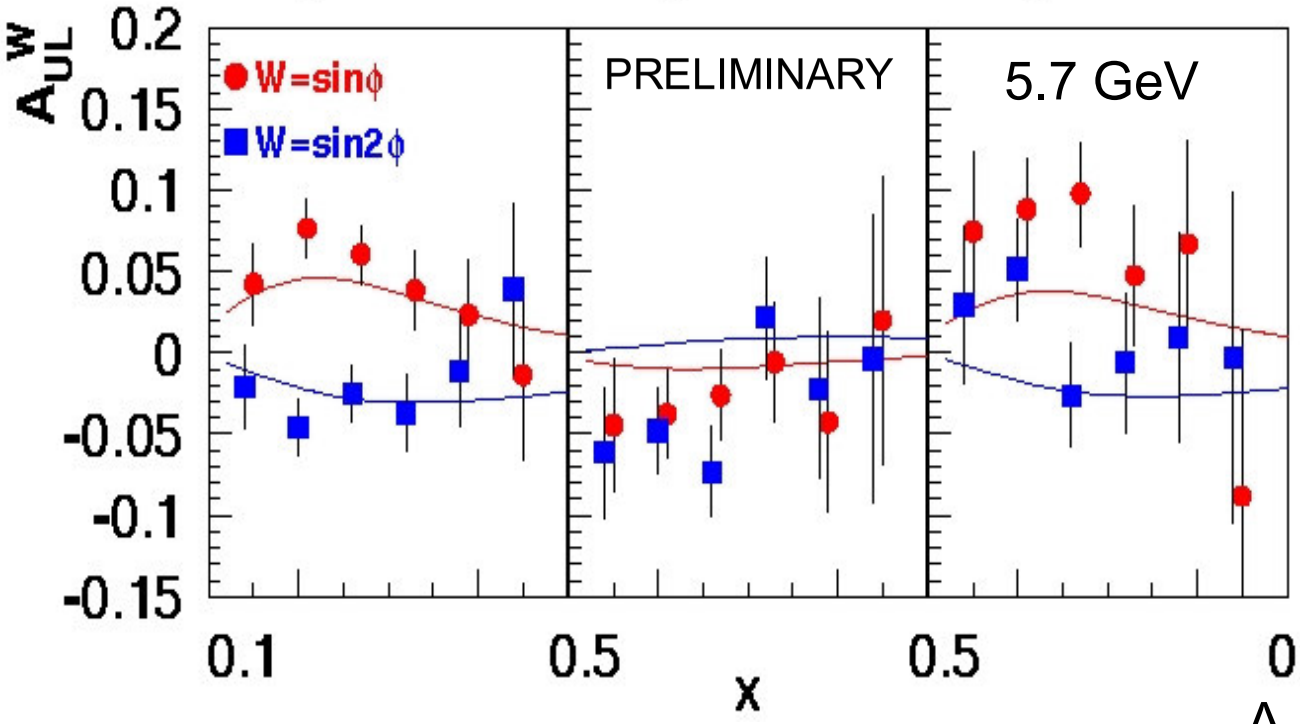
SSA: x-dependence

$$A_{UL}^{\sin 2\phi} = P_T D_{UL} \frac{\sum_q e_q^2 h_{1L}^{q\perp}(x) H_1^{q\perp}(z)}{\sum_q e_q^2 f_1^q(x) D_1^q(z)}$$

π^+ π^- π^0

$$\sigma_{UT}^{\sin\phi} \propto S_T \sum_{q,\bar{q}} e_q^2 f_{1T}^{\perp q}(x) D_1^q(z)$$

$$\sigma_{UL}^{\sin\phi} \propto S_L \frac{M}{Q} \sum_{q,\bar{q}} e_q^2 x h_L(x) H_1^{\perp q}(z)$$



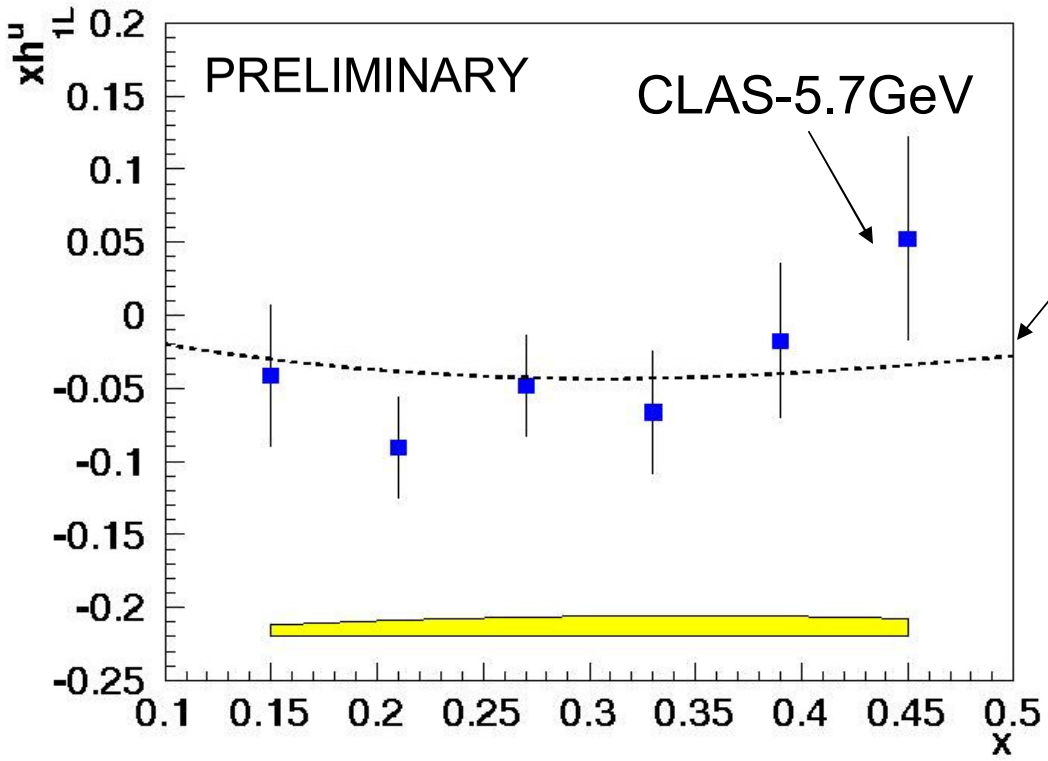
HT–SSA significant for π^+ and π^0 (non-Collins?)

