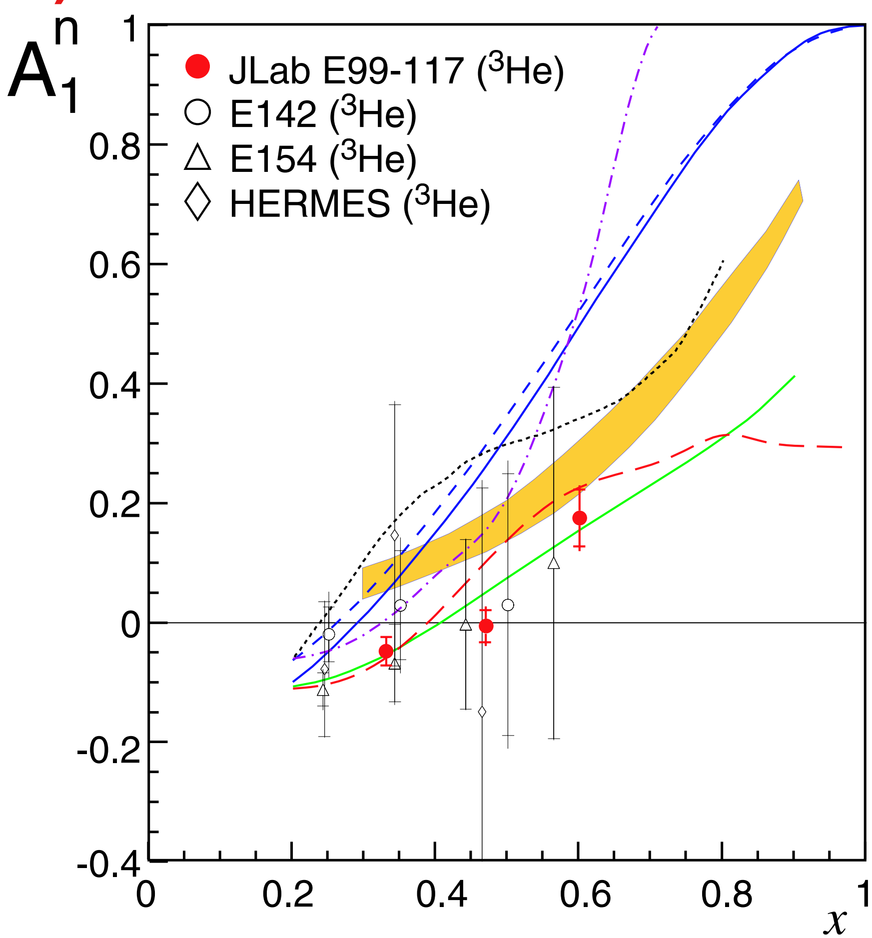
Polarized PDFs and Hall C Experiments at 6 and 11 GeV

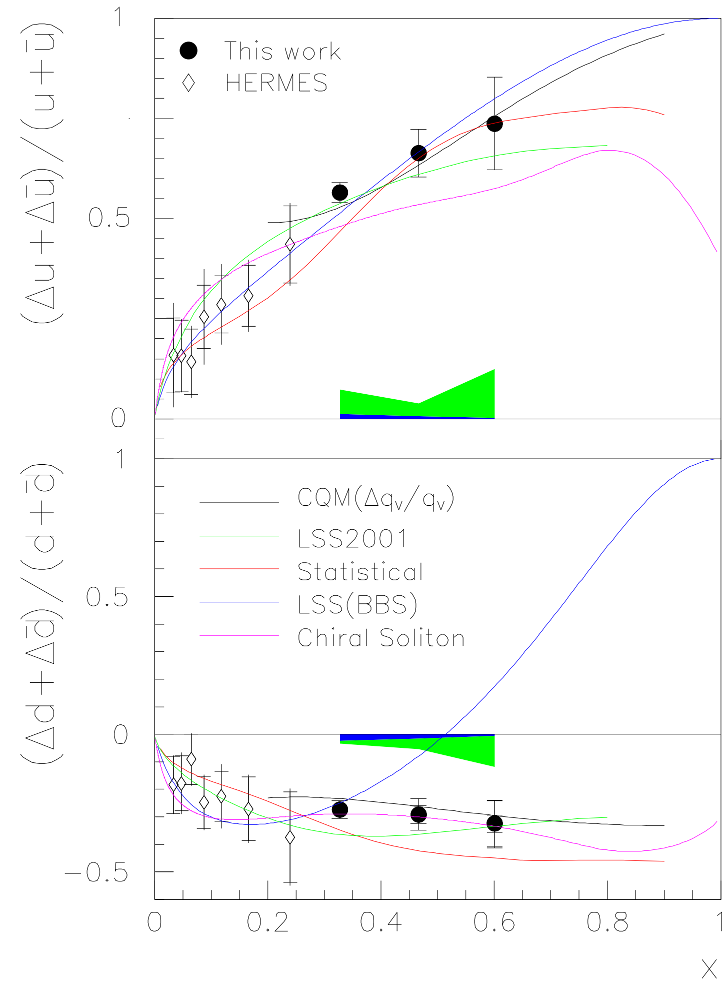
Xiaodong Jiang, Rutgers University. August 9, 2007 @ JLab Hall C workshop.

With the high intensity and high polarization electron beam at JLab 6 and 11 GeV, deep inelastic scattering experiments on polarized targets provide new constraints on polarized parton distributions.

- Inclusive DIS data and constraints on polarized PDF.
  - Measurements of A_{1p}, A_{1d}, $A_{1n}(^3\text{He}) \Rightarrow \Delta u + \Delta \bar{u}, \Delta d + \Delta \bar{d}$.
  - Constraints on ΔG.
- Semi-inclusive DIS and constraints on polarized PDF.
  - Upcoming experiment: A^h_{1p}, A^h_{1d}, $A^h_{1n}(^3\text{He}) \Rightarrow \Delta u_v, \Delta d_v, \Delta \bar{u} - \Delta \bar{d}$.
  - More constraints on ΔG.
- Access quark angular momentum, measurements of A_{LT} in SIDIS.

Jefferson Lab E99-117 (Hall A)

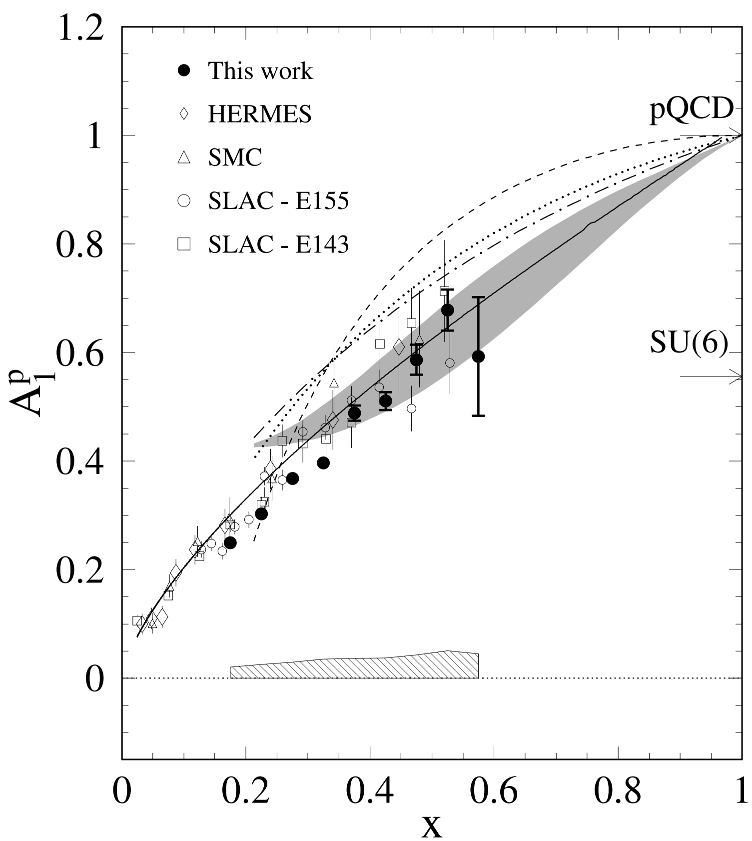


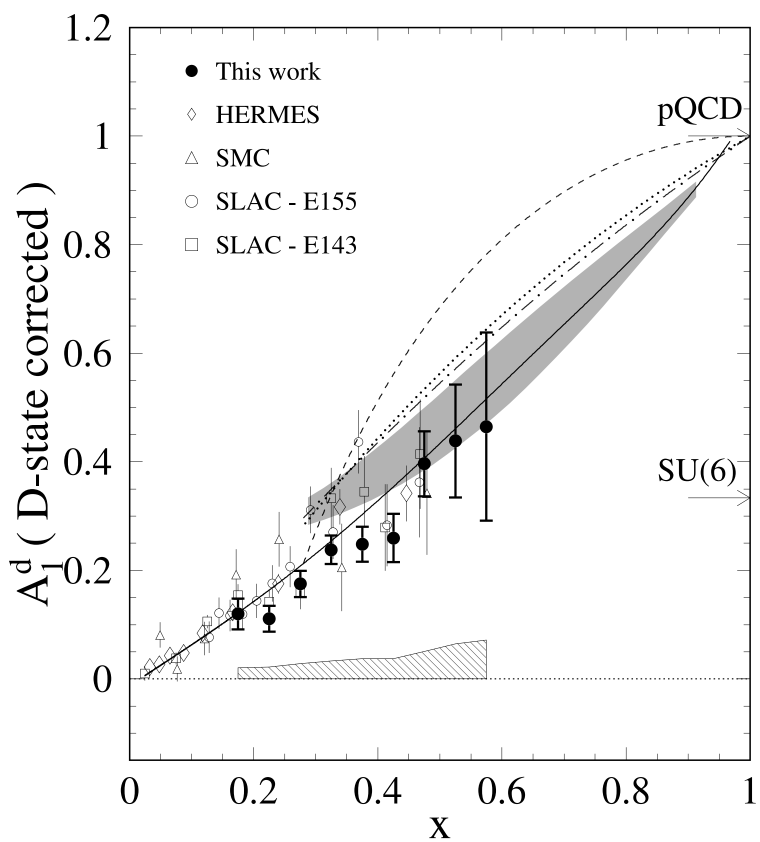


E_0=5.73 GeV beam. Polarized ^{3}He target $(\vec{e}, e')$ DIS. Measured asymmetry $A_1^n(x)$.

Phys. Rev. Lett. 92, 012004 (2004) and Phys. Rev. C 70, 065207 (2004).

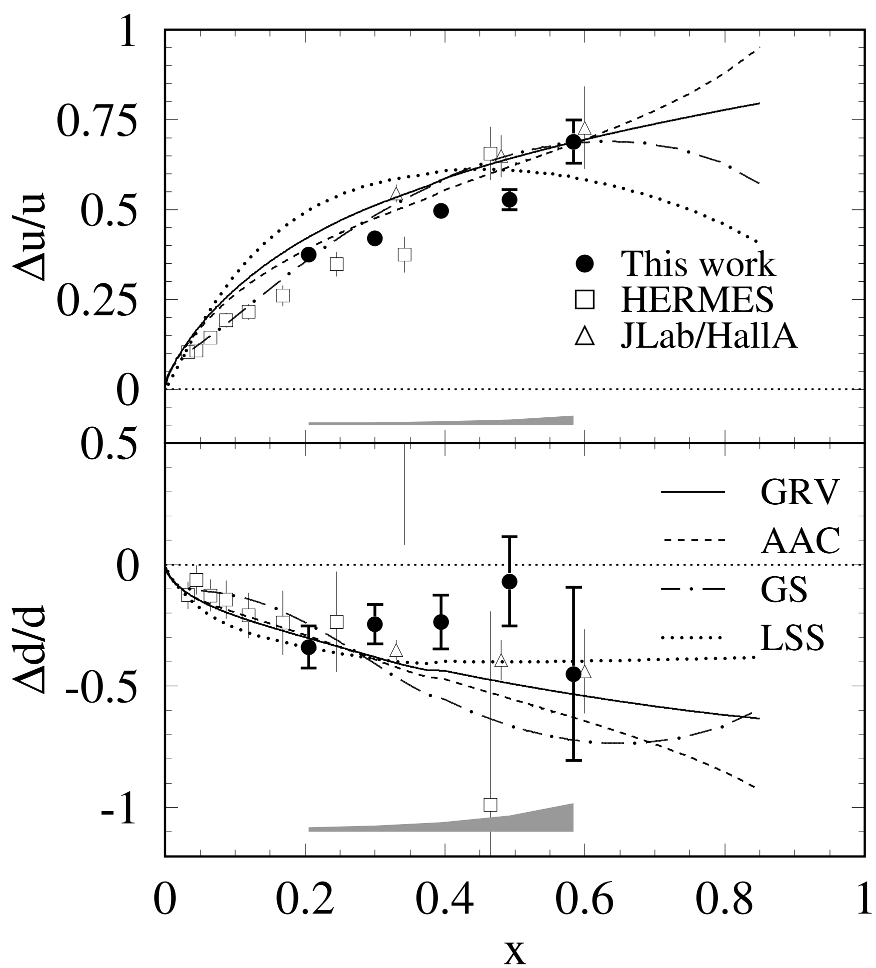
Hall B eg1b: polarized NH_3 and ND_3 targets





(nucl-ex/0605028)

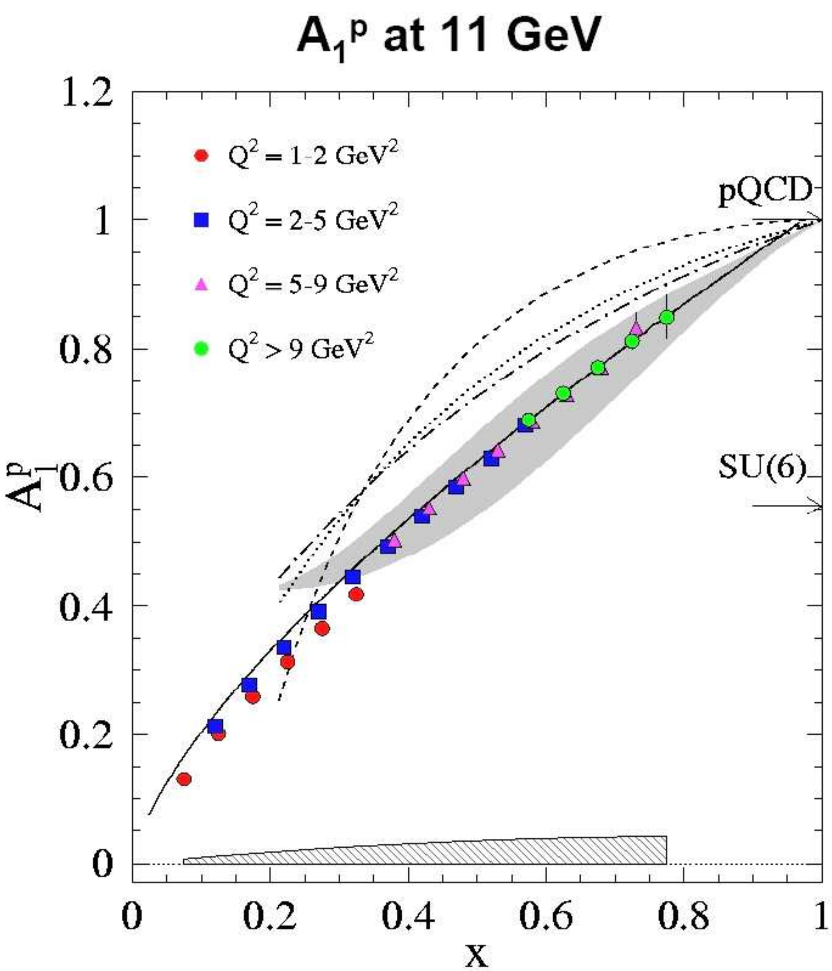
Spin-flavor decomposition from A_{1p} and A_{1d} data

