A Precision Measurement of the Neutron d_2: Probing the Lorentz Color Force

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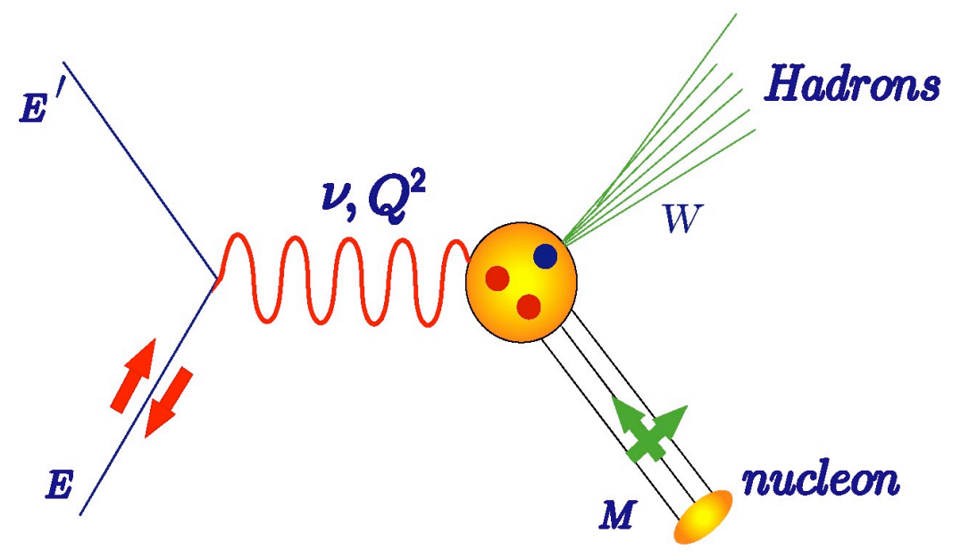
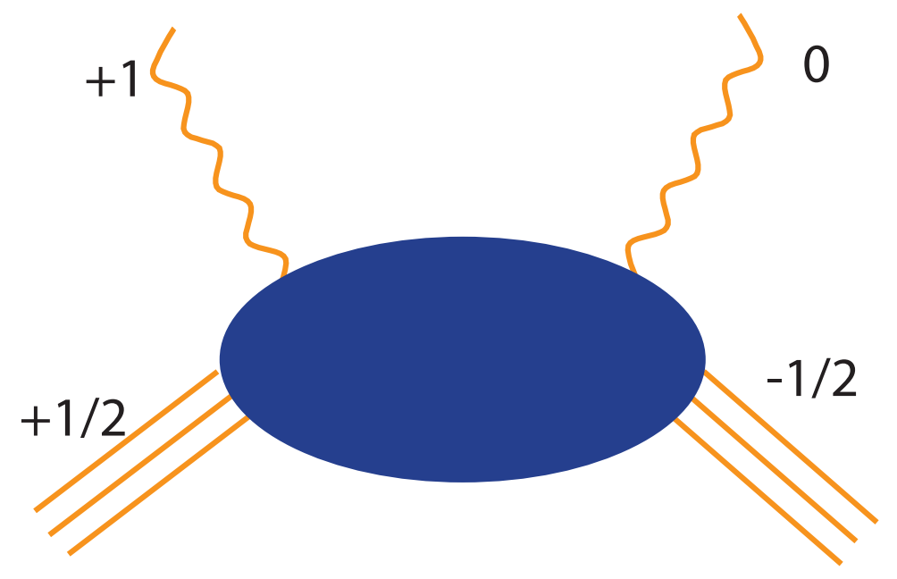
INTRODUCTION

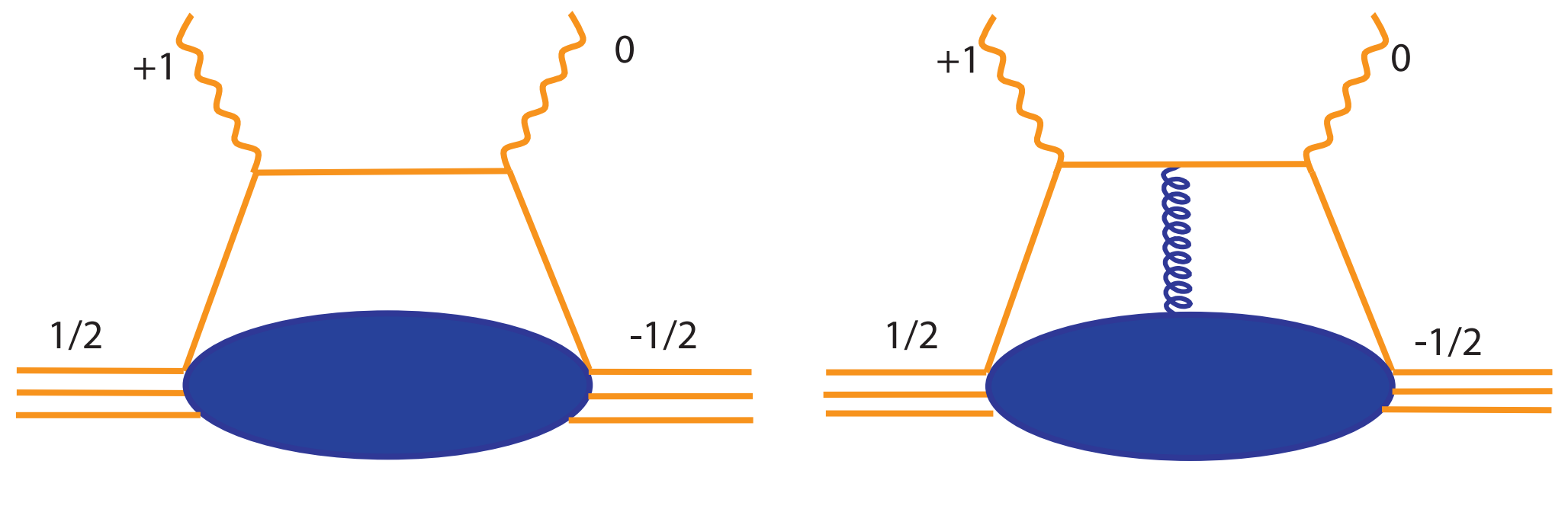
- Our experiment focuses on the spin structure of the neutron. To better understand this spin content, we probe the nucleon using a high energy longitudinally polarized electron beam focused on a polarized ^{3}He target, acting as an effective neutron target. The electrons will then interact with the 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:

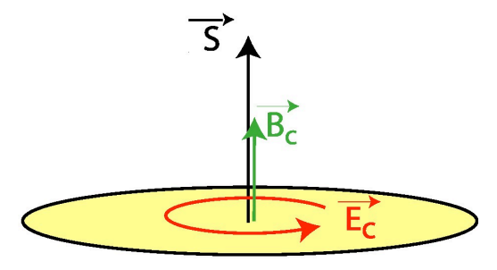
$$d_2^n = \int_0^1 x^2 \left[2g_1\left(x,Q^2\right) + 3g_2\left(x,Q^2\right)\right] dx = \int_0^1 \tilde{d}_2^n dx$$

