Quark Spin in The Nucleon

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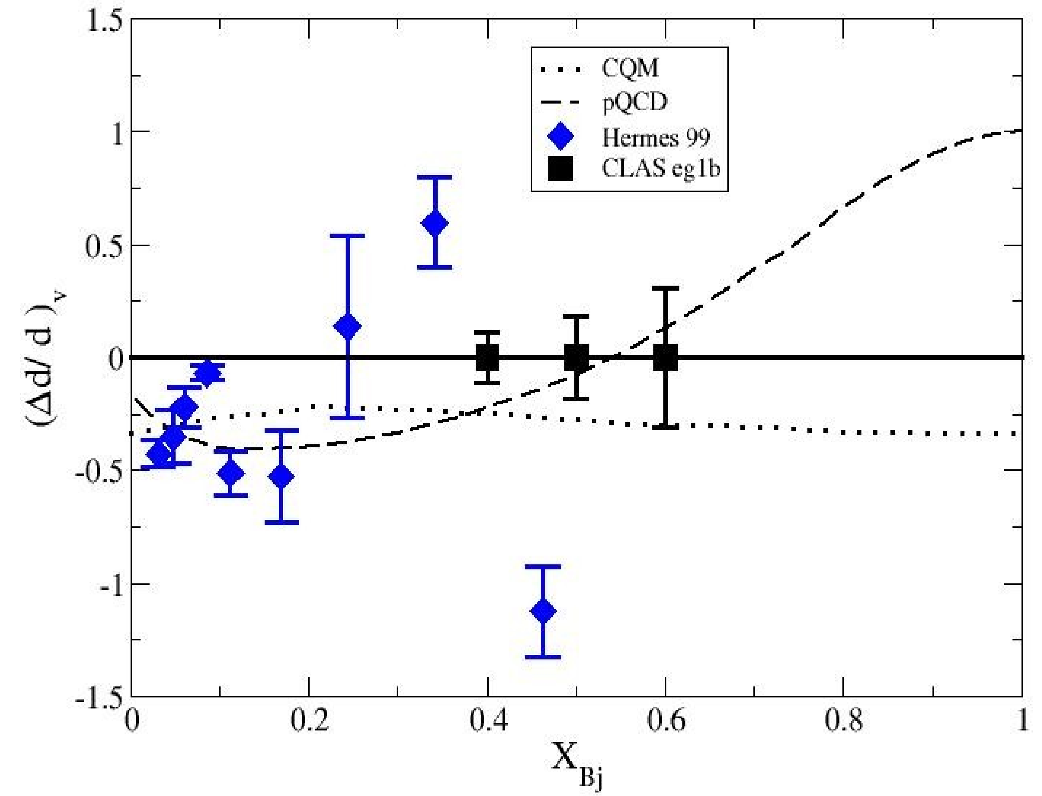
Outline

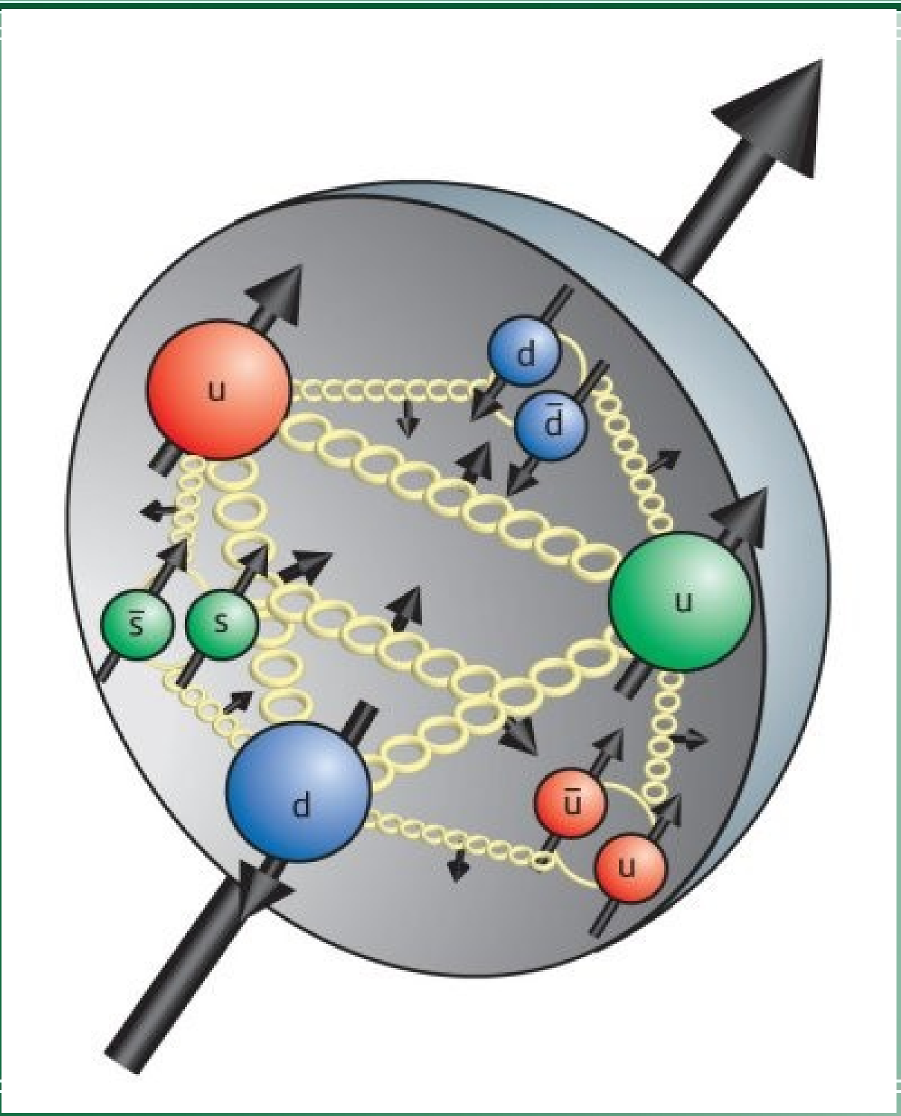
- Motivation
- Physics
- Experimental Setup
- Preliminary Results
- Detector Work in LDS

Motivation

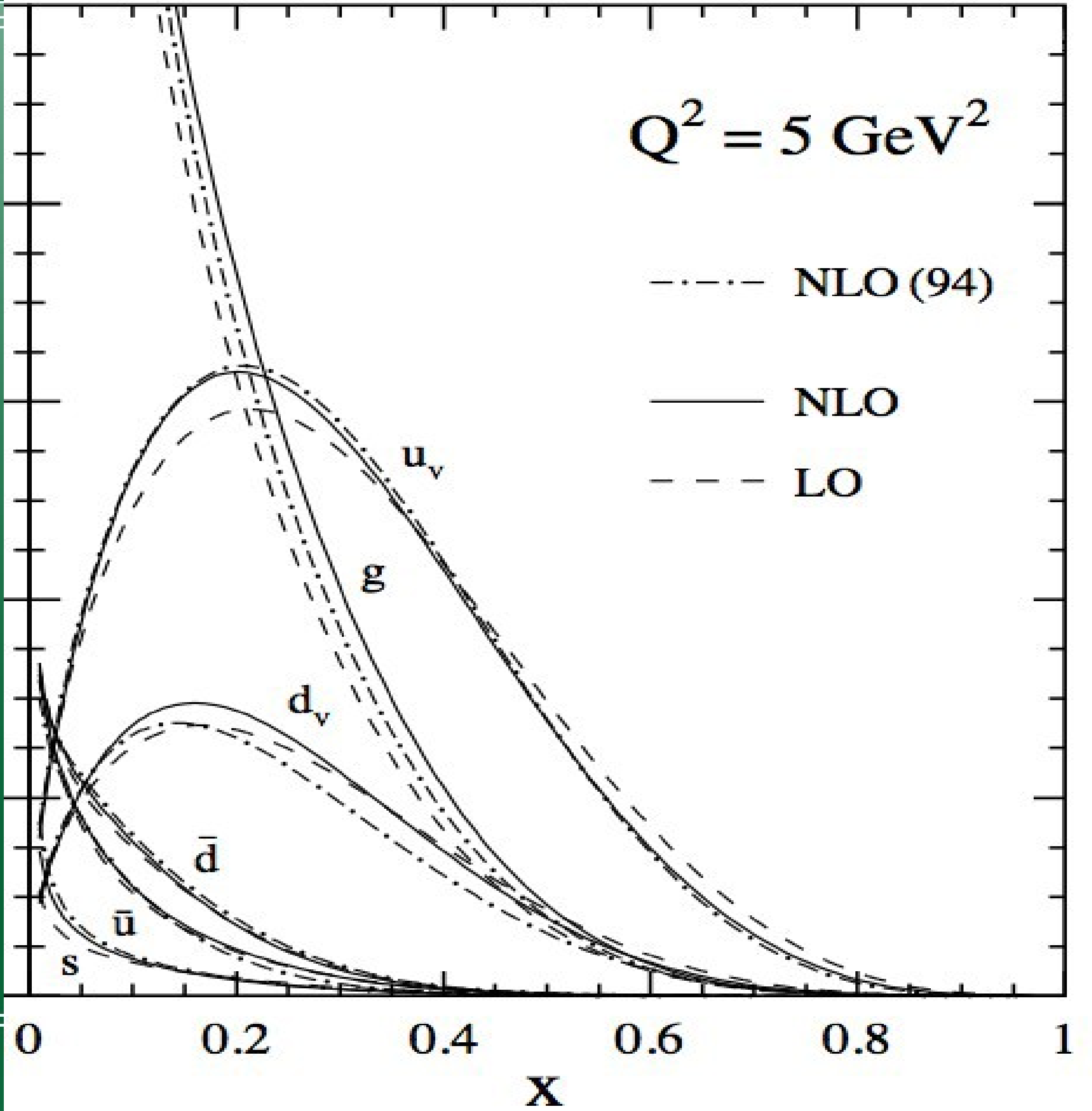
- "The proton spin crisis"
- Semi-Inclusive Double Spin Asymmetry Measurement
- Extraction of ($\Delta d/d$) observable
- The perturbative Quantum Chromodynamics(pQCD) vs the hyperfine perturbed Constituent Quark Model(CQM)



