



# Large scintillator EN-detector with natural boron for EAS study

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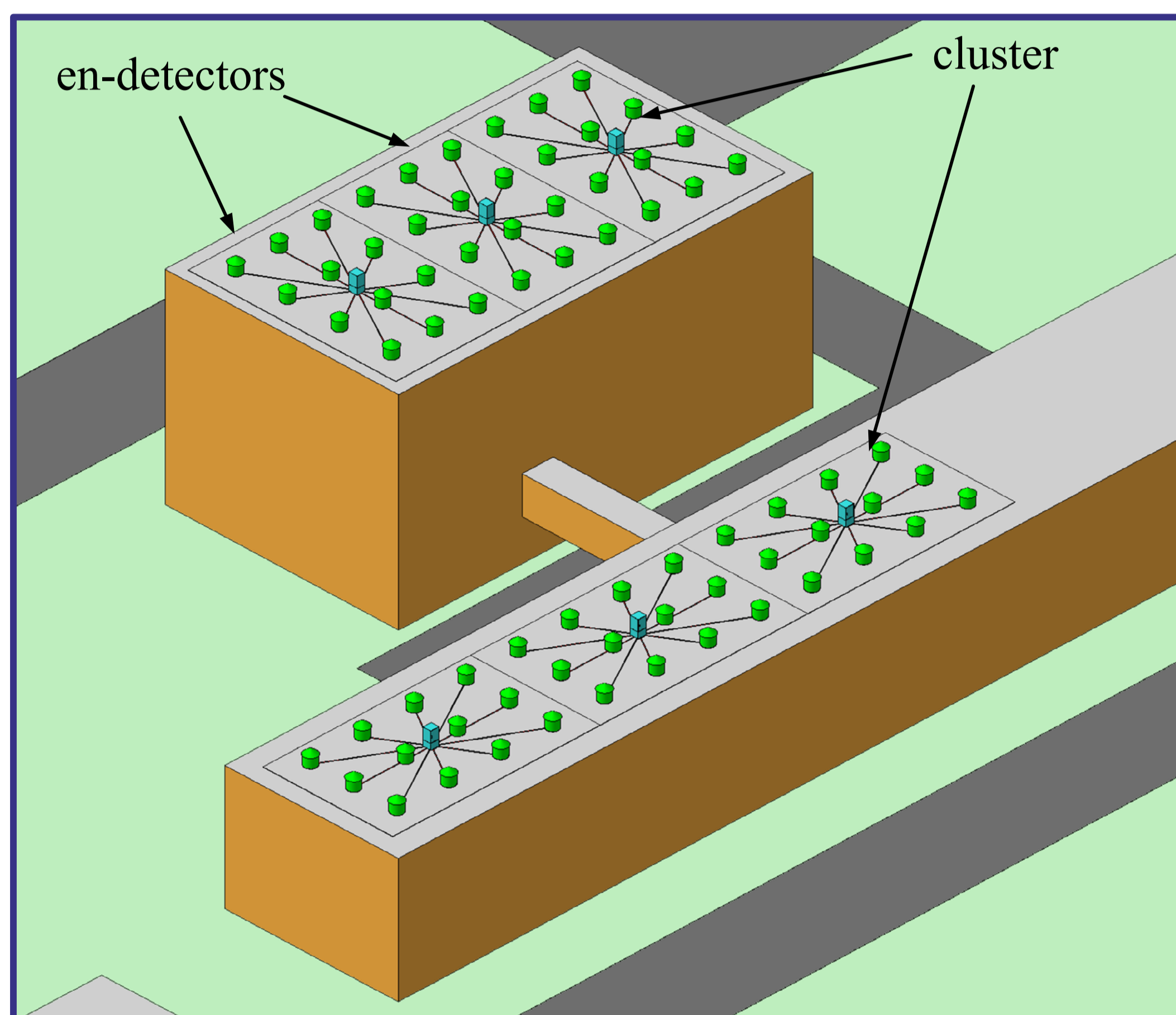
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The array for Upstairs Registration of Atmospheric Neutrons (URAN) is now under construction in MEPhI in collaboration with INR RAS. The basic element detector for the array is en-detector sensitive to both thermal neutron and electromagnetic components. EN-detector is based on a thin layer of alloyed mixture of inorganic scintillator ZnS(Ag) with B<sub>2</sub>O<sub>3</sub> as a target for neutrons. Main feature of the detector is its sensitivity to hadronic EAS component through secondary neutrons produced by high energy hadrons in the vicinity of the detector. Neutron component is almost not studied, though it is a part of the main EAS component: hadronic one.

