

Nucleon Spin Structure Measurements with Lepton Beams at Low Q^2



Spin 2016

Champaign, IL

9/27/2016

Karl Slifer

University of New Hampshire

This Talk

Brief Review

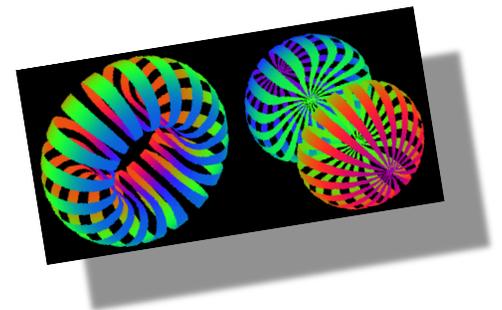
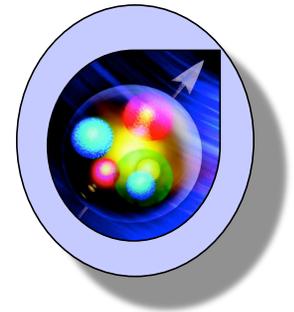
Inclusive Scattering & Structure Functions
Spin Polarizabilities & Moments.

Jlab Data

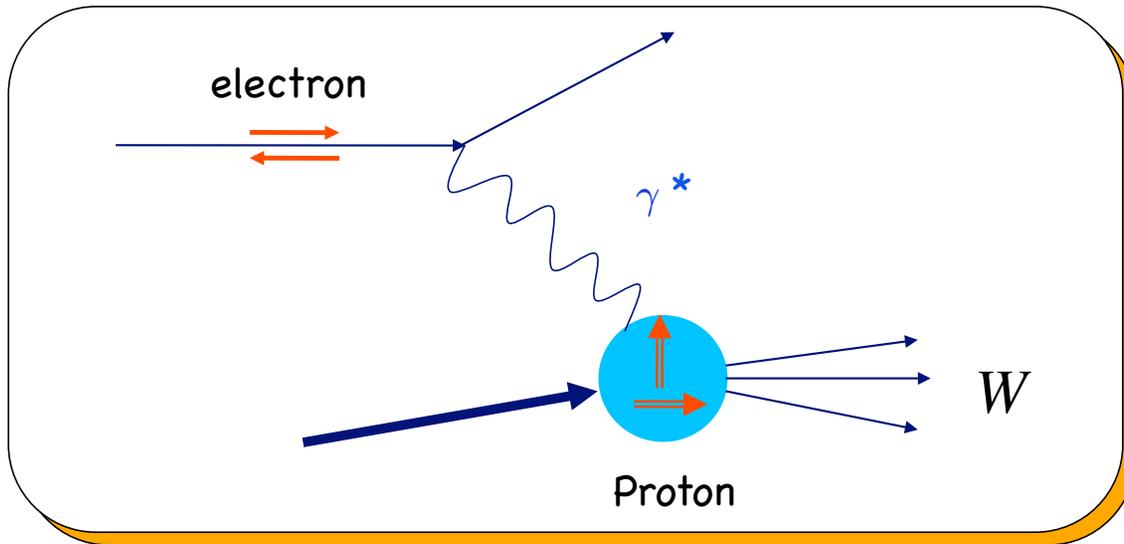
Halls A,B & C
 $0.04 < Q^2 < 6 \text{ GeV}^2$

JLab Tensor Structure Program

E12-13-011: "The b_1 experiment"
E12-15-005: " A_{zz} for $x > 1$ "



Inclusive Scattering

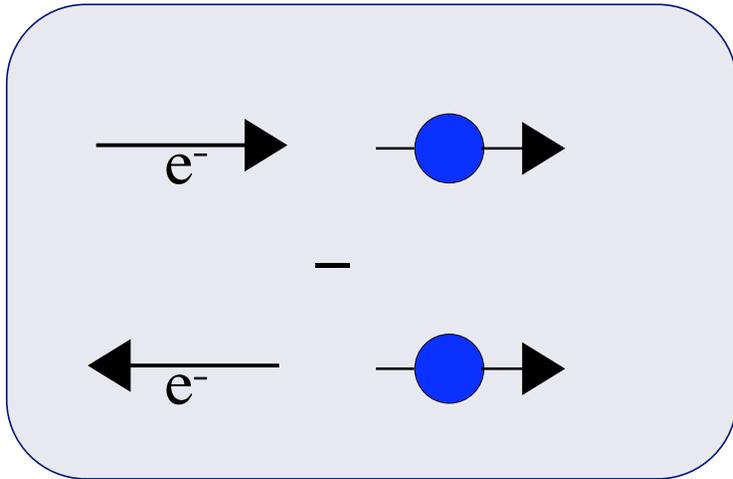


When we add spin degrees of freedom to the target and beam, 2 Additional SF needed.

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott} \left[\frac{1}{\nu} F_2(x, Q^2) + \frac{2}{M} F_1(x, Q^2) \tan^2 \frac{\theta}{2} \right] + \gamma g_1(x, Q^2) + \delta g_2(x, Q^2)$$

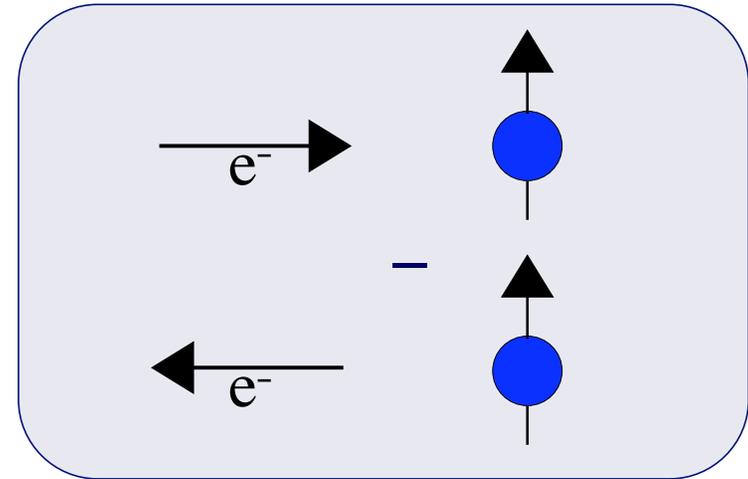
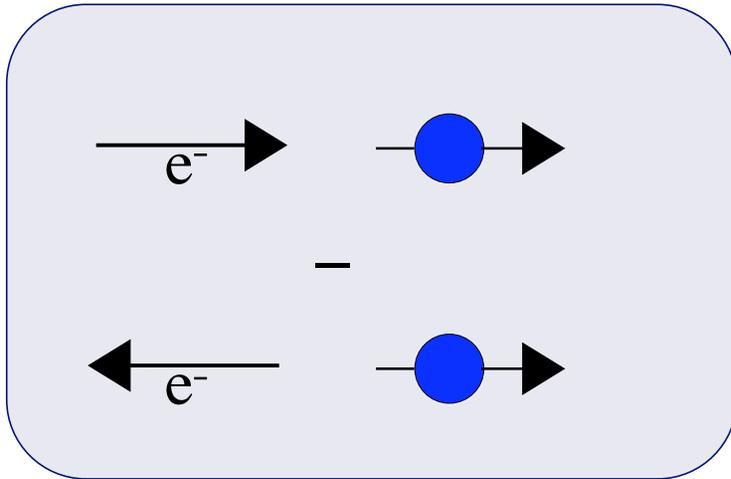
Inclusive Polarized
Cross Section

Cross Section Differences



$$\frac{d^2\sigma^{\uparrow\uparrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\uparrow}}{d\Omega dE'} = \frac{4\alpha^2}{\nu Q^2} \frac{E'}{E} [(E + E' \cos \theta) g_1 - 2Mx g_2]$$

Cross Section Differences



$$\frac{d^2\sigma^{\uparrow\uparrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\uparrow}}{d\Omega dE'} = \frac{4\alpha^2}{\nu Q^2} \frac{E'}{E} [(E + E' \cos \theta) g_1 - 2Mx g_2]$$

$$\frac{d^2\sigma^{\uparrow\Rightarrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Rightarrow}}{d\Omega dE'} = \frac{4\alpha^2}{\nu Q^2} \frac{E'}{E} \sin \theta \left[g_1 + \frac{2ME}{\nu} g_2 \right]$$

Moments

Spin
polarizabilities

$$\gamma_0(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 g_{TT}(x, Q^2),$$

$$\delta_{LT}(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 \left[g_1(x, Q^2) + g_2(x, Q^2) \right],$$

$$g_{TT} = g_1 - (4M_N^2 x^2 / Q^2) g_2$$

Moments

Spin
polarizabilities

$$\gamma_0(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 g_{TT}(x, Q^2),$$

$$\delta_{LT}(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 \left[g_1(x, Q^2) + g_2(x, Q^2) \right],$$

color
polarizability

$$\bar{d}_2(Q^2) = \int_0^{x_0} dx x^2 \left[2g_1(x, Q^2) + 3g_2(x, Q^2) \right],$$

$$g_{TT} = g_1 - (4M_N^2 x^2 / Q^2) g_2$$

Moments

Spin
polarizabilities

$$\gamma_0(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 g_{TT}(x, Q^2),$$

$$\delta_{LT}(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 \left[g_1(x, Q^2) + g_2(x, Q^2) \right],$$

color
polarizability

$$\bar{d}_2(Q^2) = \int_0^{x_0} dx x^2 \left[2g_1(x, Q^2) + 3g_2(x, Q^2) \right],$$

Generalized
GDH

$$I_A(Q^2) = \frac{2M_N^2}{Q^2} \int_0^{x_0} dx g_{TT}(x, Q^2),$$

$$\Gamma_1(Q^2) = \int_0^{x_0} dx g_1(x, Q^2),$$

$$g_{TT} = g_1 - (4M_N^2 x^2 / Q^2) g_2$$

Moments

Spin
polarizabilities

$$\gamma_0(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 g_{TT}(x, Q^2),$$

$$\delta_{LT}(Q^2) = \frac{16\alpha M_N^2}{Q^6} \int_0^{x_0} dx x^2 \left[g_1(x, Q^2) + g_2(x, Q^2) \right],$$

color
polarizability

$$\bar{d}_2(Q^2) = \int_0^{x_0} dx x^2 \left[2g_1(x, Q^2) + 3g_2(x, Q^2) \right],$$

Generalized
GDH

$$I_A(Q^2) = \frac{2M_N^2}{Q^2} \int_0^{x_0} dx g_{TT}(x, Q^2),$$

$$\Gamma_1(Q^2) = \int_0^{x_0} dx g_1(x, Q^2),$$

Burkhardt
Cottingham

$$\Gamma_2(Q^2) = \int_0^{x_0} dx g_2(x, Q^2)$$

$$g_{TT} = g_1 - (4M_N^2 x^2 / Q^2) g_2$$

Thanks to these Collaborations

EG4 Proton : M. Ripani(Contact), M. Battaglieri, A. Deur, R. De Vita

EG4 Deuteron : A. Deur(Contact), G. Dodge, K. Slifer

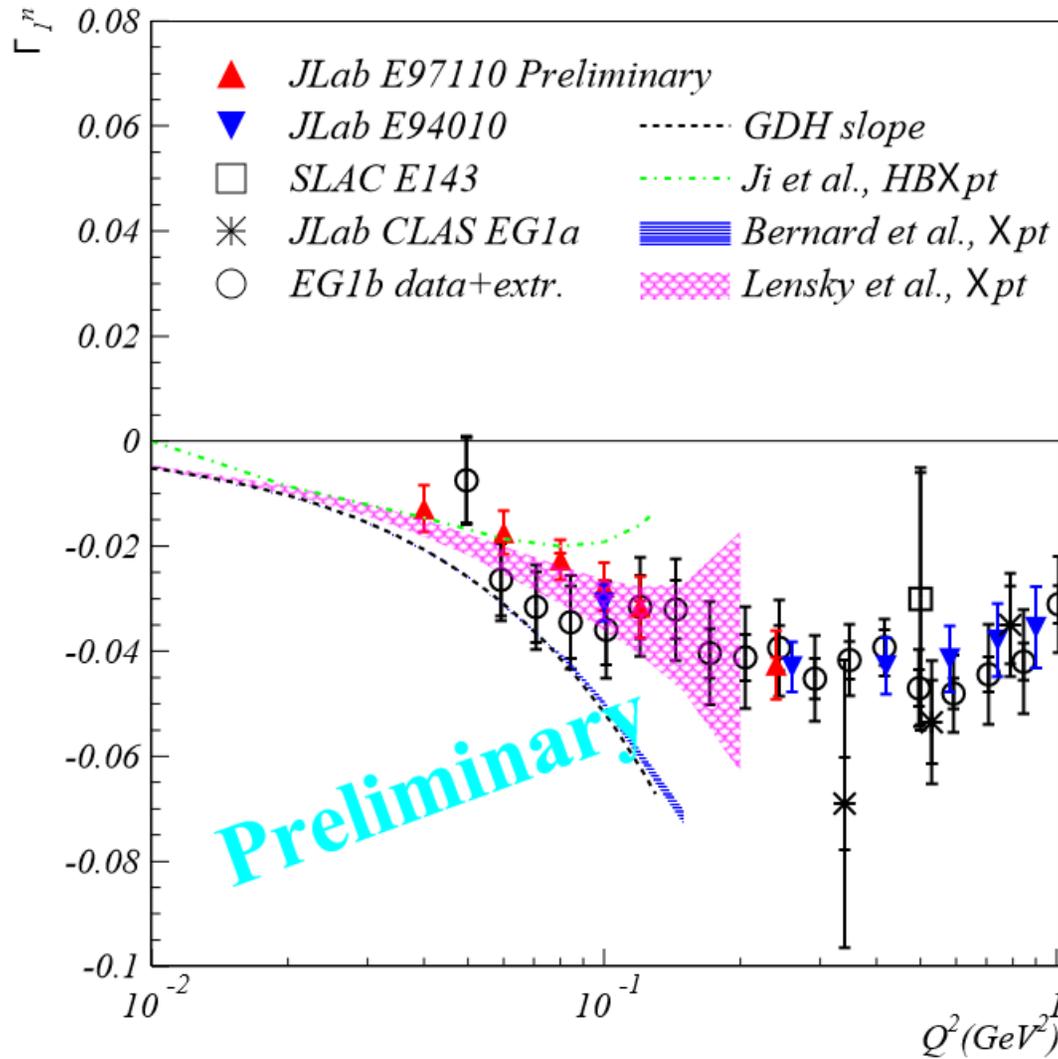
g2p : K. Slifer (contact), JP Chen, D. Crabb, A. Camsonne

sagdh : JP Chen(contact), A. Deur

SANE : O. Rondon (contact), M. Jones

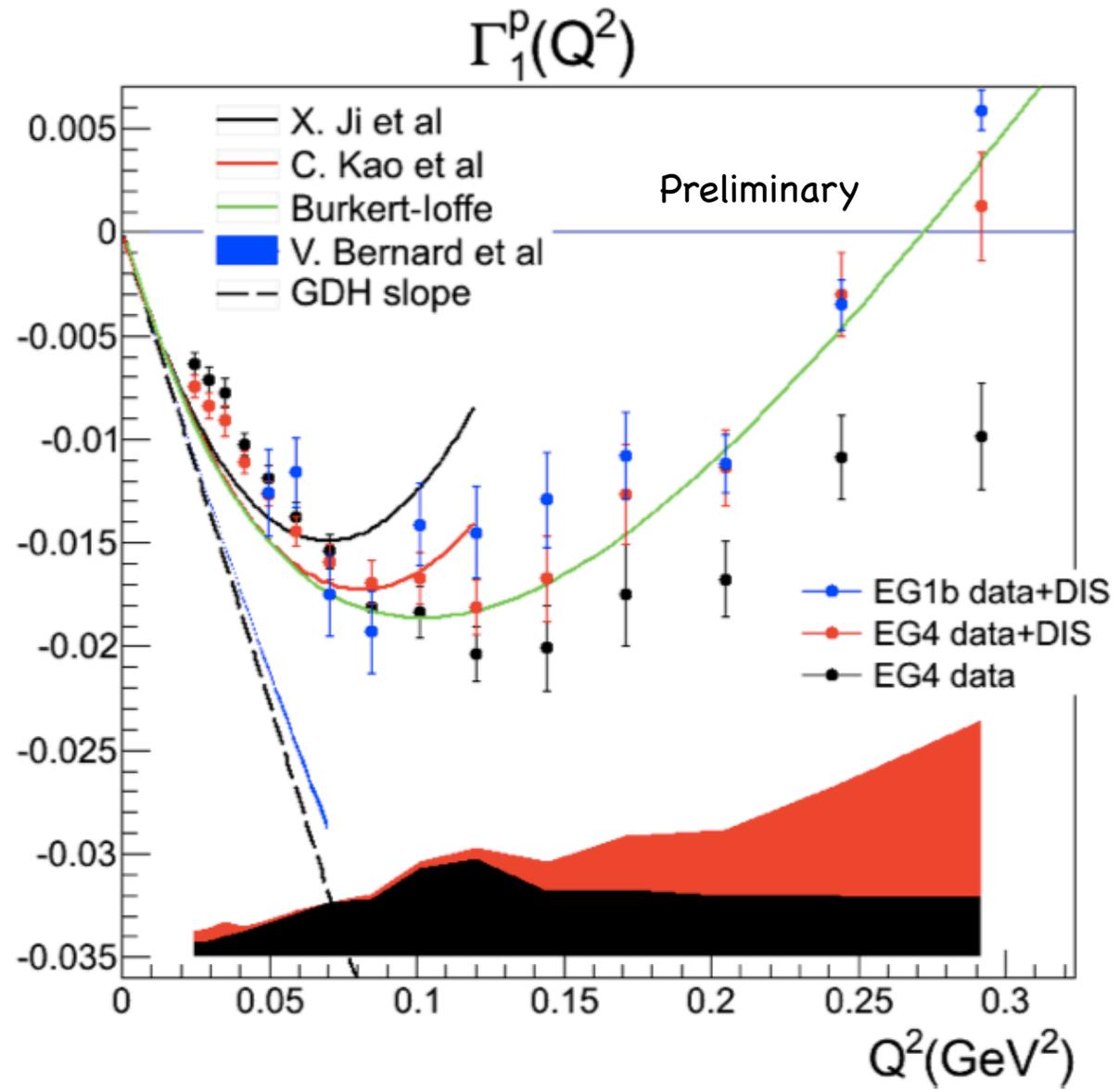
E94010: Z. Meziani (contact), G. Cates, JP Chen

