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

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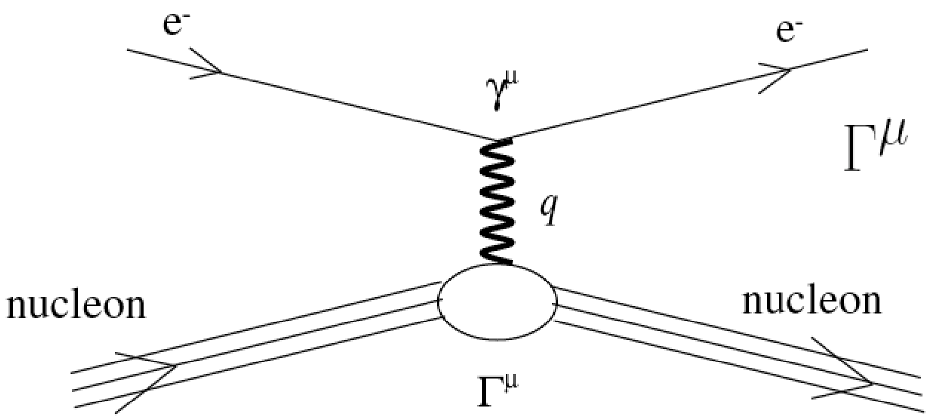
The College of William and Mary

For the E02-013 Collaboration and

Hall A Collaboration

Elastic EM Form Factors

For an extended spin-1/2 particle, the general vertex term is:



$$\Gamma^{\mu} = F_1(q^2)\gamma^{\mu} + \frac{\kappa}{2M} F_2(q^2) i\sigma^{\mu\nu} q^{\nu}$$

Elastic cross-section:

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

Or in terms of the Sachs Form factors:

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

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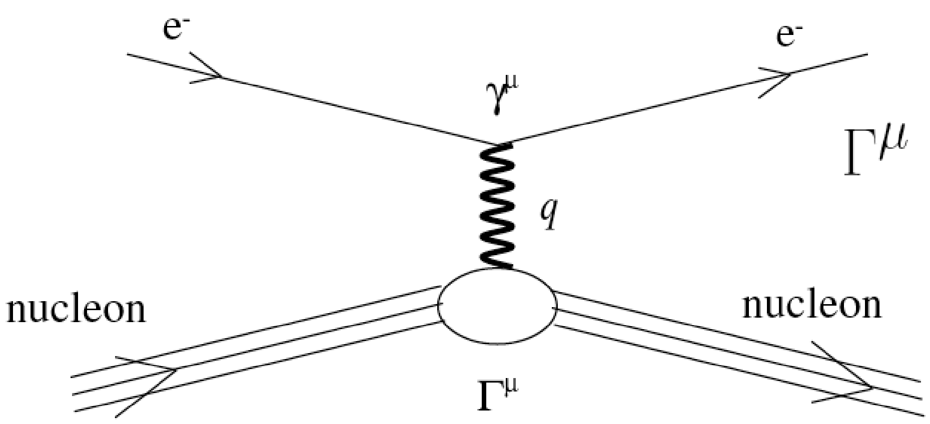

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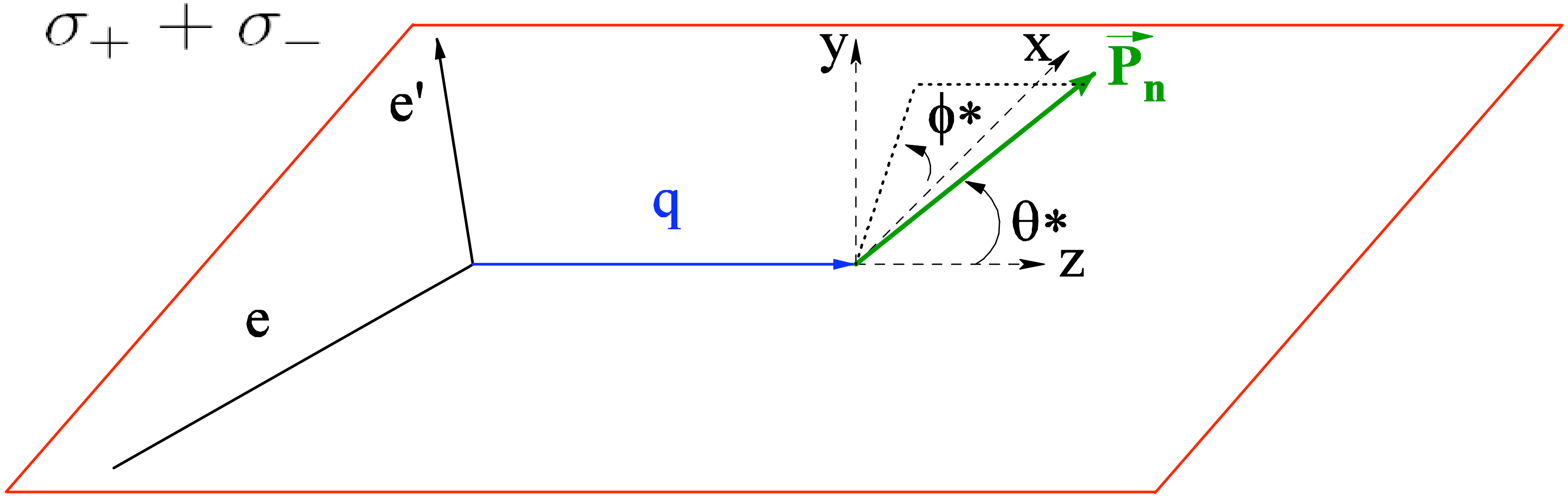
Dominate at large Q^2

