A precision measurement of the spin structure function $g_2^p(x, Q^2)$ from SLAC E155X

Nawal Benmouna
American University
Representing the E155X Collaboration

May 1, 2000

- Theoretical overview
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- Q^2 dependence of g_2^p
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E155X Collaboration

P. Anthony, R. Arnold, T. Averett, H. Band, N. Benmouna, C. Berisso, H. Borel
P. Bosted, S. Bültmann, M. Buenerd, T. Chupp, S. Churchwell, G.R. Court
D. Crabb, D. Day, P. Decowski, P. DePietro, R. Erbacher, R. Erickson
A. Feltham, H. Fonvieille, E. Frlez, R. Gearhart, V. Ghazikhanian, J. Gomez
K. Griffioen, C. Harris, M.A. Houlden, E. W. Hughes, C. Hyde-Wright, G. Igo
S. Incerti, J. Jensen, J. Johnson, P. King, Yu. G. Kolomensky, S. Kuhn
R. Lindgren, R. Lombard-Nelsen, J. Marroncle, W. Meyer, J. McCarthy
P. McKee, D. McNulty, G. Mitchell, J. Mitchell, M. Olson, S. Penttila
G. Peterson, G. G. Petratos, R. Pitthan, D. Pocanic, R. Prepost, C. Prescott
L. M. Quin, B. Raue, D. Reyna, L.S. Rochester, S. Rock
O. Rondon-Aramayo, F. Sabatie, S. St. Lorant, I. Sick, L. Sorrell, T. Smith, F. Staley
L. M. Stuart, Z. Szalata, Y. Terrien, L. Todor, A. Tobias, T. Toole,
S. Trentalange, D. Walz, R. Welsh, F.R. Wesselmann, T. Wright, C. Young
B. Youngman, M. Zeier, H. Zhu, B. Zihlmann

American University
Universität Basel
University Blaise Pascal
Ruhr-Universität Bochum
California Inst. of Technology
University of California–Los Angeles
PNC Saclay
Florida International University
Kent State University
University of Liverpool
LANL
University of Massachusetts
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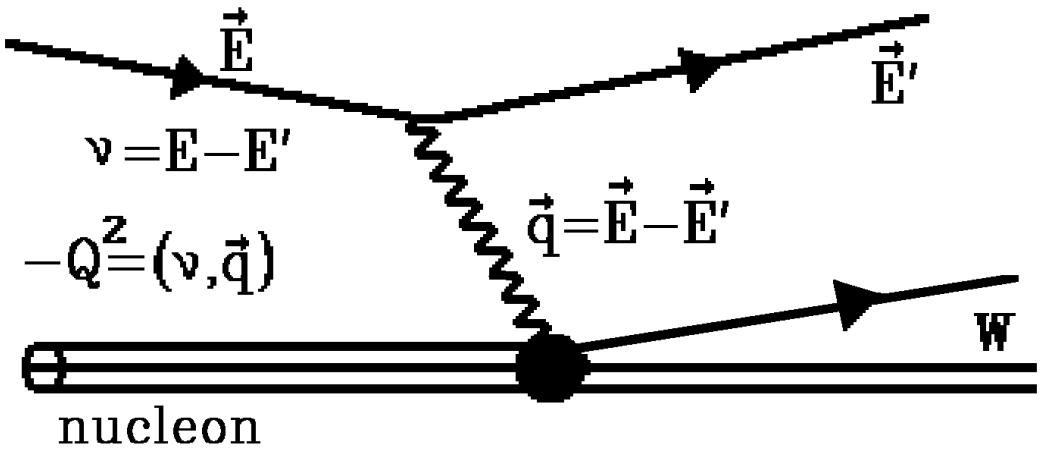
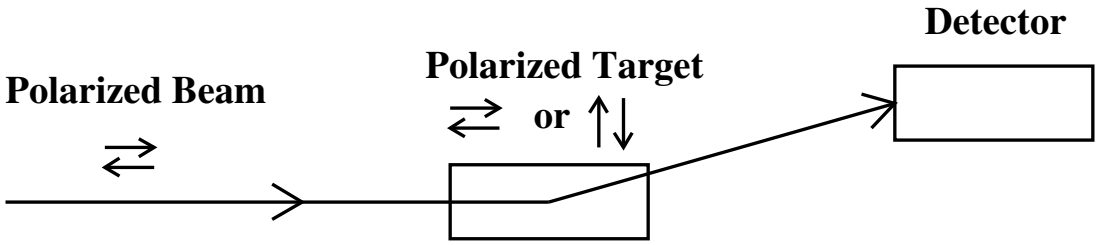
SLAC
Stanford University
TJNAF
University of Virginia
College of William and Mary
University of Wisconsin

