Towards total-body modular PET for positronium and quantum entanglement imaging

P. Moskal, J. Chhokar, D. Kamińska, E. Kubicz, Sz. Niedźwicki, S. Sharma on behalf of the J-PET collaboration

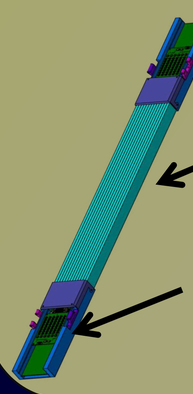
Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University,
Lojasiewicza 11, 30-348 Krakow, Poland

Email : p.moskal@uj.edu.pl

Abstract:

The purpose of the reported research is (i) the elaboration of the new imaging method based on the in-vivo measurement of properties of positronium produced inside patient during positron emission tomography, and determination of correlations between properties of positronium inside the cancer tissues and histopathological characteristics of cancers, as well as (ii) exploration of possibilities of the determination of the linear polarization of annihilation photons and development of novel prognostic indicators for cancer therapy based on the quantum information from (multipartite) entanglement of the positronium decay.

Single Module

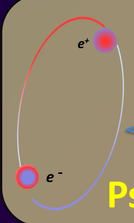


Each module is composed of 13 plastic scintillators.

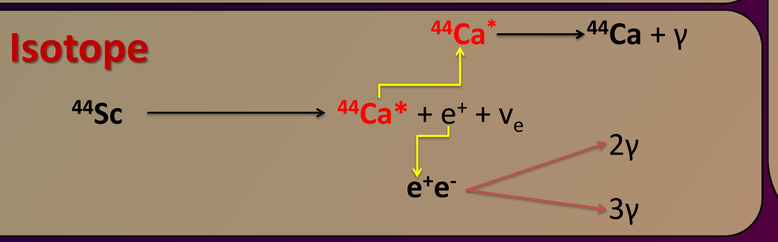
Front-end electronics is associated on each side of modules.

24 standalone Modules

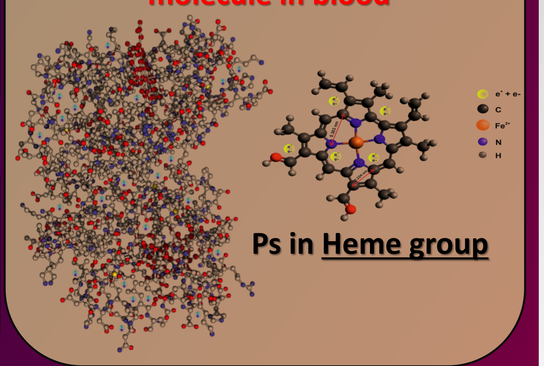
Positronium atom



Isotope

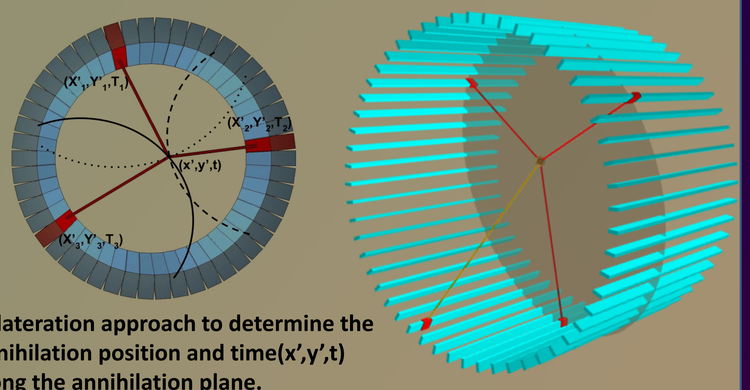


Heme group present in hemoglobin molecule in blood



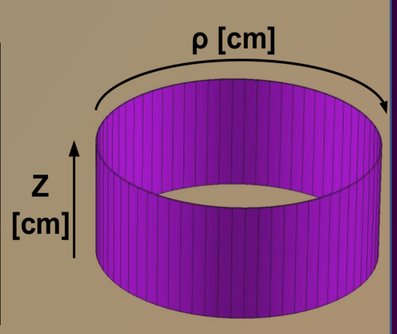
Positronium Imaging

Trilateration Method

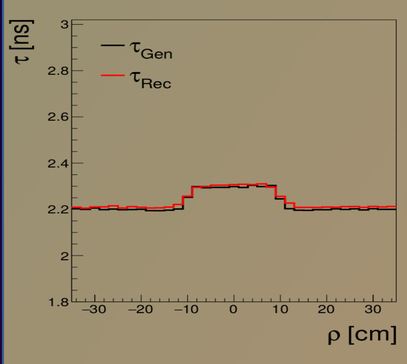


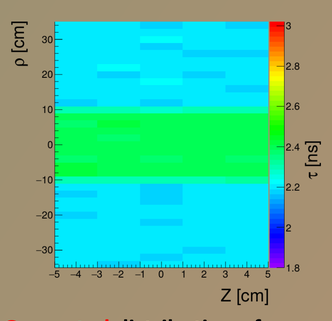
Trilateration approach to determine the annihilation position and time(x',y',t) along the annihilation plane.

