indicates that it places the value only between the limits 0.30 and 0.50. Using the value of Wu *et al.* for the L conversion probability ($N_L=f_LN_T=0.64$), and Stahel's[5] value of N_x (0.25), one obtains $f_x=0.39$, considerably lower than the value 0.475 used by Wu *et al.* (attributed to Kinsey[9]) to obtain the intensity of the 46.5-kev gamma ray from their measured intensity ratio of L x-rays to gammas.

Using scintillation spectrometry and 2π alpha counting techniques we have measured absolute intensities of the gamma rays and L x-rays of RaD, and have obtained a total gamma-ray intensity of 4.4±0.7 and an L x-ray intensity of 19±3 per hundred disintegrations. A line at 31±1 kev has been distinctly resolved by proportional spectrometry under conditions where pulse pile-up is eliminated. The intensity of this line is 0.6±0.2, and that of the 46.5-kev line is 3.8±0.6 per hundred disintegrations.

The intensity ratio of x-rays to 46.5-kev gammas obtained from the above results agrees with that reported by Wu *et al.*[2] Our value for N_x, together with their value for N_L, leads to a fluorescence yield of 0.30 ±0.05 which, in turn applied to their data, yields a 46.5-kev gamma intensity of 4±1 instead of the reported 7±2, thus bringing all reports into agreement.

Low-intensity gamma rays reported previously by us and others from proportional counter studies do not appear when pulse pile-up is eliminated by selective absorption techniques; these lines may thus be attributed, at least in part, to this effect. Limits may be set as follows: 43 kev, <0.2; 37 kev, <0.1; 23 kev, <0.1; 65 kev, <0.01; and K x-rays, <0.1 per hundred disintegrations. In addition, a thorough search for gamma rays in coincidence has been made, and no nonrandom coincidences have been found. In particular, it is clear that no line in the vicinity of 16 kev occurs in coincidence with the 31-kev gamma ray.

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Tau Meson Produced by 3.0-Bev Protons*

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Continued examination of the emulsions described in a first report[1] has disclosed ten stopping K mesons and, in addition, one τ meson. This τ meson was found in a stack of emulsions exposed at 90° to the 3.0-Bev proton beam, in position (a) of reference 1. In this stack, systematic scanning of 46 cm² of emulsion showed, in addition to the τ meson, 5 stopping K^+ mesons, and 1578 stopping π and μ mesons.

The τ meson entered the stack, from the direction of the target, with an initial energy of 92 Mev. When allowance is made for its energy loss in the cosmotron wall, its minimum energy on leaving the target was 122 Mev. The particle traveled 3.4 cm in two emulsions before stopping and undergoing the typical τ-meson decay into three coplanar charged mesons.

Of the three outgoing mesons, only one came to rest in the stack. This was a π^+ meson, showing the characteristic $\pi-\mu-e$ decay after traversing 4.9 mm of emulsion and having, therefore, an initial energy of 15.4 Mev. One meson appeared to be almost stopping after traveling 4.6 mm. Its grain density variation with range was consistent with that of a pion of 17 Mev. The track of the third outgoing light meson showed no significant grain density variation in 8 mm of track length. Its grain density was consistent with that of a pion of 40 Mev. However, in both cases, the possibility of muons cannot be eliminated, as the steepness of the tracks prevented scattering measurements. Within the experimental error of 1°, the meson tracks were coplanar; the measured angles between the tracks were 61.3°, 150.0°, and 148.5°. From the momentum of the stopped pion, the momenta of the other mesons were computed to be 70.3 Mev/c and 118.2 Mev/c. If these two particles are accepted as pions, then these momenta correspond to energies of 16.8 and 43.4 Mev. The pion energies add up to (76±5) Mev, in good agreement with the current value of 75 Mev for the Q of the τ-meson decay.[2]

It is advantageous to refer other K masses to the accurately known τ mass as a standard. In these measurements, the mean scattering angles of the τ, one K^- and one K^+ meson were 0.216°±0.015, 0.215° ±0.019°, and 0.208°±0.020°, respectively, determined for the same effective residual range[3] of 23.5 mm, and with approximately one hundred 100-μ cell lengths in each case. From the observed mean scattering angle of 0.216° and the correct τ mass of 965.5 m_e,[2] the scattering constant was calculated to be 25.8±1.8 degree-Mev. With this scattering constant, the K^- mass was $(970\pm 180)m_e$ and the K^+ mass $(1040\pm 200)m_e$. These values are in satisfactory agreement with the masses obtained by the method of grain density-range comparisons with pion tracks, namely, $(960\pm 190)m_e$ for the K^- and $(960 \pm 90)m_e$ for the K^+; this latter method gives $(960\pm 80) m_e$ for the τ mass. Here the errors are standard statistical deviations and can be reduced by measuring more calibrating tracks.

