Calibration of the particle detectors measuring secondary cosmic rays by the gamma ray beams from thunderclouds

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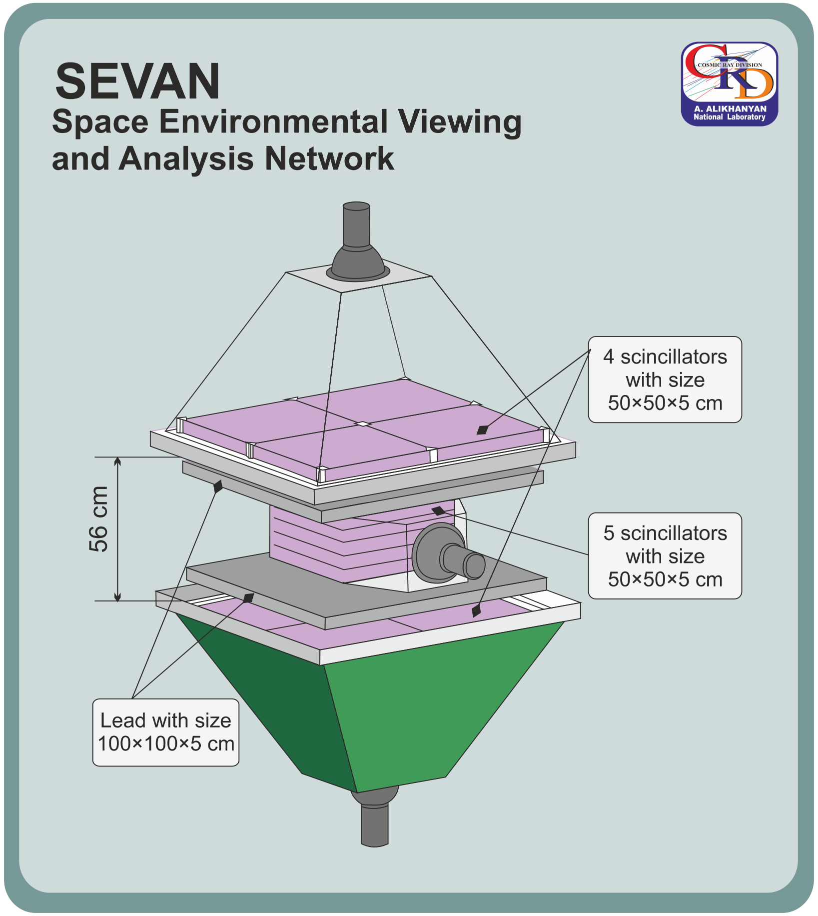
- After observation of hundreds of the Thunderstorm ground enhancements (TGEs) we measure energy spectra of coming from thunderclouds particles and use these “beams” for calibration of cosmic ray detectors located beneath clouds on altitude 3200 m at Aragats in Armenia. Calibrations of particle detectors with fluxes of TGE gamma rays are in good agreement with simulation results and allow estimating the energy thresholds and efficiencies of numerous particle detectors used for research of galactic and solar cosmic rays.

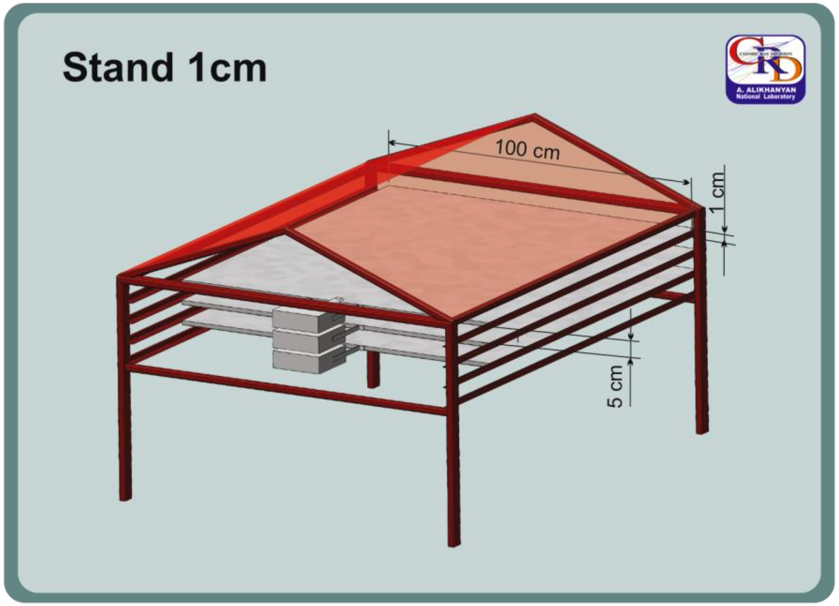
Short description of some of particle detectors

SEVAN (Space Environmental Viewing and Analysis Network) is a network of particle detectors located at middle to low latitudes.

