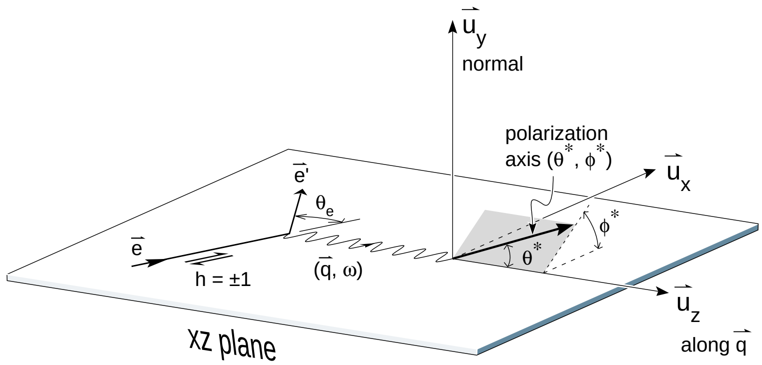
# Preliminary Results from the 1998 Run of E93–026

Donal Day

December 8, 2000

## Experimental technique for $\vec{D}(\vec{e}, \mathrm{e'n})\mathrm{p}$




Cross section:

$$\sigma = \Sigma + h\Delta\,;\;\; h = \pm 1$$

Asymmetry

$$A = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{\Delta}{\Sigma}$$

$\Sigma$ is the elastic unpolarized $e - n$ cross section

$$\Sigma = \sigma_m \frac{E'}{E_0}\left(\frac{(G_E^n)^2 + \tau\,(G_M^n)}{(1+\tau)} + 2\tau\,(G_M^n)^2 \tan^2\left(\frac{\Theta_e}{2}\right)\right)$$

$\Delta$ depends on direction of target polarization : $\Theta^\star$ , $\Phi^\star$

$$\Delta \;=\; -2\sigma_m \frac{E'}{E_0}\sqrt{\frac{\tau}{1+\tau}}\tan\left(\frac{\Theta_e}{2}\right) \left\{\sqrt{\tau\left(1+(1+\tau)\tan^2\left(\frac{\Theta_e}{2}\right)\right)}\cos\Theta^\star\,(G_M^n)^2 + \sin\Theta^\star\cos\Phi^\star G_E^n G_M^n\right\}$$

Neutron Asymmetry for $\Theta^\star = \pi/2$ and $\phi^\star = 0$

$$A_n = \frac{-2\sqrt{\tau(1+\tau)}\tan\left(\Theta_e/2\right) G_E^n G_M^n}{\left(G_E^n\right)^2 + \tau\left(1 + 2\left(1+\tau\right)\tan^2\left(\Theta_e/2\right)\right)\left(G_M^n\right)^2}$$

Deuteron asymmetry $A_{ed}^V = \gamma A_n$

$\gamma = 0.92$ : correction factor for the D-state of the deuteron

Experimental asymmetries:

$$\varepsilon = \frac{N^\uparrow - N^\downarrow}{N^\uparrow + N^\downarrow} = P_B \cdot P_T \cdot f \cdot A_{ed}^V$$

If only life were so simple!

$f$ accounts for the materials other than polarized deuterons in the target.

- The deuteron is, after all, a nucleus and the reaction mechanism is not completely described by PWIA. We must consider the dependence on the reaction mechanism, and the NN potential responsible for the binding.
- Electron interacts with a quasifree nucleon, not a free one, and is ejected over a range of angles which depend its initial momentum and the detector acceptances.
- The experimental asymmetry is distributed over a range in $E'$, $\theta_e$, $\phi^\star$ and $\theta^\star$, $\theta_{nq} \mapsto \theta_{np}^{\rm cm}$.

Solution: Arenhövel's calculations on a grid over $E'$, $\theta_e$, $\phi^\star$ and $\theta^\star$, combined with a monte carlo that averages the theoretical asymmetries over the detector acceptances.

