GEANT4 MODEL VALIDATION FOR FAST SCINTILLATION DETECTORS

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Received 12 May 2017; accepted 25 May 2017

1. Introduction

Scintillation detectors are widely used across the field of nuclear engineering. One of measuring techniques in which scintillation detectors are used is positron annihilation lifetime spectroscopy (PALS). This method provides microstructure investigations of condensed matter. The principle of this method is to detect γ-photons from decay of positron source and γ-photons from annihilation in inspected material. The time between registering γ-photon from source and γ-photon or γ-photons from annihilation gives the microstructure information of inspected material. Since mentioned time gap is in range of tens to hundreds of ps, short resolution time is required from measurement system. The PALS measurement system is characterized with FWHM and count rate [1], because these two properties have major impact on evaluation of experimental data. Current PALS measurement at [1] uses 3 detector layout with combination of BaF_2 scintillator crystals and XP2020Q.

Aim of our work was to create and validate the model of one scintillation detector, which would serve as a base for future geometry optimization of PALS measurement system at [1].

2. Simulation

Our aim was to simulate behaviour, light creation and transport in BaF_2 crystal. The model is based on Monte-Carlo (MC) based simulation tool Geant4. In order to simplify the geometry, we chose ^{137}Cs point source placed in front of the BaF_2 crystal. During model creation only fast scintillation component of BaF_2 crystal was taken into consideration, since the slow component is filtered in real measurement as well. Behind the BaF_2 crystal the layer of optical grease was placed, so the transport between different materials with various refractive indexes could be seen. The threshold for counting optical photons was given by properties of actual photo cathode placed in XP2020Q photomultiplier. Simulated frequency spectrum can be seen in figure 1. Simulation reflects 1 s of measurement. For statistical purposes 10 simulations were made with result of 21884 ± 1459 counts per second.

3. Measurement

As discussed in previous chapter the choice of source – detector geometry was made in order to neglect efficiency recalculation between simulation and measurement. BaF_2 cylindric crystal's dimensions were: 2.5 cm in diameter and 1.2 cm in height. To fulfil simulation conditions, we chose to discriminate the slow scintillation component. Sealed ^{137}Cs source was place on top of BaF_2 crystal. There was a layer of silicon grease applied on crystal, which ensured proper connection to photo cathode (PC). PC is made of borosilicate glass sensitive for wavelengths between 270 – 650 nm [2]. The conversion of optical photons in photo-electron is rated at 25%. Signal acquisition was made through dynode output of XP2020Q. Measurement results show 44464 ± 211 counts per second.

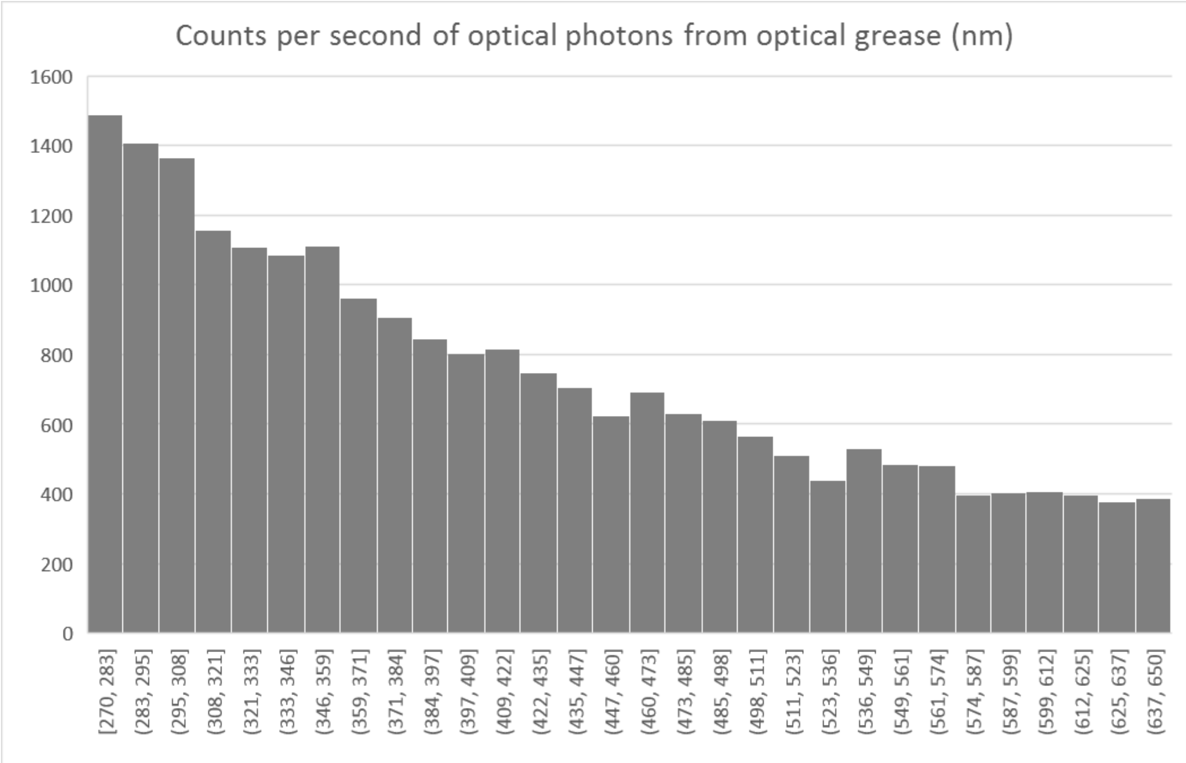

Fig. 1: *Distribution of optical photons escaping optical grease according to the wavelength*

4. Results

The Geant4 simulated behaviour of BaF_2 scintillation crystal with ^{137}Cs point source can be seen in figure 1. The comparison between simulated (21884 ± 1459) and measured (44464 ± 211 cps) shows that relative deviation between measured and simulated count rate per second is 50.8 %. Relatively high deviation can be caused with the fact that in simulation model aluminium sealing of BaF_2 crystal is not part of composed geometry, what could cause decrease of cps in simulation, since less optical photons could escape. Another contributing part to the deviation could be inaccurate setup of geometry during measurement.

5. Discussion

Validation of scintillation detector model was performed comparing the Geant4 calculation and the measurement of the count rate of dynode output of XP2020Q. Results show that further model refinement will be needed in order to decrease relative deviation. However, simulation results show, that physics setting and parameters of BaF_2 crystals are set properly. After decreasing relative deviation between simulation and measurement, we plan to optimize geometry of PALS measurement at [1] using Geant4 model, to increase detection efficiency and count rate, which is one of main properties, characterising PALS measurement system.

Acknowledgement

This work was financially supported by Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences No. VEGA 1/0104/17 and VEGA 1/0339/16.

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