Neutron 1st Moment



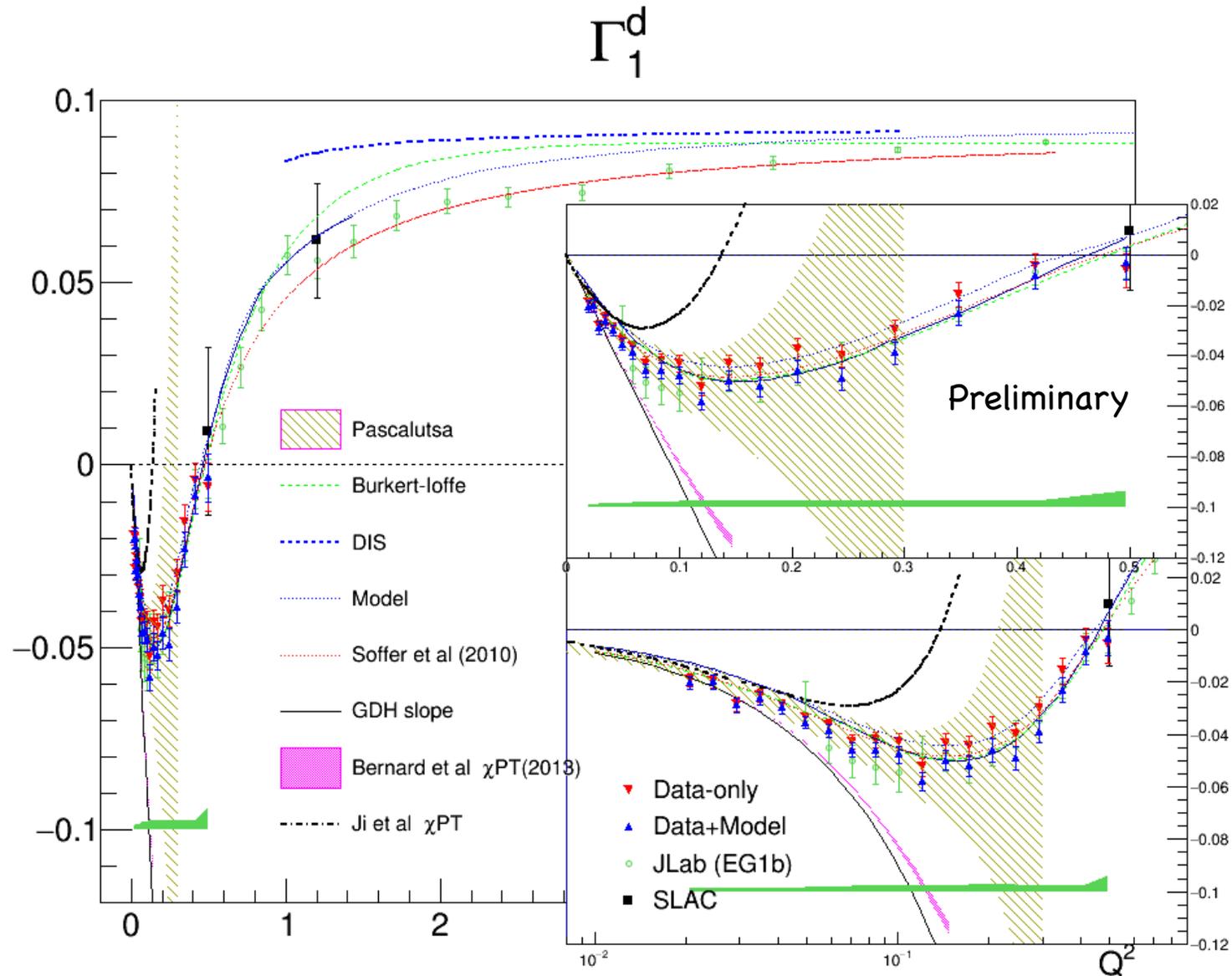
See talk of [Chao Peng, A. Deur](#)

Proton 1st Moment



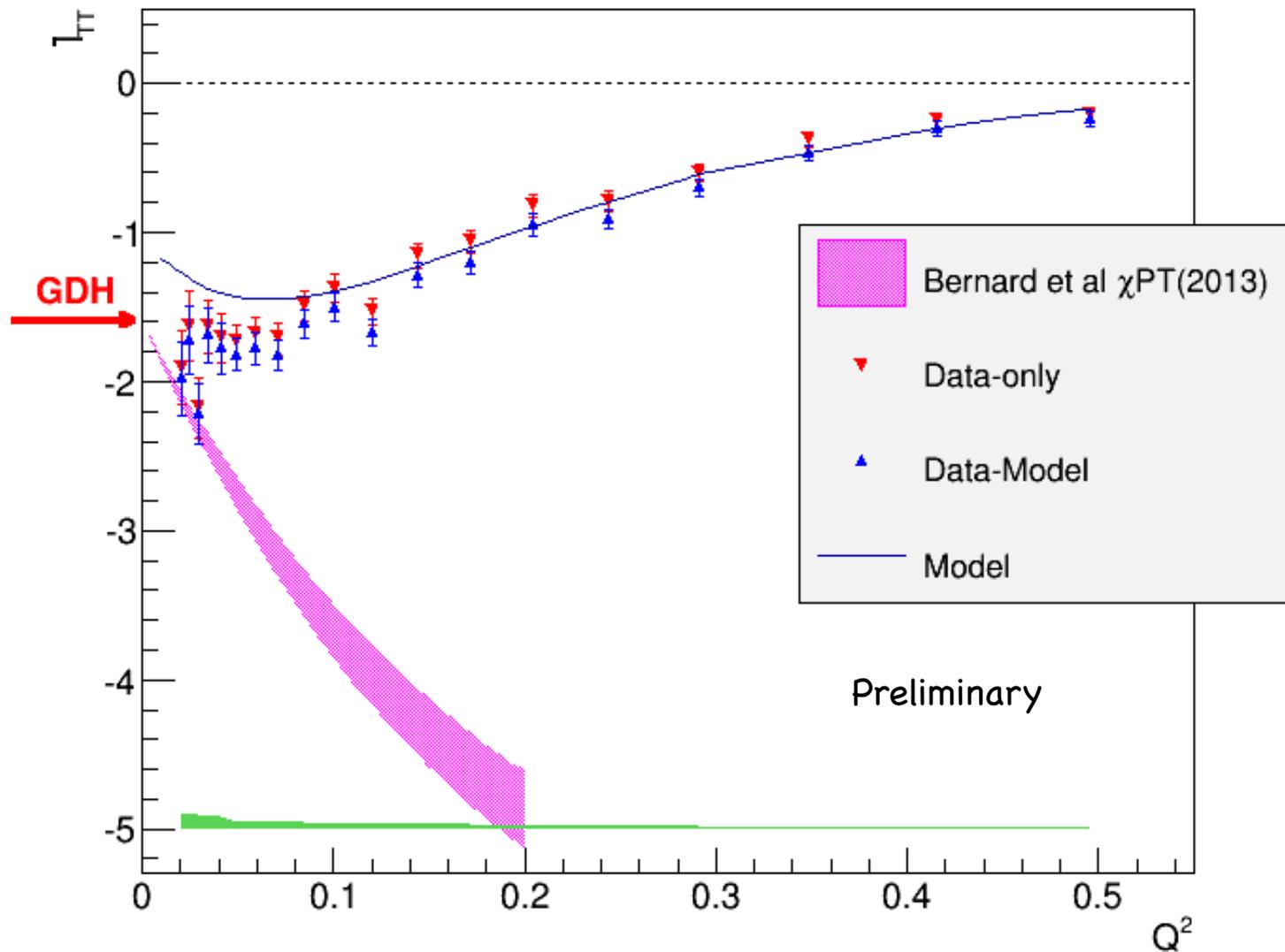
Plot courtesy of H. Kang (EG4)

Deuteron 1st Moment



Plot courtesy of K. Adhikari (EG4)

Neutron GDH Integral

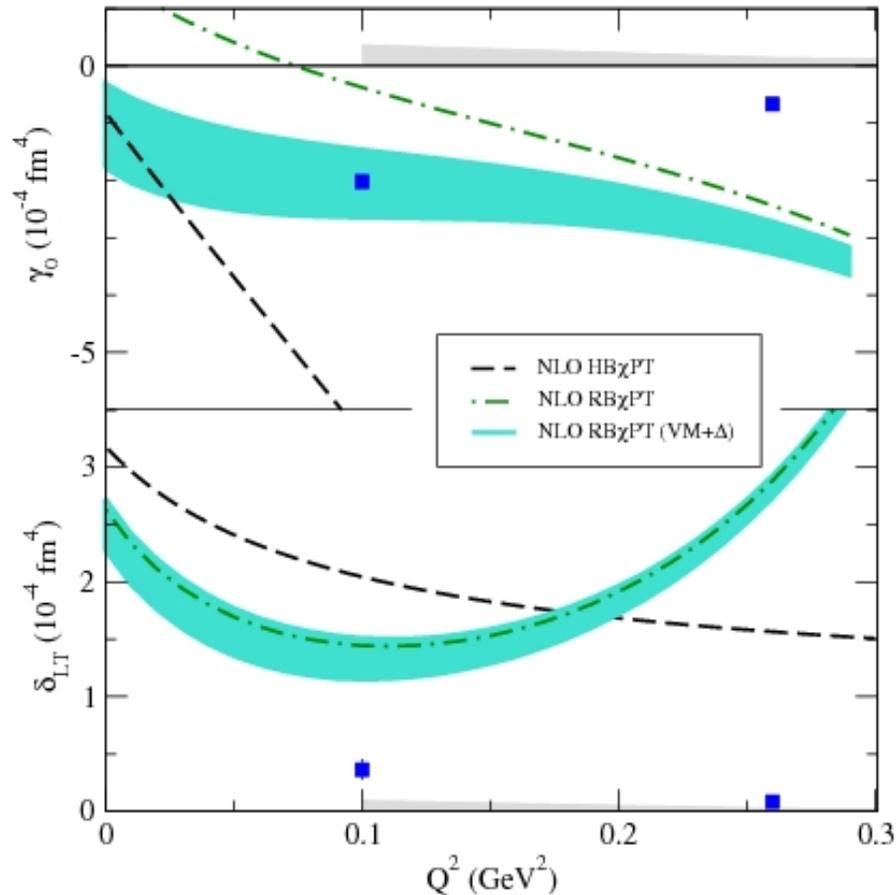


Plot courtesy of K. Adhikari (EG4)

δ_{LT} Puzzle

Neutron

PRL 93: 152301 (2004)



$$\gamma_0 = \frac{16\alpha M^2}{Q^6} \int_0^{x_0} x^2 \left[g_1 - \frac{4M^2}{Q^2} x^2 g_2 \right]$$

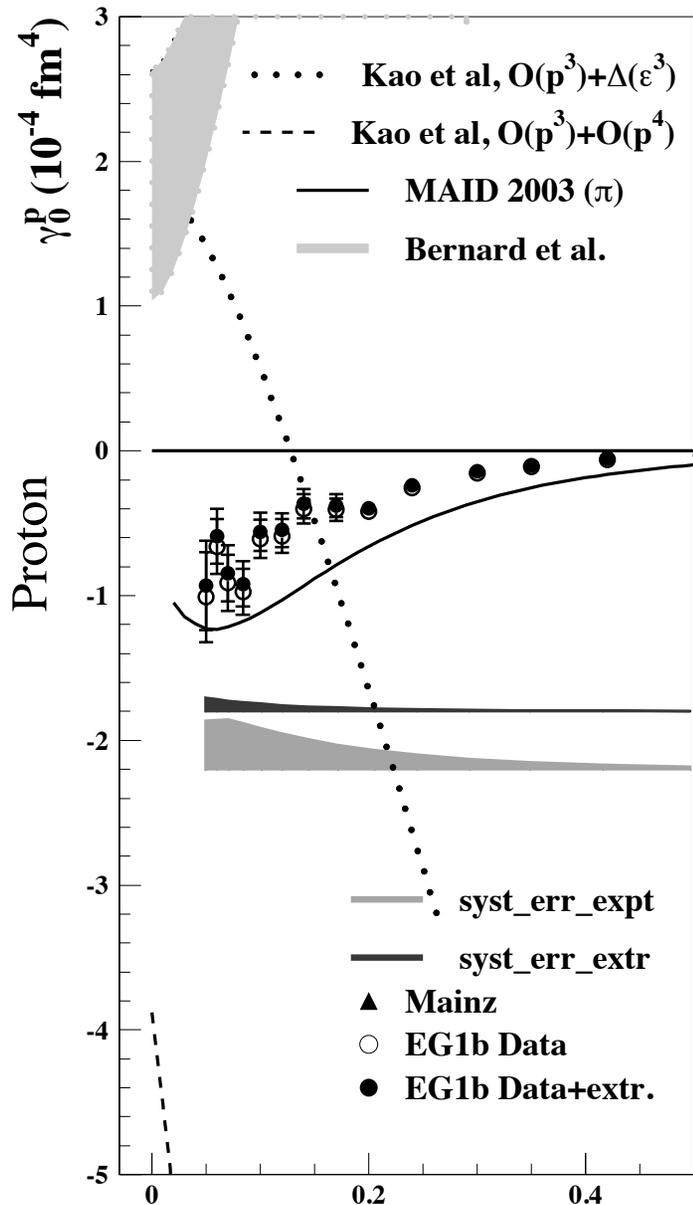
$$\delta_{LT} = \frac{16\alpha M^2}{Q^6} \int_0^{x_0} x^2 [g_1 + g_2]$$

**Dramatic Discrepancy
with χ PT**

— — Heavy Baryon χ PT Calculation
Kao, Spitzenberg, Vanderhaeghen
PRD 67:016001(2003)

— Relativistic Baryon χ PT
Bernard, Hemmert, Meissner
PRD 67:076008(2003)

Proton γ_0



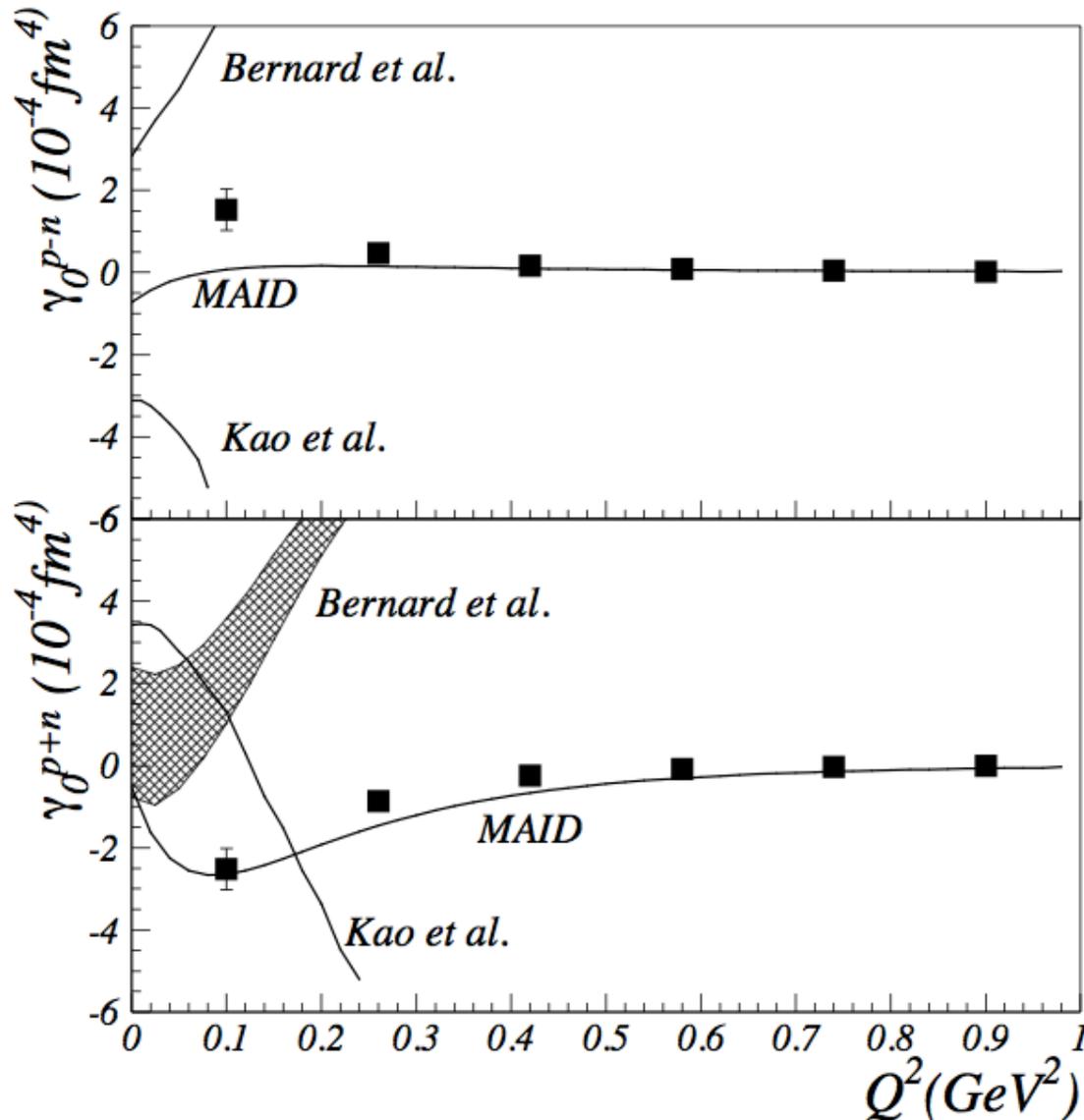
$$\gamma_0 = \frac{16\alpha M^2}{Q^6} \int_0^{x_0} x^2 \left[g_1 - \frac{4M^2}{Q^2} x^2 g_2 \right]$$