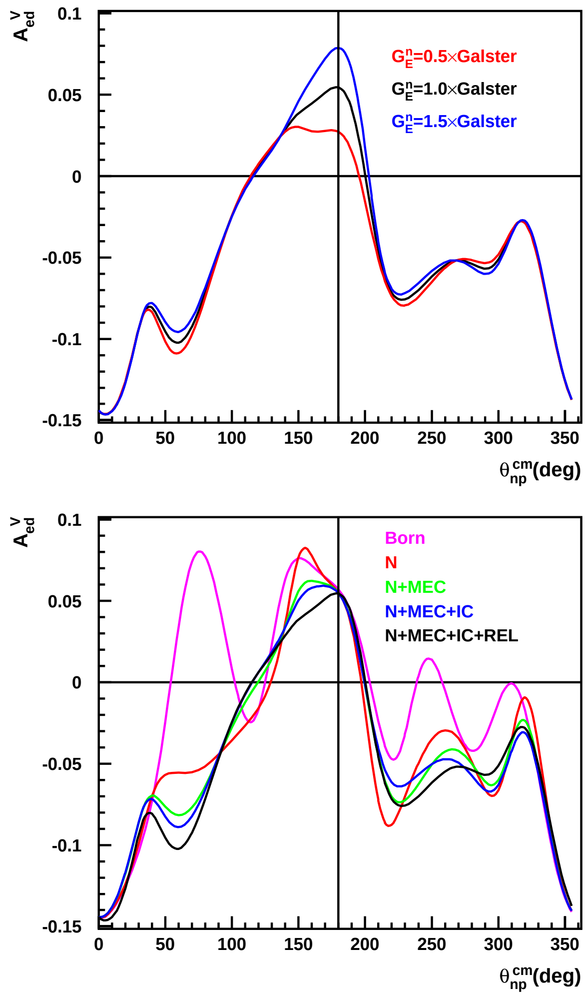



Figure 1: E=2.721 GeV, E'=2.460 GeV, $\Theta_e$=15.8 deg. $\Theta_{np}^{cm}$: Angle between $\vec{q}$ and relative n-p momentum in cm system. 180 deg corresponds to neutron in direction of $\vec{q}$.

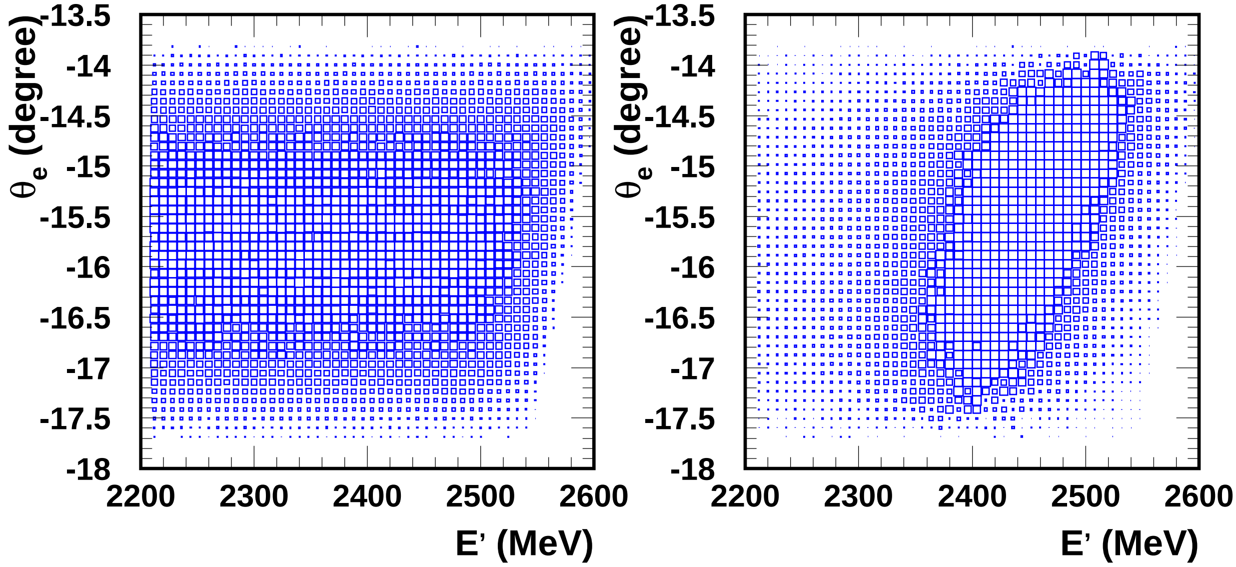



Figure 2: Final electron energy and $\theta_e$ distributions from Monte Carlo for quasielastic electron deuteron scattering in E93-026 kinematics. Cross section weighted on right.

