The BigBite Spectrometer: Tracking and Optics for the measurement of G_E^n at High Q^2 in Hall A

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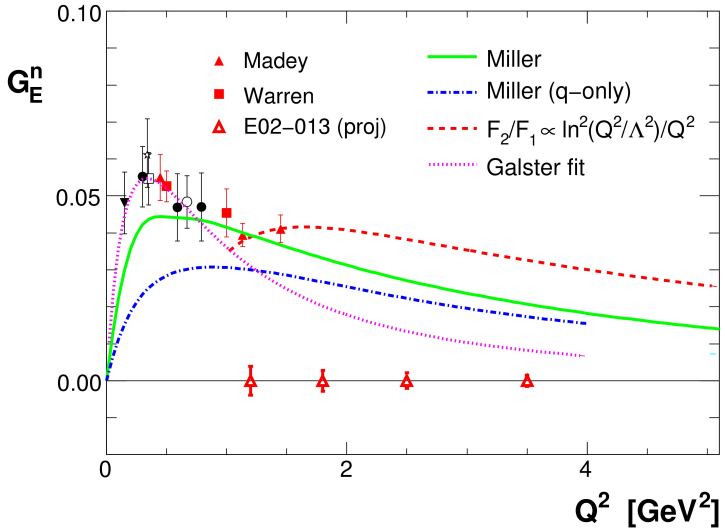
G_E^n Measurement Motivation

- G_E^n not well known compared to other nucleon form factors. Current high Q^2 measurements are imprecise



- Understanding the structure of the nucleon plays a key role in QCD and hadronic physics

- At high Q^2 pQCD can be applied for theoretical predictions, DIS is prevalent
- We wish to know where and how pQCD breaks down and give experimental evidence for theory to compare against
- GPDs provide link between parton distributions and Form Factors

$$F_1^n(t) = \int_0^1 dx \left[\frac{2}{3}H^d(x,\xi,t) - \frac{2}{3}H^u(x,\xi,t)\right] \tag{1}$$

$$F_2^n(t) = \int_0^1 dx \left[\frac{2}{3}E^d(x,\xi,t) - \frac{2}{3}E^u(x,\xi,t)\right] \tag{2}$$

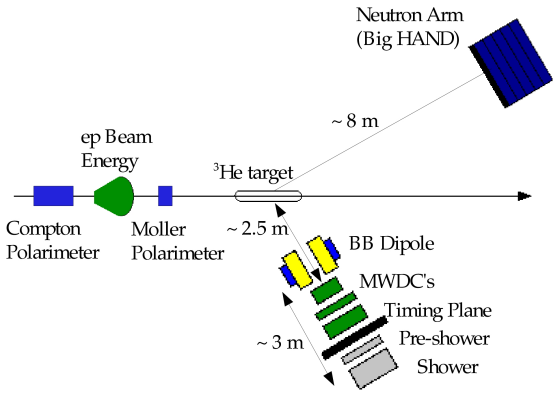
Taking forward limit (ignoring transverse momentum components)

$$\lim_{t\to 0,\xi\to 0} H^q(x,\xi,t) \to q(x) \tag{3}$$

- New G_E^n measurements will help constrain GPDs

Coincidence measurement of reaction $^3\overrightarrow{\mathrm{He}}(\vec{\mathrm{e}},\mathrm{e}'\mathrm{n})$

