The Electric Form Factor of the Neutron for SBS

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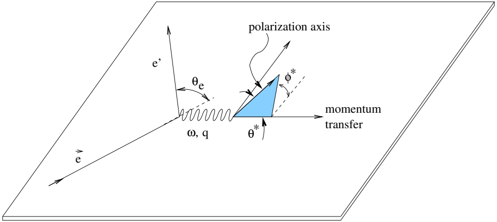
G_E/G_M at high Q^2 - Spin Observables, Pol. Target

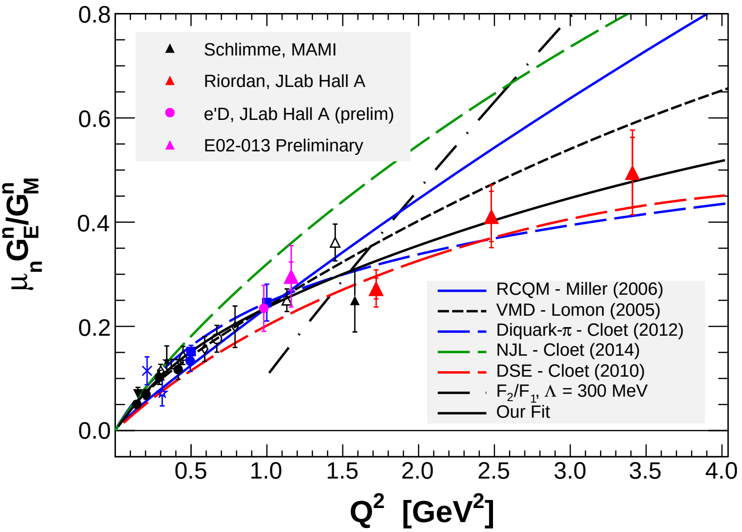
Long. polarized beam/polarized target transverse to $\vec{q}$ in scattering plane



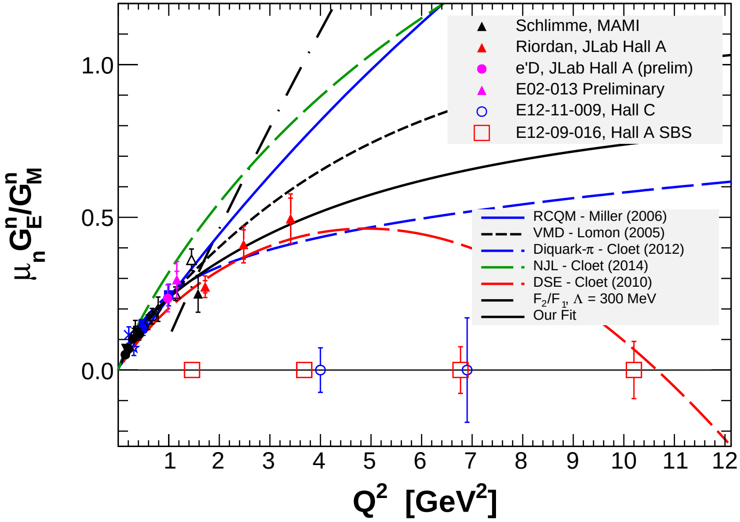
Helicity-dependent asymmetry roughly proportional to G_E/G_M

