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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-4-25. Study of Core Structure of Small Size Air Shower

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The density spectrum and the energy spectrum have been observed at sea level and at mountain altitude (800 g cm^{-2}) with AS tray. The exponent of density spectrum was obtained as -1.53 ± 0.1 at 800 g cm^{-2} and -1.55 ± 0.1 at sea level. The exponent of total energy flow spectrum was obtained as -1.7 ± 0.1 at both altitudes. The exponents of the energy flow spectra with AS coincidence both at sea level and at mountain altitude are found to continuously steepen with increasing energy flow. And the spectrum varies largely depending on the condition of AS coincidence. From these features, we found that (1) there is a clear change in the character of core at about 10^5 in size of EAS and (2) the change comes from interaction character in high energy region. The series of observation is continuing by means of water spectrometer and preliminary results are presented.

In the past several experiments were done on the density spectrum of extensive air showers—a review of most of this earlier work by Greisen[1] can be found in progress in cosmic ray physics Vol. III. Since this review, there was another experiment reported by Green and Barcus[2]. In all these experiments, the frequency of occurrence of air showers with various densities over the apparatus was studied without any reference to the energy content of the electrons producing these densities. We have done an experiment both at sea level and at mountain altitude (800 g cm^{-2}) wherein we measured the density spectrum of EAS in this usual way and, in addition, the energy flow spectrum of EAS.

The experimental set up is shown in Fig. 1. Two plastic scintillators (designated T and B) were kept one above the other with a layer of lead having a thickness of 2.5 cm in between them. Besides these two, there was a third plastic scintillator (designated AS) at distance of 2 m.

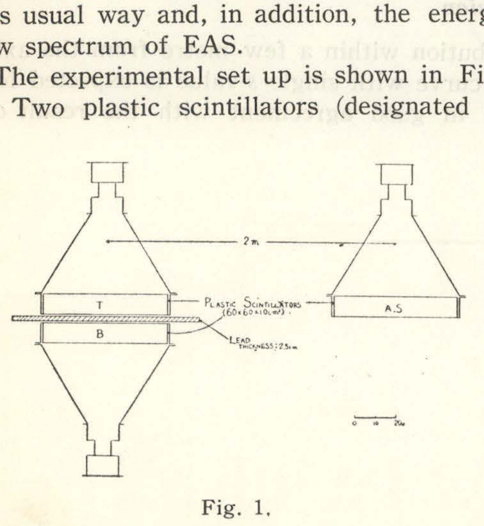


Fig. 1.

The results on the density spectrum (T+AS) and on the energy flow spectrum (B+AS) of EAS both at sea level and at mountain altitudes are presented in Fig. 2. The frequencies of occurrence of pulses of various sizes in the top and in the bottom scintillators without any demand on the air shower scintillator are also shown in the same figure (curves designated as T and B). The exponent of the density spectrum in the region of densities 15/m^2 to 800/m^2 as obtained by us is -1.53 ± 0.1 at 800 g/cm^2 and -1.55 ± 0.1 at sea level. The two exponents of the density spectrum at mountain altitude and at sea level are the same within experiment errors. There is no disagreement with the earlier work on this. The exponent of total energy flow spectrum was obtained as -1.7, and the exponents of the energy flow spectra with AS coincidence both at sea level and at mountain altitudes are found to continuously steepen with increasing energy flow. There seems to be no significant difference in the exponent of the energy flow spectra at mountain altitude and at sea level. It may be pointed out by us as was done several times before by

