Flavor decomposition at LO

H.Avakian (JLab)

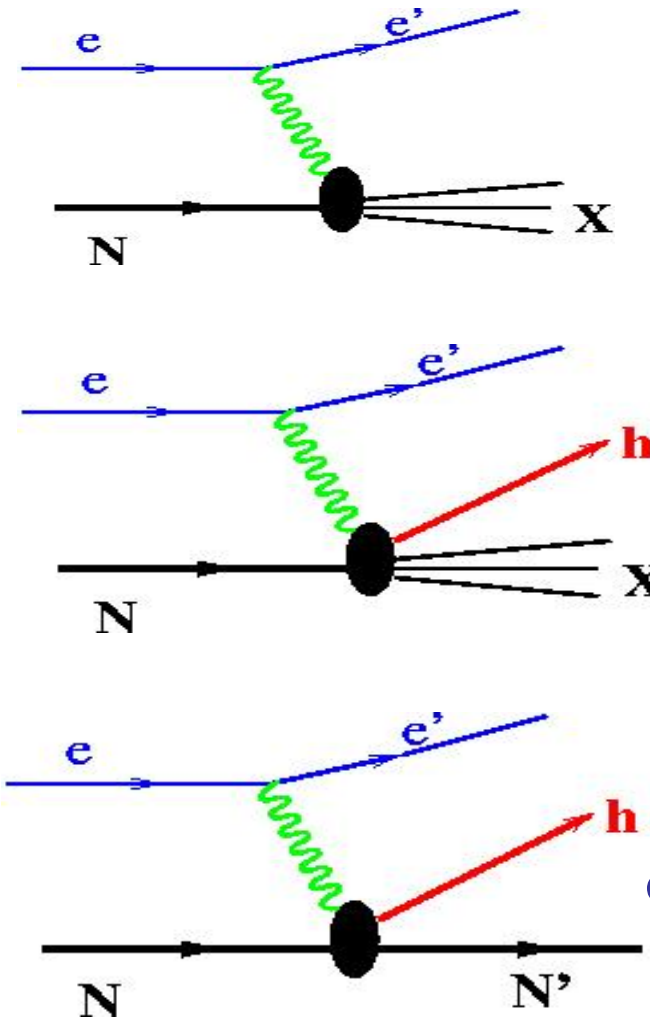
Hall-C Collaboration Meeting Aug 18, 2005

Outline

- Large-x behavior of valence PDFs and flavor asymmetries of the sea

- Applicability of partonic description at JLab energies
  - Factorization in SIDIS
  - target fragmentation, FSI in ep->e'h+X
- Methods for PDF extraction.
  - Contamination from non-DIS processes
  - target fragmentation
  - exclusive production (vector mesons)

Accessing PDFs in Deep Inelastic Scattering



Q^2

Major source of QCD tests
PDF studies

Measures $\Delta q+\Delta\bar{q}$, requires assumptions on sea

"Tagging" to distinguish different flavors and sea quarks in particular.

Additional requirments: Factorization, Fragmentation functions, particle identification, accidentals, lower rates

"Tagging" with no background from other processes (pseudoscalar mesons).

Higher Q^2 required for interpretations in terms of PDF. Only longitudinal photons, much lower x-sections.

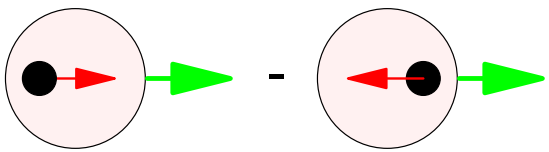
Quark Polarization from DIS

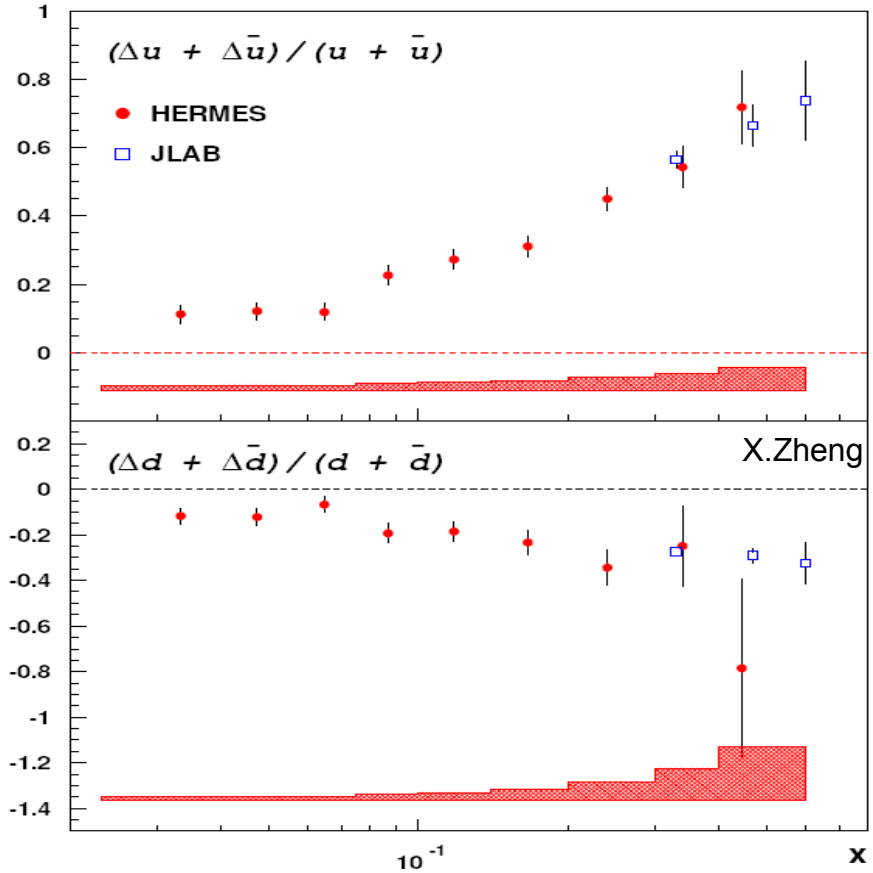
$$\sigma(x,Q^2) \propto (1+(1-y)^2)\sum_q e_q^2 q(x)$$

$$q = u, \bar{u}, d, \bar{d}, s, \bar{s}$$

$$\Delta\sigma(x,Q^2) \propto (1-(1-y)^2)\sum_q e_q^2 \Delta q(x)$$

$$\Delta q(x) = q_+(x) - q_-(x)$$

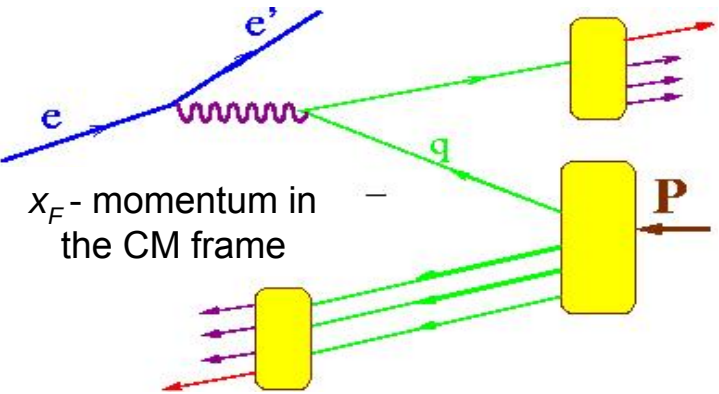
g_1 =  -



X.Zheng et al.

Good agreement in PDF measurements from DIS at different beam energies and Q^2

Single pion production in hard scattering

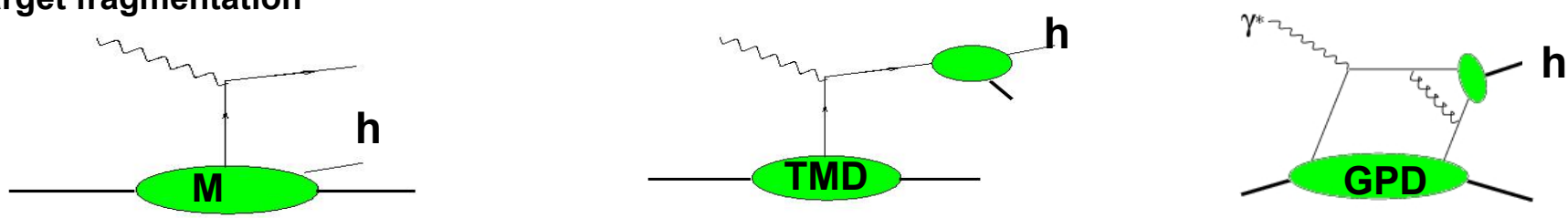


x_F - momentum in the CM frame

x_F>0 (current fragmentation)

Target fragmentation

Current fragmentation



Fracture Functions

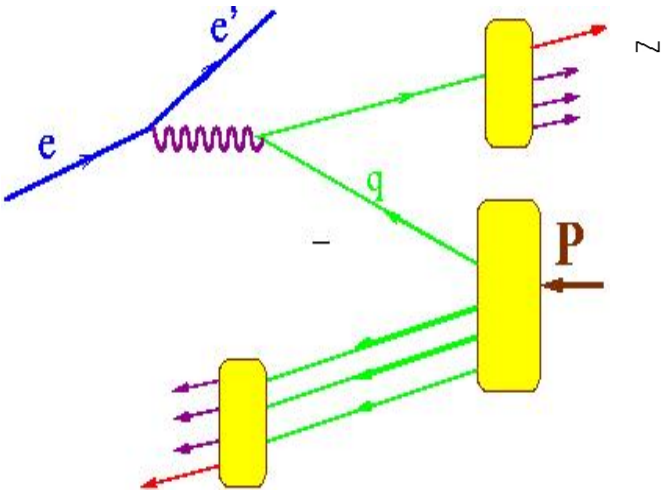
k_T-dependent PDFs

Generalized PDFs

Studies of hadronization both in the target and current fragmentation regions important to control SIDIS backgrounds

SIDIS: Target fragmentation

$x_F>0$ (current fragmentation)

