A Precision Measurement of d_2^n: Color Field Response to Nucleon Polarization

On behalf of the d2n/E06014 Collaboration

Graduate Students:

Matthew Posik[1] David Flay [1] Diana Parno [2]

[1]Temple University, Philadelphia,PA

[2]CMU

Outline

- Introduction to d_2^n
- The Experiment Setup
- Analysis Progress
- Future Work

Probing QCD through Quark-Gluon Dynamics

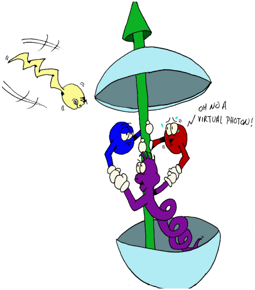
d_2^n gives access to quark-gluon correlations

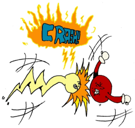
$$d_2^n = \int_0^1 x^2 \left(2g_1\left(x, Q^2\right) + 3g_2\left(x, Q^2\right)\right) dx$$

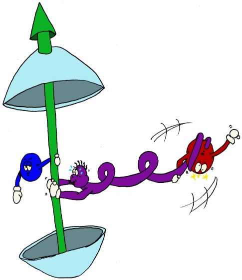
- What is d_2^n?
  - Average Lorentz color transverse force acting on a quark immediately after being struck by a virtual photon (M. Burkardt)
  - d_2^n is dominated by large x contributions

What is d_2^n?

So I still don't get it...

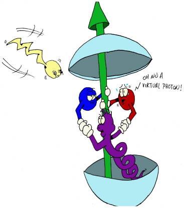


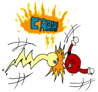


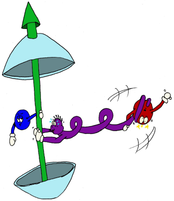


What is d_2^n?

So d_2^n is...







- A measure of quark-gluon correlations
- A force felt between the quark and gluon due to a virtual photon knocking a quark out of the nucleon

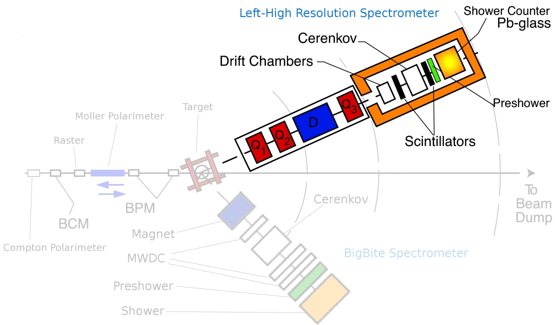
The E06014 Experiment

The E06014 Game Plan

- A longitudinally polarized electron beam at 4.7 and 5.9 GeV was scattered off polarized ^3He target
- Target polarization is changed to measure transverse and parallel asymmetries and unpolarized cross section.
- Two single arm detectors at $45°$:
  - Big Bite (BB)
  - Left High Resolution Spectrometer (LHRS)
- Kinematic Range: $0.2 < x < 0.7$ and 2 $GeV^2 < Q^2 <$6 GeV^2

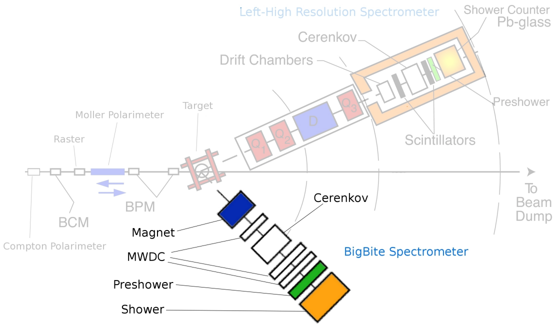
The E06014 Setup: LHRS

- LHRS used to measure σ_0
- Well understood
- Past absolute cross section measurements $\sim 4\%$ total error



The E06014 Setup: BB

- BB used to measure $A_\perp$ and $A_\parallel$
- Large acceptance allows more statistics
- Error dominated by statistics
- Many systematics will cancel in asymmetries



Measuring d_2^n

- d_2^n can be measured through the total cross section and the asymmetries

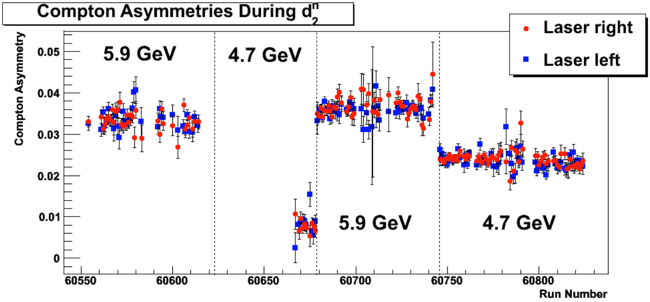
$$A_\perp = \frac{\sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}}{2\sigma_0}, A_\parallel = \frac{\sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}}{2\sigma_0}$$

$$d_2^n = \int_0^1 dx \left(\frac{MQ^2}{4\alpha^2} \frac{x^2 y^2 \sigma_0}{(1-y)(2-y)} \right)$$

$$\left[\left(3 \frac{1 + (1-y) cos\theta}{(1-y)} + \frac{4}{y} tan \frac{\theta}{2} \right) A_\perp + \left(\frac{4}{y} - 3 \right) A_\parallel \right]$$

Compton

Compton Asymmetry is proportional to beam polarization

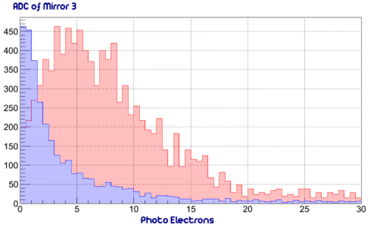


For more Compton fun see Diana Parno's talk Feb. 16th, 2:42pm room Maryland B.

