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ON A POSSIBLE STRUCTURE IN THE PROTON ELASTIC FORM FACTOR.

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ABSTRACT :

We investigate in the proton form factor the possibility to have a zero in the space-like region. As a consequence the e-p differential cross-section would have a dip and a second maximum which are accessible to experiment. If the existence of such structure would be revealed it would be very important for understanding the composite nature of the proton.

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The large q^2 behaviour of the form factors of hadrons has been reexamined recently in gauge theories [1] but none of these interesting considerations envisage the possibility of having a zero before reaching the asymptotic q^2 -region. As it is well known, the proton form factor data up to $q^2 = 33\ \mathrm{GeV}^2$ [2], exhibits a remarkable smoothness in a log-log plot. Nevertheless in the picture where the proton is assumed to be made of quarks, which may have a structure, it is plausible to expect a diffraction minimum in the elastic e-p cross section. In nuclear physics there are many such examples for elastic electron scattering on heavy and light nuclei [3] and one observes that the position of the diffraction minimum occurs at larger q^2 values for few nucleon systems. The presence of these structures is indeed related to the degree of compositeness of the nuclei and plays an essential role for a better understanding of nuclear density. Clearly the hadronic forces, which remain to be understood, are different from the nuclear forces, but without paying attention to any specific theory we would like to speculate on a possible structure in e-p elastic scattering.

Our main concern will be now to see whether the existing proton form factor data [2] can be described in terms of a function $F(q^2)$ which has the required analytic properties and which has a zero for a large-spacelike value of q^2 (*). Instead of taking simply inverse of polynomials, we propose to use the modified Bessel function of zeroth order $K_0\left(a\sqrt{q^2+\mu^2}\right)$ which has, for large q^2, the fastest allowed decrease by analyticity (**) [6]. Actually we have fitted

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(x) In Ref.[4] it has been suggested that a zero may exist in the pion form factor for space-like values.

(**) Let us notice that a Bessel function expansion for the form factor was used in Ref.[5].

the data with the following expression

$$\sum_{i=1}^{3} c_i \, K_0 \left(a_i \sqrt{q^2 + m_i^2} \right)$$

by imposing an additionnal constraint, namely that the solution should vanish for q^2 around 40–50 GeV^2. The following set of parameters provides an excellent fit (i.e. a χ^2 per point of order 1)

$$c_1 = 1.334 \quad c_2 = 0.512 \quad c_3 = -0.497$$

$$a_1 = 1.933 GeV^{-1} \quad a_2 = 0.399 GeV^{-1} \quad a_3 = 0.396 GeV^{-1}$$

$$m_1 = 0.166 GeV \quad m_2 = 0.098 GeV \quad m_3 = 0.029 GeV$$

Here we only give average values which correspond to the position of the zero at $q^2 = 45$ GeV^2. If the zero is slightly displaced, these values are a little different such that one has a range for the parameters corresponding to the same chisquared. We show in Fig.1 a comparison of the data with the result of our fit and the dramatic behaviour for $q^2 > 50$ GeV^2. As a result the e-p elastic cross section exhibits a diffraction minimum around $q^2 = 50$ GeV^2. In Fig.2 we have represented the expected differential cross section at $E_{lab} = 280$ GeV, as a function of q^2 and we see that, at the second maximum around $q^2 = 70$ GeV, the cross section is high enough to be detected experimentally. If such a structure does exist, although we don't know yet what precise feature of the hadron constituents it should be attributed to, it will be of very important value for any realistic description of the proton wave function. It is interesting to examine the Fourier transform of this form factor which gives $\rho(r)$ the change density of the proton. As expected the special large q^2 behavior of $F(q^2)$ reflects a depression of $\rho(r)$ near the origin as shown in Fig.3.

In conclusion we feel that the study of electromagnetic form factors of hadrons at large q^2 values, remains a powerful tool in determining the underlying dynamics of bound states of a small number of quarks. Indeed we urge experimentalists to search for diffraction minima in electron-hadron elastic scattering, although we do not have yet strong physical arguments to support this idea.

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- FIGURE CAPTIONS -

FIG. 1 Comparison of our fit with a compilation of the data taken from M.D. Mestayer in Ref. [2]. The shaded area corresponds to the incertainty of the solution at large q^2.