Quarks Inside the Nucleon

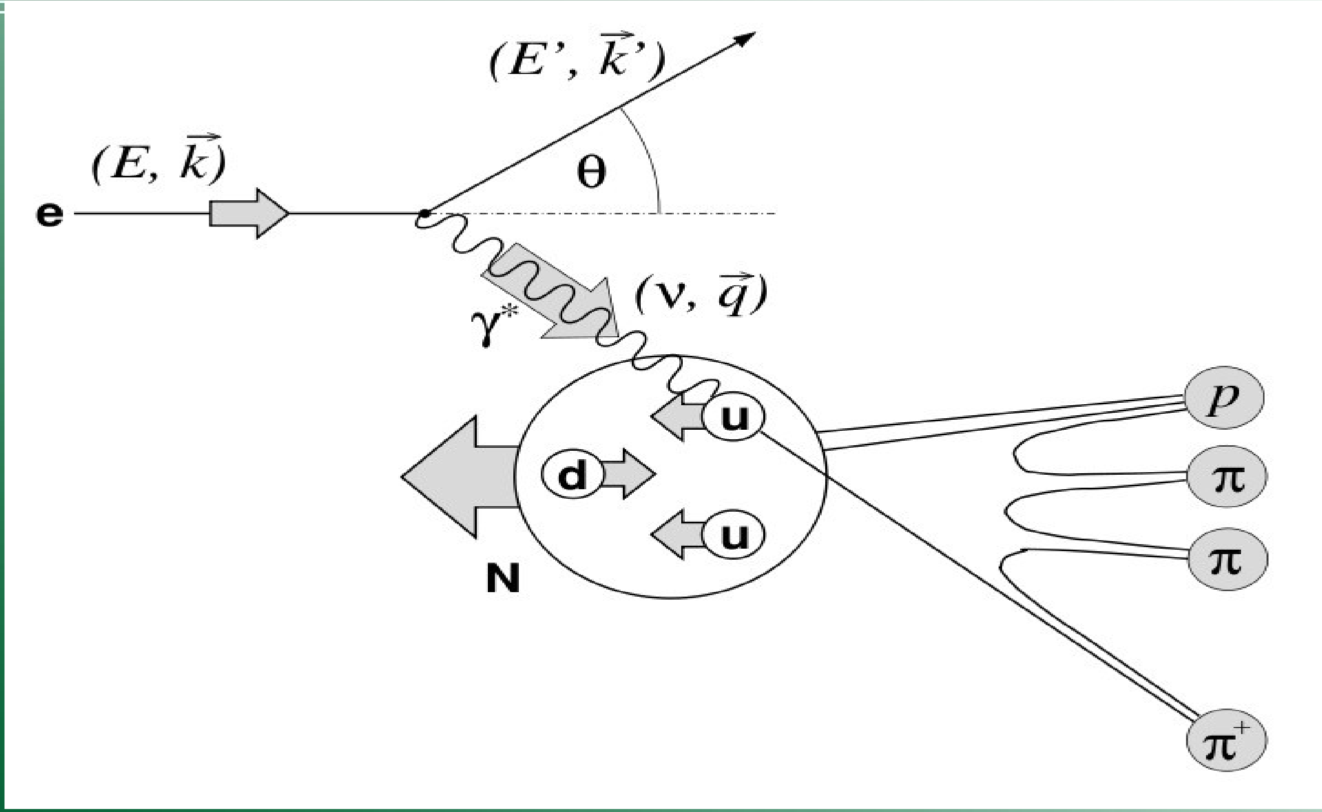


Valence Quark Region



X_bj>0.3

Semi Inclusive Deep Inelastic Scattering(SIDIS) Diagram



Fragmentation function

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

Semi Inclusive Double Spin Asymmetry

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

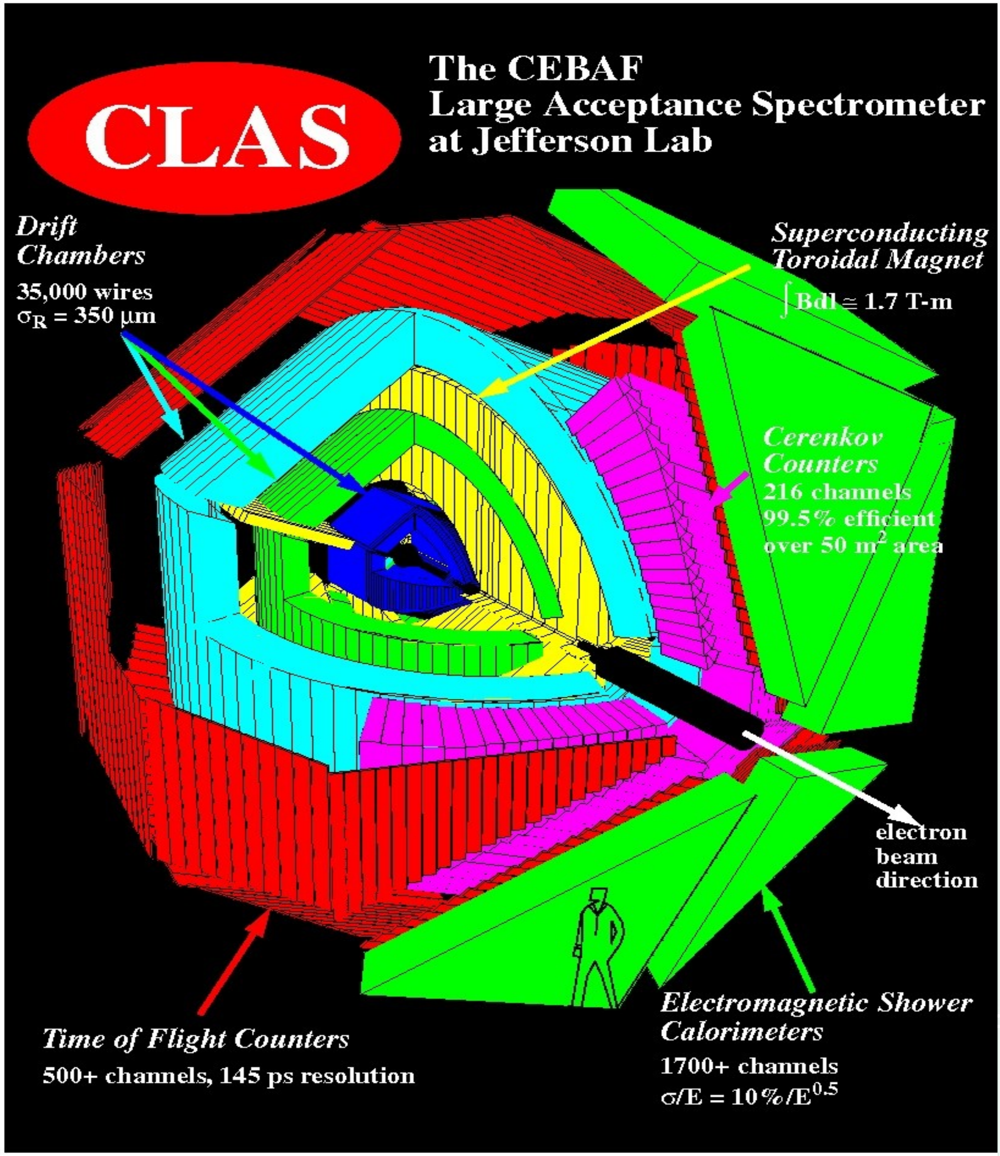
$$A_{1,p}^{\pi^+ \pm \pi^-} = \frac{4\Delta u_v(x) \pm \Delta d_v(x)}{4u_v(x) \pm d_v(x)}$$

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

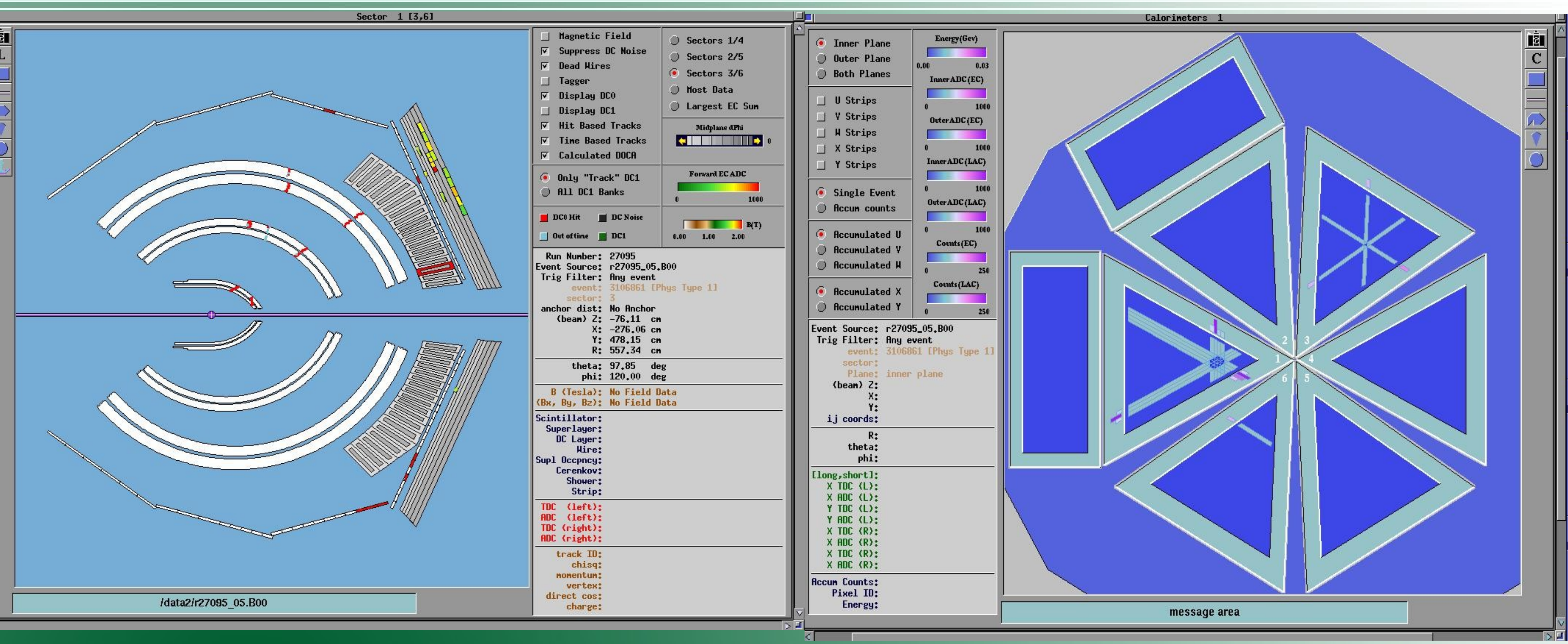
Semi Inclusive deep inelastic scattering provides and opportunity to determine the struck quark flavor.

