Highest Q^2 Polarized Measurement of the Electric Form Factor of the Neutron – E02-013

Presented by
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For the Hall A E02-013 Collaboration
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Overview

- Introduction
- Electric Form Factor of the Neutron
- Quasi-elastic Process Selection
- New Techniques
- Asymmetry Calculation and Results
- Conclusions and Future

Collaborators

Name	Institution	Responsibility
Gordon Cates	University of Virginia	Spokesperson
Nilanga Liyanage	University of Virginia	Spokesperson
Bogdan Wojtsekhowski	Jefferson Lab	Spokesperson
Robert Feuerbach	William and Mary	Post Doc and Analysis Coordinator
Current Students		
Sergey Abrahamyan	University of Yerevan	Monte Carlo, Shower and Analysis of Q^2 = 1.2 GeV^2
Brandon Craver	University of Virginia	Drift Chambers
Aidan Kelleher	William and Mary	Target and Analysis of Q^2 = 1.7 and 2.5 GeV^2
Jonathan Miller	University of Maryland	Neutron Arm and Analysis of Q^2 = 1.7, 2.5, and 2.5 GeV^2
Graduated		
Seamus Riordan, PhD	Carnegie Mellon E02-013 Post Doc	Analysis Software and Analysis of Q^2 = 1.7 and 3.5 GeV^2 and Post Doc
Tim Ngo, MS	University of California	Neutron Arm Geometry
Ameya Kolarkar, PhD	University of Kentucky	Target

The Electric Form Factor of the Neutron

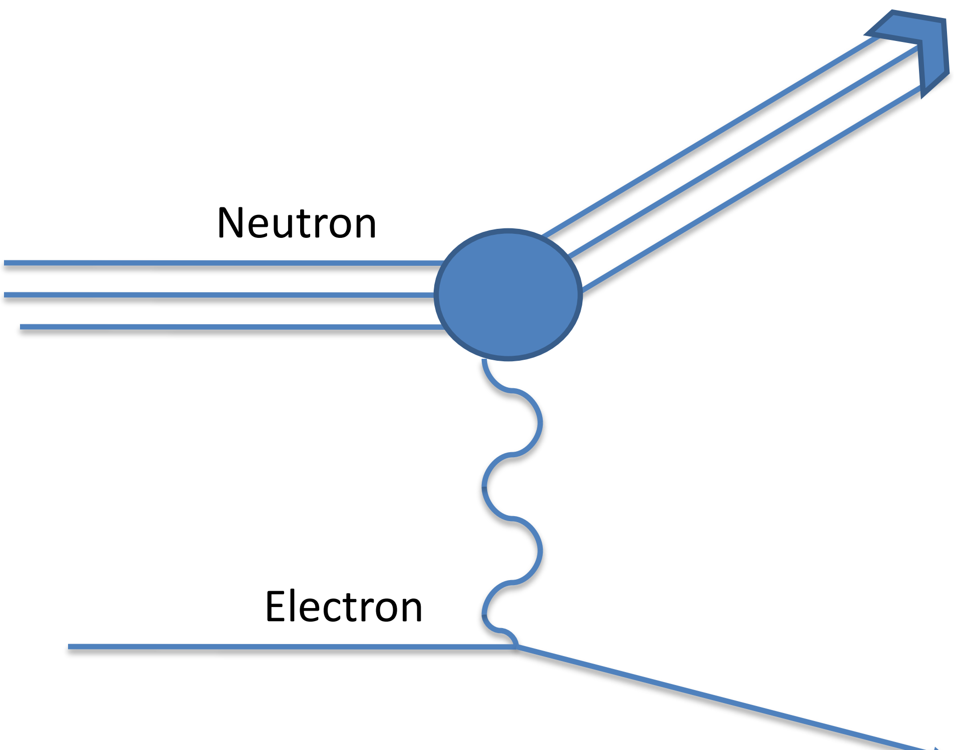
$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \frac{E_f}{E_i}\left[\frac{G_E^2 + \tau G_M^2}{1+\tau} + 2\tau G_M^2 \tan^2\frac{\theta}{2}\right]$$

$$\left(\frac{d\sigma}{d\Omega}\right)_{Mott} = \left(\frac{\alpha \cos\frac{\theta}{2}}{2E_i \sin^2\frac{\theta}{2}}\right)^2$$

