E02-013 Analysis Update

Precision Measurements of G_E^n at High Q^2

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for the E02-013 Collaboration

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Spokespeople:

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- Gordon Cates
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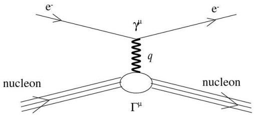
PhD Students:

- Sergey Abrahamyan - BigBite Calorimeter/Simulations
- Brandon Craver - BigBite Multiple Wire Drift Chambers
- Aidan Kelleher - Polarized ^{3}He Target
- Ameya Kolarkar - Polarized ^{3}He Target
- Jonathan Miller - Neutron Arm
- Seamus Riordan - BigBite Tracking and Optics

Masters Students:

- Tim Ngo - Neutron Arm Survey Analysis

Scattering from spin 1/2 point particle:



$$\left.\frac{d\sigma}{d\Omega}\right|_{\text{point}} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \left[1+2\tau\tan^2\frac{\theta}{2}\right]$$

where $\left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} = \left(\frac{\alpha\cos\frac{\theta}{2}}{2E\sin^2\frac{\theta}{2}}\right)^2\frac{E'}{E}$,

$\tau = \frac{Q^2}{4M^2}$

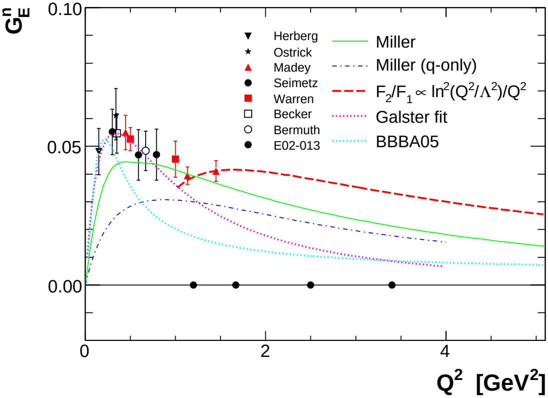
For spin 1/2 particle with structure:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \left[\left({F_1}^2 + \tau\kappa {F_2}^2\right) + 2\tau\left(F_1 + \kappa F_2\right)^2\tan^2\frac{\theta}{2}\right]$$

or with Sachs form factors:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \left[\frac{{G_E}^2 + \tau {G_M}^2}{1+\tau} + 2\tau {G_M}^2\tan^2\frac{\theta}{2}\right]$$

E02-013 ran from February - May 2006



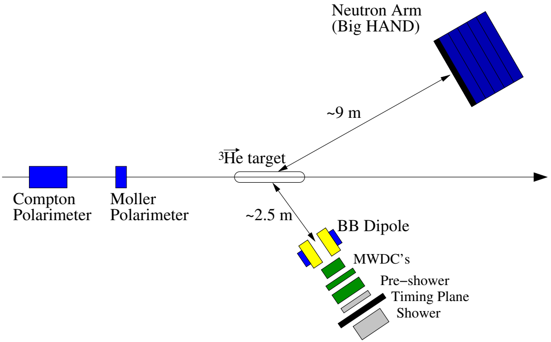
Took data for 4 kinematic points

E02-013 measures G_E^n through $^3\overrightarrow{\mathrm{He}}(\vec{\mathrm{e}},\mathrm{e}'\mathrm{n})$
Quasielastic crosssection asymmetry depends on $\frac{G_E}{G_M} = \Lambda$

$$A = \frac{\Delta}{\Sigma} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

$$\begin{aligned} A &= -\frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)\Lambda \sin\theta^* \cos\phi^*}{\Lambda^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))} \\ &\quad -\frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2(\theta/2)}\tan(\theta/2)\cos\theta^*}{\Lambda^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))} \end{aligned} \quad (1)$$

θ^*, ϕ^* are polar, azimuthal angles of $\vec{q}$ w.r.t. target polarization and scattering plane

