Spin Structure Functions at Large x

A. Deur
Jefferson Lab

Jefferson Lab Hall C summer workshop

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This talk: large-x in inclusive Deep Inelastic Scattering on nucleon

Large-x in DIS is a (relatively) simpler domain: Valence Quarks dominate

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⇒Testing ground for CQM

- How is our understanding of constituent quarks
- Strong Force degrees of freedom
  - constituent quarks vs current quarks
- How SU(6) symmetry is broken

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  - constituent quarks vs current quarks
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⇒Testing ground for QCD

- pQCD: Usually predicts { Q^2-dependence / x-dependence }, not absolute behavior.
  Exception for $x \rightarrow 1$
- Higher Twists

⇒Large-x domain essential for understanding QCD:

Life is simpler there and interesting and predictions are better.

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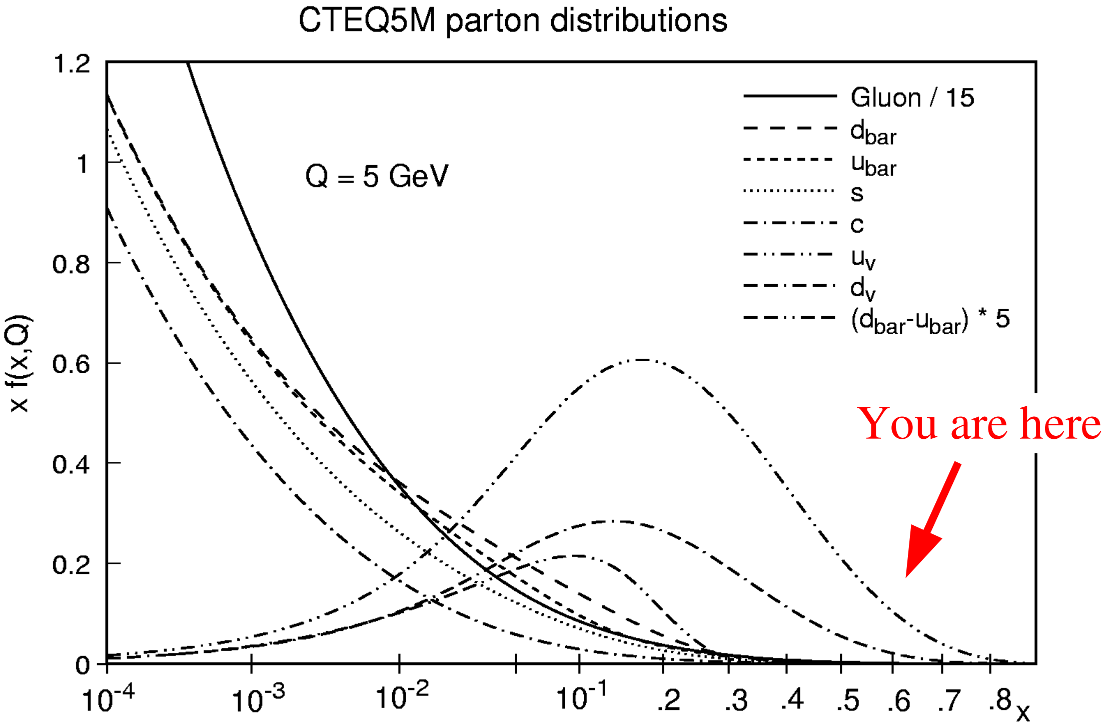
Life is simpler there and interesting and predictions are better.

But like all paradises, it is hard too reach.

Large-x:

- Small parton distributions:



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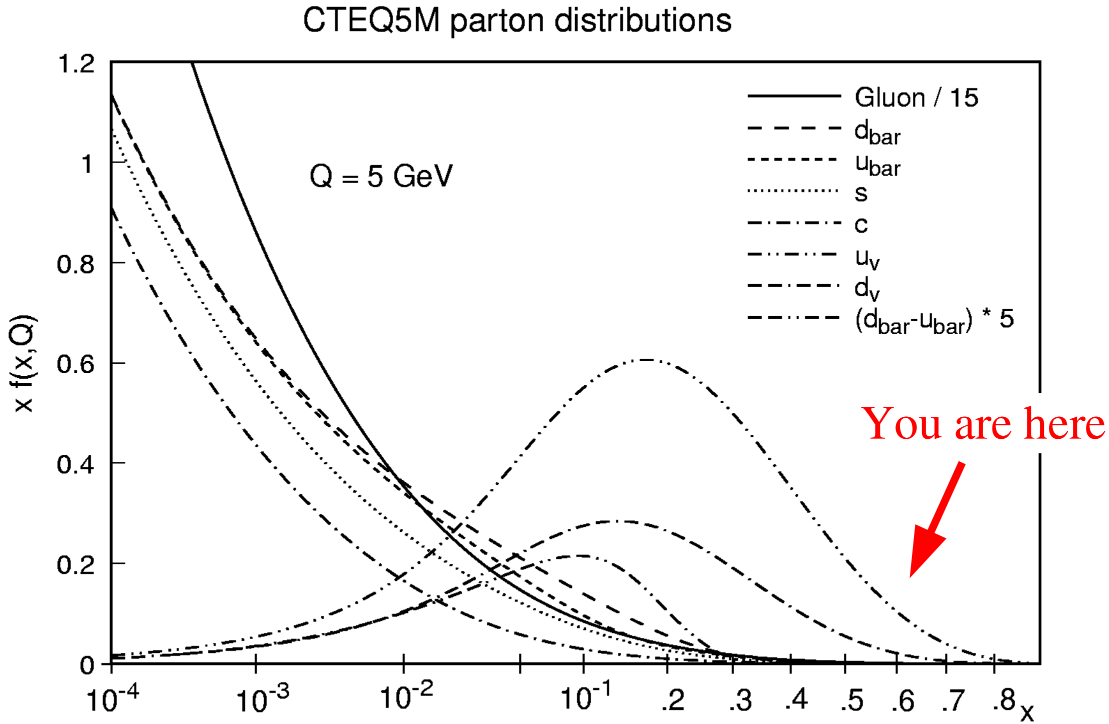

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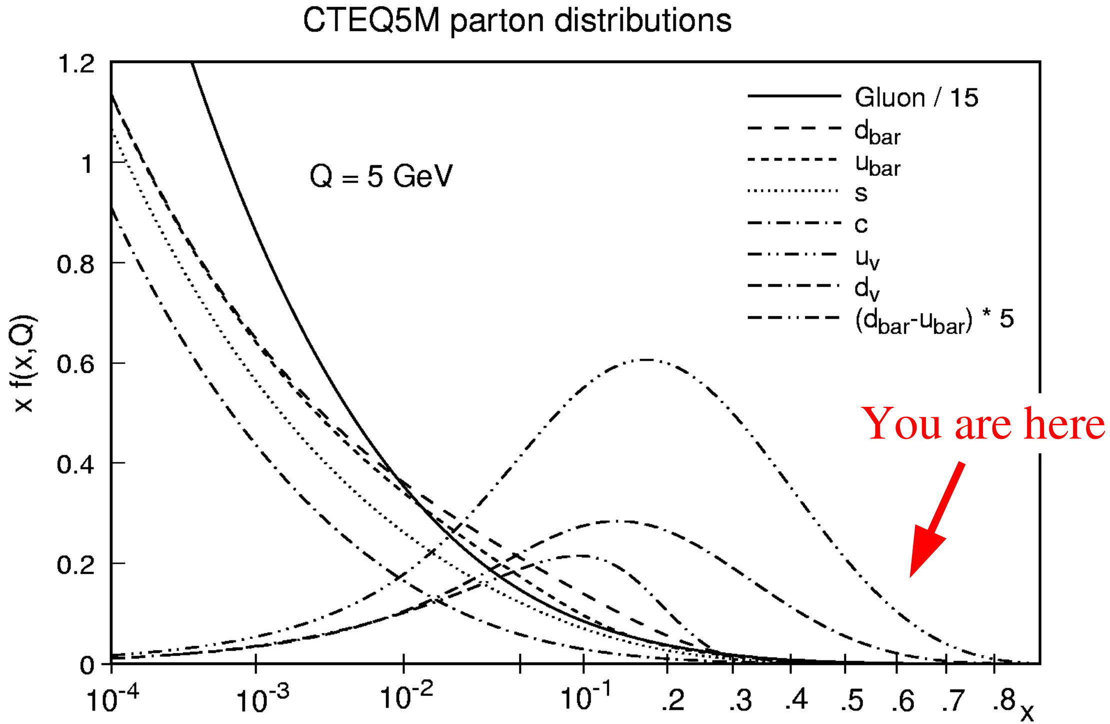


- Large ν (W>2 GeV) and even larger Q^2: $x=Q^2/2M\nu$

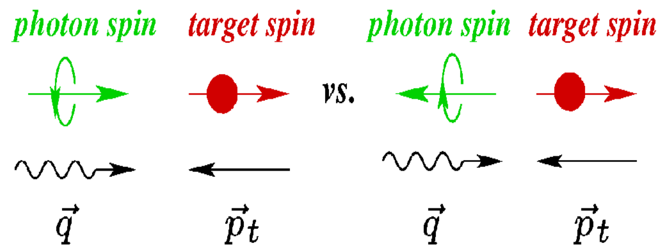
⇒kinematic suppressions

⇒Cross sections are small

Until JLab, no precise polarized data in DIS, large x.

Experimental Observables in DIS

Traditional DIS observable: $A_1 = \dfrac{\sigma_{\frac{1}{2}} - \sigma_{\frac{3}{2}}}{\sigma_{\frac{1}{2}} + \sigma_{\frac{3}{2}}}$



$$A_1 = \frac{\text{linear combination of } g_1 \text{ and } g_2}{F_1} \simeq \frac{g_1}{F_1}$$

Can also be expressed simply in term of parton distribution

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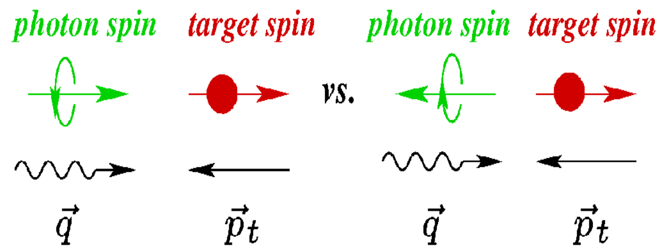

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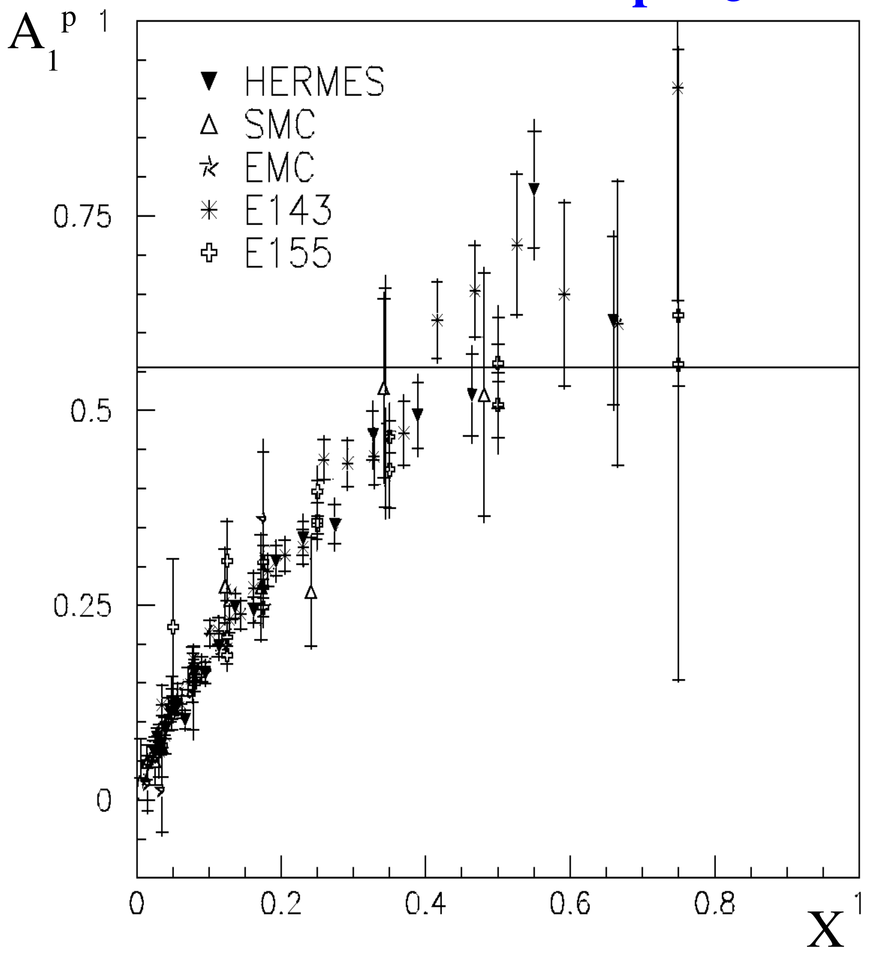
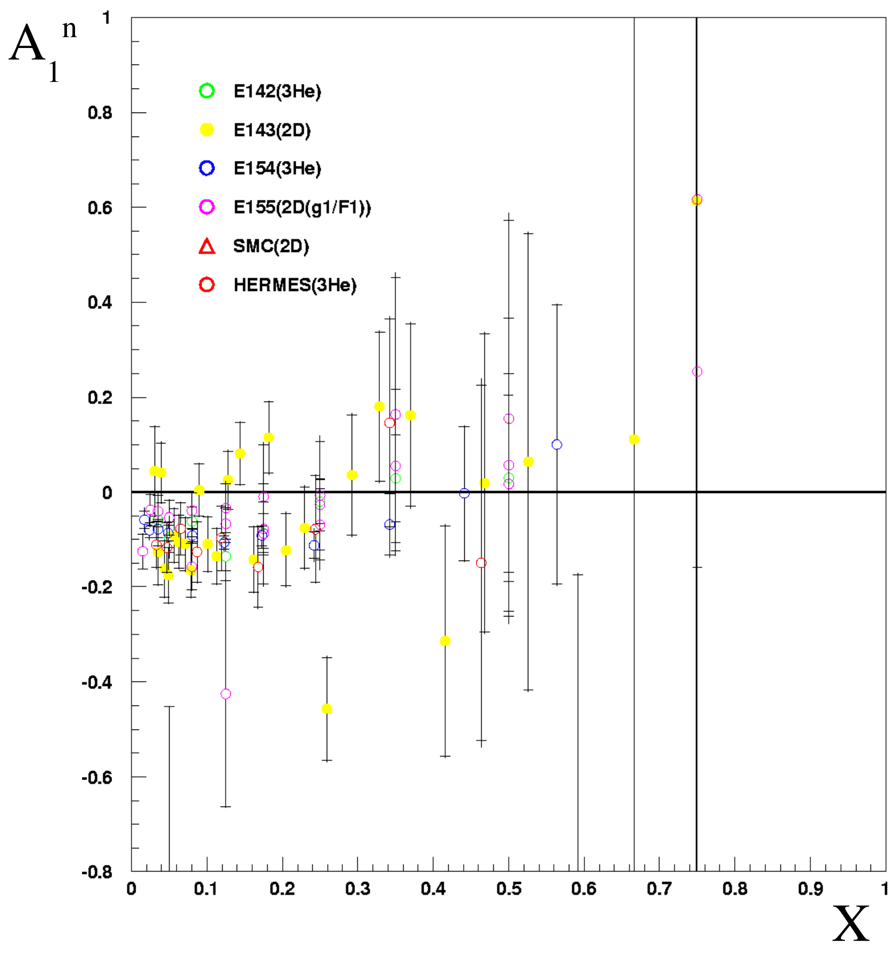
Other observable: A_2. Need transverse target polarization.