Quasielastic scattering asymmetry function of $\frac{G_E^n}{G_M^n}$

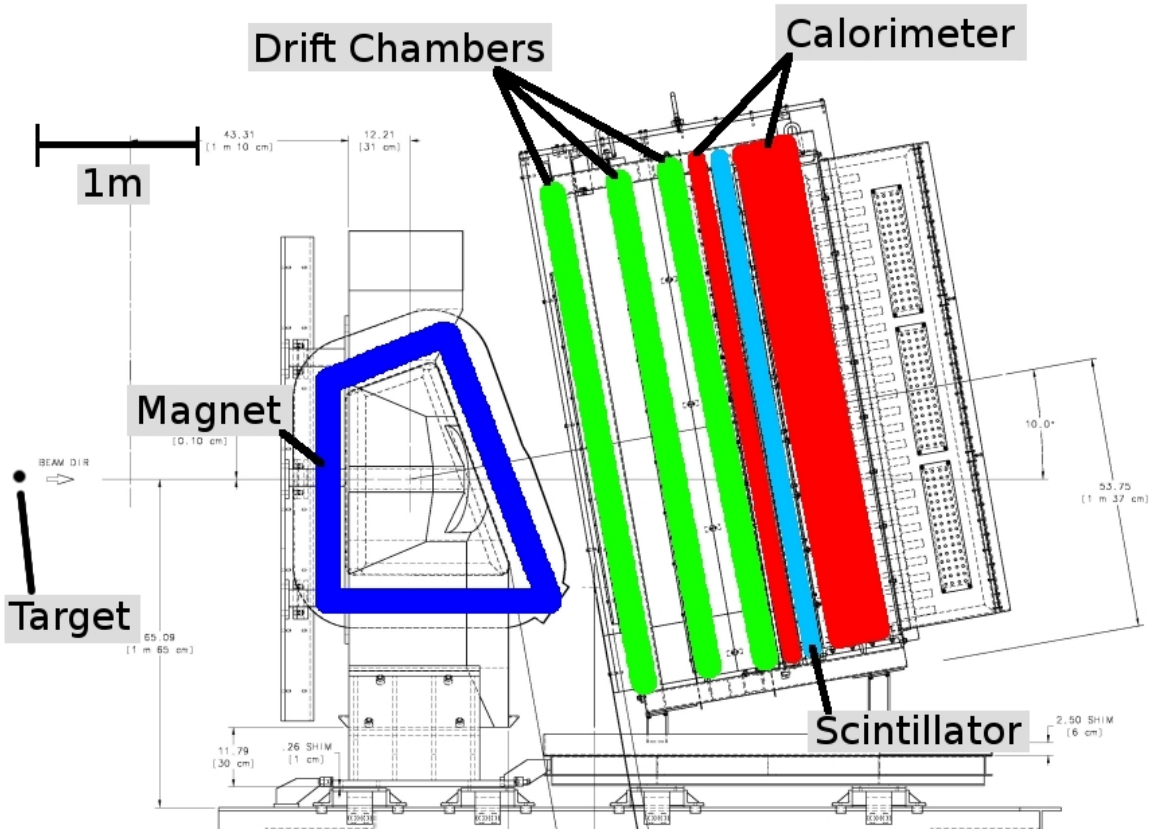


- Polarized $^3\mathrm{He}$ target provides highly polarized neutrons
- Neutron arm measures $\vec{p}_n$ through ToF; also differentiates between n and p
- BigBite measures $\vec{p}_{e'}$ to $\frac{\delta p}{p} =\sim\ 1\%$

The BigBite Spectrometer

- Non-focusing large angular and momentum acceptance spectrometer
- Approximately 76msr solid angle subtended for this experiment
- Single dipole magnet of field integral approximately 1.0 $\mathrm{T} \cdot \mathrm{m}$
- Accepting electrons between 1.0$\sim$1.5 GeV/c
- Total luminosity $5 \times 10^{36}\ \frac{\mathrm{Hz}}{\mathrm{cm}^2}$
- Newly constructed detector package first used for G_E^n

