BESS Data on Primary Cosmic Rays and Muons

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We have measured absolute fluxes of primary protons, helium nuclei and atmospheric muons with the BESS spectrometer. Precise measurement of these cosmic-ray particles is indispensable for improving the accuracy in the atmospheric neutrino calculations.

1. INTRODUCTION

The flux of atmospheric neutrino of flavor i (ϕ_{ν_i}) is

$$\phi_{\nu_i} = \phi_p \otimes R_p \otimes Y_{p\rightarrow\nu_i} + \sum_A \phi_A \otimes R_A \otimes Y_{A\rightarrow\nu_i}, \quad (1)$$

where $\phi_{p(A)}$ is the flux of primary protons (nuclei of mass A). $R_{p(A)}$ and $Y_{p\rightarrow\nu_i}$ represent the effect of the geomagnetic field and the yield of neutrinos per primary particle, respectively [1]. In order to improve the accuracy in the atmospheric neutrino calculations, these three factors ($\phi_{p(A)}$, $R_{p(A)}$, and $Y_{p(A)\rightarrow\nu_i}$) have to be known precisely.

We have measured absolute fluxes of primary protons, helium nuclei and atmospheric muons with the BESS spectrometer. The precise measurement of primary cosmic rays improves the accuracy of $\phi_{p(A)}$. The fluxes of atmospheric muons at different sites provide useful information about $R_{p(A)}$ and $Y_{p(A)\rightarrow\nu_i}$.

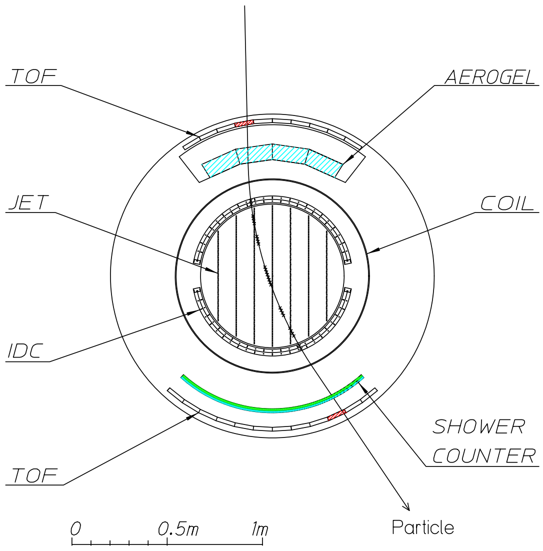

Figure 1. Cross-sectional view of the BESS.

2. BESS SPECTROMETER

The BESS (Figure 1) is a high-resolution spectrometer with a large acceptance to perform highly sensitive searches for rare cosmic-ray components, as well as precise measurement of the absolute fluxes of various cosmic rays [2–4].

A magnetic-rigidity of charged particle is measured by a spectrometer, which consists of a thin superconducting solenoidal magnet, a JET-type drift chamber, and two inner-drift-chambers (IDC's). Time-of-flight (TOF) hodoscopes provide the velocity (β) and energy loss (dE/dx) measurements. An electromagnetic shower counter has been equipped for e/μ separation. Detailed analysis procedures and the discussion of errors are described in [5] and [6].

*BESS Collaboration formed with The University of Tokyo, High Energy Accelerator Research Laboratory (KEK), Kobe University, NASA Goddard Space Flight Center, University of Maryland, and The Institute of Space and Astronautical Science.

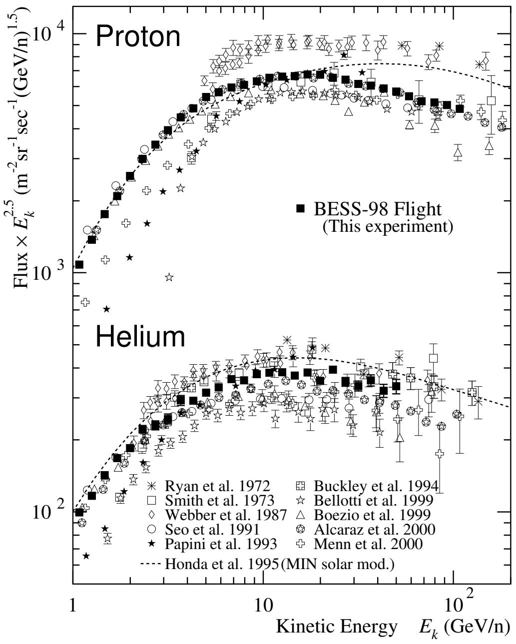

Figure 2. Absolute differential p and He spectra.

