Update for E02-013: Measurement of the Neutron Electric Form Factor G_E^n at High Q^2

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Form Factors

All of the structure for elastic electron-nucleon scattering is in the four form factors: F_1^p, F_2^p, F_1^n, F_2^n.
We can write the cross section in terms of these form factors,

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

where $\tau = \frac{Q^2}{4M_N^2}$ and $\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{Mott}}$ is the cross section for scattering from a point-like particle.

Sachs Form Factors

For experiment, use Sachs form factors:

$$G_E \equiv F_1 + \kappa\tau F_2$$
$$G_M \equiv F_1 + \kappa F_2$$

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

$$G_M^p(0) = \mu_p; \qquad G_M^n(0) = \mu_n$$

$$G_E^p(0) = 1; \qquad G_E^n(0) = 0$$

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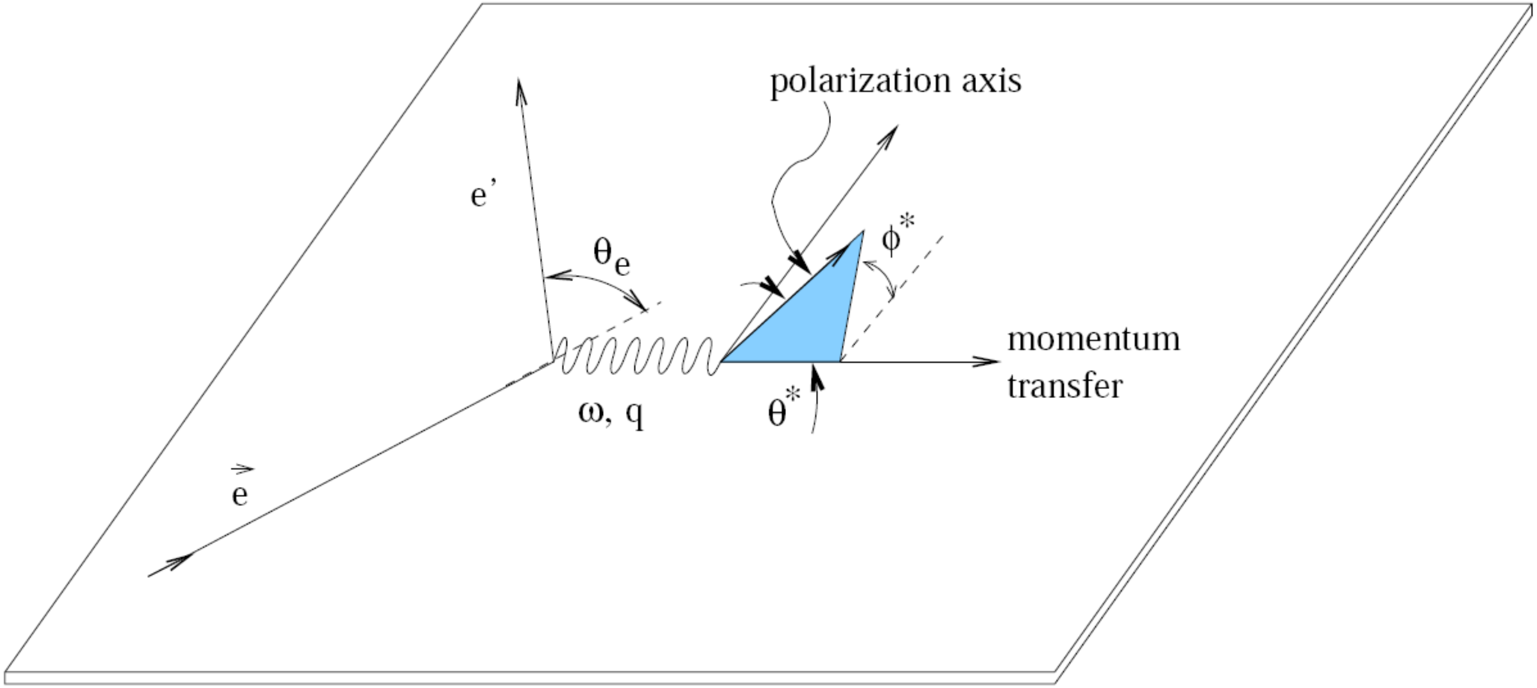
Measure the double polarized asymmetry



