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CALET Observation of Nuclear Components in Primary Cosmic Rays

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Although CALET is originally designed for detections of electrons and gamma rays, nuclear components of primary cosmic rays, from protons to iron nucleus and more, are also observable by CALET, utilizing the total absorption calorimeter (TASC). TASC has 1.6 m.f.p. for protons which is enough to measure the energy of protons up to 1000 TeV. Using the observed spectra, the following items will be discussed:
(1) the detailed structure of the spectrum, checking the change of the spectrum index and comparing indices of various components. More than 300 iron nuclei with the energy greater than 1 TeV/n will be observed.
(2) secondary/primary ratio. Especially we can observe the both of B/C ratio and sub-Fe/Fe ratio. At the space station, the observation is free from the atmospheric contamination corrections.
These observations are essential for the acceleration mechanisms and the propagation of cosmic rays.

1. Introduction

The CALET mission is proposed for observation of very high energy cosmic rays on the International Space Station. Although the detector is basically designed for detections of electrons and gamma-rays with use of electro-magnetic calorimeter, it can detect nuclear components because the total absorption calorimeter is enough thick for detection of protons up to 1000 TeV which is close to the Knee region.
The energy spectra of nuclear components in proximity of the Knee region is very important to resolve the problems of the acceleration limit and of the propagation of cosmic rays. The capability of the CALET mission for the observations of nuclear components are discussed in this report.

2. Detector

The CALET detector has two parts, an imaging calorimeter (IMC) in upper part, and a total absorption calorimeter (TASC) in lower part. The IMC has 36 layers of scintillating fiber belts for tracking of charged particles, and the TASC is composed of BGO logs with 32 r.l. of thickness for energy measurement. A silicon pad module is set at the top of the IMC to measure the precise charge of incident heavy nuclei.

The incident nuclei with the energy more than 1 TeV will be triggered by electro-magnetic cascade shower in the TASC with 0.1 Hz of the trigger rate. The particle identification of each event will be done in the IMC. The incident nuclei can make nuclear interactions and cascade showers in the TASC because it has 1.6 m.f.p. for protons which is enough thickness. The details of our detector are explained in other paper in this conference.

3. Expected Results

3.1 Exposure Factor

The number of detected nuclei i is given by

$$N^{(i)} = I^{(i)} S T \Omega^{(i)}_{eff} \ ,$$

where $I^{(i)}$ is the intensity of nuclei i, S is the area of detector and T is the time of observation. $\Omega^{(i)}_{eff}$ is the factor of geometrical solid angle including detection efficiency which depends on nuclear species i. We are planning 3 years observation by CALET, so $T = 9.46 \times 10^7$ sec. The area of TASC is 0.5m^2. Although the simulation calculations will be necessary to know the accurate value of detection efficiency for each nucleus, here $\Omega^{(i)}_{eff} = 0.3$ is used for all species for rough estimation. The expected numbers which will be detected by CALET, will be demonstrated as follows with use of above factors.

3.2 Energy Spectra

The energy spectra for proton and helium which are expected to be observed by CALET operation are shown in Fig. 1, including the data obtained by several groups[1, 2, 3, 4, 5, 6]. Single power law is assumed for estimation with -2.7 of power index for both of proton and helium, and expected statistical errors are shown together. More than 6×10^5 of protons with the energy above 1 TeV will be observed. Both of spectra will extend to just below the Knee with small statistical errors. It means that we can confirm the spectrum changing due to the acceleration limit which is predicted around there, if exists. These data will make clear the problem on the acceleration limit of cosmic rays.

The same type of plots for heavy component groups are shown in Fig. 2 with the data obtained by past experiments[3, 6, 7, 8, 9, 10]. The power indices are assumed to be -2.63 for CNO and NeMgSi groups, -2.56 for iron nuclei respectively, for calculation of expected points. More than 300 iron nuclei with energy above 1 TeV/n will be detected. The detailed structure of the spectrum for each nuclear component will be obtained up to 1000 TeV/n region. Rigidity dependence of acceleration and propagation processes will be checked basing on these data.

3.3 Secondary/Primary Ratio

The energy dependence of the ratio of secondary nuclei relative to primaries is important for understanding the propagation mechanism of cosmic rays. Especially the observation in high energy region , more than 1 TeV/n, is important for the checking of the difference between some propagation models. We show the observed ratio of boron relative to carbon obtained by previous experiment[7, 11, 12] in Fig. 3, and the ratio of sub-Fe relative to iron [7, 13] in Fig. 4.