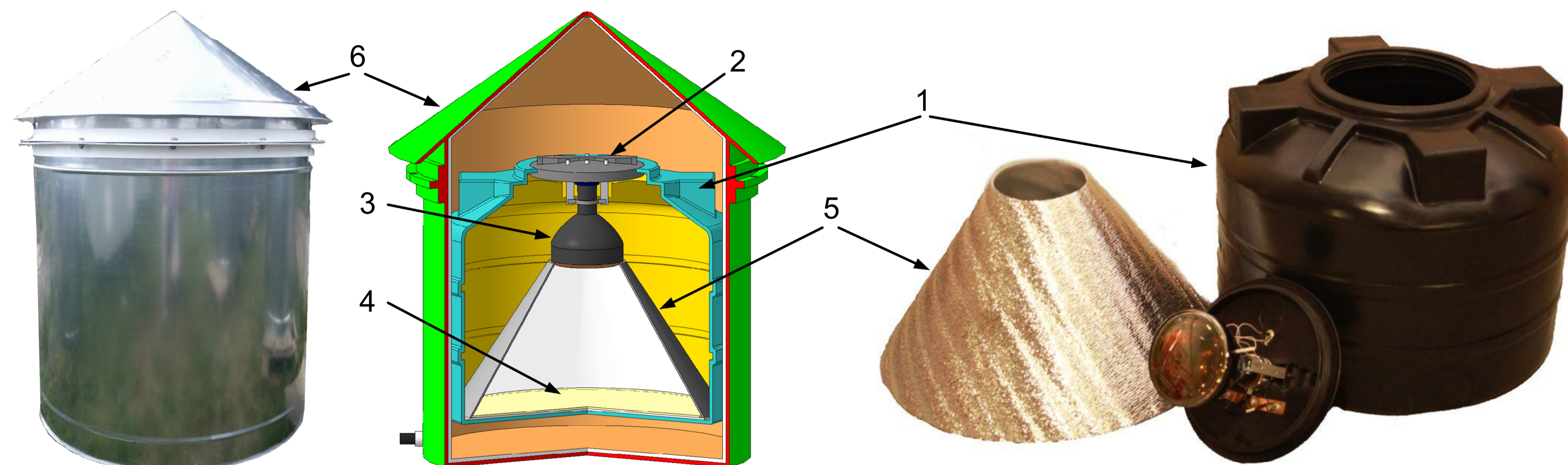
## Introduction

The URAN array will consist of 72 detectors subdivided in 6 clusters of 12 en-detectors (3x4 detectors) each, with a spacing of 4-5 m. For EAS study, we will use a special type of inorganic scintillator detectors, capable to record two main EAS components: electromagnetic (e) producing main ionisation, and hadronic one through thermal neutrons (n) recording [1]. Similar detectors were already tested in PRISMA-32 array [2, 3] which is a prototype of the URAN array.