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

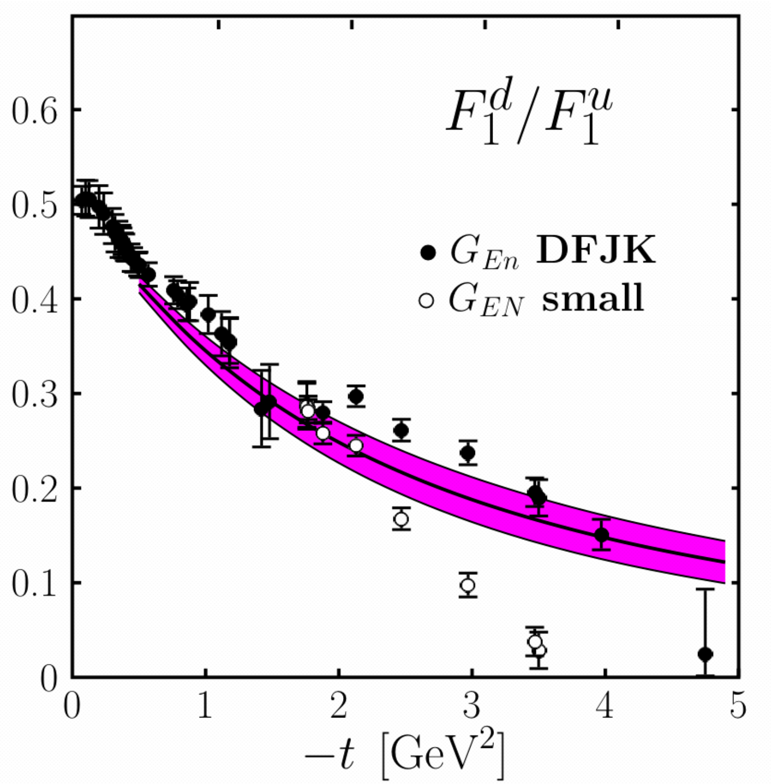
$$G_E^n\left(Q^2 = 0\right) = 0$$

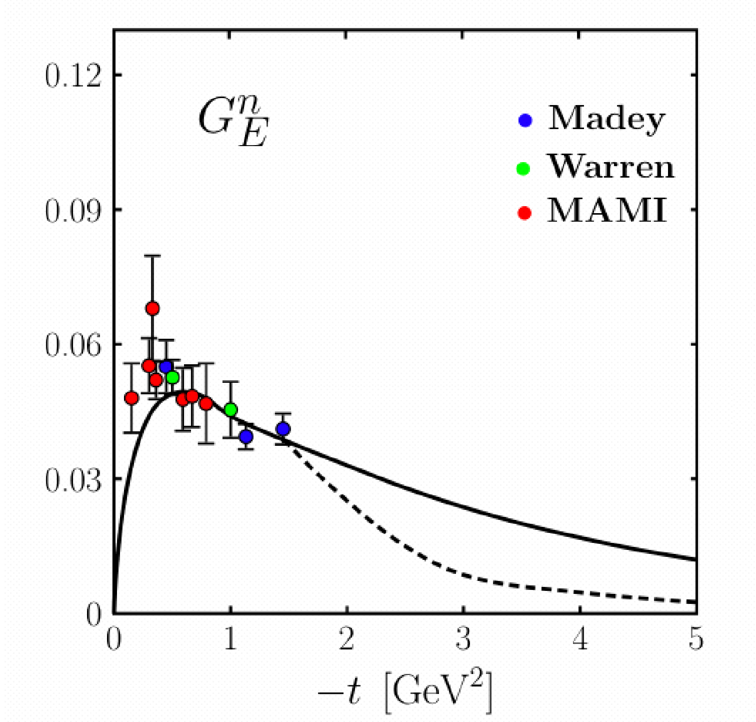
$$G_M^n\left(Q^2 = 0\right) = \mu_n$$



Generalized Parton Distributions

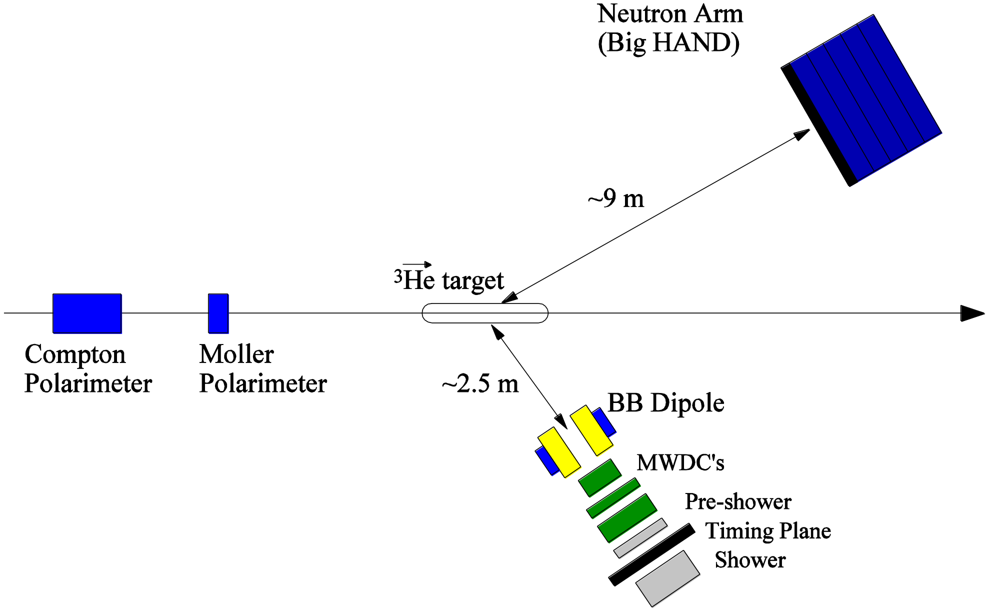
Using GPDs, the ratio of the up and down flavor components of the Dirac form factor are constrained by a measurement of the Sachs electric form factor.





A smaller value of G_e^n relates to a smaller value of the ratio.

What are we using to make the measurement?



- CEBAF provides a polarized (83%) electron beam.
- The Target provides high polarization throughout the experiment (45-50%).
- Big Bite provides the trigger, and selects for scattered electron events.
- The Neutron Arm provides selection of quasi-elastic events (using time of flight and hit location) and charge identification.

How are we measuring G_E^n?

