Precision Measurement of Neutron Asymmetry A_1^n at Large x_{Bj} Using CEBAF 5.7 GeV

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for the JLab Hall A Collaboration
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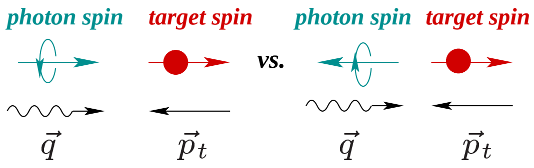
A_1^n at high x_{Bj}

What is A_1^n

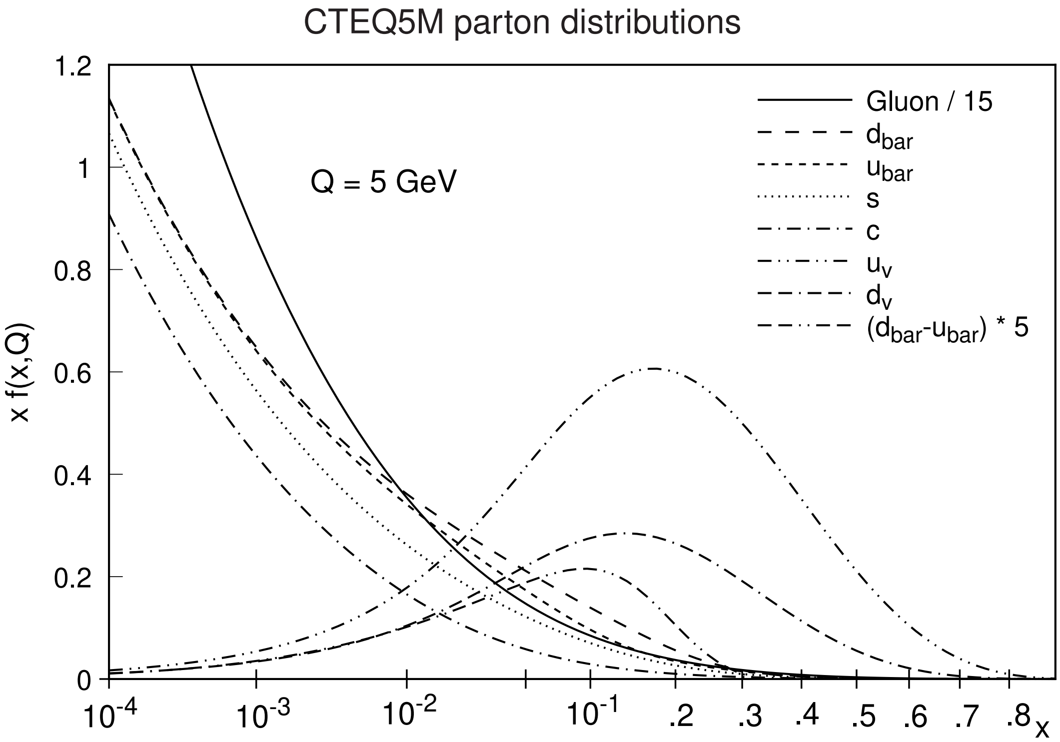
$$A_1 = \frac{\sigma_{\frac{1}{2}} - \sigma_{\frac{3}{2}}}{\sigma_{\frac{1}{2}} + \sigma_{\frac{3}{2}}}$$



$$A_1 = \frac{g_1(x,Q^2) - \gamma^2 g_2(x,Q^2)}{F_1(x,Q^2)}$$

Why at high x_{Bj}?

- Valence quarks dominate, (less contribution from $q - \bar{q}$ sea and gluons);
- pQCD calculation is possible;



Theories about A_1^n

- SU(6): $A_1^n = 0$
- SU(6) Broken:
  $A_1^n \to 1$ as $x \to 1$;
- Constituent quark models (CQM): N.Isgur
  $A_1^n \to 1$ as $x \to 1$;
- pQCD
- Statistical model, C.Bourrely, J. Soffer ;
- Duality: W. Melnitchouk;
- Instanton Model, N.I.Kochelev, $A_1^n \sim 0$ or $A_1^n < 0$;