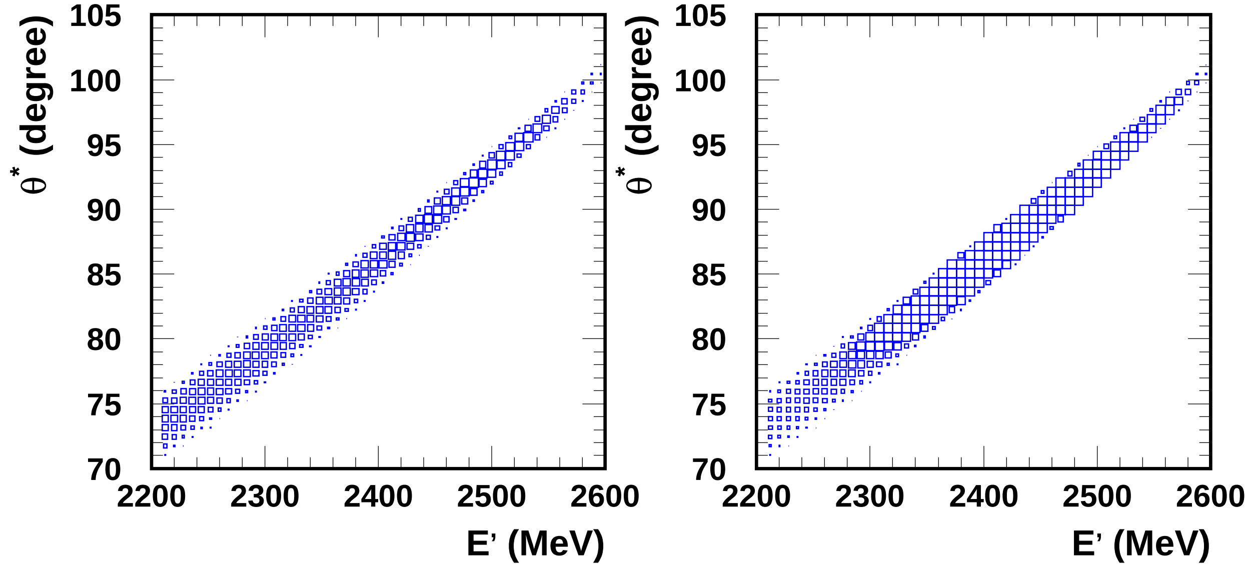



Figure 3: Final electron energy and $\theta^{\star}$ distributions from Monte Carlo quasielastic electron deuteron scattering in E93-026 kinematics. Cross section weighted on right.

Download the files

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Aved_tht_ep.pdf and Aved_thtcm_tht_e.pdf
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from the same directory. The first is a plot of $A_v^{ed}$ against $\theta_{cm}^{np}$ and $e'$ at a fixed value of $\theta_e$. The second is $A_v^{ed}$ against $\theta_{cm}^{np}$ and $\theta_e$ at a fixed value of $e'$.

$f$ accounts for the materials other than polarized deuterons in the target.

$$f = \frac{n_D \sigma_D}{(1-\eta_p) n_D \sigma_D + \eta_p n_D \sigma_p + (1-\eta_N) n_N \sigma_{15} + \eta_N n_N \sigma_{14} + \sum_i n_i \sigma_i}.$$

Solution: Monte Carlo and experimental data .

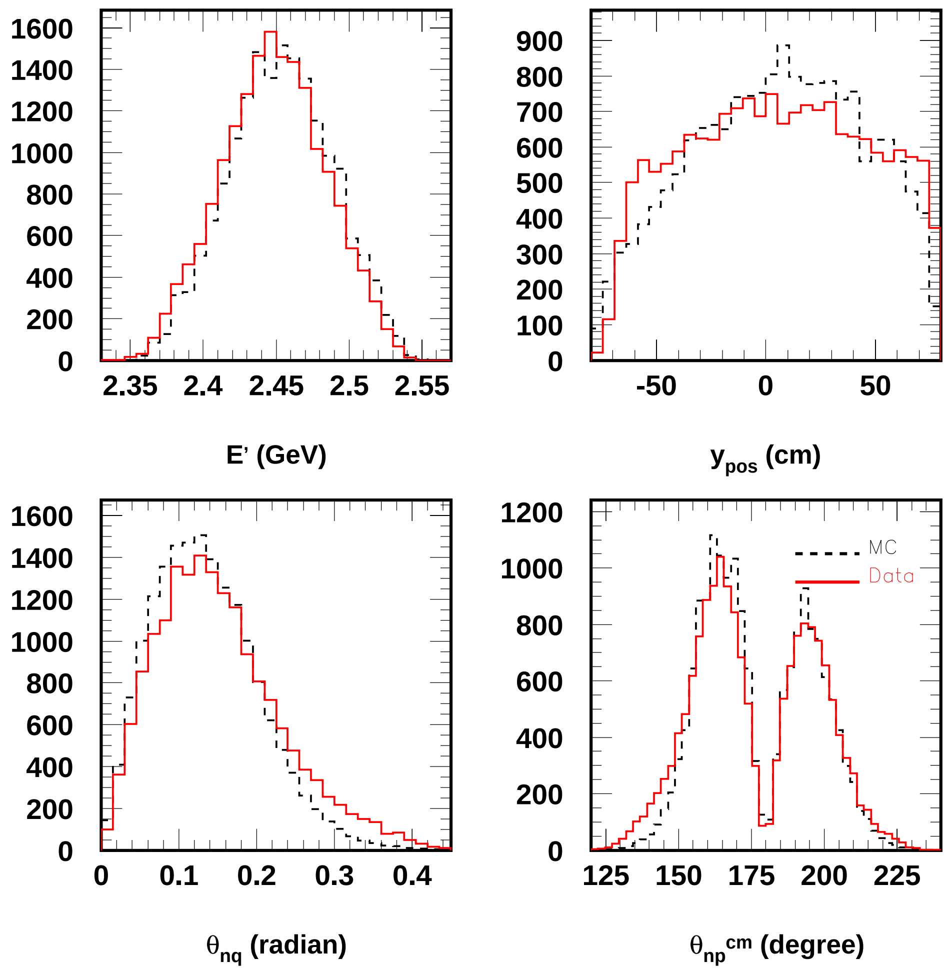



Figure 4: Comparison between data and simulation for $(e, e', n)$ from carbon. Target field, radiative effects included and W cut applied.

