Comparison of positonium lifetime in living tissues for PALS detector and J-PET tomograph.

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Jagiellonian University

“Is Quantum Theory exact? From quantum foundations to quantum applications”

24.09.2019

Motivation

Positron Annihilation Lifetime Spectroscopy (PALS) is a method based on analysis of the lifetime of positronium, used widely in material studies. This method has a potential in cancer diagnostics.

The main goal of this work was to examine the differences in o-Ps lifetime in tissues (healthy and cancer) measured with two detectors, The first setup, a standard one, consisting of two BaF_2 scintillators, and the second one, the J-PET detector consisting of around 200 plastic scintillators, arranged in three circles.

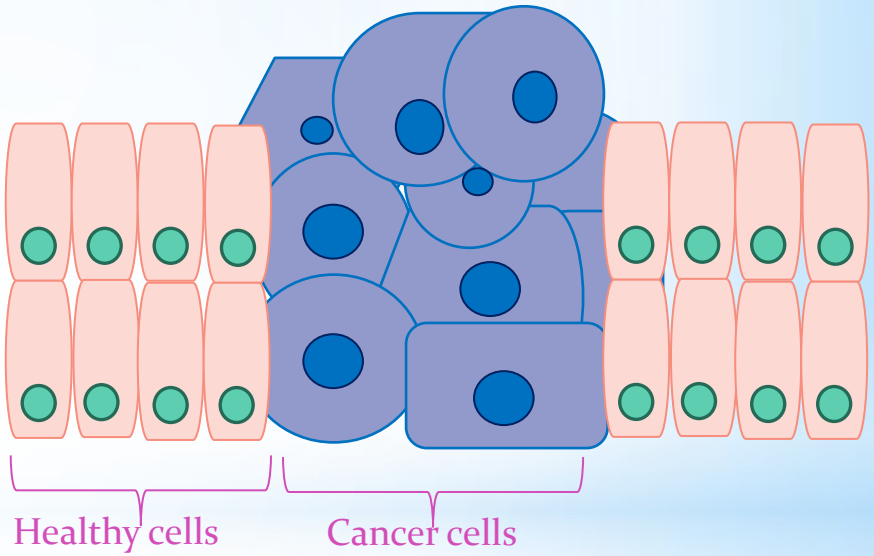
This research may help in establishing the precision of J-PET tomograph for PALS measurements.

Introduction

Specific changes associated with cancer are connected with enhanced metabolism.

Cancer cells metabolise more glucose than normal cells

Metabolism of a human body can be visualized by the Positron Emmision Tomography based on injection of a pharmaceutical labeled with a radioisotope, e.g. ^{44}Sc.



