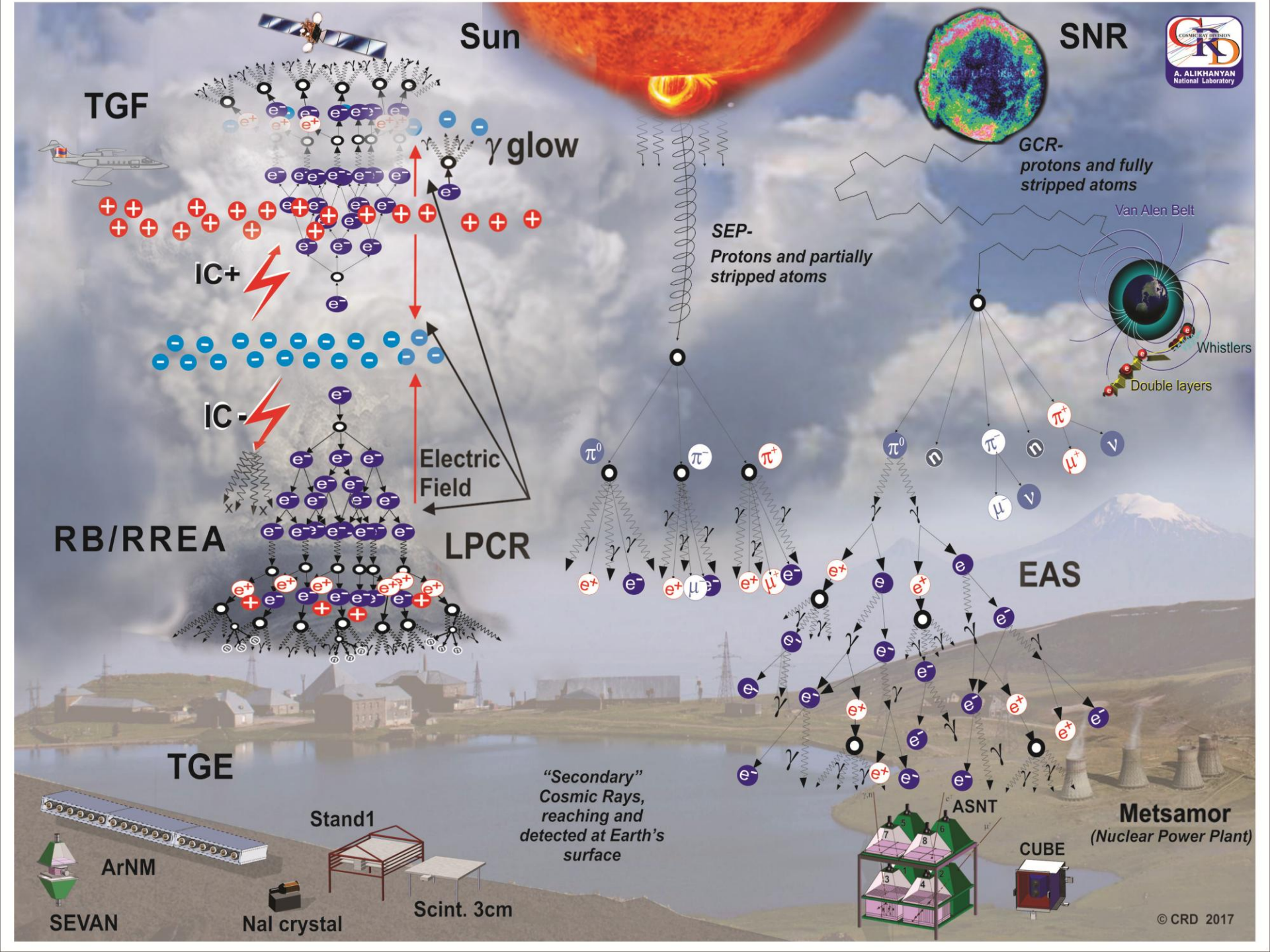
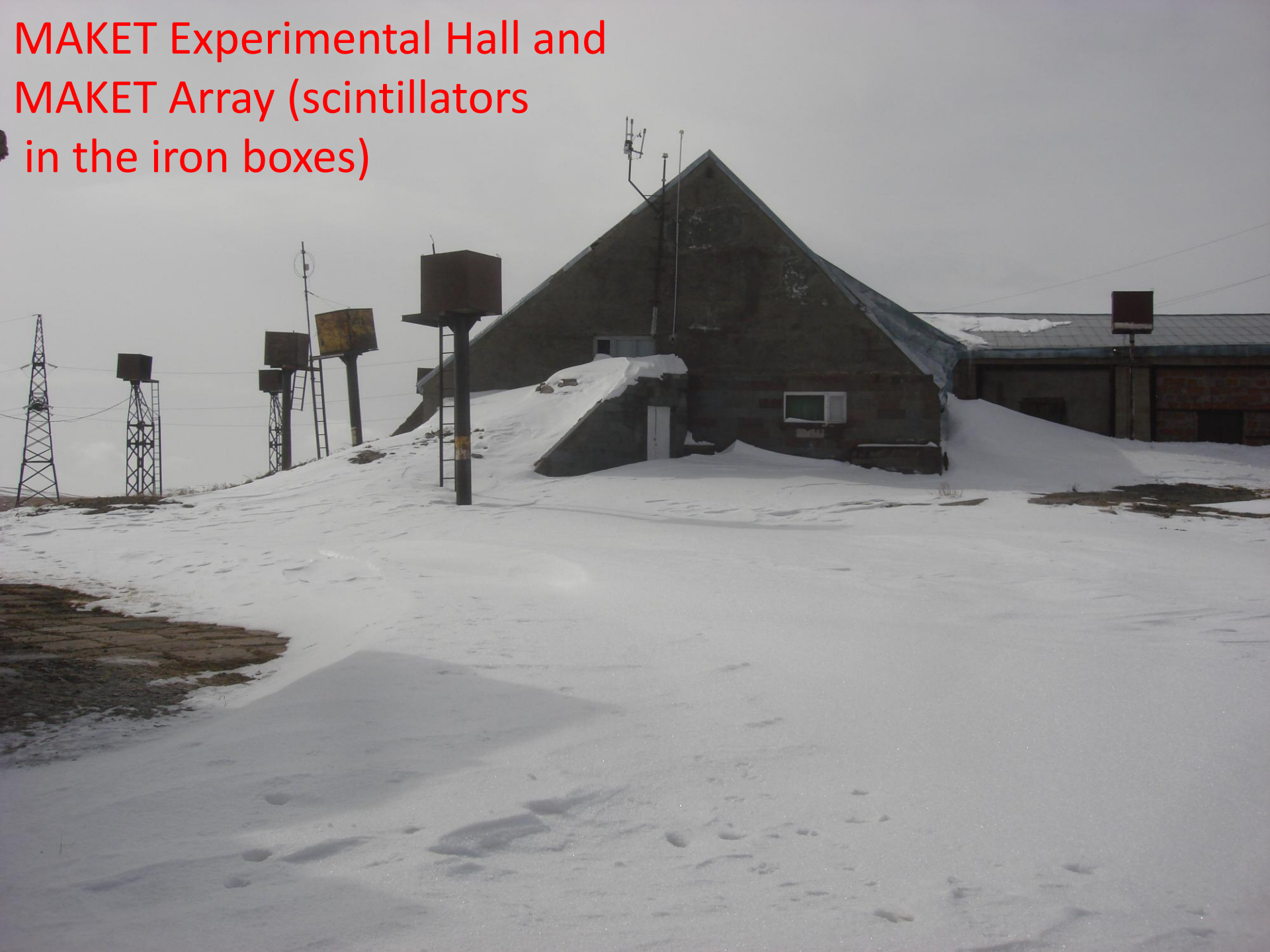

Sun
SNR
TGF
γ glow
GCR-
protons and fully
stripped atoms
Van Allen Belt
SEP-
Protons and partially
stripped atoms
Whistlers
Double layers
IC+
IC -
Electric
Field
RB/RREA
LPCR
EAS
TGE
"Secondary"
Cosmic Rays,
reaching and
detected at Earth's
surface
ArNM
Stand1
SEVAN
Nal crystal
Scint. 3cm
ASNT
CUBE
Metsamor
(Nuclear Power Plant)
© CRD 2017

Long lasting low energy TGEs : Rn222 or MOS (electric field in cloud)?

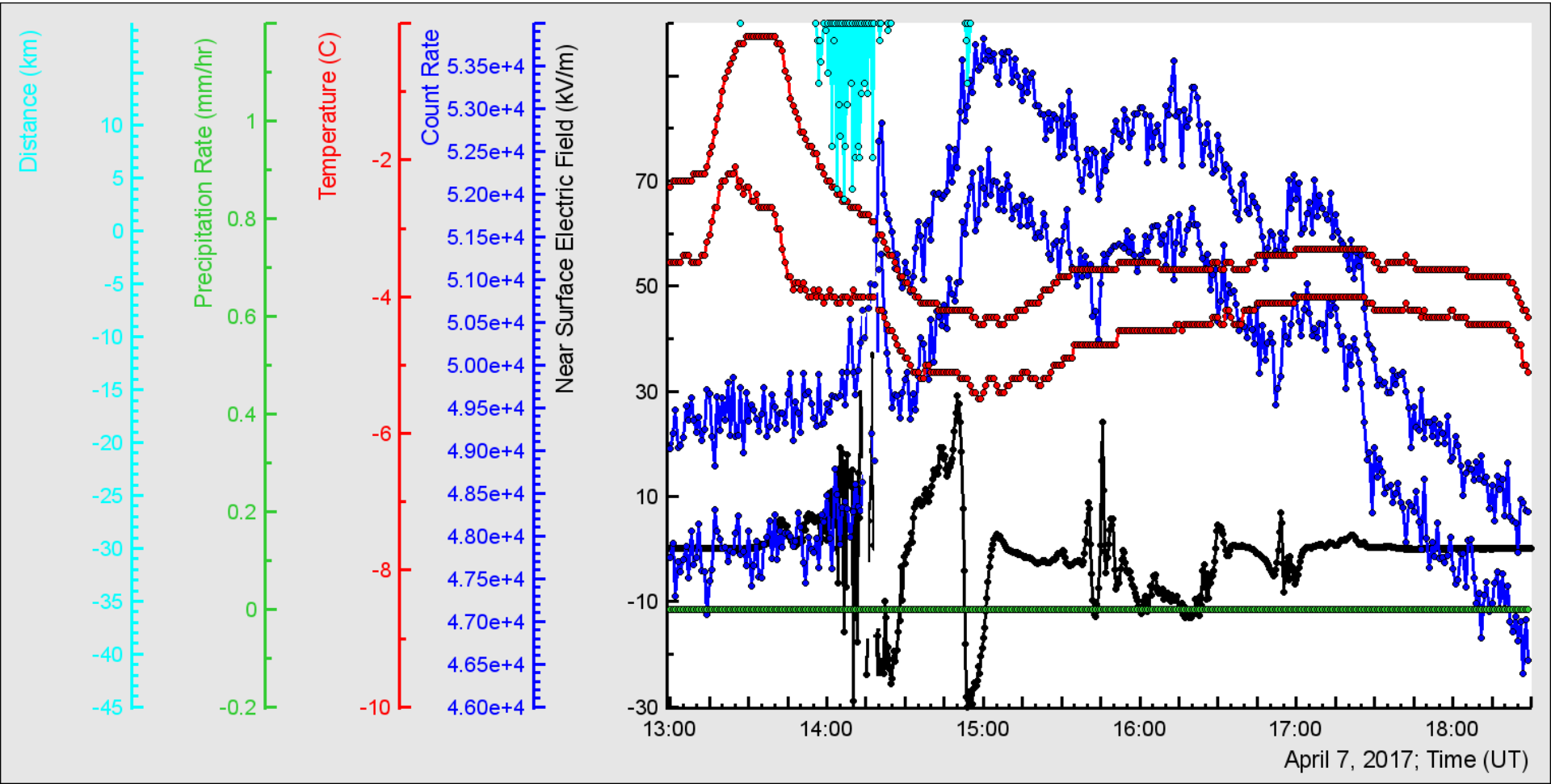
- TGE consists of a few minutes long high-energy emission (up to 30-40 MeV) and hours lasting low energy emission (<3MeV). Usually TGE started by high-energy emission;
- Emission is terminated by lightning flash occurred within 10 km from the detector site;
- The particle flux can decrease by ~50% (high-energy particles vanish) after flash. Flux can rise again to be killed by the second or third flash;
- If lightning flashes occurred at distances greater than 10 km, TGE can prolongeup to 10 minutes and the shape of bump will be symmetrical;
- The distance to the thundercloud base on Aragats is usually 50-100 m measured by “spread” - difference of the outside temperature and the dew point;
- NaI crystals located on the first floor and in the underground tunnel demonstrate much weaker enhancement of the flux compared with the NaI network located on the roof of building under 0.6 mm of iron tilt. Thus, the radiation come not from the ground (Radon daughters scenario), but from the cloud above;
- The flux enhancement is well correlated with electric field disturbances and not with rain or snow. The decay of the flux started after termination of the disturbances of electric field and is linear, not exponential;
- Rain do not influence duration and intensity of low-energy TGE. On fair weather also small clouds can slightly disturb electric field and cause LLL TGE;
- The particle flux comes from the clouds, due to electric field giving additional energy to the charged particles. Usually, after strong storm calms down, near surface electric field also stabilized to fair weather one. However, the stochastic fields remain in the cloud and can prolong enhance particle field foe hours.
- Thus, clouds are full of fields and radiation for a long time. The electric fields can introduce biases in the EAS and ACT research. Monitoring of clouds by Lidars is the necessary condition of unbised operation of surface arrays and ACTs.


South peak of Aragats (3700 m), Kare lake (3200m, already under ice) and ancient (4,000 BC) “Vishape” stone – the owner of water.

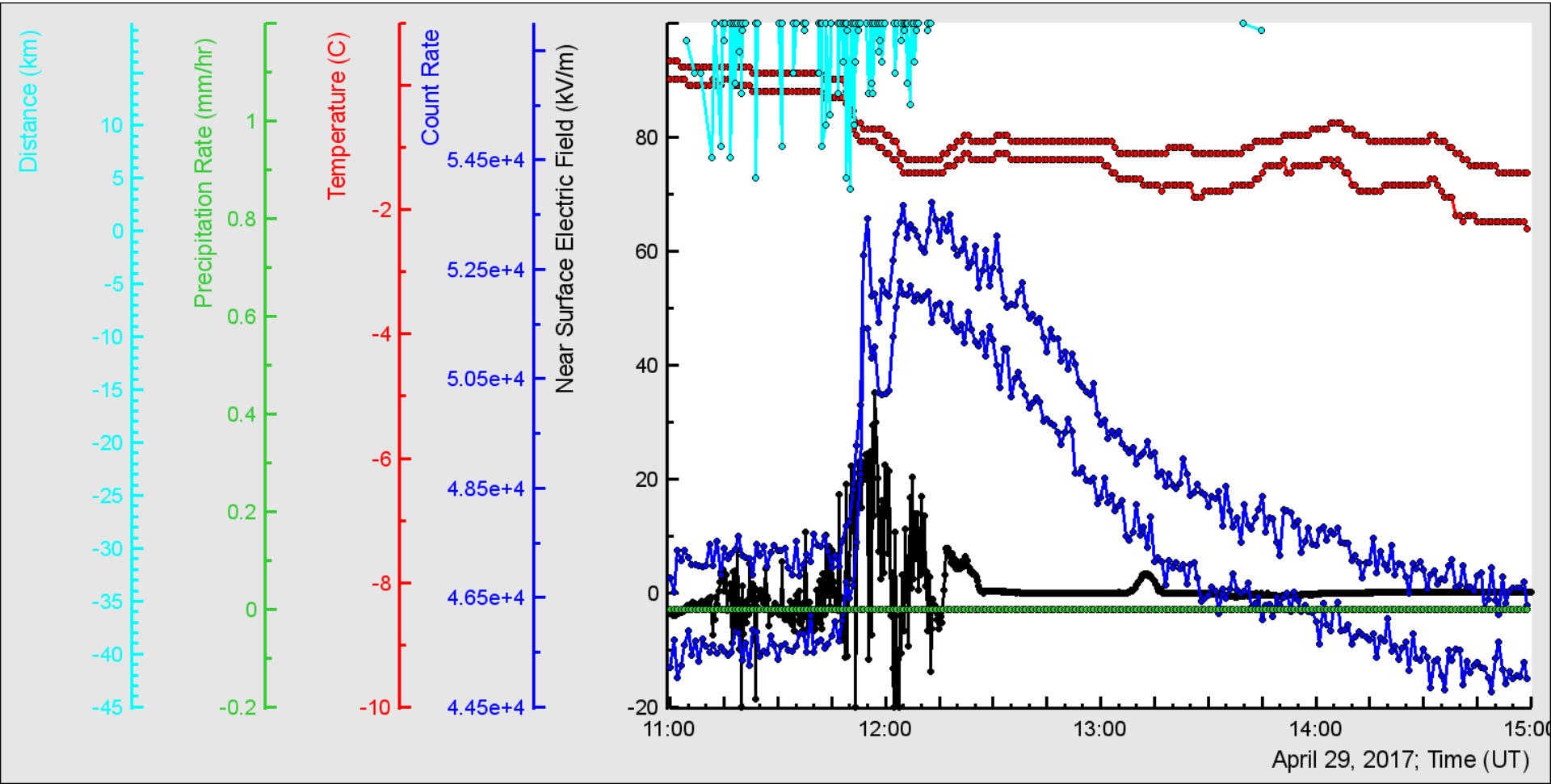

MAKET Experimental Hall and
MAKET Array (scintillators
in the iron boxes)

November 7 morning

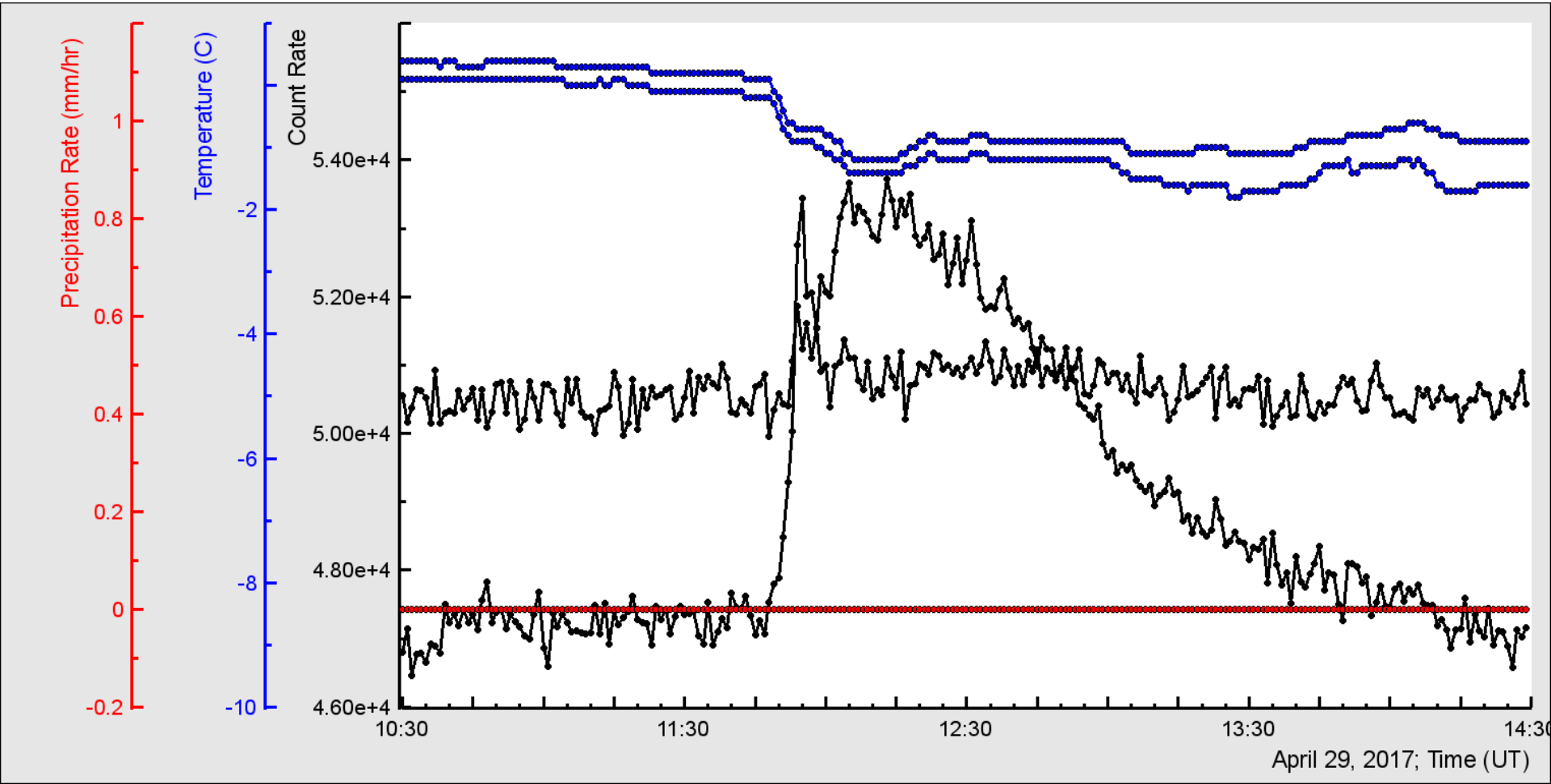
Count rate of NaI crystals N1 and N2 – energy threshold ~ 300 KeV, Electric field mill on roof of the MAKET experimental hall measures near-surface electric field and distance to the lightning flash. No Precipitation is measured by Davis automatic weather station. TGE started with short high-energy emission and continued with long-lasting low energy emission –LLL TGE.

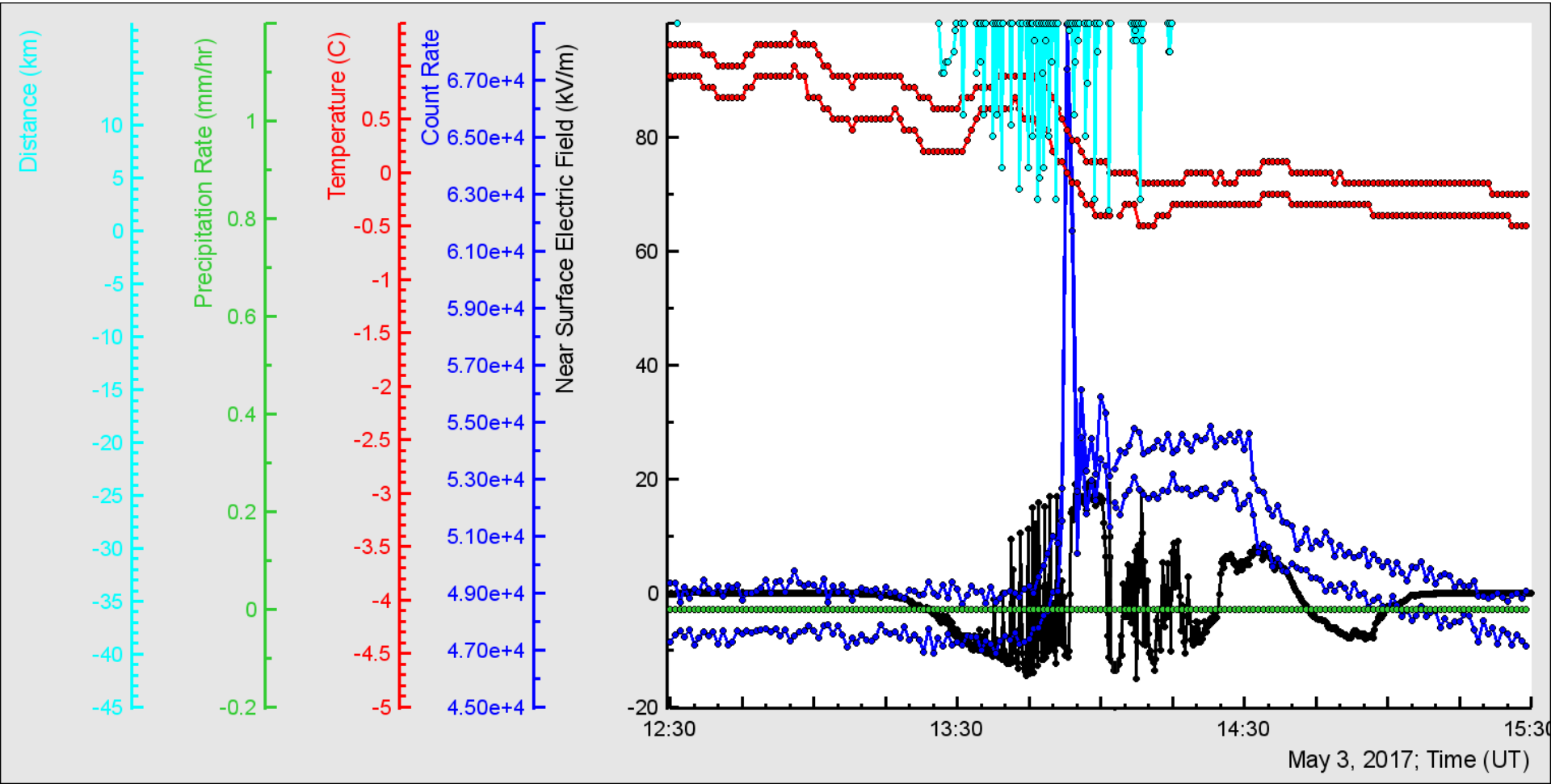


50-100 m estimated by “spread” - difference of outside temperature and dew point red lines). No rain, paricle flux decline after storm finishes, however it continued 1 hour more.

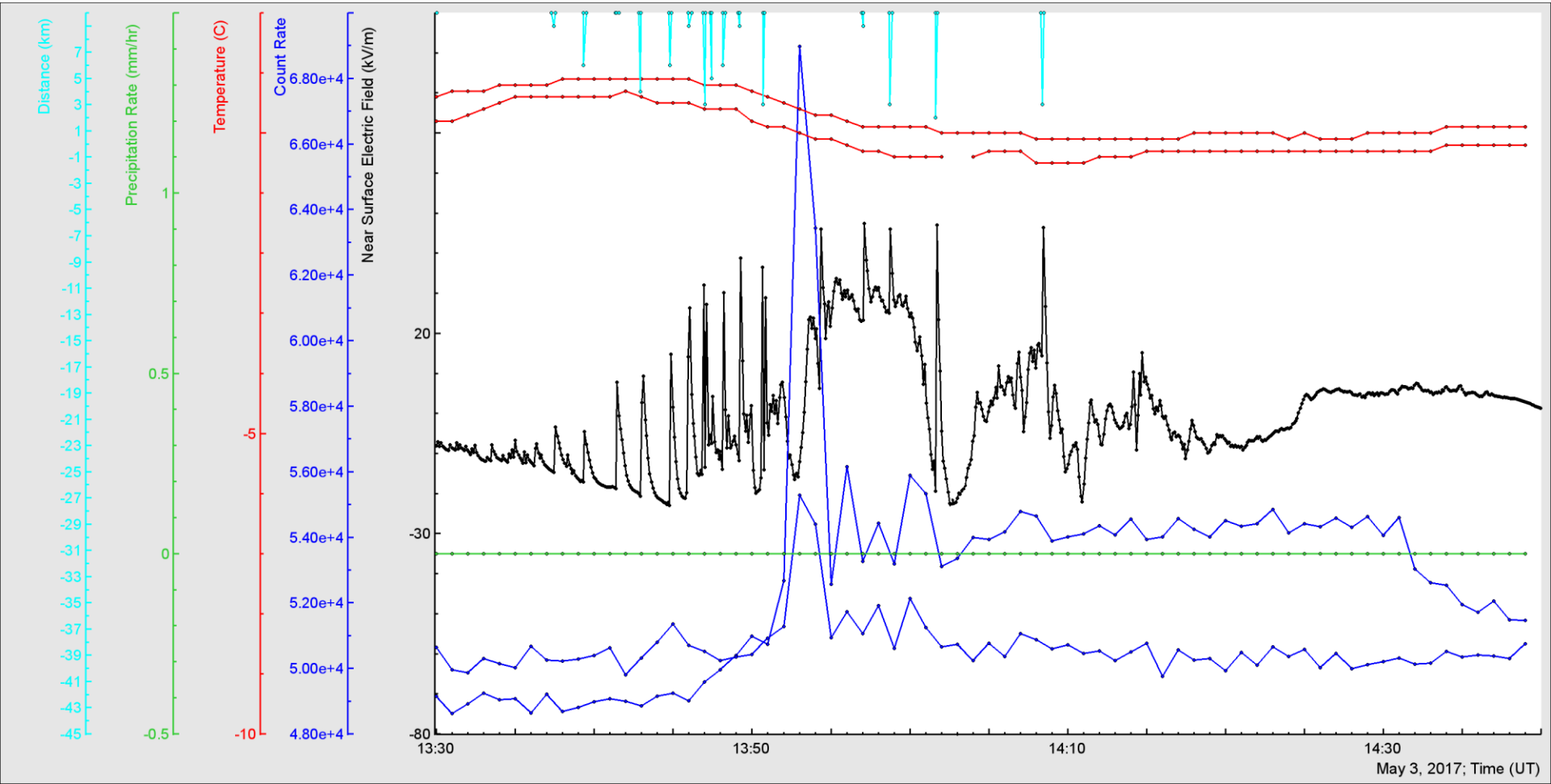


NaI crystals N2 (on the roof of SKL experimental hall – under 0.6 mm of iron tilt) and N 7 (on the first floor of SKL building under 3 cm thick wooden roof and 20 cm concrete layer. The number of additional particles in the NaI N2 is ~ 250,000 and in N7 – only 35,000. If particles come from Rn222 decays more additional particles will be registered near Earth's surface and not on the roof.

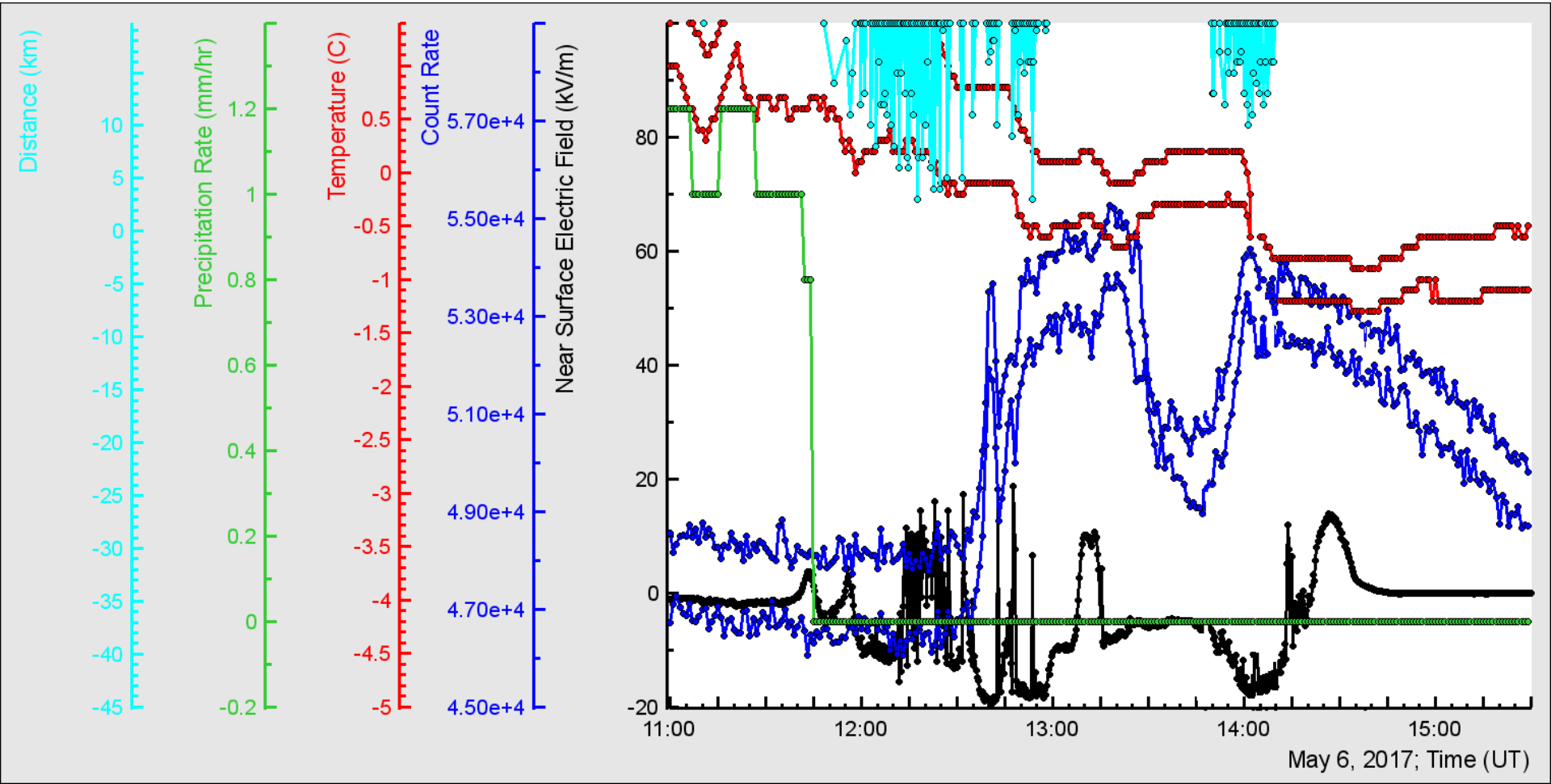



Distance (km)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
Precipitation Rate (mm/hr)
1
0.8
0.6
0.4
0.2
0
-0.2
Temperature (C)
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
Count Rate
6.70e+4
6.50e+4
6.30e+4
6.10e+4
5.90e+4
5.70e+4
5.50e+4
5.30e+4
5.10e+4
4.90e+4
4.70e+4
4.50e+4
Near Surface Electric Field (kV/m)
80
60
40
20
0
-20
12:30
13:30
14:30
15:30
May 3, 2017; Time (UT)

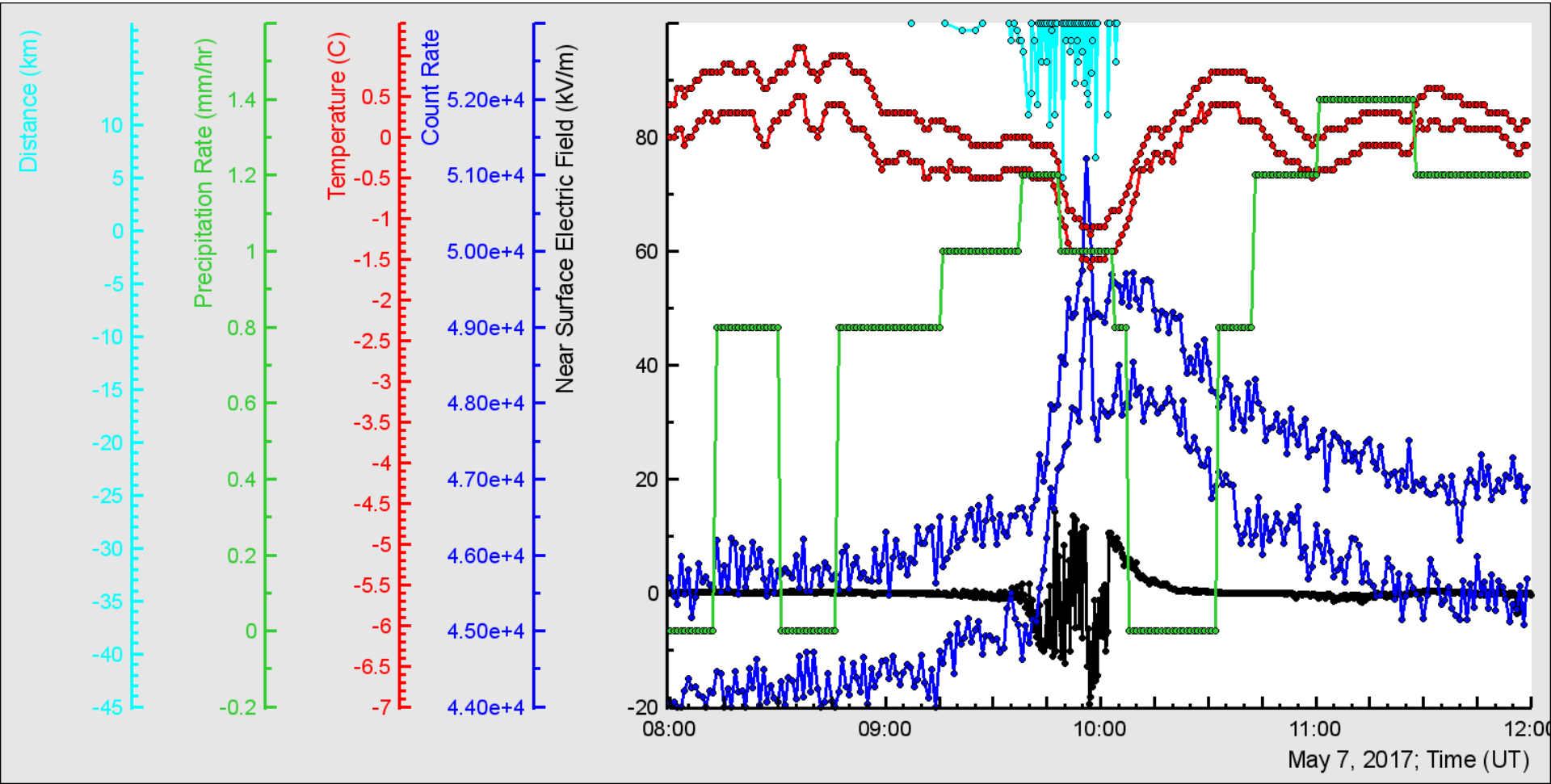
TGE with intense high-energy emission occurred after strong lightning activity. NaI crystals N2 (on the roof of SKL experimental hall – under 0.6 mm of iron tilt) and N 7 (on the first floor of SKL building under 3 cm thick wooden roof and 20 cm concrete layer (significantly lower peak intensity).



