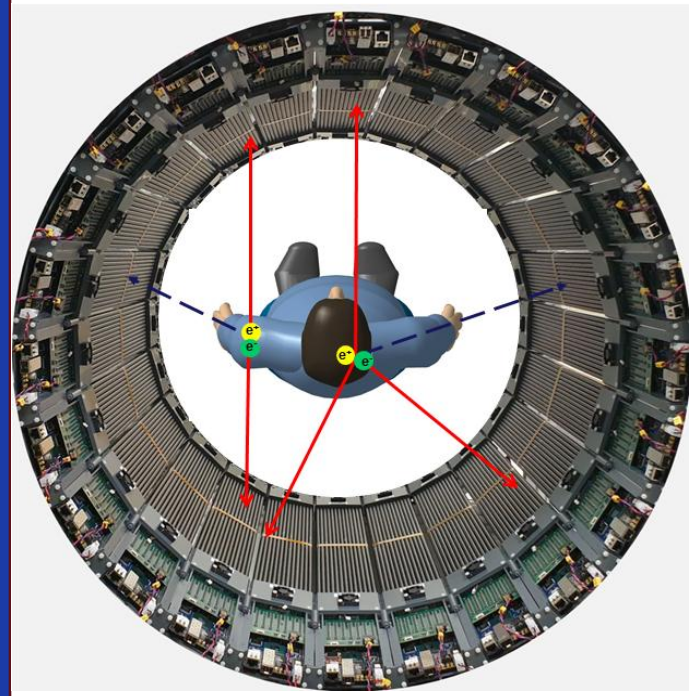
2nd Symposium on new trends in Nuclear and Medical Physics

hosted by Jagiellonian University in Kraków, AGH, Research University

24-26 September 2025

Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian Universityin Krakow, Poland

First experimental demonstration of positronium lifetime imaging with the novel radionuclides ^{55}Co and ^{52}Mn using J-PET scanner



Manish Das, Sushil Sharma, Ewa Stepien, Pawel Moskal

On behalf of the J-PET collaboration

24-09-2025

Jagiellonian University in Kraków

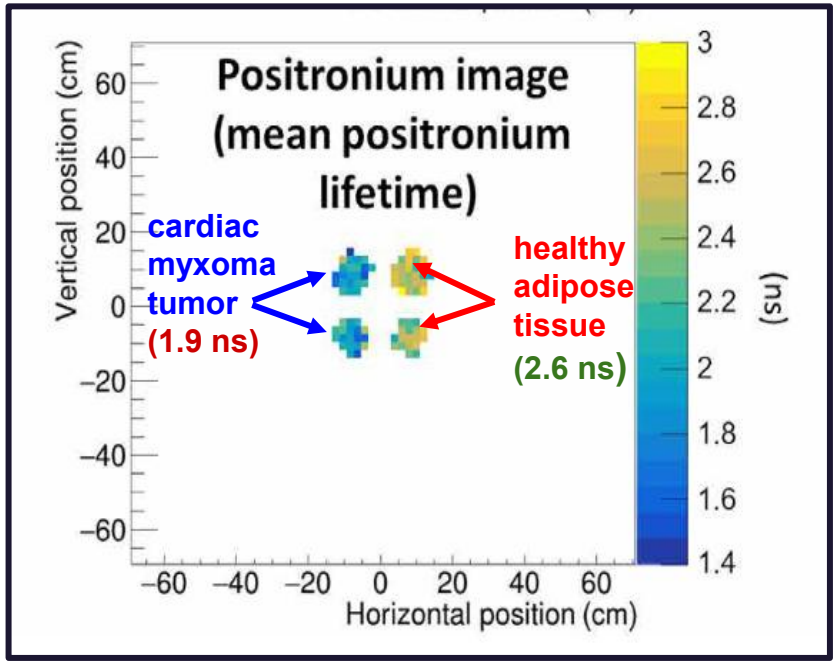
Doctoral School of Exact and Natural Sciences Jagiellonian University

