Vector Polarization Observables of the Deuteron

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Electromagnetic Structure of the Deuteron

$$(\frac{d\sigma}{d\Omega})_{unpol} = \sigma_{Mott} f_{rec}^{-1} \cdot S$$

$$S = A(Q^2) + tan^2(\theta/2)B(Q^2), \qquad \tau = \frac{Q^2}{4M_d^2}$$

$$A(Q^2) = G_C^2 + \tfrac{8}{9}\tau^2 G_Q^2 + \tfrac{2}{3}\tau G_C^2$$

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

Rosenbluth Separation: Traditional method of separating form factors by varying beam energy and scattering angle at fixed Q^2. Using this method we:

- can separate A and $B \longrightarrow$ and from B get G_M
- can not dissociate A into G_C and G_Q

We need another observable!

Polarization Observables

Cross Section in Terms of Polarization Observables[1]

$$\frac{d\sigma}{d\Omega}(h, P_z, P_{zz}) = \Sigma + h\Delta$$

- $\Sigma = \Sigma_0[1+\Gamma]$, where $\Sigma_0 = A(Q^2) + B(Q^2)tan^2\frac{\theta_e}{2}$
- Γ contains the tensor terms of the cross section
- Δ contains the vector terms of the cross section

Beam-Target Vector Asymmetry: [1,2]

$$A_V^{ed} = \frac{\Delta}{\Sigma_0} = -\sqrt{3}\ [\ \frac{1}{\sqrt{2}}cos\theta^* T_{10}^e(Q^2)\ +\ sin\theta^* cos\phi^* T_{11}^e(Q^2)]$$

θ^* and ϕ^* are the target vector polarization angles w.r.t. $\vec{q}$

1) T.W. Donnelly and A.S. Raskin, Ann. Phys. **169**, 247 (1986)., (assuming 100% polarization)

2) S.E. Darden, "Polarization in Nuclear Reactions", University of Wisconsin Press, Madison, (1971)

Scattering & Reaction Planes [1]

