High-x Physics in Hall C with 12 GeV

- 9 approved Hall C experiments from PAC30 + PAC32
  - ➡ Many of them push into the high-x, DIS region
- SIDIS, GPDs, DVCS and other "classes" of experiments are highlighted in their own forum/talks.
- I will focus on two particular experiments:
  - ➡ A_1^n (precision measurement focusing on g_1 for the neutron)
  - ➡ d_2^n (precision measurement focusing on g_2 for the neutron)

Experiment	Targets	Lengths (cm)	Currents (µA)	Angles (°)	Energies (GeV)
PAC30 Approved and Conditionally Approved Experiments					
Fpi12 (E12-06-101)	LH2, LD2, Al	8 (4)	15-90	5.5-13	2.8-10.9
[illegible]	[illegible]	[illegible]	[illegible]	5.5-13	2.8-10.9
R=L/T (E12-06-104)	LH2, LD2, Al	10	50	5.5-13	6.6-11.0
x>1 (E12-06-105)	LD2, He3, He4, Be(2%), C(1.5%), Cu(6%), Au(6%)	4	20-80	8-26	1.5-11.0
Color Transparency (E12-06-107)	[illegible]	[illegible]	[illegible]	5.52-22.73	8.8, 11.0
[illegible]	[illegible]	40	[illegible]	12.5, 30.0	11.0
g2 (E12-06-121)	^{3}He polarized	40	5-30	11-20	11.0
PAC30 LOI					
GEp (LOI-06-103)	LH2	30	75	15.7-25	6.6-11.0
Pi+ high pT (LOI-06-104)	LH2	8	90	10.06-38.474	6.0, 10.9
Photodisintegration LD2 (LOI-06-105)	LH2, LD2	15	30	12.98-28.09	2.268-6.667
[illegible]	[illegible]	[illegible]	85	[illegible]	[illegible]
EMC effect (LOI-06-106)	LH2, LD2, He3, He4, Li, Be, C, Al, Ca, Cu, Ag, Au	4	85	20-40	11.0
PAC32 Approved and Conditionally Approved Experiments					
Pion Factorization (E12-07-103)	LH2, LD2, Al	8	90	5.5-23.05	3.7-10.9
DIS-parity (E12-07-102)	LH2,LD2	20,40	10,85	13.5	6.6,11
J/psi production near threshold (E12-07-106)	LH2,LD2,Be,C,Al,Cu,Ag,Au	10% RL	50	8.0-19.1	11,10.2,8.8

* Table from http://www.jlab.org/~hornt/hallc_12gev/shms_experiments.html (T. Horn)

Why A_1^n and d_2^n?

- JLab is uniquely positioned to break new ground
  - 12 GeV upgrade allows us to access the important high-x region with unprecedented precision
    - High luminosities (Unprecedented statistics)
    - Well understood, high precision detector packages that can handle the rates (Excellent systematics)
  - JLab has the best polarized target groups in the world
    - Polarized neutron target (^{3}He)
- Polarized ^{3}He as a polarized neutron target has made a whole class of precision tests possible!
  - Probing spin in the neutron is one of the most interesting frontiers at JLab.

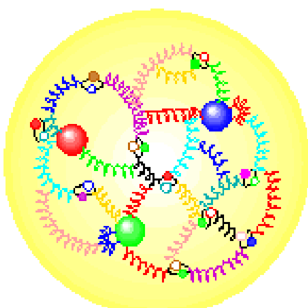
Measurement of A_1^n at 12 GeV

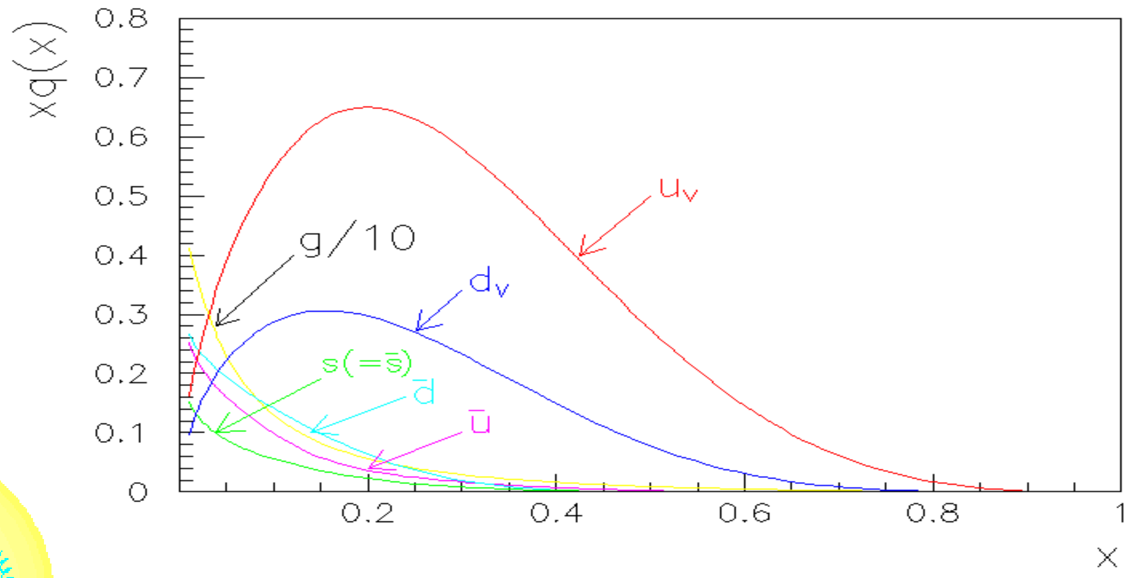
G.D. Cates (UVa), J.P. Chen (JLab), Z.-E. Meziani (Temple U), X. Zheng (UVa)

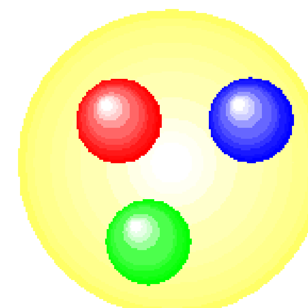
- 1988-1989: "The Proton Spin Crisis"
- Current understanding of the nucleon spin:
- $\frac{1}{2} = S_Z^N = S_Z^q + L_Z^q + J_Z^G$ (the spin "sum rule")
  - ➡ Quark spin contributes about (20~30)% to the nucleon spin
  - ➡ Little data exist on L_Z^q and J_Z^G.
- Understanding spin structure of the nucleon requires measurements of all three components, and to answer *the* question:
  - ➡ "*CAN WE UNDERSTAND THESE DATA from the first principles in QCD?*"
- However, the region where we can test QCD is limited due to the complication in QCD calculations
  - ➡ moments, structure functions at high x.

NOTE: A_1^n slides are drawn from X. Zheng and N. Liyanage's PAC presentations.

Why Large x?







- At large x, valence quarks dominate, easier to model;
- Smaller contribution from q-$\bar{q}$ sea and gluons
  - ➡ a relatively clean region to study the nucleon structure;
- To understand the nucleon spin, high-x is a good place to start.

Cross sections and Structure Functions

Unpolarized case:

$$\frac{d^2\sigma}{d\Omega dE'} = \frac{\alpha^2}{4E^2 \sin^4 \frac{\theta}{2}} \left(\frac{2}{M} F_1(x,Q^2) \sin^2 \frac{\theta}{2} + \frac{1}{\nu} F_2(x,Q^2) \cos^2 \frac{\theta}{2} \right)$$

Polarized beam + target:

$$\frac{d^2\sigma}{dE'd\Omega}(\downarrow\Uparrow - \uparrow\Uparrow) = \frac{4\alpha^2}{MQ^2}\frac{E'}{\nu E}\left[(E + E'\cos\theta) g_1(x,Q^2) - \frac{Q^2}{\nu} g_2(x,Q^2)\right] = \Delta\sigma_{\parallel}$$

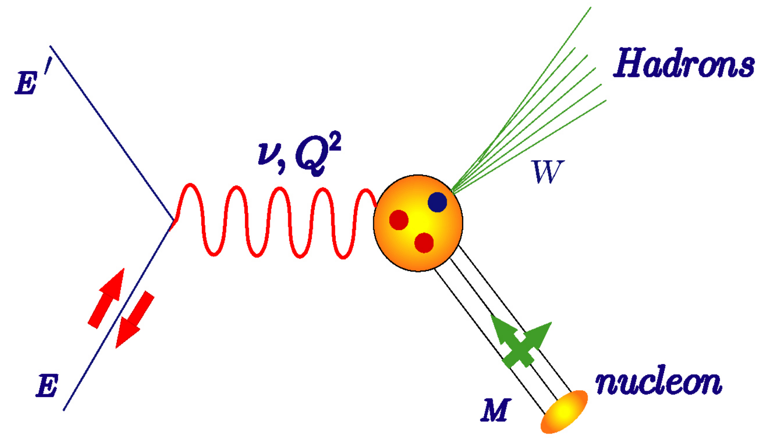
$$\frac{d^2\sigma}{dE'd\Omega}(\downarrow\Rightarrow - \uparrow\Rightarrow) = \frac{4\alpha^2 \sin\theta}{MQ^2}\frac{E'^2}{\nu^2 E}\left[\nu g_1(x,Q^2) + 2E g_2(x,Q^2)\right] = \Delta\sigma_{\perp}$$

Q^2 = 4-momentum transfer squared of the virtual photon.

ν = energy transfer.

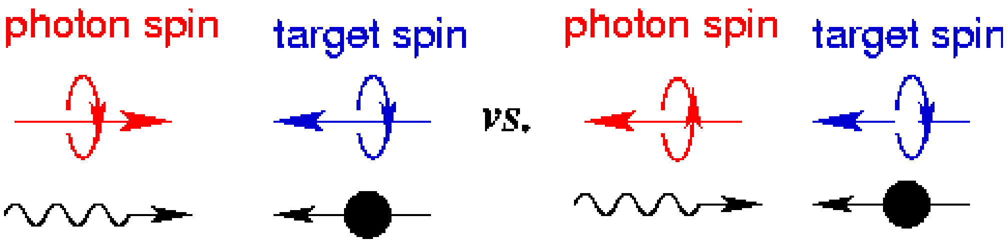
θ = scattering angle.

$x = \frac{Q^2}{2M\nu}$ fraction of nucleon momentum carried by the struck quark.



Virtual Photon Asymmetries

- Virtual photon asymmetry: $A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$



$$A_1 = \frac{g_1 - \gamma^2 g_2}{F_1} \approx \frac{g_1}{F_1} \quad \text{at large } Q^2 \qquad \gamma^2 = \frac{4M^2 x^2}{Q^2}$$

- A_1 nearly independent of Q^2 (g_1 and F_1 follow the same LO and NLO evolutions, but not in higher orders or higher twist effects).

Neutron Structure as $x_{Bj} \to 1$

$$\left|n^{\uparrow}\right\rangle = \frac{1}{\sqrt{2}}\left|d^{\uparrow}(ud)_{00}\right\rangle + \frac{1}{\sqrt{18}}\left|d^{\uparrow}(ud)_{10}\right\rangle - \frac{1}{3}\left|d^{\downarrow}(ud)_{11}\right\rangle$$

$$-\frac{1}{3}\left|u^{\uparrow}(dd)_{10}\right\rangle - \frac{\sqrt{2}}{3}\left|u^{\downarrow}(dd)_{11}\right\rangle$$

Model	F_2^n/F_2^p	d/u	Δ d/d	Δ u/u	A_1^n	A_1^p
SU(6) = SU(3) flavor ⊕ SU(2) spin	2/3	1/2	2/3	-1/3	0	5/9
Valence Quark + Hyperfine	1/4	0	1	-1/3	1	1
pQCD + HHC	3/7	1/5	1	1	1	1

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pQCD + HHC	3/7	1/5	1	1	1	1

- Nucleon spin carried by 3 constituent quarks alone, two in an S=0 or S=1 diquark state
- Exact SU(6) symmetry is (obviously) a naïve model:
  - ➡ Fails badly at low-x where sea-quarks dominate (A_1^p(x=0) is small)
  - ➡ R^{np}(x=0) ~ 1 then falls below 0.5 at high-x (SLAC, Fermilab, CERN)
    - Failure at high-x points to a fundamental problem with the wavefunction

Neutron Structure as $x_{Bj} \to 1$

$$|n^{\uparrow}\rangle = \frac{1}{\sqrt{2}}|d^{\uparrow}(ud)_{00}\rangle + \frac{1}{\sqrt{18}}|d^{\uparrow}(ud)_{10}\rangle - \frac{1}{3}|d^{\downarrow}(ud)_{11}\rangle - \frac{1}{3}|u^{\uparrow}(dd)_{10}\rangle - \frac{\sqrt{2}}{3}|u^{\downarrow}(dd)_{11}\rangle$$

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- Break the SU(6) symmetry through a 1-gluon exchange interaction
  - ➡ explains suppression of R^{np}, and the 300 MeV mass shift of the Delta
- Spin-Spin hyperfine interaction involving the S=0 diquark pair
  - ➡ lowers its energy and enhances its high-x contribution (driving A_1 -> 1 as x -> 1)
- Relativistic CQM allows non-zero quark OAM --> ~25% of nucleon spin