pre-JLab DIS Data





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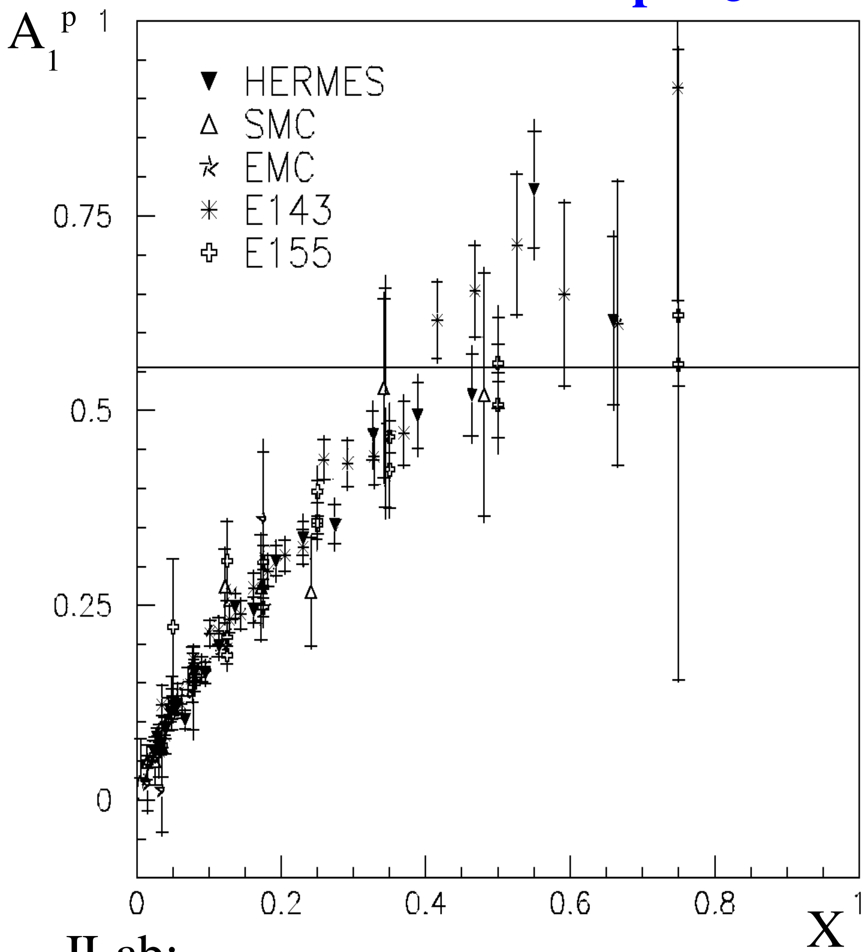
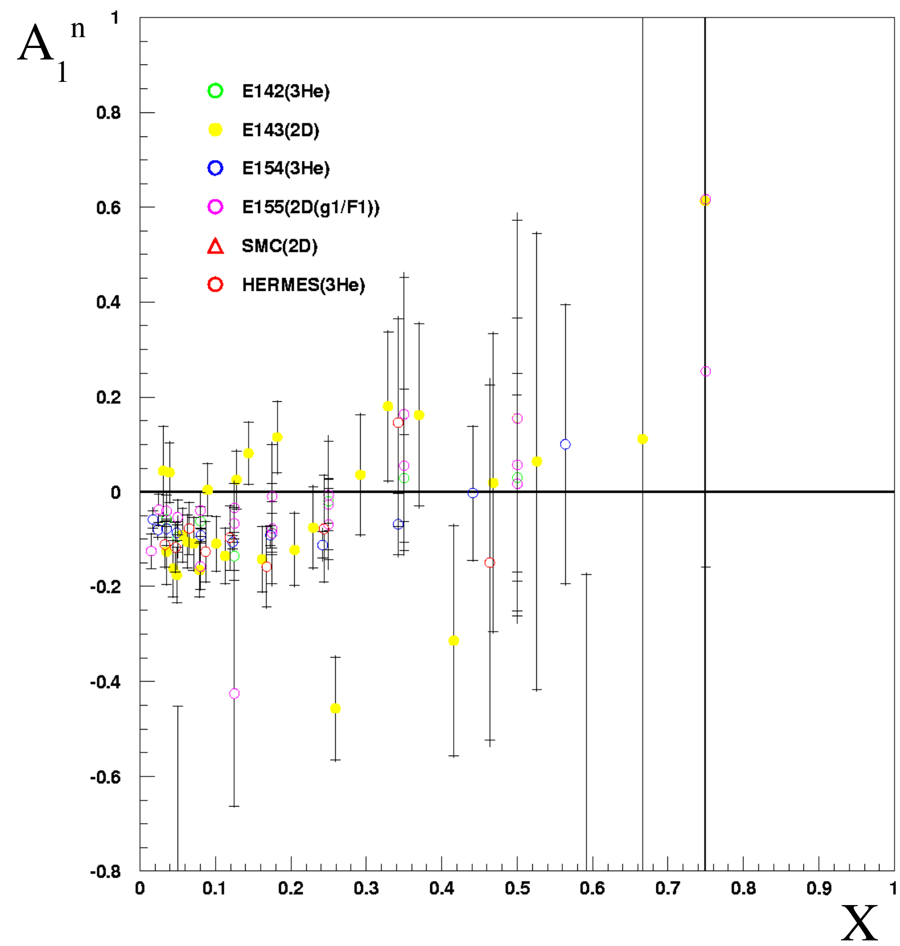
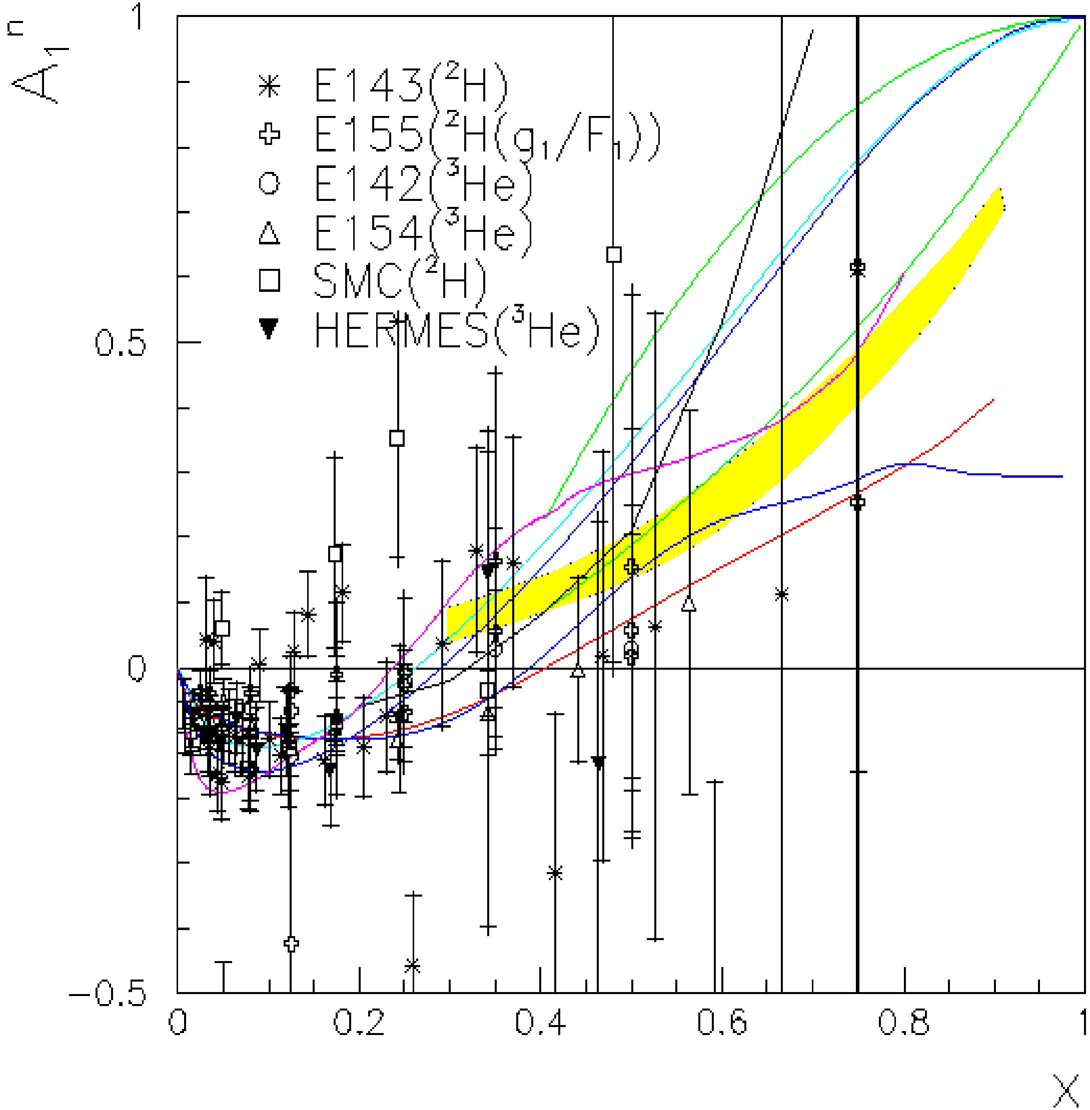




JLab:

- Hall A E99-117: A_1^n (X. Zheng *et al.*, PRL 92 012004 (2004); PRC 70 065207 (2004))
- Hall B EG1b: A_1^p, A_1^d (near-final results)
- Hall C SANE : A_1^p (to run in 2008)

Predictions on A_1^n at $x \to 1$



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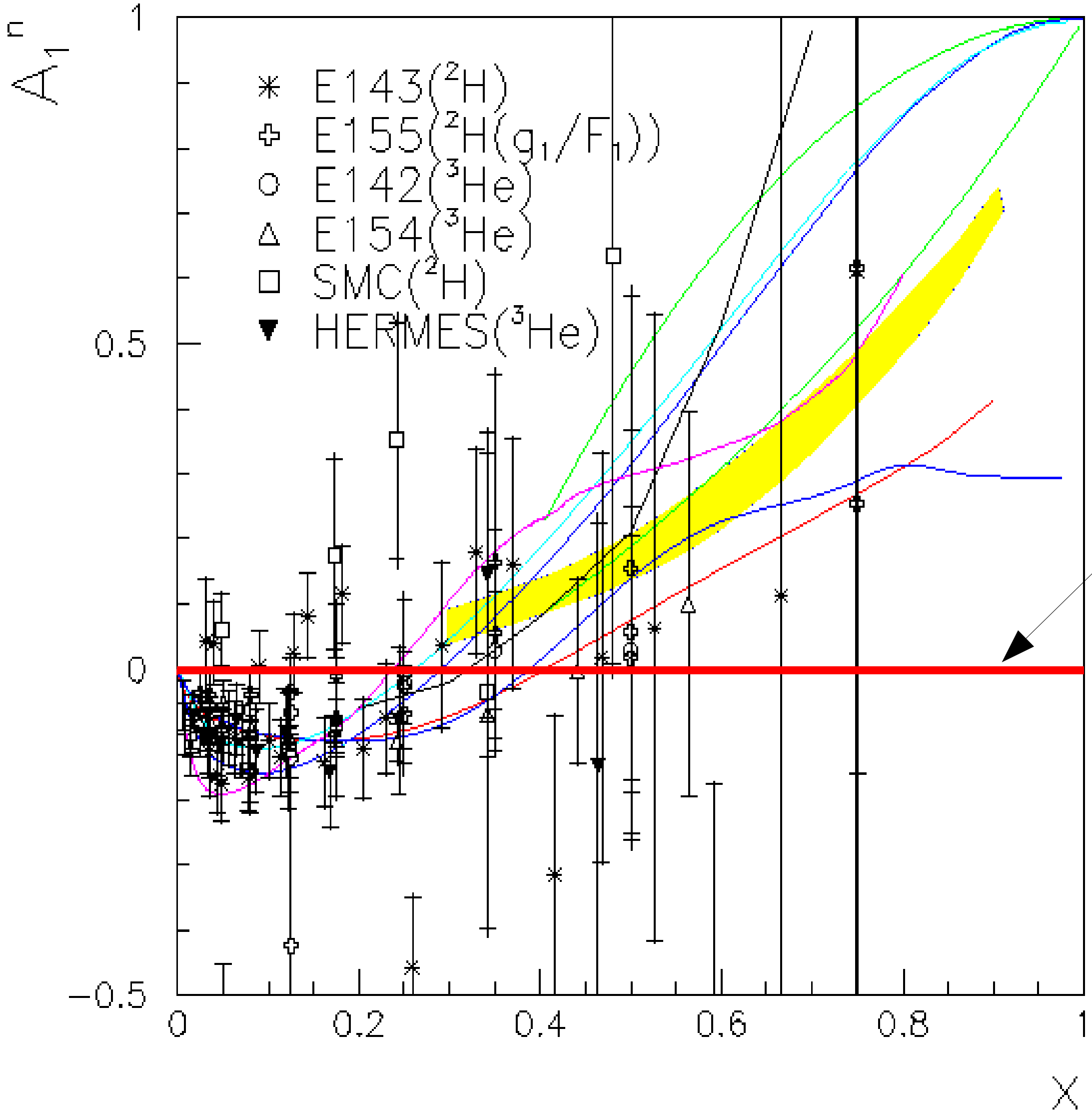
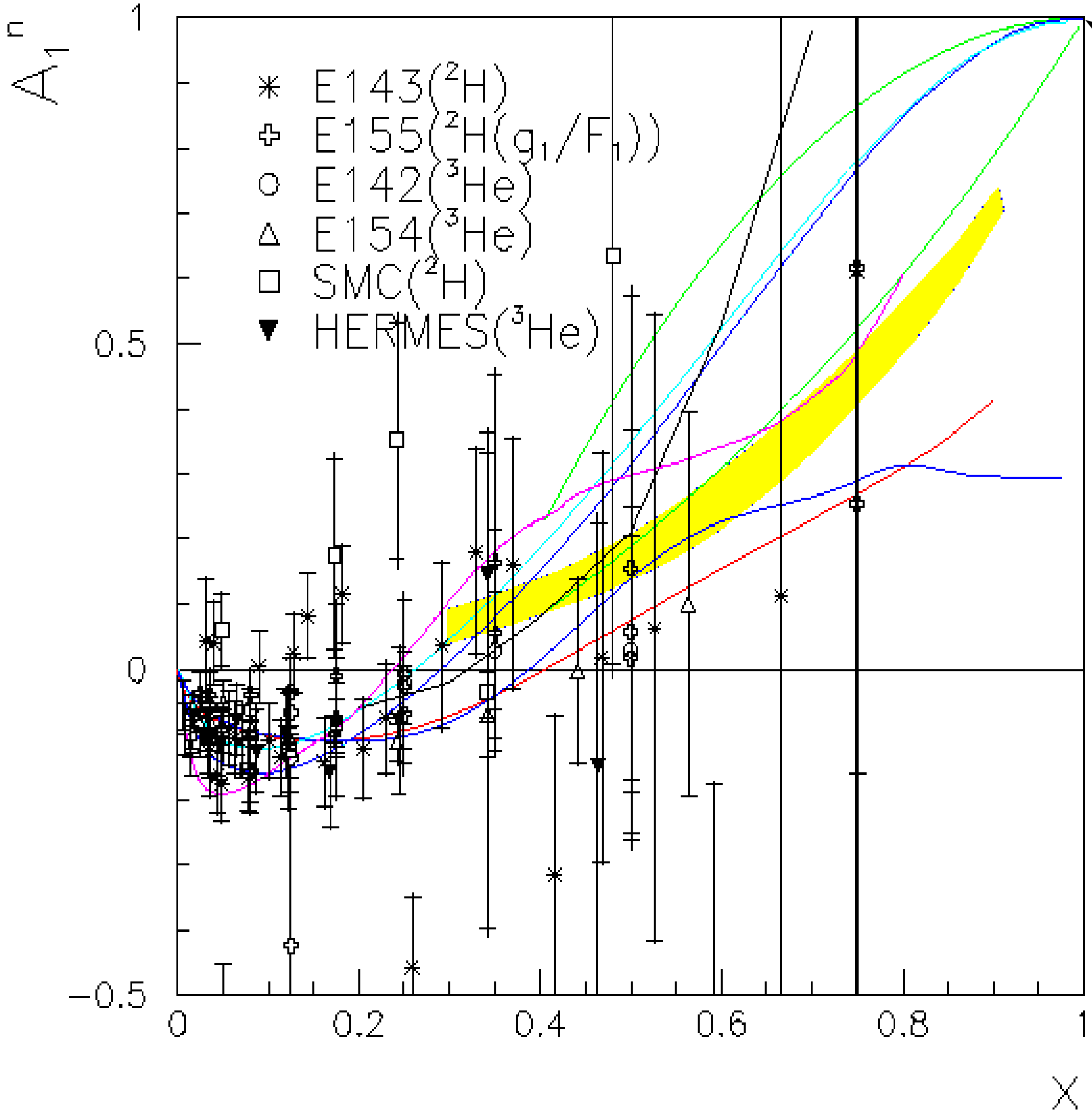


SU(6) spin flavor symmetry nrCQM

- All the nucleon spin comes from Q
- SU(6) known to be broken (Baryon mass splitting, $R^{np}(x)$,...)

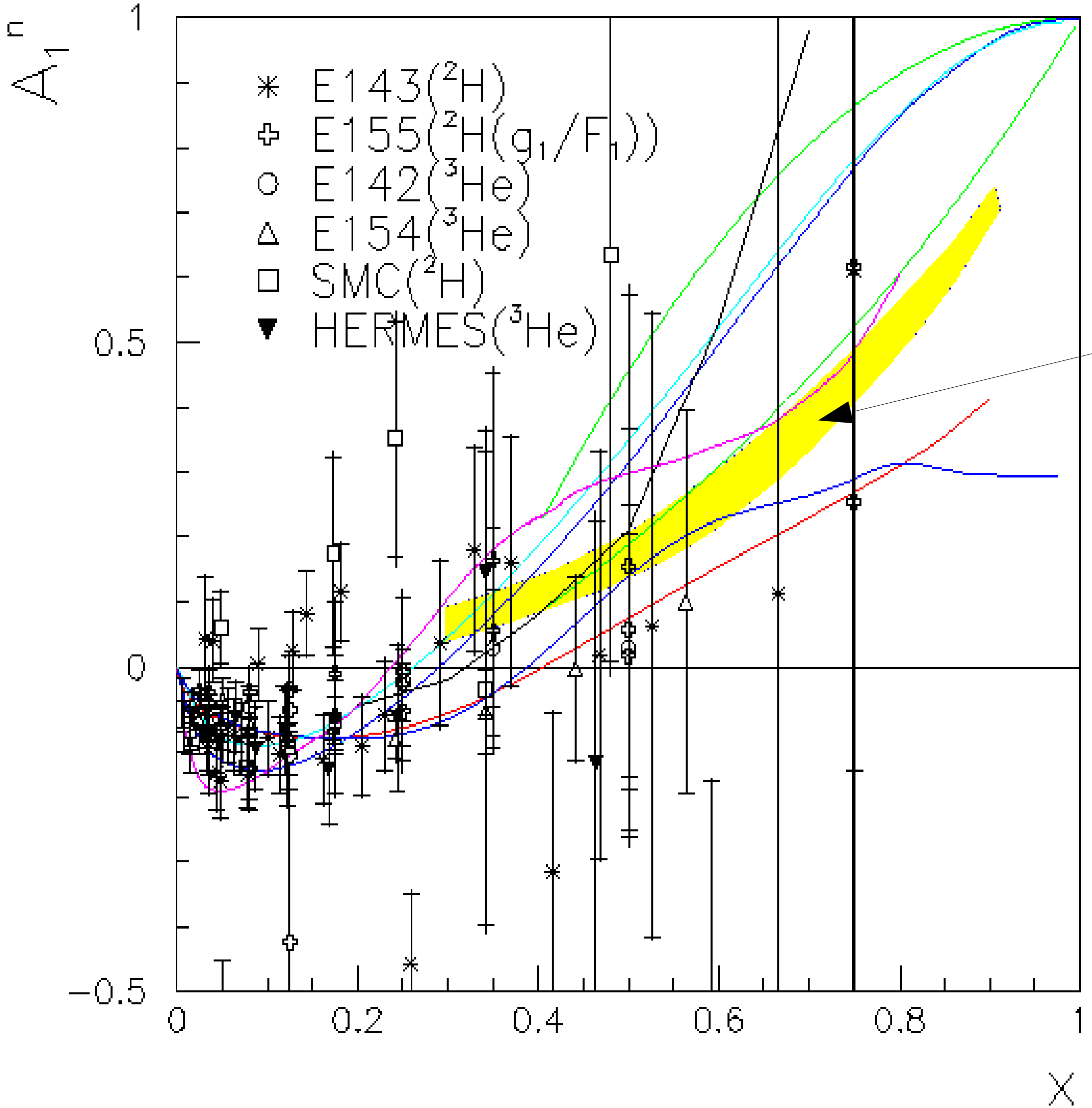
Important to understand how SU(6) is broken.

