SiPM and ZnS:Li6 based neutron detectors

Glushkova Tatyana[3]*, Trunov Dmitry[1,2,3], Marin Victor[2,3], Altynbayev Evgeniy[3], Sadykov Ravil[2], Axenov Sergei[2]

[1]*NRC "Kurchatov Institute",Moscow,Russia*

[2]*INR RAS,Moscow,Russia*

[3]*NRC "Kurchatov Institute" - PNPI, Moscow, Russia*

E-mail: glushkova_ti@pnpi.nrcki.ru, dtrunov@inr.ru

Since 2012, active work is underway to developing scintillation neutron detectors based on ZnS:Li^6 and Silicon Photomultiplier(SiPM). The first publication with the results was in 2015 [1].

First version of detector

Basic requirements for the development of the first version of the detector:
1. The active area of the detector is 10x200 mm².
2. Neutron absorber - ZnS (Ag) / LiF scintillator with lithium concentration, ensuring maximum efficiency of neutron registration.
3. Transportation of scintillation light - optical fiber from plexiglas with optimal geometry.
4. Removal of the signal from the detector - two SiPM with an active area of 3x3 mm².

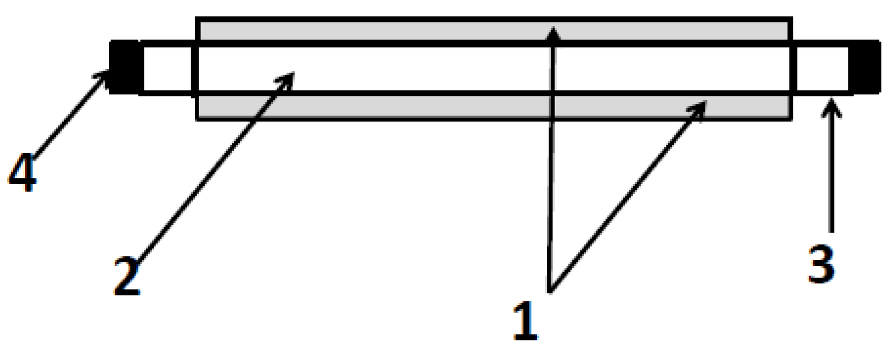

Fig. 1 The scheme of detector - 1- ZnS (Ag) / LiF scintillator, 2- light guide,3- focusing prism of the fiber, 4- Photomultiplier.

ZnS is glued to the Plexiglas light guide, prisms are located at the ends to collect the light, and 2 SiPM. This design allows you to dial the right amount of light from the scintillator. Figure 2 shows the detector testing for neutron registration.

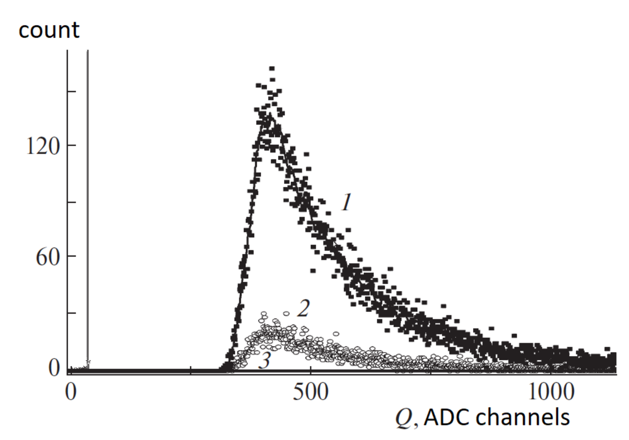

Fig. 2. The charge spectra of a type 2 counter with its neutron emission: 1 - without cadmium foil, peak corresponds to 95 photoelectrons; 2 - in cadmium foil 1 mm thick; 3 - dark noises.