$A_{UL}(\pi^0) \sim H_1^{favore} + H_1^{unfavored}$

- Study the Collins fragmentation mechanism with long. polarized target
- For π^- and π^0 SSA is sensitive to unfavored fragmentation

First glimpse of Twist-2 TMD $h_{1L}^{\perp}$

For Collins fragmentation use chirally invariant Manohar-Georgi model (Bacchetta et al)



Distribution functions from χQSM from Efremov et al

Systematic error only from unknown ratio of favored and unfavored Collins functions ($R= H_1^{d\to\pi+}/H_1^{u\to\pi+}$), band correspond to $-2.5<R<0$

- More data required with π- & π^0
- Exclusive 2 pion background may be important

π- and π^0 SSA will also give access to h_{1L}^{d} (If $R \approx -1$ deuteron data could be crucial)

π^0 in Semi-inclusive DIS

advantages:

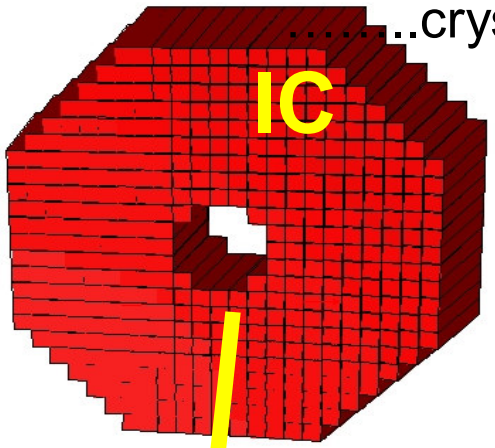
1) SIDIS π^0 production is not contaminated by diffractive ρ
2) HT effects and exclusive π^0 suppressed
3) Simple PID by π^0-mass (no Kaon contamination)
4) Provides complementary to π+/- information on PDFs

disadvantages:

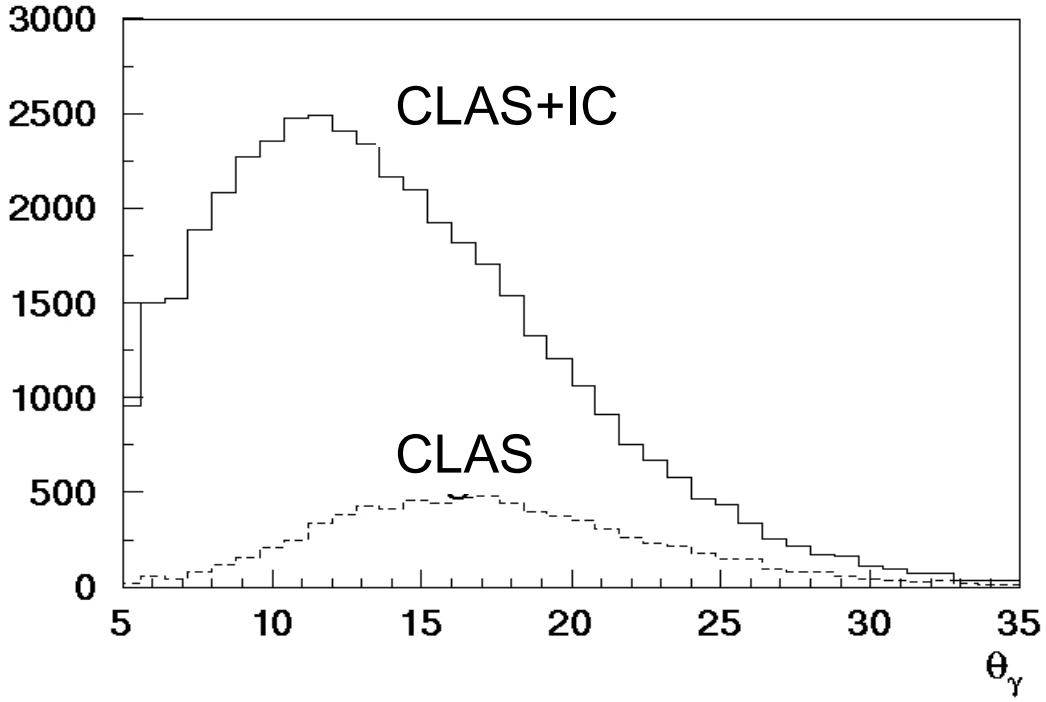
reconstruction efficiency (requires detection of 2γ)

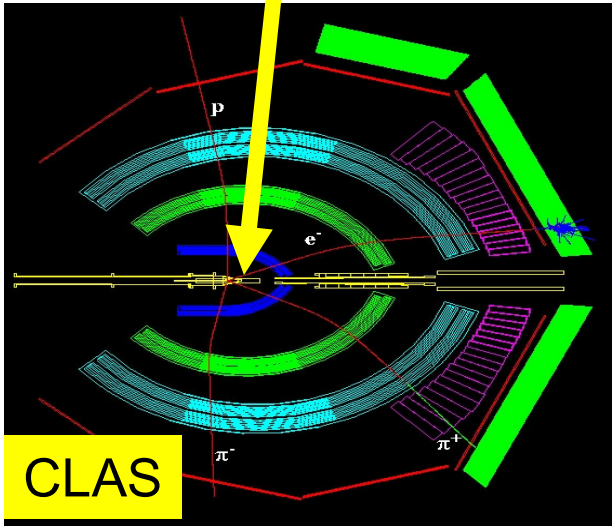
CLAS+Inner Calorimeter (IC)