J-PET

A recap to the history

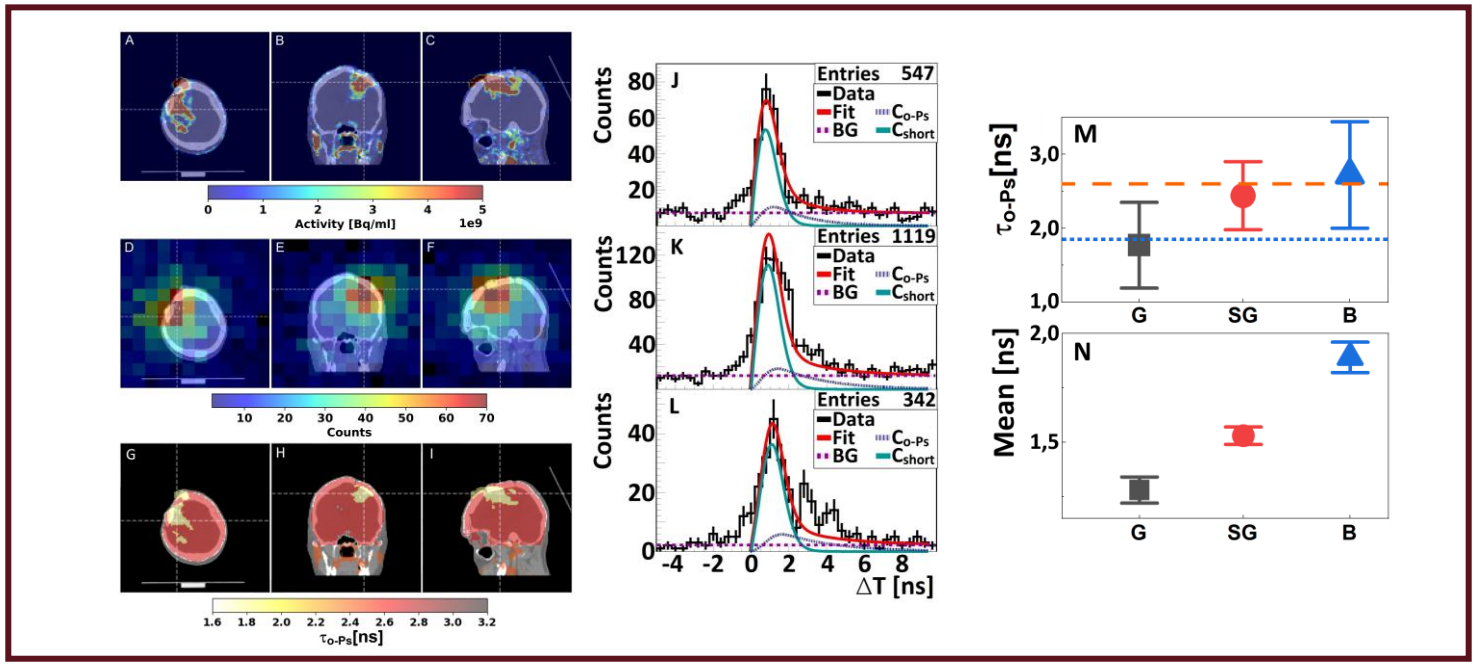
^{22}Na

1



^{68}Ga

2

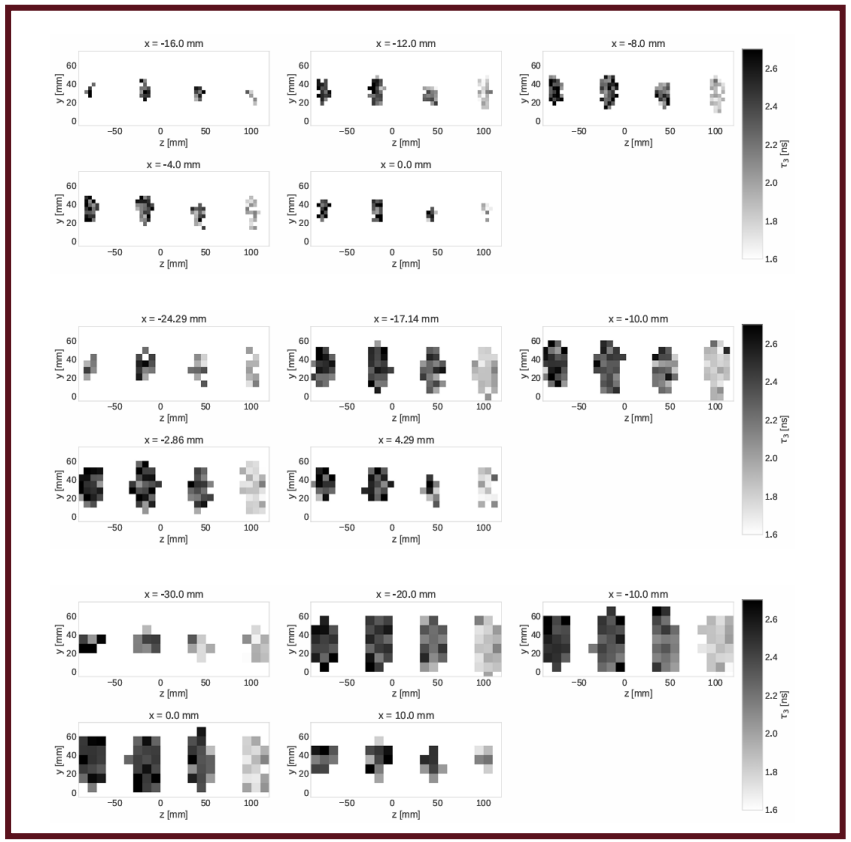


[1]Moskal, P. et. al (2021). Positronium imaging with the novel multiphoton PET scanner. *Science Advances*, *7*(42), eabh439.
[2]Moskal, P. et. al (2024). Positronium image of the human brain in vivo. *Science Advances, 10(37),* adp2840.

A recap to the history

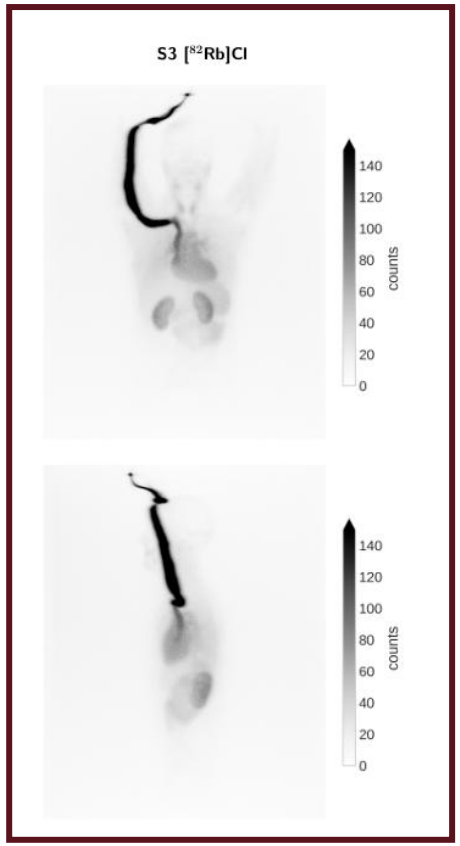
^{124}I

1



^{82}Rb

2



[1]Mercolli, L. et al (2025). Phantom imaging demonstration of positronium lifetime with a long axial field-of-view PET/CT and124I. EJNMMI Physics 12

[2]Mercolli, L. et al. (2024). In Vivo Positronium Lifetime Measurements with a Long Axial Field-of-View PET/CT. medRxiv DOI:10.1101/2024.10.19.24315509

Limitations for clinical Translation

- **^{22}Na**
  i. long half-life of 2.60 years and
  ii. Uptake in bones

- **^{68}Ga**
  i. low probability—only 1.34 %—of prompt gamma rays being emitted along with the positron emission

- **^{124}I**
  i. 12% prompt gamma yield along with the positron emission

- **^{82}Rb**
  i. Short half-life of 1.26 minutes
  ii. only 13 % of its decays yield a prompt gamma along with the positron emission