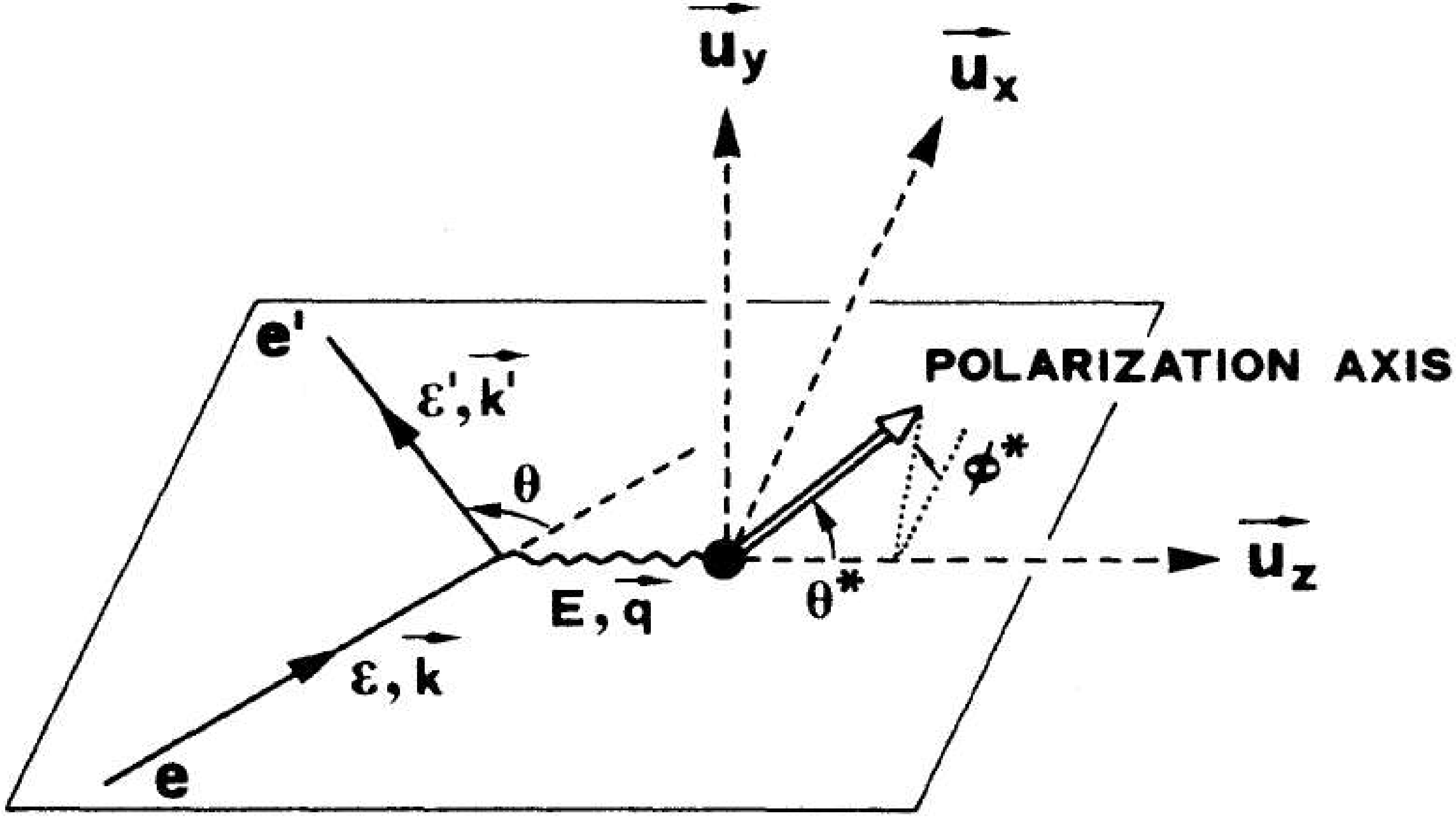


FIG. 1. Kinematics and coordinate systems for the scattering of polarized electrons from polarized nuclei.

Measuring the Beam-Target Vector Asymmetry

General cross section for scattering polarized electrons from polarized deuterium[2]:

$$\sigma(\mathbf{h},\mathbf{V},\mathbf{T}) = \sigma_0\{1 + P^d_V A^d_V + P^d_T A^d_T + P_e h(A_e + P^d_V A^{ed}_V + P^d_T A^{ed}_T)\}$$

