Table II

N	Z	Energy per nucleon in bev	N	Z	Energy in bev nucleon
6	25	5,29	1	27	2,22
	25	7,5			
	25	2,23	3	28	4,79
	25	2,64		28	17,9
	25	Without relativistic α particles		28	Without relativistic α particles
	25	,, ,,			
			1	29	4,08
6	26	100			
	26	29,2	1	30	2,0
	26	4,9			
	26	2,05	1	31	Without relativistic α particles
	26	100			
	26	Without relativistic α particles			

no variation of the density of small δ-rays was observed.

In the same group of 100 plates in the conditions previously described, we did not find primary nuclei with Z greater than 26 which stop within the emulsions.

Summary

The results of the measurements of electric charges of primary cosmic ray nuclei by the small δ-ray method are discussed, nuclei highly charged and with charges between 25 and 31 are presented.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-1-14. He^3-Nuclei in the Primary Cosmic Radiation

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The original impetus for this work lay in the same vein as that giving rise to the light element problem. The investigation of He^3 has an advantage in that secondary production in the atmosphere is expected to be small so that it should not be plagued by the same extrapolation problems as for the L-nuclei. Additionally one may hope for more definitive information about the Cosmic Ray history and source abundances by a joint extrapolation of the He^3 data with the light element data.

In the experiment presented here the ratio of $He^3/(He^3+He^4)$ is determined in two high altitude balloon flights denoted as *CRI* and *CRII*. *CRI* was at $\lambda=55°$N, 30 July, 1957 and

CRII at λ=61°N, 3 August, 1958. In both flights the emulsion package was rotated from the horizontal to a vertical position at altitude. *CRI* had an effective collection time of 8 hours and 51 minutes at 8.5 gm/cm^2 and *CR II* 8 hours and 30 minutes at 3.8 gm/cm^2. *CR I* consisted of 150 G-5 emulsions 30 cm. *X* 25 cm. *X* 400μ and *CR II* was 150 G-5, 25 cm *X* 20 cm *X* 600μ. In both cases the longer dimensional was vertical during exposure.

For calibration purposes a stack of 25 G-5 pellicles 20 cm *X* 10 cm. *X* 600μ was exposed to the 925 (total kinetic energy) Mev He^4 beam of the Berkeley synchrocyclotron with the beam approximately parallel to the 20 cm. edge; the range of the He^4 was 13.1 cm. so that all that did not interact stopped in the emulsion.

After investigation of various procedures we adopted the constant sagitta scattering scheme as giving the best resolution with maximum objectivity. A scheme was calculated giving $\bar{D}_2$=0.75μ for He^4 and was checked using the 925 MeV He^4 in the machine stack which came to rest without interaction. The distribution of $\bar{D}_2$ is shown in Fig. 1. Next an area scan was done for so called alpha-in-alpha-out interactions: specifically those in which an incident beam He^4 suffers an interaction and a doubly charged particle of the same ionization (visually) emerges at an angle $<20°$. The scan was done so that such emerging tracks would have a range > 3 cm.; the resulting $\bar{D}_2$ distribution for this sample (Fig. 2) clearly shows a resolution into two peaks, with one corresponding to He^4, the other clearly to be identified with He^3. With this justification we felt a strong reliance in the application of the procedure to the cosmic ray stacks.

In both stacks a line scan was performed one cm. from the top edge. In *CR I* tracks were accepted only if they were a zenith angle $\theta \leqq 30°$ and a potential range of 30 cms; additionally the ionization was required to be $\geqq$ 5.4 min, and the projected length $\geqq$ 5 mm, and the actual range greater than 4.5 cms. In *CR II* we required $\theta \leqq 45°$, potential range $\geqq$ 25 cms., projected length $\geqq$ 4 mm and actual range $\geqq$ 4 cm. for inclusion in the sample. In Fig. 3 we show the plot of residual range *vs* grain density in the scan plate for CR *I*; the elimination of singly

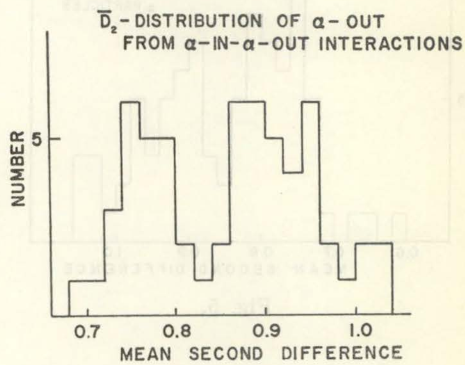

Fig. 2.

