Performance and Operational Status of Muon Detectors in the Telescope Array Experiment

T. Nonaka\textsuperscript{a}, R. Cady\textsuperscript{b}, D. Ivanov\textsuperscript{a}, J.N. Matthews\textsuperscript{a}, S. Ogio\textsuperscript{a}, T. Okuda\textsuperscript{a}, H. Sagawa\textsuperscript{a}, N. Sakurai\textsuperscript{a}, B.T. Stokes\textsuperscript{a}, and R. Takeishi\textsuperscript{a}

\textsuperscript{a} Institute for Cosmic Ray Research, University of Tokyo, Kashiwa, Chiba, Japan
\textsuperscript{b} High Energy Astrophysics Institute and Department of Physics and Astronomy, University of Utah, Salt Lake City, Utah, USA

Abstract: The Telescope Array (TA) experiment, located in the western desert of Utah, USA, at 39.38° north and 112.9° west, is collecting data of ultra high energy cosmic rays in the energy range 10^{18} - 10^{20} eV. The experiment has a Surface Detector (SD) array surrounded by three Fluorescence Detectors (FD) to enable simultaneous detection of shower particles and fluorescence photons. Measurement of shower particles at ground level, with different absorber thickness, enables a more detailed study of the experiment’s energy scale and of hadron interaction models. In this report, we present a design and first observation result of a surface muon detector using lead plate and concrete absorber.

Concept of Detector

It is planned to have multiple types of detector with different thicknesses of absorber. One type is the lead inserted segmented detector (SD), which will have the capability to measure muon and electromagnetic (EM) components separately. The second type is a concrete shielded detector to find high energy (E > 600 MeV) muons.

Estimation of accuracy of muon counting

Lead detector:

Simulation studies with air showers Monte Carlo simulation were done to estimate accuracy of muon counting. For the lead detector, we count the coincident of the rising edge within 20 nsec between the top and bottom layer. Fig. 3 shows lateral distribution of simulated muon count at vertical proton shower (10^{19} eV).

Concrete shield detector:

Because of 1.2 m of concrete shield 600 MeV is the threshold energy. Accuracy of counted number of muon depends on counting method. Fig. 7 shows counting accuracy for two method of counting. Left side is the scatter plot of the thrown and counted number of muons in the paragraph of the muons using wave rising edge. (Same method which used for lead detector) Right side is the same plot in a case counting of the muon using charge amount of signal (VEM).

Performance of assembled detector and prototype observation

Lead detector assembly:

For the lead detector, 12 modules (top and bottom pair) are assembled, each of 0.75 m thick. The Npe for 1 mip was 18.3 pe. The average Npe for 1 mip at TD SD is 24.6 ± 7.2 with same type of PMTs. The position dependence of the response for the mip were checked at 35 positions to cover entire segment which is 15x15 cm². The RMS of the distribution of 1 mip value is about 5% of the average 1 mip value.

Concrete detector assembly:

For the concrete shield detector, a total of 8 modules of 3 m² TA SD are assembled. Construction of concrete stack is completed at end of March 2015.

Test observation of air shower:

We started test observation with a prototype lead detector in December 2013. Fig. 8 shows the distribution of energies of observed air showers from Dec. 2013-May.2014. Red histogram shows showers which left signal on deployed detector. Fig. 9 and 10 show one of observed events in this time period. The reconstructed energy is 17 EeV and zenith angle is 37°. Fig. 9 shows the recorded VEM at top layer of the prototype detector and signal timing at each detector respectively. The lead detector's signal is plotted as red color. Both are well aligned along other detectors. So recorded waveform at the lead detector can be considered as a signal associated with this shower.

Summary

Performance and operation status of TA muon detector is presented. The detectors are currently being installed for the test observations in the TA array. The detector has good stability and sensitivity and uniformity. The detector collects the data of air showers in association with the TASSD. With more statistics, detailed comparison with existing MC will be done. Currently 8 of 3 m² detector segment are being installed.

Reference