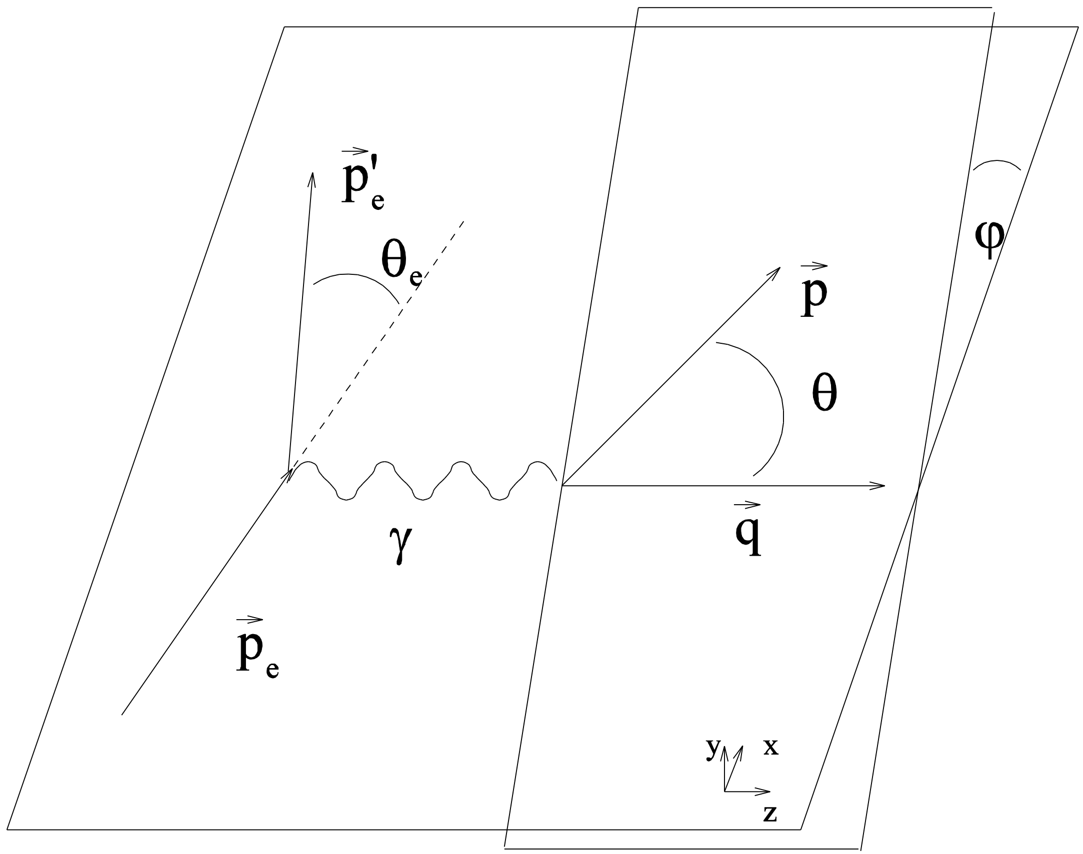
$$\overrightarrow{{}^3He}(\vec{e}, e'n)$$

$$\sigma^{pol} = \Sigma + h\Delta$$

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

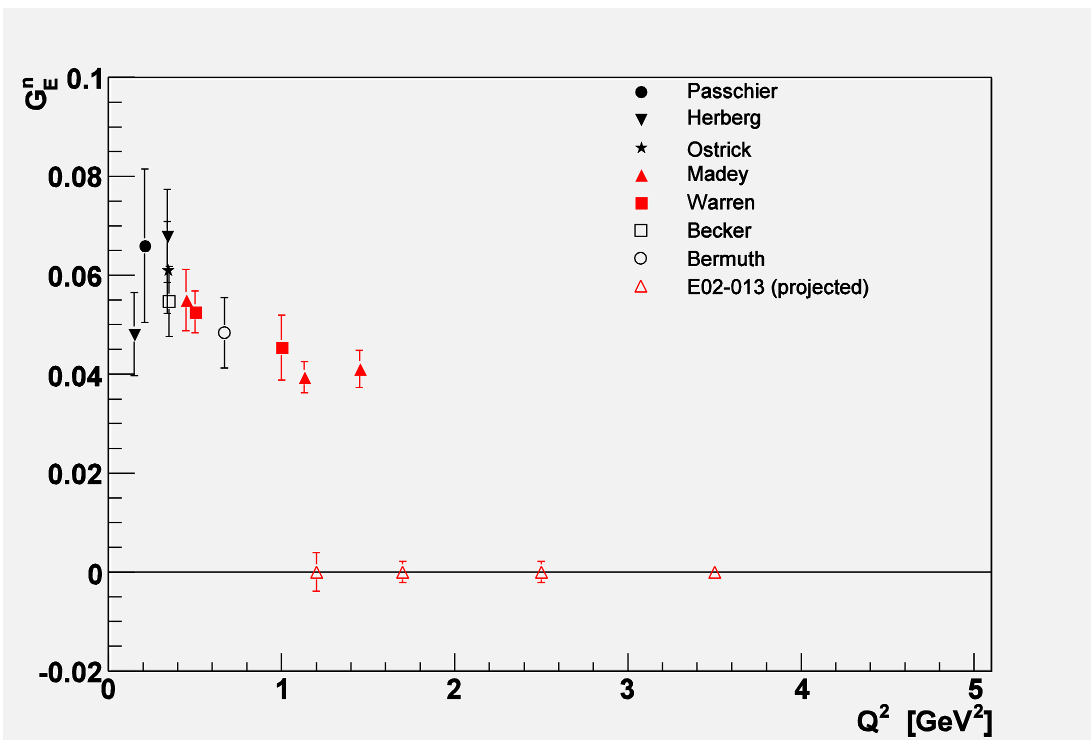
$$= \frac{\overline{a}\lambda + \overline{b}}{\overline{c}\lambda^2 + \overline{d}} \qquad \lambda = \frac{G_E}{G_M}$$

Coefficients averaged over acceptance.



