

SIZE AND SHAPE OF PROTON

NUCLEON ELASTIC FORM FACTOR

FOR THE PROTON ONE CAN DO SCATTERING EXPERIMENTS



AND MEASURE $\frac{d\sigma}{d\Omega}$ AS A FUNCTION

OF q^2 . THEN DIRECTLY MEASURE
THE FORM FACTOR

HOWEVER, BOTH ELECTRONS (THE PROBE)

AND NUCLEONS (THE TARGET) HAVE SPIN
AND ONE HAS TO GENERALIZE
THE MOTT CROSS SECTION

IN ADDITION TO HAVING

CHARGE DENSITY DISTRIBUTION

SINCE THE PROTON HAS SPIN, WE EXPECT
MAGNETIC MOMENT DISTRIBUTION

\Rightarrow TWO FORM FACTORS

SPIN $\frac{1}{2}$ PROTON HAS TWO FORM FACTORS

$$\frac{d\sigma}{dQ^2} = \left(\frac{d\sigma}{dQ^2} \right)_{MOTT} \left[\frac{G_E^2 + b G_M^2}{1+b} + 2b \frac{G_N^2 \tan^2 \theta}{2} \right]$$

$G \equiv G(q^2)$

$-q^2/2m_N^2$

THIS IS THE ROSENBLUTH CROSS SECTION
IT IS THE ONE WHICH IS ACTUALLY
RELEVANT TO PROBING STRUCTURE OF
PROTONS AND NEUTRONS

THE ELECTRIC FORM FACTOR IS

$$G_E(q^2=0) = \frac{Q}{e} \quad \begin{matrix} \leftarrow \\ \text{ELECTRON} \\ \text{CHARGE} \end{matrix}$$

$$G_E(0) \text{ PROTON} = 1$$

$$G_E(0) \text{ NEUTRON} = 0$$

THE MAGNETIC FORM FACTOR IS

$$G_M(q^2=0) = \frac{\mu}{\mu_N} \quad \begin{matrix} \leftarrow \\ \text{NUCLEAR} \\ \text{MAGNETON} \end{matrix}$$

