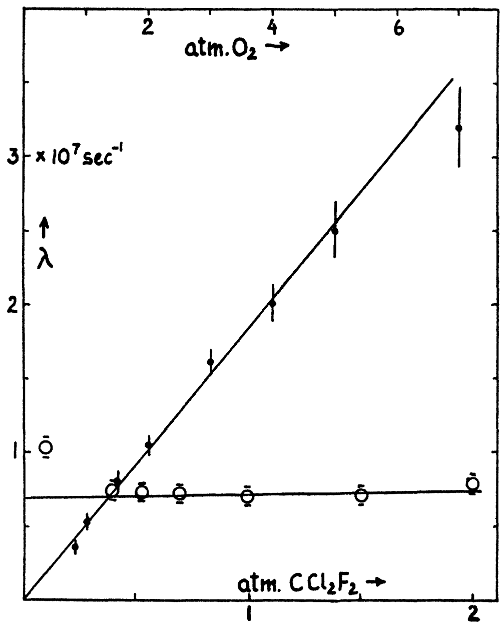

FIG. 1. Rate of decay of annihilation radiation in CCl_2F_2 (open circles) and in O_2 (full circles). The pressure scales are adjusted so that the abscissa corresponds to the same electron density in both gases.

trons, the delayed annihilation radiation in Freon at moderately high pressure seems to be due entirely to ortho-positronium. Its decay rate should depend somewhat on gas pressure p so that $\lambda=\lambda_0+ap$. The pressure proportional term represents annihilation in collisions with Freon or impurity molecules.

The method used to measure the decay rate was the same as in the previous communication.[4] Figure 1 shows the results as a function of gas pressure. The straight line represents the equation $\lambda=6.8\times10^6+0.3\times10^6 p$. The value $\lambda_0=6.8\times10^6$ sec^{-1} for the rate of three-quantum decay, obtained by extrapolating the line to zero pressure, should be good to ten percent. The coefficient $a=0.3\times10^6$ sec^{-1} atmos^{-1} is rather uncertain. In any case, a is small, in agreement with calculations of Ore concerning the great stability of positronium against collisions in most gases. The point in Fig. 1 at 0.1 atmosphere which does not fall on the straight line is included to show the effect of free positrons at low pressures.

For comparison, Fig. 1 also shows the decay rate of annihilation radiation in oxygen as a function of pressure. In this gas, at pressures above about 0.5 atmosphere all positronium is converted to the para state so rapidly that substantially all delayed annihilation radiation is due to free positrons decaying in collisions. The rate of decay is, therefore, directly proportional to gas density as shown in Fig. 1. A more detailed discussion of both curves will be given in a later communication.

We wish to thank Professor H. Primakoff for valuable discussions.

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[1] A. Ore and J. L. Powell, Phys. Rev. **75**, 1696 (1949).
[2] E. M. Lifshitz, Doklady Akad. Nauk S.S.S.R. **60**, 211 (1948).
[3] D. Ivanenko and A. Sokolov, Doklady Akad. Nauk S.S.S.R. **61**, 51 (1948).
[4] M. Deutsch, Phys. Rev. **82**, 455 (1951).

A Tentative Interpretation of the Second Maximum in the Transition Curve for Cosmic-Ray Showers

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THE experimental results on the second maximum still remain in controversy. Bothe *et al.*[1,2] have repeatedly reported the second maximum in the transition curve at 15-cm Pb. While others found a small hump not necessarily at the same place or even nothing at all, formerly Clay,[3] and recently Kameda and Miura,[4] Fenyves and Haiman,[5] and Chaudhary[6] confirmed its existence. The explanation probably lies in the interpretation of this phenomenon, and the discrepancy in experimental results arises possibly from the differences in the arrangement of counters[6] or in the sensitivity of counters to low energy photons.