Predictions on A_1^n at $x \to 1$



Broken SU(6): ‘h yperfine interaction”
(one gluon exchange)

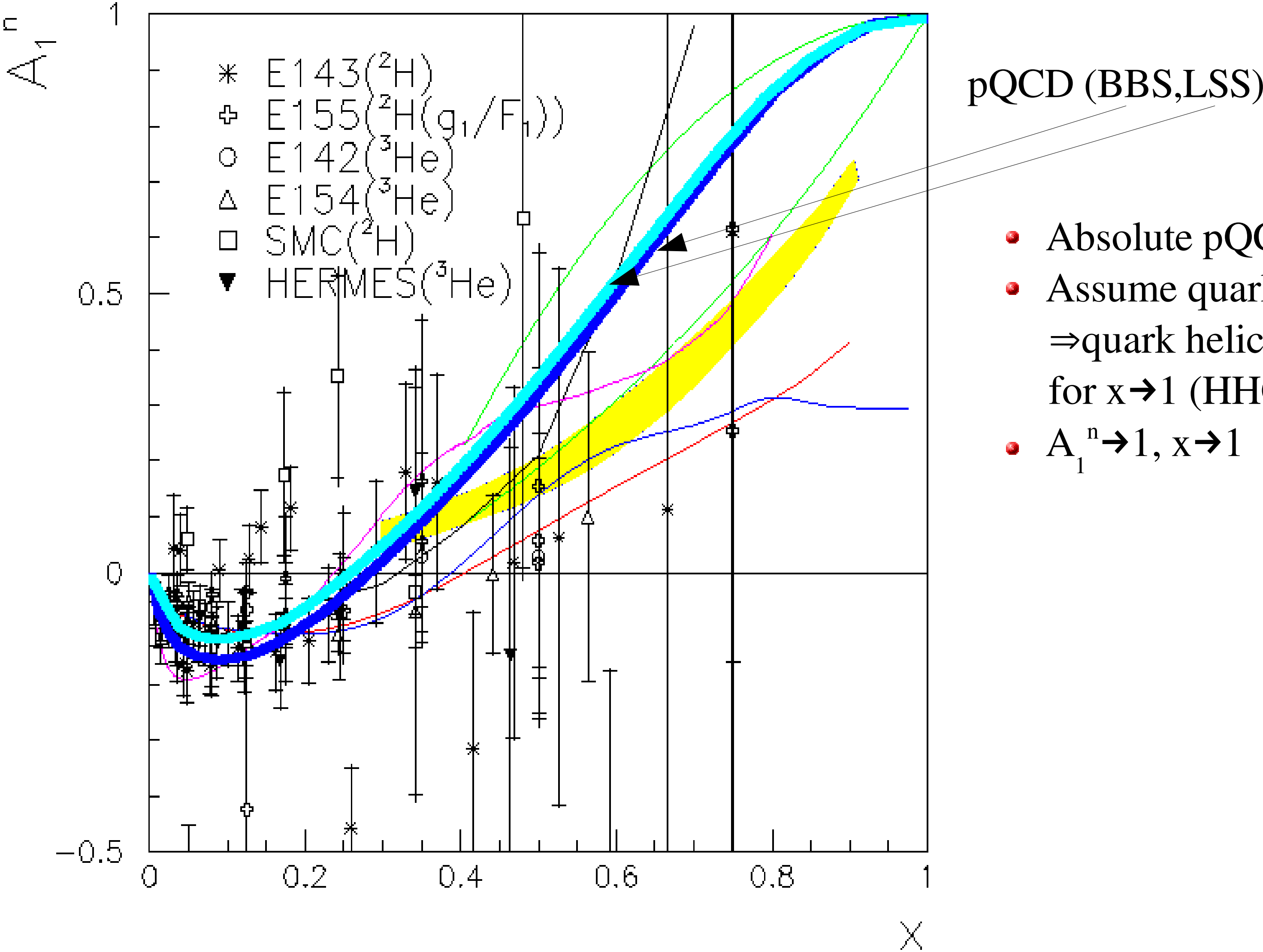
Predictions on A_1^n at $x \to 1$



rCQM (N. Isgur)

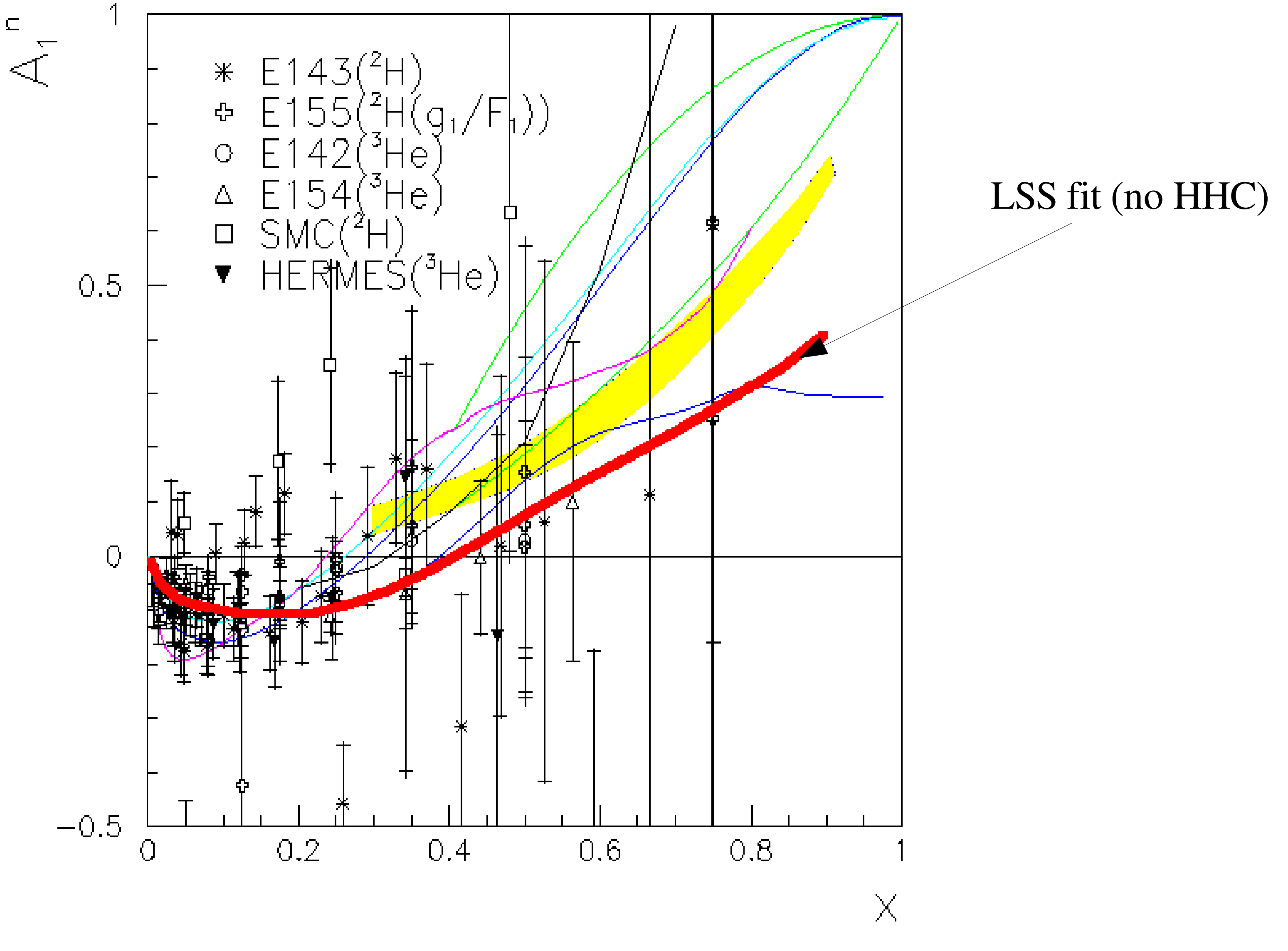
- Use hyperfine interaction
- Quark OAM: 25% (relativity)

Predictions on A_1^n at $x \to 1$



- Absolute pQCD prediction at $x \to 1$
- Assume quark OAM=0
  ⇒quark helicity = nucleon hel. for $x \to 1$ (HHC)
- $A_1^n \to 1$, $x \to 1$

Predictions on A_1^n at $x \to 1$



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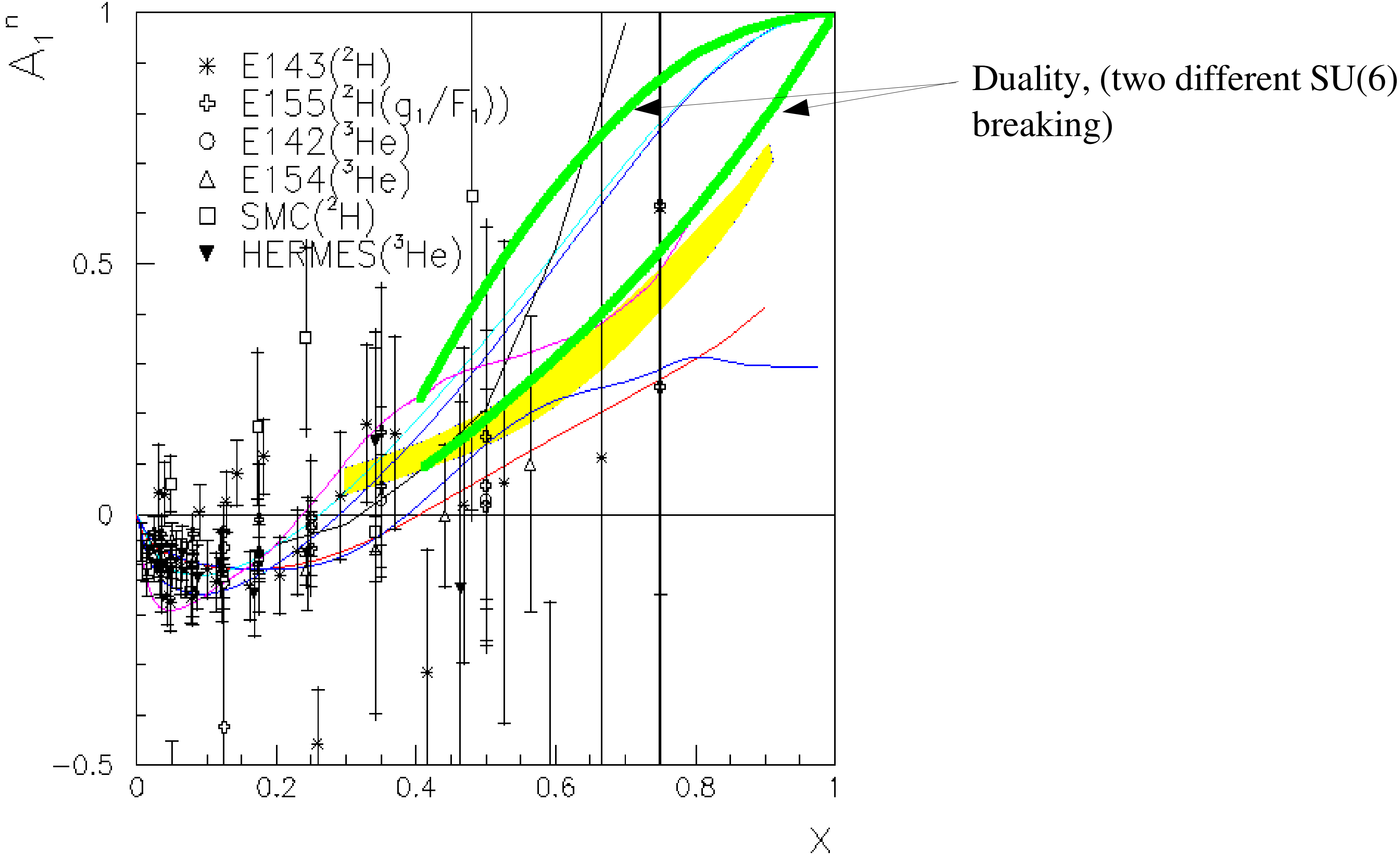

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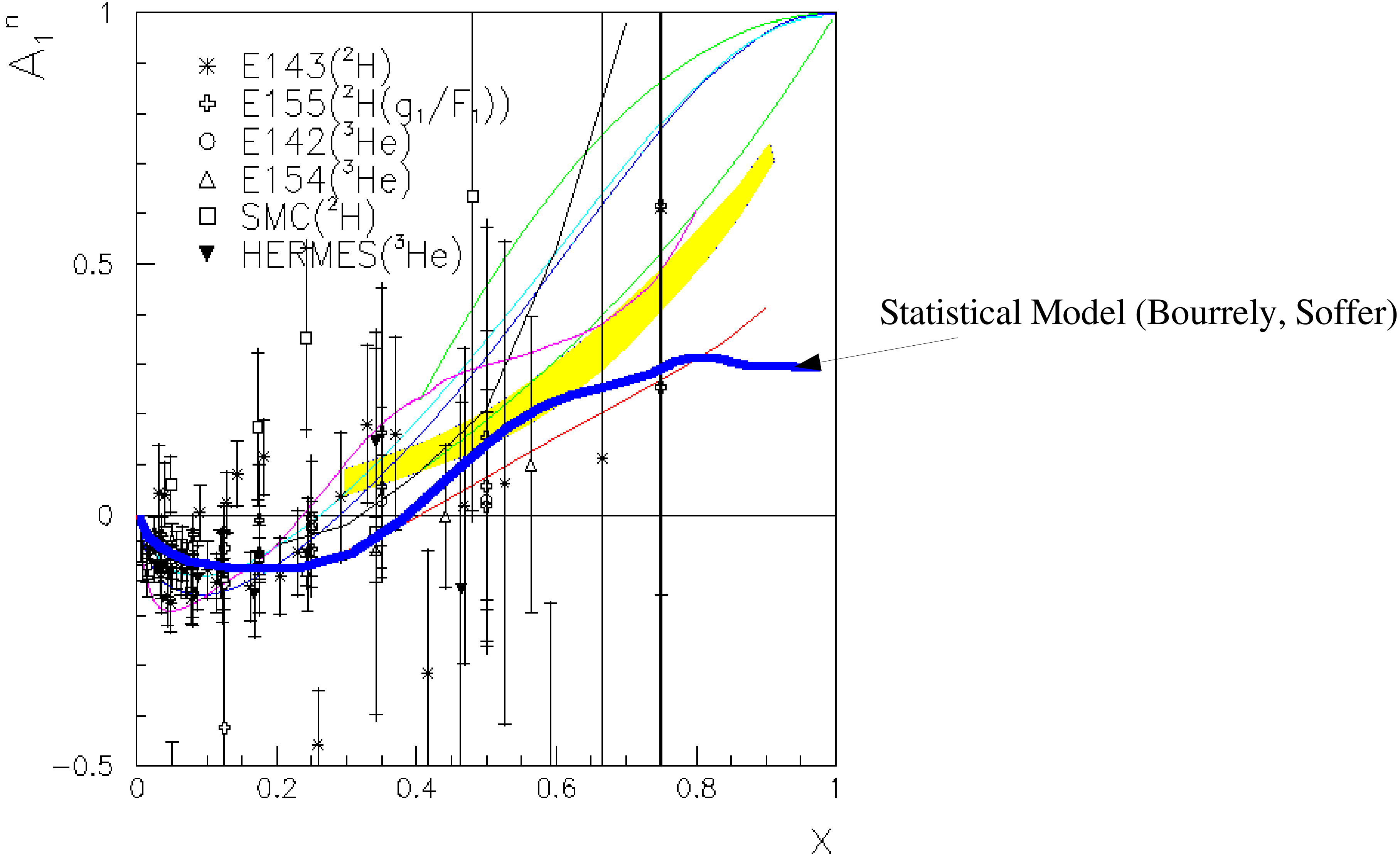

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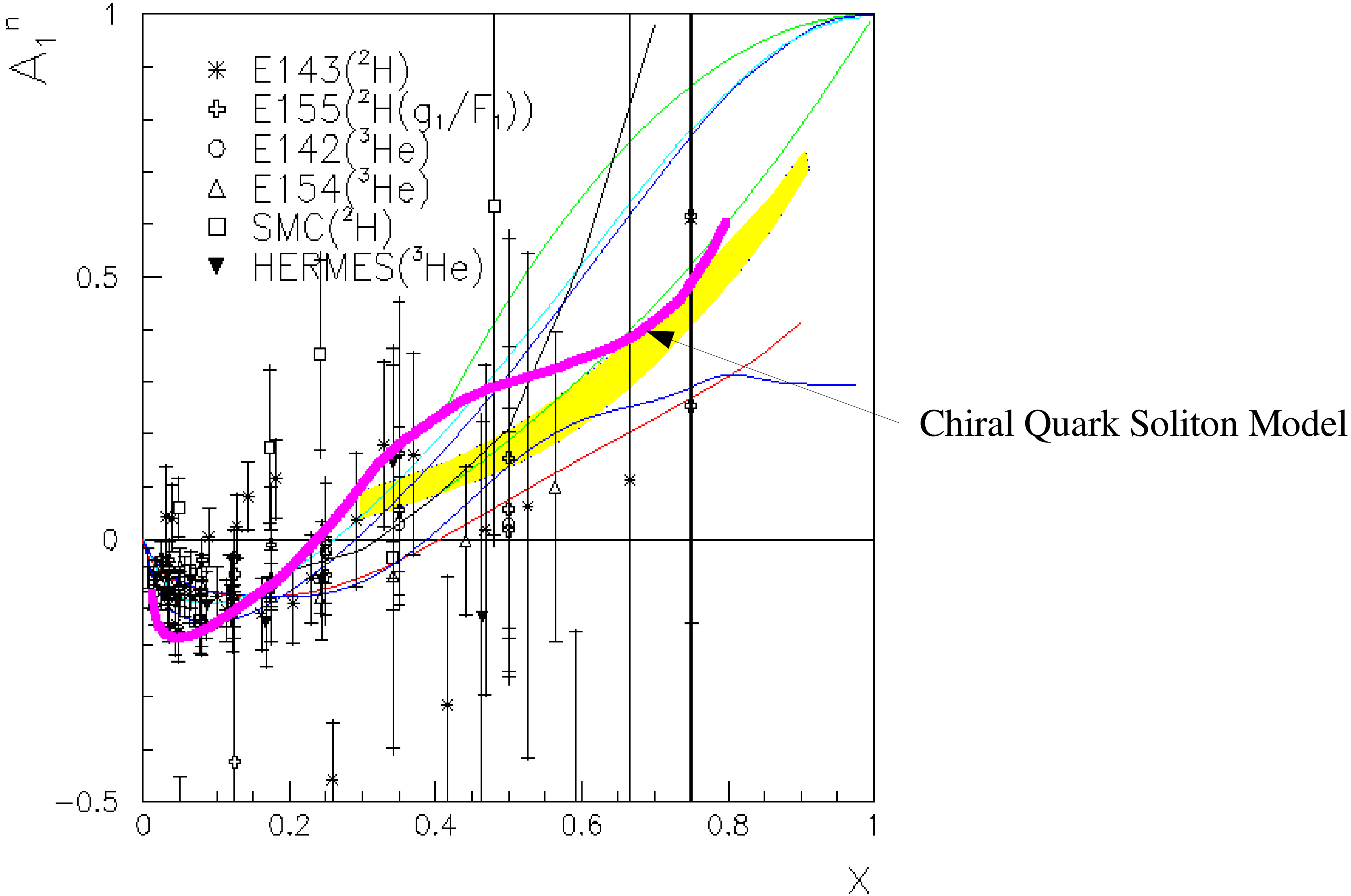