BigBite - Side View

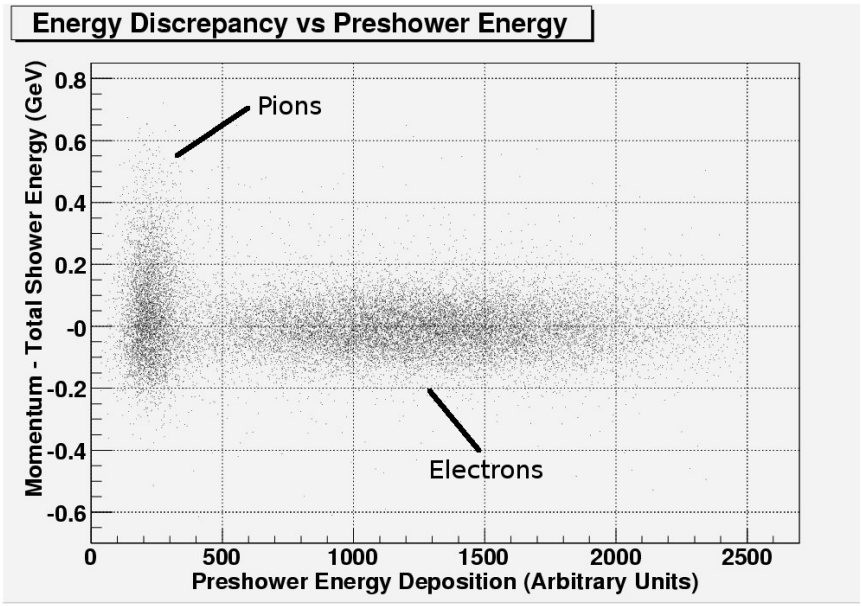


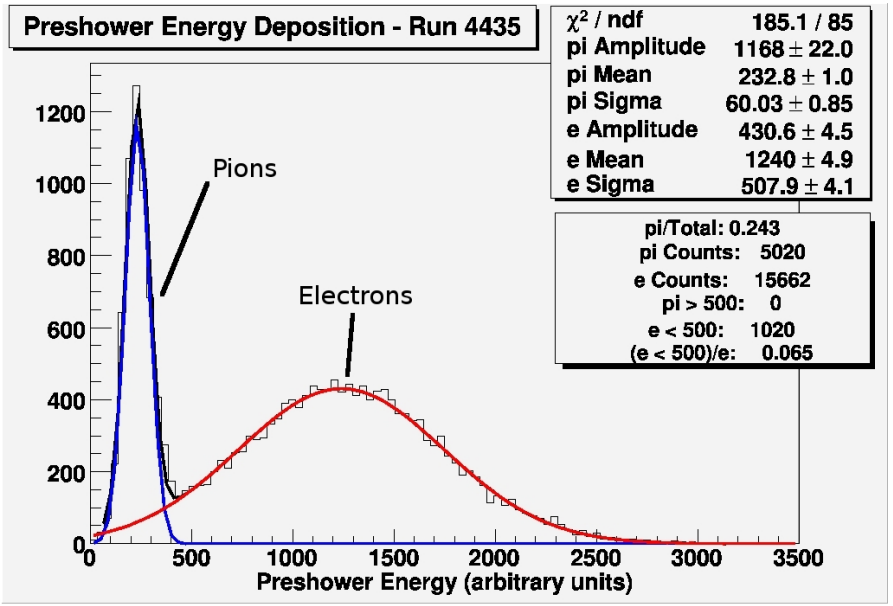
Detector Track Reconstruction

- Trigger defined by sum overlapping groups of shower blocks
- Rates in drift chambers per plane up to 20MHz
- Multiplicity per plane roughly 5 presenting complexity in tracking
- Track reconstruction starts at shower to provide background free information about track of interest