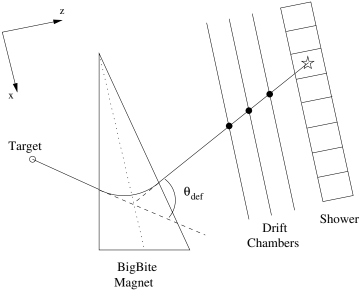


- Polarized ^3He provides effective polarized neutron target - achieved 45∼50%
- Neutron arm measures $\vec{p}_n$ through ToF; differentiates between n and p
- BigBite spectrometer measures $\vec{p}_{e'}$ to $\sigma_{\frac{\delta p}{p}} \approx 1\%$ for 95% of 76 msr acceptance

Current Status

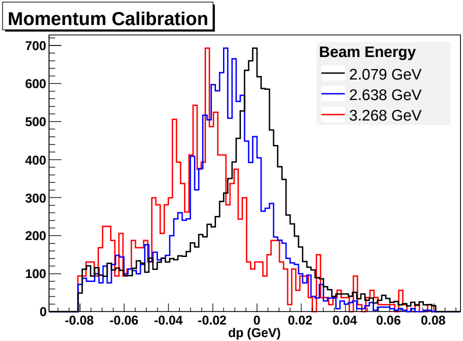
- Completed software developement/debugging
- Completed preliminary data analysis/debugging
- Analysis transitioning from calibration to preliminary results
- Calibrations complete for
  - BigBite
  - Target Polarization/polarization angle
  - Neutron arm timing calibration
- Preliminary 1.7 GeV^2 point presented at DNP2007
- Results for highest point expected in early 2007
- Still much work to do for final results

Treat all interaction in magnetic midplane



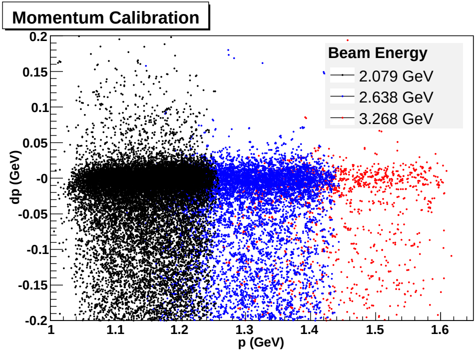
Apply first order corrections to leading order $p \sim \frac{\int B_\perp dl}{\theta}$
Calibrate using H_2 elastic scattering and carbon foils of known positions

Initial optics calibrations not consistant across all kinematics



Linear transformation of function vs p resolves kinematic problem

$$p' = cp + a$$



Vertex reconstruction modified by:

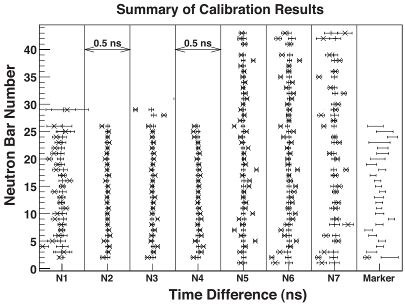
$$v_{z,\mathrm{LAB}} = c_0 z_0 + c_x x_{\mathrm{det}} + c_{x'} x'_{\mathrm{det}} + c_y y_{\mathrm{det}} + c_{y'} y'_{\mathrm{det}} + a(x_{\mathrm{bend}}, y_{\mathrm{bend}})$$

Momentum reconstruction

$$p = \frac{c_0(x_{\mathrm{bend}}, y_{\mathrm{bend}}) + c_x x_{\mathrm{bend}}}{\vartheta_{\mathrm{def}}} + c_\vartheta \vartheta_{\mathrm{targ}} + c_y y_{\mathrm{det}} + c_\varphi y'_{\mathrm{det}} + a$$

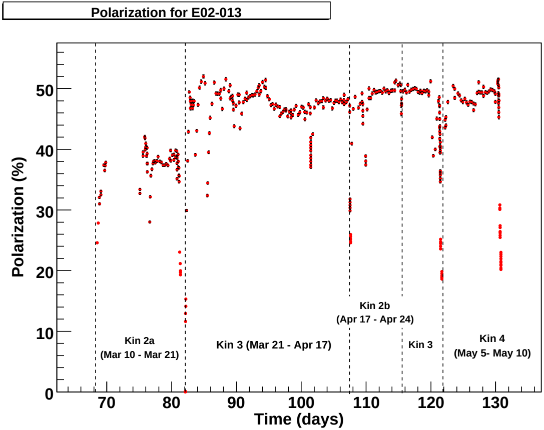
- x_{bend}, y_{bend} dependent coefficients allow for reconstruction in extreme vertical regions of the magnet
- Resolution $\sigma_{\frac{\delta p}{p}} \sim 1\%$ for 95% of 76 msr acceptance