Phantom

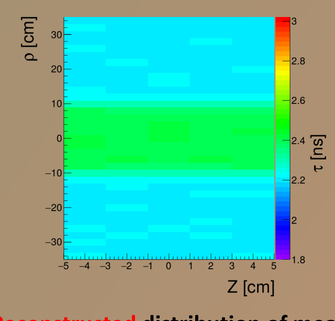


Phantom with cylindrical shape.





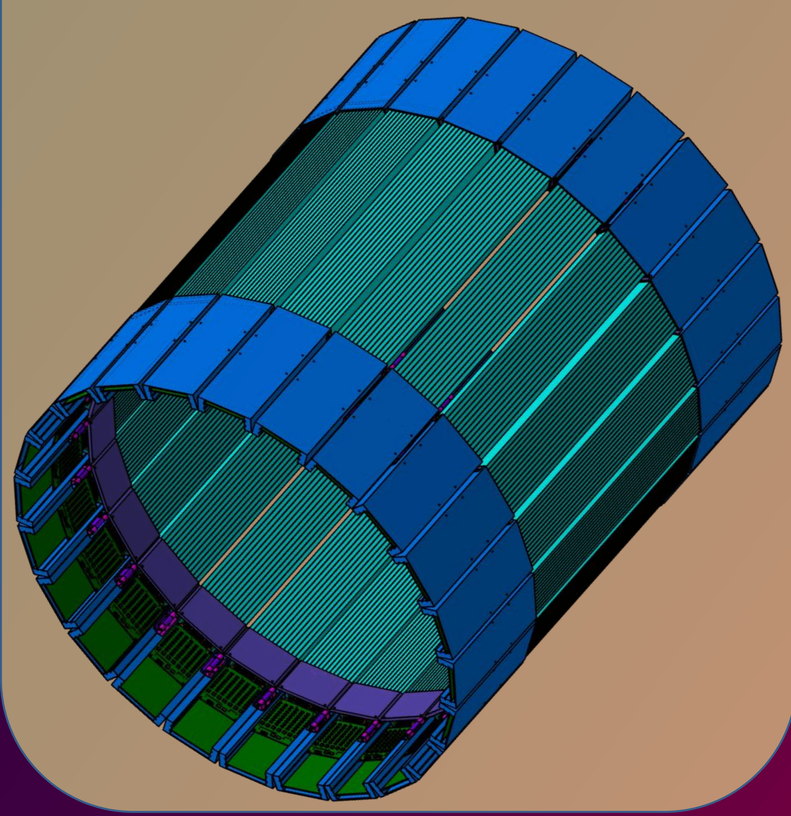
Generated distribution of mean ortho-positronium life time as f(z,ρ)



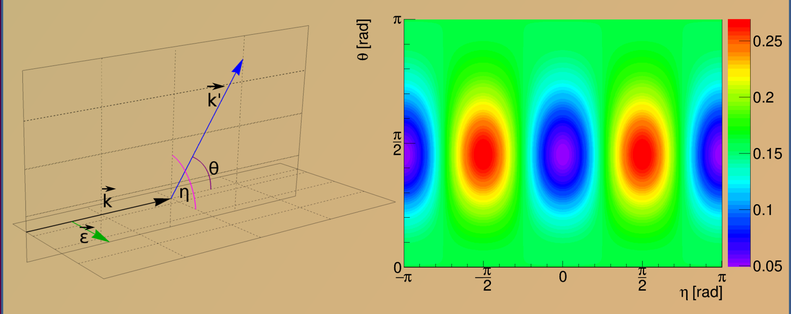
Reconstructed distribution of mean ortho-positronium life time as f(z,ρ)

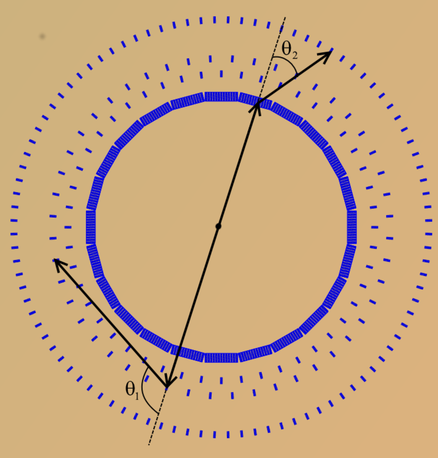
Modular J-PET

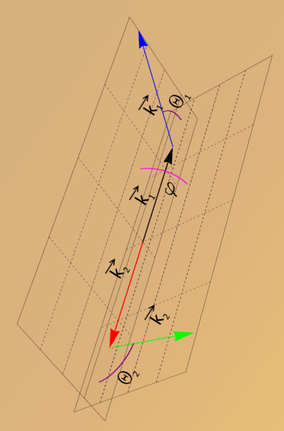
Modular, Light weight, Portable, Reconfigurable PET

