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

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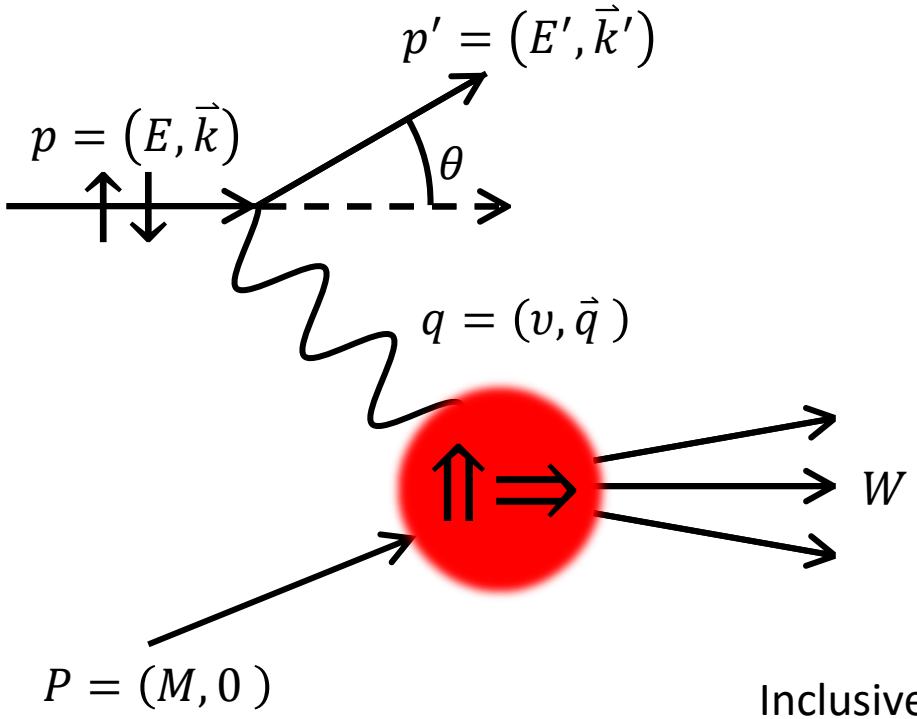
Inclusive Electron Scattering



Inclusive unpolarized cross section:

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

$$Q^2 = -q^2 = 4EE'\sin^2\left(\frac{\theta}{2}\right)$$

$$W^2 = M^2 + 2M\upsilon - Q^2$$

$$x = \frac{Q^2}{2M\upsilon}$$

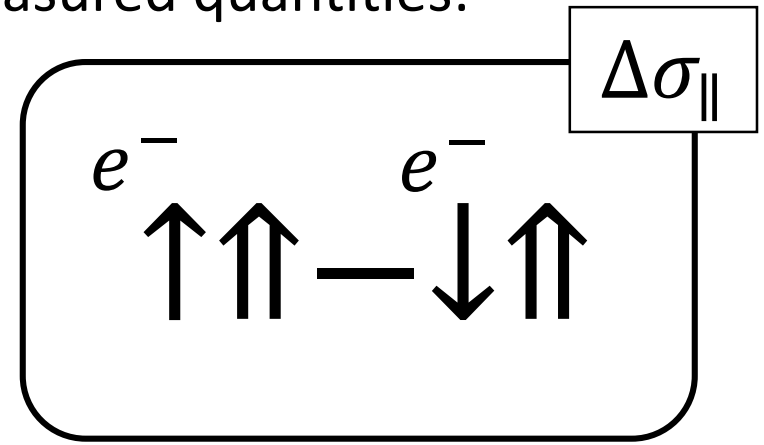
Inclusive polarized cross section differences:

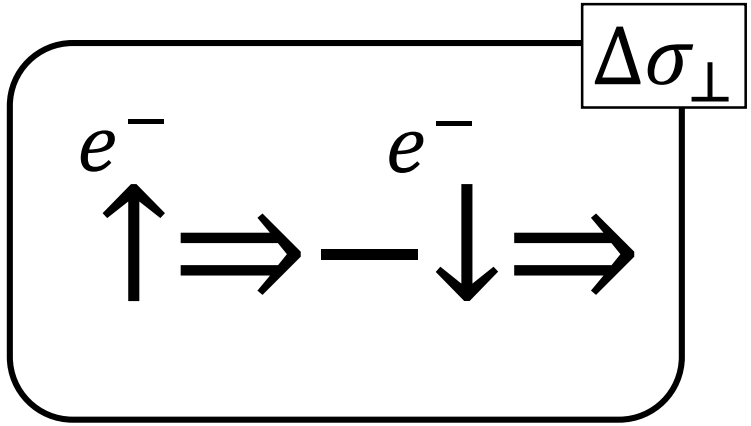
$$\frac{d^2\sigma}{d\Omega dE'}(\uparrow\Uparrow - \downarrow\Uparrow) = \frac{4\alpha^2}{MQ^2\upsilon}\frac{E'}{E}\left[(E + E'\cos\theta)\boldsymbol{g_1(x,Q^2)} - \frac{Q^2}{\upsilon}\boldsymbol{g_2(x,Q^2)}\right]$$

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

Experimental Technique

Measured quantities:





$$g_1 = \frac{MQ^2}{4\alpha_e^2}\frac{y}{(1-y)(2-y)}\left[\Delta\sigma_{\parallel} + \tan\frac{\theta}{2}\Delta\sigma_{\perp}\right]$$

$\Delta\sigma_{\perp}$ contributes only $\sim 5\%$ to g_1 at our kinematics.