$$A_{phys} = \frac{N^+ - N^-}{N^+ + N^-}$$

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$$A_{phys} = \left[\sin\theta^* \cos\phi^* A_\perp + \cos\theta^* A_\parallel\right] h P_b P_t$$

where

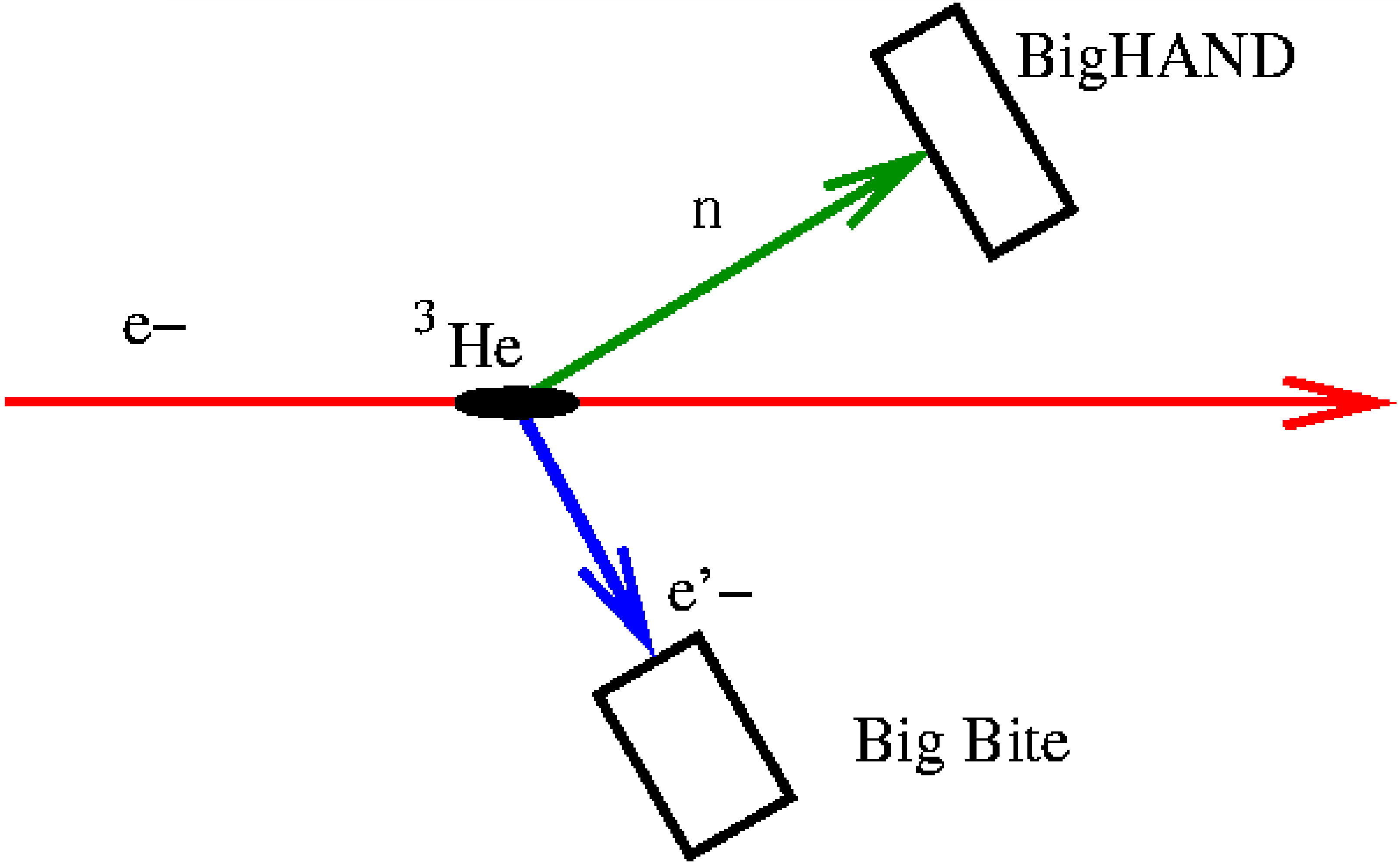
$$A_\perp = -\frac{G_E^n}{G_M^n} \cdot \frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)}{(G_E^n/G_M^n)^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

and

$$A_\parallel = -\frac{2\tau\sqrt{1+\tau+(\tau+1)^2\tan^2(\theta/2)}\tan(\theta/2)}{(G_E^n/G_M^n)^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

P_b, P_t, and h are the beam polarization, target polarization, and incident electron helicity, respectively.

