Pilot studies towards positronium imaging with the total-body PET scanners

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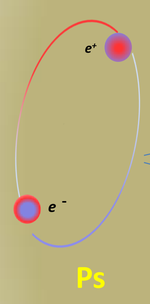
Abstract:

The purpose of the reported research is 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. During PET diagnosis positronium may be trapped inside free volumes between molecules of the examined patient. Currently, in the PET technique, the phenomenon of positronium production is neither recorded nor used for imaging. Yet in more than 40% cases, the electron-positron annihilation proceeds in the tissue via creation of positronium. We present (i) results of the feasibility studies of the positronium mean-lifetime image reconstruction with the total-body PET scanner from plastic scintillators, as well as (ii) results of pilot studies of the mean lifetime of positronium in the healthy and tumorous tissues operated from the patients. Performed experiments shows that properties of positronium atoms in uterine tissues operated from human patients reveals meaningful differences between healthy and tumorous tissues. Moreover, the performed simulations shows that in the future with the total-body PET and improved time resolution it shall be feasible to reconstruct images of positronium mean lifetime with the precision enabling to observe differences in life-time of positronium between the normal and tumorous tissues.

Positronium atom (Ps)



Decay to 2γ → **Para**–positronium (**p - Ps**), τ = 125ps, $^1S_0$

OR

Decay to 3γ → **Ortho** – positronium (**o - Ps**), τ = 142ns, $^3S_1$

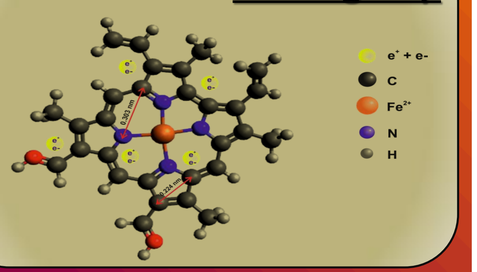
Isotope

$^{44}Ca^* \rightarrow {}^{44}Ca + \gamma$

$^{44}Sc \rightarrow {}^{44}Ca^* + e^+ + \nu_e$

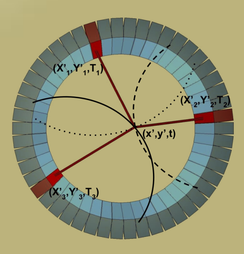
$e^+e^- \rightarrow 2\gamma$, 3γ

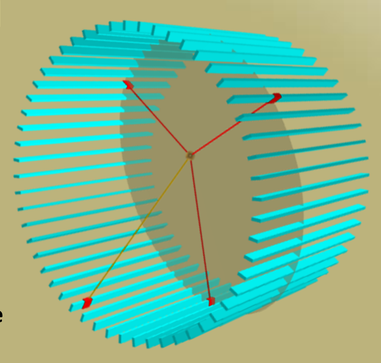
Positronium in Heme group



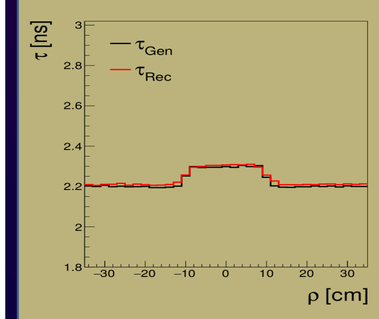
Positronium Imaging

Trilateration Method

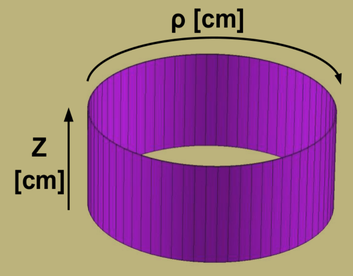




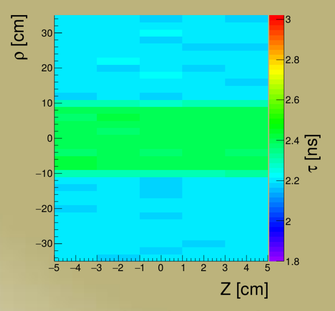
Trilateration approach to determine the annihilation position and time(x',y',t) along the annihilation plane.



