PRIMARY COSMIC RAY SPECTRA OBSERVED BY RUNJOB — spectra for heavy and all particles

RUNJOB collaboration
(For the full list of authors, see the previous paper, OG.1.2.14.)

Abstract

The absolute fluxes of heavy cosmic ray primaries, CNO, Ne Mg Si groups and Fe components are reported from RUssian Nippon JOint Balloon (RUNJOB) experiment.

Total exposure of RUNJOB turns out to be 342.4 m^2 hour at the average altitude of around 30 km in three campaigns in 1995, 1996 and 1997.

Using the angular distribution of the fragments nuclei and secondary particles, and the darkness on X-ray films, the energy of the primary particle is estimated. The flux of Fe component extends up to $5*10^{12}$ eV/nucleon. And summing up the observed spectra, we got the all particle spectrum up to 10^{15} eV/particle.

Combining with OG.1.2.14 of this conference, this paer will be the full explanation of RUNJOB experiment.

1 Introduction:

The spectrum of the haevy primary is important to study the acceleraion and propagation of cosmic rays, because the comparison of that with proton spectrum gives us the clues for them. Specially the composition near the knee regin will tell us the origin of the break in the spectrum — knee.

The exposure, the chamber structes and others are explained in OG.1.2.14.

2 Data analysis:

2.1 charge determination:

To avoid the laborous delta ray counting of the primary track for the charge determination, we develop the system to determine the primary charge, using CCD TV camera and PC. This system is calibrated by the screen type X-ray films which were used in Sanriku experiment.[1]

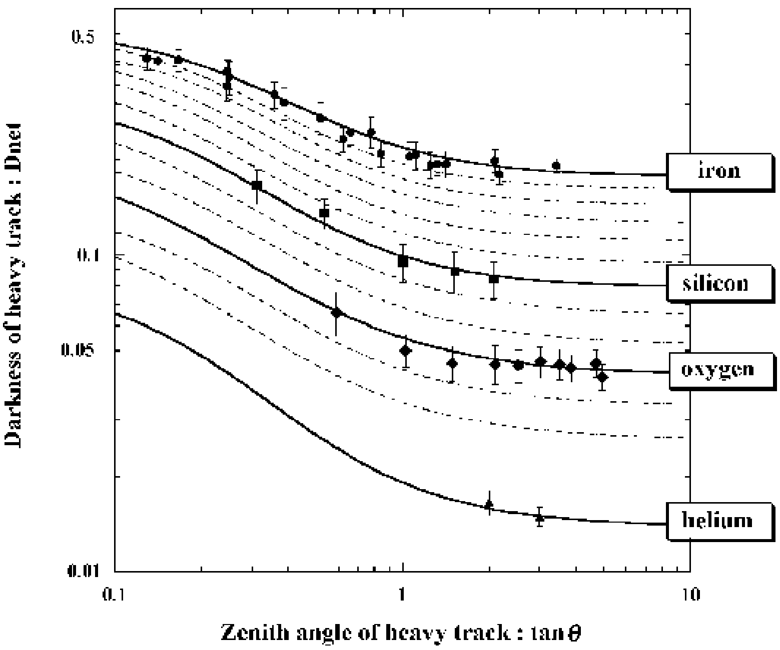


Figure 1: Charge determination calibration

2.2 enegy determination:

The thickness of the calorimeter is not thick enough to contain the whole shower development. So we use the emissin angle - the average p_T relation, though the