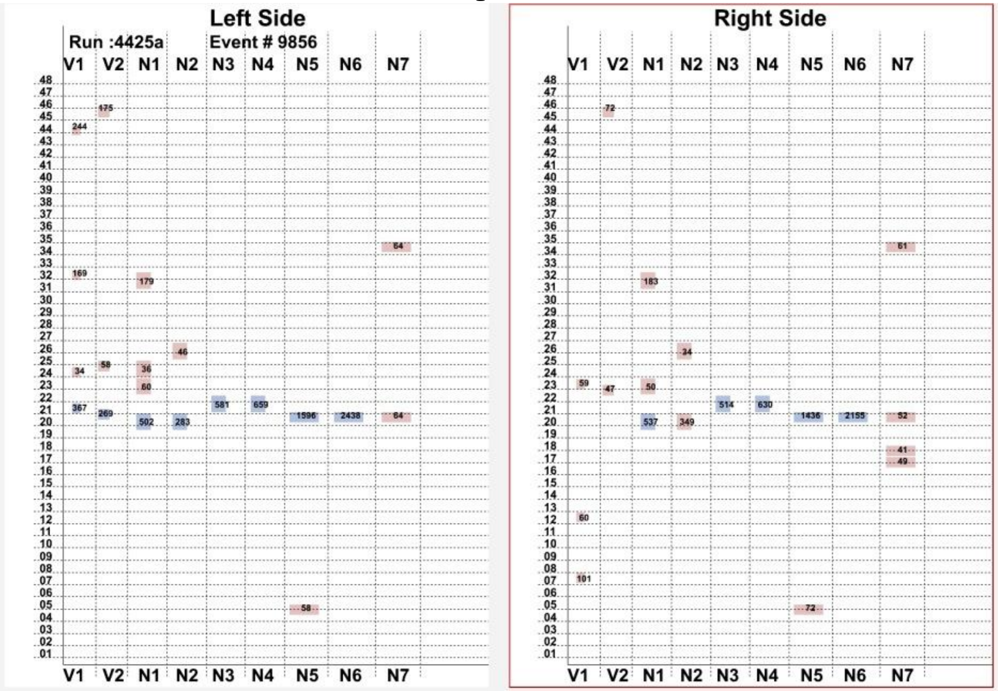
Experiment Overview

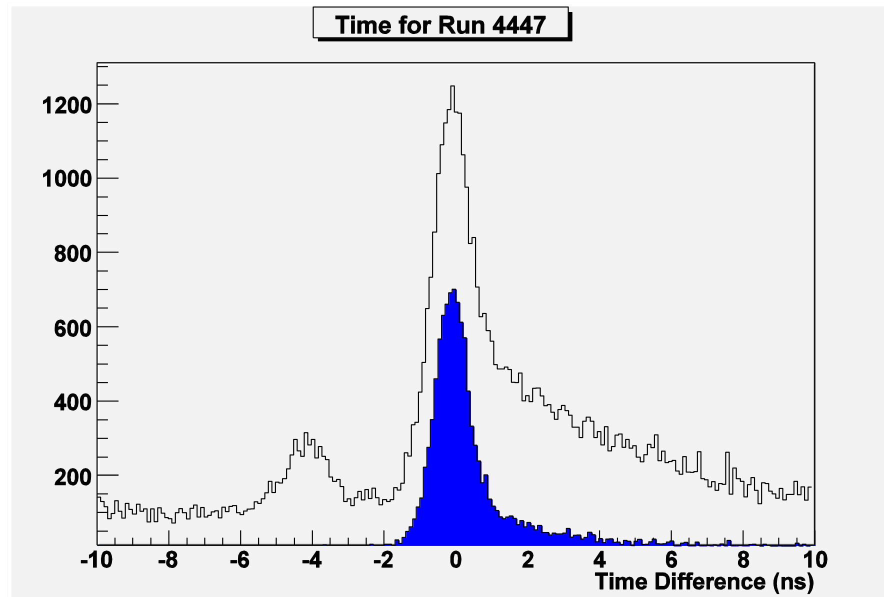
Beam Energy (GeV)	Q^2 (GeV^2)	Neutron Momentum (GeV/c)	Flight Path (m)
1.519	1.2	1.2	9
2.079	1.7	1.6	9
2.638	2.5	2.1	9
3.290	3.5	2.6	12



- Challenges:
  - High Q^2
  - High rate in the detectors
  - Determination of charged
  - Due to large fringe magnetic field caused by Big Bite