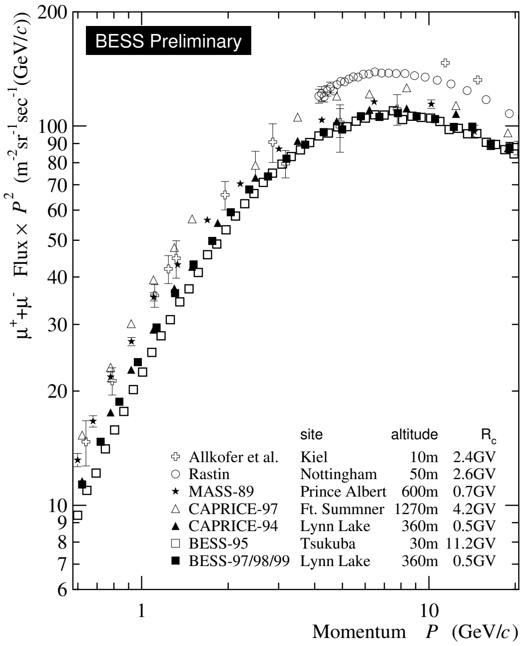

Figure 3. Absolute differential muon spectrum.

3. RESULTS

3.1. Primary cosmic rays

Figure 2 shows the absolute differential proton and helium spectra at the top of the atmosphere measured by a BESS–1998 balloon experiment [5] in comparison with other experiments [7–17].

3.2. Atmospheric muons

Figure 3 and 4 shows the absolute differential spectrum of muons ($\mu^+ + \mu^-$) at sea level [6] together with other measurements performed at various sites [18–21]. The muon intensity varies depending on environmental conditions. The altitude and cutoff rigidity for primary cosmic rays (R_c) are indicated in the figures.

As is seen in Figure 3, the muon spectra measured by BESS in Tsukuba and in Lynn Lake are in good agreement in higher momentum region, where the cutoff rigidity for primary cosmic rays can be neglected. Figure 4 shows, however, a deviation among the two spectra becomes larger with decreasing momentum. The deviation comes from the influence of the geomagnetic filed. This influence is demonstrated more clearly by μ^+/μ^- ratio as shown in Figure 5 [6].

4. CONCLUSION

As for primary protons and helium nuclei, i.e., $\phi_{p(A)}$ in Eqs. (1), BESS results, as well as other recent measurements, are more favorable to lower fluxes than the ones assumed in the atmospheric neutrino calculation [22] above a few tens of GeV. It may suggest importance of reconsideration for the atmospheric neutrino flux predictions.

The absolute fluxes of atmospheric muons are directly related to the yield of neutrinos, $Y_{p\to\nu_i}$ in Eqs. (1). The μ^+/μ^- ratio in a low momentum region is sensitive to the effect of the geomagnetic field, $R_{p(A)}$ in Eqs. (1). Detailed study of the atmospheric muons will improve the accuracy in

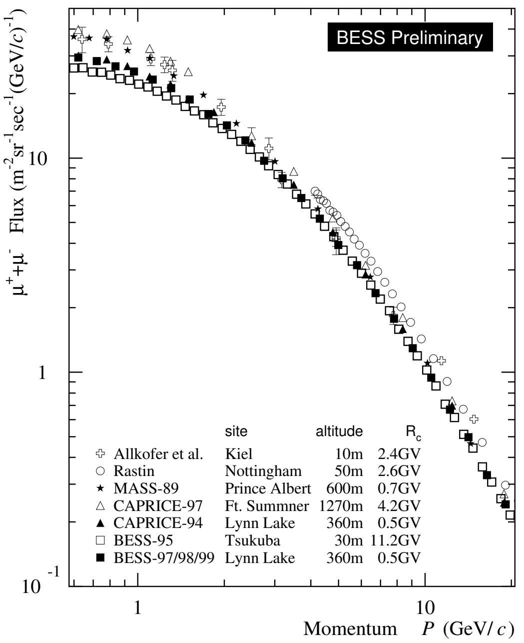

Figure 4. Absolute differential muon spectrum.

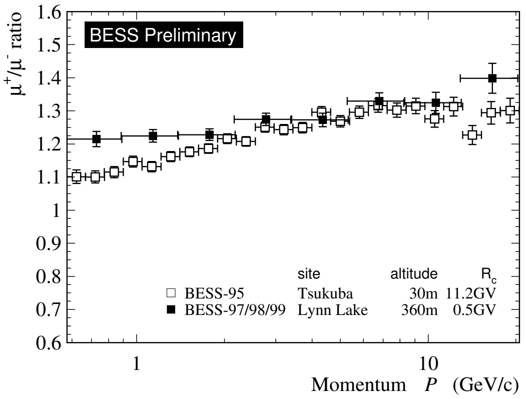

Figure 5. μ^+/μ^- ratio at sea level.

the estimation of the neutrino yield and the effect of the geomagnetic field.

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