New Radiation Detector Technologies for Time-of-Flight PET: Heterostructured Scintillators

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Time-of-flight positron emission tomography (TOF-PET) is an advanced medical imaging technique providing high-resolution images of metabolic processes in the body. To further enhance the performance of TOF-PET, it is crucial to improve the coincidence time resolution (CTR) of the detectors. Achieving a CTR below 100ps while maintaining high sensitivity is a current challenge. One potential solution to this tradeoff is the use of heterostructured scintillators, which involve combining materials with complementary properties and taking advantage of the energy sharing mechanism of the recoil photoelectron.

In this contribution, we present a comprehensive study for the understanding of heterostructured scintillators, with a specific focus on BGO&EJ232 plastic scintillator heterostructures. Our investigation started with Monte Carlo simulations to study the energy-sharing mechanism and optimize the geometry. We evaluated the improved timing performance of the heterostructures compared to bulk BGO, also measuring pixels of different lengths (3, 15, and 20 mm) to analyze the degradation of the timing performance due to the depth of interaction (DOI). To mitigate this effect, double-sided high-frequency readout measurements were performed, allowing us to estimate a DOI resolution of 6.5 mm. We experimentally validated an analytical model to describe the scintillation kinetics and CTR of the heterostructure as a linear combination of those of the two materials involved, weighted by the energy deposited in each. This result will help the research for new materials to further improve the performance of heterostructures.

Our current focus is on the scalability of our single-detector system. We have performed Monte Carlo simulation studies with Geant4 and GATE to estimate the impact of heterostructures on the quality of the reconstructed image. We are also studying machine-learning clustering algorithms to optimize event classification and testing high-frequency multichannel readout to measure the first TOF-PET module based on heterostructured scintillators.