Big Bite

5.9 GeV Čerenkov Performance

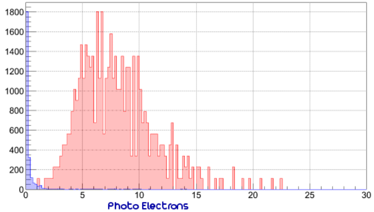
5.9 GeV He3 Production Run
~8uA



(Beam line side)

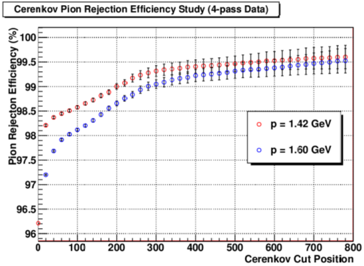
Rate ~1 MHz

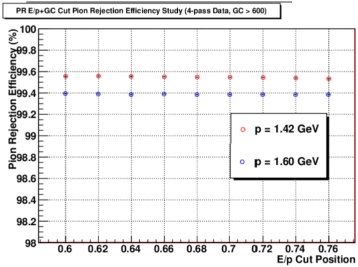
Rate ~0.1 MHz



(RHRS side)

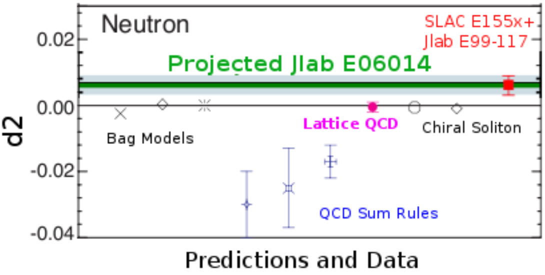
LHRS Pion Rejection At 4.7 GeV





- Select π in Pion Rejector and see how many π show up in $\check{C}erenkov$
- Plot E/p and compare to E/p with $\check{C}erenkov$ cut ($\sim 2.5pe$)

d_2^n World Data



- Provide benchmark test for Lattice QCD
- We can achieve statistical uncertainty of $\Delta d_2^n = 5 \times 10^{-4}$
- Four times better than existing world average

Future Work

- Continue Calibrations:
  - Update Analyzer Čerenkov class to use multi-hit TDCs
  - BB optics/beam calibration
  - BB Shower calibration
  - Target analysis
  - LHRS optics
- Simulation work:
  - Pion rejector
  - Pion background
  - Compton Photon Detector

I Would Like to Thank...

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- The Hall A Staff, The run coordinators and shift crew during the experiment

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$g2$ Structure Function

$$g_2(x, Q^2) = g_2^{WW}(x, Q^2) + \overline{g_2}(x, Q^2)$$

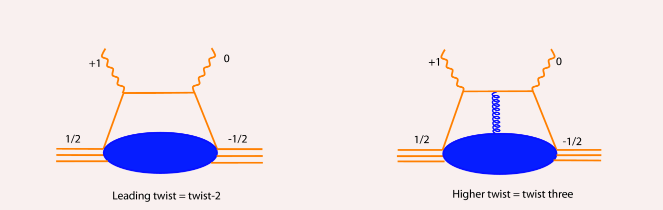
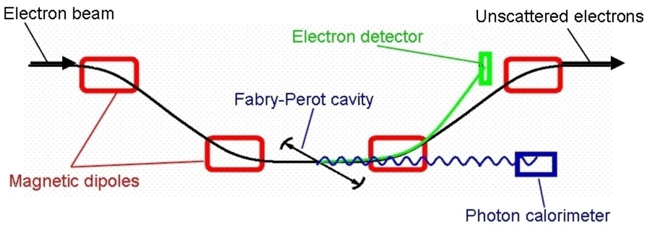


Figure: QCD allows helicity exchange through two principle means

- $g(x, Q^2)_2^{WW} = -g_1(x, Q^2) + \int_x^1 g_1(y, Q^2)\frac{dy}{y}$
- $\overline{g_2}(x, Q^2) = -\int_x^1 \frac{\partial}{\partial y}\left[\frac{m_q}{M} h_T(y, Q^2) + \xi(y, Q^2)\right]\frac{dy}{y}$

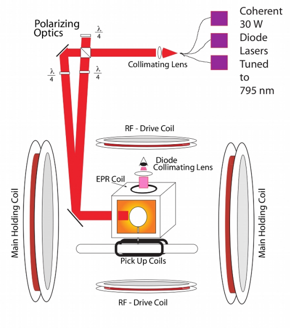
Compton Polarimeter (2)
Asymmetries and Cross Sections

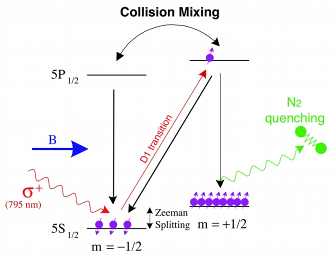


Drawing provided by D. Parno

- The final Compton asymmetry is the weighted average of the mean asymmetries for the two polarization states (L,R)

^{3}He Target





- ^{3}He is polarized through double spin exchange
  - Spin exchanged from Rb to K
  - Then K to ^{3}He