Thunderstorms, Lightning and Particle Acceleration: Physics with SEVAN

Ashot Chilingarian, Yerevan Physics Institute


SEVAN
Space
Environmental
Viewing and Analysis Network


Aragats Space Environmental Center (ASEC)– 3200 m above sea level, established in 1942 - 75 years of monitoring of various particle fluxes, fields, meteorological conditions, radio emissions, lightning flashes etc.

April 1 2019: Experimental halls on Aragats under deep snow

High-energy Physics in Atmosphere: Particle fluxes and lightnings at Aragats

Planetary Science and Particle Physics: Geo-particle physics

First expedition to Aragats in 1943: Investigation of the Attenuation of Cosmic Rays in Water

A.Chilingarian, R. Mirzoyan and M. Zazyan,
Cosmic Ray research in Armenia,
Advances in Space Research 44 (2009)
1183–119

Abram Alikhanov and Artem Alikhanyan

Alikhanov-Alikhanyan “Big” magnet; brought from Germany in 1945; used for research of particles with masses between electron and proton on Aragats

Most Important Achievements 1942-1992

- **1942 – First expedition to Aragats**
- **1943 – Establishment of the Physical-mathematical Institute of Yerevan State University; then Yerevan Physics Institute after Artem Alikanyan, now A.Alikhanyan national lab;**
- **1945-1955 – Foundation of Aragats high-mountain research station. Experiments at Aragats with Mass-spectrometer of Alikhanyan-Alikhanov: investigations of the composition of secondary CR (energies <100 GeV); exploration of the "third" component in CR; observation of particles with masses between μ-meson and proton;**
- **1957 –construction of the first Ionization calorimeter, detection of particles with energies up to 10 TeV;**
- **1960 – Foundation of the Nor Amberd high-mountain research station;**
- **1970 – Lenin prize for the Wide-gap Spark Chambers;**
- **1975 –Experiment MUON: energy spectrum and charge ratio of the horizontal muon flux;**
- **1975 – Neutron supermonitors 18NM64 at Aragats and Nor Amberd research stations;**
- **1977 – Experiment PION: measuring pion and proton energy spectra and phenomenological parameters of CR hadron interactions;**
- **1981-1989 –ANI Experiment: Commence of MAKET-ANI and GAMMA surface detector arrays for measuring cosmic ray spectra in the "knee" region (10^{14} – 10^{16} eV);**
- **1989-1992 –Introduction of multivariate methods for signal detection from γ-ray point sources, prove of the detection of Crab nebula by Whipple collaboration;**

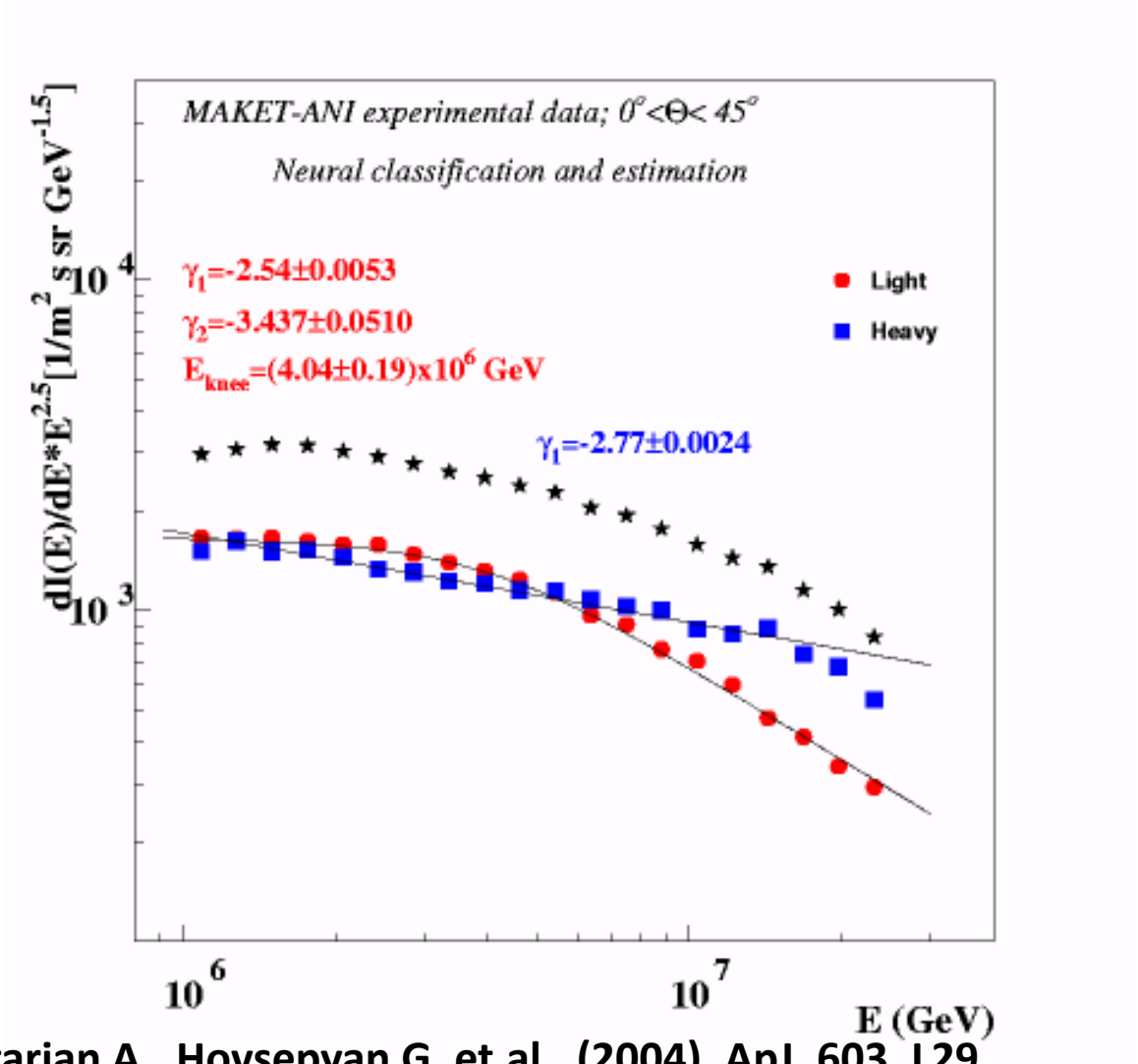
Most Important Achievements 1993 - 2008

- **1993-1996 – Development of new methodology of multivariate, correlation analysis of data from Extensive Air Shower detectors, event-by-event analysis of shower data from KASCADE experiment; classification of primary nucleus;**
- **1996-1997 – Renewal of Cosmic ray variation studies at Aragats: installation of the Solar Neutron Telescope and resumption of Nor Amberd Neutron Monitor;**
- **2000 – Foundation of Aragats Space Environmental Center (ASEC) – for Solar Physics and Space Weather research; measurements of the various secondary fluxes of cosmic rays; inclusion of the large surface arrays in monitoring of the changing fluxes of secondary cosmic rays ;**
- **2003 – Detection of the intensive solar modulation effects in September – November in the low energy charged particle, neutron and high energy muon fluxes;**
- **2004 – Measurement of the spectra of heavy and light components of GCR, observation of very sharp "knee" in light nuclei spectra and absence of "knee" in heavy" nuclei spectra, confirmed in 2007 by spectra published by GAMMA detector;**
- **2005 - Measurements of highest energy protons in Solar Cosmic Rays (GLE 69 at 20 January; detection of Solar protons with E>20GeV);**
- **2007 - Starting of SEVAN (Space Environmental Viewing and Analysis Network - a new type of world-wide network of particle detectors for monitoring of geophysical parameters**
- **2008 - Multivariate analysis and classification of the solar transient events (Ground level enhancements, Geomagnetic effects, Forbush decreases) detected by ASEC monitors during 23rd solar activity cycle.**

Most Important Achievements 2009 – 2018: High –Energy physics in Atmosphere

- Discovery of simultaneous fluxes of electrons, gamma rays and neutrons measured at mountain altitudes, proving the existence of the new high-energy phenomenon (so called Thunderstorm Ground Enhancements - TGEs).
- Discovery of the “Cloud extensive showers - CESs” – extended showers initiated in thunderclouds by the electrons accelerated in cloud electrical fields – first direct evidence of the Relativistic Runaway Electron Avalanches (RREA) in the terrestrial atmosphere.
- Discovery of long lasting radiation from the thunderclouds (up to several hours) that radically changed fundamental perception of the atmospheric natural radioactivity.
- Development of the Aragats Space Environmental center (ASEC) and Armenian geophysics measurements network. Both are equipped with various particle detectors, field meters and meteorological stations for monitoring of ionization radiation, disturbances of geomagnetic and electric field and lightning flashes.
- Founding of the worldwide network of new particle detectors for researches in space weather and solar physics, named SEVAN (Space Environment Viewing and Analysis Network). Nodes of the SEVAN network are now operating in Armenia, Bulgaria, Croatia and Slovakia, Czech Rep., planned 2 nodes in Germany.
- Introducing of new model of lightning initiation;
- Founding of Armenian Geophysics Network in 6 location of Armenia and Arcakh.

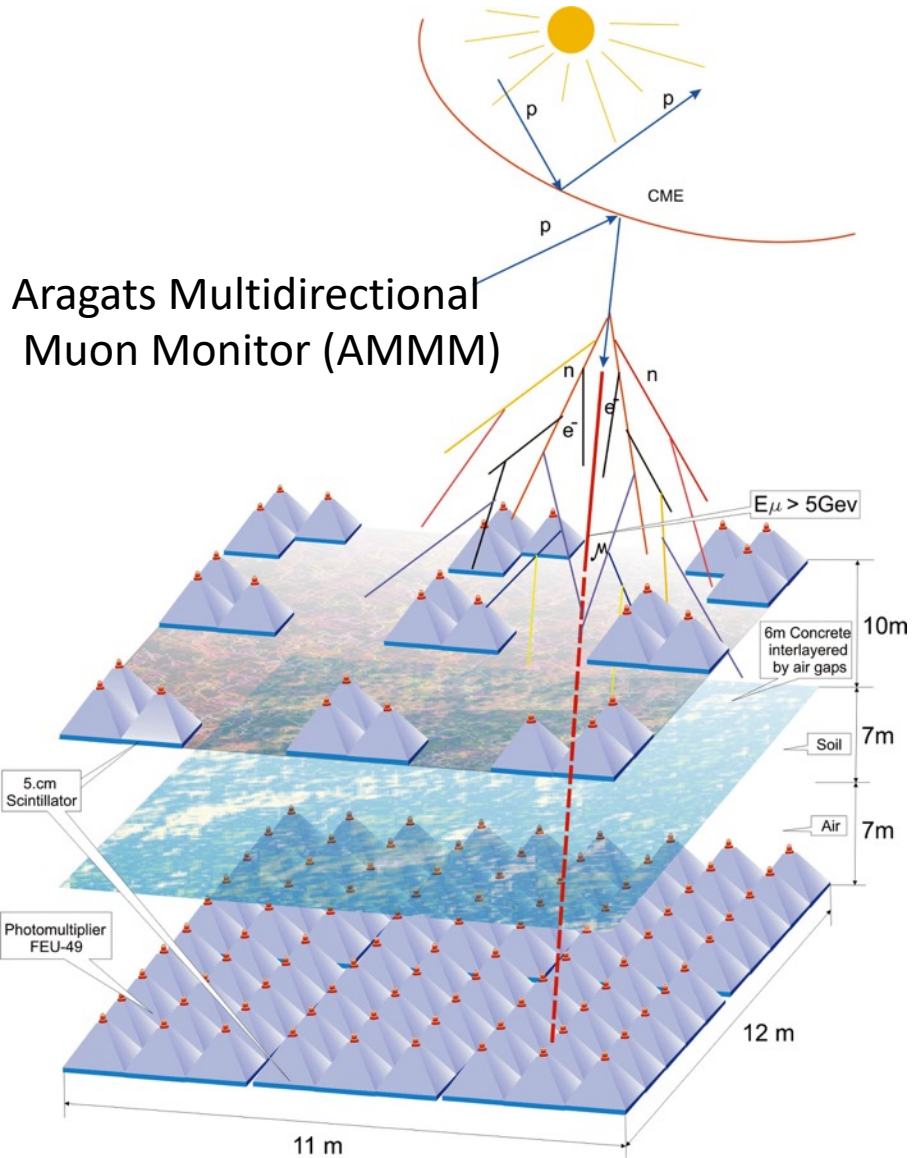
“Knee” origin: first classification of the all particle energy spectra to Light and Heavy Nuclei by Machine learning algorithms with MAKET array at Aragats

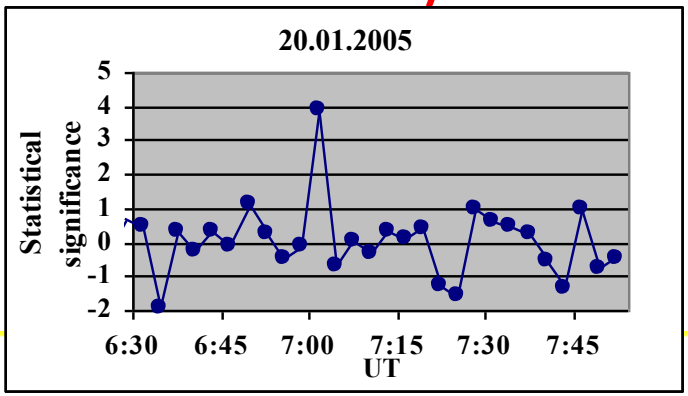


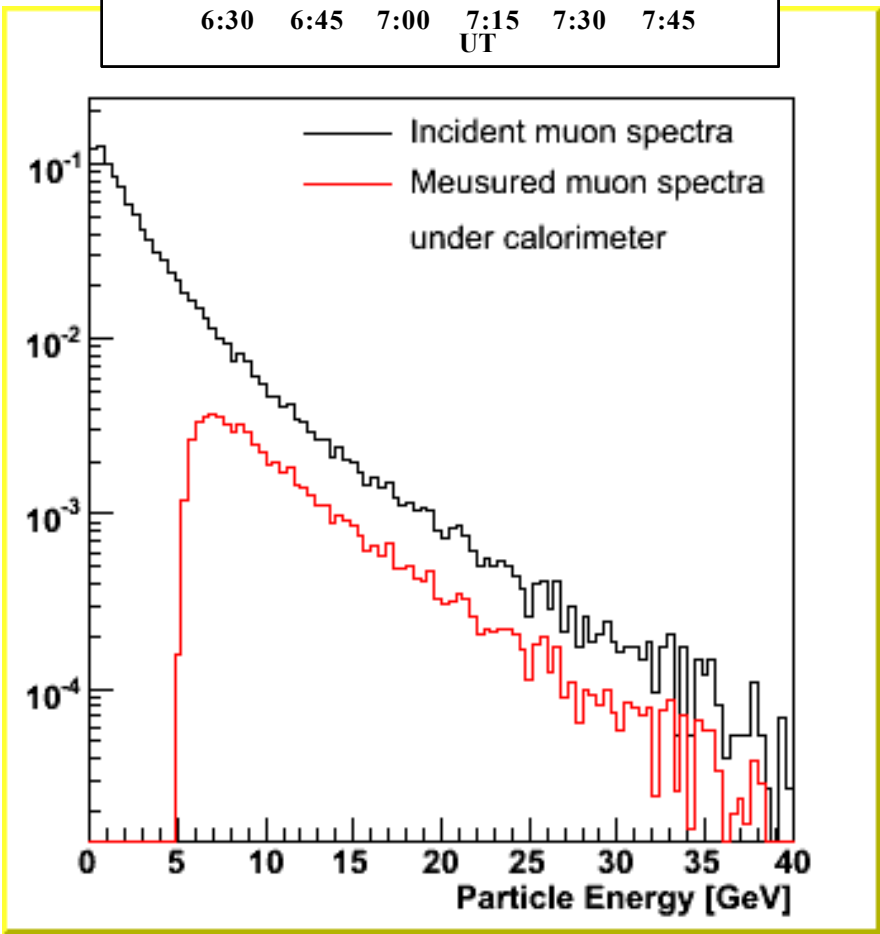
Credit, Chilingarian A., Hovsepyan G. et.al., (2004), ApJ, 603, L29

Discovery of the Highest energy Solar accelerators (> 20 GV): AMMM Detection of GLE 20 January 2005

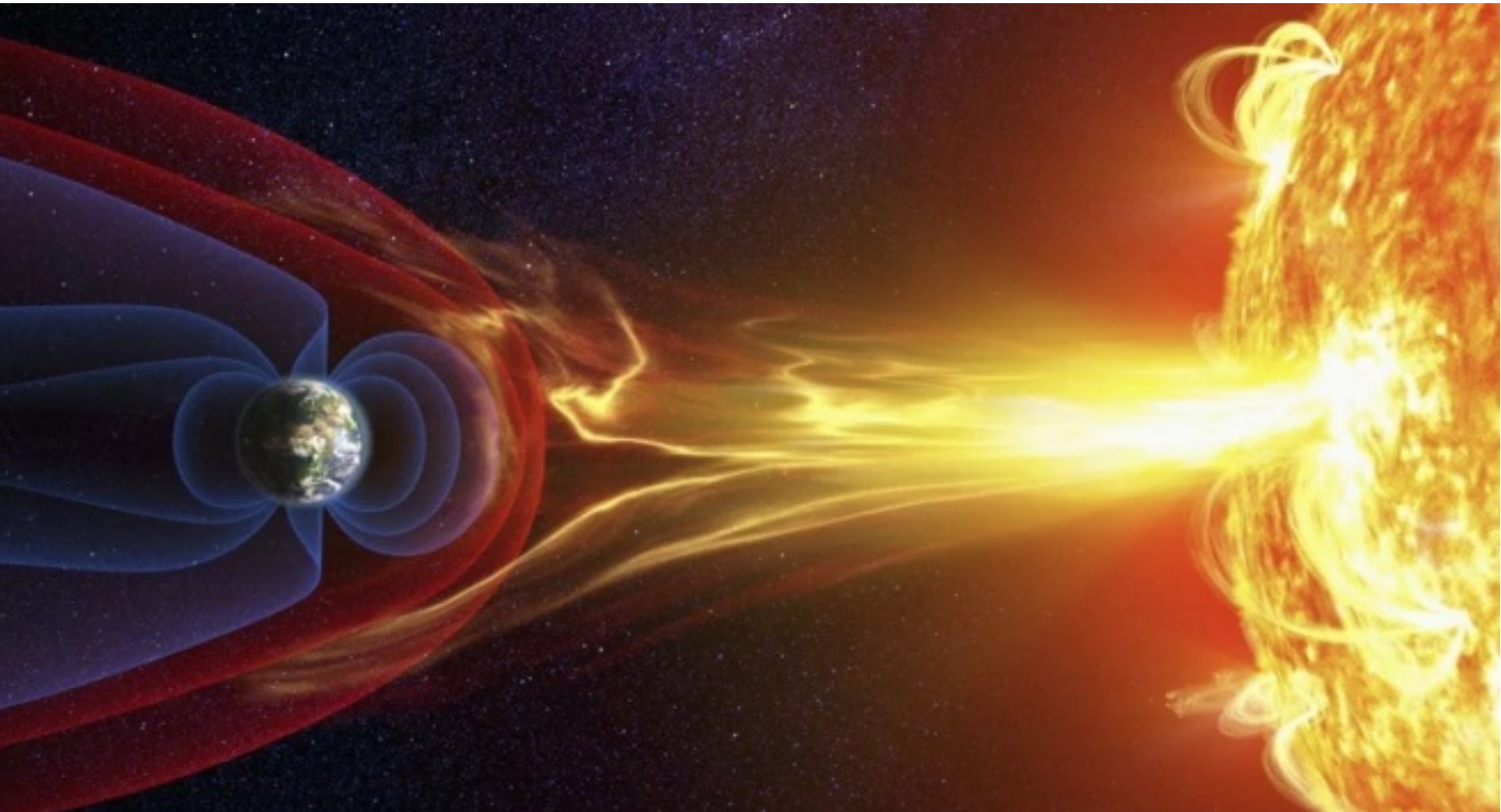
Aragats Multidirectional Muon Monitor (AMMM)

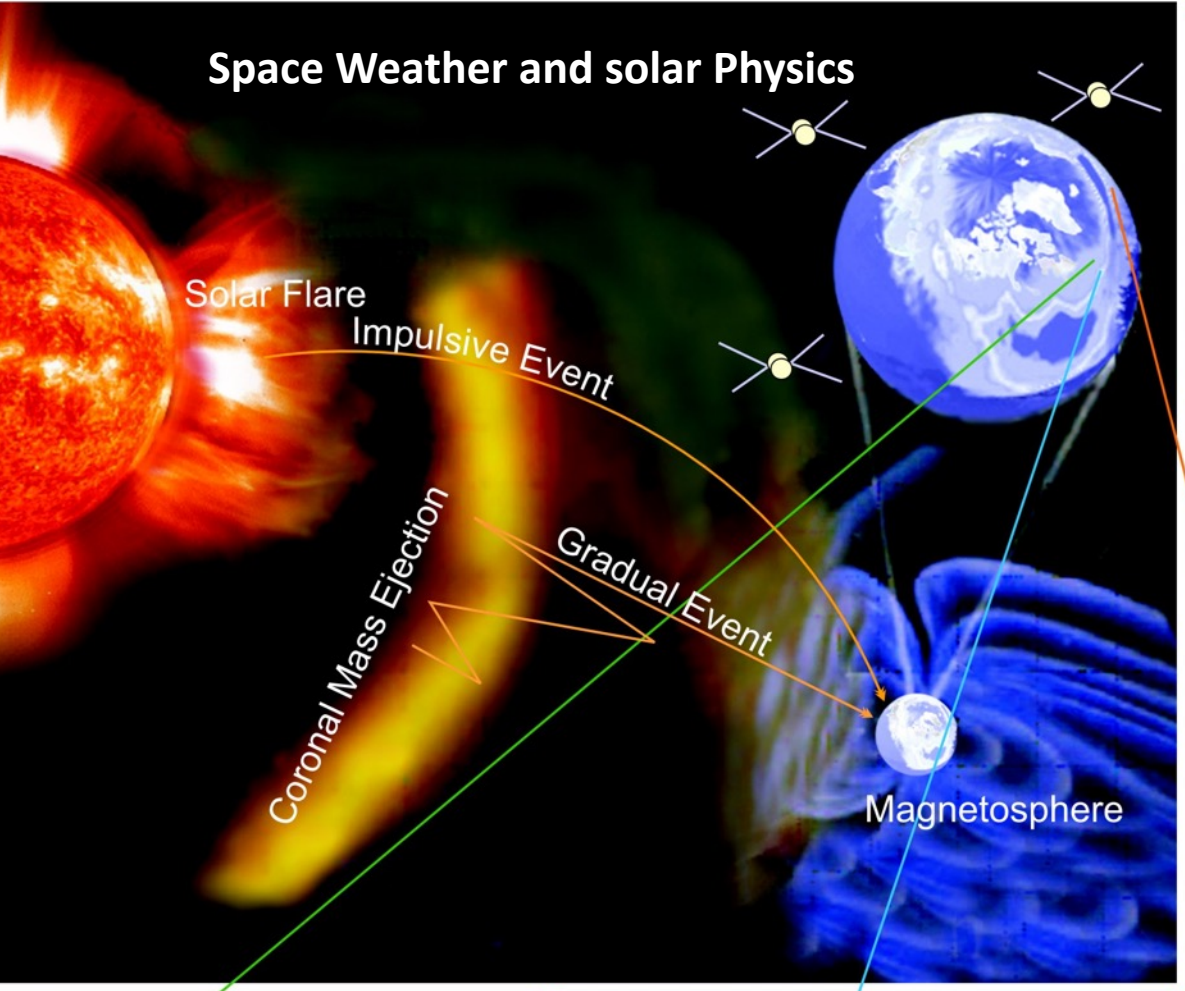


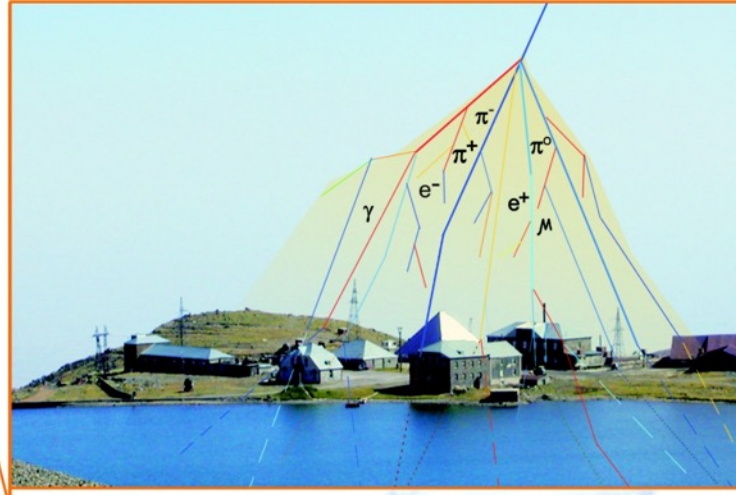




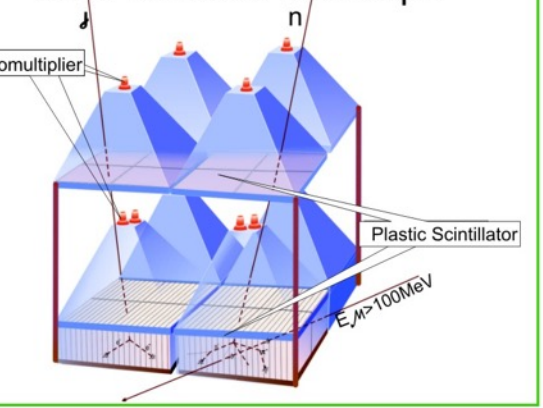
Extreme Geomagnetic Storms
Modulation of CR flux



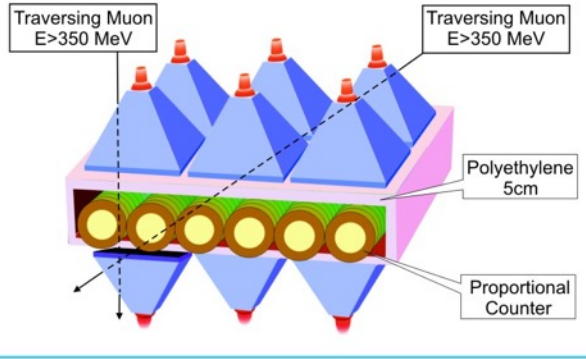




Solar-Neutron Telescope

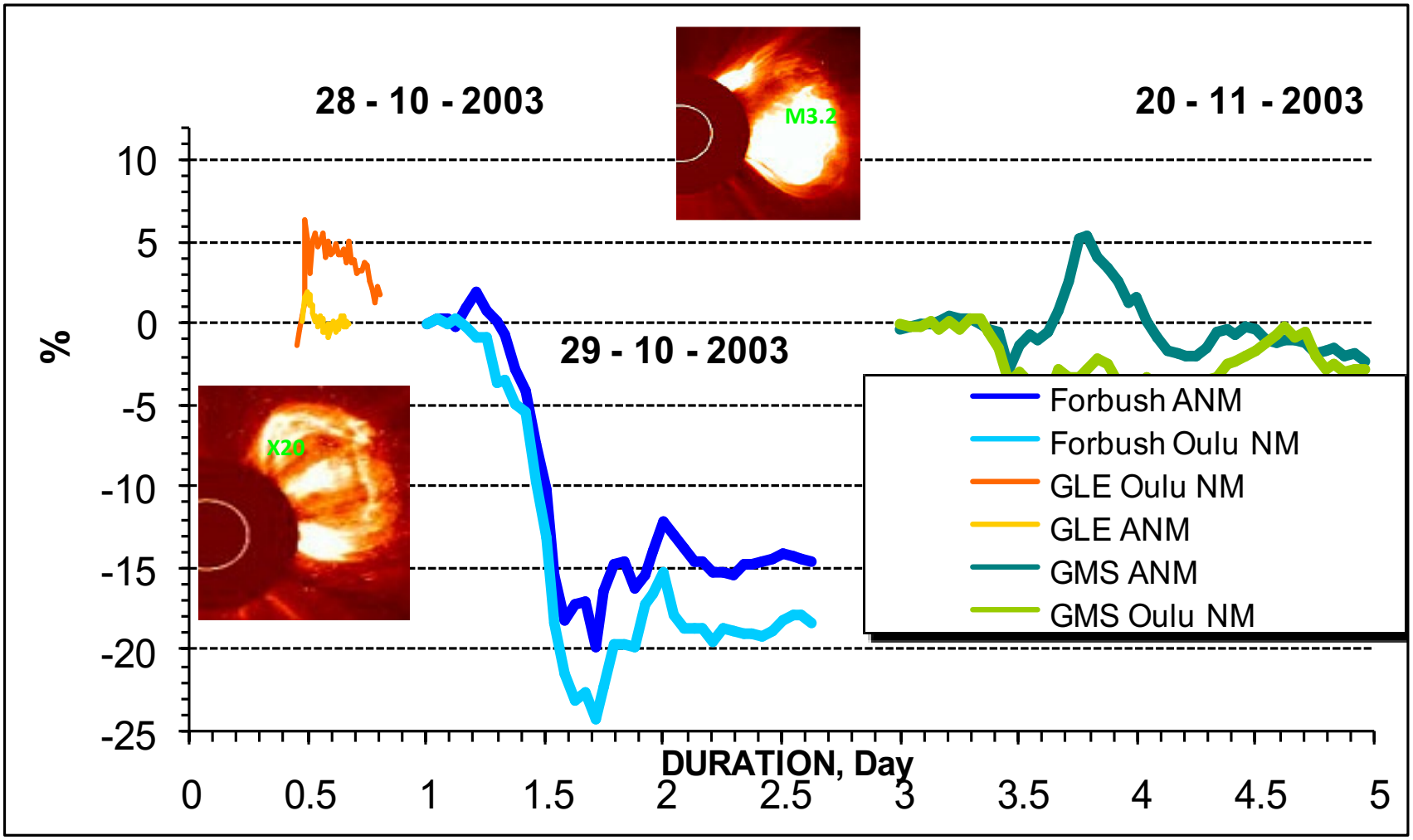


Nor-Amberd Multidirectional Muon Monitor

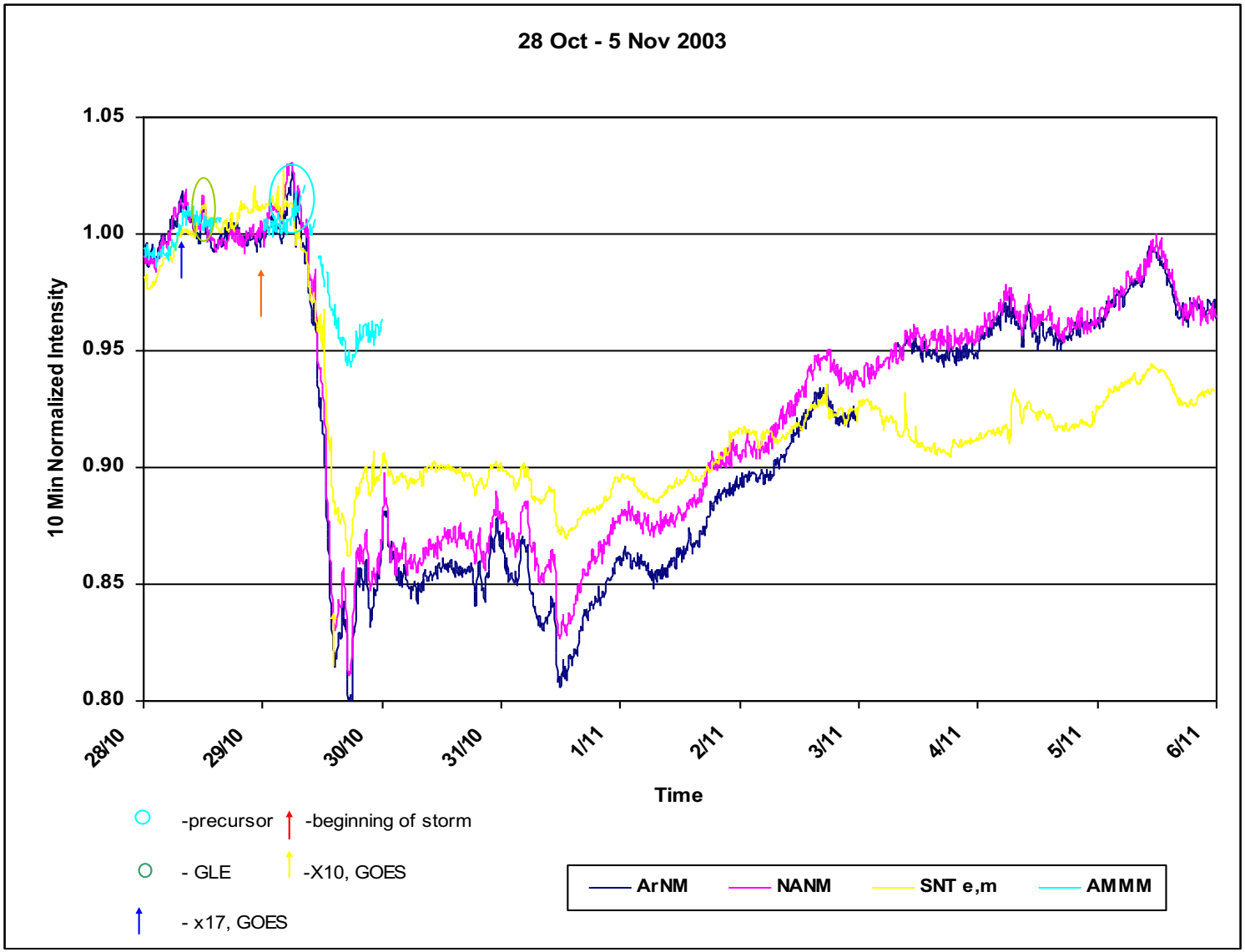


High energy cosmic rays open a window for the exploration of the dy and forceful processes in the far-corners of the universe. The A Space-Environmental Center (ASEC) of the Cosmic Ray Division in Ar http://crdlx5.yerphi.am, conducts research in the field of Galactic Cosmic and Solar Physics. The two research stations, at 3200m and 2000m ele on Mt. Aragats, are equipped with modern scientific detectors and instru which allow the scientists to make new discoveries in high energy astrop The ASEC explores the activity of our own star, the Sun, and is deve Space Weather forecasting and early warning systems and techniques strategic geographic coordinates of the ASEC research stations and the g based particle detector systems developed by the ASEC scientists, c with data from detectors in space and on the ground, will allow the intern community to develop a reliable and global Space Weather forecasting s to protect astronauts and satellites in space and power grids on the grou

Solar Modulation effects at high and middle latitudes – to detect GLE we need large count rate



Famous “Halloween” events of 2003, detected in electron & muon and neutron fluxes by ASEC monitors at different altitudes



SEVAN home page: http://crd.yerphi.am/sevan

Space Environment Viewing and Analysis Network (SEVAN) - Mozilla Firefox

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http://192.168.24.5/SEVAN/

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Space Environmental Viewing and Analysis Network(SEVAN)

SEVAN Posters
SEVAN Detectors
SEVAN Official letters
SEVAN MOU Examples
Contacts

Space Weather Definitions Approved by All Members of COST action N 724

SW definition: 28 Languages
SW definition English
SW definition Russian
SW definition Armenian

About SEVAN Project

SEVAN (Space Environmental Viewing and Analysis Network) is a network of middle to low latitude particle detectors which aims to improve fundamental research of space weather conditions and to provide short and long-term forecasts of dangerous consequences of space storms.

