Measurement of G_E^p in the two-body break-up of polarized ^{3}He

W. Bertozzi, O. Gayou, S. Gilad, P. Monaghan,

Y. Qiang, A. Shinozaki, L. Wan, Y. Xiao,

Laboratory for Nuclear Sciences, Massachussets Institute of Technology, Cambridge, MA

Z.-L. Zhou

Schlumberger-Doll Research, Ridgefield, CT

S. Širca

Dept. of Physics, University of Ljubljana, Slovenia

D.W. Higinbotham

Thomas Jefferson National Accelerator Facility, Newport News, VA

Letter of Intent LOI 04-001 for PAC 25

December 11, 2003

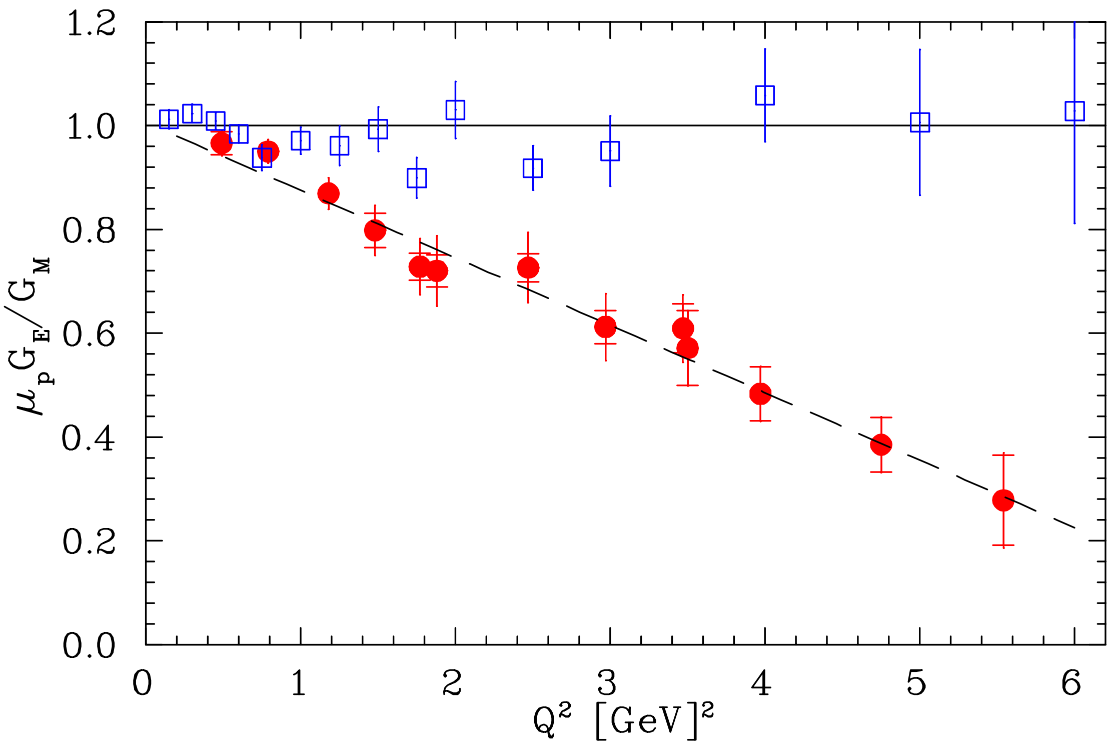
Proton Form Factor

- Rosenbluth experiments:

$$\frac{d\sigma}{d\Omega} = \frac{\sigma_{Mott}}{1+\tau}\left[\left(G_E^p\right)^2 + \frac{\tau}{\epsilon}\left(G_M^p\right)^2\right]$$

- Recoil polarization experiments:

$$\frac{G_E^p}{G_M^p} = -\frac{P_t}{P_l}\frac{E_e + E_e'}{2M_p}\tan\frac{\theta_e}{2}$$



Discrepencies

- Theoretical hypothesis of 2-photon radiative corrections

  ▷ P. Guichon and M. Vanderhaeghen

  ▷ A. Afanasev

  ▷ P.G. Bluden, W. Melnitchouk, J.A. Tjon

  $\Longrightarrow$ Different analysis give different results

- More measurements

  ▷ Rosenbluth and super-Rosenbluth done multiple times

  ▷ New polarization experiments

  $\Longrightarrow$ Extension of recoil polarization experiments to Q^2 = 9 GeV^2 in Hall C

