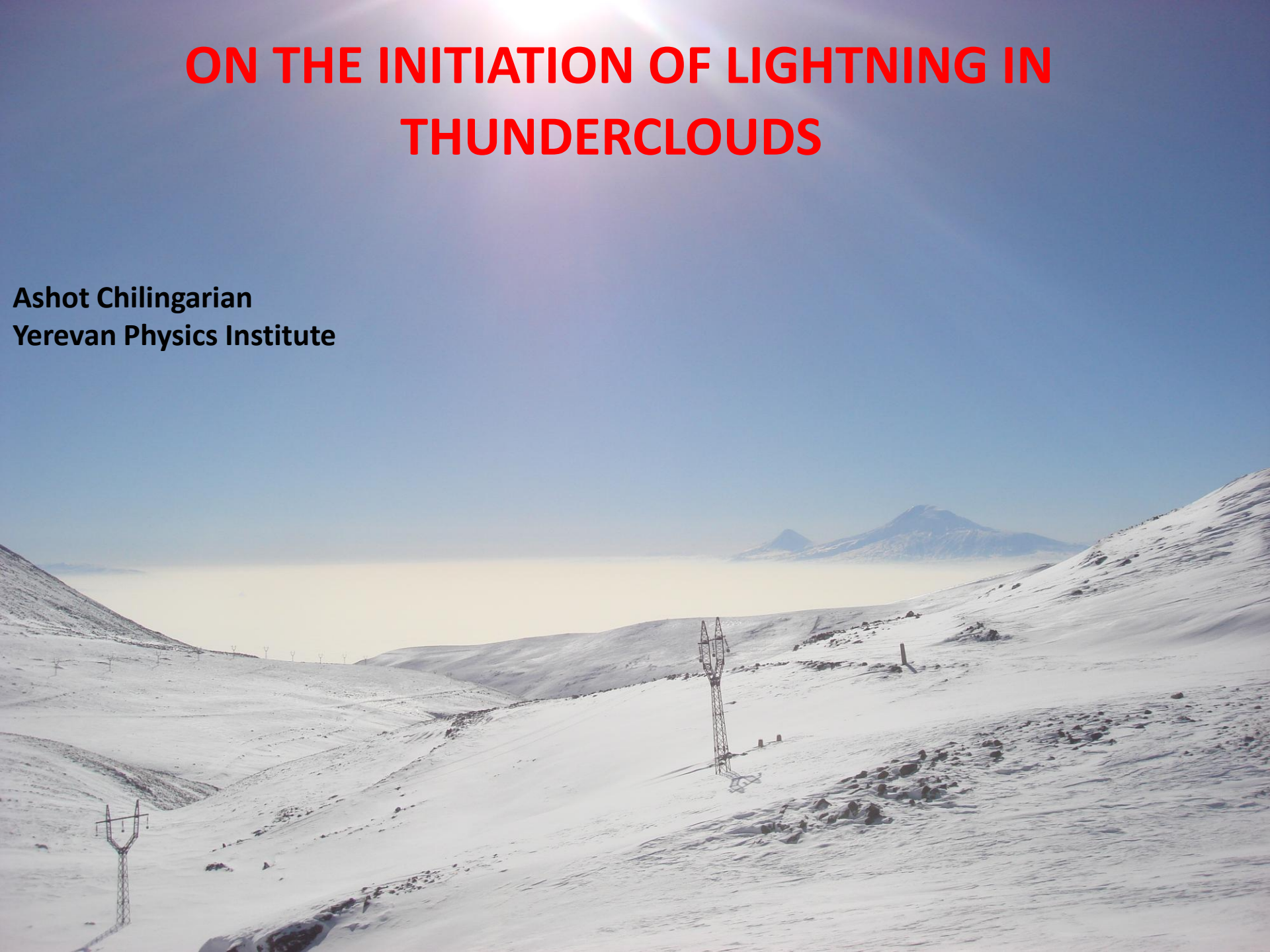
ON THE INITIATION OF LIGHTNING IN THUNDERCLOUDS

Ashot Chilingarian
Yerevan Physics Institute

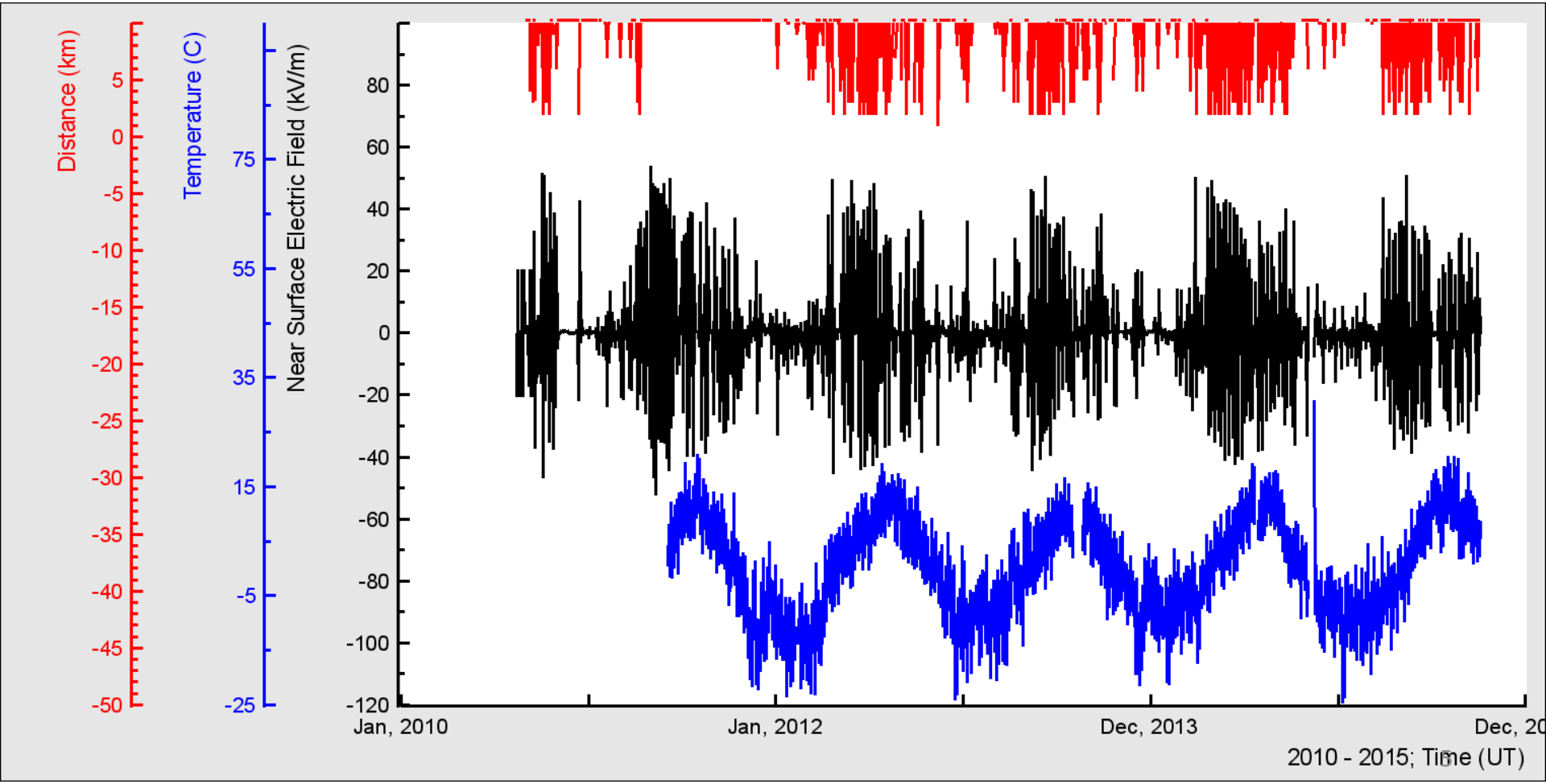


May 4 2016

Road to Aragats opened: ASEC Engineer Samvel Parsamyan 1.75 m height

Aragats staff changing scintillator of STAND1 detector near SKL experimental hall

Lightnings are common on Aragats



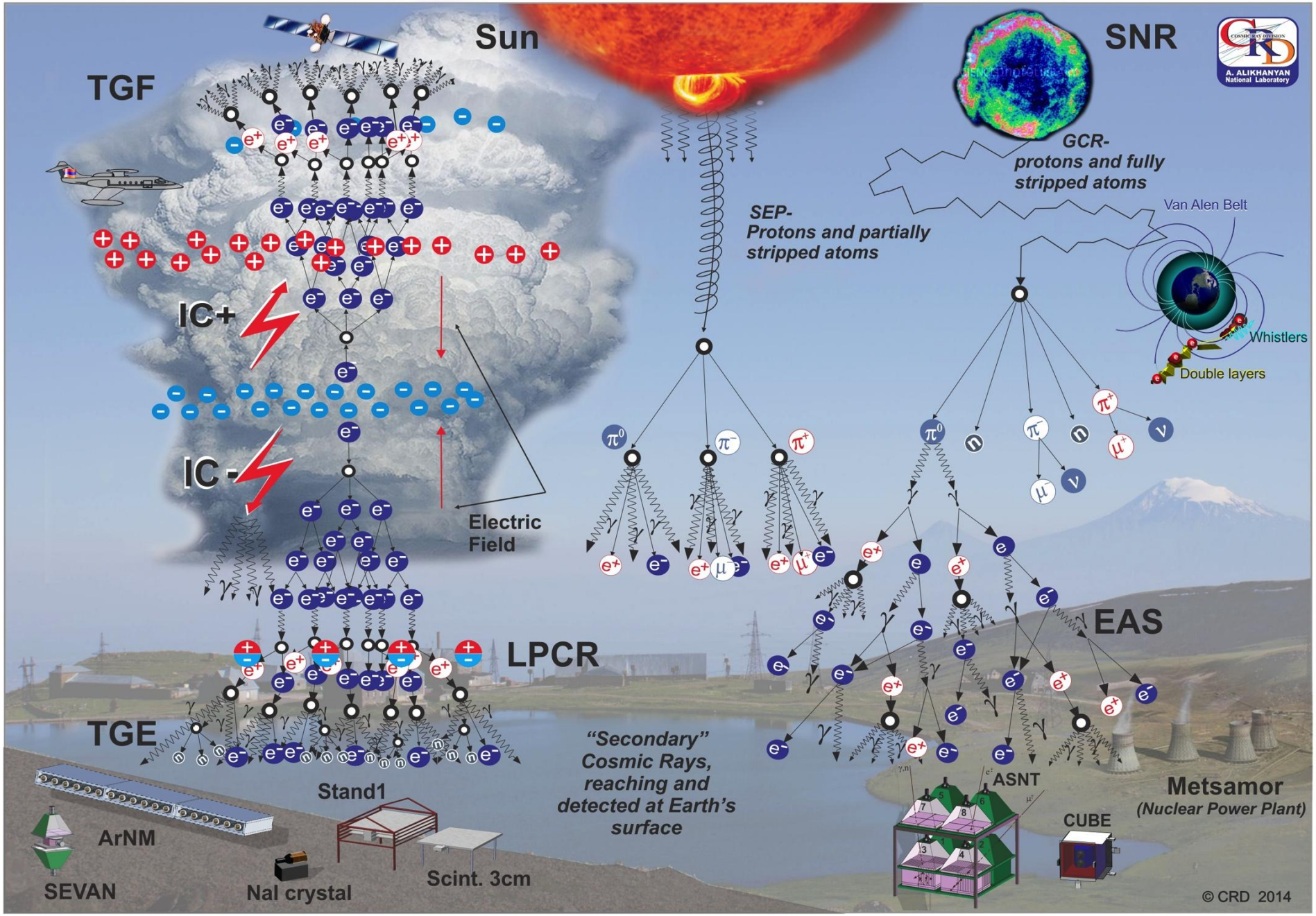

Aragats 2015/06/03 15:30:53
Aragats CAMERA 1
2015-06-03
15:30:55-04


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

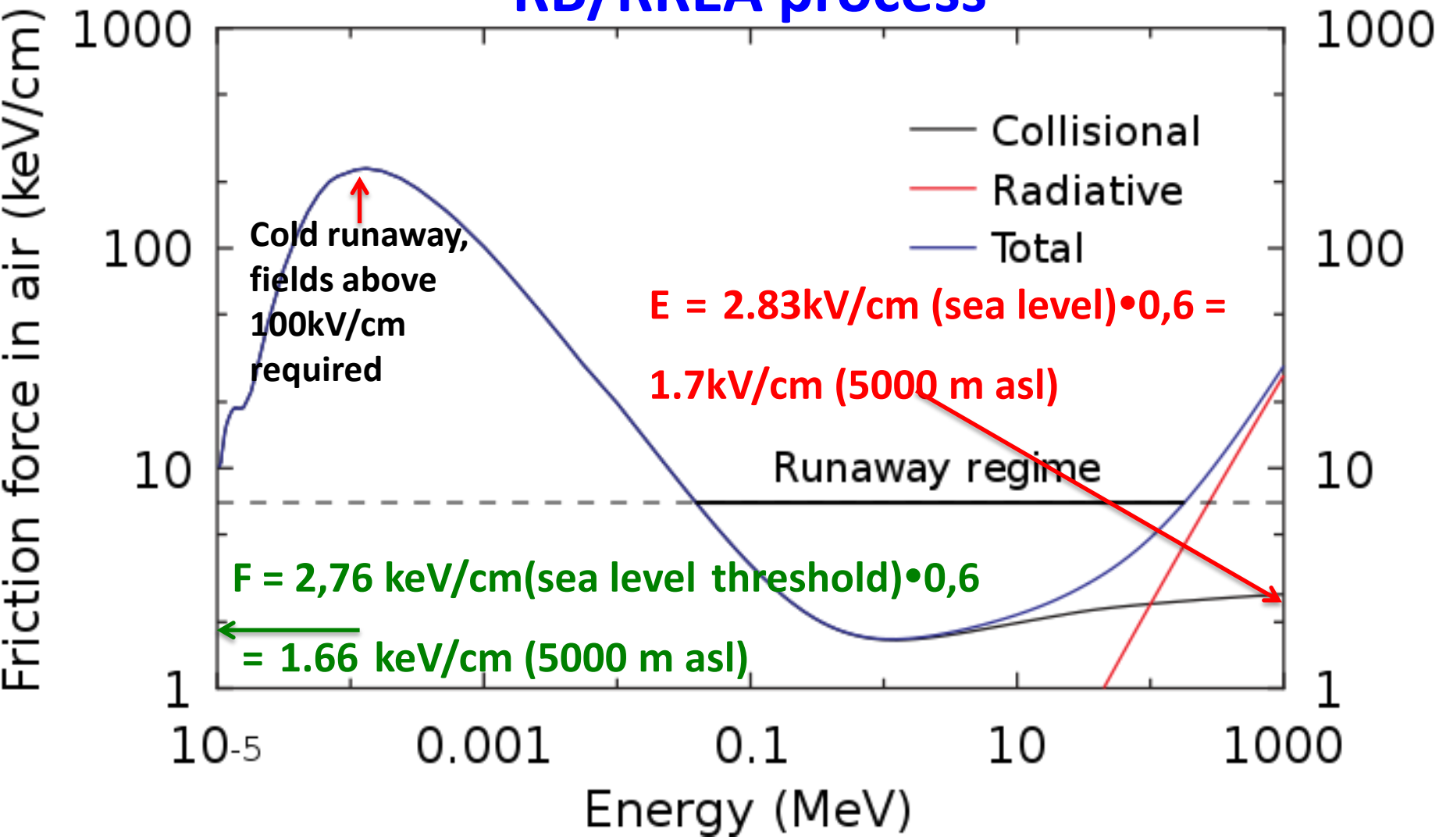

Aragats 2015/06/03 15:35:05
Aragats CAMERA 1
2015-06-03
15:35:07-03


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

Origin of Secondary Cosmic Rays

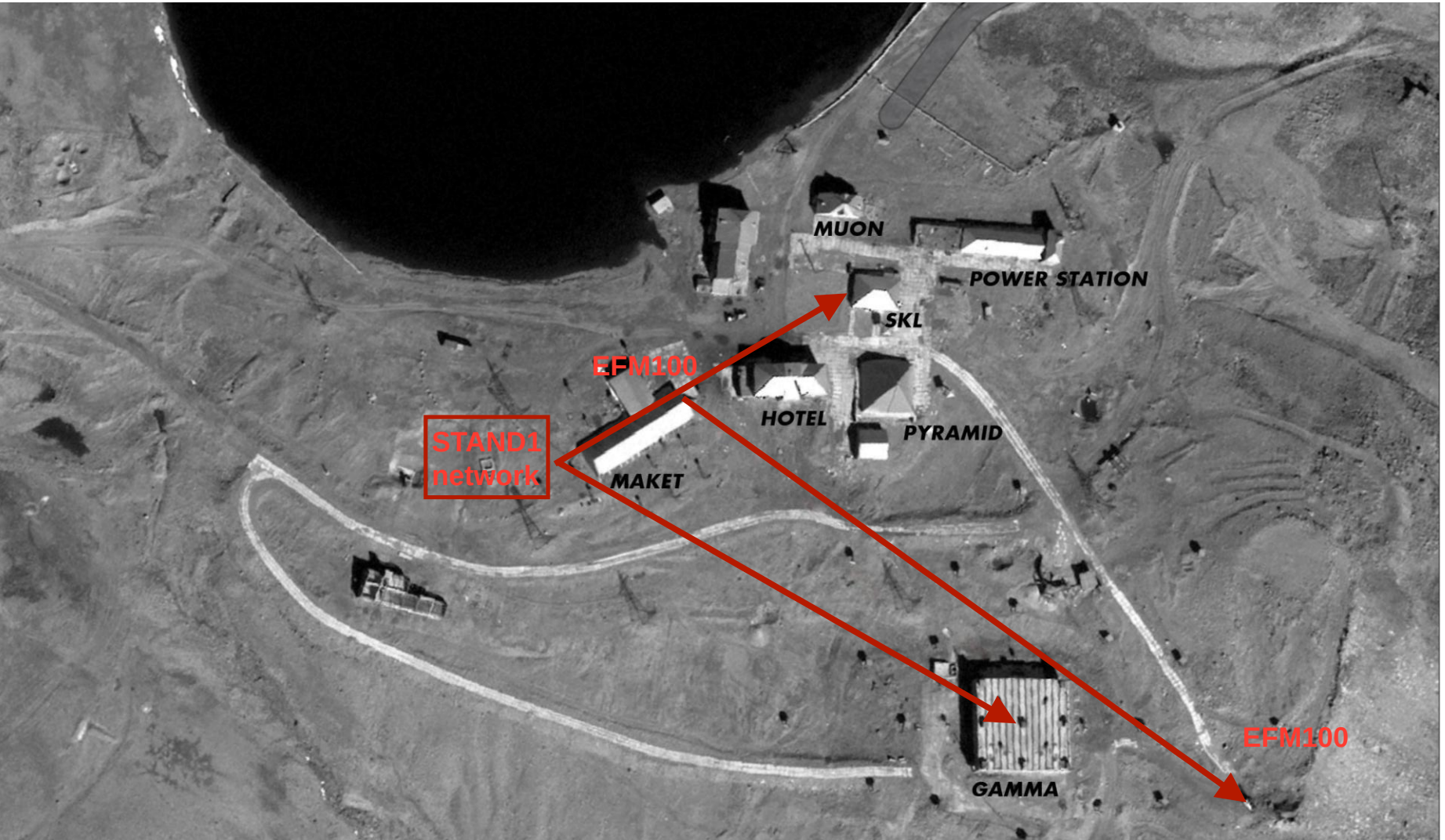


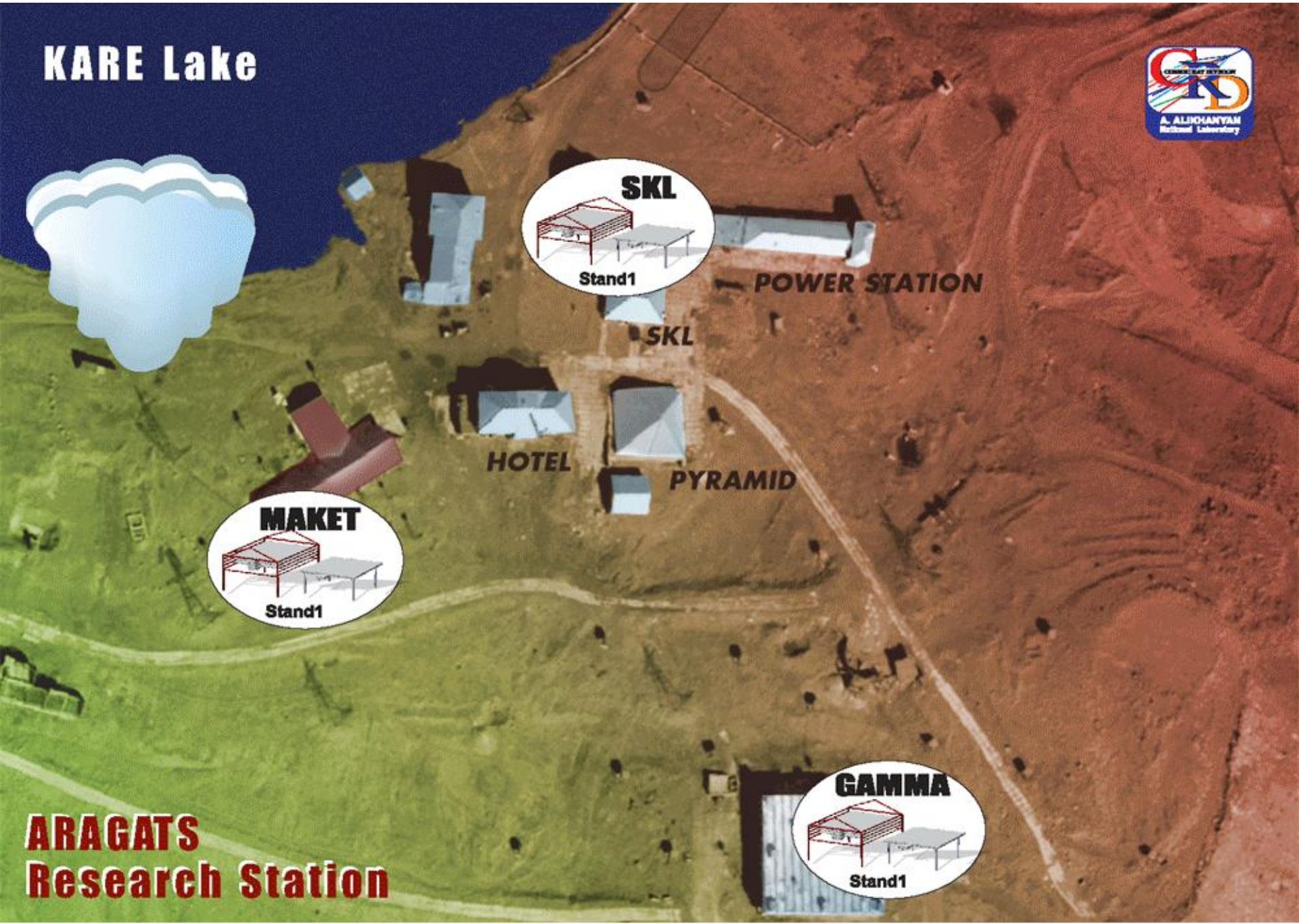
Electron energy losses in the atmosphere and energy gain from the intracloud electric field: RB/RREA process



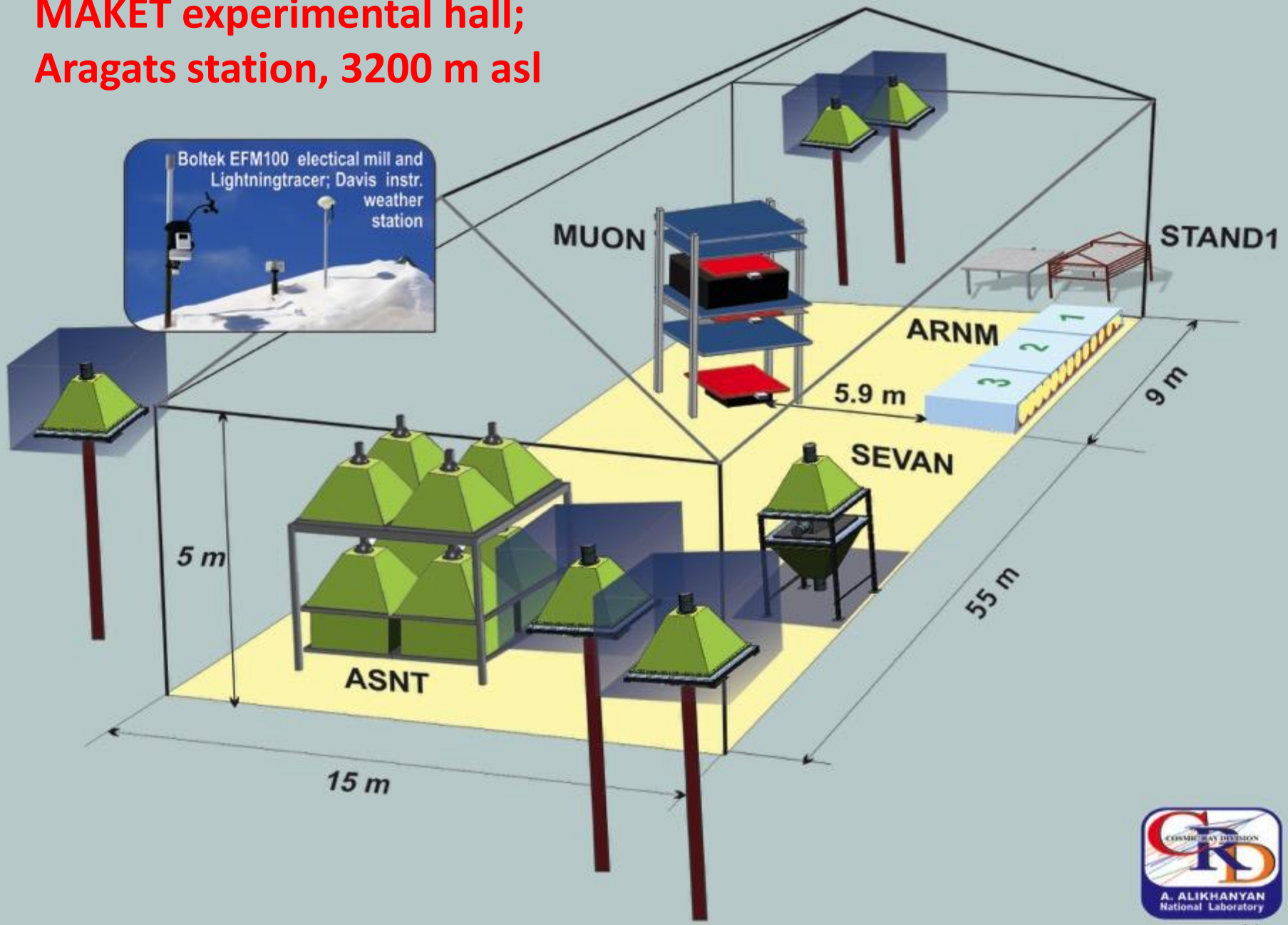
Gurevich et al., (1992), Symbalisty et al. (1998), Babich et al. (1998), Dwyer (2003), Chilingarian (2014)

Particle detector and electric mill networks comprise stacked STAND1 detectors and Boltek's EFM-100 sensors



