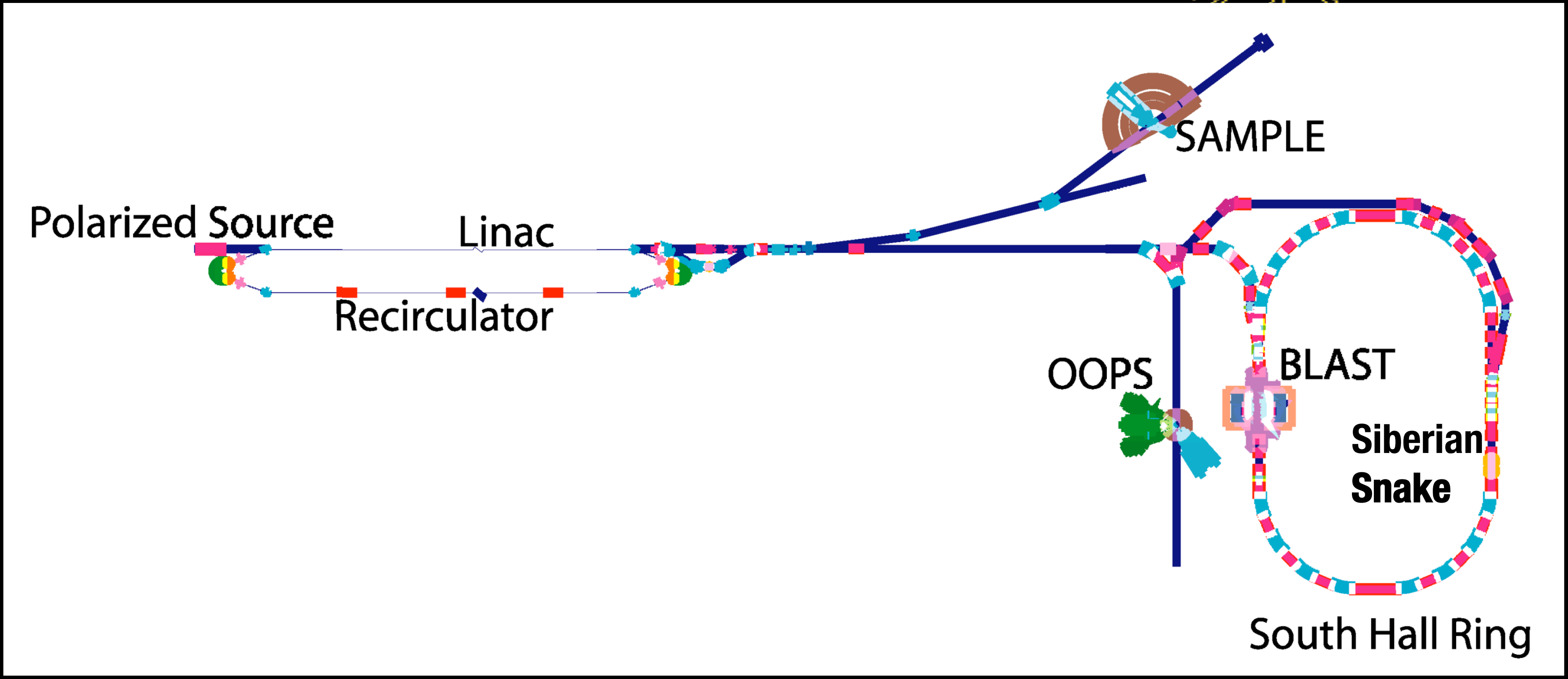
Recent Results from BLAST

Bates Large Acceptance Spectrometer Toroid

- Symmetric, large acceptance, general purpose detector
- Polarized electron beam (850 MeV, 65% polarization)
- Highly polarized, internal, gas targets of H and D
- Systematic study of the spin-dependent, electro-magnetic interaction in few nucleon systems
  - Nucleon form factors
  - Deuteron form factors
  - Study few body effects, pion production, …

MIT-BATES Linear Accelerator Laboratory



500 MeV Linac + Recirculator

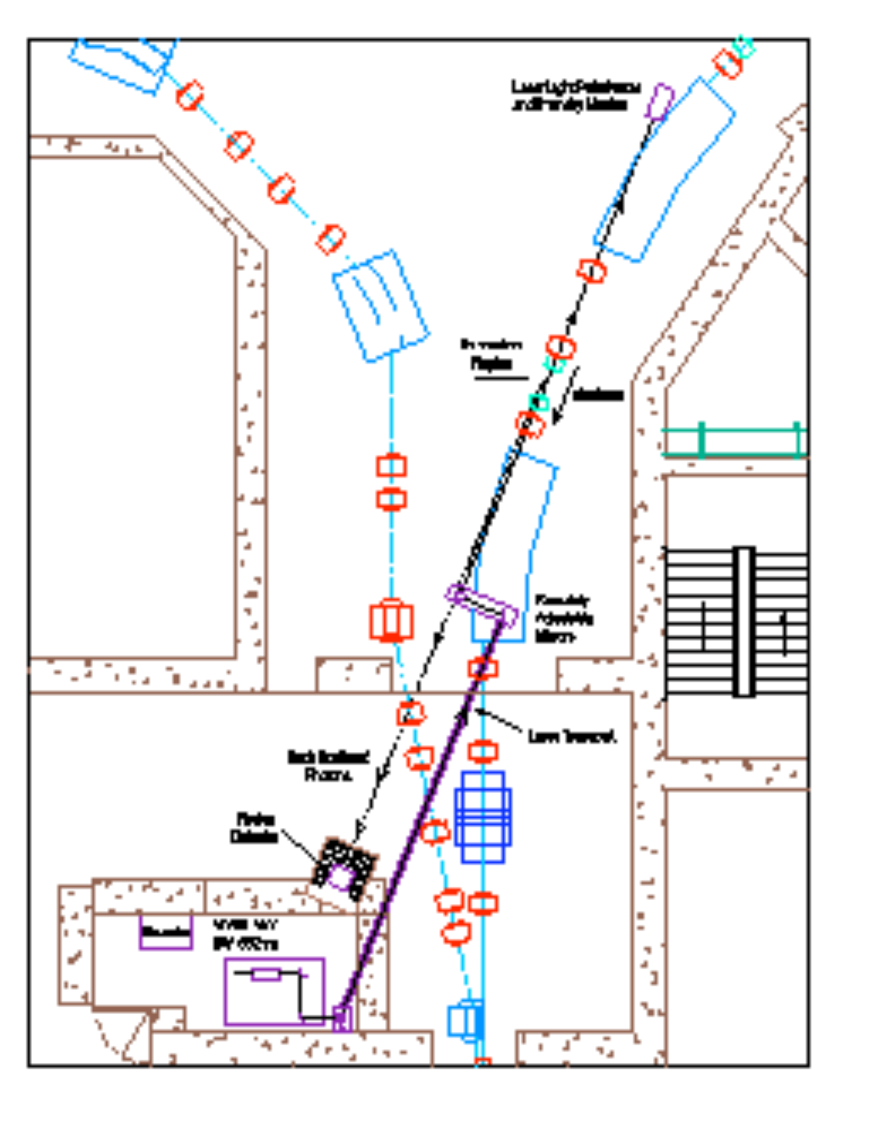
Electrons up to 1 GeV electrons

70% polarization typical

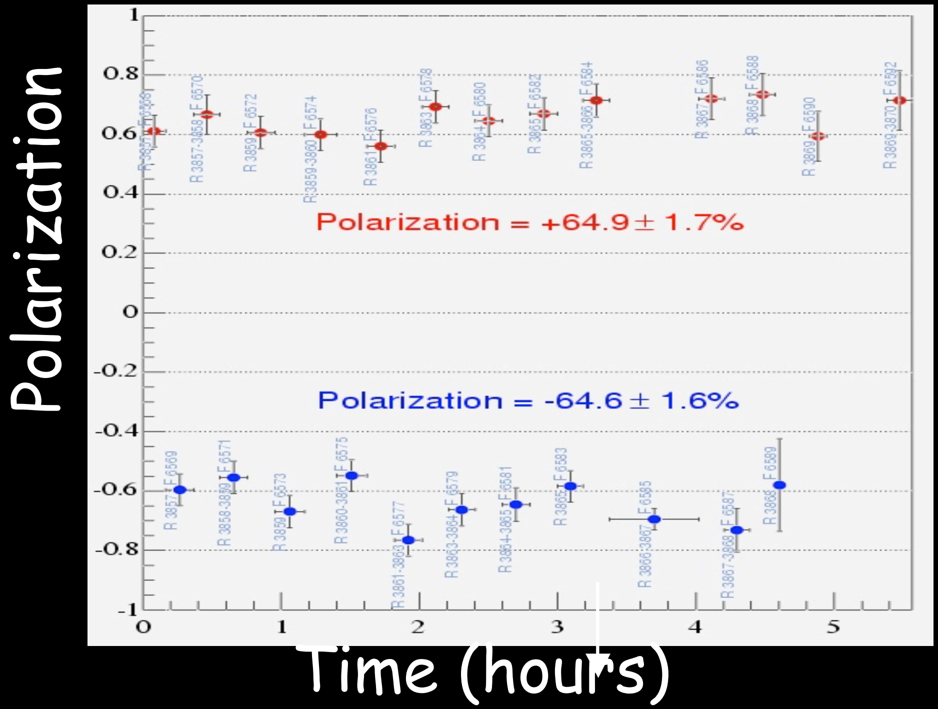
South Hall Storage Ring

- 175 mA injected, ~25 minute lifetime
- Siberian snake, spin flipper
- 65% polarization in ring typical