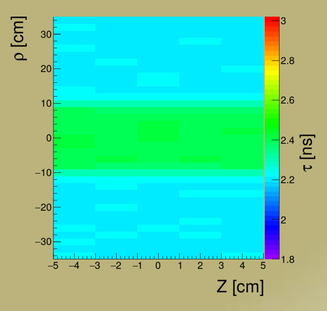
Phantom



Phantom with cylindrical shape.

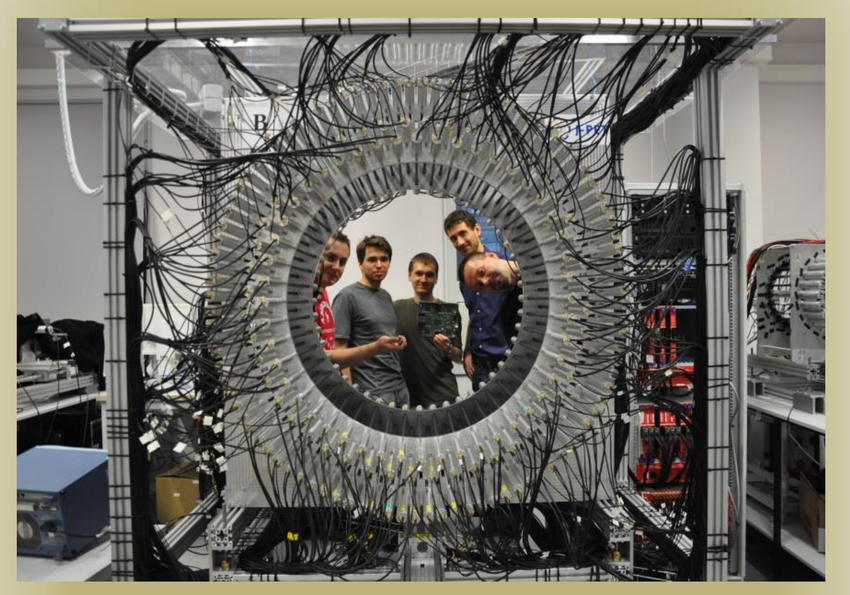


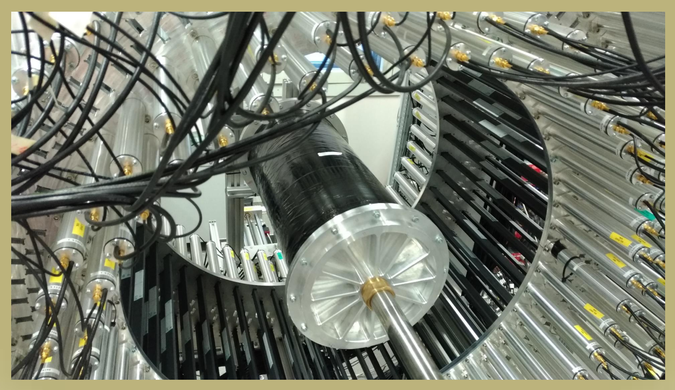
Generated distribution of mean ortho-positronium life time as f(z,ρ)