Experiment Observations

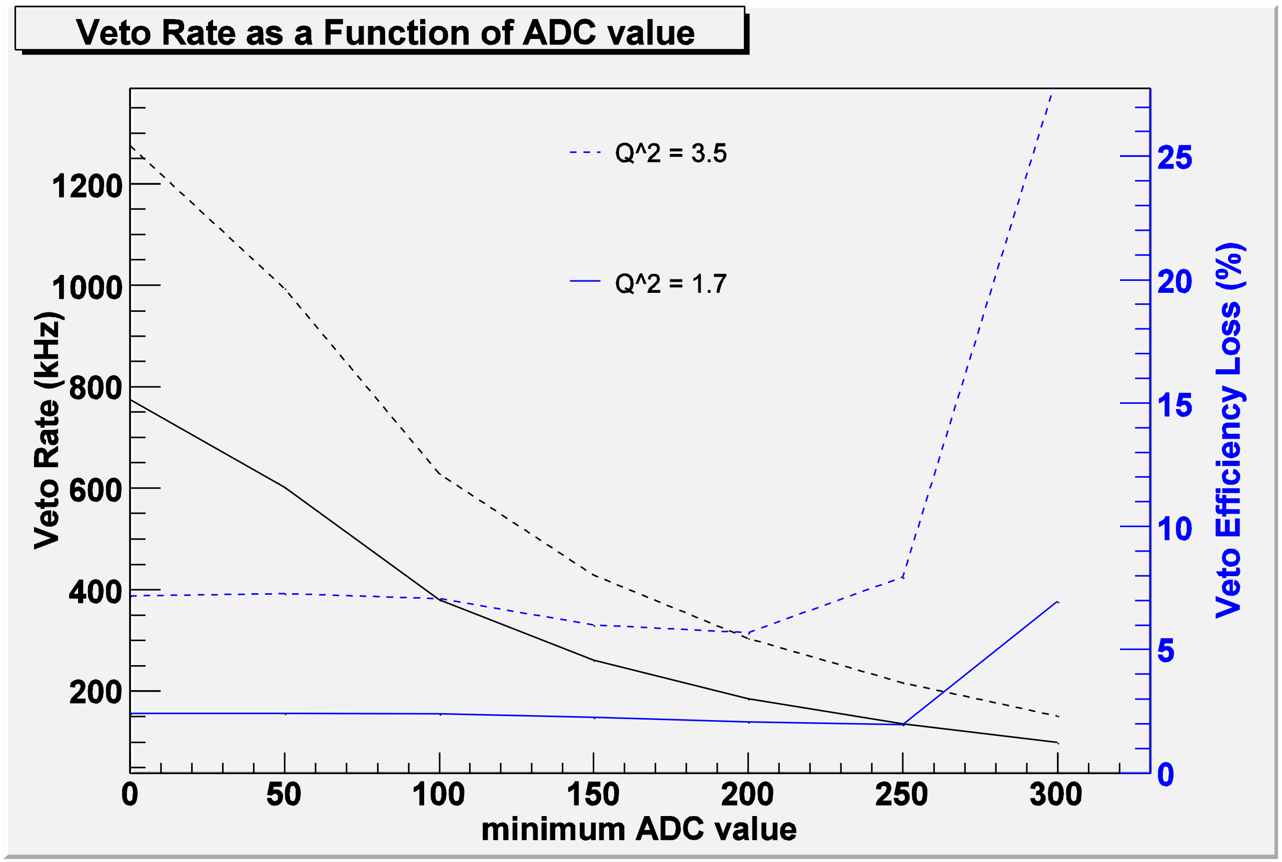




Neutron Arm Event – Shows hits within the neutron arm (veto and neutron detectors).

- The time spectrum for quasi-elastics currently has a σ <500 ps.
- Even clean events (like the one pictured) still contain many hits not relating to the event. Most events are much messier.

Charge Identification



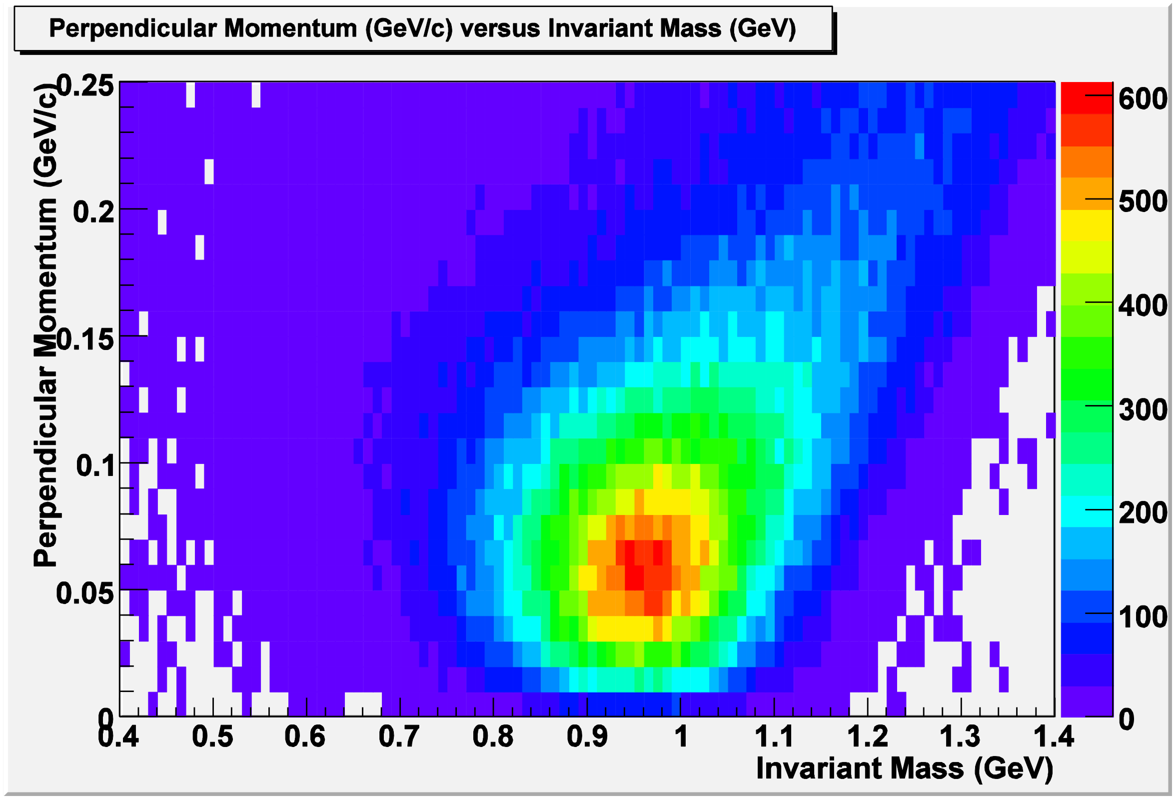
•Adjust minimum amplitude to remove lower energy hits.