Positronium imaging with ^{44}Sc

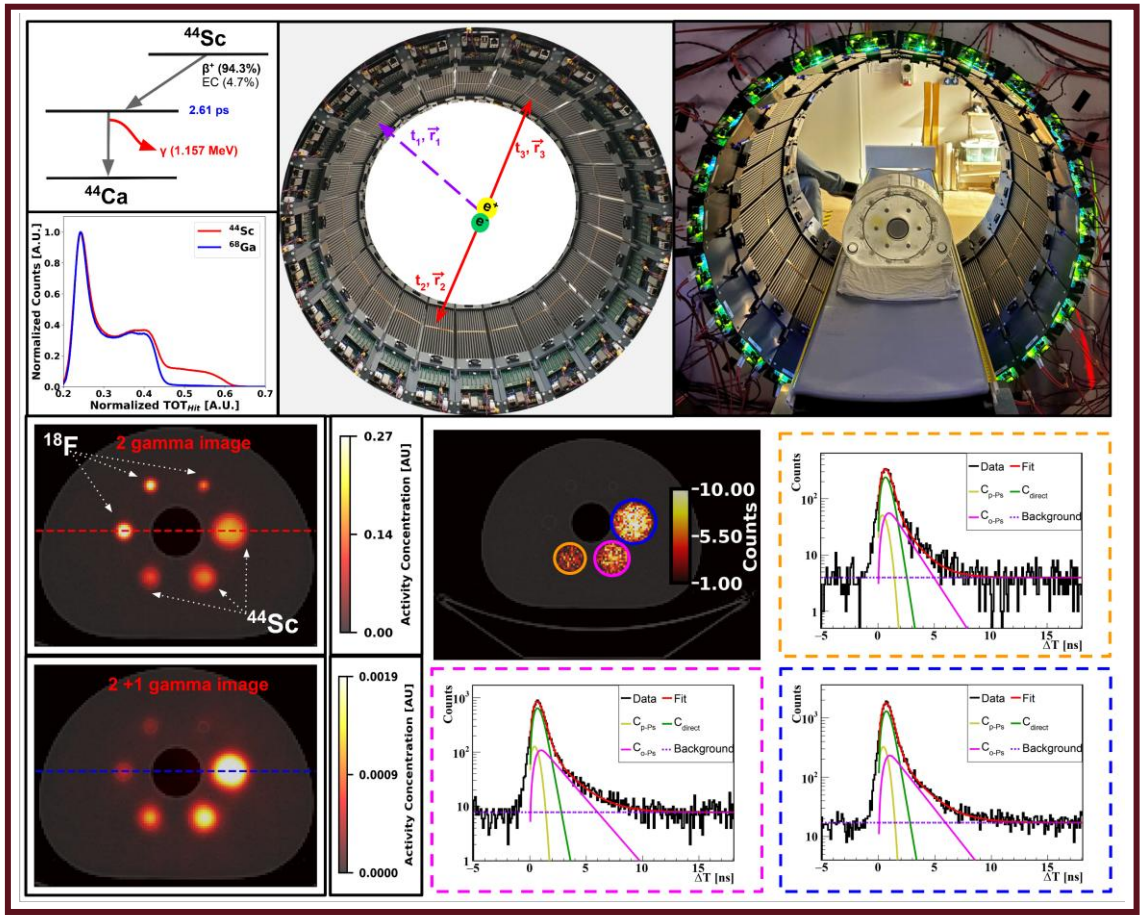
^{44}Sc

i. Clinically relevant half-life of **4.04 hours**

ii. An ultrashort de-excitation delay of **2.61 picoseconds**

iii. High yield of **94.3% of decays** resulting in positron emission followed by a high-energy prompt gamma of 1157 keV with a **100% yield.**

[1]



[1]Das M, et al. (Submitted) **First positronium imaging using 44Sc with the J-PET scanner: a case study on the NEMA-Image Quality phantom** ***IEEE Transactions on Radiation and Plasma Medical Sciences***

Isotopes for Positronium Imaging

Isotope	$t_{1/2}$	$Y_{\beta+}$ [%]	E_{max} [MeV]	R_{mean} [mm]	R_{max} [mm]	E_γ [MeV]	Y_γ [%]	$Y_{\beta+\gamma}$ [%]	$Y_{\beta+\gamma}/Y_{\beta+}$ [%]	$t_{1/2}^{deexc}$ [ps]	Comp. E. [MeV]
^{22}Na	2.60 y	89.95	0.545	0.54	1.85	1.275	99.94	89.90	99.94	3.6	1.062
^{52}Mn	5.6 d	29.40	0.575	0.58	1.99	1.434	100	30	100	0.78	1.217
						0.936	94.5	29	98.69	6.7	0.735
						0.744	90	29	98.69	41	0.553
^{124}I	4.17 d	22.69	1.822	2.15	8.53	0.603	62.9	12	52.89	6.2	0.423
						0.723	10.36	0.25	4.58	1.04	0.534
^{72}As	26.0 h	87.86	3.33	4.27	16.64	0.834	81	71	80.81	3.35	0.638
^{55}Co	17.53 h	75.89	1.5	1.72	6.79	0.931	75	59	77.74	8	0.731
						0.477	20.2	13.5	17.79	37.9	0.311
						1.409	16.9	11.3	14.89	37.9	1.192
^{44}Sc	3.97 h	94.3	1.474	1.69	6.65	1.157	99.9	94.3	100	2.61	0.948
^{68}Ga	67.71 m	88.91	1.899	2.25	8.94	1.077	3.22	1.19	1.34	1.57	0.870
^{60}Cu	23.7 m	92.59	0.653	0.67	2.37	1.333	88	81	87.48	0.735	1.118
						1.791	45.4	42	45.36	0.24	1.567
						0.826	21.7	20.4	22.03	0.59	0.631
^{82}Rb	1.26 m	95.36	3.382	4.34	16.92	0.777	15.1	13.5	14.16	4.45	0.584
^{14}O	70.6 s	99.89	1.808	2.13	8.45	2.313	99.39	99.26	99.38	0.068	2.083
^{10}C	19.3 s	99.97	2.93	3.69	14.51	0.718	100	99.97	100	710	0.530

Moskal, P. et al (2025). **Positronium Imaging: History, Current Status, and Future Perspectives.** IEEE Transactions on Radiation and Plasma Medical Science.

Isotopes for Positronium Imaging

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Moskal, P. et al (2025). **Positronium Imaging: History, Current Status, and Future Perspectives.** IEEE Transactions on Radiation and Plasma Medical Science.

Radioisotope preparation and properties

^{55}Co:

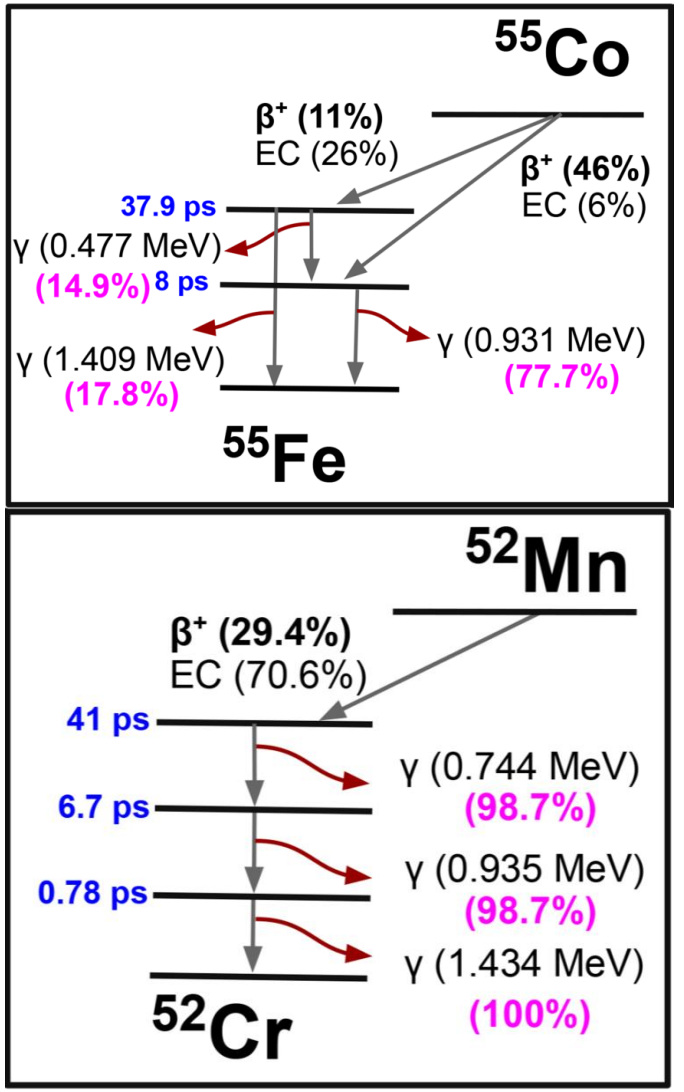
Produced at the **Heavy Ion Laboratory** of the **University of Warsaw** via the ^{54}Fe(d,n)^{55}Co reaction

i. Half life of **17.53hr**
ii. High yield of **75.89 % of decays** resulting in positron emission followed by a high-energy prompt gamma of 931 keV with a **77.7% yield.**