- CQM: N.Isgur, Phys.Rev. **D59** (1999) 034013

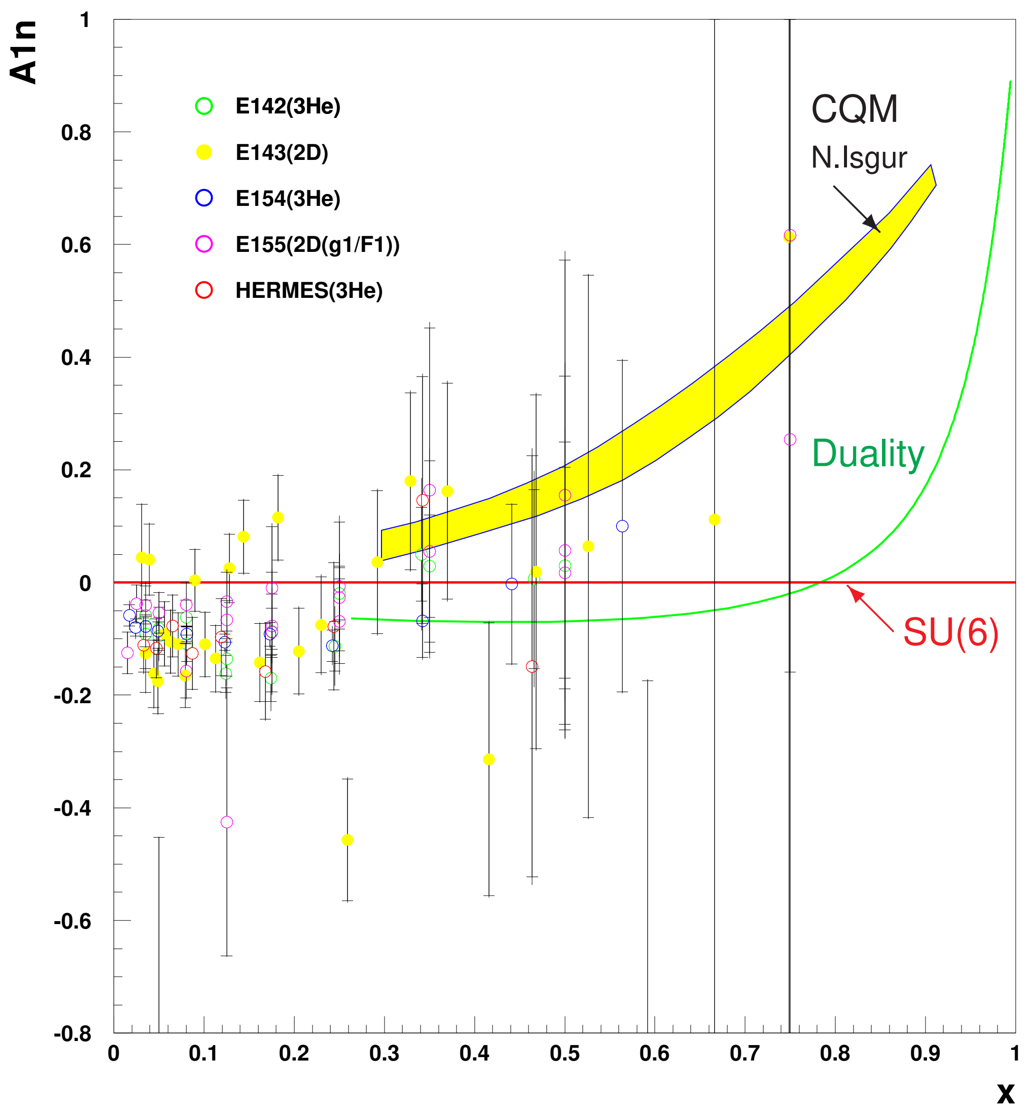
  hyperfine perturbed, A_1^p and $A_1^n \to 1$ as $x \to 1$;

- Duality: W. Melnitchouk, Phys. Rev. Lett. **86**, 35 (2001)

  – local quark-hadron duality;

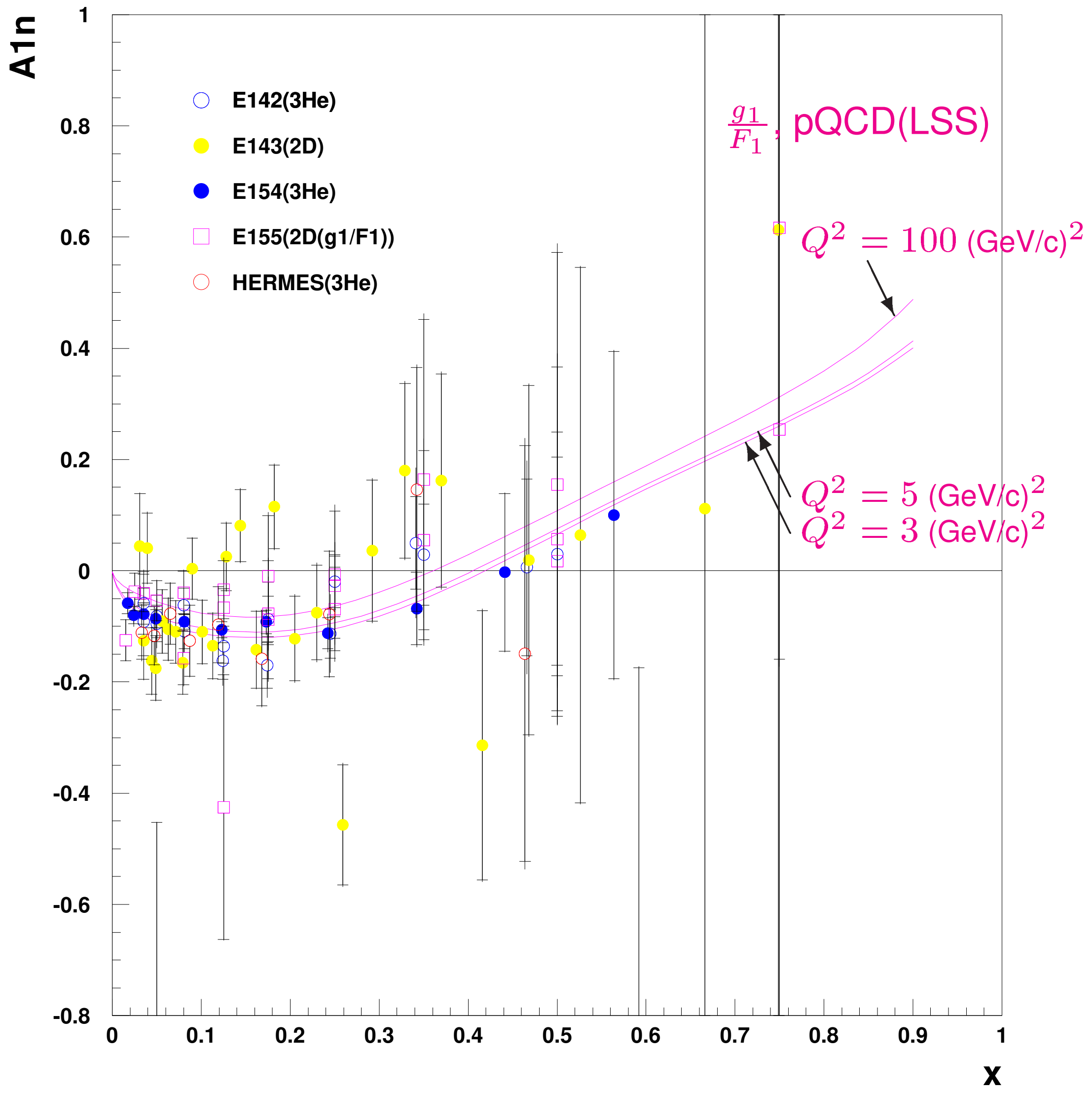
  – predict $x \sim 1$ behavior of A_1 from available data on G_E,G_M;

