Large-x Parton Distributions

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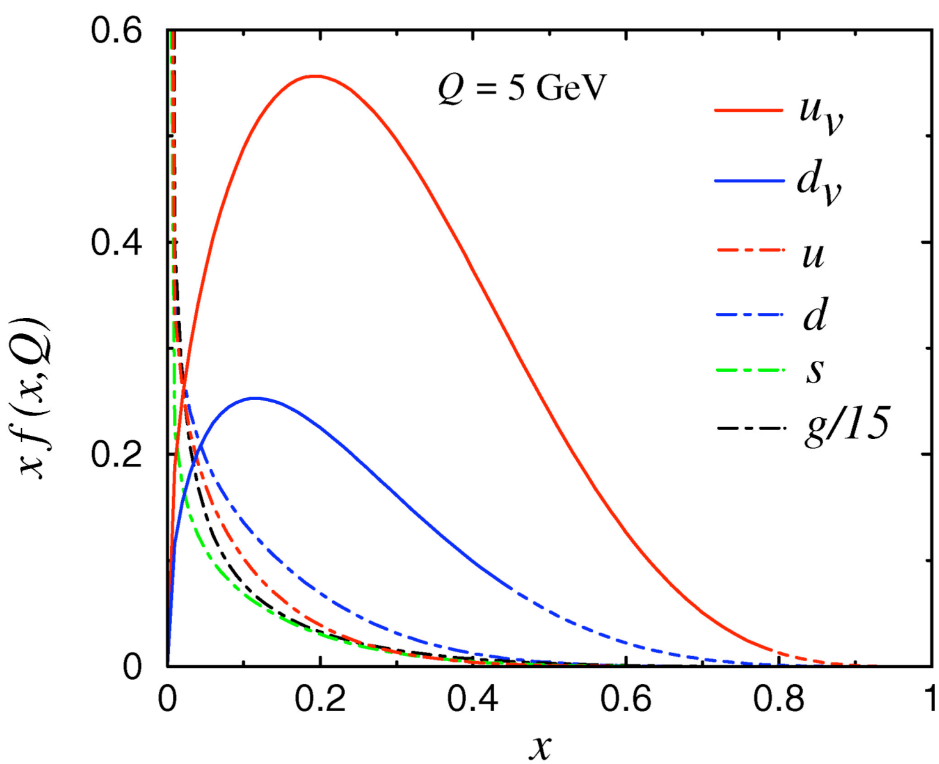
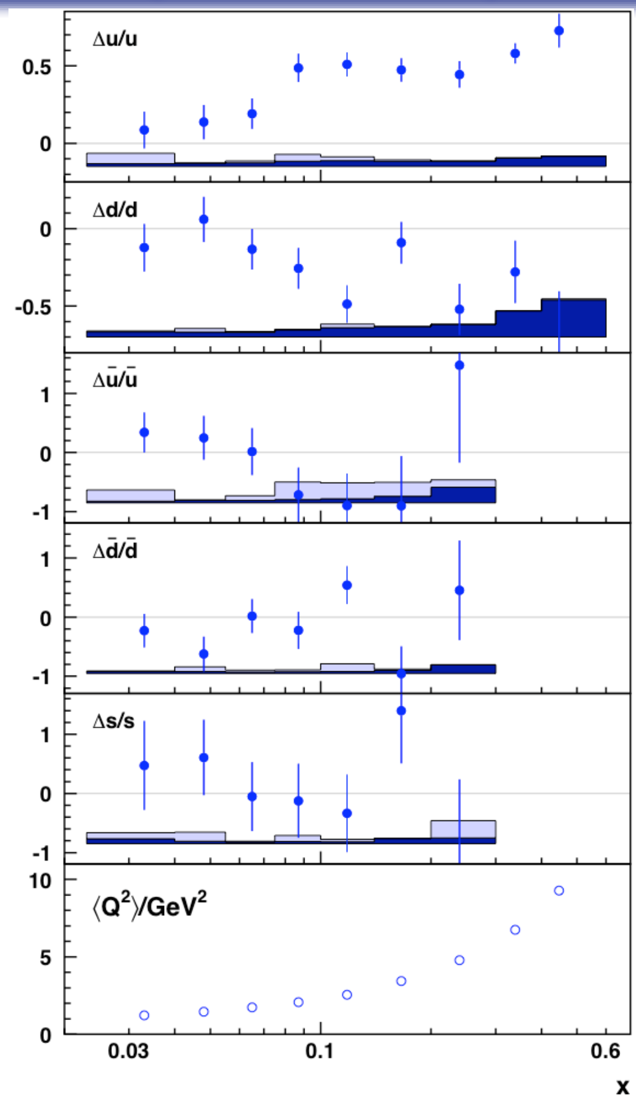
- Inclusive $l\,N$
- Inclusive $l\,N$ double spin asymmetries
- Semi-Inclusive $l\,N$ double spin asymmetries in meson production
- Single spin asymmetries in pp W production
- Summary

PDFs in the valence quark region

- large x exposes valence quarks
  - free of sea effects
- x->1 behavior – sensitive test of spin-flavor symmetry breaking
- important for higher moments of PDFs - compare with lattice QCD
- intimately related with resonances, quark-hadron duality

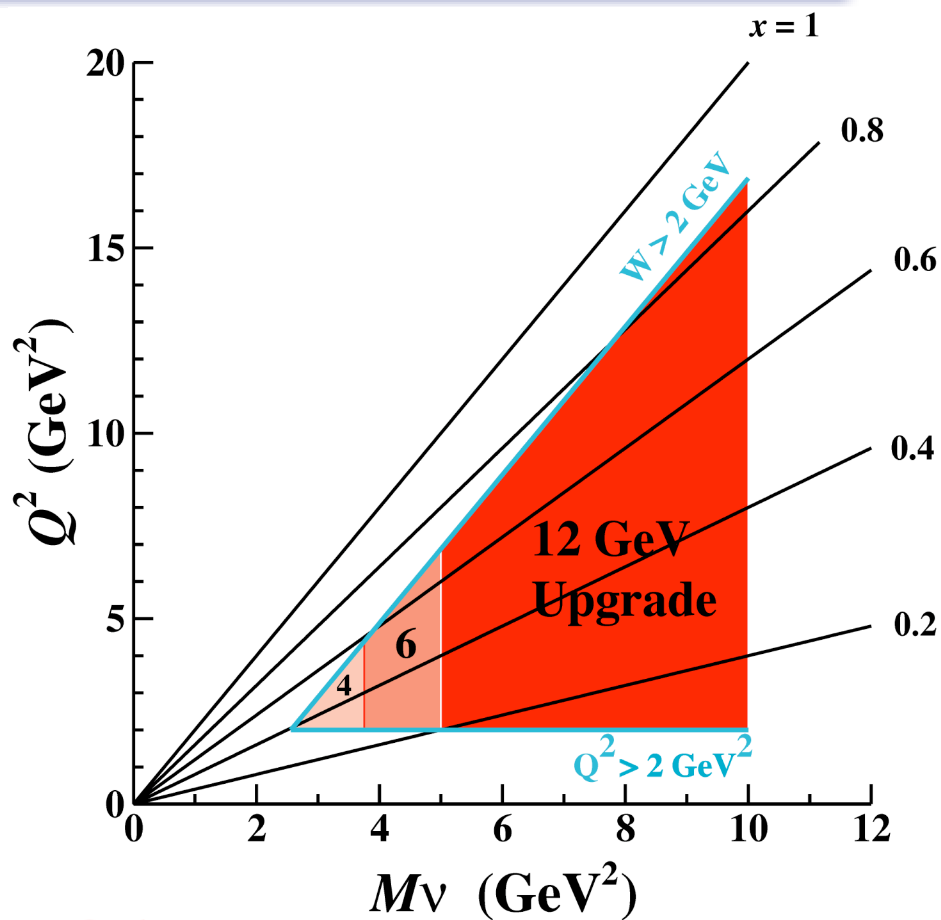


Helicity Dependent PDFs from Semi-Inclusive (HERMES)



12 GeV upgrade kinematical reach

- Access to very large x (x > 0.4)
  - Clean region
    - ✓ No strange sea effects
    - ✓ No explicit hard gluons to be included
- Quark models can be a powerful tool to investigate the structure of the nucleon
- Comparison with lattice QCD is possible for higher moments of structure functions.

