OBSERVATION OF LIGHTNING EMISSION IN DIFFERENT WAVE RANGES OF ELECTROMAGNETIC SPECTRUM

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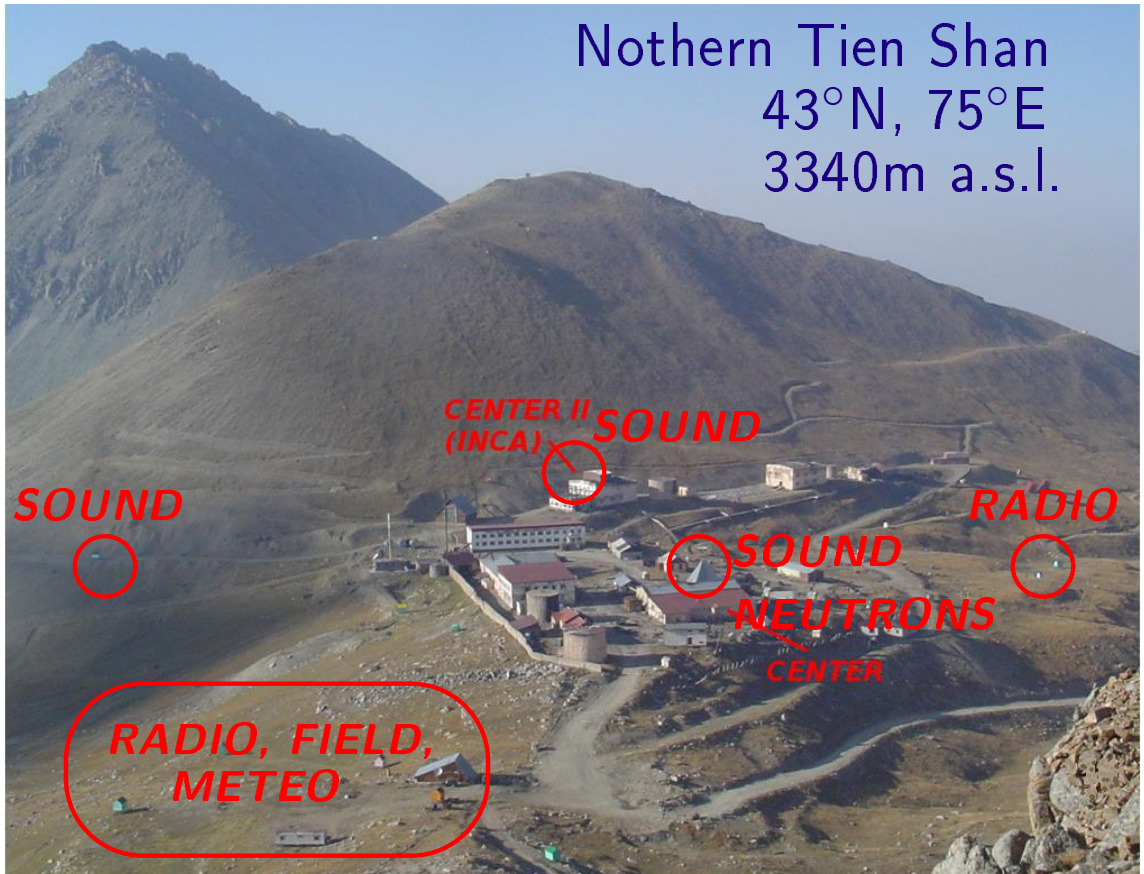
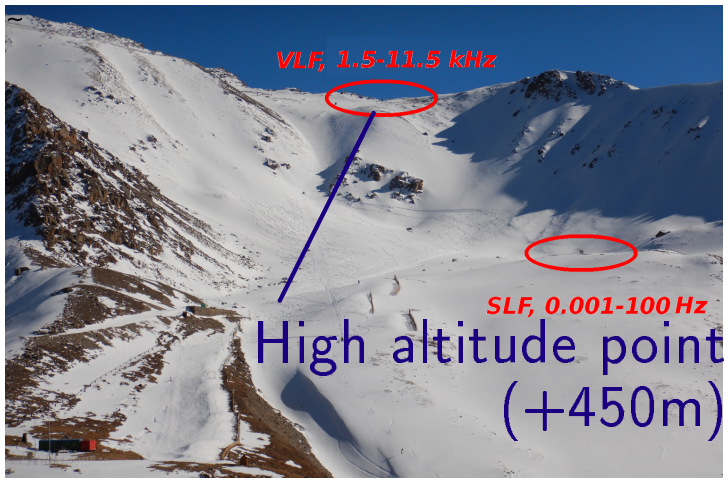
2019

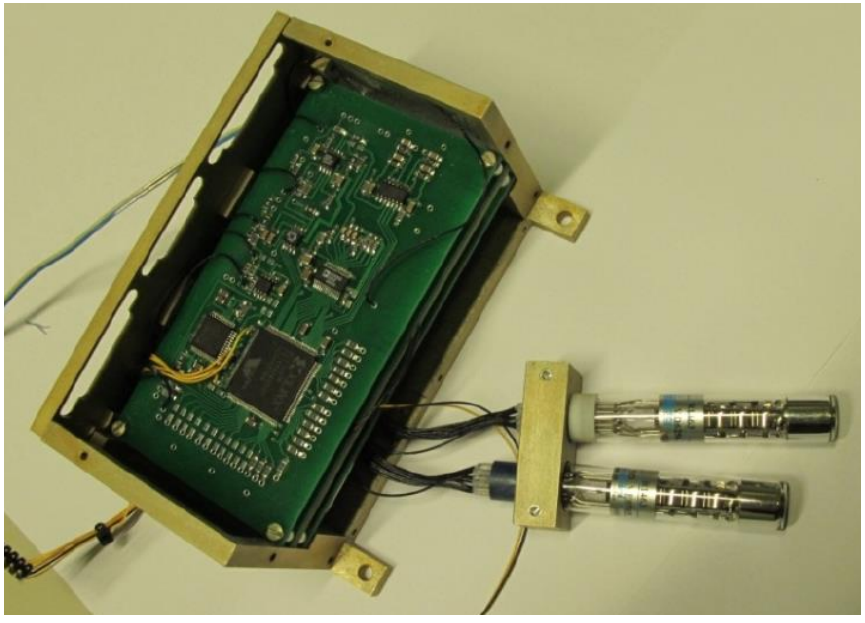
Tien Shan *'THUNDESTORM'* experiment

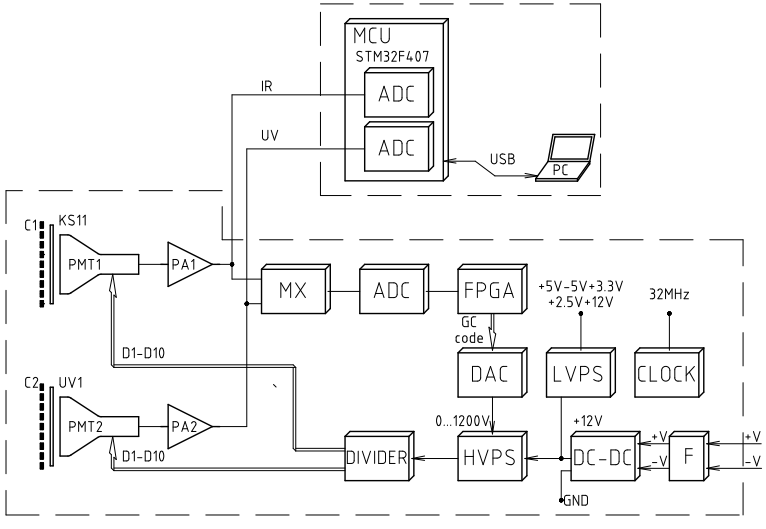
- main goal: to elucidate the mechanism of lightning initiation
- method: precise investigation of the temporal development history of atmospheric electric discharge
- experimental technique: simultaneous detection of different kinds of lightning emission
- location: Tien Shan Mountain Cosmic Ray Station of LPI





