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Observation of atmospheric gamma-rays and electrons for calibrating the atmospheric neutrino flux

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Abstract

We are calibrating our calculation (Honda et al., 1995) of neutrino flux by observing high energy photons and electrons in the atmosphere and comparing them with the calculation. So far we have performed observation at Mt. Norikura (2780 m a.s.l). A major balloon altitude observation is scheduled in the summer of 1999. Accelerator calibration is also planned in June. For these observation we use the upgraded BETS scintillating fiber imaging calorimeter. We describe our strategy, detector and status of the project. Data analysis is in progress and will be presented at the conference.

1 Introduction

The Super-Kamiokande group has given an evidence for neutrino oscillation (Fukuda, et al., 1999). The conclusion has been derived from comparison of the experimental data with corresponding neutrino flux calculations which include a certain level of uncertanity. Therefore, the comparisons have been carefully done mainly bypassing discussions in absolute scale.

To be able to discuss the oscillation more firmly, we need a reliable expected neutrino flux (under the assumption of no oscillation). The uncertanity of the flux calculation mainly comes from the one in the primary cosmic ray flux and modeling of nuclear interactions. Improvement of calculations will be possible by knowing more accurate primary flux. Another approach to reducing the uncertanity is to calibrate the calculation by measuring atmospheric cosmic rays. This approach would absorb various uncertanities coming not only from the primary flux but also other factors.

As atmospheric cosmic ray components, muons are indispensable for calibration since they are directly coupled with neutrinos. However, to make the calibration as stable and reliable as possible, we should use other components simultaneously. Among others, photons and electrons are abundant and relatively easy to measure.

2 The detector

We have been developing a detector for measuring cosmic ray primary electrons above the several GeV region. So far we have done a few balloon altitude observations with the detector and it's accelerator calibration two times at CERN. For our present purpose, it has been upgraded so that we can trigger photon induced events without loss of electron events.

The main body of the detector consists of a number of scintillating fiber (scifi) belts sandwiched between lead plates, and three sets of plastic scintillators for trigger (Fig.1). The total thickness is about 7 radiation lengths.