$$G_M(q^2=0) \text{ PROTON} = 2.79$$

$$G_M(q^2=0) \text{ NEUTRON} = -1.91$$

HOFSTADTER 1955

 $e\bar{p} \rightarrow e\bar{p}$

188 MeV

PROTON
STRUCTURE

MAGNETIC
SCATTERING

TEST OF
COULOMB
POTENTIAL
DOWN TO

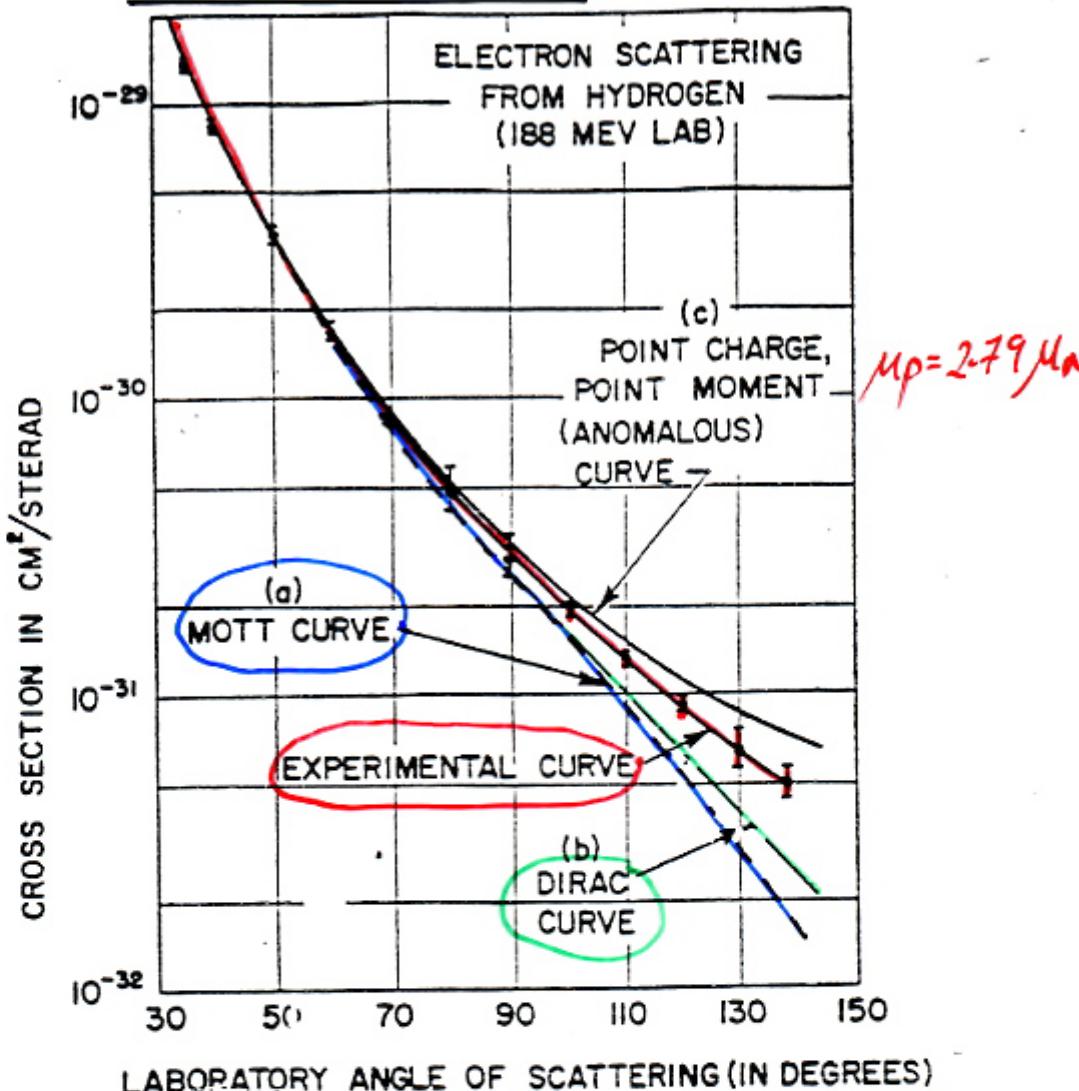
 $7 \times 10^{-14} \text{ cm.}$


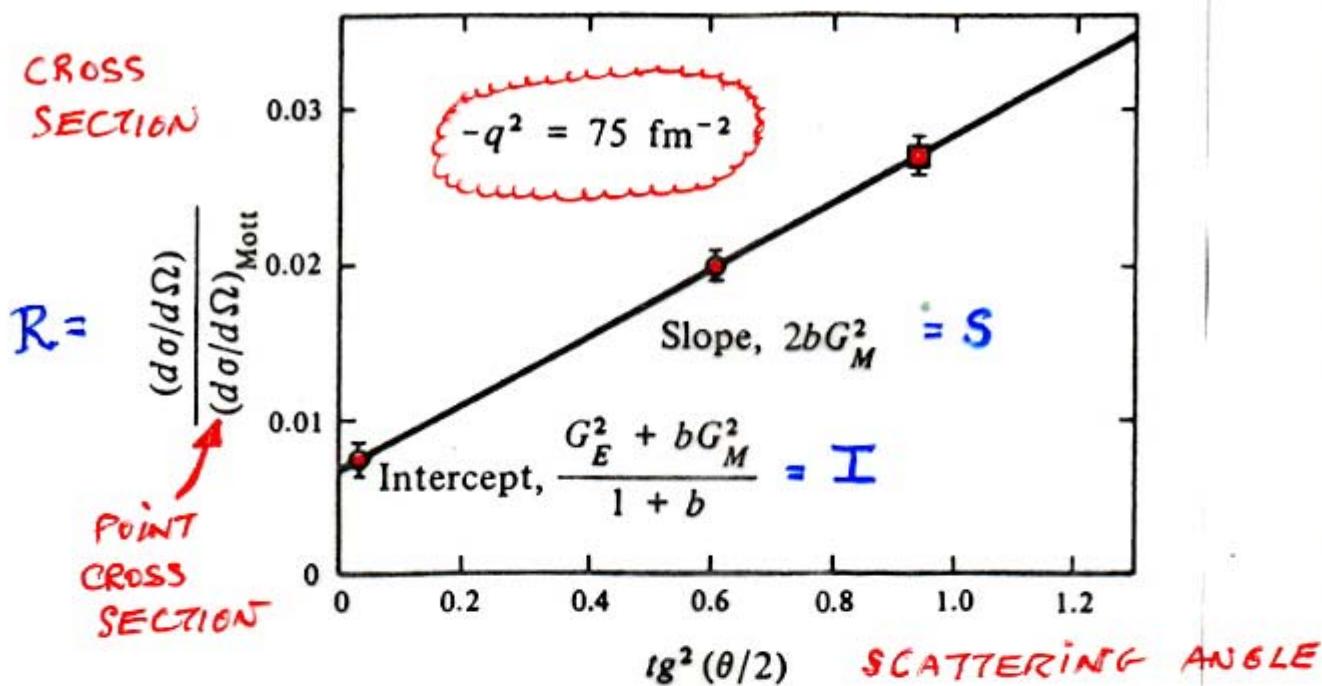
FIG. 5. Curve (a) shows the theoretical Mott curve for a spinless point proton. Curve (b) shows the theoretical curve for a point proton with the Dirac magnetic moment, curve (c) the theoretical curve for a point proton having the anomalous contribution in addition to the Dirac value of magnetic moment. The theoretical curves (b) and (c) are due to Rosenbluth.⁸ The experimental curve falls between curves (b) and (c). This deviation from the theoretical curves represents the effect of a form factor for the proton and indicates structure within the proton, or alternatively, a breakdown of the Coulomb law. The best fit indicates a size of $0.70 \times 10^{-13} \text{ cm.}$