World data on A_1^n, Prediction from CQM and duality



- pQCD (LSS2001): E. Leader, A.V.Sidorov, D.B.Stamenov, hep-ph/0111267
  - A new evaluation of NLO polarized parton densities(PPD) in the nucleon;
  - calculation done for g_1/F_1 at Q^2= 3, 5, 100 (GeV/c)^2

World data on A_1^n and pQCD prediction (g_1/F_1)

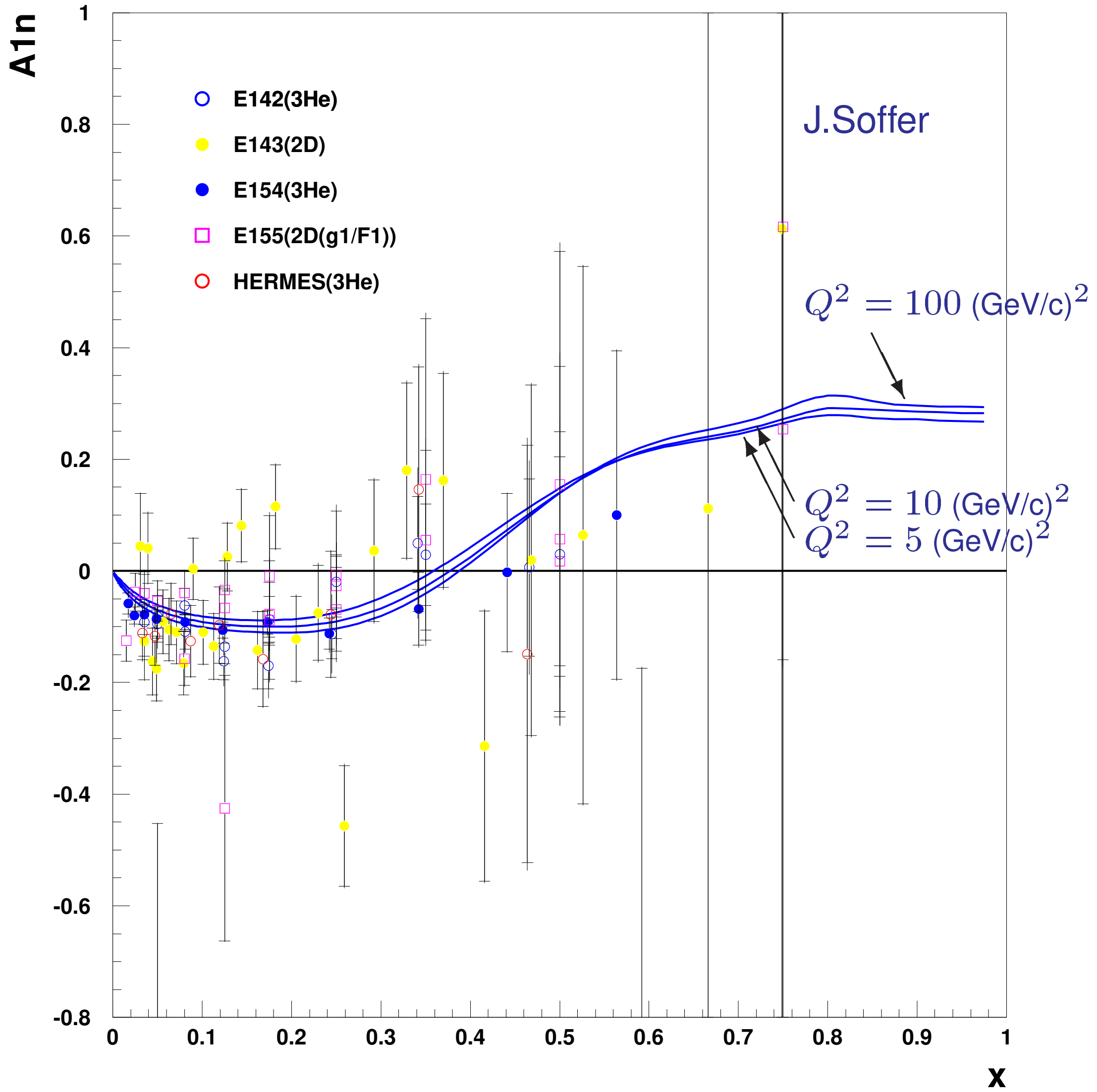


- Statistical Model: C.Bourrely, J. Soffer, hep-ph/0109160
  - global NLO QCD analysis of unpolarized and polarized DIS data;
  - parton distributions constructed in a statistical physical picture of the nucleon:

