Thunderstorm Ground Enhancements (TGEs) – effects and physical model

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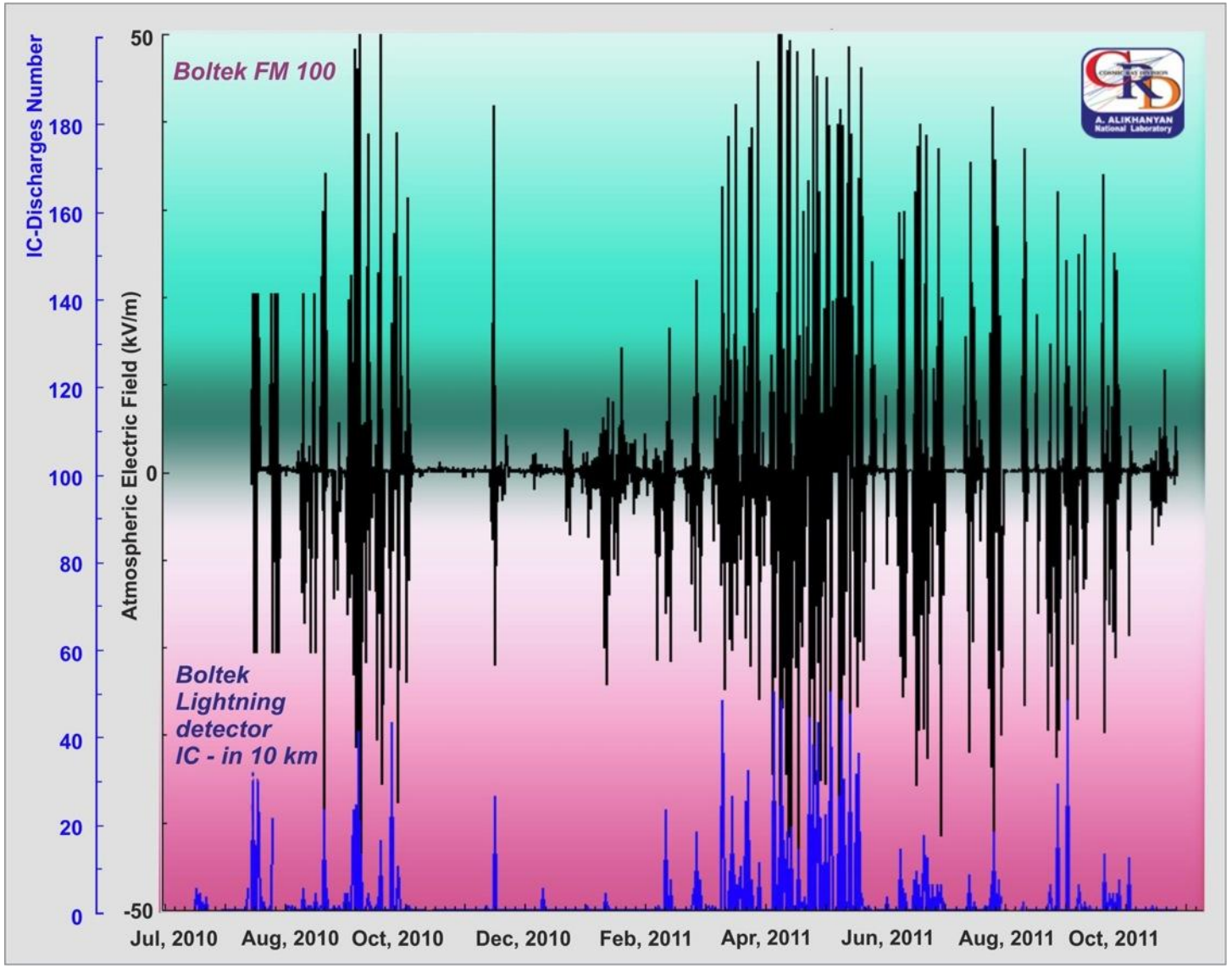
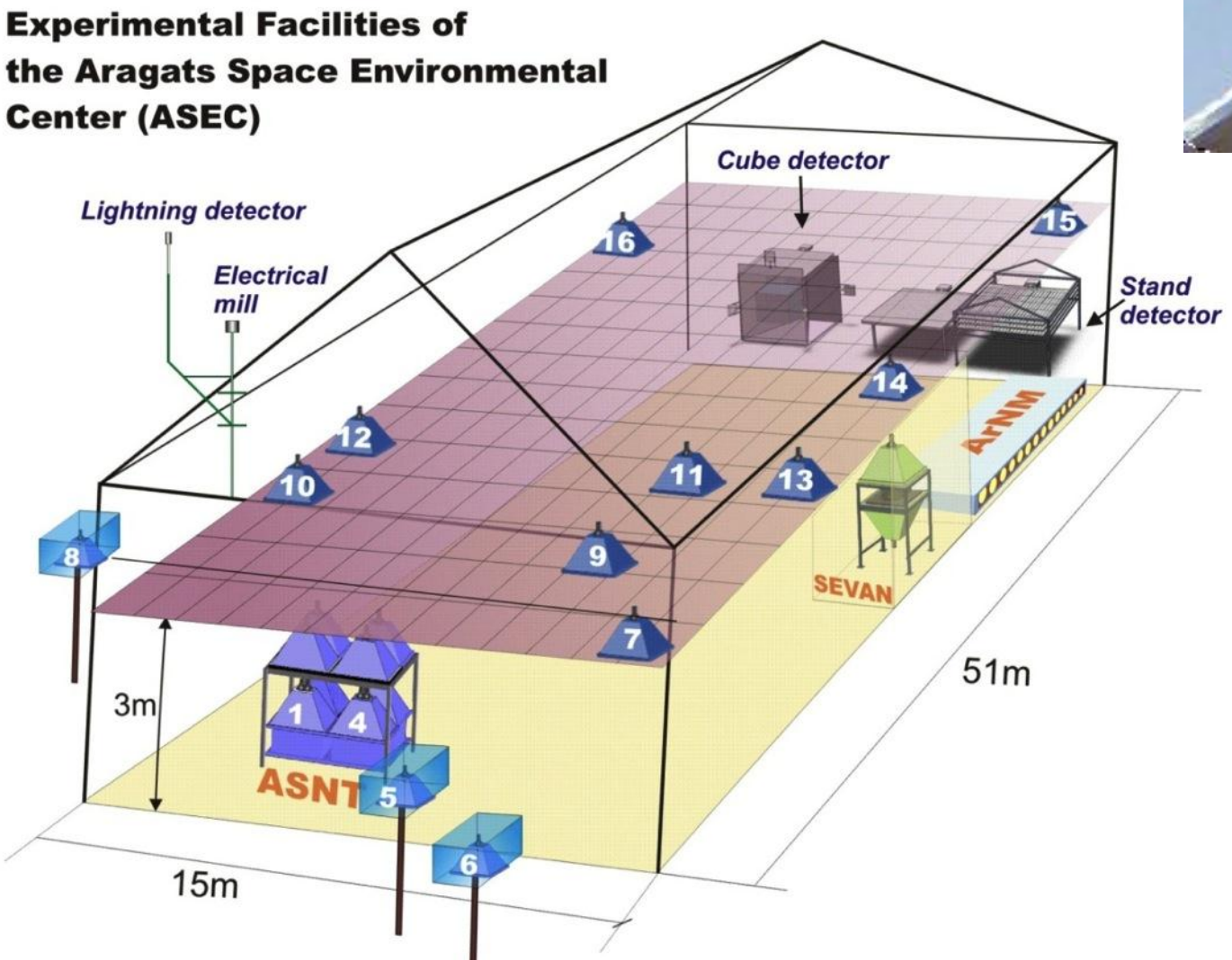
There are at least 6 physical effects manifested by TGE

- Large fluxes of the electrons and gamma rays;
- MeV energy neutron fluxes;
- Microsecond bursts of the electrons
- (“inverse TGFs”);
- Depletion of the high energy muon flux;
- Large negative near-surface electrical field;
- Depletion of the cloud-ground (CG-) lightning occurrences and enhancement of the intracloud (IC-) lightning occurrences.

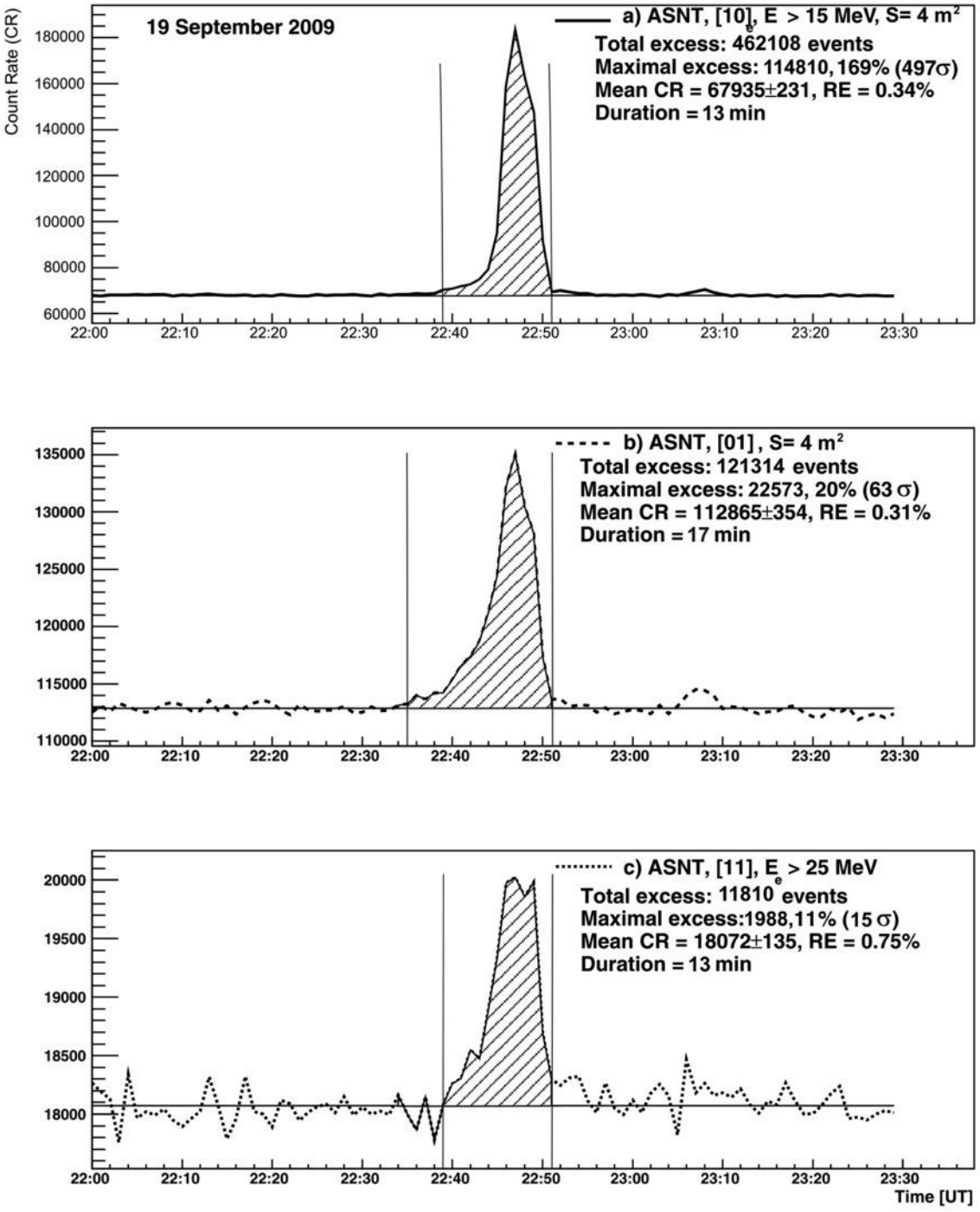
Field and lightning monitoring at Aragats– July 2010- November 2011 (>100 TGE)



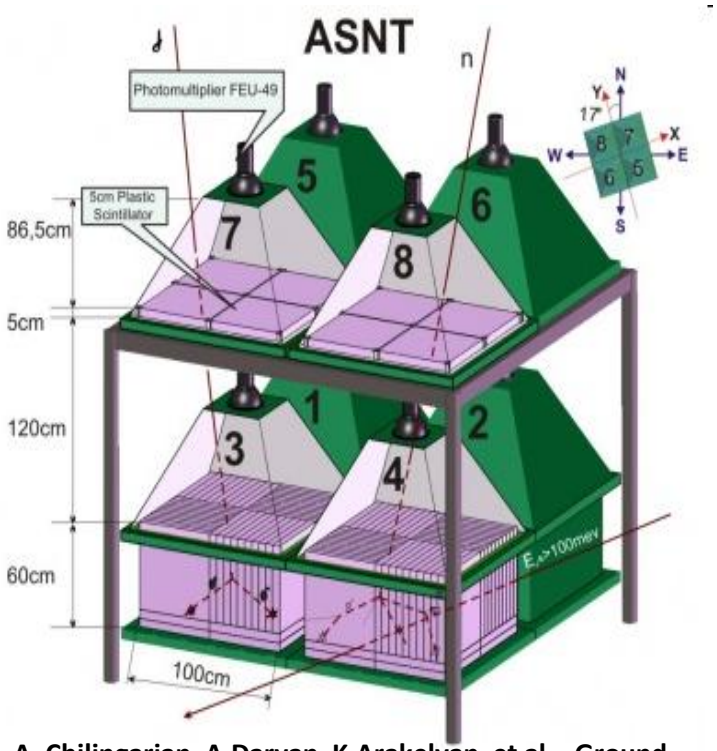
Simultaneous monitoring of fluxes, fields and meteorological conditions



Boltek EFM 100 electrical mill and Lightning tracer; Davis instr. weather station

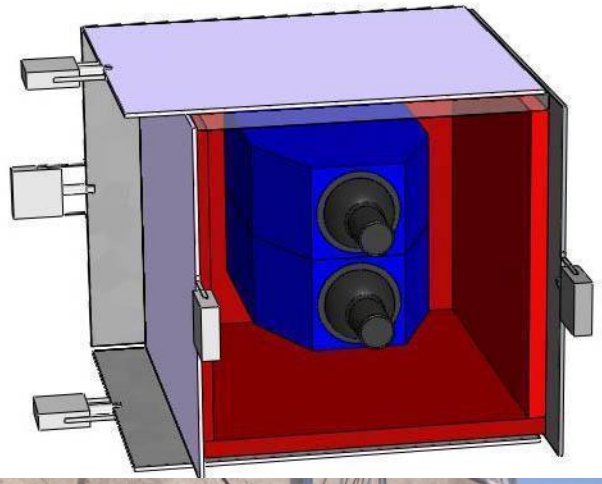


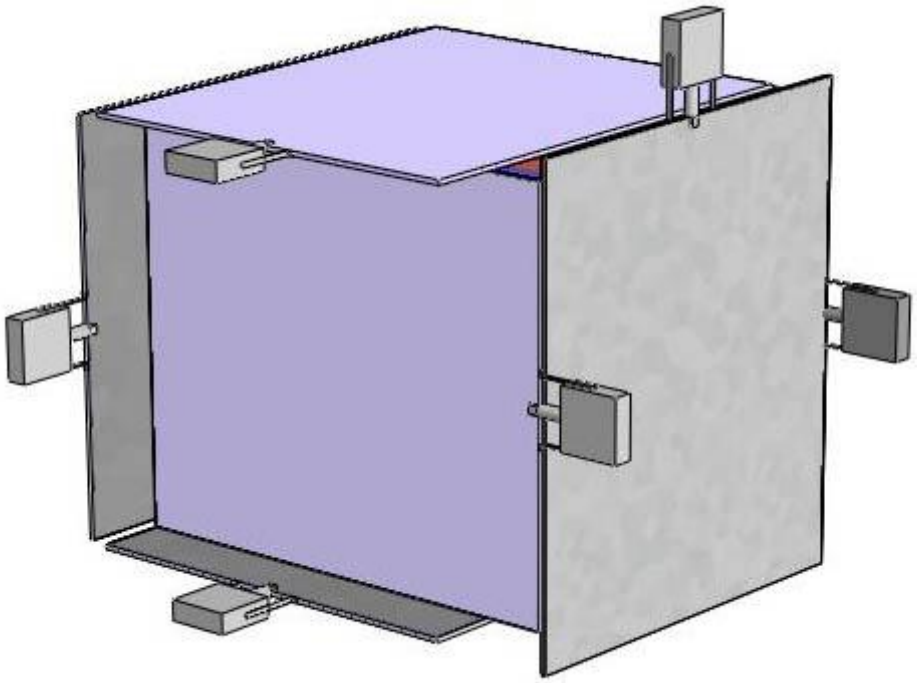
Huge TGE of 19 September, 2009 was detected by all ASEC monitors : ASNT consists of 5 cm and 60 cm thick scintillators (4 modules each 1 m.sq. area;
ASNT (11) – electrons E ~ 25 MeV - 19 September event is only event with high energy electrons detected.



