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Photographic Evidence for the Existence of a Very Heavy Meson

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A. PREVIOUS EVIDENCE

EVIDENCE for the existence of a very heavy meson was first presented in 1944 by Leprince-Ringuet and M. Lhéritier.[1] This was a Wilson chamber photograph showing the collision of a cosmic-ray particle with an electron. If one assumed an elastic collision, the mass of the incident (positive) particle was found to be $M=(990\pm 120)m_0$, m_0 denoting the electron mass.

The uncertainty in M caused by scattering has been analyzed by H. Bethe,[2] who concludes that the lower limit of the mass cannot be less than $600m_0$, while the upper limit could reach the proton mass if all the probable errors are doubled and added together with the same sign. This, however, has a probability of less than 1 percent, so that the incident particle is probably not a proton. There is still another argument that the particle is a very heavy meson and not a proton. This is based on the fact that the ejected electron is at its minimum of ionization, while the incident particle, if it were a proton, would produce an ionization 2.4 times the minimum. Now in the vicinity of the point of collision it is possible to compare the ionizations of both the primary and secondary particles, and no appreciable difference has been found. The photograph is therefore in favor of the existence of a very heavy meson.

Since that time Rochester and Butler[3] have reported evidence for the existence of a particle having a mass of the same order of magnitude but disintegrating in flight. Two photographs showing such a phenomenon were obtained, one with a charged incident particle, the other with a neutral incident particle.

Finally, new indications of a very heavy meson were given by R. Brode[4] who has measured masses of cosmic-ray particles by means of three Wilson chambers.

B. NEW EVIDENCE

In collaboration with Hoang Tchang-Fong, L. Jauneau, and D. Morellet,[5] we have observed in an Ilford plate exposed at Mont Blanc (4300 m) the striking phenomenon (Fig. 1) of two stars linked together by a σ-meson. The meson (track α) emerges from the right star, moves to the left, and produces the left star. The meson is therefore probably a σ-meson of mass of $300m_0$. Moreover, the left star has three prongs (β, γ, δ), one of which (β) is a proton of only 5 Mev; from consideration of the nuclear potential barrier, it is probable that this star represents the disintegration of a light nucleus, and this again indicates that the absorbed meson is a σ-meson of mass $300m_0$ which has its origin in the star on the right.

But now there is a strange fact: the right star itself seems to be produced by a particle (track 1) coming from a point beyond the left star. Two comments regarding track 1 may be made:

(1) The coincidence between the end of this track and the center of the right star is nearly perfect, even when examined under the highest magnification.

(2) The direction of the track is from left to right, as shown by the rapid increase in grain density from left to right, and also by the scattering. (It is true that the mass of the particle cannot be determined reliably from grain counts, since the track is only about 200μ long. The direction of the track, however, is clearly indicated.)

It thus appears that the right star was produced by a particle (track 1) which comes to rest at the center of the star. If we then compute the energy of the right star, taking into account the neutrons as well as the σ-meson, it turns out the mass of the incident particle must exceed $700m_0$. The comparison of the grain density of track 1 with that of the proton (β) of the left star leads to

[1] L. Leprince-Ringuet and M. Lhéritier, Comptes Rendus **219**, 618 (1944).

[2] H. A. Bethe, Phys. Rev. **70**, 821 (1946).

[3] G. D. Rochester and C. C. Butler, Nature **20**, 855 (1947).

[4] R. Brode, Rev. Mod. Phys. **21**, 37 (1949).

[5] L. Leprince-Ringuet, Hoang Tchang-Fong, L. Janeau, and D. Morellet, Comptes Rendus **226**, 1897 (1948).