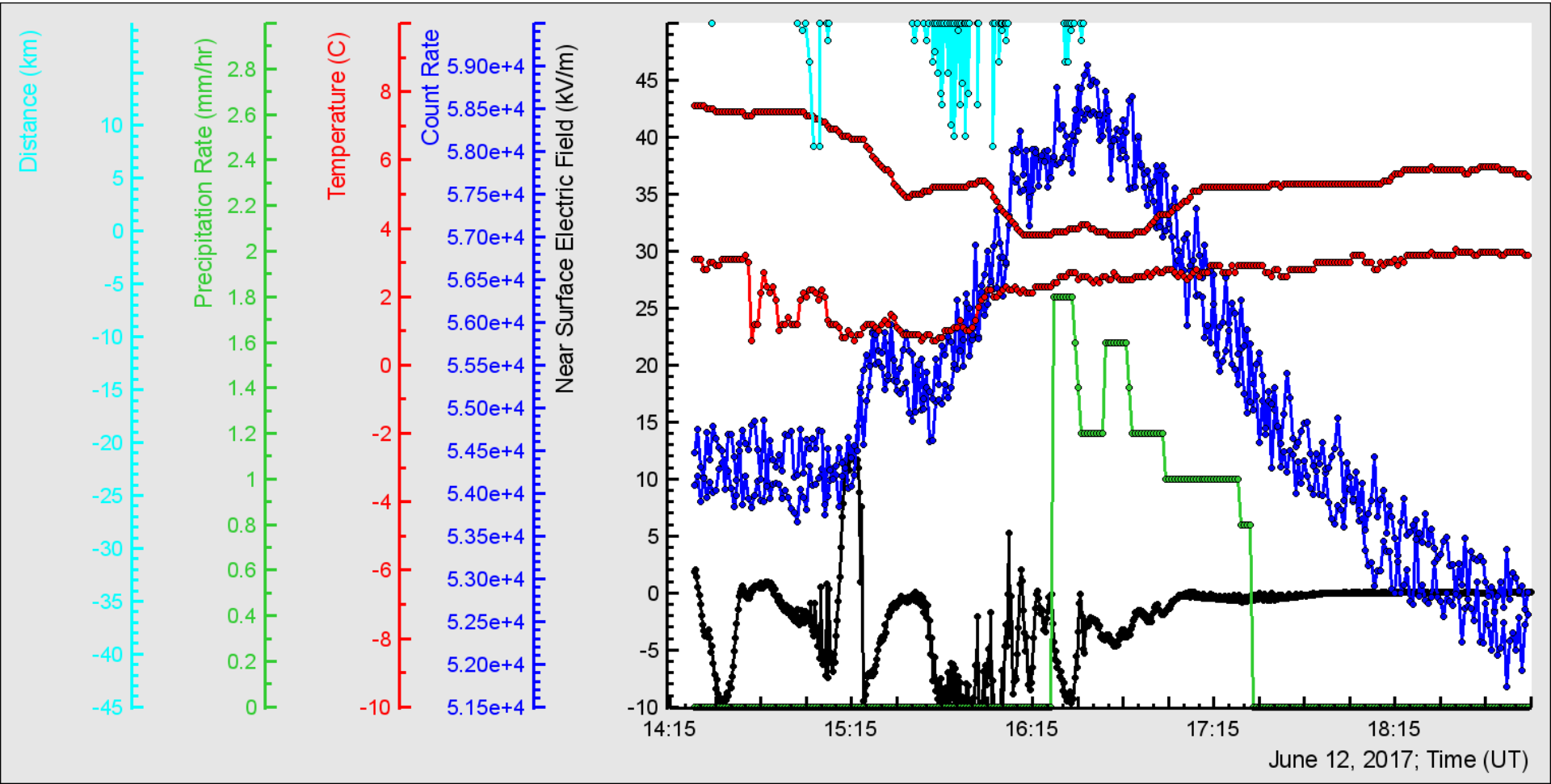
During and after rain no particle flux enhancement was detected; only after disturbances of the near surface electric field particle flux start to rose. It ceases at 13:10 when electric field return to fair weather values d continued at half-of-hour after electric field reduces down to ~20 kV.m.



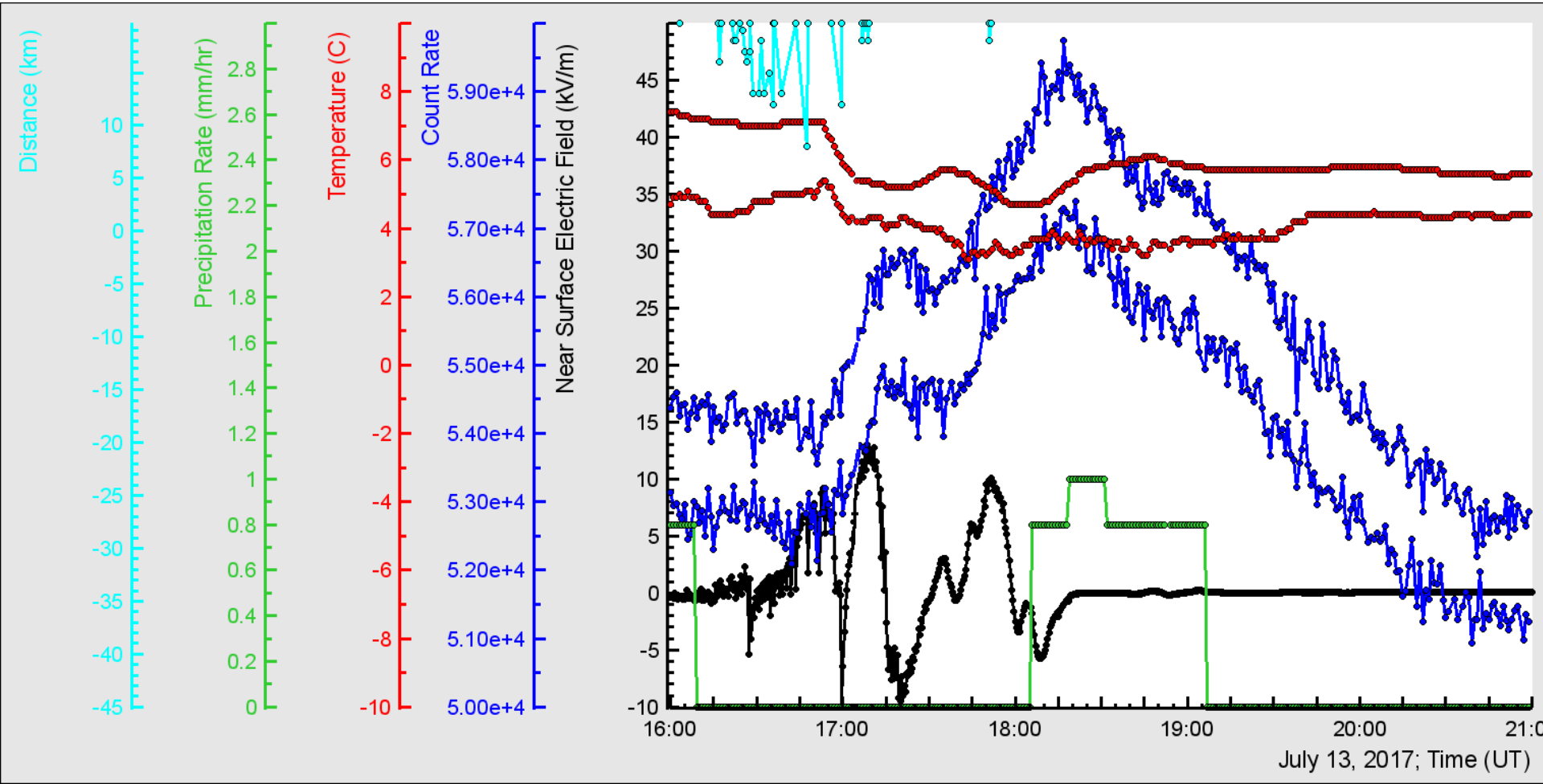
Precipitation seem not to influence TGE intensity: it decays after calming of near-surface electric field disturbances in spite of strengthening of rain.



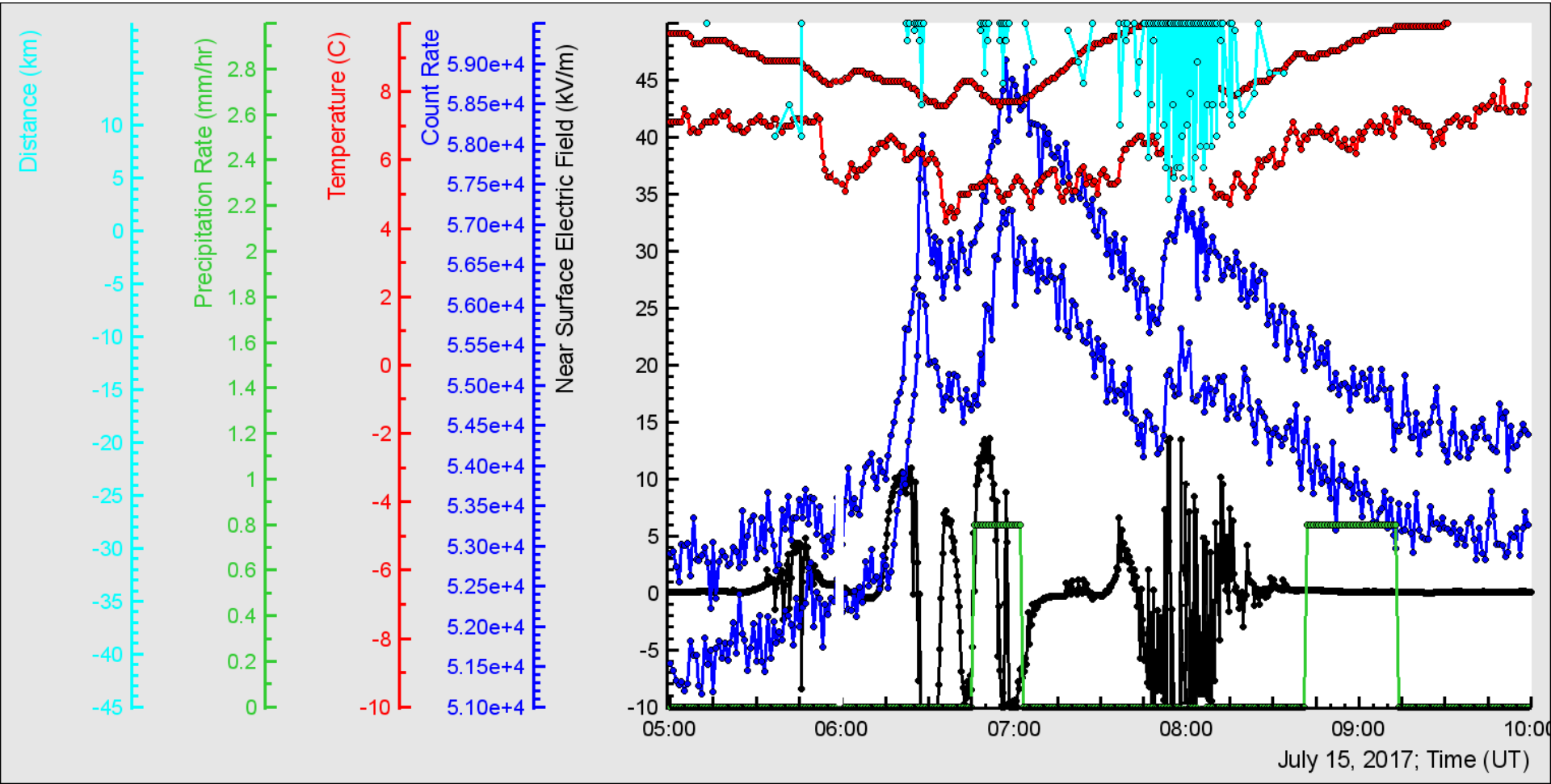
TGE started 1 hour before rain and decays on rain maximum



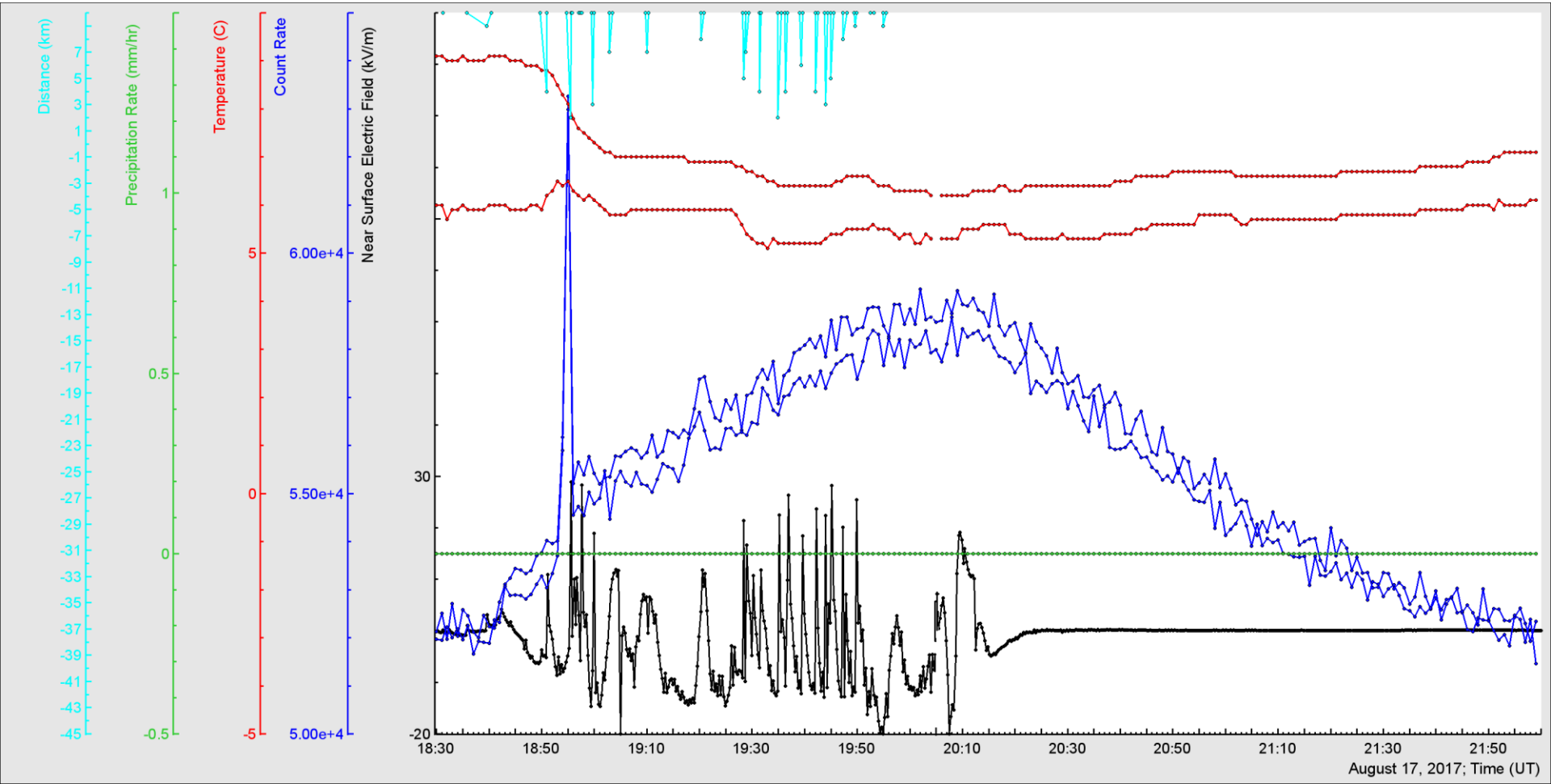
TGE started 1 hour before rain and decays on rain maximum



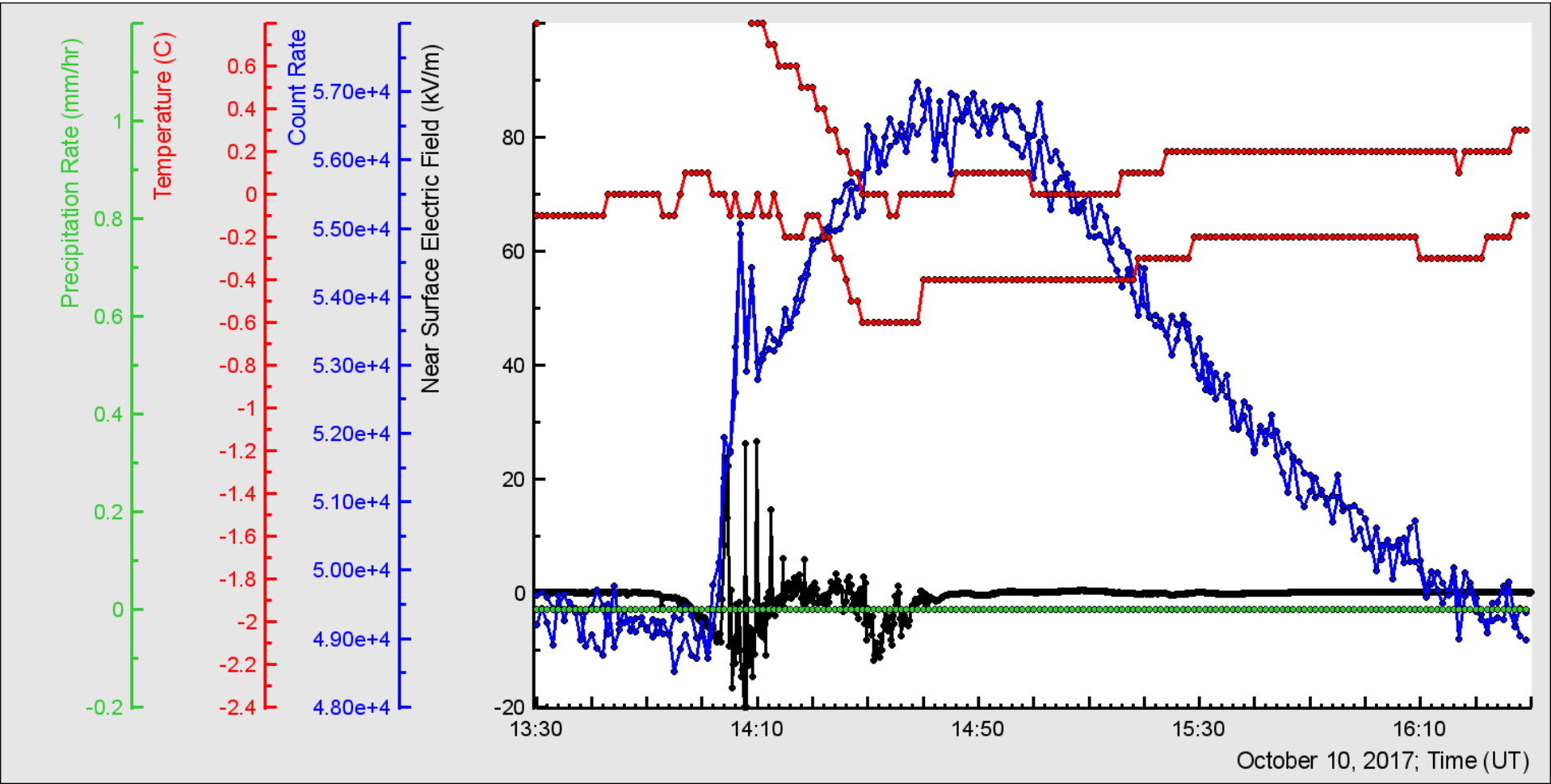
TGE started 1 hour before raining, decays on calming down disturbances of the field just after raining; then particle flux rose when disturbances strengthen and decays after it despite on starting raining: electric field and not raining is cause of TGE!



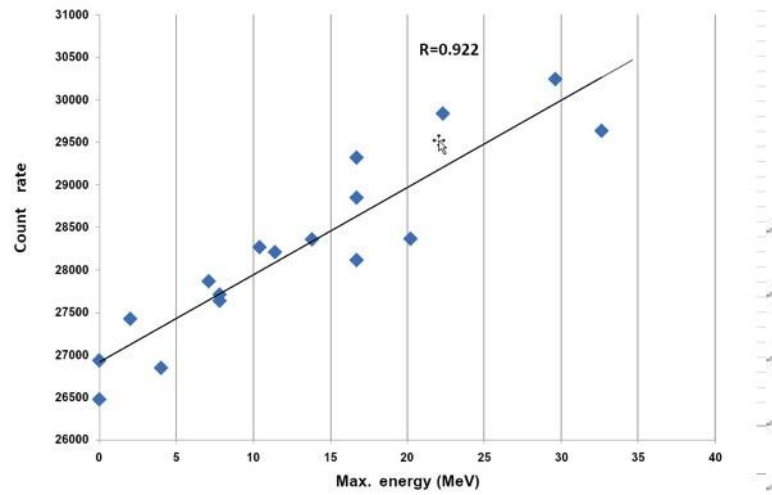
No raining; only electric field disturbances; another confirmation of the MOS process responsible for LLL TGE!

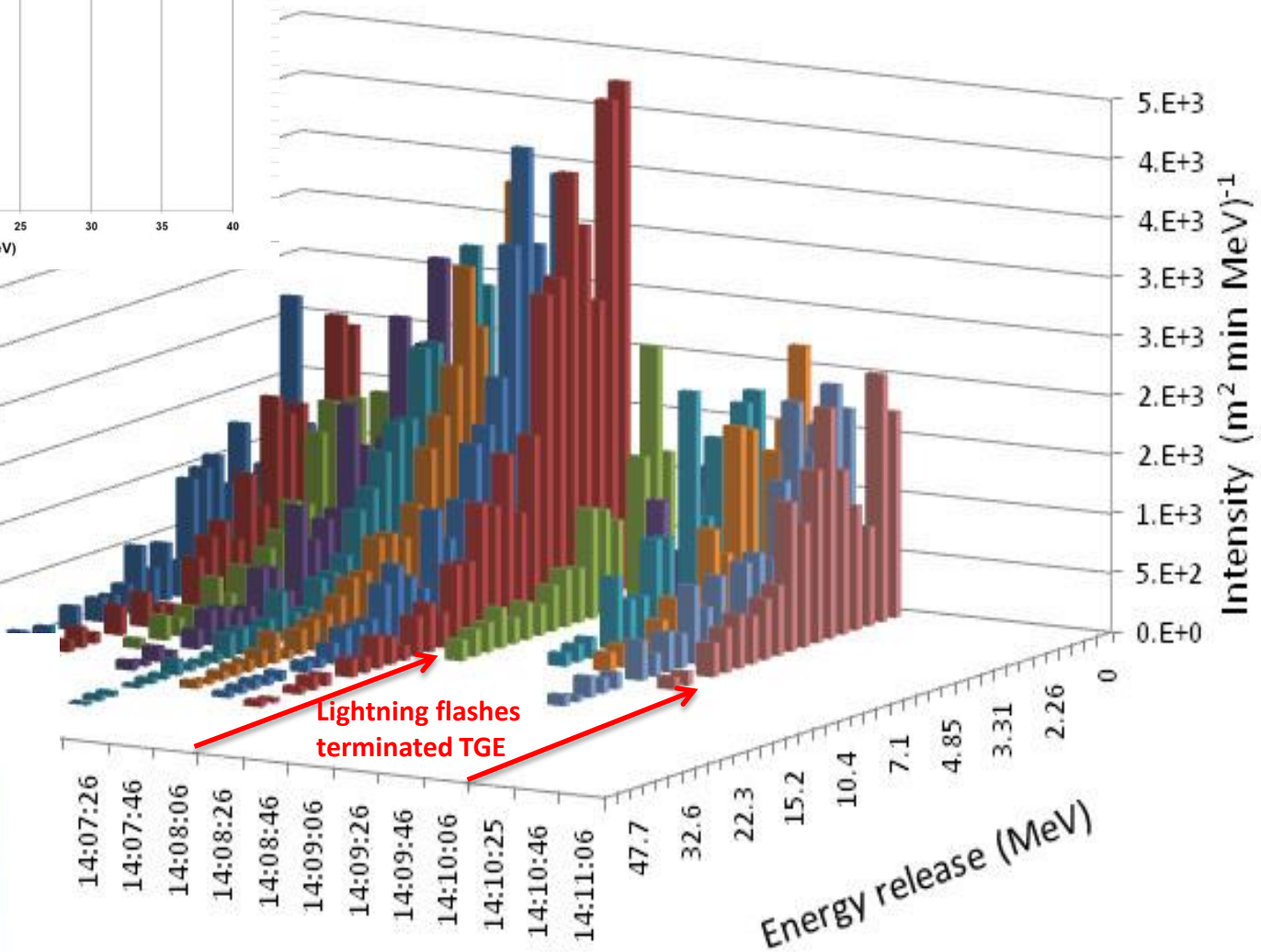


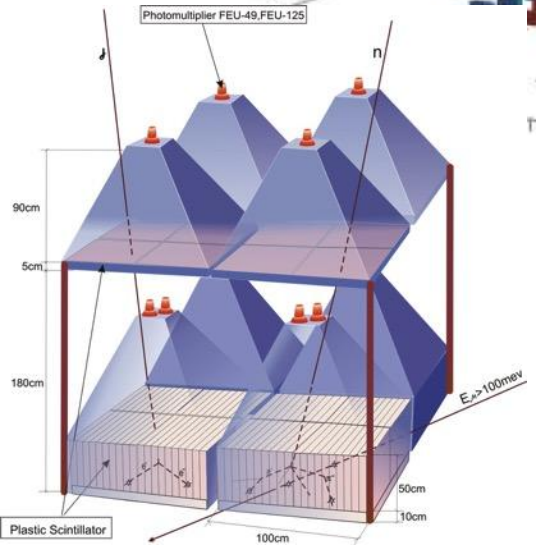
Again no raining and LLL TGE, continuing 1.5 hours after stopping disturbances of the electric field: stochastic electric field “leaved” in cloud long after storm!



Normal polarity intracloud flashes terminate TGE 2 times

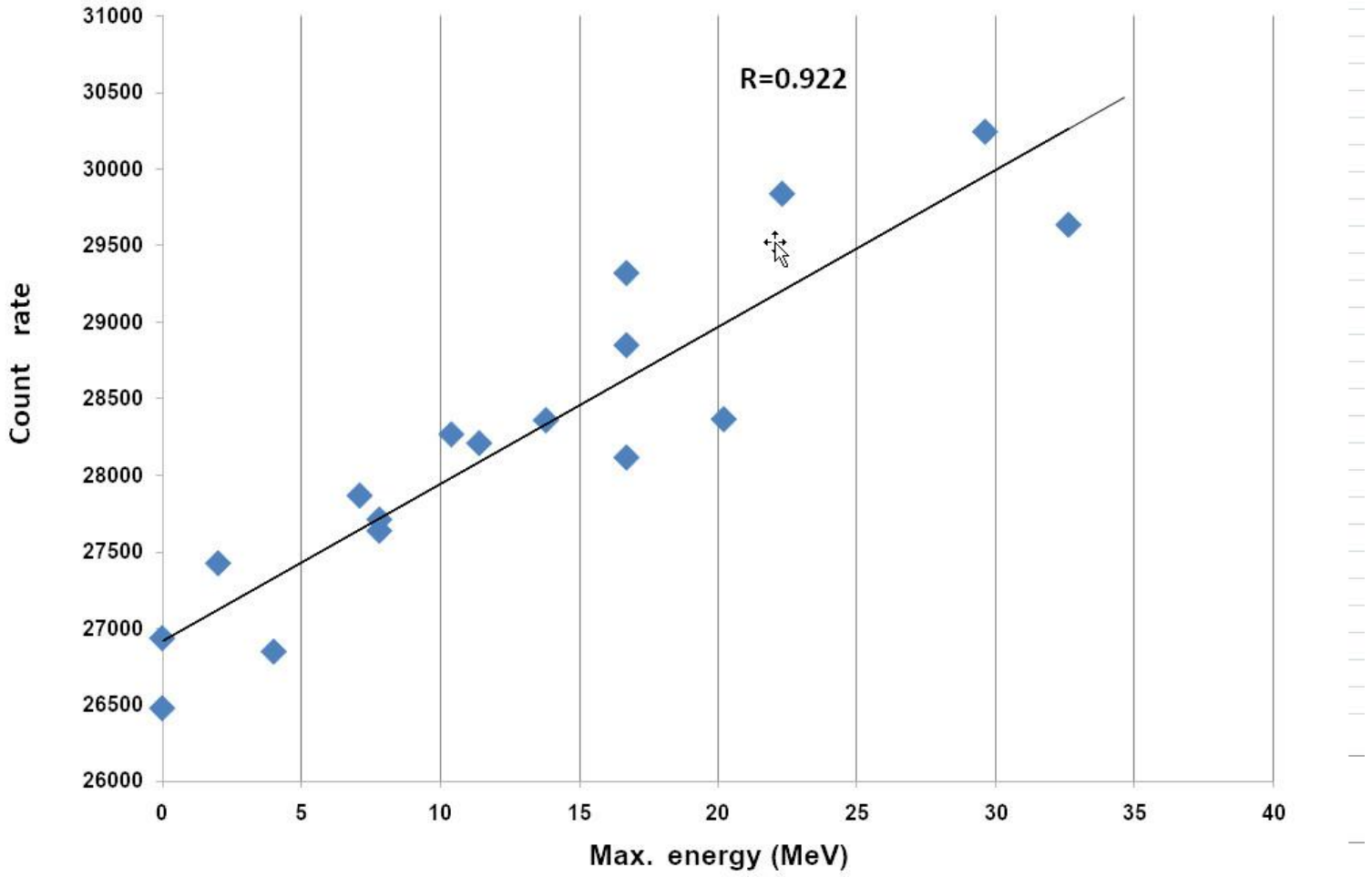


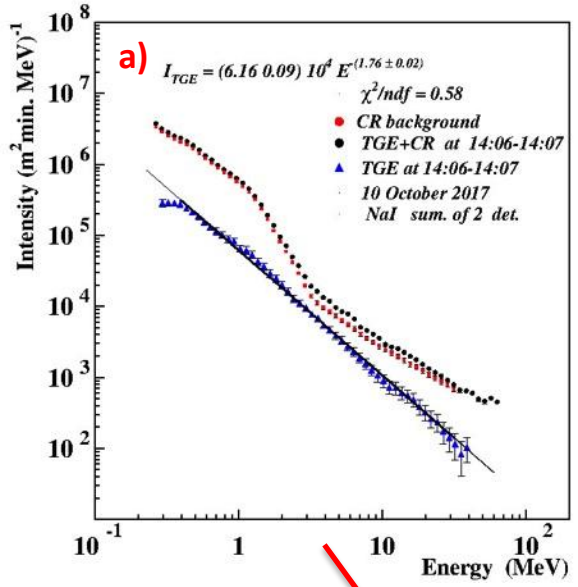


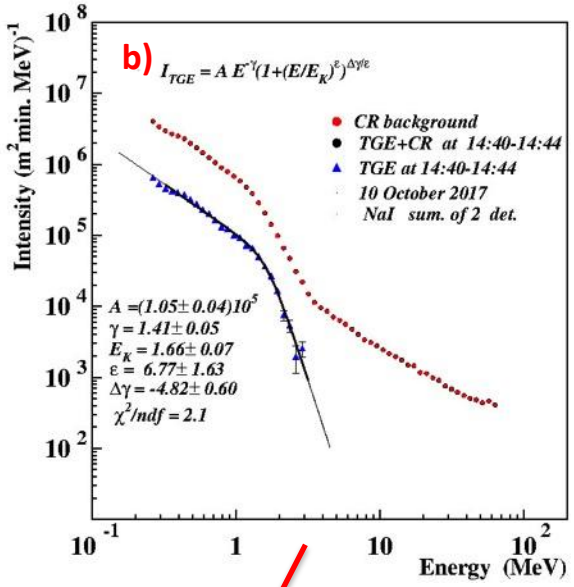


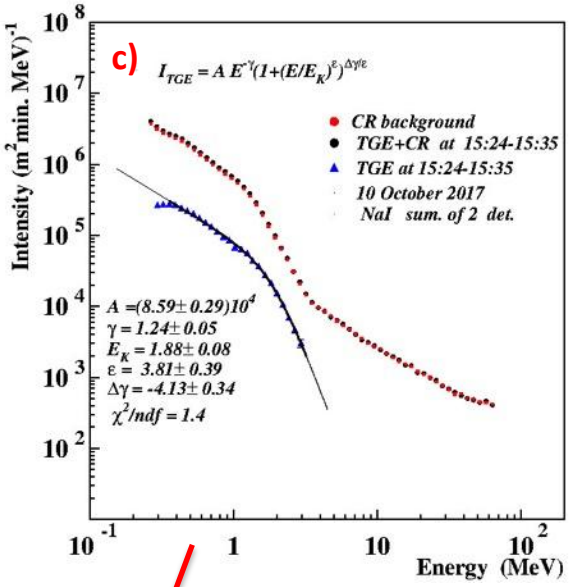
ASNT: 60 cm thick scintillators store energy release histograms each 20 seconds

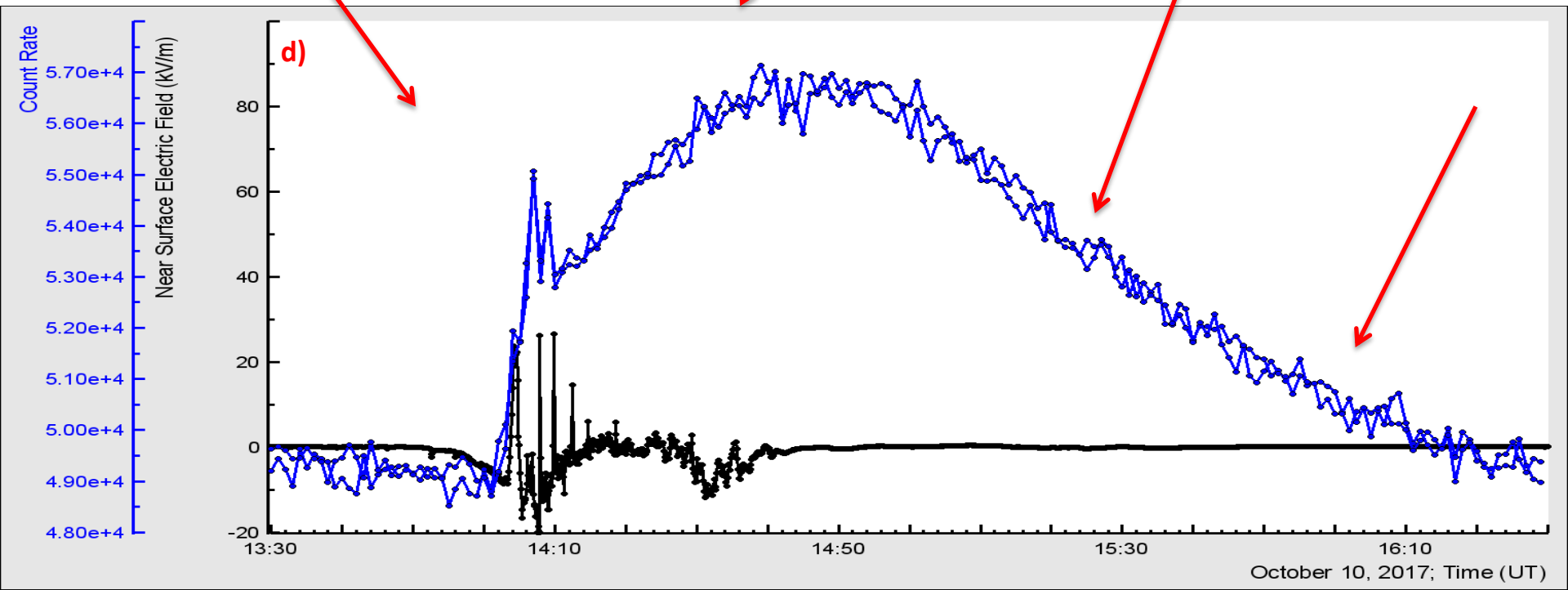
Correlation of gamma ray flux intensity and maximal energy (in strong electric fields avalanches are both intense and energetic).