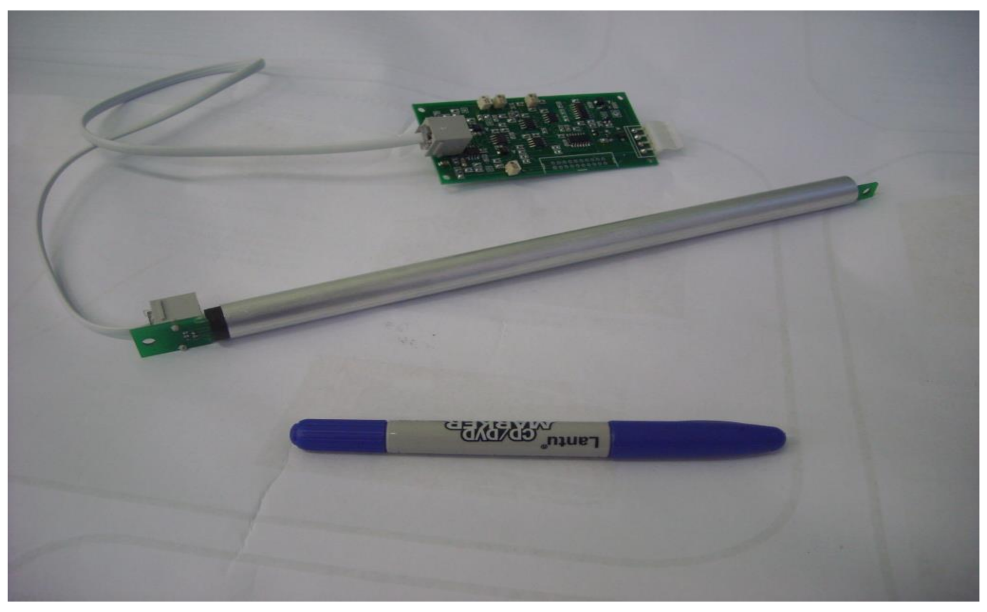

Fig. 3 Photo of first version of detector

Latest detector version.

Differences from the first version:
1. Use ZnS:Li^6 with 46% concentration of Li^6
2. A fisheye lens is used instead of a prism
3. Optimized design
4. Optimized electronics

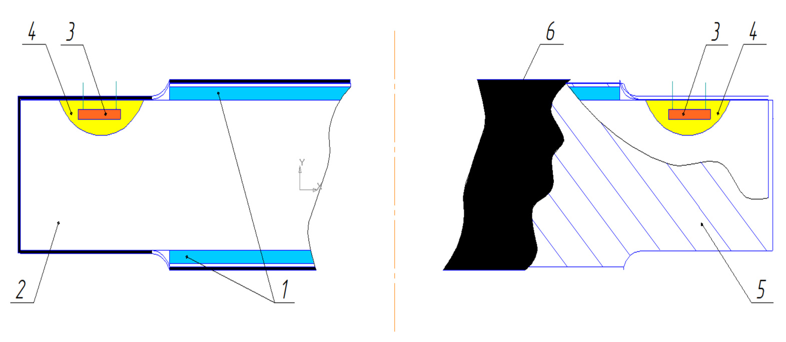

Fig. 4. The scheme of detector using a lightguide with diffuse reflection. 1 – light guide with 10x4 mm² cross section, 2 – scintillation sheet, 3 – optic compound, 4 – SiPM, 5 – Teflon tape as diffuse reflector, 6 – jacket