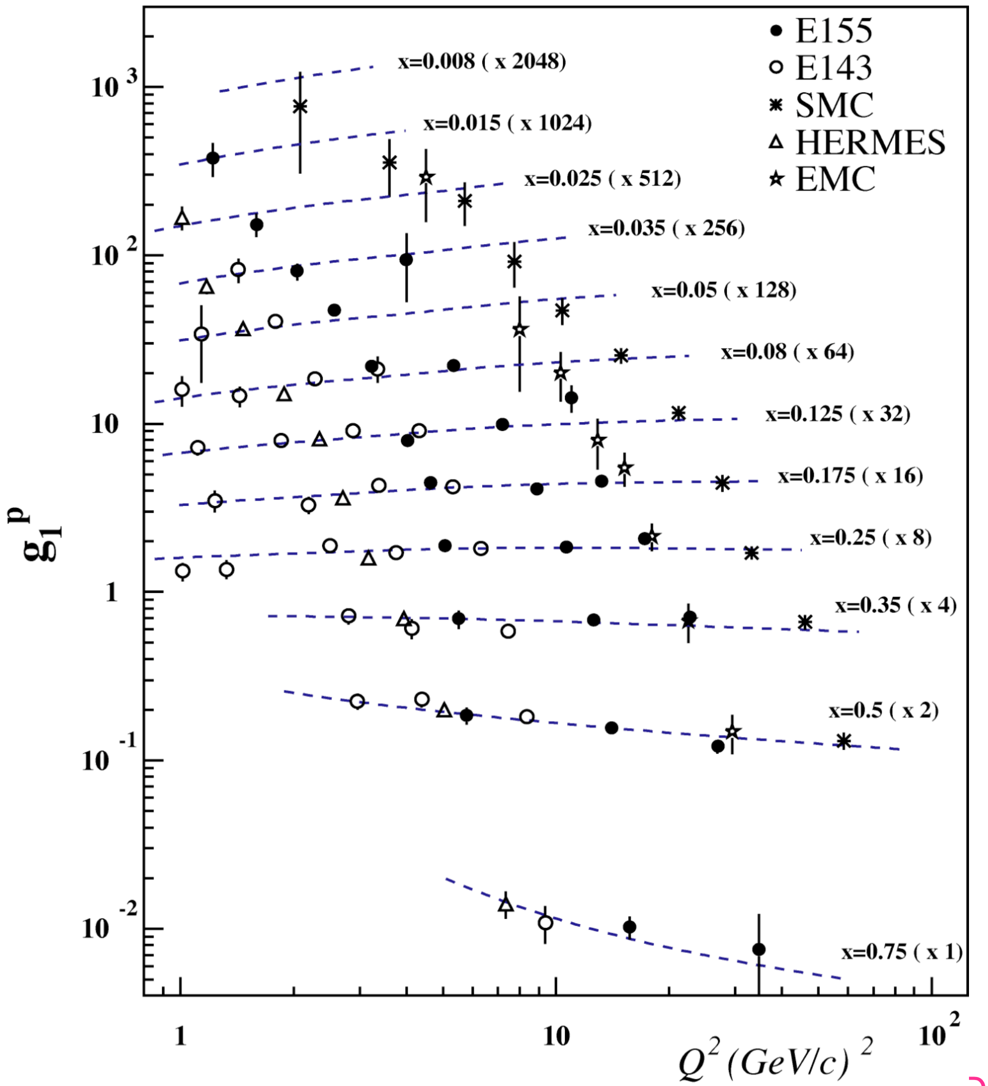


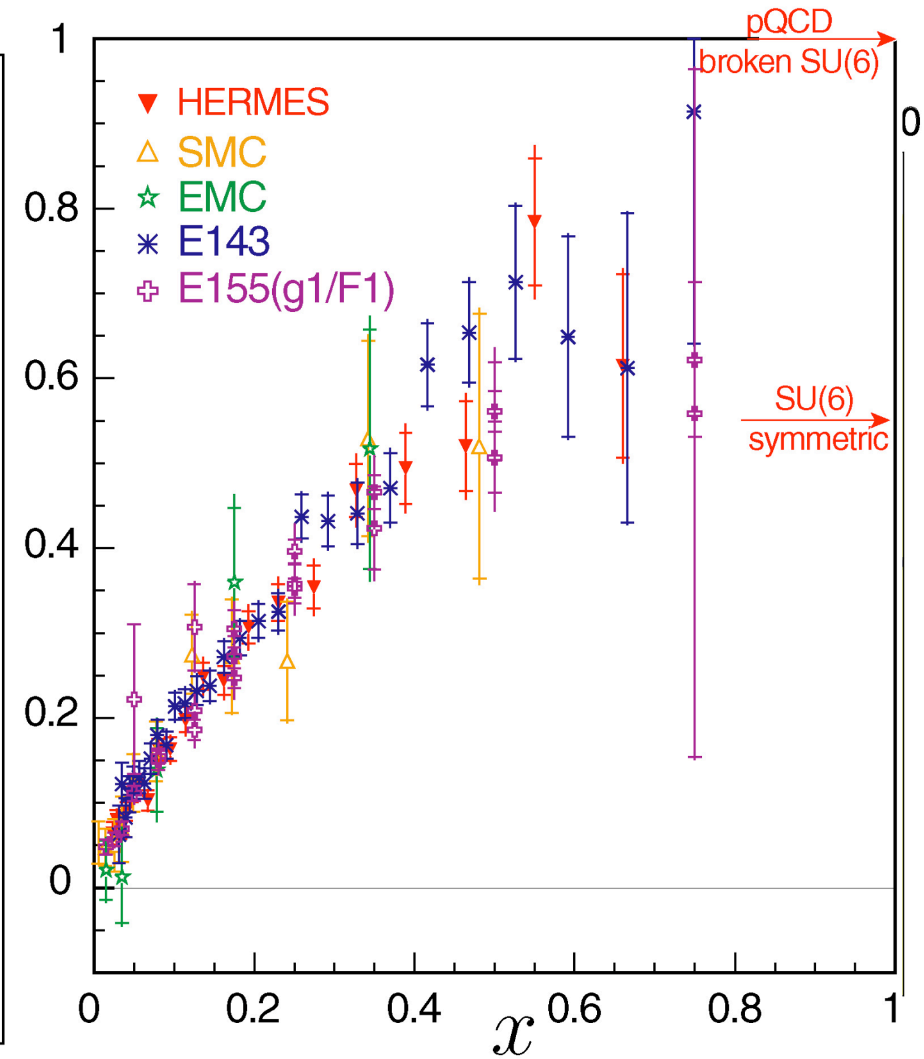
$$M_n(Q^2) = \int_0^1 dx\ x^{n-2}\ F_2(x,Q^2) \qquad n = 2, 4, ...$$

$$M_n(Q^2) = \int_0^1 dx\ x^{n-1}\ g_1(x,Q^2) \qquad n = 1, 3, 5, ...$$

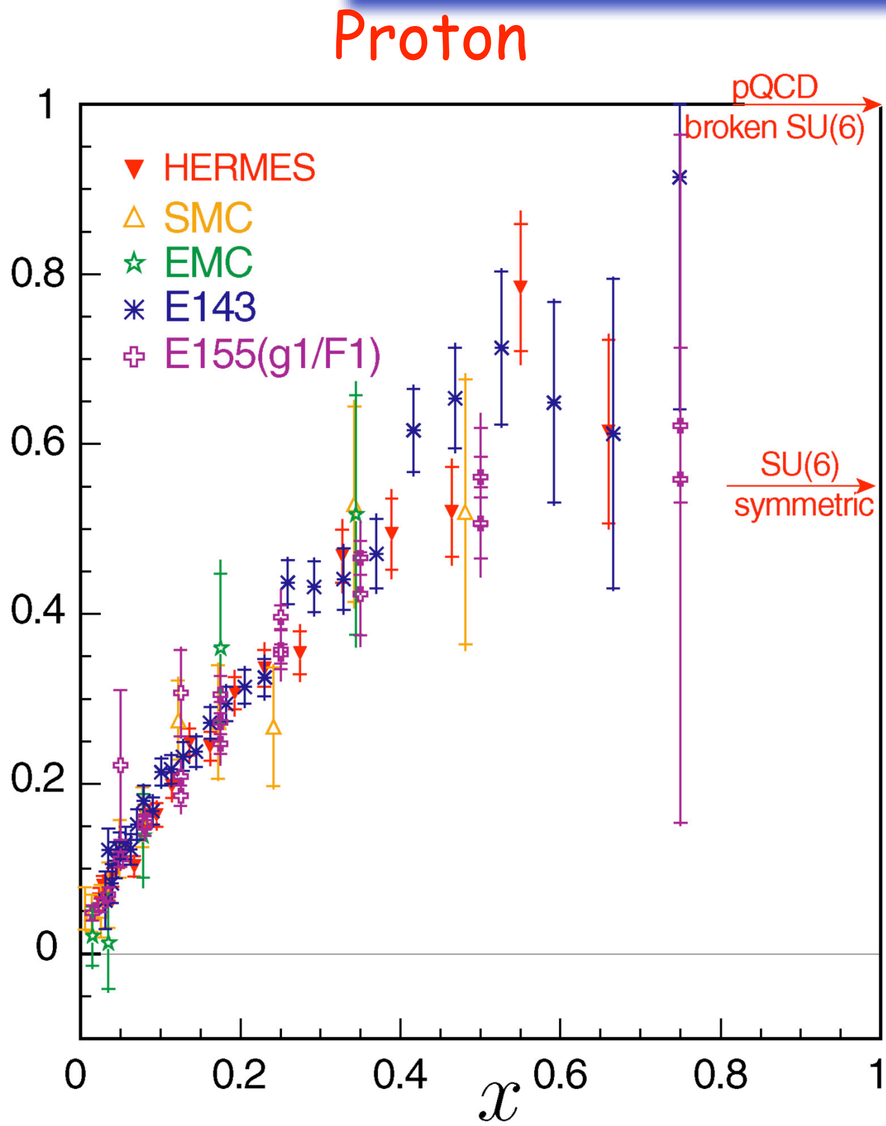
Examples of existing data and physics issues

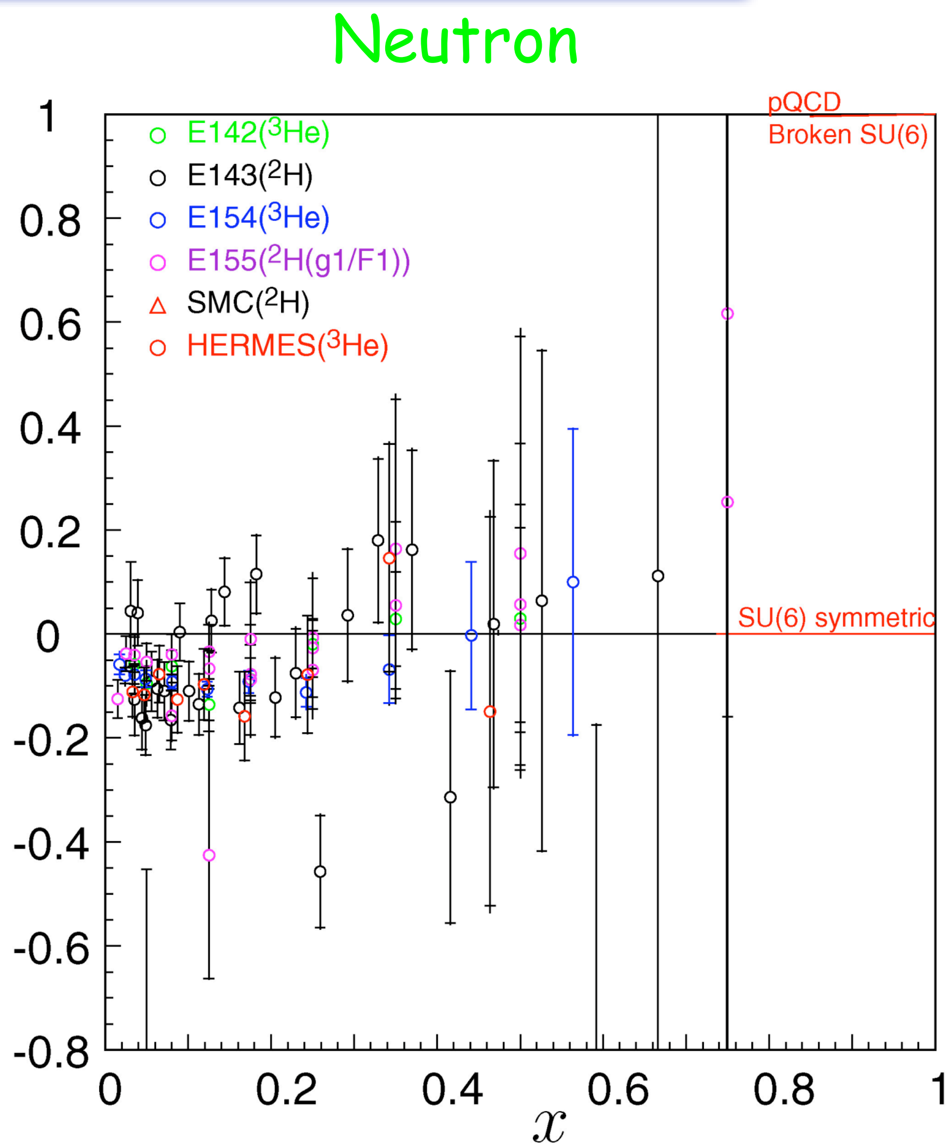
World data on g_1^p





World data for A_1



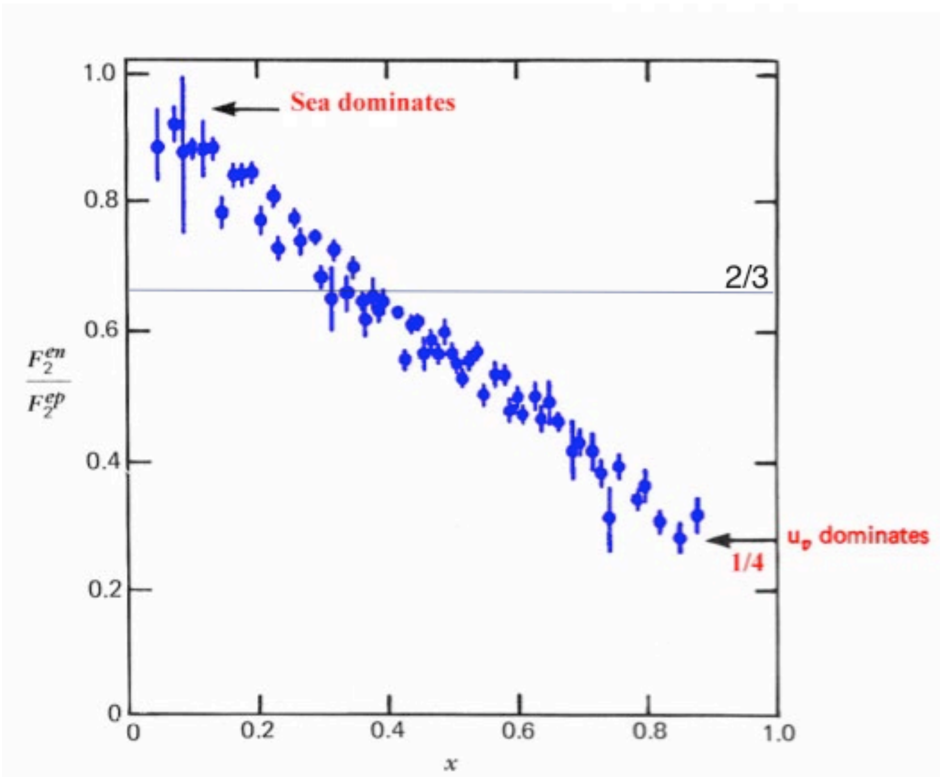


Unpolarized Neutron to Proton ratio at large x

$$\frac{F_2^n(x)}{F_2^p(x)} \xrightarrow[x\to 1]{} \frac{u_v + 4d_v}{4u_v + d_v}$$

SU(6)

$$\frac{F_2^n}{F_2^P} = \frac{2/3 + 4\times 1/3}{4\times 2/3 + 1/3} = \frac{2}{3}$$