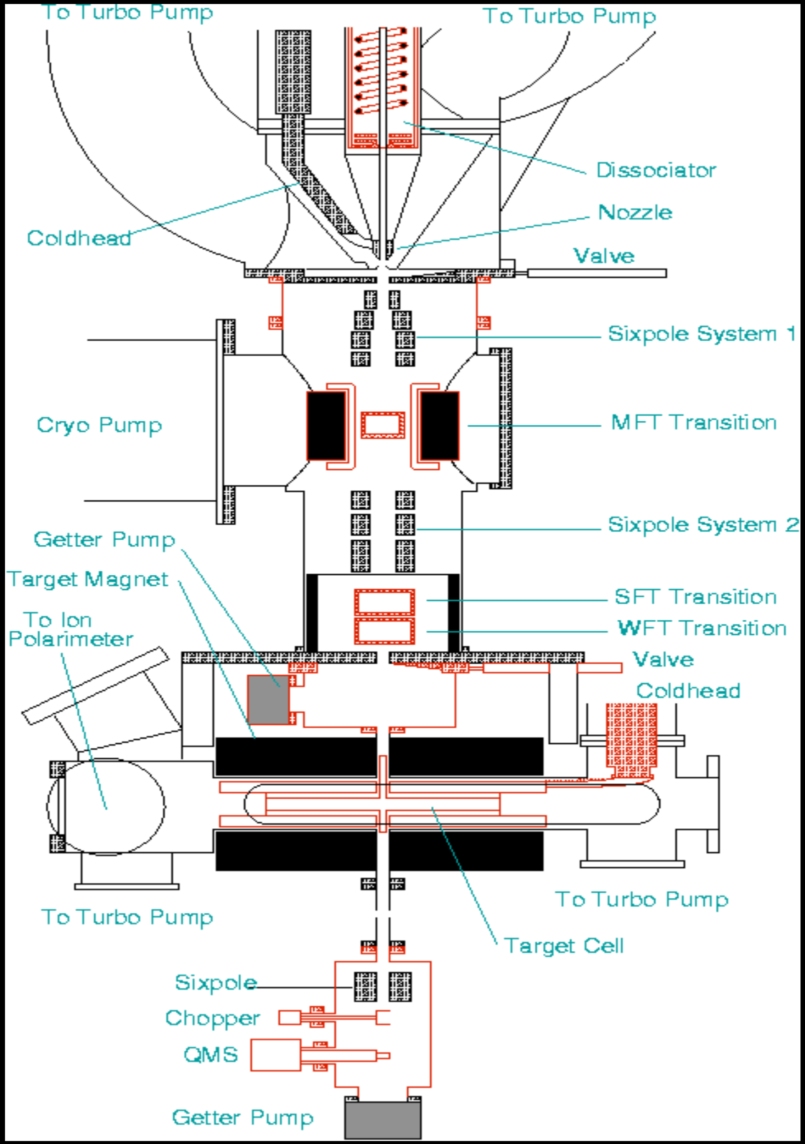
Compton Polarimeter



- Laser strikes oncoming electron beam
- Backscattered photons detected in CsI
- Laser helicity flipped in Pockels cell
- Chopper wheel allows simultaneous measure of background
- Asymmetry gives online measure of beam polarization



Polarized, Internal, Gas Target



Atomic Beam Source

- Isotopically pure H or D
  - Vector polarized H
  - Vector and Tensor polarized D
- Holding field 32 deg to left
  - Parallel/perpendicular kinematics
- Rapidly change polarization
  - Change every 5 minutes
  - Reduce systematic errors

Target thickness for D (60 cm cell)

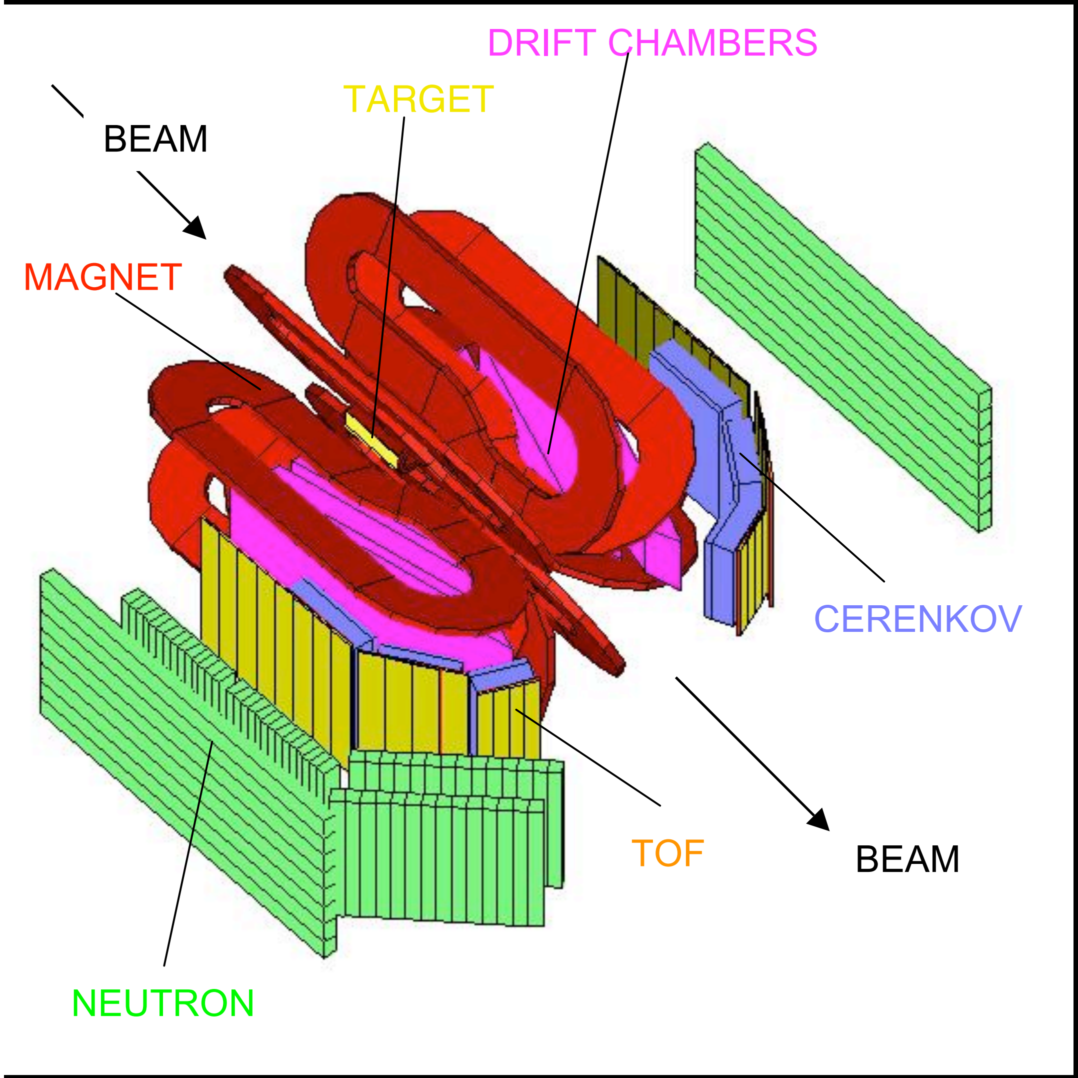
$$6 \times 10^{13}\ \mathrm{Atoms/cm^2}$$