INTERPRETATIONS OF d_2^n

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

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

- At low Q^2:
  - Analogy to a polarized atom in an external electric field
  - The virtual photon wavelength is larger than the nucleon size, the electromagnetic field of the virtual photons associated with g_2 in the interaction will appear as uniform over the nucleon volume. Subsequently, d_2^n is associated with *spin polarizabilities*[1]



- At high Q^2, the *interpretation* changes:
  - 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*[1,2]

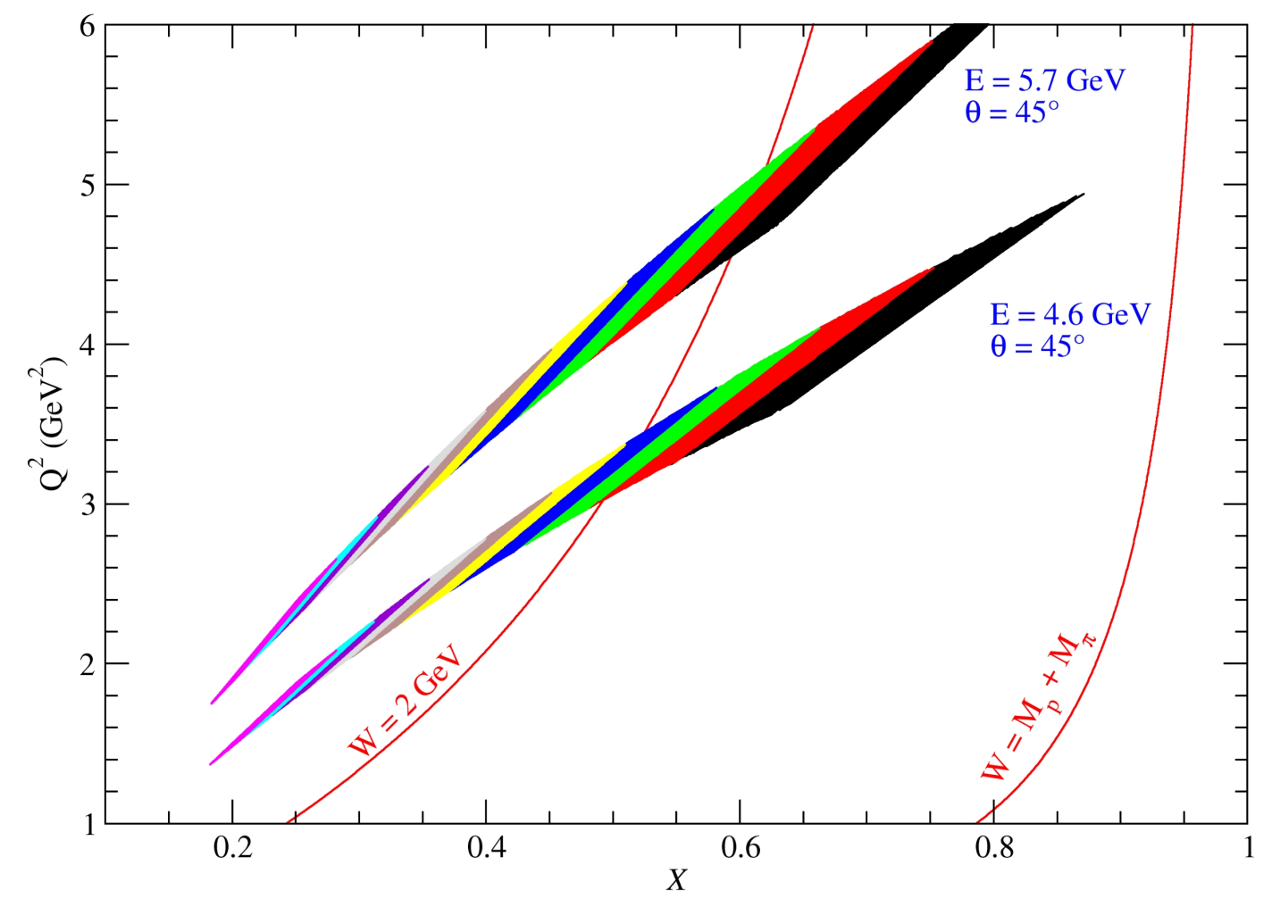
$$F^y(0) \equiv -\frac{\sqrt{2}}{2P^+}\langle P,S \mid \bar{\psi}_q(0)\, G^{+y}(0)\, \gamma^+ \psi_q(0) \mid P,S\rangle = -\frac{1}{2}M^2 d_2^n$$

THE MEASUREMENT OF d_2^n

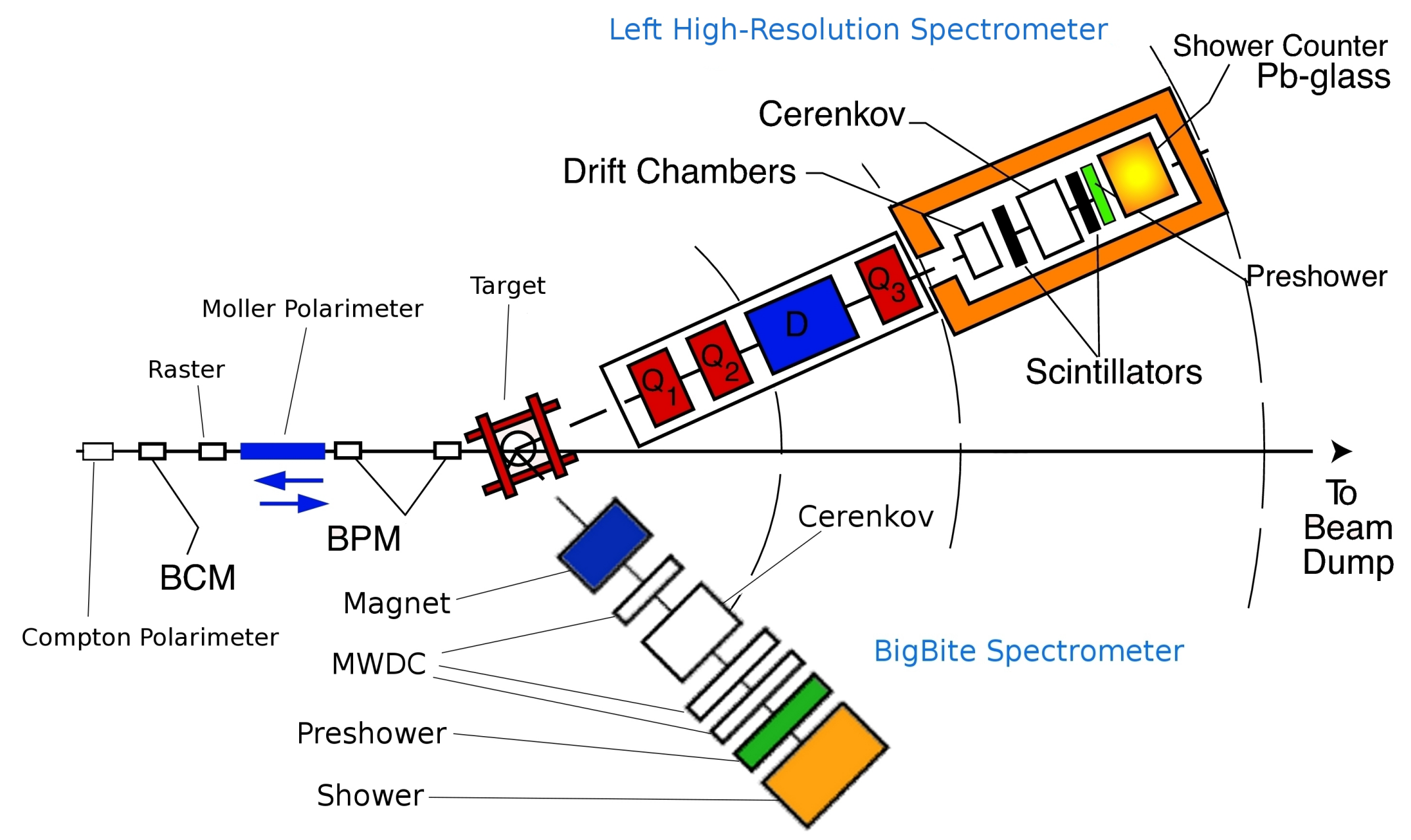
- In order to determine d_2^n experimentally, we measure the unpolarized cross section (σ_0) and the parallel $\left(A_\parallel\right)$ and perpendicular $(A_\perp)$ asymmetries. From these measurements, we determine the value of d_2^n through the relation[3]:

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

- Kinematic range covered during the experiment:

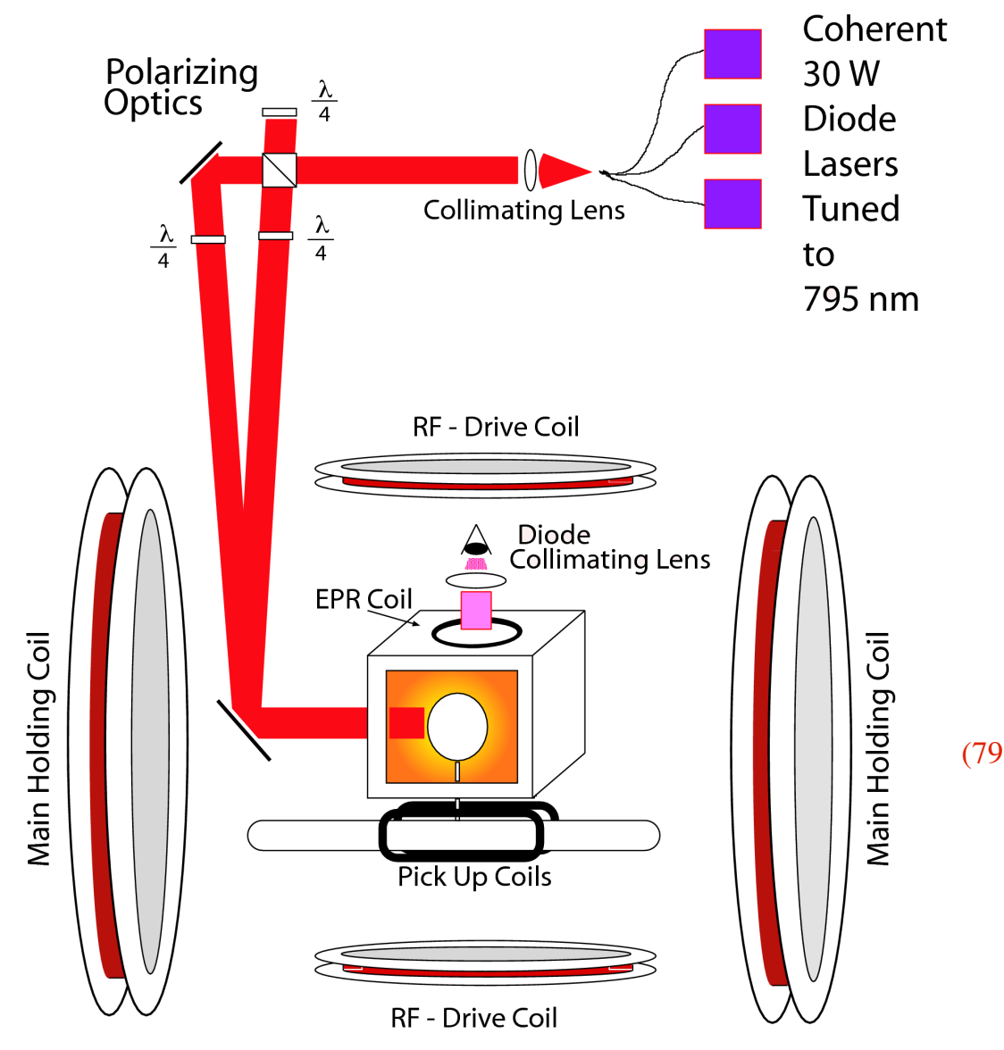


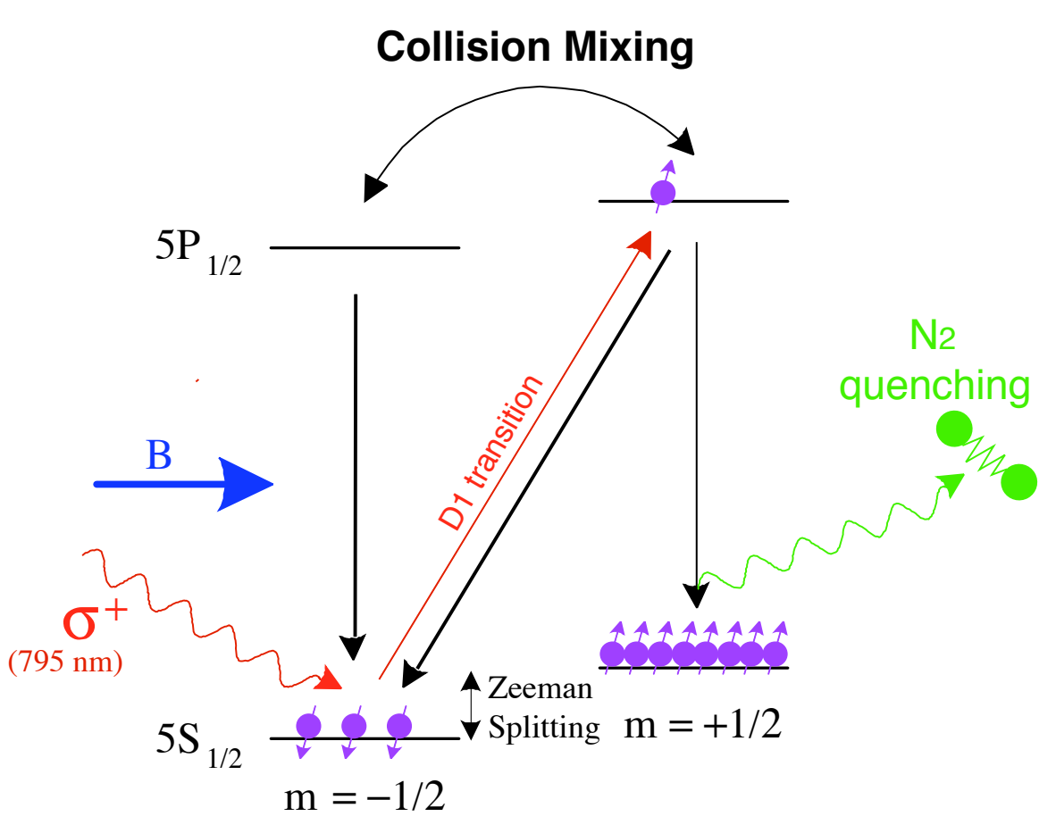
THE EXPERIMENTAL SETUP (TOP VIEW)