Double Polarization Measurement

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



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

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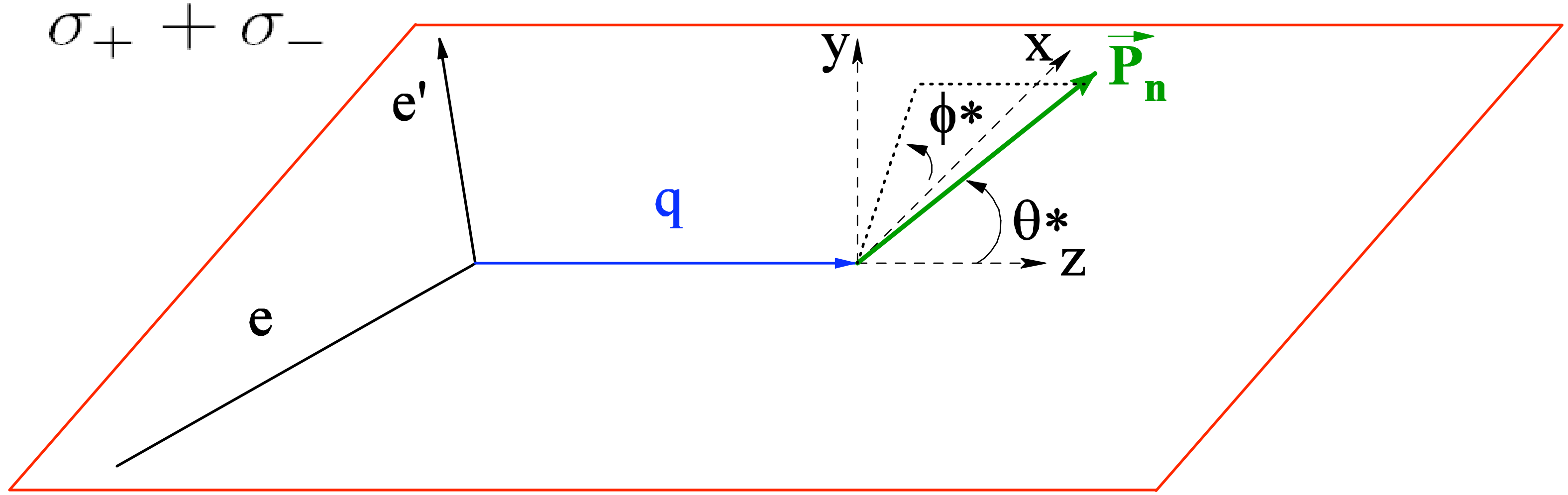

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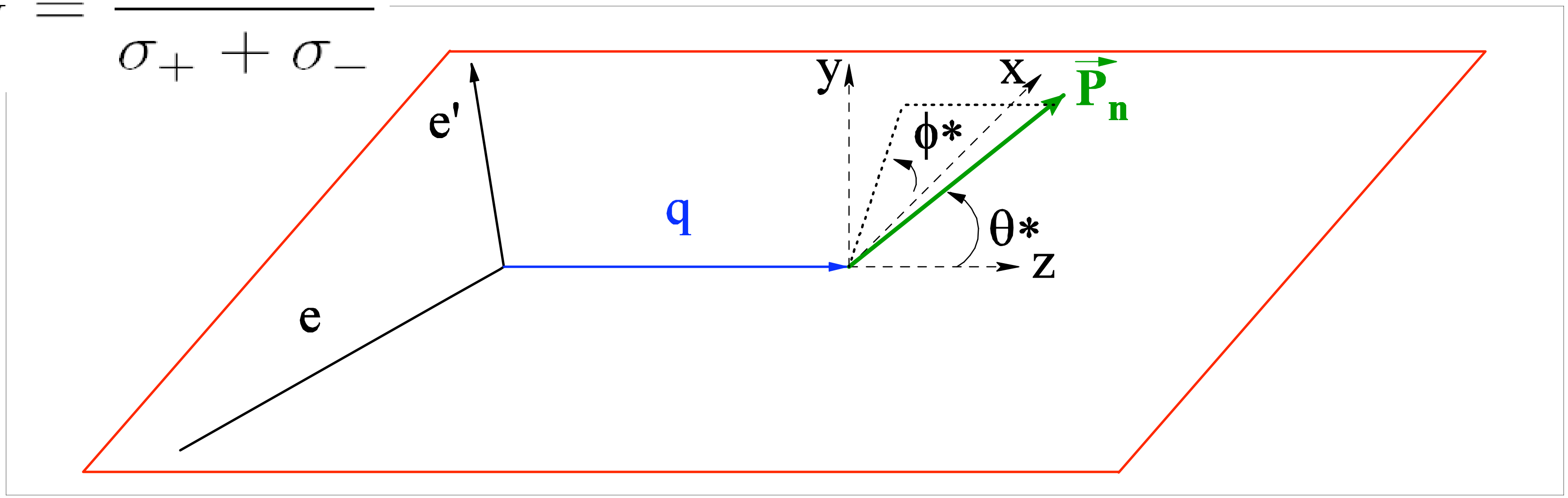

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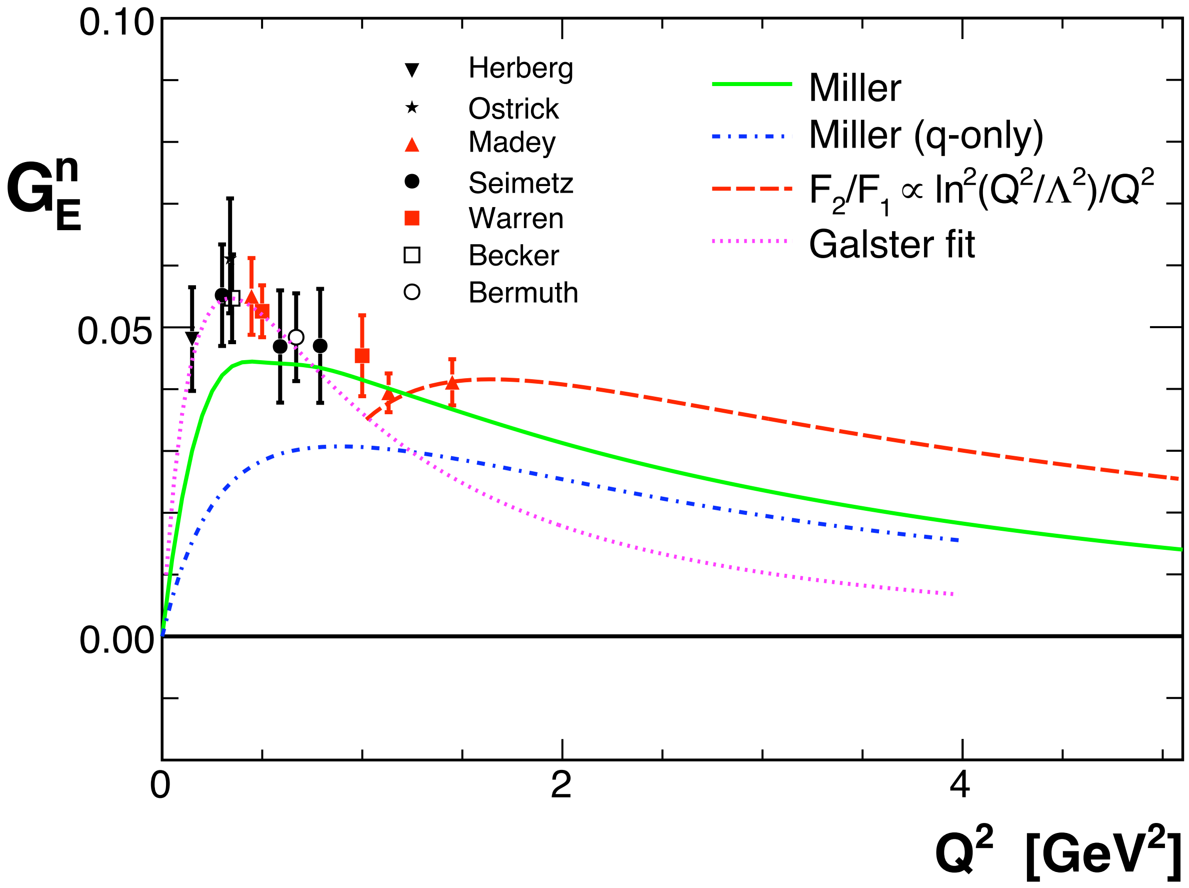
Elastic EM Form factors: the Neutron