Apparatus: the *'optic'* (IR and UV) radiation detector

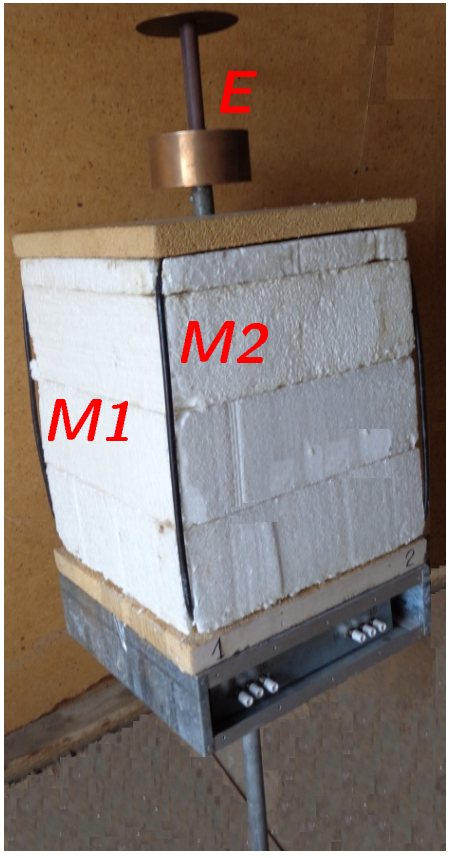




- the development of SINP MSU for using by small satellite missions *'Tatiana'*, *'Chibis'*, *'Lomonosov'* (2008–2017);
- Hamamatsu R1463 type PMT with multialkali cathode;
- UV channel: *'UVS2'* filter ($\lambda = 240 - 380$ nm) passband, quantum efficiency ∼20%;
- IR channel: *'KS11'* filter ($\lambda = 610 - 800$ nm), q. e. ∼6% at 600 nm, and ∼1% at 800 nm;
- automatic PMT regime control.

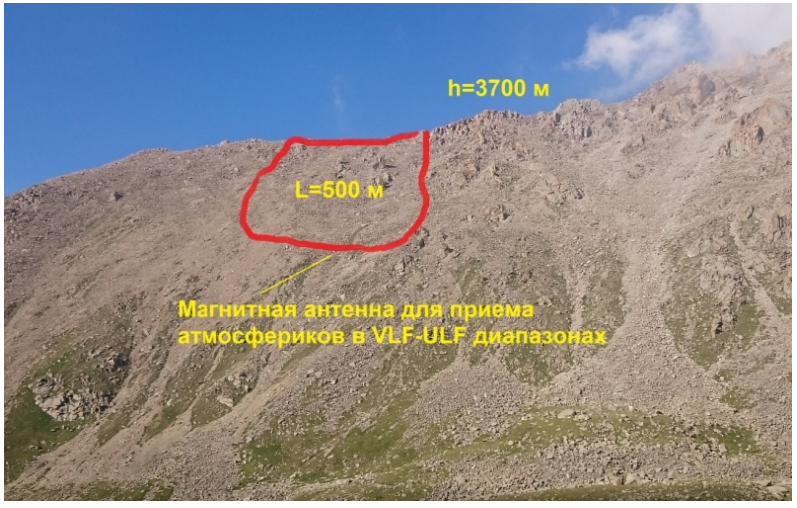
Apparatus: the radio-detection technique

- 0.1 . . . 30 MHz radio emission



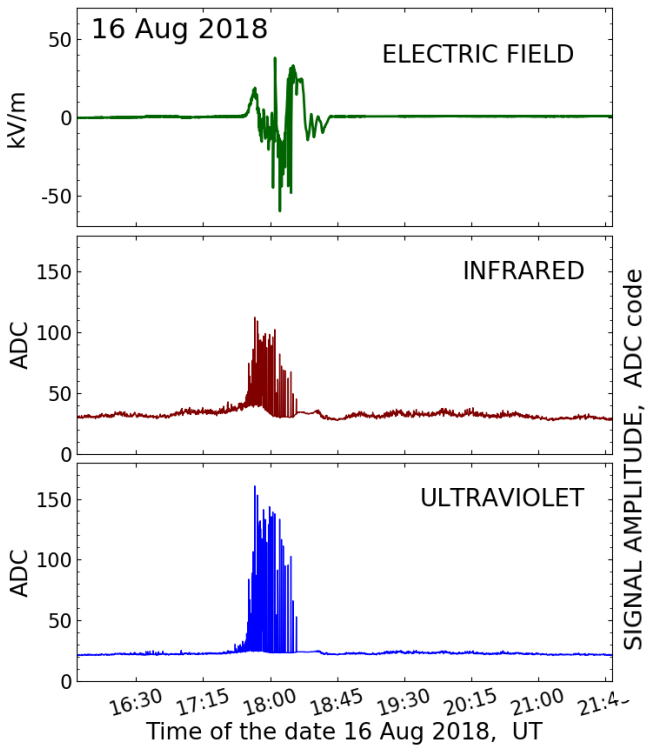
- development of the Radiophysical Research Institute and the Institute of Applied Physics of RAS, Nizhny Novgorod ;
- three channels in a single group: two mutually perpendicular loop type antennas *(M1-M2)*, and a single flagpole one *(E)*;
- one channel is used for elaboration of the lightning trigger pulse.