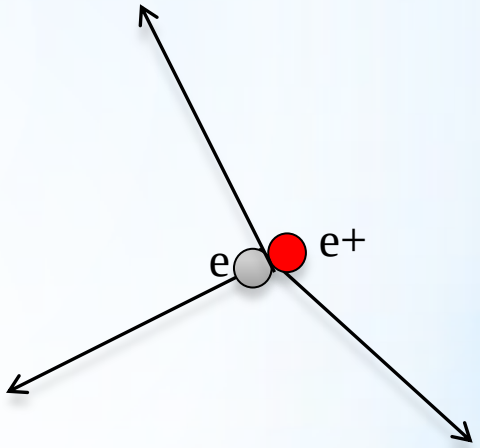
Picture 1. Cancer and Healthy cells

Introduction

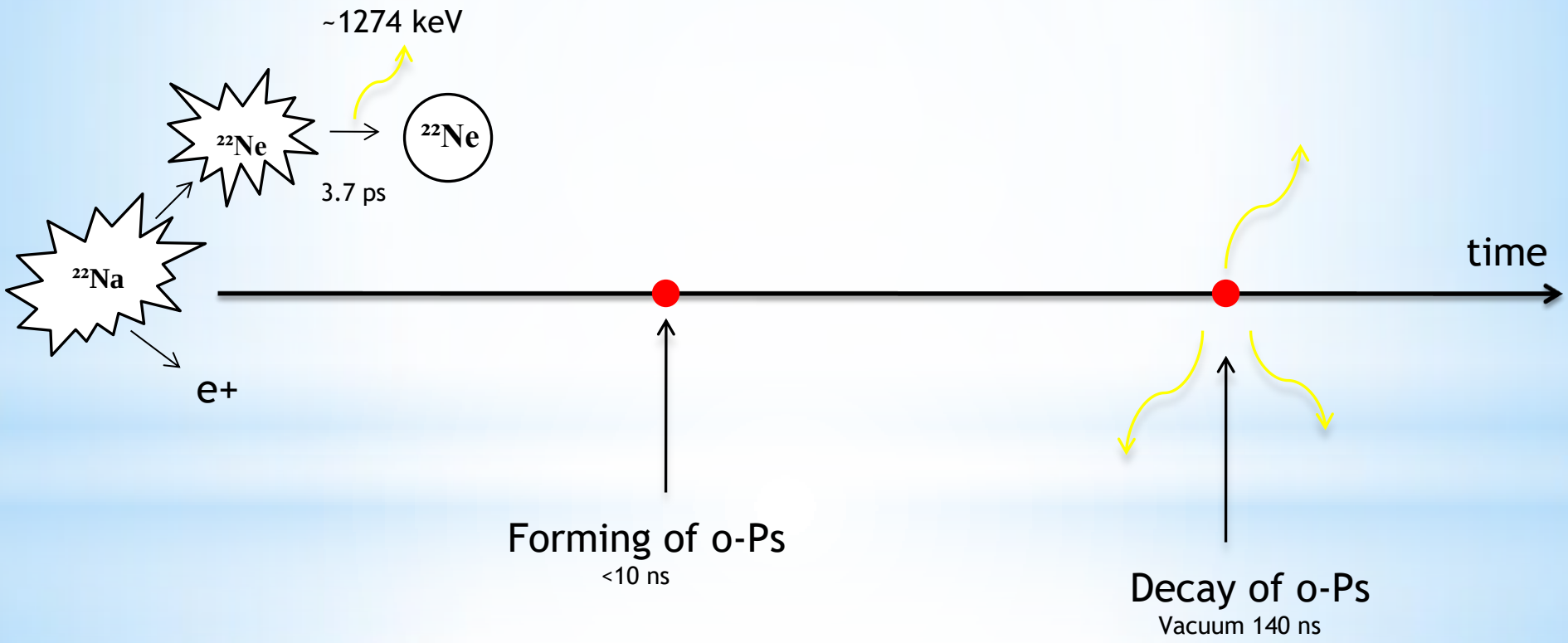
Radioisotopes are attached to biological carrier molecules that target components of cellular metabolism.

These isotopes undergo β^+ decay emitting positrons, which may form a bound state with electron in the cell called positronium.

Properties of this atom, for example lifetime, may be different in cancerous and healthy tissues due to their different structure and activity.



