A Measurement of G_E^n at High Momemtum Transfer in Hall A

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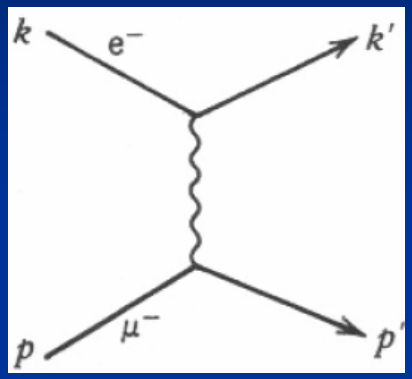
For the E02-013 Collaboration and
Hall A Collaboration

Outline

- Nucleon Form-factors
- Experimental Layout
- Data overview
- Analysis
- Summary

Elastic EM Form-factors

Electron scattering from a point spin-1/2 particle:

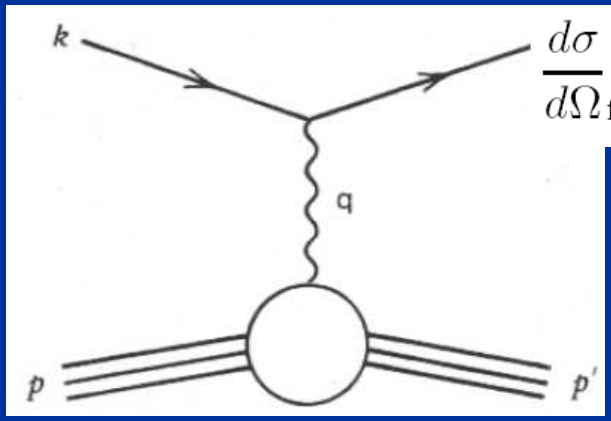


$$\frac{d\sigma}{d\Omega}_{\text{point}} = \left(\frac{d\sigma}{d\Omega}\right)_M \left[1 + 2\tau \tan^2\frac{\theta_e}{2}\right]$$

where

$$\left(\frac{d\sigma}{d\Omega}\right)_M = \left(\frac{\alpha \cos\frac{\theta_e}{2}}{2E\sin^2\frac{\theta_e}{2}}\right)^2 \frac{E'}{E}, \quad \tau = \frac{Q^2}{4M^2}$$

For an extended spin-1/2 particle:



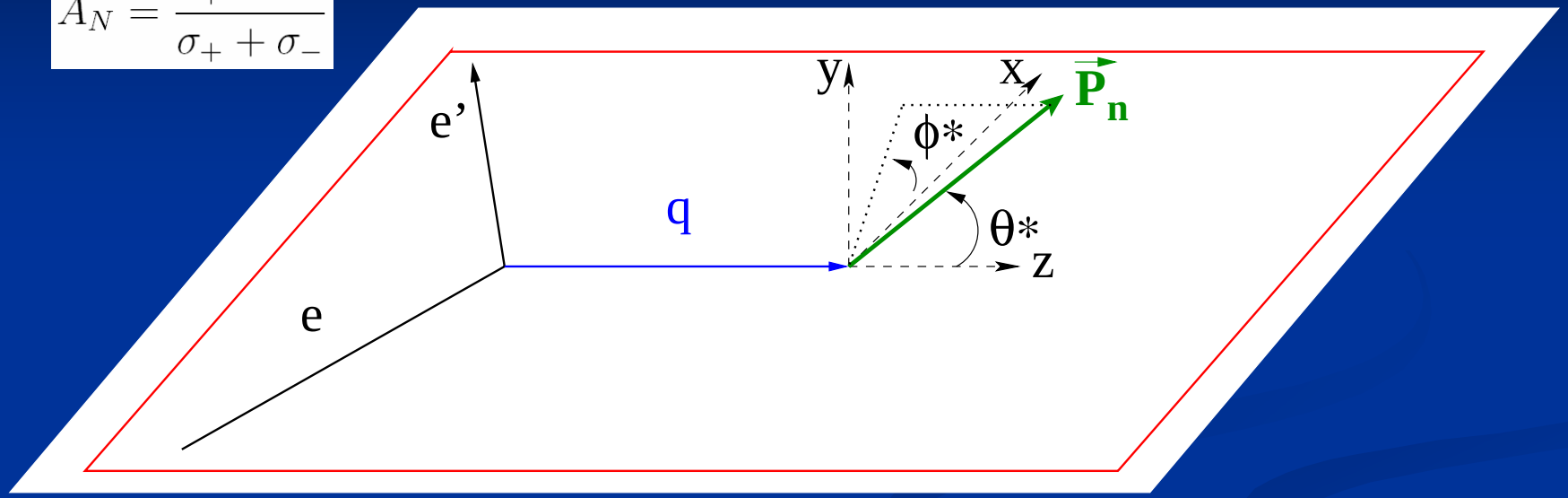
$$\frac{d\sigma}{d\Omega}_{\text{finite}} = \left(\frac{d\sigma}{d\Omega}\right)_M \left[(F_1^2 + \tau\kappa^2 F_2^2) + 2\tau\,(F_1 + \kappa F_2)^2 \tan^2\frac{\theta_e}{2}\right]$$

Or in terms of the Sachs form factors:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_M \left[\frac{{G_E}^2 + \tau\,{G_M}^2}{1+\tau} + 2\tau\,{G_M}^2 \tan^2\frac{\theta_e}{2}\right]$$