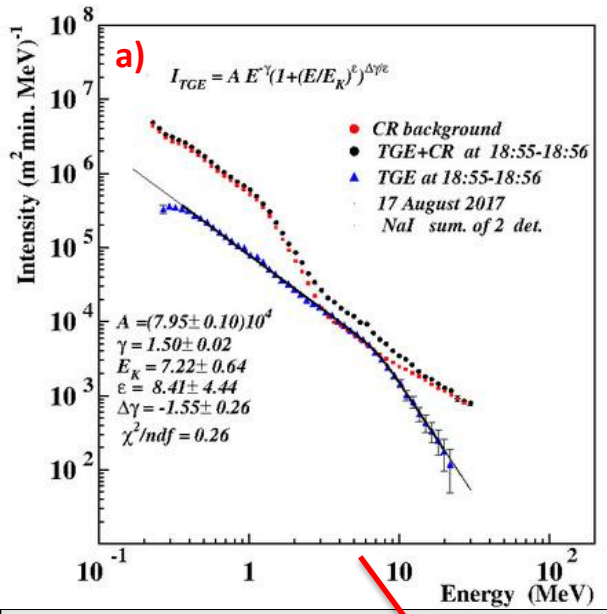


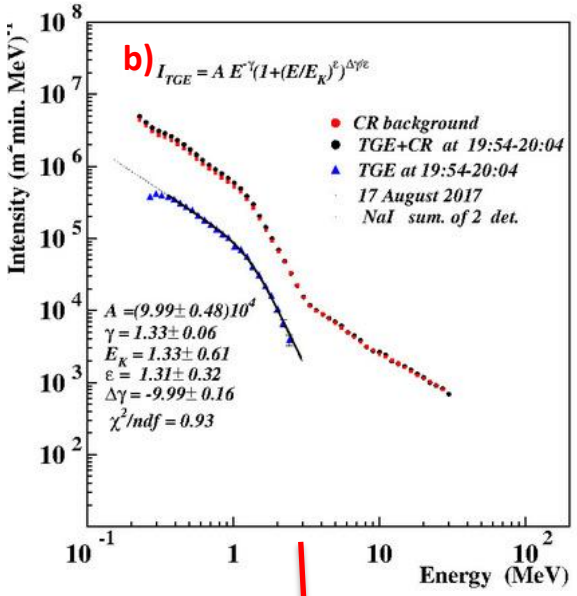

a)
$I_{TGE} = (6.16\ 0.09)\ 10^4\ E^{-(1.76 \pm 0.02)}$
$\chi^2/ndf = 0.58$
CR background
TGE+CR at 14:06-14:07
TGE at 14:06-14:07
10 October 2017
NaI sum. of 2 det.
Intensity (m^{2}min. MeV)$^{-1}$
Energy (MeV)

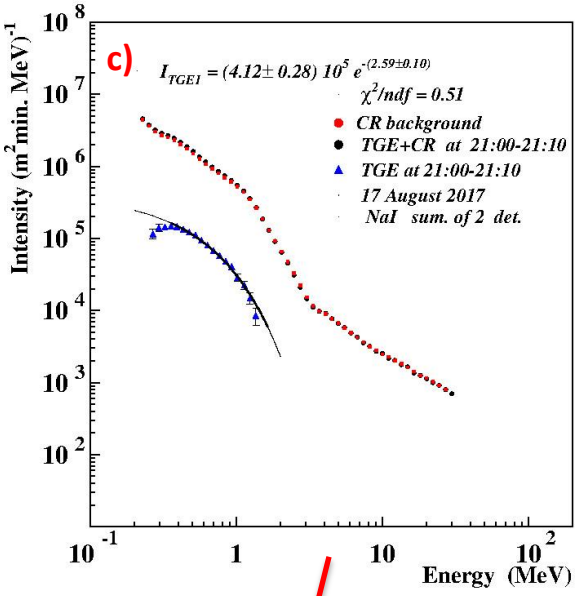

b)
$I_{TGE} = A\ E^{-\gamma}(1+(E/E_K)^{\varepsilon})^{\Delta\gamma/\varepsilon}$
CR background
TGE+CR at 14:40-14:44
TGE at 14:40-14:44
10 October 2017
NaI sum. of 2 det.
$A = (1.05 \pm 0.04)10^5$
$\gamma = 1.41 \pm 0.05$
$E_K = 1.66 \pm 0.07$
$\varepsilon = 6.77 \pm 1.63$
$\Delta\gamma = -4.82 \pm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

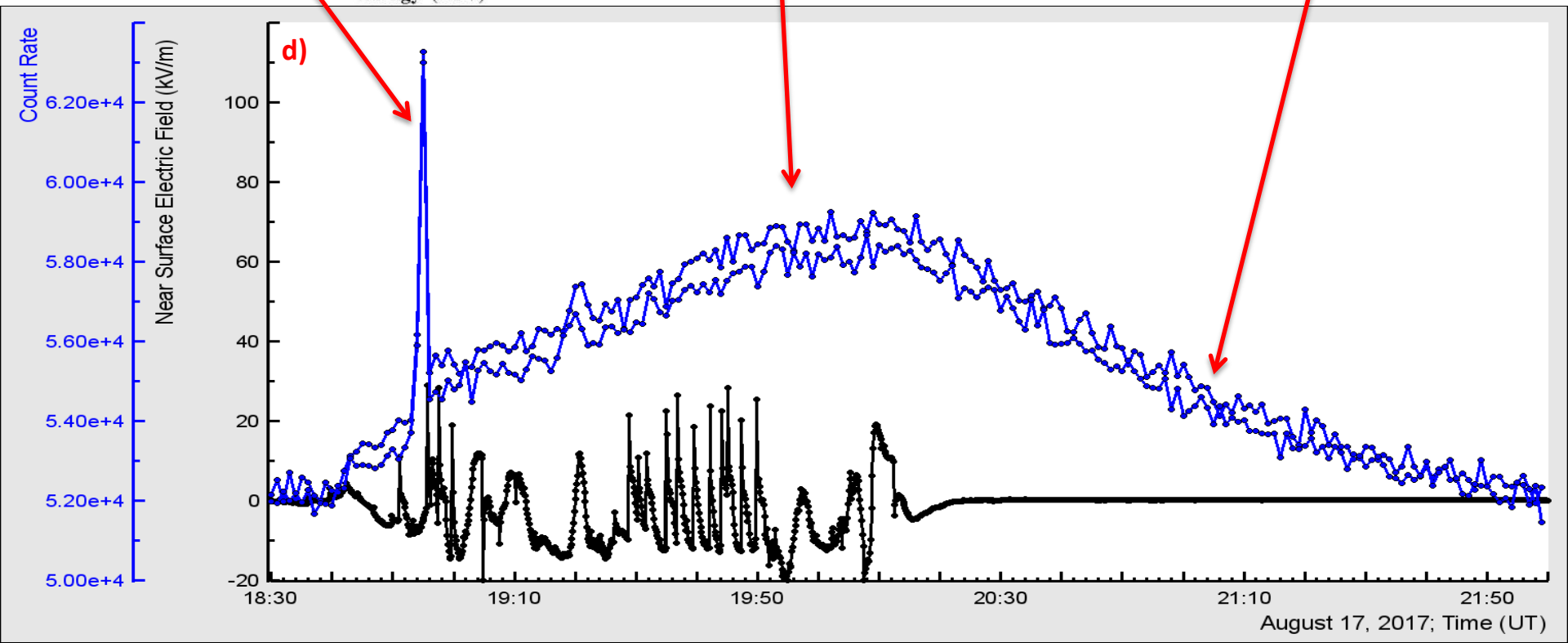

c)
$I_{TGE} = A\ E^{-\gamma}(1+(E/E_K)^{\varepsilon})^{\Delta\gamma/\varepsilon}$
CR background
TGE+CR at 15:24-15:35
TGE at 15:24-15:35
10 October 2017
NaI sum. of 2 det.
$A = (8.59 \pm 0.29)10^4$
$\gamma = 1.24 \pm 0.05$
$E_K = 1.88 \pm 0.08$
$\varepsilon = 3.81 \pm 0.39$
$\Delta\gamma = -4.13 \pm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


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

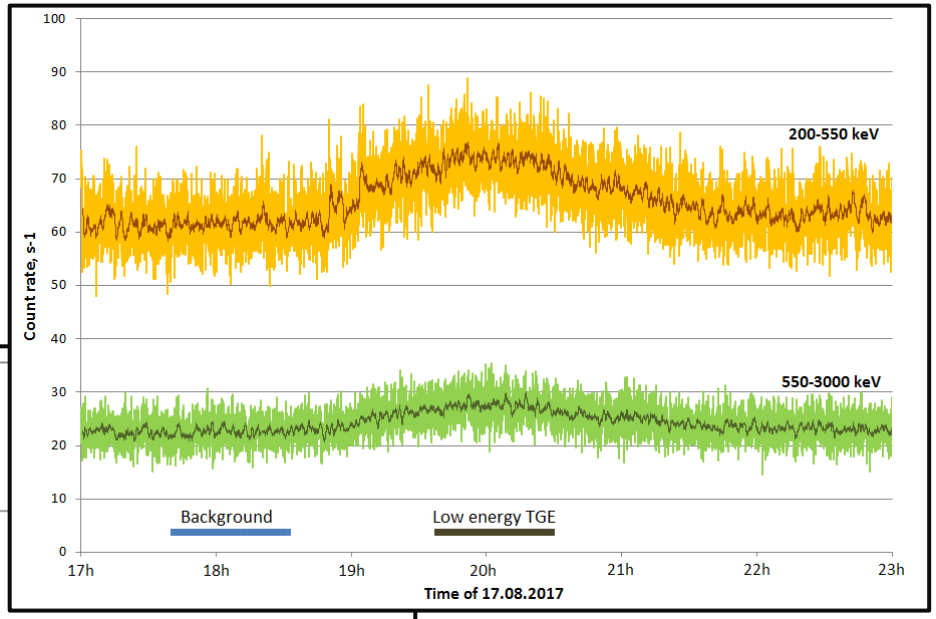

a)
$I_{TGE} = A\,E^{-\gamma}(1+(E/E_K)^{\varepsilon})^{\Delta\gamma/\varepsilon}$
CR background
TGE+CR at 18:55-18:56
TGE at 18:55-18:56
17 August 2017
NaI sum. of 2 det.
$A = (7.95\pm0.10)10^4$
$\gamma = 1.50\pm0.02$
$E_K = 7.22\pm0.64$
$\varepsilon = 8.41\pm4.44$
$\Delta\gamma = -1.55\pm0.26$
$\chi^2/ndf = 0.26$
Intensity (m^2min. MeV)$^{-1}$
Energy (MeV)

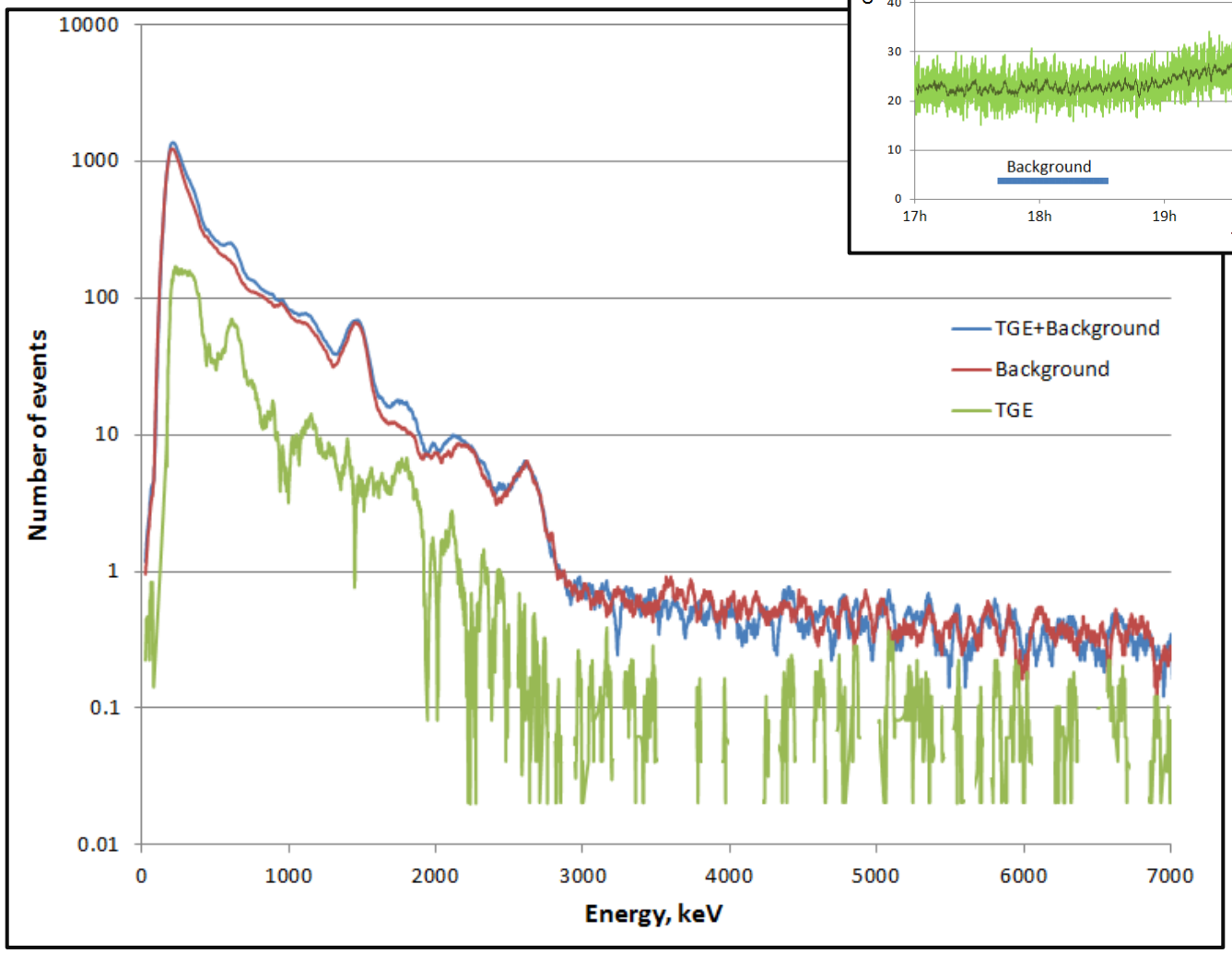

b)
$I_{TGE} = A\,E^{-\gamma}(1+(E/E_K)^{\varepsilon})^{\Delta\gamma/\varepsilon}$
CR background
TGE+CR at 19:54-20:04
TGE at 19:54-20:04
17 August 2017
NaI sum. of 2 det.
$A = (9.99\pm0.48)10^4$
$\gamma = 1.33\pm0.06$
$E_K = 1.33\pm0.61$
$\varepsilon = 1.31\pm0.32$
$\Delta\gamma = -9.99\pm0.16$
$\chi^2/ndf = 0.93$
Intensity (m^2min. MeV)$^{-1}$
Energy (MeV)


c)
$I_{TGE1} = (4.12\pm0.28)\,10^5\,e^{-(2.59\pm0.10)}$
$\chi^2/ndf = 0.51$
CR background
TGE+CR at 21:00-21:10
TGE at 21:00-21:10
17 August 2017
NaI sum. of 2 det.
Intensity (m^2min. MeV)$^{-1}$
Energy (MeV)


d)
Count Rate
Near Surface Electric Field (kV/m)
6.20e+4
6.00e+4
5.80e+4
5.60e+4
5.40e+4
5.20e+4
5.00e+4
100
80
60
40
20
0
-20
18:30
19:10
19:50
20:30
21:10
21:50
August 17, 2017; Time (UT)

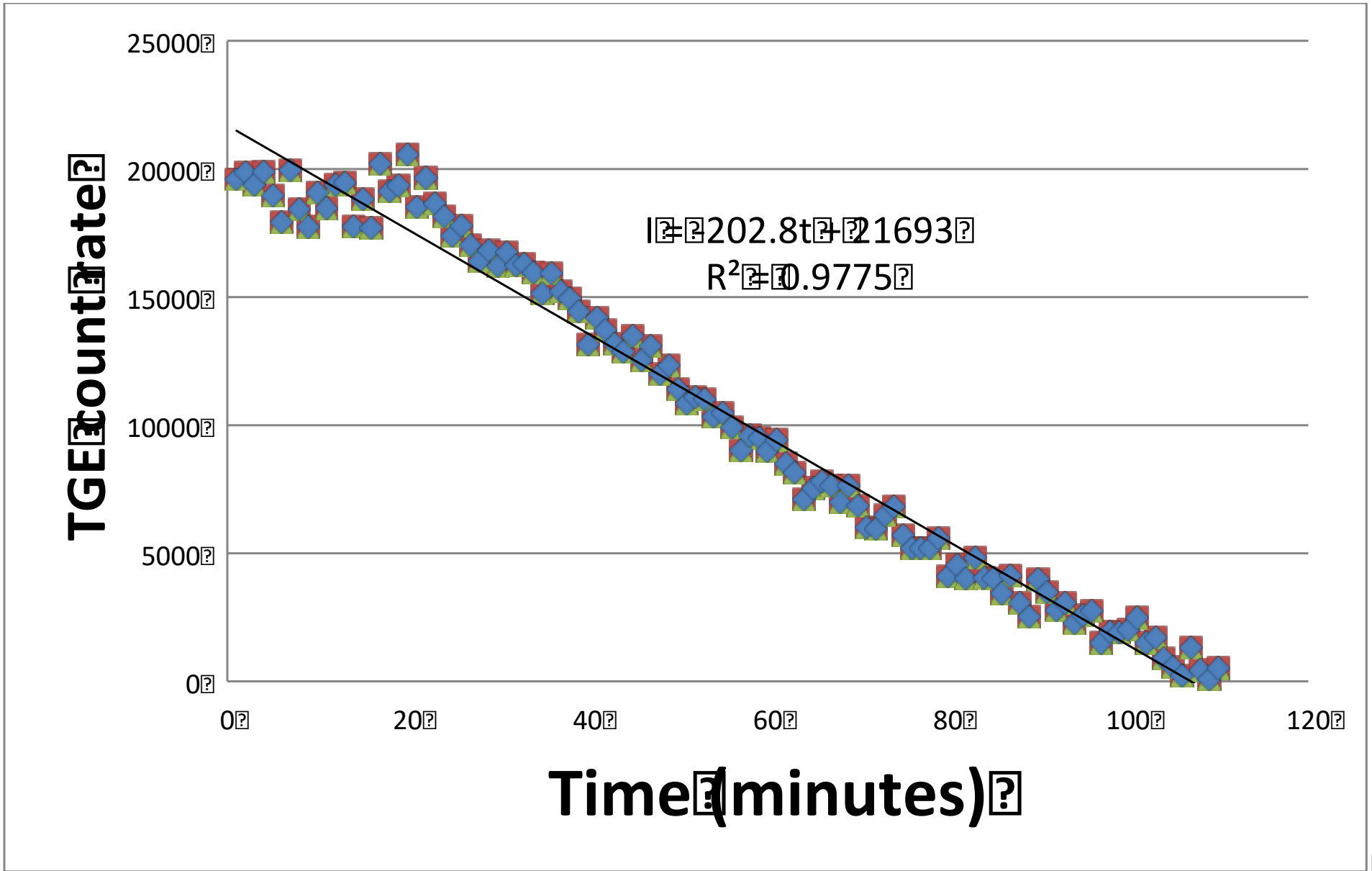
Energy spectrum of long soft part of TGE 17-08-2017



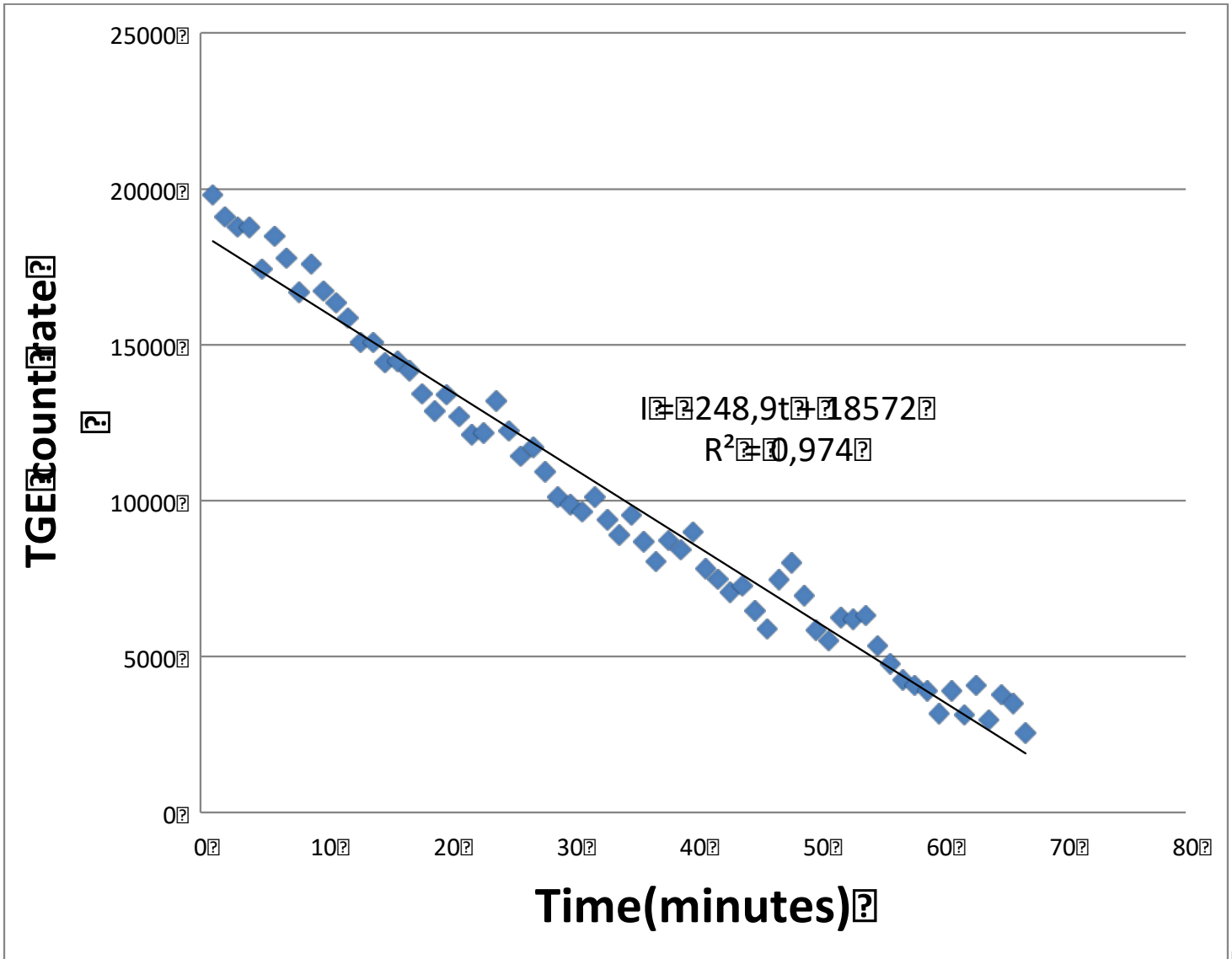


The spectrum of long part of TGE has a number of Rn-222 lines. No significant increase in the range E>3 MeV is present

Linear Decay of LLL TGE: 17 August 20:00 – 22:00

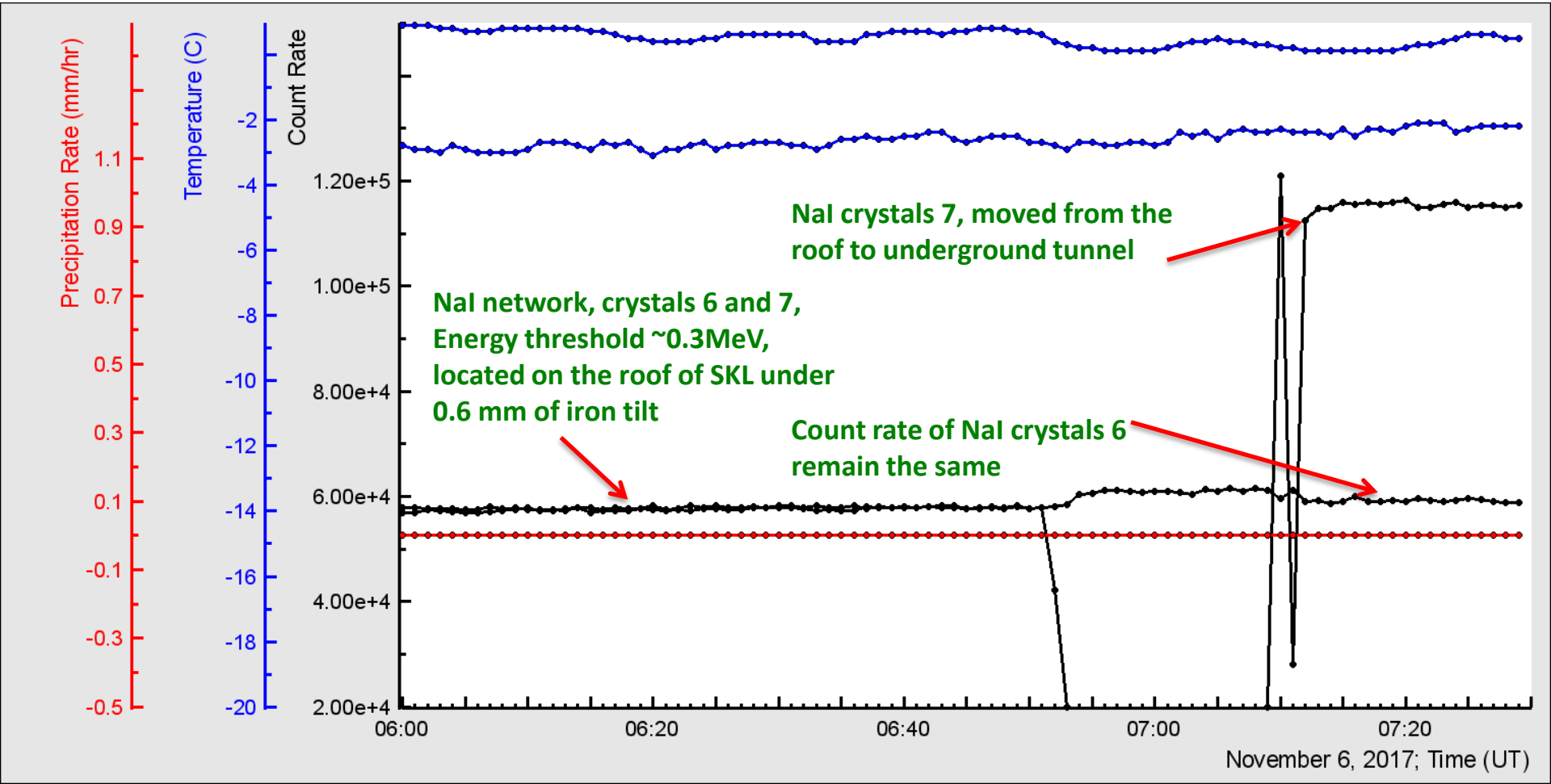


Linear Decay of LLL TGE: 10 October, 14:50:16:10

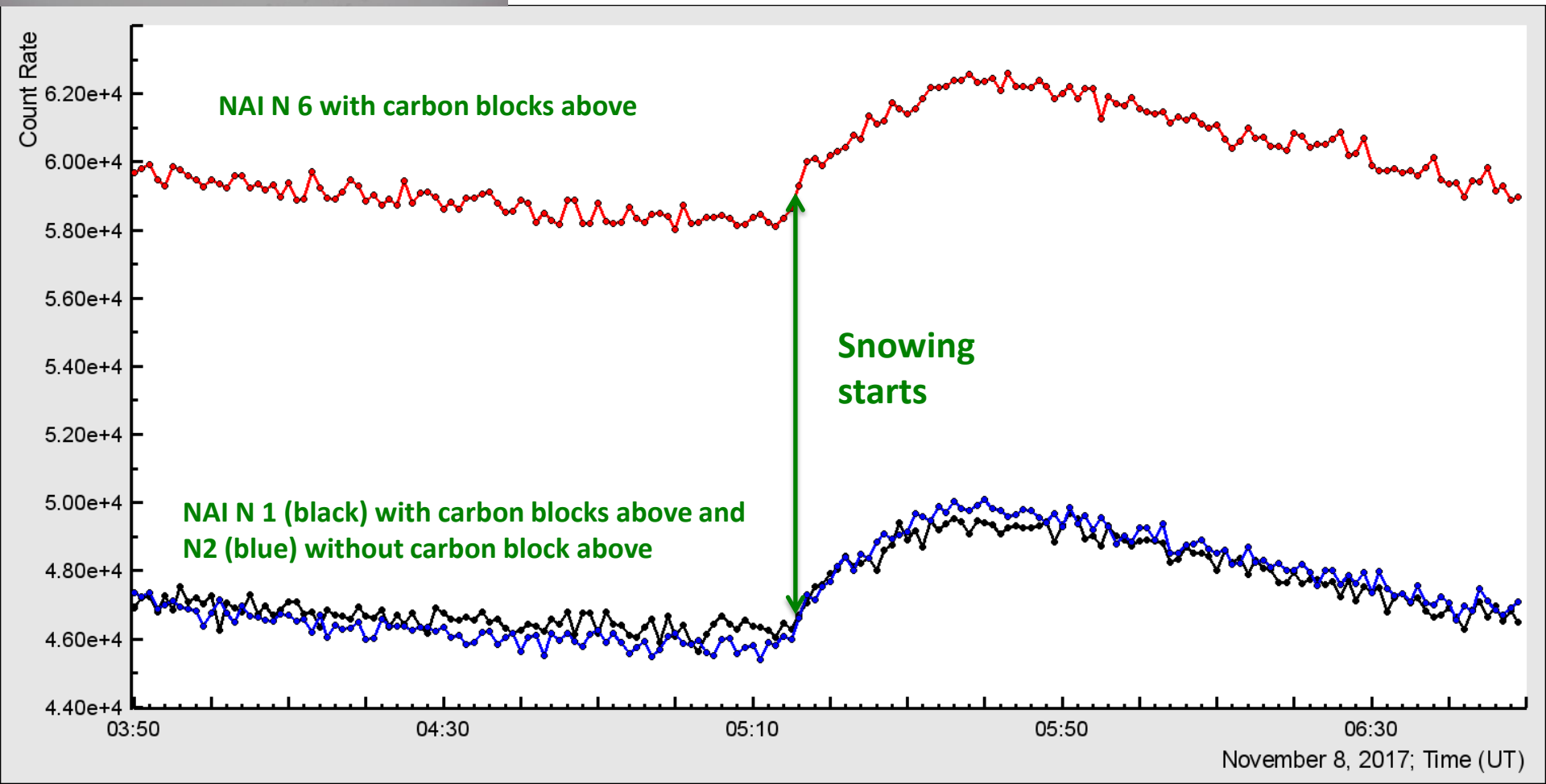



NaI crystal (13 x 13 x 26 cm) moved on
November 6 to underground tunnel
below SKL experimental

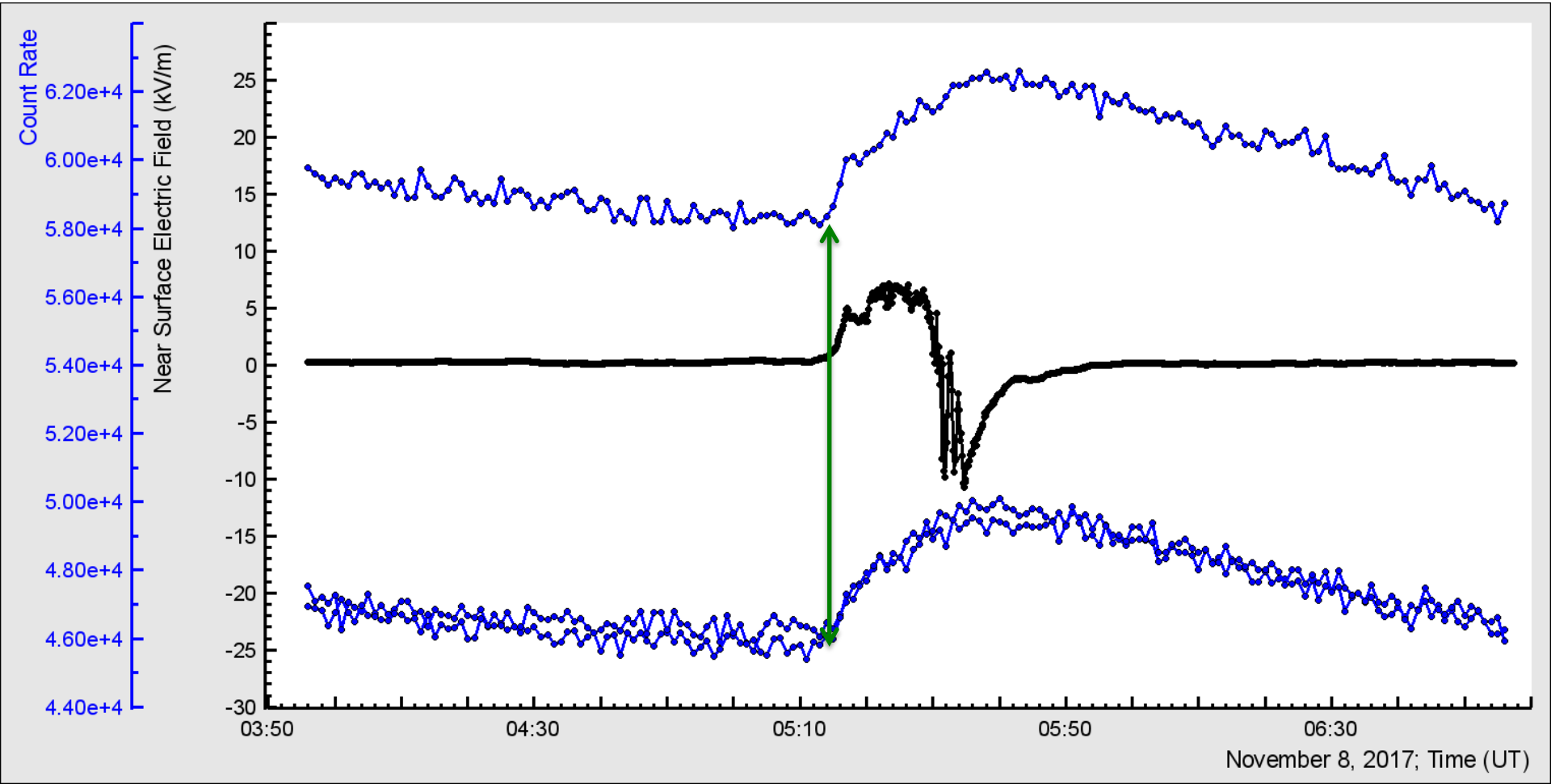
Today (November 6, 2017) in the morning we move NaI N 7 from roof to tunnel and count rate increased 2 times due to Radon decay radiation! Very nice weather, no precipitation, clouds (if any) on 300 m. Radon is going out of crust and collected in cellars!



