PhD Proposal

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

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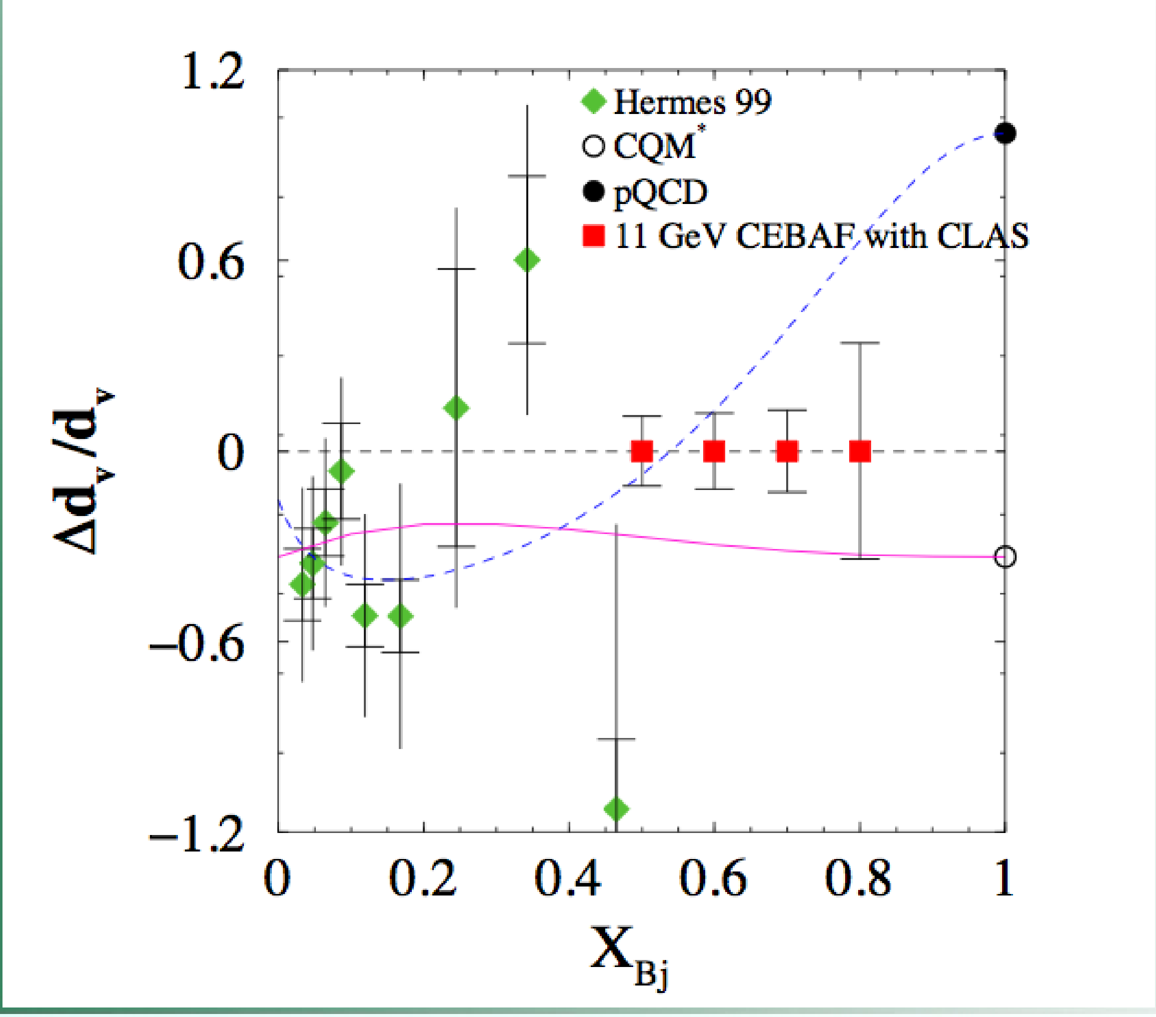
Outline