The polarized beam and target electron deuteron cross section can be expressed in the form:

$$S(h, P_1^d, P_2^d) = S_0 \Big[ 1 + hA_e + P_1^d A_d^V + P_2^d A_d^T + h(P_1^d A_{ed}^V + P_2^d A_{ed}^T) \Big],$$

where $A_e$, $A_d^V$, $A_d^T$, $A_{ed}^V$, $A_{ed}^T$ are electron asymmetry, vector and tensor target asymmetries, and electron-deuteron vector and tensor asymmetries.

$$A_e = \frac{1}{2hS_0}\left[S(h,0,0) - S(-h,0,0)\right],$$
$$A_d^V = \frac{1}{2P_1^d S_0}\left[S(0,P_1^d,P_2^d) - S(0,-P_1^d,P_2^d)\right],$$
$$A_d^T = \frac{1}{2P_2^d S_0}\left[S(0,P_1^d,P_2^d) - S(0,-P_1^d,P_2^d) - 2S_0\right],$$
$$A_{ed}^{V,T} = \frac{1}{4hP_{1/2}^d S_0}\Big\{\left[S(h,P_1^d,P_2^d) - S(-h,P_1^d,P_2^d)\right] \mp \left[S(h,-P_1^d,P_2^d) - S(-h,-P_1^d,P_2^d)\right]\Big\}.$$

Note that $S_0$ is in the denominator and we never measure $S_0$.

$$S(+h) + S(-h) \neq S_0$$

.

$$\varepsilon = \frac{(L_+ - R_+) - (L_- - R_-)}{(L_+ + R_+) + (L_- + R_-)}.$$

$$L_+ = \Phi_+ n_D S(h, P_1^d, P_2^d)$$
$$L_- = \Phi_- n_D S(h, -P_1^d, P_2^d)$$
$$R_+ = \Phi_+ n_D S(-h, P_1^d, P_2^d)$$
$$R_- = \Phi_- n_D S(-h, -P_1^d, P_2^d)$$

$$\varepsilon = \frac{h\left[(1-\beta)A_e + (1+\alpha\beta)P_1^d A_{ed}^V + (1-\beta\gamma)P_2^d A_{ed}^T\right]}{(1+\beta) + (1-\alpha\beta)P_1^d A_d^V + (1+\beta\gamma)P_2^d A_d^T},$$

$$\alpha = -\tfrac{P_{1-}}{P_{1+}}$$

$$\beta = \tfrac{\Phi_-}{\Phi_+}$$
$$\gamma = \tfrac{P_2(P_{1-})}{P_2(P_{1+})}$$
$$P_2^d = 2 - \left[4 - 3(P_1^d)^2\right]^{1/2}$$

$$A_{ed}^V = \frac{1}{h(1+\alpha\beta)P_1^d}\left\{\varepsilon\left[(1+\beta) + (1-\alpha\beta)P_1^d A_d^V + (1+\beta\gamma)P_2^d A_d^T\right] - h\left[(1-\beta)A_e + (1-\beta\gamma)P_2^d A_{ed}^T\right]\right\}.$$

With full $\phi$ acceptance $A_e$, $A_d^V$ and $A_{ed}^T$ have zero contributions. $A_d^T$ remains. For $P_1^d = 20\%$, $P_2^d \simeq 3\%$

with $A_d^T \approx 10^{-2} A_d^T$ can be ignored

$$A_{ed}^V = \frac{\varepsilon(1+\beta)}{h(1+\alpha\beta)P_1^d}.$$

With the dilution factor

$$A_{ed}^{V} = \frac{\varepsilon(1+\beta)}{h(1+\alpha\beta)P_1^d f}.$$

# ANALYSIS

- Event Reconstruction
  - HMS standard reconstruction + target magnet + raster
  - NDET tracking: Particle Identification