## The en-detector design

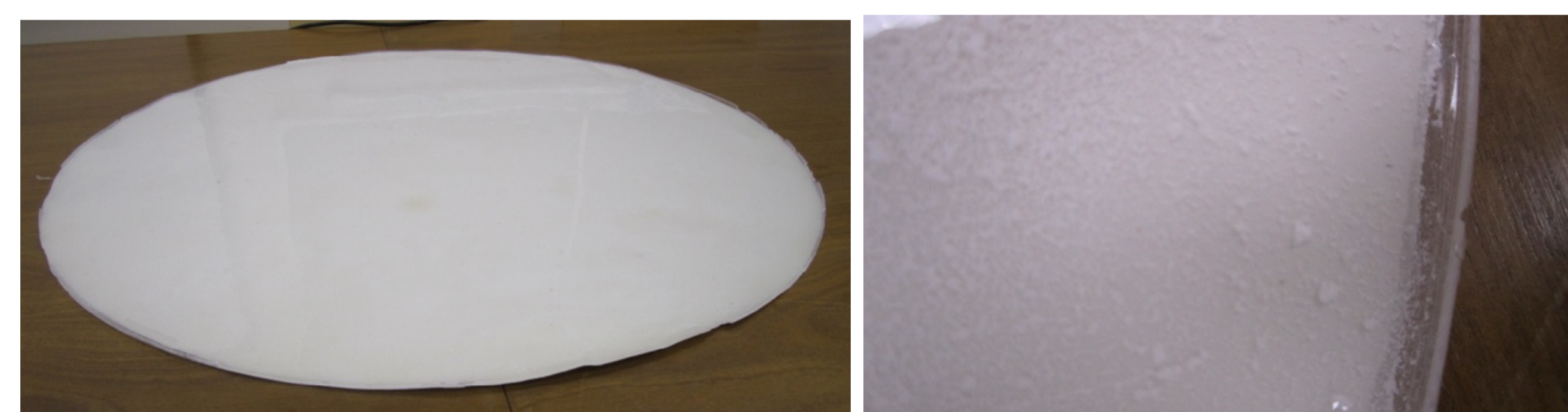
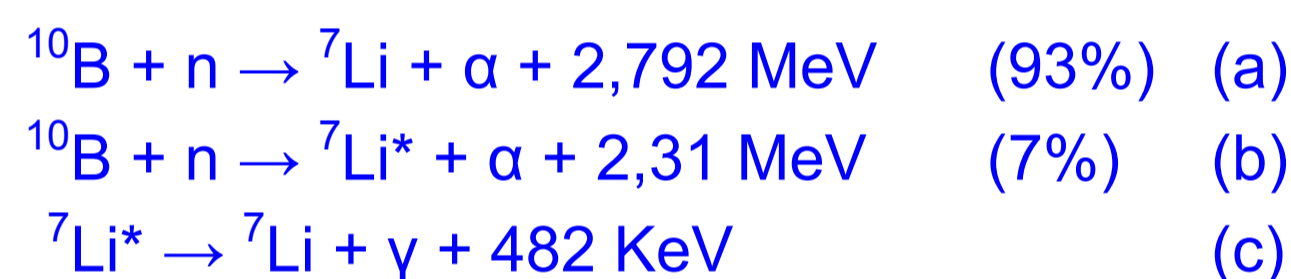
Design of the novel type en-detector is based on that developed for the PRISMA-32 array [4]. We use a black cylindrical (ø740 x 570) standard commercial plastic water tank of 200 l volume as a light protecting housing. To improve light collection, a reflecting cone is used. On the top of the cone, the 6" photomultiplier tube (FEU-200) is located, looking to the scintillator at the cone bottom. The scintillator area is equal to 0.36 m<sup>2</sup>. Zinc coated 0.9 mm iron box (ø880 x 1100) with a conic roof is used for environmental protection.



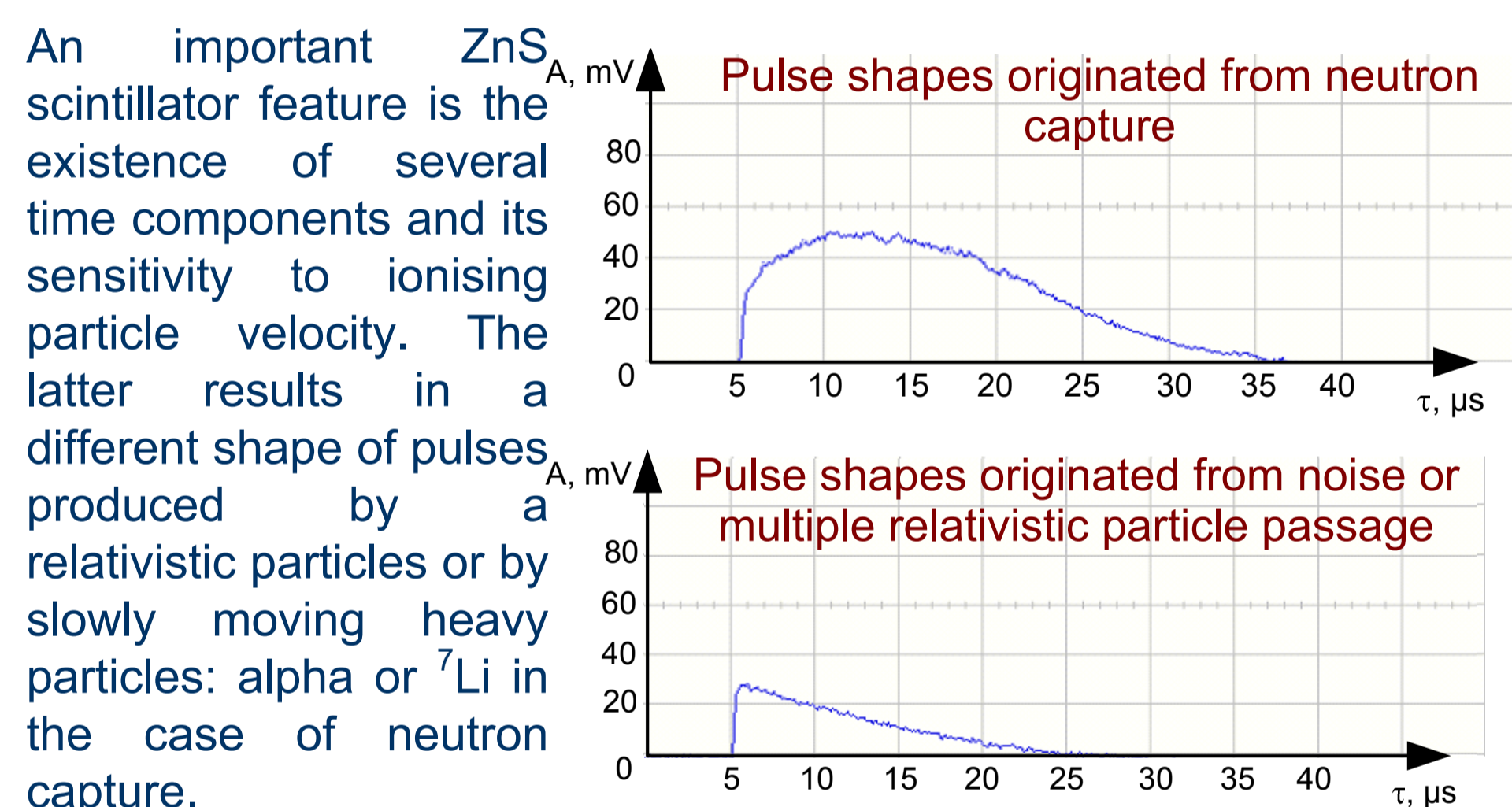
1 - light protecting housing, 2 - lid, 3 - FEU-200 PMT, 4 - scintillator layer, 5 - light reflecting cone, 6 - outer metal box.