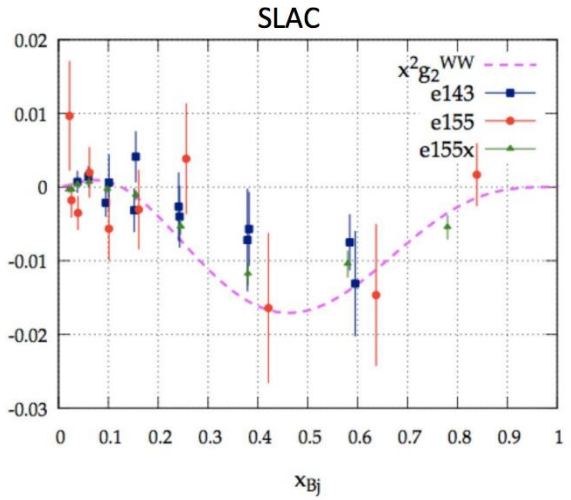
$$g_2 = \frac{MQ^2}{4\alpha_e^2}\frac{y^2}{2(1-y)(2-y)}\left[-\Delta\sigma_{\parallel} + \frac{1+(1-y)\cos\theta}{(1-y)\sin\theta}\Delta\sigma_{\perp}\right]$$

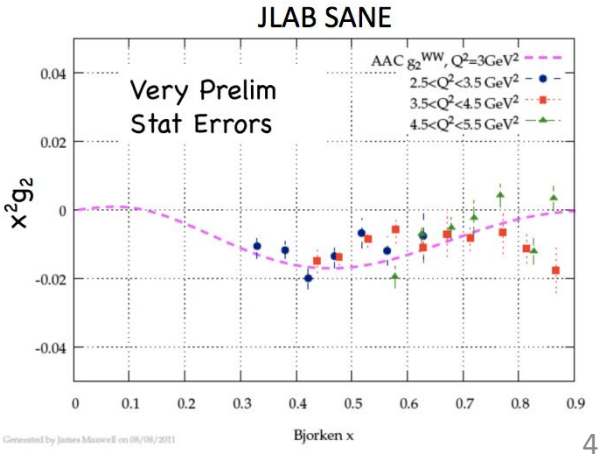
$\Delta\sigma_{\perp}$ measured during g_2^p experiment, $\Delta\sigma_{\parallel}$ contributes $\sim 2-8\%$ to g_2.

Motivation

- Very little data exists for the proton g_2 structure function.
- Measurements at Jefferson Lab:
  - RSS $(1 < Q^2 < 2\ \mathrm{GeV}^2)$ published
  - SANE $(2 < Q^2 < 6\ \mathrm{GeV}^2)$ analysis
  - g2p $(0.02 < Q^2 < 0.2\ \mathrm{GeV}^2)$ analysis
- A low Q^2 measurement will be a useful tool for testing the validity of χPT and the moments of g_2.

Existing data:





The B.C. Sum Rule

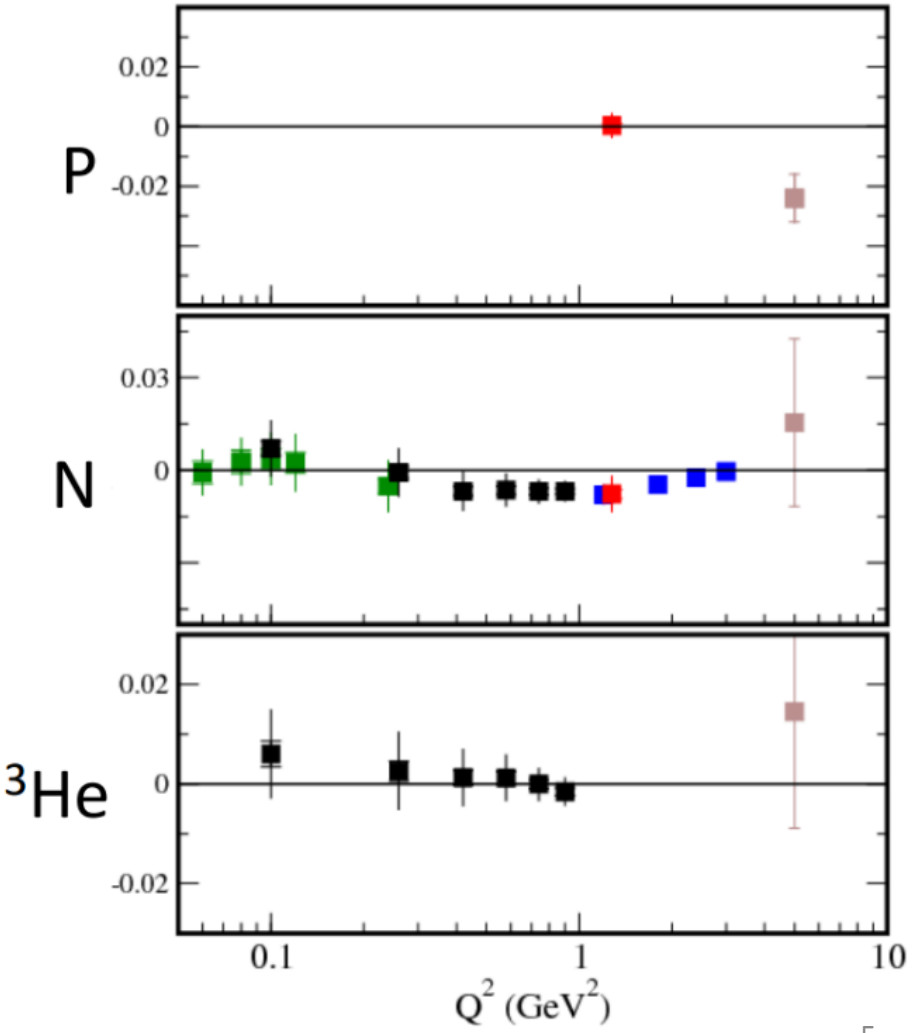
- 0^{th} moment of g_2:

$$\Gamma_2 = \int_0^1 g_2(x, Q^2)dx = 0$$

- Existing data:

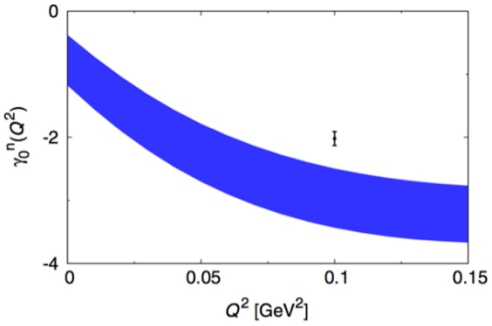
  Brown: SLAC E155x
  Red: Hall C RSS
  Black: Hall A E94-010
  Green: Hall A E97-110
  Blue: Hall A E01-012

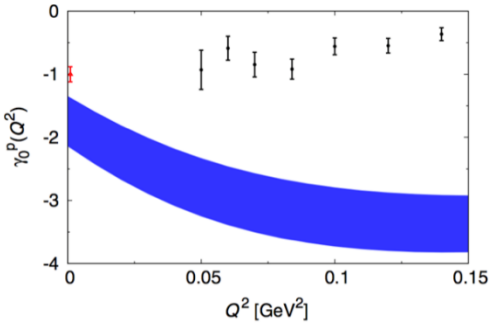
- G2p hopes to fill in low Q^2 region for the proton.

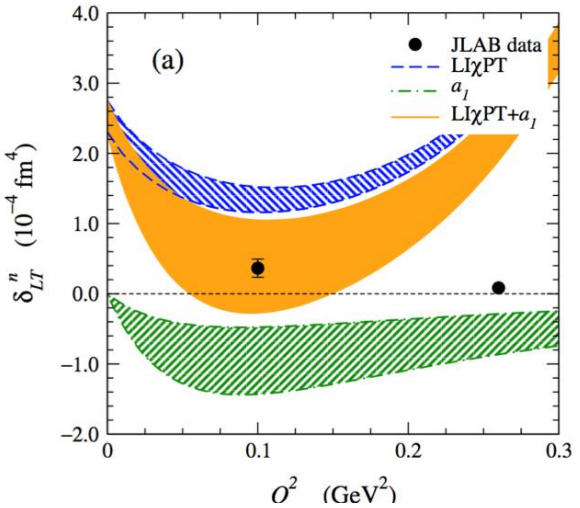


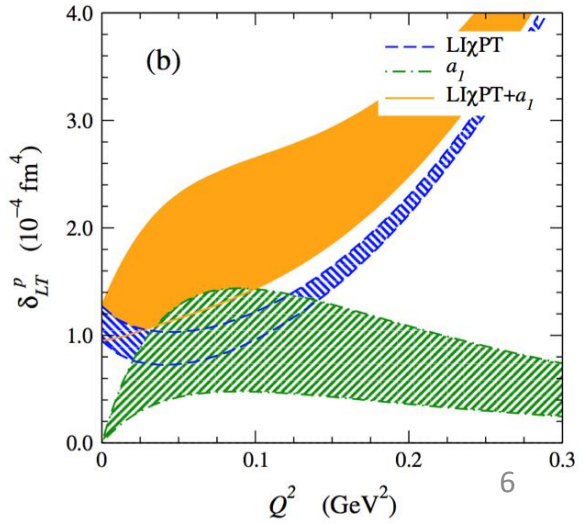
Spin Polarizabilities

- $\gamma_o = \frac{16\alpha M^2}{Q^6}\int_0^{x_o} x^2\left[g_1(x,Q^2) - \frac{4M^2}{Q^2}x^2 g_2(x,Q^2)\right]dx$
- $\delta_{LT} = \frac{16\alpha M^2}{Q^6}\int_0^{x_o} x^2[g_1(x,Q^2) + g_2(x,Q^2)]dx$
- Generalized spin polarizabilities γ_o and δ_{LT} are benchmark tests of χPT.
- Some disagreement with neutron polarizabilities.
- No proton data yet!

