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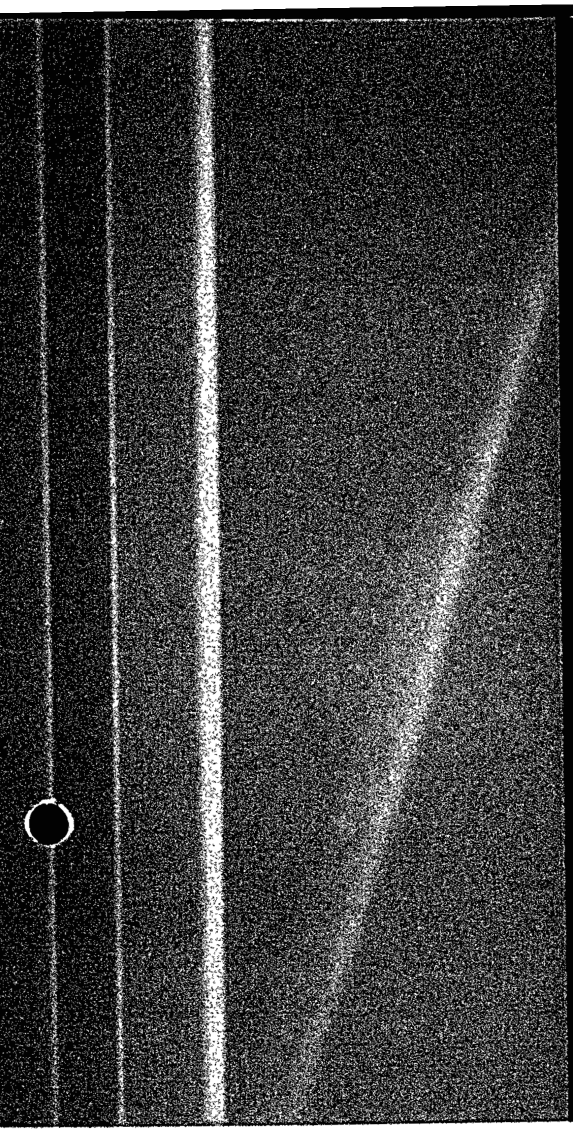

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DOES THE ROSENBLUTH FORMULA BREAK DOWN?

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Does the Rosenbluth formula break down?

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In their recently published paper Hofstadter et al.1) point out that combining their data for the electron-proton scattering at a scattering angle of 145° and an electron energy of 975 MeV with Cornell data2) at 112° and 1050 MeV a small inconsistency has possibly been uncovered. This conjecture has been corroborated by Cornell results3) at 145° and an energy of 1120 MeV which gave a scattering cross section about 2,5 times larger than what one would expect from an extrapolation of the form factors determined at lower energies.

At the Aix-en-Provence Conference on Elementary Particles (September 1961) it has been discussed whether these results imply a breakdown of the Rosenbluth formula or whether a more or less sudden change of the form factors at high q-values could explain the large cross sections at 145°. It was the general opinion that one of these two possibilities could only be singled out by measurements at energies above 1200 MeV. It is the purpose of this note, however, to show that the presently known results are in principle sufficient to prove a breakdown of the Rosenbluth formula for $q > 30$ fermi^{-1}.

In order to test the Rosenbluth formula it is convenient to write it in the following form

$$R = \frac{d\sigma/d\Omega}{\sigma_{NS}} = \frac{1}{1+t}\,(G_E^2 + tG_M^2) + 2tG_M^2 \tan^2\theta/2.$$

G_E and G_M are the electric and magnetic form factors introduced by Sachs et al.4) and $t = (\hbar q/2Mc)^2$. The other notation is standard.

Plotting R as a function of $\tan^2\theta/2$ one obtains a straight line if the formula is correct. However, it can be shown that not all straight lines drawn through experimental points are compatible with the formula. It is easy to prove that the slope α of a straight line drawn through a particular point R_a at $\tan^2\theta/2 = a$ is restricted to values

$$0 \leq \tan\alpha \leq R_a \left[a + \frac{1}{2(1+t)}\right]^{-1}$$

This implies in particular that $\tan\alpha$ cannot exceed a certain maximum value which is realized if $G_E^2 = 0$.

In the enclosed figure the experimental values of R are displayed for three values of the recoil momentum q. The broken lines indicate the largest slope compatible with the experimental points at 90° or 112°, respectively. Only points below this broken line are in agreement with the Rosenbluth formula. The measurements for $q^2 = 24{,}8\ f^{-2}$ are represented by the full line which is well below the limiting line. For $q^2 = 30\ f^{-2}$ a slight discrepancy appears and for $q^2 = 37\ f^{-2}$ the highest point is far above the line compatible with the point at 112°.

If there are no systematic errors in the experiments (and this cannot yet be excluded definitely) this consideration strongly indicates that the Rosenbluth formula breaks down for $q^2 > 30\ f^{-2}$ at backward angles.

The Rosenbluth formula has been derived on the assumption of one photon exchange between electron and nucleon (Born approximation). A breakdown of this formula suggests therefore that this approximation is not valid any longer. Drell and Ruderman(5) and Drell and Fubini(6) estimated the contribution of the two photon exchange and found that it is $\lesssim 1\%$ for energies below 1 GeV. However, in these calculations the nucleon was treated non-relativistically and it was assumed that the Compton cross section for a virtual photon is the same as that for a real one if the frequencies are the same. In view of the new experimental results a more rigorous calculation of these effects would be desirable.