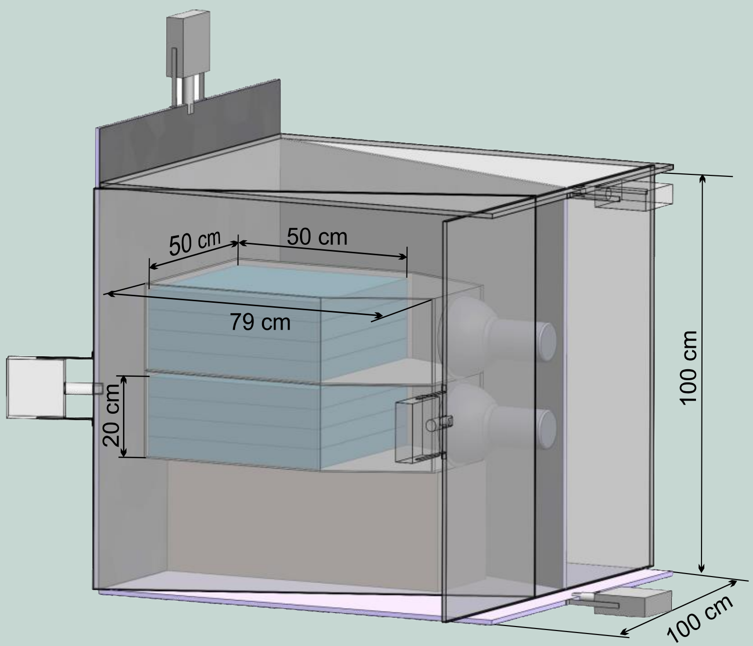
The new generation of ASEC detectors comprises from 1 and 3 cm thick molded plastic scintillators arranged in stacks (STAND1 and STAND3 detectors)

Coincidence "100" corresponds to signal registration only from upper scintillator, "010" –only middle scintillator, and so on.

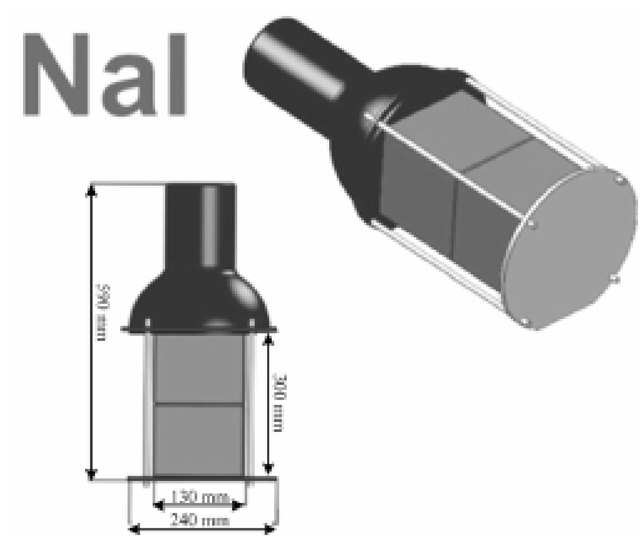




Cube (1cm scintillator)

