NaI Detector Network at Aragats

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NaI Detector Network at Aragats

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Abstract The Aragats Space Environmental Center (ASEC) [1] provides monitoring of different species of secondary cosmic rays and consists of two high altitude research stations on Mt. Aragats in Armenia. Along with solar modulation effects, ASEC detectors register several coherent enhancements associated with thunderstorm activity. The experimental techniques used allowed for the first time to simultaneously measure fluxes of the electrons, muons, gamma rays, and neutrons correlated with thunderstorm activity [2,3]. Ground-based observations by a complex of surface particle detectors, measuring in systematically and repeatable fashion, gamma quanta, electrons, muons and neutrons from atmospheric sources are necessary for proving the theory of particle acceleration and multiplication during thunderstorms. Energy spectra and correlations between fluxes of different particles, measured on Earth's surface address the important issues of research of the solar modulation effects and the atmospheric high-energy phenomena. In May 26 2011, launched 5 NaI(Tl) (thallium-doped sodium iodide) scintillation detectors and 1 plastic one in the new ASEC laboratory on Aragats to detect low energy gamma rays from the thunderclouds and short particle bursts. Including NaI(Tl) detectors in ASEC detectors system is of great importance for investigation thunderstorm phenomena because NaI(Tl) detectors have high efficiency of gamma ray detecting in comparison with plastic ones.

1. Network design

The NaI network consists of 5 NaI crystal scintillators of size 12.5 x 12.5 x 30 and plastic one of the same shape. The plastic detector is installed for comparison purposes. The chart of detector and detector distribution in the network are presented in Figs.1 and 2 respectively. The NaI crystal is placed into sealed aluminium (1 mm thick) housing (because the crystal is hygroscopic) with transparent window directed to the photo-cathode of the photomultiplier tube (PM).

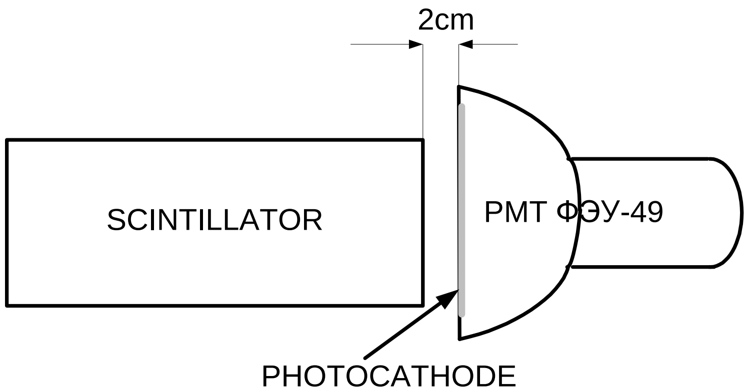

Figure 1 NaI(Tl) and PM assembly

The FEU-49 type PM has large photocathode (15 cm diameter) and therefore provides good light collecting. Spectral sensitivity range of ФЭУ-49 is 300-850 nm, that covers the spectrum of NaI(Tl) emission light.