P^d_V = Target Vector Polarization

P^d_T = Target Tensor Polarization

P_e = Beam Polarization

h = Beam helicity = ± 1

A_e = Beam Helicity Asymmetry

A^d_V = Target Vector Asymmetry

A^d_T = Target Tensor Asymmetry

A^{ed}_V = Beam-Target Vector Asymmetry

A^{ed}_T = Beam-Target Tensor Asymmetry

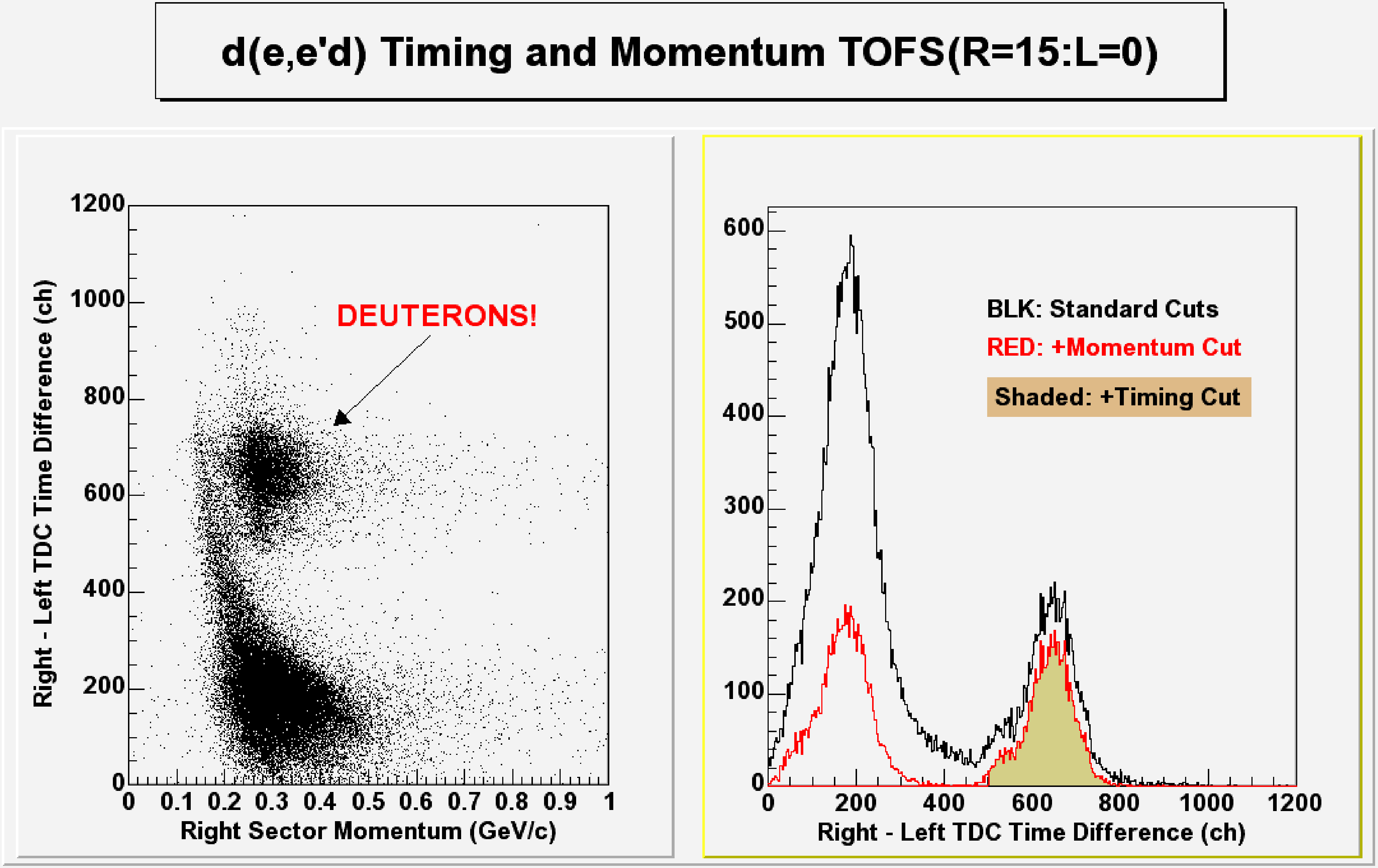
Unpolarized Cross Section: $6\sigma_0 = \sigma(+,+,+1) + \sigma(-,+,+1) + \sigma(+,-,+1) + \sigma(-,-,+1) + \sigma(+,0,-2) + \sigma(-,0,-2)$

$$A^{ed}_V = \frac{1}{4P^e P^d_V \sigma_0}[\sigma(+,+,+1) - \sigma(-,+,+1) - \sigma(+,-,+1) + \sigma(-,-,+1)]$$