The CEBAF Large Acceptance Spectrometer at JLab

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



Event Display



NH3 Target, inbending , 5.7 GeV beam energy

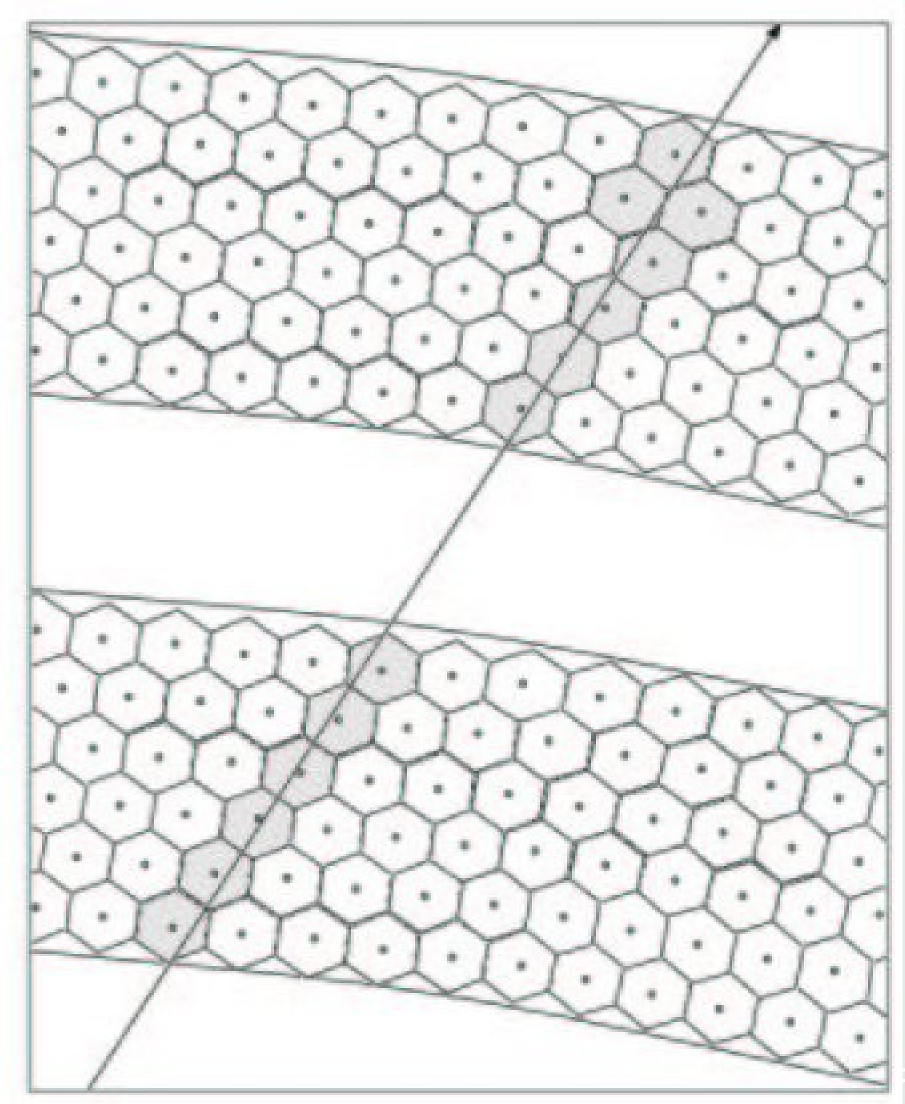
Target Materials

- 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

Y. Prok, PhD Thesis, University of Virginia(2004)

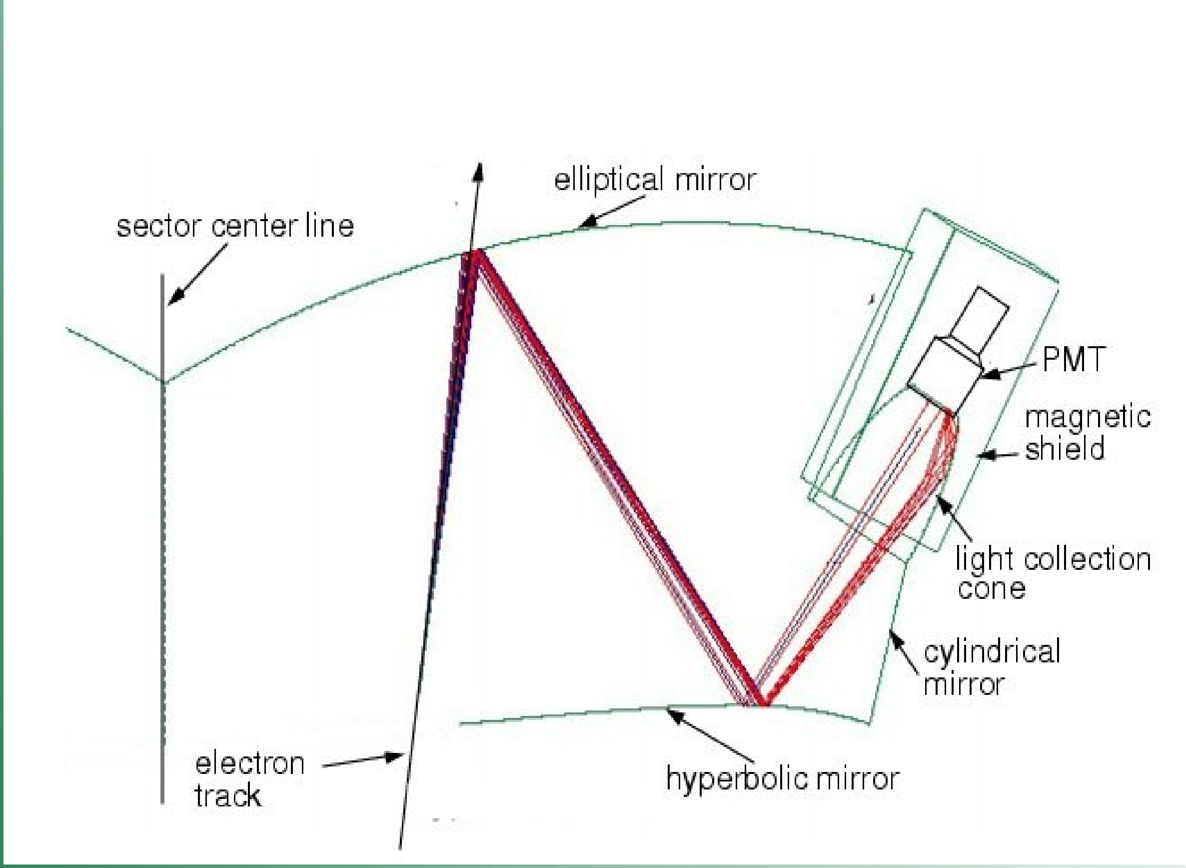
Drift Chambers

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



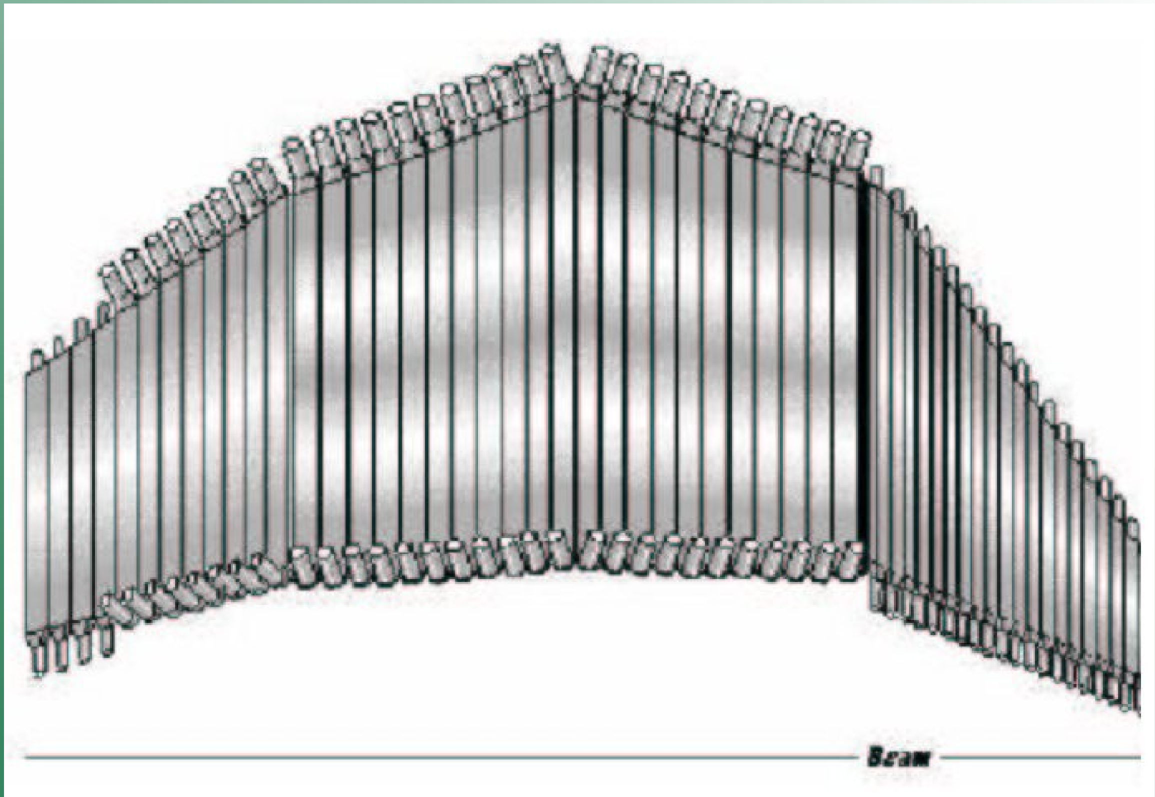
Cherenkov Detector

- 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



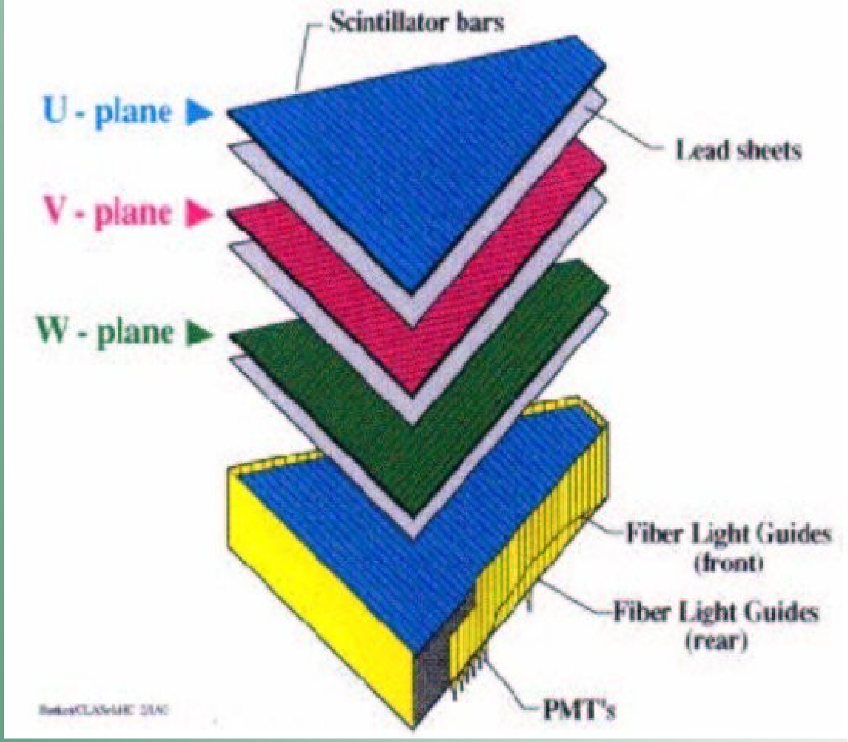
The CLAS TOF Scintillators

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



The CLAS Calorimeter

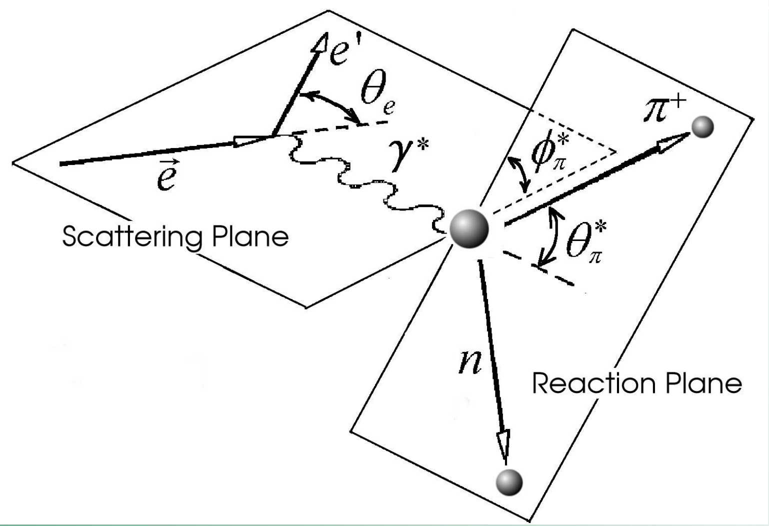
- 8 electromagnetic calorimeter modules
- Measures the total energy deposited by the crossing particle
- Neutron detection, efficiency>50% for E_n>0.5GeV
- Electron detection above 0.5 GeV
- Photon detection above 0.2 GeV



M. Amarian. *et al., Nucl. Instr. And Meth.* **A460,** 239(2001)

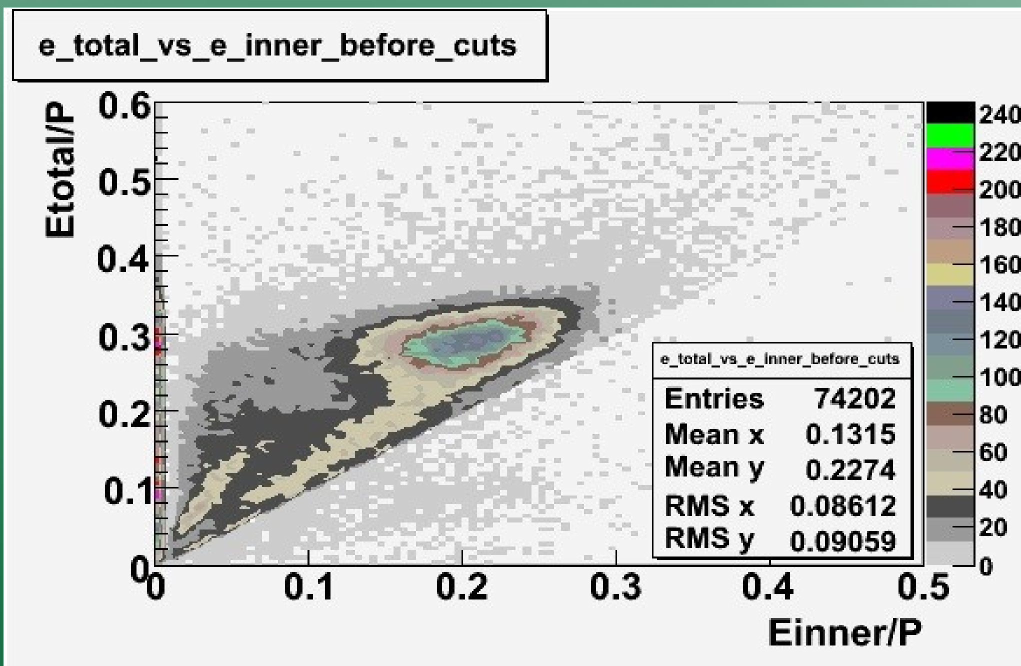
Kinematics of the exclusive single pion electroproduction