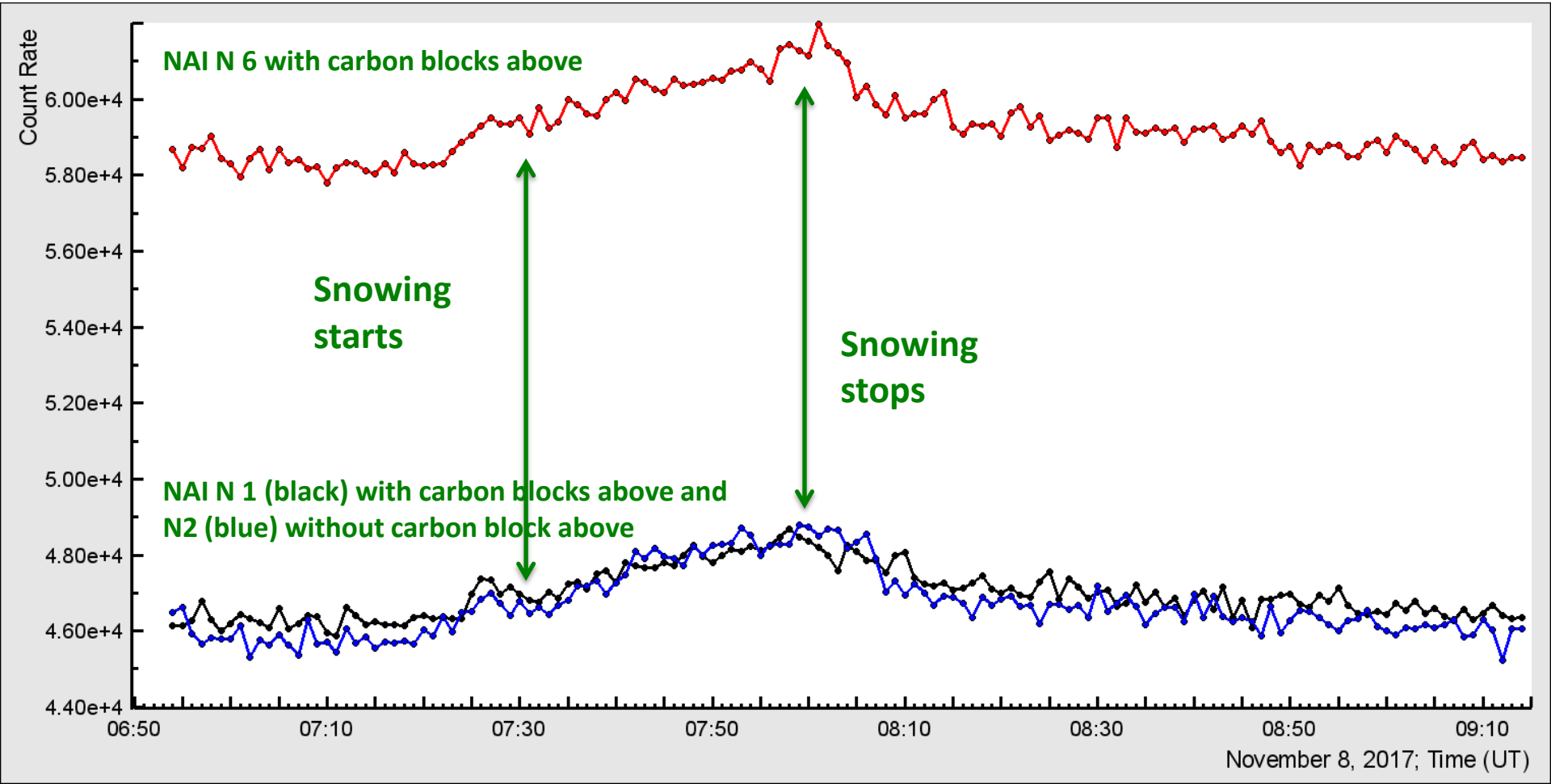
LLL TGE starts on snowing 5:15-5:40 (maximum of particle flux)



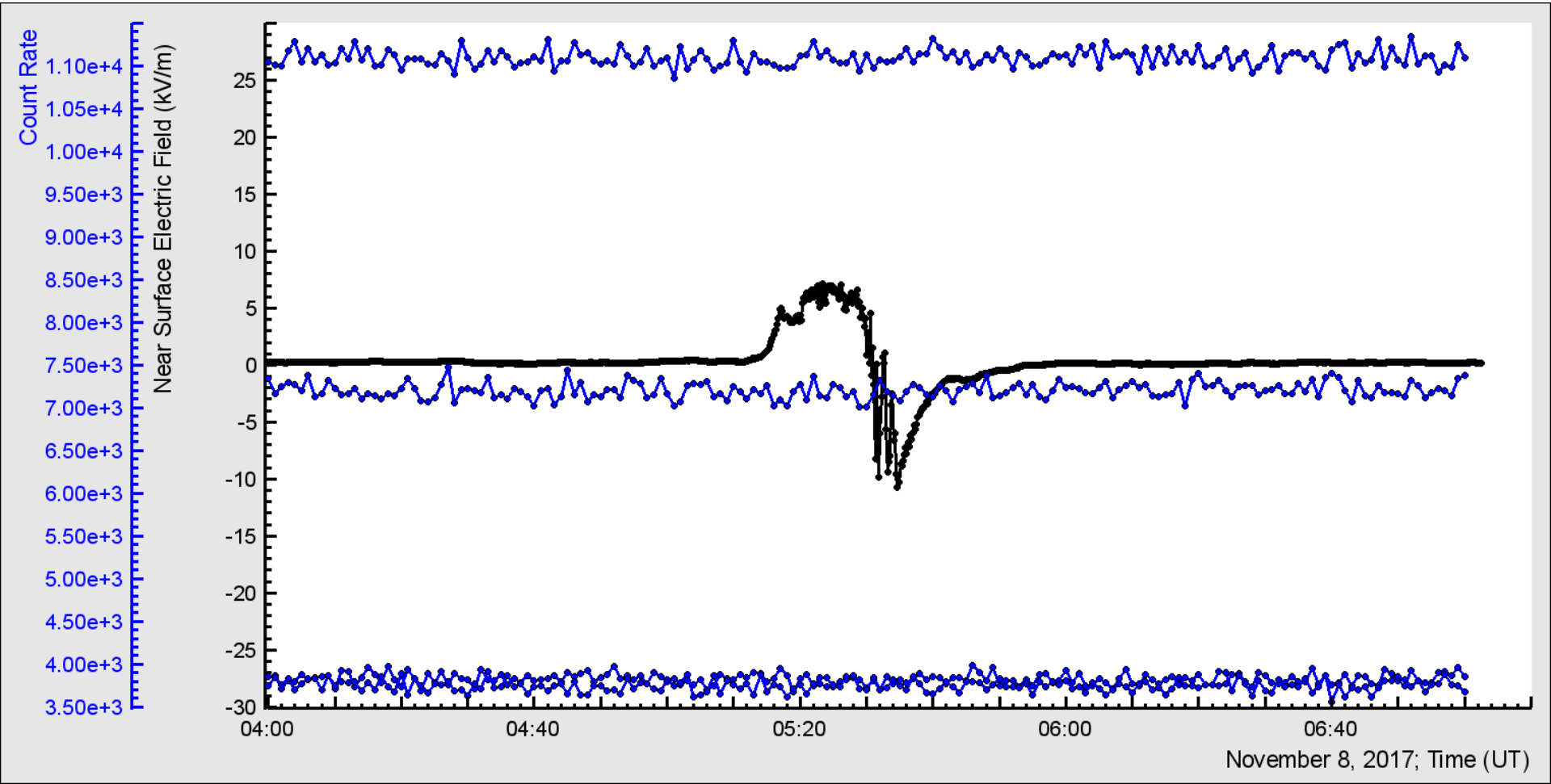
Both snowing and field: what is the cause of LLL TGE?



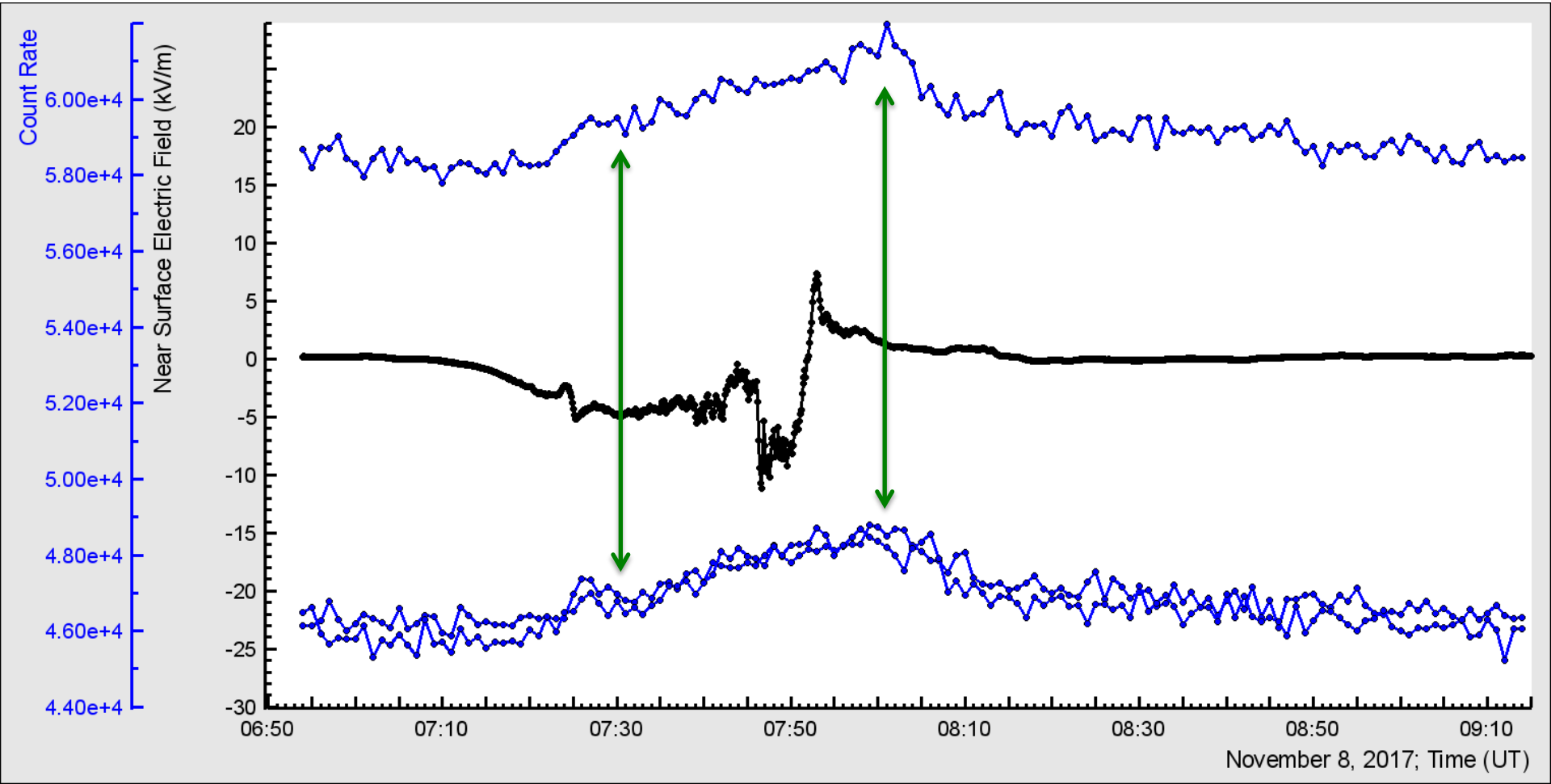
Snow starts at 7:30 stops at 8:00



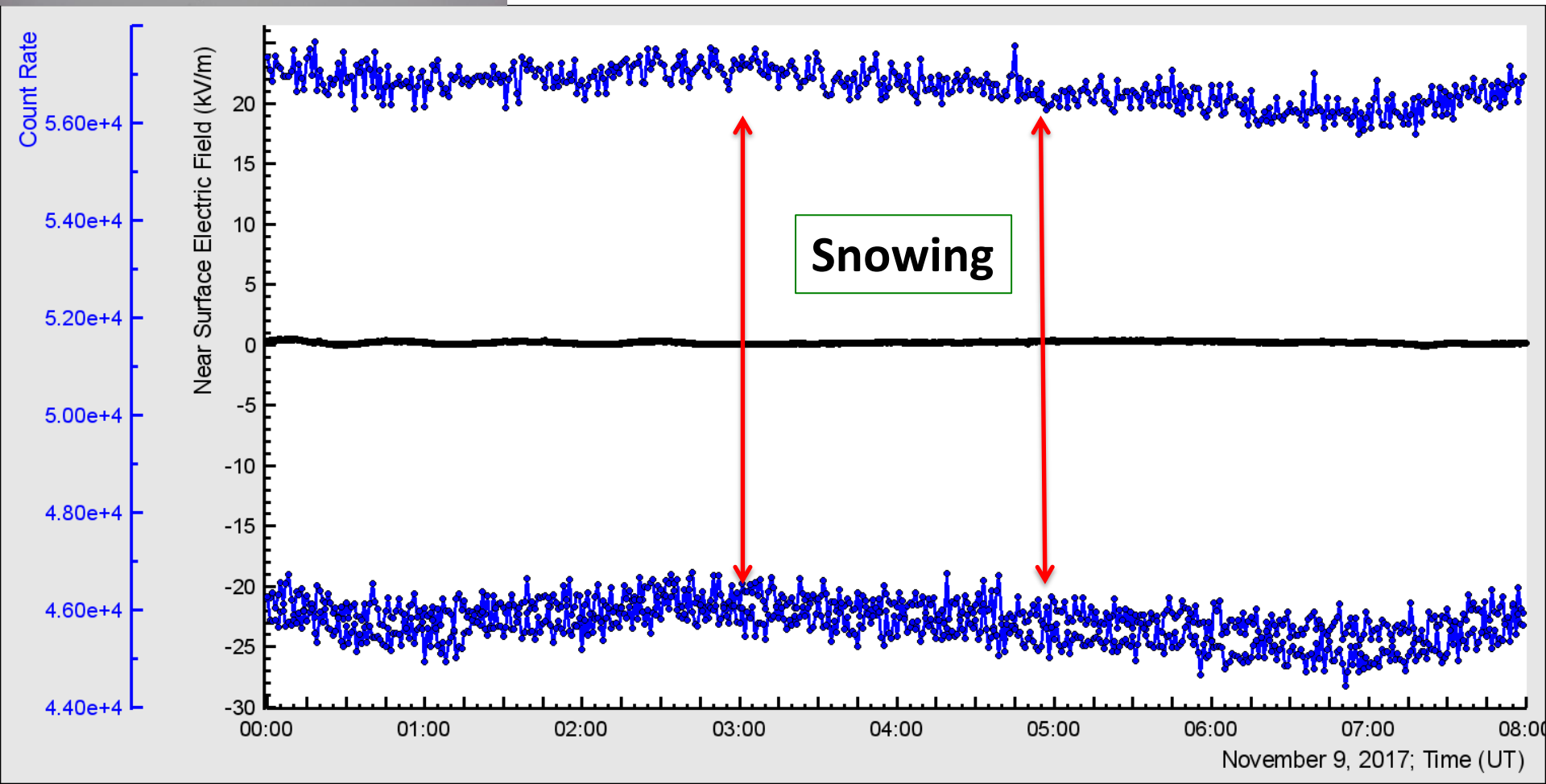
STAND3 combinations: no flux above 2-3 MeV!



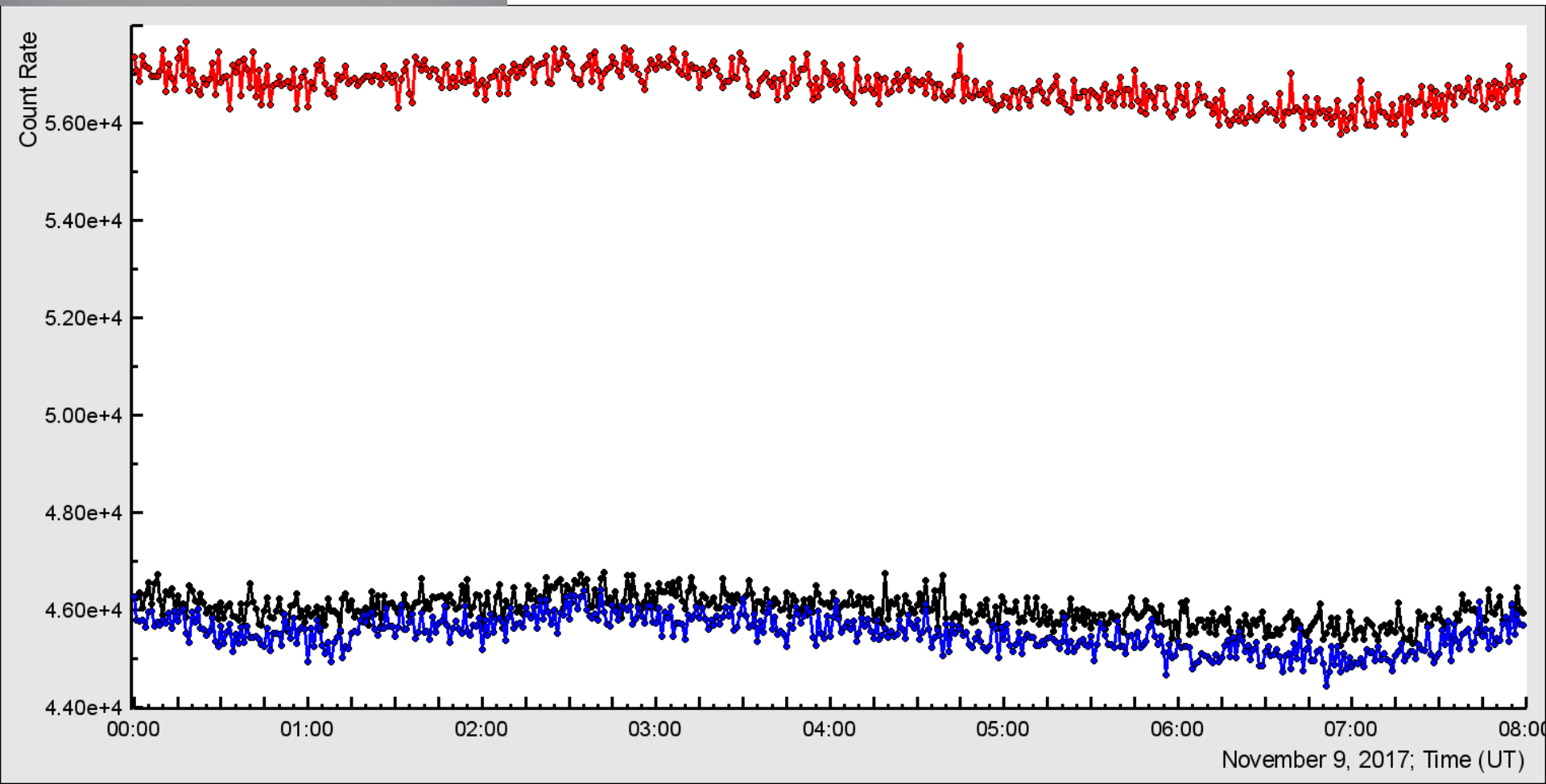
Again snowing start-stop coincides with electric field start-stop!



Much more snow, but no field and no TGE!



Much more snow, but no field and no TGE!

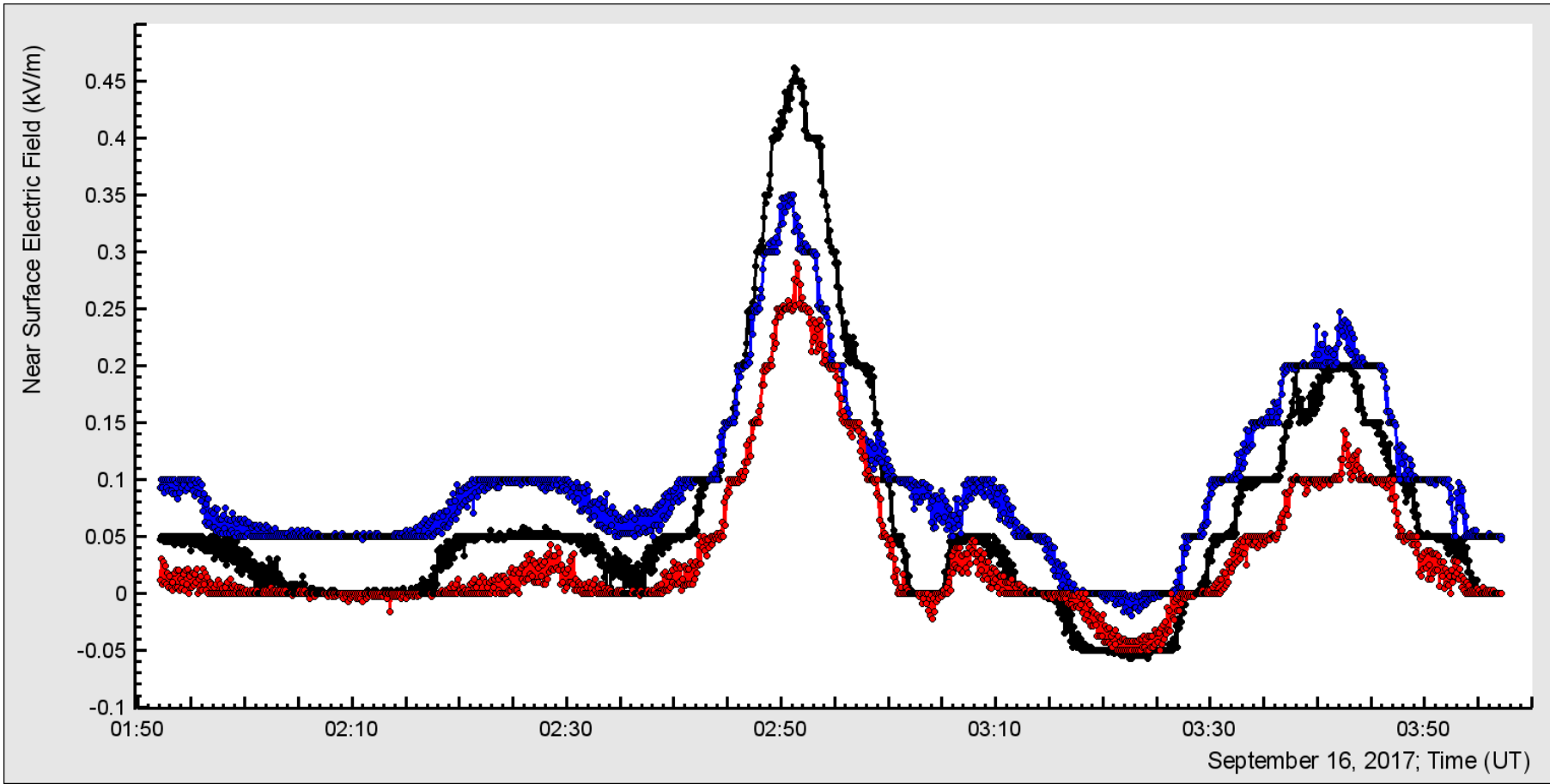


TGEs and electric field disturbances on fair weather

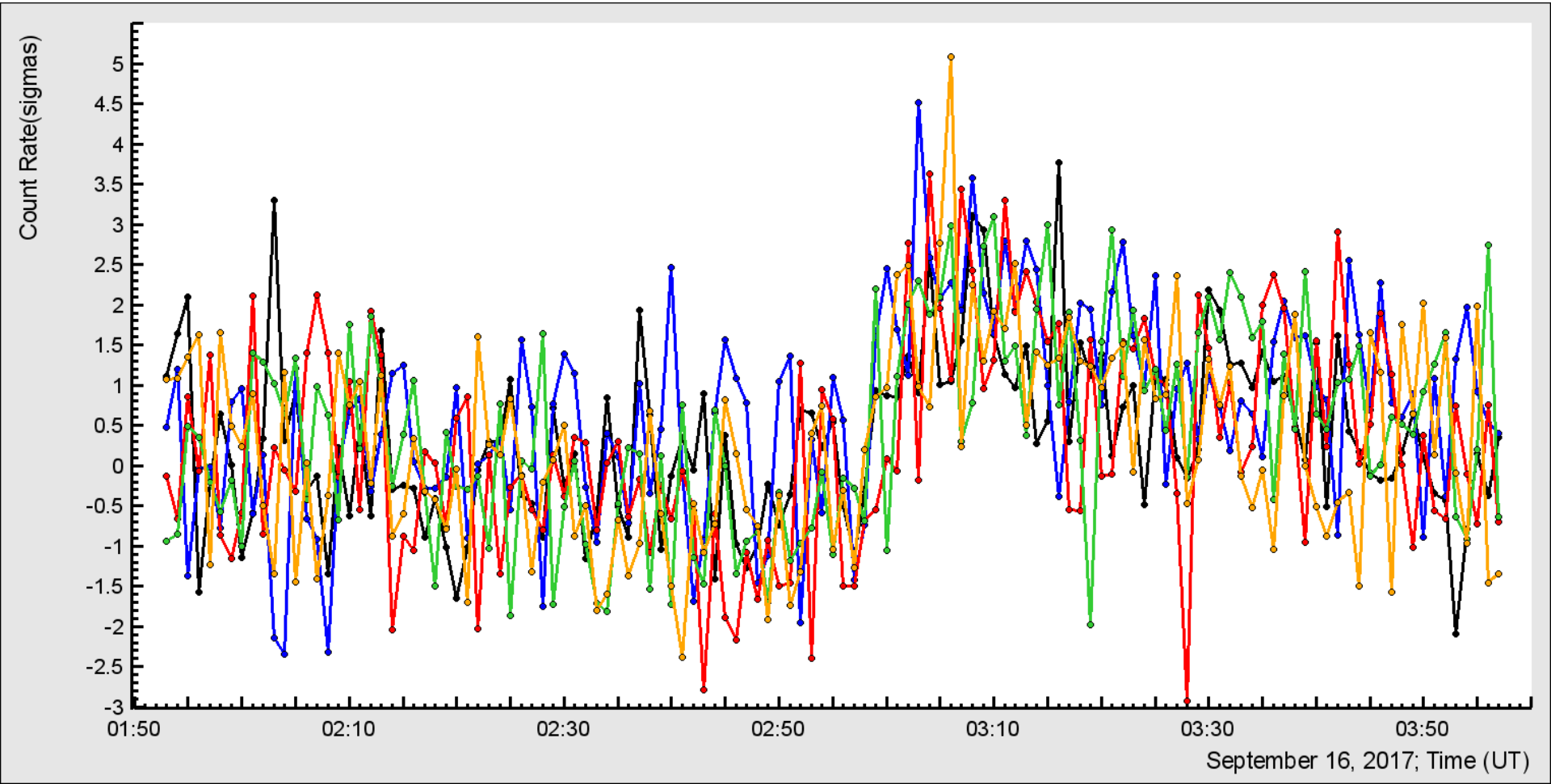
Fair weather TGE

Small cloud appears suddenly bringing no rain, nice weather; however we see small disturbances of field and sizable LLL TGE!

Very small electrostatic field disturbances by EFM-100 network



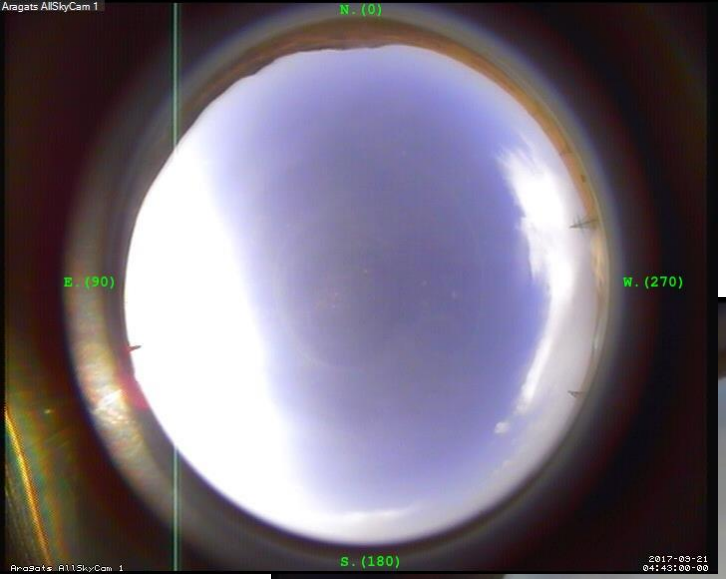
LLL TGE on fair weather without any raining: small cloud brings electric field enough to unleash MOS process!

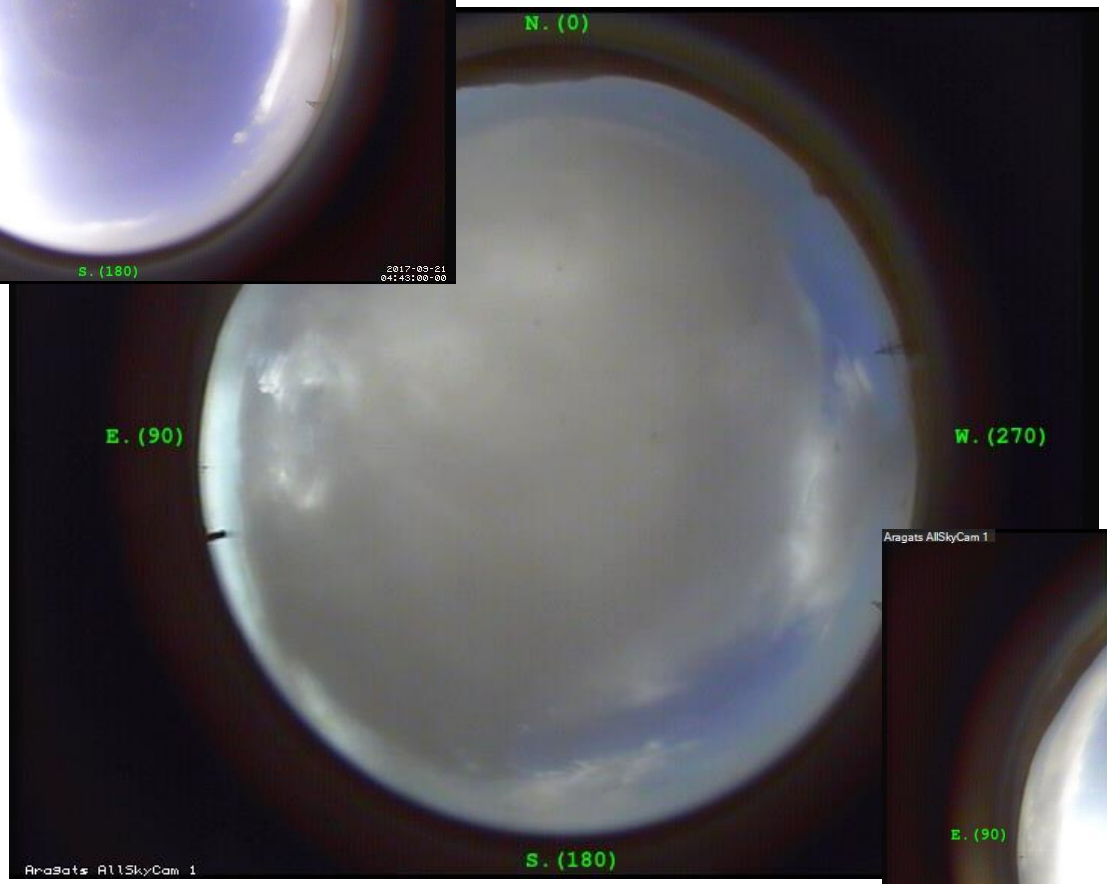


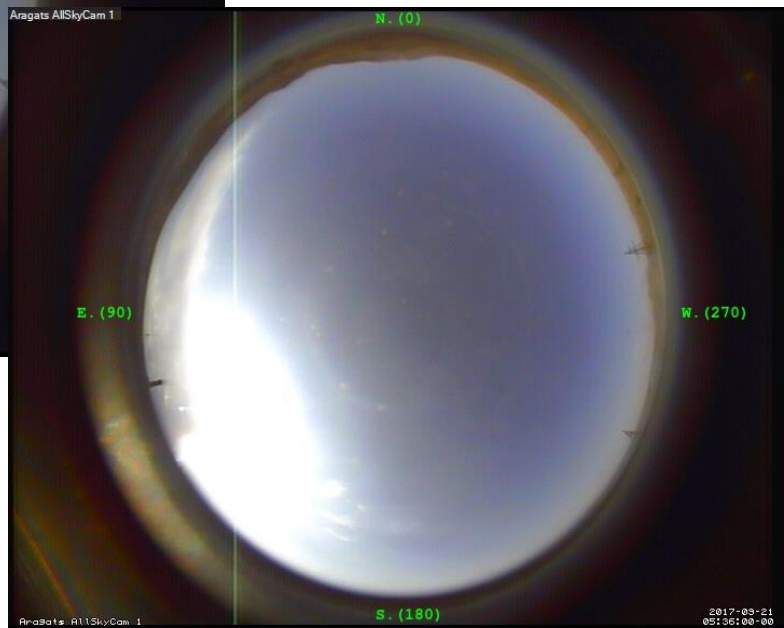
Armenian Independence Cloud

- 1 km height cloud change abruptly several parameters:
- Electrostatic field: down to -30 kV/m;
- Z component of magnetic field;
- Atmospheric pressure;
- Particle fluxes;
- Cloud was very high I hardly can understand how particles reach ground;
- What happens with magnetic field?
- Atmosphere pressure changed also because of this cloud?