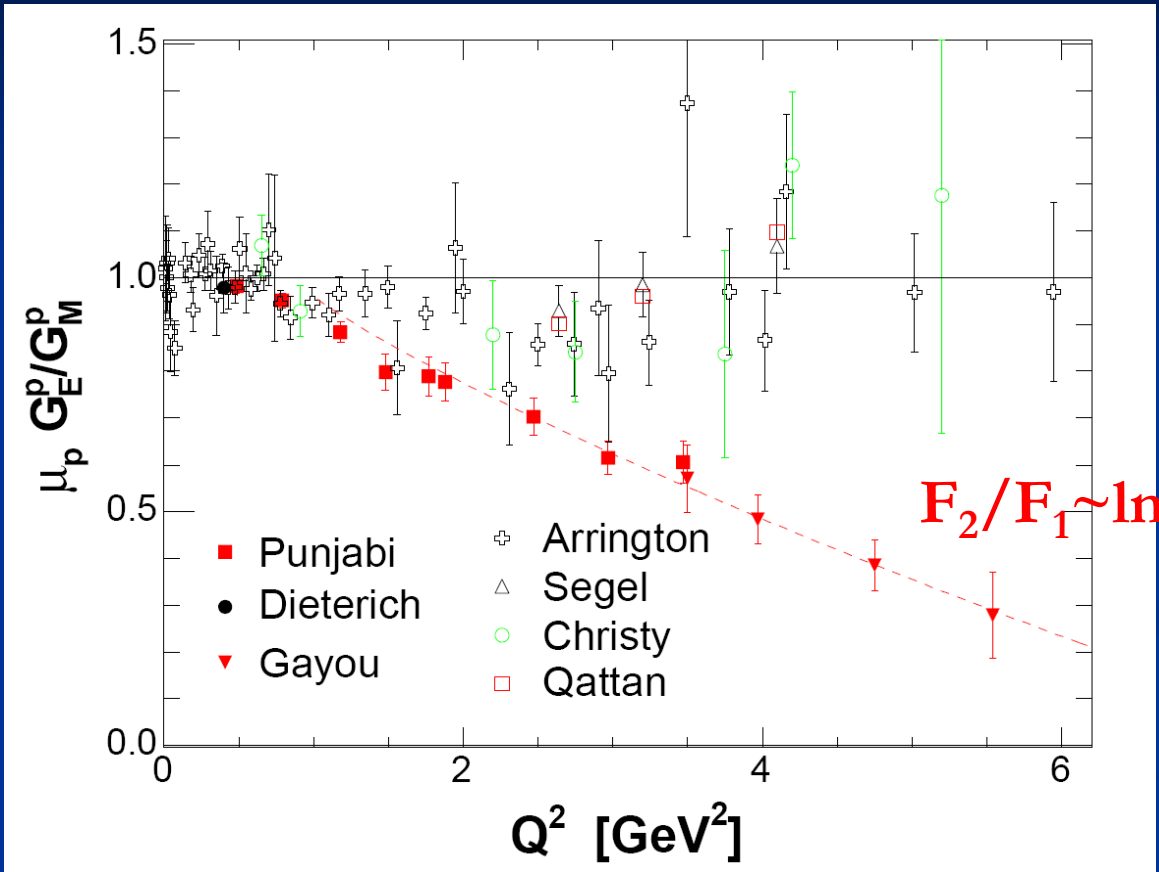
Polarization observables and Asymmetries

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



$$A_{phys} = -\left(\frac{G_E}{G_M}\right)\frac{2\sqrt{\tau(\tau+1)}\tan(\theta_e/2)\sin\theta^*\cos\phi^*}{(G_E/G_M)^2+\tau(1+2(1+\tau)\tan(\theta_e/2))}$$
$$-\frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan(\theta_e/2)}\tan(\theta_e/2)\cos\theta^*}{(G_E/G_M)^2+\tau(1+2(1+\tau)\tan(\theta_e/2))}$$

Elastic EM form factors: The Proton

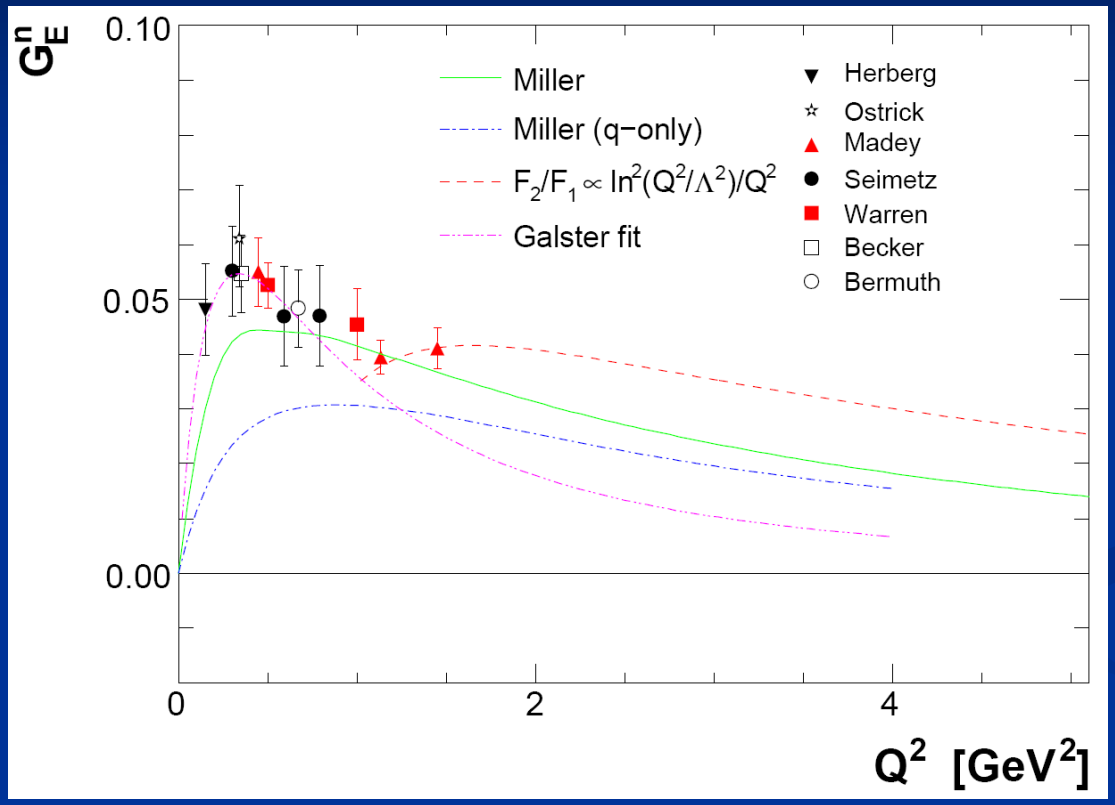


$F_2/F_1 \sim \ln(Q^2/\Lambda^2)^2/Q^2$

High precision measurements changed the picture!

