Name of research institute or organization:

Department of Physics, University of Rome La Sapienza, Italy
Department of Physics, Abant Izzet Baysal University, Turkey
Department of Physics, Carnegie-Mellon University, Pittsburgh PA, USA

Title of project:

Test for a new concept of an EAS detector for UHE neutrinos

Project leader and team:

Prof. Maurizio Iori, project leader
Prof. Jim Russ, Prof. Haluk Denizli, Ali Yilmaz, Şeyma Atik

Project description:

The detector installed at the Sphinx is a prototype of an element of a large array detector (TAUWER) designed to measure large extensive air showers (EAS) with energies greater than 10^{17} eV produced by the ultra-high energy (UHE) tau-neutrinos that interact with the Earth crust. The tau particles from interactions decay in a shower produced mainly at large zenith angles (about 90 degrees). Traditional Photomultipliers (PMT) are well-engineered photon detectors and stable in operation [1]. The recent developments made on solid state detectors, so called Silicon PhotoMultipliers (SiPMs), make the SiPM to an alternative to the conventional photomultipliers (PMTs). The SiPMs are multi-pixel avalanche photodetectors working in the Geiger mode. This device has remarkable properties such as a very compact size, high quantum efficiency, good charge resolution, fast response time (< 100 ps), large gain (about 10^6) and very low power consumption with low bias voltages.

Each detector element, as shown in Fig. 1, consists of two pairs of scintillator counters (20 x 20 cm^2, 1.4 cm thick) named 'towers', separated by 60 cm. The distance of one pair is 160 cm corresponding to 5.3 ns of the time of flight (TOF) of a horizontal track crossing the two scintillating tiles. The scintillating light produced when a cosmic ray passes trough the counter is read in each counter by a SensL silicon multiplier (SiPM). To be able to select the track direction with more efficiency we need to select only events where longitudinal or diagonal tracks are selected by an OR-AND logic. In our experiment we only need to collect the longitudinal or diagonal tracks because we have to reconstruct tau horizontal showers. In order to enhance the coincident triggering rate of these longitudinal or diagonal tracks we developed an electronics board, called trigger board (TB).

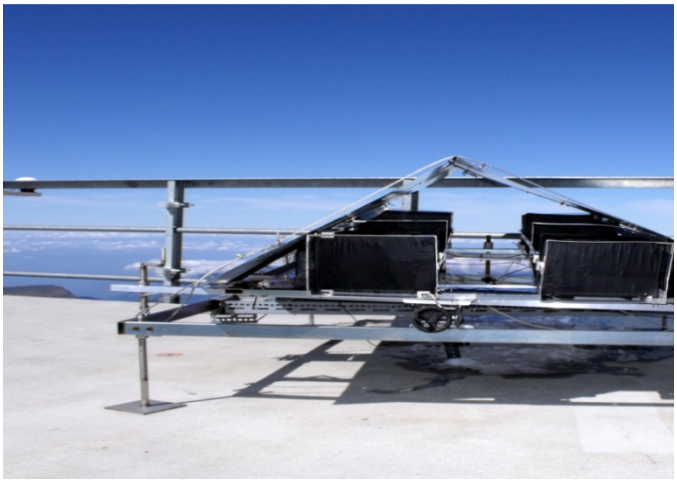

Figure 1. Prototype detector installed at the Sphinx (HFSJG) to test upward/downward particles' separation and environmental effects.

The board provides:

- low-level, ultra fast differential low threshold discriminator channels to select signals above noise
- coincident trigger under the desired conditions
- low power consumption.

The stored coincident waveform data received through the SiPM device at the High Altitude Research Station, Sphinx, is used to reconstruct downward tracks with a zenith angle of 86.7°. Fig. 2 shows the time of flight differences between the two tiles in the tower with a zenith angle of 93.3°. Because of the good time resolution, the detector prototype is capable of discriminating the direction of upward or downward tracks by measuring the TOF. As seen from Fig. 2, three peaks can clearly be distinguished. The peak around +5 ns is due to the accumulation of the incoming particles from the atmosphere at 86.7° (downward particles). The small excesses around 0 ns and +2 ns are due to the vertical and downward parallel tracks, respectively crossing the tiles.