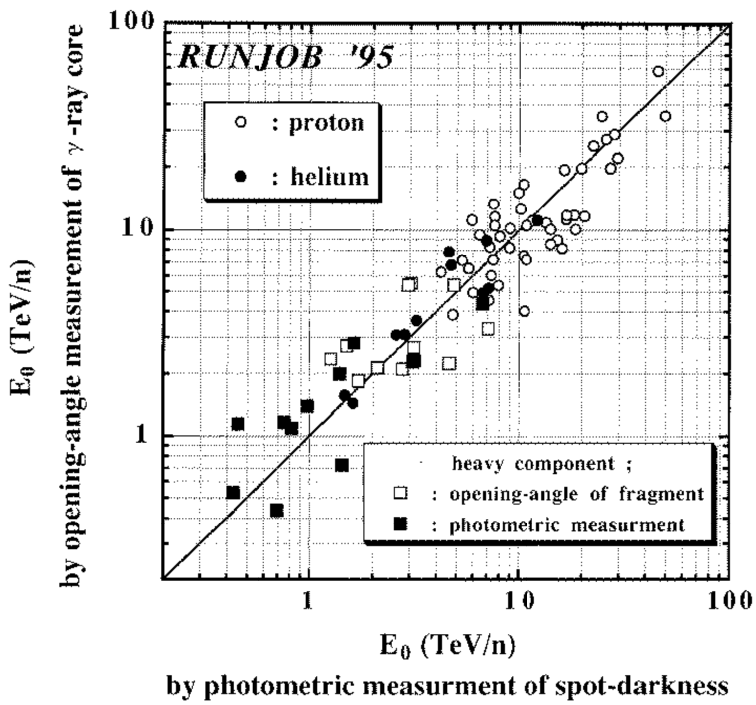


Figure 2: Cross check of energy determination

photometric method for the dark spot is adopted when it is applicable. The energy determination is explaind elsewhere [OG.1.2.38] in detail.
The energy determination for the heavy primary events are same as that for proton and helium events. But the opening angle method of fragments are also employed. In events obtained in 1995 campains, this method is mainly used and the emmission angle method of the secondary particles are checked against the fragmentation method. The correlation between two methods are shown in Fig.2.

3 Results:

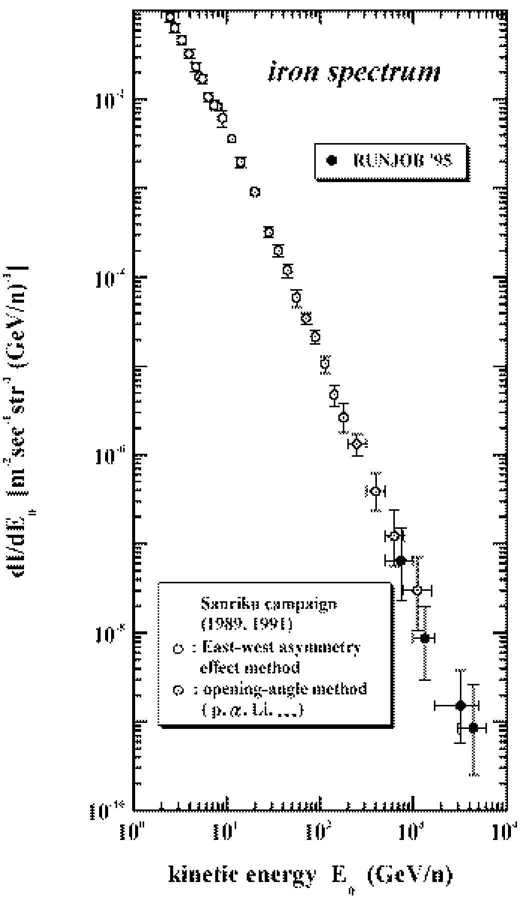
The scanning results are summarized in Table 1, some of which is shown in OG.1.2.14.

vertex	target		spacer		U.C.		L.C.		subtotal	
primary	’95	’96 IIIA	’95	’96 IIIA	’95	’96 IIIA	’95	’96 IIIA	’95	’96 IIIA
proton	10	32	5	2	57	35	45	31	117	100
helium	2	15	2	0	12	10	10	2	26	27
Li$\sim$B	0	2	0	1	2	2	1	0	3	5
C$\sim$O	6	2	0	1	1	2	2	3	9	8
Ne$\sim$Si	3	1	1	0	1	2	1	1	6	4
sub-Fe	1	1	0	0	1	0	1	0	3	1
Fe	3	0	0	0	1	0	2	1	6	1
wall	–	–	–	–	–	–	–	–	24	8
γ	–	–	–	–	–	–	–	–	174	226
not identified	–	–	–	–	–	–	–	–	13	4
total	25	53	8	4	75	51	62	38	381	384

Table 1: Scanning Results

Using the statistics from 1995 campaigns only, the iron spectrum is shown in Fig. 3 with the result of the previous Sanriku experiment[1,2]. So the agreemnet of these two experiments is very good.

