SUB-Fe/Fe RATIO OBTAINED by SANRIKU BALLOON EXPERIMENT

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Abstract

We reanalysed sub-Fe component with charge of Z=21–23 (Sc, Ti, V) obtained by Sanriku Balloon experiment. These components are very important for the study of path length of cosmic rays in our galaxy, particularly in connection with the reacceleration process during the propagation in ISM.

Recently, interesting calculations of these processes are reported by several authors on the basis of reacceleration model, with use of new cross section for the nuclear fragmentation.

We show our data on sub–Fe(Z=21–23)/Fe ratio, covering very wide rigidity region, 5–1000 GV.

1 Introduction:

We performed two times of balloon flight, in 1989 and 1991, for the observation of heavy cosmic–ray primaries with use of new type of emulsion chambers at Sanriku in Japan, and the energy spectra of heavy component with $Z > 14$ were reported [1,2]. In this results, the ratio of sub–Fe relative to Fe was included, which is very important for the study of propagation mechanism of cosmic–ray in the Galaxy. This result was referred by some authors for comparison with propagation models[3].

The sub–Fe component with Z=21–25 was used in previous reports, but it is better to use a group of Z=21–23 to avoid the contamination of primary component which is produced at the source. In this sense, we reanalysed the results of Sanriku balloon experiment, and obtained the ratio of sub–Fe(Z=21–23) relative to Fe.

2 Balloon flights and event scanning

A more thorough explanation can be found in Ref. [1,2]. Here, only the essence is explained.

Two emulsion chambers were exposed in 1989 and 1991, with ST=34.0 m^2hr and 19.3 m^2hr, respectively. We used many layers of screen–type X–ray film(hereafter called SXF) and emulsion plates in these chambers. The tracks of heavy cosmic–ray primaries with $Z > 8$ can be found on SXF as dark spots by naked eyes.

We have measured x–y coordinates and darkness for all of track spot on SXF, with use of computer-guided large x-y stage with CCD camera, and track spots were followed down layer by layer, semi–automatically. If an incident heavy particle interact in the chamber, track spot will disappear or will be smaller than upper one. So we select such tracks as a candidate of interaction event, and scan the corresponding area on the emulsion plate by microscope. Then nuclear interaction can be found.

3 Charge determination method

The charge of each cosmic–ray nucleus is determined by the darkness of track spot on SXF. We present a scatter plot of the darkness versus the incident zenith angle in Fig. 1. In this figure we can find several densely populated zones, which are corresponding to iron, silicon, magnesium, and so on. Basing on this figure, we can obtained the charge histogram as shown in Fig. 2

