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AN EXPERIMENT TO SEARCH FOR THE PRODUCTION OF CHARGE $^1/_3$ e PARTICLES AT THE CERN PROTON SYNCHROTRON

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This note proposes an experiment designed to provide evidence for or against the existence of long lived particles of electric charge $\frac{1}{3}$ e produced in proton-nucleon collisions at 28 Gev.

An elegant new scheme of meson and baryon systematics has been recently presented by M. Gell-Mann[1]. The basic states of the scheme have fractional electric charge $Q = \mp \frac{1}{3}$ e and $\pm \frac{2}{3}$ e and baryon number $\pm\, ^1/_3$. The baryon family is built up from combinations of at least three of these objects (quarks) while mesons are constructed from, at least, a quark-anti-quark pair.

It is expected that if quarks exist, some of them would be stable and that the masses should be greater than the nucleon mass[2]. In these circumstances it is conceivable that observation of quarks could, so far, have been missed, their ionising power being $\frac{1}{9}$ or $\frac{4}{9}$ of other particles and a considerable amount of energy being needed to produce them.

It is therefore desirable that an experiment to search for quarks be performed at the highest energy and with the highest intensities possible.

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A simple and very sensitive method to look for negatively charged quark production in 28 Gev proton - nucleon collisions can rely on the following points.

(1) The apparent momentum of the emitted particles, as measured by a magnetic spectrometer, can be substantially larger than the operating momentum of the accelerator.

(2) The ionising power of the particles is $^1/9$ of minimum.

(3) The time of flight over a 40 - 50 m base line is some nanoseconds longer than that of less massive stable secondaries.

Combination of these points forms a very powerful signature and it is estimated that, provided the quark mass is less than about 2.7 Gev, a minimum detectable production cross section of about 10^{-35} cm^2 can be attained.

The kinematical situation is illustrated in Figure 1, where the minimum and maximum values of the apparent momentum that a quark can have in the laboratory system, $P_{app} = 3\ P_{real}$, is plotted versus the mass M of the quark. Since quarks, Q, can be produced in pairs, the energetically most favourable reaction is $N + N \rightarrow N + N + Q + \bar{Q}$ and the limits of Fig.1 are obtained from this reaction. Other reactions in which more particles are produced presumably fill up the phase space available within the boundary curve of Fig. 1. The best momentum for detecting the quarks is thus $P_{app} = 30 - 40$ Gev/c, conveniently above the $P_0 = 28$ Gev/c of the incoming protons. In this region of momenta, say 30 ± 2 Gev/c, the background produced by ordinary secondaries is in principle zero and the detection of the quarks should be extremely favourable. The most massive quarks that could be produced by the CERN proton synchrotron would have M = 2.75 Gev.

The proposed experimental layout is shown in Figure 2. The $P_{app} = 30$ Gev/c (i.e. $P_{real} = 10$ Gev/c) negative particles emitted at an angle of 40 mr by a target placed in the doughnut of magnet No. 60, are magnetically analysed by two 2m bending magnets that produce an overall deflection of 50 mr. The positioning of the two magnets, one before and one after the shielding wall, helps in decreasing the background, due mostly to μ mesons scattered and produced in the shielding.

The detection system consists of a telescope of thick scintillation counters, $C_1\, C_2\, C_3\, C_4$, capable of detecting particles ten times less ionising than those of charged ones, extending over a length of about 40 m. $C_{1,2,3}$ are used to provide a time of flight measurement and C_4 for a linearly measure of ionisation dE/dx. A time to pulse height converter should be able to measure the time of flight of the particles between C_1 and C_3 within 1 ns. If the mass of the quarks is, e.g., 2.5 Gev, their delay with respect to light over the 40 m base is ~ 4 ns, a readily measurable quantity.