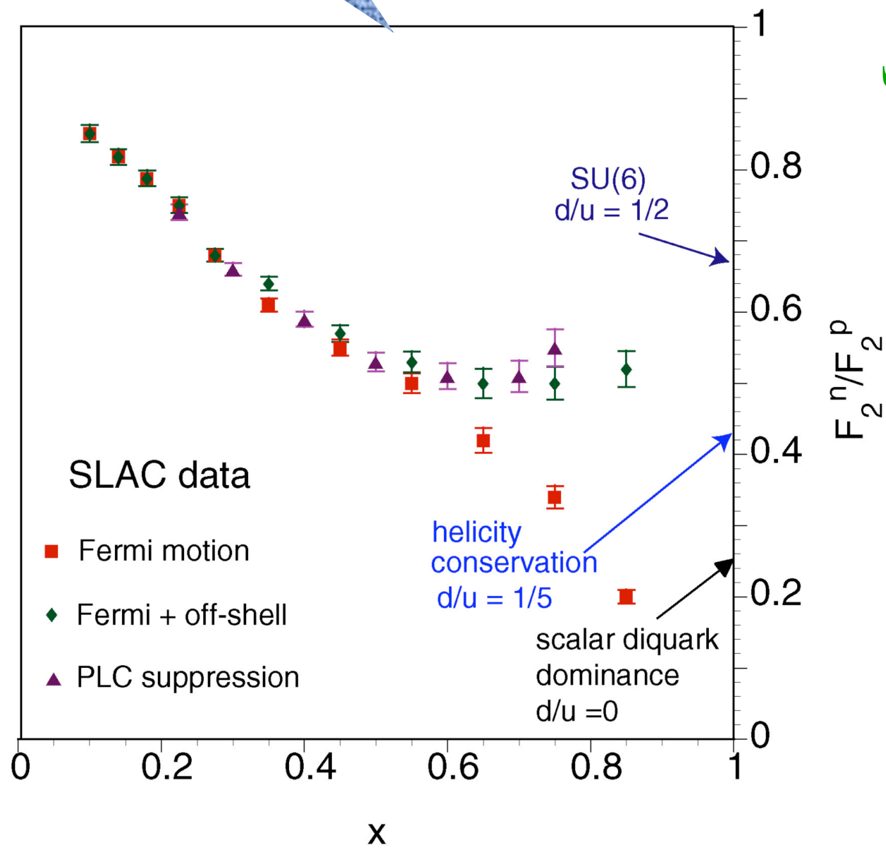


- Clearly SU(6) symmetry is broken
- Writing a wavefunction that would favor the dominance of the up quark goes towards reproducing the experimental data

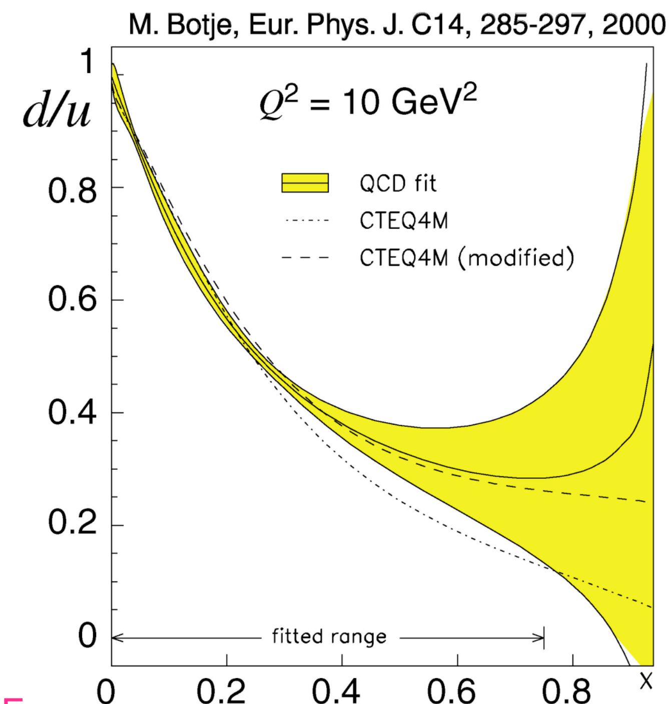
$$\frac{F_2^n(x)}{F_2^p(x)} \xrightarrow[x\to 1]{} \frac{1}{4}$$

Unpolarized Neutron to Proton ratio (continued)

- In the large x region (x>0.5) the ratio F_2^n/F_2^p is not well determined due to the lack of free neutron targets



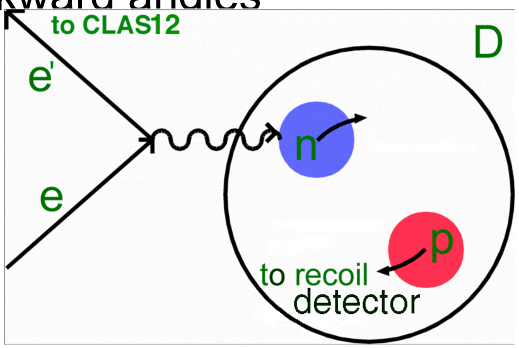
- Impact:
  - determine valence *d* quark momentum distribution
  - extract helicity dependent quark distributions through inclusive DIS
  - high x and Q^2 background in high energy particle searches.
  - construct moments of structure functions



Unpolarized Neutron to Proton ratio

Spectator tagging

- Nearly free neutron target by tagging low-momentum proton from deuteron at backward angles



- Small p (70-100 MeV/c)
  - Minimize on-shell extrapolation (neutron only 7 MeV off-shell)
- Backward angles ($\theta_{pq} > 110^o$)
  - Minimize final state interactions

DIS from A=3 nuclei

- Mirror symmetry of A=3 nuclei
  - Extract F_2^n/F_2^p from ratio of $^3He/^3H$ structure functions

$$\frac{F_2^n}{F_2^p} = \frac{2\mathcal{R} - F_2^{^3He}/F_2^{^3H}}{2F_2^{^3He}/F_2^{^3H} - \mathcal{R}}$$

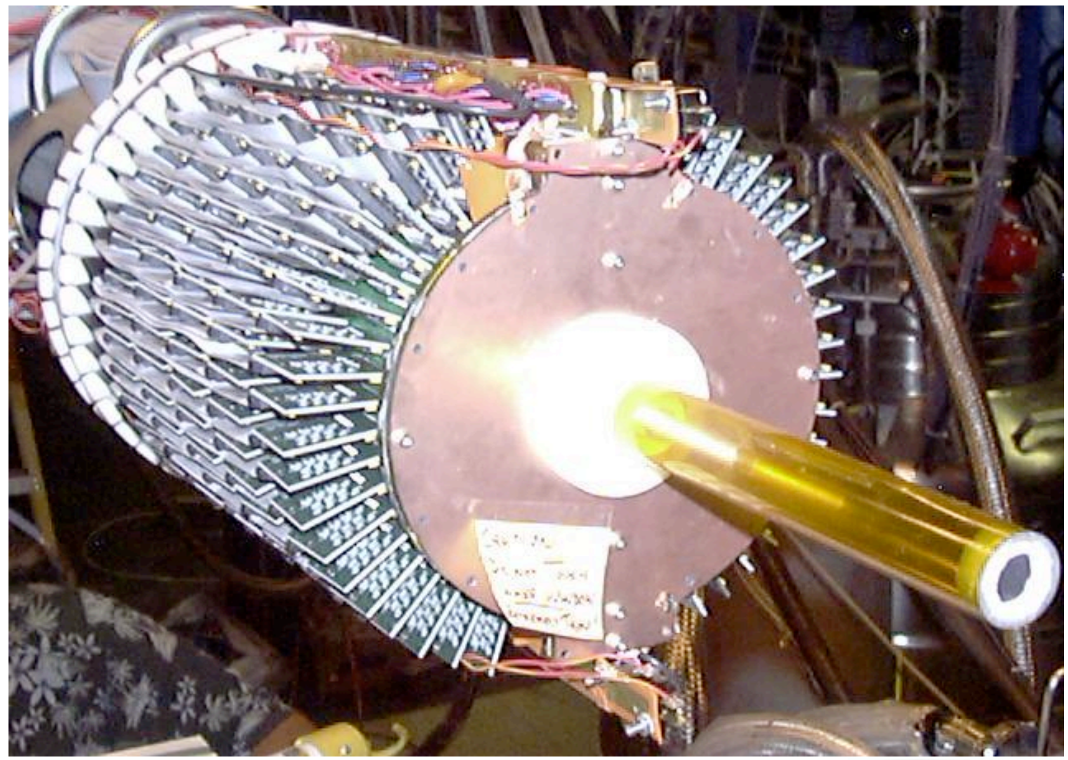
  - Super ratio
    $\mathcal{R}$ = ratio of "EMC ratios" for ^3He and ^3H

calculated to within 1%

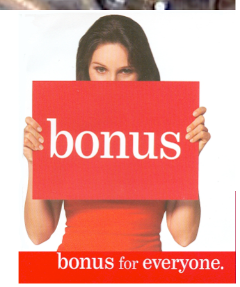
- Most systematic and theoretical uncertainties cancel

Inclusive Scattering off a “free” Neutron - the BoNuS* Experiment

- D(e,e’p_{back}) at Jefferson Lab with CLAS and RTPC**
- 1, 2, 4 and 5 GeV electrons impinging on a 6 mm Ø, 20 cm long D_2 gas target (7.5 atm) => $L = 0.2 \cdot 10^{34}/cm^2 s$
- Ran 3 months (October - December 2005)
- Jefferson Lab, Old Dominion Univ., Hampton Univ., William & Mary, James Madison Univ., Univ. of Houston and the CLAS collaboration



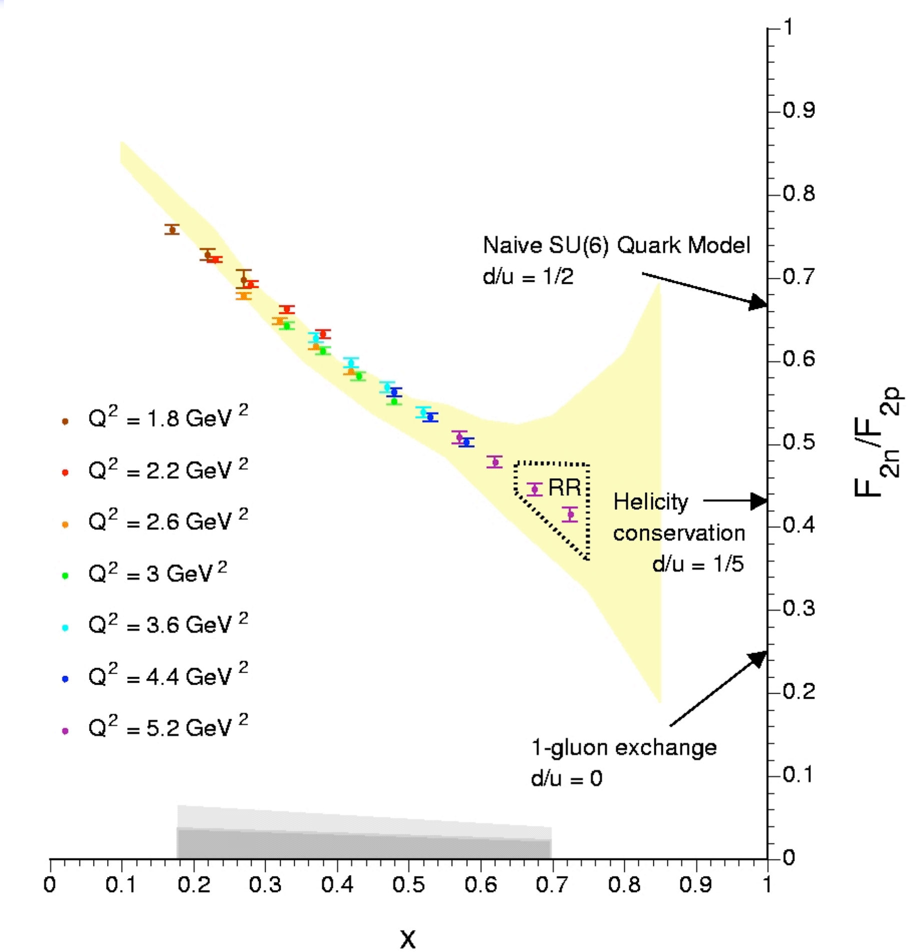
Radial TPC (view from downstream)