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

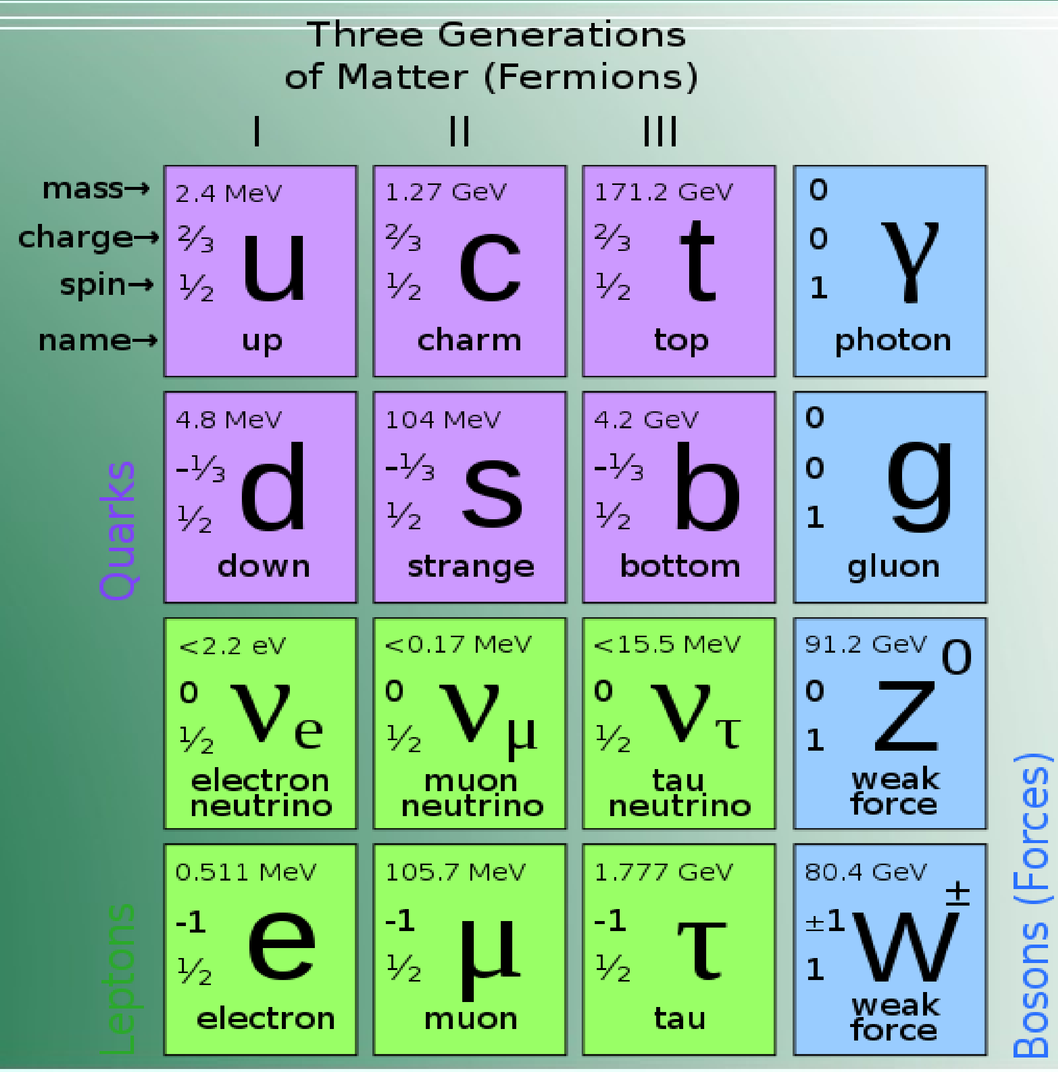
Motivation

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



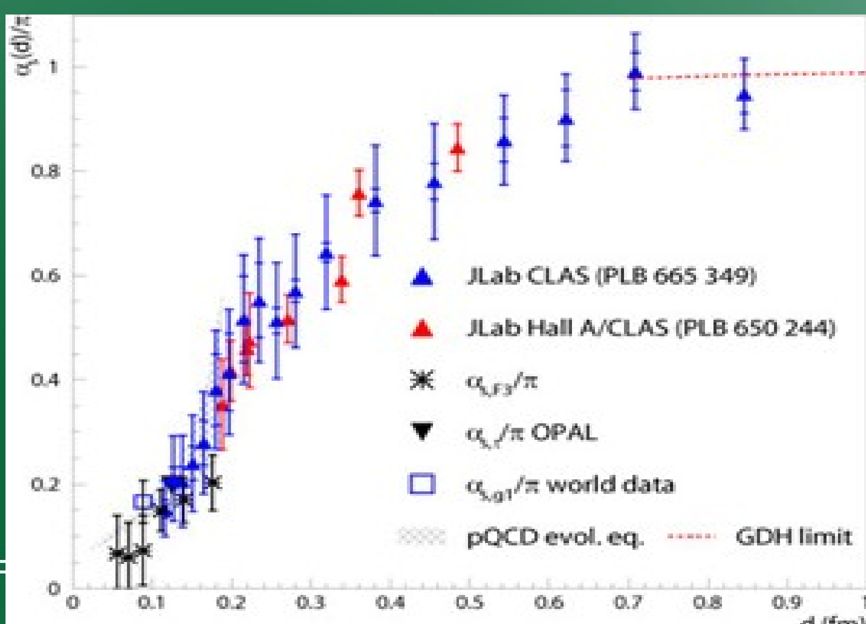
The Standard Model

- The theory of the three fundamental interactions
- Three kinds of elementary particles
- 12 – leptons, 36 – quarks, 4 – force mediators



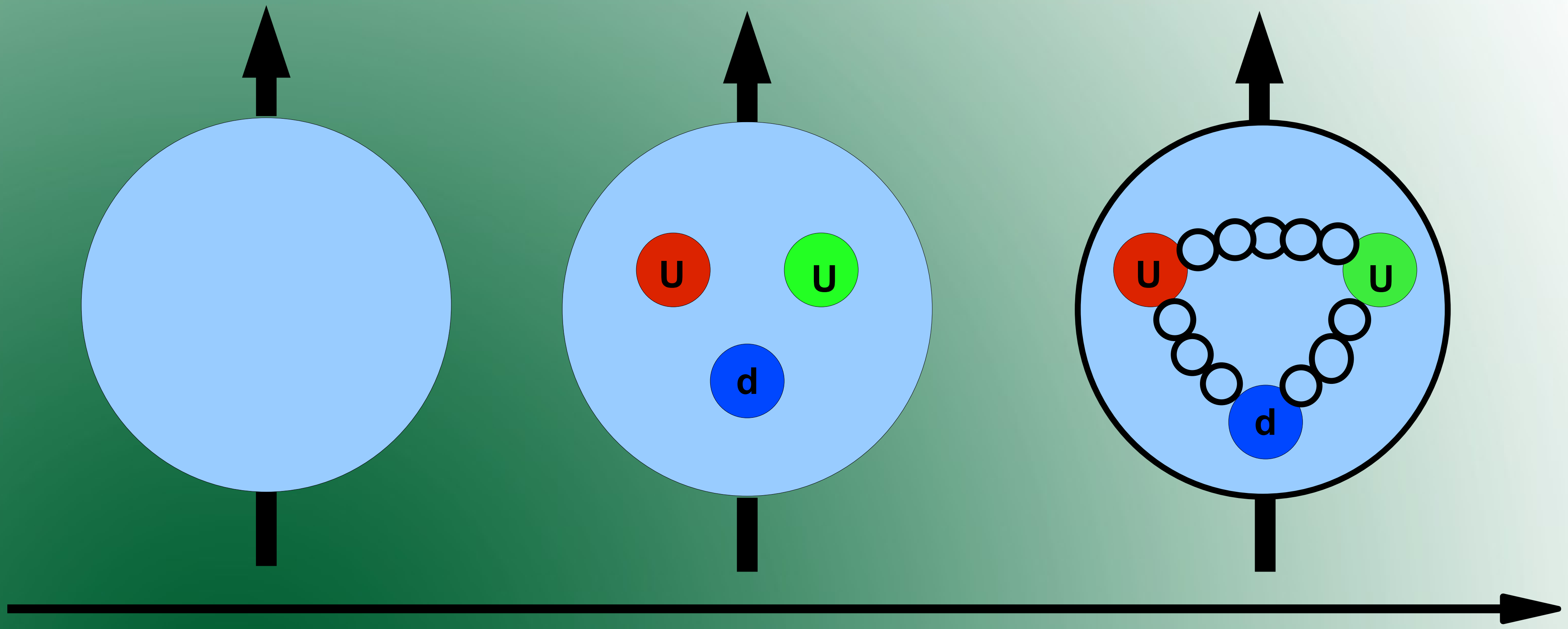
Quantum Chromodynamics vs Constituent Quark Model

- Valence, sea quarks and gluons
- Asymptotic Freedom
- Confinement



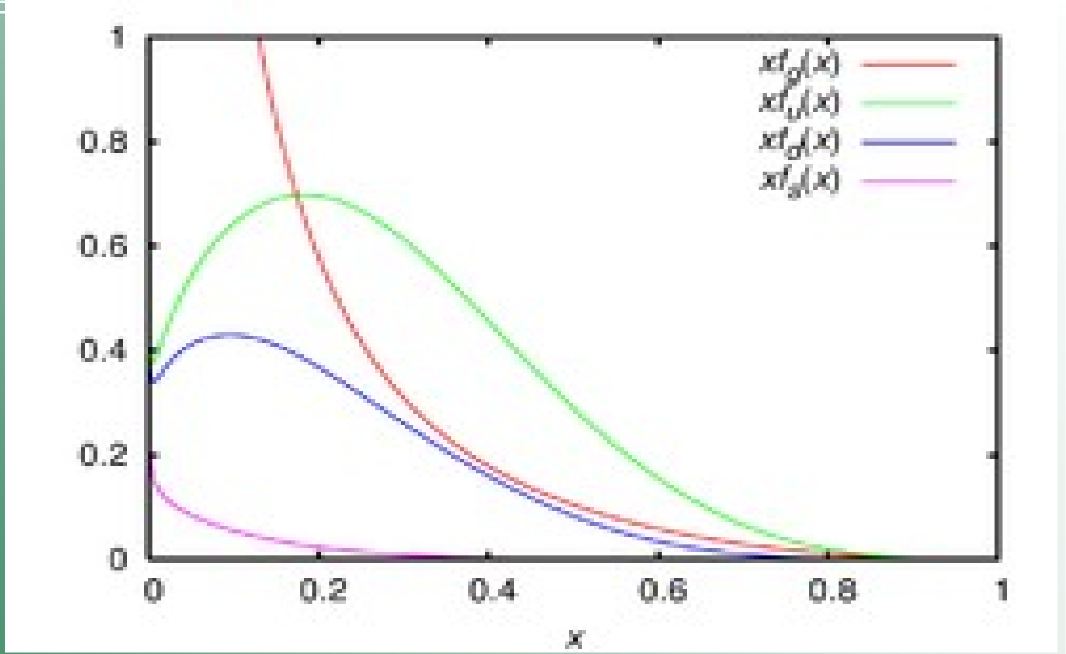
- Three types of quarks
- Baryon – qqq
- Meson – quark-antiquark
- Quark confinement