Older Calcs also failed for proton γ_0

PLB 672 12, 2009

published data goes down to about 0.06 GeV^2

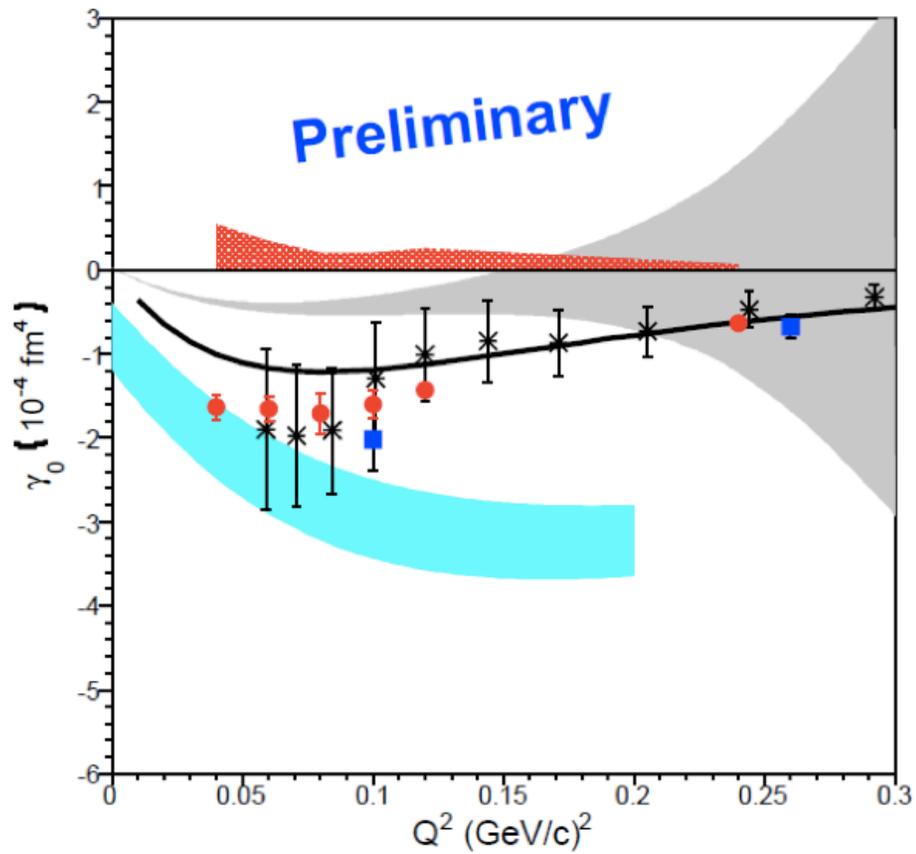
P-N and P+N γ_0



Deur et al., Phys.Rev. D78 (2008) 032001

and for isoscalar
isovector combinations

Neutron γ_0

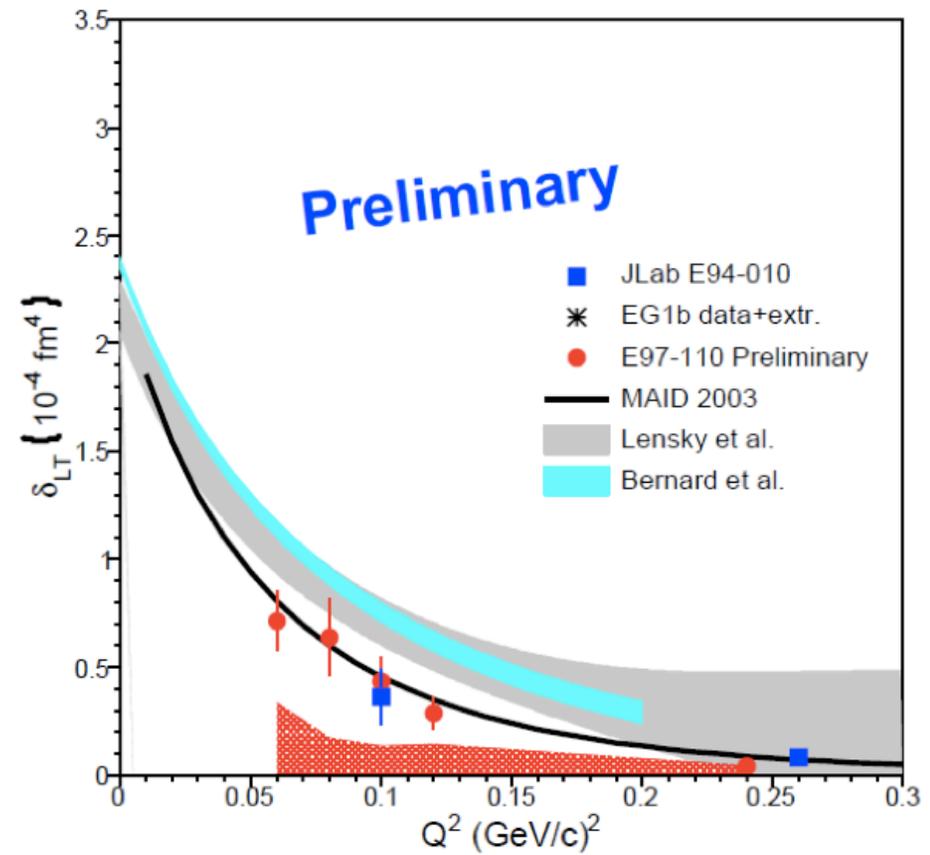
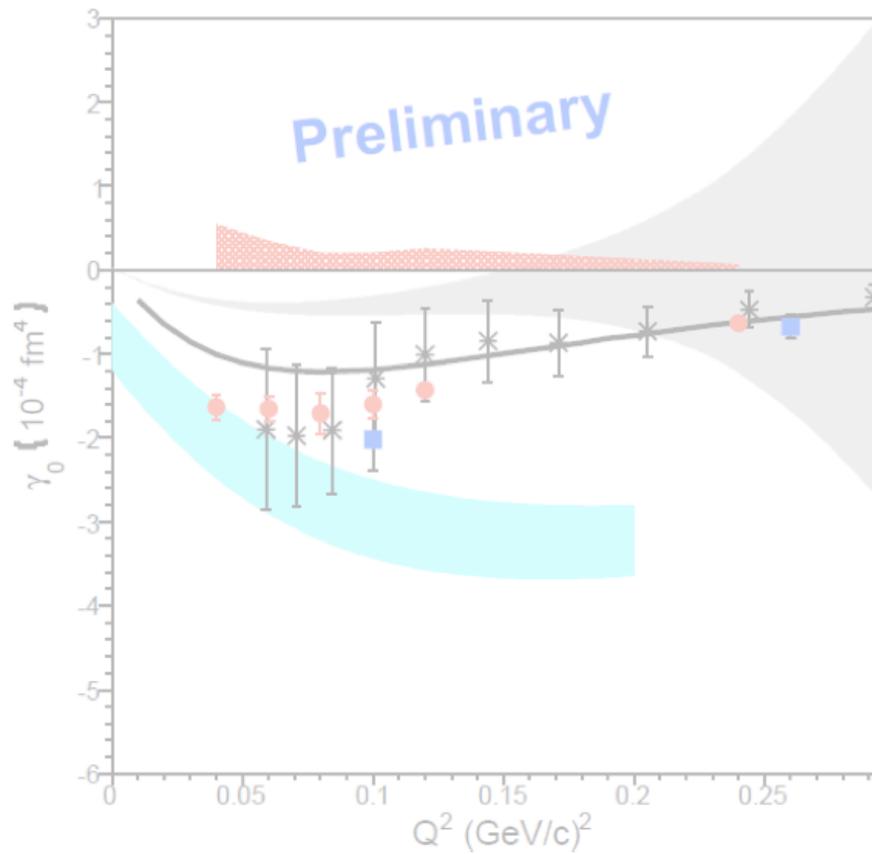


BERNARD et al. PRD 87, 054032 (2013)

Lensky et al. PRC 90(2014) 055202

See talk of **Chao Peng**

Neutron δ_{LT}

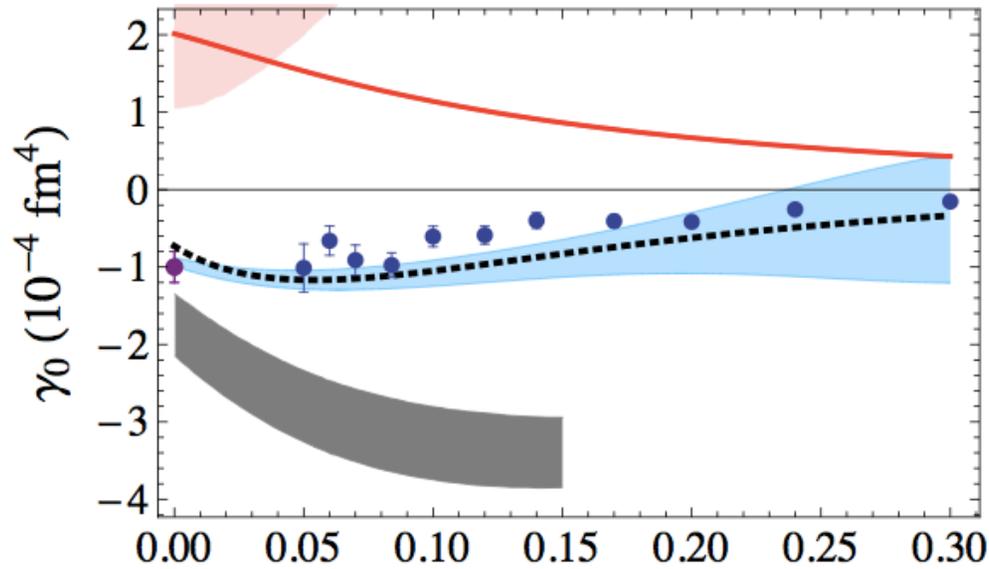


BERNARD et al. PRD 87, 054032 (2013)

Lensky et al. PRC 90(2014) 055202

See talk of **Chao Peng**

Proton γ_0



Lensky, Alarcon, Pascalutsa.

PRC 90(2014) 055202

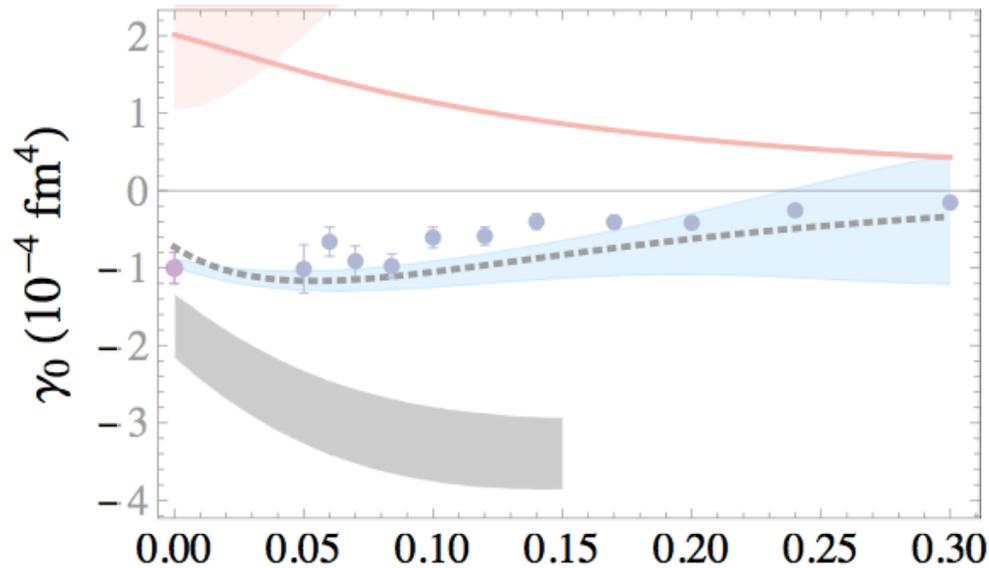
NLO: Blue Band

$B\chi\text{PT}$: good agreement with the
proton γ_0

Data: Phys. Lett. B 672, 12 (2009)

Phys. Rev. Lett. 91, 192001 (2003)

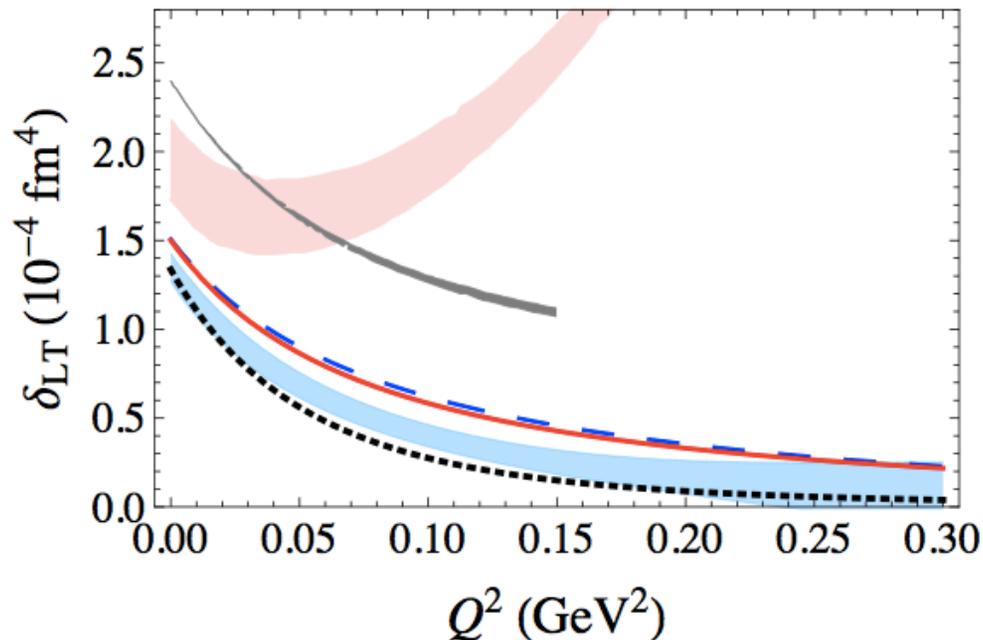
Proton δ_{LT}



Lensky, Alarcon, Pascalutsa.
arxiv:1407.2574 (2014)

NLO: Blue Band

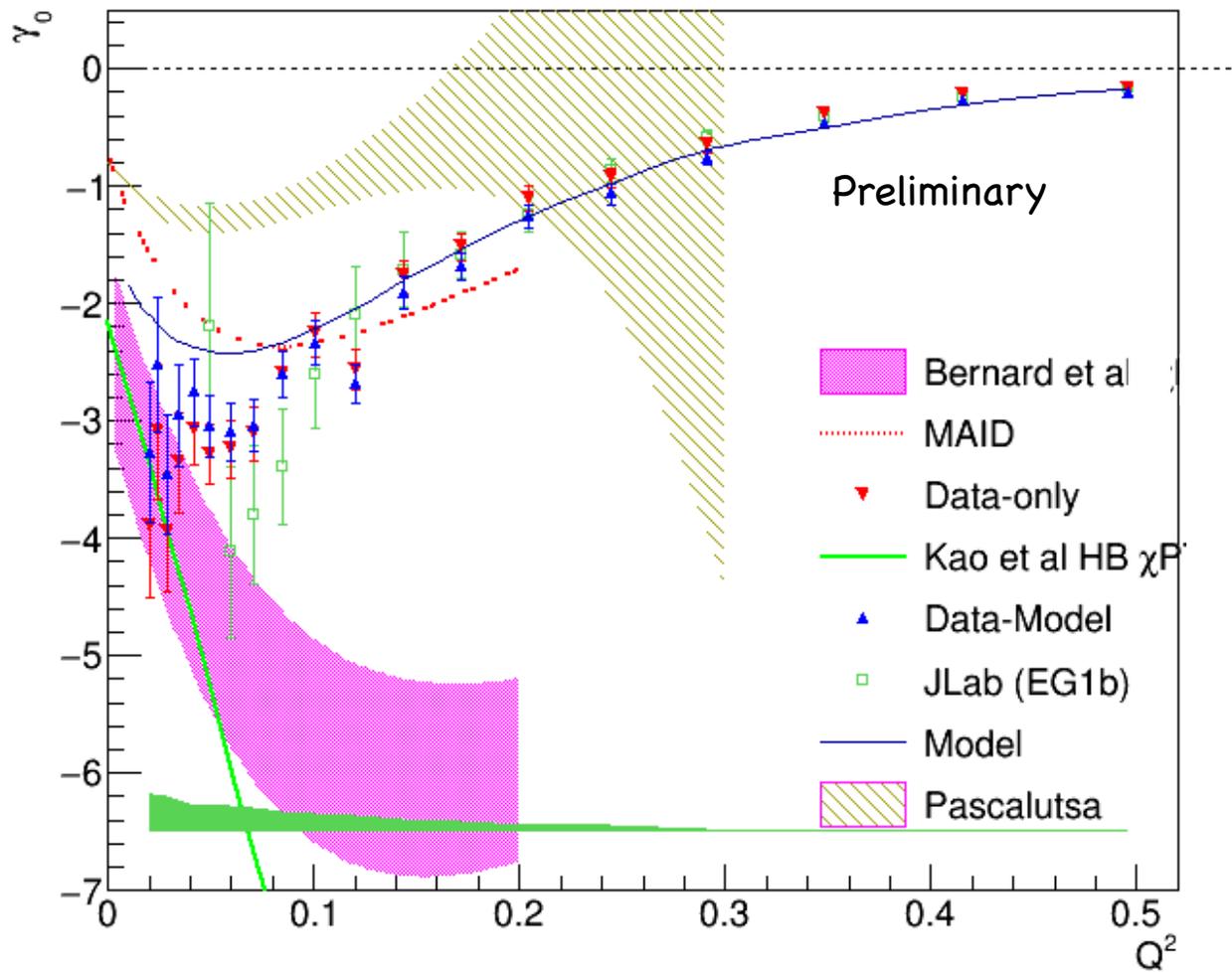
$B\chi_{PT}$: good agreement with the
proton γ_0



$B\chi_{PT}$: reasonable agreement with
MAID model for δ_{LT}

δ_{LT} puzzle Solved? Need data to confirm
data anticipated from EG4+g2p experiments

Deuteron γ_0



$$g_1^D = \left(1 - \frac{3}{2}\omega_D\right) (g_1^p + g_1^n)$$

Plot courtesy of K. Adhikari (EG4)

Spin Polarizabilities Summary

1st moments: Pretty good agreement with chPT calculations

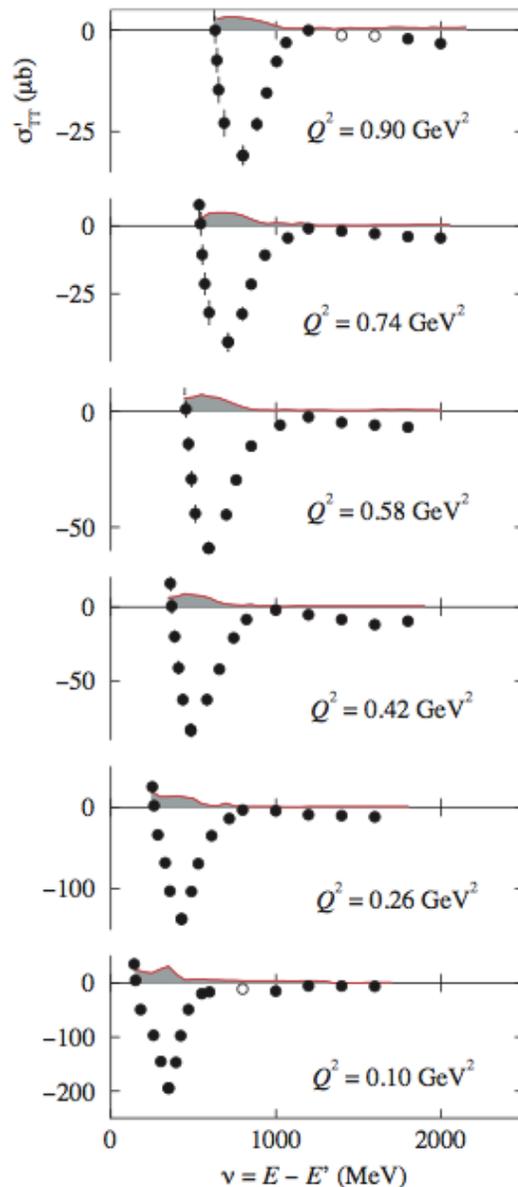
δ_{LT} : Pretty good agreement for neutron
waiting on proton data

γ_0 : Proton looks good
Neutron (&Deuteron) big discrepancy

What can be done from Experimental side?

δ_{LT} proton data
Higher order generalized spin polarizabilities?