424 $PbWO_4$ .....crystals



IC $\sigma_E/E=0.0034/E+0.038/\sqrt{E}+0.022$



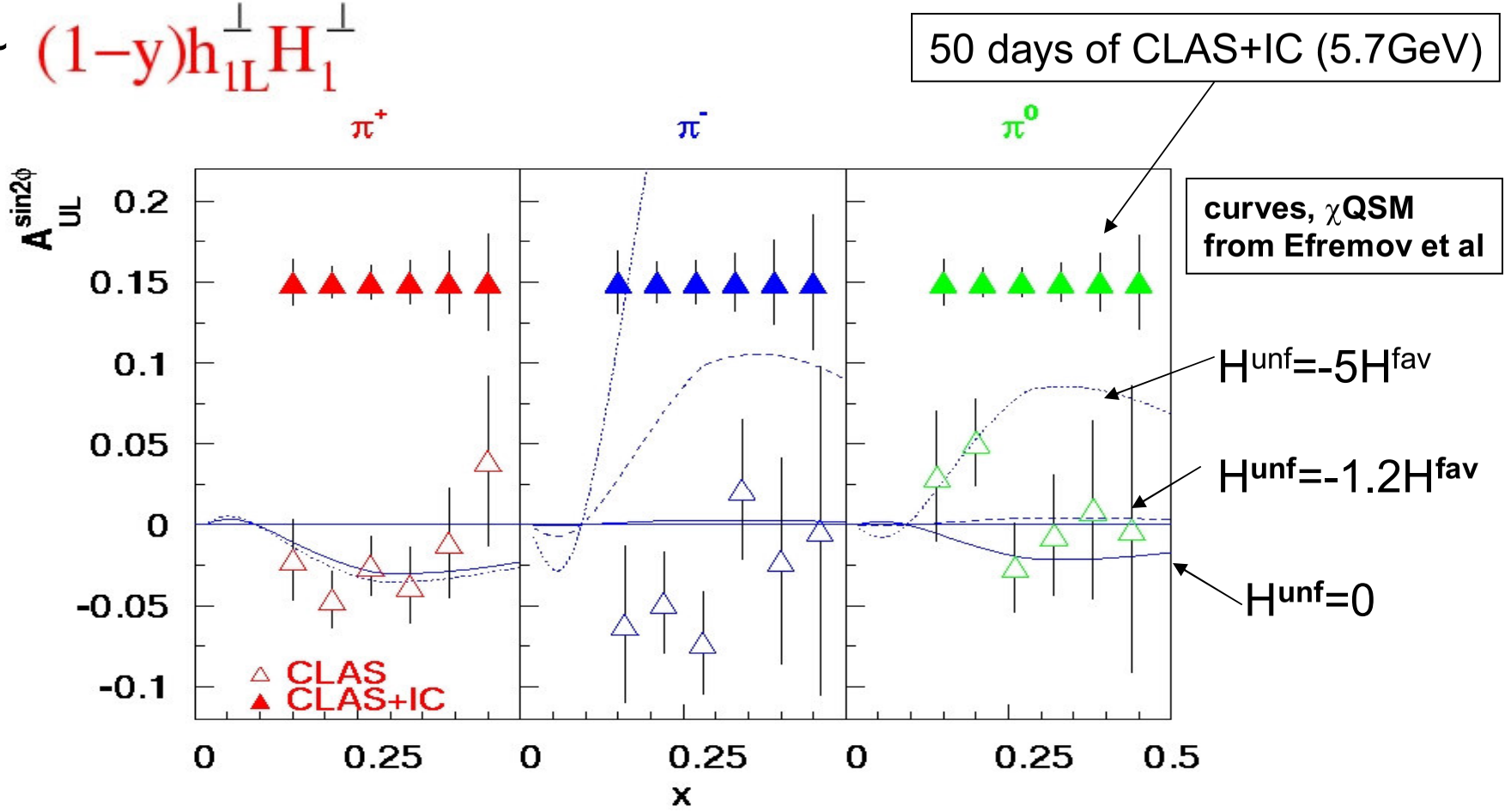


Reconstruction efficiency of high energy π^0 with IC increases ~ 4 times due to small angle coverage

IC at CLAS opens new avenue for studies of spin and azimuthal asymmetries of exclusive and semi-inclusive γ, π^0,η,ρ^+

Longitudinally polarized target SSA using CLAS+IC

$$\sigma_{UL}^{KM} \sim (1-y)h_{1L}^{\perp}H_1^{\perp}$$



- Provide measurement of SSA for all 3 pions, extract the Mulders TMD and study Collins fragmentation with longitudinally polarized target
- Allows also measurements of 2 pion asymmetries

Summary

Spin and azimuthal asymmetries measured at 5.7 GeV with longitudinally polarized target.

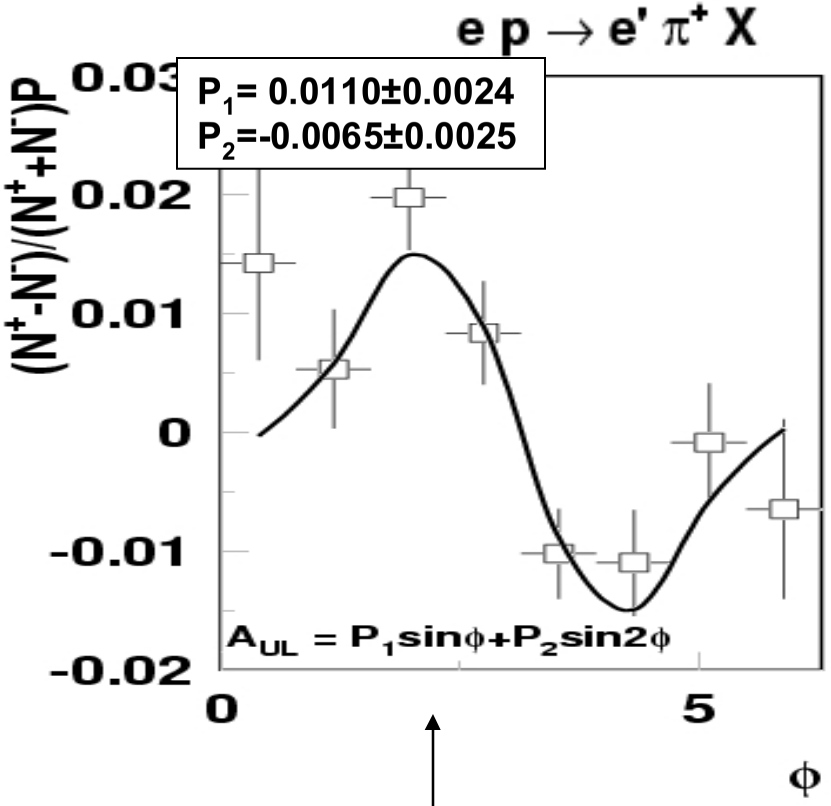
•Double spin asymmetries of pions are consistent with factorization and partonic picture

