

Research proposal for the student ROUIZI Assia

Title: Digital Characterization and Decay Time Analysis of Unknown Scintillator Materials Using SiPM-Based Single-Channel Detection Systems

Scintillation detectors are widely used in nuclear instrumentation for radiation detection, medical imaging, and high-energy physics. A key parameter for identifying and characterizing scintillation materials is the scintillation decay time constant, which reflects the de-excitation dynamics of the crystal.

Standard scintillators such as NaI(Tl) and CsI(Tl) are well documented in the literature, but in many experimental or industrial contexts, new or unknown scintillator materials may be encountered without complete characterization.

Traditional methods for decay time measurement rely on coincidence-based electronics, which are complex, expensive, and not suitable for fast exploratory material studies.

In my Master research, I developed a single-channel digital method based on SiPM and waveform acquisition, which successfully extracted decay times of known scintillators with good agreement with literature values. This provides a strong foundation for extending the method toward unknown scintillator identification and classification.

This PhD research proposal aims to develop a digital framework for the characterization and identification of unknown scintillator materials using SiPM-based single-channel detection systems. Building on my Master's work, where a low-cost digital method was developed to extract scintillation decay time constants from known scintillators such as NaI(Tl) and CsI(Tl), this project extends the methodology toward the analysis of unexplored or poorly characterized scintillation materials. The main objective is to design a generalized, library-free approach capable of extracting and analyzing scintillation pulse features without prior knowledge of material parameters. The proposed system is based on waveform digitization using a SiPM detector, a preamplifier, a high-speed oscilloscope, and dedicated software for real-time acquisition and processing. Unlike conventional methods that assume a single exponential decay model, this work will investigate more general representations, including multi-exponential and stretched exponential behaviors, in order to accurately describe complex scintillation processes. Each scintillator will be characterized through a digital fingerprint composed of decay constants, pulse shape parameters, and light output features, enabling both quantitative analysis and comparative classification. Advanced signal processing techniques will be used for pulse detection, noise suppression, and event selection, followed by statistical and clustering methods to identify similarities between known and unknown materials. The final goal is to establish a robust and low-cost experimental and computational framework capable of transforming scintillation measurement from a simple parameter estimation tool into a material identification

technique, with applications in nuclear instrumentation, detector development, and material science.

Thesis Work Plan (Chapter Titles)

Chapter 1: Introduction and Literature Review

Chapter 2: Experimental Setup and Data Acquisition System

Chapter 3: Digital Signal Processing and Pulse Analysis

Chapter 4: Generalized Decay Models and Feature Extraction

Chapter 5: Characterization of Unknown Scintillator Materials

Chapter 6: Validation, Comparison, and Performance Evaluation

Chapter 7: Conclusion and Future Perspectives