Primary Heavy Components Spectra and 2-ry/1-ry Ratio Observed by RUNJOB Collaboration

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Abstract

Using all the data with sum of gamma ray energies greater than 5 TeV, we report the energy spectra of heavy primary cosmic rays from CNO through iron. Basing on these observations, we construct energy dependence of B/C and subFe/Fe ratios and will discuss the propagation of cosmic rays in the galaxy.

1. Introduction

The measurement of heavy components in the primary cosmic rays is important to study origin, acceleration and propagation of cosmic rays, specially the origin of the knee.

The secondary - primary nuclei ratio is essential to study the propagation

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of the cosmic ray in our Galaxy because the secondary nuclei are produced during the propagation.

2. Analysis procedures

Details can be found in the reference[1], here are brief explanations.

1. scanning of X-ray films and tracing up

   Our analyses start with the canning for the dark spot on the X-ray films in the calorimeter layers by naked eyes. Then the correlated spots in the layers are traced up to the interaction point in nuclear emulsion plates. Although some of our exposed chambers are used to observe the lower energy events, events with total energy released to γ rays greater than 5 TeV are traced up in all chambers.

2. primary identification

   To show the chemical composition, it is essential to identify the primary nucleus. There two points in this procedure. One is the track identification and another is the charge determination.

   For the track identification, it is not usual to see the interaction point in our chambers. So we have to reconstruct the event three dimensionally and reduce the location area of the primary track as small as possible. Namely around 20-50 μm. For the proton primary, this accuracy is not enough to specify the track but enough to exclude heavier primaries.

   Charge determination is made by the darkness measurement with CCD equipped microscope. This method is calibrated by the track whose charge is determined by the screen type X-ray films in our previous Sanriku experiment[2].

3. energy determination

   When we started this experiment, we prepared three methods.

   (a) shower transition curve
   (b) mean transverse momentum emission angle dependence method
   (c) fragment opening angle method

   The method (a) is limited in our chamber but still useful for the inclined showers. (b) is newly developed for this experiment and works well. The third method, which is used successfully for Sanriku experiment, is seldom used.

And as explained in another paper in this proceedings, we developed new method, which called "the diffuser method". This method turns out to be very efficient to measure.

In these ways, we get $\sum E_\gamma$, which is converted to the primary energy using the inelasticity k_γ. k_γ is estimated by the Mont Carlo simulations under the assumption of the primary power-type spectra.

4. Detection efficiency
   (a) interaction model
   (b) chamber structure
   (c) detection condition

are essential items to determine the detection efficiency. This also depends on the primary energy, the interaction point and others.

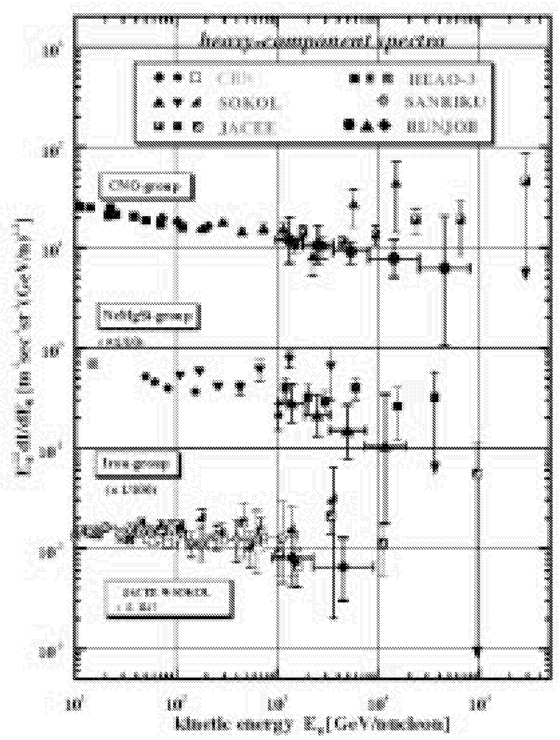
In our exposure, we are in the low detection efficiency region for iron nuclei but the statistical errors are still dominant.