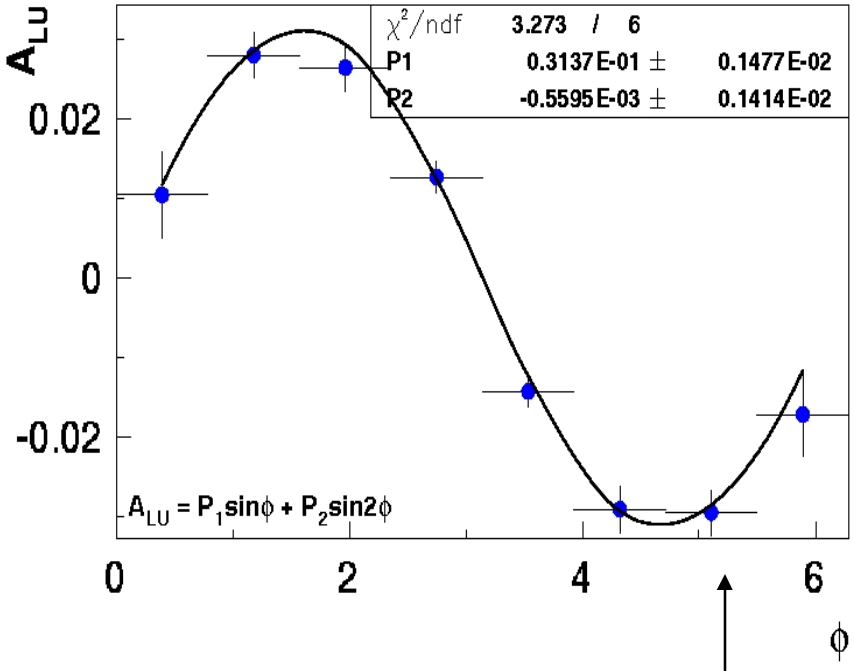
• $\sin\phi$ and $\sin2\phi$ SSA measured, providing access to the twist-2 TMD h_{1L} distribution and testing the Collins fragmentation

Studies of spin and azimuthal asymmetries at CLAS will significantly improve the error bars for charged pions and will provide a superior measurements with neutral pions allowing precision measurement of the twist-2 k_T-dependent PDF.

support slides…..

Longitudinally Pol Target: SSA for π^+



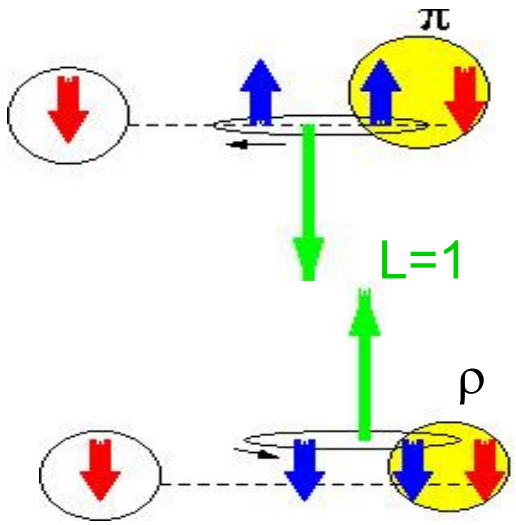


Significant sin2ϕ term in the long.pol. x-section compared to A_{LU}

•sin2ϕ moment (Kotzinian-Mulders asymmetry) is a clean source of Collins SSA

Collins effect and 2 pion production

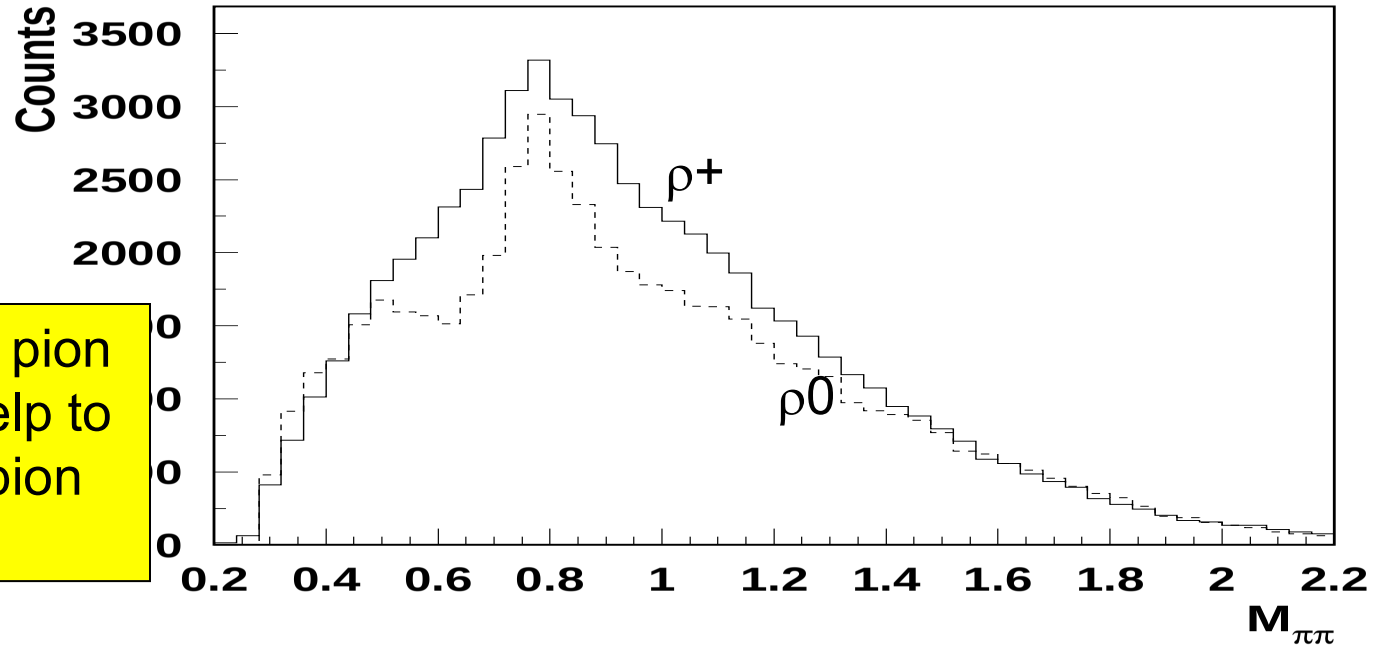
Simple string fragmentation (Artru model)



Sub-leading pion opposite to leading (into page)