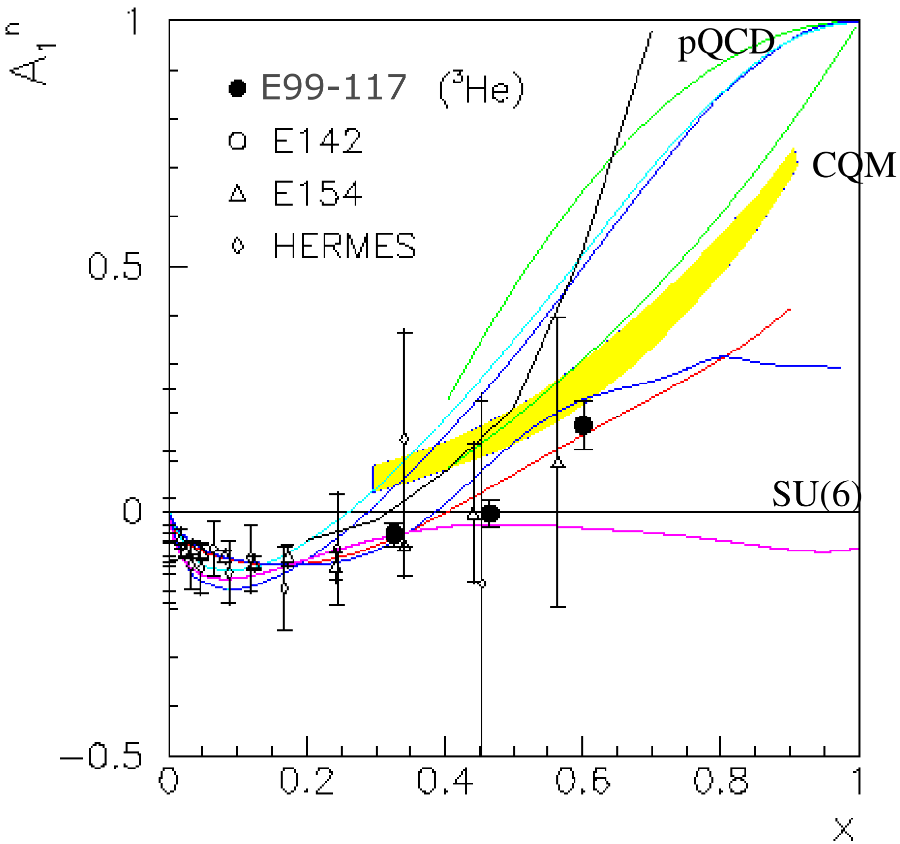
Neutron Structure as $x_{Bj} \rightarrow 1$

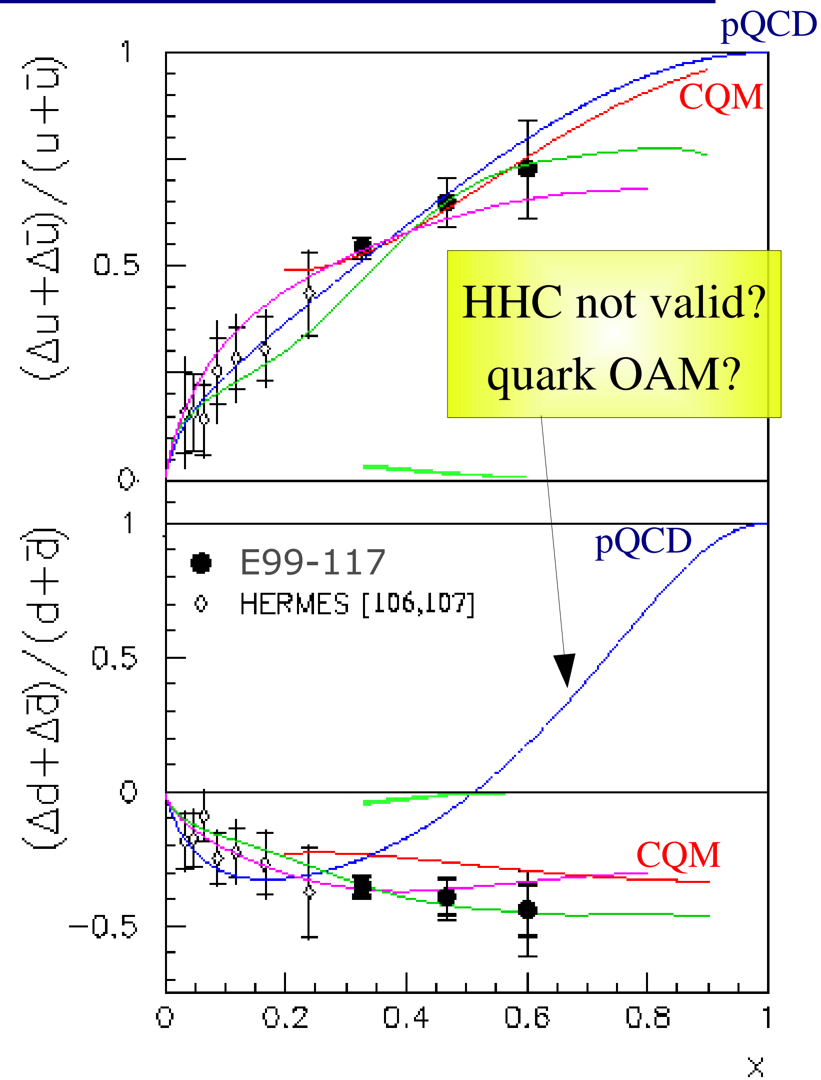
$$|n^{\uparrow}\rangle = \frac{1}{\sqrt{2}}|d^{\uparrow}(ud)_{00}\rangle + \frac{1}{\sqrt{18}}|d^{\uparrow}(ud)_{10}\rangle - \frac{1}{3}|d^{\downarrow}(ud)_{11}\rangle - \frac{1}{3}|u^{\uparrow}(dd)_{10}\rangle - \frac{\sqrt{2}}{3}|u^{\downarrow}(dd)_{11}\rangle$$

Model	F_2^n/F_2^p	d/u	$\Delta d/d$	$\Delta u/u$	A_1^n	A_1^p
SU(6) = SU(3) flavor ⊕ SU(2) spin	2/3	1/2	2/3	-1/3	0	5/9
Valence Quark + Hyperfine	1/4	0	1	-1/3	1	1
pQCD + Hadron Helicity Conservation	3/7	1/5	1	1	1	1

- At x=1, the scattering is from high-energy quark --> can treat interaction perturbatively
  - ➡ "leading order" pQCD
- quark-gluon interactions suppress S=1, S_z=1 pieces of the wavefunction
- HHC: assume no quark OAM --> struck quark must carry same spin as nucleon

World data for A_1^n and $\Delta q/q$



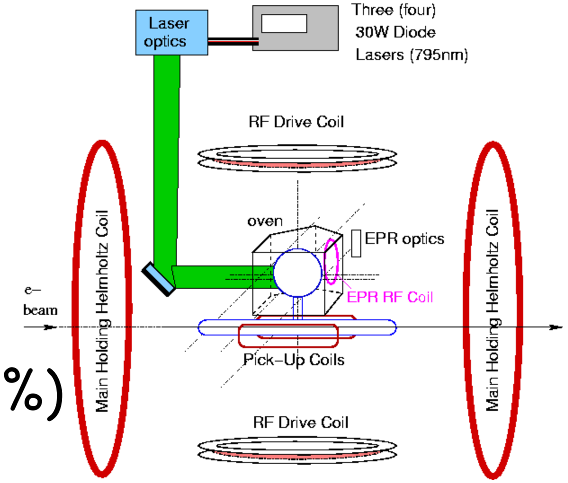


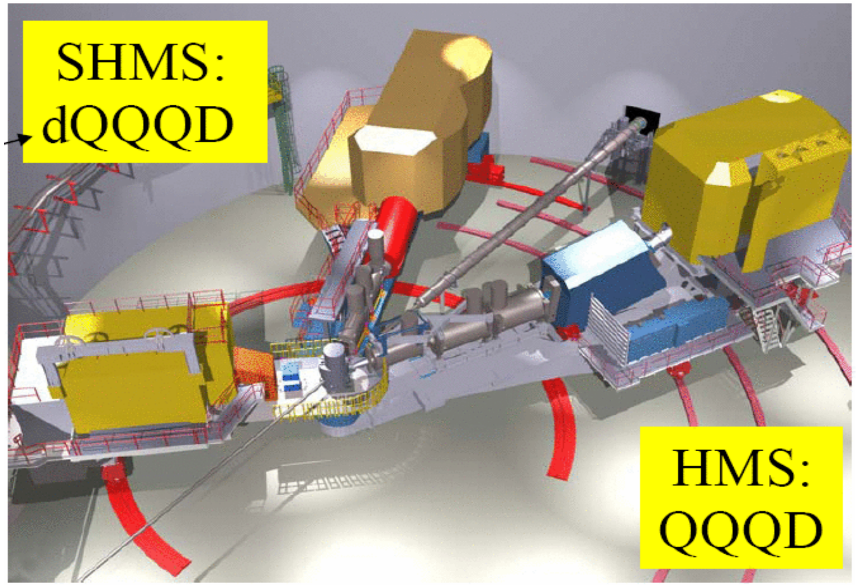
P.L. Anthony *et al.*, PRD 54, 6620 (1996);
K. Abe *et al.*, PRL 79,26(1997),PLB 405,180(1997);
K. Ackerstaff *et al.*, PLB 404, 383 (1997);
K. Ackerstaff *et al.*, PLB 464, 123 (1999);
X. Zheng *et al.*, PRL 92, 012004 (2004);

Figures from PRC 70, 065207 (2004)

A_1^n Experimental Design

- 11 GeV polarized e^- beam, P_{beam}= 80%
  - ➡ $\Delta P_b/P_b$= 2% (Compton, Moller)
- Polarized ^{3}He target,
  - ➡ hybrid pumping (K + Rb)
  - ➡ 40 cm, 14 atm @ 50°C, P_{Targ}> 50% ($\Delta P_T/P_T$ = 3%)
    - (E02-013 has achieved 55% in beam)