This iron spectrum is compared with other experiments as shown in Fig. 4, including CNO, NeMgSi groups.



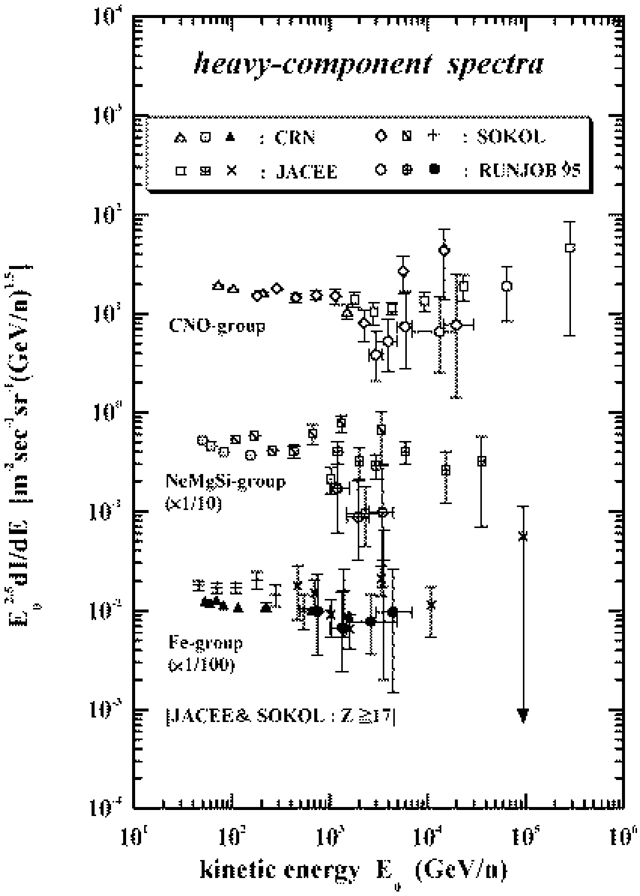


Fig. 3: Energy spectrum of iron nuclei

Fig. 4:Heavy primary energy spectrum

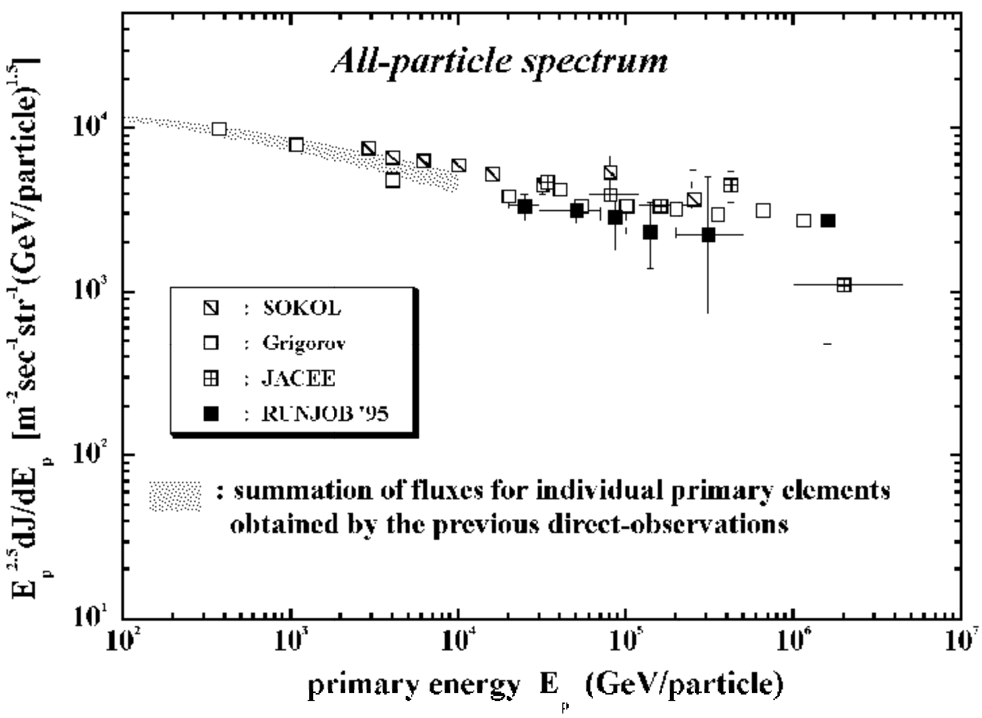


Fig. 5: All particle spectrum

Using all spectrum obtained by RUNJOB and others, all particle spectrum is constructed and shown in Fig. 6. This work is important to study the origin of the knee in the spectrum. At the conference, 1996 data will be included for this pupose.

