NEW STM32 MICROCONTROLLER BASED COSMIC RAY INTENSITY REGISTRATION SYSTEM FOR THE NEUTRON MONITOR

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Technical requirements

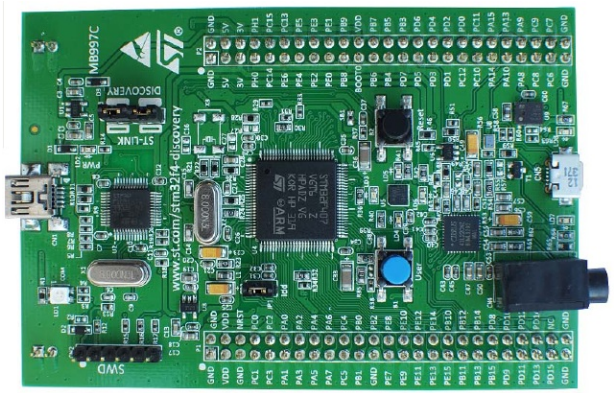
- highly stable uninterruptable measurements of the intensity of input pulse signals during many months & years long period;
- internal generation and intensity registration of various neutron multiplicity events according to different algorithms, in parallel with basic monitoring functionality;
- additional data aquisition algorithm with registration of high-resolution pulse intensity series (up to 5000-10000 succeeding counts with up to 2-5 μs time resolution), in parallel again;
- alternative operation mode with registration of the amplitude of analogue type input signal;
- possibility of a fast on-the-fly change of all operation settings in dialog regime just in the time of measurement run;

Technical requirements (continuation)

- general compactness and low power consumption with possibility of prolonged operation from an autonomous (accumulator-based) power source;
- independence on continous presence of qualified technical personnel at the detector disposition site.

Main features of the system set-up

- STM32F407 type 32-bit microcontroller unit
- *STMF4Discovery* type evaluation board

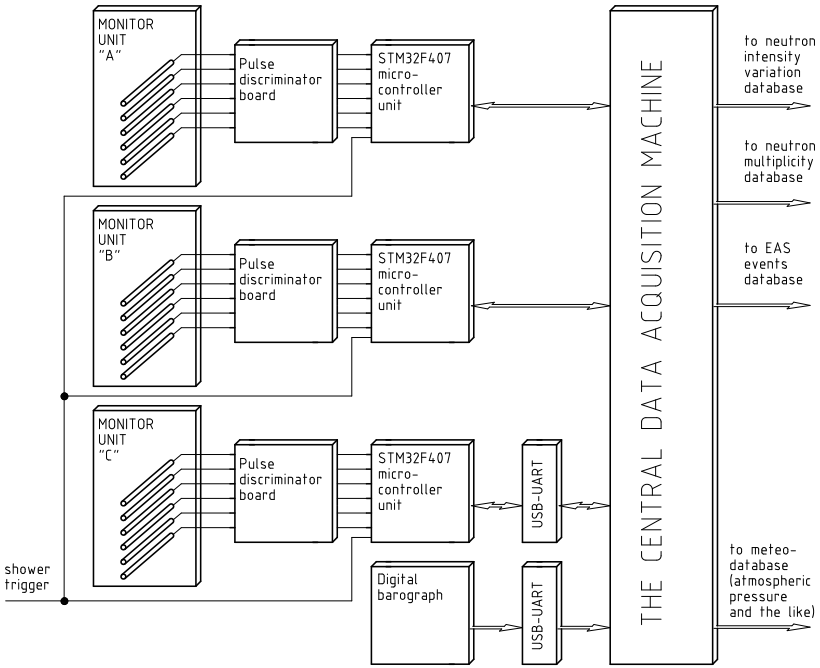


- embedded MCU program code written on the basis of the *libopencm3* ARM microcontroller programming library (*http://libopencm3.org/*) and compiled with the use of the *gnu-arm-eabi* toolchain (*https://launchpad.net/gcc-arm-embedded*);
- up to 16 informational channels per MCU;
- principally asynchronous multithread operation mode (there is its own private & independent program thread for each data channel);