*BoNuS = **B**arely **o**ff-shell **Nu**cleon **S**cattering

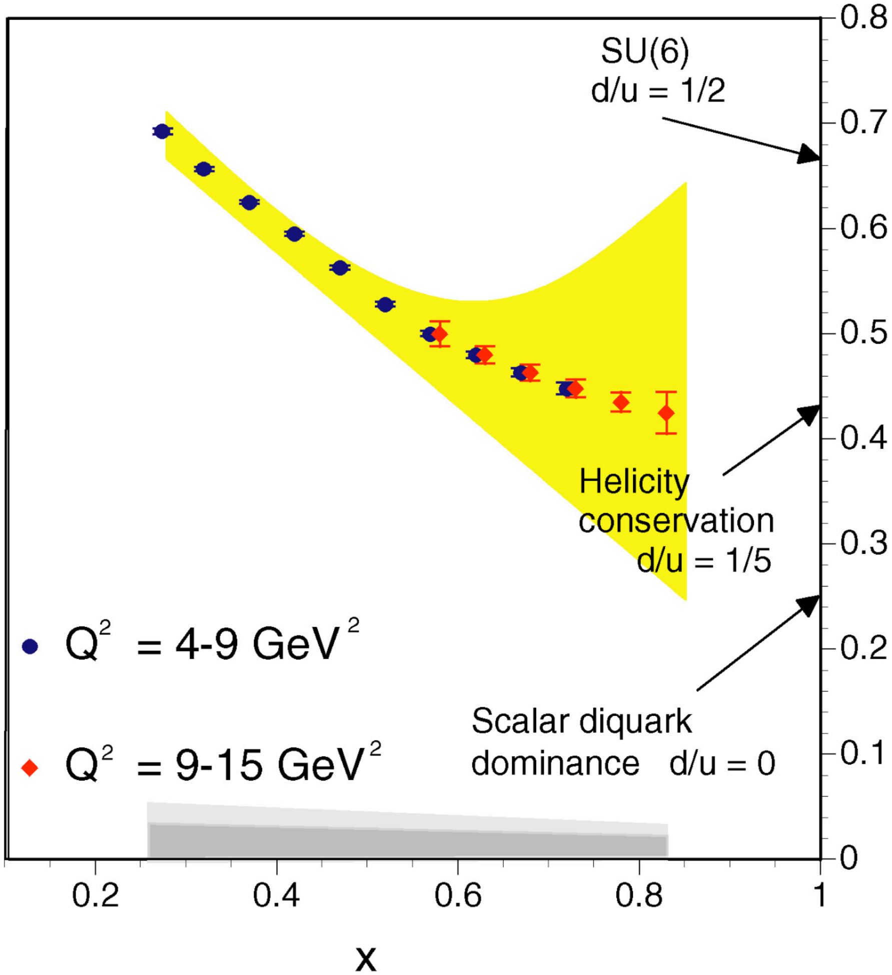
**RTPC = Radial Time Projection Chamber

Expected BoNuS Data

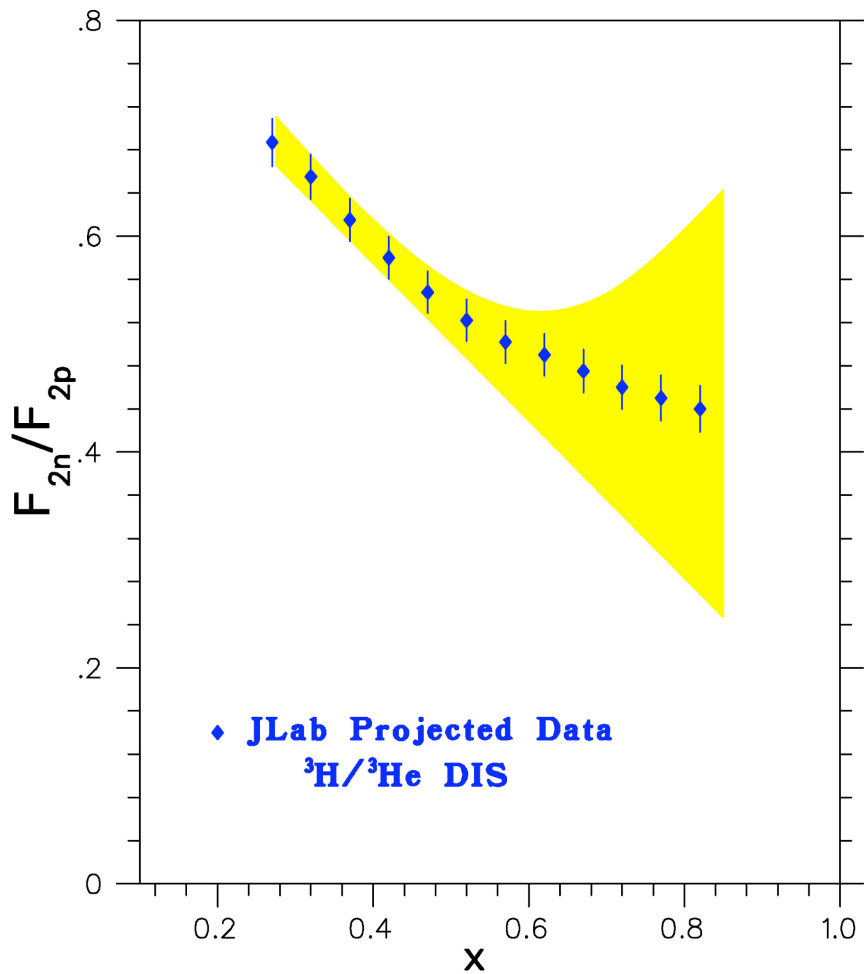


Unpolarized Neutron to Proton Ratio

HallB 11 GeV with CLAS12

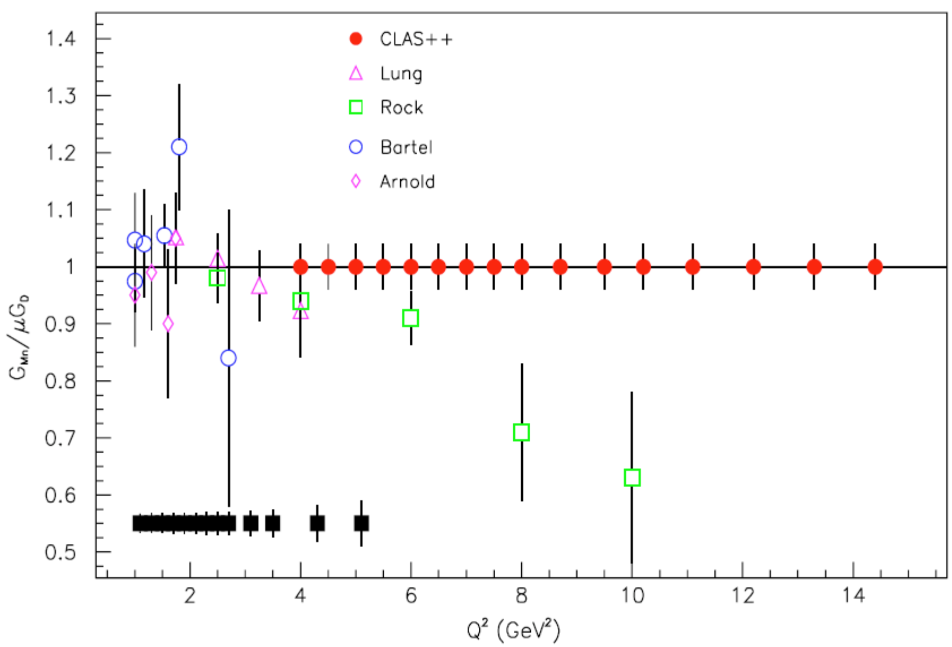


Hall C 11 GeV with HMS

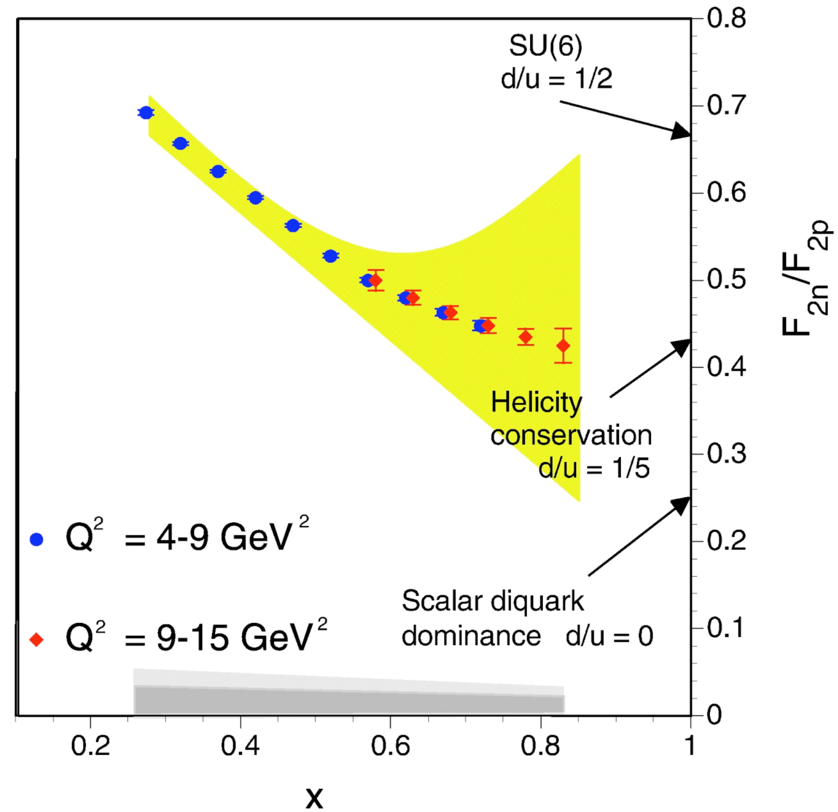


The Future - Jlab at 12 GeV

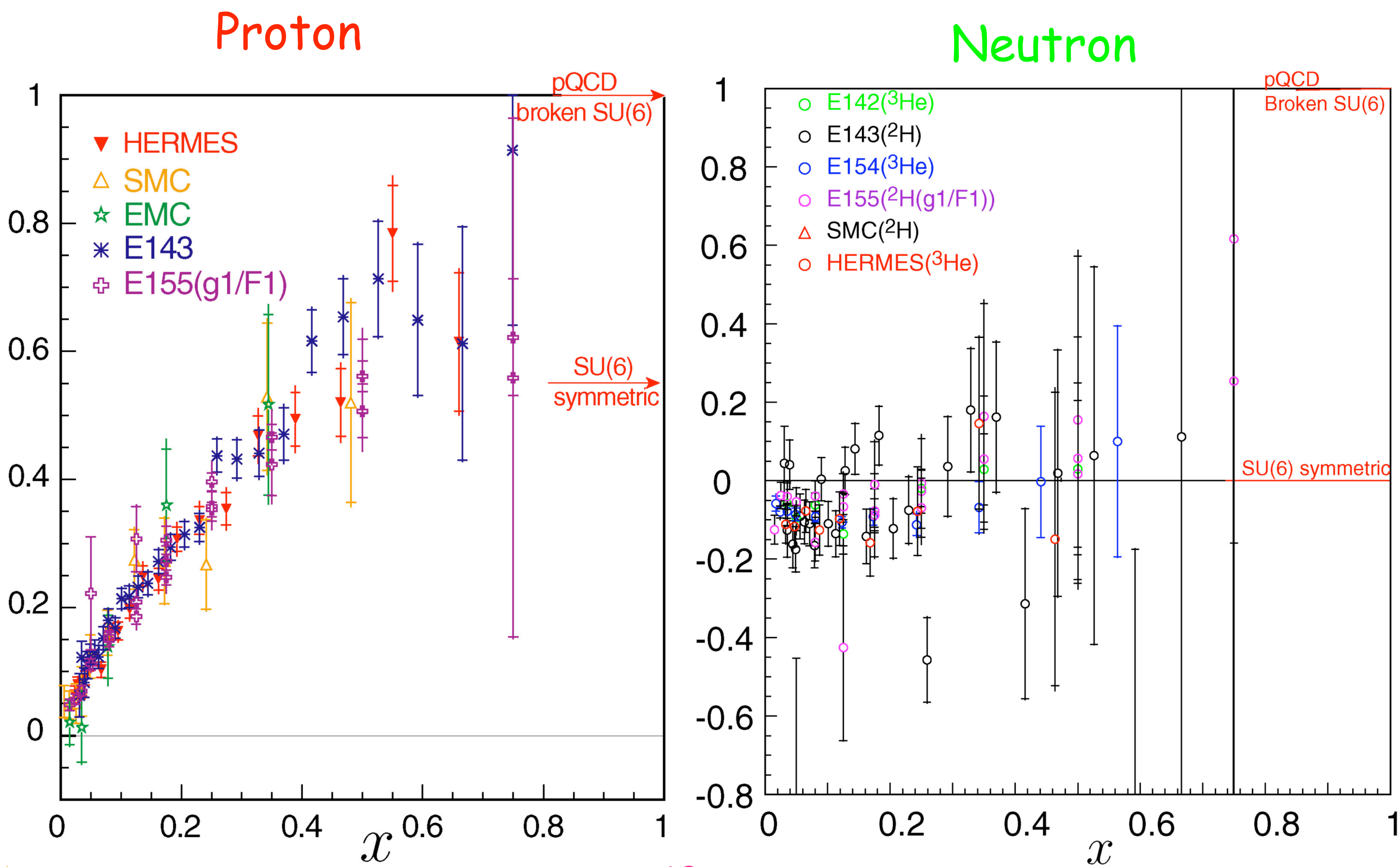
Neutron Form Factors



BoNuS



World data for A_1



SU(6) Breaking mechanism

- Relativistic Constituent Quark Model (CQM) *Close, Thomas, Isgur*
  - Introduce hyperfine $\vec{S}_i \cdot \vec{S}_j \delta^3(\vec{r}_{ij})$ interaction (N - Δ mass splitting, etc...)
  - Constrain d/u using R^{np} data : $d(x)/u(x) = (4R^{np} - 1)/(4 - R^{np})$