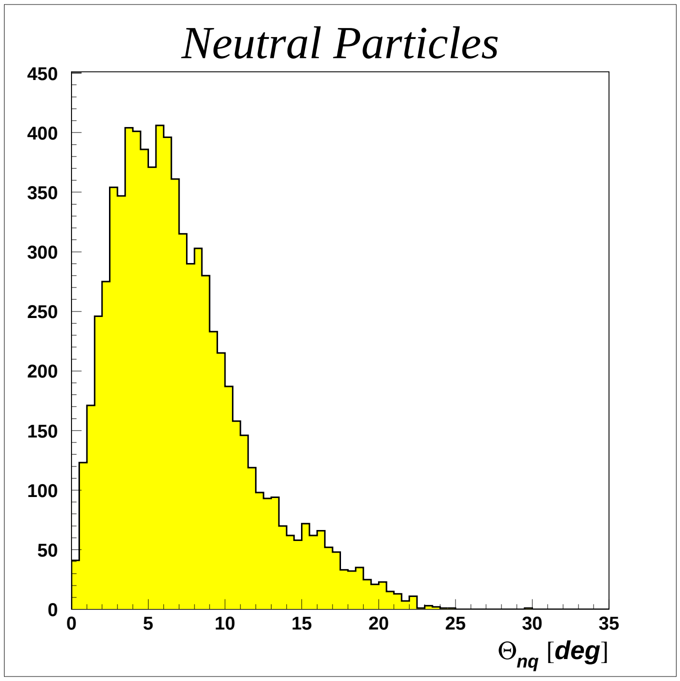
⇒variables: $w$, $Ypos$, $cointime$, $\theta_{nq}$

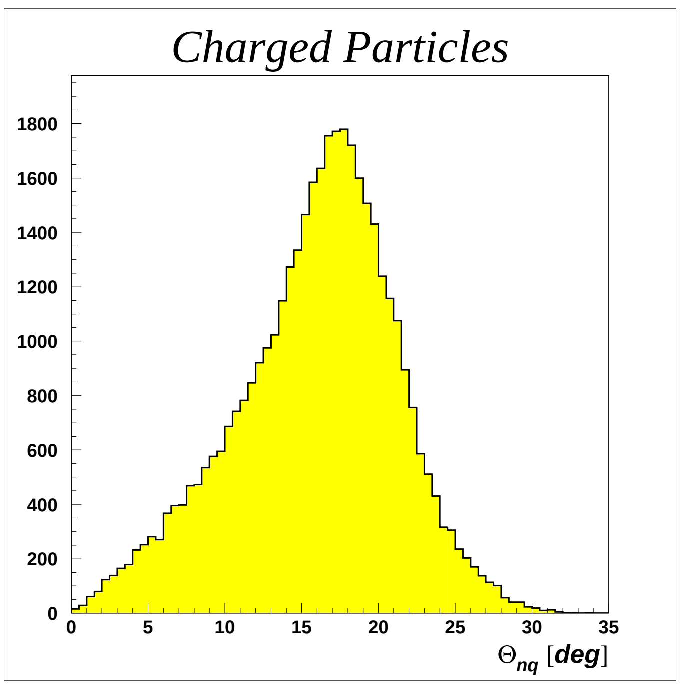
- Event Selection and Normalization
  → Normalized yields: $N^{\uparrow}$, $N^{\downarrow}$
- Experimental asymmetries:
  $\varepsilon = \frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}} = P_B \cdot P_T \cdot f \cdot A_{ed}^V$
  - Beam Polarization $P_B$ from moller polarimetry, $\simeq 77\%$
  - Target polarization $P_T$: average: 22%
  - Dilution factor $f = \frac{N_{polarized}}{N}$ from $^{12}C$ data and MC
- Radiative corrections, Accidental background subtraction

⇒ measured deuteron asymmetry $A_{ed}^V$

- Theoretical calculations of $A_{ed}^V$ (for different $G_E^n$ models) from Arenhövel for a kinematical grid
- Average theoretical $A_{ed}^V$ over experimental acceptance using MC and compare with measured $A_{ed}^V$

⇒ $G_E^n$

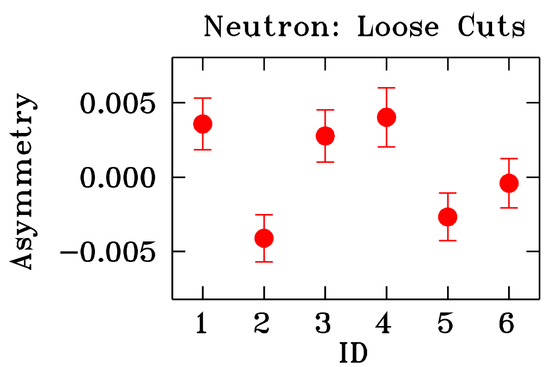

Neutral Particles
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
Θnq [deg]

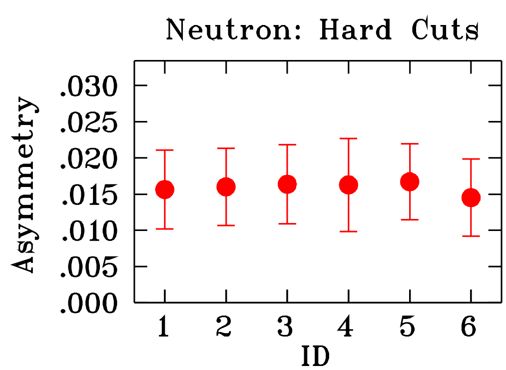

Charged Particles
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
Θnq [deg]