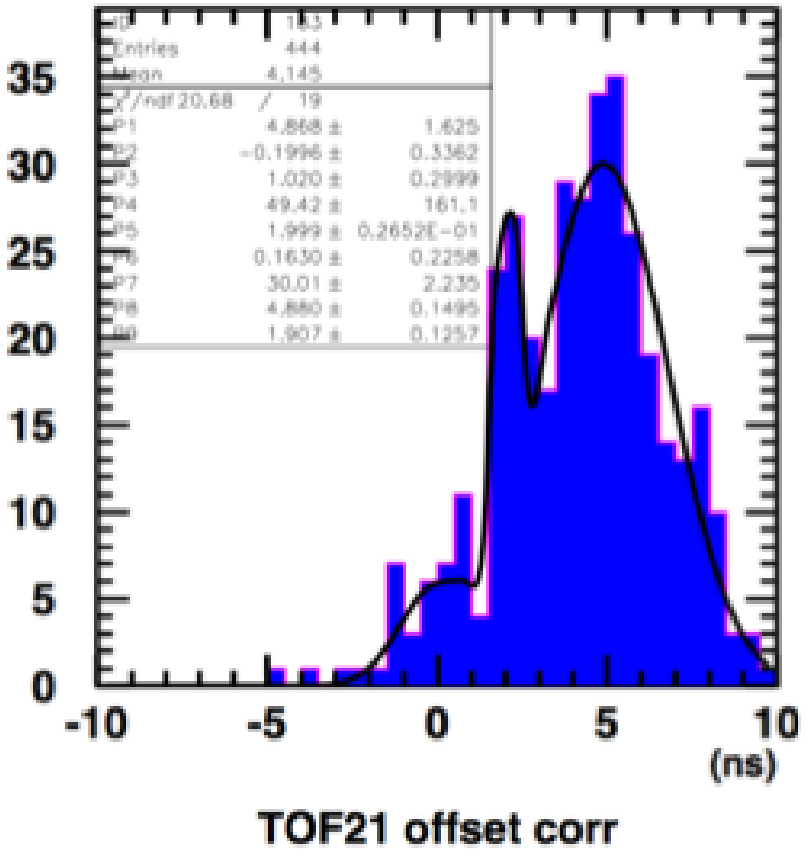

Figure 2. Time of flight difference between the tiles Δ_{t21} in the towers with a zenith angle of 93.3°. The data correspond to a live time of 474 hours. The peak around +5 ns is due to downward particles at θ: 86.7°. The peak at +2 ns is due to downward quasi-parallel particles, a small peak at 0 ns is related to vertical particles. The vertical low momentum flux is damped by the 1.5 mm iron roof.

In the last decades the Silicon photomultipler (SiPM) has been improved remarkably. This new generation of photodetectors gives a high-quality analog read-out for the measurements of the time resolution because the device has a very fast time response. The test performed at about 3570 m a.s.l. at the High Altitude Research Station Jungfraujoch shows that SiPM is a good alternative to be used in astroparticle detector systems for getting the high resolution time stamp information (in the TOF system). The shown detector prototype is capable of

discriminating upward and downward particles. The results show also that the prototype detector works stably without any problem under these harsh weather conditions at Jungfraujoch.

In 2013, we have done extensive tests with silicon photomultiplers (SiPMs). These test results were presented at the International Conference on Astroparticle Physics in Rome.

Key words:

Cosmic rays, neutrino, silicon photomultiplier, time of flight

Internet data bases:

http://pciori13.roma1.infn.it/

Scientific publications and public outreach 2013:

Refereed journal articles and their internet access

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Theses

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