- $G_M{}^n$ behavior well matched by the dipole form up to Q^2~4 GeV^2
- $G_E{}^n$ more sensitive than other FF to details of the pion-cloud at low Q^2
- $G_E{}^n$ is not precisely measured above 1.5GeV^2
- Permits disentanglement of F_2

$$F_1^n(t) = \frac{2}{3}F_1^u(t) - \frac{2}{3}F_1^d(t)$$

$$F_2^n(t) = \frac{2}{3}F_2^u(t) - \frac{2}{3}F_2^d(t)$$

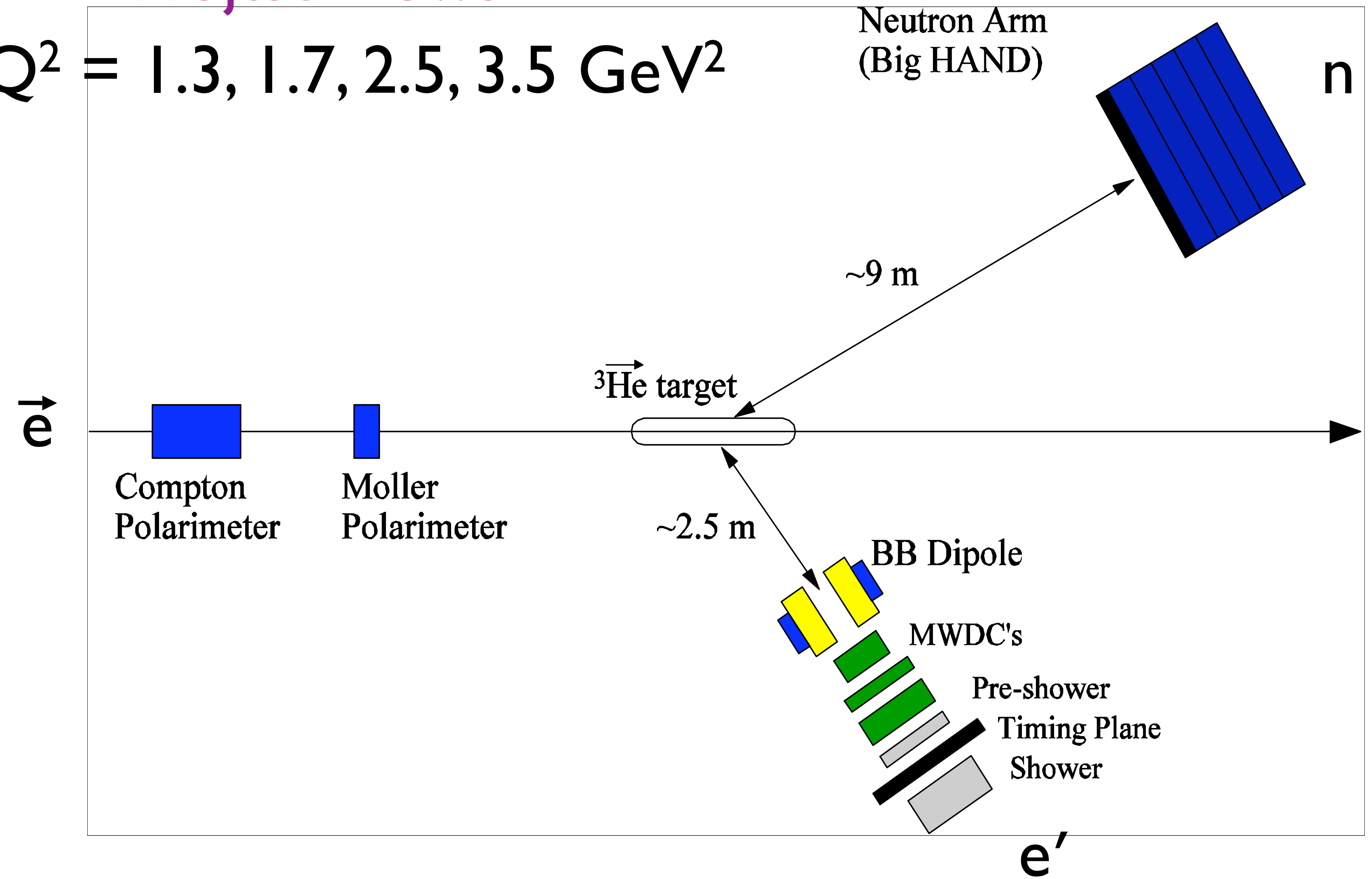
$$F_1^q(t) = \int_{-1}^{+1} dx\ e_q H^q(x,\xi,t)$$