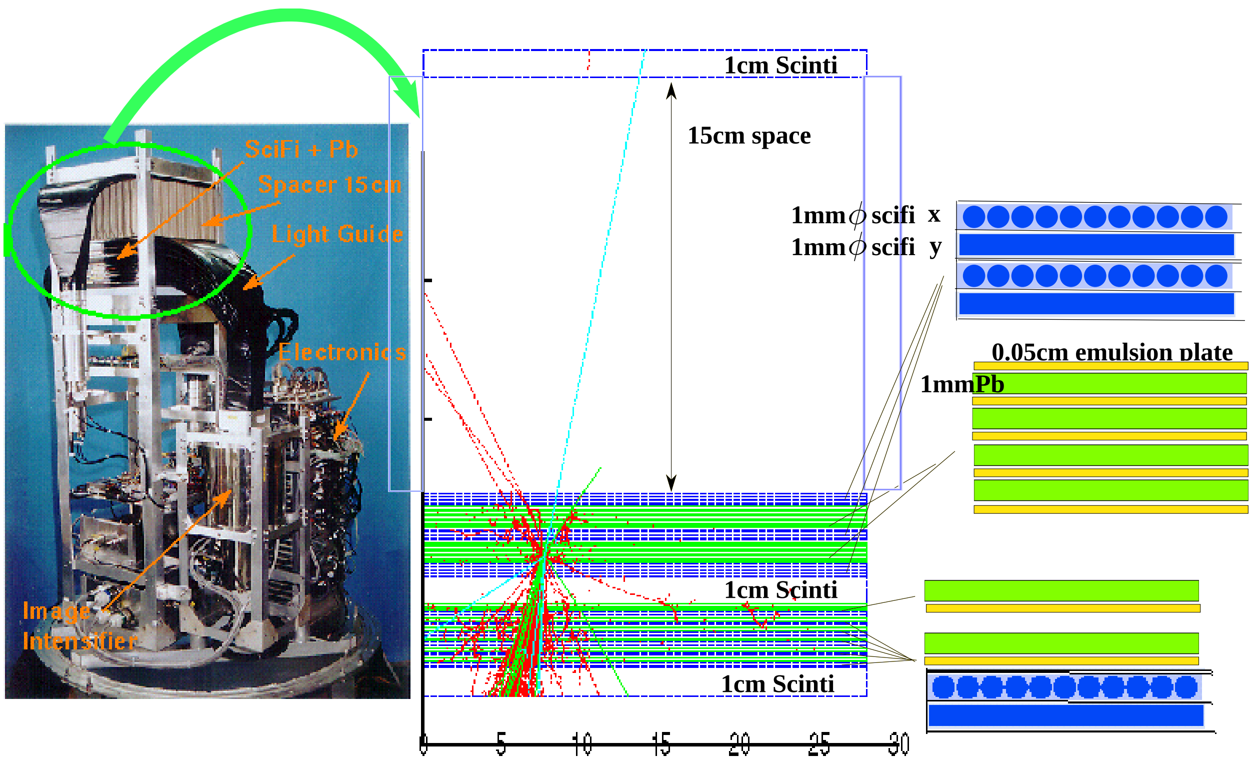

Figure 1: The BETS scintillating fiber imaging calorimeter. The vertical 1.5 cm thick scintillator plates are being implemented newly.

A layer of the scifi belt consists of 280 scintillating fibers of 1 mm ϕ. X and Y direction aligned scifi belts are fed to two image intensifiers and then to CCD's, respectively. The final output is recorded by a 8 mm tape drive. Three sets of 1cm thick plastic scintillator plates are inserted at 0, 2, and 7 radiation lengths to make trigger. The vertical ones surrounding the 15 cm space region are being implemented to reduce the trigger rate by rejecting numbers of electrons entering from the side, which are expected at medium balloon altitudes; this is another new feature being added for atmospheric cosmic ray observation.

We have shown that the energy resolution is $\sim$ 17 % in the energy region over $\sim$ 10 GeV. This is obtained using only the signal from the bottom scintillator. If we combine scifi output with those from all the scintillators, we can increase the resolution and keep it more or less below 10 GeV. This will be tested with accelerator beams, soon. Further details of the detector will be described in Torii et al., 1999a, Tamura et al., 1999 and Torii et al., 1999b.

3 Optimum observation condition

Since the neutrino anomaly happens at around 1 GeV neutrino energies, we should observe photons and electrons produced by the parents which generated such neutrinos. Figure 2 shows a Monte-Carlo result of the primary energy distribution for binned neutrino energies at sea level. For a given neutrino energy, E_ν, the corresponding median primary energy is approximately $\sim 20E_\nu$, which would be much lower if the geomagnetic rigidity cutoff had not been applied. The median energies of the primaries that generate neutrinos or photons of a given energy interval are listed in Table 1.

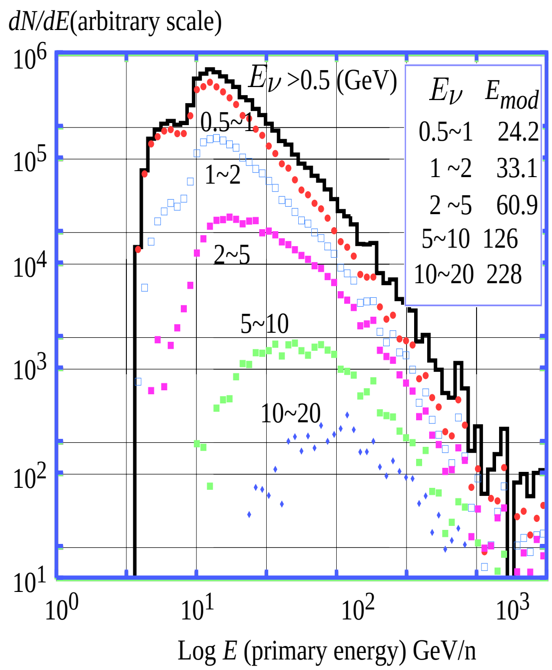

Figure 2: Primary energy distribution for the fixed range of neutrino energy. The mod energy of the primary is inlaid. The cosine of the primary angle is > 0.9.