**Scintillator:** A special inorganic compound scintillator (ZnS(Ag)+B<sub>2</sub>O<sub>3</sub> with natural boron) will be used for the URAN array construction. It is made of grains of the compound alloy LRB-1 (Russian production) in transparent silicon disk of 70 cm diameter and 5 mm thickness. Mass content of boron in the compound is equal to ~ 13%, while content of <sup>10</sup>B is 2.6%. Total compound thickness is 50 mg/cm<sup>2</sup>.

The signal is produced by heavy charged particles (alpha-particle and <sup>7</sup>Li) which loose their energy inside one grain. Scintillator ZnS is very effective for heavy particles and has a record α/e - ratio. Slow neutrons (mostly thermal and epithermal) are recorded due to reactions:



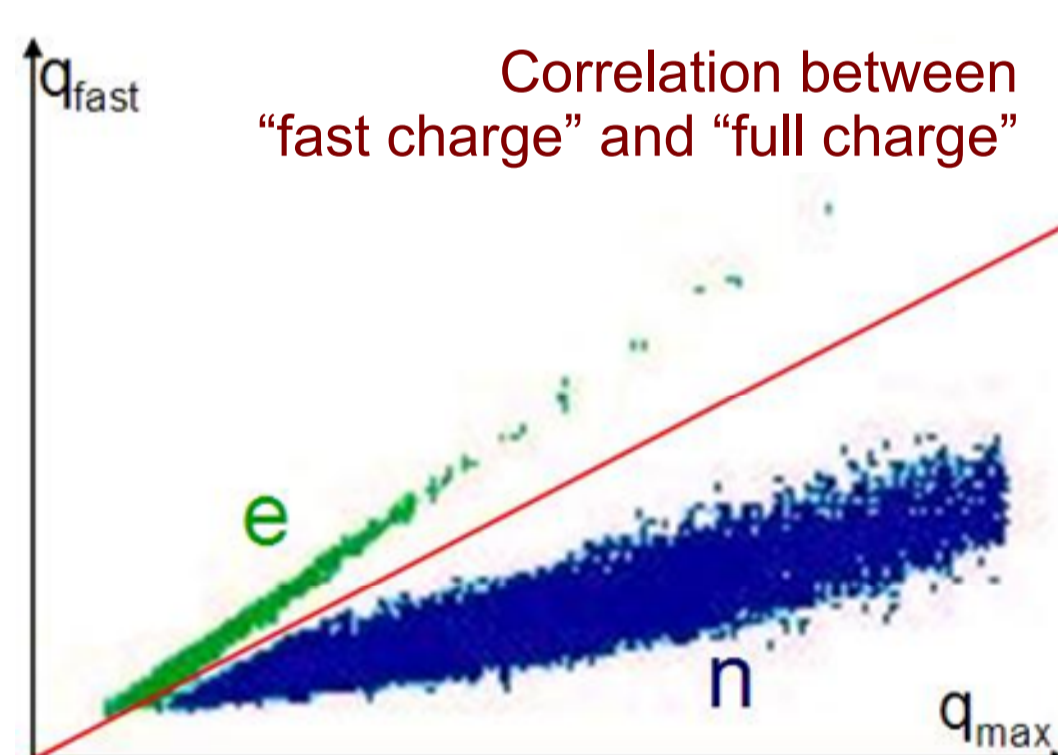
Photographs of the scintillator disk.



