sponding to about 3 to 4 collision mean free paths. The "filling-in" of the cut-off spectrum should be nearly complete, and the differences be due only to the fraction of the primaries that escaped collision. Hence the difference between the intensities of the hard component is a reasonably good approximation to the difference of the meson intensities. (Incidentally, when an attempt was made to construct the meson intensity curves, taking the observed intensities below 500 g/cm^2 as arising from mesons only and calculating the intensities expected at higher altitudes, the results were found to be identical within the accuracy of the computations.)

The next step in the analysis is subject to stronger criticism. It was assumed that the bulk of the mesons recorded were produced near the top of the atmosphere, so that a minimum energy at production can be ascribed to a particle recorded at a given depth, and under a known absorber. This procedure is satisfactory at large depths, while in the upper atmosphere local production even of hard component mesons becomes appreciable. Still, this holds only for the low energy part of the recorded intensity, and hence the error introduced by the suggested summary treatment is not critical. In this way the altitude-intensity curves at various latitudes can be transformed into "integral intensity" spectra, and their differences into the "integral spectra" produced by primary particles of various energies.

If the meson spectrum is known at a given altitude, a correction for decay in flight can be made. This was done by assuming in the customary way an exponential absorption of the primary radiation with a mean free path of 120 g/cm^2, and a constant cross section for meson production throughout the atmosphere. In a manner similar to that used in the earlier note[1] it can be argued that the latter assumption is not seriously in error for fast mesons, although its application to slow mesons would hardly be justified.

The differences between the meson intensities thus corrected, and divided by the differences between the piimary intensities at the latitudes 53° and 41°, and 41° to 0°, represent the total number of meson with energies exceeding a certain minimum value, produced per primary particle in the energy intervals of about 1.5 to 4 Bev, and 4 to 14 Bev. The results are shown in Fig. 1, where the upper curve (b) represents the integral multiplicity of meson production foi the more energetic, and the lower curve (a) that for the slower primaries. If one attempts to extrapolate these curves to include all relativistic mesons, which is a somewhat dubious procedure in view of the low degree of reliability of both the experimental values and the method of computation for the highest altitudes, he finds a total of 1 to 2 mesons in the lower, and 2 to 3 mesons in the higher energy interval. The agreement with the data from photographic plates[4] is satisfactory.

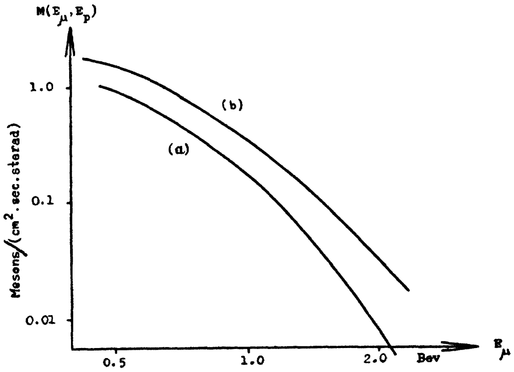

FIG. 1. The integral multiplicity $M(E_\mu, E_p)$, defined as the number of mesons with energies exceeding E_μ, produced per primary of energy E_p. Curve (a): 1.5 Bev $\leqslant E_p \leqslant$ 4 Bev. Curve (b): 4 Bev $\leqslant E_p \leqslant$ 14 Bev.

The apparent slow variation with primary energy of the total number of relativistic mesons produced per primary particle, together with the marked energy dependence of the differential multiplicity,[1] gives us some indication as to the spectral distribution of the mesons produced in a collision. Certainly the frequently used law of the form dE/E, predicting equal contributions from all primaries of sufficiently high energies at any meson energy, seems to be a rather poor approximation even at meson energies as low as 0.5 Bev. However, reliable quantitative conclusions cannot be reached until more complete experimental data are available.

* This work was supported in part by the AEC.
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Delays of Penetrating Particles in Atmospheric Showers

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WE report the preliminary results of an experiment which is in progress at the Laboratorio della Testa Grigia (3500 m, mean pressure 675 g/cm^2) to study the relative delays among the particles of an atmospheric shower in reaching the recording device.