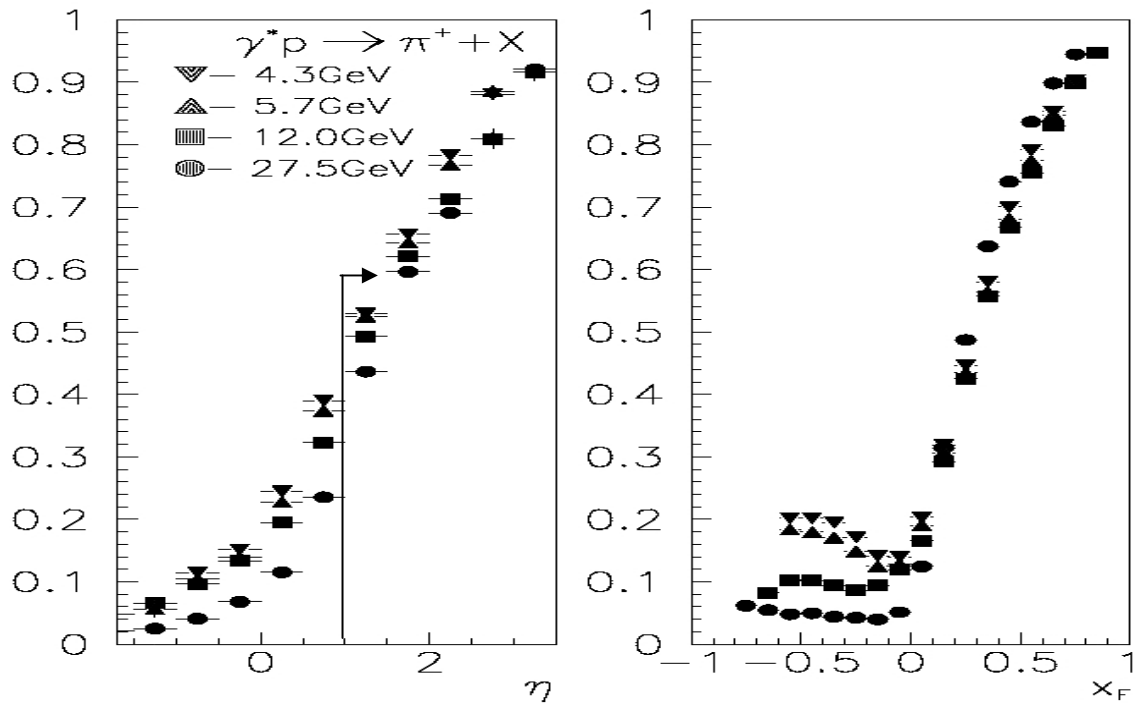


$x_F<0$ (target fragmentation, TFR)

$$z = \frac{E_h}{\nu}$$

$$x_F = \frac{p_L^*}{p_{Lmax}^*}$$

$$\eta = \frac{1}{2} ln \frac{E+p_L^*}{E-p_L^*}$$

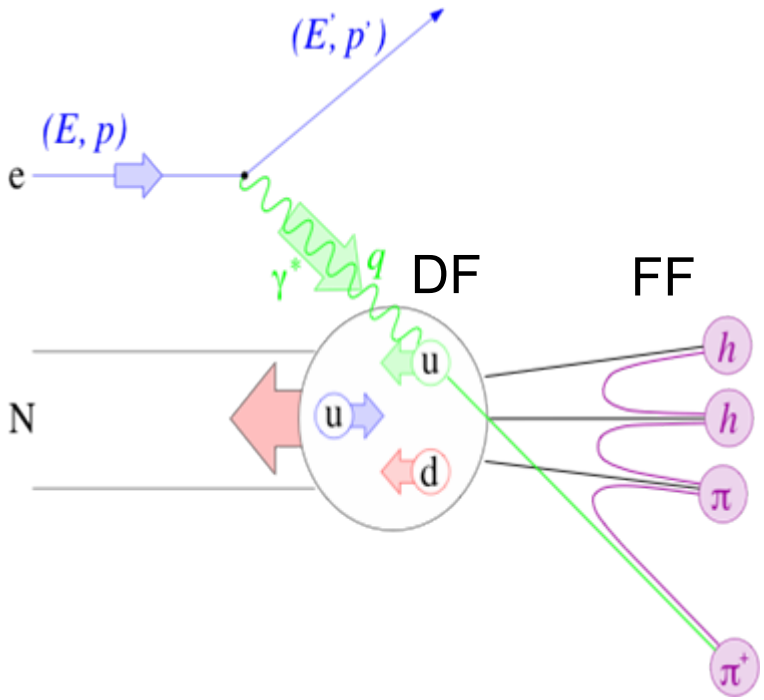


Rapidity ($\eta>1$) and x_F cuts are *on average* related to z cut

What is the fraction of target fragmentation in forward hemisphere?
What is the contribution to various observables (multiplicities, asymmetries)?

Quark Polarization from Semi-Inclusive DIS (SIDIS)

In SIDIS, a hadron h is detected in coincidence with the scattered lepton:



$$z \equiv E_h/\nu$$

Flavor Tagging: Flavor content of observed hadron *h* is related to flavor of struck quark *q* via the fragmentation functions *D*(*z*)

Favored / disfavored fragmentation

$$D_{\text{fav}}(z) \equiv D^{u\to\pi^+}(z) = D^{d\to\pi^-}(z) = \ldots$$

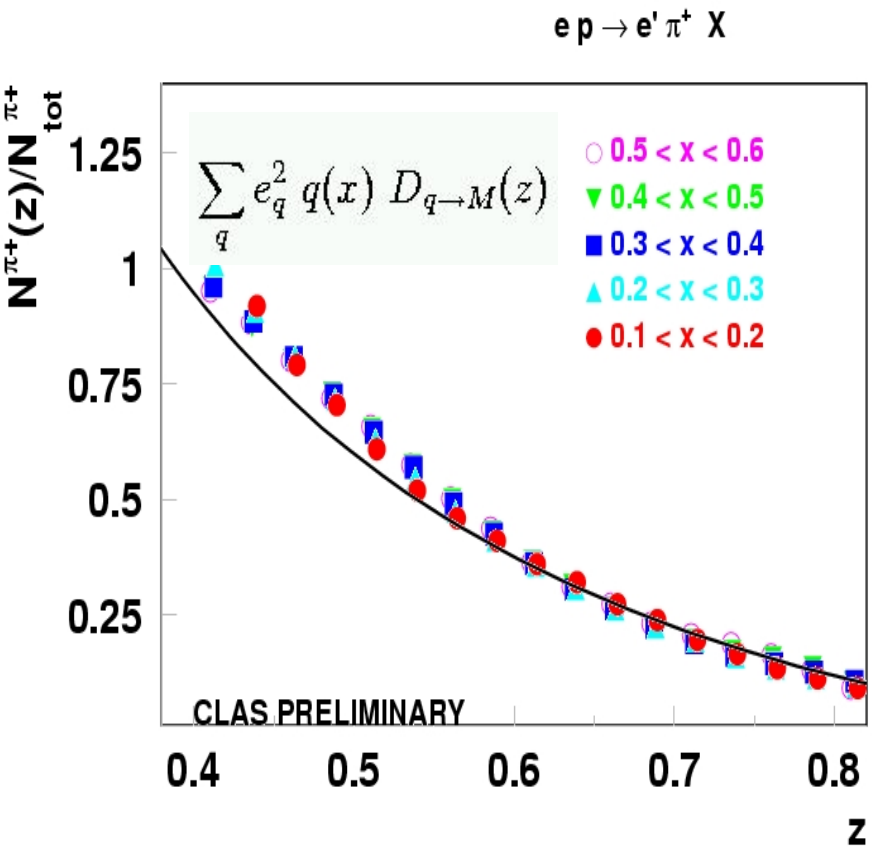
$$D_{\text{dis}}(z) \equiv D^{d\to\pi^+}(z) = D^{u\to\pi^-}(z) = \ldots$$

$$\sigma^h(x,Q^2,z) \propto (1+(1-y)^2)\sum_q e_q^2\, q(x,Q^2)\, D_q^h(z,Q^2)$$

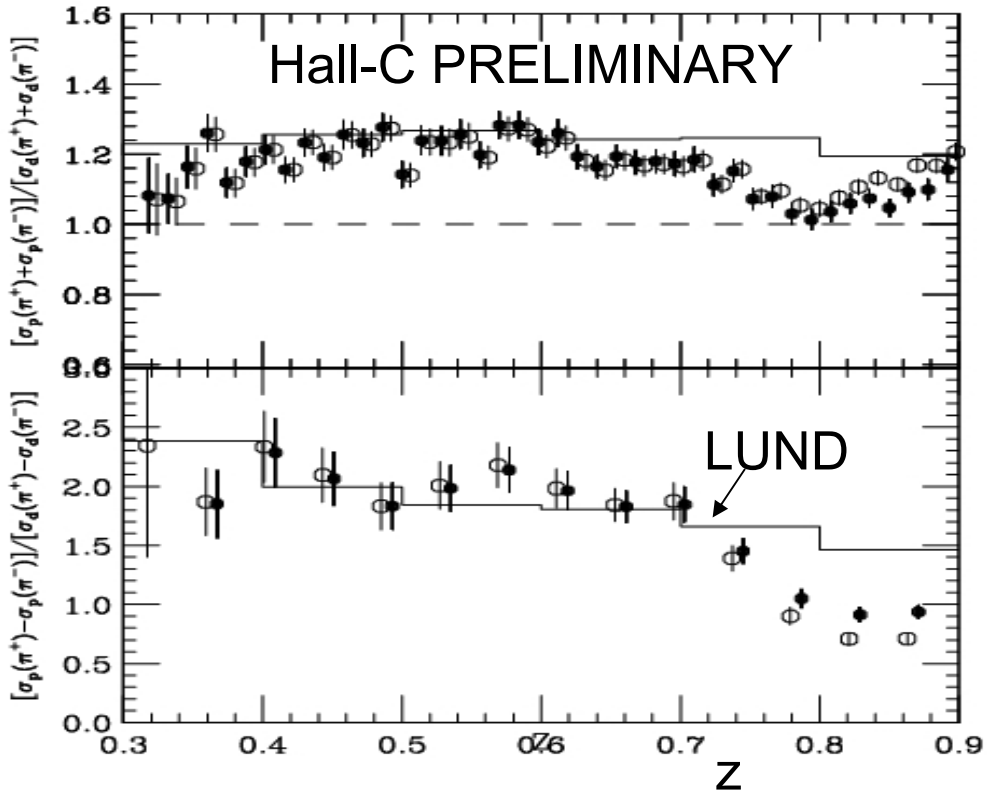
$$\Delta\sigma^h(x,Q^2,z) \propto (1-(1-y)^2)\sum_q e_q^2\, \Delta q(x,Q^2)\, D_q^h(z,Q^2)$$

$$A_1^h(x,Q^2,z) = \frac{\sum_q e_q^2\, \Delta q(x,Q^2)\, D_q^h(z,Q^2)}{\sum_q e_q^2\, q(x,Q^2)\, D_q^h(z,Q^2)}$$

SIDIS: factorization studies



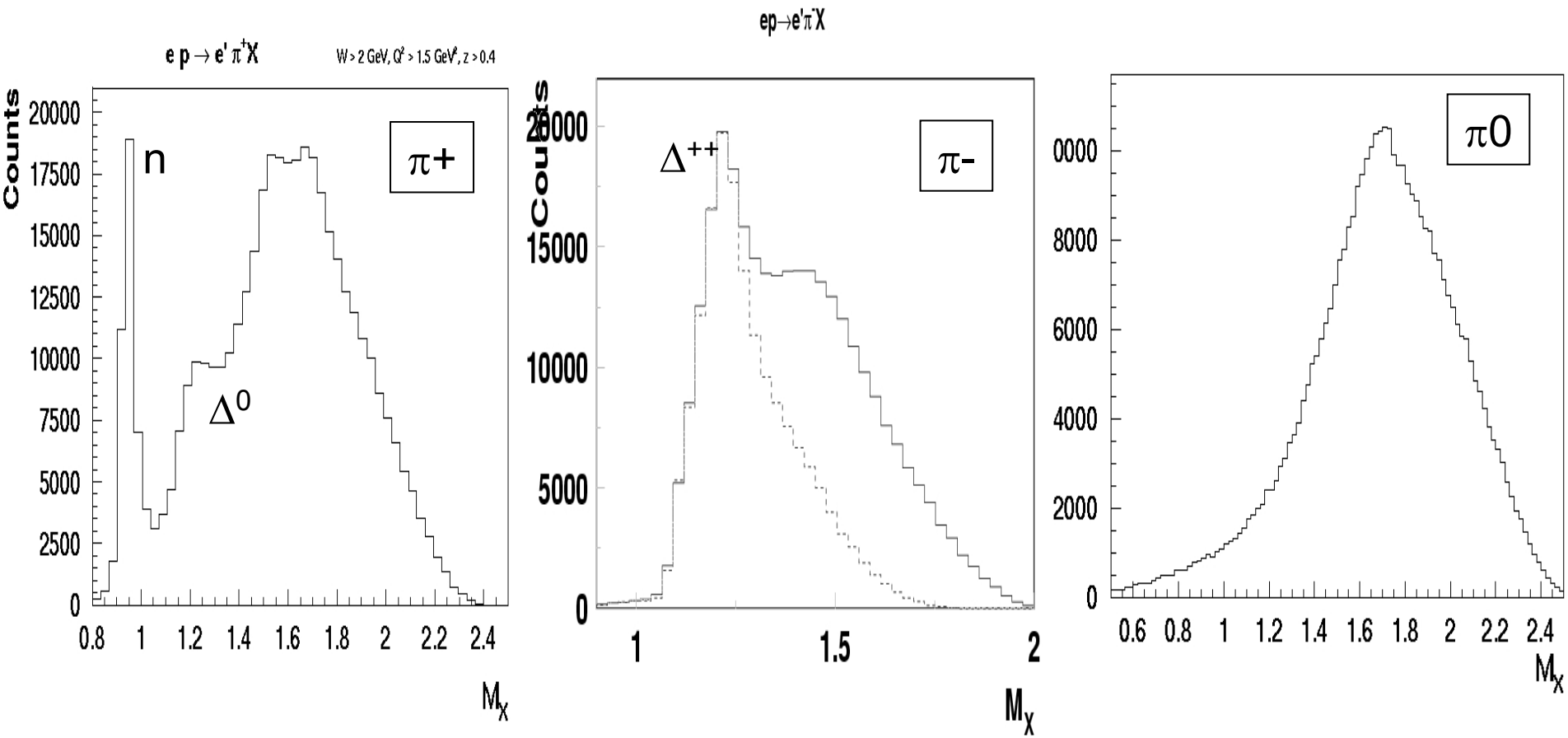
No significant variation observed in z distributions of p+ for different **x** ranges



