

# New results on SIDIS SSA from JLab

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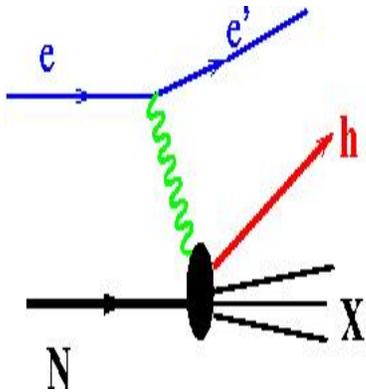
*Jefferson Lab*

DIS-2005 Apr 28

- 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)

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

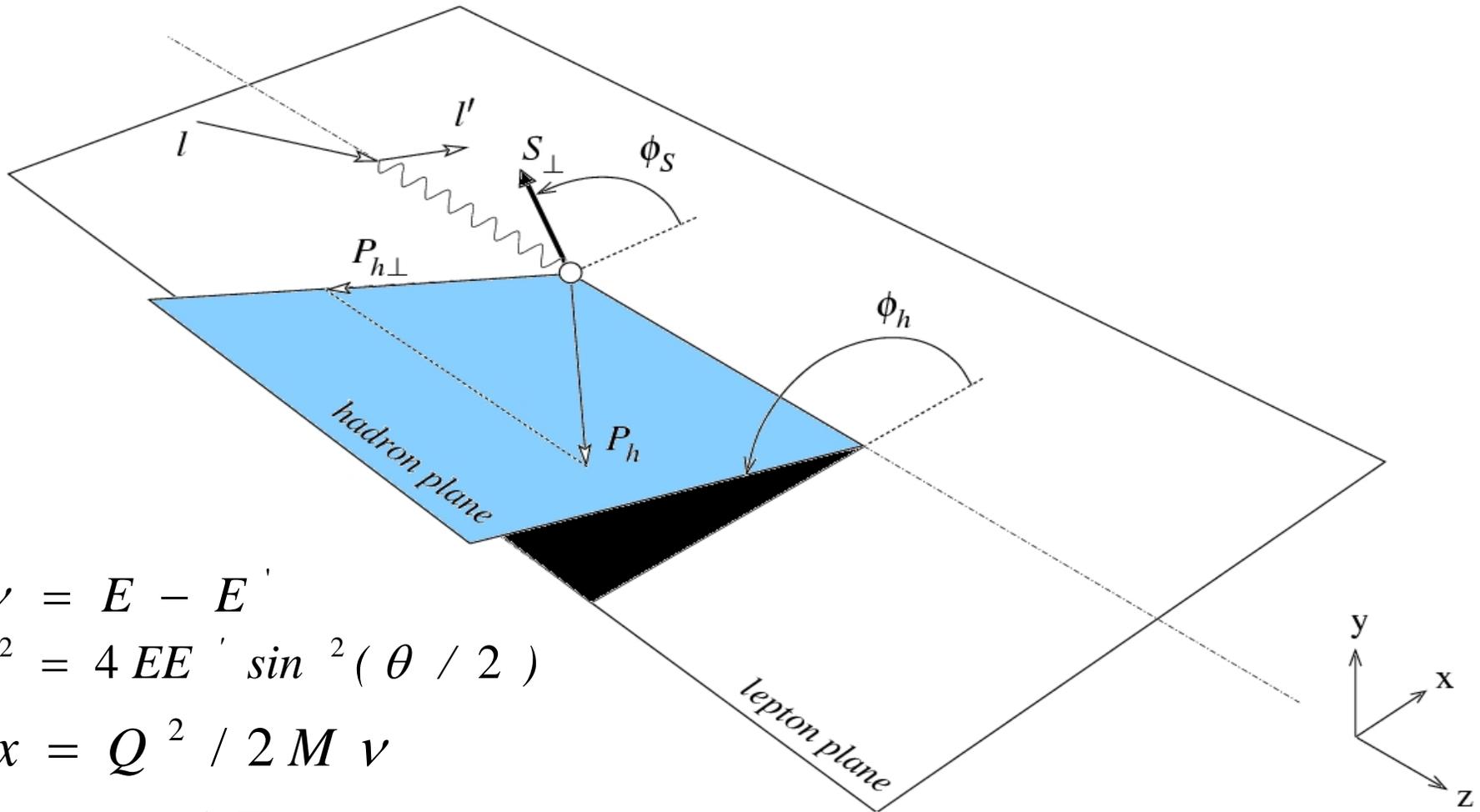
Sivers

transversity

Mulders

- 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



$$\nu = E - E'$$

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

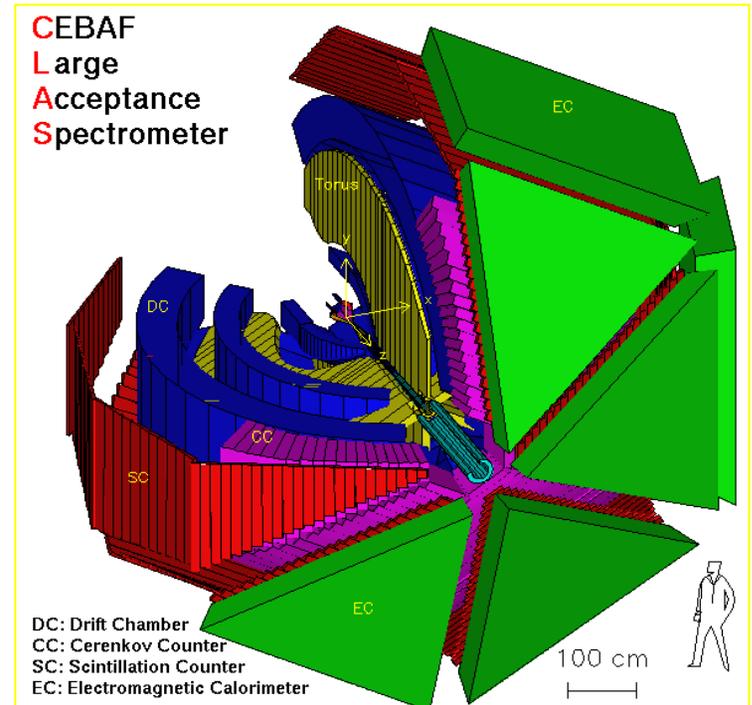
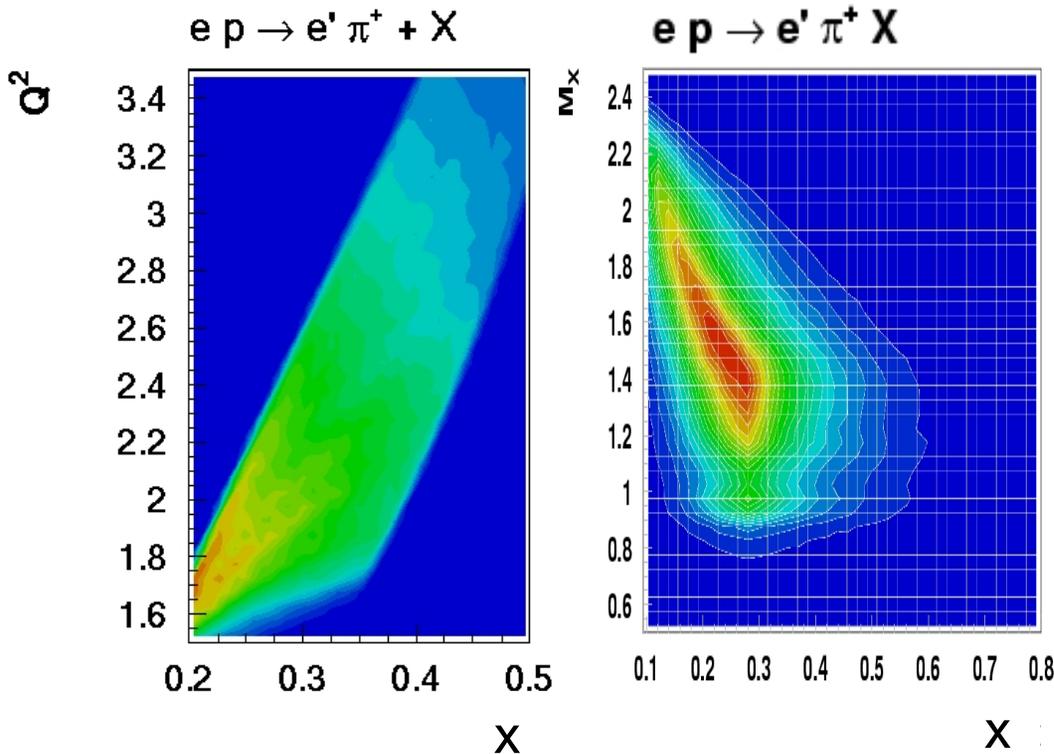
$$x = Q^2 / 2M\nu$$