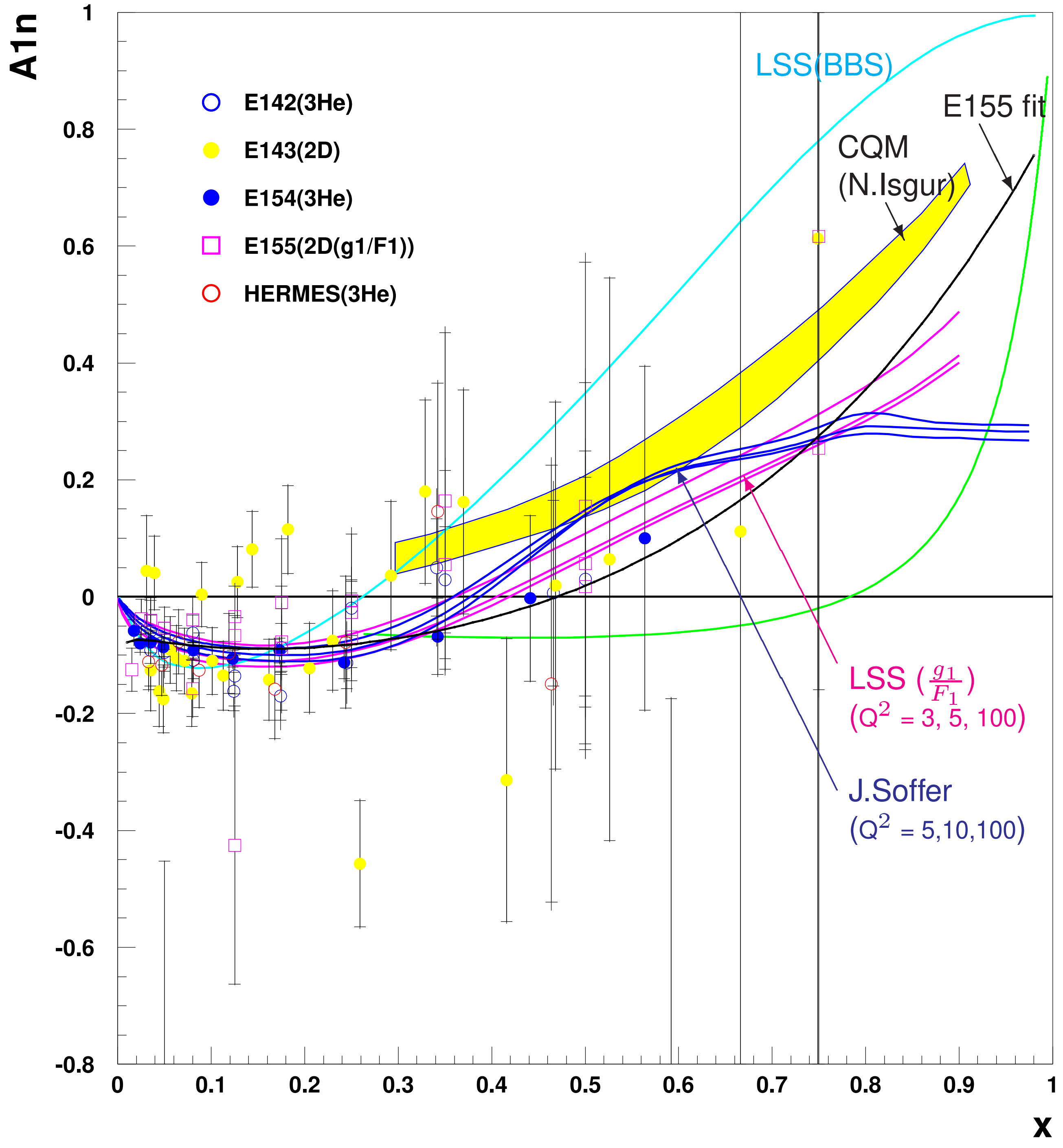
$$p(x) \propto [\exp{(x - X_{0p})/\bar{x} \pm 1}]^{-1}$$

  - calculation done for A_1 at Q^2=5, 10, 100 (GeV/c)^2, ($g_2 = g_2^{ww}$)

World data on A_1^n and Soffer's statistical model



A_1^n World Data and Theoretical Predictions



Experiment E99-117

- Measured A_1^n at:

x_{Bj}	0.331	0.474	0.609
Q^2 (GeV/c)^2	2.738	3.567	4.887
W^2 (GeV/c)^2	6.426	4.846	4.023

