Studies of the orthopositronium lifetime for cancer diagnostics with the J-PET tomograph

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The main goal of this work was to demonstrate potential of using the Positron Annihilation Lifetime Spectroscopy (PALS) method in cancer diagnostics using the J-PET scanner, a modern positron emission tomograph created at the Institute of Physics of the Jagiellonian University. For this purpose, a series of measurements of the orthopositronium lifetime in various materials, which were characterized by different porosity was done. This is an initial phase of further research on the use of PALS in diagnostics.

Introduction

Positron annihilation lifetime spectroscopy is a material testing method based on the analysis of the lifetime of positronium, which depends on the structure of the material in which it was formed. Neon formed in the decay of sodium is excited, and emits almost immediately a gamma quantum of about 1274 keV energy. Time of registration of this photon is used as a start signal for the lifetime measurement. The positron termalizes and may form the orhto-positronium with an electron in the material, which then decay to three photons. The measurements were made using J-PET.

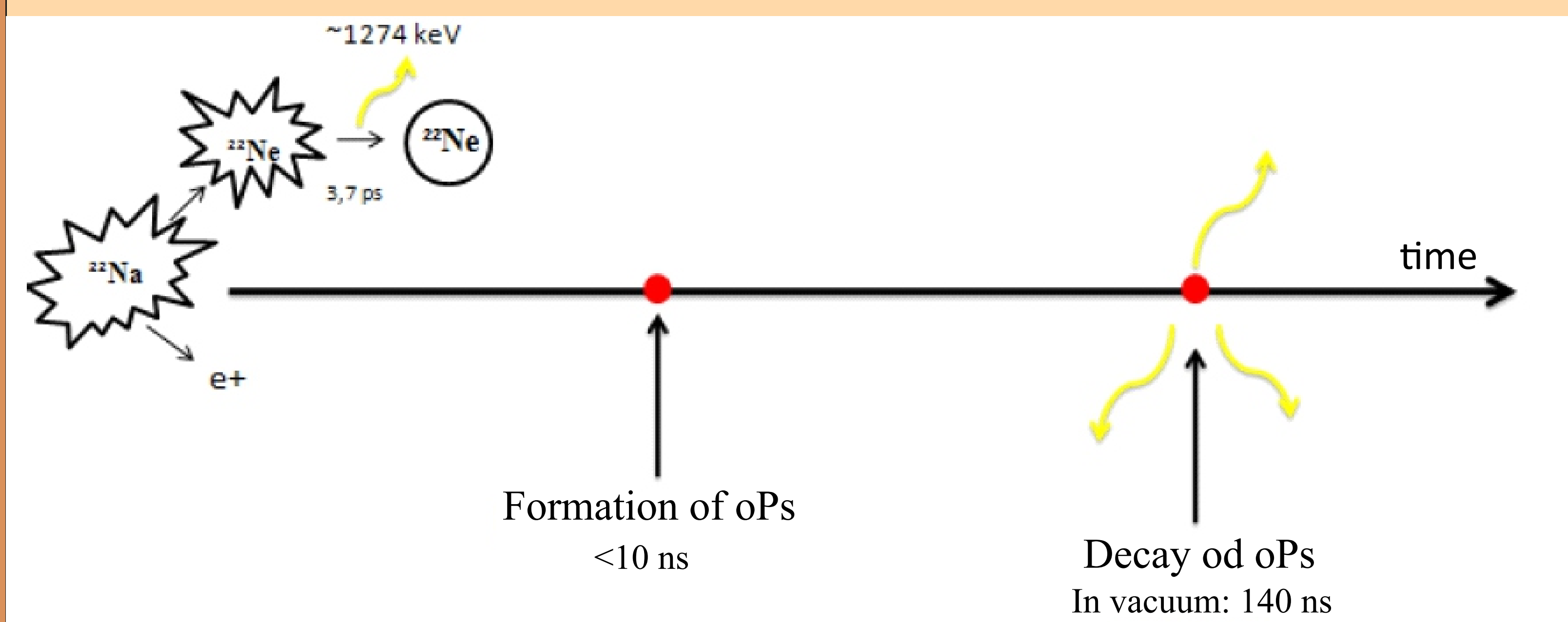


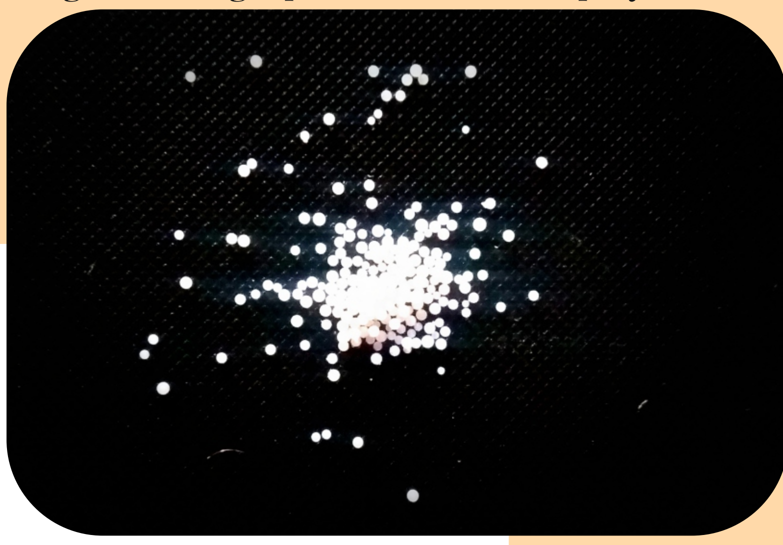
Fig. 1.Schematic representation of the o-Ps lifetime measurement.