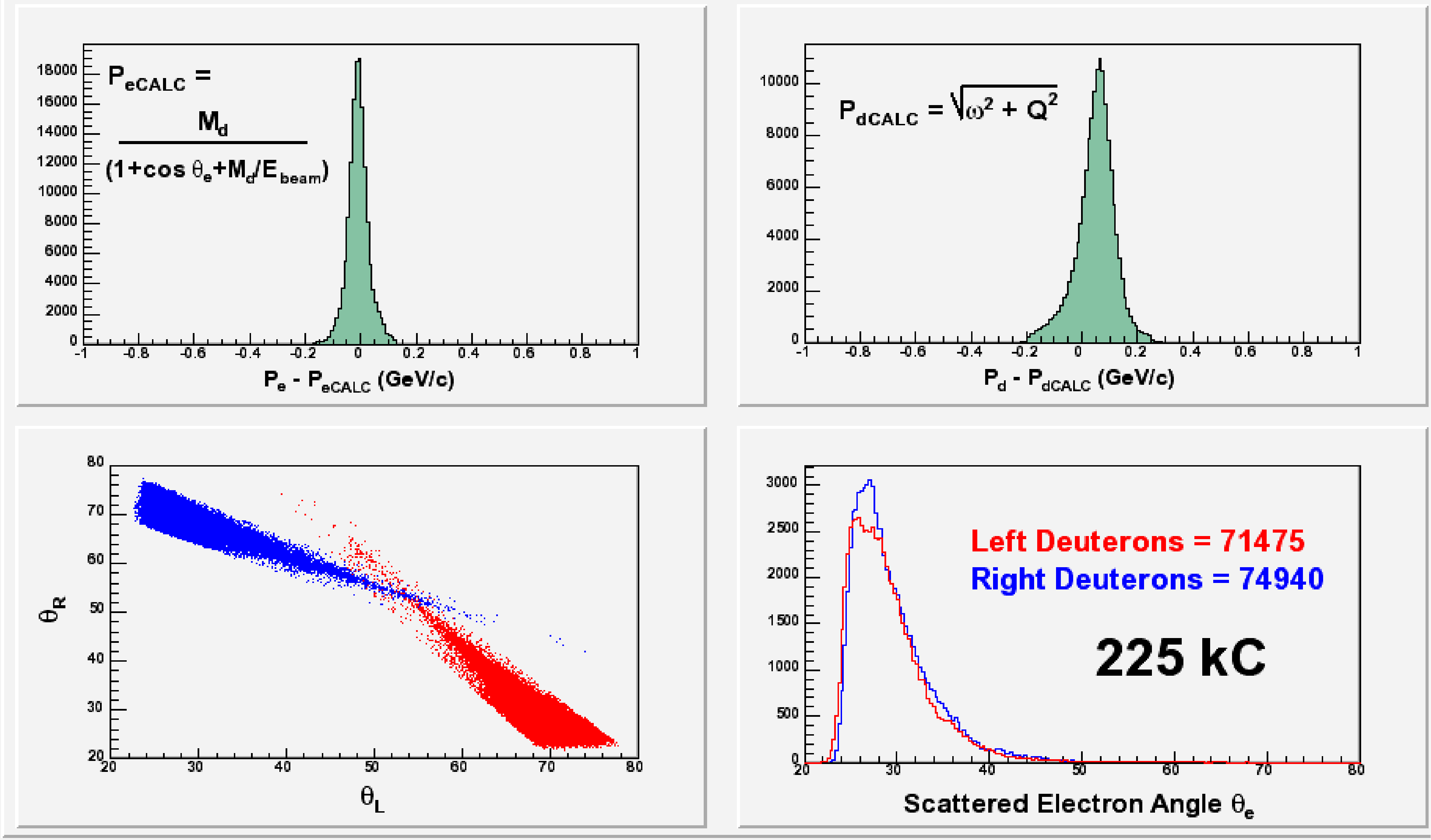
4) H. Arenhövel *et al*,. Z. Phys. **A331** (1988) 123.

