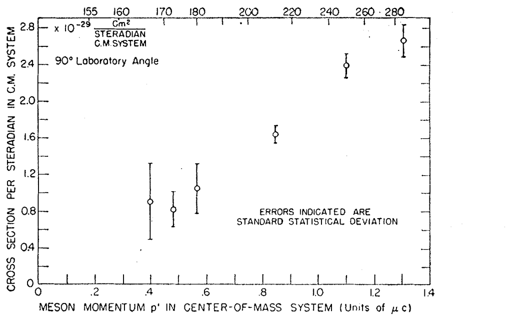

FIG. 3. π^+ photoproduction cross sections in the center-of-mass system of coordinates *versus* initial photon energy in the laboratory system and meson momentum in the center-of-mass system.

above 25 Mev, but our results seem to indicate a sharp drop near 15 Mev.

Dr. Guiseppe Fidecaro participated in the early phases of this experiment. The assistance of the M.I.T. Synchrotron crew is greatly appreciated.

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[1] J. Steinberger and A. S. Bishop, Phys. Rev. **86**, 171 (1952).
[2] Peterson, Gilbert, and White, Phys. Rev. **81**, 1003 (1951).

A Double Star Connected by a Heavy Meson

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IN the course of measurements of the mass distribution of fast particles produced in high-energy nuclear explosions, a case of a double star connected by a heavy meson of mass $1310m_e$ was found.

The double star was observed in a G5 Ilford plate, exposed to cosmic radiation at 30 km. The first star is a $4+4\alpha$ star induced by an alpha particle of 5 Bev (the energy of the primary was estimated by multiple scattering). The heavy meson travels 34 mm before it produces a $5+0K$ secondary star. Multiple scattering and grain density measurements were made along the connecting track. Using the method described by Gottstein *et al.*,[1] we found a value of $p\beta=427\pm41$ Mev/c for the first 16 mm of the track, and a value of $p\beta=417\pm42$ Mev/c for its last 18 mm. The grain density of the track along the first 5 mm is 16.55 ± 0.41 grains per 50μ.

Together with the heavy meson a proton is produced in the same nuclear collision. The proton travels in the emulsion in the direction of the heavy meson and leaves the emulsion after 6.4 mm. Measurements of multiple scattering and grain density (G.D.), for the proton, yield $p\beta=550\pm90$ Mev/c and G.D. $=17.45\pm0.42$ grains/50μ.

The plateau value of the grain density on this plate is 11.5; and the normalized value of ionization, for the heavy meson and proton are 1.44 ± 0.036 and 1.52 ± 0.037, respectively. With the help of the $p\beta$ *vs* grain density curves of Gottstein *et al.*[1] and Daniel *et al.*[2] we have found that the masses of the proton and the heavy meson are 1830 ± 295 and $1300\pm125m_e$, respectively. If we take the correct mass of the proton $m_p=1838m_e$, the corresponding mass of the heavy meson is $m_K=1310\pm245m_e$.

In deriving the last mass value we have used the formula:

$$\frac{m_K}{m_p}=\frac{K_K}{K_p}\,\frac{\bar{\alpha}_p}{\bar{\alpha}_K}\,\frac{(\gamma\beta^2)_p}{(\gamma\beta^2)_K},$$

where K_K and K_p are the scattering constants of the heavy meson and the proton, respectively. The value of $\gamma\beta^2$ has been found according to the curve: grain density *vs* γ of Shapiro and Stiller.[3] The mass of the heavy meson derived in this way is almost independent of the plateau value of the grain density.

In the same set of measurements we have found six other heavy mesons with mass between 1000 and $1300m_e$. The total length in the emulsion of the tracks of all the seven heavy mesons is 7.62 cm. According to Daniel and Perkins,[4] 10 cm of track of identified K particles with mass $1200\pm40m_e$ were examined, without finding any nuclear interaction. Assuming that all the observed heavy mesons are K particles and combining the results obtained in Bristol and in this laboratory, we have found one nuclear interaction produced by a K particle along 17.6 cm of emulsion. The interaction mean free path of pions, in the same range of energy, is 25.6 ± 7.56 cm,[5] and it seems likely that both K particles and pions have the same interaction mean free path. This is in agreement with the observation of Daniel *et al.*[2] on the interaction mean free path of shower particles ejected from jets and supports the suggestion[6] that pions and K particles interact with nuclear matter in a similar way.

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[1] Gottstein, Menon, Mulvey, O'Ceallaigh, and Rochat, Phil. Mag. **42**, 708 (1951).
[2] Daniel, Davies, Mulvey, and Perkins, Phil. Mag. **43**, 753 (1952).
[3] M. Shapiro and B. Stiller, Bagnères de Bigorre Conference, July, 1953 (unpublished).
[4] R. R. Daniel and D. H. Perkins, Royal Society Conference, London, January, 1953 (unpublished).
[5] W. O. Lock and G. Yekutieli, Phil. Mag. **43**, 231 (1952).
[6] U. Haber-Schaim and G. Yekutieli, Phil. Mag. **43**, (997) (1952).

Nonconservation of Rest Mass and the Dirac Equation

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IN recent years a number of attempts have been made to introduce a fundamental length into the quantum theory of a particle without destroying the covariance of the equations. The most notable of these attempts are the nonlocalizable field theory of Yukawa[1] and the reciprocity theories of Born and Green.[2] These theories are closely related to the notion that the coordinates and time describing the motion of a particle are not parameters but observables that must be represented by operators.

It is possible to arrive at a somewhat similar point of view by considering a system in which the rest mass m_0 is not conserved. This would be true in systems in which nonmechanical energy of some sort is produced. Let us suppose that Q is the amount of nonmechanical energy developed per unit time in the rest system of a particle. Then the rest mass will no longer be conserved, and we have[3]

$$dm_0/d\tau=Q/c^2, \tag{1}$$

where τ is the proper time and is related to the velocity u of the particle and the time t by the equation

$$d\tau=(1-u^2/c^2)^{\frac{1}{2}}dt. \tag{2}$$

We must therefore have

$$dm_0/dt=[1-(u^2/c^2)]^{\frac{1}{2}}(Q/c^2). \tag{3}$$

From this equation it is obvious that m_0 cannot be a constant of the motion and therefore cannot commute with the Dirac Hamiltonian of the particle. Since in a relativistic quantum theory of a particle $[1-(u^2/c^2)]^{\frac{1}{2}}$ is represented by the Dirac matrix β, we shall write

$$[m_0,H]=i\hbar(Q/c)\beta \tag{4}$$

as the quantum-mechanical equivalent of (3). This means that