THE SEARCH FOR NEUTRON SIGNAL FROM LIGHTNING DISCHARGES AT TIEN SHAN

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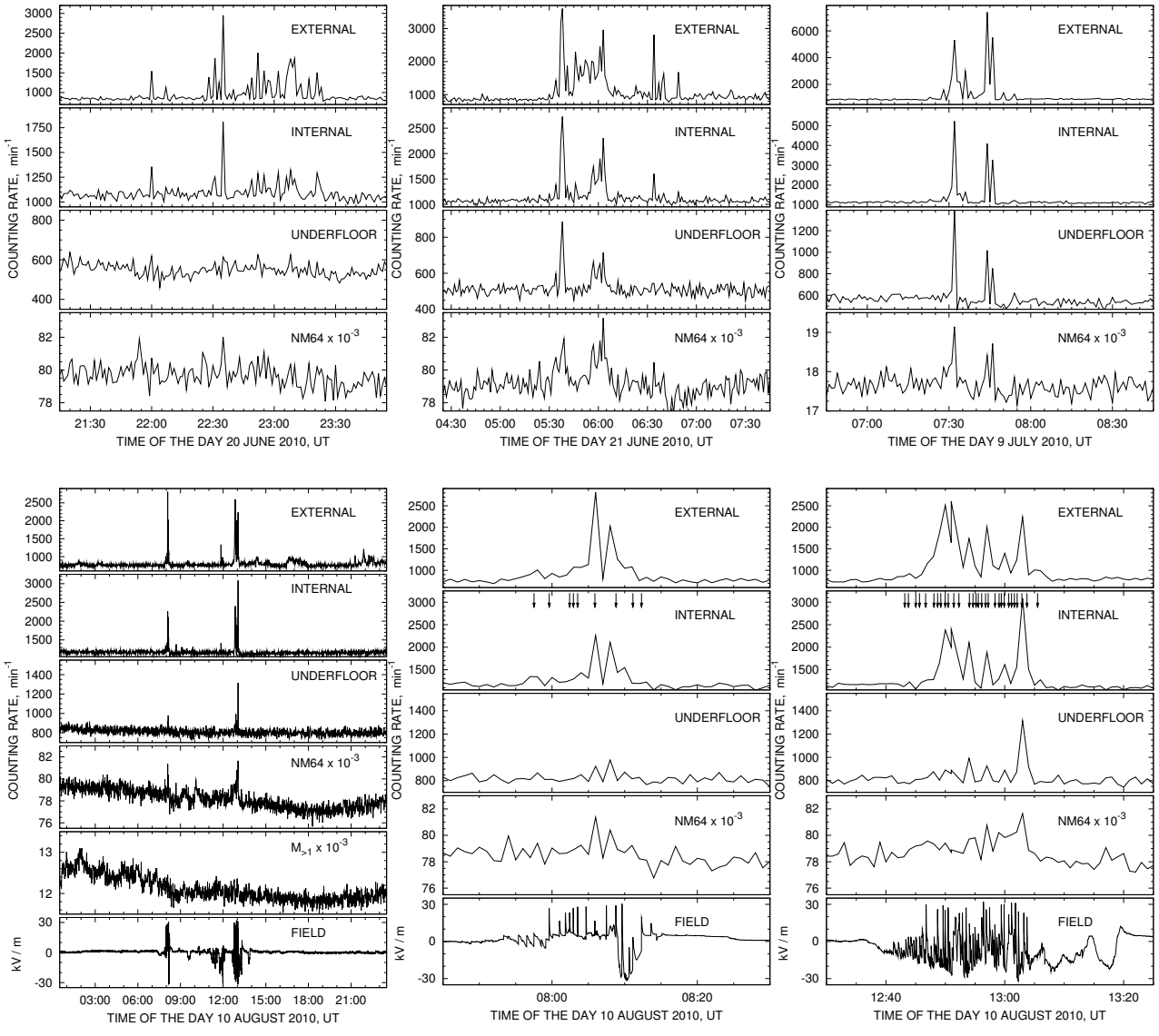
2016

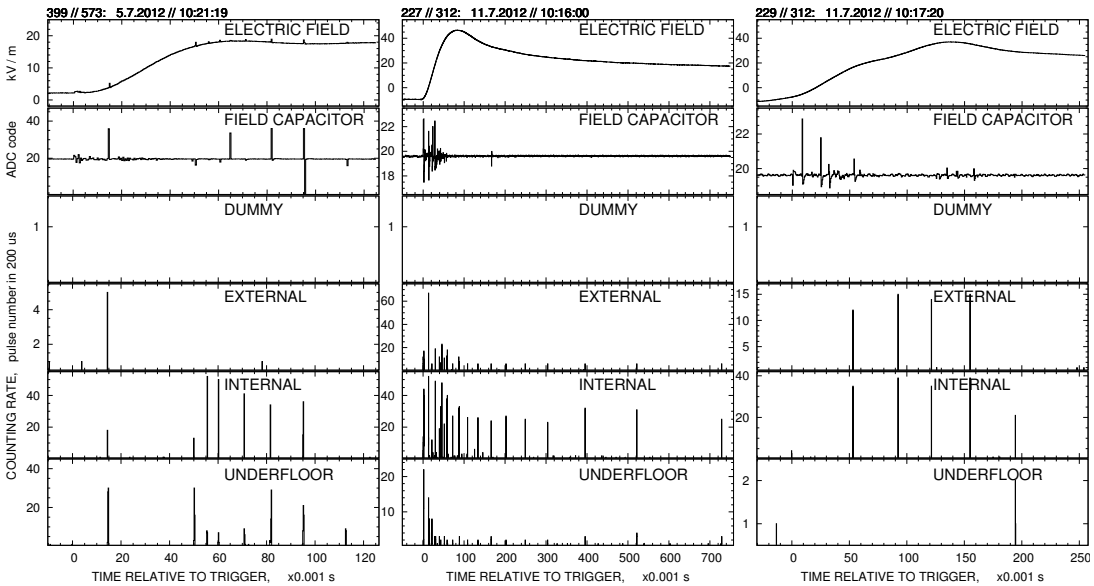
CONTENT

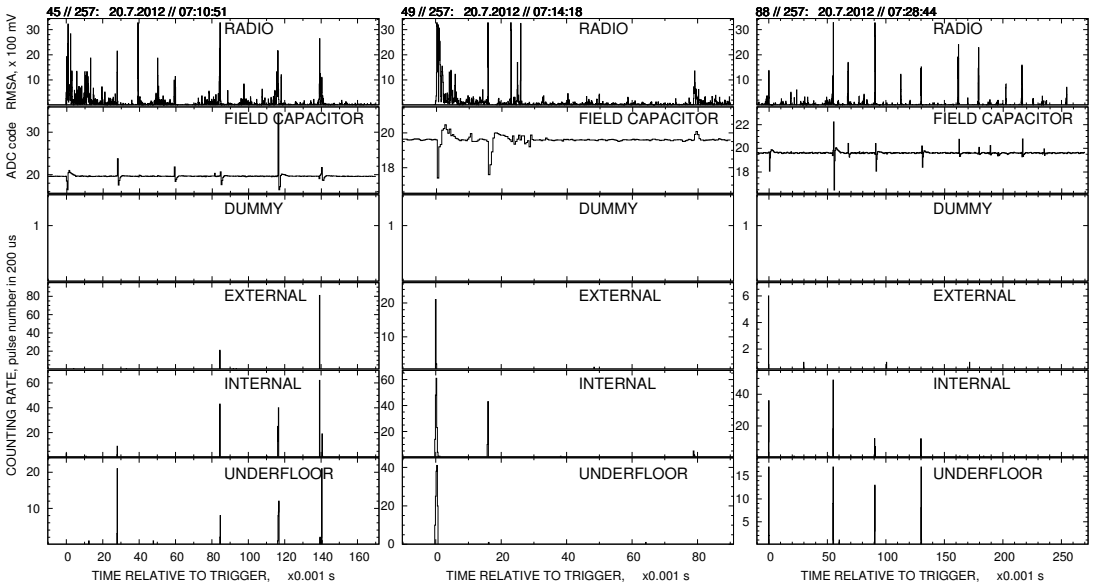
- The history of neutron detector signal investigation at Tien Shan in thunderstorm times (what's done? – 2010–2013):
  * the neutron intensity variation in the NM64 supermonitor;
  * high-resolution intensity measurements with a lightning trigger;
  * efficiency calculations for the Tien Shan neutron detectors;
  * estimations of the typical neutron energy and momentary neutron flux at lightning discharges.
- The modern scheme of Tien Shan neutron experiments:
  * the newly designed detector set-ups for accurate neutron registration under thunderstorm conditions;
  * the registration of neutron data and procedure of their operation.
- Experimental results on the search for neutron signals at thunderstorm times in 2015-2016 seasons.

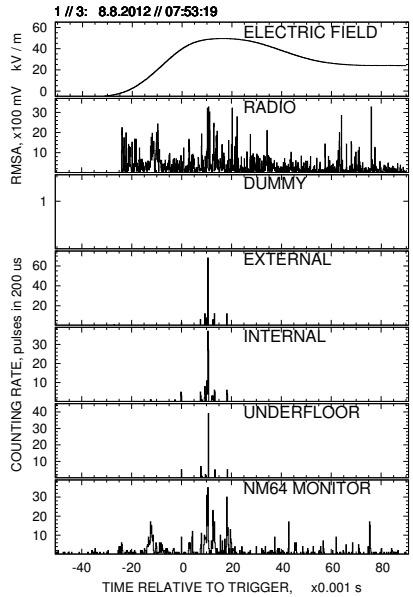
2010: an increase of the signal from Tien Shan neutron detectors at thunderstorm time