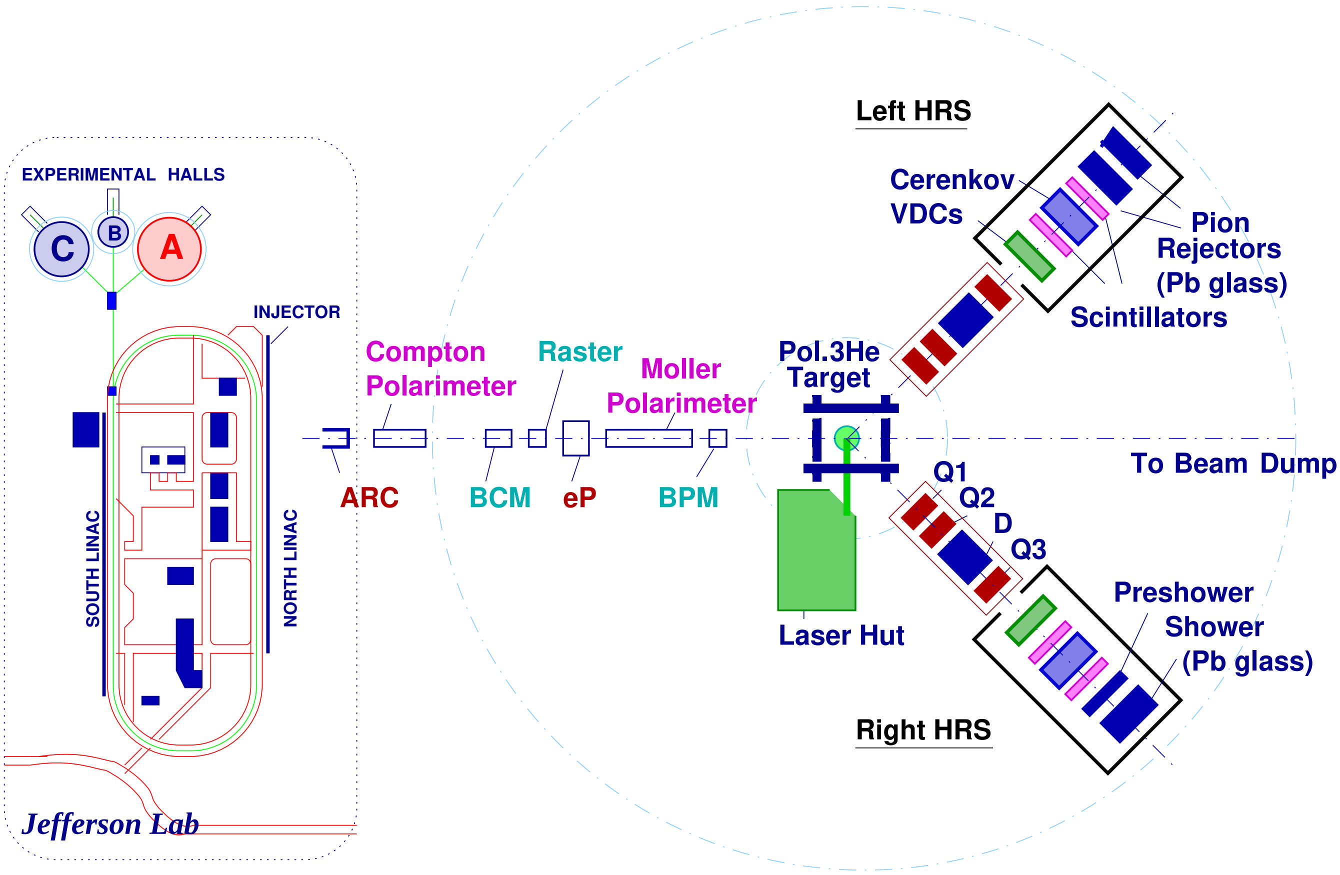
  through e^- asymmetries $A_{\|}$ and $A_{\perp}$ in inclusive $\vec{e}^- - {}^3\vec{H}e$ DIS;

- Running successfully from June 01, 2001 to August 02, 2001;
- total volume of data: 563 GByte

Experimental setup

- Jefferson Lab(JLab) polarized e^- beam, 5.734 GeV, $P_{beam} = 81\%$, 12 μA
- Hall A polarized ^3He target, $\sim$ 10 atm, $P_{targ} = 40\%$
- Two Hall A High Resolution Spectrometers (HRS) at symmetric positions