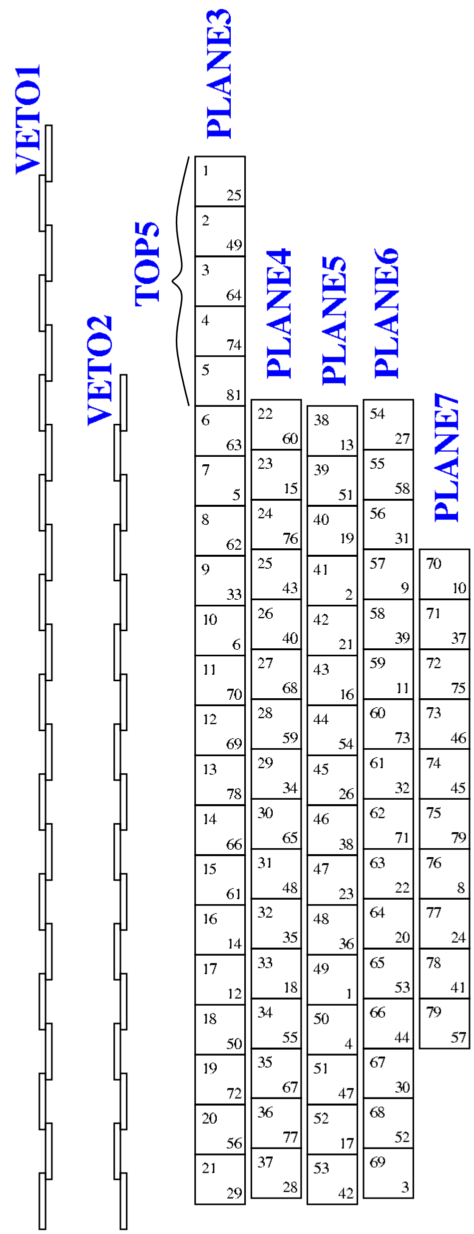
# NEUTRON IDENTIFICATION

**Definitions:**

**ID1 = Analyzer Neutron**
**ID2 = (!VETO1) && (!VETO2)**
**ID3 = ID2 && (!TOP5)**
**ID4 = ID2 && (!PLANE3)**
**ID5 = (!VETO1) && (!TOP5)**
**ID6 = (!VETO2) && (!TOP5)**



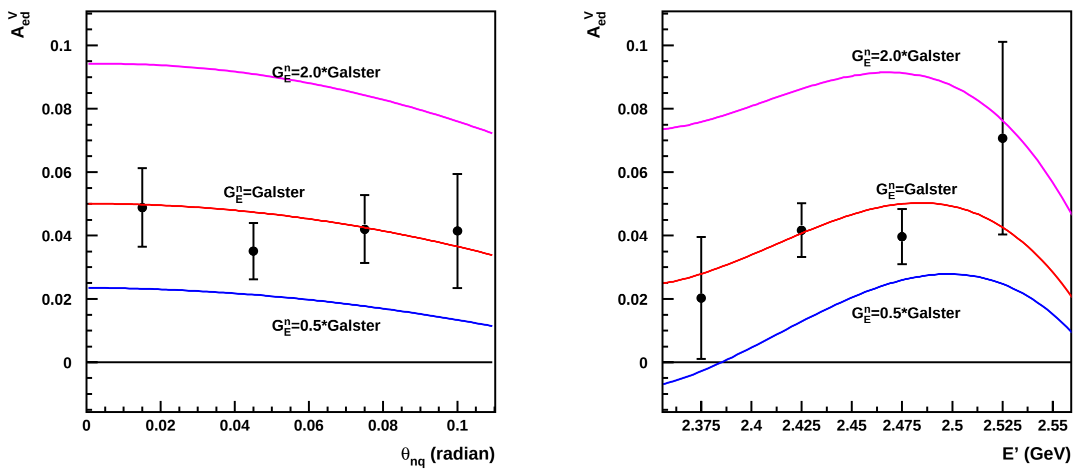



Figure 5: Right figure: $E'$: Energy of the scattered electron. Left figure: $\theta_{nq}$: Angle between 3-momentum transfer $\vec{q}$ and hadron track