E02-013 Setup

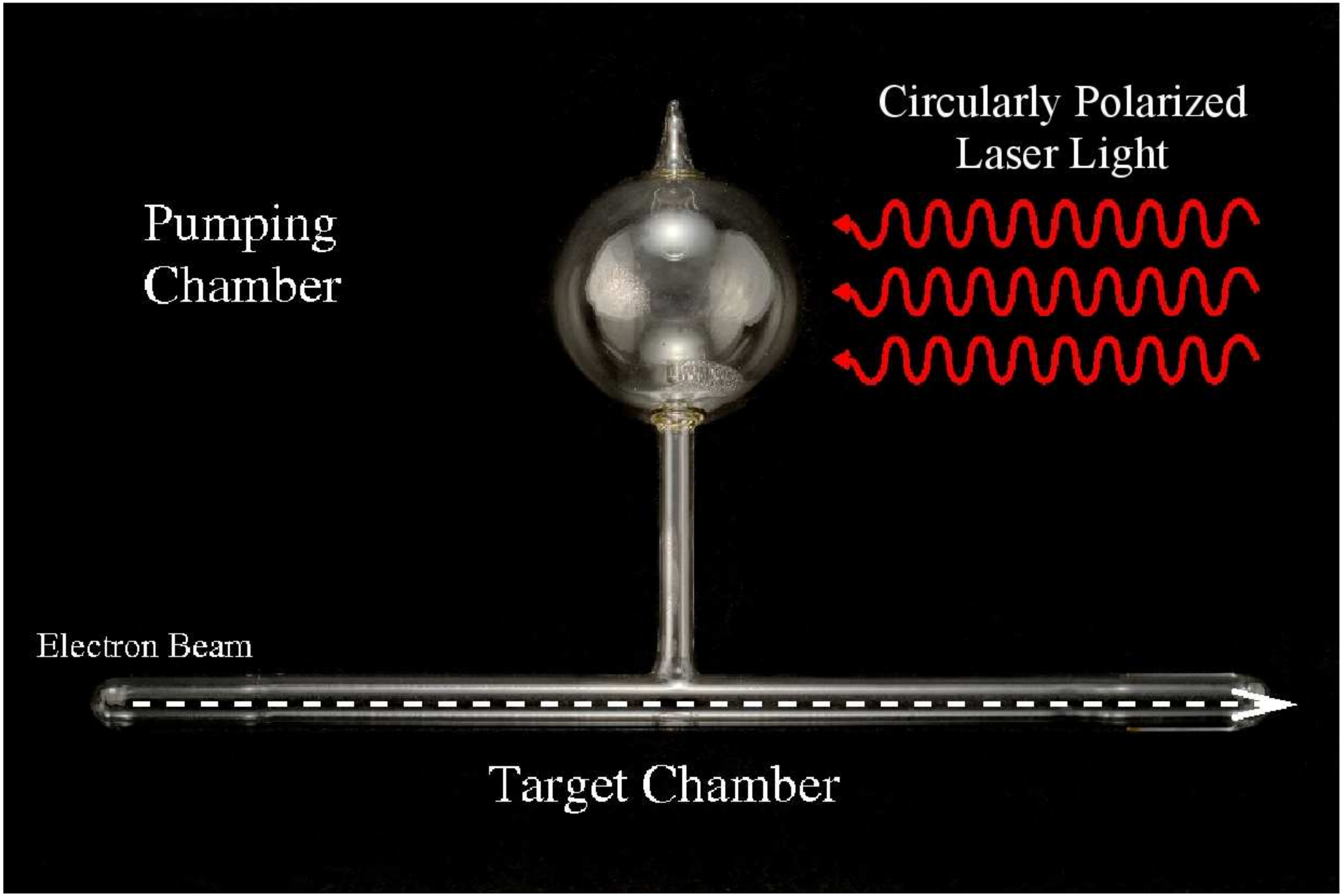


E02-013 Collaboration

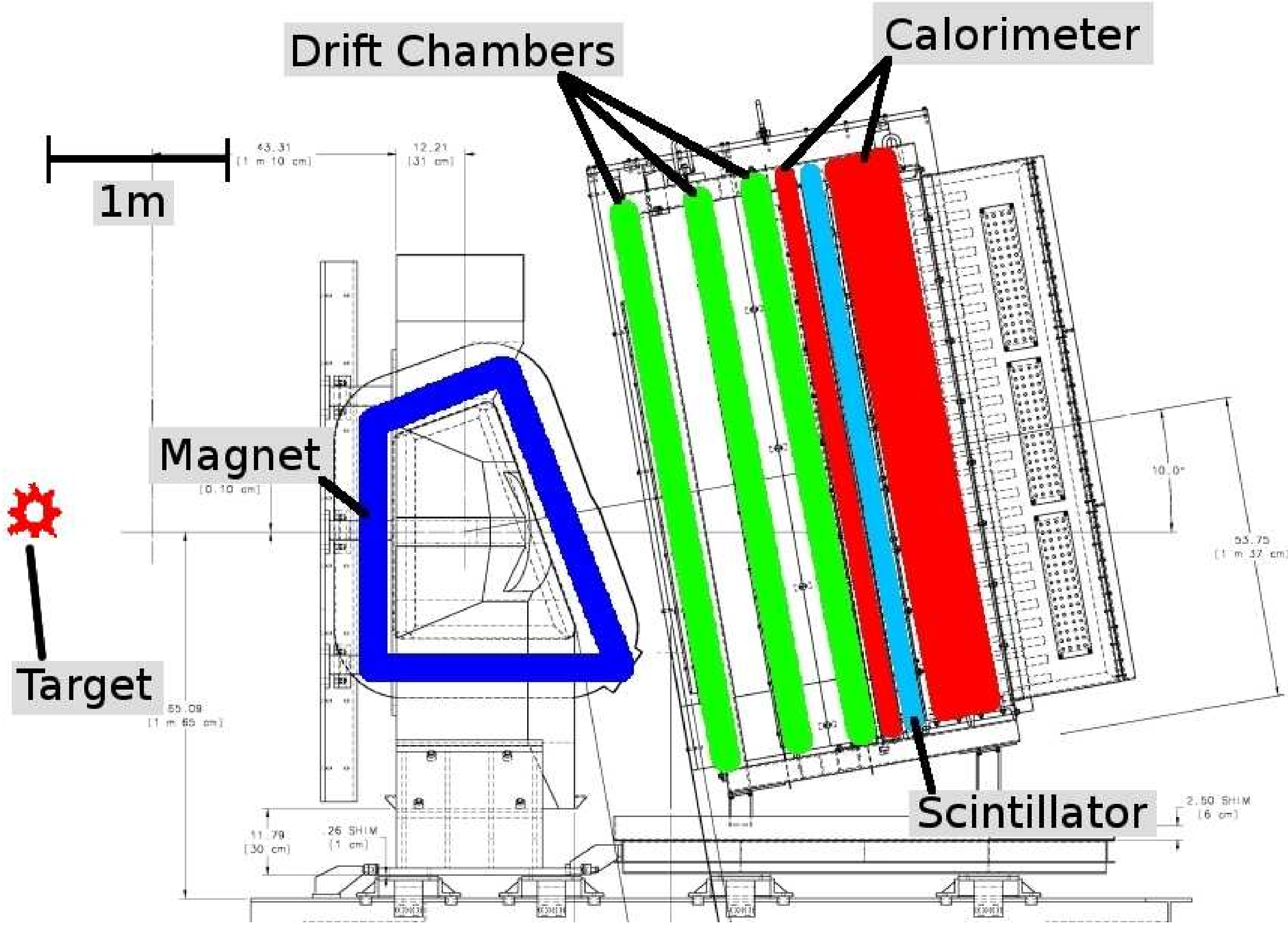
Over 100 Collaborators

- Spokespeople
  - Bogdan Wojtsekhowski – Jefferson Lab
  - Gordon Cates – University of Virginia
  - Nilanga Liyange – University of Virginia
- Analysis Coodinators
  - Rob Feuerbach – JLab, College of William & Mary
  - Seamus Riordan – Carnegie Mellon University (graduated 2008), UVA
- Graduate Students
  - Sergey Abrahamyan – Yerevan, Armenia
  - Brandon Craver – University of Virginia
  - Aidan Kelleher – College of William & Mary (passed Ph.D. defense Dec, 2009)
  - Jonathon Miller – University of Maryland (graduated 2009)
  - Tim Ngo – California State University, Los Angeles (graduated with Master's degree 2007)