Typical polarizations for D

$$P_Z \approx 72\%$$

$$P_{ZZ} \approx 68\%$$

BLAST Detector



Toroidal magnet
- B_{MAX}=3.8 kG

Drift chambers
- 3 chambers/sector
- 2 superlayers/chamber (±5°)
- 3 sense layers/superlayer
- 18 tracking layers/sector
- 954 sense wires

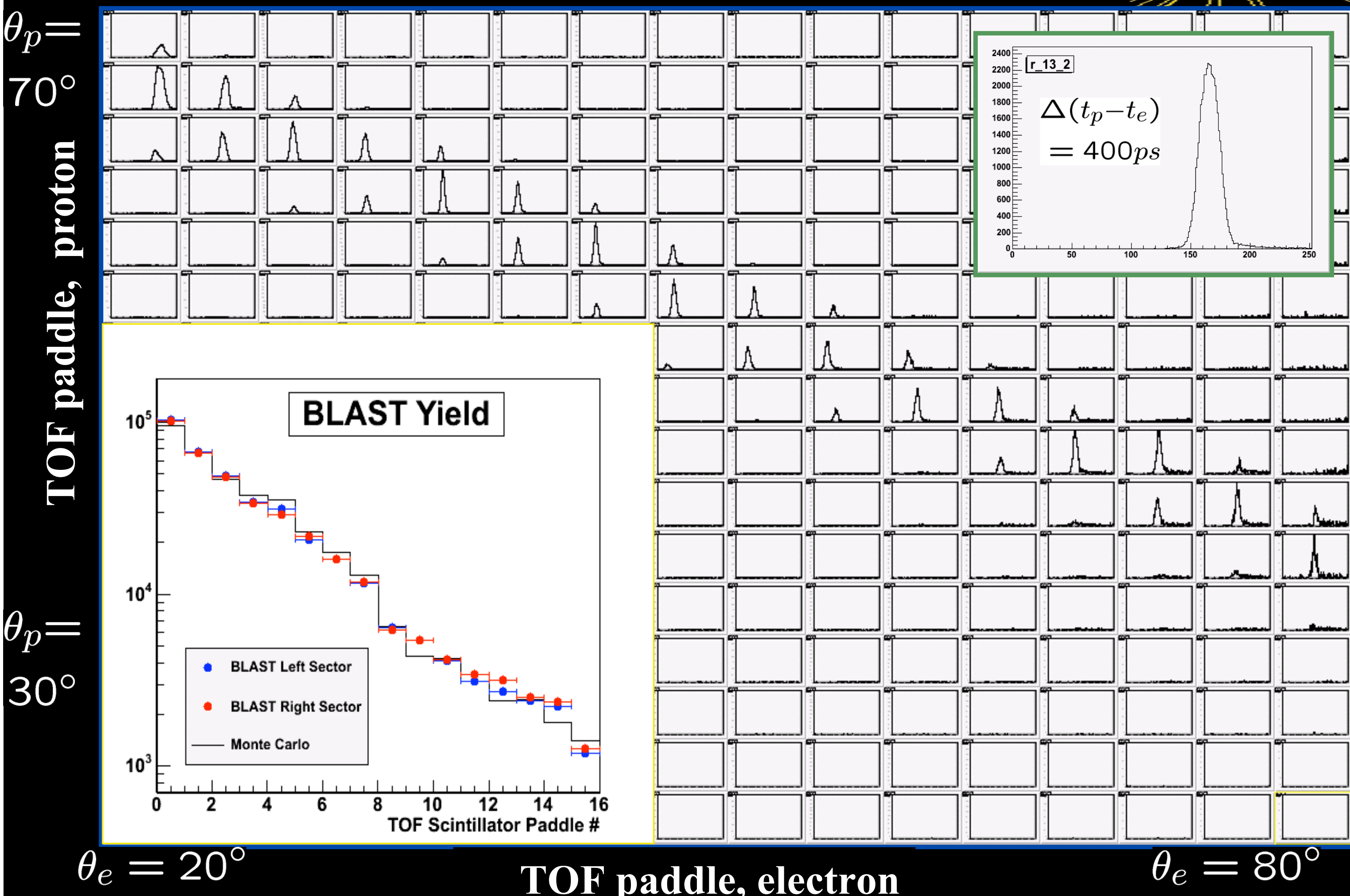
Aerogel Cerenkov detectors
- 1 cm thick
- Electron identification

Time of Flight scintillators
- 16 vertical bars 5 cm thick
- Trigger and relative timing

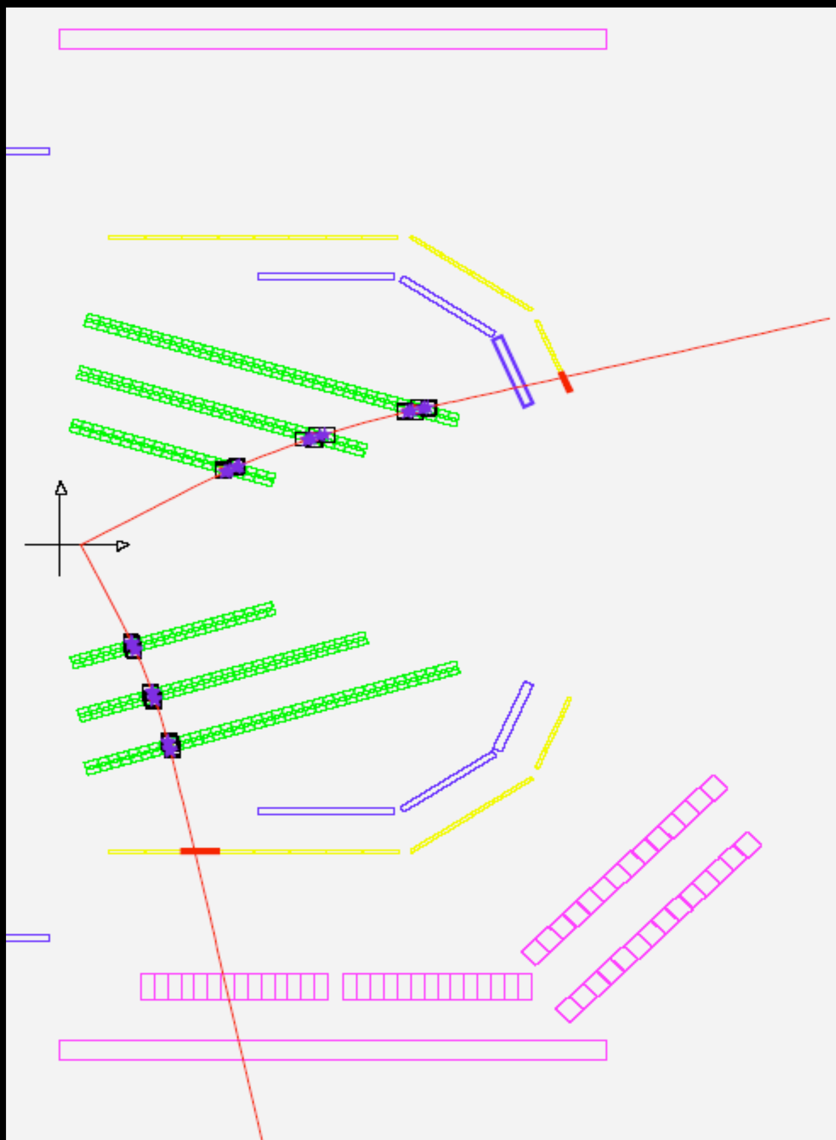
Neutron detectors
- 10 cm thick left sector
- 25-30 cm thick right sector