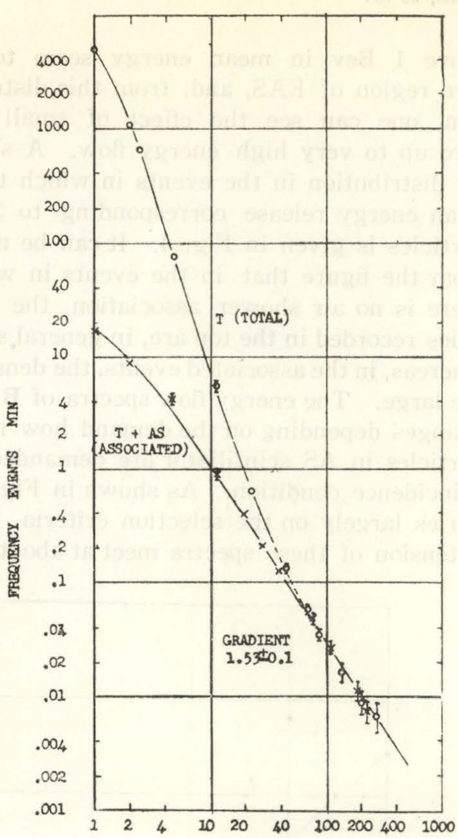


Fig. 2a. 800 gcm^{-2} T and T+AS.

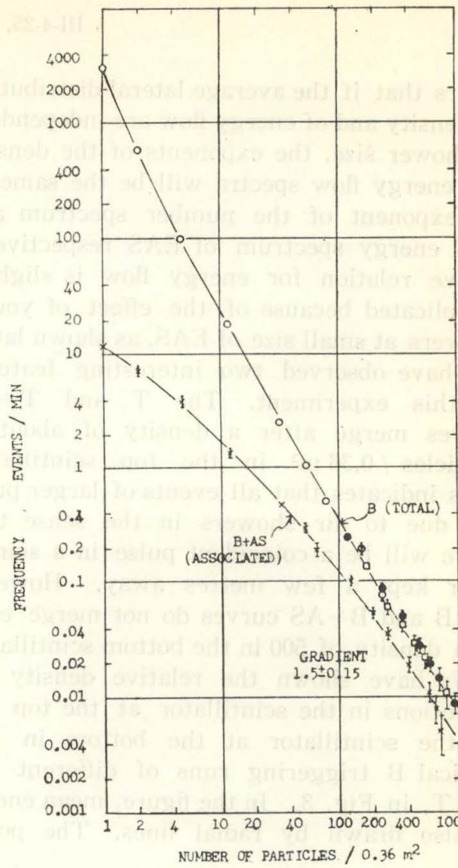
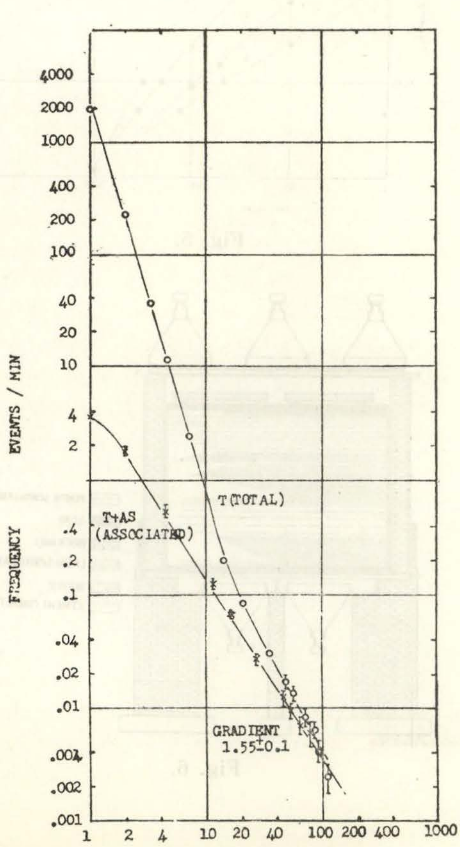
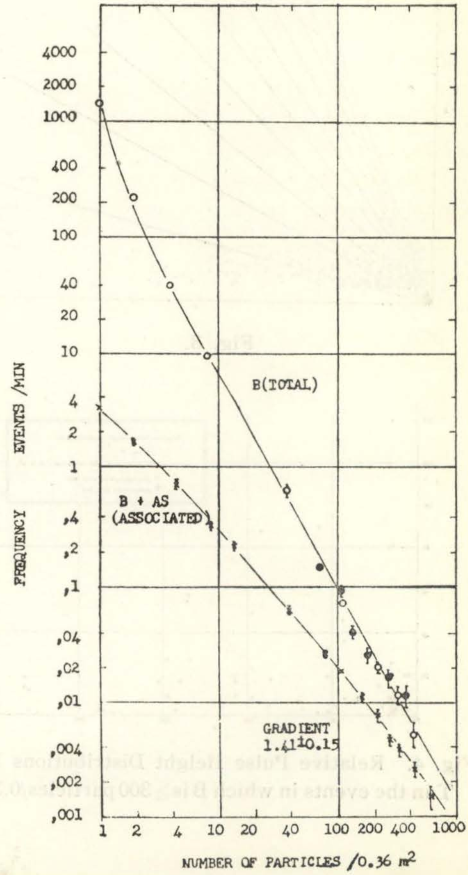