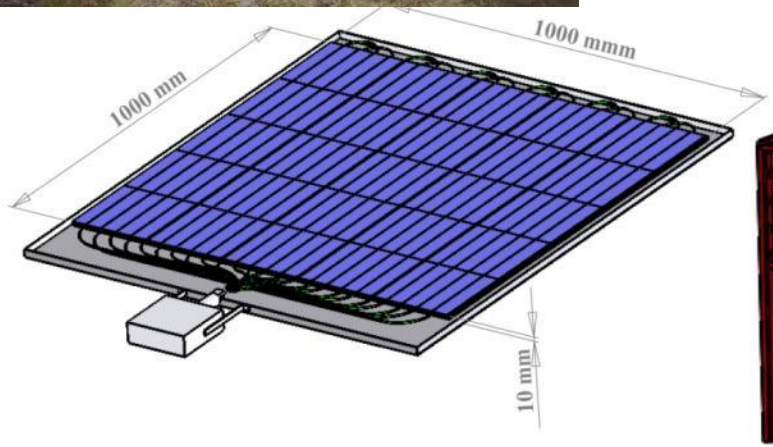
A. Chilingarian, A.Daryan, K.Arakelyan, et al., Ground-based observations of thunderstorm-correlated fluxes of high-energy electrons, gamma rays, and neutrons, Phys.Rev. D., 82, 043009, 2010

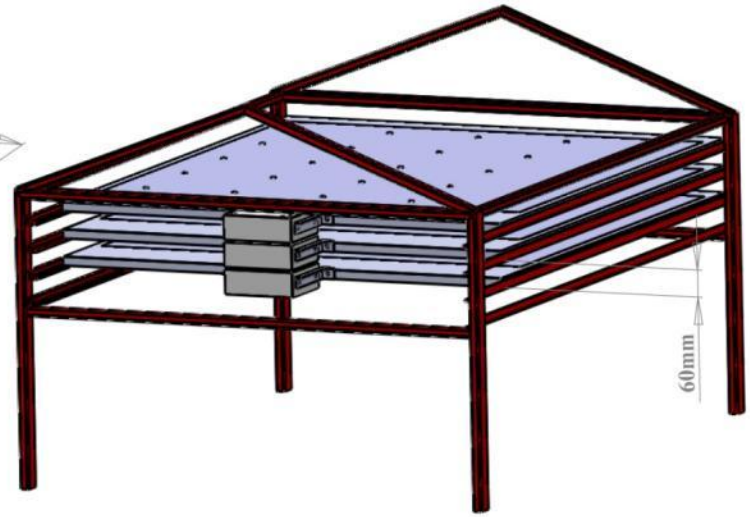
Cube Detector for detection of Neutral particle