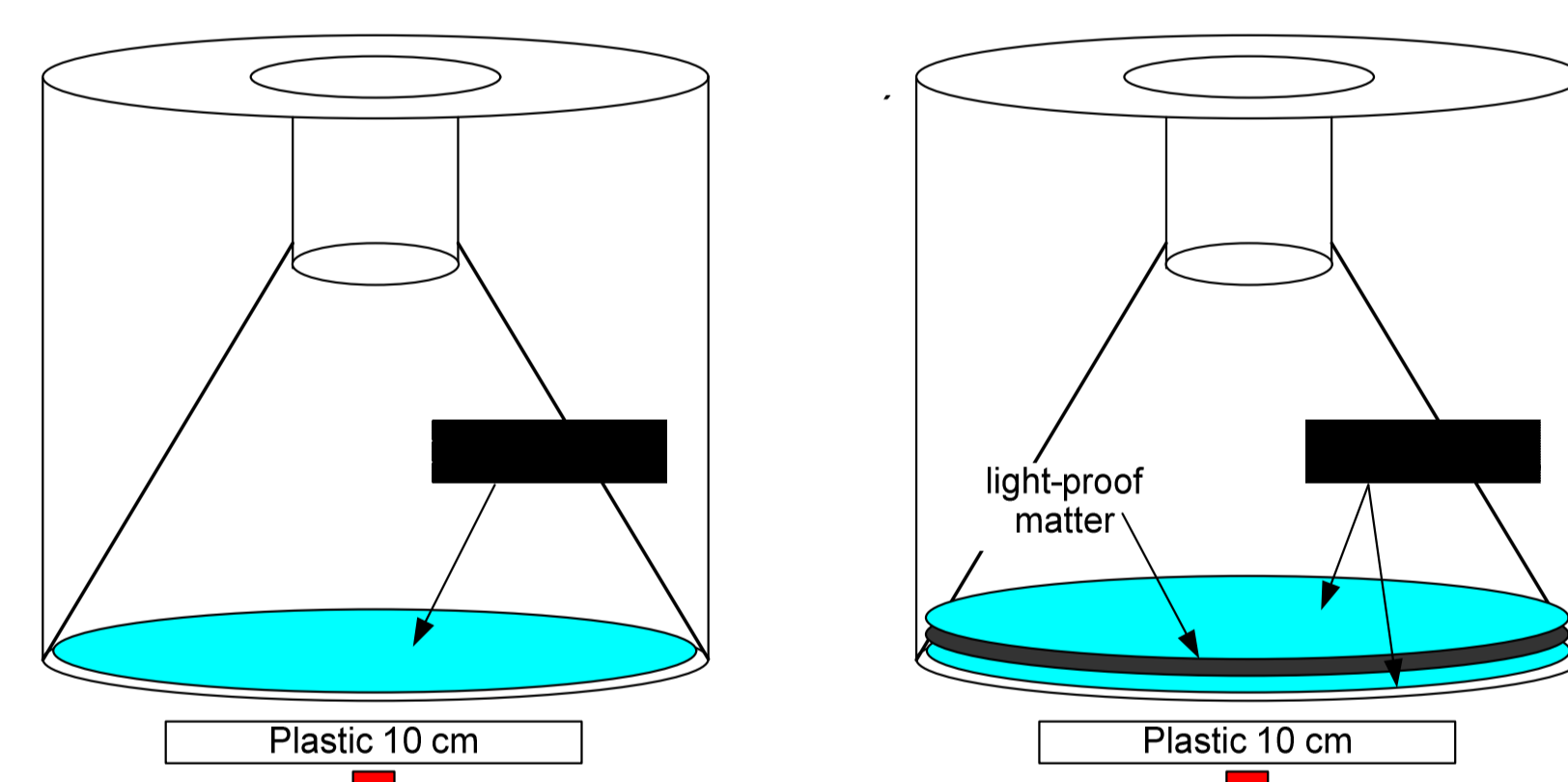
These pulses (integrated over 20 μs) are shown in the figures. One can see that charge collection time is different for these two cases, and it is no problem to distinguish the pulses.