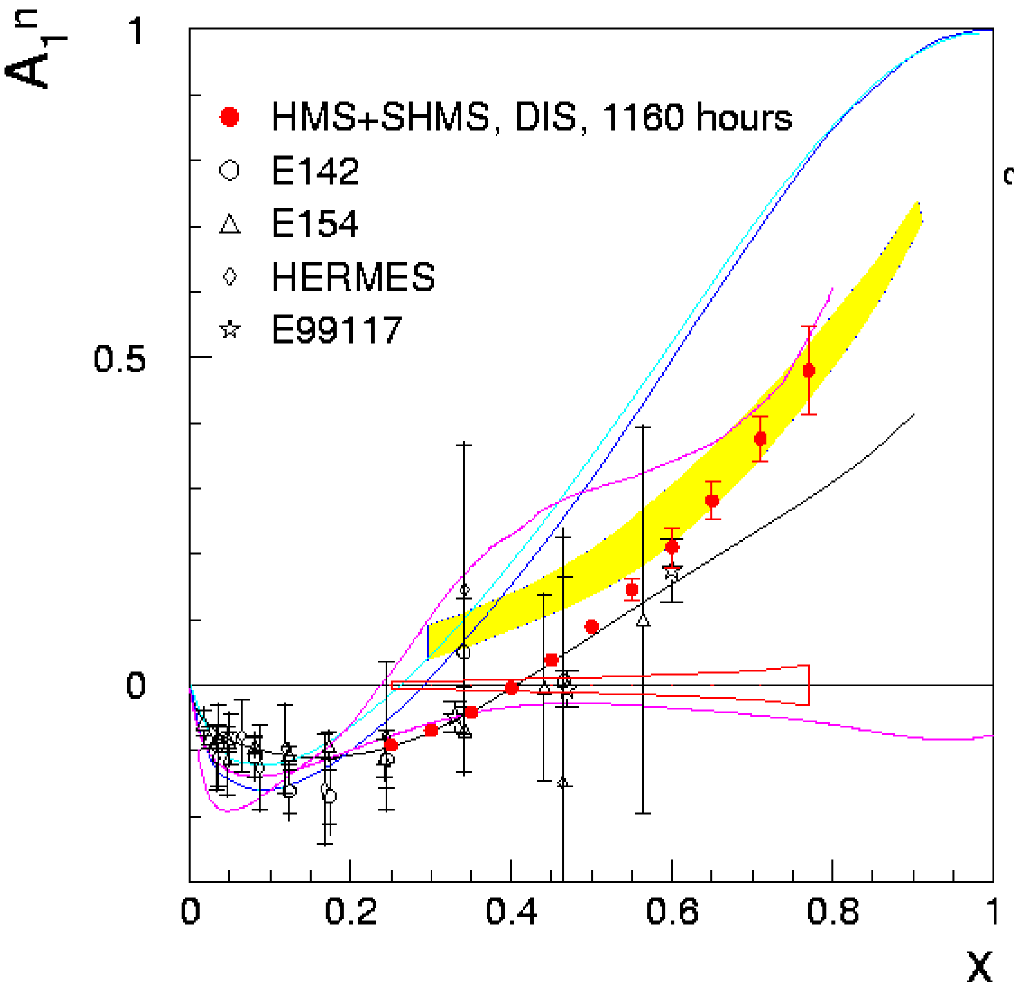


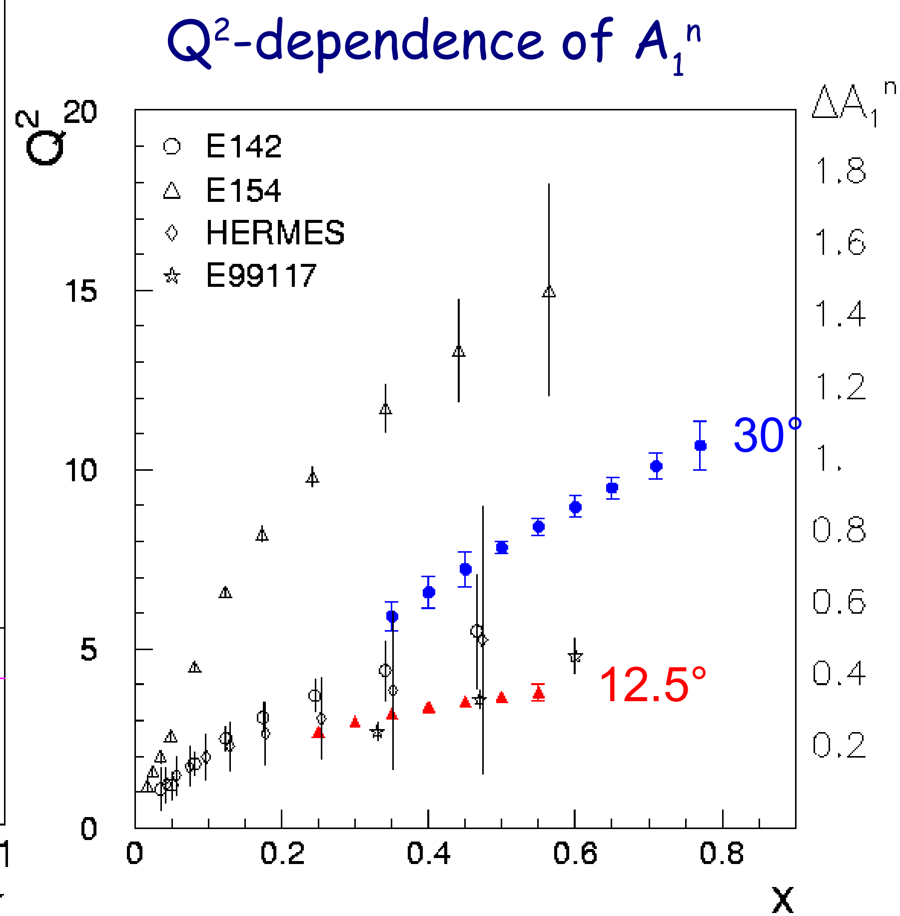
- HMS+SHMS to detect *e'*
  - ➡ measure both $A_{||}$ and $A_{\perp}$

SHMS spectrometer:
- P = 2 - 11 GeV/c,
- $\Delta P/P$=(-10%, 22%)
- $\Delta\Omega$= 4.5 msr
- Δy=±15 cm

HMS spectrometer
- P_{max}=7.5 GeV/c,
- $\Delta P/P$=(-9%, 9%)
- ΔW= 8.0 msr
- Δy=±5 cm

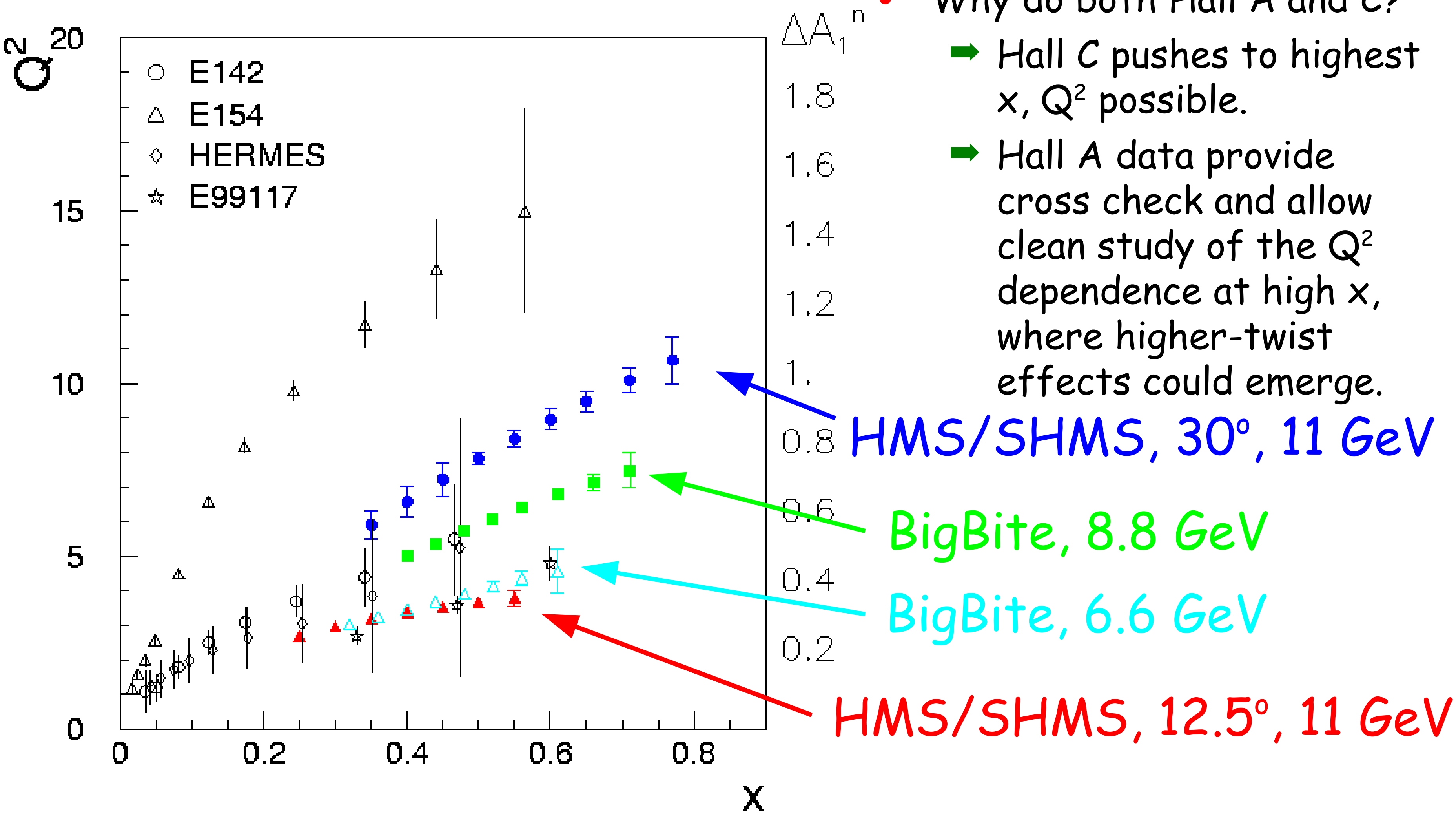
Projected A_1^n Data at 12 GeV in Hall C





To extract Δq/q — need d/u (BONUS, $^3He/^3H$, PVDIS) and g_1^p/F_1^p (fit or projected 12 GeV data from Hall B)

Complimentary to E12-06-122 in Hall A



- Why do both Hall A and C?
  - Hall C pushes to highest x, Q^2 possible.
  - Hall A data provide cross check and allow clean study of the Q^2 dependence at high x, where higher-twist effects could emerge.

A_1^n Summary

- A_1^n will be measured up to x = 0.77
  - ➡ wide Q^2 coverage (3-10 GeV^2);
- Require: pol ^3He target in Hall C + SHMS + HMS;
- Complimentary to "A_1^n using BigBite in Hall A";
- Beam time request: 53 days total
- Provide important data in the unexplored large x region:
  - ➡ Improve world polarized PDF fits;
  - ➡ Study Q^2 dependence;
  - ➡ Test pQCD/HHC and quark OAM in a "deeper" valence quark region
- Combine with (planned) proton spin and d/u data, extract Δq/q, test whether Δd/d turns positive as HHC predicted.

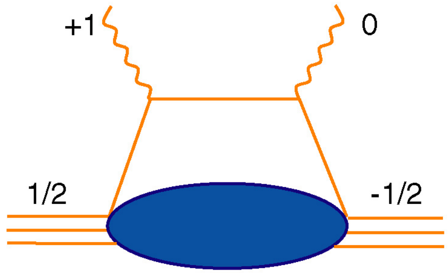
Moving on to d_2^n...

- 1988-1989: "The Proton Spin Crisis"
- Current understanding of the nucleon spin:
- $$\frac{1}{2} = S_z^N = S_z^q + L_z^q + J_z^G$$ (the spin "sum rule")
  - ➡ Quark spin contributes about (20~30)% to the nucleon spin
  - ➡ Little data exist on L_z^q and J_z^G.
- Understanding spin structure of the nucleon requires measurements of all three components, and to answer *the* question:
  - ➡ *"CAN WE UNDERSTAND THESE DATA from the first principles in QCD?"*
- However, the region where we can test QCD is limited due to the complication in QCD calculations
  - ➡ moments, structure functions at high x.

d_2^n

g_2 and Quark-Gluon Correlations

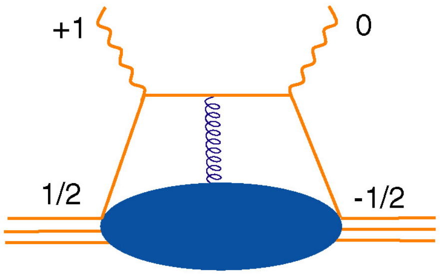
twist-2



Carry one unit of orbital angular momentum

QCD allows the helicity exchange to occur in two principle ways

twist-3



Couple to a gluon

$$g_2(x,Q^2) = g_2^{WW}(x,Q^2) + \bar{g}_2(x,Q^2)$$

- a twist-2 term (Wandzura & Wilczek, 1977):

$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 g_1(y,Q^2)\frac{dy}{y}$$

- a twist-3 term with a suppressed twist-2 piece (Cortes, Pire & Ralston, 92):

$$\bar{g}_2(x,Q^2) = -\int_x^1 \frac{\partial}{\partial y}\left(\frac{m_q}{M}h_T(y,Q^2) + \xi(y,Q^2)\right)\frac{dy}{y}$$

transversity — quark-gluon correlation

Moments of Structure Functions

$$\Gamma_1(Q^2) = \int_0^1 g_1(x,Q^2)\,dx = \mu_2 + \frac{\mu_4}{Q^2} + \frac{\mu_6}{Q^4} + \cdots$$

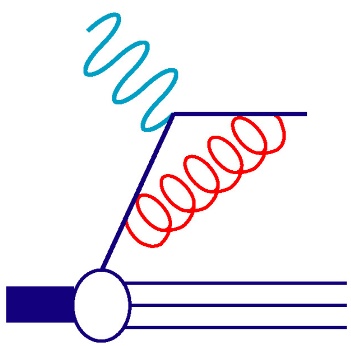
leading twist — higher twist

$$\mu_2^{p,n}(Q^2) = (\pm\frac{1}{12}g_A + \frac{1}{36}a_8) + \frac{1}{9}\Delta\Sigma$$ + pQCD corrections

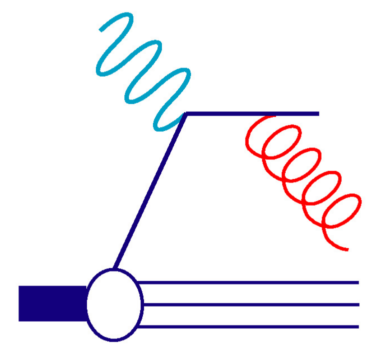
$g_A = 1.257$ and $a_8 = 0.579$ are the triplet and octet axial charge, respectively

$\Delta\Sigma$ = singlet axial charge

(Extracted from neutron and hyperon weak decay measurements)



$$g_A = \Delta u - \Delta d$$
$$a_8 = \Delta u + \Delta d - 2\Delta s$$
$$\Delta\Sigma = \Delta u + \Delta d + \Delta s$$



pQCD radiative corrections

Moments of Structure Functions (continued)

$$\mu_4(Q^2) = \frac{M^2}{9}\left[a_2(Q^2) + 4d_2(Q^2) + 4f_2(Q^2)\right]$$

Twist - 2 (TMC) Twist - 3 Twist -4

where a_2, d_2 and f_2 are higher moments of g_1 and g_2

e.g. $$d_2(Q^2) = \int_0^1 x^2[2g_1(x,Q^2) + 3g_2(x,Q^2)]dx = 3\int_0^1 x^2\,\overline{g_2}(x,Q^2)dx$$

$$a_2(Q^2) = \int_0^1 x^2 g_1(x,Q^2)\,dx$$

- To extract f_2, d_2 needs to be determined first.
- Both d_2 and f_2 are required to determine the color polarizabilities

Color "polarizabilities"

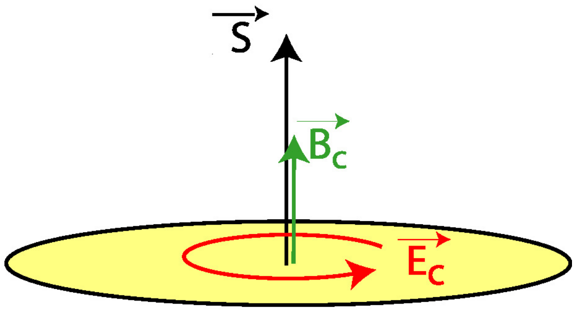
How does the gluon field respond when a nucleon is polarized ?