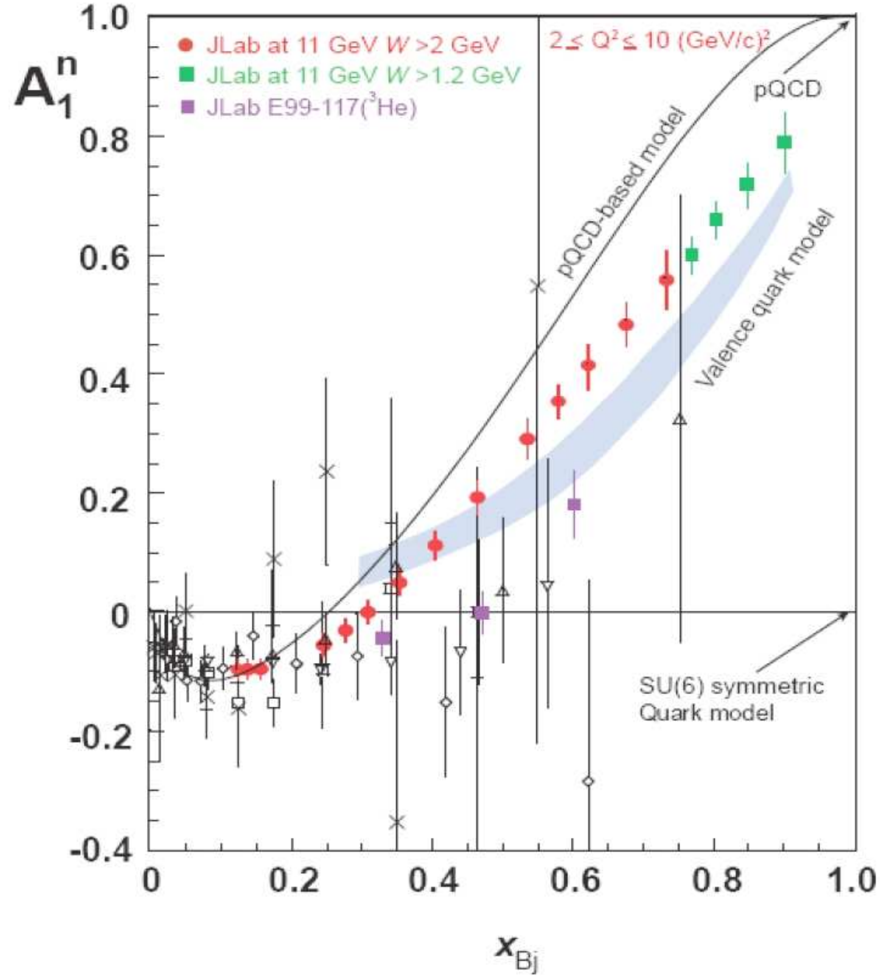


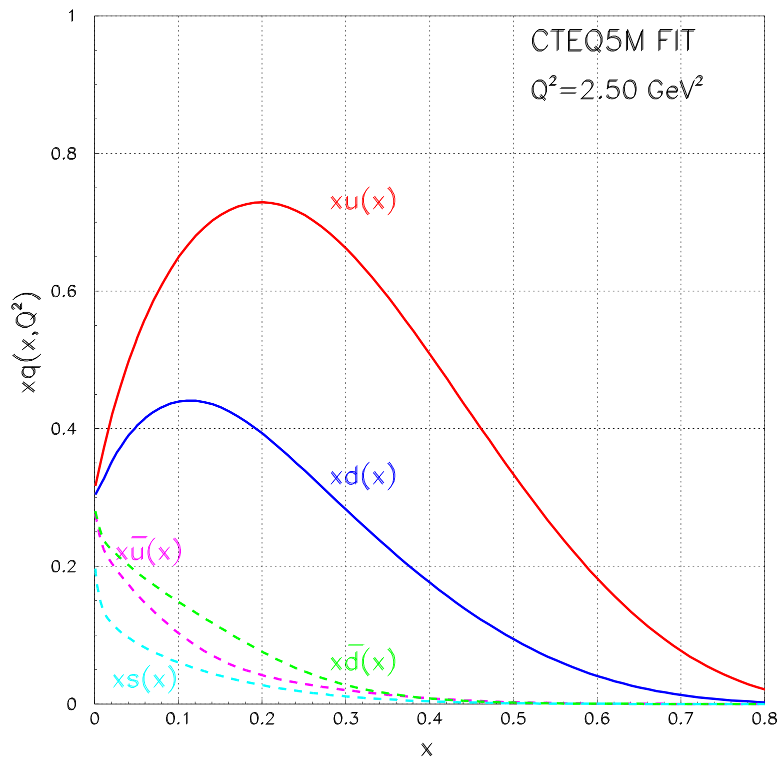
$$\frac{\Delta u + \Delta \bar{u}}{u + \bar{u}} = \frac{5g_1^p - 2g_1^d/(1-1.5w_D)}{5F_1^p - 2F_1^d}$$

$$\frac{\Delta d + \Delta \bar{d}}{d + \bar{d}} = \frac{8g_1^d/(1-1.5w_D) - 5g_1^p}{8F_1^d - 5F_1^p}$$

After JLab 12 GeV Upgrade







$\Leftarrow$ PDFs from CTEQ5M ($s = \bar{s}$).

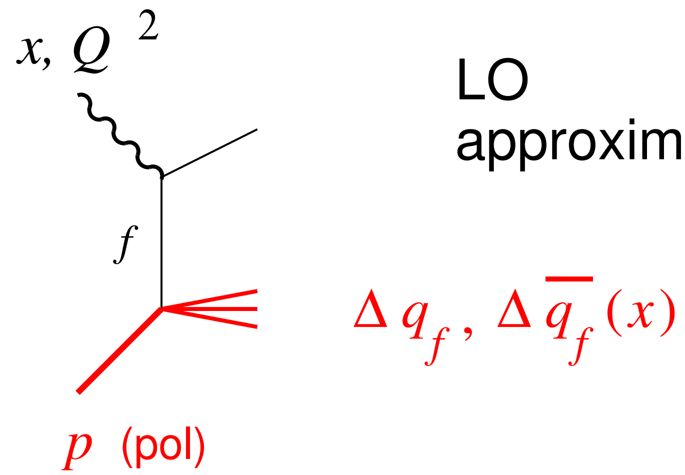
$\bar{q} \approx 0$ at $x \geq 0.4$.

$$\Delta q \approx \Delta q + \Delta \bar{q} \approx \Delta q - \Delta \bar{q}.$$

At $x \geq 0.4$, inclusive spin structure measurements on polarized proton and “neutron” provide enough information on polarized parton distributions.

- Inclusive DIS access only $q_f + \bar{q}_f$:

$$g_1(x,Q^2) = \sum_{f=u,d,s} e_f^2 \, [\Delta q_f + \Delta \bar{q}_f] \, (x, Q^2)$$

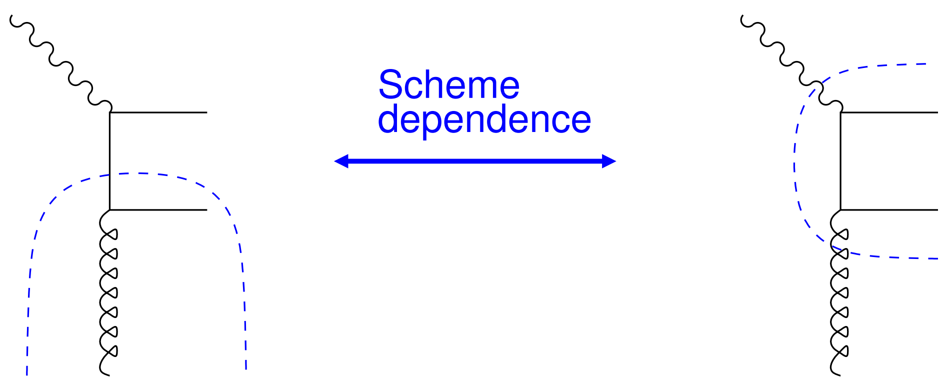


LO approximation

- Inclusive DIS access gluon via Q^2 evolution, at NLO:

$$g_1 = \sum_{f=u,d,s} e_f^2 \; C_q \otimes (\Delta q_f + \Delta \bar{q}_f) \; + \; (\sum_f e_f^2) \; \alpha_s C_g \otimes \Delta G$$

involves gluons explicitly!



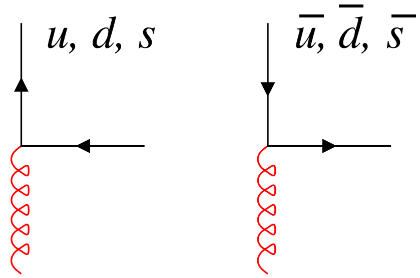
$O(\alpha_s)$ term can be attributed either to singlet quark or to gluon distribution

- QCD evolution: singlet vs. non-singlet

"Organize" PDFs according to

$$\begin{aligned} q^{(0)} &= u+d+s \\ q^{(3)} &= u-d \\ q^{(8)} &= u+d-2s \end{aligned} \qquad \begin{aligned} q_{\rm val} &= q-\bar{q} \\ q_{\rm tot} &= q+\bar{q} \end{aligned}$$

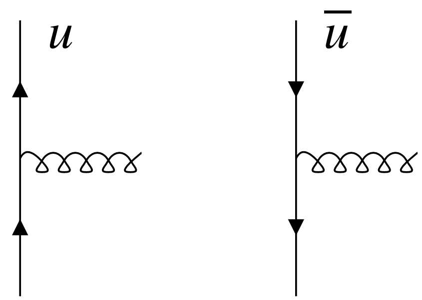
$\Delta q^{(0)}_{\rm tot} \longleftrightarrow \Delta G$



singlet

$\Delta q^{(3)}_{\rm tot}$, $\Delta q^{(8)}_{\rm tot}$ all

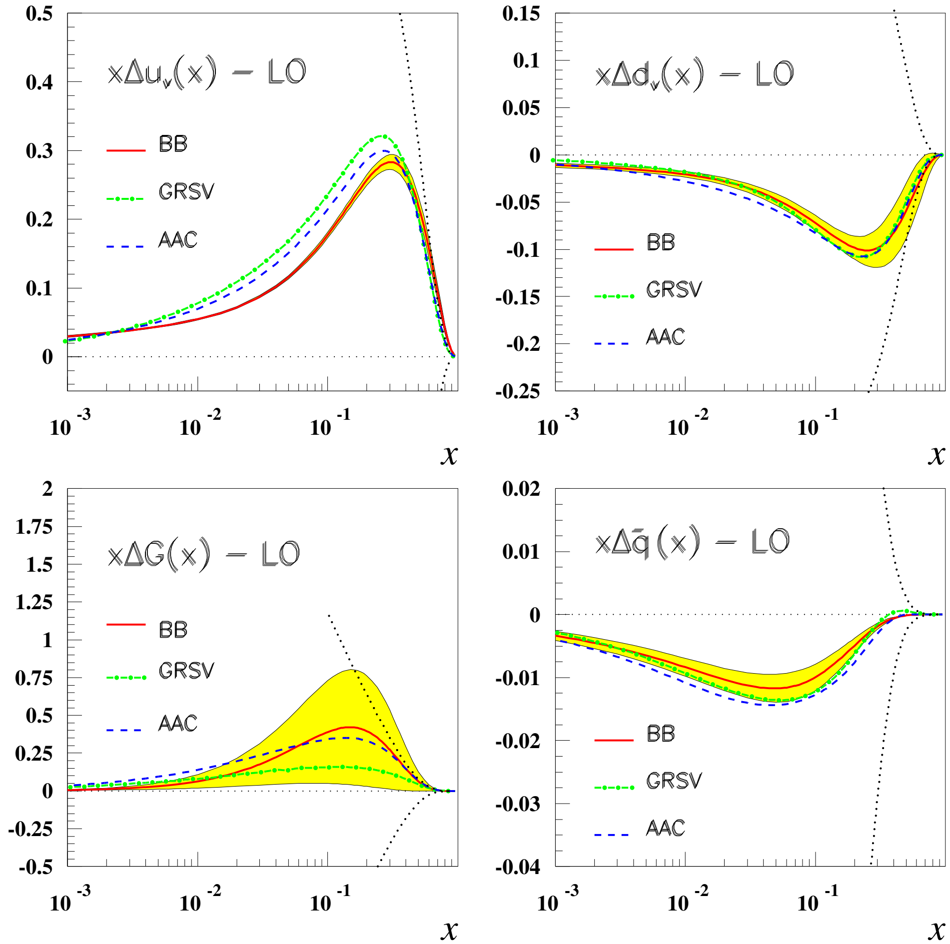
$\Delta q_{\rm val}$



flavor/charge non-singlet

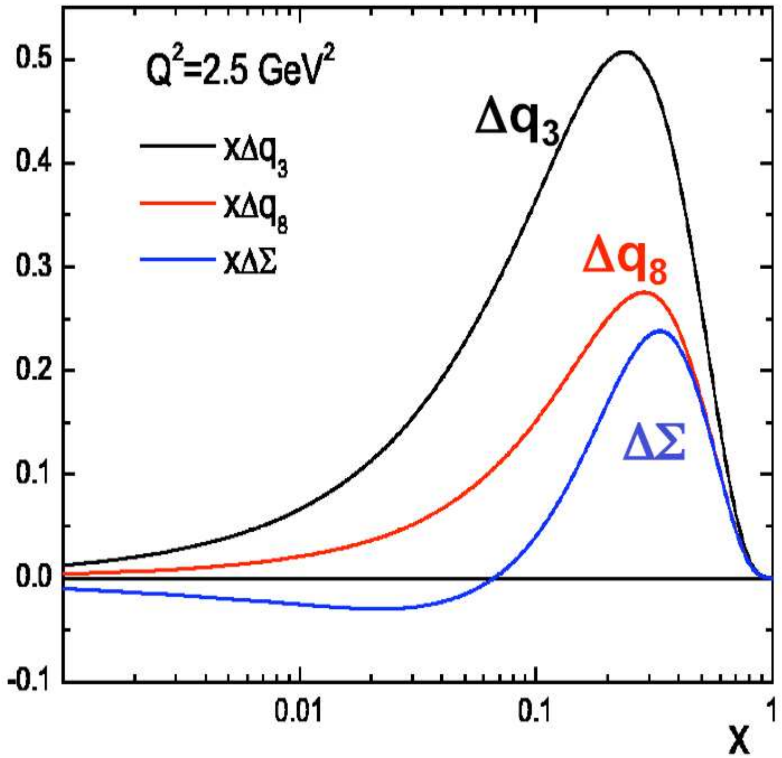
Flavor–non-singlet $(3,8)$ and valence quark distributions do not "mix with" gluon distribution ... Individual flavors $\Delta u, \Delta\bar{u}, \Delta d \ldots$ do!

Global fits to the inclusive DIS data



- Assume sea behavior. as in BB: $\Delta\bar{q} = \Delta\bar{u} = \Delta\bar{d} = \Delta\bar{s}$.
- Obtain ΔG from Q^2 evolution of $g_1(x, Q^2)$.
- Inclusive data can not distinguish q from $\bar{q}$ since $\sigma = \sum_f e_f^2 q_f$.
- Only access one flavor non-singlet: $\Delta q_3 = (\Delta u + \Delta\bar{u}) - (\Delta d + \Delta\bar{d})$.
- Can not access $\Delta\bar{u} - \Delta\bar{d}$.