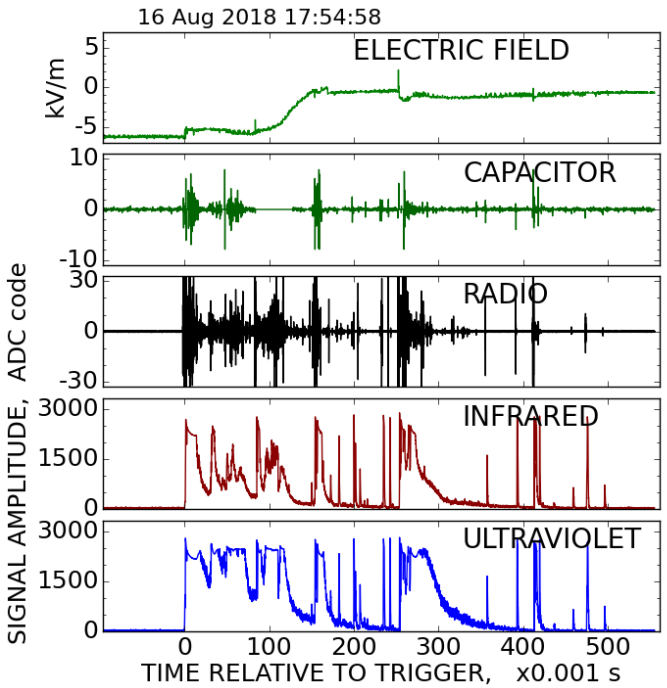
- 1.5 . . . 11.5 kHz VLF antenna

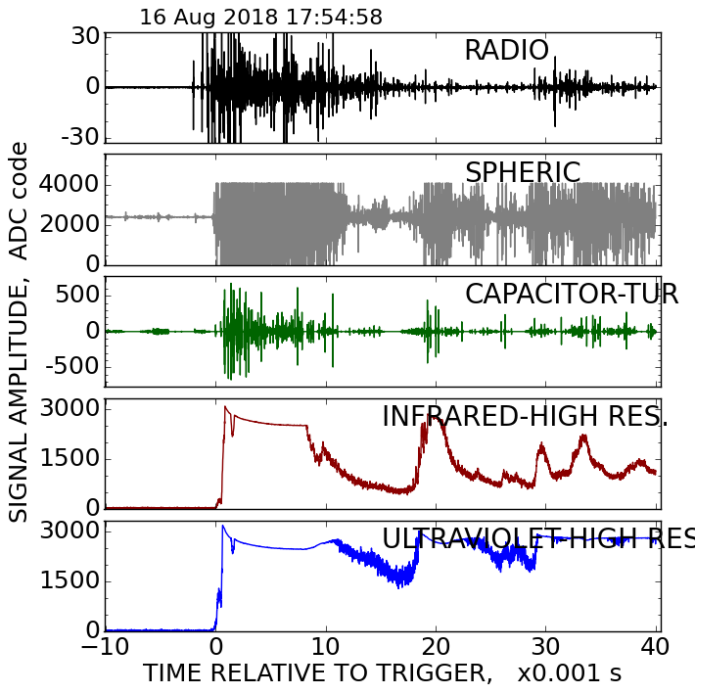


Typical sample of a night time storm event — time series of radiation intensity

- 1s resolution
- 160μs resolution
- 20μs resolution





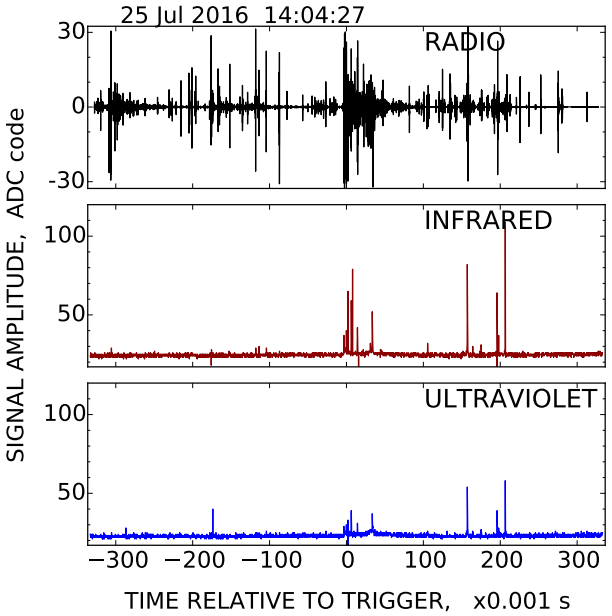


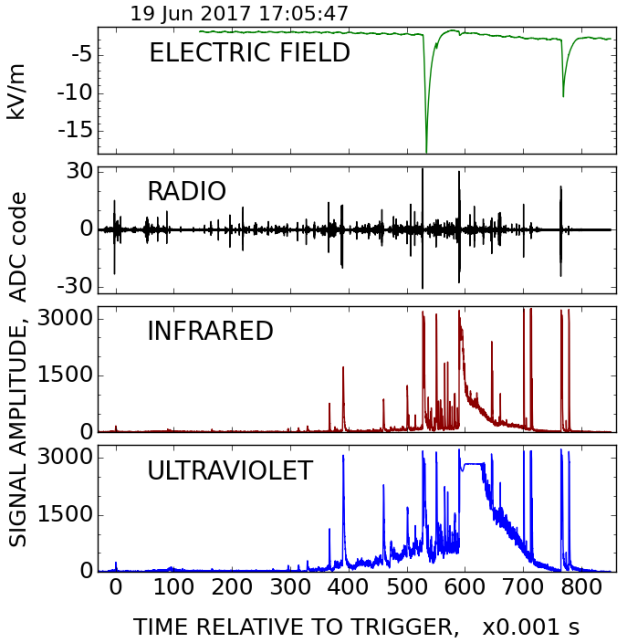
- *Legend:*

ELECTRIC FIELD—*'field mill'* type absolute sensor;
CAPACITOR—field jump detector;
RADIO—the 1 . . . 30 MHz frequency range antenna;
SPHERIC—the 1.5 . . . 11.5 kHz *VLF* signal;
TRIGGER—beginning of a lightning discharge.

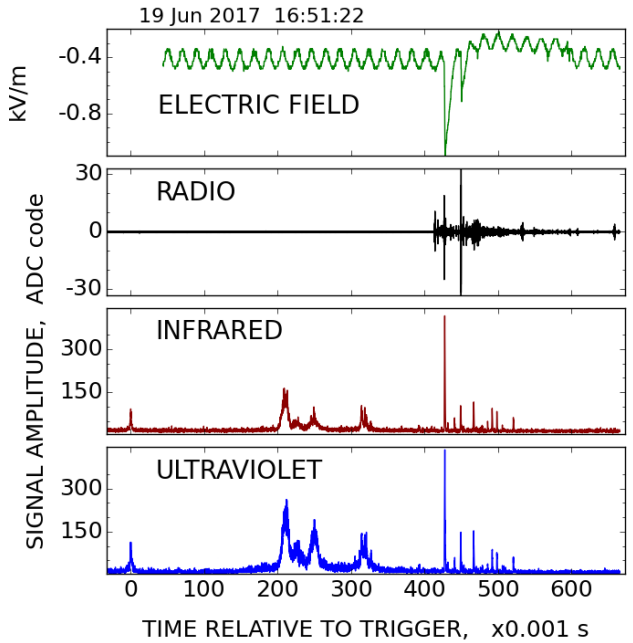
Peculiarities of the atmospheric electric discharge *(I)*