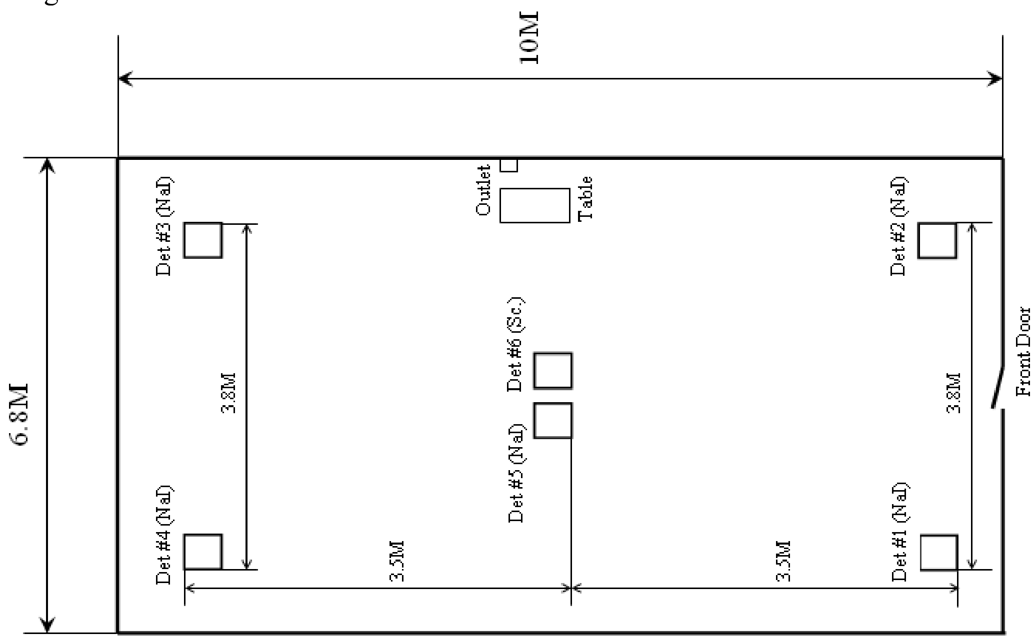

Figure 2 Disposition of NaI & plastic scintillation detectors at Aragats Cosmic Ray Station

2. Detector Simulations

Calculation of the detector response to the secondary cosmic ray flux has been carried out with "EXPACS" cosmic ray flux WEB calculator [4] and "GEANT3" code. All particle fluxes providing considerable contribution to the detector counts was taken into account in simulations. Obtained registration efficiencies are plotted in the Fig. 3. Simulations demonstrate that efficiency of the NaI exceeds that of the plastic one 3 – 4 times in the energy range 3 -100 MeV.

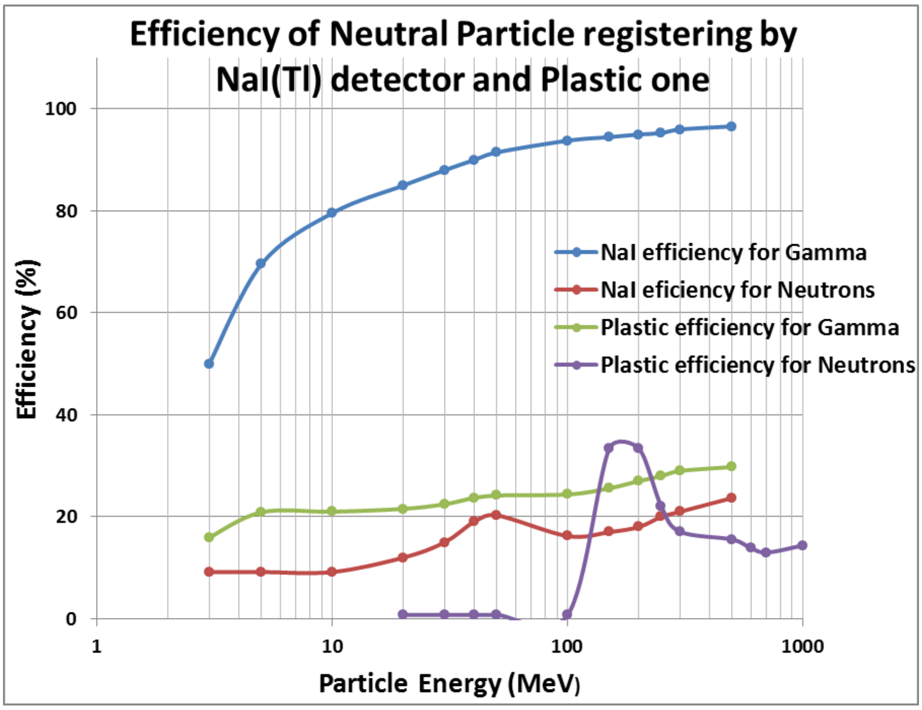

Figure 3 Registration efficiency of NaI crystal and plastic scintillator

3. 27 May of 2011 thunder ground enhancement (TGE) event at Aragats Mountain.

Just after installing NAI network, on 27 May 2011 a Thunderstorm Ground enhancement (TGE) was observed at Aragats. The maximum of enhancement was at 13:13 UT. In Fig. 4 we can see that the TGE amplitude is much larger for NaI crystals comparing with plastic scintillator.

