FERMILAB-CONF-74-129-E E138

UPPER LIMITS ON THE PRODUCTION OF PARTICLES WITH CHARM QUANTUM NUMBERS IN pp COLLISIONS AT 400 GeV/c*#

T. Ferbel
University of Rochester, Rochester, New York 14627†
(On Behalf of the Michigan-Rochester Collaboration)†

ABSTRACT

Upper limits are discussed for the production of particles with charm quantum numbers in pp collisions at 400 GeV/c.

In his presentation at the recent conference on Experimental Meson Spectroscopy, Glashow discussed the consequences of introducing an additional SU(3) singlet quark, having "charm" quantum number, for providing an aesthetically pleasing lepton-hadron symmetry and a natural suppression mechanism for neutral strangeness-changing weak currents. A particularly interesting consequence of Glashow's scheme is the predicted existence of new charmed particles which decay weakly having lifetimes in the range of 10^{-13} to 10^{-11} sec.[1] These particles could be produced in hadronic collisions, in pairs having a net charm of zero. The masses of these charmed objects would be expected to be $\lesssim$ 2 GeV (even for baryons), and their production cross sections at high energies would be comparable to yields observed for K-meson production in pp collisions.

In this note we wish to point out that rather small upper limits for the production of charmed particles, having the previously described properties, are already available, and, consequently, if the suggested model is to be useful in the area of weak neutral currents, modifications might be needed to account for the lack of observation of charmed particles in hadronic collisions.

The 30-inch NAL bubble chamber is well suited for detecting the production of short-lived objects which have macroscopic decay mean-free paths (ℓ). In particular, the scanning efficiency for neutral particles which

*This note was presented as a comment by the author at the conference on Experimental Meson Spectroscopy (Held at Northeastern Univ. 1974).

#Research supported by the U.S. Atomic Energy Commission.

†C. Bromberg, T. Ferbel, P. Slattery (Rochester), J. Cooper, R. Diamond, A. Seidl and J. C. Vander Velde (Michigan).

decay into two or more particles (even number of charged tracks) for 3 cm $\lesssim \ell \lesssim$ 30 cm is almost 100%. Similarly, the efficiency for observing charged particles which decay into three or more particles (odd number of charges) is also excellent for 3 cm $< \ell <$ 30 cm. If charmed particles are produced in pp collisions with momenta in excess of 100 GeV/c, their mean-free paths would lie, typically, in this sensitive range.

We have scanned ~ 20,000 frames of film from an exposure of the 30-inch NAL bubble chamber to 400 GeV/c protons. A search was made for anomalous decays of neutral and charged particles produced in primary pp collisions. In particular, the film was scanned for topologies which involved a materialization of 2, 4, 6 or more tracks (even in number), or the decay of a charged track into 3, 5, 7 or more odd-charged prongs, on any frame which contained a primary pp interaction.

A total of ~ 700 V's (two charged particles which suddenly materialize in the bubble chamber) were observed. In addition, one 8-pronged neutral decay candidate, and one 3-pronged charged-particle decay candidate were also observed. The measurable V events were consistent with being interpretable as $K_s^o \rightarrow \pi^+\pi^-$ (~ 200 events), $\Lambda^o \rightarrow p\pi^-$ (~ 80 events), or $\bar{\Lambda}^o \rightarrow \bar{p}\pi^+$ (~ 10 events) decays, or with being e^+e^- pairs resulting from materializations of photons (~ 400 events). The 8-pronged "V" can be interpreted as resulting from an interaction near the secondary vertex, caused by one of the prongs from a neutron interaction (odd-pronged star). The 3-pronged event is not a K-decay, but could be interpreted as a secondary interaction yielding a 4-pronged event having a low-momentum proton recoil which is too short to observe in the bubble chamber. We consider the two anomalous events as representing upper limits for the production of charmed particles.

The cross sections for K_s^o, Λ^o, and $\bar{\Lambda}^o$ production are 6 ± 1 mb, 3.4 ± 0.6 mb and 0.40 ± 0.15 mb, respectively.[2] Assuming charmed particle masses (M) between 0.5 GeV and 4 GeV, having average momenta of 160 GeV/c (i.e., produced forward in the pp center of mass), and, further, supposing charged-particle decay modes for the charmed objects, we calculate and display in Fig. 1 approximate upper limits for the production of charmed particles as a function of their expected mean lives. For comparison we provide the value of the total cross section for inclusive production of antiprotons at 400 GeV/c.[3] We wish to note that the detection efficiency for observing possible charmed particles remains substantial for mean lives $\gtrsim 10^{-11}$ because of the additional low-momentum source (production in the backward hemi-

sphere of the center of mass) which we have ignored in obtaining Fig. 1.

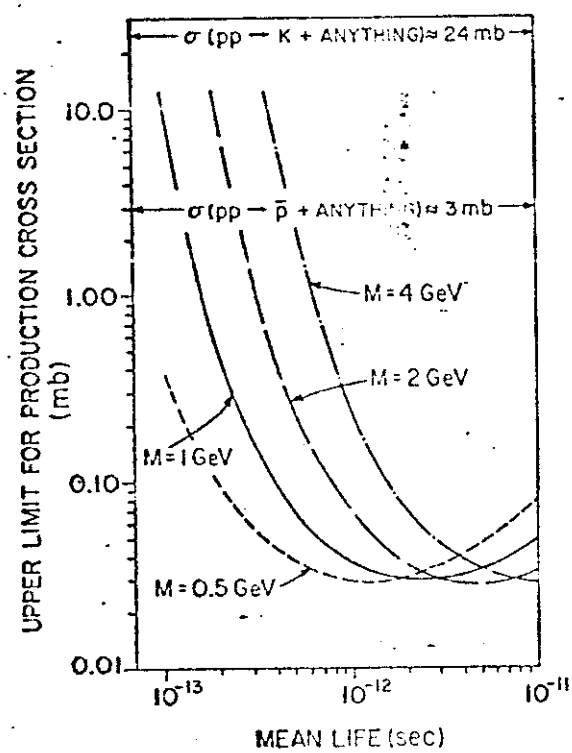

Fig. 1. Upper limits for the production of charmed particles in pp collisions at 400 GeV/c. The results are displayed as a function of the masses and mean lives of the hypothesized objects.

From the graph presented in Fig. 1 we conclude that if charmed particles are produced in pp collisions at high energies as copiously as K mesons (σ_{TOT}^{K} ~ 24 mb) then either their mean lives must lie below the expected range of 10^{-13} to 10^{-11} sec, or their masses must exceed 4 GeV. From a theoretical viewpoint, these alternatives do not appear to be appealing ones.

I wish to thank S. Prasad for helpful comments.

REFERENCES

1. For a previous discussion of these SU(4) ideas see Bjorken and Glashow, Phys. Letts. 11, 255 (1964).
2. A. Seidl et al., Bull. Am. Phys. Soc. 19, 467 (1974). A similar study at 102 GeV/c also provided no evidence for charmed particles.
3. M. Antinucci et al., Lett. Nuovo Cimento 6, 121 (1973).