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C. Castagnoli, E. Etim and P. Picchi : INTERPRETATION OF COSMIC RAY DATA BY SU3 TRIPLET PARTICLE. -

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C. Castagnoli[(x)], E. Etim and P. Picchi : INTERPRETATION OF COSMIC RAY DATA BY SU3 TRIPLET PARTICLE.

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The observation by the INS group[(1)] of horizontal air showers of large size ($10^3 < N < 10^5$) has given rise to great difficulty in understanding high energy muon-nucleon interaction. The theoretical analysis of the INS experiment has up to date consisted in a judicious exclusion of alternatives; for instance it is unlikely that the observed events could be[(1)] :

(i) air showers produced by primary (nucleons) cosmic ray particles;
(ii) bremsstrahlung of high energy muons;
(iii) showers produced by the nuclear interaction of neutrinos.

It was consequently thought that the observed showers could be the result of high energy muon-nucleon interactions[(2,3)] and that the extrapolation of the Kessler-Kessler method, already in good agreement with experiment for small energy transfer[(4)], to the high enrgy transfer region would be able to reproduce the observed data.

The agreement of this extrapolated theory with experiment was so disappointing that many were forced to invoke a new type of interaction between muons and nucleons while others dismissed the observed events as simply anomalous[(2,3)].

In a first step we have investigated a possible electromagnetic muon-nucleon interaction as an explanation of the INS events and have arrived at a negative conclusion. Our reasoning is as fol-

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lows : independently of what happens at the nucleon vertex the energy transfer (in the LAB system) $\varepsilon = E - E'$ given as the difference between the initial and final muon energies is unambiguously defined; therefore from unitarity

(1) $$\frac{d\sigma_{el}}{d\varepsilon} + \frac{d\sigma_{in}}{d\varepsilon} = \frac{d\sigma_T}{d\varepsilon}$$

where σ_{el}, σ_{in}, σ_T is the elastic, inelastic and total cross-sections respectively. The ratio

(2) $$P(\varepsilon) = \frac{d\sigma_{el}}{d\varepsilon} / \frac{d\sigma_T}{d\varepsilon}$$

defined as the probability for elastic scattering is non else but the square of the form factor of the nucleon normalized to unity for $\varepsilon = 0$. In the limit as the energy E and the energy transfer $\varepsilon = t/2M$ (t is the square of the 4-momentum transfer and M the nucleon mass) tend to infinity it can be shown[5,6] that the elastic cross-section is given by

(3) $$\frac{d\sigma_{el}}{d\varepsilon} = \frac{d\sigma_B}{d\varepsilon} G_M^2(\varepsilon)$$

where $G_M(\varepsilon)$ is the nucleon magnetic form factor, and σ_B the Born approximation. From (1), (2) and (3) and making use of the fact that $G_M(\varepsilon) \to 0$ as $\varepsilon \to \infty$ we have resolving (1) for σ_{in}

(4) $$\frac{d\sigma_{in}}{d\varepsilon} = \frac{d\sigma_B}{d\varepsilon} \frac{G_M^2(\varepsilon)}{P(\varepsilon)}, \qquad \varepsilon \to \infty$$

From the meaning attached to $G_M(\varepsilon)$ and $P(\varepsilon)$ and the fact that the electric form factor $G_E(\varepsilon) < G_M(\varepsilon)$ one expects the ratio $G_M^2(\varepsilon)/P(\varepsilon)$ to tend to a constant of the order of unity as $\varepsilon \to \infty$. However this expectation is not borne out for if the INS data are due to electromagnetic interaction of muons with nucleons then our comparison of (4) with experiment yields $G_M^2(\varepsilon)/P(\varepsilon) \sim 10^8$!

This large discrepancy has forced us to conclude that the interaction in question cannot be electromagnetic and that it must be of the strong specie. Since as noted earlier the showers could not be produced by nucleons we are led to suppose they are produced by a particle of mass greater than that of the nucleon.

The possible strongly interacting candidates with a mass many times that of the nucleon must be looked for amongst the as yet new massive cosmic ray particles whose possible existence has been suggested as a consequence of SU(3) theory[7-9]. We have therefore examined the data on the SU3 triplet particle reported by Dardo et al[10] who pointed out that it is not inconsistent to identify the particles which caused the positive delays in their underground experiments with the SU3 triplet particle. They found the following reasonable data for the triplet characteristics :

mass $M_T \sim 10\ M_N$; the interaction mean free path λ_T about 2 or 3 times that of the nucleon λ_N; the inelasticity K_T is related to that of the nucleon by $K_T M_T = K_N M_N$. We note that the value of λ_T found by Dardo et al. is in good agreement with what one would expect theoretically.