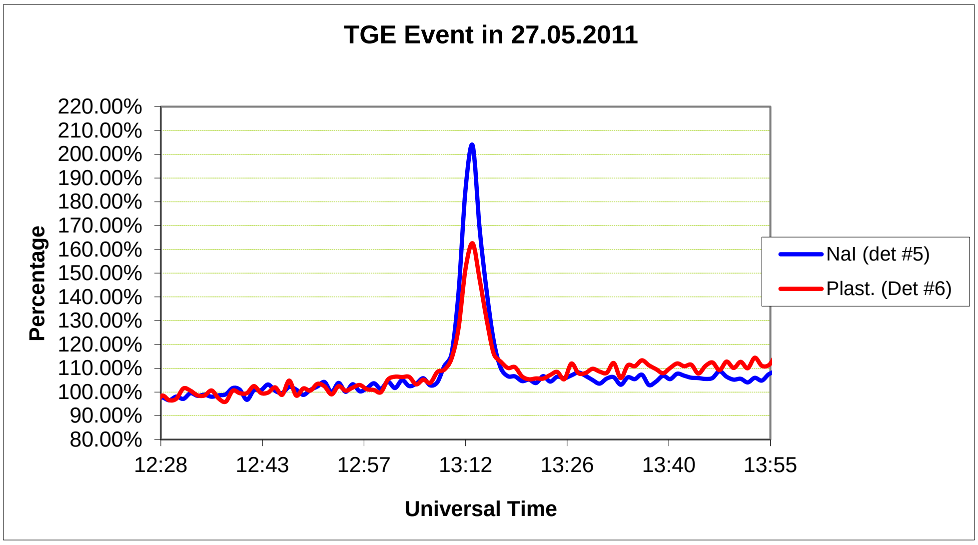

Figure 4 TGE event detected by NaI and plastic scintillator

On 26 May, 2012 very interesting TGE was detected by ASEC particle detectors on Aragats. As we demonstrate above NaI crystals have enhanced efficiency for detecting gamma rays.

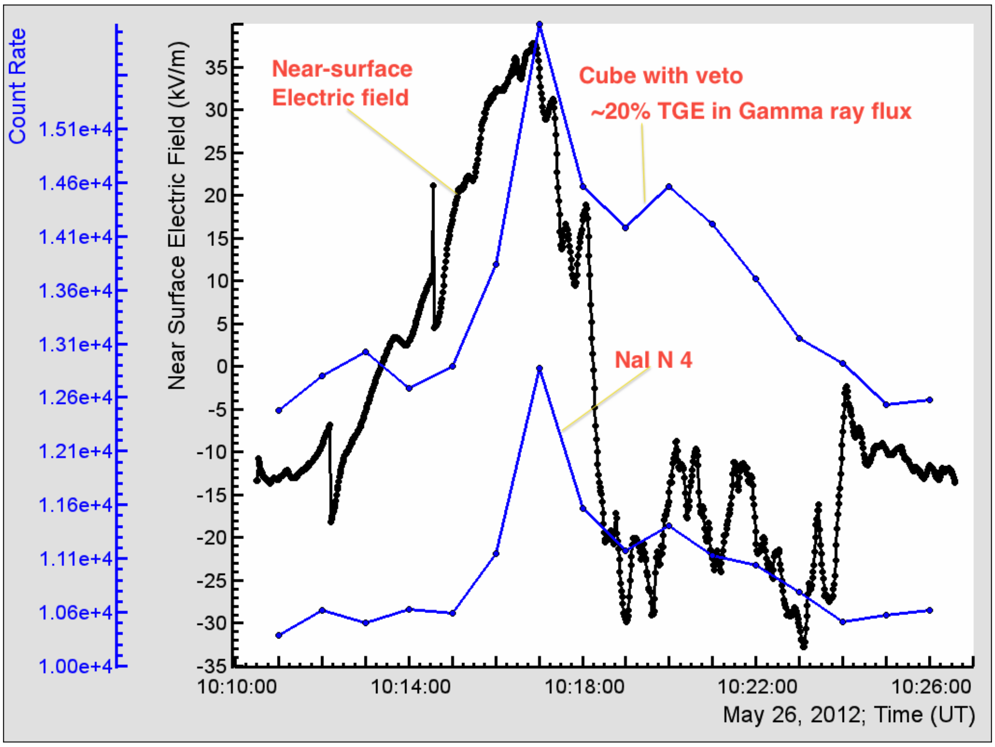

Figure 5 During positive near surface electrical field ASEC detectors sensitive to gamma rays are detected ~20% TGE with absolutely identical shape