Inclusive Deep Inelastic Scattering



- θ : scattering angle
- Q^2: 4-momentum transfer squared
- ν : energy transfer
- $x = \frac{Q^2}{2M\nu}$: Bjorken scaling variable

Polarized Deep Inelastic Scattering



$$A_{\parallel} = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}} = f_k\Big[g_1(x,Q^2)[E{+}E'\cos(\theta)]{-}\frac{Q^2}{\nu}g_2(x,Q^2)\Big]$$

$$A_{\perp} = \frac{\sigma^{\downarrow\leftarrow} - \sigma^{\uparrow\leftarrow}}{\sigma^{\downarrow\leftarrow} + \sigma^{\uparrow\leftarrow}} = f_k E'\sin(\theta)\Big[g_1(x,Q^2){+}\frac{2E}{\nu}g_2(x,Q^2)\Big]$$

- g_1 and g_2 are the polarized structure functions
- f_k includes contribution from kinematics and unpolarized structure functions

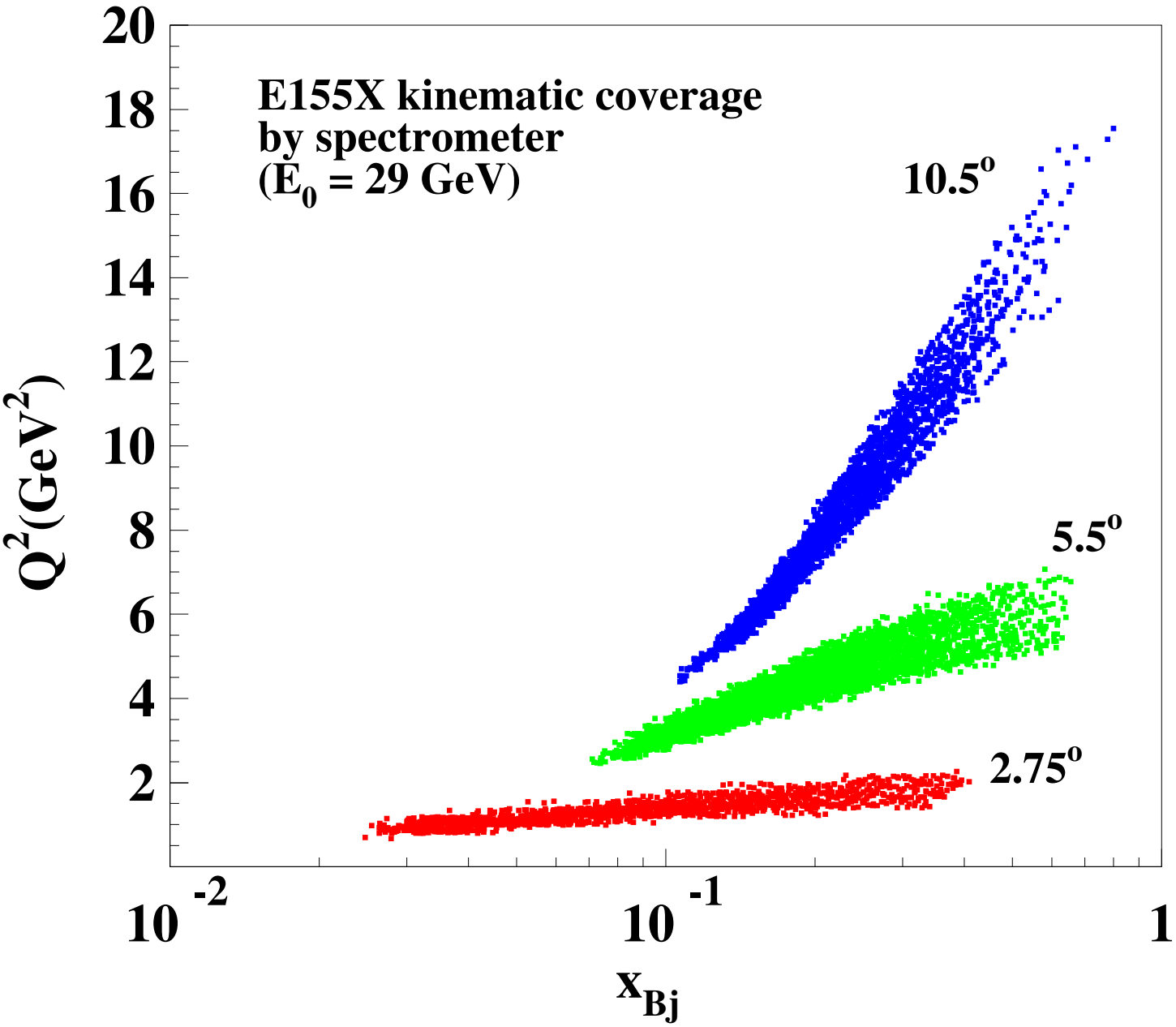
$\rightarrow$ $A_{\parallel}$ is primarily sensitive to g_1