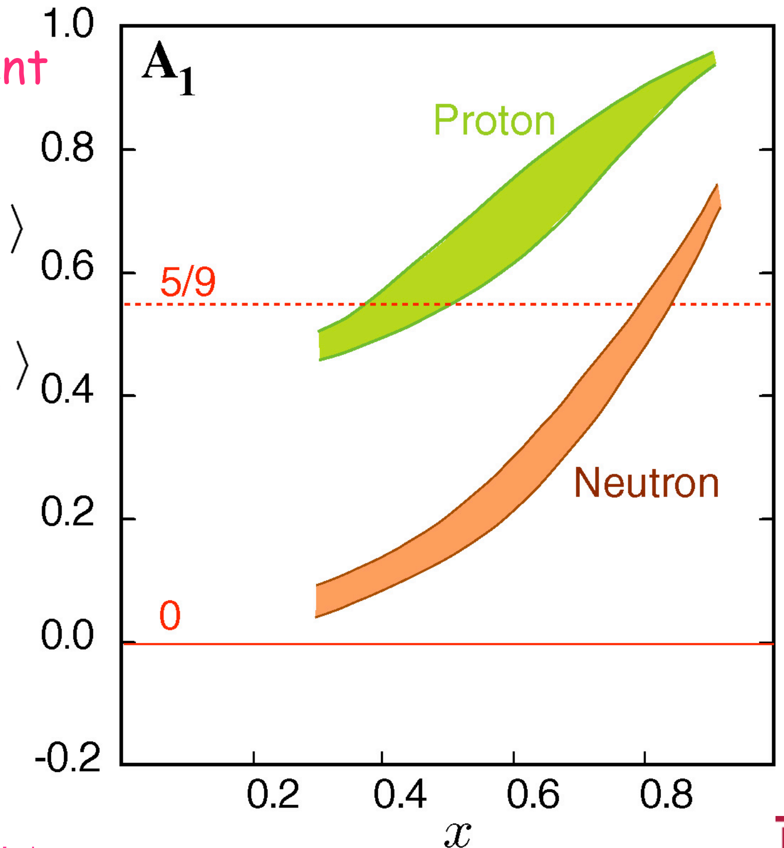
$$|n\uparrow\rangle = \frac{1}{\sqrt{2}}|d\uparrow(du)_{000}\rangle + \frac{1}{\sqrt{18}}|d\uparrow(du)_{110}\rangle - \frac{1}{3}|d\downarrow(du)_{111}\rangle - \frac{1}{3}|u\uparrow(dd)_{110}\rangle + \frac{\sqrt{2}}{3}|u\downarrow(dd)_{111}\rangle$$

Dominant component

As x-->1

$A_1^p \to 1$ $A_1^n \to 1$ $d/u \to 0$

$\Delta u/u \to 1$ $\Delta d/d \to -1/3$



Perturbative gluon exchange

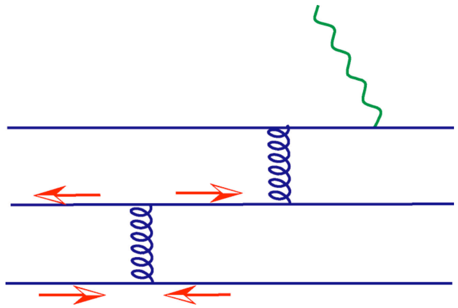
Farrar & Jackson, P.R.L. 35 (1975) 1416;
Brodsky et al., Nuc. Phys. B441 (1995) 197.