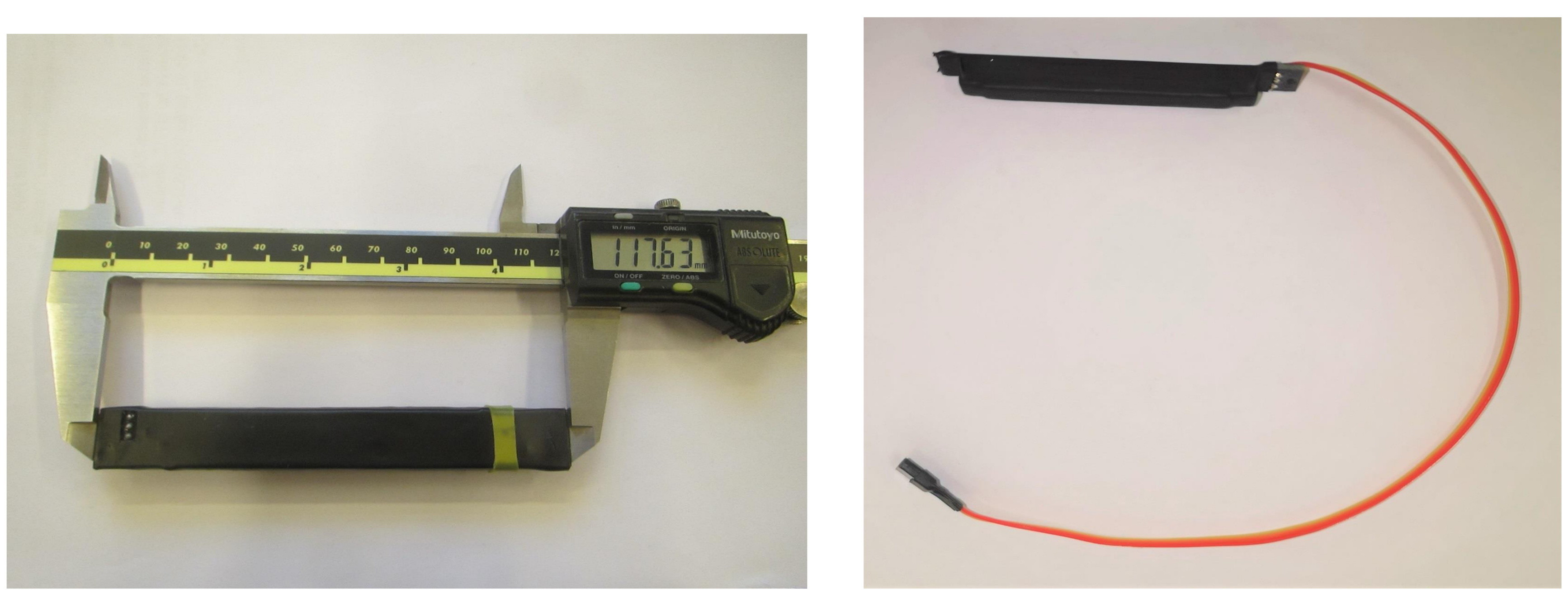

Fig. 5 Photo of last versions of detectors

Based on these detectors, a ring detector was also created. The detector consist 12 independence channel.

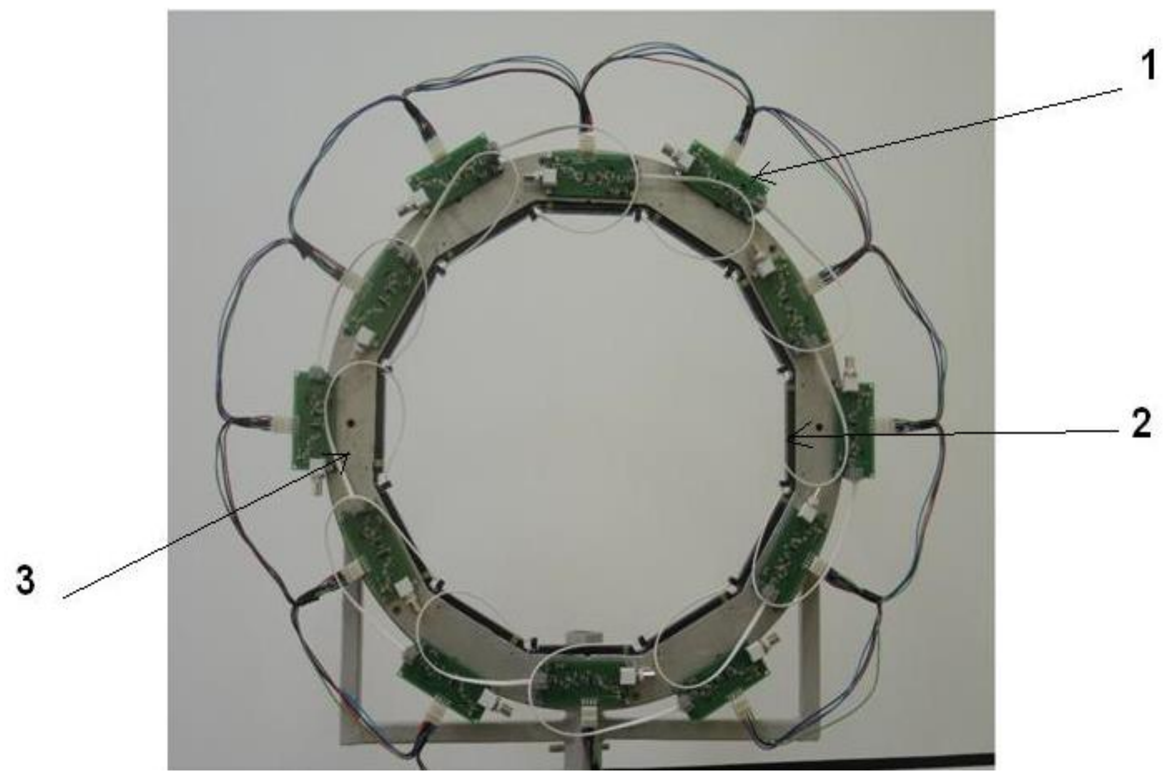

Fig 6. Photo of ring scintillation detector. 1- shaper,2- detector,3- borated polyethylene

Parameters of the neutron counter.