pQCD finds Q^2F_2/F_1 is constant at high Q^2

Elastic EM Form factors: the Neutron

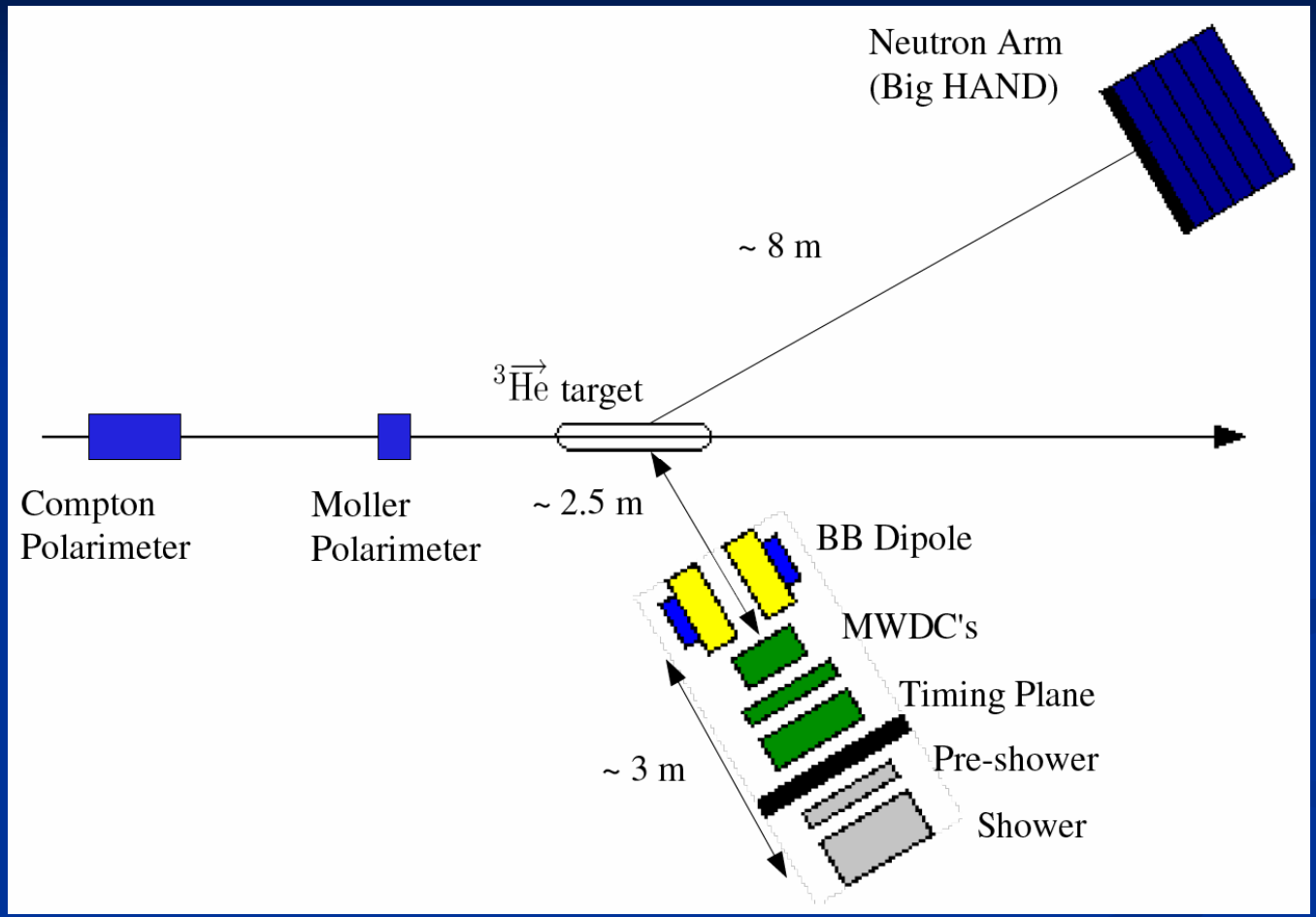


- G_M^n behavior well matched by the dipole form up to Q^2~4 GeV^2
- G_E^n is not precisely measured above 1.5GeV^2
- G_E^n more sensitive than other FF to details of the pion-cloud (Friedrich 2003)
- The orbital motion of the quarks within the nucleon play a larger role at high Q^2
- For the proton and neutron, F_1 and F_2 connect to the GPD's

Experimental Technique

- Exclusive quasi-elastic scattering of polarized electrons from polarized ^{3}He: ^{3}He(e,e' n)
- Requirements:
  - Polarized beam and target
  - Detection of scattered electron
  - Detection of struck neutron
  - Sufficient resolution to pick out QE events

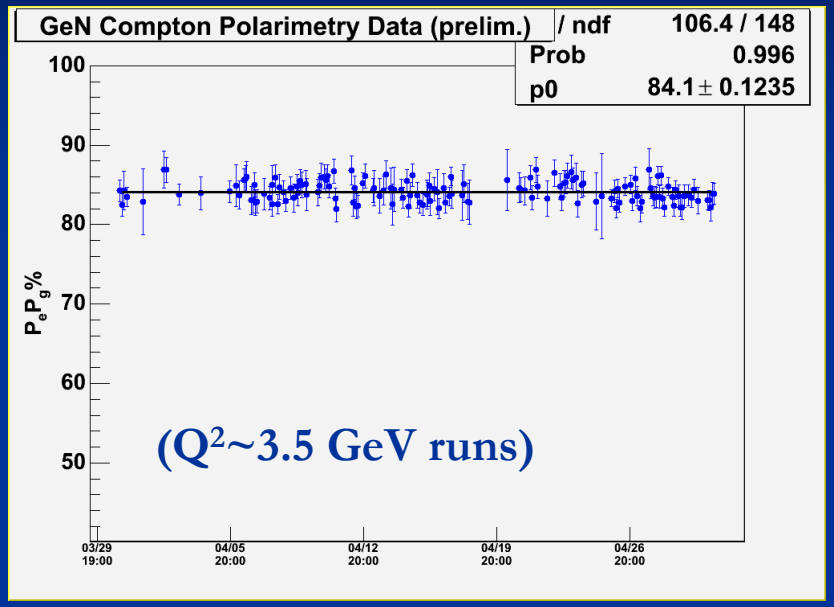
Exclusive QE scattering: ^{3}He(e,e'n)