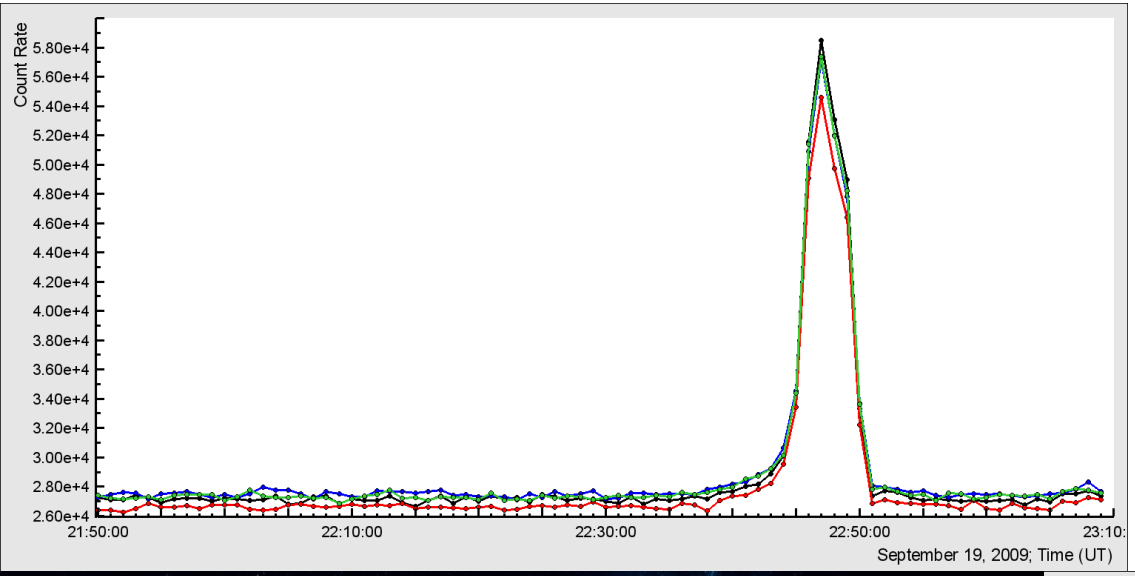

KARE Lake
SKL
Stand1
POWER STATION
SKL
HOTEL
PYRAMID
MAKET
Stand1
GAMMA
Stand1
ARAGATS
Research Station

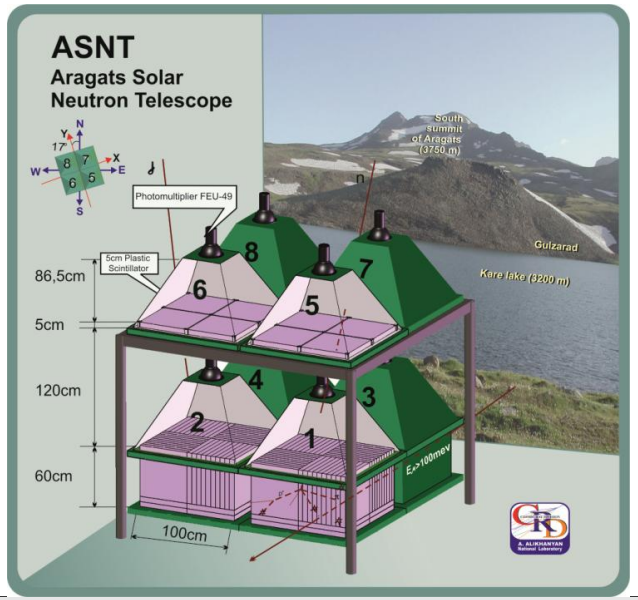
MAKET experimental hall;
Aragats station, 3200 m asl

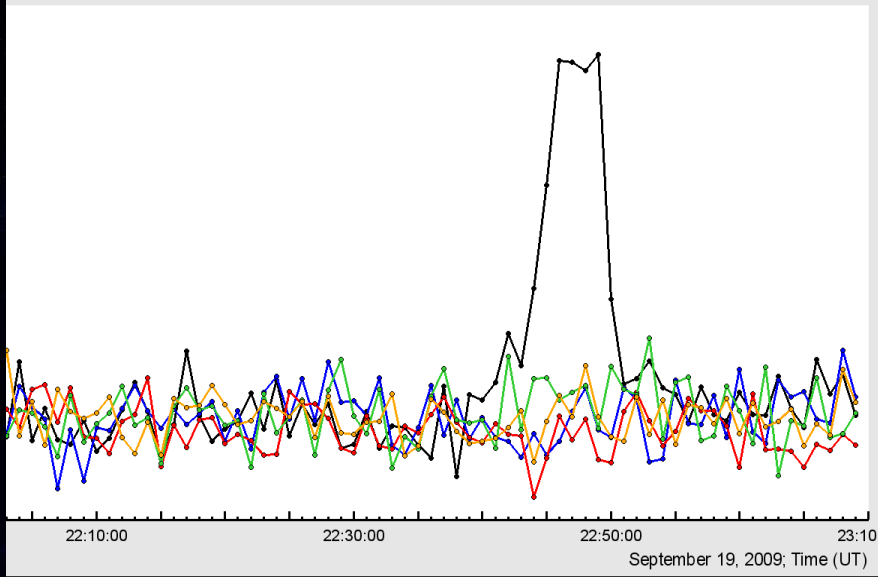


A. ALIKHANYAN National Laboratory

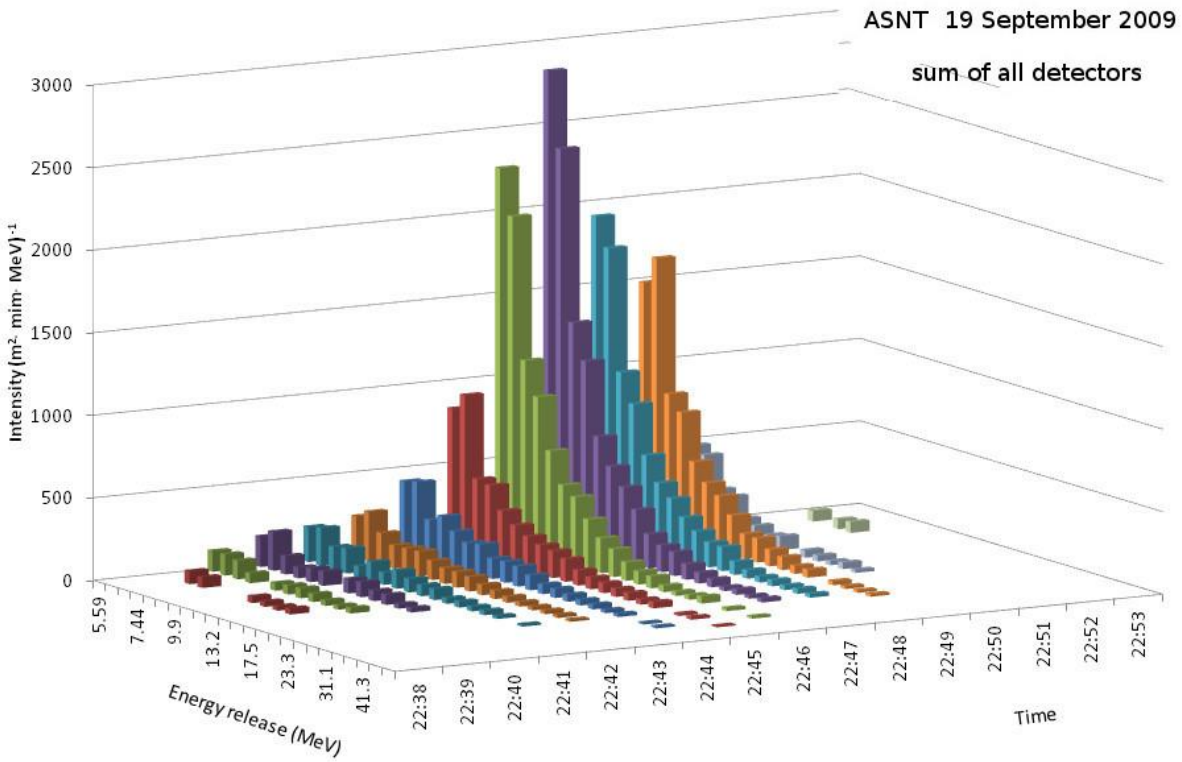
We continuously measure time-series of particle fluxes and their coincidences. Peaks in time series are the periods of enhanced fluxes – Thunderstorm Ground Enhancements – TGEs. ASNT detector data prove the Near-Vertical flux of electrons and gamma rays

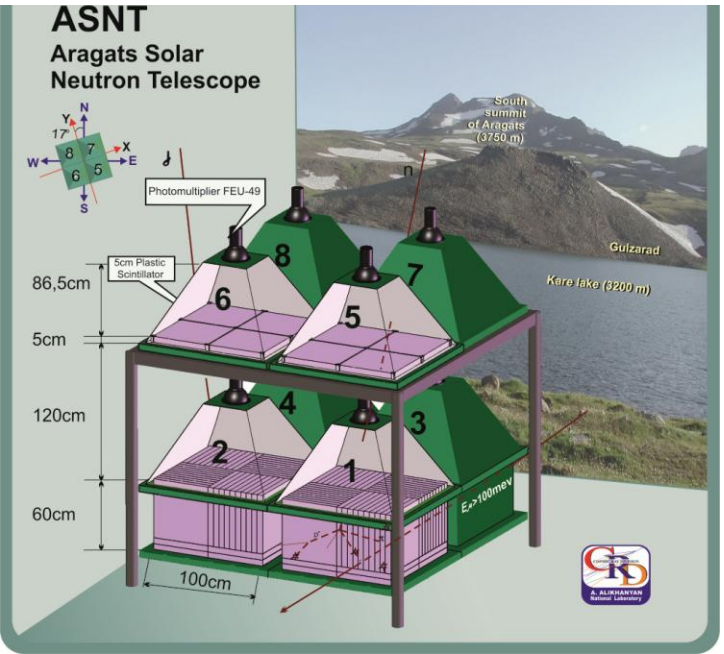


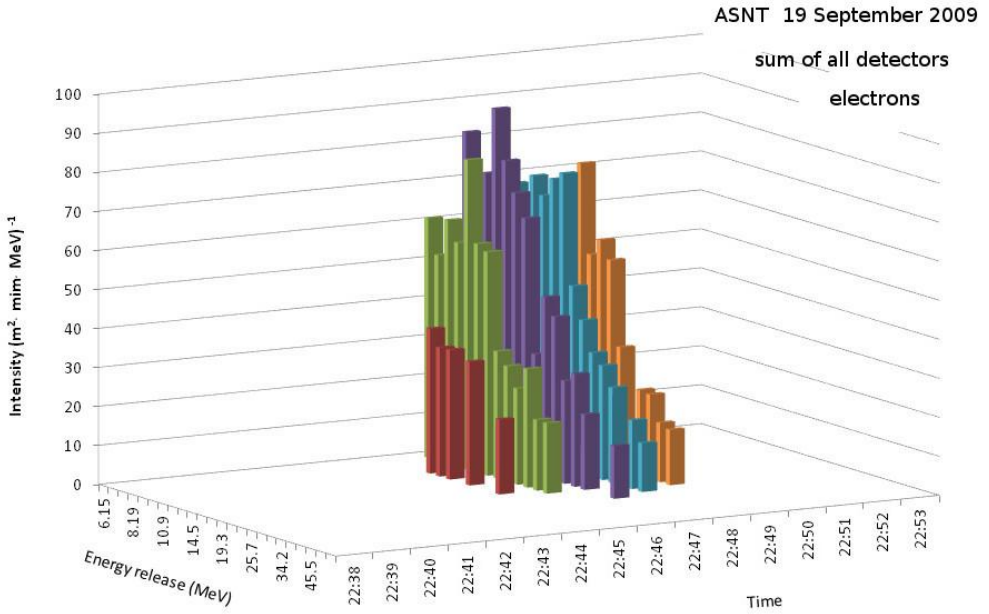


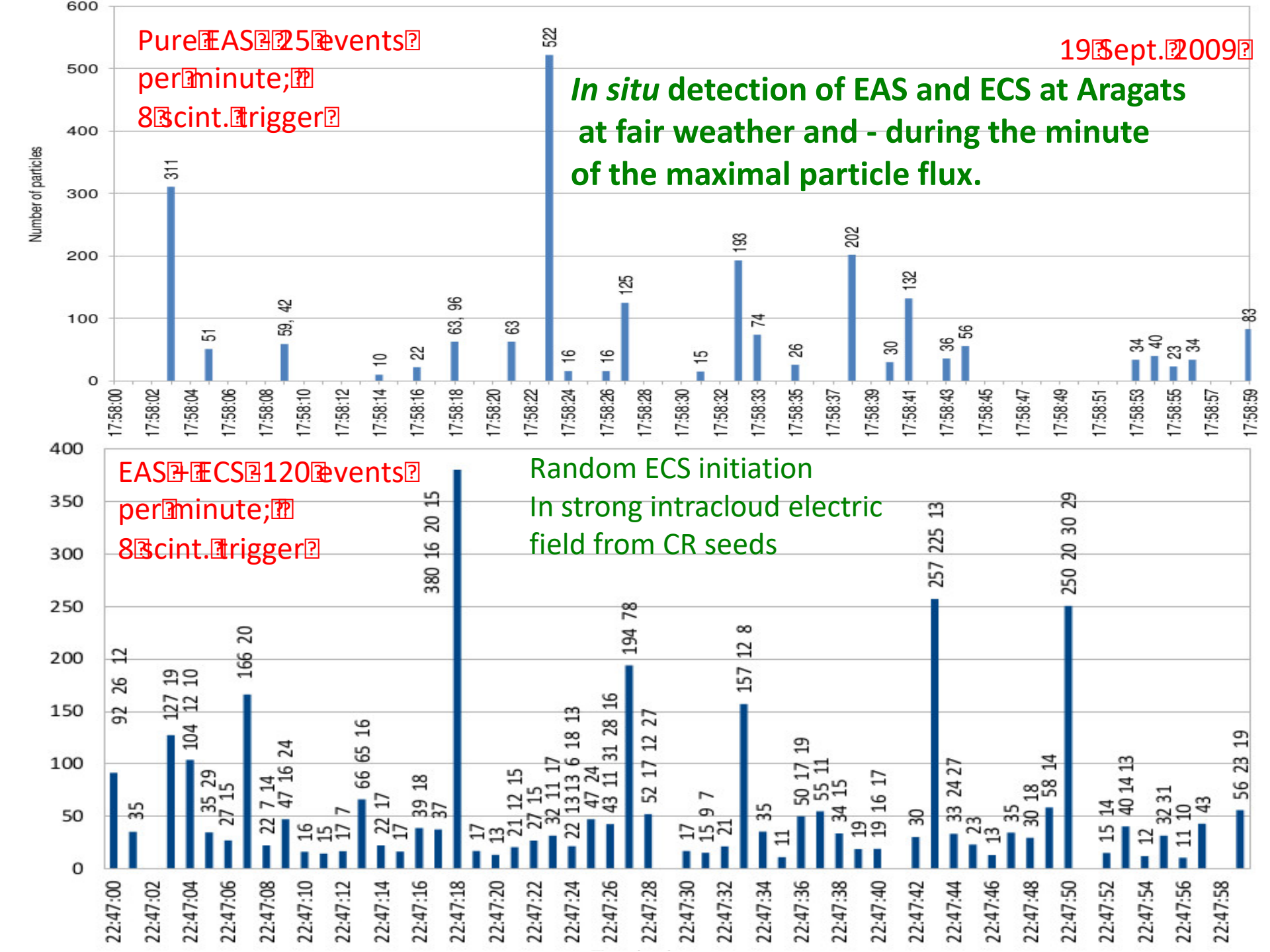


First Detection of the gamma ray and electron energy release spectra: largest TGE on 19 September 2009

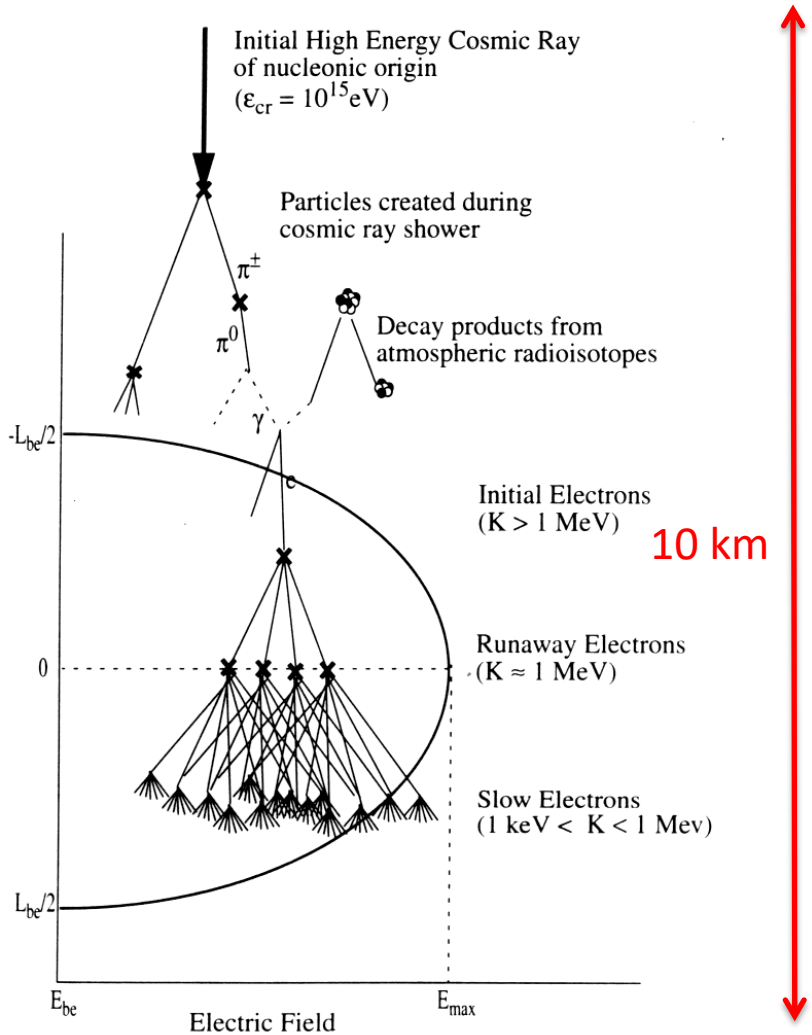


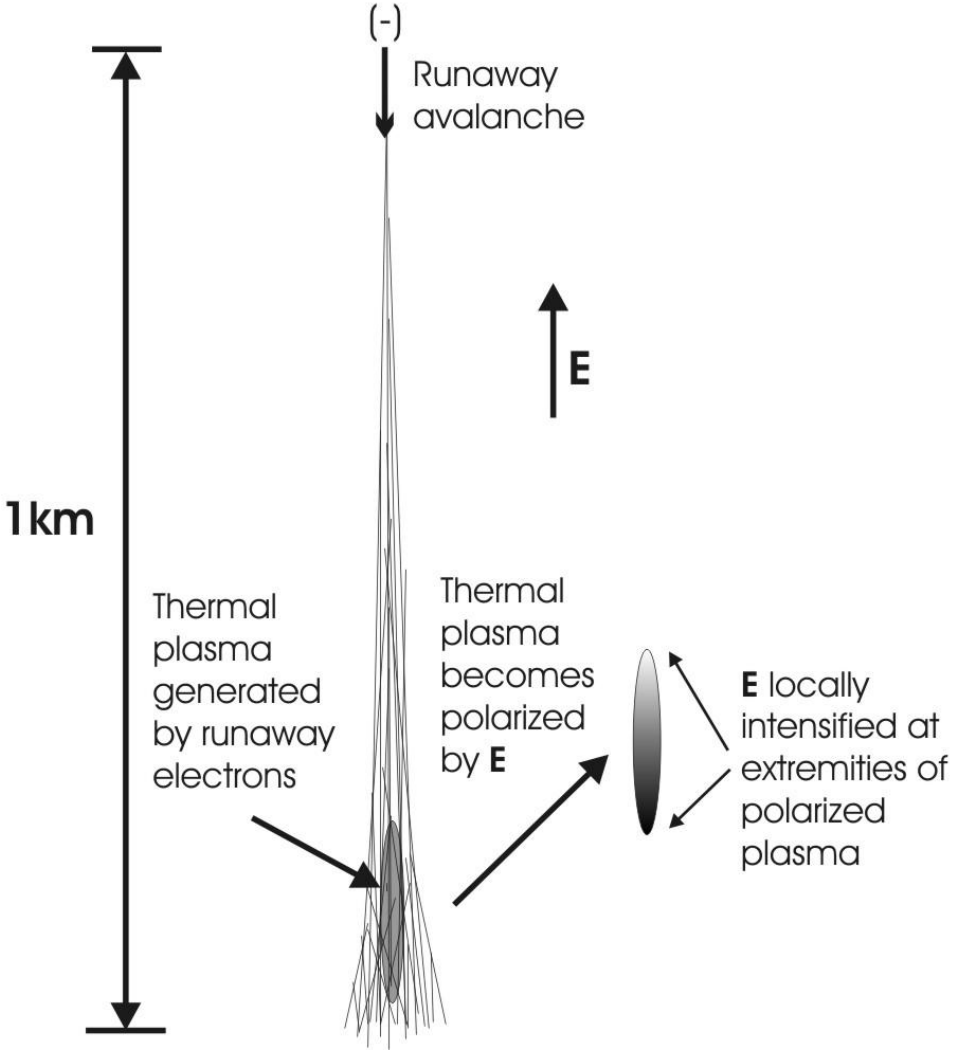




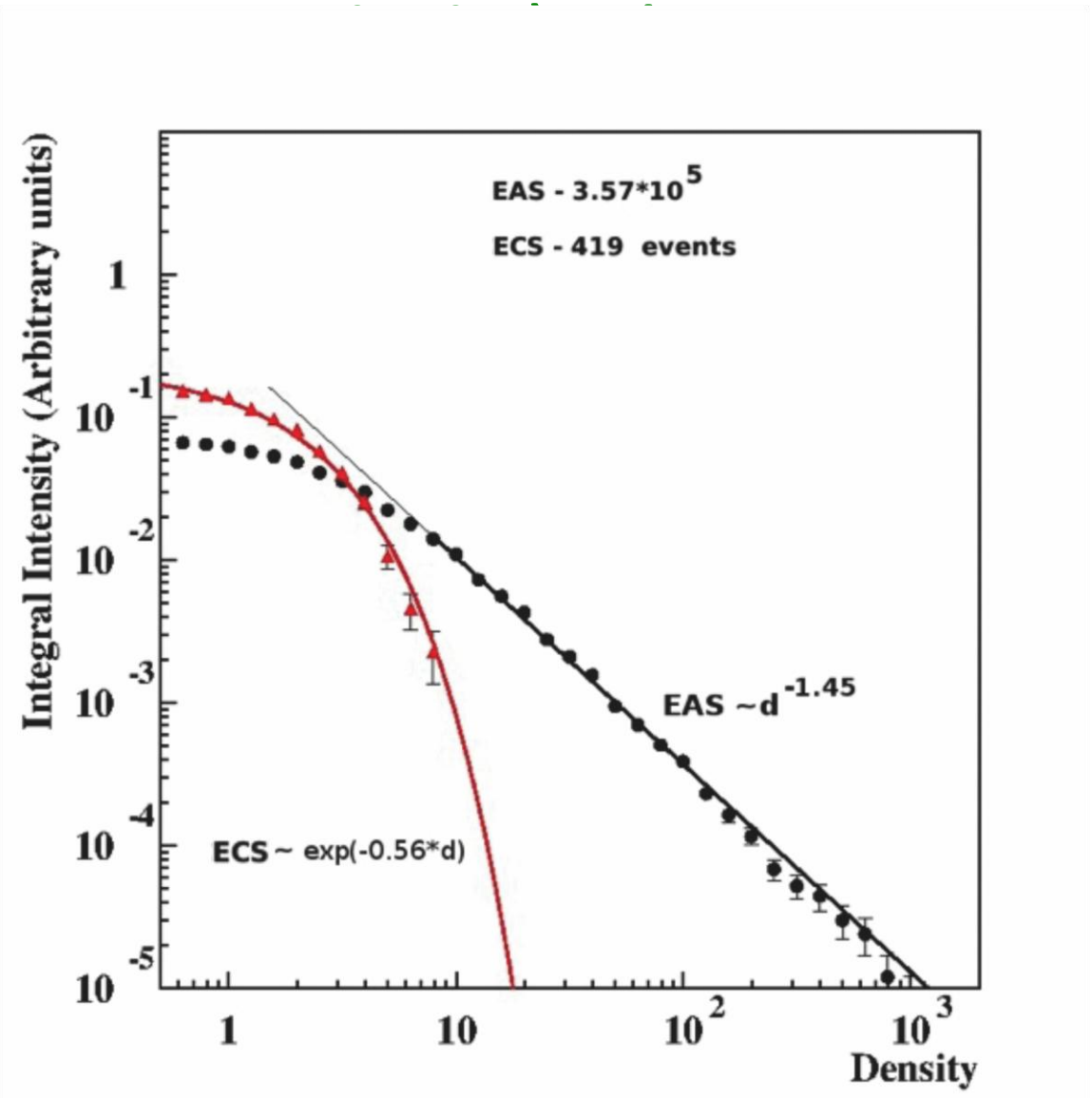

Pure EAS – 25 events per minute; 8 scint. trigger
19 Sept. 2009
In situ detection of EAS and ECS at Aragats at fair weather and - during the minute of the maximal particle flux.
Number of particles
EAS + ECS – 120 events per minute; 8 scint. trigger
Random ECS initiation
In strong intracloud electric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

ECS and EAS

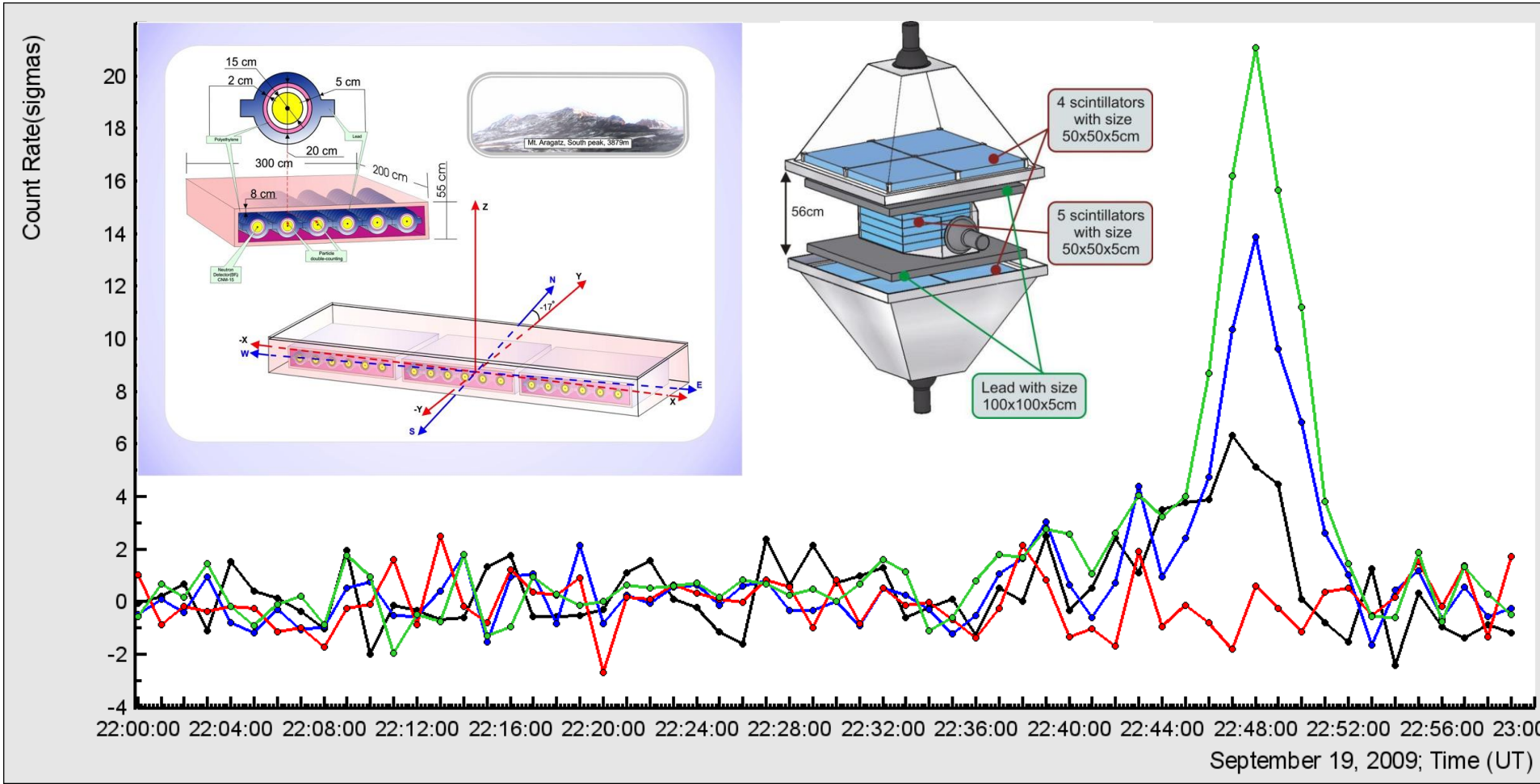

Initial High Energy Cosmic Ray
of nucleonic origin
($\varepsilon_{cr} = 10^{15}$eV)
Particles created during
cosmic ray shower
$\pi^{\pm}$
π^0
Decay products from
atmospheric radioisotopes
γ
e
Initial Electrons
(K > 1 MeV)
Runaway Electrons
(K ≈ 1 MeV)
Slow Electrons
(1 keV < K < 1 Mev)
$-L_{be}/2$
0
$L_{be}/2$
E_{be}
E_{max}
Electric Field
10 km