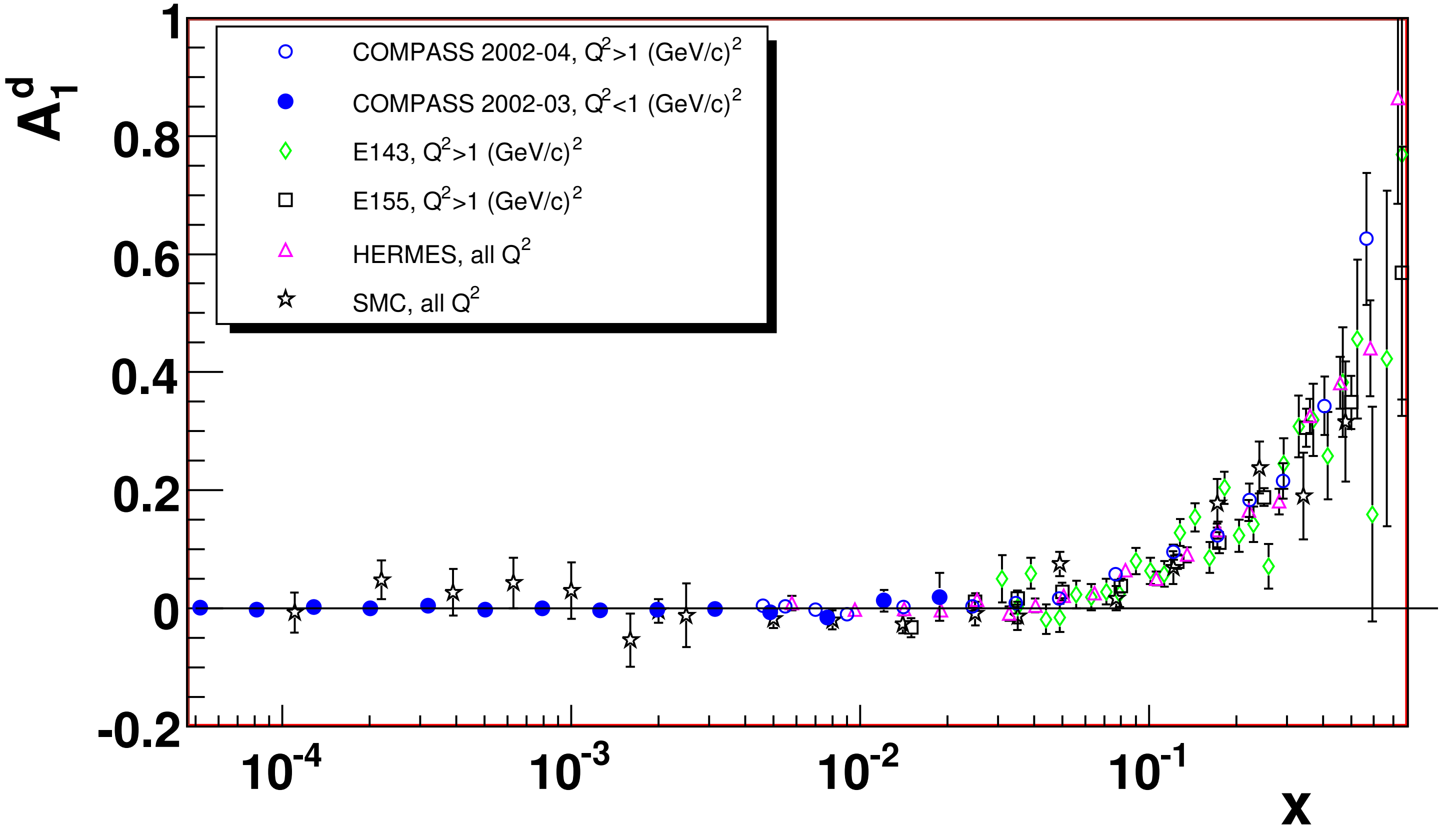
g_{1d} is more sensitive to ΔG



- Δq_3 term drops out in $p+n$, leads to a relatively larger ΔG contribution.
- High precision g_{1d} data over a wide range of Q^2 will constrain ΔG through global fit.
- COMPASS measured g_{1d} at low-x.

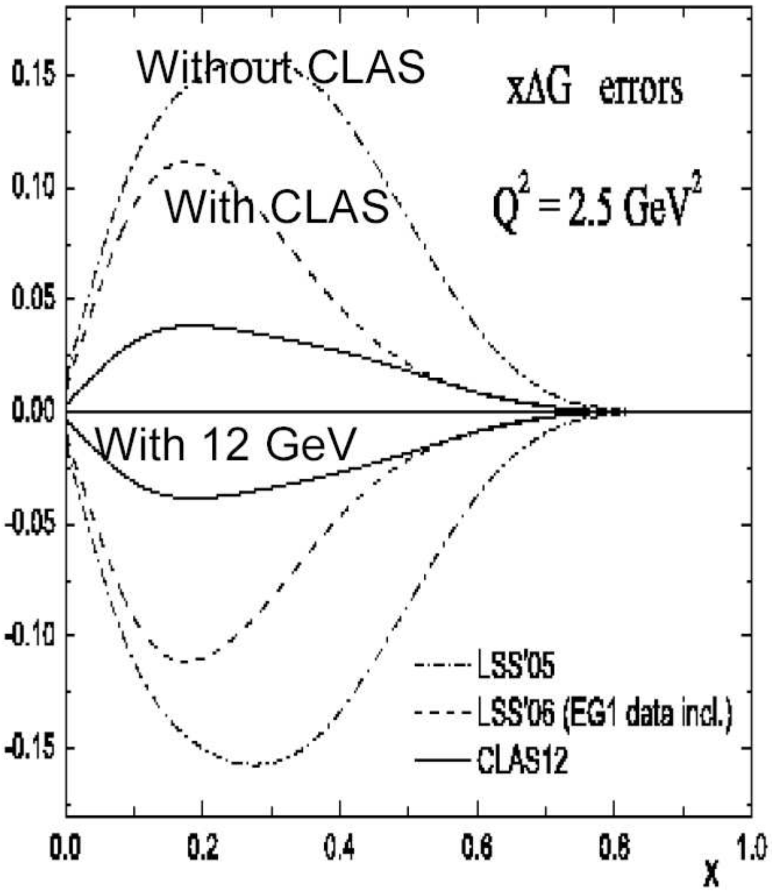
$$g_1^{p(n)} = \frac{1}{9}\left[\left(\pm\frac{3}{4}\Delta q_3 + \frac{1}{4}\Delta q_8 + \Delta\Sigma\right)\otimes\left(1+\frac{\alpha_s(Q^2)}{2\pi}\delta C_q\right) + \frac{\alpha_s(Q^2)}{2\pi}\Delta G\otimes\delta C_G\right]$$

COMPASS data on A_{1d}



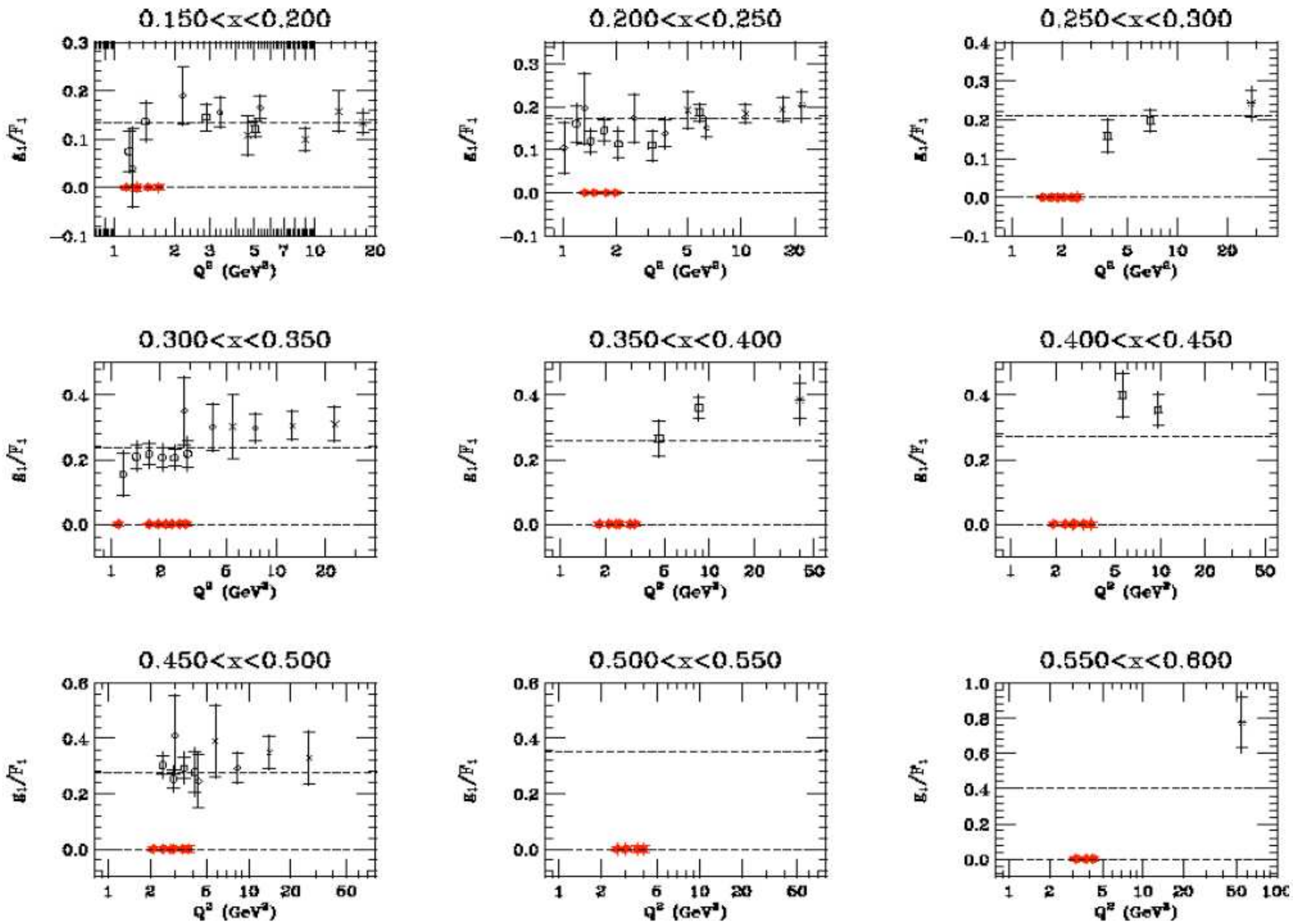
hep-ex/0701014.

CLAS eg1b data on g_{1d} reduced error on ΔG



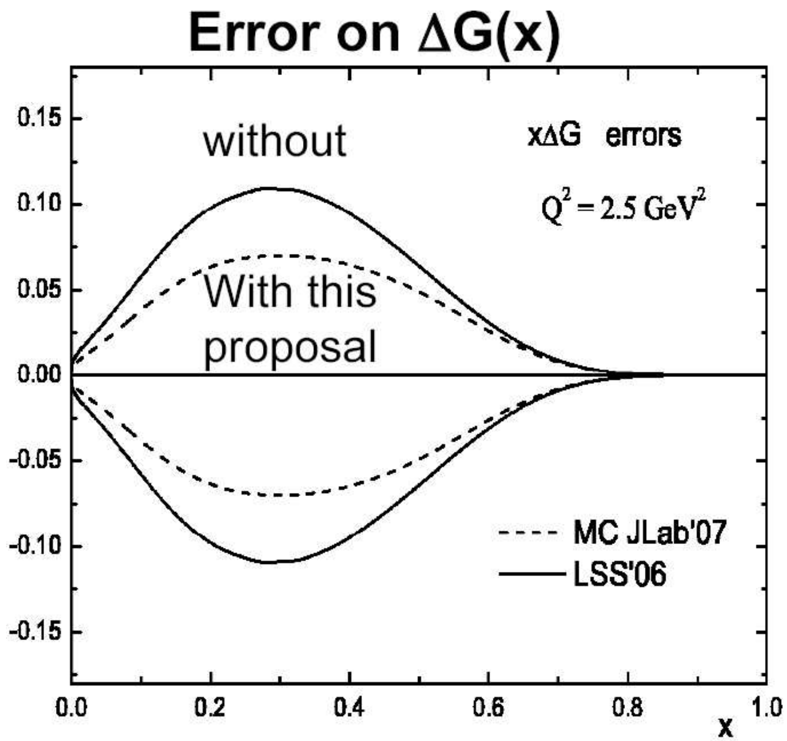
- Fit of LSS-06, including higher-twist terms.
- CLAS eg1b-06 data significantly shrunk error size of $\Delta G(x)$
- 12 GeV data will reduce $\Delta G(x)$ error by a factor of 4.
- Similar conclusions from AAC-06 analysis.

JLab @ 6 GeV: more A_{1d} data to come



Experiment E07-011 (Hall C).

JLab 6 GeV experiment on A_{1d} will reduce error band on ΔG



- Will collect data in late-2008, share beam time with E04-113.
- Same constrain power on ΔG as of RHIC $A_{LL}^{\pi^o}$ 2006 data (AAC-07).

Constrain Polarized PDF with Semi-Inclusive DIS Data

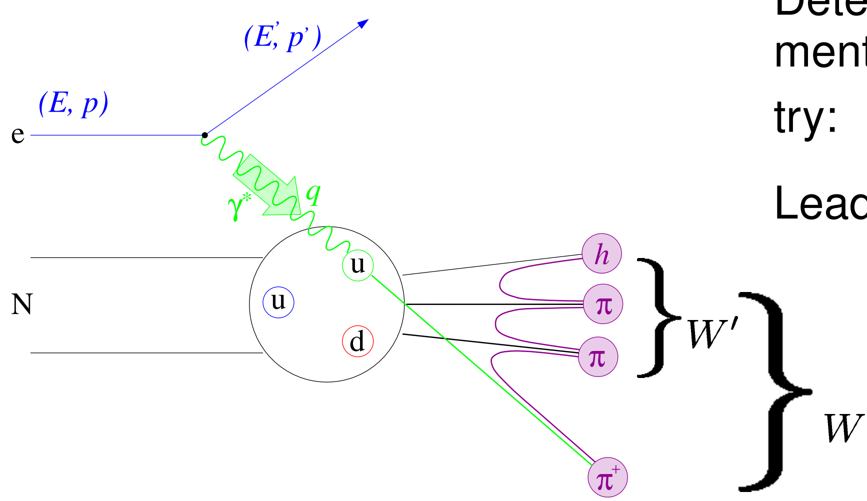
Inclusive DIS data provide constraints on $\Delta q + \Delta \bar{q}$.

In SIDIS, final state hadron tagging separates Δq from $\Delta \bar{q}$ through differences in fragmentation, data provide constraints on $\Delta q - \Delta \bar{q}$.

Measure SIDIS double-spin asymmetries in $\vec{N}(\vec{e}, e'h)$.

- Δq results from HERMES.
- Upcoming JLab experiment E04-113: precision data on A_{1p}^h and A_{1d}^h .
- Flavor/charge non-singlet combination $\pi^+ - \pi^- \Rightarrow \Delta u_v, \Delta d_v$.
- To obtain $\vec{p} - \vec{n}$: $\Delta u_v - \Delta d_v \stackrel{g_1^p - g_1^n}{\Longrightarrow} \Delta \bar{u} - \Delta \bar{d}$.
- Inputs to NLO global fit to constrain $\Delta q, \Delta \bar{q}$ and ΔG.

Flavor Tagging in SIDIS and HERMES Δq Results



$z = E_\pi / \nu$

Detect the leading hadron from the current fragmentation and measure double-spin asymmetry: $A_1^h = \Delta\sigma^h / \sigma^h$.