Higher Order Forward Spin Polarizabilities



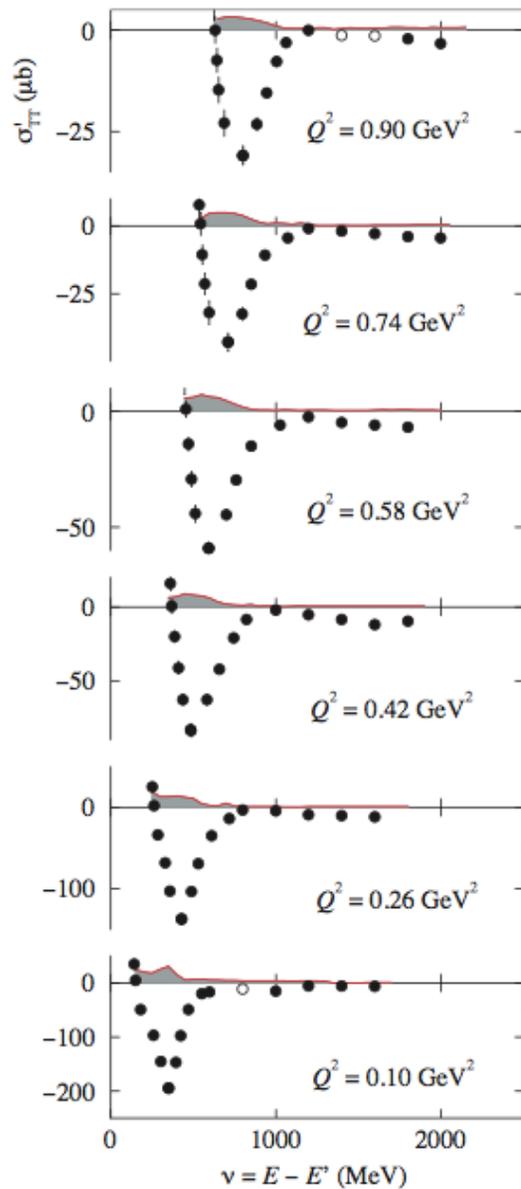
$$\overline{\gamma_0} = \frac{1}{2\pi^2} \int_{\nu_0}^{\infty} \frac{\sigma_{TT}(\nu, Q^2)}{\nu^5} d\nu$$

D. Drechsel et al. Physics Reports 378 (2003) 99–205

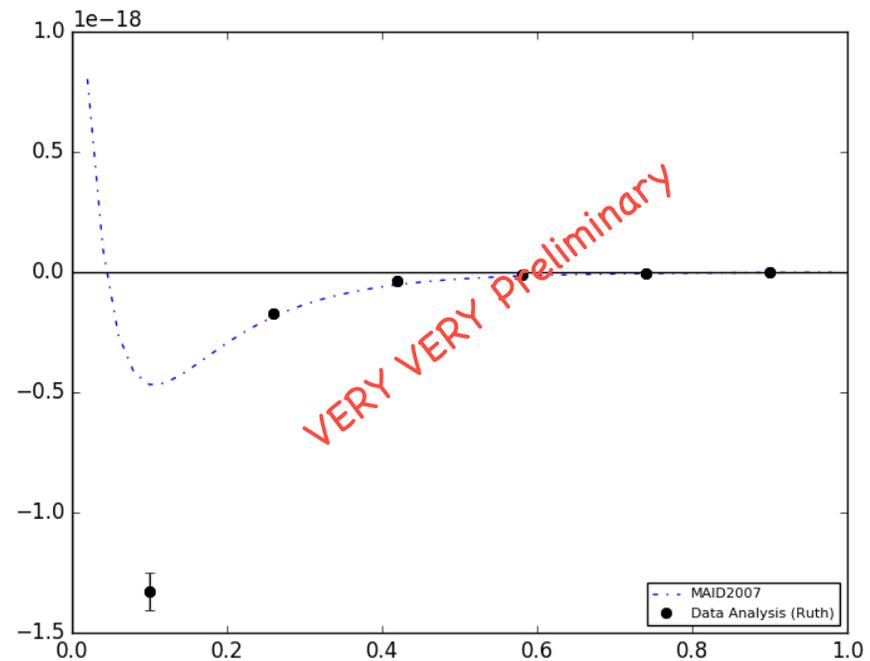
Phys.Lett.B687:160–166,2010

We can evaluate these higher moments
for neutron, proton and He-3 down to below $Q^2=0.05$

Higher Order Forward Spin Polarizabilities

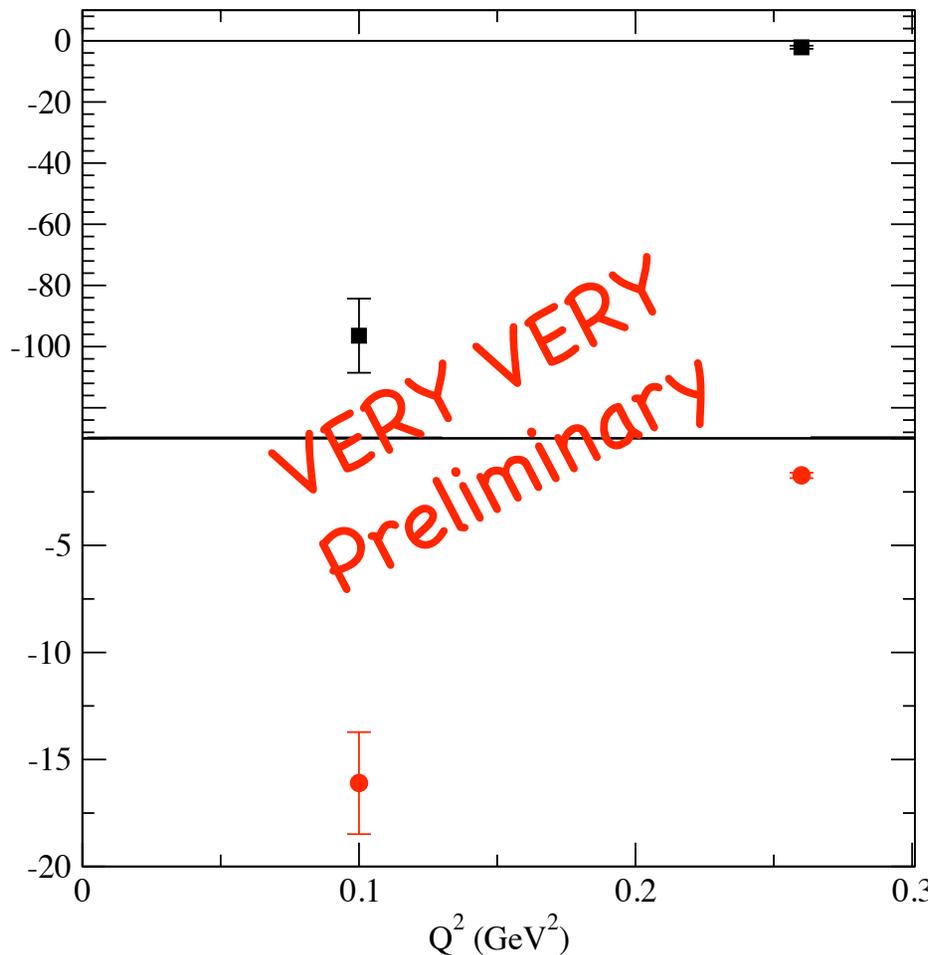


$$\overline{\gamma_0} = \frac{1}{2\pi^2} \int_{\nu_0}^{\infty} \frac{\sigma_{TT}(\nu, Q^2)}{\nu^5} d\nu$$



Higher Order Forward Spin Polarizabilities

^3He higher moments



$$\int_{x_0}^0 dx x^2 g_1^{3\text{He}}(x, Q^2)$$

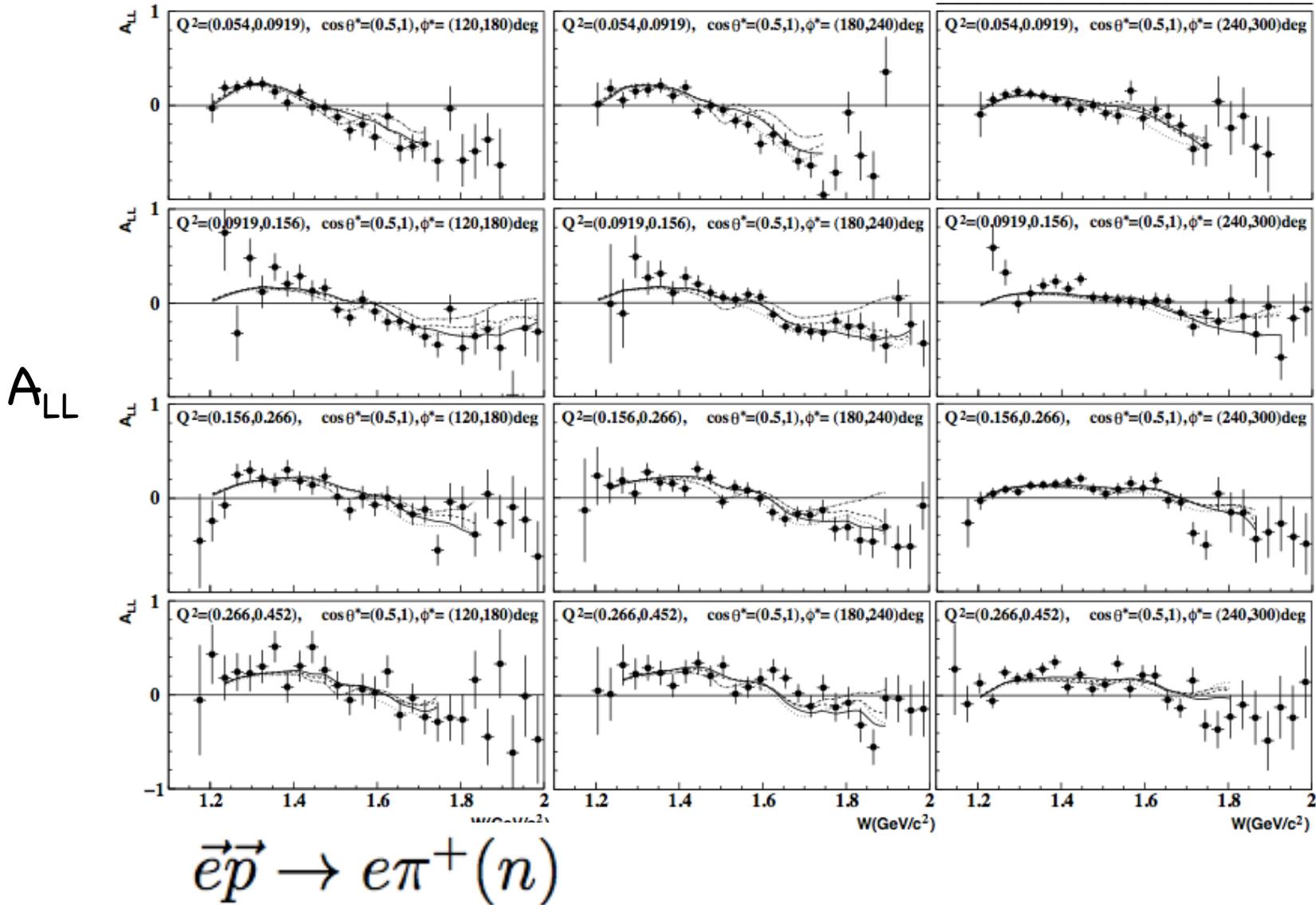
$$\int_{x_0}^0 dx x^2 g_2^{3\text{He}}(x, Q^2)$$

Free from Nuclear Corrections

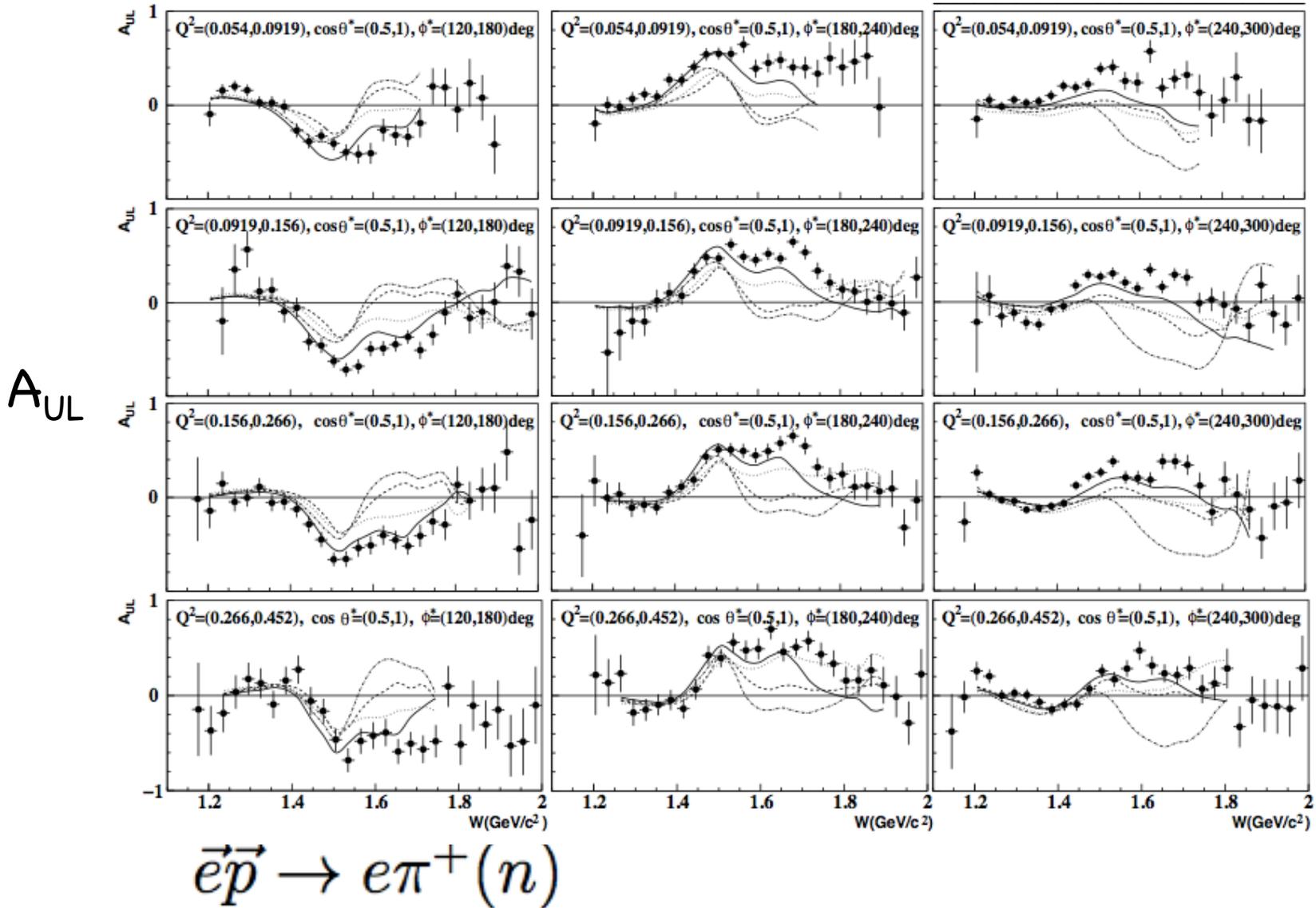
Unpublished

Would love to get theory curves on these plots. Any Interest??

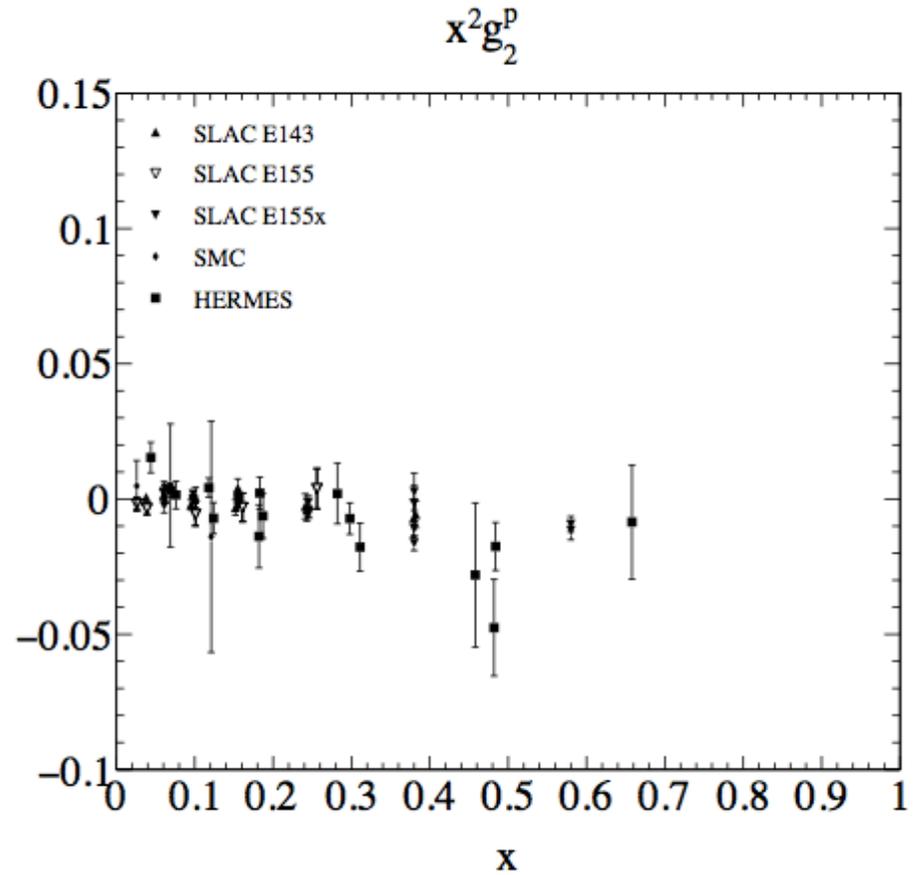
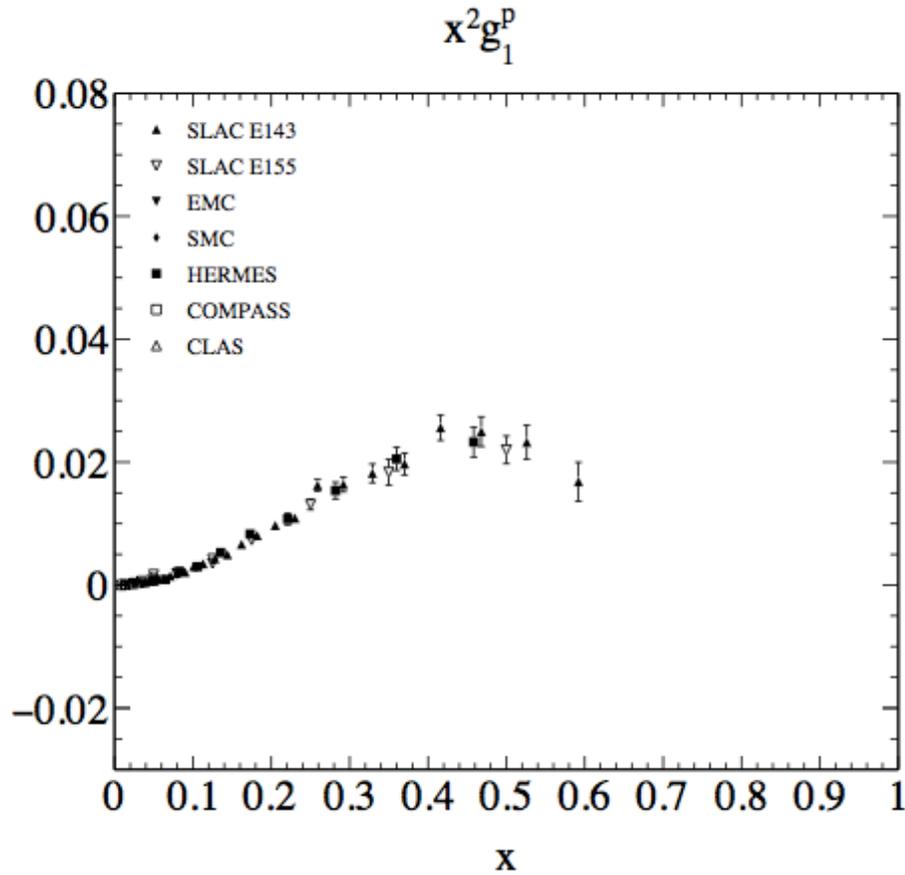
EG4 Target & Double-Spin Asymmetry