Deep Inelastic Scattering vs Q^2



Q^2 - Four Momentum Transferred Squared, d=(0.2GeV x fm)/Q

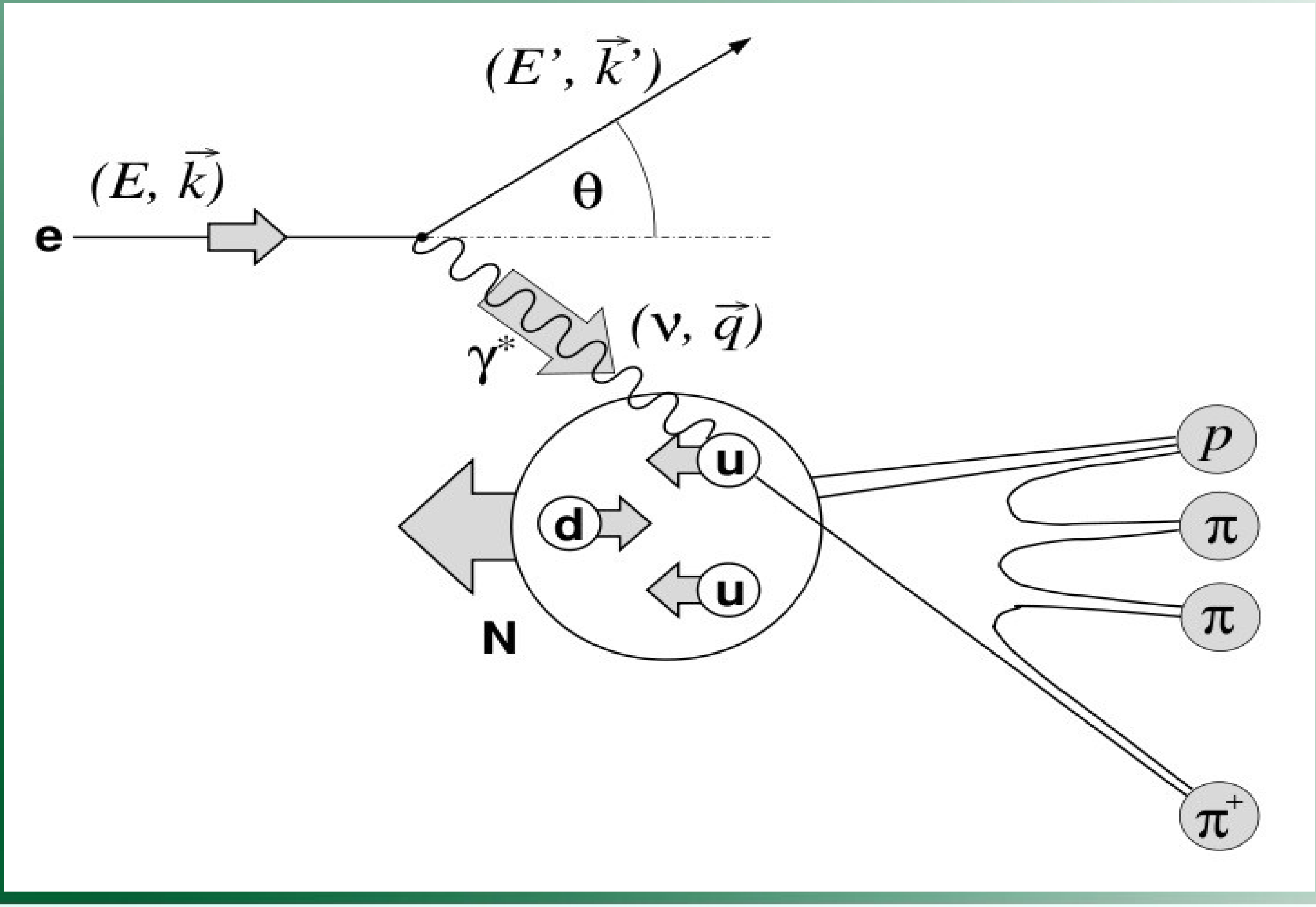
Deep Inelastic Scattering and Valence Quark Region



W(Invariant Mass)>2GeV

X_bj>0.3

Semi Inclusive Deep Inelastic Scattering(SIDIS) Diagram



Semi Inclusive Double Spin Asymmetry

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

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

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

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

Asymmetry and Quark distribution functions

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

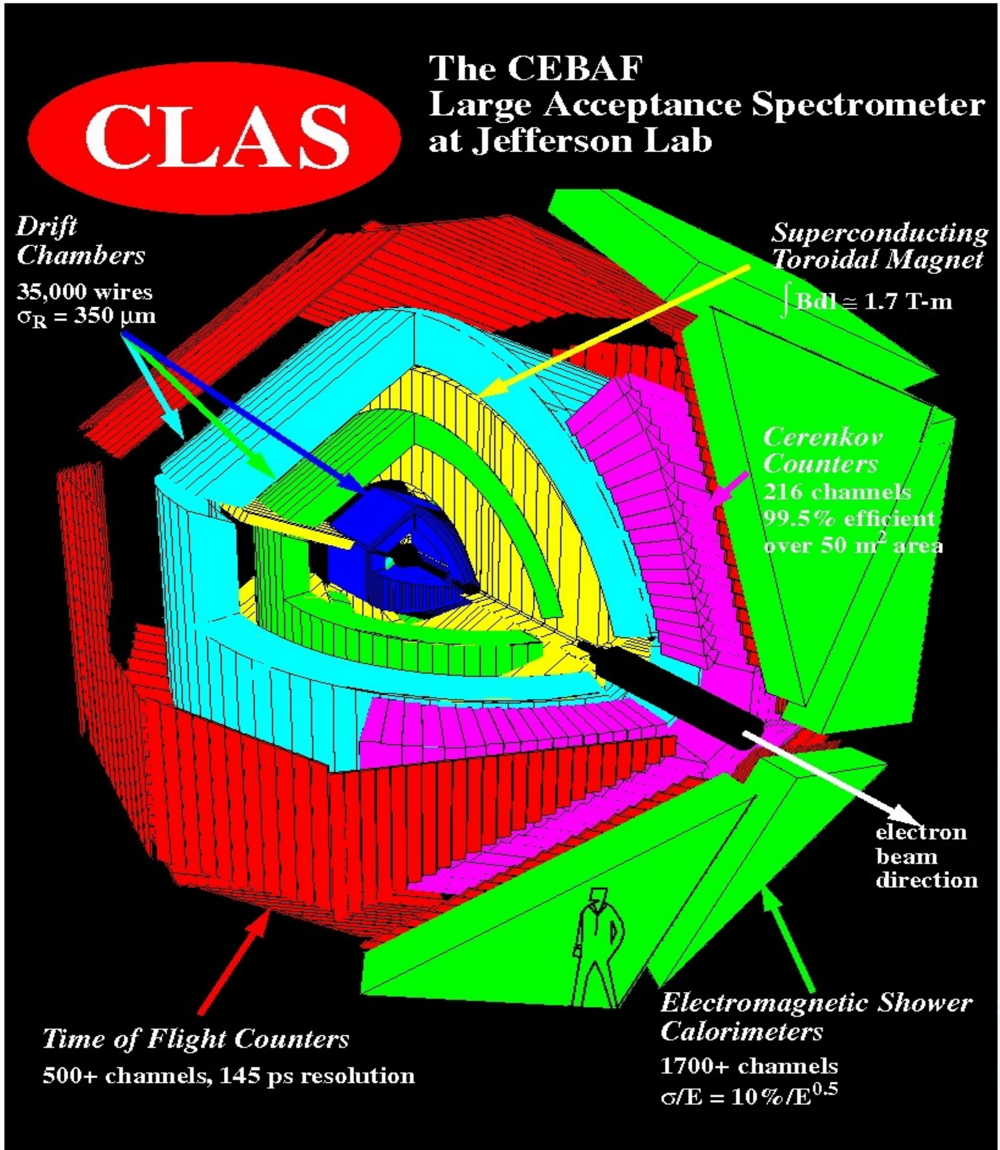
$$A_{1,2H}^{\pi^+ \pm \pi^-} = \frac{\Delta u_v(x) + \Delta d_v(x)}{u_v(x) + d_v(x)}$$