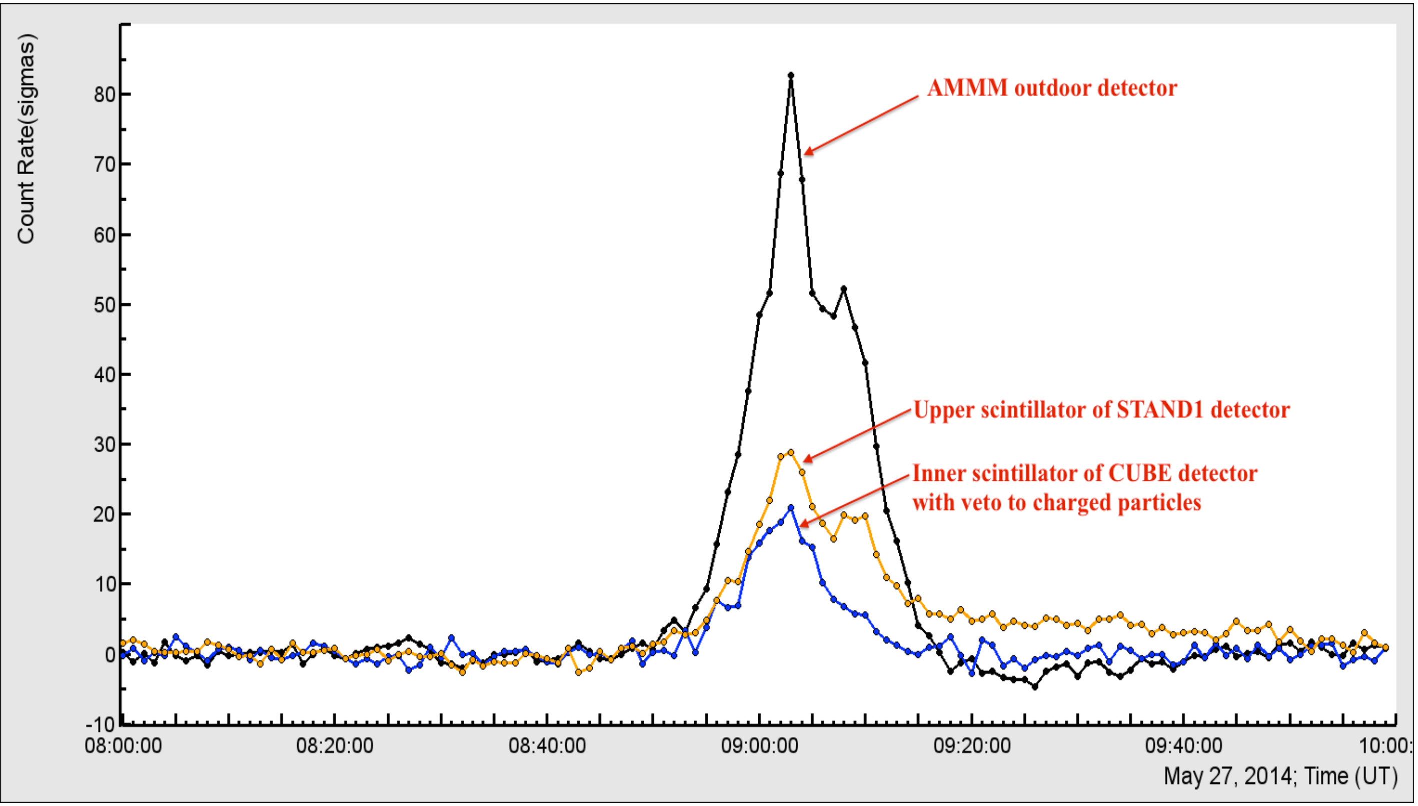


Cube detector consisted of six 1-cm thick plastic scintillators of the same type as used in the STAND1 detector fully covering two stacked 20 cm thick scintillators. The count rates of inside scintillators with veto switched on and without veto allow purify the neutral fluxes and in addition – estimate the fraction of electrons in the mixed electron and gamma ray flux.