$$y = \nu / E$$

$$z = E_h / \nu$$

# The CLAS Detector

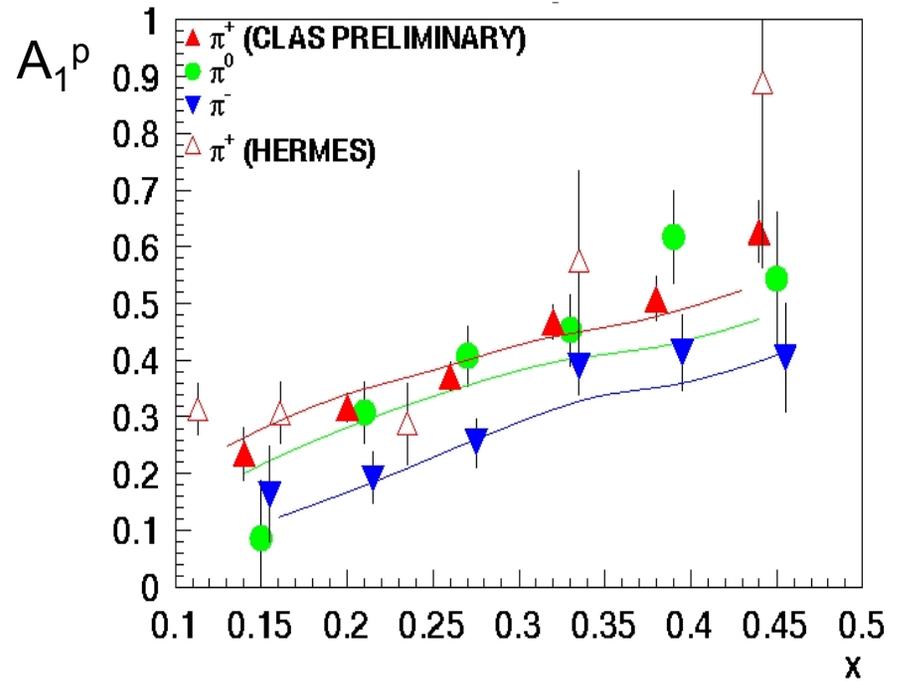
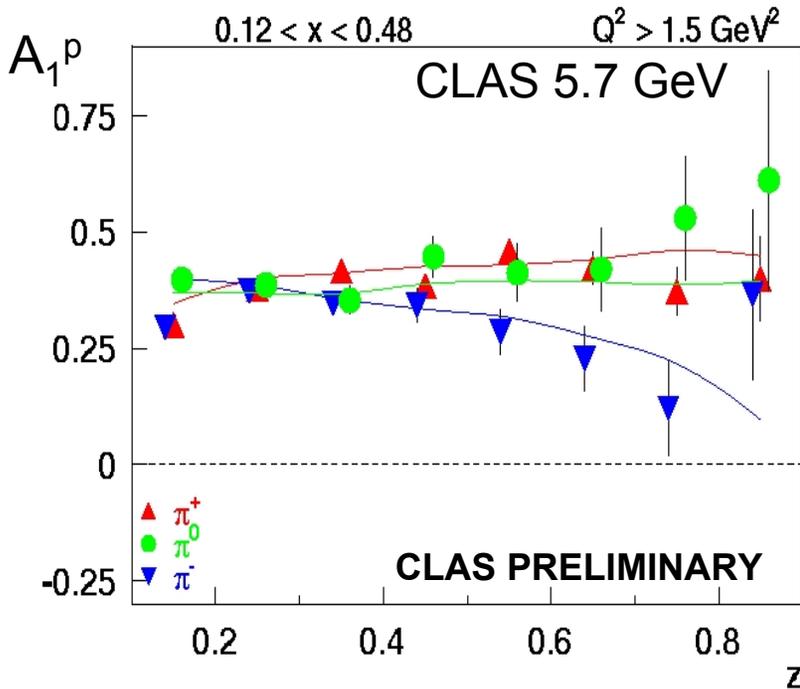
Scattering of 5.7 GeV polarized electrons off polarized  $\text{NH}_3$



- $\sim 8\text{M } \pi^+$  in DIS kinematics, SIDIS
- $Q^2 > 1.1 \text{ GeV}^2$ ,  $W^2 > 4 \text{ GeV}^2$ ,  $y < 0.85$ ,
- beam polarization 73%
- target polarization 72% ( $f=0.2$ )