Selecting Elastic (electron-deuteron) Events

(many thanks to Chi Zhang!)



d(e,e'd) Kinematics



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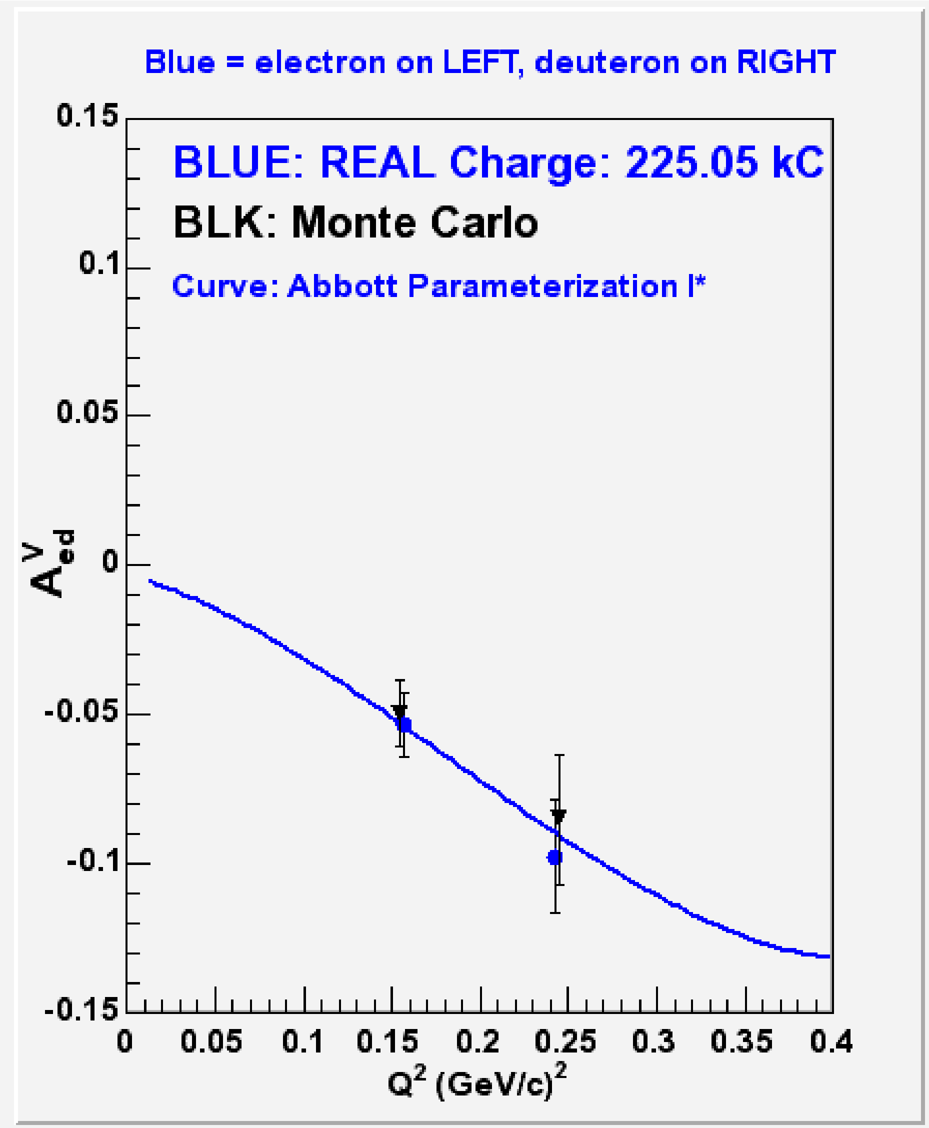
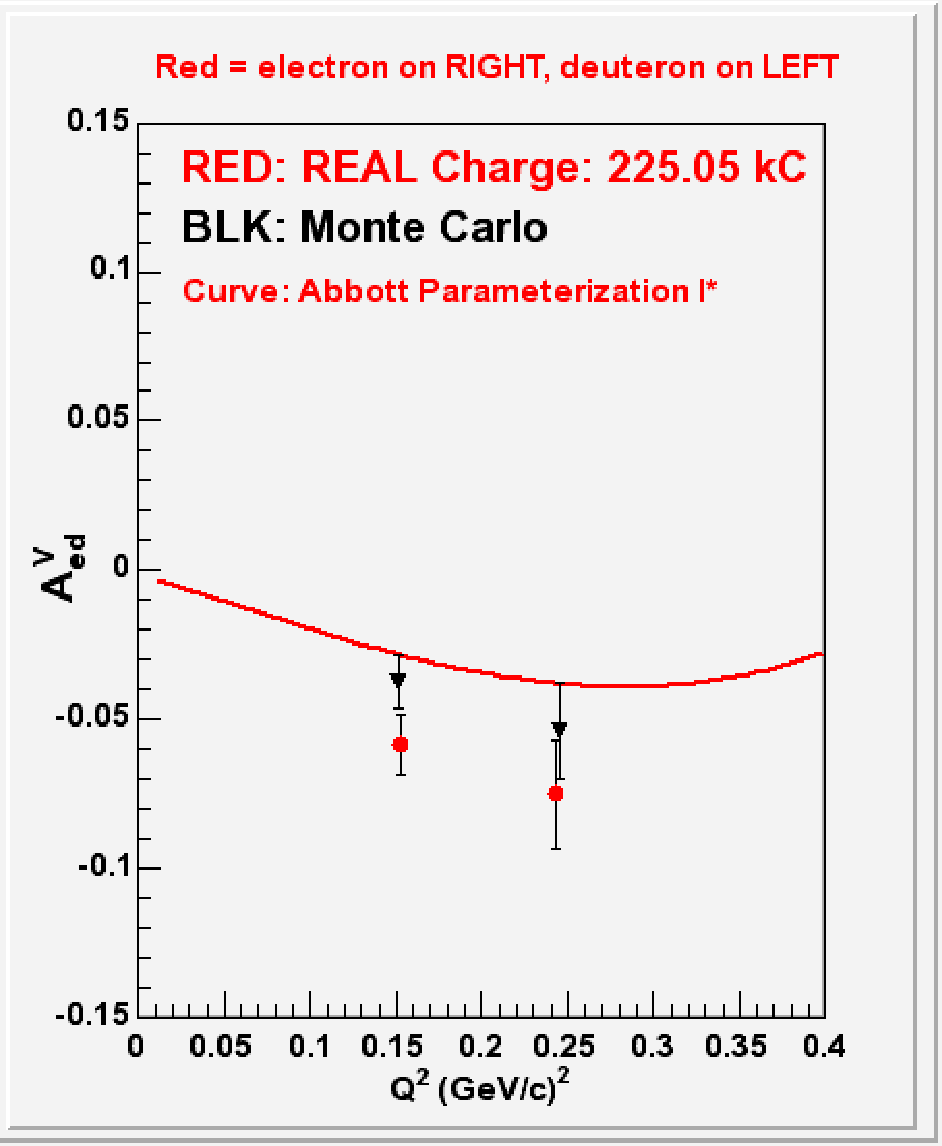
d(e,e'd) Beam-Target$_{32^\circ}$ Vector Asymmetry A^V_{ed}: May-Sept 2004 Data