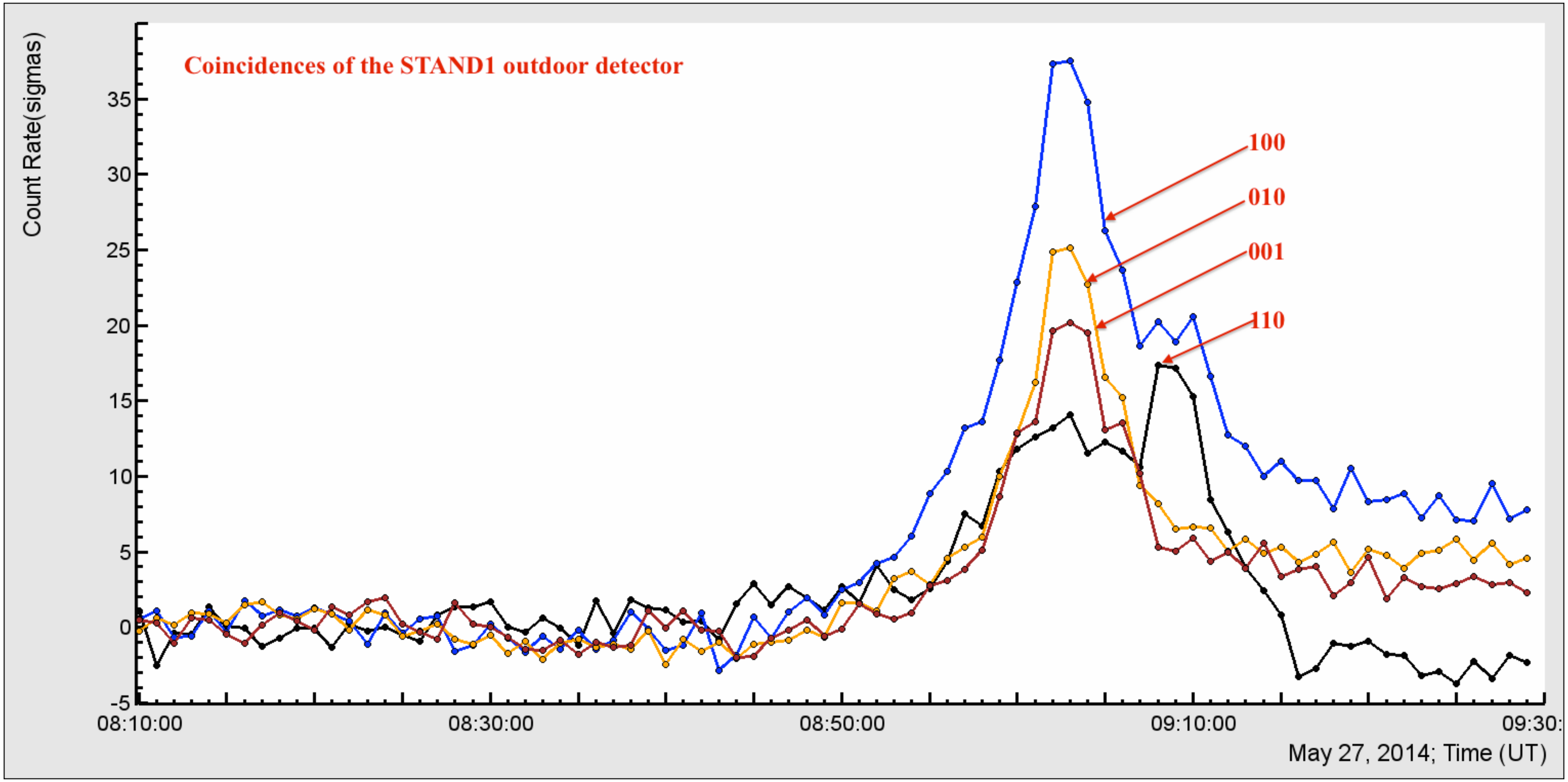


Recovering gamma ray spectra; TGE detected at 27 May 2014

Peak registered by STAND1 detector at 9:02 corresponds to p-value of ~30 σ. CUBE detector – registered enhancement equivalent to ~22 σ. The differences in p-values are due to various areas and energy thresholds of detectors.



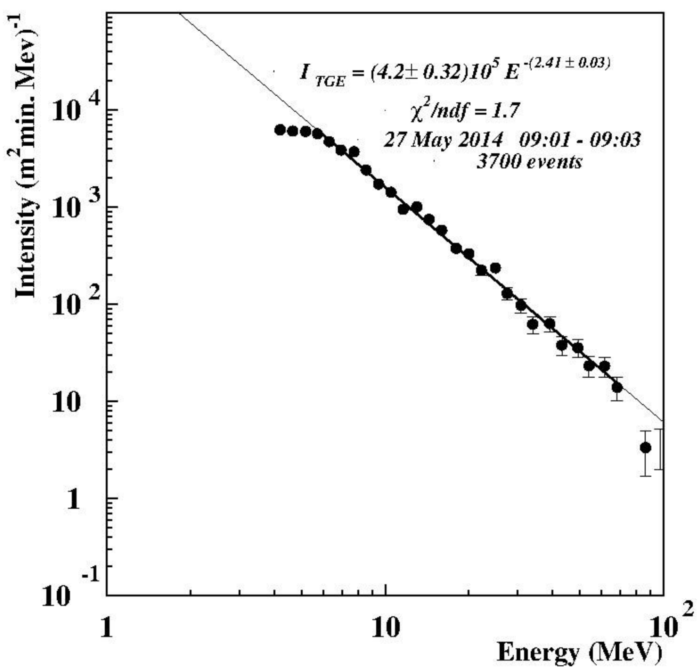
One minute time series of the p-values of the statistical t-test on belonging of peak value to background (null hypothesis).



