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Oxford. Dec. 21.

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The Primary Soft Component of Cosmic Radiation

IN a recent communication, Rossi[1] analysed burst measurements of Hulsizer[2] and concluded that if a primary soft component exists at all, it constitutes not more than a few per cent of the total primary intensity. In our opinion, Rossi's numerical interpretation of Hulsizer's results is erroneous.

Bursts were observed by Hulsizer containing a minimum of eighty ionizing particles passing through the burst chamber. The cross-section of the burst chamber was 50 cm.^{2}; it was covered by 2·5 cm. of lead. At a height 0·5 cascade units under the top of the atmosphere, 300 bursts per hour exceeding the minimum size were observed. These bursts were interpreted in the following way: (1) it was assumed that the absorption of any primary spectrum through the atmosphere above the chamber was negligible; (2) it was assumed that electrons of 4,500 MeV. can give rise to bursts of eighty particles; (3) it was assumed that half the bursts are not caused by cascade showers but by heavily ionizing particles.

Thus an upper limit for the number of electrons with energies exceeding 4,500 MeV. was derived. Comparison with the total number of incident particles led Rossi to conclude that "not more than 1 per cent of the primaries are electrons with energies exceeding 4,500 MeV.". In our opinion, the calculation requires modification.

(1) The absorption law of a power spectrum of electrons is well known; given an incident spectrum,

$$S(E;\ 0) = \frac{A}{E^{\gamma+1}}, \qquad (1)$$

at a depth of ζ cascade units, we have,

$$S(E;\ \zeta) = \{M(\gamma)\exp(-a_1(\gamma)\zeta) + N(\gamma)\exp(-a_2(\gamma)\zeta)\}\,S(E, 0) \qquad (2)$$

(see for details, for example, Jánossy, "Cosmic Rays", p. 237).

With $\gamma = 1{\cdot}7,\ \zeta = 0{\cdot}5,$

we find

$$S(E_1\ \zeta)/S(E_1\ 0) \sim 0{\cdot}5.$$

Thus the primary component is reduced to half its intensity under $\zeta = 0{\cdot}5$ (a fraction of this reduction is replaced by photons).

(2) An electron of 4,500 MeV. does not give rise to a shower of eighty particles. But, in any case, a large fraction of shower particles in lead have energies of a few MeV. only, and many of those will be lost by scattering. Thus it seems reasonable to assume that a shower which contains a total of, say, 160 particles, will just manage to produce 80 particles passing through the chamber.

Using the formalism of Bhabha and Chakrabarty, we find that a primary energy of about 20,000 MeV. is required to give rise to a burst of eighty particles in the burst chamber. Thus, accepting other details given by Rossi, we are led to conclude that not more than 2 per cent of the primary cosmic rays are electrons with energies exceeding 20,000 MeV.

If the cut-off of the power spectrum is taken to be at 2,000 MeV., the total number of electrons according to (1) must be less than

$$2 \text{ per cent} \left(\frac{20{,}000 \text{ MeV.}}{2{,}000 \text{ MeV.}}\right)^{1\cdot7} = 100 \text{ per cent.}$$

Thus no significant upper limit for the strength of the primary component can be derived from Hulsizer's measurements.

I would not go so far as to suggest that Hulsizer's measurements *prove* the existence of a soft component, as there are many *ad hoc* ways of accounting for the experiments. I would like to emphasize, however, that there is to my knowledge no valid experimental evidence against the existence of a primary soft component; while latitude effect and extensive air showers can most easily be accounted for in terms of a primary soft component forming a moderate fraction (say, 30 per cent) of the total primary intensity. General arguments supporting the existence of a primary soft component have been presented and discussed in detail by Ferretti[3].

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WE are glad that the critical remarks of Jánossy give us an occasion to reconsider the interpretation of our balloon experiments.

We have been aware of the fact that some of the figures quoted in our original paper are inaccurate. Indeed, in a paper presented by one of us at the Cosmic Ray Symposium held in Pasadena last June, a revised estimate of 10 BeV. was given for the minimum energy of an electron capable of producing the observed bursts[1]. We can, however, answer specifically Jánossy's remarks.

(1) Atmospheric absorption. Since our instrument is sensitive to electrons and photons alike, one has to consider the change in the total number of these particles and not that in the number of electrons alone. For vertical incidence and for a power spectrum with $\gamma = 1{\cdot}7$, the reduction factor at a depth of 20 gm. cm.$^{-2}$ amounts to 0·7. However, we must consider that the quantity measured by our instrument is closer to the integrated rather than to the vertical intensity. For the integrated intensity the reduction factor is 0·44.

(2) Energy E_0 of an electron which produces a shower of 80 particles through our chamber. The calculations of Richards and Nordheim, which have