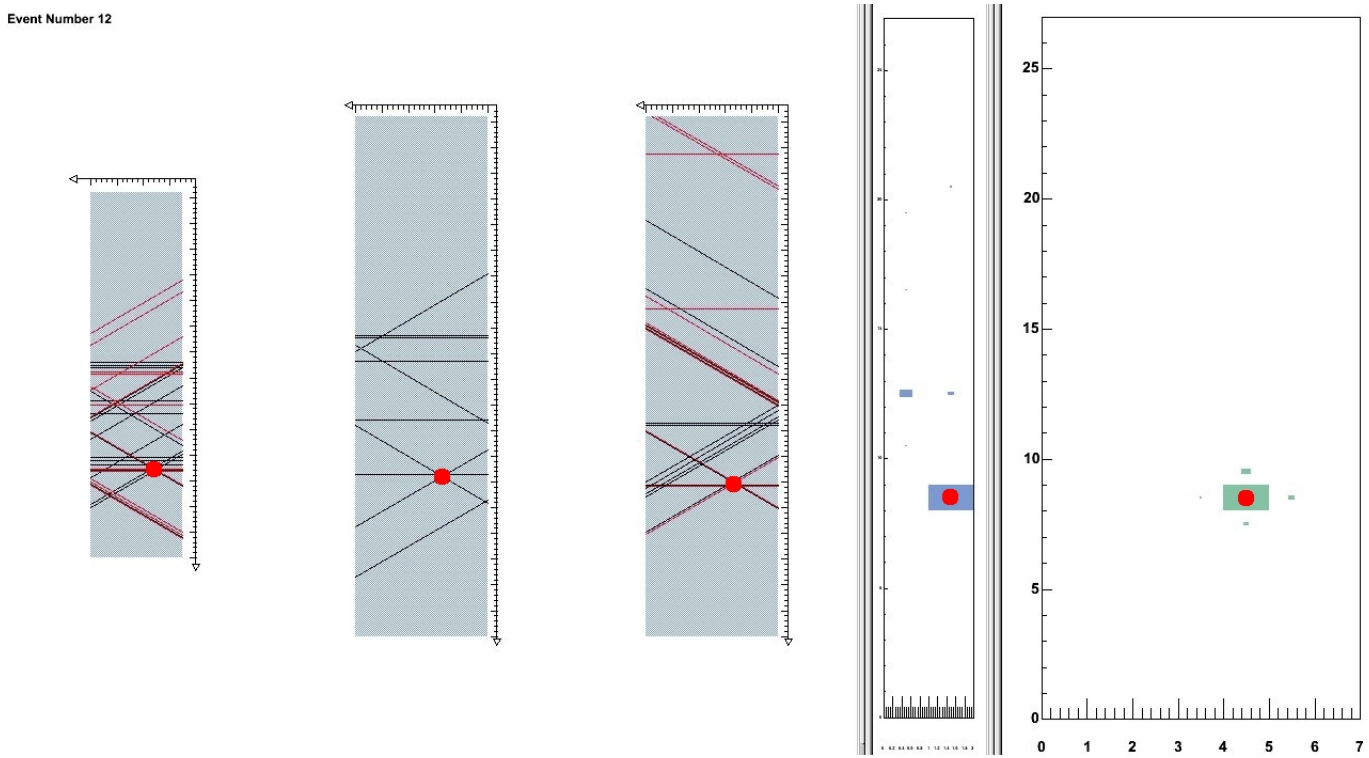
Preshower/Shower rejects pions

Total Shower Resolution $\frac{\delta A}{A} = \sim 10\%$

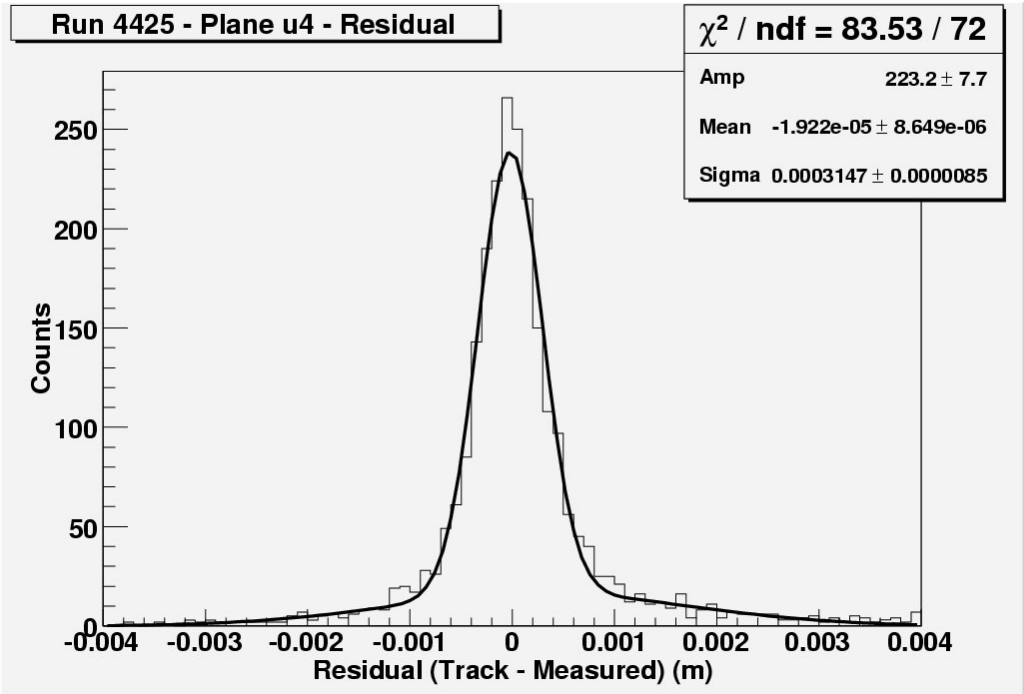




Chambers iterate over combinations of remaining wire hits to identify track



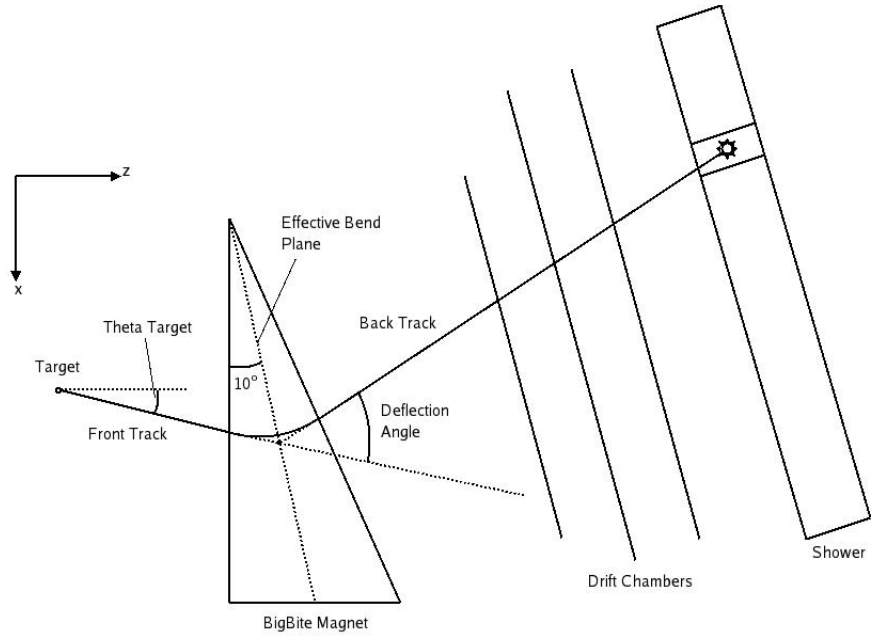
Spatial resolution per plane achieved $\sigma_{plane} = 300 \sim 350\mu\mathrm{m}$.



Reconstruction Resolution:	
σ_x	$130\mu\mathrm{m}$
σ_y	$300\mu\mathrm{m}$