- 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

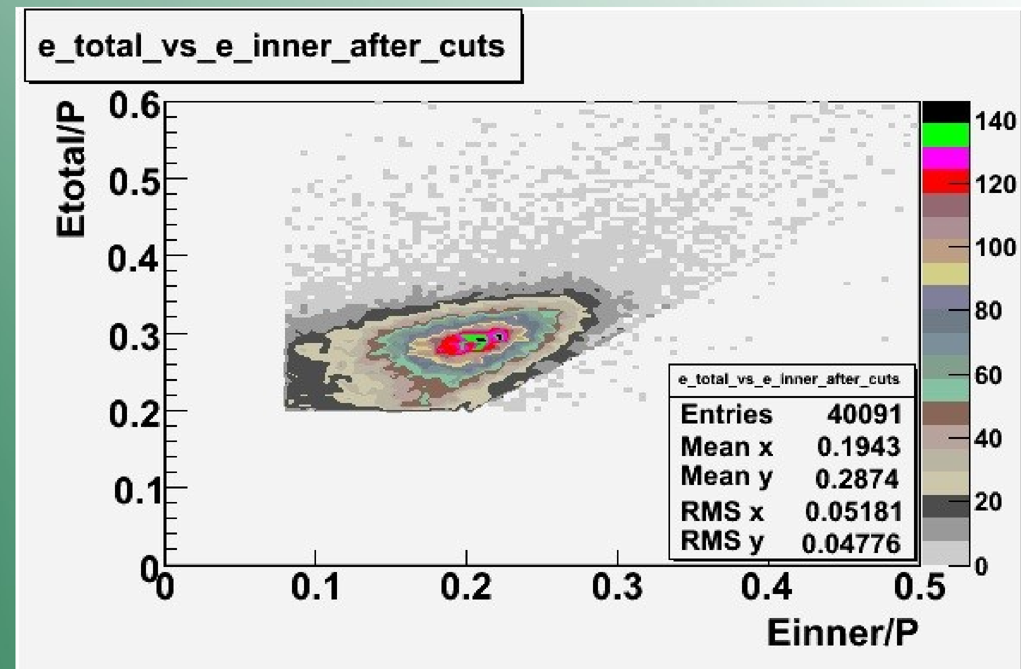


Particle Identification Using Electromagnetic calorimeter

Before EC Cuts

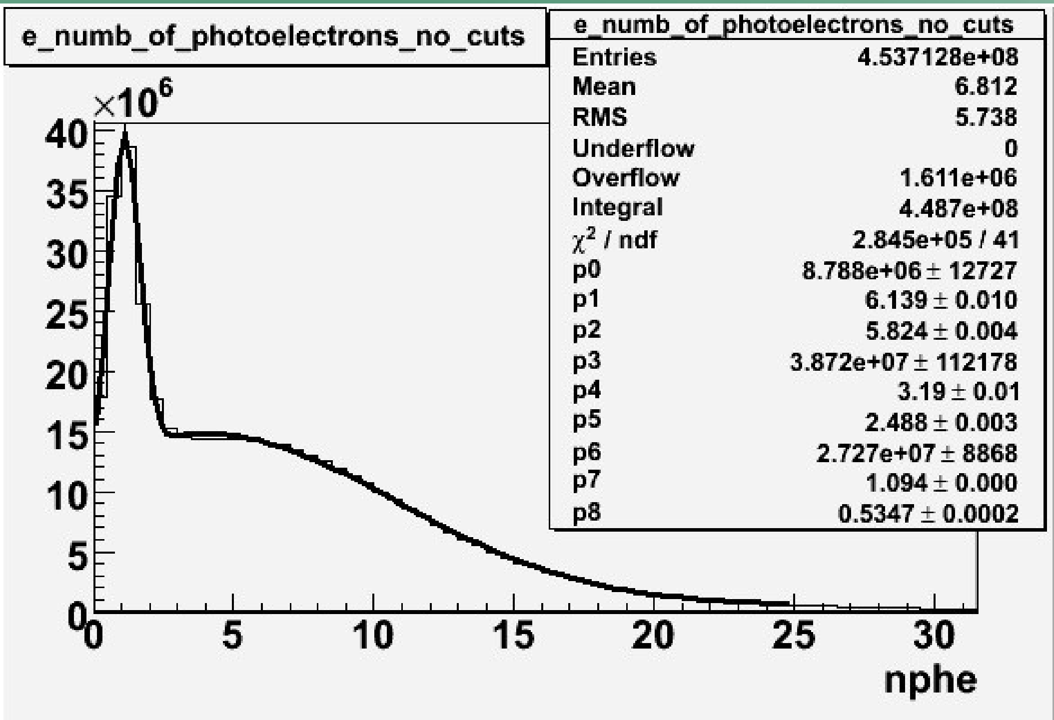


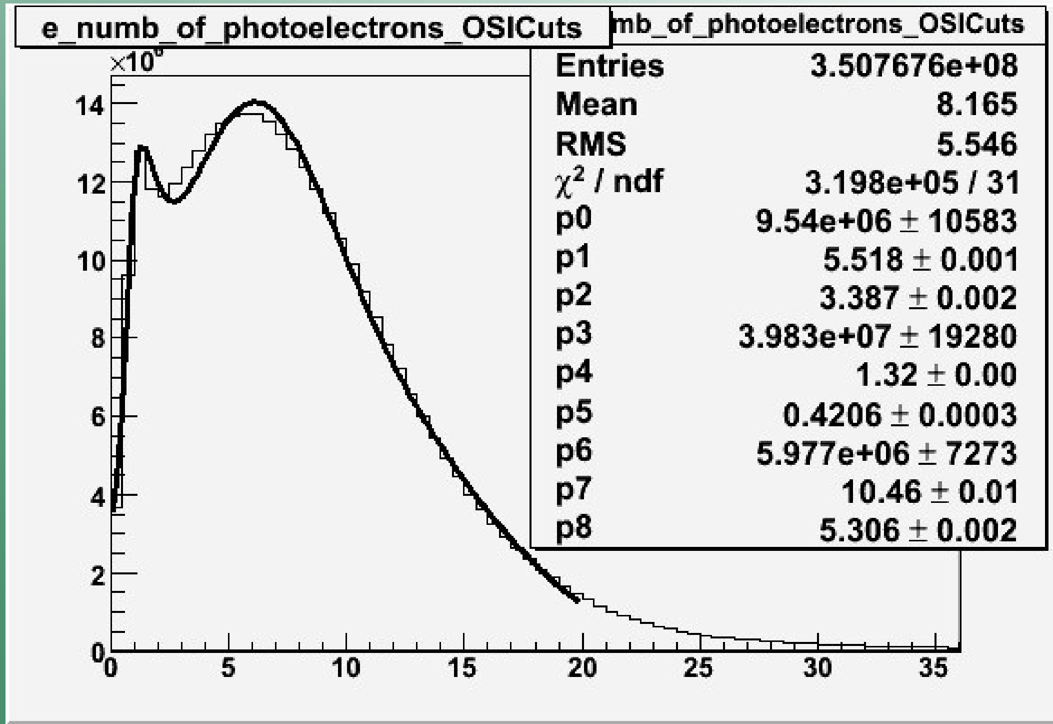
After EC Cuts



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

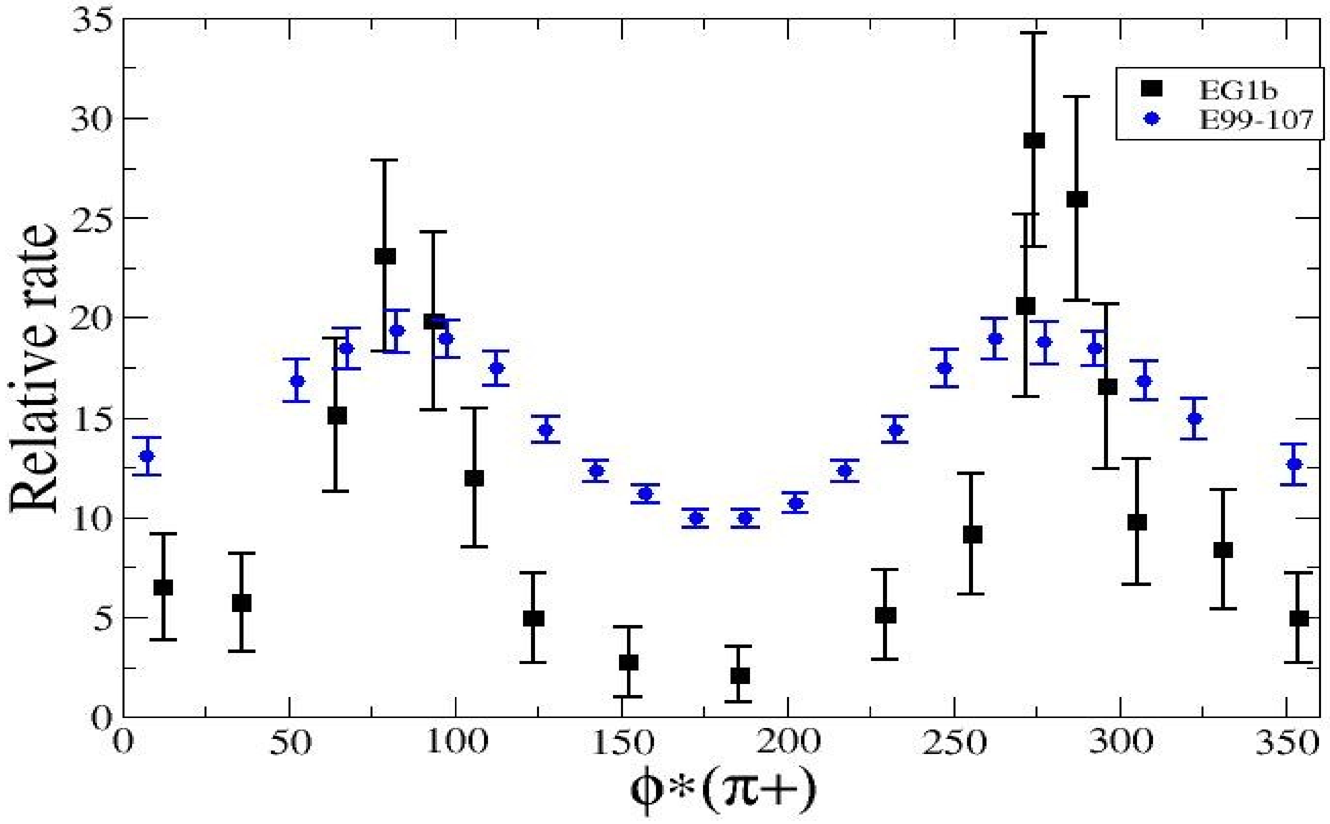
Pion Removal From The Electron Sample Using Cherenkov Counter





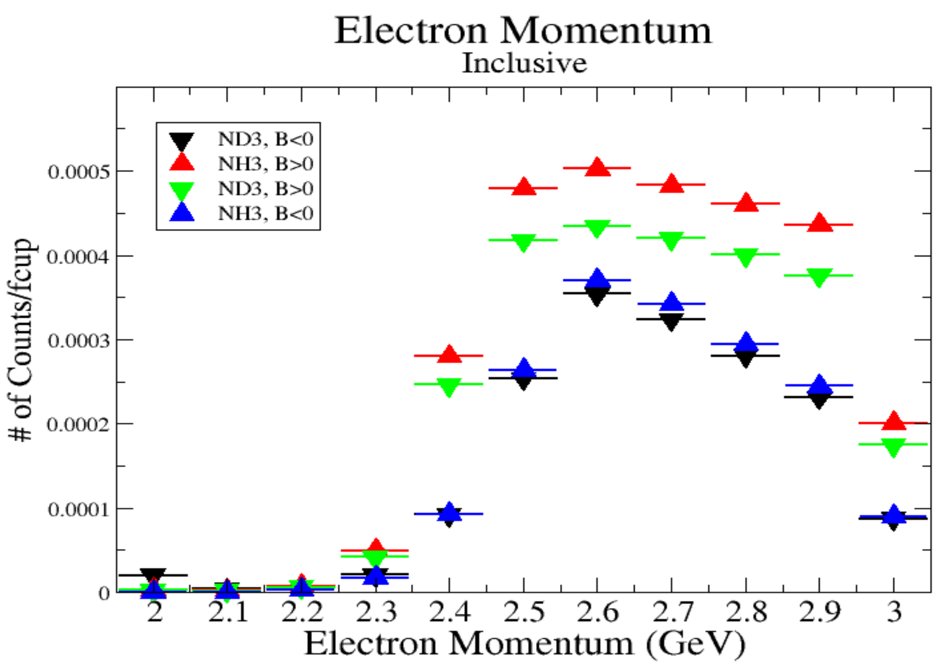
The pion contamination in electron sample is ~ 9.6 %, and for NPHE>2.5 ~ 4.03 %

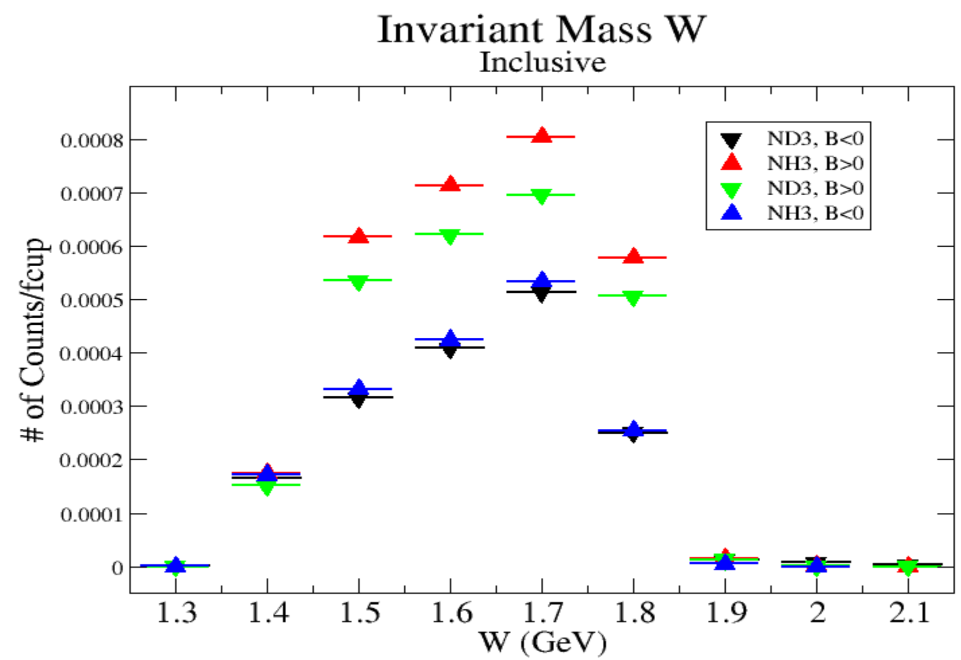
Data Comparison

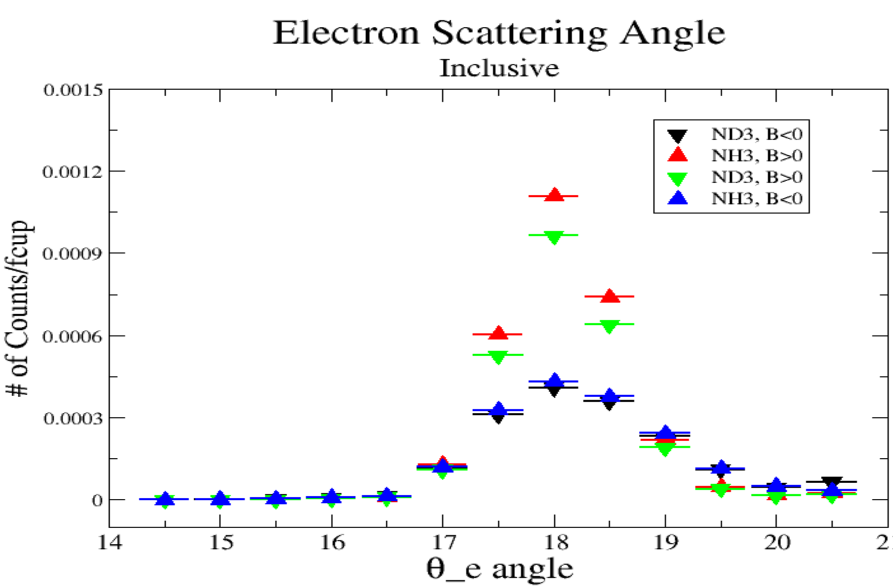


K. Park. (The CLAS Collaboration). *Phys. Rev.*, **C77**, 015208 (2008).

Inclusive Efficiencies







- Inclusive Case
- Electron kinematics
- Targets: NH3 and ND3(B<0 && B>0)
- Paddle Number of e- = 5(B>0) && Paddle Number of e- = 10 B<0

Ratios of The Inclusive Rate

$$\frac{ND3, B > 0, PaddleNumber^{e^-} = 5}{ND3, B < 0, PaddleNumber^{e^-} = 10} = 1.57 \pm 0.16$$

$$\frac{NH3, B > 0, PaddleNumber^{e^-} = 5}{NH3, B < 0, PaddleNumber^{e^-} = 10} = 1.76 \pm 0.17$$

$$\frac{ND3, B > 0, PaddleNumber^{e^-} = 5}{NH3, B < 0, PaddleNumber^{e^-} = 10} = 1.55 \pm 0.15$$

Electron Momentum=2.5 GeV, Electron Theta Angle=18 && W=1.7 GeV

The inclusive electron ratios are target independent

The “Correction Coefficient”