The nature of primary and secondary particles of the narrow showers responsible for the second maximum remains unknown. Schmeiser and Bothe[7] found that the second maximum is more prominent in the basement than under the roof. Absorption measurements[7] on the secondary particles produced in 1.5 cm Pb as well as in 15 cm Pb show that their coefficients of absorption are much smaller than those of electrons; the particles from 1.5 cm Pb are even more penetrating. In adjacent absorbers these penetrating particles produce further soft showers, the so-called *Zusatzstrahlung*.[8] Bothe[1] considered the narrow showers as the production of mesons by mesons, a new process not yet definitely confirmed by other experiments. In a sub-basement under about 60 cm concrete and with 15 cm Pb above a cloud chamber, Shutt[9] observed many showers containing two penetrating particles making an angle around 6 degrees, the frequency being 1 shower for every 4000 single penetrating particles; Jánossy[10] gave 1 in 12,000. The frequency of a meson accompanying a knock-on electron, which constitutes essentially the background of the transition curve, is 6.9 per 100 mesons[11] near sea level. Therefore, in a cloud chamber the knock-on phenomenon is at least 280 times more frequent than a penetrating pair originating from the lead above it. The selection by counters due to absorption and arrangements reduces the knock-on electrons, but a maximum as large as 35 percent (curve C^2)—that means the frequency of penetrating showers is increased about one hundred times by counters —can never be expected due to penetrating showers. Furthermore, a small maximum probably exists in the transition curve (curve d^2) for non-ionizing primaries; about 65 percent of narrow showers from 1.5-cm Pb are produced by non-ionizing primaries[8] and 25 percent from 15-cm Pb;[8] these facts quickly rule out the meson as the primary.

Kameda and Miura[4] proposed nucleons as primaries. Small angle showers are less penetrating, according to theory and experiment, but frequency considerations still render this proposal impossible. The nucleon intensity decreases much faster than the knock-on electrons in the underground, while the secondary mesons are not shower-producing. Transition curves for penetrating showers are either saturated at great thicknesses[10] or even increase appreciably;[9] no experiment[12] gives a sharp maximum. Only the soft components associated with the penetrating particles, such as knock-on electrons and gamma-radiations in nuclear phenomena, could probably produce a maximum. The striking difference[8] in the contribution of ionizing and non-ionizing primaries at 1.5 and 15 cm Pb cannot be understood with the known properties of protons and neutrons. Because nucleons have a comparatively long mean free path for showers of small multiplicity,[13] it is surely impossible that there are more penetrating showers at 1.5 cm Pb than at 15 cm.

It seems that narrow showers are intimately connected with the soft component. The only thing necessary is to explain the abnormal coefficient of absorption and the possibility of a second maximum appearing. Without introducing new unstable particles,[6] I have tentatively applied the idea of Cocconi and Greisen[14] to explain a small maximum[15] (it may be called rather an irregularity at present) between 5 and 10 cm in the transition curve. A similar irregularity in the same region was present in the curve of Altmann, Walker, and Hess,[16] and also in the Hg curves of Clay.[3] Cascade showers die out by leaving a large number of photons of the order of critical energy, their minimum coefficient of absorption, 0.19 per radiation length (or 1/2.7 per cm lead), being much smaller than that of electrons. The surviving photons degrade their energy mainly by the Compton process, and less frequently by pair production. Some electrons produce further bremsstrahlung, while the positrons annihilate and produce photons. If the multiplication or the cascade of very low energy photons compensates more than the decrease in photon-efficiency of counters, the transition curve rises again and reaches a maximum after about 5 cm Pb (twice the mean free path of the photons of minimum absorption). The counters are triggered essentially by the production of photoelectrons or Compton electrons on their metallic walls. Counters of thin glass walls covered with metal increase the maximum appreciably. The small angle arrangements of Bothe constitute another factor favorable to the maximum. Owing to Compton and coulomb scattering, low energy photons and electrons deviate widely from their origin. The concurrent particles of the shower proper may easily miss the detector, but scattering increases the chance to detect its residual rays. All the difficulties, such as the large magnitude of the maximum, the differences in the behavior of ionizing and non-ionizing primaries, the independence of angle and multiplicity,[3] the associated *Zusatzstrahlung*, etc., can be understood very well. The irregularity between 5 and 10 cm probably arises from the discontinuity in the energy spectrum of soft components; near sea level low energy electrons, and particularly photons, are more abundant below 200 Mev.[17] To avoid the nuclear phenomena and to eliminate the softer primaries, underground measurements should give better results. Whether this hypothesis is good or not can be decided by experiments.