^{52}Mn:

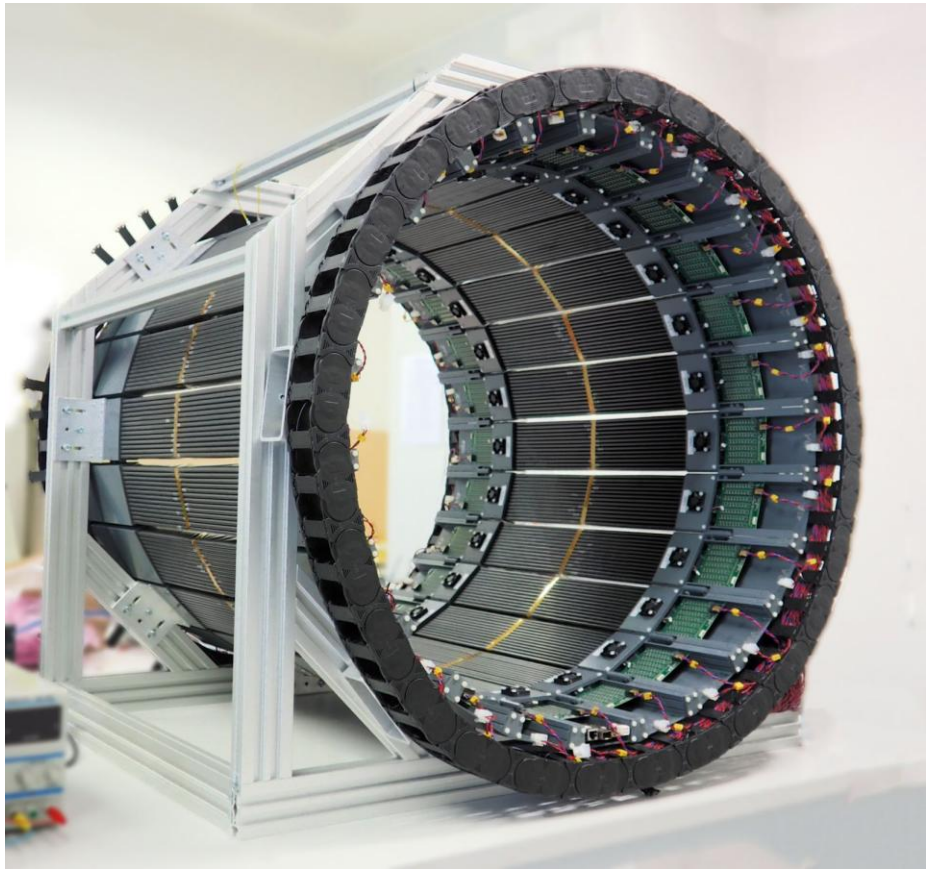
Produced at the **Hevesy Laboratory** in the **Department of Health Technology** at the **Technical University** of **Denmark** via the ^{52}Cr(p,n)^{52}Mn production route

i. Half life of **5.6 days**
ii. **29.4 % of decays** resulting in positron emission followed by a cascade of three high-energetic prompt gamma photons with ~100% yield.
iii. The prompt gamma emission with the EC **remains a challenge**



