The G0 Experiment

E99-016, E01-115 and E01-116

Caltech, Carnegie-Mellon, William+Mary, Hampton, IPN-Orsay, ISN-Grenoble, Kentucky, LaTech, NMSU, JLab, TRIUMF, UConn, U Illinois, U Manitoba, U Maryland, U Mass, UNBC, VPI, Yerevan

Parity Violating Electron Scattering from H and D

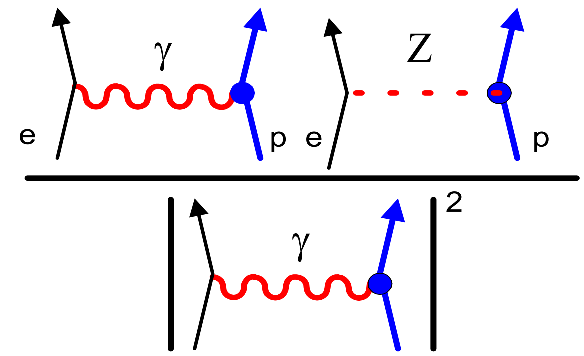
Elastic and Inelastic channels

Strange quark form factors

Proton elastic and transition axial form factors

Parity Violating Electron Scattering

polarized electrons, unpolarized target



$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \left[\frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}\right] \frac{A_E + A_M + A_A}{2\sigma_{unpol}}$$

$$A_E = \varepsilon(\theta) G_E^Z(Q^2) G_E^\gamma(Q^2)$$
$$A_M = \tau(Q^2) G_M^Z(Q^2) G_M^\gamma(Q^2)$$
$$A_A = -(1 - 4\sin^2\theta_W)\varepsilon' G_A^e(Q^2) G_M^\gamma(Q^2)$$

neutral weak form factors contain explicit contributions from strange sea

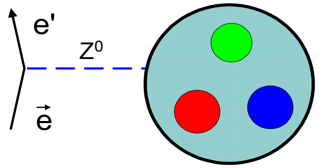
$$G_{E,M}^Z = (1 - 4\sin^2\theta_W)(1 + R_V^p) G_{E,M}^p - (1 + R_V^n) G_{E,M}^n - G_{E,M}^s$$
$$G_A^e = -G_A + \Delta s + \eta F_A + R^e$$

$$\eta = \frac{8\pi\alpha\sqrt{2}}{1 - 4\sin^2\theta_W} = 3.45$$

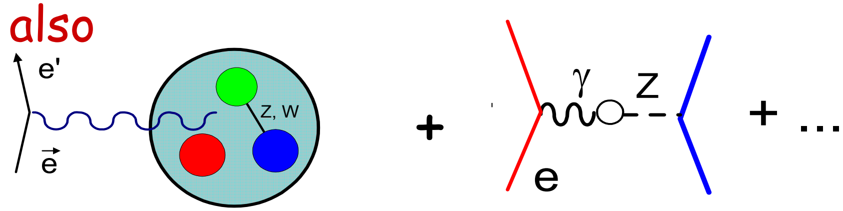
axial f.f. has uncertain anapole + radiative corrections

Axial Coupling and the Anapole Moment

A_{PV} measures



but also



$$\langle p'|J^{\mu}_{EM}|p\rangle = \bar{u}(p')\Big[F_1(q^2)\gamma_{\mu} - \tfrac{i}{2M}F_2(q^2)\sigma_{\mu\nu}q^{\nu} + \tfrac{1}{M^2}F_A(q^2)(q^2\gamma_{\mu} - \not{q}q_{\mu})\gamma_5 - \tfrac{i}{2M}F_E(q^2)\sigma_{\mu\nu}q^{\nu}\gamma_5\Big]u(p)$$

Anapole
(TRI , PV)

Electric dipole
(TRV, PV)

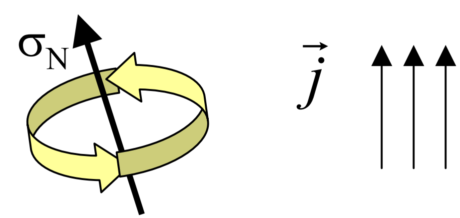
$$F_A(0) \approx M^2 G_F \approx 10^{-5}$$

Anapole: parity violating EM interaction

parity mixing in nucleon's wave function

I. Zel'dovich, JETP Lett 33 (1957) 1531

$$L_A \to -e^2 \frac{F_A}{M^2}\vec{\sigma}\cdot\vec{j}$$

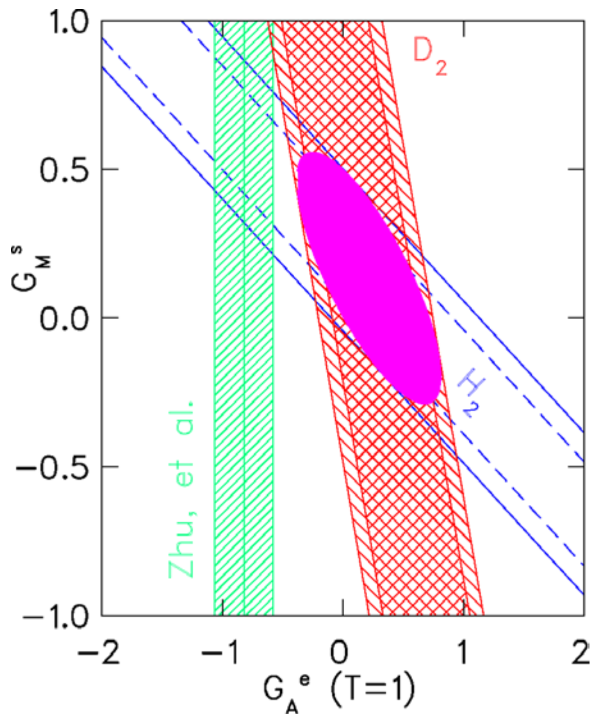


Recent updates:

- Zhu, Puglia, Holstein, Musolf, PRD62 (2000) 033008
- Maekawa, Veiga, van Kolck, PLB 488 (2000) 167
- D. Riska, NPA 678 (2000) 79