•Removes accidentals in the dead region (up to 110 ns) and in the coincidence region.

•Using a value of 200 safely removes accidentals.

•Veto Rate is accidental rate per paddle (average).

Quasi-Elastic Selection

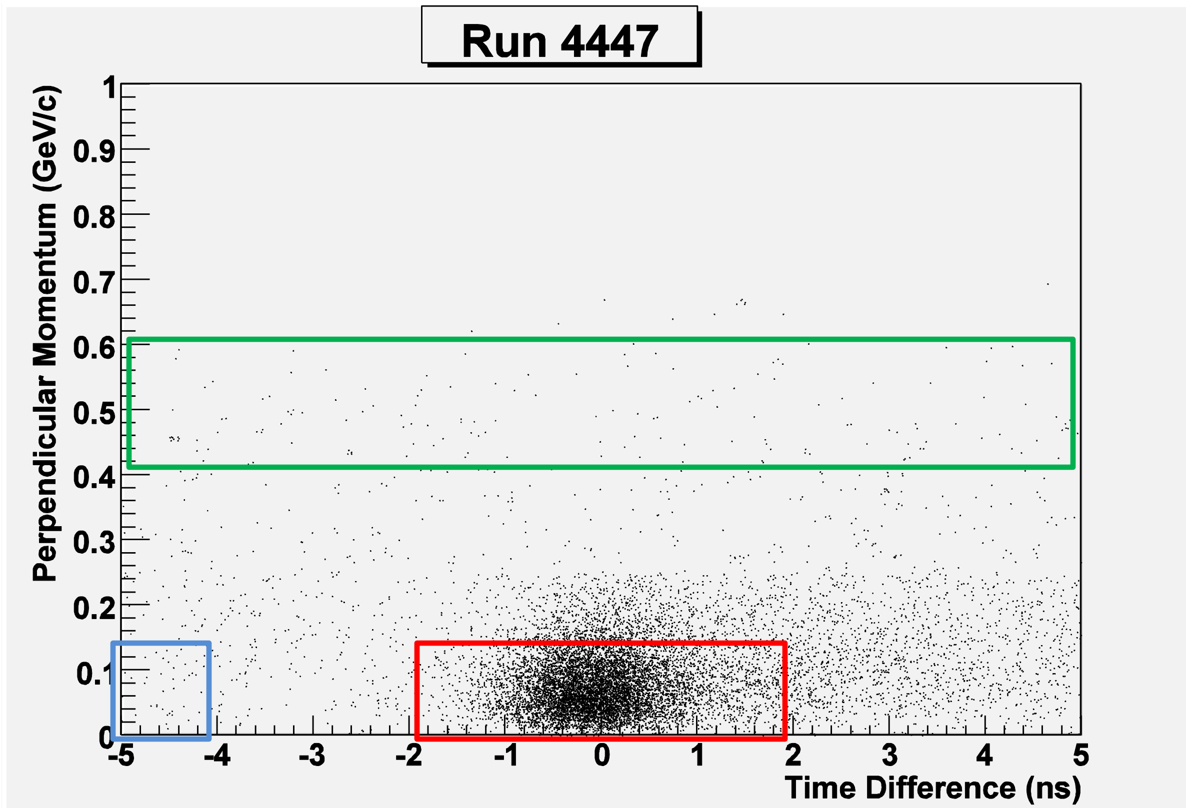


- Main selection of Quasi-elastic Events is via
  - Time of Flight
  - Perpendicular Momentum
  - Invariant Mass
- For quasi-elastics, σ of the Time Spectrum is 500 ps for Q^2 = 1.7 GeV^2 .

$$p_{\perp} = p \times \hat{q}$$

Accidental Background Technique

Blue is the region used to determine total background counts.



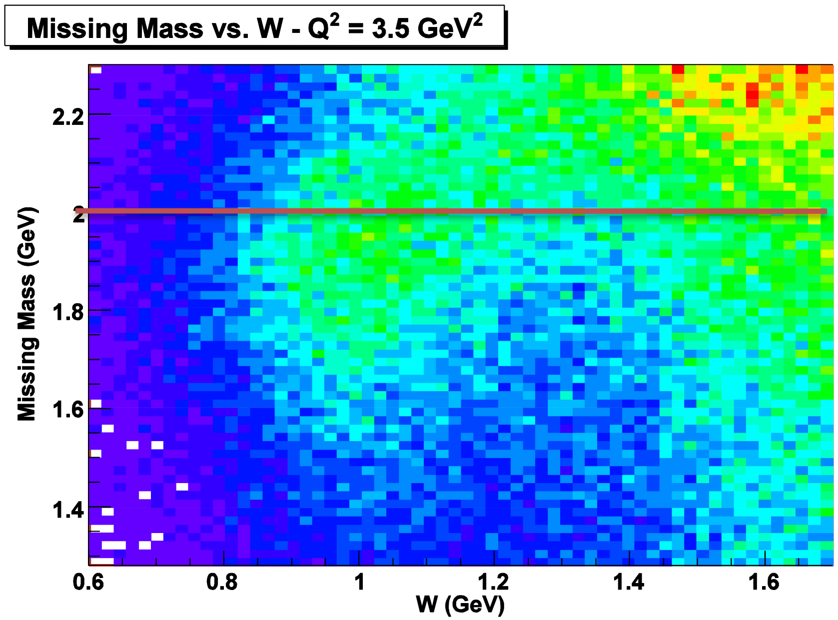
Green is region to determine the ratio of charged to uncharged.