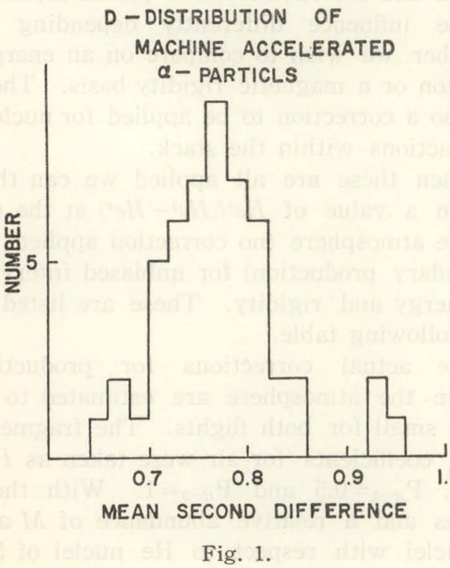

Fig. 1.

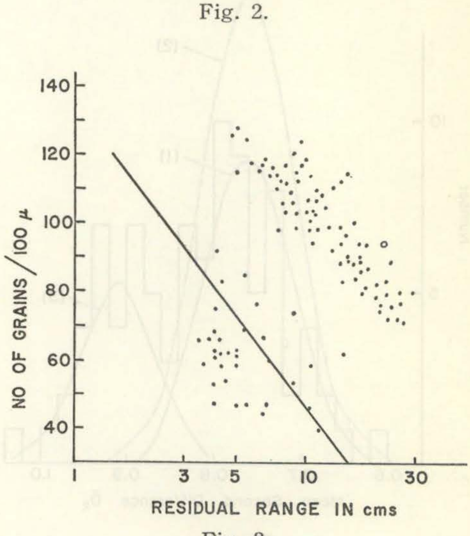

Fig. 3.

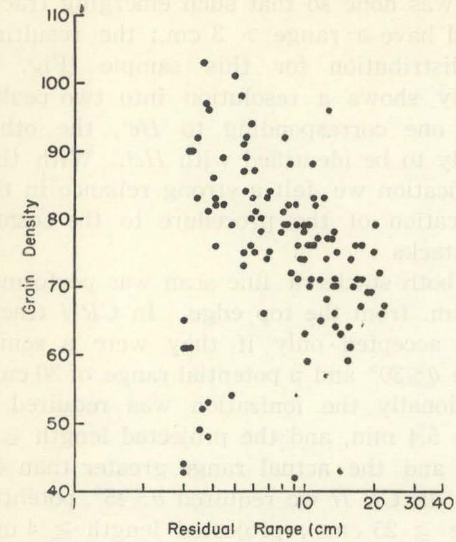

Fig. 4.

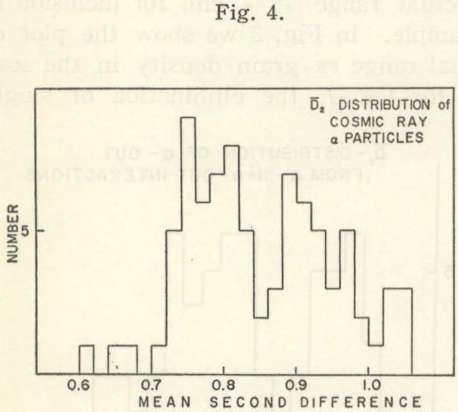

Fig. 5.

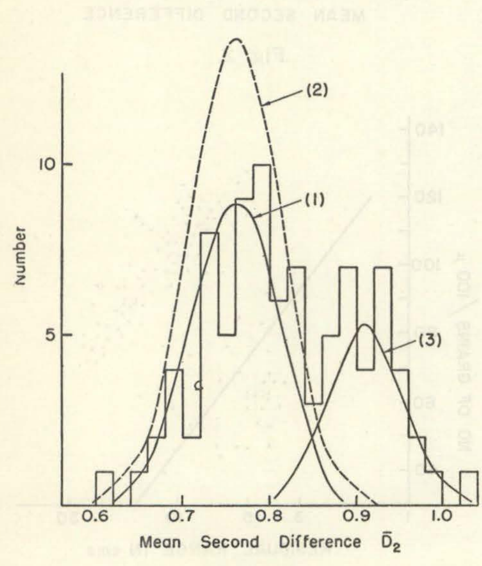

Fig. 6.

charged particles was thus easily accomplished (the line corresponds to H^3) and in Fig. 4 the same for CR II.