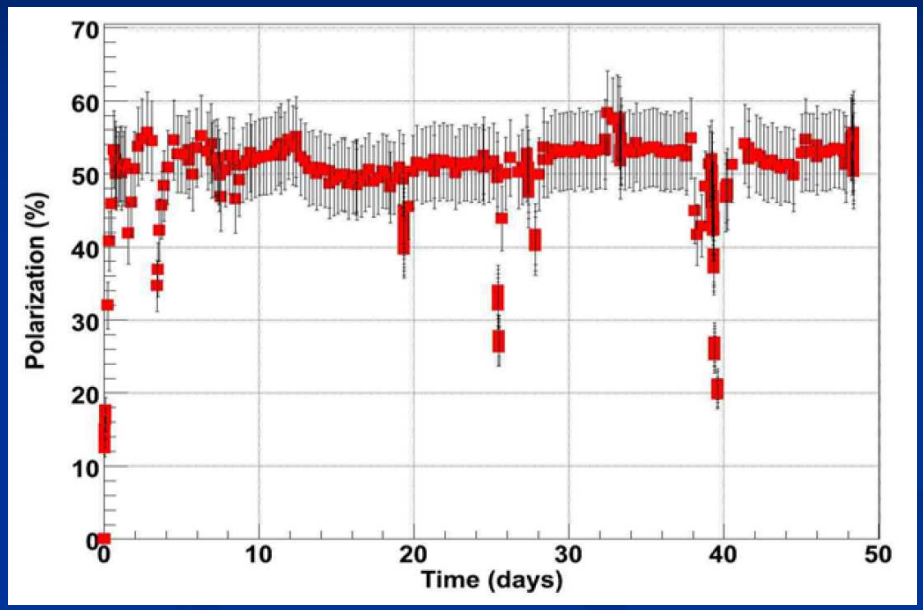
Talks detailing the equipment and event reconstruction will be held tomorrow morning in the Instrumentation II session, Cheekwood F ~11am.

Data Quality

Beam polarization ~84%



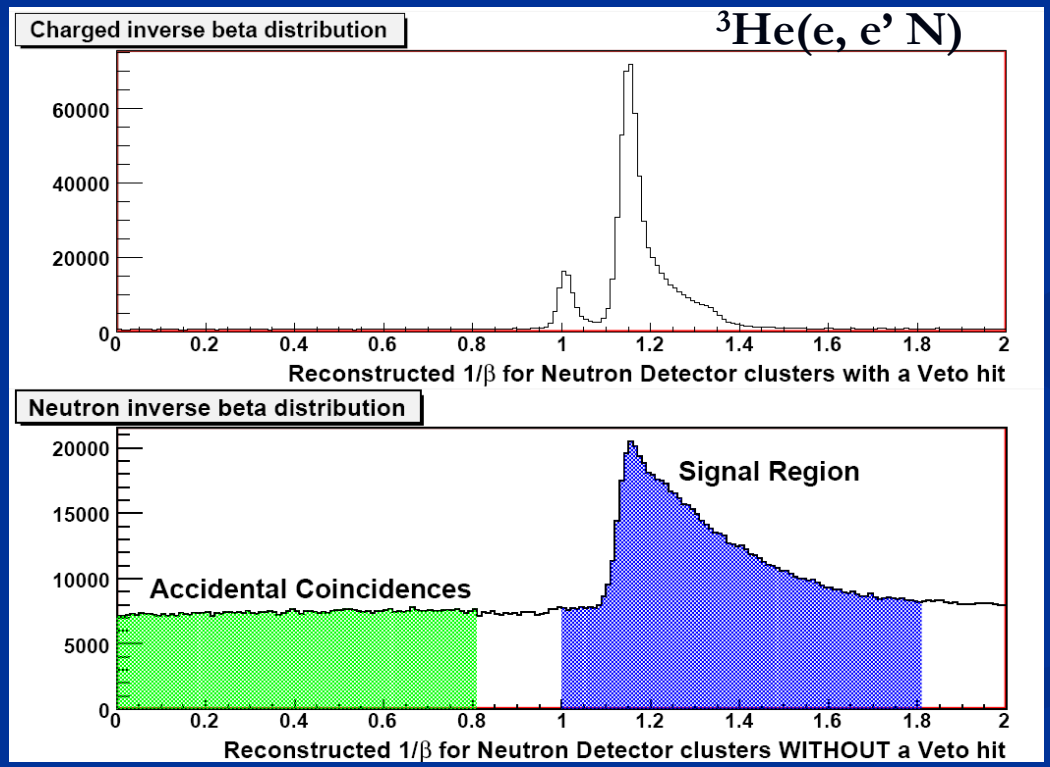
Target polarization ~50% IN BEAM



- The experiment ran for 3 months in Spring 2006.
- Four datasets (Q^2=1.4, 1.8, 2.4, 3.4 GeV^2) were taken.
- Commissioned BigBite precision detector package, BigHand, hybrid cell and advanced optics system for the target.
- Novel holding field magnet and compass to control and understand field gradients at the target.

Data Analysis

- "Results" shown are from an advanced preliminary analysis of the 1.8 GeV^2 dataset.
- "Neutrons" are ALL clusters in BigHand without matching veto hits (very loose criteria for now).
- Achieved momentum resolution from BB of dp/p~1%, BigHand timing resolution of 400ps (sigma)



Primary concerns are:

•Neutron identification

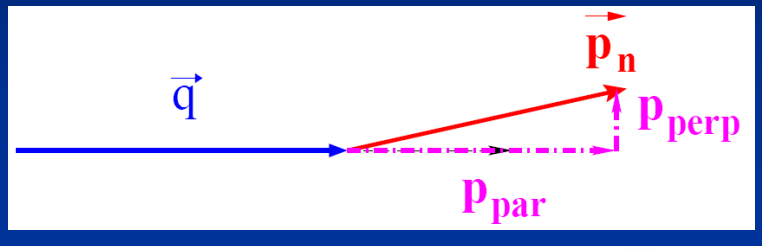
•Selection of QE events

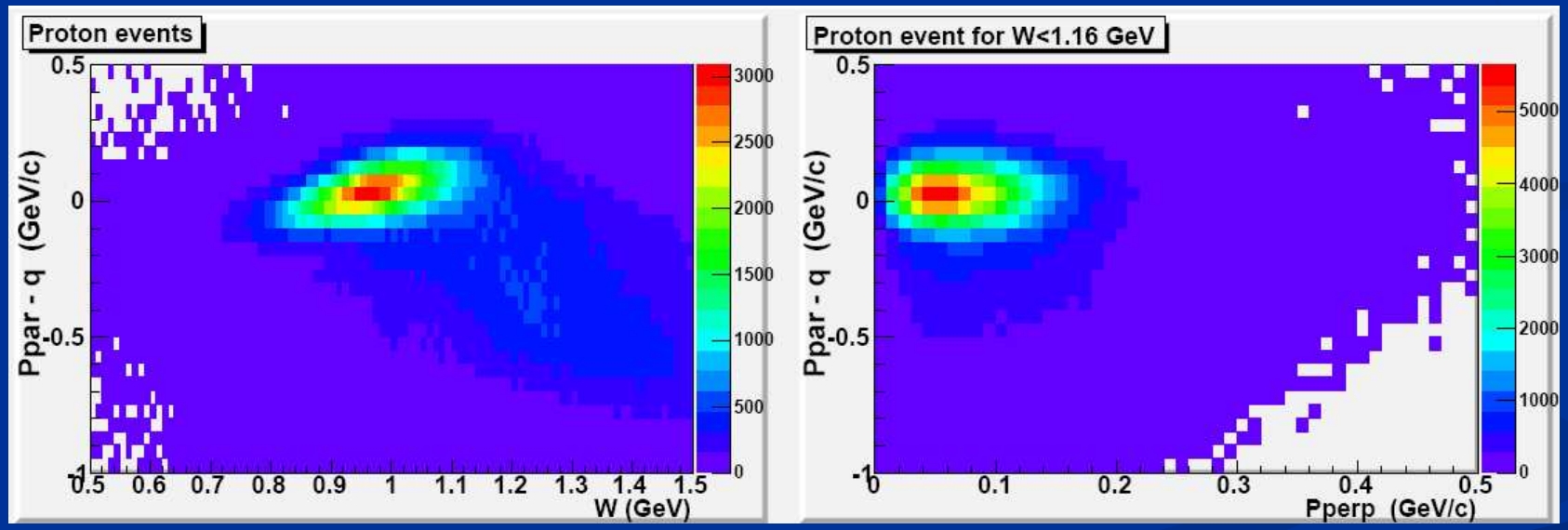
•Accouting for distortions of the asymmetry from:

- Charge exchange
- N_2(e,e' n)
- Helicity-correlated livetime
- True θ*/φ* angles

QE Event Selection

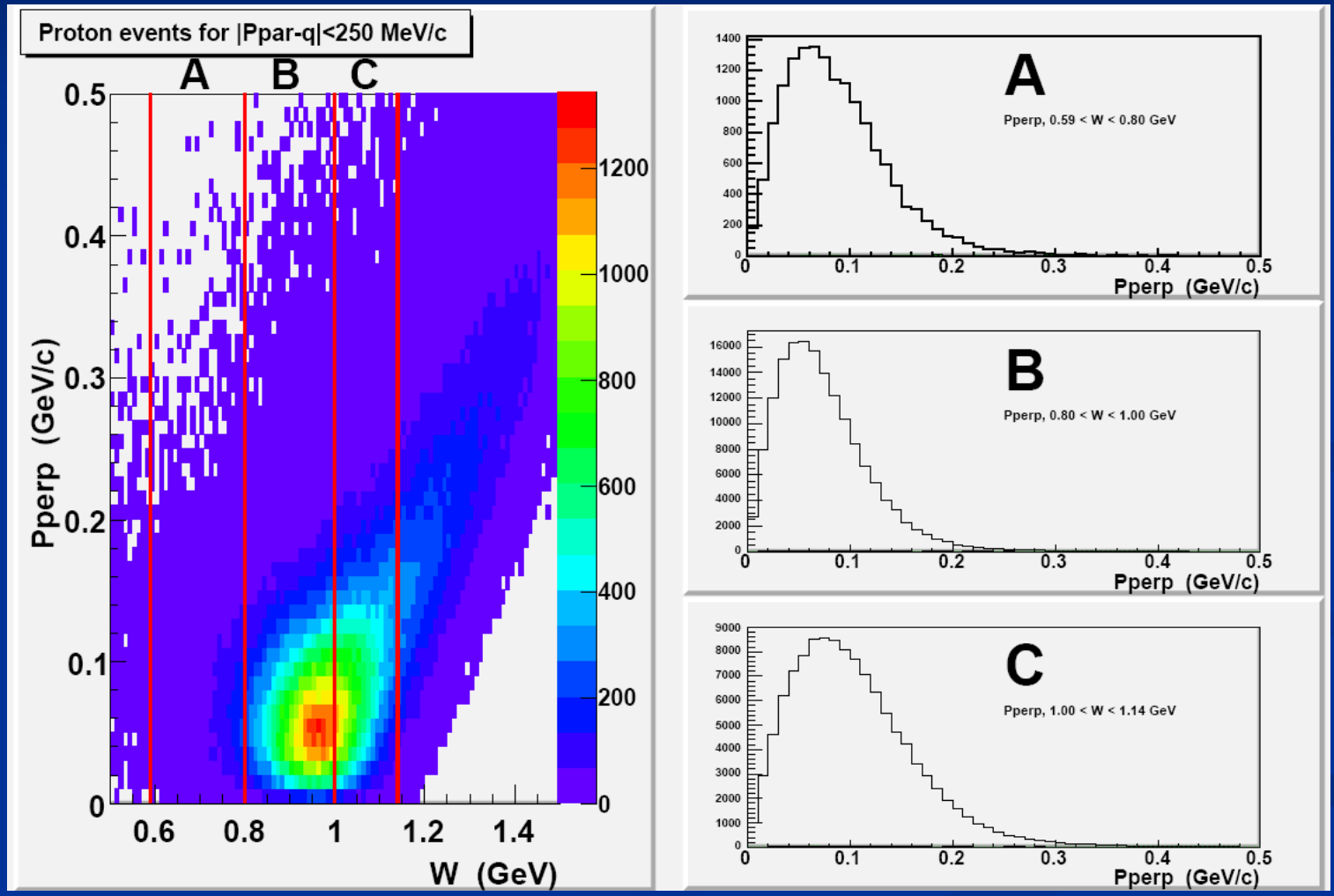
- Use missing 3-momentum to select QE events