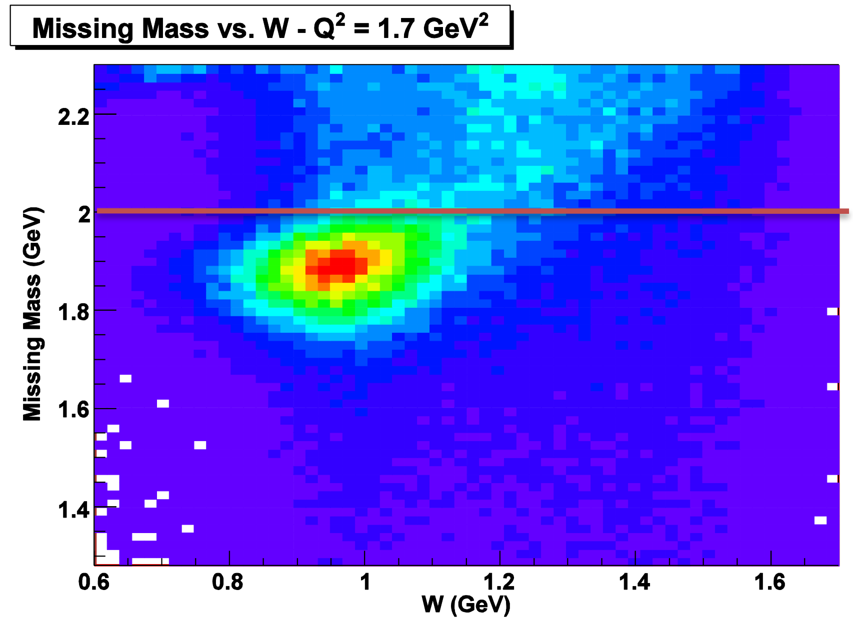
Red is the region used to select (quasi)elastics.

$$N_{total} = N_{QE} + N_{Back}$$

•To determine the ratio of charged to uncharged events, events far from the quasi-elastic region are used so that they are not effected by the quasi-elastic events.

Missing Mass





$$\overrightarrow{{}^3He}(\vec{e},e'N)X \qquad m^2_{miss} = (p_{He} + q - p_n)^2$$

•Large amounts of data need removed at Q^2 = 3.5 GeV^2 to remove pion electroproduction.
•These cuts are still necessary at Q^2 = 1.7 GeV^2.
•The cuts used are for a missing mass of <=2 GeV.

Asymmetry Calculation

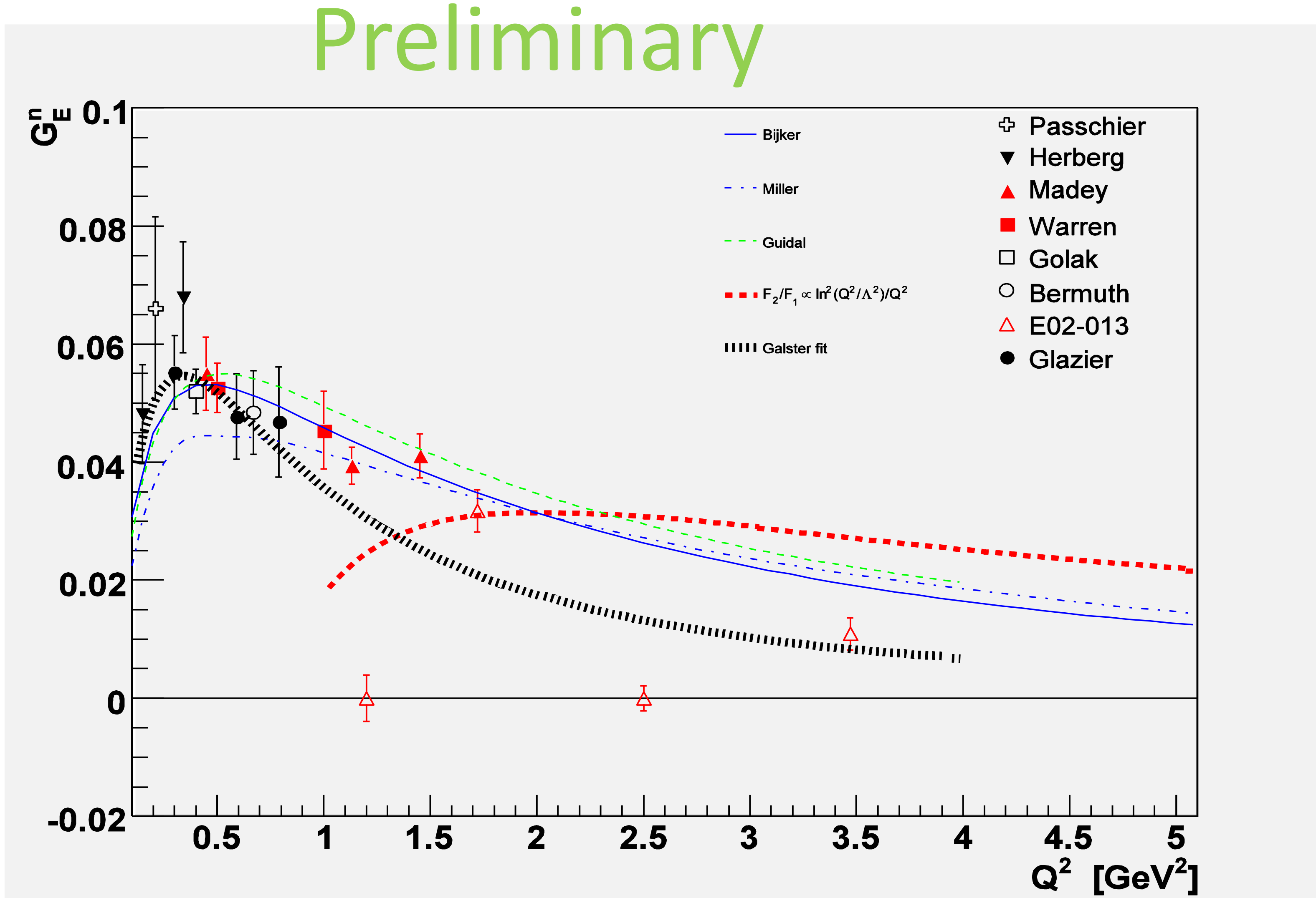
- To determine the physical asymmetry:
  - The accidental background is subtracted from the raw asymmetry.
  - Proton physical asymmetry is calculated from the known proton form factors.
  - Proton to neutron conversion between the target and the detector is accounted.
  - Various other dilution corrections are included in the Table below.

