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Applications of FAST detectors in Positron Emission Tomography

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Excellent timing resolution ($< 20\,ps$) solves the need for tomographic reconstruction when working with true coincidences in Positron Emission Tomography (PET). However, the impact of events where at least one photon undergoes Compton scattering increases, especially if very fast detector compromise energy resolution. In a human adult abdomen, $511\ keV$ photons travel up to 5 mean free paths ($\lambda \approx 10\,cm$) in tissue for the Compton scattering cross-section. The probability is mostly in the forward direction, therefore precise Compton scattering correction is fundamental for accurate PET reconstruction.

With "infinitely precise"timing information, however, it is theoretically possible to reconstruct PET coincidences without knowing whether an event has undergone Compton scattering nor its angle. The "line of response"connecting the two scintillating crystals, with infinitely precise timing and no assumptions about the Compton scattering process, becomes an arc of a circle. Therefore, full image reconstruction is possible without the need for scatter correction. We will show how this is possible, the issues in implementing this and the resulting trade-off in signal vs noise compared to the standard technique.

Greatly improved temporal resolution from electronics readout will also improve accuracy in identifying photons that underwent inter-crystal scattering in a novel detector design. This opens the possibility for collimator-free single photon tomographic imaging. Here we will show how this can be extremely useful for mid-energy ($300\,keV\ -\ 1\,MeV$) isotopes. It will also improve the field of parametric imaging, which is the basis of multiple artificial intelligence applications currently under study, and in 3-γ PET imaging, where it will enable positronium lifetime imaging, which also requires good temporal resolution.

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