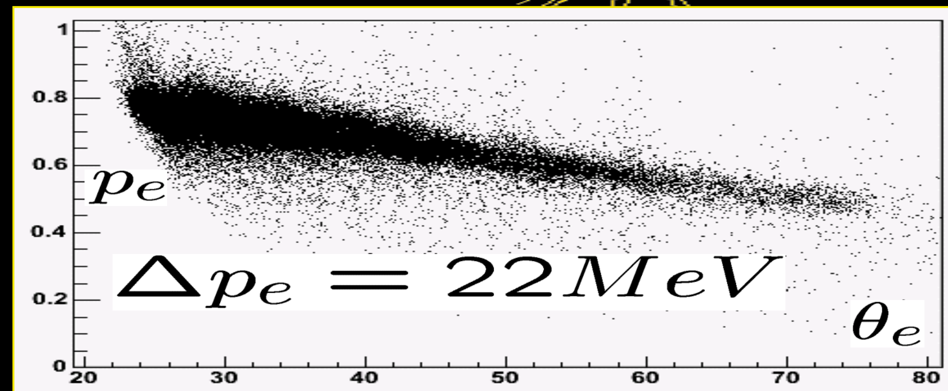
2 level Trigger system
- Several reaction channels
- Simultaneous measurements

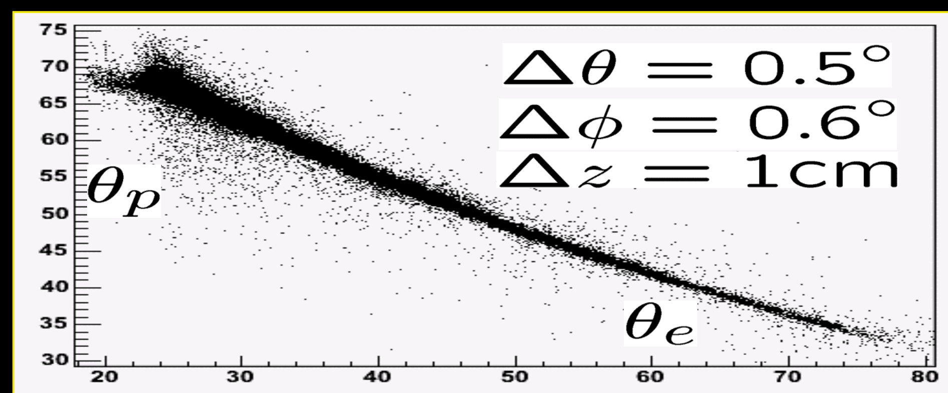
TOF Coincidence for *ep* Elastic Scattering



Track Reconstruction







	current	goal
σ_p	3%	2%
σ_θ	0.5°	0.3°
σ_ϕ	0.6°	0.5°
σ_z	1cm	1cm

BLAST Data

H run 1, December 2003

- reversed BLAST field – electrons out-bending
- 20 kC beam (3.4 pb^{-1}) $P_z = 45$ % 480k elastic events

H run 2, April 2004

- nominal BLAST field – electrons in-bending
- 57 kC beam (9.6 pb^{-1}) $P_z = 40$ % 950k elastic events

D run, May – October 2004

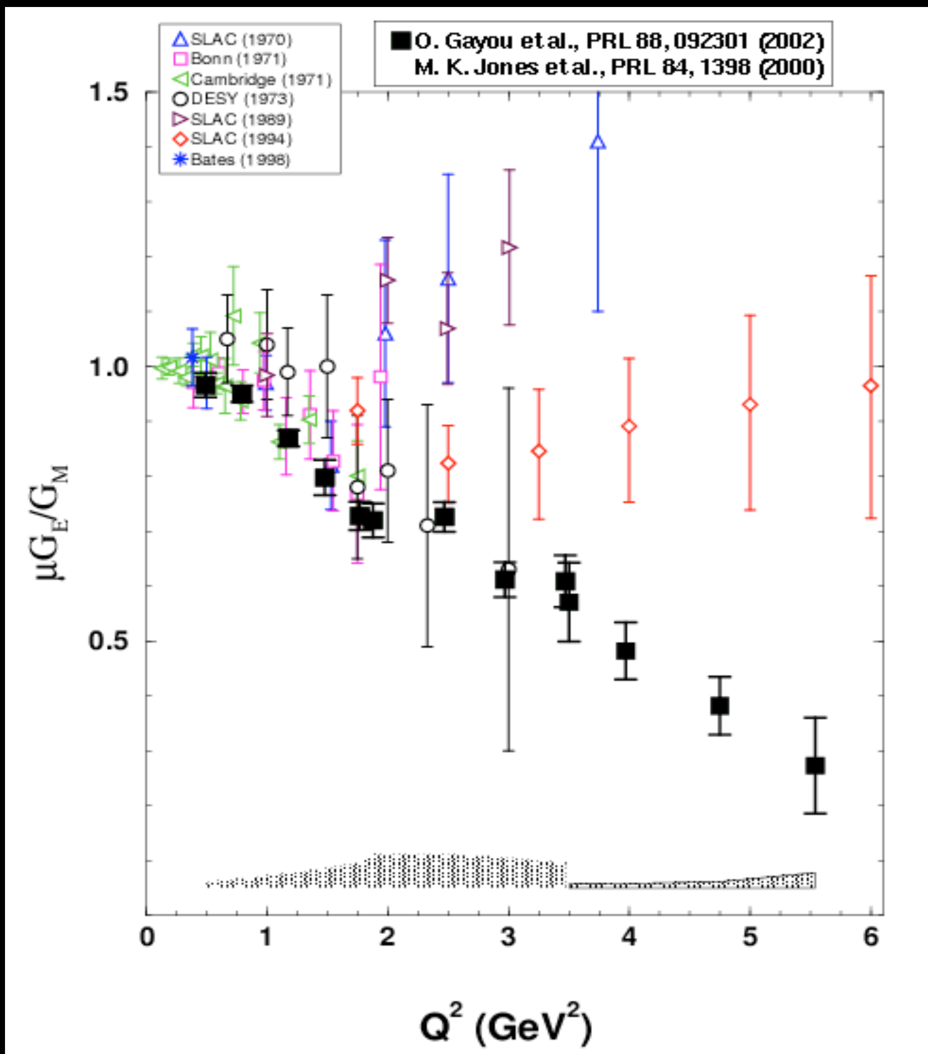
- 450 kC beam (169 pb^{-1}) $P_z = 72$ %, $P_{zz} = 68$ %,

H run 3, November 2004

- ~250 kC (~60 pb^{-1})

Following results preliminary

ep Elastic Scattering - $\mu G_E^p/G_M^p$



Ratio of Proton Form Factors

Rosenbluth separation

Unpolarized scattering

$$S = A(Q^2) + B(Q^2)\tan^2\frac{\theta_e}{2}$$

$$A(Q^2) = \frac{{G_E^p}^2 + {G_M^p}^2}{1+\tau}$$

$$B(Q^2) = 2\tau {G_M^p}^2$$

Polarization transfer

Polarized electron beam

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

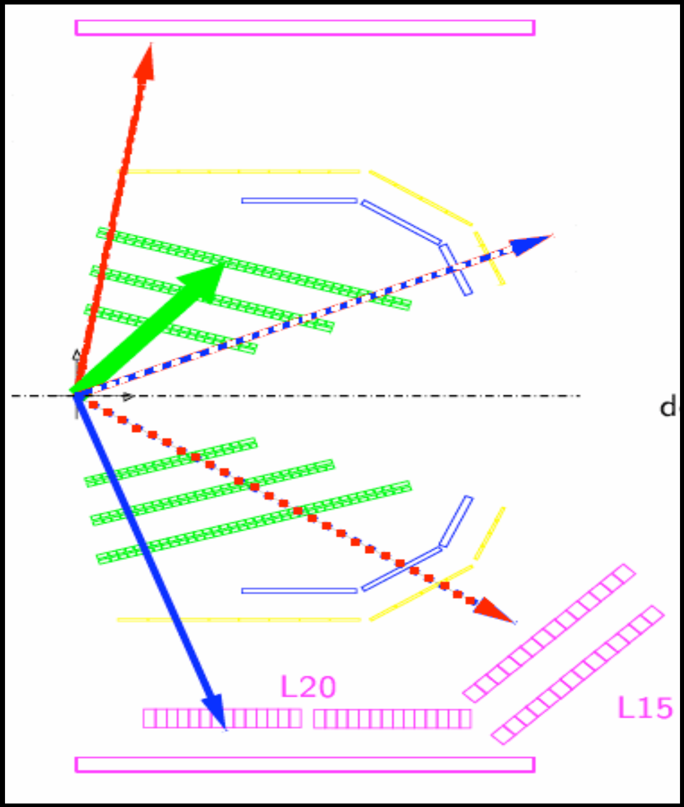
$\mu G^p_E/G^p_M$ from Ratio of Asymmetries