ρ production may produce an opposite sign A_{UT}

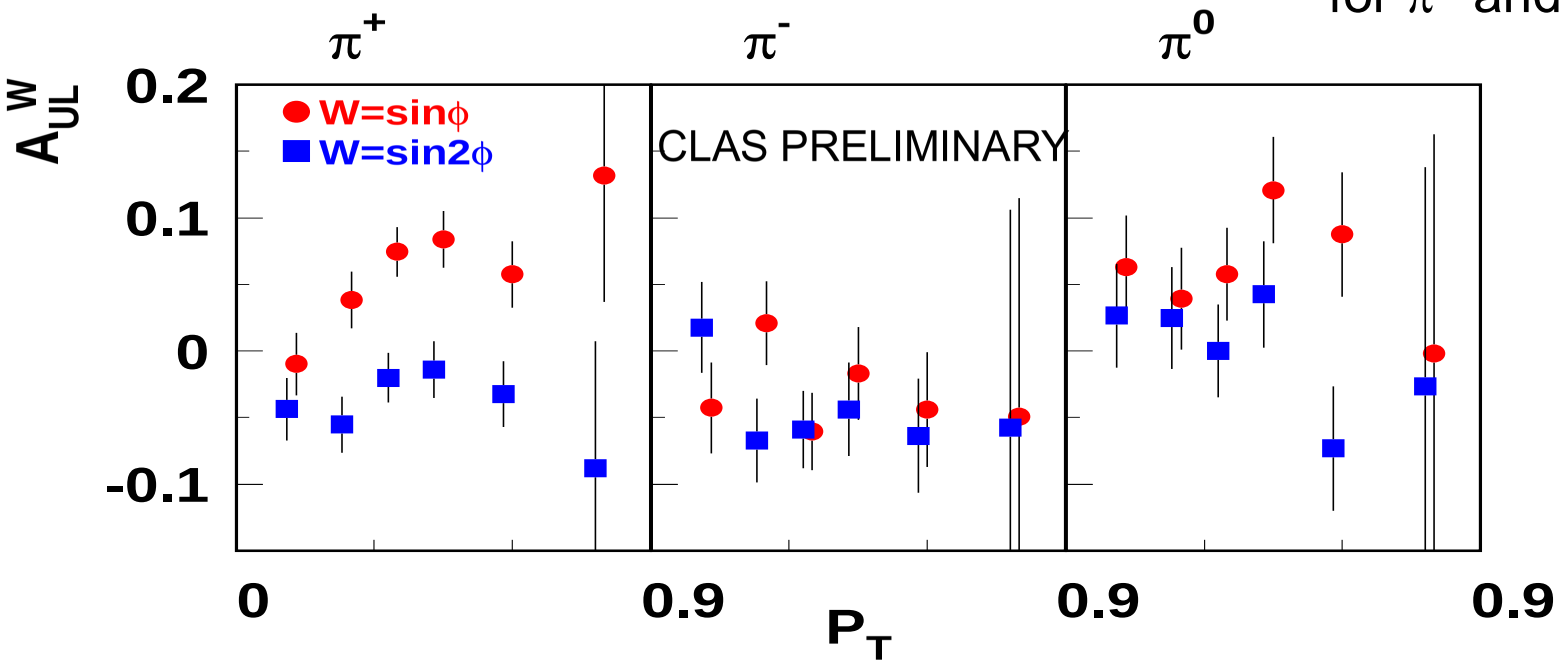
Leading ρ opposite to leading π(into page)



Understanding of 2 pion asymmetries will help to understand single pion mesurements

A_{UL} SSA: P_T-dependence

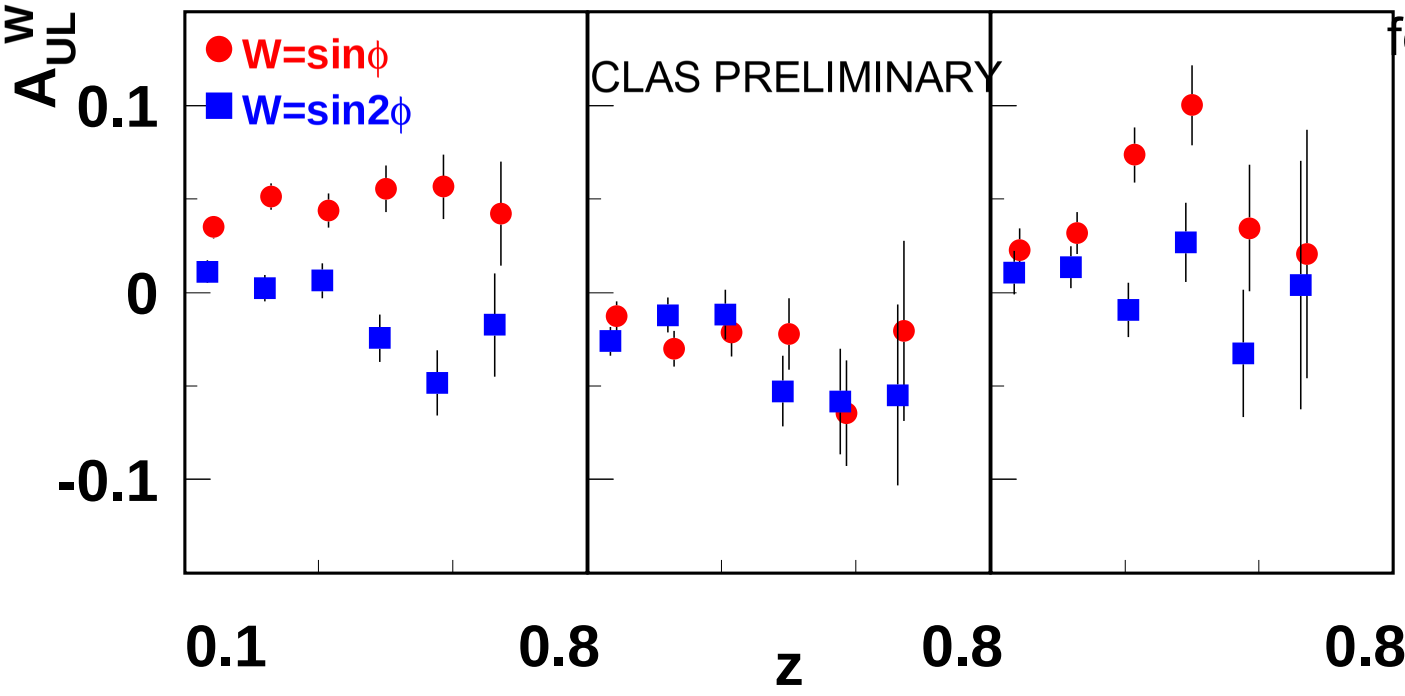
HT –SSA significant for π^+ and π^0



•sinϕ SSA π^+ increases with PT and is consistent with HERMES measurement.