  $\Longrightarrow$ Polarized target

The $\vec{p}(\vec{e}, e'p)$ reaction

$$A_x = \frac{2\sqrt{2\tau(1+\tau)}\nu_{TL'} G_E^p G_M^p}{(1+\tau)\nu_L \left(G_E^p\right)^2 + 2\tau\nu_T \left(G_M^p\right)^2}$$

$$A_z = -\frac{2\tau\nu_{T'} \left(G_M^p\right)^2}{(1+\tau)\nu_L \left(G_E^p\right)^2 + 2\tau\nu_T \left(G_M^p\right)^2}$$

- Choice of polarized proton target
  - ▷ BLAST-type, NH_3, frozen-spin (HD), ^{3}He
- Proposal PR04-017 in Hall C, using NH_3
  - ▷ High polarization (close to 80%)
  - ◁ Low luminosity (100 nA max)
  - ◁ 5 T magnetic holding field, affect beam and scattered electron optics
  - ◁ Dilution by unpolarized target material

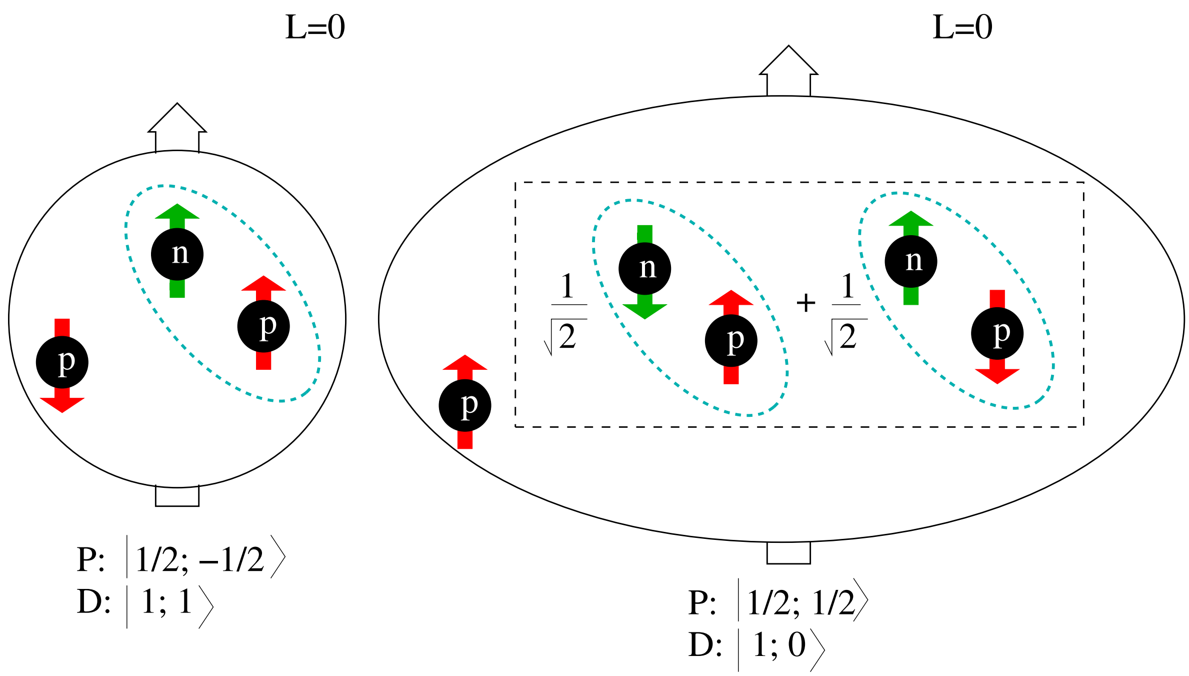
$^3\vec{He}$ as $\vec{n}$ target

- ^{3}He ground state:
  - ▷ S state: proton spins are antiparallel $\Rightarrow$ 90%
  - ▷ D state: all nucleon spin parallel $\Rightarrow$ 8%
  - ▷ S$'$ state: mixed-symmetry configuration, difference between the $T = 0$ and $T = 1$ forces $\Rightarrow$ ∼2% (E02-108)
- S-state dominance makes $^3\vec{He}$ an effective $\vec{n}$ target
- “Routinely” used in Hall A: experiments E94-010 (GDH), E95-001 (A_T), E97-103 (g_2^n), E99-117 (A_1^n) and E97-110 (nGDH)

$^3\vec{He}$ as $\vec{p}$ target ?

