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

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The array for Upstairs Registration of Atmospheric Neutrons (URAN) is now under construction in MEPhI in co-operation with INR RAS. The basic element for the array is en-detector sensitive to both thermal neutron and electromagnetic components. This detector is based on a thin layer of alloyed mixture of inorganic scintillator ZnS(Ag) with $B_2O_3$ 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. Some new features of a novel en-detector are described. It is shown that this relatively cheap detector version can have rather good performances.

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## 1. Introduction

The EAS array URAN being under construction in MEPhI in the frames of MEPhI-INR RAS cooperation will consist of 72 detectors subdivided in to 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.

## 2. Scintillator

A special inorganic compound scintillator (ZnS(Ag)+$B_2O_3$ 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 (see Fig. 1). Mass content of boron in the compound is equal to ~ 13%, while content of $^{10}B$ is 2.6%. Slow neutrons (mostly thermal and epithermal) are recorded due to reactions:

$$^{10}B + n \rightarrow {}^{7}Li + \alpha + 2{,}792\ \text{МэВ} \qquad (93\%) \qquad (a)$$

$$^{10}B + n \rightarrow {}^{7}Li^{*} + \alpha + 2{,}31\ \text{МэВ} \qquad (7\%) \qquad (b)$$

$$^{7}Li^{*} \rightarrow {}^{7}Li + \gamma + 482\ \text{КэВ} \qquad (c)$$

Total compound thickness is 50 mg/cm$^2$. The signal is produced by heavy charged particles (alpha-particle and $^7$Li) which loose their energy inside one grain. Scintillator ZnS is very effective for heavy particles and has a record α/e –ratio.

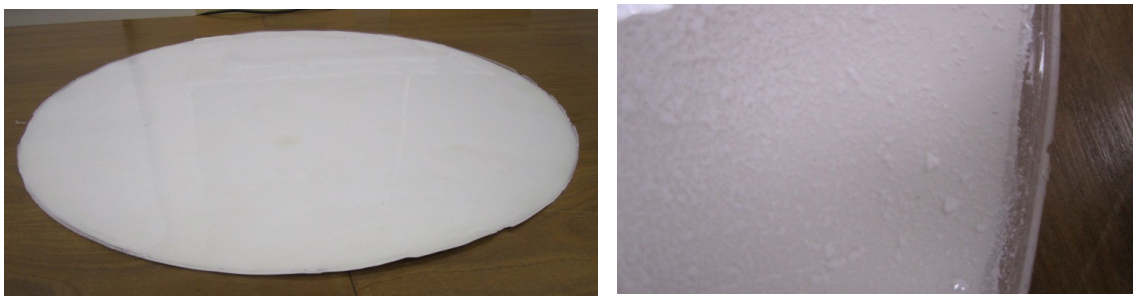

**Figure 1:** Photographs of the scintillator disk.

In the array PRISMA-32, we used a similar scintillator but with $^6$LiF as a target for neutrons. Now after comparison we can conclude that the compound with natural boron of 50 mg/cm$^2$ thickness gives the response similar to that of lithium compound enriched with $^6$Li up to 90% of 30 mg/cm$^2$ thickness. In both cases the efficiency for thermal neutron detection is close to 20% (see below).

## 3. The en-detector design

Design of the novel type en-detector (Fig. 2) is based on that developed for the PRISMA-32 array [4]. We use a black cylindrical (∅740 x 570) standard commercial plastic water tank of

200 liter 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 $m^2$. Zinc coated 0.9 mm iron housing (∅880 x 1100) with a conic roof is used for environmental protection.