- *'dark'* stage of discharge

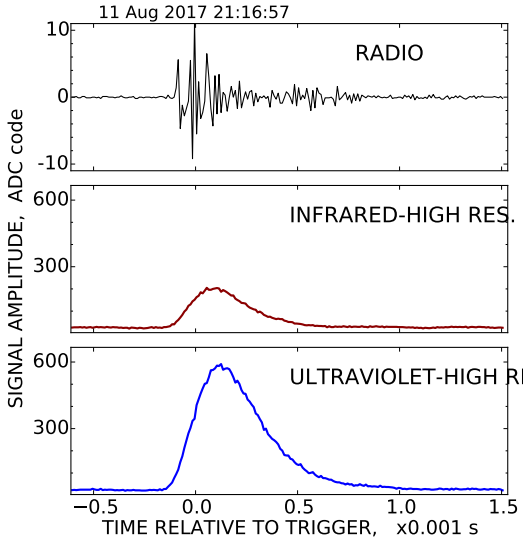


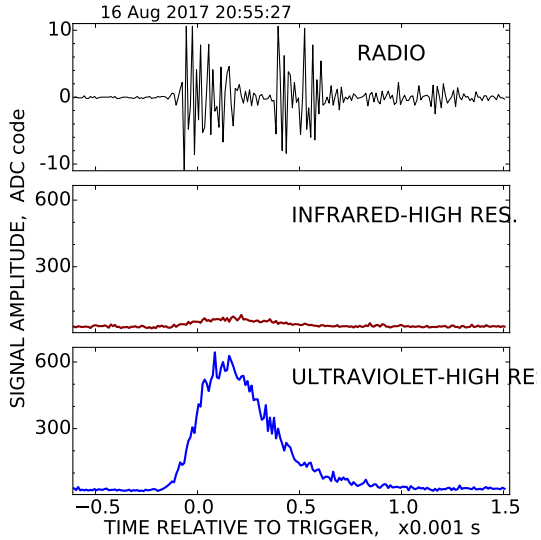


- the leading optic flash



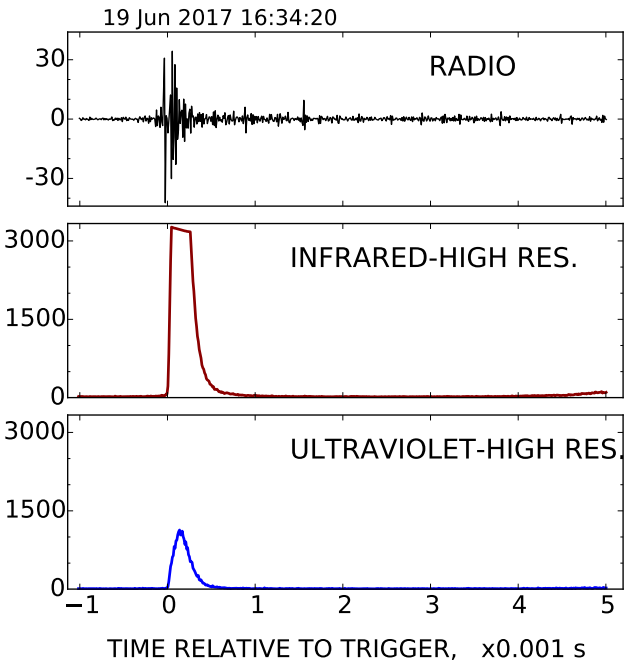
- extremely short discharge events

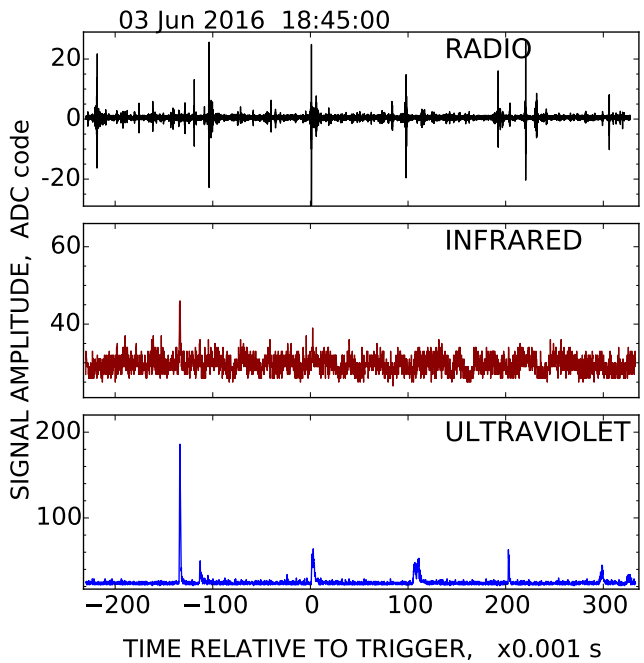


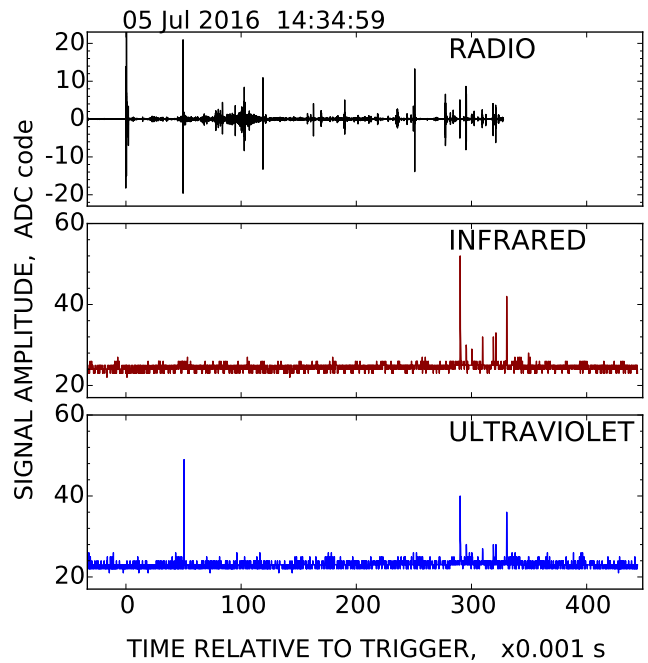


Peculiarities of the atmospheric electric discharge *(II)*

- *'red'* burst
- *'blue'* series
- *'blue'* leader

