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¹⁰The weighted average of the values given in references 4 and 5 is $\Gamma_2(\pi^+\pi^-\pi^0) = (2.69 \pm 0.39) \times 10^6 \text{ sec}^{-1}$, which, with our value of $\Gamma_2(\text{ch})$, yields $\Gamma_2(\text{lept}) = (13.1 \pm 2.0) \times 10^6 \text{ sec}^{-1}$. Following Dalitz in reference 8, we take as the weighted average of the measurements given in references 6, 7, and 8, $\Gamma_2(\pi^+\pi^-\pi^0)/\Gamma_2(\text{ch}) = 0.165 \pm 0.02$ which, with our value of $\Gamma_2(\text{ch})$, yields $\Gamma_2(\text{lept}) = (13.2 \pm 1.6) \times 10^6 \text{ sec}^{-1}$.

¹¹The value of τ_{K_2} is the weighted average of the val-

ues obtained using $\Gamma_2(\pi^0\pi^0\pi^0) = (5.1 \pm 1.2) \times 10^6 \text{ sec}^{-1}$ and $\Gamma_2(\pi^0\pi^0\pi^0)/\Gamma_2(\text{ch}) = 0.24 \pm 0.08$.

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SEARCH FOR MASSIVE PARTICLES PRODUCED IN INTERACTIONS AT 30 BeV*

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We report here the results of a search for moderately stable negatively charged particles in the mass region 2.5-5.0 BeV, produced in collisions of 30-BeV protons with tungsten nuclei at the Brookhaven AGS. The unitary symmetry¹ model of strong interactions has received an impressive amount of experimental confirmation.² This in turn has stimulated a great deal of speculation concerning the origin of such a symmetry, leading to the postulation of fundamental triplets of particles.^{3,4} Searches for massive fractionally charged particles have thus far yielded negative results.⁵ The present experiment was motivated by the conjectures of Gürsey, Lee, and Nauenberg⁴ in which the fundamental triplets have integral charge and masses large compared to that of the nucleon. The limitations on the sensitivity of this search were determined by the maximum available machine energy and experimental background.

The experiment was performed in the high-energy separated beam⁶ at the AGS using momentum analysis and time-of-flight measurement to detect the presence of heavy particles. An internal tungsten target was used with the beam emerging at an angle of 7° with respect to the circulating beam. The beam aperture was 4.8×10^{-5} steradian, and the momentum was 7 BeV/c. The beam had two stages of separation with the time-of-flight stations being placed just after the first mass split and at the end of the beam; this distance was about 190 feet. The total length of the beam was 420

feet. The time resolution of the electronics was less than one nanosecond. For a particle of 3-BeV mass, the time-of-flight difference with respect to pions is 17 nanoseconds.

The system was tuned to yield as large a rejection of π 's and \bar{p} 's as possible and yet transmit a large band of masses. This was accomplished by opening the mass slits to $\sim \frac{1}{2}$ in., which corresponds to the maximum vertical acceptance of the second stage of the beam. The voltages on the separator plates were adjusted to bring the π and \bar{p} images just below the lower edge of the mass slit. The mass bite Δm in the region of 3-BeV mass is $\Delta m = 1$ BeV. The system was calibrated on π , p , d , t , and \bar{p} particles. The separators alone yield a rejection on the total pion and antiproton flux of $\approx 2000/1$. This was further improved by a factor of 20 by the addition of a threshold Cherenkov counter⁷ at the end of the beam. The overall rejection rate was $\approx 10^8$.

The mass region from 2.5 to 5.5 BeV was covered in three settings of the separators. The sensitivity of this experiment can be expressed by giving the number of counts obtained due to massive particles, compared to the number of π 's that would have been transmitted by the system with the separators tuned for pions. The equivalent number of pions was obtained by calibrating a monitor viewing the internal target with the number of pions transmitted. The equivalent pion flux versus mass is presented in Fig. 1. The ordinate gives the num-

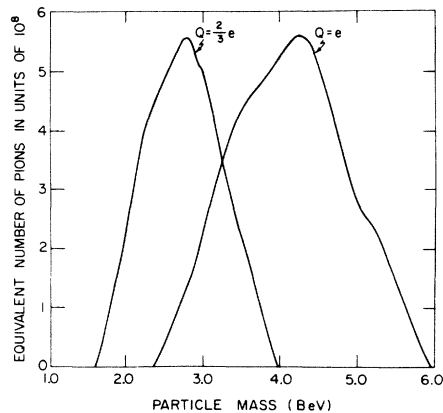


FIG. 1. Equivalent flux of pions that the beam would have transmitted versus the corresponding mass value that the beam was set to transmit. This mass range was covered in three different settings of the separators.

ber of pions that the system would have transmitted for the corresponding mass value on the abscissa. The total number of counts obtained in the mass region 2.5-5.5 BeV was eight, these being randomly distributed. At the maximum sensitivity, the upper limit for the observation of a heavy particle in the beam is $\approx 1/5 \times 10^8$, compared to pions. (Also shown on the graph is the mass acceptance for particles of charge $\frac{2}{3}e$. The signal outputs from the counters were set large enough so that $\frac{2}{3}$ charged particles would have been counted.) It should be noted that the ratio of \bar{p}/π in this beam is 1/100.

The center-of-mass energy available in a 30-BeV p - p collision is 8 BeV, of which ~ 6 BeV is available for production of new particles. If these particles are produced in pairs, the maximum detectable mass is 3 BeV. It is possible, however, to extend the available energy by making use of the Fermi motion in a heavy nucleus or the coherent recoil of clusters of nucleons.⁸ The extent to which this is possible has been recently investigated by Led-

erman et al.⁹ at the Lawrence Radiation Laboratory in searching for \bar{p} production below threshold as a function of primary proton energy. Using these preliminary results one could then say that if other massive particles are produced in interactions with the same coupling strength as \bar{p} 's, then at 3-BeV mass we should have observed $\sim 10^8$ particles and at 4 BeV about three particles. We have observed none. These are only rough order-of-magnitude estimates.

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