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Development and research of a single-plane Compton gamma camera

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The detection of environmental radiation is of great importance and efficient, compact, and cost-effective instruments are highly needed. One of the potentially suitable detection tools for the detection of gamma radiation is the Compton gamma camera (CGC), which, in contrast to gamma cameras with mechanical collimations, uses electronic collimation based on the kinematics of the Compton scattering. The evolution of CGCs started with semiconductor detectors, which provide excellent spatial resolution, but suffer from complexity and high costs, later shifted to scintillator detectors, initially with photo-multiplier tubes and more recently with Silicon photomultipliers (SiPMs). Scintillator-based CGCs have lower, yet still acceptable angular resolutions compared to the ones based on semiconductors, but higher efficiencies and lower cost. Most CGC realizations comprise two separate detector planes, the scatterer and the absorber or they implement complex realizations to be able to determine the depth-of-interaction of the incoming gamma radiation.

We designed a novel concept of a single-plane CGC based on segmented scintillators, read out on a single side by silicon photomultipliers (SiPM). In this concept, a detector element consists of two identical GAGG:Ce scintillator crystals of 3 mm x 3 mm x 3 mm optically coupled by a plexiglass light guide of 3 mm x 3 mm x 20 mm between them. Detector elements are placed in an 8x8 matrix with a 3.2 mm pitch, separated by an ESR reflector. In this configuration, the front scintillator layer is acting as the scatterer and the back scintillator layer is acting as the absorber, while both are read out by the same silicon photomultiplier array coupled to the back side of the matrix. This is the most prominent feature of this concept since it keeps the minimum number of read-out channels, which is crucial for a compact and portable device. The silicon photomultiplier array is read out by the TOFPET2 data acquisition system. We constructed the Compton gamma camera according to the above-mentioned design and tested it in our laboratory by irradiating it with gamma-ray sources of different energies. The average energy resolution of the front and the back detector layer was found to be 8.9 ± 1.9% and 10.8 ± 1.6%, respectively for gamma-ray of 662 keV energy. The basic imaging test obtained with a Cs-137 source (diam. ≈ 3 mm) placed 50 mm in front of the detector using a simple back-projection algorithm, shows a Gaussian peak standard deviation of
σ=5.1±0.2 mm. In this contribution, we present the results of the detailed characterization of the detector performance at gamma-ray energies of 511 keV and 662 keV as well as the estimate of its imaging capabilities for gamma sources located at various positions within the field-of-view. Finally, we will discuss the potential of the designed detector for application as a highly-compact and portable Compton gamma camera.

Key words: Radiation detection, Compton camera, gamma imaging, GAGG, SiPM

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