PhD Proposal

Measurement of Polarized Valence Quark Distribution Functions using Polarized Proton and Deuteron Targets

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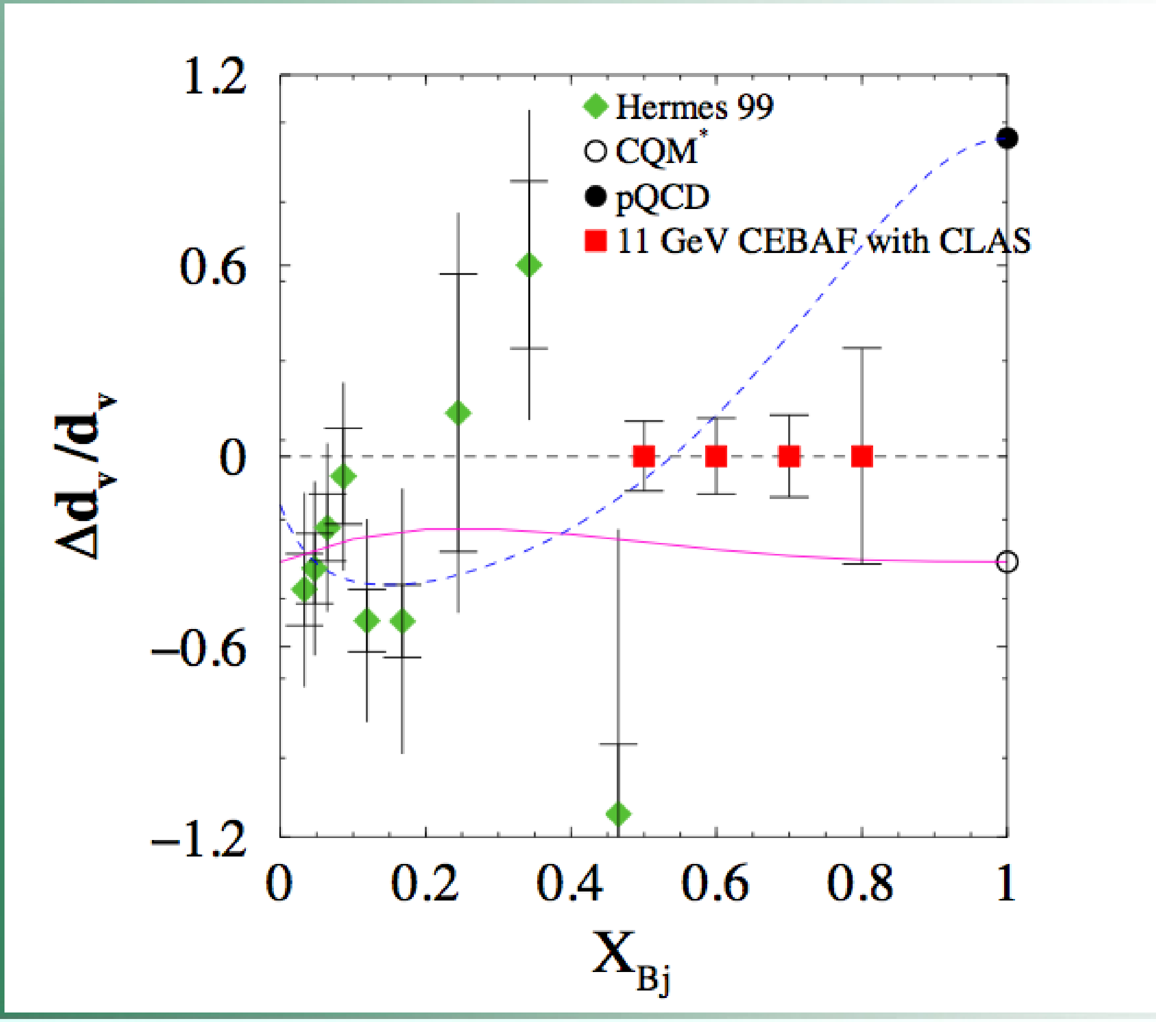
Outline

