Atmospheric Muon Measurements at Sea Level III: Muon Flux

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Abstract

We have measured the atmospheric muon fluxes at sea level using the Okayama telescope. In 2001, that was improved the larger acceptance and higher momentum resolution than previous one. One of the characteristic of Okayama telescope is able to measure the muon fluxes in any directions. Our aim is to examine the geomagnetic effects for atmospheric muon fluxes. We report the muon fluxes 8 azimuthal directions at zenith angle 20°.

1. Introduction

Atmospheric muons are produced by π/K decay at the top of atmosphere and pass through the atmosphere or decay. They have a close relation to the atmospheric neutrino, because neutrino is produced when the muon is produced and decayed. The atmospheric neutrino flux calculations[1,3,5] are considered the terrestrial magnetism and environment of atmosphere. Therefore, Information of propagation the atmosphere of secondary cosmic ray is necessary. The terrestrial magnetism affects the muon because of muon have a charge. Coming from the east a positive muon has a long path, positive muon fluxes thus decrease in this direction by geomagnetic effect and vice versa. We have measured the azimuthal angular dependence of atmospheric muon fluxes using the Okayama telescope. It is able to move by a servomotor mechanism allowing any azimuthal and zenith angle and measure the incoming directions, the momentum and charge sign of incident muon.

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2. Experiment

- The Okayama telescope
  The Okayama telescope(34° 40' N latitude, 133° 56' E longitude, 28m above sea level) is installed in the building of Okayama university in Japan. Rigidity cutoff is about 12GV. That is more detail described as [6].

- Measurement
  The periods are from 2002 to 2003. In 8 azimuthal at zenith angle 20° measurement, open angle is ±9° for the azimuthal and ±5° for the zenith, observation time is a week and number of events are about 50,000 for one azimuthal.

3. Results

We have analyzed the muon fluxes in 8 azimuthal directions at the zenith angle 20° in momentum range 1 ∼ 10 GeV/c. Fig .1,2 shows the muon fluxes in momentum range 1 ∼ 2GeV/c, 3 ∼ 10GeV/c respectively. The results are presented in tabulated from in Table 1. The azimuth dependences of the positive excess($2 \times \frac{\mu^+ - \mu^-}{\mu^+ + \mu^-}$) are shown in Fig. 3 in momentum range 1 ∼ 2GeV/c, 3 ∼ 10GeV/c respectively. Positive Excess is used to investigate the geomagnetic effect for atmospheric muon fluxes. Subtracting negative muon flux from positive muon flux, Geomagnetic effect for primary cosmic ray don't affects that[2,4].

Table 1. The results of the muon fluxes at zenith angle 20° in momentum range 1 ∼ 10 GeV/c.

μ^+	average flux ($cm^{-2}sr^{-1}s^{-1}$)	West/East fraction (%)
1 ∼ 2 GeV/c	$5.84 \times 10^{-4} \pm 0.7\%$	-24 ± 3
3 ∼ 10 GeV/c	$1.09 \times 10^{-3} \pm 0.4\%$	-13 ± 2
μ^-	average flux ($cm^{-2}sr^{-1}s^{-1}$)	West/East fraction (%)
1 ∼ 2 GeV/c	$5.13 \times 10^{-4} \pm 0.7\%$	-9 ± 4
3 ∼ 10 GeV/c	$8.85 \times 10^{-4} \pm 0.5\%$	-7 ± 2

4. Conclusion

The Okayama telescope was improved the large acceptance and high momentum resolution than previous one in 2001. We have measured the atmospheric muon fluxes at sea level in 8 azimuthal directions at zenith angle 20° in momentum range 1 ∼ 10 GeV/c. Muon measurements in west and east at zenith angle 20° showed the tendency of geomagnetic effect. Coming from the east a positive

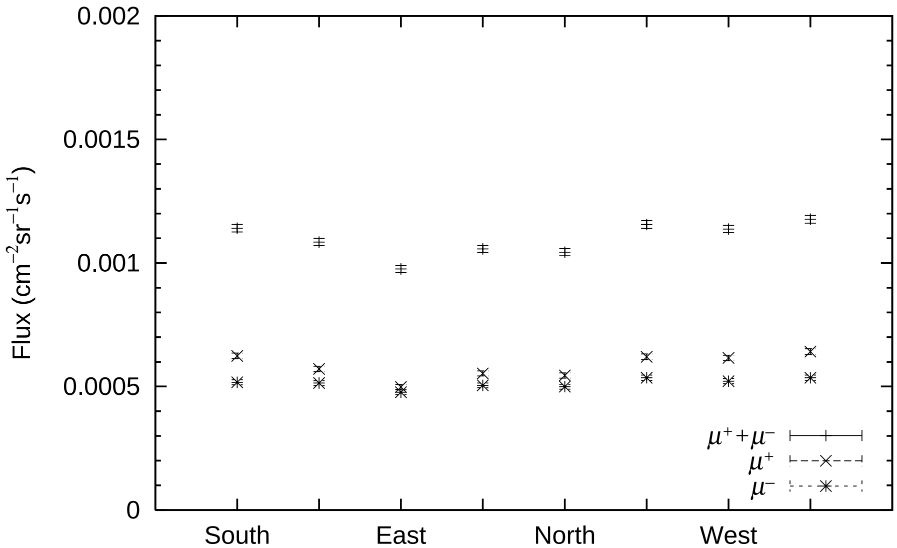

Fig. 1. The muon fluxes in 8 azimuthal directions at zenith angle 20° in momentum range $1 \sim 2$ GeV/c.