TARGET

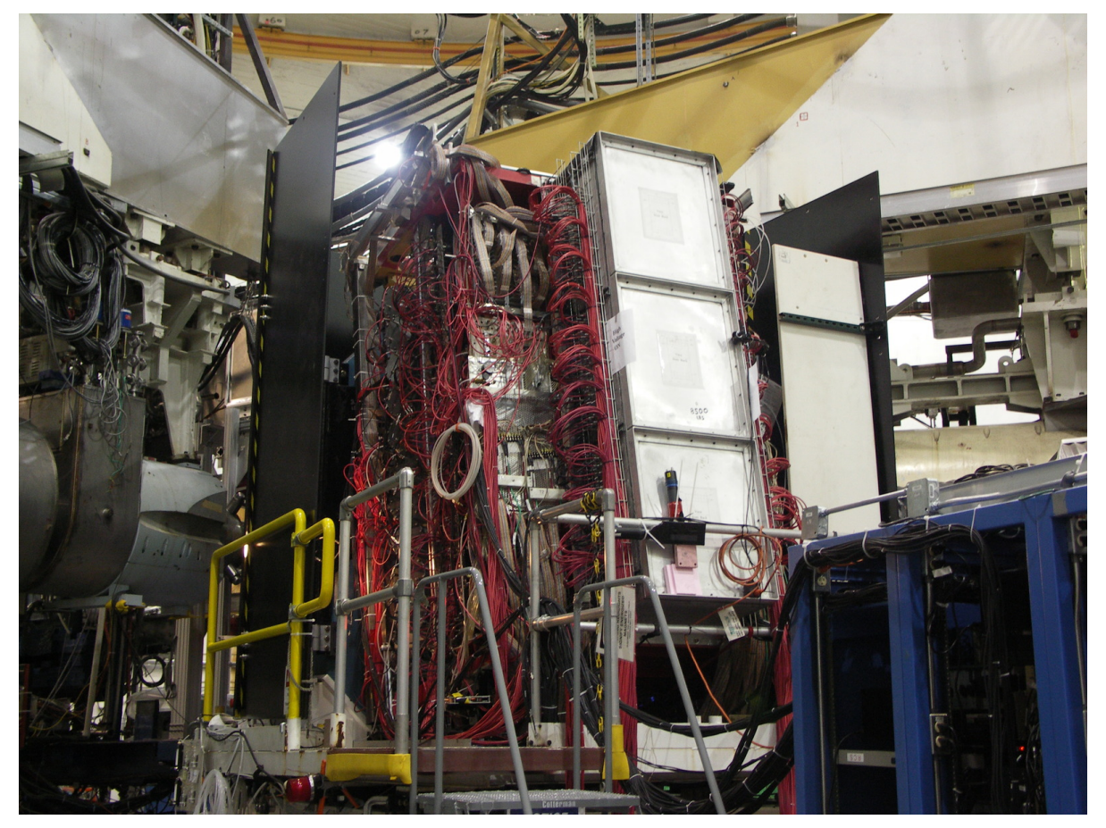
- ^{3}He serves as an effective neutron target since roughly 86% of the polarization is carried by the neutron. This is due to the two protons in the nucleus being primarily bound in a spin singlet state[4,5]
- The pumping chamber sits just above the target chamber filled with ^{3}He and small amounts of Rubidium and Potassium to assist in the polarization process
  - ^{3}He is polarized via *double spin exchange* from Rb to K, and then from K to ^{3}He