Define color magnetic and electric polarizabilities (in nucleon rest frame):

$$\chi_{B,E} 2M^2 \vec{S} = \langle PS|\vec{O}_{B,E}|PS\rangle$$

where $\vec{O}_B = \psi^\dagger g \vec{\boldsymbol{B}} \psi$

$$\vec{O}_E = \psi^\dagger \vec{\alpha} \times g\vec{\boldsymbol{E}} \psi$$

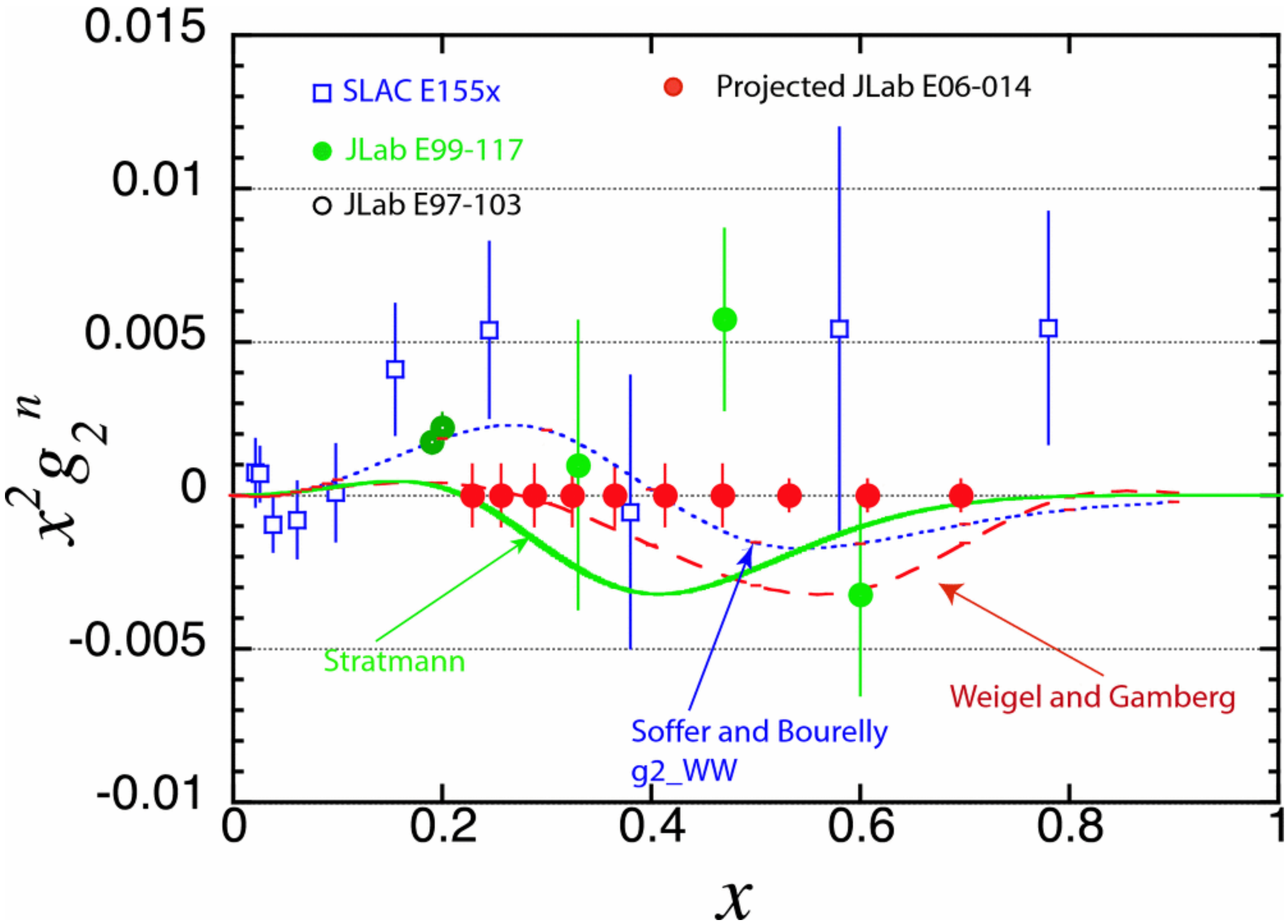


$$\chi_E^n = (4d_2^n + 2f_2^n)/3$$

$$\chi_B^n = (4d_2^n - f_2^n)/3$$

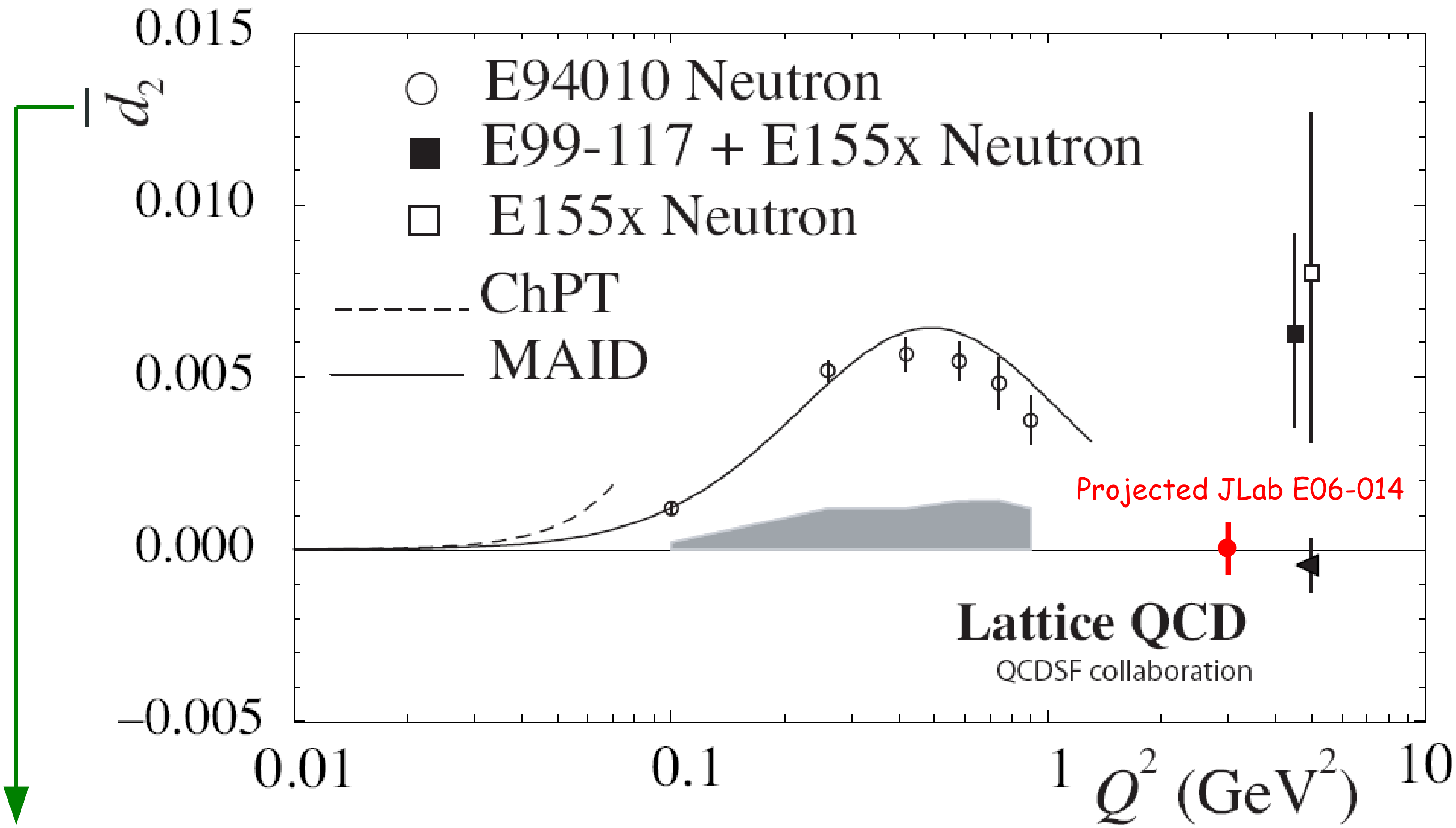
χ_E and χ_B represent the response of the color $\vec{B}$ & $\vec{E}$ fields to the nucleon polarization

World Data on on g_2^n



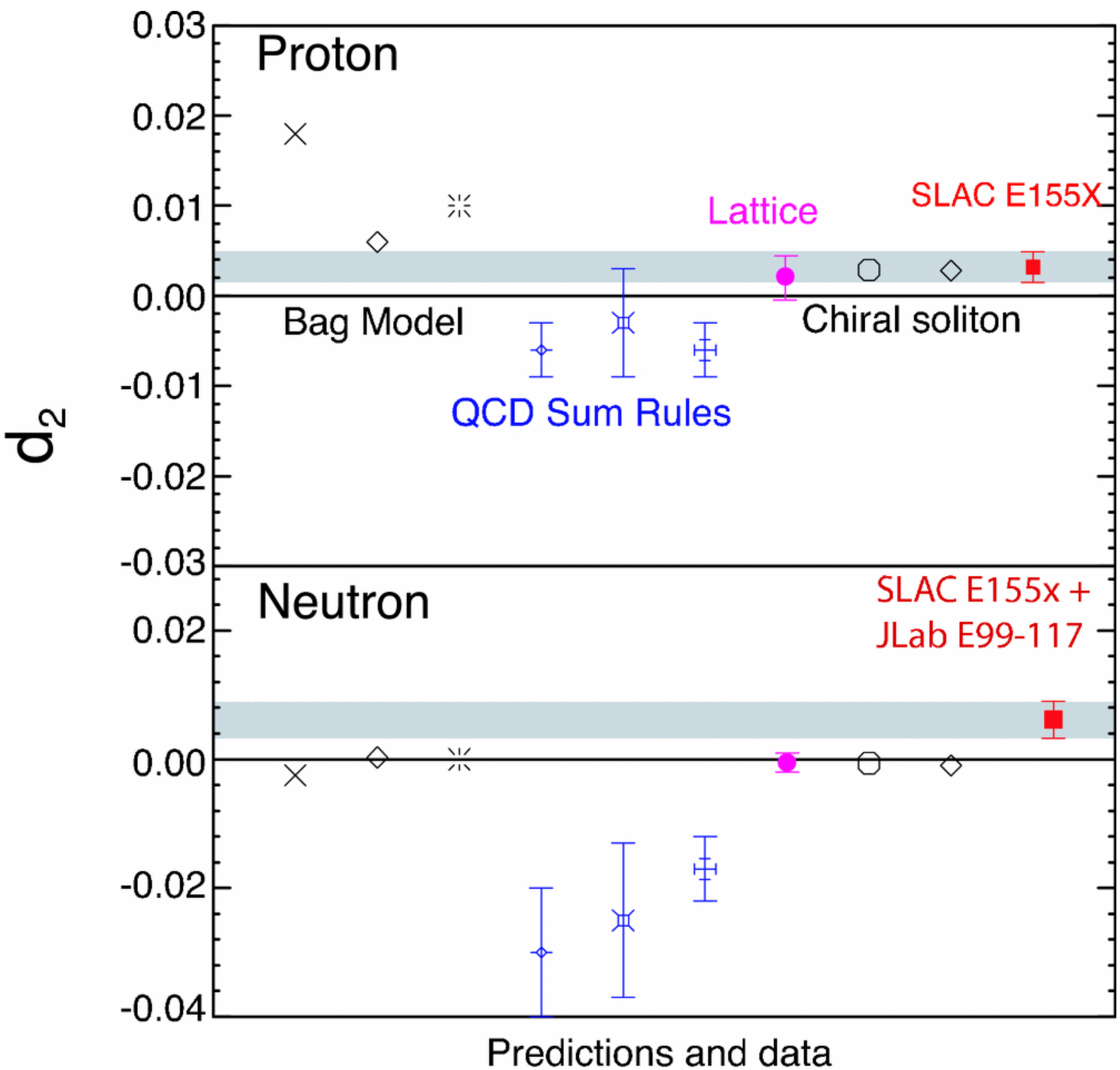
- However, Q^2 values for these data range from 0.1 – 15 GeV^2

World Data on $\bar{d}_2$



(nucleon elastic contribution suppressed)

Model evaluations of d_2



Precision measurement of g_2^n and d_2^n in Hall C

W. Korsch (U. of Kentucky), Z.-E. Meziani (Temple U.), B. Sawatzky (Temple U.), T. Averett (W&M)

- An Experiment in Hall C:
  - A polarized electron beam of 11.0 GeV and polarized ^{3}He target
  - Measure $\Delta\sigma_\perp = \sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}$, $\Delta\sigma_\parallel = \sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}$ for $^3\vec{\mathrm{He}}(\vec{e},e')$ reaction using both the SHMS and HMS running in parallel for 3 kinematic settings each
    - SHMS: (p_0= 8.0 GeV/c, θ = 11.0°), (p_0= 7.0 GeV/c, θ = 13.3°), (p_0= 6.3 GeV/c, θ = 15.5°)
    - HMS: (p_0= 4.2 GeV/c, θ = 13.5°), (p_0= 5.0 GeV/c, θ = 16.4°), (p_0= 3.4 GeV/c, θ = 20.0°)
- Determine d_2^n and g_2^n using the relations:

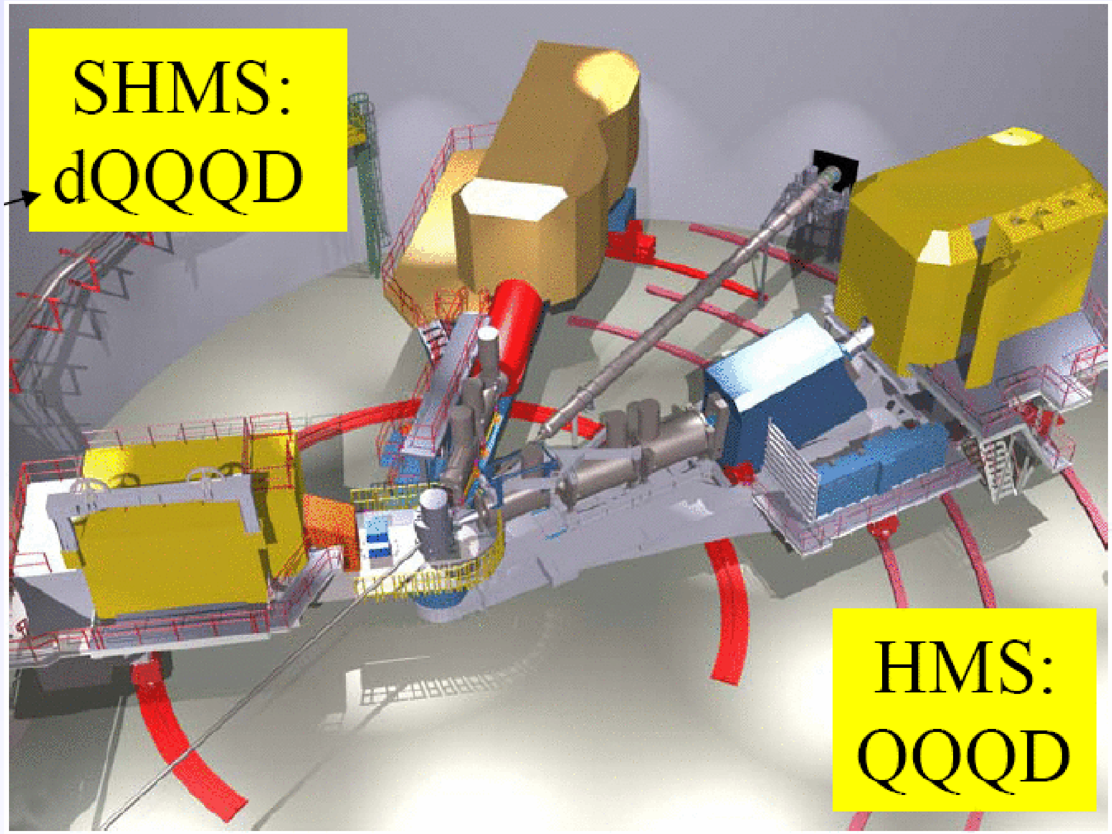
$$\tilde{d}_2 = x^2(2g_1+3g_2) = \frac{MQ^2\nu}{8\alpha_e^2}\frac{E}{E'}\frac{x^2(4-3y)}{(E+E')}\left[\Delta\sigma_\parallel + \left(\frac{4-y}{(1-y)(4-3y)\sin\theta_e} - \cot\theta_e\right)\Delta\sigma_\perp\right]$$

$$g_2 = \frac{MQ^2\nu^2}{4\alpha_e^2}\frac{1}{2E'(E+E')}\left[-\Delta\sigma_\parallel + \frac{E+E'\cos\theta_e}{E'\sin\theta_e}\Delta\sigma_\perp\right]$$

I_{beam} = 10 μA
P_{beam} = 0.8
P_{targ} = 0.5

where $\Delta\sigma_\parallel = \sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}$, $\Delta\sigma_\perp = \sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}$ and $y = \nu/E$.

Floor layout for Hall C

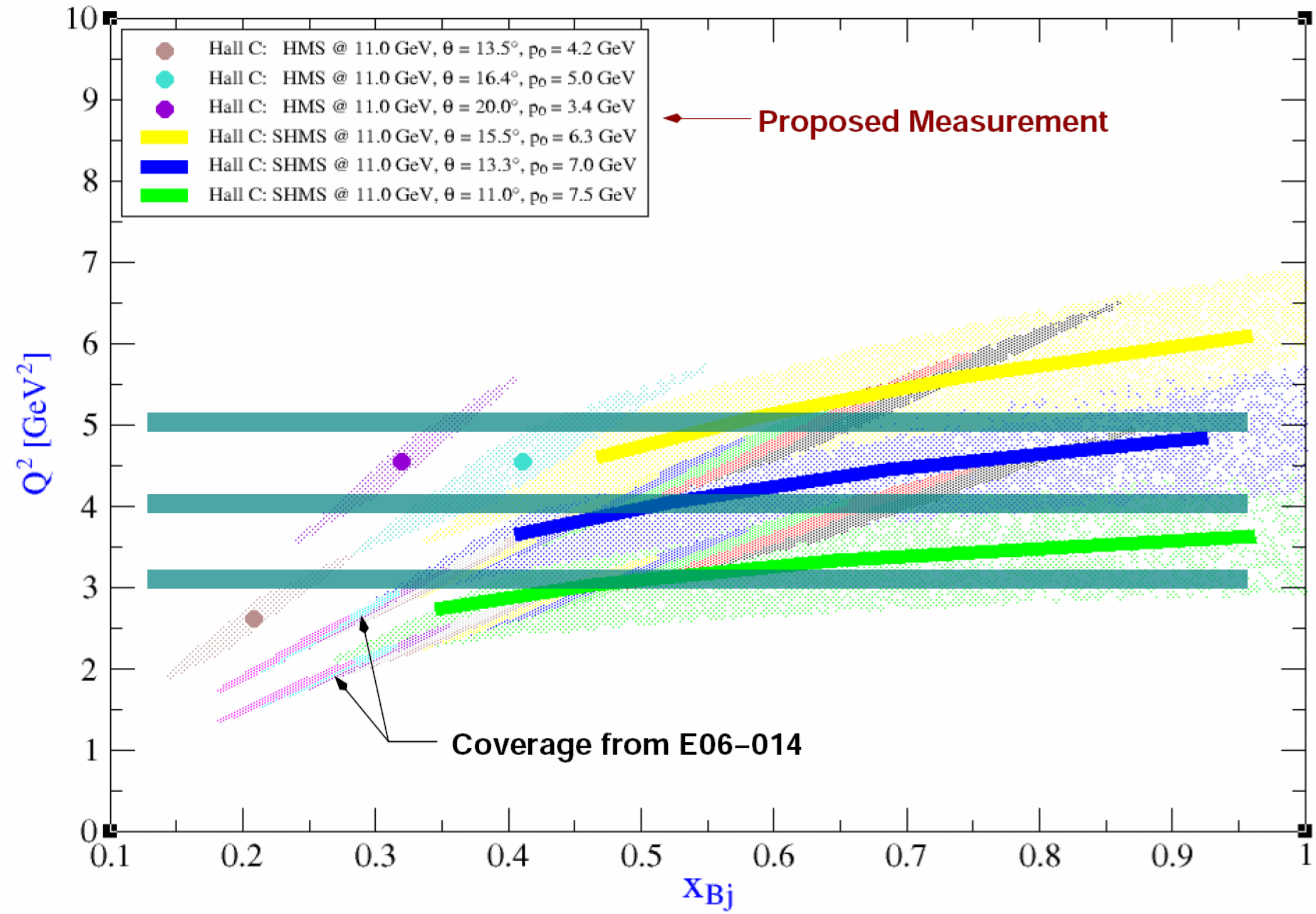


Hall C

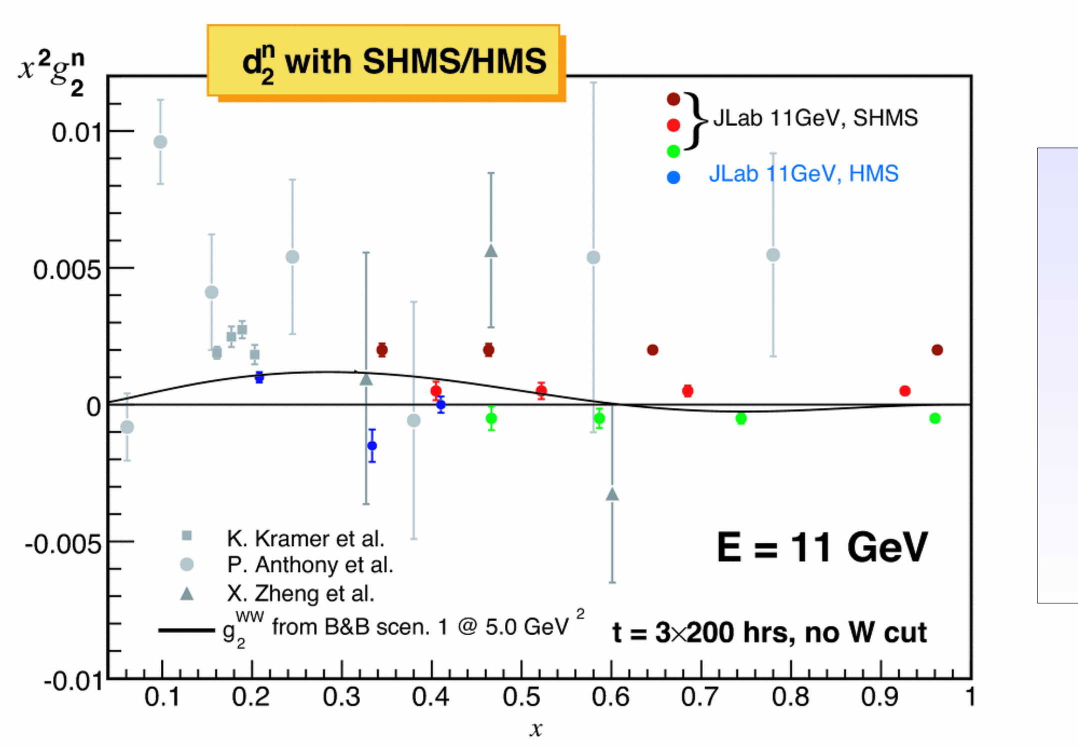
- One beam energy
  - ➡ 11 GeV
- Each arm measures a total cross section independent of the other arm.
- Experiment split into three pairs of 200 hour runs with spectrometer motion in between.

- SHMS collects data at Θ = 11°, 13.3° and 15.5° for 200 hrs each
  - ➡ data from each setting divided into 4 bins
- HMS collects data at Θ = 13.5°, 16.4° and 20.0° for 200 hrs each

d_2^n Kinematics for Hall C (cont…)



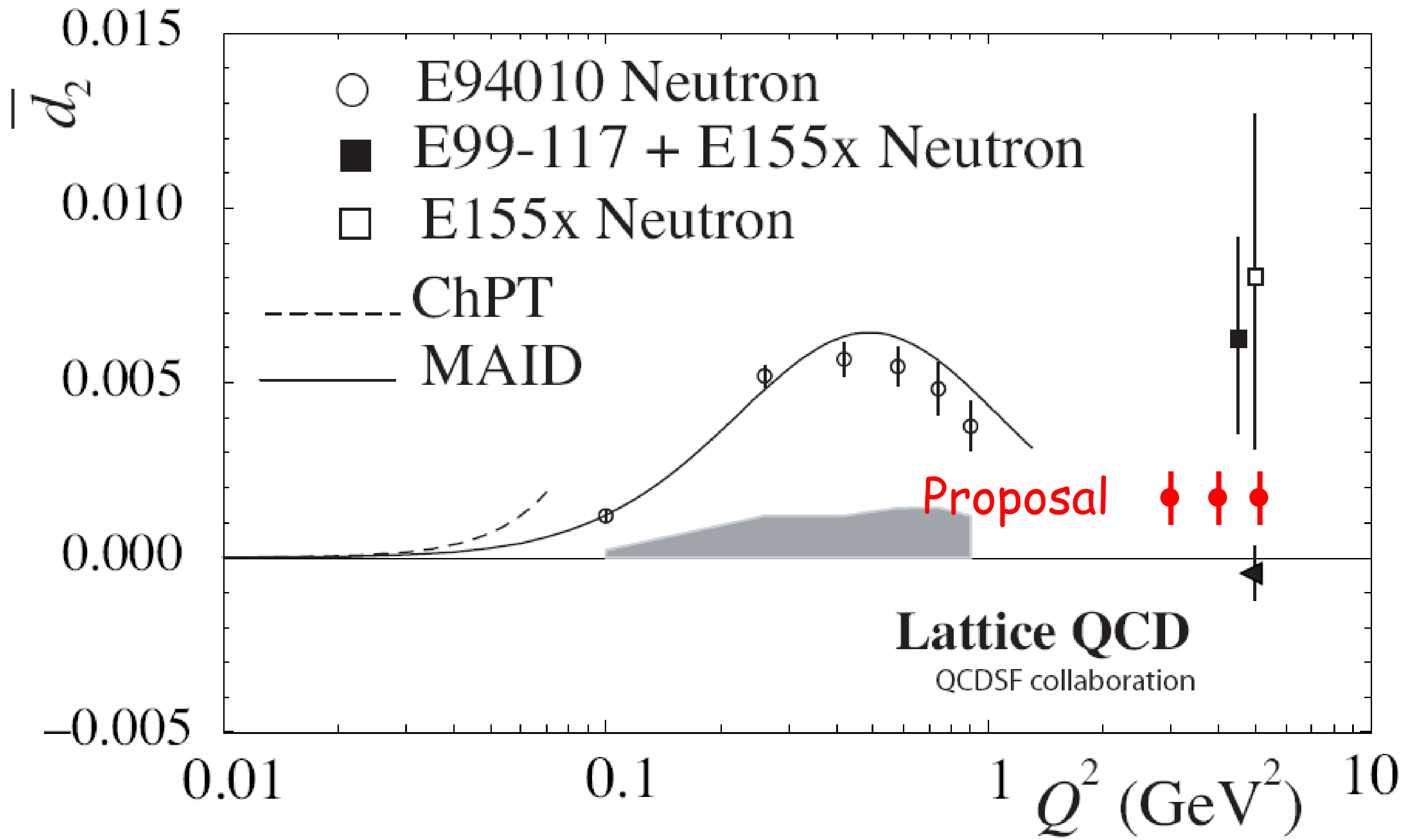
Projected $x^2 g_2(x,Q^2)$ results from Hall C



Projected points are vertically offset from zero along lines that reflect different (roughly) constant Q^2 values from 2.5—6 GeV^2.