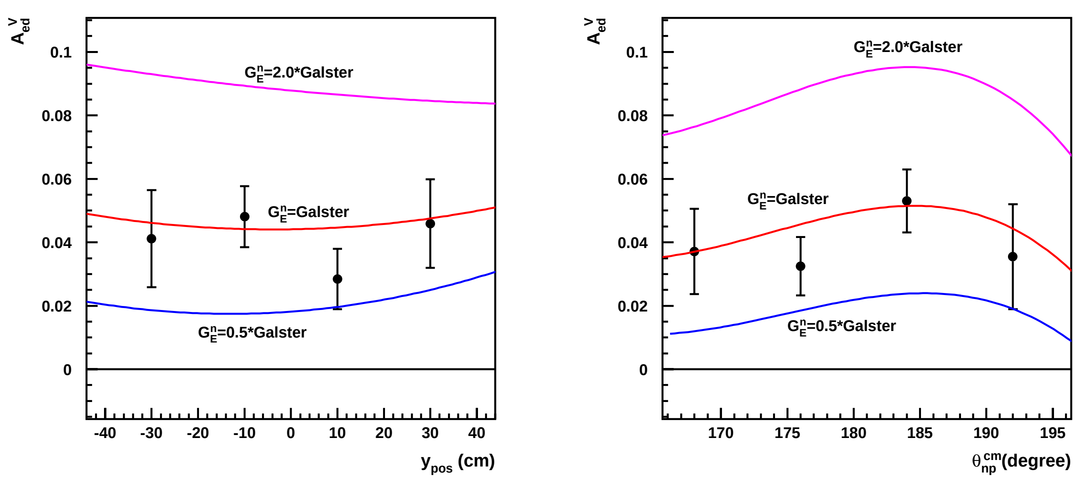
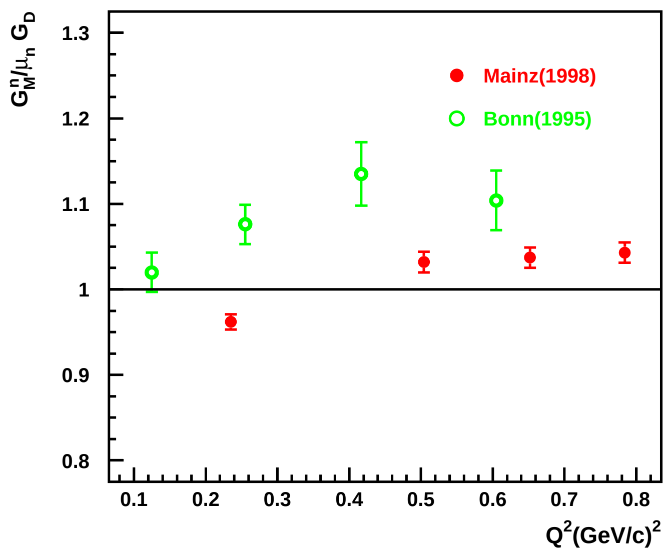



Figure 6: Left Figure: $Y_{pos}$: Horizontal coordinate of the hadron track in the neutron detector. Right Figure: $\theta^{cm}_{np}$: Angle between 3-momentum transfer $\vec{q}$ and relative n-p momentum in the cm system (180 deg corresponds to neutron in direction of $vecq$ )