Topview of JLab Accelerator and Hall A floor plan



Asymmetry Analysis

Electron Asymmetries

$$A_{raw} = \frac{N^+/Q^+ - N^-/Q^-}{N^+/Q^+ + N^-/Q^-}$$

$$A_{\parallel,\perp} = \frac{A_{raw}}{f P_b P_t}$$

^{3}He Asymmetries

$$A_1 = \frac{A_\parallel}{D(1+\eta\xi)} - \frac{\eta A_\perp}{d(1+\eta\xi)}$$

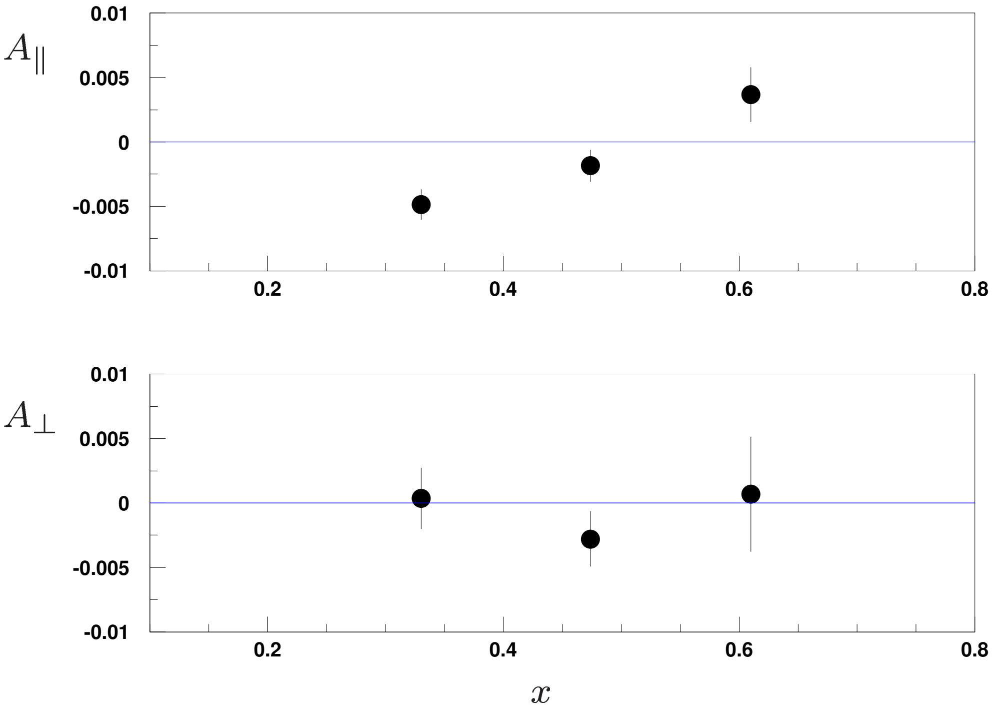
$$A_2 = \gamma\left\{\frac{1-\frac{y}{2}}{D'} A_\parallel + \frac{1}{D'}\left[\tan(\theta/2) + \frac{y}{2\sin\theta}\,\frac{1+(1-y)\cos\theta}{1-y}\right] A_\perp\right\}$$

$$g_1(x,Q^2) = \frac{F1(x,Q^2)}{D'}\left[A_\parallel + \tan(\theta/2)\cdot A_\perp\right]$$

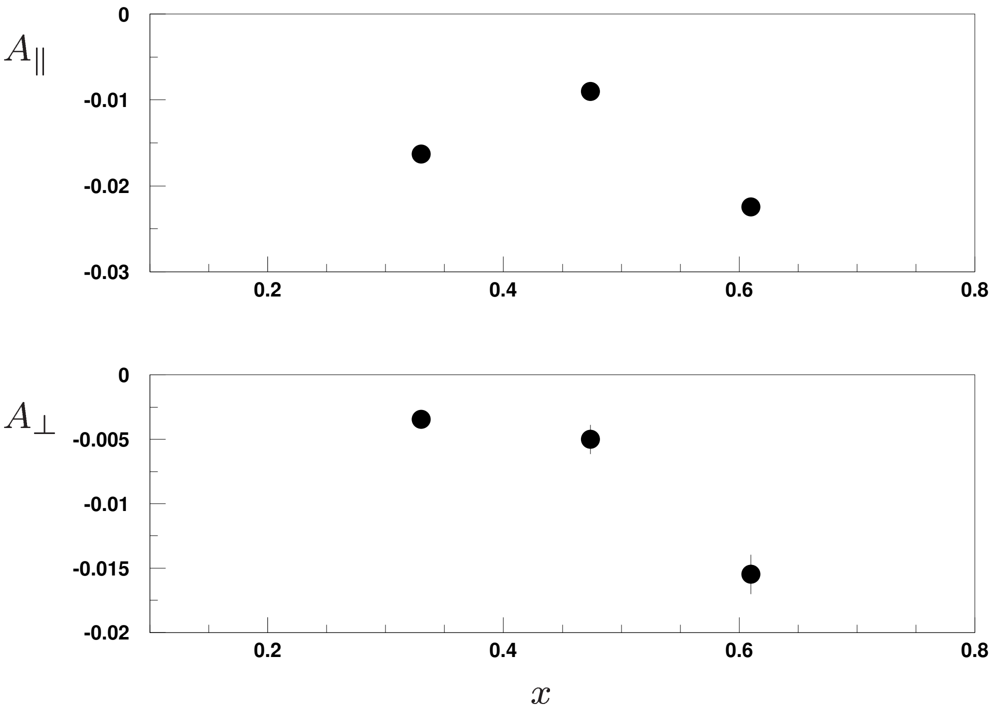
$$g_2(x,Q^2) = \frac{F1(x,Q^2)}{2D' y \sin\theta}\left[\frac{E+E'\cos\theta}{E'} A_\perp - \sin\theta\cdot A_\parallel\right]$$