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

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

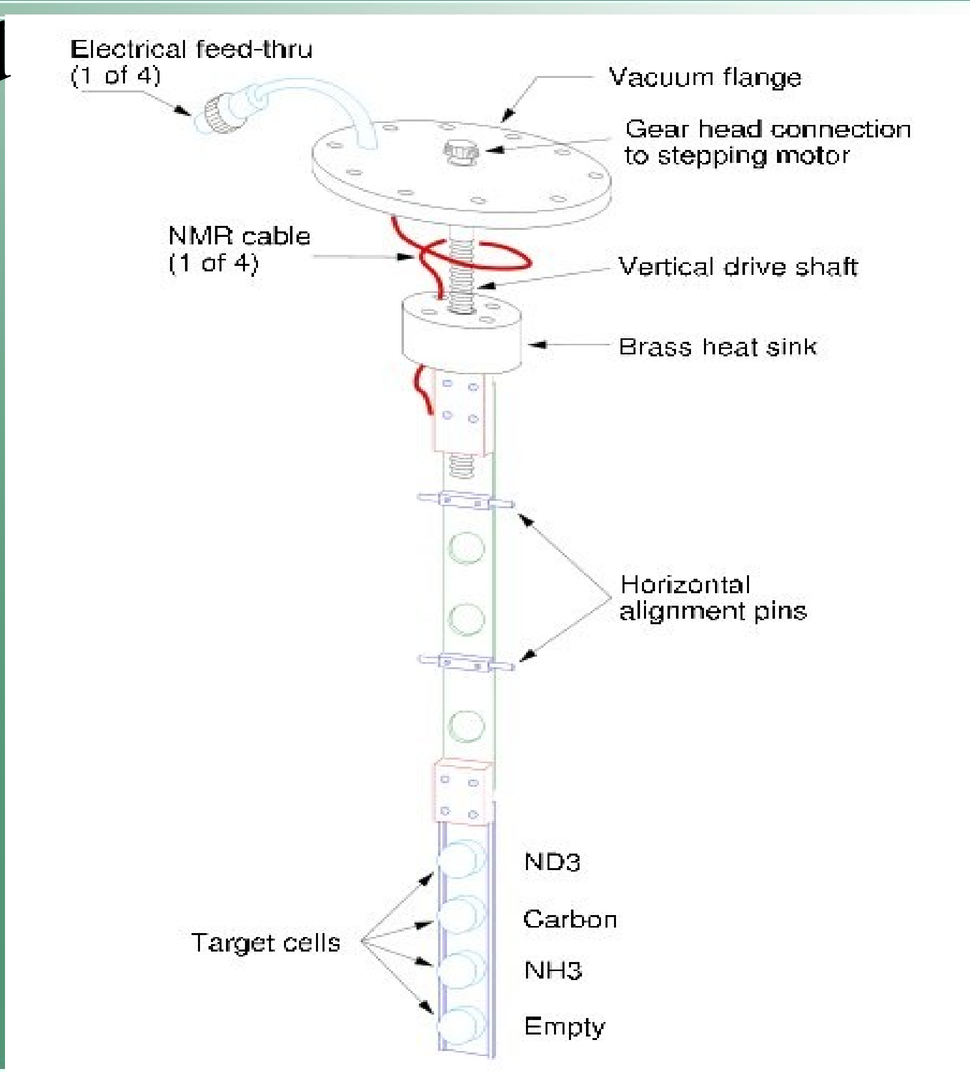
The CEBAF Large Acceptance Spectrometer at JLab