# Impact of $G_M^n$

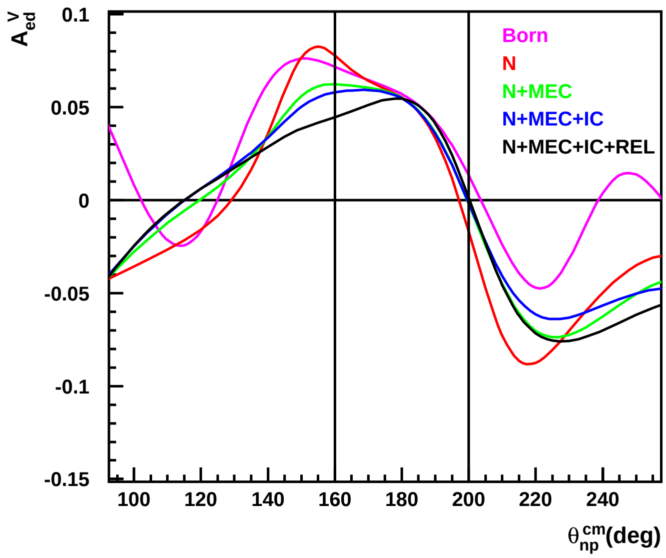



Difference between $G_M^n = \mu_n G_D$ and

$G_M^n$ Mainz: 3%

$G_M^n$ Bonn: 10%

# Reaction Mechanism Dependence

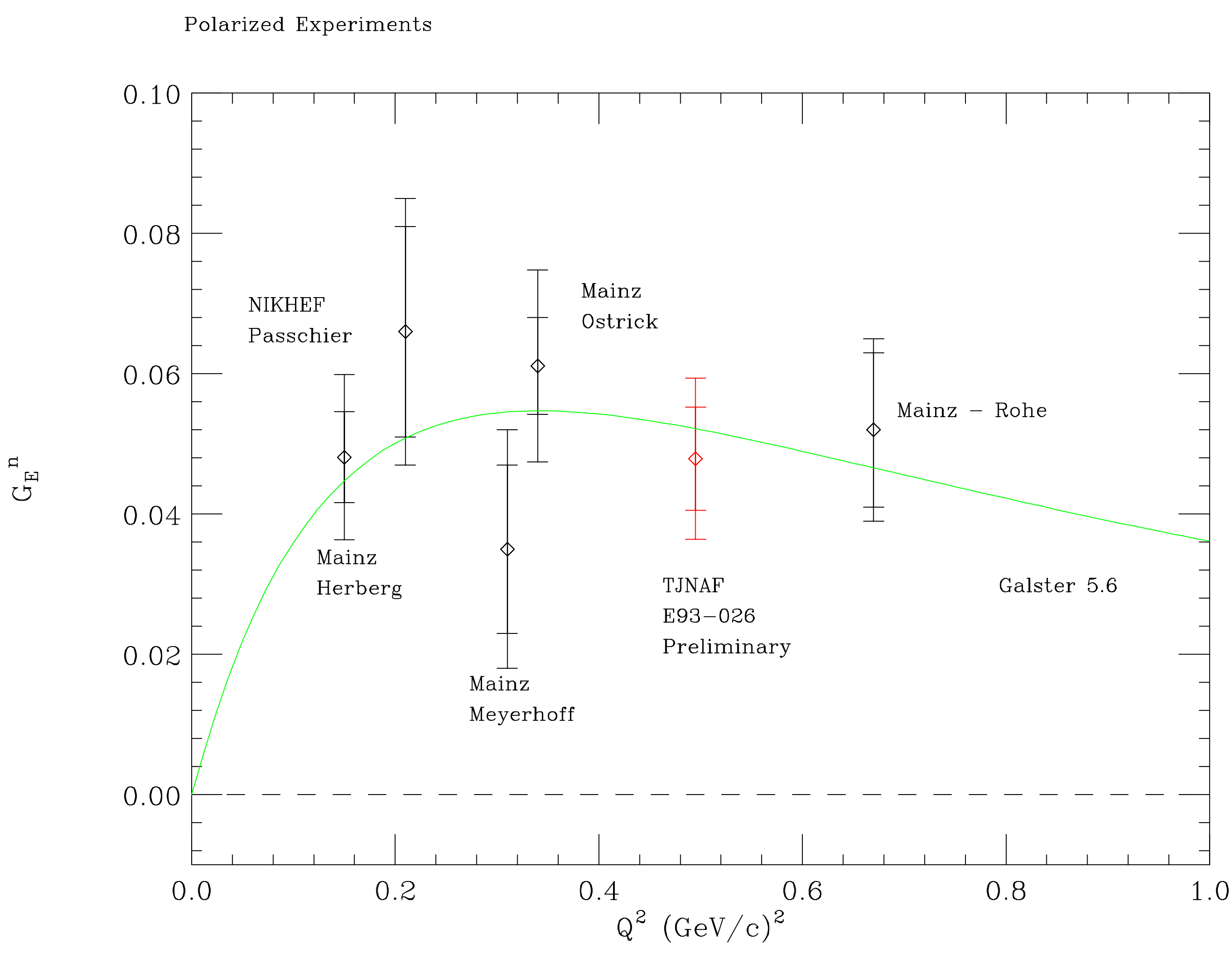



Experimental acceptance: $160\,\mathrm{deg} < \theta_{np}^{cm} < 180\,\mathrm{deg}$

Difference between full Calculation and

Born: 14%

Born + REL: $\simeq$8%



Polarized Experiments
0.10
0.08
0.06
0.04
0.02
0.00
0.0
0.2
0.4
0.6
0.8
1.0
Q^2 (GeV/c)^2
G_E^n
NIKHEF
Passchier
Mainz
Ostrick
Mainz - Rohe
Mainz
Herberg
Mainz
Meyerhoff
TJNAF
E93-026
Preliminary
Galster 5.6

# RESULTS

Preliminary result for $Q^2 = 0.5\,(GeV/c)^2$ :

$$G_E^n = 0.04788 \pm 0.00737_{stat} \pm 0.00378_{syst}$$

Systematics:

| Source | Contribution | status |
|---|---|---|
| $G_M^n$ | 3.3% | $\surd$ |
| Beam Polarization | 1.1% | $\surd$ |
| Target Polarization | 5.3% | $\surd$ |
| Dilution factor | 5% | $\surd$ |
| Radiative Corrections | 1.0% | $\surd$ |
| $A_{ed}^V$ averaging | 0.4% | $\surd$ |
| Kinematic Uncertainties | 1.9% | $\surd$ |
| NDet position offset | 1.4% | $\surd$ |
| Total $(\Delta G_E^n/G_E^n)_{syst}$ | 7.9% | $\surd$ |