Gamma-ray imaging using a single segmented HPGe detector and a lightweight Pulse Shape Analysis (PSA) machine learning method

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Abstract

Gamma-ray imaging based on Compton scattering typically requires a two-component system, consisting of a scatterer and an absorber. The present work explores an alternative approach using a single, segmented high-purity germanium (HPGe) detector from the Advanced GAmma Tracking Array (AGATA) [1] collaboration for reconstructing the position of a radioactive source. A key advantage of using a single HPGe detector is its superior detection efficiency, compared to a scatterer-absorber device, as it can simultaneously capture and process gamma rays from nearly the full solid angle. The detector's segmentation, 36 segments and a central core contact, allows pulse shape analysis (PSA) [2,3] techniques to enhance position resolution of the gamma rays interactions. Additionally, the excellent energy resolution of HPGe intrinsically reduces uncertainty in the half-opening angle of the Compton cone, enhancing the reconstructed image resolution.

The present study introduces a lightweight PSA machine learning model based on a 3D basis of waveforms, of more than 46000 points equally spaced by 2 mm along X, Y and Z axes in the HPGe crystal volume, constructed using the IPHC scanning table with the Pulse Shape Comparison Scan (PSCS) [4] method. By replacing the computationally intensive χ^2 comparison between recorded waveforms and a 3D database, this model improves processing speed, making it well-suited for real-time applications. These advancements highlight the potential of a single segmented HPGe detector for time-efficient and precise gamma-ray imaging.

Keywords Gamma-ray imaging, 4π-detection, lightweight PSA, single-volume device

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