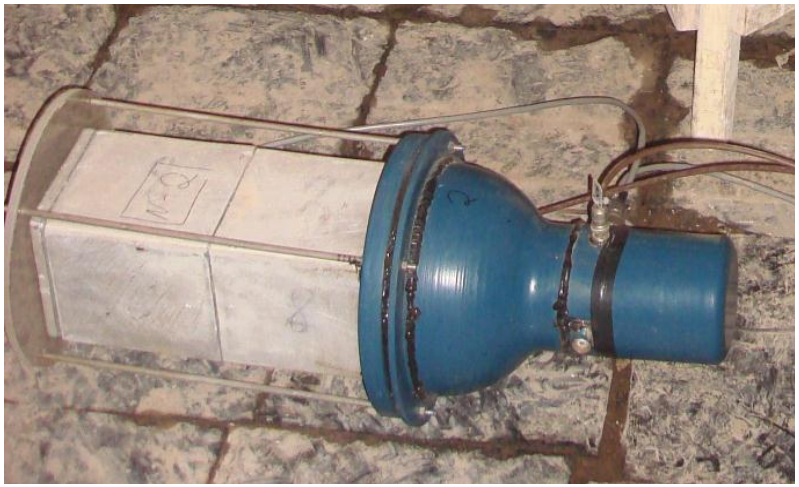


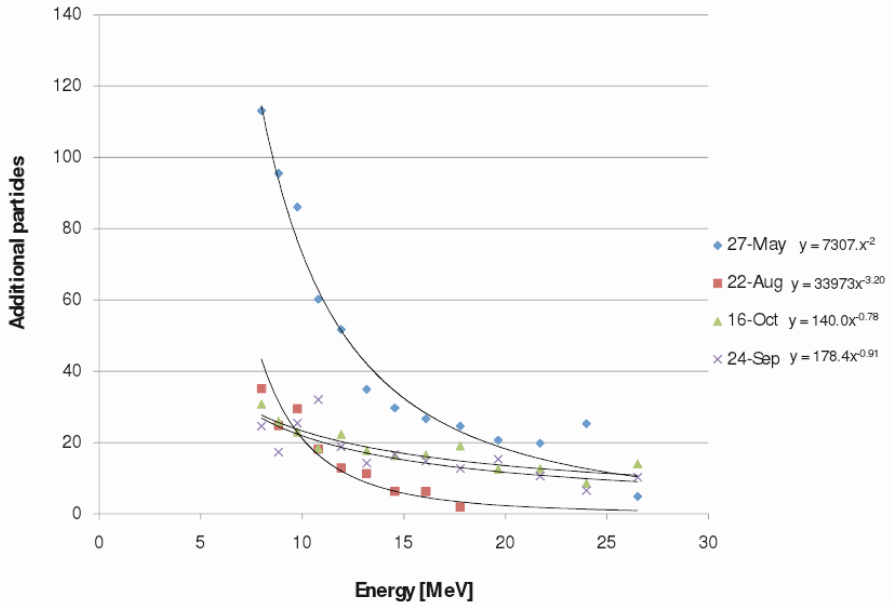
STAND multilayered Detector

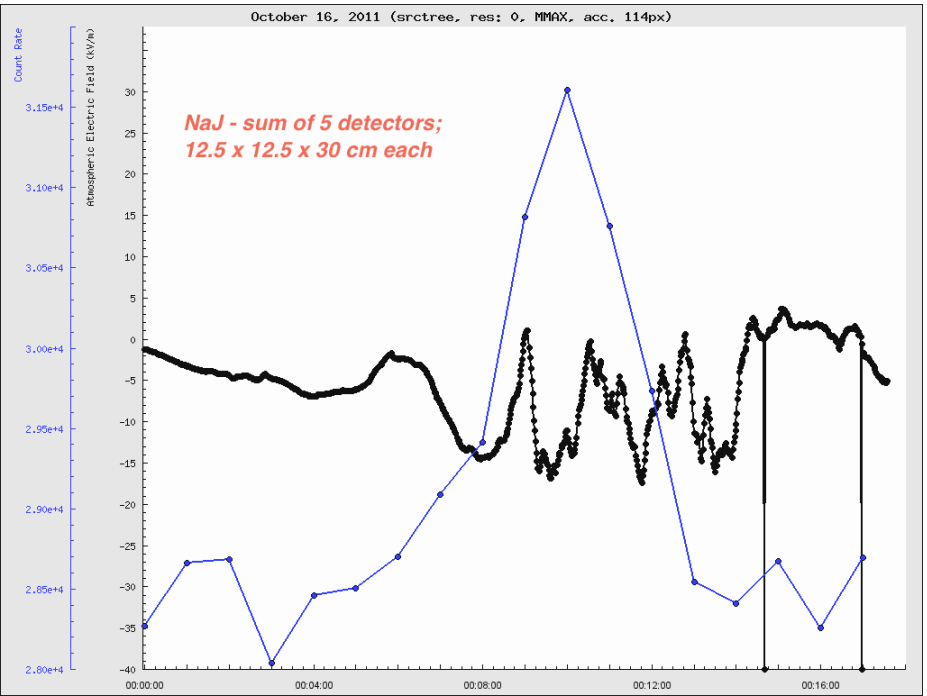


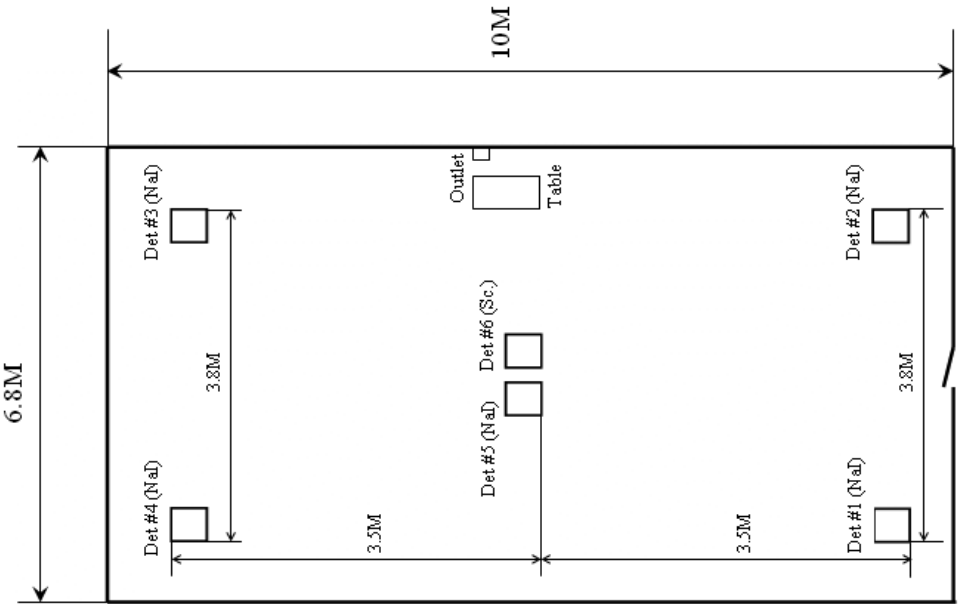


NaI network 5 detectors 12.5 x 12.5 x 30 each

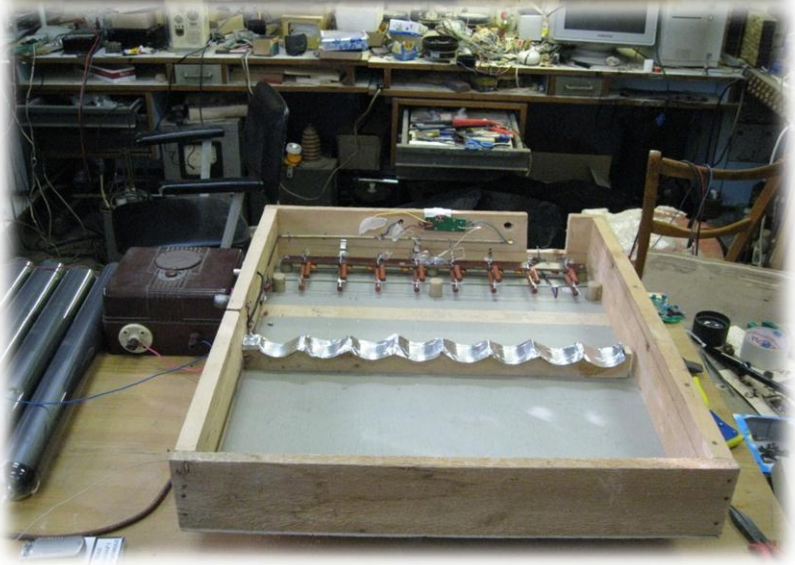




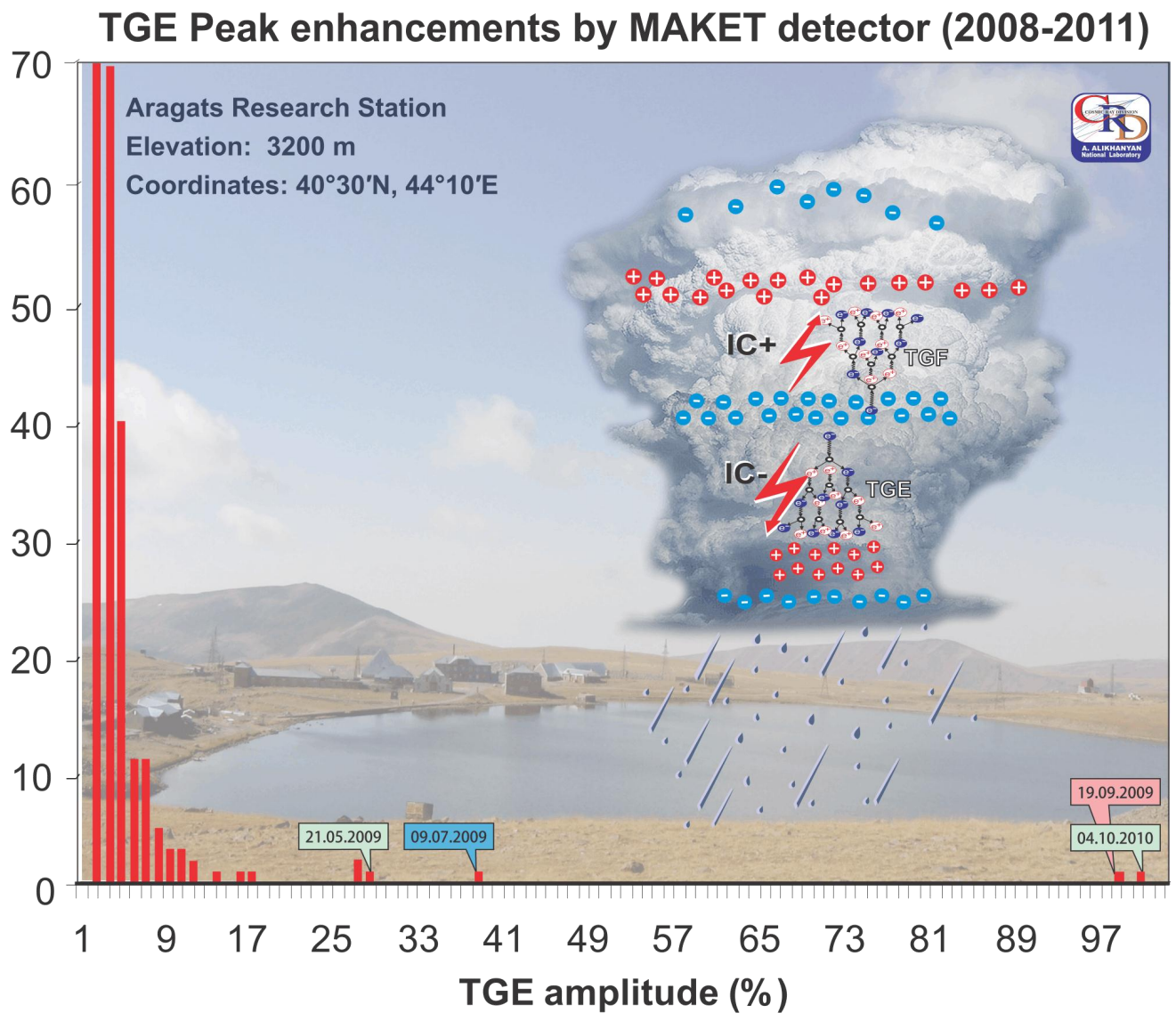




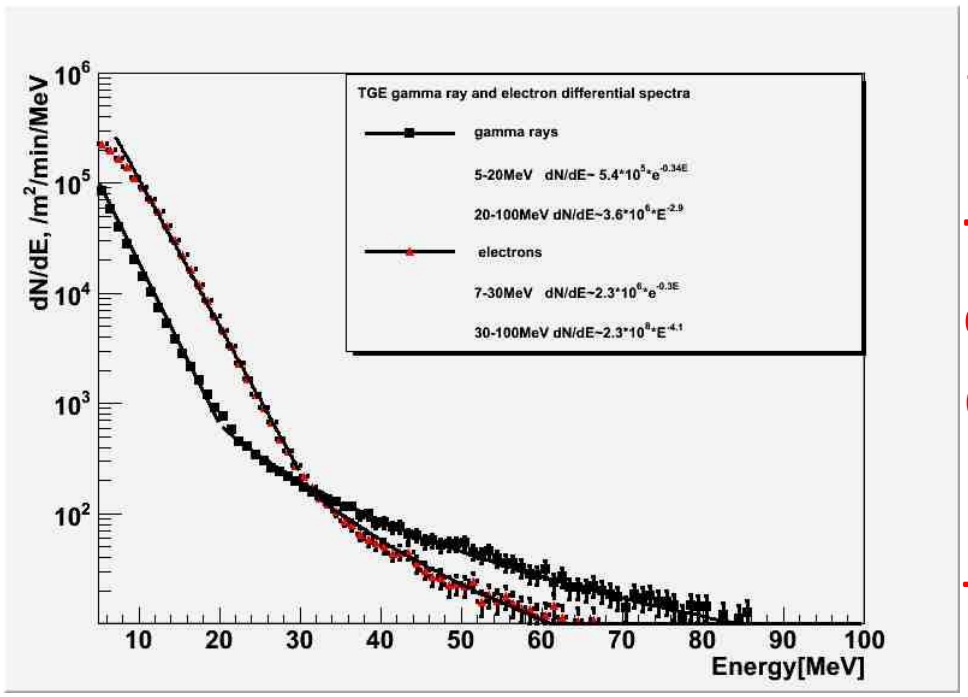
Tray of Geiger counters to be installed on Aragats in 2012



Model of TGE events

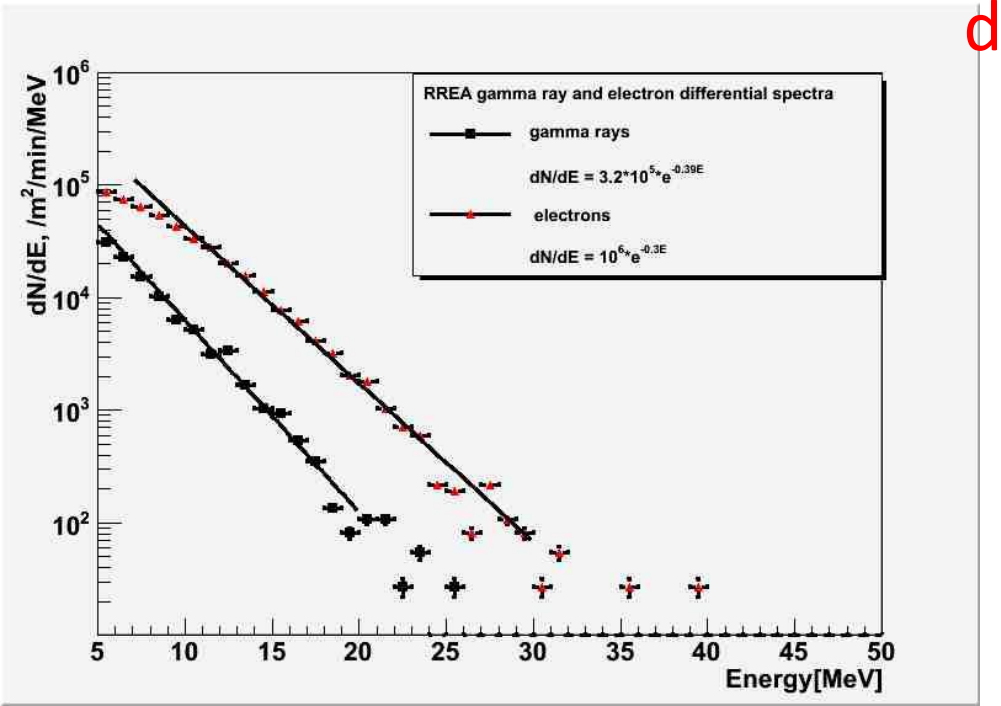


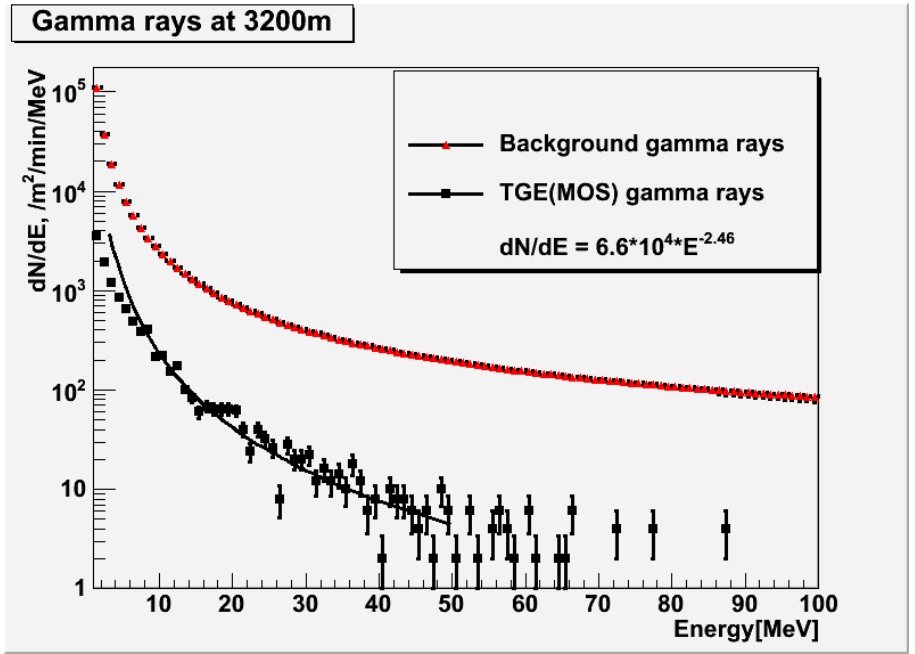
TGE is complex phenomenon originated in the thunderstorm clouds due to passage of cosmic rays in the strong electrical fields. TGE manifested itself by large (up to 1000%) long duration enhancements of electromagnetic component, by short (<50usec) particle showers; IC- lightning occurrences are enhanced and CG- and IC+ lightning occurrences are depleted during TGE. The physical mechanism is the RREA and MOS developing in atmosphere using as seeds ambient population of MeV cosmic ray electrons and modification of the energy spectra of higher energy cosmic rays.



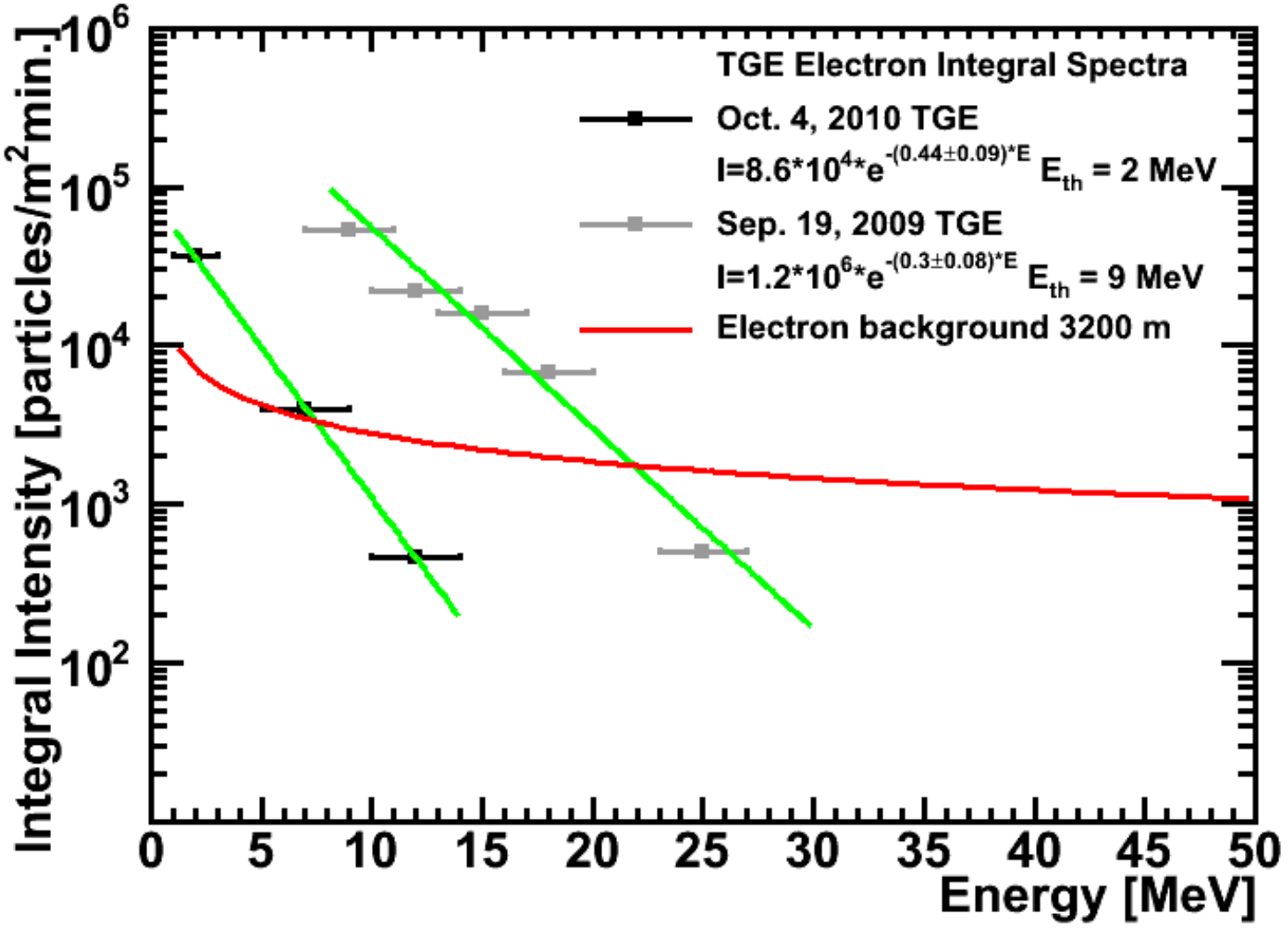
2-component model of TGE: RREA and MOS (**modification of the energy spectra of charged cosmic rays in the electrical fields**)

GEANT4 simulation of TGE: Uniform Electrical fields of 1.3 – 2.0 kV/m between 5000 and 3600 m; detectors at 3200 m.