Leading order cross section:

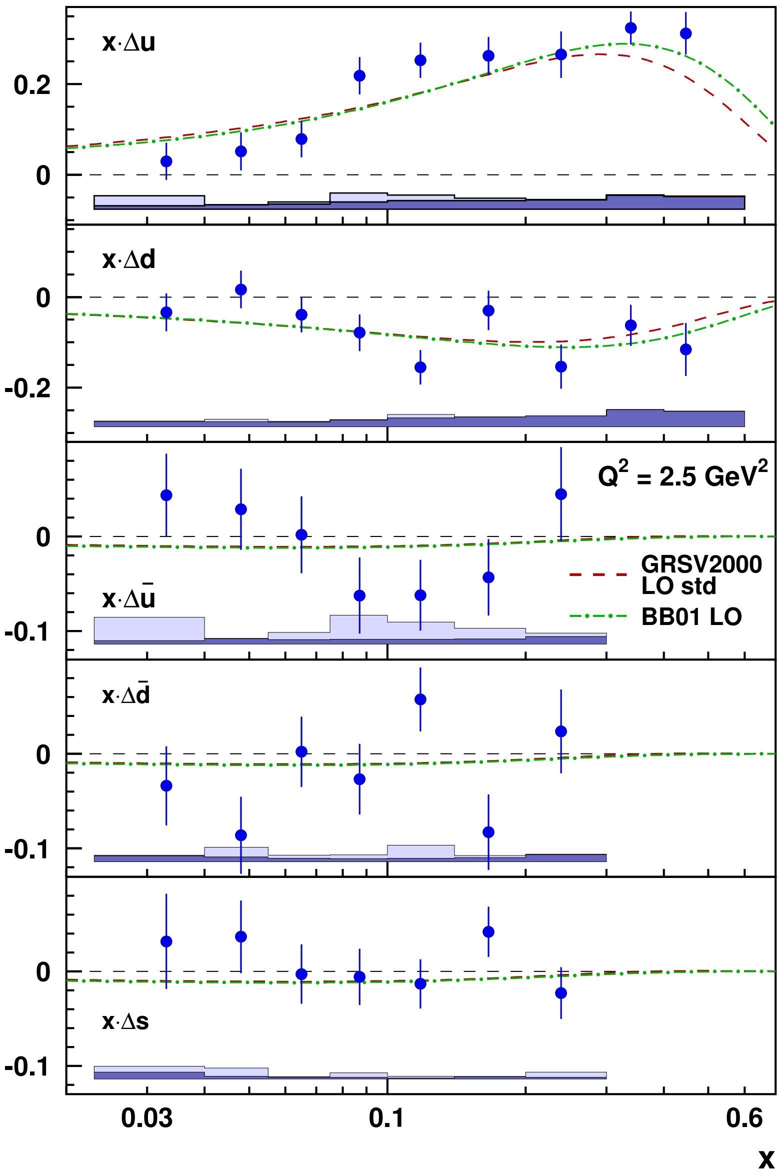
$$\Delta\sigma^h = \sum_{f=q,\bar{q}} e_f^2 \, \Delta q_f(x) \, D_f^h(z)$$

HERMES calculated "purity" from a LUND based Monte Carlo:

$$A_1^h = \sum_a \underbrace{\frac{e_a^2 \, q_a(x) \, D_a^h(z)}{\sum_b e_b^2 \, q_b(x) \, D_b^h(z)}}_{P_a^h(x,z)} \frac{\Delta q_a(x)}{q_a(x)}$$

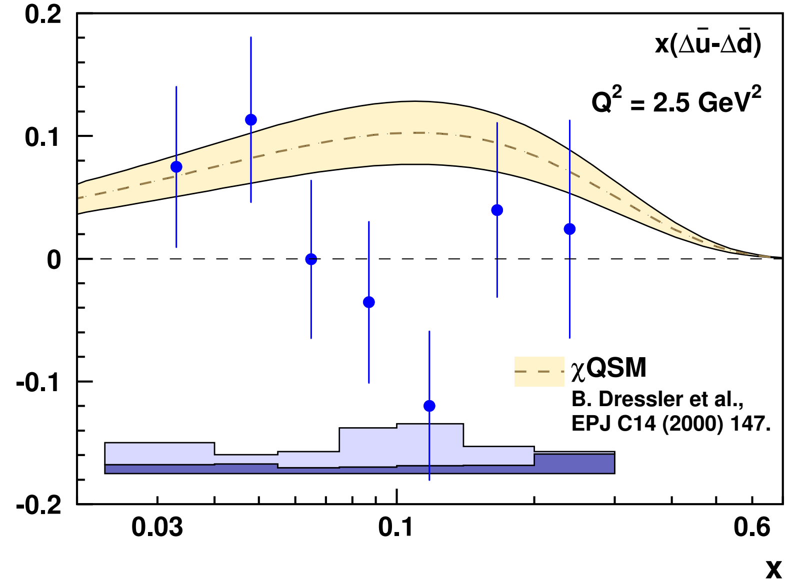
Fragmentation "tags" flavor

and charge of struck quark.



Solve for $\vec{A} = \mathcal{P}_f^h(x) \cdot \vec{Q}$

$$\vec{A} = \left(A_{1p}^{\pi^+}, A_{1p}^{\pi^-}, A_{1d}^{\pi^+}, A_{1d}^{\pi^-}, A_{1d}^{K^+}, A_{1d}^{K^-}, A_{1p}, A_{1d} \right)$$



Assume:

Leading order cross section and current fragmentation.

Isospin symmetry and charge conjugation.

“Purity” calculated from Monte Carlo depends on the detailed knowledge of the fragmentation process.

An alternative method to obtain flavor non-singlet $\Delta\bar{u} - \Delta\bar{d}$

Flavor non-singlet:

$$\Delta q_3(x) = [\Delta u(x) + \Delta\bar{u}(x)] - \left[\Delta d(x) + \Delta\bar{d}(x)\right].$$

$$\Delta\bar{u}(x) - \Delta\bar{d}(x) = \frac{1}{2}\Delta q_3(x) - \frac{1}{2}\left[\Delta u_v(x) - \Delta d_v(x)\right].$$

At the leading order:

$$\Delta q_3(x)|_{LO} = 6\left[g_1^p(x) - g_1^n(x)\right].$$

$$\left[\Delta\bar{u}(x) - \Delta\bar{d}(x)\right]_{LO} = 3\left[g_1^p(x) - g_1^n(x))\right] - \frac{1}{2}(\Delta u_v - \Delta d_v)|_{LO}.$$

- Obtain non-singlet $\Delta q_3(x)$ through inclusive data $g_1^p(x) - g_1^n(x)$.
- Obtain $\Delta u_v - \Delta d_v$ through SIDIS data, rather than Δu, Δd, $\Delta\bar{u}$ and $\Delta\bar{d}$ separately.

Flavor Non-Singlet $\Delta u_v(x) - \Delta d_v(x)$ at LO

Frankfurt *et al.* 1989, Christova and Leader, 2001.

$$A_{1p}^{\pi^+-\pi^-}(\vec{p}) = \frac{\Delta\sigma_p^{\pi^+} - \Delta\sigma_p^{\pi^-}}{\sigma_p^{\pi^+} - \sigma_p^{\pi^-}} = \frac{4\Delta u_v - \Delta d_v}{4u_v - d_v}$$

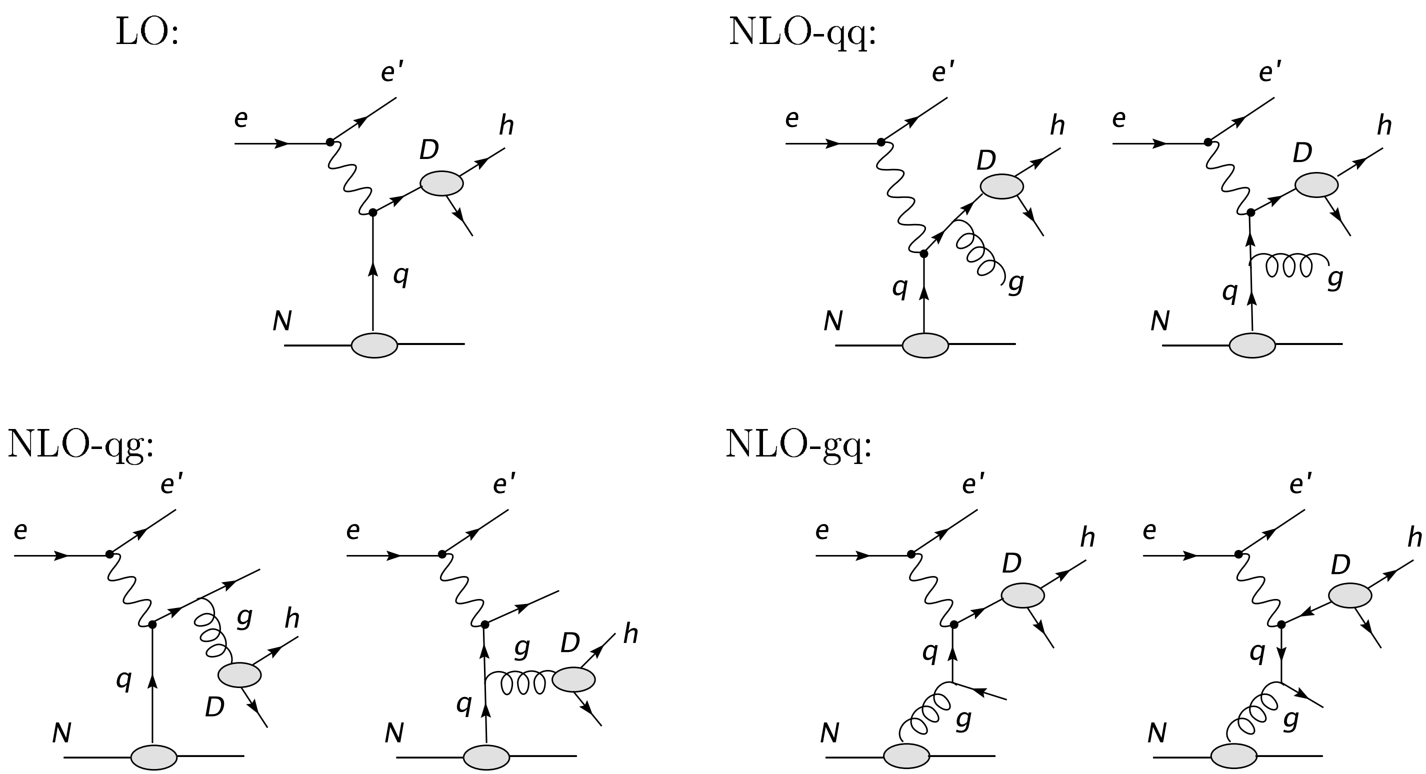
$$A_{1d}^{\pi^+-\pi^-}(\vec{p}+\vec{n}) = \frac{\Delta\sigma_d^{\pi^+} - \Delta\sigma_d^{\pi^-}}{\sigma_d^{\pi^+} - \sigma_d^{\pi^-}} = \frac{\Delta u_v + \Delta d_v}{u_v + d_v}$$

$$(\Delta u_v - \Delta d_v)_{LO} = \frac{1}{5}\left[2\left(4u_v - d_v\right)A_{1p}^{\pi^+-\pi^-} - 3(u_v + d_v)A_{1d}^{\pi^+-\pi^-}\right)\right]$$

- Fragmentation functions drop out at LO (isospin symmetry and charge conjugation).
- Measurements on three polarized targets, proton, deuteron and Helium-3, over-constrain $(\Delta u_v - \Delta d_v)_{LO}$.

SIDIS Beyond the Leading Order

Extend SIDIS cross sections beyond LO (Christova and Leader 2001, de Florian, Navarro and Sassot 2005).



- Extension to NLO is well known (Wilson coefficients, D. Graudenz, 1994).
- Flavor non-singlet observables related to $\pi^+ - \pi^-$ are theoretically clean, do not mix with gluon density and gluon fragmentation function at any QCD order.

At the Next-to-Leading-Order:

$$q(x,Q^2)\cdot D(z,Q^2) \Rightarrow \int \frac{dx'}{x'}\int\frac{dz'}{z'}q\left(\frac{x}{x'}\right)C(x',z')D\left(\frac{z}{z'}\right) = q\otimes C\otimes D$$

C are well-known Wilson coefficients (D. Graudenz, 1994).

$$\begin{aligned}\Delta\sigma^h &= \sum_i e_i^2 \Delta q_i \left[1+\otimes\frac{\alpha_s}{2\pi}\Delta C_{qq}\otimes\right] D_{q_i}^h \\ &+ \left(\sum_i e_i^2\Delta q_i\right)\otimes\frac{\alpha_s}{2\pi}\Delta C_{qg}\otimes D_G^h + \Delta G\otimes\frac{\alpha_s}{2\pi}\Delta C_{gq}\otimes\left(\sum_i e_i^2 D_{q_i}^h\right)\end{aligned}$$

- In flavor/charge non-singlet combinations $\pi^+ - \pi^-$ gluon terms drop out.
- Isospin symmetry and charge conjugation: $D_G^h = D_G^{\bar{h}}$, $\sum_i e_i^2 D_{q_i}^h = \sum_i e_i^2 D_{q_i}^{\bar{h}}$.

$A_1^{\pi^+-\pi^-}$ **is theoretically clean.**

NLO $\Delta u_v(x)$ and $\Delta d_v(x)$ From $A_1^{\pi^+-\pi^-}(x)$

E. Christova and E. Leader, 2001.

$$\frac{\Delta\sigma_p^{\pi^+} - \Delta\sigma_p^{\pi^-}}{\sigma_p^{\pi^+} - \sigma_p^{\pi^-}} = \frac{(4\Delta u_v - \Delta d_v)\left[1 + \otimes(\alpha_s/2\pi)\Delta C_{qq}\otimes\right] D_u^{\pi^+-\pi^-}}{(4u_v - d_v)\left[1 + \otimes(\alpha_s/2\pi)C_{qq}\otimes\right] D_u^{\pi^+-\pi^-}}$$

$$\frac{\Delta\sigma_d^{\pi^+} - \Delta\sigma_d^{\pi^-}}{\sigma_d^{\pi^+} - \sigma_d^{\pi^-}} = \frac{(\Delta u_v + \Delta d_v)\left[1 + \otimes(\alpha_s/2\pi)\Delta C_{qq}\otimes\right] D_u^{\pi^+-\pi^-}}{(u_v + d_v)\left[1 + \otimes(\alpha_s/2\pi)C_{qq}\otimes\right] D_u^{\pi^+-\pi^-}}$$

- Δu_v and Δd_v are non-singlets which do not mix with gluon and sea.
- Proton data is sensitive to Δu_v, neutron data is sensitive to Δd_v.

"Bjorken-type Sum Rule" links the moments at all orders of QCD (Sissakian *et al.* PRD68, 031502 (2003)).

