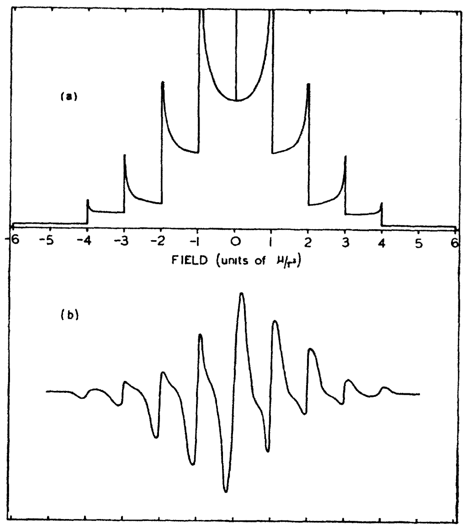

FIG. 1. (a) Calculated line shape for Sb^{121} in a polyoriented assembly of $[SbF_6]^-$ ions. (b) Line shape derivative after broadening the line shown in (a).

closely with the experimental curve of Proctor and Yu. The outer pair of lines are each derived from a configuration of weight 1 in 64 only, and for this reason scarcely show on their record. (The left-hand member is actually just visible.) This also explains why the second moment of their curve is rather less than the calculated value of 7.2 gauss². The nine lines are separated by intervals of $\mu(F^{19})/r^3$ or 1.79±0.05 gauss. The separation on the experimental record is 1.86±0.05 gauss, in satisfactory agreement with the theory.

It now remains to explain why the ionic reorientation frequency about one tetrad axis should be higher than the frequency line width, while about other axes it is lower. A probable explanation is to be found in terms of the well-known polymerization of hydrogen fluoride. In the gas the molecules form zigzag hydrogen-bonded chains of about four units; the solid consists of infinite zigzag chains; the liquid is certainly associated although the degree is not known. Thus, it seems possible that the $[SbF_6]^-$ ion can form a link in a hydrogen fluoride chain, two subchains $(HF)_n$ being connected to two opposite fluorine atoms of the octahedral ion. If the effective length of the chain is $\sim r$ times the ionic diameter, the reorientation frequency about the tetrad axis through the connected corners will be $\sim r^3$ times that for end-over-end motion of the chain.[6] Intramolecular reorientation of the ion about this tetrad axis is also very likely. For $r \sim 10$, in order that the end-over-end frequency be less than the frequency line width, the viscosity of the liquid need only be ~2 poise, which is a more reasonable value.

[1] W. G. Proctor and F. C. Yu, Phys. Rev. **81**, 20 (1951).
[2] J. H. Van Vleck, Phys. Rev. **74**, 1168 (1948).
[3] This represents the intramolecular contribution only.
[4] H. S. Gutowsky and G. E. Pake, J. Chem. Phys. **18**, 162 (1950).
[5] Bloembergen, Purcell, and Pound, Phys. Rev. **73**, 679 (1947).
[6] P. Debye, *Polar Molecules* (Dover Publications, New York, 1945), Chapter V.

Transition Effects of Star-Producing Cosmic Radiation in Lead*

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THE frequency of cosmic-ray stars produced under various thicknesses of lead has been investigated by Bernardini, *et al.*,[1] and by George and Jason.[2] Continuing former experiments of our laboratory with photographic emulsions concerning the star-producing radiation,[3] we have studied[4] in more detail transition effects of star production under absorbers of lead and carbon at the Zugspitze observatory (2950 m).

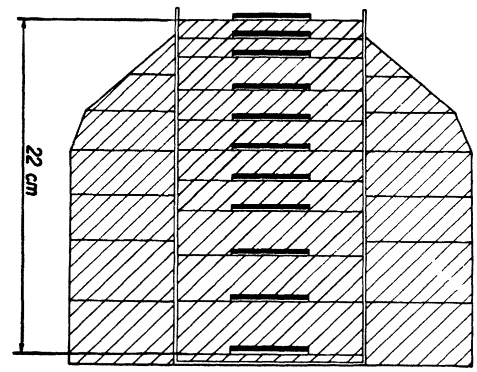

FIG. 1. Lead absorber.