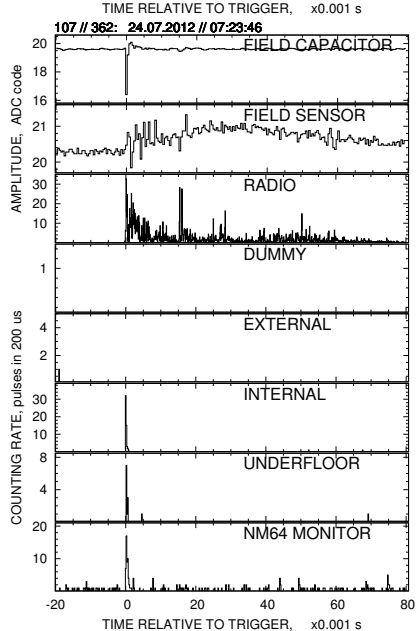


2011–2012: neutron intensity measurements with enhanced temporal resolution

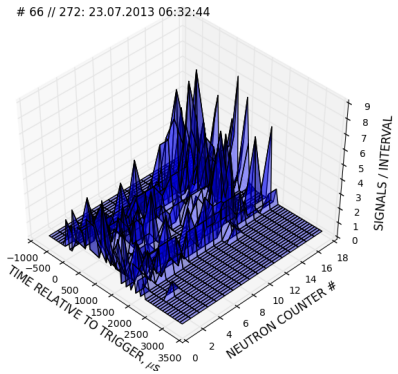


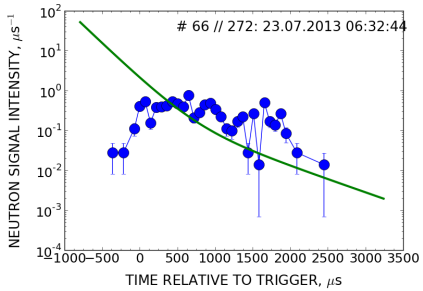


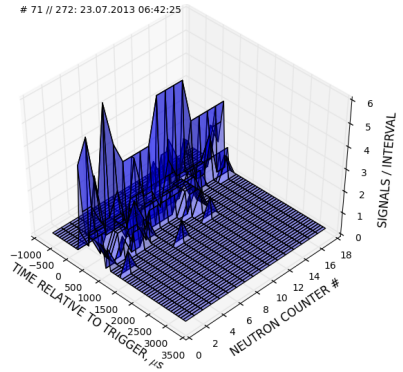


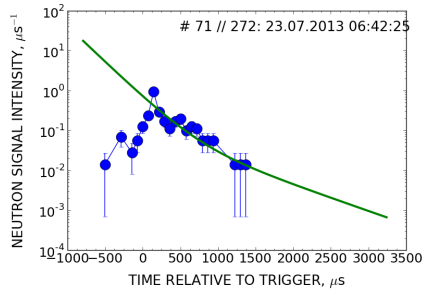


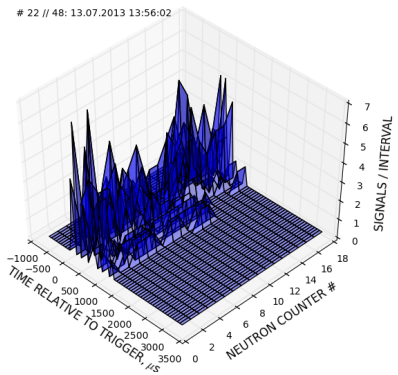
2013: precise registration of the neutron monitor signal

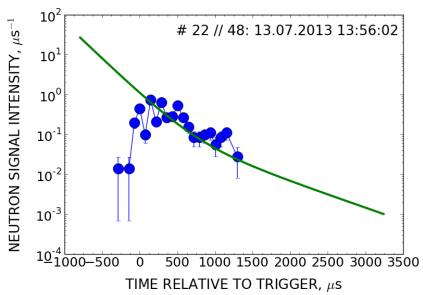


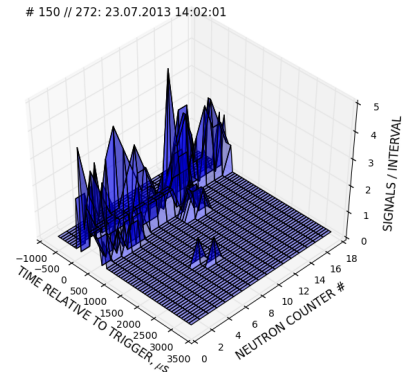


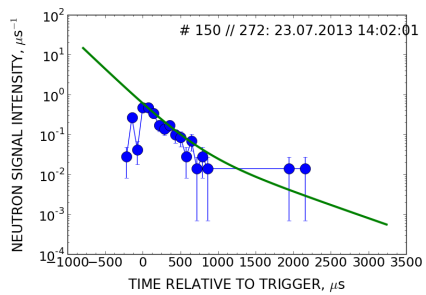


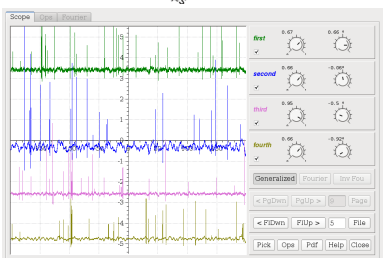


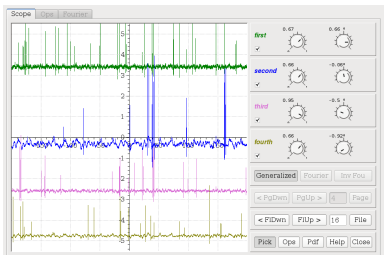


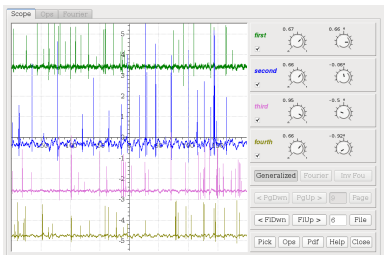


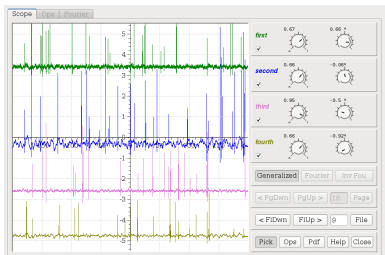


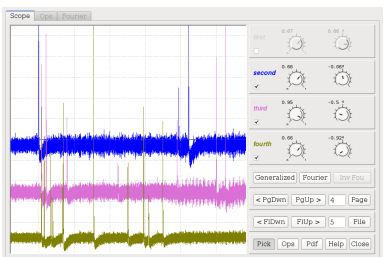


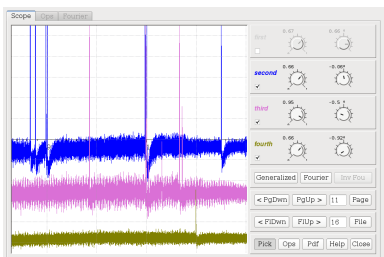


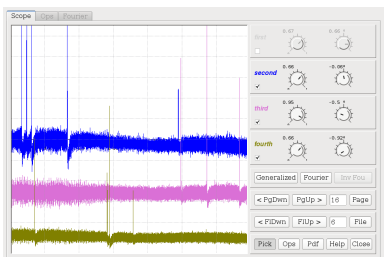


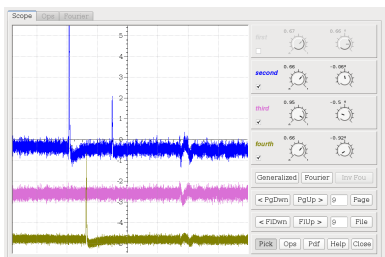




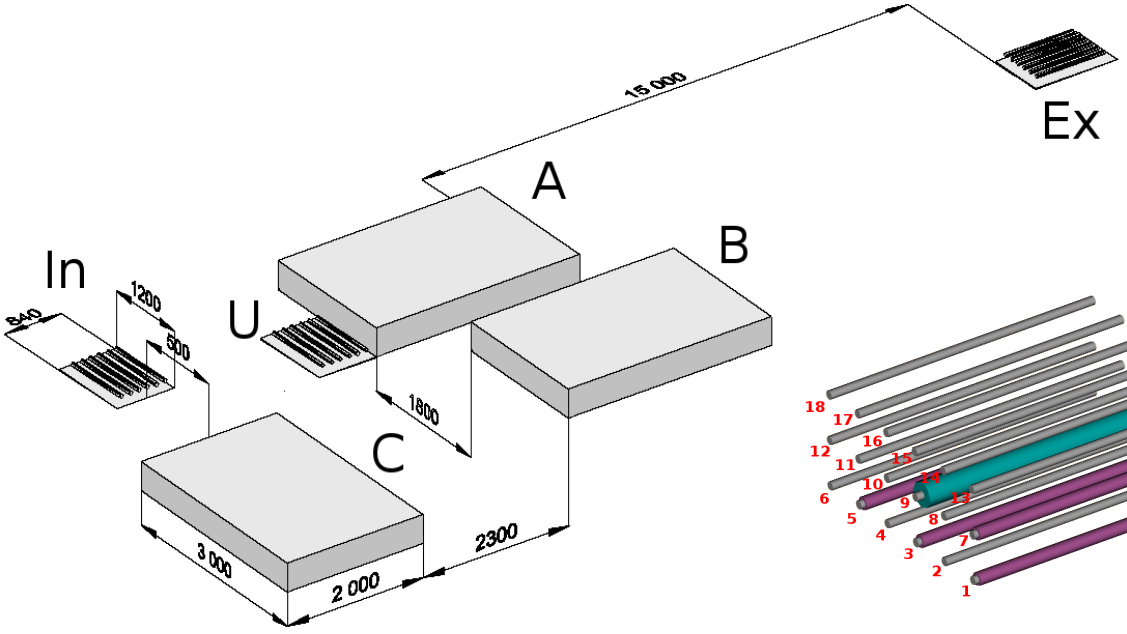


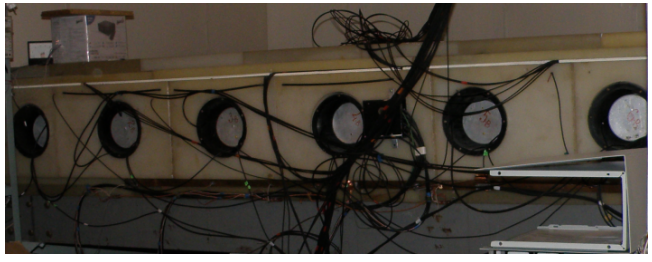






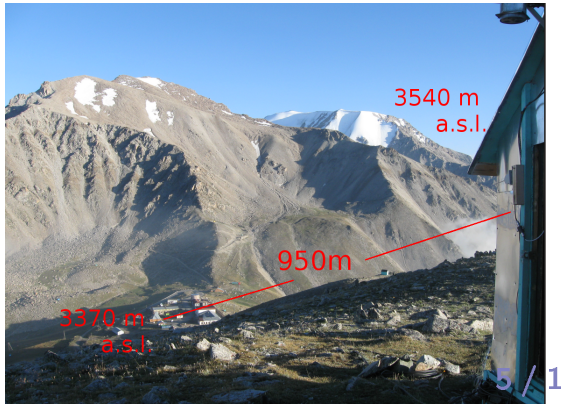
Tien Shan neutron detector set-ups in 2010–2013