Corrections	Value
Beam Polarization	83.5% ± 1.1%
Target Polarization	48.7% ± 2%
Neutron Polarization	86% ± 2%
Nitrogen Dilution	94.3% ± 0.9%

G_E^n Calculation

Name	Q^2 = 1.7 GeV^2 (± Sta ± Sys)	Q^2 = 3.5 GeV^2 (± Sta ± Sys)
Raw Asymmetry	-0.058 ± 0.003	-0.026 ± 0.008
Number of QE	156061	15325
Q^2	1.72	3.47
Physical Asymmetry	-0.256 ± 0.011 ± 0.02	-0.117 ± 0.036 ± 0.012
Lambda (form factor ratio)	-0.207 ± 0.029	-0.213 ± 0.057
G_E^n (not including FSI)	0.0317 ± 0.002 ± 0.0029	0.0109 ± 0.0026 ± 0.0008

Results

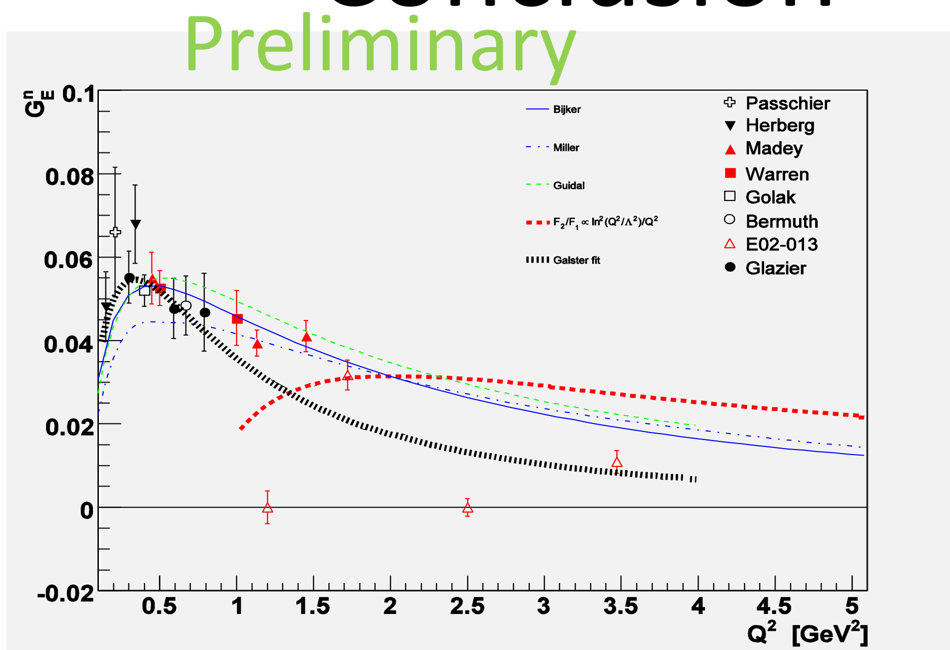


Preliminary
G_E^n
0.1
0.08
0.06
0.04
0.02
0
-0.02
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Q^2 [GeV^2]
Bijker
Miller
Guidal
$F_2/F_1 \propto \ln^2(Q^2/\Lambda^2)/Q^2$
Galster fit
Passchier
Herberg
Madey
Warren
Golak
Bermuth
E02-013
Glazier

To Do

- Final State Interaction calculations in progress.
- Implement Ole Hansen's new Big Bite tracking code.
- Finalize Target, Big Bite and Neutron Arm calibrations.
- Results for $Q^2 = 1.2$ and $2.5\ GeV^2$.
- Improve Monte Carlo to account for Pion Electroproduction.
- Members of the analysis group will be working to have published all kinematics by early 2009.

Conclusion



- Preliminary values of G_E^n for Q^2 = 1.7 and 3.5 GeV^2 achieved.
- The Q^2 = 3.5 GeV^2 point shows the discriminating power of our results, and suggests a reevaluation of our understanding of GPDs and the orbital momentum of the quarks.