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p-p AND e-p ELASTIC SCATTERING AT LARGE MOMENTUM TRANSFERS

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In the past few years there has been considerable speculation about the proton structure as revealed in elastic proton-proton and electron-proton scattering at high energies and large momentum transfers [1,2]. Many attempts have also been made to link qualitatively the p-p and e-p scattering data [1,2]. The connection proceeds, as suggested by Wu and Yang [1], by relating asymptotically the p-p differential cross section $d\sigma/dt$ and the fourth power of the electromagnetic form factor $G_{Mp}(t)$. The results were not very convincing, in the high momentum transfer region, particularly because of the uncertainty in choosing the function which would represent the p-p data [3].

Recently [4] we have given the following formula for the elastic p-p differential cross section:

$$\frac{d\sigma}{dt} = \frac{A}{p^4} \exp(-\sqrt{s}/T)\{\exp(-\sqrt{t}/T) + \exp(-\sqrt{u}/T)\} \qquad (1)$$

where p is the proton momentum in C. M. S., A and T are two constants.

The formula (1), which is in very good agreement with the experimental data for high values of the momentum transfer t, has been derived from the expression (see ref. 4):

$$d\sigma \propto \int f^2 \exp[S(t)-S(t_0)]\, P_{NB}(t) P_{NB}(t')\delta(t-t')dt dt', \qquad (2)$$

which consists essentially of three factors: $P_{NB}(t)$ and $P_{NB}(t')$, which are defined as the probability that a proton does not break up when the momentum transfer takes the value t or t'; $f \exp[S(t)-S(t_0)]dt$, which represents the thermodynamical probability to realize a final state characterized by a value of the momentum transfer between t and $t+dt$. $S(t)$ is the entropy, an increasing function of t, which grows up with the different channels that are open. $S(t_0)$ is the maximum value of the entropy attained at $t=t_0$.

The factor $\exp[S(t)-S(t_0)]$, which obviously favours processes with high values of t, is the main departure from previous statistical approaches to the elastic p-p scattering.

By taking into account the relations:

$$P_{NB}(t) = P_0 \exp[-S(t)] \qquad (3)$$

and

$$S(t) = \sqrt{t}/T \qquad (4)$$

derived in the previous paper [4], and by symmetrizing according to the identity of the final particles, we obtain the relation (1) from (2).

The s, t and u-dependence of the formula (1) and the agreement with the experimental data for high values of $t(t \gtrsim 8\ (\mathrm{GeV}/c)^2)$, indicates that the relation between the e-p and p-p elastic scattering, cannot be the simple one suggested by Wu and Yang [1] and used by others:

$$d\sigma/dt \sim \text{const} \times G^4_{Mp}(t)\ . \qquad (5)$$

On the other hand the possibility of connecting the p-p to the e-p scattering is very appealing. We propose therefore a different approach, which appears to be in good agreement with the experimental data. This consists simply of identifying asymptotically the square of the electromagnetic form factor $G_{Mp}(t)$ with the probability $P_{NB}(t)$, defined above. In other words, we write for the differential cross section of the electron proton scattering, for high values of t:

$$\frac{d\sigma}{dt}\ \text{e-p} = \frac{d\sigma_B}{dt} P_{NB}(t) \qquad (6)$$

where $d\sigma_B$ is the cross section given by quantum electrodynamics, and $P_{NB}(t)$ is taken from the p-p elastic scattering. This means that, asymptotically, we have:

$$G^2_{Mp}(t) \sim \exp(-\sqrt{t}/T)\ . \qquad (7)$$

This form of $G_{Mp}(t)$ is the same as suggested by Wu and Yang [1], but with a different value of T. In fig. 1 $G^2_{Mp}(t)$ is plotted as a function of $\sqrt{t}$. As can be seen, for $t \gtrsim 8(\mathrm{GeV}/c)^2$, the same region in which the formular (1) is found to be valid in the p-p scattering, the straight line calculated with $T = 0.544$ GeV fits quite well the experimental data. The lower t region is also fitted by a