Qualitatively it is plausible at least that deviations show up first at large angles as the scattering cross section drops off rapidly with increasing angle whereas the higher correction terms do not depend strongly on the angle. Hence their relative contribution becomes larger at backward angles.

1) Bumiller, Croissiaux, Dally and Hofstadter, Phys. Rev. 124, 1623, 1961

2) Olson, Schopper and Wilson, Phys. Rev. Lett. 6, 286, 1961

3) Littauer, Schopper and Wilson, Phys. Rev. Lett. 7, 141 and 144, 1961
Wilson, Aix-en-Provence Conference on Elementary Particles, September 1961

4) Ernst, Sachs and Wali, Phys. Rev. 119, 1105, 1960

5) Drell and Ruderman, Phys. Rev. 106, 561, 1957

6) Drell and Fubini, Phys. Rev. 113, 741, 1959

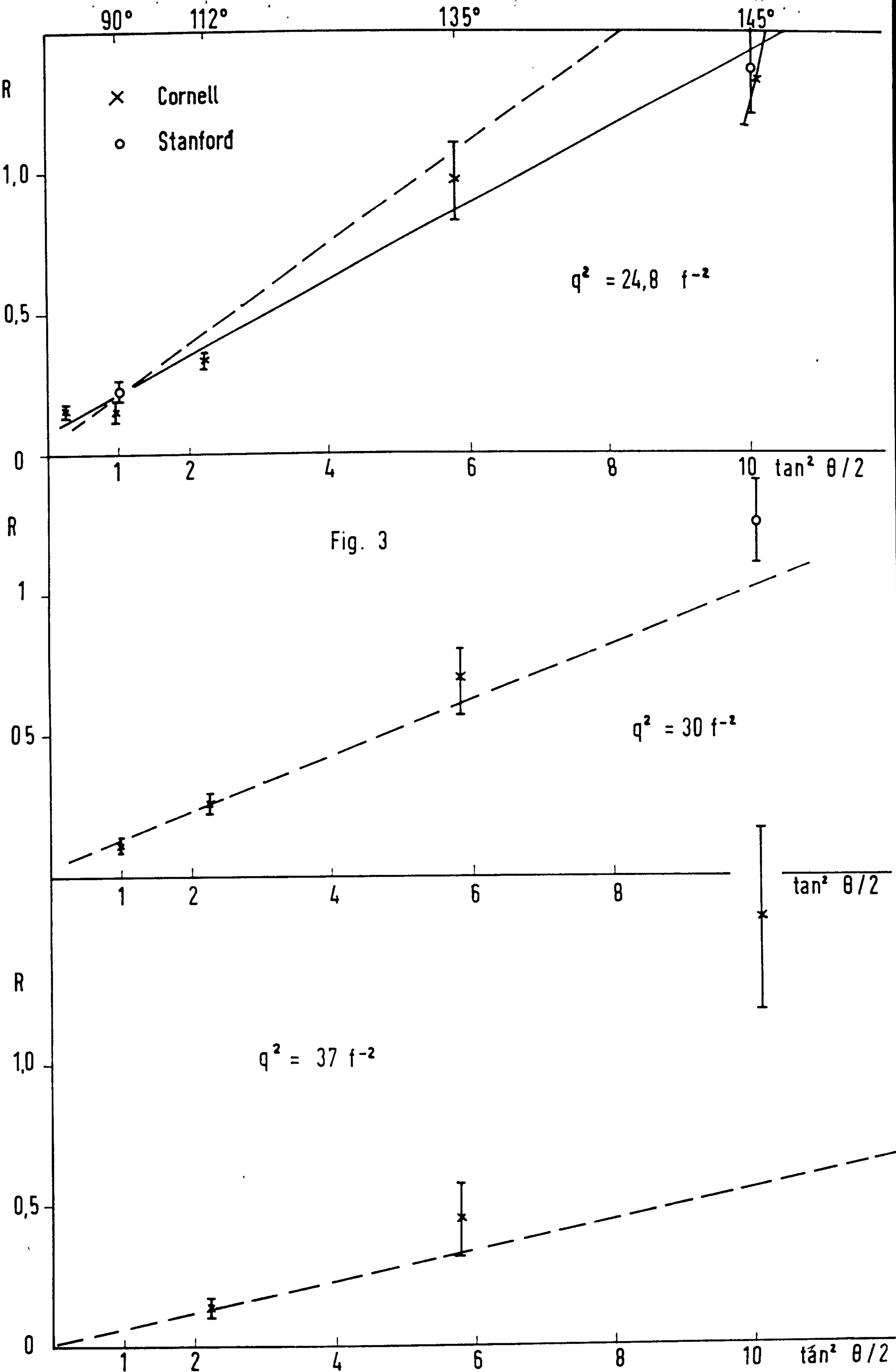
90°
112°
135°
145°
R
× Cornell
o Stanford
1,0
0,5
0
$q^2 = 24,8\ f^{-2}$
1
2
4
6
8
10
tan² θ/2
R
1
0,5
$q^2 = 30\ f^{-2}$
1
2
4
6
8
tan² θ/2
R
$q^2 = 37\ f^{-2}$
1,0
0,5
0
1
2
4
6
8
10
tan² θ/2

Fig. 3