this advantage of the shorter millimeter wave region for measurement of the moments of radioactive nuclei.

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Angle of Divergence of Pairs Produced by Photons

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ILFORD nuclear emulsions (G 5, 600μ) were scanned systematically for high-energy electron pairs produced by γ rays from cosmic radiation. The plates were exposed for three weeks on the Monte Rosa (Capanna Margherita 4550 m) and processed at our laboratory in Berne according to the Brussels method.[1] The plateau blob density obtained was 30.6 blobs per 100μ.

The angle of divergence and the photon energy of 126 pairs have been measured for 212 pairs found in a certain area. The photon energy $k=E_+ + E_1$ was determined by multiple scattering measurements on both tracks of the pairs. E_+ and E_- are the total energies, the pairs being supposed to be electron-positron pairs. The measured values of the angle ω were reduced to values

$$\omega_{\text{red}}=\omega[\phi(a=0.5)/\phi(a)], \quad a=E_1/k,$$

corrected for symmetrical energy partition, E_1 being the lower one of the particle energies. $\phi(a)$ is a function given by Borsellino,[2] which represents the influence of the energy partition according to his Eq. (15) for the most probable values of the angle:

$$\omega_p=(4mc^2/k)\phi(a).$$

Figure 1 shows the values of k *vs* ω_{red}. Curve 1 is Borsellino's theoretical most probable value ω_p for $a=0.5$. Curve 2 is the root-mean-square value $\langle\omega^2\rangle$ of Stearns.[3] Both curves represent the values for symmetrical energy partition. The limits of error of the experimental values were calculated with the relative mean deviation $0.75/\sqrt{N}$ of the second differences (sagitta method of multiple scattering measurement), N being the number of the independent second differences on the track. The points indicated by triangles are measurements given by Occhialini.[4]

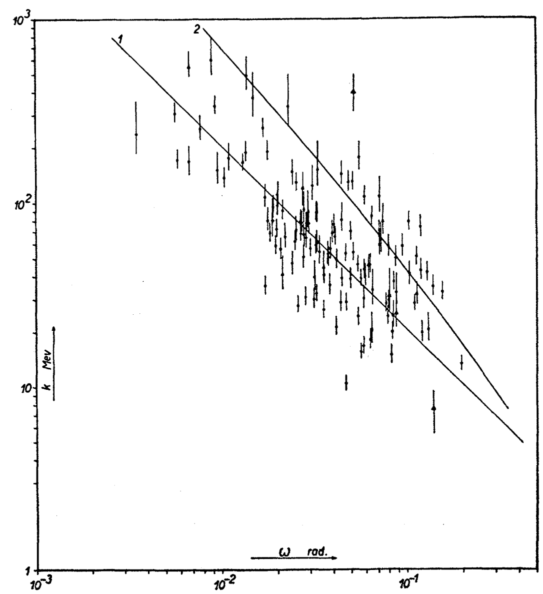

FIG. 1. The correlation between angle of divergence and photon energy k. The experimental points represent the reduced values ω_{red} belonging to the symmetrical energy distribution. Curve 1 is Borsellino's most probable value ω_p and curve 2 the root-mean-square value $\langle\omega^2\rangle$ of Stearns.

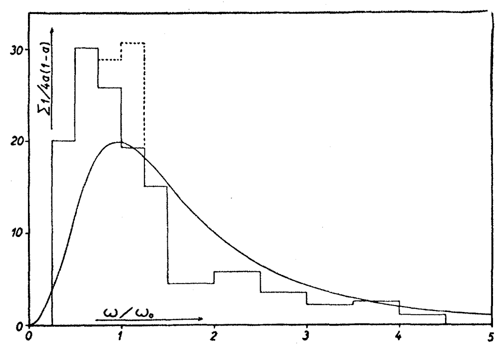

FIG. 2. The distribution of pairs in ω/ω_0. The full-line histogram includes the pairs with $a>0.1$; the dotted line shows the histogram including all pairs where both ω and k have been measured. Theoretical curve: Borsellino's probability.