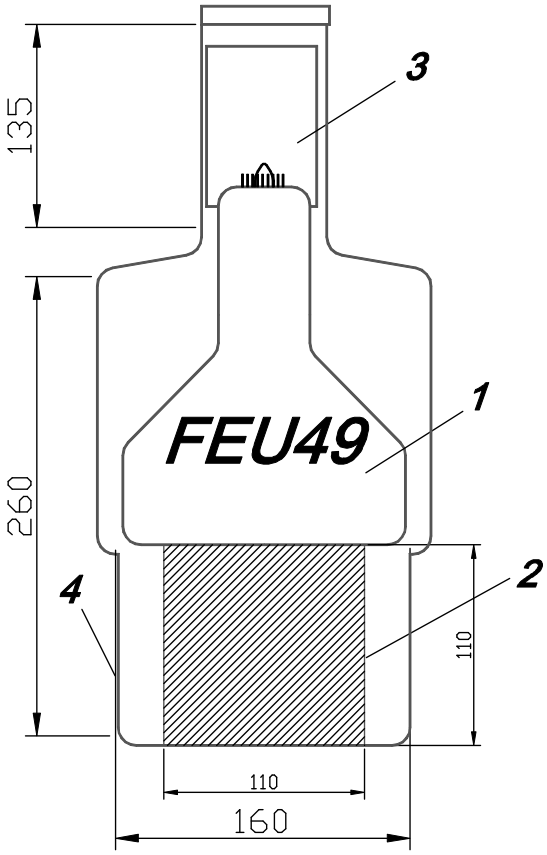






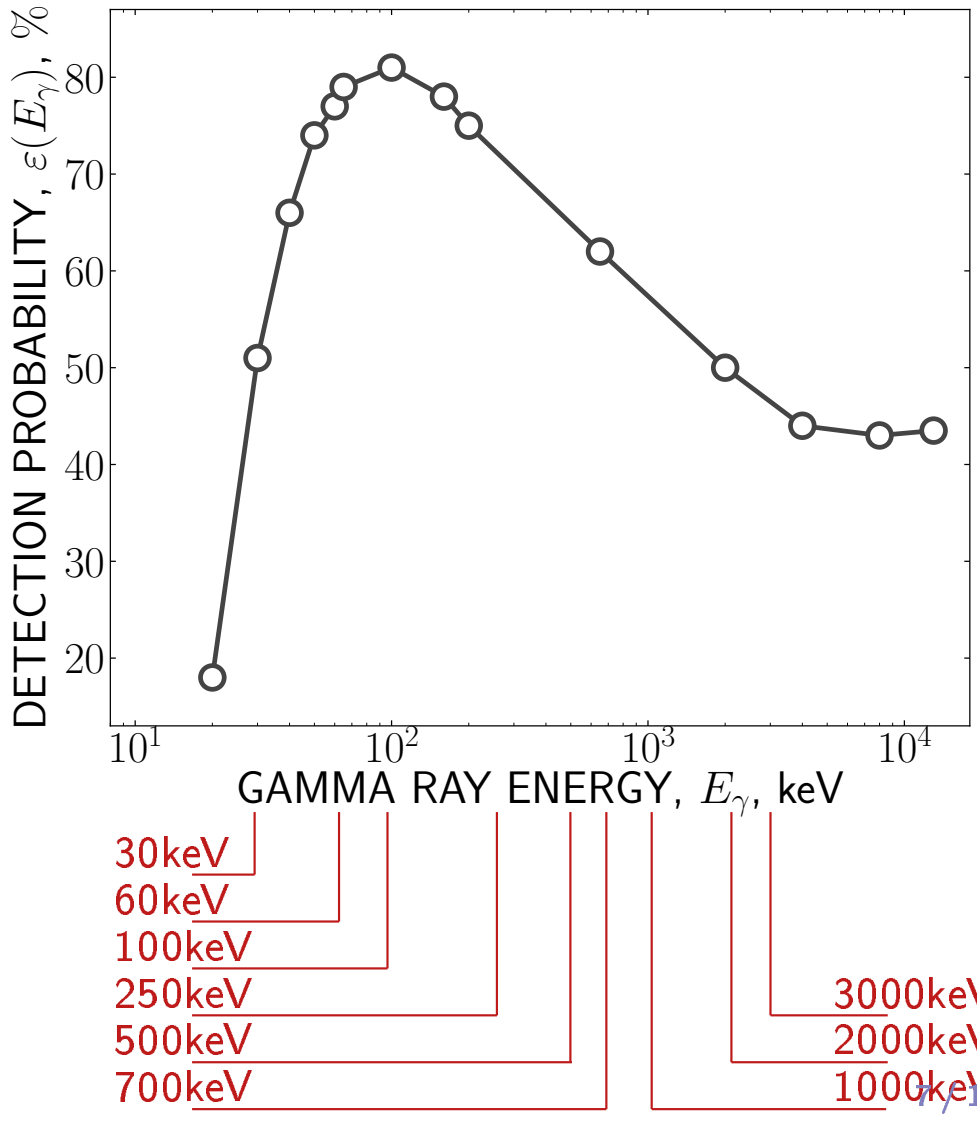
Apparatus: low energy gamma ray detector

- Internal set-up

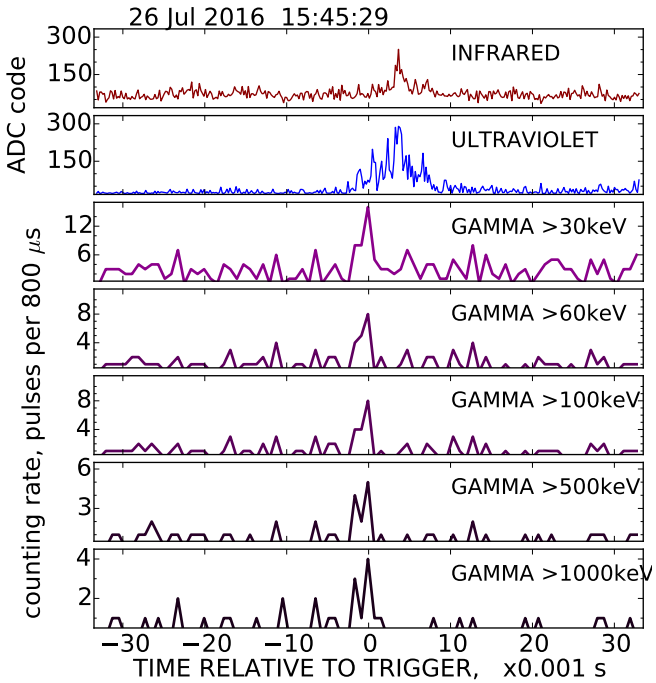


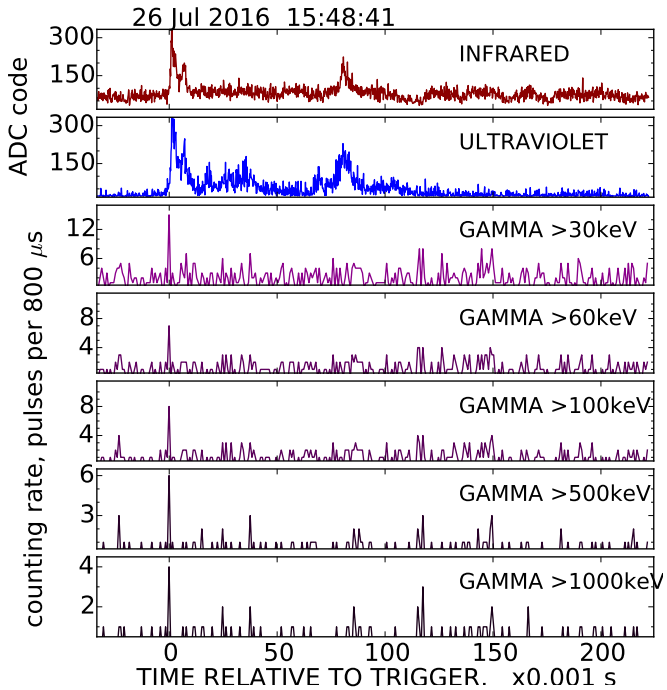
(1) – PMT, (2) – NaI crystal,
(3) – electronics board,
(4) – 1mm thick outer aluminum housing.

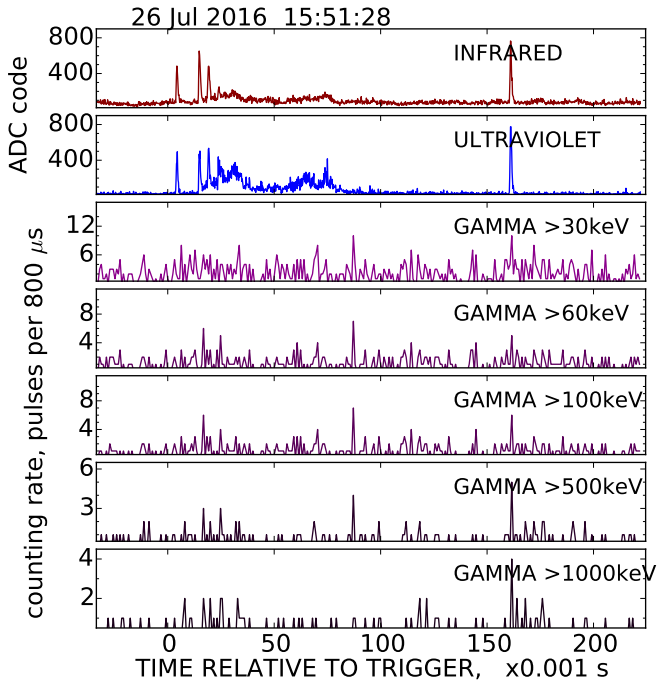
- Efficiency of gamma ray detection (*Geant4* simul.)