The actual scattering procedure employed was to obtain second differences from the third differences. A replacement procedure was applied to the third differences (*i. e.* all $D_3 > 4 < D_3 >$ were replaced with $4 < D_3 >$ and then $\bar{D}_2$ (the second difference) was obtained in the usual way. No tracks were used with a projected length less than 2 mm./emulsion in the last 1 cm. of the track. We note also that the use of an elimination procedure for large scatterings did not appreciably influence the results.

The results obtained are shown in Fig. 5 for *CR I* and Fig. 6 for CR *II*. In Fig. 6 curve 2 is a Gaussian drawn with center at 0.76μ and normalized to the total number of tracks. Curve 1 is a gaussian centered at 0.76μ and normalized to the number of tracks to the left of 0.85μ and Curve 3 is a gaussion centered at 0.92μ and normalized to the number of tracks to the right of 0.85μ. The width of the Gaussians are chosen corresponding to an average of 110 cells per track, the minimum for any track in the sample. This gives strong support for the separation of the sample into two mass groups. Similar results hold for both *CR I* and the machine stacks.

In order to obtain the true numbers of He^3 and He^4 we must account for the biases introduced by our method of selection of tracks and the requirements placed there on. These influence differently depending on whether we wish to compare on an energy/nucleon or a magnetic rigidity basis. There is also a correction to be applied for nuclear interactions within the stack.

When these are all applied we can then obtain a value of $He^3/(He^3+He^4)$ at the top of the atmosphere (no correction applied for secondary production) for unbiased intervals of energy and rigidity. These are listed in the following table.

The actual corrections for production within the atmosphere are estimated to be quite small for both flights. The fragmentation coefficients for air were taken as $P_{4-3}=0.1$, $P_{M-3}=0.5$ and $P_{H-3}=1$. With these values and a relative abundance of *M* and *H* nuclei with respect to He nuclei of 5%

	$R = He^3/(He^3 + He^4)$			
	R	Energy/nucleon in Mev	R	Magnetic Rigidity in Bv
CR I	0.38 ± .09	200-400	0.42 ± 0.11	1.3 -1.6
CR II	0.3 ± .08	160-355	0.33 ± 0.08	1.05-1.48

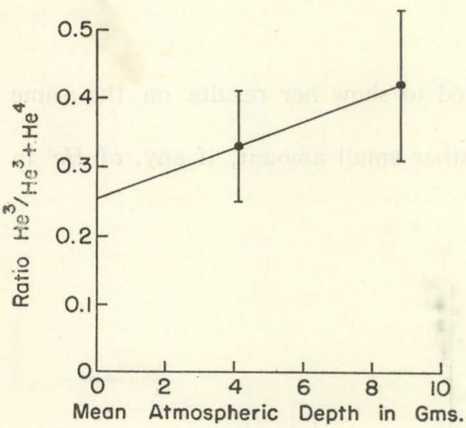

Fig. 7.

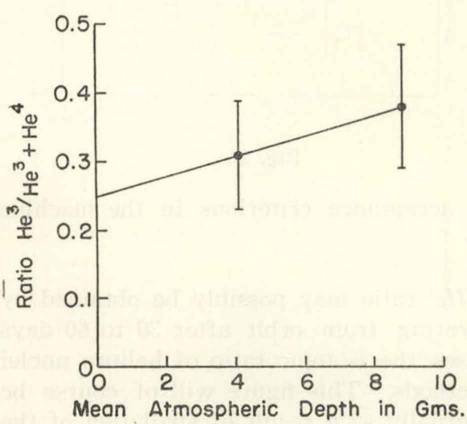

Fig. 8.

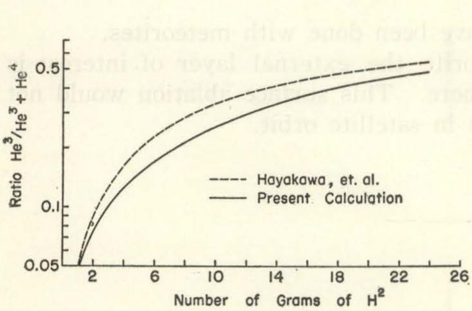

Fig. 9.

and 1.6% respectively, the correction is less than 5% for *CR I* and 2.5% for CR II. A lower limit may be obtained by assuming the He^3 ratio is time independent and does not vary strongly with energy or rigidity over the intervals concerned here; then one can extrapolate from the two flight altitudes to *o* gm/cm². This is shown in Figs. 7 and 8 for energy/nucleon and rigidity respectively.