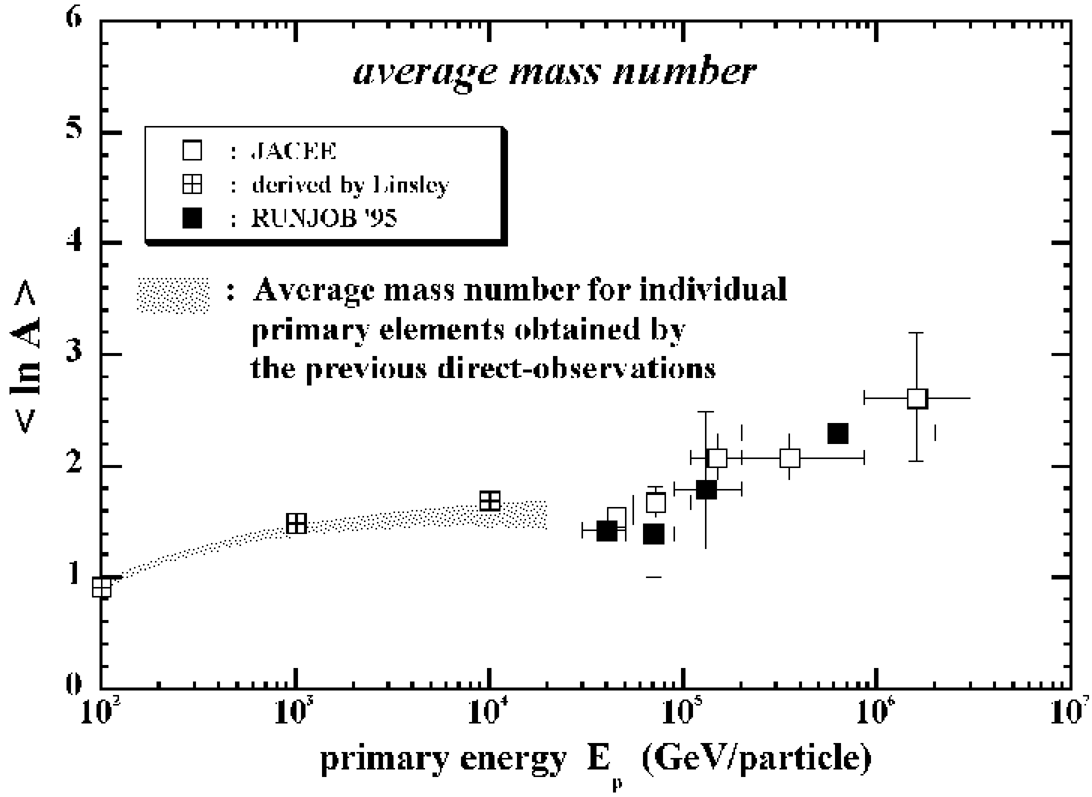


Fig. 6: Average mass number of primary cosmic rays

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4 References:

1. Ichimura et al. Phys. Rv. D48, 1949 (1993)
2. Kamioka et al. Astrop. Phys. 6, 155 (1997)
3. CRN data Swordy et al. ApJ 403, 658 (1993)
4. JACEE data Tominaga et al. Proc. 24 ICRC (Roma, Italy) Vol.2, 707 (1995)
5. Ivanenko et al. Proc. 23rd ICRC (Calgary, Canada) Vol.2, 17 (1993)