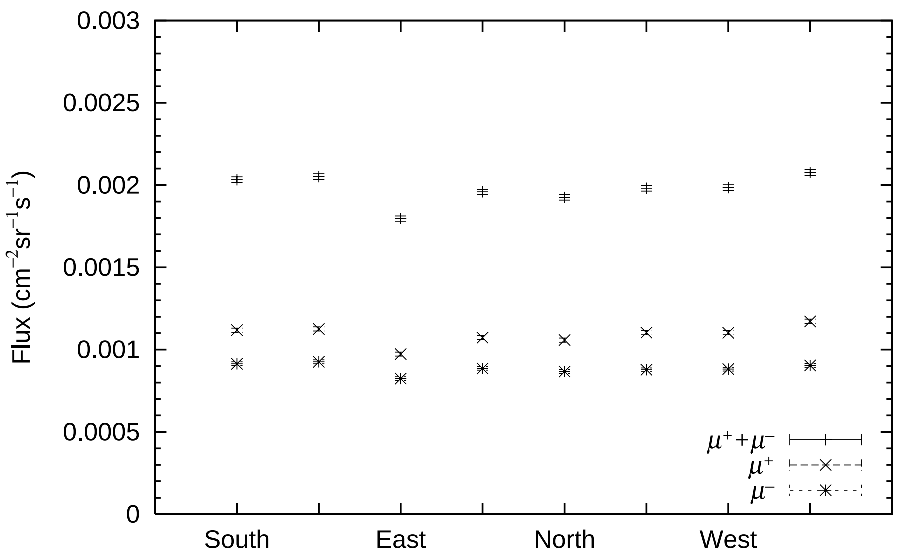

Fig. 2. The muon fluxes in 8 azimuthal directions at zenith angle 20° in momentum range $3 \sim 10$ GeV/c.

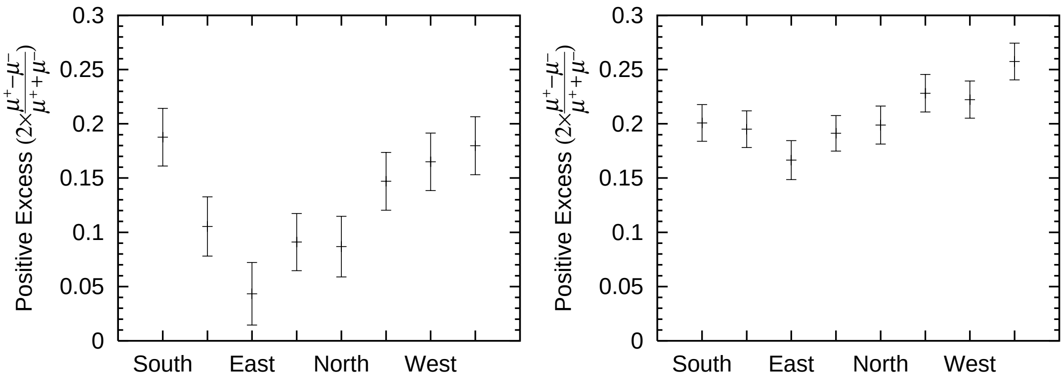

Fig. 3. The azimuthal angular dependence of the positive excess in 8 azimuthal directions at zenith angle 20° in momentum range 1 $\sim$ 2 GeV/c(left) and 3 $\sim$ 10 GeV/c(right).

muon fluxes decrease and a negative muon fluxes increase by the geomagnetic effect and vice versa. Our results showed that amplitude of positive excess increase in momentum region 1 $\sim$ 2 GeV/c than 3 $\sim$ 10 GeV/c as shown Fig. 3. Variation of the atmospheric muon fluxes affects the atmospheric neutrino fluxes that are produced by the muon decay. Thus, calculations of propagating of secondary cosmic ray should be taken into account the geomagnetic effect.

5. References

1. Battistoni G. 2001, Nucl.Phys.Proc.Suppl.100, 101-106
2. Hayakawa S. 1969, COSMIC RAY PHYSICS, Nuclear and Astrophysical Aspects (WILEY-INTERSCIENCE a division of John Wiley & Sons, New York)
3. Honda M., Kajita T., Kasahara K., Midorikawa S. 2001, Phys.Rev.D, 64, 053011
4. Kamiya Y. et al. 1962, J.Phys.Soc.Japan, 17 Suppl.A-III, 315
5. Lipari P. 2000, Astropart. Phys. 14, 3, 171-188
6. Tokiwa M. et al. 2003, Proceedings in this conference, Atmospheric Muon Measurements at Sea Level I: The Detector