- Variable active area of the counter
- Scintillator ZnS(Ag)/LiF with efficiency of 46%
- Own efficiency of the counter was 70%.
- The count rate of detector is better than 10^5/s
- Gamma sensitivity on the order of 10^{-7}

Electronics

The detector is connected to the amplifier shaper, which implements the coincidence circuit, SiPM thermal stabilization and SiPM charge compensation function. Output signal NIM or TTL.

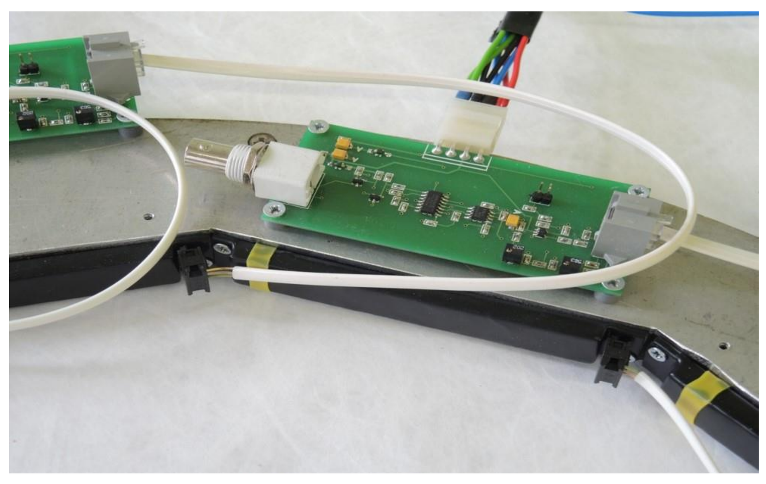

Fig 7. Photo of amplifier shaper

Experiments

All experimental data obtained at the neutron source IN-06 INR RAS

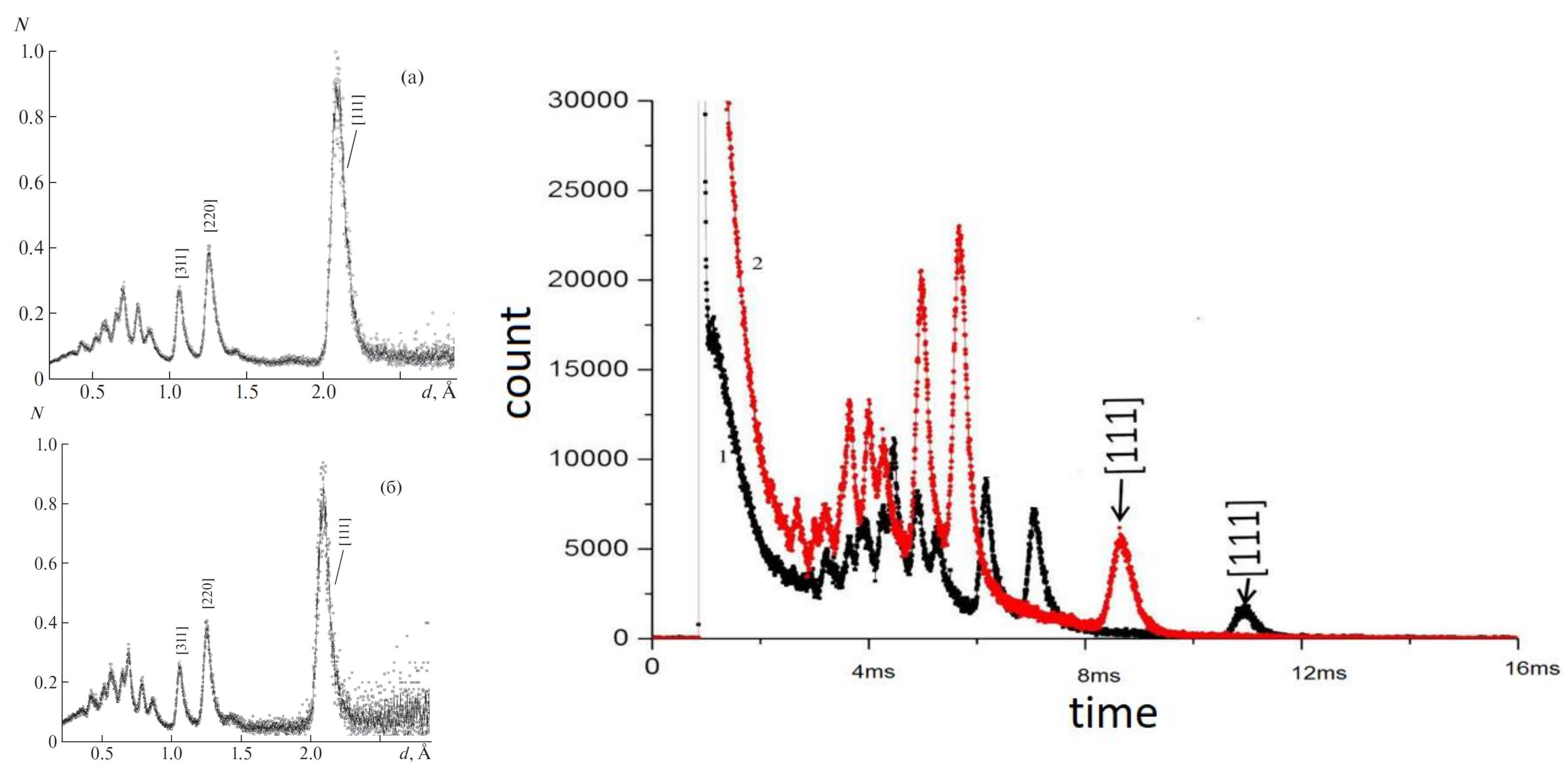

Fig 8. left -TOF-spectra measured on synthetic diamond powder using helium (a) and new scintillation (b) counters, right – scintillator detector on different angle

Conclusion

1. The efficiency of 70% was obtained for designed counters, comparable to the efficiency of the helium counters.
2.The time resolution of the counters is better than 1 µs, that allows the use of detectors for time-of-flight measurements.
3.Low sensitivity to gamma quanta ~10^{-6}.
4.Absence of thermal noise at the threshold of 10 ph.e. and temperature of +30 ^{0}C.
5.Low voltage supply +6V.
6.The same values of power voltage and thresholds for all counters. No needs for individual tunings. Simple and noise-immune electronics.
7.It is possible to manufacture the detectors with the length up to several tens of cm.

