Study of TGEs and Gamma-Flashes from Thunderstorms in 20-3000 keV Energy Range with SINP MSU Gamma-Ray Spectrometers

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A number of experiments with scintillator gamma-spectrometers were provided by SINP MSU for study of spectral, temporal and spatial characteristics of TGEs as well as for search of fast hard x-ray and gamma-ray flashes probably appearing at the moment of lightning. The measurements were done in Moscow region and in Armenia at Aragatz mountain.

TEPA-2015, 07.10.2015

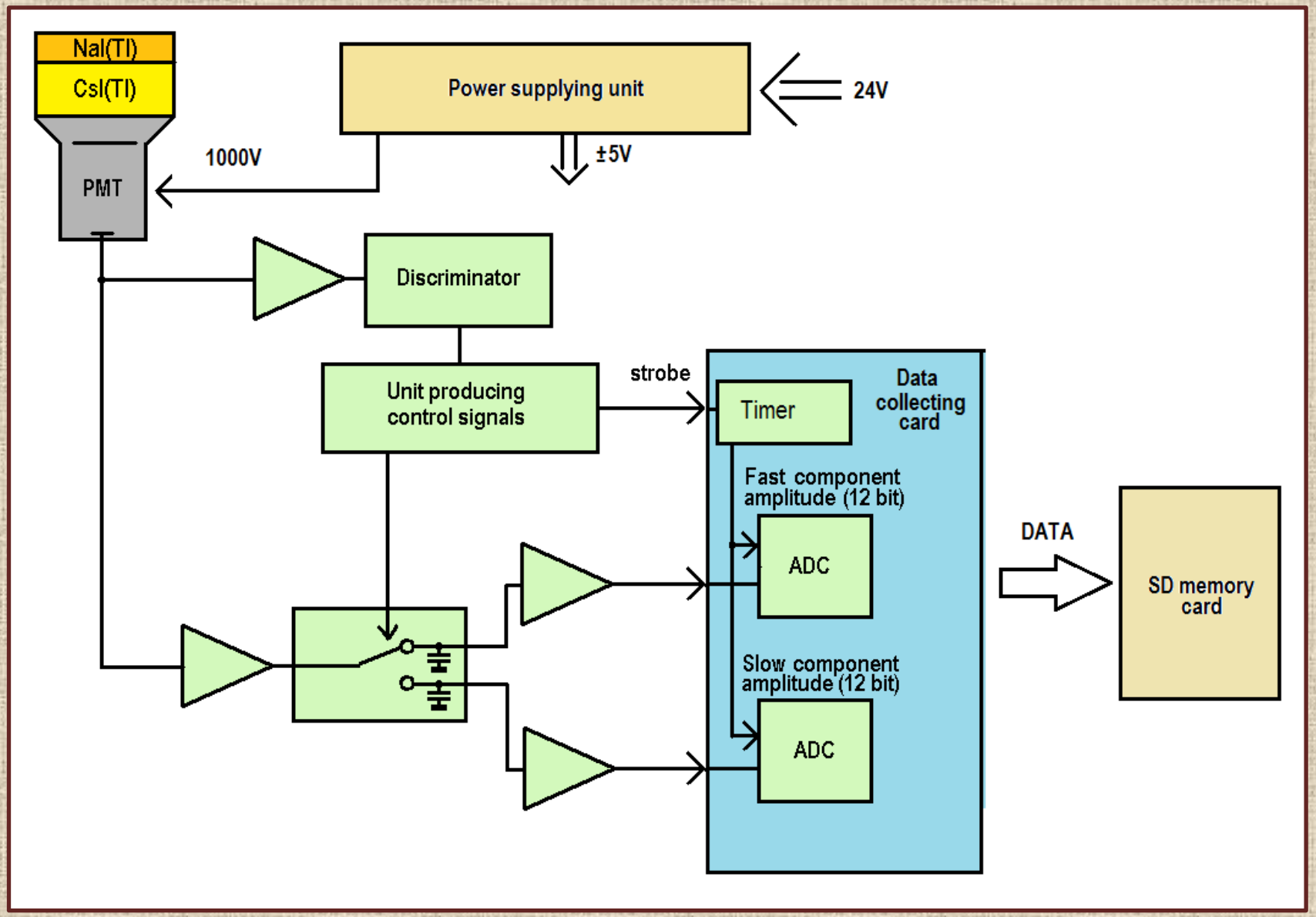
Scientific goal:

- Study of spectral characteristics of TGEs in 20-3000 keV range
- Measure of the direction of TGE gamma-radiation
- Search for fast gamma-ray flashes from lightnings

Principles of instrument design:

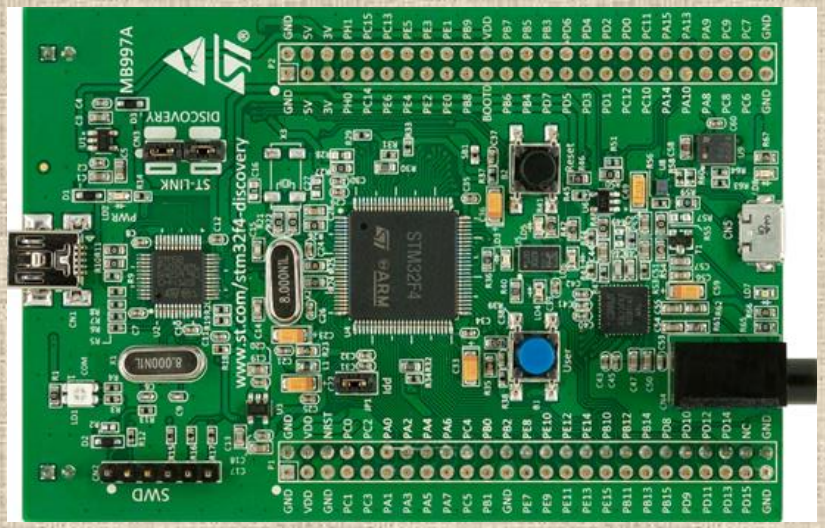
- Detectors are scintillator spectrometers with NaI(Tl) or CsI(Tl)
- Electronics allows to analyze pulse shape in order to use phosvich detectors and to remove imitations of gamma-events by thunderstorm electric discharges
- Recording all data in “event” mode with fine time resolution
- All data are recorded to SD card for further analysis
- Measurements with collimated detector placed on rotating platform are provided

Design of instrument electronics



Digital electronics and data format

- **Producing time data with accuracy 1s. Stability of internal timer is ~1s/day**
- **Forming data frames each second.**
- **Producing ~15mcs timer data starting at the beginning of the frame**
- **Interrupt on the request from analog card and digitize pulses of fast and slow components**
- **At the beginning of a frame digitize signal on the analog input**



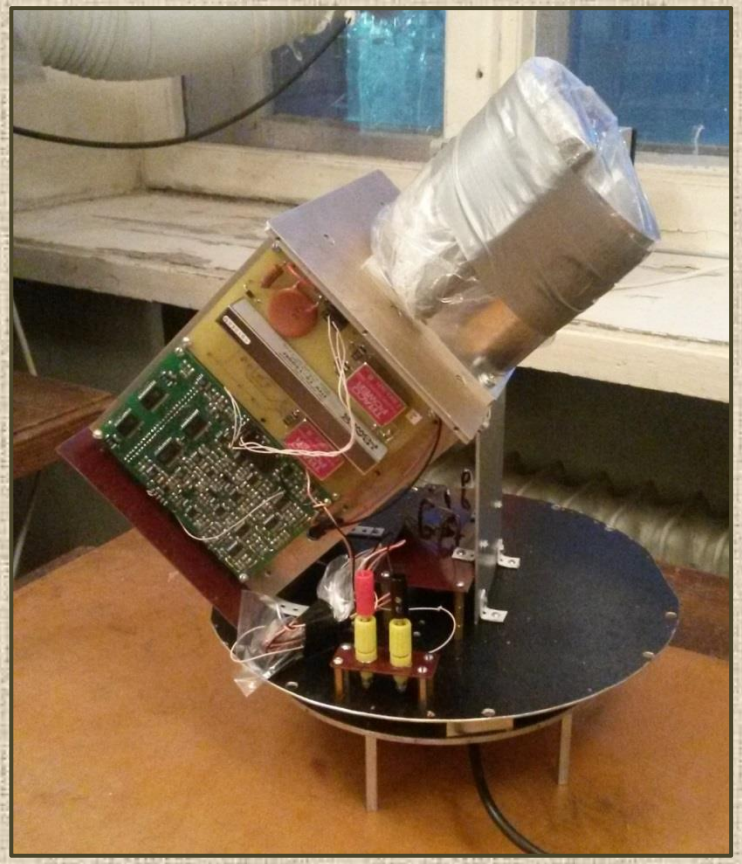
Board STM32F4 DISCOVERY with Cortex M4 microcontroller

7b - Frame start marker - E4 57 B4 C0 3F 66 99
4b – Frame number
6b - Time – YY MM DD hh mm ss
2b – Number of events in the frame
4b – Number of counts of 15mcs timer during the frame
2b – ADC data for external analog input
N*(3b+3b) – Data records: ADC data + timer value
4b – Frame end marker – CC 11 00 00

Two gamma-ray spectrometers used in this work:

Detector: NaI(Tl) 40x40 mm
PMT: ФЭУ-176
Range: 20 кэВ-1 МэВ
Resolution 12% at 662 keV

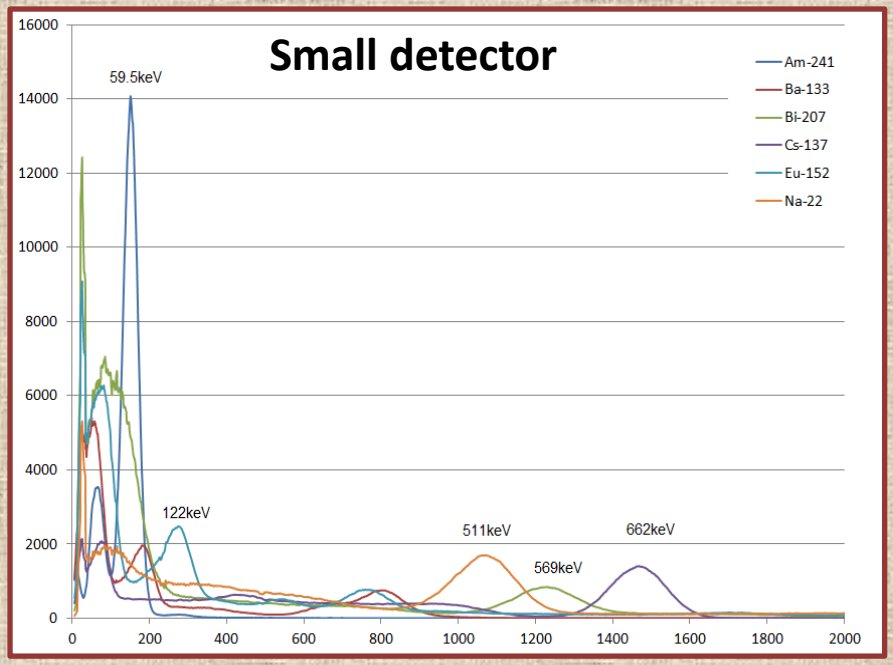
Detector: CsI(Tl) 80x80 mm
PMT: Hammamatsu R1307
Range: 20 кэВ-3 МэВ
Resolution 7.5% at 662 keV
Placed on rotating platform