Blue = electron on LEFT, deuteron on RIGHT


Red = electron on RIGHT, deuteron on LEFT

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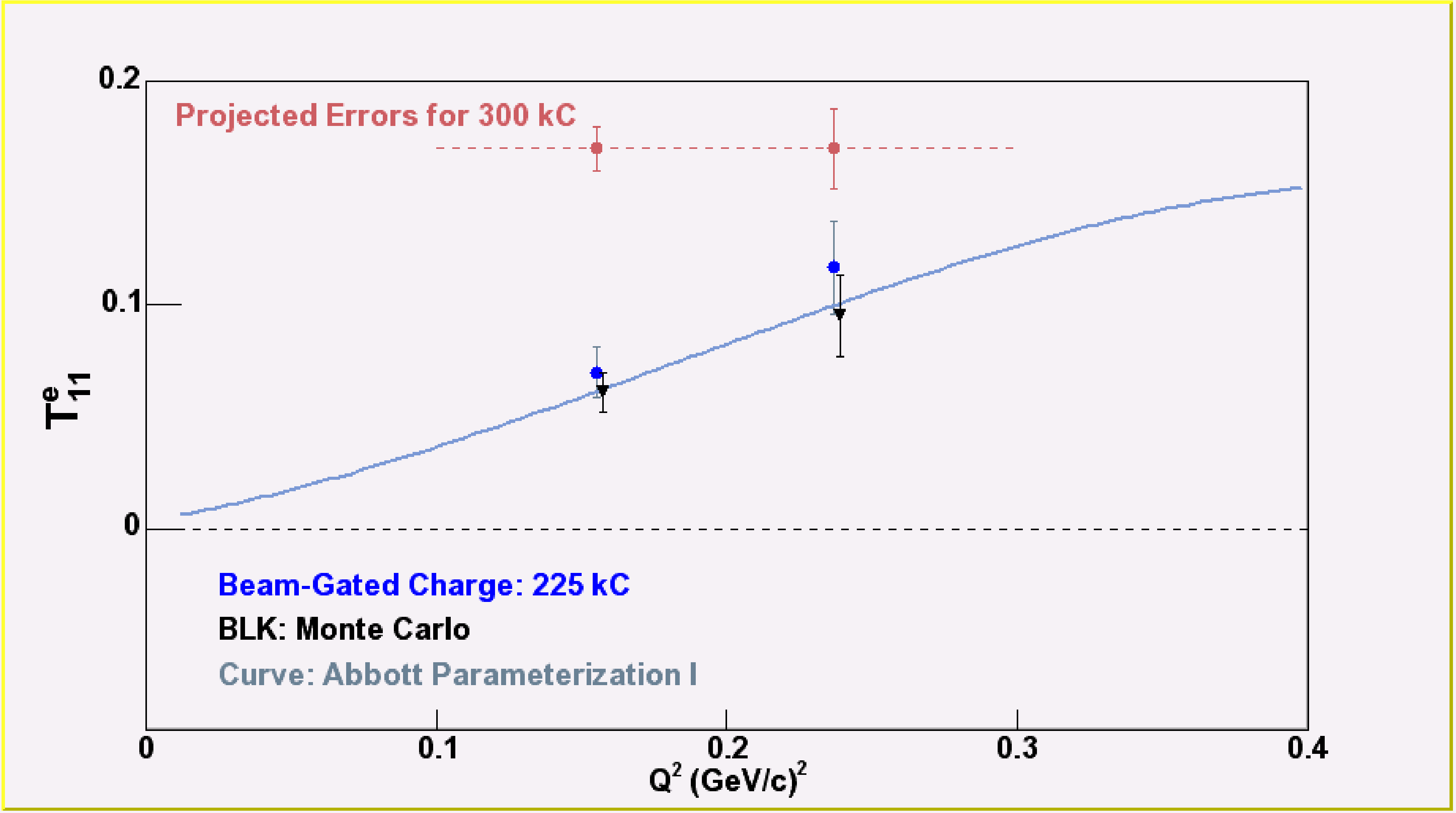
d(e,e'd) Vector Analyzing Power T^{e}_{11}



The Vector Analyzing Power T_{11}^{e} and the Form Factor G_M [3]

T_{11}^{e} can be written in terms of the deuteron elastic form factors G_C, G_Q, and G_M.

$$T_{11}^{e} = \frac{\sqrt{3}}{2\Sigma_0}\frac{4}{3}[\tau(1+\tau)]^{1/2}G_M(G_C+\frac{1}{3}\tau G_Q)tan\frac{\theta_e}{2}$$

Extracting G_M from T_{11}^{e}: [4]

- At low Q^2, T_{11}^{e} is dominated by the product $G_M G_C$.
- G_C is known very well in this region.[5]