Picture 2. o-Ps decay

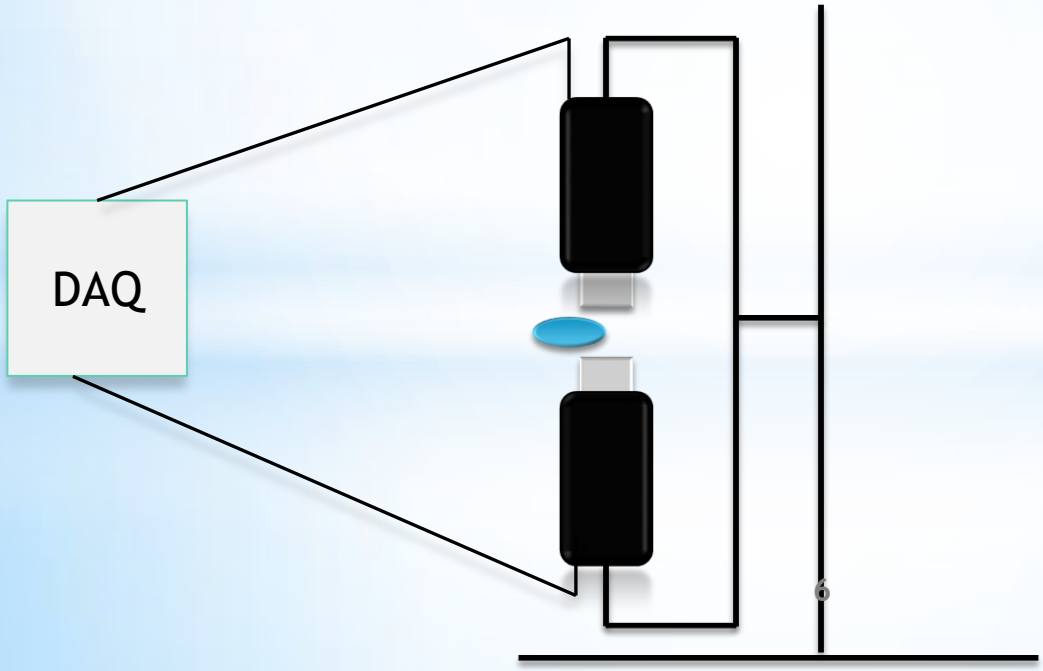

~1274 keV
^{22}Ne
^{22}Ne
3.7 ps
^{22}Na
e+
time
Forming of o-Ps
<10 ns
Decay of o-Ps
Vacuum 140 ns

Measurements with crystal detectors

In measurements we used 22-sodium radioisotope with activity 1 MBq.

Tested samples were delivered from the University Hospital in Krakow. Both normal and cancerous tissues come from large intestine.

The sample (containing two parts of the same tissue fixed in formaline) was inserted between two crystal detectors. Each measurement lasted about one hour.



Picture 5. PALS detector

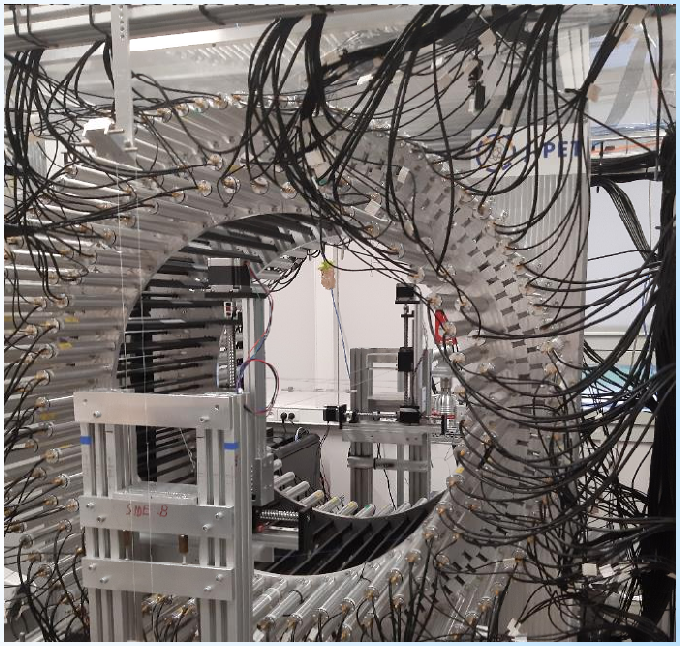
Picture 4. PALS detector

Measurements with the J-PET detector

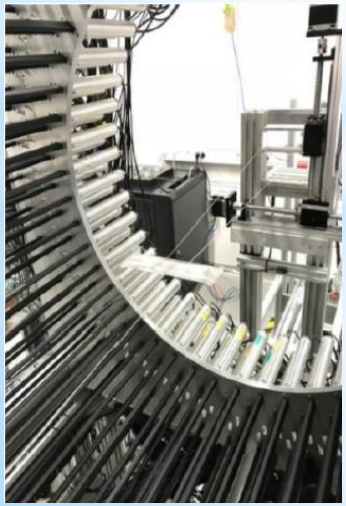
For second part of measurements the same samples were measured with the J-PET detector.

We have used ^{22}Na source with activity of 0.77 MBq and 0.61 MBq for cancer and normal tissue, respectively.

