

Subtracting from our measured intensities the level of star intensity, given by the exponential absorption law with $L_{Pb}=320$ g/cm², e.g., by the points of George and Jason, we find an additional intensity of mainly few-pronged stars, very similar to the transition curve of photon-produced showers.⁶ However, there are some difficulties. From the comparison of the known multiplication of the cascade-component in lead with the peak of our transition maximum of stars, one is led to the conclusion that several percent of the stars in air should be initiated by photons; the cross section would be $\sigma_{air} \sim 10^{-26} - 10^{-27}$ cm². This is not consistent with recently reported results of Kikuchi,⁷ showing a cross section $= 4 \times 10^{-28}$ cm² for star production by 300-Mev photons. As far as our experiments go, we can, from an energy point of view, exclude a transition effect of nucleons as responsible for the additional frequency of stars at this altitude.⁸ There remains the possibility of an interaction of mesons.

It is difficult, too, to understand the second increase of star frequency beginning at about 15 cm Pb, which is scarcely due to statistical deviations. Together with a point of George and Jason at 28 cm Pb, it suggests a second maximum. One may suppose a connection between this phenomenon and the second maximum of the Rossi curve, recently published by Bothe and Thurn.⁹

Further experiments aiming at a more detailed study of these phenomena are in progress.¹⁰

* Reported at the conference of Verband Deutscher Physikalischer Gesellschaften, Bad Nauheim, October, 1950.

¹ Bernardini, Cortini, and Manfredini, *Phys. Rev.* **74**, 845 (1948).

² E. P. George and A. C. Jason, *Proc. Phys. Soc. (London)* **62**, 243 (1949).

³ K. H. Höcker and E. Schopper, *Ann. Physik* **6**, 338 (1949).

⁴ With special nuclear track microscopic equipments supplied by Fr. Ernst Leitz, Wetzlar (Germany).

⁵ Heitler, Powell, and Heitler, *Nature* **146**, 65 (1940).

⁶ B. Rossi and L. Janossy, *Proc. Roy. Soc. (London)* **A175**, 88 (1940).

⁷ S. Kikuchi, *Phys. Rev.* **80**, 492 (1950).

⁸ Schopper, Höcker, and Kuhn, *Phys. Rev.* **82**, 445 (1951).

⁹ W. Bothe and H. Thurn, *Phys. Rev.* **79**, 544 (1950).

¹⁰ To be published in *Z. Naturforsch.*

Secondary Nucleons in Lead

E. SCHOPPER, K. H. HÖCKER, AND G. KUHN

Technische Hochschule, Stuttgart, Germany, and Forschungsstelle für Physik der Stratosphäre, Weissenau, Germany

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TRANSITION effects of cosmic-ray stars¹ and of low energy neutrons, observed in lead at 3000 m, suggest some considerations concerning the production of secondary nucleons in lead.

As to stars, there is good reason to believe that most of them at this altitude are produced by secondary nucleons originating in nuclear disintegrations. Thus the formation of the nuclear component is a cascadelike process, which may happen in different ways in absorber material and in air, respectively.

We have observed in our experiments an increase in the number of neutron-produced single tracks of protons, beginning and ending in the photographic emulsion (Kodak NT 4 plates), by a factor of roughly 2.5 with varying thickness of the lead absorber (Fig. 1). This is in agreement with experiments of Tongiorgi.²

The particles of the nucleonic component can be divided roughly into three groups. The first, containing particles of relativistic energy, produces mesons and secondary nucleons. For the second group (10^9 ev $> E > 10^8$ ev) meson production is negligible. The third group ($E < 10^8$ ev), containing mainly neutrons, gives rise to single protons but not to stars.

Assuming the probability of nuclear collisions per gram to be proportional to A^{-1} (A = mass number) and the number of secondary nucleons starting in a nuclear disintegration to be proportional to $A^{2/3}$, we find the number N of secondaries per gram proportional to $A^{1/3}$, and the ratio $N_{Pb}/N_{air} = 2.4$. The energy transferred to these secondary nucleons is due to the energy loss

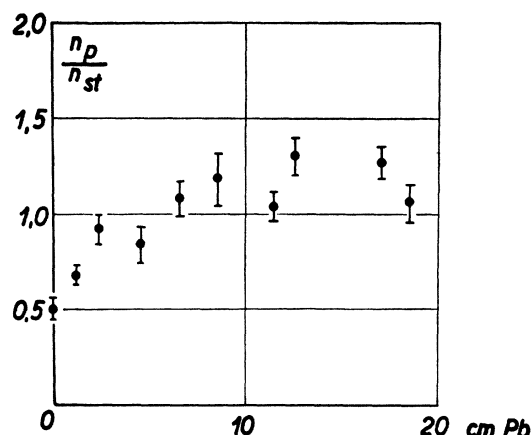


FIG. 1. Intensity of neutron-produced single proton tracks (n_p) under Pb screens, relative to the star intensity of the unscreened plate (n_{st}).

of their primaries, that is, proportional to A^{-1} . Thus, we have a greater number of secondaries in lead with smaller energy.

Nucleons of the first group being rather rare at 3000 m, the main contribution to star production will be made by nucleons of the second group. From the foregoing considerations their secondaries in lead are not expected to initiate further stars at a sizable rate, since they belong mainly to the third group. It seems, therefore, not probable that the transition effect of stars in lead³ can be attributed to secondary nucleons produced in lead, regardless of the shape of the transition curve itself. This is, however, not conclusive for higher altitudes, where a nucleonic transition effect of star intensity in lead may occur because of the comparatively greater frequency of first-group nucleons.⁴

¹ Schopper, Höcker, and Kuhn, *Phys. Rev.* **82**, 444 (1951).

² V. C. Tongiorgi, *Phys. Rev.* **76**, 517 (1949).

³ Bernardini, Cortini, and Manfredini, *Phys. Rev.* **74**, 845 (1948); **76**, 1792 (1949).

⁴ G. N. Whyte, *Phys. Rev.* **78**, 630 (1950).

A Cloud-Chamber Study of the New Unstable Particles*

H. S. BRIDGE AND M. ANNIS

Department of Physics and Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

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IN a set of pictures taken with a large multiple-plate cloud chamber at 700 g cm⁻² atmospheric depth, we have observed 10 examples of tracks that deviate suddenly in the gas of the chamber. These are similar to the "V" tracks reported by Rochester and Butler,¹ by Seriff, Leighton, Hsiao, Cowan, and Anderson,² and recently by Fretter.³ Of these 10 events, 4 can be interpreted as neutral-particle decays, 4 as charged-particle decays, while 2 are uncertain as to type.

Of the 4 neutral-particle decays, 2 show one of the decay products ionizing heavily and stopping in a plate. In 2 cases it is possible to say from ionization, range, and scattering that one of the decay products is probably a meson.

In general, we could not ascertain whether the plane of the "V" contained the origin of the event which gave rise to the neutral particle. However, in one case in which many penetrating particles were seen to traverse the chamber vertically, the plane of the "V" was nearly horizontal. In most events of this type reported up to the present, the triggering system was such as to favor events in which the V was vertical.