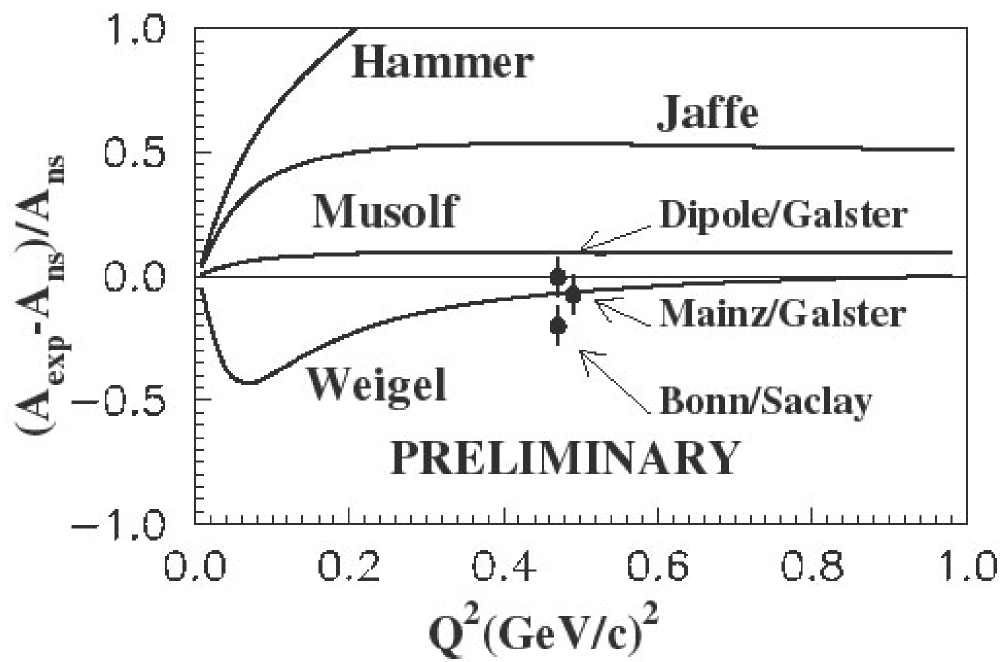
Recent Results

SAMPLE: $Q^2 = 0.1\ (GeV/c)^2$



R. Hasty, et al., Science 290 (2000) 2117

HAPPEX: $Q^2 = 0.5\ (GeV/c)^2$



K. Aniol, et al., Phys. Lett. B509 (2001) 211

PVA4 at Mainz:	$Q^2 = 0.23\ (GeV/c)^2$
SAMPLE 2001:	D_2 at $Q^2 = 0.03\ (GeV/c)^2$
HAPPEX H and ^{4}He:	$Q^2 = 0.1\ (GeV/c)^2$

The G0 experiment at JLAB

• Forward and backward angle PV e-p elastic and e-d (quasielastic) in JLab Hall C

G_E^s, G_M^s and G_A^e separated over range $Q^2 \sim 0.1 - 1.0$ (GeV/c)^2

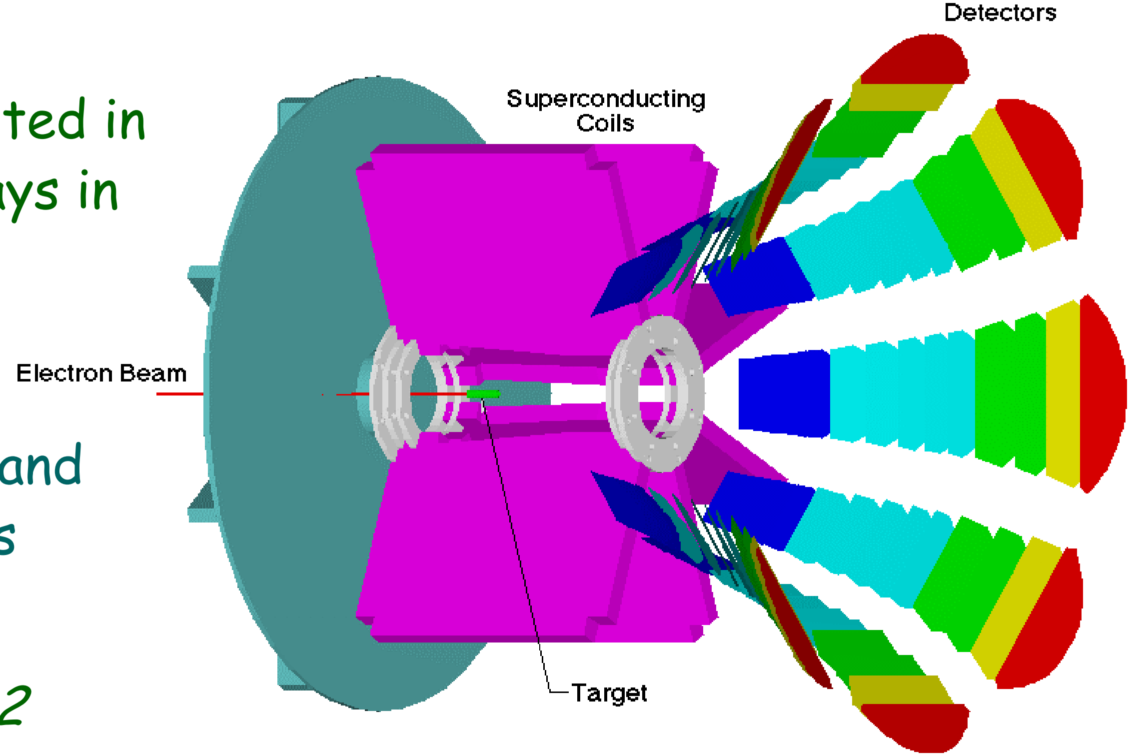
• superconducting toroidal magnet

• scattered particles detected in segmented scintillator arrays in spectrometer focal plane

• custom electronics count and process scattered particles at > 1 MHz

• *first engineering run 2002*

• *first data taking 2003*



G0 elastic scattering program

A_F : one measurement for all Q^2 $\rightarrow$ detect recoil protons
A_B : three measurements for three Q^2 values: $\rightarrow$ detect electrons at 108°
A_d : Quasielastic scattering (x3) from deuterium $\rightarrow$ detect electrons at 108°

report G0-00-045 by R. Tieulent, et al.

$$\begin{pmatrix} A_F \\ A_B \\ A_d \end{pmatrix} = \begin{pmatrix} \xi_F & \chi_F & \psi_F \\ \xi_B & \chi_B & \psi_B \\ \xi_d & \chi_d & \psi_d \end{pmatrix} \begin{pmatrix} G_E^s \\ G_M^s \\ G_A^e \end{pmatrix} + \begin{pmatrix} \eta_F \\ \eta_B \\ \eta_d \end{pmatrix}$$

at $Q^2 = 0.44\ (\mathrm{GeV}/c)^2$

	η (ppm)	ξ (ppm)	χ (ppm)	ψ (ppm)
A_F	-13.77	51.80	18.63	1.01
A_B	-25.01	16.10	31.41	6.96
A_d	-34.00	13.13	7.07	8.41