Fig. 2c. 800 gcm^{-2} B and B+AS.





others that if the average lateral distribution of density and of energy flow are independent of shower size, the exponents of the density and energy flow spectra will be the same as the exponent of the number spectrum and total energy spectrum of EAS respectively. Above relation for energy flow is slightly complicated because of the effect of young showers at small size of EAS, as shown later. We have observed two interesting features in this experiment. The T and T+AS curves merge after a density of about 50 particles / 0.36 m² in the top scintillator. This indicates that all events of larger pulse are due to air showers in the sense that there will be a coincident pulse in a scintillator kept a few metres away. However the B and B+AS curves do not merge even at a density of 500 in the bottom scintillator.

We have shown the relative density distributions in the scintillator at the top and in the scintillator at the bottom in two typical B triggering runs of different bias for T, in Fig. 3. In the figure, mean energy is also drawn by radial lines. The points

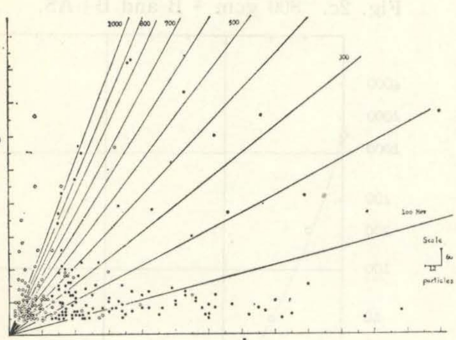


Fig. 3.

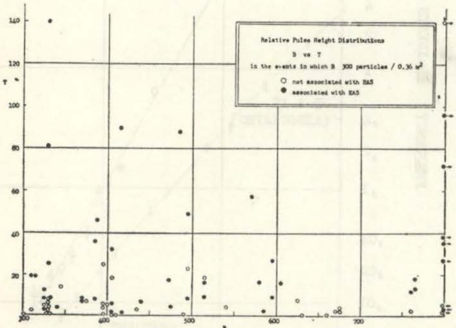


Fig. 4. Relative Pulse Height Distributions B vs T in the events in which B is ≥ 300 particles/0.36m²

above 1 Bev in mean energy seem to be core region of EAS, and, from this distribution, one can see the effect of small size core up to very high energy flow. A similar distribution in the events in which there is an energy release corresponding to ≥300 particles is given in Fig. 4. It can be noted from the figure that in the events in which there is no air shower association, the densities recorded in the top are, in general small whereas, in the associated events, the densities are large. The energy flow spectra of B+AS changes depending on the demand how many particles in AS scintillator are demanded for coincidence condition. As shown in Fig. 5 it varies largely on the selection criteria. The extension of these spectra meet at about 1000

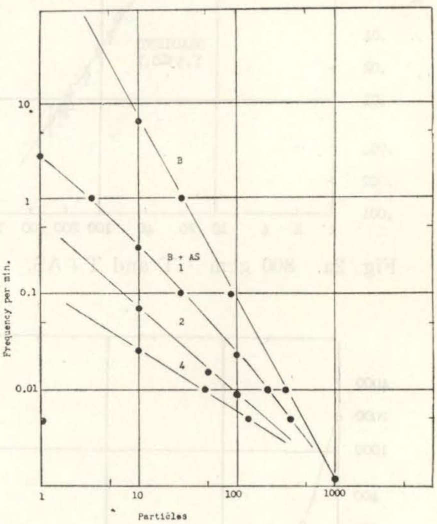


Fig. 5.