Ratios consistent with factorization and with LUND MC predictions (large z-> low Mx)

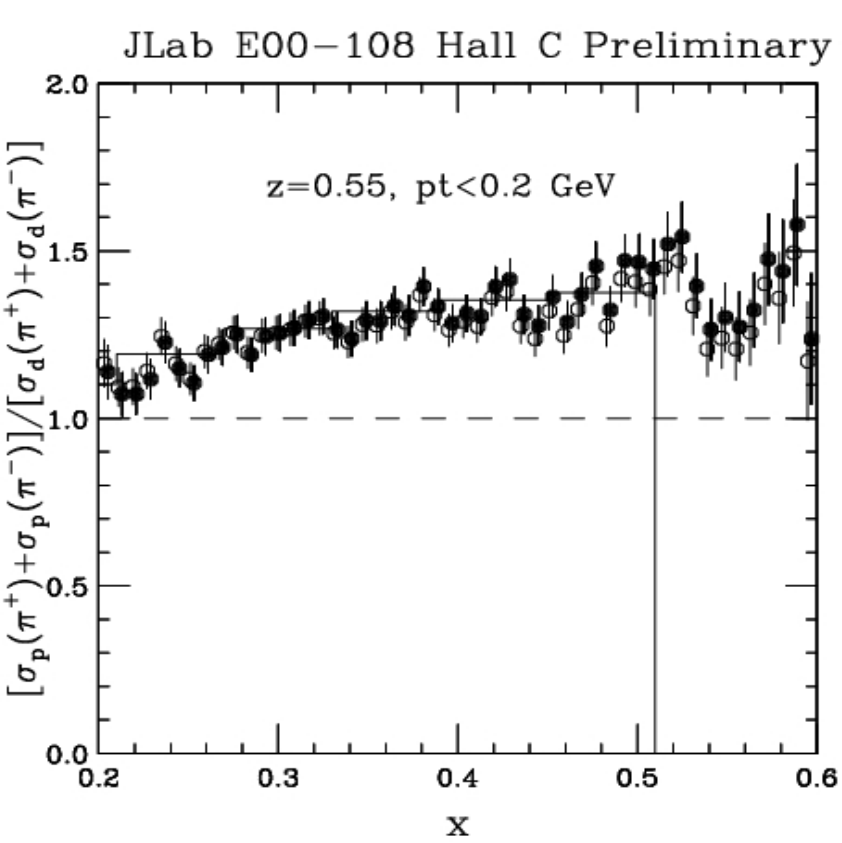
JLab data at 6GeV are consistent with factorization and partonic description for variety of ratio observables.

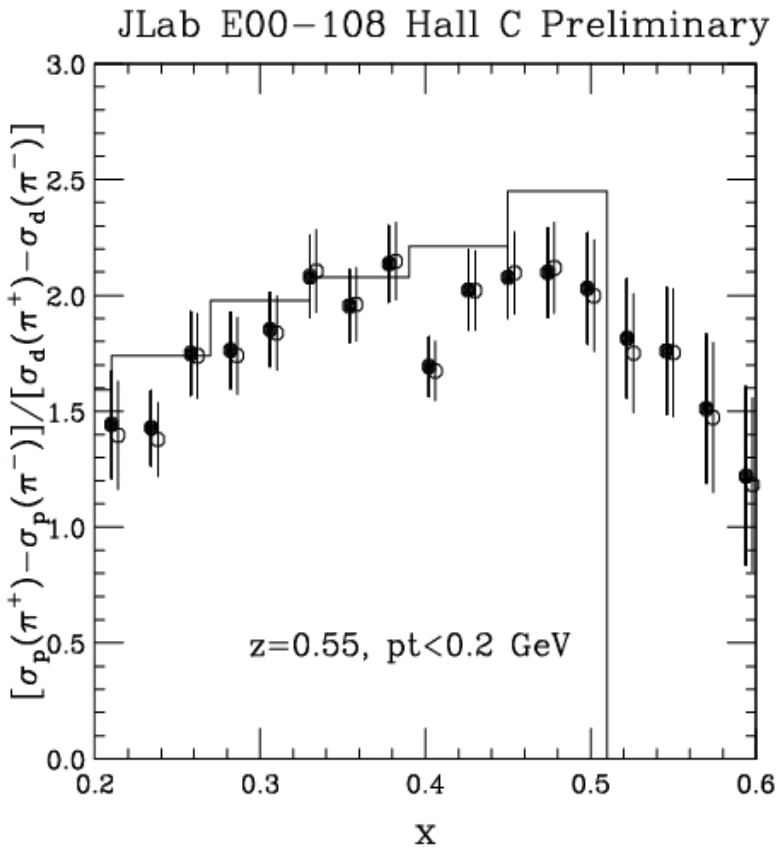
SIDIS: Missing mass of pions in ep→e'πX



No resonances seen in the target fragment for M_X>1.4 (Q^2>1.5,W^2>4)

SIDIS: factorization studies

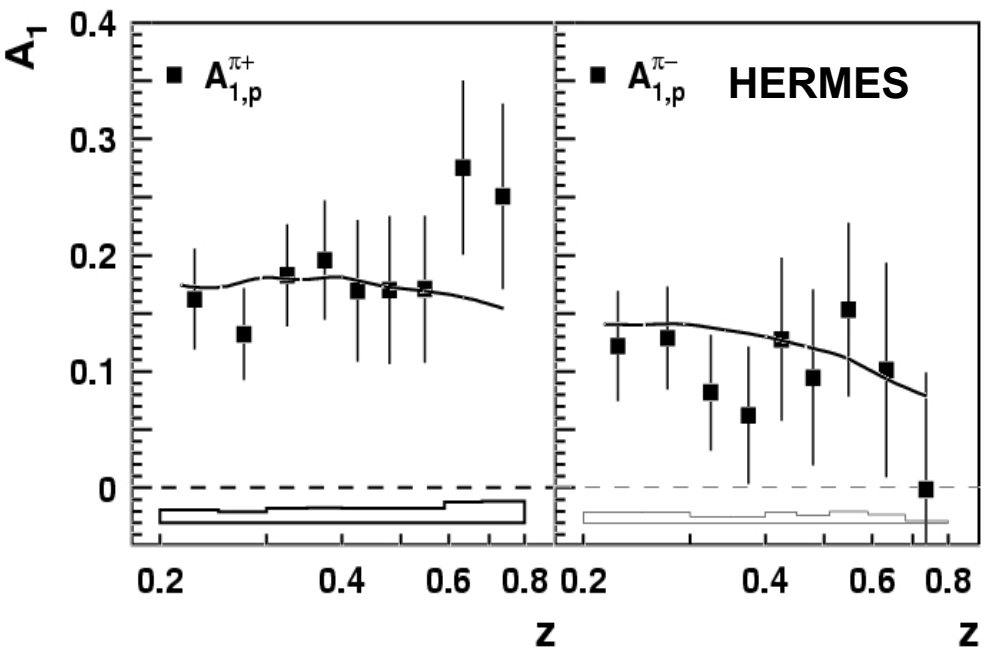


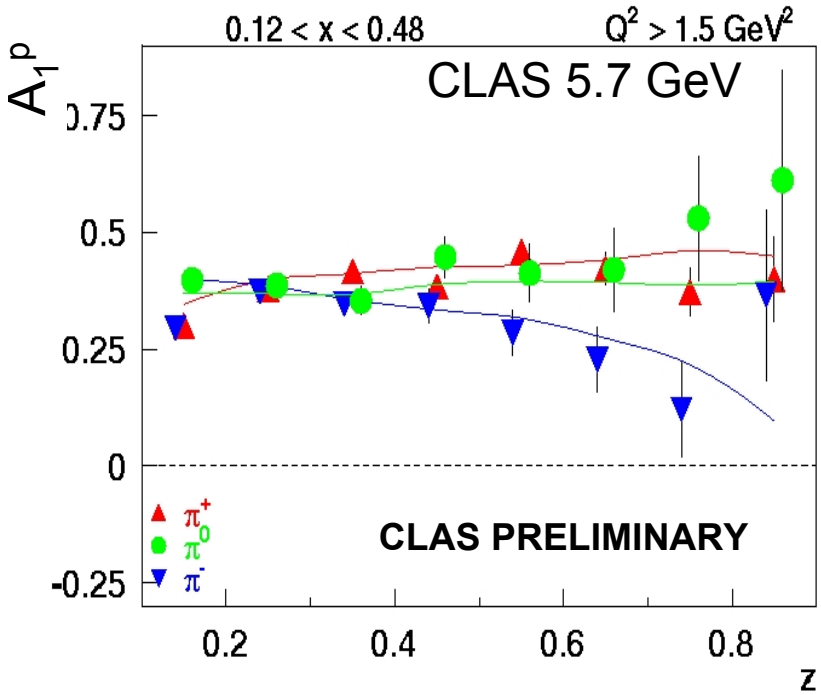


JLab data at 6GeV are consistent with factorization and partonic description for variety of ratio observables

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

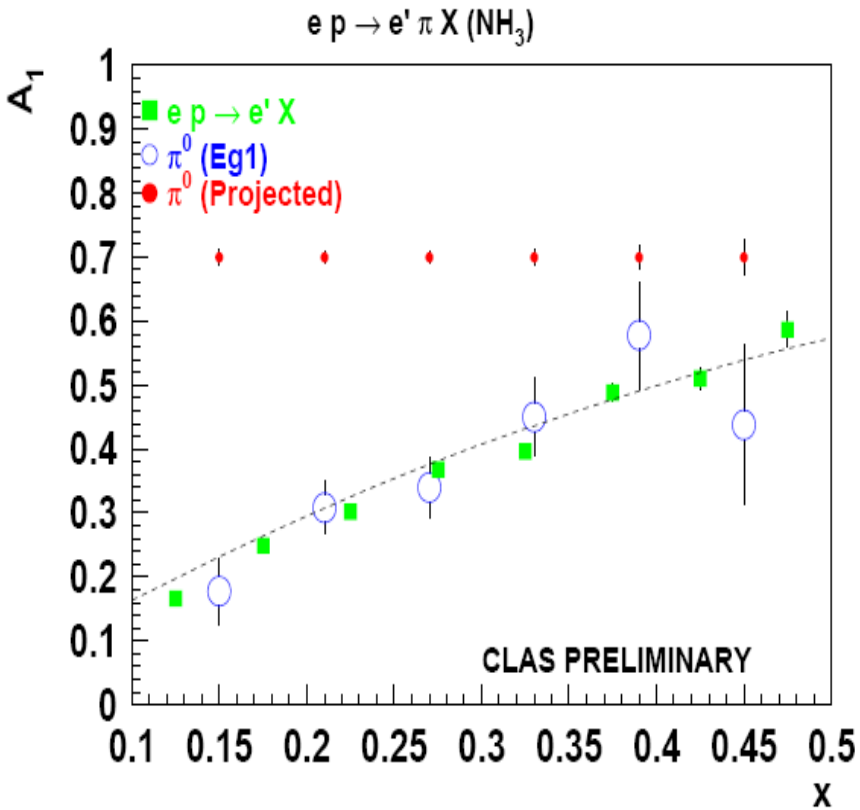
$$A_1^p \approx \frac{1}{P_B P_T f D_{LL}(y)} \frac{N^{+-} - N^{++}}{N^{+-} + N^{++}} \propto \frac{g_1}{f_1}$$

