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Design and initial results of a total-body PET with TOF and DOI capabilities

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Interest towards high sensitivity multiparametric imaging modalities has increased during the last years. In this context, high precision Positron Emission Tomography (PET) scanners have shown great potential. Two paths to further enhance PET sensitivity have been outlined: (i) including photon Time-of-Flight (TOF) information during the image reconstruction process; or (ii) increasing the axial length of the scanner, i.e., total-body PET (TB-PET). Yet, the ideal scenario would be a TB-PET with precise TOF capabilities but, this imposes major technological challenges.
Following this goal, the I3M is developing a clinical TB-PET scanner of approximately 80 cm diameter and 70 cm axial coverage, based on 7 rings. The detector design is based on 8 slabs of 25.8×3.1×20 mm3 LYSO crystals coupled to an array of 8×8 SiPMs from Hamamatsu Photonics. The slab configuration is key to achieve good timing resolution while providing accurate 3D photon impact positioning, and our custom designed electronics includes a novel multiplex readout electronics that reduces from N2 to 2N the number of signals to digitize. In addition, the electronic chain is combined with PETsys ASIC for compactness and scaling up of the detector technology.
Simulations of the system have been carried out demonstrating a Noise Equivalent Count Rate (NECR) of 91 kcps at 9.1 kBq/mL (for a 20 cm axial coverage), which is comparable with state-of-the-art scanners.
Moreover, the first modules have been already ensembled. Experiments have been carried out by displacing a collimated 22Na source - using a slit of 0.45 mm thick- across the entire entrance and lateral faces of the module. In a first stage without including the multiplexing readout electronics, the x- and DOI- coordinates were estimated using a Neural Network and the timing was estimated applying an energy-weighted average method. Average results for one mini-module showed energy resolution of 10±1.8%, 221±9 ps CTR, 2.9±0.6 mm FWHM along monolithic direction and 3.9±0.9 mm FWHM DOI resolution. In a second stage, the multiplexing readout was included and energy resolution values of 13.4±0.9% and CTR of 305±5 ps were achieved. The flood map quality was also good. Note that these values were calculated analytically, without using the NN which is being implementing at this moment. Results will be shown at the conference.
These promising results brings us closer to the goal outlined at the beginning of this abstract: boosting sensitivity by building practical and transferrable TB-PET systems.

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