G_E^n with Super-BigBite at 12 GeV

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Outline

- Form factors/status of G_E^n
- Setup and Measurement
- Anticipated Results and Errors

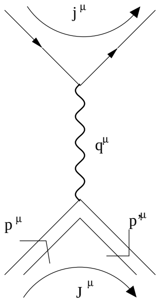
Form Factor Motivation

- Form factors are a fundamental property of the nucleon
- Provide excellent testing ground for QCD and QCD-inspired models
- Are not yet calculable from first principles
- Can be used to constrain broader models of nucleon structure

Nucleon Currents

Scattering matrix element, $M \sim \frac{j_\mu J^\mu}{Q^2}$
Generalizing to spin 1/2 with arbitrary structure, one-photon exchange, using parity conservation, current conservation the current parameterized by two form factors

$$J^\mu = e\bar{u}(p')\left[F_1(q^2)\gamma^\nu + i\frac{\kappa}{2M}q_\nu\sigma^{\mu\nu}F_2(q^2)\right]u(p)$$



Form Factors

- Dirac - F_1, chirality non-flip
- Pauli - F_2, chirality flip

Sachs Form Factors

Replace Dirac and Pauli FF with Sachs Form Factors

$$G_E = F_1 - \kappa\tau F_2$$
$$G_M = F_1 + \kappa F_2, \tau = \frac{Q^2}{4M}$$

Rosenbluth Formula

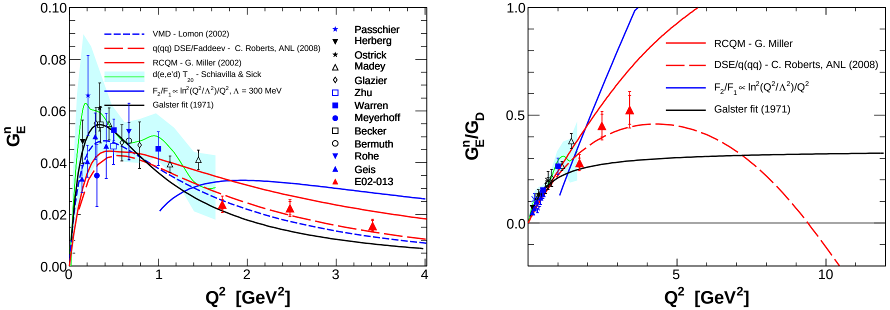
$$\frac{d\sigma}{d\Omega} = \left.\frac{d\sigma}{d\Omega}\right|_{\mathrm{Mott}} \frac{E'}{E} \left[\frac{G_E^2 + \tau G_M^2}{1+\tau} + 2\tau G_M^2 \tan^2\frac{\theta}{2} \right]$$

$\lim_{Q^2 \to 0}$

$$G_E^p(0) = 1, \qquad G_M^p(0) = \mu_p = 2.79$$
$$G_E^n(0) = 0, \qquad G_M^n(0) = \mu_n = -1.91$$

Testing Models

- Polarization measurements allow for highest Q^2 G_E^n measurements



- DSE/q(qq) approach predicts zero crossing for G_E^n
- Recent pQCD predictions give scaling behavior for F_2/F_1
- G_E^n up to Q^2 of other FFs allows for flavor decomposition

12 GeV Plans

- Polarized 12 GeV beam offers new opportunities to go to higher Q^2
- Two experiments at PAC34 approved
  - E12-09-006, B. D. Anderson, J. Arrington, S. Kowalski, R. Madey, B. Plaster, A.Yu. Semenov
    - Hall C, similar concept as earlier Madey experiment
    - $^2\mathrm{H}(\vec{e},e'\vec{n})p$
    - $Q^2 = 2.2, 4.0, 5.2, 6.9\ \mathrm{GeV}^2$
  - E12-09-016, B. Wojtsekhowski, G. Cates, S. Riordan
    - Super-BigBite Family
    - $^3\overrightarrow{\mathrm{He}}(\vec{e},e'n)pp$
    - $Q^2 = 5.0, 6.8, 10.2\ \mathrm{GeV}^2$

E12-09-016 Collaboration

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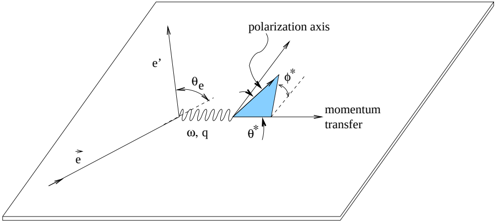
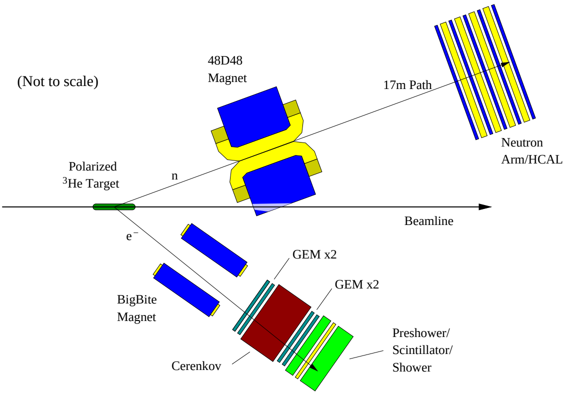
Long. polarized beam/polarized target transverse to $\vec{q}$ in scattering plane