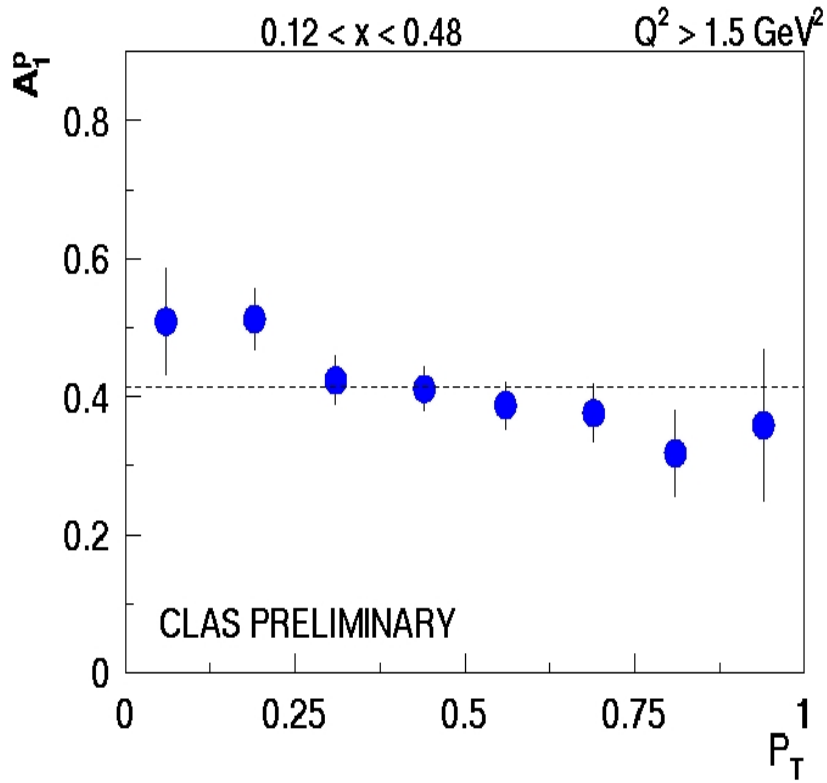




- No significant z-dependence of A_1 in the range $0.3<z<0.7$
- **x** dependence of CLAS $\mathbf{A_1^p}$ ($A_\perp=0$) consistent with HERMES data at 3 times higher Q^2 and with LUND-MC (lines).

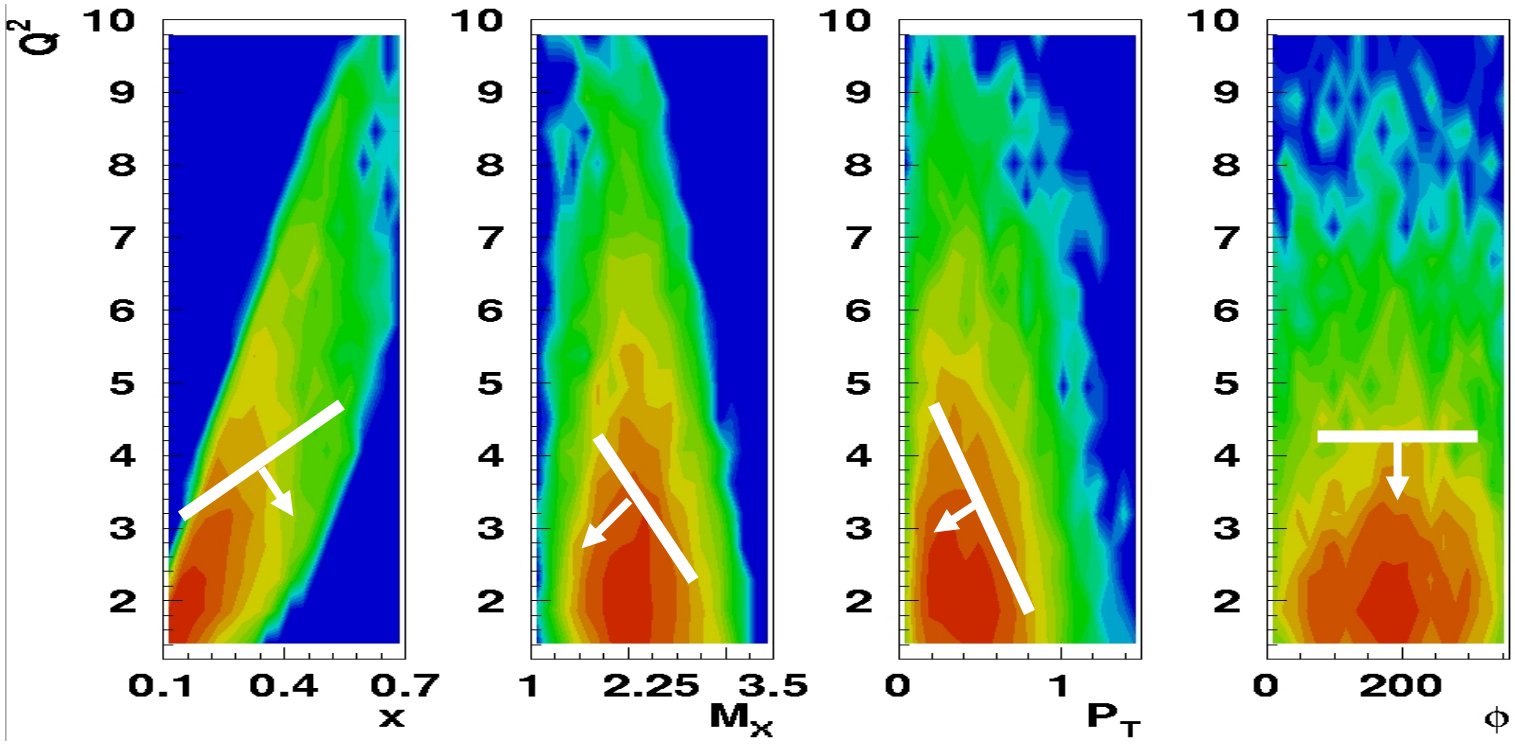
SIDIS: factorization studies





- A_1 inclusive and π^0 are consistent
- A_1^p P_T-dependence can serve an important check of HT effects and applicability of simple partonic description.

ep→e'πX: kinematic coverage at 12 GeV



- High luminosity. L=10^{37}(Hall A/C), L=$10^{36/35}$(Hall B)
- Wide acceptance (SIDIS, exclusive, target fragmentation)
- Wide kinematic range (test factorization, measure HT).
- Good particle ID (compare different final state particles).

SIDIS @12 GeV: analysis strategy

Use the MC (PYTHIA) and data comparison to tune the MC

- Extract PDFs from Data/MC and define corrections due to different factors (MC).
  - Strikman et al. (Christova&Leader) method
  - Purity method
  - NLO fits
- Define kinematic regions (in z,M_x,) where contributions from non-DIS processes and HT effect are not significant within statistical accuracy of specific measurement.

Perform studies of all contributing mechanisms, including

1) Higher Twist effects
2) Target fragmentation
3) Exclusive channels

Quark Polarization from Semi-Inclusive DIS (SIDIS)

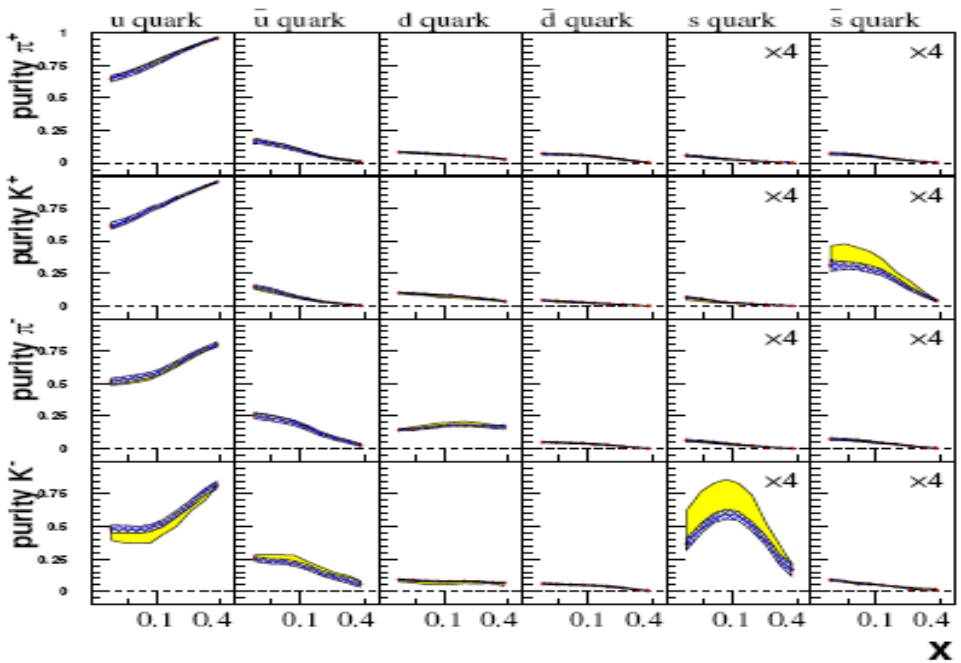
$$A_1^h(x) = \frac{\int\int dQ^2 dz g_1^h}{\int\int dQ^2 dz F_1^h} = \frac{\sum_f e_f^2 \int dQ^2 \Delta q_f(x,Q^2) \int dz \tilde{D}_f^h(x,Q^2,z)}{\sum_{f'} e_{f'}^2 \int dQ^2 q_{f'}(x,Q^2) \int dz \tilde{D}_{f'}^h(x,Q^2,z)}$$

$$A_1^h(x) = \sum_f \frac{e_f^2 \int dQ^2 q_f(x,Q^2) \int dz \tilde{D}_f^h(x,Q^2,z)}{\sum_{f'} e_{f'}^2 \int dQ^2 q_{f'}(x,Q^2) \int dz \tilde{D}_{f'}^h(x,Q^2,z)} \cdot \frac{\int dQ^2 \Delta q(x,Q^2)}{\int dQ^2 q(x,Q^2)}$$