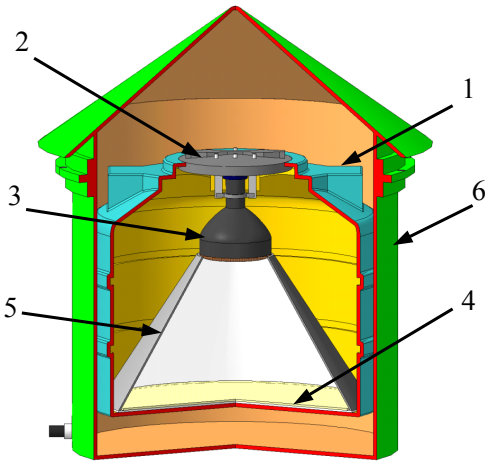


**Figure 2:** En-detector design; 1 - light protecting housing, 2 – lid, 3 – FEU-200 PMT, 4 – scintillator layer, 5 - light reflecting cone, 6 – outer metal housing.

## 4. Neutron detection and the scintillator testing

An important ZnS scintillator feature is the existence of several time components and its sensitivity to ionising particle velocity. The latter results in a different shape of pulses produced by relativistic particles or by slowly moving heavy particles: alpha or $^7$Li in the case of neutron capture. These different pulses (after integration with time constant 20 μs) are shown in Fig. 3. One can see that charge collection time is different for these two cases, and it is no problem to distinuish the pulses.

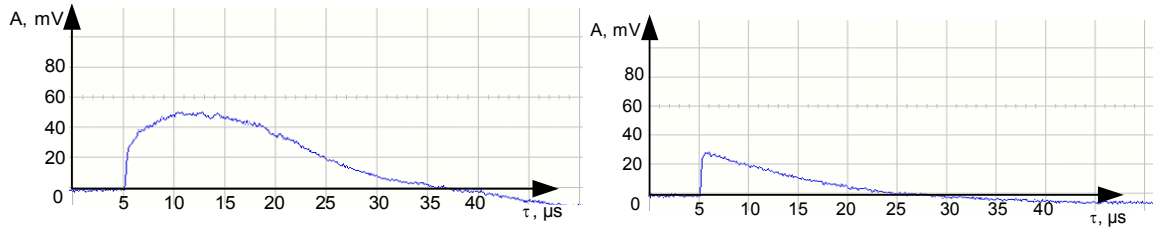


**Figure 3:** Pulse shapes originated from neutron capture (left) and from noise or multiple relativistic particle passage (right).

The separation procedure is clearly seen in Fig. 4 (left panel) where a correlation plot between a "fast charge" collected in the first time bin ($q_{fast}$) and a full collected charge ($q_{max}$) is shown. Neutron capture events were selected by settings a cut on the parameter $R = q_{fast}/q_{max} < 0.85$.

In the right panel of Fig. 4, the spectra of events selected as "neutrons" obtained by using this separation procedure are presented. The upper histogram represents data obtained with the $^{252}$Cf neutron source while the lower one corresponds to environmental neutrons.

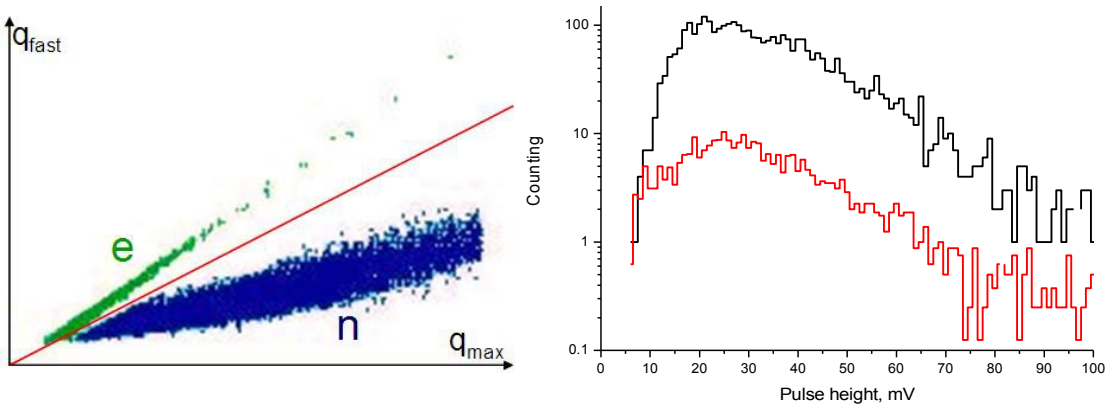


**Figure 4:** Correlation graph between "fast charge" and "full charge" illustrating pulse shape separation procedure (left) and selected neutron capture energy deposit spectra (right) obtained with (upper histogram) and without (lower one) thermal neutron source.