$\rightarrow$ $A_{\perp}$ is more sensitive to g_2

Experimental Overview

- SLAC electron beam:
  - Longitudinal polarization $P_b = 0.83$
  - 120 HZ, 400 nsec spills, 25 nA current
  - Energy $E = 29.1$GeV or $E = 32.3$GeV
- Transversely Polarized Targets:
  - Dynamic Nuclear Polarization at 1K and 5T
  - NH3 for protons ($< P_t >= 0.75$)
  - LiD for deuterons ($< P_t >= 0.22$)
- Scattered electrons detected:
  - At central angles 2.75, -5.5, and 10.5 degrees
  - Gas cherenkov and lead glass for particle i.d.
  - Scintillator hodoscopes for tracks

Kinematics


E155X kinematic coverage
by spectrometer
(E_0 = 29 GeV)
10.5°
5.5°
2.75°
Q^2(GeV^2)
x_{Bj}
20
18
16
14
12
10
8
6
4
2
10^{-2}
10^{-1}
1

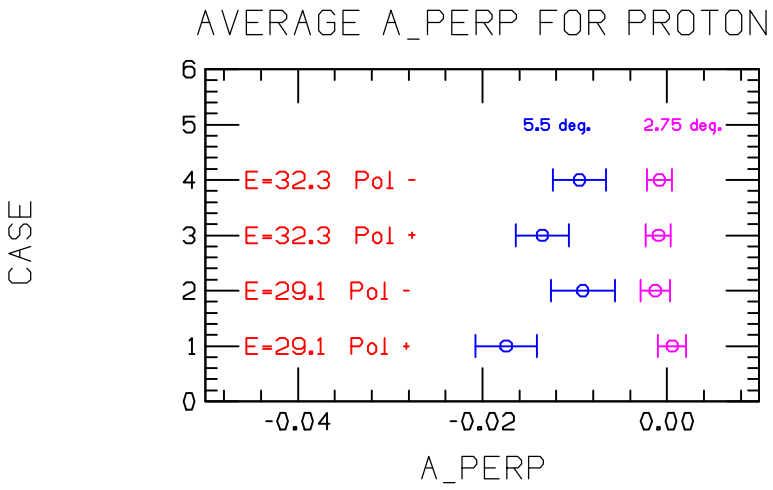
Experimental $A_\perp$ Asymmetry

$$A_\perp = \frac{C_1}{f P_t f_{RC} \cos(\phi)} \left(\left(\frac{N_L - N_R}{N_L + N_R} \right) \frac{1}{P_b} + A_{EW} \right) + A_{RC}$$

- N_L and N_R are rates for L and R beam helicities, corrected for pair-symmetric contributions (few %), pions mis-identified as electrons (few %)
- C_1 is correction for polarized ^{15}N or Li
- P_b is beam polarization
- P_t is target polarization
- $\cos(\phi)$ is the angle between plane of electron/proton spins and plane of electron scattering.
- f is dilution factor (≈ 0.16 proton)
- A_{EW}: Electroweak Asymmetry ($\approx 8 \times 10^{-5} Q^2$)
- f_{RC} and A_{RC} are radiative corrections

Systematic Checks

- Target polarization aligned (+) or anti-aligned (-) with B field
- Beam energy changed by 3.2 GeV to precess spin by π in transport line
- Correct for EW asymmetry (depends only on beam helicity)
- Additional false asymmetries (i.e helicity-dependent beam position) would produce a difference in the average $A_\perp$



Determination of $g_2(x, Q^2)$

- We use measured $A_\perp$ and E155 g_1 fit to obtain g_2 using:

$$g_2(x,Q^2) = \frac{\nu}{2E}[\frac{A_\perp}{f_k E' \sin(\theta)} - g_1(x,Q^2)]$$