The network will detect changing fluxes of different species of secondary cosmic rays at different altitudes and latitudes, thus turning into a powerful integrated device used to explore solar modulation effects.

To facilitate SEVAN network creation, CRD will design and develop the basic hybrid SEVAN particle detector module and assume responsibility for all electronics and advanced data acquisition system (ADAS). CRD will also fabricate and test the SEVAN prototype module, as well as provide free scintillator slabs and photomultipliers to be installed at the host institutions

International Heliophysical Year(IHY)

- About IHY
- IHY websites
- IHY reports
- IHY Newsletters
- IHY Brochure

Done

www.aragats.am

COSMIC RAY DIVISION
Alikhanyan Physics Institute,
Alikhanyan Brothers 2,
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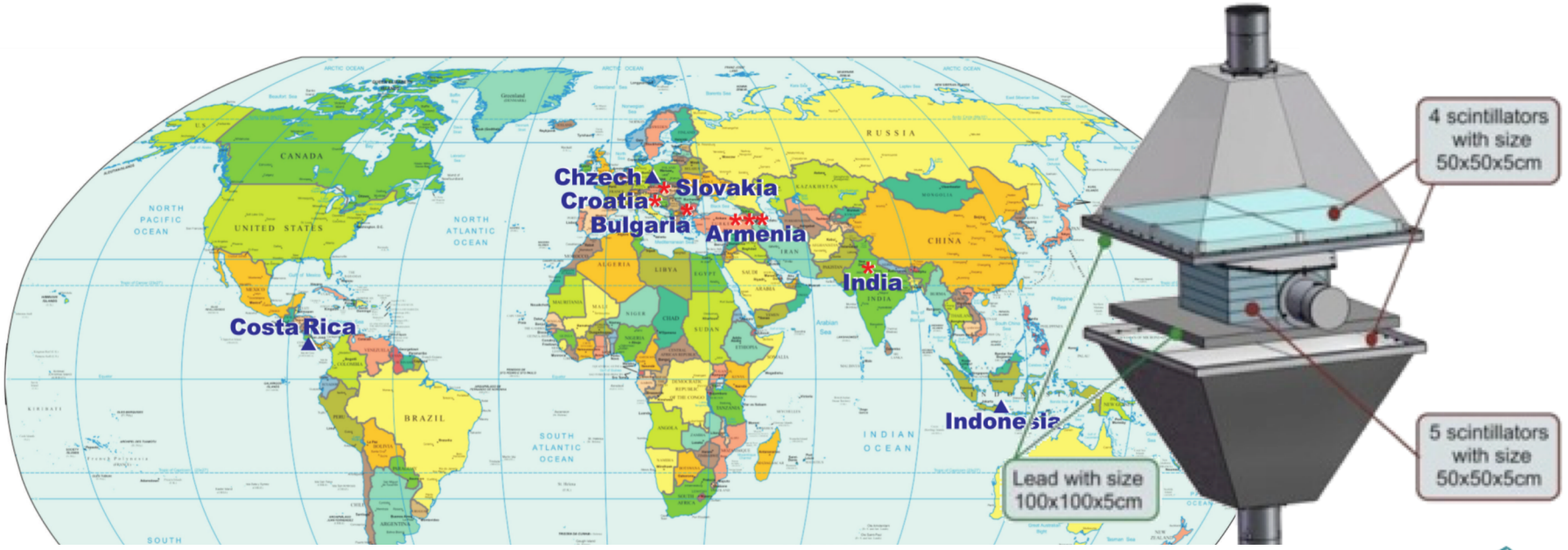
Space Environmental Viewing and Analysis Network (SEVAN)

A network of middle to low latitude particle detectors called SEVAN (Space Environmental Viewing and Analysis Network) is planned in the framework of the International Heliophysical Year (IHY), to improve fundamental research of the Solar accelerators and Space Weather conditions. The program of TGE detection with SEVAN network started in 2016.



COSMIC RAY DIVISION
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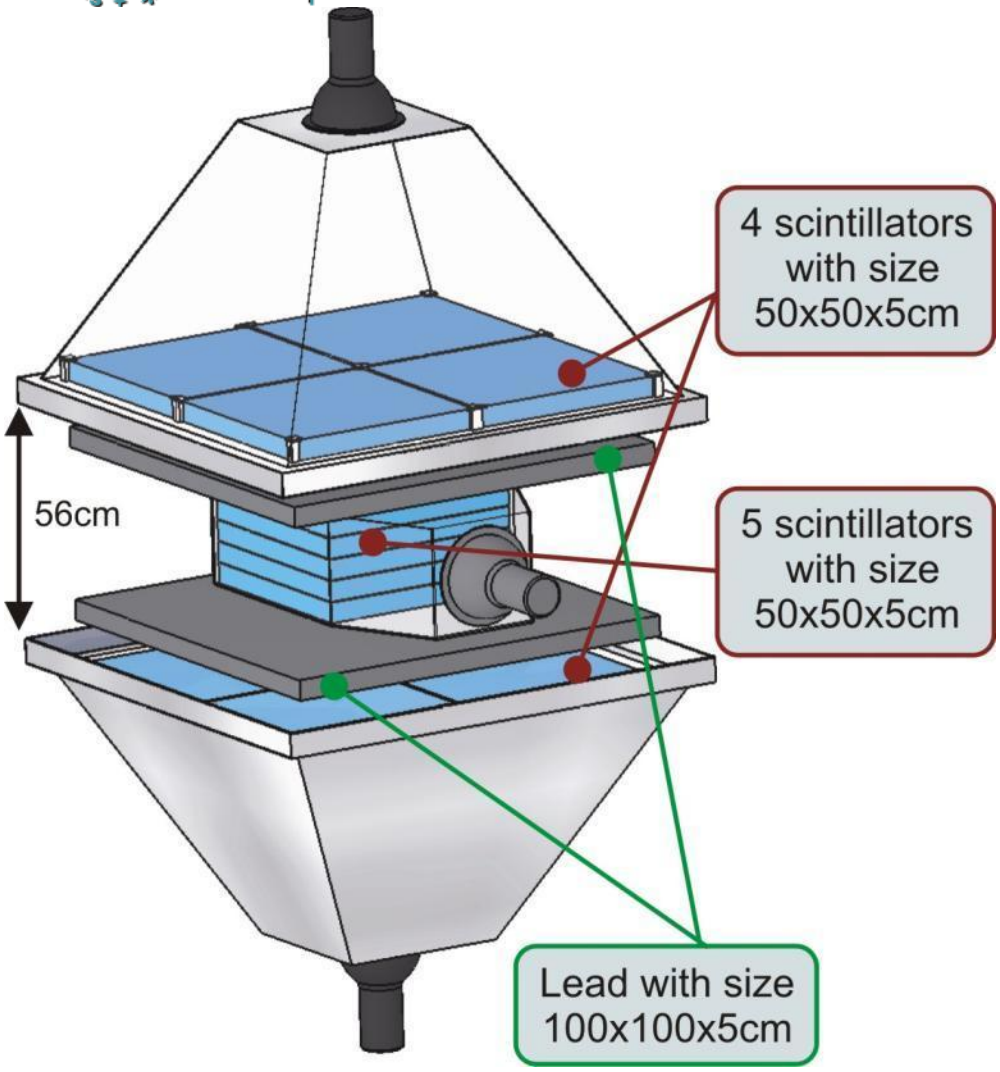
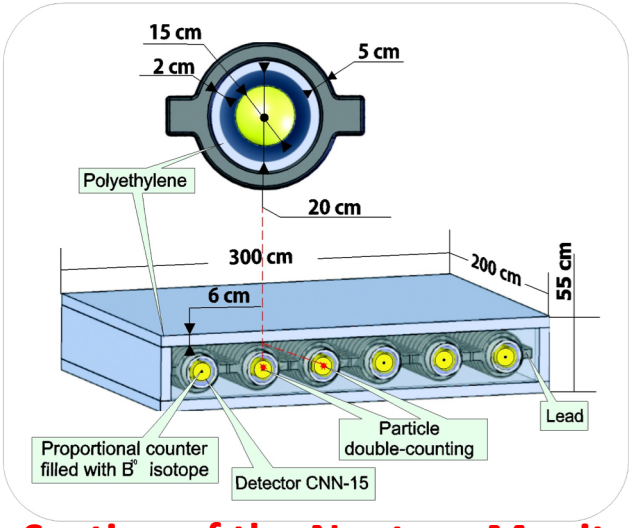
SEVAN basic unit: monitoring 3 species of secondary CR



100 – low energy charged particle;

010 – neutral particle (gamma ray or neutron;

111 & 101 – high energy muon (>250MeV);



Section of the Neutron Monitor

COSMIC RAY DIVISION
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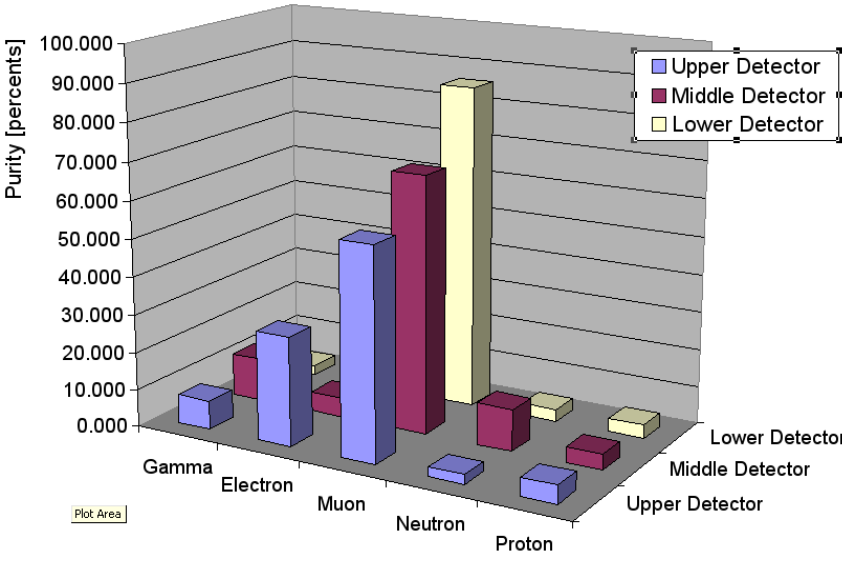
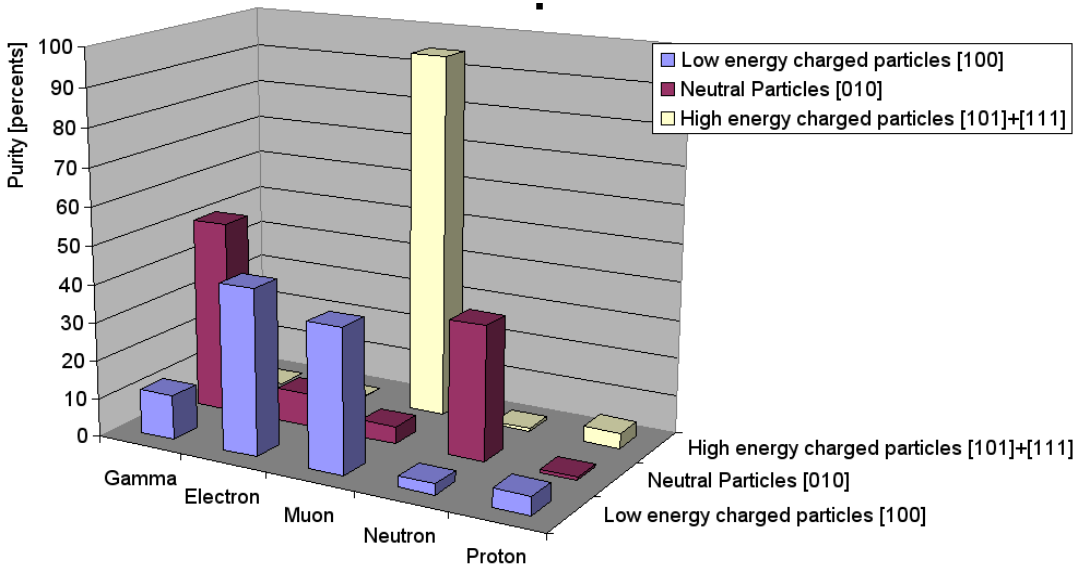
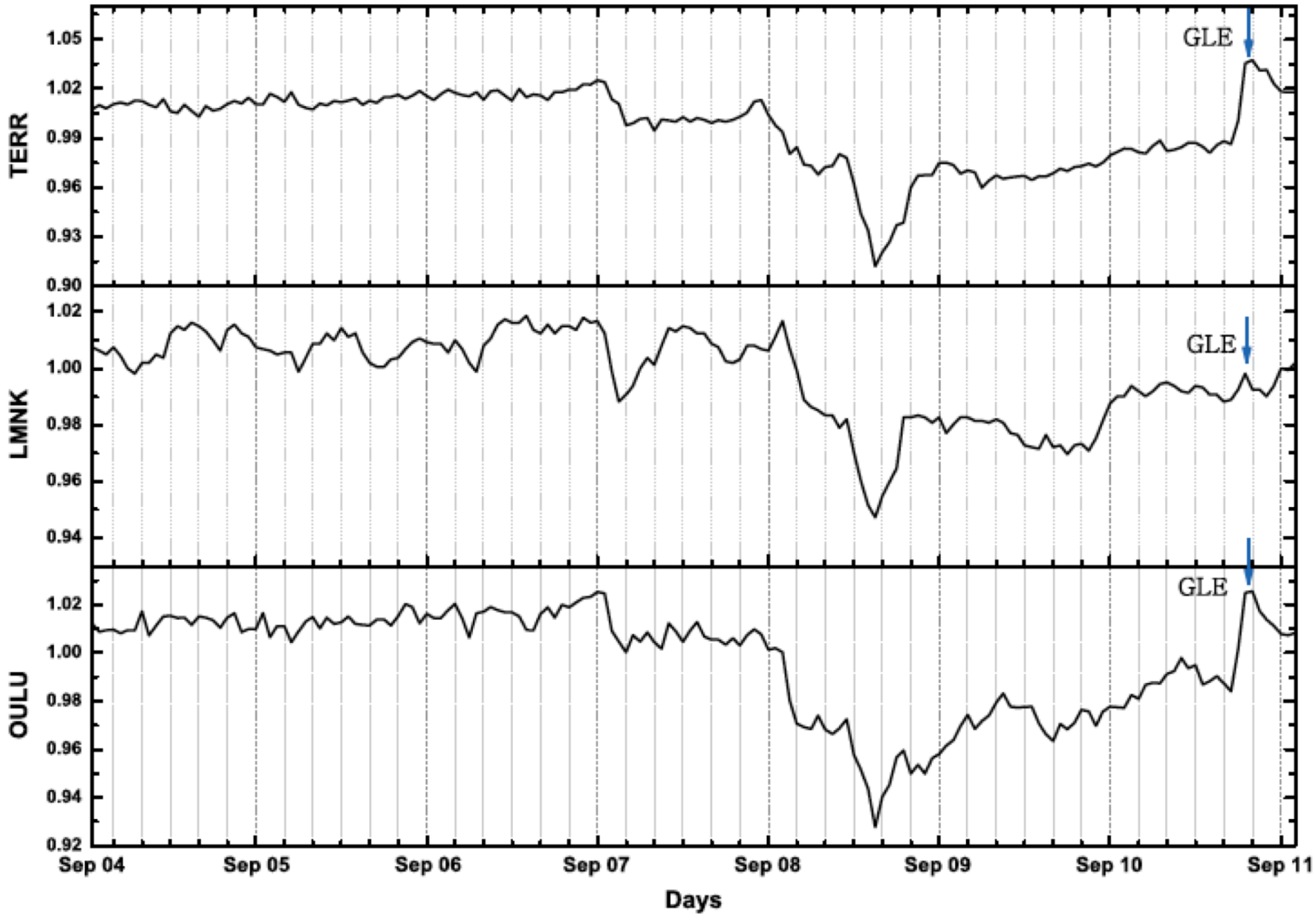
Selection of Secondary Cosmic Rays by SEVAN ; Aragats research station, 3200 m.

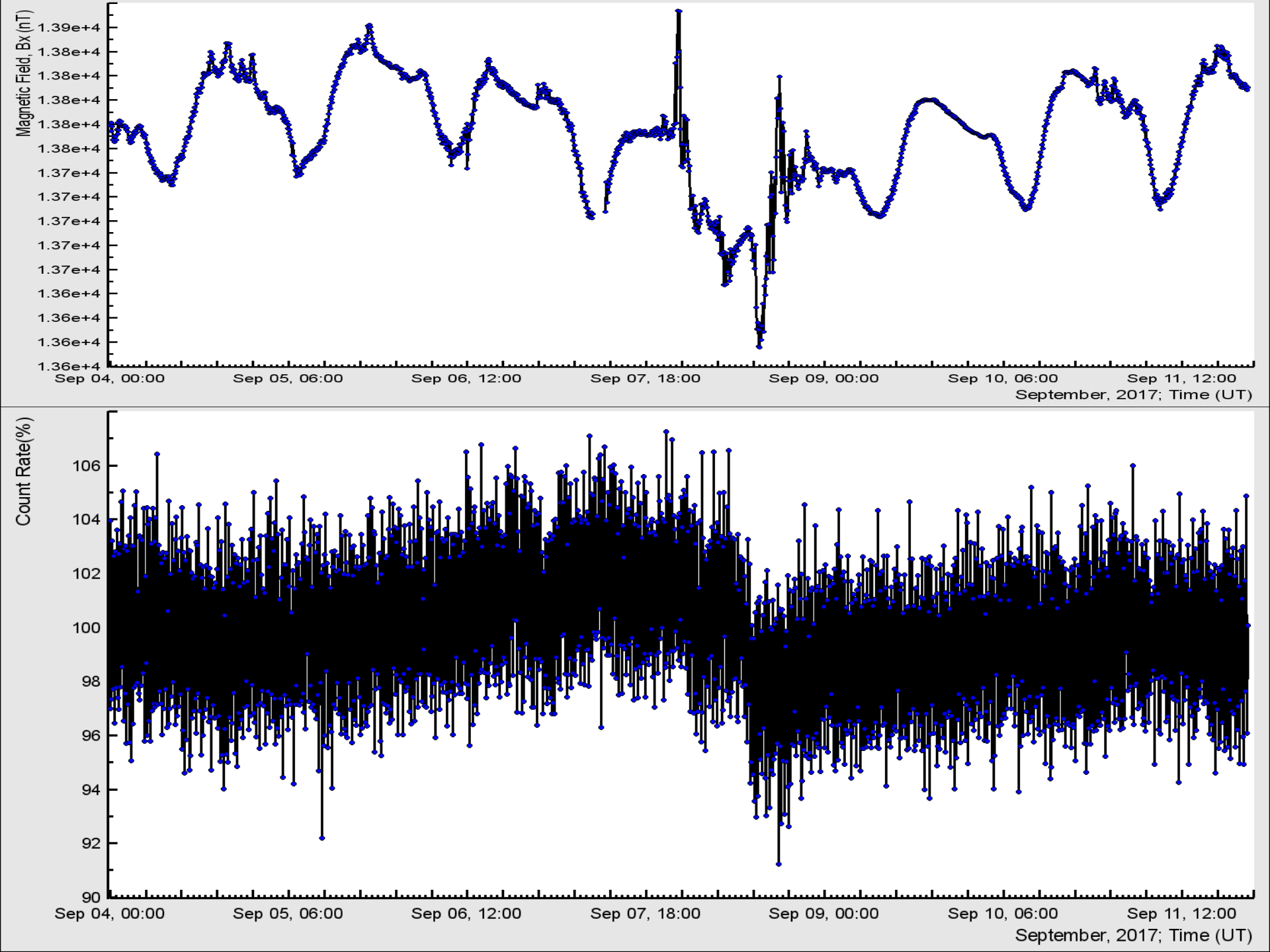


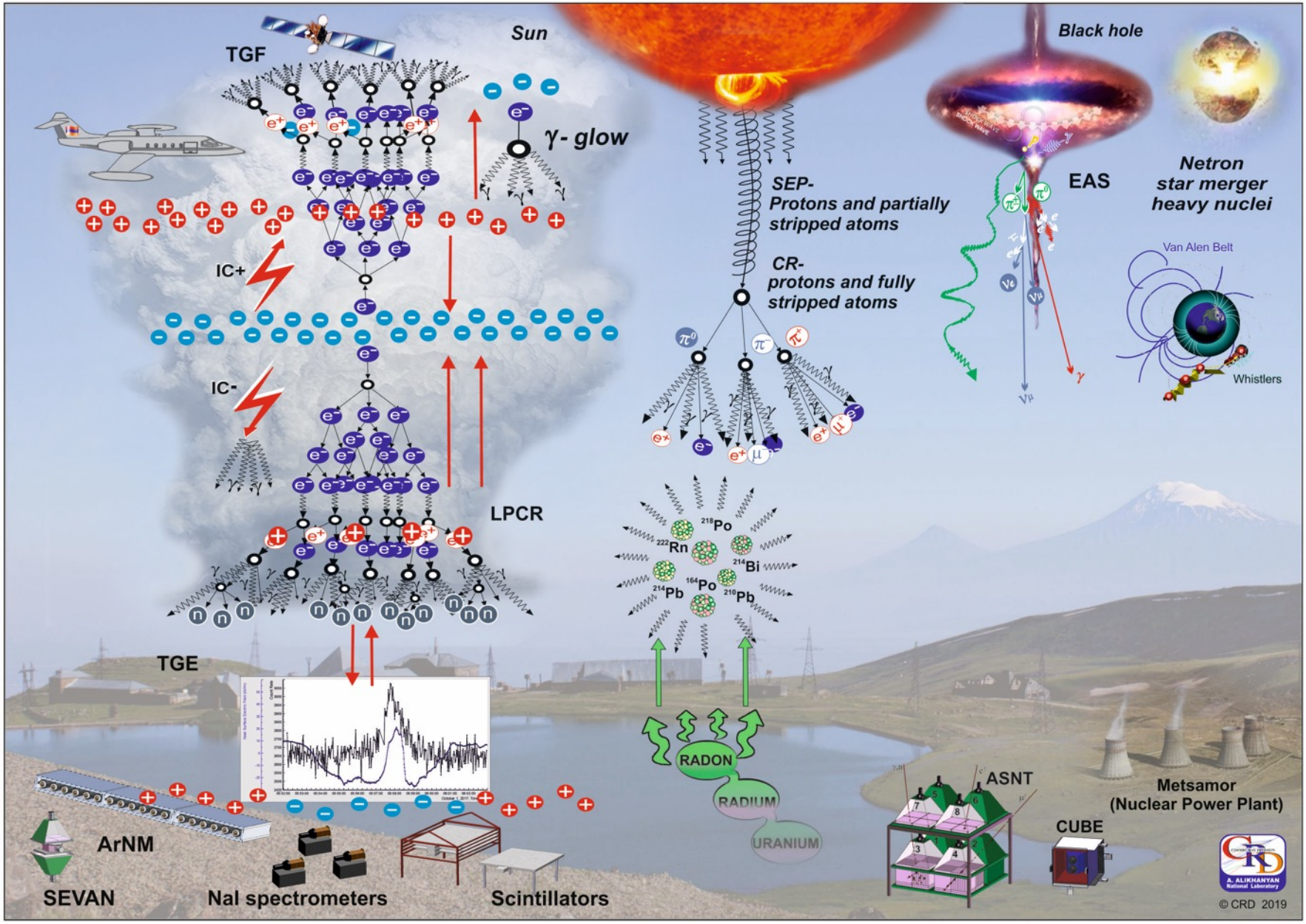


	Gamma	Electron	Muon	Neutron	Proton
Registered particles Purity by special combination					
Low energy charged particles [100]	11.605	43.300	37.380	2.838	4.804
Neutral Particles [010]	50.612	8.837	4.494	35.071	0.972
High energy charged particles [101]+ [111]	0.002	0.106	94.904	0.808	4.077
Registered particles Purity by count rate of the detectors					
Upper Detector	7.616	28.952	56.080	2.448	4.814
Middle Detector	11.550	5.223	67.913	11.038	4.167
Lower Detector	2.696	4.438	85.873	3.267	3.634

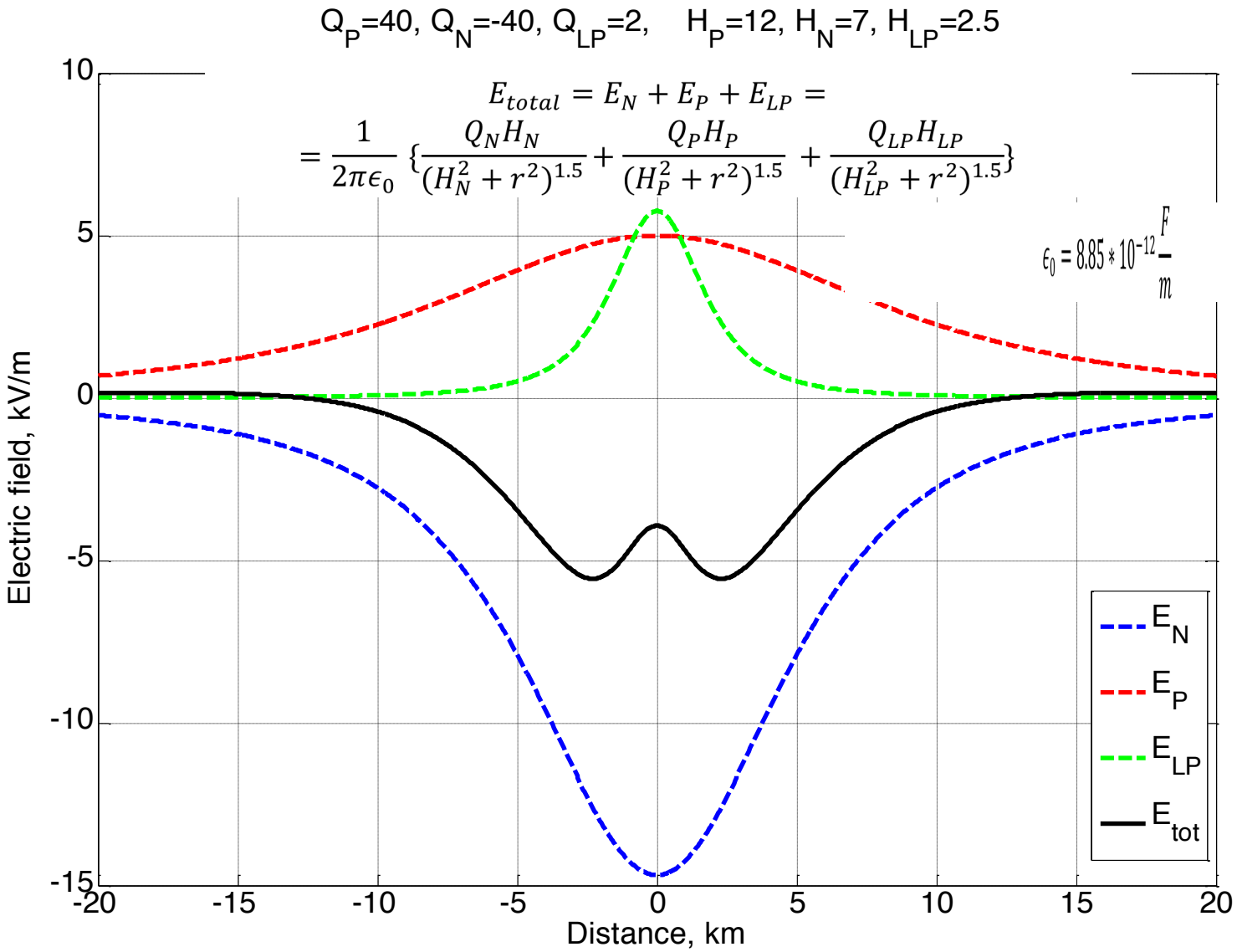


Hourly values of cosmic ray intensity at three neutron monitors with different geomagnetic cutoffs and average count rates (Oulu 65.05°N, 25.47°E, vertical cutoff rigidity Rc = 0.81 GV, sea level; average count rate ~120/s; Lomnický štít 49.20°N, 20.22°E, Rc = 3.84 GV, 2,634 m above sea level, average count rate ~470/s; Terre Adelie 66.65°S, 140°E, 0.0 GV, sea level).