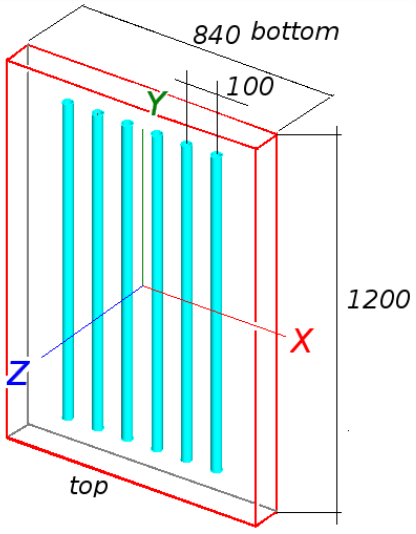


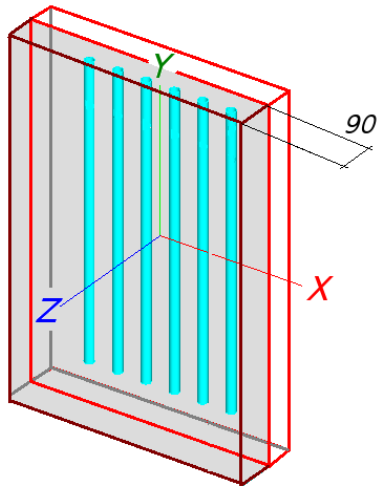
Neutron detectors:

- External (*Ex*);
- Internal (*In*);
- Underfloor (rubber shielded, *U*);
- the NM64 type neutron monitor (three units: *A*, *B*, *C*);
- neutron counters in *160M* detector point(*PUP*, 2013).

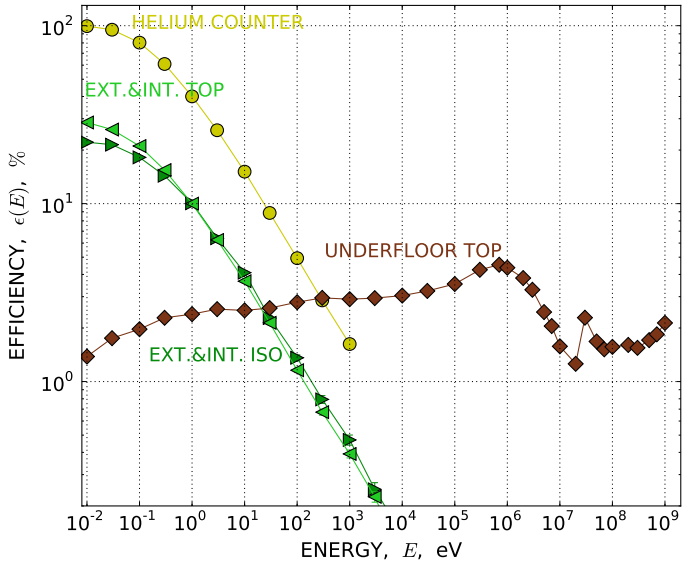


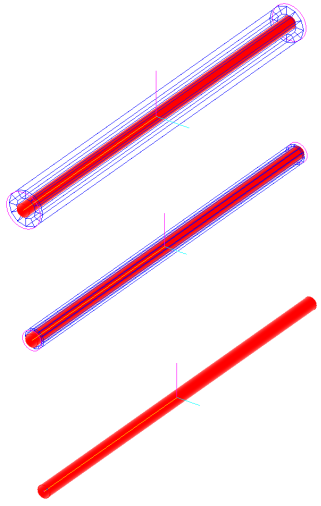
Calculations of the neutron detection efficiency (*Geant4*)

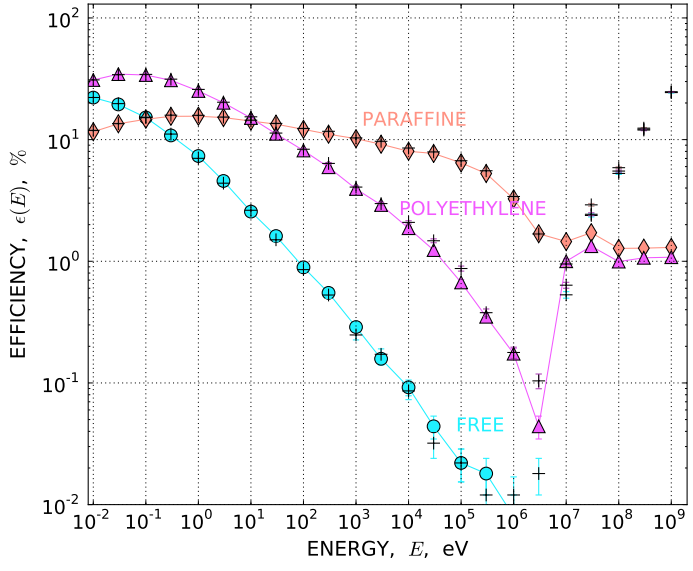




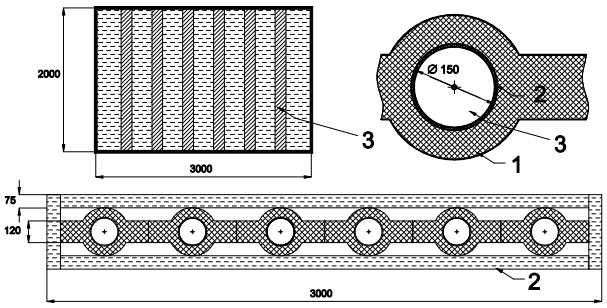
$$n + {}^3He \rightarrow {}^3H + p$$

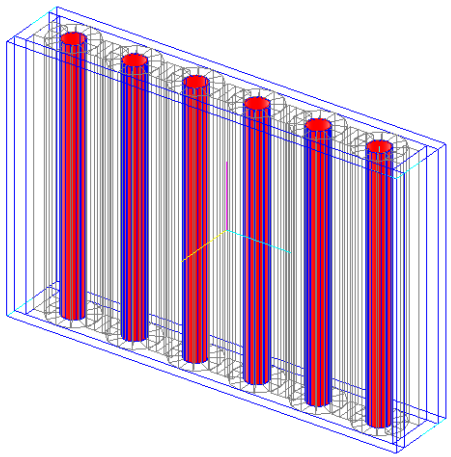




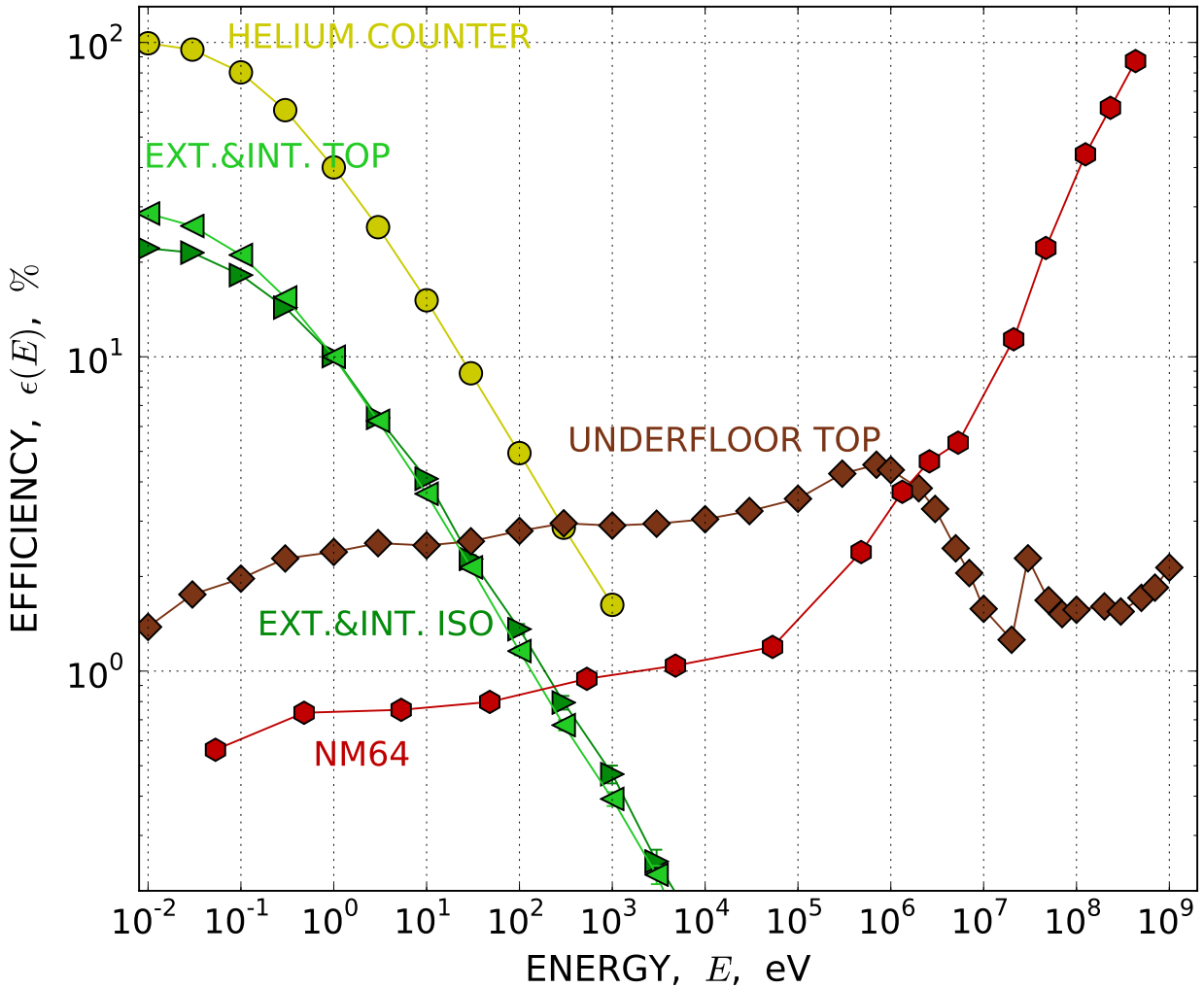


Efficiency of the neutron supermonitor (*Geant4*)