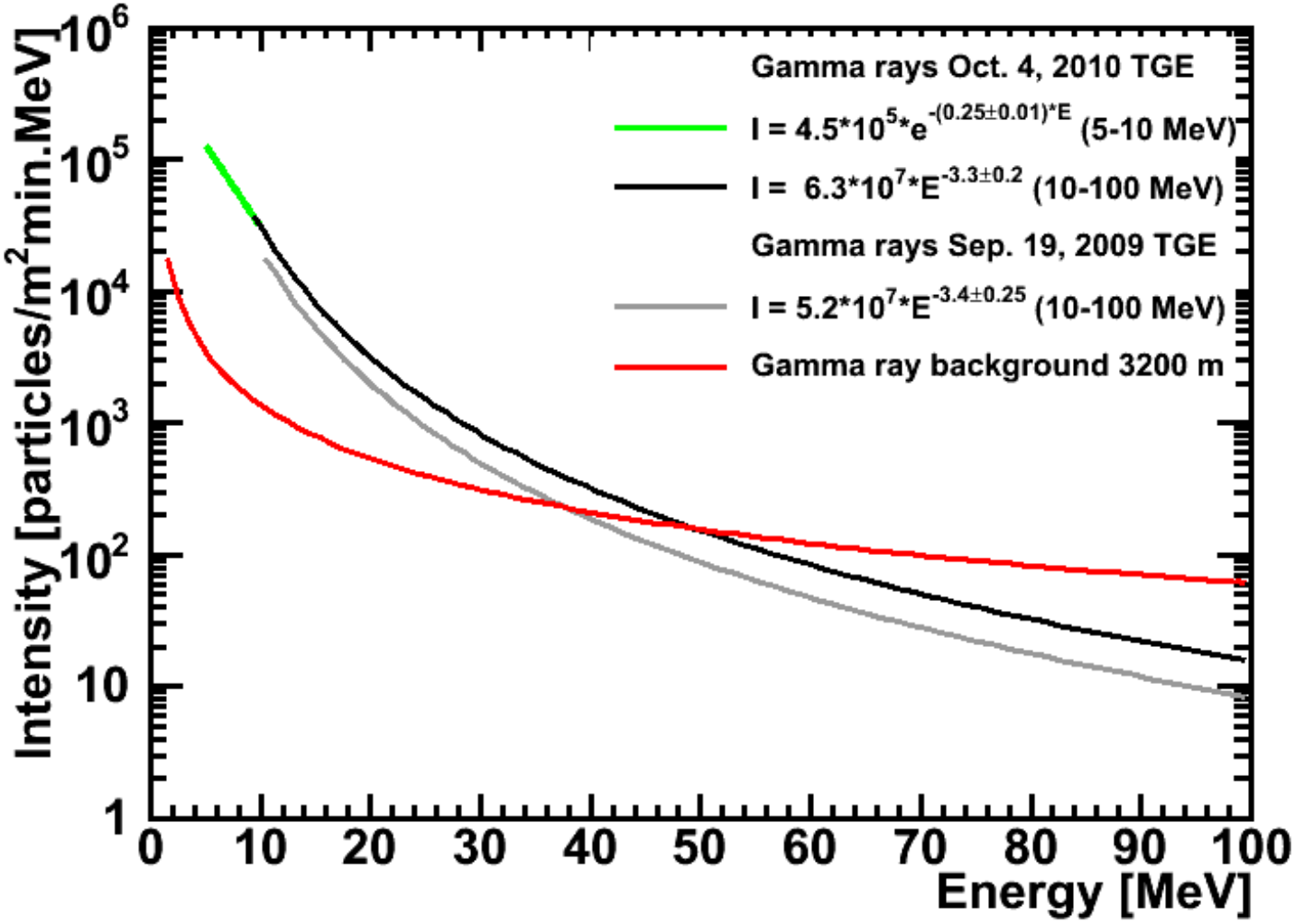




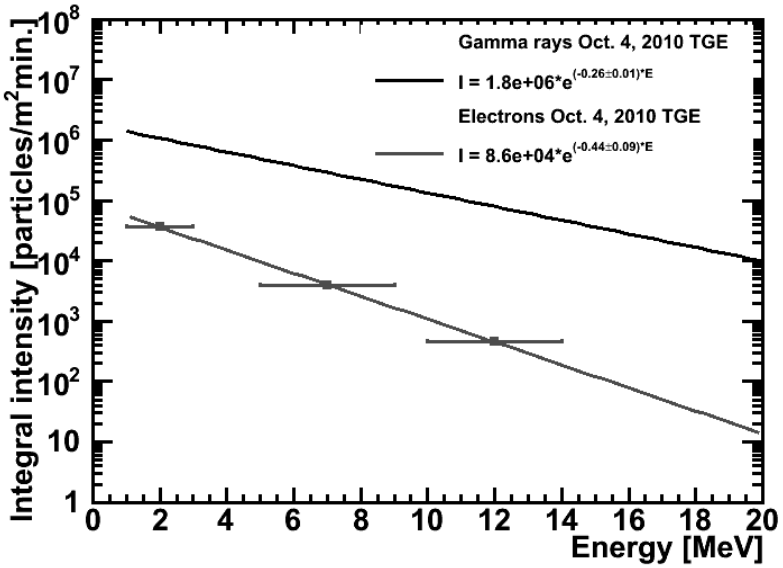
Electron Integral Energy spectra for 2 largest TGEs



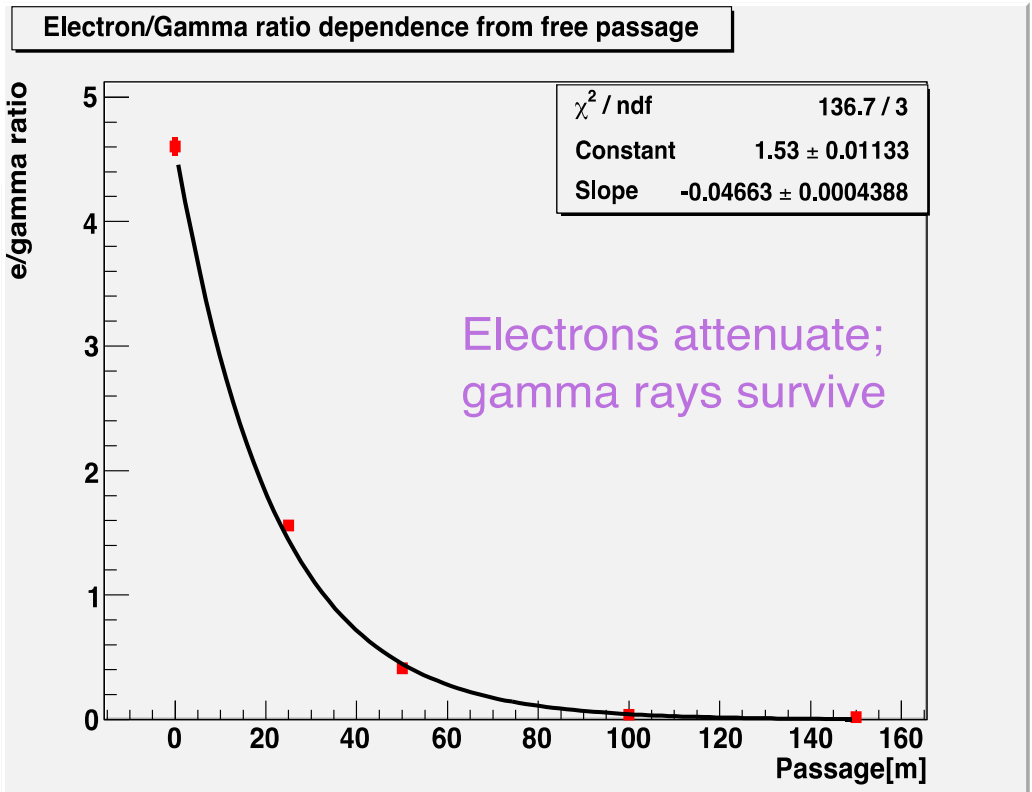
Gamma ray Energy Spectra

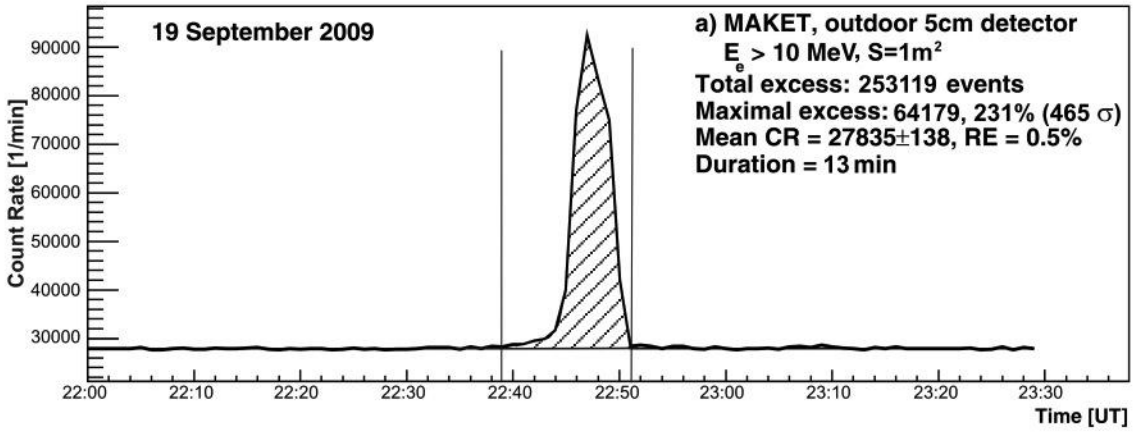


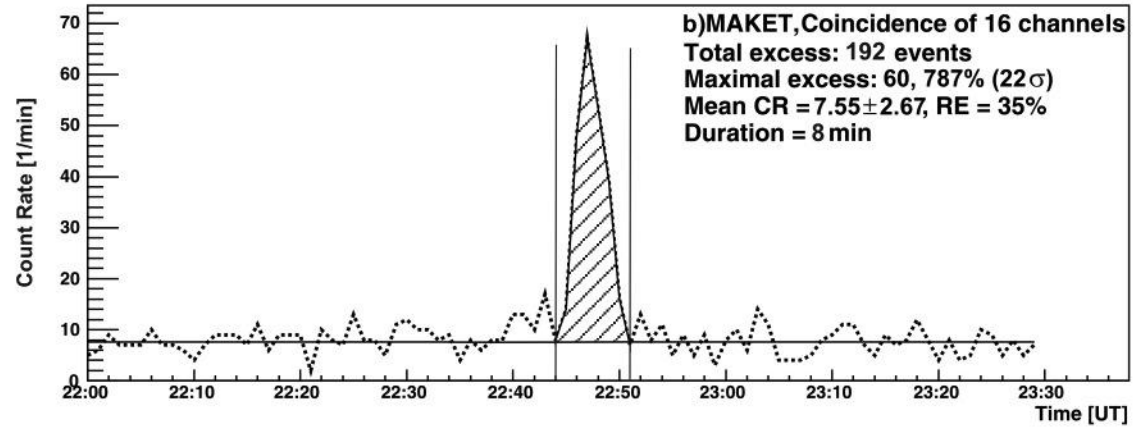
Estimation of the thundercloud height

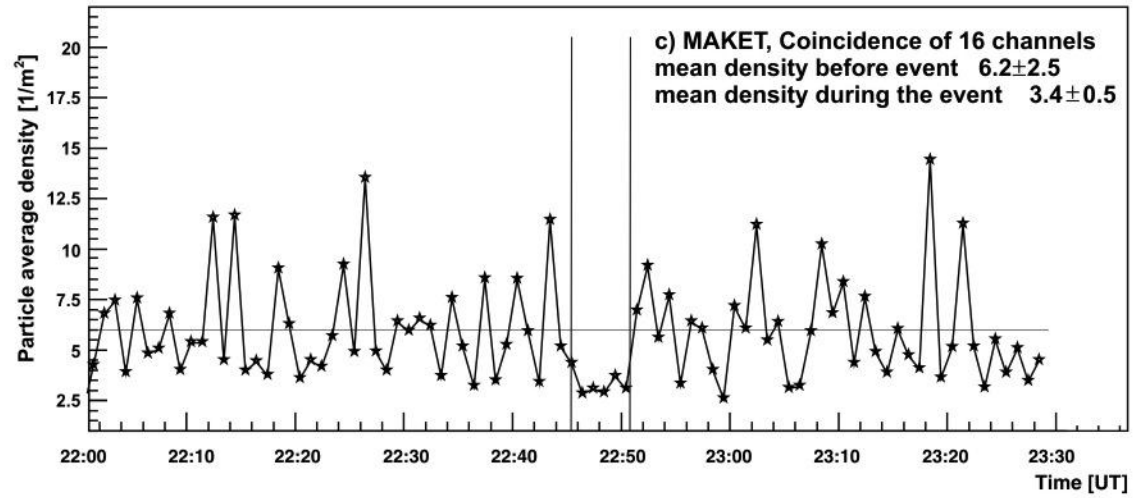


10 MeV Electron-to-gamma ray ratio
at 4 October 2010 was 0.012,
That corresponds to ~ 130 m hieght



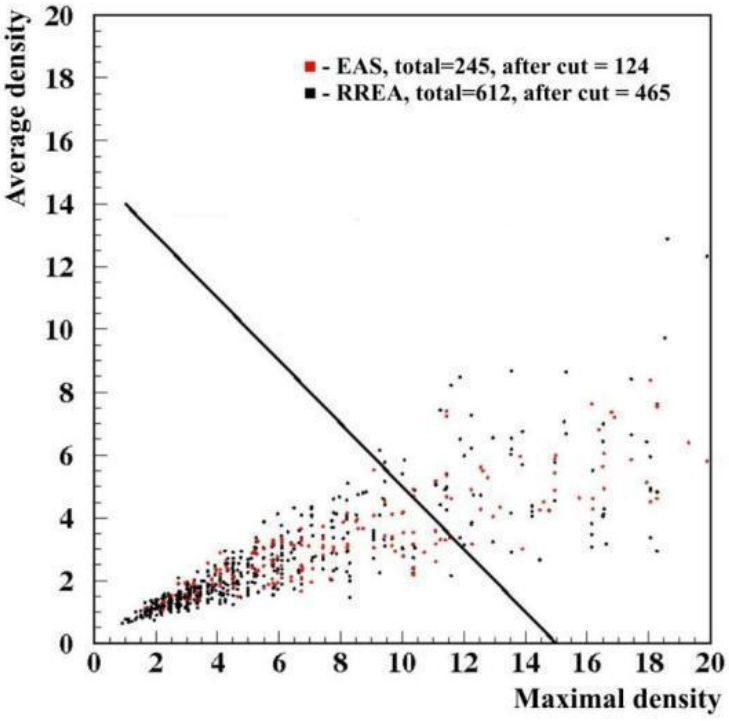




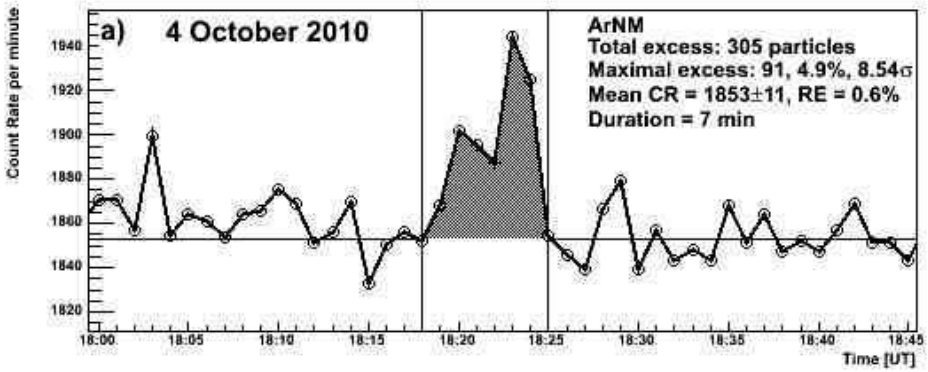


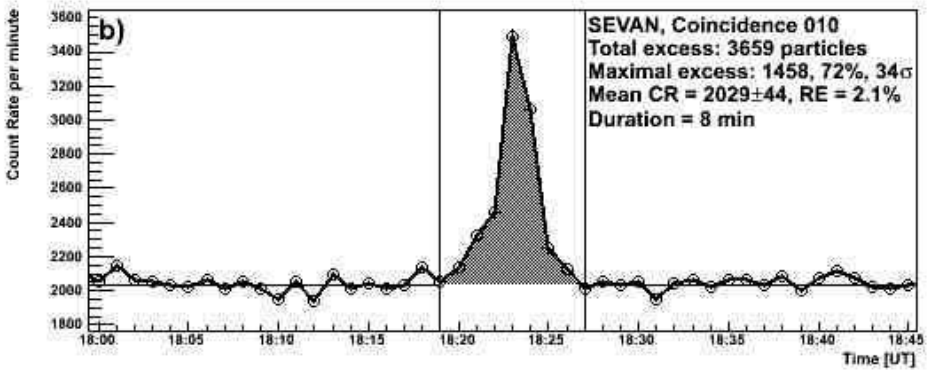
New type of EAS from RREA!