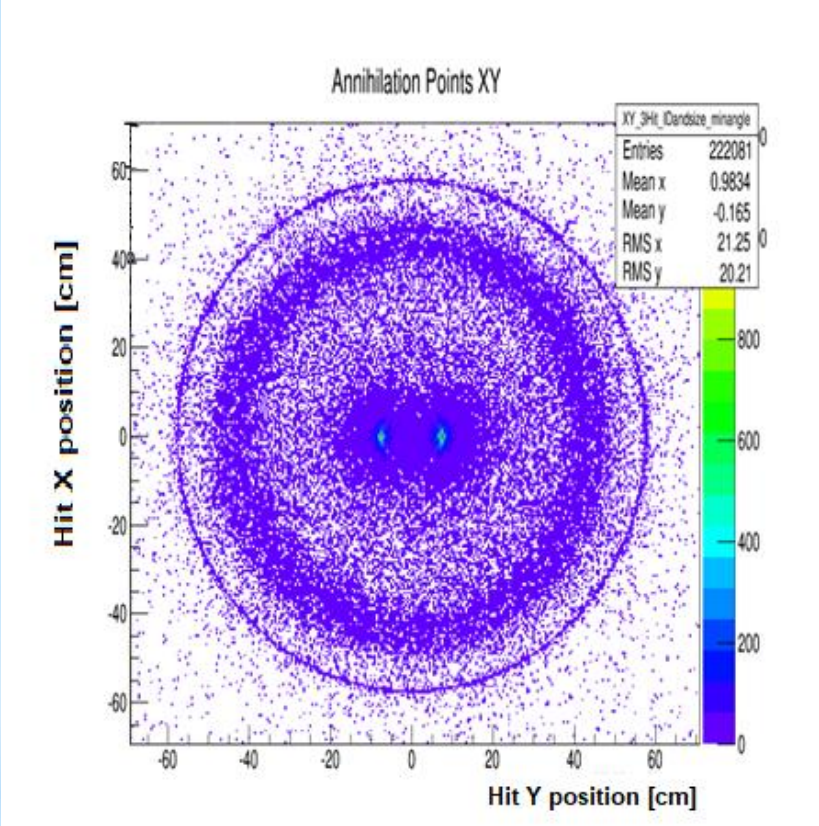
Both cancer and healthy tissues delivered from the same patient were measured at the same time but in different chambers. Getting results for one patient took half of the day.