- Motivation
- Physics
- Experimental Setup
- Prelim Results
- Conclusions

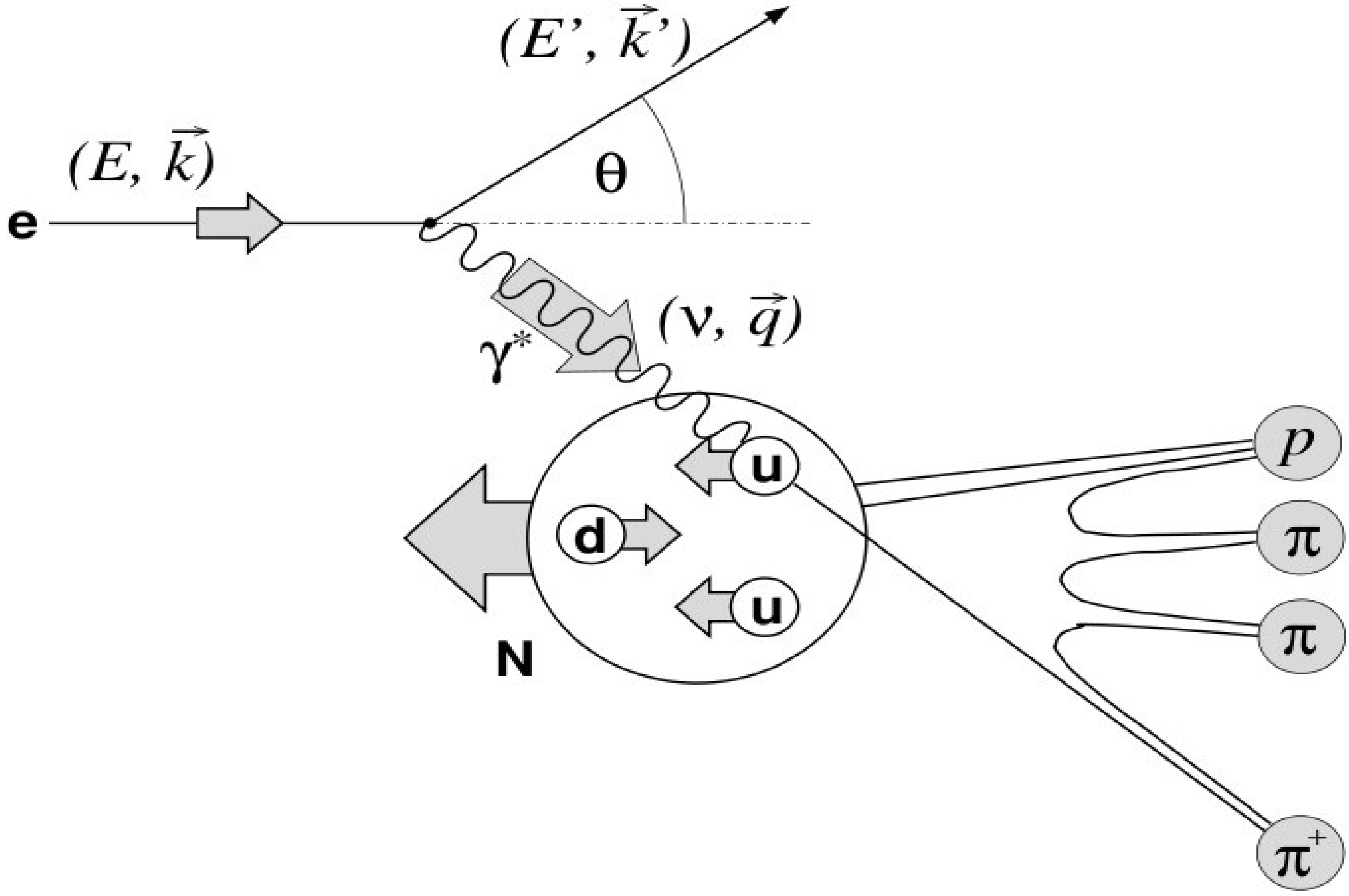
Motivation

- Semi-Inclusive Double Spin Asymmetry Measurement
- Extraction of (d/d) observable
- The perturbative Quantum Chromodynamics(pQCD) vs The hyperfine perturbed Constituent Quark Model(CQM)



Q^2 dependence on the depth of probe

Semi Inclusive Deep Inelastic Scattering(SIDIS) Diagram



Semi Inclusive Double Spin Asymmetry

$$A_1^h = \frac{\sigma_{1/2}^h - \sigma_{3/2}^h}{\sigma_{1/2}^h + \sigma_{3/2}^h}$$

$$\frac{d^3\sigma^h_{1/2(3/2)}}{dx\,dQ^2\,dz} \approx \Sigma_q e_q^2 q^{+(-)}(x,Q^2) D_q^h(z,Q^2)$$

Semi Inclusive deep inelastic scattering provides and opportunity to determine the struck quark flavor.

Polarized and Unpolarized Structure Functions

$$A(x,Q^2) = \frac{g_1(x)}{F_1(x)}$$

Asymmetry

Unpolarized structure function

$$F_1(x) = M_h W_1 = \frac{1}{2}\Sigma_q e_q^2 q(x)$$

Polarized structure function

$$g_1(x) = \frac{1}{2}\Sigma_q e_q^2 (q^+(x) - q^-(x)) = \frac{1}{2}\Sigma_q e_q^2 \Delta q(x)$$

Fragmentation Independence

$$A_{1,p}^{\pi^+\pm\pi^-} = \frac{\Delta\sigma_p^{\pi^+\pm\pi^-}}{\sigma_p^{\pi^+\pm\pi^-}} = \frac{[(\sigma_p{}^{\pi^+})_{1/2} - (\sigma_p{}^{\pi^+})_{3/2}] \pm [(\sigma_p{}^{\pi^-})_{1/2} - (\sigma_p{}^{\pi^-})_{3/2}]}{[(\sigma_p{}^{\pi^+})_{1/2} + (\sigma_p{}^{\pi^+})_{3/2}] \pm [(\sigma_p{}^{\pi^-})_{1/2} + (\sigma_p{}^{\pi^-})_{3/2}]}$$

$$A_{1,2H}^{\pi^+\pm\pi^-} = \frac{\Delta\sigma_{2H}^{\pi^+\pm\pi^-}}{\sigma_{2H}^{\pi^+\pm\pi^-}} = \frac{[(\sigma_{2H}{}^{\pi^+})_{1/2} - (\sigma_{2H}{}^{\pi^+})_{3/2}] \pm [(\sigma_{2H}{}^{\pi^-})_{1/2} - (\sigma_{2H}{}^{\pi^-})_{3/2}]}{[(\sigma_{2H}{}^{\pi^+})_{1/2} + (\sigma_{2H}{}^{\pi^+})_{3/2}] \pm [(\sigma_{2H}{}^{\pi^-})_{1/2} + (\sigma_{2H}{}^{\pi^-})_{3/2}]}$$

$$D_u^{\pi^+\pm\pi^-} = D_u^{\pi^+} \pm D_u^{\pi^-} = D_d^{\pi^+\pm\pi^-}$$

$$\sigma_p^{\pi^+\pm\pi^-} = \frac{1}{9}[4(u+\bar{u}) \pm (d+\bar{d})]D_u^{\pi^+\pm\pi^-}$$

$$\sigma_n^{\pi^+\pm\pi^-} = \frac{1}{9}[4(d+\bar{d}) \pm (u+\bar{u})]D_u^{\pi^+\pm\pi^-}$$

Asymmetry and Quark distribution functions

$$A_{1,p}^{\pi^+\pm\pi^-} = \frac{4\Delta u_v(x) \pm \Delta d_v(x)}{4u_v(x) \pm d_v(x)}$$