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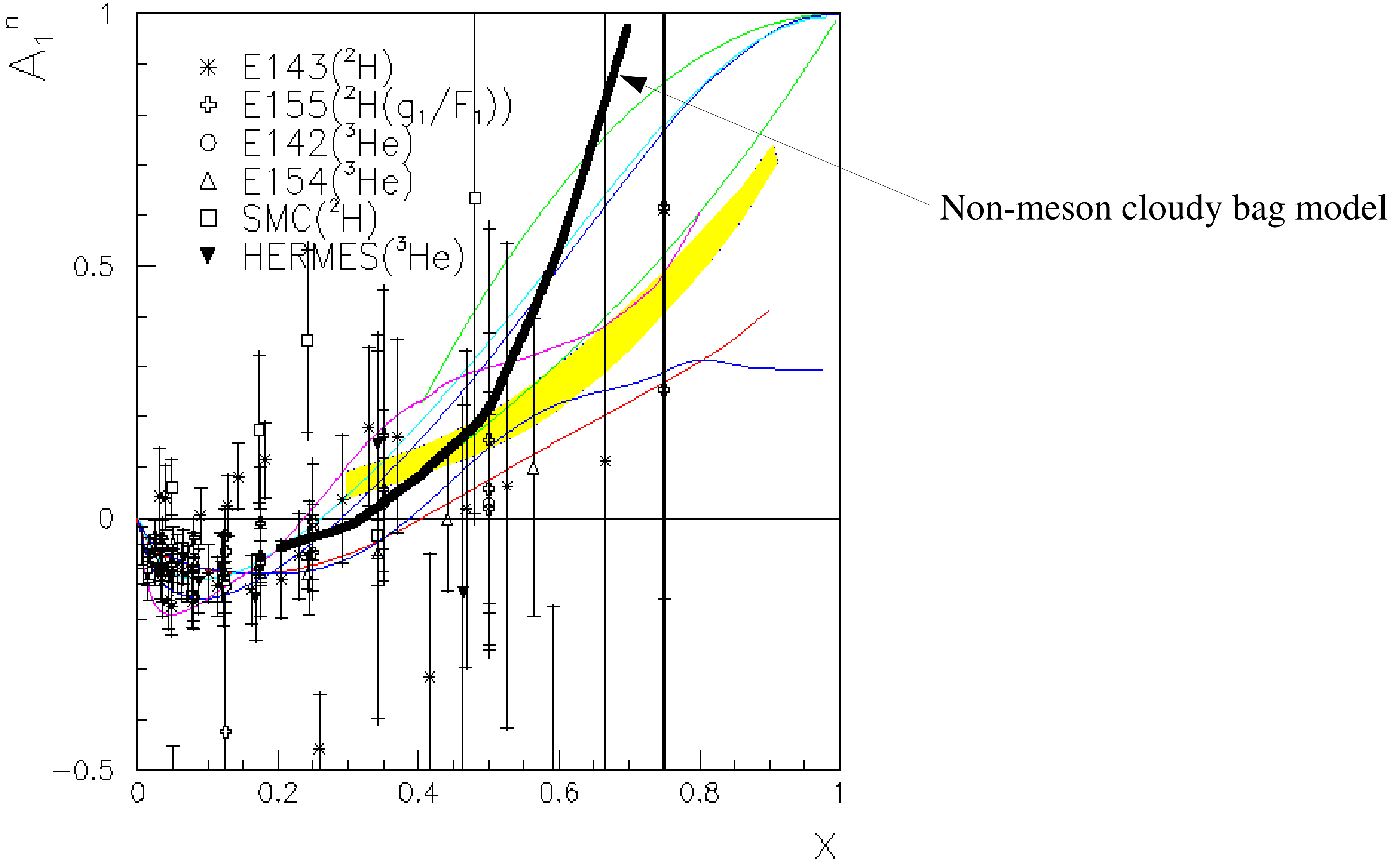
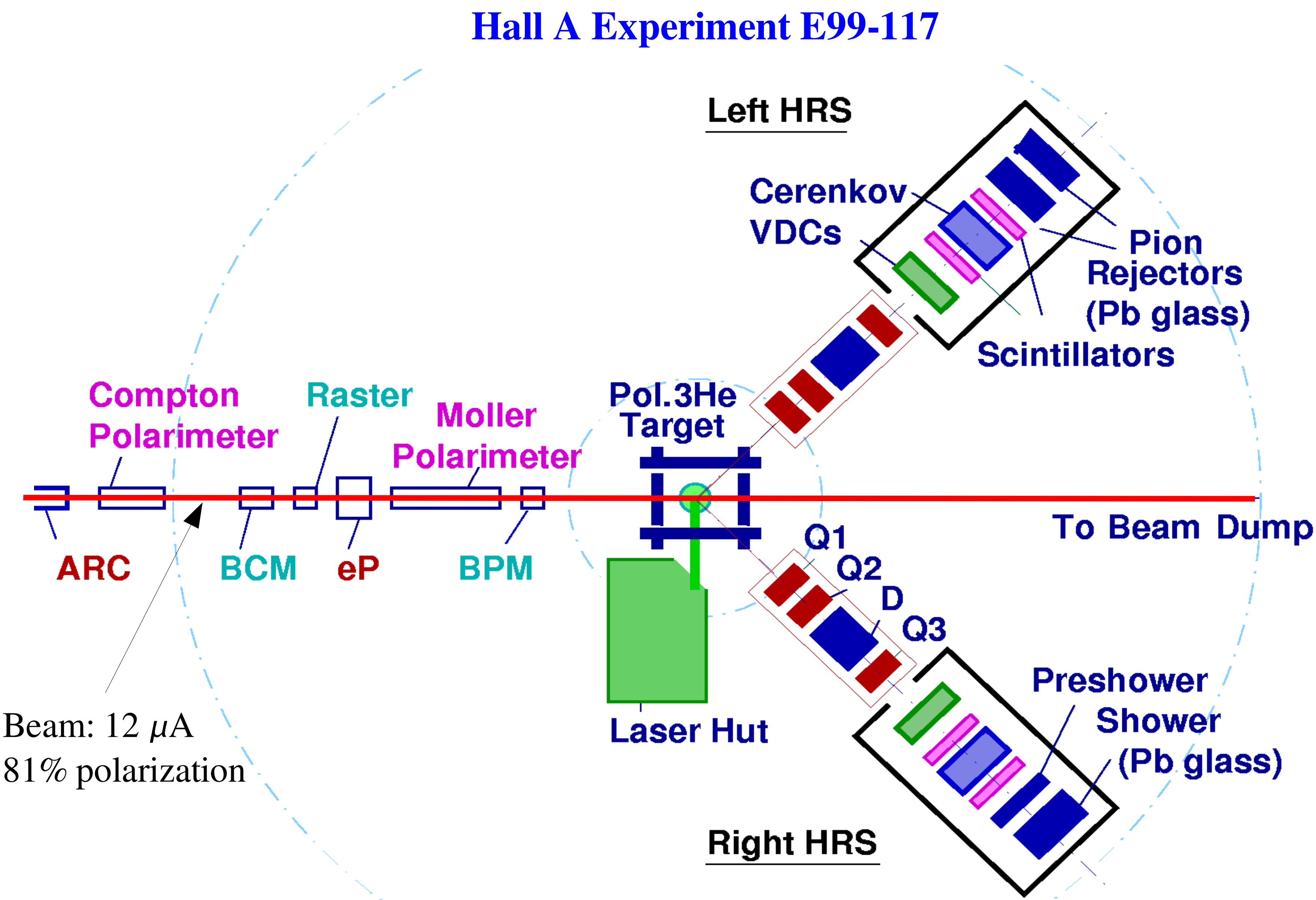


Hall A Experiment E99-117

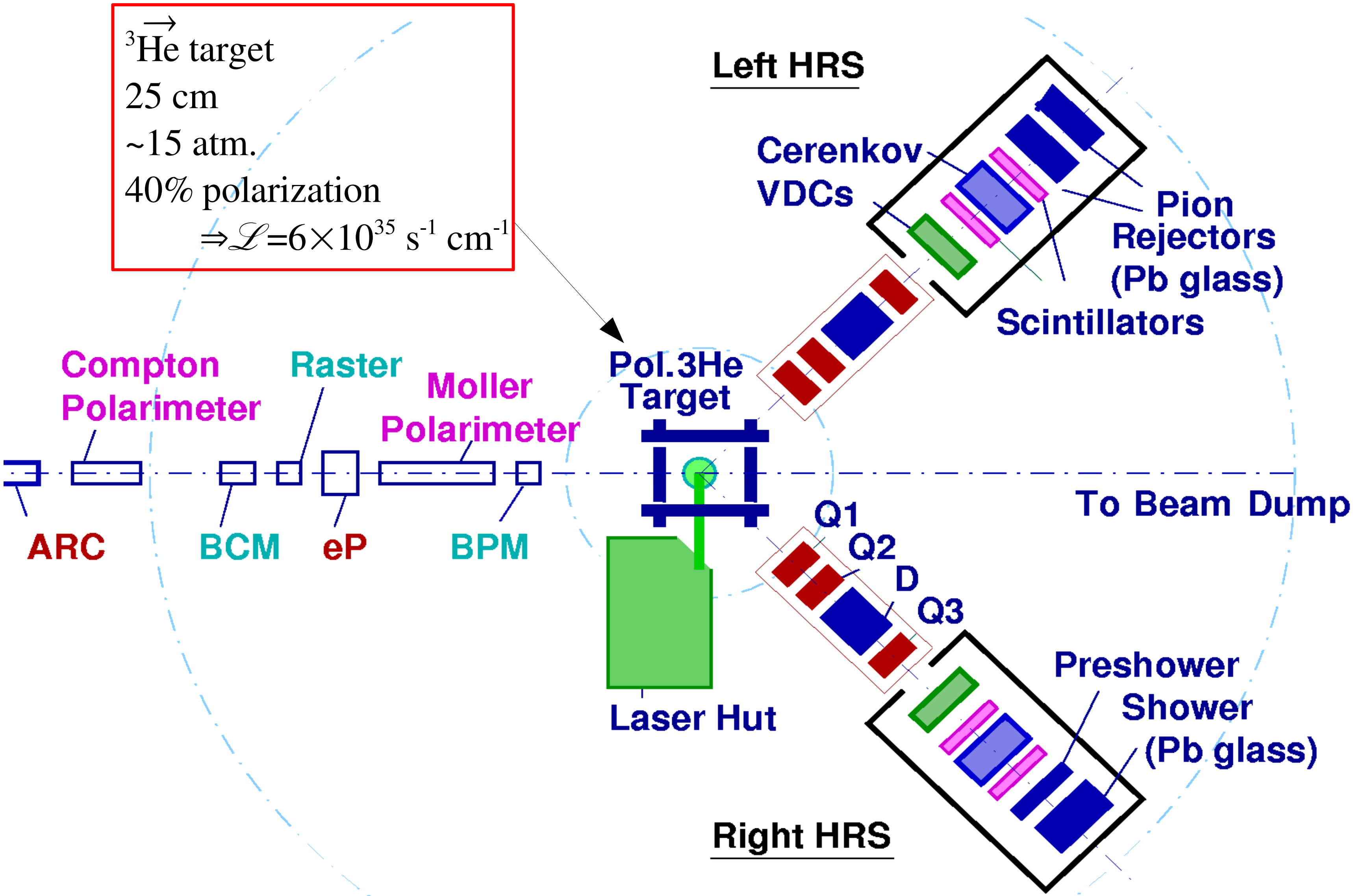
Doubly polarized inclusive $^3\overrightarrow{\text{He}}(\overrightarrow{e},e')$ at E=5.7 GeV

Measured A_1^n and A_2^n for 3 kinematics:

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


Hall A Experiment E99-117
Left HRS
Cerenkov
VDCs
Pion
Rejectors
(Pb glass)
Scintillators
Compton
Polarimeter
Raster
Moller
Polarimeter
Pol.3He
Target
ARC
BCM
eP
BPM
To Beam Dump
Q1
Q2
D
Q3
Laser Hut
Preshower
Shower
(Pb glass)
Beam: 12 μA
81% polarization
Right HRS

Hall A Experiment E99-117



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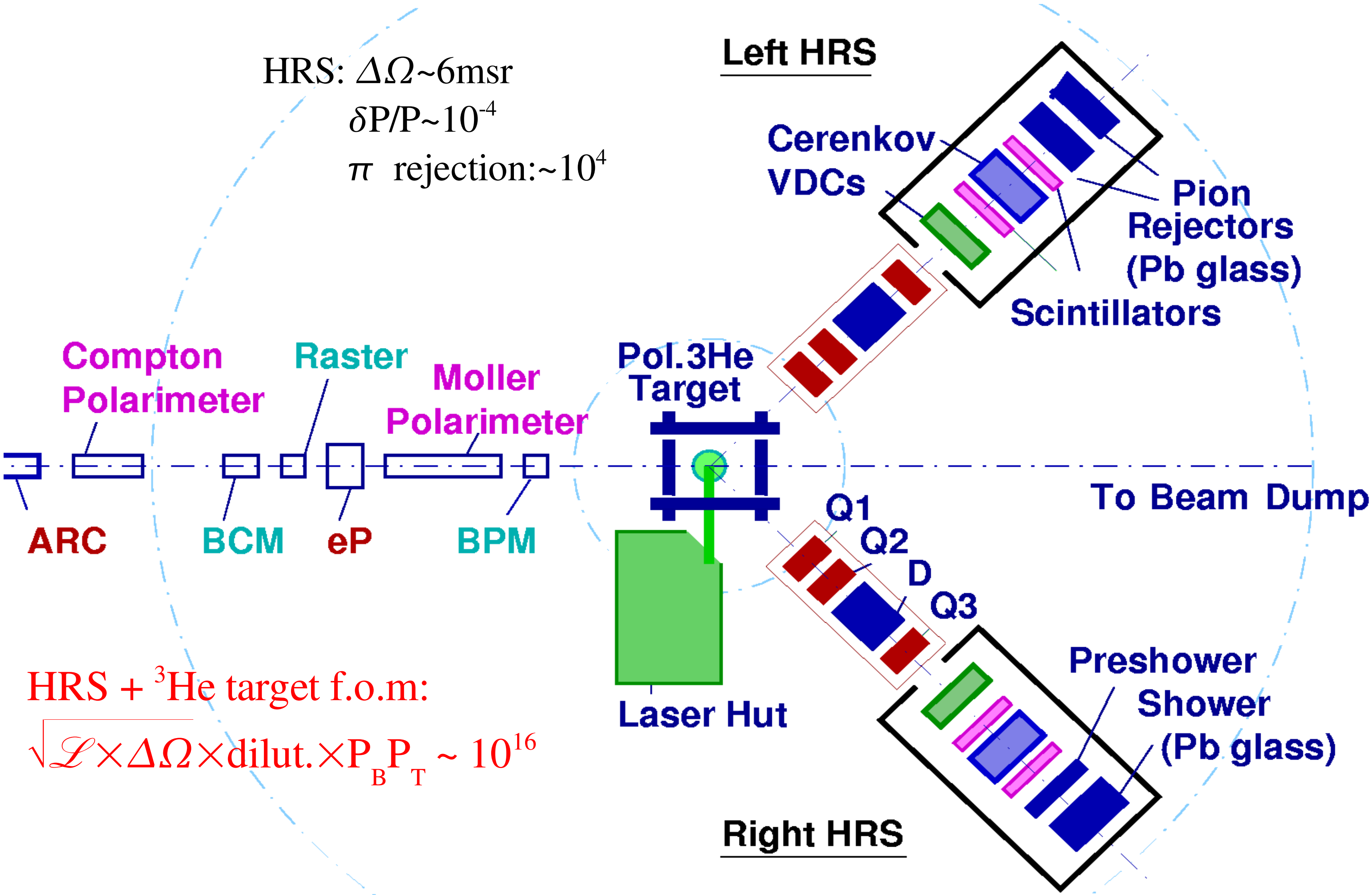
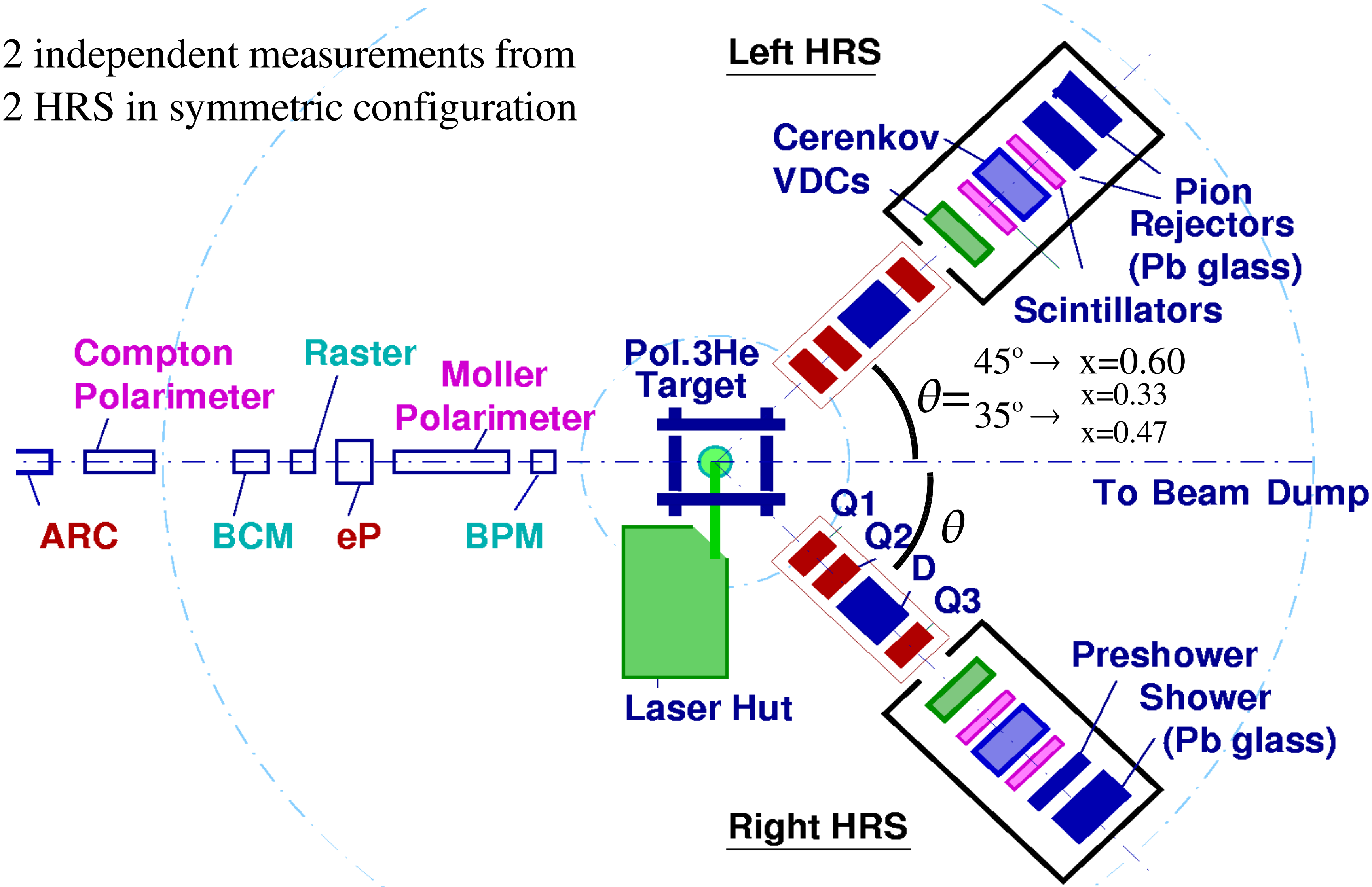


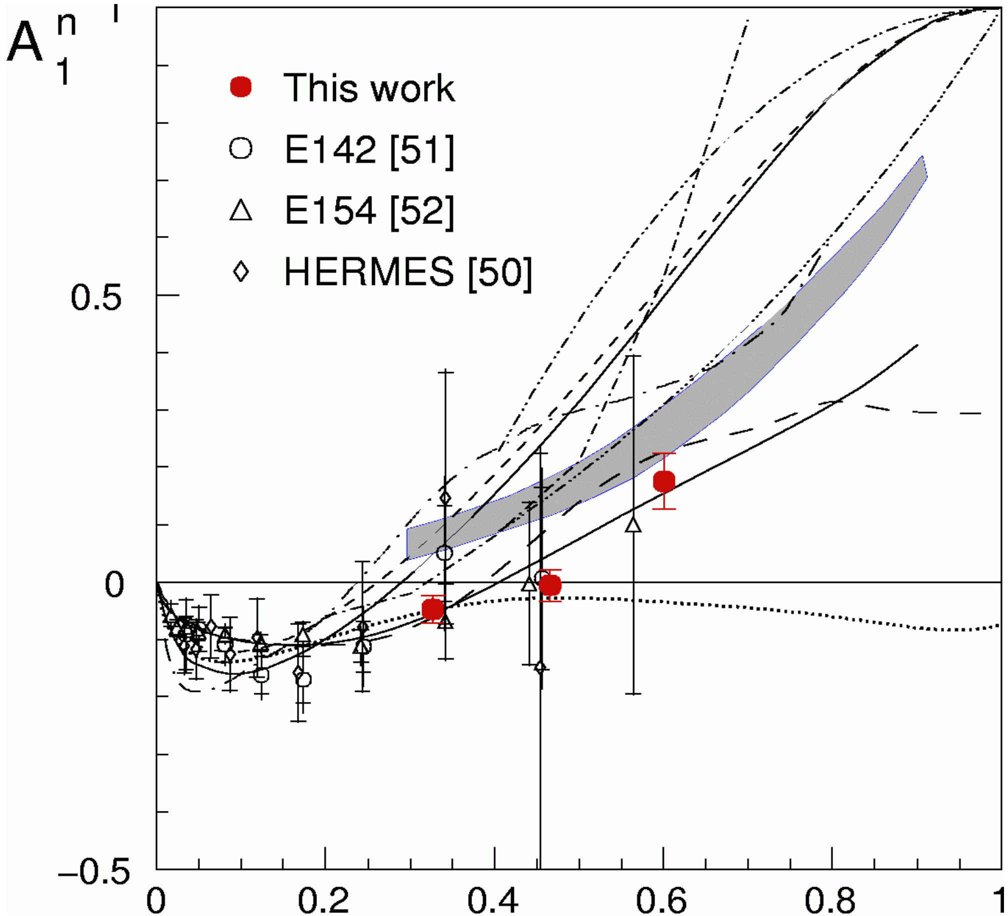
Hall A Experiment E99-117

2 independent measurements from
2 HRS in symmetric configuration



$A_1 = \frac{1}{D}(\alpha A_{\parallel} + \beta A_{\perp})$ with $D(\sigma^L/\sigma^T)$

+ radiative correction, $^3He \rightarrow n$ corrections, etc...