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

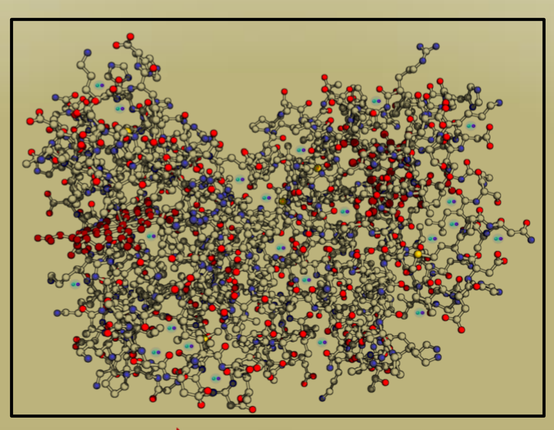
J-PET Detector

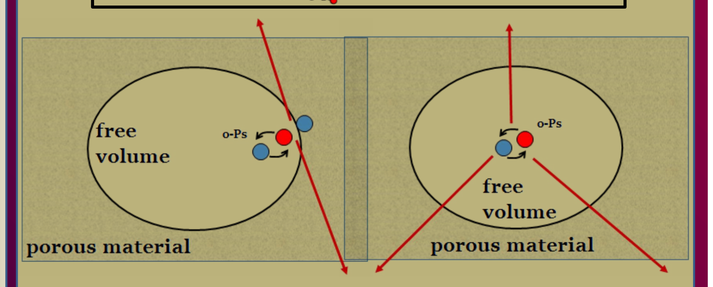




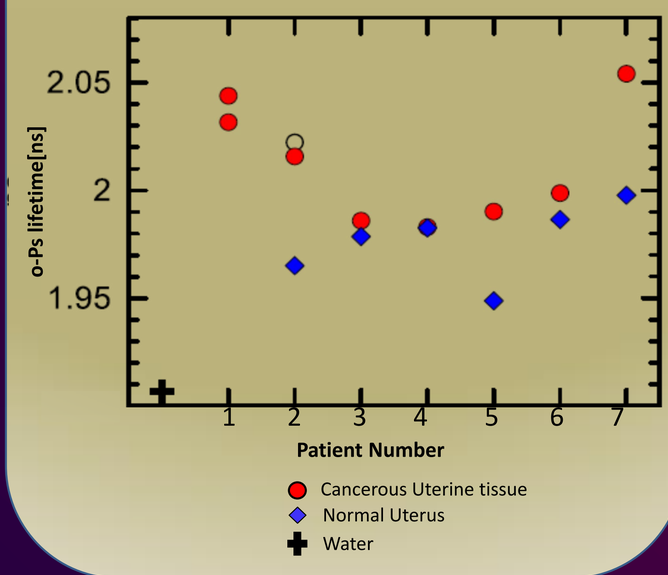
Cylindrical Phantom inside J-PET

Heme group present in hemoglobin molecule in blood

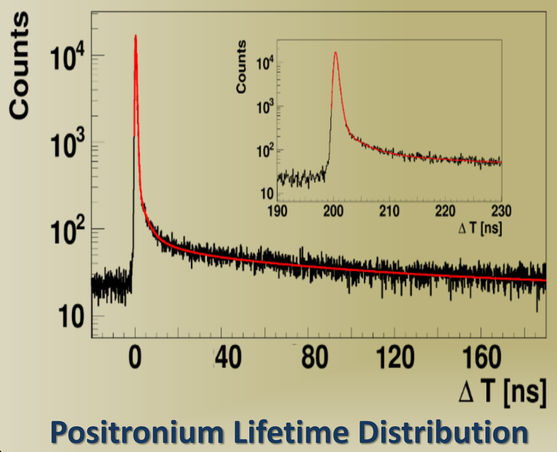




Ps production probability in human body is 30-40%

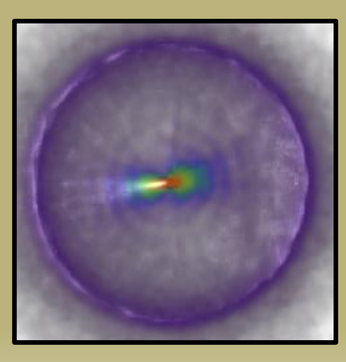


Experimental Results



Positronium Lifetime Distribution

Cylindrical Phantom photo



Cylindrical Phantom Image

Conclusions:

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 indicate that, as suggested in references [2,5], 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:

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Acknowledgement:

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