N-Δ axial transition form factor

S. Wells et al., LaTech

$$A_{inel} = -\frac{G_F Q^2}{4\pi\alpha\sqrt{2}}\left[\Delta^{\pi}_{(1)} + \Delta^{\pi}_{(2)} + \Delta^{\pi}_{(3)}\right]$$

$\Delta_{(1)} = 2(1-\sin^2\theta_W) = 1$

$\Delta_{(2)} =$ non-resonant contrib. (small)

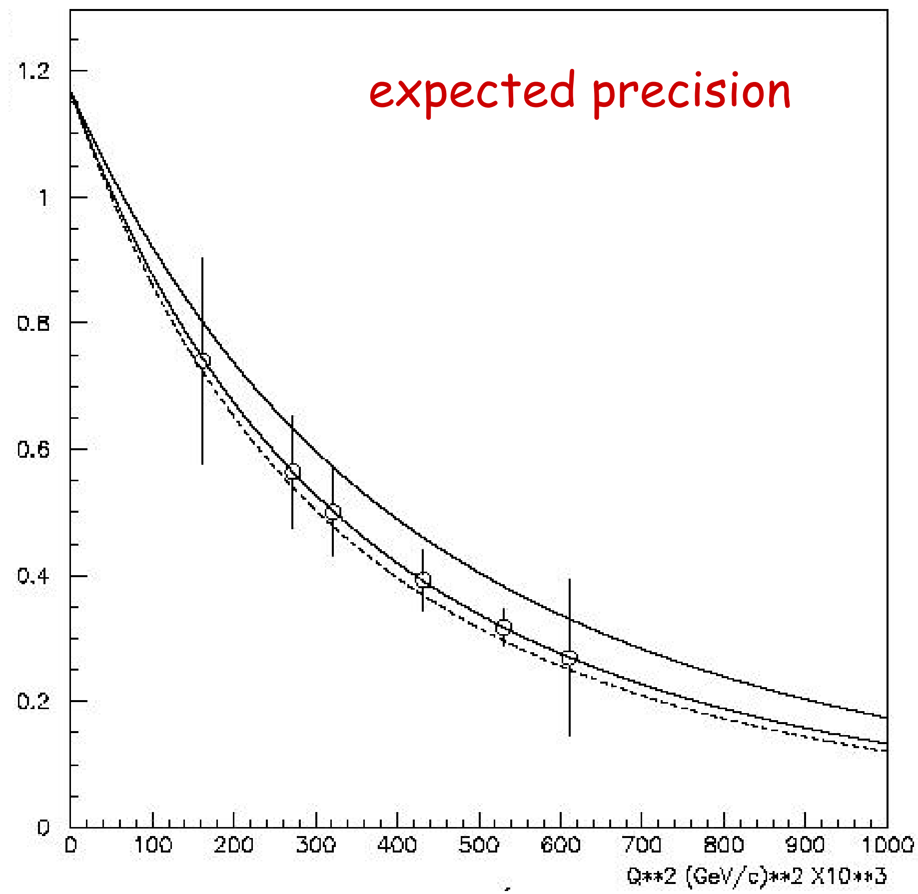
$\Delta_{(3)} = 2(1-4\sin^2\theta_W)\, F(Q^2,s)$

at tree-level:

$$F(Q^2,s) \rightarrow G^A_{N\Delta}(Q^2)$$

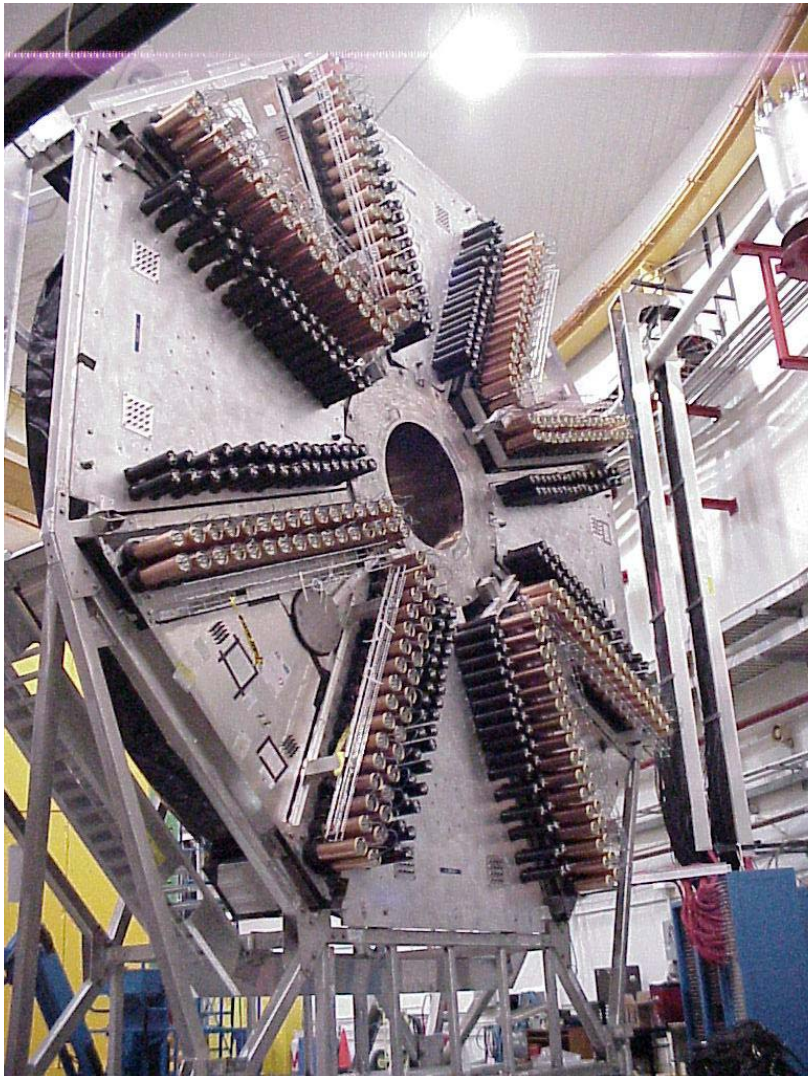
- First measurement in neutral current process