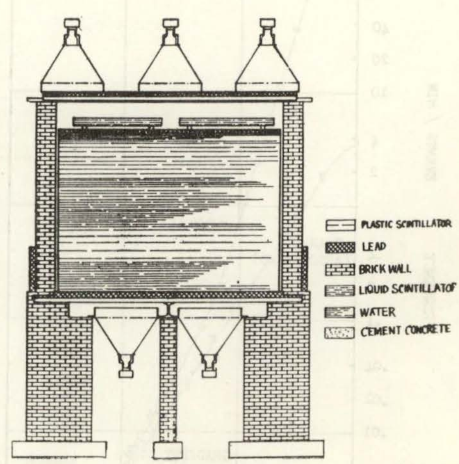


Fig. 6.

Table Ia.

Energy Flow Trigger		Densities (No. of Ptls per area 0.36 m²)					Energy Flow (Bev) 1 m²				NAP Energy (Bev)						Estimated Energy of γ-ray (ev) Lower Limit
Date	Time	D_1	D_2	D_3	D_4	D_5	E_1	E_2	E_3	E_4	N_1	N_2	N_3	N_4	N_5	N_6	
4-8-61	0919	—	80	3	4	2	—	—	13	27	—	—	—	—	—	—	$>4.10^{12}$
	0942	—	5	4	101	2	—	7	100	5	—	—	—	—	—	—	4.10^{12}
	1039	—	—	—	34	—	—	—	74	—	—	—	—	—	—	—	10^{12}
	1238	—	46	7	—	4	4	15	70	30	—	—	—	—	—	—	10^{12}
	1346	35	120	28	64	2550	350	26	21	600	60	26	—	10	10	20	10^{14}
	1524	37	—	10	—	—	84	110	2	—	—	—	—	—	—	—	4.10^{12}
	1725	—	1	1	38	2	4	280	260	—	—	—	—	—	—	—	10^{12}
	2122	56	78	58	2500	58	110	110	420	50	12	9	34	69	16	17	10^{14}
	2154	10	19	17	2500	12	8.5	110	150	11	—	—	—	—	—	—	10^{14}
5-8-61	0714	—	47	—	2	5	25	22	211	55	—	—	—	—	17	—	10^{12}
	1114	—	38	—	2	—	5.6	11	90	42	—	—	—	—	—	—	10^{12}
	1550	—	78	—	—	—		1.5	210	10	—	—	—	—	—	—	4.10^{12}
	1802	—	—	—	37	40			140		—	—	—	—	—	—	10^{12}
	1902	100	5000	100	160	115	2600	300	7000	340	400	75	1700	100	35	180	5.10^{14}
	1927	—	2	2	520	—	—	—	7.4	42	—	—	—	—	—	—	2.10^{13}
	2048	—	—	—	52	—	—	—	390	—	19	180	—	—	—	—	10^{12}
	2201	3	—	2	34	—		45	45	7	—	—	—	—	—	45	10^{12}
	2424	122	190	78	2500	250	74	70	80	150	—	—	100	—	—	—	10^{14}
6-8-61	1013	—	40	—	—	—	—	140	—	—	—	—	—	—	120	—	10^{12}
	1055	—	3	4	47	—	1.7	2.5	300	12							10^{12}
	1319	36	82	48	2500	63	50	47	1700	35	75	—	11	21	11	84	10^{14}
	1407	3	2	5	390	5		8.2	100	10	—	17	—	—	—	12	2.10^{13}
	1449	43	90	4000	640	390	130	300	420	150	250	100	180	45	80	220	2.10^{14}
	1729	36	45	37	1900	40	8.5	25	100	11	—	—	—	—	—	140	10^{14}
	1736	—	6	—	170	—	—	1.1	70	17	—	—	—	—	—	—	10^{13}
	1952	220	300	125	2500	110	1350	300	1500	370	600	15000	60	52	80	20	10^{14}
	1959	4	6	5	2500	6	2.7	13	100	11	22	—	—	—	—	32	10^{14}
	2156	—	42	7	—	—	—	6.5	260	3	—	—	—	—	—	—	10^{12}

Total effective time 52.5 hrs. E. F. Triggering.