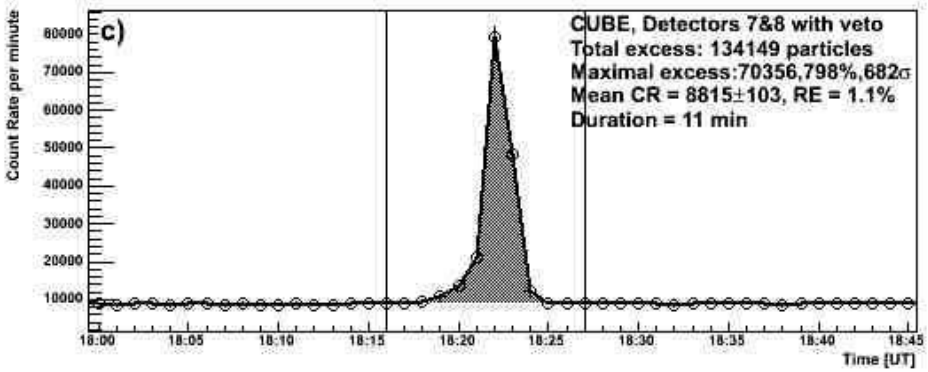
MAKET – a surface array counts Extensive Air showers (EAS) triggers from area of ~1,000 m.sq., energy of primary greater than 200-300 TeV; MAKET detect short coherent bursts of electrons/gamma rays (within 1 μsec); Short TGE EAS (not CR EAS!) counts 7 times more than CR EAS! TGE EAS have smaller densities – can be distinguished from CR EAS.

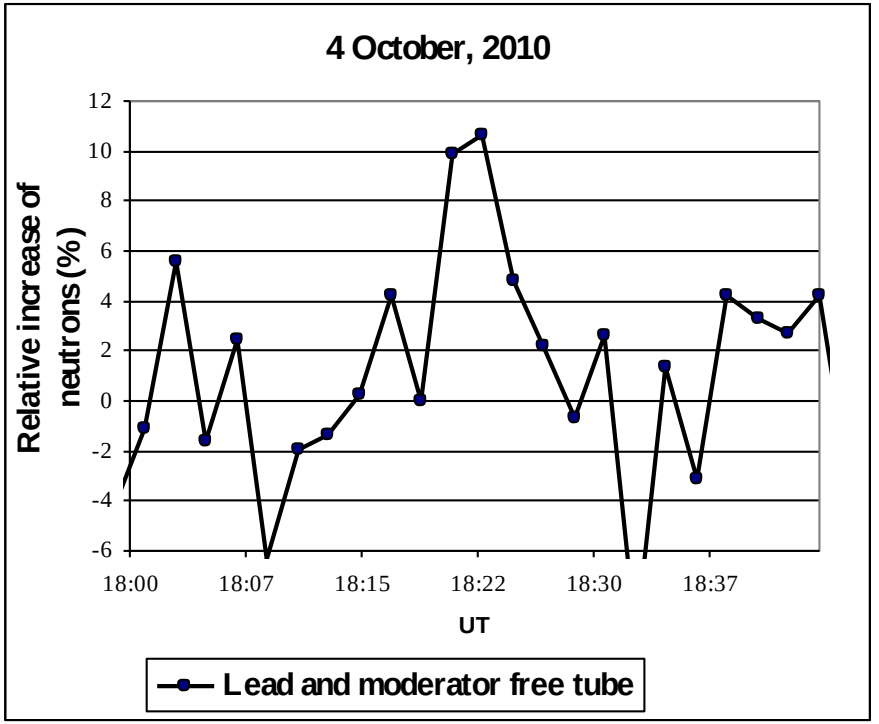


Measured enhancements in Aragats neutron monitor and in proportional counter sensitive to thermal neutrons



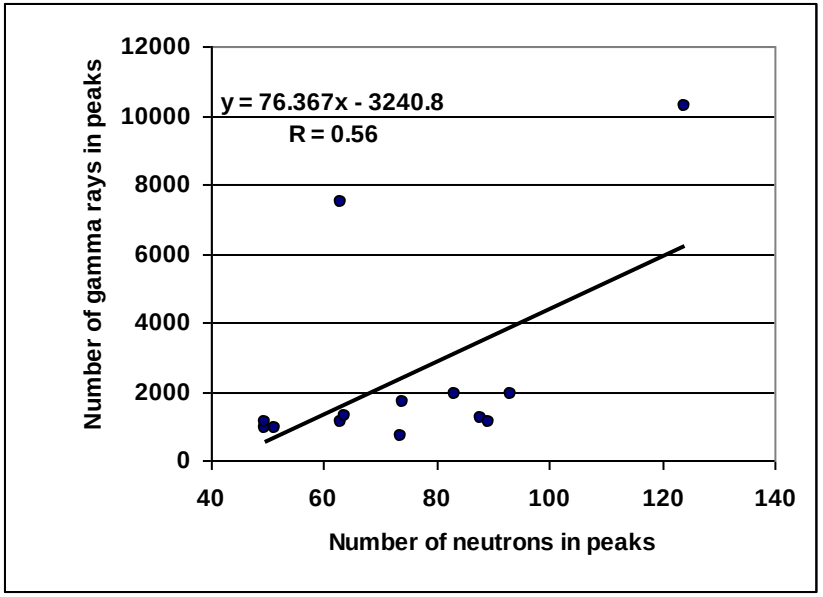


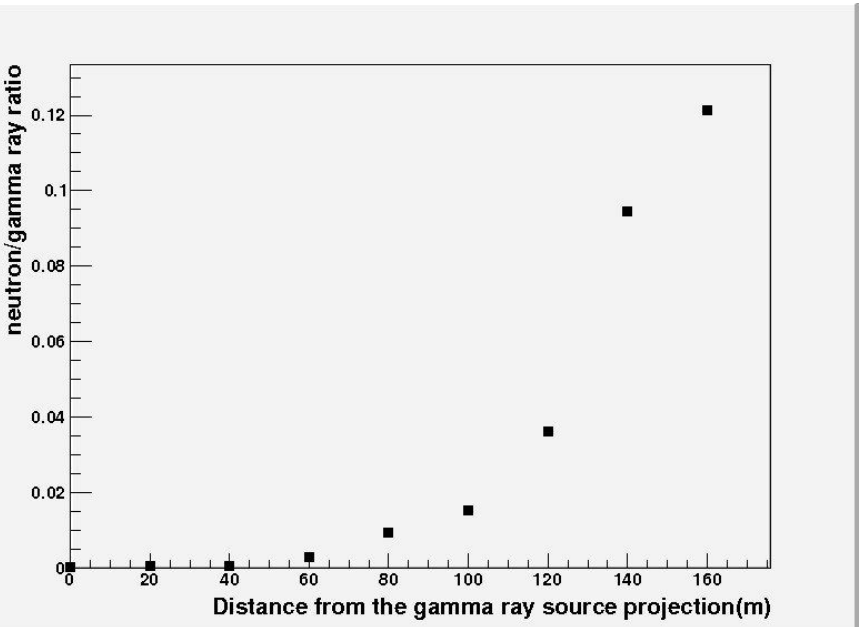


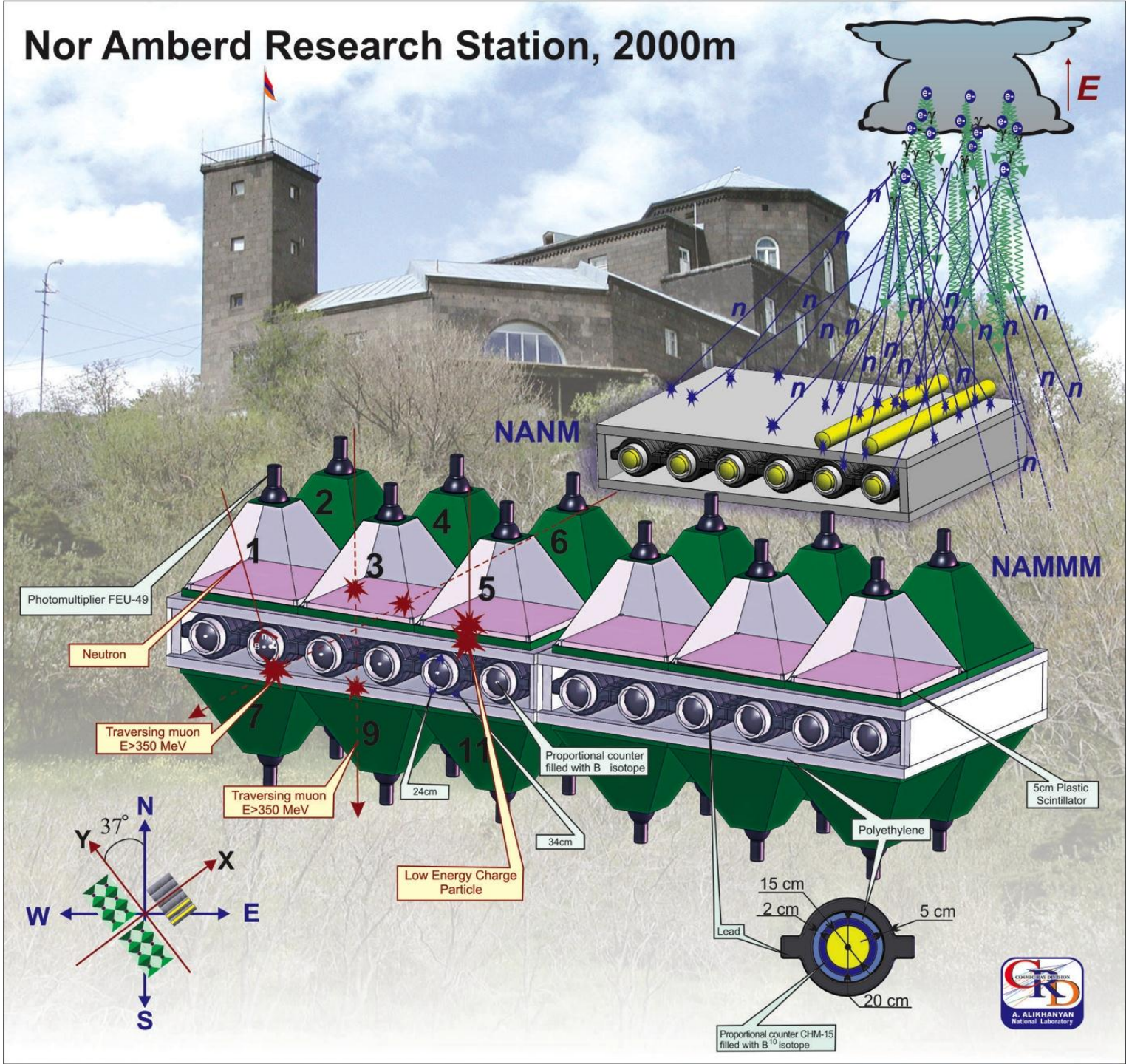


TGEs with Neutrons 2009-2010: large TGEs(neutron content 2-3%) smaller TGEs can reach 10%

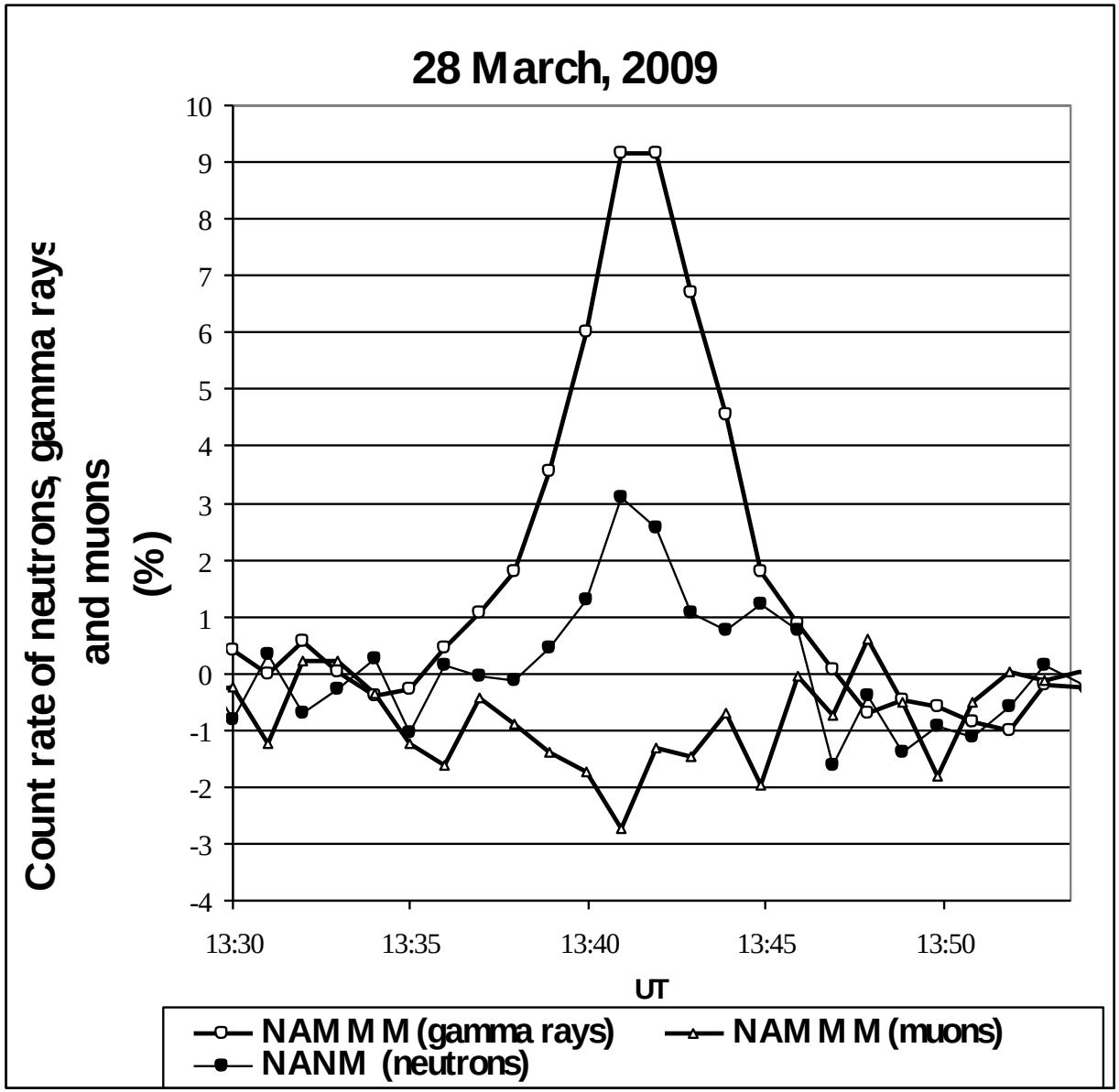
Day/month/ year	Number of additional neutrons detected by ANM at minute of maximal excess (min^{-1},m^{-2})	Relative increase of neutrons detected by ANM (%) /N(σ)	Recovered neutron intensity at 3200m (min^{-1},m^{-2})	Number of additional gamma rays detected by ASNT (combination 01) at minute of maximal excess min^{-1},m^{-2}	Relative increase of gamma rays in (%) /N(σ)	Recovered gamma ray intensity at 3200 by (min^{-1},m^{-2})	Ratio of neutron to gamma ray flux/ ratio of intensities for largest TGE events
21/05/09*	83	3.8/5	3420	1920	7/12		0.043
21/05/09*	94	4.3/5.7	3847	1921	7/12		0.049
03/06/09*	88	3.9/5.2	3613	1215	4/7		0.072
03/06/09*	89	3.9/5.2	3666	1076	3.6 /6		0.083
08/07/09*	63	2.7/3.5	2591	1116	3.3/5.3		0.056
08/07/09*	64	2.7/3.6	2624	1290	4.1/6.5		0.050
09/07/09	74	3.2/4.2	3050	1690	5.3 /9.5		0.044
20/08/09	51	2.3/3.2	2110	940	3/4.8		0.054
02/09/09	50	2.5/3.3	2032	900	3/5.2		0.055
19/09/09	63	2.8/3.7	2574	7452	23/41	104,000	0.008/0.025
02/11/09	50	2.3/3.1	2041	1101	3.3/6		0.045
04/10/10	124	5.8/7.7	5091	10280	32/58	153,000	0.012/0.033