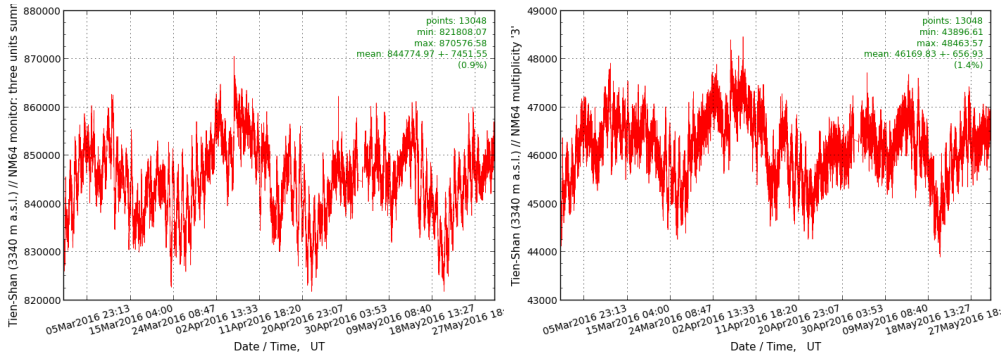
Main features of the system set-up (continuation)

- any communication with outer world succeeds in a simple textual form through in-build asynchronous port (UART) of MCU (typically, connected to an UART↔USB interface converter at the side of master machine);
- all the necessary internal parameters which define any particulars of microcontroller operation can be set at any time by sending a simple *name=value* textual messages to MCU UART port;
- modular structure of embedded code;
- two flavours of embedded code aimed for the input pulse counting and ADC kind measurements.

Use case: the Tien Shan 18NM64 type neutron supermonitor

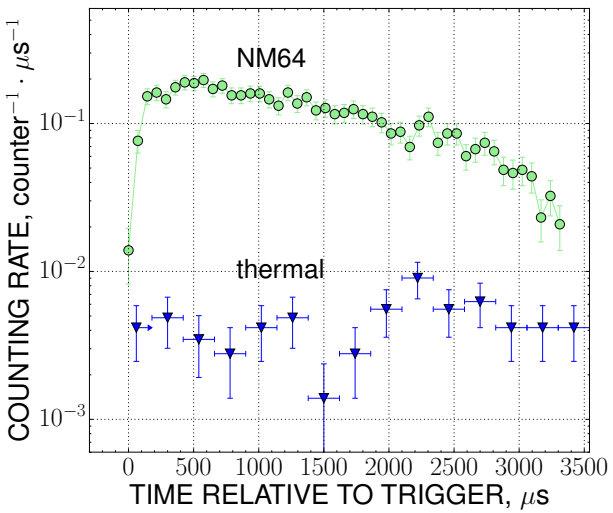


- the neutron intensity monitoring with a 1 min periodicity (simultaneously on three 6-counter monitor units);
- internal generation and intensity monitoring of the neutron multiplicity signals;



Neutron intensity and triple multiplicity signal variation during the Spring 2016.

- measurement of the neutron intensity time series with a 40 μs resolution and synchronization both from internal and external (typically, caused by a close extensive air shower (EAS) passage) trigger types.