The inner 20 cm thick plastic scintillators of Cube detector fully sorrounded by the 1-cm thick veto scintillators also registered gamma ray flux with deeply suppressed charged flux. As we see in Figure 5 both detectors demonstrate identical time history of TGE detection. It once more proves high efficiency and reliability of the NaI crystal network. The Boltek firm electrical mill monitored the near-surface electrical field. During positive near surface electric field and corresponding negative electric field in the thundercloud electrons cannot be accelerated in direction to earth. During negative near-surface electrical field electrons are accelerated downward and along with gamma rays can be detected by surface particle detetors. As we can see in the Fig. 6 after field reversal the particle detectors sensitive to charged flux and insensitive to gamma rays; namely 11 combination of the STAND 1 cm detector and 1100[1] combination of STAND 3 cm detector, register ~ 25% TGE mostly in electron flux.

[1] Stand detectors comprise from stacked horizontally 1 and 3 cm thick plastic scintillators. Count rates of all combinations of scintillator hits are registered and stored. Combinations 110 and 1100 denote the situation when signals come only from 2 upper scintillators. The probability that gamma ray initiate these combinations is veru low.

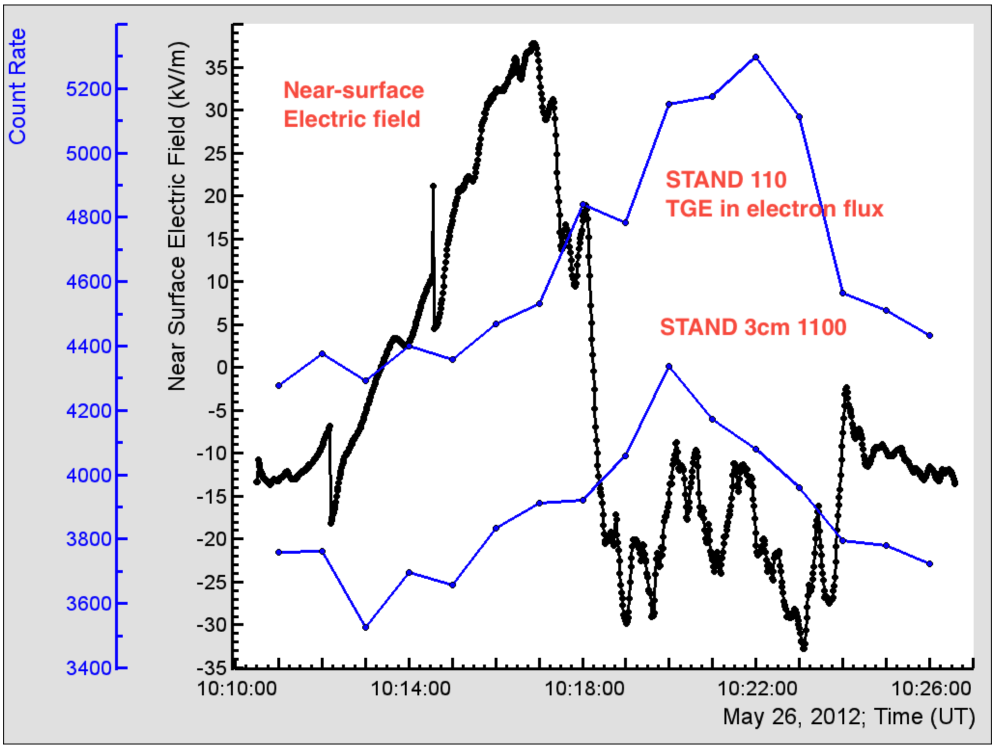

Figure 6 During negative near-surface electrical field ASEC detectors sensitive to charged particlesdetect ~25% TGE, peaking at 10:20-10:22

Conclusion

New detector network is taking data 24 hours a day, detecting high energy phenomena in atmosphere and solar modulation effects: efficiency of detecting gamma rays is ~4 times larger than that of plastic scintillators.

References

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