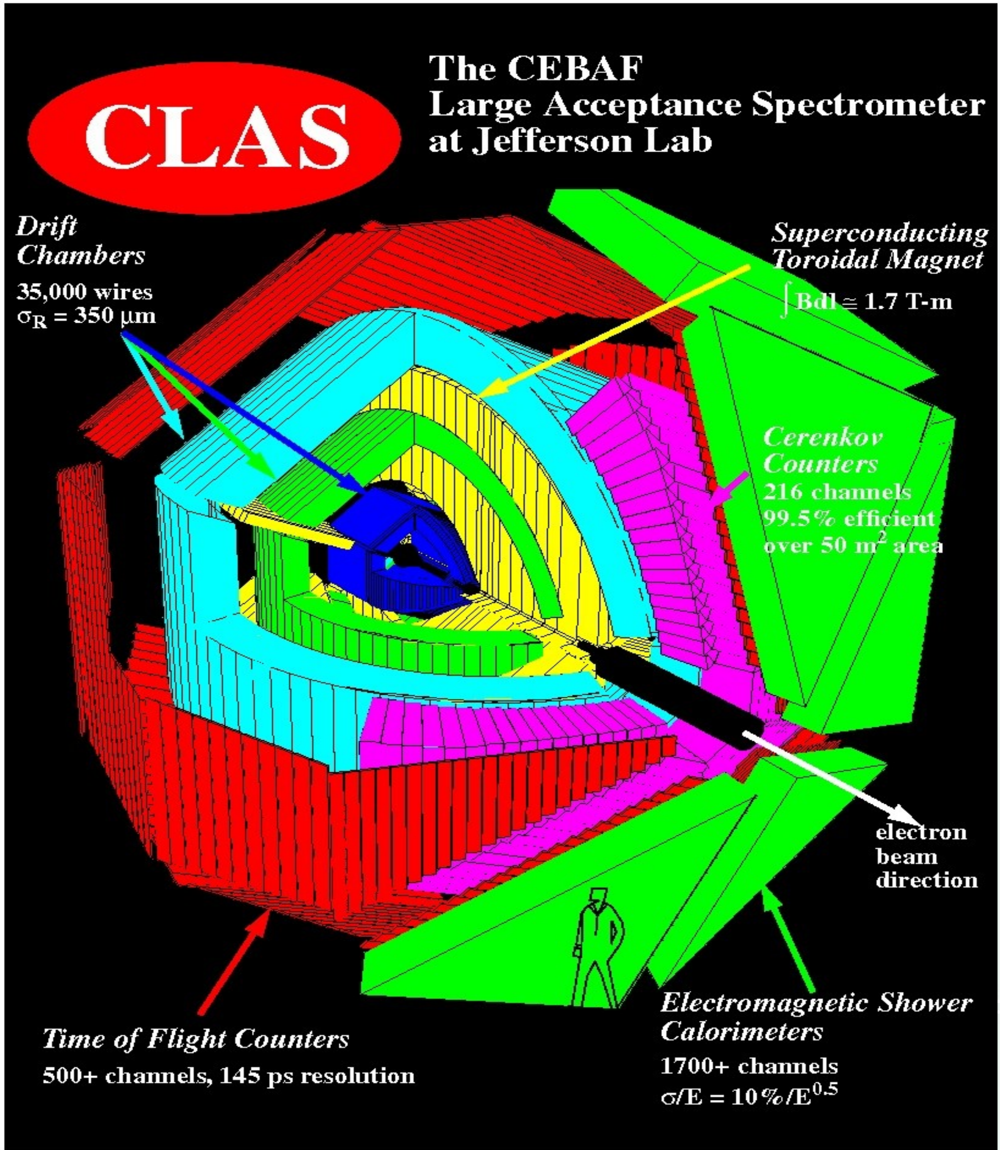
$$A_{1,2H}^{\pi^+\pm\pi^-} = \frac{\Delta u_v(x) + \Delta d_v(x)}{u_v(x) + d_v(x)}$$

$$\frac{\Delta u_v}{u_v}(x,Q^2) = \frac{\Delta\sigma_p^{\pi^+\pm\pi^-} + \Delta\sigma_{2H}^{\pi^+\pm\pi^-}}{\sigma_p^{\pi^+\pm\pi^-} + \sigma_{2H}^{\pi^+\pm\pi^-}}(x,Q^2)$$

$$\frac{\Delta d_v}{d_v}(x,Q^2) = \frac{\Delta\sigma_p^{\pi^+\pm\pi^-} - 4\Delta\sigma_{2H}^{\pi^+\pm\pi^-}}{\sigma_p^{\pi^+\pm\pi^-} - 4\sigma_{2H}^{\pi^+\pm\pi^-}}(x,Q^2)$$

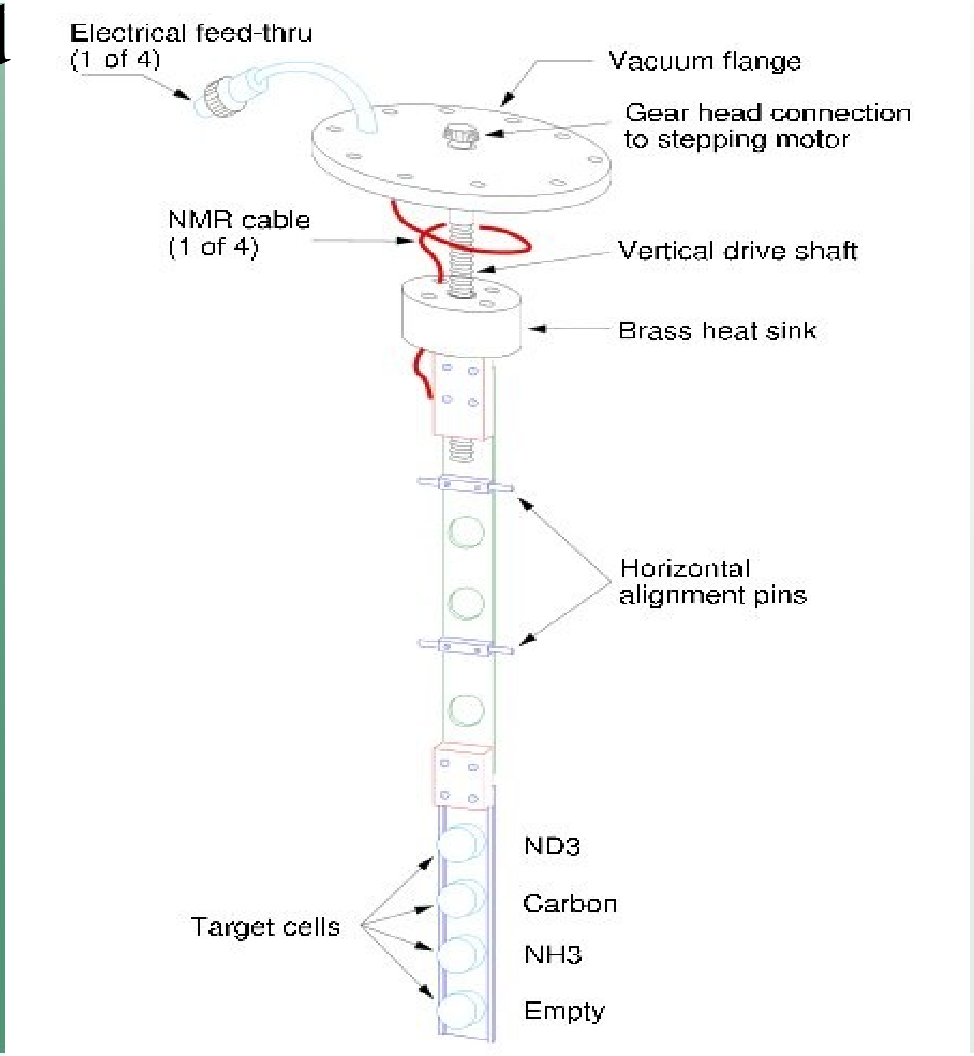
The CEBAF Large Acceptance Spectrometer at JLab