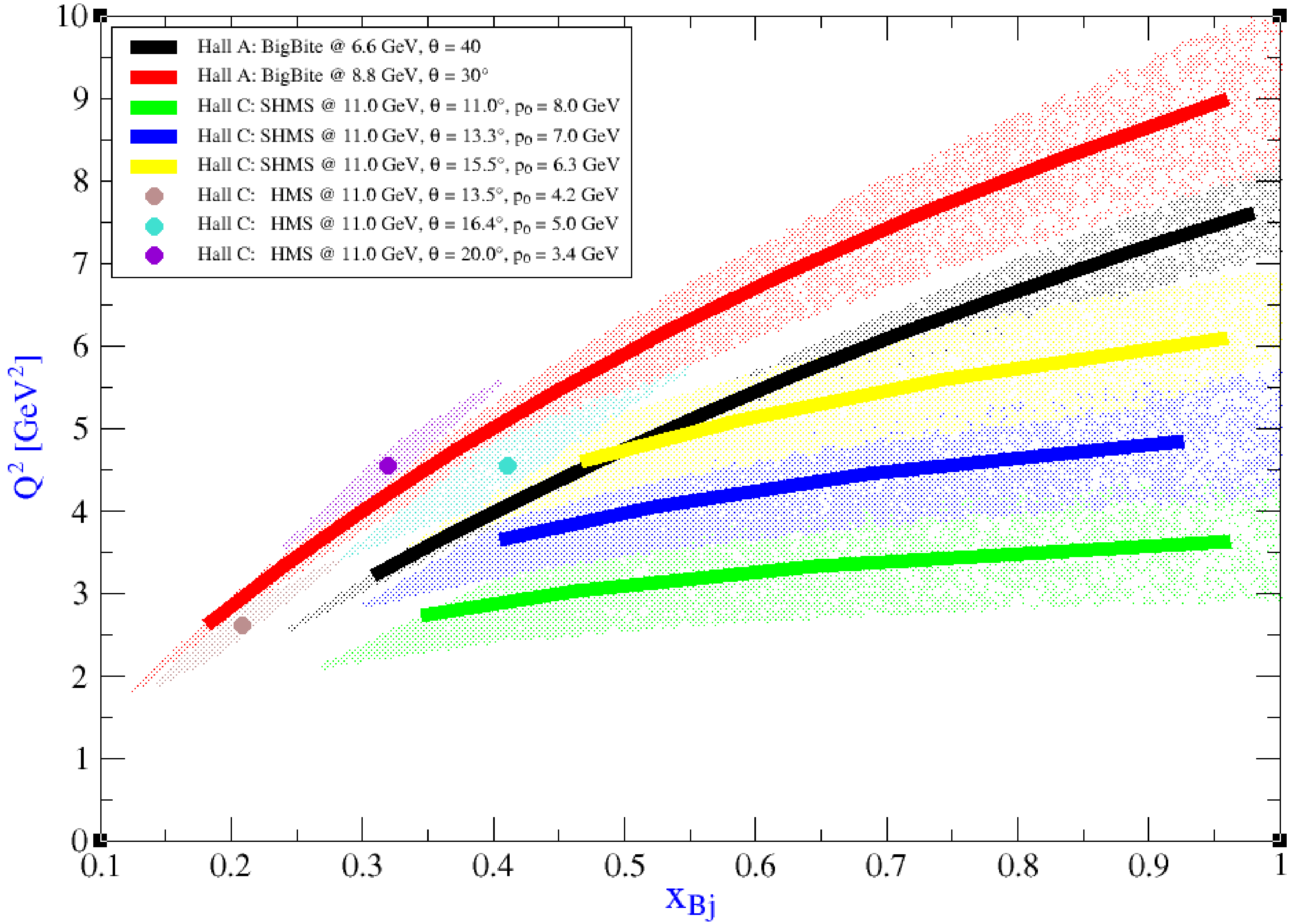
- g_2 for ^{3}He is extracted directly from L and T spin-dependent cross sections measured within the same experiment.
- Strength of SHMS/HMS:
  nearly constant Q^2 (but less coverage for $x < 0.3$)

Expected Error on d_2^n

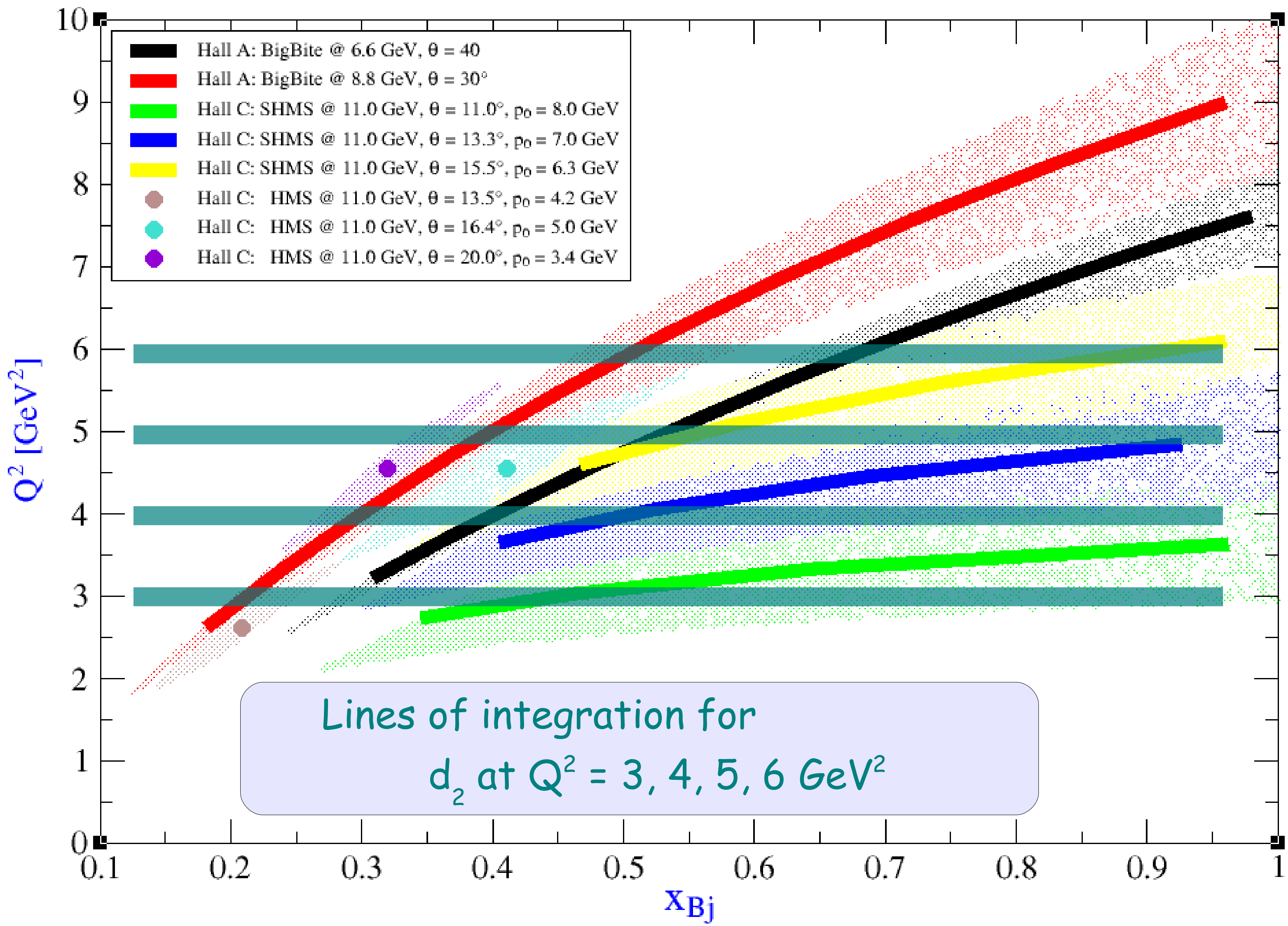


- The proposed measurements are at ***constant Q^2***
- The dominant E155x point includes data evolved down from as far as 15 GeV^2!