Analysis by X. Zheng

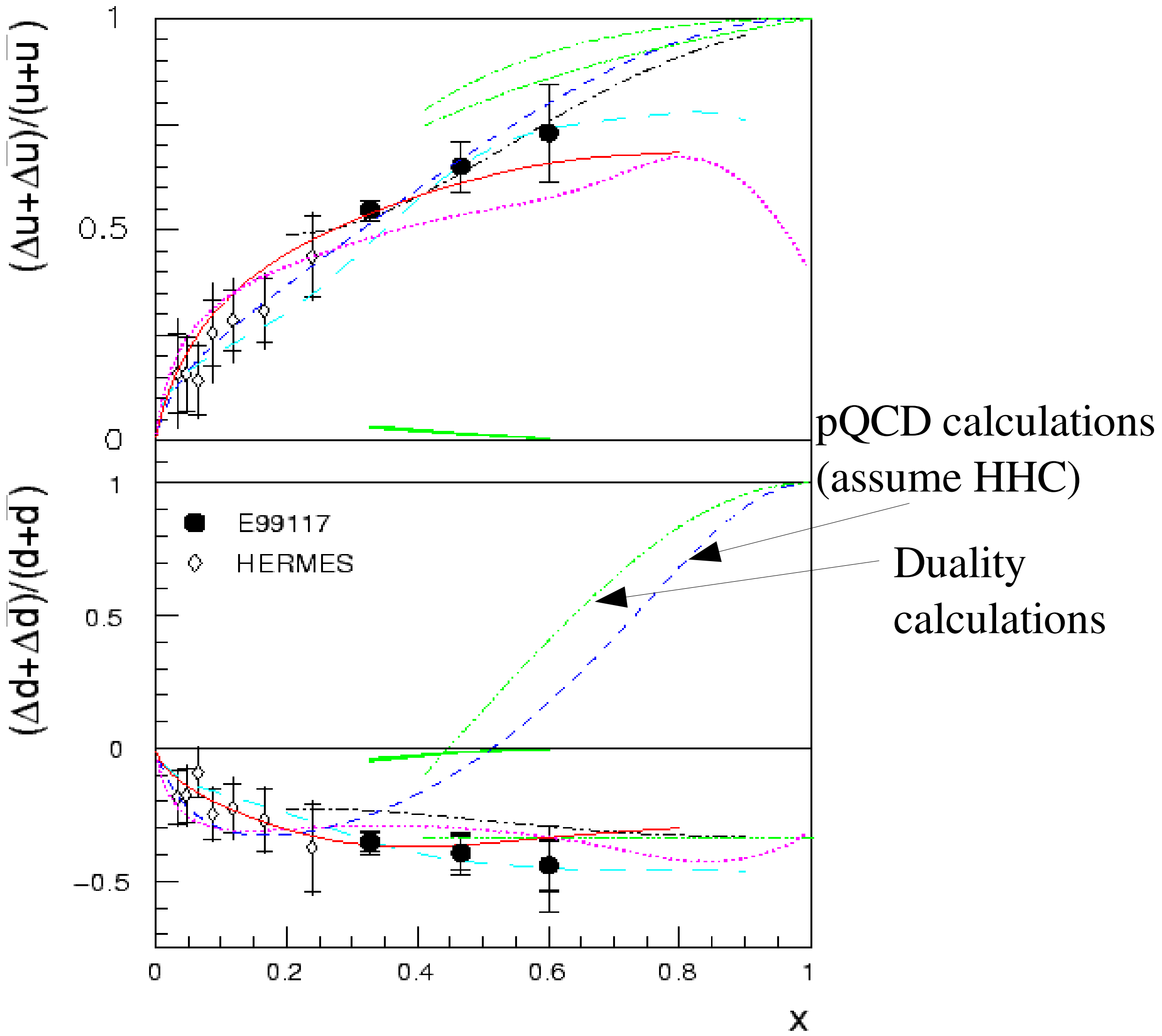
A_1^n clearly positive.

Polarized Quark Distributions

Combine A_1^n, A_1^p and d/u results

Δu/u follows expectations
Δd/d disagrees with pQCD calculation

⇒Role of quark OAM ?



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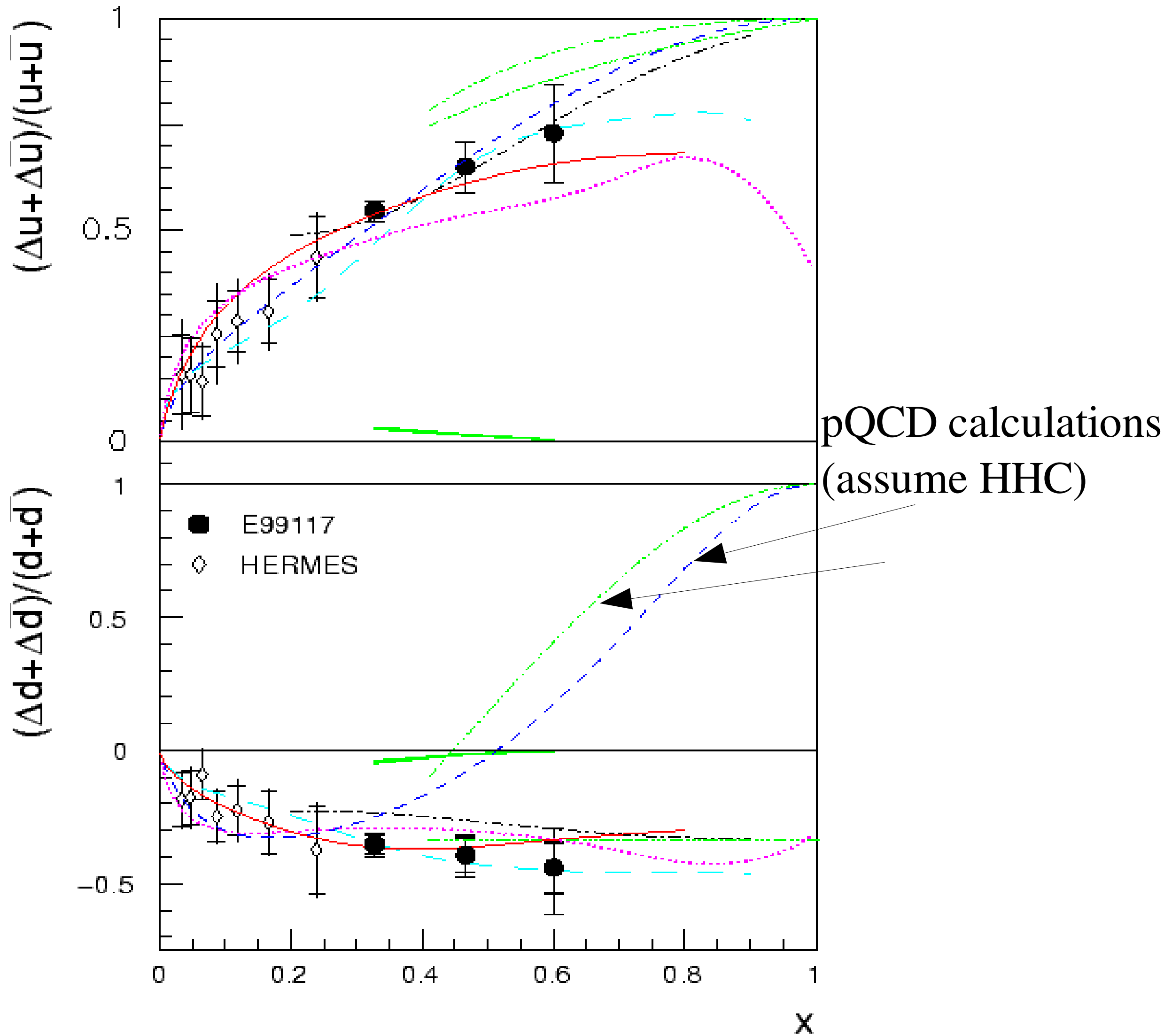
⇒Role of quark OAM ?

This result went to the news ! :

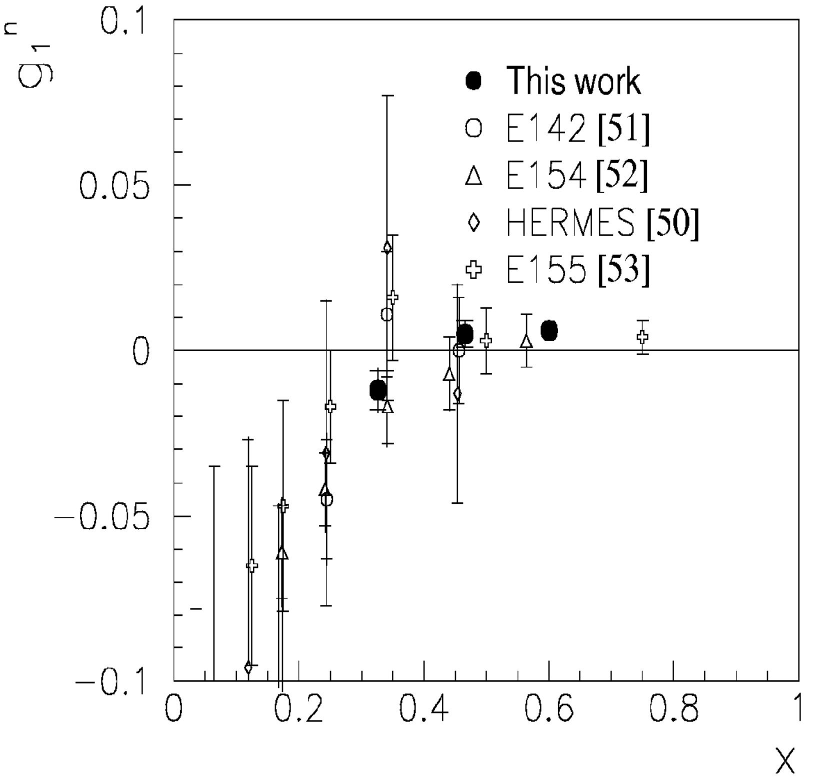
AIP Physics News Update,
Physics Today Update,
Science Online (Science Now),
Science News,
DNP web feature article.



Other results from E99-117 at large-x

g_1^n, g_2^n and A_2^n,

Better precision than world data at large x



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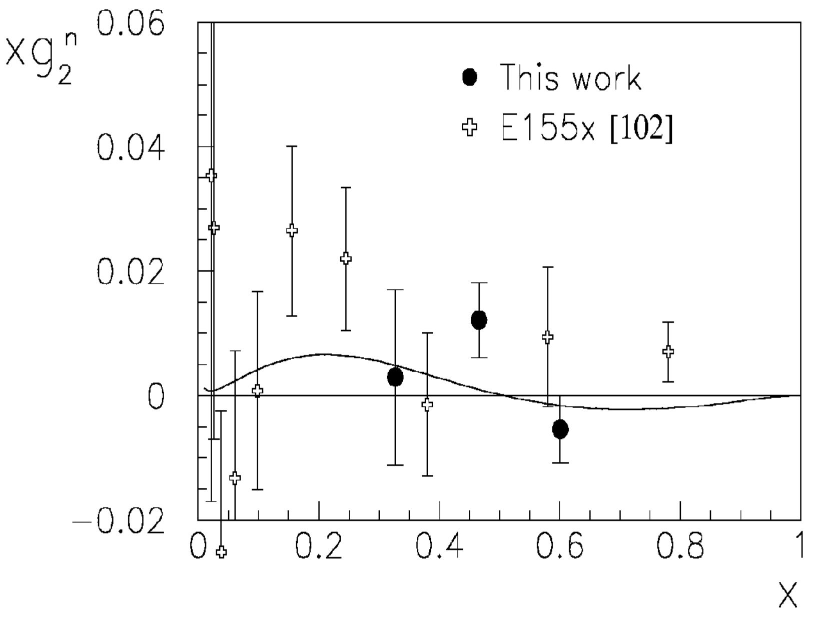
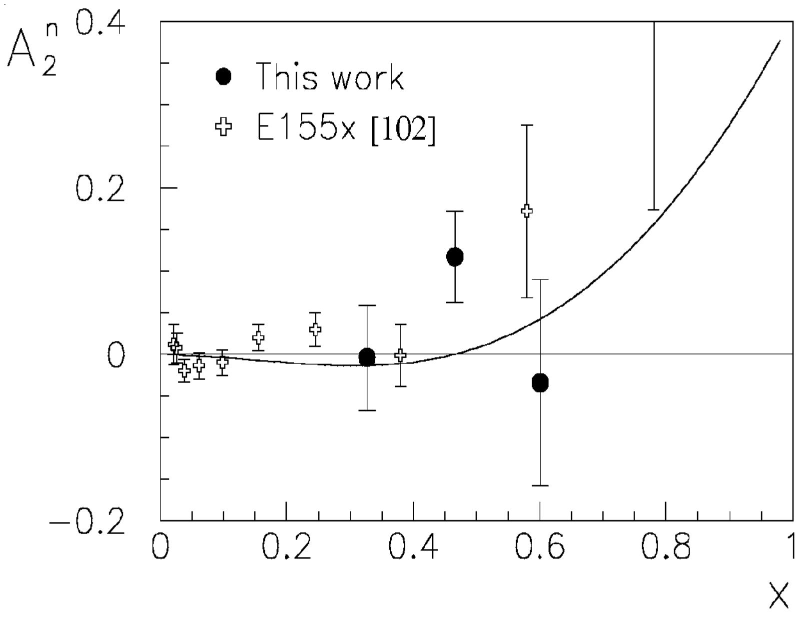