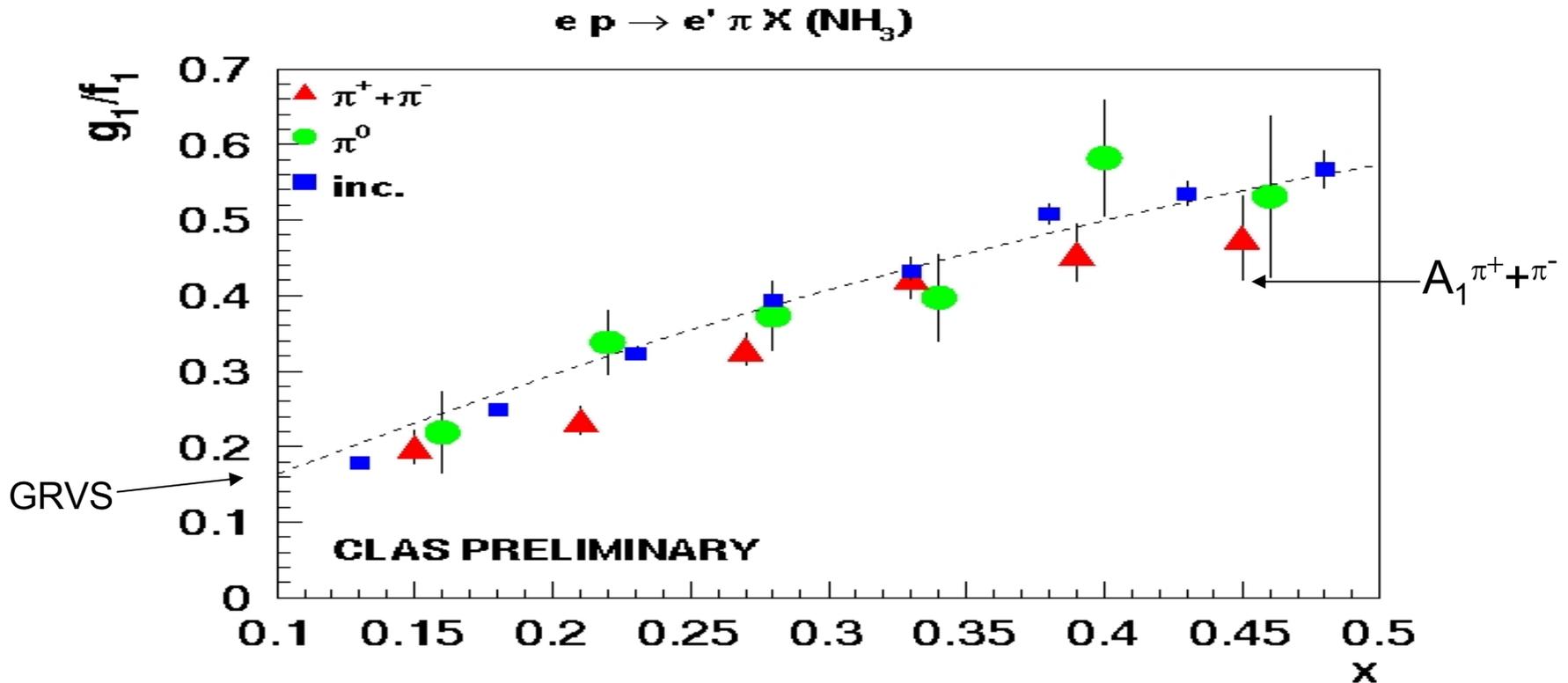
# $A_1^p$ -kinematic dependence for $\pi^{+/-/0}$

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



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

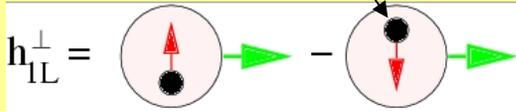
# SIDIS: factorization studies



- $A_1$  inclusive, from  $\pi^+\pi^-$  sum and  $\pi^0$  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  $z$ .

