102,000 ft. (0.75 cm Hg pressure). The altitude dependence of the neutron intensity obtained in this flight is shown in Fig. 1, where the counting rate is plotted against pressure in centimeters of Hg. The maximum in the slow neutron distribution as a function of altitude appears at about 8.5 cm Hg and drops down sharply to about one-fourth of its maximum value at 1 cm Hg.

A detailed account of the experiment and the analysis of the results are being prepared for publication and will appear shortly.

* Assisted by the Joint Program of the AEC and the ONR.
** Now at Brookaven National Laboratory, Upton, L. I., New York.

[1] Luke C. L. Yuan, Phys. Rev. **76**, 1267, 1268 (1949). Luke C. L. Yuan and R. Ladenburg, Bull. Am. Phys. Soc. **23**, No. 2, 21 (1948).
[2] Luke C. L. Yuan, Phys. Rev. **74**, 504 (1948).

The Zenith Angle Dependence of the Cosmic Radiation above the Atmosphere at $\lambda = 41°$N* †

S. F. SINGER
Applied Physics Laboratory, Johns Hopkins University, Silver Spring, Maryland
January 9, 1950

IN a previous note[1] we gave preliminary results on the average flux and primary specific ionization above the atmosphere as measured with a G-M counter telescope (Fig. 1) in a V-2 rocket. We wish to present here a more refined breakdown of these results based on analysis of the motion and orientation of the rocket during flight.

In the present experiment, the telescope pointed along an axis parallel to the longitudinal axis of the V-2 rocket. The zenith angle of the missile, therefore, gave the zenith angle of the axis of the telescope independent of the roll orientation of the missile. Very good information on the zenith angle and azimuth during flight was obtained through analysis of photographs of the earth taken by a camera which was mounted in the rocket (Fig. 2). The coincidences of telescope ABC and $AB'C$, not accompanied by guard counts, were assigned to the proper zenith angle interval leading to the results of Table I and Fig. 3.

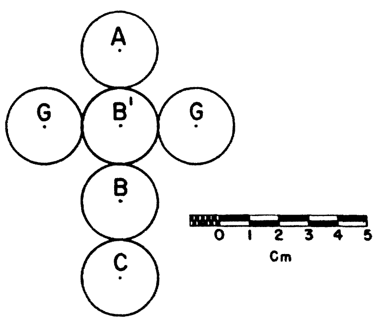

FIG. 1. Low efficiency telescope. All counters have an effective diameter of 2.38 cm and an effective length of 14.5 cm. The low efficiency counter B' is filled with hydrogen to a pressure of 5 cm Hg. Telemetered coincidences: (ABC), $(AB'C)$, and (ACG).

TABLE I. Zenith angle dependence of coincidence counting rate.

Time interval (sec.)	Zenith angle interval	No. of coinc. (ABC)	No. of coinc. $(ABC)\cdot(AB'C)$	Av. directional intensity (telescope ABC) (particles-sec.$^{-1}$-cm^{-2}-sterad.$^{-1}$)	Efficiency: $(ABC)\cdot(AB'C)$ / (ABC)
70–130	0°–15°	58	37	0.078 ±0.010	0.646 ±0.045
130–180	15°–30°	55	36	0.087 ±0.012	
180–270	30°–60°	128	87	0.112 ±0.010	0.680 ±0.041
270–318	>60°	69	51	0.114 ±0.014	0.730 ±0.054

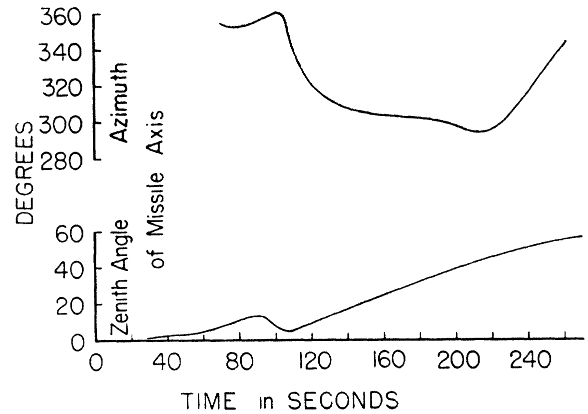

FIG. 2. Zenith angle and azimuth of V-2 rocket fired on February 17, 1949 at the White Sands Proving Ground, New Mexico.

All errors quoted in Table I are standard errors assigned only on the basis of the number of counts.