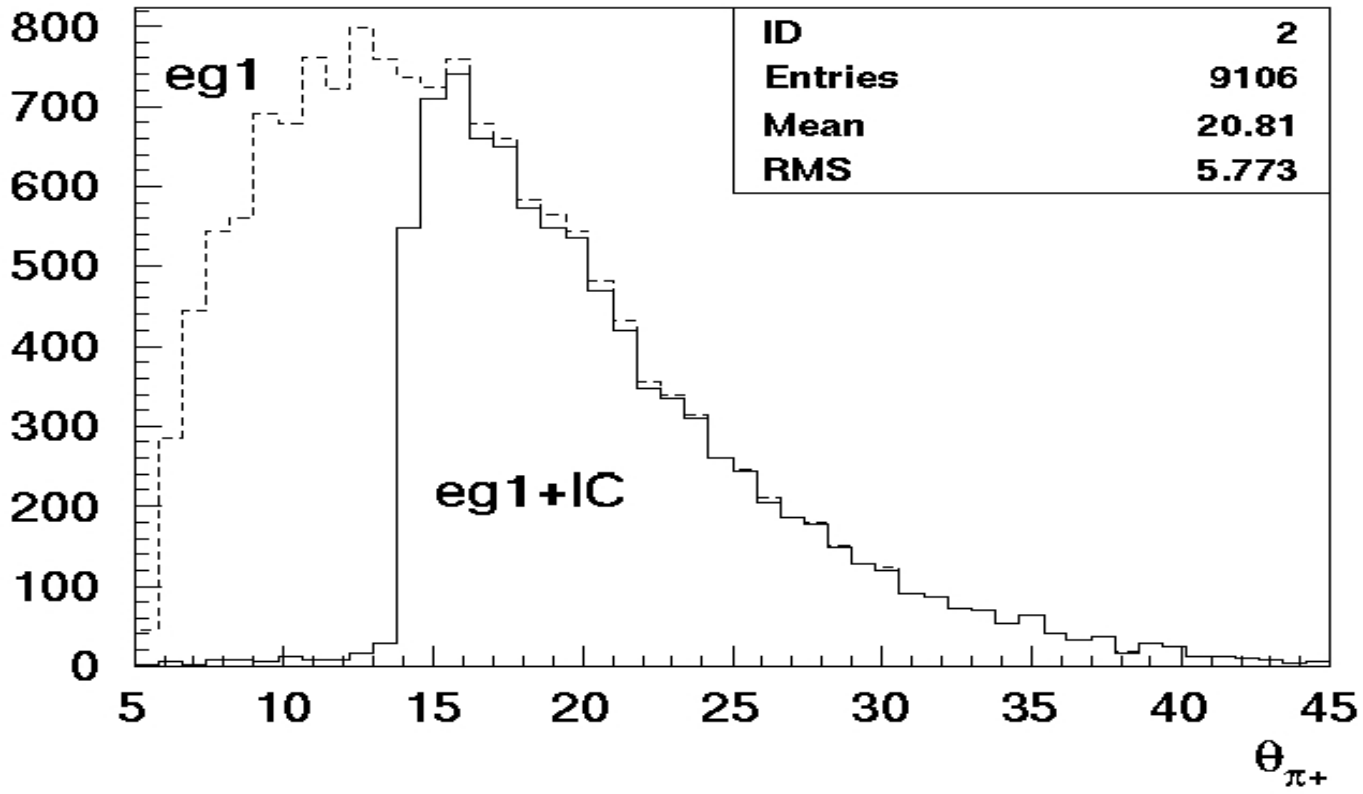
A_{UL} SSA: z-dependence

HT –SSA significant for π^+ and π^0



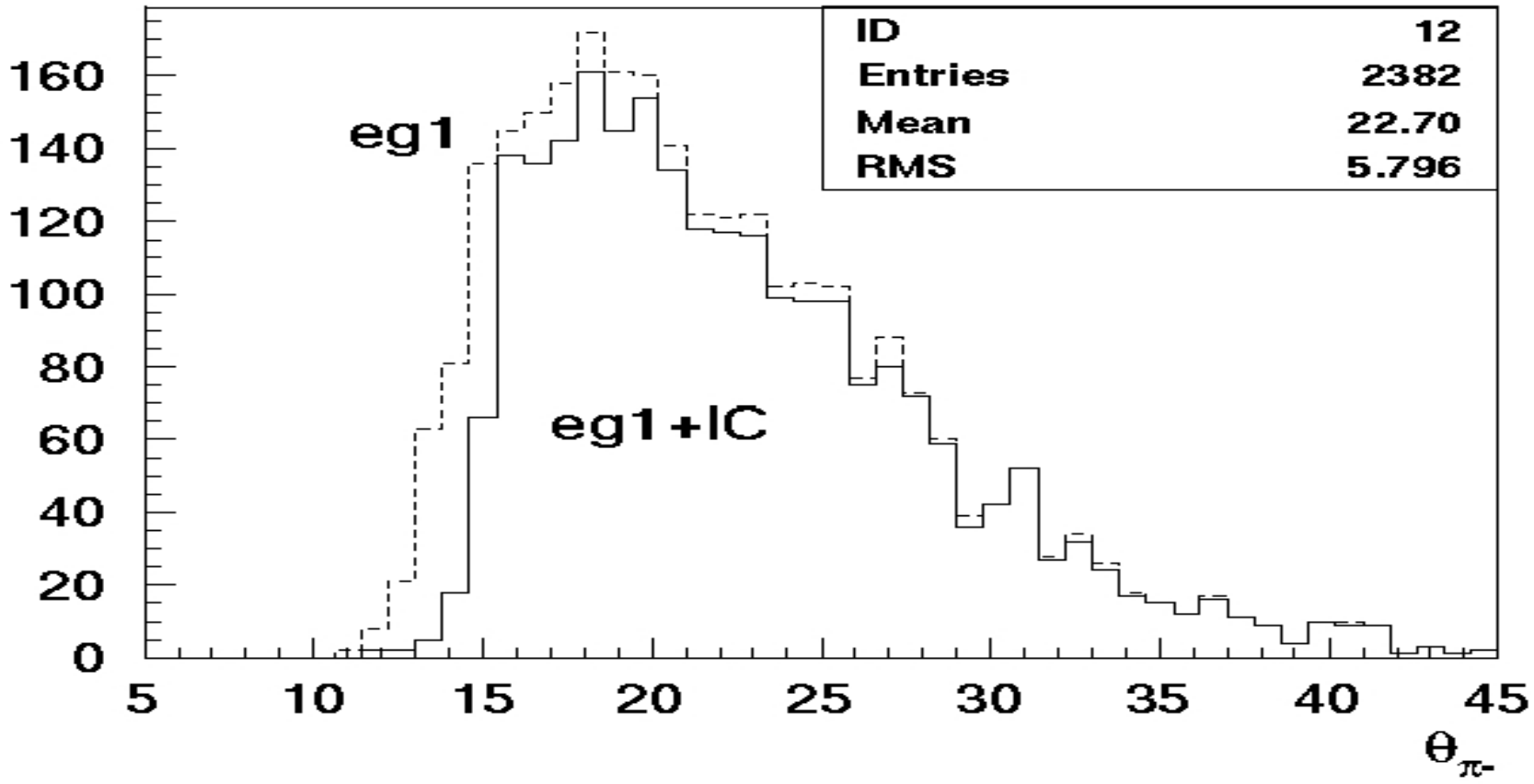
•sinϕ SSA π^+ increases with PT and is consistent with HERMES measurement.