Polarized beam and target ➔ can use asymmetries

$$A_{exp} = P_b P_t \frac{-2\tau v_{T'} \cos\theta^* \, {G^p_M}^2 + 2\sqrt{2\tau(1+\tau)} v_{TL'} \sin\theta^* \cos\phi^* \, G^p_M G^p_E}{(1+\tau) v_L \, {G^p_E}^2 + 2\tau v_T \, {G^p_M}^2}$$

Target spin angle 32° into sector

- **Electron into left sector**
  - q roughly perpendicular to spin, $\theta^* \sim 90°$
- **Electron into right sector**
  - q roughly parallel to spin, $\theta^* \sim 0°$

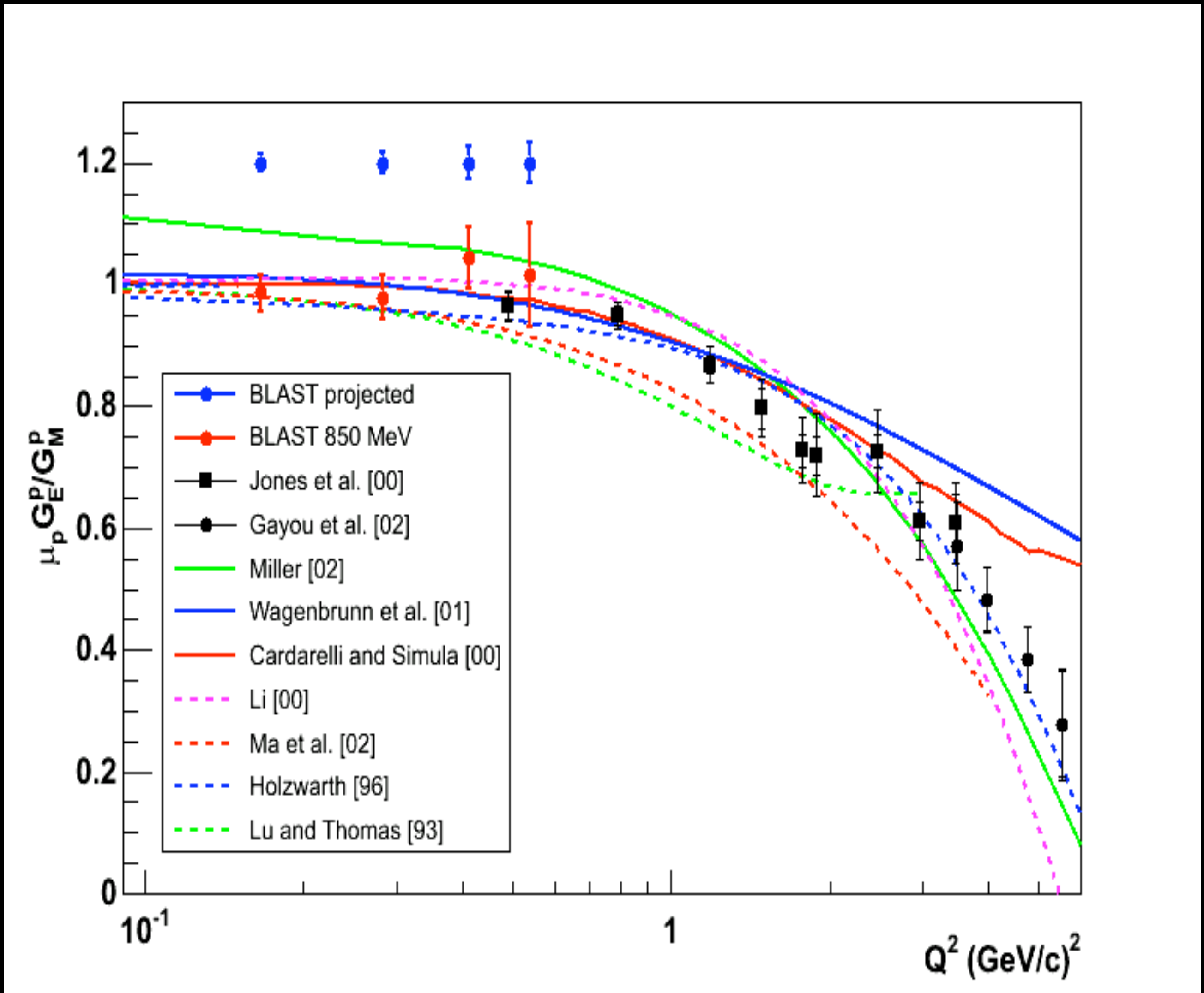


Symmetric detector ➔ form ratio of L/R asymmetries

- **Denominator cancels**

$$R_A = \frac{A_L}{A_R} = \frac{z^*_L - x^*_L \cdot G^p_E/G^p_M}{z^*_R - x^*_R \cdot G^p_E/G^p_M}$$

Preliminary Super-Ratio Results



Preliminary data

5x more to come

to 0.8 (GeV/c)^2

Low Q^2

- **independent measurement**
- **nomalization**
- **proton radius**
- **information on pion cloud**

eD Elastic Scattering

Deuteron form factors G_C, G_M, and G_Q

– G_Q arising from D state contributions → tensor force

Rosenbluth separation insufficient

$$A(Q^2) = G_C^2(Q^2) + \frac{8}{9}\eta^2 G_Q^2(Q^2) + \frac{2}{3}\eta G_M^2(Q^2)$$

$$B(Q^2) = \frac{4}{3}\eta(1+\eta)G_M^2(Q^2)$$

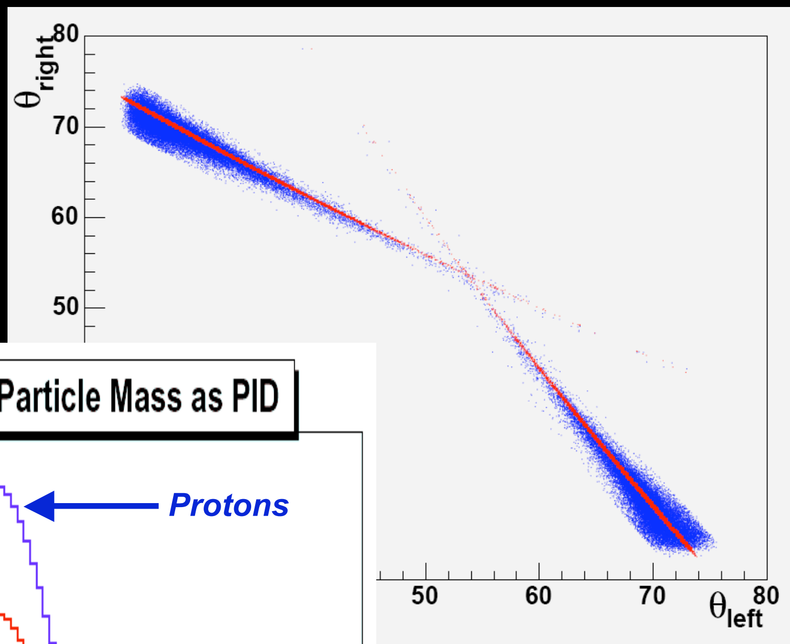
Need extra measurement → tensor asymmetry

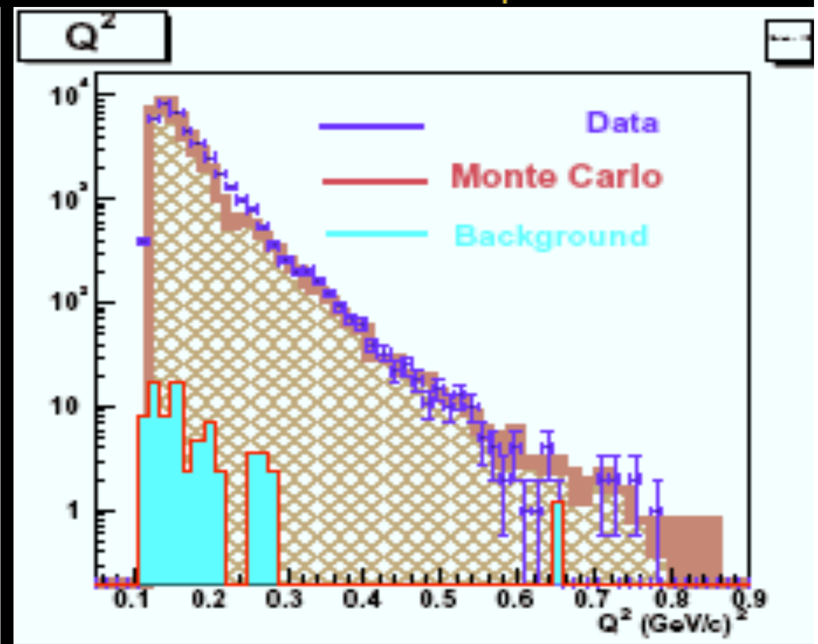
$$A = \sqrt{2}\frac{N^+ - N^-}{N^- P_{zz}^+ - N^+ P_{zz}^-}$$