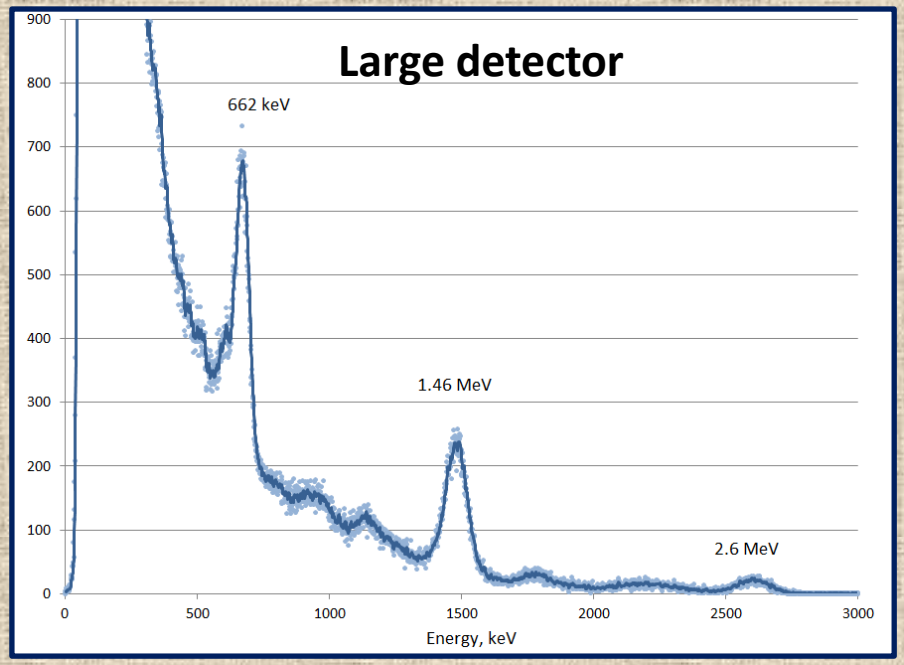


Calibration and data processing

Gamma to gamma data were processed and three kinds of secondary files were produced:

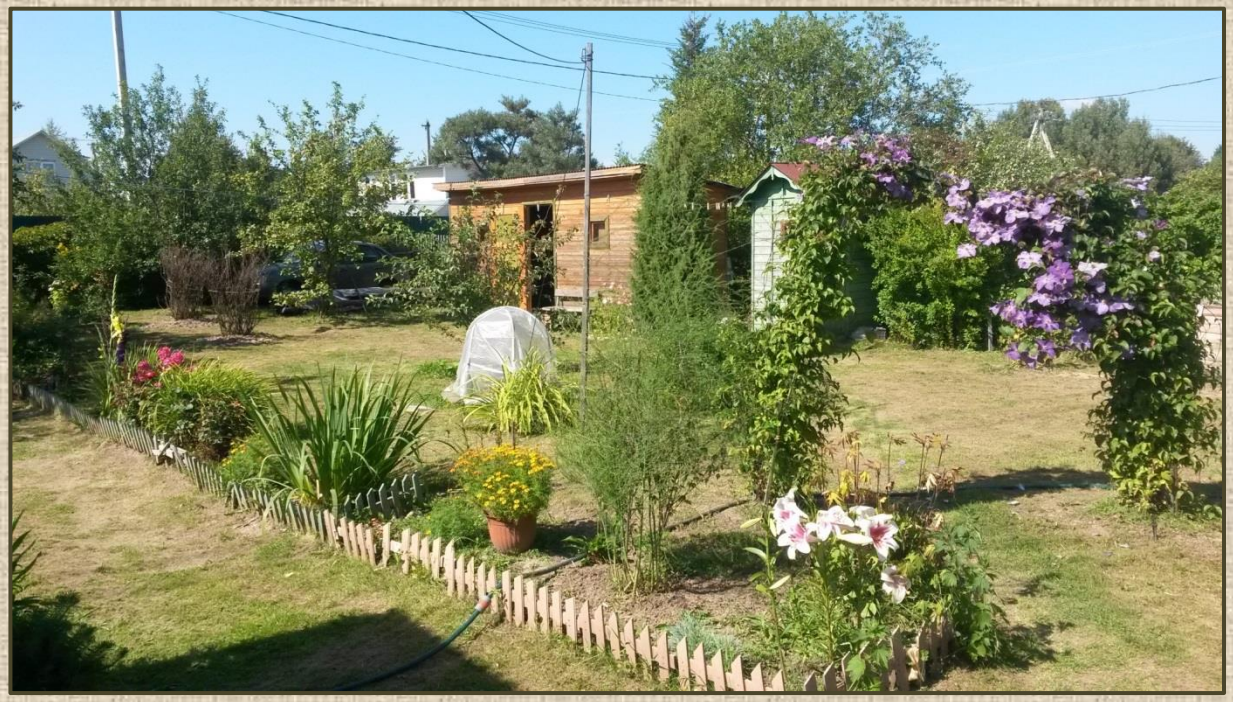
1)Monitoring time sequences in several energy channels with 1s resolution
2)Detailed energy spectra for requested periods
3)Event data sequences (useful for short burst search)



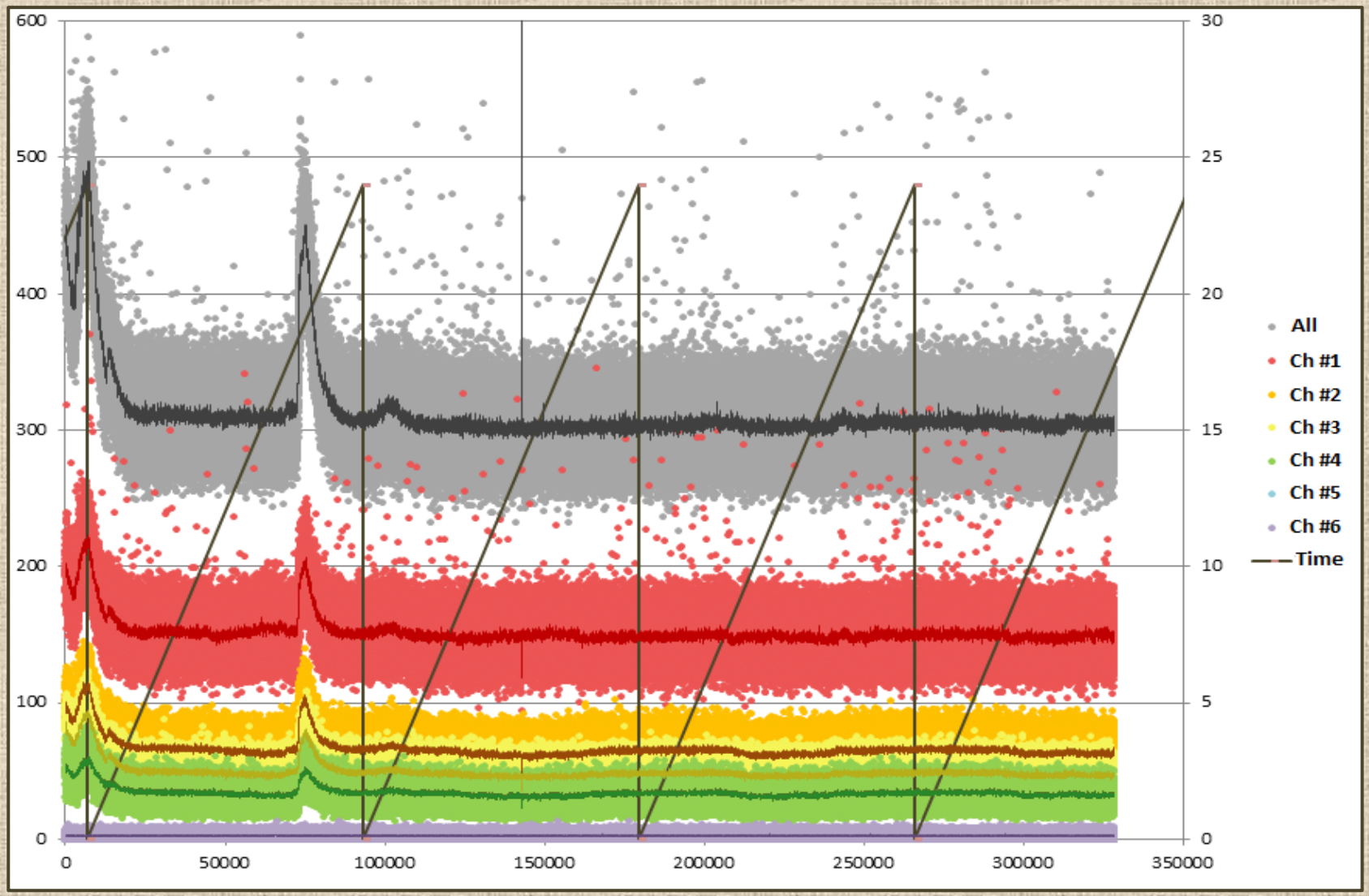


Autocallibration *alhorythm was used for large detector data: every 300s of the data the program determined the actual position of well visible 1.46 MeV background gamma-line of K-40, then the energy of gammas in keVs was calcullated. It allowed to minimize the effects of false variations connected with temperature drift of the detector characteristics*