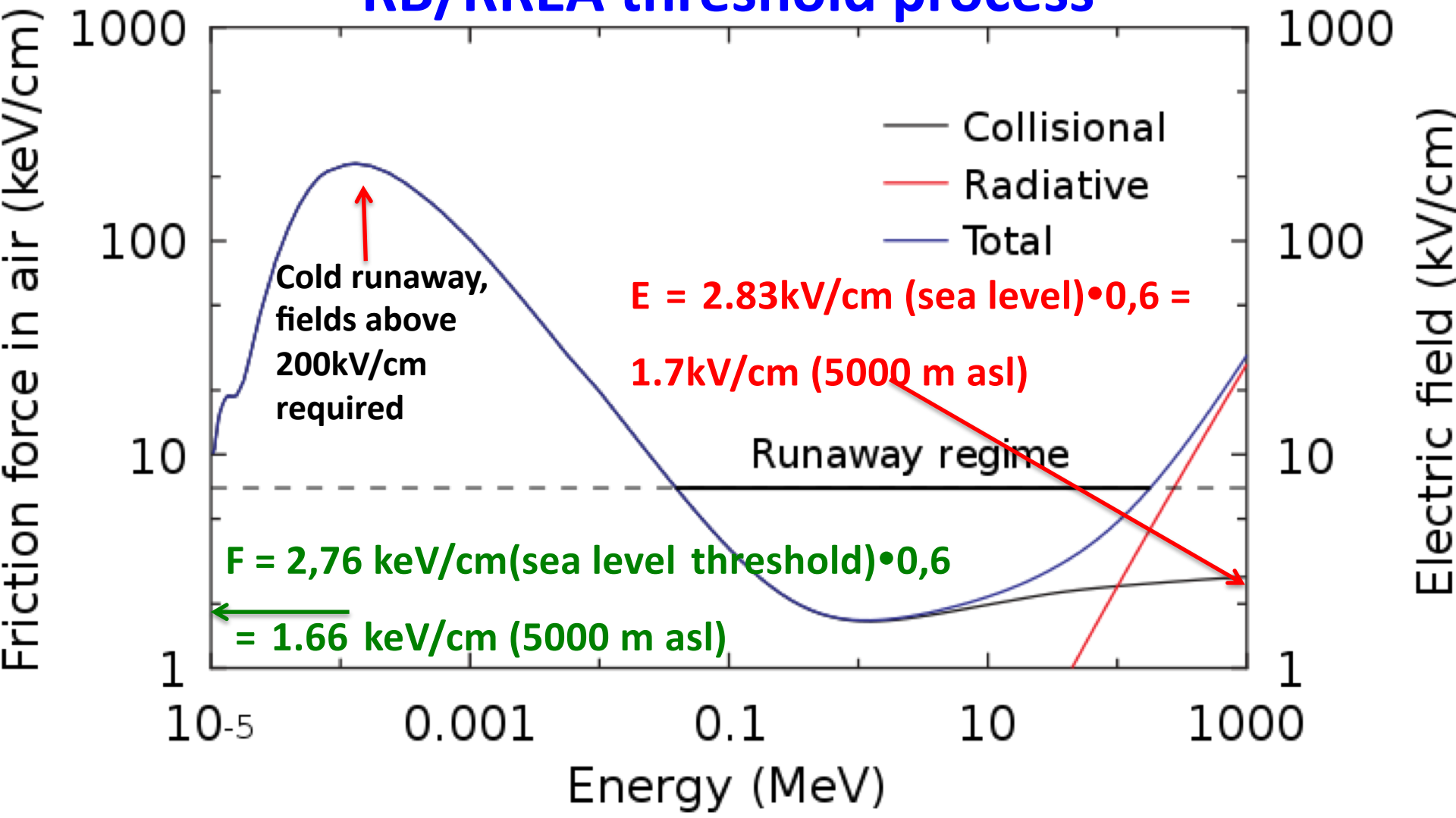

Magnetic Field, Bx (nT)
1.39e+4
1.38e+4
1.38e+4
1.38e+4
1.38e+4
1.38e+4
1.37e+4
1.37e+4
1.37e+4
1.37e+4
1.37e+4
1.36e+4
1.36e+4
1.36e+4
1.36e+4
Sep 04, 00:00
Sep 05, 06:00
Sep 06, 12:00
Sep 07, 18:00
Sep 09, 00:00
Sep 10, 06:00
Sep 11, 12:00
September, 2017; Time (UT)
Count Rate(%)
106
104
102
100
98
96
94
92
90
Sep 04, 00:00
Sep 05, 06:00
Sep 06, 12:00
Sep 07, 18:00
Sep 09, 00:00
Sep 10, 06:00
Sep 11, 12:00
September, 2017; Time (UT)


TGF
Sun
γ- glow
IC+
IC-
LPCR
TGE
SEP-
Protons and partially
stripped atoms
CR-
protons and fully
stripped atoms
Black hole
EAS
Netron
star merger
heavy nuclei
Van Alen Belt
Whistlers
RADON
RADIUM
URANIUM
ASNT
CUBE
Metsamor
(Nuclear Power Plant)
ArNM
SEVAN
NaI spectrometers
Scintillators
© CRD 2019

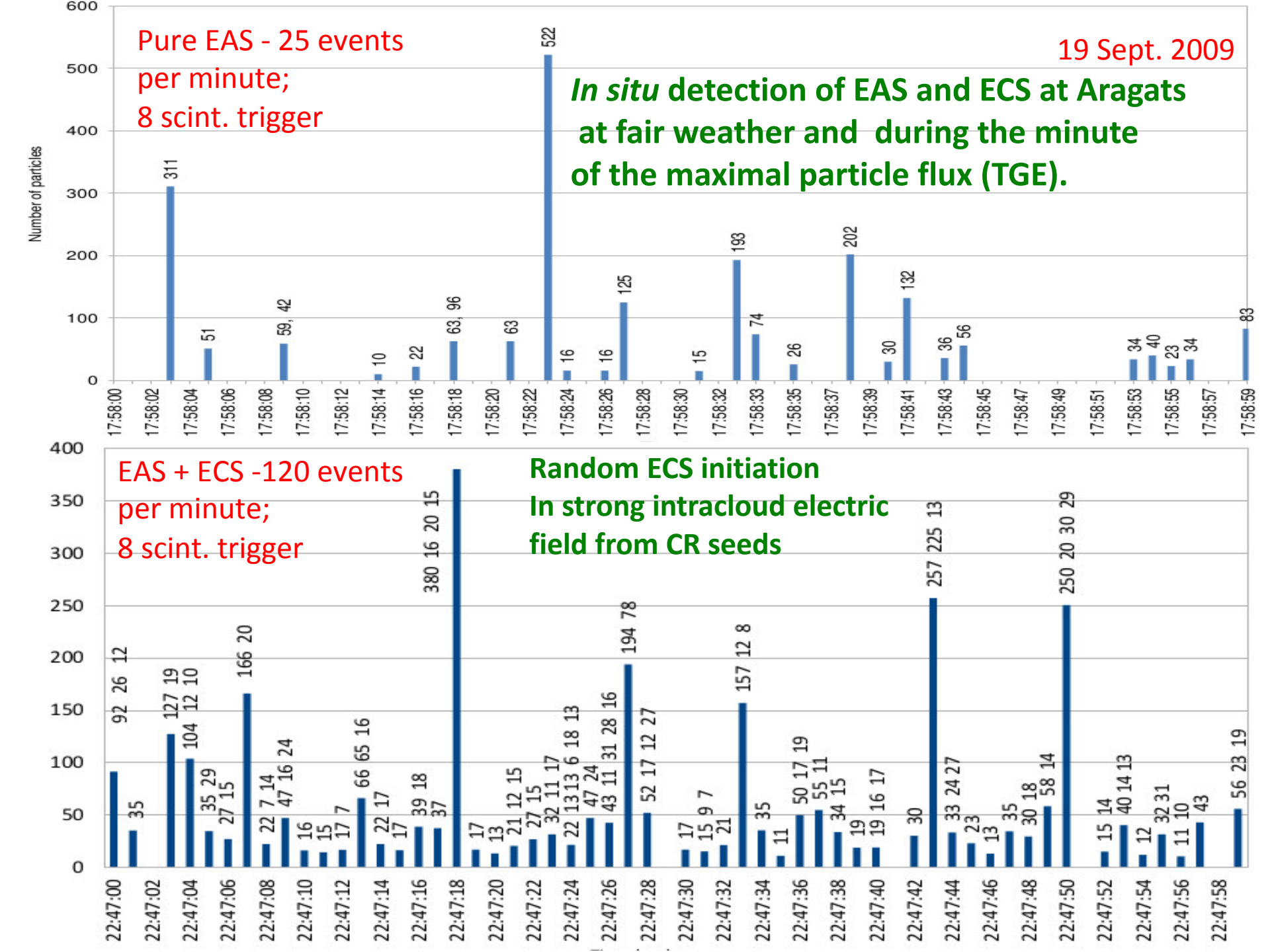
Tripole model of cloud charge structure: electric field at the ground is superposition of fields from the 3 charges above



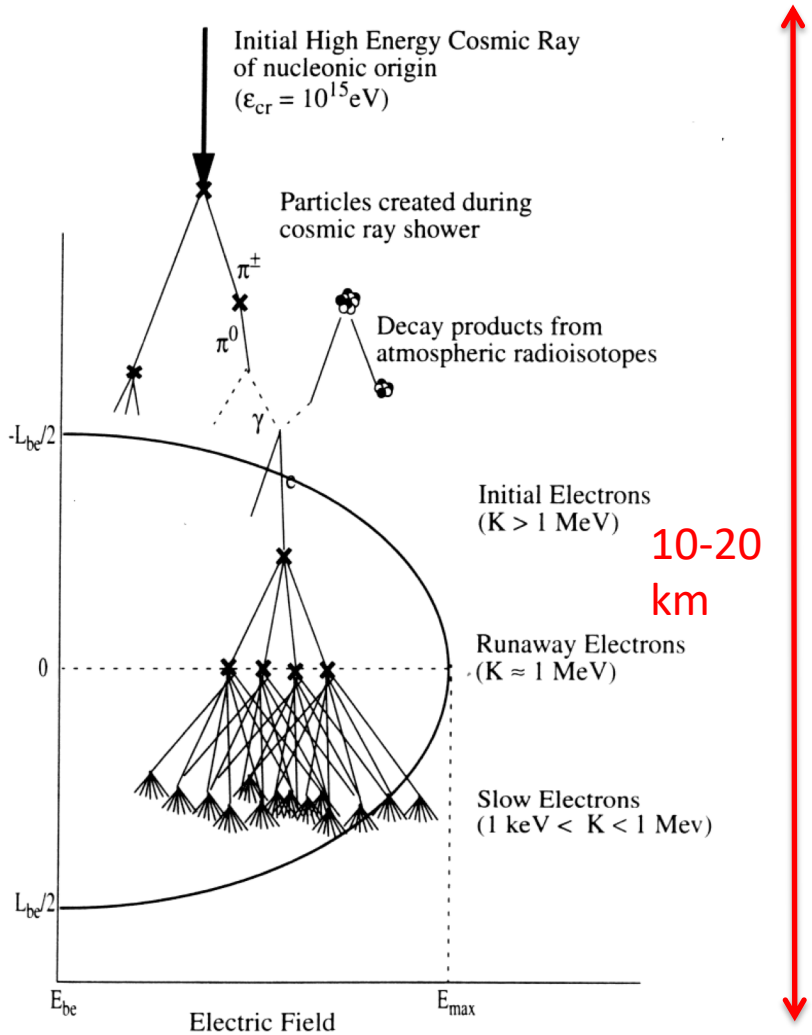
Electron energy losses in the atmosphere and energy gain from the intracloud electric field: RB/RREA threshold process



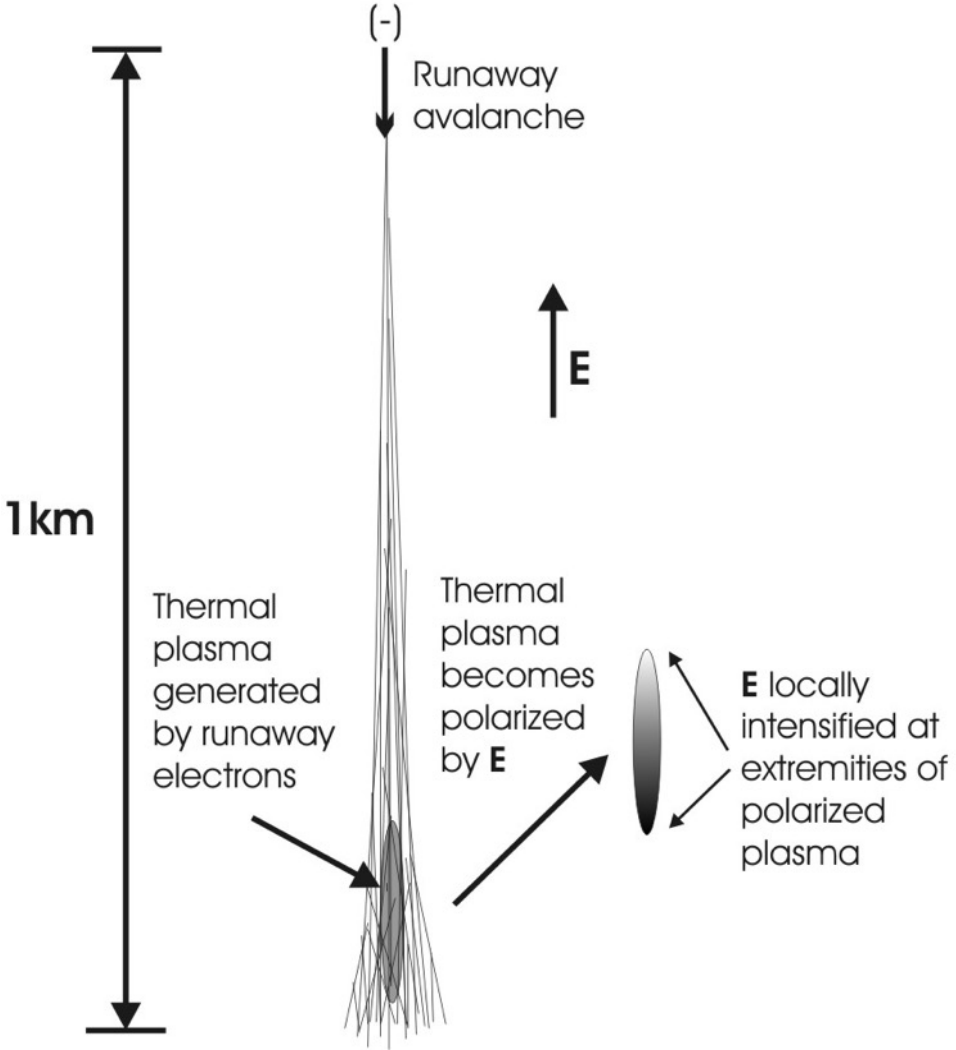
Gurevich et al., (1992), Symbalisty et al. (1998), Babich et al. (1998), Dwyer (2003), Chilingarian (2014)


Pure EAS - 25 events
per minute;
8 scint. trigger
19 Sept. 2009
In situ detection of EAS and ECS at Aragats
at fair weather and during the minute
of the maximal particle flux (TGE).
Number of particles
EAS + ECS -120 events
per minute;
8 scint. trigger
Random ECS initiation
In strong intracloud electric
field from CR seeds

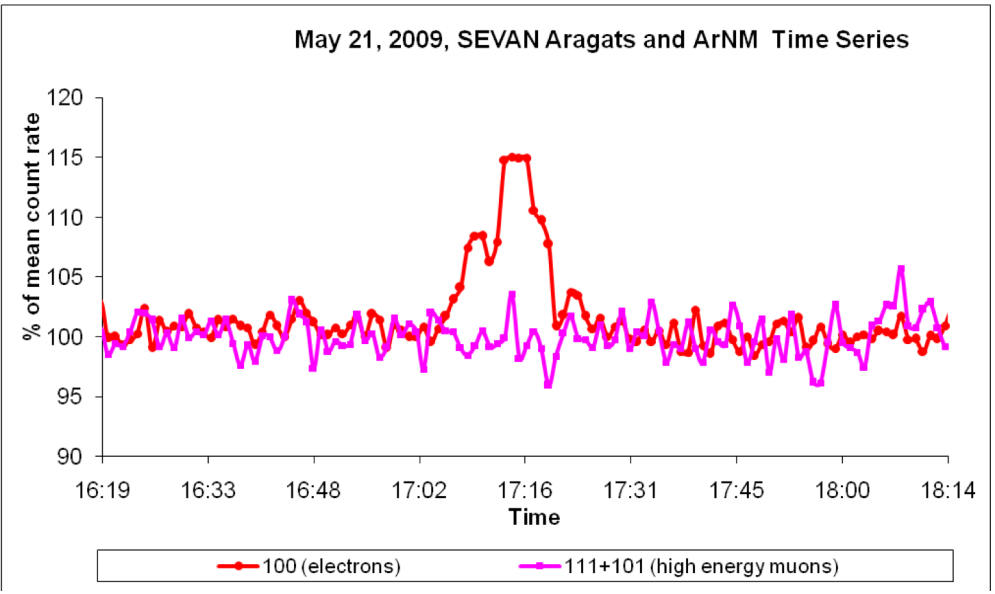
ECS and EAS

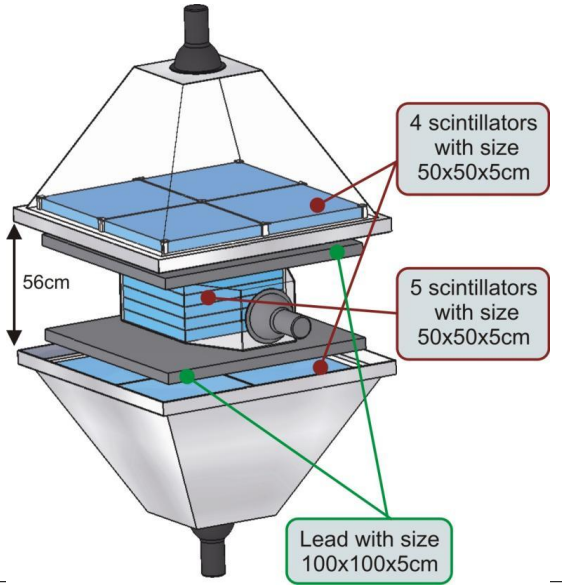


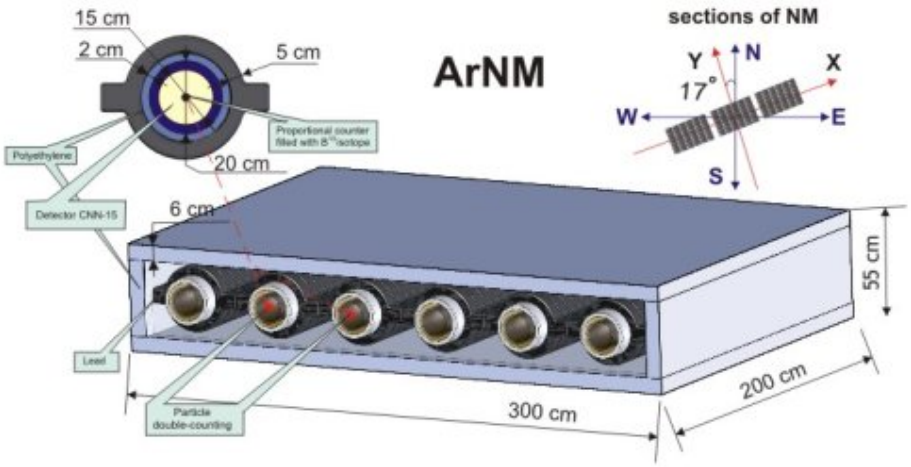
10-20 km

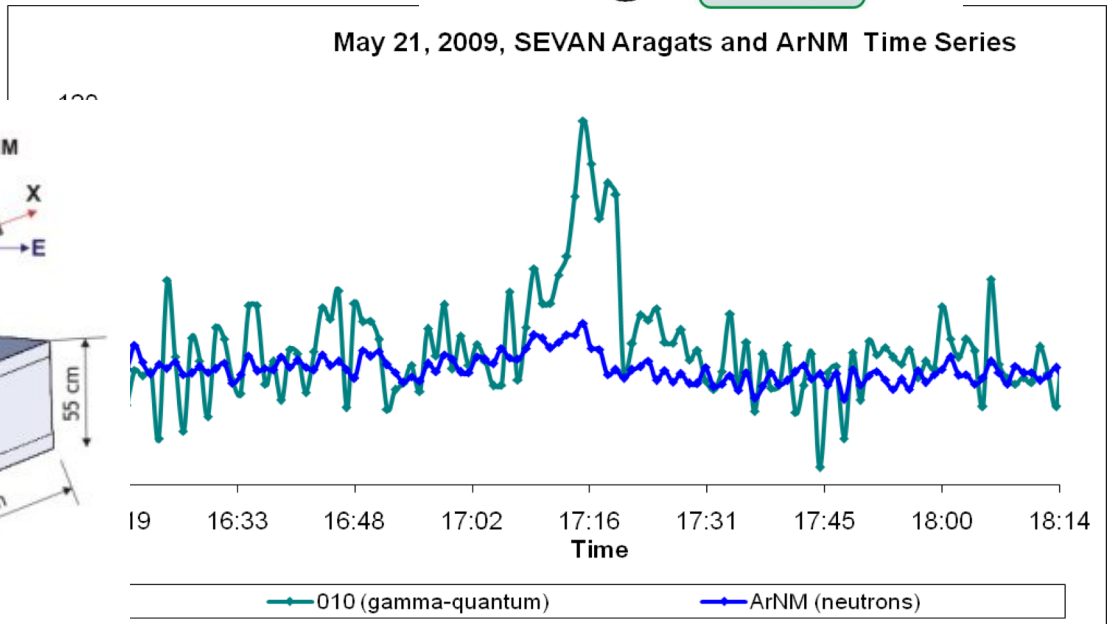


RREA Gamma rays detected by SEVAN and Neutrons – by ANM





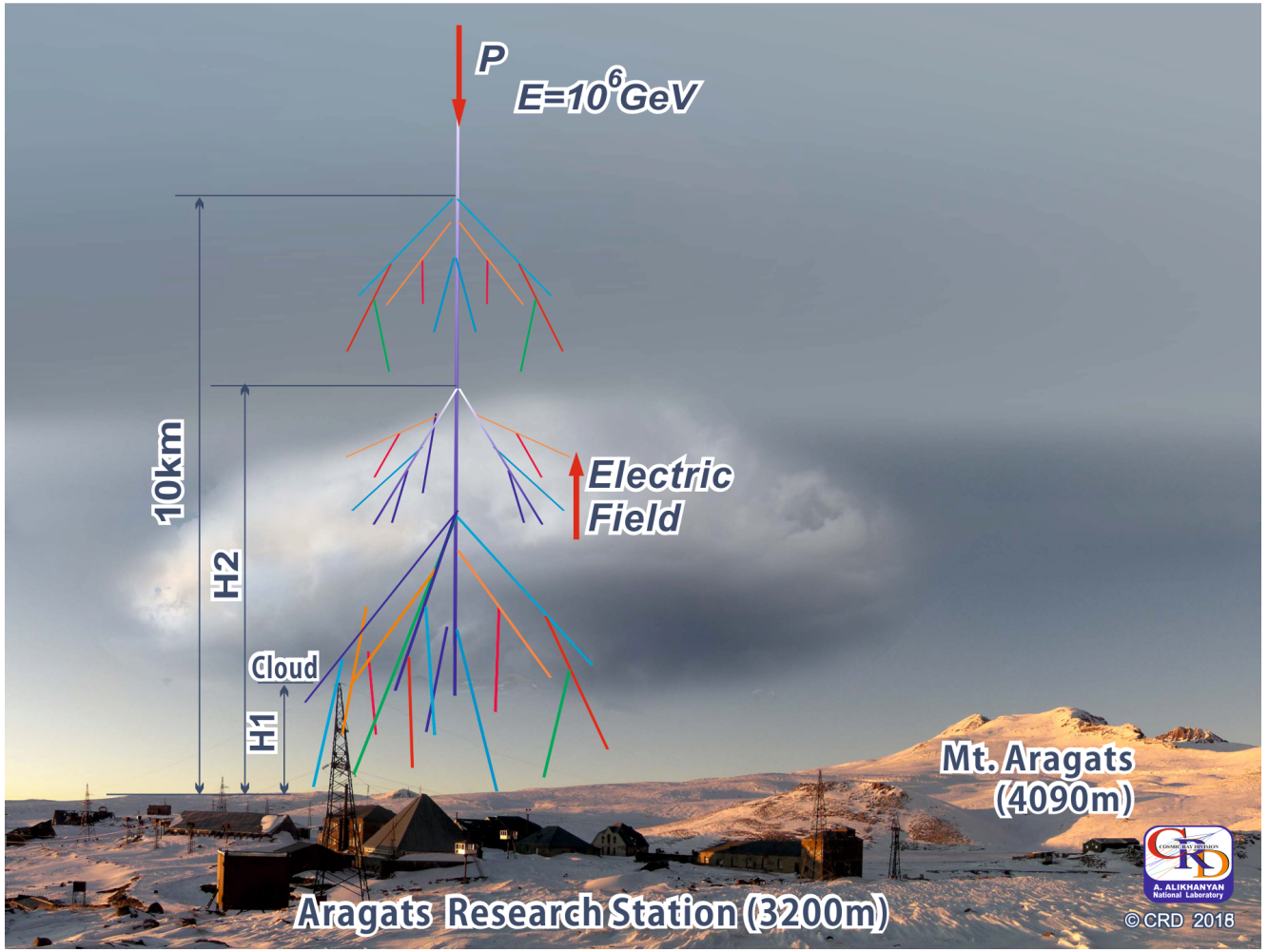




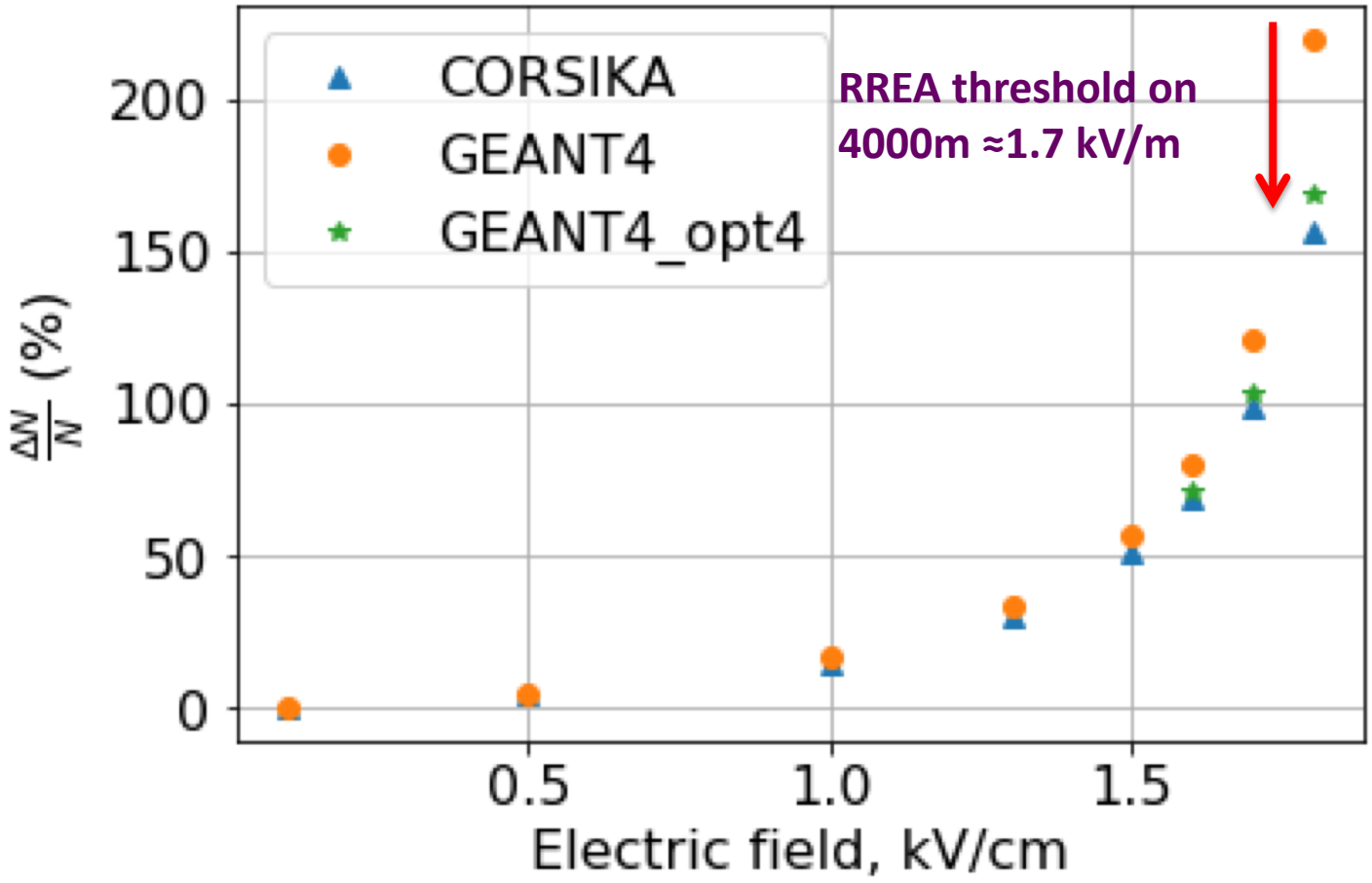
Origin of particle fluxes from thunderclouds? Structures of intracloud electric fields?

- **Threshold process:** RB/RREA: Runaway breakdown, Relativistic Runaway Electron Avalanches: up to and beneath 50 MeV with intensities 10 times more than CR background;
- **Additive process:** MOS Modification of the CR electrons energy spectra: gamma rays with energies up to 100 MeV with intensities of 1-2% of CR background ;
- Both processes are confirmed with CORSIKA and GEANT4 simulations

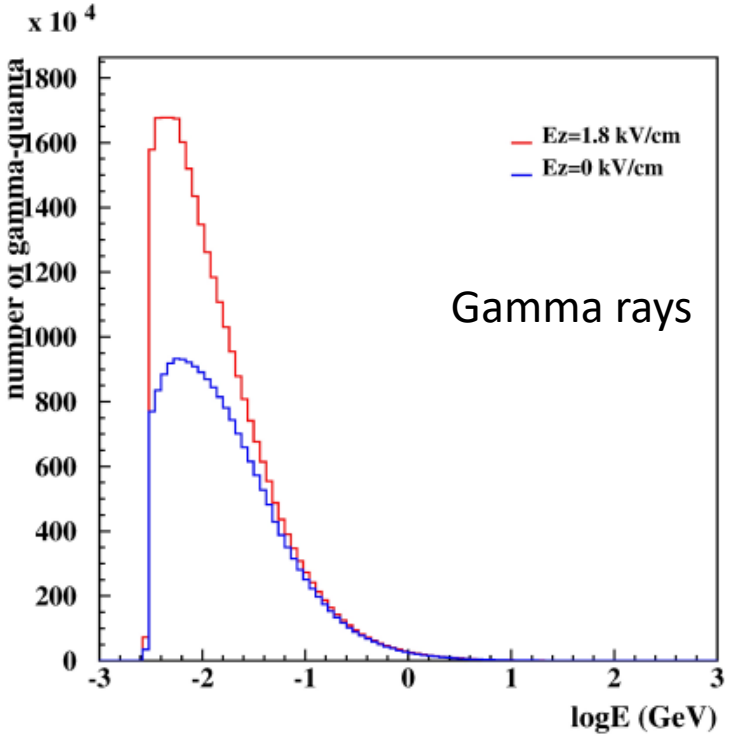
The simplest electric field configuration is used in the CORSIKA and GEANT-4 codes - $Ez \neq 0$ between H_1 and H_2.