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

Neutron Form Factors

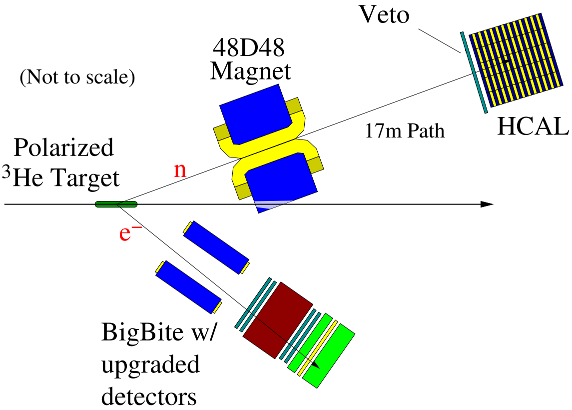


Neutron Form Factors



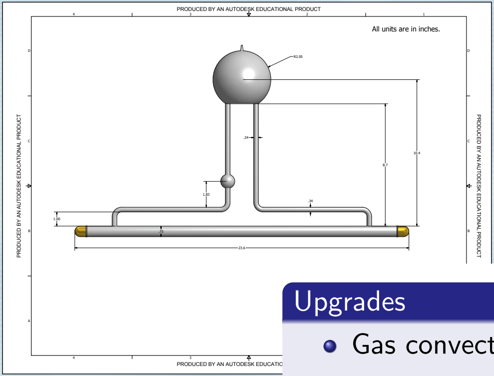
- Models for G_E^n are highly divergent for high Q^2

High Q^2 G_E^n Experimental Layout



- Upgraded Bigbite detector stack for higher rates, better PID
- Hadron calorimeter at 17 m
- Place magnet $B \cdot dl = 1.7\ \mathrm{T} \cdot \mathrm{m}$ at 2.8 m from target to deflect protons

Target cell design for SBS G_E^n experiment



- 60 cm target-chamber length will deliver desir
- Convection-based design, now well tested in Pro
- Contains 6 STP liters of ^{3}He in 750 cm^3 volume
- Will use copper metal end windows with gold el

Wednesday, October 21, 15

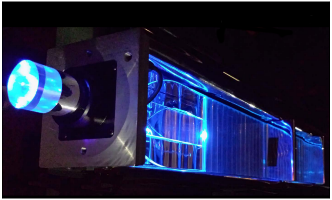
Upgrades

- Gas convection
- Metal windows
- 10 μA $\rightarrow$ 60 μA
- 40 cm $\rightarrow$ 55 cm
- $P = 45\% \rightarrow 60\%$

Stolen from Gordon Cates

HCAL + 48D48

- HCAL uses 12×24 $15 \times 15\ \mathrm{cm}^2$ iron/scintillator design for hadron calorimetery
- 48D48 removes background and deflects protons out of QE acceptance - loss of 20% statistics at 2.8 m for extended target



  - Spatial resolution of 1.5 $\mathrm{cm} \rightarrow 10\ \mathrm{mrad}$
  - ToF resolution critical for QE selection - see later slides
  - Detector plane can provide additional PID

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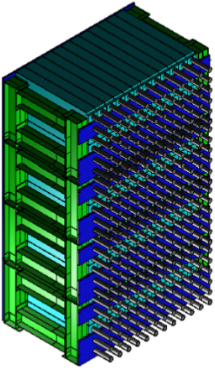

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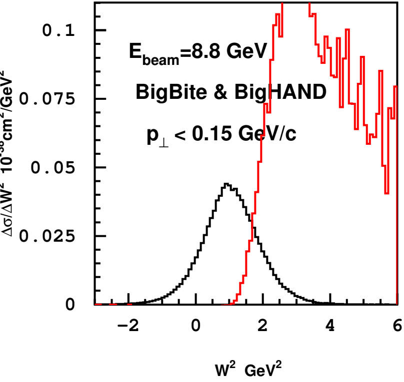
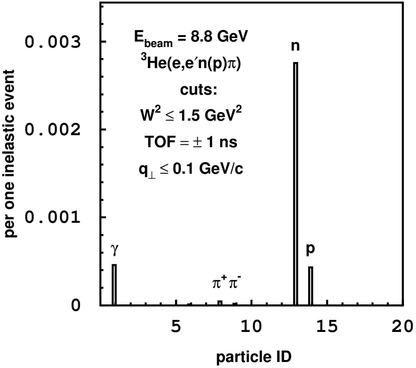
Quasielastic Selection and Backgrounds

- Cuts on missing momenta (θ_{pq} and ToF), invariant mass allow for suppression of inelastic events
- Inelastics can be corrected using Monte Carlo with MAID or sideband subtraction/deconvolution

