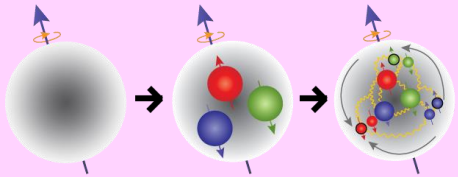
A Strong-QCD Measurement of the Proton's Spin Structure

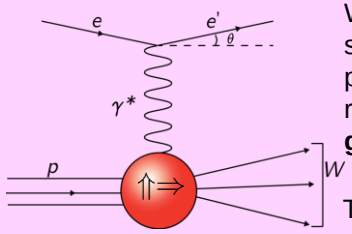
David Ruth
K. Slifer, J.P. Chen, A. Camsonne (Spokespeople)

University of New Hampshire
Jefferson Lab
Thomas Jefferson National Accelerator Facility
UNH-NPG



Despite accounting for more than 90% of visible matter, the proton's structure is not well understood…

Inclusive ep Scattering



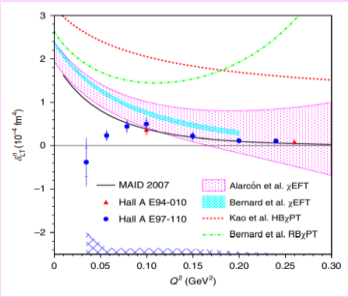
With polarized electron scattering from a spin-polarized proton target, we reveal structure functions **g1** and **g2**

These characterize the spin-structure of the proton!

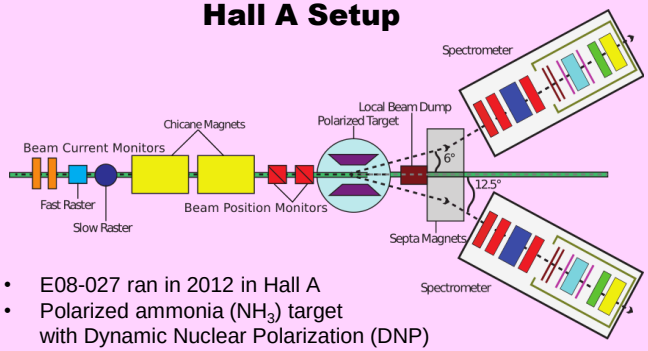
Necessary Low Q² QCD Benchmark

At low Q^2, Chiral Perturbation Theory (χPT) predicts QCD, but fails to reproduce structure function moments for the neutron!

Same for proton? Important to find out!

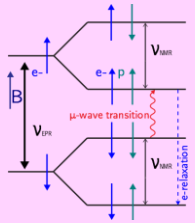


Hall A Setup



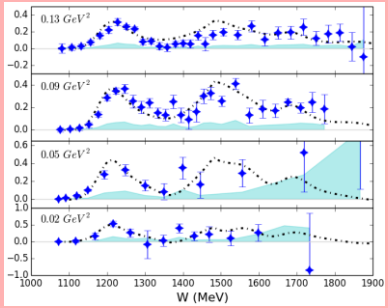
- E08-027 ran in 2012 in Hall A
- Polarized ammonia (NH_3) target with Dynamic Nuclear Polarization (DNP)
- Yields measured with Hall A high resolution spectrometers (HRS)

Polarized Target



- >2.5T B-Field: 99% electron polarization
- Microwaves stimulate hyperfine coupling, causing electrons to drag proton polarization with them!

Results



- Final results support χPT predictions and help resolve discrepancy
- Analysis **complete** and first paper **under review for publication in Nature Physics**

$$\delta_{LT} = \frac{16\alpha M^2}{Q^6}\int_0^{x_{th}} x^2[g_1(x,Q^2) + g_2(x,Q^2)]dx$$

$$\overline{d_2} = \int_0^{x_{th}} x^2[2\,g_1(x,Q^2) + 3\,g_2(x,Q^2)]dx$$

Extracting g_2

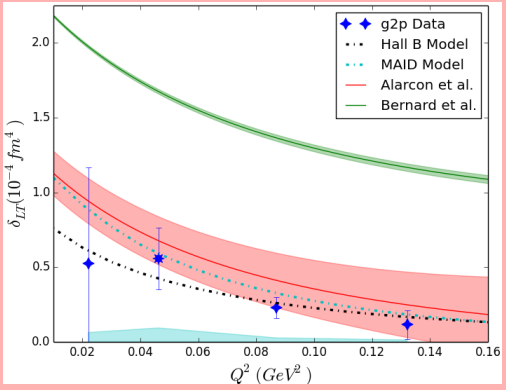
Compare forward and backward helicity scattered electrons:

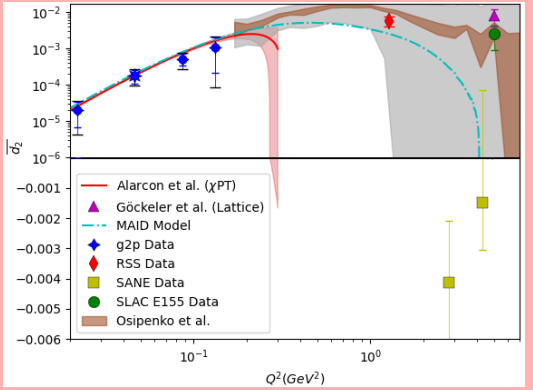
$$A_\perp = \frac{\frac{d^2\sigma}{d\Omega dE'}(\downarrow\Rightarrow - \uparrow\Rightarrow)}{\frac{d^2\sigma}{d\Omega dE'}(\downarrow\Rightarrow + \uparrow\Rightarrow)}$$

$$\Delta\sigma_\perp = \frac{d^2\sigma}{d\Omega dE'}(\downarrow\rightarrow - \uparrow\rightarrow) = 2\cdot A_\perp \sigma_0$$

With lots of world data for unpolarized xs σ_0 and longitudinal structure function g_1, using models for both lets us solve for g_2!

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





Figures included from https://www.sciencenews.org/article/theres-still-lot-we-dont-know-about-proton and V. Sulkosky, C. Peng, J.P. Chen, et al., "Measurement of the generalized spin polarizabilities of the neutron in the low-Q2 region", Nature Physics, 17:687–692, 2021. Thank you to Karl Slifer, Jian-Ping Chen, Ryan Zielinski, and the rest of the g2p analysis group and collaboration