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



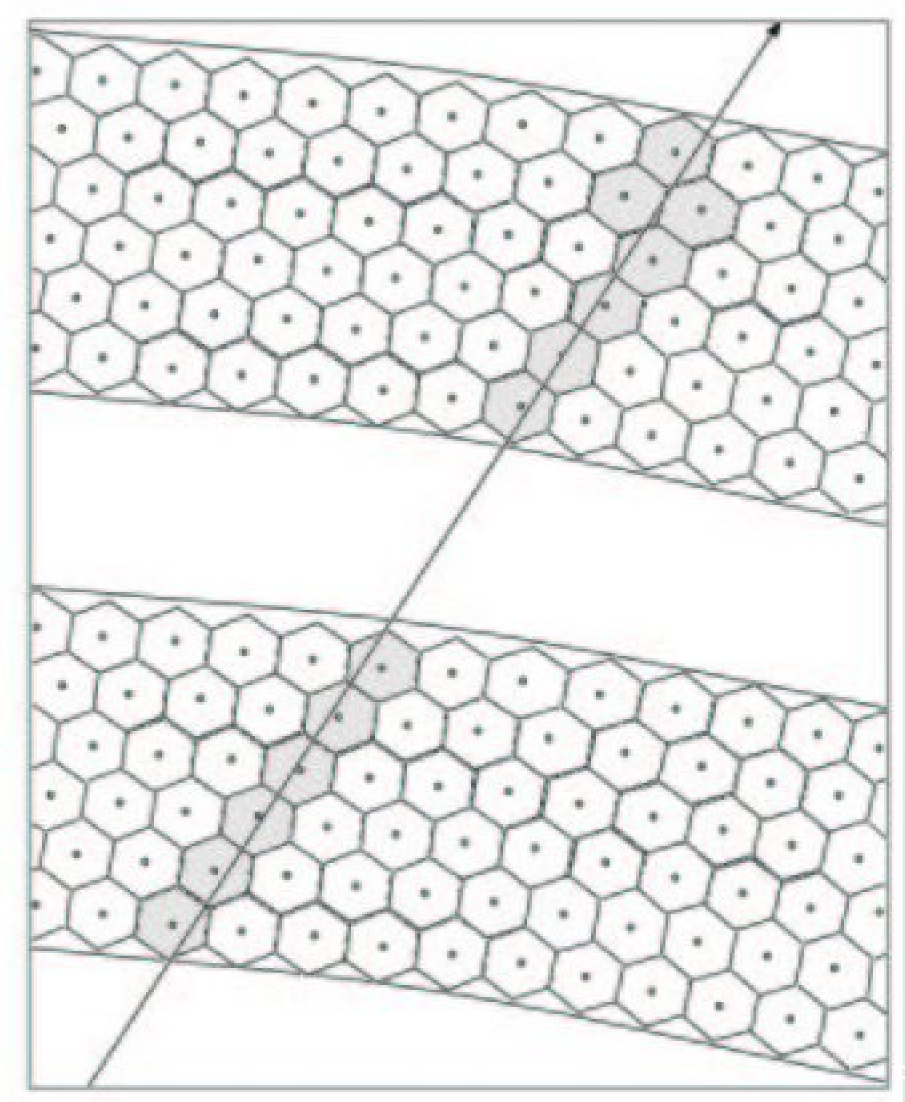
Target Materials

- 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



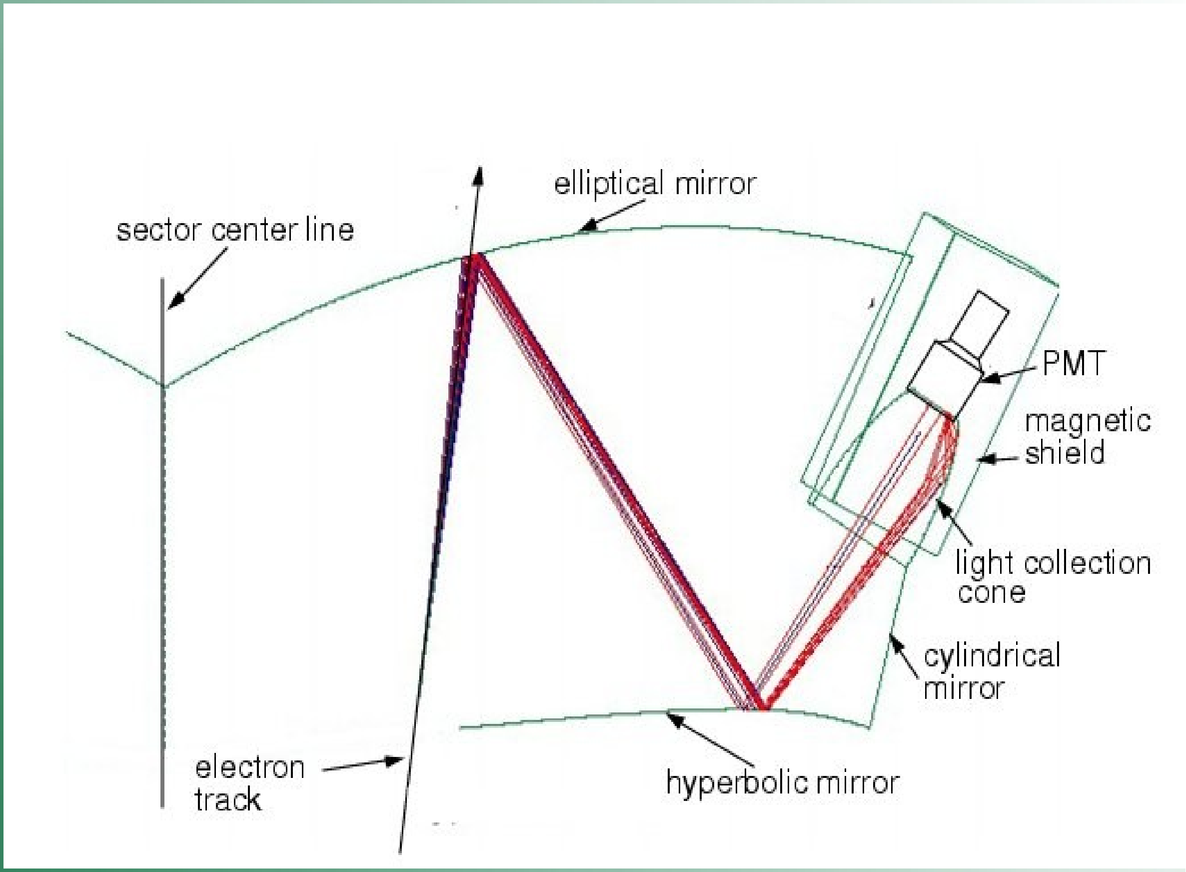
Drift Chambers

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



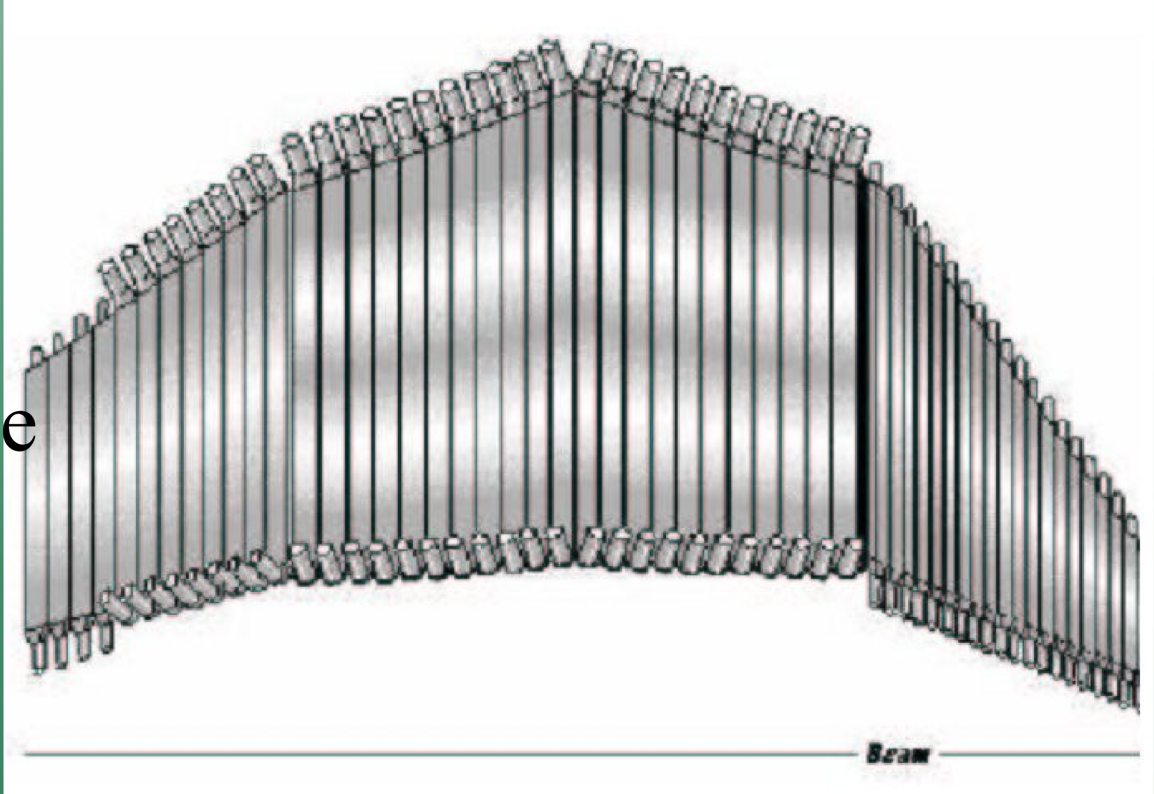
Cherenkov Detector

- The threshold detector
- Differentiate electrons from pions
- Gas – C_4F_{10} (n=1.00153, high photon yield)
- Thresholds: 9 MeV for electrons and 2.5 GeV for pions