Longitudinally polarized target+IC: π^+



Reconstruction efficiency with IC decreases ~ 40%

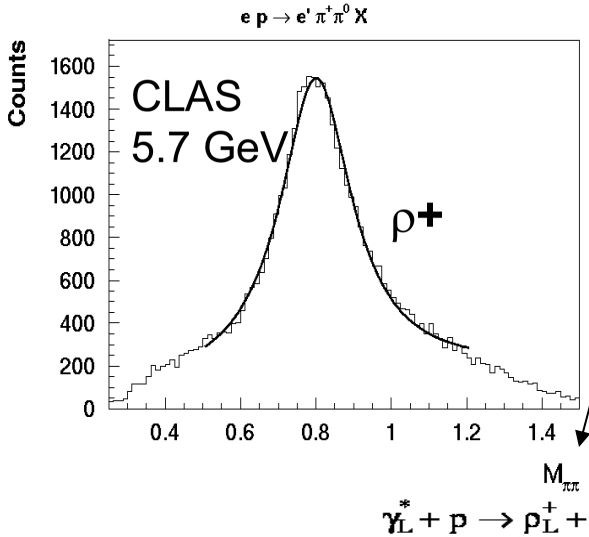
Longitudinally polarized target+IC: π^-



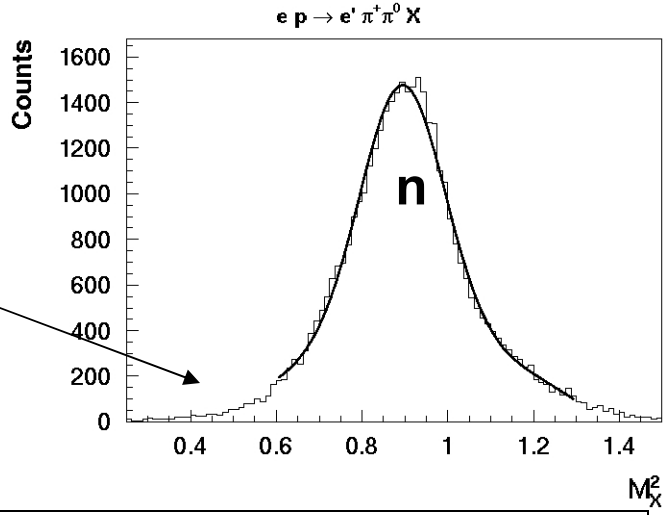
Reconstruction efficiency with IC decreases ~ 10%

Exclusive ρ+ production

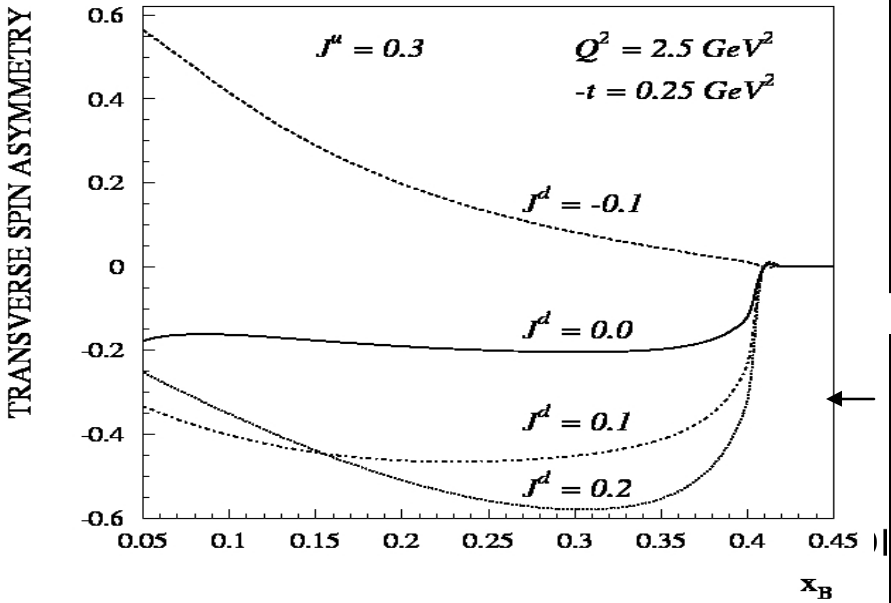
$e^- p \rightarrow e^- n\rho+$, $\rho+ \rightarrow \pi^+\pi^0$



Exclusive ρ+n separated by invariant and missing masses.



$\gamma_L^* + p \rightarrow \rho_L^+ + n$



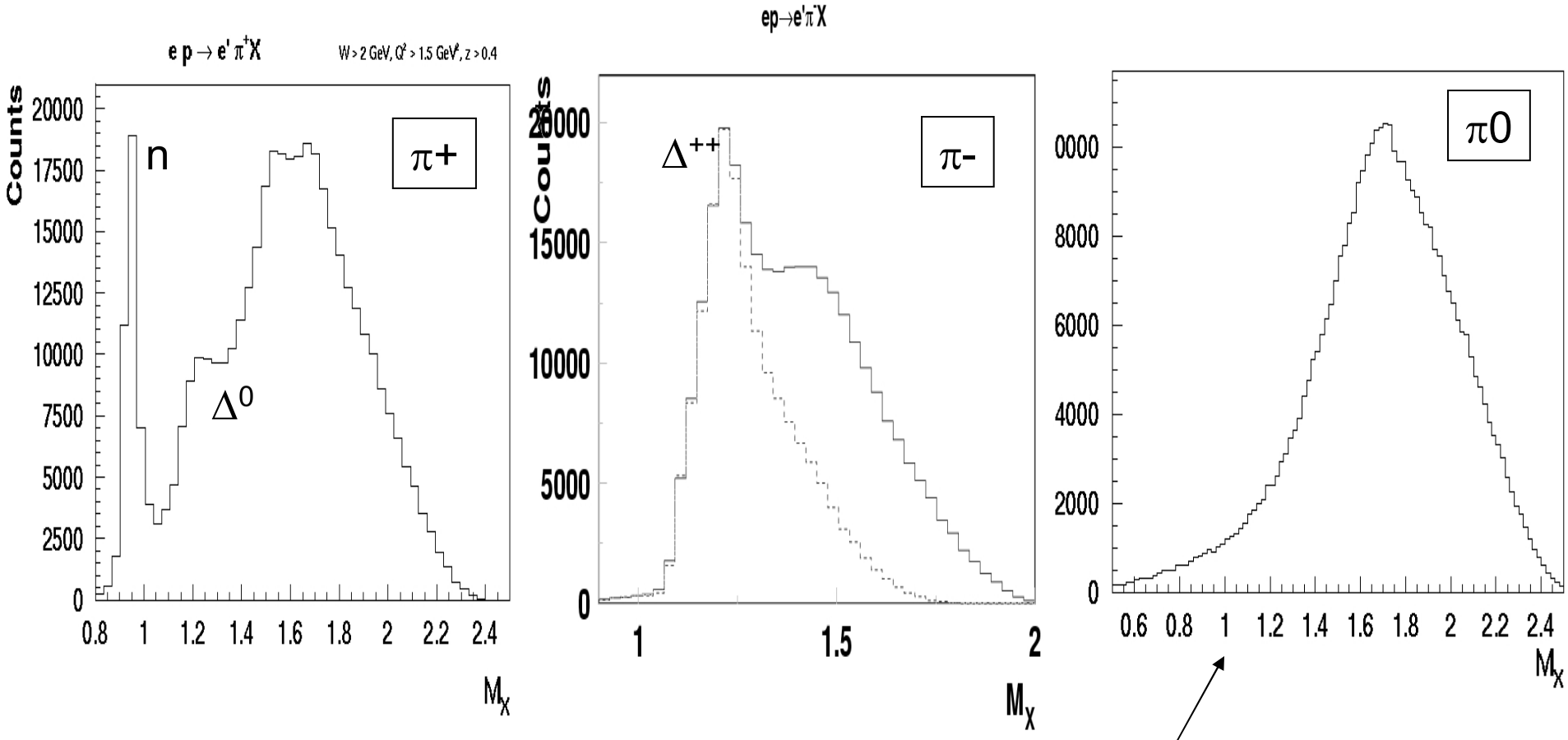
Provide access to different combinations of orbital momentum contributions J^u,J^d