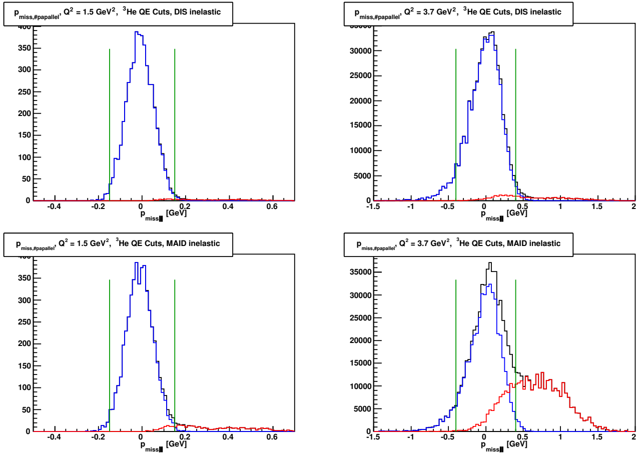




- Background mostly neutrons, photons probably removable with energy resolution, some inelastic protons

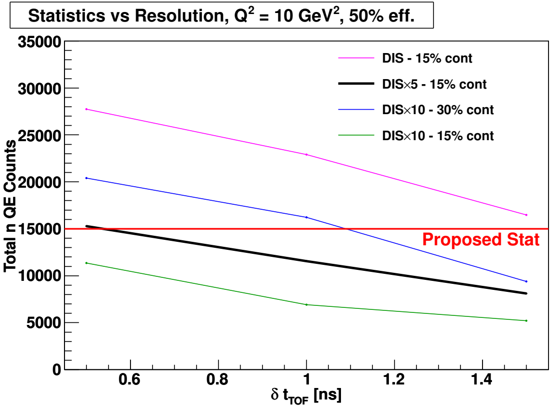
MAID vs. DIS - $p_{m,\parallel}$

$\delta t = 0.5$ ns



Black - all, blue - QE, red - Inelastic

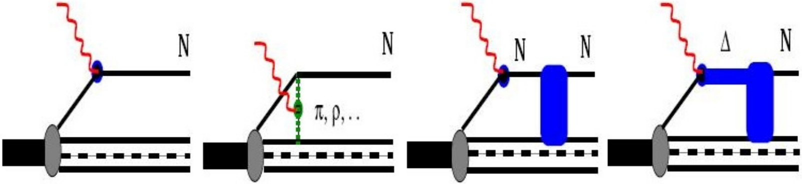
Counts vs. Time of Flight Resolution



- Scaling DIS $\times$ 5, 15% contamination needs about 0.5 ns resolution
- Could probably do OK with 1 ns resolution, loss of 20% statistics

Nuclear Corrections

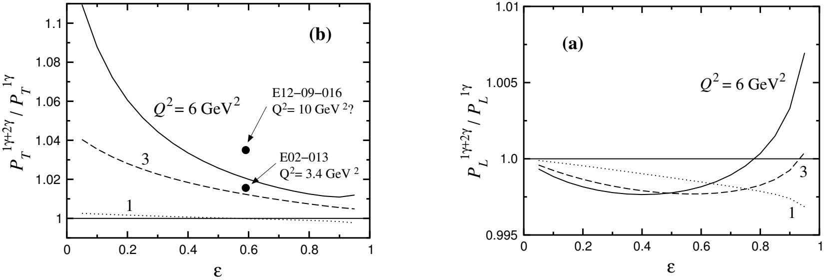
- Nuclear effects evaluated by M. Sargsian in Generalized Eikonal Approximation
  - Determine effective neutron/proton polarization
  - Evaluate rescattering effects on asymmetry
- Considers four main diagrams



- PWIA, MEC, FSI, IC

Needs to be redone for new kinematics

- Two photon effects for polarized target related to effects in polarization transfer
- Only considered proton ground state for box diagrams
- Asumming similar size correction as proton:



Blunden, Melnitchouk, Tjon, Phys. Rev. C 72, 034612 (2005)

