E02-013 Analysis Update

Measurements of G_E^n at High Q^2

Seamus Riordan
Carnegie Mellon University
riordan@jlab.org

for the E02-013 Collaboration

June 12, 2008

Spokespeople:

- Bogdan Wojtsekhowski - JLab
- Gordon Cates - University of Virginia
- Nilanga Liyanage - University of Virginia

Postdocs:

- Seamus Riordan - Carnegie Mellon University

Ph.D. Students:

- Sergey Abrahamyan - Yerevan
- Brandon Craver - University of Virginia
- Aidan Kelleher - College of William and Mary
- Jonathan Miller - University of Maryland, College Park
- Ameya Kolarkar - University of Kentucky

Masters Students:

- Tim Ngo - California State University, Los Angeles

Outline

- Introduction
- E02-013 Overview
- QE Elastic Selection
- Identifying Dilution
- BigBite Tracking
- Conclusion

Nucleon Form Factors

- Sachs form factors, $G_{E,M}^{p,n}$, describe EM structure of nucleons
- Related to electric charge and magnetic moment distribution in Briet frame
- Are exactly Fourier transforms in non-relativistic limit
- One-photon approximation:

$$\left.\frac{d\sigma}{d\Omega}\right|_{\mathrm{LAB}} = \frac{\alpha^2 \cos^2\frac{\theta}{2}}{4E^2 \sin^4\frac{\theta}{2}} \frac{E'}{E} \left(\frac{G_E^2 + \tau G_M^2}{1+\tau} + 2\tau G_M^2 \tan^2\frac{\theta}{2} \right)$$

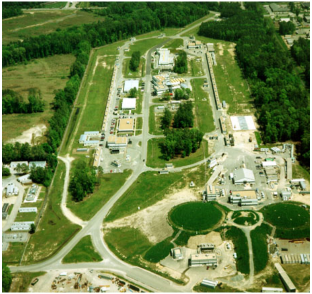
G_E/G_M through Cross Section Asymmetry

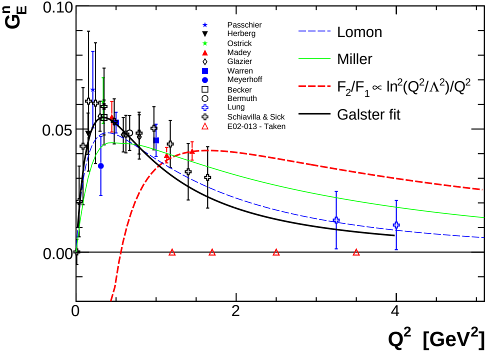
- G_E^n typically difficult to measure
- Measure cross section asymmetry for QE $^3\overrightarrow{\mathrm{He}}(\vec{e}, e'n)pp$

$$A_{\mathrm{phys}} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$
$$= -\frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)\Lambda\hat{n}\cdot(\hat{q}\times\hat{T})}{\Lambda^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))} - \frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2(\theta/2)}\tan(\theta/2)(\hat{q}\cdot\hat{T})}{\Lambda^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

- Most sensitive to $\Lambda = G_E/G_M$ when target at 90° to $\vec{q}$

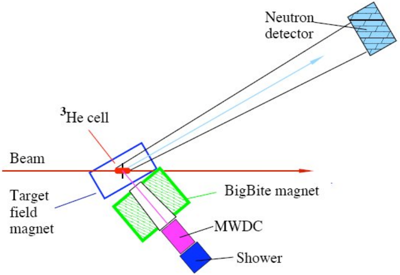
E02-013 ran in Hall A at TJNAF in Spring 2006





Kin	Q^2 (GeV^2)	E_{beam} (GeV)	Run Time (days)
1	1.3	1.519	8
2	2.4	2.642	19
3	3.5	3.291	33
4	1.7	2.097	9

- Polarized $^3\mathrm{He}$ target acts and neutron source
- Two arms to measure coincidence e' and n



  - BigBite - large acceptance spectrometer, measures $\vec{e}'$
  - Neutron arm - matches BB acceptance, measures neutron momentum through ToF, performs nucleon charge ID

Analysis

Major goals:

- Provide accurate electron track/momentum reconstruction
- Reliably separate QE events
- Identify charge of nucleons
- Remove contributions from background events