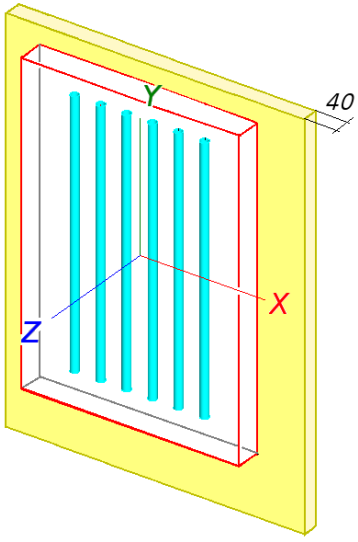


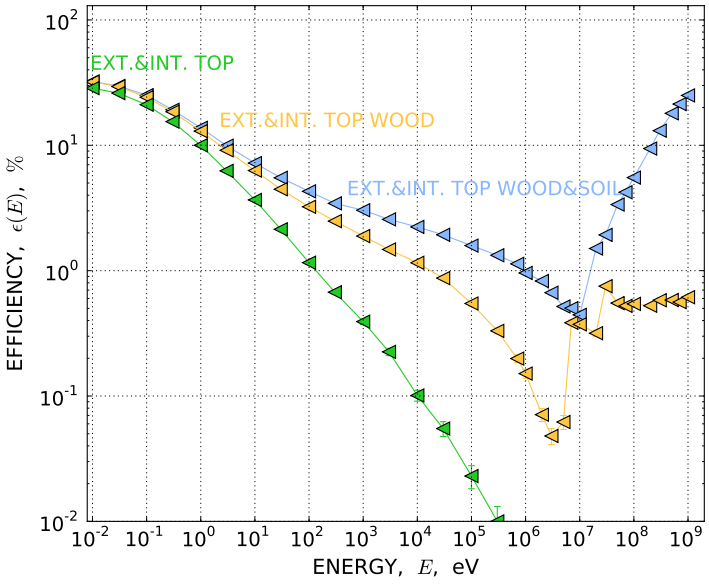


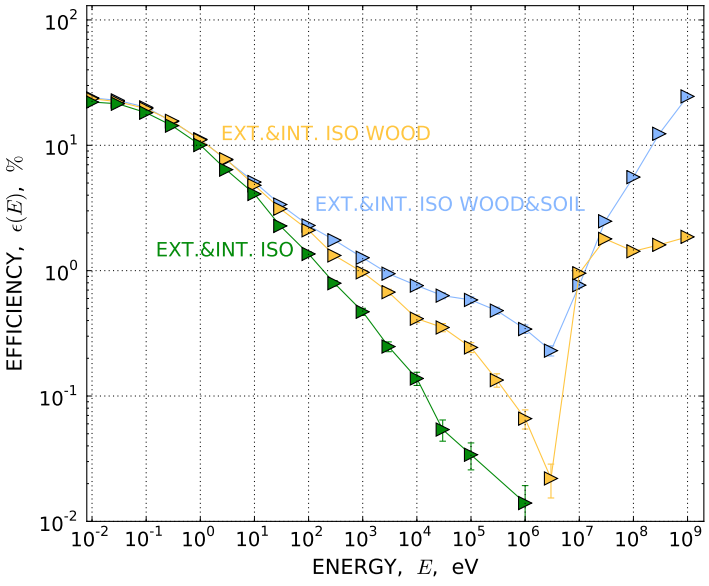
$$n + {}^{10}B \rightarrow {}^{7}Li + \alpha$$

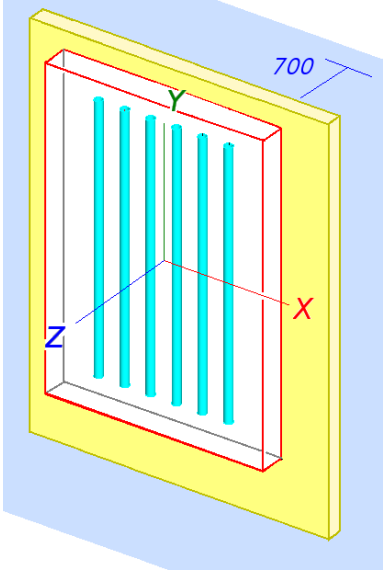


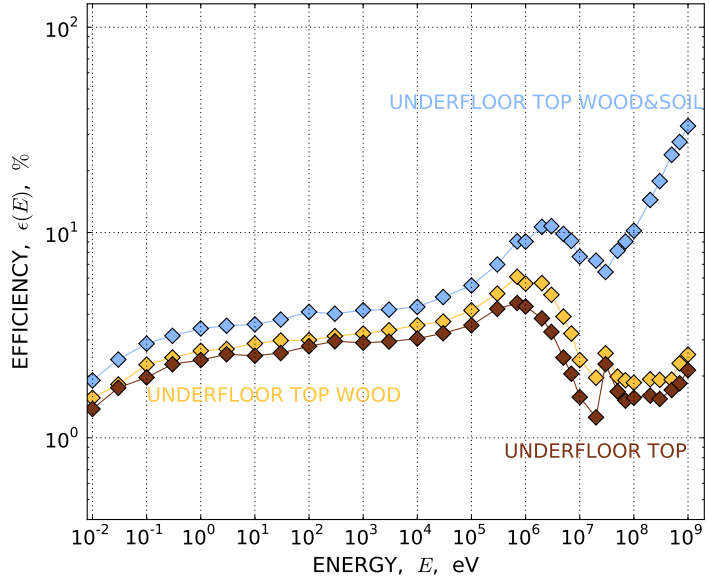
Neutron detectors & outer environment (*Geant4*)