(-)
Runaway
avalanche
E
1km
Thermal
plasma
generated
by runaway
electrons
Thermal
plasma
becomes
polarized
by E
E locally
intensified at
extremities of
polarized
plasma

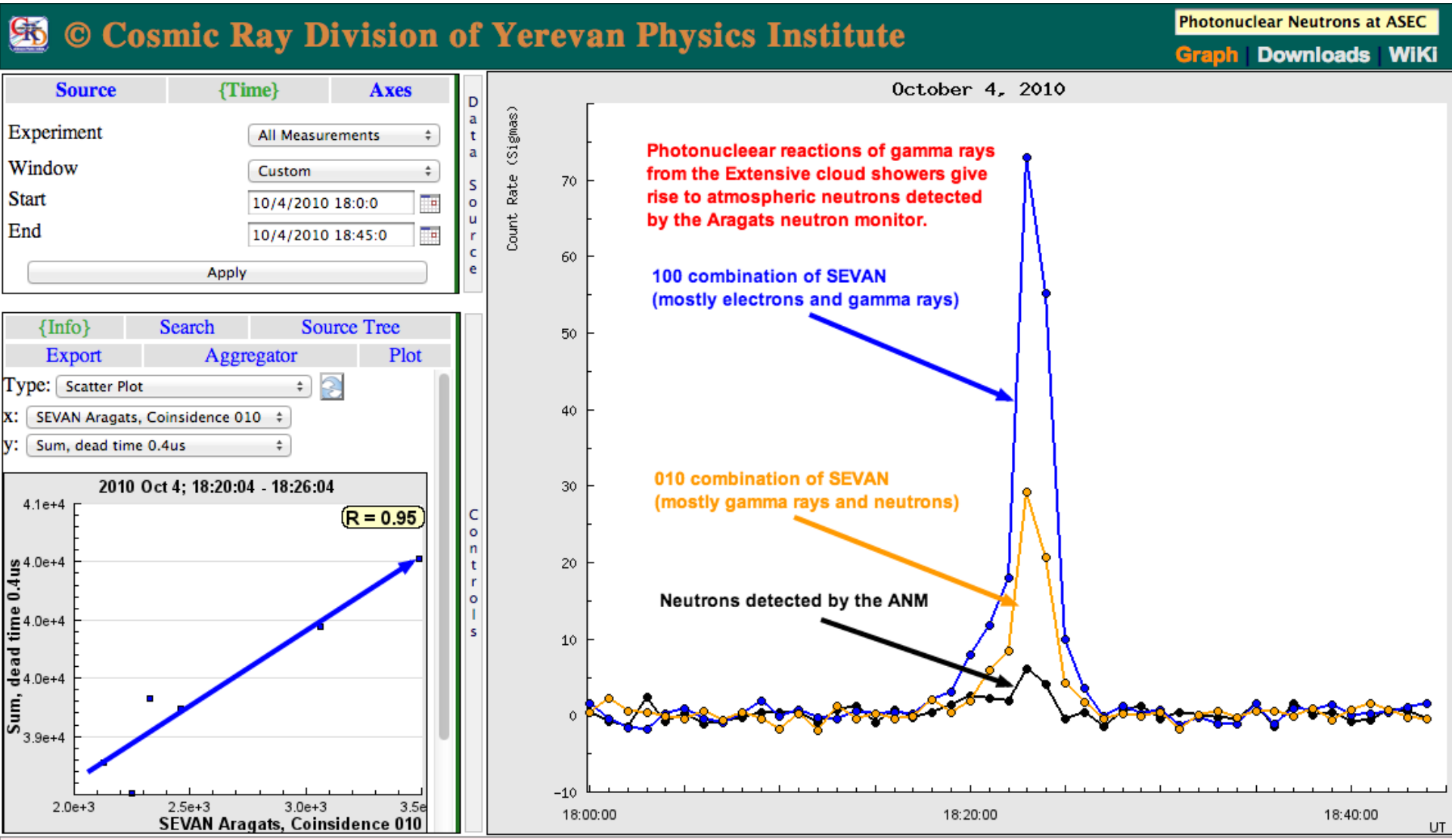
Extensive cloud showers (ECSs, or MRBs, or inverse TGFs or gamma ray bursts) are systematically different from Extensive air showers (EASs). Density spectra of 2 classes: ECS (with ~20% EAS

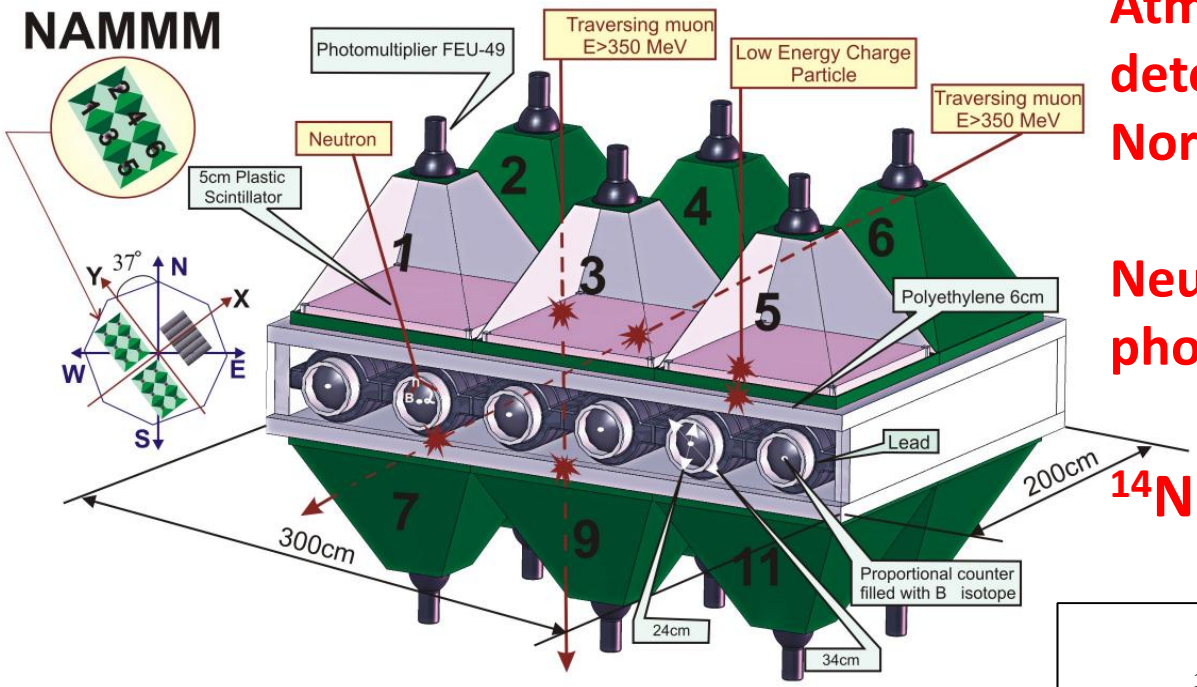


Neutron Detection in TGE: photonuclear reaction in the atmosphere and in the lead: ArNM and SEVAN evidence



Neutrons from photonuclear reactions

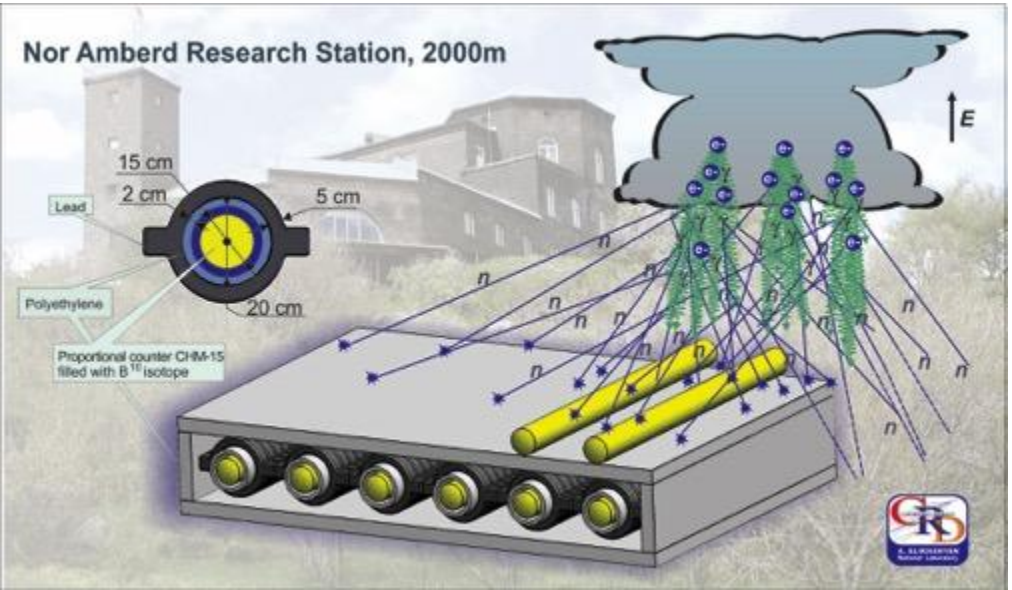


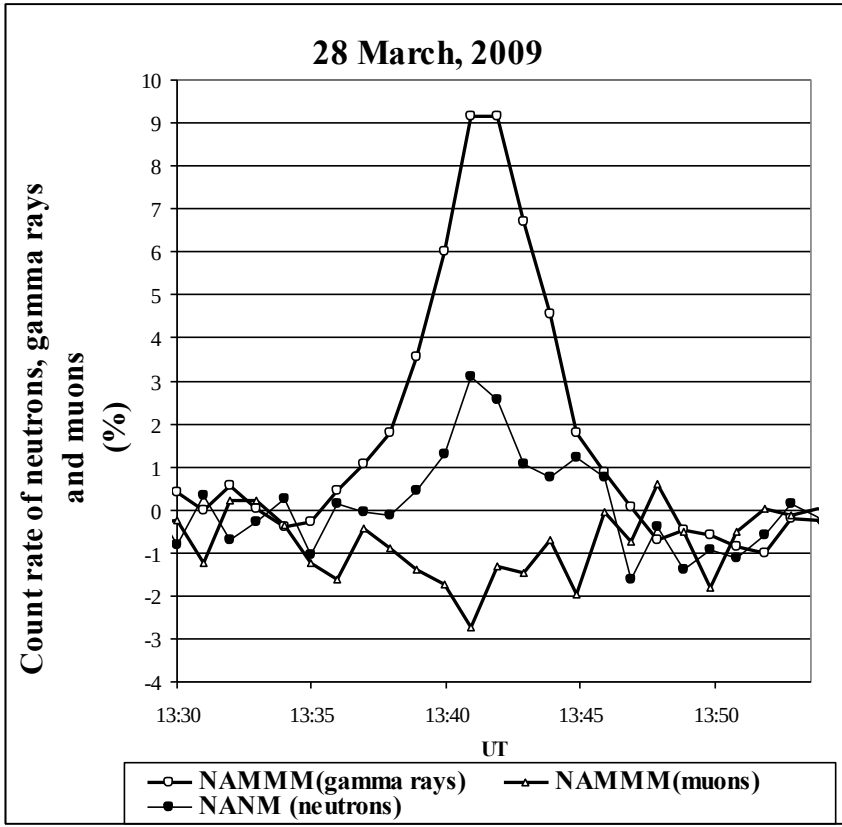


Atmosphérique neutron detection in Nor Amberd 2000 m asl

Neutrons born in the photonuclear reactions

$^{14}N(\gamma,n)\,^{13}N$

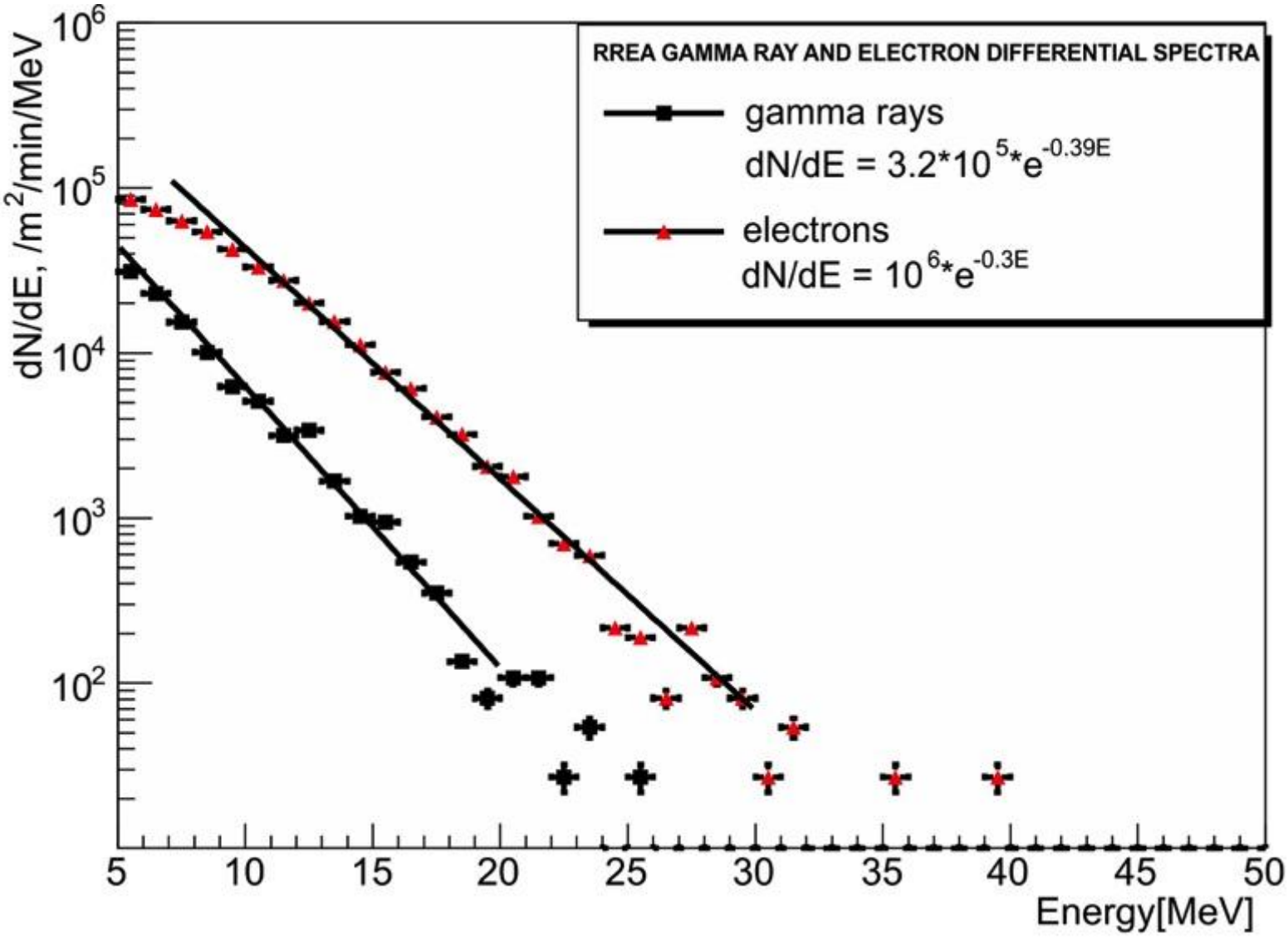




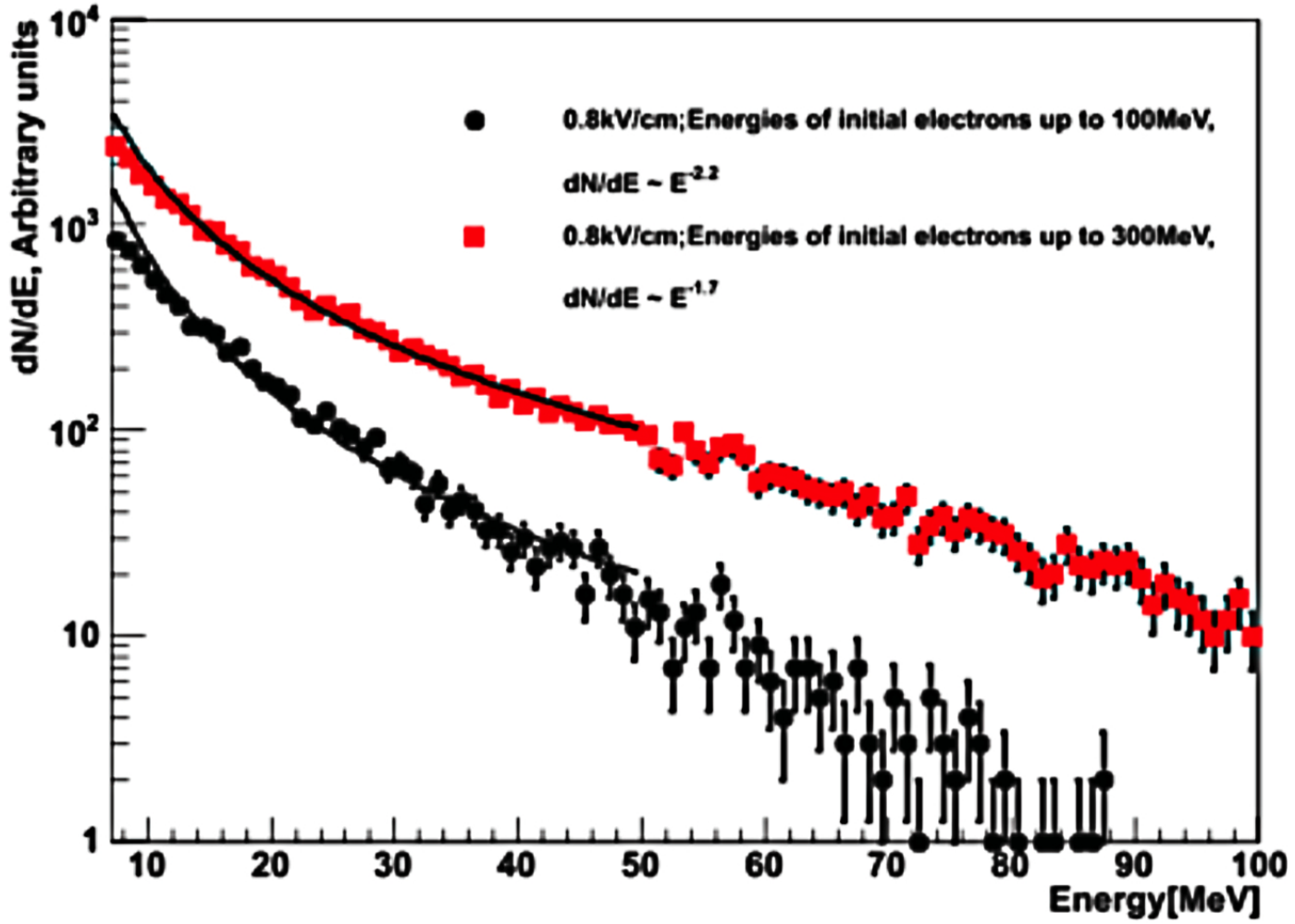
GEANT4 simple simulation

- Uniform electric field above Aragats from 5000m down until 3400- 3200 m, field strength varied 0.8 -2 kV/cm;
- Seed particles – Cosmic Ray electrons generated by EXPACS WEB-calculator (PARMA model), energies 0.1 -300 MeV;
- Thinning of atmosphere with height was introduced as well;
- All electromagnetic processes in GEANT4 were switched on.

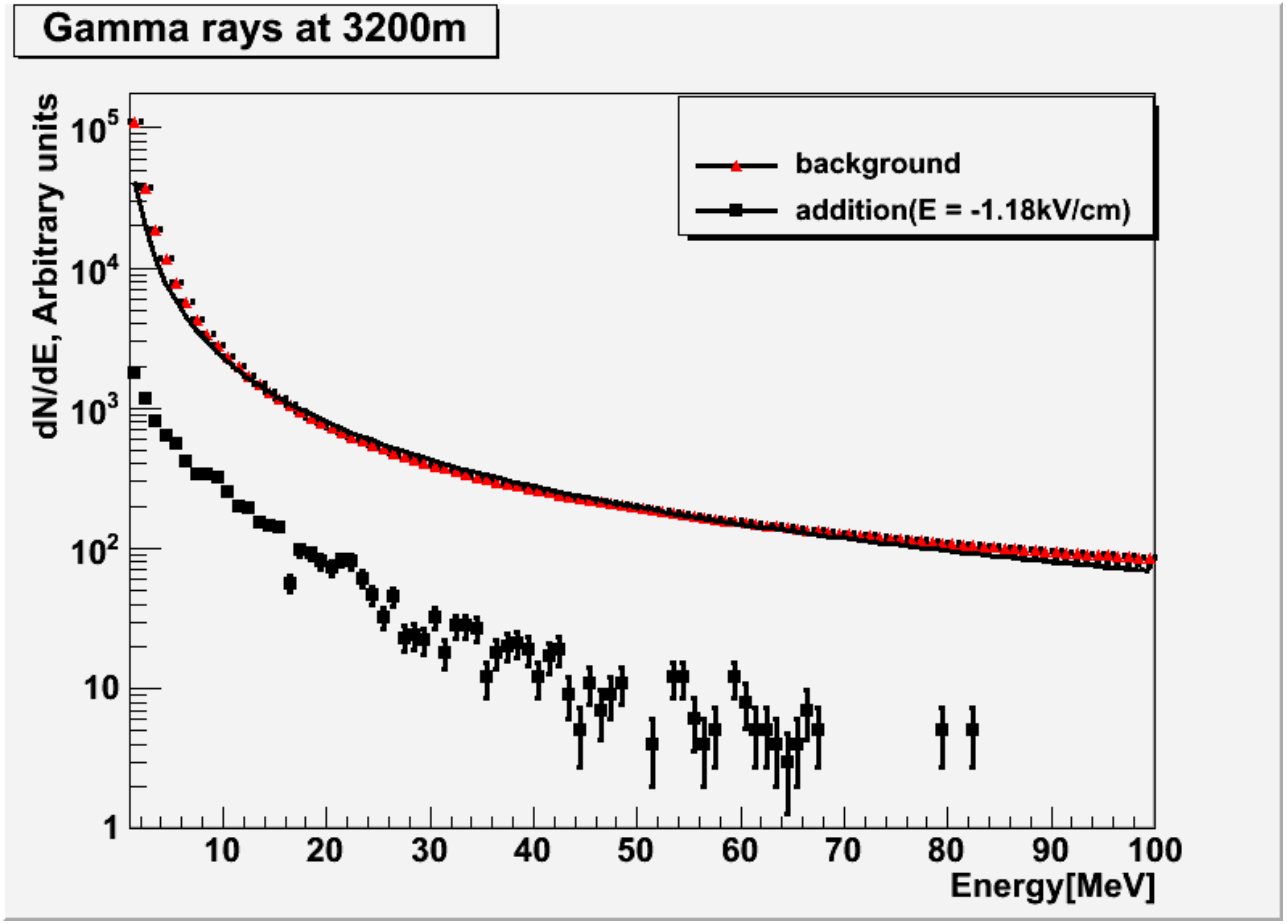
Simulation of the “pure” RB/RREA process: electron and gamma energy spectra from electrons accelerated in electric field of 1.8 kV/cm prolonged from 5000 till 3300 m with 1 MeV electrons as seeds



MOdification of CR electrons energy Spectra (MOS process) – electric field strength is below RREA threshold; seed particles – CR electrons with energies up to 100 and 300 MeV gain energy from the electric field and radiate more gamma rays



Comparison of background gamma ray spectrum with the MOS gamma rays spectrum: MOS do not cause avalanches and do not multiply particle flux!