One-minute time series of the coincidences of 3-layered stacked STAND1 detector (p-values)

Recovered intensity of electrons and gamma rays on Aragats above STAND1 outdoors detector for the 27 May 2014 TGE estimated by "100" and "010" coincidences

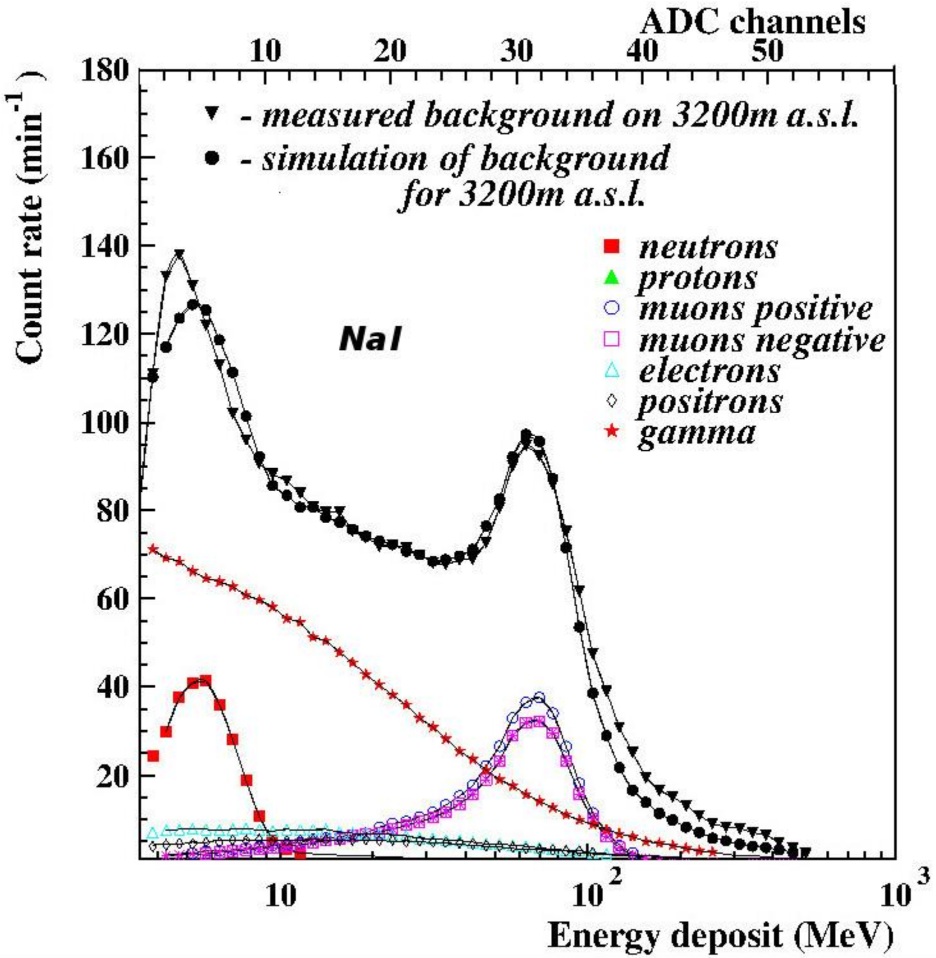
Date year 2014	Count rate 100/010	Mean Count rate 100/010	Difference (N of σ)	e flux m^2min	γ flux m^2min	e/γ flux ratio (%)
27.05 9:01-9:03	29058 24081	22200 18500	6858 (44.0) 5581 (34.9)	2323	285640	0.76
27.05 9:08:9:10	26012 20355		3812 (24.4) 1855 (11.6)	2314	95805	2.4