$$F_2^q(t) = \int_{-1}^{+1} dx\ e_q E^q(x,\xi,t)$$

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

E02-013: Cates, Liyanage, Wojtsekhowski

Q^2 = 1.3, 1.7, 2.5, 3.5 GeV^2



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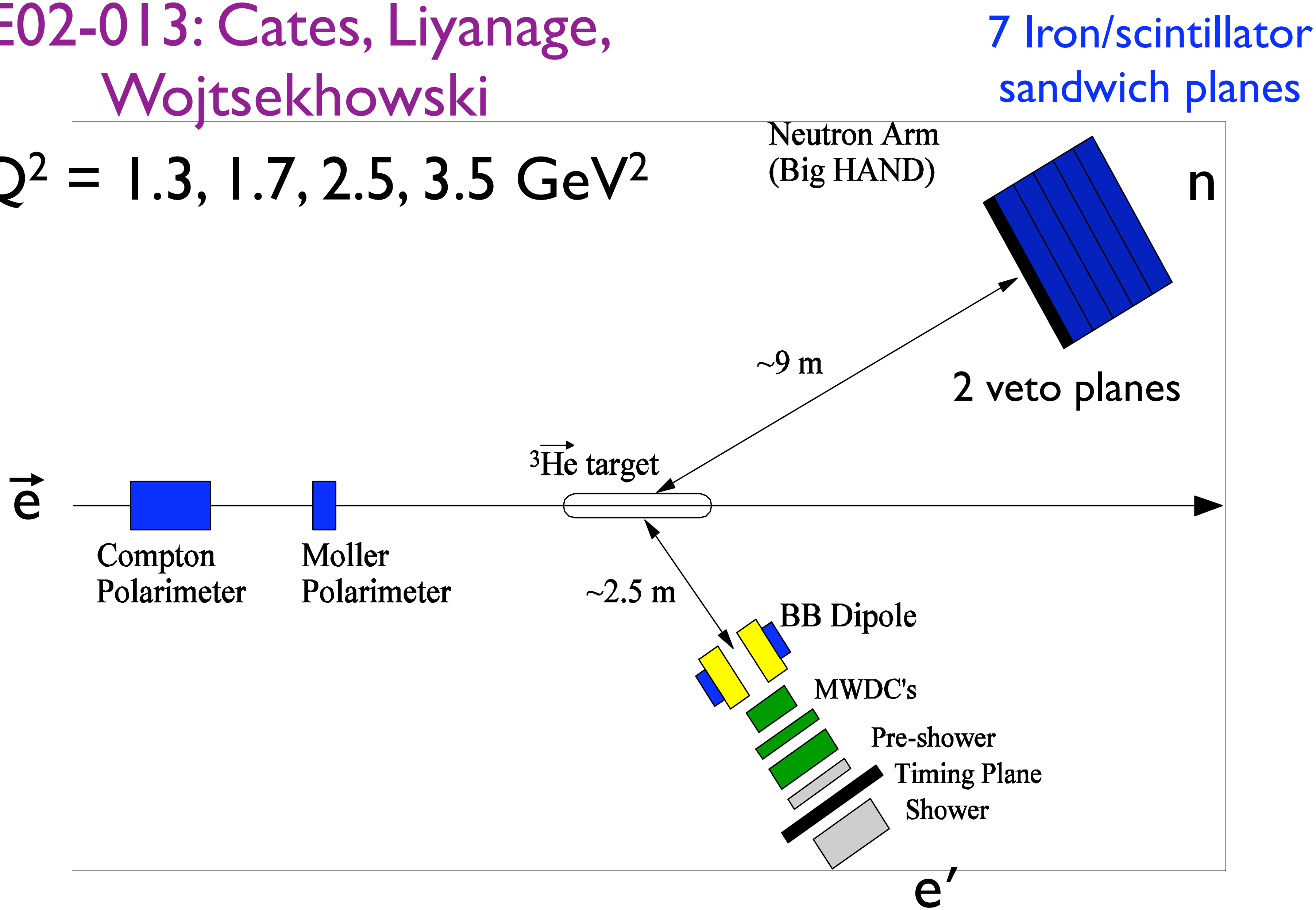