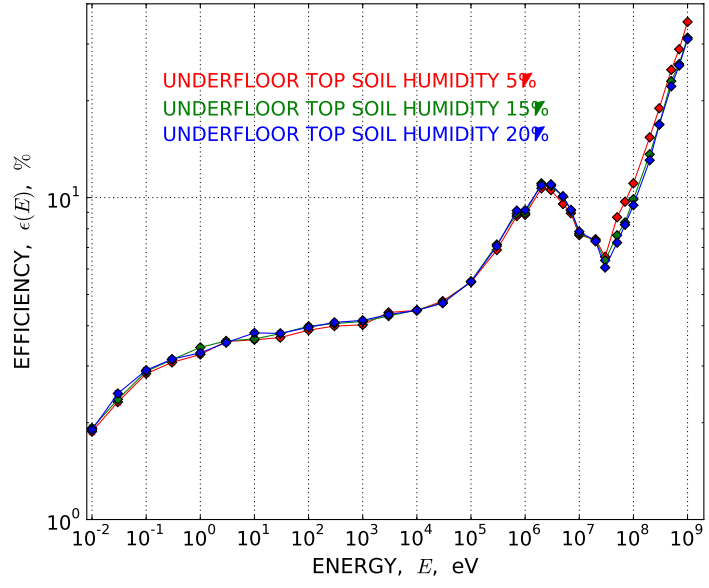




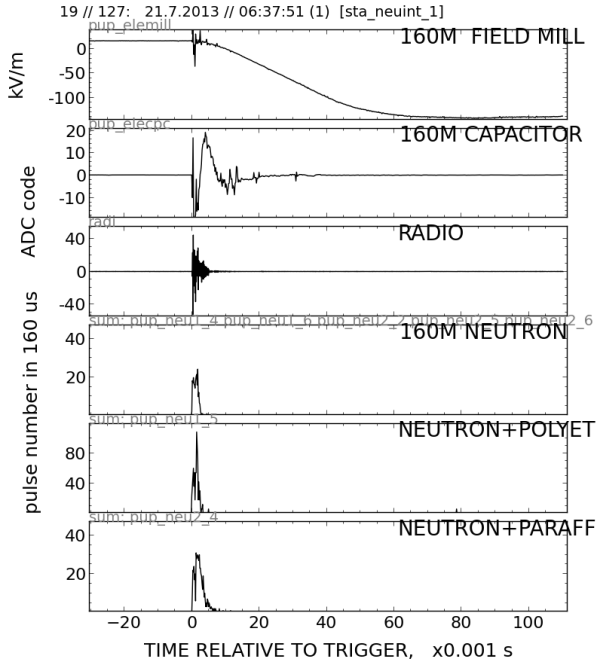


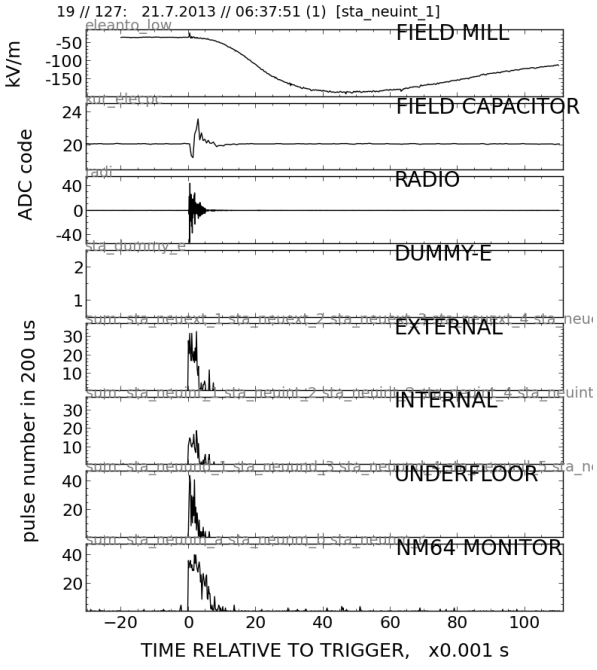


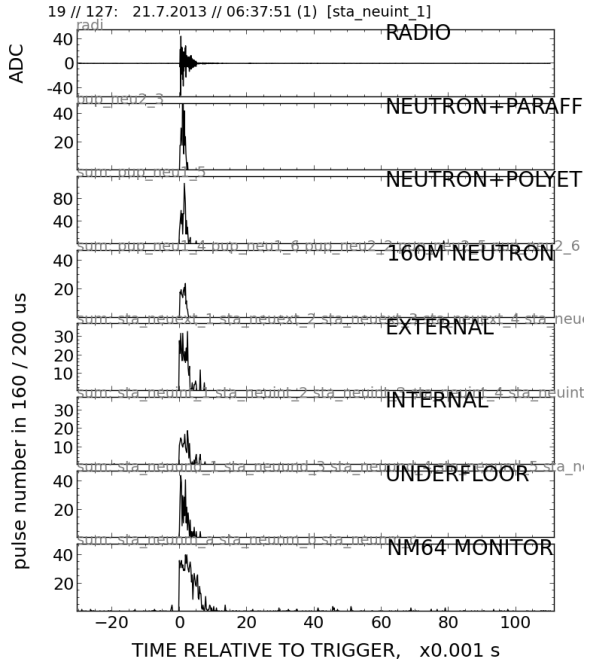


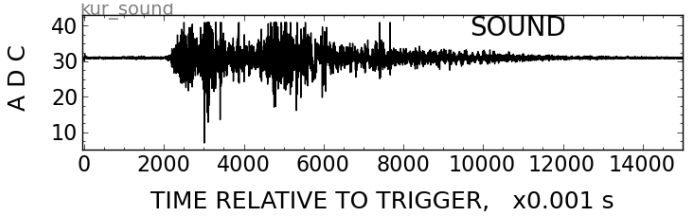


Effective energy and fluence of the neutron flux

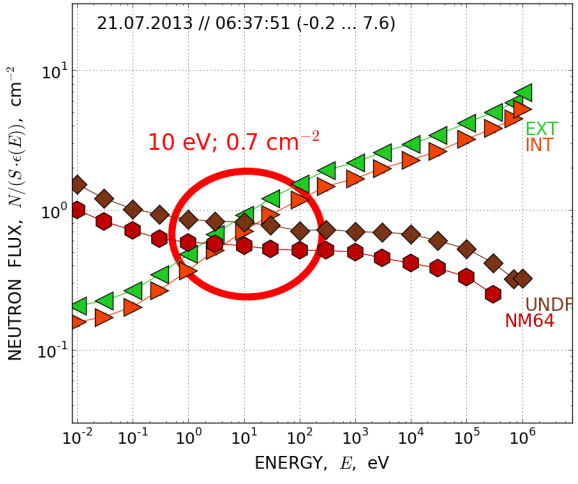


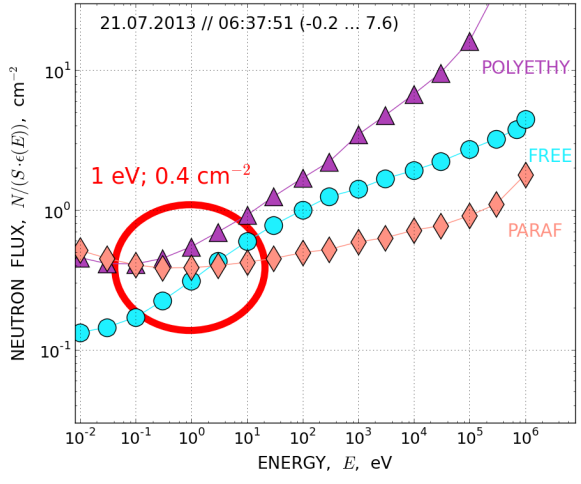




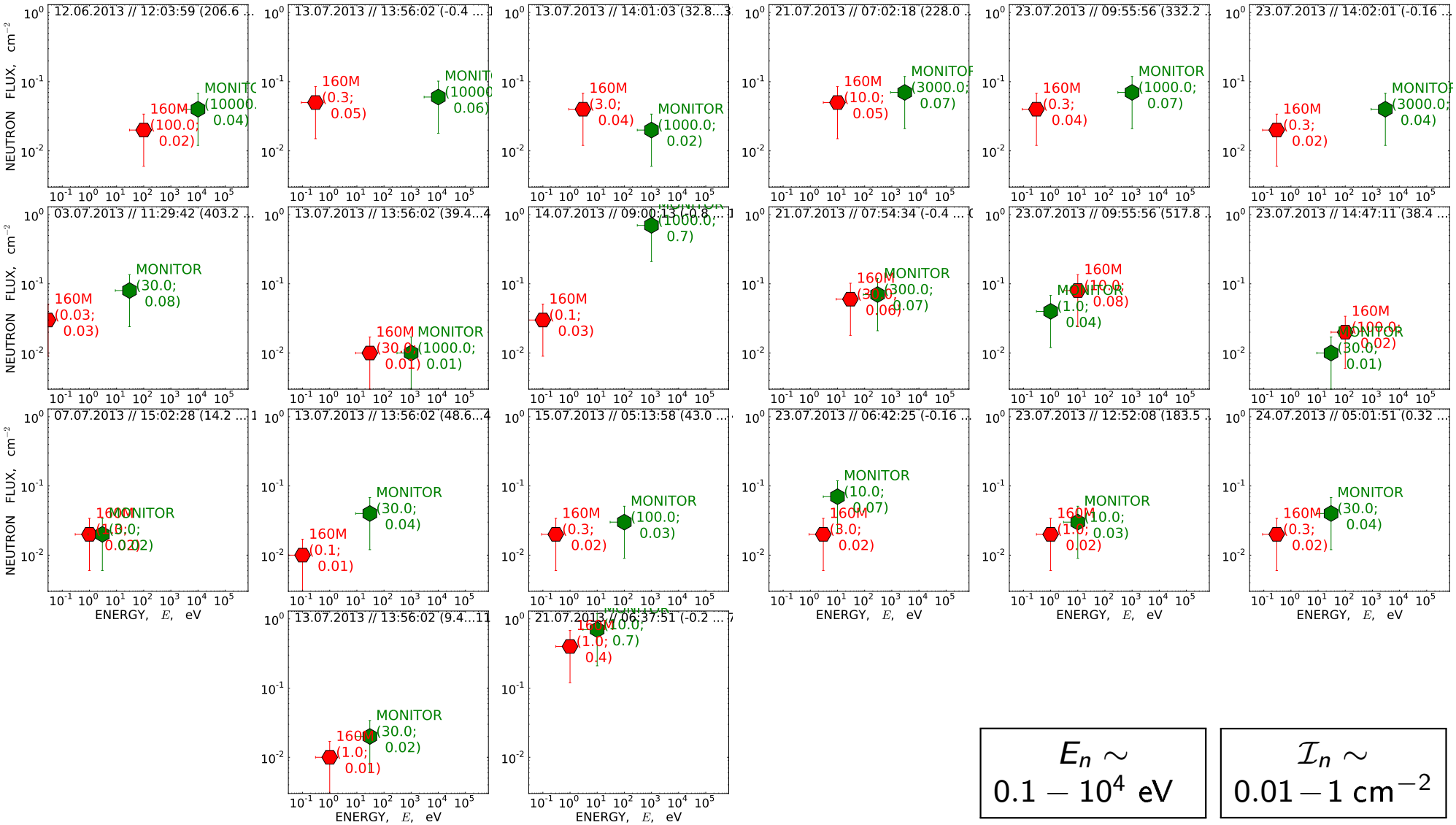


$$F = N_p/(S \cdot \epsilon(E))$$





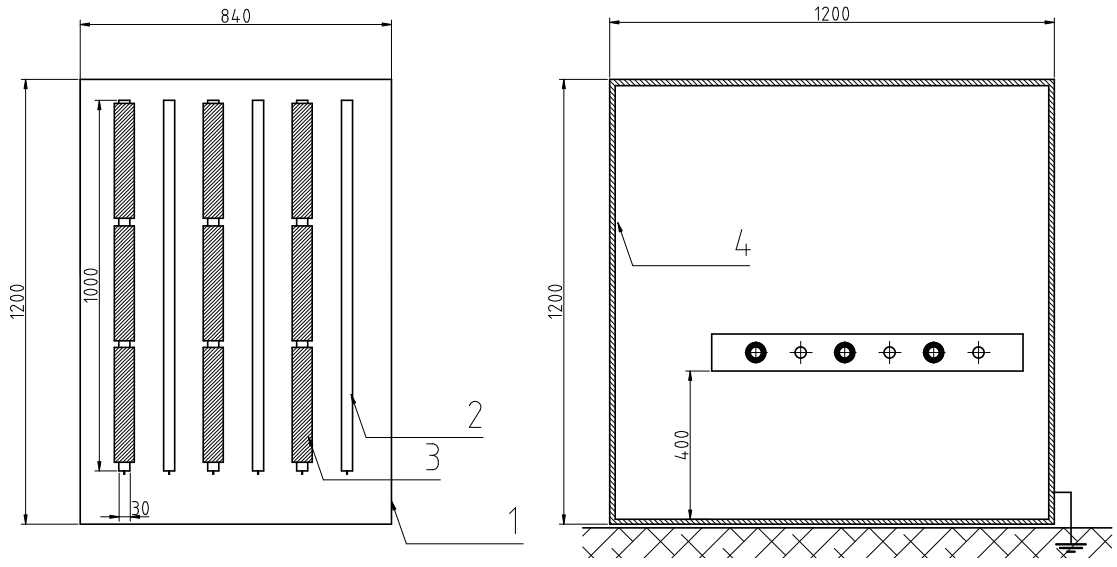
Fluence & energy estimations of transient neutron flashes

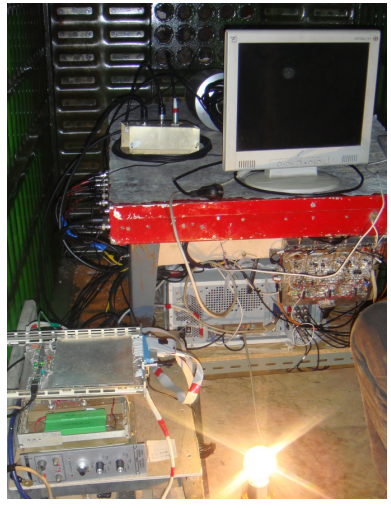


$E_n \sim$ $0.1 - 10^4$ eV

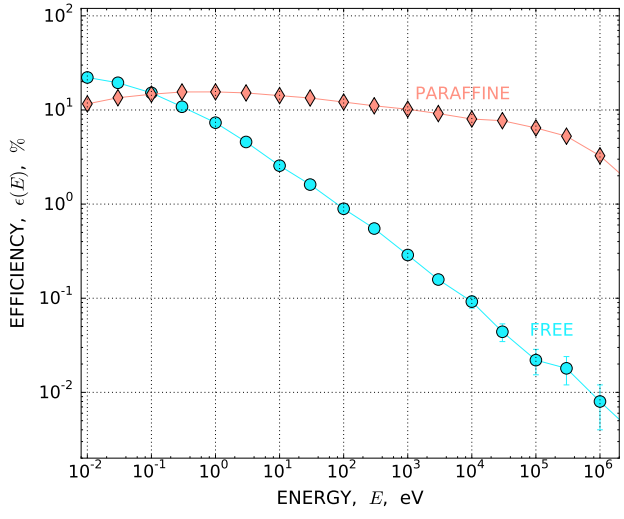
$\mathcal{I}_n \sim$ $0.01 - 1\ \mathrm{cm}^{-2}$