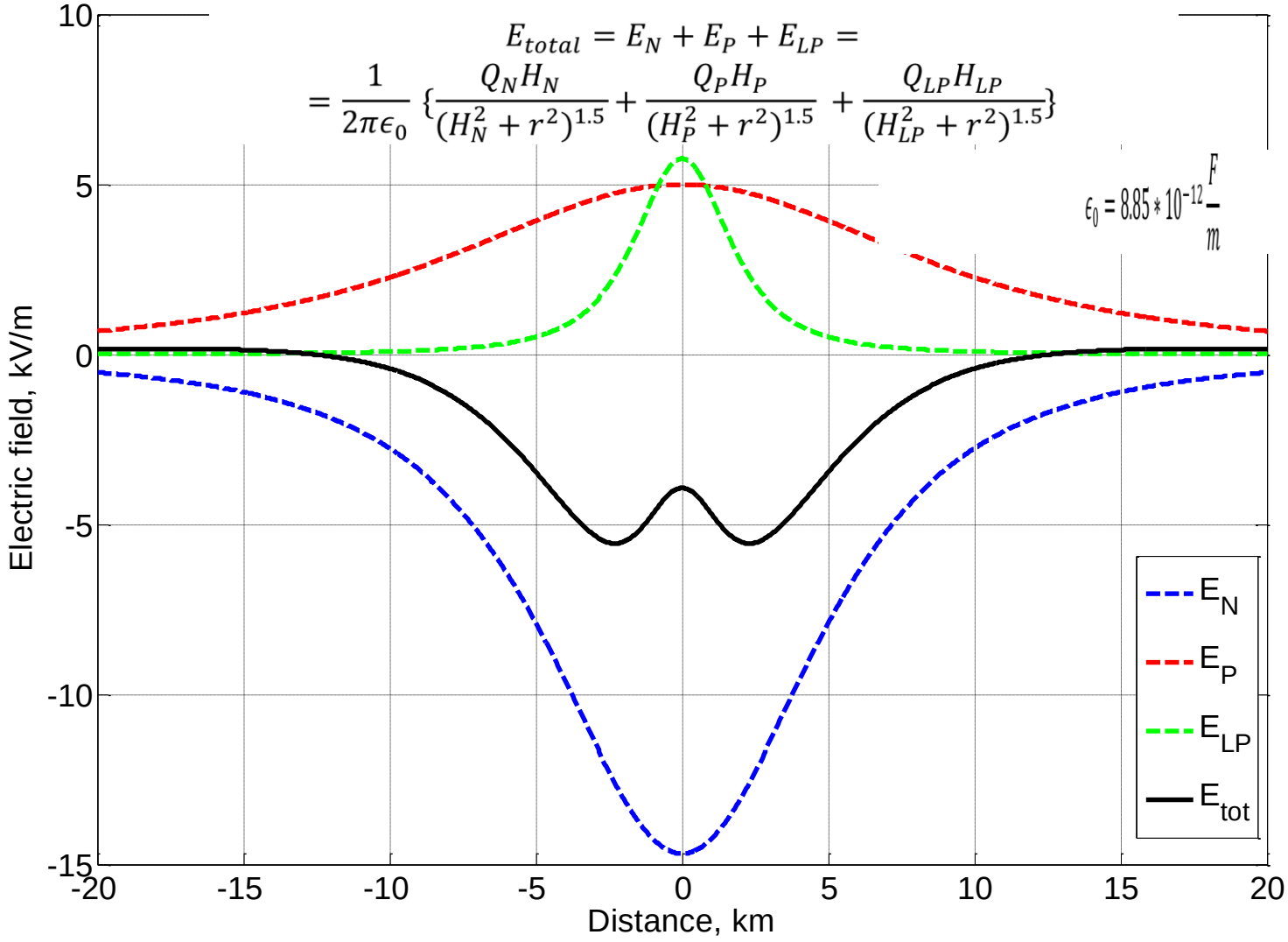
CR electrons were accelerated in the homogenous field of strength 1.18 kV/cm below the critical field for the RREA initiation

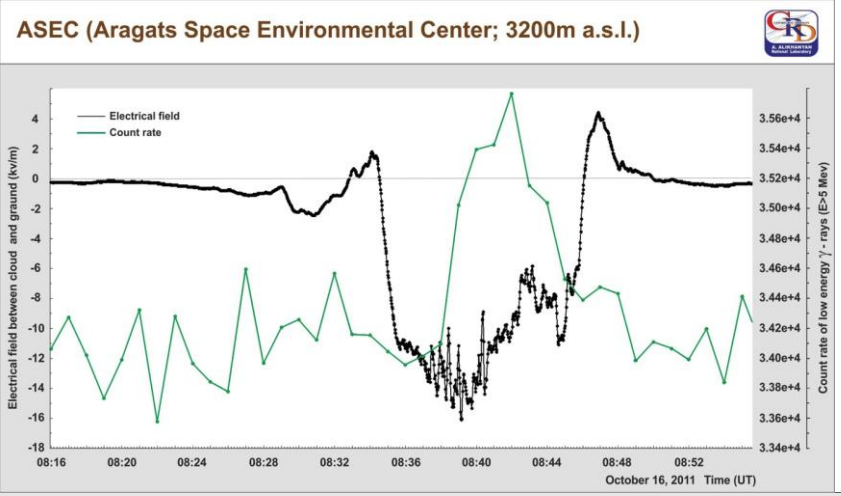
The electric field at ground due to the vertical tripole according to the "atmospheric electricity" sign convention

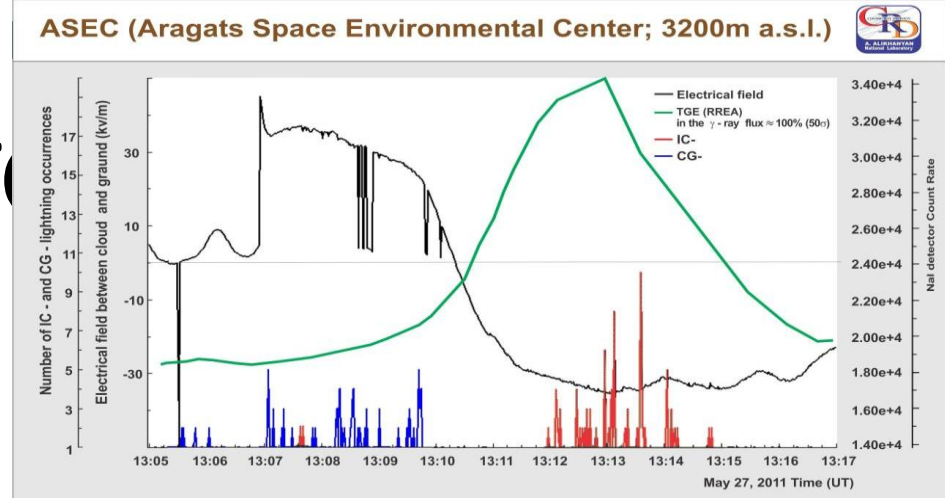
Q_P=40, Q_N=-40, Q_{LP}=2, H_P=12, H_N=7, H_{LP}=2.5

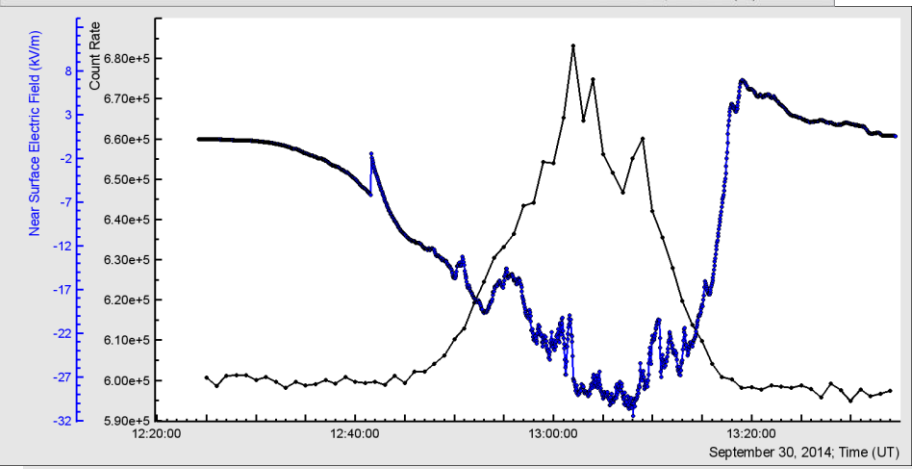
$$E_{total} = E_N + E_P + E_{LP} = \frac{1}{2\pi\epsilon_0}\left\{\frac{Q_N H_N}{(H_N^2 + r^2)^{1.5}} + \frac{Q_P H_P}{(H_P^2 + r^2)^{1.5}} + \frac{Q_{LP} H_{LP}}{(H_{LP}^2 + r^2)^{1.5}}\right\}$$

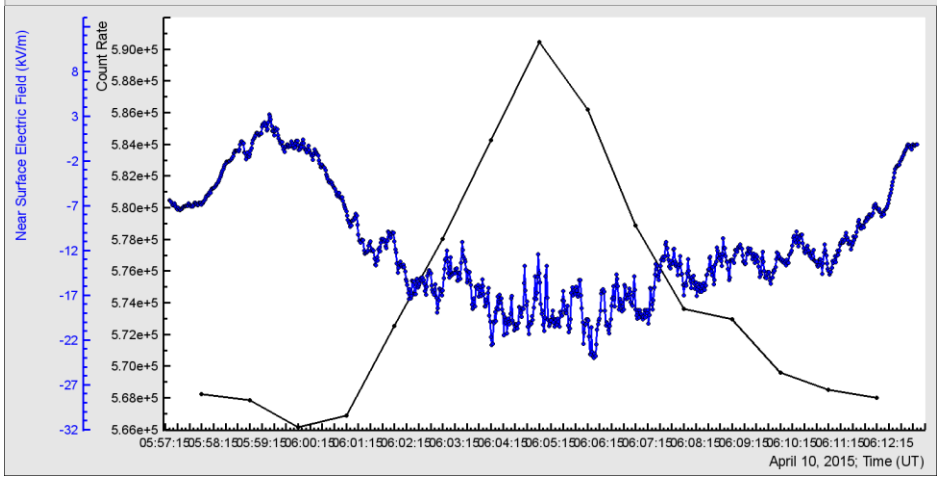
$$\epsilon_0 = 8.85 * 10^{-12} \frac{F}{m}$$

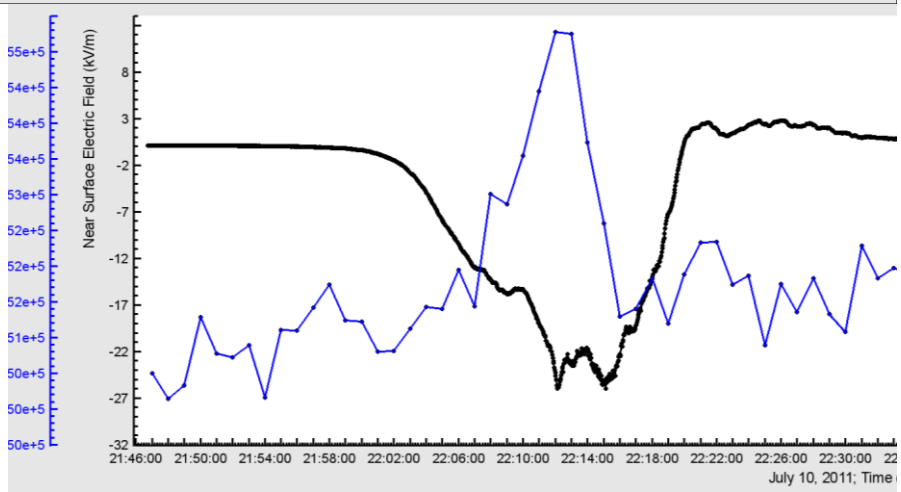


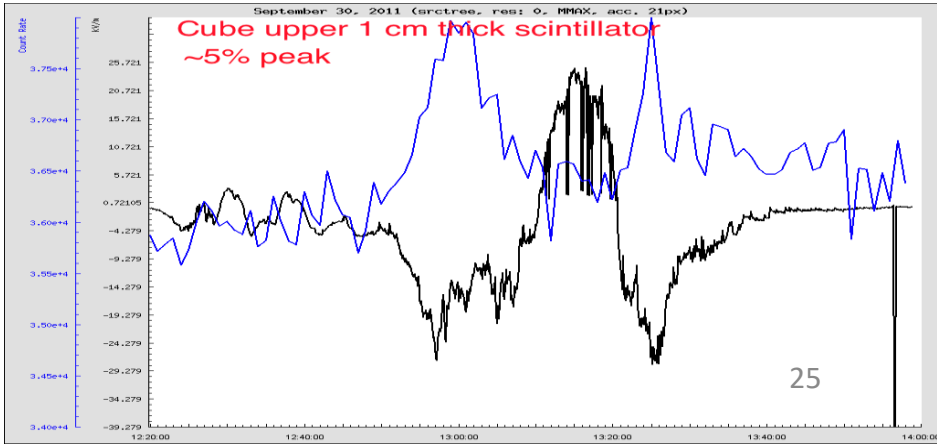

ASEC (Aragats Space Environmental Center; 3200m a.s.l.)
Electrical field
Count rate
Electrical field between cloud and graund (kv/m)
Count rate of low energy γ - rays (E>5 Mev)
October 16, 2011 Time (UT)

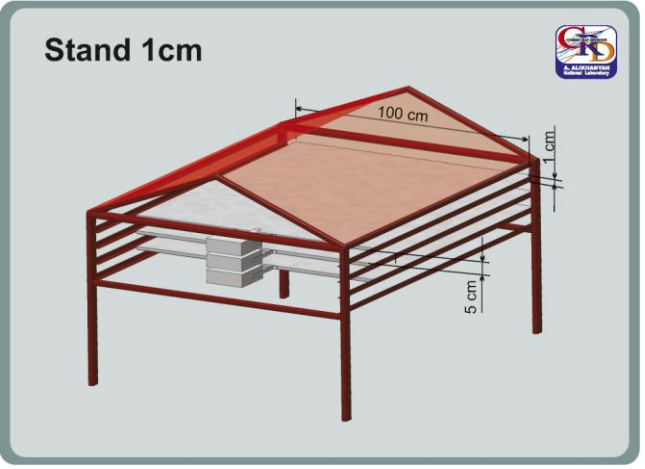

ASEC (Aragats Space Environmental Center; 3200m a.s.l.)
Electrical field
TGE (RREA)
in the γ - ray flux ≈ 100% (50σ)
IC-
CG-
Number of IC - and CG - lightning occurrences
Electrical field between cloud and graund (kv/m)
Nal detector Count Rate
May 27, 2011 Time (UT)


Near Surface Electric Field (kV/m)
Count Rate
September 30, 2014; Time (UT)

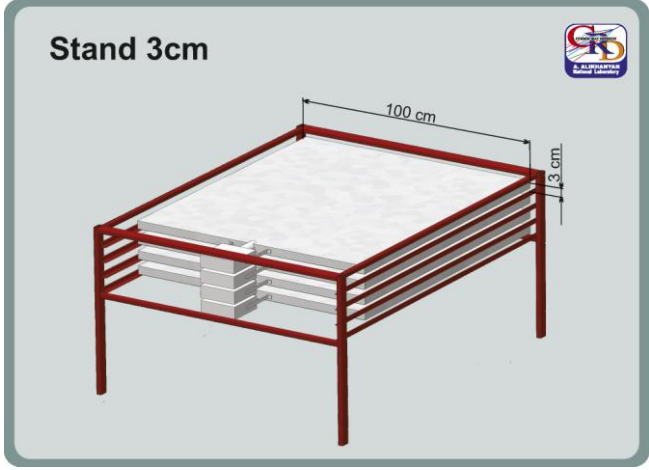

Near Surface Electric Field (kV/m)
Count Rate
April 10, 2015; Time (UT)

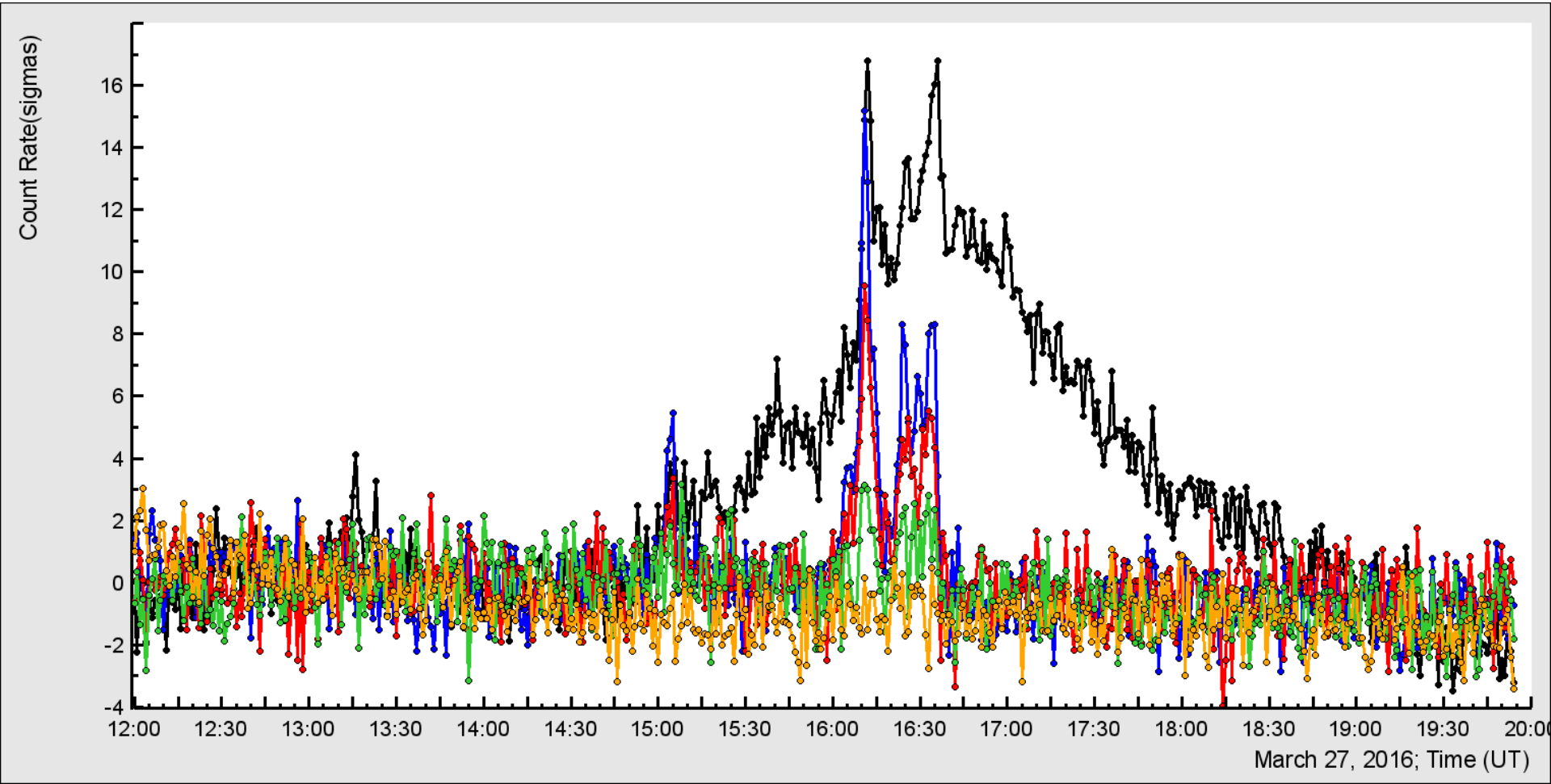

Near Surface Electric Field (kV/m)
July 10, 2011; Time


Cube upper 1 cm thick scintillator
~5% peak

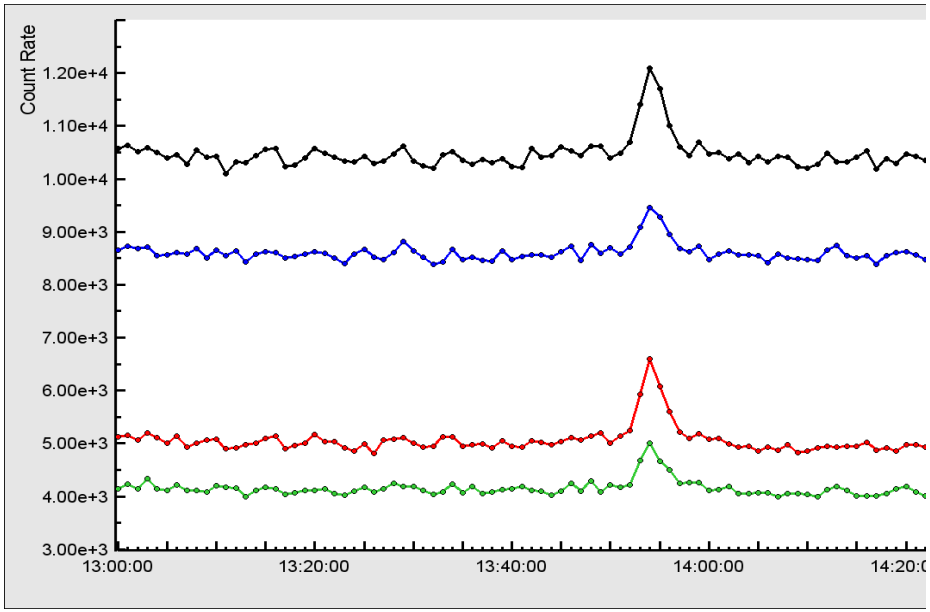


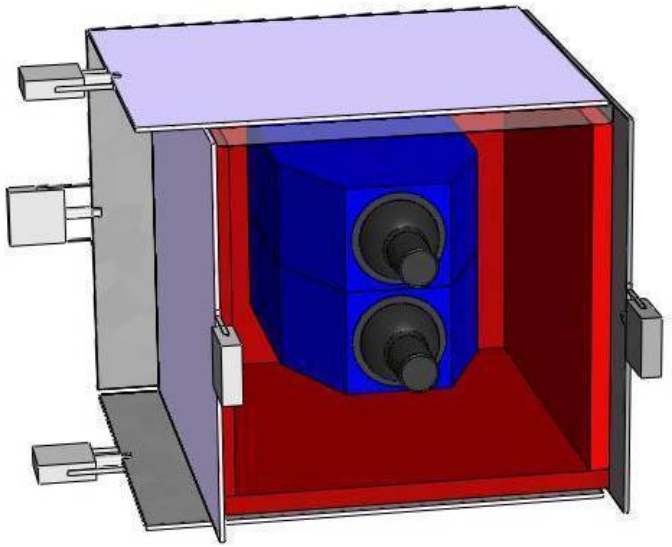
STAND1 001 STAND3 1000,1100,1110,1111





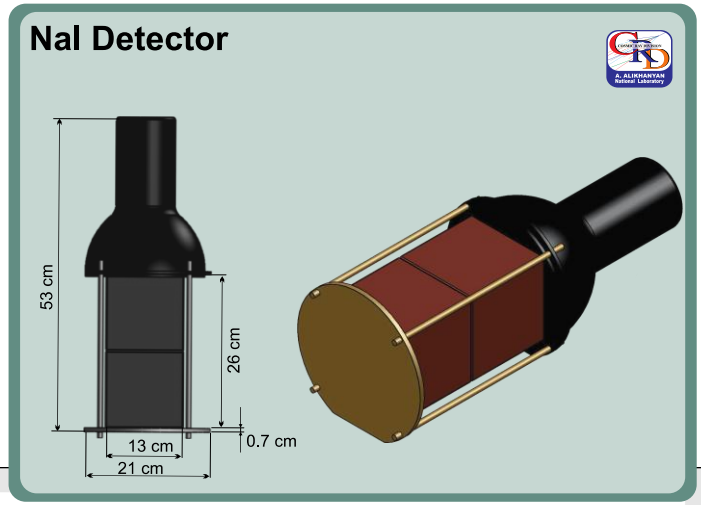
Recovering of the Electron and gamma ray fluxes by CUBE detector

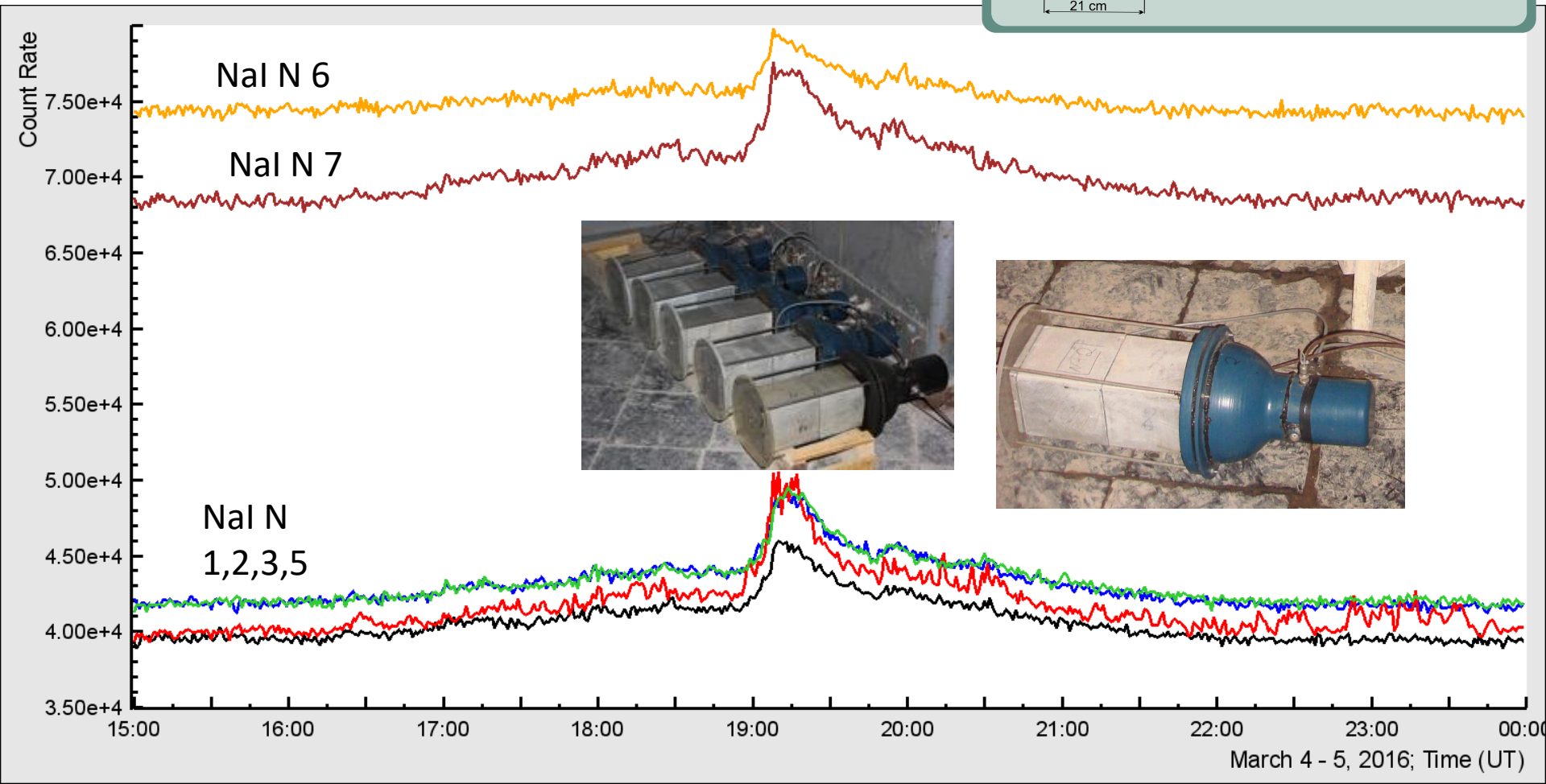


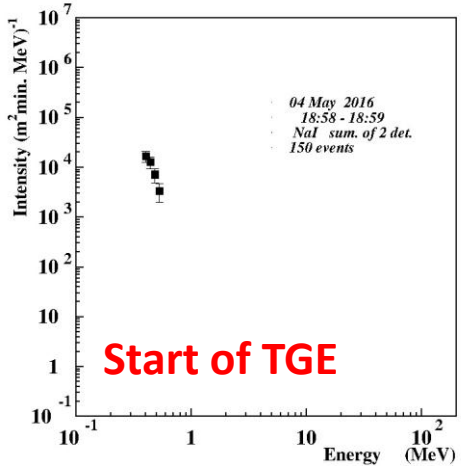


Date 28 July 2016	Upper scintillator			Bottom scintillator		
	e intensity ($1/m^2min$)	γ intensity ($1/m^2min$)	e/γ (%)	e intensity ($1/m^2min$)	γ intensity ($1/m^2min$)	e/γ (%)
13:54-13:55	460	23328	2.0	0	3524	-
13:55-13:56	992	15608	6.4	760	9532	8.0
13:56-13:57	92	8540	1.1	0	1500	-
13:57-13:58	0	772	-	0	460	-