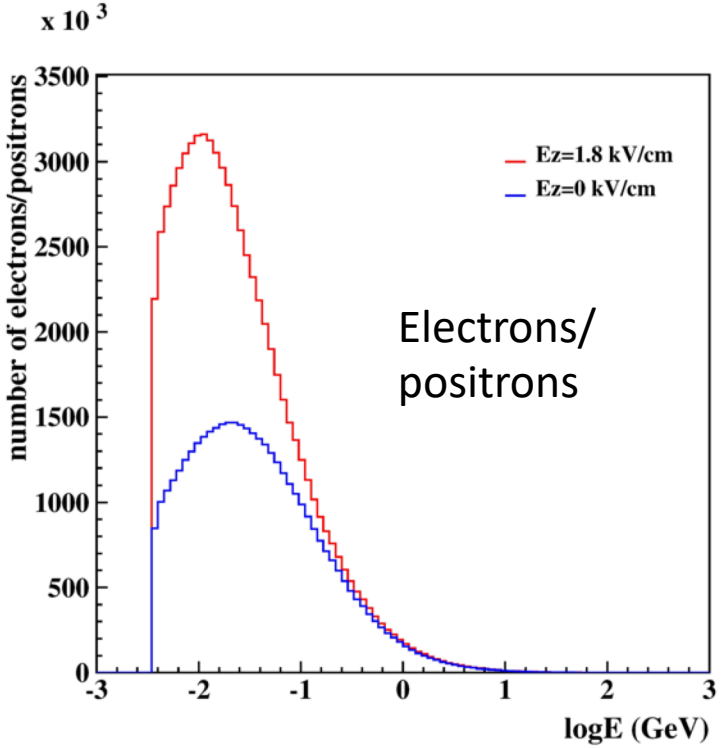


MOS and RREA (started from 1.7 kV/cm



Secondary particle energy spectra with and without atmospheric electric field





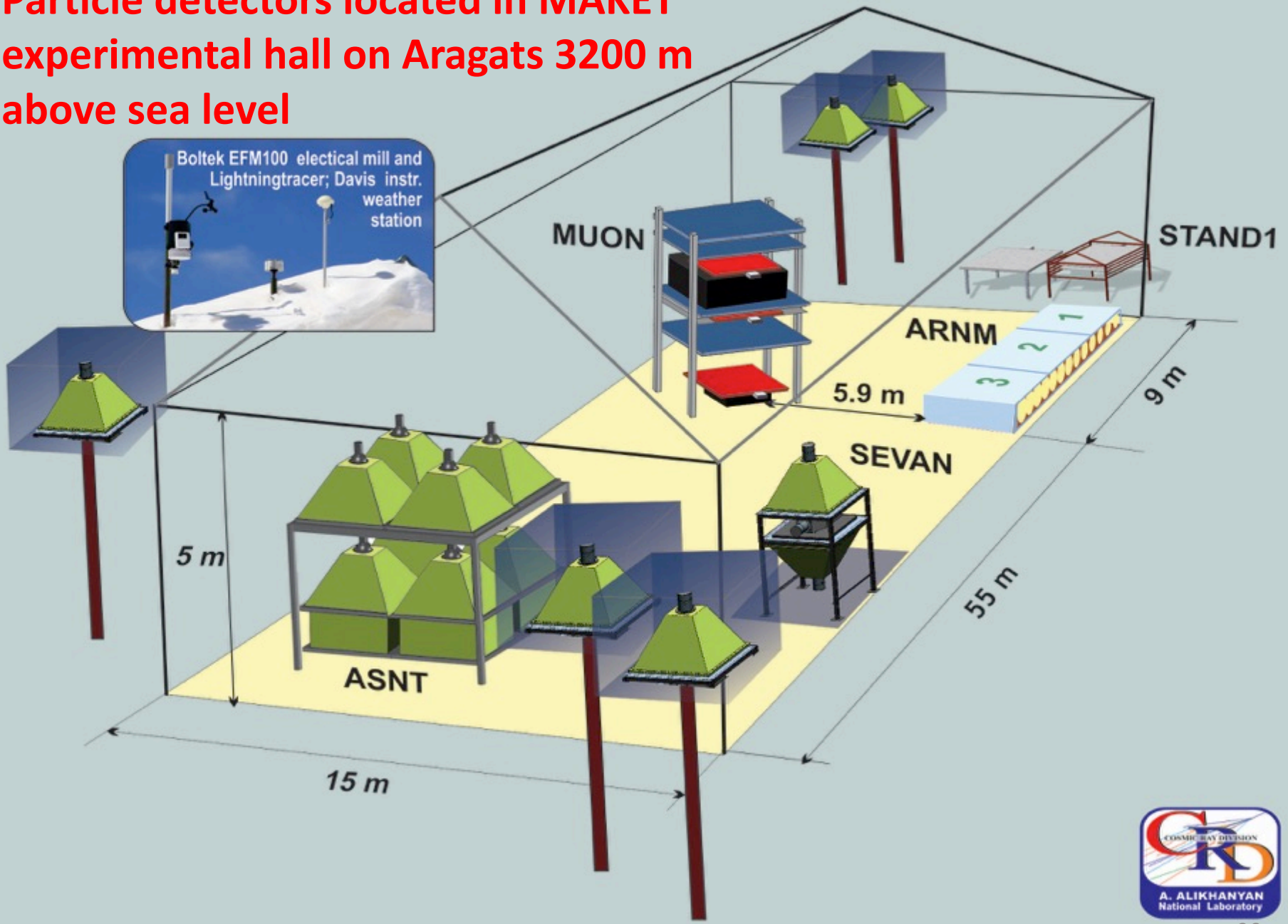
The initial particle energy estimation by EAS measurements $E_{0(sim)} = 10^6$ GeV

Estimated primary particle energy: $\log E_0[\mathrm{GeV}] = 1.03 * \log(N_e + 25N_\mu)$

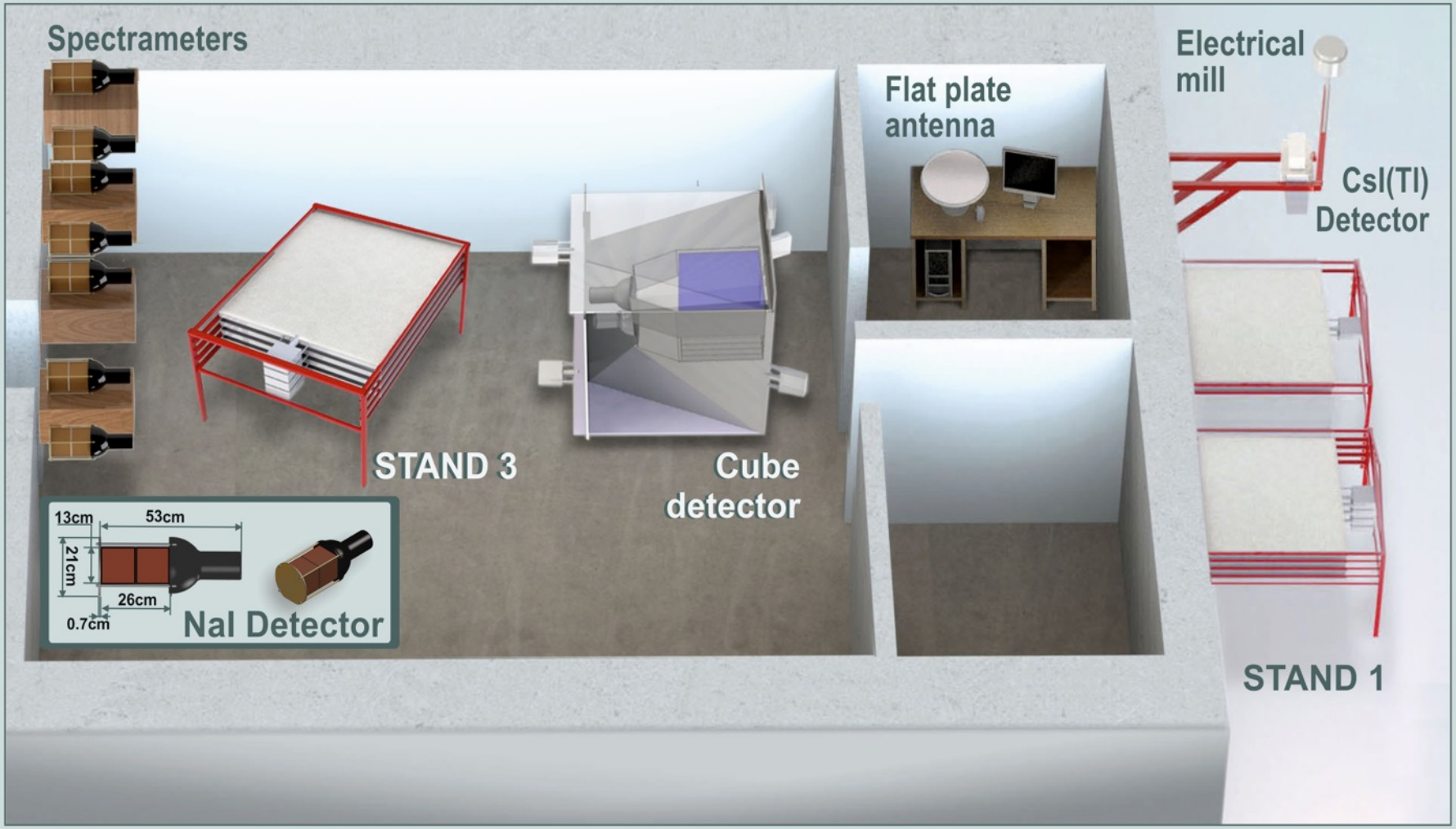
	Ez=0	Ez=1.8 kV/cm at 3250m <H<4250m	Ez=1.8 kV/cm at 4200m<H<5200m	Ez=1.0 kV/cm at 4200m<H<5200m
E_{est}	10^6 GeV	1.54 10^6 GeV	1.1 10^6 GeV	1.05 10^6 GeV

The CASA-MIA (10^{14} - 10^{16} eV) experiment: measuring Nμ and Ne

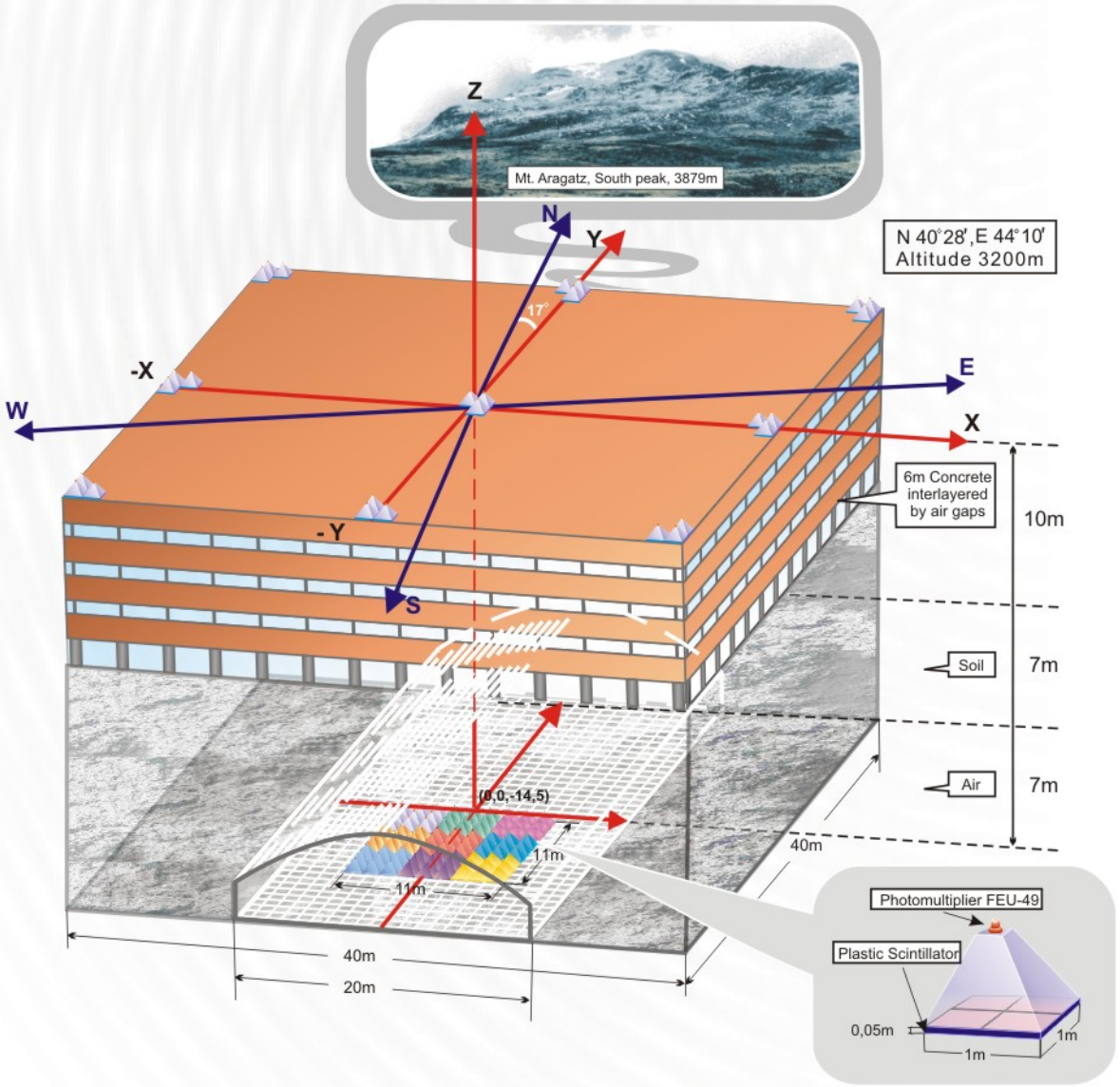
Particle detectors located in MAKET experimental hall on Aragats 3200 m above sea level



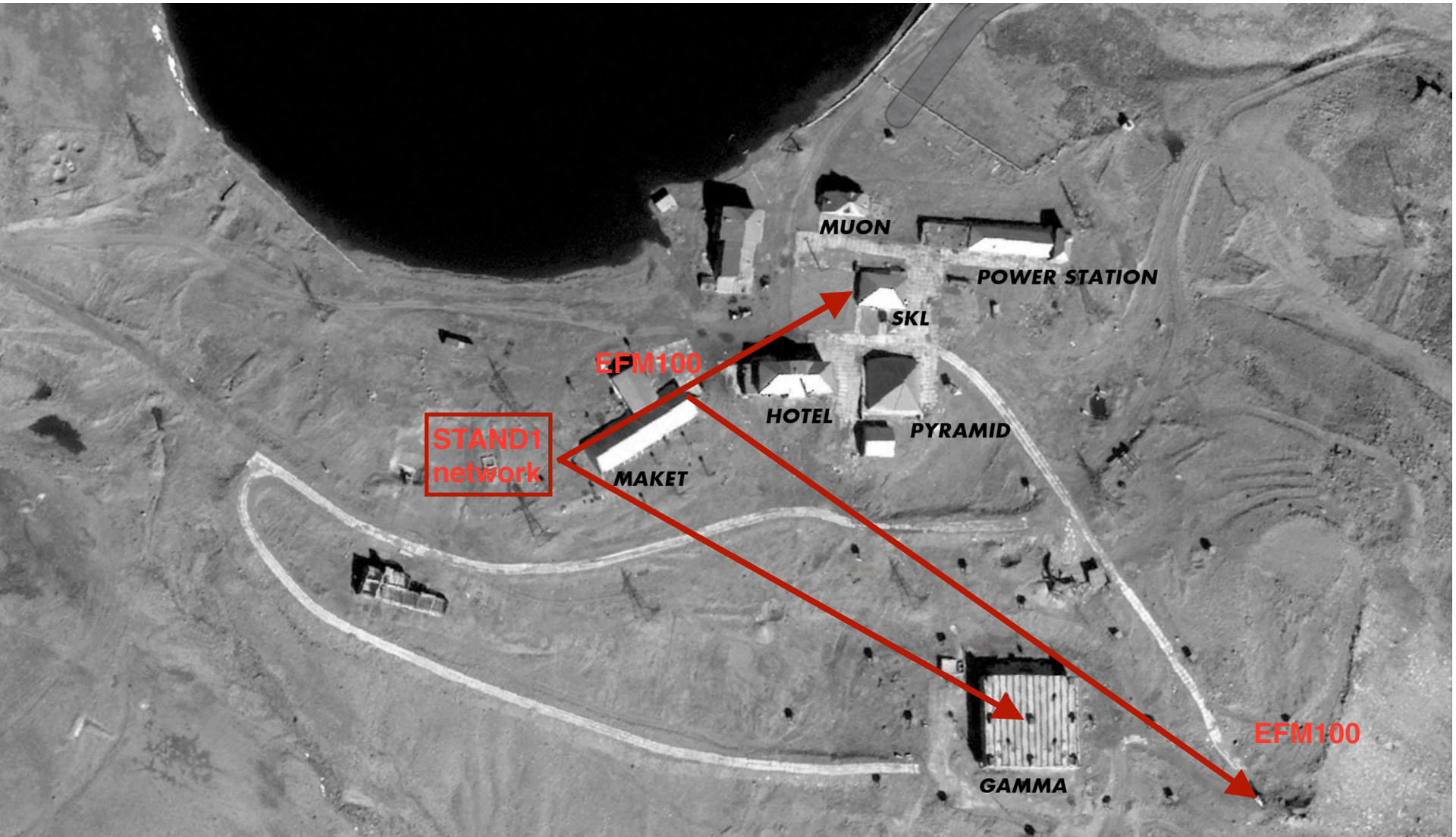
SKL EXperimental Hall

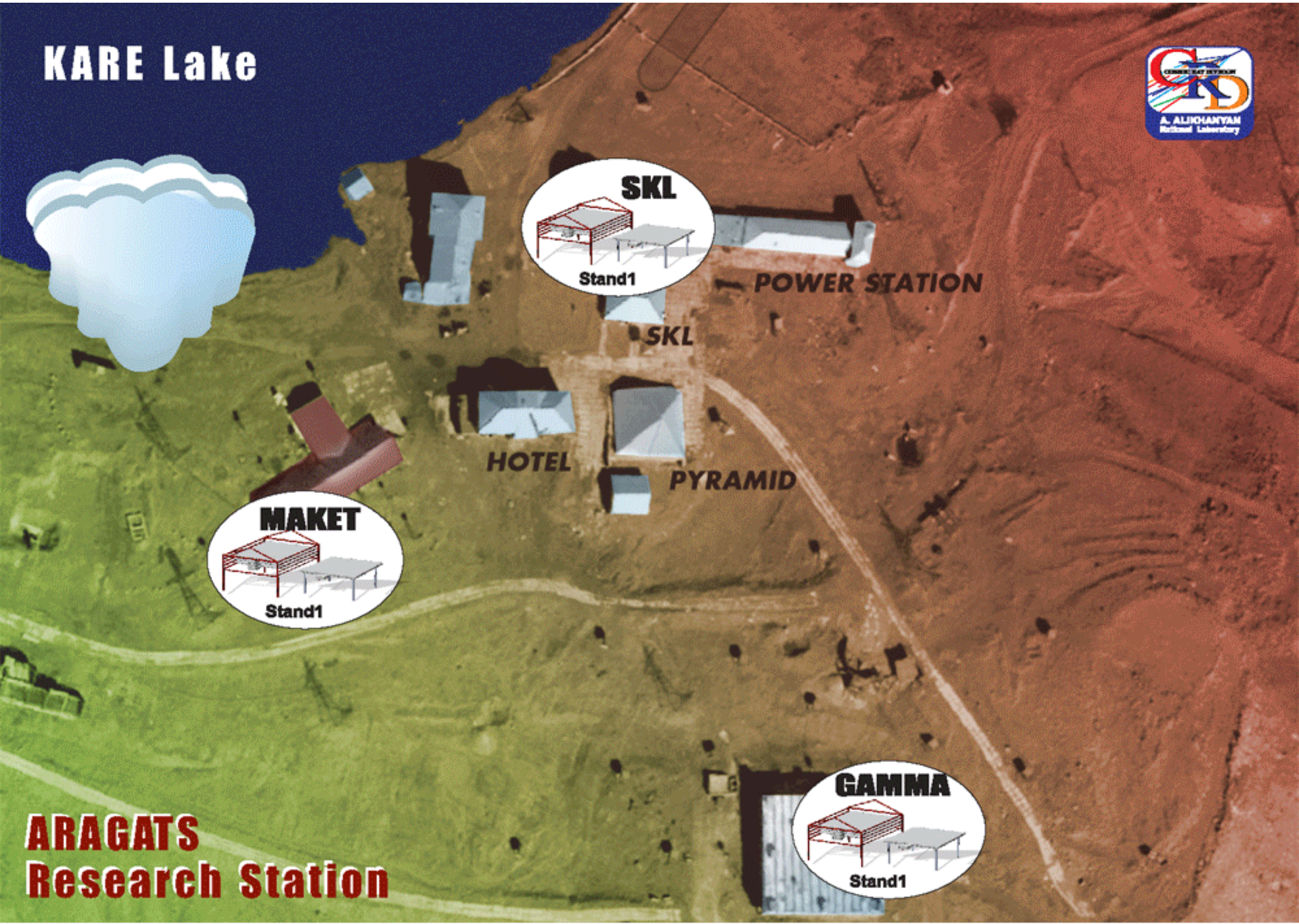


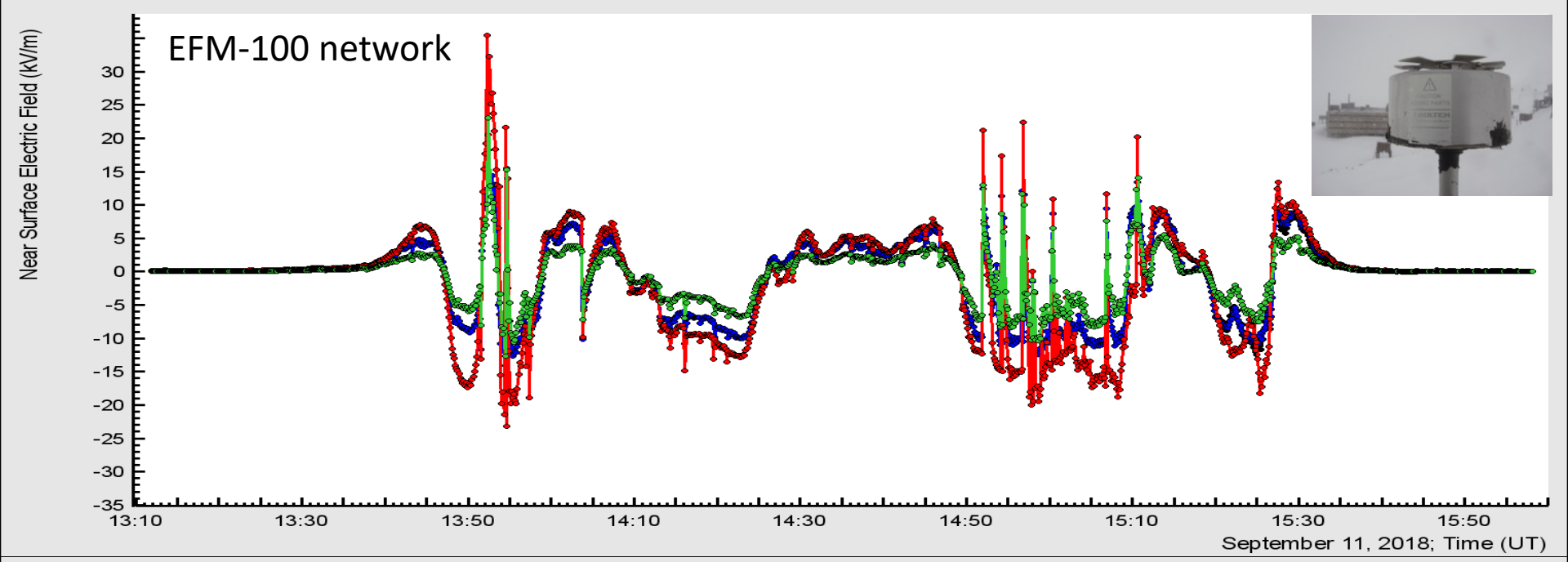
ANI calorimeter-GAMMA array: selection of gamma showers by muon-poor EAS

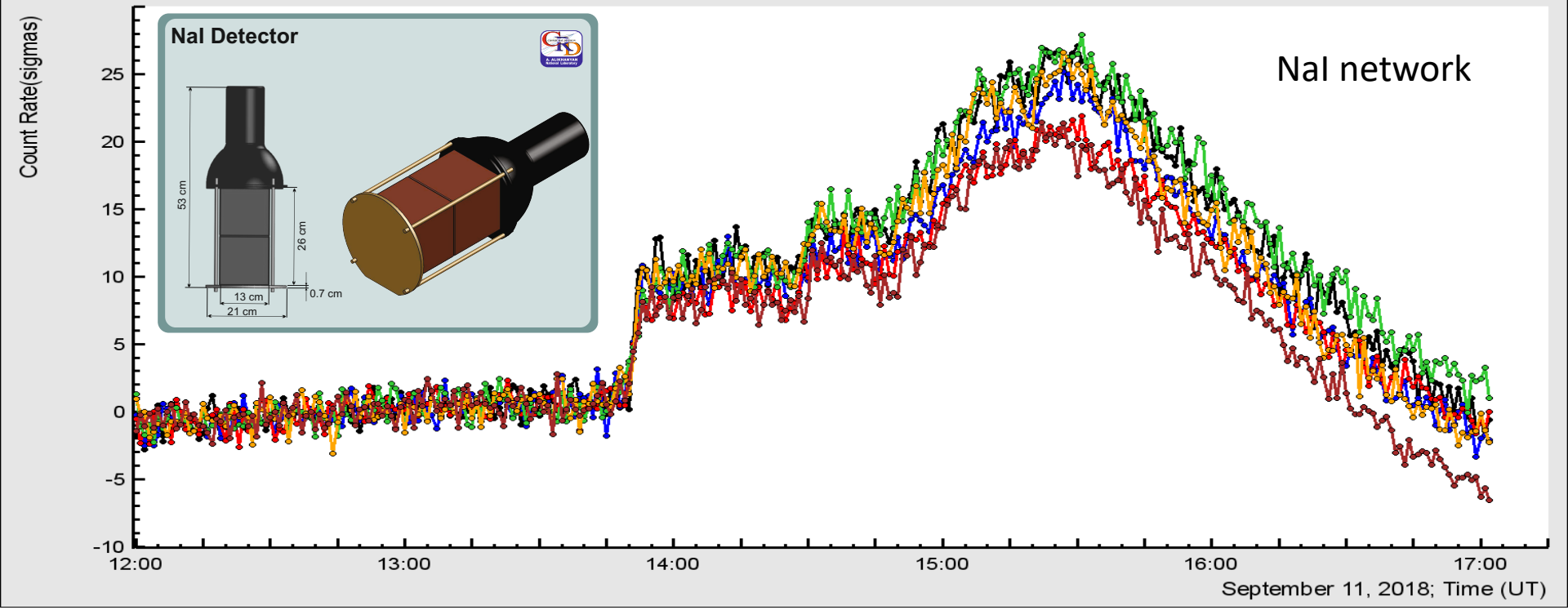


Thunderstorm observation:
Origin of lightning flashes and high energy particle bursts?
Is it only a correlation or a causal relation?

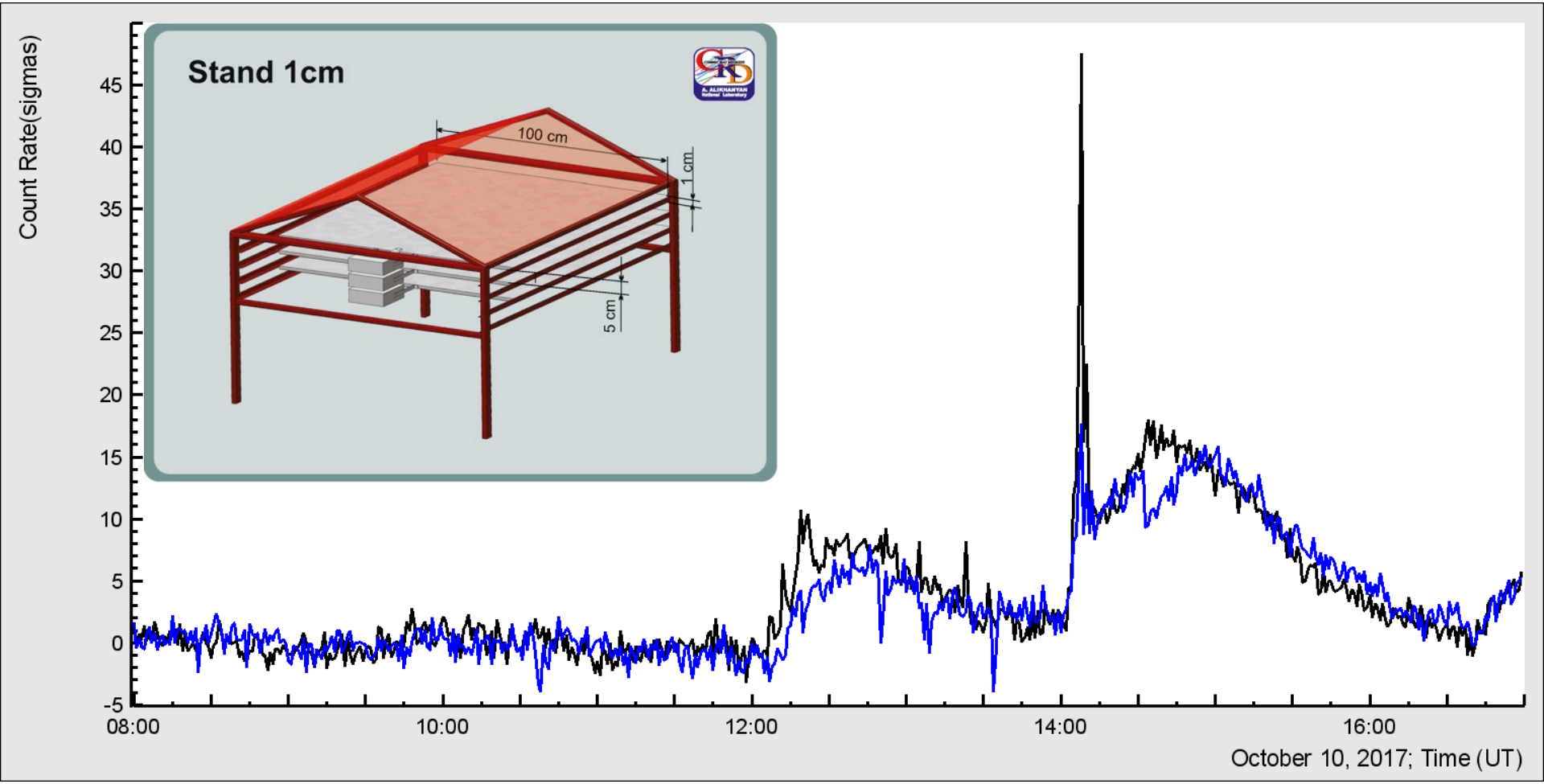


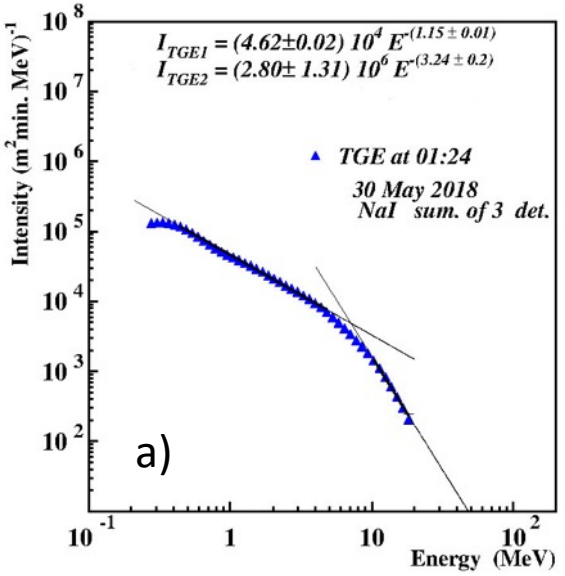

KARE Lake
SKL
Stand1
POWER STATION
SKL
HOTEL
PYRAMID
MAKET
Stand1
GAMMA
Stand1
ARAGATS
Research Station

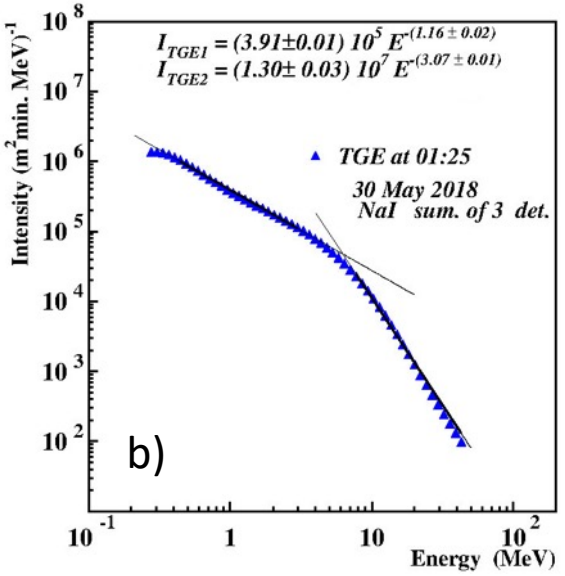

EFM-100 network
Near Surface Electric Field (kV/m)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
13:10
13:30
13:50
14:10
14:30
14:50
15:10
15:30
15:50
September 11, 2018; Time (UT)

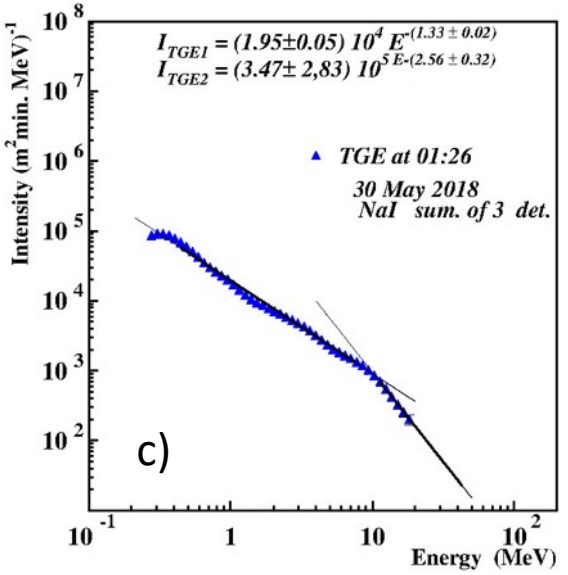

NaI Detector
53 cm
26 cm
13 cm
21 cm
0.7 cm
NaI network
Count Rate(sigmas)
25
20
15
10
5
0
-5
-10
12:00
13:00
14:00
15:00
16:00
17:00
September 11, 2018; Time (UT)