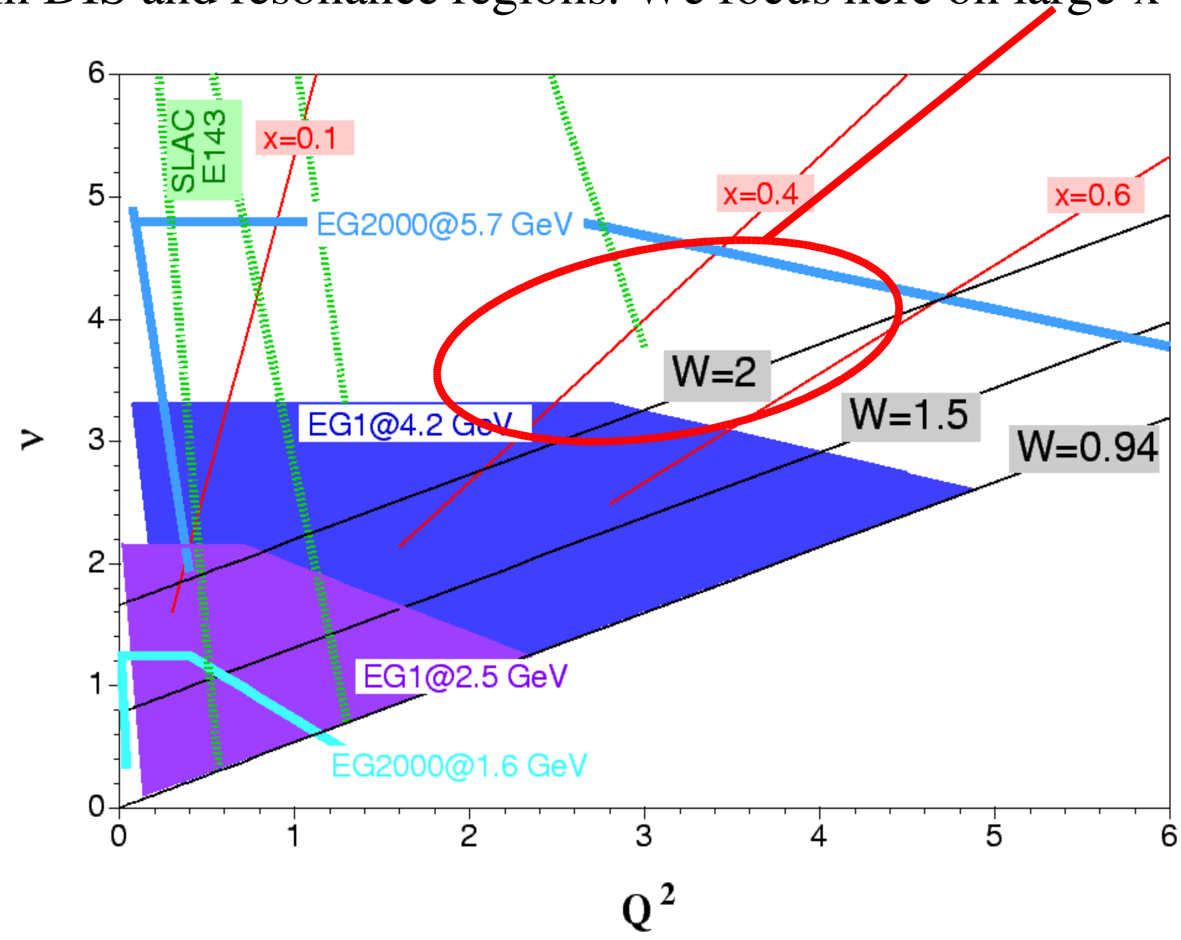


⇒ Twist 3 coefficient $d_2 = 3\int x^2(g_2 - g_2^{WW})dx = 0.0062 \pm 0.0028$

Hall B EG1 experiment

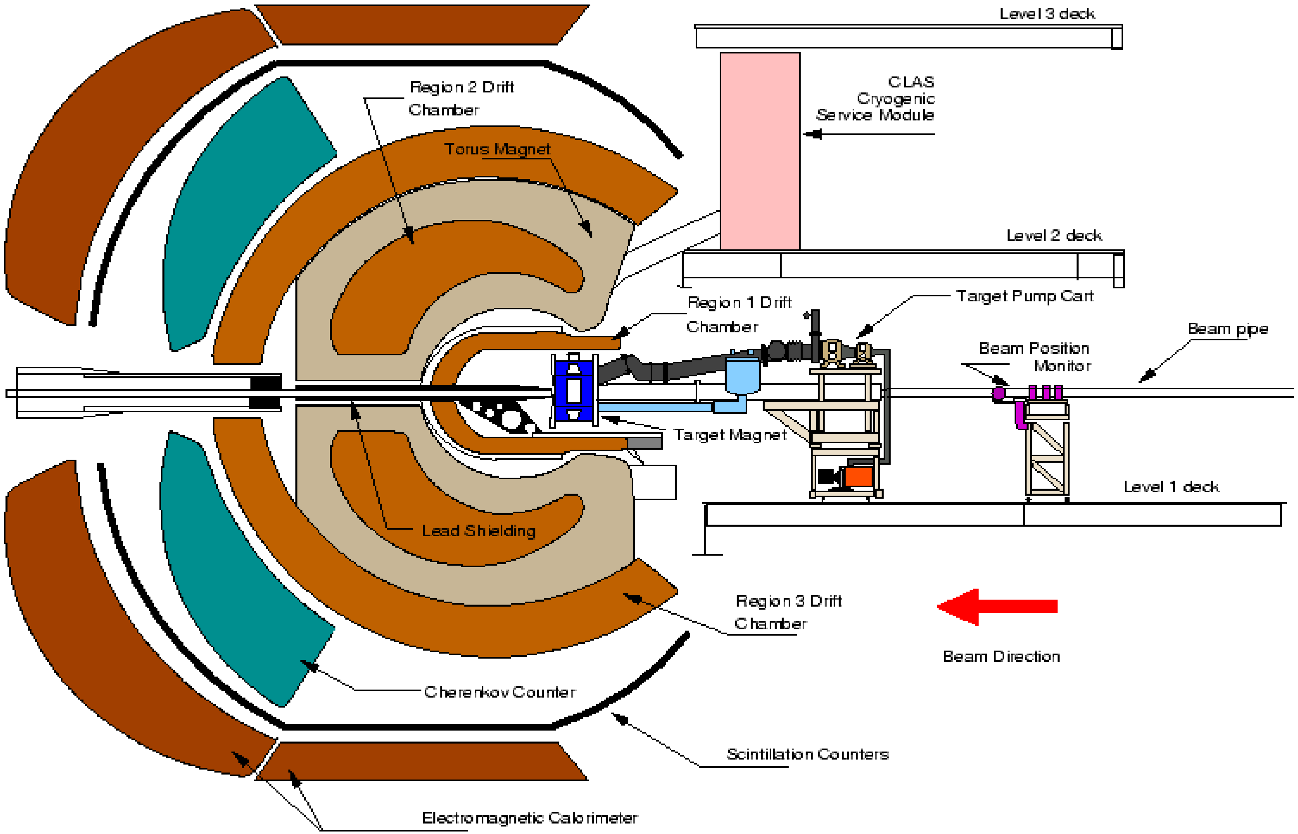
Doubly polarized inclusive $\vec{H}(\vec{e},e')$ and $^2\vec{H}(\vec{e},e')$

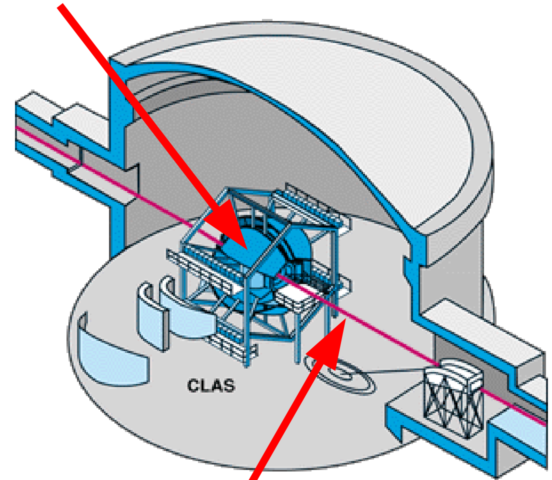
Measured $A_{\parallel}$ in DIS and resonance regions. We focus here on large-x



CLAS Detector

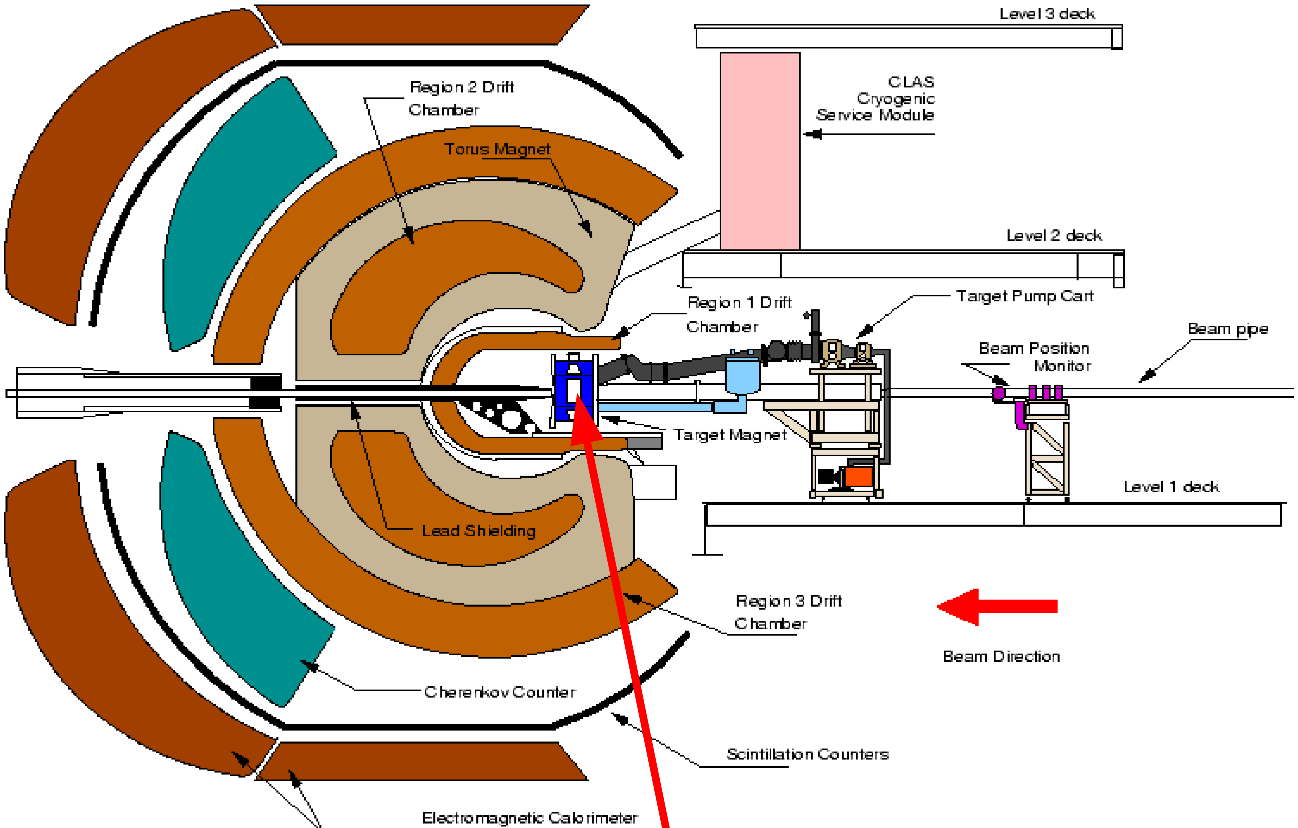
Large acceptance: ~2.5π





Beam current: ~nA

CLAS Detector



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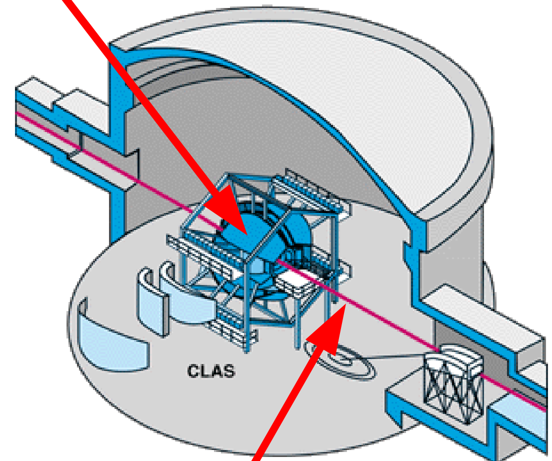


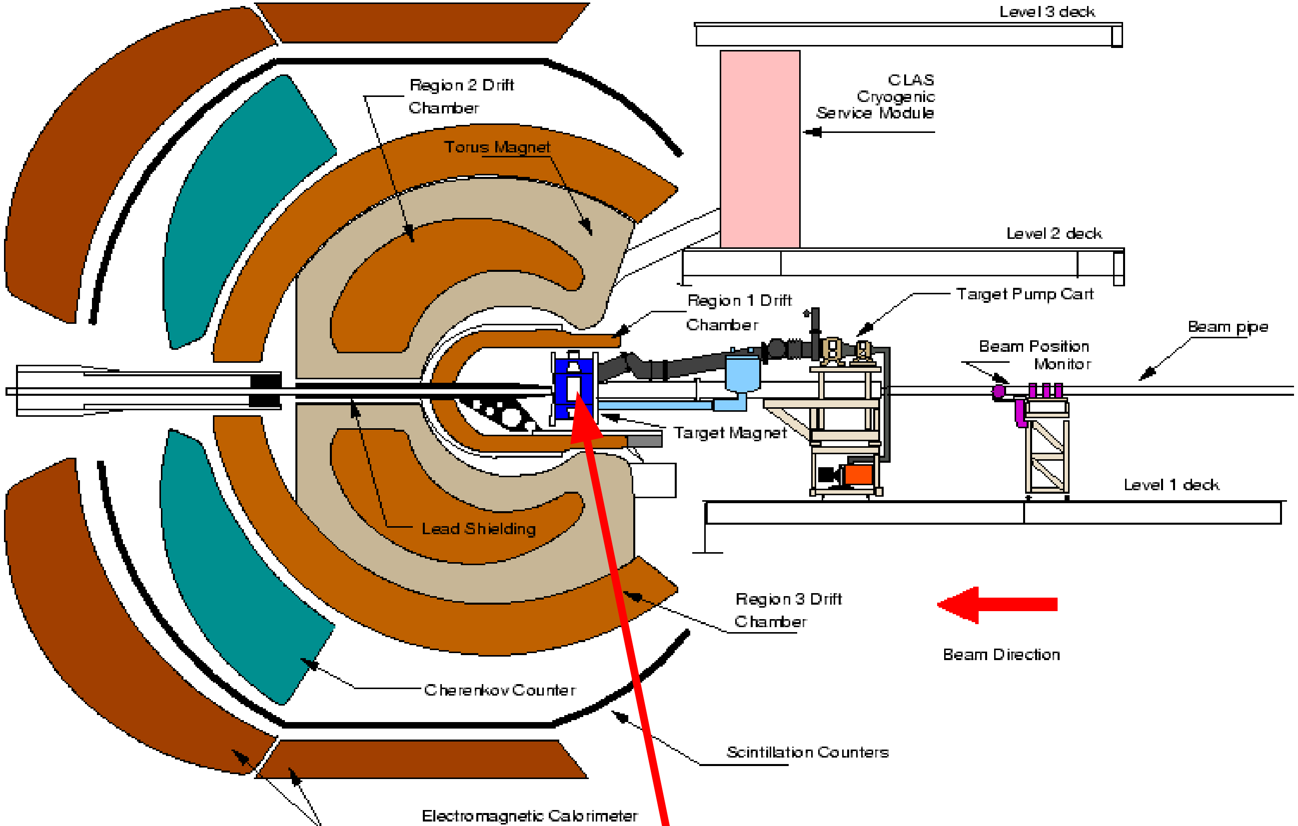
Beam current: ~nA

$\Rightarrow \mathscr{L}$=~10^{33} s^{-1} cm^{-2}

NH_3 or ND_3 1cm cells

Typical Pol.: 70% 30%

CLAS Detector



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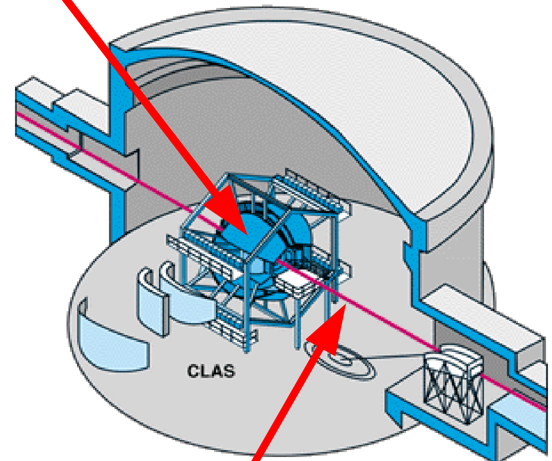

Beam current: ~nA

$\Rightarrow \mathscr{L} = \sim 10^{33}\ s^{-1}\ cm^{-2}$

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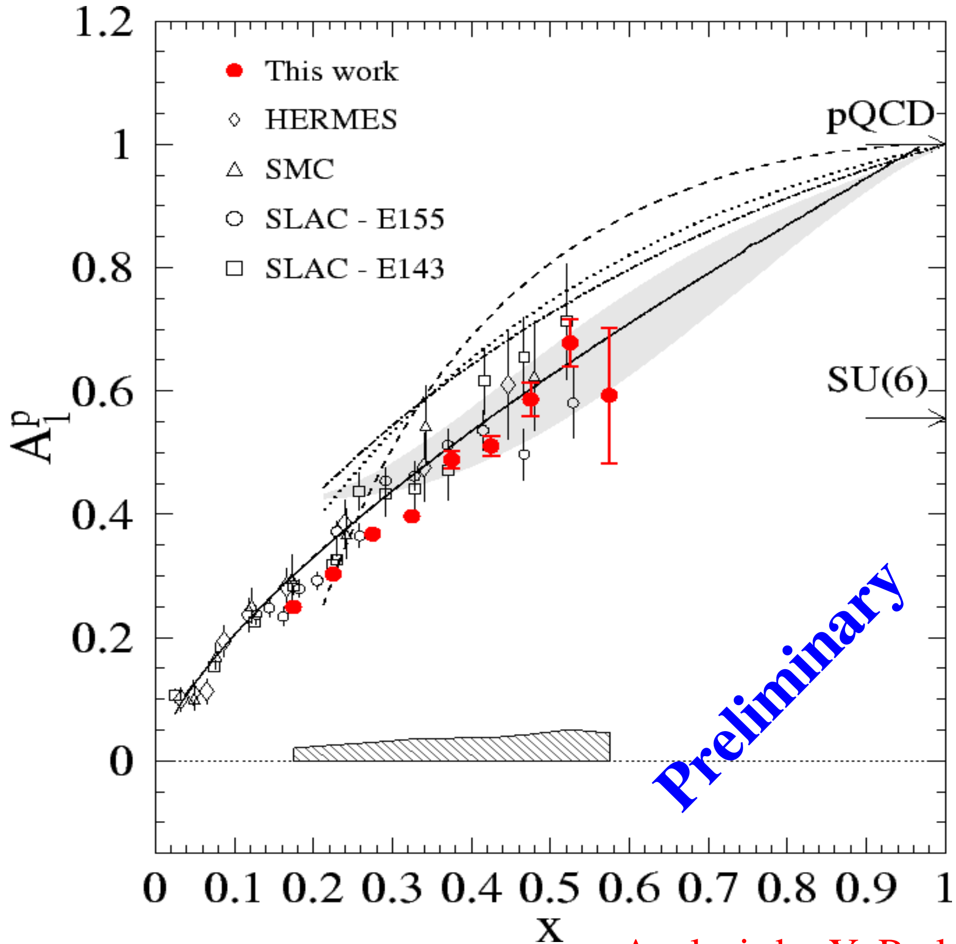
Typical Pol.: 70% 30%

$\Rightarrow$ f.o.m: $\begin{cases} NH_3 : 3\times10^{15} \\ ND_3 : 1\times10^{15} \end{cases}$ (but not all the data are at large x)