## Neutron detection and the scintillator testing

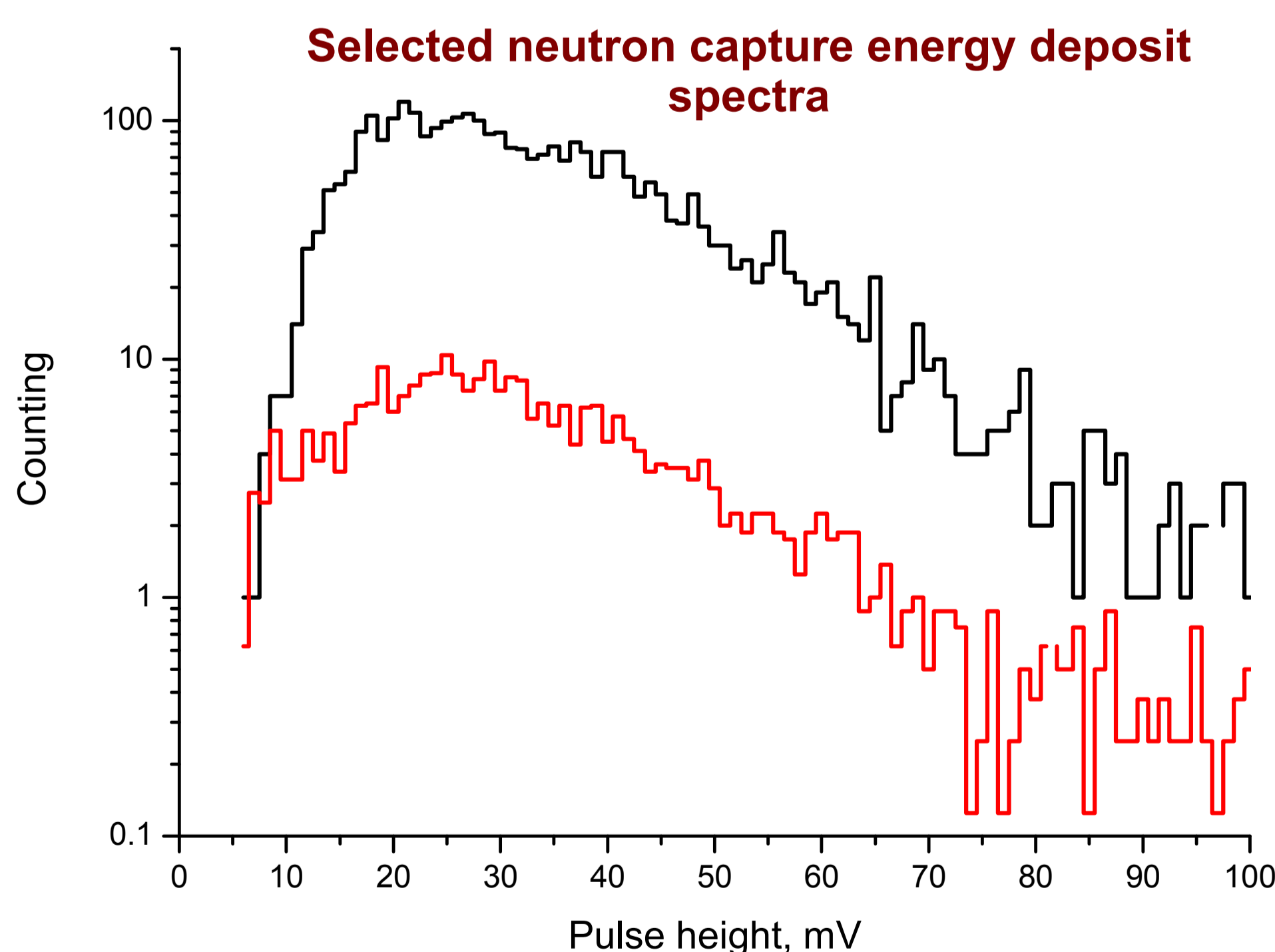
The separation procedure is clearly seen in the lower figure, where a correlation plot between a "fast charge" collected in the first time bin ( $q_{\text{fast}}$ ) and a full collected charge ( $q_{\text{max}}$ ) is shown. Neutron capture events were selected by settings a cut on the parameter  $R = q_{\text{fast}}/q_{\text{max}} < 0.85$ .



