Calibration of SiPM-based Neutron Monitors for CMS Experiment

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Introduction

Development of a distributed system of the neutron monitors is required to estimate the neutron spectra and monitor the neutron fields in the CMS experimental cavern [1]. The proposed neutron monitor is based on the ^{6}Li-enriched scintillator coupled to SiPM. During LHC Run 2, several monitor samples were successfully commissioned at the CERN laboratory and tested in CMS environment with the set of Bonner spheres [2]. To rescale collected data to the absolute value of the neutron flux the same SiPM-based monitor samples with the set of Bonner spheres were calibrated at the CERN Radiation Protection (RP) calibration facility.

SiPM-based neutron monitors

To demonstrate the usability of SiPM-based neutron monitor in the CMS environment, several monitor samples of different configuration were set up. Calibrated samples are shown in Fig. 1 and their main characteristics are reflected in the Table.

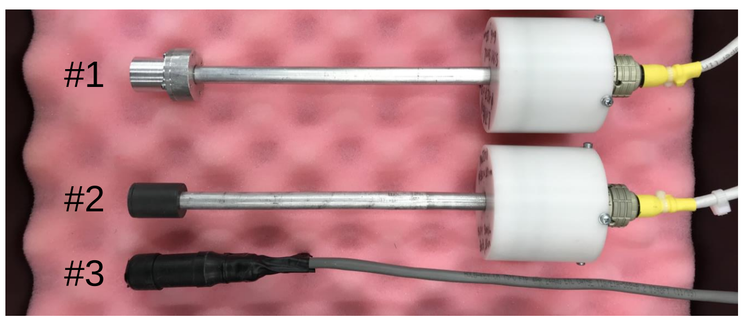

Fig. 1. Three samples of SiPM-based neutron monitor.

Sample	#1	#2	#3
Scintillator	LiI(Eu)	ZnS(Ag)/^{6}LiF	ZnS(Ag)/^{6}LiF
Scintillator area, cm^2	Ø1.27x0.3	0.5	0.1
SiPM manufacturer	SensL	SensL	KETEK
SiPM active area, mm^2	6x6	3x3	3x3
Pixel pitch, μm	35	35	25
Readout	ADC	ADC	Counter

Summary

Three samples of SiPM-based neutron monitor with the set of Bonner spheres were calibrated in the neutron field at the CERN RP calibration facility. Amplitude spectra were recorded for the first two samples, counts per second – for the third one. Results of calibration are presented. The readings of samples measured in the CMS radiation field and in the standard calibration field will be deconvoluted to the neutron spectra by means of the unfolding procedure.

References

[1] CMS Collaboration. (2020). The Phase-2 Upgrade of the CMS Beam Radiation, Instrumentation, and Luminosity Detectors: Conceptual Design. https://cds.cern.ch/record/2706512?ln=en

[2] Popova E. et al. (2019). SiPM-based Neutron Monitors for CMS Experiment. JPS Conf. Proc. 27

[3] Brugger M. et al. (2014). New radiation protection calibration facility at CERN. Radiation Protection Dosimetry, 161(1-4), 181-184.

Experimental setup

Calibration measurements were carried out at the CERN RP calibration facility, that can provide ISO standard calibration fields [3]. Experimental setup is shown in Fig. 2. Three samples, located in the center of Bonner spheres, were placed at the distance of 90 cm from the neutron source and aligned to the same plane. Am-Be with activity of 888 GBq was used as a reference neutron source. In addition, measurements with ^{60}Co gamma source were performed. Each sample was calibrated without moderator and with the set of six Bonner spheres.