ρ^0 -> $2J^u + J^d$

ρ^+ -> $J^u - J^d$

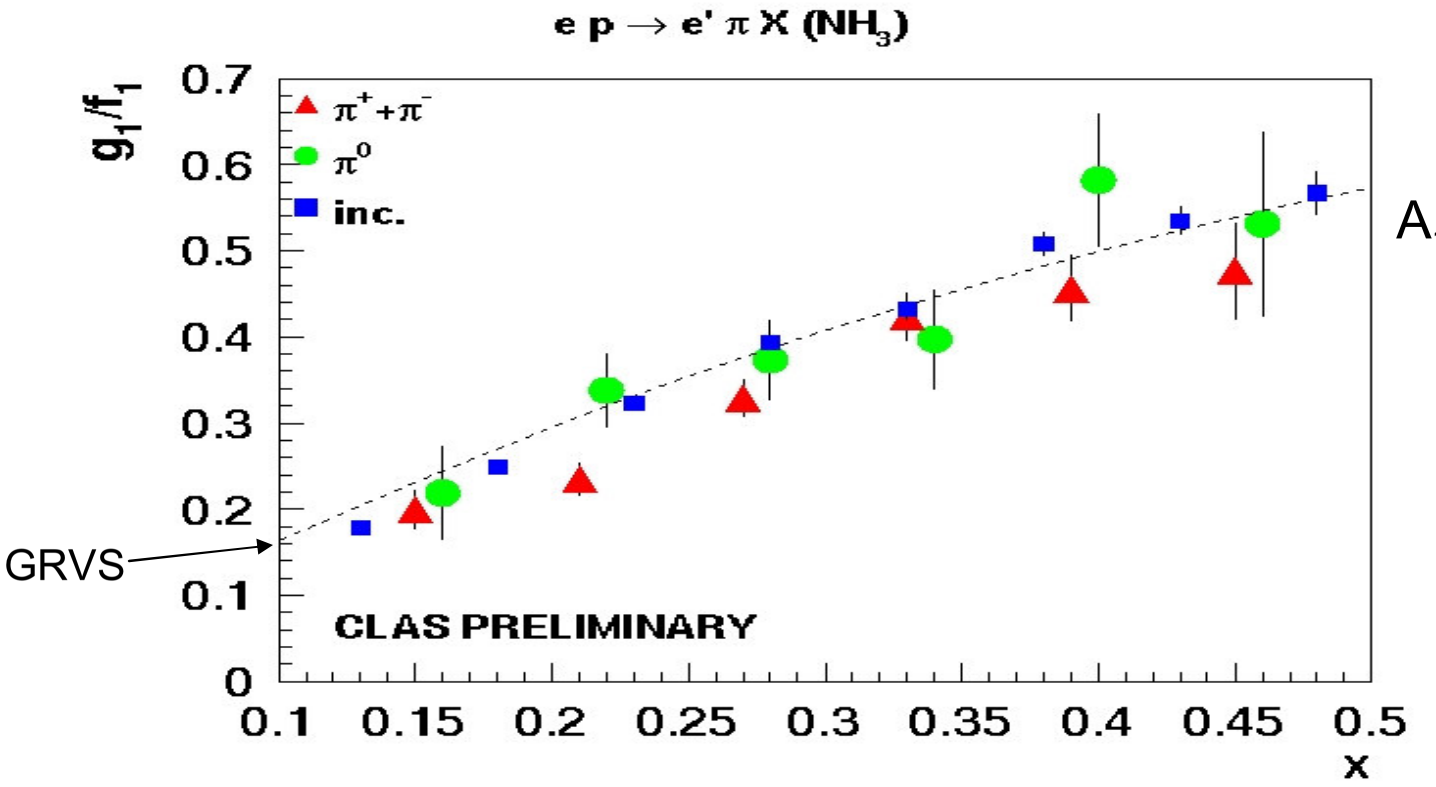
•Significant transverse target SSA predicted for exclusive ρ^+ accesible with long.pol. Target with effective polarization ~20%

Missing mass of pions in ep→e'πX



In accessible kinematics (Q^2>1.5,W^2>4) low M_X(large **z**) for π0 are suppressed by current CLAS acceptance.

SIDIS: factorization studies



$$A_1^{\pi^+ + \pi^-} = \frac{A_1^{\pi^+} + \alpha A_1^{\pi^-}}{1+\alpha}$$

$$\alpha = \frac{\sigma^{\pi^-}}{\sigma^{\pi^+}}$$

α from-MC

- A_1 inclusive, from $\pi^+\pi^-$ sum and π^0 are consistent (in range 0.4<z<0.7)
- A_1^p dependence can serve an important check of HT effects and applicability of simple partonic description.
- There is an indication that A_1^p of $\pi^+ + \pi^-$ is lower than inclusive at large z.