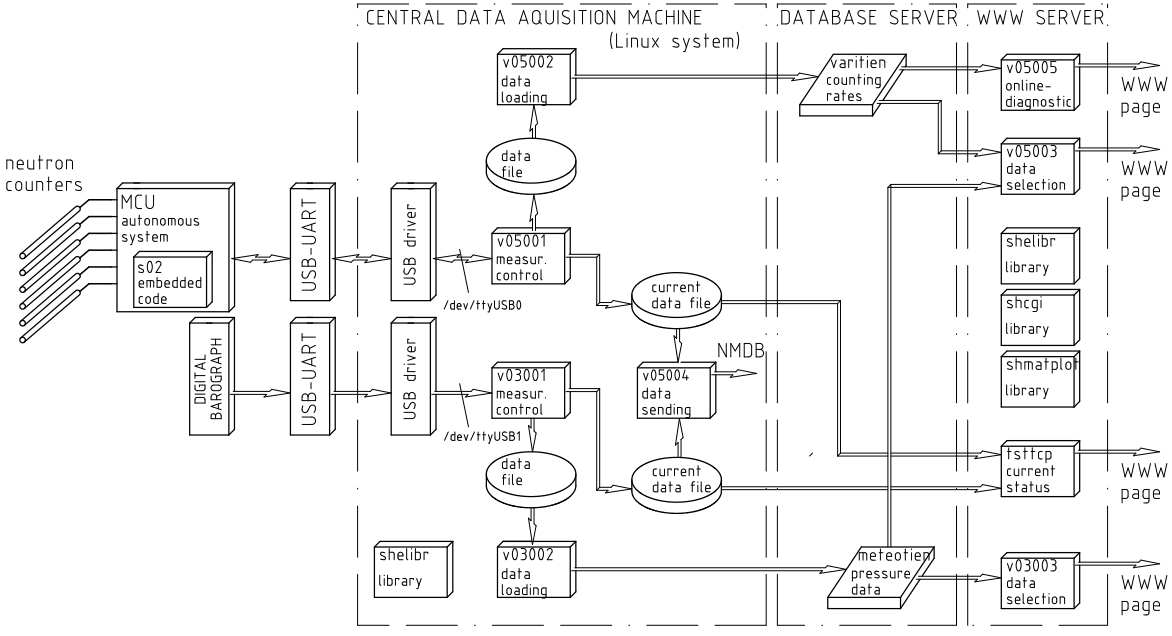


High-resolution time series of neutron signal after a 10^{17} EAS core passage through the neutron monitor.

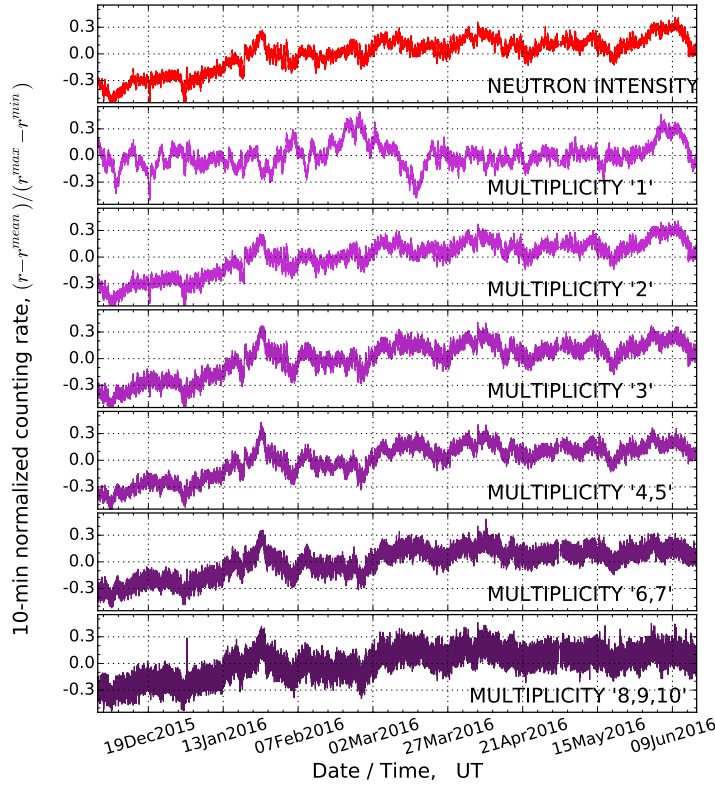
The compact neutron monitor data registration system