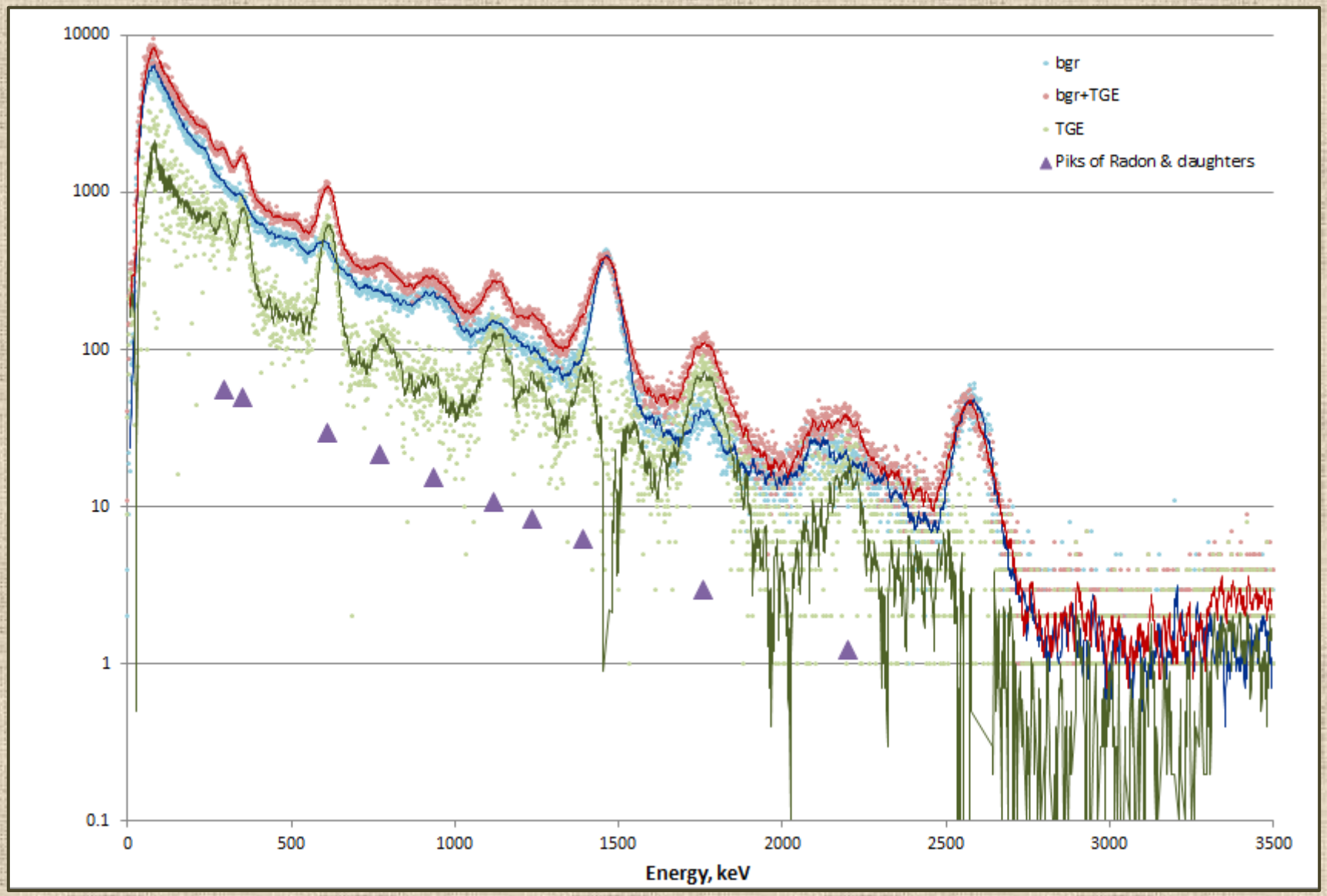
Observations 50 km North from Moscow



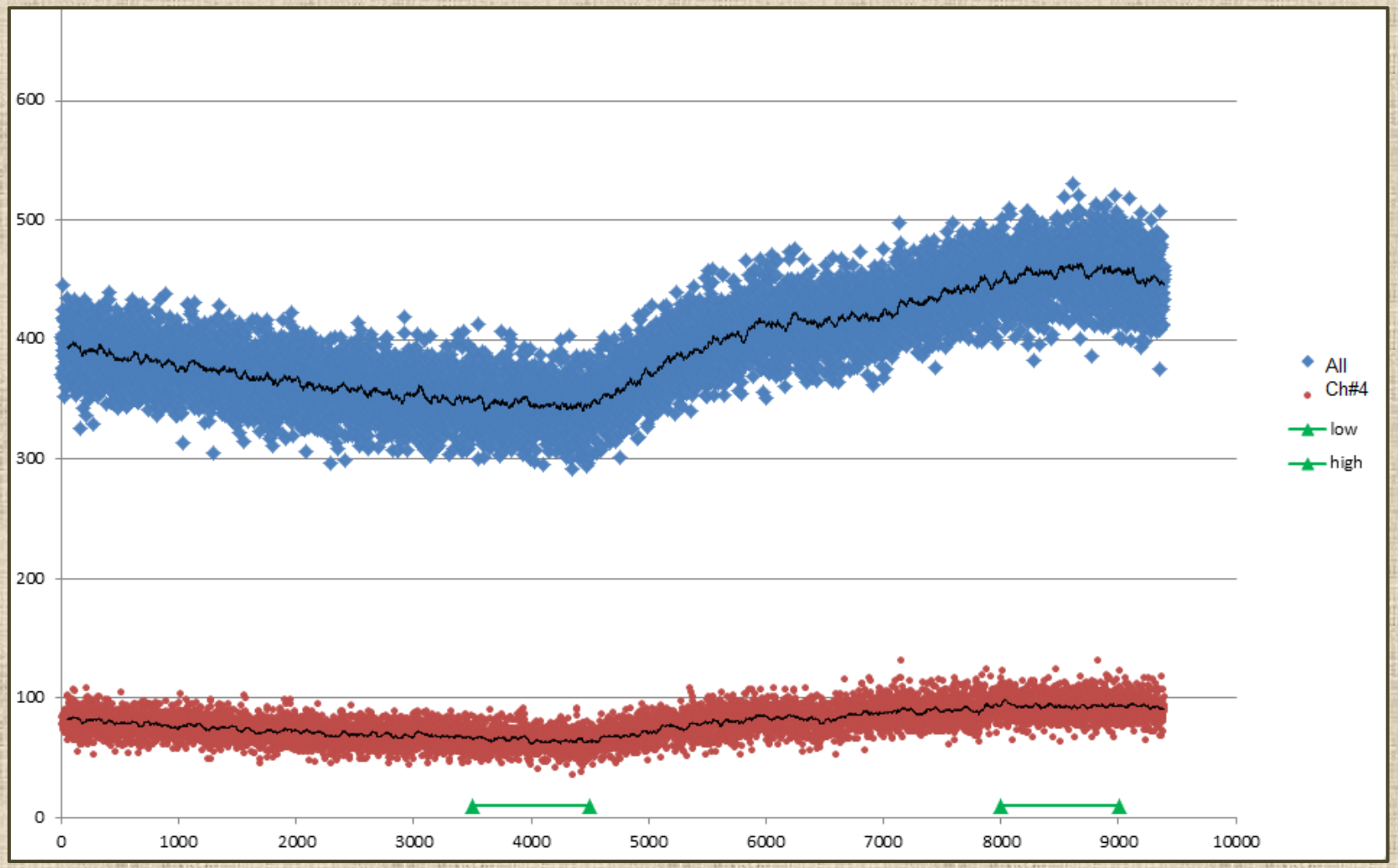
27-30 of July 2015.
Conditions: thunderstorms (peaks), rain, next - clear weather