The time of flight and correlated dE/dx signals are conveniently displayed on a 32×32 matrix in a 1000 channel pulse height analyser. With the last counters C_3 , C_4 of 20×20 cm^2 surface located 100 m away from the target ($d\omega = 4\;10^{-6}$ ster, $dP_{app} = 3$ Gev/c) and 10^{11} protons interacting in the target every 5 seconds, a counting rate of one coincidence per hour corresponds to a differential cross section for the production of the quarks $\frac{d\sigma}{d\omega dP_{app}} = 5\;10^{-35}$ cm^2/(ster.Gev/c). Since the forward solid angle of emission of the quarks in the laboratory, limited by an average transverse momentum of a fraction of a Gev/c, can be guessed to be $\Delta\omega \approx 10^{-2}$ ster and their apparent momentum is limited within an interval $\Delta P_{app} \approx 20$ Gev/c, the above differential cross section corresponds to a total cross section for production of quarks of $\sigma_{prod} \approx 2\;10^{-35}$ cm^2. The minimum cross section detectable with the method here proposed is thus about 10^{-35} cm^2.

We estimate that the experiment can be performed in one week of continuous running with at least 50% of the PS beam on the target. A period of two weeks is necessary for preparing and calibrating the detecting system.

As a final comment it must be said that the probability of success of any experiment on quarks looks a priori very slim, but that on the other hand if we do not try soon the chance of success is zero.