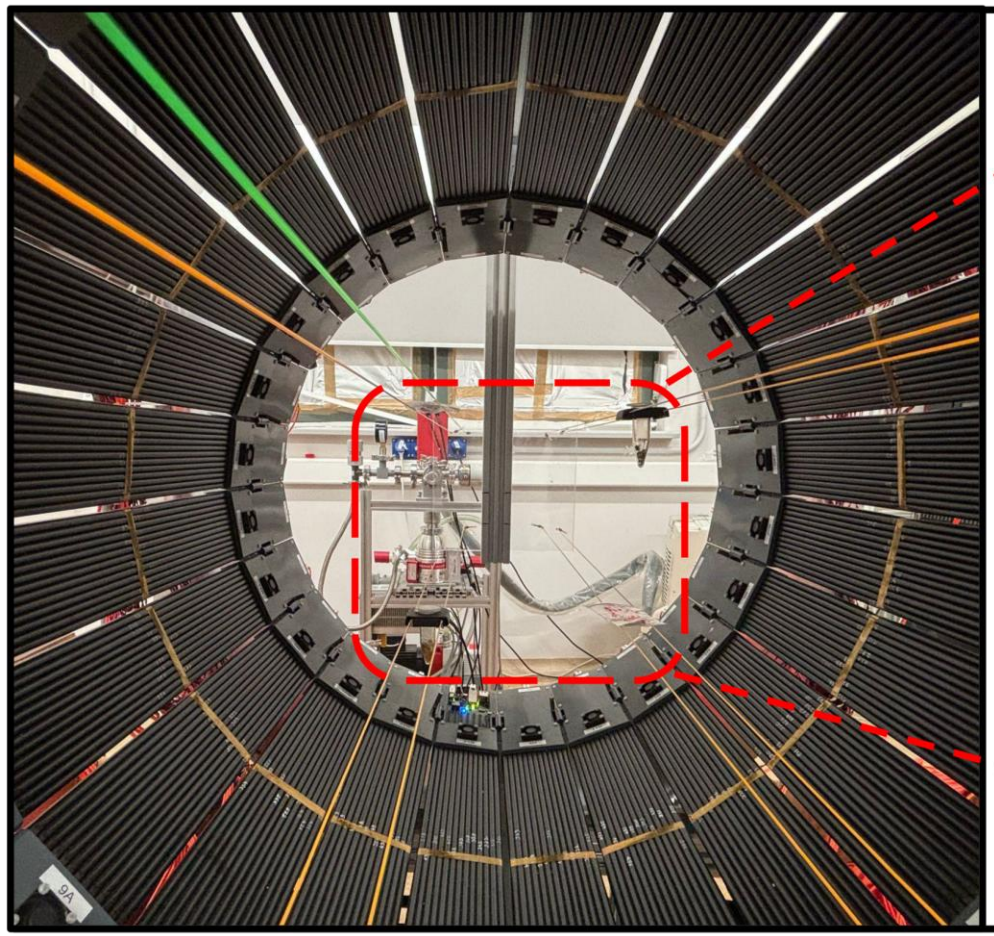
Modular J-PET

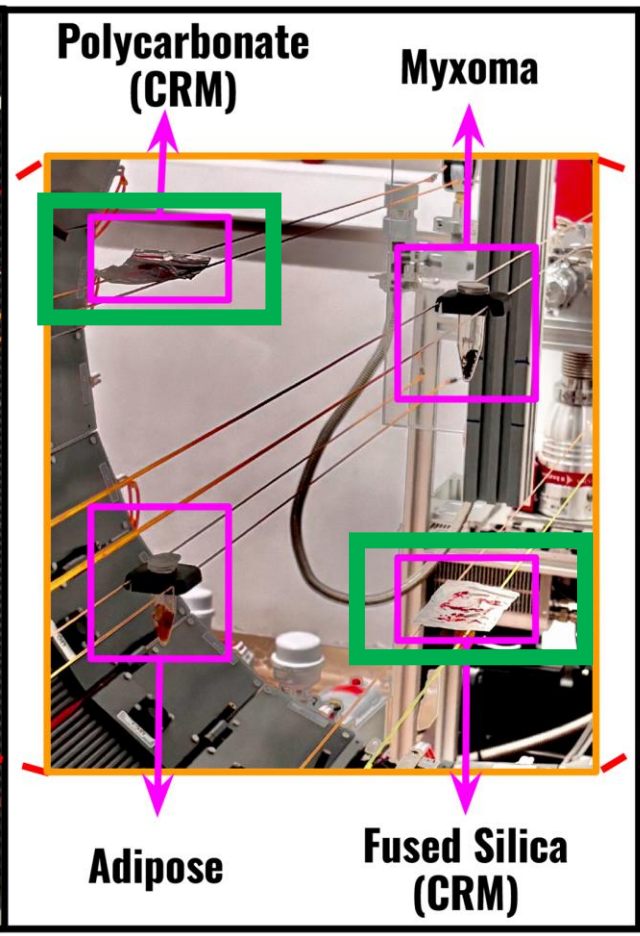
- 24 detection modules, Each contains 13 plastic scintillator strips with 4 SiPM on each side of a scintillator
- Triggerless data acquisition system
- Modular and Portable
- Weighs around 60 kg

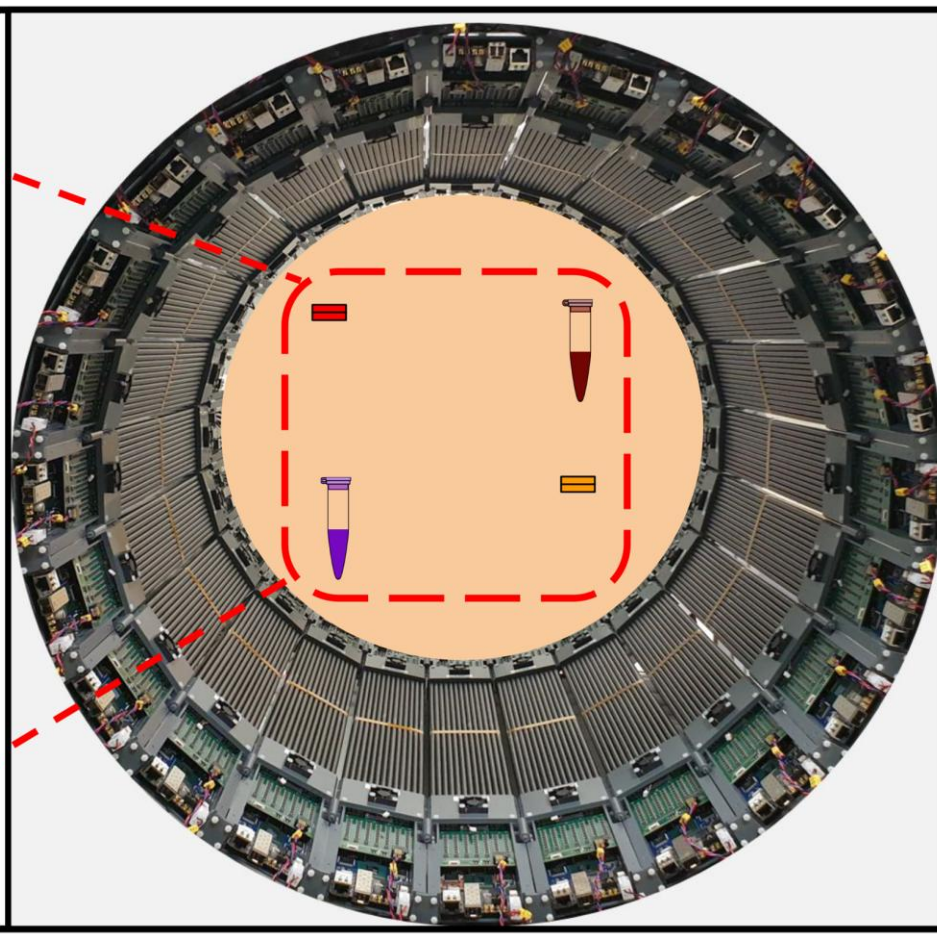


P. Moskal and E. Ł. Stępień, "Prospects and Clinical Perspectives of Total-Body PET Imaging using Plastic Scintillators," *PET Clinics*, vol. 15, no. 4, pp. 439–452, Jul. 2020.

Experimental Setup







Experimental Setup

For the ^{55}Co measurement:

- Cardiac myxoma: 1.032 MBq,
- Human adipose tissue 1.020 MBq,
- Polycarbonate: 1.092 MBq, and
- Fused silica: 1.071 MBq

This measurement lasted 15 hours and 5 minutes.

For the ^{52}Mn measurement:

- Cardiac myxoma:1.278 MBq
- Human adipose tissue: 1.298 MBq
- Polycarbonate: 1.346 MBq
- Fused silica 1.354 MBq

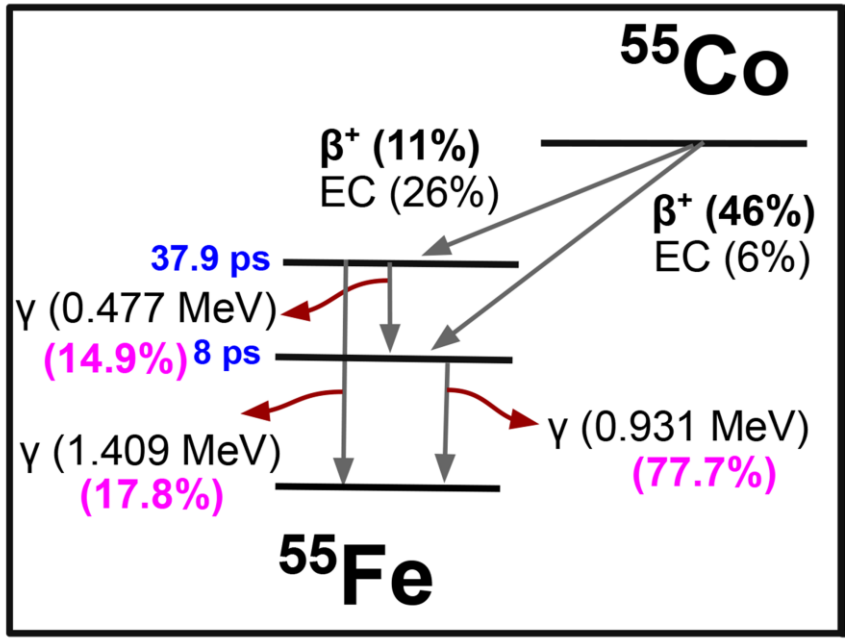
This measurement lasted 19 hours and 44 minutes.