The work is fulfilled with the financial support of Russian Ministry of Science, agreement №075-15-2019-954 by 31.05.2019, unique identification number of project RFMEFI60718X0200.

Publications

[1] A New Type of Thermal Neutron Detector Based on ZnS(Ag)/LiF Scintillator and Avalanche Photodiodes Marin, V.N., Sadykov, R.A., Trunov, D.N. et al. Tech. Phys. Lett. (2015) 41: 912. https://doi.org/10.1134/S1063785015090242

[2] A Ring Neutron Detector for a Time-of-flight Diffractometer Based on Linear Scintillation Detectors with Silicon Photomultipliers Marin V.N., Sadykov R.A., Trunov D.N., Litvin V.S., Axenov S.N. Instruments and Experimental Techniques. 2018. T. 61. № 1.

[3] The HIGH-RESOLUTION DIFFRACTOMETER AT the PULSED NEUTRON SOURCE IN-06 of INR RAS Kuznetsov, S. P., and Litvin V. S., Marin V. N., Trunov D. N., Aksenov S. N., Swan J. B., Meshkov I. V., Sadykov R. A. // SURFACE. X-RAY, SYNCHROTRON AND NEUTRON STUDIES. - 2018. No. 5. p. 29-35.

[4] Scintillation neutron detectors based on solid-state photomultipliers and lightguides Litvin V.S., Marin V.N., Karaevsky S.K., Trunov D.N., Axenov S.N., Stolyarov A.A., Sadykov R.A. Crystallography Reports. 2016. T. 61. № 1. C. 106-110.

[5] The patent for useful model RU 177857, Ring detector of thermal neutrons, authors: marine Victor Nikolaevich,Sadykov Ravil askhatovich, Litvin Vasily Sergeevich, Aksenov Sergey Nikolaevich,Trunov Dmitry Nikolaevich.Registered in the State register of utility models of the Russian Federation on March 14, 2018.