Prague, Czech Republic June 21-25, 2021

Contribution ID: **216** Type: **Oral presentation**

#11-216 Experimental and Simulation Investigation of Micro- and Nano-Structure Neutron Detectors

Wednesday, June 23, 2021 9:40 AM (20 minutes)

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In this project, we are investigating different micro- and nano-structure approaches to neutron detection based on inorganic scintillators. Specifically, we have been assessing various micro- and nano-geometries to maximize the fast-neutron detection efficiency. Our approach is based on extensive Geant4 simulations that are supported through tailored experiments aimed at thorough validation of our simulation models.
Some inorganic-scintillator-based sensors that are used for neutron detection utilize two types of materials: One of them serves as a neutron converter (to convert neutrons into another, shorter-range radiation type), while the other one is typically an inorganic scintillator. The neutron converter captures incoming neutrons and emits heavy charged particles (HCPs), while the scintillator converts the HCP energy into visible light. One such detector is EJ-426 sheet from Eljen Technologies. EJ-426 neutron detector sheets are manufactured by mixing 6LiF and ZnS(Ag) powders in a transparent binder material, and this scintillator has served as the reference material for our project in terms of neutron detection efficiency.
Accurate modeling of such micro- and nano-structure materials has proven challenging for a variety of reasons. One of those reasons is the highly irregular nature of the detector's constituents with varying grain size of powders and the volumetric grain nonuniformity within the detector medium. Other reasons include unknown or poorly known optical properties of the constituent materials. The method that we have investigated to accurately model the existing and new-generation neutron detectors necessitates mutiple experiments in which grain size distribution, positional distribution of powders, and optical densities and refractive indices of constituent materials are measured. Moreover, in order to improve our Geant4 simulations, we are in the process of measuring the single photon response (SPR) of the photosensors that are being utilized for the neutron detection experiments. Experiments that involve extensive material characterization have been carried out in Material Characterization Laboratory (MCL) at the Pennsylvania State University. Specifically, Cary 7000 UV-VIS-NIR spectrophotometer from Agilent has been used to measure the total reflectance and transmittance for different EJ-426 sheets. Absorption length, which is one of the most crucial parameters for scintillator simulations, has been calculated for these EJ-426 sheets and used for the simulations. In addition, the Scanning Electron Microscopy (SEM) facility of MCL is being used to investigate the morphology of the different types of EJ-426 sheets. These investigations will involve the characterization of grains size variation and grain distribution in the sheets to improve the detector simulation models. In addition to measuring the optical properties of bulk EJ-426 sheets, optical properties of individual LiF and ZnS powders are investigated after depositing them in thin layers.
Resulting data from the aforementioned experiments will substantially strengthen our simulation models. Finally, single photon counting (SPC) experiments are being carried out for various Silicon Photomultipliers (SIPMs) to investigate the single photon response (SPR) for these sensors. ZFL-1000LN+ low noise amplifiers from Mini-Circuits are used to amplify the single photon signals. In addition, an air-cooler from TE technology will be employed to cross-check the SPR as a function of temperature. The SPR information will be beneficial for comparing the experiments to simulations more accurately since the ultimate simulation result in Geant4 is the number of light photons detected by photosensors. The experimental results, which will include optical absorption depth, grain size morphology, and SPR will be used as experimentally acquired inputs to accurately simulate EJ-426 sheets by using realistic geometry models and optical parameters. These improved simulations are paramount for our ongoing investigation of designing and optimizing various micro-

and nano-structure neutron detectors.

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Session Classification: 11 Current Trends in Development of Radiation Detectors

Track Classification: 11 Current Trends in Development of Radiation Detectors