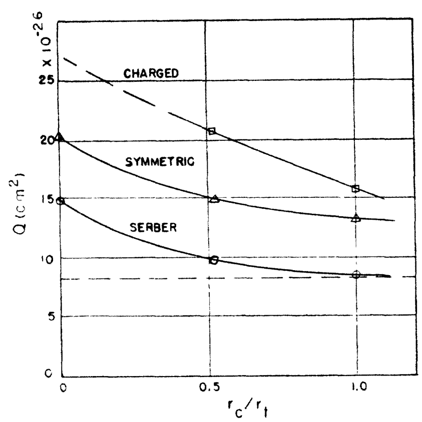

FIG. 2. Total cross section Q for symmetric, charged and Serber interactions plotted against r_c/r_t.

TABLE I. Total n–n and n–p cross sections Q in units of 10^{-26} cm² and ratio of scattering at 180° to 90° for potentials A and B.

	A				*B*	
	Neutron-proton		Neutron-neutron		Neutron-proton	
	Q	$\sigma(180°)/\sigma(90°)$	Q	$\sigma(180°)/\sigma(90°)$	Q	$\sigma(180°)/\sigma(90°)$
Symmetric	14.91	9.59	4.23	25.37	20.29	5.60
Charged	20.68	8.87	21.20	16.96	Over 22	——
Serber	9.92	4.09	——	——	14.92	4.64

wave functions as solutions outside the well. The phases were then corrected by adding a perturbation inside the well to allow for the Coulomb field there. The resulting phases differed in most cases by less than one percent from the n–p phases and the greatest difference was two percent. At this energy therefore it is reasonable to neglect the Coulomb potential in the calculation of the phases.

The angular distributions for n–n and p–p scattering are shown in Fig. 3 for the charged and symmetrical cases. The cross section at 90° (center-of-mass system) is considerably less than that given by Ashkin and Wu[7] at 100 Mev using the potential of Rarita and Schwinger[8] including the tensor forces. This could therefore be regarded as an effect arising from the double range.

At about 15° the p–p cross section falls below the n–n. The opposite is the case in the distributions described by Barker and Ravenhall[9] where the p–p cross section remains steadily above the n–n. The reason for this is that in the central force case the ^3P phase is negative and so the imaginary parts of the scattered amplitude add. For the potential used here, the $^3P_0$ phase is large and positive, and the interference between the Coulomb and the nuclear wave gives rise to the above effect. The total cross sections for n–n scattering for the charged and symmetric cases and also the ratios of the differential cross sections at 90° to those at 180° are given in Table I.

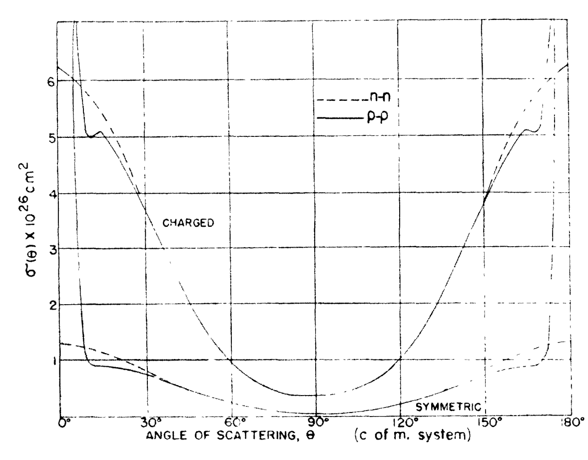

FIG. 3. Differential p–p and n–n cross sections for potential A.

We would like to thank Dr. Hu and Dr. Burhop for their assistance and suggestions, and Professor Massey for his continued interest.

[1] M. Camac and H. A. Bethe, Phys. Rev. **73**, 191 (1948).
[2] J. M. Blatt, Phys. Rev. **74**, 92 (1948).
[3] D. Padfield, Nature **163**, 22 (1949).
[4] R. B. Sutton *et al.*, Phys. Rev. **72**, 1147 (1947); C. G. Shull *et al.*, Phys. Rev. **73**, 842 (1948).
[5] F. Ledsham (to be published).
[6] Massey, Burhop, and Hu, Phys. Rev. **73**, 1403 (1948).
[7] J. Ashkin and T. Wu, Phys. Rev. **73**, 973 (1948).
[8] W. Rarita and J. Schwinger, Phys. Rev. **59**, 436 (1941); **59**, 556 (1941).
[9] Barker and Ravenhall, Nature **163**, 20 (1949).