- Polarized electron beam
- Polarized targets
- Superconducting toroid magnet
- Drift chambers
- Cherenkov counter
- Electromagnetic calorimeter



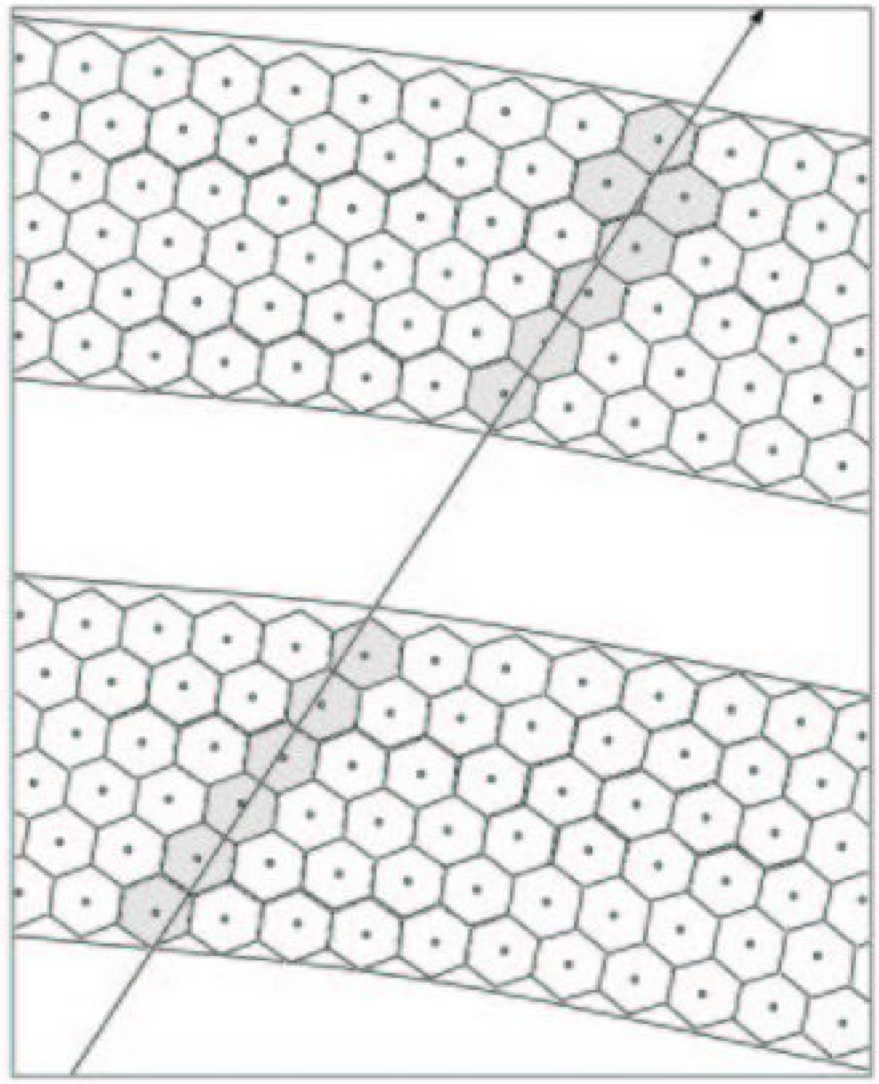
Target Materials

- Frozen ammonia: the polarized proton and neutron
- For background elimination: C12, liquid Helium and Nitrogen
- Polarized using the Dynamic Nuclear Polarization(DNP) Method
- ~96% and ~46% polarization for the proton and neutron targets



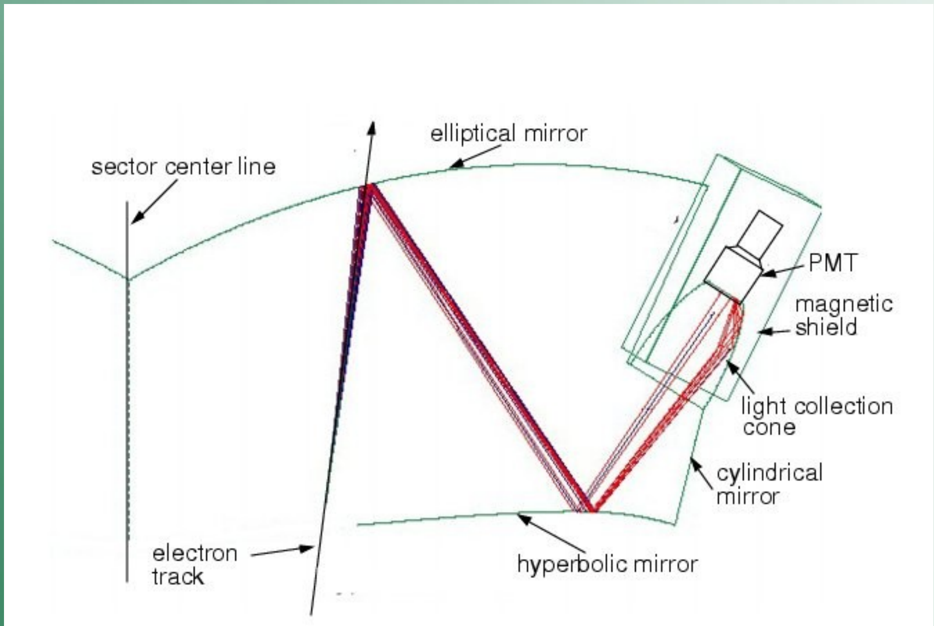
Drift Chambers

- The trajectory of the charged particle
- Three regions
- $ArCO_2$ (90/10%) - gas mixture
- The drift time and drift velocity



