Proceedings of ICRC 2001: 1622 © Copernicus Gesellschaft 2001

ICRC 2001

All particle spectrum observed by RUNJOB

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Abstract. We report the all particle spectrum and the average mass spectrum of cosmic ray primaries obtained by Japanese Russian joint balloon experiment. We performed 10 of long duration balloon flights for cosmic–ray observation, and 45% of observed data have been analyzed.

The all particle spectrum is obtained in the energy range of 20 $\sim$ 1000 TeV/particle by our experiment. Our results seems to be $\sim$30% less than others in the higher energy region beyond 100 TeV/particle. It seems no drastic change in this energy region, though the statistics is not yet enough to confirm it. The average primary mass number seems to increase slightly or to be constant in this energy region.

1 Introduction

The "knee" problem has been discussed in relation to the acceleration and propagation mechanisms of galactic cosmic–rays. To solve this problem, the detailed study of the energy spectrum and the chemical composition around the knee region are most important.

RUNJOB group(RUssia–Nippon JOint Balloon program) had performed 10 balloon flights successfully from 1995 through 1999 for observation of cosmic–ray primaries. Total exposure are accumulated to be 574.4 m^2·hour, and 45 % of all data have been analyzed.

Basing on this analysis, we obtained the all particle spectrum and the average primary mass in the energy region of 20 $\sim$ 1000 TeV/particle. We don't mention details of experiment and analysis, because these are reported in other reports in this conference. Here the obtained results are discussed mainly.

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2 Energy spectrum for each component

For making the all particle spectrum, the energy spectra for each component are summarized in Fig.1. Only our RUNJOB data are marked with filled symbols to discriminate with others. The data obtained by BESS(**?**) and IMAX(Menn et al., 1997) are shown here for proton and helium primaries, and by HEAO–3(Engelmann et al., 1990, 1981, 1983) and Sanriku group(Kamioka et al., 1997) are also plotted in this figure for heavy component. We use the same symbol for all data except RUNJOB for making it easy to see.

One can see the spectral feature for each become softer with mass number. Such tendency is consistent with rigidity cut–off scenario of galactic cosmic–ray propagation. Details for each component are discussed in other reports in this conference.

3 All particle spectrum

Summing up the spectra for each component in Fig.1, we can get the all particle spectrum. In Fig.2, we show it together with data obtained by other groups of direct measurement(Asakimori et al., 1998; Ivanenko et al., 1993; Grigorov et al., 1971) and of indirect measurement(Amenomori et al.,2000; Antoni et al., 2001; Swordy and Kieda, 2000;