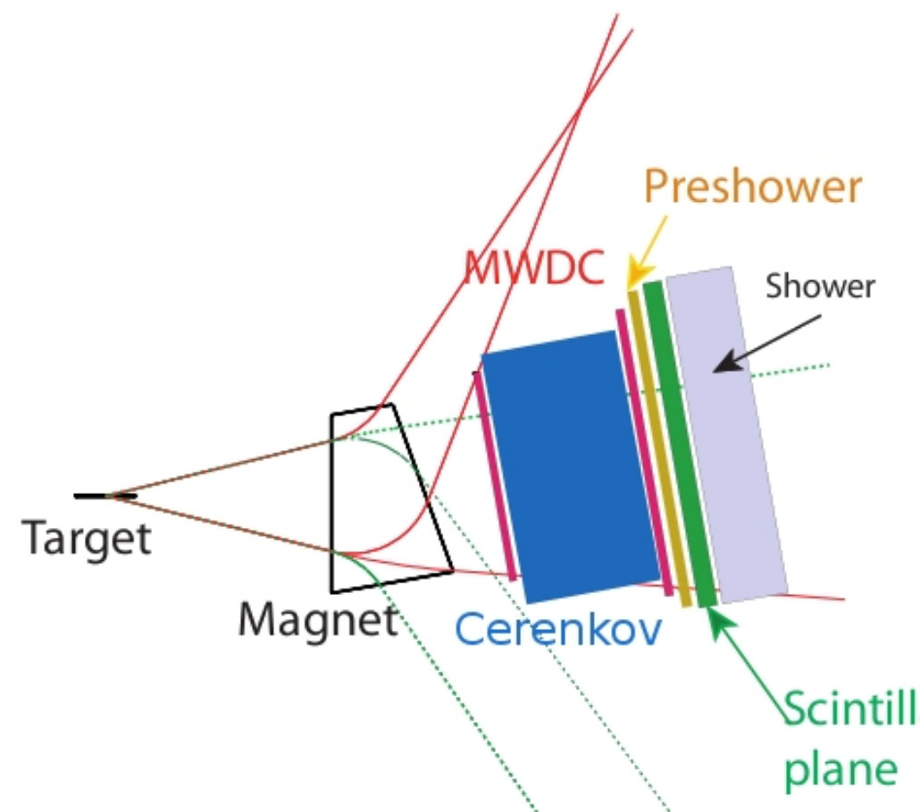




BIGBITE SPECTROMETER

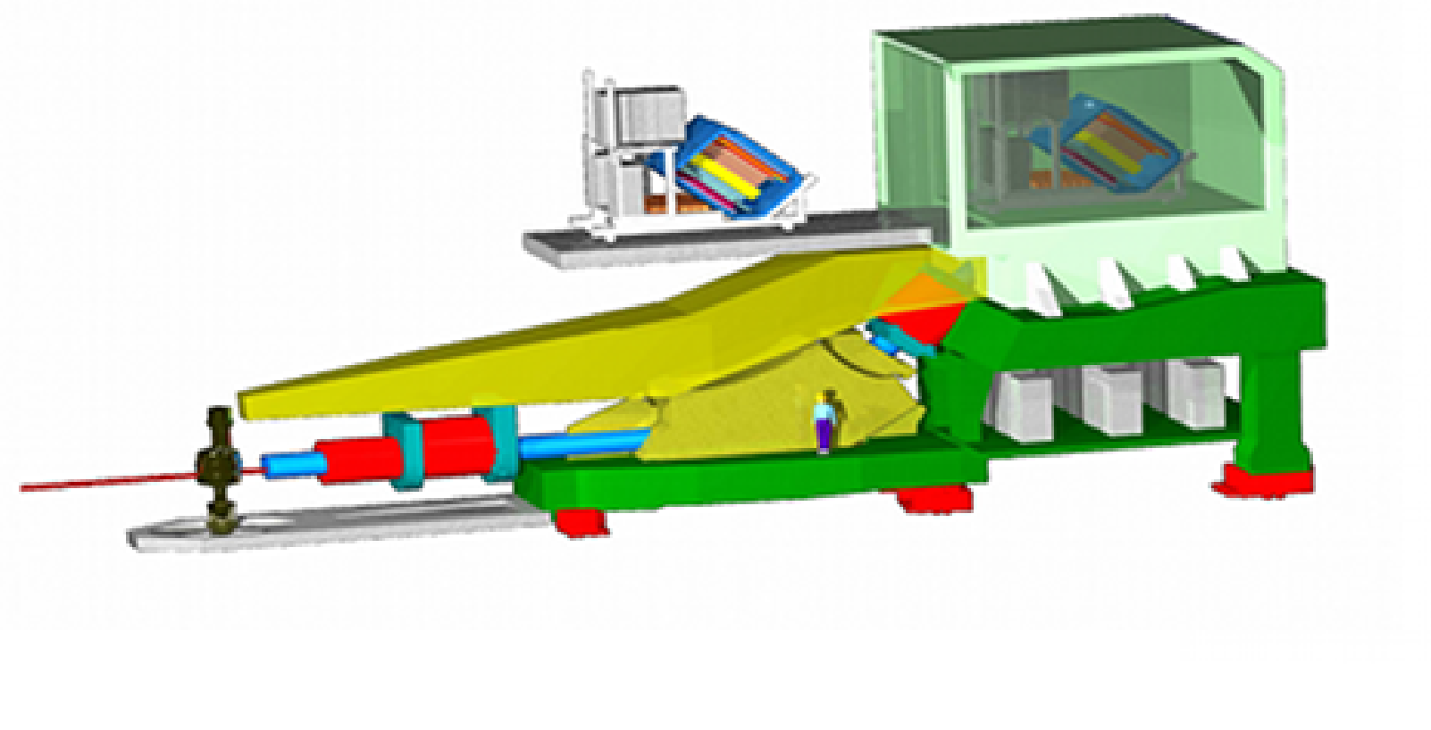
- Three sets of Multiwire Drift Chambers (MWDC) to track the particle trajectories
- A gas Čerenkov counter and a double layer lead glass calorimeter for pion rejection
- A set of scintillators for triggering on charged particles
- Measures parallel $\left(A_\parallel\right)$ and perpendicular $(A_\perp)$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

