Introduction of the DOI capable Total-Body J-PET: a simulation study

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Introduction

The development of Total-Body PET technology is one of the most recent trends in the medical imaging field. Having a large axial field of view (AFOV), they provide a greater detection area and therefore an increased sensitivity

J-PET technology

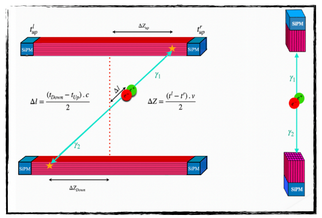

Fig. 1: J-PET technology vs current PET scanners

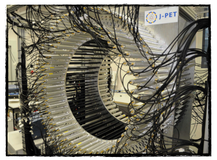

Fig. 2: First generation of J-PET tomograph with 50 cm AFOV

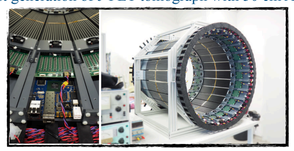

Fig. 3: 24 Modular J-PET with 50 cm AFOV

Total-Body J-PET

Jagiellonian PET (J-PET) collaboration from Krakow, Poland is currently developing novel PET tomographs based on organic, plastic scintillators [1-3]. Such a unique design allows not only for the introduction of a cost-efficient Total-Body system but also is able to solve challenges connected with such tomographs.

- Limited axial detector coverage
- Lower detection probability
- Multiple bed positioning imaging
- High dose scanning

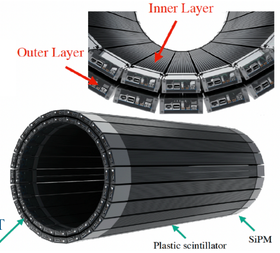

Fig. 4: 3D rendered visualization of the proposed Total-Body J-PET

Methods

The presented study has been performed using GATE simulation software dedicated to medical imaging [4]. Two Total-Body tomographs designed based on the J-PET technology were simulated [5].

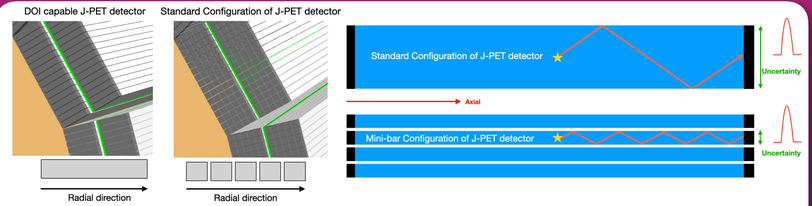

Fig. 5: Standards Vs. DOI capable J-PET

Results

To investigate the effect of the new configuration on the percentage share of the coincidences, a 70 cm cylindrical phantom with a diameter of 20 cm and a 70 cm line source have been simulated. The present results show the similarity in both scanners

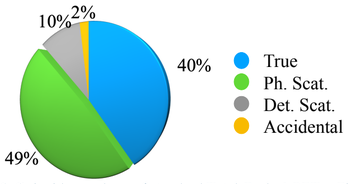

Fig. 6: Coincidence share of standard Total-Body J-PET

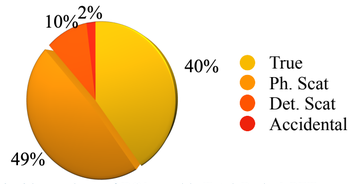

Fig. 7: Coincidence share of DOI capable Total-Body J-PET

Applying Acceptance Criterion

Applying an acceptance angle can remove the contribution of the oblique coincidences in the image reconstruction and as the consequence avoid degradation of the axial resolution caused by parallax error.

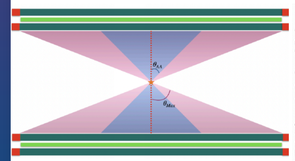

Fig. 8: Concept of acceptance angle [6].

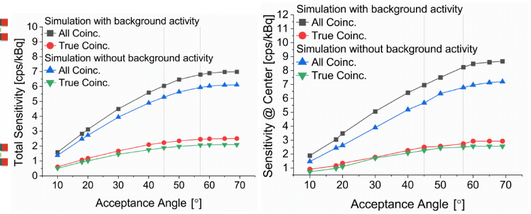

Fig. 9: Effect of the acceptance angle on the sensitivity of the scanner

DOI capable Total-Body J-PET

The main aim of the study was to improve axial resolution without losing sensitivity by applying an acceptance angle. For this case, a point source in various cylindrical phantom which mimics different BMI has been simulated, and corresponding axial resolutions were calculated.

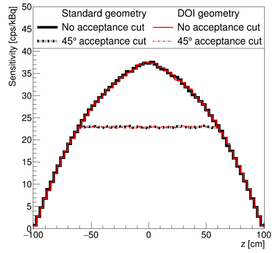

Fig. 10: Sensitivity profile of Standard Vs. DOI capable Total-Body J-PET

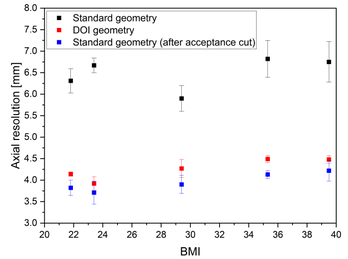

Fig. 11: Axial resolution of Standard and DOI capable Total-Body J-PET.

Conclusion

The aim of the presented study was to provide a solution to improve the axial resolution of the Total-Body J-PET scanner. The obtained results show that the presented configuration improves the axial resolution without any losses in the sensitivity and additional negative effects on other characteristics.

Acknowledgments

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References

1. Moskal, P., et al. Nat. Commun., vol. 12, no. 1, 2021.
2. Moskal, P., Stępień, E. PET Clinics 15(4), 439–452, (2020).
3. Vandenberghe S., Moskal P., Karp, J. EJNMMI 7(35),(2020).
4. Kowalski, P, et al. Bio.Algo. Med. Syst., vol. 10, no. 2, 2014.
5. Smyrski, J.,et al. Nuclear Instruments and Methods in Physics Research A 851(5), 39–42 (2017)
6. Dadgar, M., Parzych, S.and Tayefi, F., in MIUAOxford, UK, 2021, pp. 189–200.