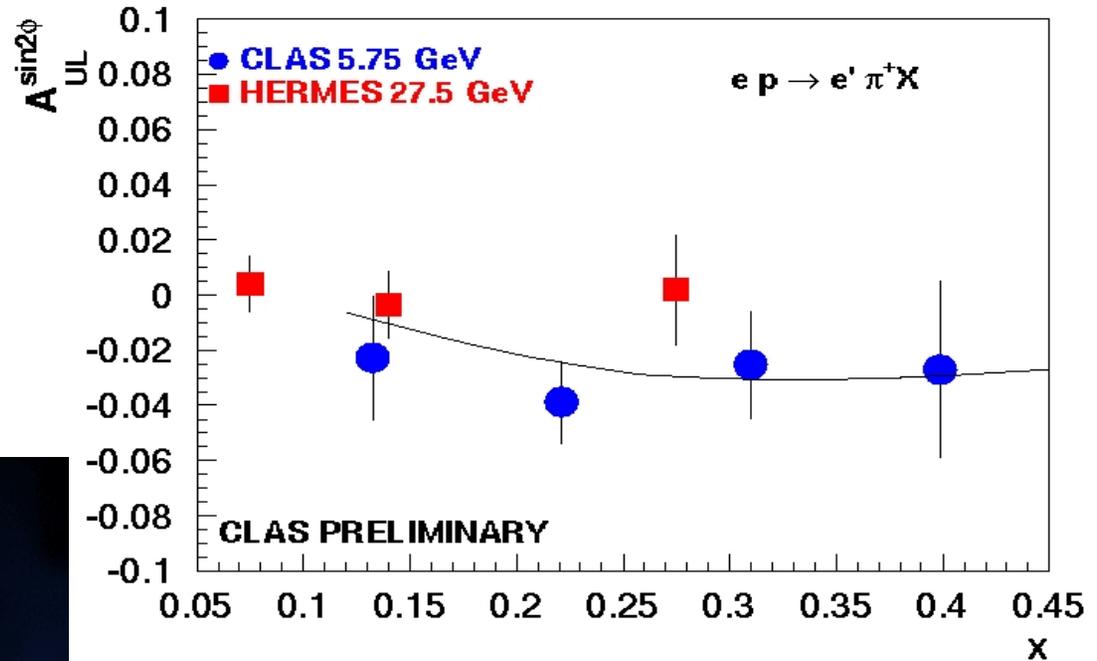
# Longitudinally polarized Target SSA

$Z \backslash q$	U	L	T
U	$f_1$		$h_{1T}^{\perp}$
L		$g_1$	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	$h_{1T}^{\perp}, h_{1L}^{\perp}$