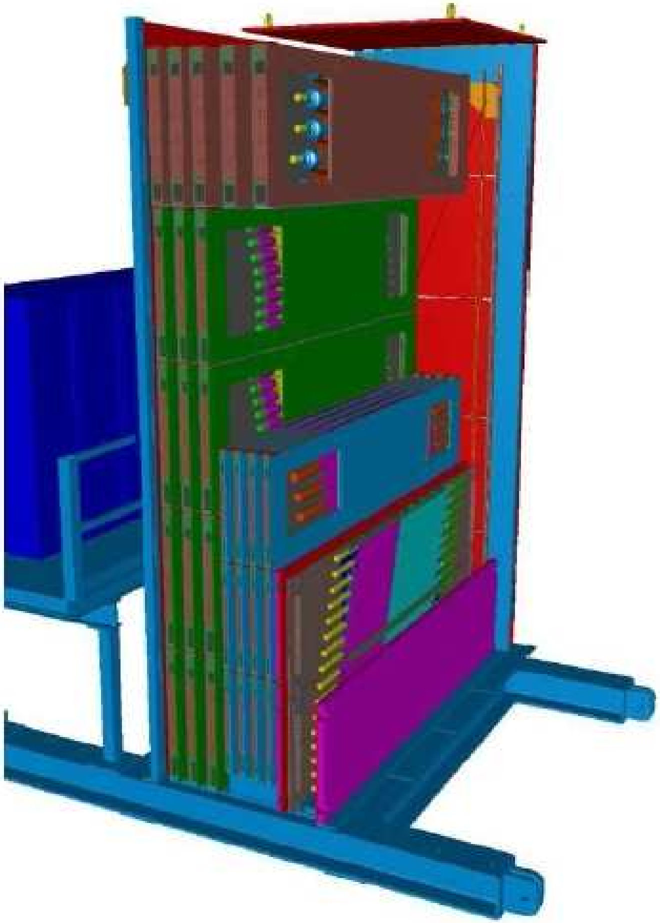
Polarized Target

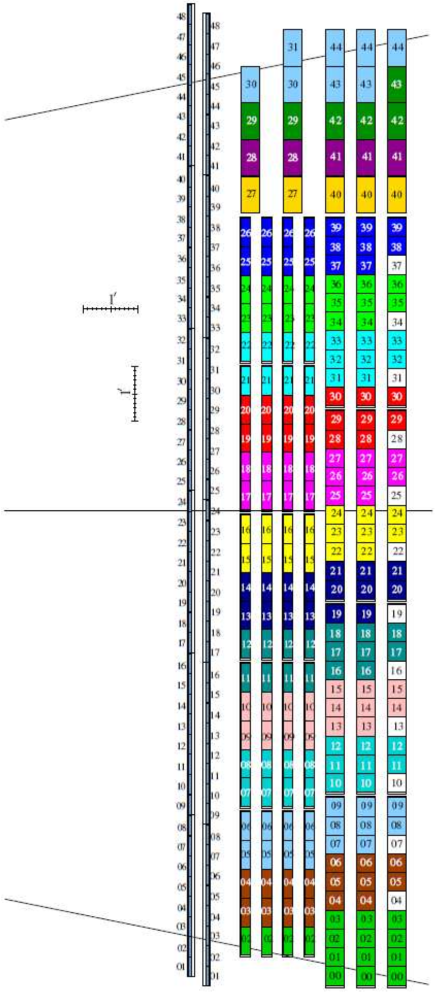


Electron Detector

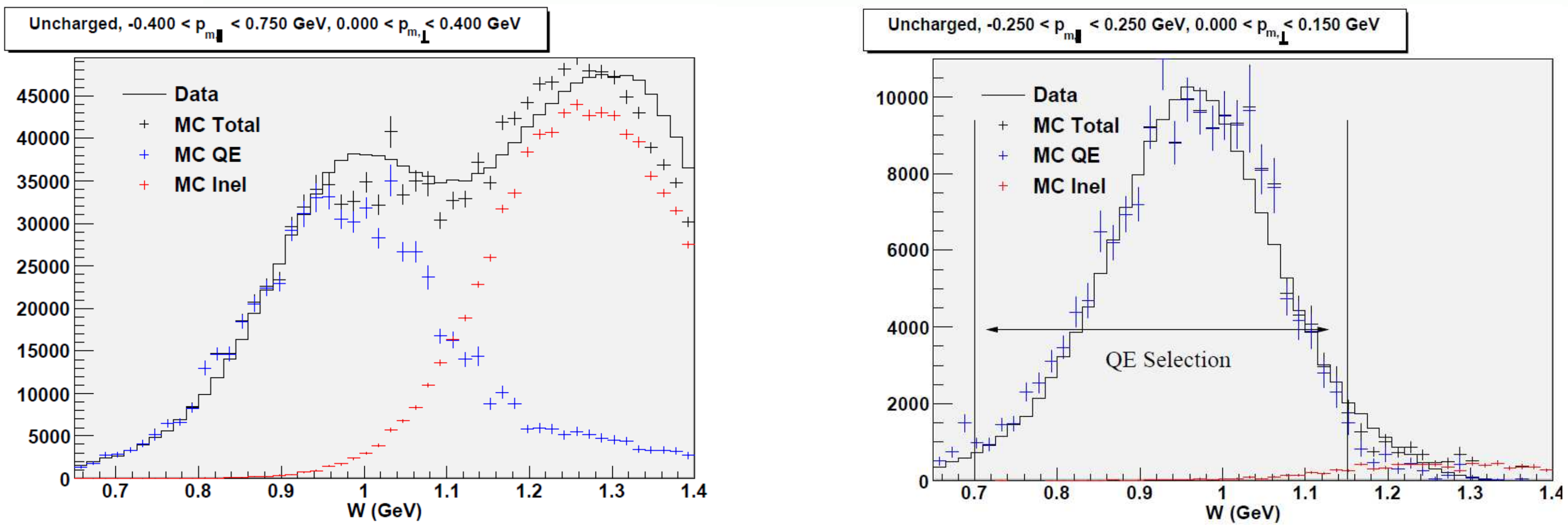


Neutron Detector



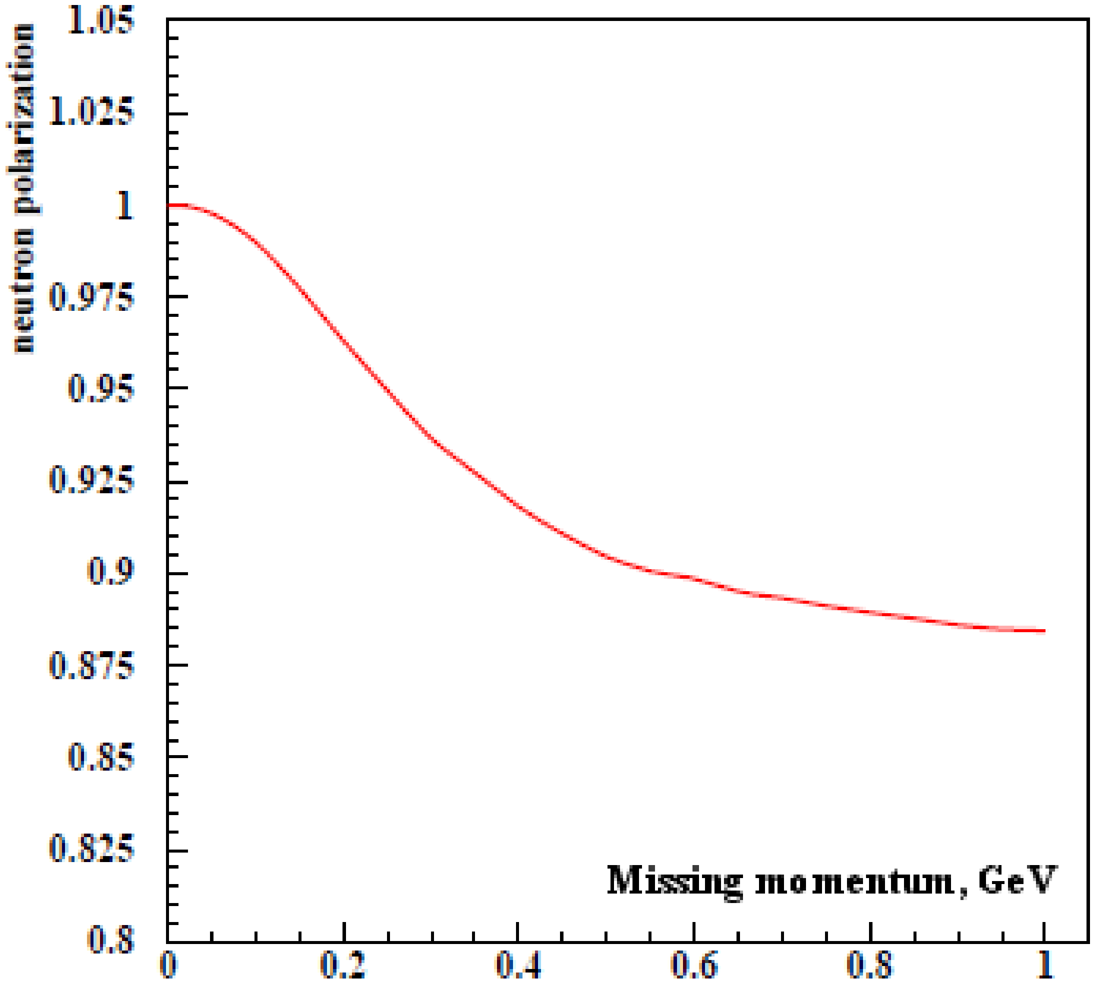


Inelastic Contribution from Monte Carlo



Monte Carlo results without quasi-elastic cuts on TOF and missing momentum on the left.
Results with quasi-elastic cuts on the right show the size of the contribution to our sample.