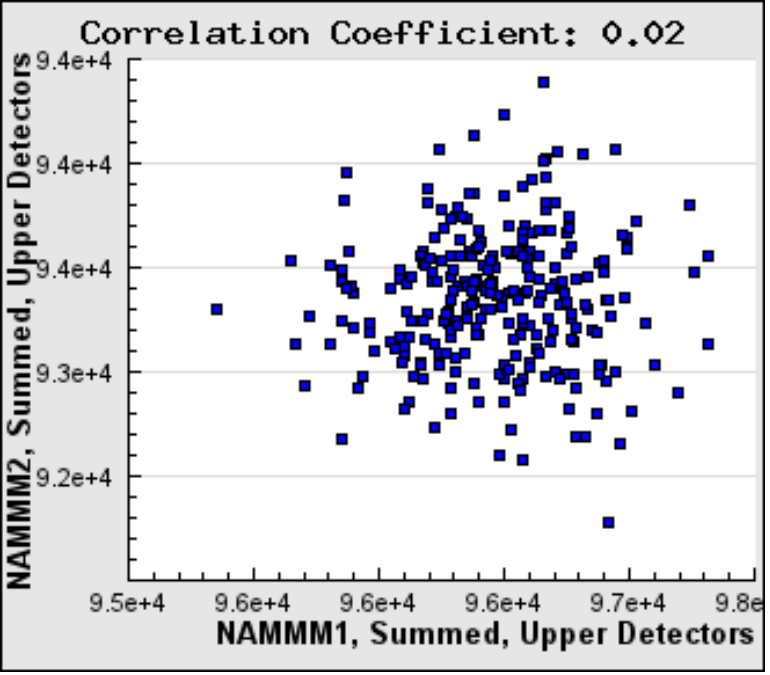


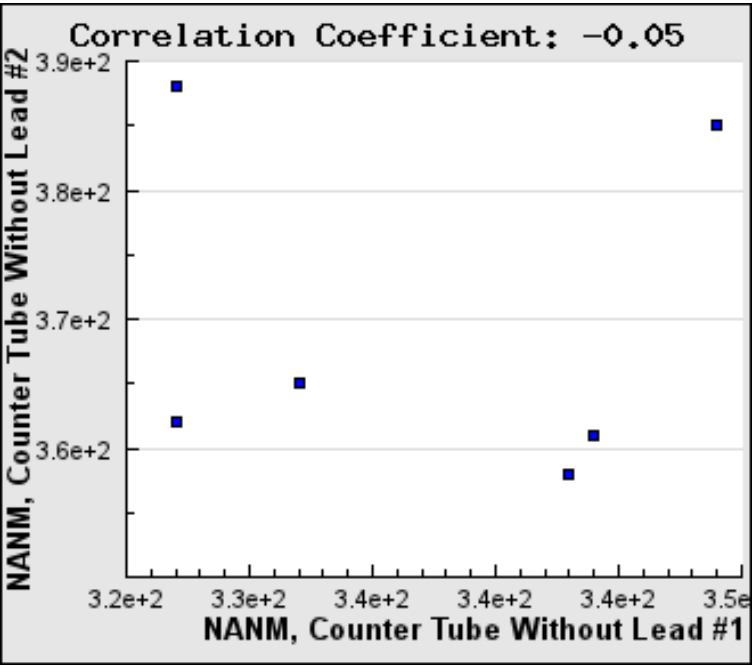



Nor Amberd Research Station, 2000m
E
NANM
NAMMM
Photomultiplier FEU-49
Neutron
Traversing muon E>350 MeV
Traversing muon E>350 MeV
24cm
34cm
Low Energy Charge Particle
Proportional counter filled with B isotope
5cm Plastic Scintillator
Polyethylene
15 cm
2 cm
5 cm
Lead
20 cm
Proportional counter CHM-15 filled with B10 isotope
N
S
W
E
X
Y
37°
A. ALIKHANYAN National Laboratory

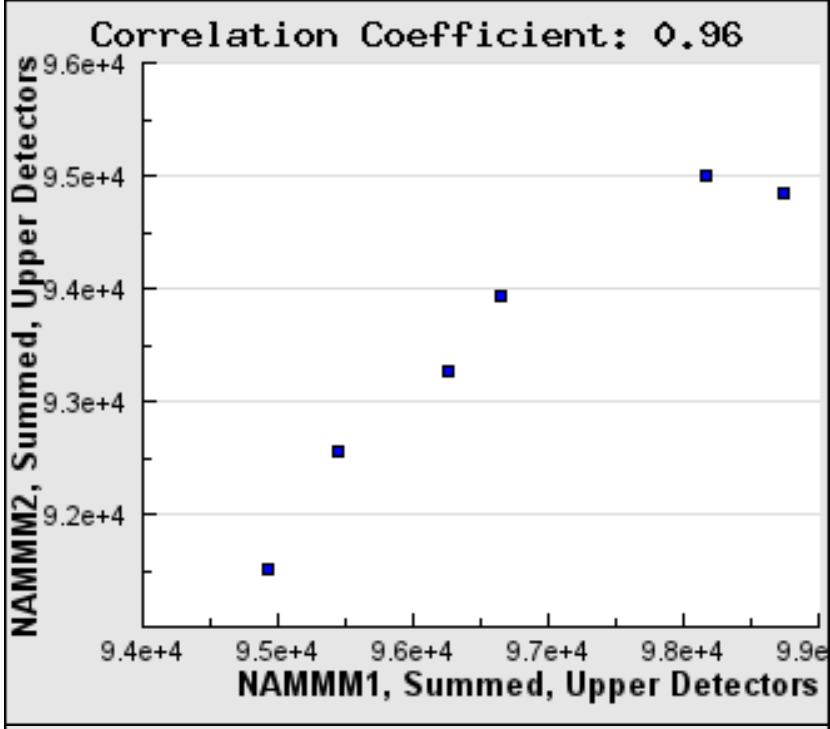
Nor Amberd TGE: enhancement of gamma rays and neutrons and depletion of muons

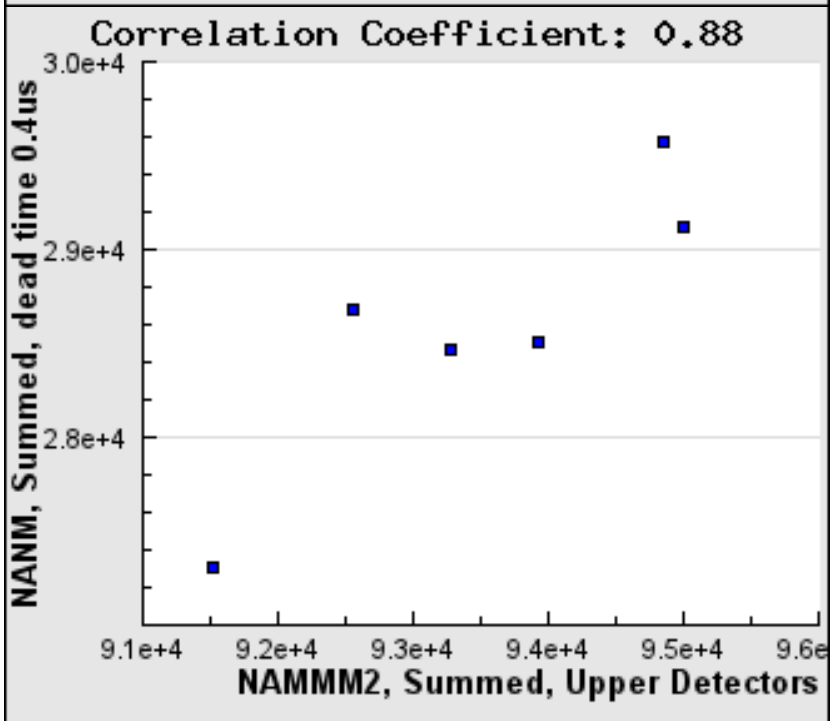


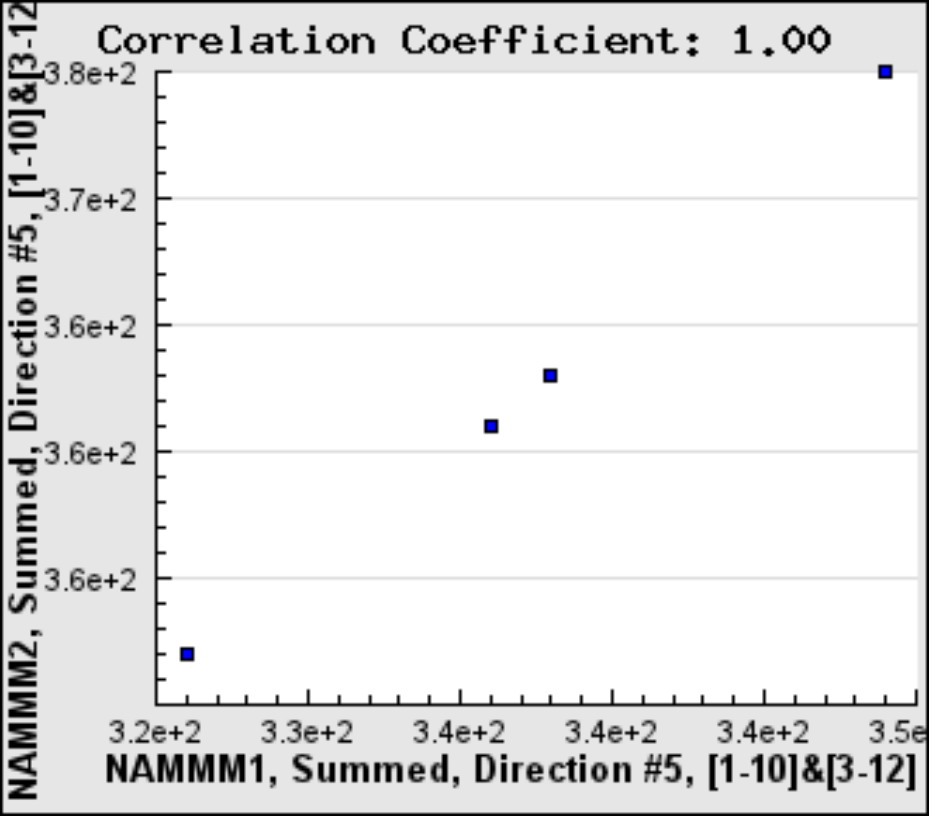




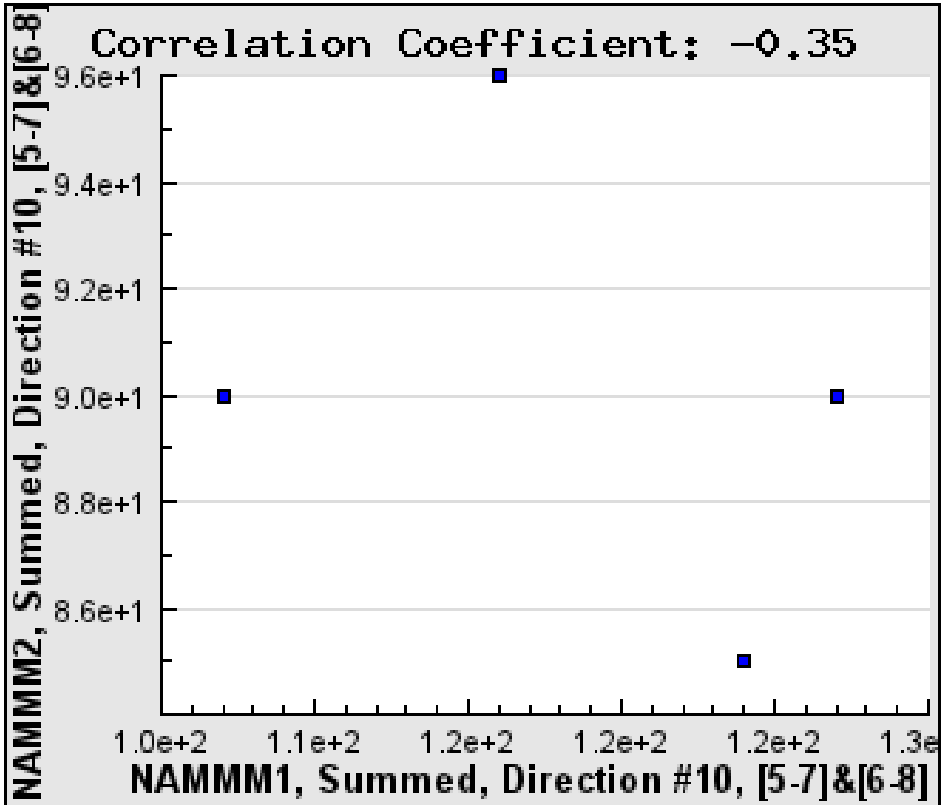
Correlation



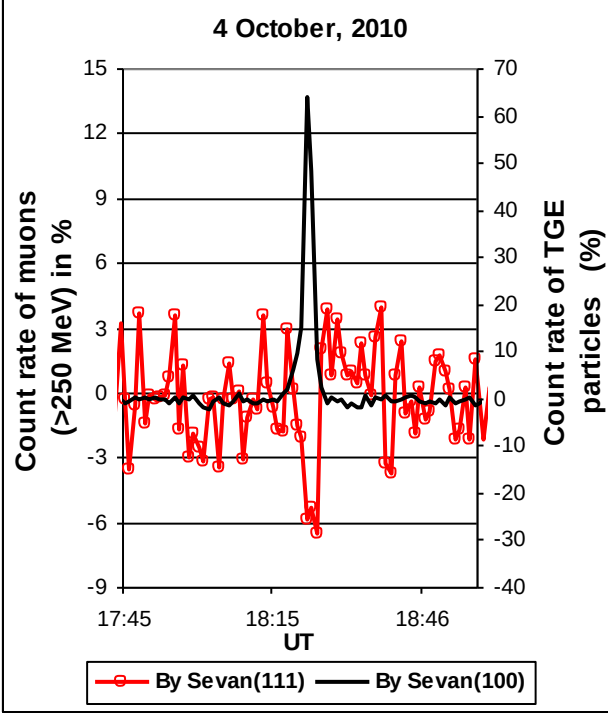


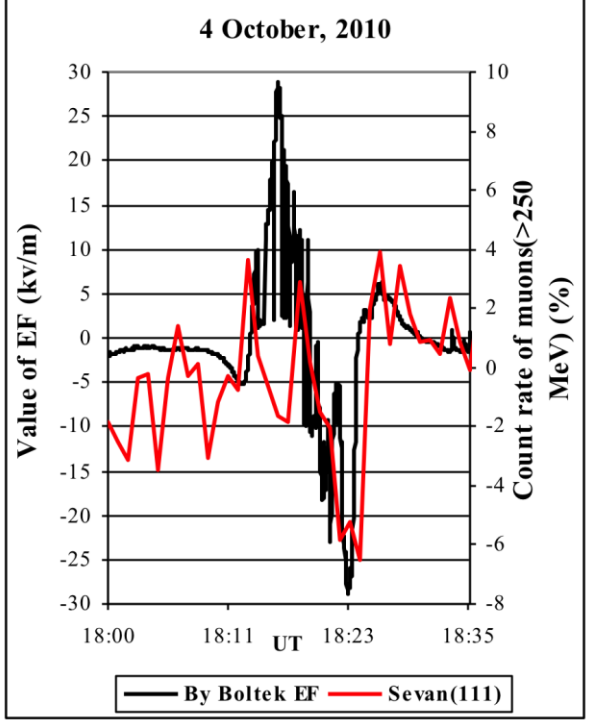


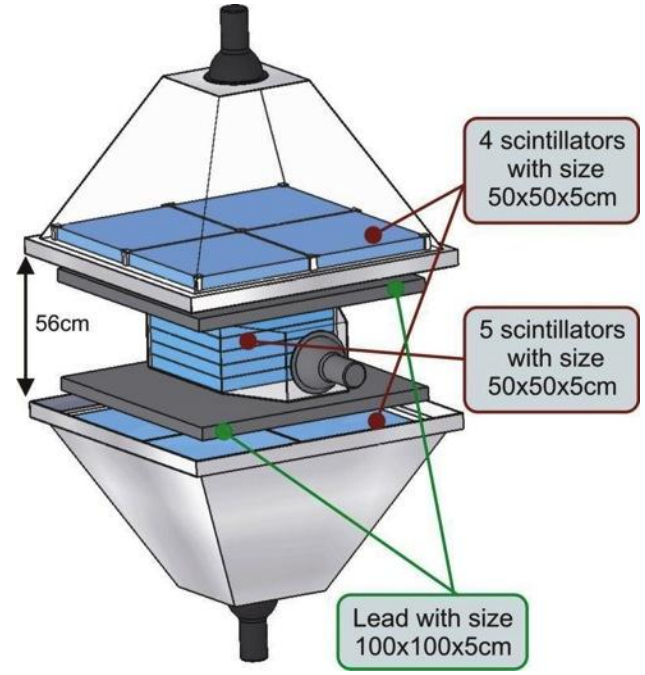
Depletion of muons is not uniform from different directions: possibility to locate the thundercloud! Correlations from definite direction is 1, and from others = arbitrary!