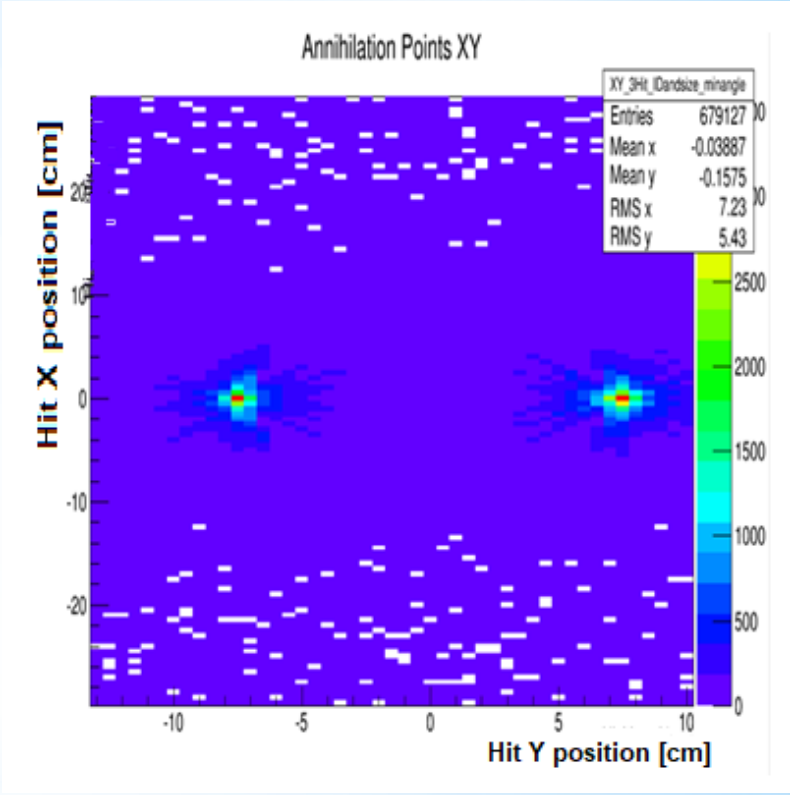


Picture 6. J-PET

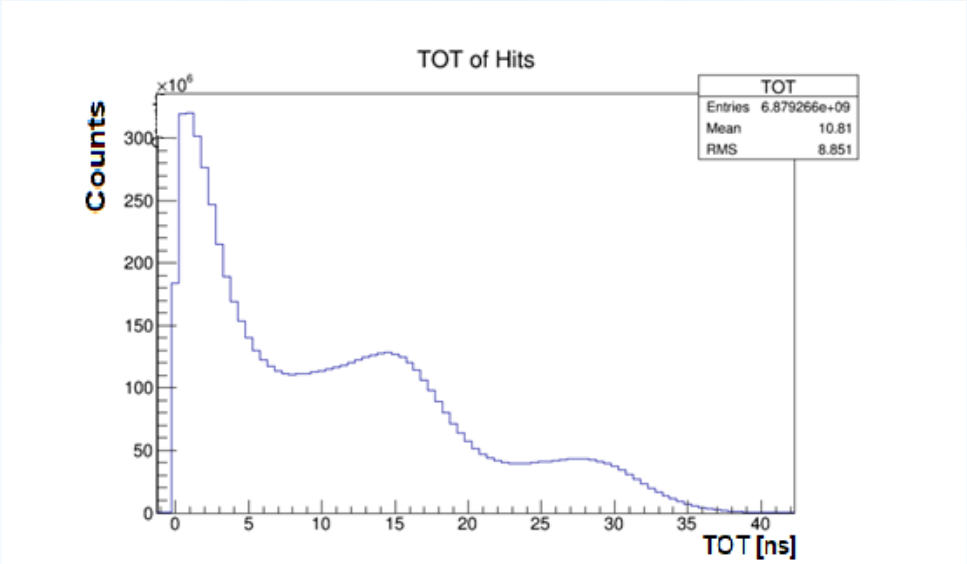


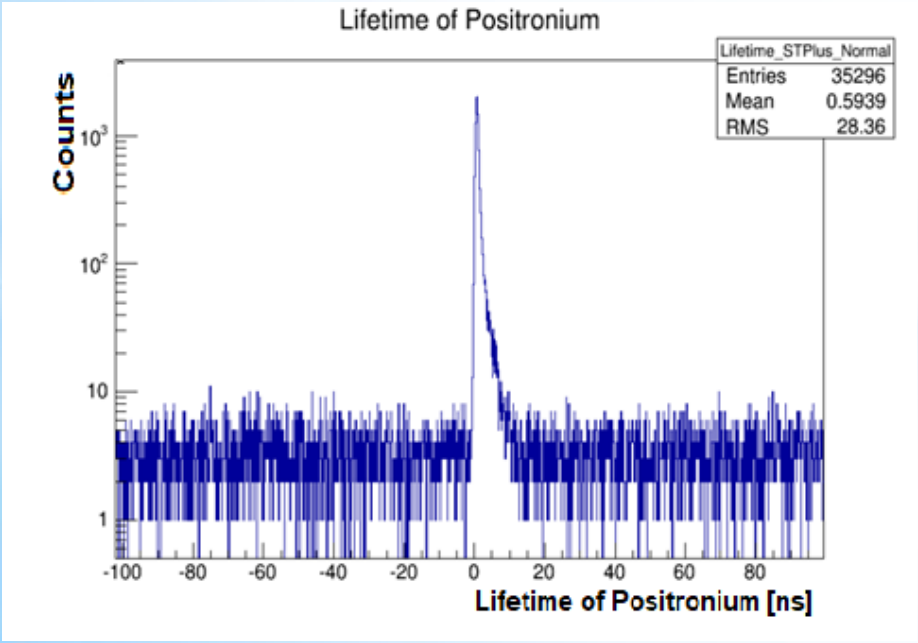
Picture 7 The way of holding samples in the detector