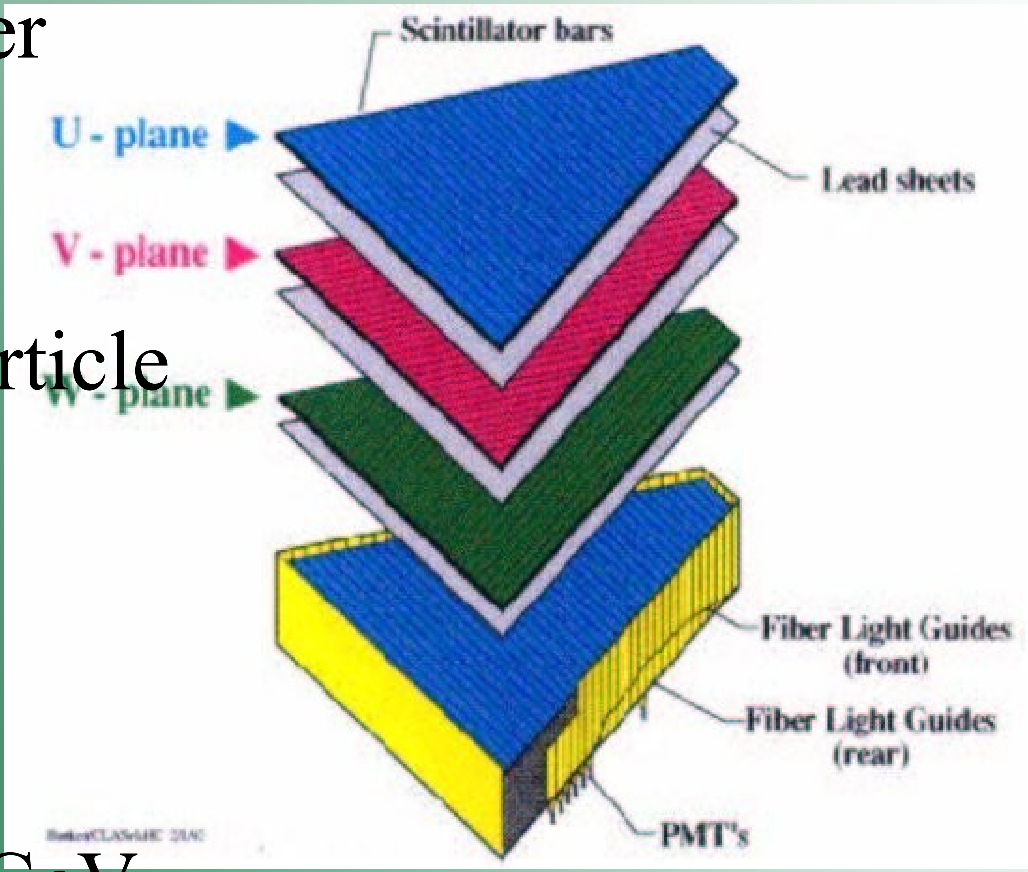
CLAS Scintillators

- 288 scintillators
- The time of flight for charged particle
- Coincidence for particle
- 120ps – 250ps time resolution
- The length from 30 cm to 450 cm



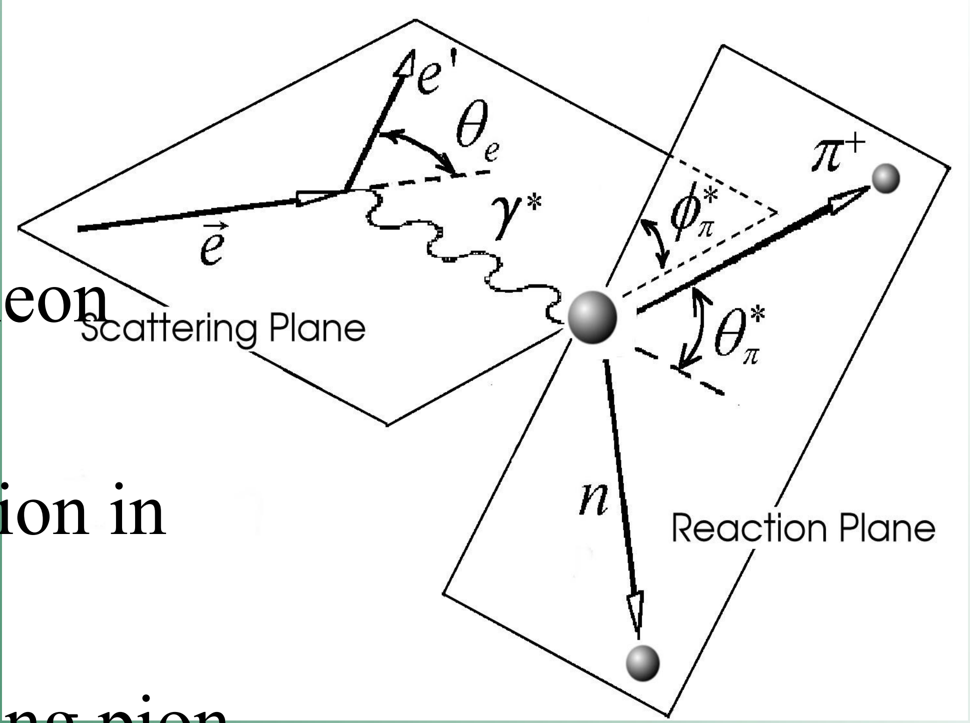
The CLAS Calorimeter

- 8 electromagnetic calorimeter modules
- Measures the total energy deposited by the crossing particle
- Neutron detection
- Electron detection above 0.5 GeV
- Photon detection above 0.2 GeV



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 scattered electron angle



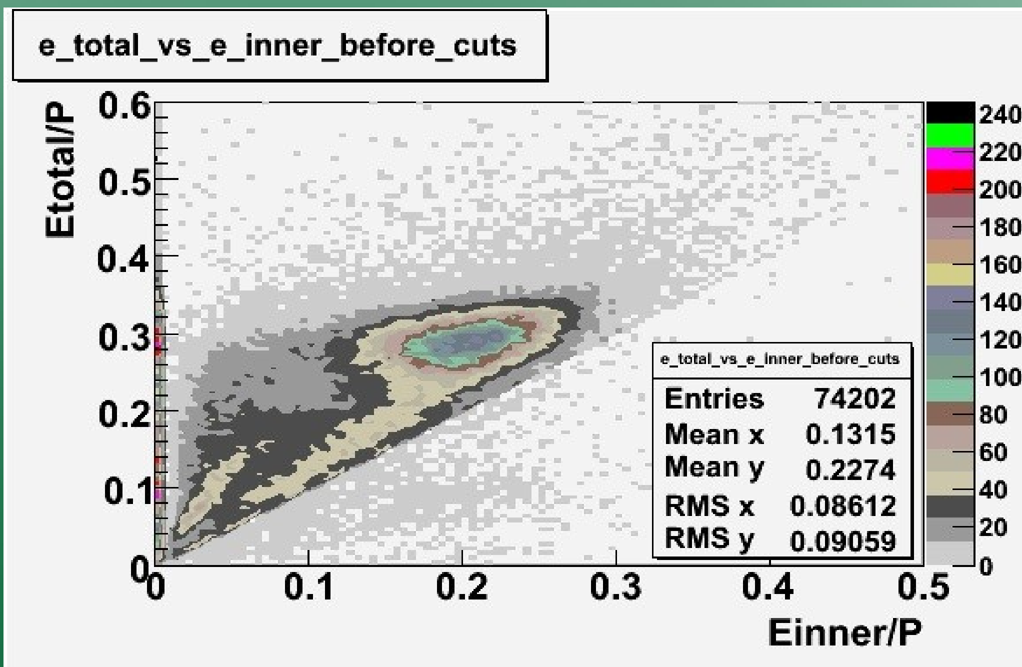
The Five-Fold Differential Cross Section

