

First three-photon positronium image obtained with the J-PET scanner: towards multi-photon imaging

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Positronium atoms, i.e. bound states of electron and positron, produced by up to 40% of positrons in conventional Positron Emission Tomography (PET) scans, are presently not utilized for imaging. However, their annihilations may carry essential information complementary to the functional imaging of PET [1].

The recently proposed technique of multi-photon imaging with the Jagiellonian Positron Emission Tomography (J-PET) scanner [2] aims at spatially-resolved determination of positronium properties in the examined volume. To date, use of two-photon positronium annihilations to obtain a positronium lifetime image was demonstrated [2]. Another conceivable modality comprises obtaining an image as a map of the ratio of two-photon to three-photon annihilations of positronium, for which spatial reconstruction of three-photon annihilations of the positronium trilepton state is required.

The talk will discuss the capability of the J-PET scanner to record, identify and reconstruct three-photon positronium annihilations. Methodology and results of the first test of three-photon imaging with J-PET [3] will be presented, including the first image of an object of extensive dimensions obtained solely using ortho-positronium annihilations into three photons. Performance of this imaging method will be discussed and compared to that of conventional two-photon imaging with the same setup.

References:

- [1] P. Moskal, B. Jasińska, E. Ł. Stępień and S. D. Bass, „Positronium in medicine and biology”, *Nat. Rev. Phys.*, vol. 1, pp. 527-529, 2019, doi: 10.1038/s42254-019-0078-7.
- [2] P. Moskal, et al., „Positronium imaging with the novel multi-photon PET scanner”, *Science Advances*, to be published.
- [3] Moskal et al., „Testing CPT symmetry in ortho-positronium decays with positronium annihilation tomography”, *Nat. Commun.*, vol. 12, pp. 5658, 2021, doi:10.1038/s41467-021-25905-9.

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