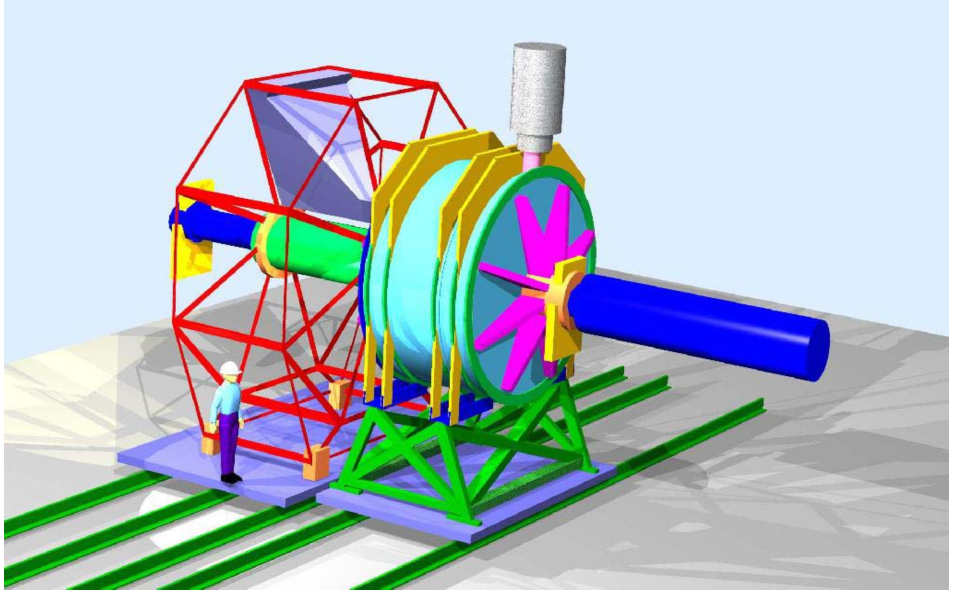
- sensitive to hadronic radiative corrections

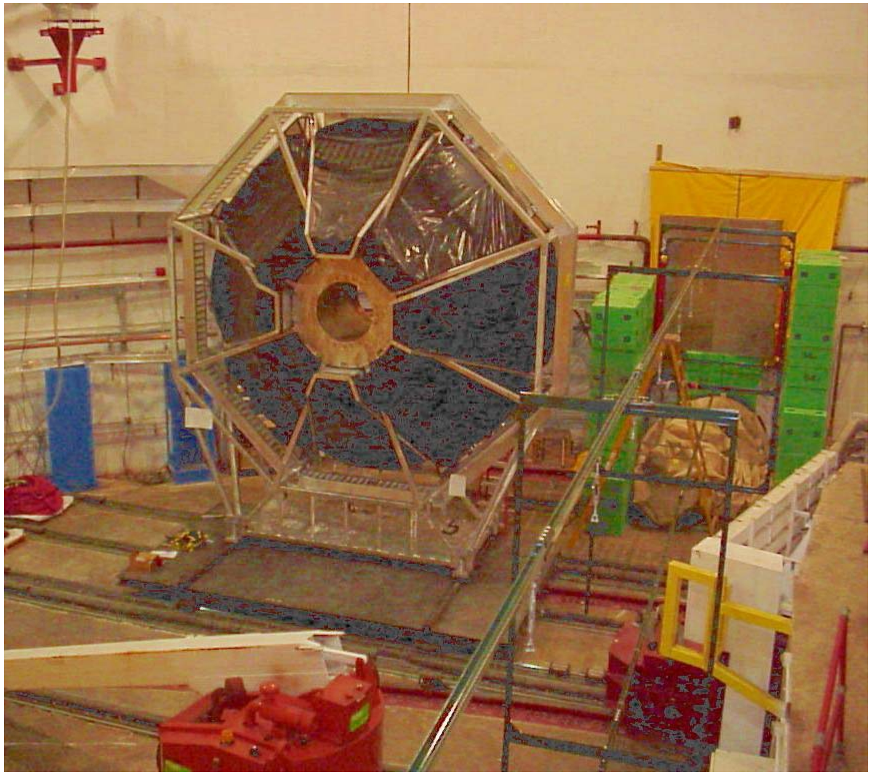


- *data comes for free w/ back-angle G0 elastic measurement*

G0 Detector System







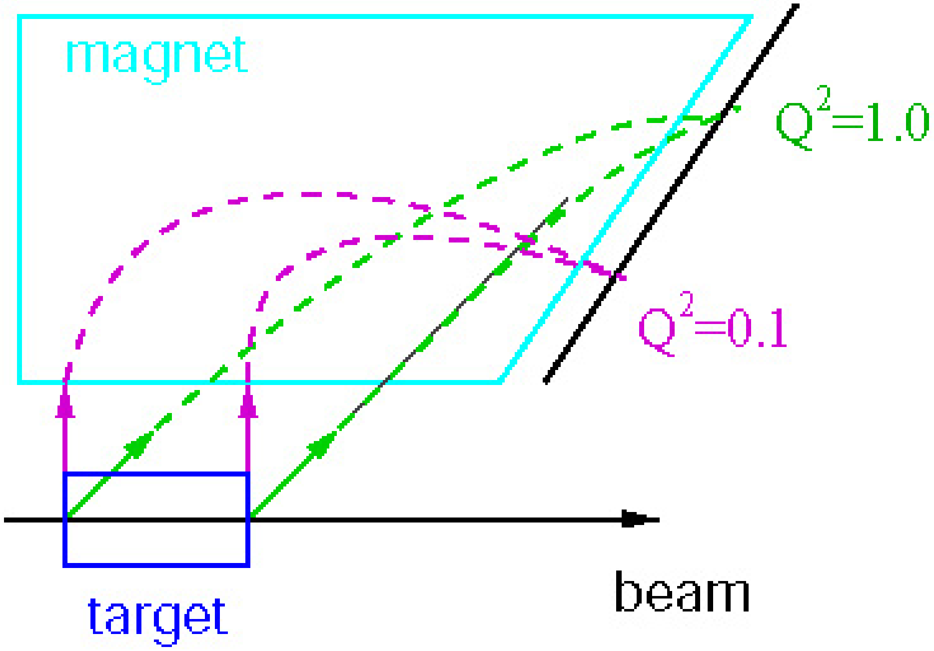
G0 Forward Mode

proton detection:

Magnet sorts protons by Q^2 at one setting

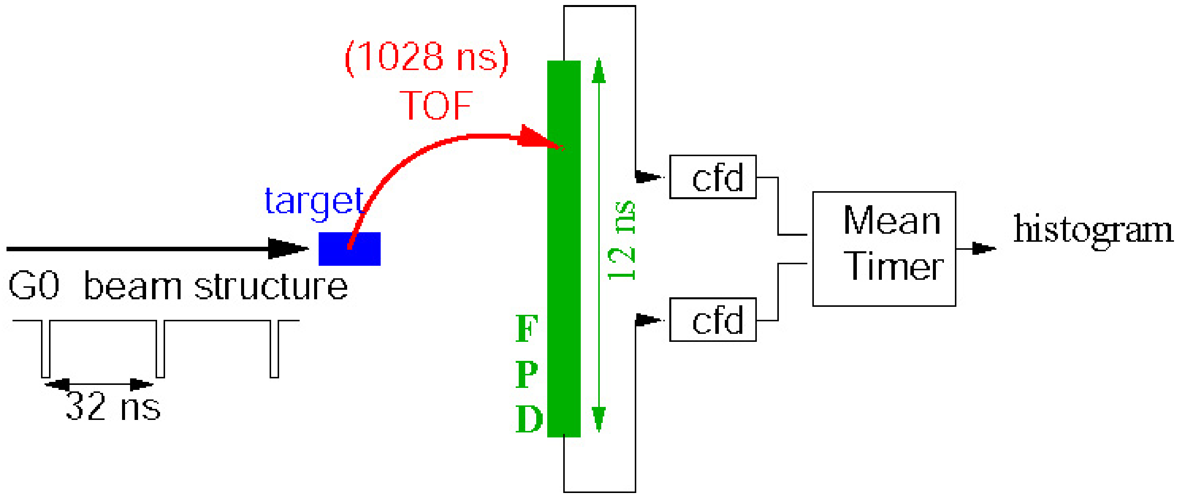
TOF separates p and π^+

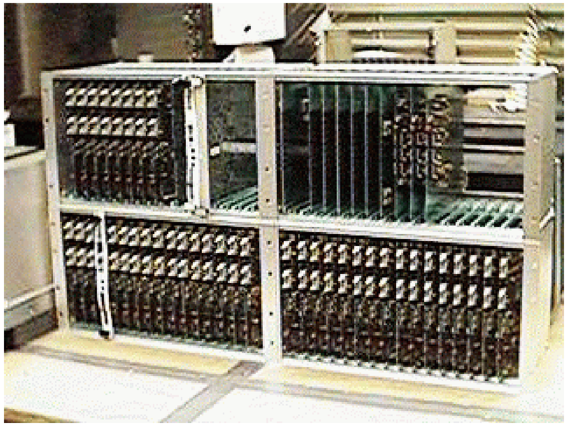
FR octant 2



NA octant 7

G0 Electronics and DAQ





LTD crate 1/2 (CMU)

Beam structure: 32 ns between pulses

NA octants: MT → latching time digitizer → scalers (1 ns)

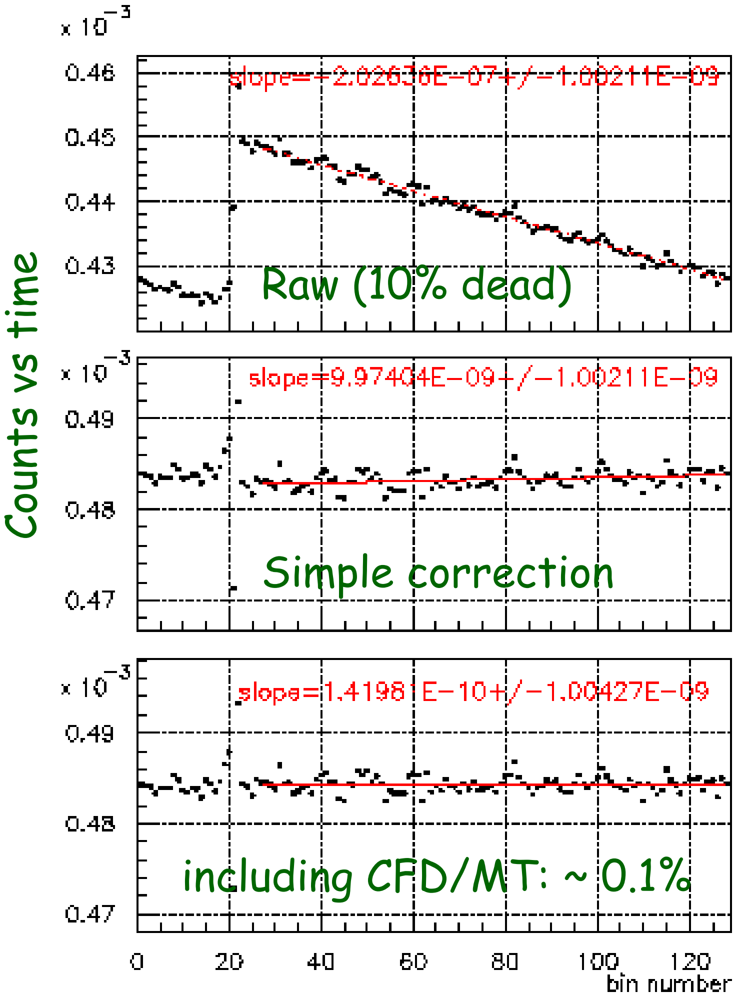
FR octants: MT → flash TDCs (0.25 ns)

"Buddy" system for real time deadtime monitoring

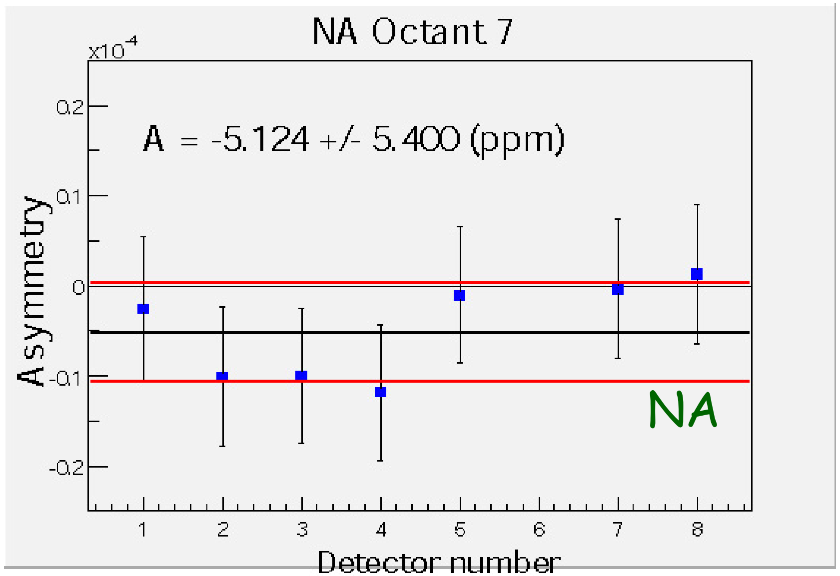
DMCH16 Module 1/8 (Orsay)