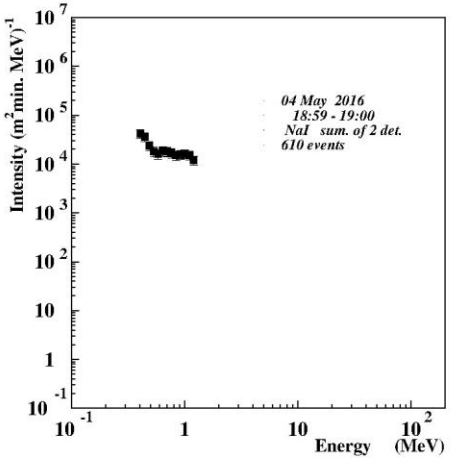
NaI spectrometers network

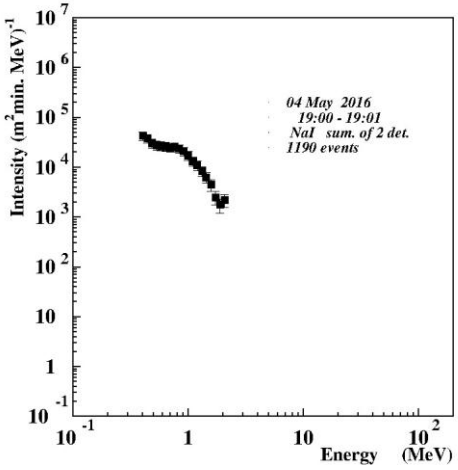


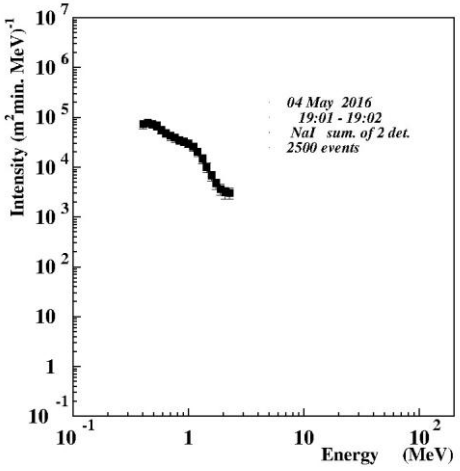


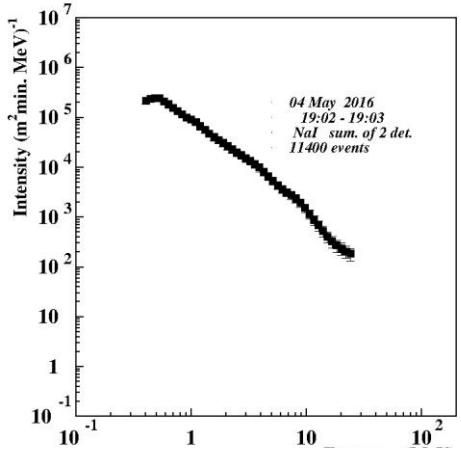


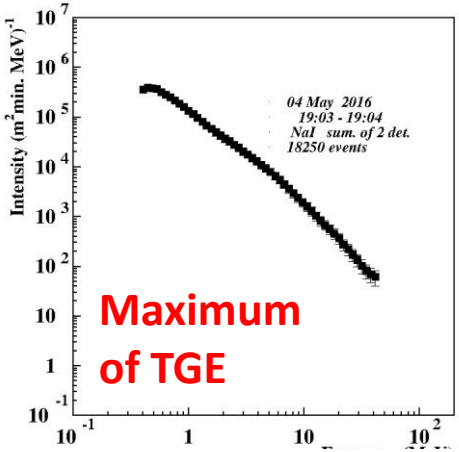
Start of TGE



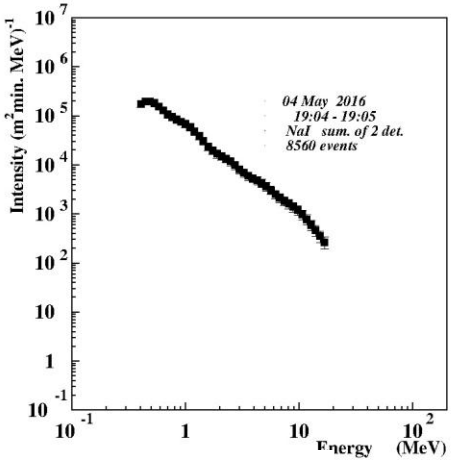


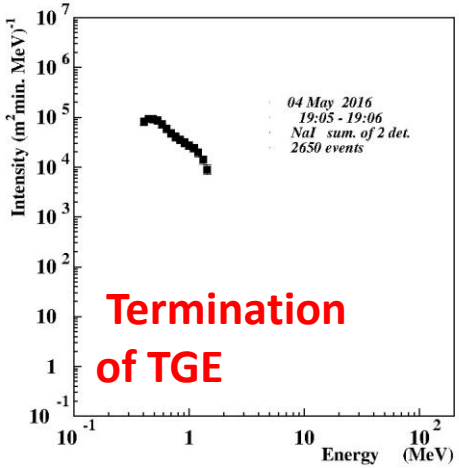




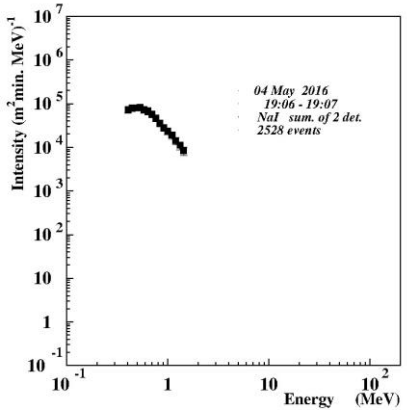


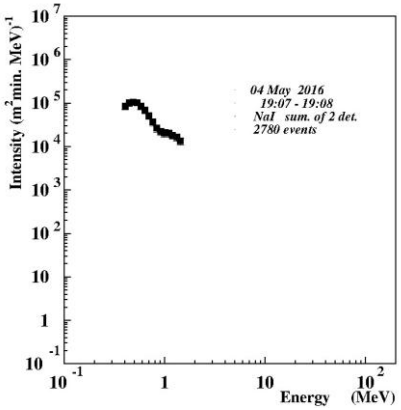
Maximum of TGE

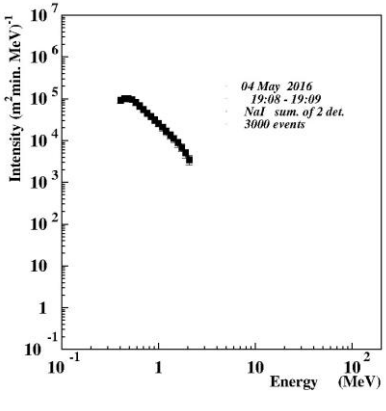


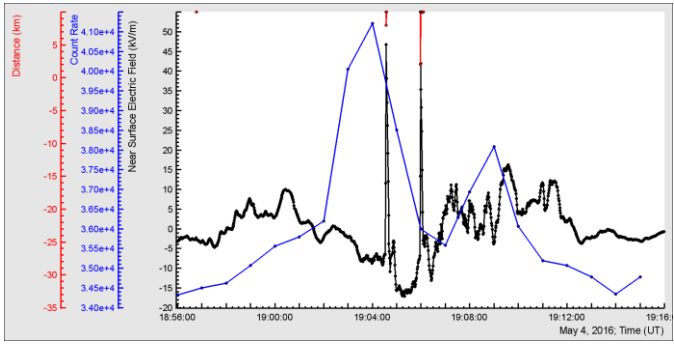


Termination of TGE

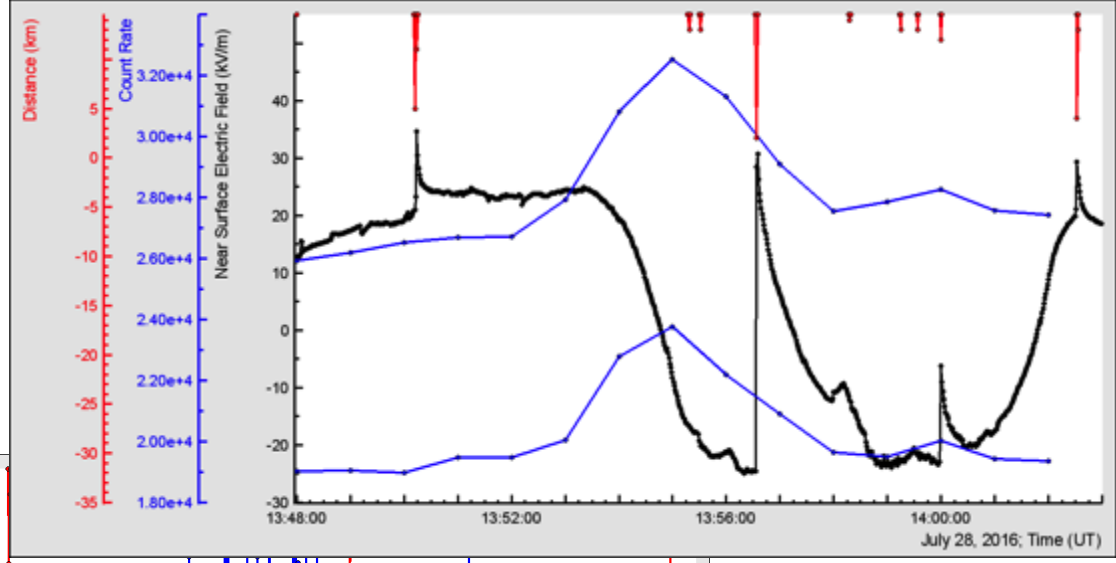


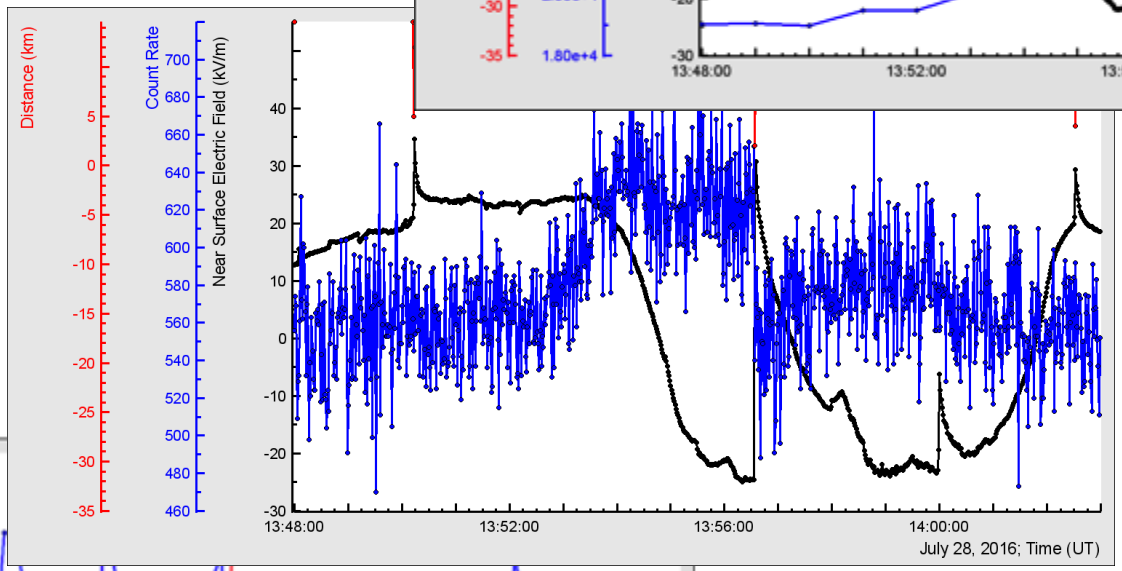


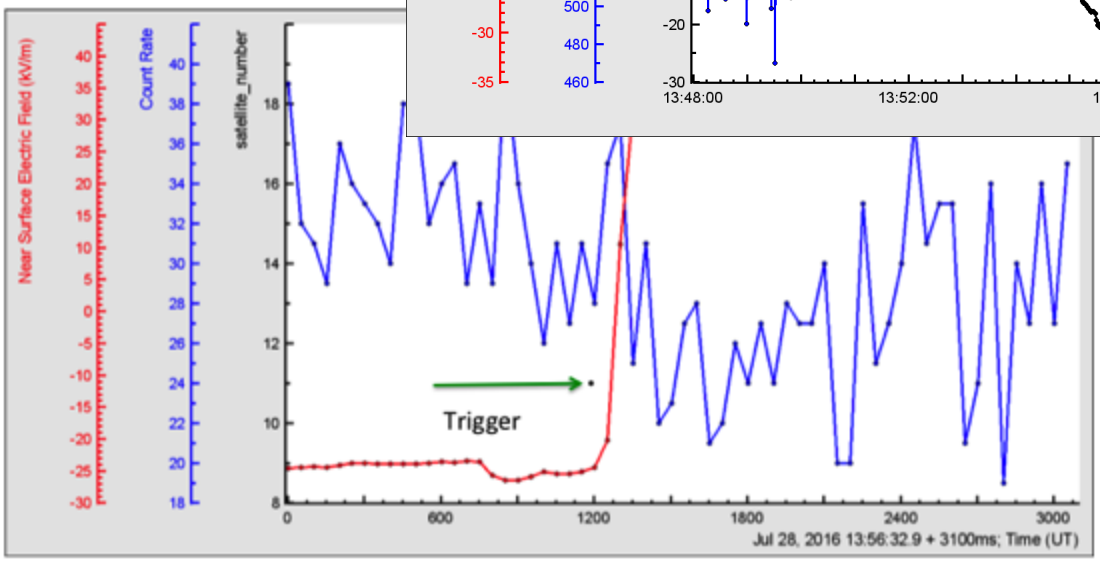




Time-series on different scales







"The balloon passed through a region of high electric field on which time increase in X ray intensity of 2 orders of magnitude occurred, lasting for approximately 1 min. The X ray intensity returned to background level at the time of a lightning flash that reduced the electric field strength measured at the balloon", near Norman, Oklahoma in the spring of 1995.

X-rays in Thunderstorms

interval, from one of the 1984 flights, in Figure 1. The passive channel shows only a thermal noise count rate with no statistically significant deviations during this same time period. In this instance, there is no evidence of electromagnetic interference in the passive detector and we conclude that the count rate increase in the active

The left- most peak precedes an observed flash near aircraft. Center peak precedes a strike to the aircraft. Rightmost "'hump" is not associated with any observed lightning

McCarthy, M.P., Parks, G.K. 1985. Further observations of X-rays inside thunderstorms. *Geophys. Res. Lett.* **97**, 5857–5864

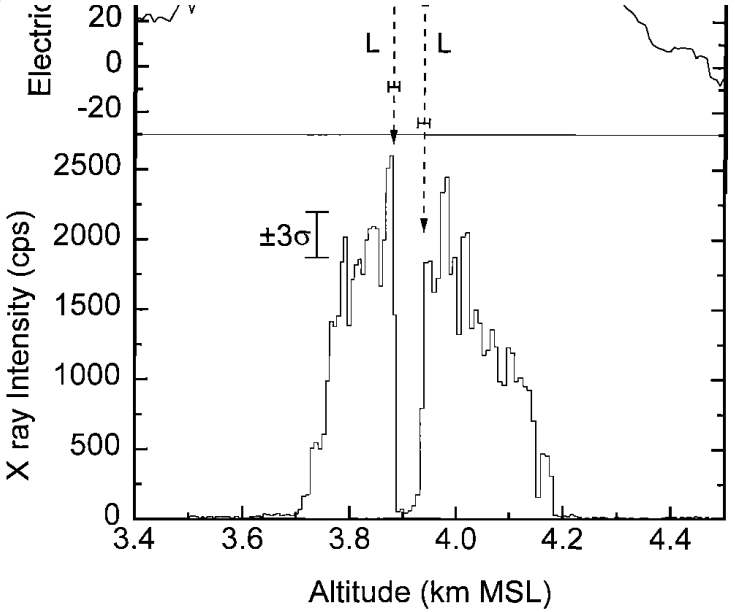
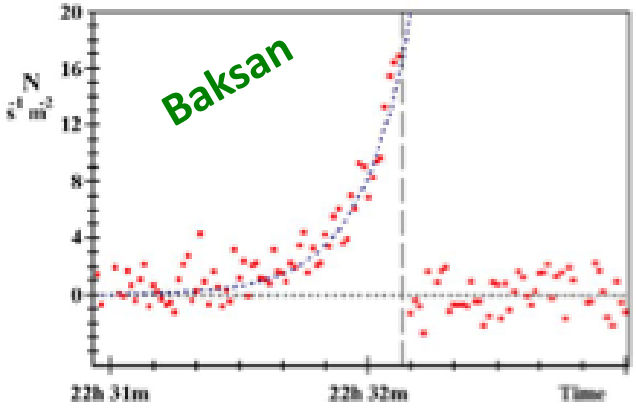


Figure 3. Detail of X ray and electric field sounding near 4 km msl. Electric field measured at the balloon and the breakeven field strength (E_{BE}) are plotted in the top panel. Electric field transients due to lightning are marked by an "L" and vertical dashed lines. The horizontal error bars (±1 s) depict the timing error between the two plots. X ray intensity for X rays between 30 and 120 keV is plotted in the bottom panel. The vertical error bar represents 3 standard deviations in the count rate.

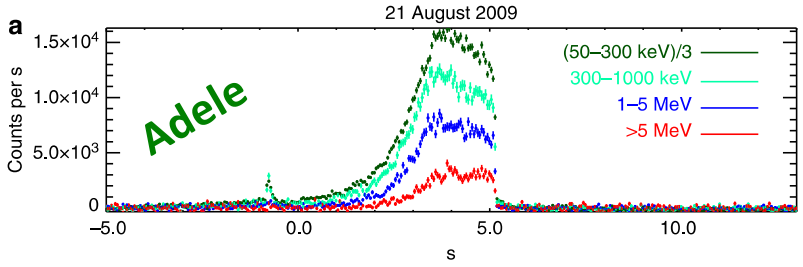
Eack, K.B, W.H. Beasley, W.D. Rust, T.C. Marshall, M.Stolzenburg, Initial results from simultaneous observations of x rays and electric fields in a thunderstorm, J.Geophys. Res., 101, 29637-29640. 1996.

Lightning terminates particle fluxes on Earth's surface and in aircraft



The large distance to lightning channels probably means that the above enhancements are not directly related to the lightning activity. We can rather suppose that the lightning serves in our case as a switch-off for the electric field.

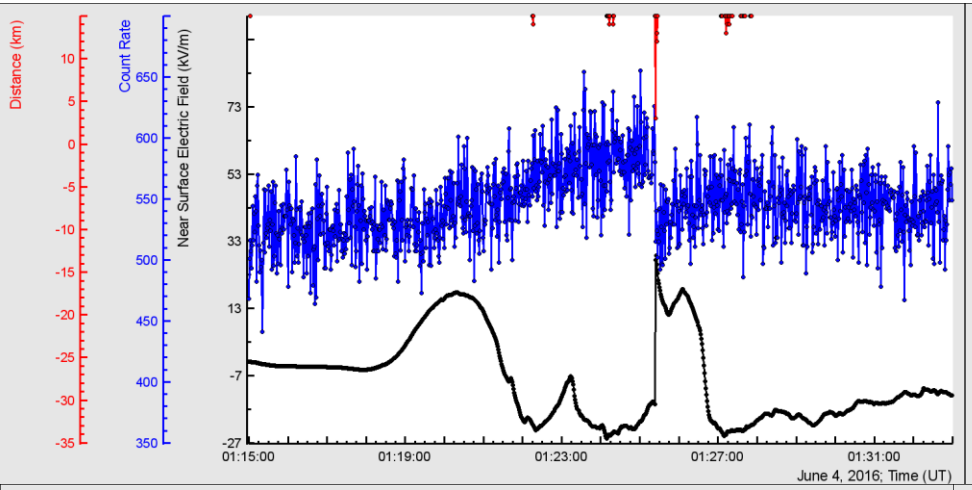
Alexeenko V.V., Khaerdinov N.S., LidvanskyA.S., and PetkovV.B., 2002. Transient Variations of Secondary Cosmic Rays due to Atmospheric Electric Field and Evidence for Pre-Lightning Particle Acceleration, *Physics Letters A*, 301, 299-306.

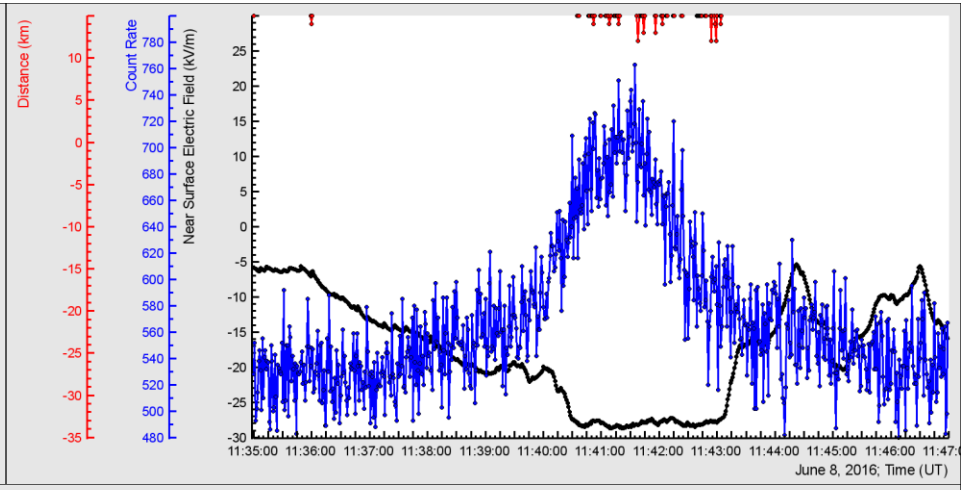


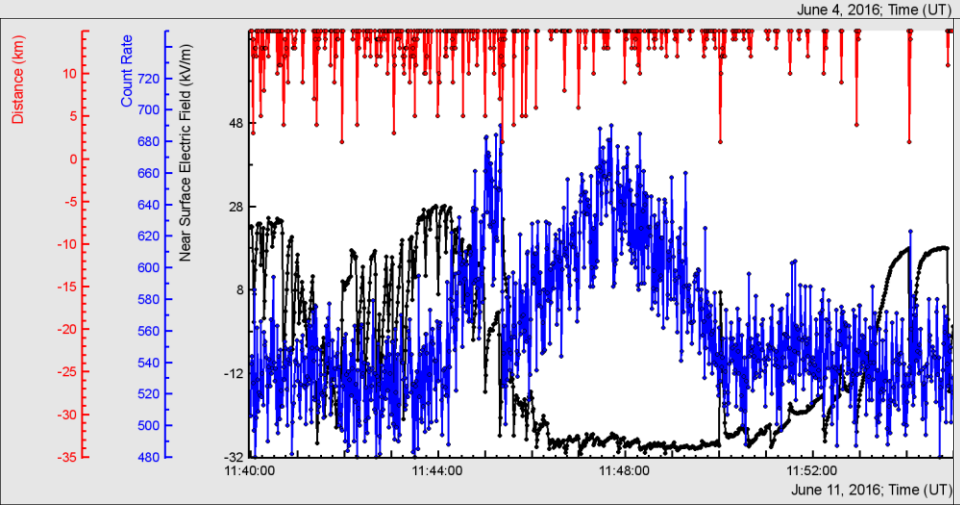
Examining the strongest glow measured by the airborne detector for energetic emissions, we show that this glow is measured near the end of a downward RREA, consistent with occurring between the upper positive charge layer and the negative screening layer above it.

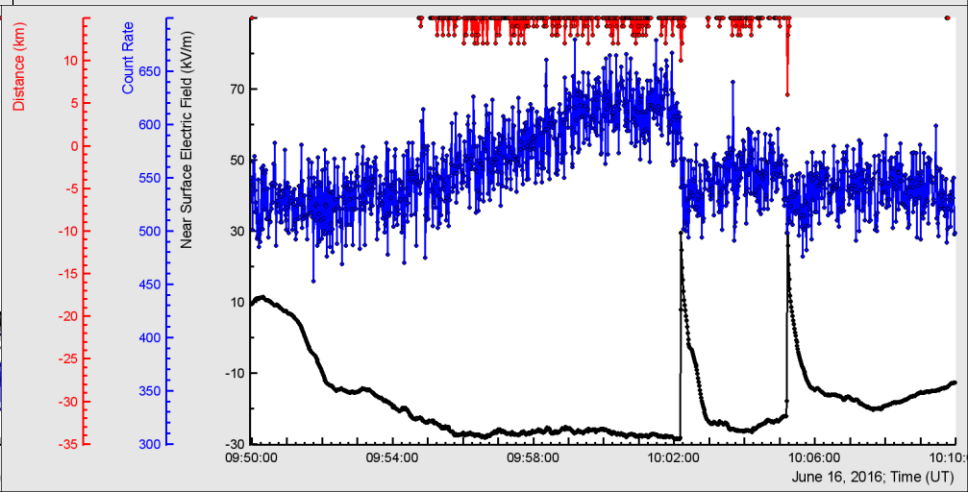
N. A. Kelley, D. M. Smith, and J. R. Dwyer et al., Relativistic electron avalanches as a thunderstorm discharge competing with lightning, Nat. Commun. 6, 7845 (2015).

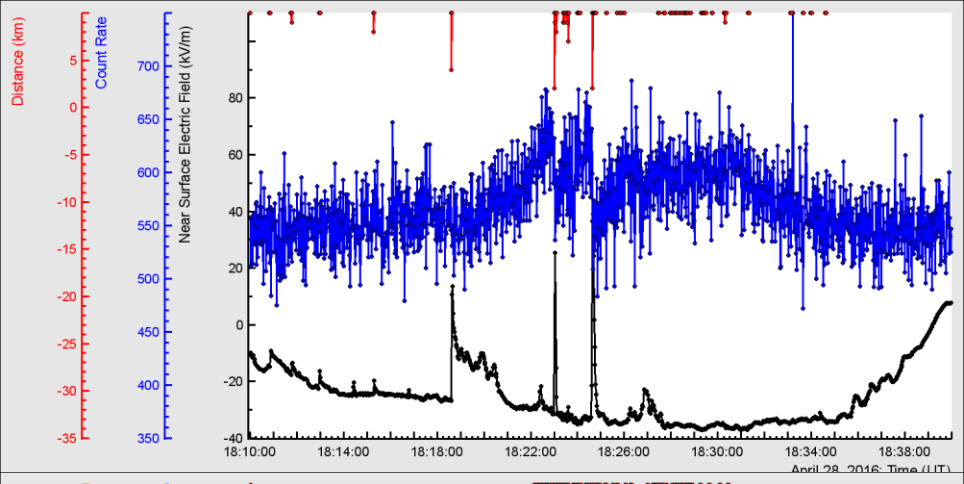
2016 TGEs occurs at prolonged (3-7 min)deep negative electrostatic field(~ -30 kV/m); lightning abruptly terminates TGE; largest TGEs occurred when there is no nearby lightnings.