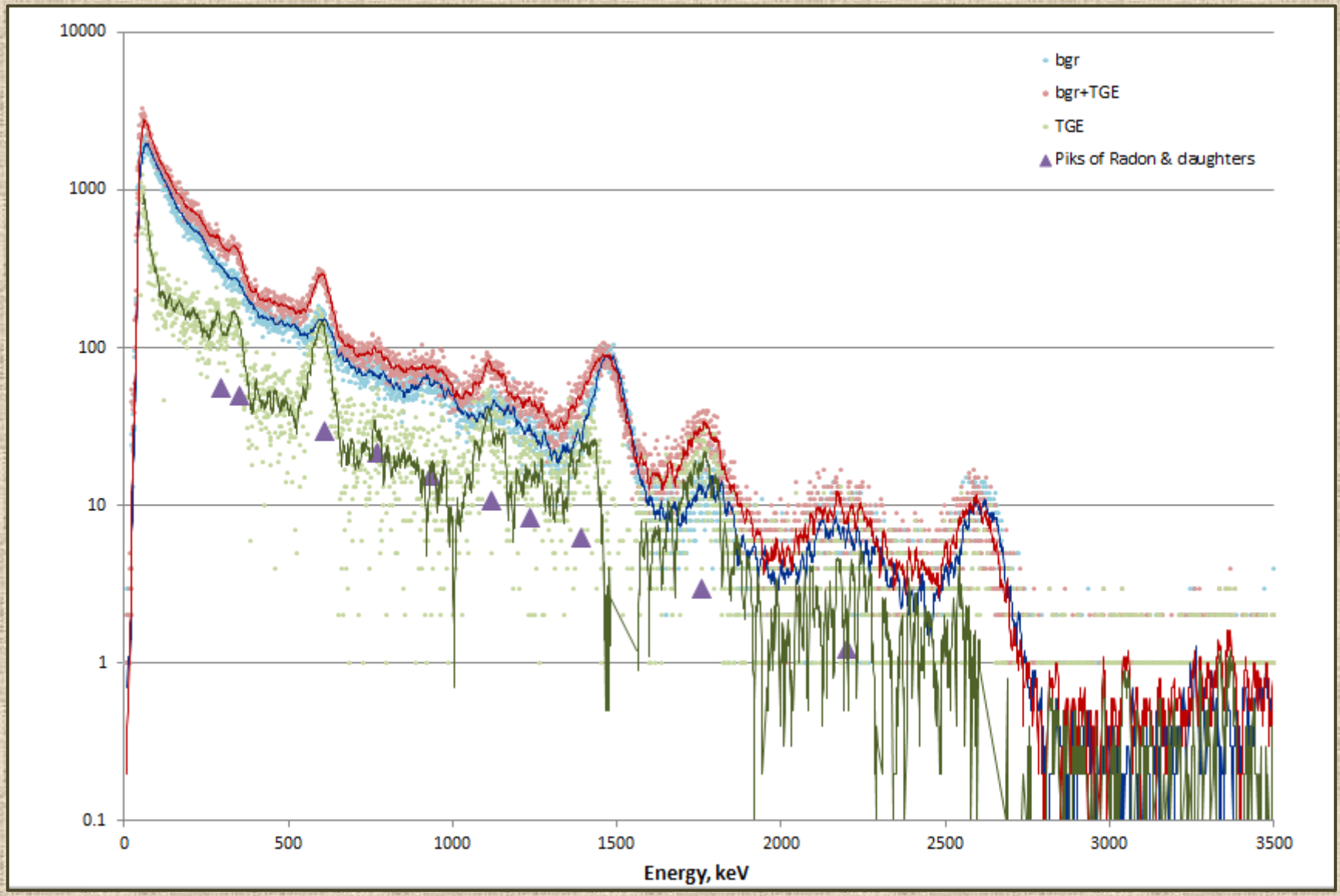
Energy spectrum of TGE 28.07.2015



05 of September 2015.
Conditions: small rain without thunderstorms

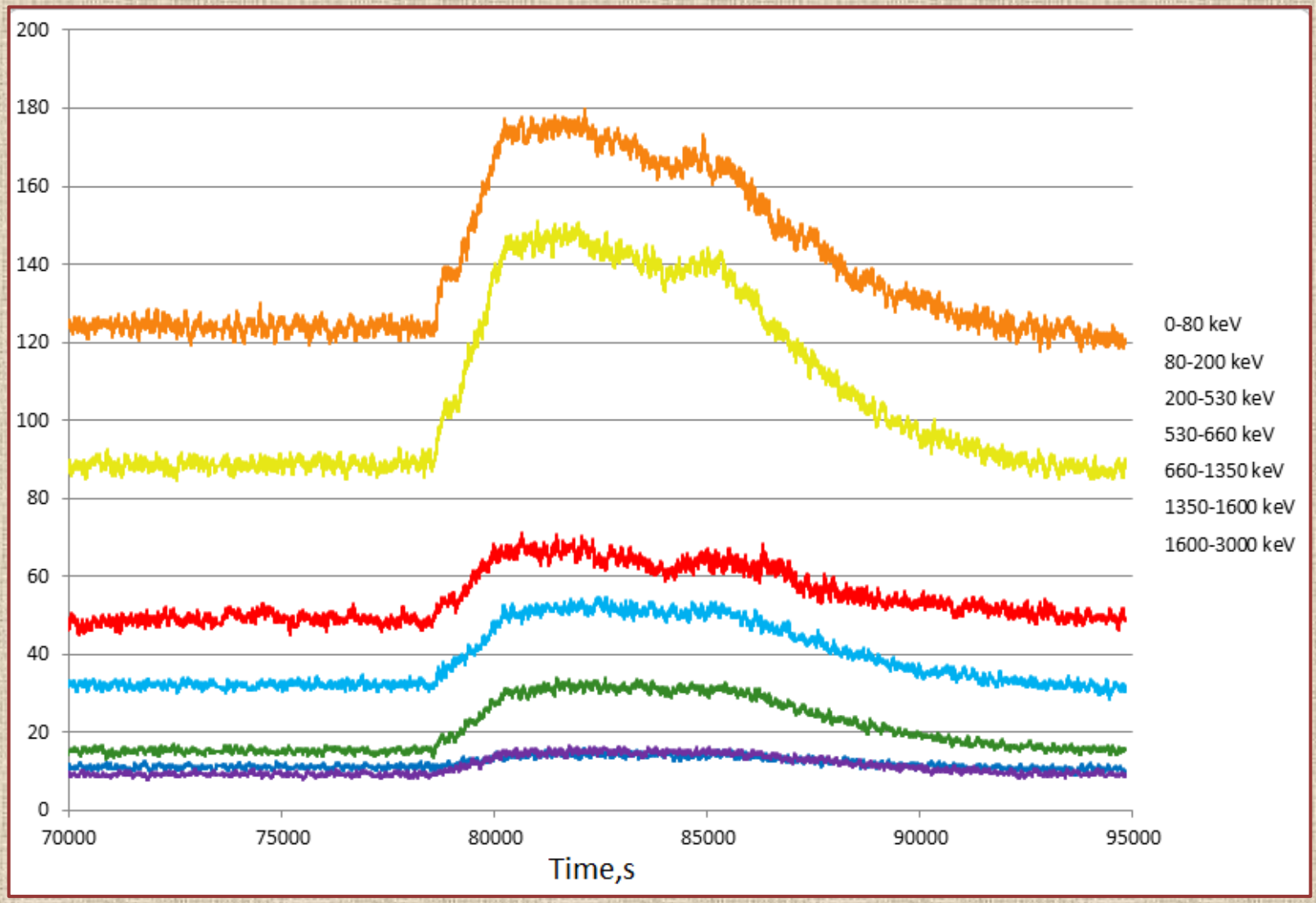


Energy spectrum of 05.09.2015

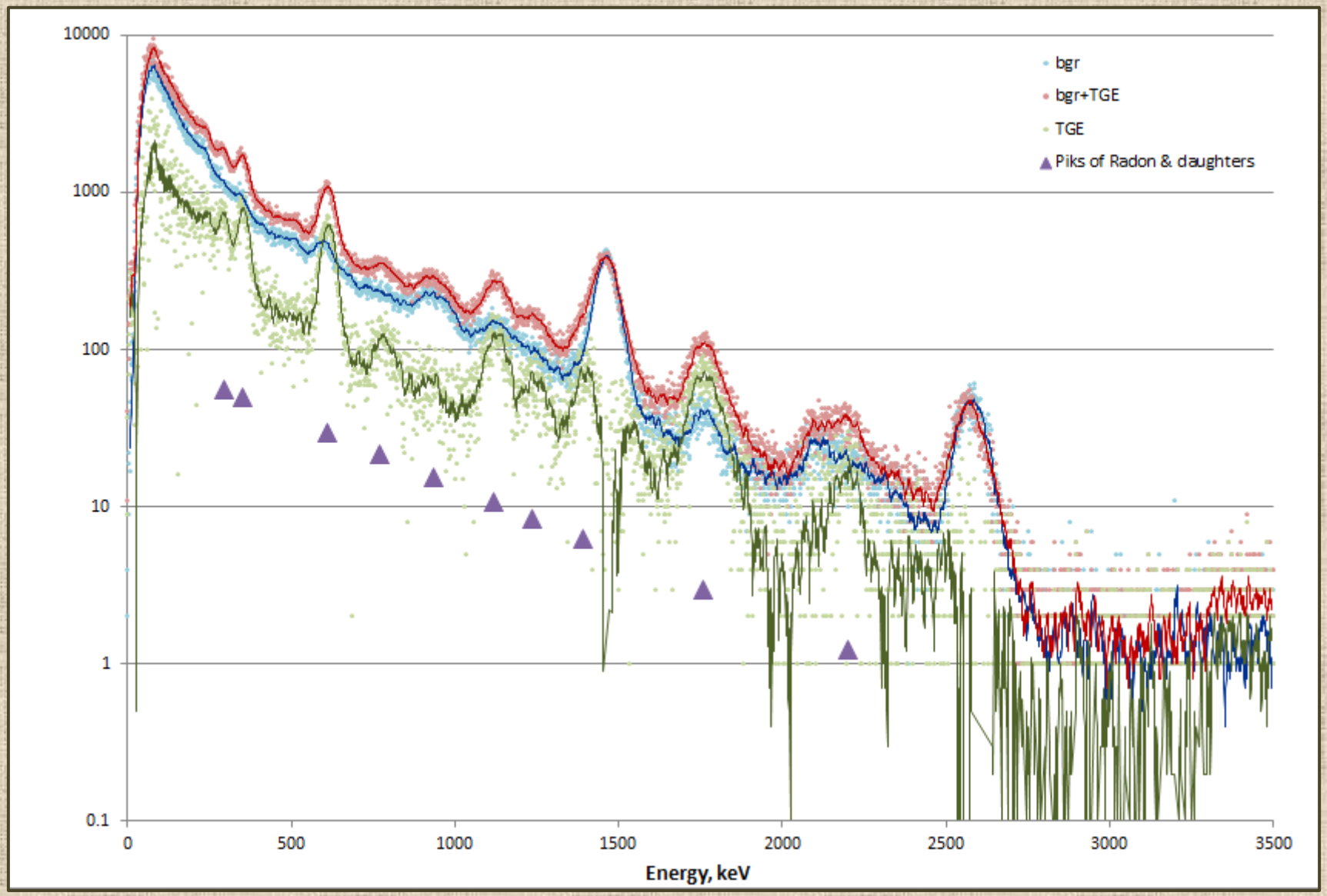


27 of September 2015.

Conditions: clear weather, then thunderstorm with powerful rain, then the rain stopped and the sun appeared



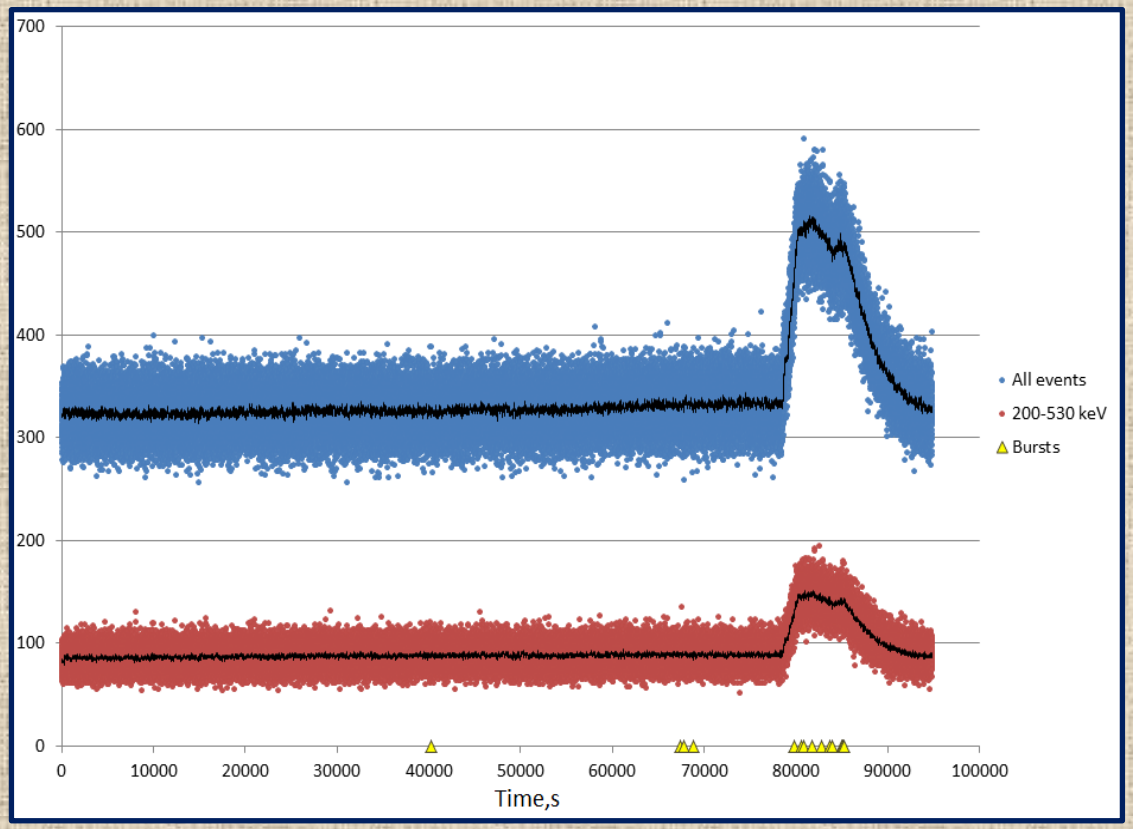
Energy spectrum of TGE 28.07.2015

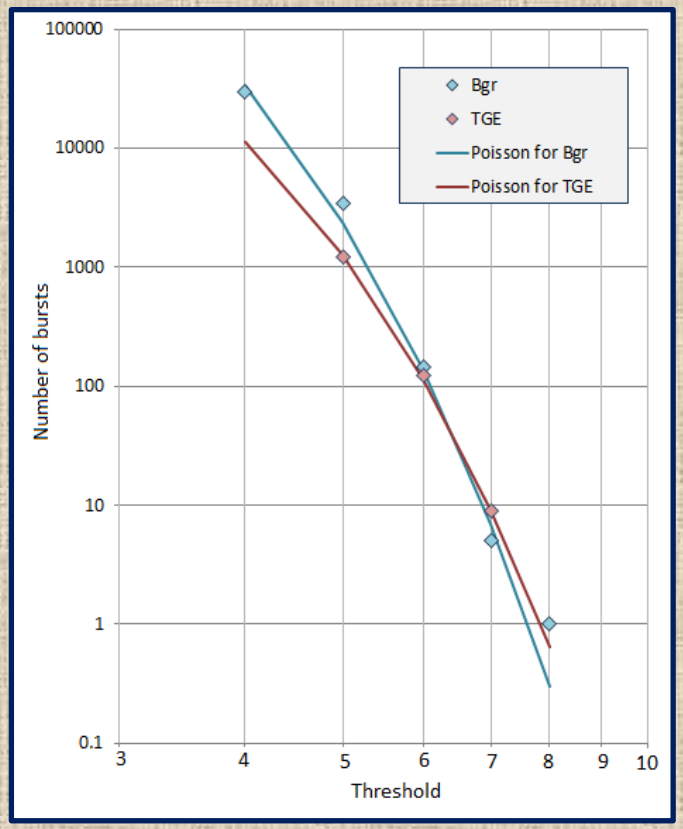


Search for short bursts

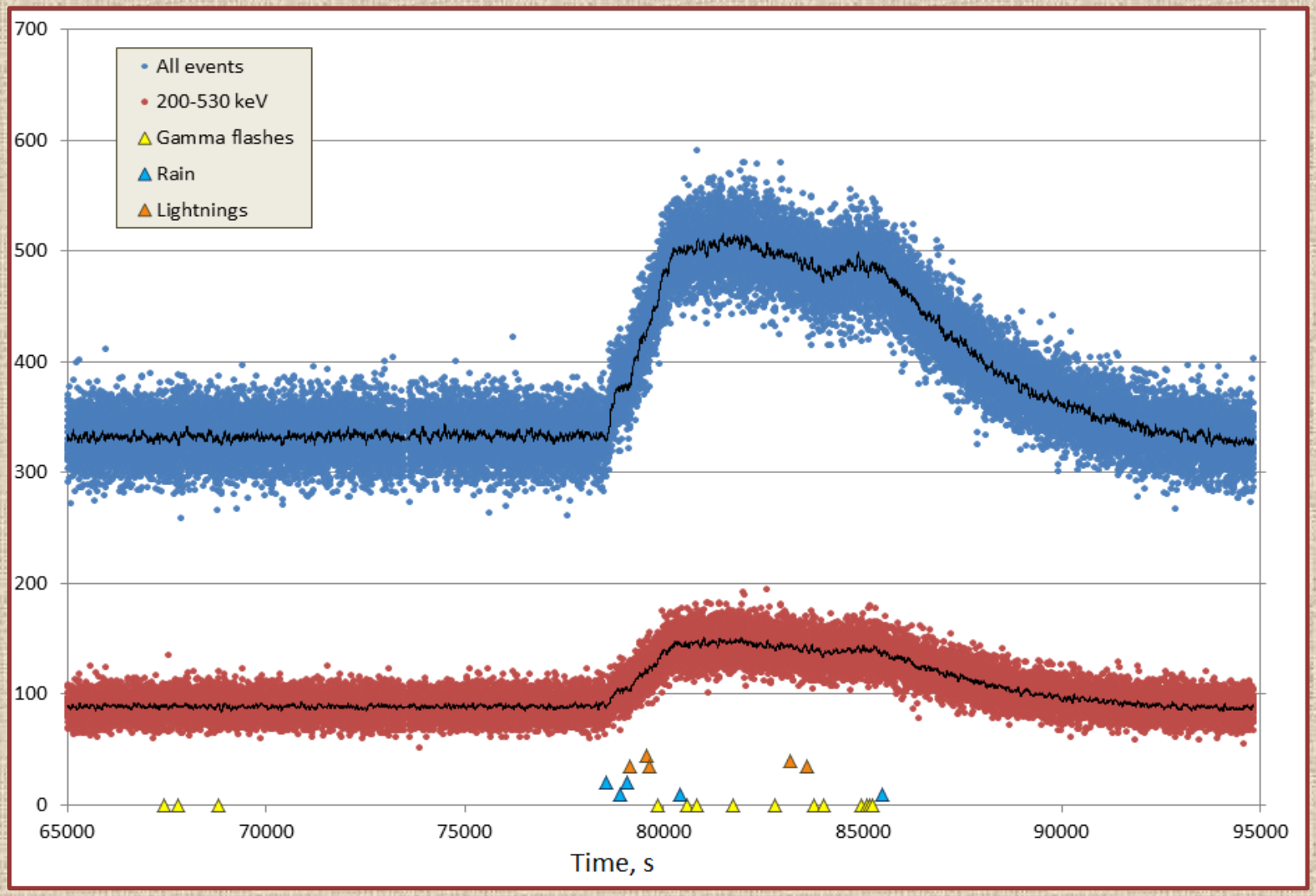
The data of thunderstorm 27.09.2015 were processed. The moments of short burst candidates when >7 gammas occur in 1 ms were determined (yellow triangles)

The graph of expected number of imitations vs threshold value shows that probably all candidates pointed on the left figure are random and the criterion must be some harder with threshold of 9 gammas per 1 ms. Such events were not observed.