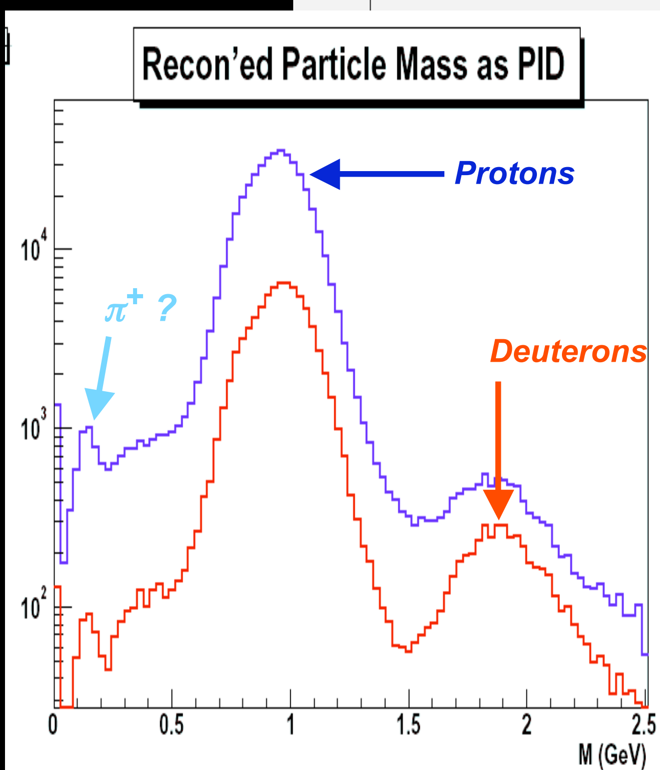
$$A = \frac{3\cos^2\theta_d^* - 1}{2}T_{20} - \sqrt{\frac{3}{2}}\sin 2\theta_d^* \cos\phi_d^* T_{21} + \sqrt{\frac{3}{2}}\sin^2\theta_d^* \cos\phi_d^* T_{22}$$

$$T_{20} = -\frac{1}{\sqrt{2}S}[\frac{8}{3}\eta G_C G_Q + \frac{8}{9}\eta^2 G_Q^2 + \frac{1}{3}\eta[1 + 2(1+\eta)\tan^2\frac{\theta_2}{2}]G_M^2]$$

eD Elastic Event Selection







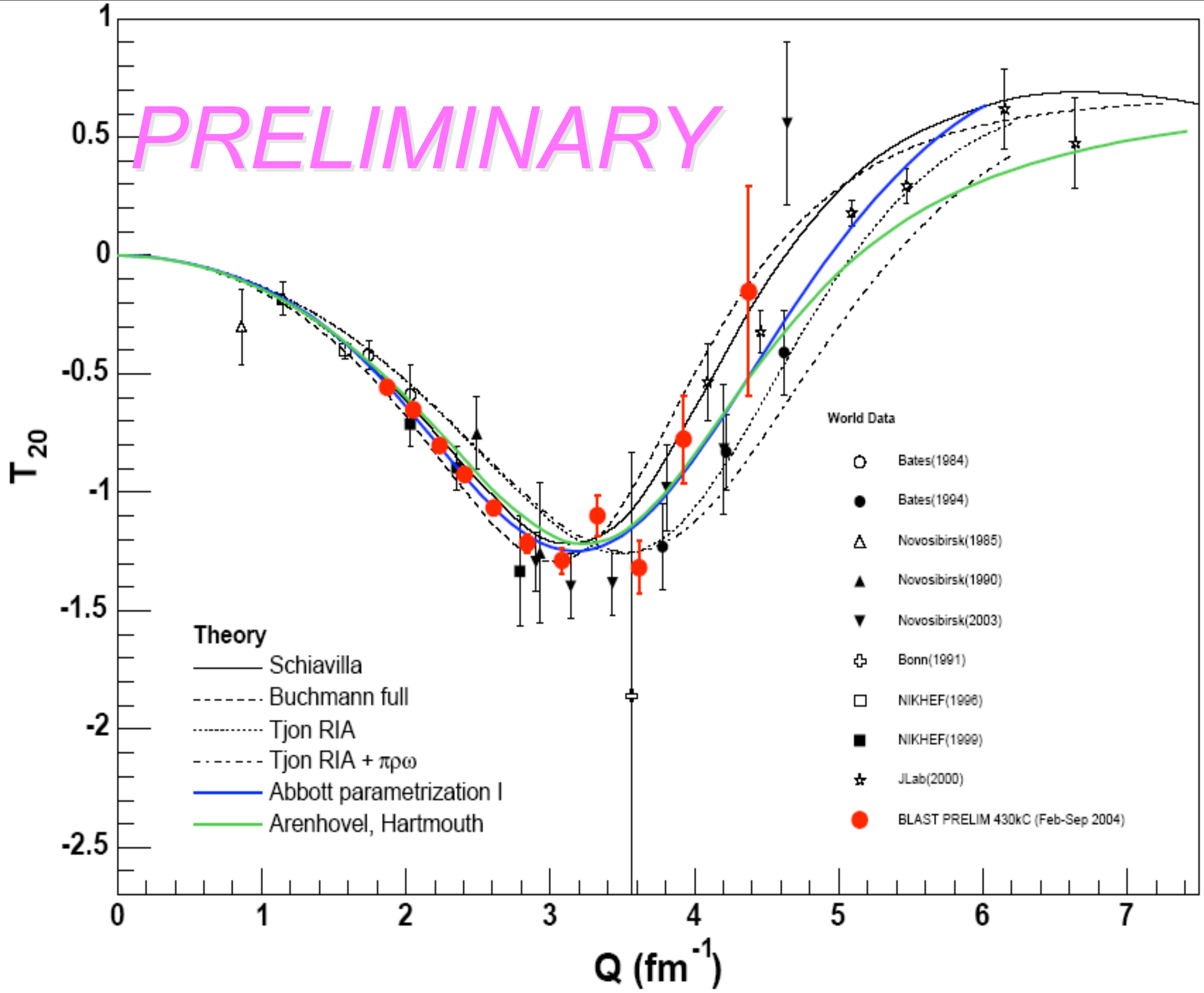
Event selection

- basic timing cuts
- 2 oppositely charged tracks + coplanarity
- D mass from momenta and energy from timing

Background

- cell walls, positrons from beam halo, misidentified protons
- study with empty and H runs

T_{20} Measurement



80% of available data included in this analysis (280 K)

Tensor polarization of target obtained by normalizing at low Q^2

Systematics still need to be checked

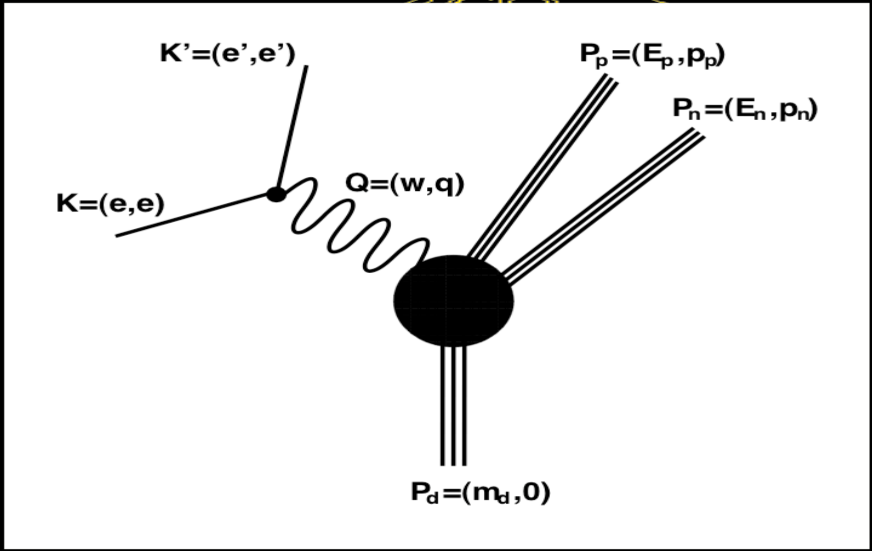
Consistency checks with T_{11} and T_{10}