Current experiments – *I*: the *SHIELDED* neutron detector

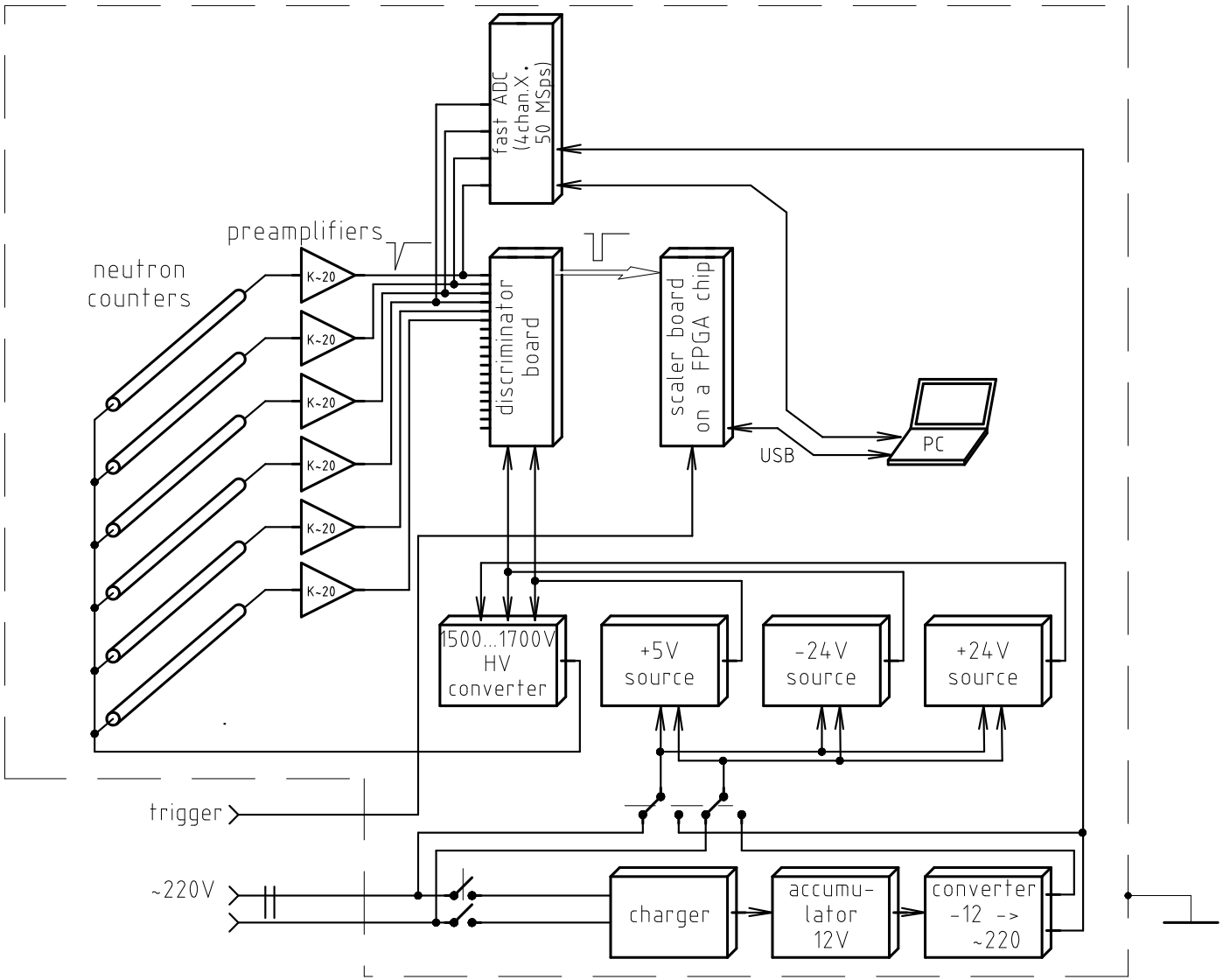




1 – aluminum box with 1 mm wall thickness;
2 – the "Helium-2"neutron counter,
3 – 10 mm thick paraffin moderator;
4 – the solid electromagnetic shielding of 2 mm iron sheets.

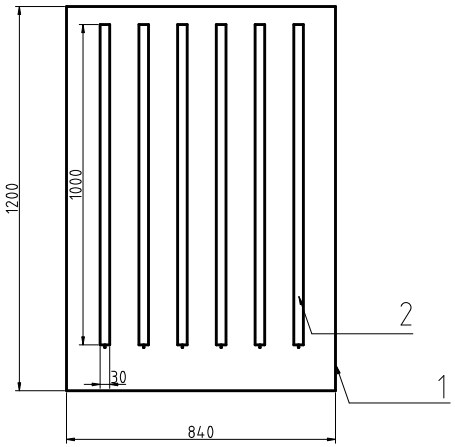


Shielded neutron detector: the basic operation principles

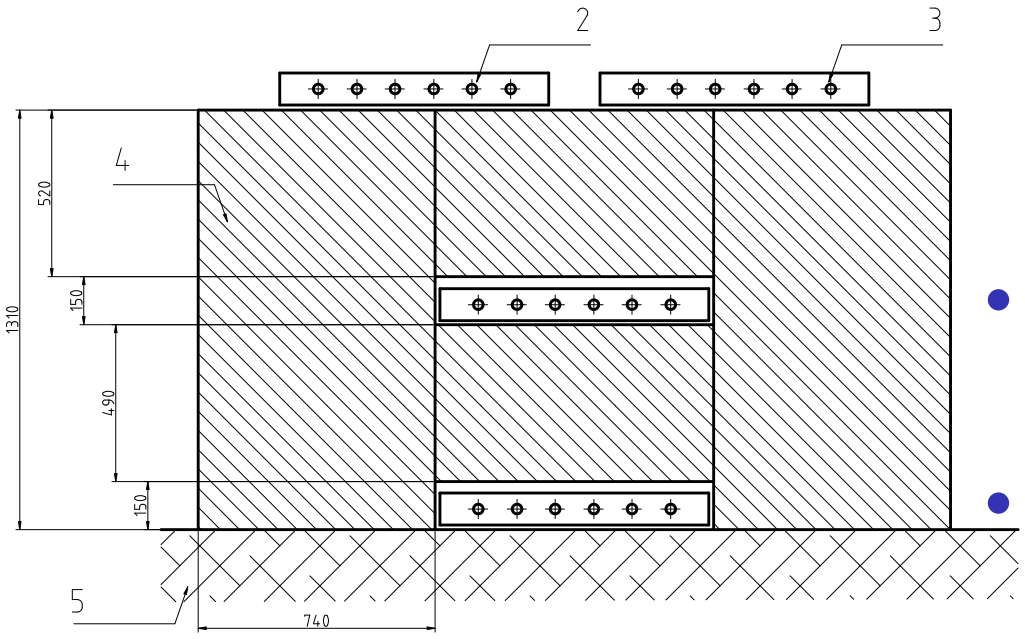


- 160 μs resolution of pulse intensity measurements;
- synchronization with lightning trigger;
- simultaneous check of the neutron signal waveform with a 20 ns resolution;
- simultaneous monitoring of pulse intensity variation with a 1–10 s resolution;
- fully autonomous powering from internal accumulator source in thunderstorm time.

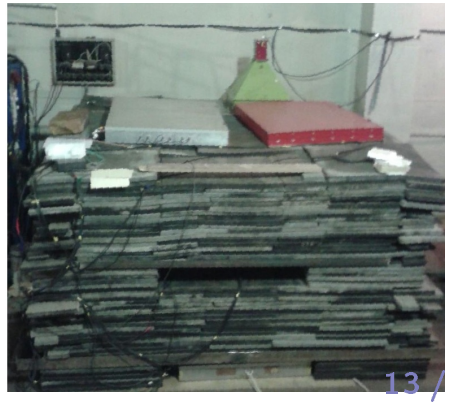
Current experiments – *II*: the neutron detector with *DEEP* absorber



- UPPER
- UPPER(SNM18)
- MIDDLE
- LOWER



1 – aluminum box with 1 mm wall thickness;
2 – the "Helium-2"neutron counter,
3 – the "SNM-18"neutron counter,
4 – neutron absorber/reflector of rubber $(C_2H_2)_n$;
5 – concrete floor.



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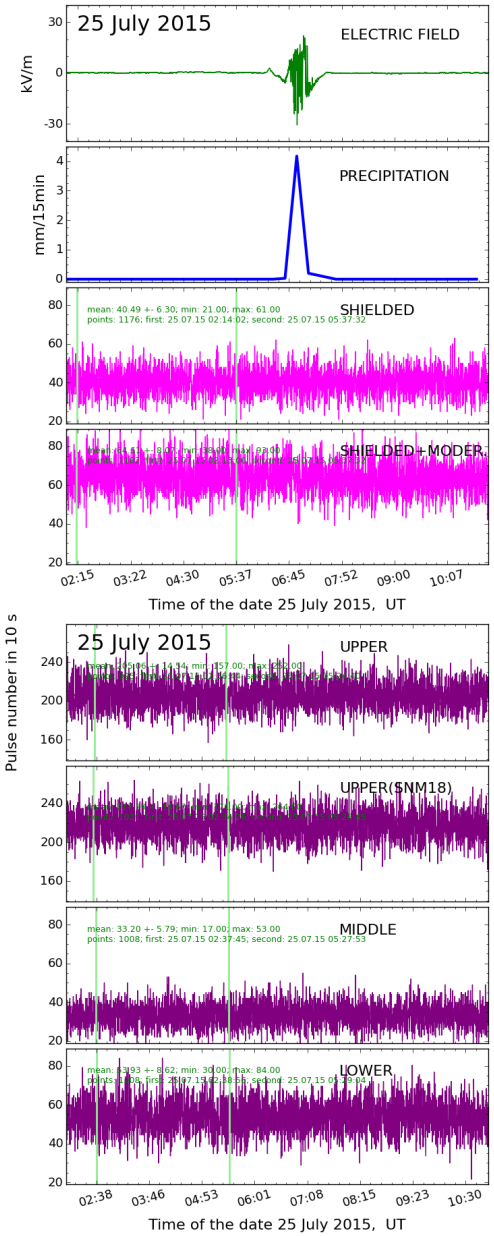