- Select the $^3\vec{He}(\vec{e},e'p)d$ channel; if we consider only S-state (e.g by selecting low p_{miss}):

$$|\frac{1}{2},\frac{1}{2}\rangle = \sqrt{\frac{2}{3}}|1,1\rangle \otimes |\frac{1}{2},-\frac{1}{2}\rangle - \sqrt{\frac{1}{3}}|1,0\rangle \otimes |\frac{1}{2},\frac{1}{2}\rangle$$

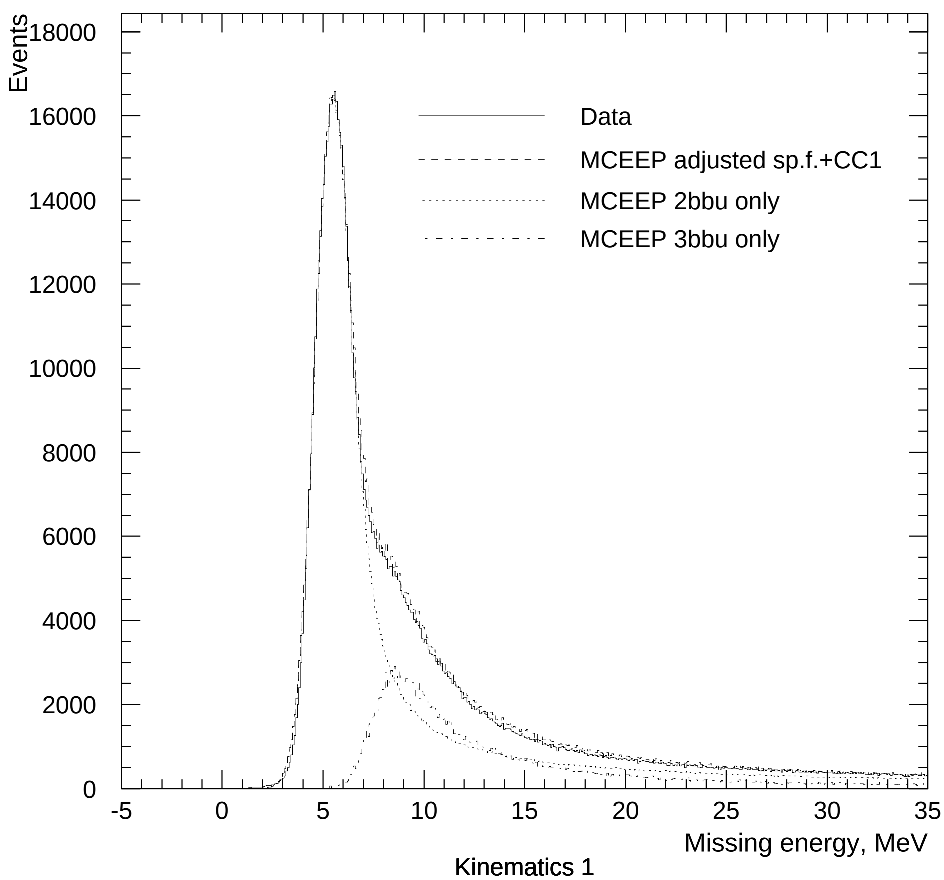


$$\frac{2/3 \quad - \quad 1/3}{2/3 \quad + \quad 1/3} = 1/3$$

$$\Longrightarrow P_p = P(^3He)\cdot(-\tfrac{1}{3}) \sim -12\%$$

2-body breakup reconstruction

- Need a good E_{miss} resolution to select d-channel
  - ▷ From E89-044 (worst kinematics, E=4.8 GeV):



- 3-body contributions $\Rightarrow$ polarization modifications, thought to be small
- Keep $E_{miss} < 7$ MeV and $|p_{miss}| \leq 100$ MeV

Choice of kinematics

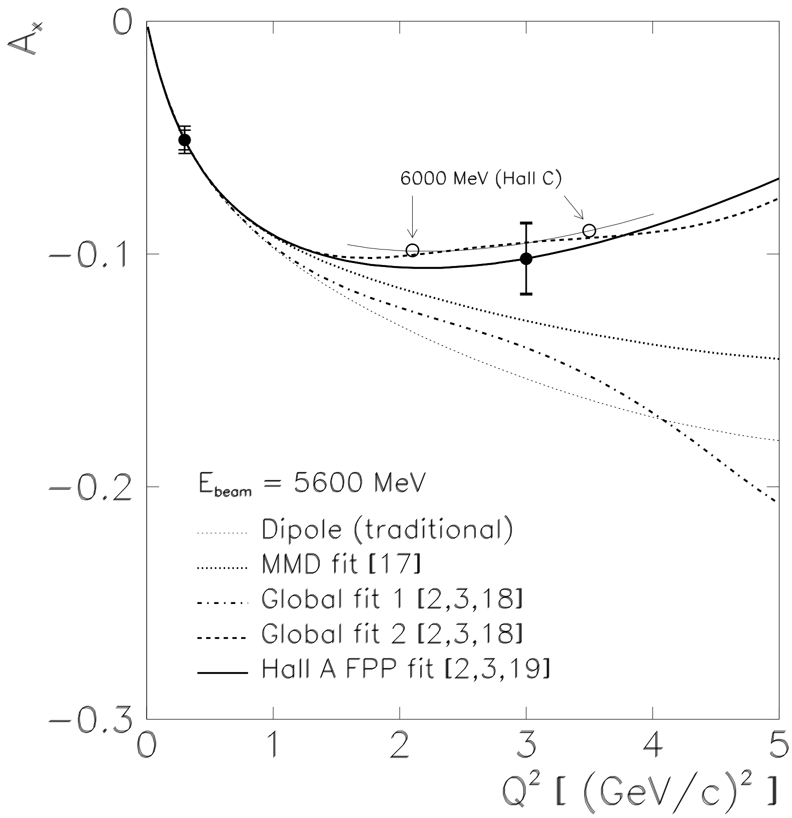
- Goal:

  ▷ measure $A_x \Rightarrow G_E^p$

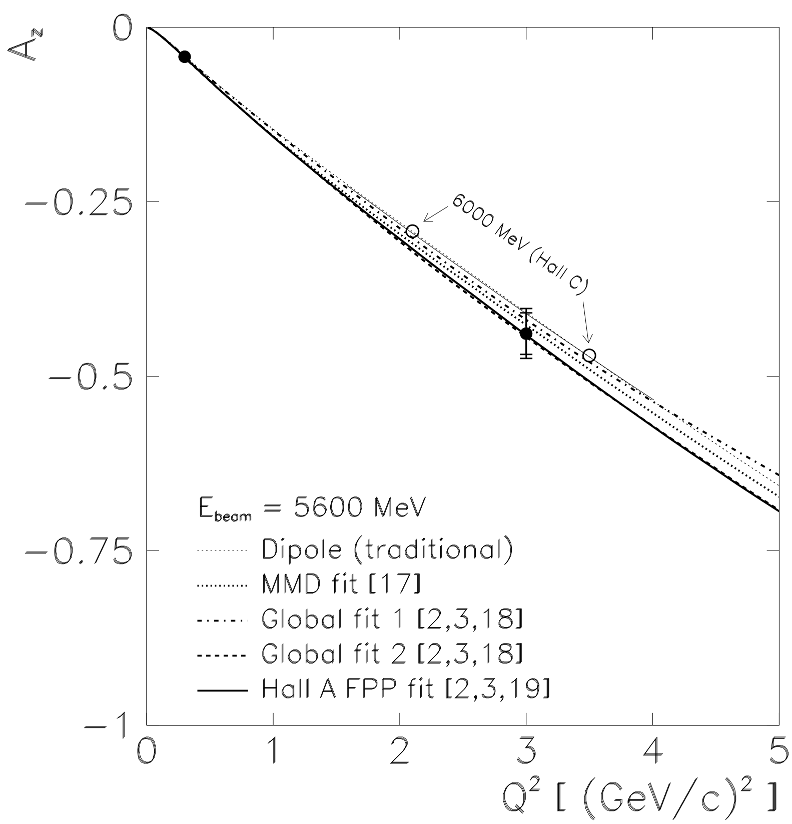
  ▷ measure $A_z \Rightarrow G_M^p$, and use good knowledge of G_M^p for polarimeter

- Asymmetries decrease as E_{beam} increases

$E_{\rm beam}$ [MeV]	2400	5600
Q^2 [(GeV/c)^2]	0.3	3.0
$E'_{\rm e}$ [MeV]	2240.0	4001.2
$\theta_{\rm e}$ [°]	13.6	21.1
$p_{\rm p}$ [MeV/c]	570	2356
$\theta_{\rm p}$ [°]	67.1	37.6



A_x
0
−0.1
−0.2
−0.3
0
1
2
3
4
5
Q^2 [(GeV/c)^2]
6000 MeV (Hall C)
E_beam = 5600 MeV
Dipole (traditional)
MMD fit [17]
Global fit 1 [2,3,18]
Global fit 2 [2,3,18]
Hall A FPP fit [2,3,19]



A_z
0
−0.25
−0.5
−0.75
−1
0
1
2
3
4
5
Q^2 [(GeV/c)^2]
6000 MeV (Hall C)
E_beam = 5600 MeV
Dipole (traditional)
MMD fit [17]
Global fit 1 [2,3,18]
Global fit 2 [2,3,18]
Hall A FPP fit [2,3,19]

Expected beam time and results

- Rate of 0.22 Hz at Q^2 = 3.0 GeV^2
  - ▷ A_x $\sim$-0.102$\pm$0.015 in 400 hours
  - ▷ A_z $\sim$-0.439$\pm$0.030 in 100 hours
  - ▷ Additional time for Q^2 = 0.3 GeV^2, EPR, NMR, E_e

$\Rightarrow$ Total 570 hours