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Positronium Imaging with the J-PET detector for the medical purposes

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Positronium Imaging [1-4] is a branch of Positron Emission Tomography (PET) which focuses on the spatial and structural correlation probed by positronium (positron-electron atom) formation in the test sample or in the tissues of patient. It is possible due to the (main) influence of the size of the free volumes (nm scale) on the mean lifetime of the long-lived positronium state - ortho-positronium (total spin number S = 1) [1-6]. Moreover, the position of positronium decay can be reconstructed based on its decay products – high-energy photons [1-8]. Therefore, by using additional marker of the positronium formation the lifetimes and the positions of a single decays of positronia can be collected during a scan. The positronium images consist of an estimate of the mean positronium lifetime in each image voxel. Such marker that can be used to estimate the formation of the positronium is an additional photon associated with the creation of a positron which forms positronium with an electron from the tested sample [1-4]. Due to the additional contrast that can differentiate healthy cells from neoplastic cells from the mean lifetime of the positronium, the potential of PET to detect neoplastic lesions may be increased, where the possibilities of determining the degree of malignancy from positronium imaging are also discussed [1-4]. The first demonstration of positronium imaging was performed on the J-PET detector [1], which is based on an innovative technology that benefits from the excellent timing capabilities of plastic scintillators (resolution ≈ 100 ps) as well as a relatively large axial field-of-view (FOV ≈ 0.5 m) [3, 5-8]. Fundamentals of positronium imaging and results from the imaging of the phantom consisting of heart tumor tissues (Cardiac Myxoma) and normal pericardial tissues by the J-PET detector will be shown. These are also the first images obtained by positronium imaging, and the J-PET detector is the first device capable of collecting such images.

References:
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