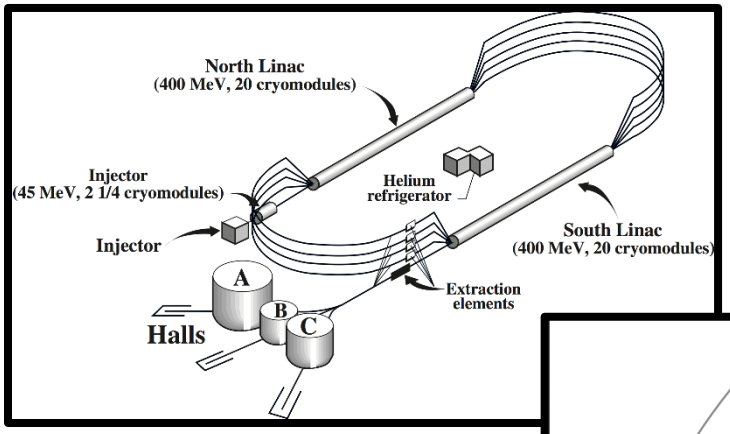








Experimental Setup

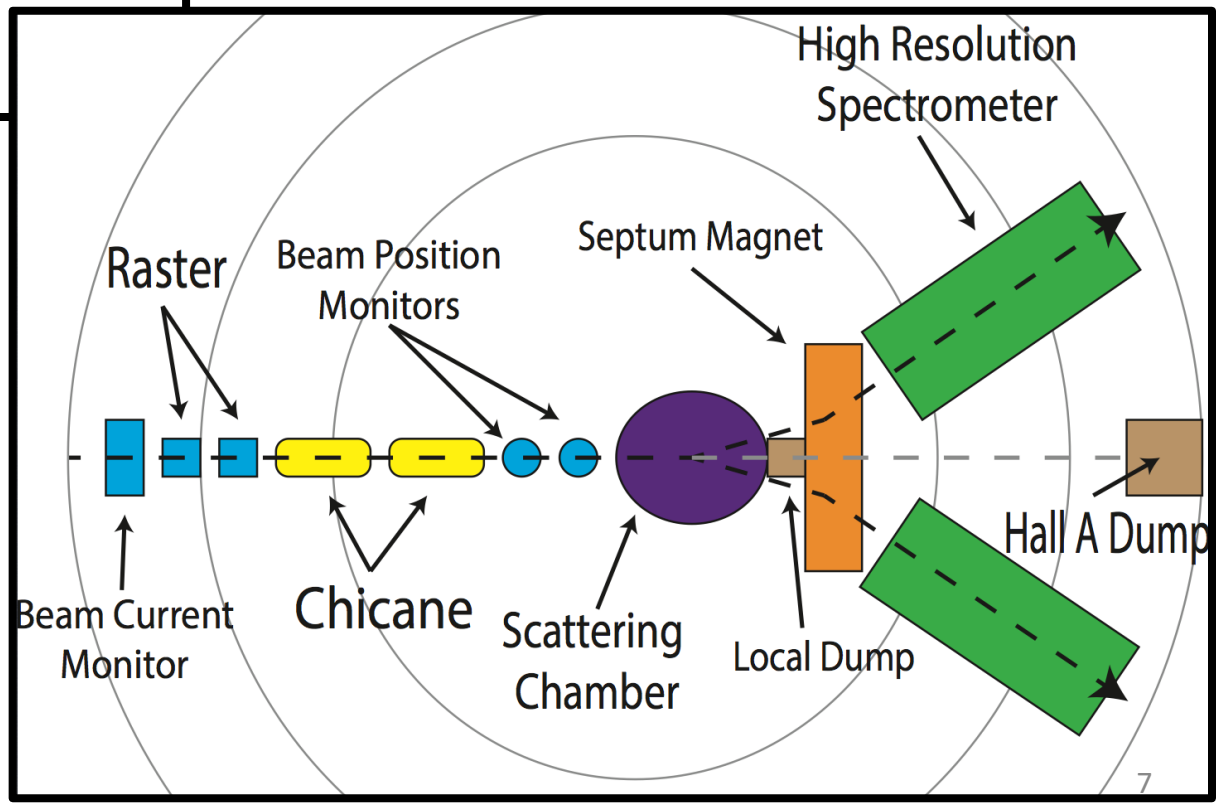


Jefferson Lab CEBAF:

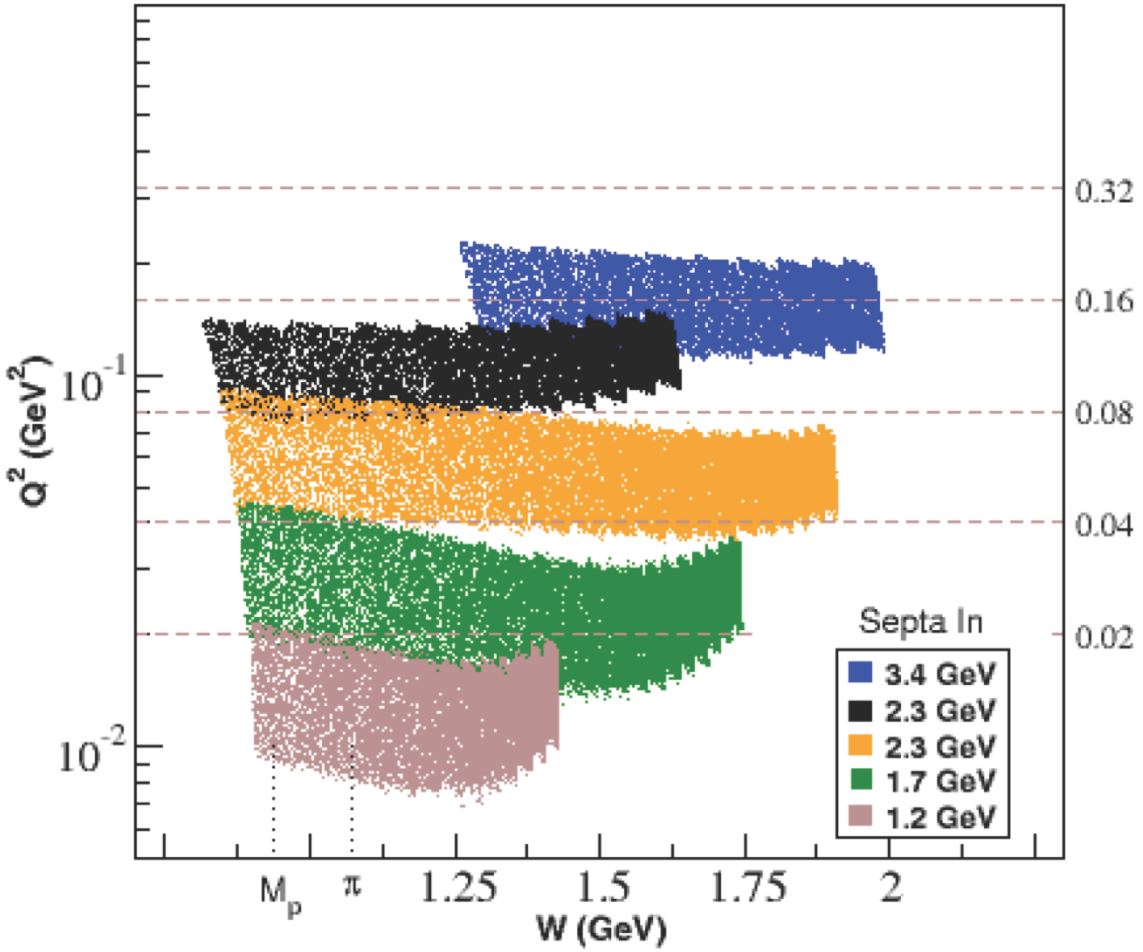
- 12 GeV maximum beam energy
- 200 μA maximum current
- 85% electron polarization