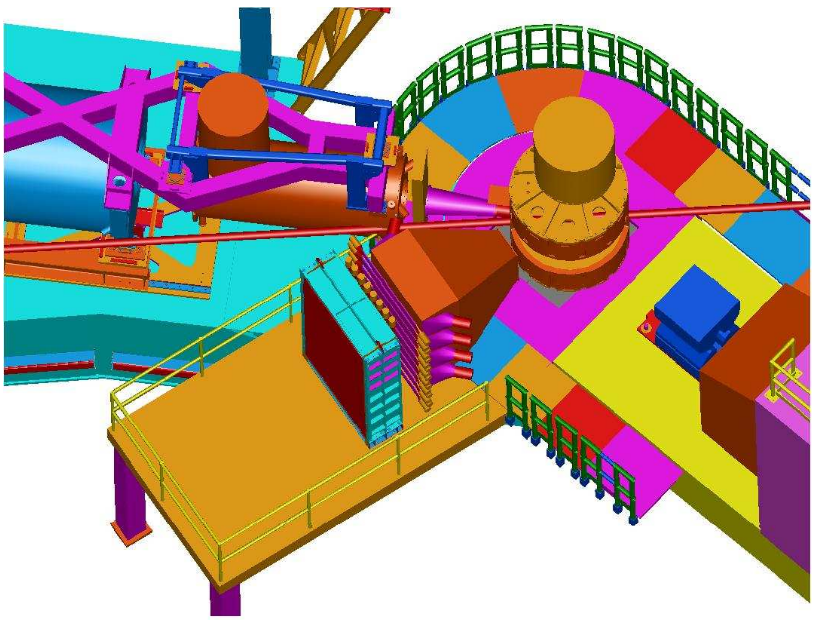
$$2\int_0^1 (\Delta\bar{u} - \Delta\bar{d})dx + \int_0^1 (\Delta u_v - \Delta d_v)dx = \left|\frac{g_A}{g_V}\right| = 1.2670 \pm 0.0035$$

Semi-SANE (E04-113): A Hall-C 6 GeV Experiment

X. Jiang, P. Bosted, D. Day and M. Jones co-spokespersons

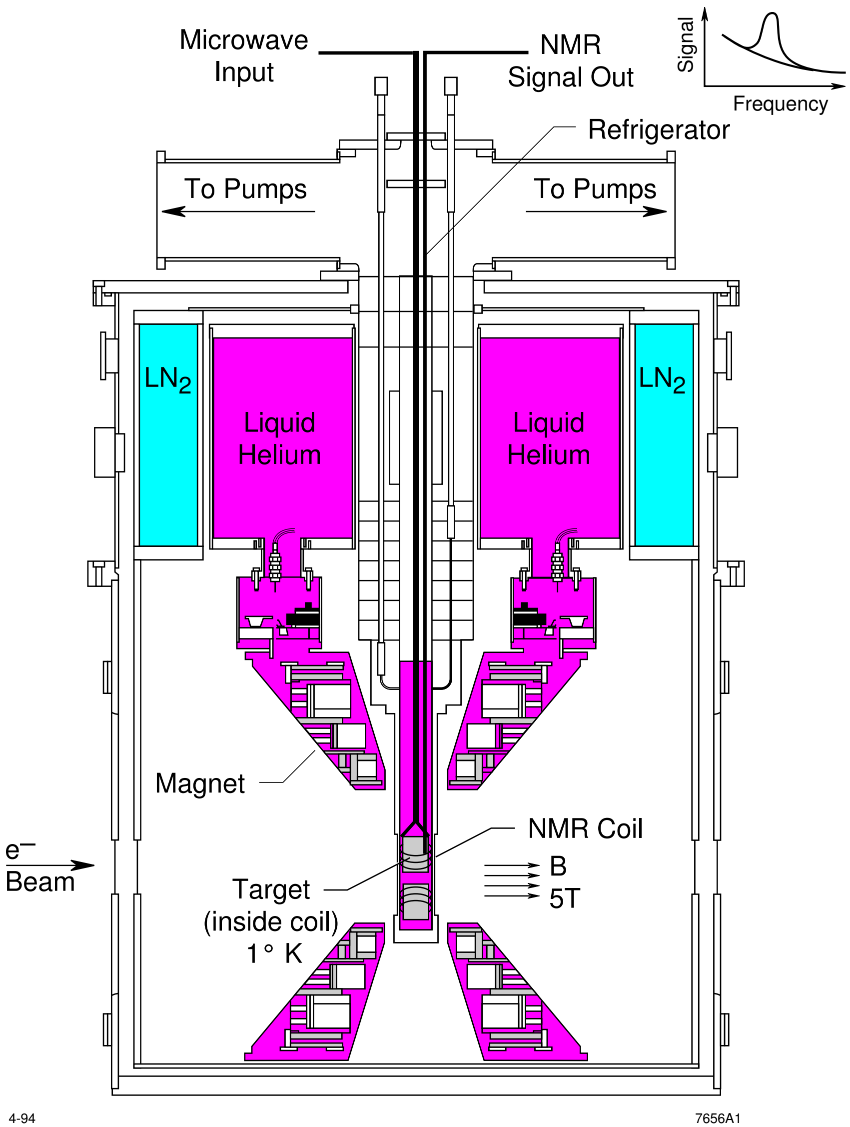
Duke, FIU, JLab, Kentucky, Norfolk, RPI, Rutgers, Temple, UVa, W&M, Yerevan, IHEP-Protvino.

High precision asymmetry data in deep-inelastic $\vec{N}(\vec{e}, e'h)$ ($N = p, d, h = \pi^{\pm}, K^{\pm}$).



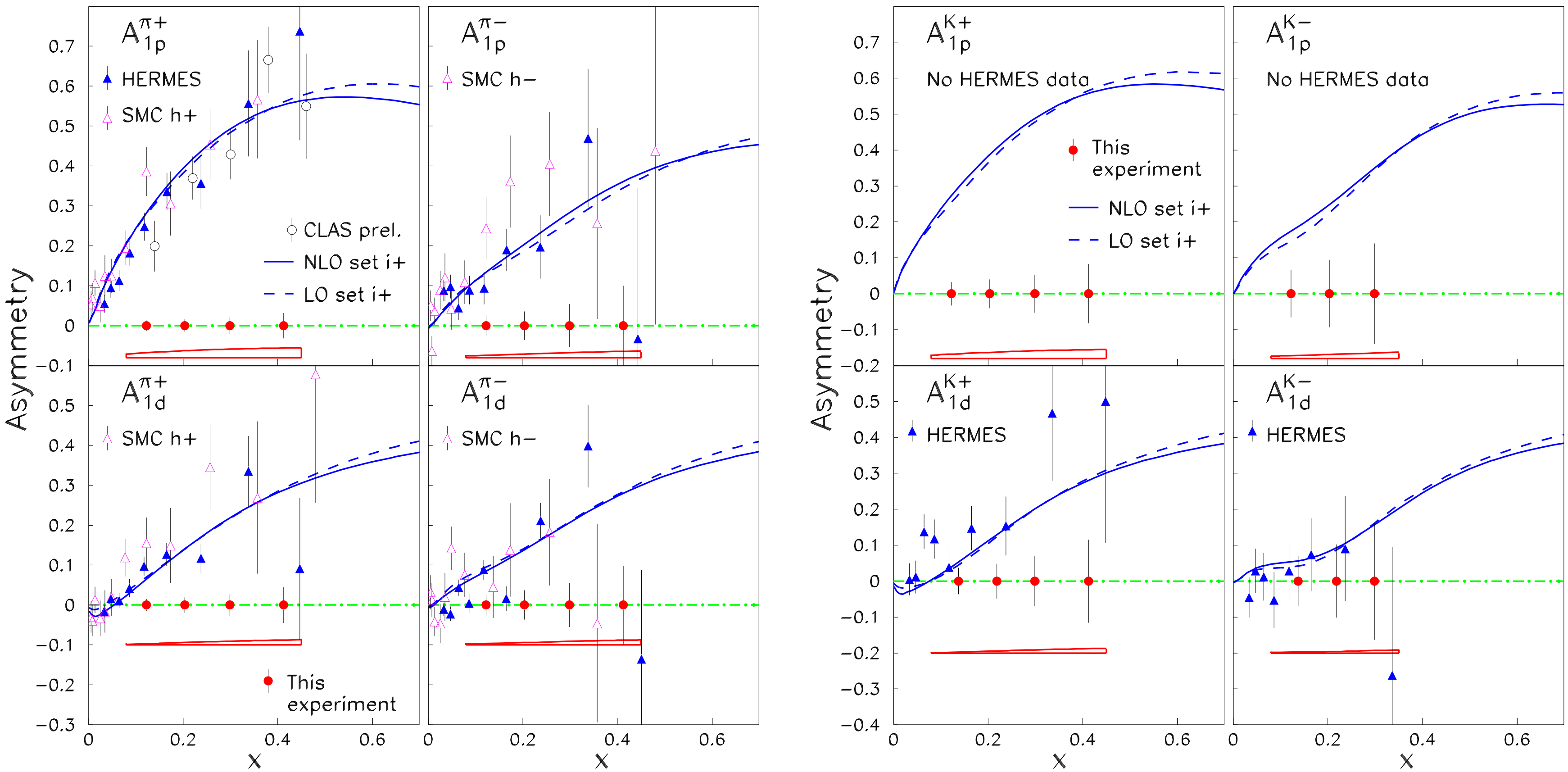
- $E_0 = 6$ GeV, $P_B = 0.80$.
- e-Arm: a calorimeter array @30°.
- h-Arm: HMS spectrometer @10.8°, 2.71 GeV/c, $z \approx 0.5$.
- Target: polarized NH_3 ($\vec{p}$), ND_3 and ^{6}LiD ($\vec{d} = \vec{p} + \vec{n}$).

UVa/SLAC/Hall-C Polarized Target ($\vec{p}$, $\vec{d}$)



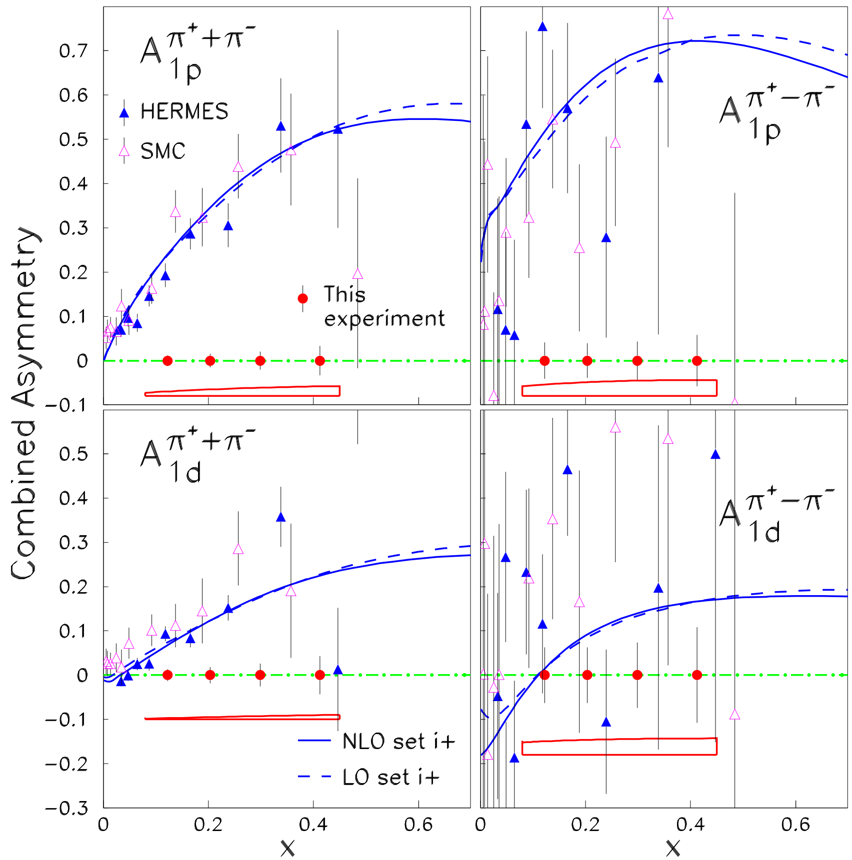
- Dynamic nuclear polarization.
- Strong field (5 T), low temperature (1K).
- P_T(NH_3)=0.8, P_T(ND_3, ^{6}LiD) $= 0.2 \sim 0.4$.
- Dilution factor: $f^h = 0.17 \sim 0.22$(NH_3), $0.40 \sim 0.45$ (LiD).

The Expected Results: Double-Spin Asymmetries A_{1N}^h



Expect significant improvements on $A_{1N}^{\pi^\pm}$. First data on $A_{1p}^{K^\pm}$.

Combined Asymmetries: $A_{1N}^{\pi^+ + \pi^-}$ and $A_{1N}^{\pi^+ - \pi^-}$



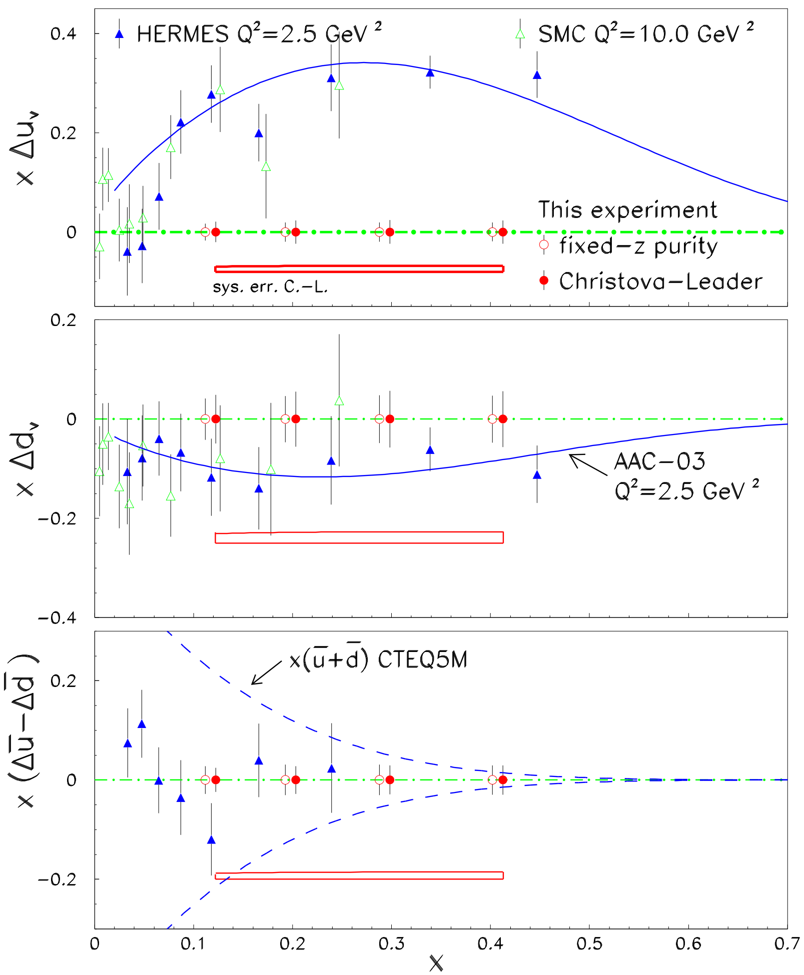
$A_{1N}^{\pi^+ - \pi^-}$: flavor/charge non-singlet, gluon densities do not contribute.

