Optimizing the design of a Timepix4 based compact gamma camera with validated Geant4 Monte Carlo simulations

L. A. Cerbone[1], A. Sarno[1], M. Fiorini[2], N. V. Biesuz[2], R. Bolzonella[2], G. Mettivier[1], P. Russo[1]

[1]Dept. of Physics "Ettore Pancini", University of Naples Federico II & INFN Naples, Naples (Italy).
[2]Dept. of Physics, University of Ferrara, & INFN Ferrara, Ferrara (Italy).

Background: We optimized the design of a new compact gamma camera (MediPROBE4) for coded aperture imaging in nuclear medicine [1] adopting the Timepix4 read-out circuit. The performance of the coded aperture (CA) mask (which permits 3D depth imaging) was investigated to optimize its constructive parameters for scintigraphy with Tc^{99m}. A CdTe pixel detector response was simulated.

Material and Methods: A Geant4 Monte Carlo code was developed to simulate point-like and extended sources emitting photons at 140.5 keV (Tc^{99m}). Photoelectric, coherent and incoherent scatter interactions were simulated, as well as de-excitation processes. The source was placed at various distances from the phantom of the CA mask, located at 1 cm from the detector. The mask (32×32 NTHT MURA scheme) was modelled as 1-mm thick tungsten slab with the apertures pattern comprising 480 round holes with 0.25 mm diameter. Image reconstruction was via a cyclic autocorrelation algorithm. Software validation was carried out experimentally using a Timepix3 detector and an available high resolution CA mask.

Preliminary results: The calculated FWHM spatial resolution was 1.7 mm at 50 mm source-to-collimator distance (SCD), with a FOV of 90×90 mm^2. An image of an extended source in air obtained with 10^7 photons collimated on the detector is shown in Fig 1a; the source SNR was as high as 14±2. A reconstruction artifact is visible, to be mitigated by a mask/antimask procedure. The collimator geometric efficiency was ca. 290 times higher than for a single hole in the mask (Fig. 1b). The longitudinal resolution was 5 mm at 50 mm SCD.

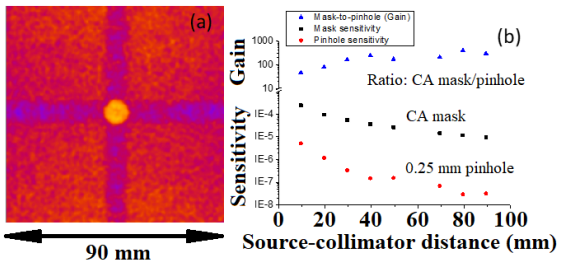

Figure 1: (a) Reconstructed image of a circular planar source (diameter 10 mm) centrally located; (b) background-subtracted collimator sensitivity vs. SCD, for a single hole in the mask, for the CA mask, and sensitivity gain (ratio mask/hole).

[1] P. Russo *et al.*, Phys. Med., 69 (2020) 223-232.