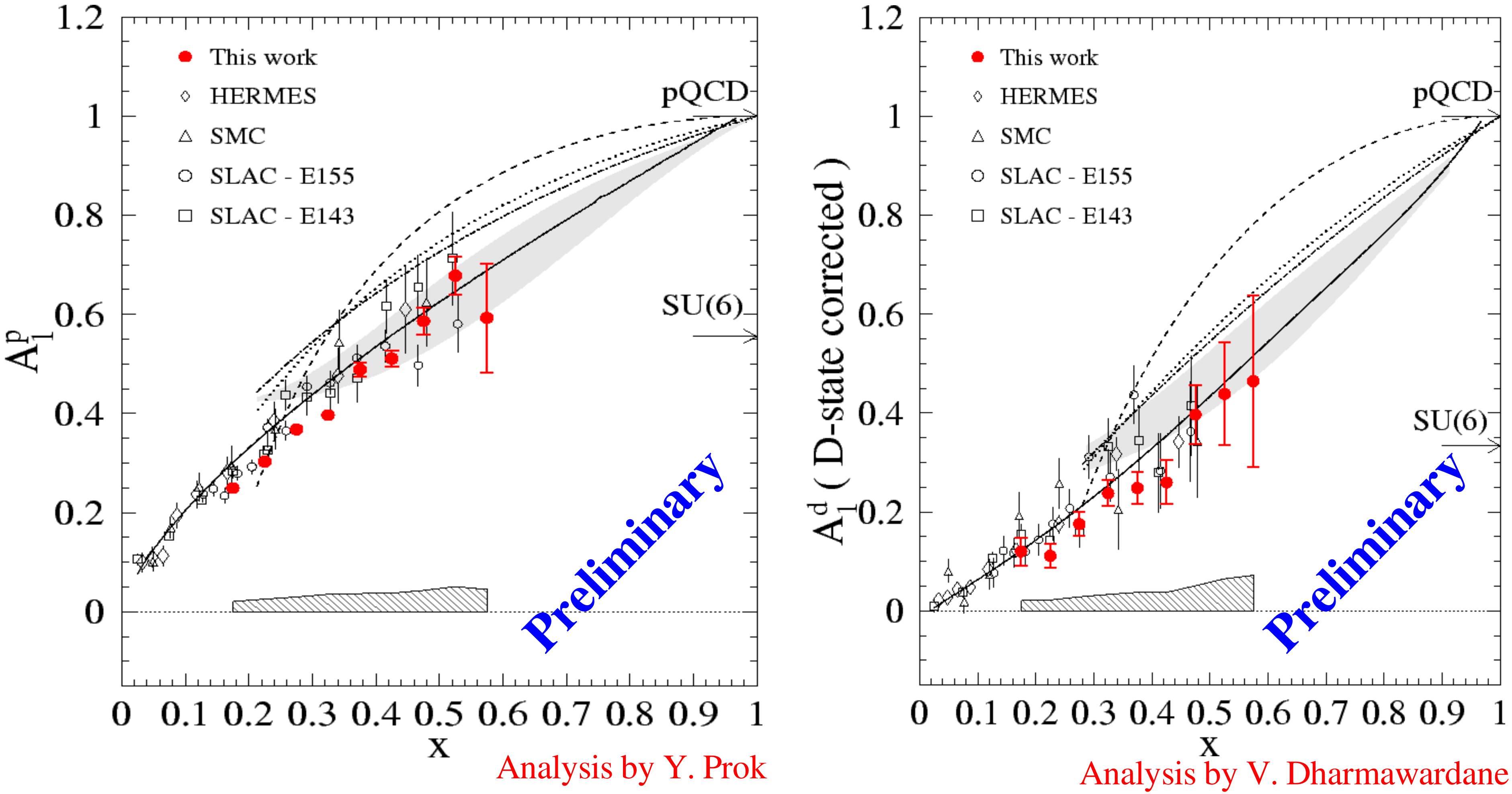
A_1^p and A_1^d at Large x



Analysis by Y. Prok

Q^2>1 GeV^2, W>2 GeV

A_1^p and A_1^d at Large x



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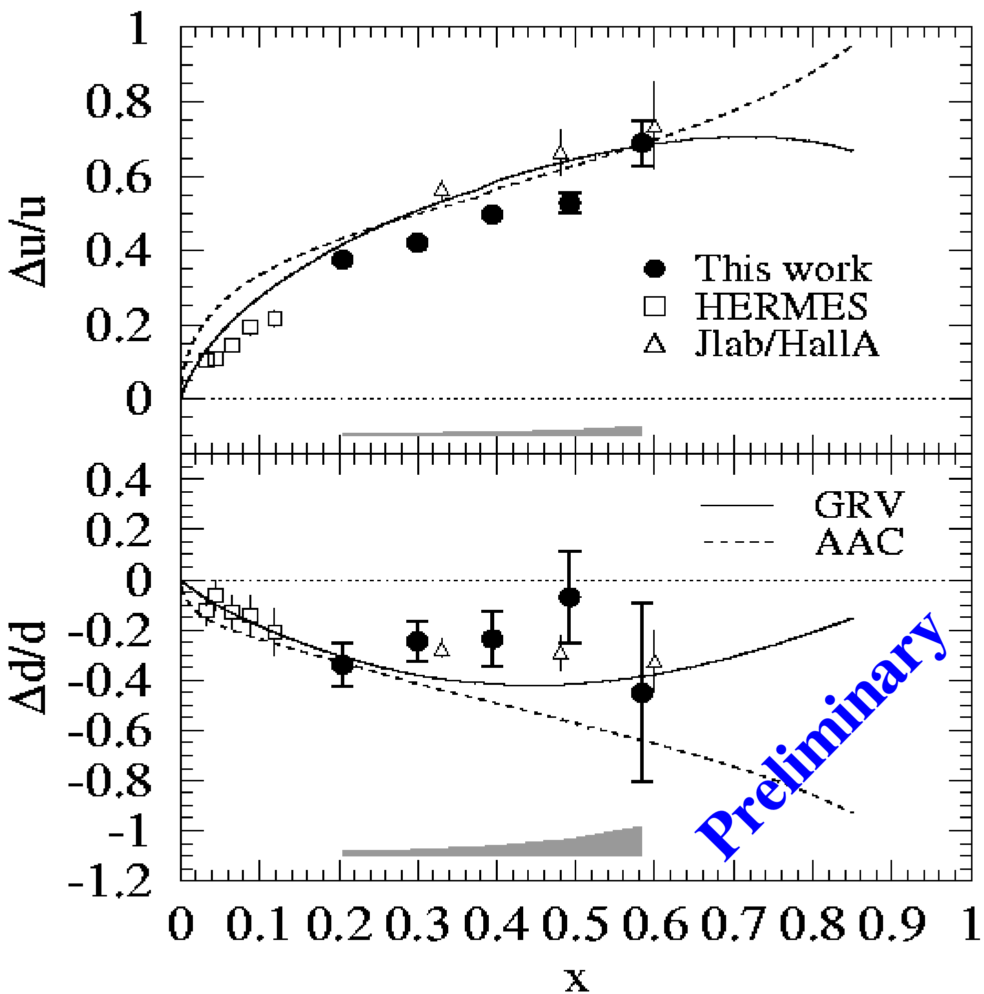
Polarized Quark Distributions



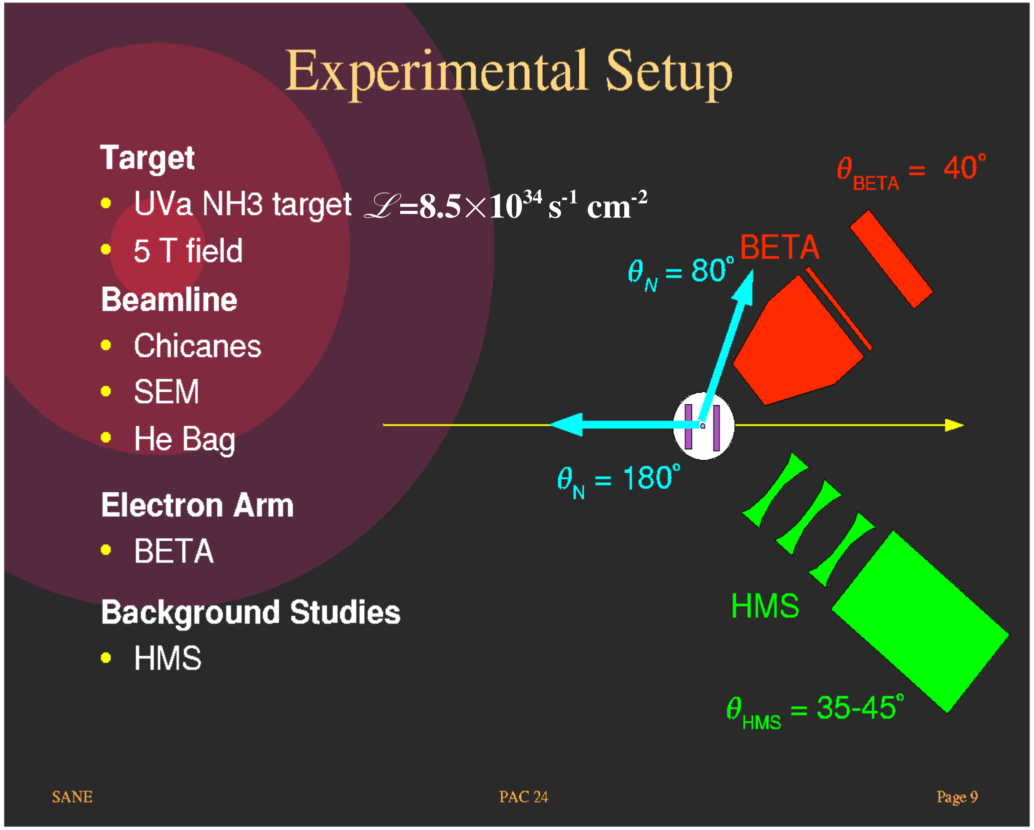
Q^2>1 GeV^2, W>1.75 GeV

Future large x experiment: SANE

Spin Asymmetries on the Nucleon Experiment

Spokespeople: O. Rondon, Z-E Meziani and Seonho Choi

Will measure A_1^P and g_2^P at $0.3<x<0.8$ and $2.5<Q^2<6.5$ GeV^2.



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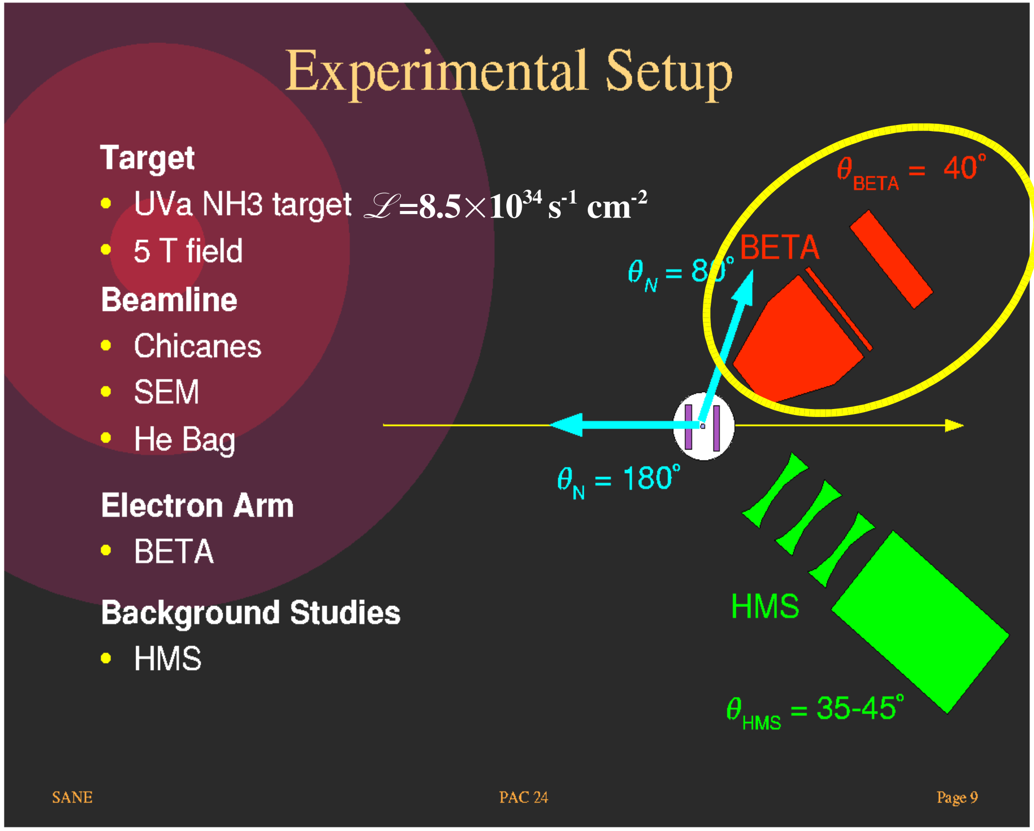

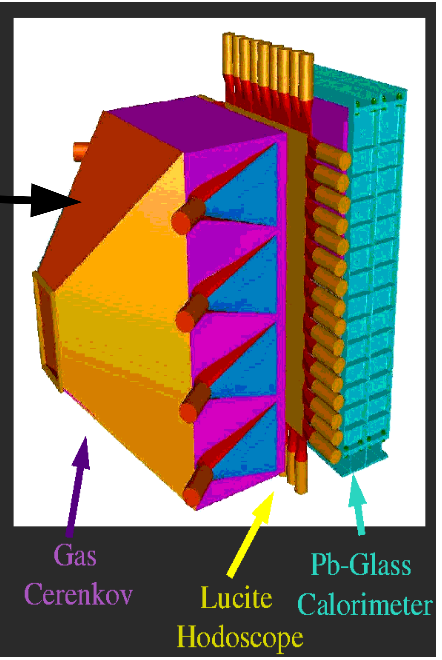

$\Delta\Omega$~200 mSr

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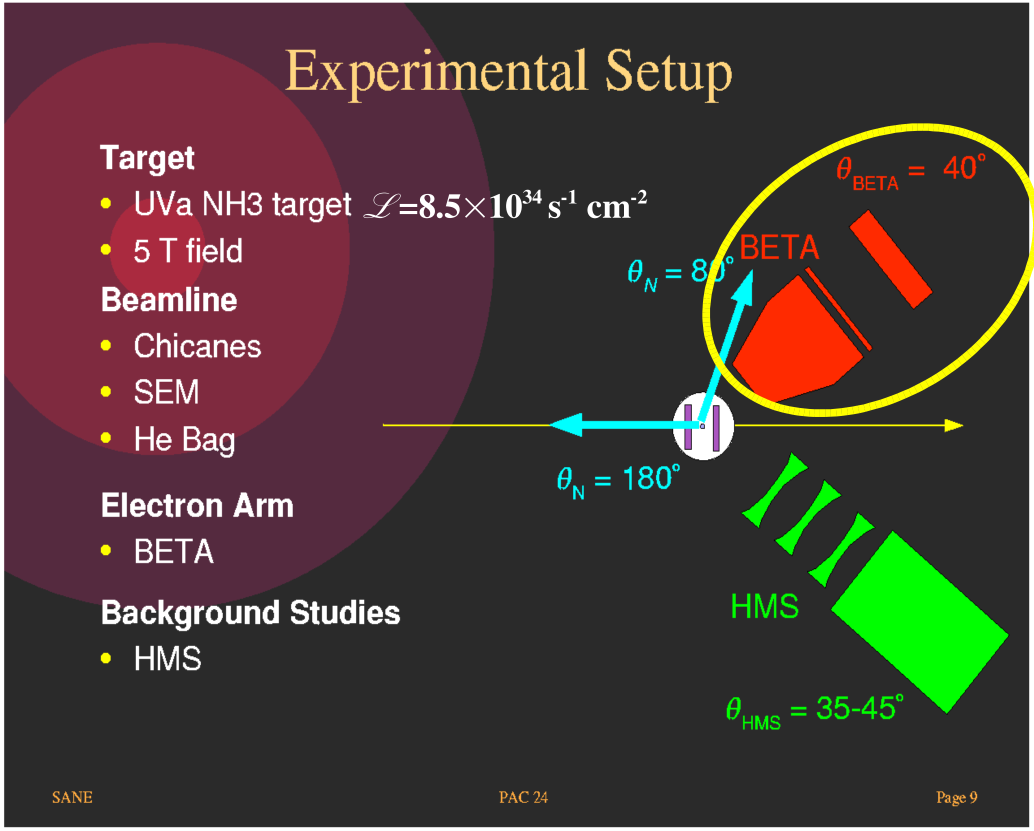
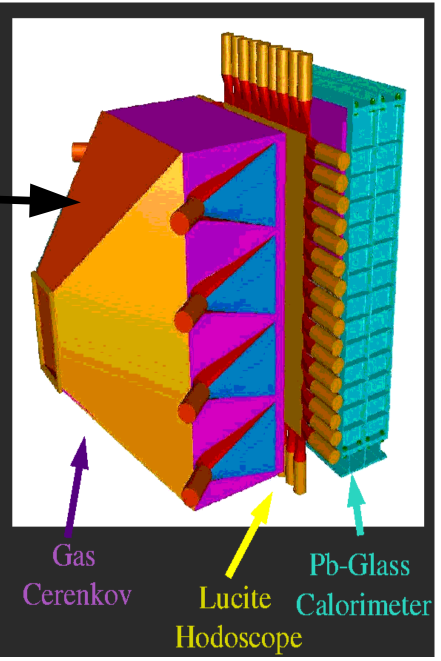


