Primary Proton and Helium Spectra Observed by RUN-JOB Collaboration

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Abstract

From 1995 through 1999, RUssian Nippon JOint Balloon collaboration (RUNJOB) had 10 successful balloon flights to observe primary cosmic rays by emulsion chambers.

We have reported the half of the total exposure, 575 m^2 hour and in this paper we will report the spectra of protons and alpha particles, using all the data with sum of gamma ray energies greater than 5 TeV, though some chambers are scanned for the lower energy events. And we have got the spectra up to 10^{15} eV/nucleon. We also report the technical details for the energy determination method newly employed, basing on the lateral spread of cascade showers.

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1. Introduction

RUssian Nippon JOint Balloon (RUNJOB) experiment started 1995 to get the clue of the knee problem in the cosmic ray spectrum. The existence of the knee was first observed by Kulikov and Khristiansen in 1959. Since then the knee has been the long-standing problem in cosmic ray physics.

If the knee were due to the accerelation limit, the chemical composition would be changed. Under the assumption that the acceleration is due to the magnetic interaction, each nucleus can be accelerated to the same energy if we use rigidity. So heavier nucleus can reach to higher energy if we measure the spectrum in the total energy par particle.

Due to the exposure limit, we cannot observe the cosmic spectrum in the knee region but should have the indication of the composition change if any. So it is crucial to extend the direct observation region towards the knee region.

2. Exposure

All balloons are launched from the balloon base in Kamchatka peninsula and recovered before reaching to the Volga river region. We have 10 successful flight out of 11 launching, which are summarized in Table 1.. Each flight has the the chamber with the area of 0.4 m^2. Thus the total exposure sums up to 575 m^2 hour. And the balloon trajectories are shown in Fig.1.

Table 1. RUNJOB Campaigns

	1995		1996		1997		
flight no	1	2	3	4	5	6	7
exposure time [h]	130.0	167.0	134.0	147.5	139.5	139.5	fail
altitude [g/cm^2]	10.0	9.6	9.8	10.2	10.5	10.7	
PI weight [kg]	230.0	230.0	260.0	254.0	260.0	260.0	

	1999			
flight no	8	9	10	11
exposure time [h]	141.0	145.0	148.0	146.0
altitude [g/cm^2]	9.5	9.2	9.2	9.0
PI weight [kg]	227.0	227.0	227.0	227.0

Balloon Specifications

Balloon	Envelop	Ballast	Parachute	Control Device	subtotal
180,000 m^3	650 kg	800 kg	180 kg	220 kg	1,850 kg

PI	Total
230270 kg	$\sim$ 2 ton

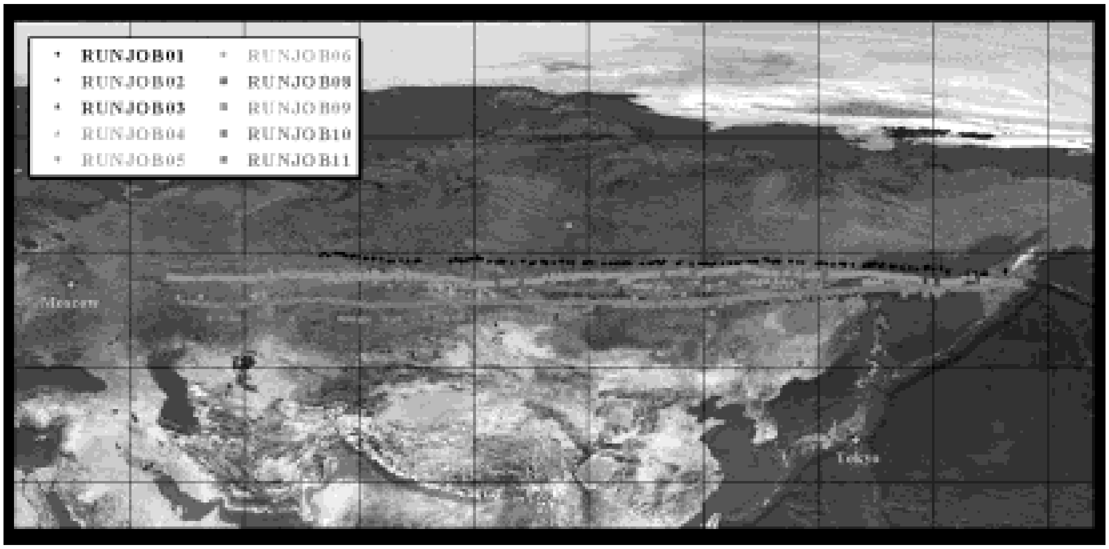
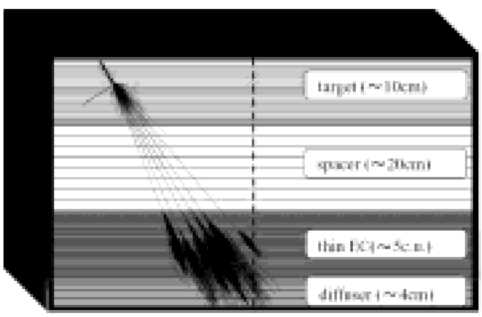