EG4 Target & Double-Spin Asymmetry

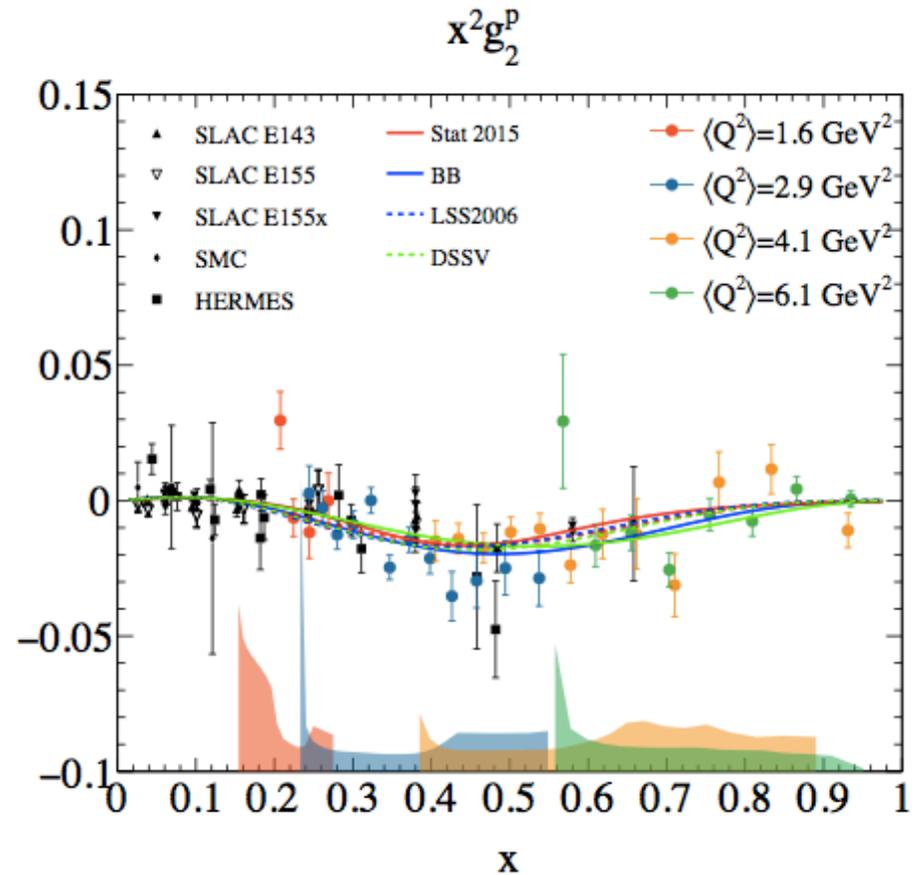
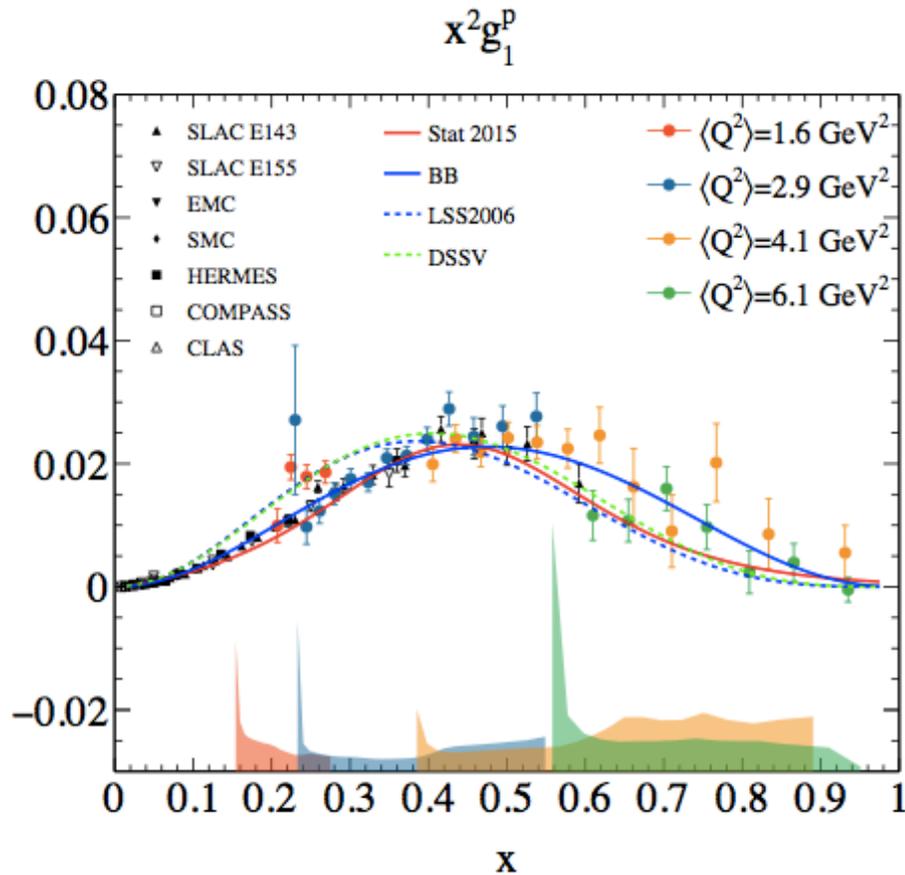


Proton x^2g_1 and x^2g_2



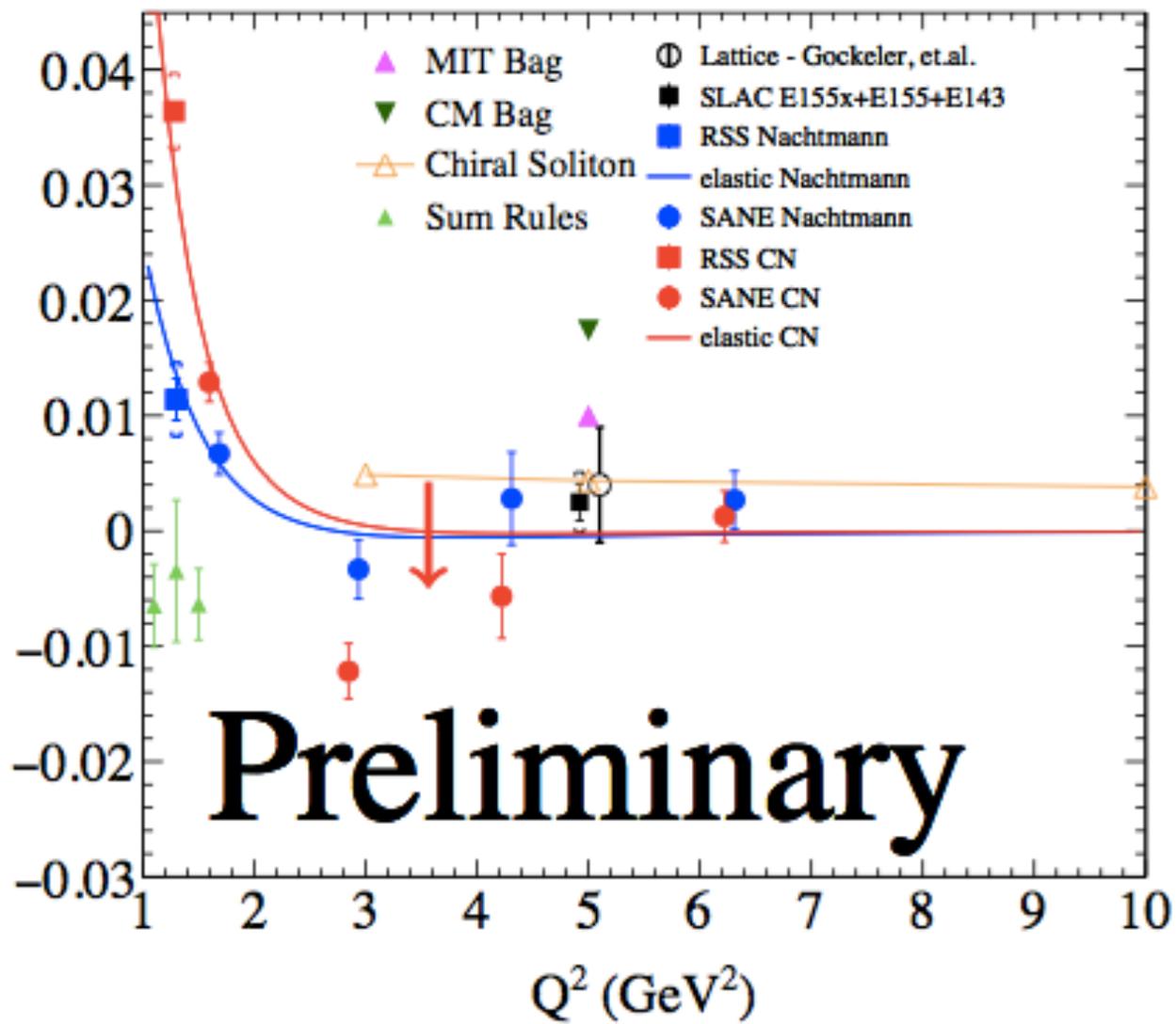
Plot courtesy of W. Armstrong (SANE)

SANE Proton results for x^2g_1 and x^2g_2



Plot courtesy of W. Armstrong (SANE)

SANE Proton results for d_2



Plot courtesy of W. Armstrong (SANE)

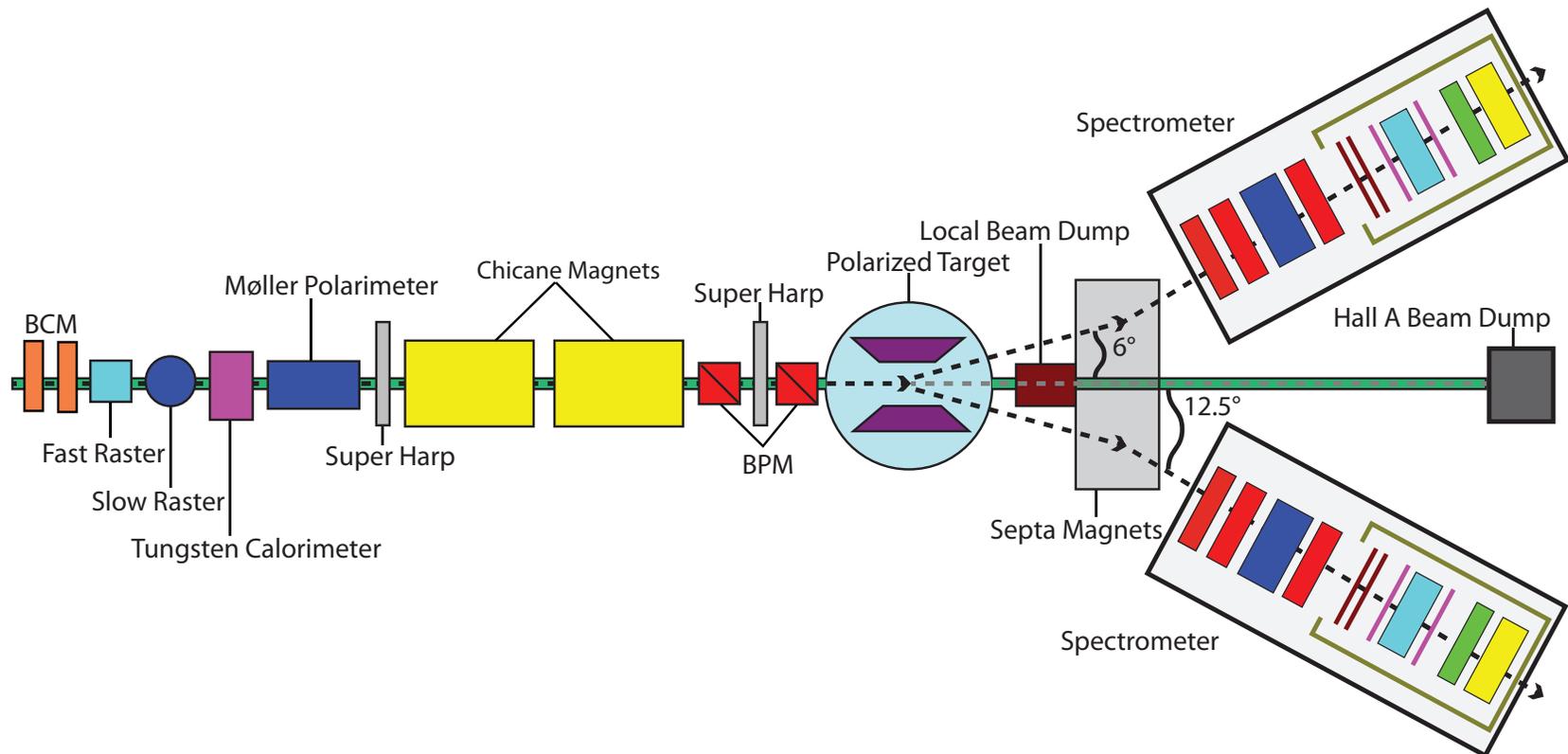
E08-027 : Proton g_2 Structure Function

Camsonne, Crabb,

BC Sum Rule : violation suggested for proton at large Q^2 ,
but found satisfied for the neutron & ^3He .

Chen, Slifer

Spin Polarizability : Major failure ($>8\sigma$) of χ_{PT} for neutron δ_{LT}



Largest Installation in Hall A History

Polarized proton target

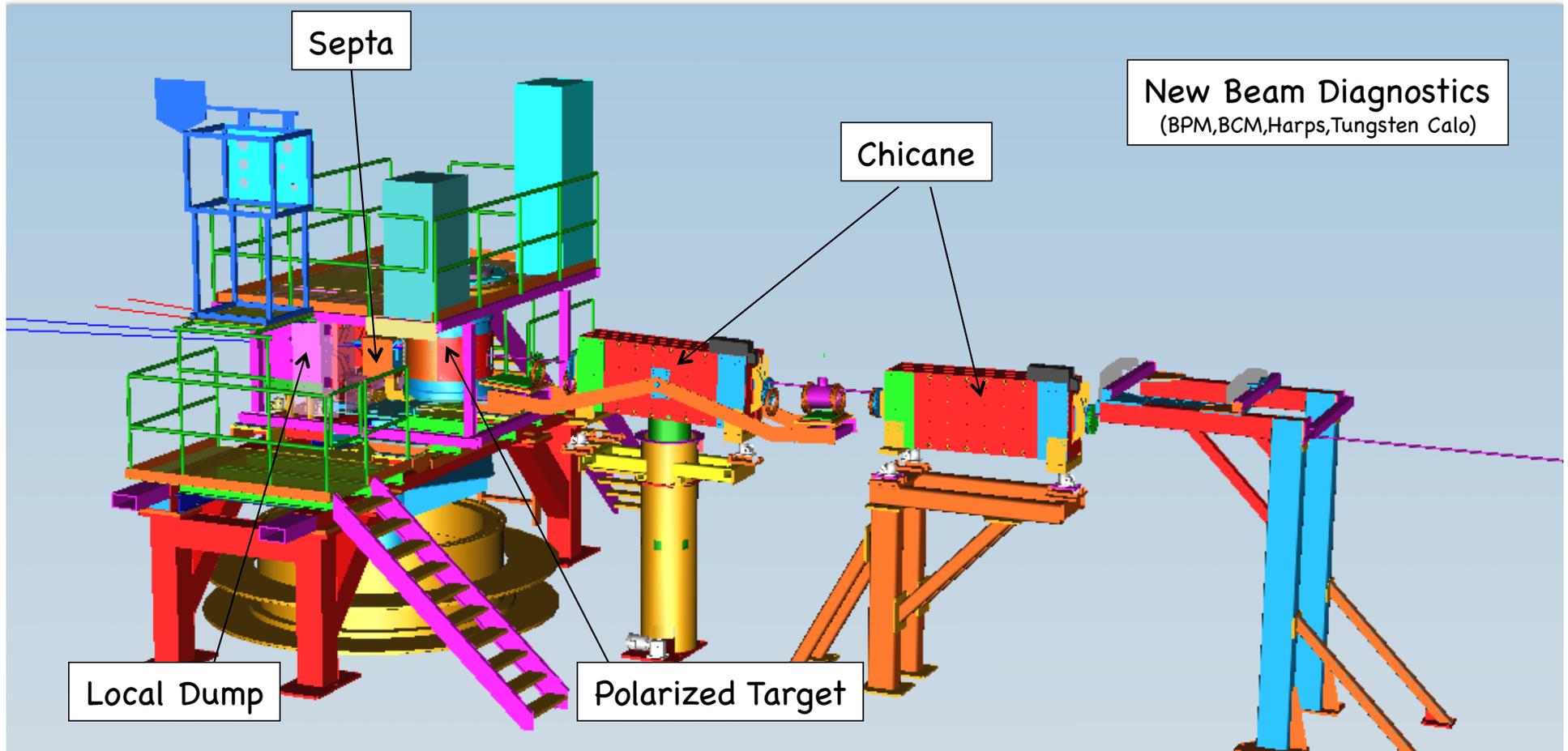
upstream chicane
downstream local dump

Low current polarized beam

Upgrades to existing Beam Diagnostics to work at 85 nA

Lowest possible Q^2 in the resonance region

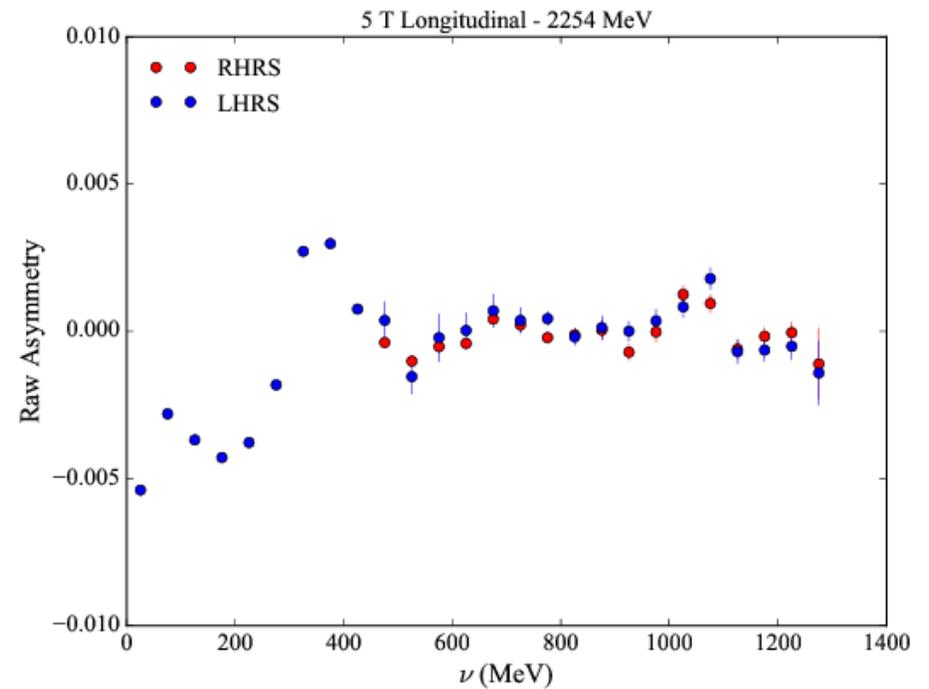
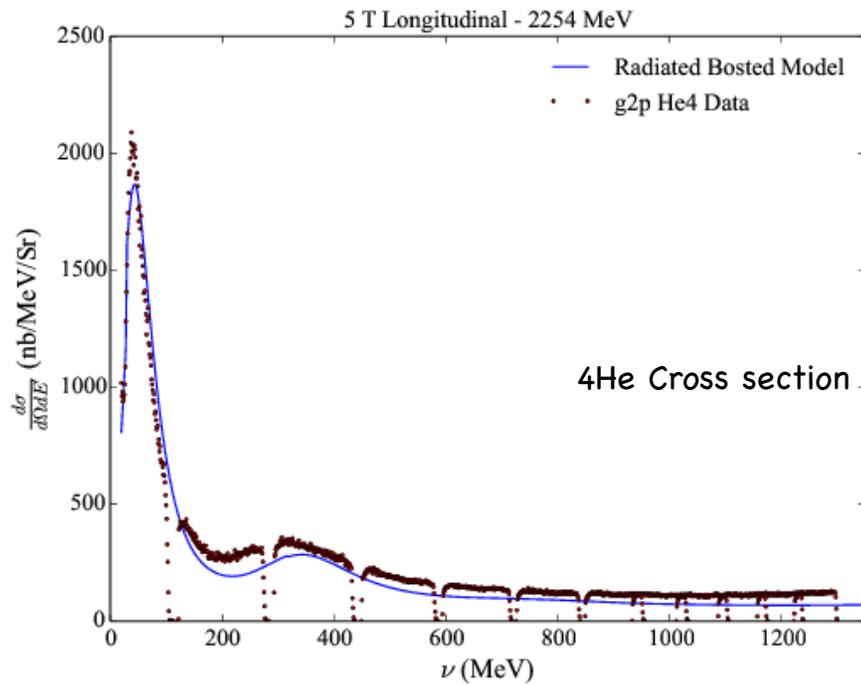
Septa Magnets to detect forward scattering