Cosmic Rays at a Great Depth

Y. MIYAZAKI
Scientific Research Institute, Ltd., Tokyo, Japan
September 30, 1949

AFTER our experiments[1] at 1400 meter water equivalent in Shimizu Tunnel by using arrangement I in Fig. 1, we continued the same kind of measurements at 3000 m.w.e. in the same tunnel from August, 1940, to the end of 1945 with the same apparatus, and proved that intensities at the latter point were about 1/10 those at the former depth as shown in Fig. 2. The intensity *versus* depth curve is given in Fig. 3. We also measured the absorption by lead of various thickness and found that the shape of the absorption curve was almost the same as at 1400-m.w.e. depth and the existence of showers was remarkable just as at 1400 m.w.e. Therefore the cosmic-ray particles at 1400- and 3000-m.w.e. depth are concluded to have the same nature. The absorption curve is of a form similar to that on the ground and therefore the particles are presumably mu-mesons which are the decay product of pi-mesons.

The showers-to-singles under various thicknesses of lead at the two depths can be seen from Fig. 2. They are about $\frac{1}{4}$ and $\frac{1}{3}$ at 1400 m.w.e. and 3000 m.w.e., respectively.

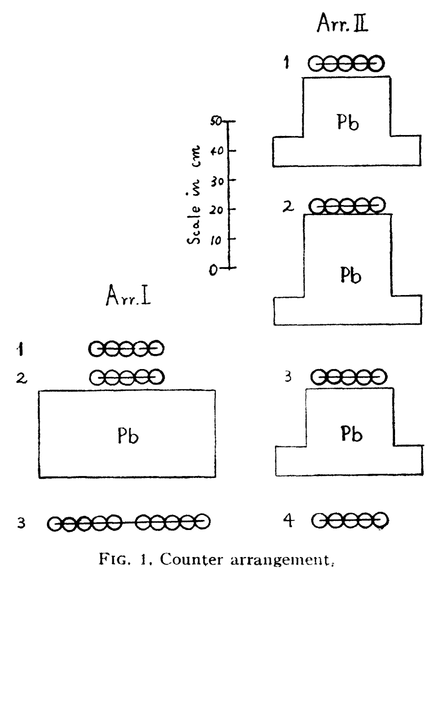

FIG. 1. Counter arrangement.

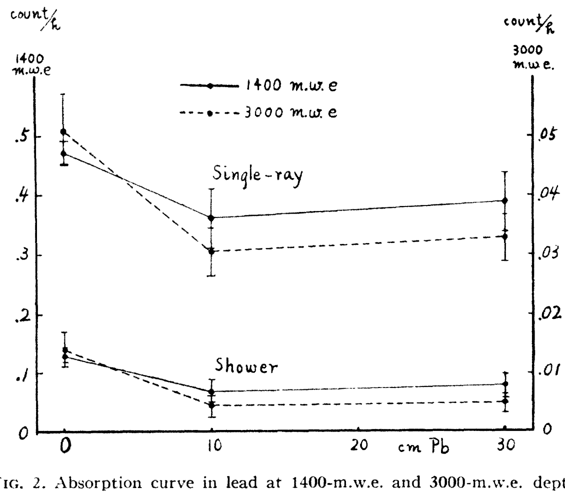

FIG. 2. Absorption curve in lead at 1400-m.w.e. and 3000-m.w.e. depth.

Barnothy and Forro[2] published their results, stating that almost all of the particles were absorbed by 90 cm of lead at a depth 1000 m.w.e. Therefore we increased the thickness of the lead up to 100 cm using arrangement II as shown in Fig. 1. Our results agree with the data published later by these authors.

The vertical incident radiation computable from $\cos^2$ distribution law yields the following value:

$$J_{\text{Arr I}} = 0.0039\ h^{-1}\ \text{cm}^{-2}\ \text{sterad}^{-1},$$
$$J_{\text{Arr II}} = 0.0038\ h^{-1}\ \text{cm}^{-2}\ \text{sterad}^{-1}.$$

The results of absorption obtained by arrangements I and II are plotted on one curve as shown in Fig. 4. From this, we see that a greater part of cosmic-ray particles are absorbed, but about $\frac{1}{5}$ still remained under 100 cm of lead. It is not possible to decide whether the cosmic rays which penetrate such a large amount of rocks and come to this depth are ionizing rays or non-ionizing ones.