REFERENCES

1 M. Gell-Mann, A schematic model of baryons and mesons, Submitted to Phys.Letters, January 1964.

2 G. Zweig, Private Communication.

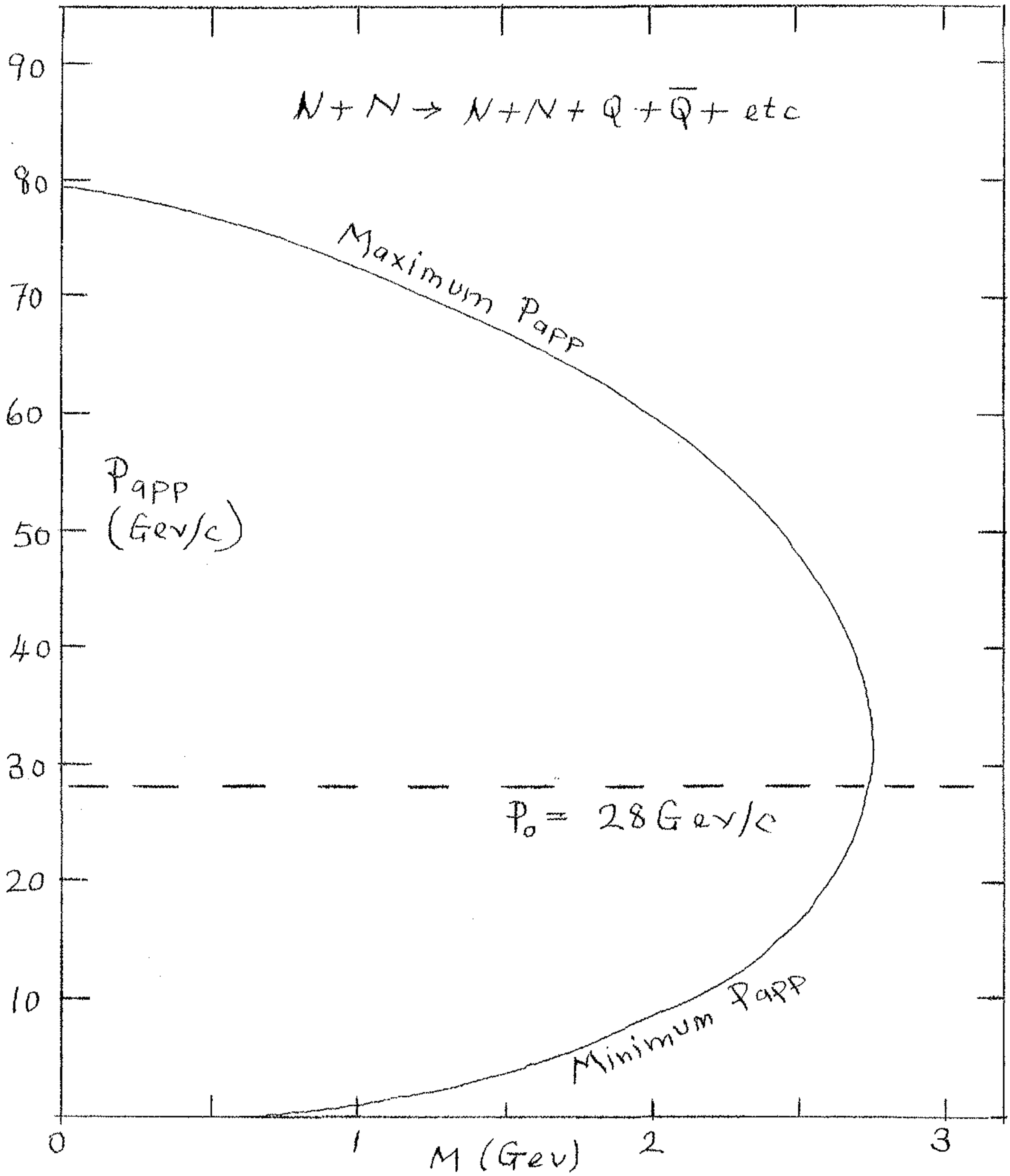

Figure 1: Maximum and minimum apparent momentum of quarks produced by 28 Gev/c protons, as a function of the quark mass, M.

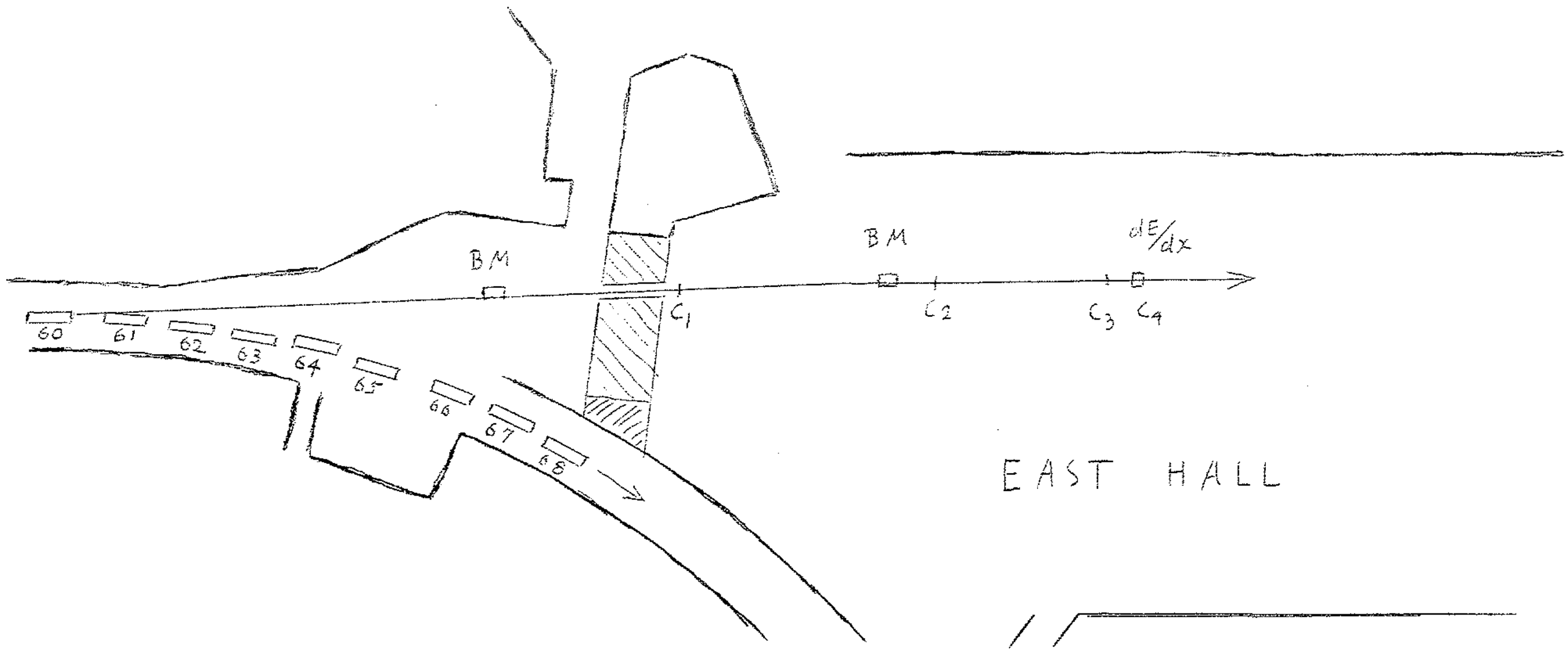

Figure 2 : Layout of the beam in the East Area.