Need well-controlled hadron-arm phase space and PID to determine:

$$r = \frac{\sigma^{\pi^-}}{\sigma^{\pi^+}} = 0.3 \sim 0.6.$$

$$A_{1N}^{\pi^+ - \pi^-} = \frac{\Delta\sigma_N^{\pi^+} - \Delta\sigma_N^{\pi^-}}{\sigma_N^{\pi^+} - \sigma_N^{\pi^-}} = \frac{A_{1N}^{\pi^+} - A_{1N}^{\pi^-} \cdot r}{1 - r}.$$

E04-113: Expected Results on Δq_v and $\Delta\bar{u} - \Delta\bar{d}$



$$\Delta u_v = \Delta u - \Delta\bar{u}$$
$$\Delta d_v = \Delta d - \Delta\bar{d}$$

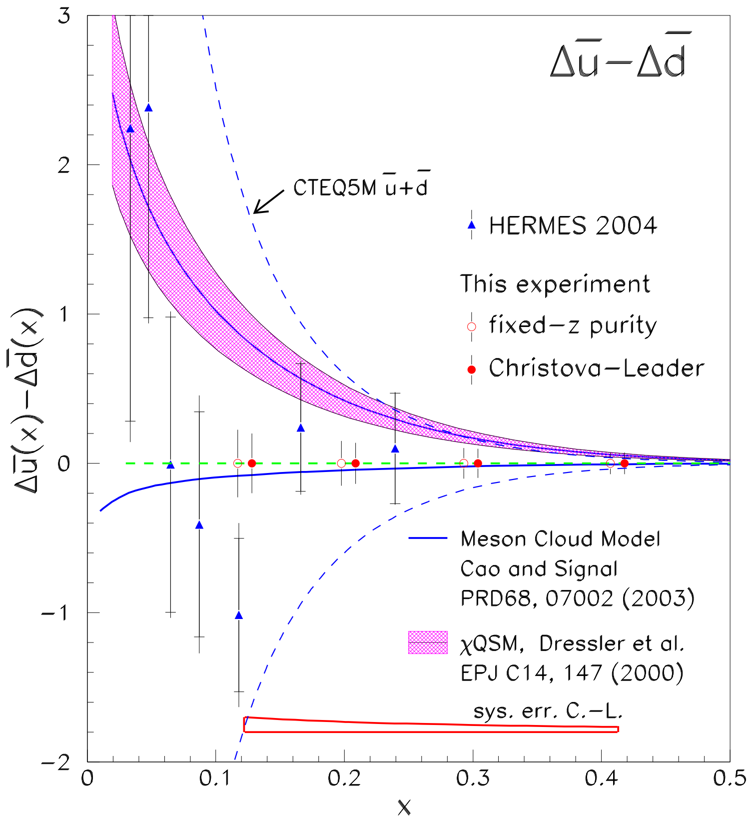
Tow independent methods of flavor decomposition:

i, Christova-Leader method.

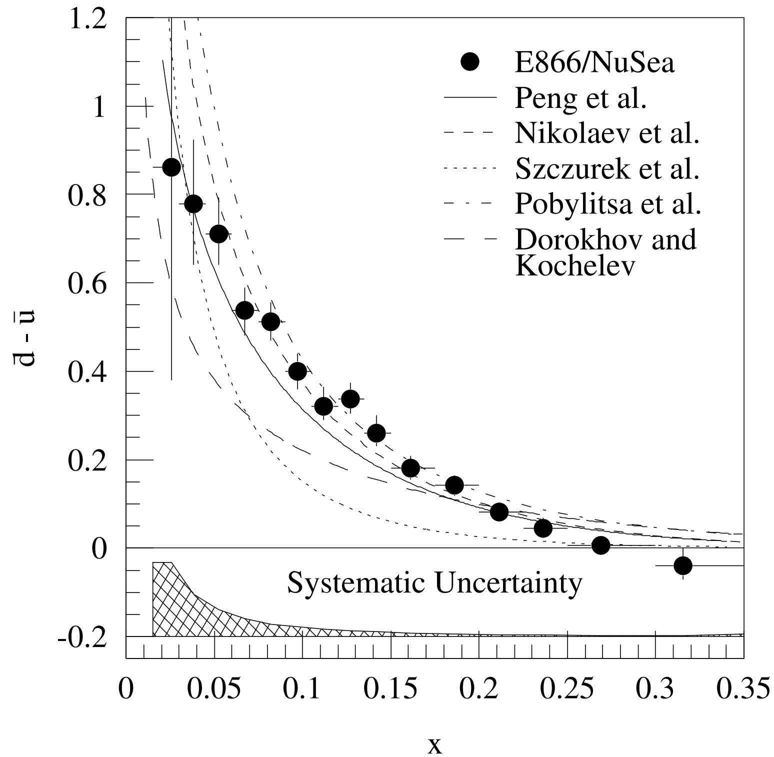
ii, “Purity” at a fixed-z.

One expects at least $\Delta\bar{u} - \Delta\bar{d} > (\bar{d} - \bar{u})$!!!

E04-113: Access Flavor Asymmetry in the Nucleon Sea



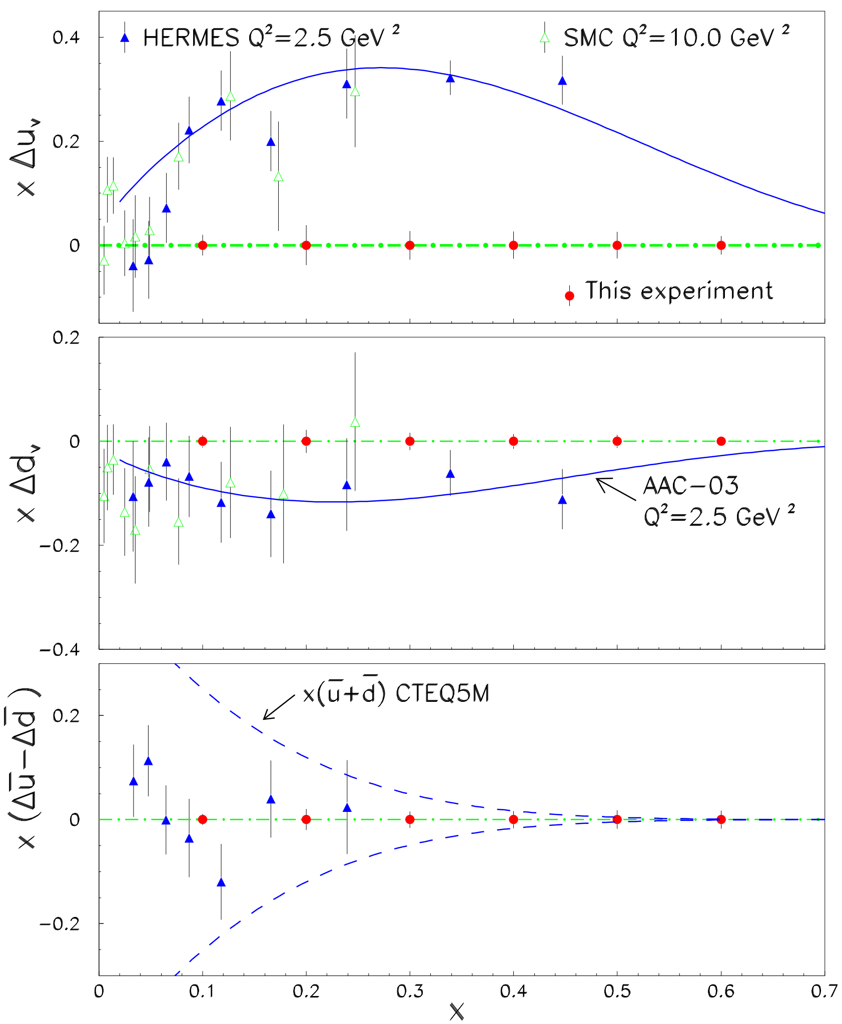
Many other model predicted large $\Delta\bar{u} - \Delta\bar{d}$. In Chiral-quark soliton model, $\Delta\bar{u} - \Delta\bar{d}$ appears in LO (N_c^2) while $\bar{d} - \bar{u}$ appears in NLO (N_c).



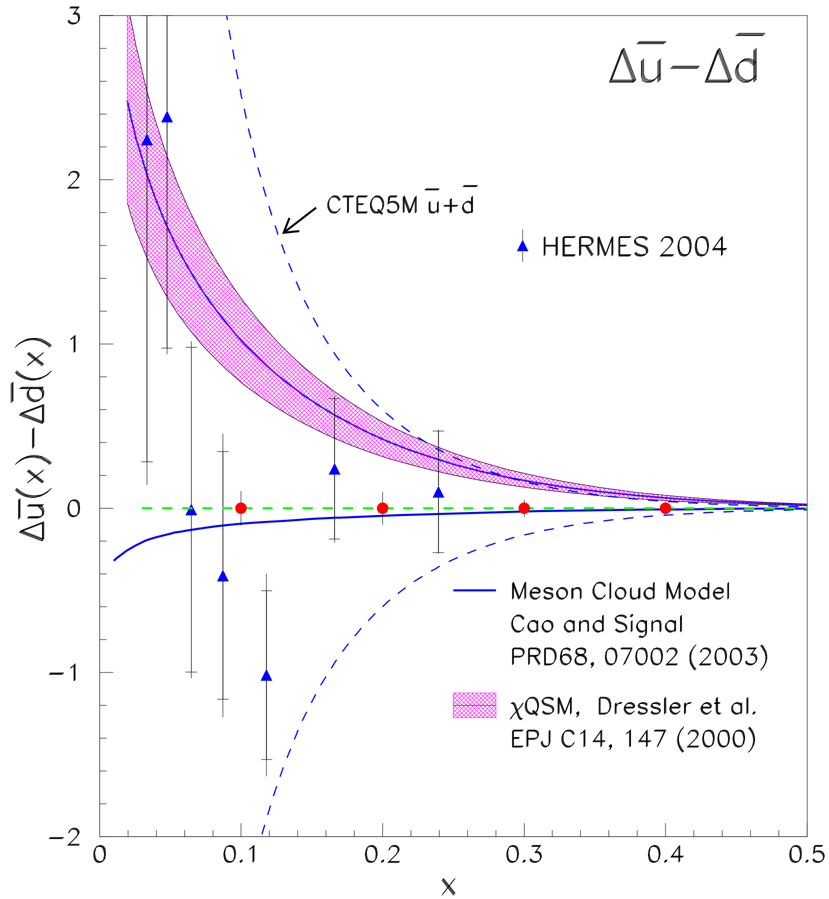
Fermilab $pp, pd \to \mu^+\mu^-$ data. Many models explain $\bar{d} - \bar{u}$, including the meson-cloud model (π) which predicts $\Delta\bar{u} = \Delta\bar{d} = 0$.

Pauli-blocking model: $\int_0^1 [\Delta\bar{u}(x) - \Delta\bar{d}(x)]dx = \frac{5}{3} \cdot \int_0^1 [\bar{d}(x) - \bar{u}(x)]dx \approx 0.2$.

After 12 GeV Upgrade: Spin-Flavor Decomposition through SIDIS

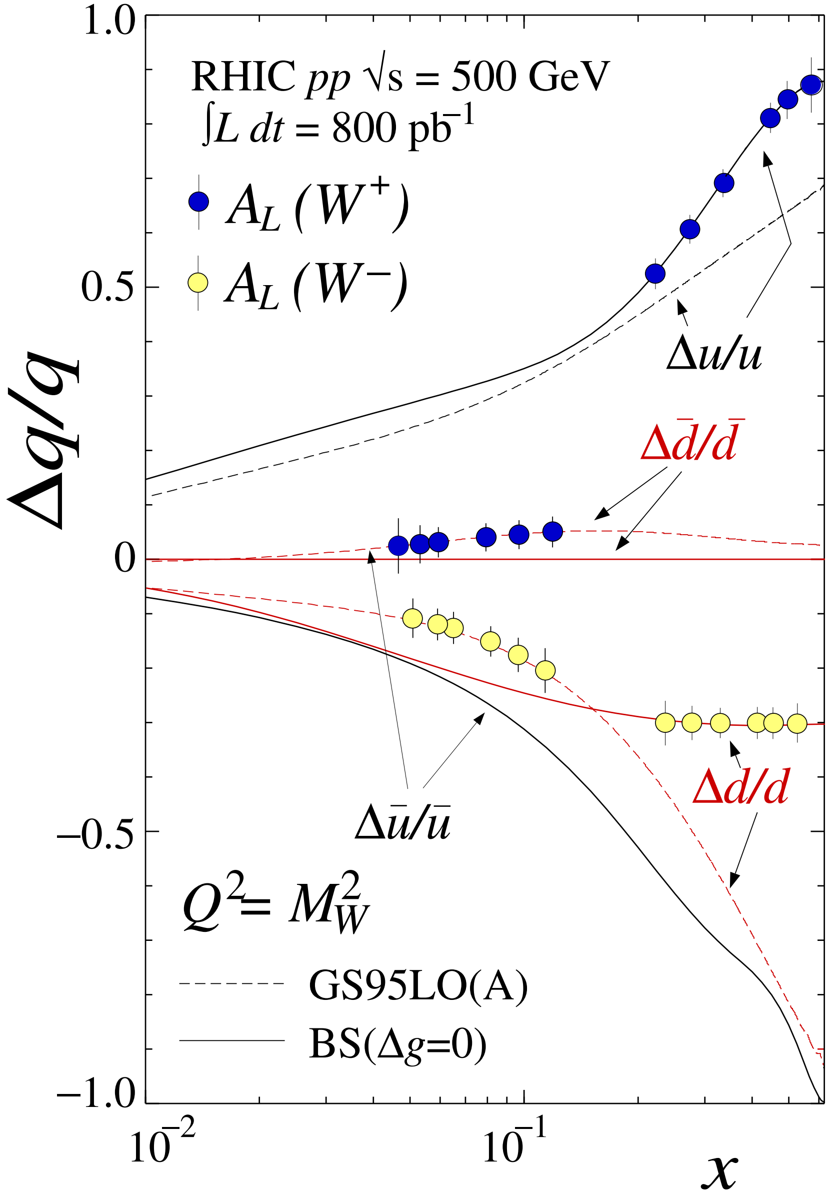


11 GeV beam on NH_3 (1200 hours) and ^{3}He (400 hours) targets.

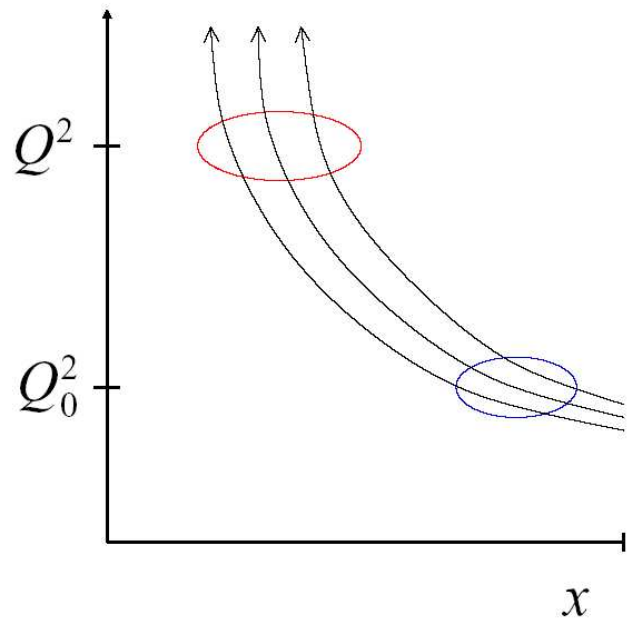


(X. Jiang, JLab 12 GeV upgrade CD1 report.)