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

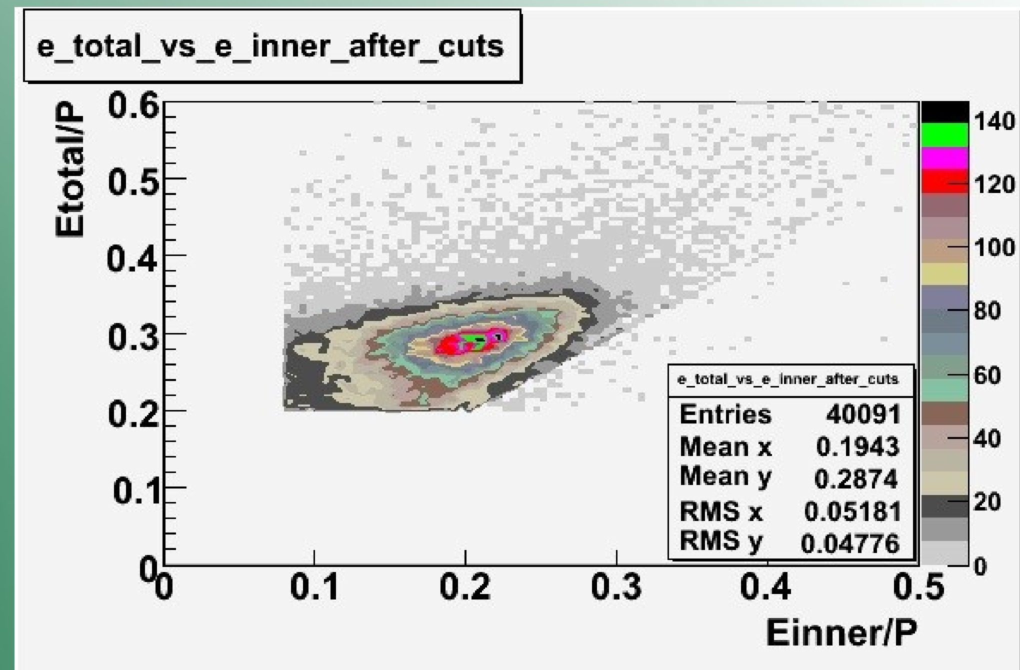
$$\frac{d(W,Q^2)}{d(E_f,cos\theta_e)} = \frac{2M_pE_iE_f}{W}$$

Particle Identification Using Electromagnetic calorimeter

Before EC Cuts

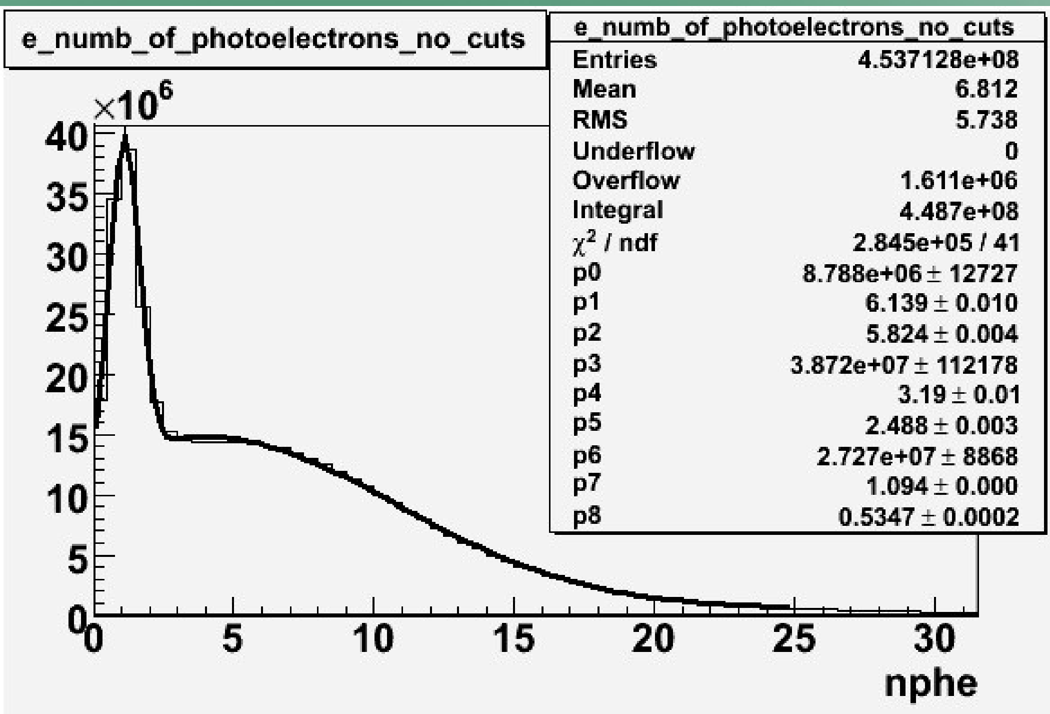


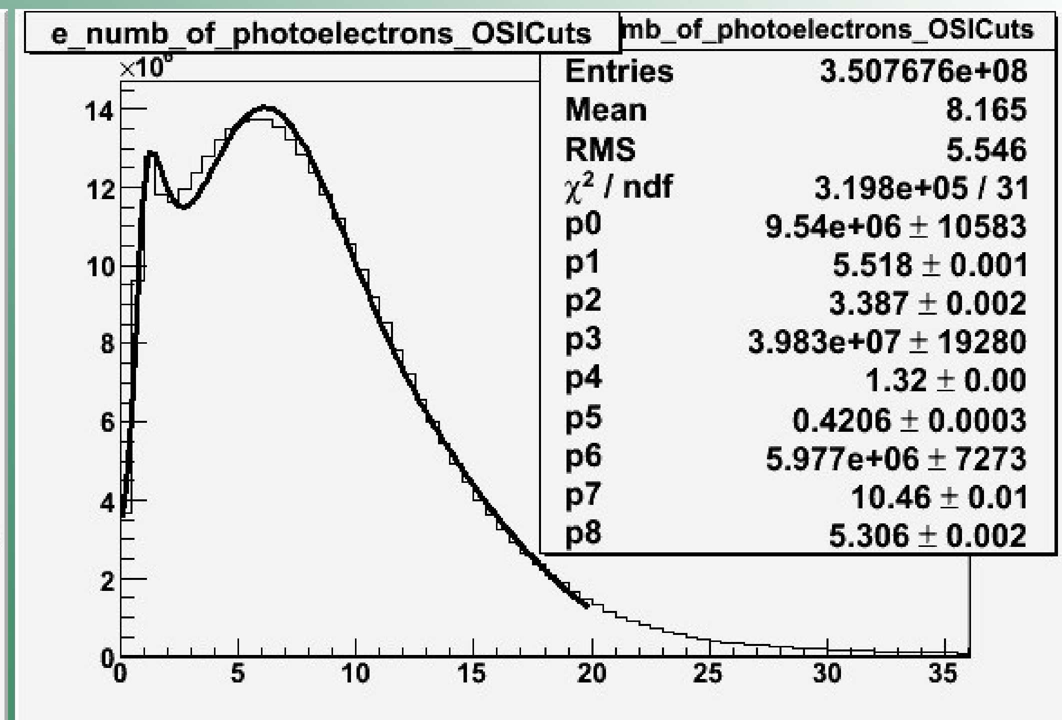
After EC Cuts



Cuts on the energy deposited in the electromagnetic calorimeter (ECtotal>0.2*p and ECinner>0.06*p)