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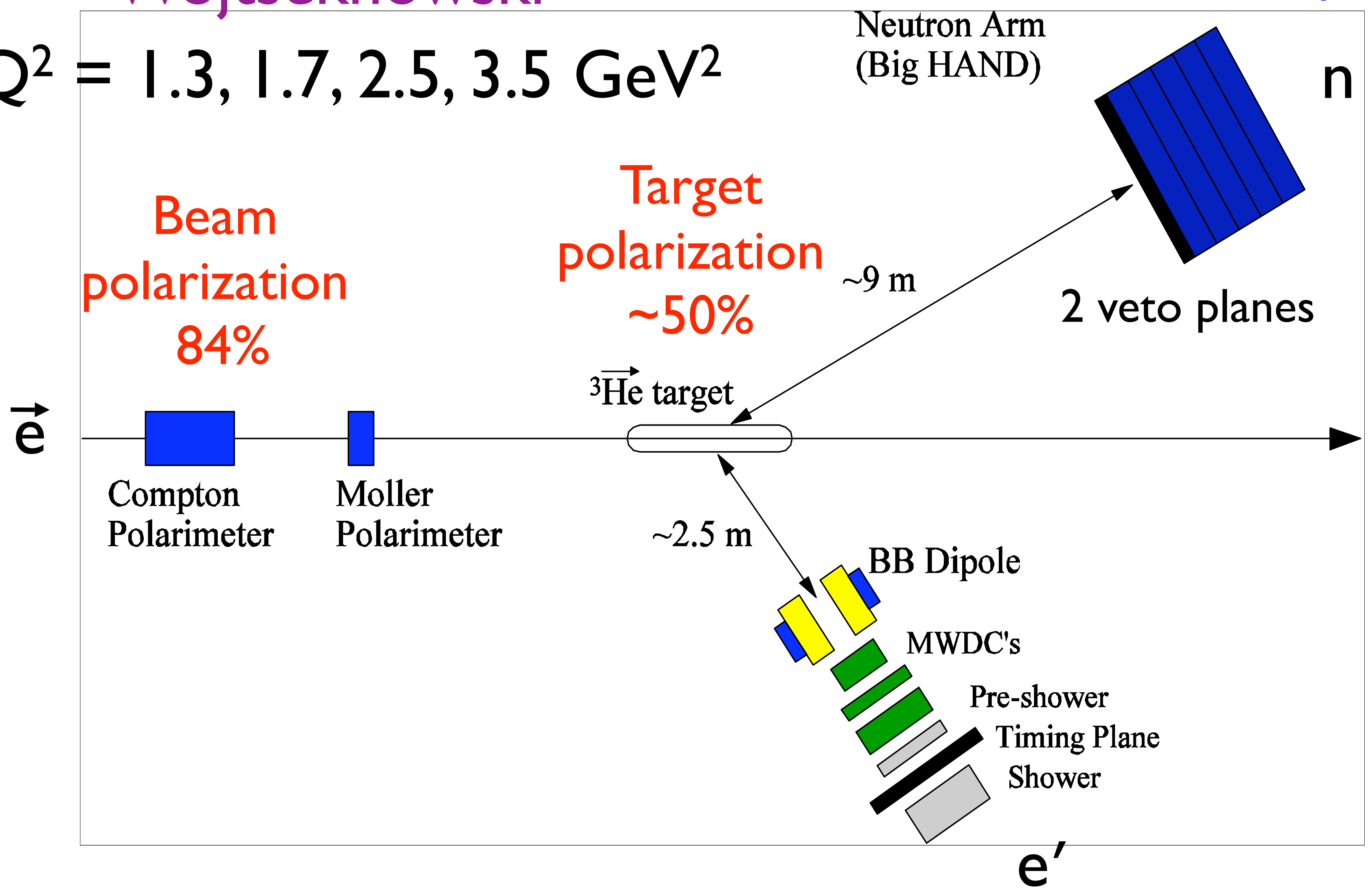
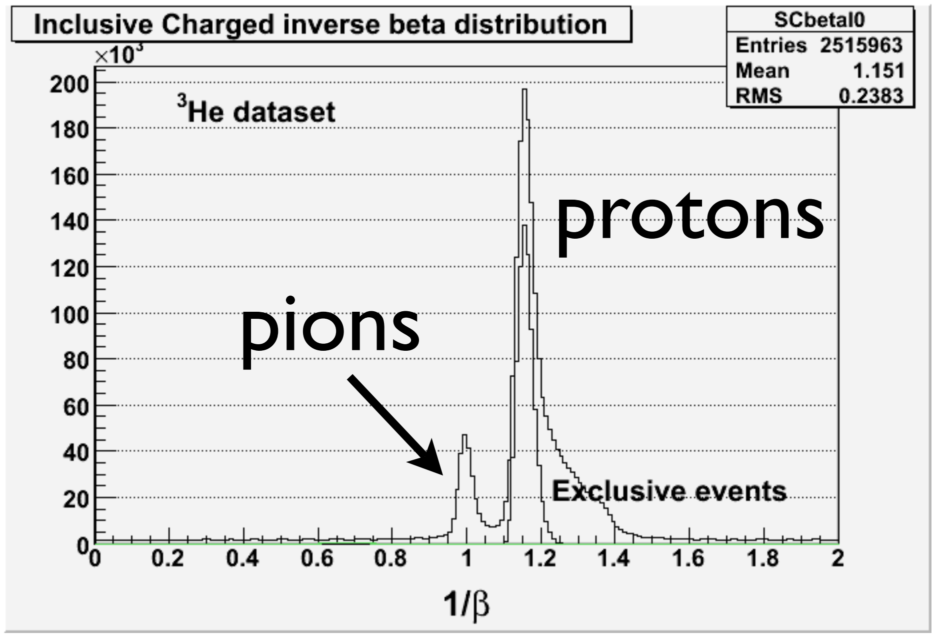
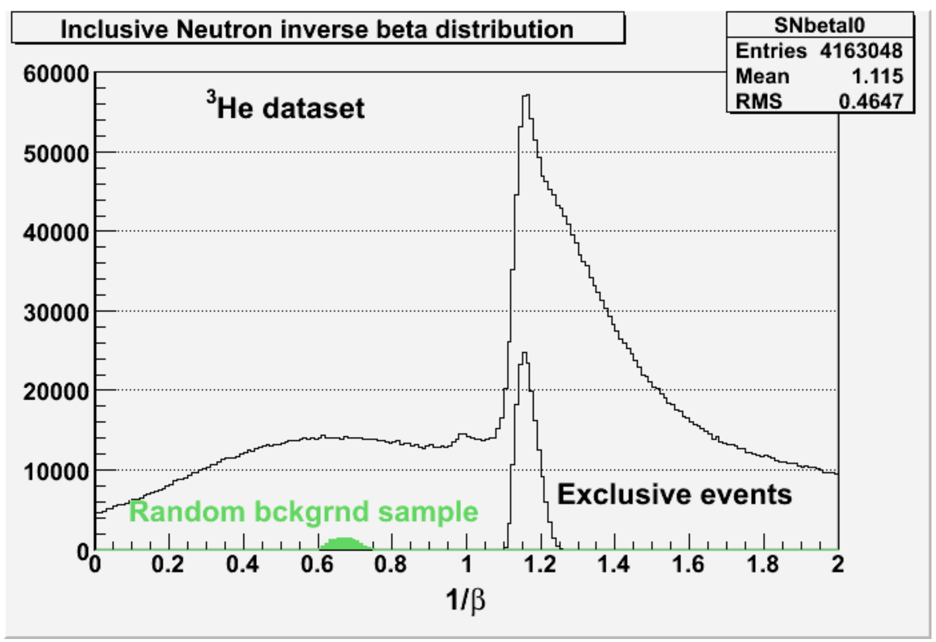


Data analysis: BigHand and BigBite

Charged hits



Neutral hits

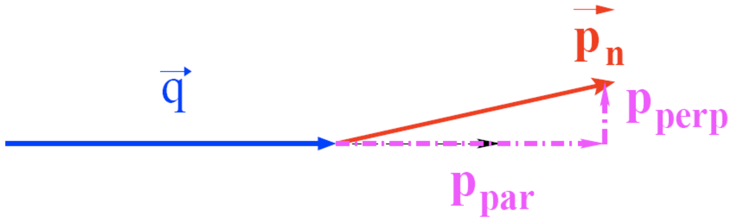


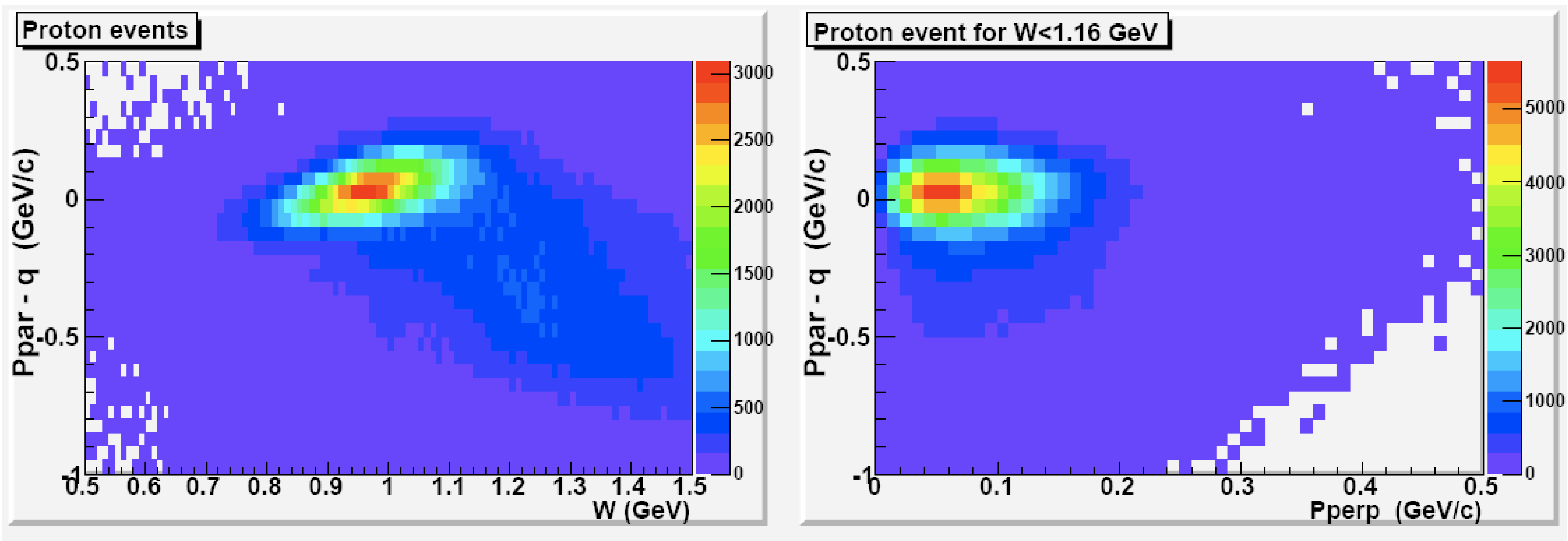
- Progress of 1.7 GeV^2 dataset shown
- σ_{BH} ~ 400ps timing resolution achieved
- σ_P/p ~ 0.8% for BigBite