σ_θ	$0.3\mathrm{mr}$
σ_ϕ	$0.7\mathrm{mr}$

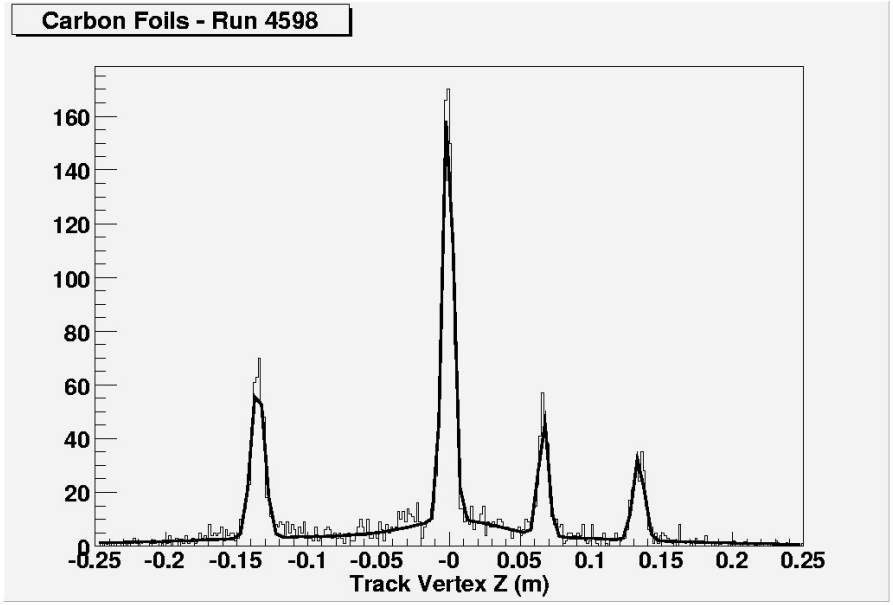
Optics and Momentum Reconstruction

Optics are done using simple dipole model with first order corrections



Treat all interaction at magnetic midplane

Use carbon foil data to ensure fitting done correctly



Resolution along beamline 3.9mm sigma

This differs from theoretical expectation of 6mm

Scattering angle of elastic events from H_2 target used to calibrate momentum:

$$p_{elas} = \frac{E_{beam} m_p}{m_p + E_{beam}(1 - \cos\theta_{scat})} \tag{4}$$

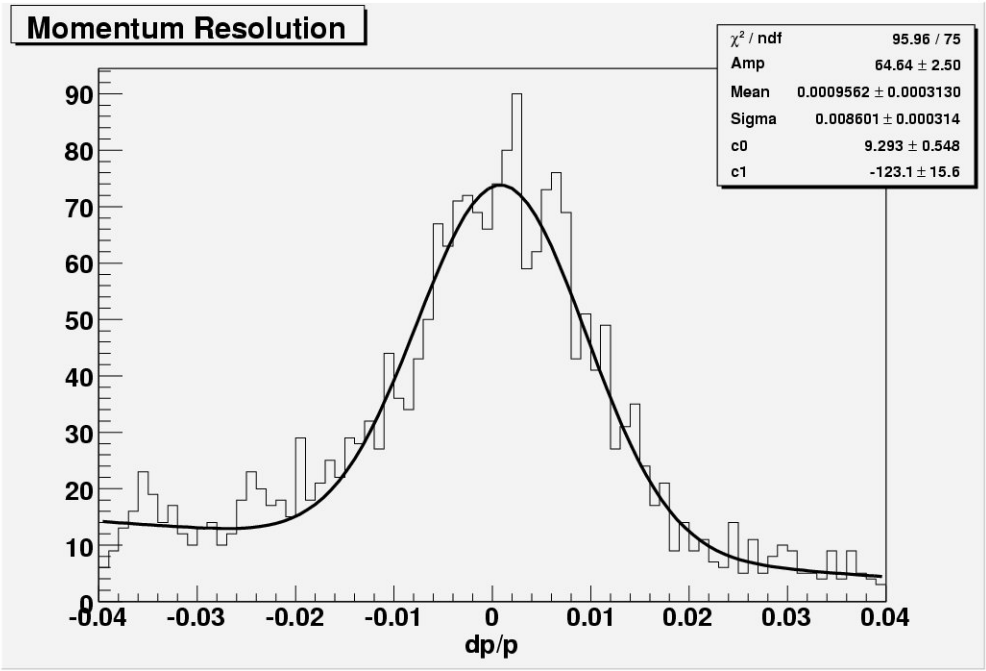
Use simple equation for momentum

$$p = \frac{c_0 + c_x x_{bend}}{\vartheta_{def}} + c_\vartheta \vartheta_{targ} + c_y y_{det} + c_\varphi y'_{det} \tag{5}$$

$$\vartheta_{def} = \cos^{-1}\left(\frac{\vec{x}_{front} \cdot \vec{x}_{back}}{|\vec{x}_{front}||\vec{x}_{back}|}\right) \tag{6}$$

Spatial resolution $\sim 300 \mu\mathrm{m}$

Momentum resolution roughly 0.86% - 0.6% expected



BigBite Future

- Data taken successful
- Approved for at least 5 new experiments
- BigBite Scheduling exceeds 2 years of experiment run time
- 1 experiment approved and 4 proposed after 12GeV upgrade at CEBAF

Summary

- This experiment will reduce uncertainty in G_E^n by order of magnitude at high Q^2
- G_E^n preliminary analysis obtained $\frac{\delta p}{p} = 1\%$
- Analysis package developed to understand and analyze data in spectrometer to handle high rates of 20MHz per plane and provides clean quasielastic and elastic data
- Spectrometer of 76msr and operated at luminosity at $5{\times}10^{36}$ $\frac{\mathrm{Hz}}{\mathrm{cm}^2}$ will continue to be used for further experiments