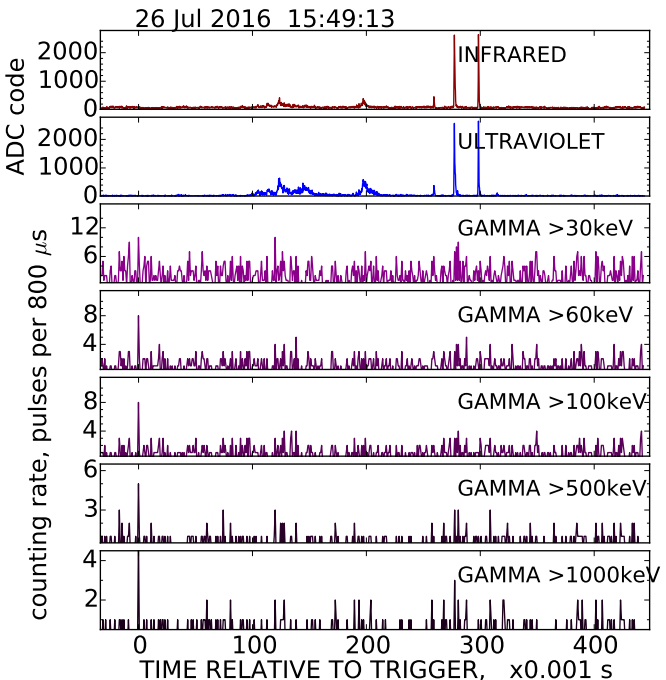


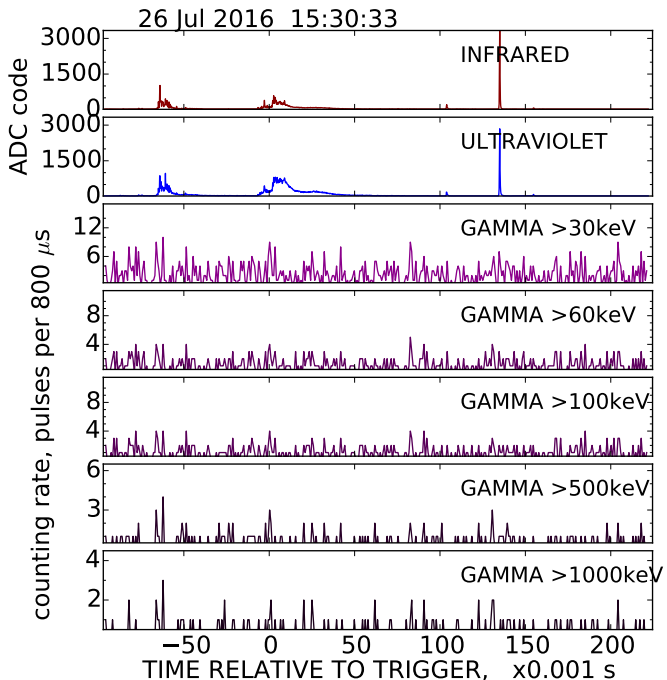
Optics & gamma



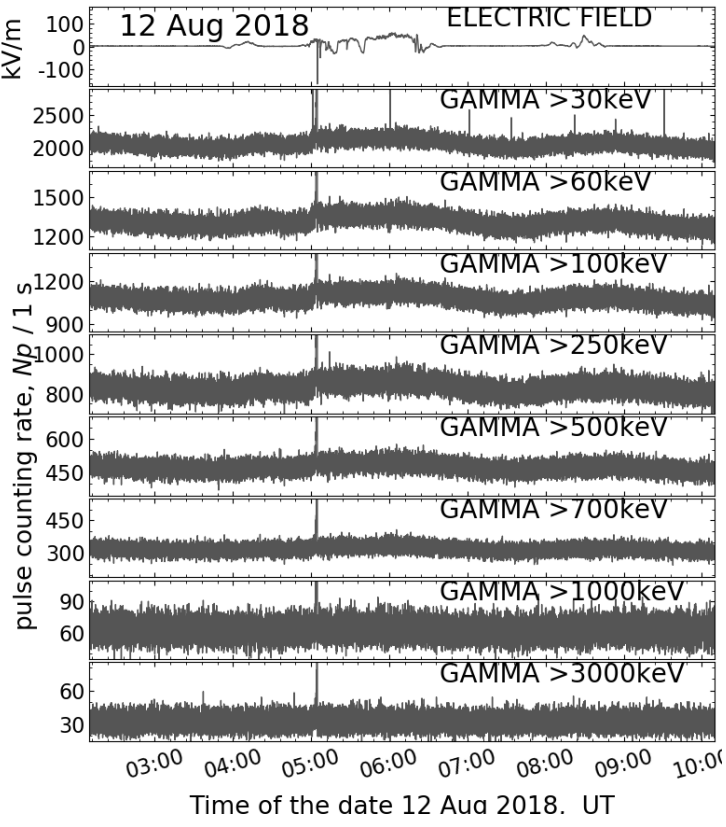




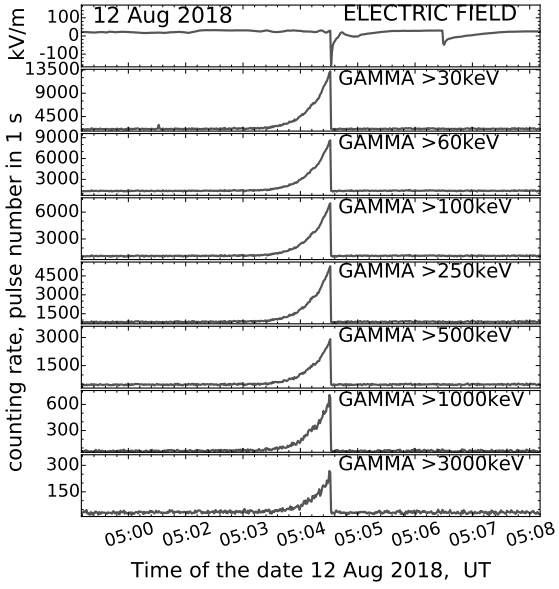


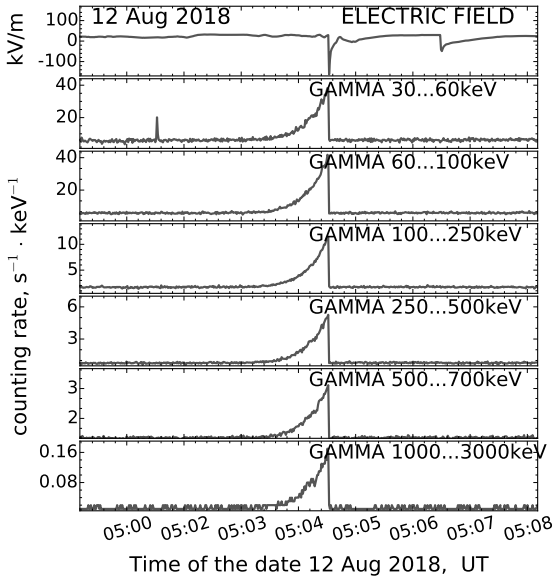