If we assume them to be ionizing rays, at least $\frac{4}{5}$ of the particles found at this depth must be of secondary origin produced in rocks and the primary cosmic rays must be less than $\frac{1}{5}$. On the other hand, if we assume them to be non-ionizing rays, most of the particles which were measured at this depth must be hard shower particles produced by non-ionizing rays, $\frac{1}{5}$ of them having such a high energy as to enable them to penetrate one meter of lead.

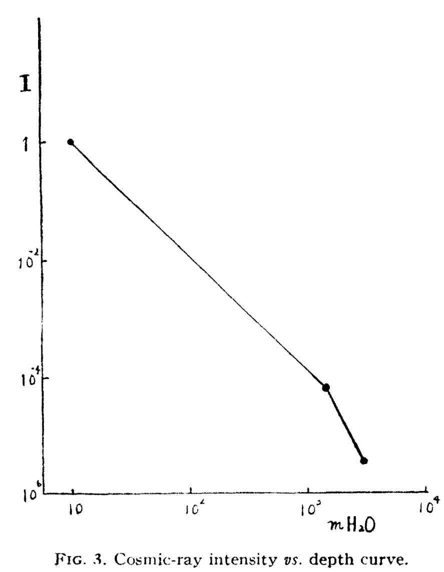

FIG. 3. Cosmic-ray intensity *vs.* depth curve.

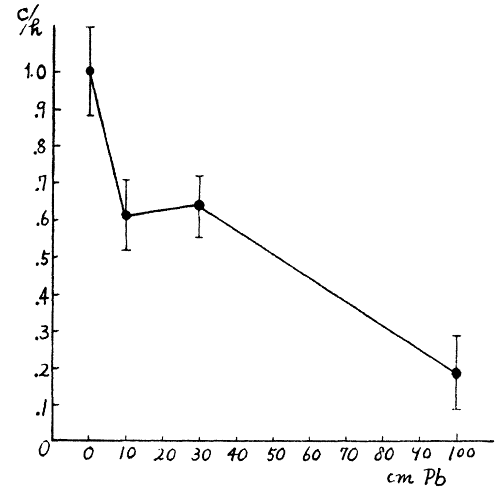

FIG. 4. Absorption of cosmic rays in lead at 3000 m.w.e.

In order to ascertain the nature of cosmic rays underground at such a depth, it is necessary to use a thicker absorber, and also a hodoscope and cloud chamber for determining the relation between various particles observed.

Unfortunately this work had not been completed when fire destroyed all instruments in February, 1946. It is very difficult to reconstruct new equipment at present but we intend to carry out the measurements in the future.

This work was done as a part of the program of the Cosmic-Ray Subcommittee of the Japan Society for the Promotion of Scientific Research. Our measurements were made possible by the help rendered by the Department of Railways and we wish to express our cordial thanks to all officials concerned. I should like to express my heartful thanks to Dr. Y. Nishina for his kind guidance and encouragement throughout this work. I also express my coridal thanks to Dr. Y. Sekido and Mr. T. Masuda who helped me in the preparation as well as in the observation throughout this work. But for their help, this work would have not been performed. We also acknowledge the kind help given by Messrs. C. Ishii, M. Iio, the late T. Ikeda, Y. Kawabata, the late H. Muromachi, and all members of Cosmic-Ray Research Group of our Institute.

[1] Nishina, Sekido, Miyazaki, and Masuda, Phys. Rev. **59**, 401 (1941).
[2] J. Barnothy and M. Forro, Phys. Rev. **58**, 844 (1940).

Note on Analysis of Delayed Coincidence Counting Experiments

F. W. VAN NAME, JR.
Department of Physics, Franklin and Marshall College, Lancaster, Pennsylvania
October 10, 1949

IN a recent note in this journal, Binder[1] has described an analysis of delayed coincidence counting experiments. Reference is made to my work[2,3] on the same subject in a way that might be misleading.

In my calculations a triangular distribution of pulse-time delays was used. Since a triangular distribution cannot easily be represented by a single, smooth and analytic function, the range of artificial delays was divided into six regions for calculation purposes only. This division had no bearing on the physical result obtained, as might be inferred from Binder's note.

[1] D. Binder, Phys. Rev. **76**, 856 (1949).
[2] F. W. Van Name, Jr., Phys. Rev. **75**, 100 (1949).
[3] F. W. Van Name, Jr., Ph.D. dissertation, Yale University (1948).