A Measurement of the Proton Spin Structure Function g_2 at low Q^2

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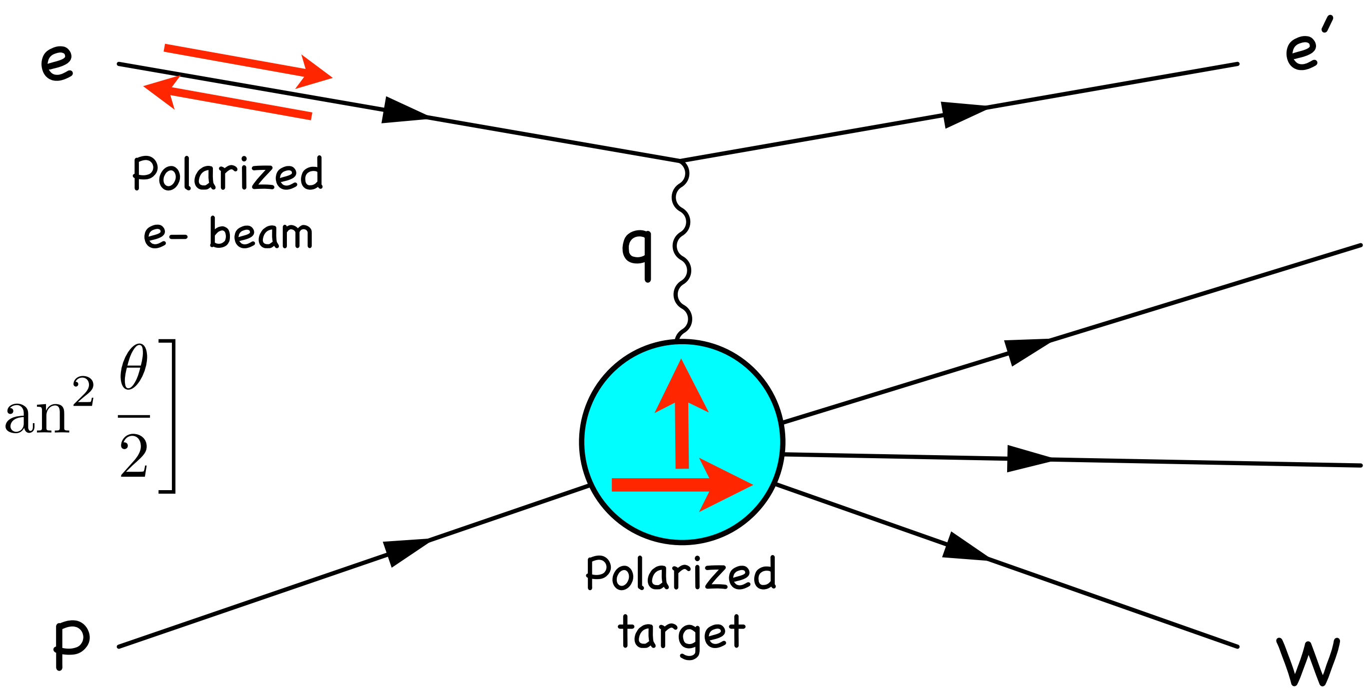
On Behalf of the Jefferson Lab Hall A E08-027 Collaboration

UNIVERSITY of VIRGINIA   Jefferson Lab   DNP2015, Oct 2015

Inelastic scattering

- Inclusive unpolarized cross section:



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

Structure Function which indicates the parton distribution

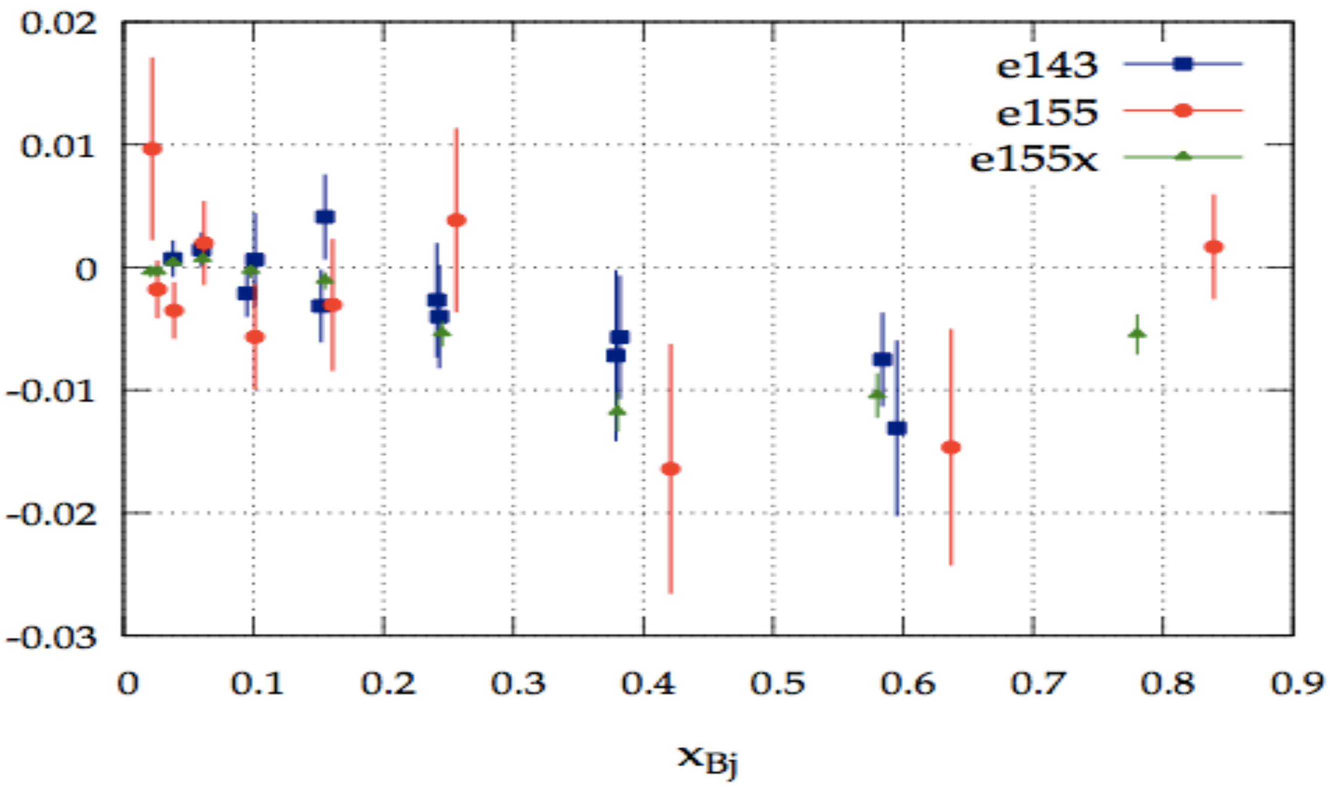
- Inclusive polarized cross section:

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

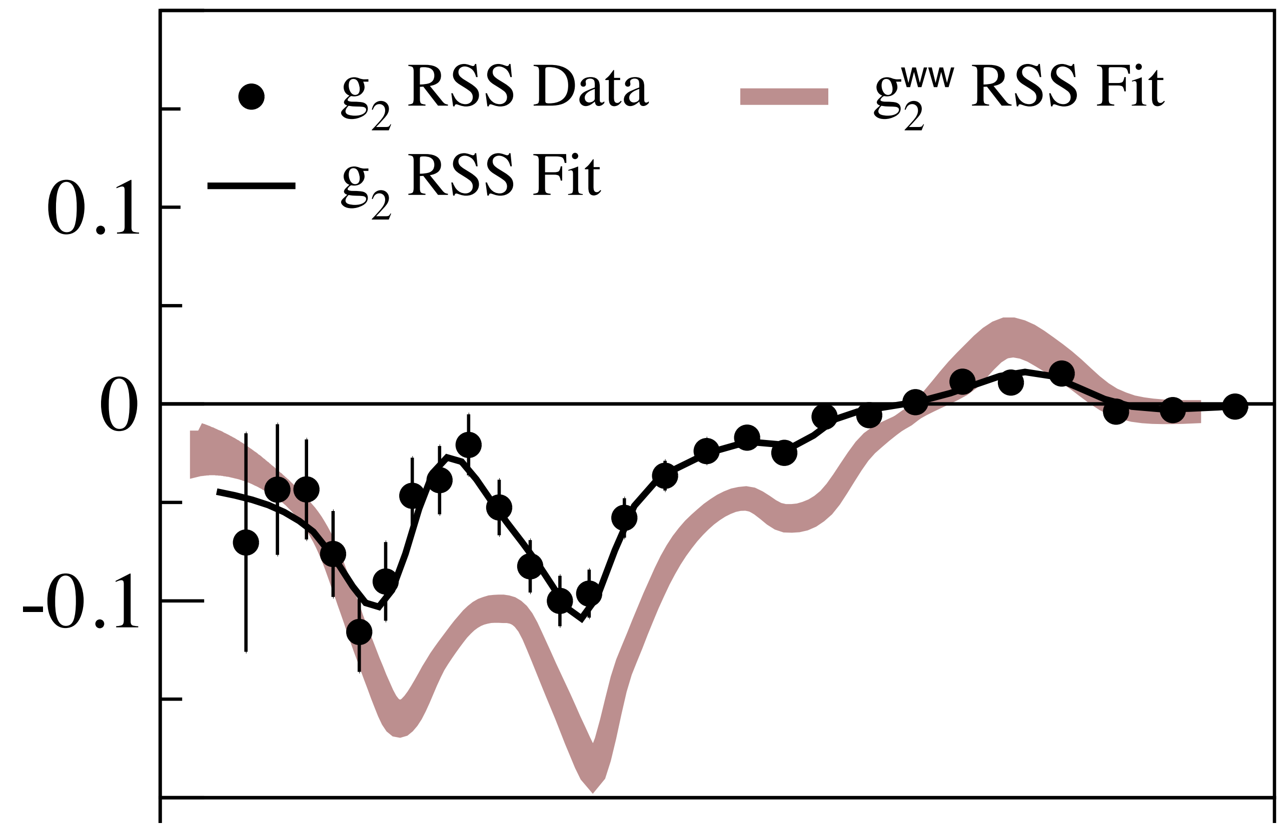
2 addition Structure Function which related to the spin distribution