Figure 2 represents the frequency distribution of the pairs in ω/ω_0, with

$$\omega_0=(mc^2k)/(E_+E_-).$$

The histogram represents the correct number of pairs in a interval 0.25 of ω/ω_0. Each pair has been multiplied by a weight factor

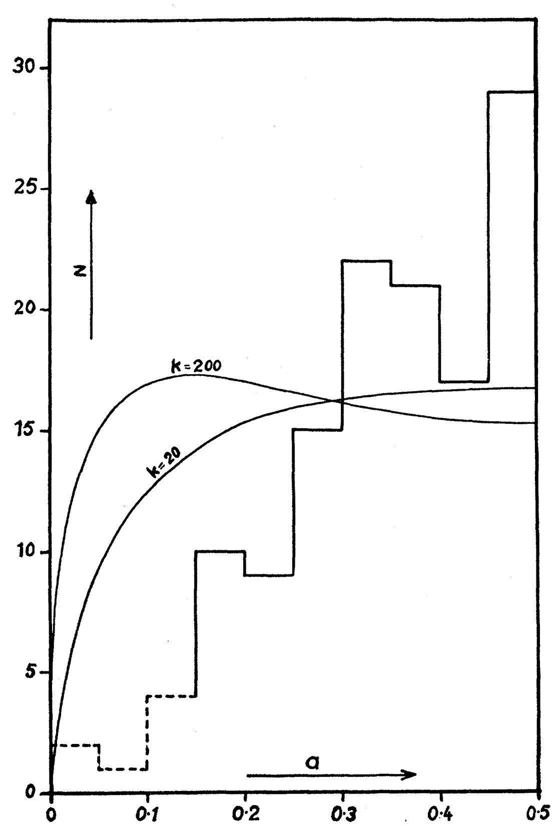

FIG. 3. The distribution of pairs in a. Theoretical curves: Bethe and Heitler for $k=20$ Mev and $k=200$ Mev, normalized to the same area with the histogram in the interval $0.15<a<0.5$.

$1/4a(1-a)$ in order to correct for symmetrical energy partition. The fully drawn line includes the pairs with $a>0.1$, the dotted line includes all pairs for which ω and k have been determined. The theoretical curve is derived from the probability curve of Borsellino (Fig. 3 in his paper) for $k=51$ Mev by normalizing it to the same area as the experimental histogram in the interval $0<\omega/\omega_0<5$. The probability curves for different values of k do not vary considerably, the maximum probability being displaced to $\omega/\omega_0=1.02$ for $k=100$ Mev and to 1.06 for $k=\infty$.

In Fig. 3 are plotted the experimental and theoretical frequency distributions of the pairs *vs* a. The theoretical probability curves are those of Heitler[5] and of Bethe and Ashkin[6] for $k=20$ Mev and $k=200$ Mev, both normalized to the same area as the experimental histogram in the interval $0.15<a<0.5$ (the energy distribution of the pairs can be seen in Fig. 1). The histogram for $a<0.15$ is plotted in dotted lines, because pairs with strong asymmetrical partition are more easily overlooked in scanning than others.

The results indicate that Borsellino's most probable value ω_p is more useful for estimating energies from pair angles than the root-mean-square value of Stearns. The histogram in ω/ω_0 also seems not to be in contradiction with Borsellino's probability (cross section) curve. However, the experimental distribution in a is different from the Bethe-Heitler theoretical curves. It seems that for low a values, the probability is less than that predicted by theory.

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The detailed account of this work will be published in *Helvetica Physica Acta*.

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A Čerenkov Counter-Cloud Chamber Measurement of Multiply-Charged Primary Cosmic Rays*

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THE flux of fast particles with $Z\geqslant 2$ has been measured at balloon altitude by means of a cloud chamber triggered by a Čerenkov counter.