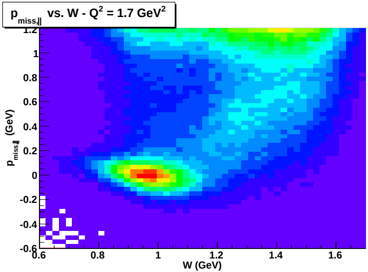
QE Selection

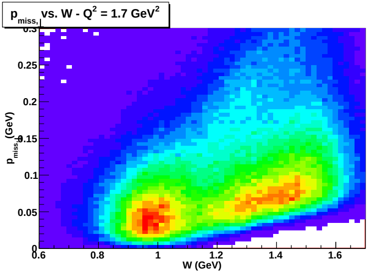
- Use cuts on:

$$
\begin{aligned}
p_{\mathrm{miss},\parallel} &= \hat{q}\cdot(\vec{q}-\vec{p}_{\mathrm{NA}}) && (1)\\
p_{\mathrm{miss},\perp} &= \left|\vec{q}-\vec{p}_{\mathrm{NA}}-\hat{q}p_{\mathrm{miss},\parallel}\right| && (2)\\
W^2 &= (p_{i,n}+q)^2 && (3)\\
m^2_{\mathrm{miss}} &= (m_{^3\mathrm{He}}+\nu-E_{f,n})^2-p^2_{\mathrm{miss}} && (4)
\end{aligned}
$$

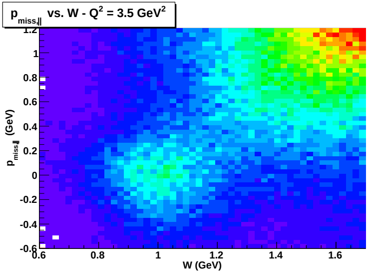
- For W, assume $p_{i,\mathrm{nucl}}$ is at rest
- Missing mass, X: $^3\overrightarrow{\mathrm{He}}(\vec{e},e'N)X$

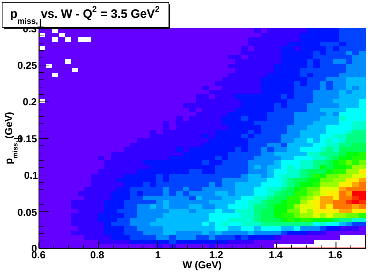
$Q^2 = 1.7\ \mathrm{GeV}^2$



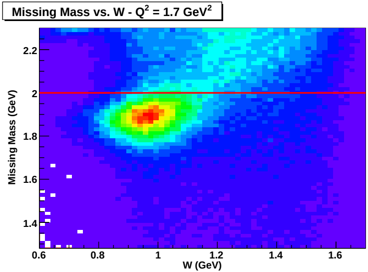


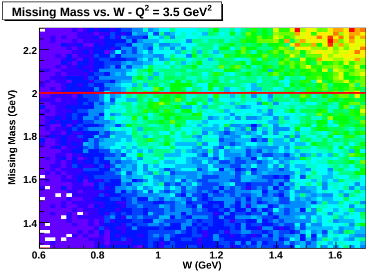
$Q^2 = 3.5\ \mathrm{GeV}^2$





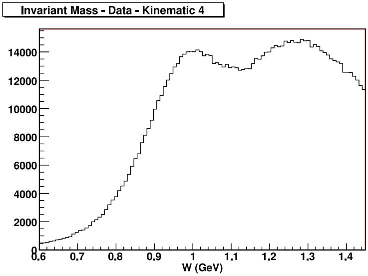
- Missing mass of $^3\mathrm{He}(\vec{e}, e'n)X$ gives pion production rejection
- Pion production threshold at $2m_N + m_\pi \sim 2$ GeV
- Sensitive to $p_{\mathrm{miss},\parallel}$ resolution from ToF



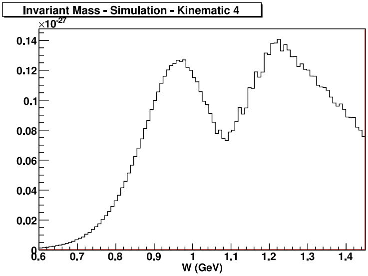


- Monte Carlo tells remaining contribution from resolution
- Initial $^3\mathrm{He}$ momentum distribution from R. Schiavilla
- Using MAID data production cross section are given
- Resolution effects calculated from H_2
- Does not include radiative corrections, sophisticated acceptance tests

$Q^2 = 1.7\ \mathrm{GeV}^2$:

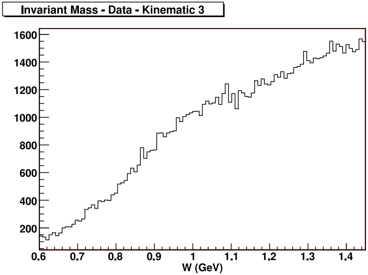


Data

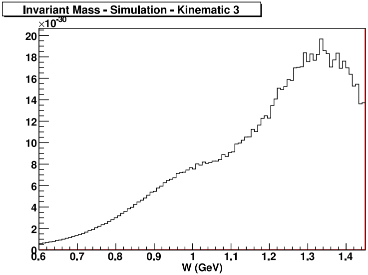


Simulation

Less agreement at higher $Q^2 = 3.5\ \mathrm{GeV}^2$:



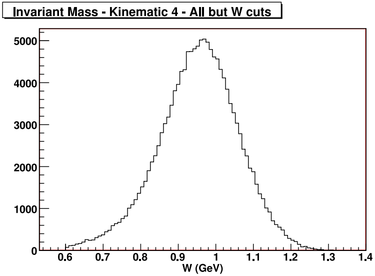
Data



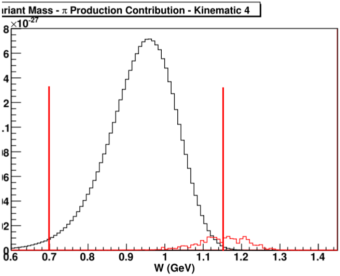
Simulation

Inelastic Contribution with QE Cuts

$Q^2 = 1.7\ \mathrm{GeV}^2$

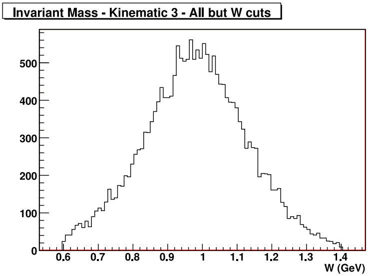


Data

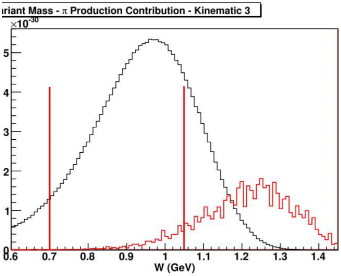


Simulation

$Q^2 = 3.5\ \mathrm{GeV}^2$



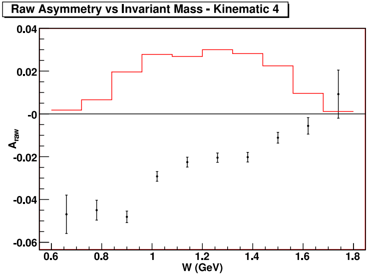
Data

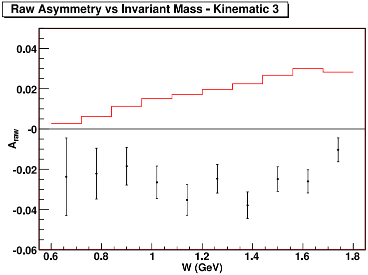


Simulation

Larger contamination cuts heavily on statistics

Asymmetry for pion production similar to QE asymmetry
MC could evaluate asymmetry contributions



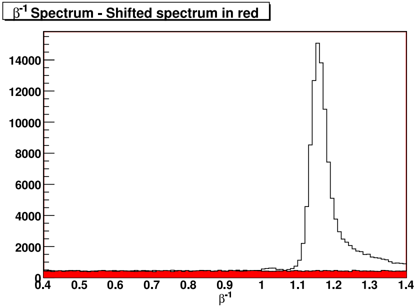


Need to evaluate contributions of:

1. Accidental random background
2. Protons with misidentified charge
3. Scattering from N_2 present in the target
4. Final state interactions

$$A_{\text{phys}} = \frac{A_{\text{raw}} - \frac{\Delta_{\text{back}}}{\Sigma} - \frac{\Delta_p}{\Sigma}}{P_{^3\text{He}} P_{\text{n}} P_{\text{beam}} D_{\text{back}} D_{\text{N}_2} D_p D_{\text{FSI}}} \tag{5}$$