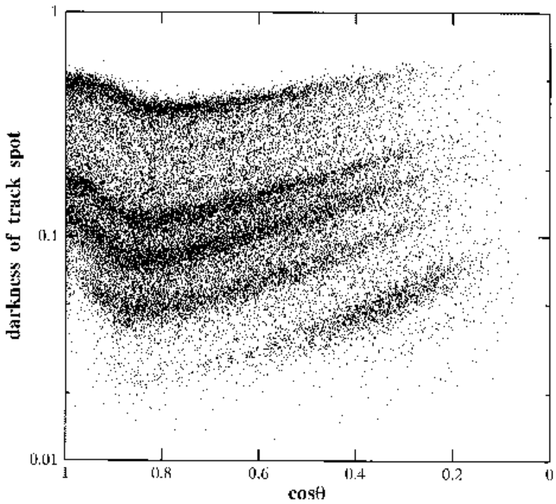

Figure 1: Scatter plot of darkness vs cosθ

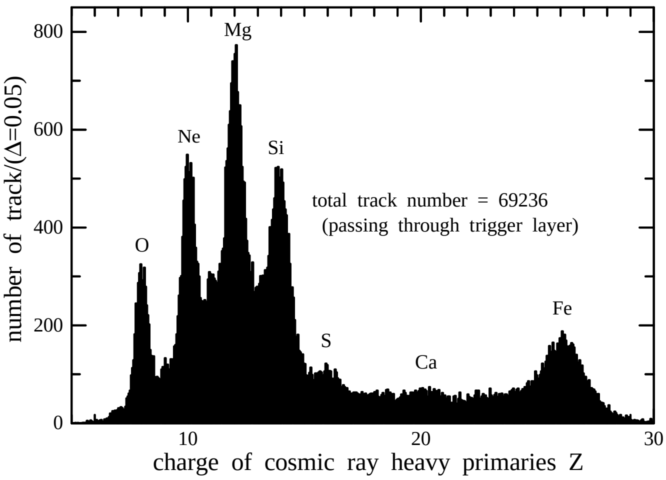

Figure 2: Charge histogram

with taking the zenith–angle dependence of the spot darkness into account. According to previous analysis, the charge resolution is 0.44 charge unit for silicon and 0.82 charge unit for iron [2].

4 Energy determination method

4.1 Opening–angle method

We measured the opening–angle of each fragment particle for all of detected interaction on emulsion plate under microscope. With use of these opening–angle, θ_f, 'reduced angle' Θ is calculated as follows,

$$\Theta = \sqrt{\frac{A_f(A_P - 1)}{A_P - A_f}}\theta_f \quad ,$$

where A_P and A_f are the mass numbers of the projectile and the fragment, respectively. Using Θ above, we can estimate the energy of heavy primary.

We show the results of energy calibration of this method by heavy–ion beams at several energies in Fig. 3. Details of this method are presented in Ref. [1].

4.2 East–West asymmetry effect method

Since the emulsion chamber exposed in 1991 has been azimuthally controlled, we can estimate the energy spectrum in the region of 2–15 GeV/nucleon with use of east–west asymmetry effect. We can know the incident zenith and azimuthal angles of heavy primaries from SXF measurement, which are corresponding to cut–off rigidity by geomagnetic field.