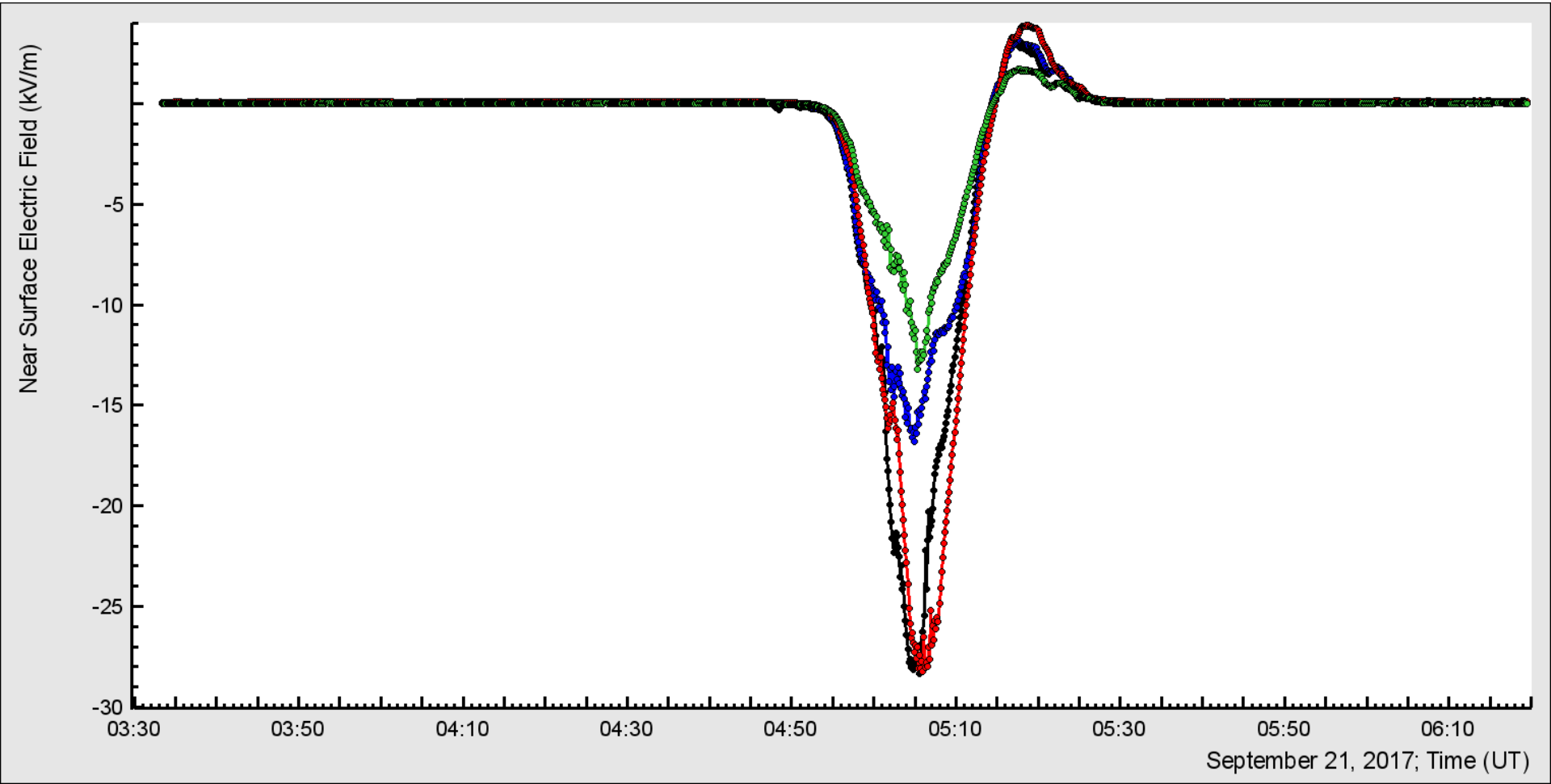
A large cloud on 1 km height appearing above for a half-of-hour dramatically influence geophysical parameters



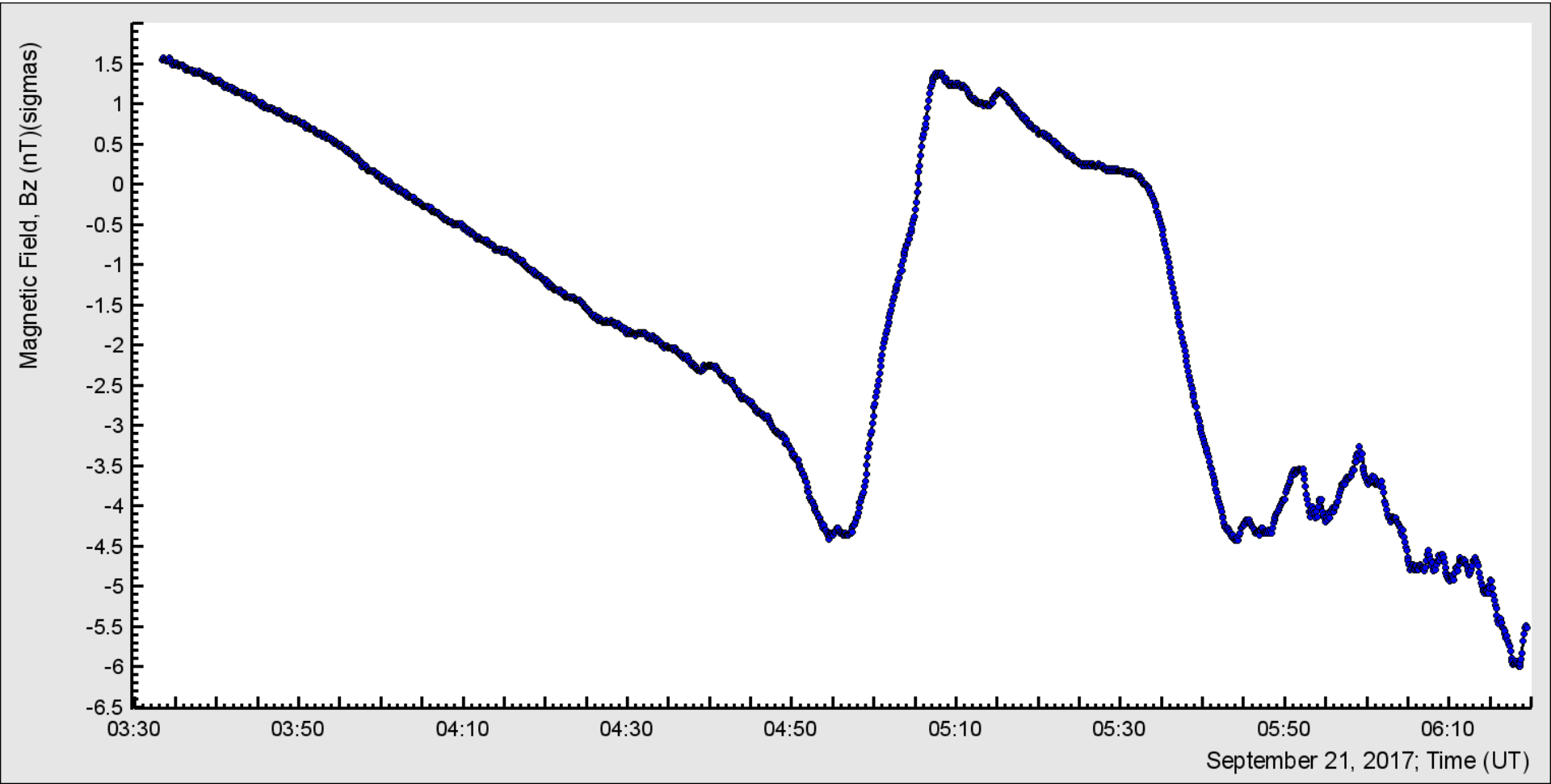




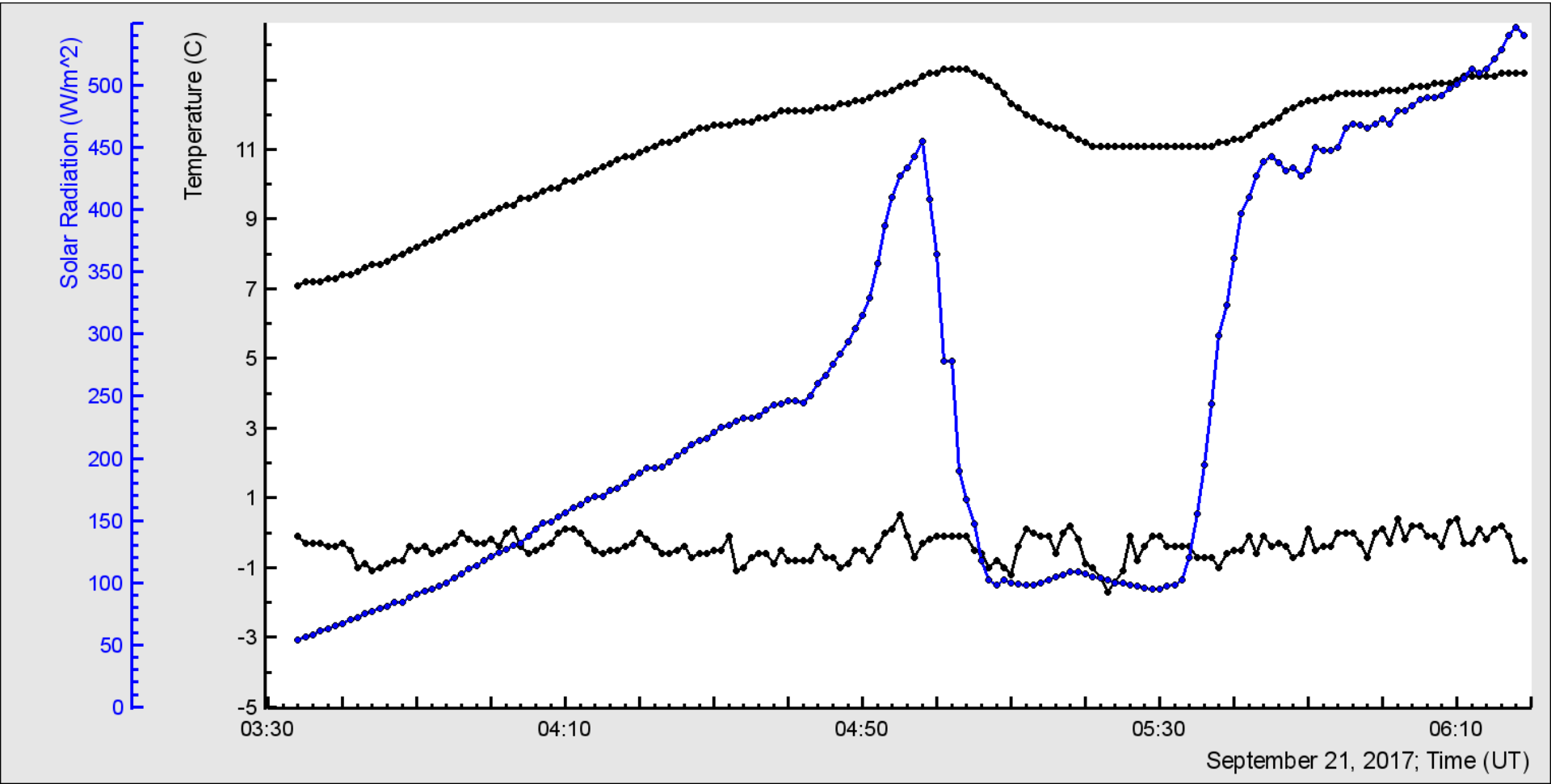
Near Surface electric field go down abruptly and reach minimum at 5:06



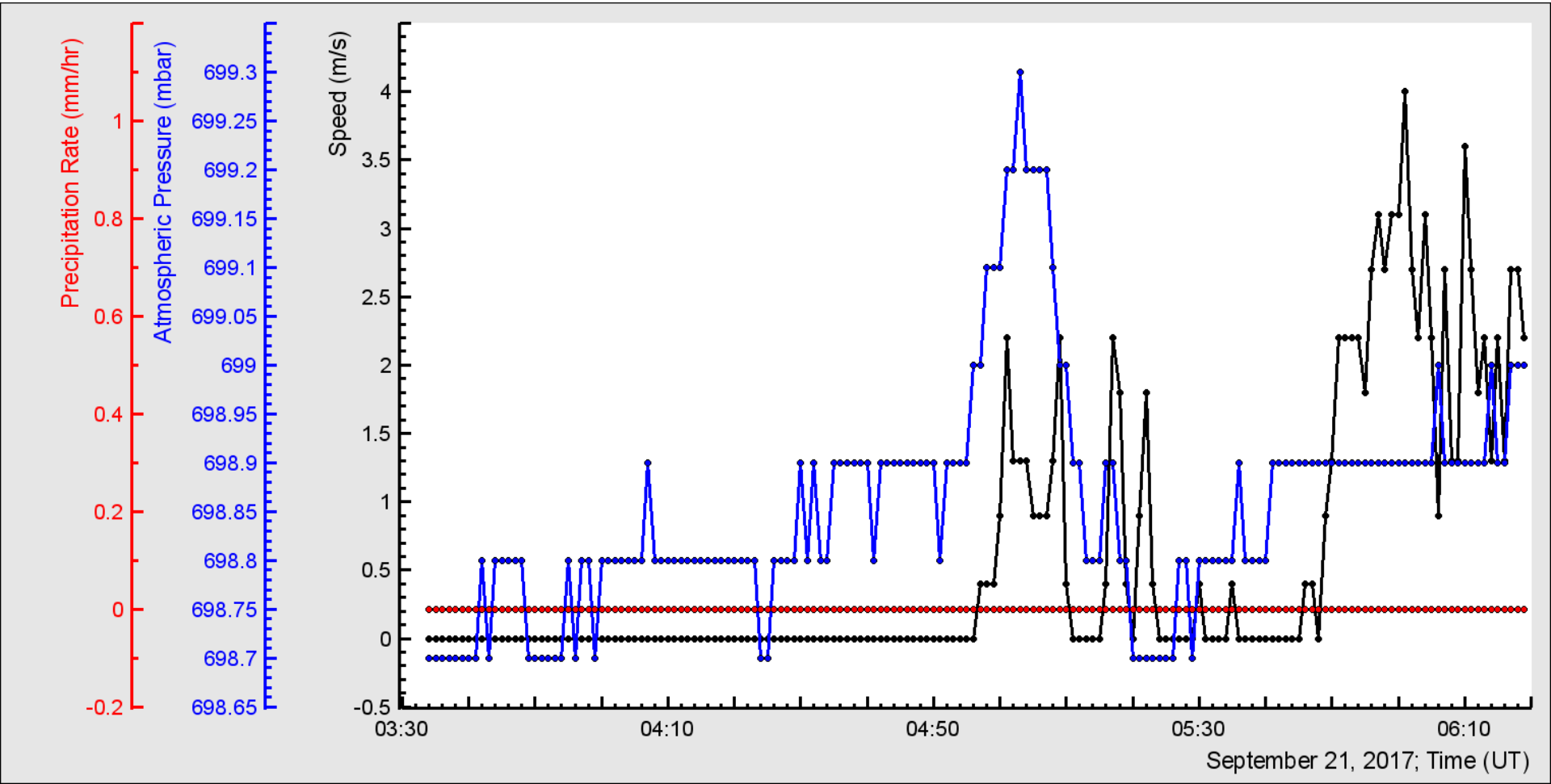
Z component of magnetic field disturbs the same time



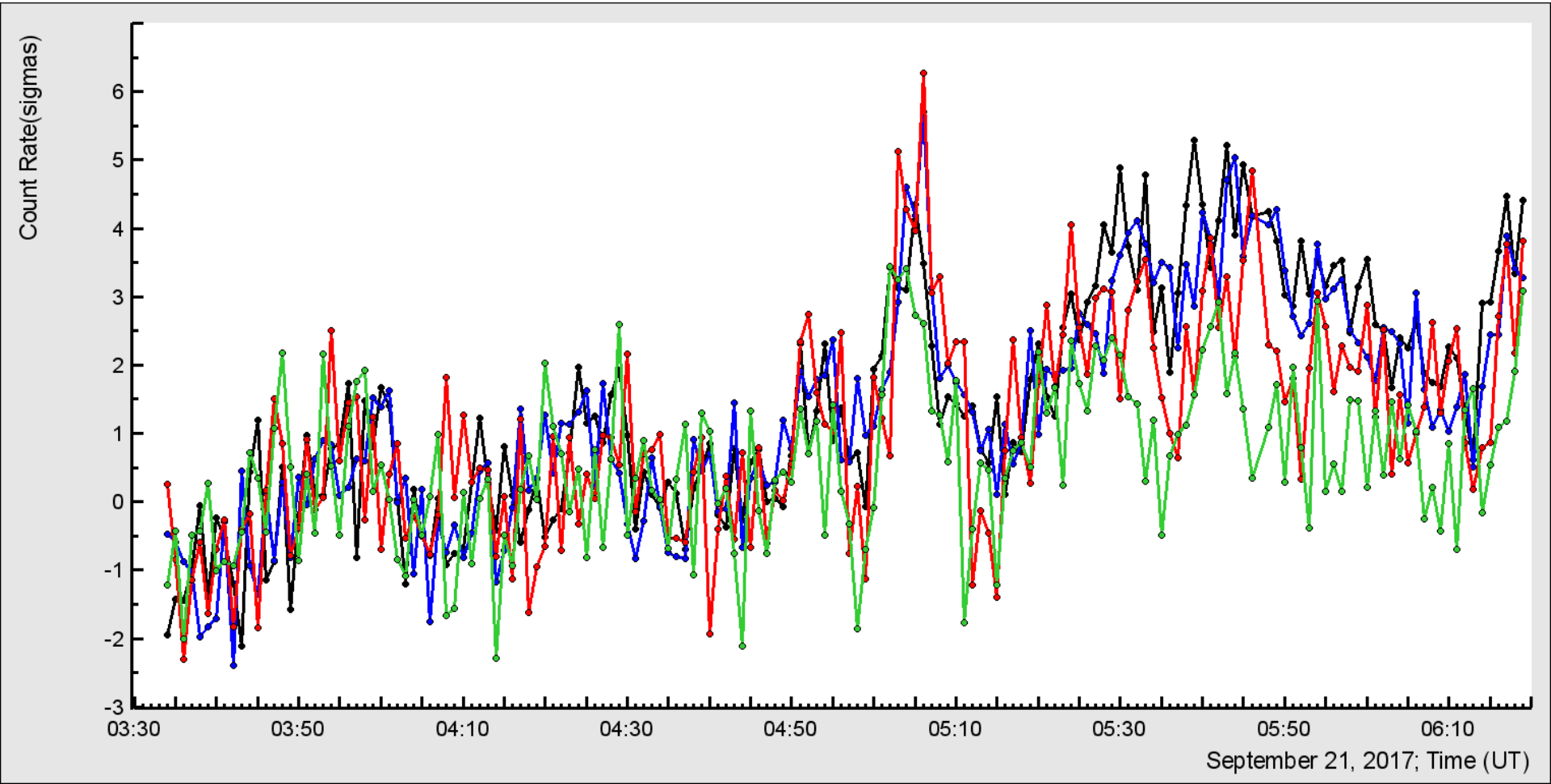
Solar Radiation go abruptly down the same half-of-hour



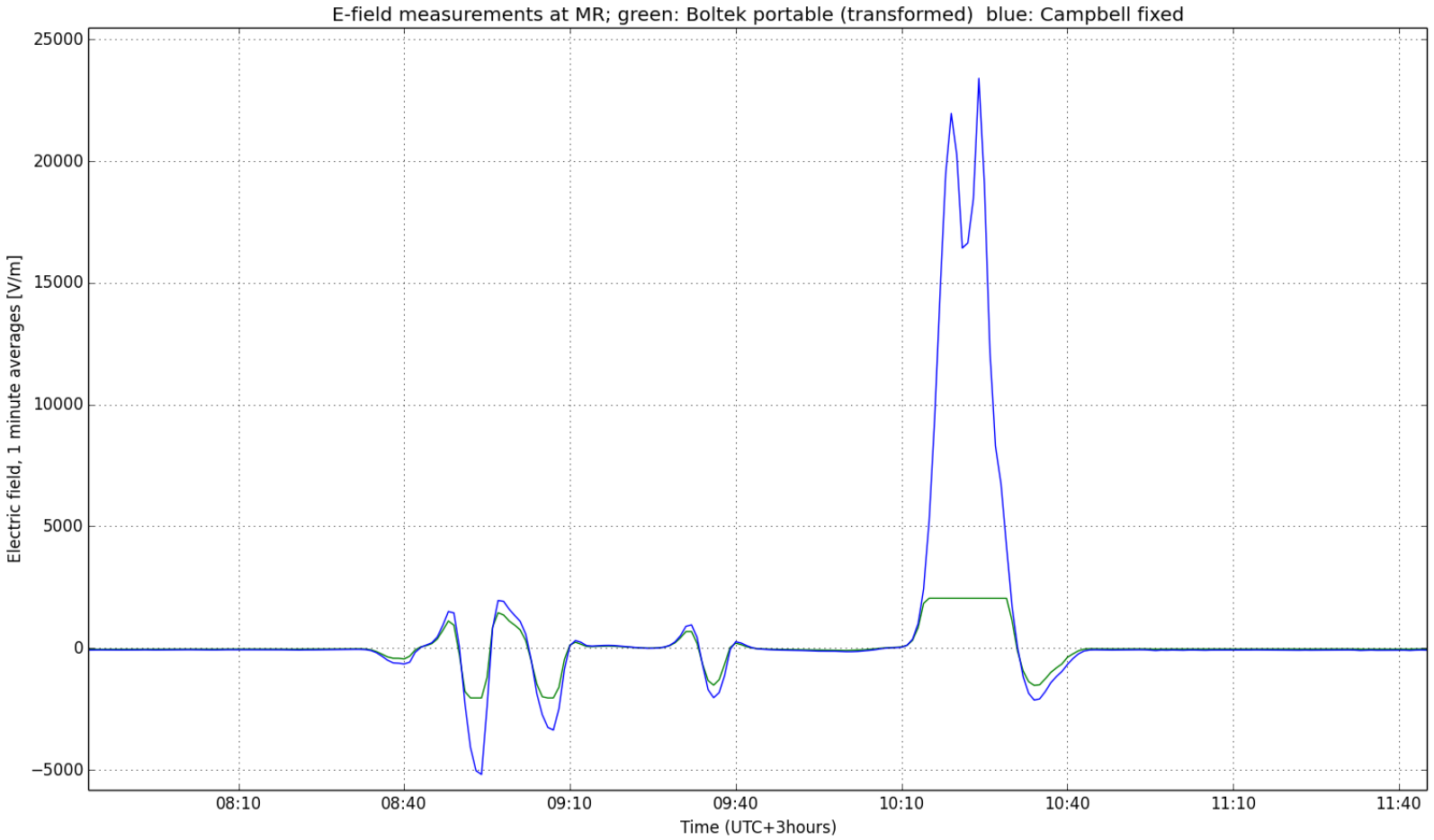
Atmospheric pressure also peaked at 5:06



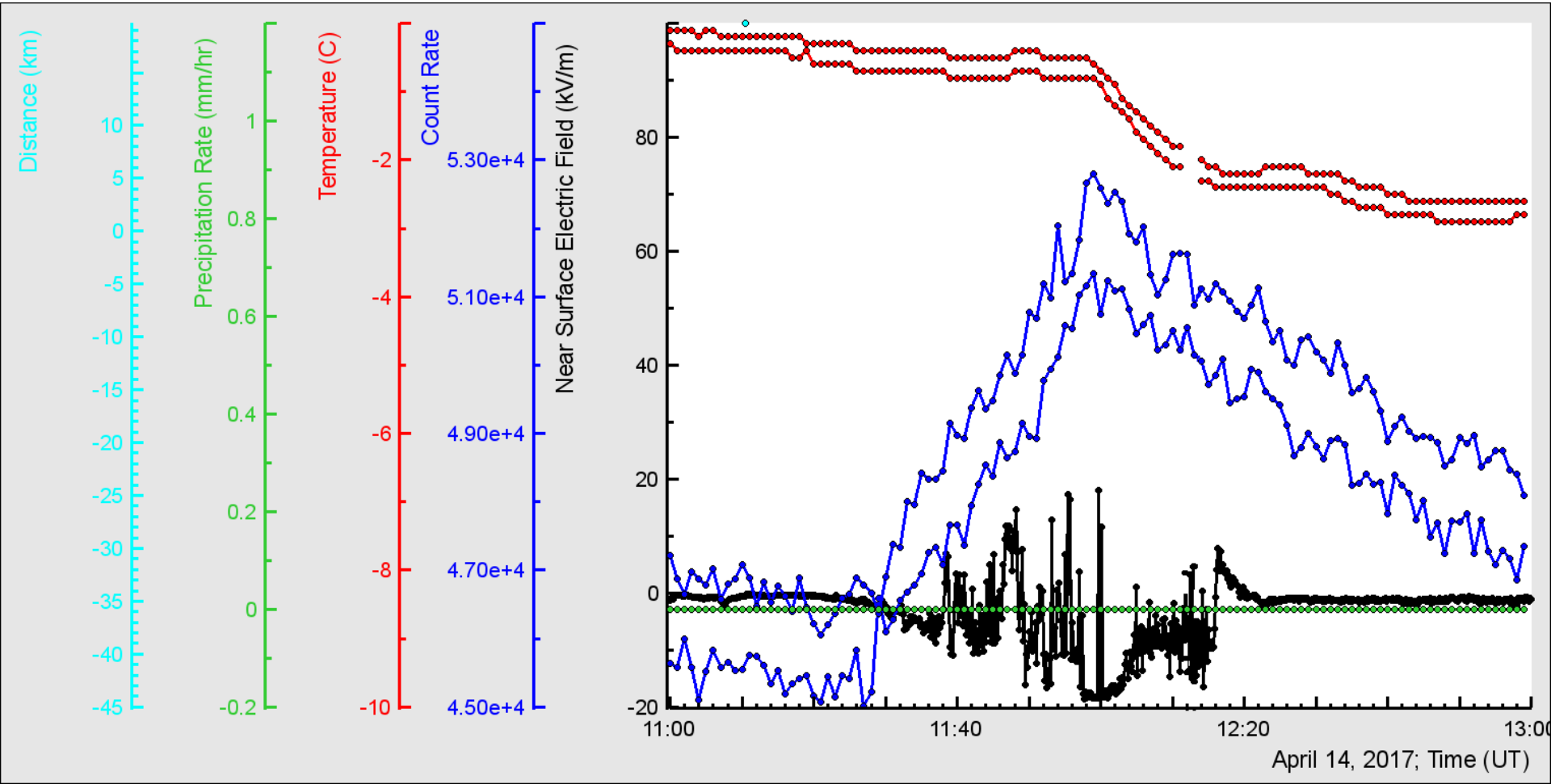
5-cm thick scintillators of MAKET array



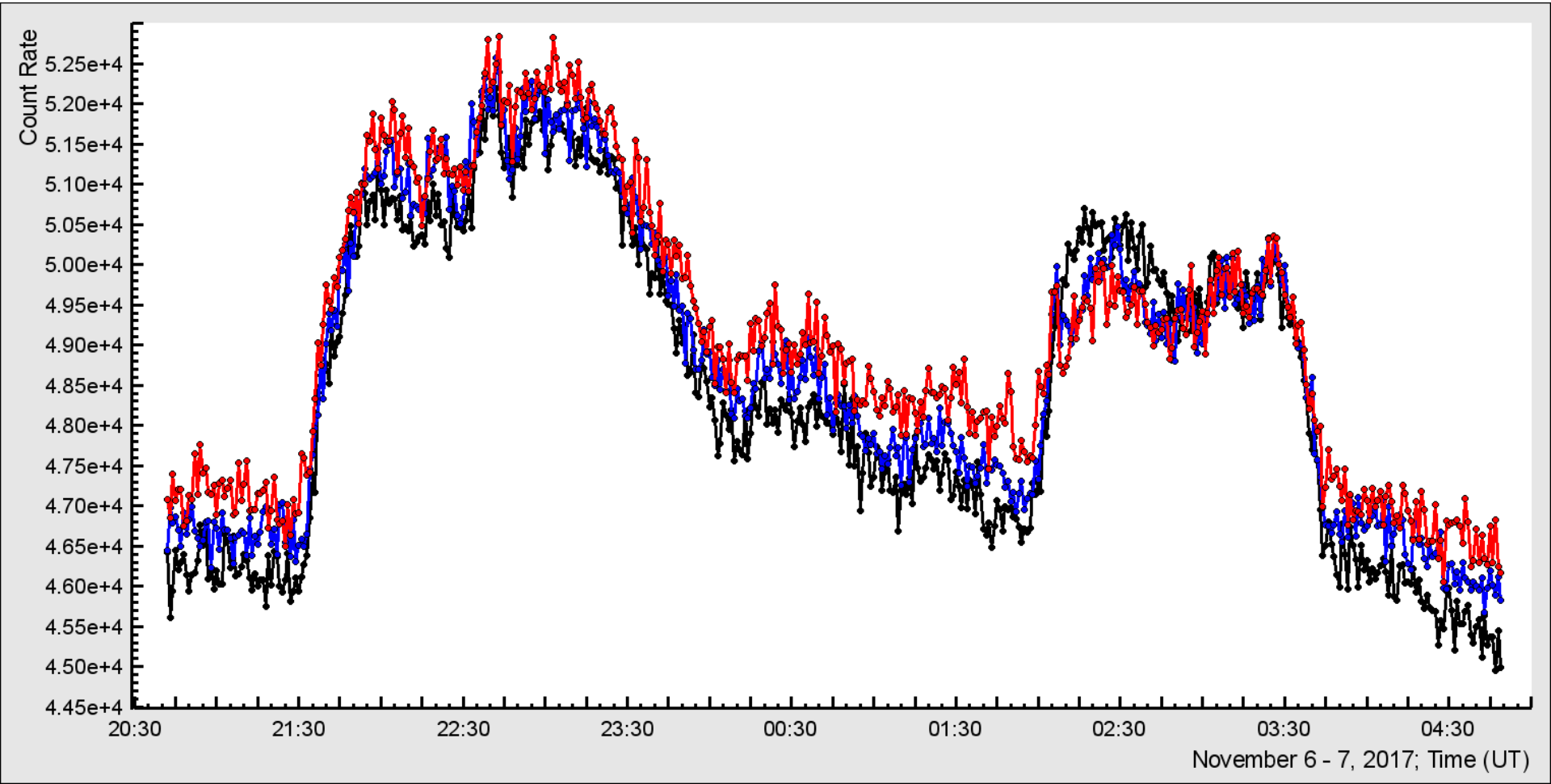
Mitzpe Ramon, Israel on 8 February, 2017 (light rain no thunderstorm)



Miscellaneous


Distance (km)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
Precipitation Rate (mm/hr)
1
0.8
0.6
0.4
0.2
0
-0.2
Temperature (C)
-2
-4
-6
-8
-10
Count Rate
5.30e+4
5.10e+4
4.90e+4
4.70e+4
4.50e+4
Near Surface Electric Field (kV/m)
80
60
40
20
0
-20
11:00
11:40
12:20
13:00
April 14, 2017; Time (UT)

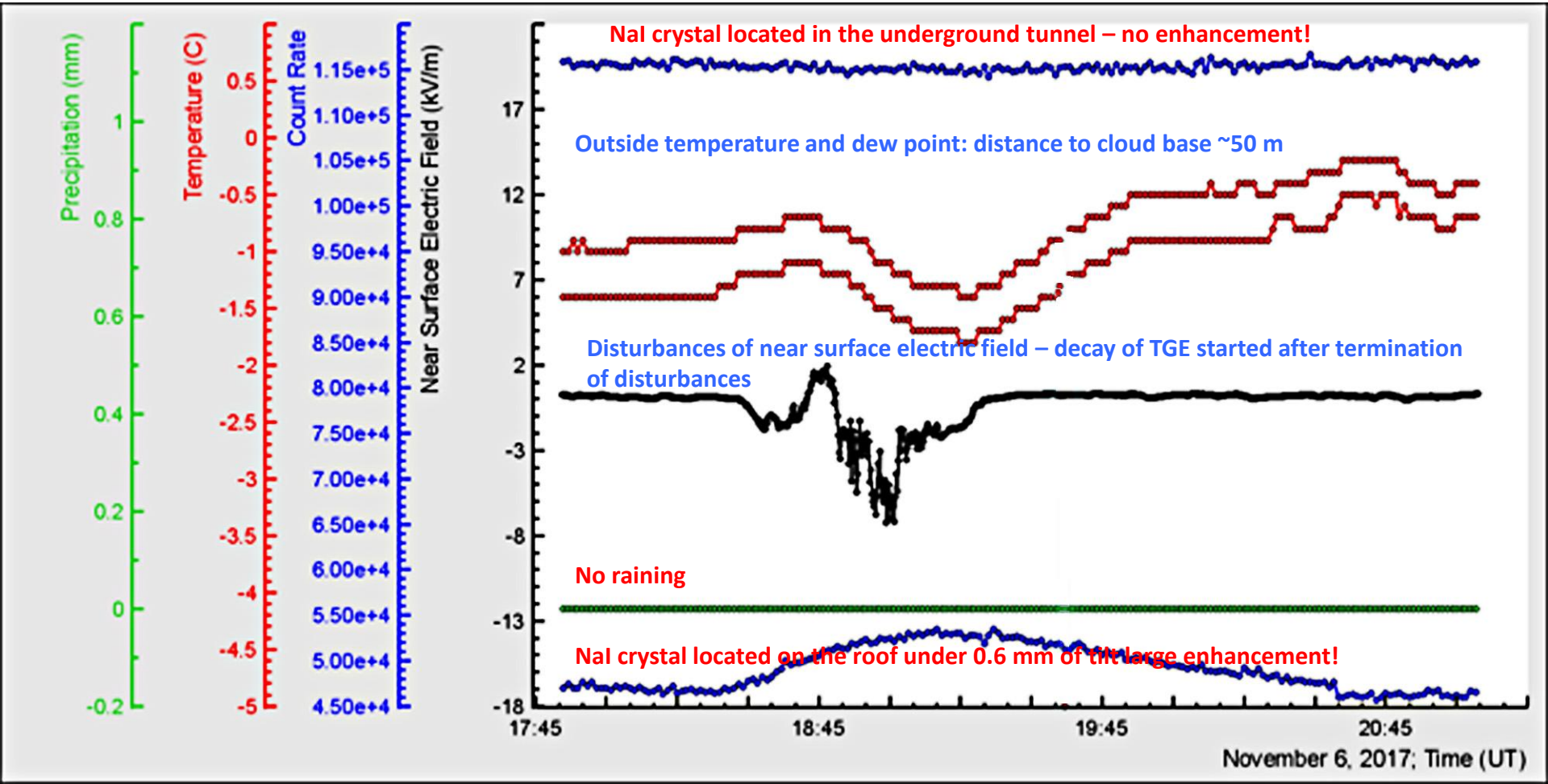
Low energy long lasting (LLL) TGE related to electrified low cloud (NaI 1,2,3 well cohere!)