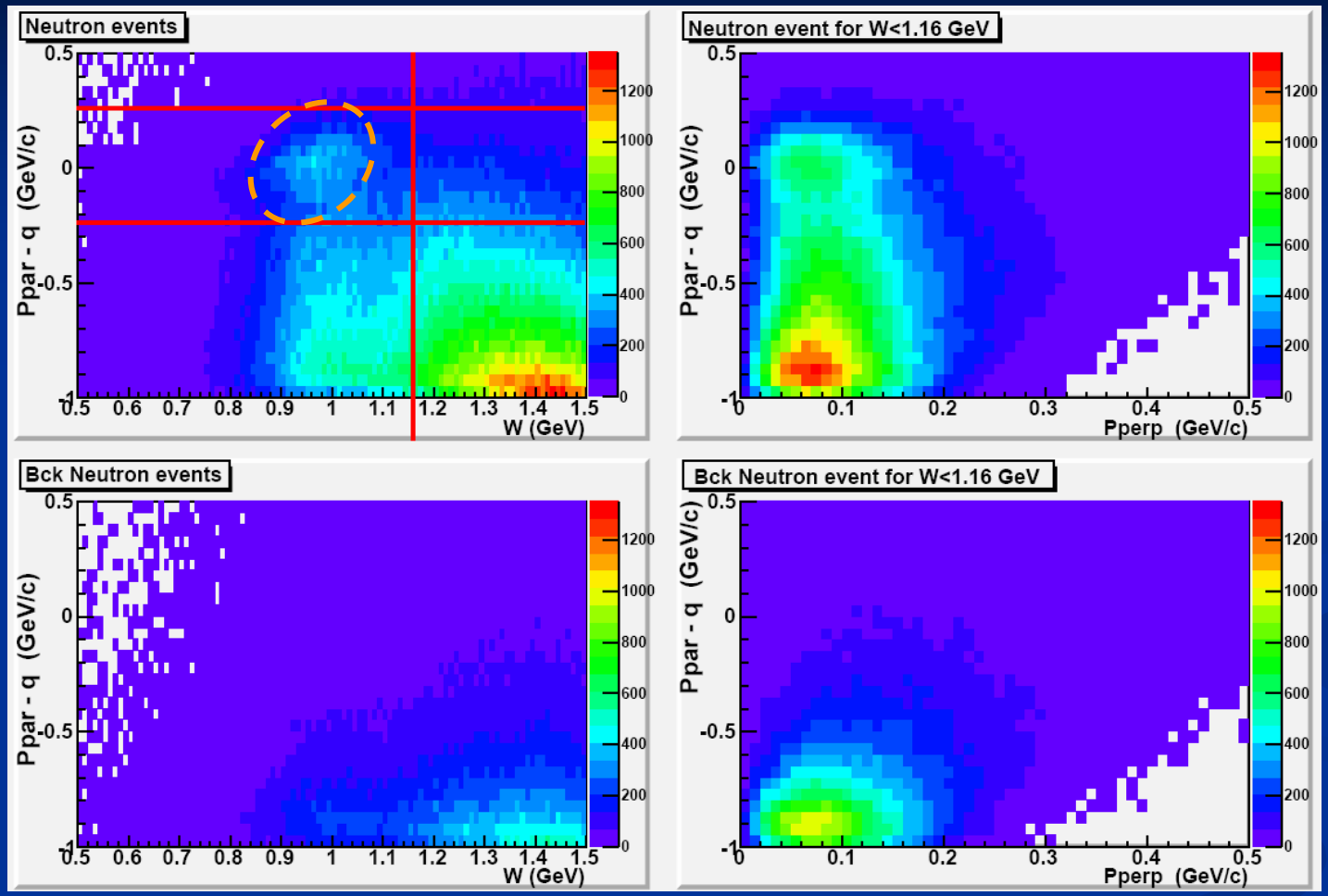


QE Event selection: Protons

Nuclear effects can distort the observed asymmetry … Pperp < 150 MeV/c

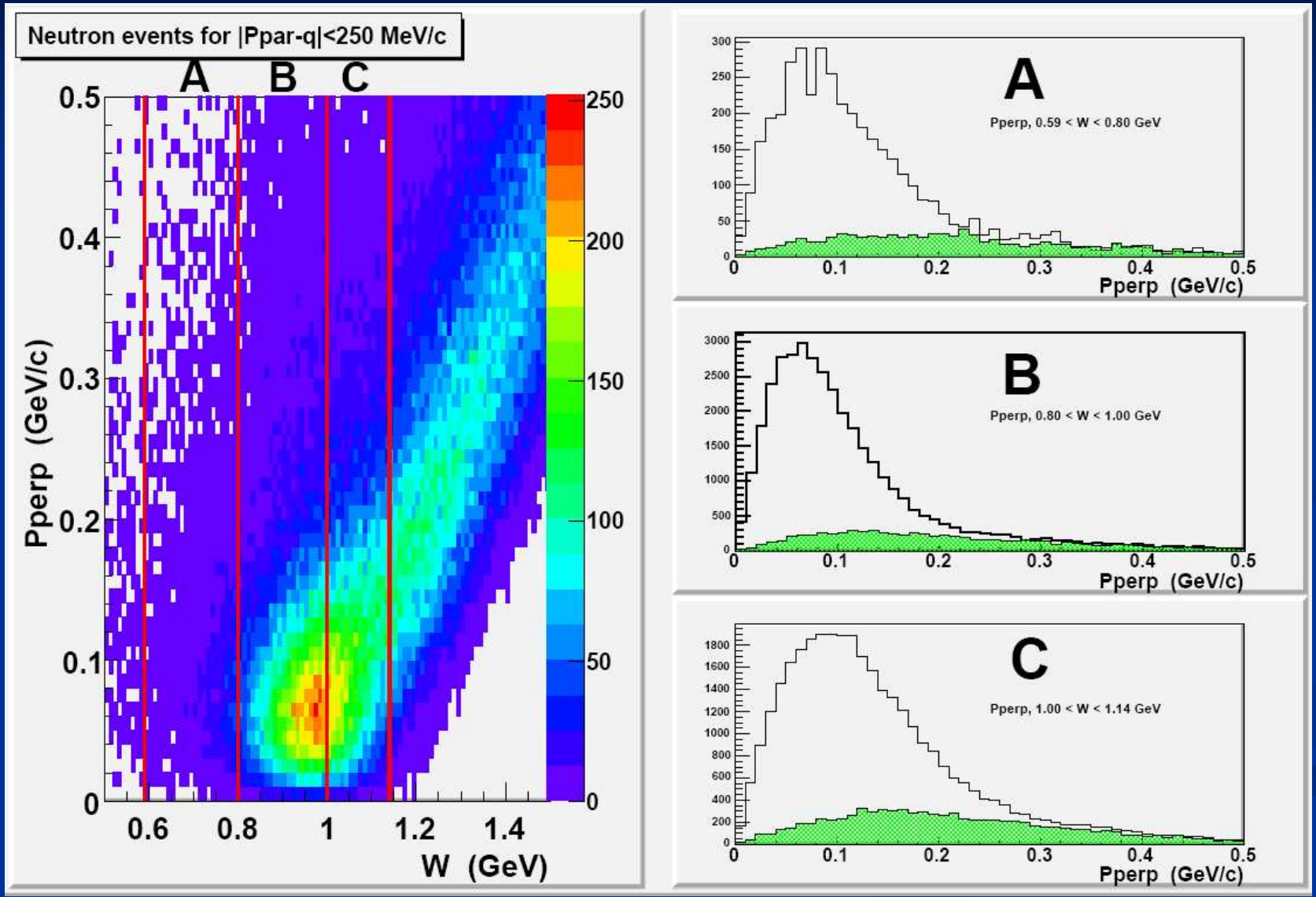