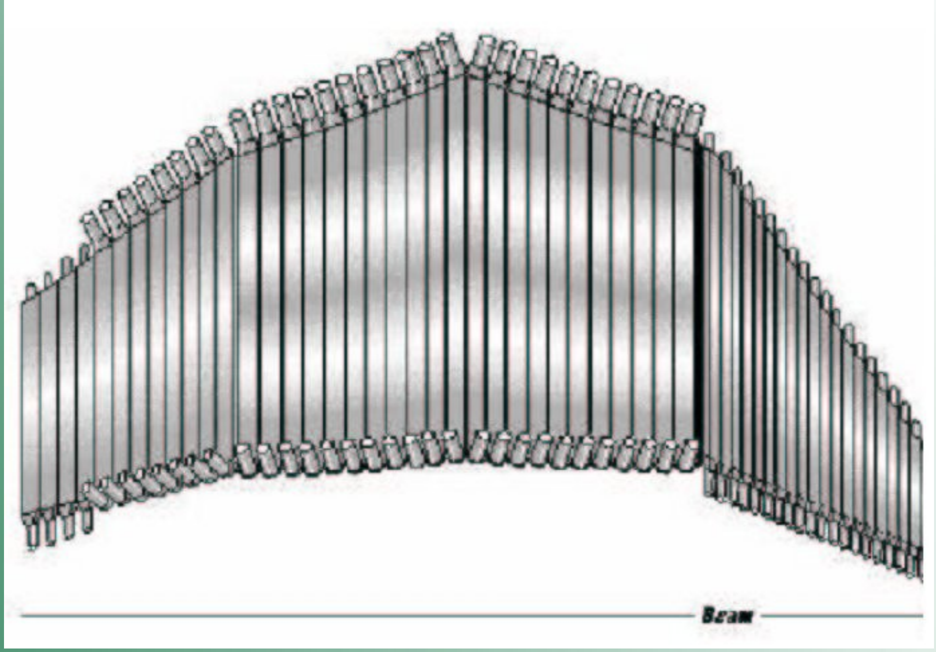
Cherenkov Detector

- The threshold detector
- Differentiate electrons from pions
- Gas – C_4F_{10} (n=1.00153, high photon yield)
- Thresholds: 9 MeV



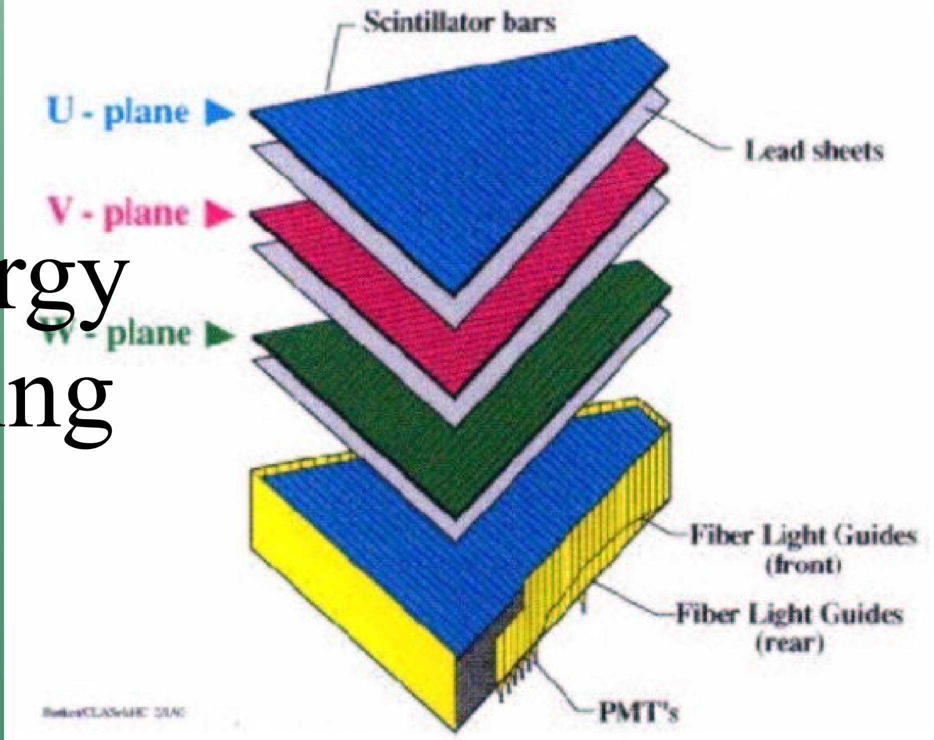
CLAS Scintillators

- 288 scintillators
- The time of flight for charged particle
- Coincidence for particle
- 120ps – 250ps time resolution
- The length from 30



Calorimeter

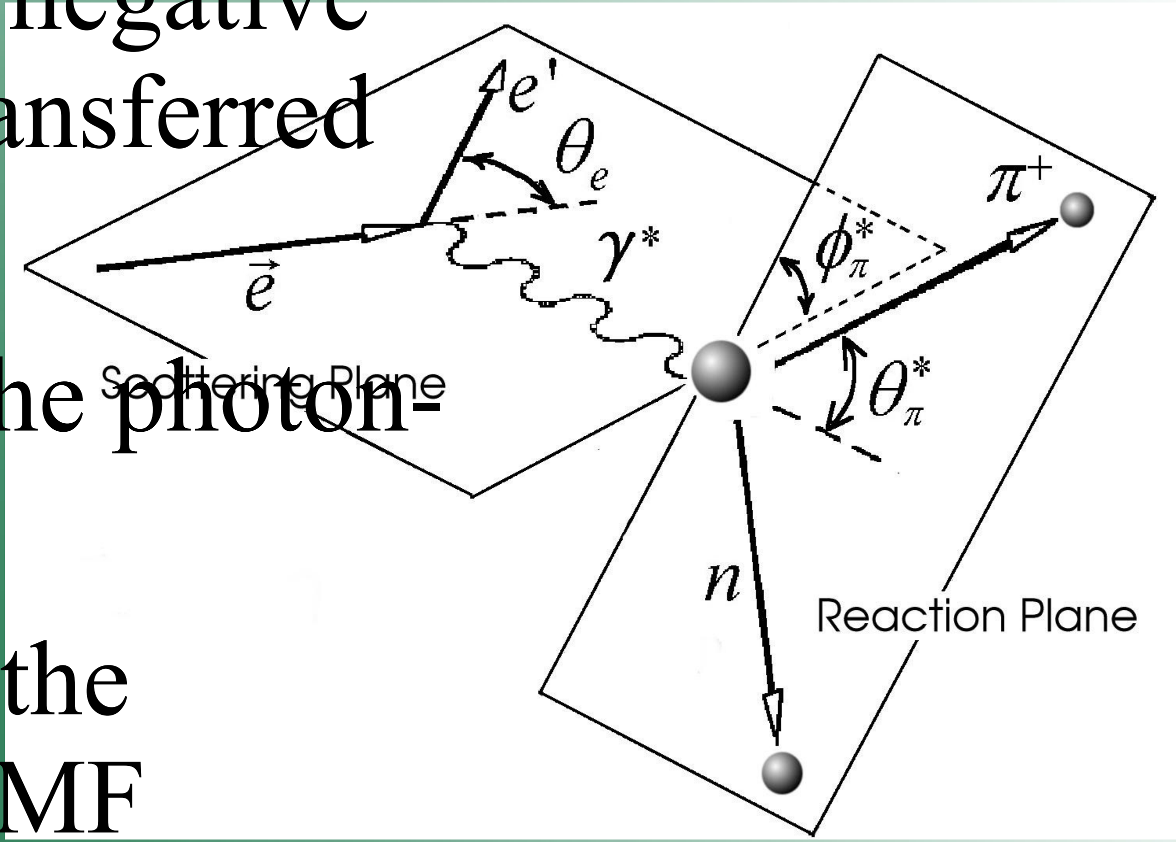
- 8 electromagnetic calorimeter modules
- Measures the total energy deposited by the crossing particle
- Neutron detection
- Electron detection above 0.5 GeV