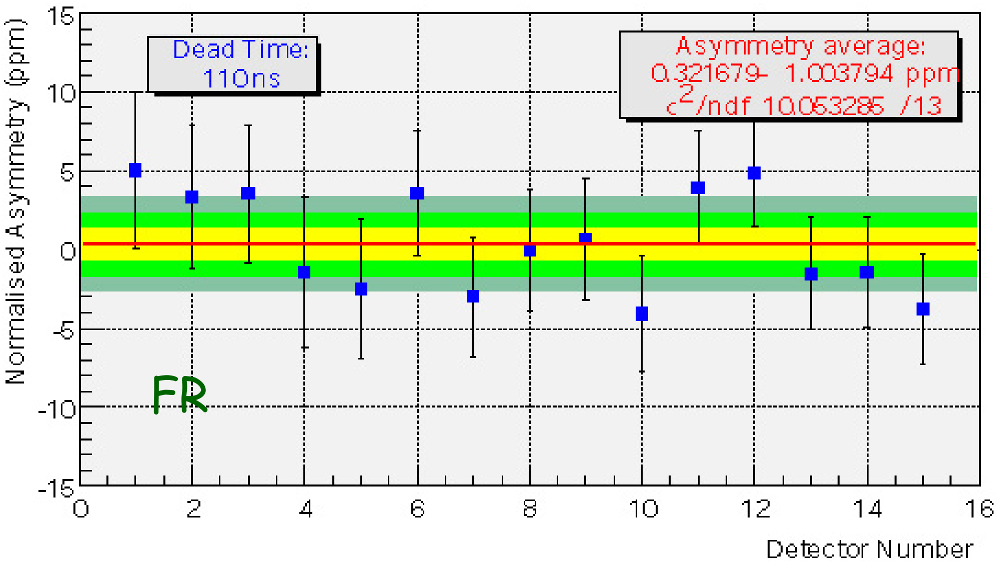
Tests of Detectors and Electronics

FR Electronics Dead Time Tests



Asymmetry Tests w/ beam





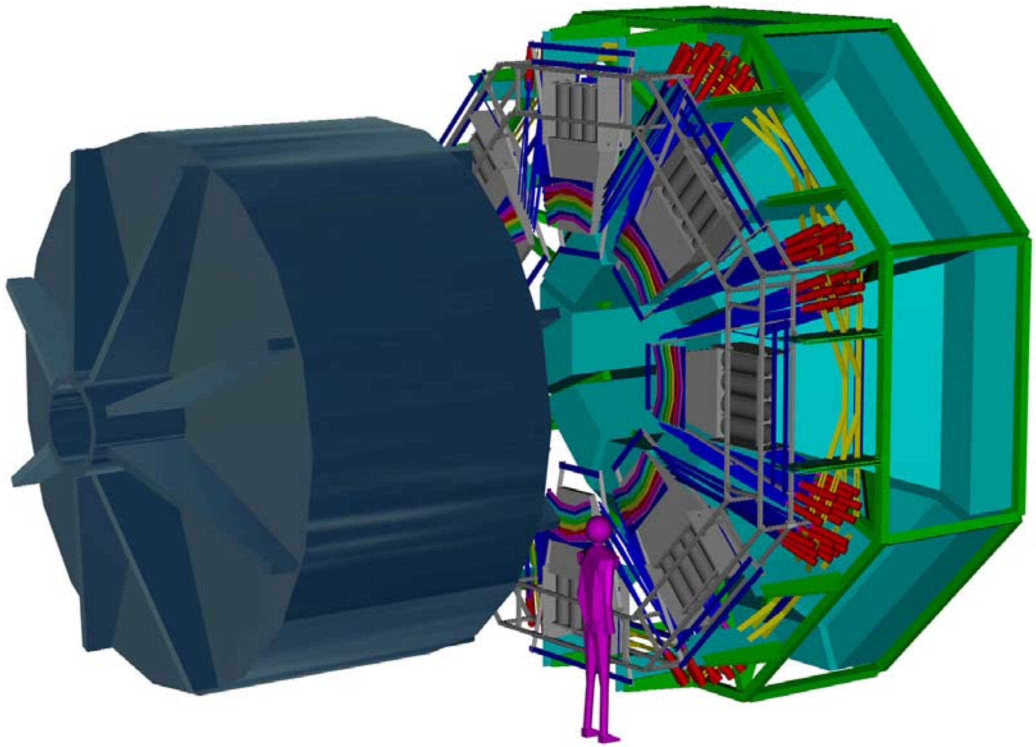
G0 Backward Angle

Electron detection: one Q^2 per magnet setting
Add Cryostat Exit detectors to define electron trajectory
1 scaler per channel FPD/CED pair

Deuterium: pion rejection required →
aerogel Cerenkov detector (Caltech, TRIUMF, Grenoble)

Ebeam	π/e ratio	
(MeV)	H	D
424	0.01	0.4
585	0.04	1.0
799	0.4	11.4

(J. Martin, Caltech)



G0 SMS Magnet

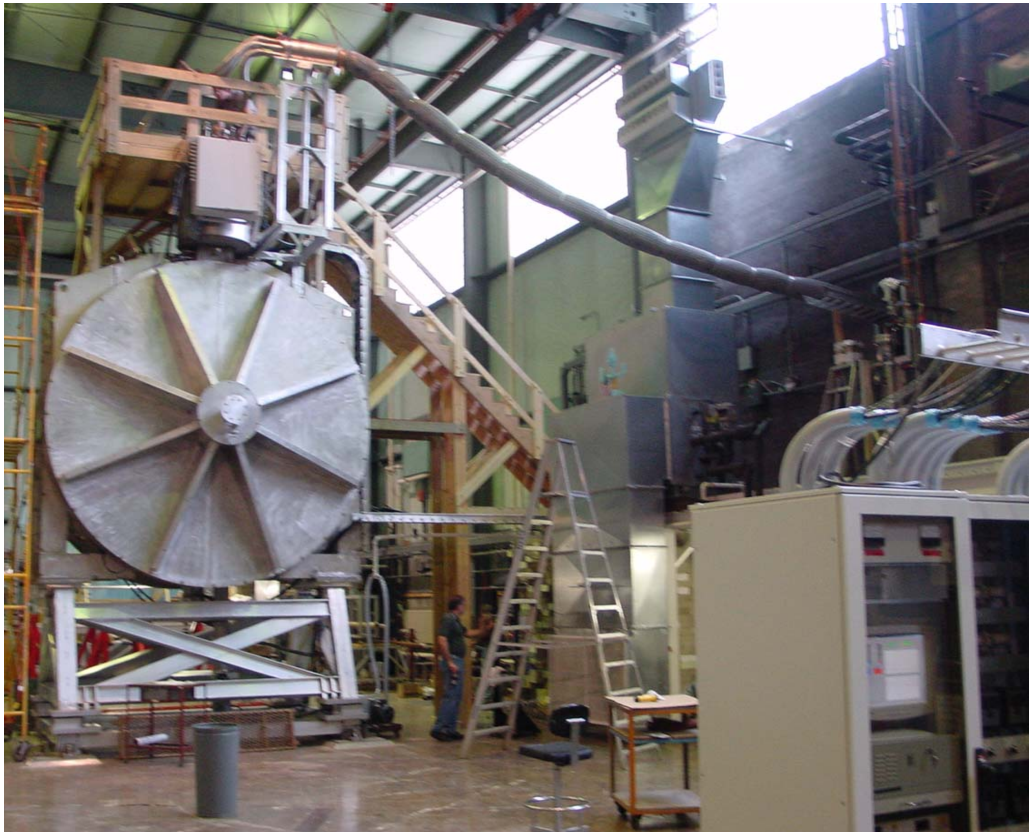
Construction and installation at UIUC complete