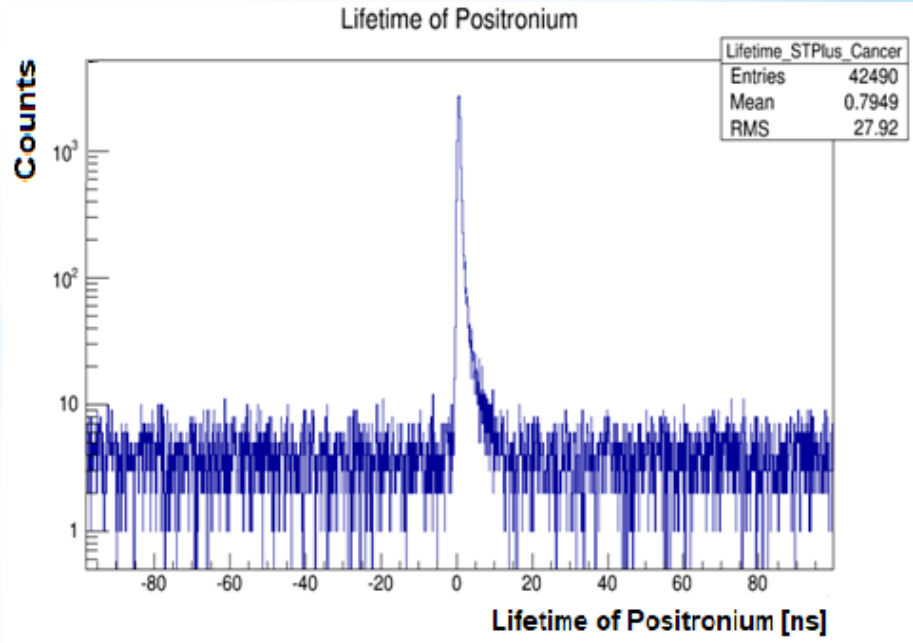

Annihilation Points XY
XY_3Hit_IDandsize_minangle
Entries 222081
Mean x 0.9834
Mean y -0.165
RMS x 21.25
RMS y 20.21
Hit X position [cm]
Hit Y position [cm]


Annihilation Points XY
XY_3Hit_IDandsize_minangle
Entries 679127
Mean x -0.03887
Mean y -0.1575
RMS x 7.23
RMS y 5.43
Hit X position [cm]
Hit Y position [cm]