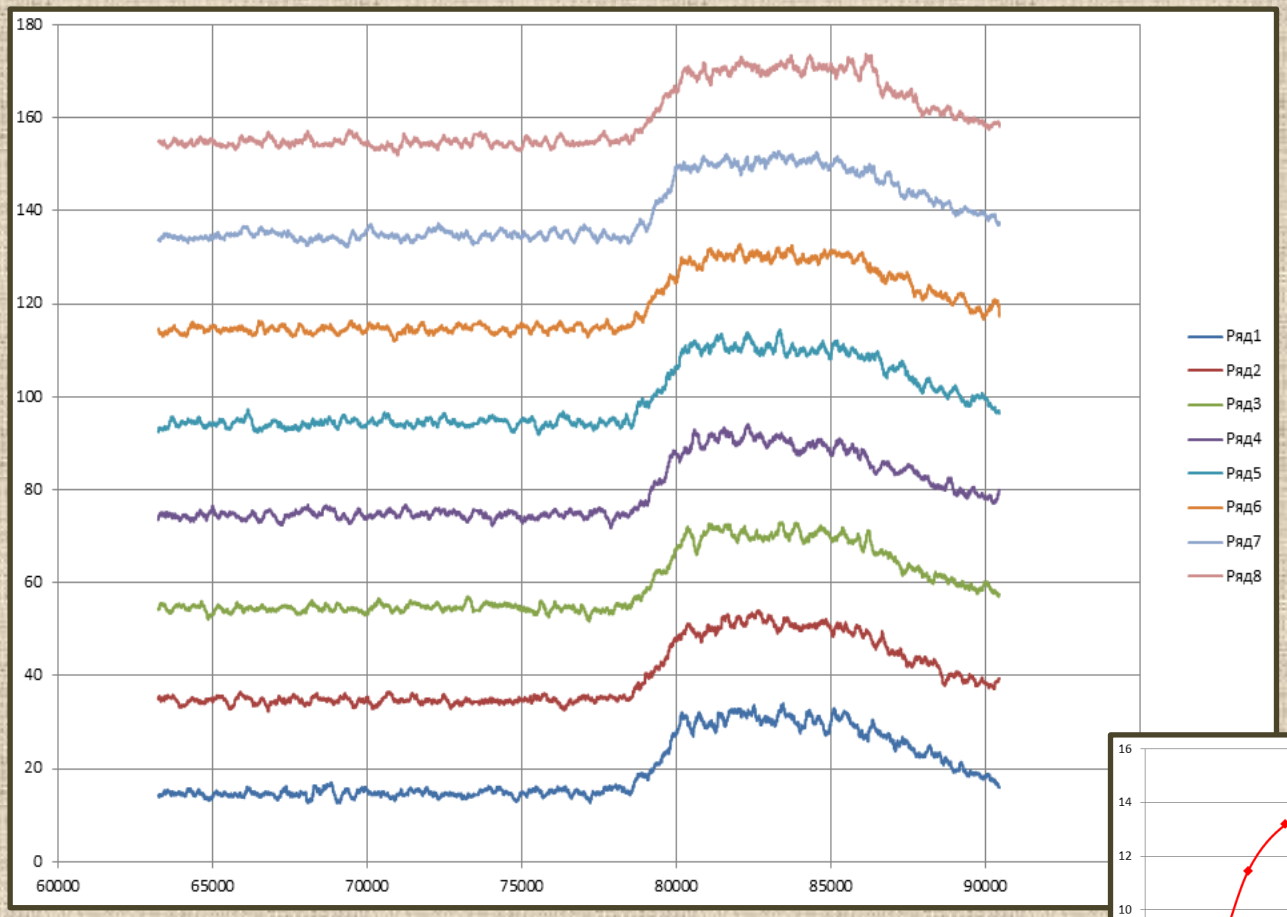


Comparison with weather

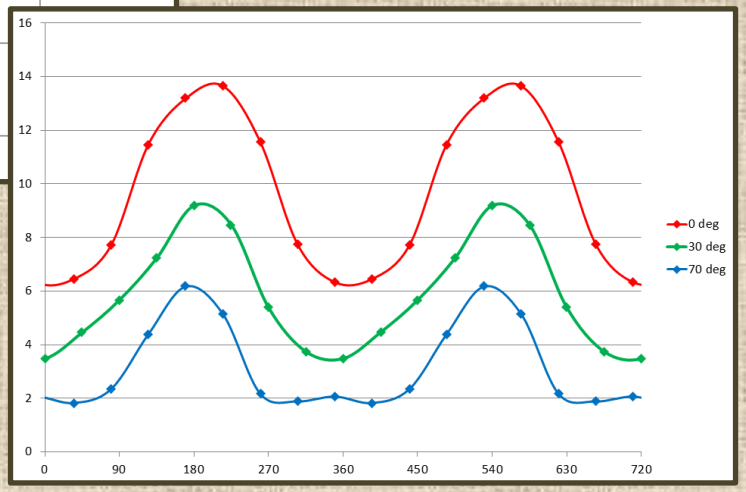


1) There are no gamma-ray flashes at the moments of lightenings
2) The moment of gamma-ray flux increase exactly coincide with the rain start.
3) When the rain stops the TGE decays exponentially with time index ~1h

Test for directivity



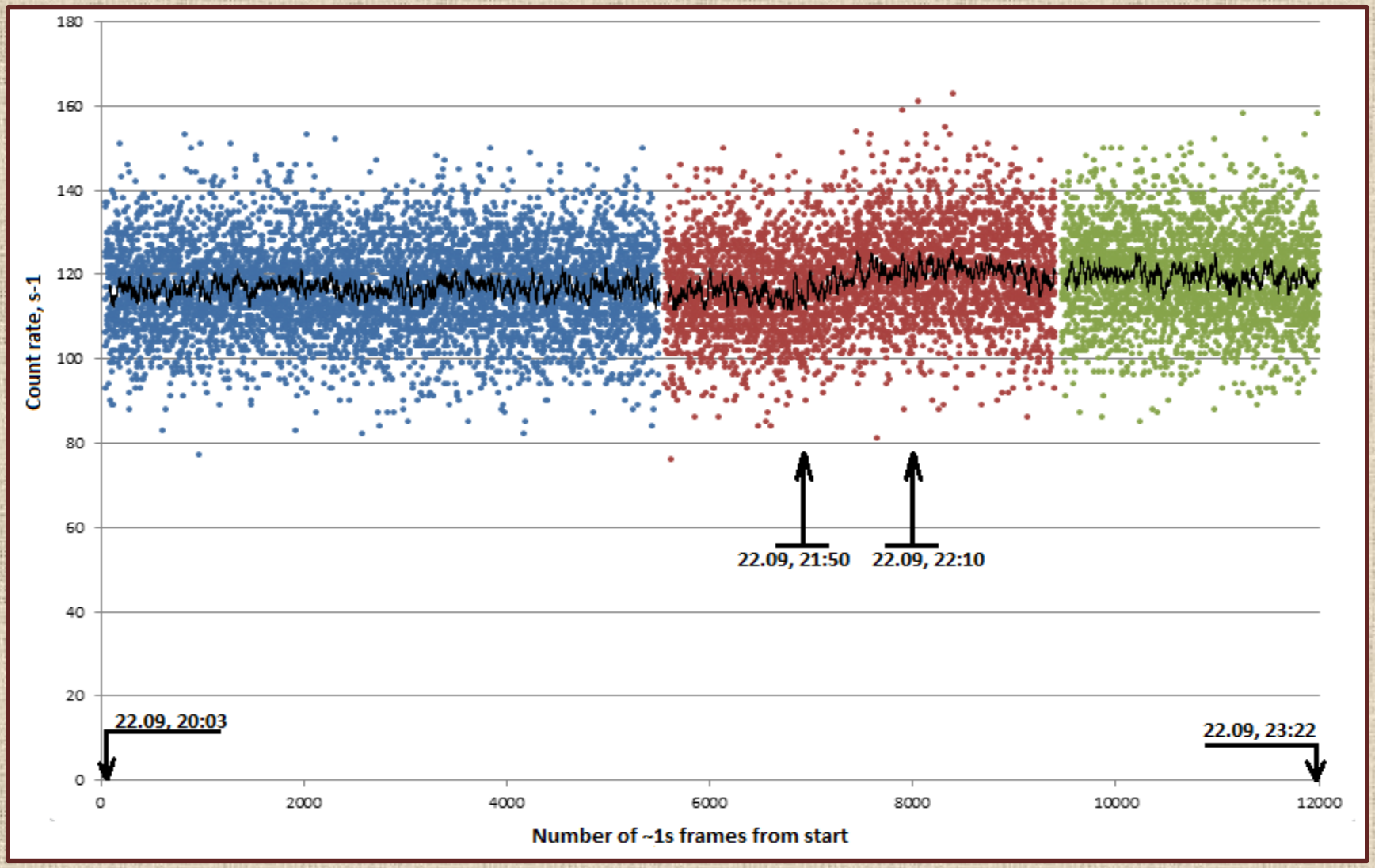
Monitoring data plotted separately for 8 directions (graphs are shifted with 20 unit step)



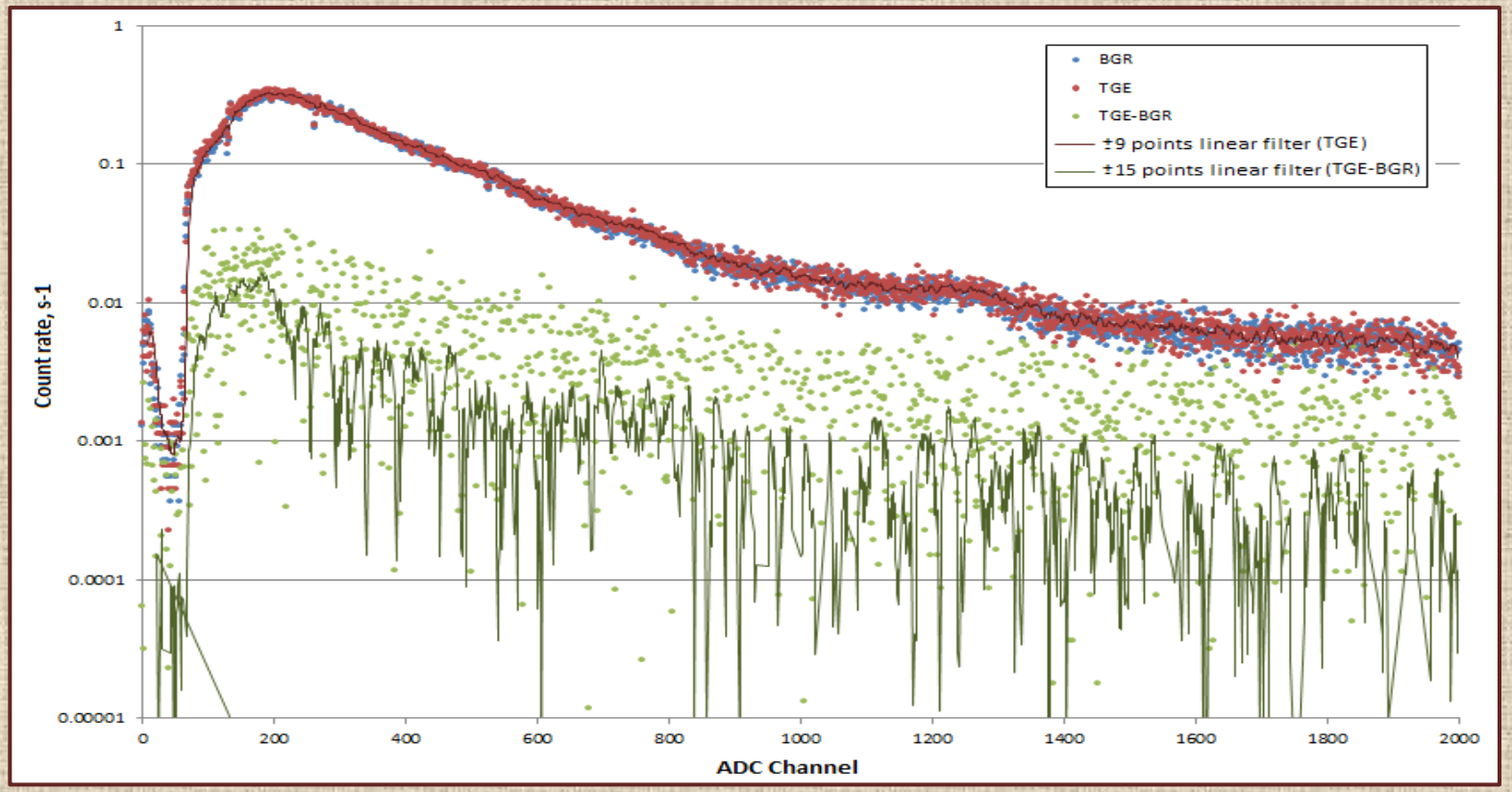
Angular characteristics for 662 keV for tetta=0 deg, 30 deg and 70 deg