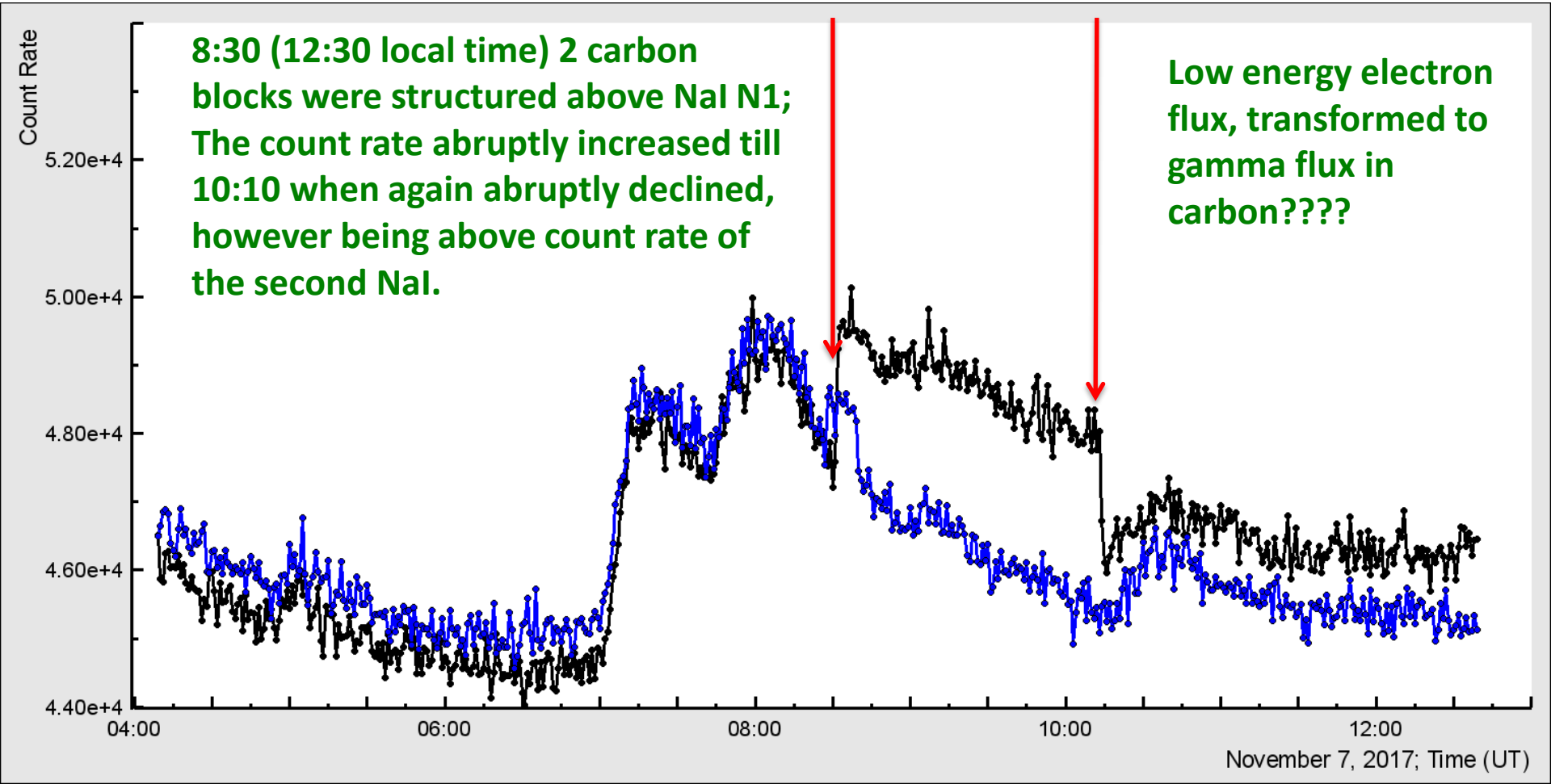
12:30 local time on Nov. 17 above NaI

N 1 2 Carnon blocks were located

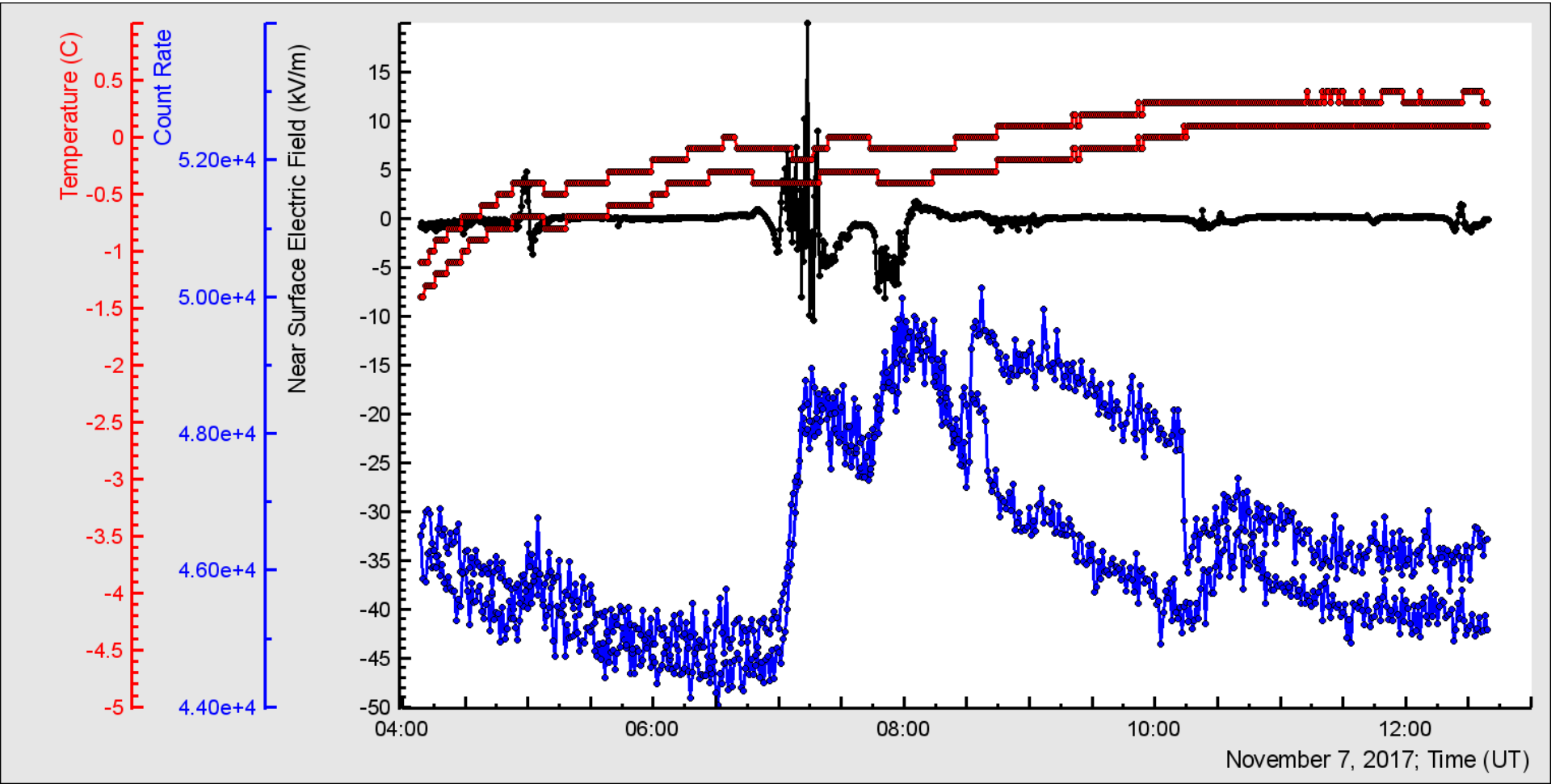
One episode of LLL GLE



The count rate of NaI N1 abruptly changed



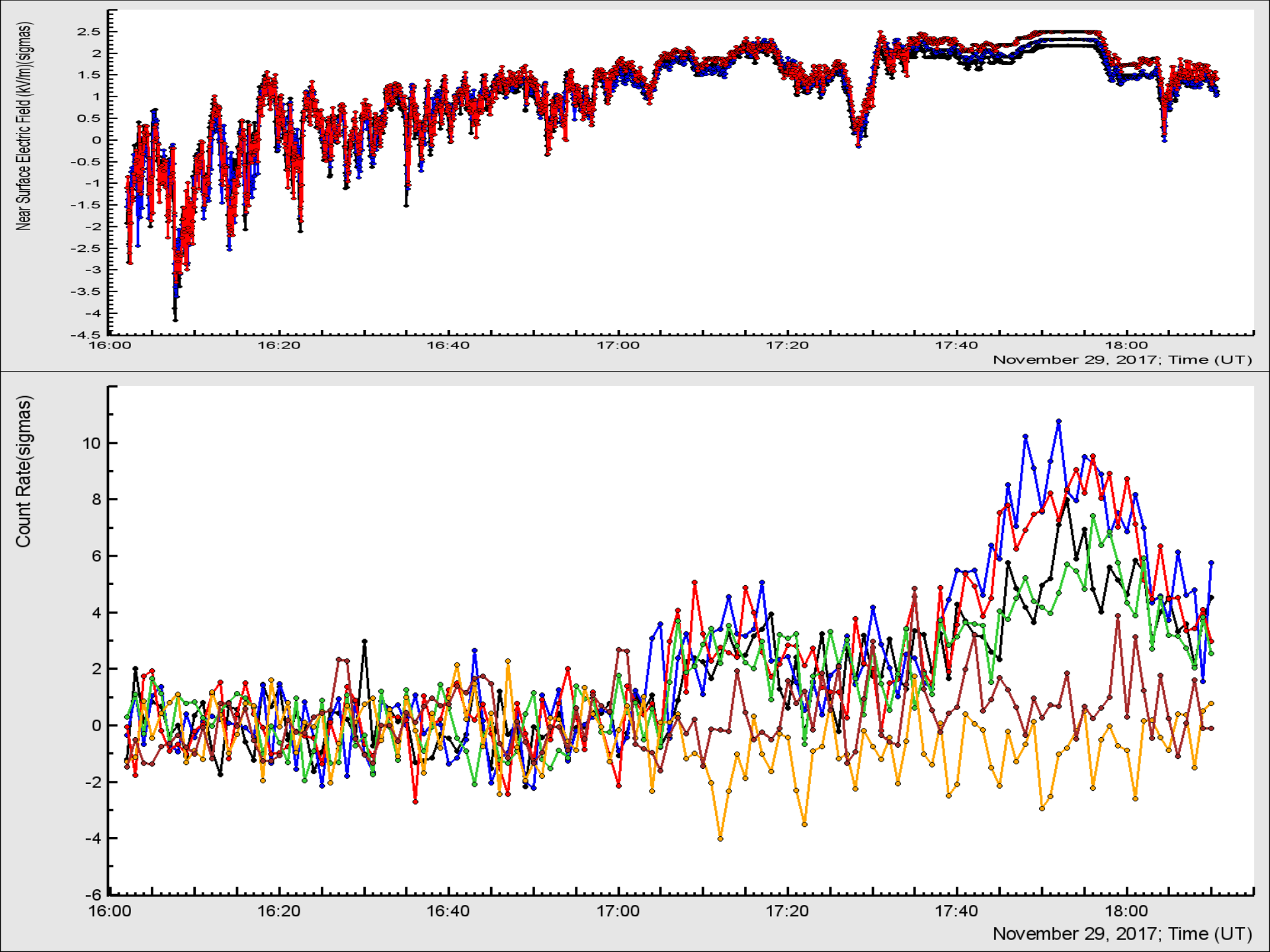
Distance to cloud base ~50 m, small disturbances of electric field after 8:30

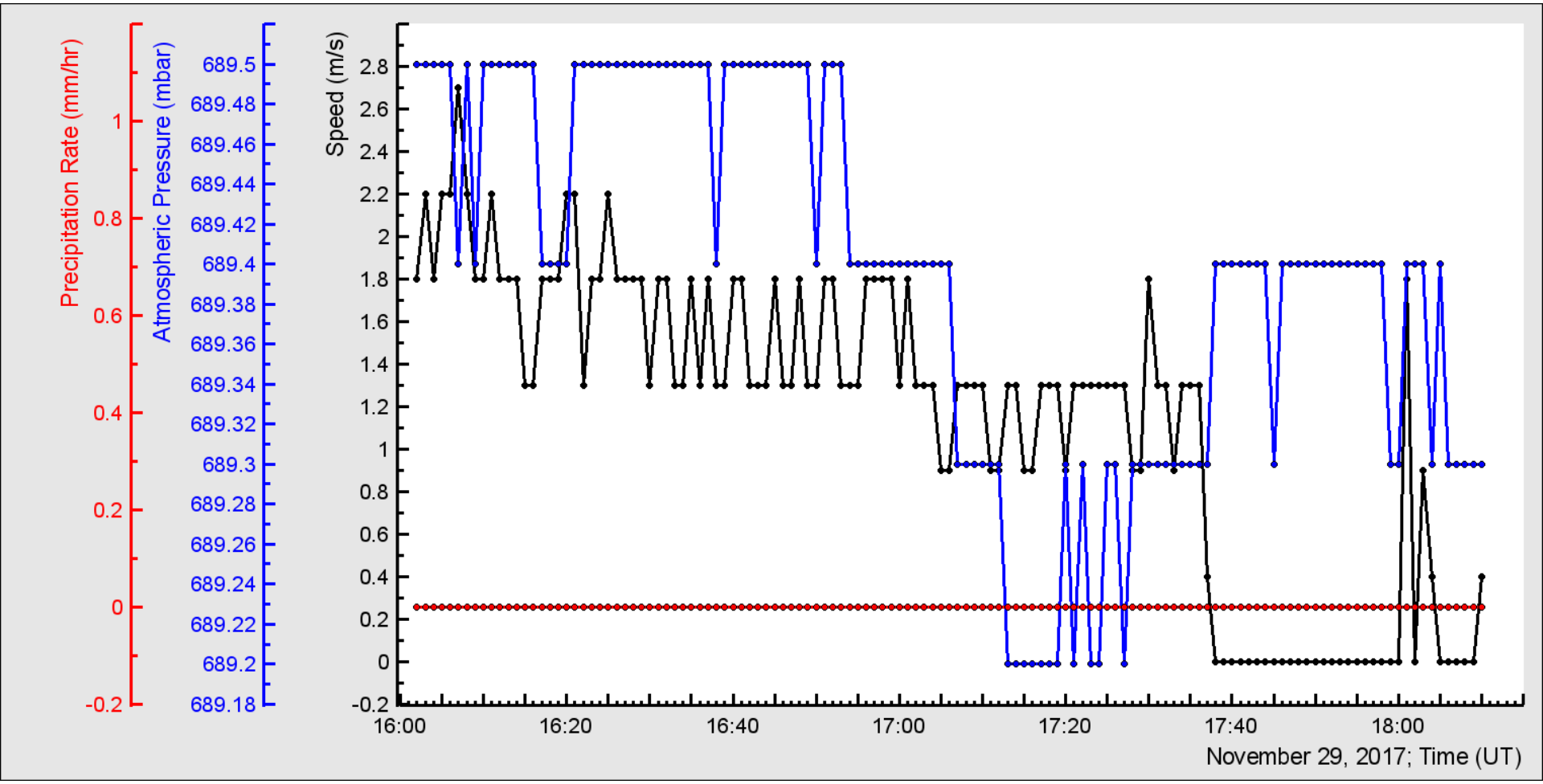


November29: Sudden enhancement of the Low energy gamma ray flux !

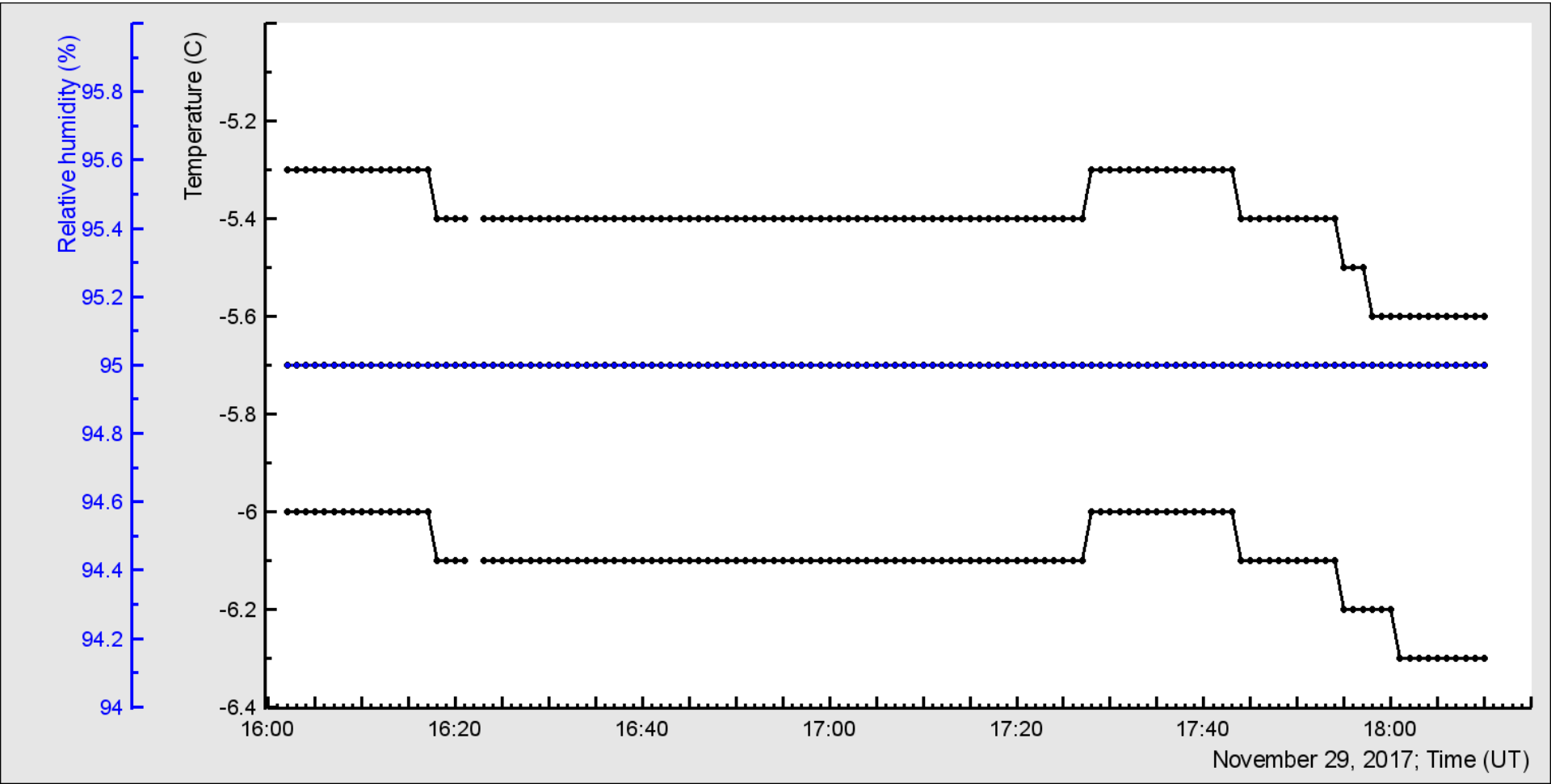
Low energy gamma rays without any geomagnetic reasons. Precursor of upcoming TGE (random emerging fields in atmosphere?)

- Without any disturbances of the near surface electric field NaI network again show very significant peaks. What is going on in the cloud?
- Randomly emerging electric fields accelerate electrons, but fail to join in a way to induce any significant field on the earth's surface?
- So, we will not aware in biases in estimation of energy for EAS and ACT events?

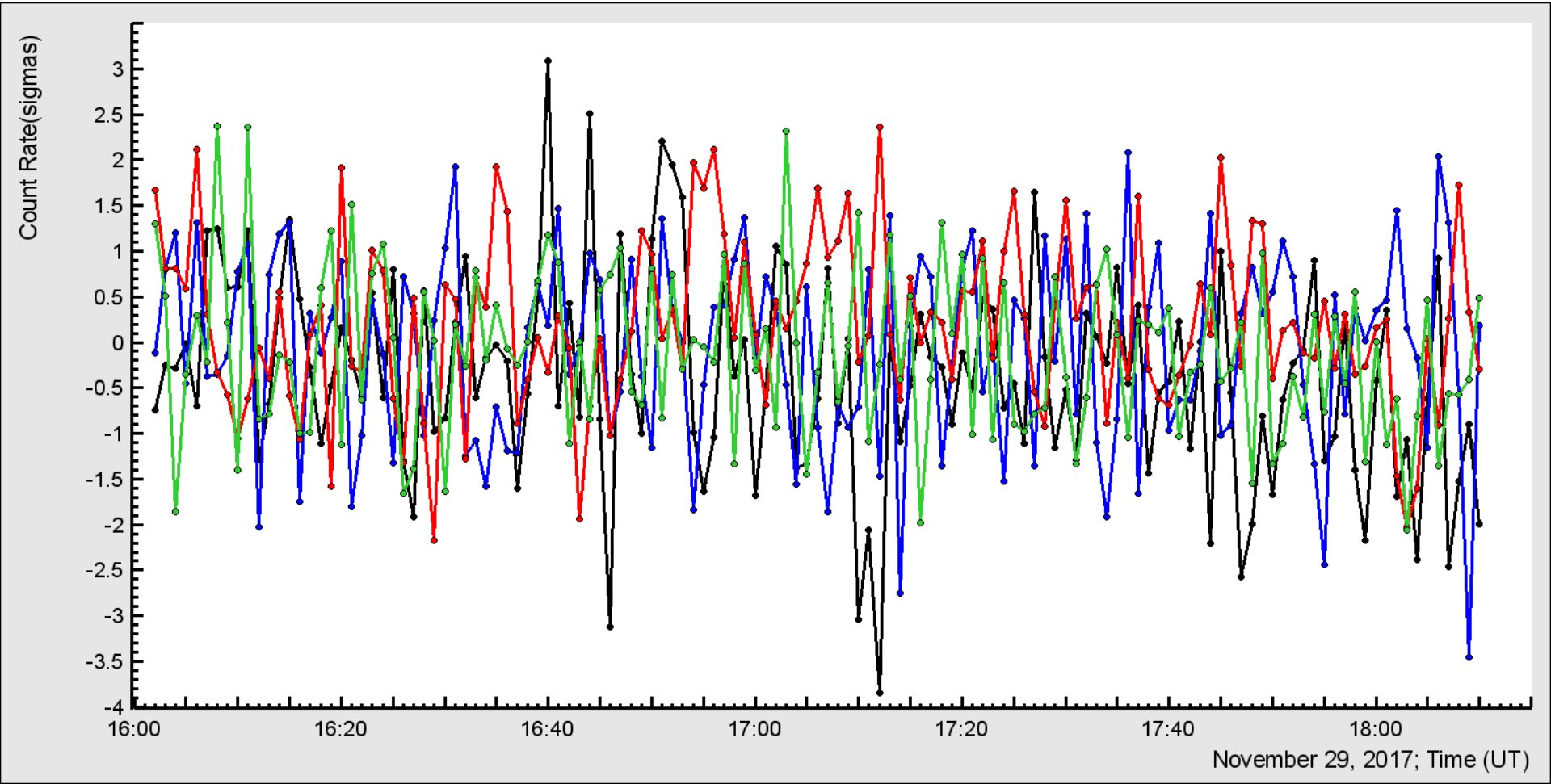

Near Surface Electric Field (kV/m)(sigmas)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
16:00
16:20
16:40
17:00
17:20
17:40
18:00
November 29, 2017; Time (UT)
Count Rate(sigmas)
10
8
6
4
2
0
-2
-4
-6
16:00
16:20
16:40
17:00
17:20
17:40
18:00
November 29, 2017; Time (UT)


Precipitation Rate (mm/hr)
1
0.8
0.6
0.4
0.2
0
-0.2
Atmospheric Pressure (mbar)
689.5
689.48
689.46
689.44
689.42
689.4
689.38
689.36
689.34
689.32
689.3
689.28
689.26
689.24
689.22
689.2
689.18
Speed (m/s)
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
16:00
16:20
16:40
17:00
17:20
17:40
18:00
November 29, 2017; Time (UT)

Cloud base height ~ 100m, RE – 95%



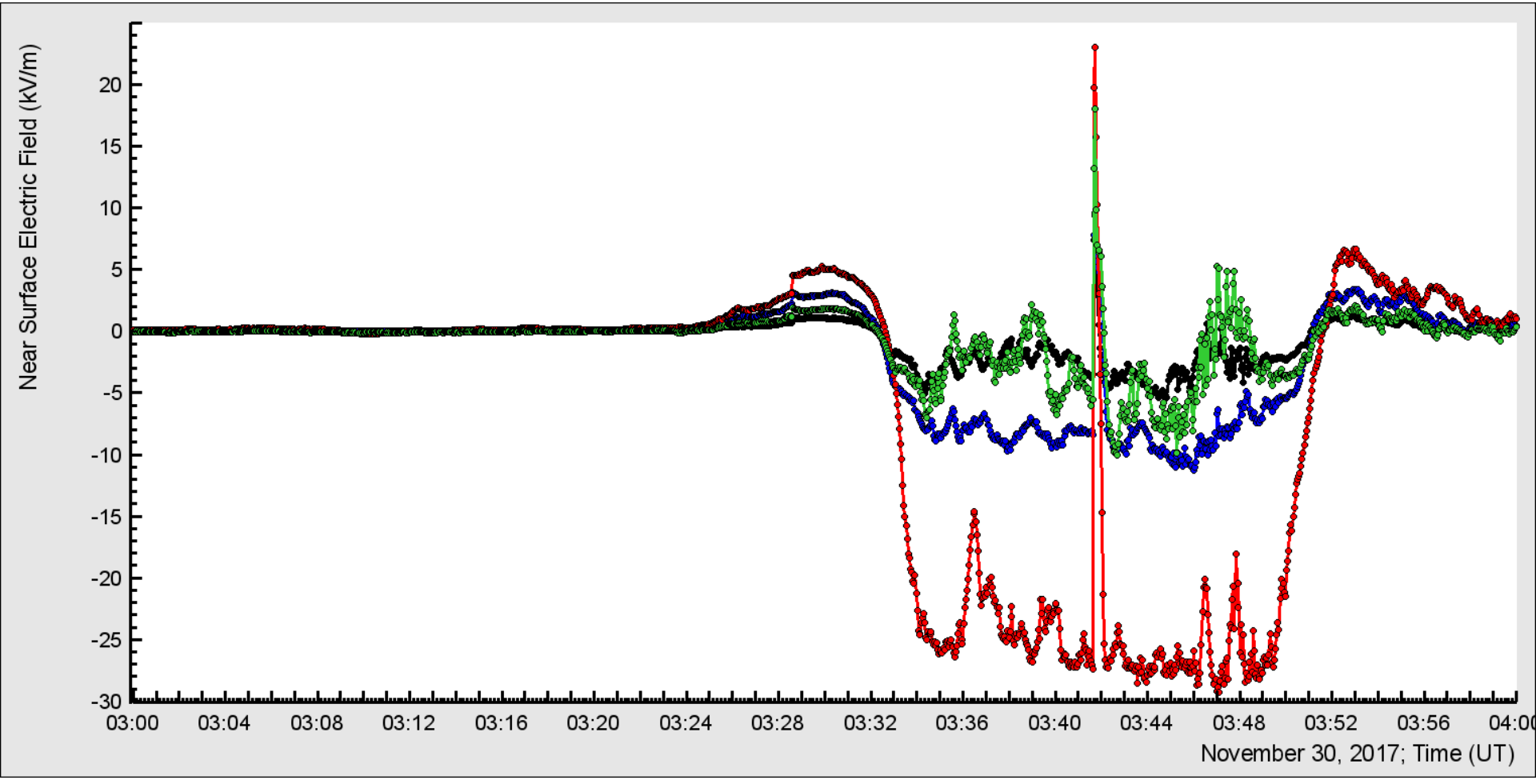
STAND3 – no enhancement in all channels



November 30 late (maybe last in 2017) TGE

- 3 ASNT 60 cm thick scintillators from 4 operate rather uniformly!
- STAND1 network operates very good, congratulations! Now we have possibility to research the movement of the emitting region in the cloud!
- Only MAKET EFM demonstrates near lightning flash!
- NaI N1 under 10 cm of carbon demonstrates smaller significance comparing with N 1 and 3 – only gamma rays in TGE! (usually carbon converts electrons to gamma rays and count rate increases)!
- Underground NaI demonstrates decrease, no Radon, but why decrease?
- Fast field demonstrate both EMI and genuine particle pulses (easy to distinguish)!
- UV and IR radiation is registered should be analyzed: Garik is there any new physics?
- We also register pulse shape (for one second after pre-lightning trigger) of NaI (Bogomolov) spectrometer. Vitaly, are you interested to look in it?
- Interferometer also triggered, however quality is not very good; we have to understand the analysis methodology from 5 events under analysis now in IKI. Maybe NN group also is interested in analysis?

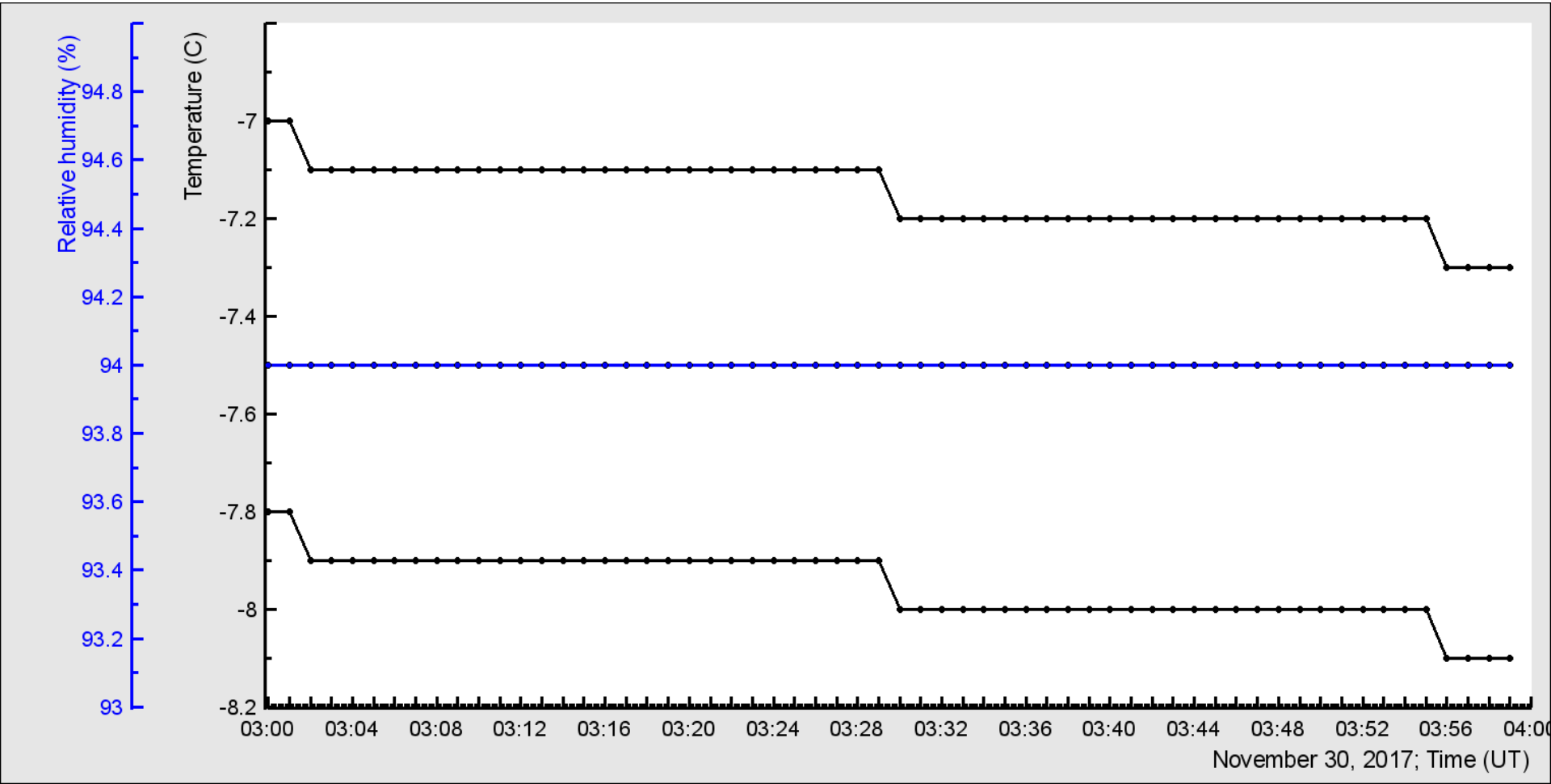
20 minutes of very “flat” negative field with lightning in the middle, not coinciding with maximal particle flux!