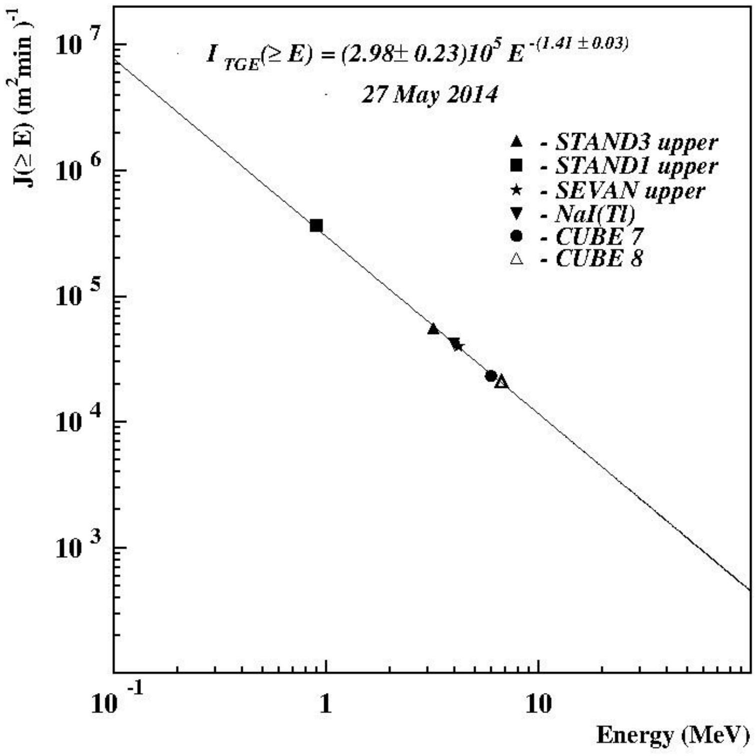
The gamma ray spectrum recovered by NaI crystal network

Measured differential energy spectrum at 9:01-9:03 contains less than 1% of electrons, thus we can neglect electron contamination and use recovered spectrum for other detector calibration.

we obtain simulated background spectrum (in MeV) by calculating detector response to superposition of almost all species of secondary cosmic rays. Simple overlying of the experimentally measured background (in units of ADC codes) gives the correspondence between 2 scales.



Particularly inNaI spectrometer 31-st code is corresponding to the 60 MeV. The threshold of the spectrometer is calculated as the energy corresponding to the 1 code, for the detector measured background in Fig. 10 the first ADC code corresponds to 3.6 MeV.



By locating particle detector count rate on the integral energy spectrum and reading corresponding energy from the X-coordinate axes beneath we readily obtain the "effective" threshold

Integral energy spectra of gamma rays with intensities measured by different ASEC particle detectors

Effective energy threshold of ASEC detectors estimated by recovering gamma ray flux of TGEs observed at 12.5.13; 19.06.13; 9.07/13;27.05.14;12.06.14

Detector	Estimated “effective” energy threshold (MeV)	Estimated energy threshold based on CR background (MeV), “first code” energy
CUBE inner 20 cm thick scintillator (upper)	5.3 ± 0.6	5.8± 0.6
CUBE inner 20 cm thick scintillator (bottom)	5.4 ± 1.1	6.4± 0.6
SEVAN upper 5 cm. thick scintillator	3.6 ± 0.6	*
STAND1 upper 1 cm. thick scintillator	0.7 ± 0.1	*
STAND 3 upper 3 cm. thick scintillator	2.9 ± 0.3	3.5± 0.4

Conclusions

We use gamma ray fluxes from thunderclouds, so called, Thunderstorm ground enhancements (TGES), for calibration of the particle detectors belonging to the Aragats Space Environmental center (ASEC) and used for research of Galactic cosmic rays, Solar terrestrial connections and high energy phenomena in the atmosphere. Measurements of gamma ray energy spectra by the network of large NaI crystals allows obtaining energy thresholds of the various particle detectors. Introduced notion of the "effective energy threshold" allows to avoid arbitrariness of the previously used method of the "first code" and is applicable as well to particle detectors measuring only count rate and not energy spectra.