- prototypic set-up

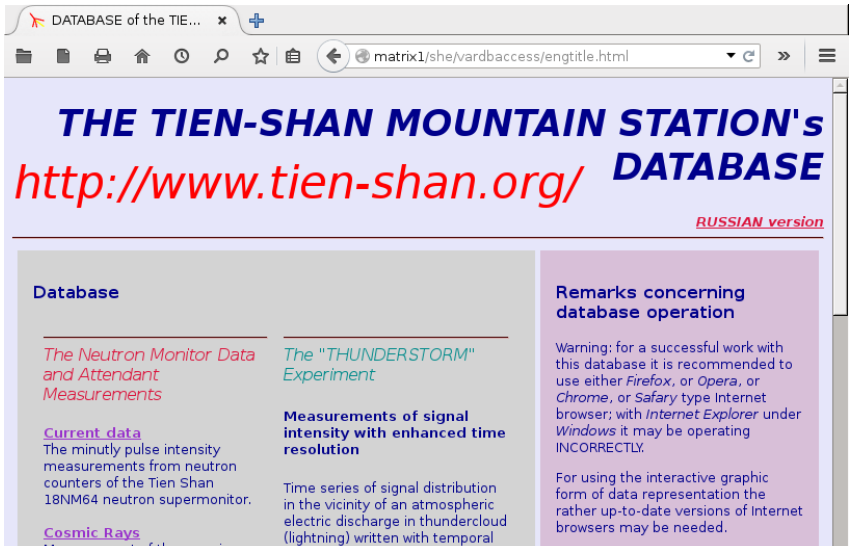
- block diagram of software complex

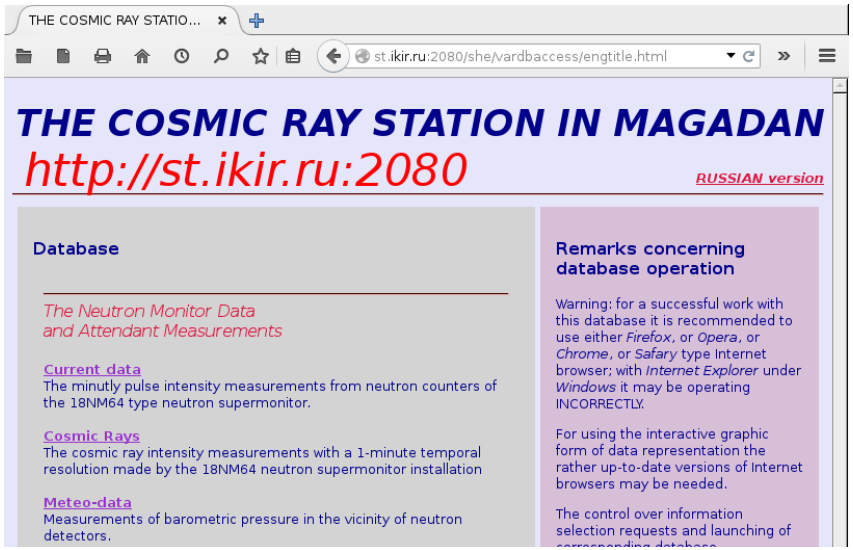


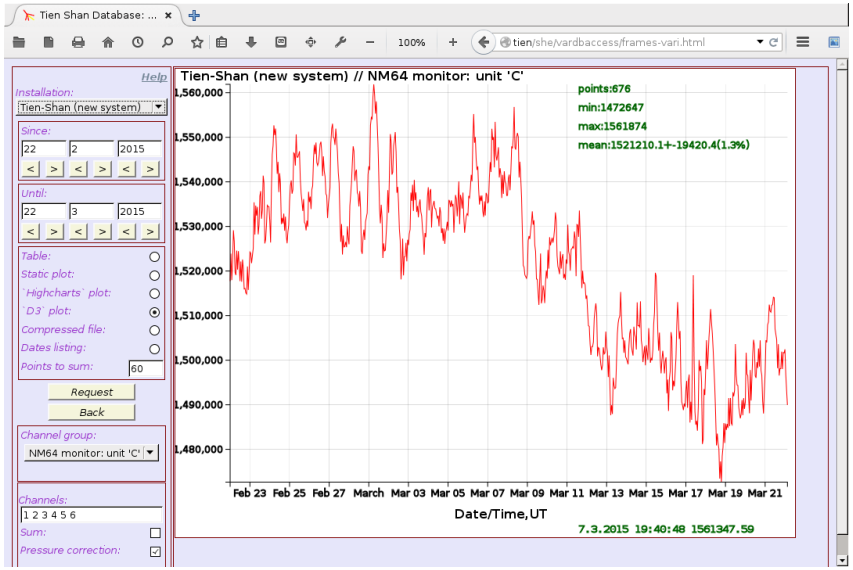
- a sample of a half-year long data set

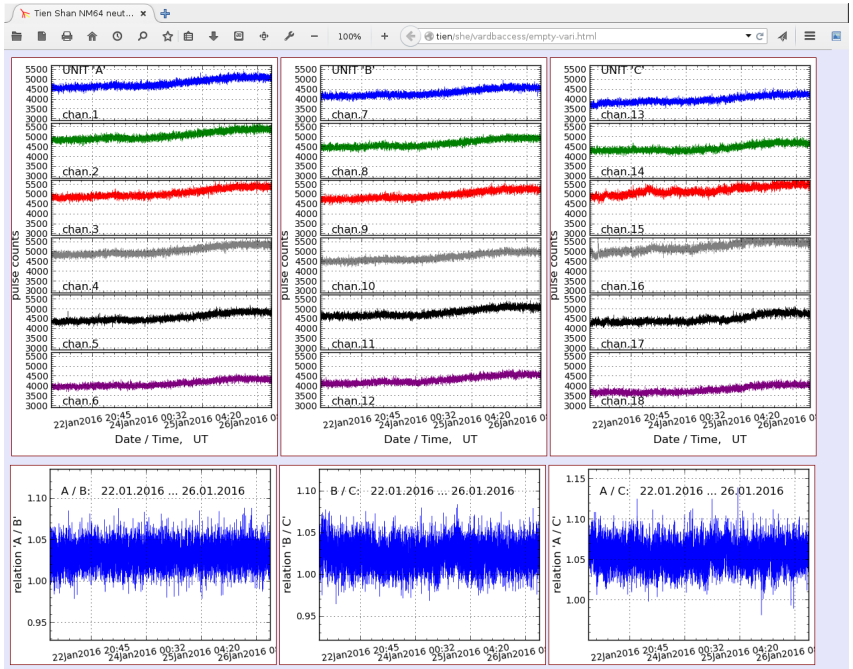