Table Ib.

NAP Trigger		Densities (No of Ptls per area 0.36 m²)					Energy Flow (Bev) 1 m²				NAP Energy (Bev) Det area 0.36 m² each						Estimated Energy of γ-ray (ev) Lower Limer
Date	Time	D_1	D_2	D_3	D_4	D^5	E_1	E_2	E_3	E_4	N_1	N_2	N_3	N_4	N_5	N_6	
7-8-61	0645	15	6	600	7	11	24	300	14	17	5000	26	11	30	10	15	2.10^{13}
	0956	3	2	—	7	37	1.5	3.6	5	17	13	9	11	100	900	17	10^{12}
8-8-61	0322	14	200	8	7	9	30	300	110	120	26	700	600	155	35	80	5.10^{12}
9-8-61	0739	3	6			37	—	—	—	90	—	—	500	13	22	160	10^{12}
	1529	23	350	17	43	17	3600	300	320	55	330	760	46	38	15	32	2.10^{13}
	1712	320	5000	170	170	370	3600	300	1200	9300	54	95	2200	100	42	1400	2.10^{14}

Total effective time=42 hrs. *N* component triggering.

particles in the bottom scintillator. Because of high mean energy, the events near the meeting point correspond to the core of various sizes. The result shows that the character of the core of EAS fluctuate largely below certain size which can be estimated from corresponding density or absolute frequency. In the series of this experiment, the critical size was estimated as about 10^5. From the observed frequencies of air showers (T+AS and B+AS) at sea level and at mountain altitude, the absorption length of rate was 115 ± 10 g/cm^2, then, we can conclude that the change of character in the core of EAS is not due to the primaries but to the character of interaction in high energy region.

Fig. 6 shows new arrangement to study the core structure of small size EAS. We can observe simultaneously density and core position at the top, and energy flow carried by soft component and of N-component which interact in the water tank. In the initial stage of construction, the water was not wed and six energy flow detectors were used to measure the area of highest energy flow which correspond to core region, and this was estimated as about 0.5 m in diameter. Later the water tank was set up and we found that the events triggered by energy flow are not mainly due to nucleon component since the rate did not change much with and without water. We are now taking runs with various kind of triggering namely, by the density, energy flow and nucleon component. The observation is now going on and some preriminaly result from the energy flow and nucleon component triggering runs are given in the following table for nearly same time of operation (52 and 42 hours respectively). The energy flow triggering is very useful to detect cores of small size EAS, and we find frequently the existence of steep cores which are probably due to γ-rays of energy greater than 10^{12} ev, as can be seen in the table.

References

1) K. Greisen: Progress in Cosmic Ray Physics Vol. III. (North Holland Publishing Company, 1956).
2) J. R. Green and J. R. Barcus: Nuovo Cimento, **14** (1959) 1356.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-4-26. Cloud Chamber Study of Extensive Air Showers near the Sea Level

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A multiplate cloud chamber was operated at Institute for Nuclear Study during the past one year and a half. The cloud chamber has the illuminated region of 120 cm width, 50 cm depth and 100 cm height at the centre, and contains 7 plates of 8 mm thickness of lead lined with 5 mm thickness of iron, and 8 plates of 18 mm thickness of lead lined with 5 mm thickness of iron.

§ 1. Lateral distribution and energy spectra of the high energy electronic components

Table I shows the values of the exponent n, when the energy spectra in various bands of distance from the axis are assumed to be represented by the power law of the form E^{-n}. Examples of the lateral distribution of the high energy electronic components are shown in Figs. 1, 2. The former is the lateral distribution of particles of more than 5 Bev, and the density of each point is normalized to EAS with total number of 10^5. The latter shows that of particles of more than 1.5 Bev. The triangles in the figure are the results obtained at Mt. Norikura, 2770 m elevation, and they coincide well with