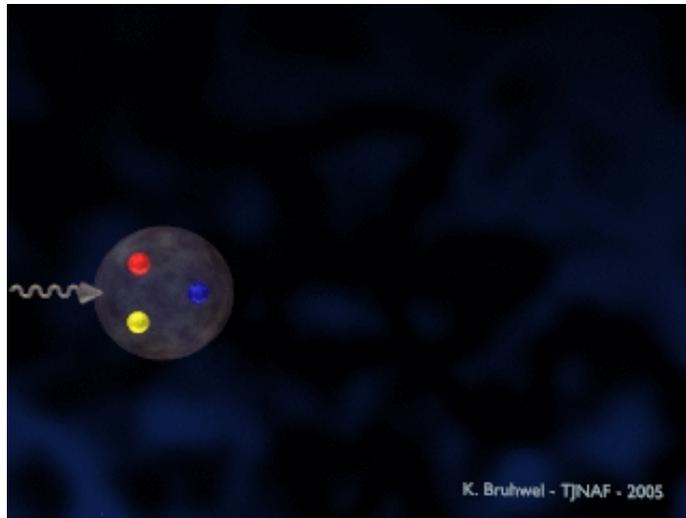


Real part of interference of wave functions with  $L=0$  and  $L=1$

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



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



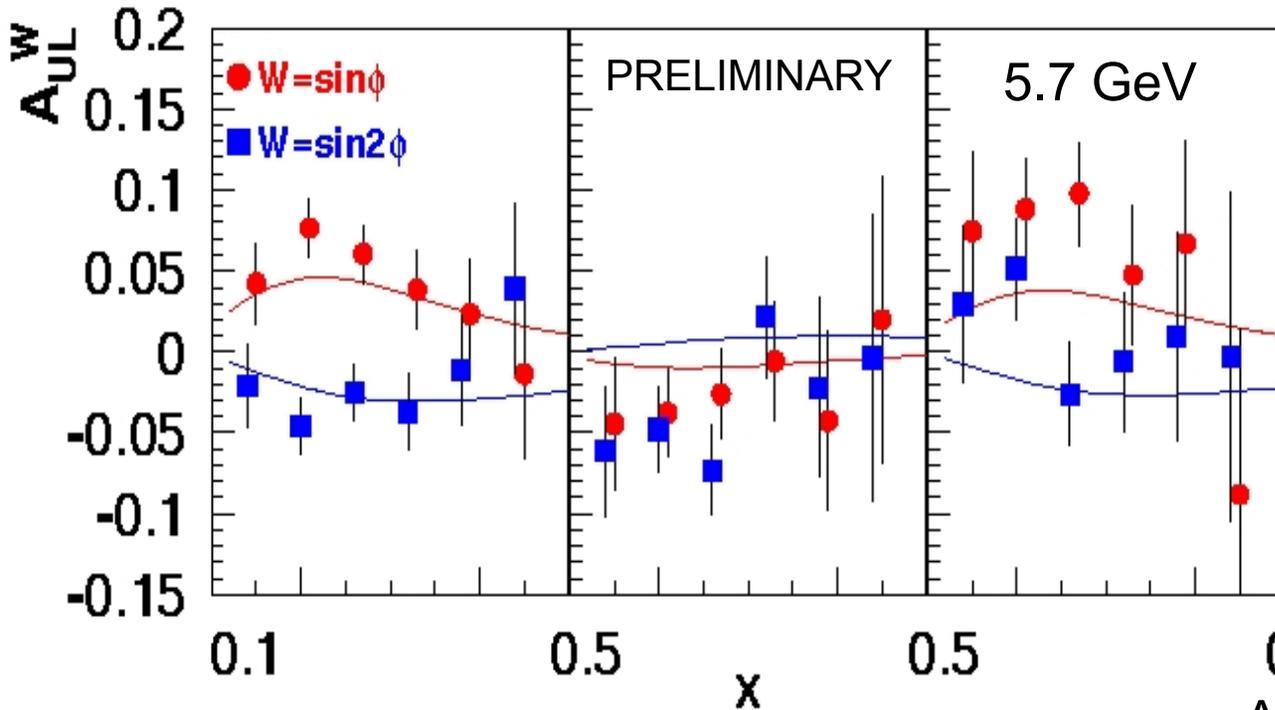
K. Bruhwal - TJNAF - 2005

# SSA: x-dependence

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

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

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



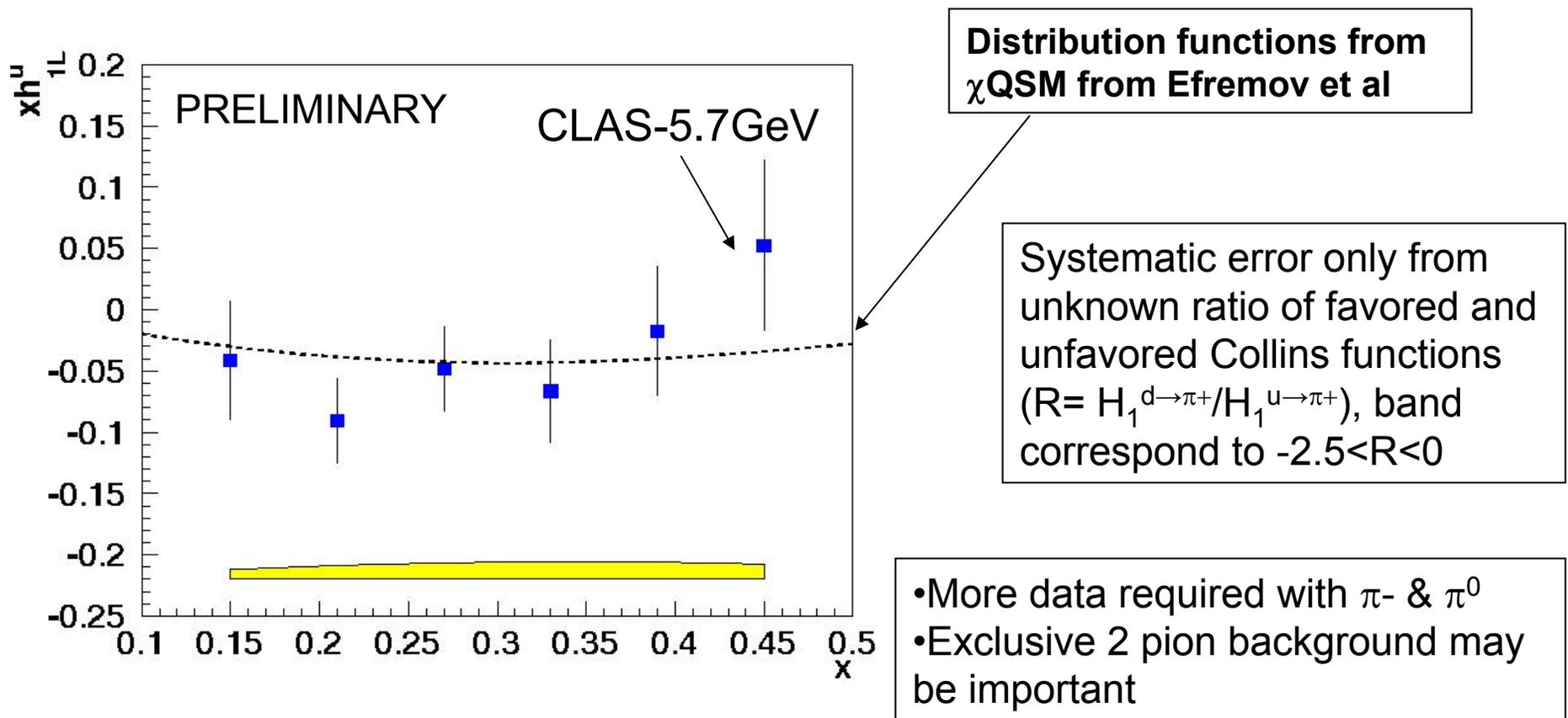
HT-SSA significant for  $\pi^+$  and  $\pi^0$  (non-Collins?)