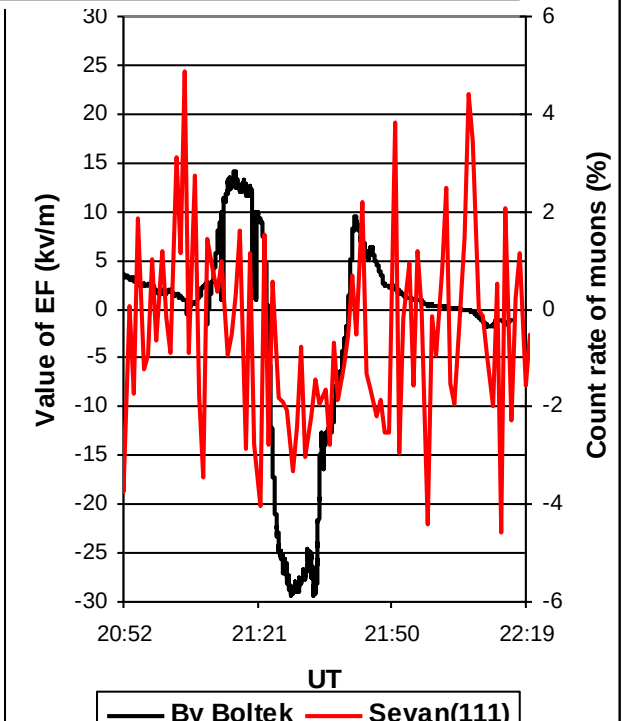


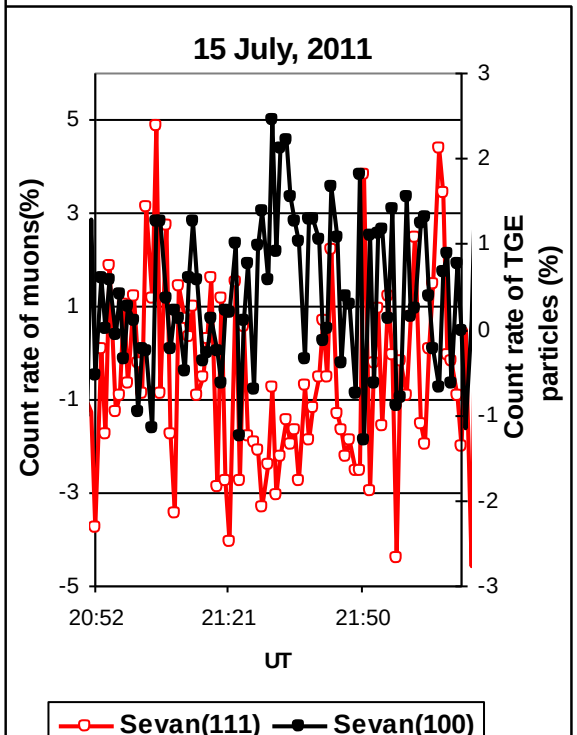
Deficit of high energy muons- positive muons stop: evidence of large potential drop in thundercloud



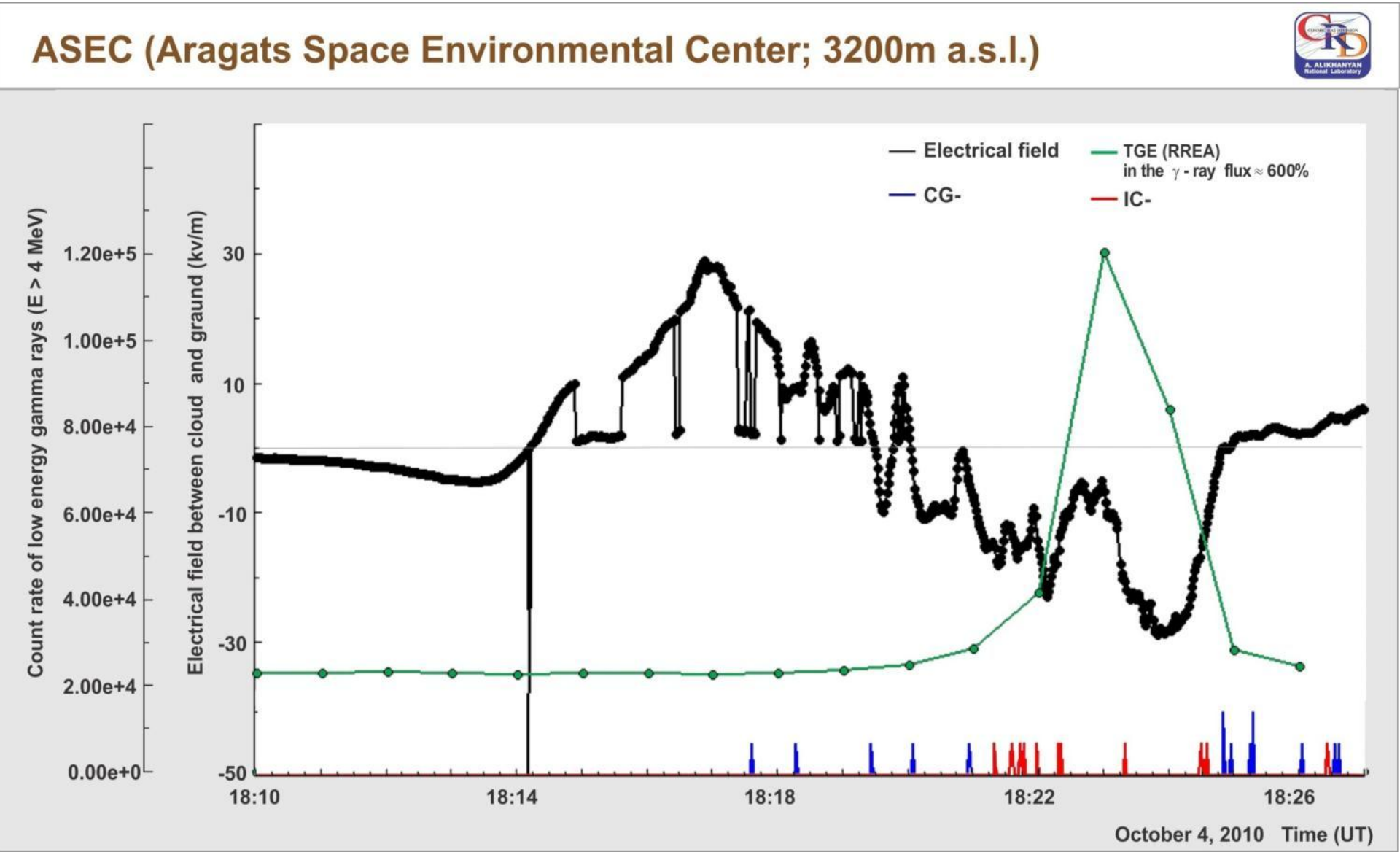




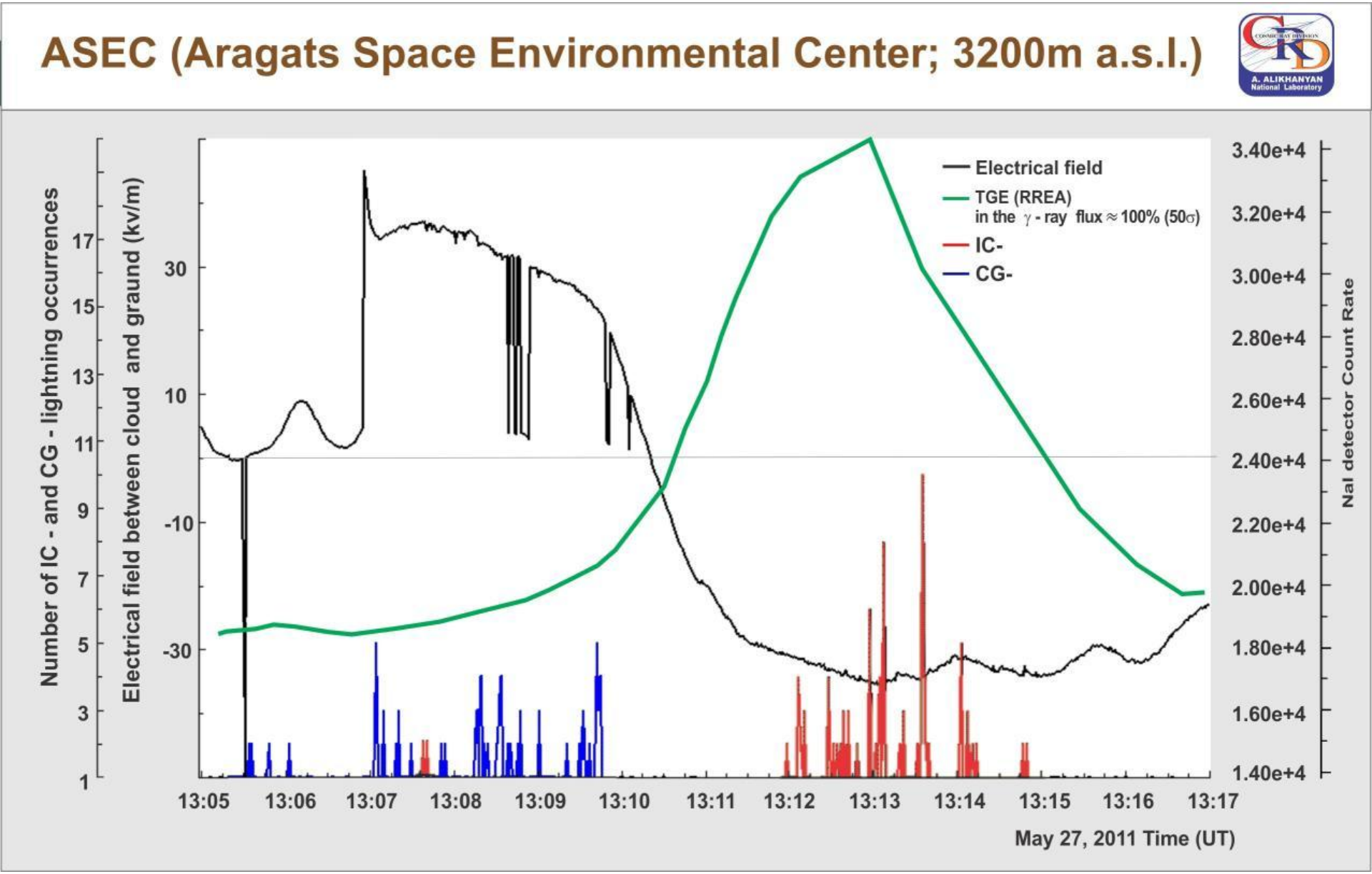




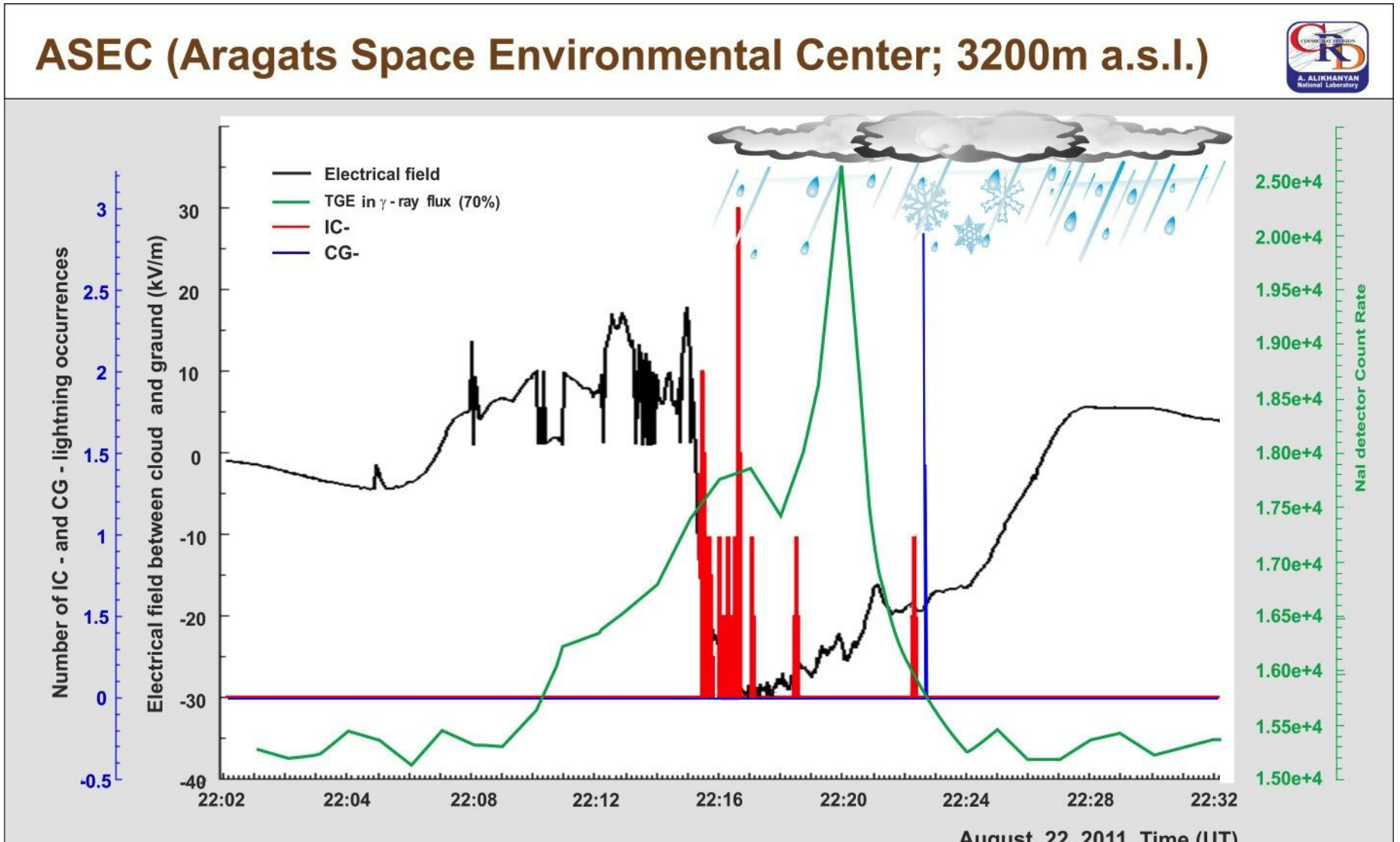
TGE are detected at large negative near surface electrical field; at the same time often occurred IC-lightning, CG- are suppressed.



