Characterization of the 192-strip J-PET detector for multi-photon positronium imaging.

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Abstract

Positronium imaging is a promising new technique that can enhance the diagnostic capabilities of Positron Emission Tomography (PET), based on a new structural index derived from ortho-positronium interaction with the environment in which it annihilates [1,2]. Simultaneous reconstruction of the position of o-Ps annihilation and its average lifetime, it becomes possible to characterize the structure of a given part of the sample in space. Currently, the J-PET detector [1-3] is the only detector that is capable of obtaining positronium images. The positronium images of the two phantoms measured by the 192-strip J-PET detector will be shown [1,4]. Additionally, data on the sensitivity and purity of two- and three-photon positronium imaging will be presented on the basis of simulation data [4].

Multi-photon positronium imaging by the J-PET detector

(2G)   **(3G)**
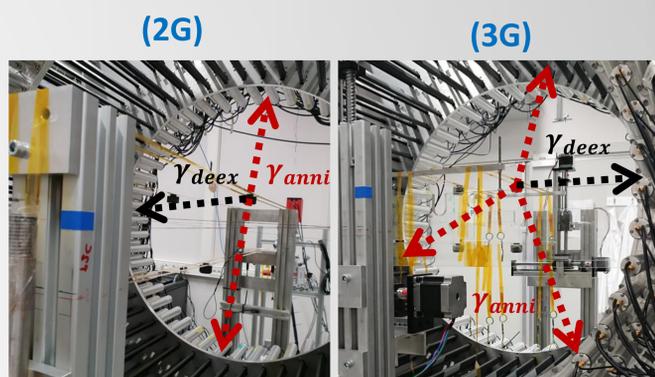
Two phantoms measured:
- Porous samples **IC3100, XAD, PVT**
- Tissue samples **Cardiac Myxoma** and **Adipose Tissue**

Possible types of background in the data sample in the event

(DeexScat)   **(AnniScat)**   **(AnniMix)**

(2G)

(3G)
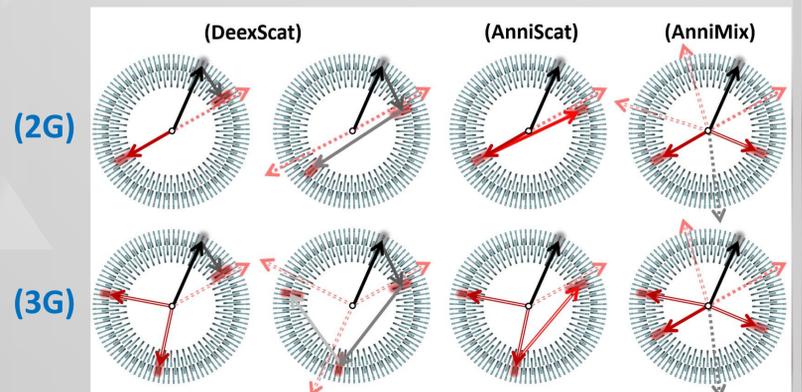
Purity and sensitivity

Simulations with the J-PET Geant4 software were conducted in order to estimate sensitivity and purity of each type of the positronium imaging event for the 192-strip J-PET detector. Simulations were analysed with the J-PET Framework to apply the same reconstruction algorithm and data selection as for real data.

In addition, fraction of each type of the background was estimated based on the tracking of the photons origin and history during the analysis.
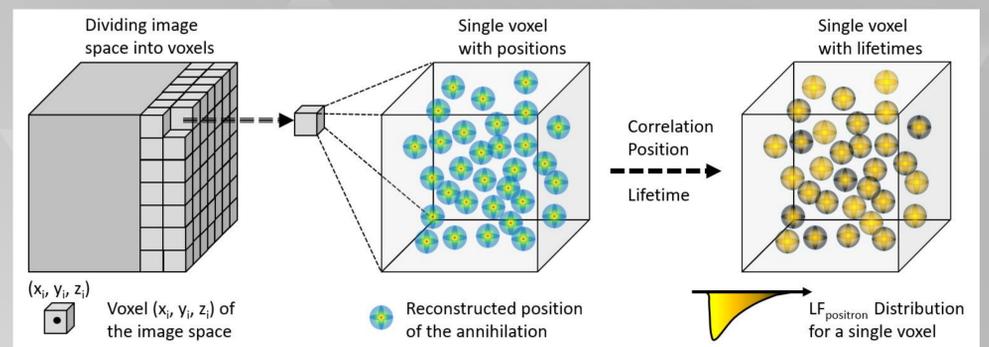
(2G)					
Sensitivity [$\cdot 10^{-6}$]	Purity [%]	(DeexScat) [%]	(AnniScat) [%]	(AnniMix) [%]	(3G) [%]
1.17	**94.71**	0.44	1.84	2.10	0.90