Fig.1 Balloon trajectries

3. Chamber design and Analysis

Fig.2 Chamber



Our chamber mainly consists of X-ray films, nuclear emulsion plates, lead plates and spacer materials. Their designs are changed basing on the analysis procedures. And the chamber design in the last campaign is shown in Fig.2.

Here it should be noticed that the thickness of the calorimeter is very thin because of the balloon limitation. Therefore we cannot observe the shower development up to the shwer maximum. To overcome this defect, we developed the new energy determination method basing on the average transverse momentum angular dependence of the secondary particles. This method is checked using the events in which the shower maximum is observed.

The method explained above was started to develop before the balloon campaign but the new method was developped basing on our experience in this experiment.

We have reported the highest energy event directly observed.[1] In its analysis, the X-ray films set out side of the chamber box works for the measure of the lateral cascade shower structure, which give us the estimate of the energy for the cascade showers even when their shower maximum is not observed.

After this experience, we employ this method for energy determination and inserts X-ray films after some spacer at the botom of the chamber. And using the shower simulation data accumulated by Shibata, the energy estimation procedure is established. The details of this method is published elsewhere.[2]

Our scanning procedures are expalained in detail in the published article[1], but the brief explanation can be found in the another article in this proceedings.[3]

4. Proton and Helium spectra

Thus obtained spectra of protons and helium nuclei are shown below with the comparisons of other direct observation experiments.

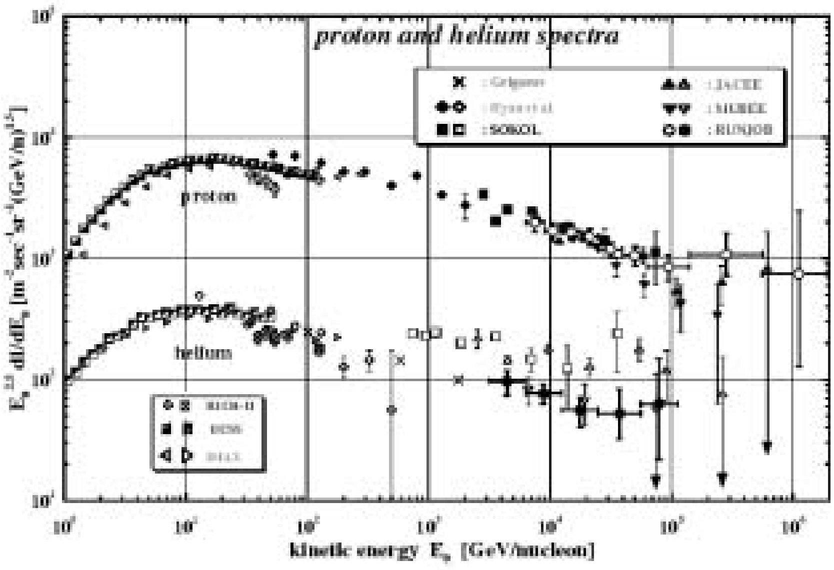


Fig.2 Proton and Helium Spectra

From our observation, the spectra of proton and helium nuclei are almost parallel and donot show any tendency of the steepning yet. So no indication of the acceleration limit up tp this energy region.

From the beginning of this experiment, He flux is lower than that of most other experiments by about 40 %. Even after the statistics is increased, this tendency is not changed.

5. References

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