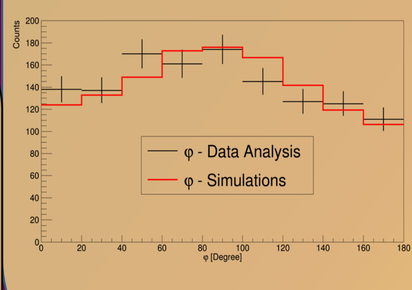


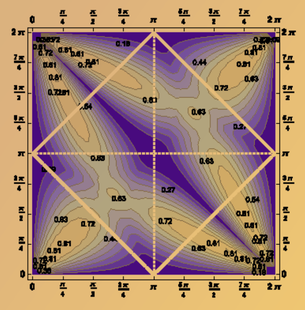
Quantum Entanglement Imaging





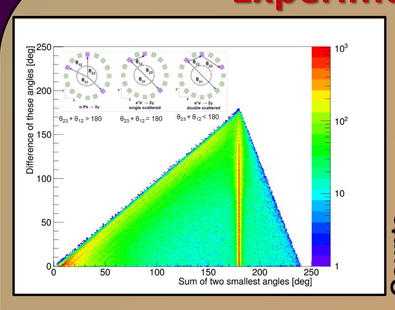




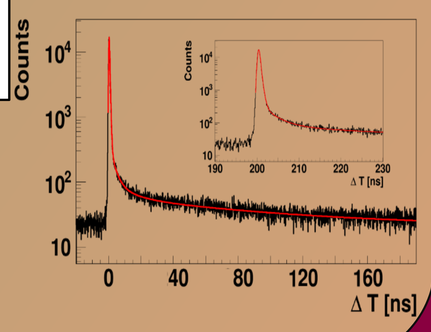


Entanglement Witness[10]

Experimental Results



Angular correlation



Positronium Lifetime Distribution

Acknowledgement:

This work was supported by The Polish National Center for Research and Development through grant INNOTECH-K1/IN1/64/159174/NCBR/12, the Foundation for Polish Science through the MPD and TEAM/2017-4/39 programmes, the National Science Centre of Poland through grants no. 2016/21/B/ST2/01222, 2017/25/N/NZ1/00861, the Ministry for Science and Higher Education through grants no. 6673/IA/SP/2016, 7150/E338/SPUB/2017/1 and 7150/E-338/M/2017, 7150/E-338/M/2018, and the Austrian Science Fund FWF-P26783.

Conclusion:

Pilot investigations of properties of positronium atoms in uterine tissues operated from human patients indicate meaningful differences between healthy and tumorous tissues. The obtained results [1] show that, as suggested in references [2,4], measurements of properties of ortho-positronium atoms (such as lifetime and production probability, or 3γ to 2γ rate ratio) which are formed inside the human body during a routine PET imaging may deliver information useful for the diagnosis. The feasibility studies of the imaging of positronium properties show that it is possible to obtain such images with the future total-body PET modalities.

Refrences:

[1] J-PET: Moskal P et al., arXiv:1805.11696, submitted to Phys. Med. Biol. (2018).
[2] J-PET: Moskal P et al., Patent No: US 9851456 (2017); PL 227658 (2013); PCT/EP2014/068374.
[3] Hiesmayr B and Moskal P, arXiv:1807.04934, submitted to Scientific Reports (2018).
[5] J-PET: Moskal P et al., (2015) Nucl. Instr. Meth. A775, 54.
[6] J-PET: A. Gajos et al. (2016) Nucl. Instr. Meth. A819, 54.
[7] J-PET: Moskal P et al., (2016) Phys. Med. Biol. 61, 2025.
[8] J-PET: Moskal P et al., (2016) Acta Phys. Polon. B47, 509.
[9] J-PET: D. Kamińska et al., (2016) Eur. Phys. J. C76 (2016) 455.
[10] Hiesmayr B and Moskal P (2017) Scientific Reports 7, 15349.
[11] Jasinska B and Moskal P (2017) Acta Phys. Polon. B48, 1577.
[8] J-PET: Raczynski L et al., (2017) Phys. Med. Biol. 62, 5076.
[7] J-PET: Niedzwiecki Sz et al., (2017) Acta Phys. Polon. B48, 1567.
[12] J-PET: Jasinska B et al., (2017) Acta Phys. Polon. B48, 1737.
[13] J-PET: Kowalski P et al., (2018) Phys. Med. Biol. 63, 165008.
[14] Cern Courier, Oct(2018)
[15] G. Korcyl et. al., IEEE Transactions on Medical Imaging37(2018)11