$P_f^h(x)$ "purity"-probability of a hadron to come from a certain quark

$$\mathcal{P} = \begin{pmatrix} P_{f_1}^{h_1}(x_i) & \dots & P_{f_m}^{h_1}(x_i) \\ \vdots & \ddots & \vdots \\ P_{f_1}^{h_m}(x_i) & \dots & P_{f_n}^{h_m}(x_i) \end{pmatrix}$$

$$\vec{A}(x) = \mathcal{P}(x) \cdot \vec{Q}(x),$$

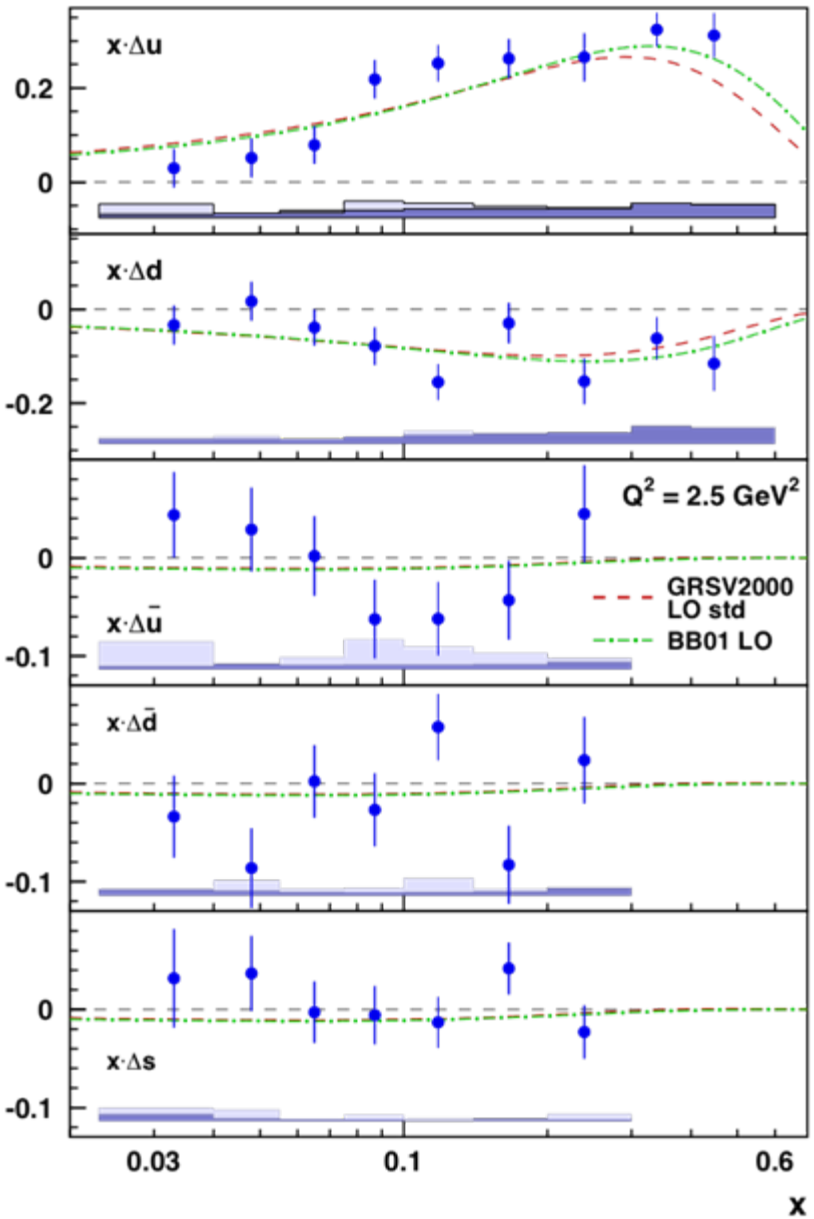


$$\vec{A} = \begin{pmatrix} A_1^{h_1}(x_i) \\ \vdots \\ A_1^{h_m}(x_i) \end{pmatrix}, \quad \vec{Q} = \begin{pmatrix} \Delta q_{f_1}/q_{f_1}(x_i) \\ \vdots \\ \Delta q_{f_n}/q_{f_n}(x_i) \end{pmatrix}$$

- Some account of TFR and factorization breaking
- May be sensitive to ρ contamination

More studies needed

Final Δq Measurement from HERMES

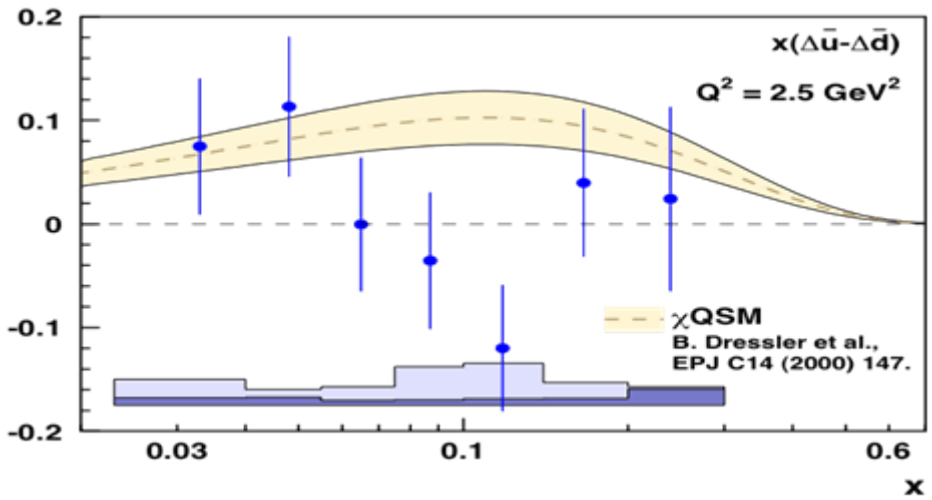


HERMES polarized data from 1996 - 2000

First 5-flavor fit to Δq(x)

No evidence of anti-quark polarization, or flavor-asymmetry, Δs≈0

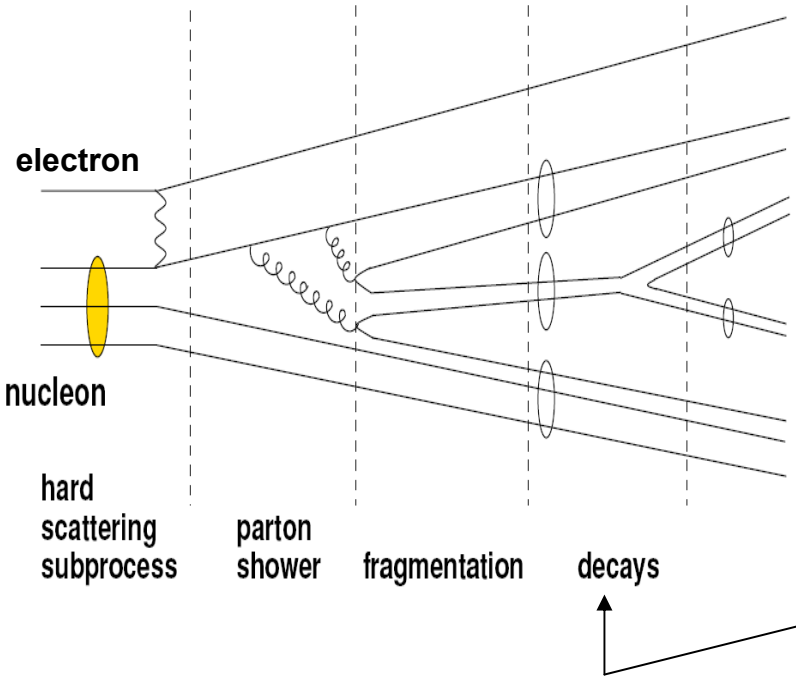
Non-negative strange quark polarization is almost ***impossible?***