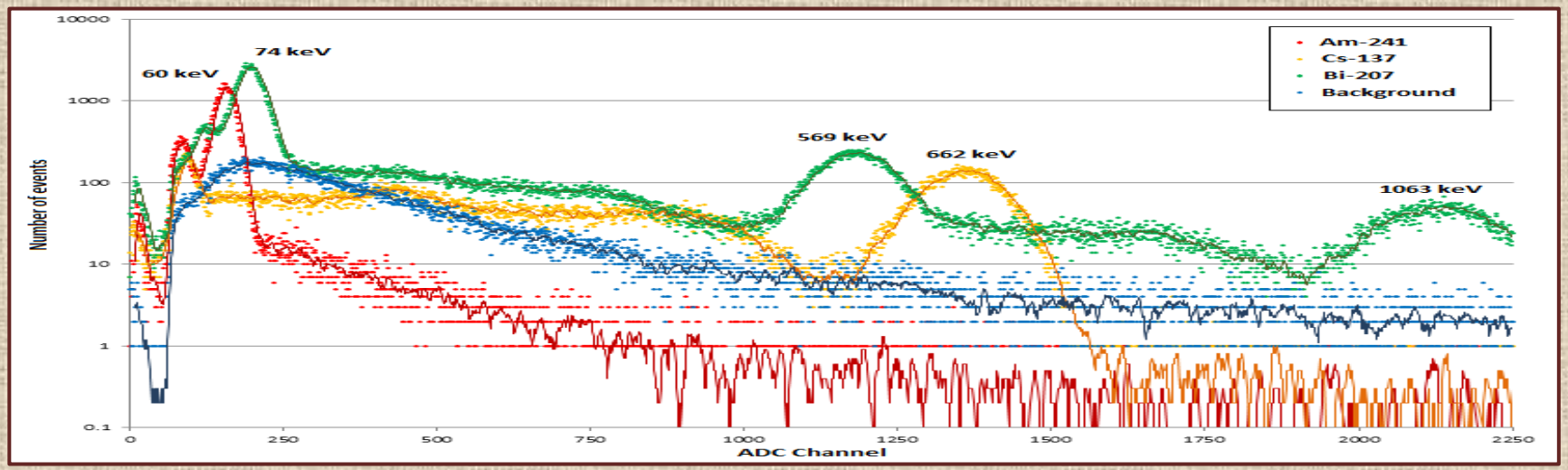
Measurements with NaI(Tl) detector in Nor-Amberd

22.09.2014 (during TEPA-2014)

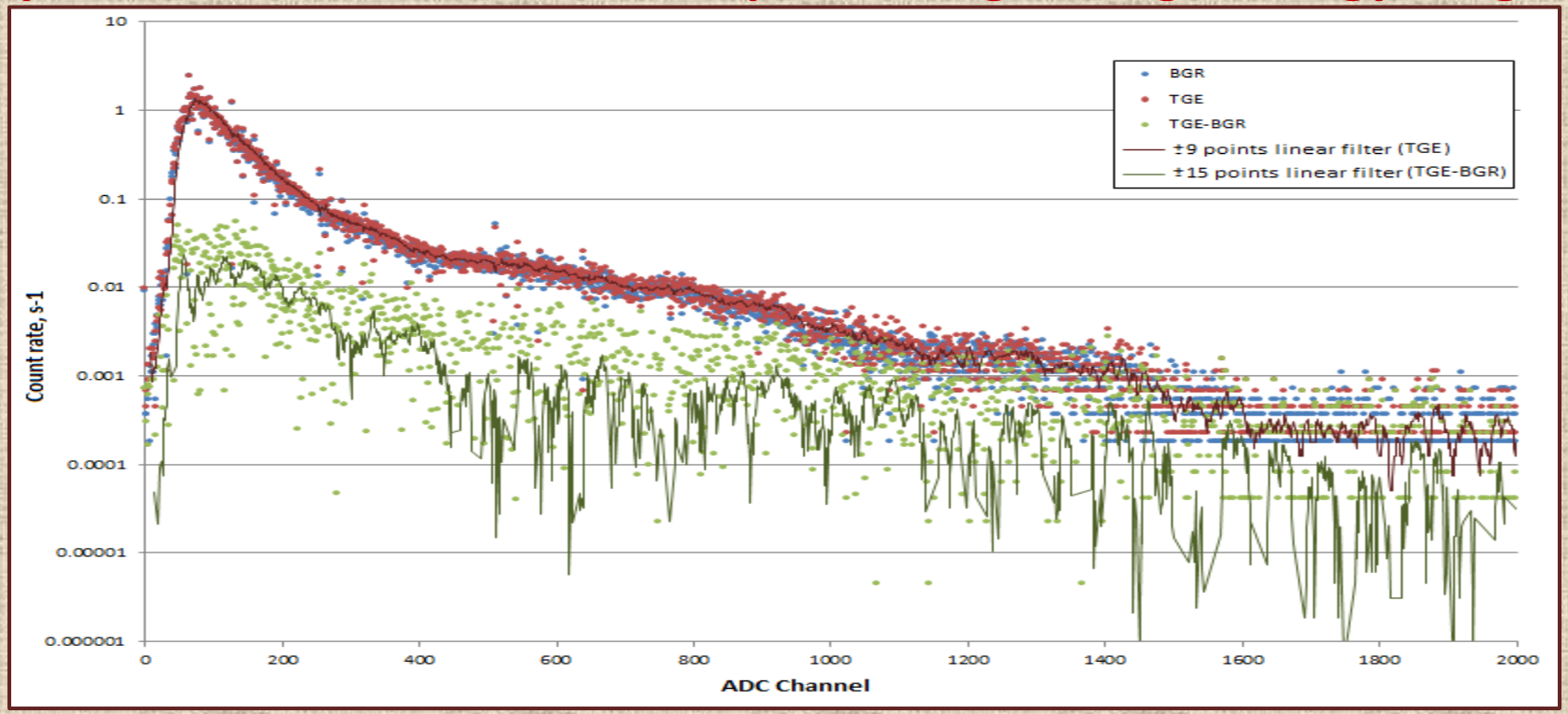


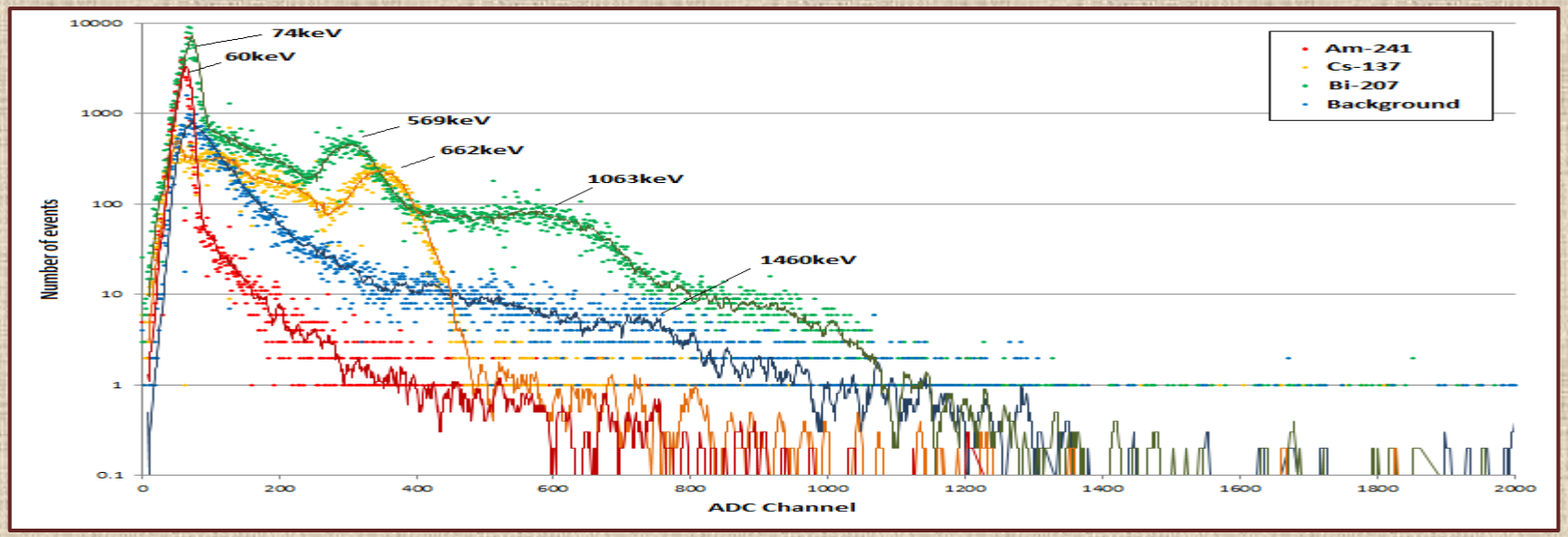
Energy spectrum of TGE 22.09.2014





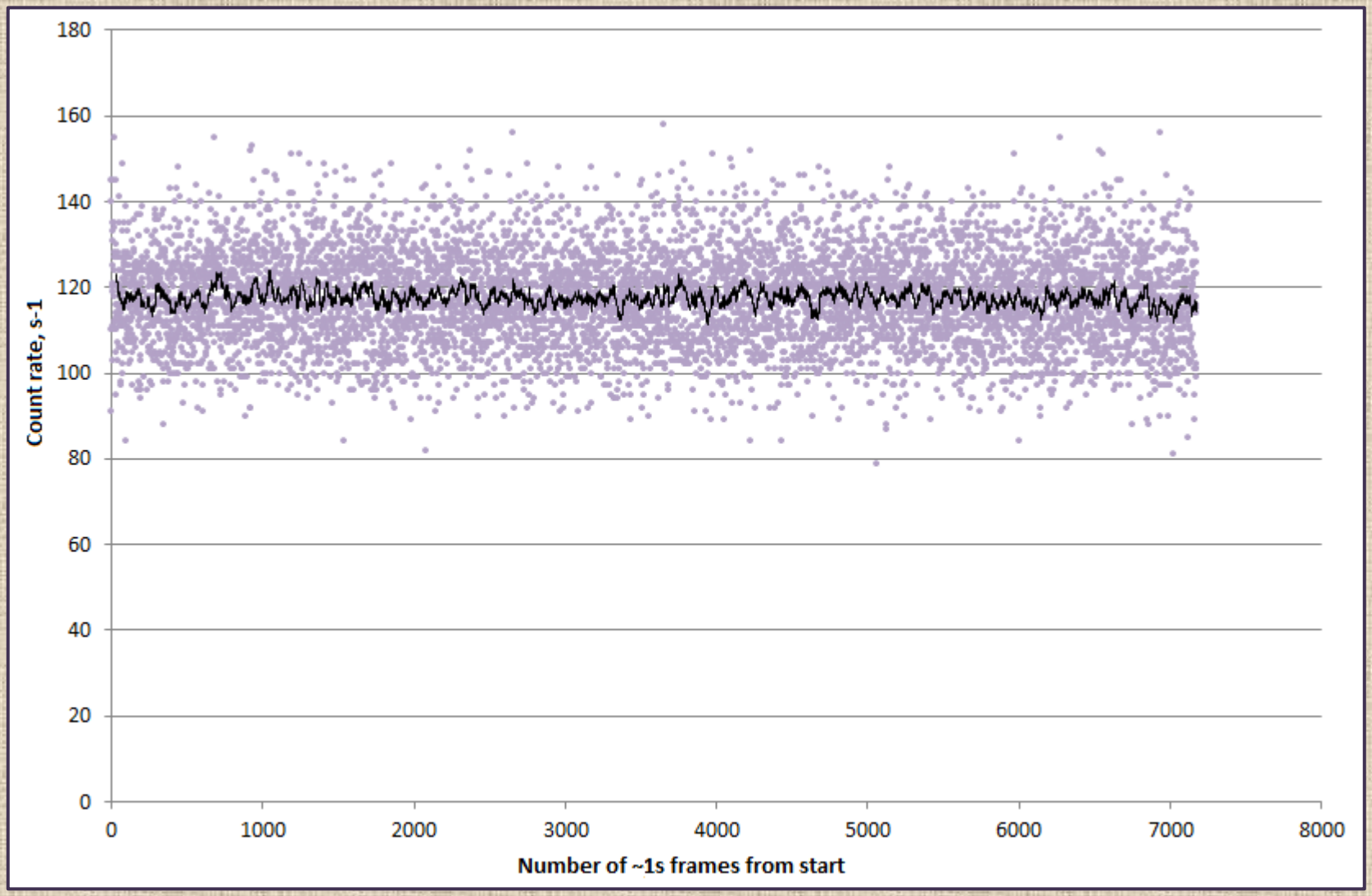
Spectrum of TGE 22.09.2014 – processing for high energy range