Helicity-dependent asymmetry roughly proportional to G_E/G_M

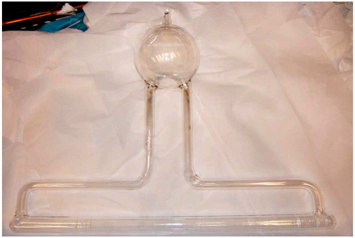
$$\frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = A_\perp = -\frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2) G_E/G_M \hat{n}\cdot(\hat{q}\times\hat{T})}{(G_E/G_M)^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

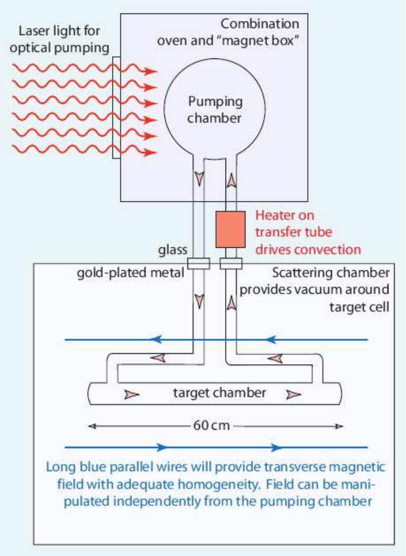
Experimental Layout



- Same neutron arm/(or HCAL) at 17 m, but no veto
- Place magnet $B \cdot dl = 1.7\ \mathrm{T} \cdot \mathrm{m}$ in front to deflect protons - reduces background by factor of 5

Upgraded ^{3}He Target

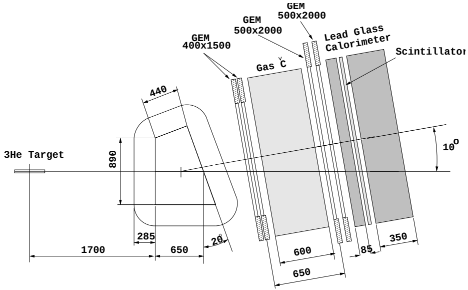




- Simulations show sustainable polarization of 62% with $I = 60\ \mu\text{A}$
- Overall effective luminosity gain of 15

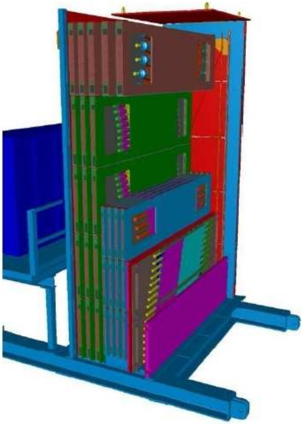
Super-BigBite Components

- Estimated rates are 60 $\mathrm{kHz/cm^2}$ - current drift chambers replaced by GEM chambers
- GEM detectors shown to work up to 2500 $\mathrm{kHz/cm^2}$ at CERN
- Momentum resolution of $\sigma_p/p \sim 0.5\%$ for e^- of $3-4$ GeV
- Existing BigBite Cerenkov+preshower pushes pion contributions $< 0.1\%$



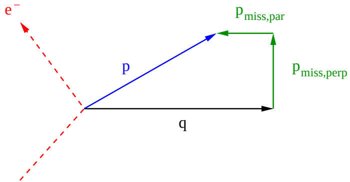
Neutron Arm

- Neutron arm detects recoiling proton/neutron
- Measures momentum through ToF, charge through veto layers
- Covers 5m $\times$ 1.6m about about 17 m away - matches BigBite acceptance for QE electrons
- Time resolution $\sigma_t = 300\ \mathrm{ps}$, only $\sim 20\%$ momentum resolution for $6.3\ \mathrm{GeV}$ neutrons
- Cuts on $p_{\mathrm{miss},\perp}$ allows for selection on QE, suppress FSI



Quasielastic Selection

Need to reliably separate neutral QE events

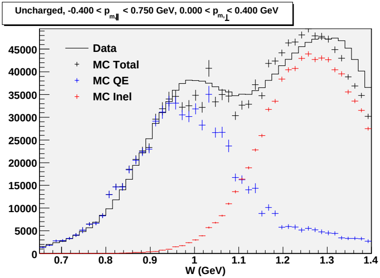


Cut on:

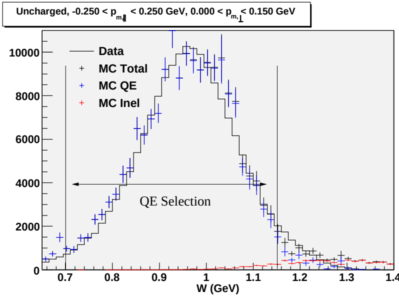
- Components of missing momentum wrt $\vec{q}$
- Invariant mass assuming free stationary nucleon target

Inelastic Contributions

- For E02-013, $Q^2 = 1.7\ \mathrm{GeV}^2$



QE cuts →



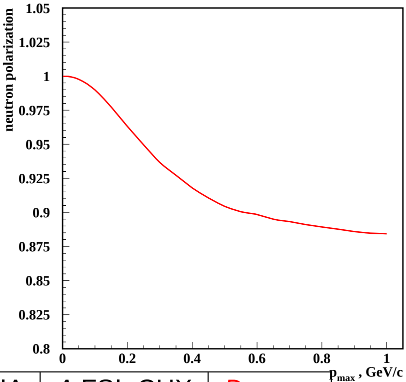
- Using more strict cuts, inelastic contribution is predicted to be about $\sim 25\%$ of final neutral sample
- Similar case was present for E02-013, 5% contribution to the final systematic error should be achievable

FSI, n polarization for E02-013

- Nuclear effects evaluated by M. Sargsian in Generalized Eikonal Approximation
  - Determine effective neutron/proton polarization
  - Evaluate rescattering effects on asymmetry
- MEC and IC become suppressed at higher Q^2
- At high p, total cross sections for σ_{pp}, σ_{pn} becomes roughly constant
- Charge exchange can modify final asymmetry

FSI Results

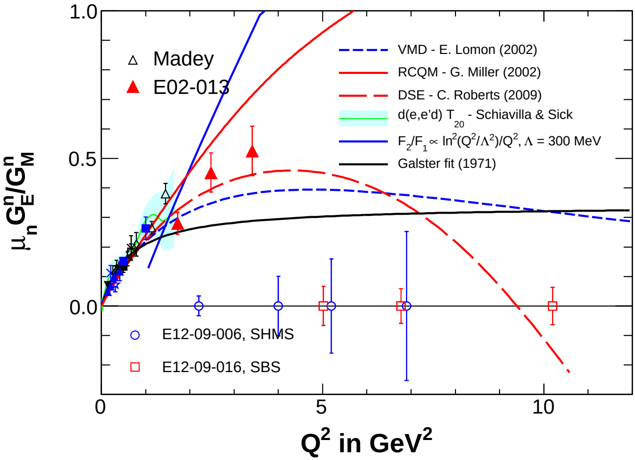
- Effective polarization highly dependent on missing momentum cuts
- Very different from 86% inclusive assumption
- Lower Q^2 detector acceptances and cuts:



$\langle Q^2 \rangle$ (GeV^2)	A Free n	A PWIA	A FSI+CHX	$D_{\mathrm{pol,FSI}}$
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

Goals

Brings GEn up to similar range as other form factors with 55 days of beam



Conclusion

- Hall A BigBite program was been very productive over the last several years - we anticipate similar success with SBB
- Measurements at 12 GeV Jefferson Lab have a significant impact on the range of Q^2 form factors are measured - almost triples G_E^n measured range.

Goals

Q^2 (GeV^2)	time (days)	Counts	G_E^n/G_M^n (Galster)	stat. err.	sys. err.	G_E^n (Galster)	Total ΔG_E^n (G_M^n known)
5.0	2	20000	-0.1770	0.0319	0.0222	0.0046	0.0010
6.8	6	45000	-0.1918	0.0259	0.0253	0.0028	0.0005
10	36	30000	-0.2098	0.0380	0.0161	0.0014	0.0003

Quantity (for $Q^2 = 10$ GeV^2)	Expected Value	Rel. Uncertainty
Raw asymmetry (Galster+Kelly)	-0.0292	19.9% (stat)
Beam polariation P_e	0.85	2.4%
Target polariation $P_{^3He}$	0.60	3.3%
Neutron polariation P_n	0.86	2.3%
Nitrogen dilution D_{N_2}	0.94	2.1%
Accidental dilution D_{back}	0.95	$< 1\%$
Final state interactions	0.95	5.3%
Inelastic correction	0.8-1.2	5.0%
Statistical error in G_E^n/G_M^n		18.1%
Systematic error in G_E^n/G_M^n		7.7%

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Goals

	Beam Energy (GeV)	Data Taking Time (hours)	Total Time (hours)
Calibration Runs	4.400		48
$Q^2 = 5.0\ \mathrm{GeV}^2$	4.400	38	48
$Q^2 = 6.8\ \mathrm{GeV}^2$	6.600	154	192
$Q^2 = 10.2\ \mathrm{GeV}^2$	8.800	864	1080
Configuration Changes			16
Total		1055	1384

Inelastic Contributions