Preliminary Results

Kinematics of single pion electroproduction

- The virtual photon negative four-momentum transferred squared
- Invariant mass of the photon-nucleon system
- The polar angle of the outgoing pion in CMF
- The azimuthal angle of the outgoing pion in CMF



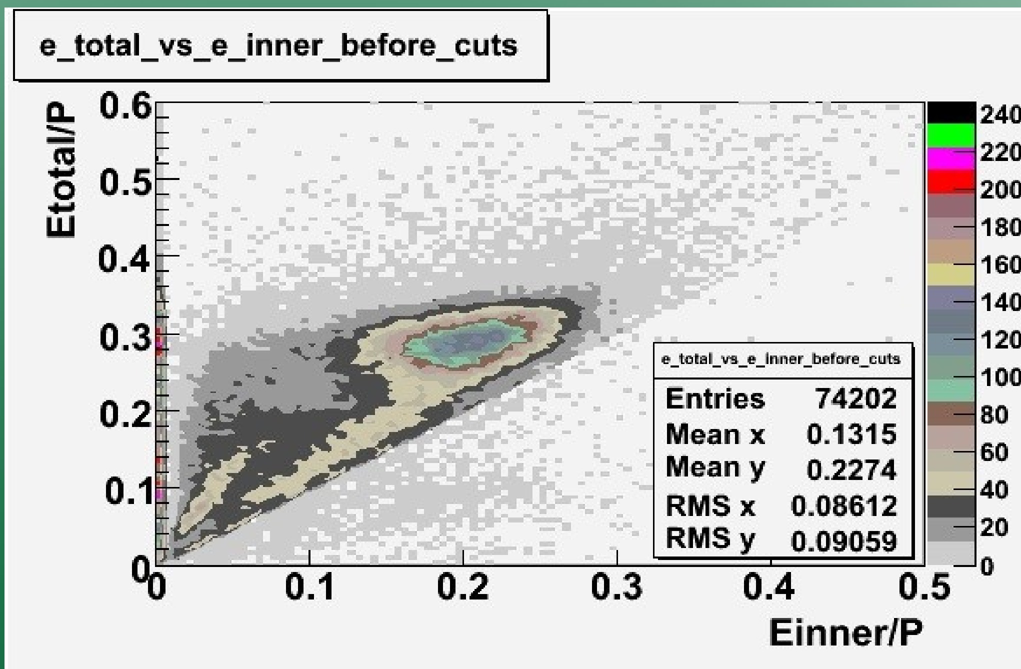
The Five-Fold Differential Cross Section

$$\frac{\partial^5\sigma}{\partial E_f \partial\Omega_e \partial\Omega_\pi{}^*} = \frac{1}{2\pi}\Sigma\frac{1}{L_{int} A_{cc} \epsilon_{CC} \Delta W \, \Delta Q^2 \Delta cos\theta_\pi{}^* \Delta\phi_\pi{}^*} \frac{d(W,Q^2)}{d(E_f, cos\theta_e)}$$

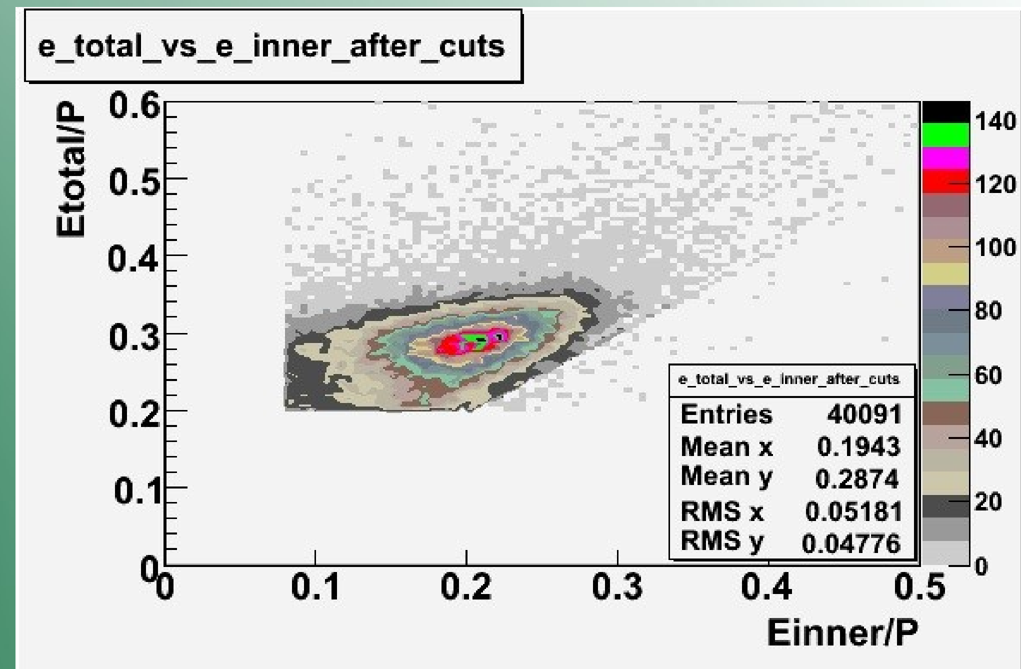
$$\frac{d(W,Q^2)}{d(E_f, cos\theta_e)} = \frac{2M_p E_i E_f}{W}$$

