Precision Measurement of the Neutron d_2: The Color Field Response to the Polarized Nucleon

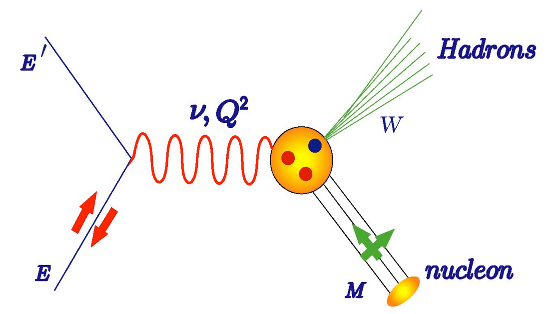
D. Flay[1] Advisor: Z.-E. Meziani[1]

[1]Temple University Physics Department, Philadelphia, PA 19122

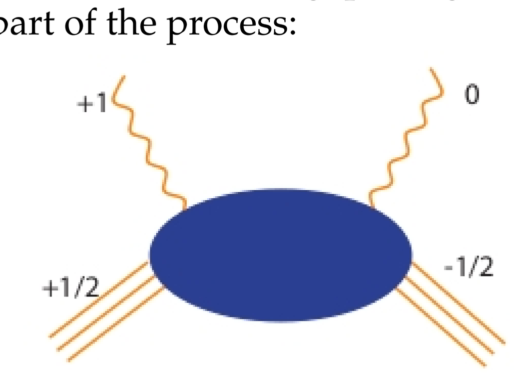
Jefferson Lab — Thomas Jefferson National Accelerator

Introduction

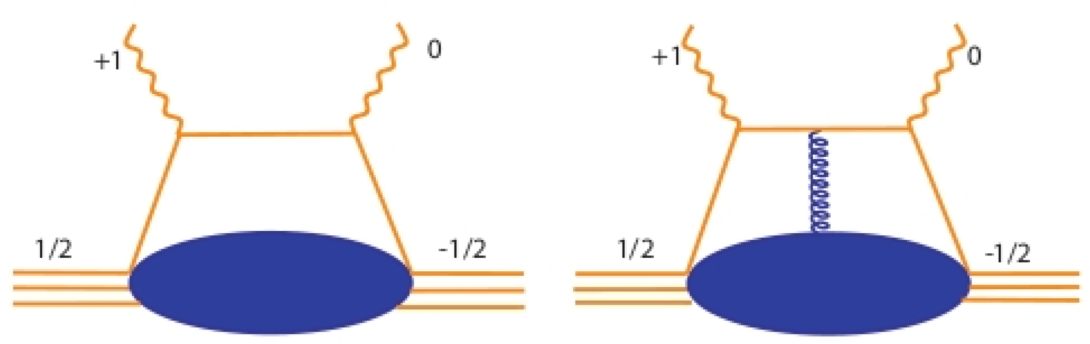
- Our experiment focuses on the spin structure of the neutron. To better understand this spin content, we probe the nucleon using a high energy longitudinally polarized electron beam focused on a polarized ^{3}He target. Since the two proton spins in ^{3}He will couple to $s = 0$, the remaining neutron spin is aligned along the direction of the polarization, making ^{3}He effectively a neutron target. The electrons will then interact with the neutrons in the target via the exchange of a virtual photon, which probes inside the neutron:



- This exchange gives access to the *spin structure functions* g_1 and g_2. These structure funtions may be accessed due to having a polarized beam and two different polarizations of the target
- g_2 contains information concerning quark-gluon correlations via the imaginary part of the process:



- This is a t-channel helicity exchange process, composed of two parts:



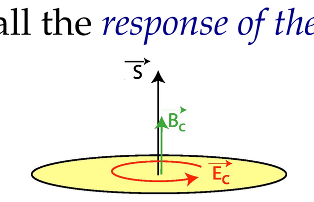
Leading twist = twist-2 Higher twist = twist three