National Institute of Advanced Industrial Science and Technology (AIST) in Tokyo, Japan

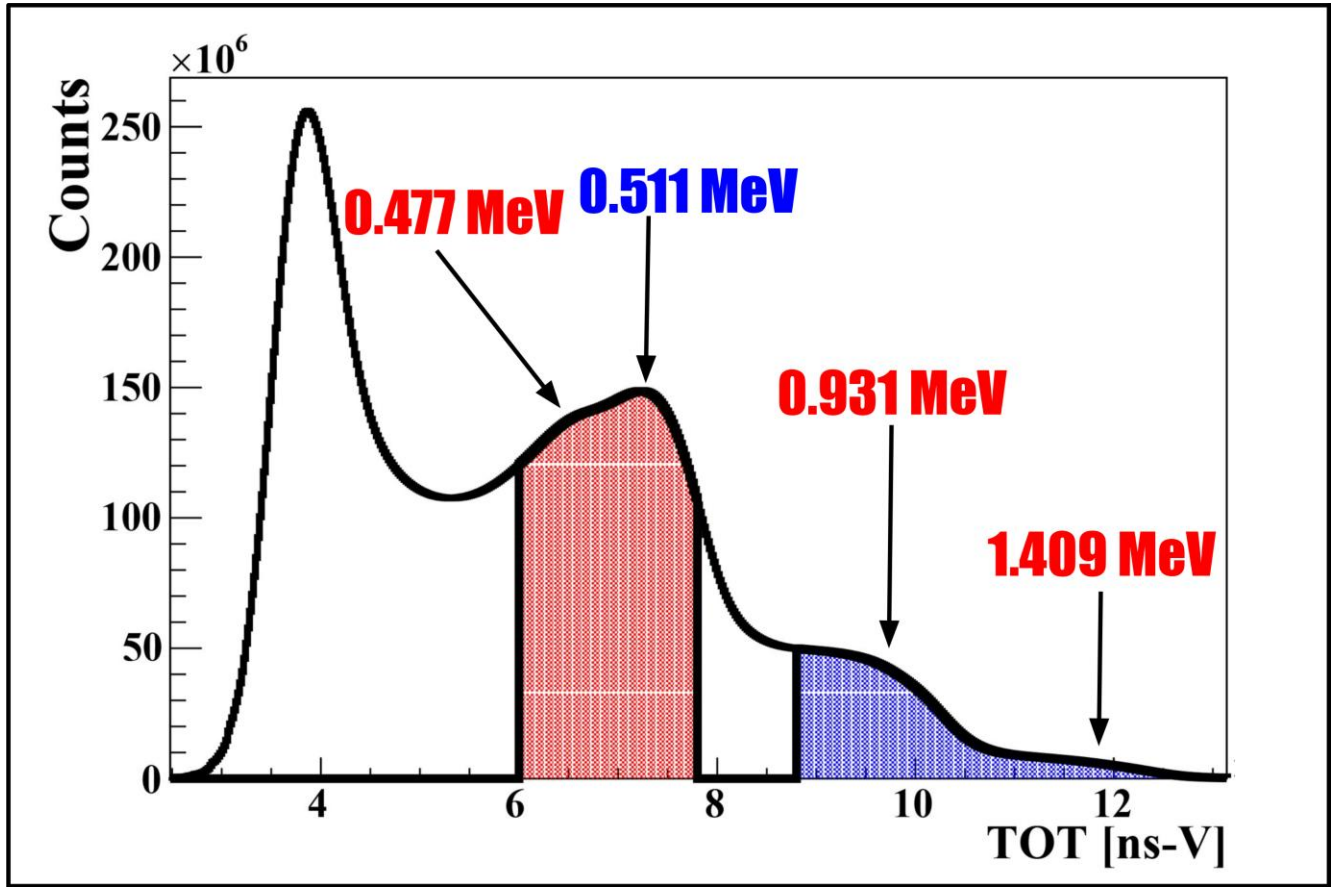
Certified material **Polycarbonate: 2.10 ± 0.05 ns**

