Contribution ID: **14** Type: **Poster presentation**

Evaluation of ZnS/6LiF and ZnO/6LiF scintillation neutron detectors read out with SiPMs

Tuesday 19 September 2017 10:11 (1 minute)

Helium-3 has been for several decades the most widely used converting material in detectors for neutron scattering experiments. The world-wide shortage of its supply stimulated the development of alternative detector technologies [1]. One of these alternatives is the scintillation technology based on 6Li (10B) loaded ZnS scintillators read out by wavelength-shifting (WLS) fibers. Currently all detectors of this kind utilize photomultiplier tubes (PMTs) as photosensors. Different light-sharing schemes (channel coding) are used to reduce the number of PMTs. While in such parameters as the detection efficiency and the gamma-sensitivity these detectors approach those based on 3He, the count rate up to which they can be operated without significant event losses is rather low, which is attributed to the slow emission of the ZnS scintillator. Here, however, one should clearly distinguish between two different sources for the event losses, such as: a) finite dead time of a readout channel and b) coding errors.

At the Paul Scherrer Institut in Switzerland we are working on a novel approach [2,3] for the realization of ZnS-based scintillation detectors for neutron scattering applications. The absorption volume of the detector represents an (1D or 2D) array of individual sensitive elements (pixels), each equipped with its own signal conversion and processing chain. An efficient light collection from the scintillator is achieved by embedding WLS-fibers into its volume. The conversion of the collected light into electrical signals is done by a Silicon Photomultiplier (SiPM). This compact and inexpensive photosensor is well suited for application in multi-channel detection systems. As the channel coding is abandoned, significant improvement of the rate capability can be expected.

We demonstrated the potential of this approach by building a high efficiency, low gamma-sensitivity, high count rate capable 1D neutron detector aimed as a possible replacement of the 3He detector of the POLDI time-of-flight diffractometer [3]. The detector showed stable performance up to a counting rate of about 50 kHz/pixel with 10% dead-time conditioned event losses at 17 kHz/pixel [2]. Such count rate capability is already well above the requirements of most neutron powder diffraction instruments including those planned at bright neutron sources like ESS. However, to be of general applicability including also inelastic neutron scattering experiments, where spot counting rates in the order of 50 kHz/pixel are expected [1], the rate capability of our detector needs to be further improved. One way is to reduce the dead time, which is possible at the expense of the trigger efficiency [2]. Another way is to use a faster ZnO:6LiF neutron scintillator instead of the one based on ZnS. Such fast neutron detection screen has become recently available from Scintacor (UK). In this work we compare the performance of single channel neutron detectors built from ZnS/6LiF and ZnO/6LiF scintillators following the characterisation procedure developed in [2].

[1] K. Zeitelhack, Neutron News 23(4) (2012) 10

[2] A. Stoykov et al., IEEE TNS 63(4) (2016) 2271

[3] J.-B. Mosset et al., NIM A 845 (2017) 494.

Has accepted

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Session Classification: Poster Session 1

Track Classification: P1_applications