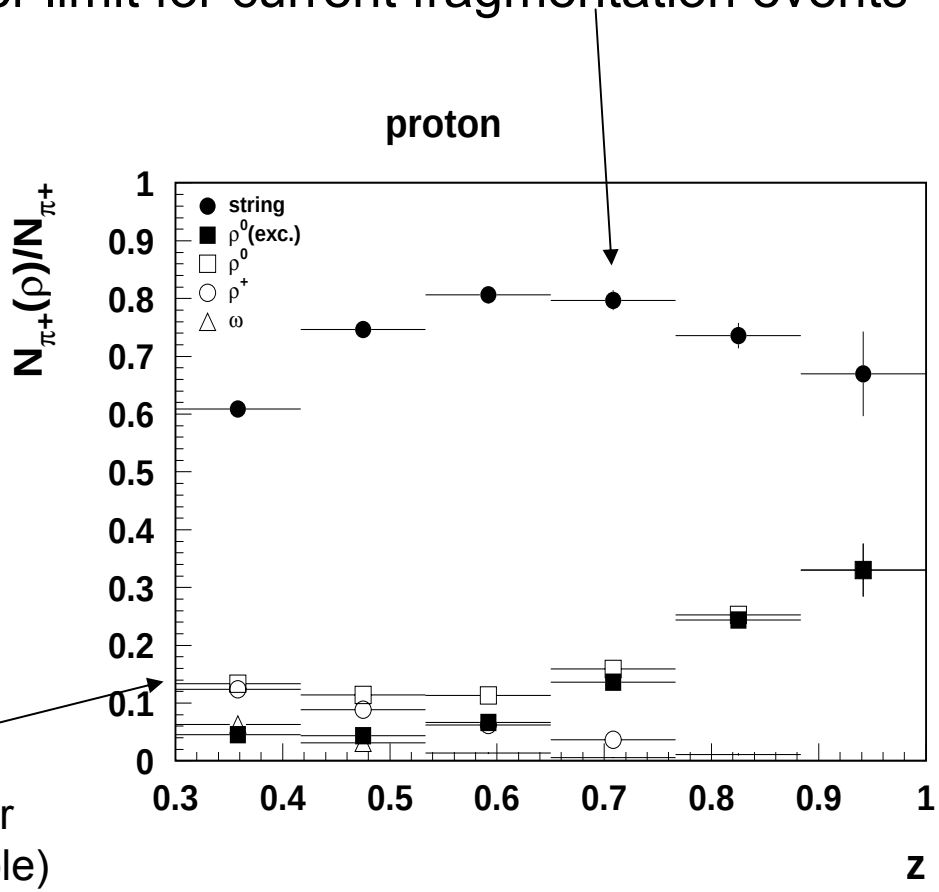


Sensitive to factorization

exclusive production background

Pions from string present the lower limit for current fragmentation events

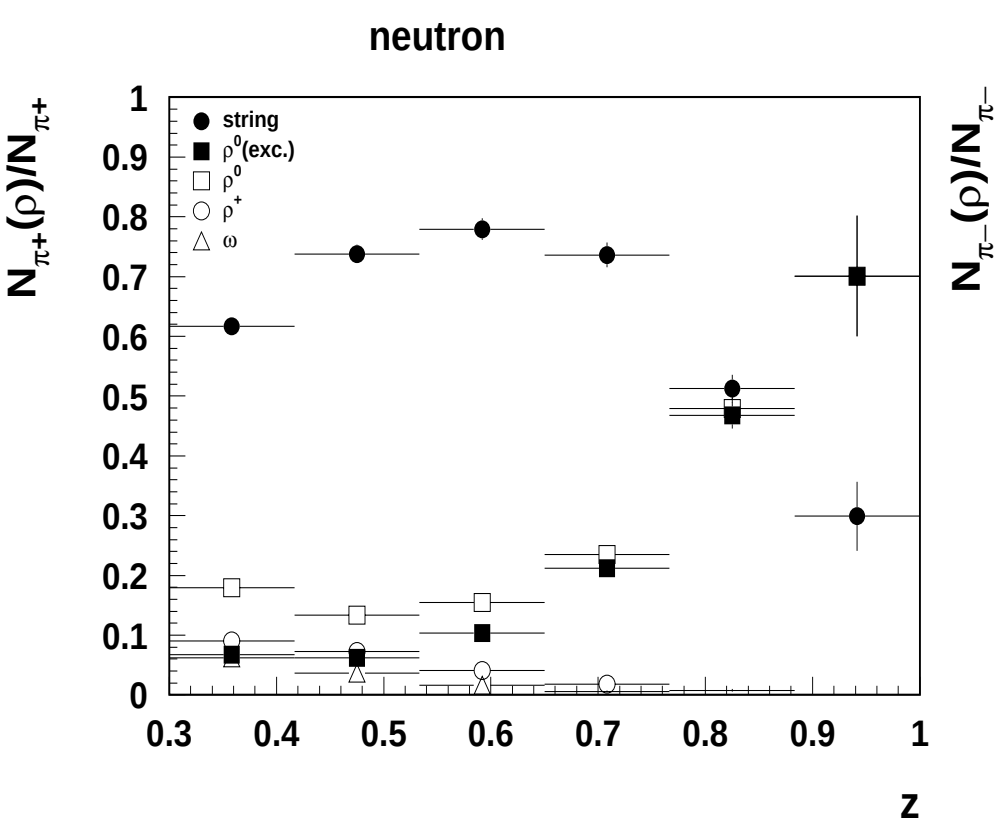


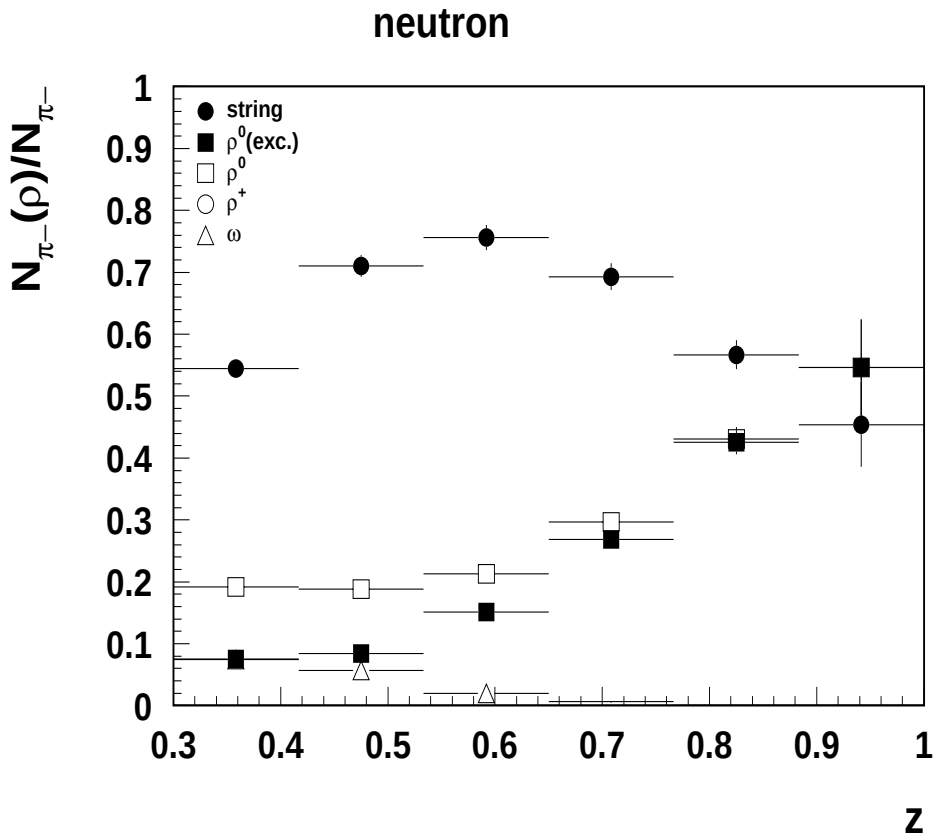


Fraction of pions from non-diffractive vector mesons adds up to direct pions (SIDIS sample)

Fraction of pions from exclusive ρ^0(black squares) should have a special treatment

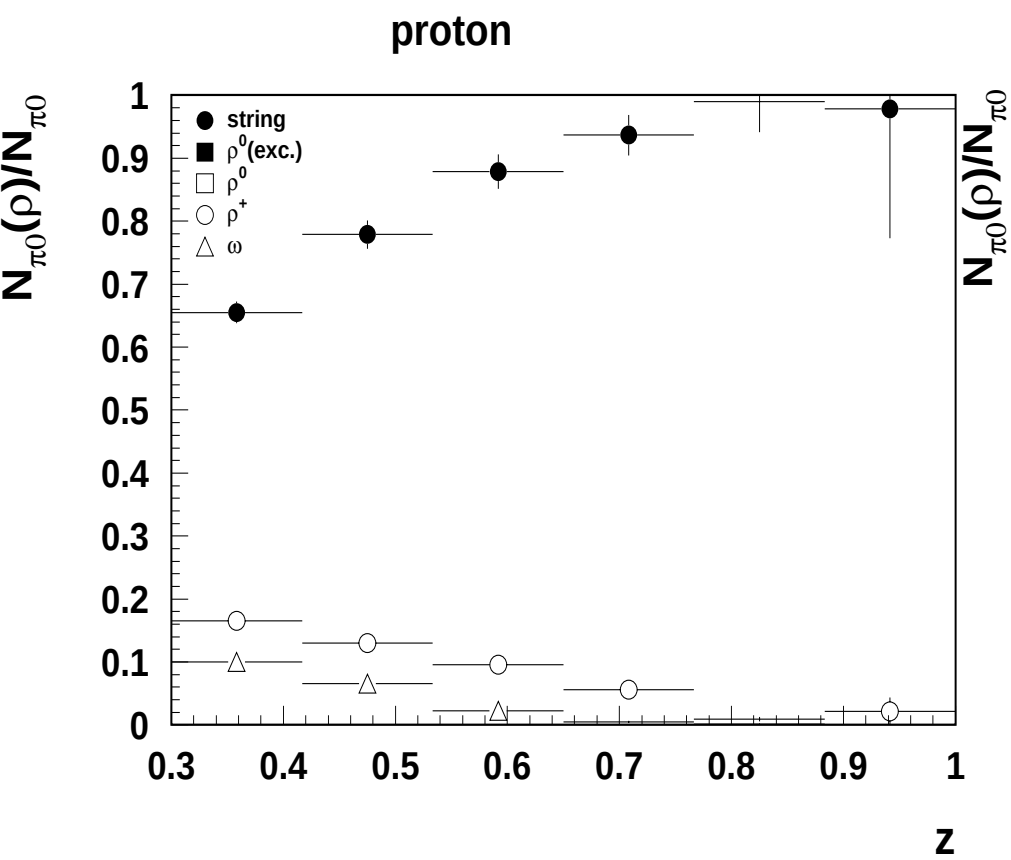
exclusive production background

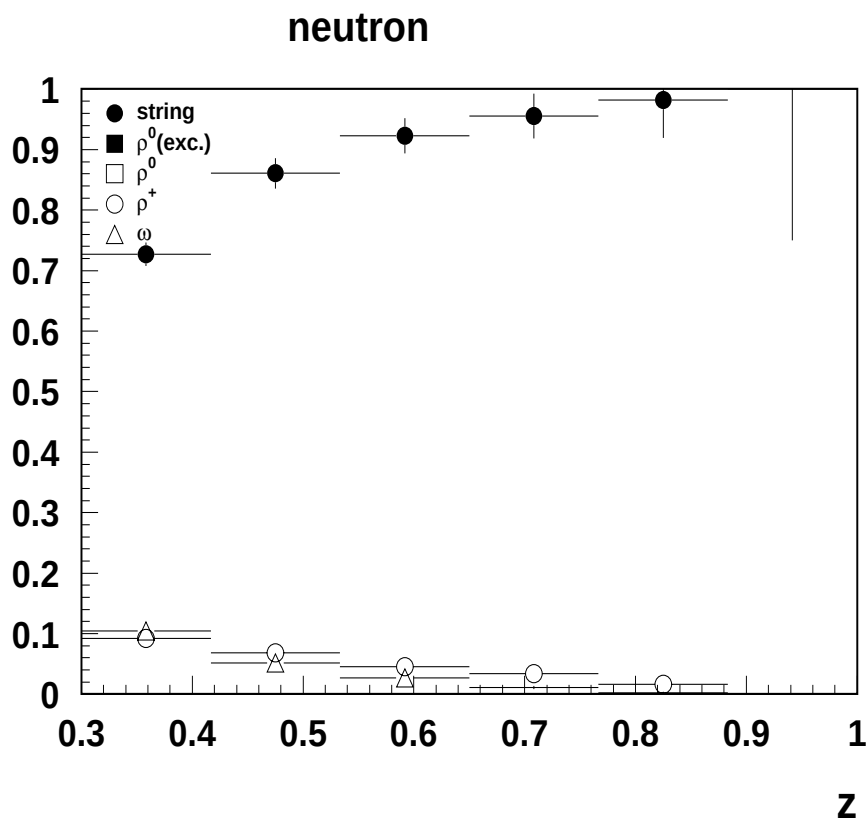




Fraction of charged pions from rho-0 especially high for neutron target

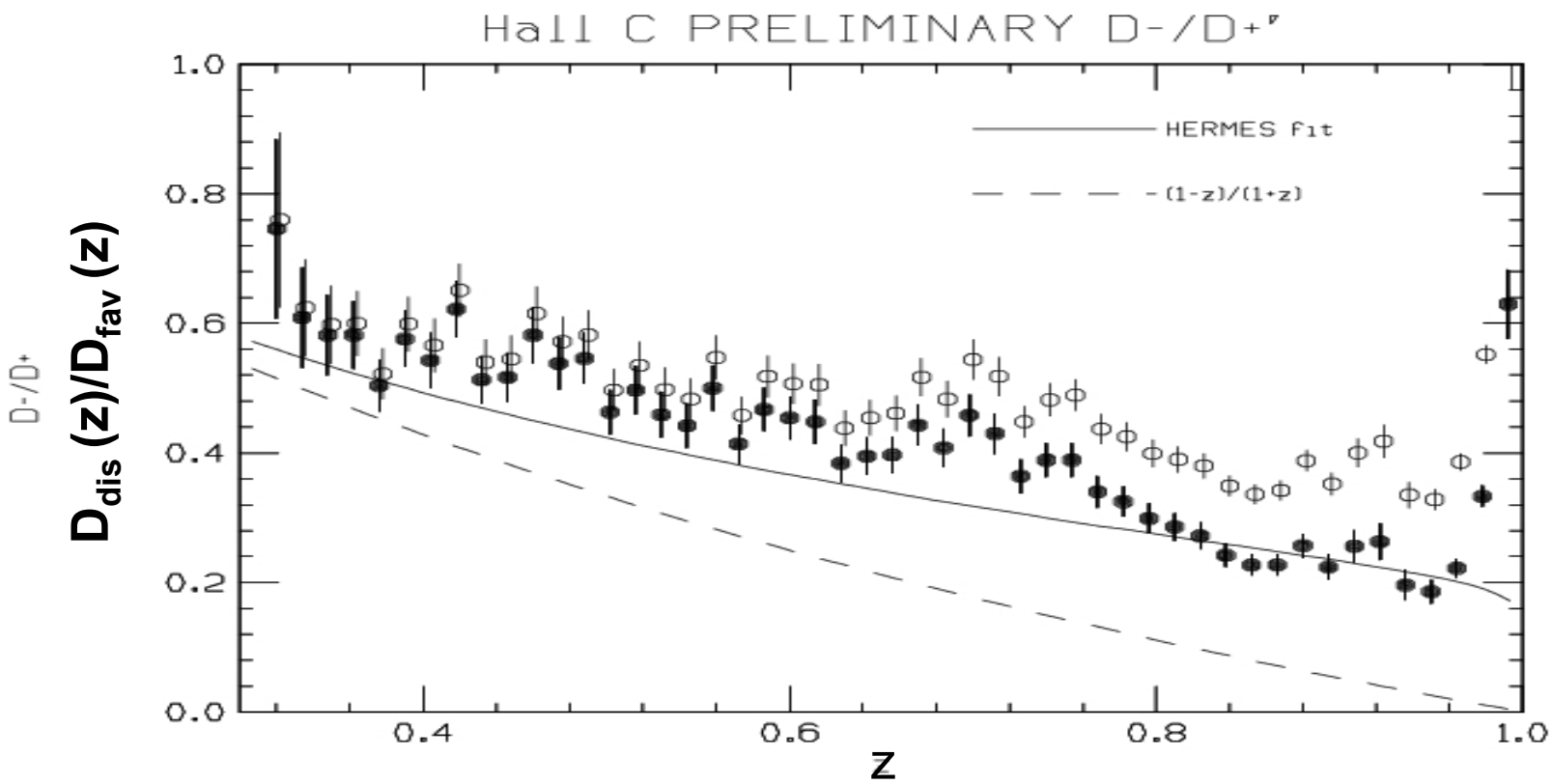
production background from exclusive events