We made rough estimations of expected ratio which will be observed in CALET, assuming both of these ratios are simply decreasing by single power law. The CALET mission will provide unique results for these ratios

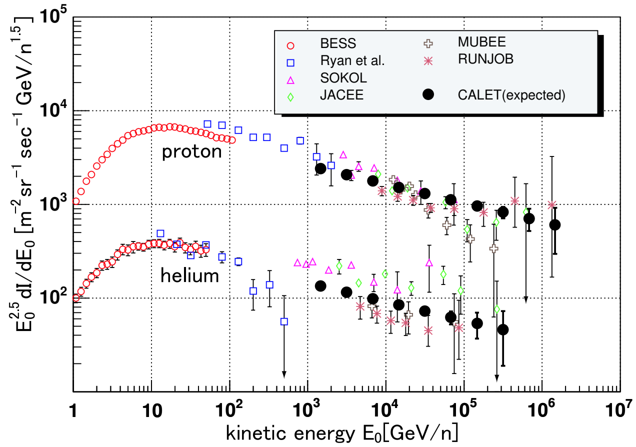

Figure 1. Expected proton and helium spectra which will be observed in CALET mission(filled circles). Other points are observed data by various kinds of balloon borne experiments[1, 2, 3, 4, 5, 6].

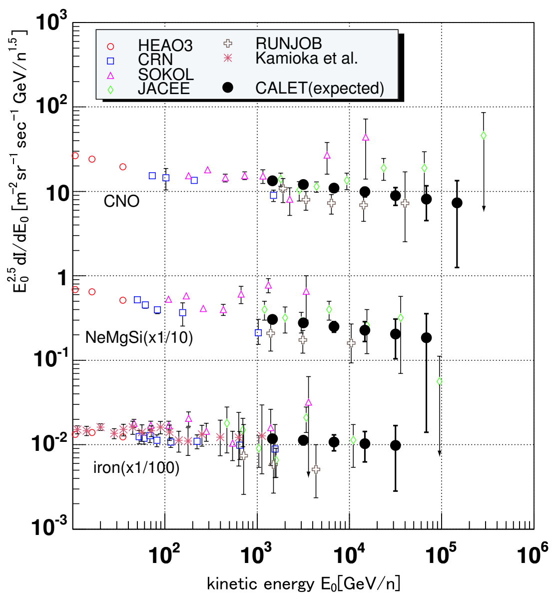

Figure 2. The energy spectra for CNO group, NeMgSi group and iron nuclei. Filled circles are expected points for CALET mission, others are obtained by past direct observations[3, 6, 7, 8, 9, 10].

up to several TeV/n. We are considering to lower the triggering energy threshold from 1 TeV down to several times 10 GeV for these observation, because there are no observed data in the energy region above 100 GeV/n up to now. The estimated points are plotted in Figs. 3 and 4 for the energy more than 10 GeV/n with filled circles. They will put severe restriction on the current propagation models.

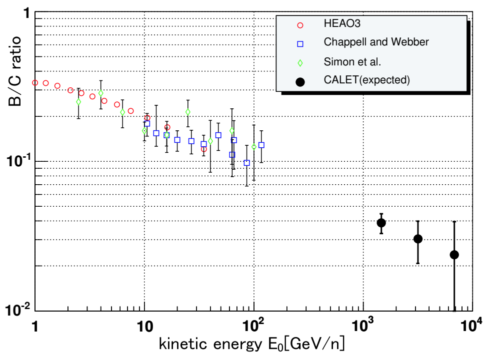

Figure 3. The energy dependence of the ratio of boron relative to carbon. The expected data for CALET mission are plotted with filled circles in TeV/n region. The previous measurements [7, 11] are covering the energy region less than 100 GeV/n.

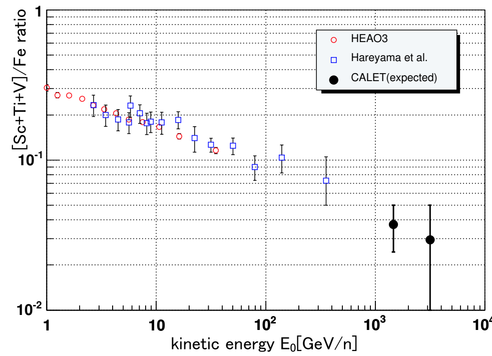

Figure 4. The ratio of sub-Fe group ($Z = 21, 22, 23$) relative to iron nuclei. The expected points for CALET mission (filled circles) are plotted with the observed data obtained by HEAO3[7] and Hareyama et al.[13].

3.4 Summary

The energy spectra for nuclear components and the secondary/primary ratios which will be observed in CALET mission are roughly estimated with simple assumptions. The variation of spectra in the energy region just below the Knee will be obtained for many species. Also the unique data for B/C ratio as same as sub-Fe/Fe ratio will be obtained in TeV/n region. The CALET will provide such important informations for nuclear component which are very important to solve the problems on acceleration and propagation mechanisms of cosmic rays.

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