The values of the directional intensity were obtained by dividing the counting rates (after minor corrections for telescope inefficiency, deadtime, and accidental coincidences) by the telescope's geometric factor (12.6 cm²-sterad.) corresponding to flux incident isotropically from the upper hemisphere, assuming the flux incident from the lower hemisphere to be zero. Because of the "smearing out" caused by the rather wide aperture of the telescope used in this exploratory experiment, the data of Table I and Fig. 3 refer to a directional intensity *averaged* over the geometry of the telescope. The actual variation with zenith angle is probably more rapid than that shown.

From geomagnetic theory and an estimate of the penumbra[2] an "effective" cut-off energy for primary protons has been assigned to sets of zenith and azimuth angles taken from Fig. 2. These cut-off energies range from 4.0 to 3.4 Bev. Assuming a differential energy spectrum of primary protons of the form $E^{-\gamma}dE$, expected intensities have been computed for two extreme values of the

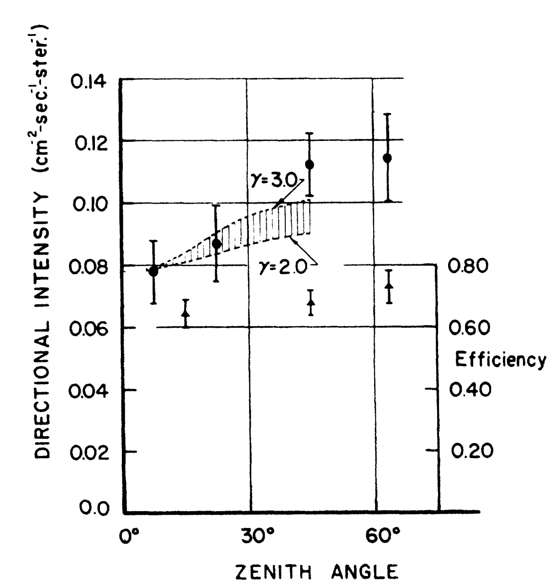

FIG. 3. The average directional intensity (circles) and efficiency of the telescope $AB'C$ (triangles) as a function of zenith angle in a northwesterly direction at $\lambda = 41°$N. The shaded area represents the spread of expected intensities assuming values of the spectrum exponent γ between 2.0 and 3.0.

exponent: $\gamma=2$ and $\gamma=3$. We have superimposed the spread of expected intensities on the experimental points of Fig. 3 for the purpose of comparison. There appears to be a rather definite increase in experimental intensity above the expected value, starting near a zenith angle of 45°.[3] There is also the barest indication of a rise in efficiency with zenith angle, but the number of counts is not large enough to place the increase definitely outside of the statistical error.

Taking these results at their face value, we reach the tentative conclusions: (i) that the near vertical intensity ($j=0.078\pm0.010$ sec.$^{-1}$-cm^{-2}-sterad.$^{-1}$) represents the best upper limit to the primary intensity, and (ii) that low energy secondary radiation produced within the atmosphere contributes to the directional intensity at large zenith angles.

These conclusions are in good accord with those of Van Allen, which are based on a telescope experiment[4] in an Aerobee sounding rocket (Round A-5) at $\lambda=41°$N and also with theoretical considerations by Vallarta[5] on the zenith dependence of the albedo.

I wish to thank Dr. J. A. Van Allen and Professor M. S. Vallarta for valuable discussion, and Messrs. L. W. Fraser, R. S. Ostrander, and F. W. Loomis for their aid in carrying out the experiment and analyzing the camera record.

* This work was supported by the Navy Bureau of Ordnance under Contract NOrd 7386.
† A preliminary account of this work was given at the Echo Lake Conference (June, 1949).
[1] S. F. Singer, Phys. Rev. **76**, 701 (1949).
[2] M. S. Vallarta, Phys. Rev. **74**, 1837 (1948); R. A. Alpher, APL/JHU Internal Report CF-1308 (July 18, 1949).
[3] Based on vertical intensity measurements at $\lambda=0°$ and $\lambda=41°$N, Van Allen and Gangnes have deduced a value for γ of 1.9 [Phys. Rev. (to be published)].
[4] J. A. Van Allen, Echo Lake Conference (June, 1949), and private communication.
[5] M. S. Vallarta (private communication).