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

- Study the Collins fragmentation mechanism with long. polarized target
- For  $\pi^-$  and  $\pi^0$  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)



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

# $\pi^0$ in Semi-inclusive DIS

advantages:

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

disadvantages:

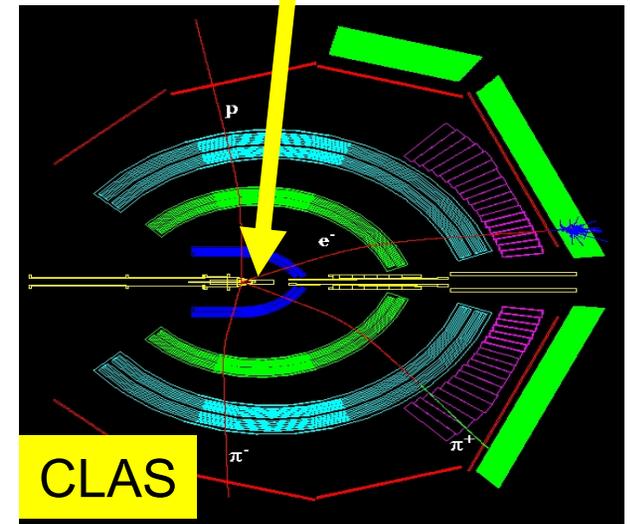
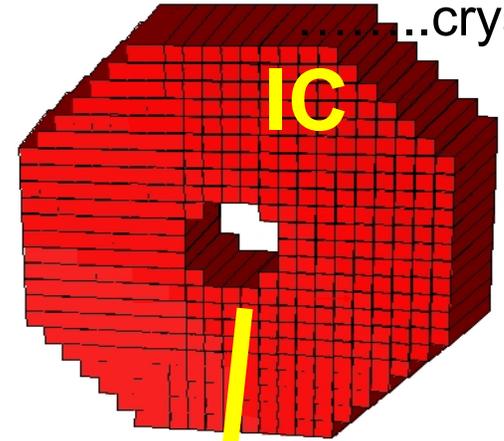
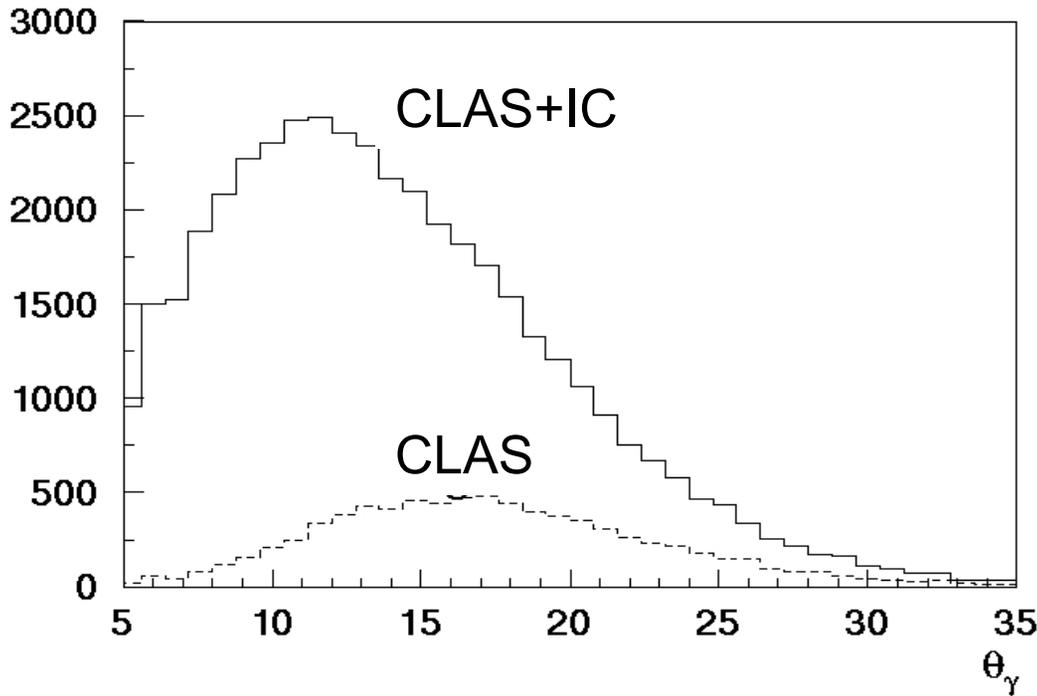
reconstruction efficiency (requires detection of  $2\gamma$ )