[1] W. Bothe, Revs. Modern Phys. **11, 82 (1939)**, and the references contained in this article.
[2] W. Bothe and H. Thurin, Phys. Rev. **79**, 544 (1950).
[3] J. Clay, Revs. Modern Phys. **11**, 287 (1939); **21**, 82 (1949).
[4] T. Kameda and I. Miura, Prog. Theor. Phys. **5**, 323 (1950).
[5] E. Fenyves and O. Haiman, Nature **165**, 244 (1950).
[6] P. K. Sen Chaudhary, Phys. Rev. **81**, 274 (1951).
[7] K. Schmeiser and W. Bothe, Ann. Physik **32**, 161 (1938).
[8] K. Schmeiser, Z. Physik **110, 443** (1938); **112**, 501 (1939).
[9] R. P. Shutt, Phys. Rev. **69**, 261 (1946).
[10] L. Jánossy, Proc. Roy. Soc. (London) **A179**, 361 (1941); Phys. Rev. **64**, 345 (1943); L. Jánossy and G. D. Rochester, Proc. Roc. Soc. (London) **A183**, 181 (1944).
[11] Brown, McKay, and Palmatier, Phys. Rev. **76**, 506 (1949).
[12] Up to the present time the only exception seems to be the experiment of Kameda and Miura. Their transition curves for narrow and wide angle penetrating showers are at complete variance with other workers. It is not clear that they are really contributed entirely by penetrating particles. One does not know whether their first and second maxima at 5 and 17 cm are really the second and third maxima (total thicknesses of lead equal to 15 and 27 cm) or not.
[13] W. D. Walker, Phys. Rev. **77**, 687 (1950).
[14] Cocconi, Cocconi Tongiorgi, and Greisen, Phys. **Rev. 75, 1063** (1949); K. Greisen, Phys. Rev. **75**, 1071 (1949).
[15] R. Maze and Tsai-Chü, Compt. rend. **232**, 224 (1951).
[16] Altmann, Walker, and Hess, Phys. Rev. **58, 1011** (1940).
[17] D. J. X. Montgomery, *Cosmic Ray Physics* (Princeton University Press, Princeton, New Jersey, 1949), p. 263.

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Proceedings of the American Physical Society

Minutes of the Meeting at Schenectady, New York, June 14–16, 1951

THE 307th meeting of the American Physical Society, being the 1951 Summer Meeting in the East, was one of the delightful small meetings which more or less alternate with those that are huge and congested; and it was particularly delightful because of the excellent planning of our hosts, who were the General Electric Company and Union College. It was held at Schenectady, New York, on Thursday, Friday, and Saturday, June 14, 15, and 16, 1951. The attendance was over 400; this is believed to have made it the largest summer meeting which we have ever held, apart from the Semi-Centennial Meeting of 1949. The programme comprised sixty-four contributed papers and seventeen invited papers, their topics distributed widely over the field of physics: it is reproduced *in toto* on the following pages. Cool rain fell throughout the Thursday and the Friday, distressing to those who did not remember that sunny June days in the Northeast are likely to be hot, distressing also to our hosts of General Electric who had hoped to offer us the hospitality of their gardens as well as that of their laboratory "The Knolls." Mention should be made that General Electric provided a fleet of buses to take our members to and fro between their living-quarters and the Knolls, and gave us a reception on the Thursday afternoon; and that Union College extended to our members the privilege of living in its new dormitory, and put three of its buildings at our disposal for the scientific sessions. The heads of the very efficient Local Committee were L. R. Apker and M. H. Hebb of General Electric, and H. E. Way of Union College.

The banquet of the Society was held in the Van Curler Hotel on the Friday evening with an attendance of 170. Messrs. Hebb and V. Rojansky made brief and witty remarks, and V. J. Schaefer gave the principal after-dinner speech under the title "Cloud Physics."

The Council met on the Friday afternoon, and elected three candidates to Fellowship and one hundred and forty-seven to Membership: their names are appended. It was decided that beginning in 1952, *Journal of Chemical Physics* shall be offered to our members on membership subscription as an "option" alternative to *Physical Review*—without payment beyond regular dues. Also beginning in 1952, as stated in the Minutes of the Washington meeting, an extra payment of \$2.00 (in addition to dues) will be required from each member who subscribes to either section of Science Abstracts and an extra payment of \$7.50 from any member who subscribes to both. The Society will also make an annual grant or subsidy to the management of "Science Abstracts" as a contribution to the fixed charges of that journal, and the Council approved a specific proposition, in line with the report of the Committee on Science Abstracts at the Washington meeting.

Reports reaching the office of the Society indicate that we have lost through death Arnold Sommerfeld