The plates (Kodak NT 4) were placed horizontally in different depths of the absorber as shown in Fig. 1 and exposed simultaneously for about 20 days in October, 1949, and May, 1950, respectively. In order to avoid fading effects the plates were kept in a nitrogen atmosphere and were developed to nearly two times minimum ionization, thereby facilitating particle discrimination.

In Fig. 2 the relative star intensity under lead has been plotted (solid circles) *versus* thickness of the absorber. We have recorded all events with at least two tracks, one of them longer than 70μ, radiating from a common center. Possible cases of scattering were excluded. We have added the data of George and Jason (open squares) and those of Bernardini and collaborators (open triangles), normalized at 0 cm Pb. They are in good agreement with our results, regarding the general shape of the absorption curve given by the mean range $L_{Pb} = 320$ g/cm² for *N*-radiation. For the absolute star intensity in the unscreened plate we find $z = 14.5$ stars cm⁻³ day⁻¹.

The more detailed variation of absorber thickness in our arrangement leads to a distinct maximum at about 1.2 cm Pb, confirming the existence of a transition effect. We could also find the transition effect for single protons, not plotted here, previously observed by Heitler and Powell.[5]

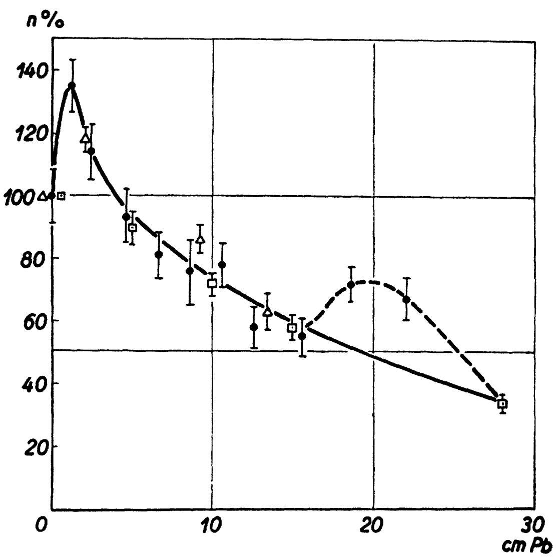

FIG. 2. Relative number of cosmic-ray stars (*n* percent) at 2950 m under various thicknesses of lead. The solid circles represent our data, the open squares the data of George and Jason, and the open triangles the data of Bernardini, *et al.*

Subtracting from our measured intensities the level of star intensity, given by the exponential absorption law with $L_{Pb}=320$ g/cm^{-2}, 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 $\sigma_{air}\sim 10^{-26}-10^{-27}$ cm^2. This is not consistent with ecently reported results of Kikuchi,[7] showing a cross section $=4\times 10^{-28}$ cm^2 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

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Transition effects of cosmic-ray stars[1] 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 $A^{-\frac{1}{3}}$ (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 $A^{+\frac{1}{3}}$, and the ratio $N_{Pb}/N_{air}=2.4$. The energy transferred to these secondary nucleons is due to the energy loss

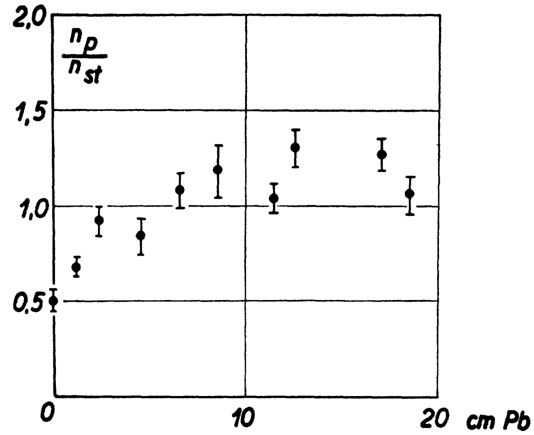

Fig. 1. Intensity of neutron-produced single proton tracks (n_p) under Pb screens, relative to the star intensity of the unscreened plate (n_{st}).

of their primaries, that is, proportional to $A^{-\frac{1}{3}}$. 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 lead[1,3] 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*

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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.