- d_2^n is written as the second moment of a linear combination of g_1 and g_2:

$$d_2^n = \int_0^1 x^2 \left[2g_1\left(x,Q^2\right) + 3g_2\left(x,Q^2\right)\right] dx = \int_0^1 \tilde{d}_2^n dx$$

d_2^n in Terms of the Color 'Polarizabilities'

- Analogy to a polarized atom in an external electric field
- Inside the polarized nucleon, the quark spins line up along the direction of polarization corresponding to a quark current characterized by the exchange of gluons. When the incoming electrons interact with one of the quarks, it gains energy and tries to move. It feels a 'force' due to the other two quarks (and their associated gluons). This 'force' due to the unaffected constituents is precisely what we call the *response of the color field*



- In terms of the electric (χ_E) and magnetic (χ_B) 'polarizabilities':

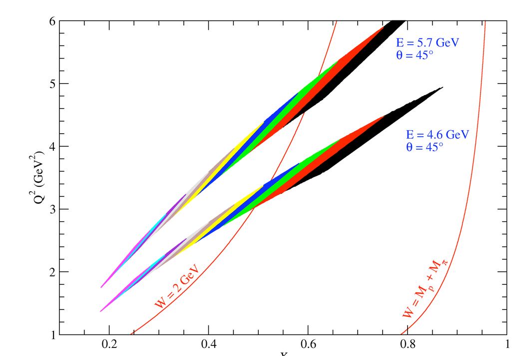
$$d_2^n = \frac{1}{8}(\chi_E + 2\chi_B)$$

The Measurement of d_2^n

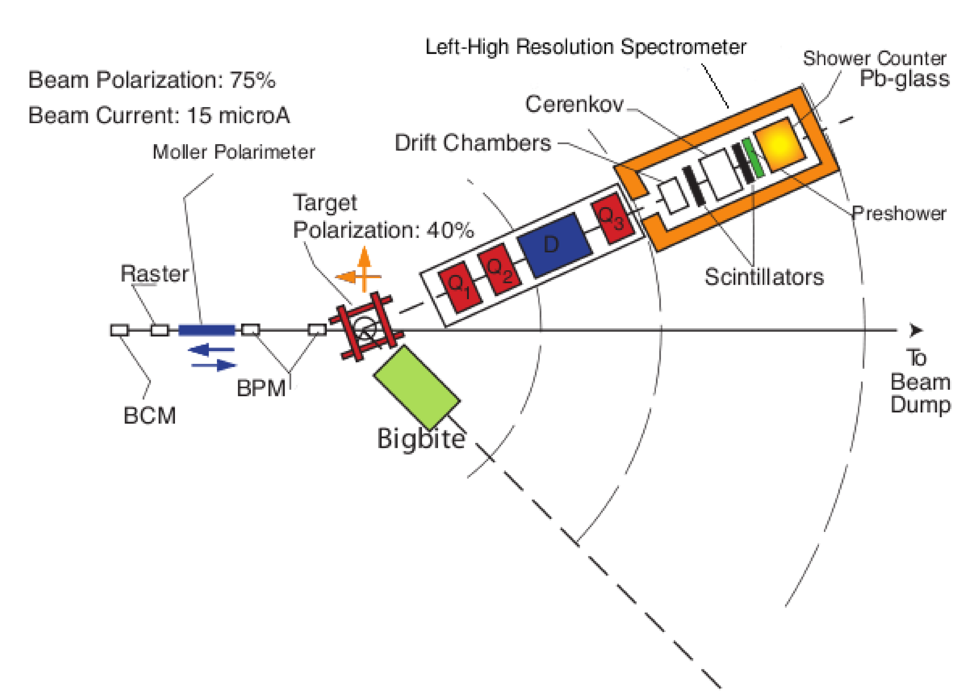
- In order to determine d_2^n experimentally, we measure the unpolarized cross section (σ_0) and the parallel $(A_\parallel)$ and perpendicular $(A_\perp)$ asymmetries. From these measurements, we determine the value of d_2^n through the relation[1]:

$$\tilde{d}_2^n = \frac{MQ^2}{4\alpha^2}\frac{x^2y^2}{(1-y)(2-y)}\sigma_0 \times$$
$$\left[\left(3\frac{1+(1-y)\cos\theta}{(1-y)\sin\theta} + \frac{4}{y}\tan\frac{\theta}{2}\right)A_\perp + \left(\frac{4}{y} - 3\right)A_\parallel\right]$$

