THE PHASES OF G_E AND G_M

STEPHEN ROCK

e^+e^- Workshop
May 2, 2000

- **SPACE-LIKE**
- **TIME-LIKE**
- **POLARIMETRY**

Reference: A. Z. Dubnickova, S. Dubnicka and M. Rekalo
ll Nuovo Cimento 109 (1996) 241

SPACE-LIKE

$G_E(Q^2)$ **and** $G_M(Q^2)$ **ARE REAL**
Due to Hermiticity and C-Invariance

UNPOLARIZED $eP \to eP$

$$\mathbf{d\sigma/d\Omega \propto \frac{(G_E^2 + \tau G_M^2)}{1+\tau} + 2\tau G_M^2 \sin^2(\theta/2)}$$

ONLY ABSOLUTE VALUES OF FORM FACTORS

POLARIZED $eP \to eP$

- **POLARIZED BEAM AND TARGET**

♠ **TARGET POLARIZATION** $\perp$ q **VECTOR IN SCATTERING PLANE:**

$$\mathbf{A_\perp = -P_e P_t \frac{\sqrt{2\tau(1-\epsilon)}G_E G_M}{\epsilon G_E^2 + \tau G_M^2}}$$

♠ **TARGET POLARIZATION** $\parallel$ **TO** q **VECTOR:**

$$\mathbf{A_\parallel = -P_e P_t \frac{\sqrt{1-\epsilon^2}\tau G_M^2}{\epsilon G_E^2 + \tau G_M^2}}$$

$$\mathbf{\frac{G_E}{G_M} = \sqrt{\frac{\tau(1+\epsilon)}{2\epsilon}} \frac{A_\perp}{A_\parallel}}$$

- **POLARIZED BEAM AND POLARIZATION OF RECOIL**

♠ **RECOIL POLARIZATION $\perp$ TO q VECTOR IN SCATTERING PLANE:**

$$P_x = -P_e \frac{\sqrt{2\tau(1-\epsilon)} G_E G_M}{\epsilon G_E^2 + \tau G_M^2}$$

♠ **RECOIL POLARIZATION $\parallel$ TO q VECTOR:**

$$P_z = P_e \frac{\sqrt{1-\epsilon^2}\tau G_M^2}{\epsilon G_E^2 + \tau G_M^2}$$

$$\frac{G_E}{G_M} = -\sqrt{\frac{\tau(1+\epsilon)}{2\epsilon}} \frac{P_x}{P_z}$$

TIME-LIKE

$G_E(s)$ and $G_M(s)$ ARE COMPLEX Due to Unitarity

MEASURE $|G_E|, |G_M|$, PHASE DIFFERENCE

- **UNPOLARIZED $e^+e^- \rightarrow N\bar{N}$**

♠ **CROSS SECTION**

$$d\sigma/d\Omega = \frac{\alpha^2\sqrt{1-4M^2/x}}{4s}[|G_E|^2\sin^2(\theta)/\tau + |G_M|^2(1+\cos^2\theta)]$$

MEASURE $|G_E|$ and $|G_M|$

WITH ROSENBLUTH SEPARATION

♠ **RECOIL POLARIZATION ⊥ to SCATTERING PLANE**

$$P_y = -\frac{\sin(2\theta)\mathrm{Im}[G_E G_M^*]/\sqrt{\tau}}{|G_E|^2\sin^2(\theta)/\tau + |G_M|^2(1+\cos^2\theta)}$$

⇒ **MEASURE PHASE DIFFERENCE**

⇒ **MEASURE AT ALL SCATTERING ANGLES SIMULTANEOUSLY**

• **LONGITUDINALLY POLARIZED $e^+e^- \rightarrow N\bar{N}$**

♠ **ONE LEPTON POLARIZED**

♠ **RECOIL POLARIZATION $\parallel$ to BARYON**

$$\mathbf{P_z} = -\mathbf{P_e} \frac{\mathbf{2}\cos(\theta)|\mathbf{G_M}|^\mathbf{2}}{|\mathbf{G_E}|^\mathbf{2}\sin^\mathbf{2}(\theta)/\tau + |\mathbf{G_M}|^\mathbf{2}(\mathbf{1}+\cos^\mathbf{2}\theta)}$$

♠ **RECOIL POLARIZATION $\perp$ to BARYON in SCATTERING PLANE**

$$\mathbf{P_x} = -\mathbf{P_e} \frac{\mathbf{2}\sin(\theta)\mathbf{Re}[\mathbf{G_E}\mathbf{G_M^*}]/\sqrt{\tau}}{|\mathbf{G_E}|^\mathbf{2}\sin^\mathbf{2}(\theta)/\tau + |\mathbf{G_M}|^\mathbf{2}(\mathbf{1}+\cos^\mathbf{2}\theta)}$$

PREDICTIONS FOR G_E AND G_M

THRESHOLD

- $N\bar{N}$ **ARE IN L=0** (G_s) **OR 2** (G_d)
- $\mathbf{G_M = G_s - G_d}$
- $\mathbf{G_E = \frac{\sqrt{s}}{2M} G_s + 2G_d}$
- **AT THRESHOLD** $\mathbf{G_d = 0}$

♠ $\mathbf{G_M(4M^2) = G_E(4M^2)}$

♠ $\mathbf{Im[G_E G_M^*] = 0 \Rightarrow P_y = 0}$

VMD MODEL

- **RAPID VARIATION OF PHASE WITH ENERGY**

♠ **Dubnicka, Dubnickova, Strizenec**

♠ **Dubnicka, Dubnicova, Strizenec**

MEASURING POLARIZATION

- **PRECESSION IN MAGNETIC FIELD**
- **SCATTER RECOIL NUCLEON AND MEASURE ANGLE**

  ♠ **CARBON SCATTERER USED TO 2.2 GeV (JLAB)**

$$\mathbf{N}(\theta', \phi') = \mathbf{N_o}(\mathbf{1} + \mathbf{P} \times \mathbf{A_{eff}} \sin \mathbf{\Phi}')$$

  ♠ A_{eff} **is EFFECTIVE ANALYZING POWER**

  ♠ Φ' **is SECOND SCATTERING ANGLE**

  ♠ **AXIS TO GET** P_y **DEPENDS ON PRECESSION**

- **CAN WE USE SCATTERING IN MULTILAYED SHOWER COUNTER?**
- **DO WE HAVE THE RATES?**

ERRORS

- **200** $N\bar{N}$**/day**
- **Assume Analyzing Power at JLAB**

  ♠**CARBON SCATTERER:**
  UP TO 0.5 METERS

  ♠**0.5 at 230 MeV**

  ♠**0.1 at "few GeV"**

  ♠**Probability of Scattering** P_s **= 0.01 to 0.1**

  ♠$A\sqrt{P_s} \sim 0.07$

  ♠**NUMBER OF SCATTERED PROTONS**
  $N_s = P_s N$
- $\delta P \sim 1/(A\sqrt{N_s})$
- **FOR** $\delta P = 0.1 \Rightarrow \sim 100$ **days.**
- **FOR** Λ **USE SELF ANALYZING**

CONCLUSIONS

- G_M **AND** G_E **COMPLEX FORM FACTORS**
- **NUCLEONS ARE POLARIZED FOR UN-POLARIZED BEAM**
- **MODELS PREDICT RAPID VARIATION OF PHASE NEAR THRESHOLD**
- **CAN WE BUILD THE POLARIMETER?**