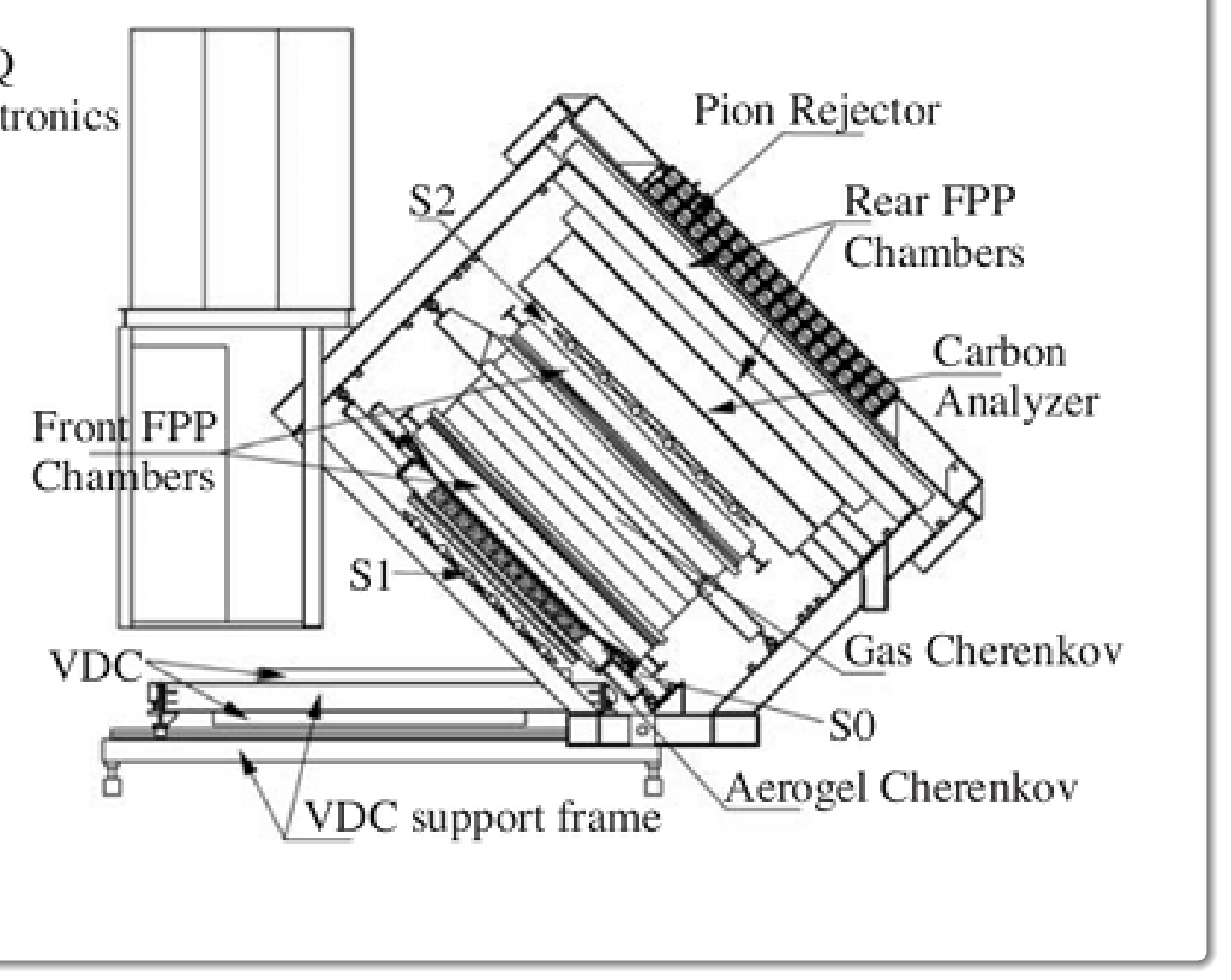




LEFT HIGH-RESOLUTION SPECTROMETER

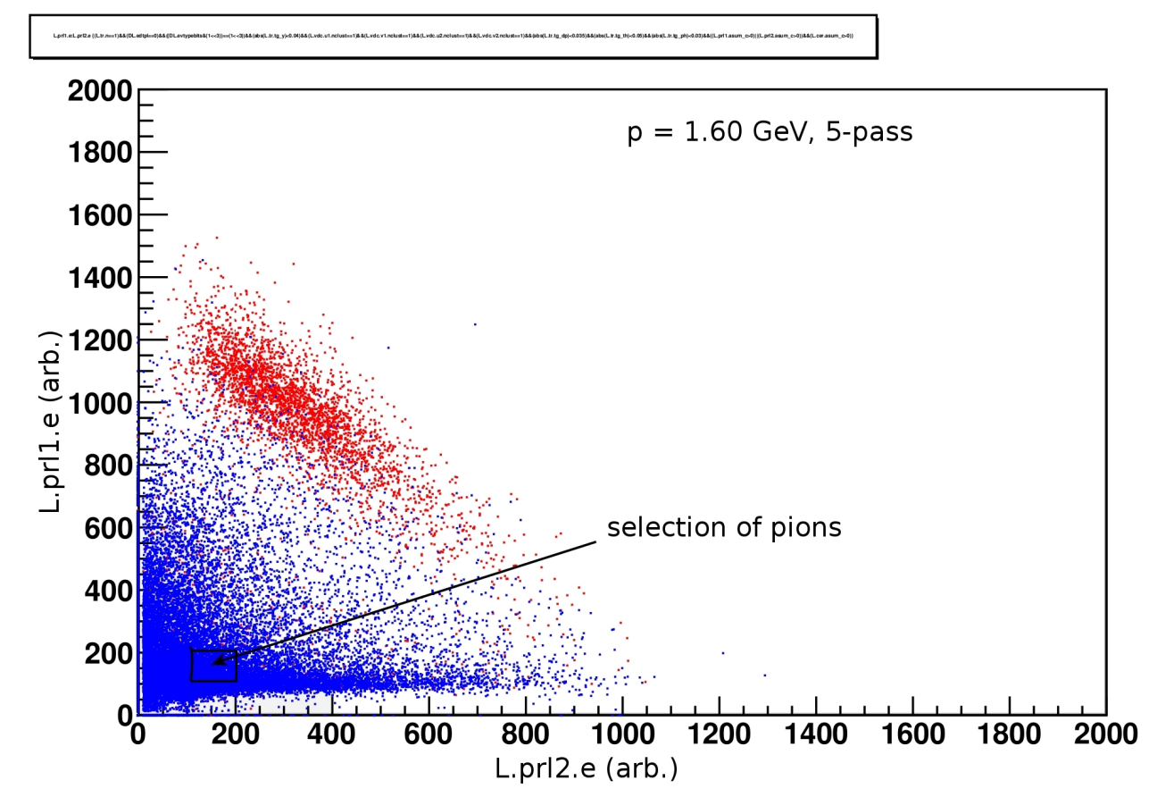
- Two Vertical Drift Chambers (VDC) for measurement of momentum and production (scattering) angle
- A gas Čerenkov counter and a double layer lead glass calorimeter for pion rejection
- A set of scintillators for triggering on charged particles
- Measures the absolute cross section (σ_0)