An output sample of the neutron monitor database

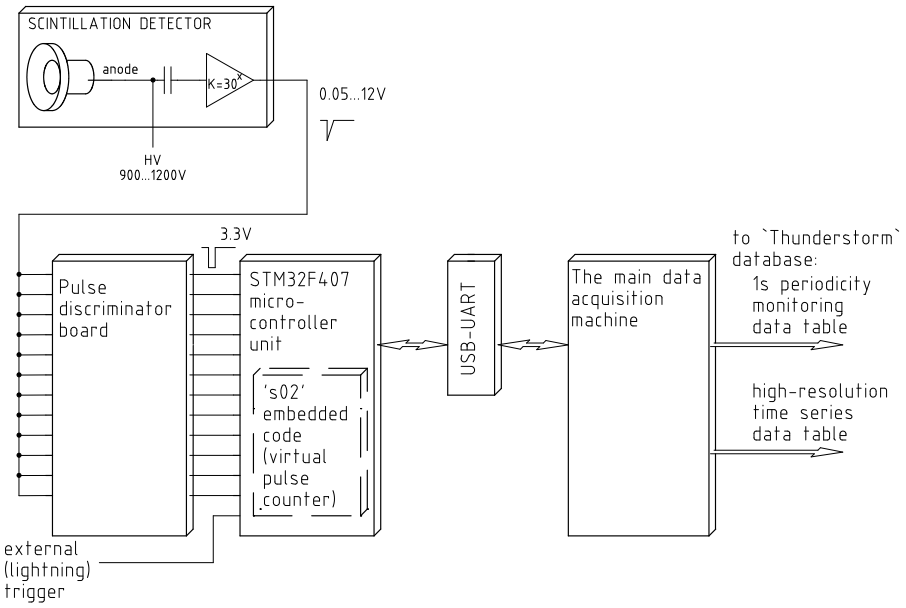




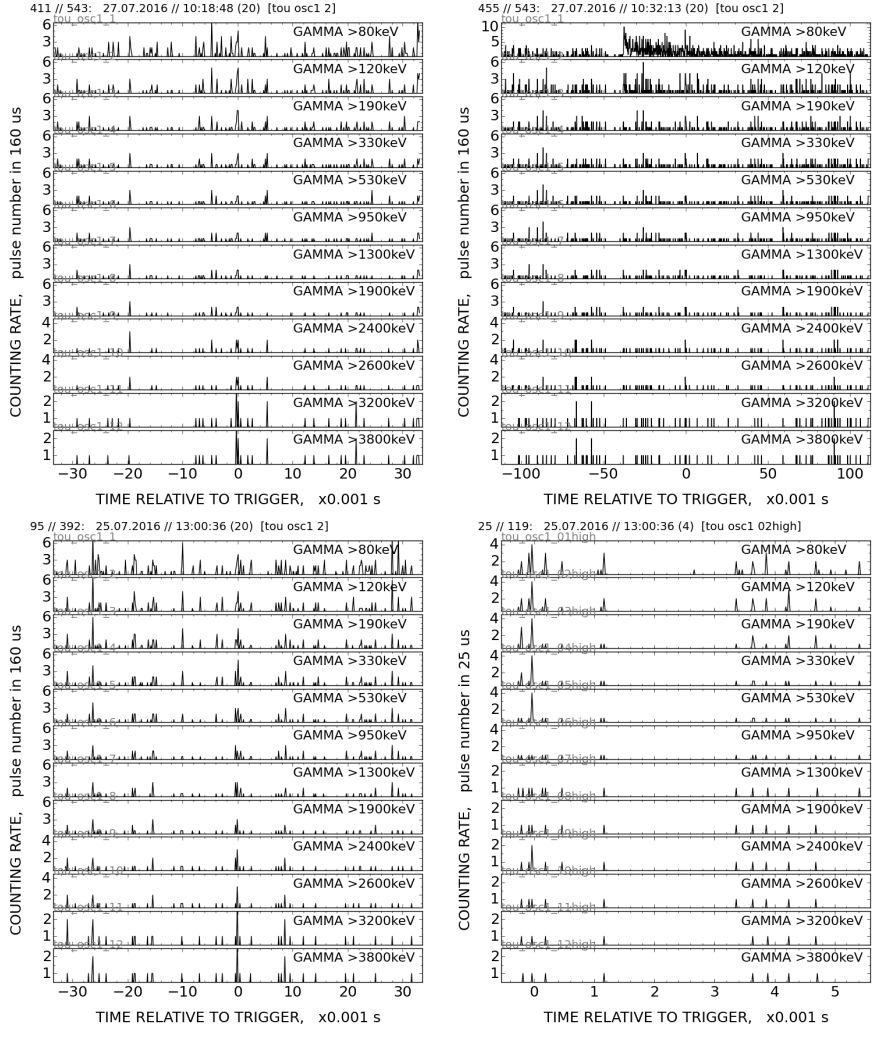




Use case: remote gamma-ray detector (3750 m a.s.l.)

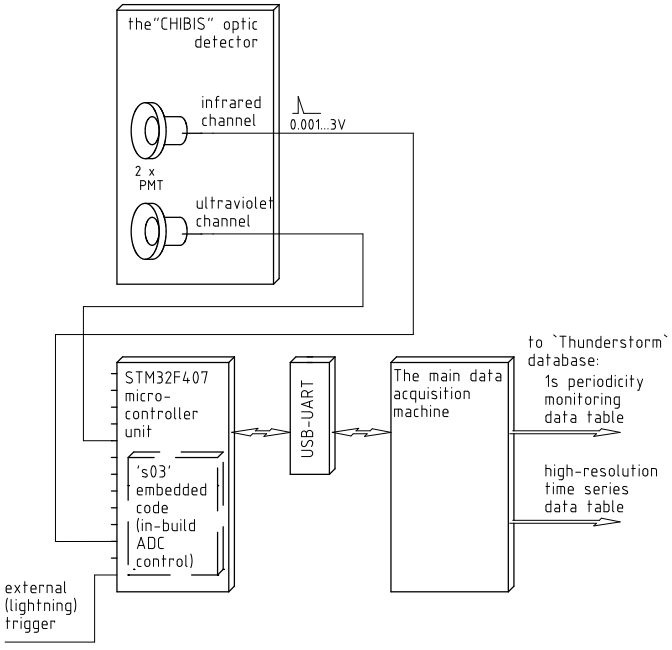


The remote detector point in vicinity of a mountain peak (400 m above the level of Tien Shan station; 3750 m a.s.l.), electromagnetically shielded scintillation gamma-ray detector with autonomous powering installed in this point, and its compact, microprocessor based data acquisition system.