Unfold deuteron form factors

D state contribution

Quasi-Elastic Scattering from Deuterium

- Deuterium readily breaks up into two nucleons
  - e + d → e' + p + n
  - electro-disintegration
- d(e,e'N)N cross section can be written as:



$$S(h,P_z,P_{zz}) = S_0\left(1+P_zA_d^V+P_{zz}A_d^T+h\left(A_e+P_zA_{ed}^V+P_{zz}A_{ed}^T\right)\right)$$

In Born approximation $A_e = A_d^V = A_{ed}^T = 0$

$$S = S_0(1 + P_{ZZ}A_d^T + hP_ZA_{ed}^V)$$

A_{ed}^V → $\sim G_E G_M$

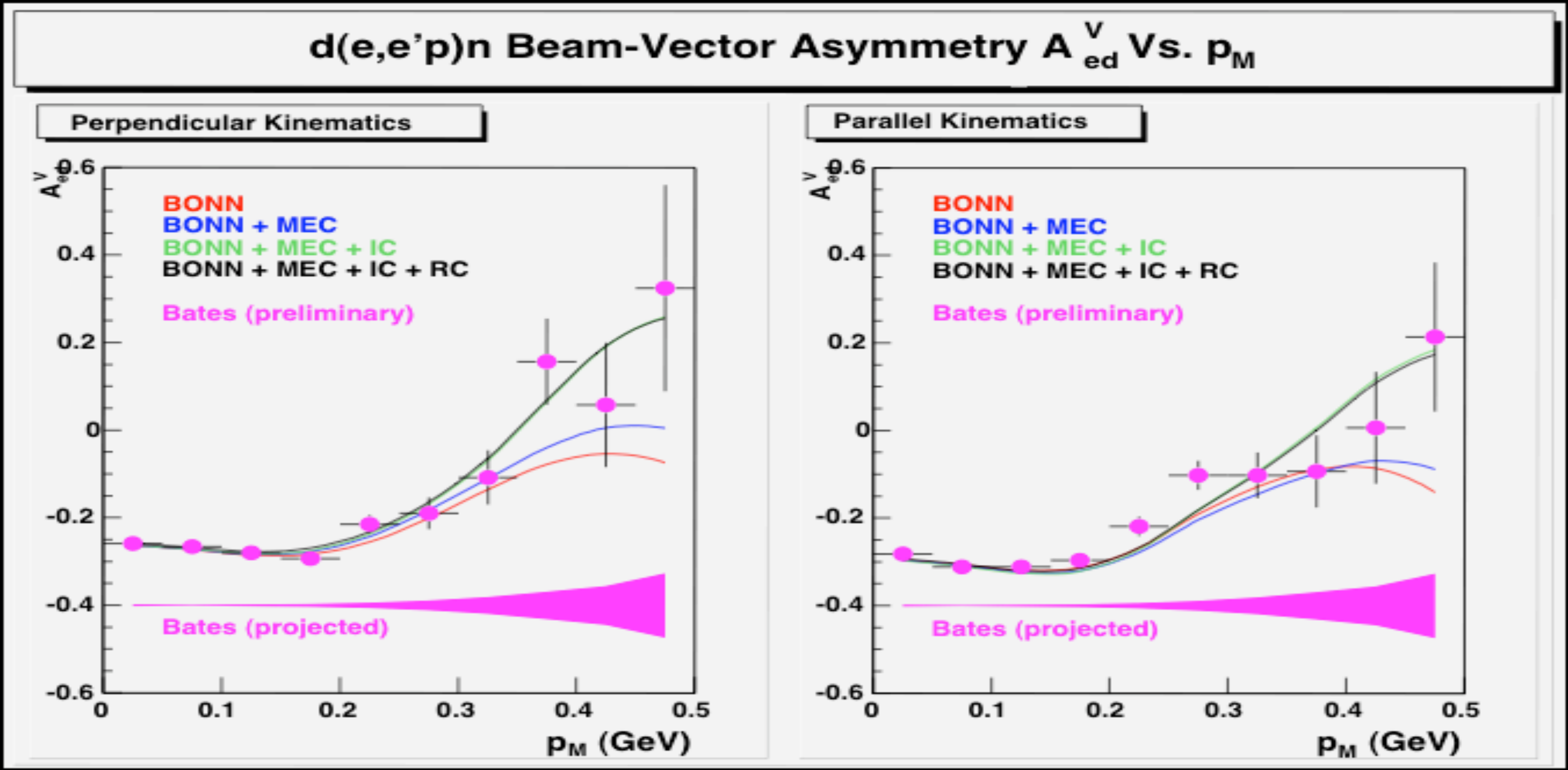
A_d^T → = 0 for S state

e'p Vector Asymmetry Results

Analysis of 200kC of 450kC collected data

Vector polarization from fitting asymmetry below p_M = 0.15GeV

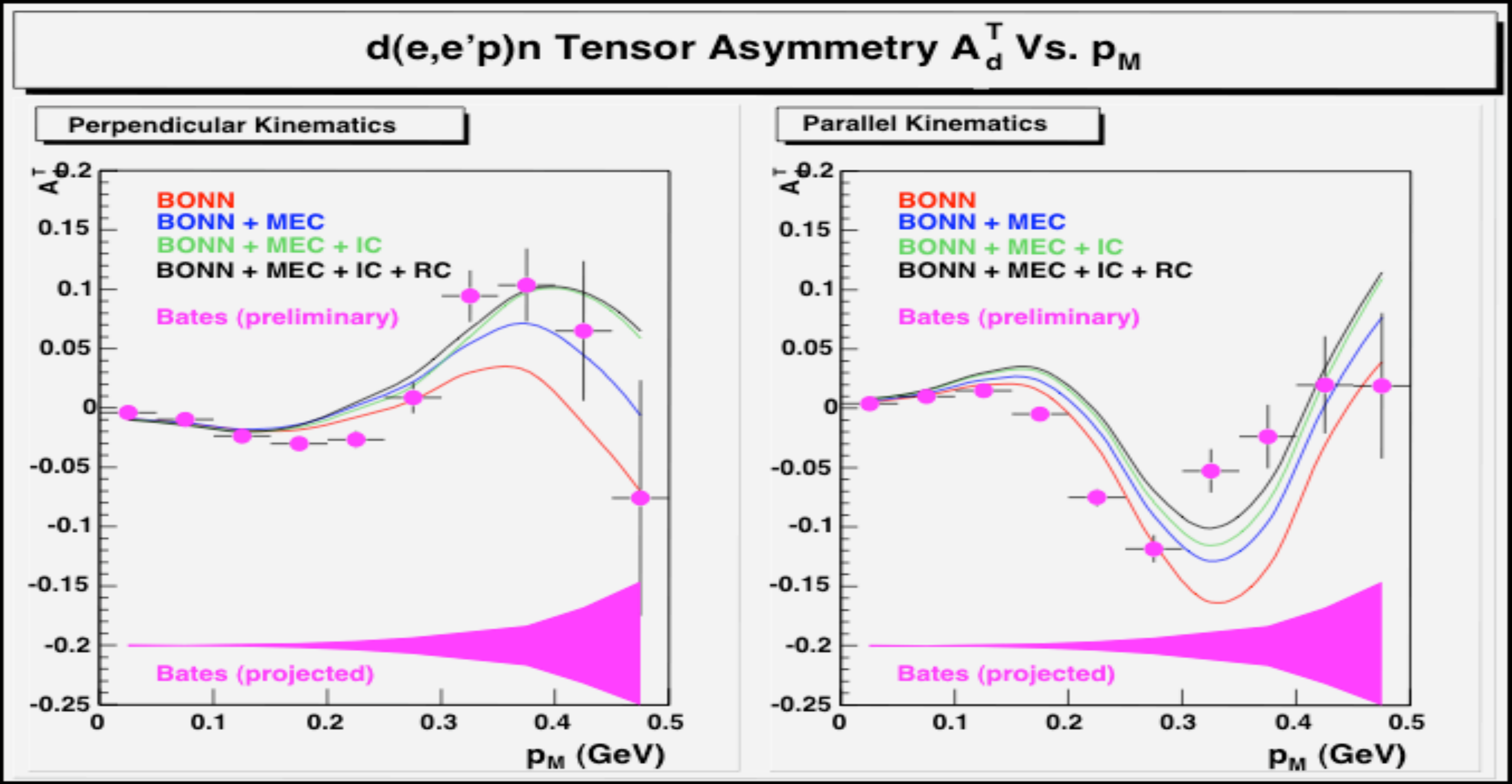
Vector asymmetry sensitive to $G_E^p G_M^p$ see subnuclear effects