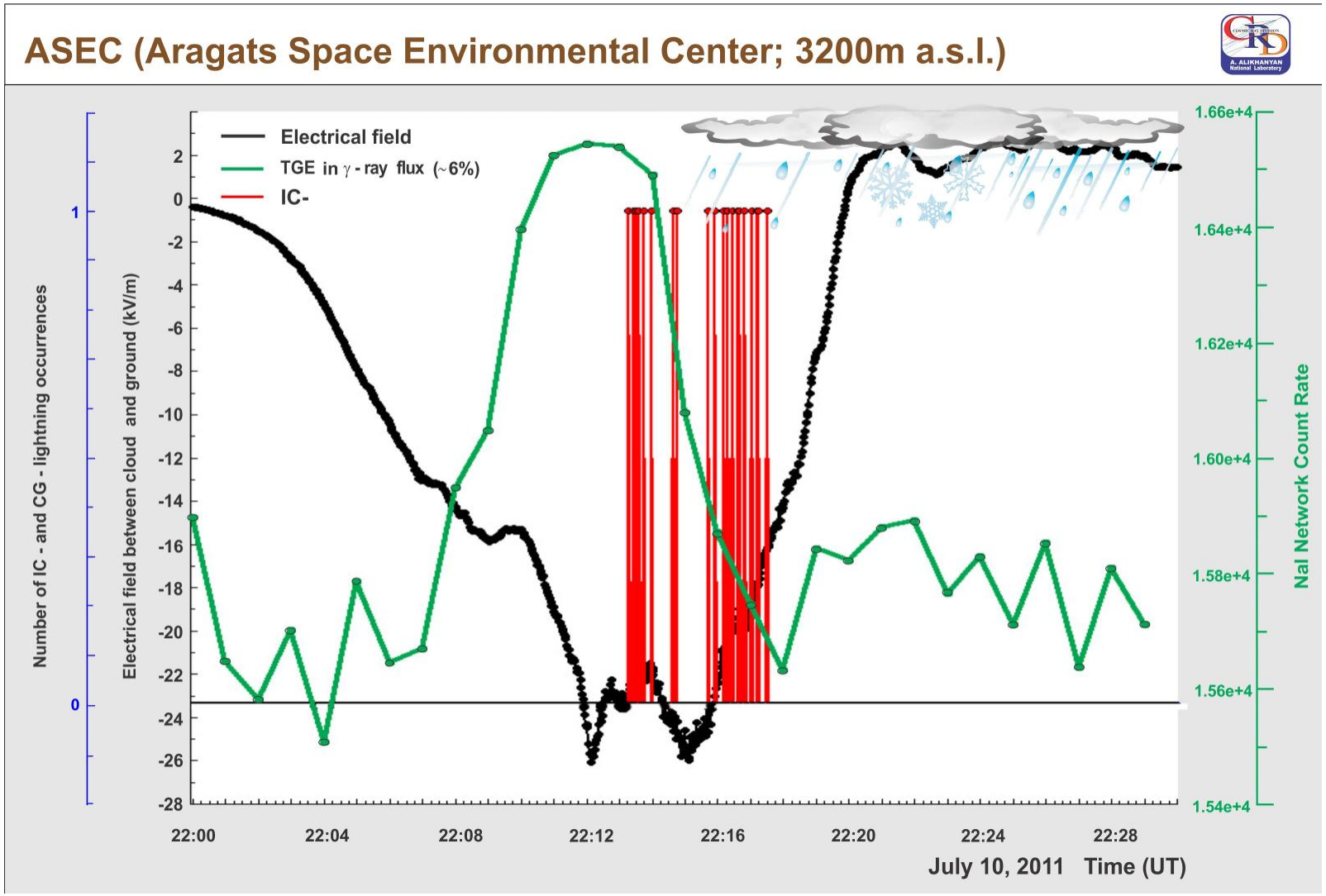
The dynamic of a TGE event



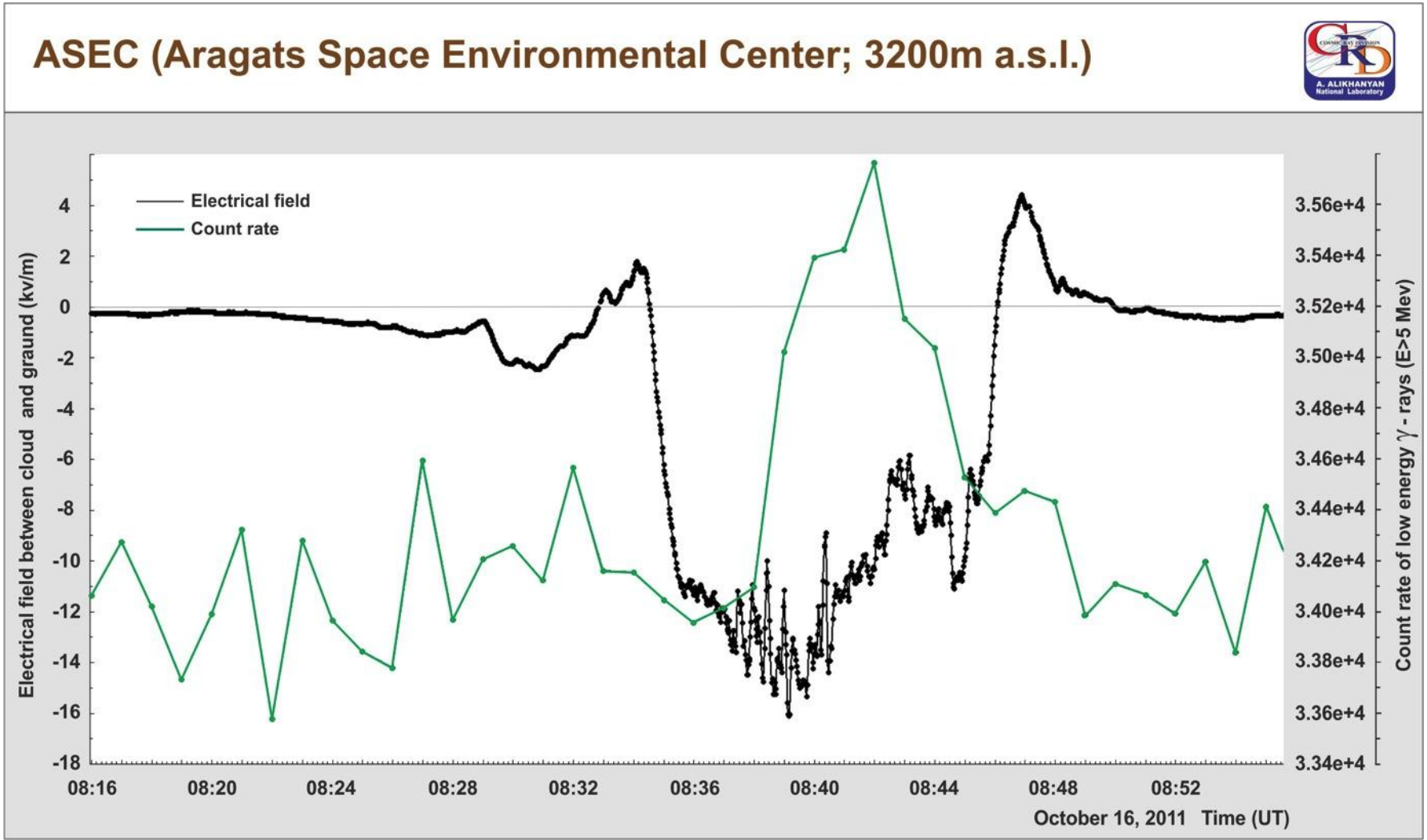
August 22 GLE:rain washed out positive layer(?)



July 10, 20011 TGE (no positive field)



TGE – small effects (transformation of the energy spectra – no lightning!)



What we know about TGEs?

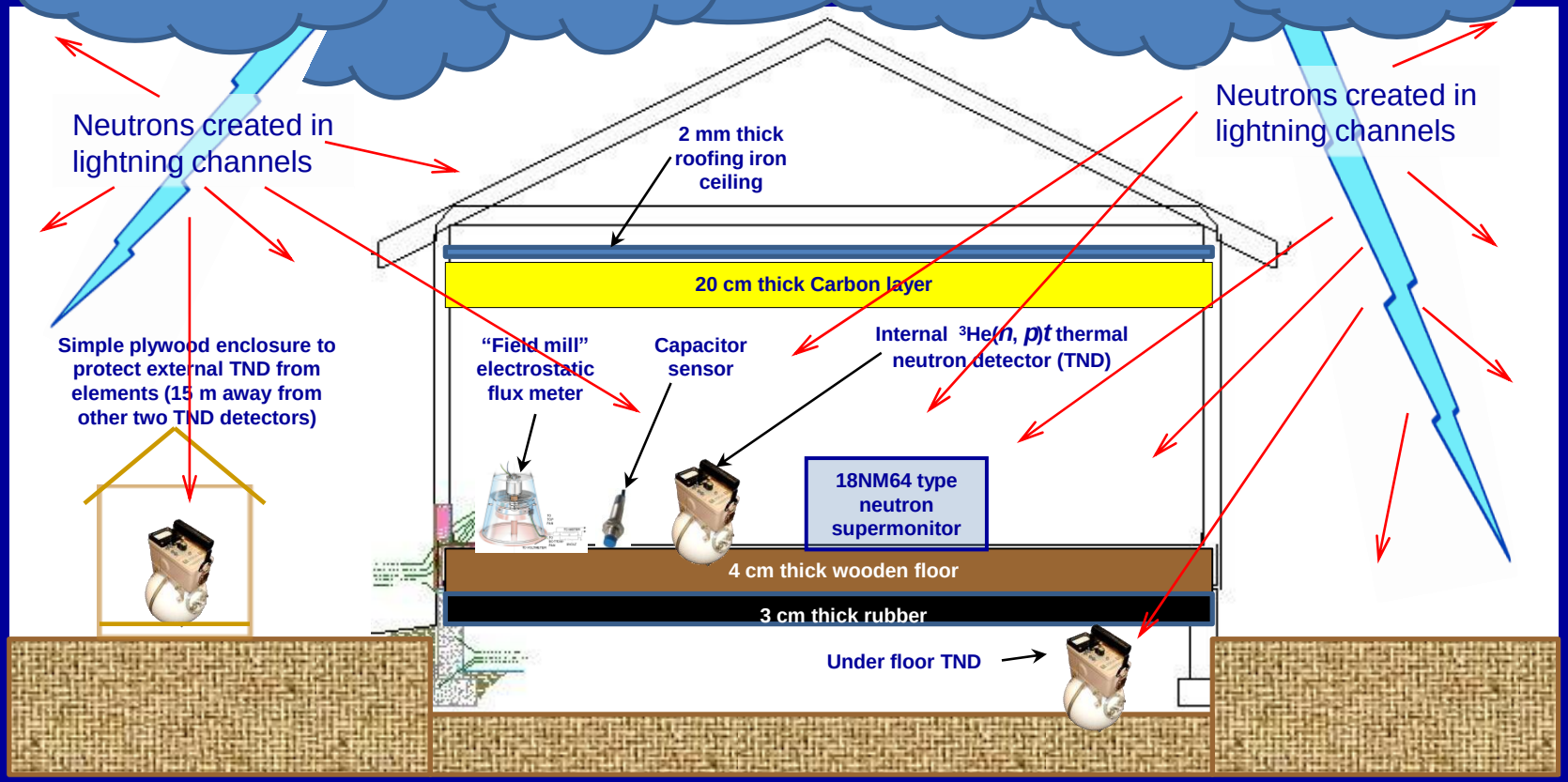
- We prove TGE existence by 6 effects: TGE can be detected in electron, gamma ray and neutron fluxes (large peaks) and in high energy muon flux (depletion, the amplitude of depletion gives possibility to estimate potential drop in the thundercloud!);
- Origin of TGE is mixture of 2 processes RREA (1 -40 MeV, up to 10 times above CR bkg) and modification of CR energy spectra MOS (1- 100 MeV up to 0.1 of bkg).
- Electrical fields in thunderclouds transfer effectively field energy to electrons; electrons generate gamma rays and gamma rates by photo-nuclear reactions born neutrons detected on earth's surface;
- RREA can generate particle bursts with duration less than 50 usec ("inverse" TGF); overall duration of TGE is ~ 10 minutes, during 10 minutes large amount of individual "inverse TGFs" occurs ;
- Largest TGE events allows to estimate energy spectra: energy spectra of electrons and low energy gamma rays are exponential, of gamma rays above 10 MeV power law in overal agreement with BGEAN4 simulation;
- TGEs usually occures on negative near surface electrical field varied from -10 to -30 kV/m;
- During TGEs the fraction of IC- lightning occurrences is strictly increased CG-lightning are suppressed – creation of lower dipole – LCPR!

Commercializing a next-generation source of CLENR energy

New evidence for low energy neutron fluxes in lightning - V

Data consistent with WLS many-body collective magnetic mechanism

Conceptual schematic of Gurevich *et al.*'s experimental setup



Neutrons from lightning bolt or from nuclei?

- Additional neutron fluxes during thunderstorm on Tien-Shan Mountain Cosmic Ray Station, Kazakhstan (altitude 3340 m) reaches the extremely high values of the order of (3-5) 10^{-2} neutrons cm^2 sec; at 4 October we had ~10^{-2} neutrons. 18,000-30,000per m^2 min, on Aragats 5,000
- We need ~10 times more Gamma rays in the energy range 10–30 MeV, 180 – 300,000; we measure 50,000-100,000 at Aragats, so maybe they have 180,00 on Tien-Shan, but they do not report it! And it is not 3 orders of magnitude less than the needed value, Tien Shan group claim.
- The drastic difference is absence of thermal neutrons at Aragats;only once for maximal neutron flux we measure albedo thermal neutrons bu “bare” NM counter!