The geometry of the apparatus is shown in Fig. 1. An incoming beam was defined by a Geiger counter telescope whose area-solid angle product was measured to be 0.72 ± 0.03 cm^2 steradian. The average angle to the vertical of incoming particles was about six degrees. The Čerenkov counter was calibrated by measuring the pulse-height distribution for cosmic-ray muons with a multichannel analyzer. The measured distribution had a width at half-maximum 0.75 times the mean pulse height and fitted $P(10,n)$, the Poisson distribution for a mean of 10, except for a "tail" from knock-on electrons. Most of the width is the result of fluctuations in the number of photoelectrons from the multiplier cathode. The cloud chamber was triggered by a coincidence between the upper GM counter tray, the lower GM counter, and a pulse from the Čerenkov counter $\geqslant 2.1\pm0.2$ times the mean from a fast muon. The cloud chamber sensitive region was 4 in. $\times$8 in. in plan and 8 in. in height and contained five transverse $\frac{1}{4}$-in. thick copper plates (28 g/cm^2 total). A track within the telescope solid angle traversed all the plates within the illuminated region. Stereoscopic photographs were taken of the events.

The balloon flight[1] was extremely level at mean atmospheric depth 16.4 millibars for 345 minutes. During that time the pressure, which was recorded by photographing the dial of a calibrated Wallace and Tiernan aneroid gauge, varied no more than 0.3 millibar from its mean value. There was no evidence of any significant malfunction of the equipment. After the flight it was recovered undamaged and as soon as spent batteries were replaced performed just as it had before.

The chamber was triggered 157 times during level flight. The sensitive time of the trigger circuit was $1.015\pm0.012\times10^4$ sec.

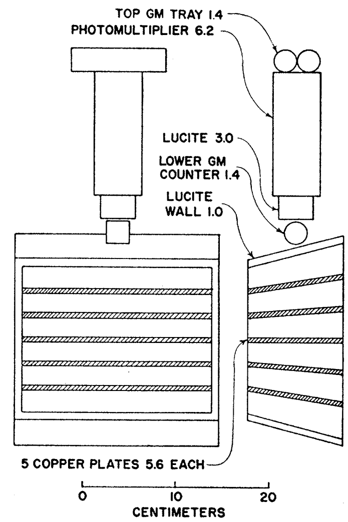

FIG. 1. Diagram of telescope and cloud chamber. Thicknesses are given in g/cm^2.

Sixty-two photographs showed counter-age tracks identified to be those of He nuclei by their ionization and the fact that the photographs showed no evidence of related incoming particles. In but two cases there was reasonable uncertainty about the identification of an alpha track. Each of them satisfied the necessary condition that its projection on the focal plane of each stereo camera pass through the projection of the telescope apertures. Thirteen photographs showed unaccompanied counter-age tracks of particles with $Z>2$ that satisfied the same projection criterion. One heavily ionizing particle stopped in the fourth copper plate and therefore had $Z\geqslant 7$, since its energy had to be above 350 Mev/nucleon when it entered the Čerenkov counter. By comparison with that track and among all the tracks, it is estimated that at least three of the particles had $Z<6$.

At the latitude of the flight (55°N geomagnetic) the energy spectra of the particles detected were cut off by the Čerenkov detector rather than geomagnetic effects. The mean threshold energy for He nuclei entering the counter was 650 ± 100 Mev/nucleon entering the counter. For particles with $3\leqslant Z\leqslant 5$ the threshold would be 410-Mev/nucleon and for $6\leqslant Z\leqslant 8$, 375-Mev/nucleon—only slightly above the energy, 342-Mev/nucleon, corresponding to the critical velocity in Lucite. The uncertainty in threshold caused by that in the pulse-height bias was insignificant except for alphas.

To consider flux above the atmosphere one must correct the energy thresholds for ionization loss in the material above the Čerenkov counter and must take into account nuclear interactions in all material above the cloud chamber sensitive volume (17-g/cm^2 air, 13-g/cm^2 local matter). The corrected thresholds are 710 ± 100-, 540-, 600-Mev/nucleon for He, (Li Be B), (C N O) in that order. The mean free paths 44 g/cm^2 in air, 60 g/cm^2 (average) in local matter[2] were used to correct the He flux for attenuation. The number of fast alphas expected to be secondary