

Poster 3. Gadolinium and Terbium-covered Bismuth-loaded Plastic Scintillators for Thermal Neutron Detection

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NEUTRON radiation detection forms a critical branch of nuclear-related issues, whether flow monitoring on industrial infrastructures, dose rate monitoring for radioprotection or radiological material detection addressing CBRN threats are concerned. The last decade has been driven by the quest for competitive alternative technologies to neutron detectors based on the helium-3 isotope whose announced worldwide shortage has generated massive market value fluctuations. In this context, the loading of plastic scintillators with organometallic complexes has shown a high potential for the deployment of sensitive and cost-effective detectors. Bismuth has thus been extensively studied as a dopant for low and medium-energy gamma-ray pseudo-spectroscopy. Now the implementation of gadolinium, which exhibits the largest cross section (48890 barns) available among stable elements for the radiative capture of incident thermal neutrons, as a converter used in conjunction with bismuth-loaded plastic scintillators opens an apparently straightforward potential for competitive innovation. A technical conundrum however lies within the separation of the scintillation signal due to the prompt gamma-rays most significantly emitted after the (n,γ) neutron radiative capture from the scintillation signal attributable to ambient gamma-rays and falling into the same energy range. To address this issue, the authors propose a neutron detection system based on three key features:

- 1) the use of natural gadolinium as a covering of the scintillator sensor to convert incident thermal neutron radiation into a photon (prompt gamma-rays and X-rays) and electron (internal conversion and Auger electrons) source term;
- 2) a two-identical bismuth-loaded plastic scintillator system, where:
 - the first scintillator, named *detection scintillator*, is covered with a gadolinium foil in which incident thermal neutron absorption occurs, while both the scintillator and the foil interact with incident photon radiation (and more marginally incident fast neutrons);
 - the second scintillator, named *compensation scintillator*, is covered with a terbium foil of same thickness as the gadolinium one. Both the scintillator and the foil interact with the photon and fast neutron part of the incident radiation, while thermal neutron absorption in terbium is negligible. In order to select energy windows of interest when studying the response to radiations, the sensors must allow for low-energy pseudo-spectroscopic performance through the enhancement of photoelectric and Compton interactions, hence the choice of bismuth-loading for the scintillators;
- 3) a unit for the compensation treatment of the signals collected on both channels, which isolates the signature of the interaction between thermal neutrons and gadolinium in the detection scintillator by subtracting the compensation scintillator response (incident photon and fast neutron radiation) to the total detection scintillator response (incident photon, fast and slow neutron radiation).

This paper describes the simulation-based scaling of the sensors and insulation of measurement channels, the synthesis of bismuth-loaded plastic scintillators, the experimental energy calibration of these scintillators, the nonlinear smoothing of the raw counting signals and the setting of a hypothesis test to discriminate the signal generated by the radiative signature of thermal neutron captures in gadolinium from statistical fluctuations over the compensation of both independent channels. The neutron measurement by compensation carried out over two gadolinium- and terbium-covered bismuth-loaded plastic scintillators has allowed the detection of a neutron activity in the photon radiation background of the californium-252 source at the exit of the HDPE block (estimated about $1.2 \mu\text{Sv}\cdot\text{h}^{-1}$ with a standard radiameter, which matches the typical constraints of a “monitored area” in the context of radioprotection applications), thus validating the concept of a new neutron detection system, robust to “controlled area” typical photon background, portable, compatible with online implementation, and whose cost-

effectiveness advantageously compare to inorganic, silicon-based compensation schemes. In order to increase the counting rates, as well as the precision associated to them, future works will be turned towards a scale-up over the loaded scintillating samples, with all the known challenges associated to such a process: homogeneity issues with the loading and self-absorption of the scintillator to quote the more obvious of them.

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