- Twist-2 model of Wandzura-Wilczek

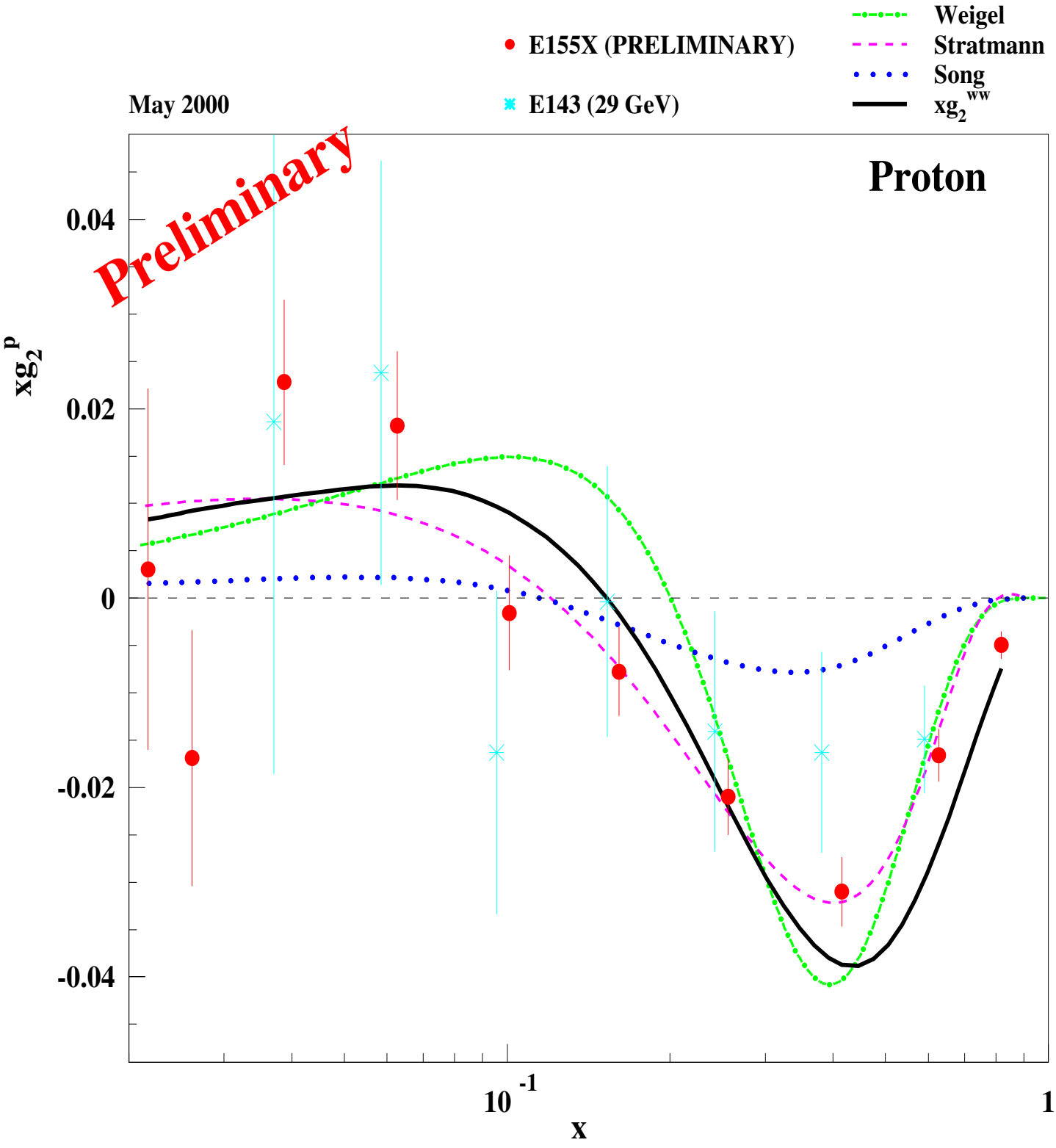
$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 \frac{dy}{y} g_1(y,Q^2)$$