Existing g_2 Data

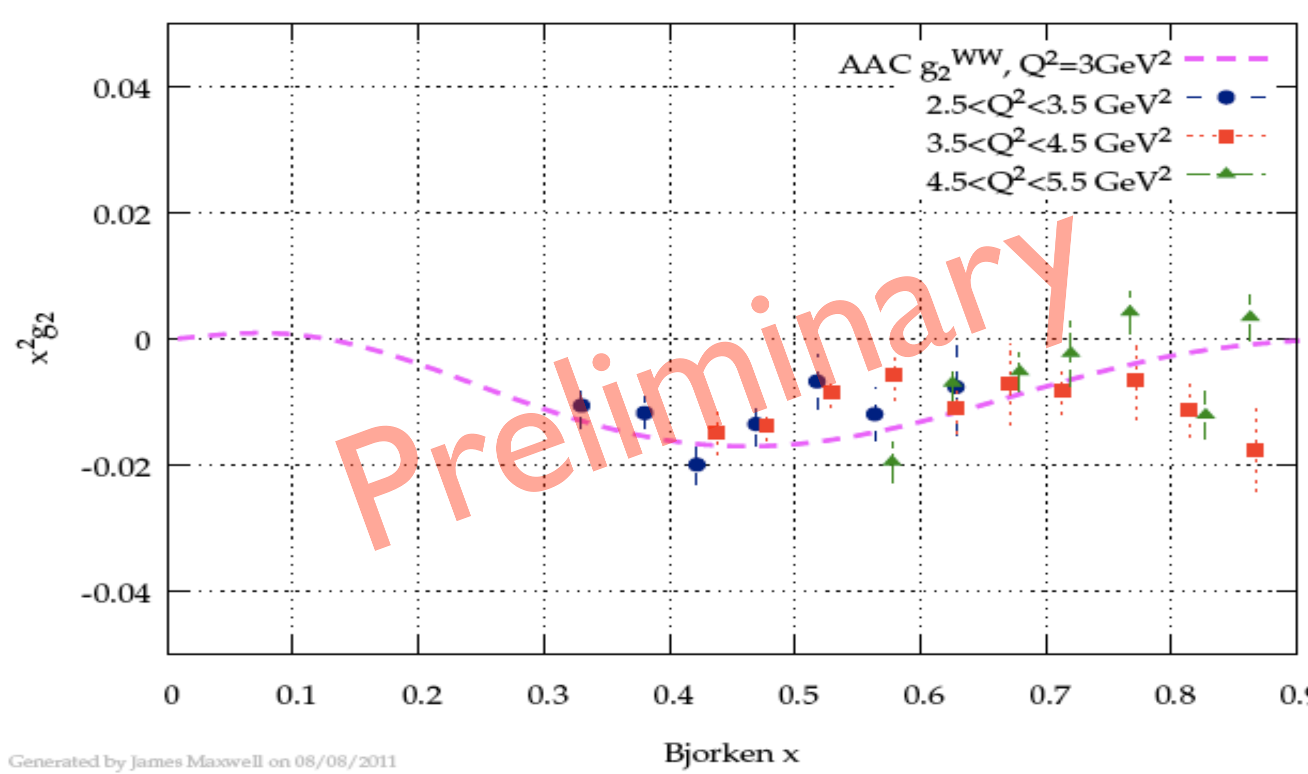
SLAC



RSS



JLab SANE



SLAC: Q^2 ~5GeV^2

JLab SANE: Q^2 3~6GeV^2

JLab RSS: Q^2 ~1.3GeV^2

Motivation

- Measure the proton structure function g_2 in the low Q^2 region (0.02-0.2GeV^2) for the first time
  - Extract the generalized longitudinal-transverse spin polarizability δ_{LT} as a test of Chiral Perturbation Theory (χPT) calculations
  - Test the Burkhardt-Cottingham (BC) Sum Rule
  - Crucial inputs for hydrogen hyperfine splitting and proton charge radius measurements

Generalized Longitudinal-Transverse Polarizability

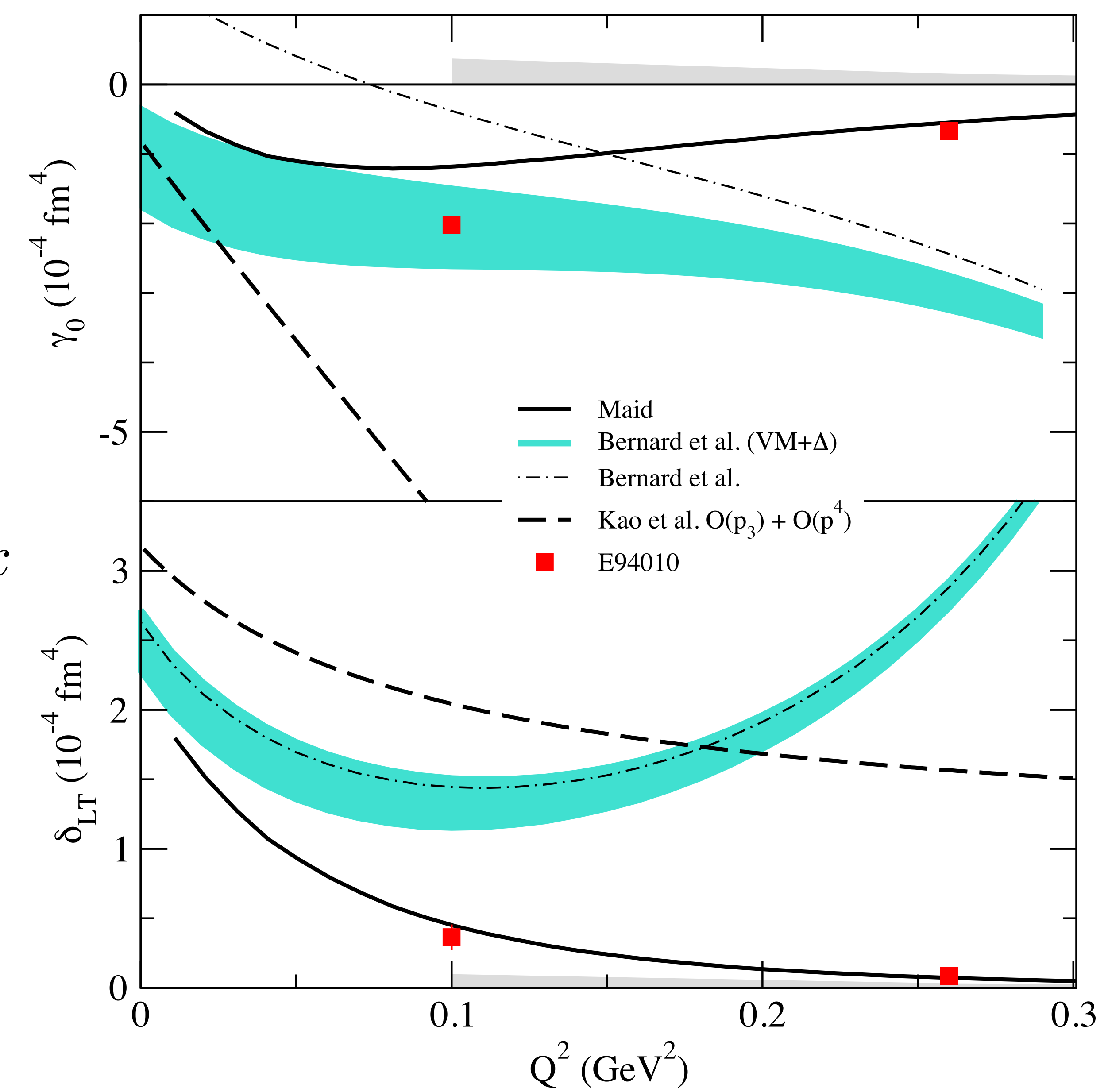
- Can be calculated via Chiral Perturbation Theory:
  - Difficult to include the nucleon resonance contributions, especially the Δ resonance
  - δ_{LT} is insensitive to the Δ resonance