To obtain the amount of interstellar matter traversed we consider the limiting case of one dimensional diffusion and no He^3 at the source. Since H^3 will also be produced and its lifetime is only 12.3 years, it will appear as He^3 so that we need to know the fragmentation coefficients P_{X-3+t}, for X incident on a proton. The values used are $P_{4-3+t}=0.4$, $P_{M-3+t}=0.2$ and $P_{H-3+t}=0.15$. Using these and respective mean free paths in hydrogen of 14.6, 6 and 3 gm/cm² we have obtained the growth curve shown in Fig. 9. For comparison the calculation of Hayakawa and his collaborators is also presented. Our ratios observed correspond to a lower limit of 9.8 gm/cm² as obtained from the extrapolation of Figs. 7 and 8 and for the two flights I and II we have respectively: I-15.7$^{+7.3}_{-4}$ (energy per nucleon), 18.3$^{+8.5}_{-6}$ (rigidity); II-12.3±4.1 (energy per nucleon), 13.7±4.4 (rigidity).

One of the first questions we should like to answer is with respect to the time dependence of those ratios. Our flights were only 1 year apart and certainly do not serve as any firm basis for answering such questions. Statistically they are compatible with a constant ratio over this period though clearly much work needs to be done concerning this question.

For both flights we observed the geomagnetic cut-off operative. For CR I the expected cut-off according to Quenby and Webber is 145 Mev/nucleon for He^4 and none were observed less than 200. For CR II the cut-off has a value of 90 Mev/nucleon and none were observed at less than 137.

It is clear that our determination of the amount of matter traversed is not compatible with the figure of 3 gm/cm² obtained from the most recent study of the light element problem. However, it should be stressed that those results are valid for an average energy/nucleon of 3 Bev and thus cannot be meaningfully compared with the results obtained here. The possible implications of this and its relevance to other experimental evidence is discussed in the Plenary Session paper on Isotopic Composition.

Discussion

Koshiba, M.: I wonder if Mrs. Aizu be allowed to show her results on the same subject?

The results were shown which indicated a rather small amount, if any, of He^3 in $Z=2$ component.

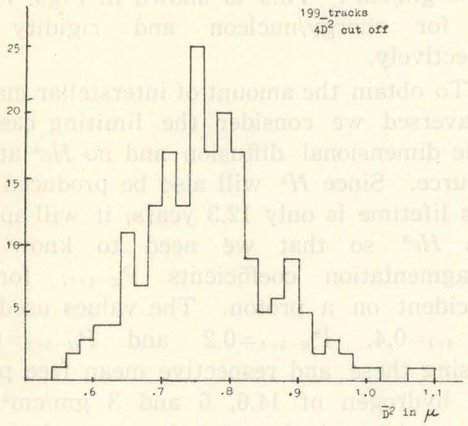

Fig. 1′.

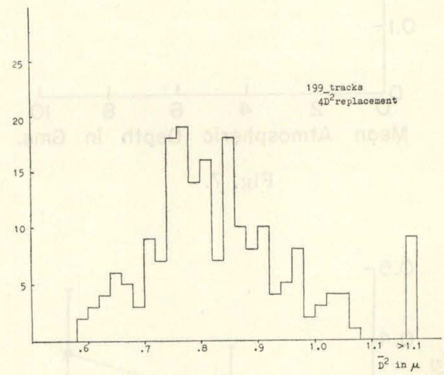

Fig. 2′.

Koshiba: Was there any difference in the acceptance criterions in the machine stack and cosmic ray stack?

Kaplon, M.F.: No.

Yagoda, H.: Some information on the He^3/He^4 ratio may possibly be obtained by exposing degased metals on satellites and recovering from orbit after 30 to 60 days exposure. By extracting the accumulated gases the isotopic ratio of helium nuclei can be measured by micro-masspectrometric methods. This figure will of course be an average for helium which is produced internally as a result of spallation of the target nucleus plus that present in the external primary cosmic beam. However, by measuring He^3/He^4 as a function of depth in the target the external contribution may be capable of extrapolation.

Peters, B.: If this were possible it would have been done with meteorites.

Yagoda: Yes, but in the case of a meteorite the external layer of interest is destroyed when the meteor enters the atmosphere. This surface ablation would not occurr in the case of a man-made meteor flown in satellite orbit.