Cooled and powered Dec 2001

1 of 8 superconducting coils
quenched at 1400 Amps

Found section of power lead
not thermally insulated,
repair underway

Magnet to be shipped to JLab
in March 01



G0 Magnet at UIUC

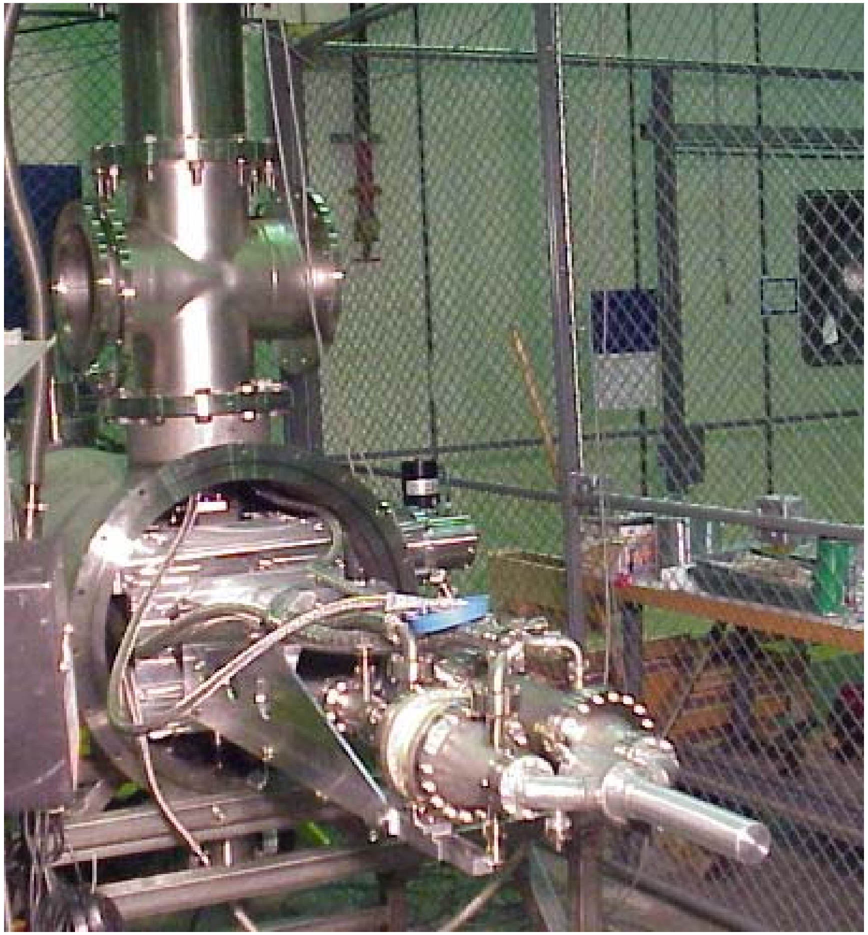
G0 Target

Designed and constructed at Caltech
(Controls system by U Md/JLab)

- 20 cm LH_2 cell
- High circulation rate to minimize target density fluctuations
- 250 W heat load from beam

Has been tested w/ He gas. HEX performance good, pump motor OK but marginal for LH_2 running.

Two new pump motors under consideration, will be necessary for deuterium running.



Target loop in Jlab Test Lab

Beam Requirements and Systematic Errors

32 ns between beam pulses for TOF reconstruction

tests carried out w/ 125 MHz laser

31.5 MHz production laser tests spring 2002

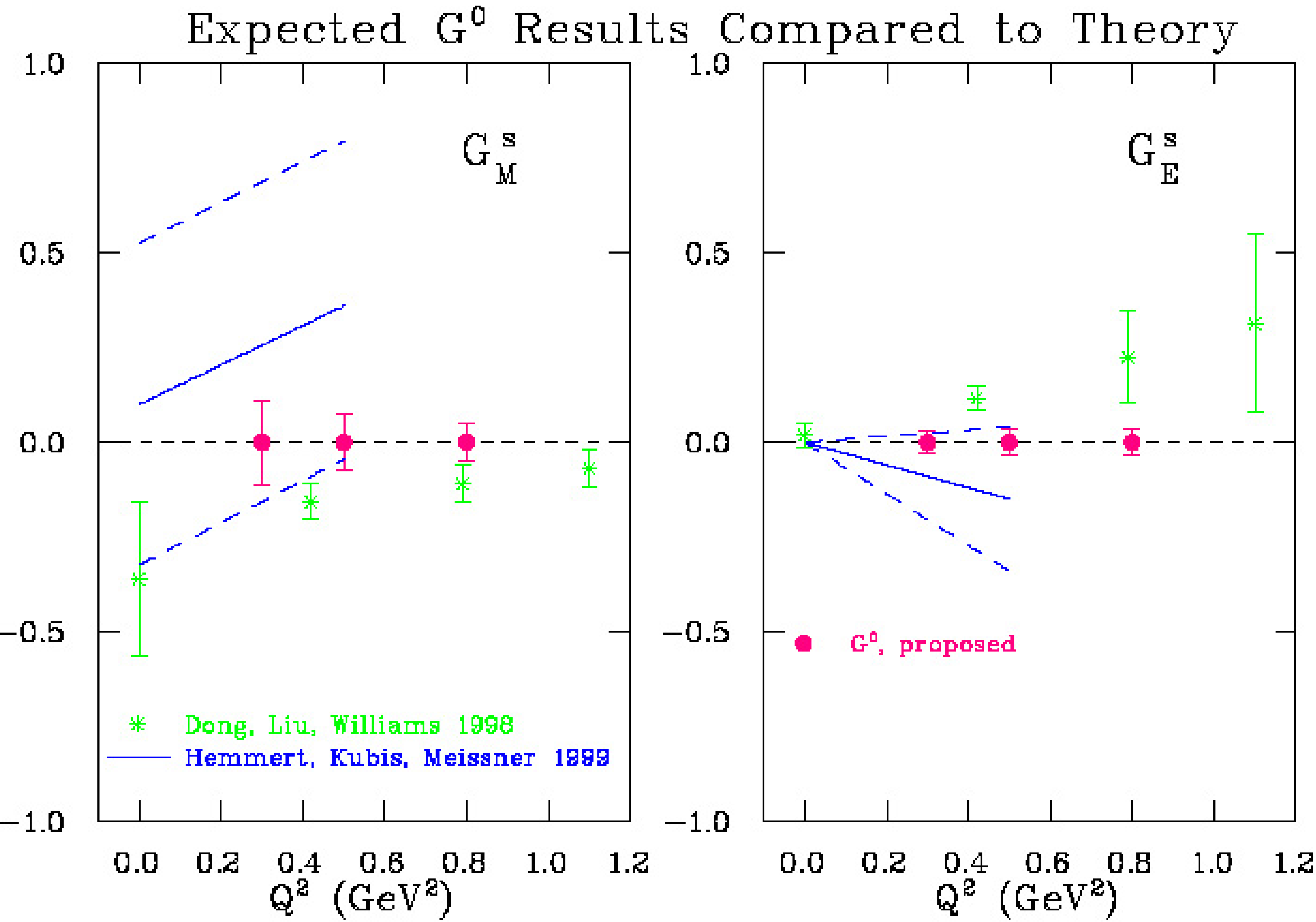
$2 < A_{meas} < 50$ ppm, $(\Delta A/A)_{STAT} \sim 5\%$