The experimental arrangement is sketched in Fig. 1. In the counter groups T_1, T_2, T_3, each of 8 counters of 2 cm diameter

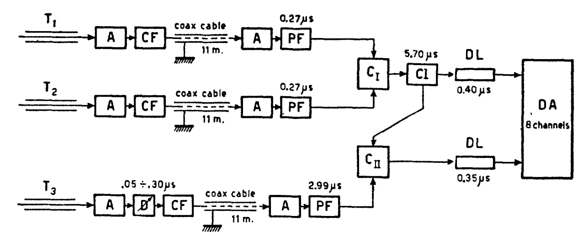

FIG. 1. Experimental arrangement. A = amplifier. CF = cathode follower. PF = pulse forming circuit. Cl = clipping circuit. DL = delay line. D (arrow) = adjustable delay. DA = delay analyzer. C = coincidence circuit. T = counter tray.

and 50 cm effective length are placed at the vertices of an almost equilateral triangle with sides about 5.5 m. The counter pulses, after high amplification, are fed into the coincidence circuit C_I between trays T_1 and T_2, and into the coincidence circuit C_{II} (resolving time 8.70 μsec) between the output of C_I and the tray T_3. The output pulses from C_I and C_{II} are fed into the delay-analyzer, which discriminated all of the threefold coincidences (123) into 8 delay-channels according to the relative delay (positive and negative) between the outputs of C_I (12) and C_{II} (123). The apparatus[1] is so adjusted that a threefold coincidence is recorded in the first channel when the delay of the input pulse to the third coincidence branch, relative to the latter of the input pulses of branches 1 and 2, has a value in the interval -3.25 to $+0.05$ μsec, and in successive channels when the delay exceeds $+0.05$ μsec.

Measurements were taken with trays T_1 and T_2 always unshielded and tray T_3 alternately shielded and unshielded (the shielding used was 17.5 or 22.5 cm of lead). The results are plotted in Fig. 2. The time scale for the abscissae is a "mean" scale, which takes into account the fluctuations due to the counters, the spread of the resulting distribution being ± 0.17 μsec. The rates recorded by the 8th channel are well accounted for, within the limits of experimental errors, by chance coincidences; the contribution of the latter to the counting rates of the remaining channels is in every case negligible.

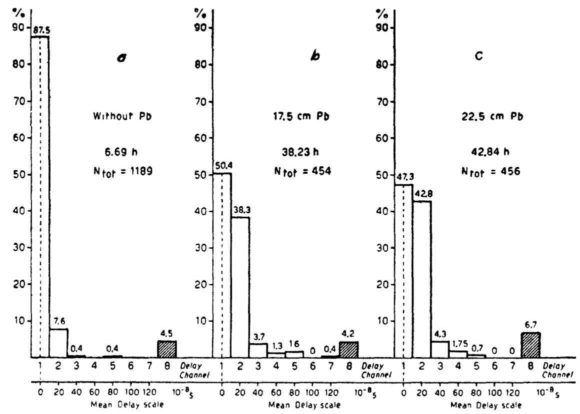

FIG. 2. Experimental results. The true scale for the abscissa is a "mean" scale, which takes into account the spreading due to the counter fluctuations.

One can calculate readily that under our experimental conditions the time origin is given, in more than 98 percent of the cases, by the arrival of an electron. Thus, the histograms (b) and (c) can be assumed to give the actual distributions of penetrating events relative to the electrons. They are in fairly good agreement with the results of McCusker and his co-workers,[2] who rule out the existence of delays greater than about 1.5 μsec. As it is reasonable to assume that the electron-photon component travels with the velocity of light throughout the whole development of the shower, the most plausible interpretation of the delays found is that they are due to the velocities of the penetrating particles produced in the development of the shower, these velocities being, on the average, smaller than those of the electron-component.

For a rough comparison, we have calculated the delay distribution to be expected on the hypothesis that all of the pairs produced in atmospheric showers are mesons which are created, together with the electron-photon component, at a definite height vertically above the apparatus (corresponding to a pressure of 100 g/cm^2) with a generation spectrum of the type $E^{-3}dE$, and are absorbed in the atmosphere by ionization loss and natural decay. The calculated distribution is cut off at $\tau = 0.45$ μsec, owing to the lead shield; this is obviously independent of the generation spectrum and practically independent of the height of formation chosen, at least for heights greater than that chosen. The cut-off time is thus an upper limit for the delays due to a penetrating particle, always in the form of a meson or particle of lighter mass, which can be traced back from the apparatus to the origin of the shower. The counting rates of the delay channels 4 to 7 (about 2 to 3 percent of the total number of penetrating events) must therefore be due to pairs which have traveled for a noticeable fraction of their paths from the origin of the shower, as particles with a mass much larger than that of the meson. The experimental results are in rough agreement with the calculated distribution for $\tau \leqslant 0.45$ μsec, but no great significance can be attached to this agreement as an indication of the accuracy of the hypothesis made.