(3G)					
Sensitivity [$\cdot 10^{-6}$]	Purity [%]	(DeexScat) [%]	(AnniScat) [%]	(AnniMix) [%]	(2G) [%]
0.41	**56.27**	4.73	14.46	10.88	13.66

Results

Dividing image space into voxels — Single voxel with positions — Single voxel with lifetimes

Correlation Position Lifetime

(x_i, y_i, z_i)

Voxel (x_i, y_i, z_i) of the image space

Reconstructed position of the annihilation

$LF_{positron}$ Distribution for a single voxel

Lifetime spectra in each voxel fitted with PALS Avalanche software [5]
Ortho-Positronium component separated and mean lifetime used for Positronium imaging
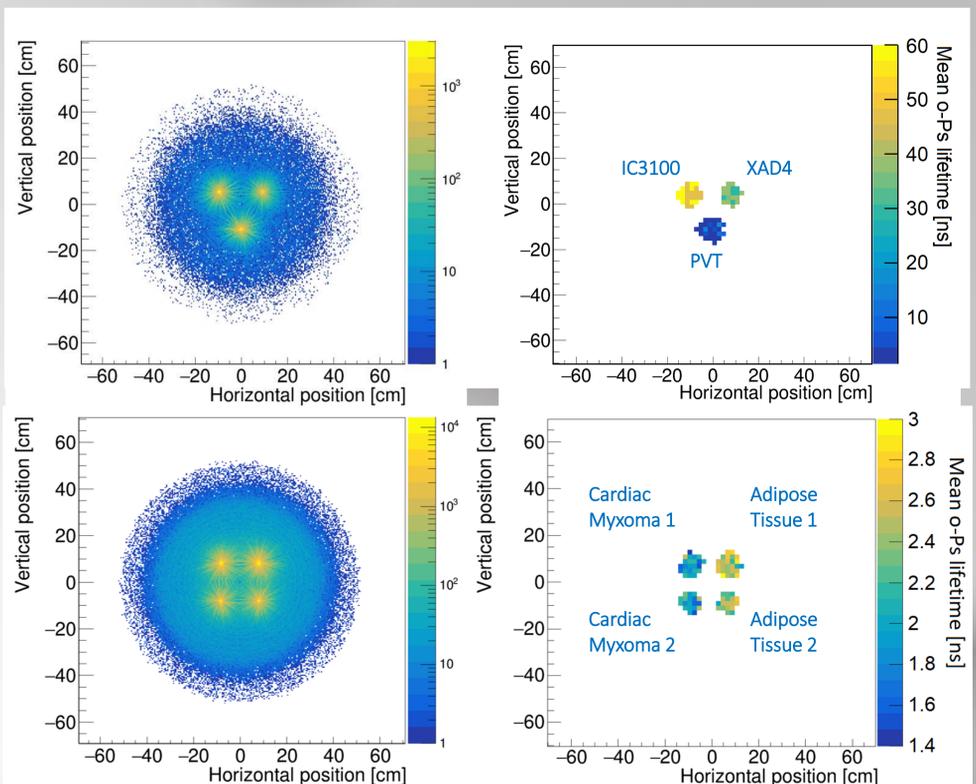

Conclusions

Two phantoms were measured with the 192-strip J-PET detector – the first consisting of samples with different porosit and the second consisting of organic samples. For both phantoms it was possible to collect positronium images alongside the standard positron-electron annihilation distribution. For both phantoms different samples were characterized with different mean o-Ps lifetime. Based on the simulations sensitivity and purity were estimated for the multi-photon positronium imaging for the 192-strip J-PET detector

References

[1] P. Moskal, K. Dulski, N. Chug et al., Positronium imaging with the novel multiphoton PET scanner, Science Advances 7 (2021) eabh4394

[2] P. Moskal and E.Ł. Stępień, Positronium as a biomarker of hypoxia, Bio-Aglorithms and Med-Systems 17 (2021) 311-319

[3] P. Moskal, S. Niedźwiecki, T. Bednarski et al., Test of a single module of the J-PET scanner based on plastic scintillators. Nucl. Instr. and Meth. A 764, 317-321 (2014)

[4] K. Dulski, PhD Thesis: Development of positronium imaging with the 192-strip J-PET detector (2022)

[5] K. Dulski, PALS Avalanche - A New PAL Spectra Analysis Software