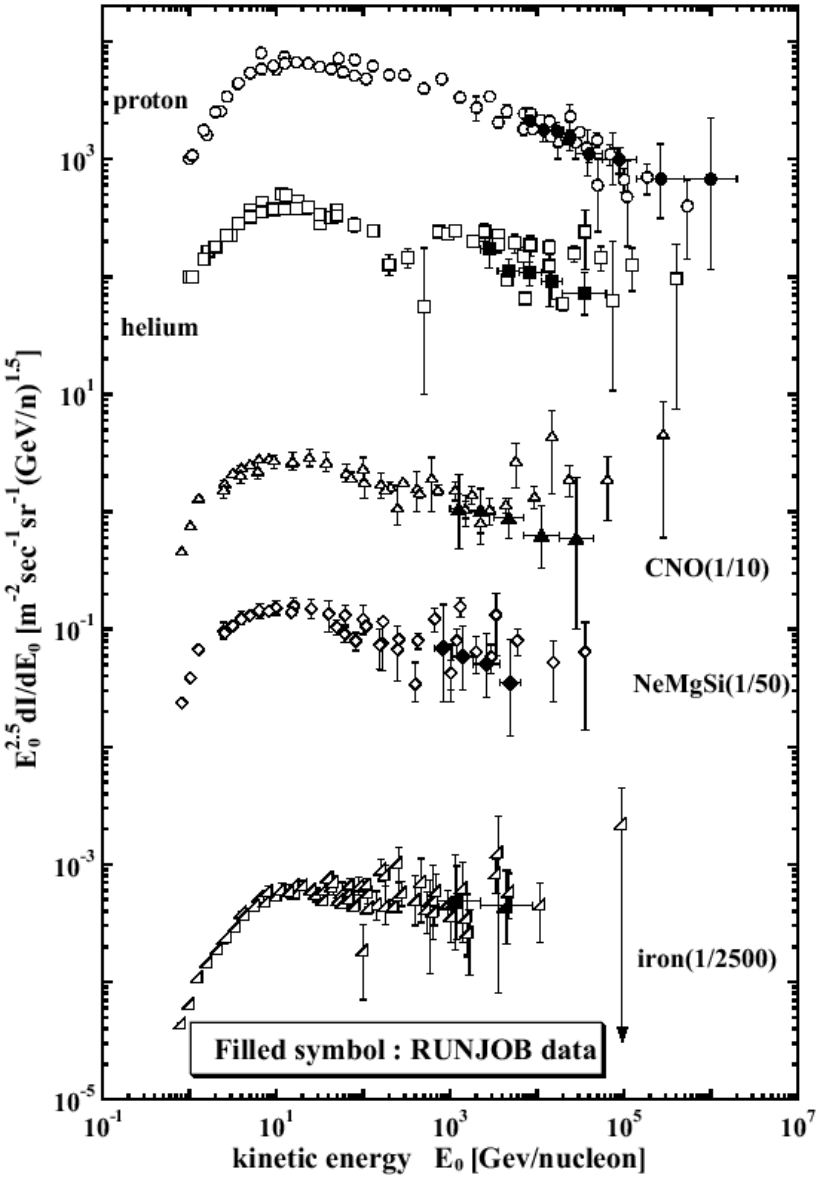

Fig. 1. Energy spectra for each component, proton, helium, CNO group, NeMgSi group and iron. RUNJOB data are denoted by filled symbols. Vertical axis is multiplied by $E_0^{2.5}$

Fowler et al., 2001; Glasmacher et al., 1999). Here the grey zone(Ichimura et al.,, 1993) denotes the summation of individual intensities obtained by the past direct measurement with use of counter devices. Horizontal axis is primary energy per particle, E_p, and vertical axis is the absolute intensity multiplied by $E_p^{2.5}$. The indirect data are displayed by open symbols.

Comparing our data with other direct measurements, while all the data are well consistent with one another in the energy region $\leq$ 100 TeV/particle, our all particle intensity is approximately 30% less than those obtained by others in the higher energy region $\geq$ 100 TeV/particle, though statistics are poor.

Let us compare with indirect data obtained by air shower experiments. One can see 2 groups of air shower data on Fig.2, higher intensity group and lower one. The lower data is rather near by ours than the higher one. On the other hand, the higher data is good consistent with JACEE data. Former combination means the smooth dropping feature of spectrum, and later combination means the flattering feature. We cannot say definitely which is better in this stage. But this problem is very interesting related to the cosmic–ray origin and the acceleration mechanism.

4 Average mass number

The chemical composition is very important information to study the origin and the acceleration mechanism of high energy cosmic–rays, particularly around the knee region. But it is difficult to observe separately each element with enough statistics in such high energy region. So we estimate the av-