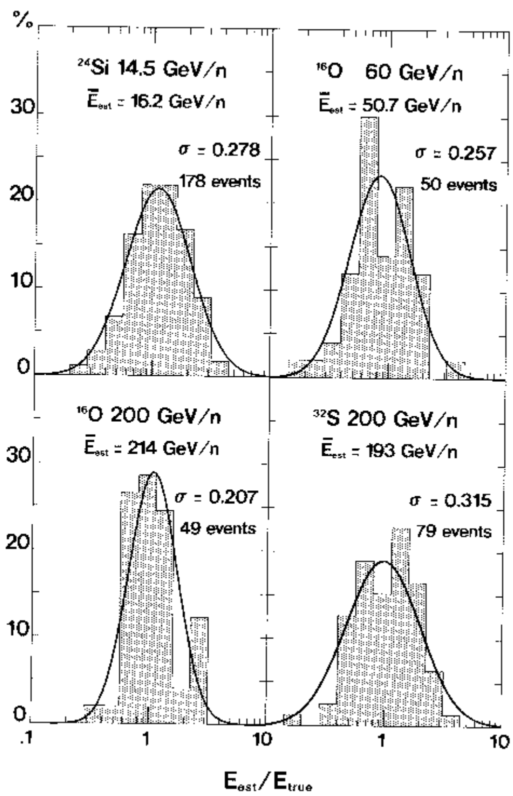

Figure 3: Energy resolution

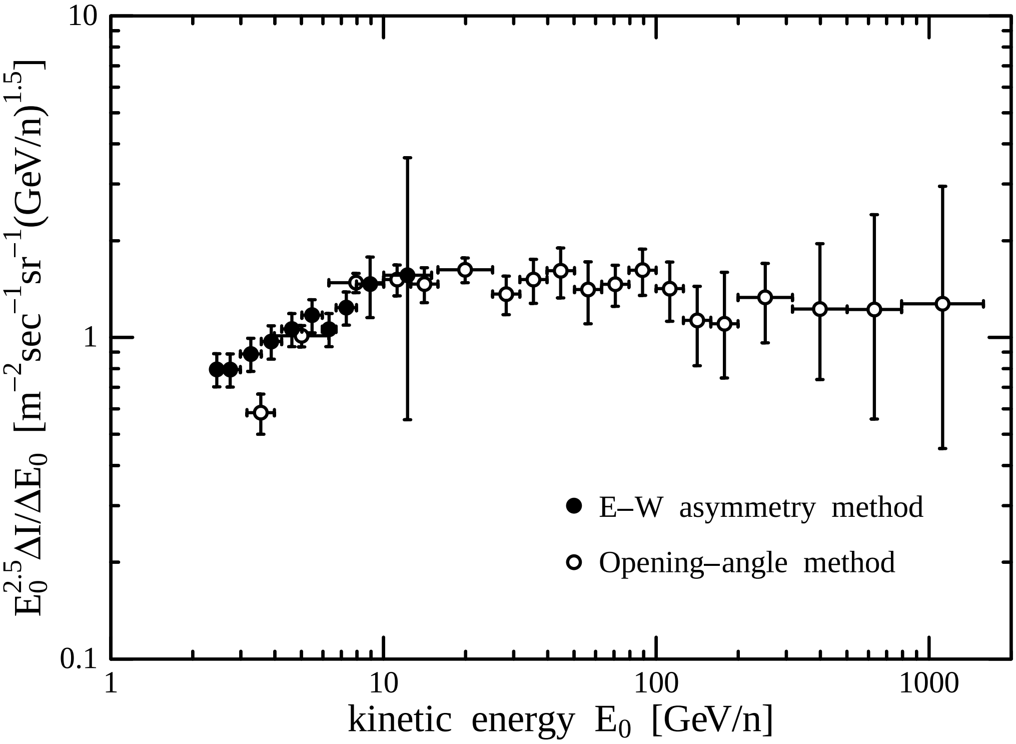

Figure 4: Absolute intensity of Fe

All of tracks measured on SXF are used for measurement of flux by this method. The reliable flux is obtained with rich statistics, though it is only for low energy region. Details are presented in Ref. [2].

5 Results

After taking the effects of propagation in atmosphere and detection efficiency of emulsion chamber, the absolute intensities of Fe and sub–Fe(Z=21–23) component are obtained as shown in Figs 4 and 5. One can see the feature of spectrum clearly, because our data covered wide energy range from 2 GeV/n up to 1 TeV/n with rich statistics.

Basing on these data, the abundance ratio of sub-Fe(Z=21–23) relative to Fe versus rigidity is presented in Fig. 6, with other data which is compiled by Grove et al.[4]. It seems that our data become flat in the rigidity region more than 100 GV, though statistics is not enough in this region. This rigidity region is very important to check the difference of propagation models. It is necessary to get more statistics in higher rigidity region.