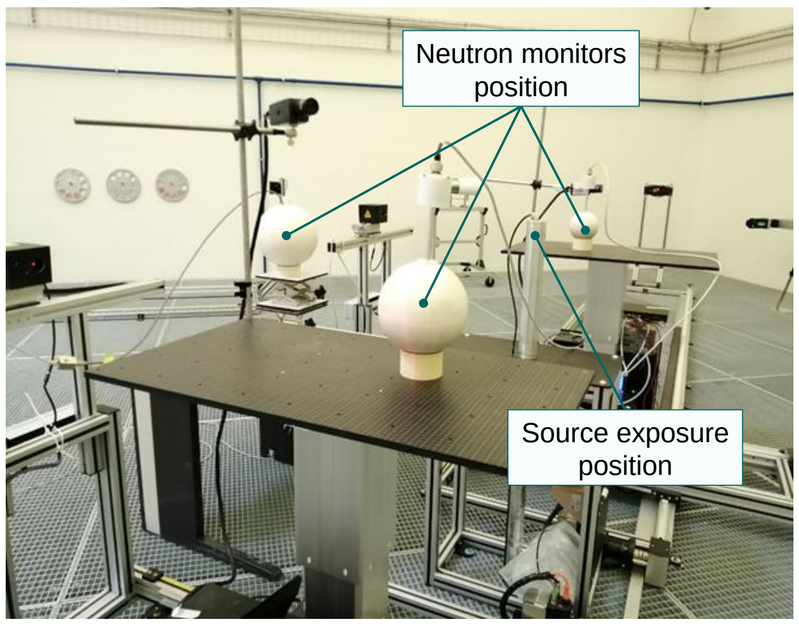

Fig. 2. Experimental setup at CERN RP calibration facility.

Results

Amplitude spectra were recorded for samples with ADC readout #1 and #2 (Fig. 3). As for the sample #1 with LiI(Eu) scintillator, a broad peak in the region of 1750 to 2550 ADC channels corresponds to the interaction between neutron and ^{6}Li nucleus with the Q-value of 4.78MeV. Since the sample #2 with ZnS(Ag)/^{6}LiF scintillator has low sensitivity to gamma radiation, neutron-related events are from 260 to 4096 ADC channel.

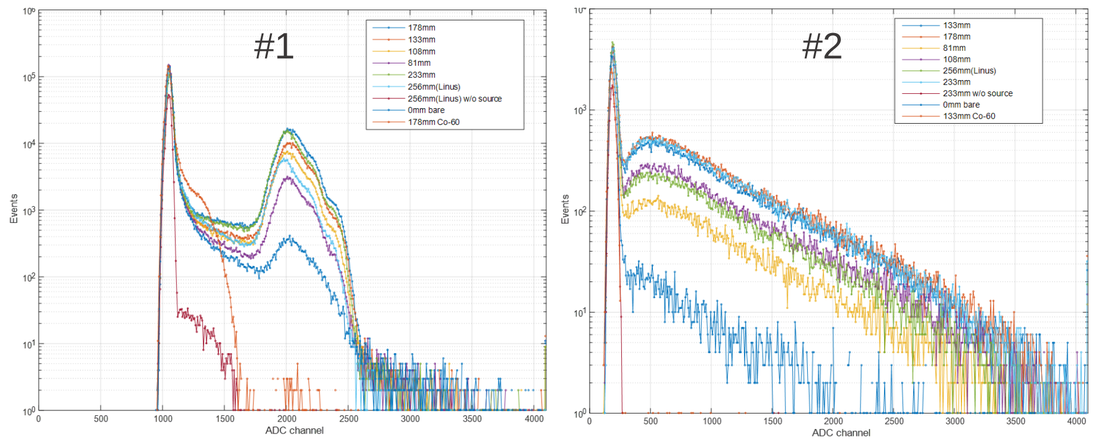

Fig. 3. Amplitude spectra for samples #1 and #2.

Fig. 4 illustrates average counts per second in dependence on moderator size for three samples. Green and yellow circles mark measurements without any source and with ^{60}Co source respectively. For all samples, the dependencies behave alike and peak at the moderator diameter of 178 mm.

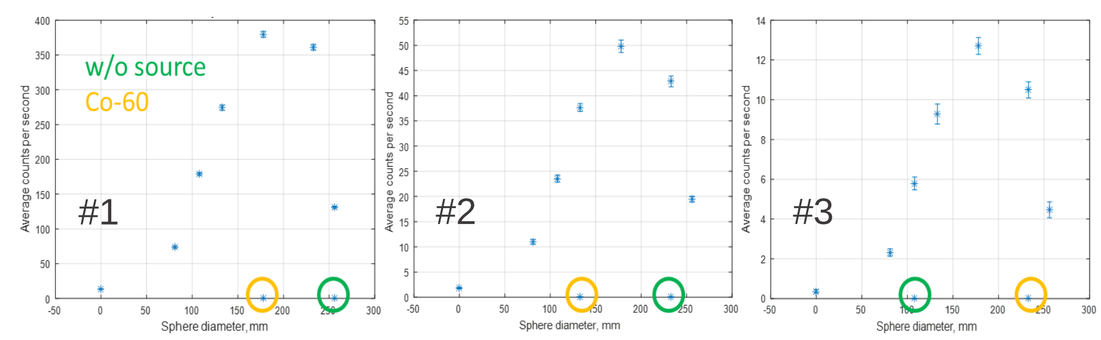

Fig. 4. Average counts per second in dependence on moderator size for three samples.