Software developed to handle timing calibration of 400 PMTs in the neutron arm

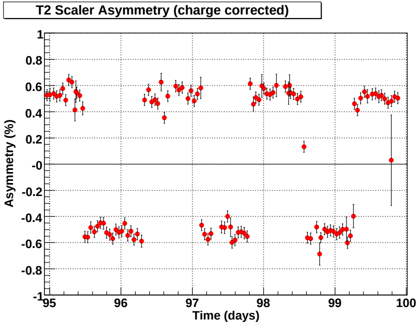


Acheived roughly $\sigma_t = 380\text{ps}$

Polarization of target has been calculated for entire run period



- Raw asymmetries can be seen purely in scaler rates
- Can be used to verify HWP/target direction flips

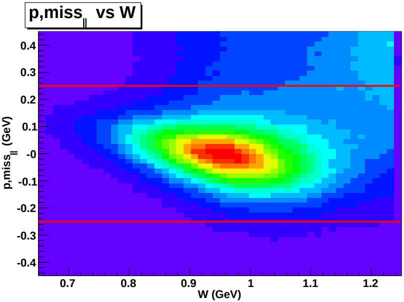


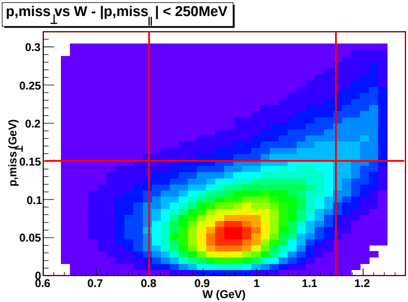
- Includes additional π^- production asymmetry

Quasielastic Neutron Selection

Quasielastic selection done by using $p_{\text{miss},\parallel}$, $p_{\text{miss},\perp}$, and W where $\vec{p}_{\text{miss}} = \vec{q} - \vec{p}_{\text{NA}}$

- For $Q^2 = 1.7\text{GeV}^2$:





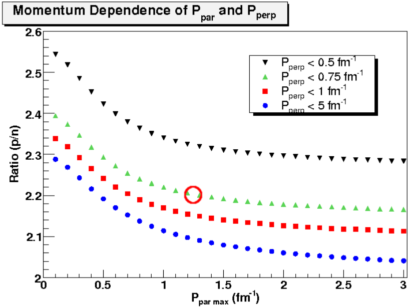
- Asymmetry sensitive to proton contamination in neutron sample and must be corrected
- Expect around 30% of neutron sample to be misidentified protons

$$A_{raw} = \frac{N_+ - N_-}{N_+ + N_-}$$

$$A_{n,raw} = \frac{N_+ - N_- - (N_{+,\mathrm{prot}} - N_{-,\mathrm{prot}})}{N - N_{\mathrm{prot}}} = \frac{1}{D_{\mathrm{prot}}} A_{raw} - \frac{1 - D_{\mathrm{prot}}}{D_{\mathrm{prot}}} A_{\mathrm{prot}}$$

- By using charged/uncharged ratios of three targets: H_2, ^3He, N_2 can calculate efficiency of veto and charge tagging
- Error can contribute significantly to systematics

- Theory used to calculate relative density of p and n in $^3\mathrm{He}$ for our cuts
- Naively expect 2:1 for $^3\mathrm{He}$