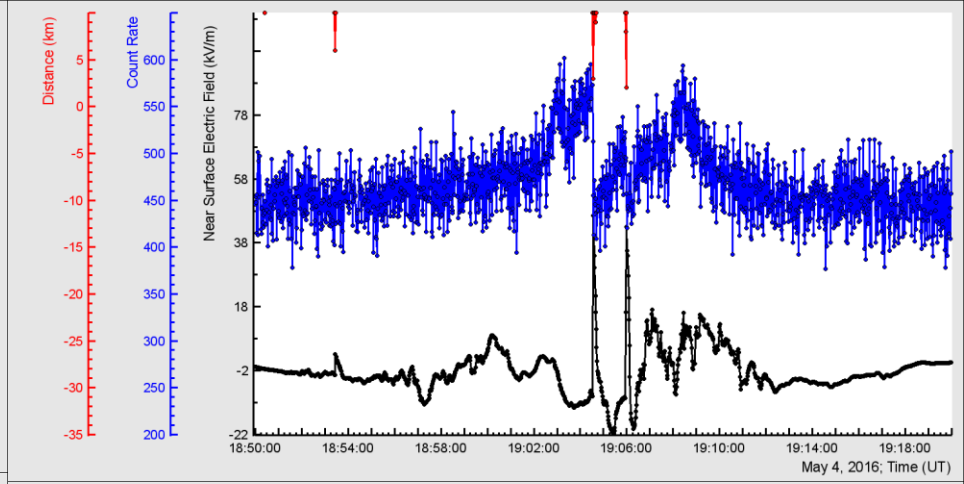


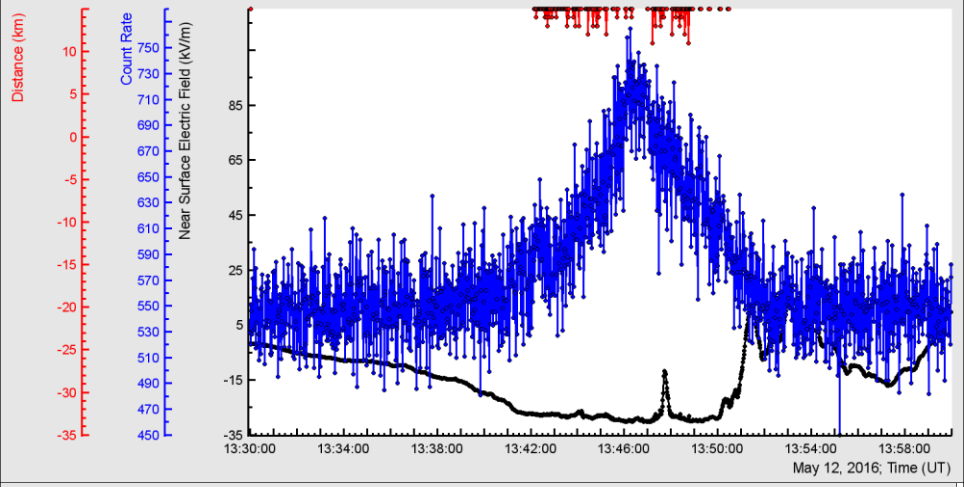


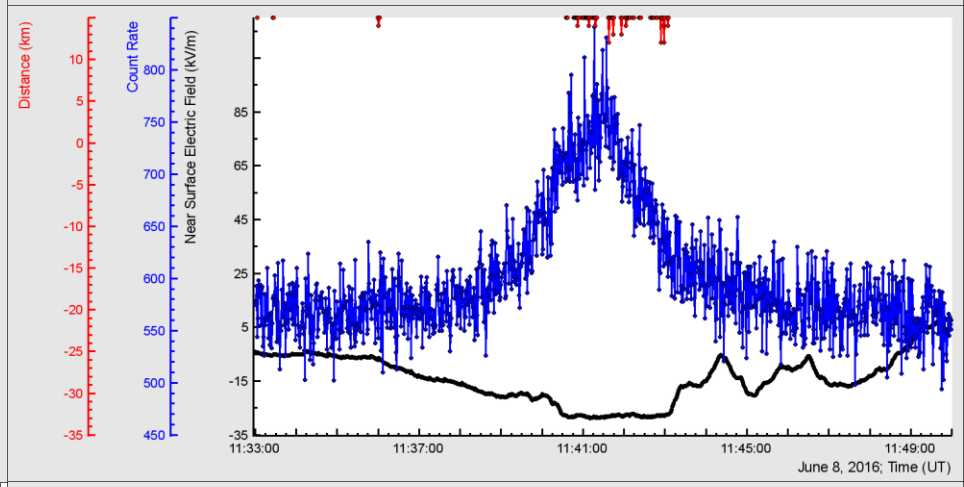


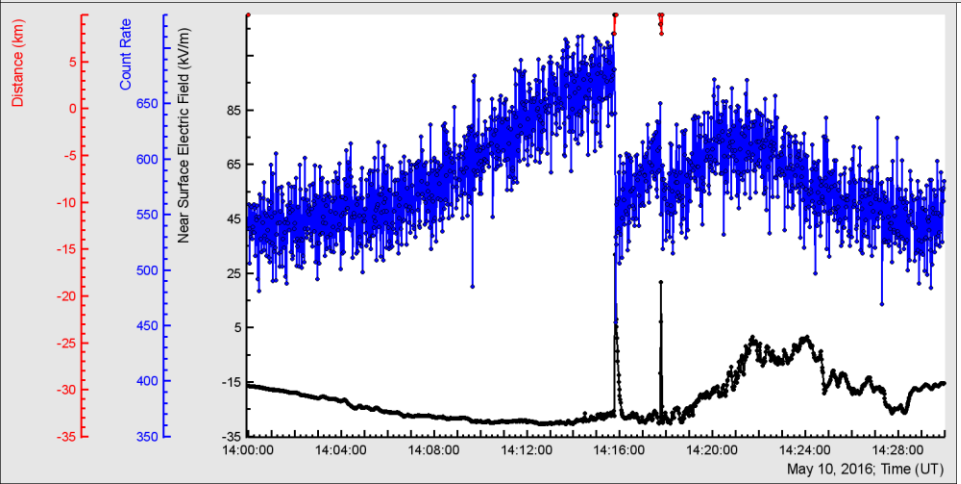


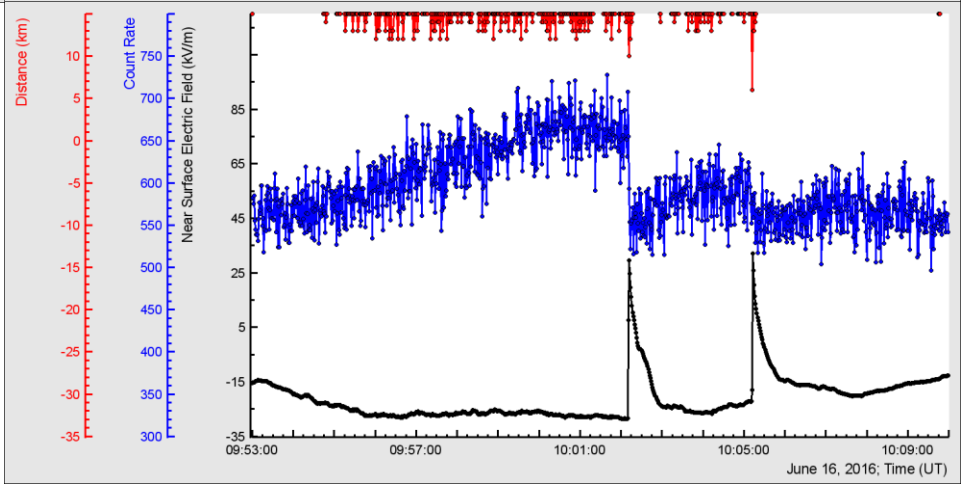

Distance (km)
Count Rate
Near Surface Electric Field (kV/m)
18:10:00
18:14:00
18:18:00
18:22:00
18:26:00
18:30:00
18:34:00
18:38:00
April 28, 2016; Time (UT)


Distance (km)
Count Rate
Near Surface Electric Field (kV/m)
18:50:00
18:54:00
18:58:00
19:02:00
19:06:00
19:10:00
19:14:00
19:18:00
May 4, 2016; Time (UT)

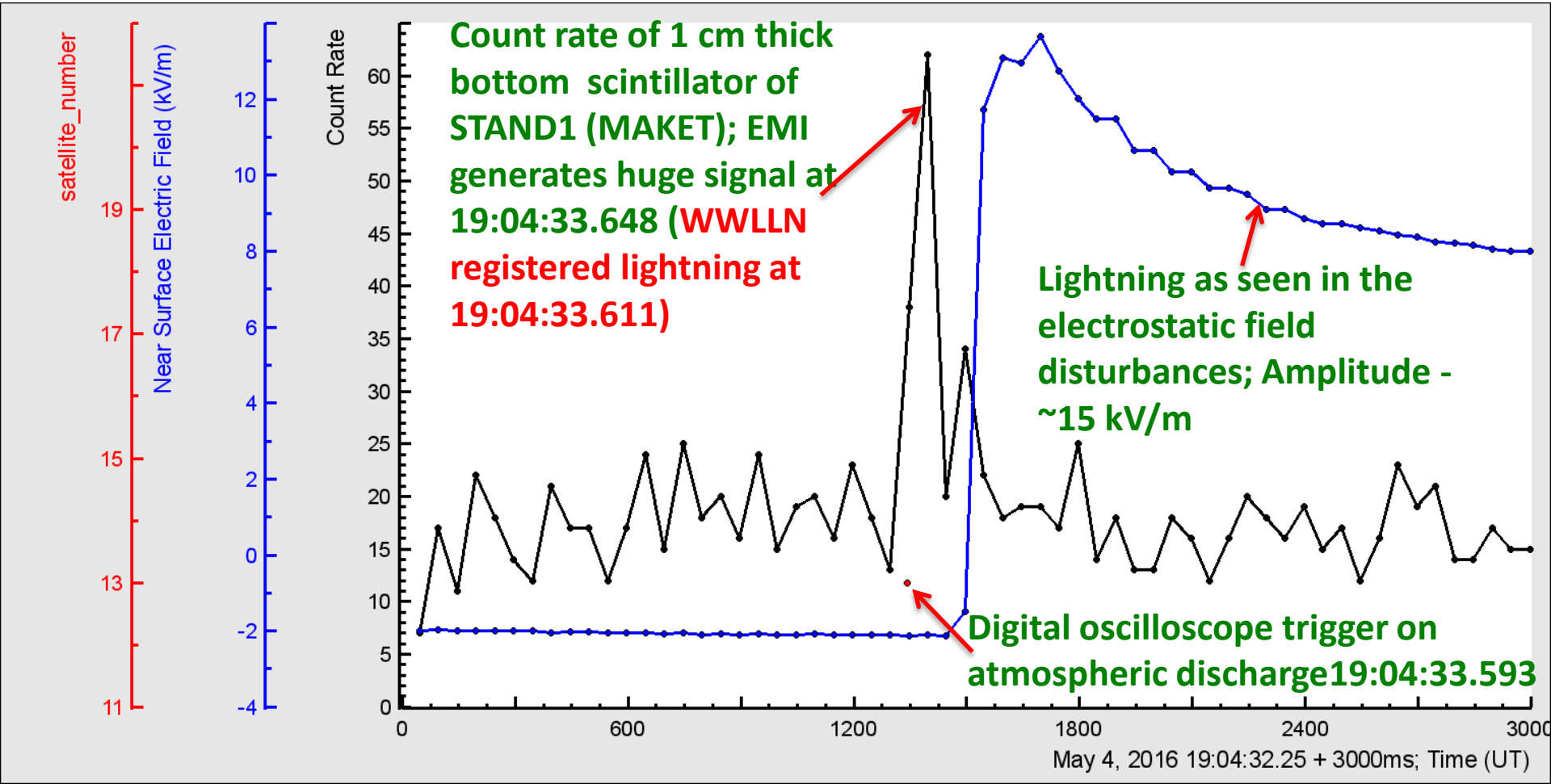

Distance (km)
Count Rate
Near Surface Electric Field (kV/m)
13:30:00
13:34:00
13:38:00
13:42:00
13:46:00
13:50:00
13:54:00
13:58:00
May 12, 2016; Time (UT)

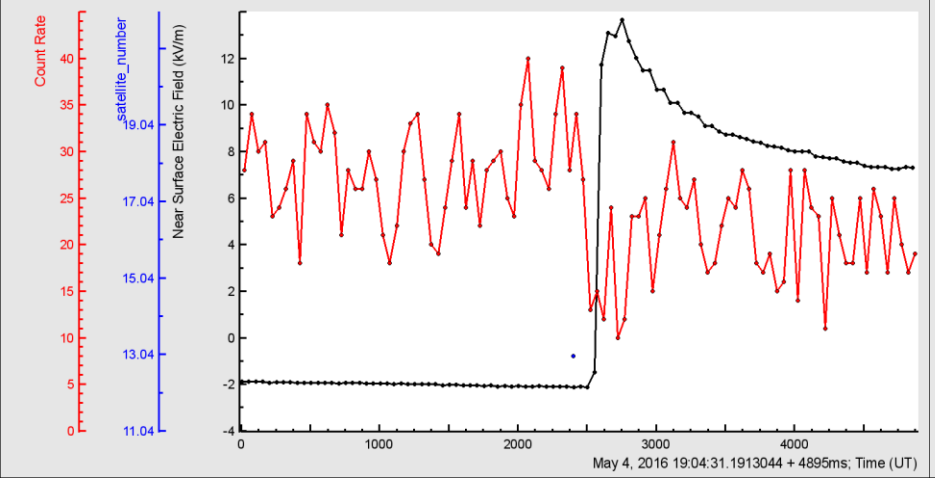

Distance (km)
Count Rate
Near Surface Electric Field (kV/m)
11:33:00
11:37:00
11:41:00
11:45:00
11:49:00
June 8, 2016; Time (UT)

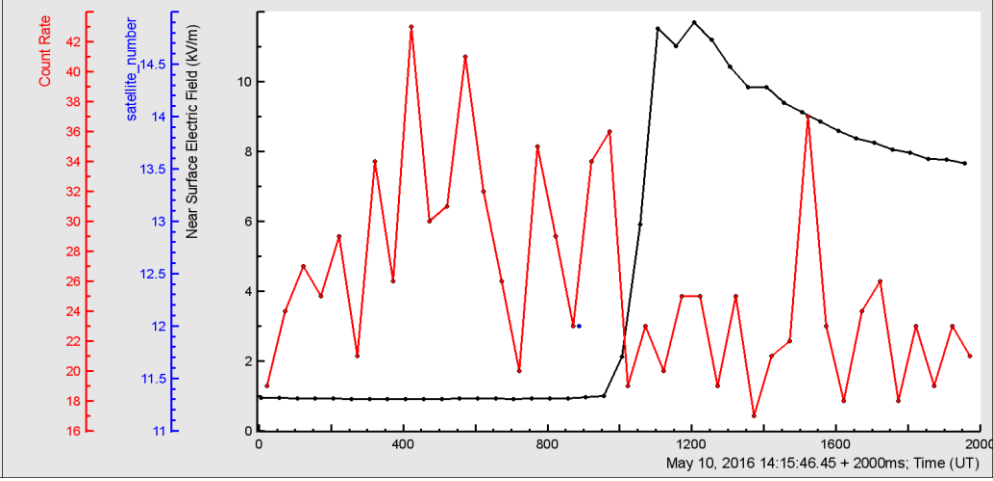

Distance (km)
Count Rate
Near Surface Electric Field (kV/m)
14:00:00
14:04:00
14:08:00
14:12:00
14:16:00
14:20:00
14:24:00
14:28:00
May 10, 2016; Time (UT)


Distance (km)
Count Rate
Near Surface Electric Field (kV/m)
09:53:00
09:57:00
10:01:00
10:05:00
10:09:00
June 16, 2016; Time (UT)

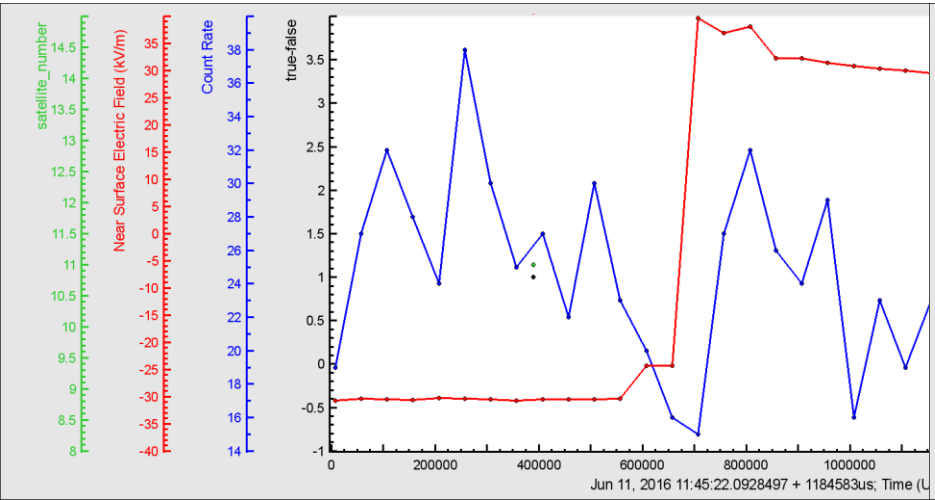
3 seconds of 50 ms particle time series including lightning occurrence and electrostatic field disturbances

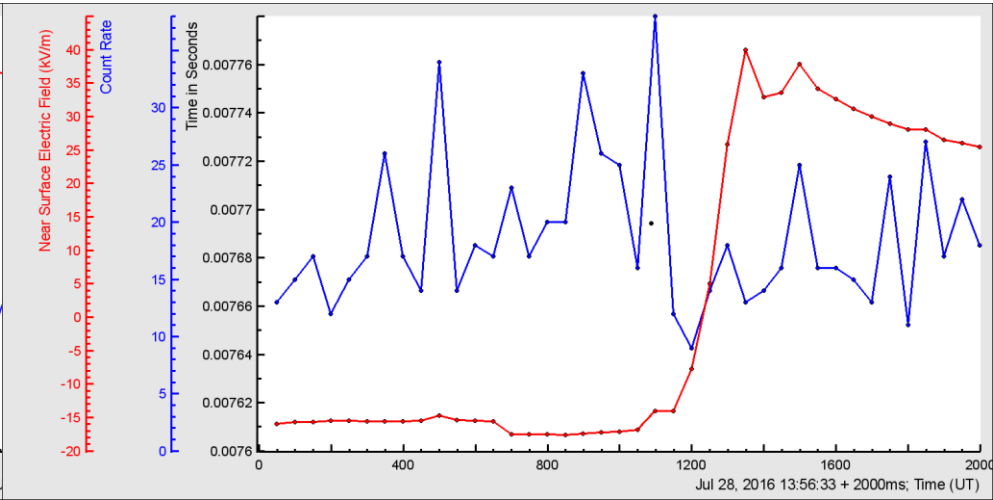


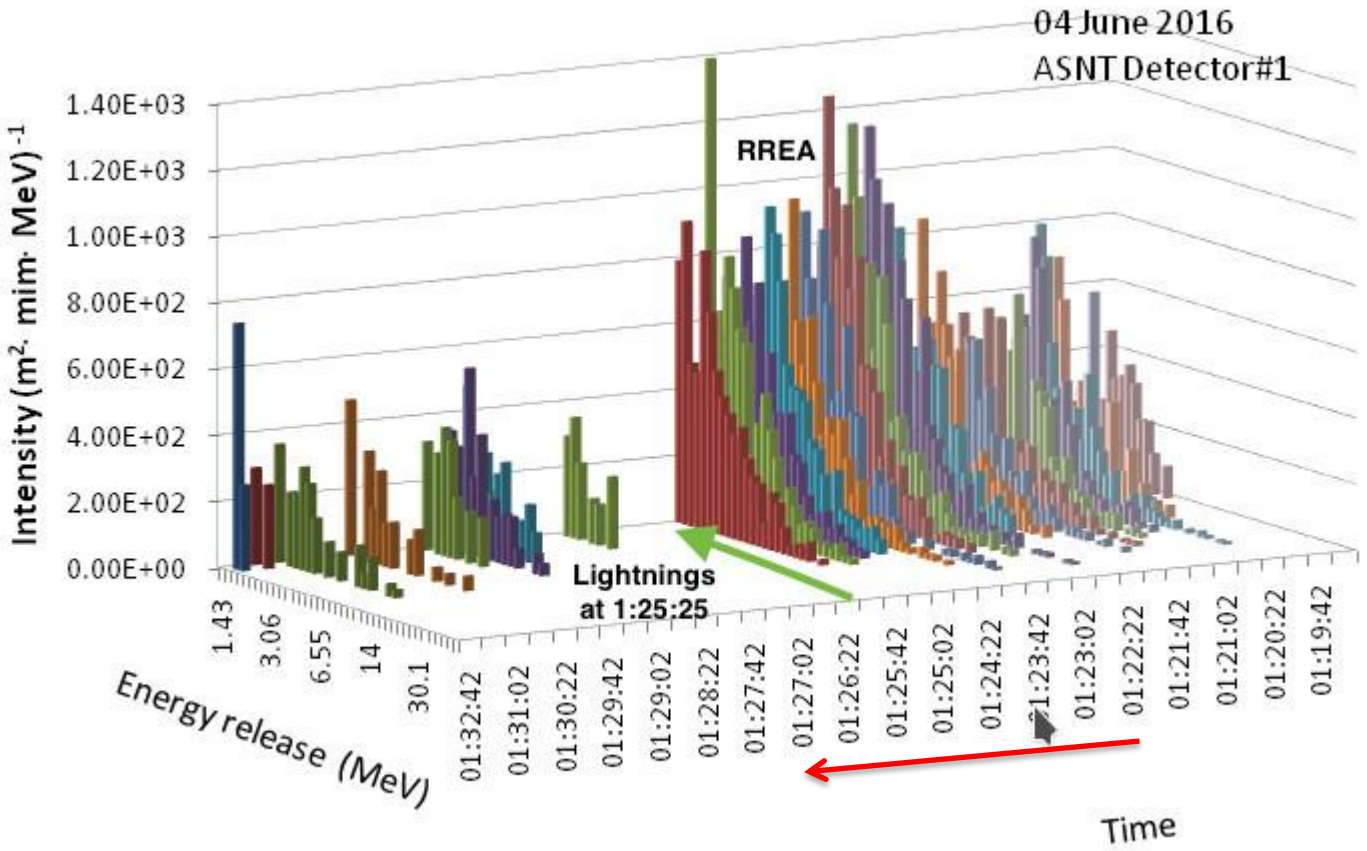

Count Rate
satellite_number
Near Surface Electric Field (kV/m)
May 4, 2016 19:04:31.1913044 + 4895ms; Time (UT)


Count Rate
satellite_number
Near Surface Electric Field (kV/m)
May 10, 2016 14:15:46.45 + 2000ms; Time (UT)

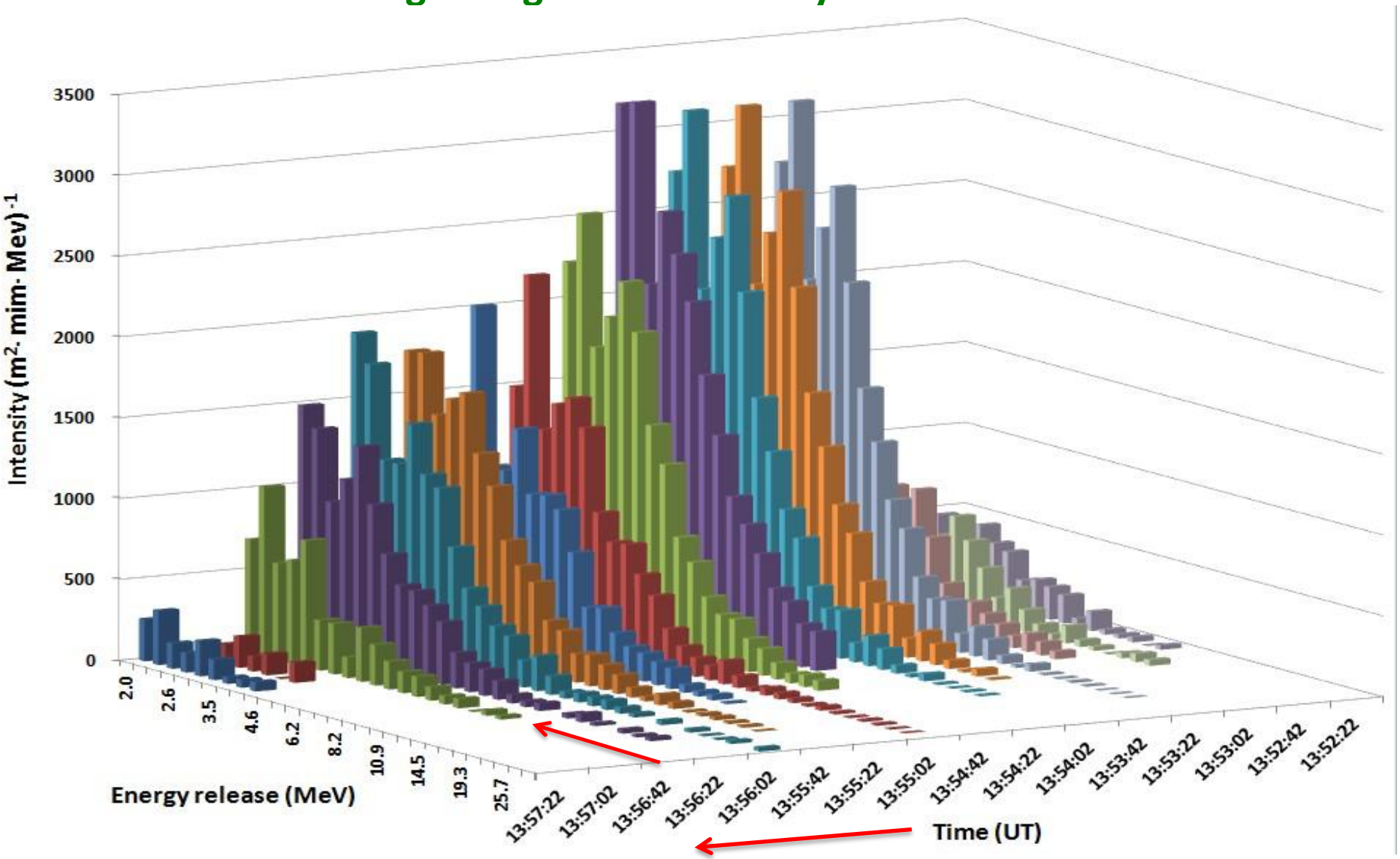

2016-07-26
13:56:34-03


satellite_number
Near Surface Electric Field (kV/m)
Count Rate
true-false
Jun 11, 2016 11:45:22.0928497 + 1184583us; Time (U


Near Surface Electric Field (kV/m)
Count Rate
Time in Seconds
Jul 28, 2016 13:56:33 + 2000ms; Time (UT)


04 June 2016
ASNT Detector#1
RREA
Lightnings
at 1:25:25
Intensity (m-2· mim· MeV) -1
1.40E+03
1.20E+03
1.00E+03
8.00E+02
6.00E+02
4.00E+02
2.00E+02
0.00E+00
1.43
3.06
6.55
14
30.1
Energy release (MeV)
01:32:42
01:31:02
01:30:22
01:29:42
01:29:02
01:28:22
01:27:42
01:27:02
01:26:22
01:25:42
01:25:02
01:24:22
01:23:42
01:23:02
01:22:22
01:21:42
01:21:02
01:20:22
01:19:42
Time

Differential Energy release spectrum of TGE (20 sec) by ASNT: red arrow – lightning flash on 28 July 2016 at 13:56:34