Neutron Polarization

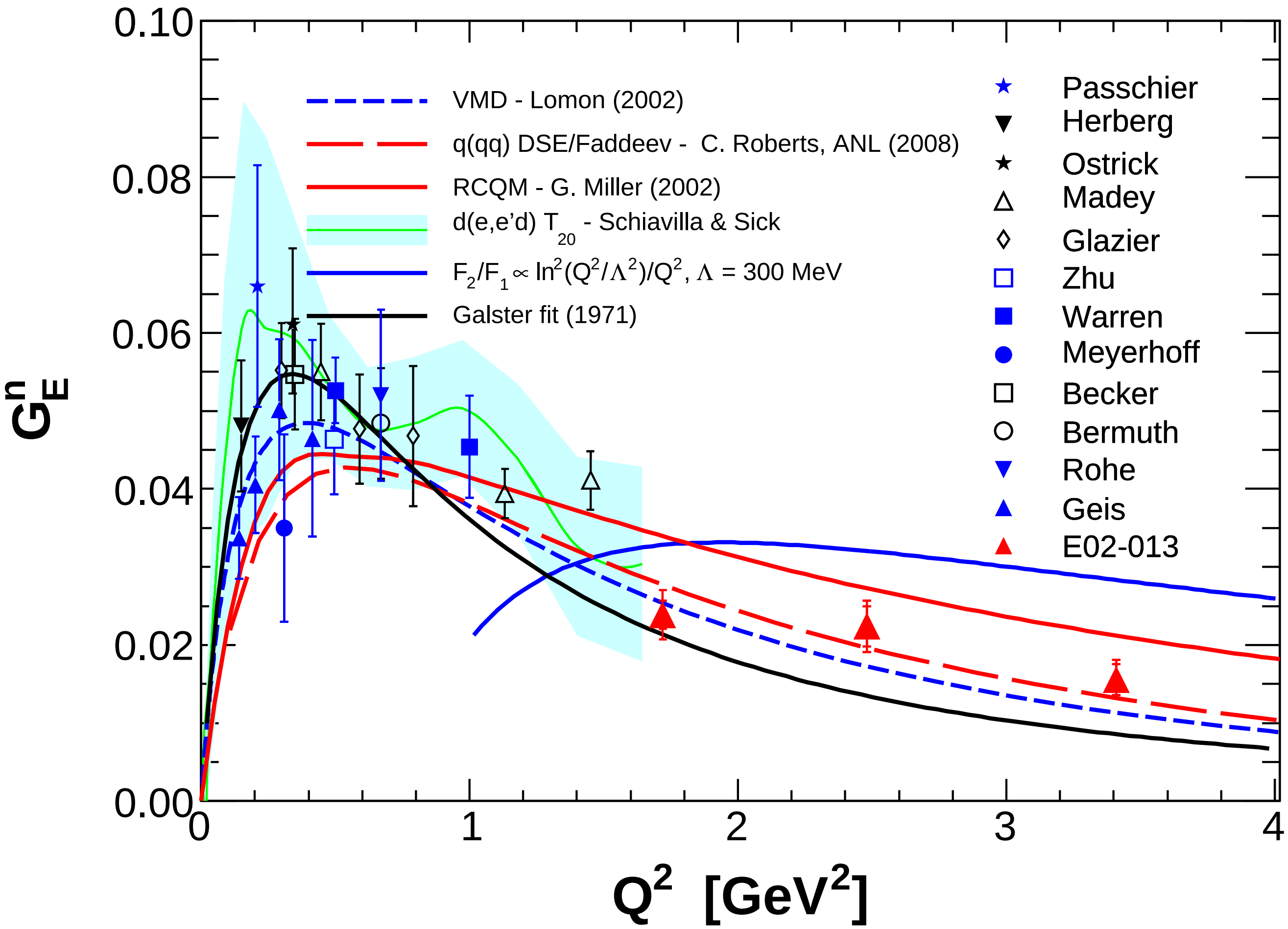


FSI Corrections

- Calculation provided by Misak Sargsian of FIU
- Using Generalized Eikonal Approximation
- Calculated combination of neutron polarization and FSI corrections

$\langle Q^2 \rangle$ (GeV^2)	A Free n	A PWIA	A FSI+CHEX	$D_{\mathrm{pol,FSI}}$
1.7	-0.2163	-0.2079	-0.1952	0.9025
2.5	-0.1635	-0.1592	-0.1509	0.9229
3.4	-0.1081	-0.1080	-0.1042	0.9648

Results


VMD - Lomon (2002)
q(qq) DSE/Faddeev - C. Roberts, ANL (2008)
RCQM - G. Miller (2002)
d(e,e'd) T_{20} - Schiavilla & Sick
$F_2/F_1 \propto \ln^2(Q^2/\Lambda^2)/Q^2$, Λ = 300 MeV
Galster fit (1971)
Passchier
Herberg
Ostrick
Madey
Glazier
Zhu
Warren
Meyerhoff
Becker
Bermuth