- Kinematic range covered during the experiment:

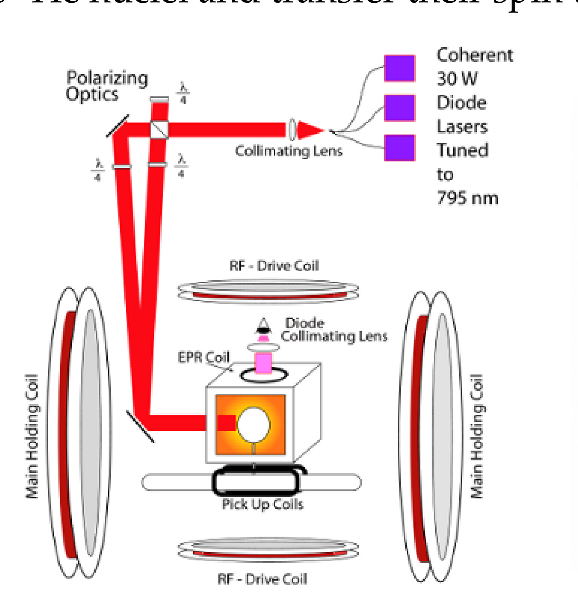


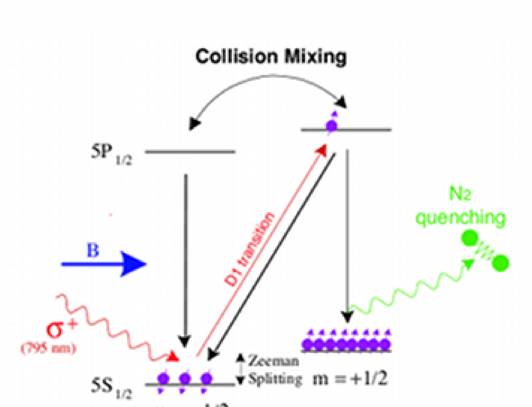
The Experimental Setup (Top View)



Target

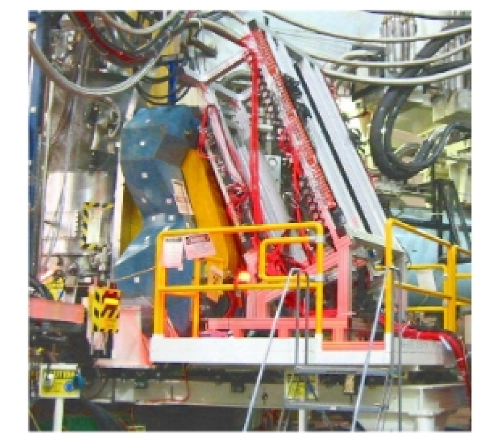
- Two sets of Helmholtz coils provide the magnetic field necessary for maintining the polarization of the ^{3}He nuclei
- The pumping chamber sits just above the target chamber filled with vaporized Rubidium, necessary for polarizing the target
- Rubidium gas is optically pumped with circularly polarized light in order to polarize the electrons, then the Rubidium electrons interact with the ^{3}He nuclei and transfer their spin to the nuclei via *collision mixing*[2]