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

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

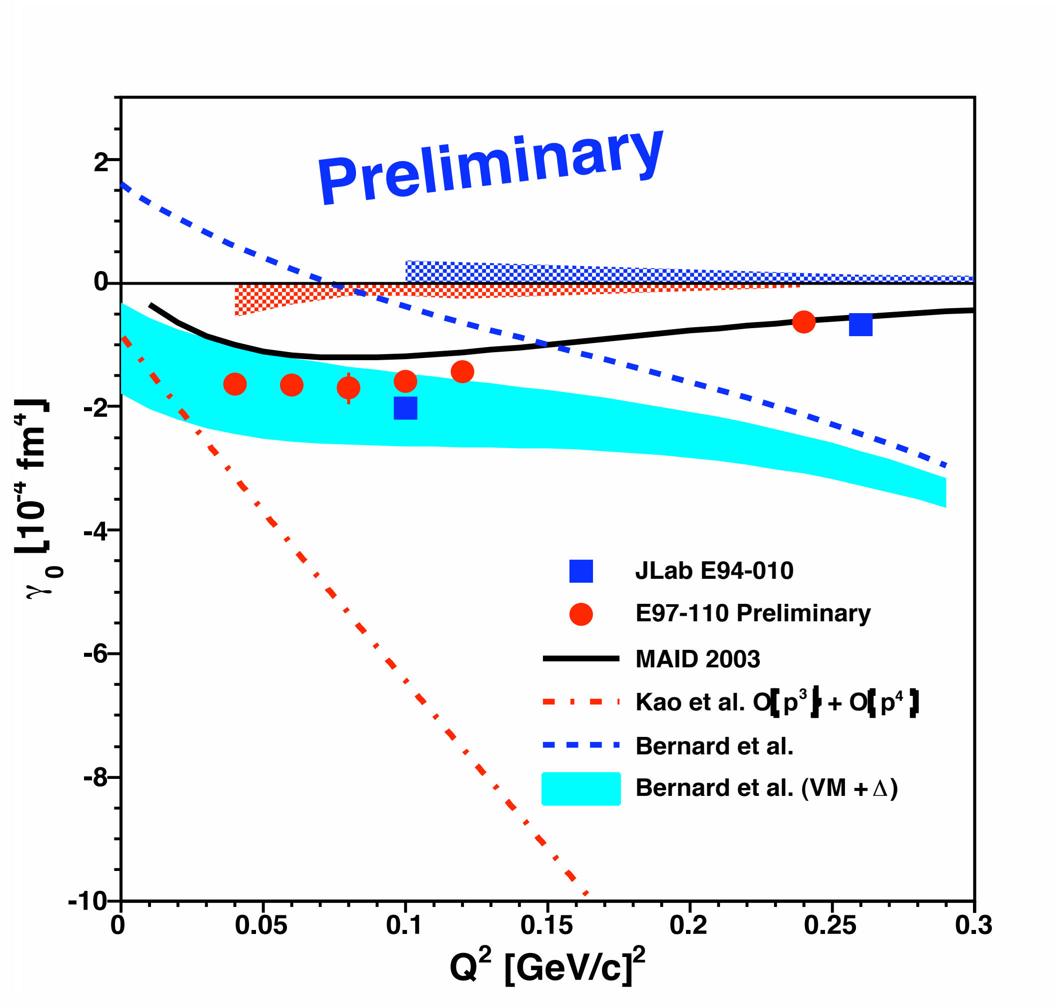
- Neutron Data shows a large deviation from the χPT calculations
- No proton data yet

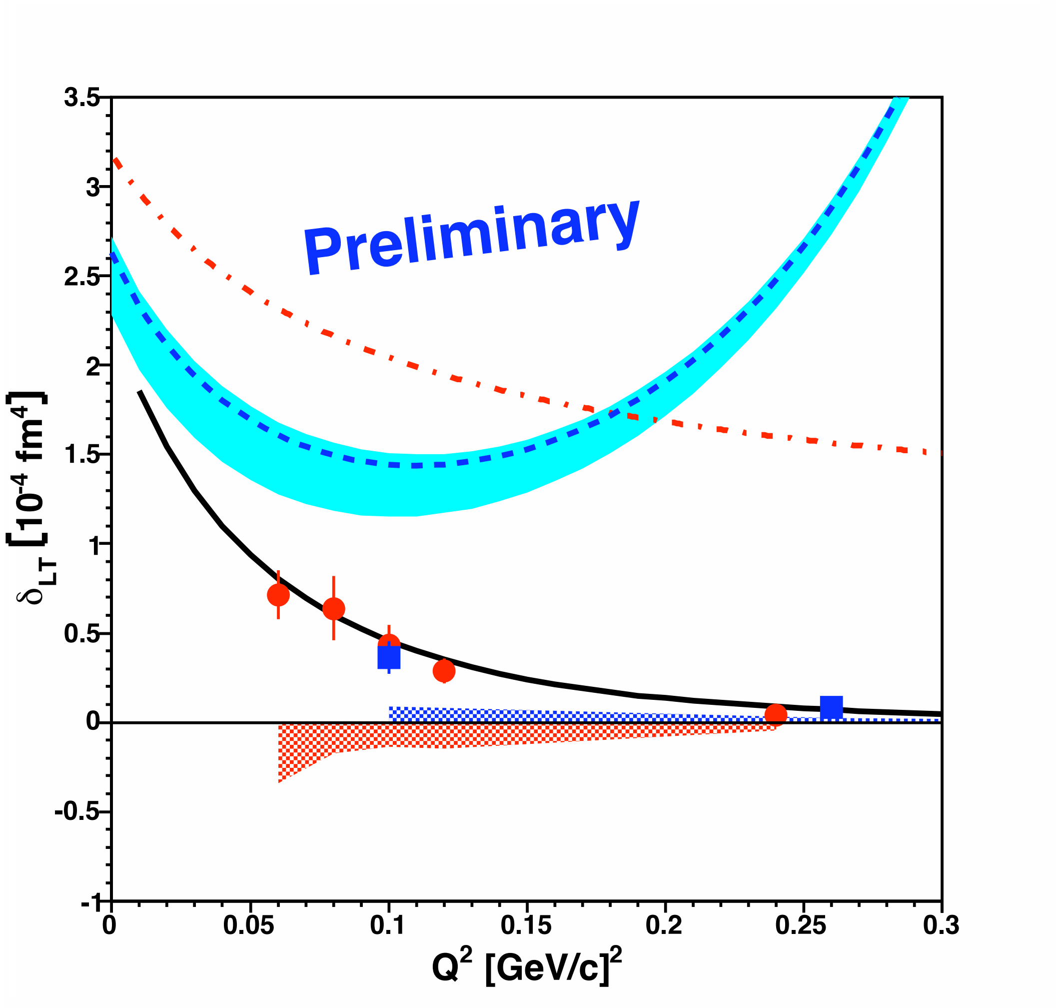
Neutron Data for γ_0 and δ_{LT}



δ_{LT} puzzle

More neutron δ_{LT} data from JLAB E97-110:

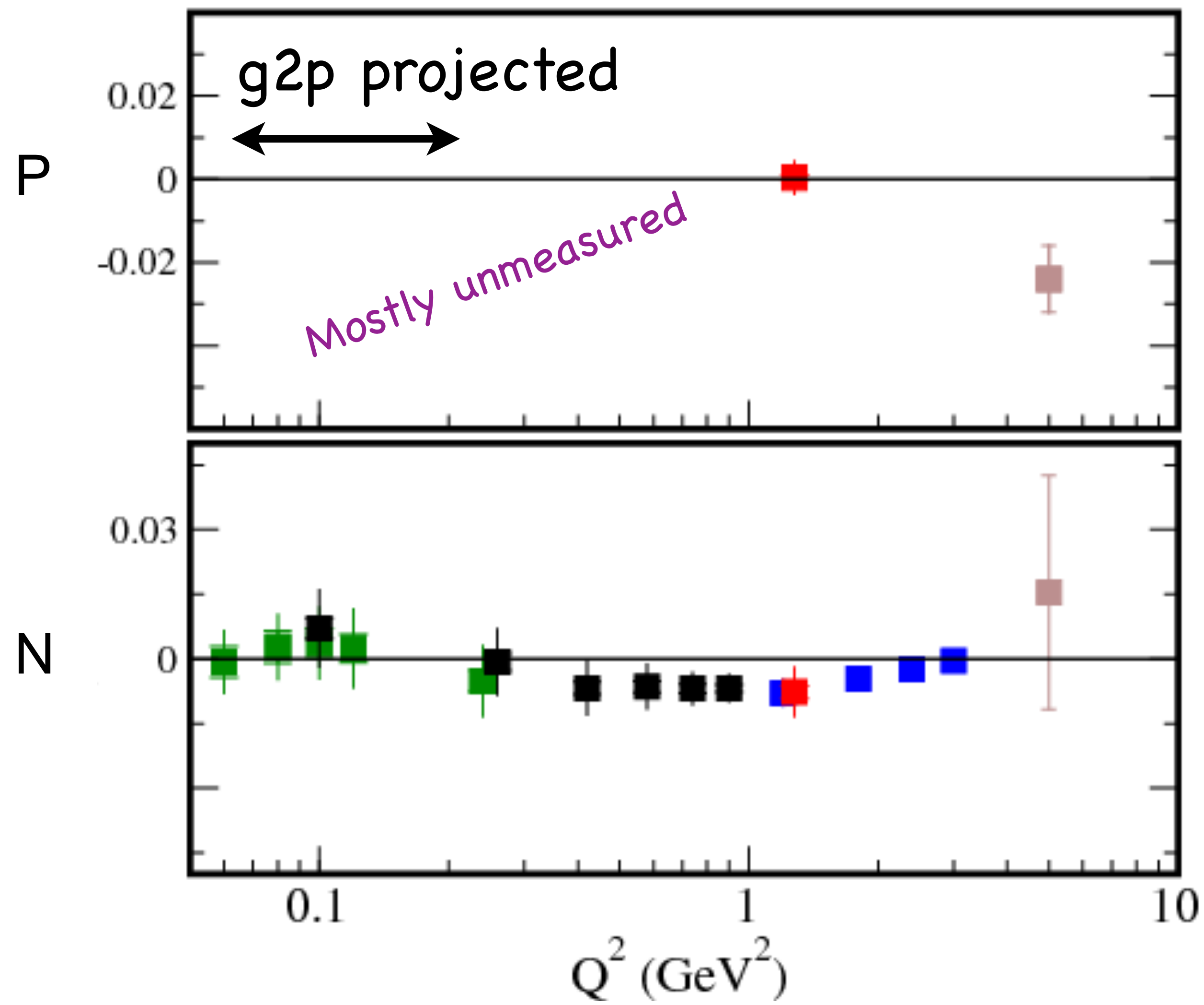




There is still large discrepancy with Neutron δ_{LT}

Plots courtesy of V. Sulkosky

BC Sum Rule



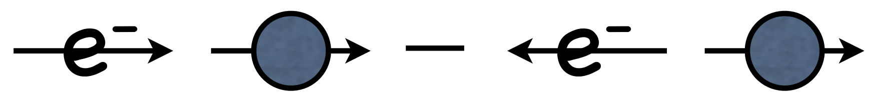
SLAC E155x
Hall C RSS
Hall A E94-010
Hall A E97-110 (preliminary)
Hall A E01-012 (preliminary)

- BC Sum Rule:

$$\int_0^1 g_2(x, Q^2)\mathrm{d}x = 0$$

- Violation suggested for proton at large Q^2
- But found satisfied for the neutron
- Mostly unmeasured for proton
- To experiment test BC sum rule, one need to combine measured g_2 data with some low x model and elastic contribution

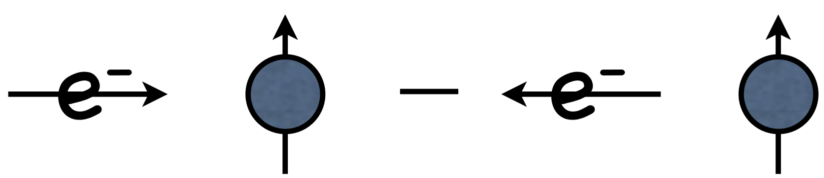
How to get g_2

$\Delta\sigma_{\parallel} =$ 

$$= \frac{d^2\sigma^{\uparrow\Uparrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Uparrow}}{d\Omega dE'}$$

$$= \frac{4\alpha^2 E'}{M\nu Q^2 E}[(E + E'\cos\theta)g_1 - 2Mxg_2]$$

JLab Hall B experiment EG4 measured this quantity and extracted g_1^p at low Q^2

$\Delta\sigma_{\perp} =$ 

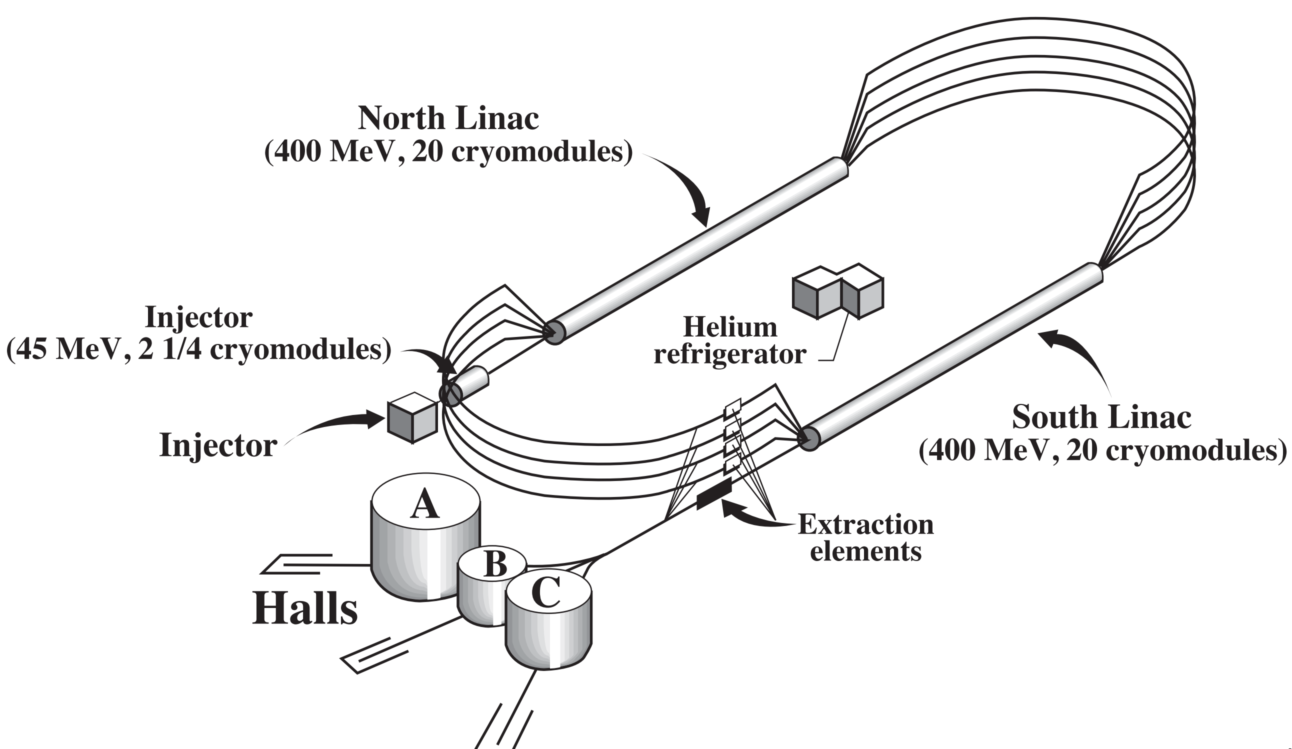
$$= \frac{d^2\sigma^{\uparrow\Rightarrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Rightarrow}}{d\Omega dE'}$$