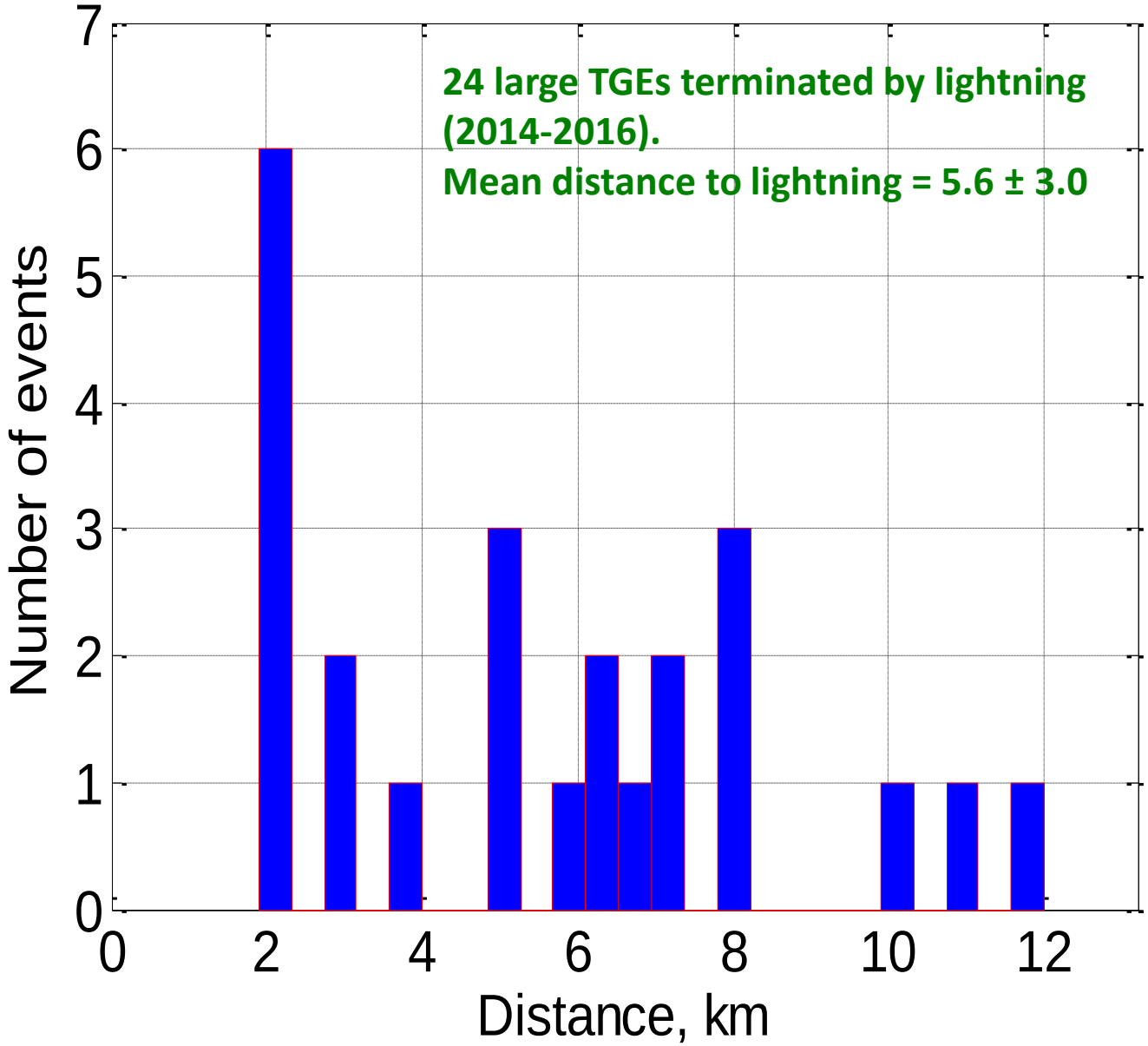


Main parameters of the TGE events terminated by lightnings

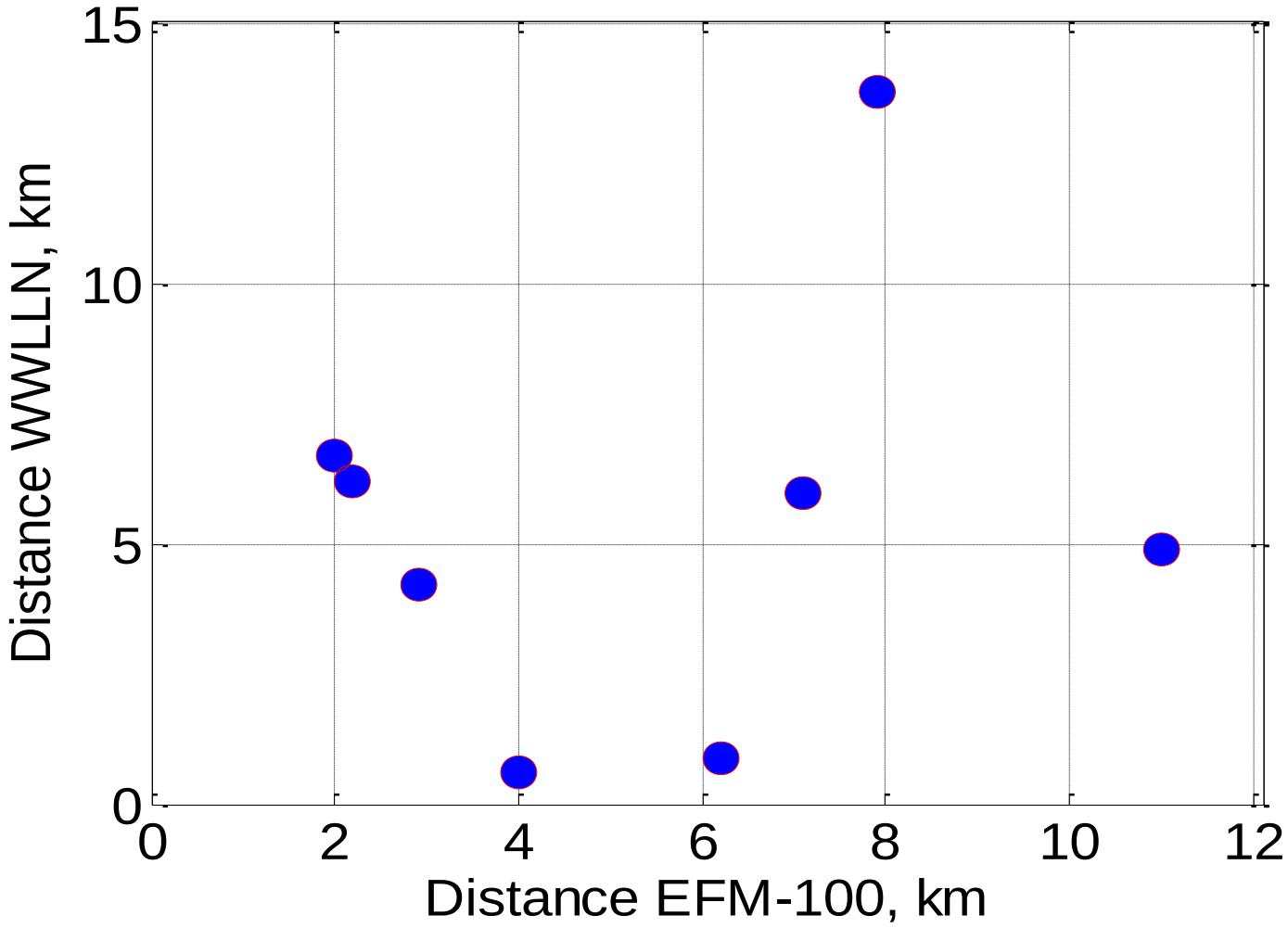
N	Date	Start of lightning (UT) and el. field value kV/m	Time of maximum (UT) and el. field max value kV/m	Rise time (ms)	Decay time fwhm sec	Drop of flux %	Surge of el. field kV/m	EFM Dist. km	WWLLN Dist km	WWLLN time (UT)
1	11/05 2015	16:29:36.380 -5.7	16:29:36.580 57.3	200	8	24	63	4.0	0.6	16:29:36. 337
2	11/05 2015	16:32:06.550 -6.5	16:32:06.800 60	250	6	70	66.5	7.9	13.7	16:32:06. 521
3	11/05 2015	16:35:06.550 5.5	16:35:06.800 61.5	250	5	44	56	2.9	4.2	16:35:06. 534
4	20/04 2015	18:00:14.100 1.2	18:00:14.350 49.2	250	1.1	91	48	2	6.7	18:00:14. 757
5	20/04 2015	18:02:01.100 -3.4	18:02:01.300 39.2	200	1.2	25	42.6	7.8	N/A	N/A
6	4/10 2014	14:13:32.400 -25.5	14:13:32.550 58.5	150	5	32	84	6.8	N/A	N/A
7	2/06 2014	20:58:10.050 -25.2	20:58:10.350 48.8	300	4	24	74	7.8	N/A	N/A
8	2/06 2014	21:00:11.000 -23.2	21:00:11.000 52.2	350	4	22	75.4	2	N/A	N/A

According to measurements of the electric mill located near GAMMA array the lightning was much closer and amplitude of near-surface electric field disturbances was much larger. Unfortunately, lightning kills this electric mill and it is another evidence along with staff reports that lightning was much closer than 11 km.

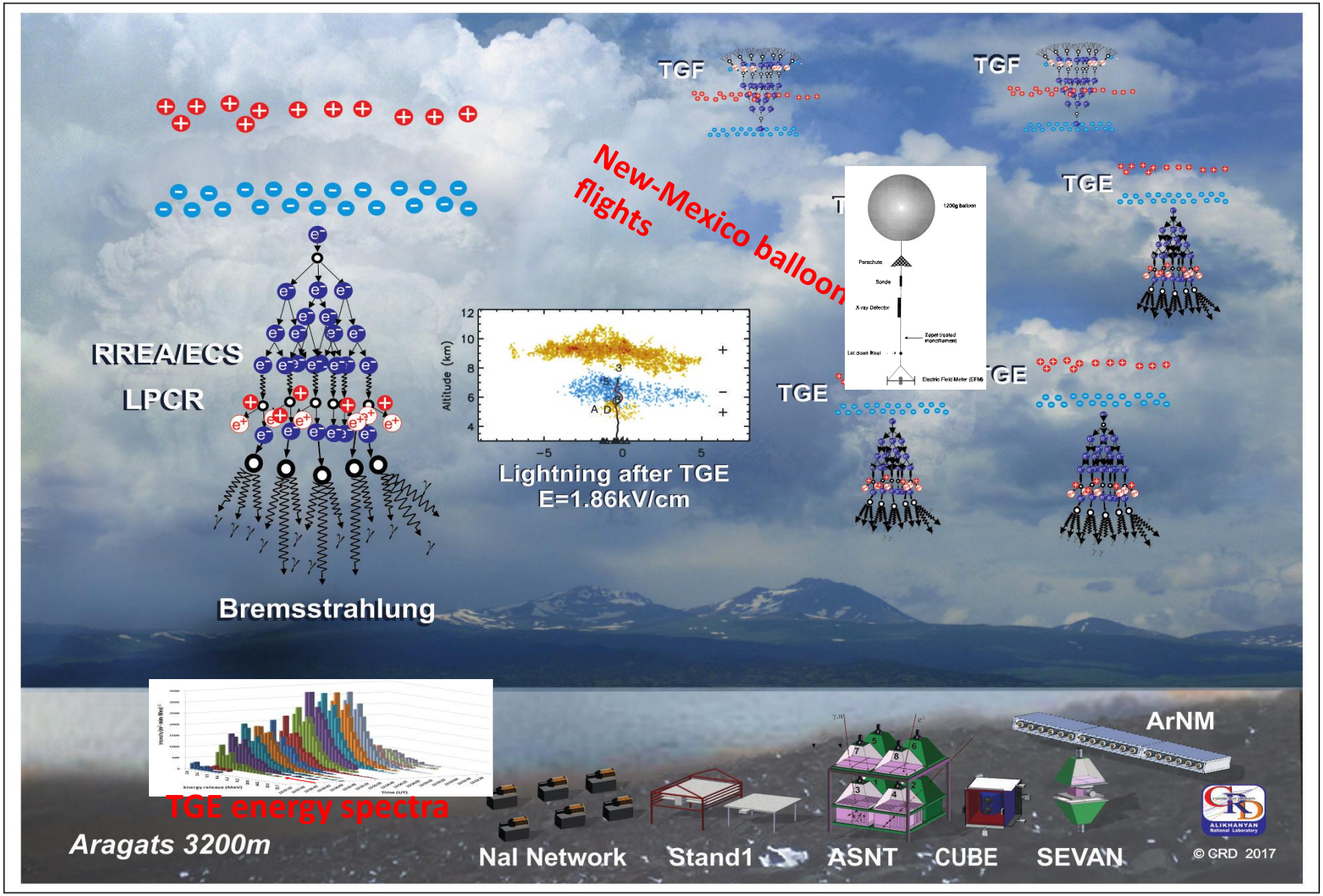
TGEs terminated by lightning



Scatter plot: distances to 8 lightnings detected both by WWLLN and EFM-100, correlation coefficient R~ 0.2



One from numerous randomly emerging TGEs in the thundercloud open path to the lightning leader!



Research of Thunderstorm Ground Enhancements (TGEs)

- **Observations during 2009-2016 of the TGEs and their energy spectra on Aragats as well as detection on the millisecond time scales particle fluxes, lightning flashes and disturbances of the electrostatic field allows:**
- **Confirm the RB/TGE process as a source of the high-energy particle fluxes from thunderclouds;**
- **Confirm the mechanism of lightning initiation (RB/TGE);**
- **Thundercloud is full of radiation and randomly the RB/TGE process is initiated in several places of cloud cell. By chance one of the TGE made enough ionization to make easier the lightning leader path through the LPCR and –CG flash strikes! If LPCR is to thick normal intracloud flash happened.**

TEPA 2016

THUNDERSTORMS & ELEMENTARY PARTICLE ACCELERATION

Edited by

A. Chilingarian

3-7 October 2016

Yerevan Physics Institute

TEPA 2017

ORGANIZERS:
Cosmic Ray Division of Yerevan Physics Institute, Armenia
Skobeltsyn Institute of Nuclear Physics of Moscow State University, Russia

THUNDERSTORMS AND ELEMENTARY PARTICLE ACCELERATION

Internationanl symposium

From March 2017
Registration open!!!

STRUCTURE OF THE SYMPOSIUM:

We anticipate the following sessions:

1. Models of high-energy emissions in thunderclouds;
2. Multivariate observations of thunderstorms from the Earth's surface and from space;
3. Particle fluxes and lightnings – any causal relations?
4. Research of the Thunderstorm ground enhancements (TGEs);
5. Research of the Terrestrial gamma-ray flashes (TGF);
6. Extensive air showers, lightning and RB/RREA process;
7. Atmospheric High-energy phenomena observations by space-born facilities
8. Instrumentation

Topics to be covered during oral and poster sessions:

* Research of the Thunderstorm ground enhancements (TGEs), measurements of electrons, gamma rays and neutrons by networks of particle detectors located on Earth's surface;
* Research of the Terrestrial gamma-ray flashes (TGFs) observed by the orbiting gamma-ray observatories;
* Radio emissions produced by atmospheric discharges and particle fluxes;
* Lightning initiation and its relation to particle fluxes originated in thundercloud;
* Neutron production during thunderstorms;
* Ultraviolet and infrared emissions during thunderstorms;
* Monitoring of thunderclouds and particle emission from orbit;
* Monitoring of the thunderstorms by high speed cameras e;
* Methods of the remote sensing of the thundercloud structure and electric field;
* X-ray emissions from the lightning;
* Abrupt termination of the particle flux by the lightning flash;
* Precise electronics for the high-energy atmospheric research;
* Relations to the climate and space weather issues;
* Possibility of joint observations by space-born and ground-based facilities.
* The global electrical circuit.

October 2 - 6

Nor Amberd International Conference Centre
Yerevan Physics Institute,
Byurakan, Aragatsotn Province, Armenia

BACKGROUND:

New emerging field of high-energy atmospheric physics (HEAP) is still lacking firmly established concepts and theories. The relationship of lightning and elementary particle fluxes in the thunderclouds is not fully understood to date. HEAP presently includes 2 main physical phenomena: Terrestrial Gamma Flashes (TGFs) - brief burst of gamma radiation (sometimes also electrons and positrons) registered by the orbiting gamma ray observatories in the space and Thunderstorm ground enhancements (TGEs) -the prolonged particle fluxes registered on the ground level [. Both TGFs and TGEs are related to the thunderstorms and lightning flashes: TGEs - by directly detecting electric field and lightning occurrences above the detector site; TGFs by making rather complicated synchronization with worldwide lightning detecting networks. The central engine initiated TGE is believed to be the Relativistic Runaway Electron avalanches (RREA) accelerated seed electrons from ambient population of cosmic rays (CR) in the large-scale thundercloud electric field up to 40-50 MeV. Observation of numerous TGEs by the Japanese, Russian, Armenian, Chines, Slovakian groups prove that RREA is a robust and realistic mechanism for electron acceleration and multiplication leaving no doubts about correctness of the RREA model for the TGE initiation. Models using CERN origin GEANT4 code support in situ measurements of electron and gamma ray energy spectra at Aragats. Another model of the gamma glow initiation was used for explaining gamma ray detections by TERA array in Florida. The main idea of the model is thermal electron acceleration in the streamer tips up to energies of □65 keV; thereafter these electrons runaway and accelerate further by the extreme electric field in the streamer zone in vicinity of negative lightning leader. This 2-stage model includes development of very strong electric fields in very short times. Correspondingly, the model includes compatible theories and models with several parameters which values are very difficult to measure or estimate (for instance the electric field of 260 kV/cm in the lightning leader tip, ee- field strength and elongation in the streamer zone where runaway electrons suppose to reach MeV energies). Thus, many questions about thundercloud electrification and discharge mechanisms, lightning initiation, propagation and attachment processes, the global electrical circuit, and transient luminous events do not have a complete and common accepted explanation yet. One of the most important problems "do lightning flashes produce relativistic particles or not?" is still open. TEPA meeting is great opportunity for scientist to meet, discuss, invent new ideas and make new bridges for collaborative works.

INTERNATIONAL ADVISORY COMMITTEE:

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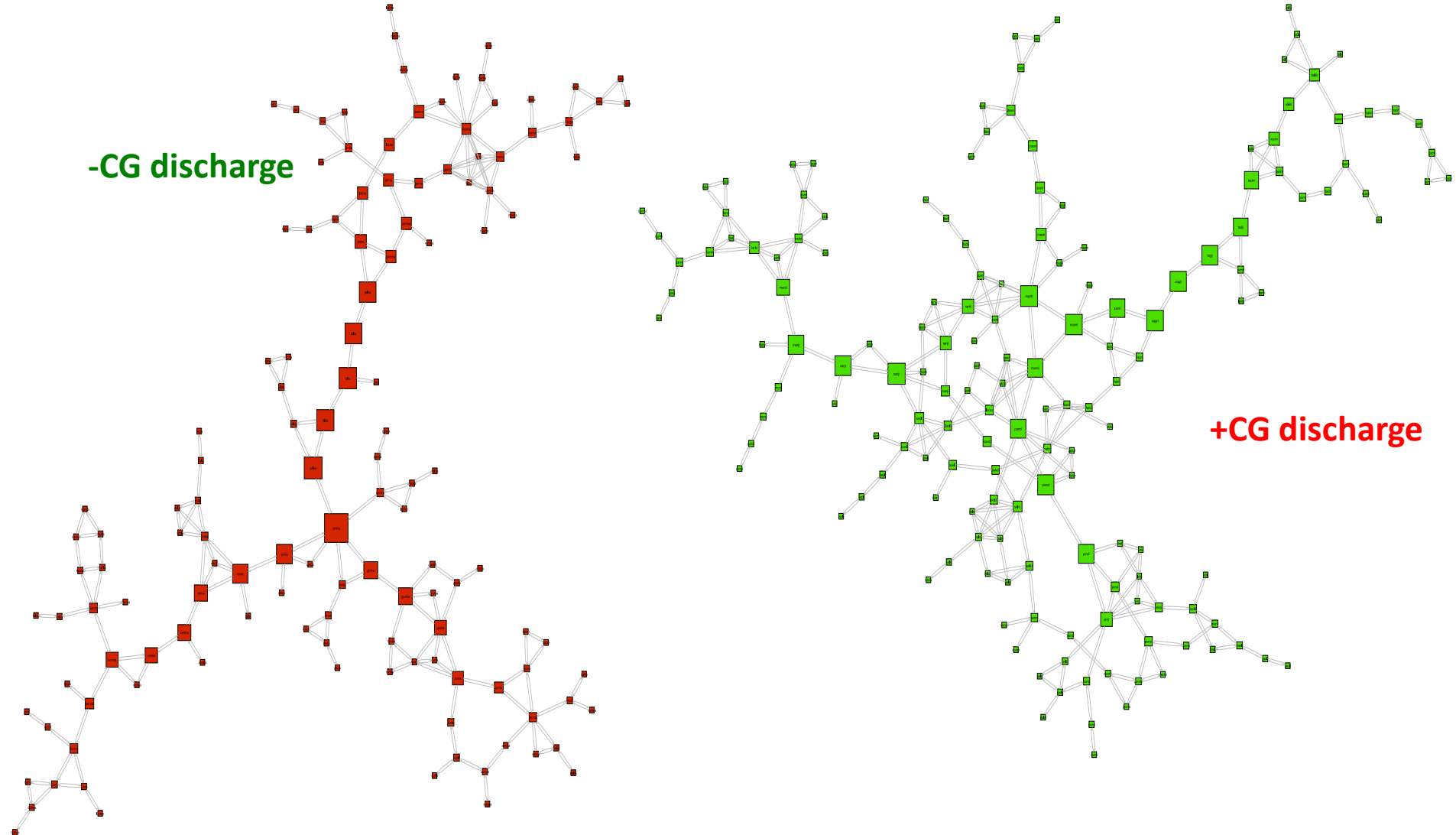
ALIKHANYAN National Laboratory

http://crd.yerphi.am/Conferences/tepa2016/home

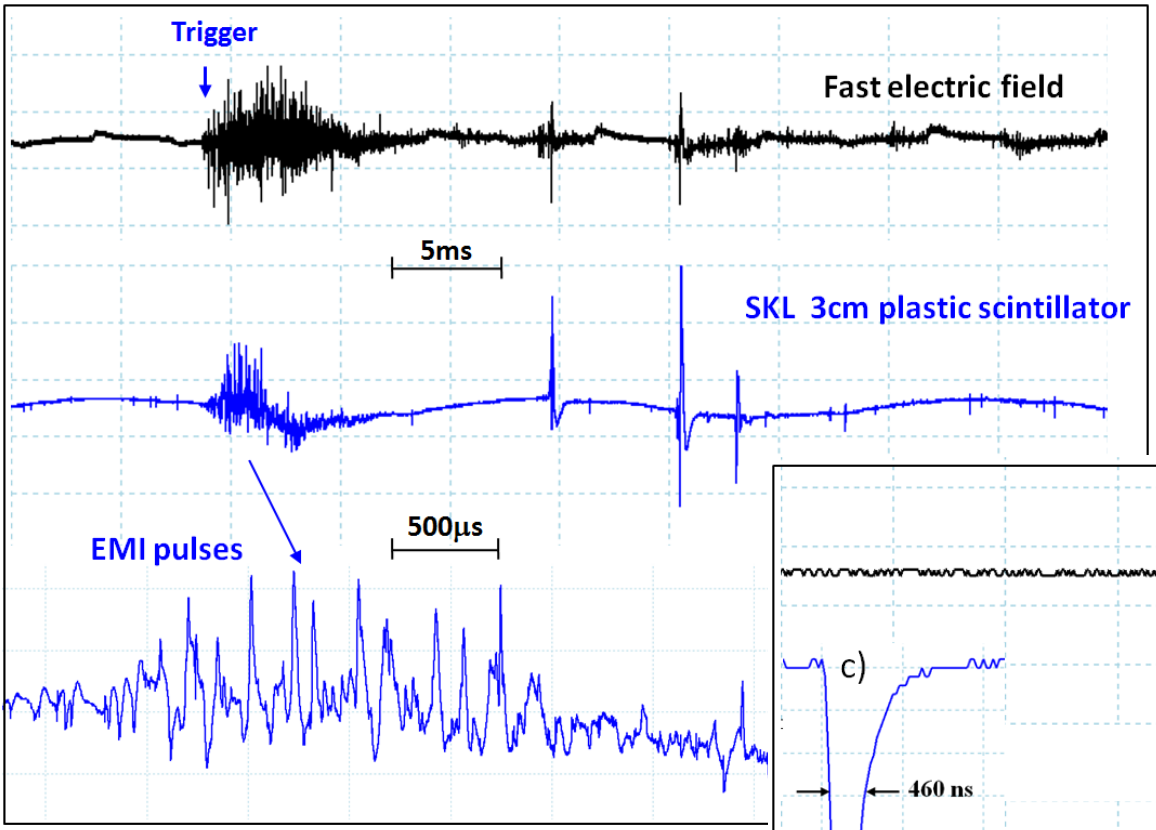
SCA CRD

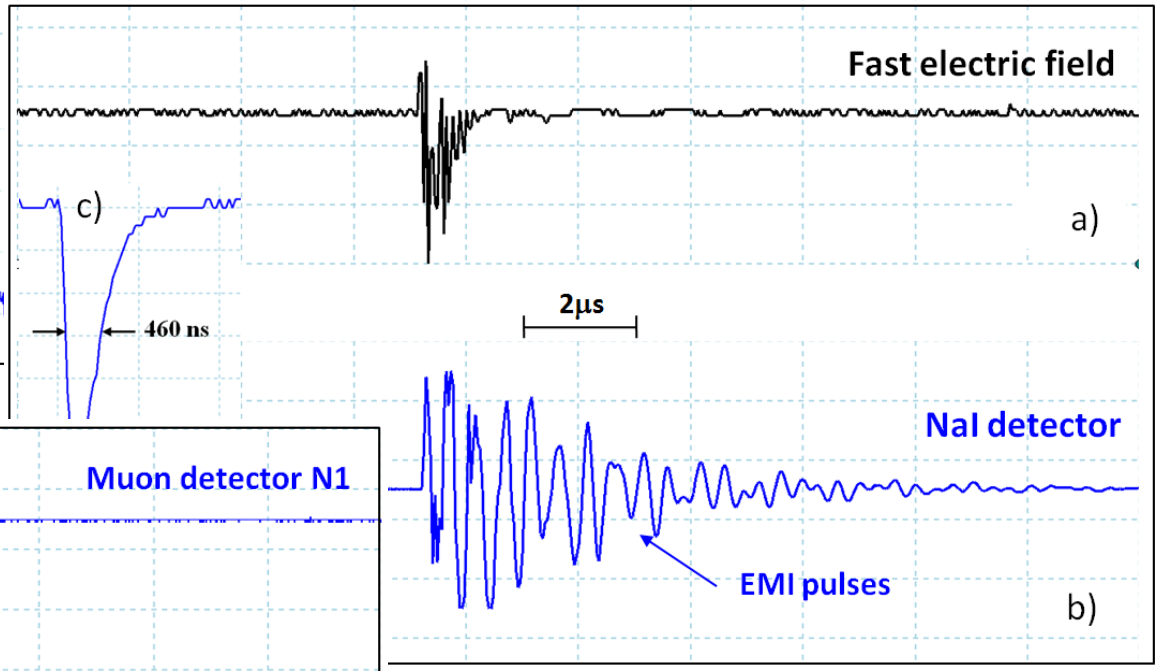
Miscellaneous

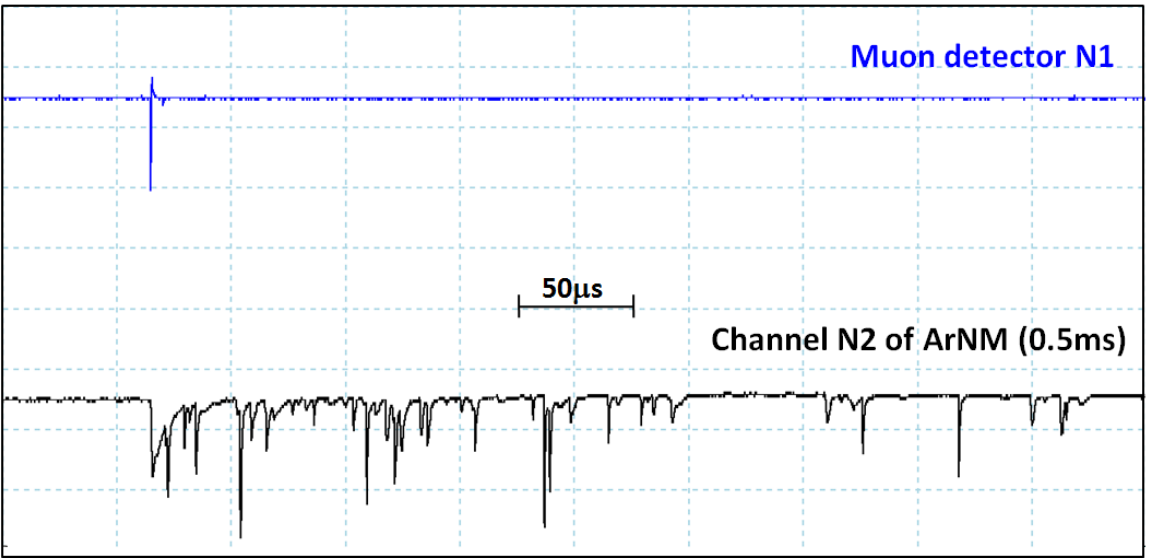
Percolation theory describes the behavior of connected clusters in a random 3-dimensional graph: will the discharges be able to make its way via the ionization “spots” and reach the earth’s surface making lightning flash?