Particle Identification Using Electromagnetic calorimeter

Before EC Cuts

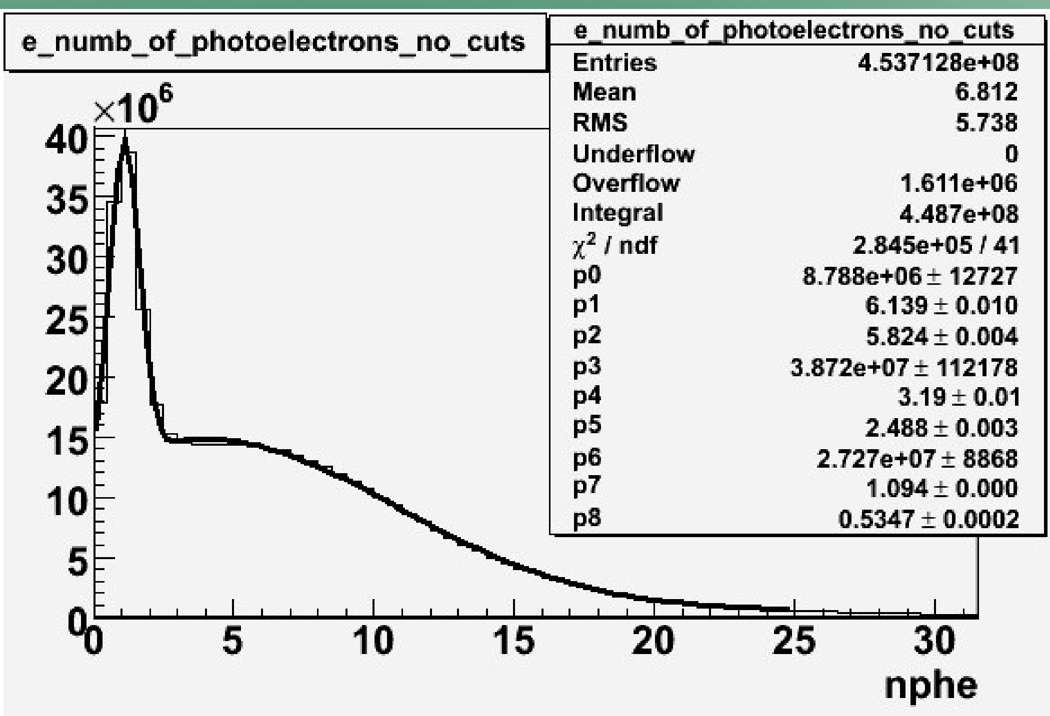


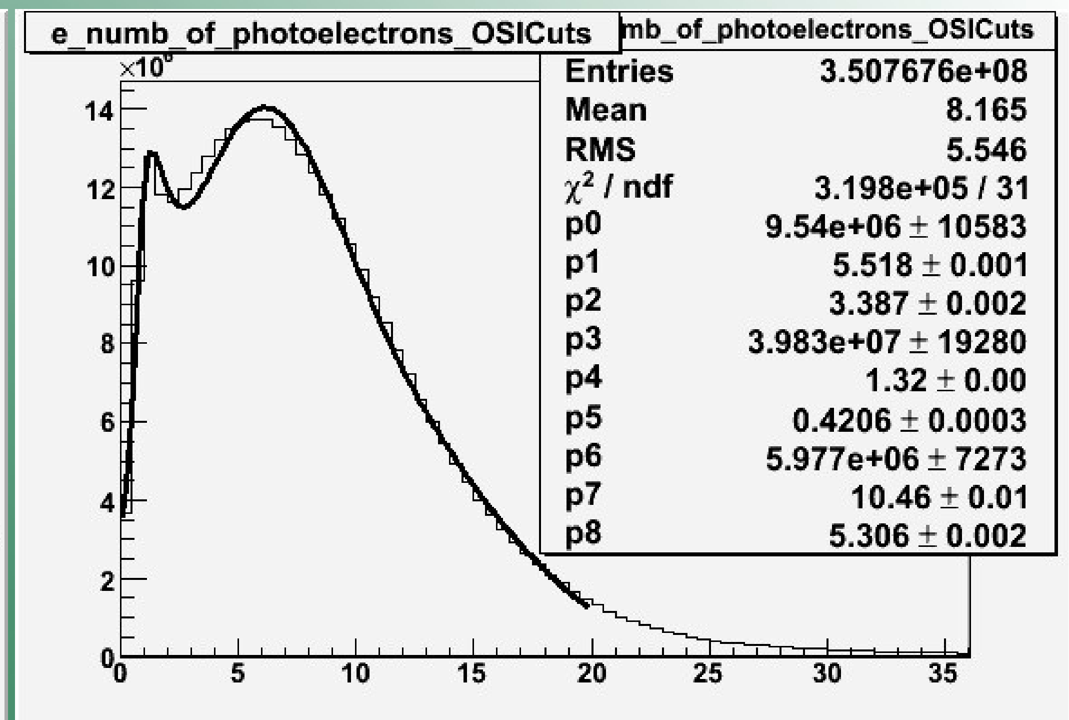
After EC Cuts



Cuts on the energy deposited in the electromagnetic calorimeter ($EC_{total}>0.2*p$ and $Ec_{inner}>0.06*p$)