$\pi0$ “clean” (non string pions are mainly from semi-inclusive $\rho+$, ω)

production background from exclusive events



- Correction for ρ^0 at large z could be very significant
- Sensitive to target fragmentation
- More experimental studies of π contamination from exclusive 2π (ρ) required

Flavor decomposition of g_1

In the LO SIDIS

$$\sigma^h(x,Q^2,z) \propto (1+(1-y)^2)\sum_q e_q^2\, q(x,Q^2)\, D_q^h(z,Q^2)$$

$$\Delta\sigma^h(x,Q^2,z) \propto (1-(1-y)^2)\sum_q e_q^2\, \Delta q(x,Q^2)\, D_q^h(z,Q^2)$$

$$A_1^h(x,Q^2,z) = \frac{\sum_q e_q^2\, \Delta q(x,Q^2)\, D_q^h(z,Q^2)}{\sum_q e_q^2\, q(x,Q^2)\, D_q^h(z,Q^2)}$$

With A_1 measurements for $\pi+\pi-$ on neutron and proton ($\Delta\pi=\pi^+-\pi^-$)

$$\Delta u_v(x) = \tfrac{4}{15}\left[A_{1,p}^{\Delta\pi}\left(4u_v - d_v\right) + A_{1,n}^{\Delta\pi}\left(d_v - u_v/4\right)\right]$$

$$\Delta d_v(x) = \tfrac{4}{15}\left[A_{1,n}^{\Delta\pi}\left(4d_v - u_v\right) + A_{1,p}^{\Delta\pi}\left(u_v - d_v/4\right)\right]$$

- Not too sensitive to ρ contamination
- May be sensitive to TFR and factorization breaking
- $\pi+\pi-$ asymmetries on neutron close.

A_1^p -for $\pi^+ + \pi^-, \pi^0$

$$n^{\uparrow\downarrow}(x,z) \equiv \frac{1}{\sigma_{\uparrow\downarrow}^T}\frac{d\sigma_{\uparrow\downarrow}^{(\pi^+ + \pi^-)}}{dz} = \frac{[\frac{4}{9}u_+(x)+\frac{1}{9}d_+(x)]D(z)+\frac{1}{9}s_+(x)D_s(z)}{[\frac{4}{9}u_+(x)+\frac{1}{9}d_+(x)+\frac{1}{9}s_+(x)]}$$

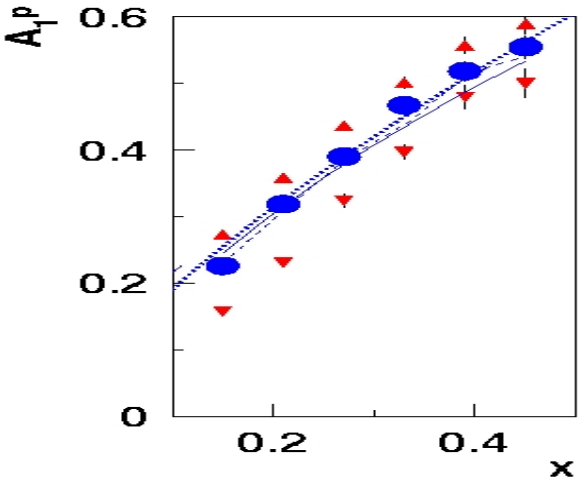
$$n^{\uparrow\downarrow}(x,z)-n^{\uparrow\uparrow}(x,z)=[n^{\uparrow\downarrow}(x,z)+n^{\uparrow\uparrow}(x,z)-2D(z)]\left(\frac{\Delta s(x)-A_1^p(x)s(x)}{s(x)-A_1^p(x)\Delta s(x)}\right)$$

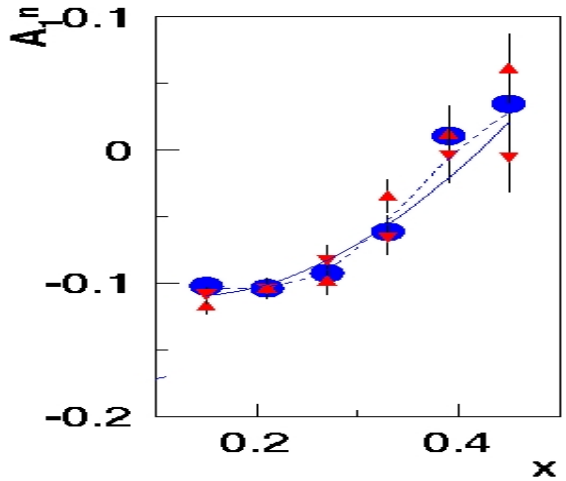
Multiplicity of π^0 $(\pi^+ + \pi^-)$ is spin independent.(**if no strangeness**) and provides a unique test of partonic description

- **A_1** for π^0 $(\pi^+ + \pi^-)$ can be a source of information on $\Delta s/s$

(Frankfurt, Strikman et al. 1989)

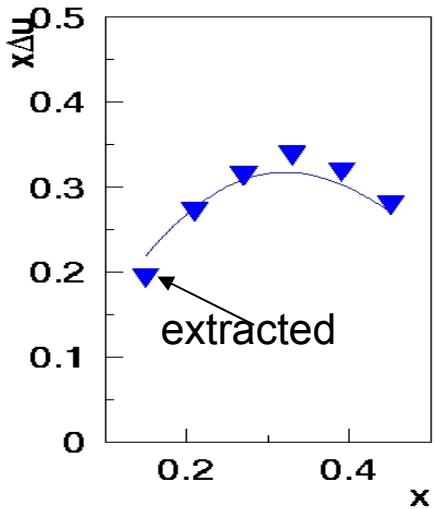
PEPSI MC asymmetries

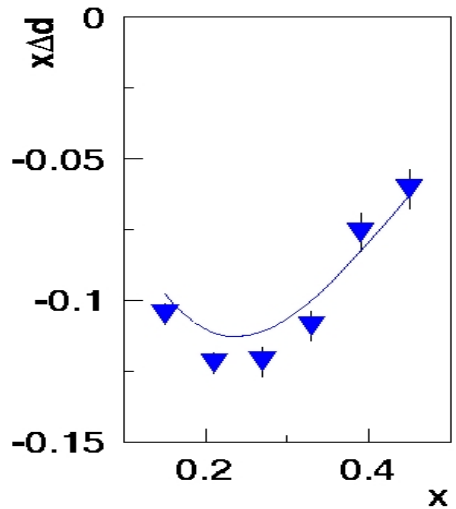




GRVS set used

A_1 for 3 pions from MC histo-data files

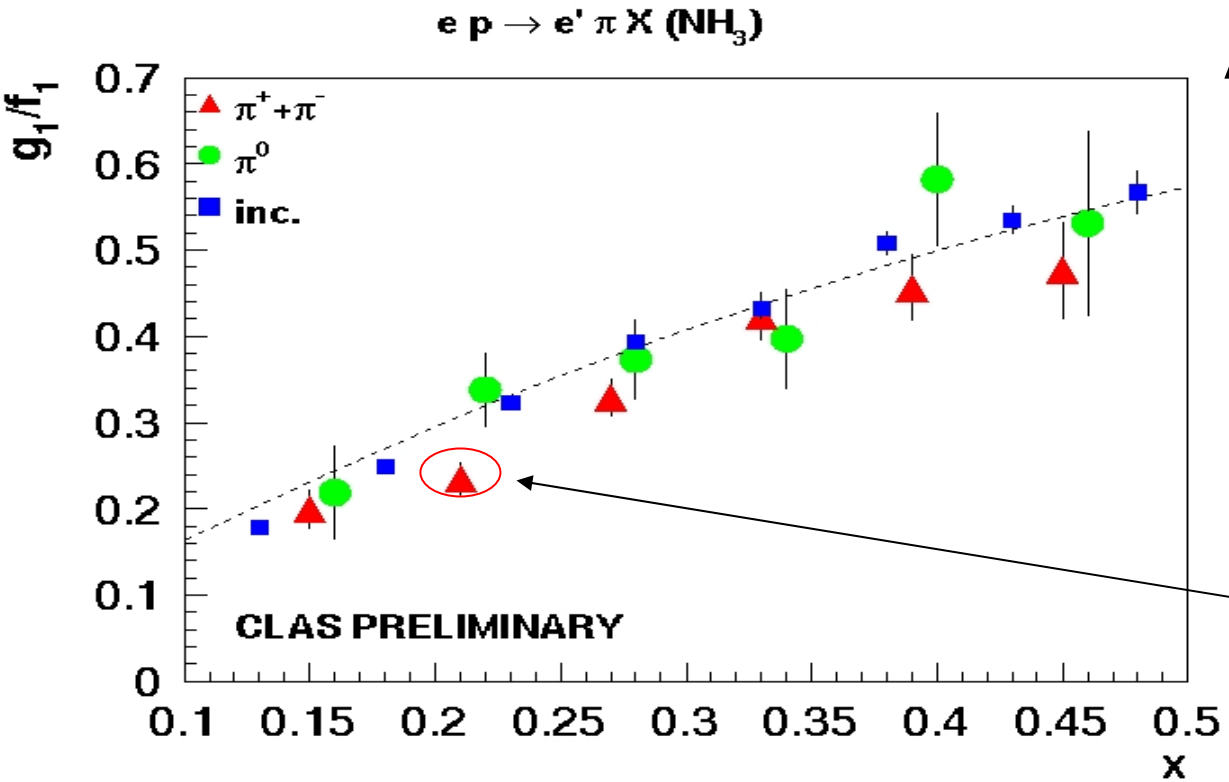




Testing extraction procedure:
Extract Δu and Δd using π^0 Asymmetries on proton and deuteron

More tests required!

SIDIS: factorization studies



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

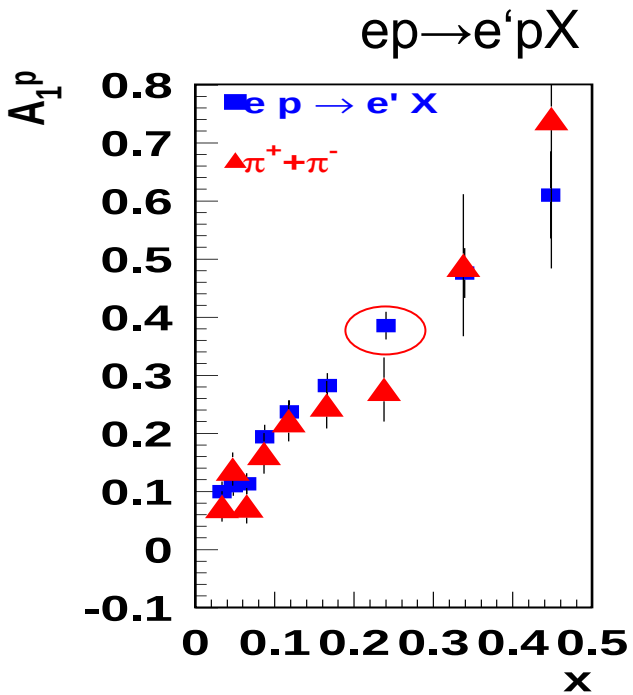
$$\alpha = \frac{\sigma^{\pi^-}}{\sigma^{\pi^+}}$$

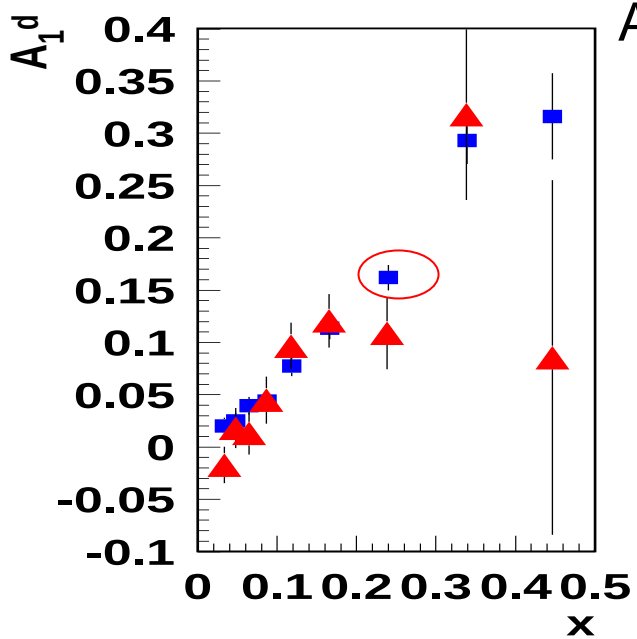
LUND-MC used to get α

Higher twist?