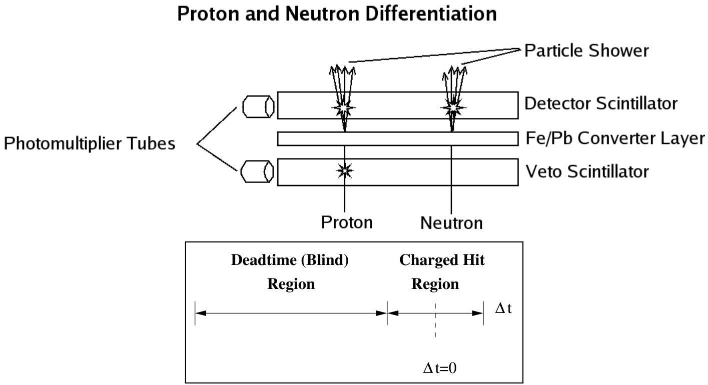
- Accidental background comes from shifting in time



- Nitrogen contribution evaluated from N_2 target with same analysis scaled to charge and density (contributes $\sim 5\%$)

Nucleon Charge Identification

Nucleon Charge ID comes from veto scintillators:



Veto amplitude analysis can improve identification

- Misidentification of protons as neutrons must be understood
- Use 3 targets to separate "mixing constants", η:

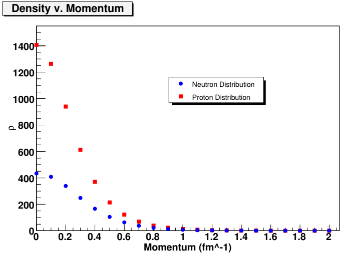
$$N_b^{(a)} \propto f_{\rm targ}\sigma_b\eta_b^{(a)}, \qquad D_p = \frac{N_n^{(n)}}{N_n^{(n)} + N_p^{(n)}} \tag{6}$$

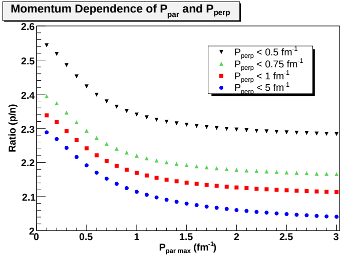
$$R_{\rm H_2} = \eta_p^{(n)}/\eta_p^{(p)} \tag{7}$$

$$R_{\rm ^3He} = \frac{\frac{\sigma_n}{\sigma_p}(\eta_n^{(n)}/\eta_p^{(p)}) + (f^p_{\rm ^3He}/f^n_{\rm ^3He})(\eta_p^{(n)}/\eta_p^{(p)})}{\frac{\sigma_n}{\sigma_p}(\eta_n^{(p)}/\eta_p^{(p)}) + (f^p_{\rm ^3He}/f^n_{\rm ^3He})} \tag{8}$$

$$R_{\rm N_2} = \frac{\frac{\sigma_n}{\sigma_p}\eta_n^{(n)}/\eta_p^{(p)} + \eta_p^{(n)}/\eta_p^{(p)}}{\frac{\sigma_n}{\sigma_p}(\eta_n^{(p)}/\eta_p^{(p)}) + 1} \tag{9}$$

Factor $(f^p_{^3\mathrm{He}}/f^n_{^3\mathrm{He}})$ is p_{miss} dependent:

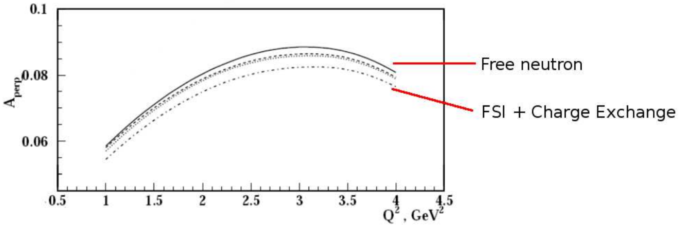




Value for our cuts $\sim = 2.15$

Final State Interactions

Largest nuclear effect comes in the form of charge exchange



Sargsian
arXiv:nucl-th/0110053 and Private Comm.

Preliminary results show systematic decrease in $A_{\rm phys}$ of 5%
More accurate calculations available soon

Tracking

- New tracking code for BigBite by Ole Hansen available
  - Provides substantial increase in processing time
  - Could provide up to 30% increase in statistics
- Summer undergraduate will work on improving drift chamber resolution

Conclusion

- G_E^n analysis is moving smoothly
- Pion production MC and improved tracking will improve statistics at $Q^2 = 3.5\ \mathrm{GeV}^2$ by 50%
- Analysis on $Q^2 = 1.3$ and $2.4\ \mathrm{GeV}^2$ will begin soon
- Final results and publication early next year

(Current results will be shown Saturday, 4:30pm)