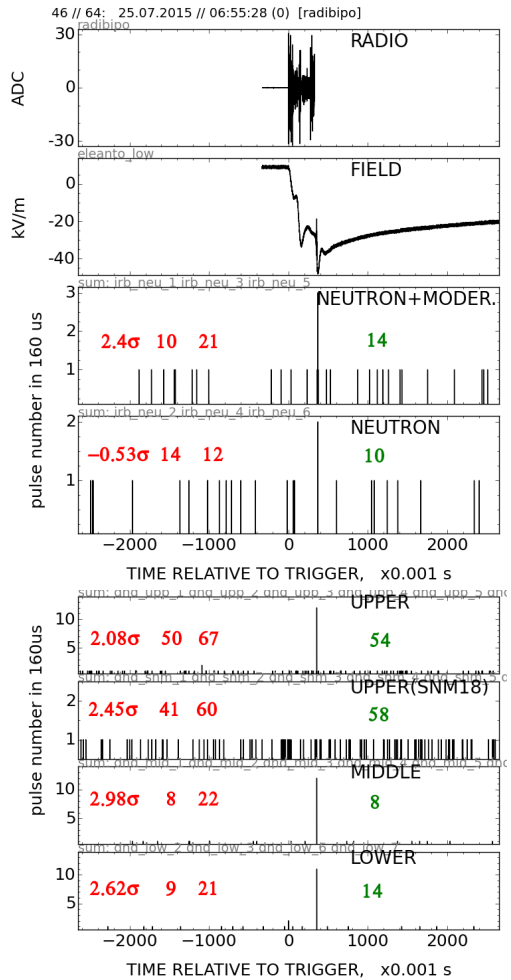

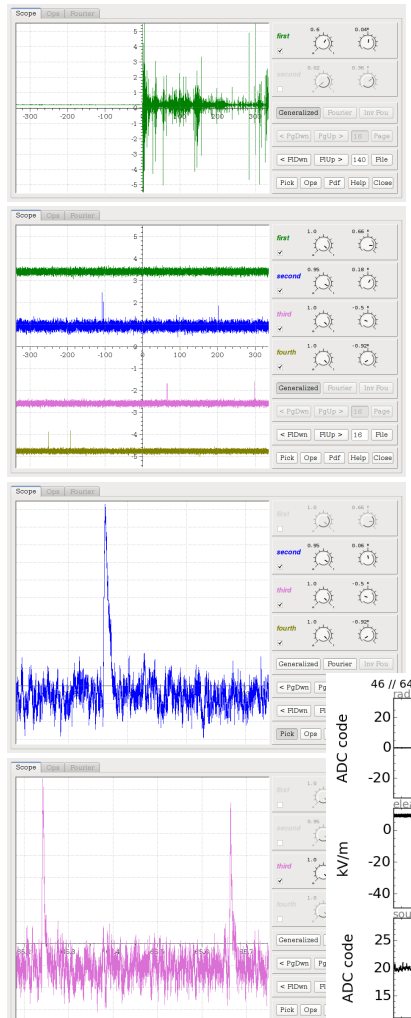

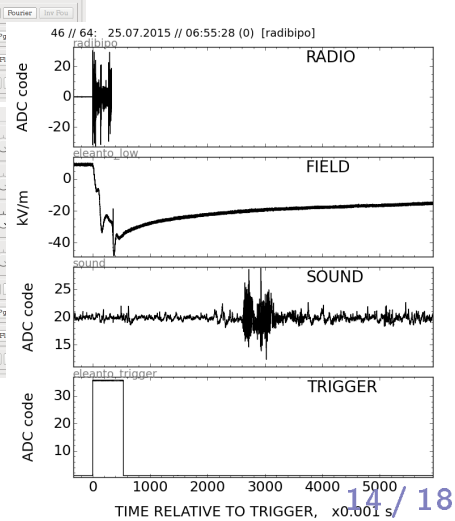

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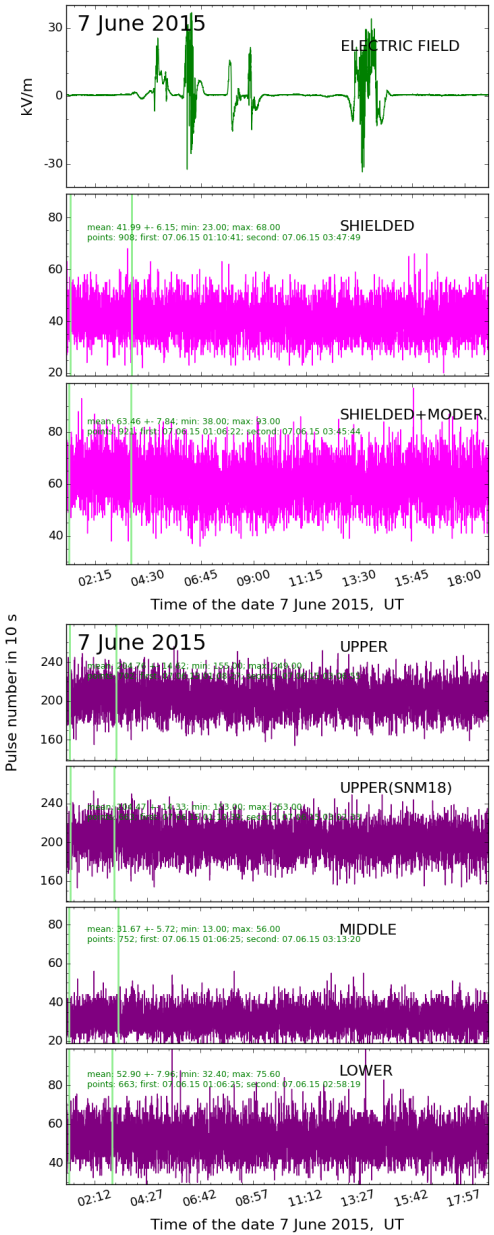
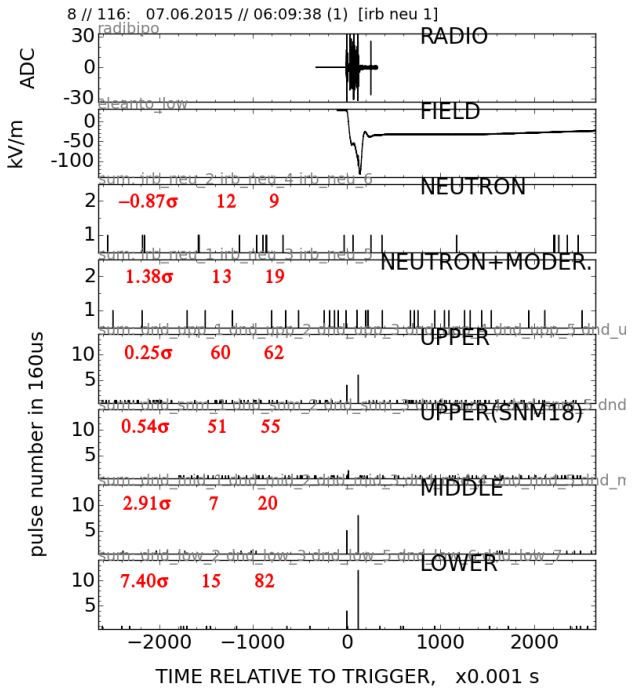
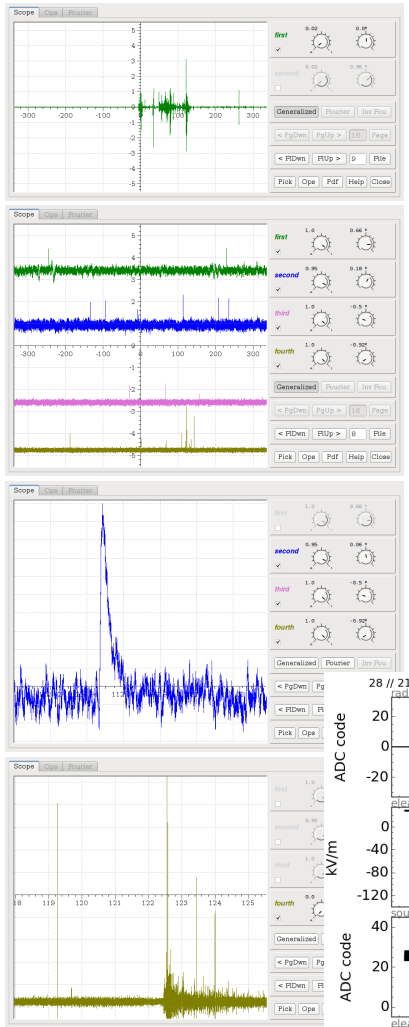
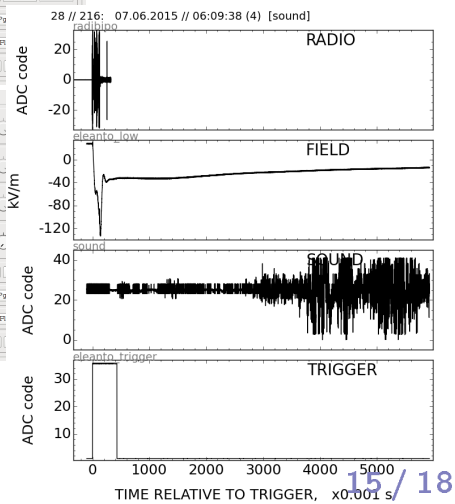
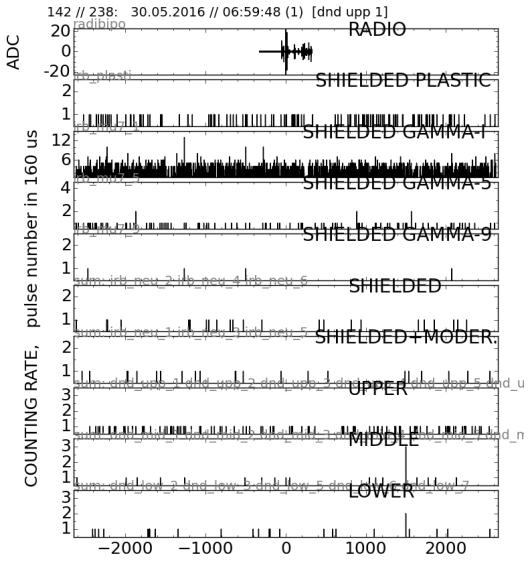