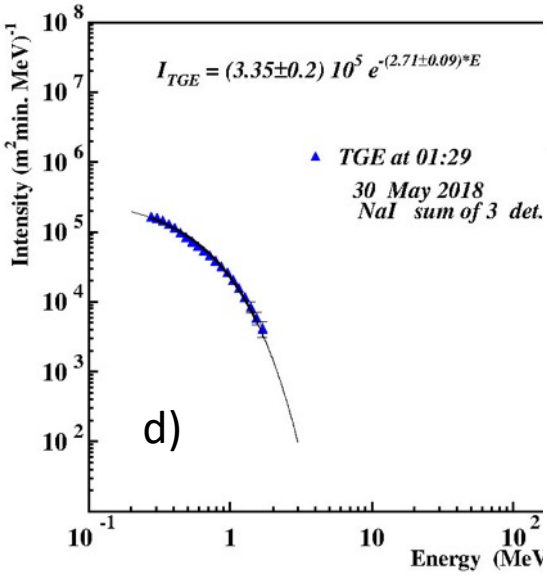
STAND1 (MAKET), stack of 1 cm thick plastic scintillators 100 and 010 combinations

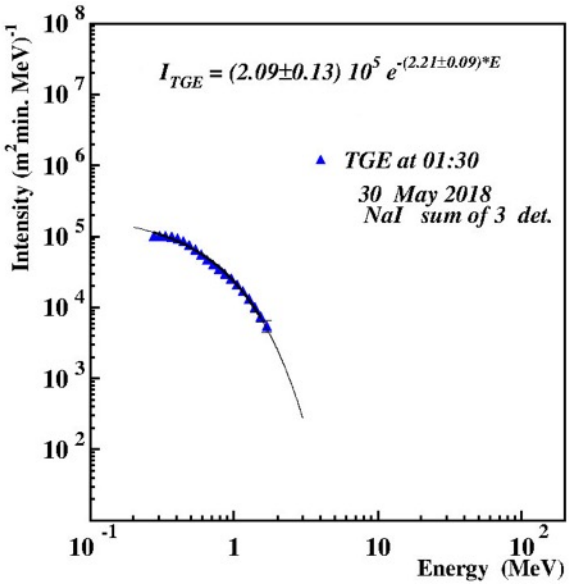


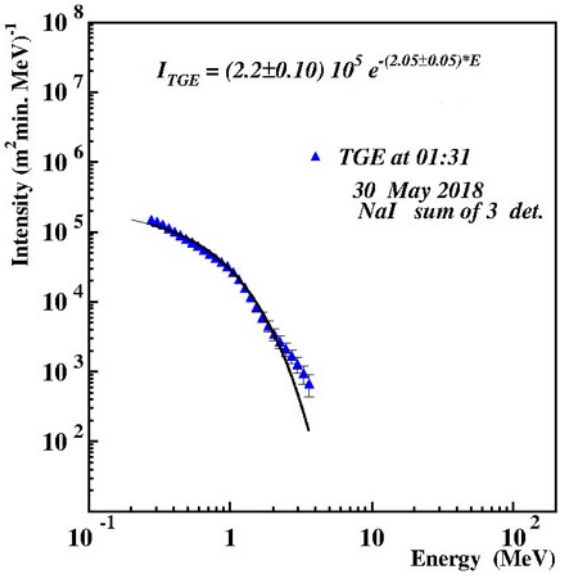

$I_{TGE1} = (4.62\pm0.02)\ 10^4\ E^{-(1.15\pm0.01)}$
$I_{TGE2} = (2.80\pm 1.31)\ 10^6\ E^{-(3.24\pm0.2)}$
TGE at 01:24
30 May 2018
NaI sum. of 3 det.
a)
Intensity (m^{2}min. MeV)$^{-1}$
Energy (MeV)


$I_{TGE1} = (3.91\pm0.01)\ 10^5\ E^{-(1.16\pm0.02)}$
$I_{TGE2} = (1.30\pm 0.03)\ 10^7\ E^{-(3.07\pm0.01)}$
TGE at 01:25
30 May 2018
NaI sum. of 3 det.
b)
Intensity (m^{2}min. MeV)$^{-1}$
Energy (MeV)

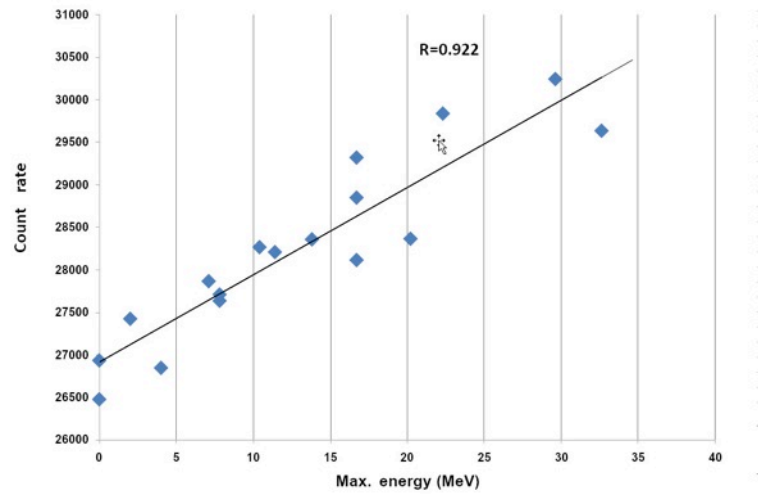

$I_{TGE1} = (1.95\pm0.05)\ 10^4\ E^{-(1.33\pm0.02)}$
$I_{TGE2} = (3.47\pm 2,83)\ 10^5\ E^{-(2.56\pm0.32)}$
TGE at 01:26
30 May 2018
NaI sum. of 3 det.
c)
Intensity (m^{2}min. MeV)$^{-1}$
Energy (MeV)

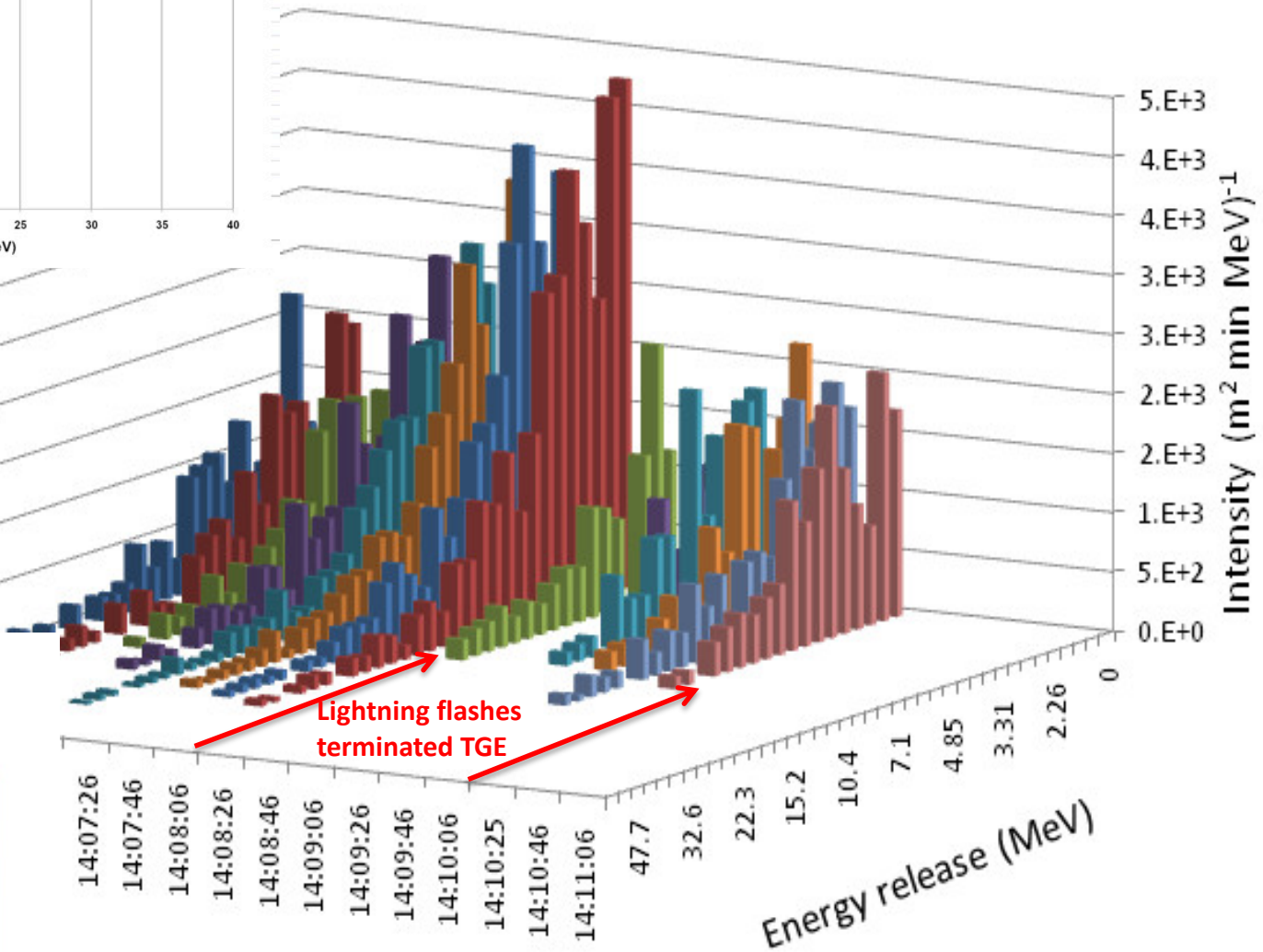

$I_{TGE} = (3.35\pm0.2)\ 10^5\ e^{-(2.71\pm0.09)*E}$
TGE at 01:29
30 May 2018
NaI sum of 3 det.
d)
Intensity (m^{2}min. MeV)$^{-1}$
Energy (MeV)

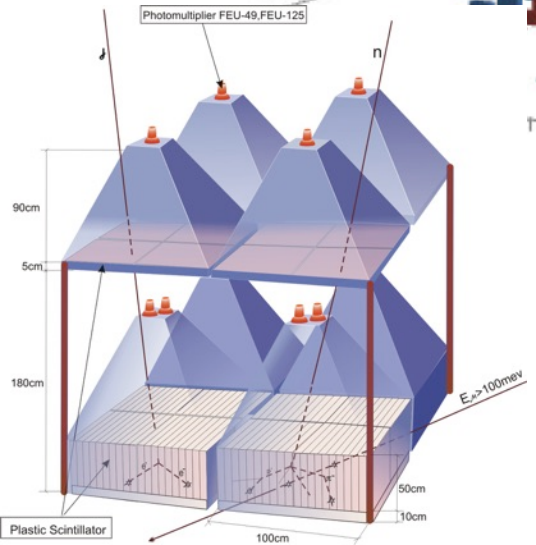

$I_{TGE} = (2.09\pm0.13)\ 10^5\ e^{-(2.21\pm0.09)*E}$
TGE at 01:30
30 May 2018
NaI sum of 3 det.
Intensity (m^{2}min. MeV)$^{-1}$
Energy (MeV)


$I_{TGE} = (2.2\pm0.10)\ 10^5\ e^{-(2.05\pm0.05)*E}$
TGE at 01:31
30 May 2018
NaI sum of 3 det.
Intensity (m^{2}min. MeV)$^{-1}$
Energy (MeV)

Normal polarity intracloud flashes terminate TGE 2 times

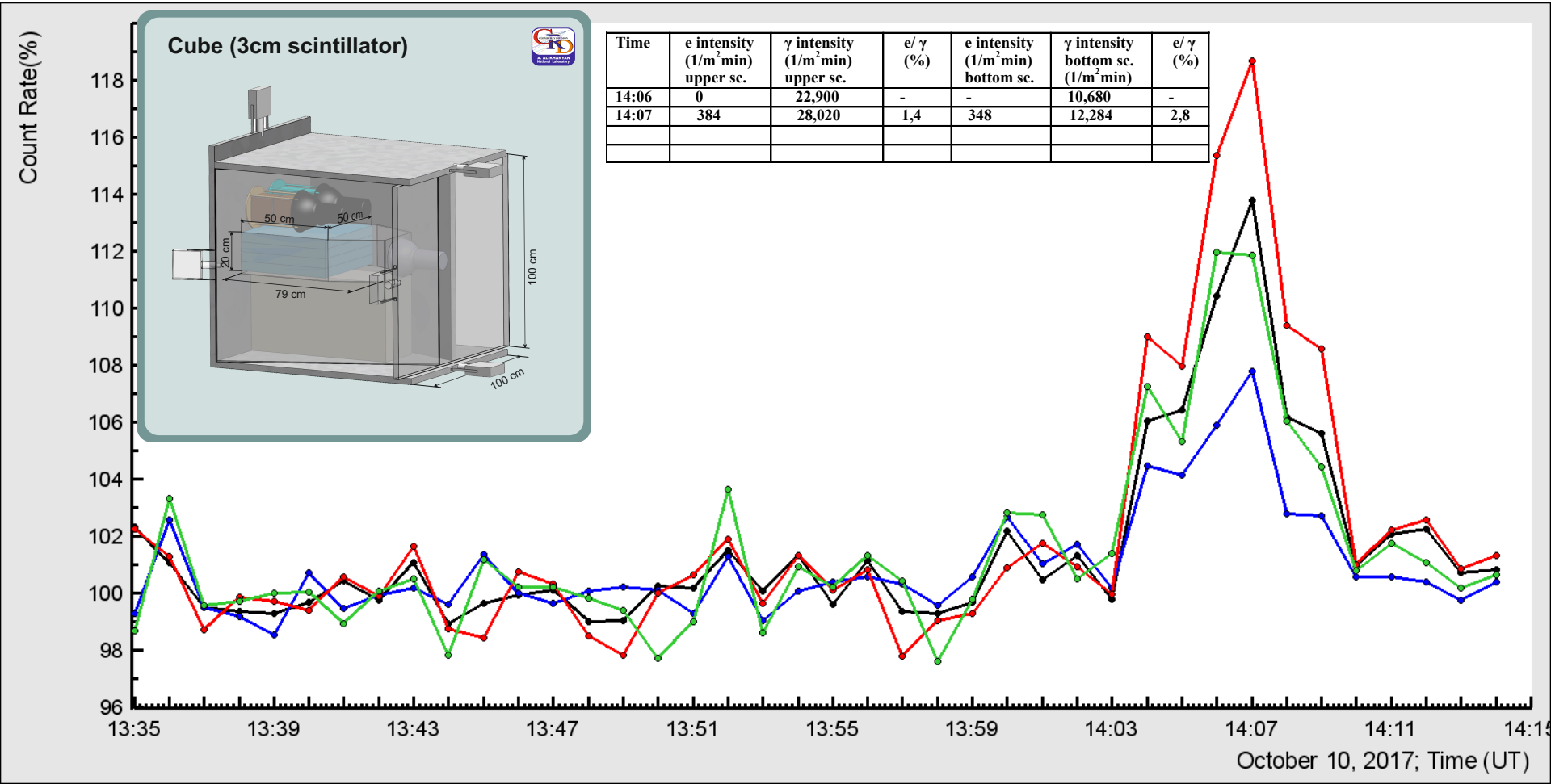






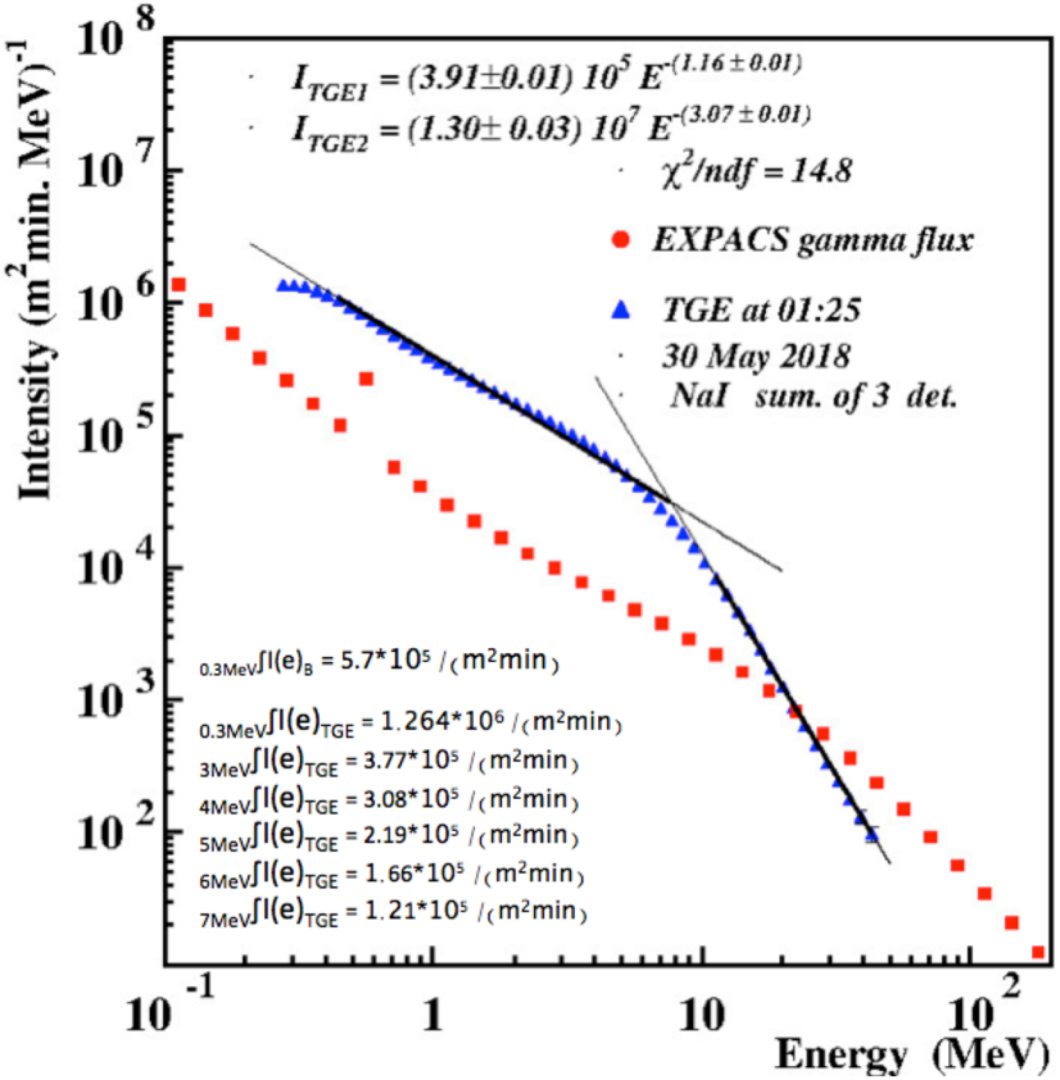
ASNT: 60 cm thick scintillators store energy release histograms each 20 seconds

10 October 2017, Recovered fraction of electrons and gamma rays in TGE (cloud height ~ 150m)

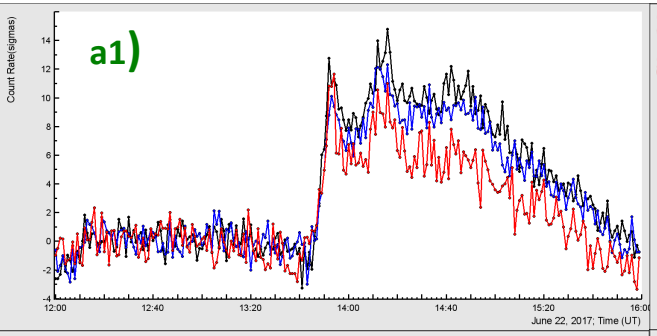


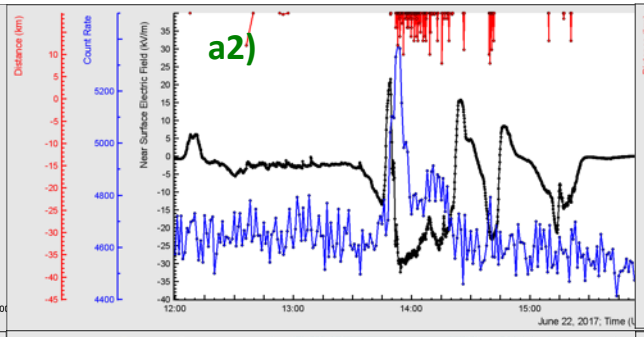
Time	e intensity ($1/m^2$min) upper sc.	γ intensity ($1/m^2$min) upper sc.	e/ γ (%)	e intensity ($1/m^2$min) bottom sc.	γ intensity bottom sc. ($1/m^2$min)	e/ γ (%)
14:06	0	22,900	-	-	10,680	-
14:07	384	28,020	1,4	348	12,284	2,8

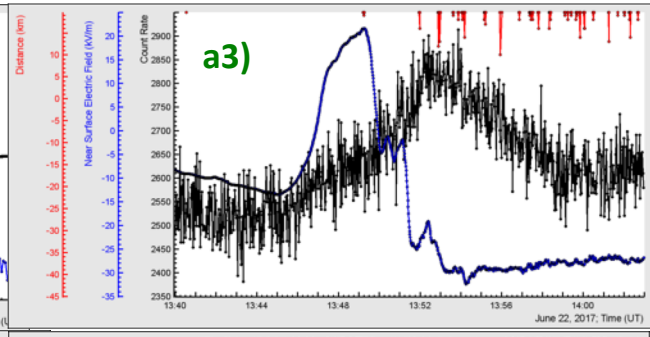
CR background spectrum and TGE spectrum observed on 30 May 2018. In the left bottom corner - values of integral spectrum calculated for different energy thresholds.

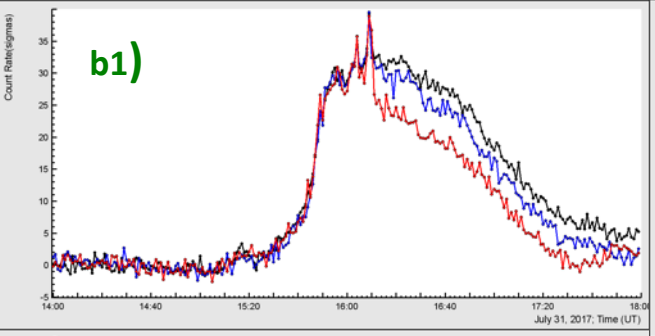


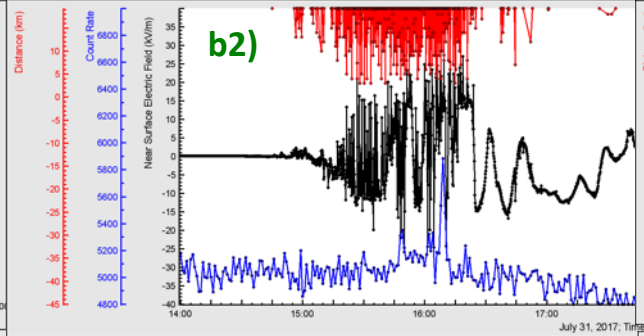
2017 Summer TGEs, Aragats, Armenia

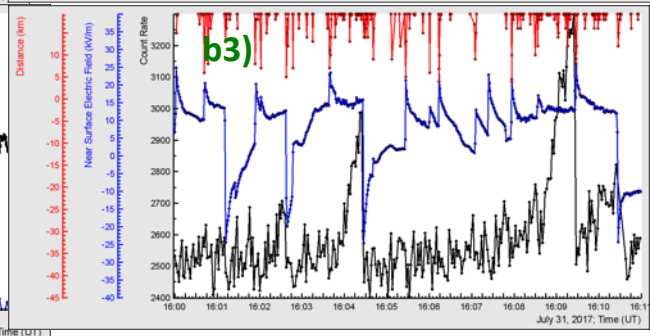


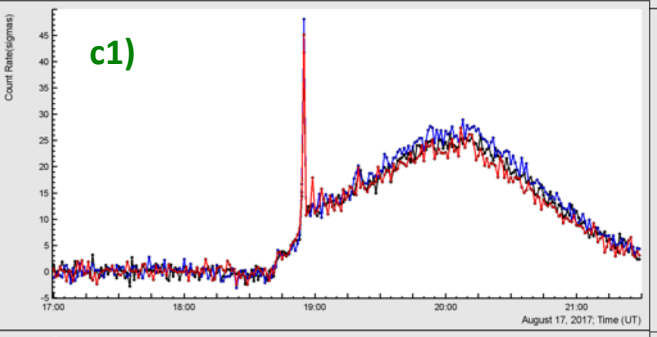


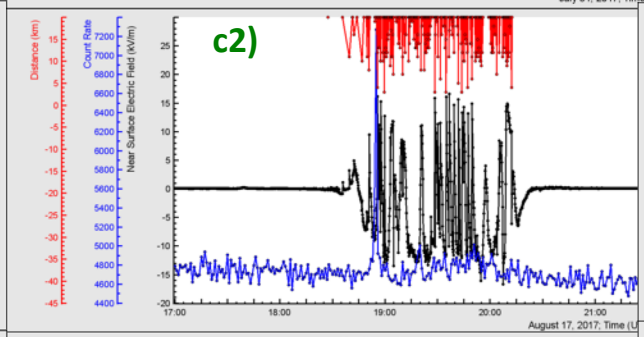


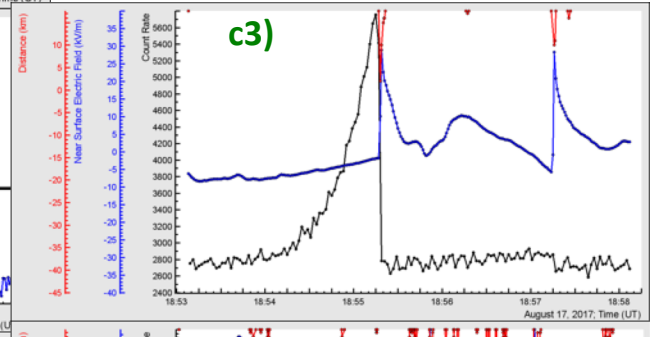


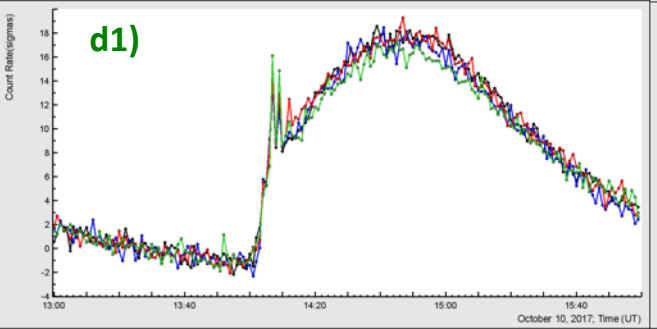


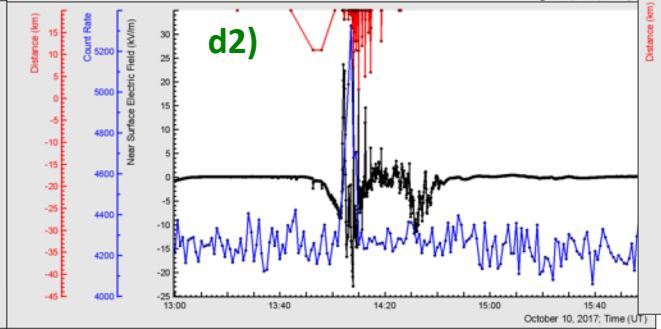


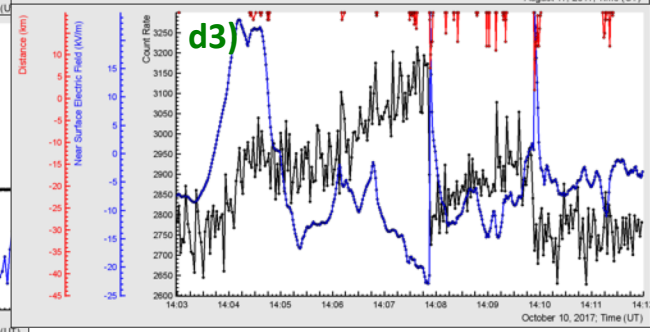


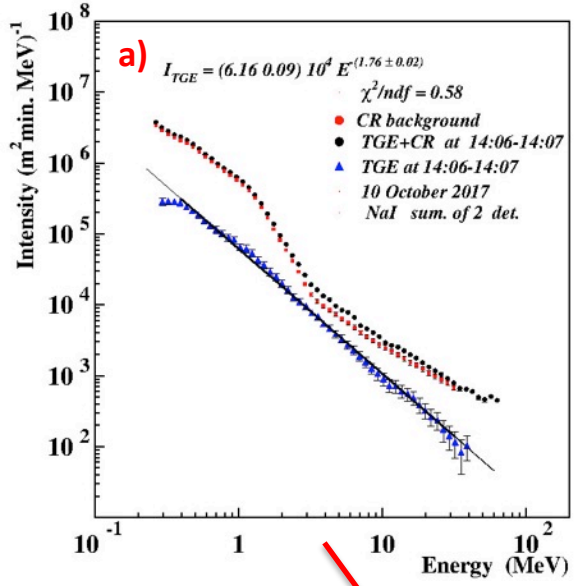


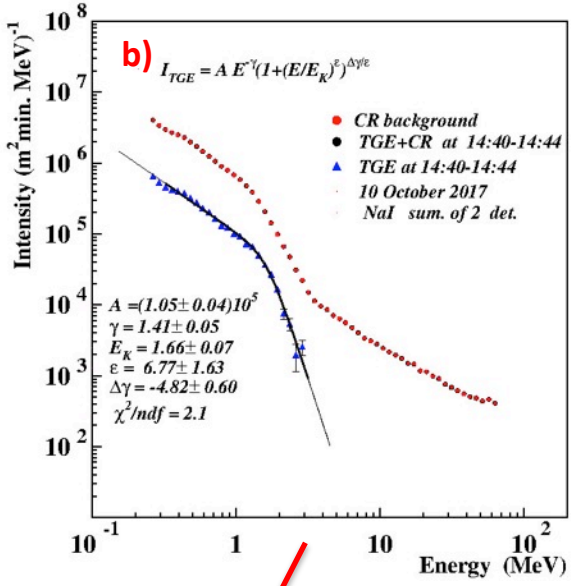


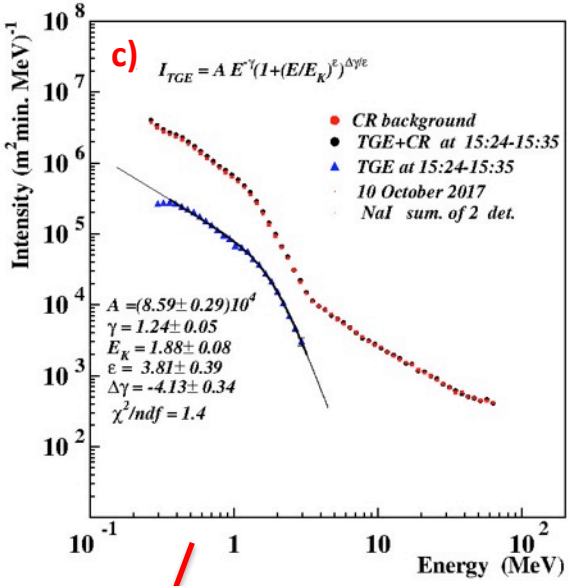


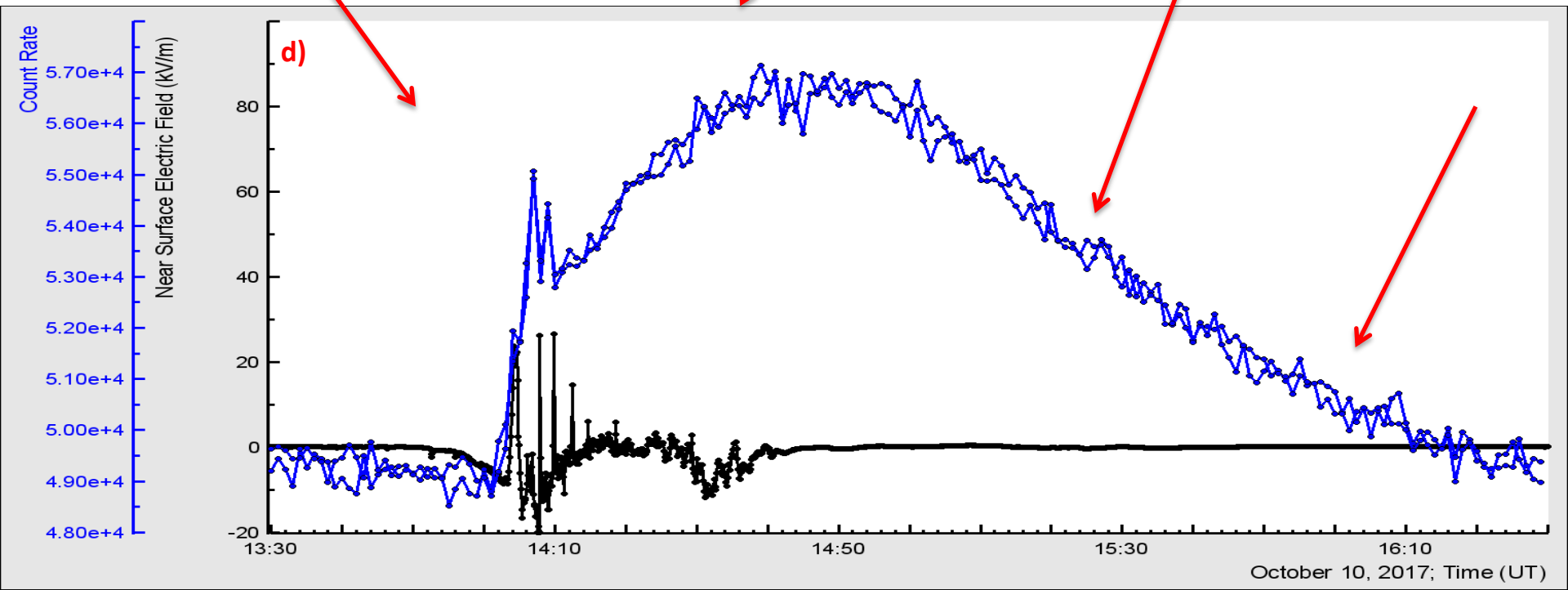


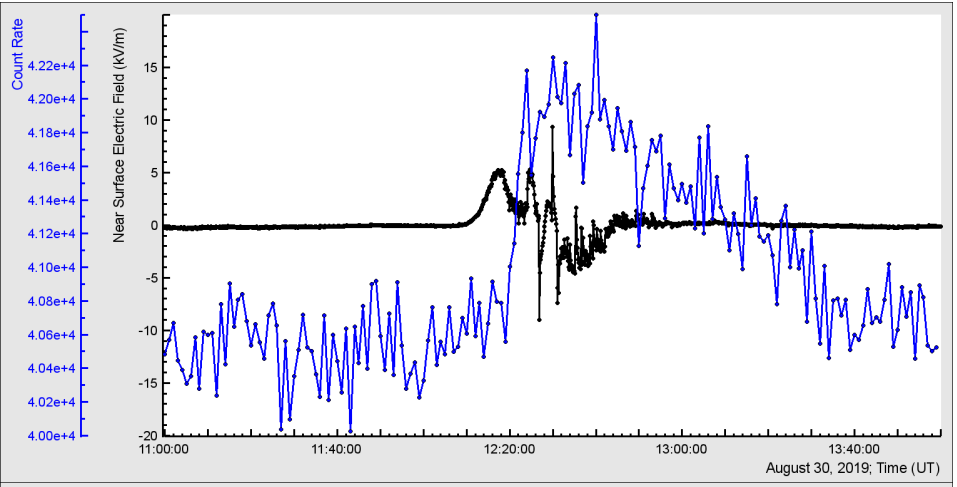


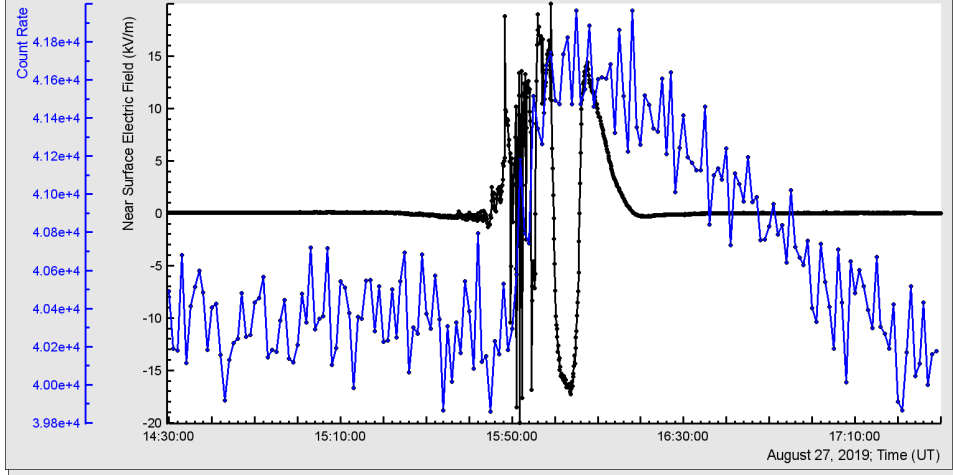

a)
$I_{TGE} = (6.16\ 0.09)\ 10^4\ E^{-(1.76 \pm 0.02)}$
$\chi^2/ndf = 0.58$
CR background
TGE+CR at 14:06-14:07
TGE at 14:06-14:07
10 October 2017
NaI sum. of 2 det.
Intensity (m^2min. MeV)$^{-1}$
Energy (MeV)