FIG. 2 The expected e-p elastic differential cross section at E_{lab} = 280 GeV as a function of q^2. The shaded area corresponds to the incertainty of the solution at large q^2.

FIG. 3 The charge density of the proton plotted as a function of r . The shaded area corresponds to the incertainty of the solution at small values of r .

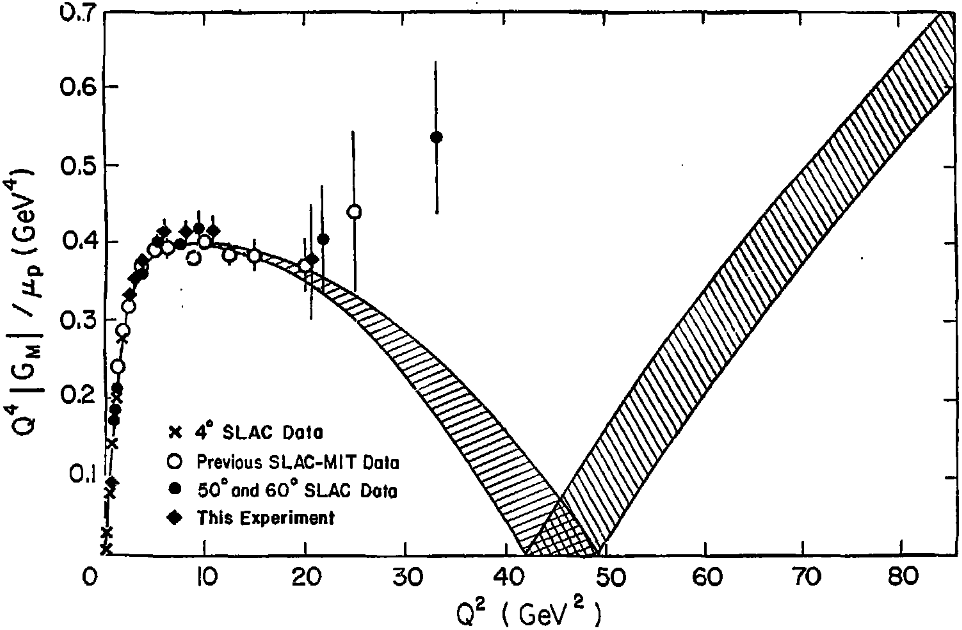
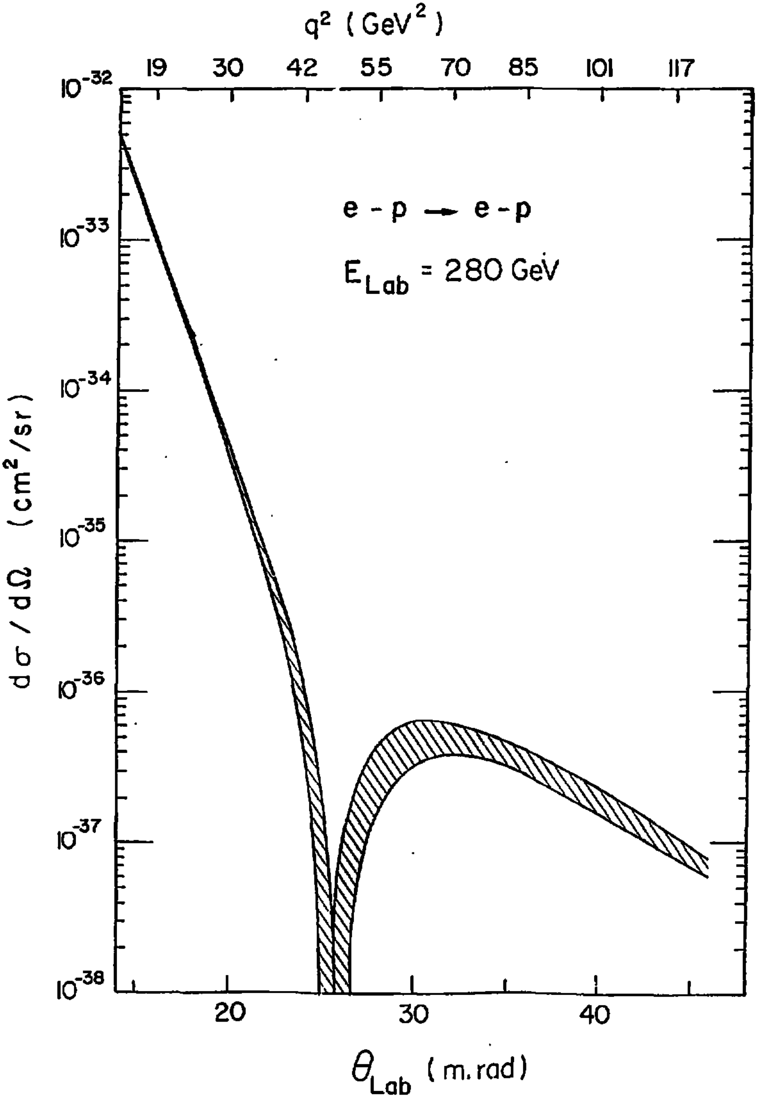