Hall A:

- All new beam diagnostics (BPM, BCM, rasters)
- Chicane installed for transverse target field
- 2.5/5T rotatable target field
- Septum magnet for small scattering angles



Kinematic Coverage



Beam Energy (GeV)	Target Field (T)
3.352	5
2.254	5
2.254	2.5
1.706	2.5
1.158	2.5

Model estimated kinematic coverage

Dilution and Packing Fraction

- The physics asymmetry first requires the calculation of two target quantities:
  - The length ratio of material in the target cup, called the *packing fraction.*

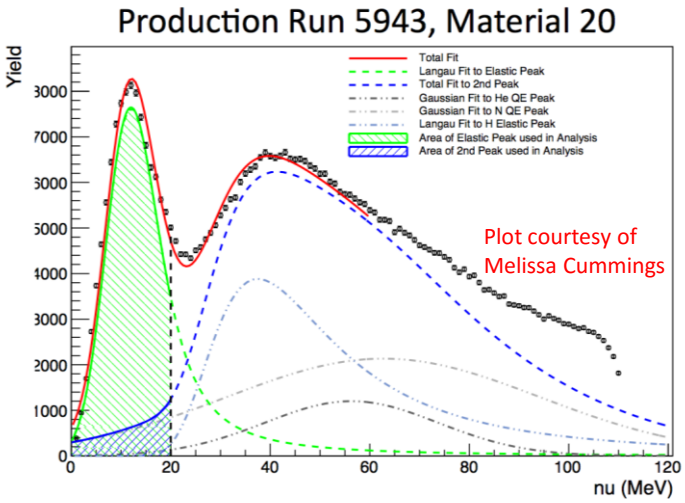
$$Pf = \left(\frac{Y_p}{Y_E} - 1\right)\left(\frac{\chi_N\sigma_N + \chi_H\sigma_H}{\chi_{He}\sigma_{He}}\right)^{-1}$$

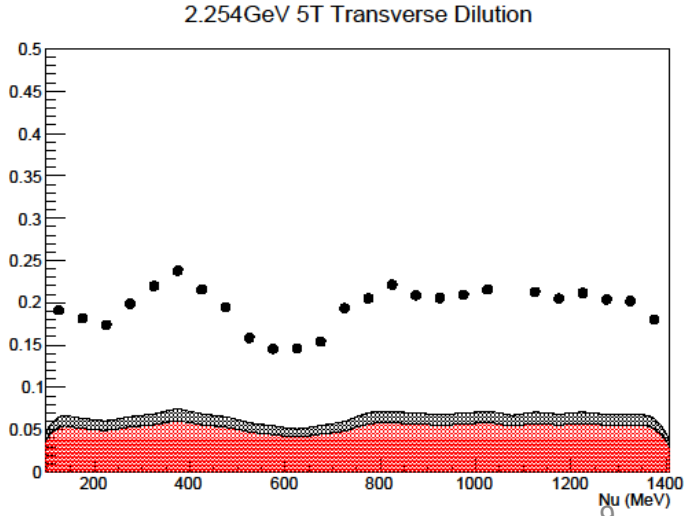
  - The fractional composition of proton material in the target, called the *dilution factor.*

$$f = 1 - \frac{Y_{BG}}{Y_P}$$

- The asymmetry is then calculated as:

$$A_{phy} = \frac{1}{fP_bP_t}\frac{Y_+ - Y_-}{Y_+ + Y_-}$$





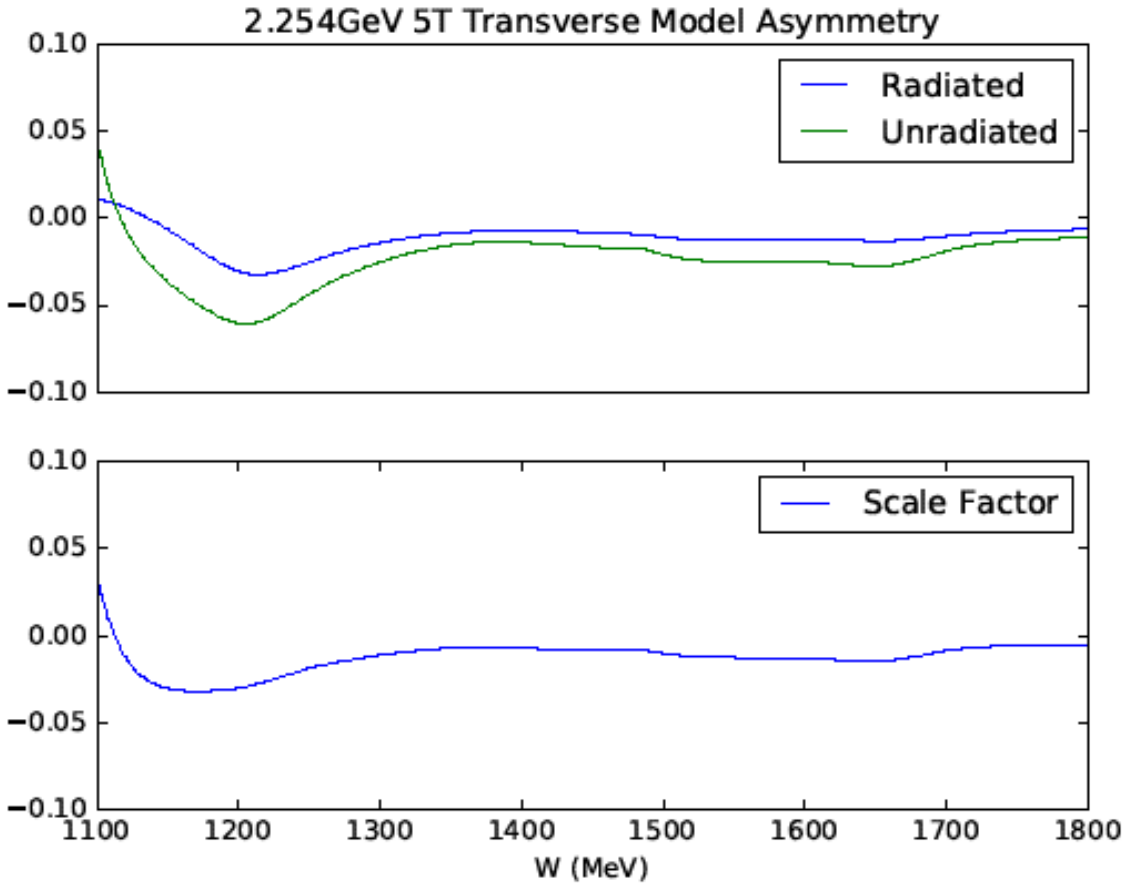
Radiative Corrections

- Preliminary polarized radiative correction:

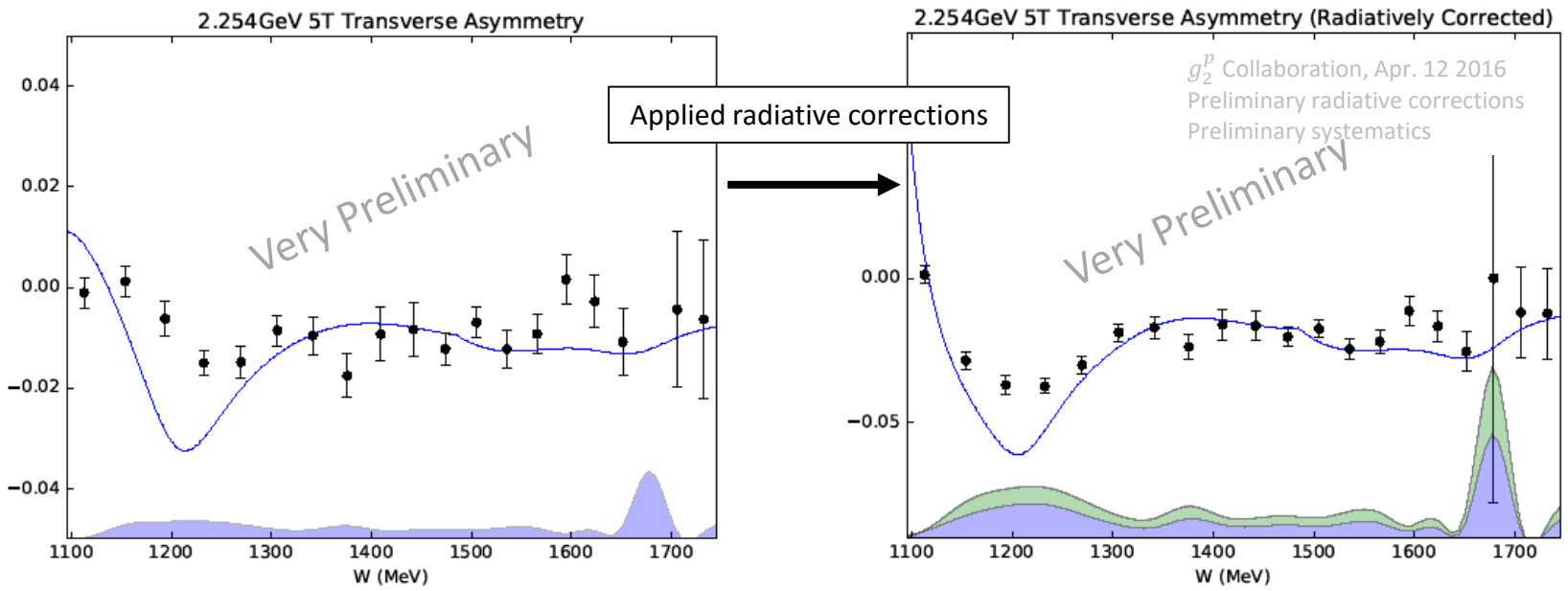
$$R = A_{unrad} - A_{rad}$$

- $A_{(un)rad}$ is generated from MAID.