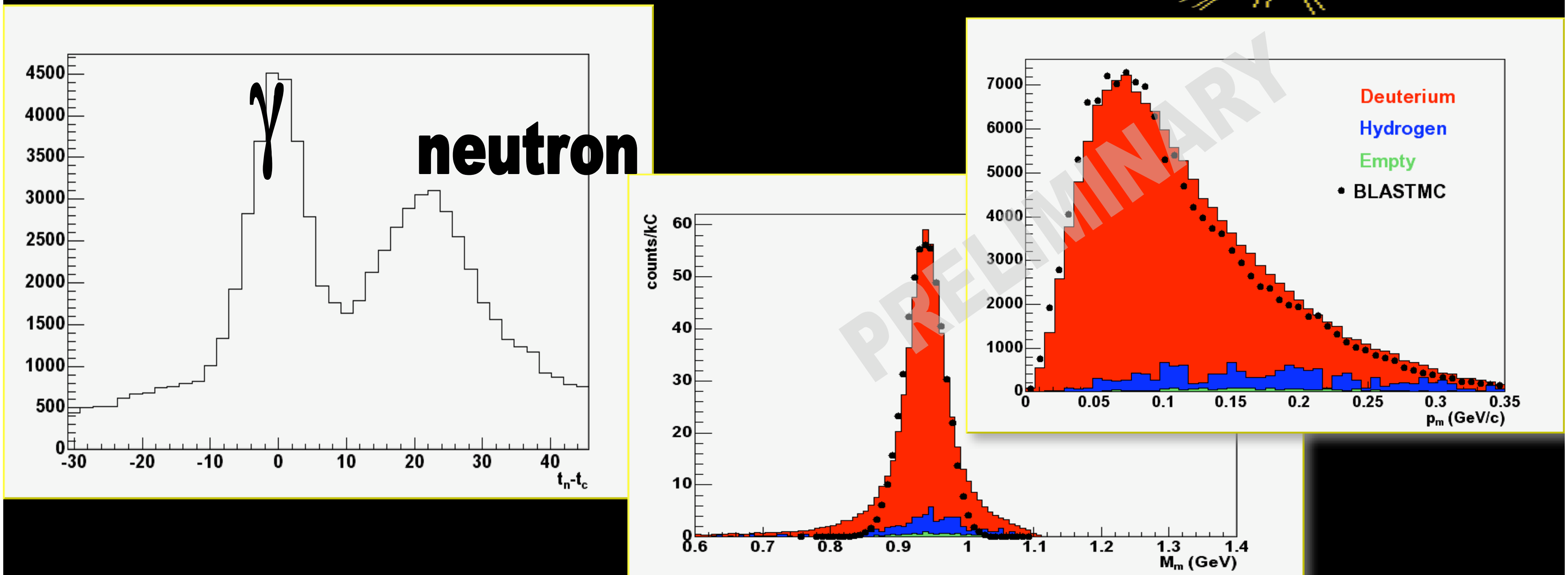
e'p Tensor Asymmetry Results

Tensor polarization from independent T_{20} fit

Sensitive to D state contributions



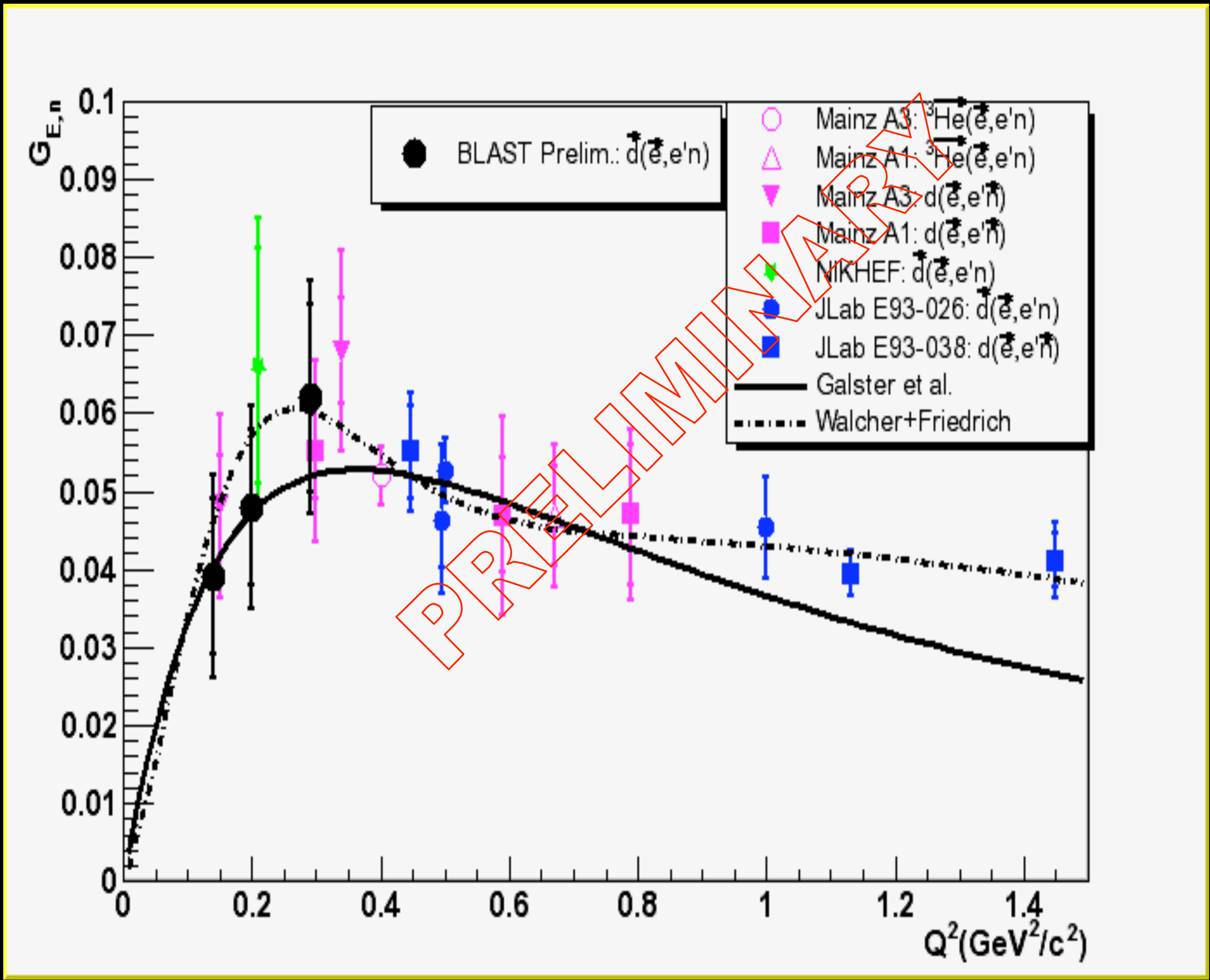
e'n Event Selection, Missing Mass/Momenta



- timing cuts, only 1 charged track, hit in neutron detector
- time resolution of ~5 ns
- Neutron momentum resolution: ~5%
- require missing mass to be m_p

- High signal to noise ratio
- 140k total neutrons after cuts
- <2% empty target contribution
- ~10% background from hydrogen

Preliminary G^n_E World Plot



Preliminary result

Only 60% of data, final data should reach 0.5

Use Arenhovel's calculations for G^n_M and contribution of G^n_E

Need to combine with other BLAST measurements for global fit

Provide low Q^2 data

- Check bump
- Pion cloud

BLAST Results Still to Come

G_M^n from inclusive electron scattering from D

T_{10} and T_{11} from *eD* elastic scattering

Pion production

Preliminary

2005 polarised ^{3}He target

- effective polarised n target
- cross check for G_E^n results
- elastic ^{3}He
- $N \rightarrow \Delta$

BLAST Collaboration