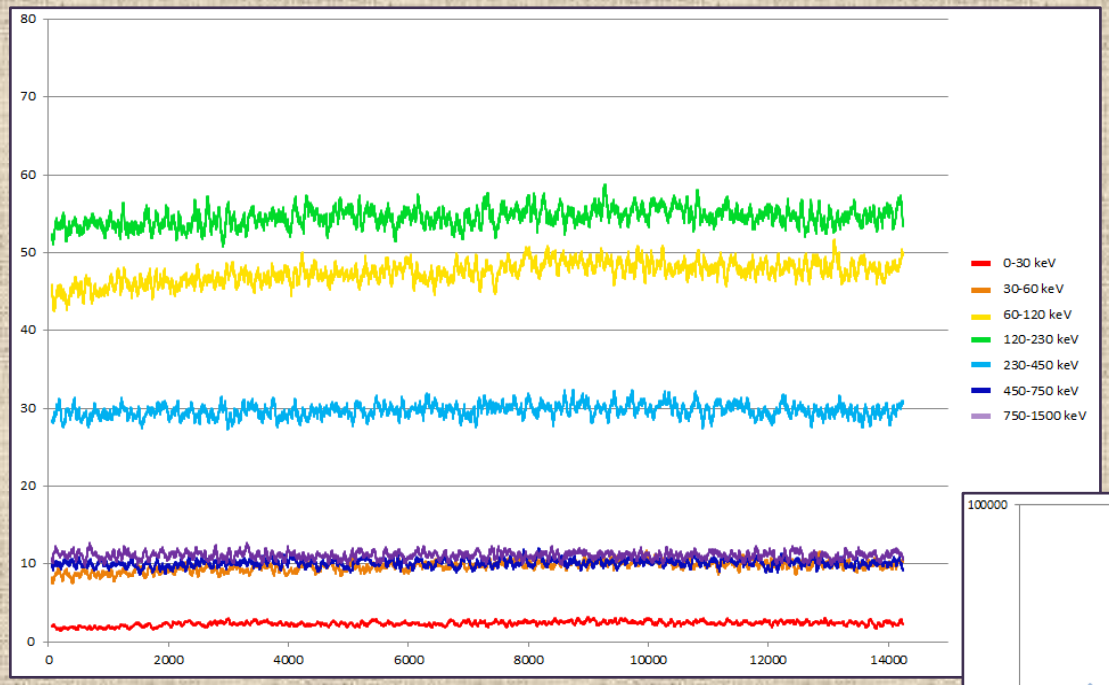
Measurements on 3200 m

24.09.2014 (during TEPA-2014)



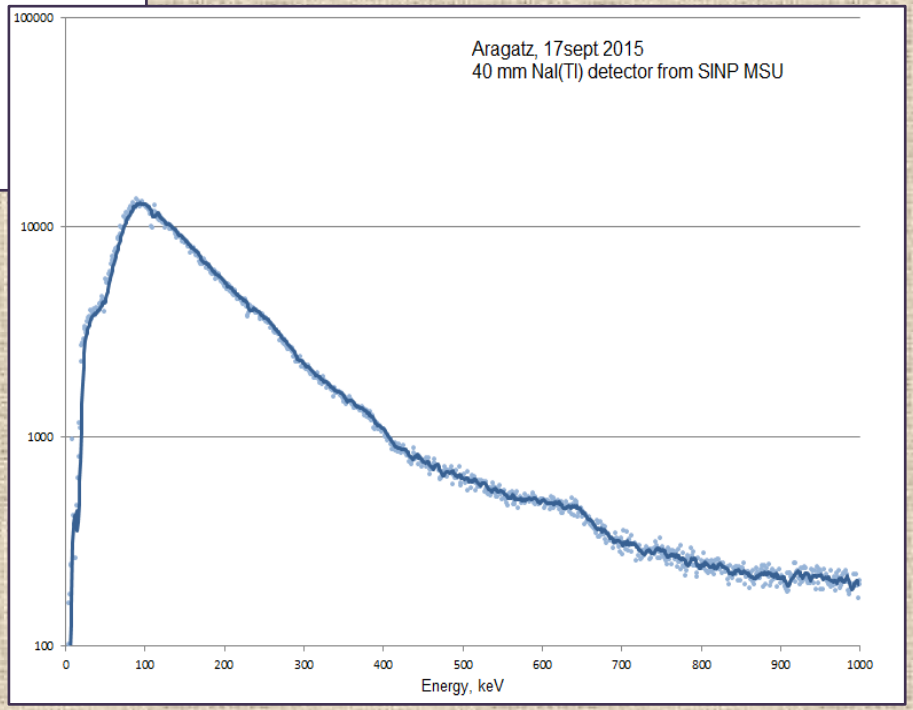
Measurements on 3200m in 2015

17.09.2015



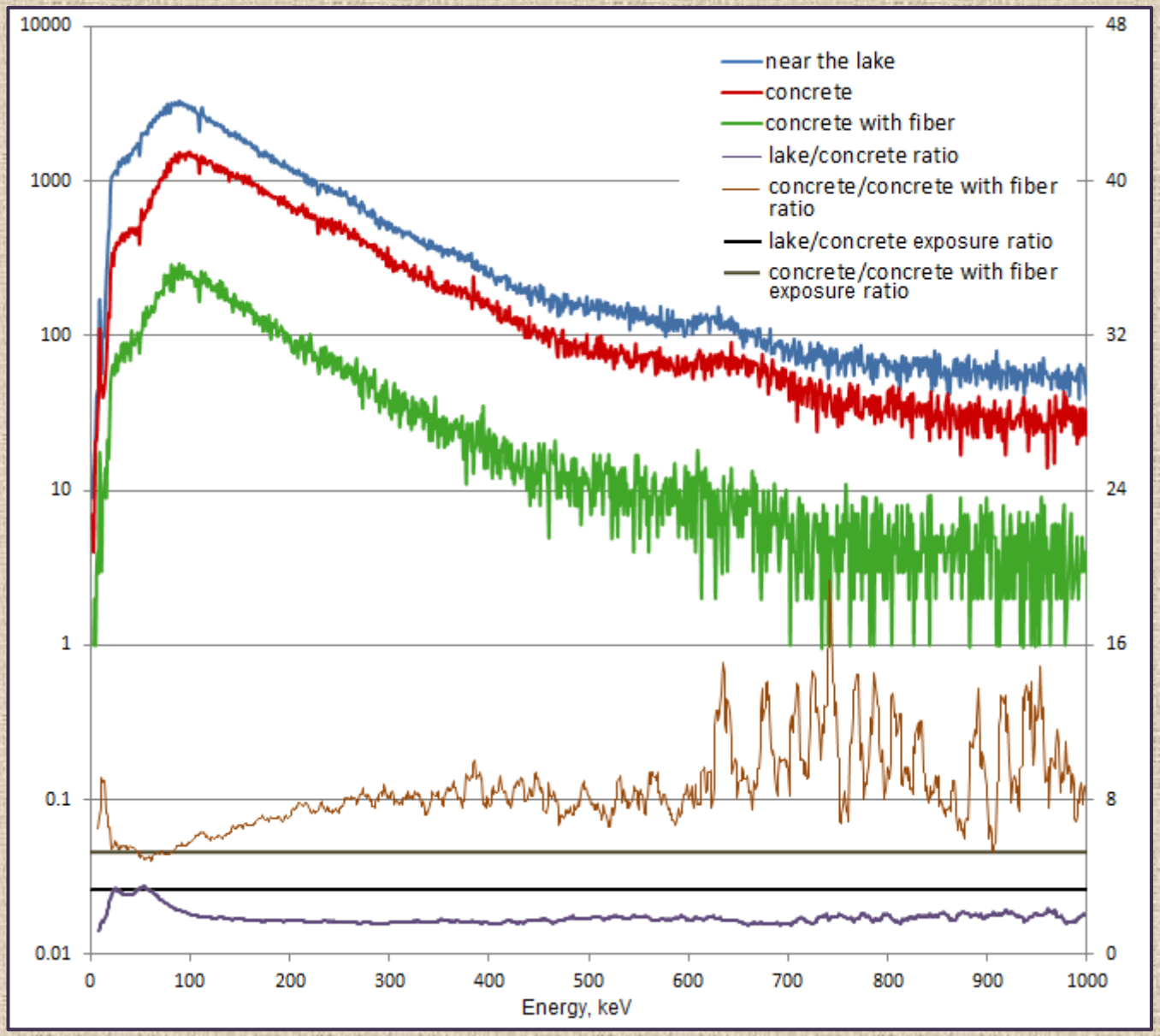
Monitoring in 7 channels

Energy spectrum



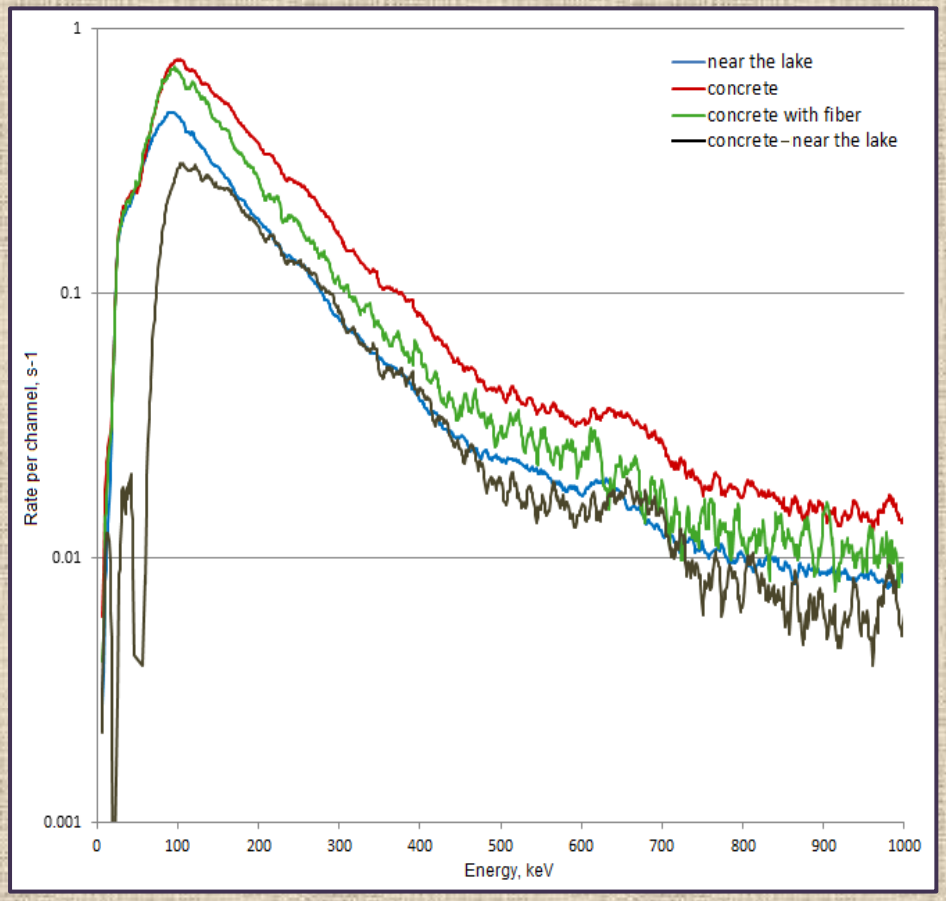
Spectra at different sites of Aragatz station