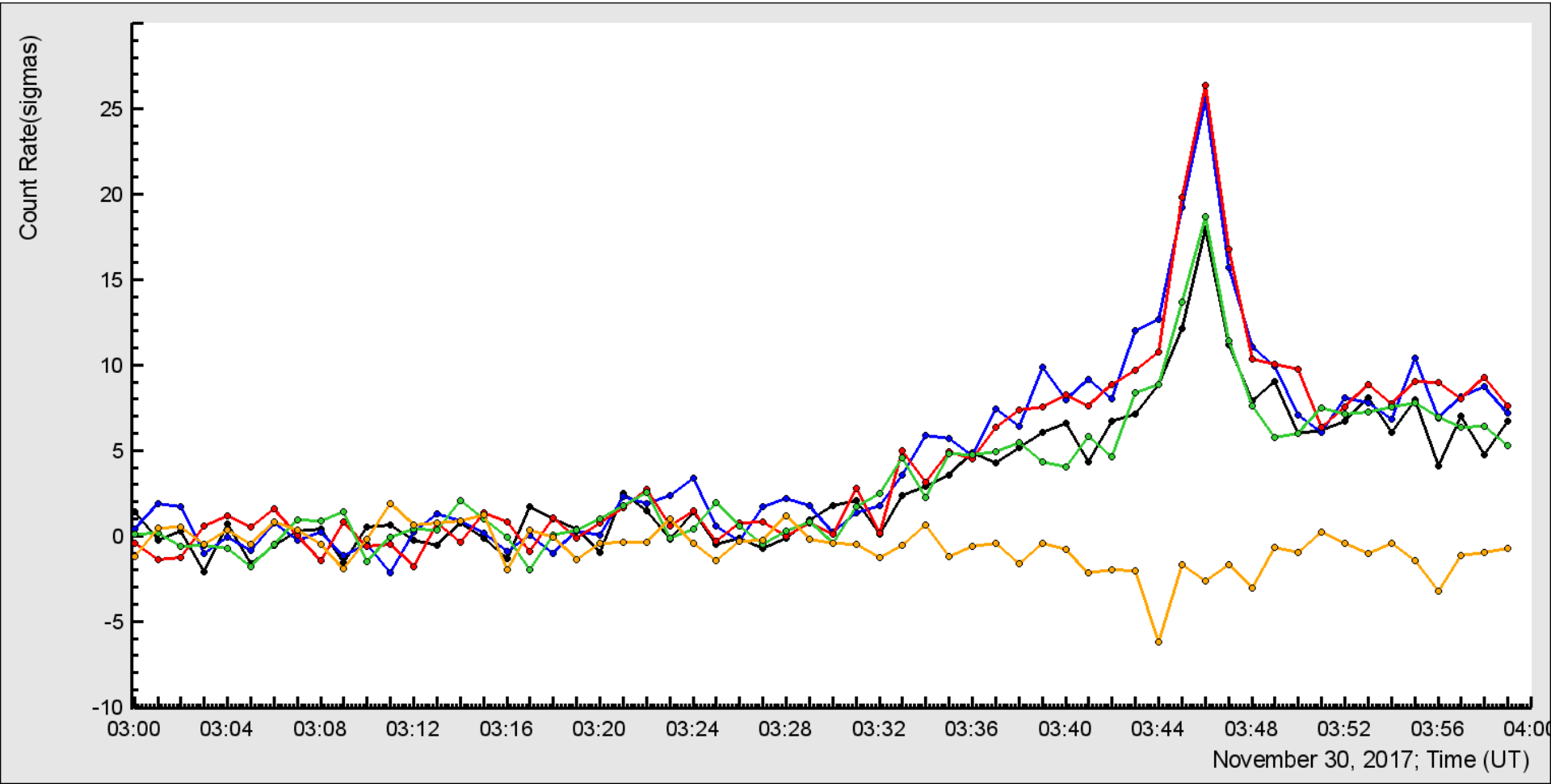

N. (0)
E. (90)
W. (270)
S. (180)
Cloud is “sitting” just on the station
AraSats AllSkyCam 1
2017-11-30
03:48:00-00


Aragats, 30 November, 8:30 local time, snowing

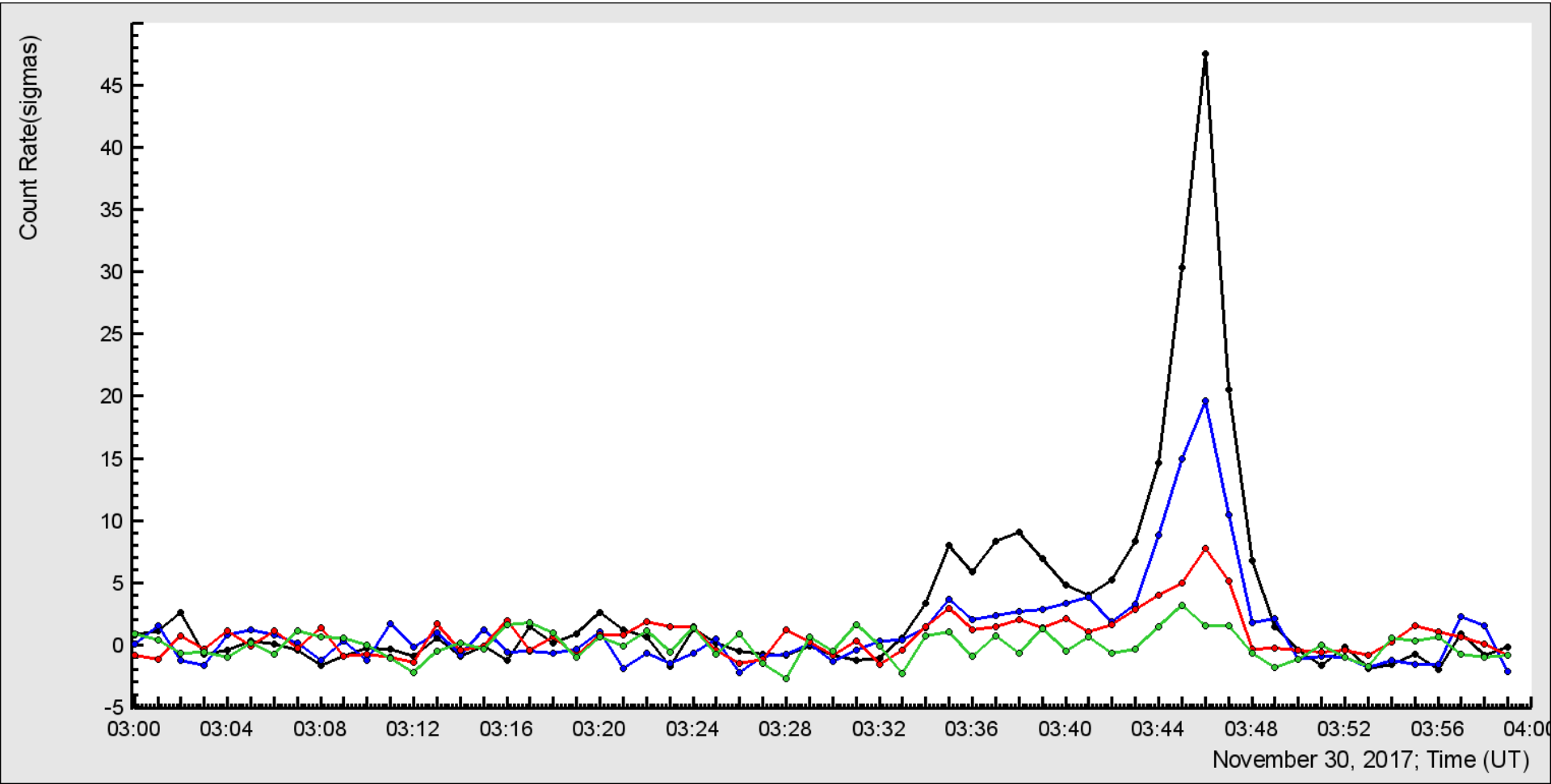
Weather conditions



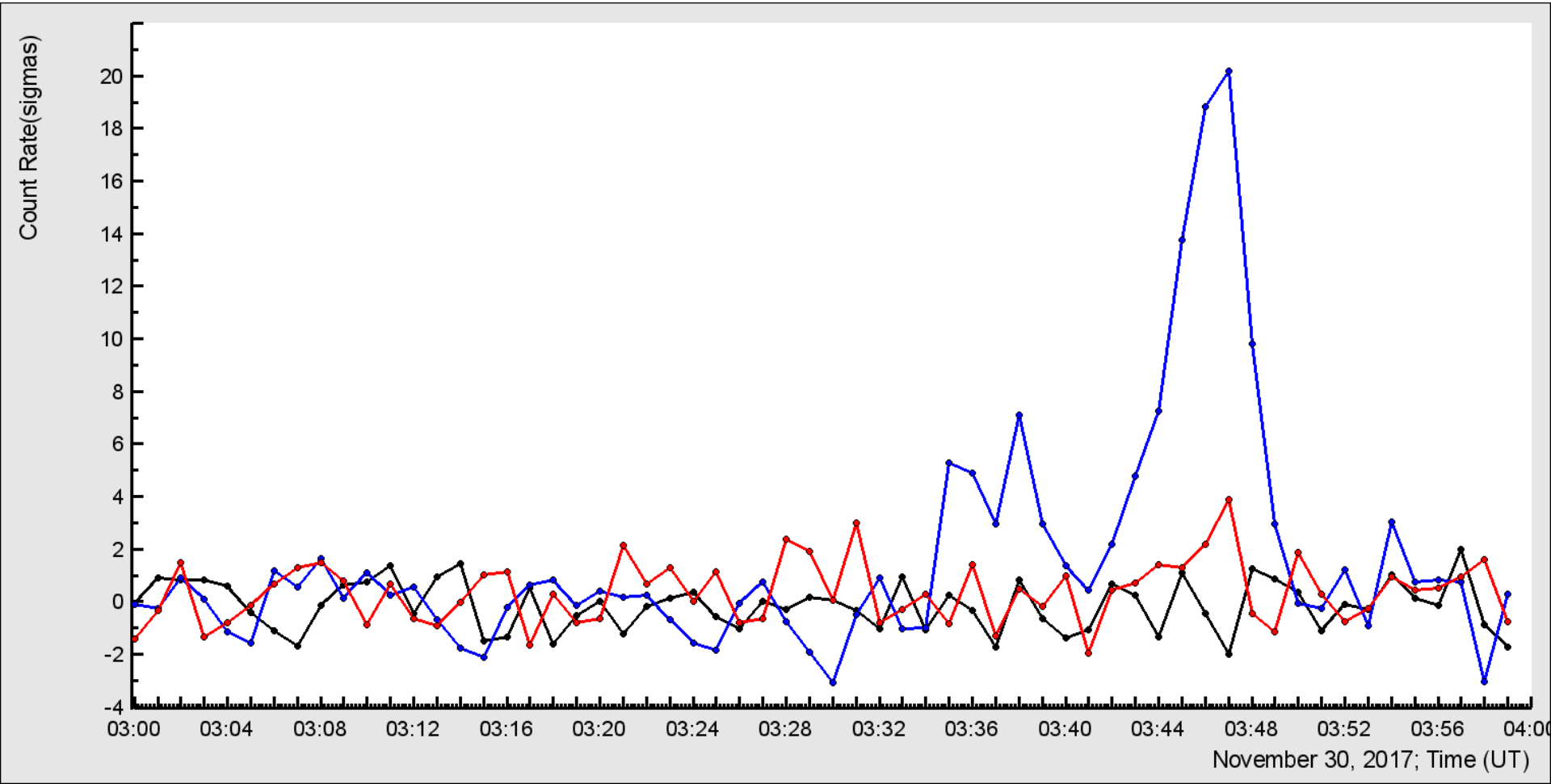
NaI network, now with additional clues: N1 (black) and N 6 (green) under 10 cm of carbon; N 7 in the underground tunnel (check for Radon, neutron emissions)



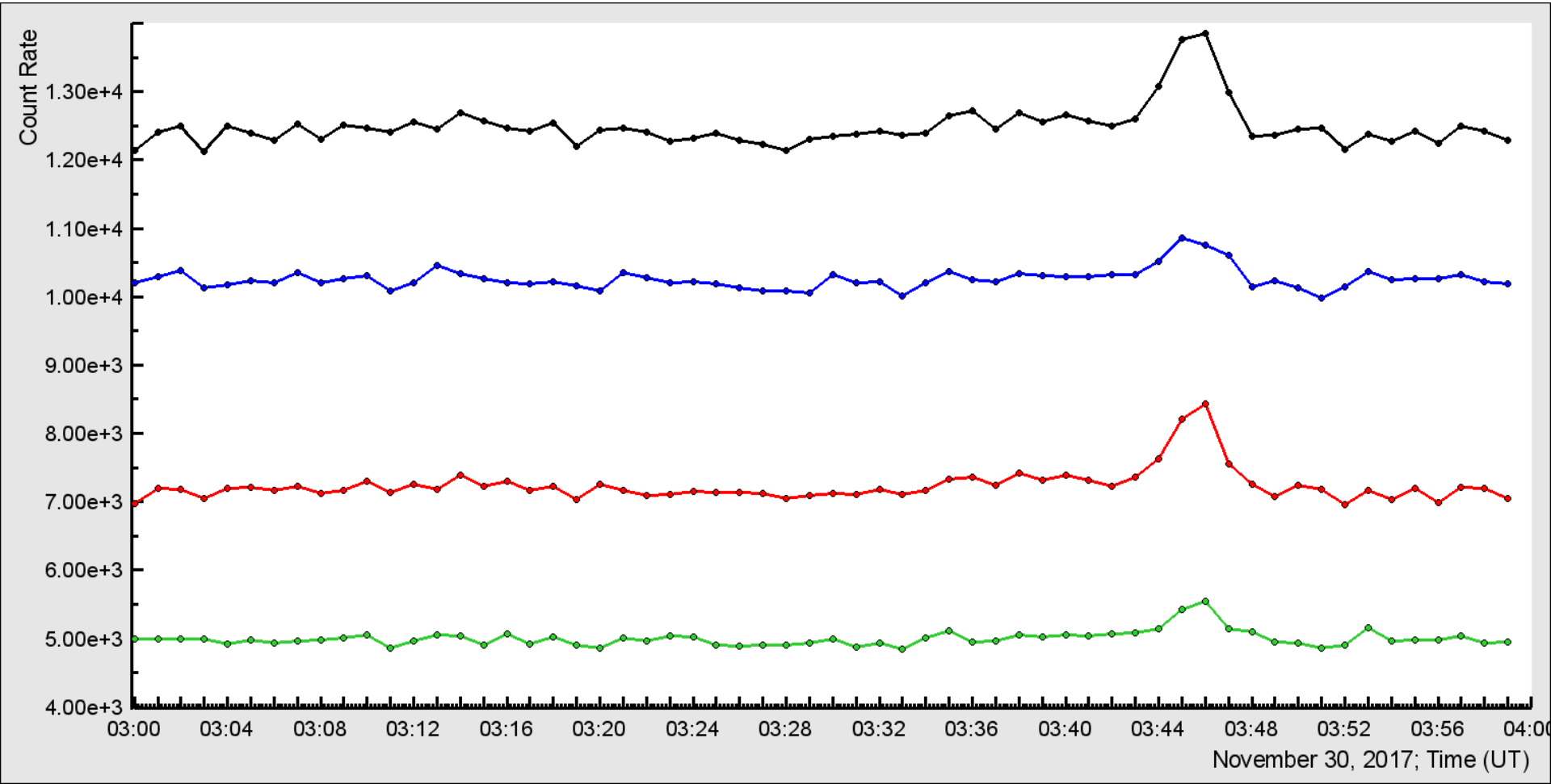
STAND3 combinations



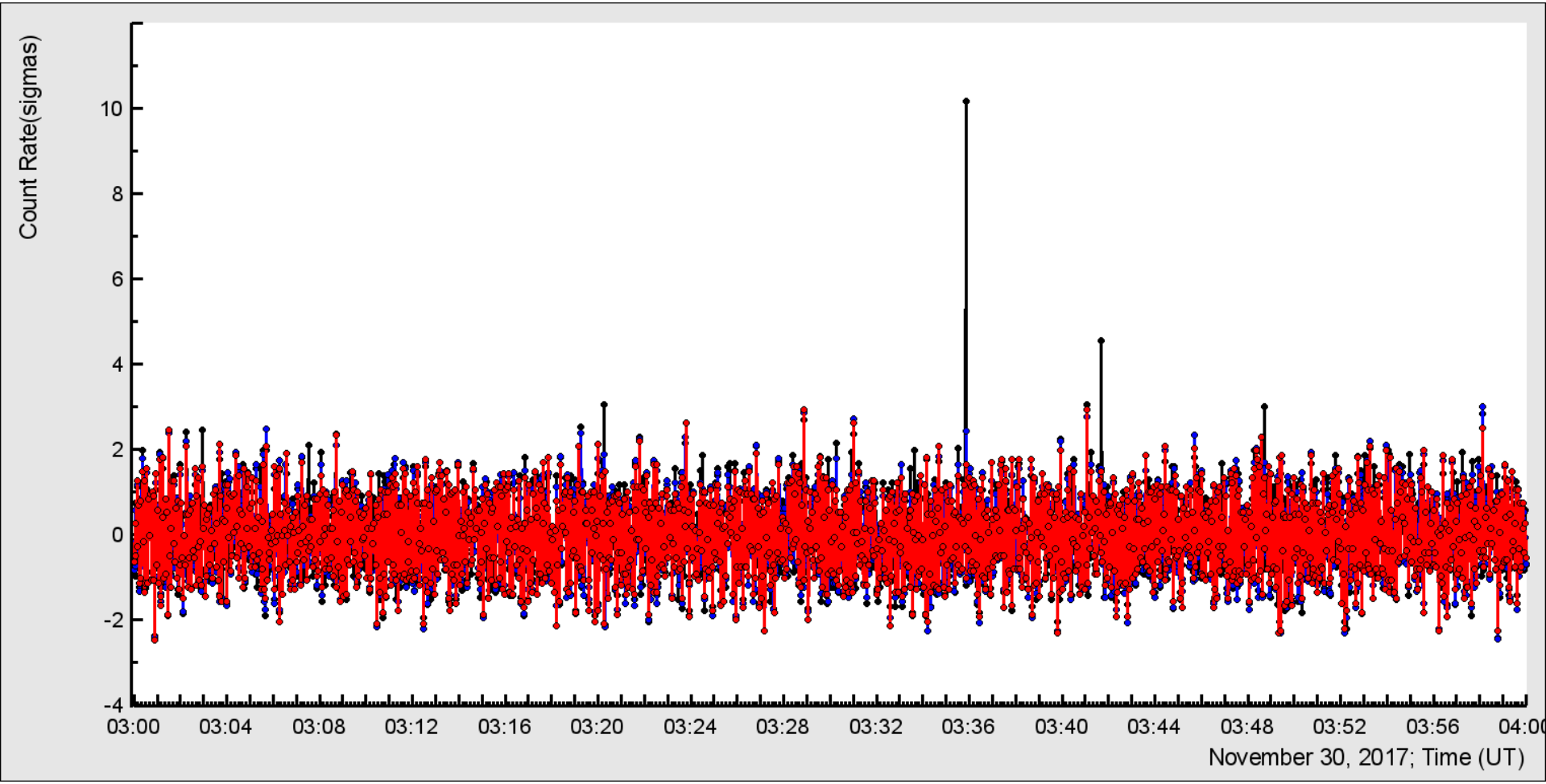
STAND1 (MAKET) combinations



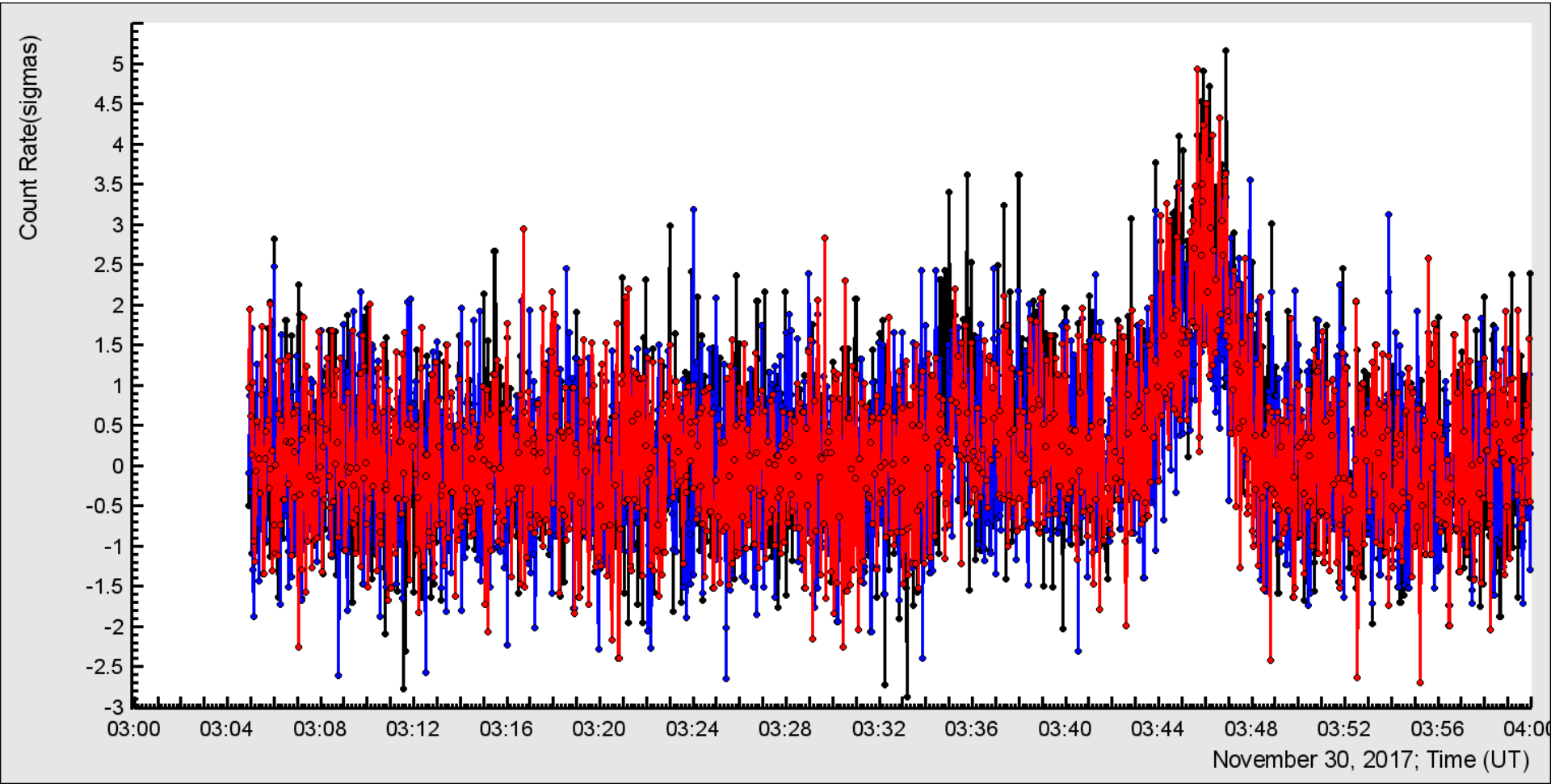
CUBE with and without veto



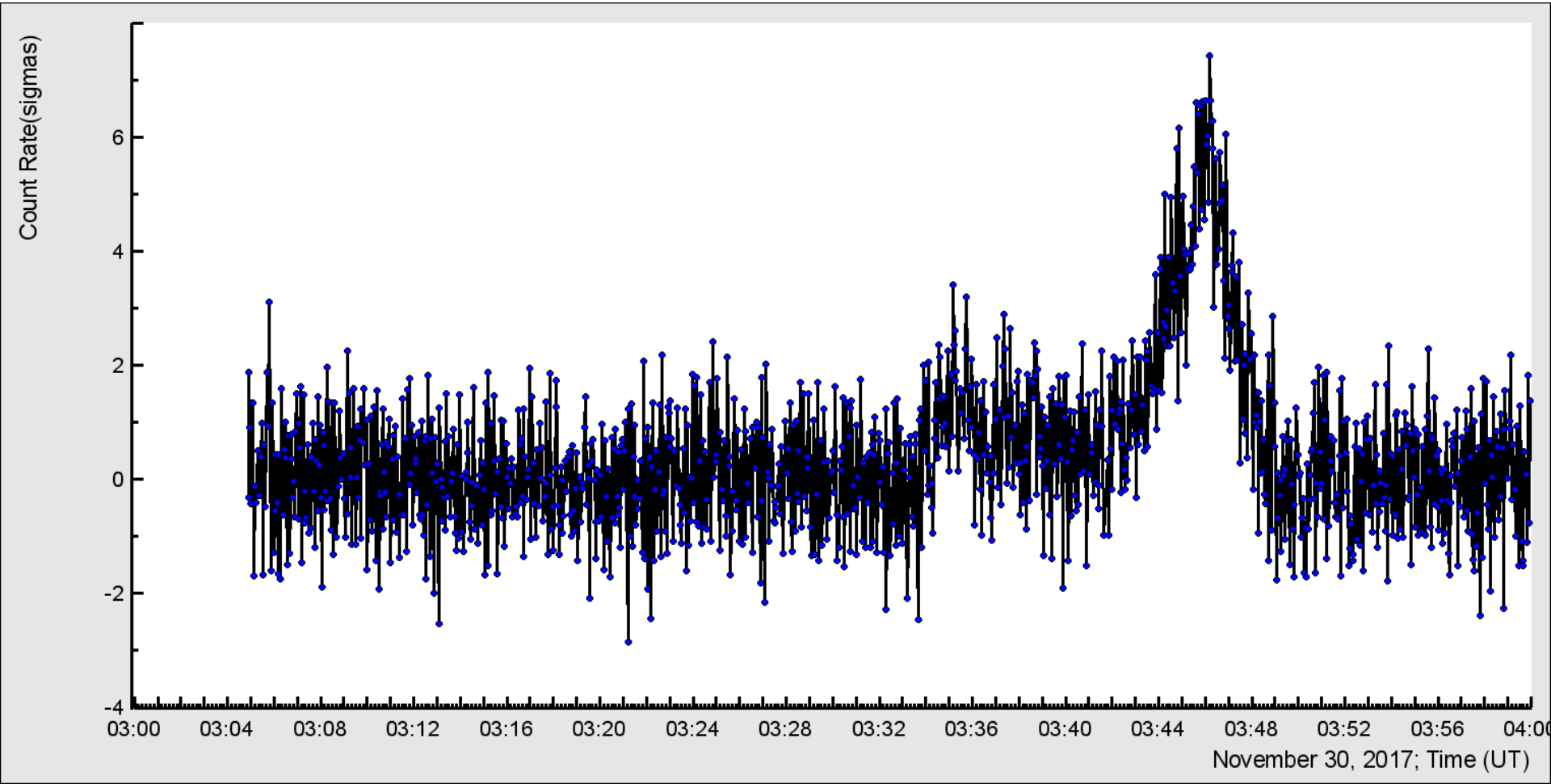
No neutrons!


Count Rate(sigmas)
10
8
6
4
2
0
-2
-4
03:00
03:04
03:08
03:12
03:16
03:20
03:24
03:28
03:32
03:36
03:40
03:44
03:48
03:52
03:56
04:00
November 30, 2017; Time (UT)

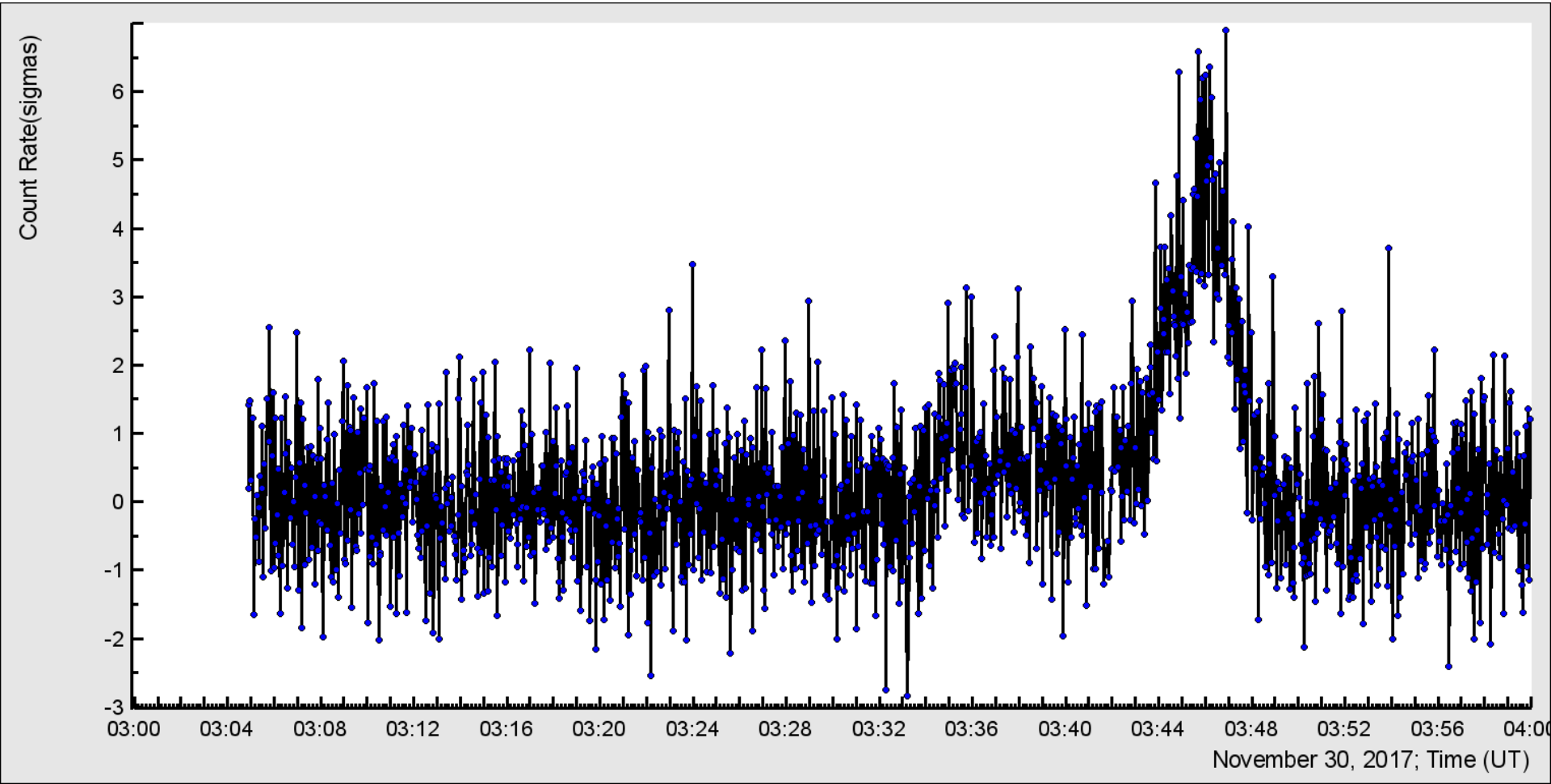
ASNT 60 cm thick (note uniformity of 3 channels)!



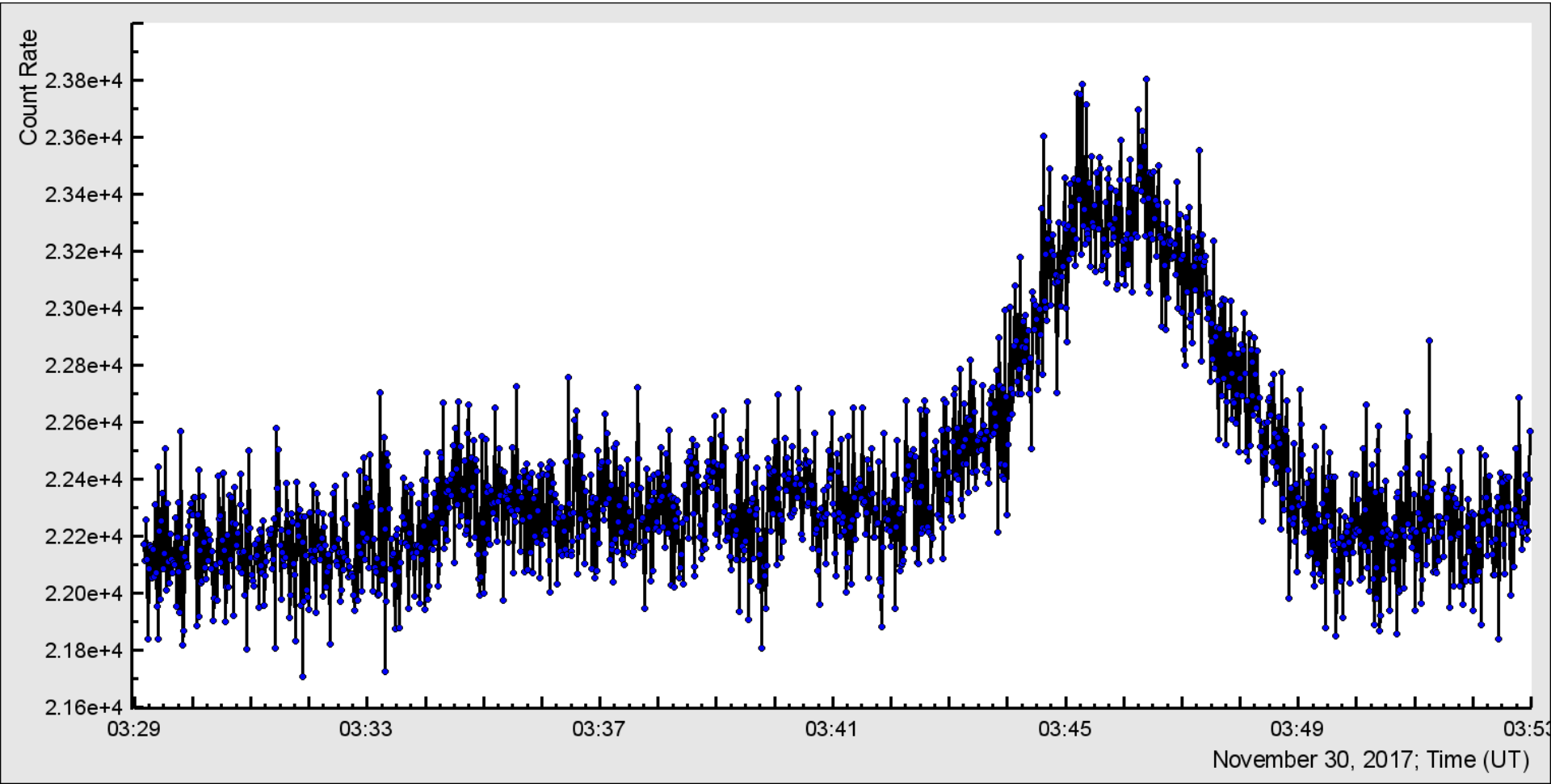
ASNT 01 combination, note increase of significance comparing with single channel!