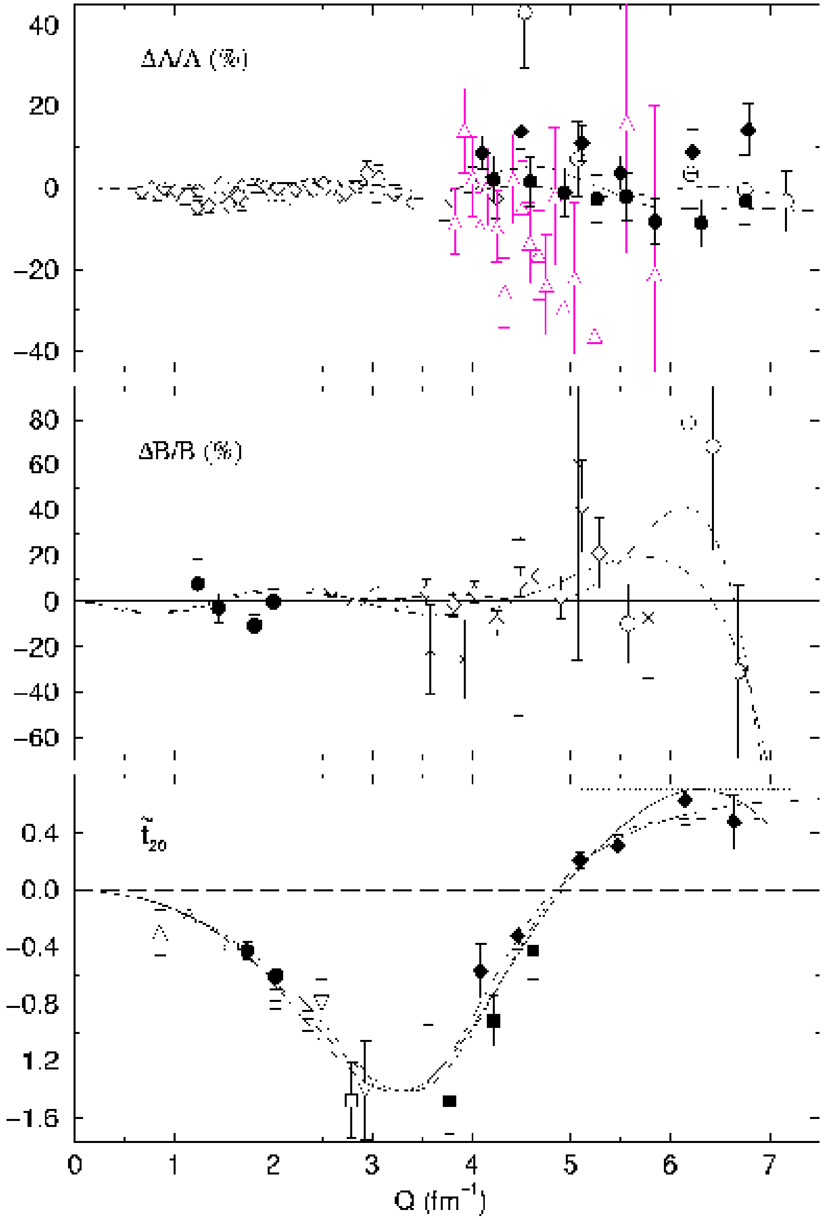
With the above and our measurement of T_{11}^{e} we can provide a check on the value of G_M in the region ($Q^2 < 0.35\ (GeV/c)^2$).

[3] Zilu Zhou, Ph.D. Thesis, University of Wisconsin, (1996)

[4] John Calarco and the BLAST Collaboration MIT-Bates Proposal (2001)

[5] D. Abbott *et al.*, Eur. Phys. J. **A7**, 421 (2000).

What is going on with $\Delta B / B$ at low Q?



D. Abbott et al, Eur Phys. J A7, 421 (2000)