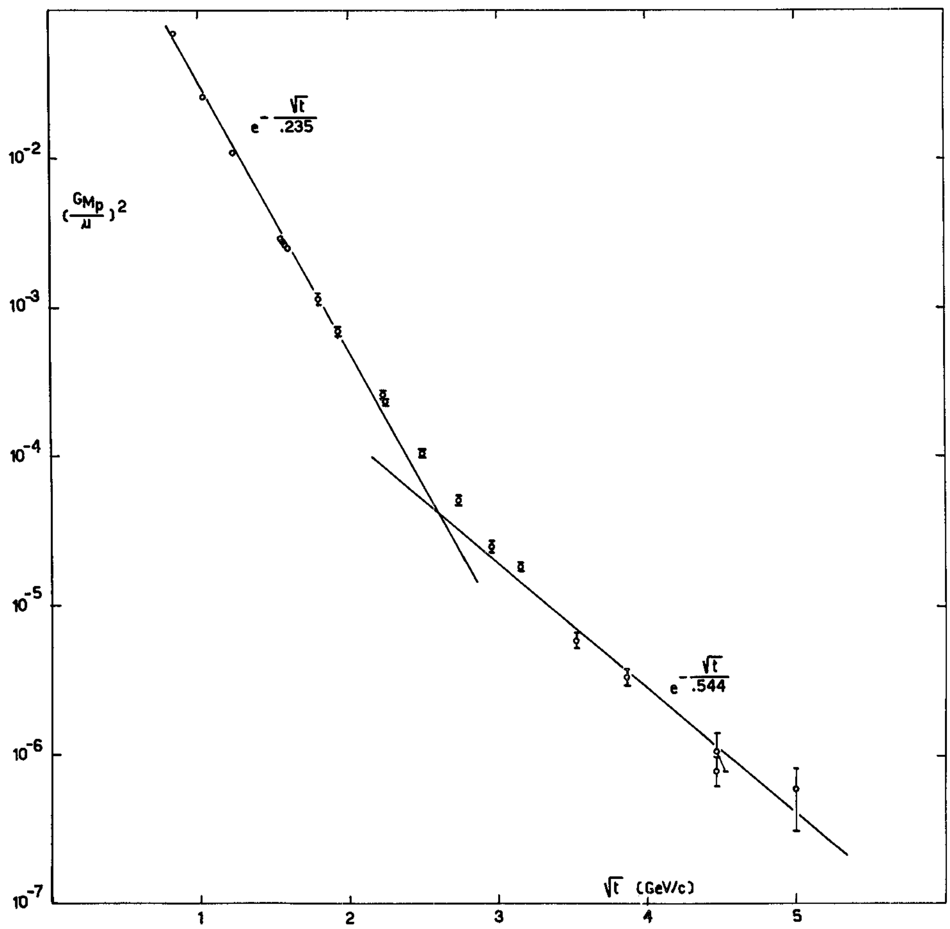

Fig. 1. $[G_{Mp}(t)/\mu]^2$ is plotted against $\sqrt{t}$. $G_{Mp}(t)$ is normalized to $G_{Mp}(0)/\mu = 1$. The experimental points are the SLAC data taken from ref. 3.

straight line with a different slope, $T = 0.235$ GeV.

We have tried therefore to extend the analysis of the previous paper [4] for $t < 8$ $(\mathrm{GeV}/c)^2$.

In fig. 2 we have plotted the experimental data of $(d\sigma/d\Omega)_{C.M.}$ of the p-p elastic scattering, for fixed s, as a function of t. For C.M. scattering angles θ far away from 90°, so that the u-dependence of eq. (1) can be neglected, and for $\sqrt{t}$ lying between about 1.5 and 2.5 (GeV/c), the experimental data can still be fitted by straight lines with a value of T of approximately 0.200-0.250 GeV, to be compared with the above $T = 0.235$. The agreement, therefore, is quite good.

The reason of the change of the slope at $t \approx 7$ $(\mathrm{GeV}/c)^2$ is not clear, and we do not intend to discuss here specific ideas or models. It is worth while, however, to stress that the connection between the electromagnetic and the strong structure of the proton seems to be strongly confirmed by the experimental data. A better understanding of the above phenomena can be achieved in the p-p case, by exploring continuously, at fixed energy, a wide range of values of t, with the same accuracy as previous experiments. On the other hand our conclusions depend on the accuracy of the measurements of $G_{Mp}(t)$, so that it is very important to reduce the size of the present experimental errors on the e-p data, together with a closer spacing of the experimental points. Recently, in fact, a q^{-4} dependence on the momentum transfer q^2, of the form factors, has been theoretically supported by various authors [e.g. 6].

Finally it will be interesting to see if the simple expression (7) for the form factors, will hold also for time-like values of t. To this question only the future high energy storage rings will give a definite answer.

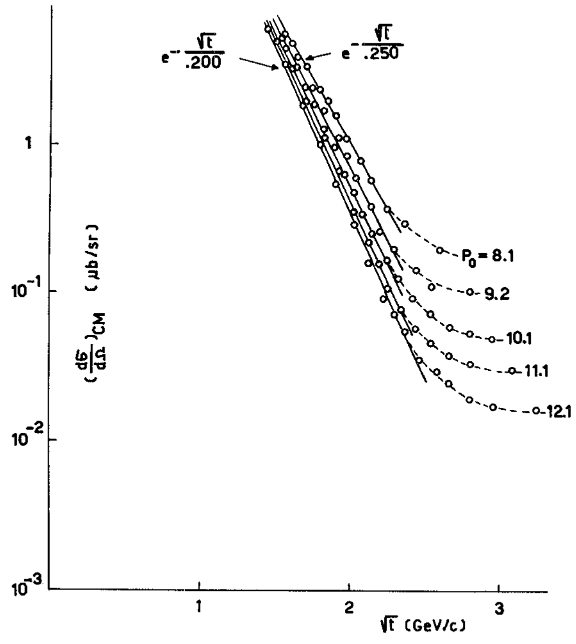

Fig. 2. p-p differential cross reaction $(d\sigma/d\Omega)_{C.M.}$ in units of 10^{-30} cm^2/sr, as a function of $\sqrt{t}$. The experimental points are taken from ref. 5. Dashed lines connect the experimental points with the same value of p_0.

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