... and from RHIC-II $W^{\pm}$ decay one expects

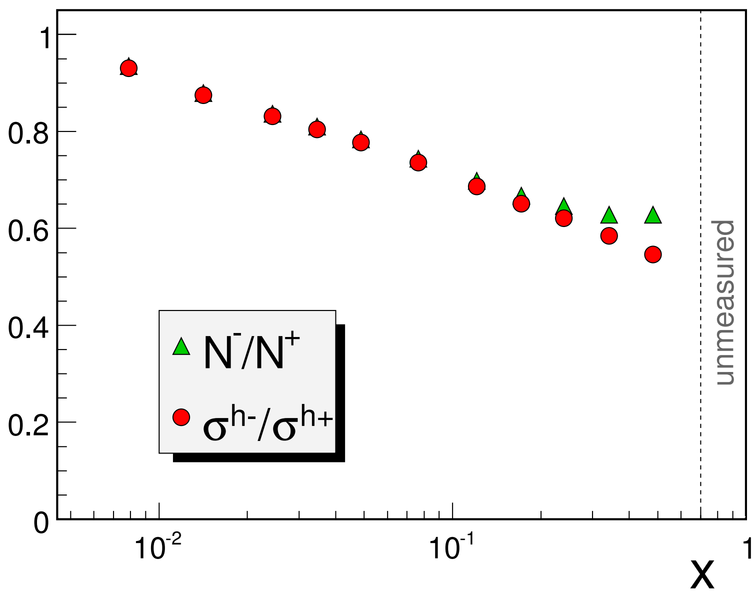


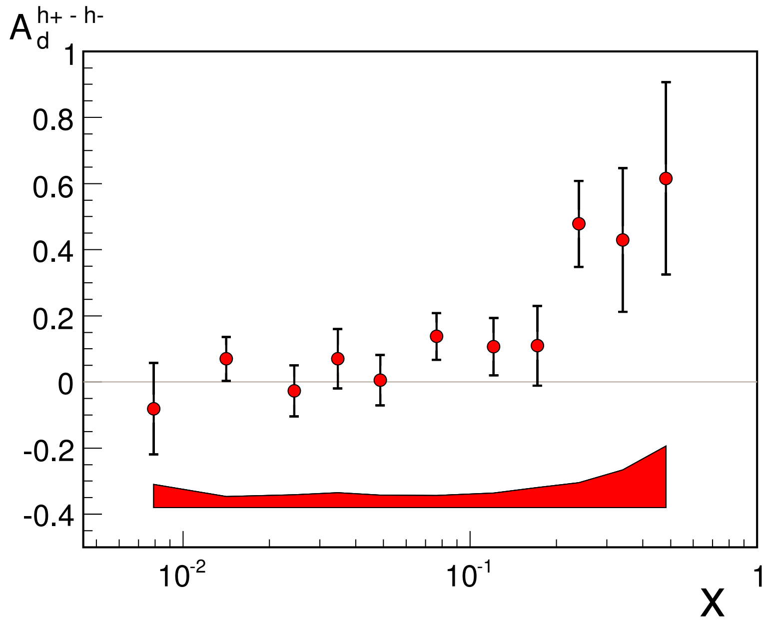
DGLAP evolution equation links high-x low-Q^2 region to low-x high-Q^2 region.



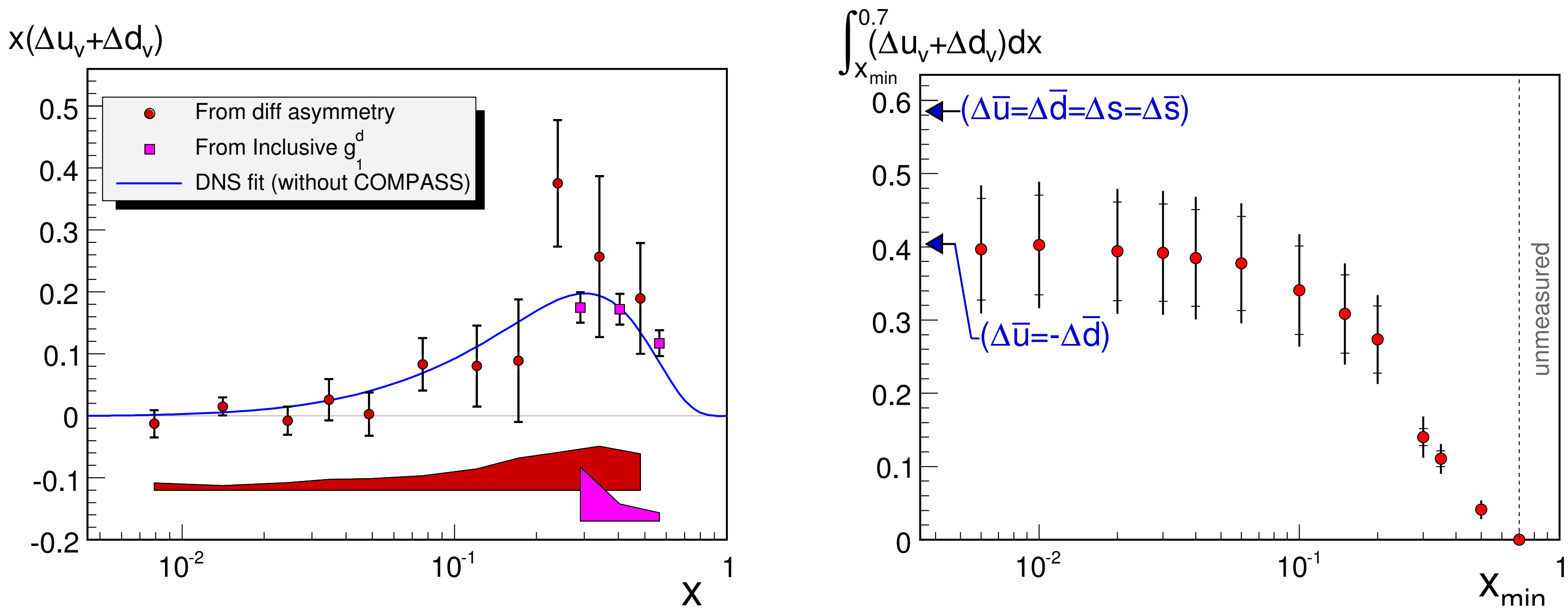
Data at increasing Q^2 probe higher and higher x in input PDF at Q_0^2.
Non-singlet evolution is straight forward.

COMPASS-2007: $A_{1d}^{h^+-h^-}$ and $\Delta u_v + \Delta d_v$





arXiv:0707.4077. ^{6}LiD target, $\langle Q^2 \rangle = 10$ GeV^2



$$\int_{0.006}^{0.7}[\Delta u_v(x) + \Delta d_v(x)]dx = 0.40 \pm 0.07(stat.) \pm 0.05(sys.).$$

Δq, $\Delta\bar{q}$ and ΔG: NLO global fits to DIS and SIDIS data

de Florian, Navarro and Sassot. PRD71, 094018, (2005).

X. Jiang, Navarro and Sassot. EPJC47, 81, (2006).

- Fit inclusive and semi-inclusive DIS data to NLO in PDFs and fragmentation functions.
- Allow different parameterizations of F.F. (KRE and KKP).
- Gives error bands on polarized PDF. Translate into error bands on observables.
- Constraints on ΔG, compare with RHIC $A_{LL}^{\pi^0}$ data.

Inclusive:

$$g_{1N}(x,Q^2) = \frac{1}{2}\sum_{q,\bar{q}} e_q^2 \left[\Delta q(x,Q^2)\right.$$
$$\left. + \frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{dz}{z}\left\{\Delta C_q(z)\Delta q(\frac{x}{z},Q^2) + \Delta C_g(z)\Delta g(\frac{x}{z},Q^2)\right\}\right].$$

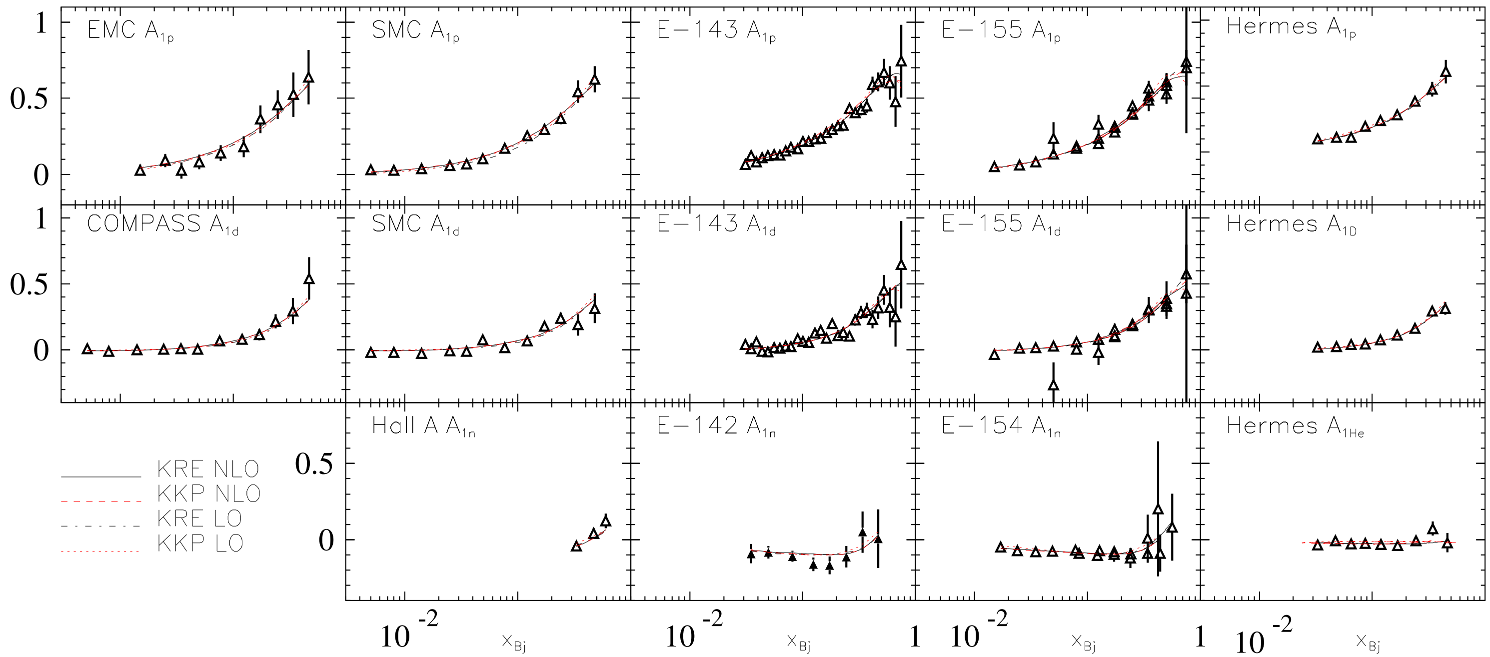
Semi-inclusive:

$$g_{1N}^h(x,z,Q) = \frac{1}{2}\sum_{q,\bar{q}} e_q^2 \left[\Delta q\left(x,Q^2\right) D_q^H\left(z,Q^2\right) + \right.$$

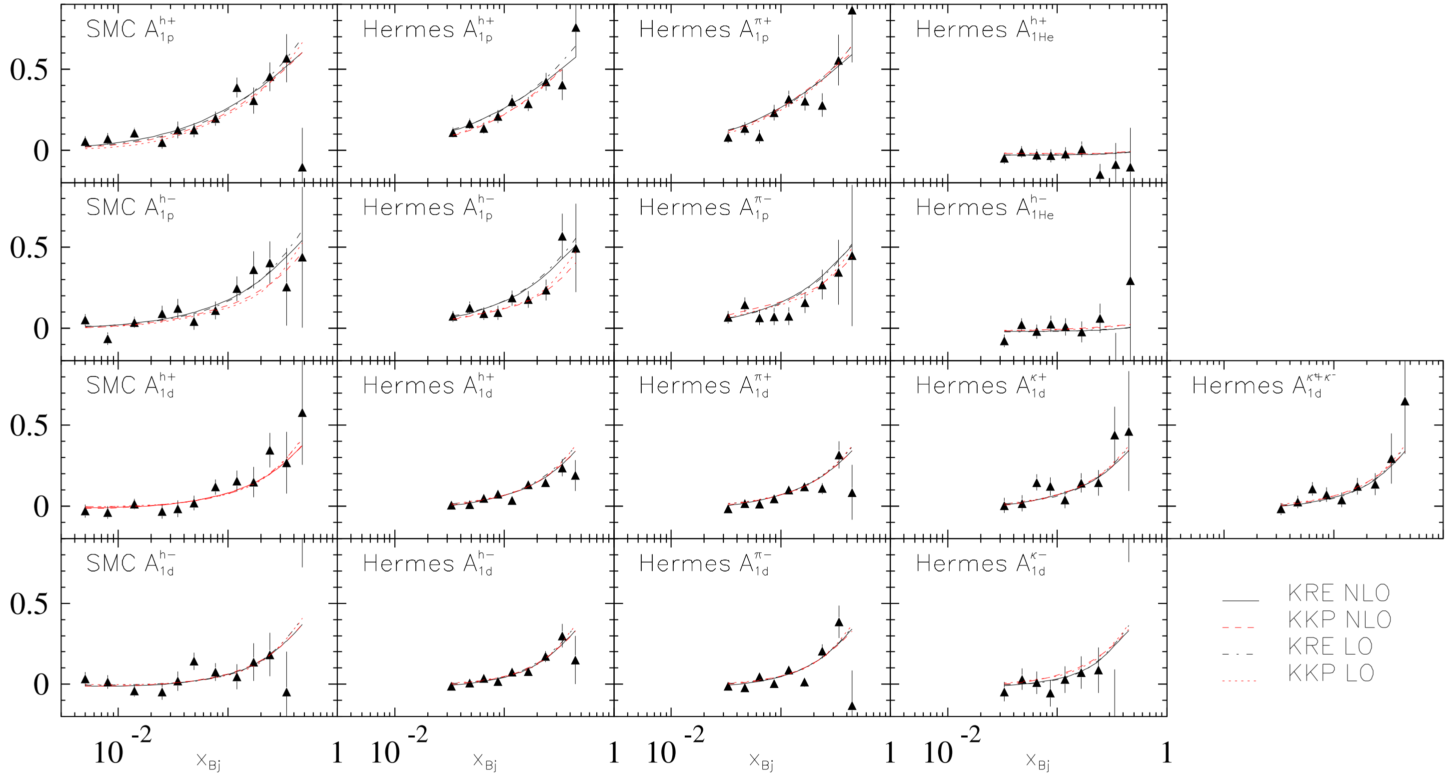
$$\frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{d\hat{x}}{\hat{x}}\int_z^1 \frac{d\hat{z}}{\hat{z}}\left\{\Delta q\left(\frac{x}{\hat{x}},Q^2\right)\Delta C_{qq}^{(1)}(\hat{x},\hat{z},Q^2) D_q^H\left(\frac{z}{\hat{z}},Q^2\right) + \right.$$

$$\Delta q\left(\frac{x}{\hat{x}},Q^2\right)\Delta C_{gq}^{(1)}(\hat{x},\hat{z},Q^2) D_g^H\left(\frac{z}{\hat{z}},Q^2\right) + \Delta g\left(\frac{x}{\hat{x}},Q^2\right)\Delta C_{qg}^{(1)}(\hat{x},\hat{z},Q^2) D_q^H\left(\frac{z}{\hat{z}},Q^2\right)$$