- Polarized radiative correction study is still underway, results will be updated when complete.



Physics Asymmetry



Preliminary systematics:

Target Polarization	2%
Inelastic XS Model	10%
Packing Fraction	45%
MAID	40%
Radiative correction	10%

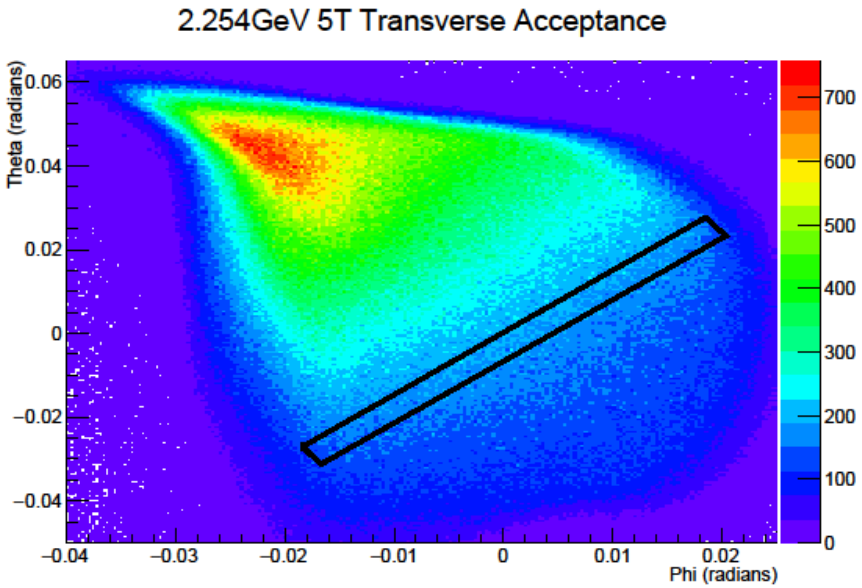
Unpolarized Cross Section

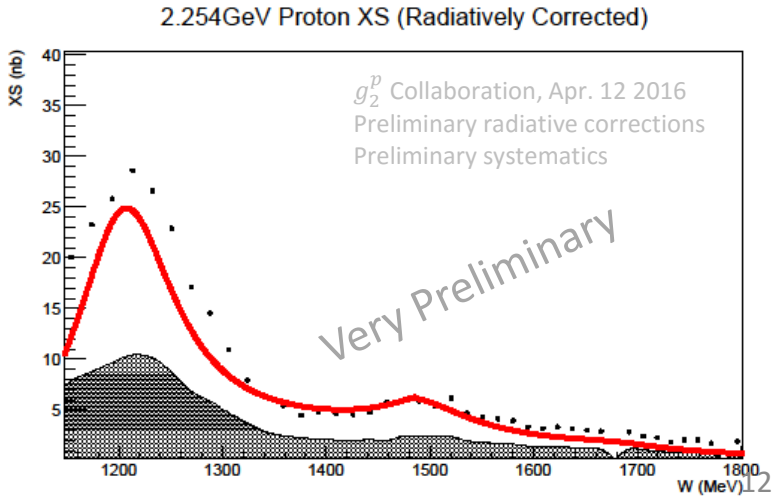
- Acceptance correction study is still underway.
- An acceptance cut is chosen such that the theta/phi distribution is flat within the cut region.
- Proton XS is calculated as:

$$\frac{d\sigma}{d\Omega dE} = \frac{eM_{NH3}}{A\rho_{NH3}Z_{NH3}} f Y_{NH3}$$

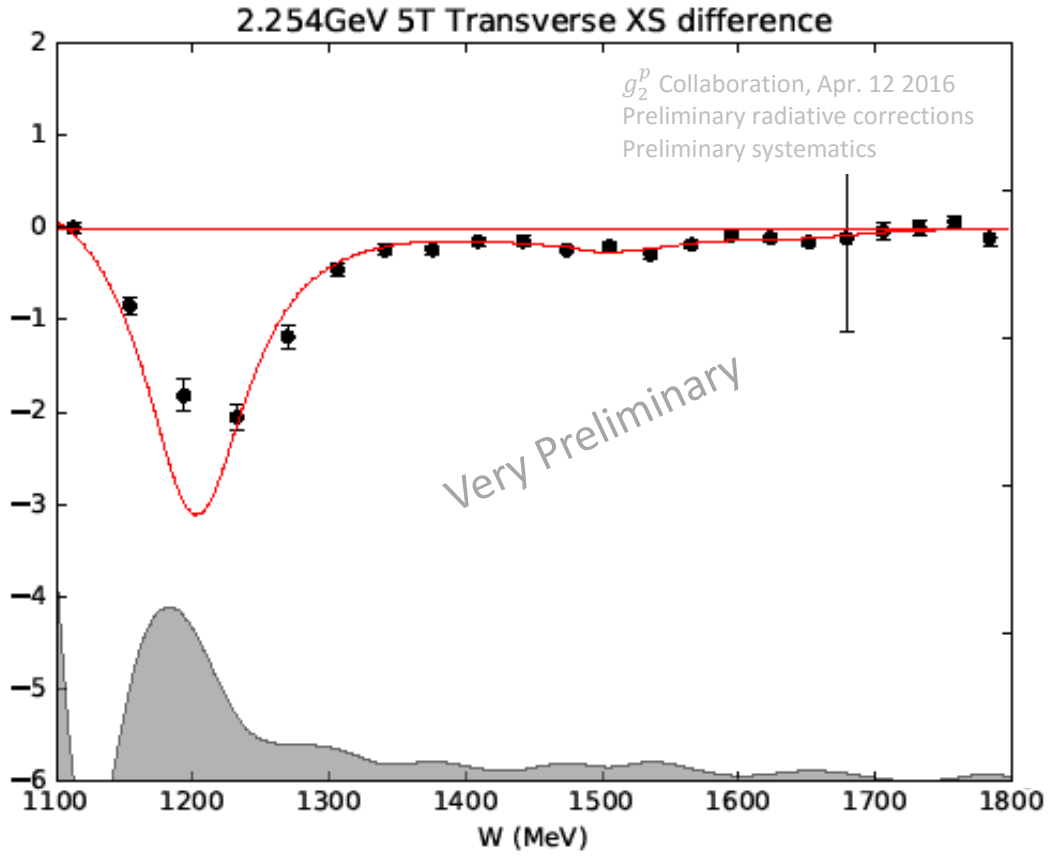
Preliminary systematics:

Unpolarized XS model	10%
Packing Fraction	45%
Unpolarized XS model (dilution)	10%





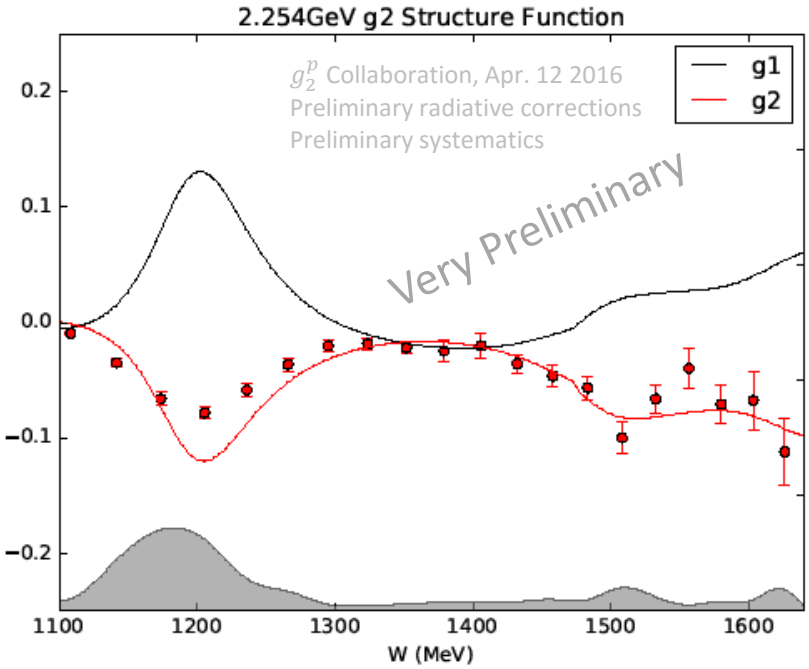
Cross Section Differences

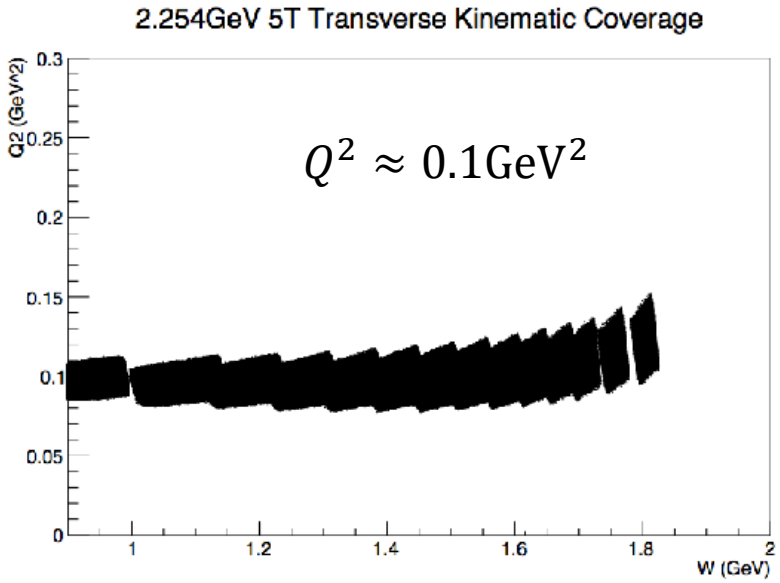


Preliminary systematics:

Unpolarized XS model	10%
MAID	40%
Target polarization	3%
Acceptance	25%

Proton Spin Structure Functions





Preliminary systematics:

Unpolarized XS model	10%
MAID	40%
Target polarization	3%
Acceptance	25%

Summary

- A measurement of the proton spin structure function g_2 at low Q^2 is an important component in the testing of a number of effective theories of QCD.
- The g2p experiment, which measured g_2 in a Q^2 region of $0.02 - 0.2\mathrm{GeV}^2$, successfully ran at Jefferson Lab during the spring of 2012 and analysis is still ongoing.
- Preliminary methods for determining the acceptance and radiative effects give promising results for the spin structure at a Q^2 of $0.1\mathrm{GeV}^2$.
- Current efforts are focused on improving these methods and reducing systematics.
- More results to come shortly!

Thank You!

G2p Analysis Team:

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