On the Nature of the Cosmic Radiation near the Pfotzer Maximum at $\lambda=41°$N* †

S. F. Singer
Applied Physics Laboratory, Johns Hopkins University, Silver Spring, Maryland
January 9, 1950

A DIRECT measurement of the primary specific ionization of the cosmic radiation above the atmosphere by means of a "low efficiency telescope" [1] in a V-2 rocket launched at White Sands, New Mexico ($\lambda=41°$N) has been previously reported.[2] The measurement was carried out essentially by comparing the efficiency of a low pressure hydrogen-filled G-M counter near sea level and above the atmosphere. A small but definite increase was found in the efficiency above the atmosphere leading to the conclusion that the radiation above the atmosphere is predominantly singly charged, but has an average primary specific ionization appreciably higher than minimum. This result is consistent with the interpretation that the charged radiation consists predominantly of high energy (primary) protons of minimum specific ionization with an admixture of (primary) alpha-particles and/or low energy (secondary) protons.

The purpose of this note is to report on data obtained by the telescope in its passage through the atmosphere. In spite of a rather small number of counts, it is apparent that the efficiency of the low pressure counter, and, therefore, the primary specific ionization of the radiation, show a maximum near the position of the Pfotzer maximum of the total cosmic-ray flux. The efficiency measured for the altitude interval 9 to 29 km (approximately 330 to 14 g-cm^{-2}) was 0.764 ± 0.058, compared to a sea-level efficiency[2] of 0.585 ± 0.019 and efficiency above the atmosphere[2] of 0.670 ± 0.027. After applying the corrections discussed previously,[2] this result leads to an average primary specific ionization near the Pfotzer maximum of 1.65 ± 0.35 times the sea-level value. This ratio may have a much higher peak value since it is "smeared out" by the large altitude interval over which the data were taken.

The immediate gross conclusion, which is valid in spite of the large statistical error of the result, is that the bulk of the cosmic-ray flux at high altitudes, which is known to be easily absorbable,[3] does not consist of low energy electrons (5–50 Mev). The argument runs as follows: The particles registered by the telescope after traversing the low pressure counter must possess an additional range of about 2 g-cm^{-2} of copper. For electrons this corresponds to an energy of at least 6 Mev. However, electrons in this energy range exhibit a primary specific ionization near the minimum value. Our experimental result can be interpreted plausibly in terms of slow protons and mesons. A 100-Mev proton, for example, has a residual range of about 10 g-cm^{-2} and a primary specific ionization slightly higher than that of an alpha-particle.

Further experiments within the atmosphere are planned to determine the composition of the cosmic-ray flux at various altitudes; however, the present result, though somewhat crude, is sufficiently discriminating to provide evidence against the electronic nature of the bulk of the soft component at very high altitudes. A similar conclusion, based on entirely different considerations, has been reached by others.[3]

I am greatly indebted to Dr. J. A. Van Allen for valuable discussion.

* This work was supported by the Navy Bureau of Ordnance under Contract NOrd 7386.
† A preliminary account of this work was given at the Echo Lake Conference (June, 1949).
[1] See Fig. 1, preceding letter.
[2] S. F. Singer, Phys. Rev. **76**, 701 (1949).
[3] M. A. Pomerantz, Phys. Rev. **75**, 69 (1949).

Resonance Neutron Scattering in Na^{23} at 3000 Ev

C. T. Hibdon, C. O. Muehlhause, W. Selove, and W. Woolf
Argonne National Laboratory, Chicago, Illinois
January 16, 1950

NEUTRON resonance overlapping between sodium and manganese has been observed by using a neutron scattering counter[1] and an epi-cadmium neutron beam from the Argonne heavy water reactor. With either material serving as scattering detector and the other as absorber about 20 percent overlapping was observed. That is, about 20 percent of the scattered neutrons from one material had a transmission cross section of approximately 120 b for the other material. Similarly, when sodium was used as both scattering detector and absorber about 50 percent of the scattered neutrons had a high transmission cross section.

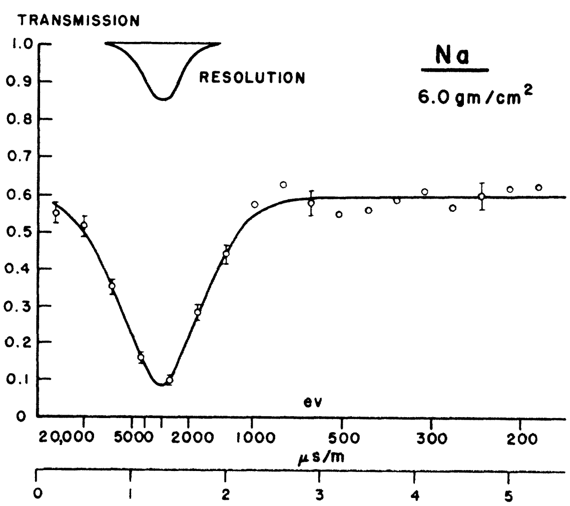

FIG. 1. Neutron transmission of sodium *vs.* neutron energy.