LARGE SCATTERING ANGLE



LARGE MOMENTUM TRANSFER

EXTRACTION OF FORM FACTOR FROM EXPERIMENT



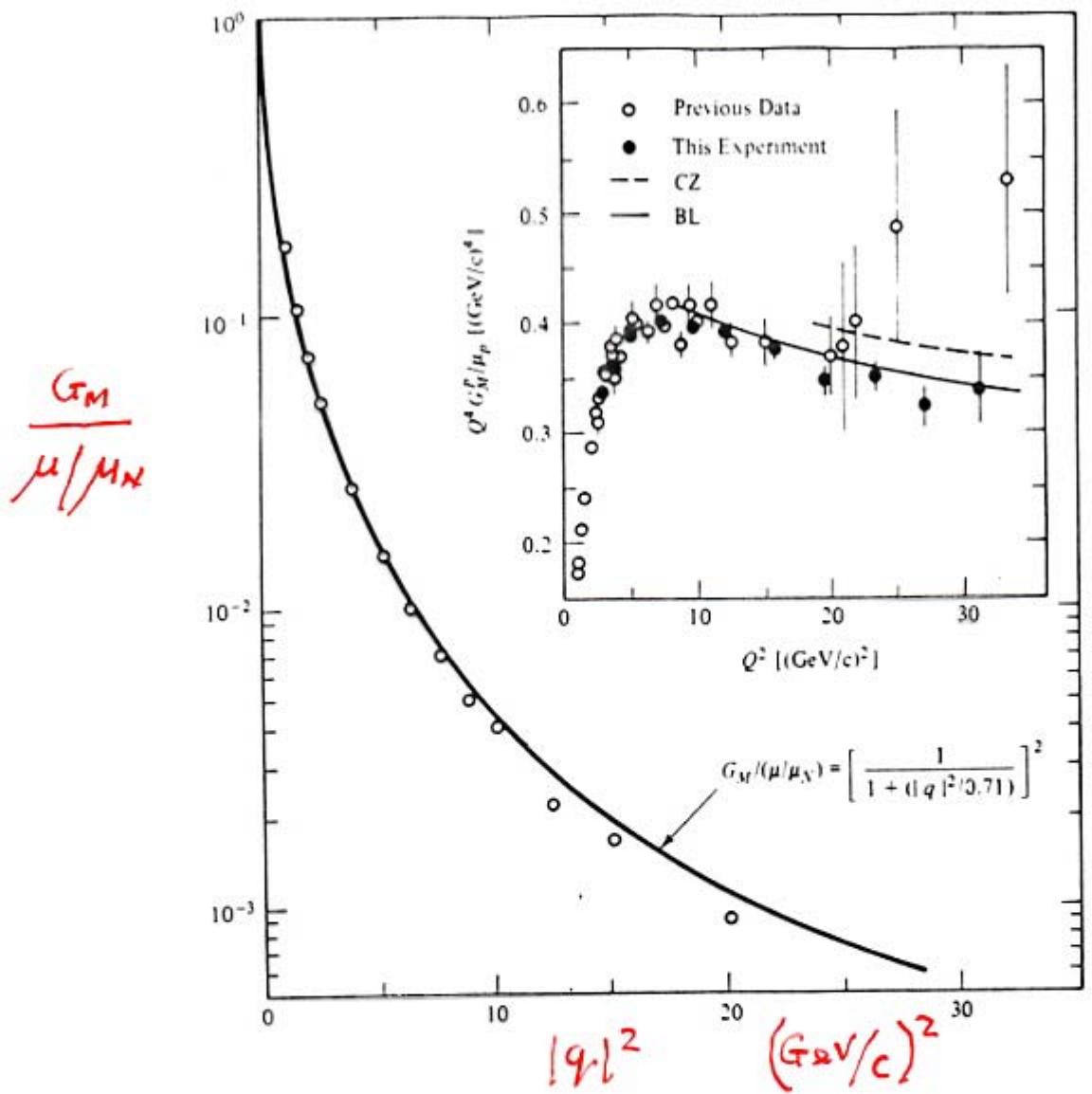
FOR EACH q^2 MEASURE

$$R = I + S \tan^2 \frac{\theta}{2}$$

ONE COULD VARY q^2 BY VARYING
THE INCIDENT BEAM MOMENTUM

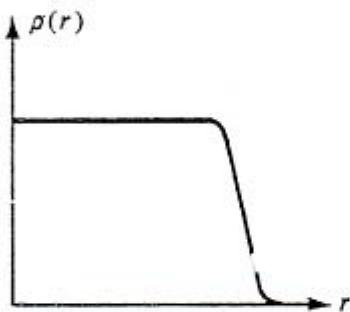
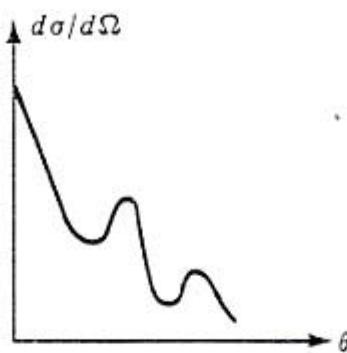
OR THE RECOIL MOMENTUM

AND SCANNING IN ANGLE θ

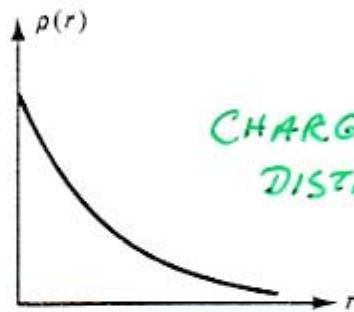
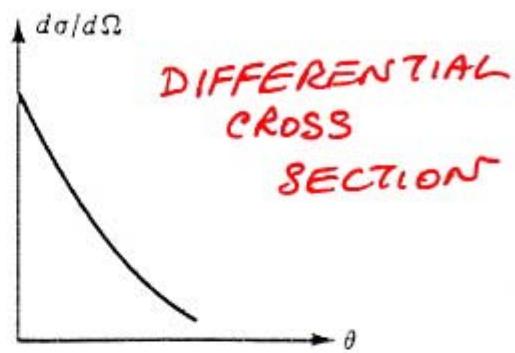


THE "MAGNETIC DIPOLE" DENSITY
 ALSO EXHIBITS A DIFFUSE FORM

NOTICE DIFFERENCE BETWEEN NUCLEI
AND THE PROTON



NUCLEI



NUCLEONS
PROTON

NUCLEI HAVE A RELATIVELY SHARP SURFACE
→ HENCE DIFFRACTION LIKE DIFFERENTIAL
CROSS SECTION

PROTONS HAVE A MUCH MORE DIFFUSE
CHARGE DISTRIBUTION

THE QUESTION (FOR "DEEP INELASTIC"
SCATTERING) IS HOW THIS DIFFUSE
CHARGE IS DISTRIBUTION IN SMALL
INTERVALS OF SPACE TIME