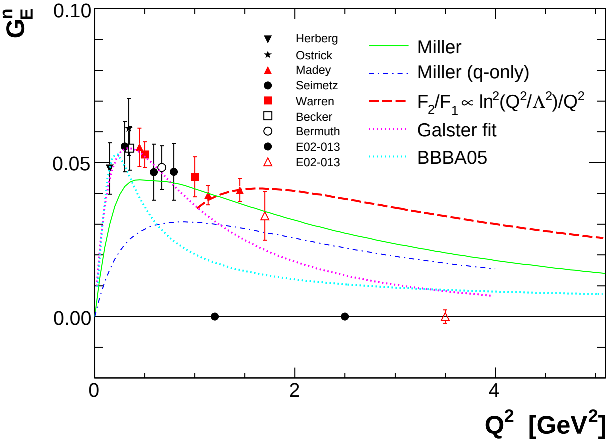


- Used in determination of $p \rightarrow n$ misidentification

G_E^n calculation

Raw n asymmetry	0.0510 ± 0.0026
Average Q^2	$1.67\ \mathrm{GeV}^2$
n background asymmetry	0.0144 ± 0.0074
$p \longrightarrow n$ dilution	0.7016 ± 0.0437
Proton G_E/G_M	0.293
Average target polarization	0.482 ± 0.020
Beam Polarization	0.85 ± 0.02
N_2 dilution	0.950 ± 0.020
Neutron polarization in $^3\mathrm{He}$ target	0.86 ± 0.02
p/n density	2.2
Est. Glauber Correction	0.95 ± 0.05
G_M^n	-0.1677
G_E^n	0.03271 ± 0.0073

- Preliminary results for $Q^2 = 1.7\ \mathrm{GeV}^2$ presented at DNP



3.4 GeV^2 Kinematic Status

- Have roughly 500 runs to analyze
- Elastic cross section significantly smaller than $Q^2 = 1.7\mathrm{GeV}^2$ by factor of 20
- Have roughly 25000 QE events - Expect $\times$1.5$\sim$2.0 more with more analysis
- Preliminary analysis for data done
- Looking at variation of cuts
- Looking at veto analysis

To Do

- 1.2 and 2.5 GeV^2 analysis
- Veto Analysis
- BigBite timing calibration could improve resolution
- BigBite calorimeter calibrations
- Full scale Monte Carlo analysis

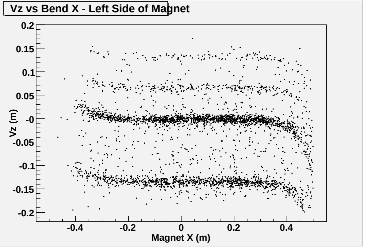
Conclusion

- BigBite optics consistant for different kinematics for 95% acceptance
- Neutron arm timing and target polarization now well calibrated
- Preliminary 1.7 GeV^2 point calculated
- More results expected in early 2007

kin. #	E_{beam}, GeV	average $\theta_{e'}$, degrees	Q^2, $(\mathrm{GeV}/c)^2$	Q_{beam} Coulomb
1	1.519	56.26	1.2	1.2
2	2.640	51.59	2.5	5.5
3	3.291	51.59	3.4	11.4
4	2.079	51.59	1.7	2.2

BigBite vertex reconstruction problematic in extreme regions of acceptance

Left



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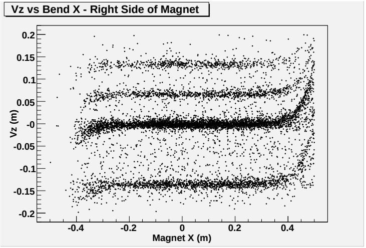

Momentum reconstruction also problematic

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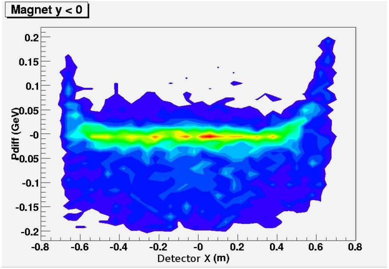

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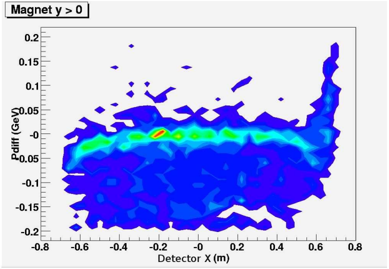

- π^- production asymmetry expected for different helicities
- Useful for higher Q^2 runs