As x-->1

$A_1^p \to 1$ $A_1^n \to 1$ $d/u \to 1/5$

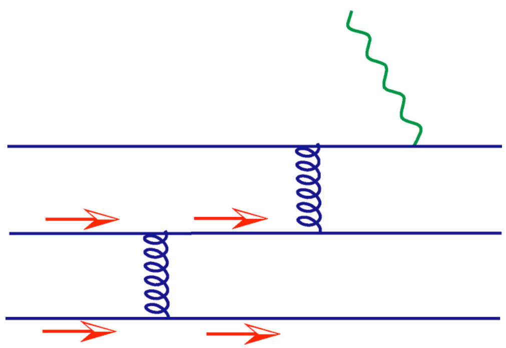
$\Delta u/u \to 1$ $\Delta d/d \to 1$

$S_z = 0$ {

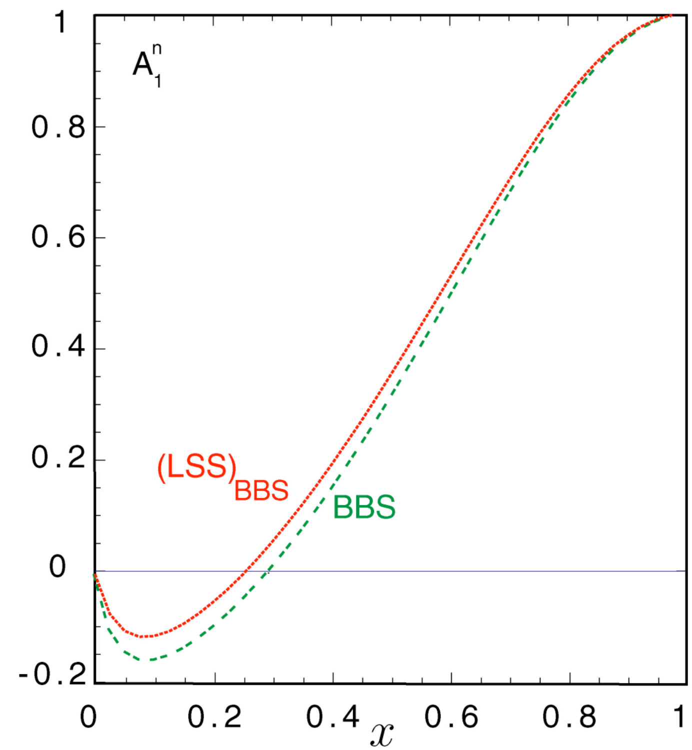


➥Can exchange transverse gluon- flipping both spins

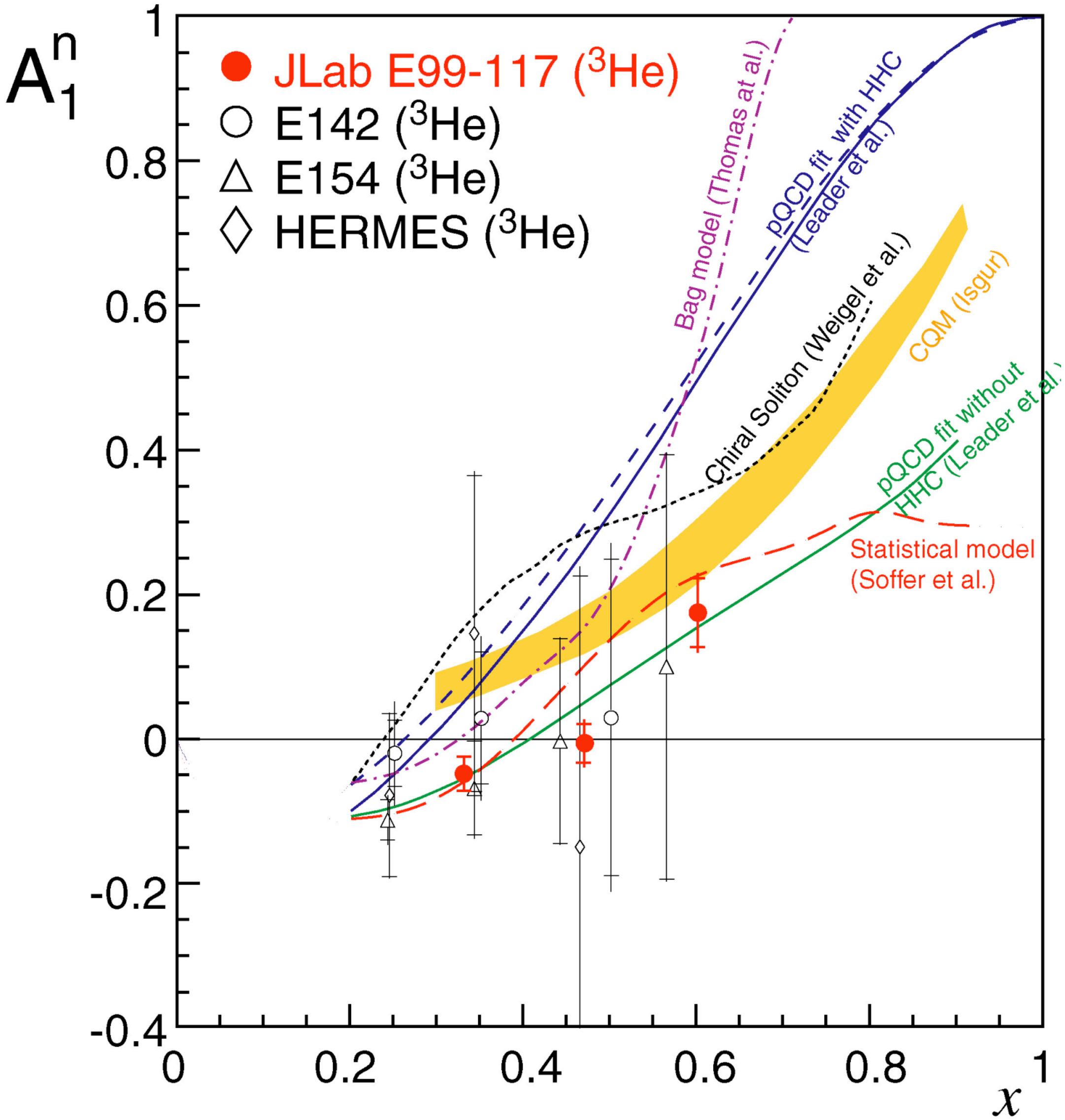
$S_z = 1$ {

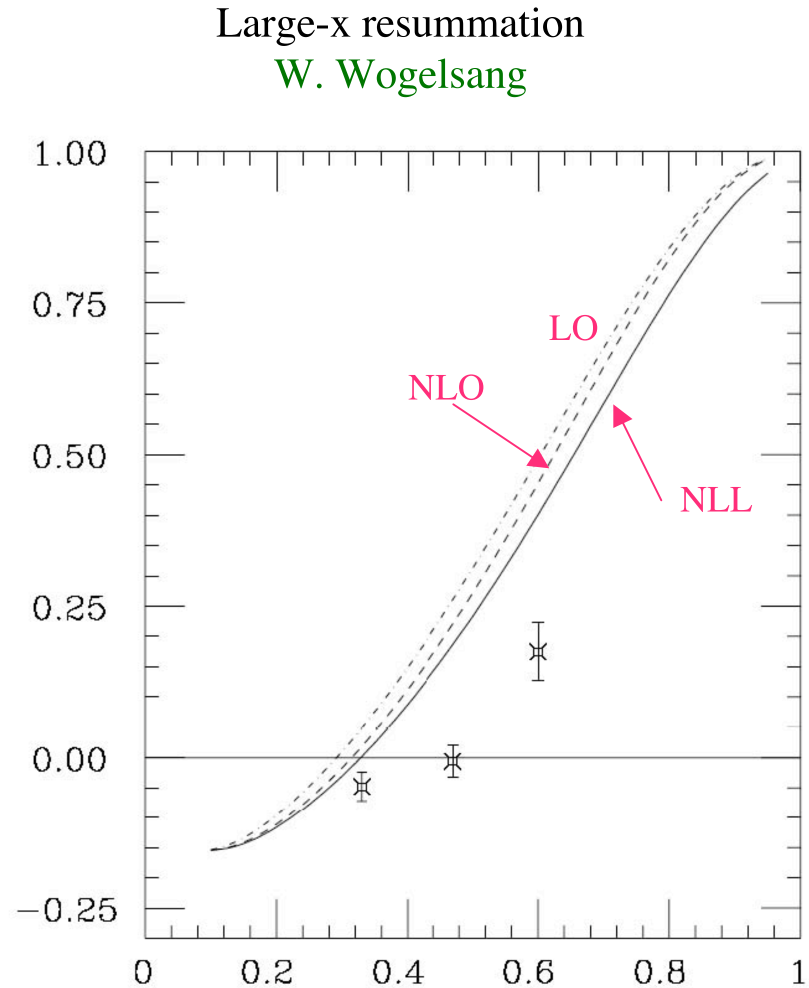


➥Only longitudinal gluons- cannot flip spins



A_1^n in DIS from ^{3}He in Hall A



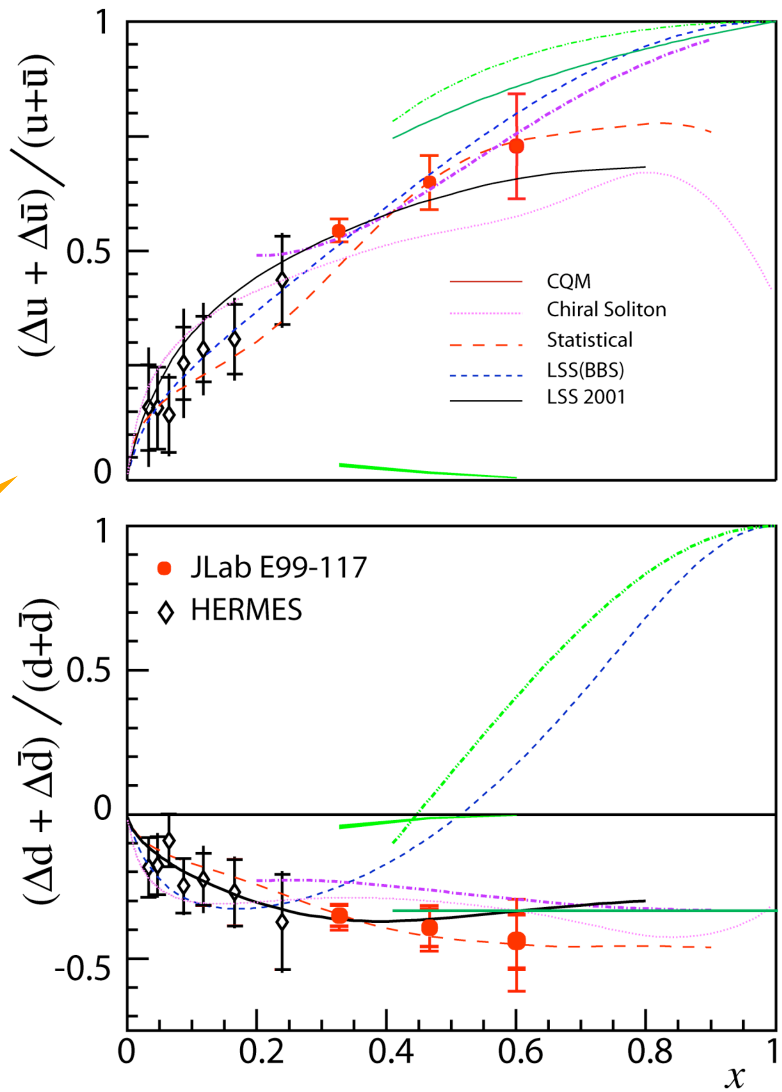


Helicity-Flavor Decomposition

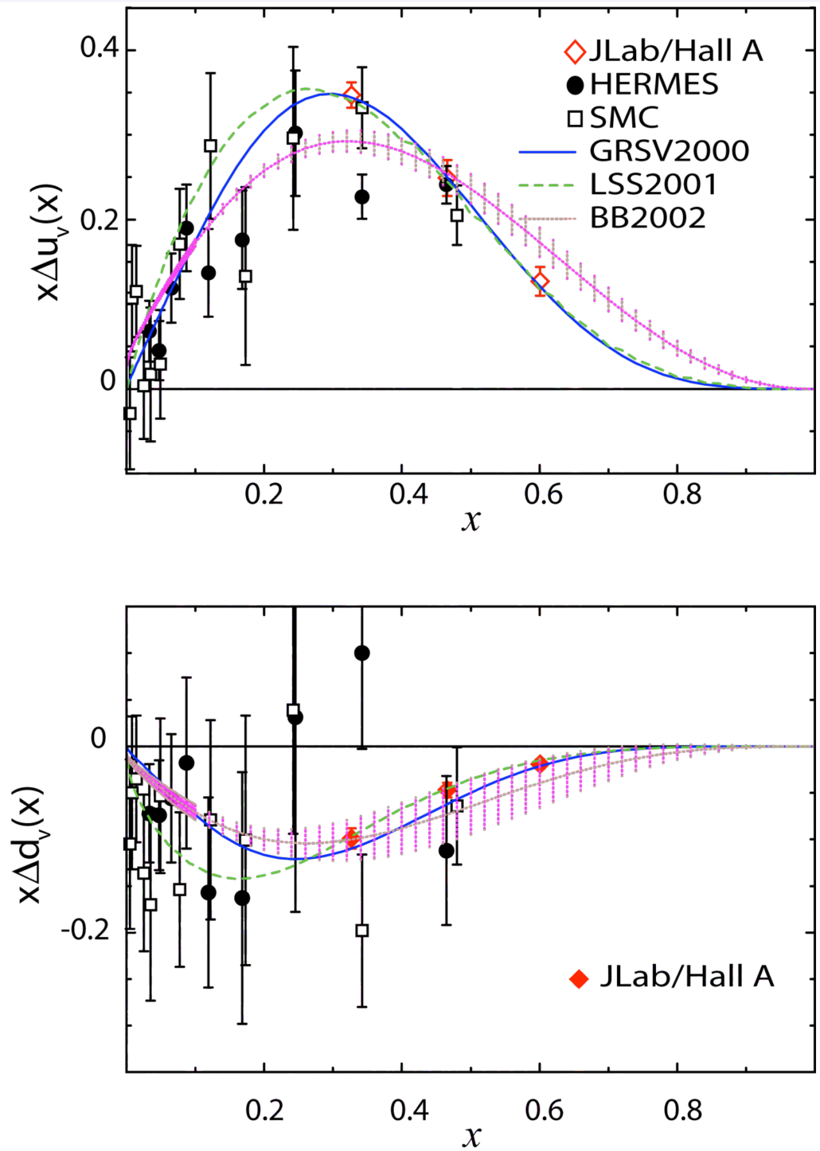
$$\frac{\Delta u + \Delta \bar{u}}{u} = \frac{4}{15}\frac{g_1^p}{F_1^p}(4 + R^{du}) - \frac{1}{15}\frac{g_1^n}{F_1^n}(1 + 4R^{du})$$

$$\frac{\Delta d + \Delta \bar{d}}{d} = \frac{4}{15}\frac{g_1^n}{F_1^n}(4 + \frac{1}{R^{du}}) - \frac{1}{15}\frac{g_1^p}{F_1^p}(1 + 4\frac{1}{R^{du}})$$

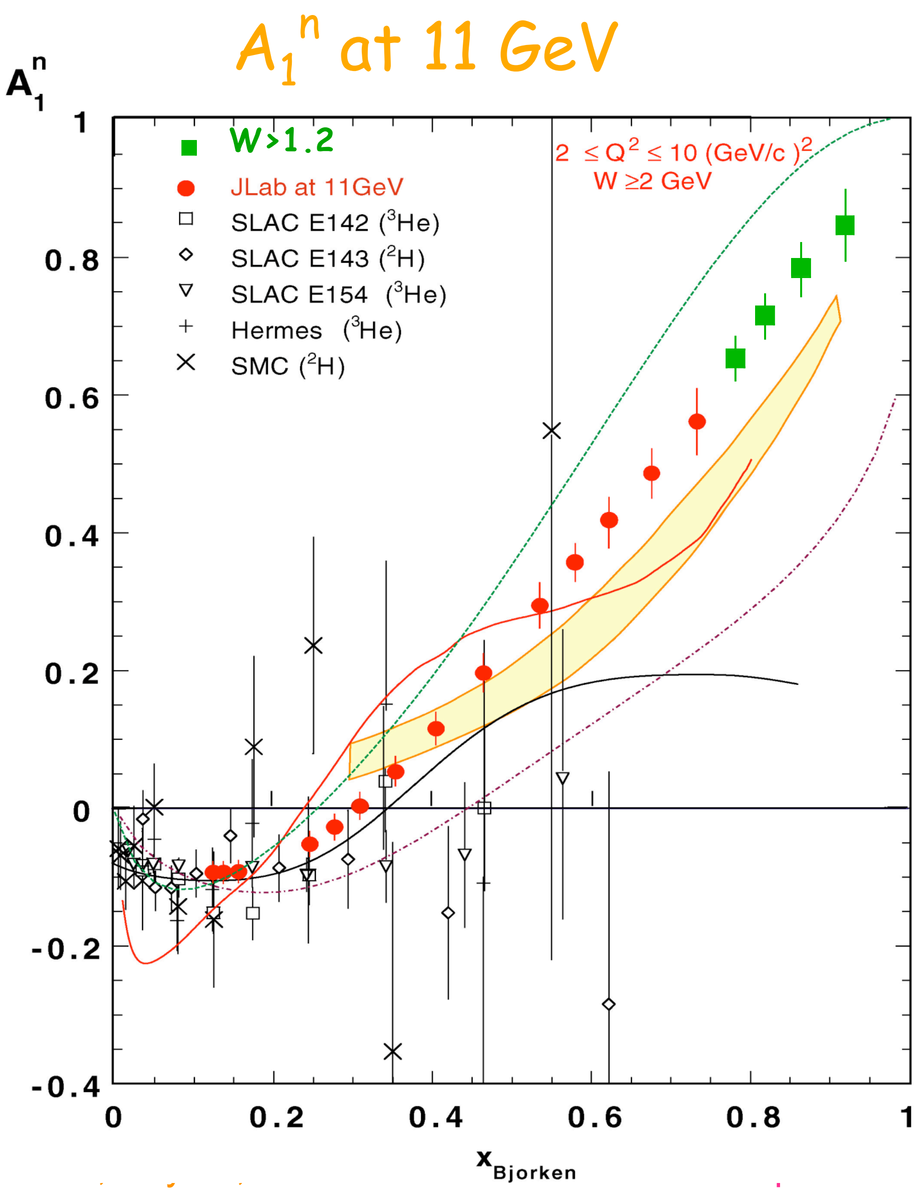
$$R^{du} = \frac{d + \bar{d}}{u + \bar{u}}$$