20.09.2015

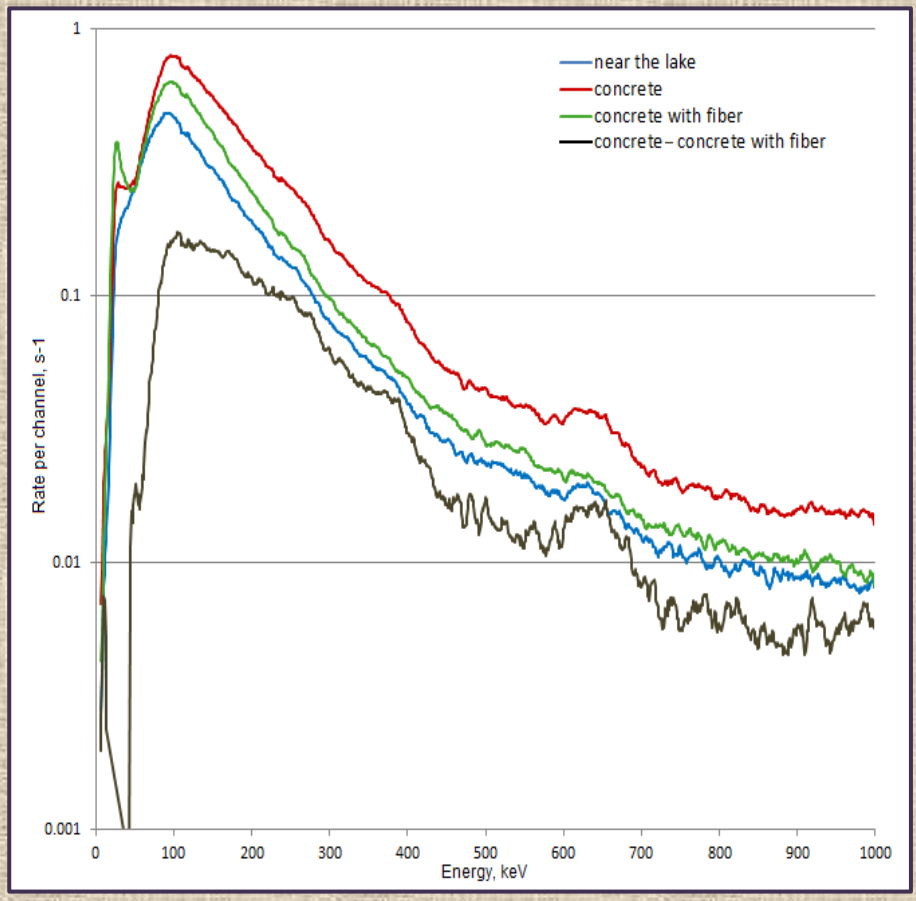


Comparison of spectra at different sites of Aragatz station

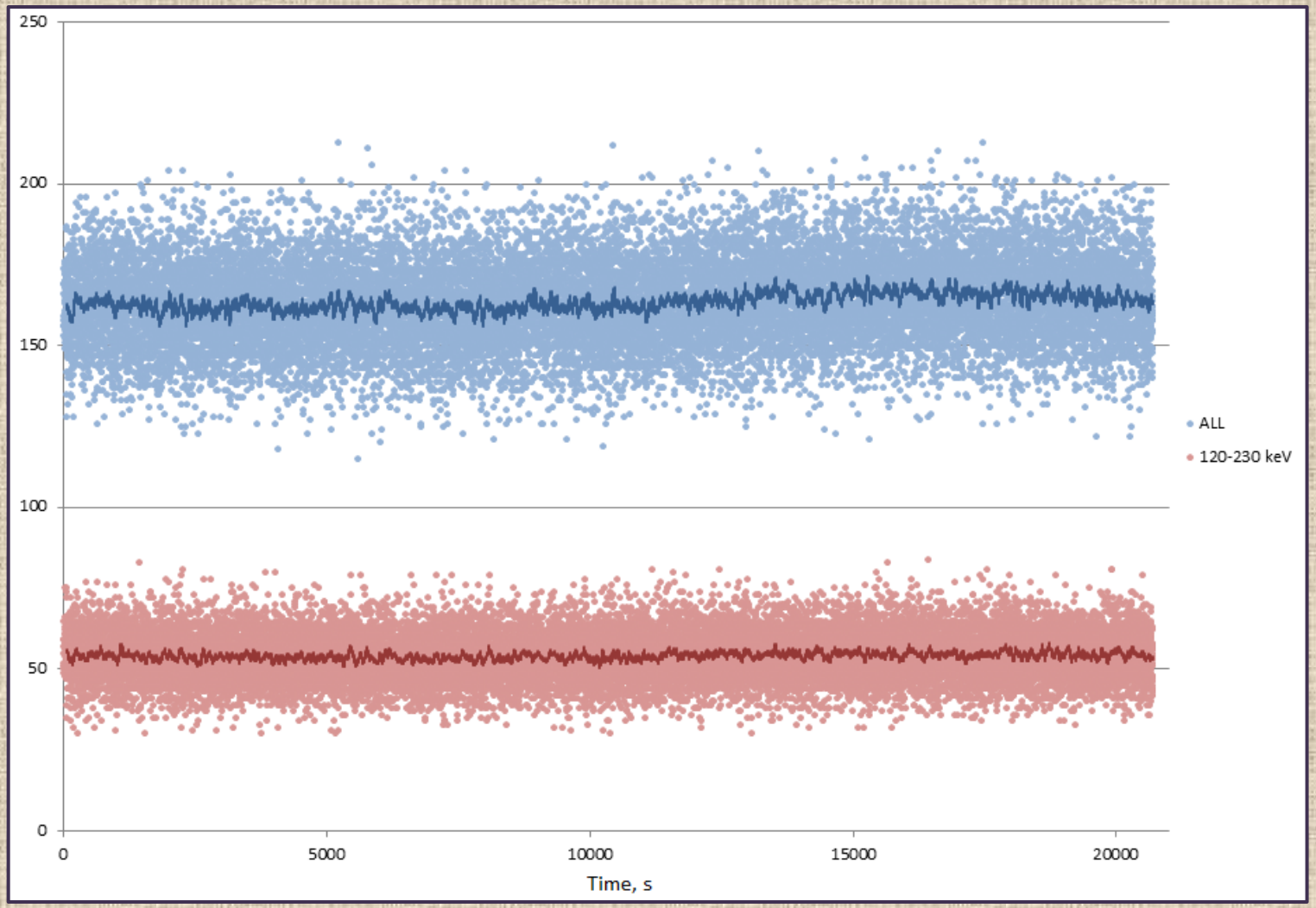
20.09.2015



22.09.2015

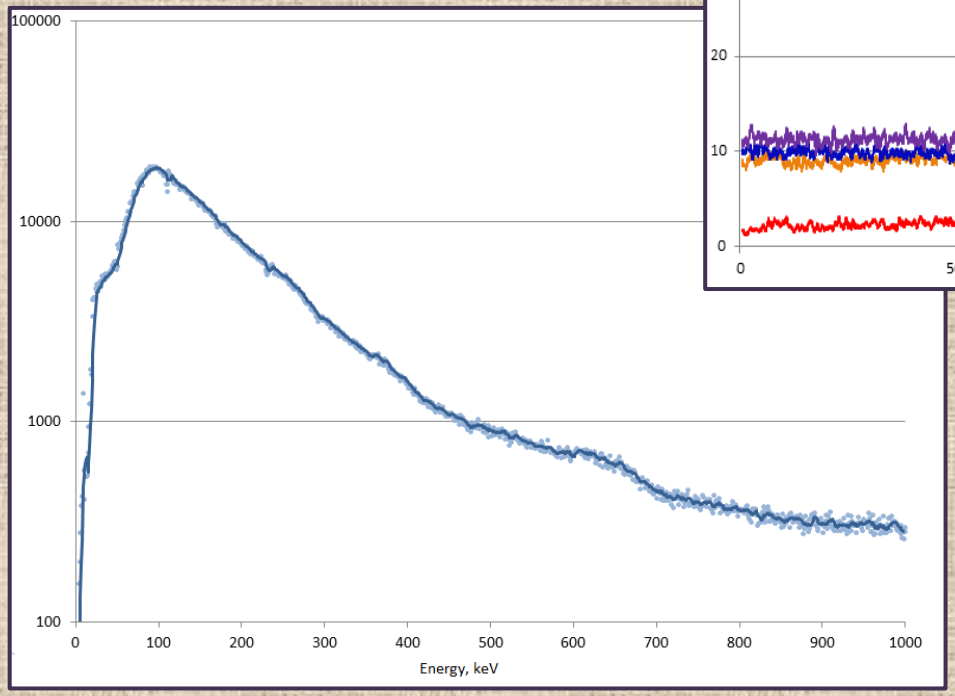


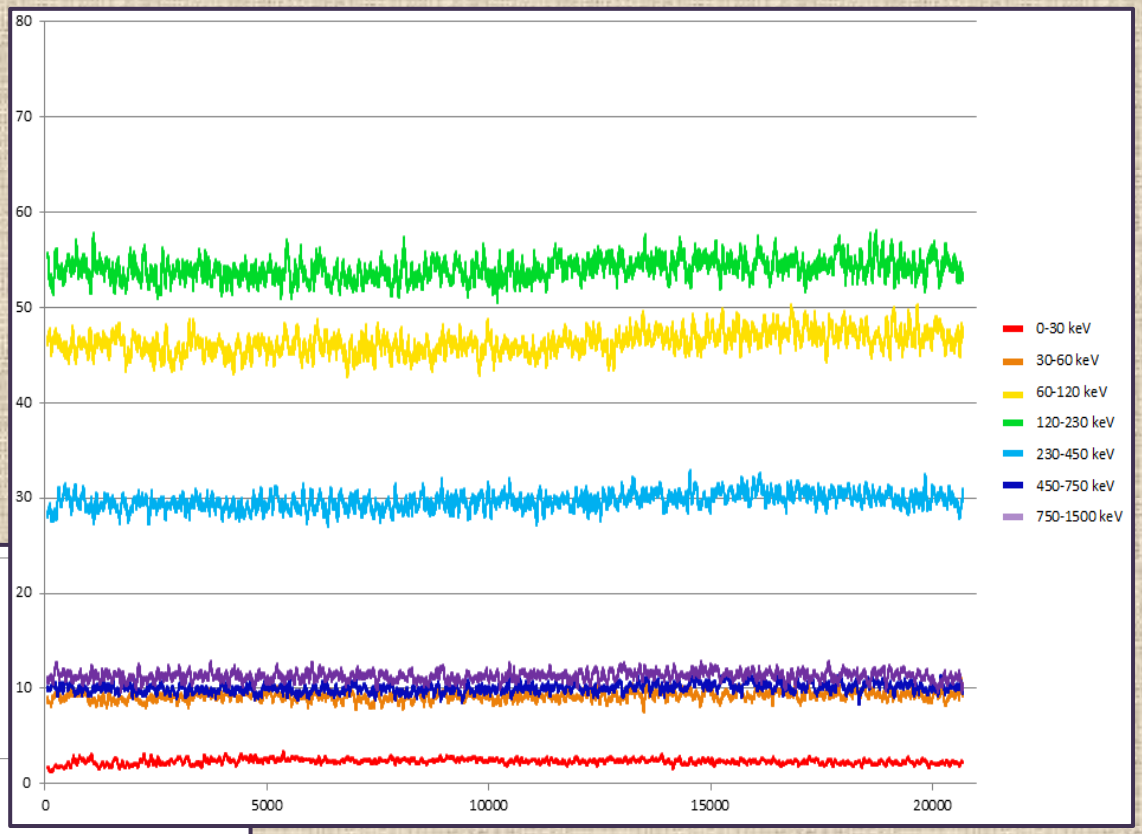
Measurements on Aragatz during TGE 04.10.2015



Energy spectrum obtained during TGE 04.10.2015

Energy spectrum





Monitoring in several channels