References

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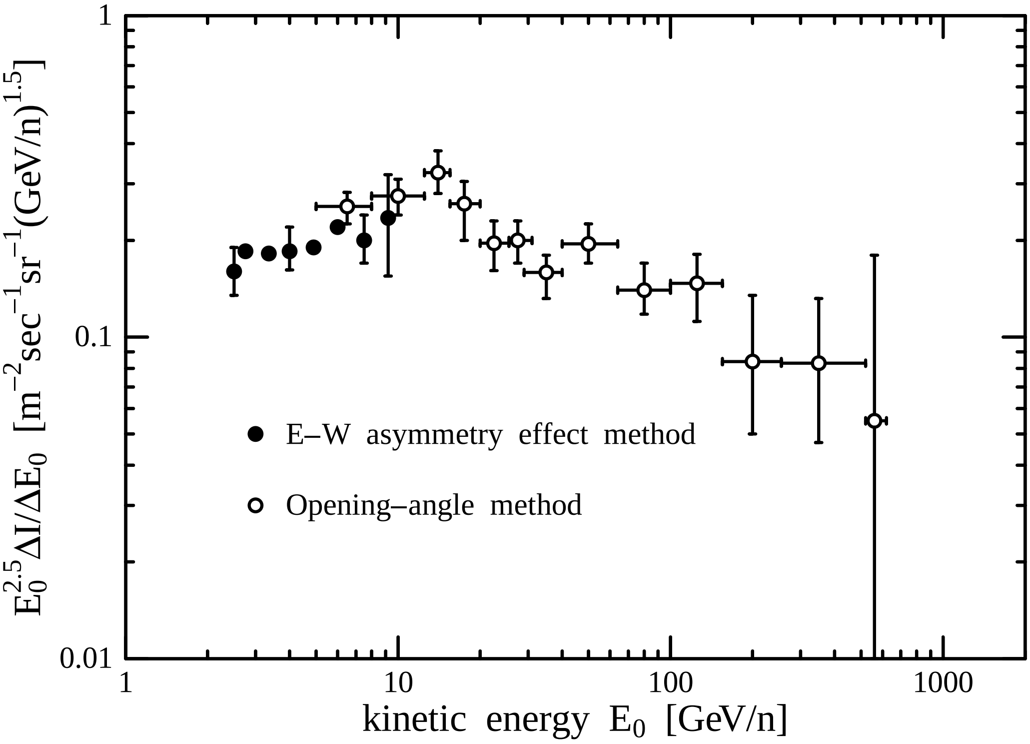

Figure 5: Absolute intensity of sub-Fe(Z=21–23)

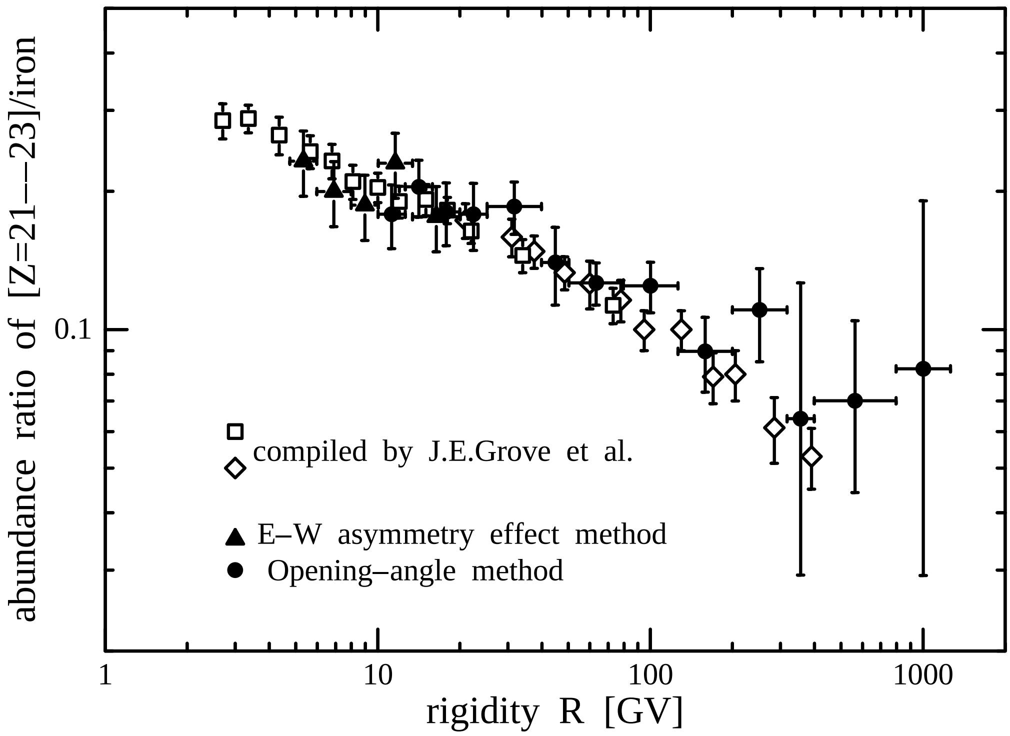

Figure 6: Abundance ratio of sub-Fe(Z=21–23) relative to Fe