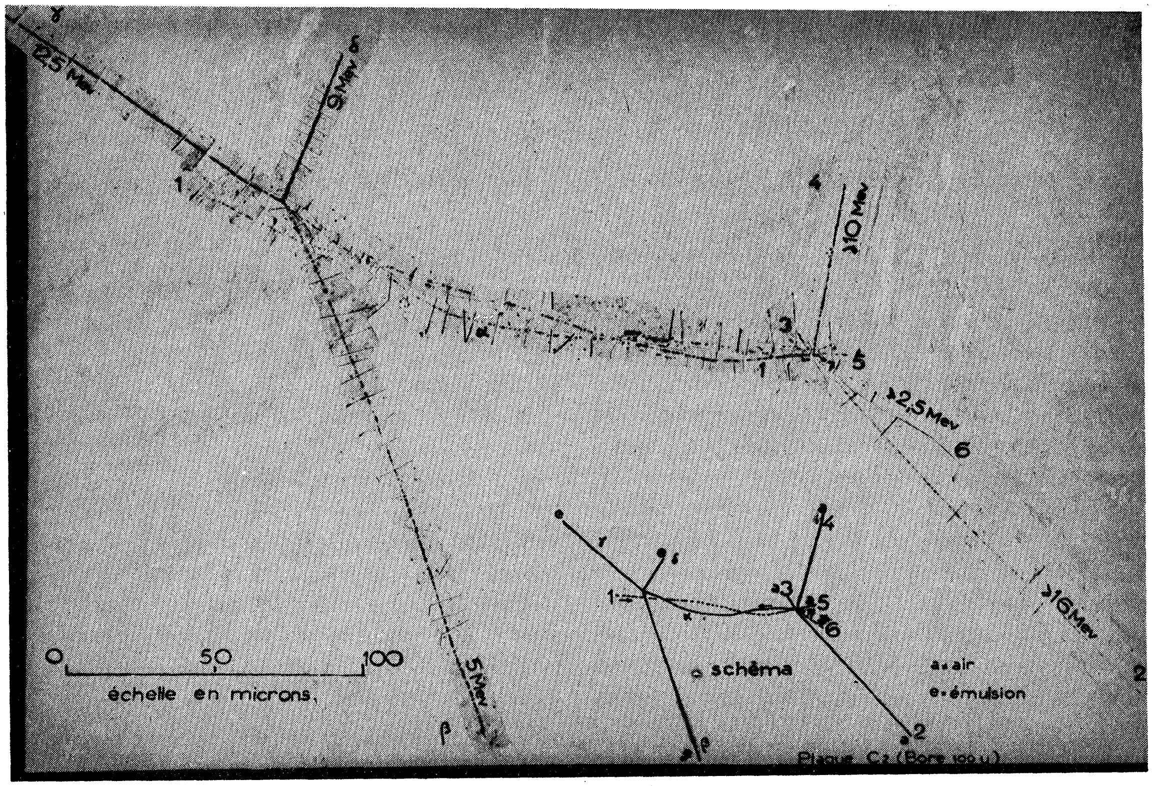

FIG. 1. Two stars linked by a σ-meson.

a conclusion which is in good agreement with this assumption.

As another possible (but very improbable) explanation of this phenomenon, one may assume that track 1 is a faded proton track which is in no way related to the two stars but by pure accident happens to end at the center of the right star; the probability for this is certainly less than 1 percent.

This photograph, therefore, furnishes evidence in favor of the existence of a negative meson whose mass is at least $700m_0$ and which interacts with nuclei. It appears probable that this particle is the same as that mentioned in (A), except that its manifestation is different, since in the present case it produces a nuclear disintegration, while in the previous cases observations were made during the motion of the particle or at the moment of its disintegration in flight.

We may then ask if, among the isolated mesons observed in photographic emulsions, there are very heavy mesons which we call τ-mesons. This question cannot be answered at present because our plates are usually exposed over a period of several weeks, thus causing fading among the tracks with the result that we get from the grain counts a mass spectrum almost continuous between $200m_0$ and the proton mass. We are therefore unable to detect with certainty the τ-mesons which come to rest in the emulsion without giving rise to nuclear phenomena.

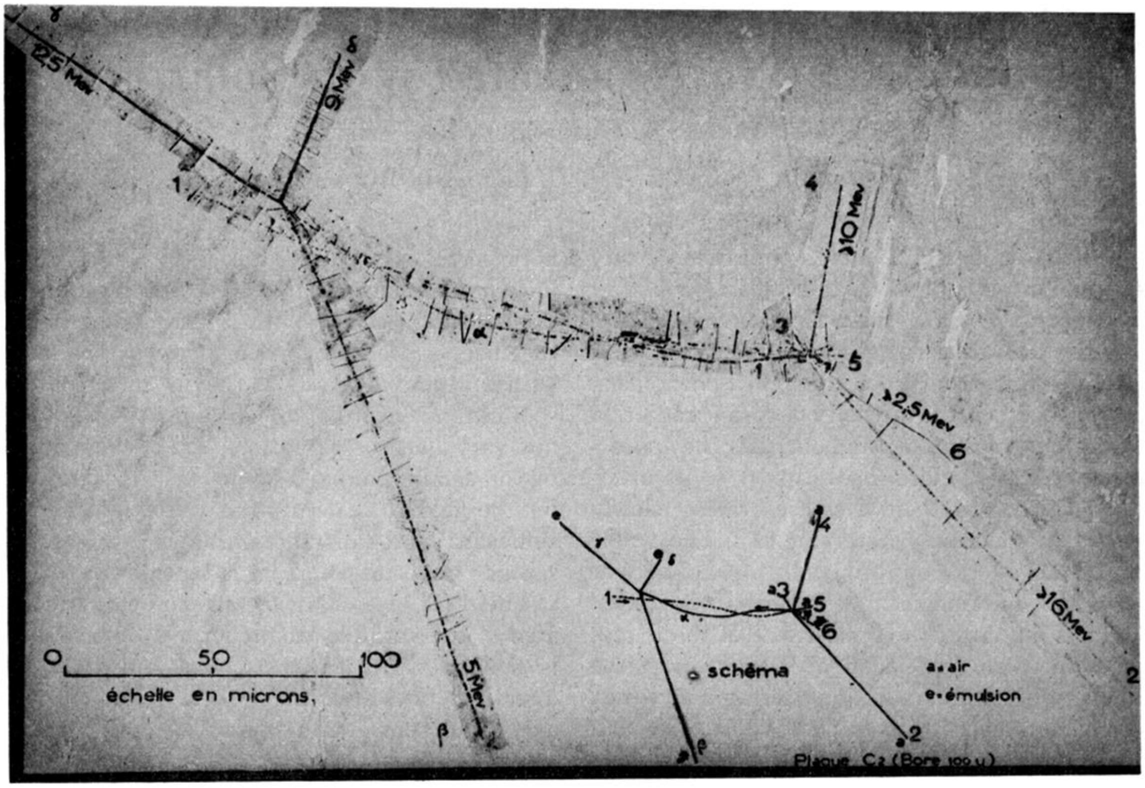

FIG. 1. Two stars linked by a σ-meson.