To find out if the triplet could be responsible for the shower events observed by the INS group we have used the formula :

$$(5) \qquad I_o(\mathcal{E}_m) = J_o(E_m)\frac{\Delta X}{\lambda_T}$$

to derive the integral flux $J_o(E_m)$ of the incident primaries with energy greater than E_m. We have compared $J_o(E_m)$ so derived with that given by Dardo et al. $I_o(\mathcal{E}_m)$ is the integrated flux of secondaries with energy greater than $\mathcal{E}_m$ which can be obtained from ref. (1) (the horizontal flux has been converted to vertical using the experimental ratio given by Dardo). $\Delta X \simeq 400$ gm cm^{-2} is the mean distance between the starting point of the event and the point of observation(1). On the average E_m is given by $E_m = \mathcal{E}_m/K_T$.

In fig. 1 we have plotted $J_o(E_m)$ so obtained from the INS data with corresponding errors (rectangles) against the energy E_m. The fluxes of Dardo et al. obtained from both the fireball model and the dissociation model within a factor three are shown as straight lines in fig. 1. From the comparison one sees that there is remarkable agreement between the INS data and the fireball model of triplet production.

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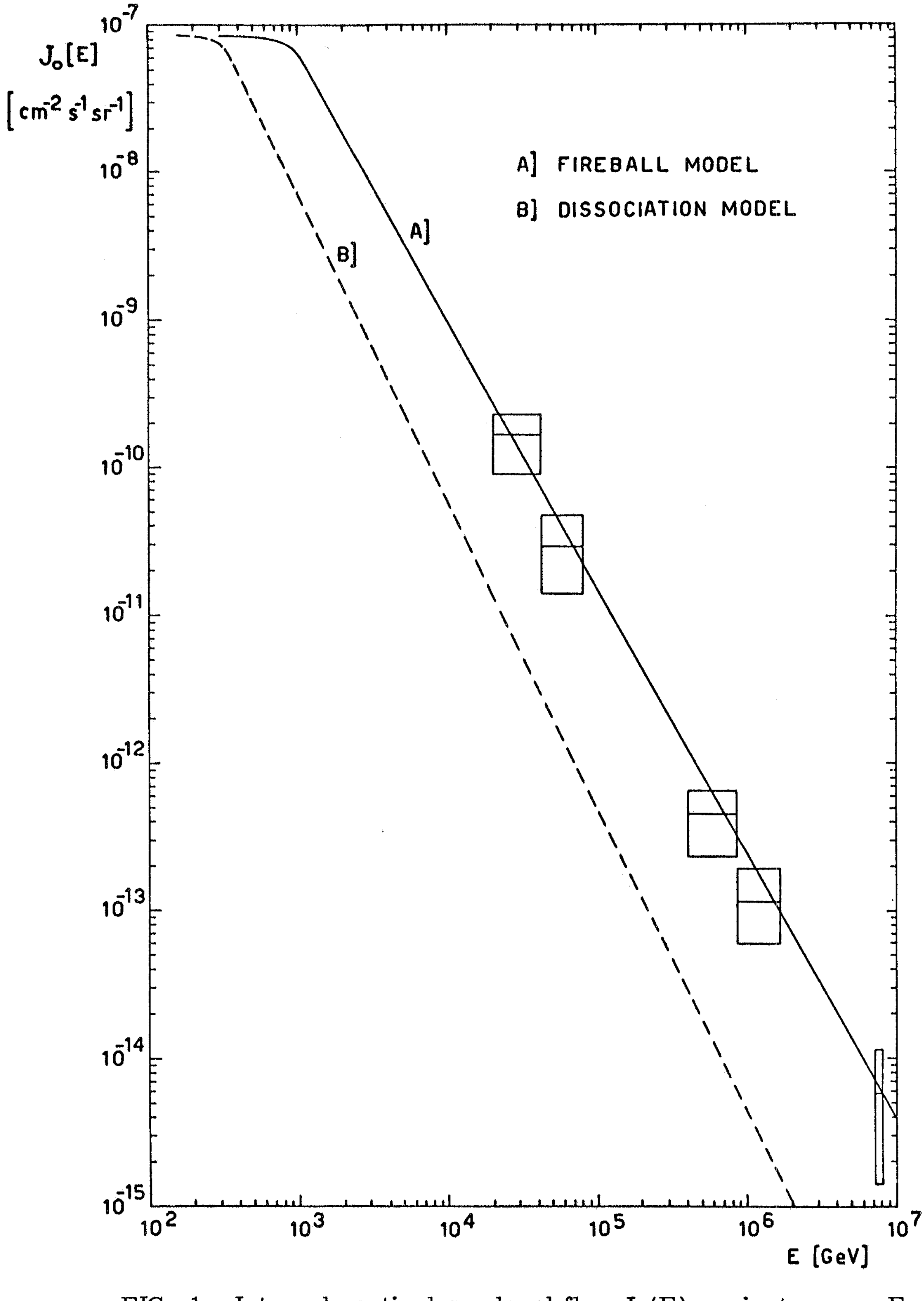

FIG. 1 - Integral vertical sea level flux $J_o(E)$ against energy E. The rectangles have been obtained using the INS data. The straight lines are from ref. (10).

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