The emission of a τ meson of 122 Mev at 90° to the 3.0-Bev proton beam makes unlikely the conclusion that this meson was produced, in a single nucleon-nucleon interaction, paired with another K meson; for if a target nucleon is assumed to have a Fermi energy even as high as 25 Mev, there is not enough energy to produce a τ meson of 965.5 m_e and a K meson heavier than 800 m_e.[4]

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Primary Cosmic-Ray Spectrum Deduced from an Analysis of Jets

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During a systematic analysis of high-energy collisions, recorded in nuclear emulsions flown at high altitudes, sufficient data were obtained to attempt the determination of the energy spectrum of singly charged particles.

The method of selection was such as to inculde all stars with 5 shower particles or more having a "half-angle" of $\theta_{\frac{1}{2}} \leq 10°$. No restriction was imposed on the number of heavy or gray prongs. The only condition for the measurement of a star was that at least half the shower particles have a projected angle of $\leq 10°$ with respect to the direction of the primary. The angle of dip generally increases the true angle with the primary. Hence, from 75 stars measured hitherto, only 41 were selected as having $\theta_{\frac{1}{2}} \leq 10°$. We believe that in this way all events with that half-angle and $n_s \geq 5$ from the scanned area were included in our analysis. Only five stars of comparable energy having a neutral primary have been found. This fact as well as the high altitude at which the emulsion were flown ($\sim$30 km) suggest that the large majority of the singly charged particles are protons of primary origin.

The energies of the individual stars were estimated according to two different methods, both assuming multiple production. The first method does not involve a particular theory of meson production in nucleon-nucleon collision. It is based on the following assumptions: (a) all the shower particles have their origin in a single collision; (b) the angular distribution of the particles is symmetrical in the c.m. system and the velocity of most of them is larger than the velocity of the c.m. with respect to the laboratory system.

Since the incoming nucleon has to penetrate on the average a considerable length in nuclear matter (e.g., Ag, Br, or C, N, O nuclei), one may interpret assumption (a) to mean that the mesons that actually leave the nucleus are produced by a composite particle colliding with the last nucleon on the path. This composite particle is supposed to consist of that fraction of nucleons and pions already produced which are closely collimated in the forward direction.[1,2] The above-mentioned c.m. system refers to those two particles. If this is accepted, the energy of the primary is given by the well-known expression $E = 2/\theta_{\frac{1}{2}}^2$ in nucleon mass units. Curve I (Fig. 1) shows the integral spectrum obtained in this way. The large change of the slope below $E = 65Mc^2$ is due to our method of selection. Therefore, with the lower limit of the spectrum taken at $E_0 = 65Mc^2$ (corresponding to $\theta_{\frac{1}{2}} = 10°$) and the spectrum assumed to be of the form $N(>E) \sim E^{-s}$, the method of maximum likelihood gives for the 41 events $s = 1.40_{-0.21}^{+0.23}$. The errors represent those values of s which are less probable by a factor of $e^{\frac{1}{2}}$ than the most probable one. This coincides with the standard deviation for a Gaussian distribution.

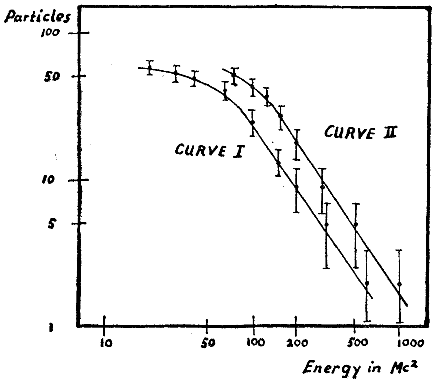

FIG. 1. The integral energy spectrum. In curve I, $E = 2/\theta_{\frac{1}{2}}^2$, in curve II, $E = 2k/\theta_{\frac{1}{2}}^2$.

Our value for s is higher than that obtained recently by Hoang[3] by a similar method. The discrepancy is possibly due to the rejection of stars with $N_{\mathrm{H}} \geqslant 4$ by Hoang.

For $E \geqslant 100Mc^2$ we have 25 events which by the same method yield $s = 1.50_{-0.28}^{+0.31}$ in agreement with the results of Haber-Schaim[1] and Barrett *et al.*[4] for the same energy interval.

In the second method for the estimation of the energy, the possibility is taken into account that in the last and pertinent collision more than one nucleon (at rest) were hit simultaneously.[5,6] If k nucleons are hit, the energy of the primary as determined from the half-angle is $E = 2k/\theta_{\frac{1}{2}}^2$. In order to determine k, one has to assume a relation between the observed multiplicity n_s and the energy. This has been done on the basis of Fermi's theory of meson production by Cocconi,[6] who obtained the relation

$$k = (n_s \sqrt{\theta_{\frac{1}{2}}})/2.6.$$

Let α_k be the probability for a collision with k nucleons $(=1\cdots4)$, $\sum_k \alpha_k = 1$, and let the energy spectrum according to the first model have the form E^{-s}. Then we obtain for the spectrum, according to the second