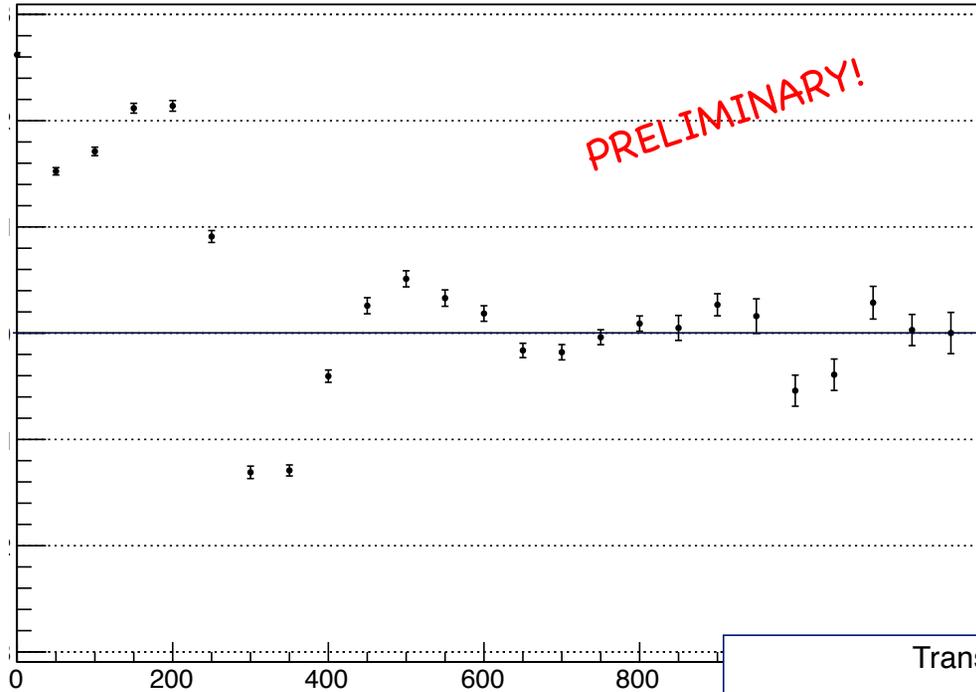
E08-027 Highlights & Prelim Results

Acceptance and Dilution Analysis ongoing

Most other tasks complete

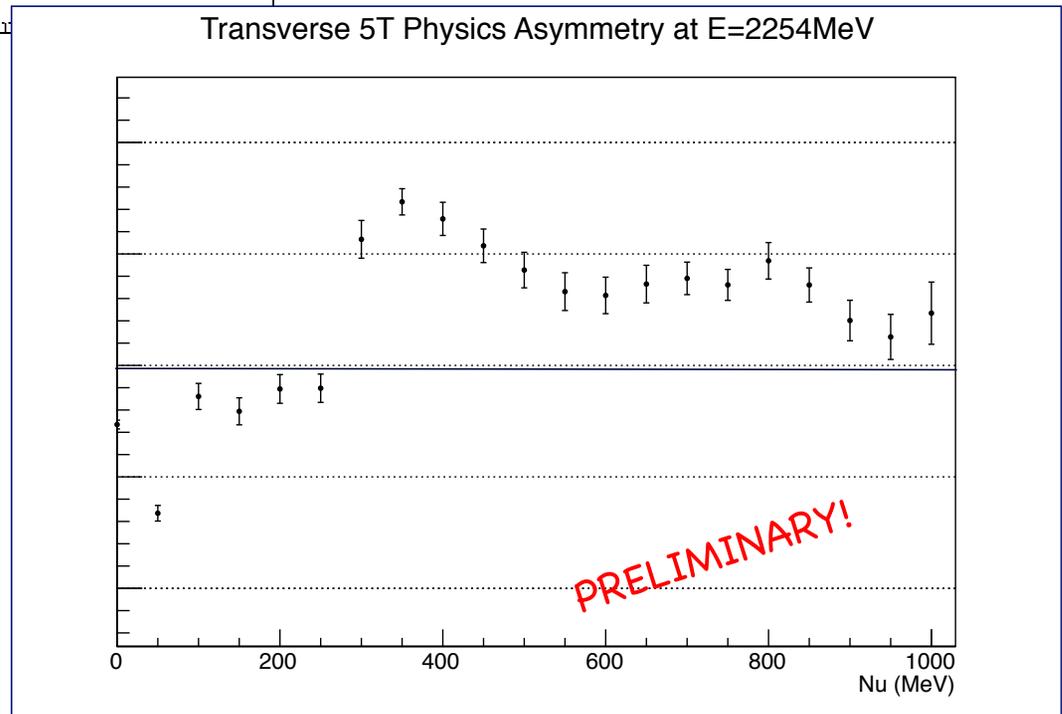


Longitudinal 5T Physics Asymmetry at E=2254MeV

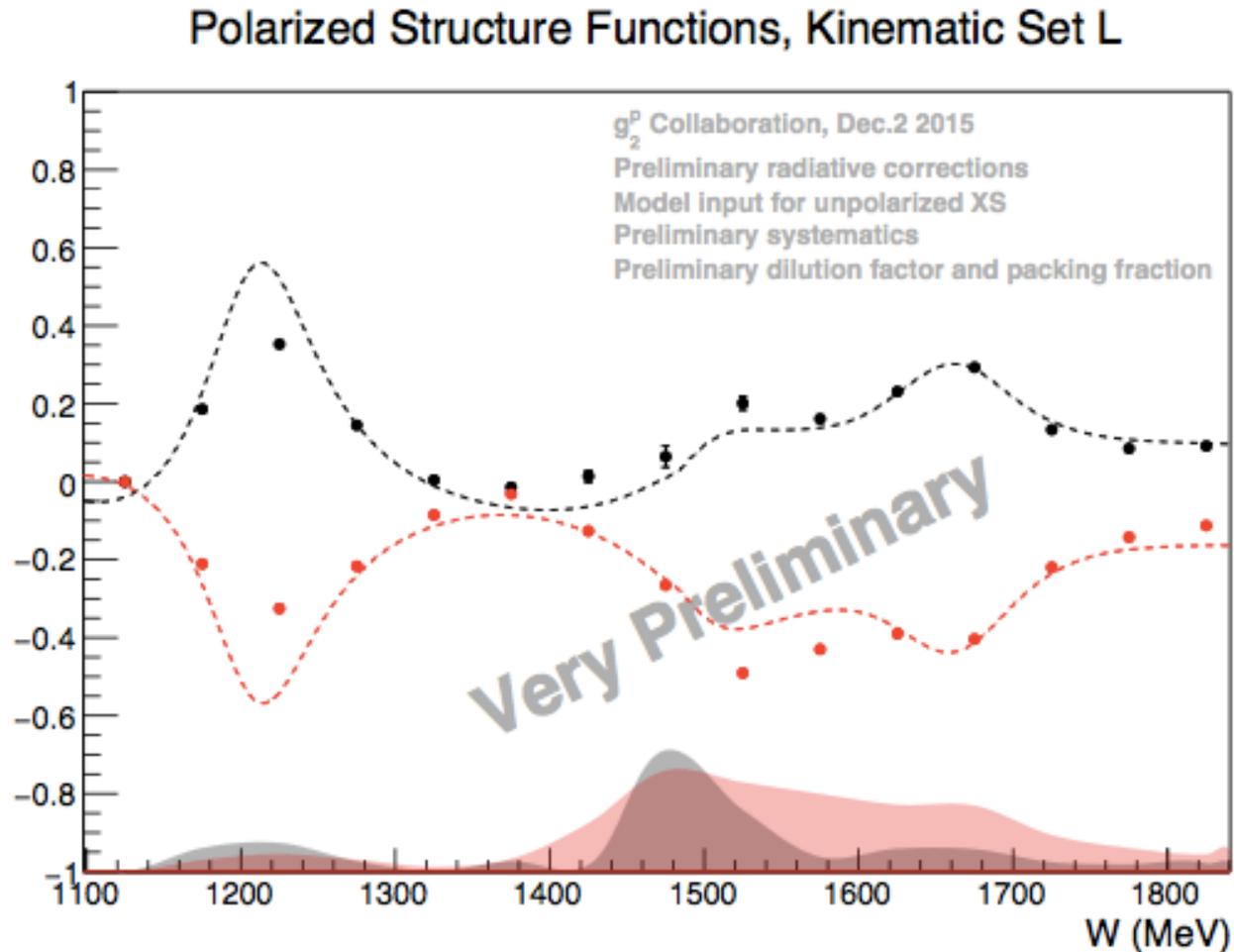


$$\langle Q^2 \rangle \approx 0.1 \text{ GeV}^2$$

Transverse 5T Physics Asymmetry at E=2254MeV



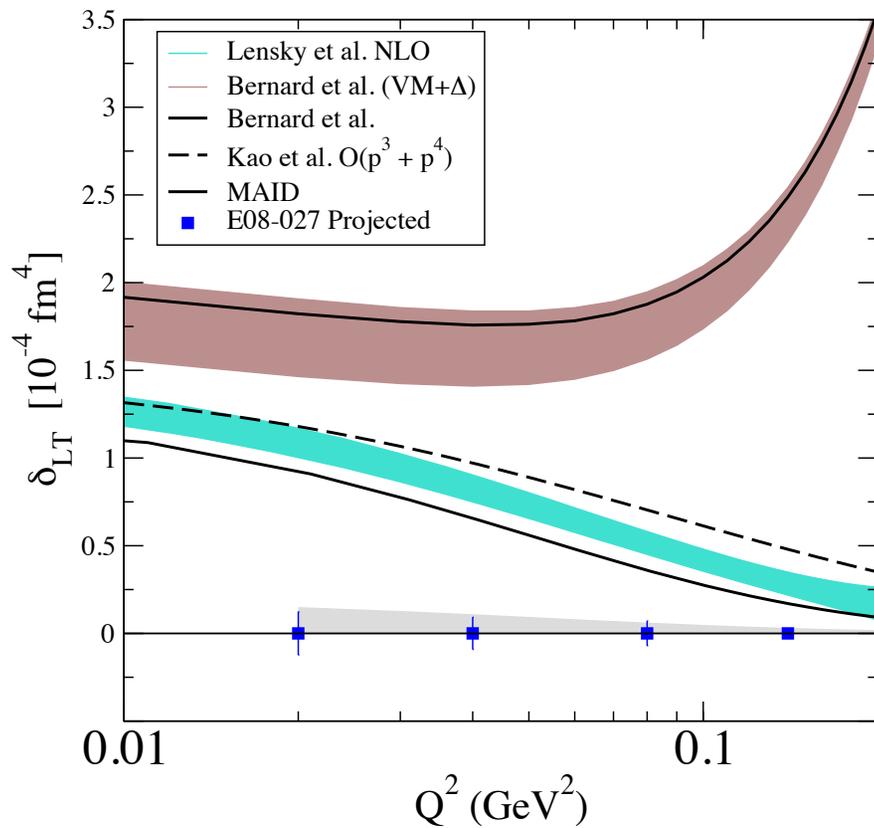
E08-027 Highlights & Prelim Results



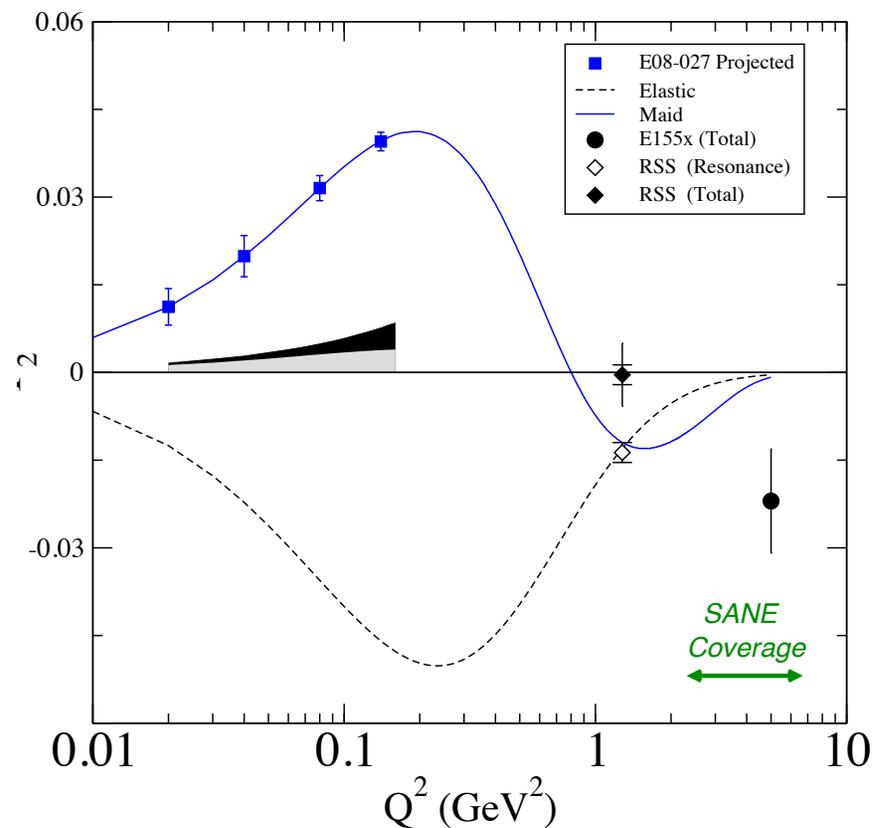
courtesy M. Cummings (W&M)

Projections

LT Spin Polarizability



BC Sum Integral Γ_2



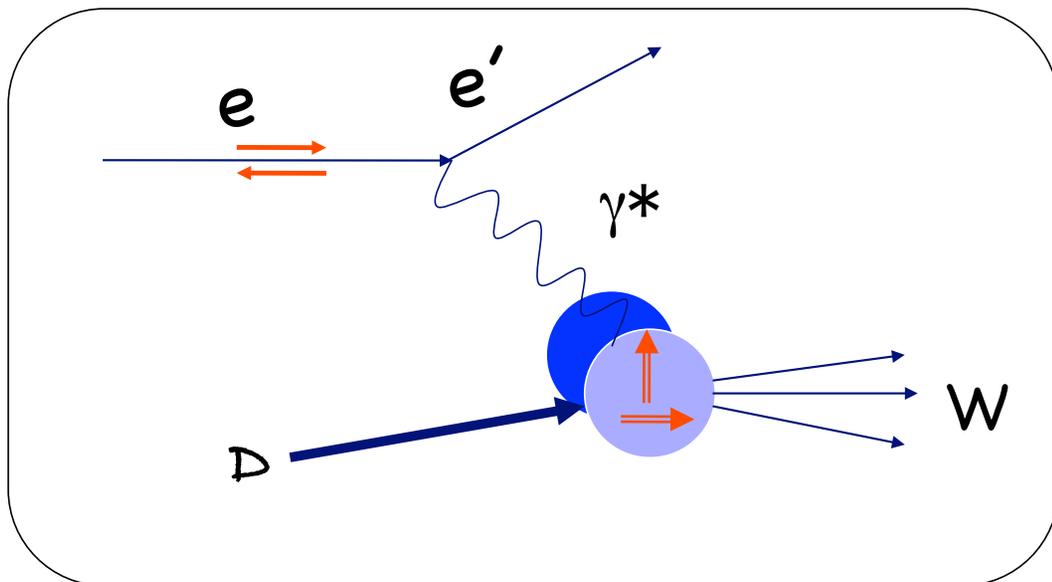
Tensor Program



E12-13-011: "The b_1 experiment"
30 Days in Jlab Hall C
A- Physics Rating
Conditional Approval (Target Performance)

E12-15-005: " A_{zz} for $x > 1$ "
44 Days in Jlab Hall C
A- Physics Rating
Conditional Approval (Target Performance)

Inclusive Scattering



Construct the most general
Tensor W consistent with
Lorentz and gauge invariance

Frankfurt & Strikman (1983)

Hoodbhoy, Jaffe, Manohar (1989)

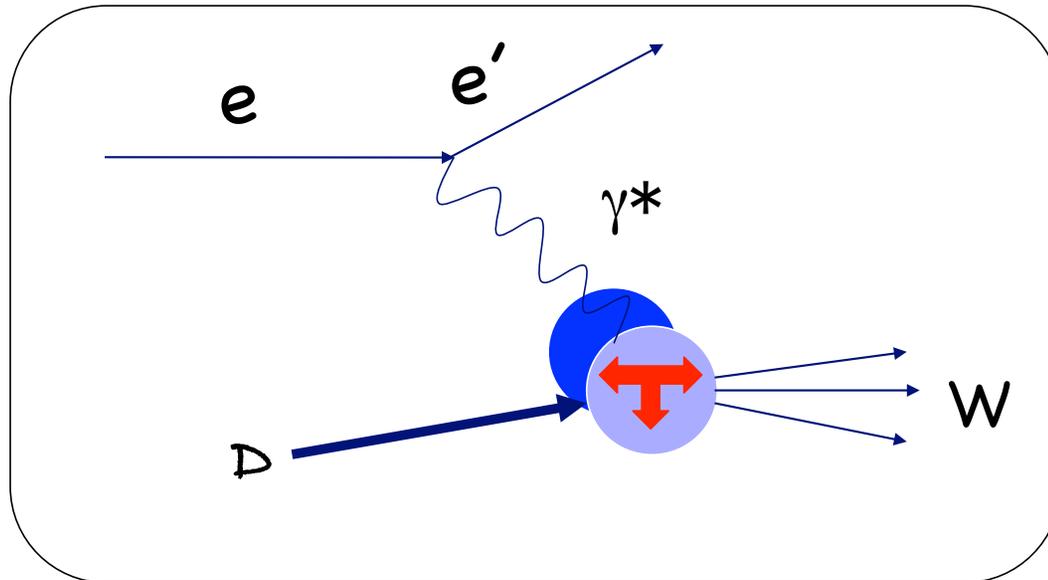
$$W_{\mu\nu} = -F_1 g_{\mu\nu} + F_2 \frac{P_\mu P_\nu}{\nu}$$

Unpolarized Scattering

$$+ i \frac{g_1}{\nu} \epsilon_{\mu\nu\lambda\sigma} q^\lambda s^\sigma + i \frac{g_2}{\nu^2} \epsilon_{\mu\nu\lambda\sigma} q^\lambda (p \cdot q s^\sigma - s \cdot q p^\sigma)$$

Vector Polarization

Tensor Structure Functions



Construct the most general
Tensor W consistent with
Lorentz and gauge invariance

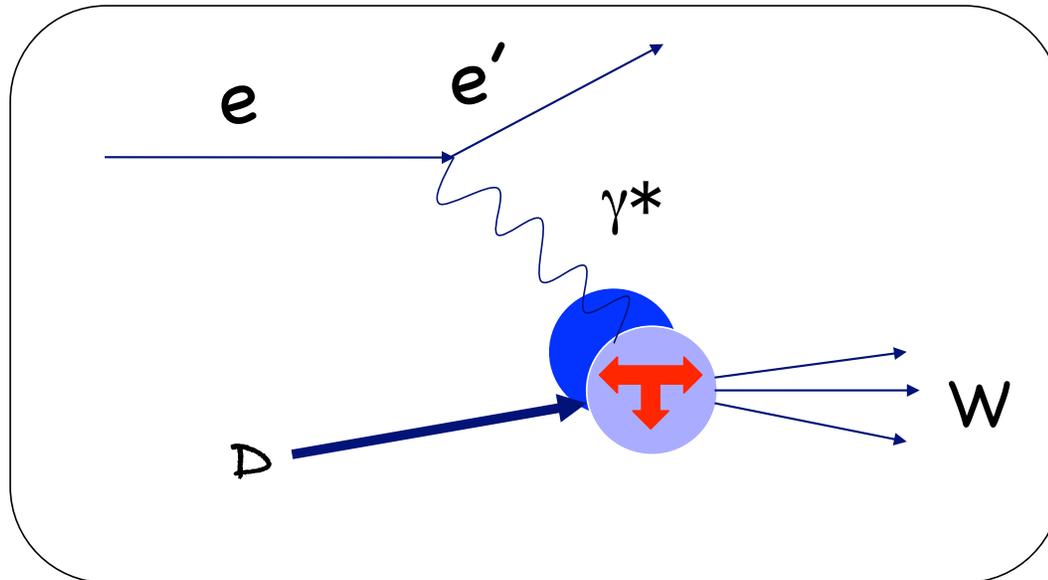
Frankfurt & Strikman (1983)