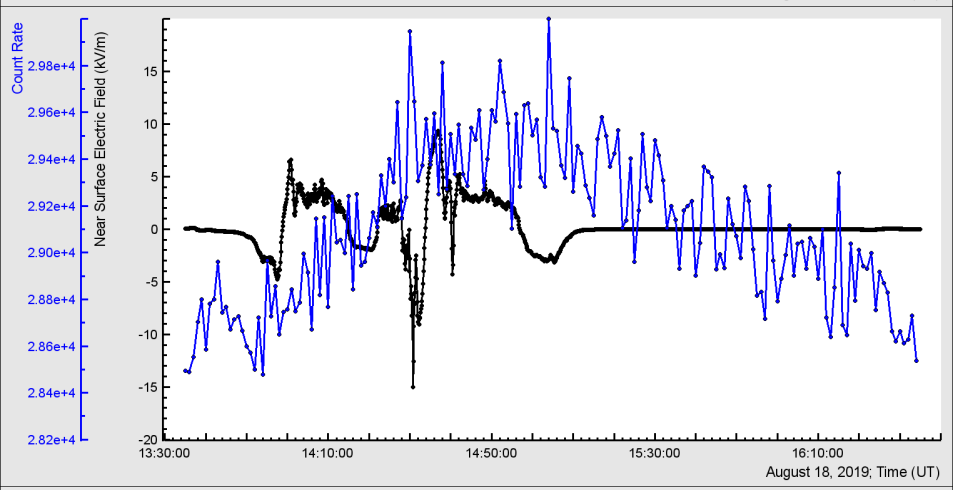

b)
$I_{TGE} = A\ E^{-\gamma}(1+(E/E_K)^{\varepsilon})^{\Delta\gamma/\varepsilon}$
CR background
TGE+CR at 14:40-14:44
TGE at 14:40-14:44
10 October 2017
NaI sum. of 2 det.
$A = (1.05 \pm 0.04)10^5$
$\gamma = 1.41 \pm 0.05$
$E_K = 1.66 \pm 0.07$
$\varepsilon = 6.77 \pm 1.63$
$\Delta\gamma = -4.82 \pm 0.60$
$\chi^2/ndf = 2.1$
Intensity (m^2min. MeV)$^{-1}$
Energy (MeV)

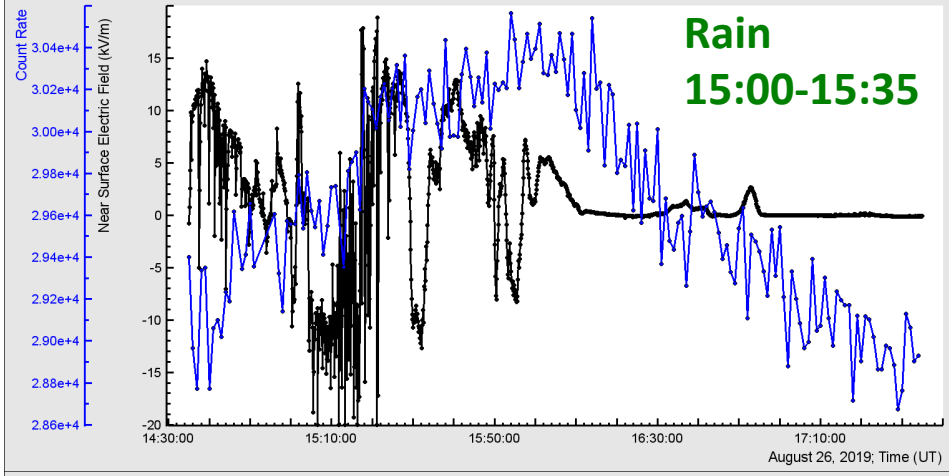

c)
$I_{TGE} = A\ E^{-\gamma}(1+(E/E_K)^{\varepsilon})^{\Delta\gamma/\varepsilon}$
CR background
TGE+CR at 15:24-15:35
TGE at 15:24-15:35
10 October 2017
NaI sum. of 2 det.
$A = (8.59 \pm 0.29)10^4$
$\gamma = 1.24 \pm 0.05$
$E_K = 1.88 \pm 0.08$
$\varepsilon = 3.81 \pm 0.39$
$\Delta\gamma = -4.13 \pm 0.34$
$\chi^2/ndf = 1.4$
Intensity (m^2min. MeV)$^{-1}$
Energy (MeV)

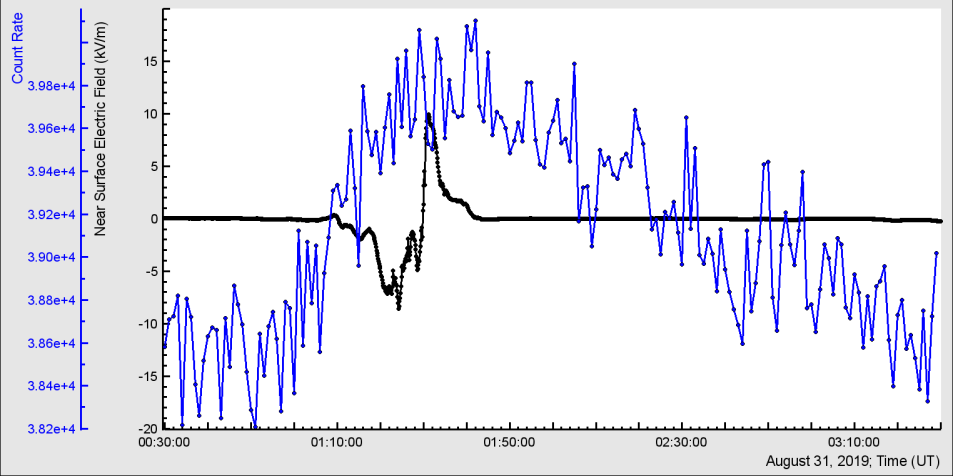

d)
Count Rate
Near Surface Electric Field (kV/m)
October 10, 2017; Time (UT)

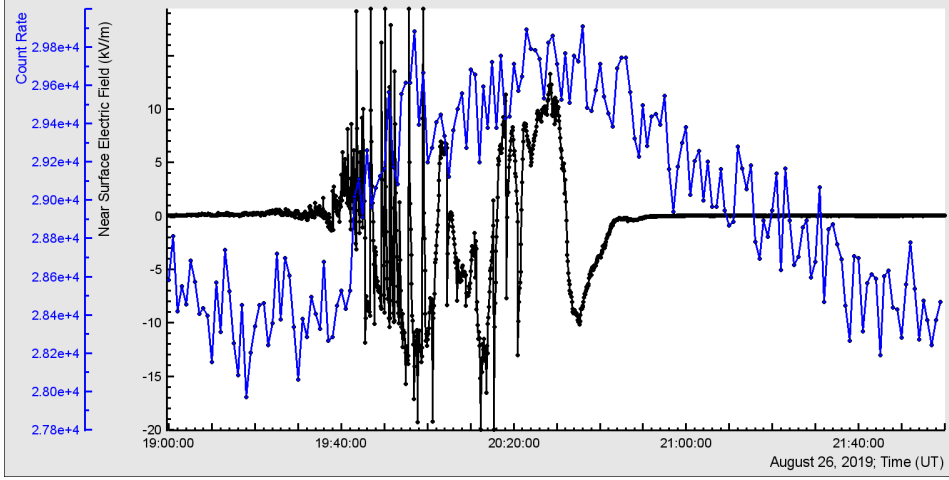

Count Rate
Near Surface Electric Field (kV/m)
August 30, 2019; Time (UT)


Count Rate
Near Surface Electric Field (kV/m)
August 27, 2019; Time (UT)

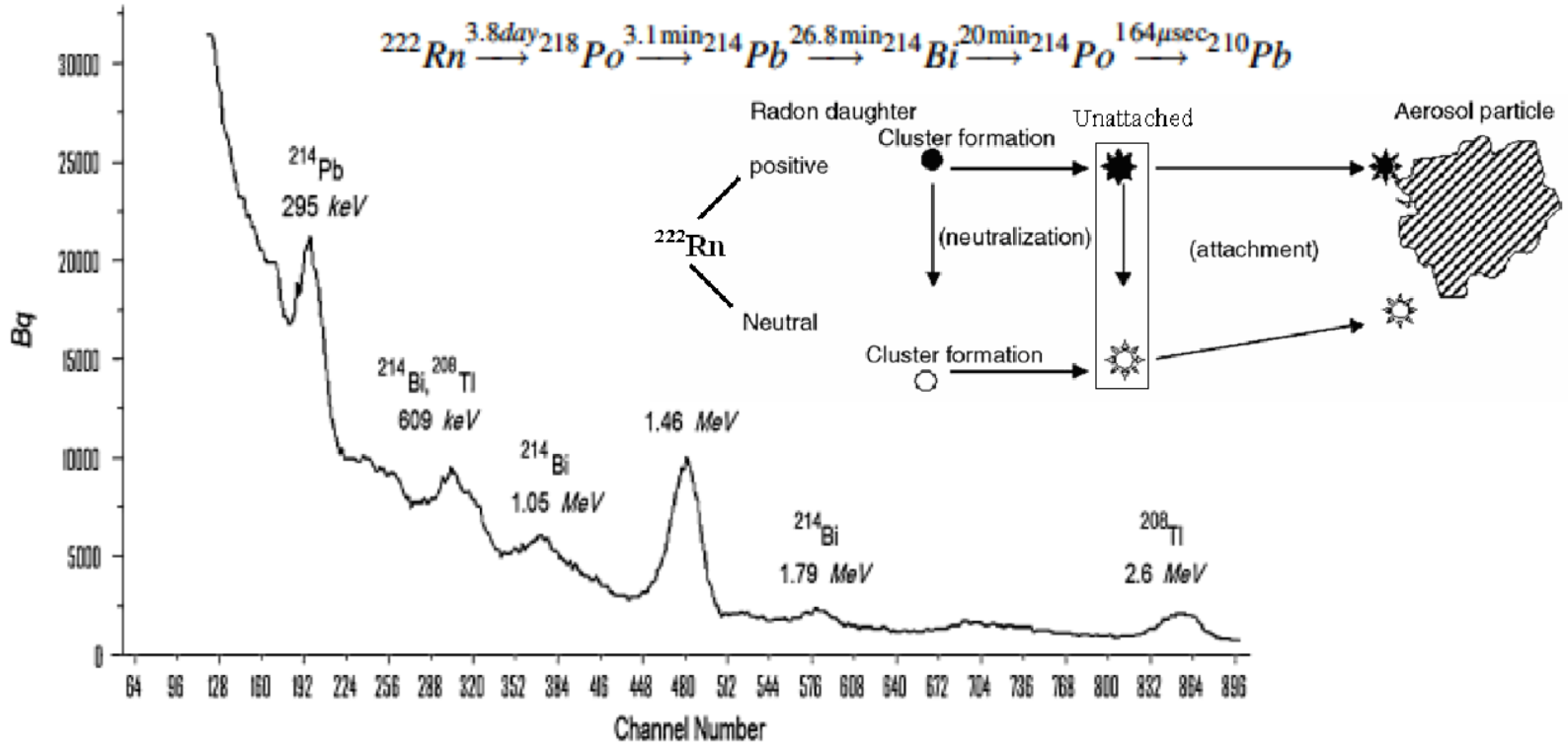

Count Rate
Near Surface Electric Field (kV/m)
August 18, 2019; Time (UT)


Rain
15:00-15:35
Count Rate
Near Surface Electric Field (kV/m)
August 26, 2019; Time (UT)


Count Rate
Near Surface Electric Field (kV/m)
August 31, 2019; Time (UT)

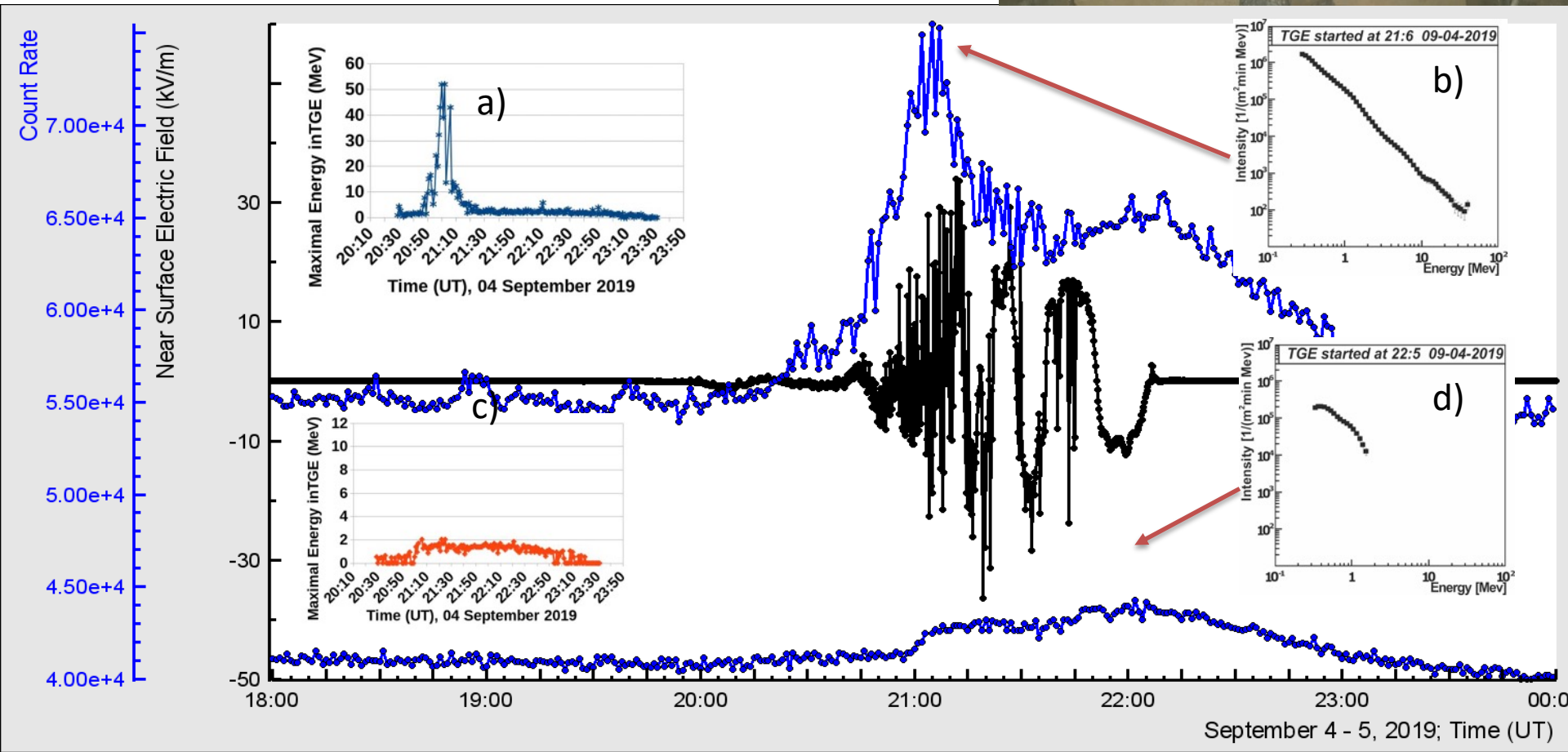

Count Rate
Near Surface Electric Field (kV/m)
August 26, 2019; Time (UT)

Half live time of ^{222}Rn progenies coincides with TGE measurements!

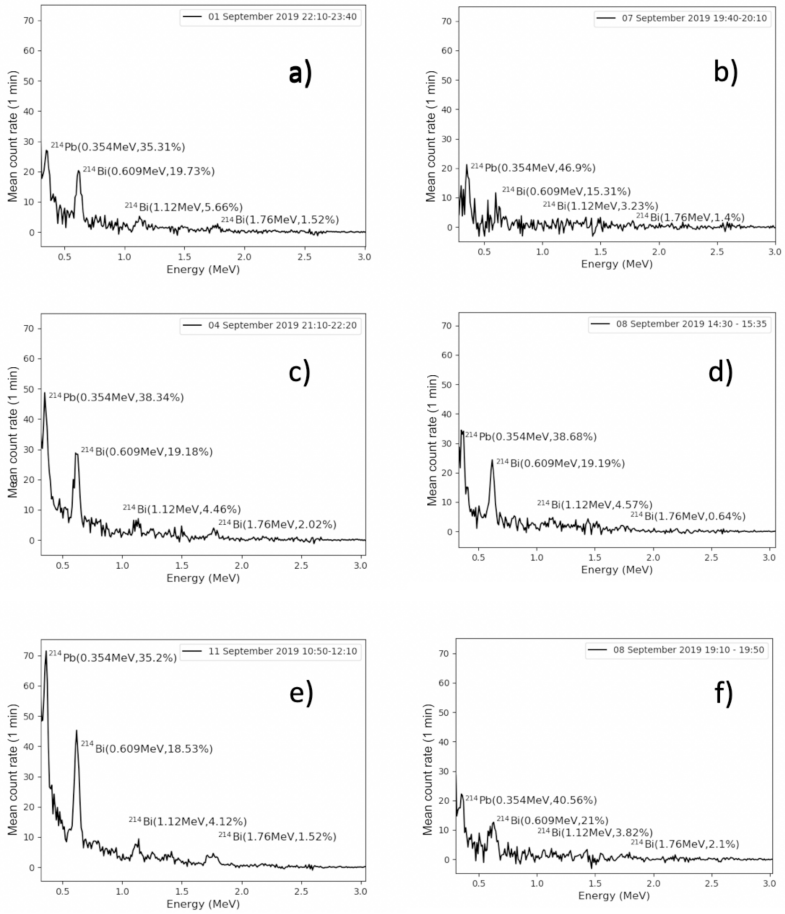


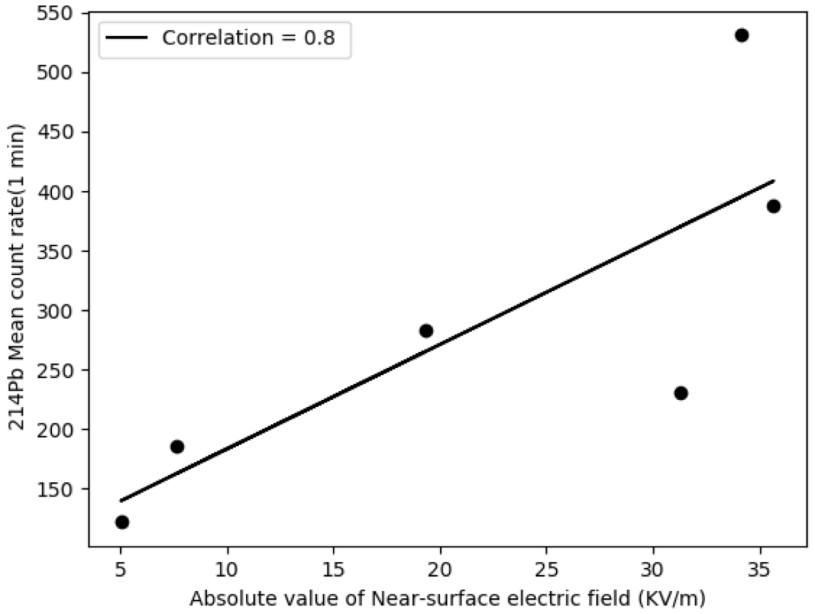
Opposite to that 222Rn with its much longer half-life 222Ra = 3.8 day disperse into the whole atmosphere populating it with progenies from the decay chain:
Owing to their longer half-life 214Pb and 214Bi are the most abundant radon progenies in the atmosphere. The solid radon progenies become airborne and immediately attach to the dust particles, aerosols and water droplets existing in the atmosphere. These particles undergo intensive convection aligning its concentration in the atmosphere (Kumar et al. 1999).

Comparison of TGE registered by NAI 1 (energy spectrum at 15:56 prolonged up to 10 MeV) and 4 (energy spectrum on 15:56 prolonged up to 1.2 MeV)

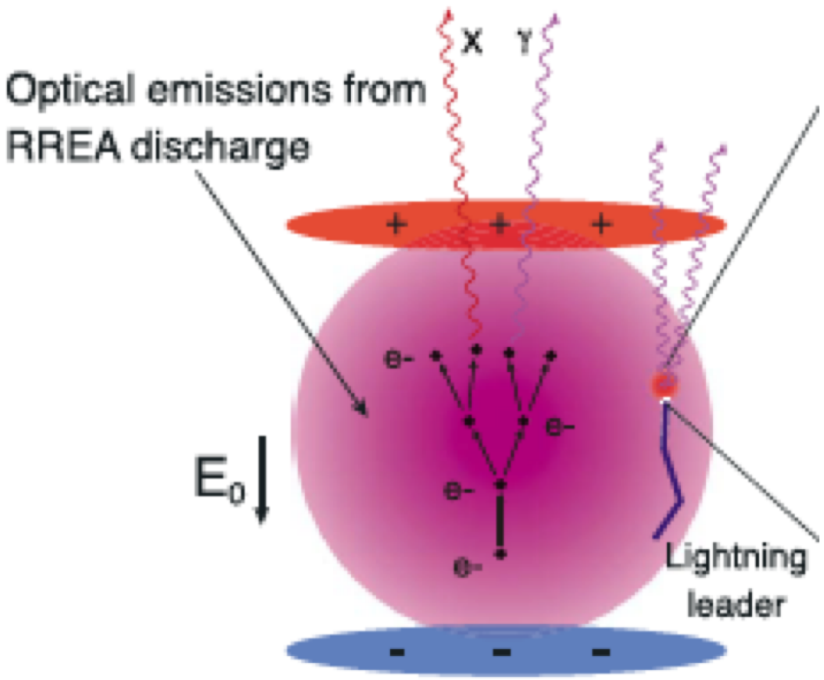


Cumulative spectrum of low energy gamma radiation measured by ORTEC NaI spectrometer



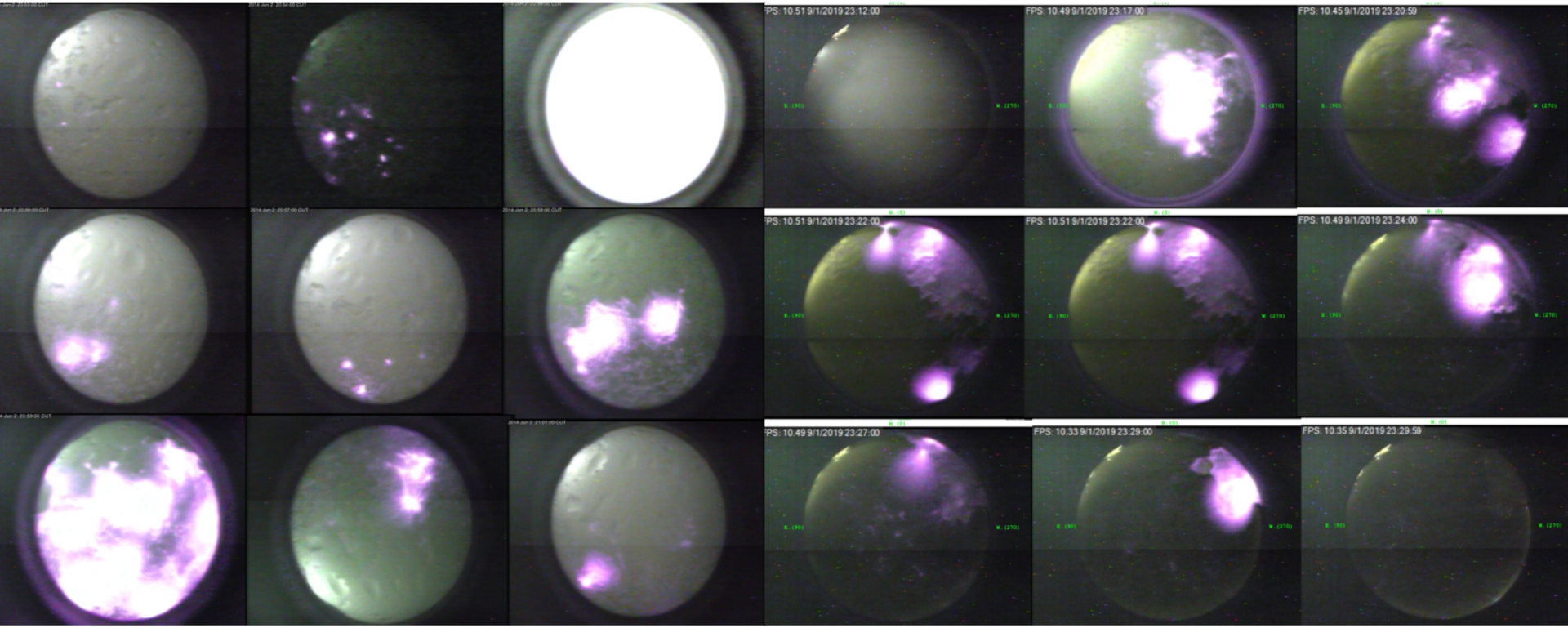


Wei Xu, Sebastien Celestin, and Victor Pasko, Optical emissions associated with terrestrial gamma ray flashes



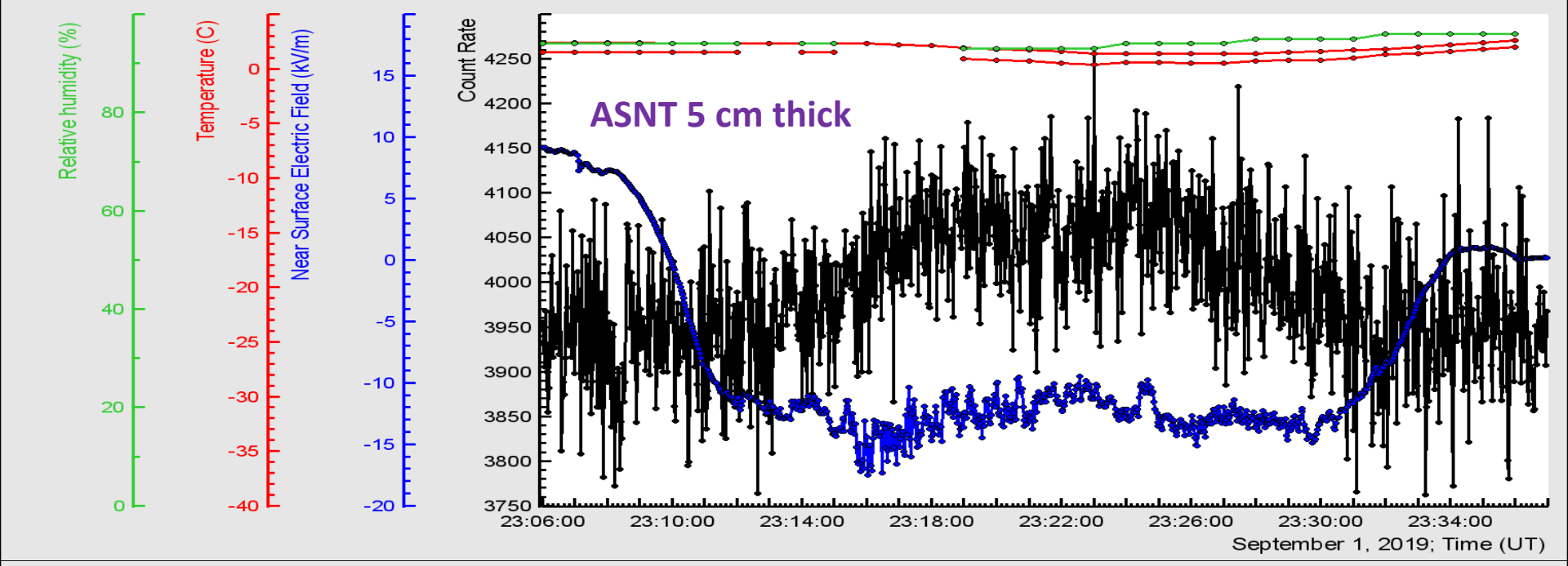
From the knowledge of the electron energy distribution, we have quantified the optical emissions that are possibly generated during the production of TGFs. Modeling results indicate that TGFs are most likely accompanied with detectable levels of optical emissions.