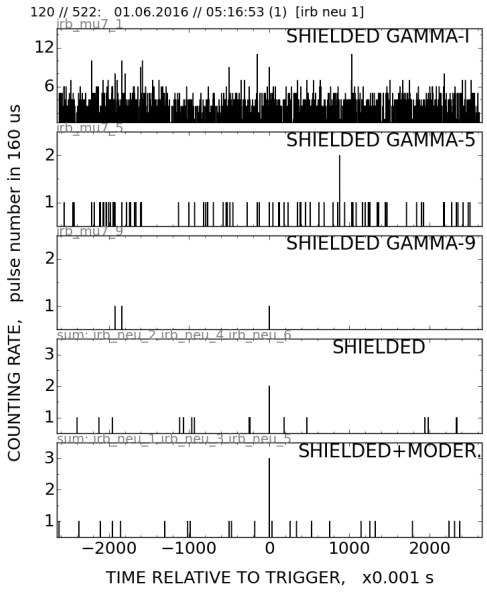


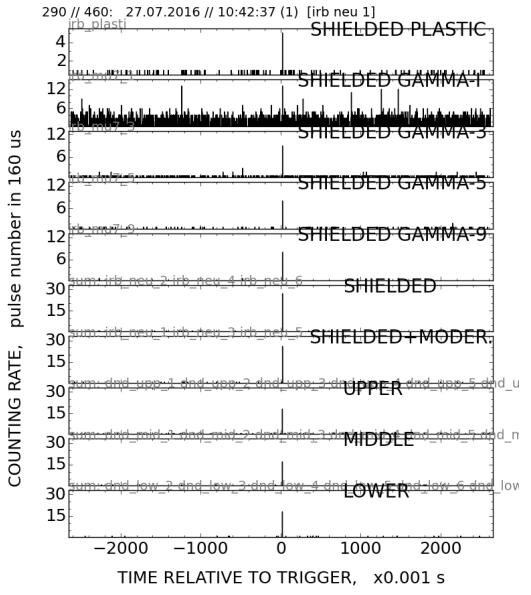


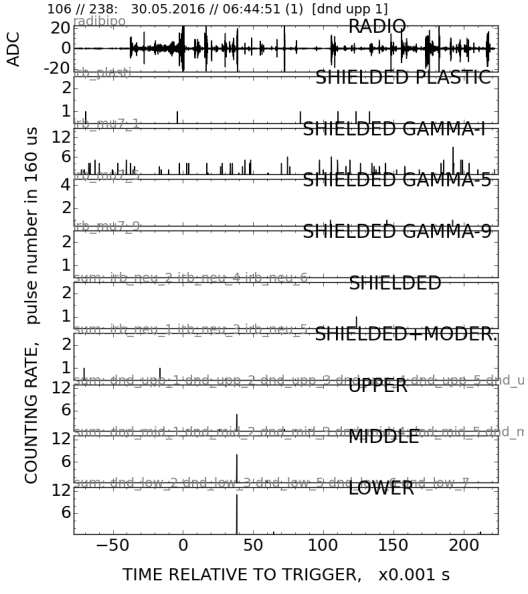


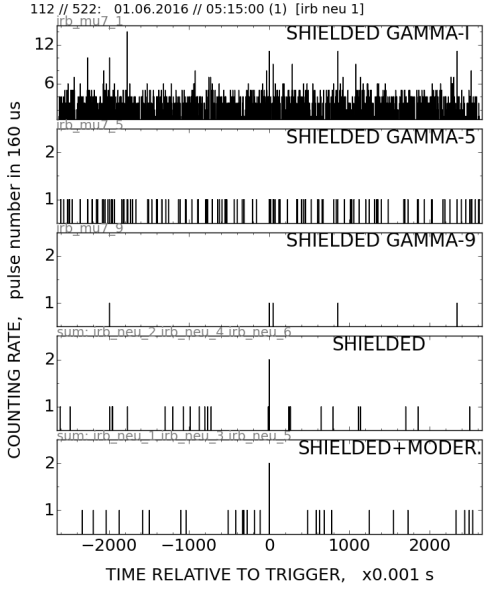
Neutron events of the 2016 summer season

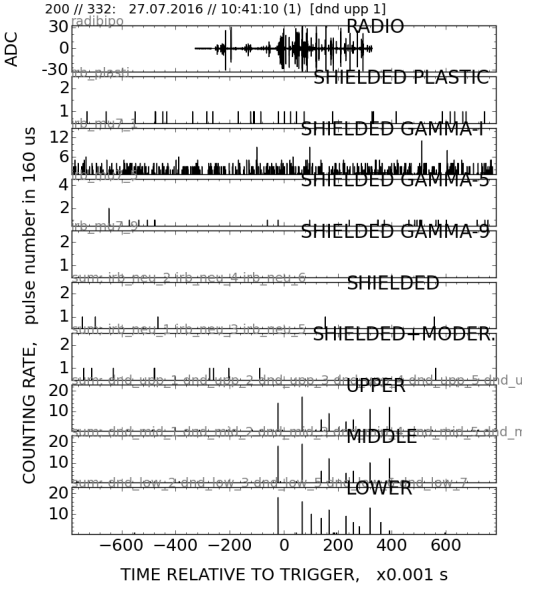












CONCLUSION

- the following results were obtained in previous measurements at Tien Shan for the transient neutron flux enhancements at the km-scale distance from the region of lightning discharge:
  * typical duration < 1 ms;
  * characteristic neutron energy in the limits of $0.1 - 10^4$ eV;
  * the fluence about $0.01 - 1$ neutron/cm^{-2}.

- to check reliability of these conclusions, at the present time (during the 2015-2016 summer seasons) the registration succeeds on a number of neutron detectors with advanced electromagnetic shielding and different operation conditions, and the set of newly obtained data is now under consideration.

As an afterward: the *ERG* experiment (LPI, Moscow)

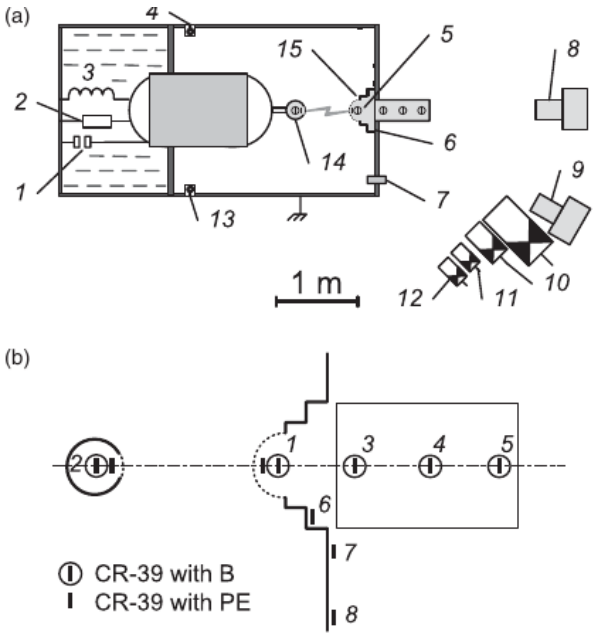
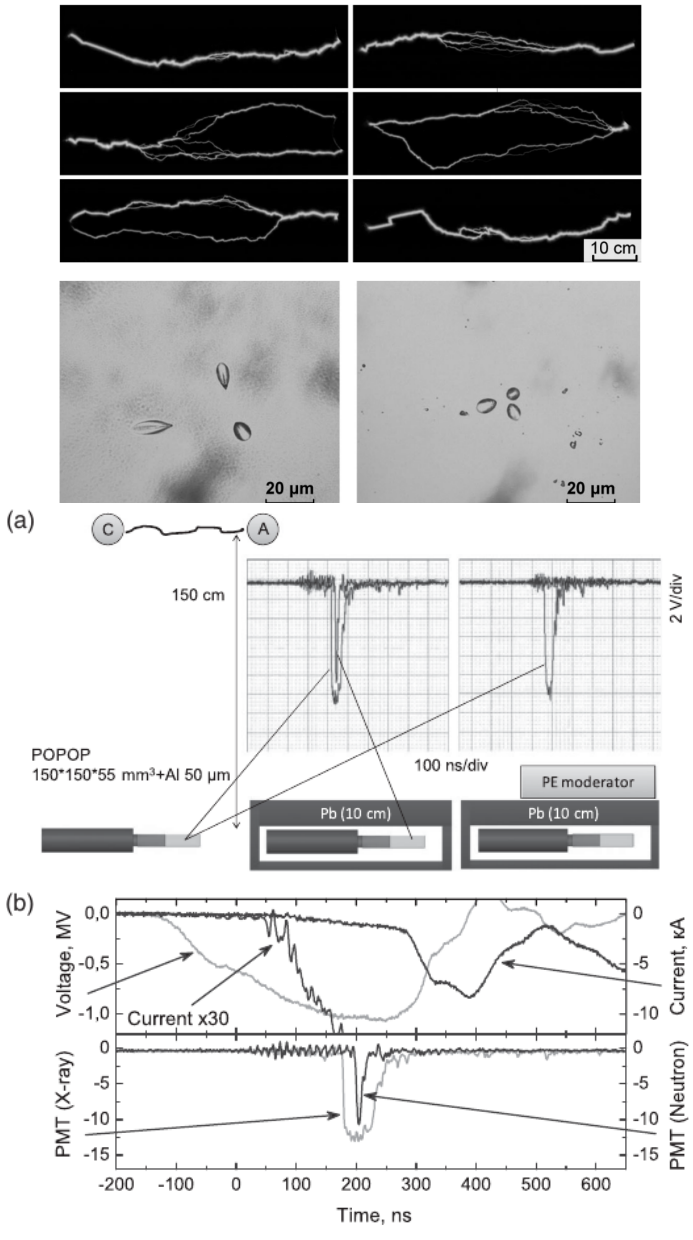


FIG. 1. The scheme of the laboratory experiment. (a) Layout of diagnostics: 1, 2, capacitive and active dividers; 3, high voltage input from Marx generator; 4, 13, magnetic probes; 5, track detectors; 6, anode shunt; 7, Rogowski coil; 8, 9, integral cameras; 10, scintillation detectors; 11, UV radiation detector; 12, PMT to visible light; 14, cathode; 15, anode. (b) Layout of CR-39 track detectors: 1, inside the anode; 2, inside the cathode; 3, 4, 5, axially placed in water; 6, 7, 8, radially placed at different distances from the discharge.



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