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Monte Carlo simulations on performance of double-scattering Compton camera

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Compared with conventional gamma-ray emission imaging device based on mechanical collimation, the Compton imaging technique based on so-called 'electronic collimation'could provide better performance in terms of imaging resolution and sensitivity when the gamma-ray source to be imaged has relatively high energy, i.e., more than a few hundreds keV. We have developed a prototype double-scattering Compton camera which consists of two double-sided silicon strip detectors (DSSDs) for scatter detectors and a cylindrical NaI(Tl) scintillation detector for absorber detector for nuclear decommissioning applications and particle therapy applications both of which involve imaging high energy gamma-ray sources. The basic idea of the double-scattering Compton camera is to maximize the imaging resolution by measuring two successive interaction positions of Compton scattering very accurately because the imaging resolution is mostly limited by the spatial resolution of the component detectors which consequently affects the accuracy in determining the axis of the reconstruction cone. In the present study, the performance of the double-scattering Compton camera was compared with that of a single-scattering Compton camera with similar dimensions as a function of the source energy by using Geant4 Monte Carlo simulations. The optimal geometry of the multiple-detector-type double-scattering Compton camera was also studied by comparing the performance of the Compton camera for two extreme cases, that is, when the additional scatter detectors are placed in the planar direction and in the axial direction. In addition, the performance of the double-scattering Compton camera was evaluated when additional side absorber detectors were used to register the double-scattered photon in the backward direction. In this case, we can easily expect that the imaging sensitivity will be enhanced; however, the imaging resolution could be degraded by the increase of the number of events with wrong interaction sequences. We hope that the results of this simulation study will provide a guideline to researchers to find a proper design of Compton camera for a given objective.

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