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
70
80
$Q^4 |G_M| / \mu_p$ (GeV^4)
Q^2 (GeV^2)
4° SLAC Data
Previous SLAC-MIT Data
50° and 60° SLAC Data
This Experiment

FIG. 1



q² (GeV²)
19
30
42
55
70
85
101
117
10^-32
10^-33
10^-34
10^-35
10^-36
10^-37
10^-38
e - p → e - p
E_Lab = 280 GeV
dσ / dΩ (cm²/sr)
20
30
40
θ_Lab (m. rad)

FIG. 2

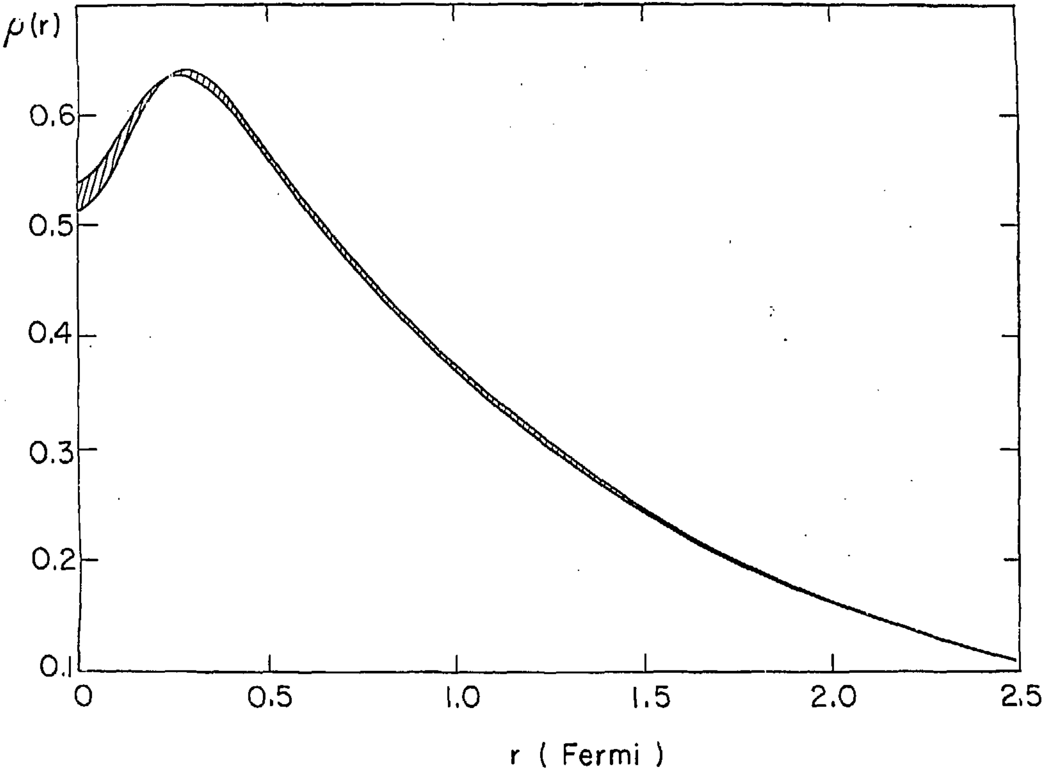


FIG. 3