Certified material **Fused silica: 1.62±0.05 ns**

Positronium imaging with ^{55}Co

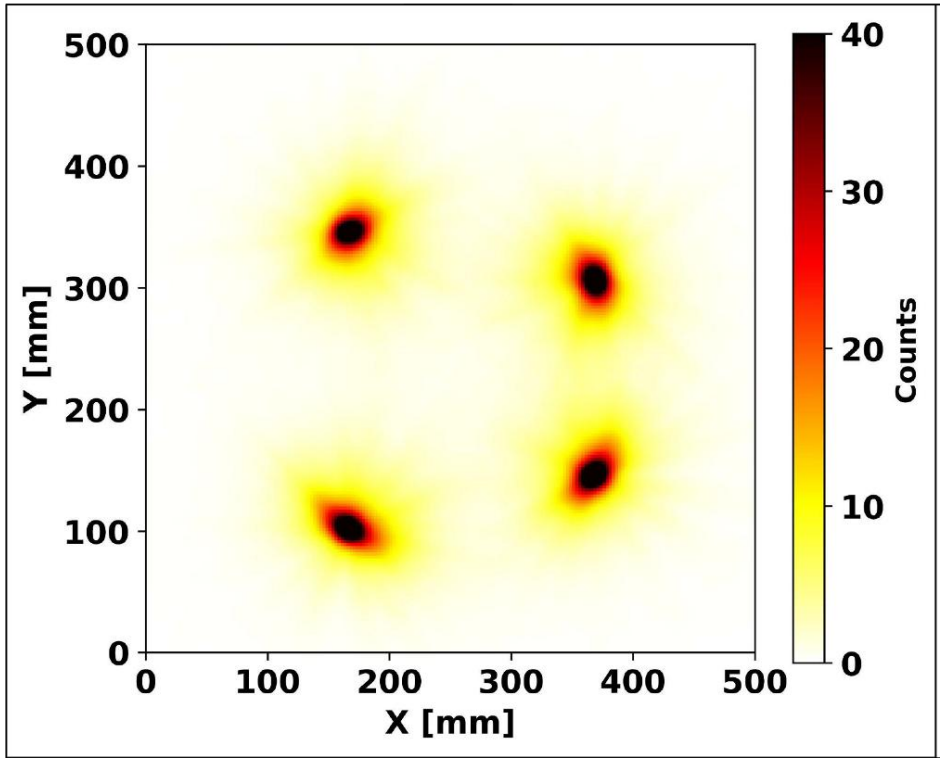


TOT as a measure of the **Energy**

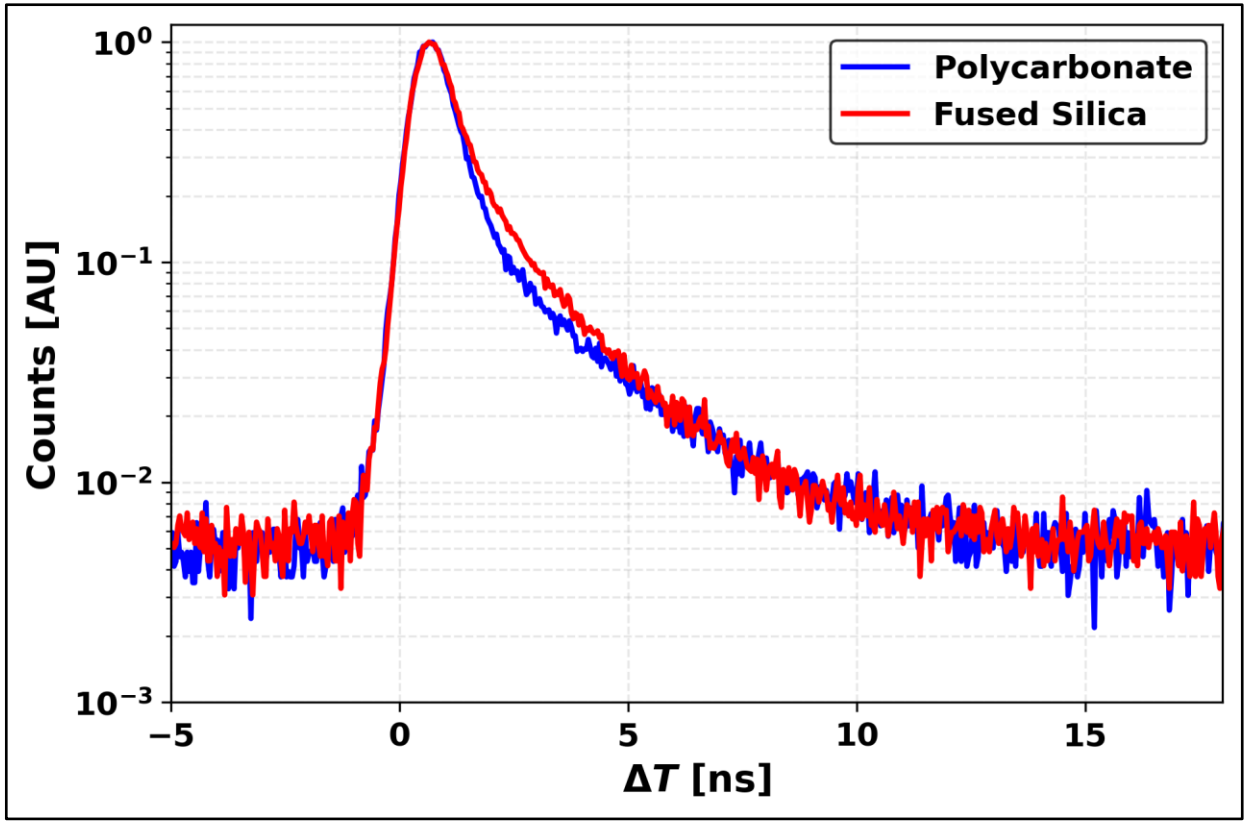


Result: Positronium imaging with ^{55}Co

2+1 gamma image

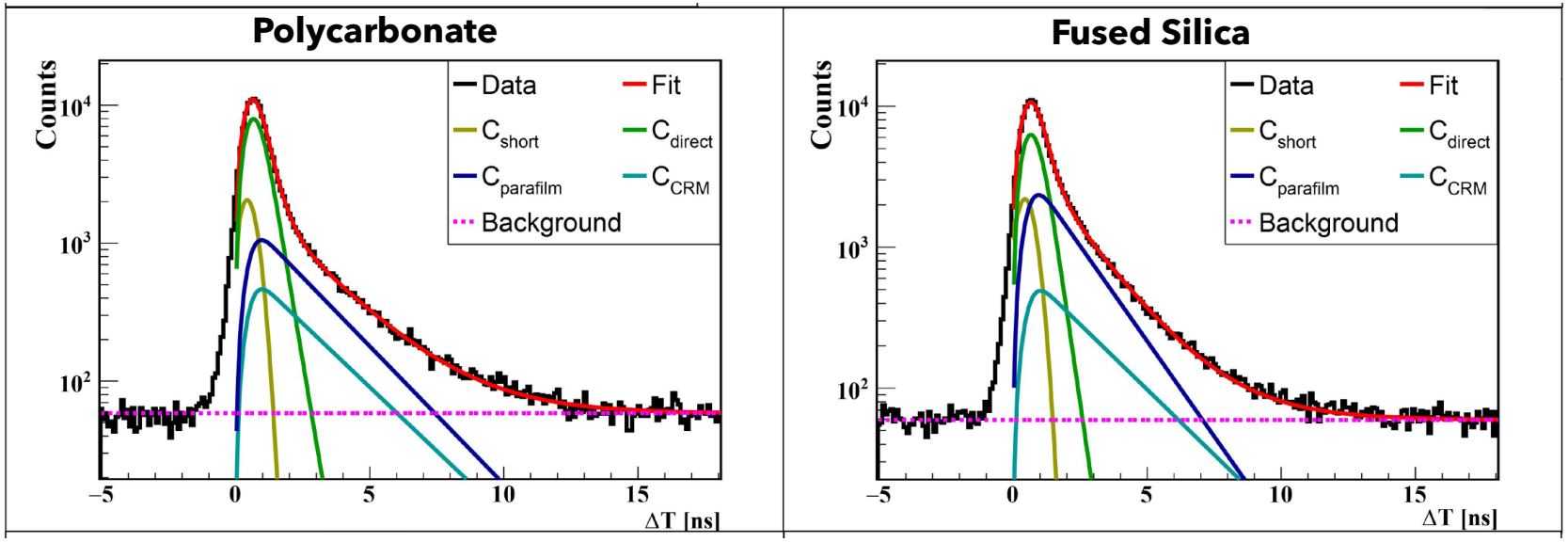


Lifetime Spectra from CRM samples

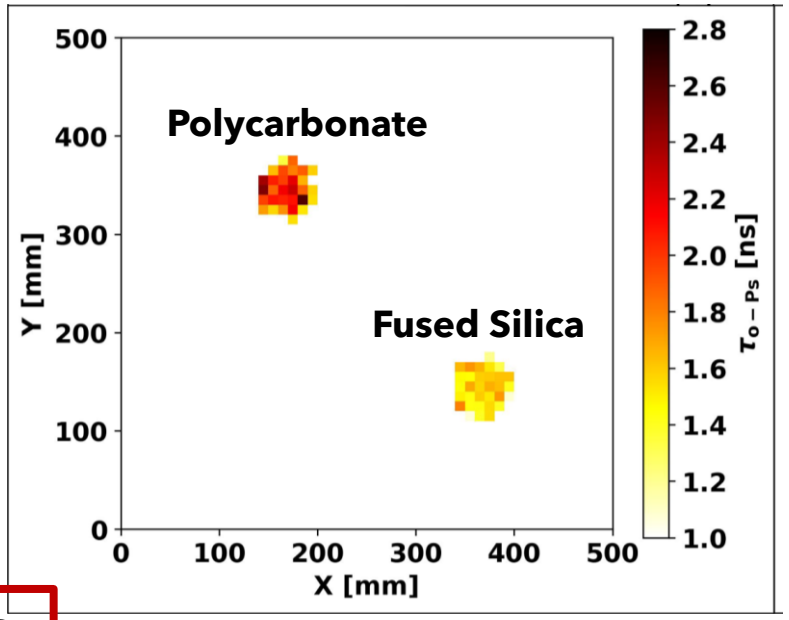


Result: Positronium imaging with ^{55}Co

Fit Results from Polycarbonate and fused silica



Voxel wise mean o-Ps lifetime ($\tau_{o\text{-}Ps}$)