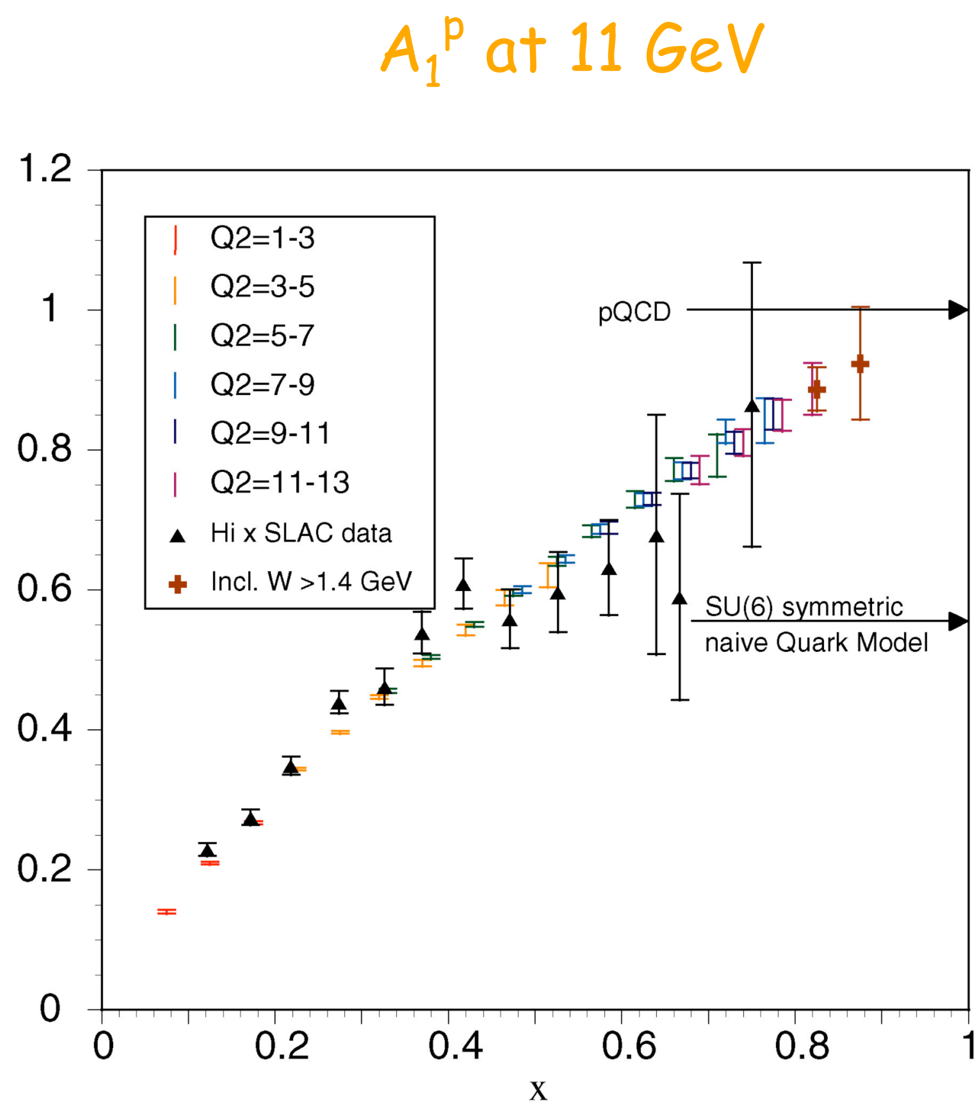


Flavor Decomposition: PDFs



Inclusive measurements of asymmetries



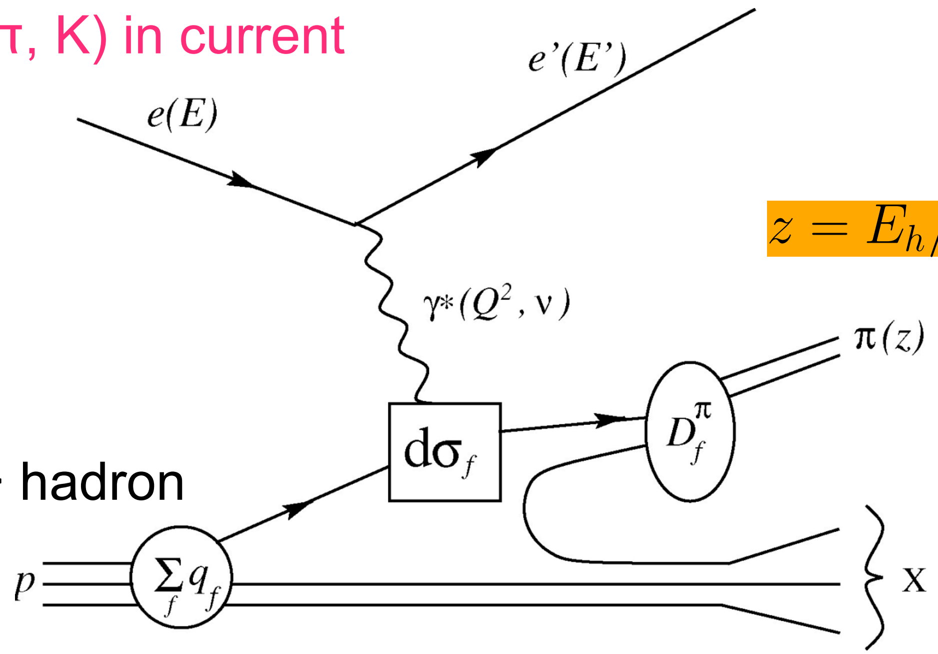


Semi-inclusive DIS

- Spin-flavor decomposition of valence and sea quarks by tagging hadron (e.g. π, K) in current fragmentation region

$$d\sigma = \sum_f e_f^2\, q_f(x)\, D_f^h(z)$$

$z = E_h/\nu$

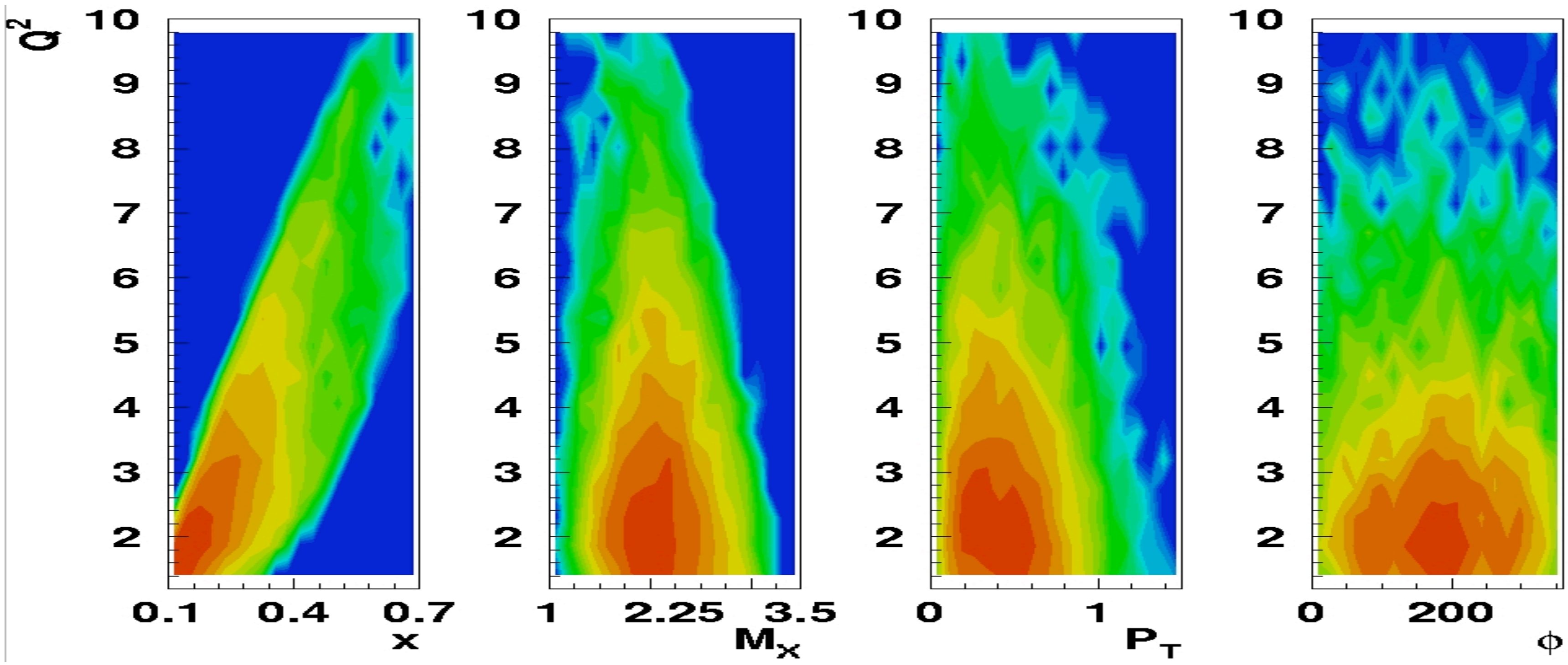


$D(z)$ quark--> hadron

fragmentation function

- unpolarized or polarized beam and target
- mass of unobserved X system, W_X > 2 GeV

ep→e'πX: kinematic coverage at 11 GeV

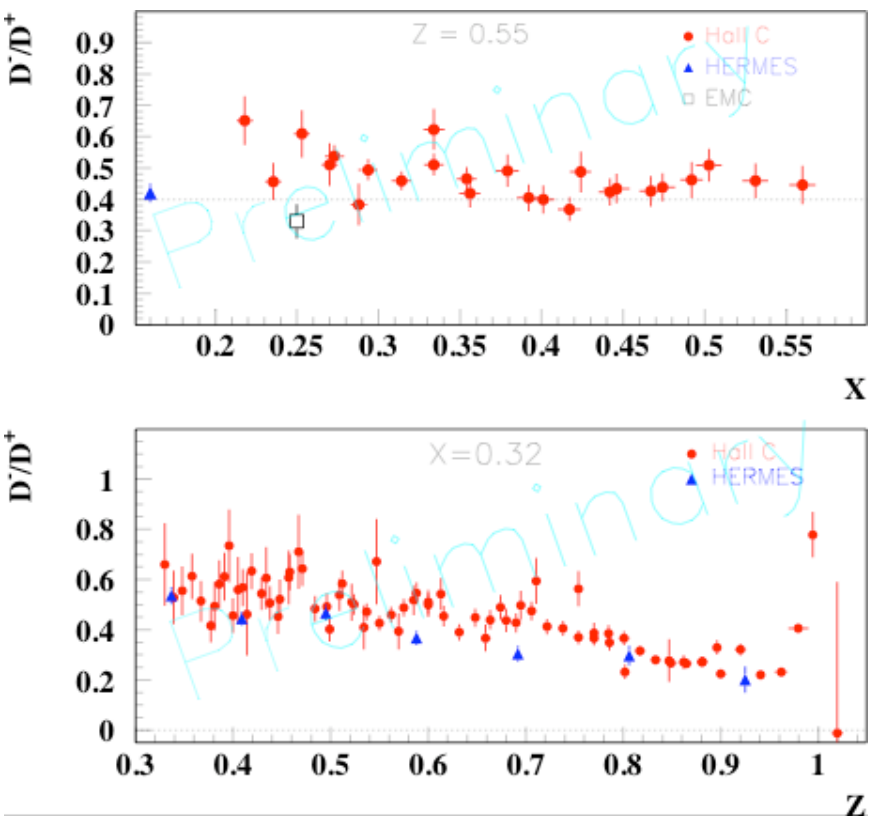


➢Acceptance in Q^2,M_x,P_T gained with high luminosity and energy upgrade (at 6 GeV M_x< 2.5GeV, Q^2<4.5 GeV^2, P_T< 1GeV)

➢test factorization in a wide kinematical range
➢study the transition between the non-perturbative and perturbative regimes of QCD
➢measure PDFs and study higher twists

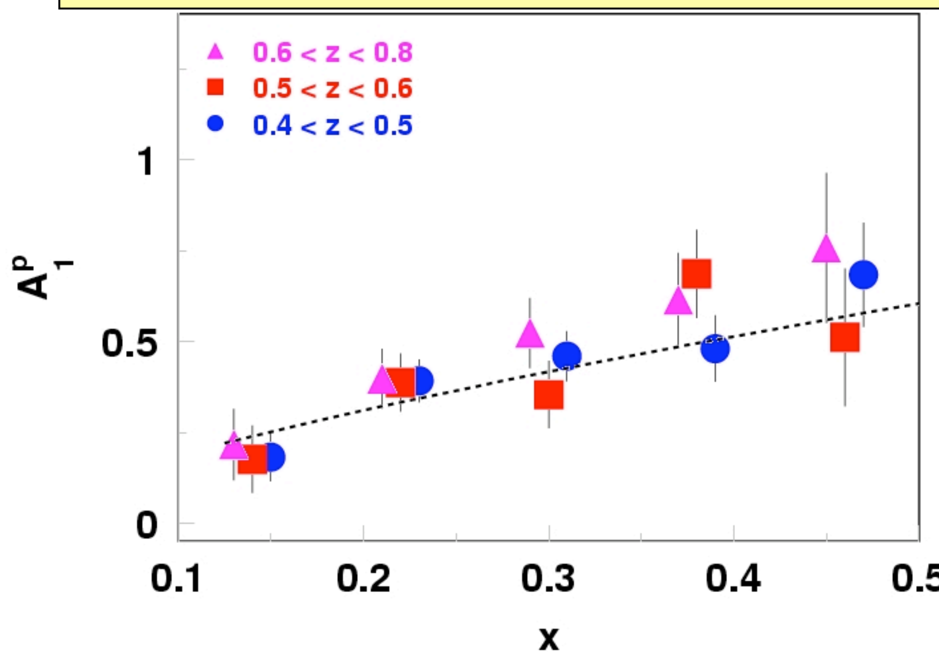
Semi-inclusive DIS (Factorization!)