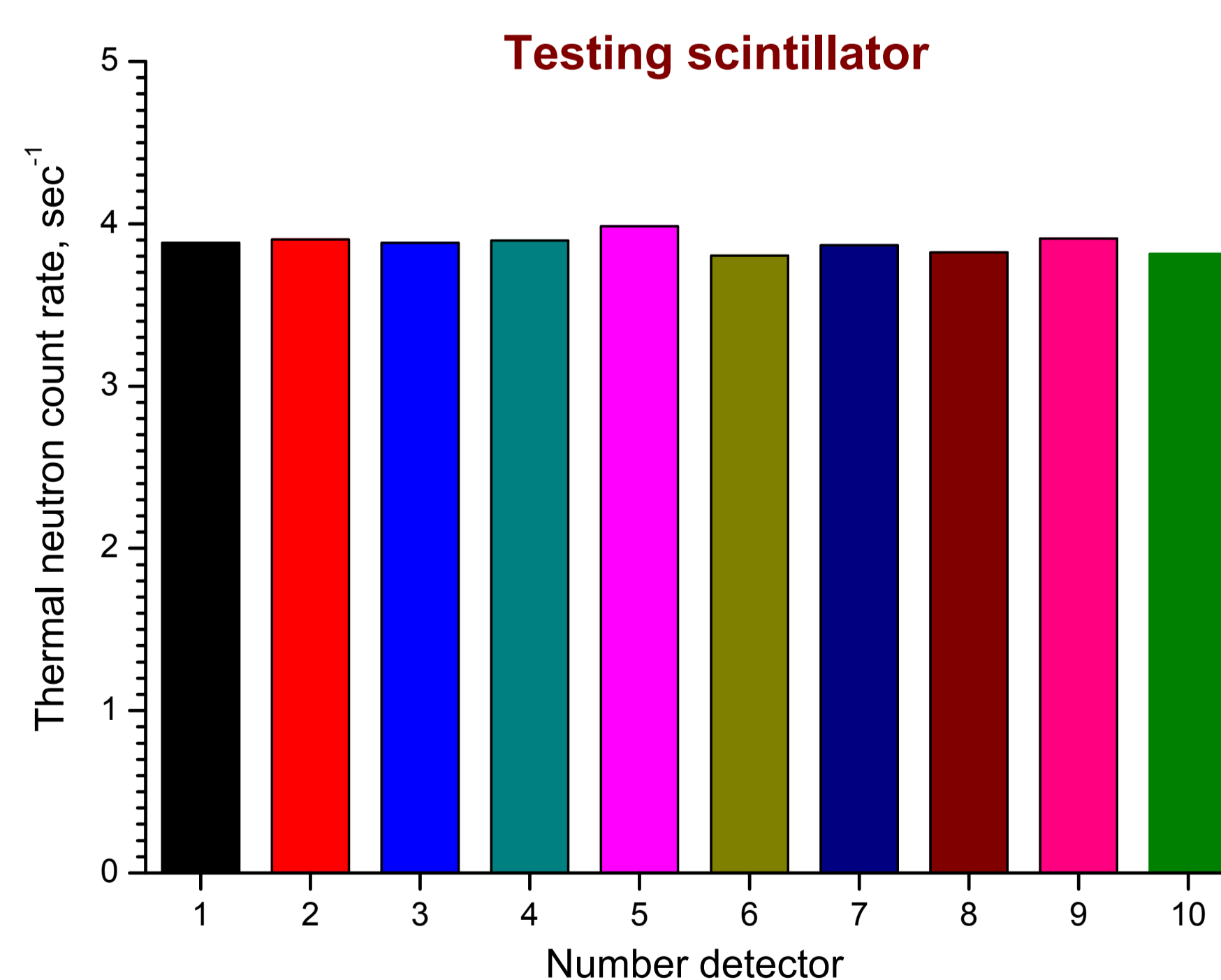
The source of thermalized neutrons was also used to measure the scintillator layer efficiency of thermal neutron detection. The measurements were carried out with one layer (left panel) and then with two layers of scintillator when the second one (under the sheet of black paper) was used as an absorption screen (right panel).