[1] A detailed description of the electronics employed, as well as a discussion of the effect of the fluctuations in the times of discharge of the counters will appear shortly in *Nuovo Cimento*. For the method used in the calibration of the time axis see *Energia Elettrica*, November, 1950.
[2] McCusker, Ritson, and Nevin, Nature **166**, 400 (1950).

Microwave Spectra of Deutero-Ammonias

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APPROXIMATELY 125 lines of ND_3, ND_2H, and NDH_2 have been found[1] in the region from 2000 to 17,000 Mc. This work is part of a program to provide precise reference standards for frequency and intensity to lower frequencies than previously available as an adjunct to compilation of microwave spectra tables.[2]

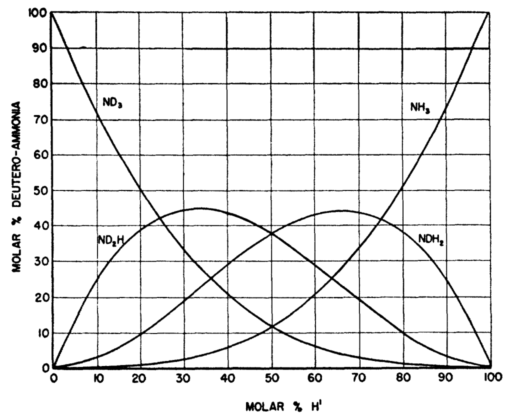

FIG. 1. Deutero-ammonia equilibrium ratios *vs* H^1 contamination.

All measurements were made using a 5-kc, zero-based, square-wave-modulated Stark spectrograph employing a synchronous detector.[3] A new design of mica and metal *S*-band absorption cell allowed high temperature outgassing.[4] Hyperfine spacings were found to be somewhat different from NH_3; hyperfine lines are not included in Table I.

The source of the deutero-ammonias for this work was a high pressure bomb of ND_3 containing up to 5 or 10 percent H^1. In the presence of other H^1 containing molecules, the partially deuterated ammonias are known to be formed rapidly[5] in the ratios indicated in Fig. 1. This effect was utilized to generate the partially deuterated ammonias and to provide a means of isotopic assignment of the lines on the basis of intensity growth. Excluding the NH_3 lines, measurements showed that there were three qualitatively distinct types of lines. Within one-half hour after insertion of a fresh sample of ND_3, type (0) lines decreased perhaps 10 percent or more of their initial strong values; type (1) lines increased by 10 to 100 percent above the initial strong intensity; and type (2) lines increased from essentially zero to an intensity many times the initial value. A reference to Fig. 1 indicates that, in a system where the hydrogen contamination drives the equilibrium from

TABLE I. Deutero-ammonia microwave spectrum.[a]

Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.
2094^{0}	43	4161	8	5236	3	7104	10	12620	40
2186^{0}	75	4199	12	5364	99	7238^{1,b}	3	12778	1290
2290^{0}	15	4216	8	5368	5	7388^{1}	90	13065	169
3261		4219	9	5392	120	7562^{2}	350	13119	523
2403^{0}	5	4241	7	5415	200	7803	185	13175	23
2408		4282	2	5495	210	8278		13210	1200
2431		4407	105	5508^{1}	84	8283	470	13316	400
2480		4410	30	5549	2	8778	60	13488	234
2533^{0}	5	4511	25	5574	3	8903	54	13626	580
2599		4721	36	5582^{1}	320	8922		13657	106
2614	4	4850	72	5632^{1}	55	9014	220	13923	586
2652	7	4859	141	5635^{1}	114	9521	600	14067	620
2668		4907	90	5689	1	9636		14102	700
2699		4915	23	5726	2	9829		14566	530
2746		4938	14	5786^{1,b}	110	9967		15004	18
2786		4948	96	5787^{1,b}	120	10091		15132	384
2800	4	4956	37	5964^{1,b}	126	10660	50	15524	35
2900	3	5025	27	6105^{1,b}	132	10844	1750	15634	9
2939	3	5030	7	6164^{1,b}	120	11400	100	15772	280
2978	3	5122	3	6390^{1,b}	45	11975	250	15935	20
3010	3	5124	6	6463	153	11983	250	16320	134
3187	17	5192	42	6598	46	12147	500	16455	210
3470^{1}	29	5199^{1}	290	6641^{1,b}	27	12150	1833	16493	153
3865^{1}	290	5213	2	6922^{1,b}	13	12392	700	16497	34
4086^{1}	13	5230	5	6975	1	12444	75		

[a] Superscripts 0, 1, 2 denote, respectively, line types 0, 1, 2.
[b] Assignments subject to further tests.