# CLAS + Inner Calorimeter (IC)

424  $\text{PbWO}_4$

.....crystals

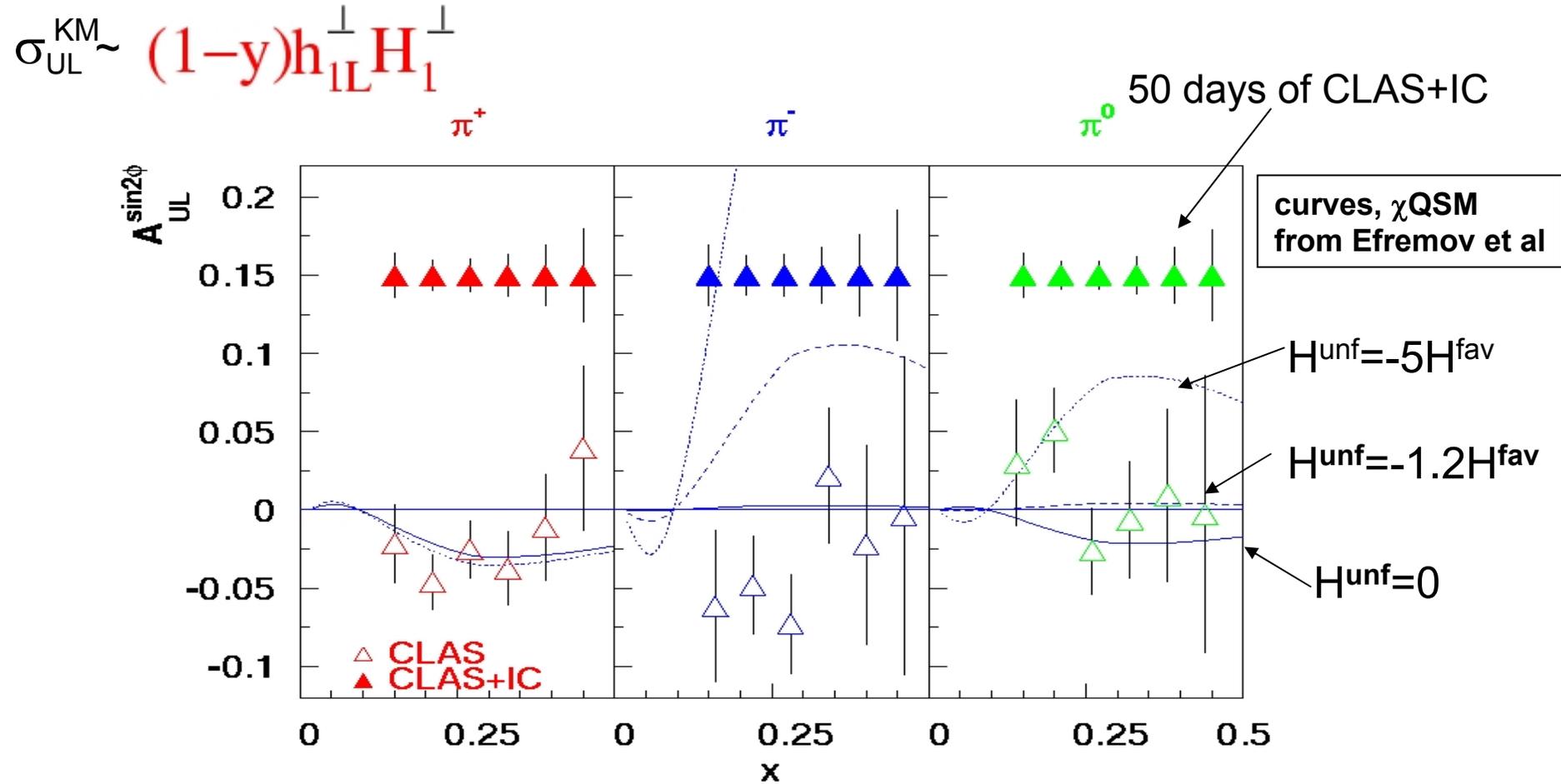
$$\text{IC } \sigma_E/E = 0.0034/E + 0.038/\sqrt{E} + 0.022$$



Reconstruction efficiency of high energy  $\pi^0$  with IC increases  $\sim 4$  times due to small angle coverage

IC at CLAS opens new avenue for studies of spin and azimuthal asymmetries of exclusive and semi-inclusive  $\gamma, \pi^0, \eta, \rho^+$

# Longitudinally polarized target SSA using CLAS+IC



- 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  $\sin 2\phi$  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 superior measurements with neutral pions allowing precision measurement of the twist-2  $k_T$ -dependent PDF.