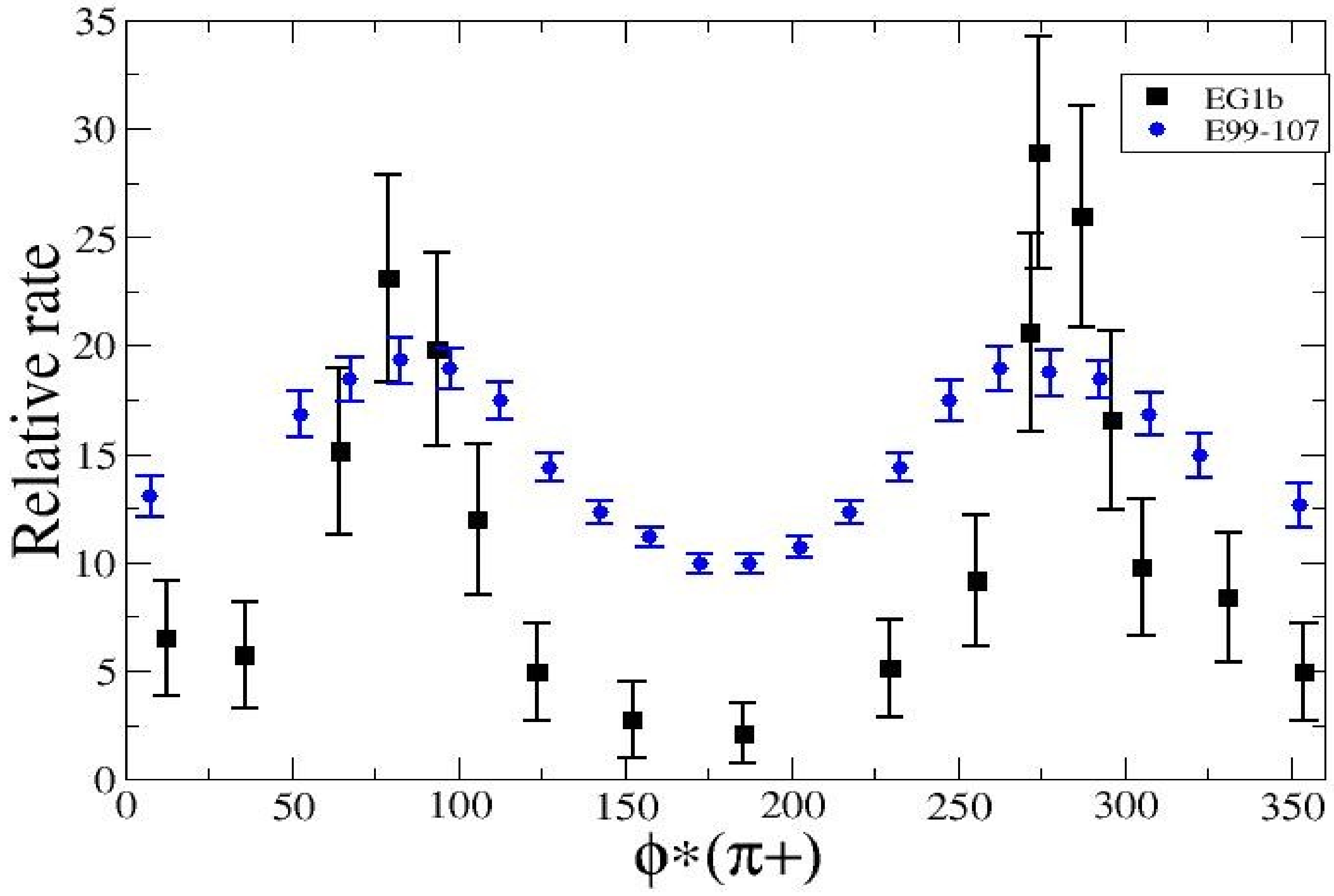
Pion Removal From The Electron Sample Using Cherenkov Counter



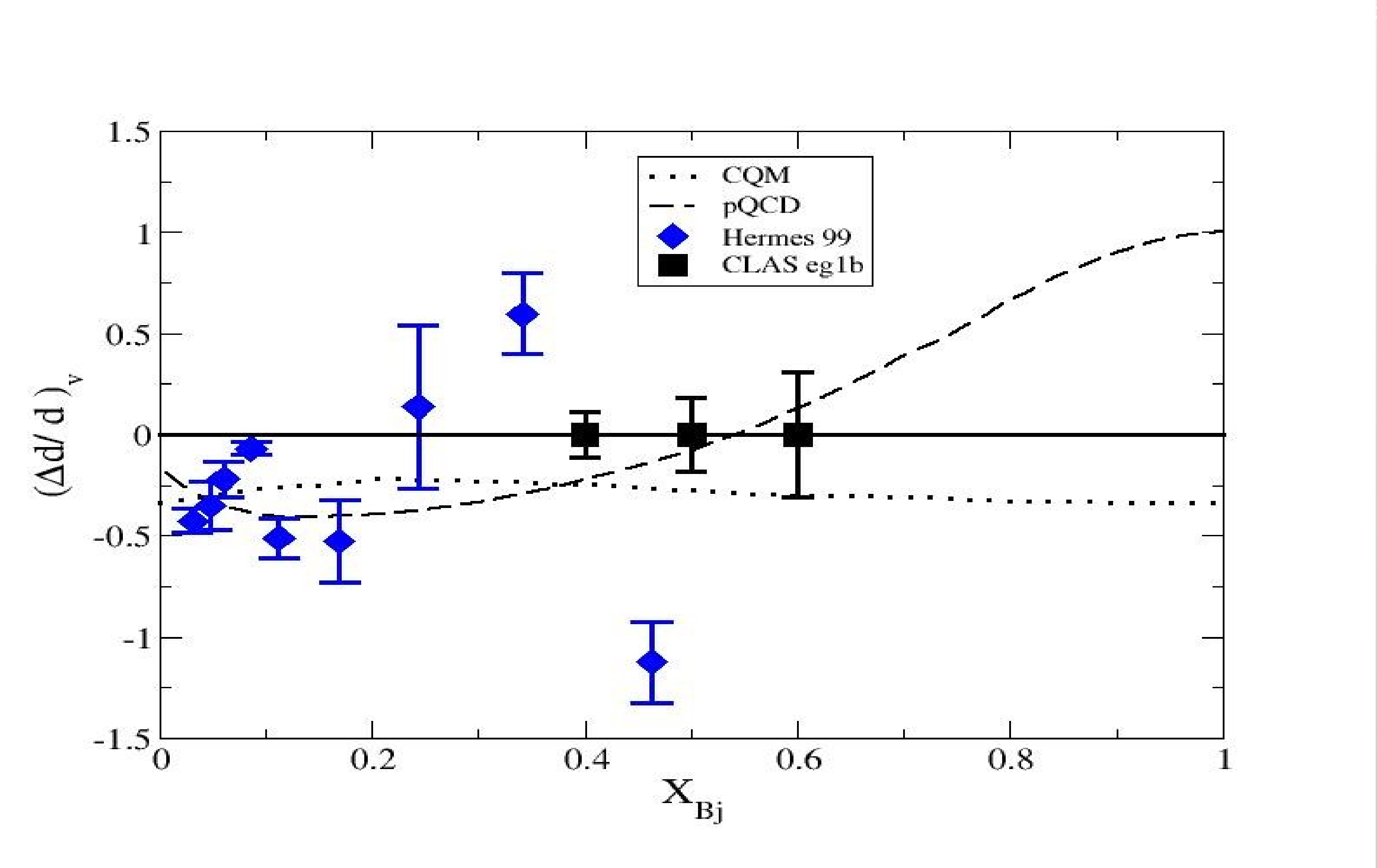


The pion contamination in electron sample is ~ 9.6 %, and for NPHE>2.5 ~ 4.03 %

Data Comparison



The Expected Precision of This Analysis



The ratio of polarized to unpolarized valence down quark distribution function vs Xbj

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