^{3}He Asymmetries

- Electron asymmetries



- Pion asymmetries



From ^{3}He to Neutron

CONVOLUTION APPROACH

C. Ciofi degli Atti et.al., Phys.Rev.**C48**, R968(1993); Phys. Lett., **B404**, 223(1997)

COMPLETE ANALYSIS

F. Bissey et. al., hep-ph/0109069

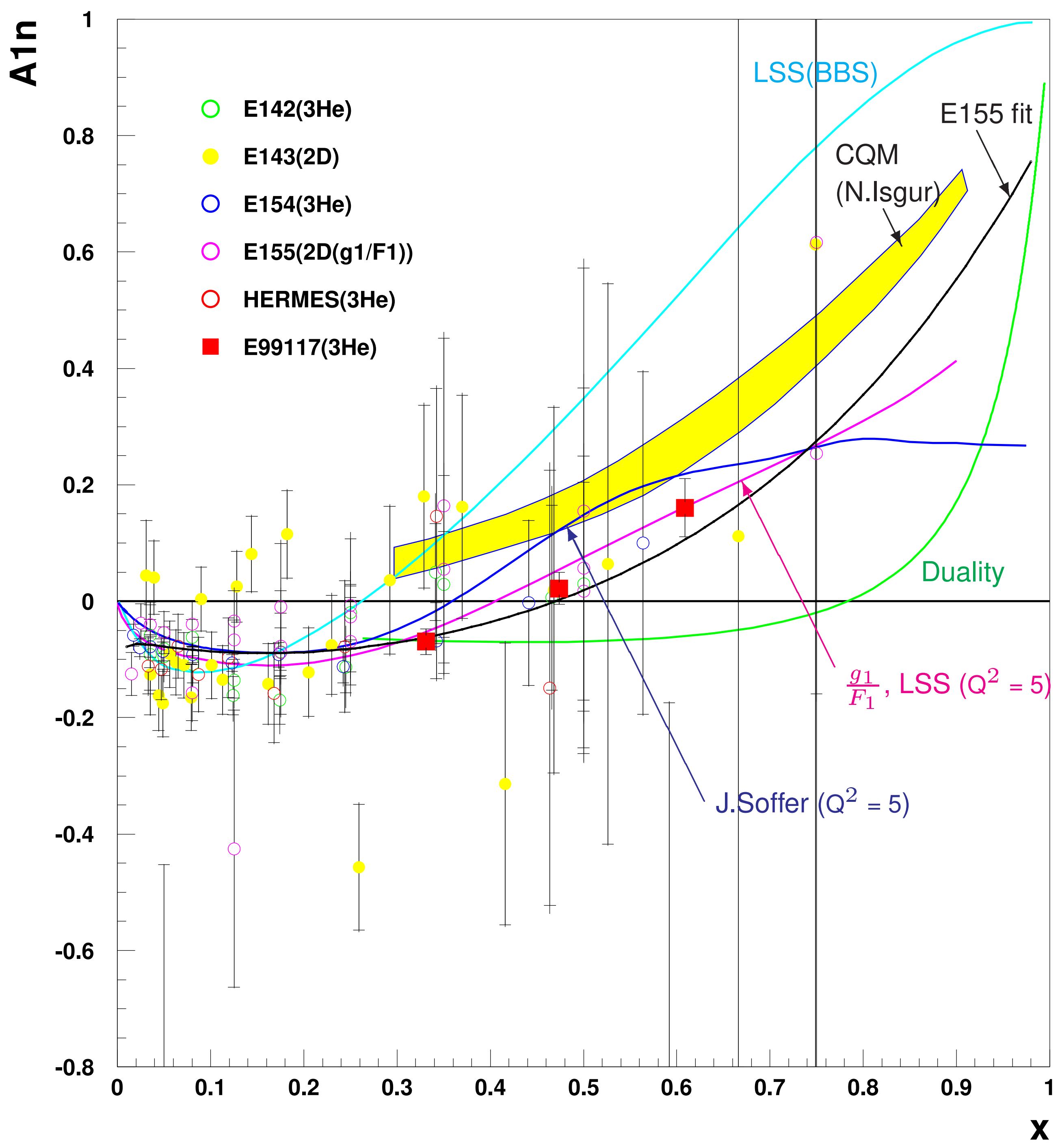
(16:40-17:00, talk by M. Strikman)

- Δ isobar in ^3He wavefuntion

$$A_1^n = \frac{F_2^{^3He}}{P_n F_2^n(1+\frac{0.056}{P_n})}[A_1^{^3He} - 2\frac{F_2^p}{F_2^{^3He}} P_p A_1^p(1-\frac{0.014}{2P_p})]$$

- $R(x,Q^2)$ from E143 fit: K. Abe et. al., hep-ex/9808028
- F_2^p, F_2^d from NMC95 fit: M. Arneodo et. al., hep-ph/9509406,
- F_2^p resonance from SLAC94 fit,
- Effective nucleon polarization P_p, P_n
  - use $P_p = -0.028 \pm 0.004$,$P_n = 0.86 \pm 0.02$
    C. Ciofi degli Atti et.al.,Phys.Rev.**C48**, R968(1993)
  - $P_p = -0.018$,$P_n = 0.897$
    CD-Bonn2000 + TM (Tucson-Melbourne) 3NF, A. Nogga, Ph.D. thesis, (2001)
- g_1^p/F_1^p, g_1^n/F_1^n
  - E155 fit, P. L. Anthony et. al., Phys.Lett.**B493**:19-28,(2000) (hep-ph/0007248)
  - fit to world data on A_1, then iterate to g_1/F_1;
- g_2, using g_2^{ww}

A_1^n Preliminary Result



Error Analysis

Statistics

- ΔA_1^n =5% at $x = 0.61$;