Factorization of current and target fragmentation



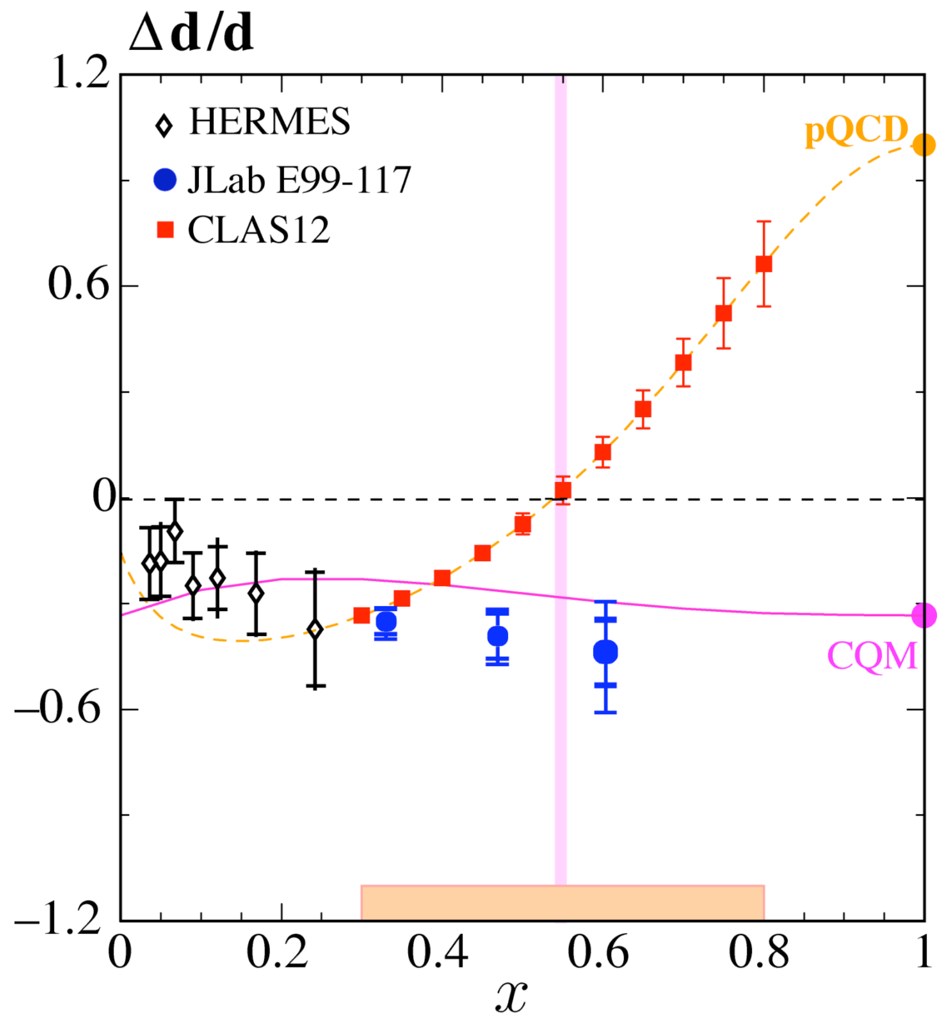
- Berger criterion $\Delta\eta > 2$ to avoid contamination from target fragmentation ($z > 0.4$)

ep -> e’ π^+ X (E_e =5.7 GeV, $M_X > 1.1$)



Flavor decomposition (2)

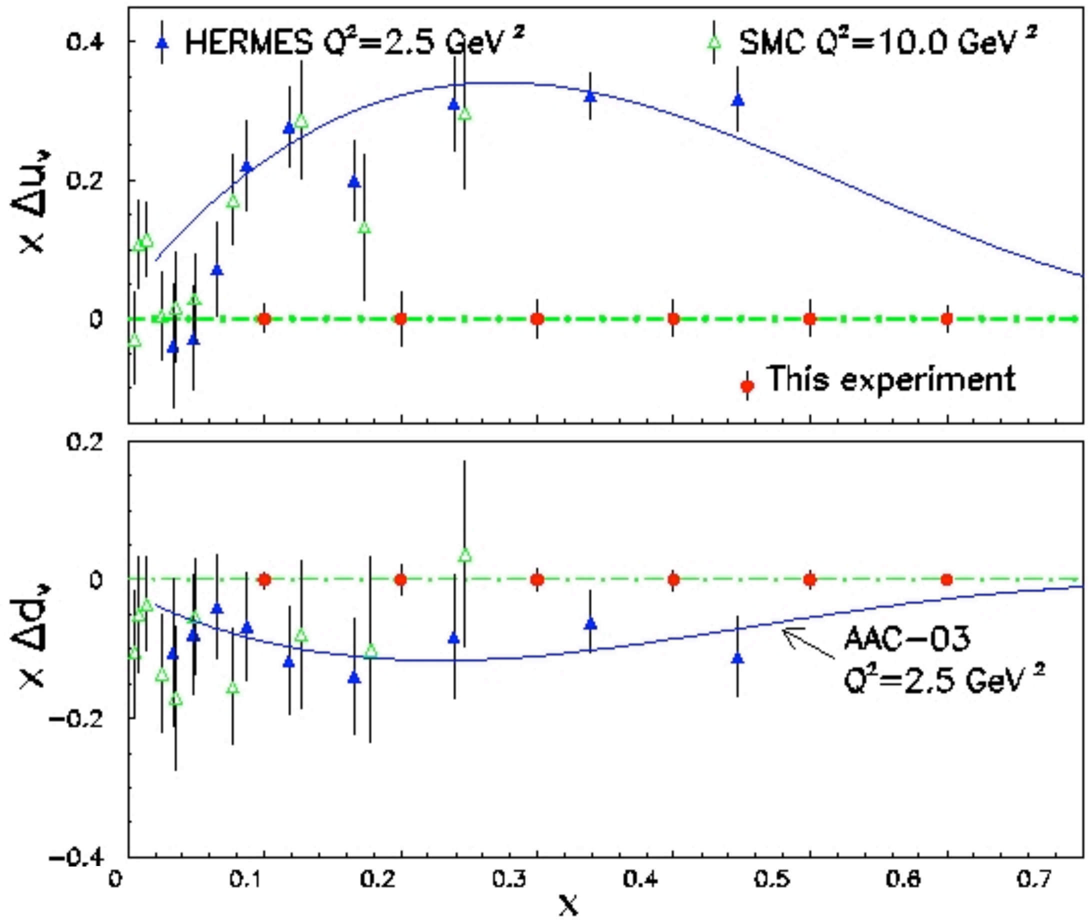
At JLab 12 GeV with SIDIS



Flavor decomposition (2)

E_e =11 GeV NH_3 and ^3He

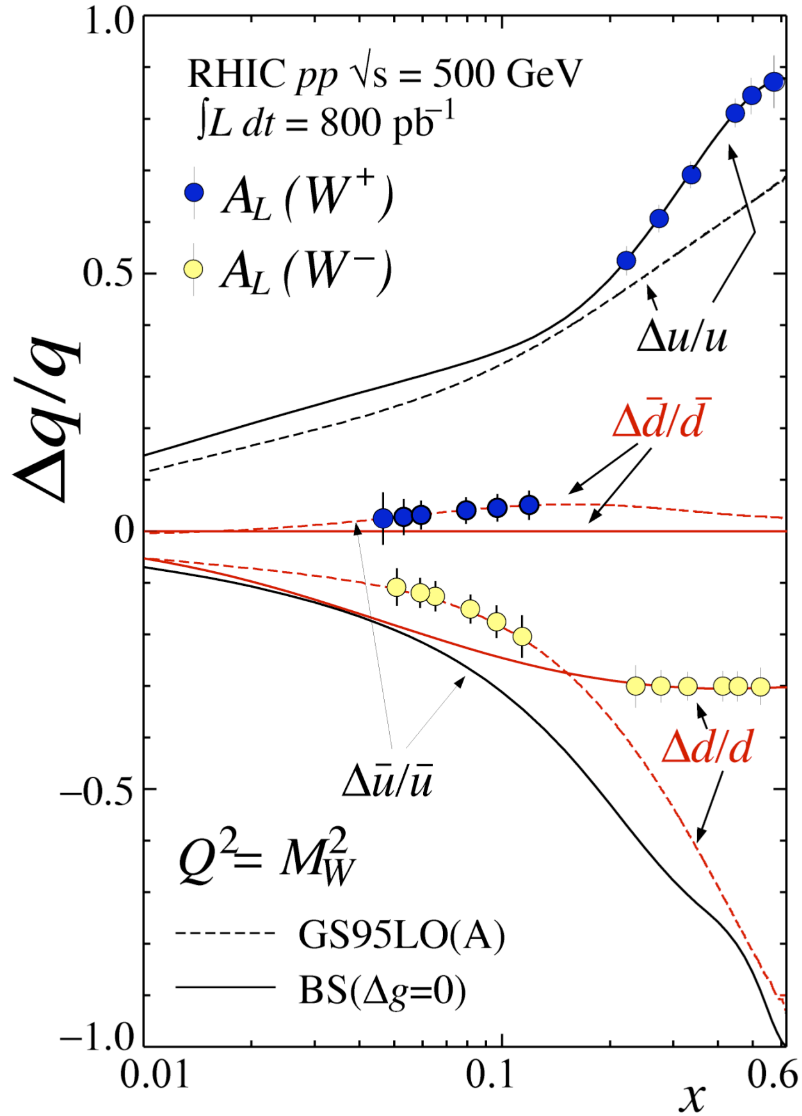
- Asymmetry measurements with different hadrons (π+,π–) and targets (p,n) allow flavor separation



At RHIC with W production in $\vec{p}\,p$

$$A_L^{W^+} = \frac{\Delta u(x_1)d(x_2) - \Delta\bar{d}(x_1)u(x_2)}{u(x_1)d(x_2) + \bar{d}(x_1)u(x_2)}$$

$$A_L^{W^+} = \frac{\Delta u(x_1)}{u(x_1)}$$



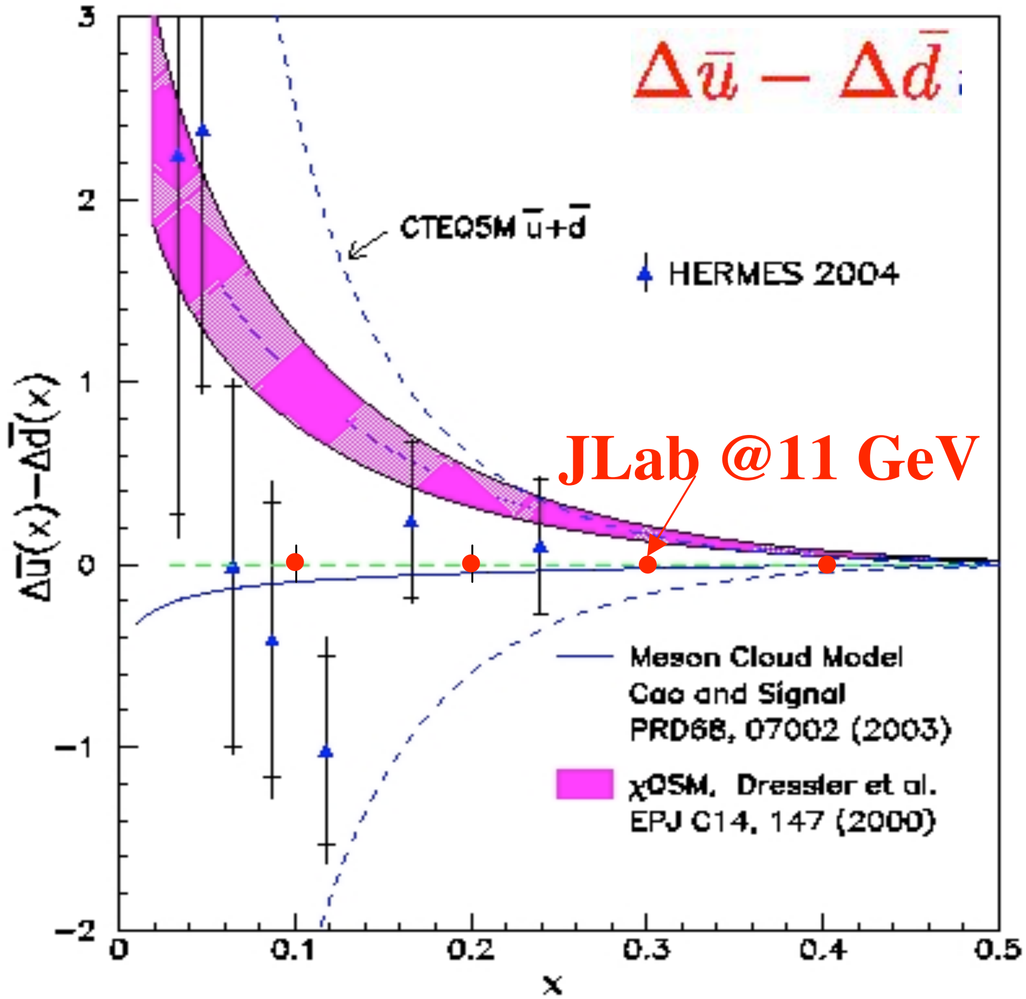
Flavor decomposition: polarized sea

- Predictions:
  - Instantons (χQSM):

$$\Delta\bar{u} \approx -\Delta\bar{d}$$

- First data from HERMES

$$\Delta\bar{u} - \Delta\bar{d} \approx 0$$



Summary

- Inclusive measurement will allow to extract the helicity dependent and independent up and down parton distributions at large x but with the following caveats:
  - Log resummations,
  - Higher twists effects
  - Nuclear effects

- Semi-inclusive asymmetry measurements with different hadrons (π.,K) and targets (p,n) will provide these distributions for all flavors.
  - The x range is determined by kinematics
  - The large x reach is not as high as in inclusive.
  - Systematics different and thus a powerful cross check for the up and down distributions from inclusive.

- W production at RHIC in pp will provide an independent measurement.
  - Different systematics compared to semi-inclusive
  - x range consistent with semi-inclusive