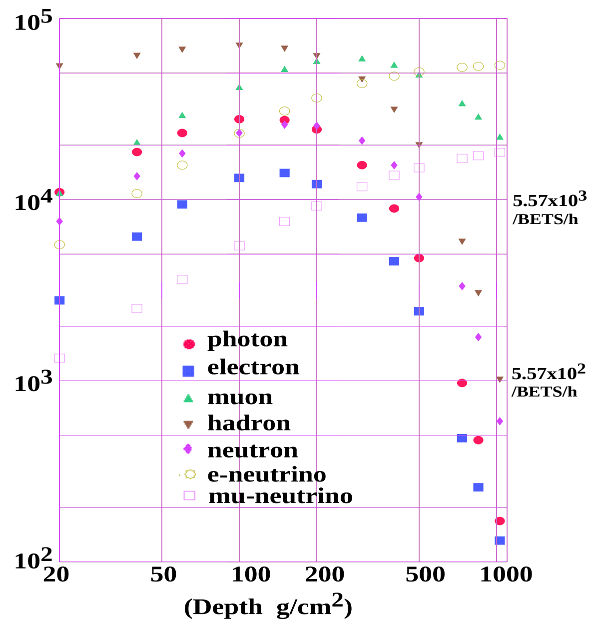

Figure 3: Transition of various components with energy >1GeV and cosine of the primary angle $>$ 0.9. Expected number of particles entering into the BETS detector per hour is shown on the right hand side.

	Median primary energy (GeV)			
Energy range	For neutrinos	For gamma rays		
E_ν or E_γ(GeV)	at sea levell	at 100 g/cm^2	at 150 g/cm^2	at 200 g/cm^2
$0.5 \sim 1$	24.2	23.9	28.7	33.9
$1 \sim 2$	33.1	27.0	33.4	40.5
$2 \sim 5$	60.9	39	51	61
$5 \sim 10$	126	82	104	115
$10 \sim 20$	228	148	185	193

Table 1: Median energies of the primaries responsible for neutrinos and photons of fixed energy intervals. The cosine of the primary angle is > 0.9

The optimum depth for the observation is, as one can naturally expect, around 100 g/cm^2 where neutrinos are most abundantly produced (Honda et al.,1995) and the photon flux becomes maximum.

To have an idea of how much events are expected with the BETS detector, we plot transition curves of various components of atmospheric cosmic rays as a function of depth in Fig.3. The number of photons entering into the detector at around 100 g /cm^2 in an hour is expected to exceed 10^4 above 1 GeV, so the observable number would be at least a few times 10^3 with a detector efficiency of ~ 0.4.

3.1 background

Since we are interested in photons and electrons above $\sim$ 1 GeV, muons are not triggered. Hadrons (p, n, pion, kaon) are 2$\sim$3 times as abundant as photons and can be a major source of the background. We have shown that the primary electrons can be selected with high efficiency from the source of e/p ratio $< 10^{-2}$ (Torii et al., 1999a,b. Tamura et al. 1999). The atmospheric condition is much better than this. However, neutrons at deep depths may be harmful at low energies for photon observations. This is being examined.

4 Observation at 735 g/cm^2

We have done a test observation at Mt. Norikura (735 g/cm^2) in Sep., 1998 to see the detector performance for photons. The data itself can be used to calibrate the calculation, though the depth is little bit too large (The median energy of the primary for $\sim$ 1.5 GeV photons is $\sim$ 100GeV). The data was taken during $\sim$ 17 days. Then, we expect $\sim 2 \times 10^5$ events above 1 GeV, and $\sim 4 \times 10^3$ above 10 GeV. The analysis is in progress. Examples of a photon and hadron like events are shown in Fig.4 and Fig.5, respectively. They are raw CCD images and we need some further reconstruction of x-y coordinate for true image.

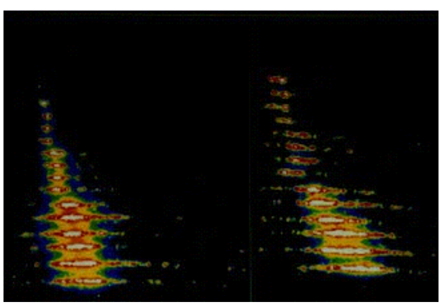

Figure 4: Photon like event. X (left) and Y(right) images are shown

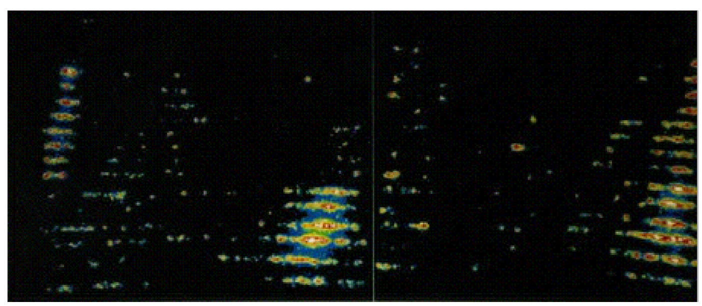

Figure 5: Hadron like event

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