Requirements for Instrumentation in G_E^n/G_M^n Measurement

To achieve $\sim$ 10% at $Q^2 = 10\ \mathrm{GeV}^2$ given luminosity $6 \times 10^{36}\mathrm{Hz/cm}^2$ (60 cm target, 60 μA), 60% polarization:

BigBite Requirements	
2 $150 \times 40\ \mathrm{cm}^2$ chambers	
2 $200 \times 50\ \mathrm{cm}^2$ chambers	
e^- acceptance	40 msr
p_e	$1 - 3.0$ GeV
δp_e	1%
Angular Range	$35 - 40°$
e^- detector rates	$100\ \mathrm{kHz/cm}^2$
e^- ToF	0.25 ns
δE	$\sim 10\%$
π rejection	100-300:1
$\delta\theta_e$	~ 1 mrad
δv_z	~ 0.5 cm

Nucleon Arm Requirements	
N acceptance	30 msr
p_n	$1 - 10$ GeV
Angular Range	$17 - 40°$
$\delta\theta_{p_n}$	10 mrad
δt_{ToF}	0.5 ns
$B \cdot dl$	$1.7\,T \cdot m$
Total rate	20 kHz

Summary

- G_E^n can be measured to $Q^2 = 10\ \mathrm{GeV}^2$ with SBS to $\sim 10 - 20\%$ accuracy
- HCAL needs ToF resolution on order of $0.5 - 1\ \mathrm{ns}$
- Upgraded target that can handle 60 $\mu\mathrm{A}$ with 60% polarization required
- Other requirements fall within SBS defintions

BACKUP SLIDES

Polarized Target Measurements - Nulling asymmetry

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

$$\frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = A_\perp \sin\theta^* \cos\phi^* + A_\parallel \cos\theta^*$$

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

$$-\frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2(\theta/2)}\tan(\theta/2)\cos\theta^*}{(G_E/G_M)^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

- $A_\parallel$ provides "reference asymmetry" that is mostly dependent just on kinematic variables
- Setting $A_\parallel$ and $A_\perp$ to cancel by rotating target pol. angle reduces uncertainties contributed by scaling effects in asymmetry such as target and beam polarization
- Need to know G_E^n a priori to do it correctly, only for low Q^2

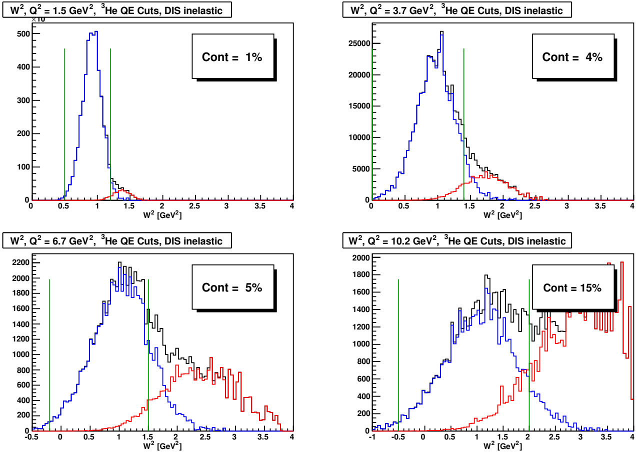
Assuming Galster for G_E^n, Kelly for G_M^n:

Q^2 [GeV^2]	time [days]	stat [%]	sys [%]
1.5	1	1.3	2.4
3.7	2	6.0	4.4
6.8	4	19.8	7.3
10.2	31	22.5	6.6

Systematic uncertainties to asymmetries at highest Q^2

Quantity	Expected Value	Rel. Uncertainty
Beam polarization P_e	0.85	2.4%
Target polarization $P_{^3\mathrm{He}}$	0.60	3.3%
Neutron polarization P_n	0.86	2.3%
Nitrogen dilution D_{N_2}	0.94	2.1%
Background dilution D_{back}	0.95	$<1\%$
Final state interactions	0.95	2.1%
Inelastic correction	0.8-1.2	5.0%
Angular error from $A_\parallel$		$<1\%$
Systematic error in G_E^n/G_M^n		6.6%