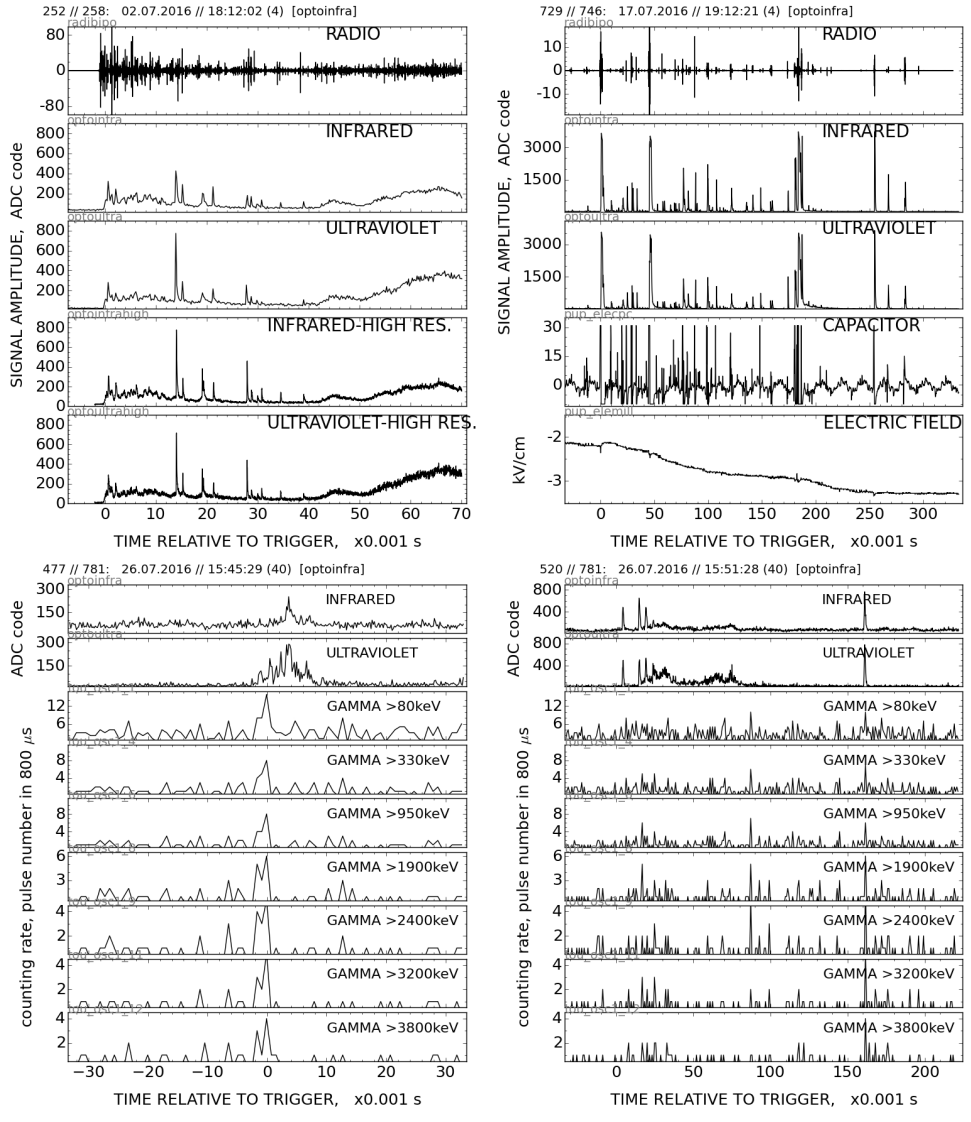


A sample of the events registered at remote detector point: time series of gamma-ray intensity written with a 160μs and 25μs resolution around the moment of nearby lightning discharge (at $T = 0$).

Use case: analogue signal of the optic lightning emission



- registration of distant lightning emission during the night time in infrared and ultraviolet diapasons;
- synchronization either with internal or external (lightning) trigger;
- simultaneous registration of input signal intensity with a low (190μs) and high (20μs) time resolution.



Time series of lighting emission measured simultaneously with a 190μs and 20μs (*HIGH RES*) time resolutions. Development of lightning discharge can be traced by intensity of its attendant radio-signal (*RADIO* panels, 10μs resolution).

CONCLUSION

- the modern cheap MCU based technique is perspective for mass application in experimental cosmic ray physics;
- its effective use was checked practically in a number of experiments held at Tien Shan in 2015–2017 years, including the long term & high stability neutron monitor signal registration.