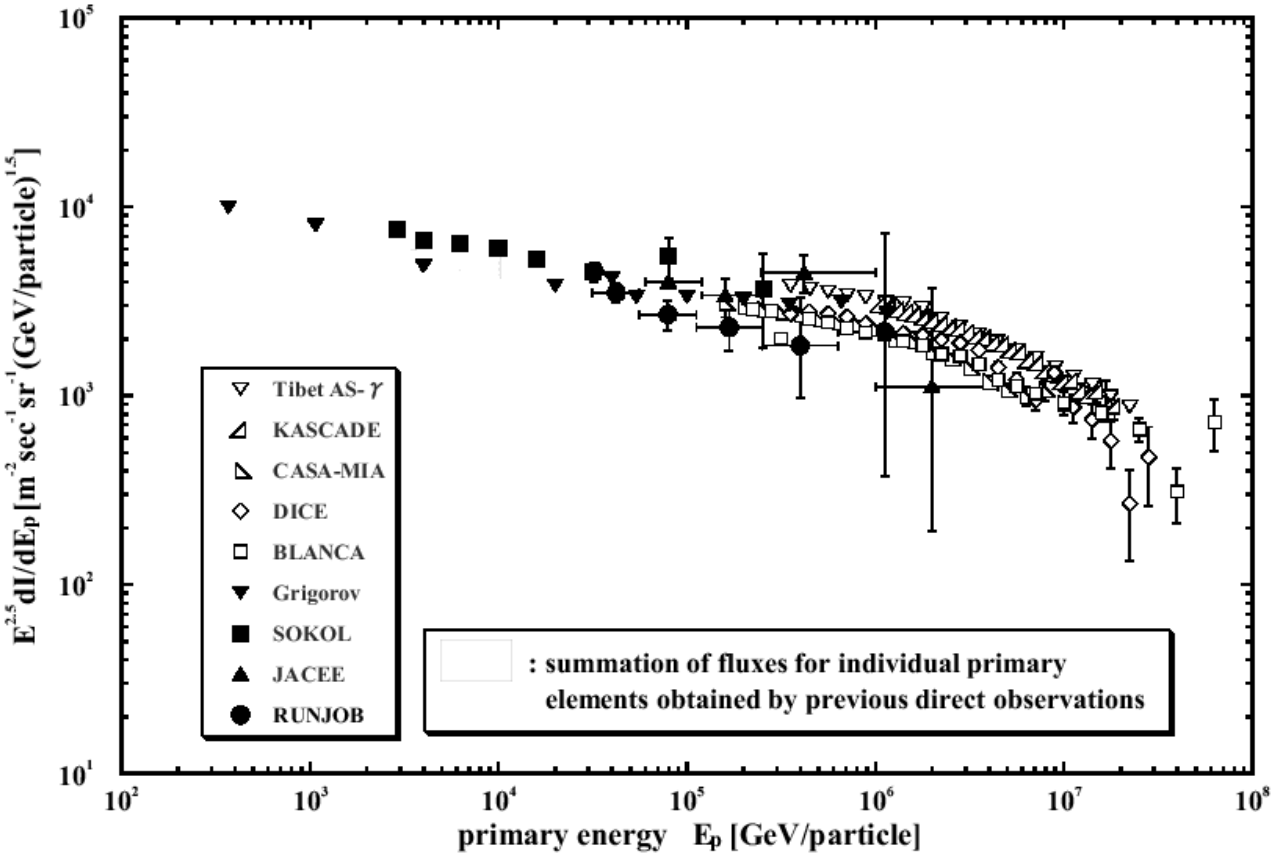

Fig. 2. All particle spectrum obtained by different groups.

erage mass number with use of the following quantity.

$$< \ln A > (E_p) = \frac{\sum_\ell \Delta J_\ell \ln A_\ell}{\sum_\ell \Delta J_\ell}$$

where E_p is a primary energy per particle, and ΔJ_ℓ is a differential intensity in the energy bin $(E_p, E_p + \Delta E_p)$ for the element ℓ with mass number A_ℓ.

In Fig.3, we show the present result together with JACEE data(Asakimori et al., 1998), where the grey zone(Ichimura et al.,, 1993) corresponds to the average mass number estimated from the past direct observations with use of counter devices. The results given by several groups of air shower experiment(Swordy and Kieda,2000; Fowler et al., 2001; Glasmacher et al., 1999; Antoni et al., 1999) are shown in this figure in the energy region greater than several times 100 TeV/particle, but there are big differences each other.

One finds the average mass number is 4∼6(He∼Li) around 10 TeV/particle. It is remarkable that JACEE and our data are in nice agreement with each other in the energy region ≤ 100 TeV/particle. JACEE data show, however, a gradual increase in mass number at higher energies, while our data seem to be almost constant over the wide energy range, $20 \sim 1000$ TeV/particle.

It is difficult to conclude whether the mass increase significantly with the energy beyond hundred TeV because of poor statistics. We reserve the conclusion until the completion of full data analysis of RUNJOB experiments.

5 Summary

We present the all particle spectrum and the average mass number spectrum basing on RUNJOB experiment. The all particle spectrum is quite consistent with those given by other groups in the past in the energy region ≤ 100 TeV/particle. But the present intensity is about 30% less than others in the higher energy region beyond 100 TeV/particle.

Present results are based on 45% of data obtained in RUNJOB experiments, and the results of complete analysis will be reported in the near future.