QE Event selection: Neutrons



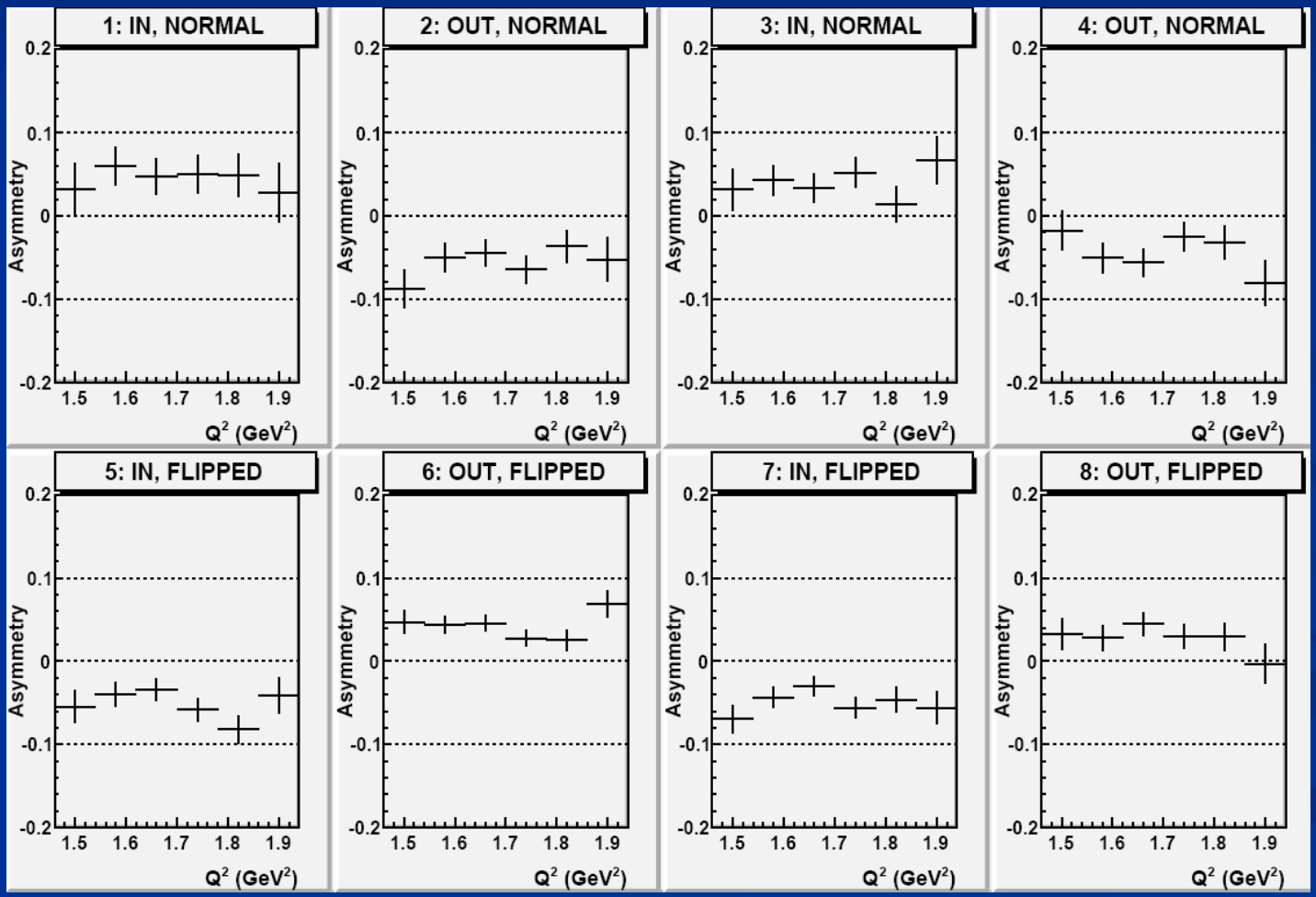
Selecting only the most energetic cluster removes much of the background (not shown)