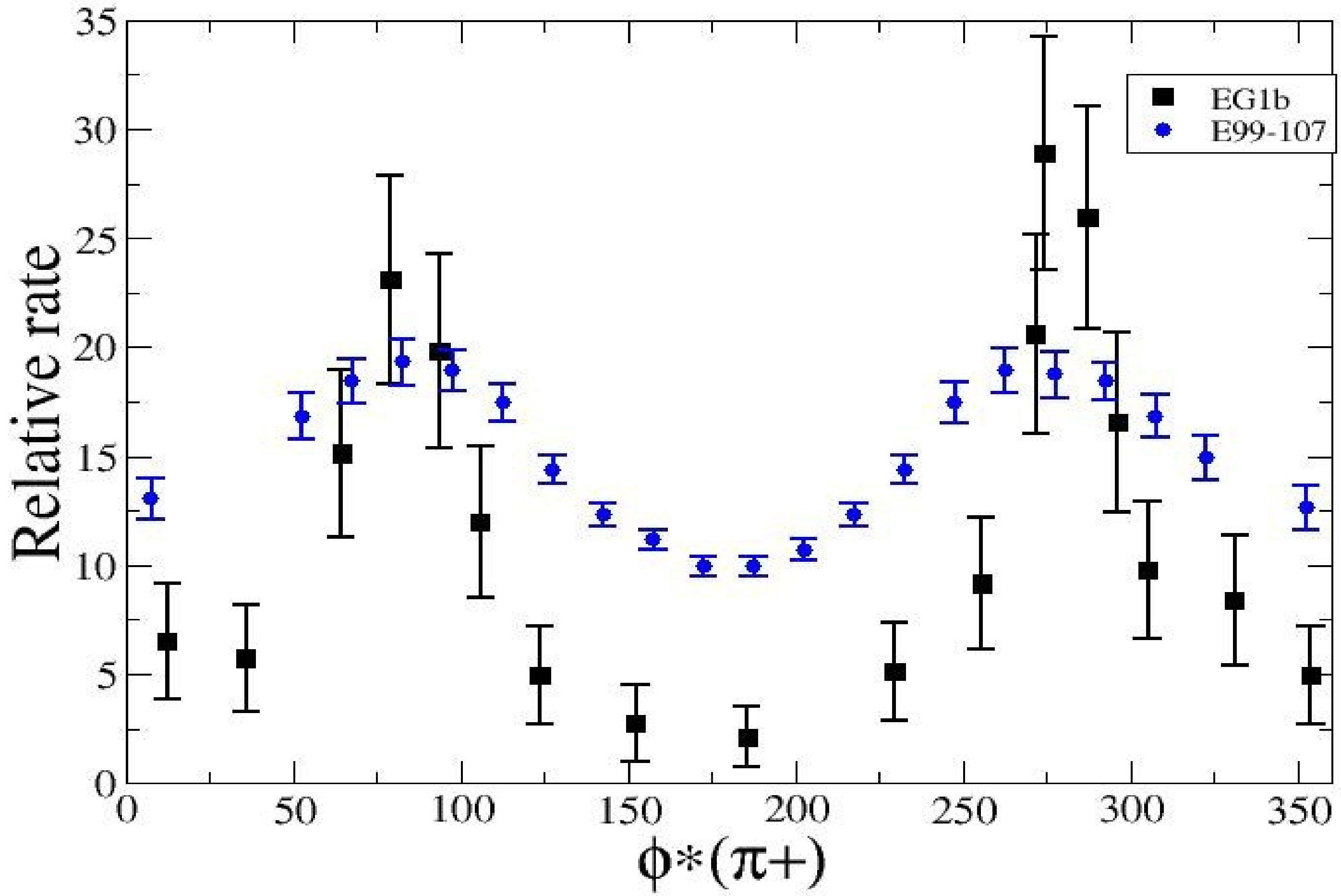
Pion Removal From The Electron Sample Using Cherenkov Counter





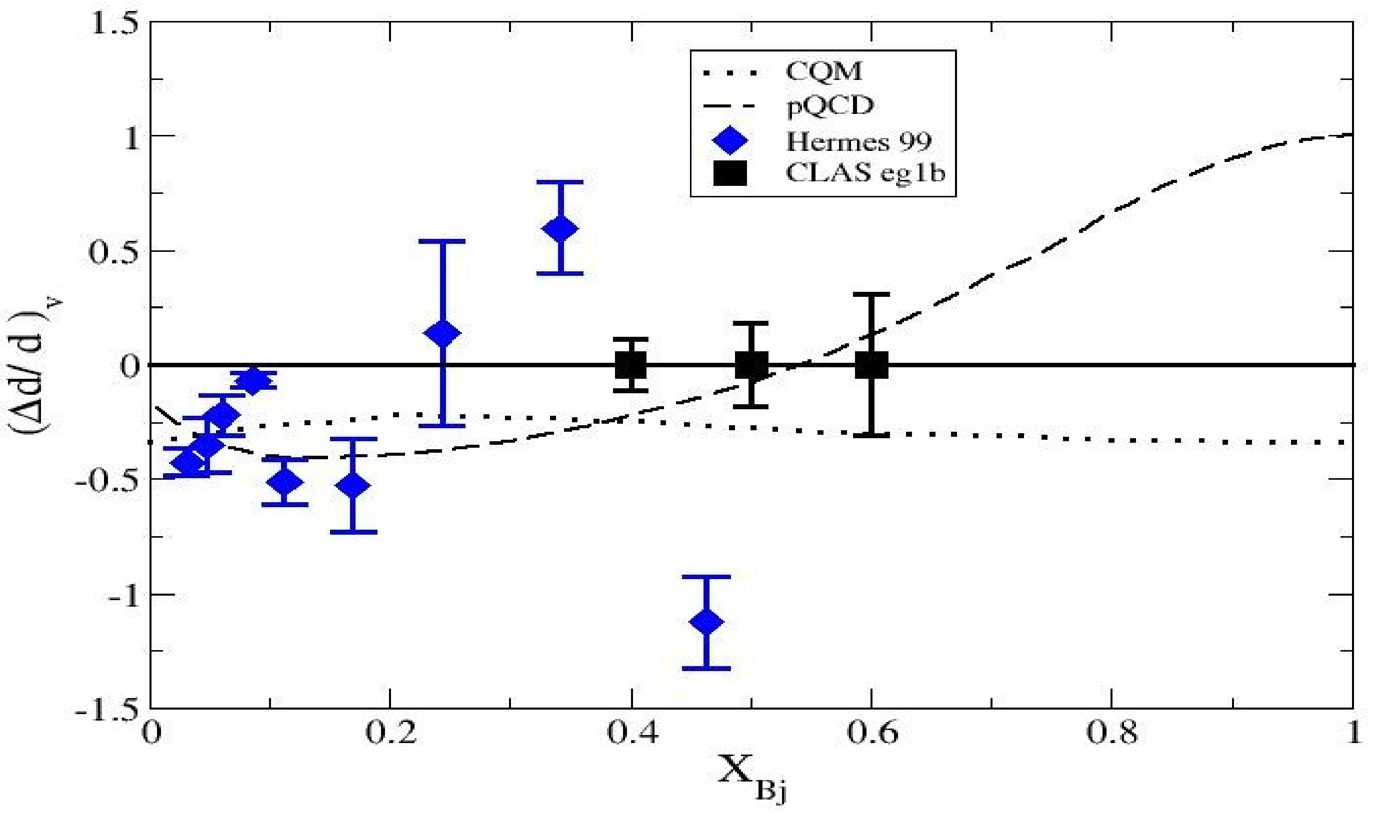
The pion contamination in electron sample is ~ 9.6 %, and for NPHE>2.5 ~ 4.03 %

Data Comparison



$\varphi_\pi{}^*$ vs Relative rate for fixed $\cos\theta_{pion}^{CM} = 0.5$ and $W = 1.45GeV$

The Expected Precision of This Analysis



The ratio of polarized to unpolarized valence down quark distribution function

Future Plans

- Measure asymmetries using the knowledge of the probe and target's polarization state
- The double spin asymmetries
- About three data points will be extracted from this analysis