Hoodbhoy, Jaffe, Manohar (1989)

$$\begin{aligned}
 W_{\mu\nu} = & -F_1 g_{\mu\nu} + F_2 \frac{P_\mu P_\nu}{\nu} \\
 & + i \frac{g_1}{\nu} \epsilon_{\mu\nu\lambda\sigma} q^\lambda s^\sigma + i \frac{g_2}{\nu^2} \epsilon_{\mu\nu\lambda\sigma} q^\lambda (p \cdot q s^\sigma - s \cdot q p^\sigma) \\
 & - b_1 r_{\mu\nu} + \frac{1}{6} b_2 (s_{\mu\nu} + t_{\mu\nu} + u_{\mu\nu}) \\
 & + \frac{1}{2} b_3 (s_{\mu\nu} - u_{\mu\nu}) + \frac{1}{2} b_4 (s_{\mu\nu} - t_{\mu\nu})
 \end{aligned}$$

} Tensor Polarization

Tensor Structure Functions



Construct the most general
Tensor W consistent with
Lorentz and gauge invariance

Frankfurt & Strikman (1983)

Hoodbhoy, Jaffe, Manohar (1989)

$$\begin{aligned}
 W_{\mu\nu} = & -F_1 g_{\mu\nu} + F_2 \frac{P_\mu P_\nu}{\nu} \\
 & + i \frac{g_1}{\nu} \epsilon_{\mu\nu\lambda\sigma} q^\lambda s^\sigma + i \frac{g_2}{\nu^2} \epsilon_{\mu\nu\lambda\sigma} q^\lambda (p \cdot q s^\sigma - s \cdot q p^\sigma) \\
 & - b_1 r_{\mu\nu} + \frac{1}{6} b_2 (s_{\mu\nu} + t_{\mu\nu} + u_{\mu\nu}) \\
 & + \frac{1}{2} b_3 (s_{\mu\nu} - u_{\mu\nu}) + \frac{1}{2} b_4 (s_{\mu\nu} - t_{\mu\nu})
 \end{aligned}
 \quad \left. \vphantom{W_{\mu\nu}} \right\} \text{Tensor Polarization}$$

Caution : There is an alternate similar formulation by Edelman, Piller, Weise

Tensor Structure Functions

| | Nucleon | Deuteron |
|-------|---|--|
| F_1 | $\frac{1}{2} \sum_q e_q^2 [q_{\uparrow}^{1/2} + q_{\downarrow}^{-1/2}]$ | $\frac{1}{3} \sum_q e_q^2 [q_{\uparrow}^1 + q_{\uparrow}^{-1} + q_{\uparrow}^0]$ |
| g_1 | $\frac{1}{2} \sum_q e_q^2 [q_{\uparrow}^{1/2} - q_{\downarrow}^{-1/2}]$ | $\frac{1}{2} \sum_q e_q^2 [q_{\uparrow}^1 - q_{\downarrow}^1]$ |
| b_1 | \dots | $\frac{1}{2} \sum_q e_q^2 [q^0 - q^1]$ |

Leading Twist

F_1 : quark distributions averaged over target spin states

g_1 : difference of distributions of quarks aligned/anti-aligned with hadron

b_1 : difference of helicity-0/helicity non-zero states of *the deuteron*

Tensor Structure Functions

| | Nucleon | Deuteron |
|-------|---|--|
| F_1 | $\frac{1}{2} \sum_q e_q^2 [q_{\uparrow}^{1/2} + q_{\downarrow}^{-1/2}]$ | $\frac{1}{3} \sum_q e_q^2 [q_{\uparrow}^1 + q_{\uparrow}^{-1} + q_{\uparrow}^0]$ |
| g_1 | $\frac{1}{2} \sum_q e_q^2 [q_{\uparrow}^{1/2} - q_{\downarrow}^{-1/2}]$ | $\frac{1}{2} \sum_q e_q^2 [q_{\uparrow}^1 - q_{\downarrow}^1]$ |
| b_1 | \dots | $\frac{1}{2} \sum_q e_q^2 [q^0 - q^1]$ |

Leading Twist

F_1 : quark distributions averaged over target spin states

g_1 : difference of distributions of quarks aligned/anti-aligned with hadron

b_1 : difference of helicity-0/helicity non-zero states of *the deuteron*

b_2 : related to b_1 by A Callan-Gross relation

b_4 : Also Leading Twist, but kinematically suppressed for a longitudinally polarized target.

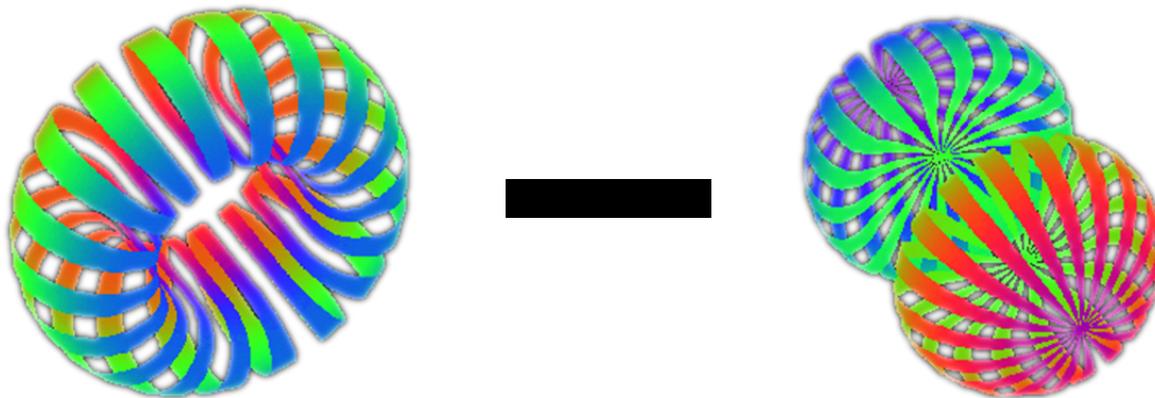
b_3 : higher twist, like g_2

b_1 Structure Function

$$b_1(x) = \frac{q^0(x) - q^1(x)}{2}$$

q^0 : Probability to scatter from a quark (any flavor) carrying momentum fraction x while the *Deuteron* is in state $m=0$

q^1 : Probability to scatter from a quark (any flavor) carrying momentum fraction x while the *Deuteron* is in state $|m| = 1$



Nice mix of nuclear and quark physics

measured in DIS (so probing quarks), but depends solely on the deuteron spin state

Investigate nuclear effects at the level of partons!

b_1 Structure Function

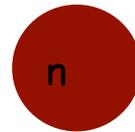
Hoodbhoy, Jaffe and Manohar (1989)

b_1 vanishes in the absence of nuclear effects

i.e. if...



=



+



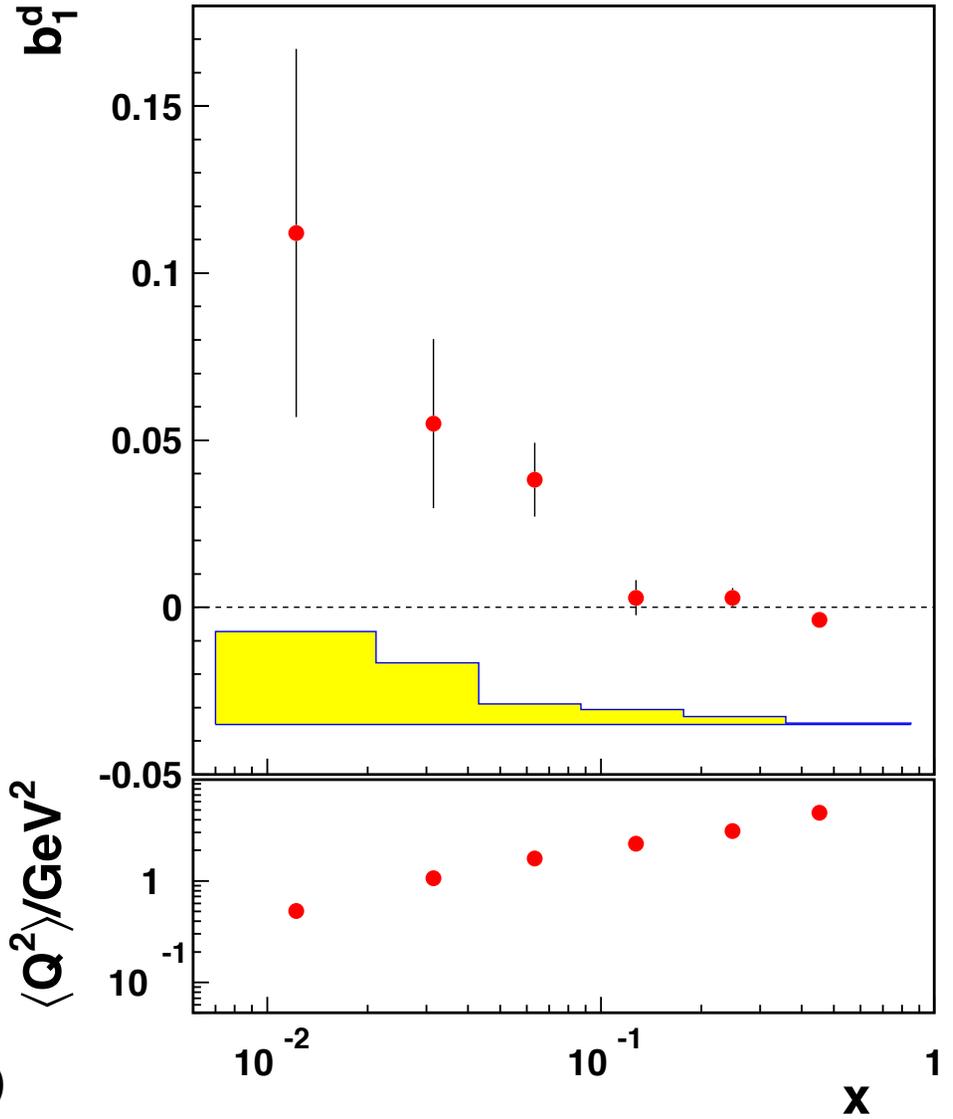
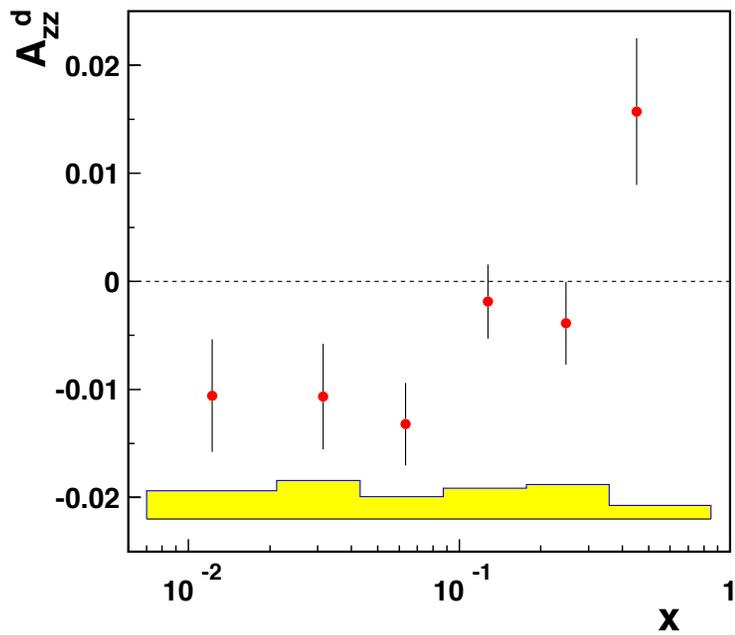
Proton Neutron in relative S-state

Even accounting for D-State admixture b_1 expected to be vanishingly small

Khan & Hoodbhoy, PRC 44 ,1219 (1991) : $b_1 \approx O(10^{-4})$
Relativistic convolution model with binding

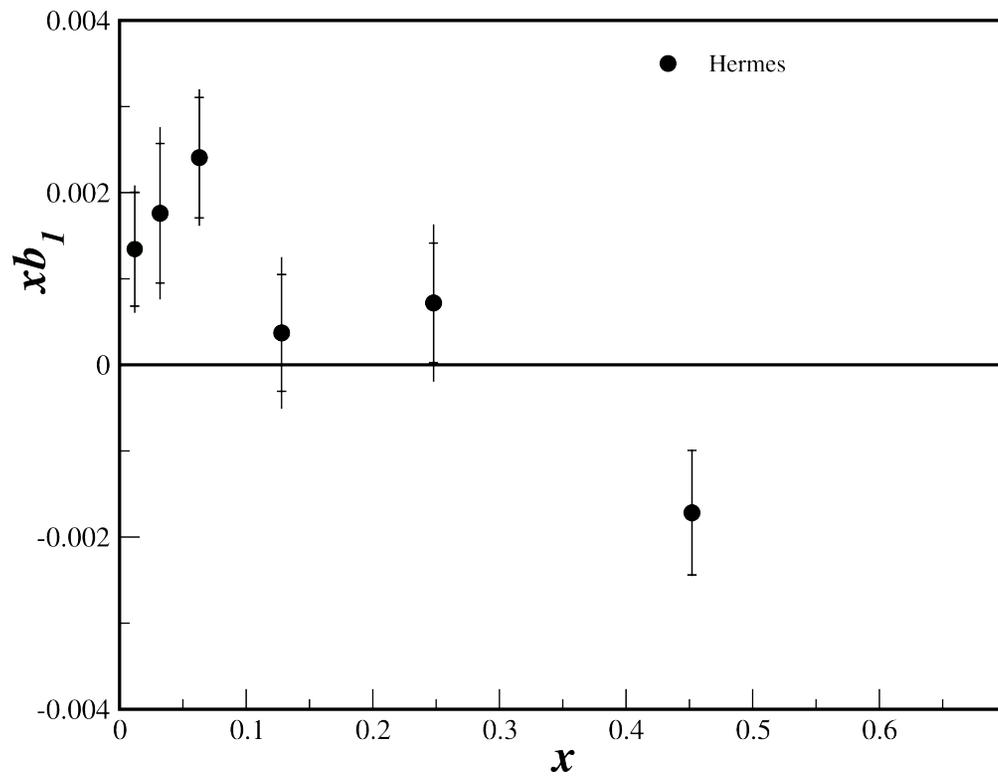
Umnikov, PLB 391, 177 (1997) : $b_1 \approx O(10^{-3})$
Relativistic convolution with Bethe-Salpeter formalism

Data from HERMES



C. Reidl PRL **95**, 242001 (2005)

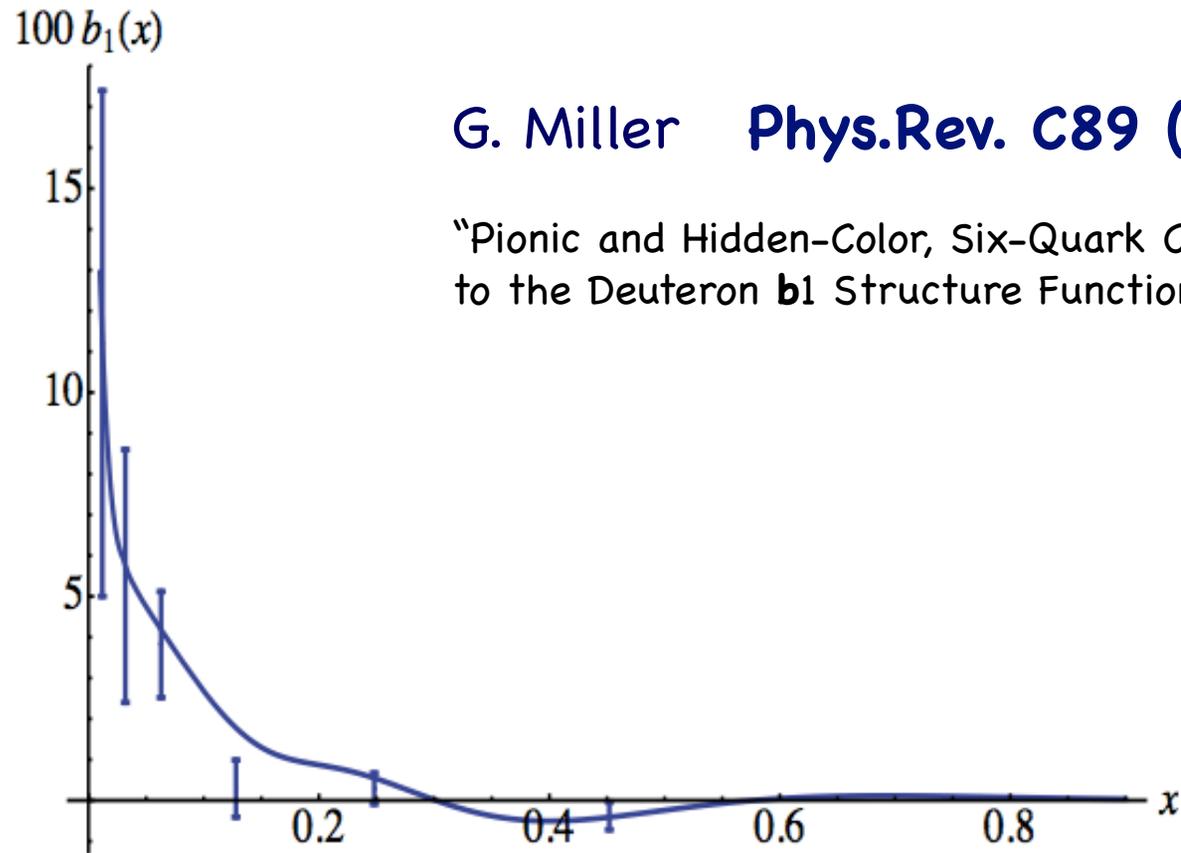
Data from HERMES



$$b_1 = -\frac{3}{2}F_1A_{zz}$$

C. Reidl PRL **95**, 242001 (2005)

Unique Signal of Hidden Color



G. Miller **Phys.Rev. C89 (2014) 045203**

“Pionic and Hidden-Color, Six-Quark Contributions to the Deuteron b_1 Structure Function”

no conventional nuclear mechanism can reproduce the Hermes data,

but that the 6-quark probability needed to do so ($P_{6Q} = 0.0015$) is small enough that it does not violate conventional nuclear physics.