QE Event Selection

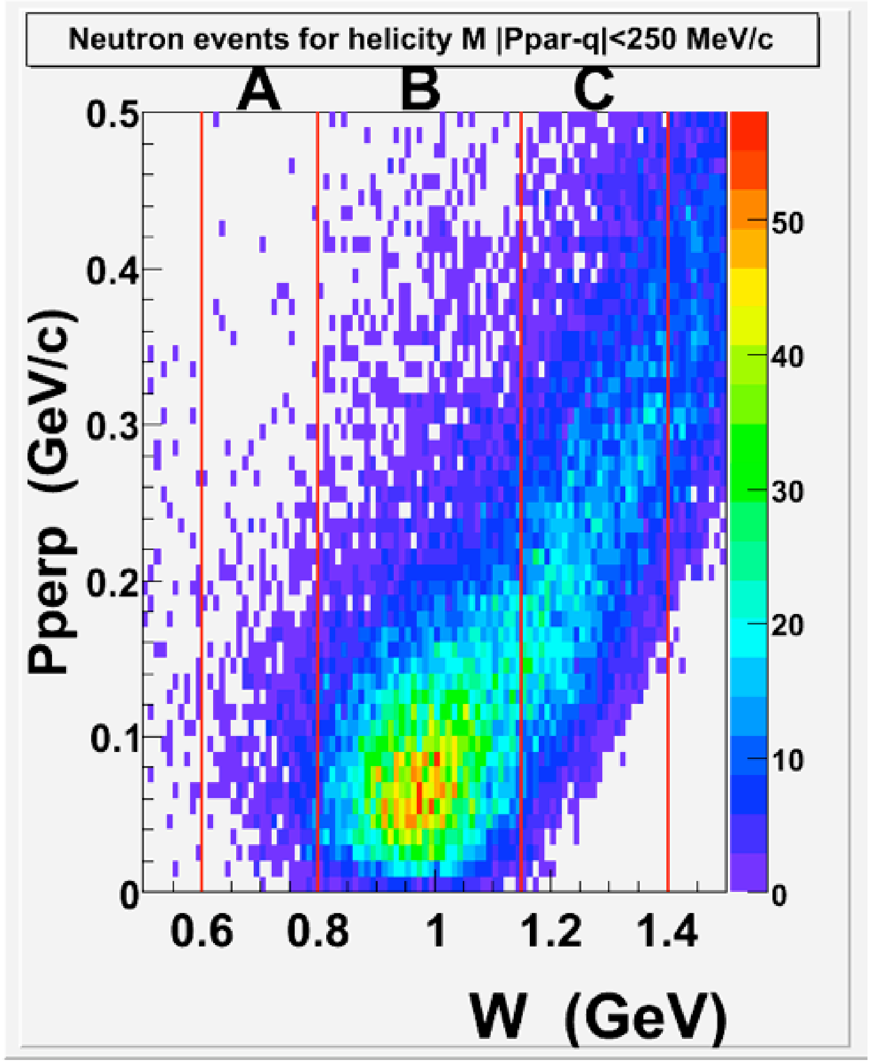
- Use "W" and missing 3-momentum to select QE events; (here W assumes scattering from stationary nucleon)

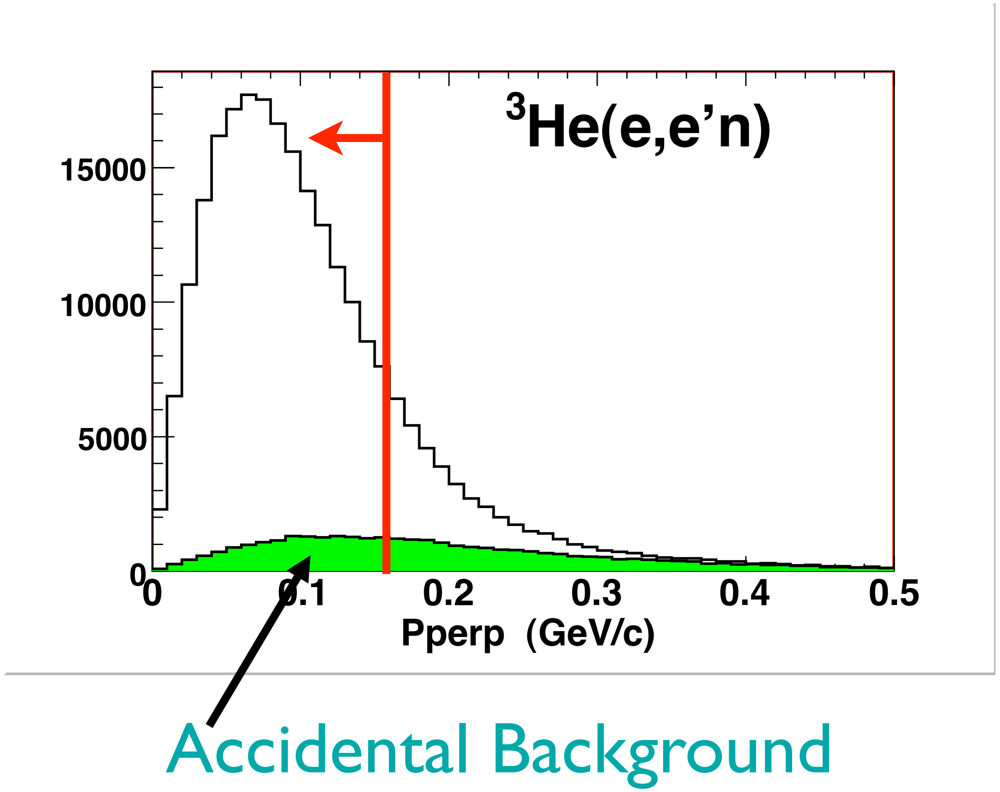
For protons from ^{3}He(e,e′p):