- General expression

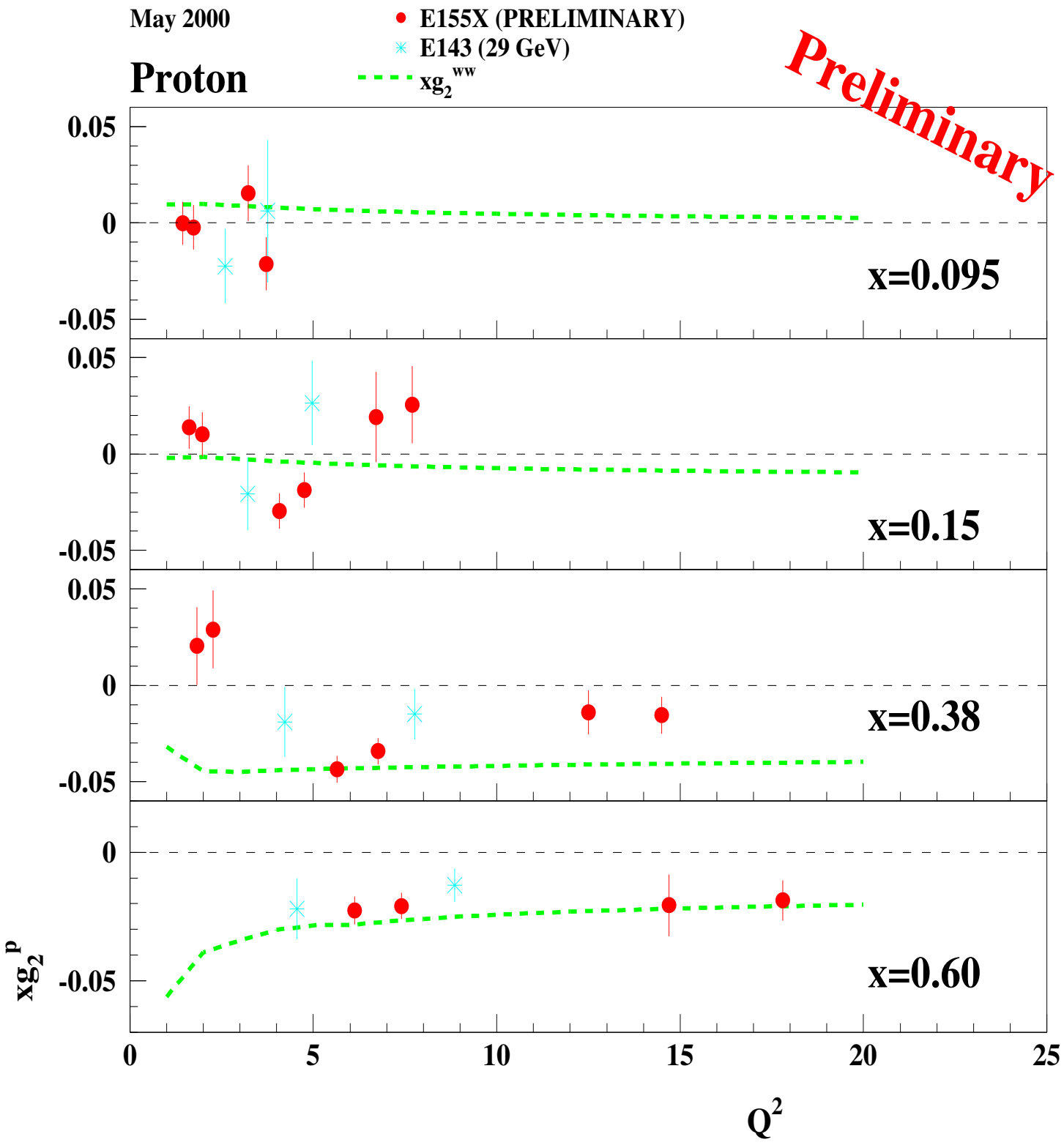
$$g_2(x,Q^2) = g_2^{WW}(x,Q^2) - \int_x^1 \frac{\partial}{\partial y}(\frac{m}{M} h_T(y,Q^2) + \xi(y,Q^2))\frac{dy}{y}$$

g_2^{WW}: twist-2; h_T: twist-2; ξ: twist-3

Results for Q^2-averaged $xg_2(x)$



Q^2-DEPENDENCE OF xg_2



Summary

- E155x uncertainty $\approx 3\times$ smaller than previous results
- Radiative corrections need refinement
- First g_2 results with ability to distinguish between different models
- Rough agreement seen with g_2^{ww} model, Bag model of Stratmann et al., and Chiral model of Weigel et al.
- Proton g_2 clearly negative for $x > 0.2$ and positive for $x < 0.1$
- Future g_2 measurements at Jefferson lab in different kinematic range?