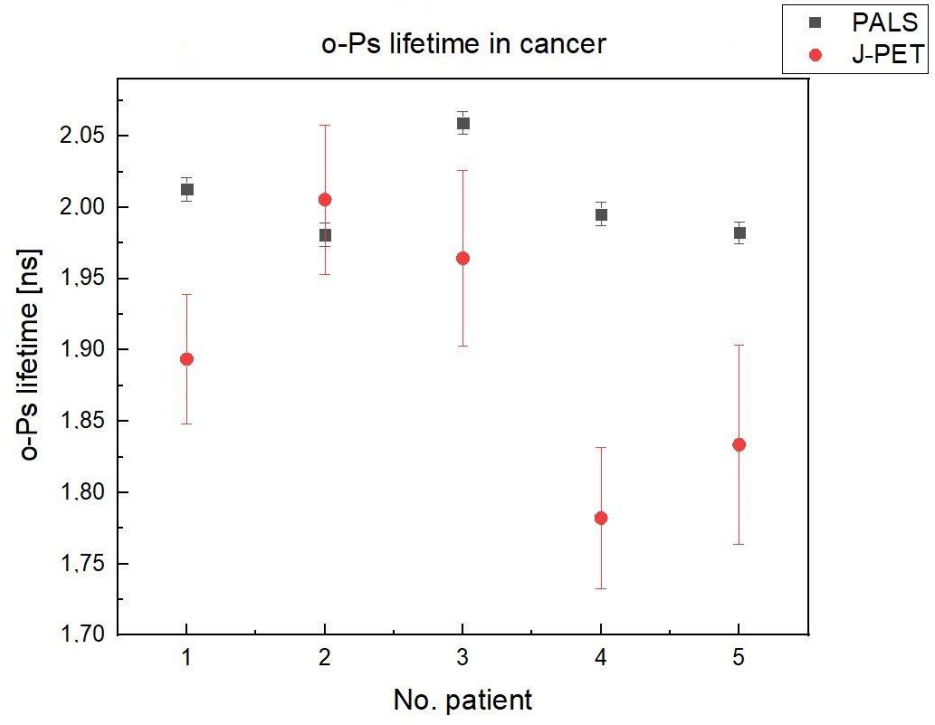
Results- Control histograms

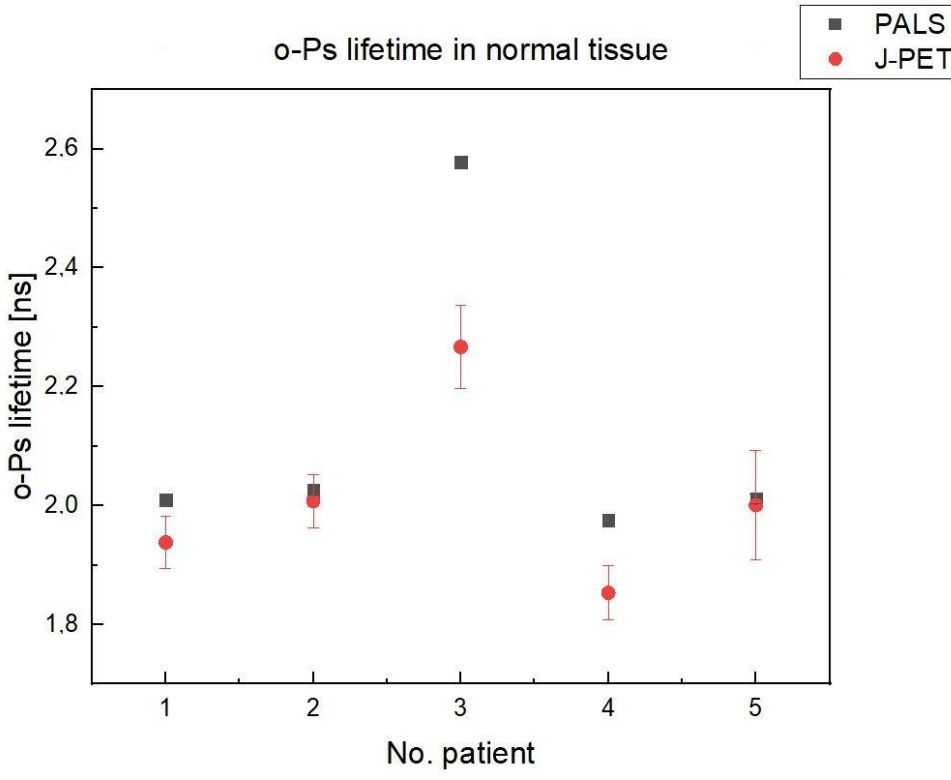




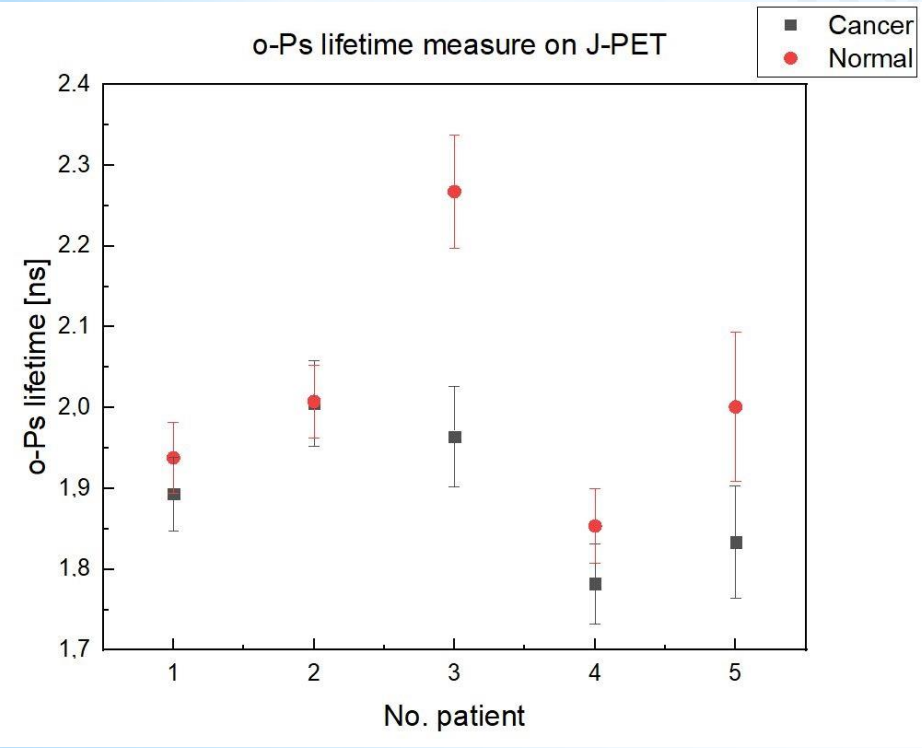


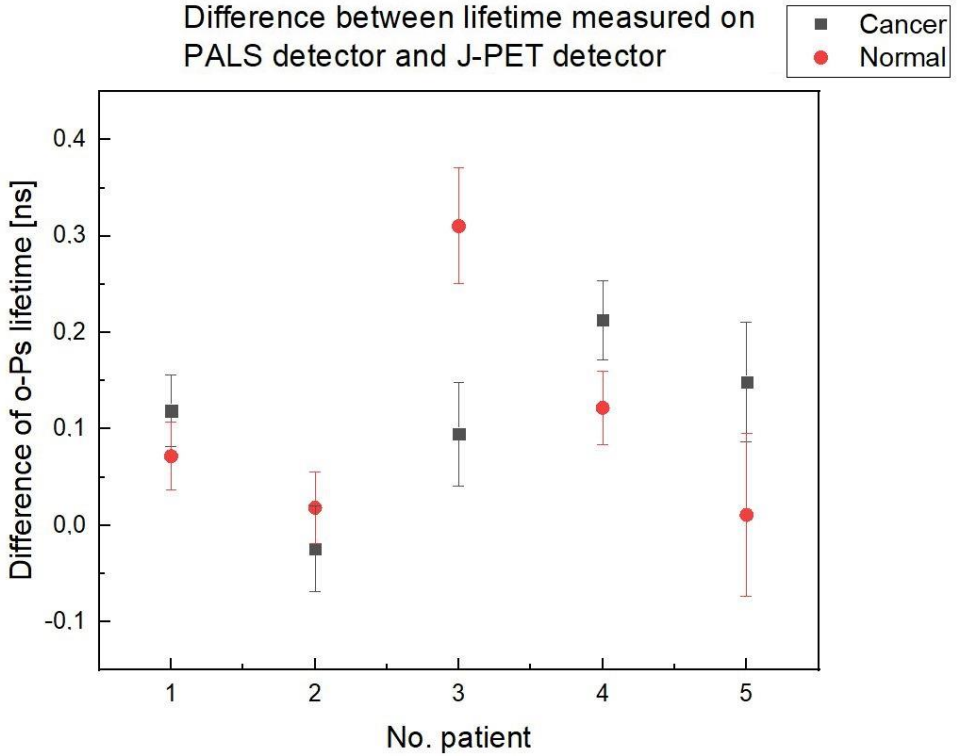
Results


o-Ps lifetime in cancer
PALS
J-PET
o-Ps lifetime [ns]
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1
2
3
4
5
No. patient


o-Ps lifetime in normal tissue
PALS
J-PET
o-Ps lifetime [ns]
2.6
2.4
2.2
2.0
1,8
1
2
3
4
5
No. patient

Results


o-Ps lifetime measure on J-PET
Cancer
Normal
o-Ps lifetime [ns]
2.4
2.3
2.2
2.1
2,0
1,9
1.8
1,7
1
2
3
4
5
No. patient


Difference between lifetime measured on
PALS detector and J-PET detector
Cancer
Normal
Difference of o-Ps lifetime [ns]
0.4
0.3
0.2
0.1
0,0
-0.1
1
2
3
4
5
No. patient

Summary and outlook

- Patient number 3-> lots of fat in normal tissue
- Time window used in analysis was too wide.
- The resolution of J-PET detector is worst than crystal BaF2 detectors for PALS measurement.

FWHM [ns]	
PALS	J-PET
0.29844(90)	0.638(12)
0.30104(90)	0.616(12)
0.29720(89)	0.675(15)

Amount of patients measured by:		Amount of data file for one person	Summary
day	14	700	9800
night	10	1300	13000
weekend	3	6500	19500
			42300

1 data file= 1 hour of analysis; Max 15 analysis run in 1 hour

42300 data file/15 data file/h=2820h=117.5days=3.9 month

In future we plan to end the analysis for 27 samples and start measuring new samples from Hospital. Also in addition we want to check the impact of the holder for cancer and healthy tissues o-Ps results.

Bibliography

[1] P. Moskal et al., Physic in Medicine and Biology 055017, 64 (2019)

[2] P. Moskal et al., Phys. Med. Biol. 2025, 61 (2016)

[3] E. Kubicz et al., Nukleonika 60(4),749 (2015)

[4] P. Moskal et al., Nucl. Instrum. & Meth. A 775, 54 (2015)

Acknowledgements

Special thanks goes to Prof. Paweł Moskal and Dr Michal Silarski for time, help and many valuable remarks that enriched this work. I would also like to thank Mr. Kamil Dulski, Mrs. Ewelina Kubicz for disinterested help in analyzing the results. This work is supported by the Fundation for Polish Science through the TEAM/2017-4/39 programe.

Thank you