QE Event selection: Neutrons





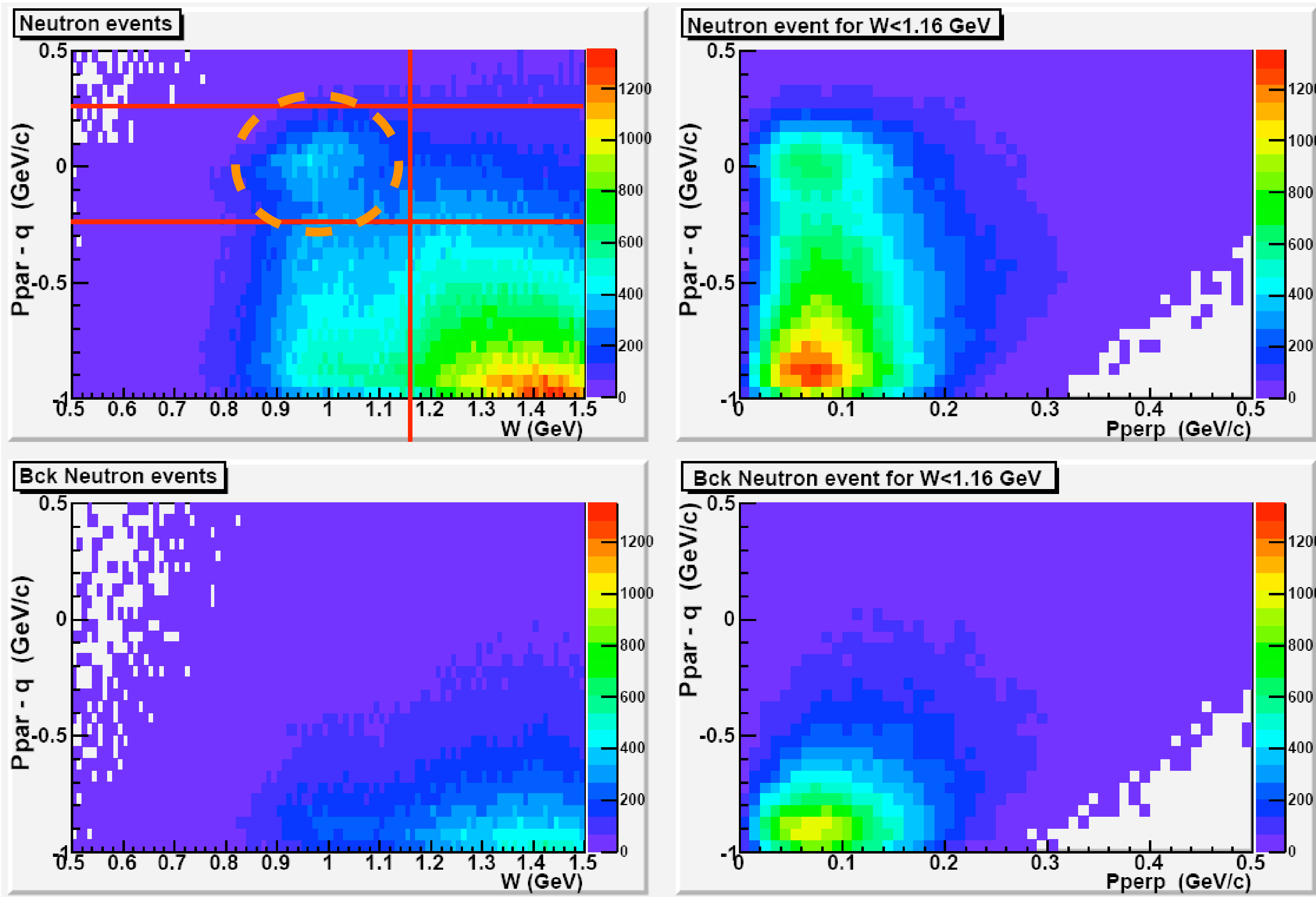
Quasi-elastic defined as:

0.8<W<1.15 GeV

$|P_{par}-q|<250$ MeV/c

$P_{perp}<150$ MeV/c

QE Event selection: Neutrons

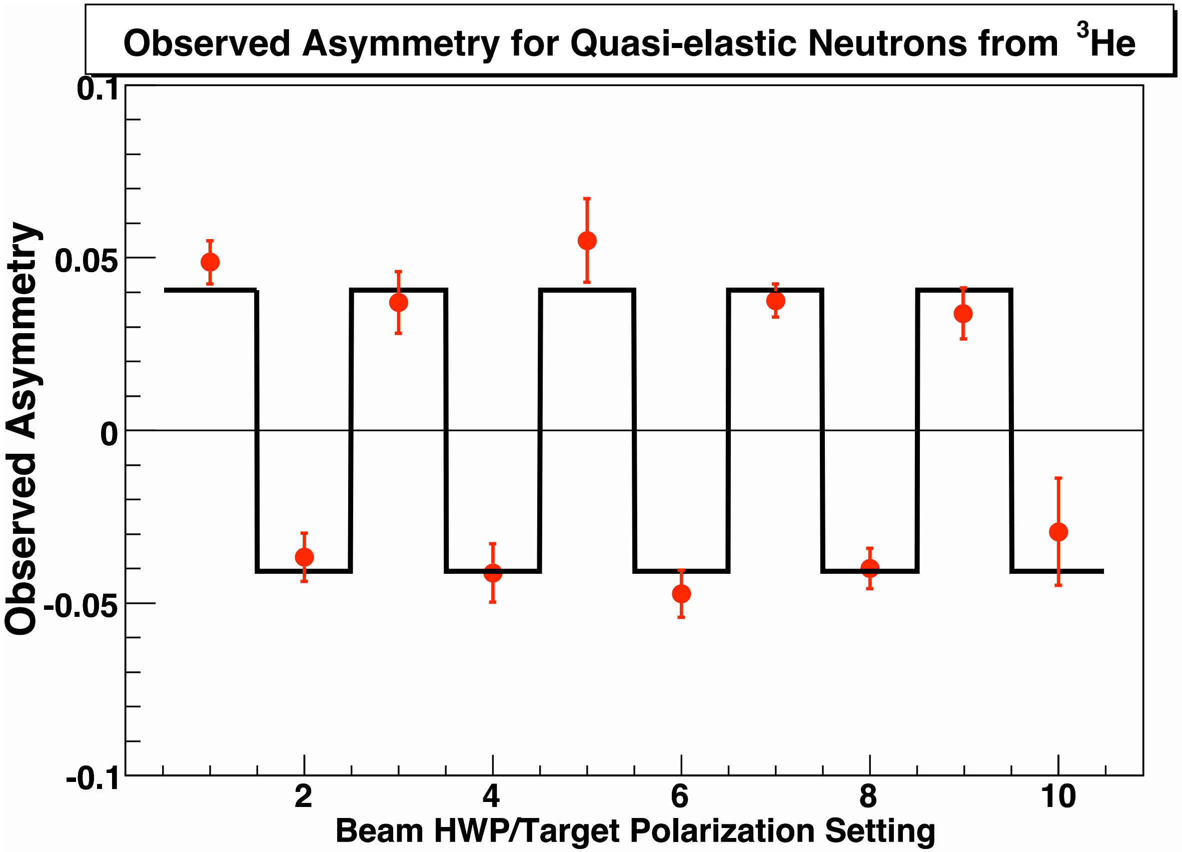


Neutrons

Accidental Background

A significant fraction of "neutron" background not from accidental coincidences, but are protons.

Observed Asymmetry at 1.7 GeV^2



Observed asymmetry is
0.0439 ± 0.0024

(5.5% relative statistical uncertainty)

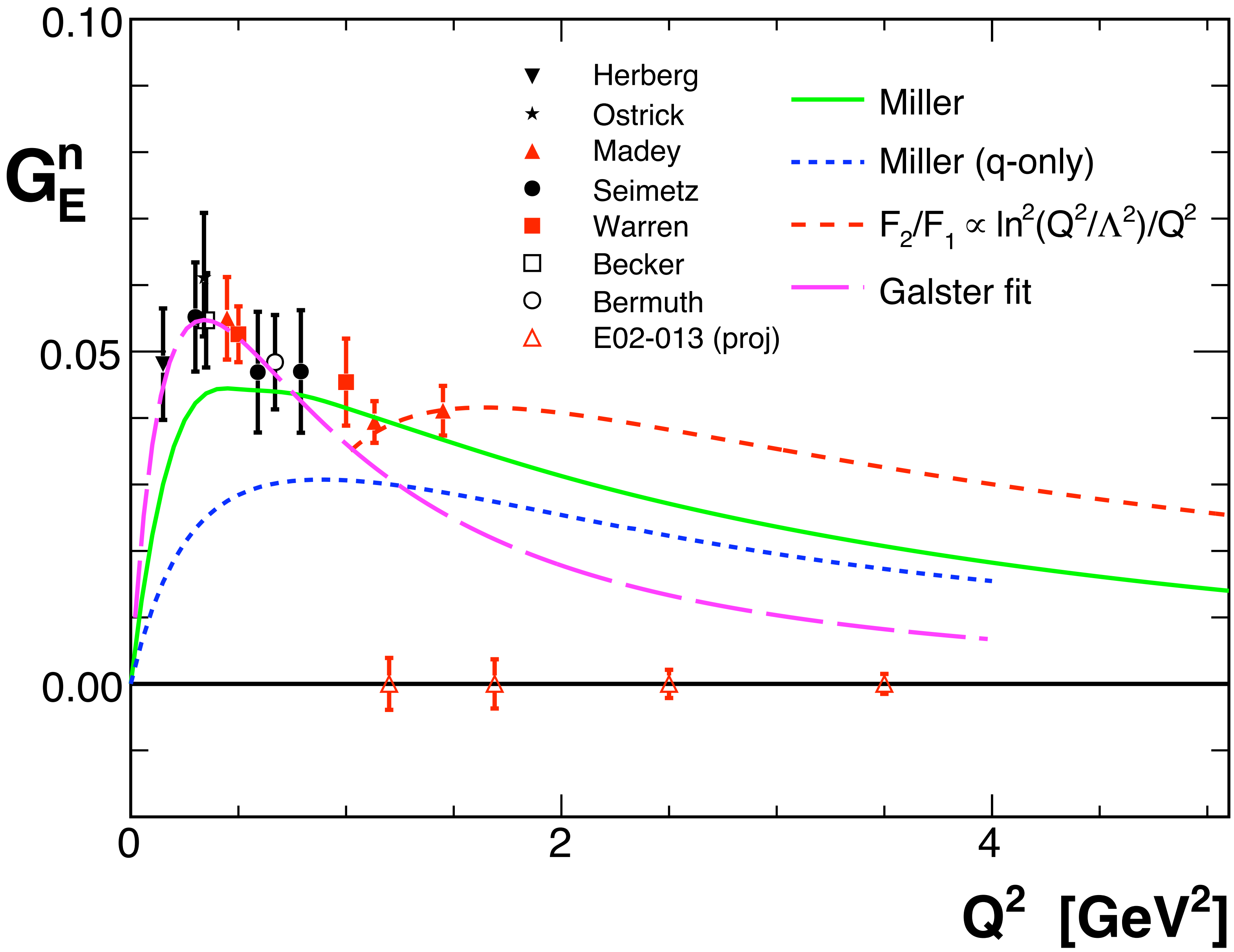
Requires:

- proton→neutron conv.
- finite acceptance corr.
- dilution factors
- polarization factors

Contributions to G_E^n at 1.7 GeV^2

Quantity	Value	Effective Uncertainty Relative to G_E^n
Raw Asymmetry	0.0439	5.5 %
Instr. Asymmetry	-0.006	0.1 %
Accid. Background	0.002	1.5 %
Beam Polarization P_e	0.84	3 %
Target Polarization P_{He}	0.49	4 %
Neutron Polarization P_n	$0.86 \cdot P_e$	2 %
Dilution factor from N_2	0.95	3 %
Dilution due to $p \rightarrow n$		in process
Correction for $A_{\|\|}$		in process
FSI/nuclear correction factor	0.85 to 1	in process
G_M^n	-0.170	1 %

Impact



0.10
0.05
0.00
G_E^n
Herberg
Ostrick
Madey
Seimetz
Warren
Becker
Bermuth
E02-013 (proj)
Miller
Miller (q-only)
$F_2/F_1 \propto \ln^2(Q^2/\Lambda^2)/Q^2$
Galster fit
0
2
4
Q^2 [GeV^2]

Summary and Outlook

- We have collected data for the first high-precision measurement of G_E^n up to Q2=3.5 GeV^2.
- Analysis of 1.7 GeV^2 set is nearing completion, and 3.5 GeV^2 is underway.
- The same experiment could be done at 4.5 GeV^2, and (with “super-BigBite) up to 7.5 GeV^2.
- The precision measurement at high Q^2 will determine F_1 and F_2, and the related GPD’s.