- 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.

SIDIS: factorization studies (HERMES)





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

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

LUND-MC used to get α

- $\mathbf{A_1}$ inclusive and from $\pi^+\pi^-$ (HERMES published) show similar trend.
- Low $\mathbf{A_1^p}$ for $\pi^+ + \pi^-$ will lead to positive Δs (require more studies)

Conclusions

Kinematic dependence of SIDIS observables at 6GeV are consistent with factorization and simple partonic picture

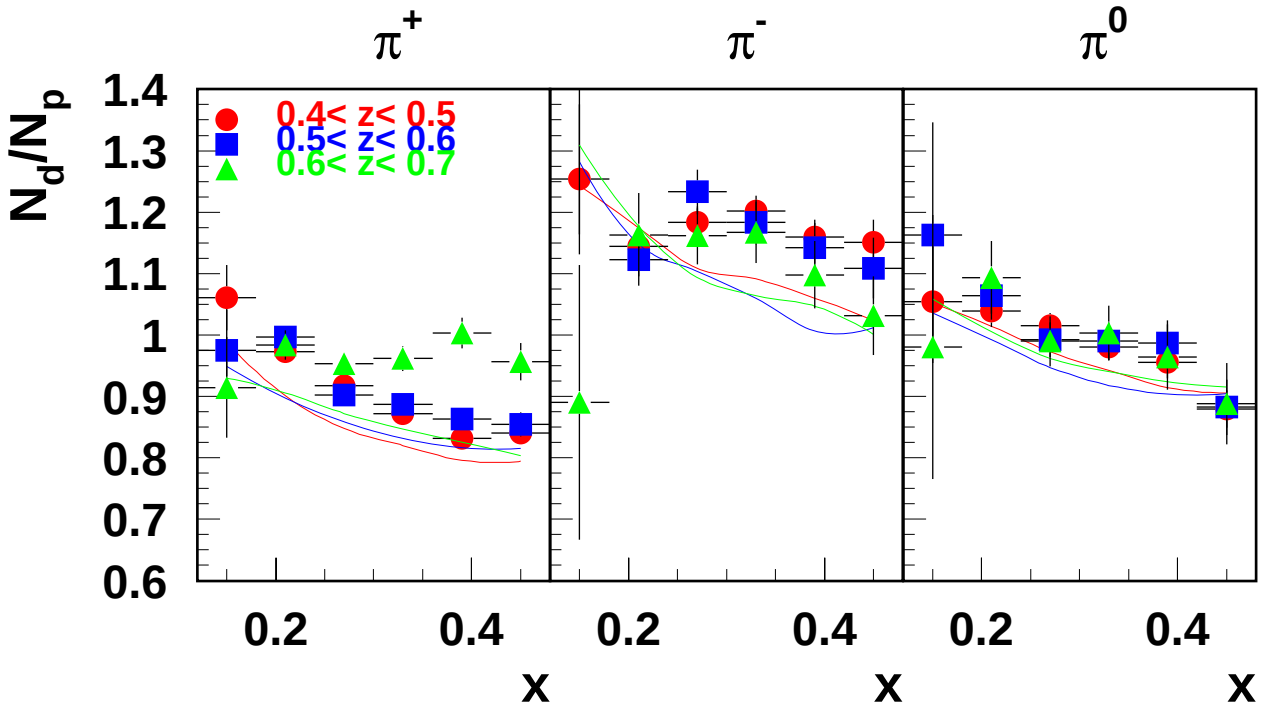
Precision measurements of parton distribution and fragmentation functions in hard scattering kinematics at JLab@12 GeV require:

- **Studies of semi-inclusive and exclusive processes and hadronization for different hadrons in target and current fragmentation regions**
- **MC generator (based on PYTHIA,JETSET) tuned for JLab, including:**
  - **Semi-Inclusive DIS**
  - **Exclusive Processes**
  - **Radiative Processes**
  - **T-odd Distribution and Fragmentation**

After testing with CLAS this MC may provide basis for precision measurements of PDFs and FFs at JLab

support slides…

Deuteron to proton pion ratios

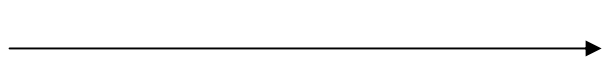


Pion ratios from e6 data at 5.7 GeV

SIDIS: MC and data analysis

"histo-data" files (P.Bosted) contain counts per bin, occupy small disk space and are used for data analysis.

N(i,j,k,l,m,n,h) array in a data file per run



i=1,7 Q2-bins 0.453, 0.645, 0.919, 1.31, 1.87, 2.66, 3.79, 5.40

j=1,6 x-bins 0.12-0.48

k=1,8 z-bins 0.1-0.9

l=1,6 P_T-bins 0.0-1.2

m=1,12 ϕ–bins 0.0-360.0

n= 1-$\pi+$, 2-$\pi-$, 3-$\pi 0$

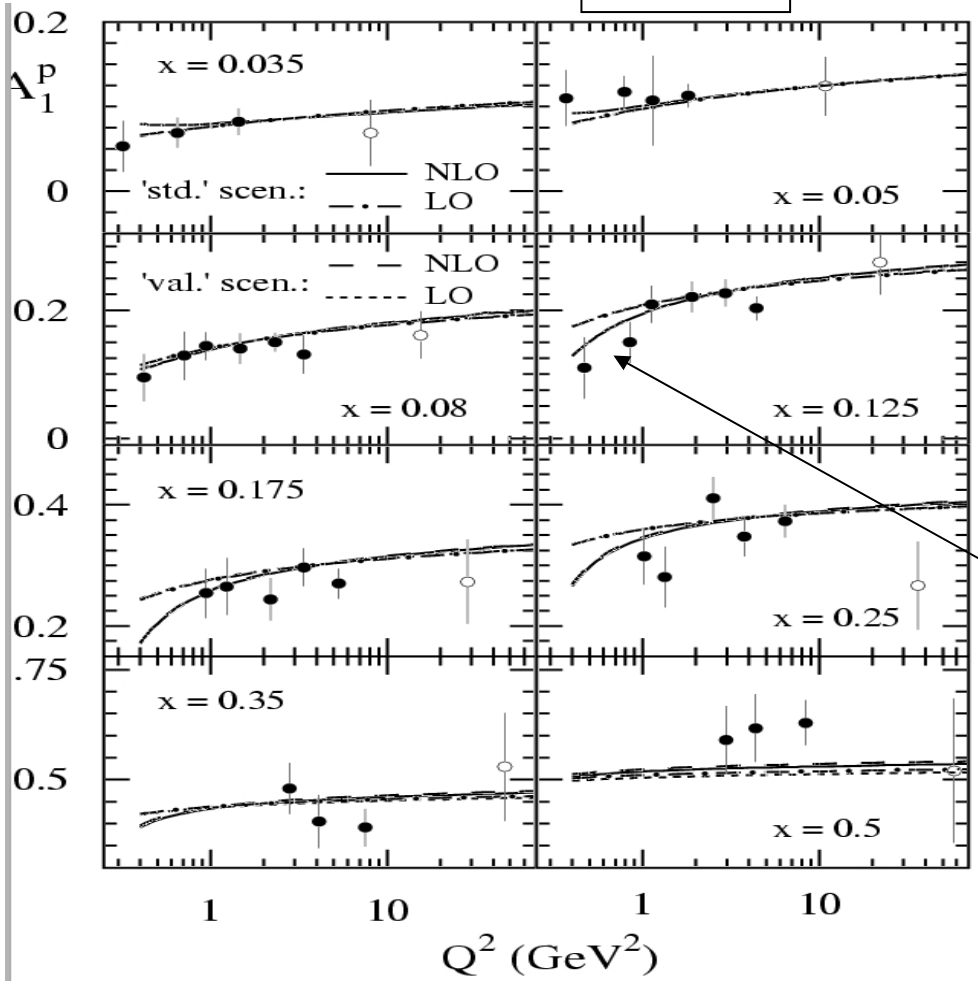
h=1 helicity+
h=2 helicity-

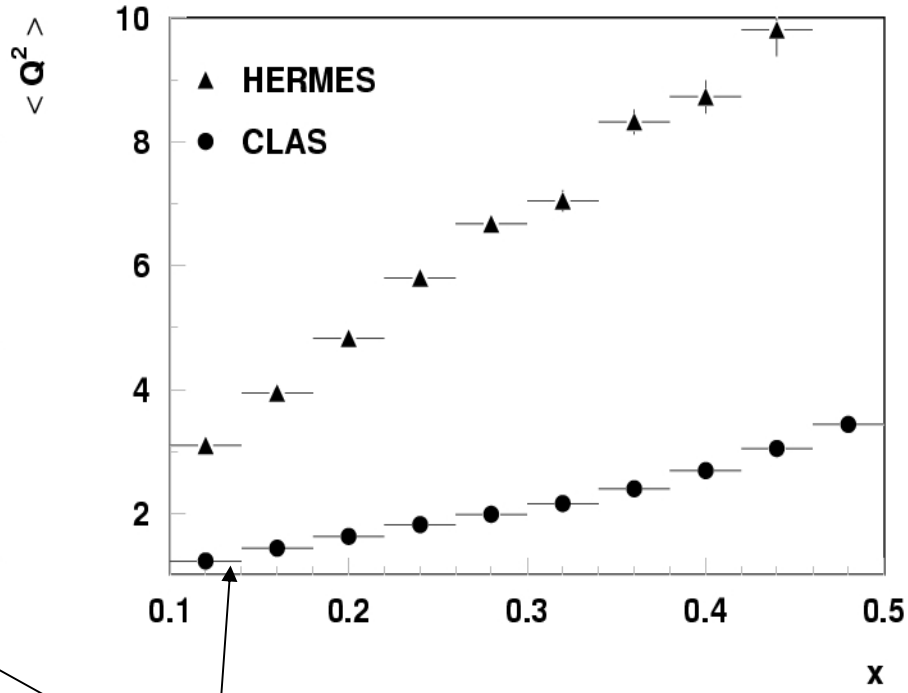
The same structure created using the PEPSI-MC with CLAS acceptance and smearing included

Polarized target: HERMES vs CLAS at 5.7GeV

$$A_1^p \approx \frac{1}{P_B P_T \, fD(y)} \frac{N^{+-} - N^{++}}{N^{+-} + N^{++}}$$

GRSV95





x3 difference in$\langle Q^2 \rangle$ may account for ~15-20% in A_1^p at low x