Exclusive Efficiencies

γ + proton $(NH_3) \longrightarrow \pi^+$ + neutron

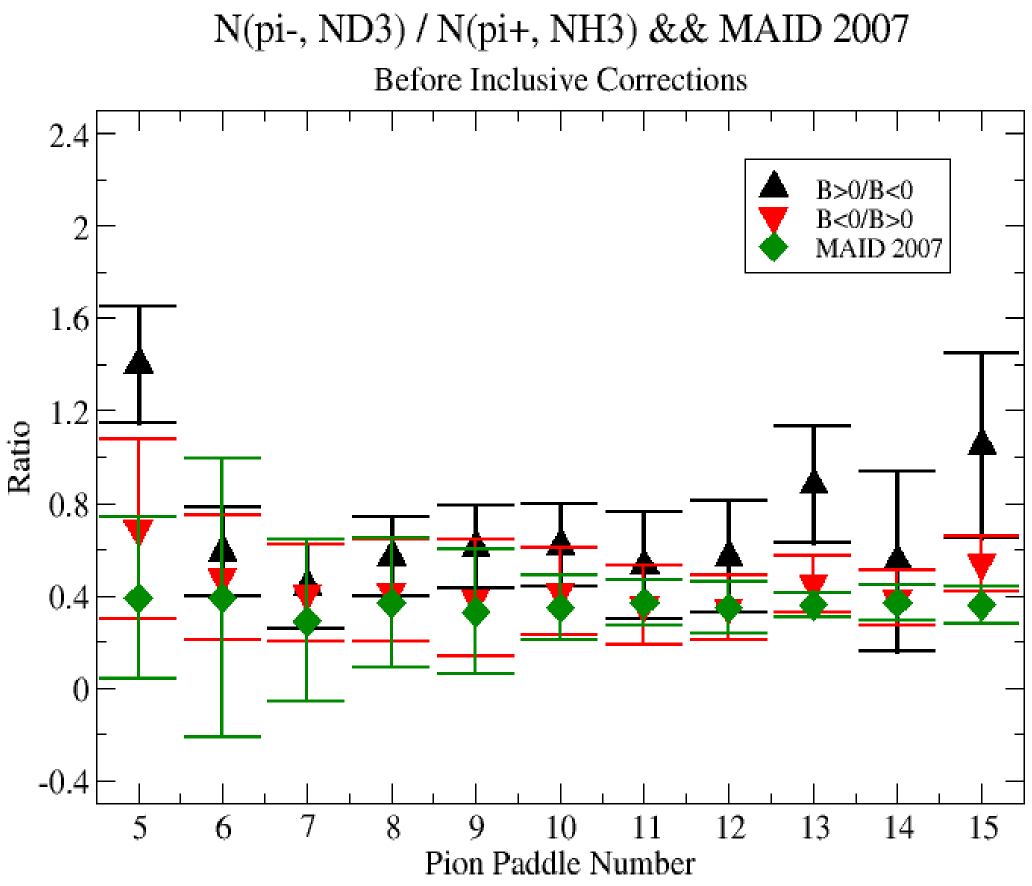
γ + neutron $(ND_3) \longrightarrow \pi^-$ + proton

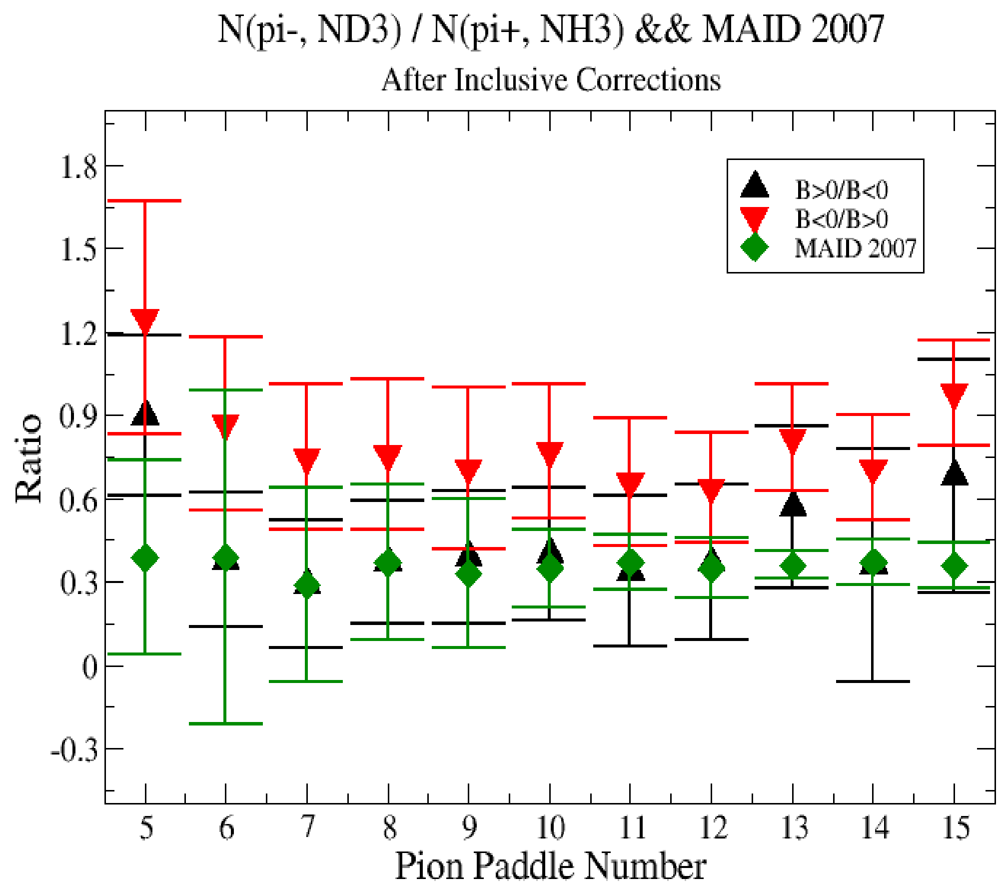
- Exclusive case
- Same Kinematics as above
- MAID 2007 Model
- Total Cross Section

1.7 GeV < W < 1.8 GeV && Q^2 = 1.1 GeV^2

$$\sigma = \sigma_T + \epsilon\sigma_L + \sqrt{2\epsilon(1+\epsilon)}\sigma_{LT} cos\phi_\pi{}^{CM} + \epsilon\sigma TT cos2\phi_\pi{}^{CM} + h\sqrt{2\epsilon(1-\epsilon)}\sigma_{LT'} sin\phi_\pi{}^{CM}$$

