Performance measurements of Total Body PET scanner simulations using the Geant4 toolkit

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Total-Body PET (TB PET) is a novel imaging modality that can image the whole body in a single scan. It has increased sensitivity, improved spatial resolution, reduced imaging times compared to conventional clinical PET scanners, and has the potential to detect smaller lesions and multiorgan diseases. Commercially available TB PET scanners include the Siemens Biograph Vision Quadra [1] and the United Imaging uEXPLORER [2].

This study uses the Geant4 toolkit [3] to create a simulation model of two different TB PET detector geometries; Siemens Biograph Vision Quadra and uEXPLORER. Analysis of simulated data and performance measurements were carried out in Python. The study follows the NEMA NU-2 2018 standard [4]. The simulation was used to explore the effect of different scintillator crystals and evaluates the count rate performance and the sensitivity of the scanner. The simulated data was compared to published experimental data from Siemens and Explorer.

Good agreement between the count rates of simulated and experimental data was observed for both geometries. The simulated Siemens Quadra measured a system sensitivity value of 178.6 cps/kBq showing a 2% difference compared to the experimental data of 175.3 cps/kBq for LSO crystals. Axial sensitivity profiles plotted also match well. The comparison of different scintillators showed that BGO performs best as it has the highest peak NECR, thus good signal-to-noise ratio. LSO and LYSO also perform well and their physical properties are similar. NaI and CsI exhibit the worst performance; with low true count rates and the random count rates increased almost linearly with activity concentration.

Our simulations compared well against experimental data, allowing us to test further scintillator materials and radioisotopes. After implementing image reconstruction and relevant corrections, this simulation can be used for validation of various research ideas in the future.

References:

(1) George A. Prenosil, Hasan Sari, Markus Fürstner, Ali Afshar-Oromieh, Kuangyu Shi, Axel Rominger and Michael Hentschel. *Performance characteristics of the Biograph Vision Quadra PET/CT system with long axial field*

of view using the NEMA NU 2-2018 standard. Journal of Nuclear Medicine, March 2022, **63** (3) 476-484. DOI: 10.2967/jnumed.121.261972 .

(2) Benjamin A. Spencer, Eric Berg, Jeffrey P. Schmall, Negar Omidvari, Edwin K. Leung, Yasser G. Abdelhafez, Songsong Tang, Zilin Deng, Yun Dong, Yang Lv, Jun Bao, Weiping Liu, Hongdi Li, Terry Jones, Ramsey D. Badawi, Simon R. Cherry*. Performance evaluation of the uEXPLORER total-body PET/CT scanner based on NEMA NU 2-2018 with additional tests to characterize long axial field-of-view PET scanners.* Journal of Nuclear Medicine June 2021, **62** (6) 861-870. doi: 10.2967/jnumed.120.250597

(3) Benjamin M. Wynne, Hanna Borecka-Bielska, Matthew Needham, and Adriana Tavares. *Parameterised Geant4 simulation for total body PET research*. arXiv:2311.16689, November 2023.

(4) National Electrical Manufacturers Association. Performance Measurements of Positron Emission Tomographs (PET). NEMA Standards Publication, 2018.