Experimental systematics

- Beam energy: 5.734 GeV, $\frac{\Delta E_b}{E_b} < 5 \times 10^{-4}$;
- Spectrometer momentum: $\frac{\Delta E_e}{E_e} < 5 \times 10^{-4}$;
- Spectrometer angle: $\Delta\theta_e < 0.1^\circ$;
- Beam polarization: 81%, $\frac{\Delta P_b}{P_b}$ $<$3%;
- Target polarization: 40%, $\frac{\Delta P_t}{P_t}$ $<$4%;
- Target spin orientation: $\Delta\theta_{targ}$ $<$1°;

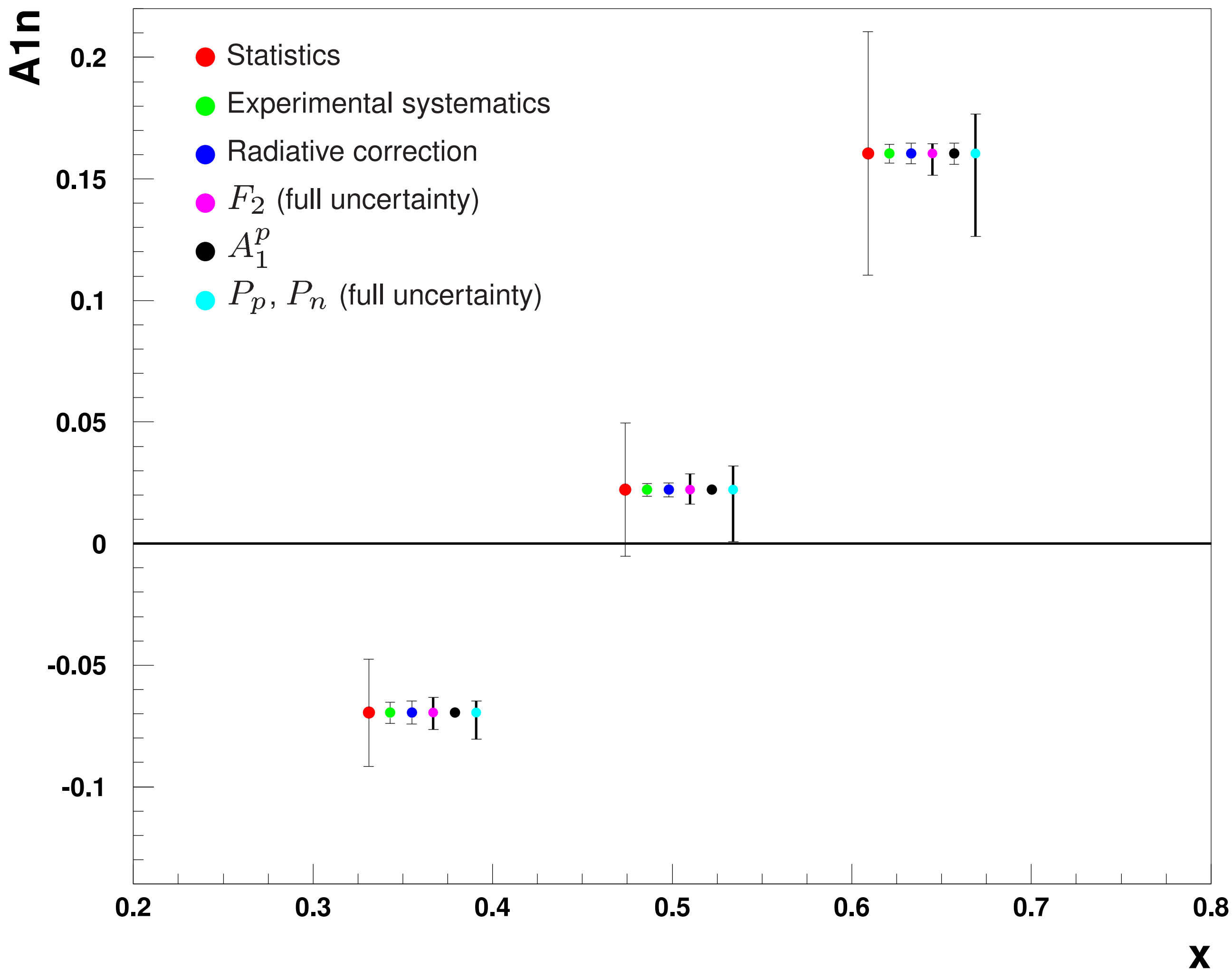
Radiative Correction

- Correct $A_{\parallel}^{^3He}$, $A_{\perp}^{^3He}$ directly;
- F_2 variation (5 models), $F_2^{p,\mathrm{res}}$ (2);
- g_1 variation, g_1/F_1 variation (3), $g_1^{^3He,\mathrm{res}}$ variation;
- g_1/F_1 - Q^2 dependence;
- g_2 variation (g_2^{ww} vs. $g_2 = 0$);

Nuclear correction

- $F_2^p, F_2^d; A_1^p; P_p, P_n$

Figure 1: E99-117 error analysis



Summary and Outlook

Experiment E99-117

- Provides the first precise data of A_1^n at $x > 0.4$;
- Data on g_1^n, A_2^n, g_2^n will be available;
- Provide new constraint on pQCD, models;
- Help to understand constituent quark models

Future of A_1^n

- E01-012, Measurement of neutron spin structure functions in the resonance region, spokesperson: N. Liyanage, J.P.Chen, S.Choi
  - test quark-hadron duality in spin structure functions;
- A_1^n at JLab 12 GeV upgrade.