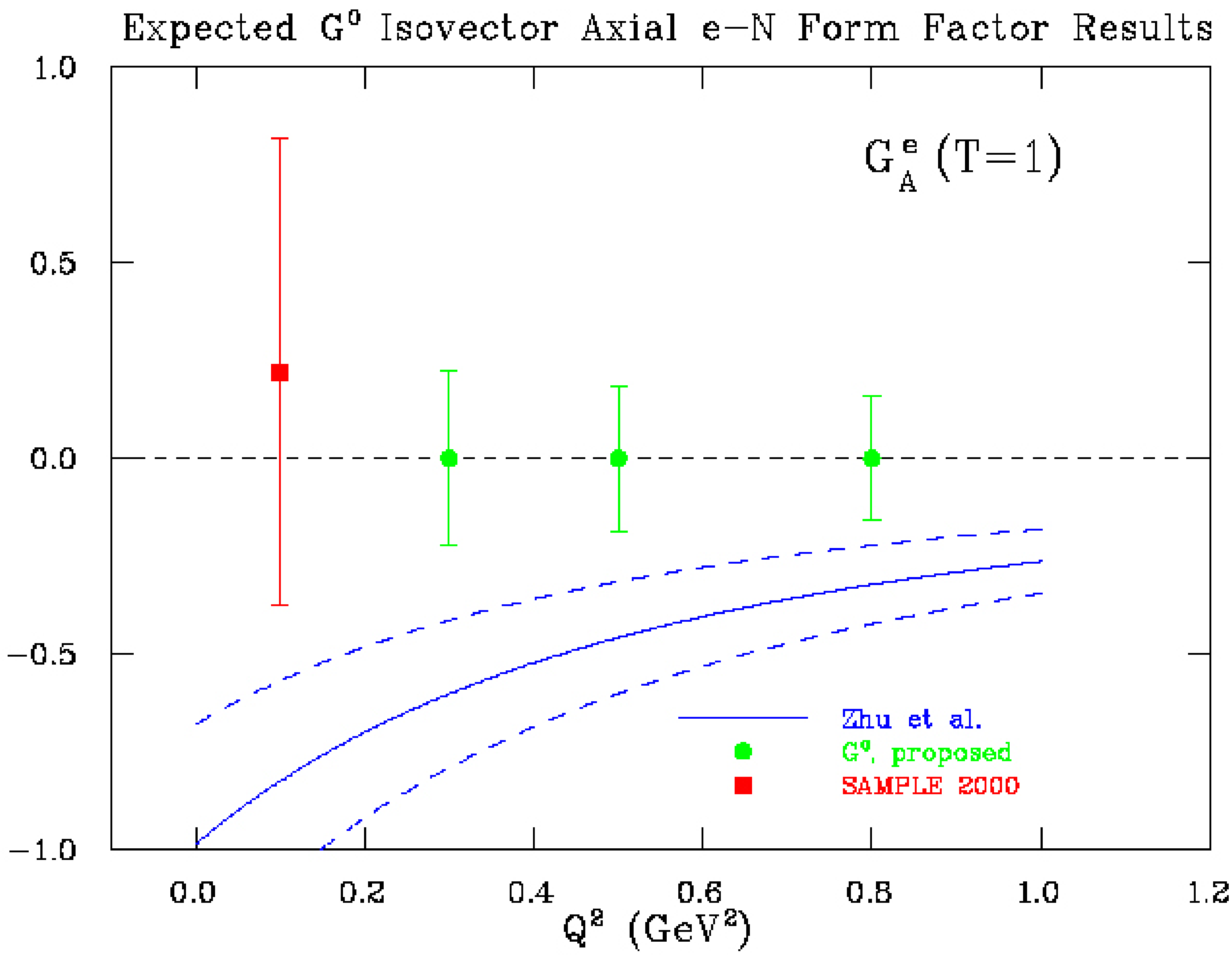
Beam Property	Nominal value	helicity corr. in 30 days
Energy	3 GeV	$< 2.5 \times 10^{-8}$
Current	40 μA	< 1 ppm
Position		< 20 nm
Angle		< 2 nrad

achieved in 1999 w/ strained GaAs for HAPPEX

G0 intensity+position feedback to be tested spring 2002

Large dynamic range halo monitor under development


Expected G0 Results Compared to Theory
1.0
0.5
0.0
−0.5
−1.0
G s M
G s E
Dong, Liu, Williams 1998
Hemmert, Kubis, Meissner 1999
G0, proposed
0.0 0.2 0.4 0.6 0.8 1.0 1.2
Q2 (GeV2)



Expected G0 Isovector Axial e–N Form Factor Results
G_A^e (T=1)
Zhu et al.
G0, proposed
SAMPLE 2000
1.0
0.5
0.0
−0.5
−1.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Q^2 (GeV^2)

G0 Experiment Schedule

- Installation
  - All 8 Octants and Ferris Wheel installed
  - Much infrastructure already completed
  - (Jan '02 – Readiness Review III)
  - Feb – May '02: magnet and target installation

- Forward angle
  - First commissioning: summer '02
  - Second commissioning, physics '03

- Backward angle
  - Approved by PAC Jul '01
  - Turnaround, first physics '04
  - 2nd, 3rd Q^2 points '05