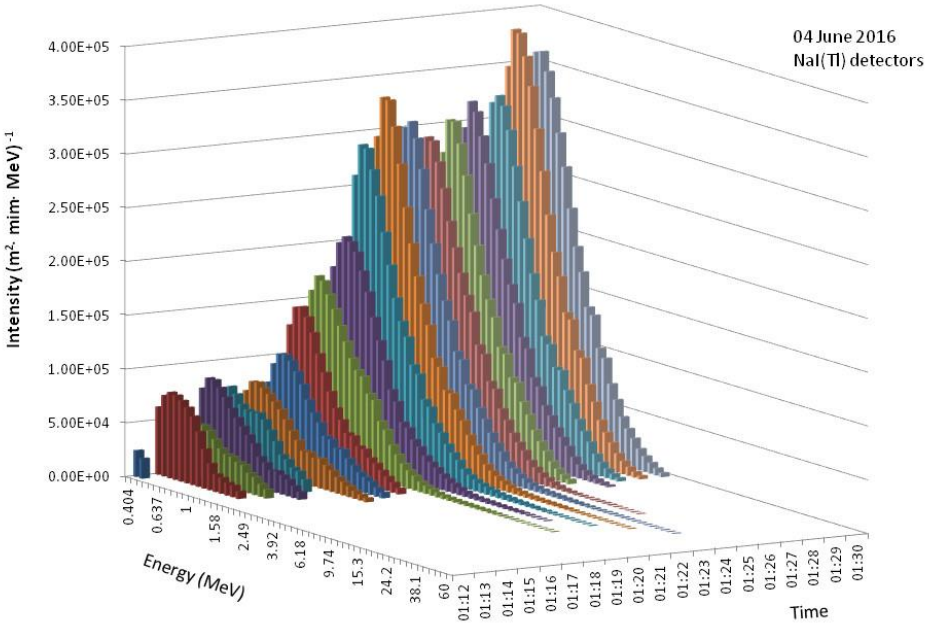


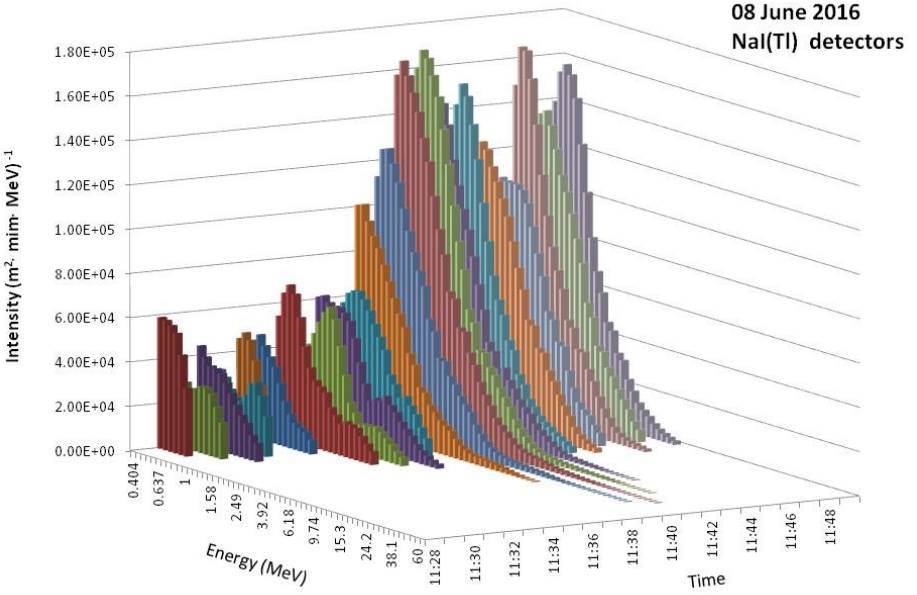
Lightnings does not originate particles

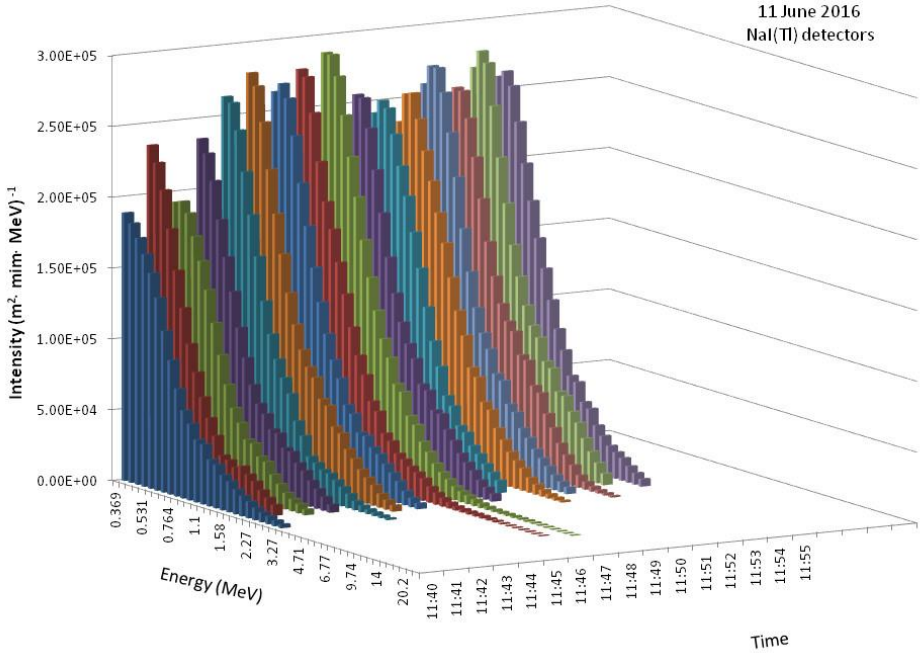


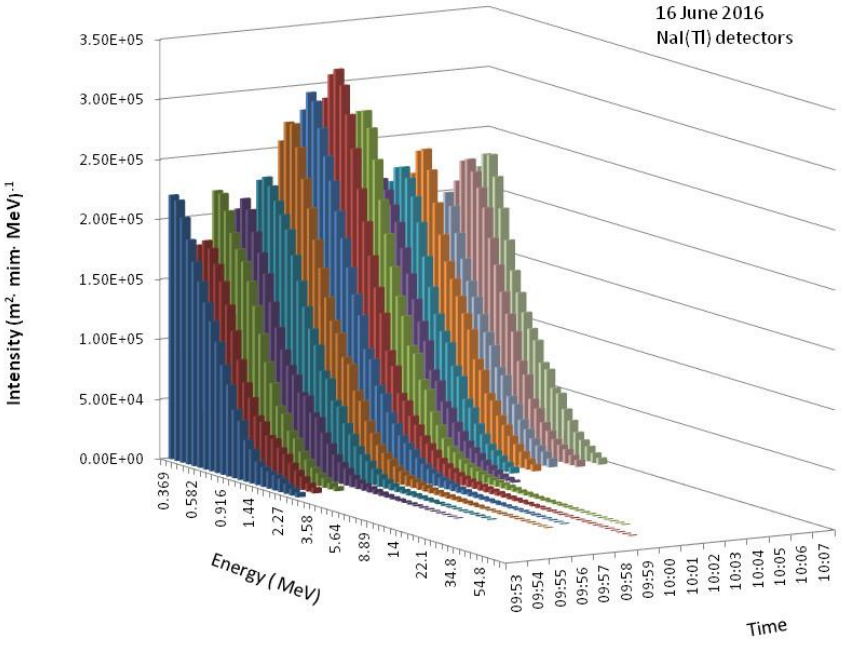


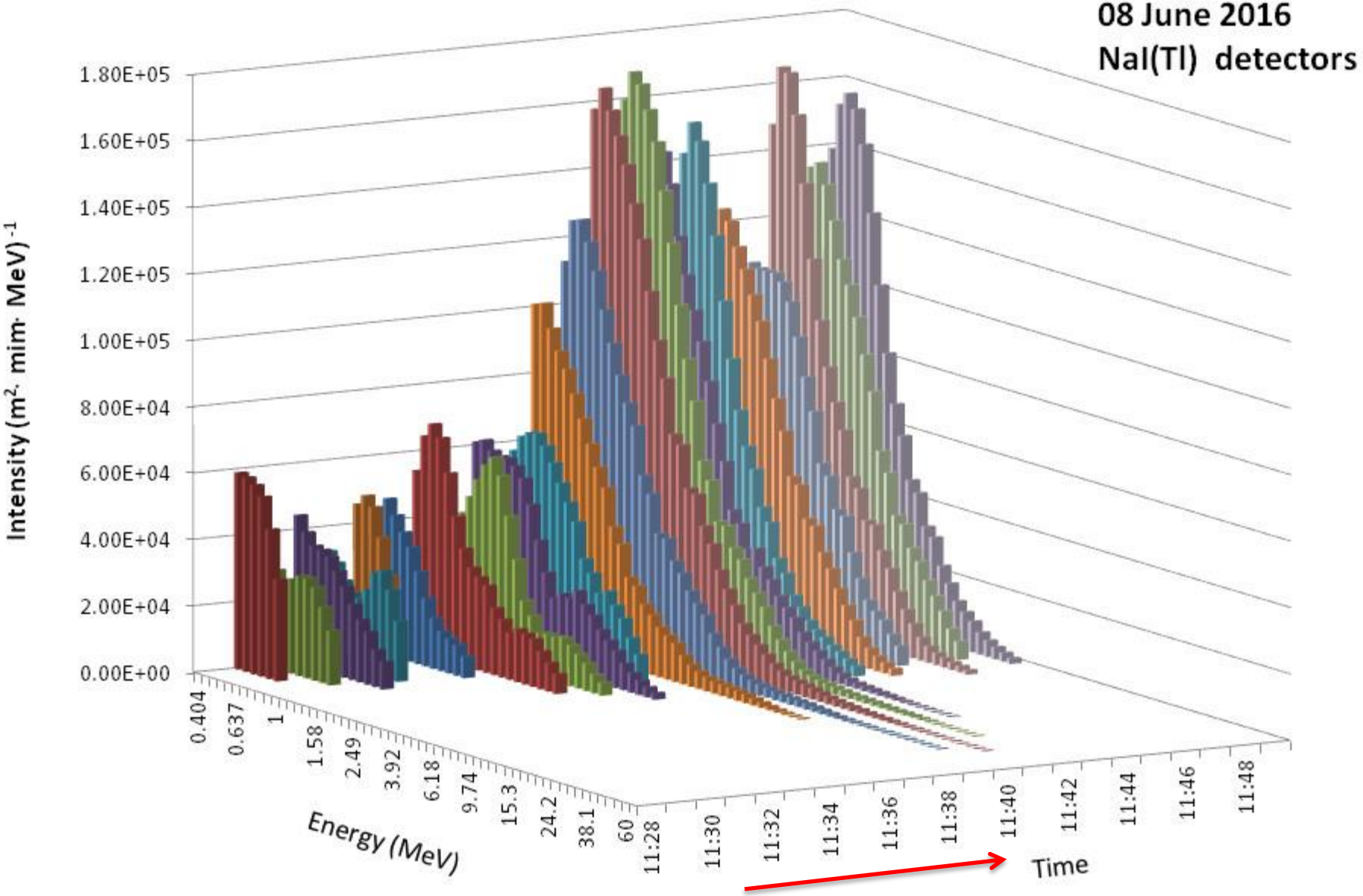


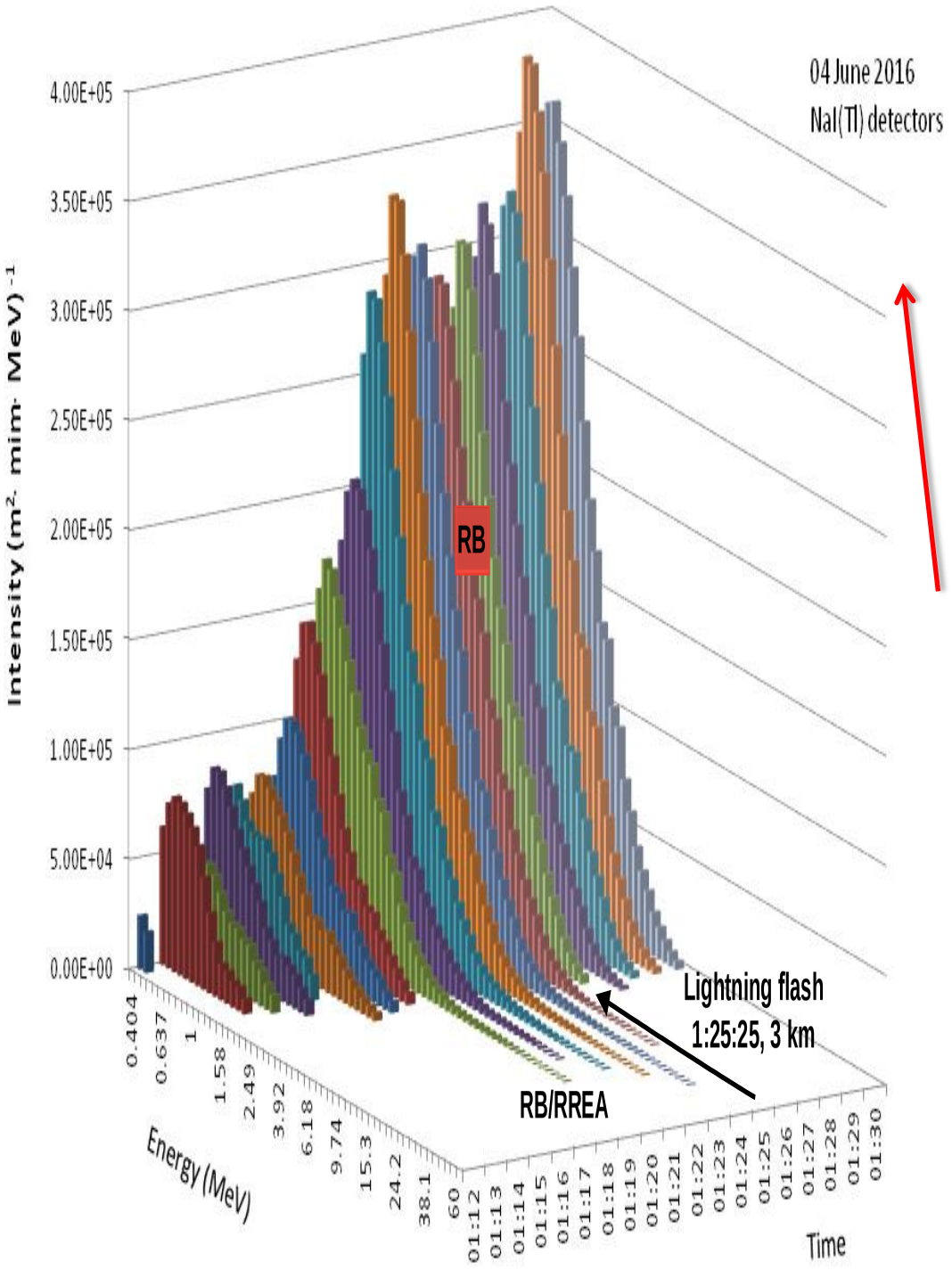

04 June 2016
NaI(Tl) detectors
Intensity (m-2· mim· MeV)-1
4.00E+05
3.50E+05
3.00E+05
2.50E+05
2.00E+05
1.50E+05
1.00E+05
5.00E+04
0.00E+00
0.404
0.637
1
1.58
2.49
3.92
6.18
9.74
15.3
24.2
38.1
60
Energy (MeV)
01:12
01:13
01:14
01:15
01:16
01:17
01:18
01:19
01:20
01:21
01:22
01:23
01:24
01:25
01:26
01:27
01:28
01:29
01:30
Time

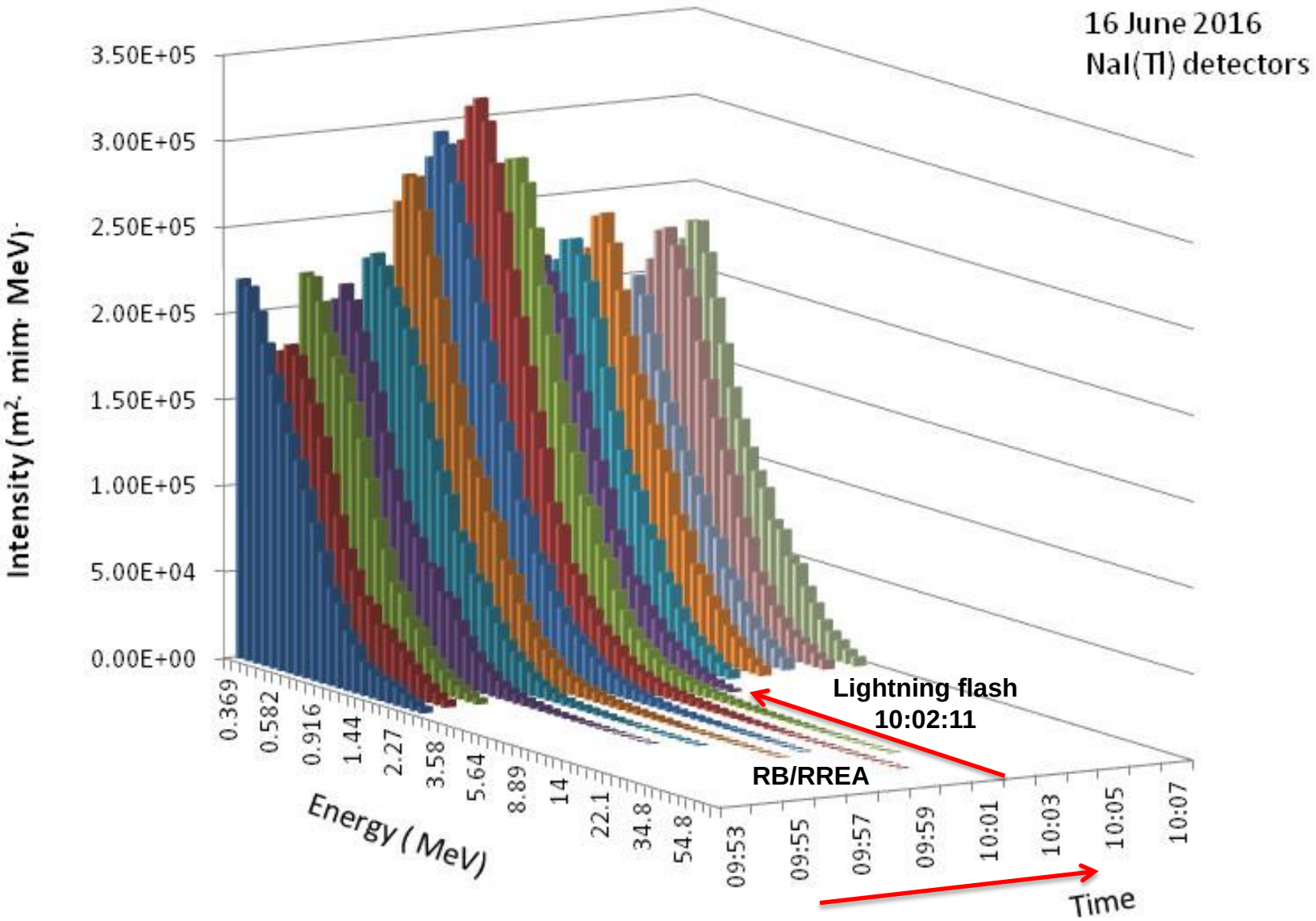

08 June 2016
NaI(Tl) detectors
Intensity (m-2· mim· MeV)-1
1.80E+05
1.60E+05
1.40E+05
1.20E+05
1.00E+05
8.00E+04
6.00E+04
4.00E+04
2.00E+04
0.00E+00
0.404
0.637
1
1.58
2.49
3.92
6.18
9.74
15.3
24.2
38.1
60
Energy (MeV)
11:28
11:30
11:32
11:34
11:36
11:38
11:40
11:42
11:44
11:46
11:48
Time


11 June 2016
NaI(Tl) detectors
Intensity (m-2· mim· MeV)-1
3.00E+05
2.50E+05
2.00E+05
1.50E+05
1.00E+05
5.00E+04
0.00E+00
0.369
0.531
0.764
1.1
1.58
2.27
3.27
4.71
6.77
9.74
14
20.2
Energy (MeV)
11:40
11:41
11:42
11:43
11:44
11:45
11:46
11:47
11:48
11:49
11:50
11:51
11:52
11:53
11:54
11:55
Time

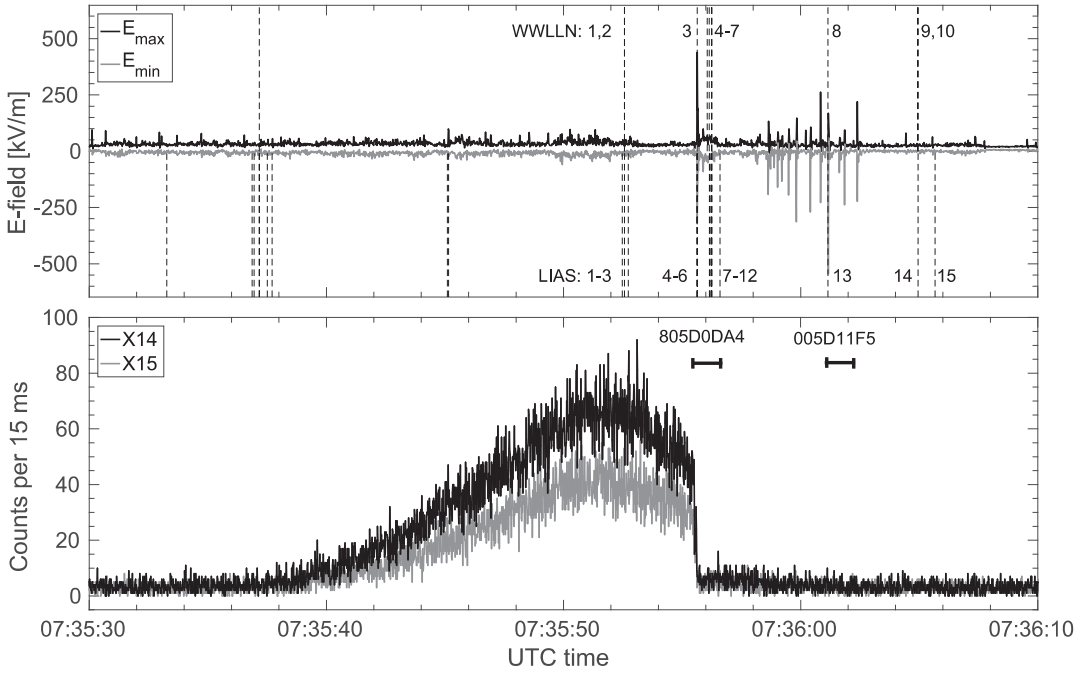

16 June 2016
NaI(Tl) detectors
Intensity (m-2· mim· MeV)-1
3.50E+05
3.00E+05
2.50E+05
2.00E+05
1.50E+05
1.00E+05
5.00E+04
0.00E+00
0.369
0.582
0.916
1.44
2.27
3.58
5.64
8.89
14
22.1
34.8
54.8
Energy (MeV)
09:53
09:54
09:55
09:56
09:57
09:58
09:59
10:00
10:01
10:02
10:03
10:04
10:05
10:06
10:07
Time


08 June 2016
NaI(Tl) detectors
Intensity (m2. mim. MeV)-1
1.80E+05
1.60E+05
1.40E+05
1.20E+05
1.00E+05
8.00E+04
6.00E+04
4.00E+04
2.00E+04
0.00E+00
0.404
0.637
1
1.58
2.49
3.92
6.18
9.74
15.3
24.2
38.1
60
Energy (MeV)
11:28
11:30
11:32
11:34
11:36
11:38
11:40
11:42
11:44
11:46
11:48
Time


04 June 2016
NaI(Tl) detectors
Intensity (m^{-2} min^{-1} MeV^{-1})
4.00E+05
3.50E+05
3.00E+05
2.50E+05
2.00E+05
1.50E+05
1.00E+05
5.00E+04
0.00E+00
RB
Lightning flash
1:25:25, 3 km
RB/RREA
Energy (MeV)
0.404
0.637
1
1.58
2.49
3.92
6.18
9.74
15.3
24.2
38.1
60
Time
01:12
01:13
01:14
01:15
01:16
01:17
01:18
01:19
01:20
01:21
01:22
01:23
01:24
01:25
01:26
01:27
01:28
01:29
01:30

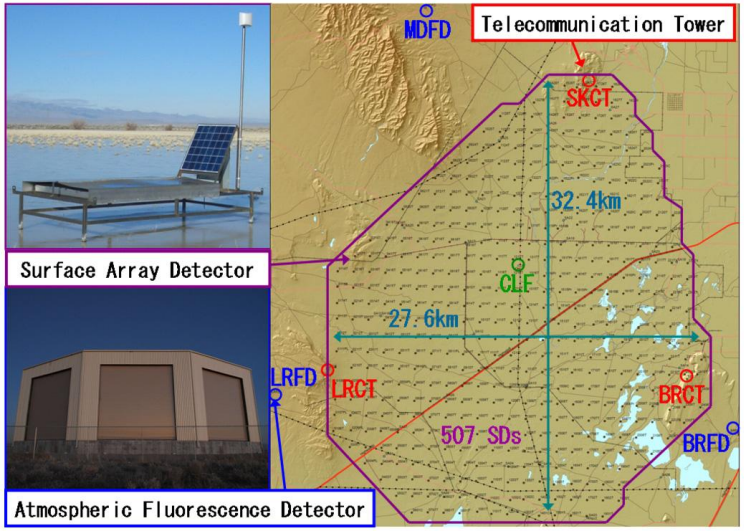

16 June 2016
NaI(Tl) detectors
Intensity (m2· mim· MeV)·
3.50E+05
3.00E+05
2.50E+05
2.00E+05
1.50E+05
1.00E+05
5.00E+04
0.00E+00
0.369
0.582
0.916
1.44
2.27
3.58
5.64
8.89
14
22.1
34.8
54.8
Energy (MeV)
09:53
09:55
09:57
09:59
10:01
10:03
10:05
10:07
Time
Lightning flash
10:02:11
RB/RREA

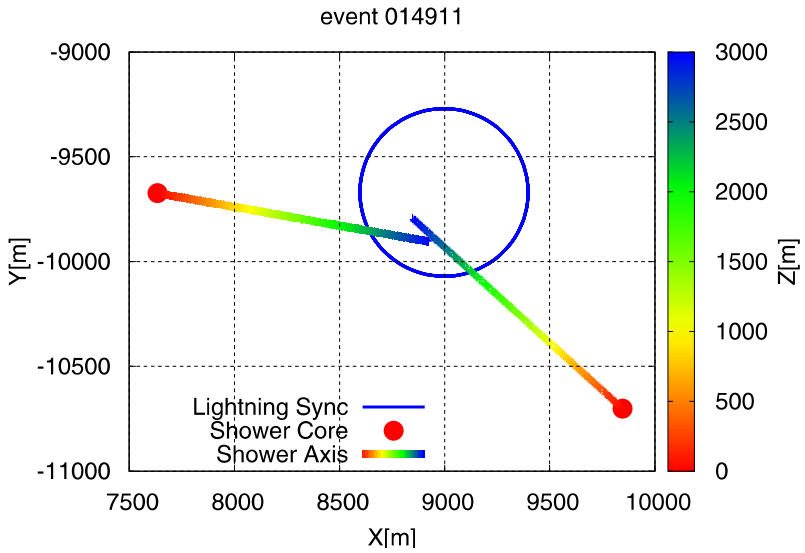
An Airbus A340 aircraft flew over Northern Australia with ILDAS system installed on-board: The most intense emission was observed at 12 km altitude and lasted for 20 s. Its intensity was 20 times the background counts and it was abruptly terminated by a distant lightning flash.



The gamma glow was abruptly terminated by a distant lightning flash. This is consistent with previously formulated assumption that glows are created by high E-filed regions inside thunderclouds.

The Telescope Array (TA) experiment, located in Midwest Utah, USA(39.3N, 112.9W)





TA operates Surface Detector (SD) comprised from 507 plastic scintillation counters with equivalent energy for trigger threshold ~ 0.7 MeV. The counters are deployed as a square grid array with 1.2 km spacing, and covers 680 km^2 altogether. When three adjacent detectors detect a signal, each of which corresponds to more than three particle equivalent in 8 μs, judges that their signals are from an air shower, causing signal waveforms to be digitized from all detectors within ±32 μs of the trigger time. In the trigger data collected from May 11, 2008 to May 04, 2013 the authors of (Abassi et al., 2017) found ten cases in which at least three air shower triggers were recorded within 1 ms, called bursts. The reconstructed air shower directions for individual bursts appear to point to small regions at altitudes lower than the expected first interaction depth of cosmic ray air showers of comparable size. These bursts were checked against the Vaisala lightning database from U.S. National Lightning Detection Network (NLDN, Nag et al., 2011). The number of the detected lightning was 10,073. All 10 selected shower burst events were under thunderstorm, though only 4 of them were clearly synchronized with negative intracloud lightning. The peak current of the synchronized lightning is very large for the currents observed for negative intracloud lightning. Synchronized burst shower events occur nearly at the same time of lightning or earlier than lightning.