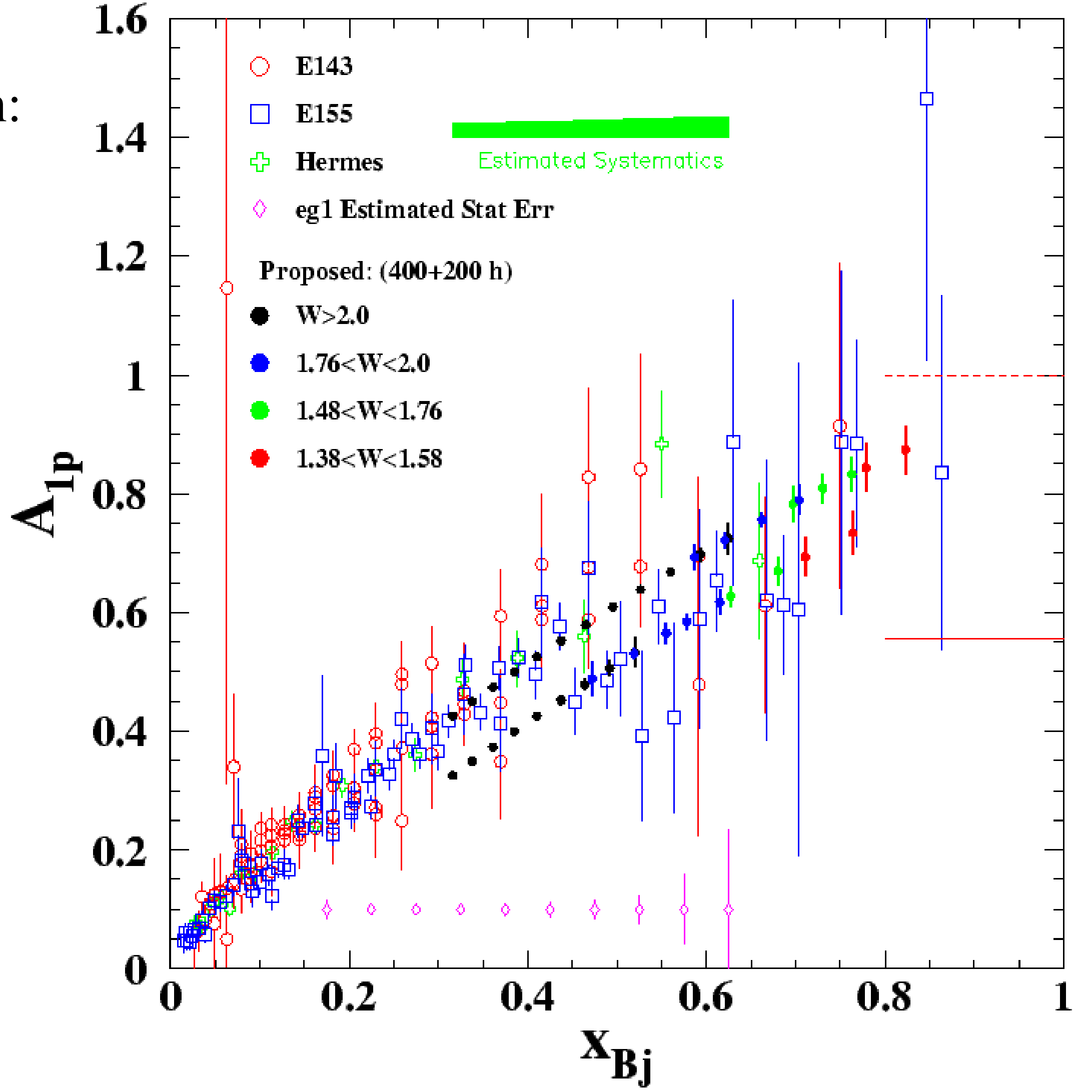


$\Delta\Omega$~200 mSr

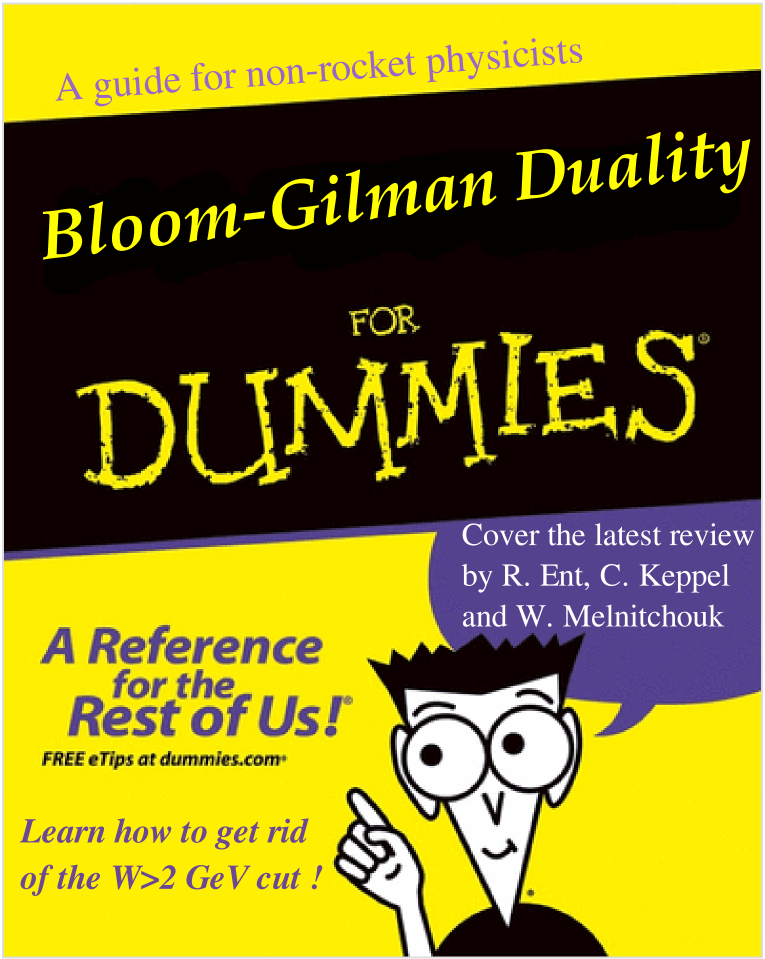
f.o.m: 3×10^{16} (assuming P_T=70% & and P_B=80%

Future large x experiment: SANE

Expected precision:



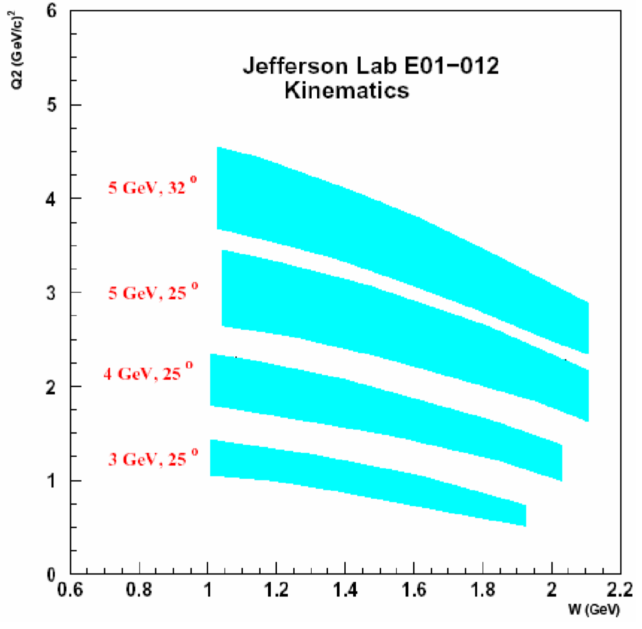
A Possible Easier Way to Access Large x: Quark-Hadron Duality



Quark-hadron duality: Resonance data on structure functions follow DIS data when averaged over resonances (i.e. overall highertwist effects are small).

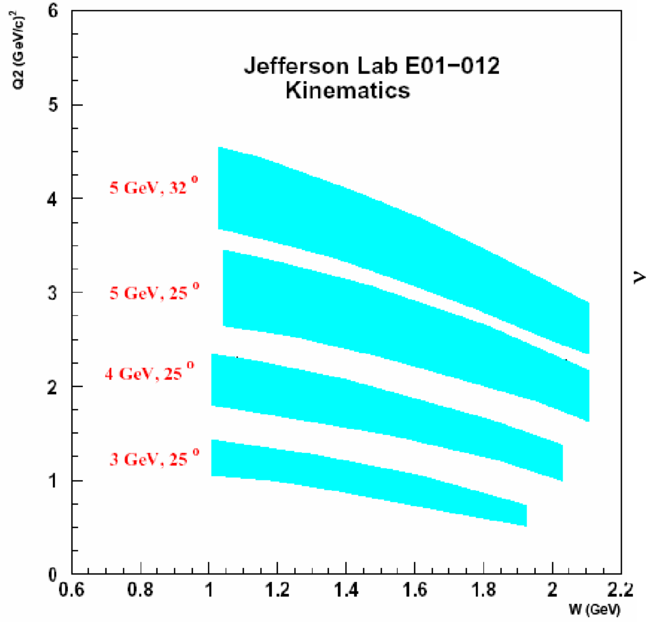
Quark-Hadron Duality in Spin Sector

Hall A Experiment E01-012

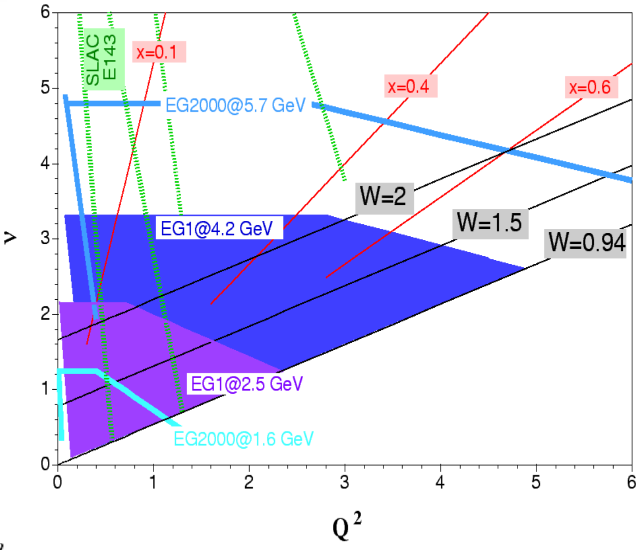


Quark-Hadron Duality in Spin Sector

Hall A Experiment E01-012

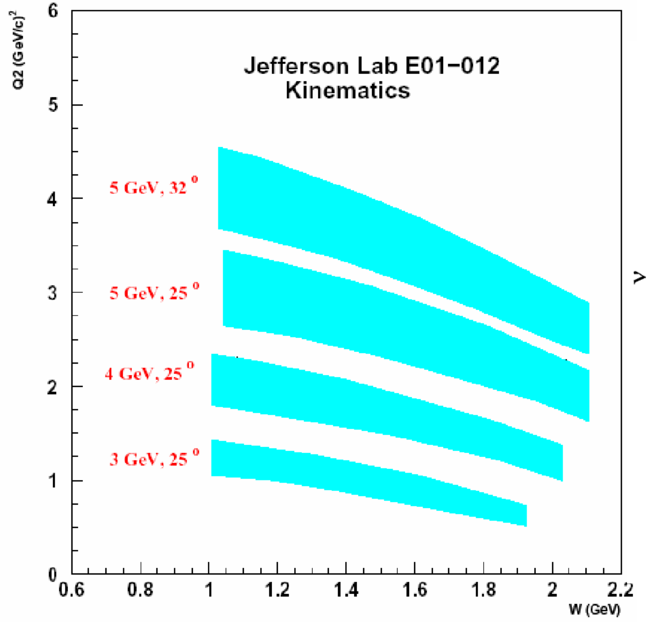


Hall B Experiment EG1



Quark-Hadron Duality in Spin Sector

Hall A Experiment E01-012



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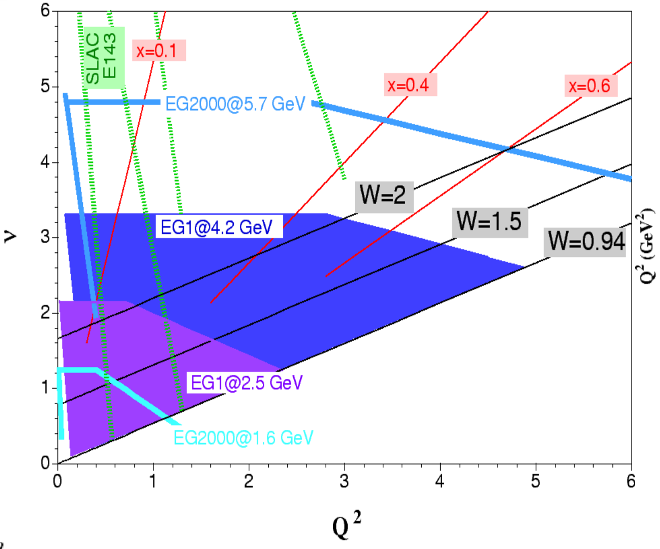
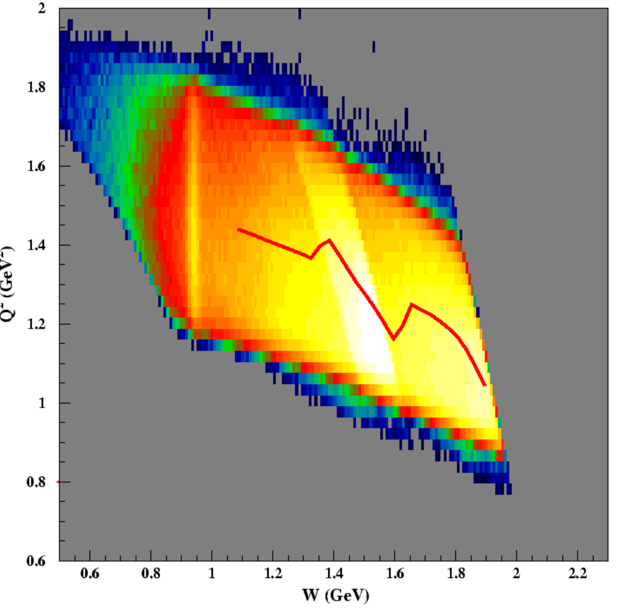
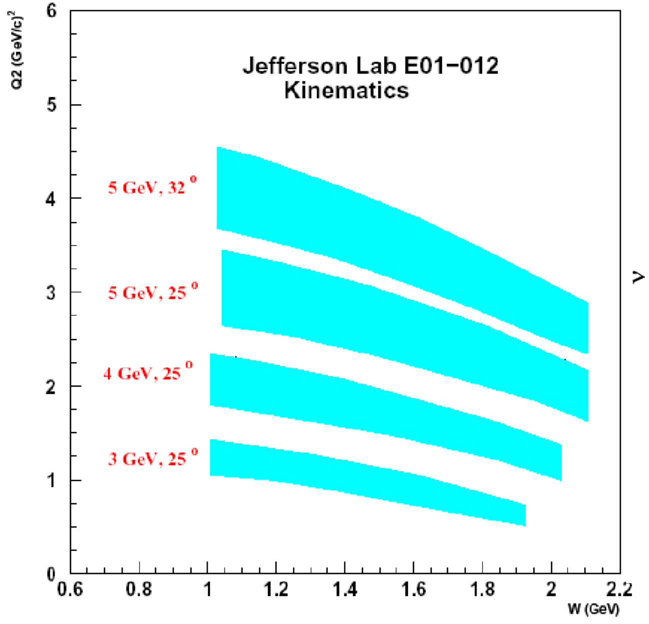


Hall C Experiment RSS

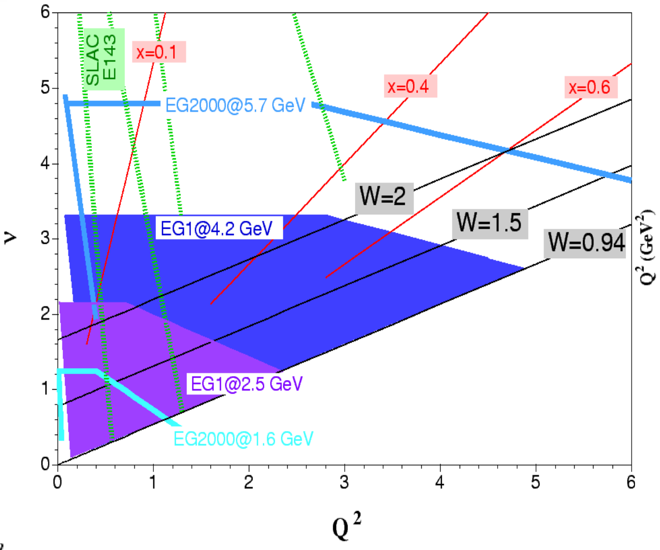


Quark-Hadron Duality in Spin Sector

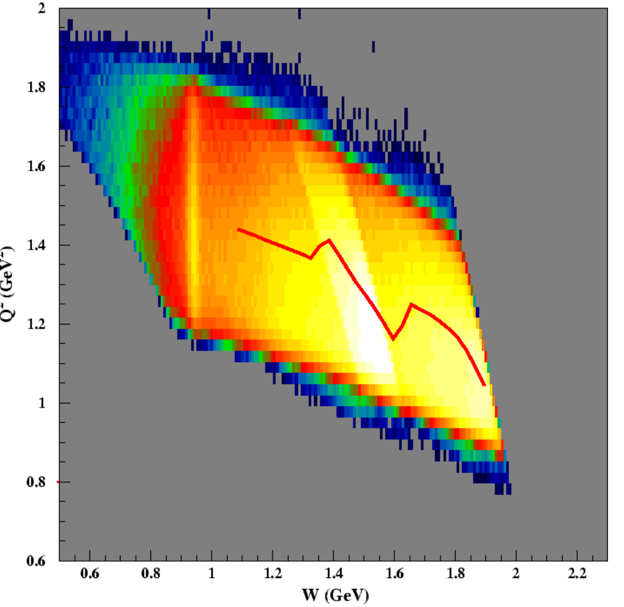
Hall A Experiment E01-012



Hall B Experiment EG1



Hall C Experiment RSS



These data: to be compared to DIS

If duality is established within the theory (and not just observed empirically)

⇒resonance data can be used to:

- Investigate large x physics with much higher statistics
- Push forward the high-x frontier

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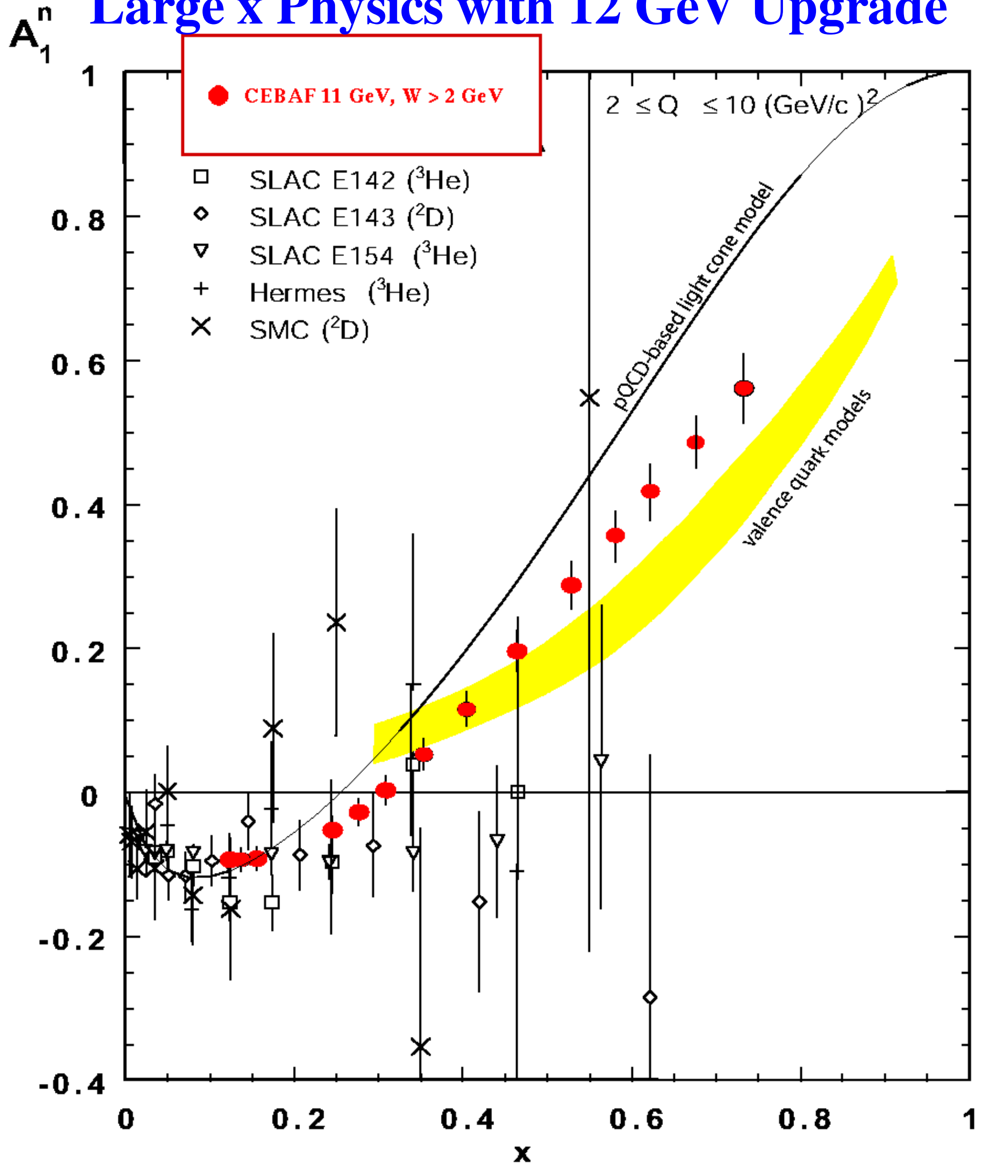
or/and

Establish Parton-Hadron duality at any x

(and know to what accuracy it is valid)

Large x Physics with 12 GeV Upgrade



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