TGE event of 12 Aug 2018

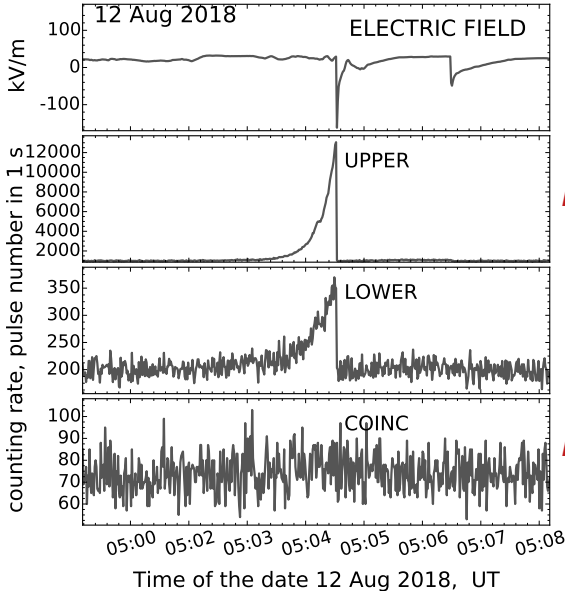


- gamma ray intensity





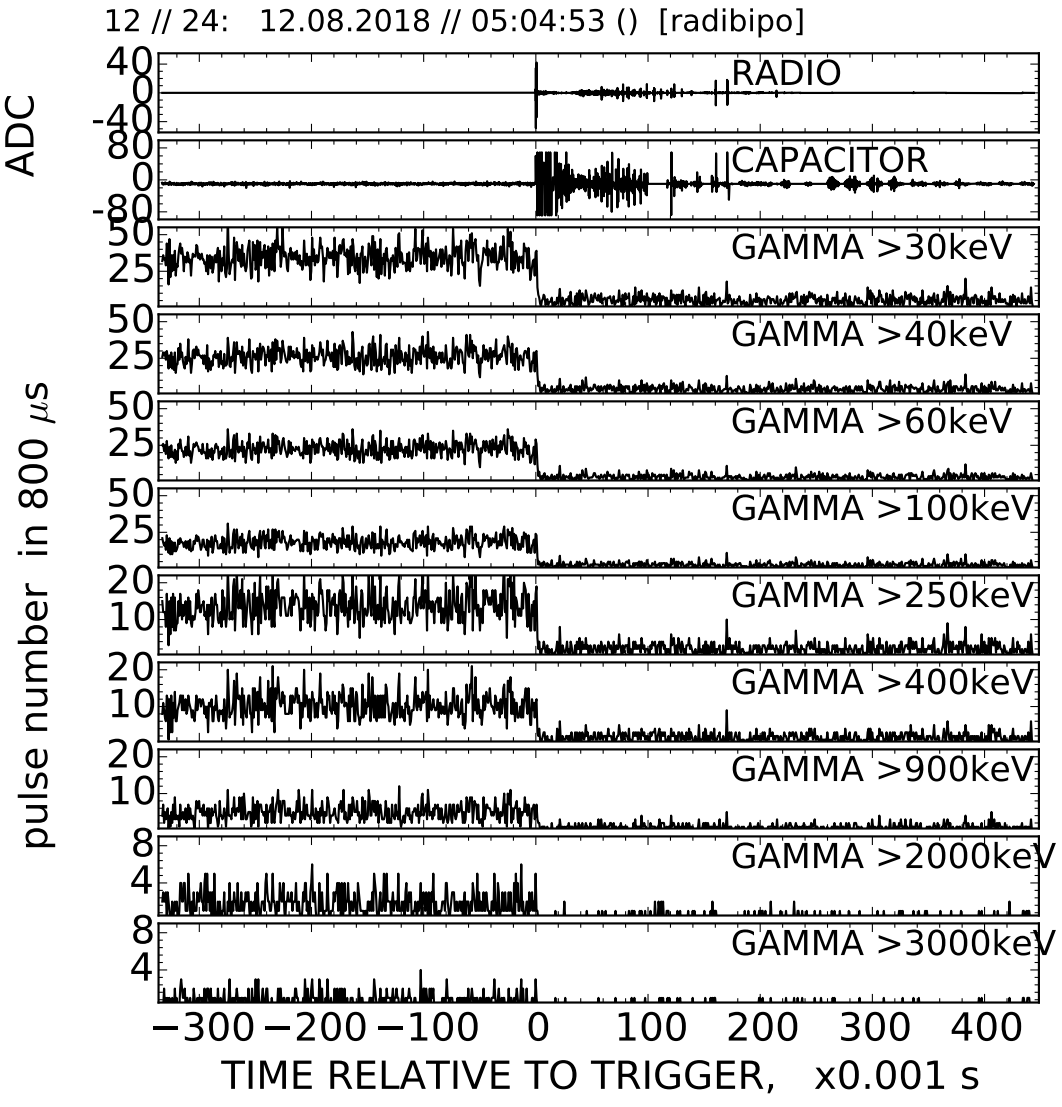
- electron detector (with a 40g/cm^2 thick internal absorber)