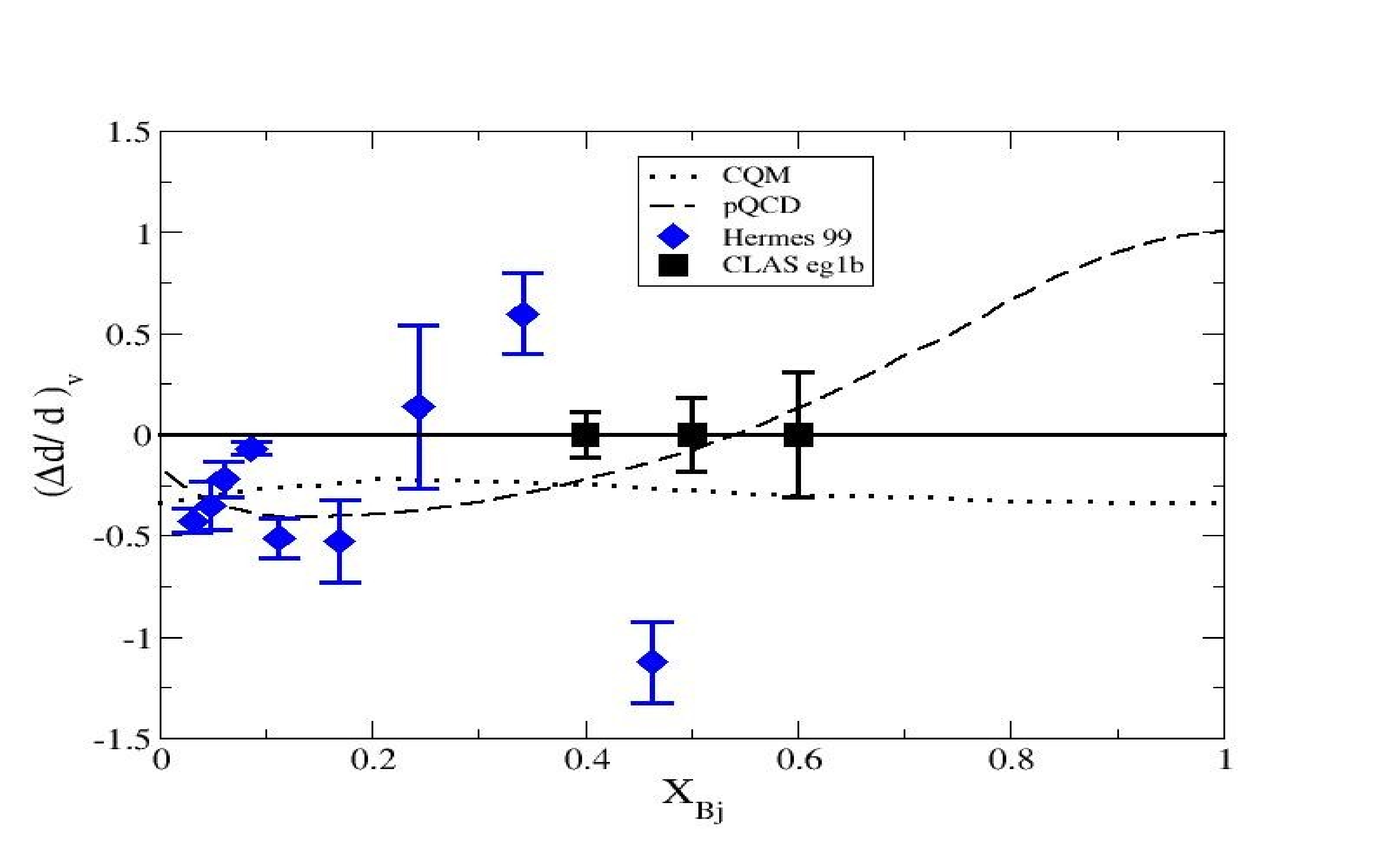
Exclusive Ratios





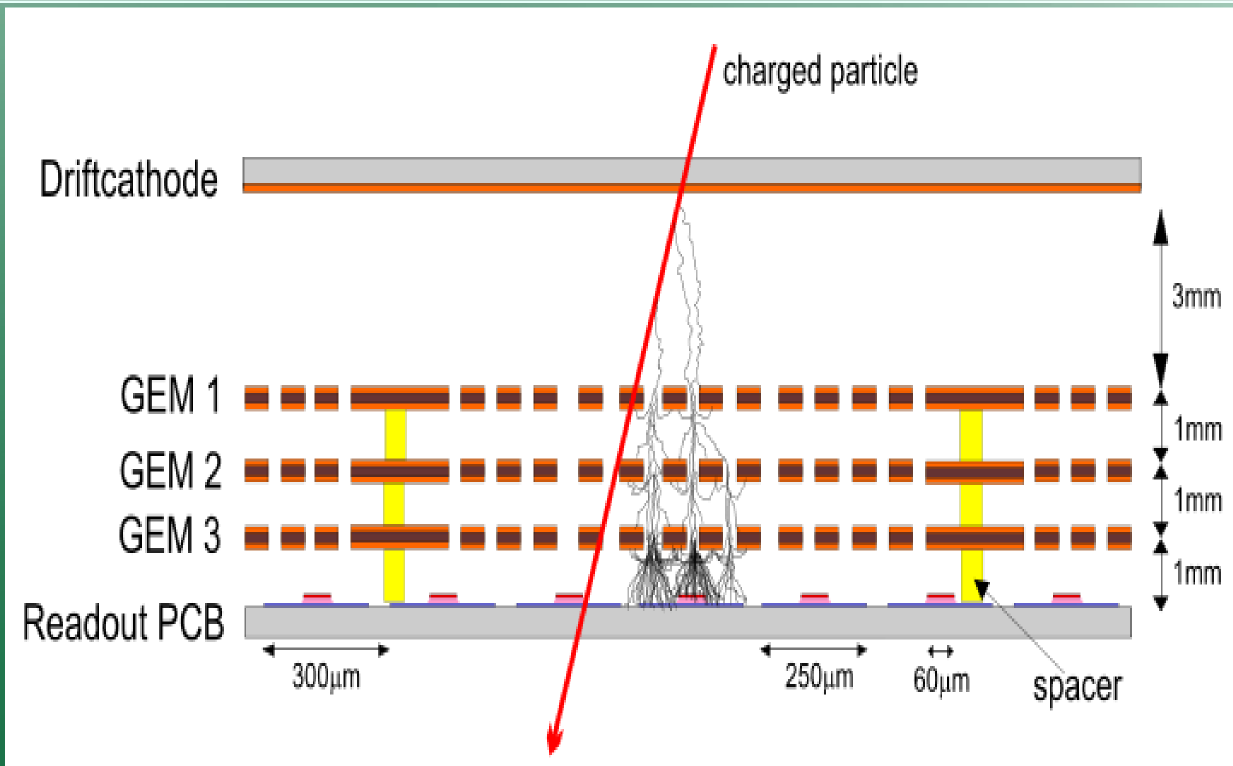
Before and after inclusive corrections

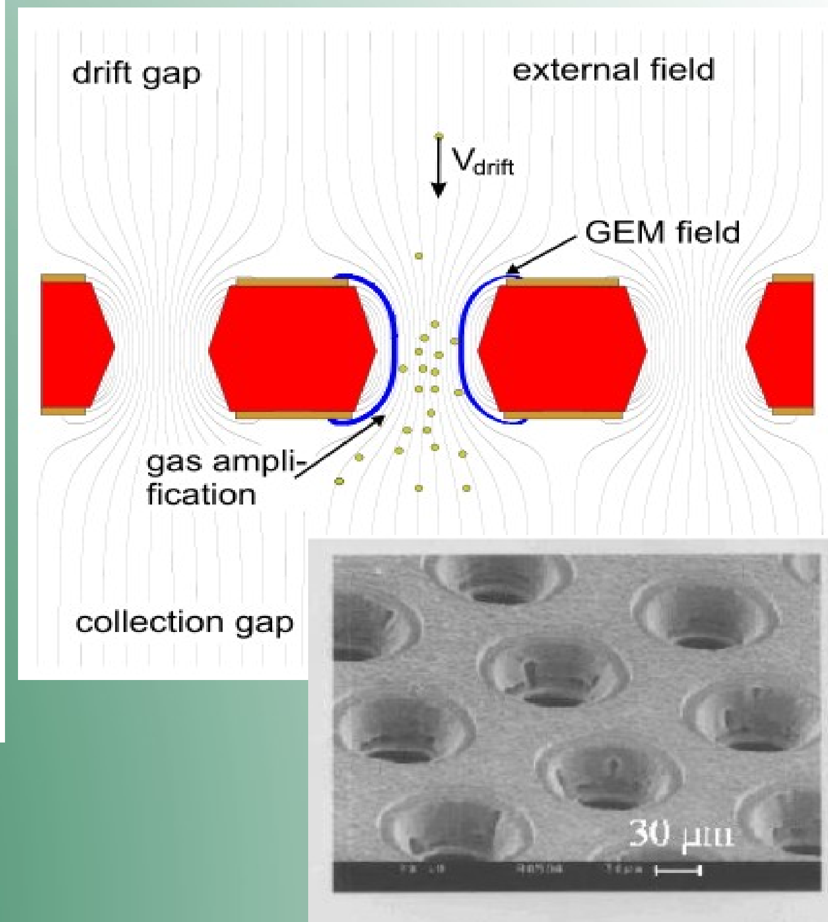
The Expected Precision of This Analysis



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

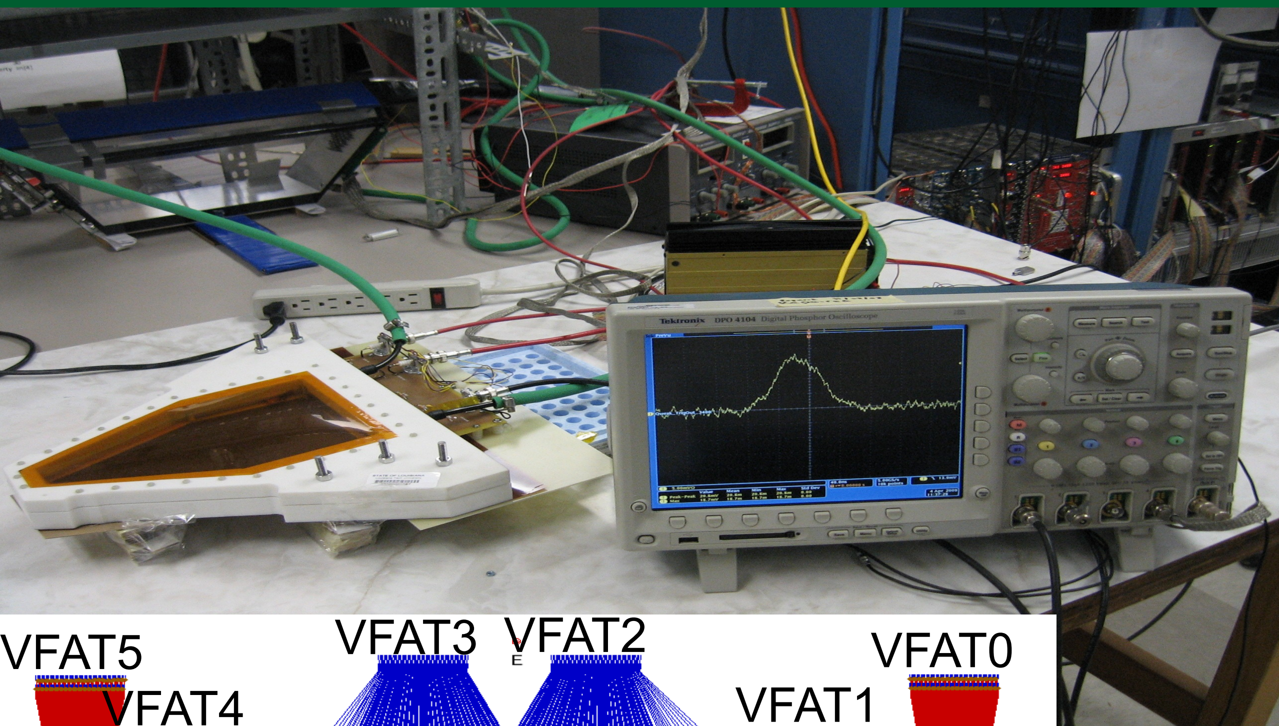
GEM Physics

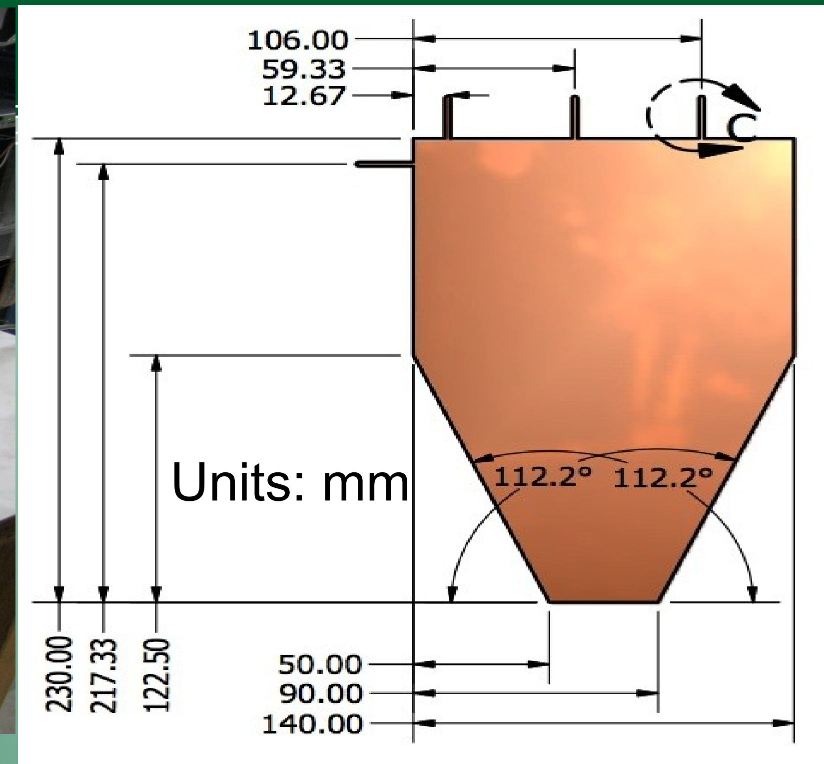


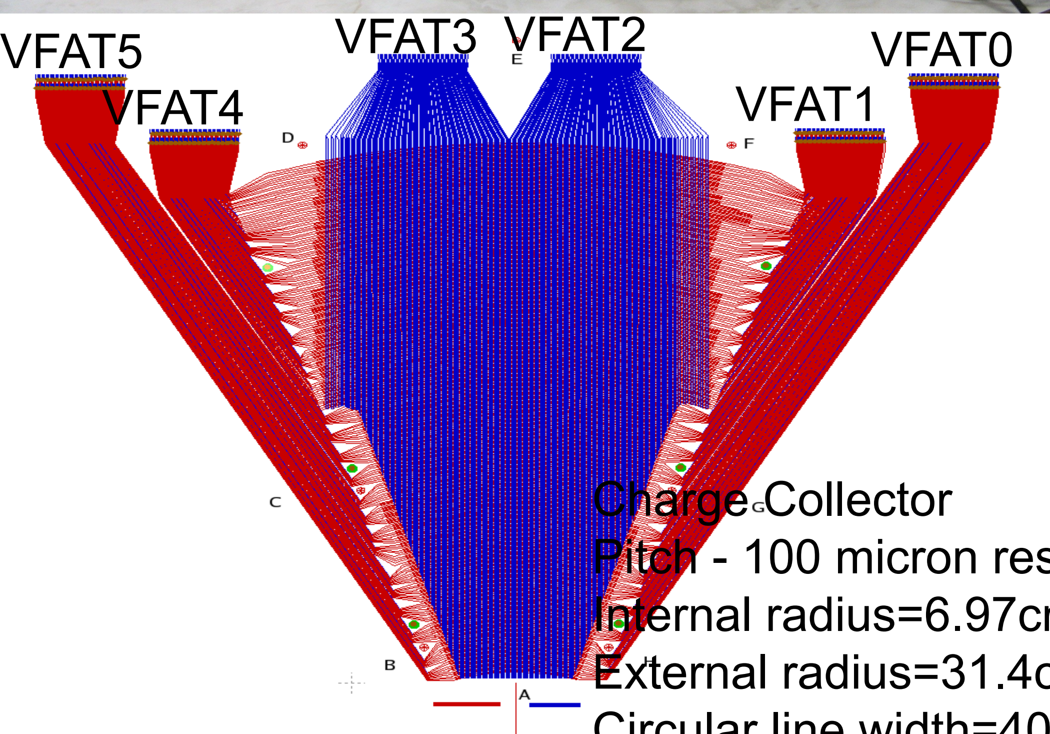


M. Ziegler, Ph.D Thesis, Development of a Triple GEM Detector for the LHCb Experiment(2002)

Qweak GEM Detector



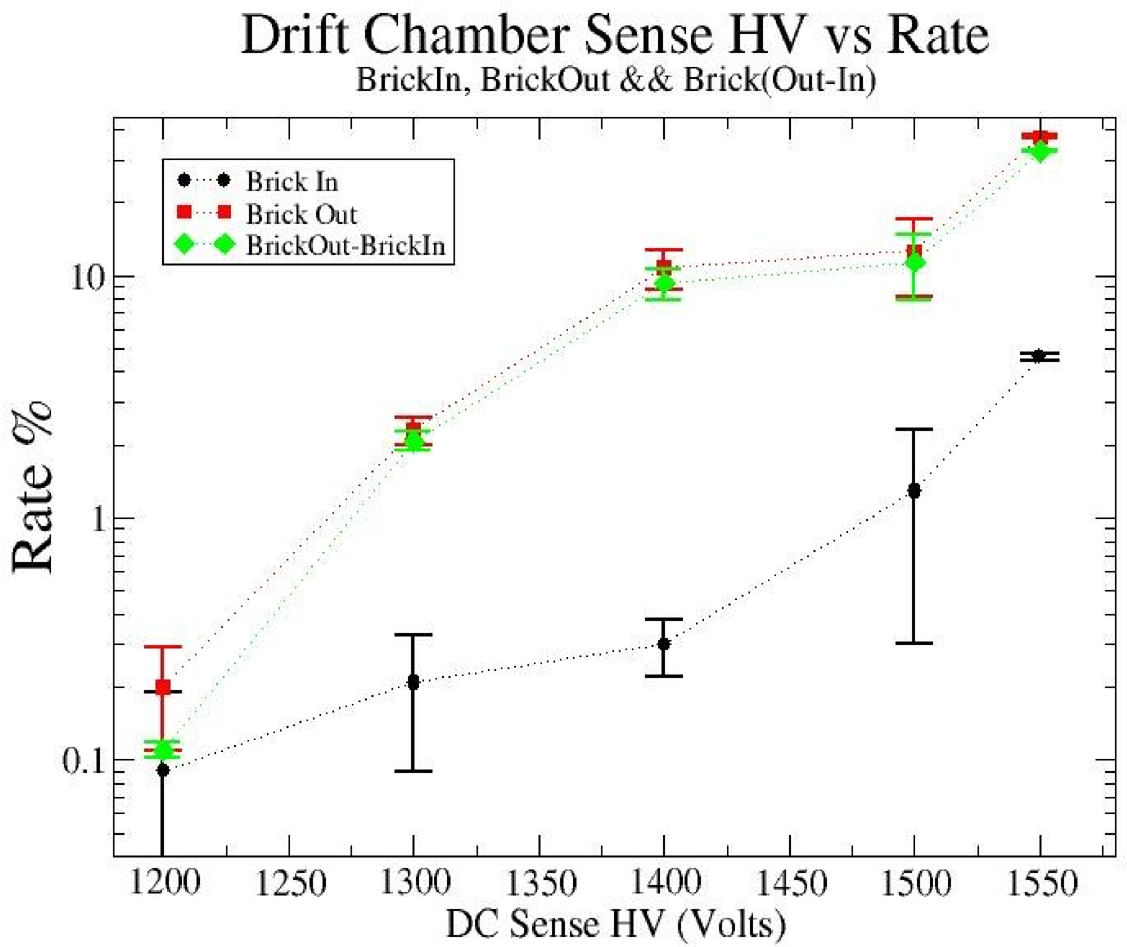




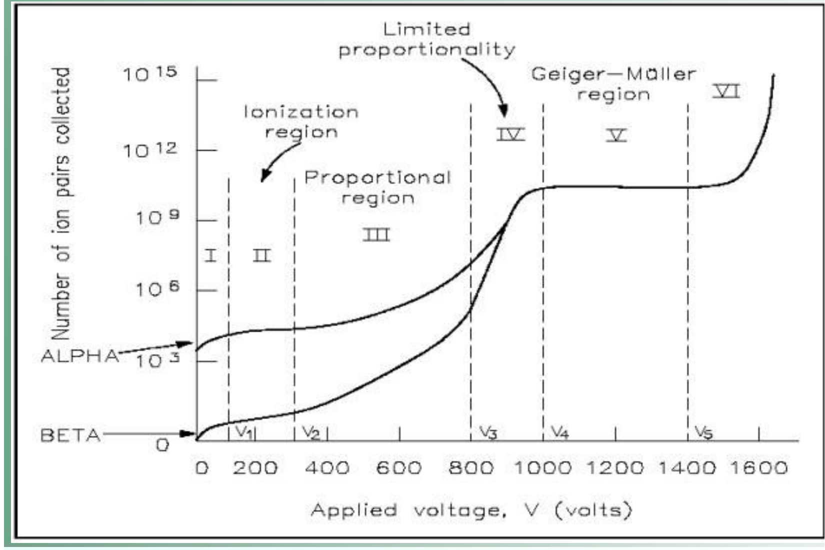
