

## A Compton-TDCR experiment for low energy non-linearity measurement of scintillators

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The light output of a scintillator exhibits nonlinearity as a function of the deposited energy and the type of incident radiation. Compton-based experiments were proposed in the 1990s to evaluate the light yield of scintillators as a function of electron energy [1]. Using a multiple-gamma spectrometer, a more advanced setup (the SLYNCI device) was subsequently developed, enabling significantly higher measurement statistics [2]. These experiments made it possible to study the non-proportionality of a wide range of inorganic scintillator crystals over a broad energy interval, typically from 10 to 662 keV [3]. However, unless very bright scintillators are used, the low-energy region of the non-proportionality curves remains difficult to access. An alternative approach based on tunable synchrotron radiation has enabled measurements down to 2 keV, in the case of YAP:Ce, using X-ray fluorescence analysis.[4]

The triple-to-double coincidence ratio (TDCR) method, which allows the measurement of very low numbers of produced photons per interaction, has motivated the development of a portable Compton-TDCR device to accurately explore lower energy ranges down to 2 keV [5]. The evaluation of the light output does not rely on photopeak analysis, enabling precise characterization of a wide variety of scintillators (liquid, organic, and inorganic) as a function of deposited electron energy. In addition to light output measurements, the method allows the analysis of timing properties, which is crucial for understanding scintillation mechanisms. Beyond scintillator characterization, this approach also opens the way to new primary measurement methods that are independent of models, a key requirement in radioactivity metrology.

A new Compton-TDCR device offering improved sensitivity and energy resolution is currently under development. It combines three photomultiplier tubes for scintillation photon collection with three HPGe detectors for precise determination of the energy deposited in the scintillator. The system is coupled to new CAEN digitizers optimized for handling large data volumes. First results obtained with energies down to 1 keV on organic scintillators, together with the performance of the setup, will be presented.

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[2] Ahle, L. et al. Studies of non-proportionality in alkali halide and strontium iodide scintillators using SLYNCI. *IEEE Trans. Nucl. Sci.* 40, 1164 (2009).

[3] Arnold Burger, Emmanuel Rowe, Michael Groza, Kristle Morales Figueroa, Nerine J. Cherepy, Patrick R. Beck, Steven Hunter, Stephen A. Payne; Cesium hafnium chloride: A high light yield, non-hygroscopic cubic crystal scintillator for gamma spectroscopy. *Appl. Phys. Lett.* 5 October 2015; 107 (14): 143505.

[4] Khodyuk, I.V., Rodnyi, P.A. & Dorenbos, P. Energy dependence of the relative light output of YAlO<sub>3</sub>:Ce, Y<sub>2</sub>SiO<sub>5</sub>:Ce, and YPO<sub>4</sub>:Ce scintillators. *Instrum Exp Tech* 55, 187–197 (2012).

[5] Sabot, B., Dutsov, C., Cassette, P. et al. A compact detector system for simultaneous measurements of the light yield non-linearity and timing properties of scintillators. *Sci Rep* 14, 6960 (2024).