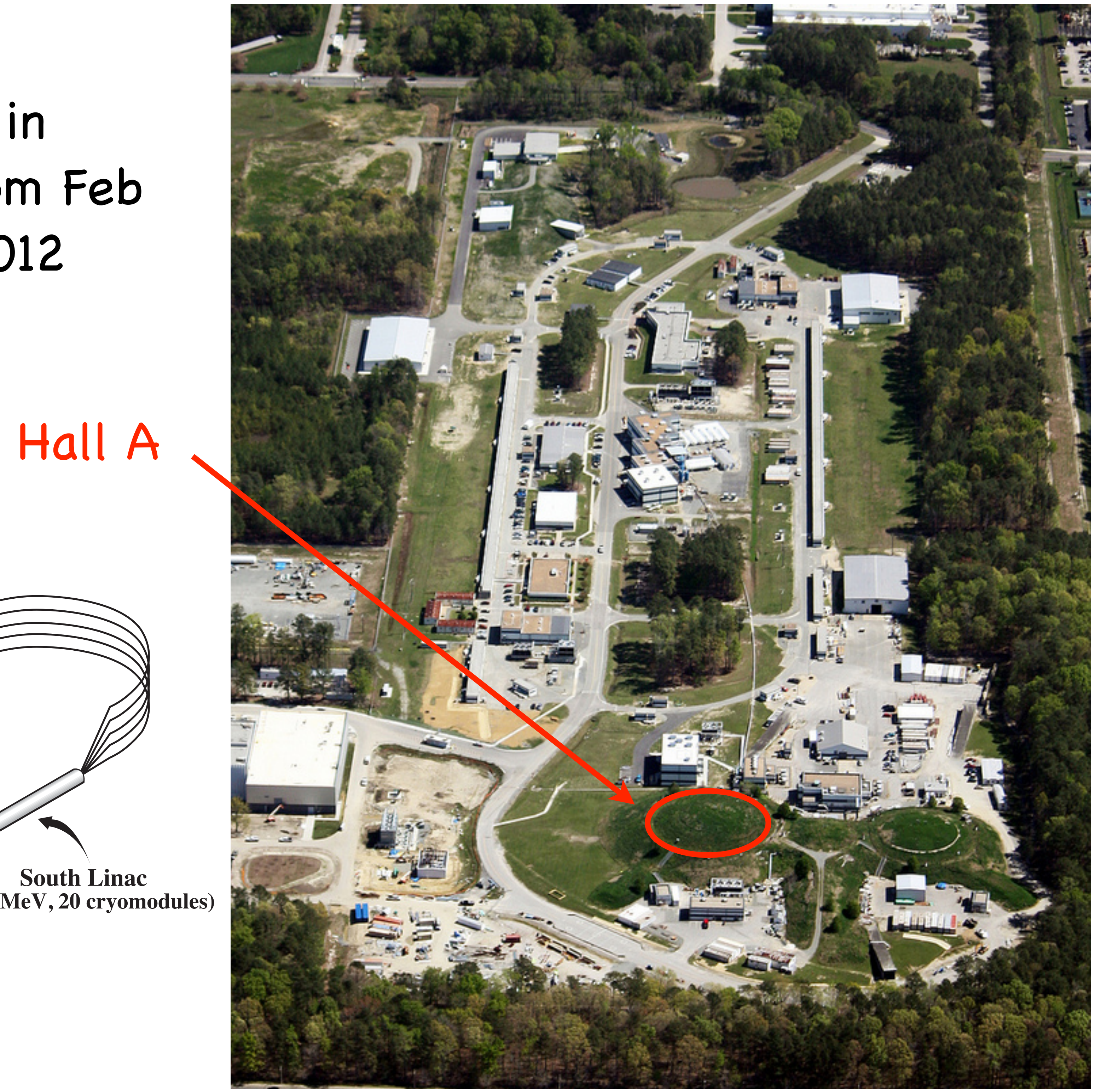
$$= \frac{4\alpha^2 E'^2}{M\nu Q^2 E}\sin\theta[g_1 + \frac{2E}{\nu}g_2]$$

g_2^p experiment will measure this, combing the EG4 g_1^p data to get g_2^p at low Q^2