The source of thermalized neutrons was also used to measure the scintillator layer efficiency of thermal neutron detection. The measurement lay-out is shown in Fig. 5. 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).

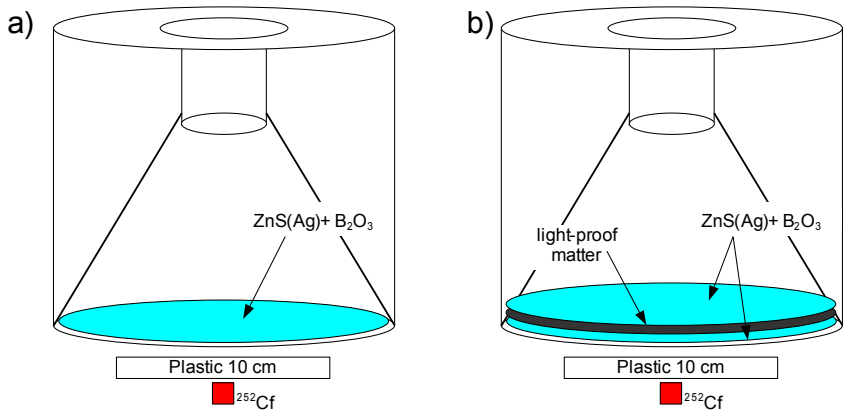


**Figure 5:** Lay-out of the scintillator efficiency measurement using the source of thermalized neutrons.

The results of the measurements are the following: one layer – 11.1 n/s/m$^2$; two layers – 8.8 n/s/m$^2$. It is easy to estimate the decrease of the thermal neutron flux by an additional layer as: dF = (11.1-8.8)/11.1 = 0.207. In an assumption that all absorbed neutrons are recorded, the efficiency of our scintillator layer of 50 mg/cm$^2$ thickness is close to 21%, and is also close to that achieved with the enriched lithium compound for 30 mg/cm$^2$ thickness which we used earlier in PRISMA-32 array.

An example of the EAS event recorded with the boron en-detector is shown in fig. 6. 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 is presented.

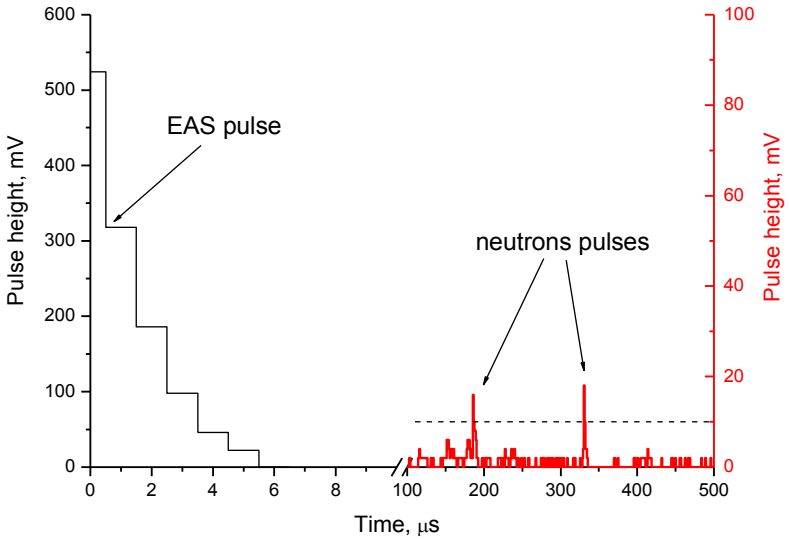


**Figure 6:** Example of the EAS oscillogram: electron pulse (left) and delayed neutron pulses right.

## 5. 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 $^{6}$Li compound. Test measurements with the detector gave rather good response, which is not worse than that for the previous version based on the compound with $^{6}$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.

### Acknowledgements

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