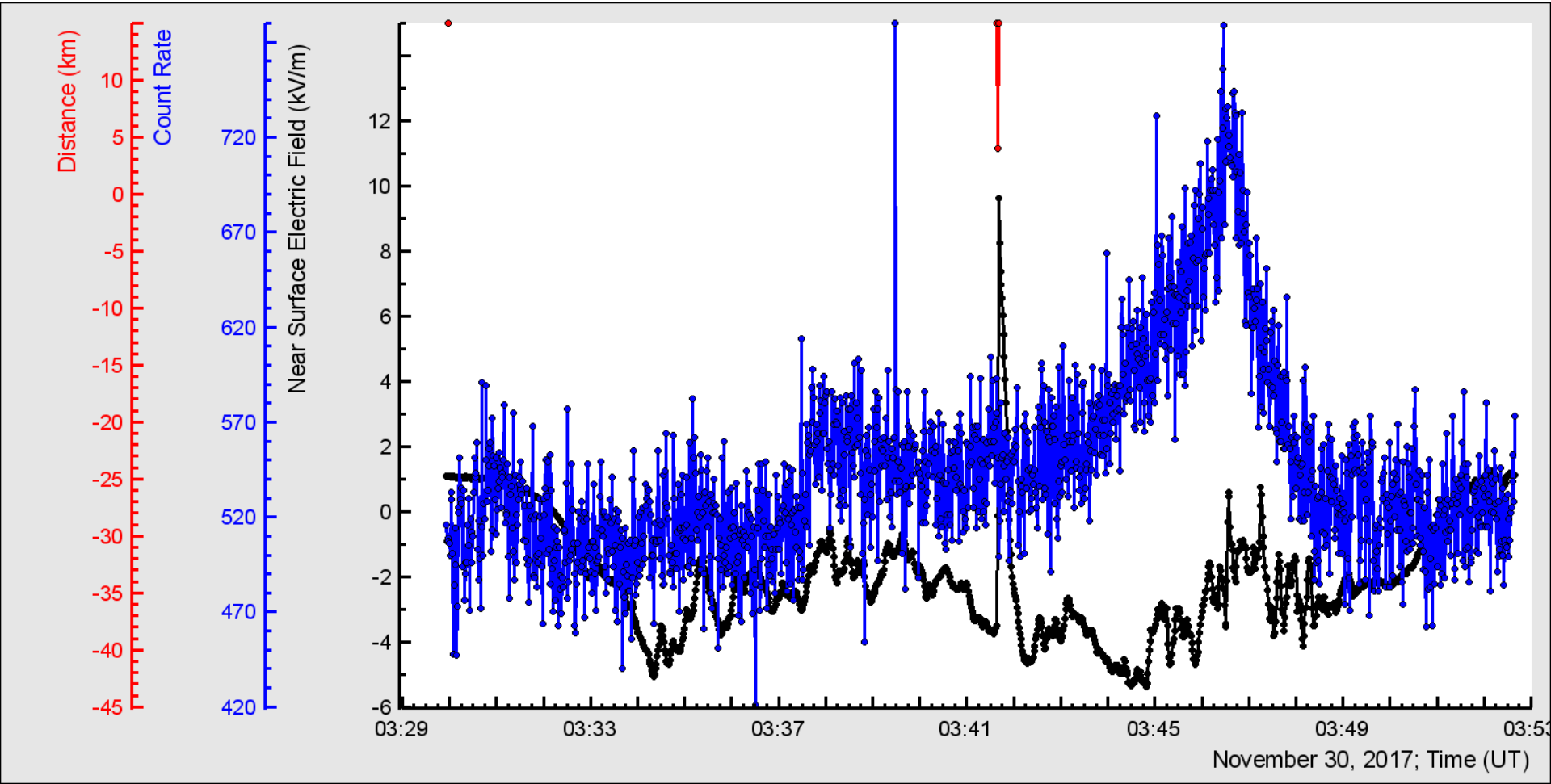
Sum of 3 60 cm thick scintillators



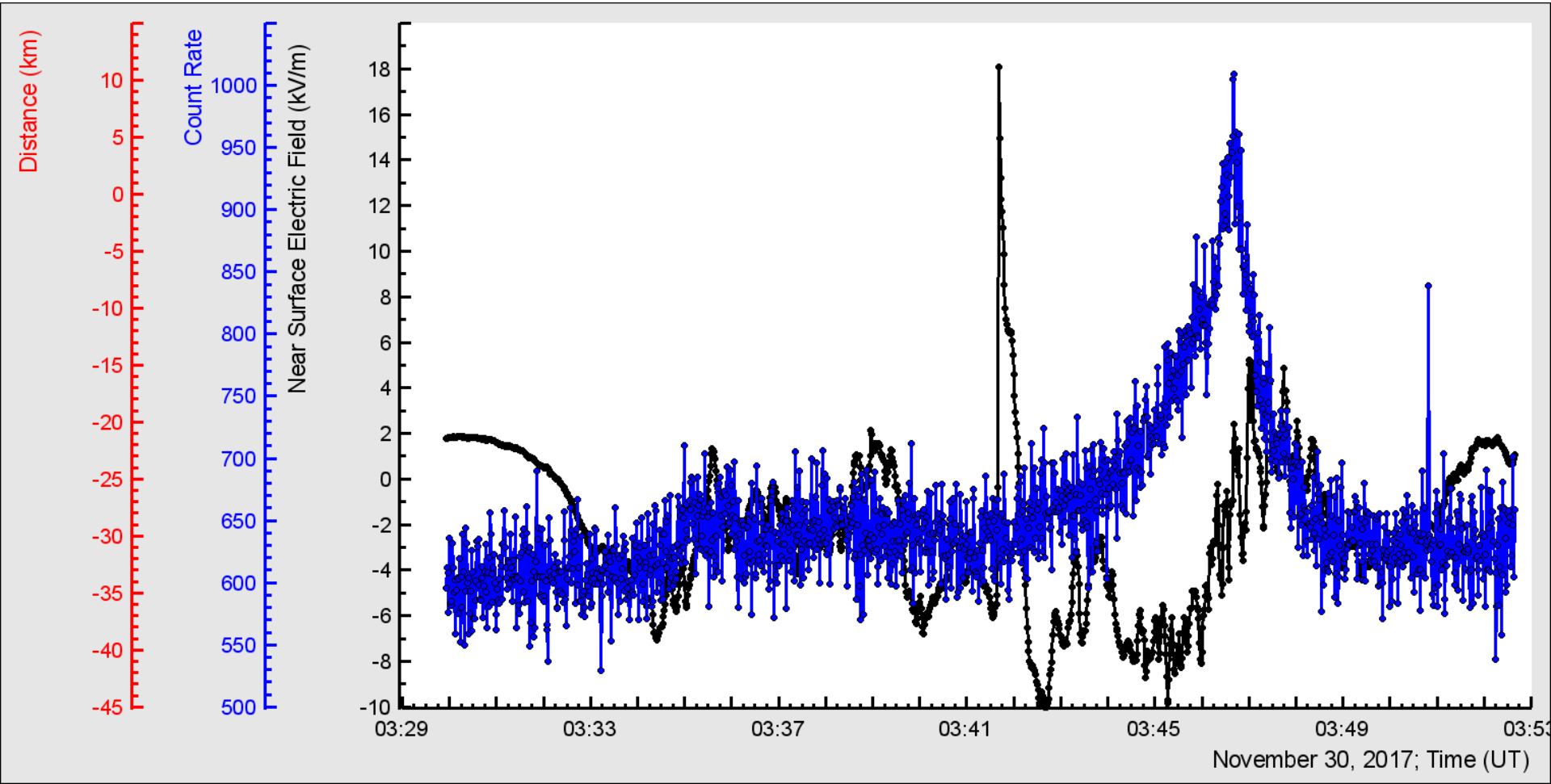
27 m^2 scintillators (AMMM) again in play!



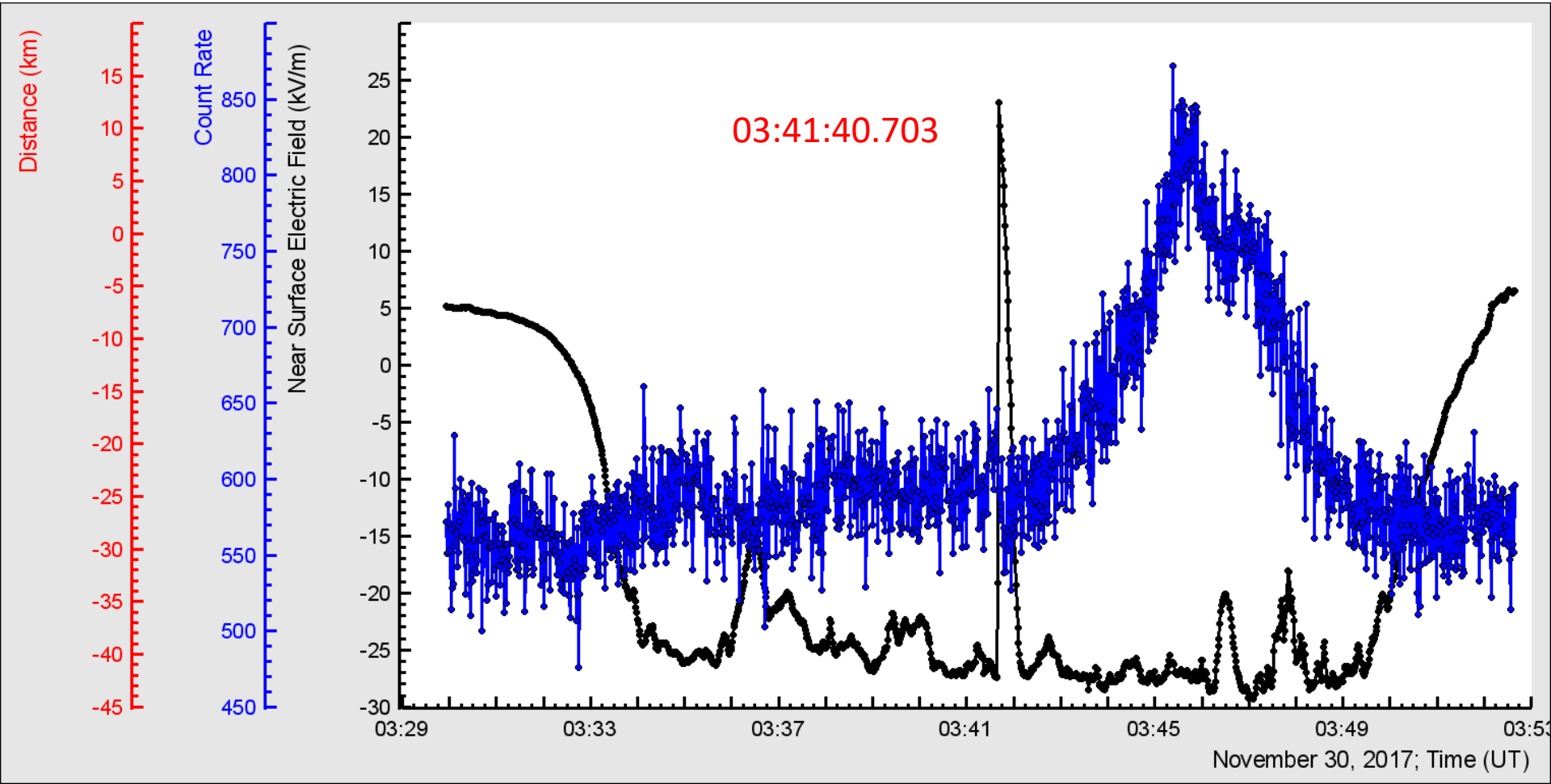
Upper Stand1 MAKET



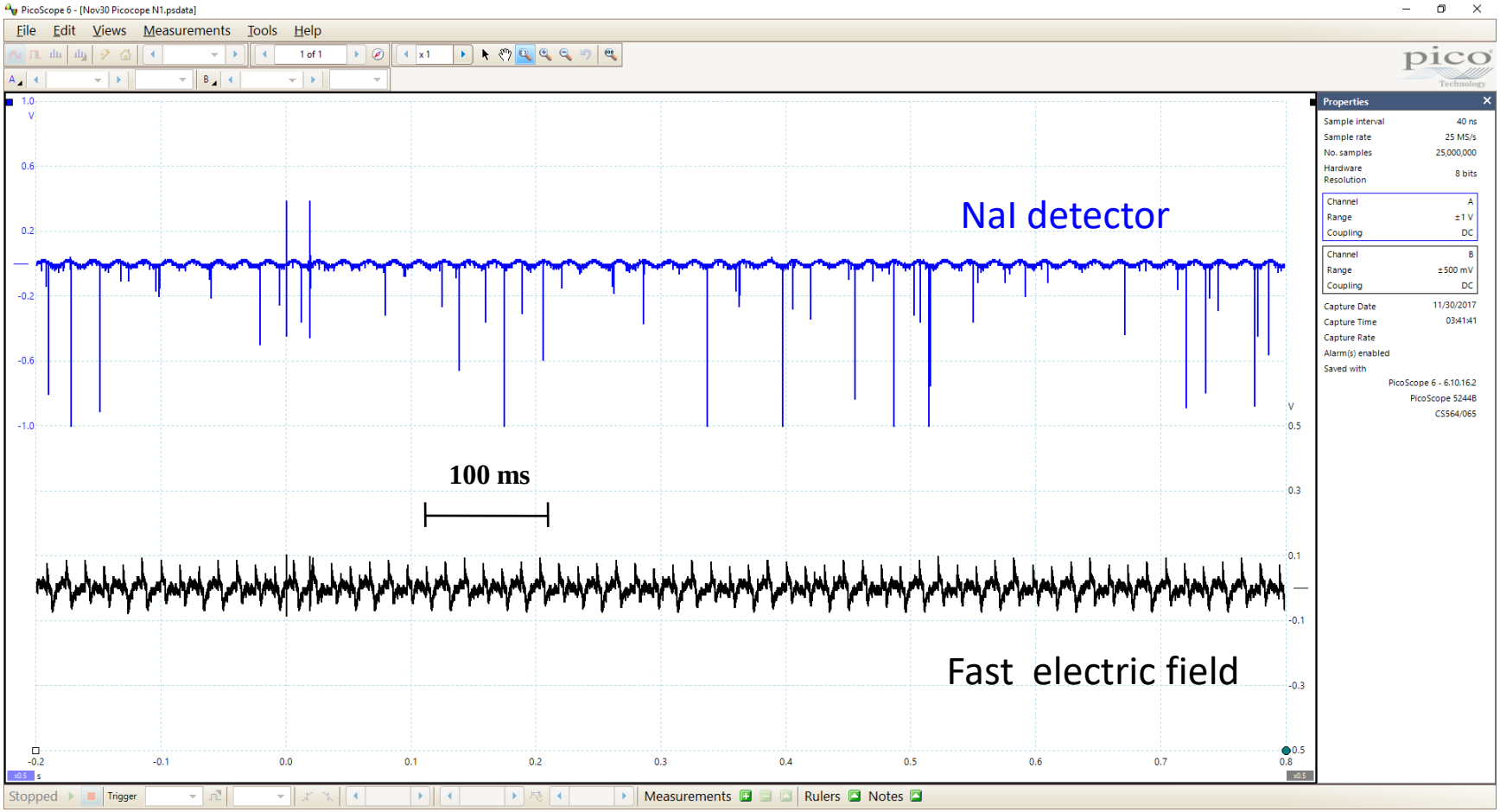
Upper STAND1 SKL



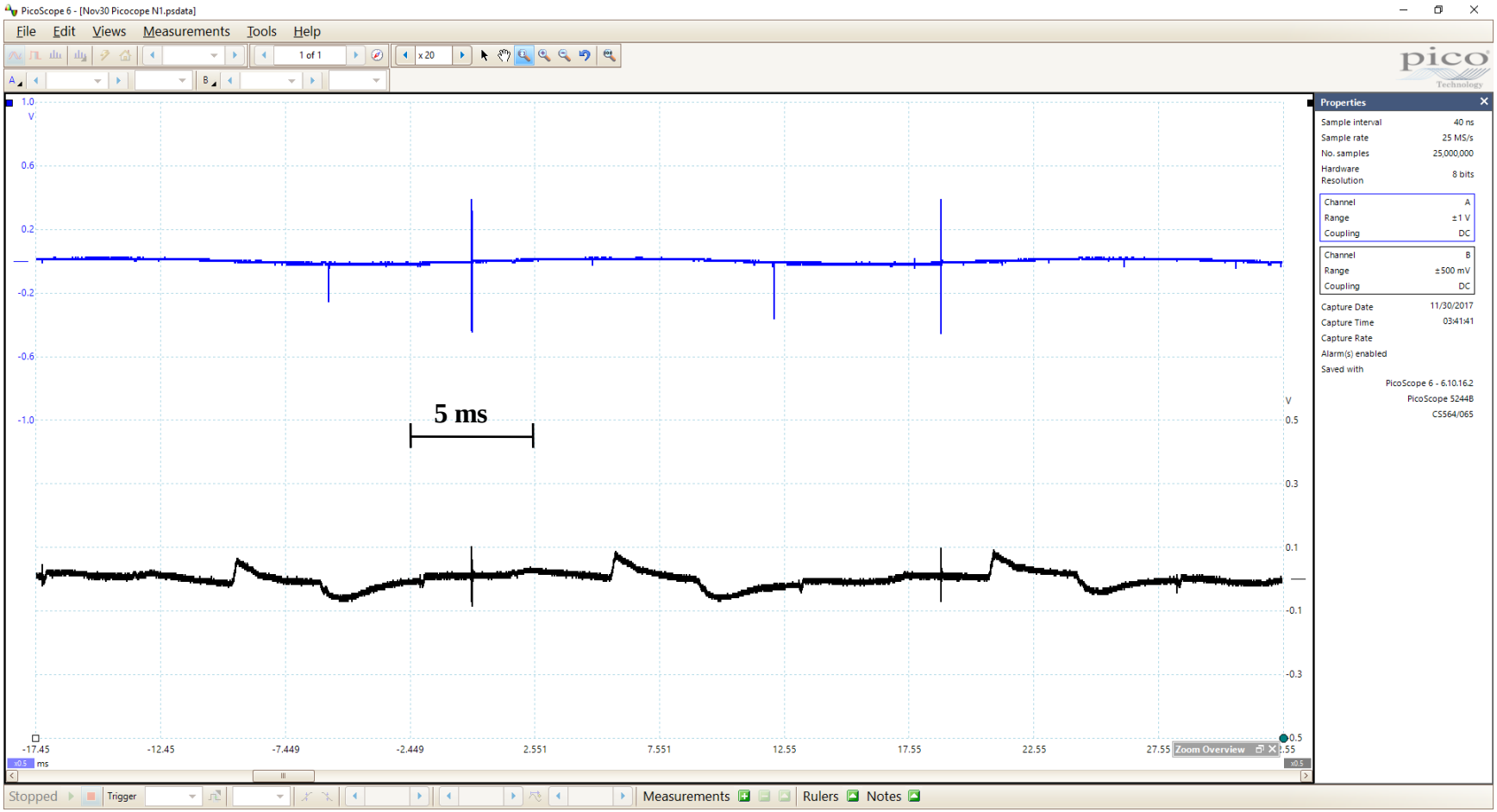
Upper STND1 GAMMA



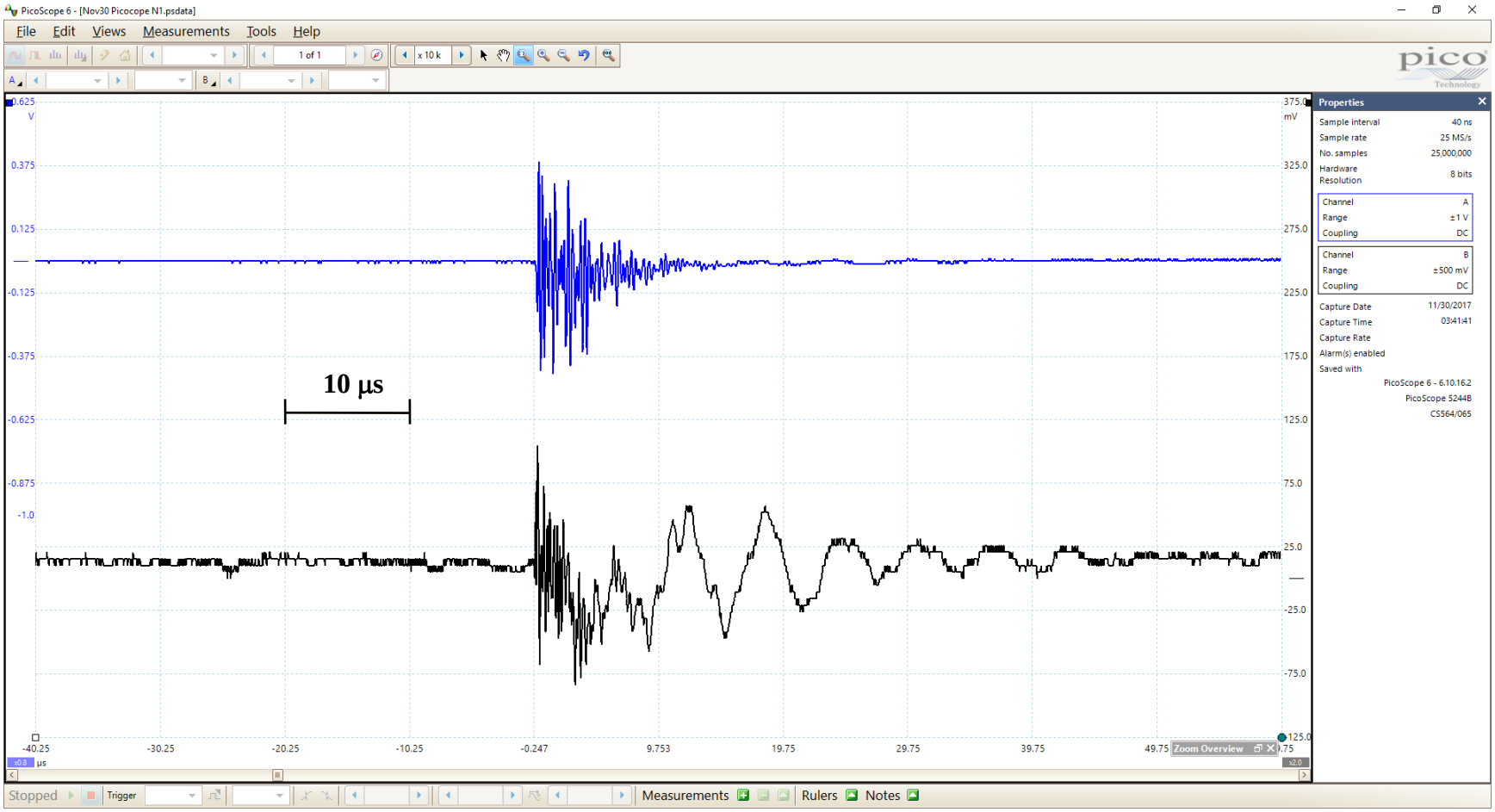
Picoscope N1 SKL
Fast electric field and NaI detector



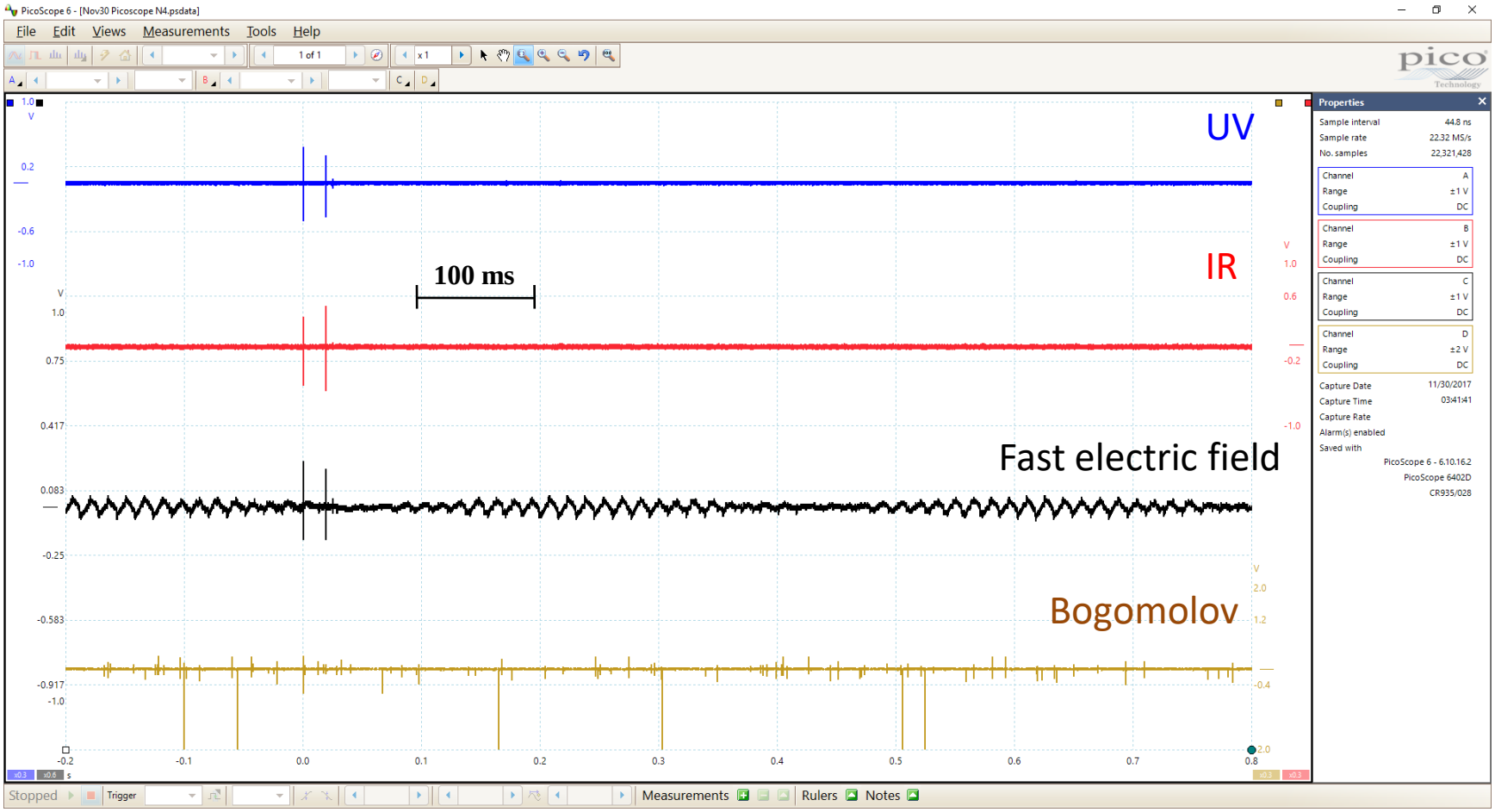
Picoscope N1 SKL
Fast electric field and NaI detector



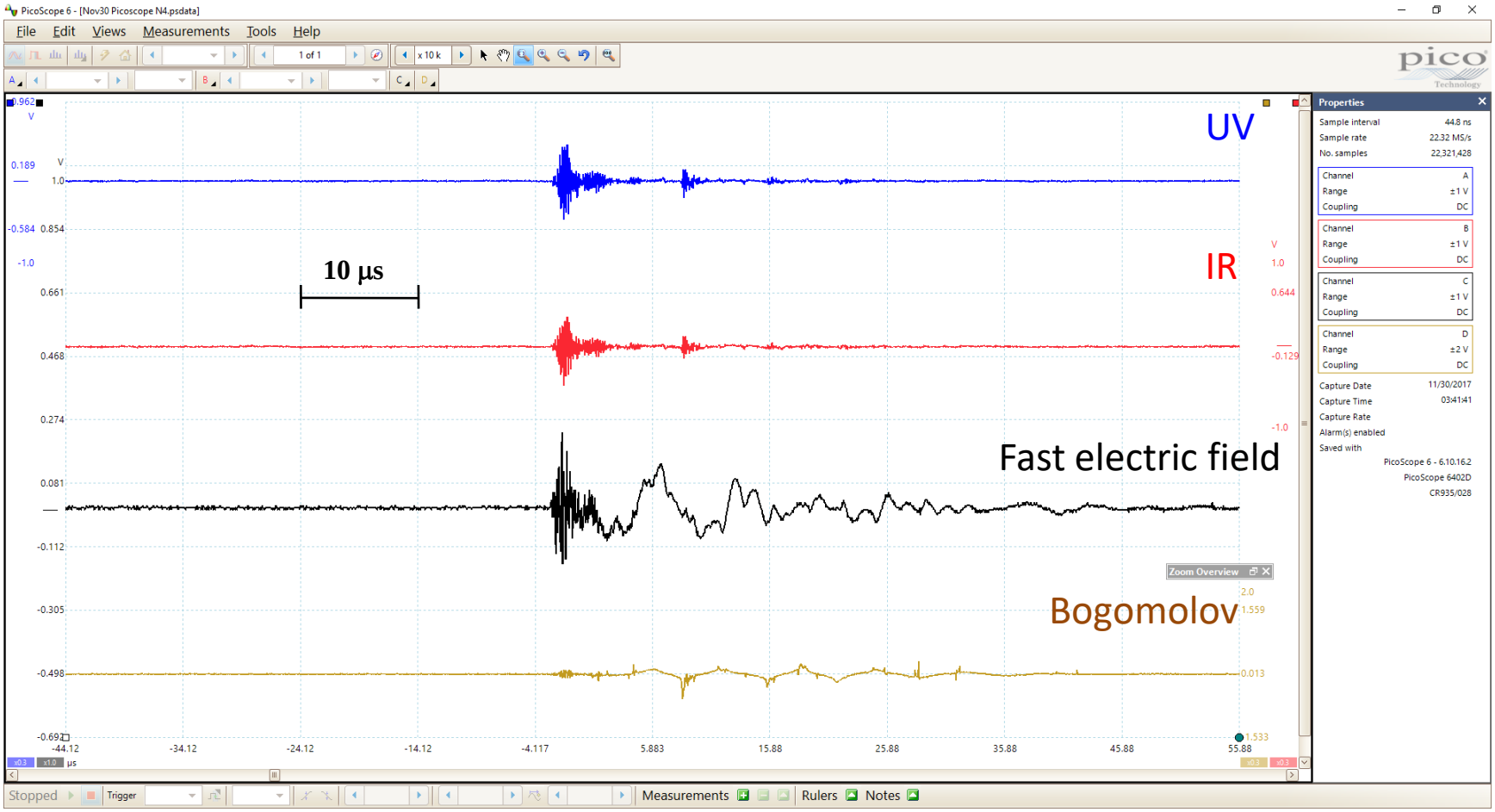
Picoscope N1 SKL
Fast electric field and NaI detector



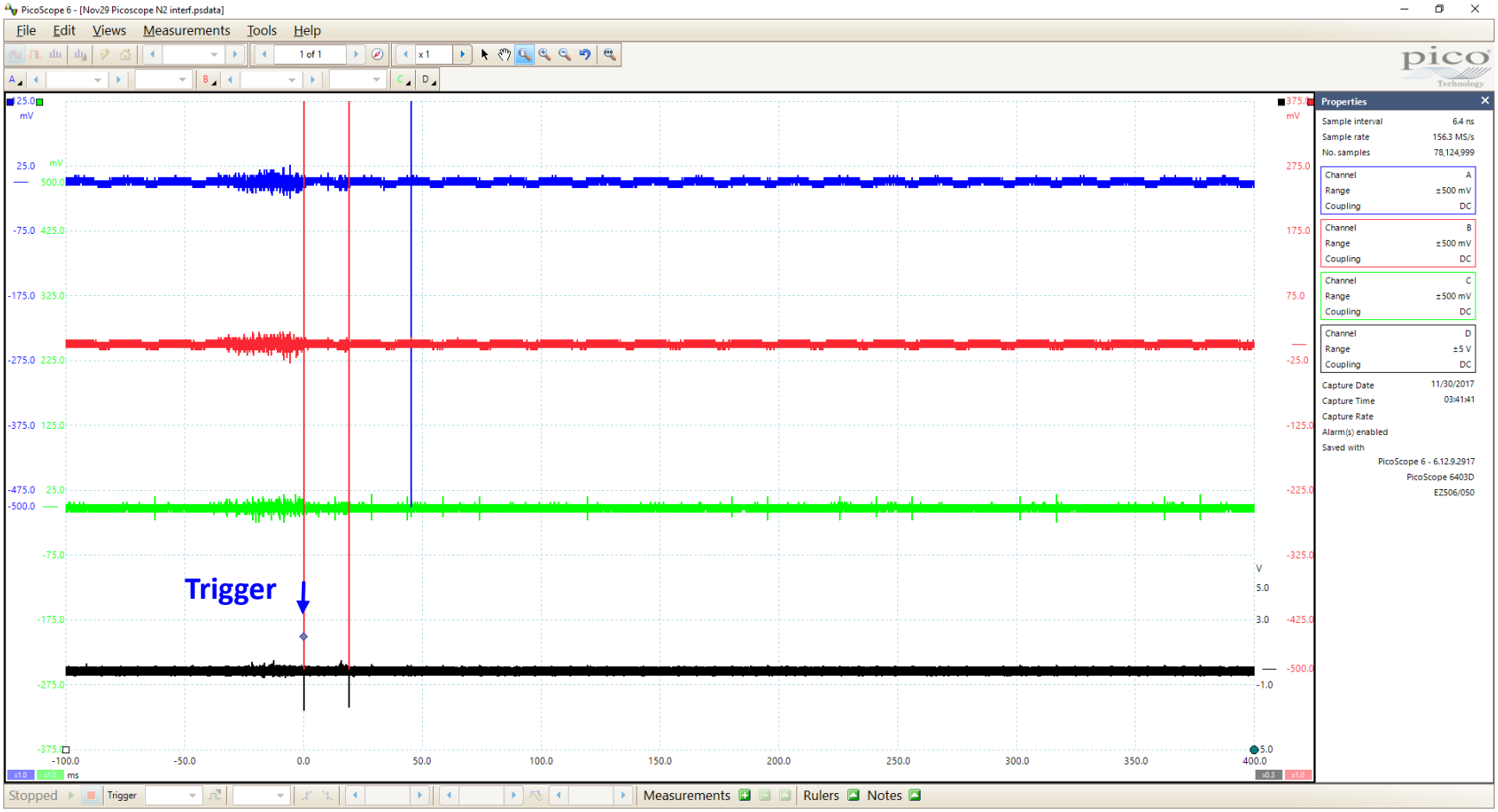
Picoscope N4 HOTEL



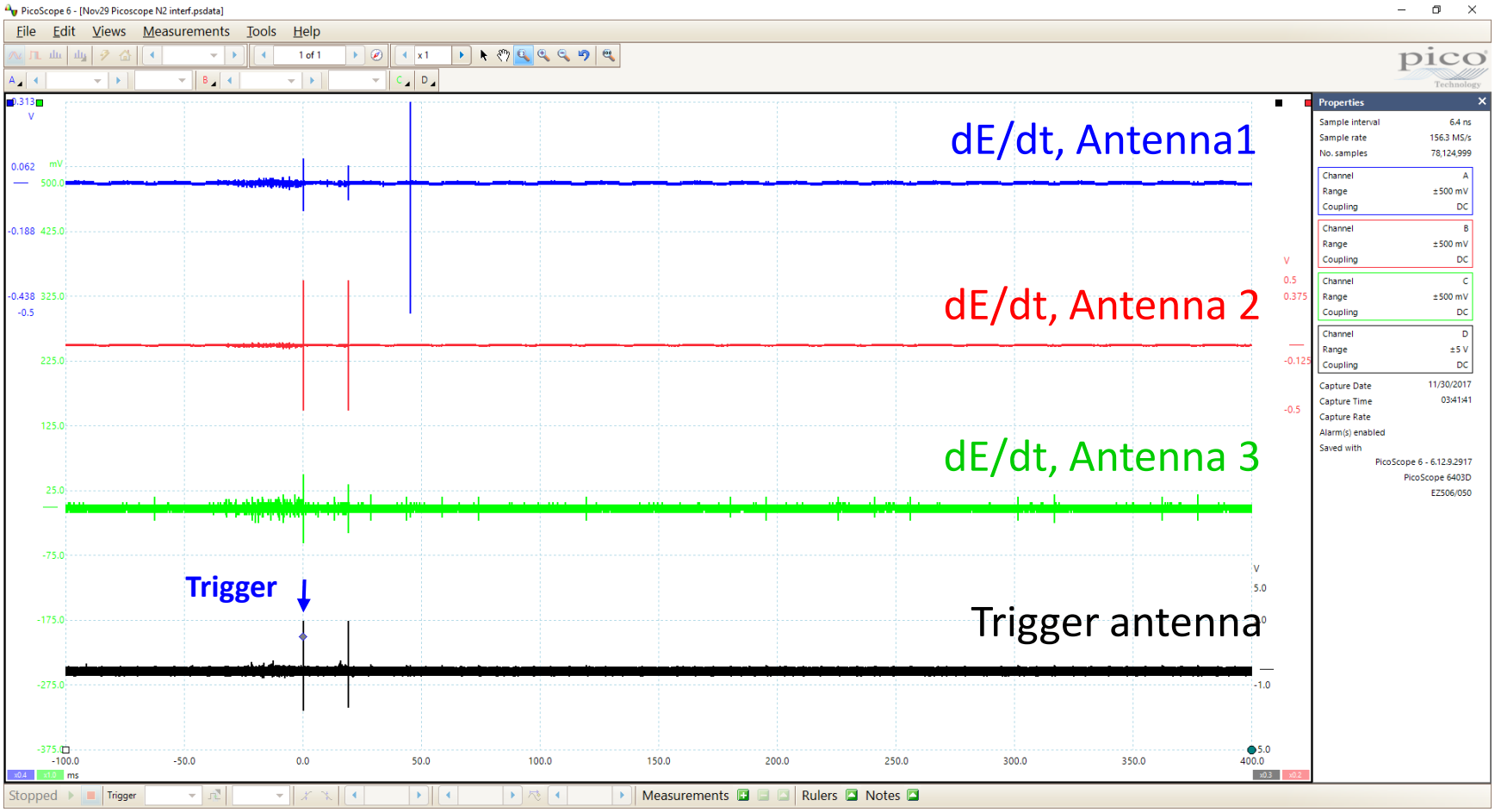
Picoscope N4 HOTEL



Lightning flash detected by interferometer
November 30,2017, 03:41:40.703
Record length 500 ms, sample interval 6.4 ns



Lightning flash detected by interferometer
November 30,2017, 03:41:40.703
(amplitude scales modified)



SEVAN site at Milesovka hill Czech republic (50° 33' 18'' N, 13° 55' 53'' E, 837m asl). Alexander von Humboldt claimed the view to be the third nicest view in the world.