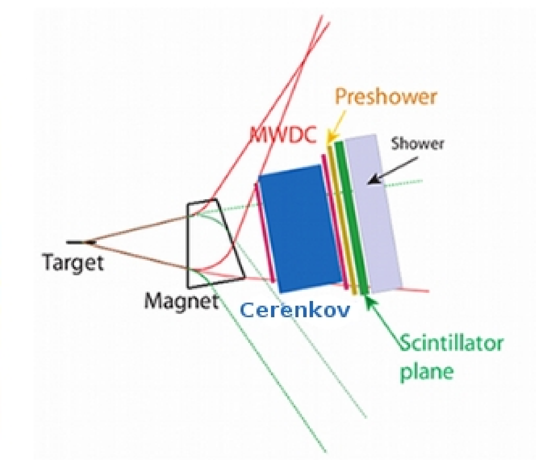




BigBite

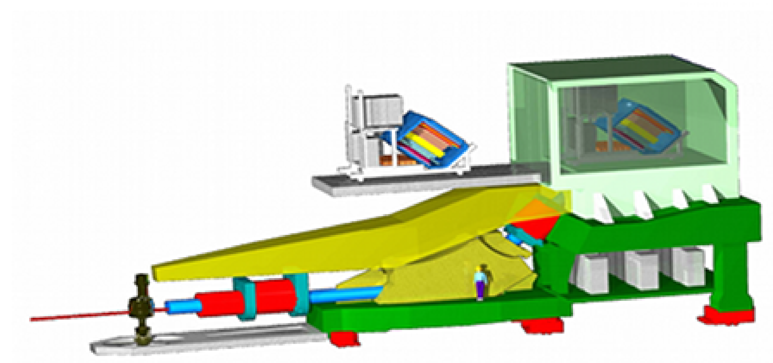
- Three sets of Multiwire Drift Chambers (MWDC) to track the particle trajectories
- A gas Cerenkov counter and a double layer lead glass calorimeter for pion rejection
- A set of scintillators for triggering on charged particles
- Measures parallel $(A_\parallel)$ and perpendicular $(A_\perp)$ asymmetries

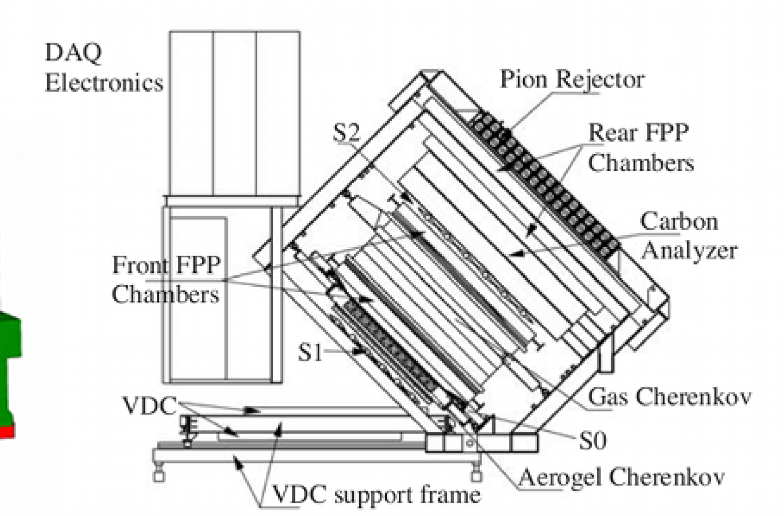




Left-High Resolution Spectrometer

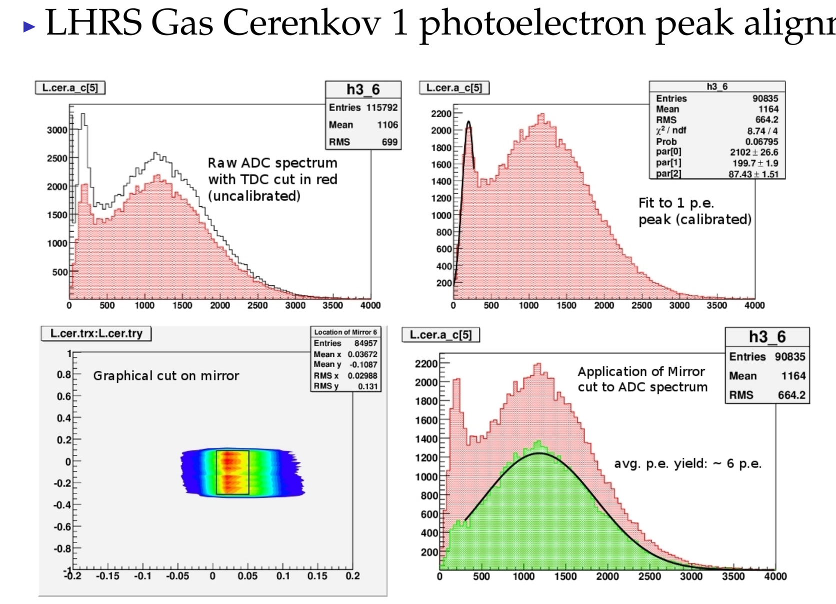
- Two Vertical Drift Chambers (VDC) for measurement of momentum and production (scattering) angle
- A gas Cerenkov counter and a double layer lead glass calorimeter for pion rejection
- A set of scintillators for triggering on charged particles
- Measures the absolute cross section (σ_0)