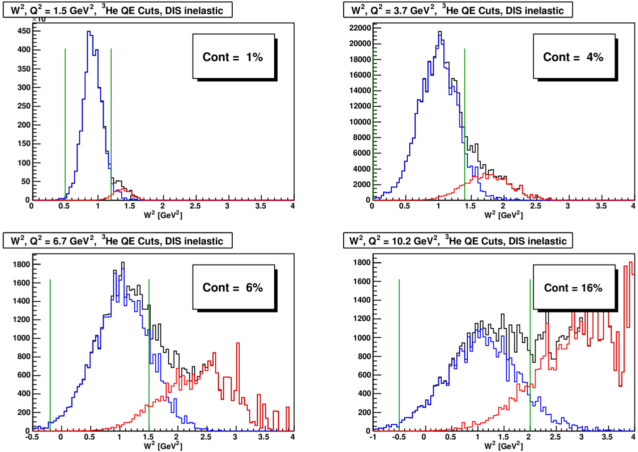
$\delta t = 1.0$ ns



- Adjusting cuts so contamination is about the same, loss of statisics is about 20%

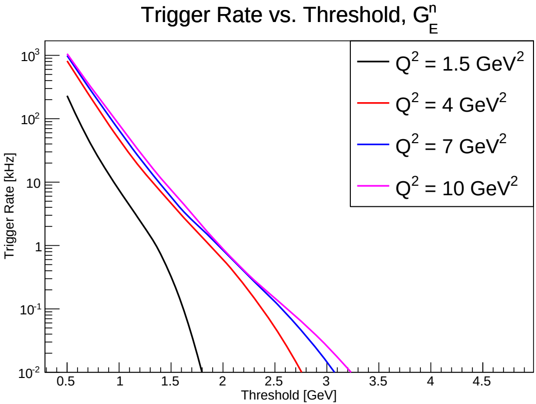
DIS - W^2

$\delta t = 1.5$ ns



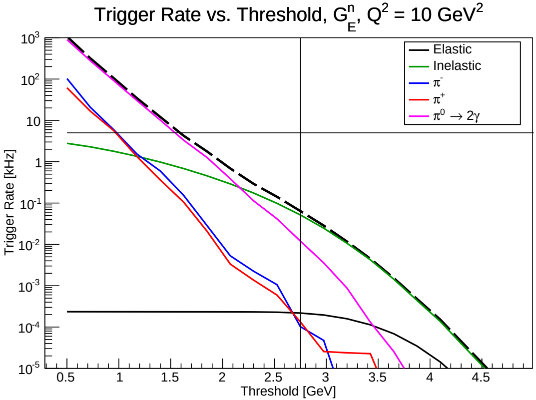
- Adjusting cuts so contamination is about the same, loss of statisics is about 50%

Trigger



- Rates above include elastic e^-, DIS e^-, and π^{+-0}
- Single arm shower/preshower (with ps cut) keeps will have $< 2\ \mathrm{kHz}$ trigger rate without affecting QE cuts
- Need to allow some inelastic in trigger - prescale lower threshold

Trigger



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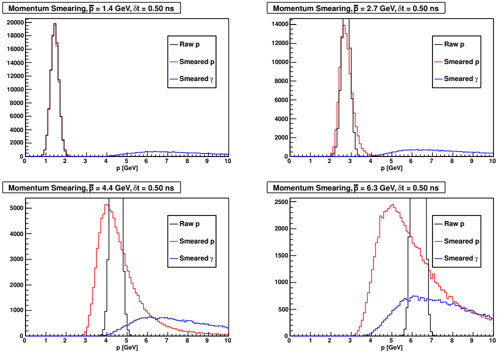
Smearing and Photons



- Smearing ToF is asymmetric in p
- For highest momentum transfers $\beta = 1$ particles can get smeared in (from small $p_{m,\parallel}$)
- 48D48 and energy resolution of HCAL should suppress
- π^0 production could contribute - need to study responses, rates