Charge Collector
Pitch - 100 micron resolution
Internal radius=6.97cm
External radius=31.4cm
Circular line width=400um

- The Ionization Chamber
- The Charge Collector
- The Amplifiers(GEM Foils)

Drift Chamber Plateau Measurement

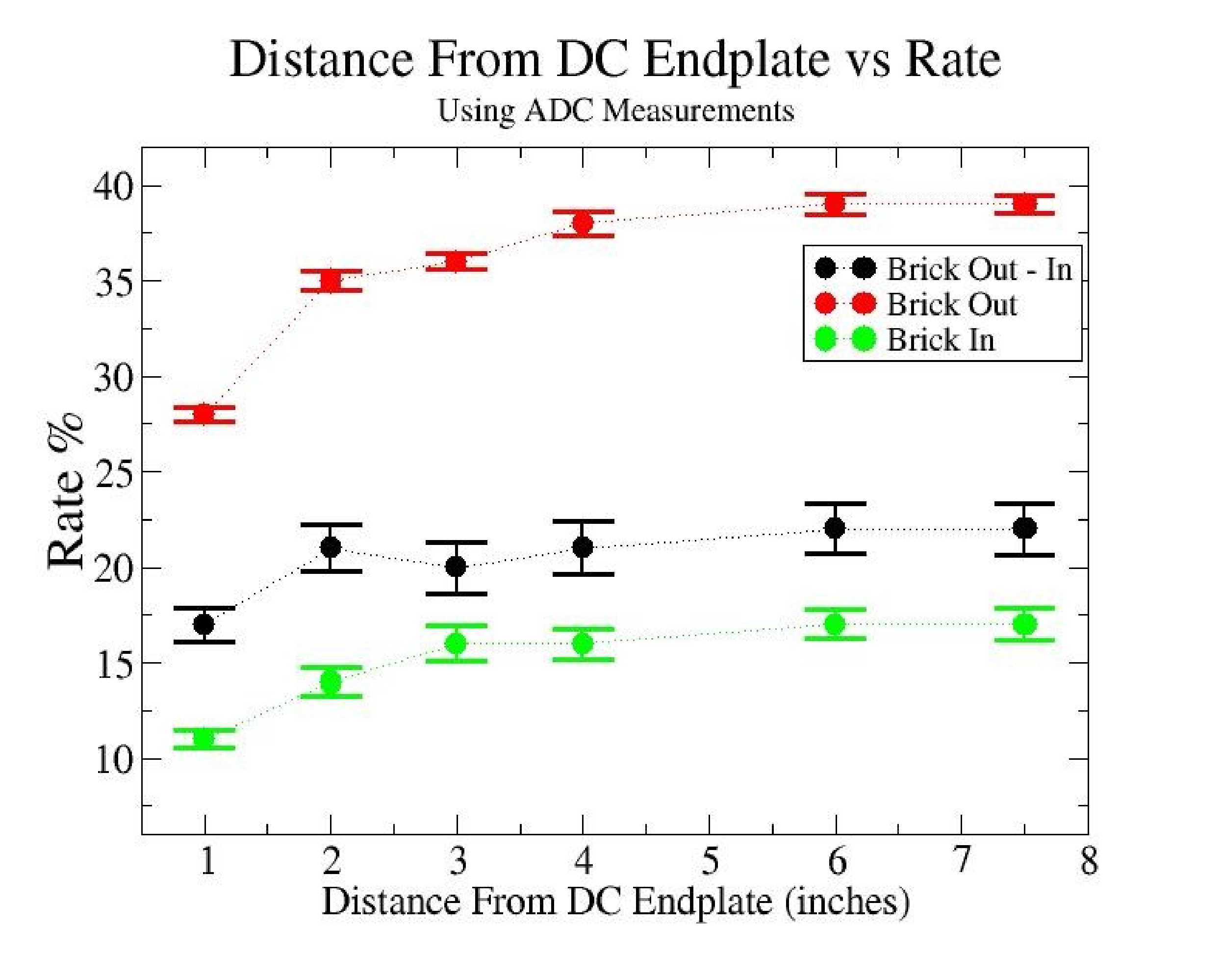


- 3 MeV electrons
- 2X4X8 Al brick shutter
- Scintillator + DC + RF
- ODU_Result=1400Volts



Rate=(DCSenseWire4 + FrontPMT + RF)/RF_Pulse

Drift Chamber(DC) Position Measurement



- DC sandwiched between PMTs
- DC Sense Voltage 1450 Volts
- Trigger = 3 PMTs + RF

Rate=ADC Counts(FC>1000 && ADC>80)/ADC Counts(FC>1000)