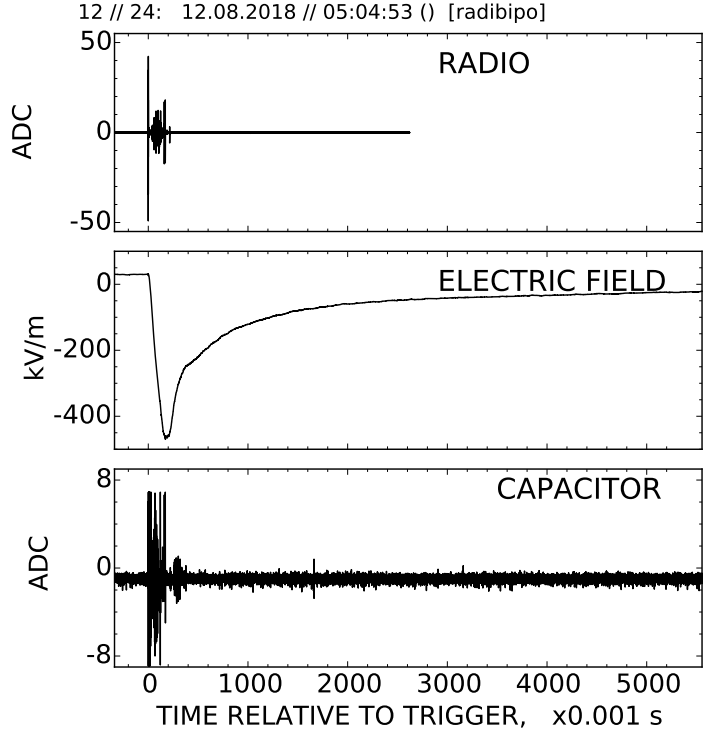


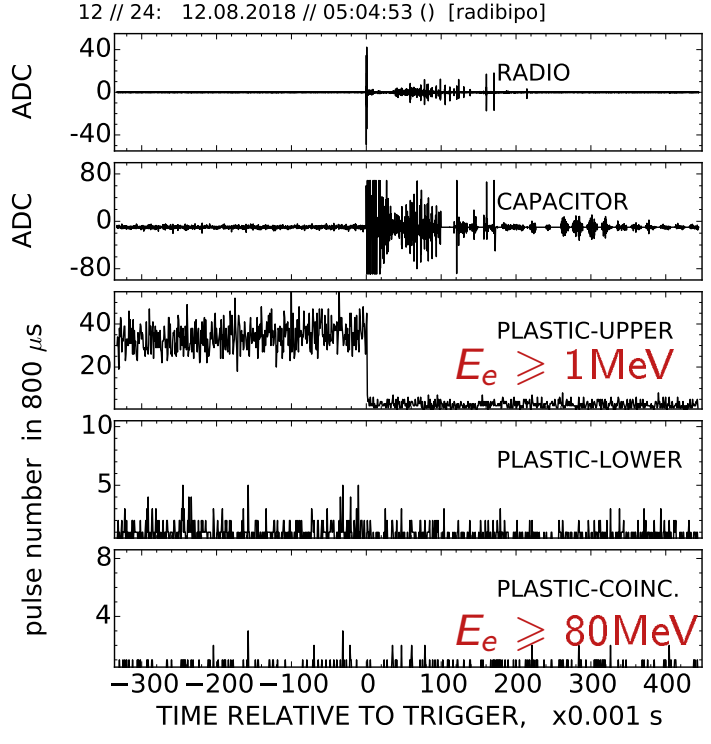
$E_e \geqslant 1$MeV

$E_e \geqslant 80$MeV

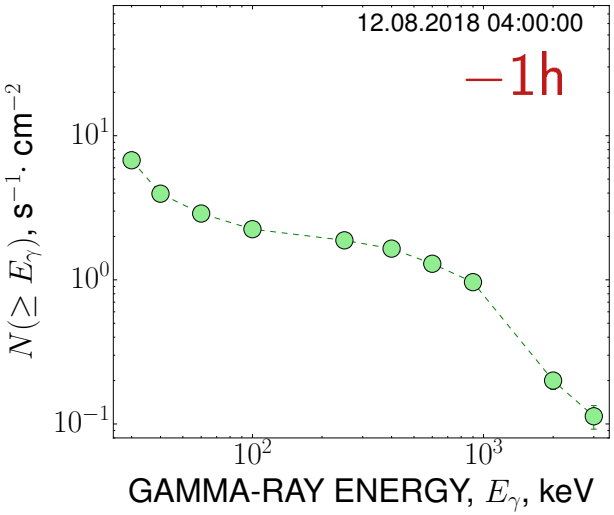
TGE event of 12 Aug 2018: high resolution time series

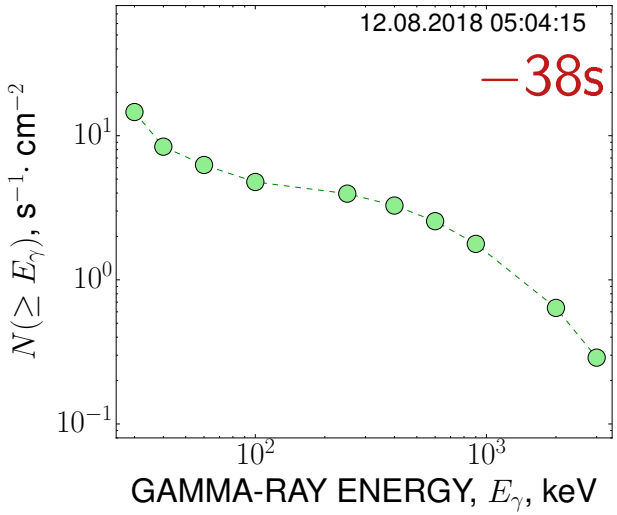


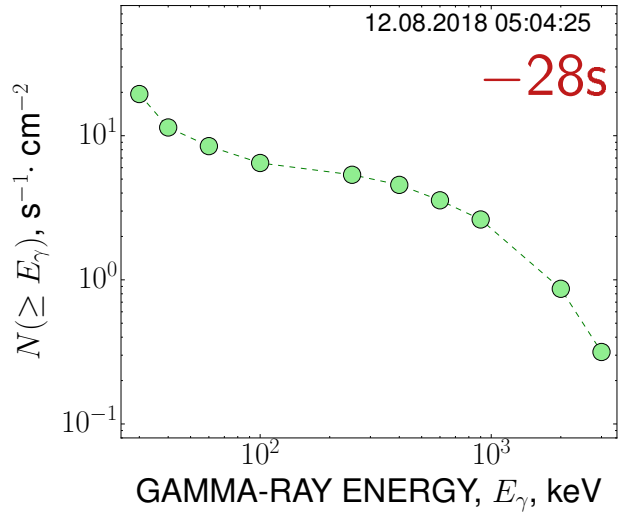


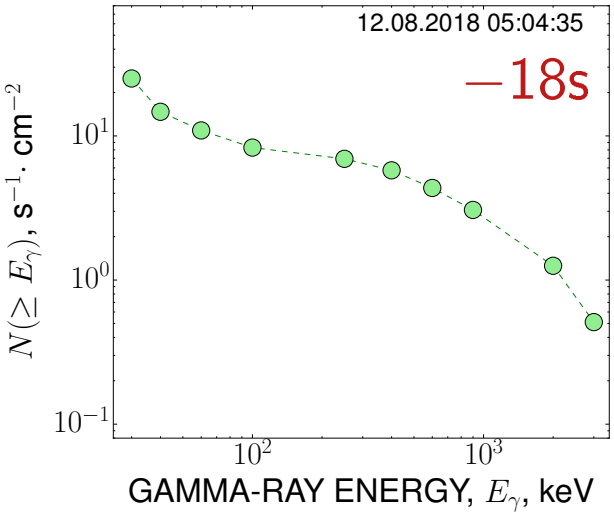


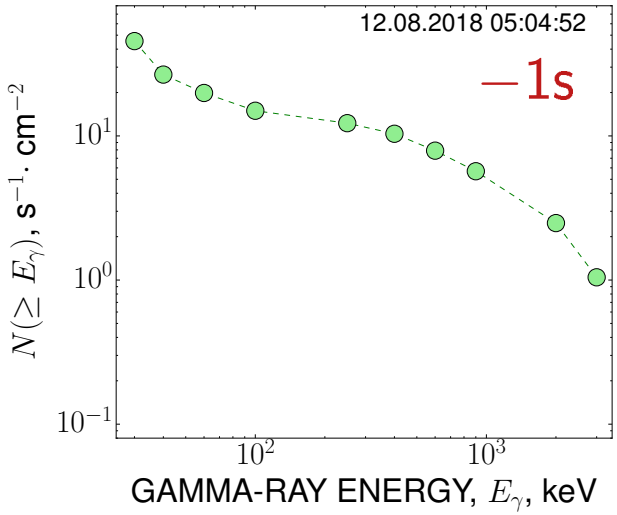
TGE event of 12 Aug 2018:
integral energy spectra of the gamma-radiation

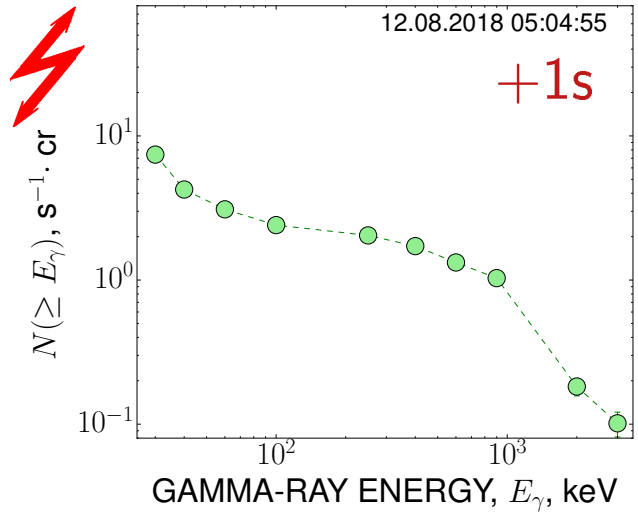












Conclusion

- the multispectral detection approach permitted to reveal a number of peculiar types of atmospheric electric discharge:
  - *'dark'* discharges without any significant optic radiation;
  - prolonged continuous optic flashes of about some milliseconds which 'fill' the gaps between succeeding discharges;
  - short-time intensive optic flashes with sub-millisecond duration;
  - transient flashes with decisive predominance of UV radiation in their optic spectrum;
  - inversely, the *'red'* flashes with intensive IR signal and with the absence of any noticeable ultraviolet emission.
- sometimes a transient gamma radiation burst signal was seen from a thundery front in correlation with optic and radio ones; the duration of these bursts is about a few milliseconds or shorter, which complies well with typical *TGF* duration but is much shorter than the *TGE*.