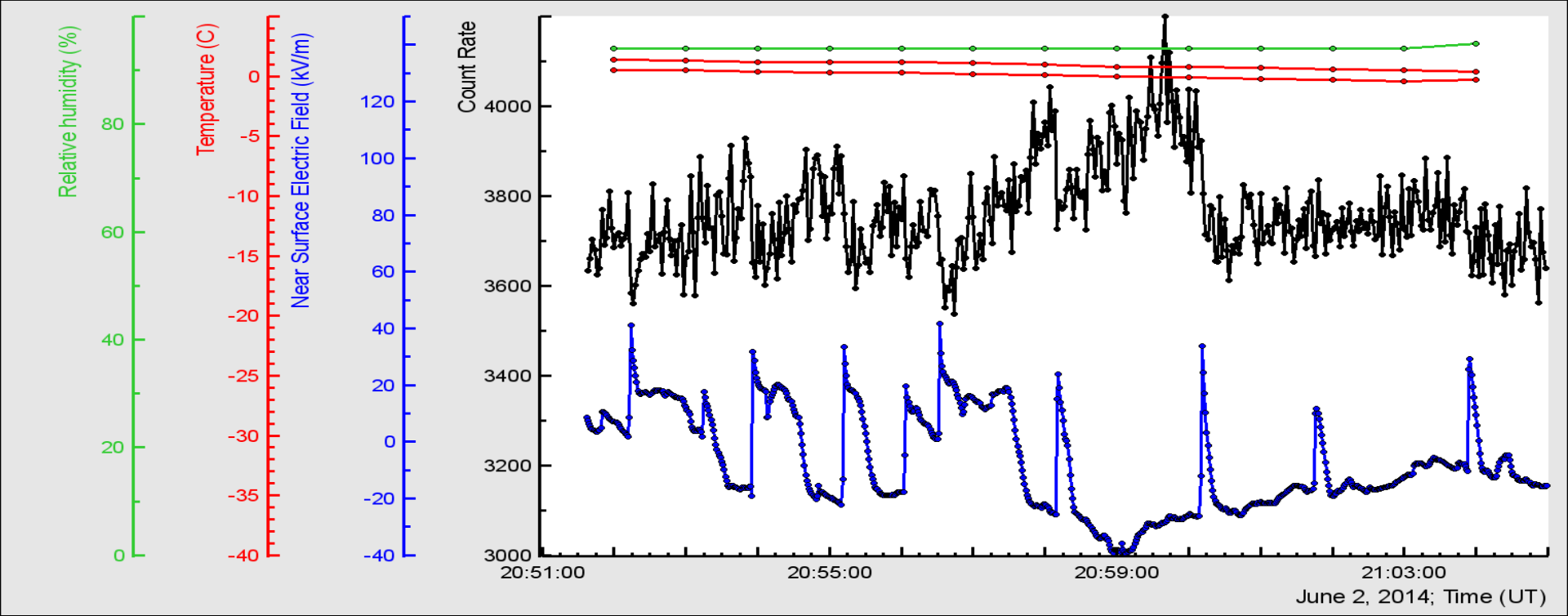
Optical images of RREA



2 June 2014 glow, 8 minutes lightning flashes

1 September 2019, 15 minute glow no flashes


Relative humidity (%)
Temperature (C)
Near Surface Electric Field (kV/m)
Count Rate
ASNT 5 cm thick
23:06:00
23:10:00
23:14:00
23:18:00
23:22:00
23:26:00
23:30:00
23:34:00
September 1, 2019; Time (UT)

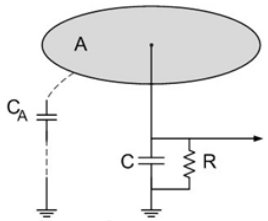

Relative humidity (%)
Temperature (C)
Near Surface Electric Field (kV/m)
Count Rate
20:51:00
20:55:00
20:59:00
21:03:00
June 2, 2014; Time (UT)

MFJ-1022 active antenna
0.3-200MHz

Optical
cable

Picoscope 5244B
f_s=25MS/s , 40ns sampling;
1sec record length

NI-myRIO board
with GPS timing and 7
digital inputs



Flat plate antenna

A B Ext Out

Signals from particle
detector: 3 cm thick
scintillator; or NaI crystal

50 ms time series of el. field;
particles from 4-channel
STAND1 detector; SKL hall.

ArNM 8 channel: EAS
trigger source for Picoscope

NI-myRIO board
with GPS timing
Trigger threshold:
Count rate above 80/sec

Picoscope 5244B
f_s=25MS/s , 40ns sampling;
1sec record length

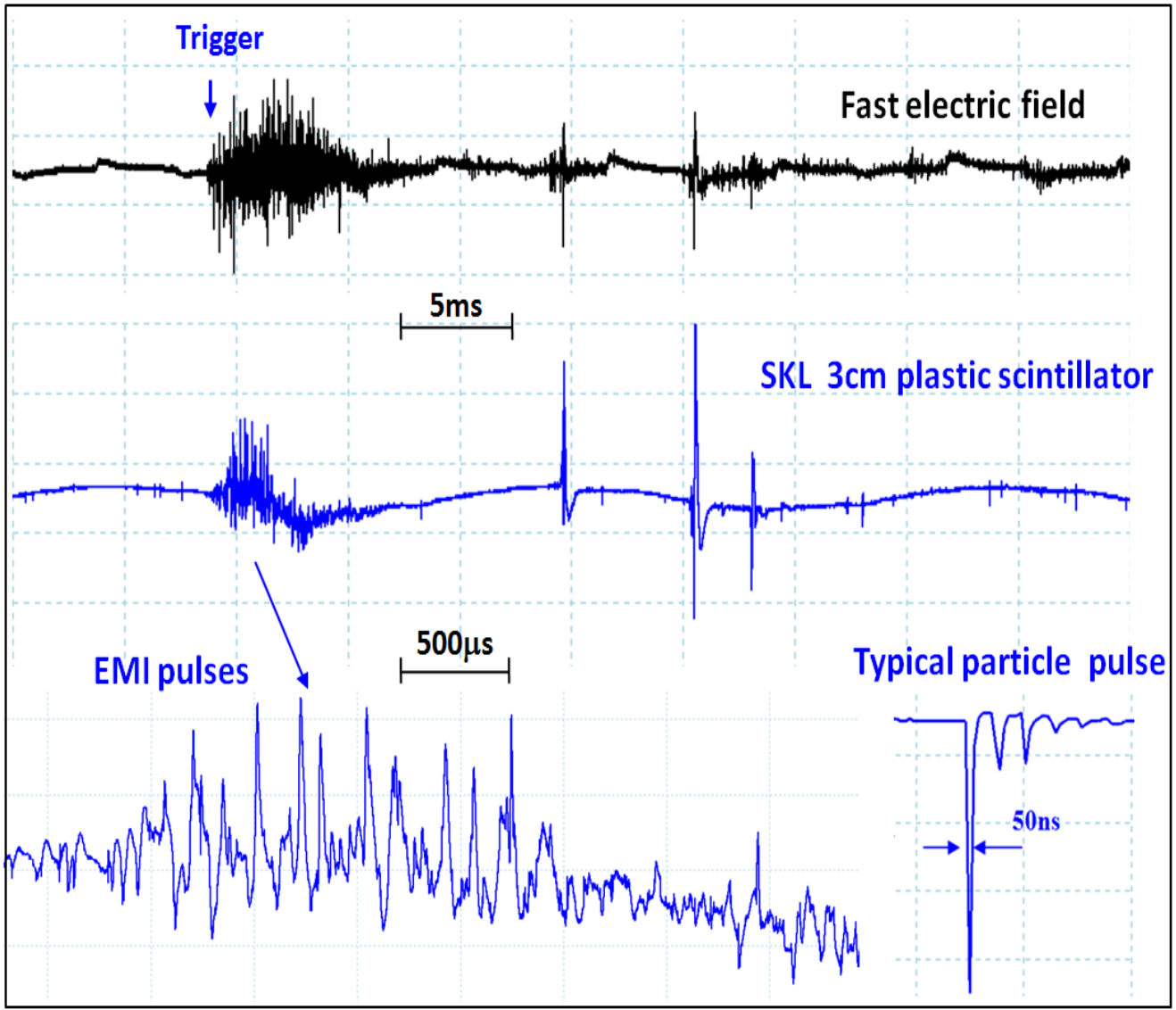
A B Ext

Muon 1 channel ArNM 9 channel

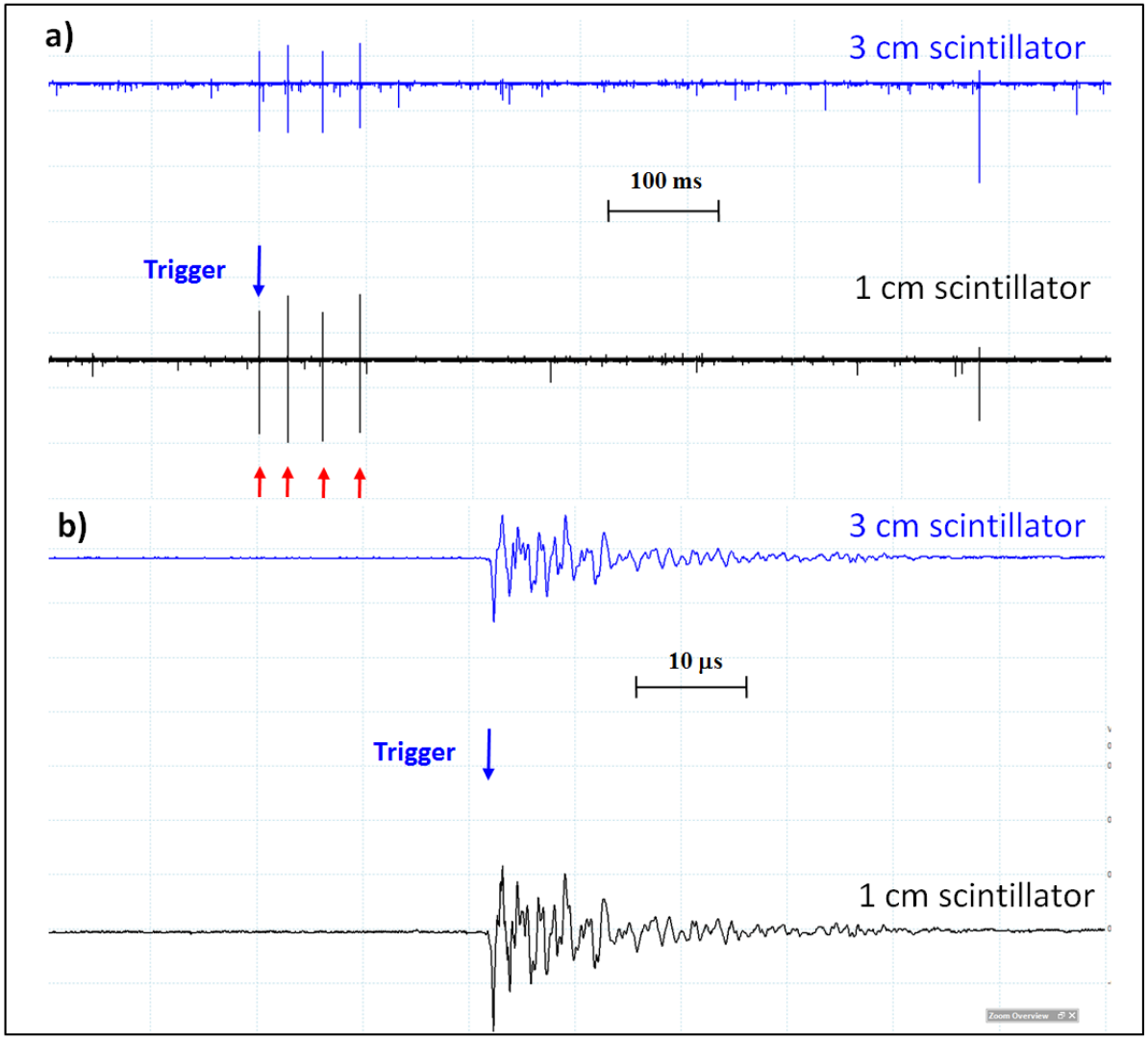
NI-myRIO board
with GPS timing and 7
digital inputs

50 ms time series: el. field;
particles from 4-channel
STAND1 and muon detector;
MAKET exp. hall

EMI activity. Typical EMI signature from atmospheric discharges in the particle detector waveform. Synchronized time-series of the pulses of fast electric field and signals from plastic scintillator. SKL trigger occurred at 14:32:34.205



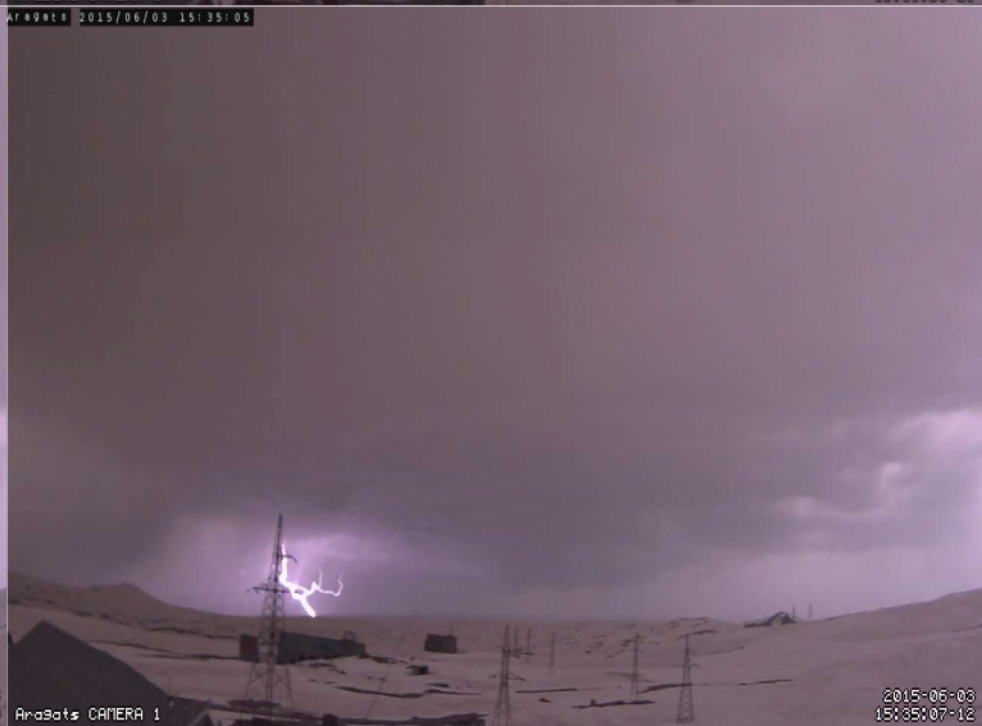
The “Shower Burst” event detected on 14 April 2014 by 1 sm thick and 3-cm thick 1 m area plastic scintillators located in the experimental hall MAKET. The signal shapes were synchronized with lightning flash (atmospheric discharge trigger was detected at 11: 59:51.75).



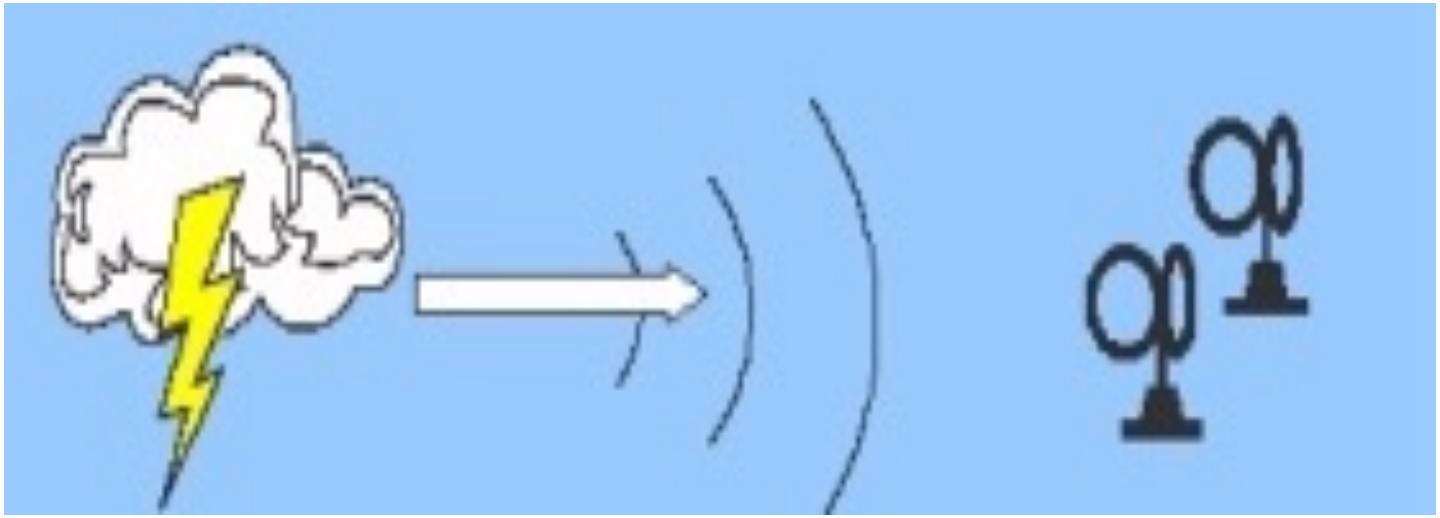

Aragats 2015/06/03 15:30:53
Aragats CAMERA 1
2015-06-03
15:30:55-04


Aragats 2015/06/03 15:33:54
Aragats CAMERA 1
2015-06-03
15:33:56-21


Aragats 2015/06/03 15:35:05
Aragats CAMERA 1
2015-06-03
15:35:07-09

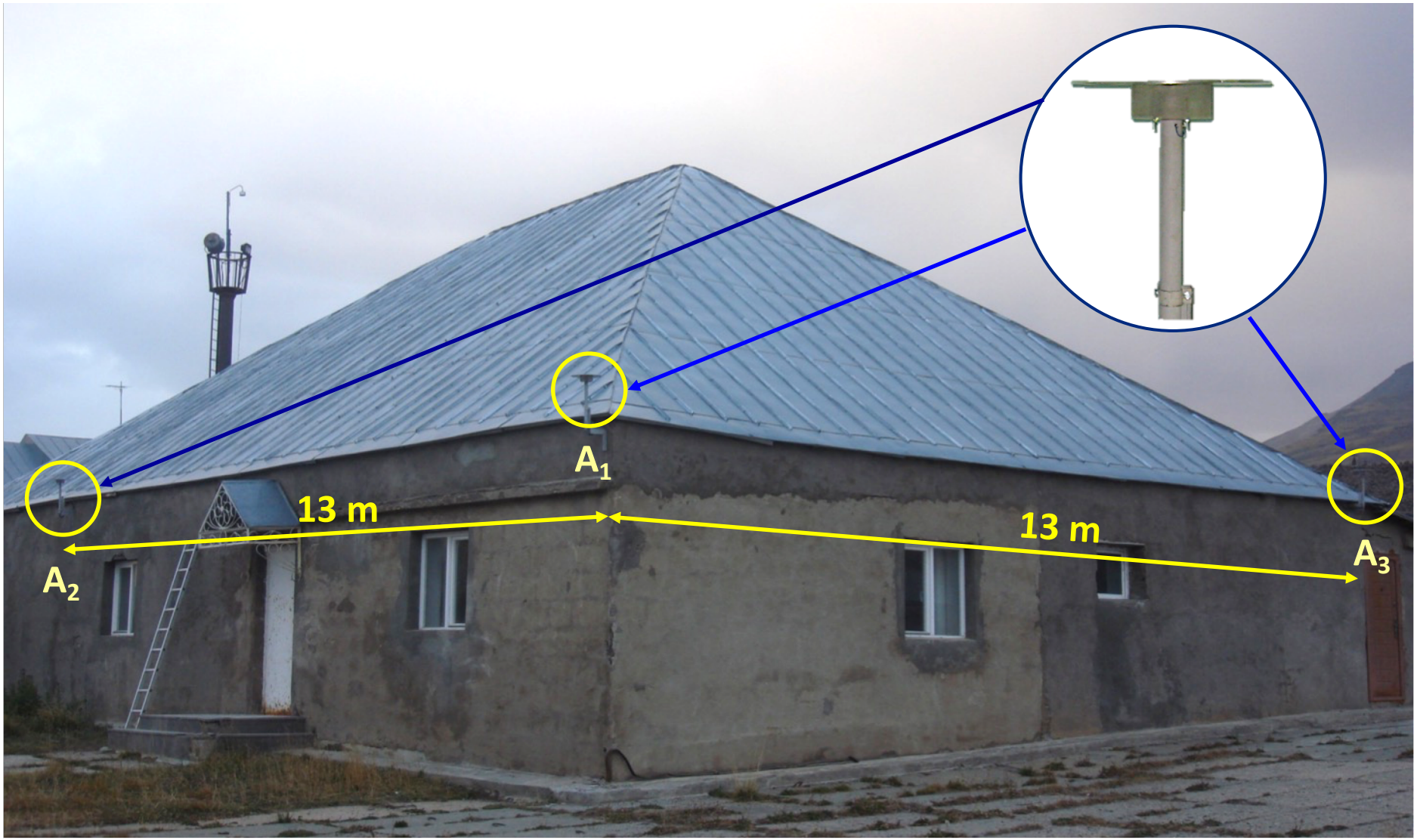

Aragats 2015/06/03 15:35:05
Aragats CAMERA 1
2015-06-03
15:35:07-12

VHF interferometer (24-82 MHz) for lightning location



An instrument which determines the direction to a lightning-produced radio point source with microsecond time resolution by correlating the signal received at two or more antennas

Three flat plate antennas of VHF interferometer installed at SKL hall of Aragats station



Interferometer

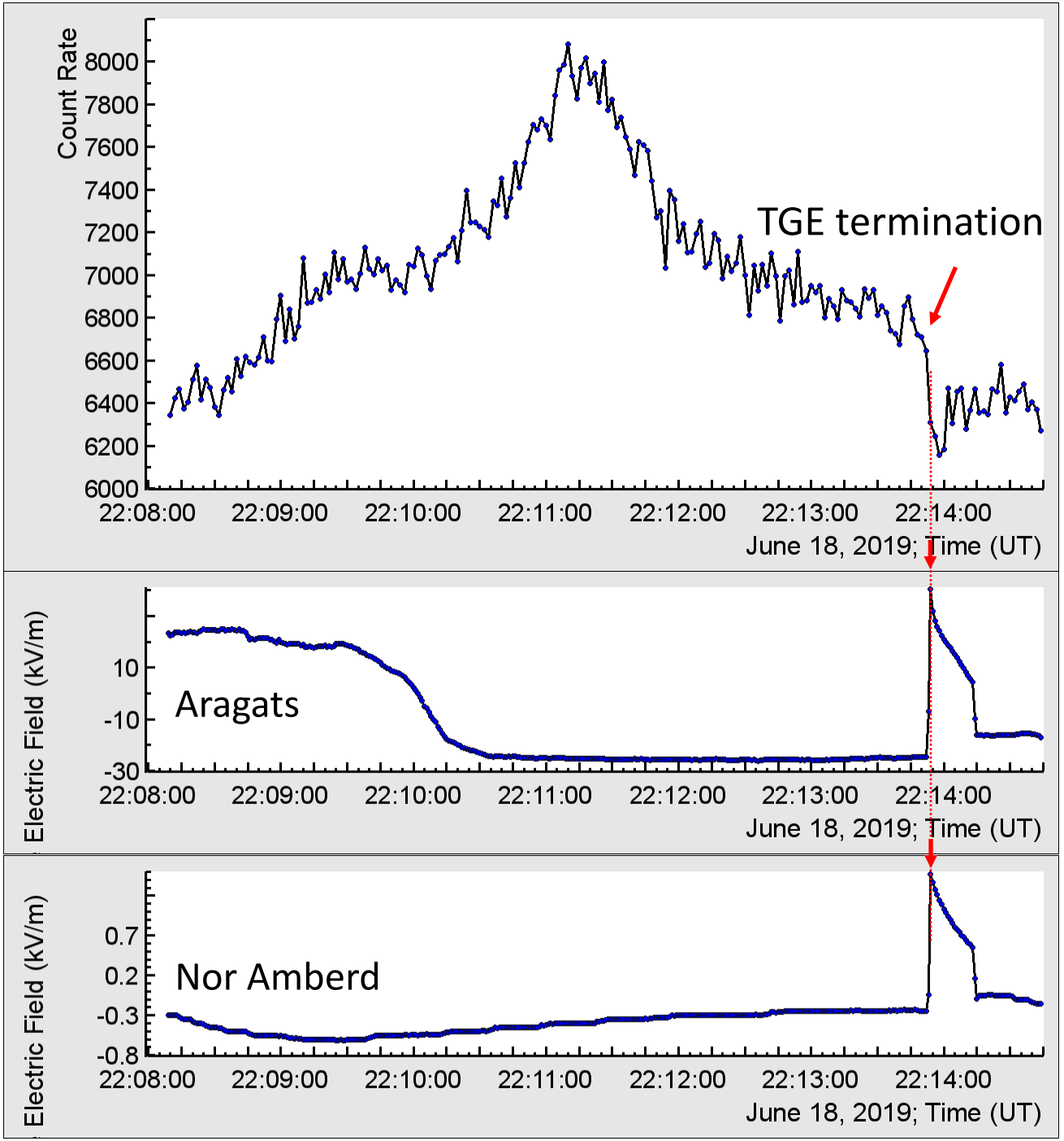
- Nearly 400 lightning flashes detected in 2019 (100 ~ 270 in 2018). I will take several months to analyze all data acquired during 2019.
- Analysis software tuned; different modes of filtering tested;
- Cabling improved. Signal/Noise ratio significantly enhanced by installing low noise broadband amplifiers;
- Analysis of interferometer data combined with analysis of data of fast wideband electric field and near-surface electrostatic field , as well as the WWLLN data is in progress.

June 18, 2019, 22:13:53.661
TGE terminated by –CG lightning flash

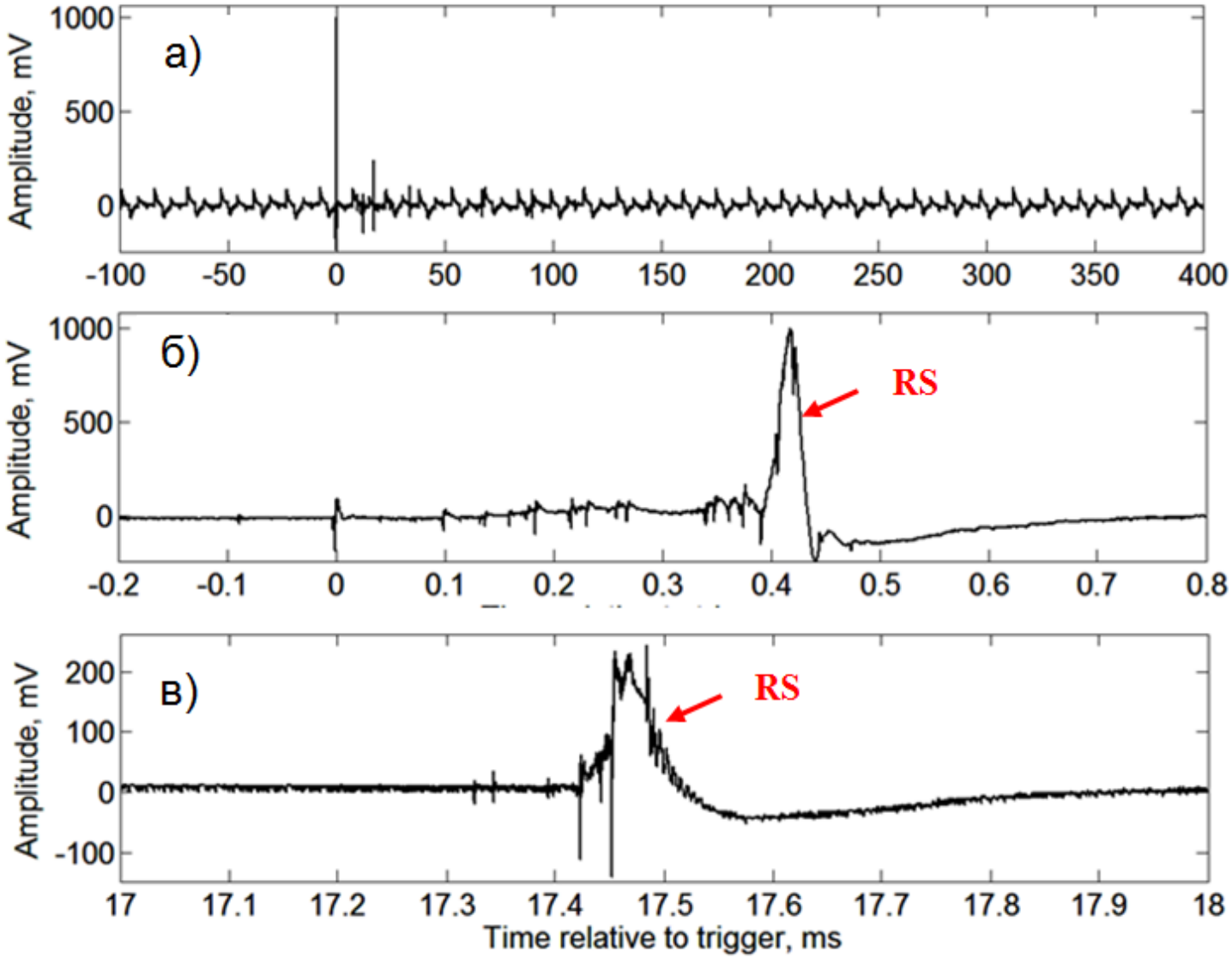
TGE shown in next slide was recorded by the ASNT detector, coincidence One 60cm-Zero 5cm. Electrostatic field change ΔE is positive in Aragats and Nor Amberd, polarity reversal was not detected. Fast electric field record shows wide pulses, that can be attributed to RS pulses of –CG. Identification: -CG

Detected also by WWLLN:

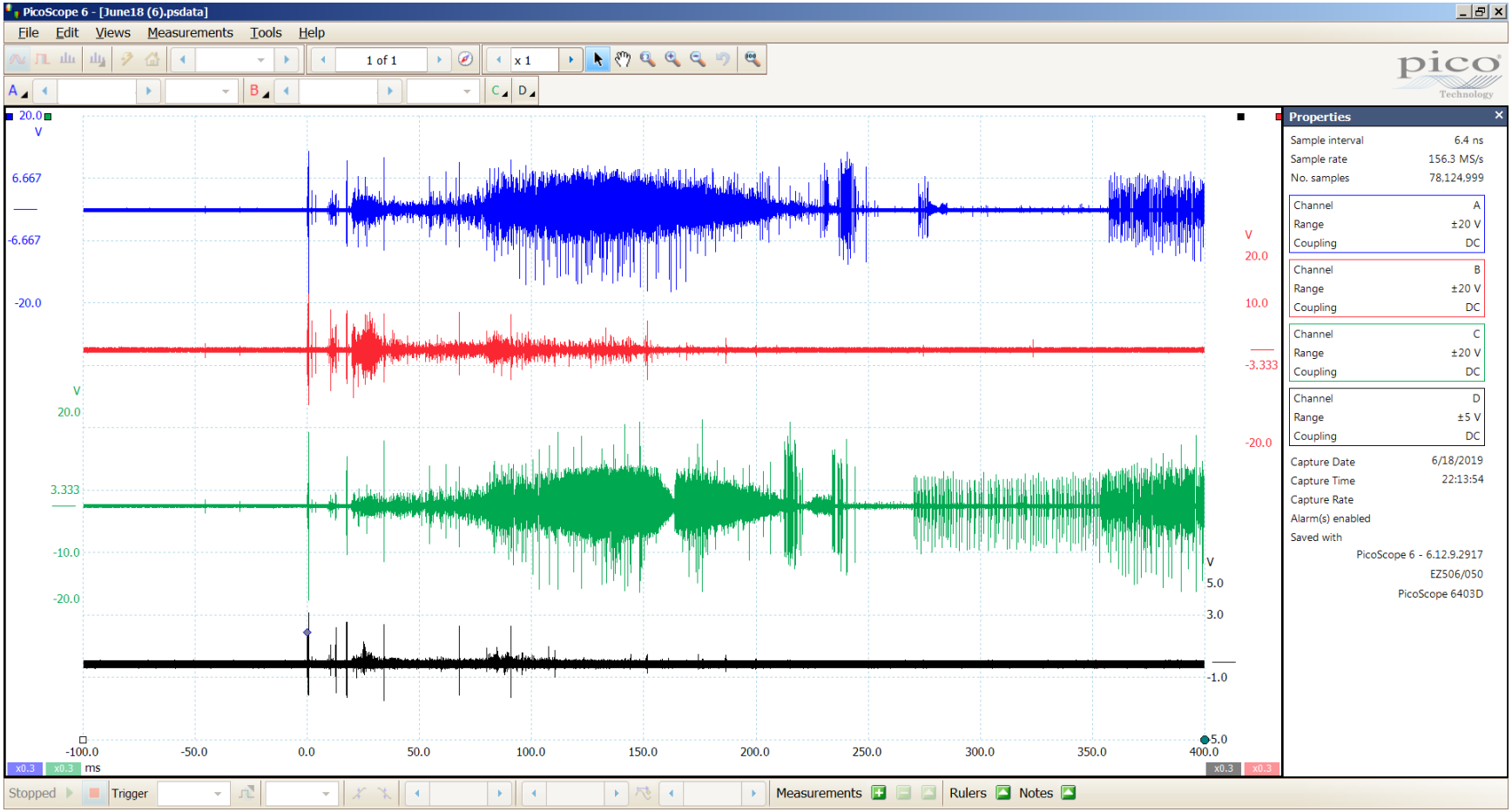
Date	Time	Latitude	Longitude	ResErr	Nsta	Distance	Bearing
18-Jun-19	22:13:53.662	40.5039	44.1846	14.7	10	3.6	3.6
18-Jun-19	22:13:53.662	40.5089	44.1771	11	5	4.2	-5.5