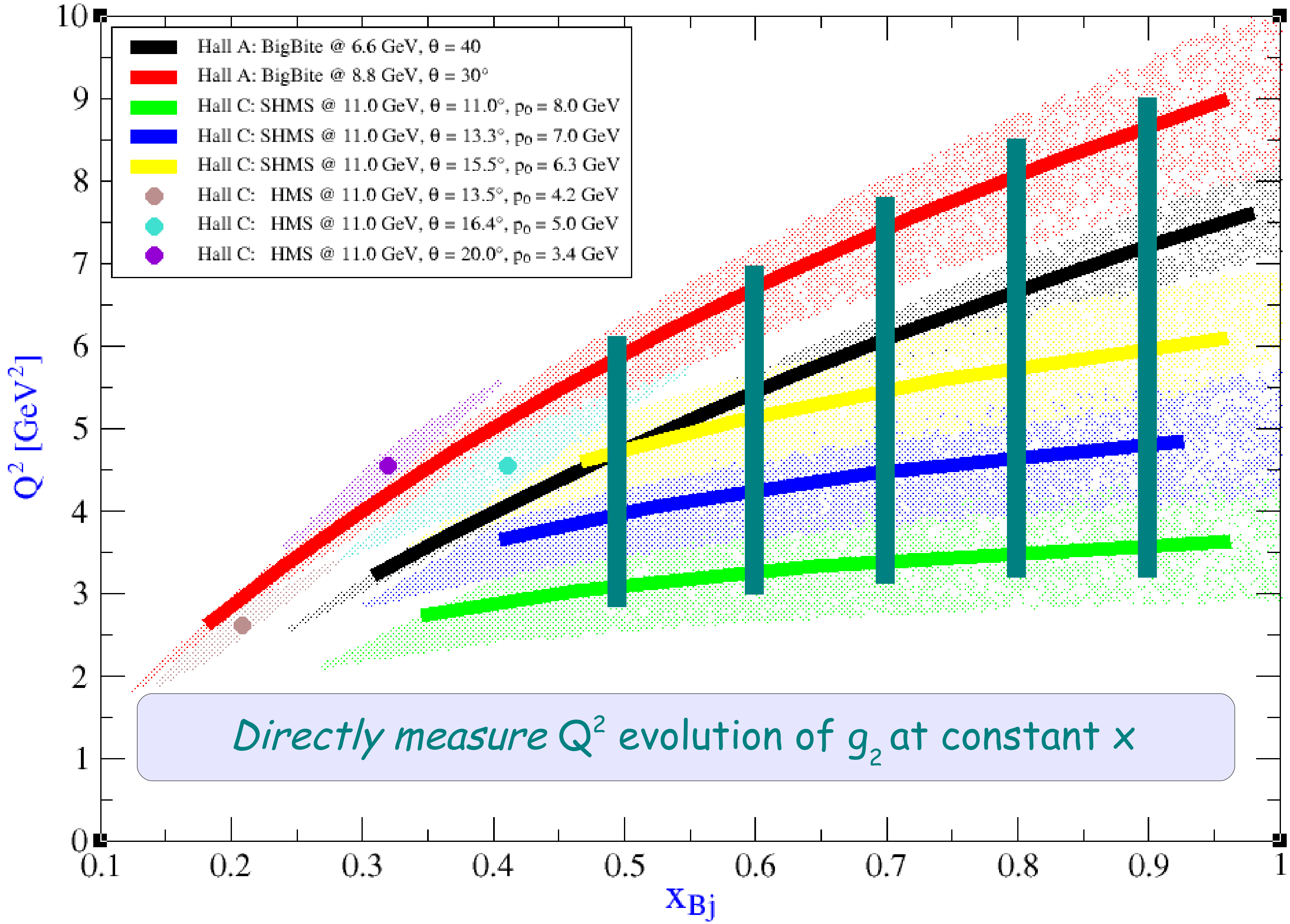
Combined Kinematics from both Halls



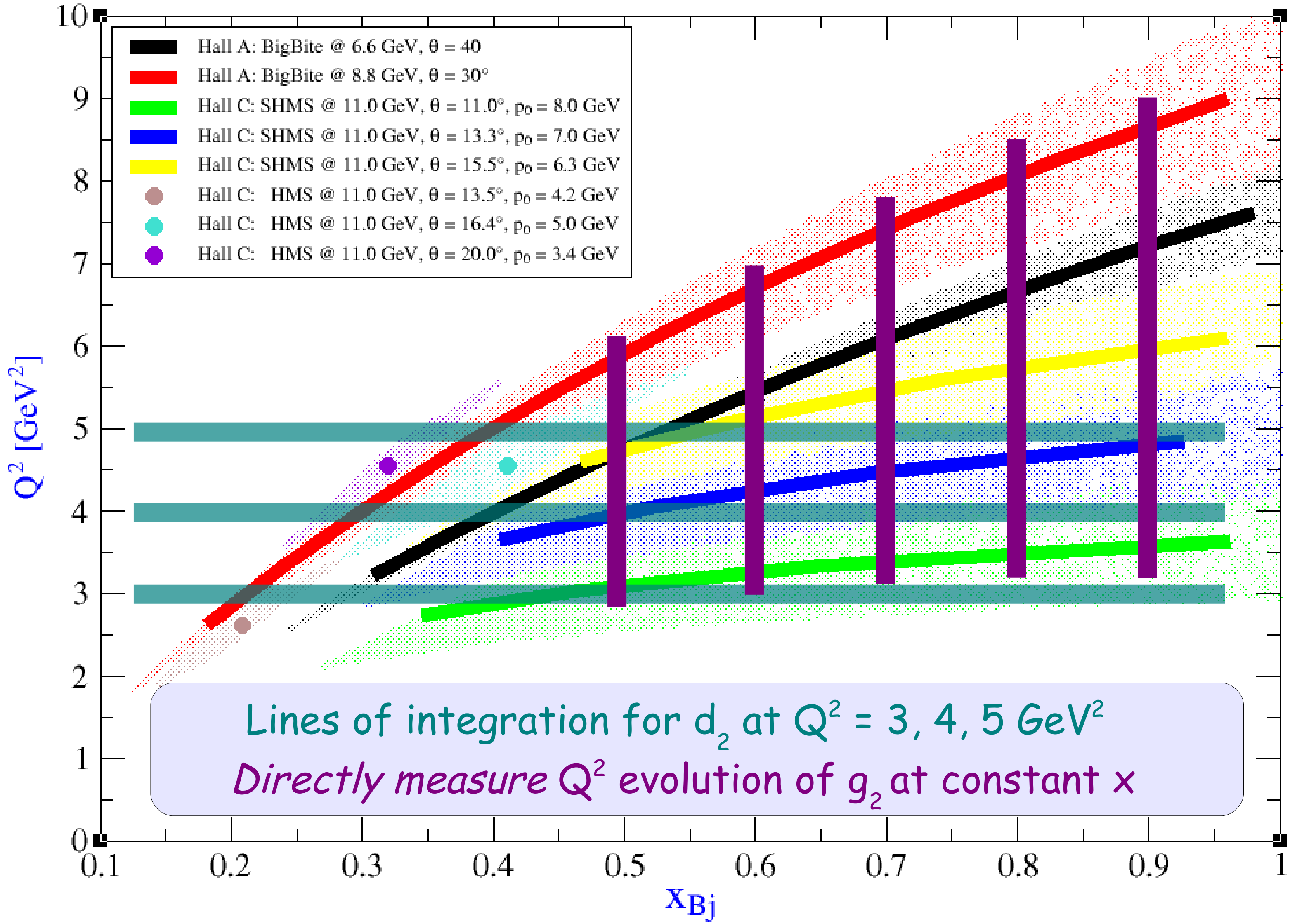
Q^2 evolution of d_2 (both Halls)



Q^2 evolution of d_2 (both Halls)



d_2 and g_2 evolution (both Halls)



d_2^n & g_2^n Summary

- A Hall C measurement using baseline equipment + polarized ^{3}He target
  - ➡ map out g_2 with unprecedented x, Q^2 coverage and precision
  - ➡ precisely measure the neutron d_2^n at $Q^2 = 3$, 4, and 5 GeV^2.
  - ➡ first look at Q^2 evolution of $g_2^n(x)$ for $x > 0.5$

- Provide a rigorous test for theory (lattice QCD).
  - ➡ we can achieve a statistical uncertainty of $\Delta d_2^n \sim 5 \times 10^{-4}$
    - measurements done at constant Q^2 (never been done before!)

- Significantly improve our knowledge of $g_2^n(x)$
  - ➡ vastly improve the available data for $x > 0.2$, all with better precision
  - ➡ (Hall A proposal would extend Q^2 coverage for $x > 0.5$ up to 9 GeV^2)

Final Thoughts

- A_1^n will be measured up to x=0.77 over wide Q^2 coverage (3-10 GeV^2);
- Provide important data in the unexplored large x region:
  - ➡ Improve world polarized PDF fits;
  - ➡ Study Q^2 dependence of A_1^n
  - ➡ Test pQCD/HHC and quark OAM in a "deeper" valence quark region
- Combine with (planned) proton spin and d/u data, extract Δq/q,
  - ➡ test whether Δd/d turns positive as HHC predicted.

- $d_2^n(Q^2)$ will be measured for Q^2 = 3, 4, and 5 GeV^2.
  - ➡ map out g_2^n with unprecedented x, Q^2 coverage and precision
  - ➡ first look at Q^2 evolution of $g_2^n(x)$ for x > 0.5
- Provide a rigorous test for theory (lattice QCD).
  - ➡ we can achieve a statistical uncertainty of $\Delta d_2^n \sim 5 \times 10^{-4}$
    - measurements done at constant Q^2 (never been done before!)

- A lot of exciting new precision data will be coming out of JLab early in the 12 GeV program!

Backup Slides

Systematic Error Contributions to g_2^n and d_2^n

Item description	Subitem description	Relative uncertainty
Target polarization		1.5 %
Beam polarization		3 %
Asymmetry (raw)		
	• Target spin direction (0.1°)	$< 5 \times 10^{-4}$
	• Beam charge asymmetry	$<$ 50 ppm
Cross section (raw)		
	• PID efficiency	$<$ 1 %
	• Background Rejection efficiency	$\approx$ 1 %
	• Beam charge	$<$ 1 %
	• Beam position	$<$ 1 %
	• Acceptance cut	2-3 %
	• Target density	$<$ 2%
	• Nitrogen dilution	$<$ 1%
	• Dead time	$<$1%
	• Finite Acceptance cut	$<$1%
Radiative corrections		$\leq$ 5 %
From ^{3}He to Neutron correction		5 %
Total systematic uncertainty (for both $g_2^n(x,Q^2)$ and $d_2(Q^2)$)		$\leq$ 10 %
Estimate of contributions to d_2 from unmeasured region	$\int_{0.003}^{0.23} \tilde{d}_2^n \, dx$	4.8×10^{-4}
Projected absolute statistical uncertainty on d_2		$\Delta d_2 \approx 5 \times 10^{-4}$
Projected absolute systematic uncertainty on d_2 (*assuming* $d_2 = 5 \times 10^{-3}$)		$\Delta d_2 \approx 5 \times 10^{-4}$

- Systematics comparable for Halls A & C
- Radiative correction uncertainty cross-checked with E01-012 (Spin Duality) experiment
  - ➡ worst case: 4.4%
- Pion rejection ratio of ~10000:1 should be achievable with standard SHMS/HMS detectors.

The proposal for Hall A and BigBite

- A 6.6 and 8.8 GeV polarized electron beam scattering off a polarized ^{3}He target
- Measure unpolarized cross section for $^3\vec{\mathrm{He}}(\vec{e},e')$ reaction $\sigma_0^{^3\mathrm{He}}$ in conjunction with the parallel asymmetry $A_\parallel^{^3\mathrm{He}}$ and the transverse asymmetry $A_\perp^{^3\mathrm{He}}$ for 0.2 < x < 0.9 with 2.5 < Q^2 < 9 GeV^2.
  - ➡ Asymmetries measured by BigBite for two kinematic settings:
    - E_{beam} = 6.6 GeV and θ = 40°, E_{beam} = 8.8 GeV and θ = 30°
  - ➡ Absolute cross sections measured simultaneously by L-HRS
- Determine d_2^n and g_2^n using the relations

$$\tilde{d}_2(x,Q^2) = x^2[2g_1(x,Q^2)+3g_2(x,Q^2)]$$
$$= \frac{MQ^2}{4\alpha^2}\frac{x^2y^2}{(1-y)(2-y)}\sigma_0\left[\left(3\frac{1+(1-y)\cos\theta}{(1-y)\sin\theta}+\frac{4}{y}\tan\frac{\theta}{2}\right)A_\perp+\left(\frac{4}{y}-3\right)A_\parallel\right]$$

$$g_2 = \frac{MQ^2}{4\alpha^2}\frac{y^2}{2(1-y)(2-y)}2\sigma_0\left[-A_\parallel+\frac{1+(1-y)\cos\theta}{(1-y)\sin\theta}A_\perp\right]$$

where,

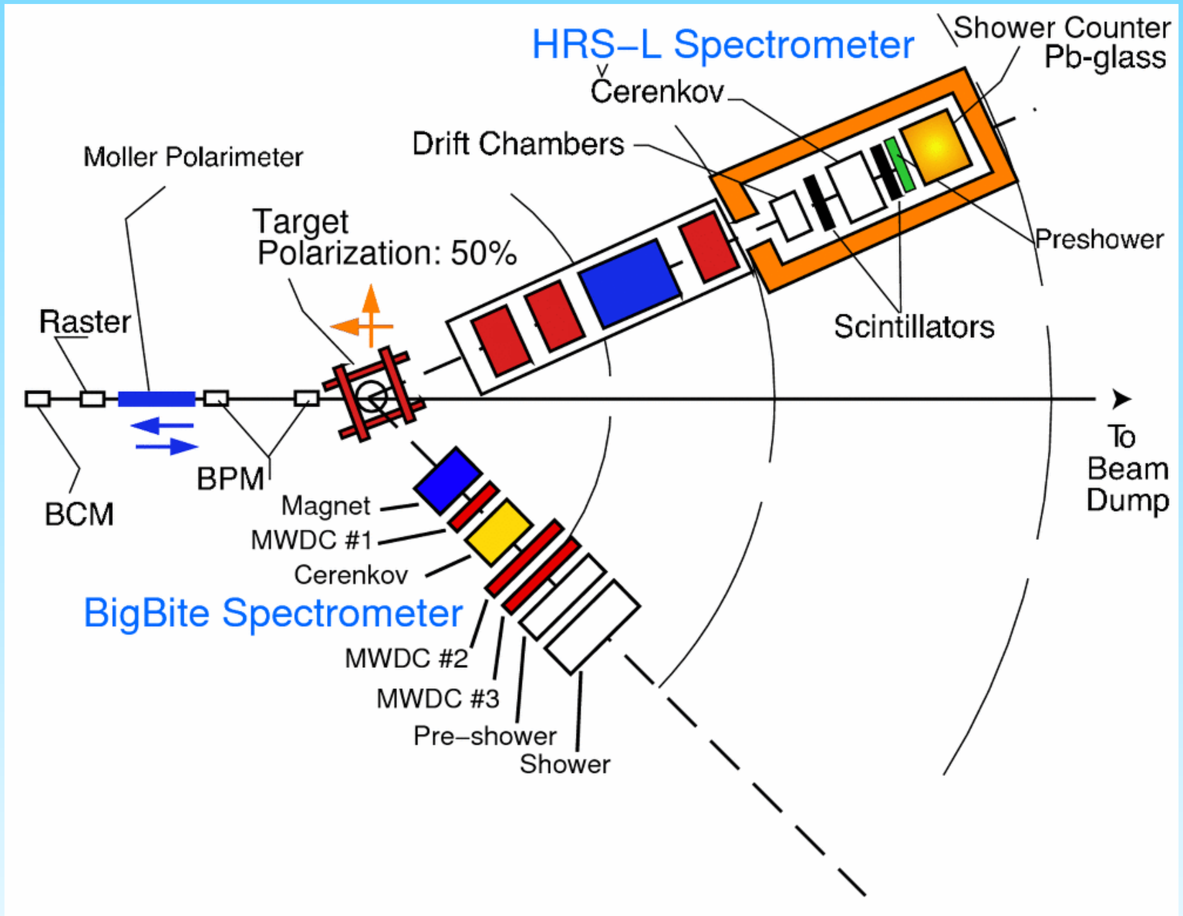
$$A_\perp = \frac{\sigma^{\downarrow\Rightarrow}-\sigma^{\uparrow\Rightarrow}}{2\sigma_0} \qquad A_\perp^{^3He} = \frac{\Delta_\perp}{P_bP_t\cos\phi} \qquad A_\parallel^{^3He} = \frac{\Delta_\parallel}{P_bP_t}$$

$$A_\parallel = \frac{\sigma^{\downarrow\Uparrow}-\sigma^{\uparrow\Uparrow}}{2\sigma_0} \qquad \Delta_\perp = \frac{(N^{\uparrow\Rightarrow}-N^{\uparrow\Rightarrow})}{(N^{\uparrow\Rightarrow}+N^{\uparrow\Rightarrow})} \qquad \Delta_\parallel = \frac{(N^{\downarrow\Uparrow}-N^{\uparrow\Uparrow})}{(N^{\downarrow\Uparrow}+N^{\uparrow\Uparrow})}$$

ϕ = angle between scattering plane and transverse target pol.