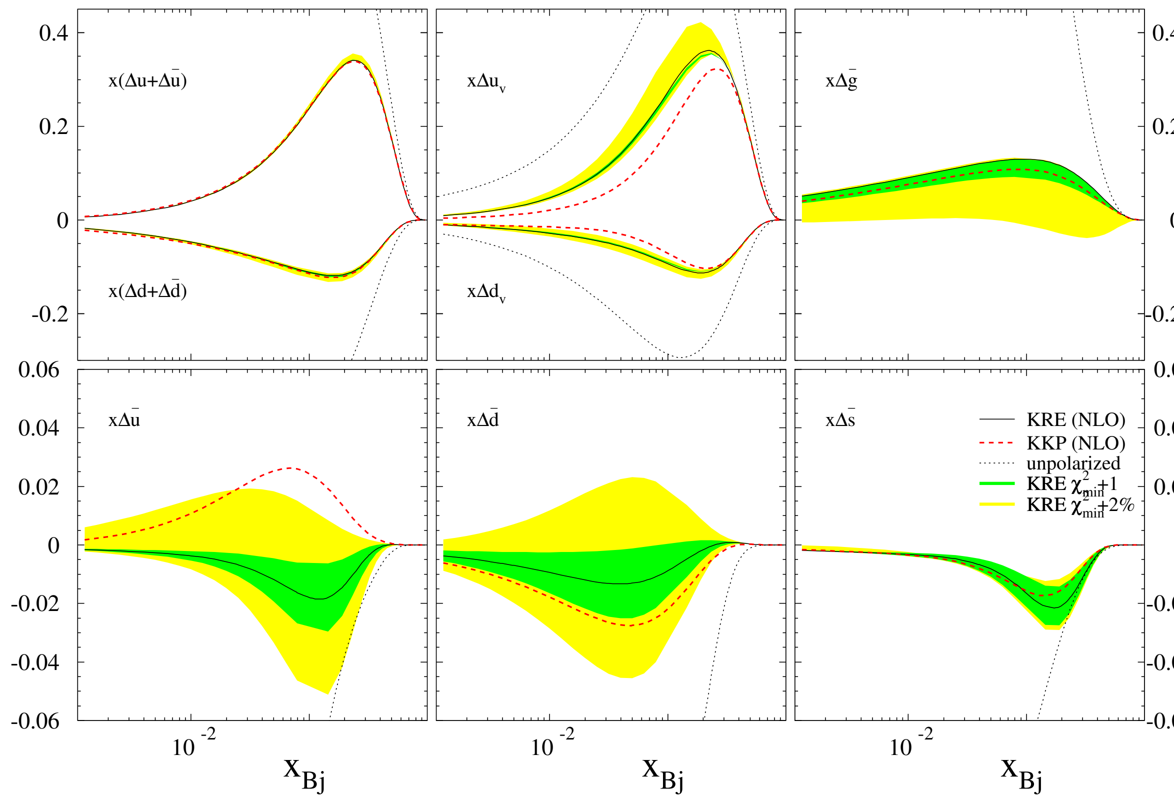
Fit Compared with Inclusive Data



Fit Compared with Semi-Inclusive DIS Data

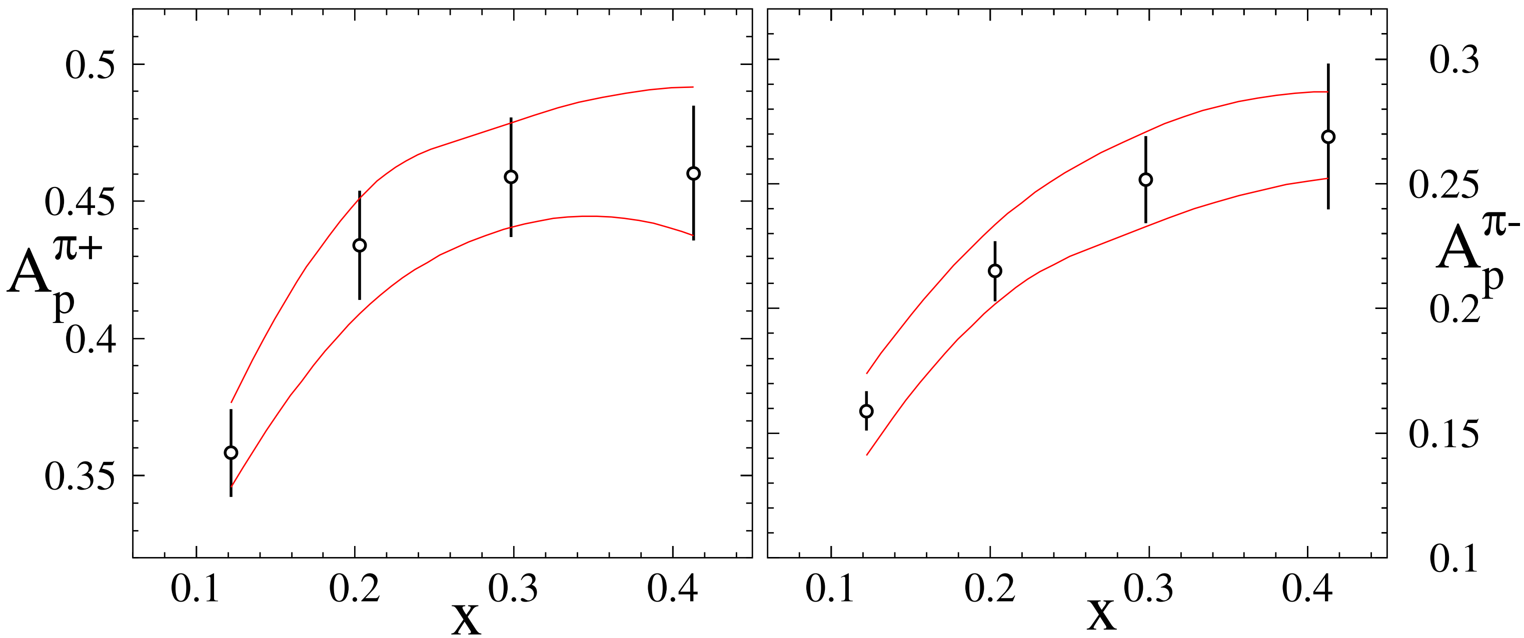


Error bands of NLO polarized PDF



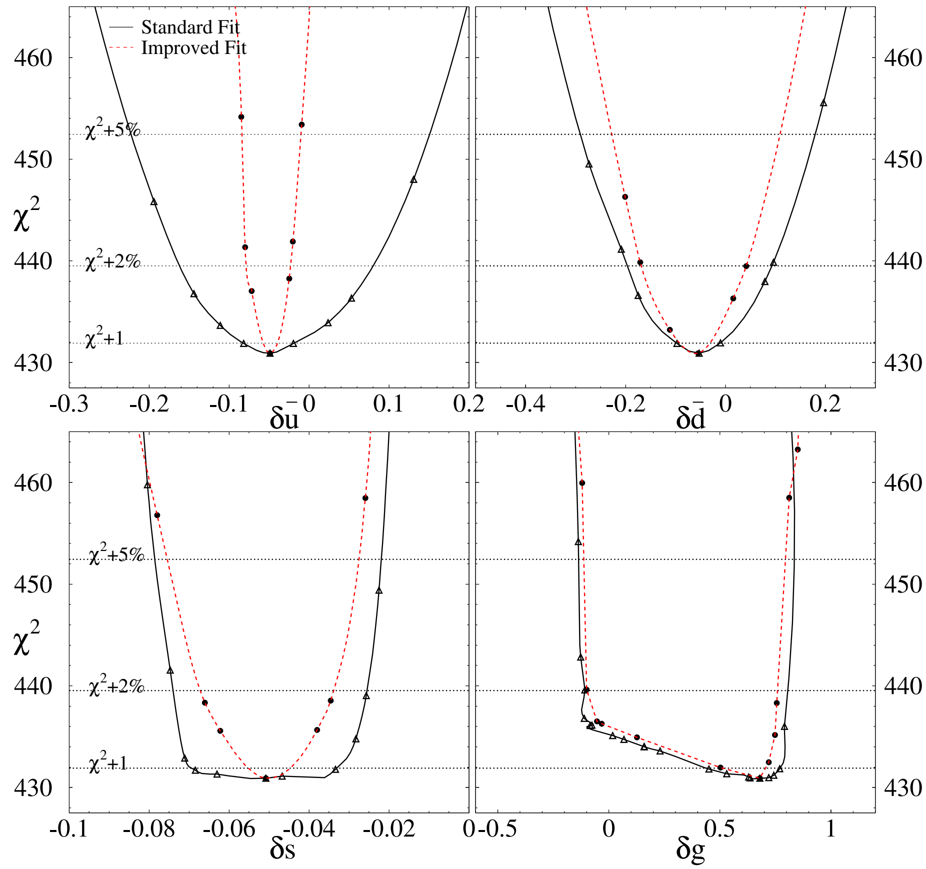
Impacts of semi-SANE proton data on NLO global fit

X. Jiang, G.A. Navarro and R. Sassot, 2006.



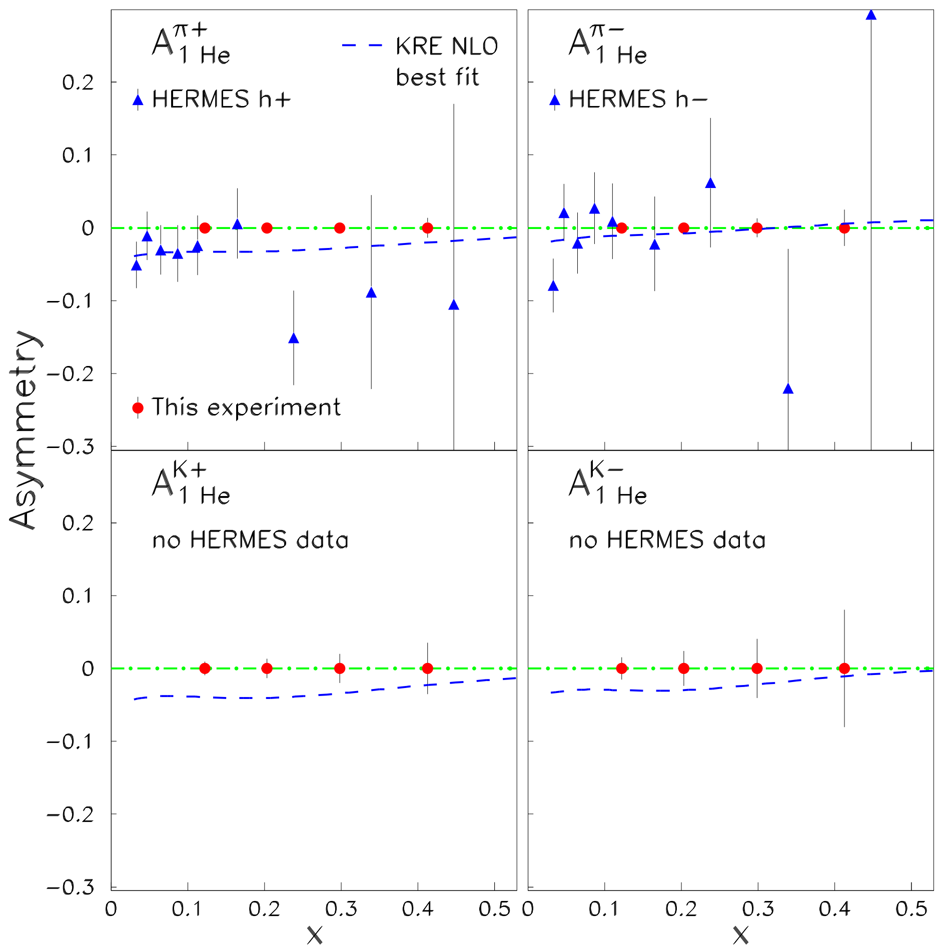
Existing constraints compared with semi-SANE projected error bars on $A_{1p}^{\pi^+}$ and $A_{1p}^{\pi^-}$.

Improved constraints on the moments of polarized PDF



Adding the projected semi-SANE proton data significantly improves the $\Delta\bar{u}$ moment.

SIDIS with a longitudinally polarized ^{3}He target: A^h_{1He}

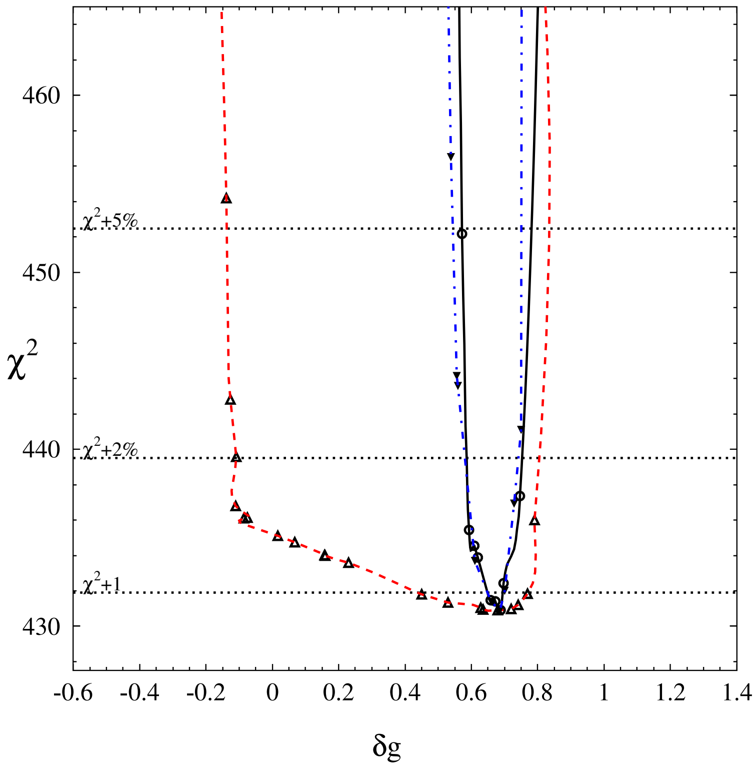


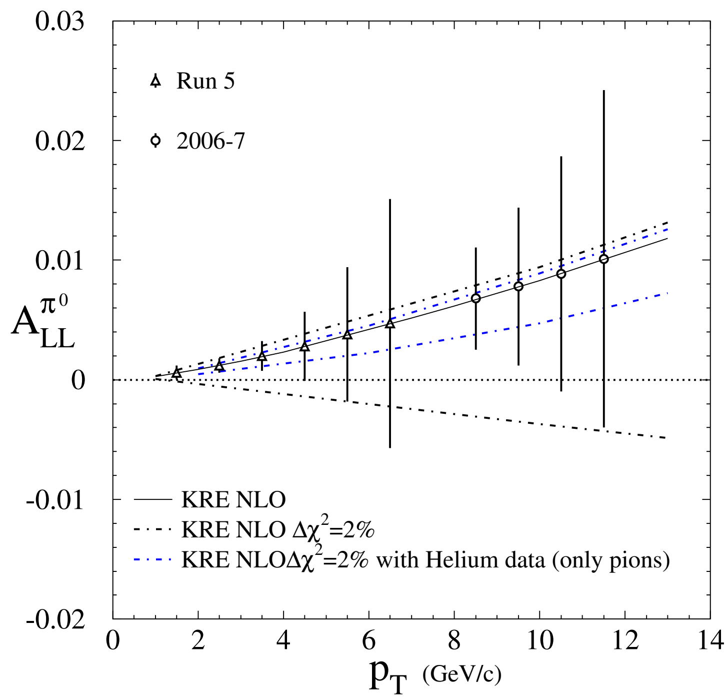
- A JLab 6 GeV proposal (PR05-112). Will improve HERMES-95 data.
- High luminosity polarized ^{3}He target to obtain A^h_{1n}.
- Sensitive to Δd_v.
- Add strong constraints to ΔG through NLO global fit.

Adding ^{3}He SIDIS data: indirect constraints to ΔG

X. Jiang, Navarro and Sassot. EPJC47, 81, (2006).

Since $g \to q\bar{q}$, once Δq_v is fixed in SIDIS, there's less freedom for ΔG in Q^2 evolution of g_{1N}.





Improve ΔG by a factor of 4.

Constrain ΔG as strong as RHIC $A_{LL}^{\pi^0}$ 2006.

Summary: JLab Experiments

The high luminosity at JLab allows precision measurements of inclusive and semi-inclusive asymmetries on polarized targets.

Inclusive A_{1p}, A_{1d}, A_{1n}(^{3}He):

- Spin-flavor decomposition $\Delta u + \Delta\bar{u}, \Delta d + \Delta\bar{d}$.
- Constrain ΔG through global fits.

Semi-inclusive A^h_{1p}, A^h_{1d}, A^h_{1n} (^{3}He):

- Flavor tagging separates Δq from $\Delta\bar{q}$.
- Flavor non-singlet observable $A_1^{\pi^+ - \pi^-}$ provide clean access $\Delta u - \Delta\bar{u}, \Delta d - \Delta\bar{d}$.
- In addition to asymmetries, one needs to determine relative cross section ratio $\sigma^{\pi-}/\sigma^{\pi+}$.

Combine inclusive and semi-inclusive data:

- $\Delta u_v - \Delta d_v \overset{g_1^p - g_1^n}{\Longrightarrow} \Delta\bar{u} - \Delta\bar{d}$.
- Constrain $\Delta q, \Delta\bar{q}$ and ΔG through NLO global fits.