3. Results

1. spectra of heavy nuclei

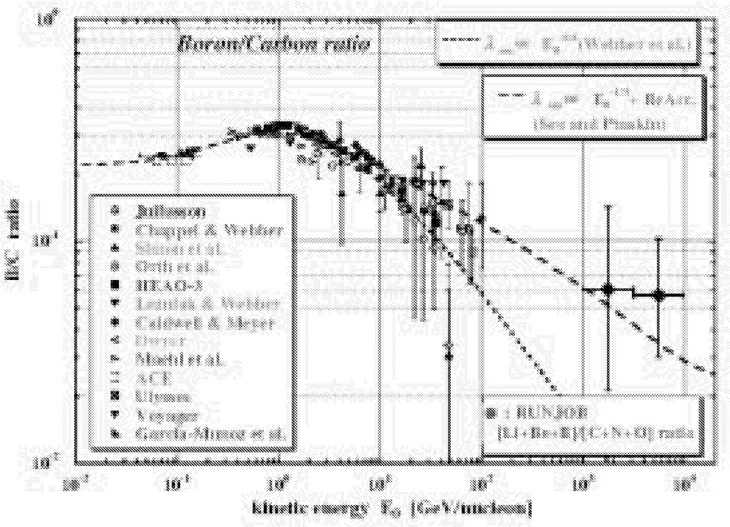
The energy spectra of heavy nuclei are shown in Fig.1 with comparisons of other experiments.
From these we can see the spectra of heavier nuclei get more stiff and this should be interpreted by the acceleration and propagation mechanisms.

Fig.1 heavy primary spectra



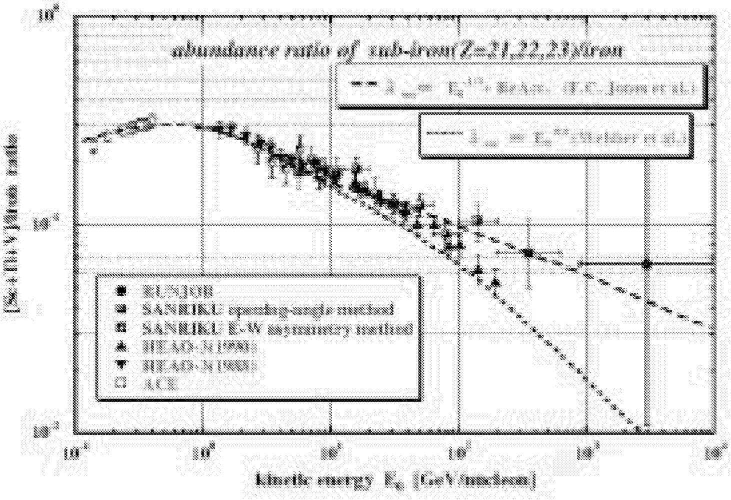
2. 2ry/1ry ratio

Fig.2 (Li+Be+B)/(C+N+O)



2ry/1ry ratio give us the knowledge about the amount of the matter traversed by cosmic rays because 2ry nuclei are produced by the fragmentation process of the 1ry nuclei. The typical examples are B/C and sub-Fe/Fe ratios. In our case, due to the statistical limits, (Li+Be+B)/(C+N+O) and sub-iron (Z=21,22,23) /iron are calculated and shown in Fig.2 and Fig.3. In these figures, the leaky box model and the modified leaky box model with re-acceleration curves are included, too.

Fig.3 (sub Fe)/(Fe)



It is customary to compare these ratios with the leaky box model. The leaky box model is simple and intuitive but not realistic. Moreover if the escape length decreases as the energy increase, then the anisotropy becomes significant which is not the case.

So here we put the curves from the modified leaky box model including the re-acceleration during the propagation.

Although our statistics is poor, the points in higher energy region is important to determine the model and indicate the ratios do not decrease in such a way that the simple leaky box model predicts.

4. References

1. Apanasenko A.V. et al. 2001, Astroparticle Phys. 16, 13
2. Ichimura M. et al. 1993, Phy. Rev. D48, 1949