Acknowledgements. This work is supported by Institute of Cosmic Ray Research(ICRR), University of Tokyo, Institute of Space and Astronautical Science(ISAS), Japan Society of Promotion of Science(JSPS), the Grant-in-Aid for scientific research of Ministry of Education, Science and Culture in Japan, and Russian Foundation of Fundamental Research, International Projects of Russian Ministry of Science and Technology, Russian grants RFBR 99-02-17772 and RFBR 00-15-96632, and Russian Commission on Balloon Research

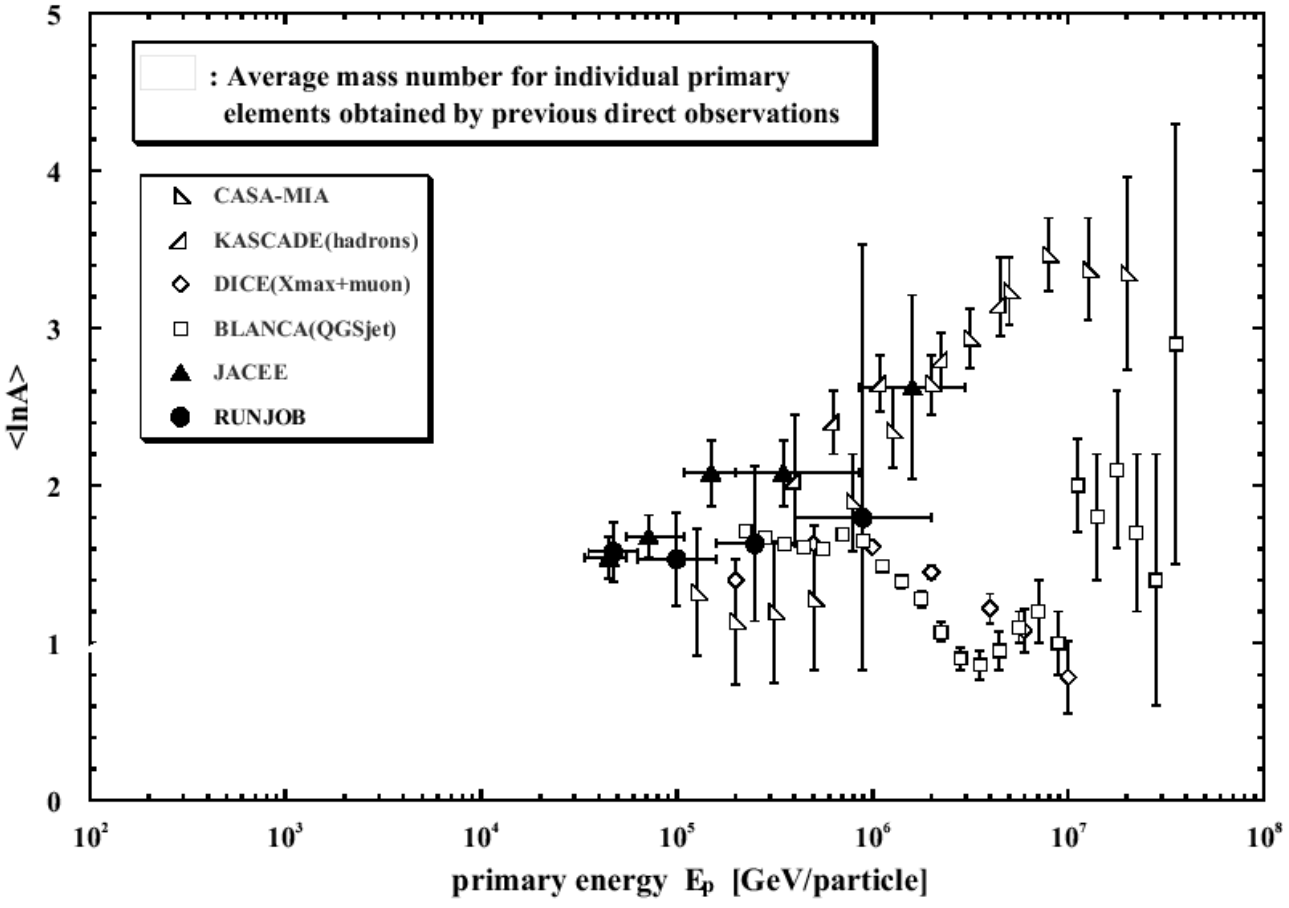

Fig. 3. Energy dependence of average mass number of primary cosmic–ray particles.

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