The Deuteron Polarized Tensor Structure Function b_1

JLAB E12-14-011

A⁻ rating by PAC40

(C1: conditional on target performance)

Spokespersons

Slifer (contact), Solvignon, Long, Chen, Rondon, Kalantarians

Experimental Method

$$A_{zz} = \frac{2}{fP_{zz}} \frac{\sigma_{\uparrow} - \sigma_0}{\sigma_0}$$

$$= \frac{2}{fP_{zz}} \left(\frac{N_{\uparrow}}{N_0} - 1 \right)$$

Observable is the Normalized XS Difference

B-Field, density, temp, etc. held same in both states

$$b_1 = -\frac{3}{2} F_1^d A_{zz}$$

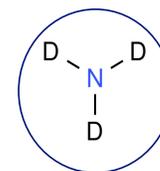
σ_{\uparrow} : Tensor Polarized cross-section

σ_0 : Unpolarized cross-section

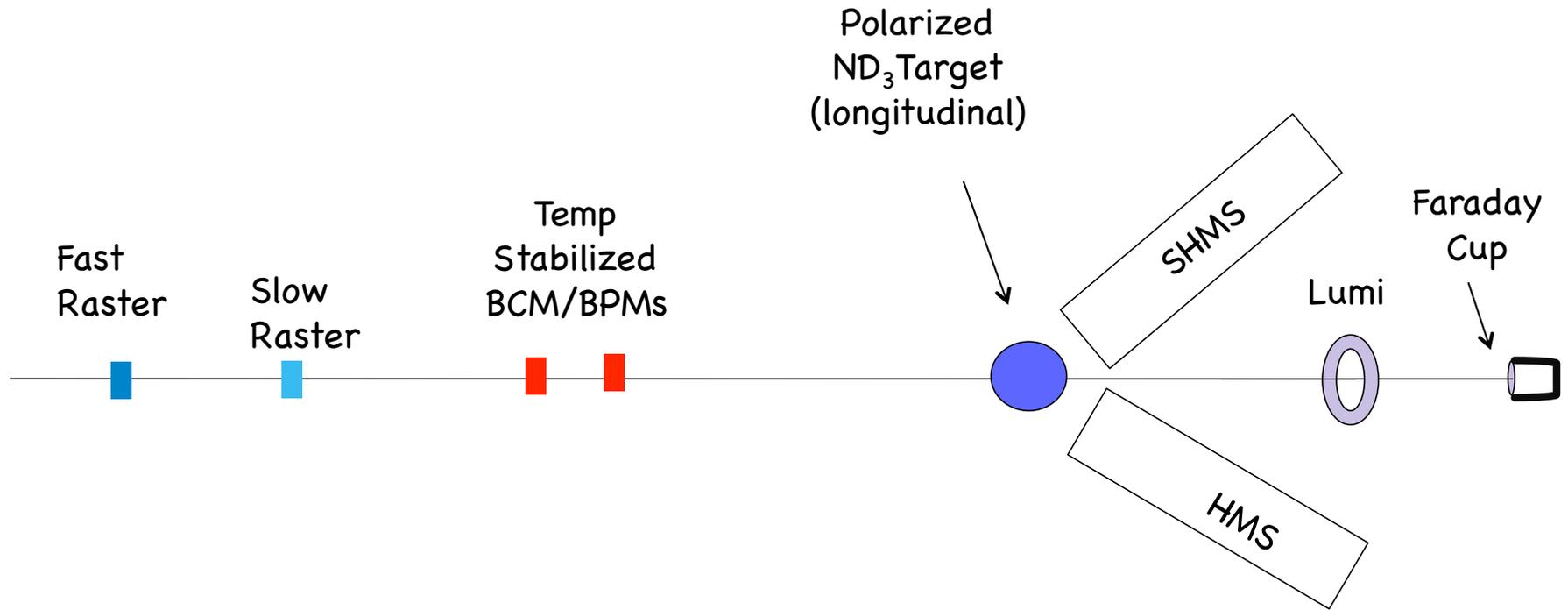
P_{zz} : Tensor Polarization

dilution factor

$$f \approx \frac{6}{20}$$



Jlab Hall C

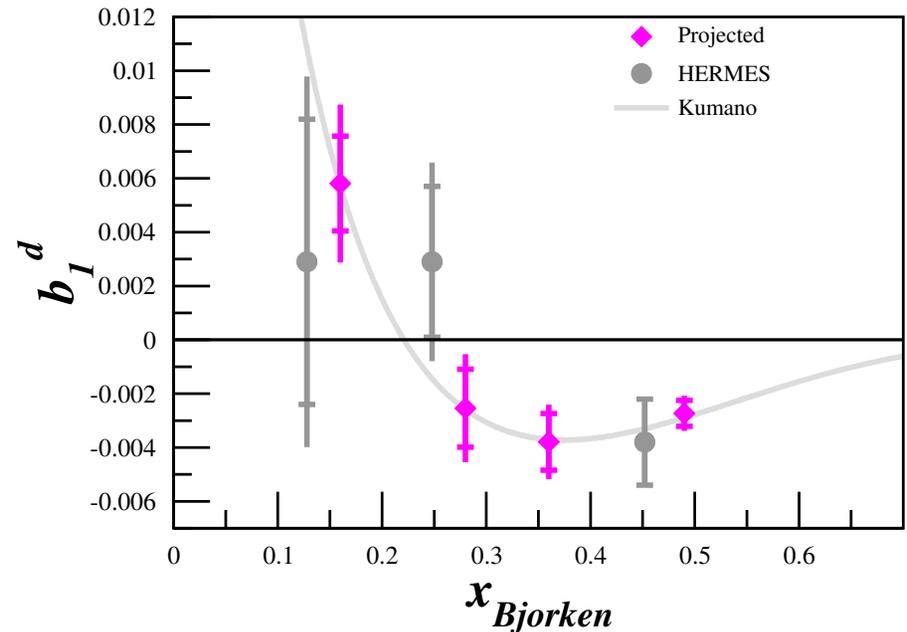
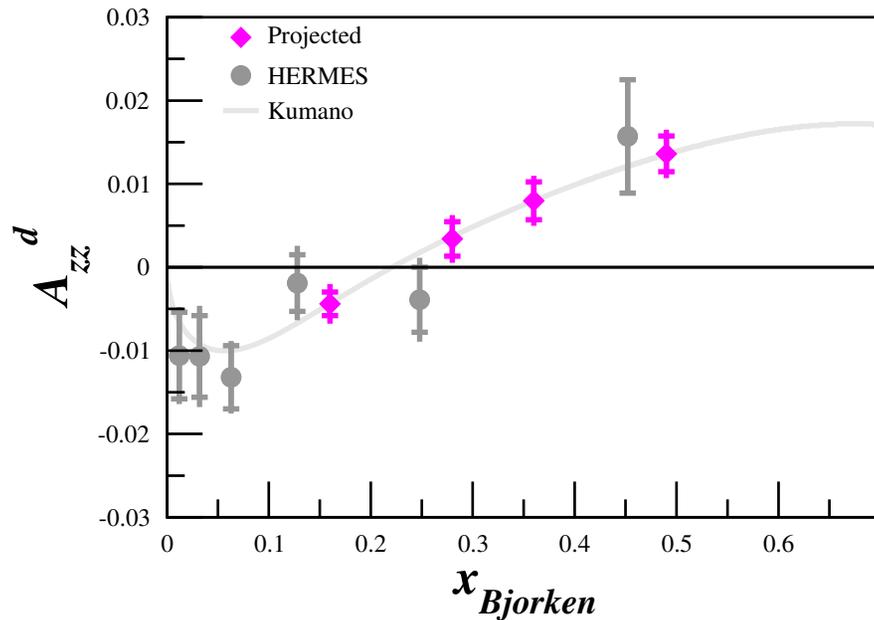


Unpolarized Beam
UVa/JLab Polarized Target

Magnetic Field Held Along Beam Line at all times

$$\mathcal{L}=10^{35}$$

Projected Results for $P_{zz} = 35\%$



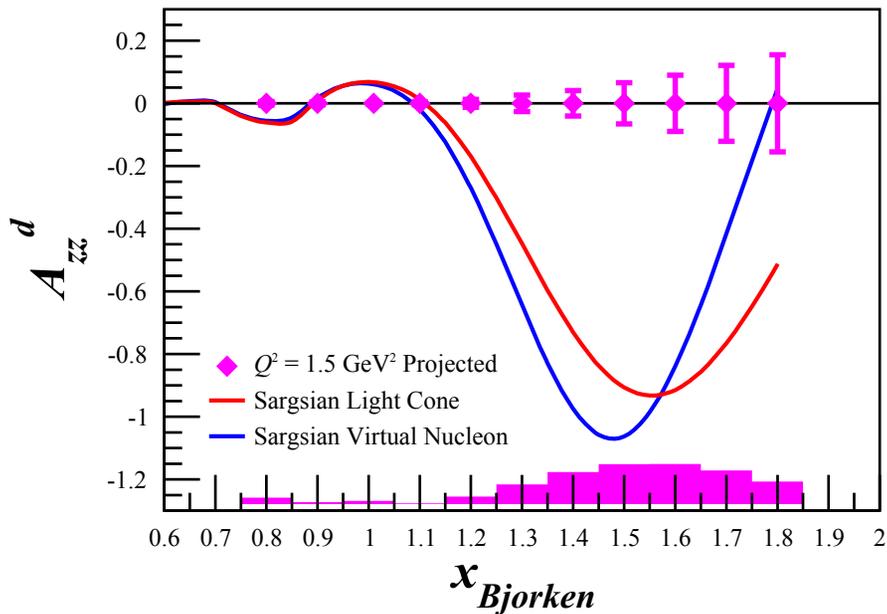
30 Days in Jlab Hall C
 A- Physics Rating
 Conditional Approval (Target Performance)

false asymmetries suppressed by $1/P_{zz}$

$$\delta A_{zz} = \pm \frac{2}{f P_{zz} \sqrt{N_{cycles}}} \delta \xi$$

E12-15-005

A_{zz} in the $x > 1$ Region



See Ellie Long's talk

Ellie Long (contact), Slifer, Solvignon,
Day, Higinbotham, Keller

Very Large Tensor Asymmetries predicted

++Measure T_{20} over widest ever Q^2 range

Sensitive to the S/D-wave ratio in the
deuteron wave function

4σ discrim between hard/soft wave functions
 6σ discrim between relativistic models

"further explores the nature of short-range
pn correlations, the discovery of which was
one of the most important results of the
6 GeV nuclear program."

LOI-12-16-006

See James Maxwell's talk

"Nuclear Gluonometry"

Look for novel gluonic components in nuclei that are not present in nucleons

Non-zero value would be a clear signature of **exotic gluon states in the nucleus**

Deep inelastic scattering experiment:

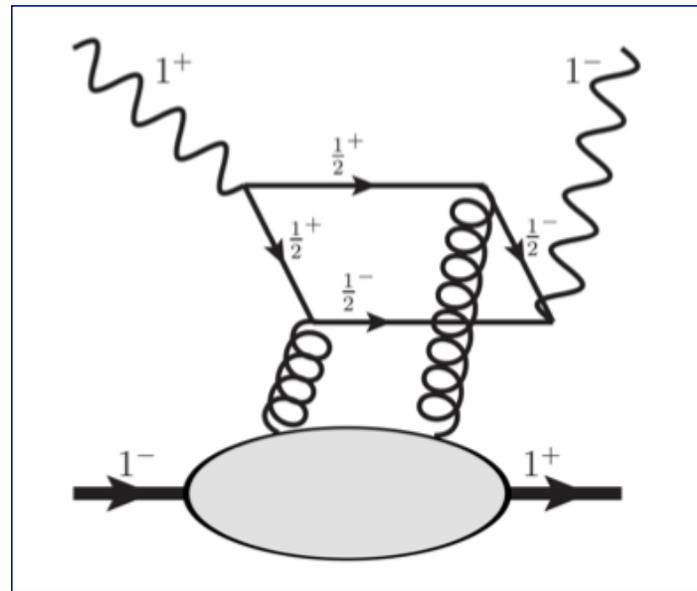
Unpolarized electrons

Polarized $^{14}\text{NH}_3$ Target

Target spin aligned transverse to beam

New IQCD result for first moment of $\Delta(x, Q^2)$

Detmold, Shanahan, arXiv:1606.04505



$\Delta(x, Q^2)$ double helicity flip structure function

Encouraged for full submission by PAC44

TENSOR SPIN OBSERVABLES WORKSHOP

MARCH 10-12, 2014
JEFFERSON LAB

TOPICS:

- Tensor Polarization in DIS
- Tensor Structure Functions
- Hidden Color at Large x
- Tensor Observables in $x > 1$
- Solid Tensor-Polarized Target Development
- Elastic Deuteron Form Factors
- Tensor Polarization at EIC
- Analyzing Powers in Scattering From Tensor-Polarized Targets

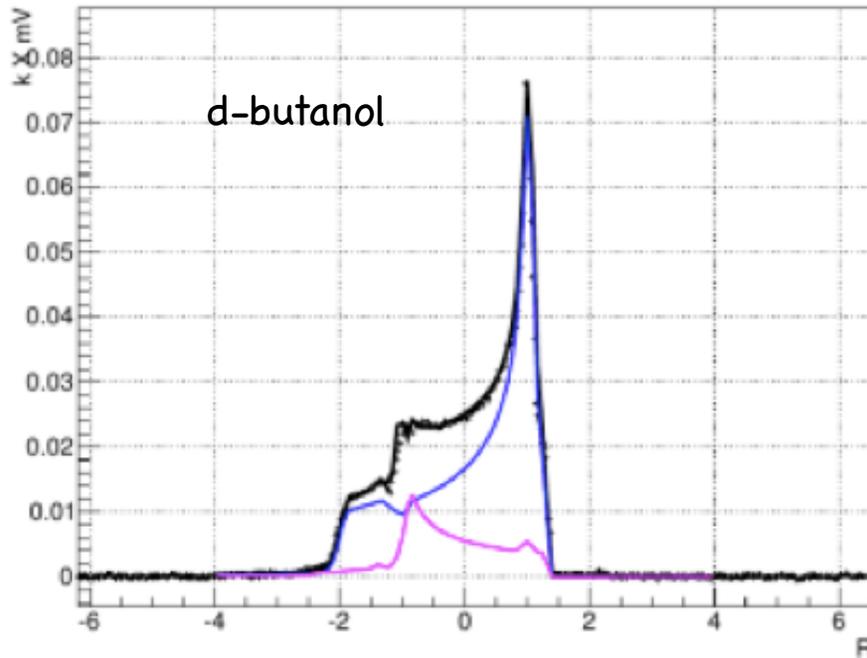


ORGANIZING COMMITTEE:

Karl Slifer (Chair, University of New Hampshire)
Douglas Higinbotham (Jefferson Lab)
Christopher Keith (Jefferson Lab)
Elena Long (University of New Hampshire)
Misak Sargsian (Florida International University)
Patricia Solvignon (University of New Hampshire)

www.jlab.org/conferences/tensor2014

Tensor Polarized Target



MC overlap with d-but. NMR experimental points (Pn=51→45, Qn:20→31%)

Significant progress at UVA

Enhancing P_{zz}

understanding the NMR lineshape

D Keller, Eur.Phys.J.A., in review (2016)

D Keller, PoS, PSTP2015:014 (2016)

D Keller, J.Phys.Conf.Ser., **543**(1):012015 (2014)

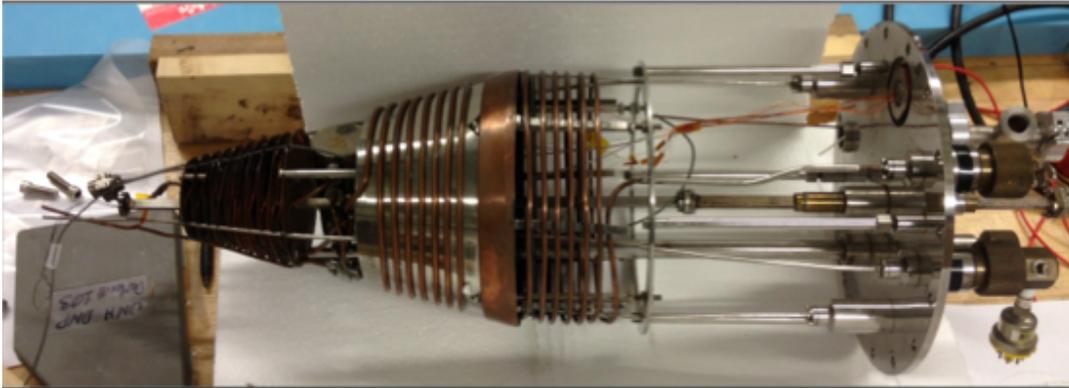
D Keller, Int.J.Mod.Phys.Conf.Ser., **40**(1):1660105 (2016)

See Dustin Keller's talk

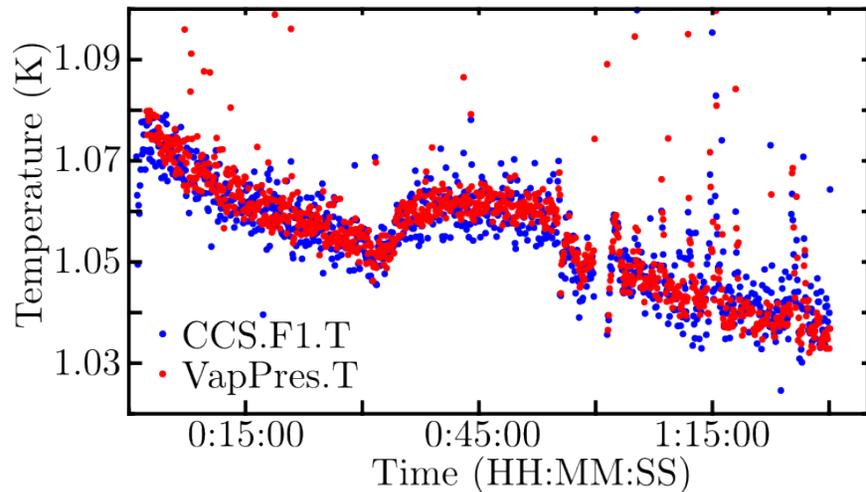
Promising, but need to confirm in ND_3

T20 measurement at Higs to verify NMR analysis

UNH Polarized Target Lab



Helium Evaporative Refrigerator
Calibrated Target Cup Temperature



Just Began Construction of new Vertical fridge for use in 5T superconducting solenoid.

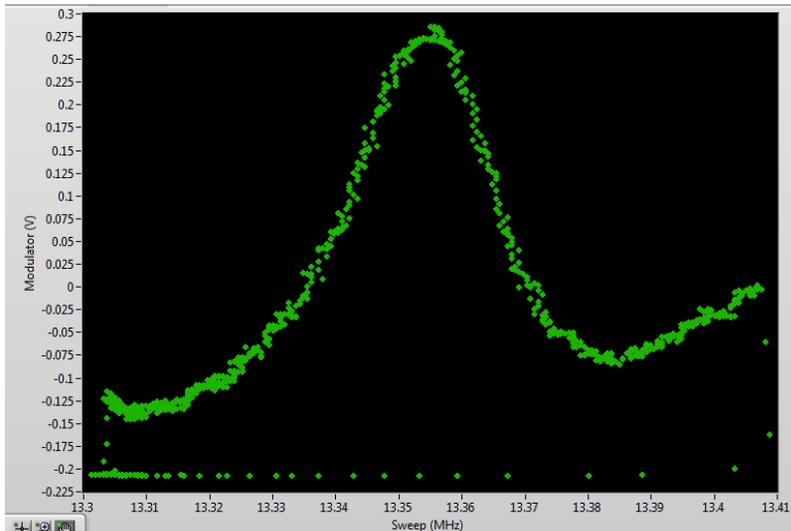
Roots pump set : 7000 m³/h
6000 + 1000 m³/h,
backed by rotary vane DUO 65
KNF Neuberger Separator Pump
PM27186-1200

Oxford ITC readout of Sensors
CCS
Allen Bradley
Cernox



UNH Polarized Target Lab

NMR circuit and Labview controls



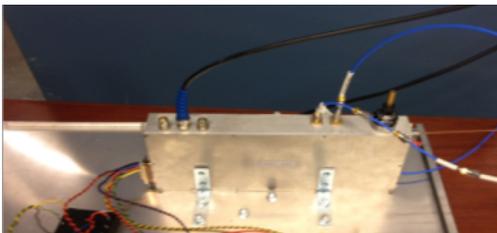
1 T @ room temperature

Q-Meter tuned to 12.8 MHz (proton@0.3T)

$\lambda/2$ cable=9.9m

12.8 MHz Crystal Oscillator

We can also tune to 32.7 MHz (Deuteron@ 5T)
and 213 MHz (Proton@5T)



Summary

Spin Polarizabilities

δ_{LT} puzzle and χ_{PT} calculations : progress is being made.
but stil large discrepancies data/calcs

New proton data under analysis should help clarify.

Higher order generalized spin polarizabilities.

Tensor Program

E12-13-001: Tensor Polarized Structure function b_1 of the Deuteron

E12-14-002: Tensor Asymmetry A_{zz} for $x > 1$

LOI12-14-001: Tensor Structure Function Δ

Significant progress has been made to develop the targets.