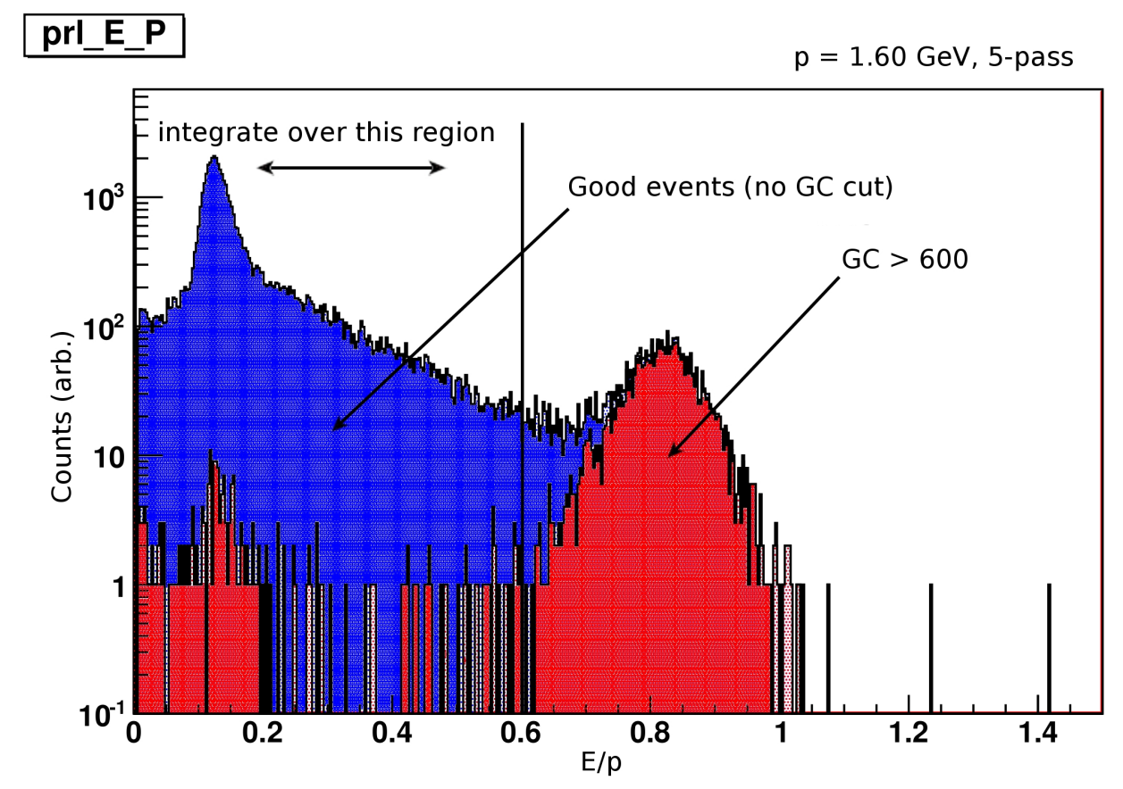


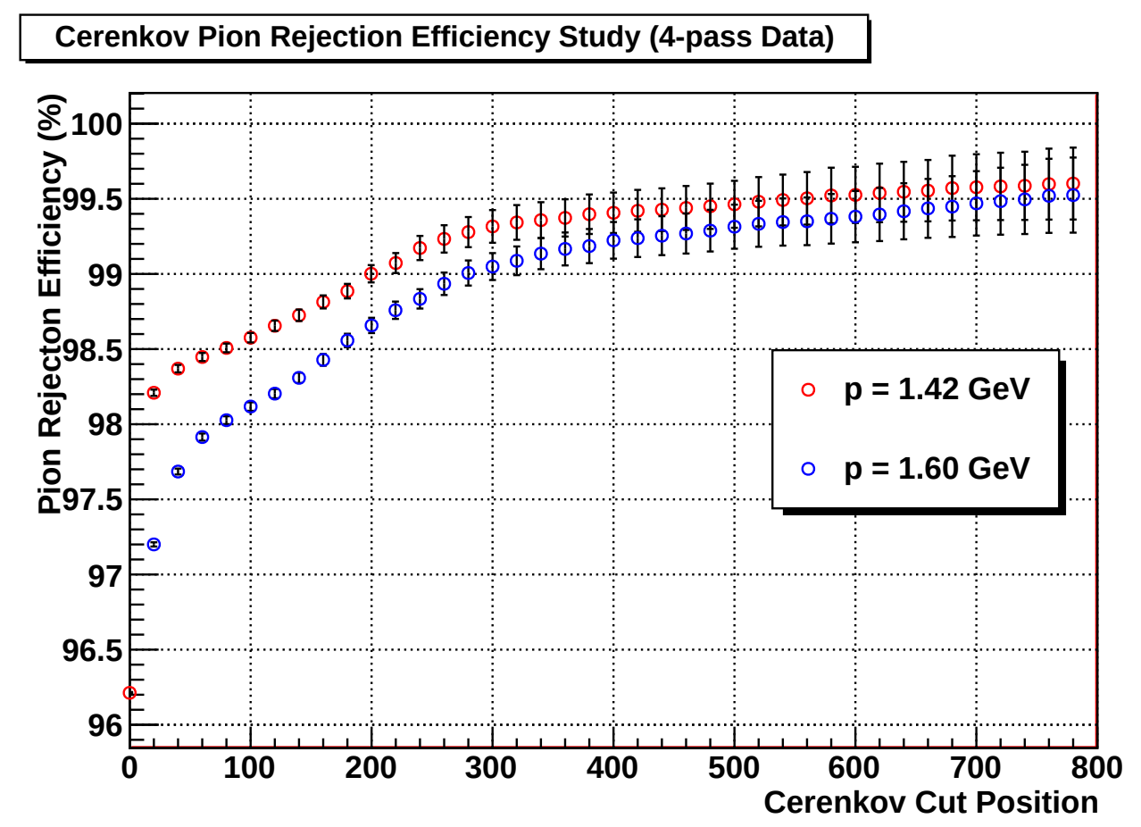


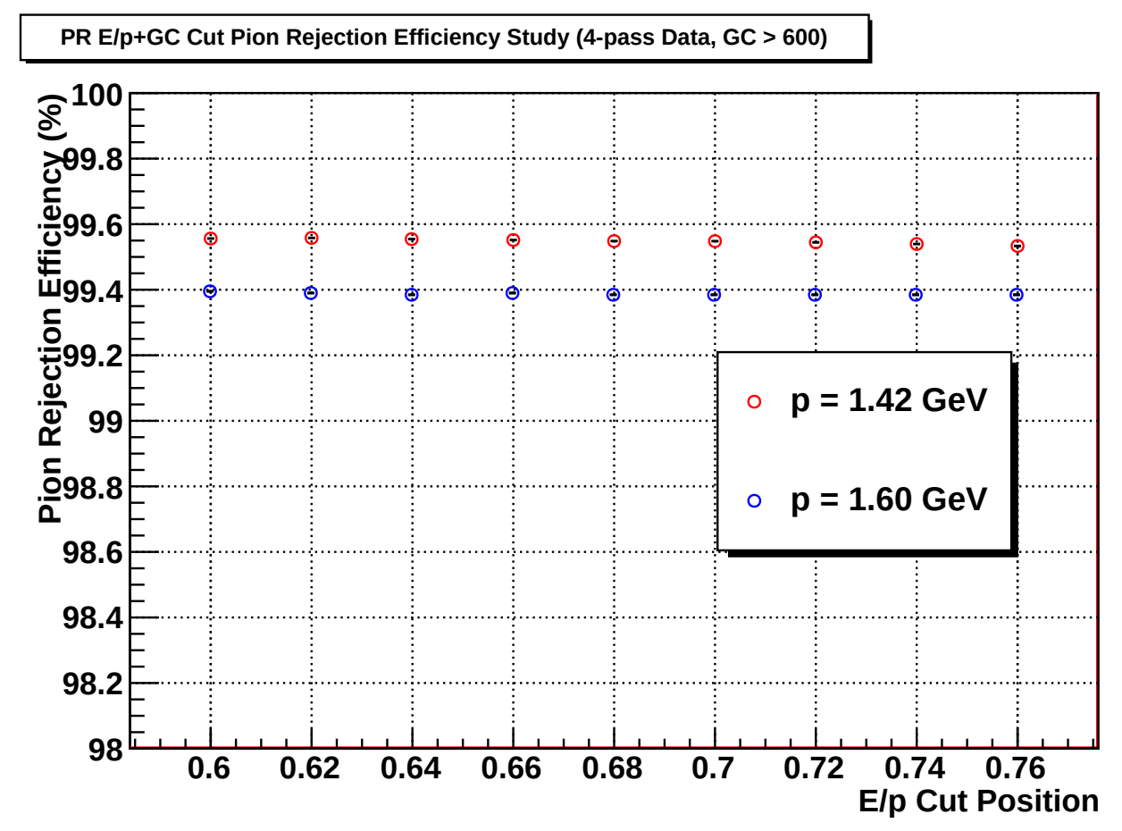
LHRS PRELIMINARY ANALYSIS

- π^- rejection in the gas Čerenkov and Pion Rejector
  - *pion rejection factor = the ratio of the number of pions rejected by the detector to that of the number of pions that are mis-identified as electrons*
- *Gas Čerenkov Study*: We select π^- in the Pion Rejector and see how many events show up in the gas Čerenkov ADC spectrum
- *Pion Rejector Study*: We plot the E/p distribution, and compare it to E/p subject to a cut on the gas Čerenkov ADC spectrum
- Sample calculations are shown below:

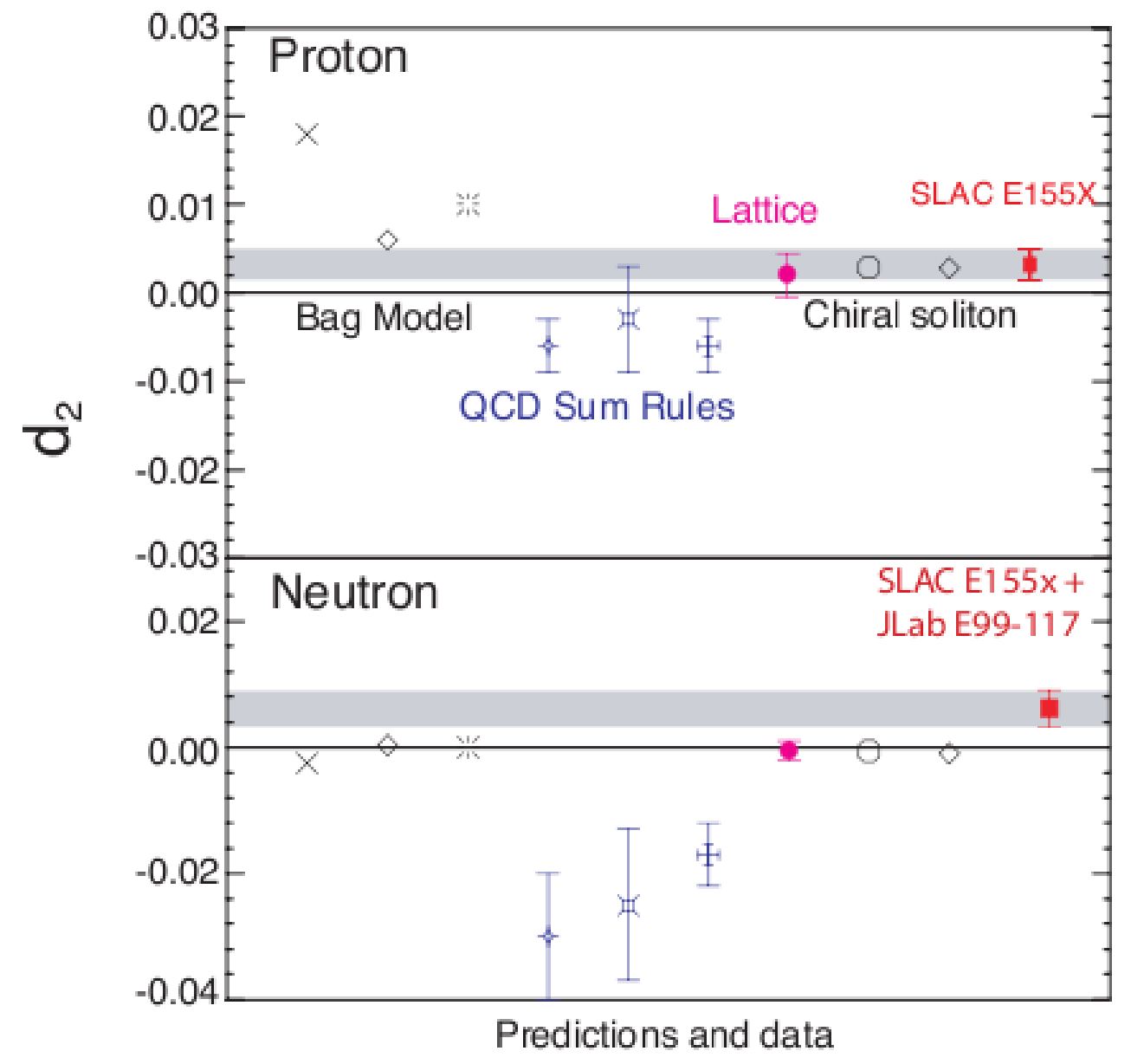




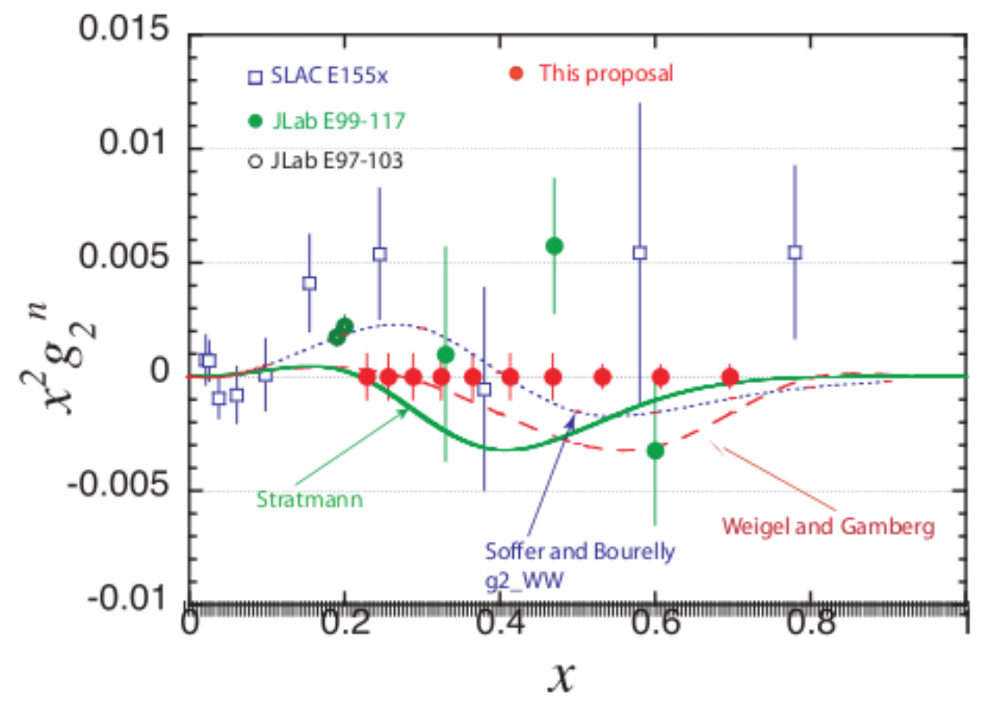




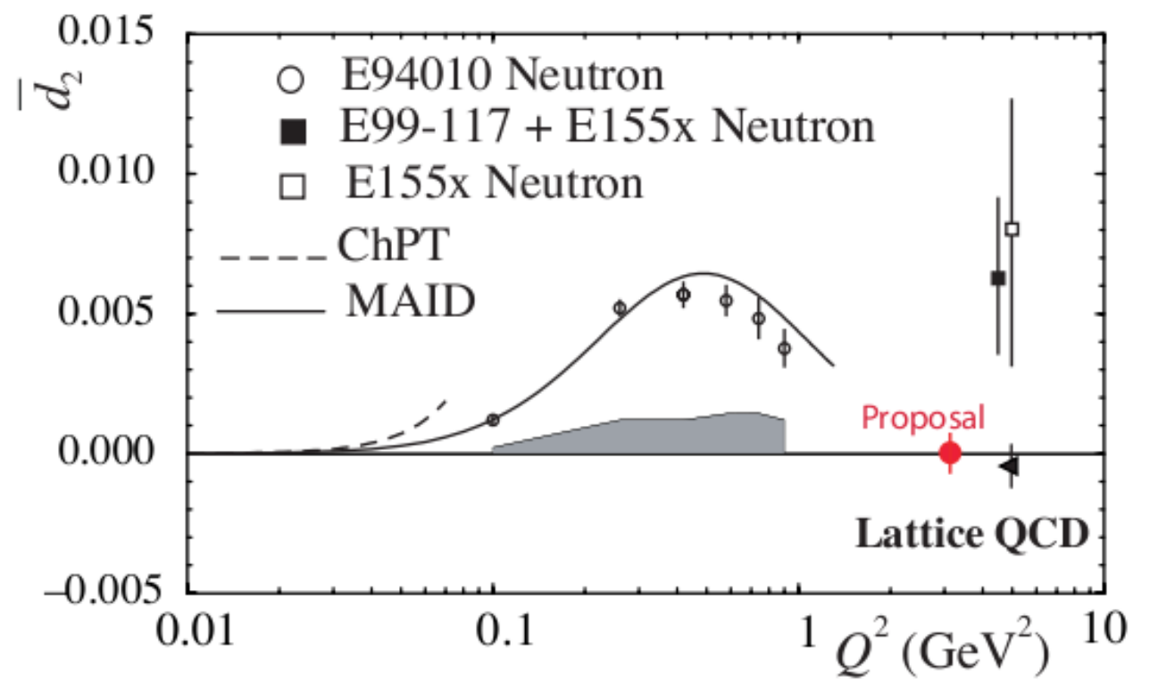
PROJECTED RESULTS



- Bag and soliton model calculations yield a value consistent with Lattice QCD. Current experimental values are approximately two standard deviations away from these predictions[3].



- 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.



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

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http://hallaweb.jlab.org/experiment/E06-014/

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