QE Event selection: Neutrons

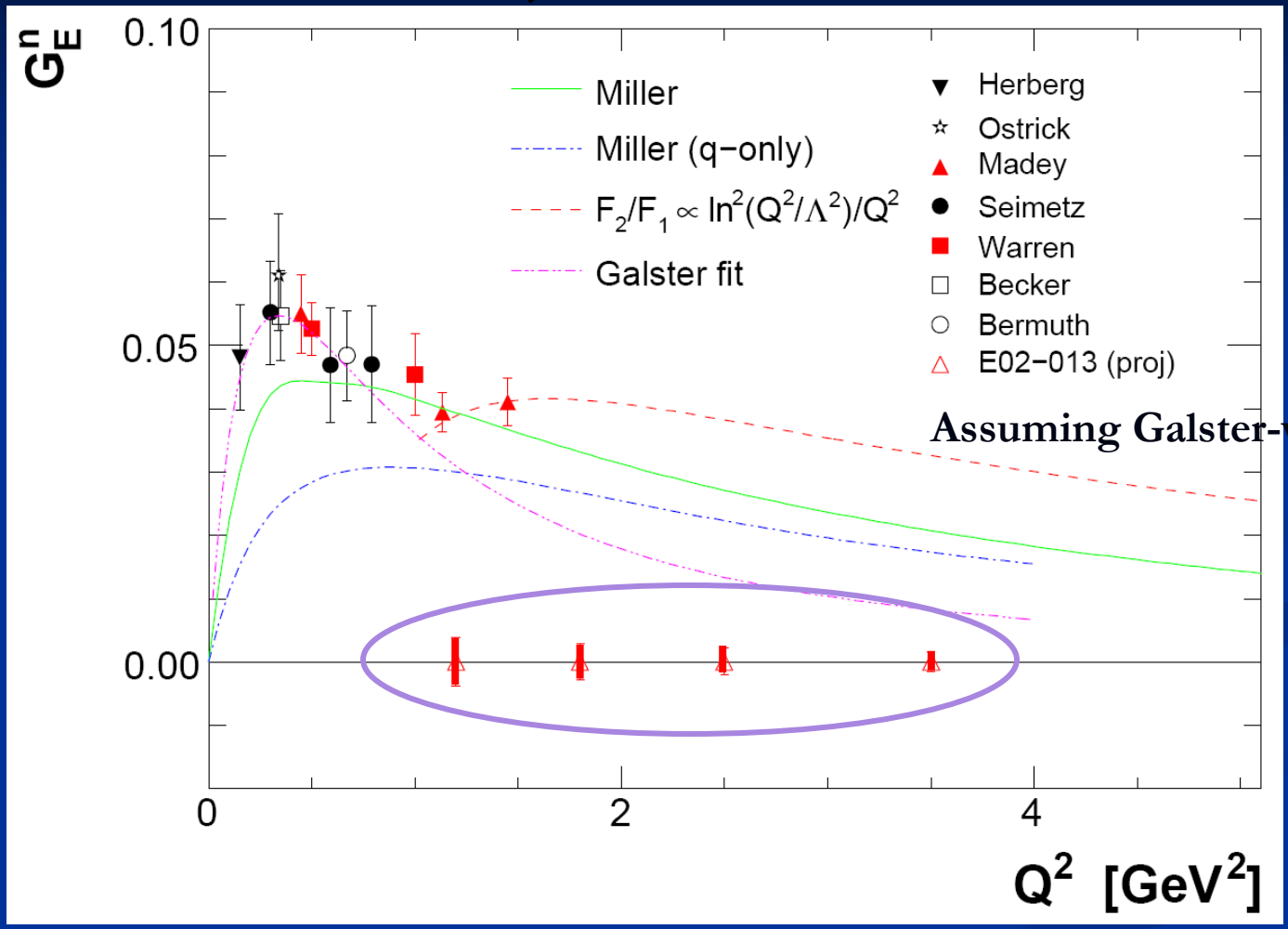


Rough Asymmetries for $Q^2 = 1.8\ GeV^2$ dataset

Integrated Asymmetries (NOT corrected for many several %-size effects) for different Beam ½-wave plate settings and Target polarization direction changes.



Projected Results



Systematic uncertainties for highest Q2 point still smaller than shown statistical uncertainty.

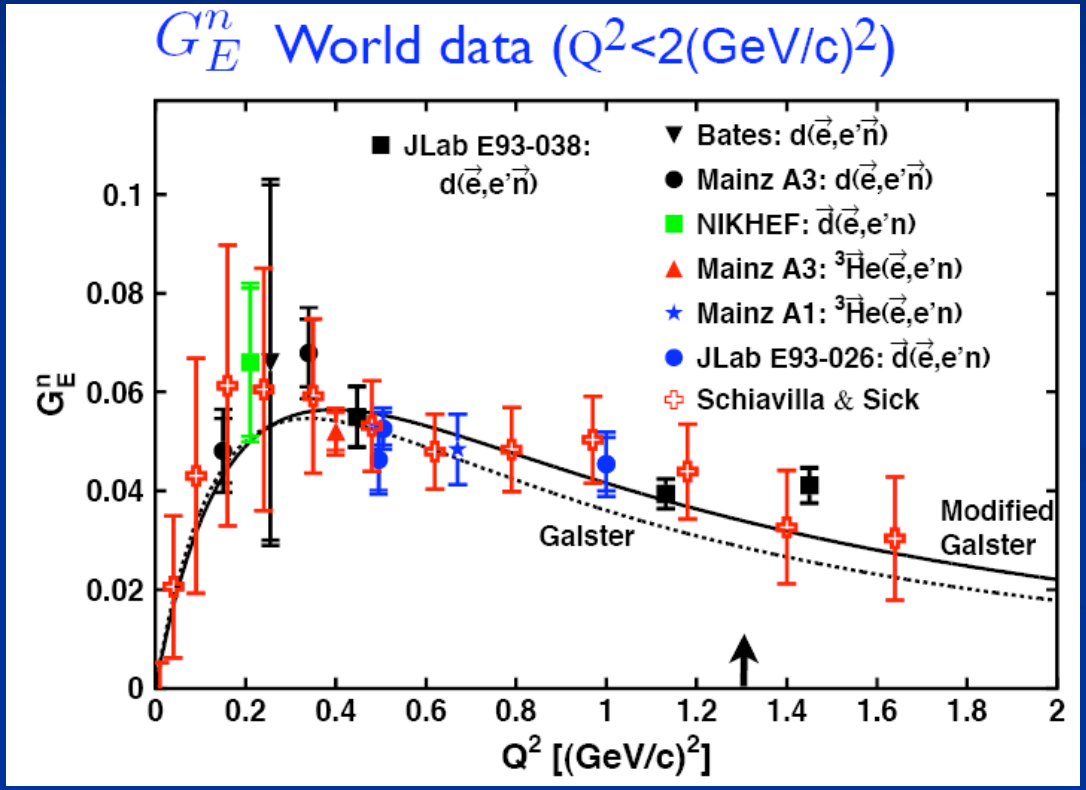
Summary

- We have collected data for the first high-precision measurement of G_E^n at $Q^2>1.5$ GeV^2.
- The precision measurement will provide for the calculation of F_1 and F_2, and insight into the orbital angular momentum component of the nucleon.
- Analysis of ¼ of the dataset is underway, with expected physics results by next spring.

- Please see the talks in Instrumentation II for more details about the experiment!

Backup slides

World data on G_E^n



^{3}He as a polarized neutron target