Jefferson Lab

g2p experiment ran in Jefferson Lab Hall A from Feb 29th to May 18th, 2012





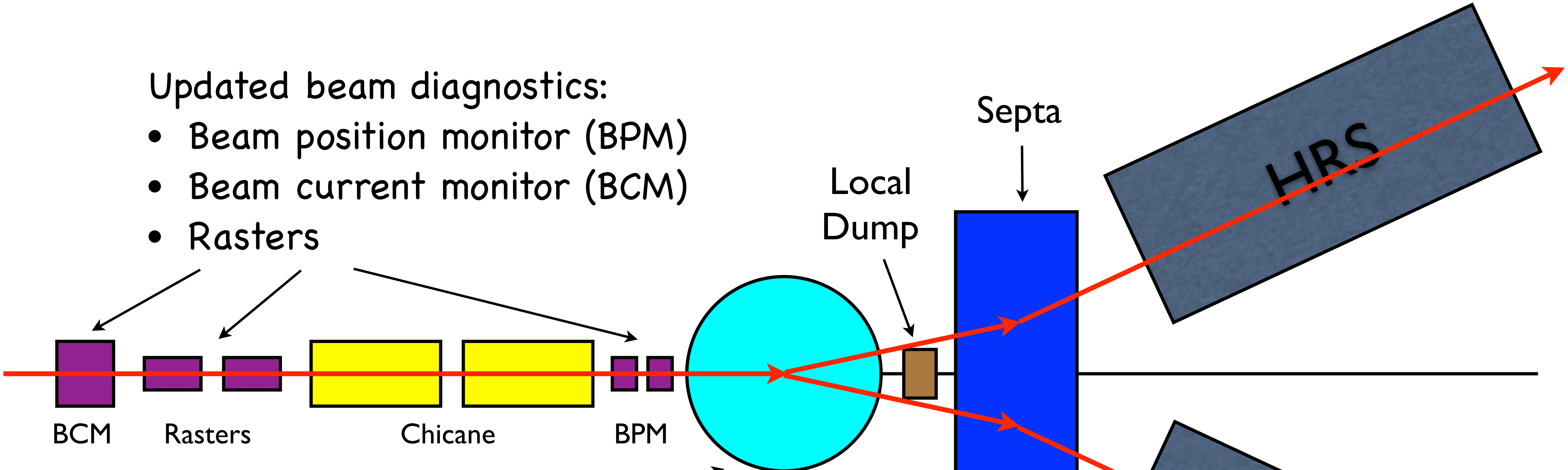
Thomas Jefferson National Accelerator Facility

Experiment Setup

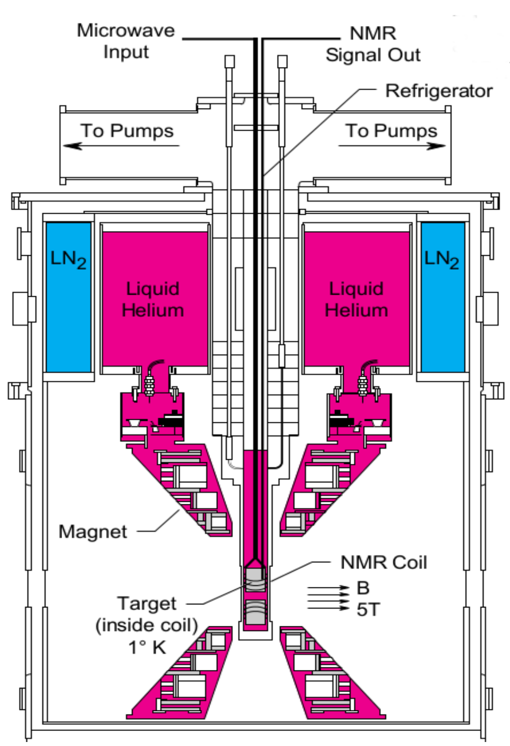
Jefferson Lab Hall A

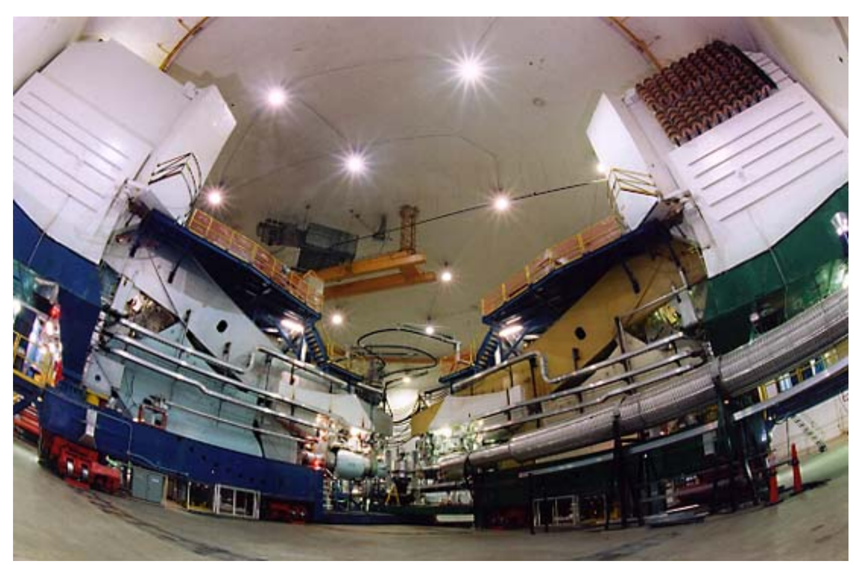
Updated beam diagnostics:

- Beam position monitor (BPM)
- Beam current monitor (BCM)
- Rasters



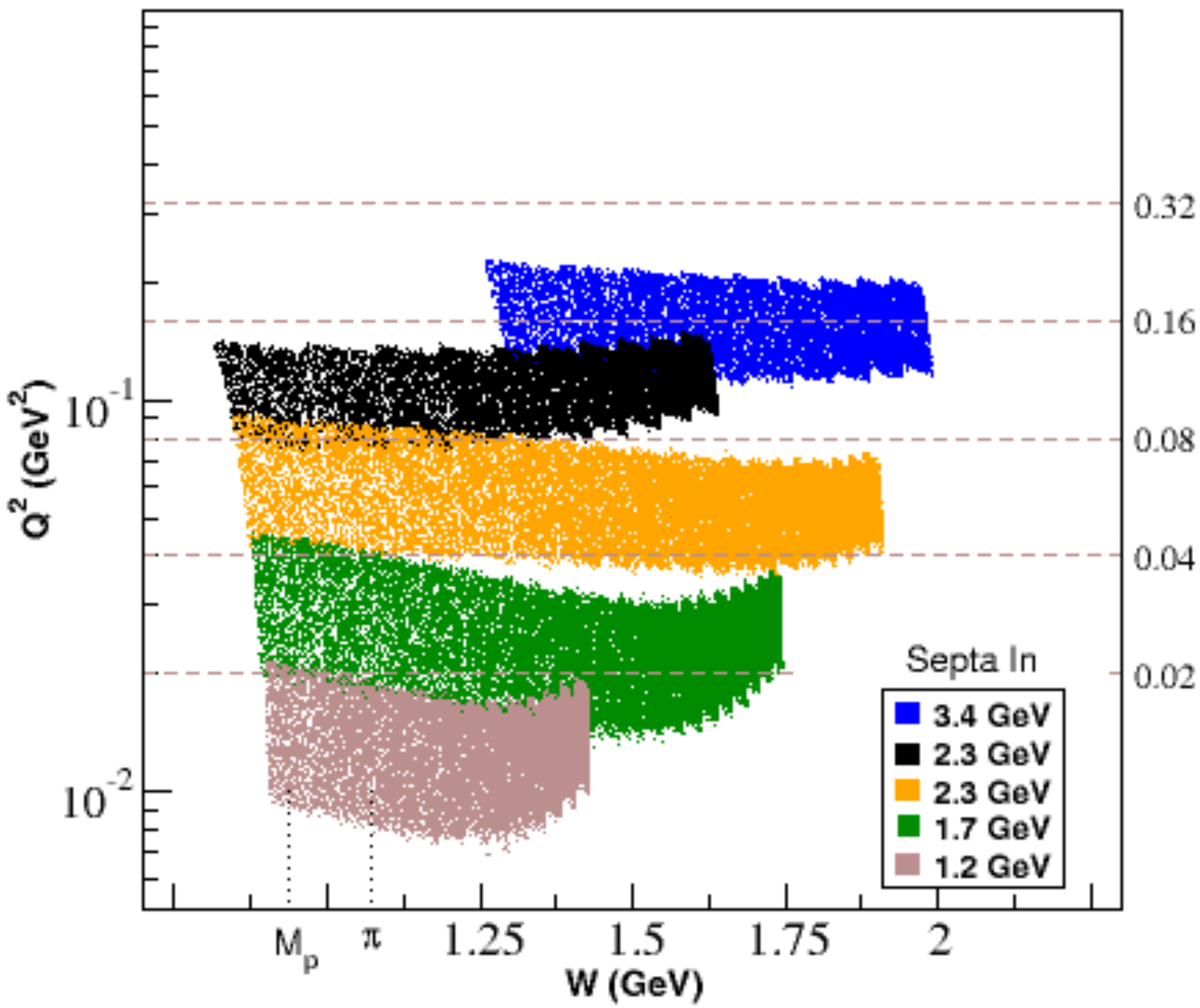
Polarized NH_3 Target





Hall A High Resolution Spectrometer (HRS)

Kinematics Coverage



$$M_p < W < 2 \text{ GeV}$$

$$0.02 < Q^2 < 0.2 \text{ GeV}^2$$

- The Experiment was conducted at JLab Hall A successfully from 3/2/2012 to 5/18/2012
- Statistics:

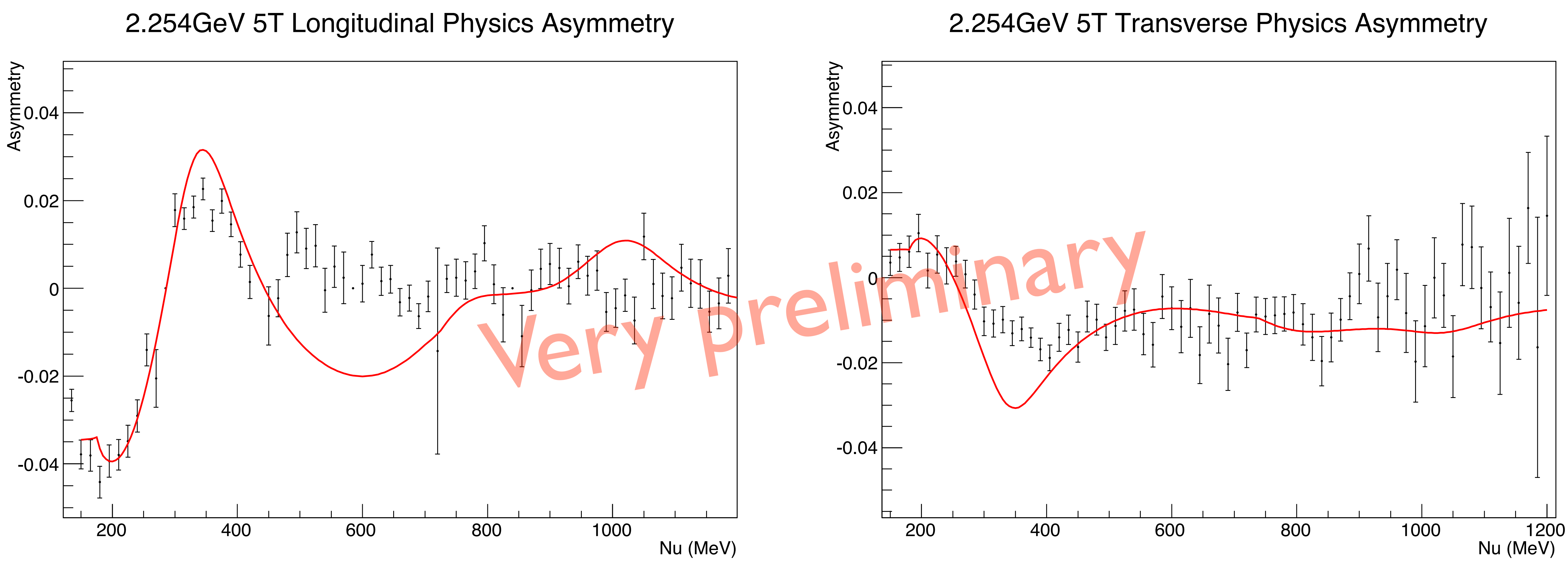
Beam Energy / GeV	Target Field /T	Recorded trigger
2.254	2.5	3.8E+09
1.706	2.5	3.2E+09
1.158	2.5	4E+09
2.254	5	7E+08
3.352	5	4E+08

Analysis Status

- Completed:
  - Detector calibrations/efficiencies
    - VDC t_0 calibration
    - Deadtime calculation
  - HRS Optics
    - Field measurement analysis
    - Simulation package
    - Optics reconstruction
  - Beam information
    - Helicity decoding
    - BCM calibrations
    - BPM calibrations/Raster size calibration (*paper accepted by Nucl. Instrum. Meth.*)
  - Target polarizations (*Nucl. Instrum. Meth. A738(2014)54*)

- In Progress:
  - Dilution and packing fraction analysis
  - Acceptance study
  - Polarized and unpolarized radiative corrections
  - Asymmetry analysis
- To Do:
  - Unpolarized/polarized cross sections
  - Determination of g_2/moments

Preliminary Results



- Fully radiated MAID 2007 (solid curve) asymmetries:
  - Unpolarized/polarized elastic tail
  - Mo/Tsai for unpolarized radiative correction
  - Akushevich/Ilyichev/Shumeiko for polarized radiative correction

Plots courtesy of T. Badman

Conclusion

- The g2p experiment ran in spring 2012 and took data covering $0.02 < Q^2 < 0.20$ GeV^2
- Will provide an accurate measurement of g_2 in low Q^2 region for the first time
    - Extract the fundamental quantities δ_{LT} to provide a test of χPT calculations
    - Test the Burkhardt-Cottingham (BC) Sum Rule
- New instruments are demonstrated working well during the experiment
- Data analysis is currently underway

g2p Collaboration

Spokespeople

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Thanks