Count Rate
8000
7800
7600
7400
7200
7000
6800
6600
6400
6200
6000
TGE termination
22:08:00
22:09:00
22:10:00
22:11:00
22:12:00
22:13:00
22:14:00
June 18, 2019; Time (UT)
Electric Field (kV/m)
10
-10
-30
Aragats
22:08:00
22:09:00
22:10:00
22:11:00
22:12:00
22:13:00
22:14:00
June 18, 2019; Time (UT)
Electric Field (kV/m)
0.7
0.2
-0.3
-0.8
Nor Amberd
22:08:00
22:09:00
22:10:00
22:11:00
22:12:00
22:13:00
22:14:00
June 18, 2019; Time (UT)

June 18, 2019, 22:13:53.661
Fast electric field

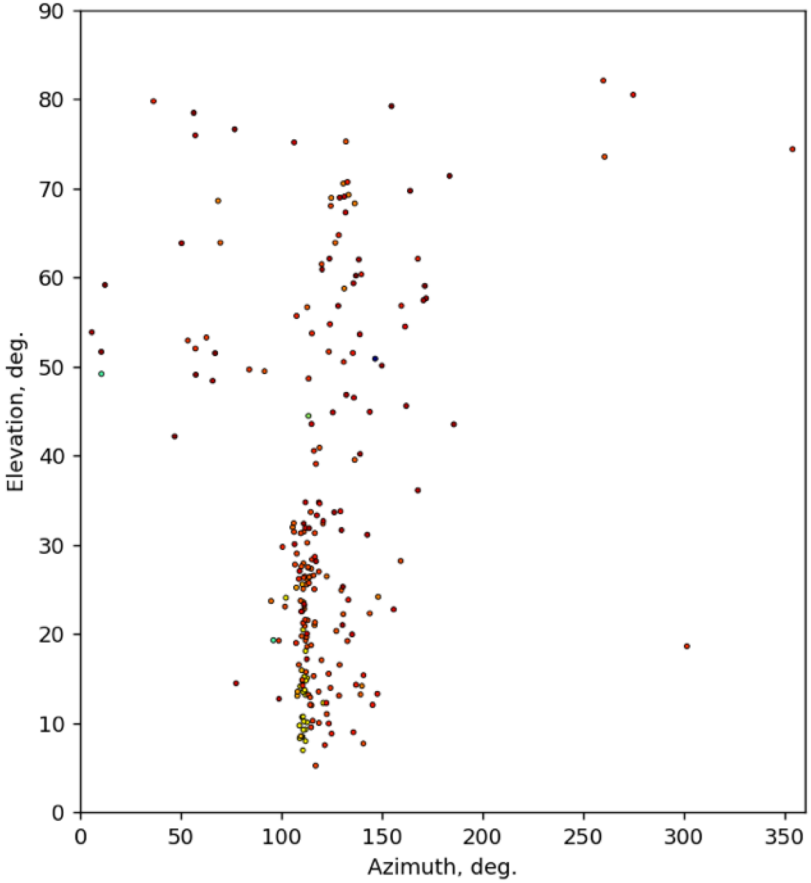


June 18, 2019, 22:13:53.661
VHF interferometer record

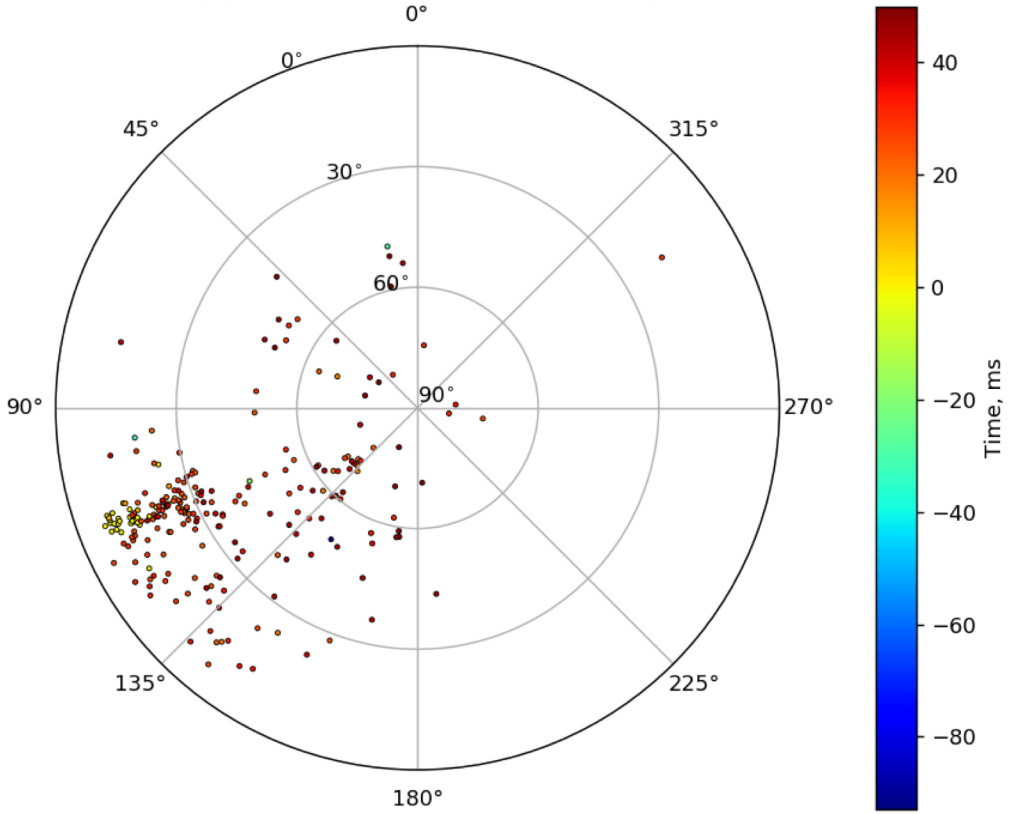


June 18, 2019, 22:13:53.661
Cloud-to-ground lightning detected by interferometer

Time window: from -100 ms before trigger to 50 ms after trigger
Color indicates time



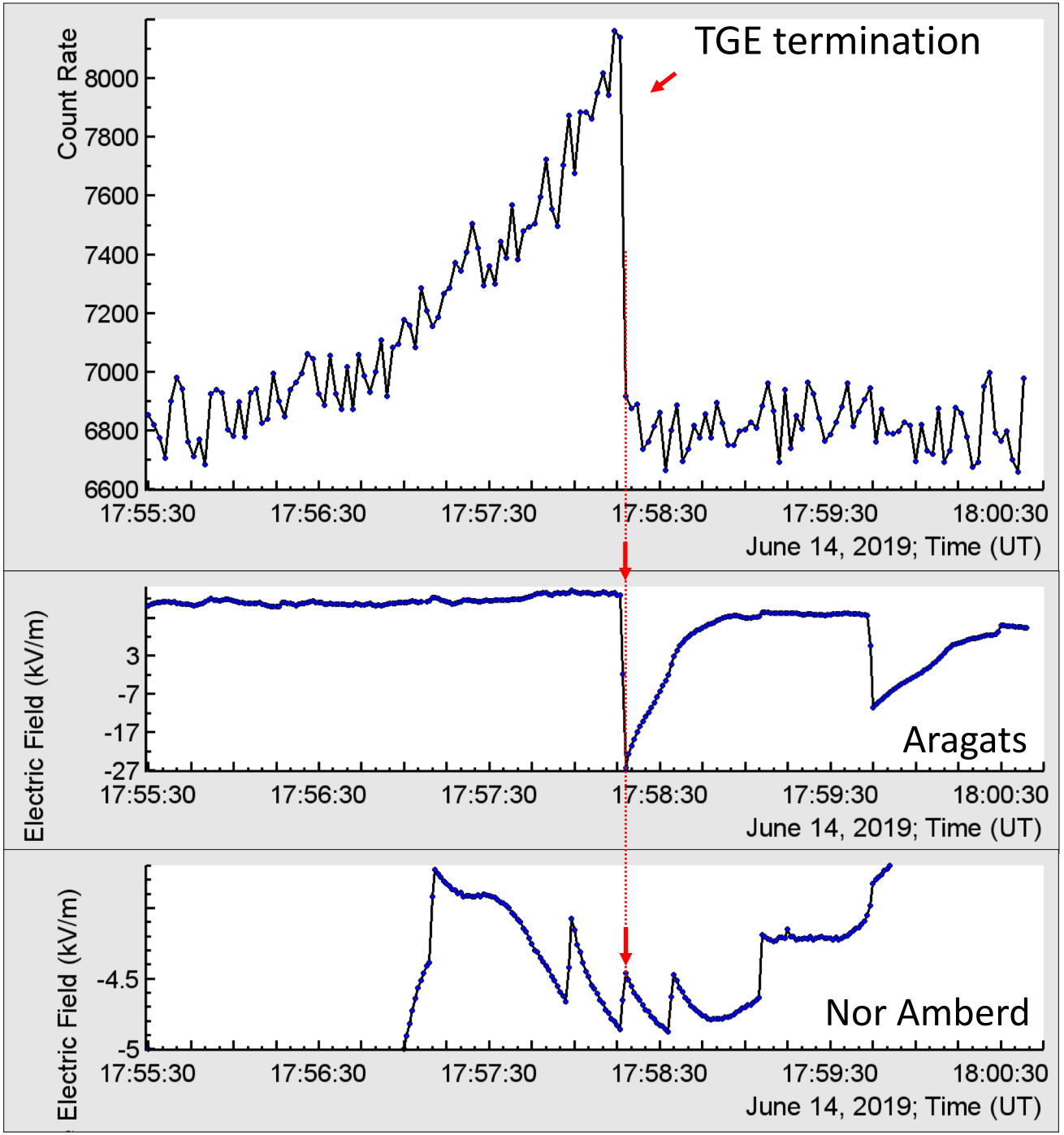
Rectangular sky plot



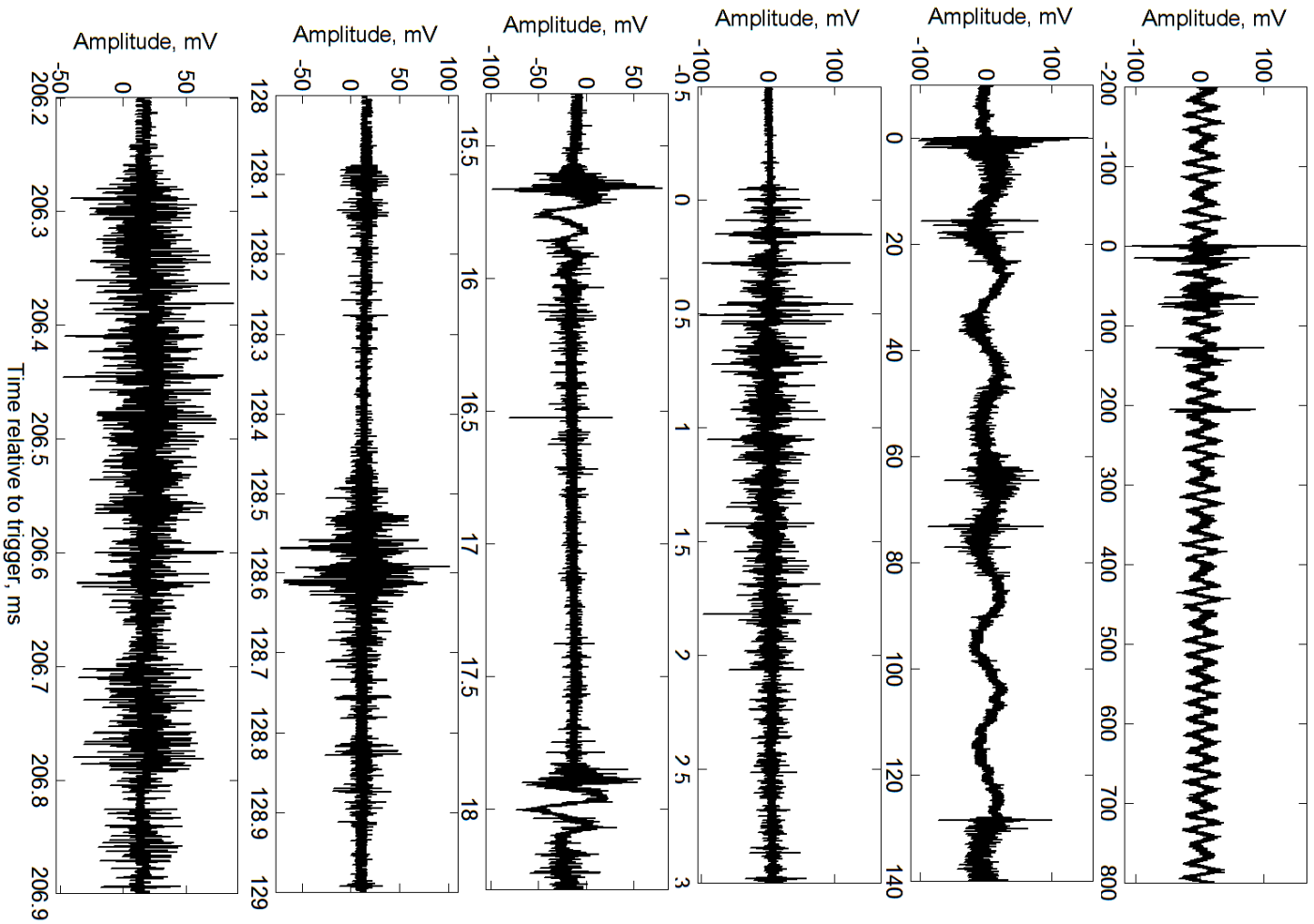
Polar sky plot

June 14,2019, 17:58:17.473
TGE termination by inverted-polarity IC
ASNT detector, coincidence One 60cm-Zero 5cm

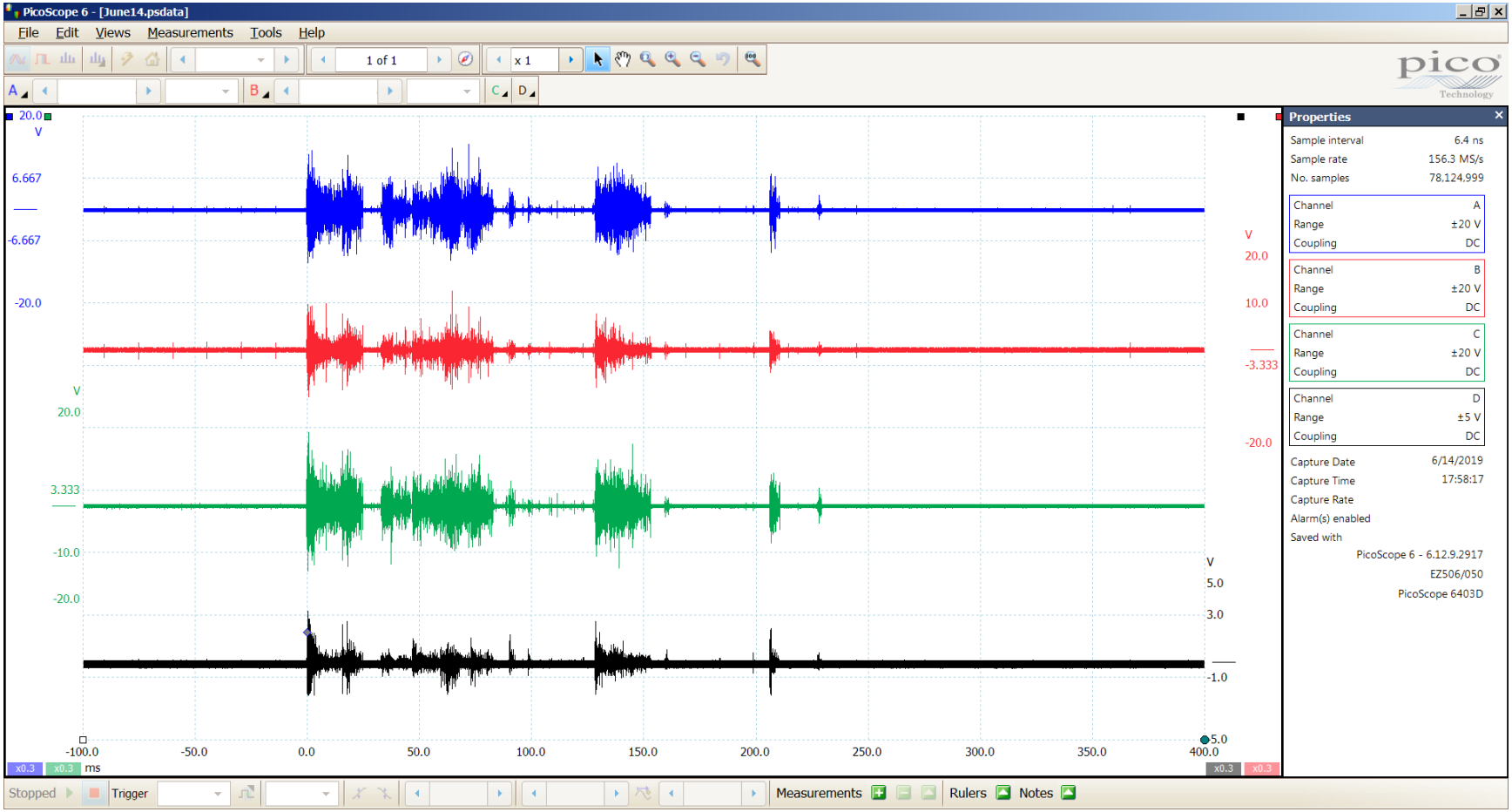
Electrostatic field ΔE change is negative in Aragats and positive in Nor Amberd, that is polarity reversal of ΔE is detected. Larger ΔE corresponding to closer station is negative. Fast electric field record contain only short pulses indicative of cloud discharge. Identification of lightning type: inverted-polarity IC


TGE termination
Count Rate
8000
7800
7600
7400
7200
7000
6800
6600
17:55:30
17:56:30
17:57:30
17:58:30
17:59:30
18:00:30
June 14, 2019; Time (UT)
Electric Field (kV/m)
3
-7
-17
-27
Aragats
17:55:30
17:56:30
17:57:30
17:58:30
17:59:30
18:00:30
June 14, 2019; Time (UT)
Electric Field (kV/m)
-4.5
-5
Nor Amberd
17:55:30
17:56:30
17:57:30
17:58:30
17:59:30
18:00:30
June 14, 2019; Time (UT)

June 14, 2019 17:58:17.473 Picoscope N3 MAKET



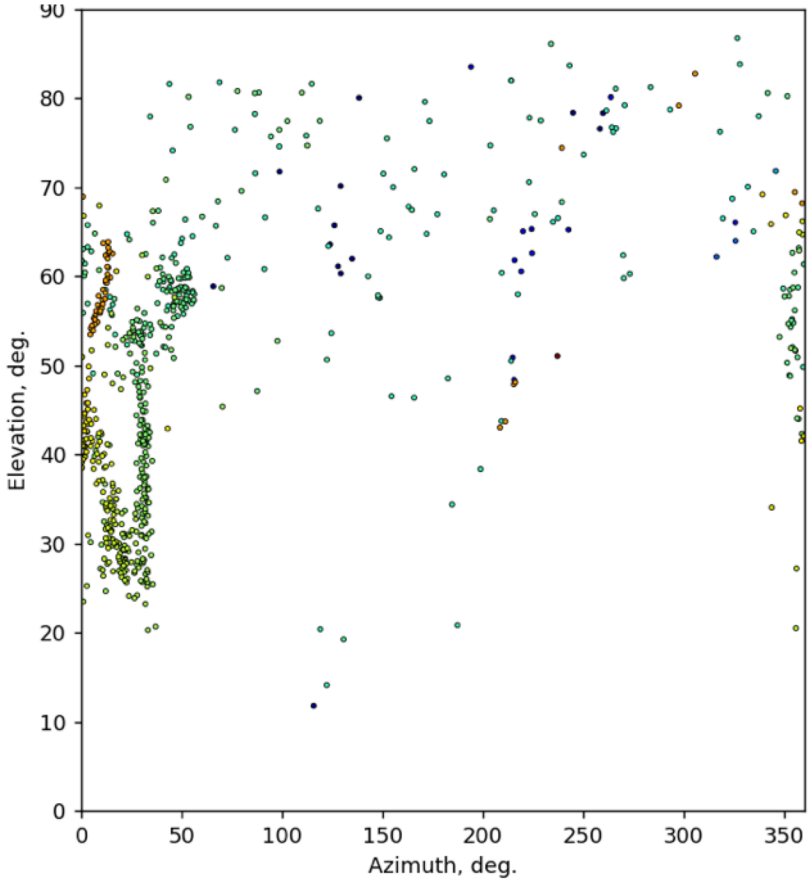
June 14, 2019, 17:58:17.473
TGE termination



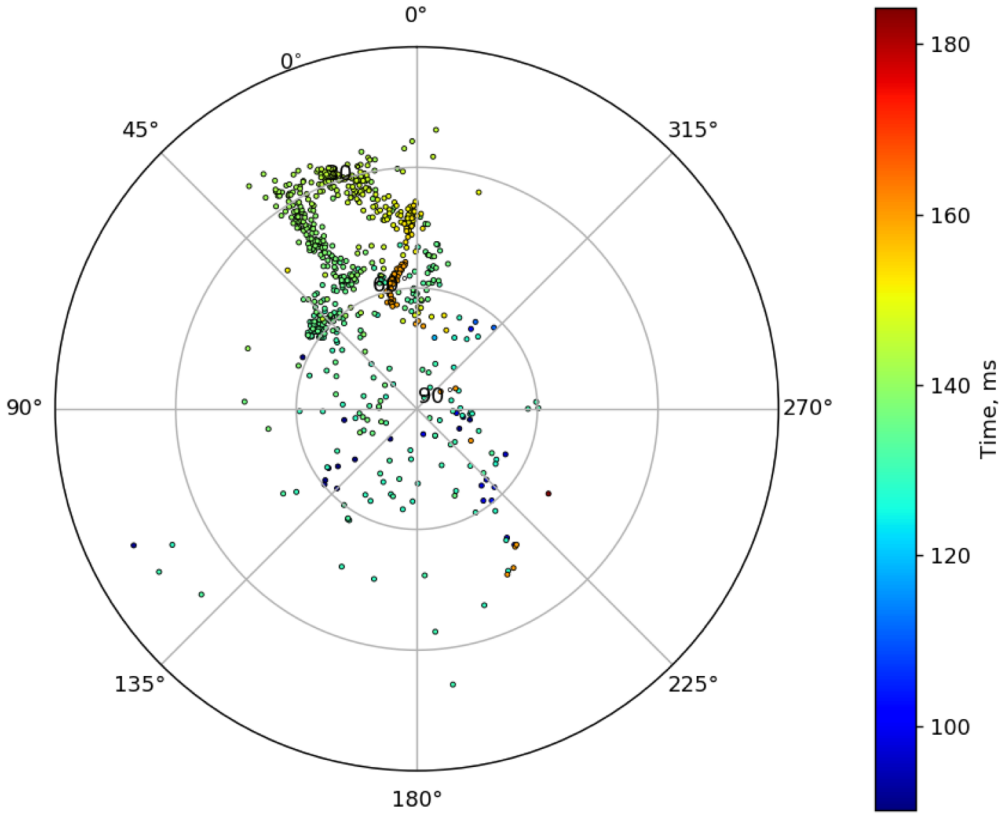
June 14, 2019, 17:58:17.473
Inverted IC flash detected by interferometer

Time window: from 90 ms to 190 ms after trigger

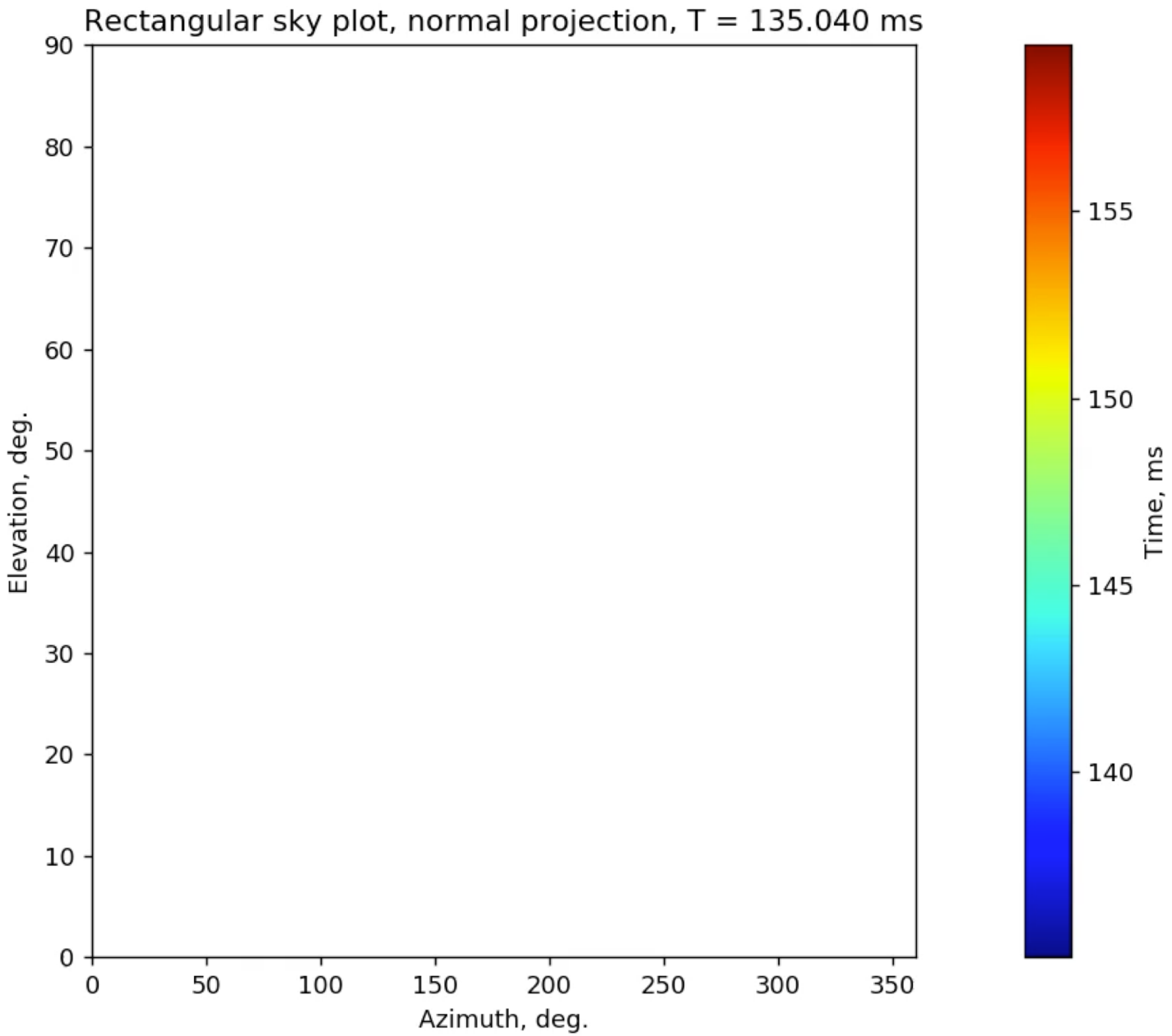
Color indicates time



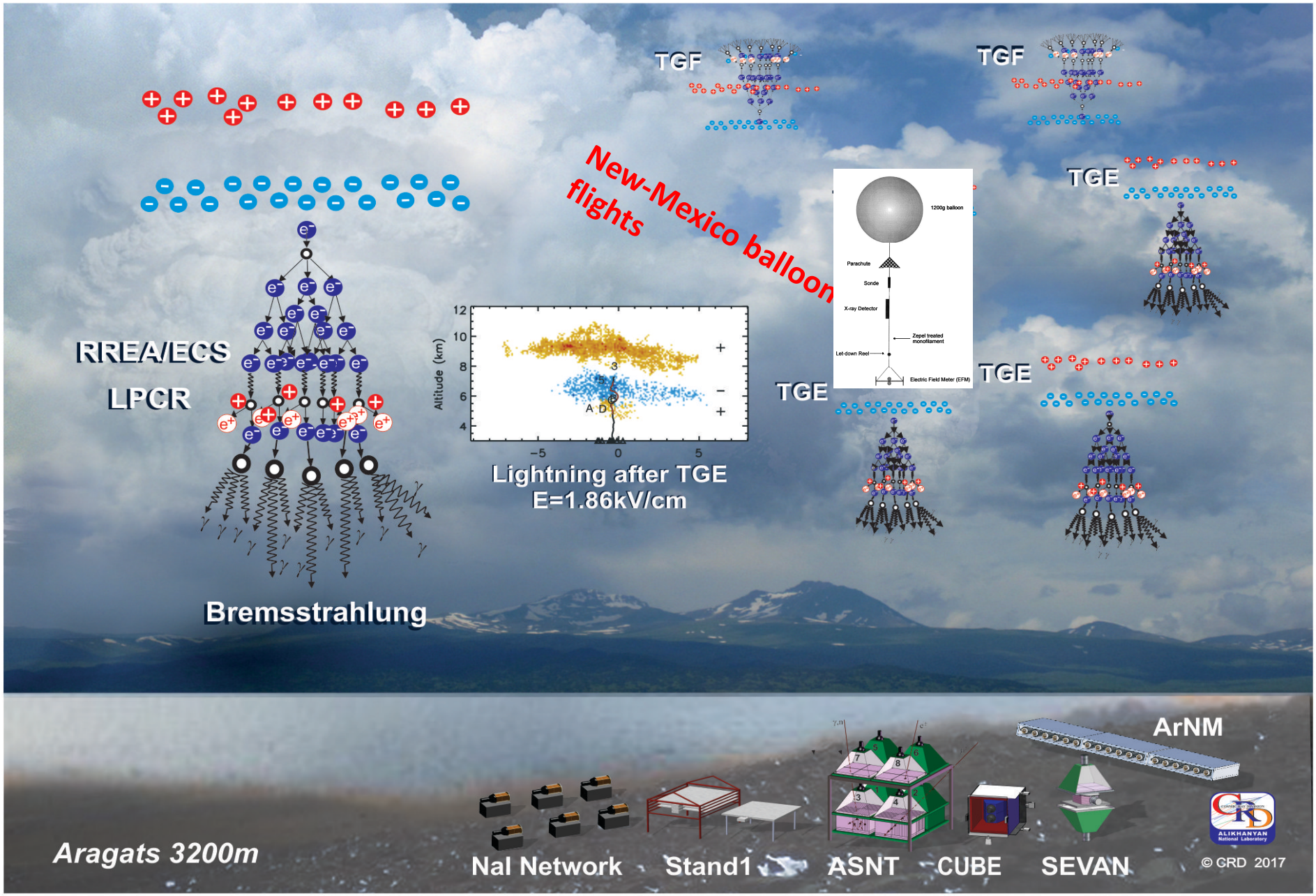
Rectangular sky plot



Polar sky plot


Rectangular sky plot, normal projection, T = 135.040 ms
Elevation, deg.
Azimuth, deg.
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
Time, ms
140
145
150
155

Only small fraction of RB/RREA become TGE, but many random emerging radiating regions in the cloud give raise to ionization and open path to the lightning leaders!



Nor Amberd International Conference Center

TEPA-2019

GENERAL INFORMATION:

TIME: October 14-17, 2019

LOCATION: Nor Amberd International Conference Centre of the Yerevan Physics Institute, Byurakan, Aragatsotn Province, Armenia.

SYMPOSIUM WEBSITE:

http://www.crd.yerphi.am/TEPA_2019