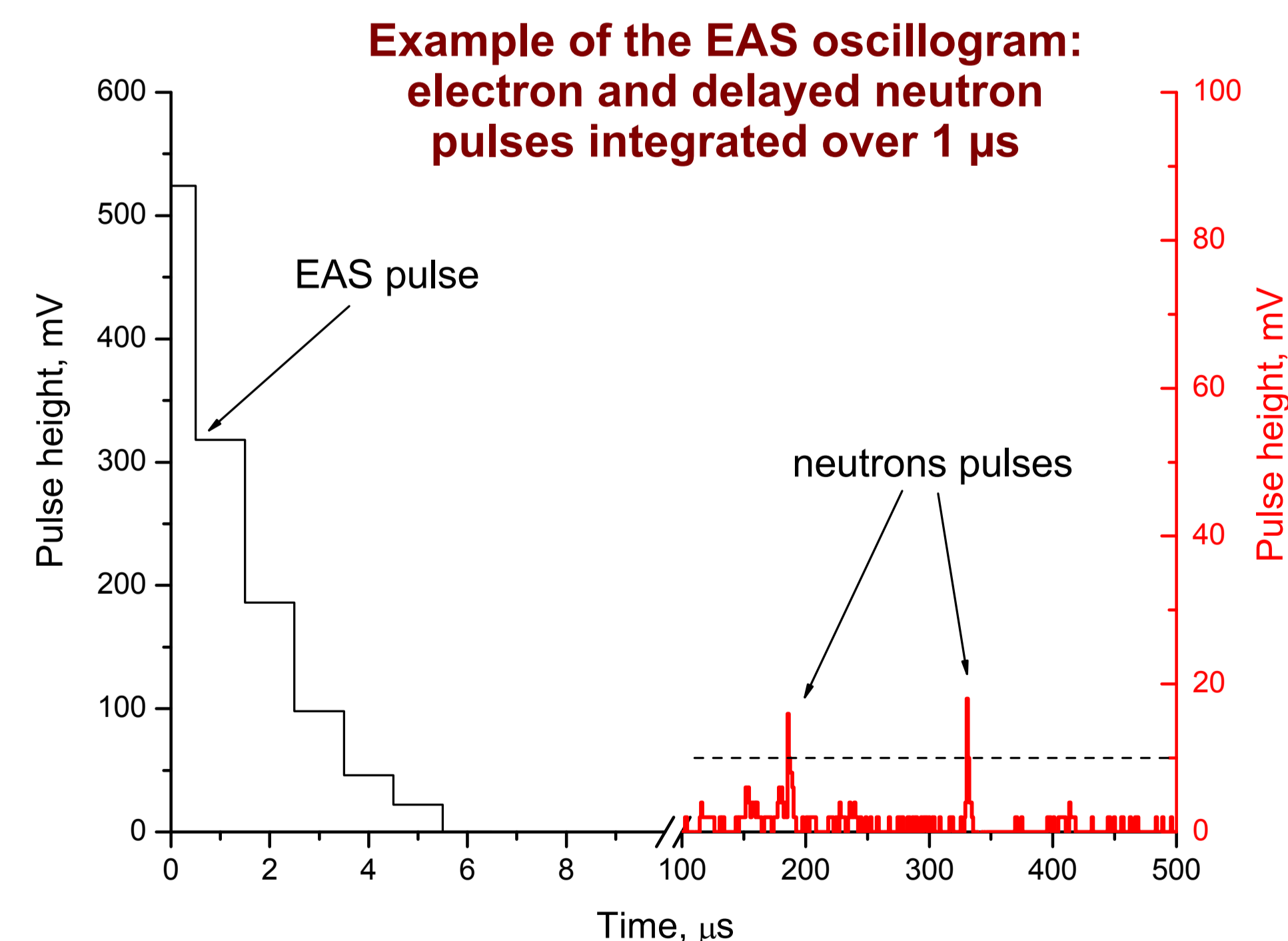
The decrease of the thermal neutron flux by an additional layer gives an estimate of the detection efficiency. In an assumption that all absorbed neutrons are recorded, the efficiency of our scintillator layer of 50 mg/cm<sup>2</sup> thickness is close to 20%, and is also close to that achieved with enriched lithium compound for 30 mg/cm<sup>2</sup> thickness which we used earlier in PRISMA-32 array.



The spectra of events selected as "neutrons" obtained by using this separation procedure are presented. The upper histogram represents data obtained with the neutron source <sup>252</sup>Cf while the lower one corresponds to environmental neutrons.



Test of 10 samples of the scintillator on the stand using a neutron source showed that the difference between different samples does not exceed 5%. The average count rate is  $(3.88 \pm 0.05)$  neutrons/s<sup>-1</sup>.



The first 10 μs part of the plot is expanded to show the first large pulse produced by EAS electromagnetic component, and then a detailed time scale from 100 to 500 μs showing 2 delayed neutron pulses are presented.

## Conclusion:

A novel type en-detector sensitive to electromagnetic and neutron EAS components is developed. It is not expensive due to the usage of the natural boron compound instead of the <sup>6</sup>Li compound. Test measurements with the detector gave rather good response, which is not worse than that for the previous one based on the compound with <sup>6</sup>Li enriched admixture. So we can conclude that such detectors are very perspective for usage both in EAS arrays and in neutron flux variation measurements.

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## References:

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