Rohe
Geis
E02-013
G_E^n
Q^2 [GeV^2]
0.10
0.08
0.06
0.04
0.02
0.00
0
1
2
3
4

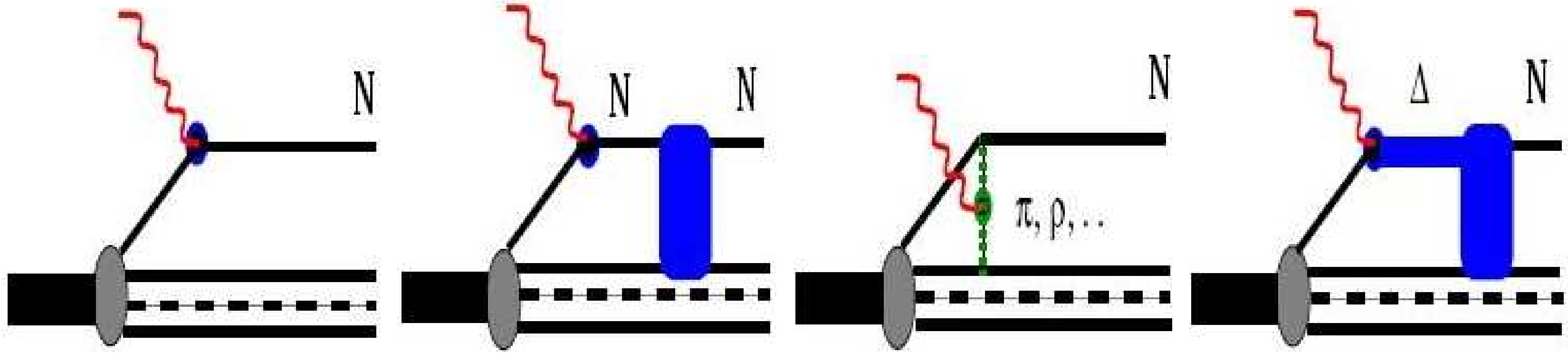
Conclusions

- Sucessfully completed measurement of G_E^n at $Q^2 = 1.7, 2.5, 3.4\ \mathrm{GeV}^2$
- Paper detailing results
  - Submitted to Hall A collaboration.
  - Making revisions.
  - Will submit to arXiv/PRL soon.
- Analysis of $Q^2 = 1.4\ \mathrm{GeV}^2$ point is underway. Result in approximately 6 months.

Backup Slides

Final State Interactions

There are 4 main classes of interactions: Impulse Approximation, Final State Interactions, Meson Exchange Current, Isobar Current



MEC and IC small for high momentum transfer ($Q^2 \geq 1 GeV^2$)

Generalized Eikonal Approximation