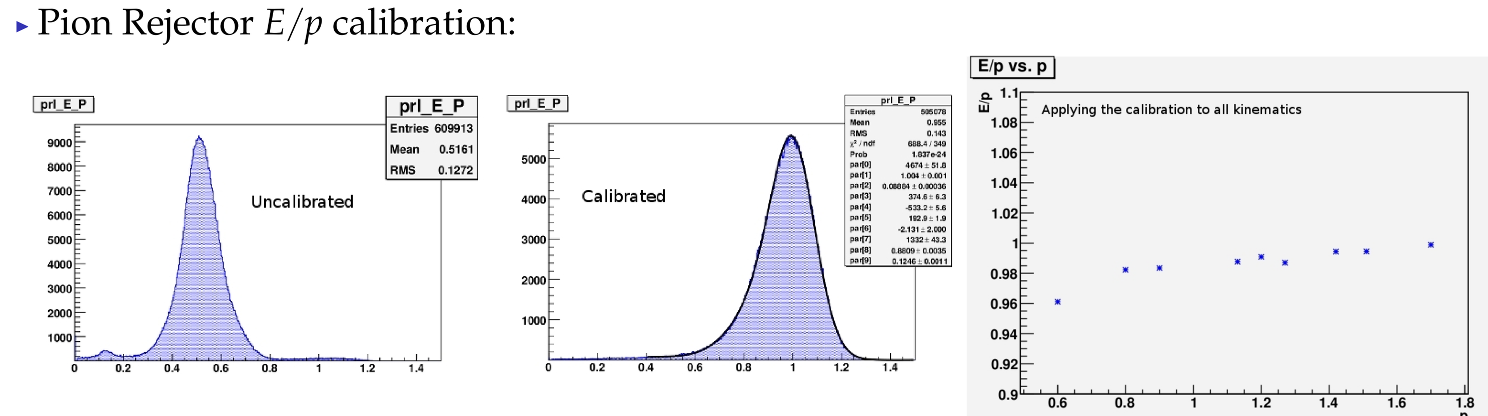
Preliminary Analysis

- Calibrations for elastic (1-pass) data, $p = 1.0$ GeV/c
- LHRS Gas Cerenkov 1 photoelectron peak alignment and average photoelectron yield:

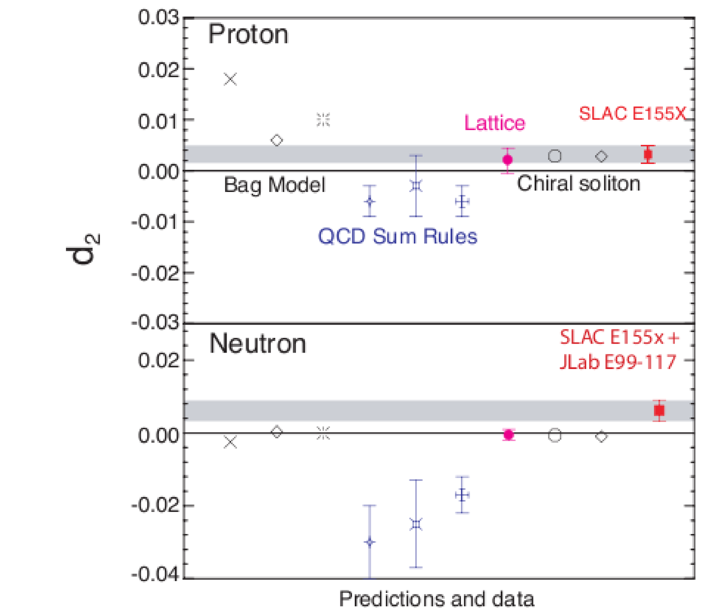


Mirror	1 p.e.	$n_{\text{p.e.}}$	# p.e.
1	196.8	967.3	4.45
2	198.6	715.3	3.48
3	198.4	1335	6.73
4	197.8	1344	6.75
5	198.5	1154	5.83
6	199.7	1184	5.93
7	199.5	1212	6.08
8	198.6	1225	6.17
9	194.9	1072	5.50
10	196.7	1010	5.13

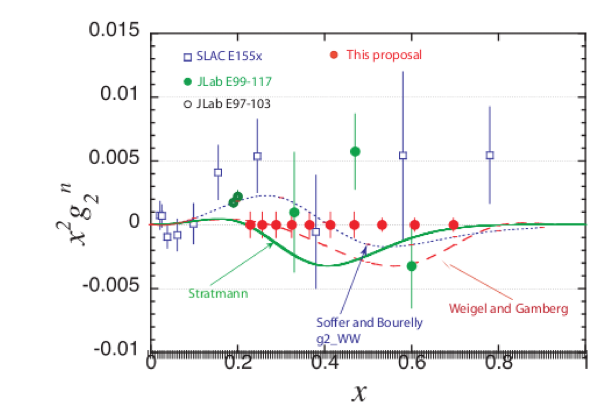
- Pion Rejector E/p calibration:



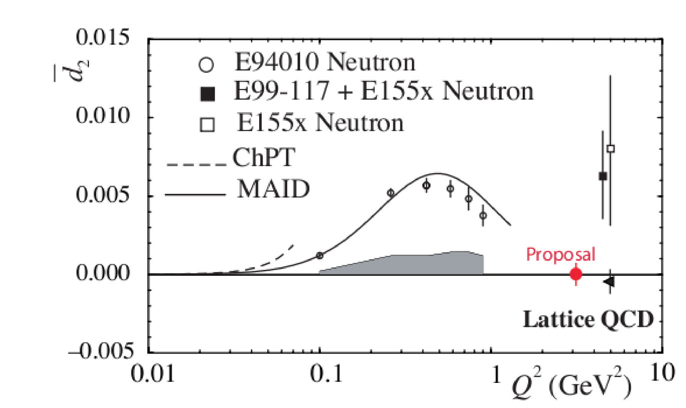
Projected Results



- Bag and soliton model calculations yield a value consistent with Lattice QCD. Current experimental values are approximately two standard deviations away from these predictions[1].



- In previous experiments, large error bars affect the overall sign of d_2^n. Therefore, the sign and magnitude of the neutron d_2 is unclear[1].



- The high precision of this experiment will provide for a more difinitive statement regarding the overall value of d_2^n.

Acknowledgements

- I would like to thank Zein-Eddine Meziani, Brad Sawatzky, Patricia Solvignon, and Vincent Sulkosky for their generous suggestions, insight, and continued support.
- Diagrams taken from www.jlab.org, http://hallaweb.jlab.org/experiment/E06-014/talks/pac29.pdf, http://hallaweb.jlab.org/experiment/E06-014/talks/poster.pdf, and http://hallaweb.jlab.org/equipment/Hall-A-NIM.pdf

References

- [1] Seonho Choi, Z.-E. Meziani, B. Sawatzky, X. Jiang *et. al.*, Jefferson Lab, 2005; PR-06-014
- [2] Solvignon, Patricia H., Ph.D., Temple University, 2006; AAT 3247311

http://hallaweb.jlab.org/experiment/E06-014/ e-mail: flay@jlab.org; http://quarks.temple.edu/~dflay