I_{beam} = 10 μA
P_{beam} = 0.8
P_{targ} = 0.5

Floor layout for Hall A

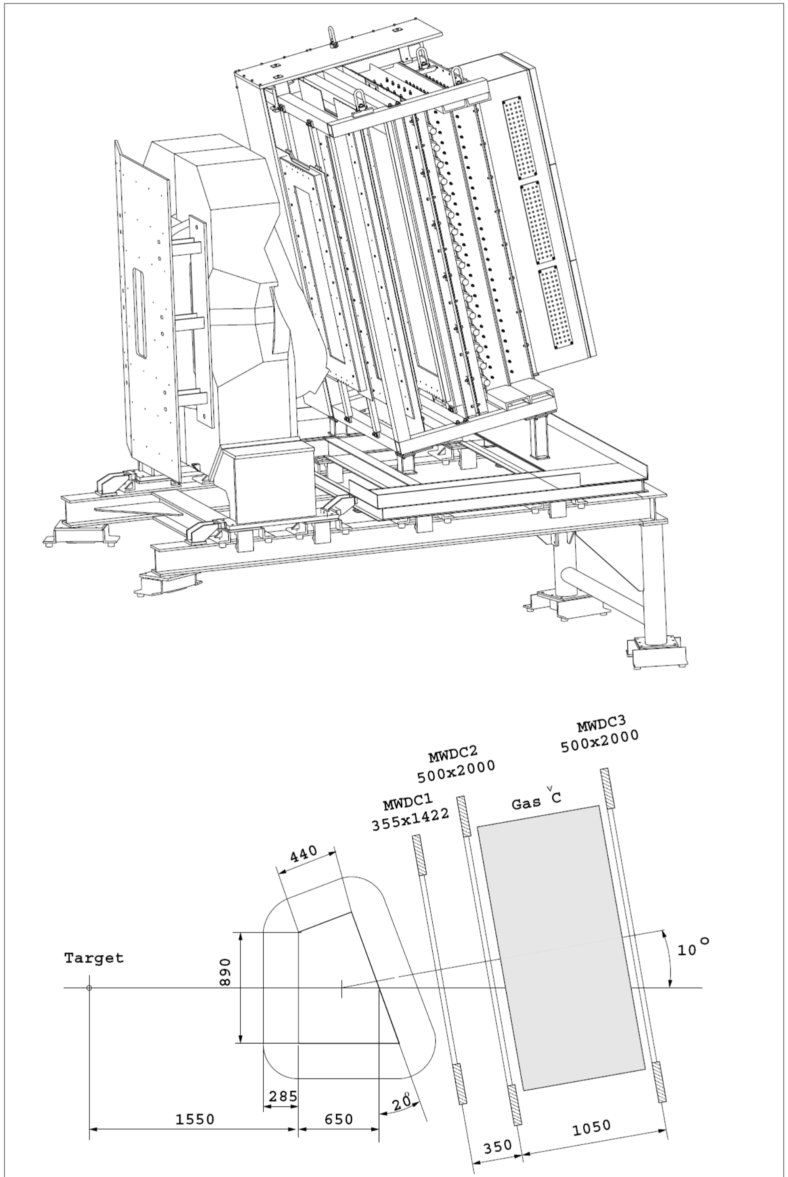


Hall A

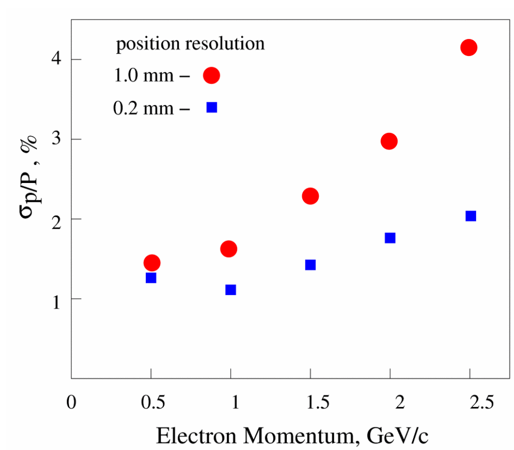
- Two beam energies
  - ➡ 6.6, 8.8 GeV
- 200 hours for 6.6 GeV data set
  - ➡ 175 hrs transverse
  - ➡ 25 hrs parallel
- 400 hours for 8.8 GeV data set
  - ➡ 360 hrs transverse
  - ➡ 40 hrs parallel

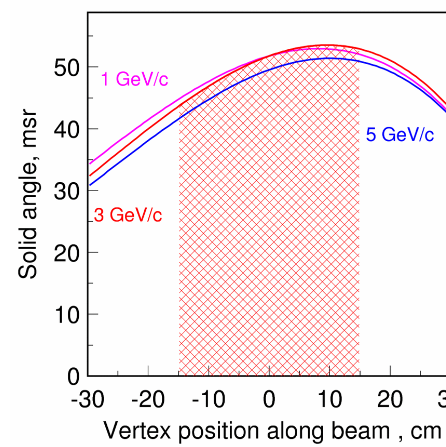
- HRS used to measure σ_0 at 10 momentum settings for each beam energy.
  - ➡ will also reverse the field to monitor π^-/π^+ and e^-/e^+ asymmetries
- BigBite measures $A_{\parallel}^{^3\mathrm{He}}$ and $A_{\perp}^{^3\mathrm{He}}$ with single configuration at each beam energy.

BigBite in Hall A

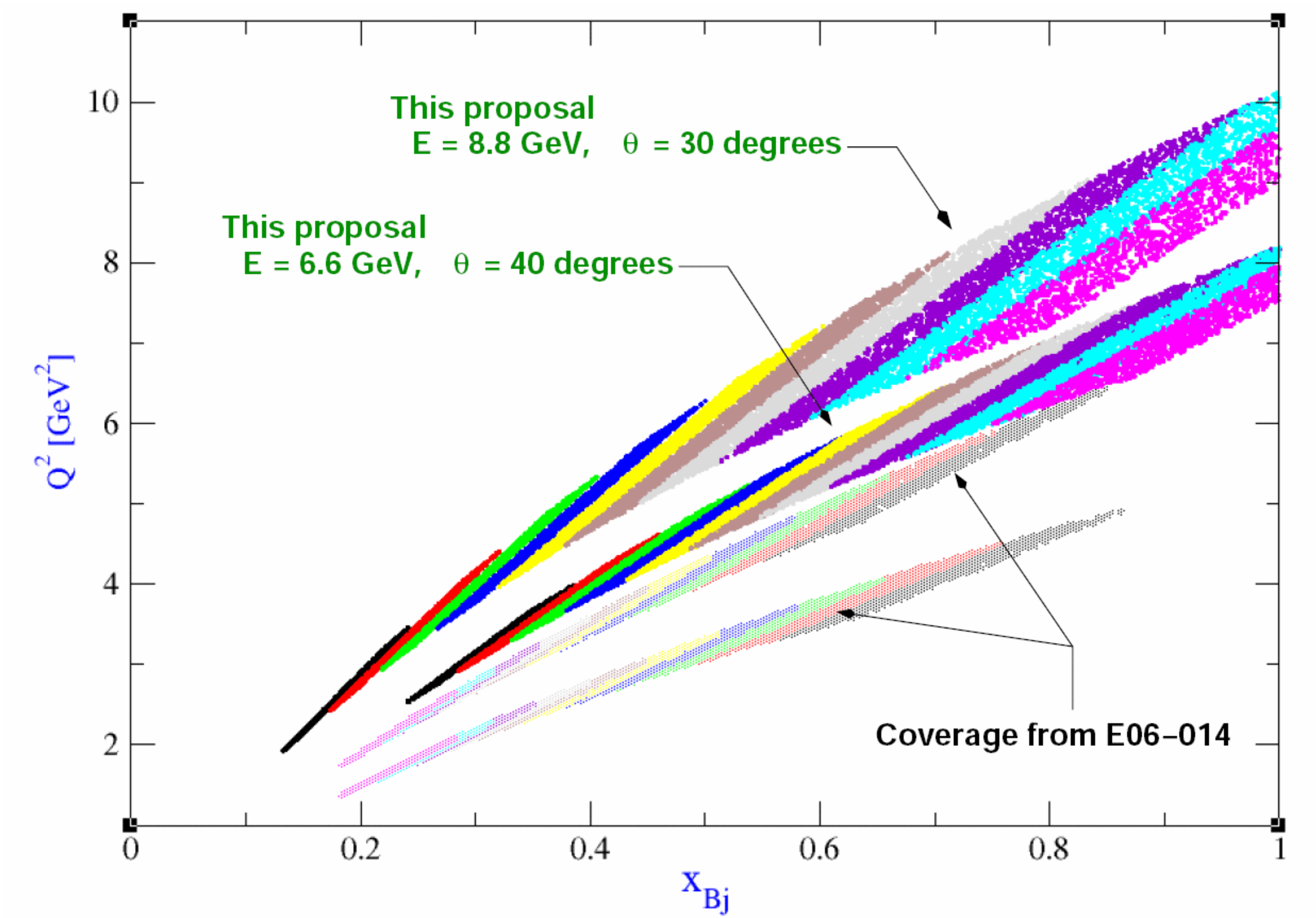


- GeN electron detector package (upper left) will modified by increasing the MWDC spacing to improve the high momentum position resolution (lower left).
- The Gas Cerenkov (currently under construction for E06-014) will be used to suppress pion backgrounds.

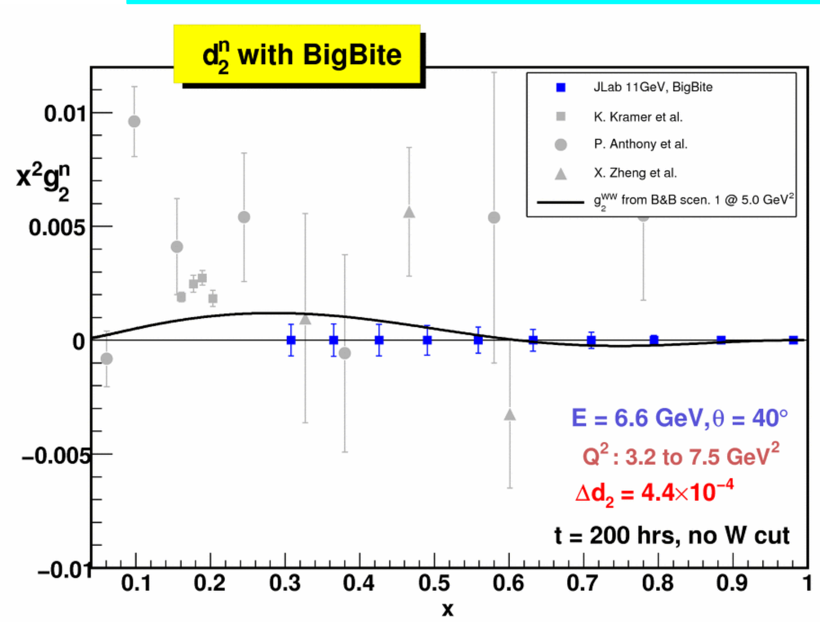


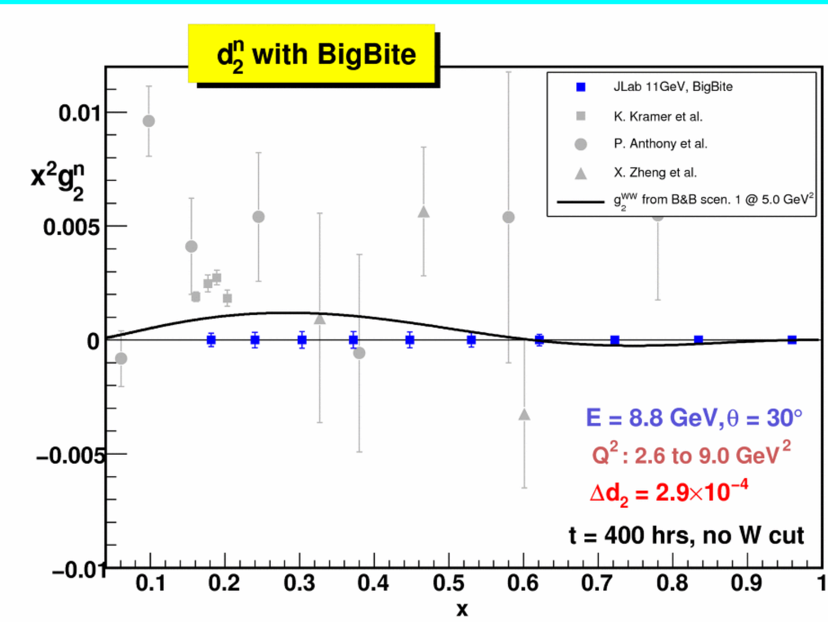


Kinematics for Hall A (cont...)



Projected $x^2 g_2(x,Q^2)$ results from Hall A





- g_2 for ^{3}He is extracted directly from L and T spin-dependent cross sections measured within the same experiment.
- Strength of BigBite:
  large x coverage per setting (but large Q^2 variation)

Measuring the Neutron g_2 and d_2 at 12 GeV

PR12-06-120 (Hall A) • PR12-06-121 (Hall C)

- Goal:
  - Clearly map out Q^2 evolution of neutron g_2 for x > 0.5
  - Determine the neutron d_2 at $\langle Q^2 \rangle$ = 3, 4, 5 GeV^2
- An Experiment in Hall A: (approved by the Hall A Collaboration)
  - A polarized electron beam of 6.6, 8.8 GeV and polarized ^{3}He target
  - Measure unpolarized cross section for $^3\vec{\mathrm{He}}(\vec{e},e')$ reaction $\sigma_0^{^3\mathrm{He}}$ in conjunction with the transverse asymmetry $A_\perp^{^3\mathrm{He}}$ and the parallel asymmetry $A_\parallel^{^3\mathrm{He}}$ for $0.2 < x < 0.9$ with $2.5 < Q^2 < 9$ GeV^2.
- An Experiment in Hall C:
  - A polarized electron beam of 11.0 GeV and polarized ^{3}He target
  - Measure $\Delta\sigma_\perp = \sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}$, $\Delta\sigma_\parallel = \sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}$ for $^3\vec{\mathrm{He}}(\vec{e},e')$ reaction for $0.2 < x < 0.9$ with $2 < Q^2 < 6$ GeV^2.

- Spokespeople:
  - Hall A: T. Averett, J.P. Chen, W. Korsch, B. Sawatzky
  - Hall C: T. Averett, W. Korsch, Z.E. Meziani, B. Sawatzky