Fig.2. Photograph of the J-PET tmograph taken during comissioning.

Description of performed research

The analyzed samples were: polymer-XAD-4, Vycor glass and a heart tumor. The radiation source was enclosed in a Kapton foil of about 6μm thickness, that was placed between two sample layers.

Fig. 3.Photograph of the XAD-4 polymer.



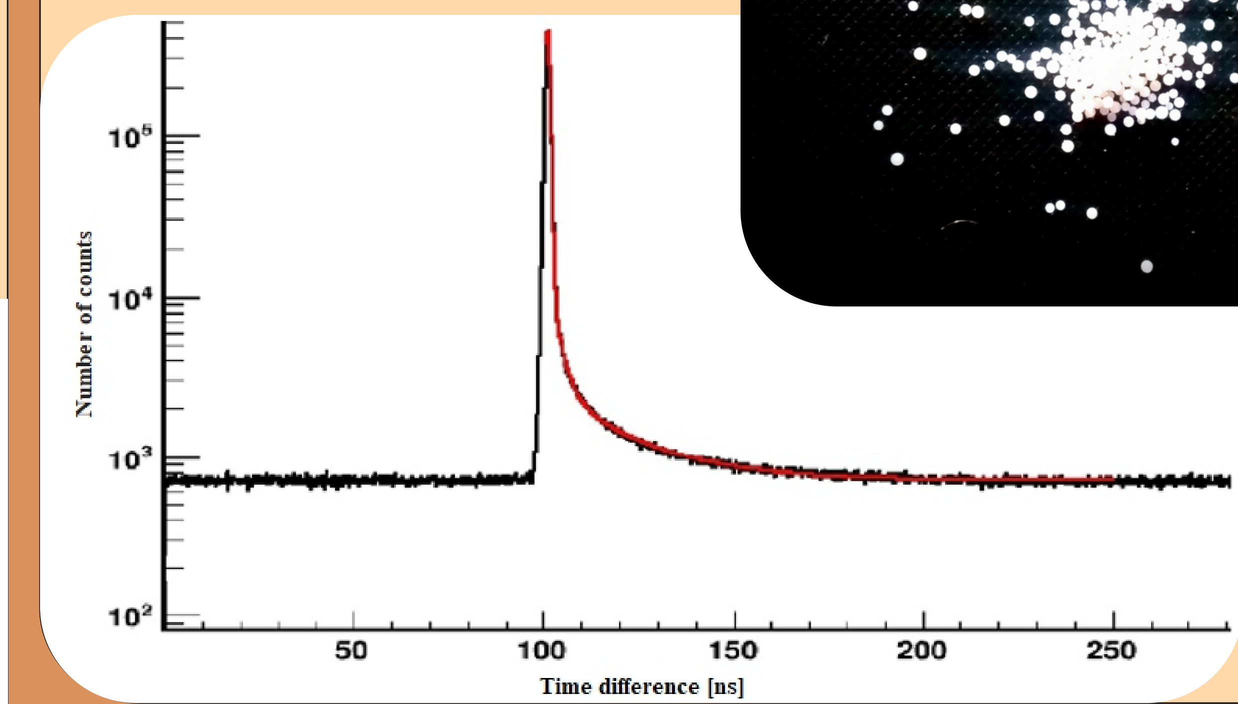


Fig. 4.Example of function fitting.

Summary and perspectives for further studies

	τ_1[ns]	$\Delta\tau_1$[ns]	I_1[%]	ΔI_1[%]	τ_2[ns]	$\Delta\tau_2$[ns]	I_2 [%]	τ_3 [ns]	$\Delta\tau_3$[ns]	χ^2/L
B20	19.69	0.14	6.05	0.05	0.22	0.01	22.33	0.33	0.01	1.39
PIII	46.33	0.3	9.35	0.08	0.22	0.02	22.33	0.39	0.02	1.60
Tumor	2.24	0.03	5.58	0.03	0.18	0.01	23.34	0.19	0.01	4.38
XAD4	87.67	0.39	29.53	0.57	0.2	0.01	11.82	0.31	0.01	1.88

Fig.5. Results for all samples. τ1 is the lifetime of orto-positonium, τ2- lifetime of para-positonium, and τ3- lifetime of the component derived from free annihilation. I1 and I2 are the intensities of the ortho- and para-positron. Intensity of p-Ps was determined as 33% of intensity of o-Ps. The L parameter is the number of degrees of freedom of fit, and χ^2 / L is the measure of the quality of the fit of the model.

The results show that the lifetime of positronium depends on the material in which it was trapped. The smallest life time is characterized for a tumor, because the structure of cells and tissues is characterized by the presence of large areas with free volume , and o-Ps life-spans result from electrostatic interactions with water molecules and other cell building compounds as proteins or lipids. In the future, it is planned to compare the life time with the dimensions of free volumes in the tested materials and further measurements on biological samples.

References

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