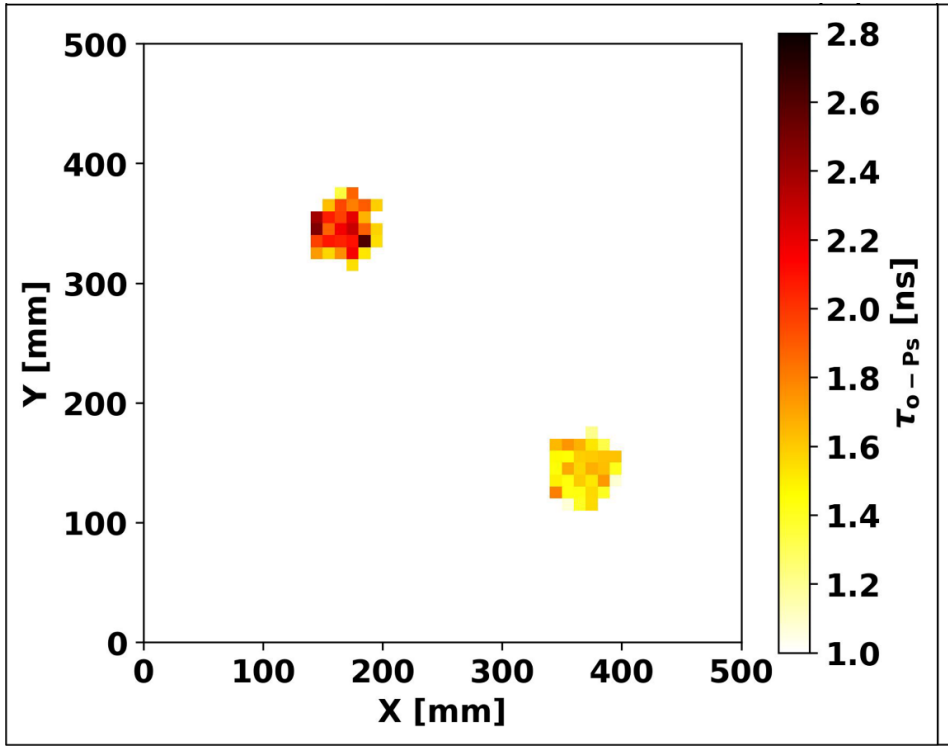
Certified lifetime: Polycarbonate: **2.10 ± 0.05 ns** Fused silica: **1.62±0.05 ns**

^{55}Co

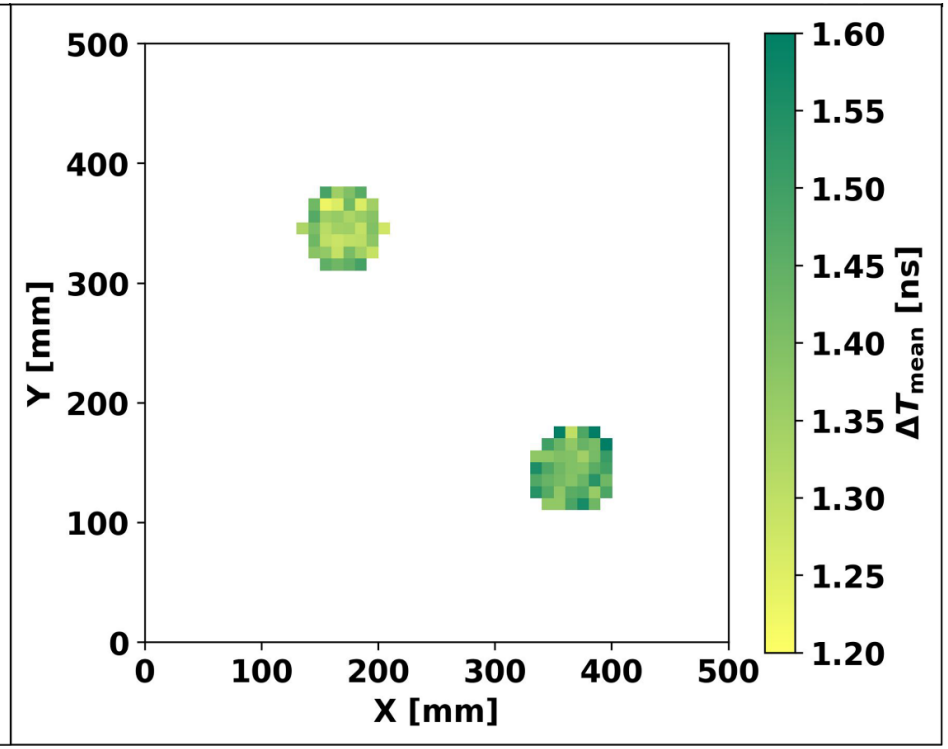
Sample Name	τ_{oPs} [ns]	I_{oPs} [%]	I_{direct} [%]	I_{pPs} [%]	ΔT_{mean} [ns]
Polycarbonate	2.174 ± 0.024	20.34 ± 0.21	59.76 ± 0.24	9.90 ± 0.19	1.303 ± 0.003
Fused Silica	1.607 ± 0.012	36.30 ± 0.22	42.54 ± 0.22	11.15 ± 0.18	1.395 ± 0.003

Result: Positronium imaging with ^{55}Co

Voxel wise mean o-Ps lifetime ($\tau_{o\text{-}Ps}$)

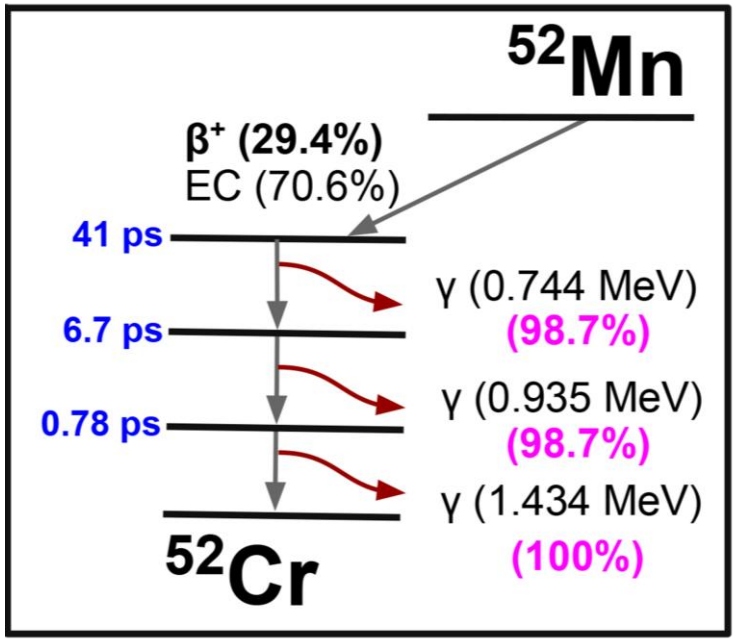


Voxel wise mean positron lifetime (ΔT_{mean})

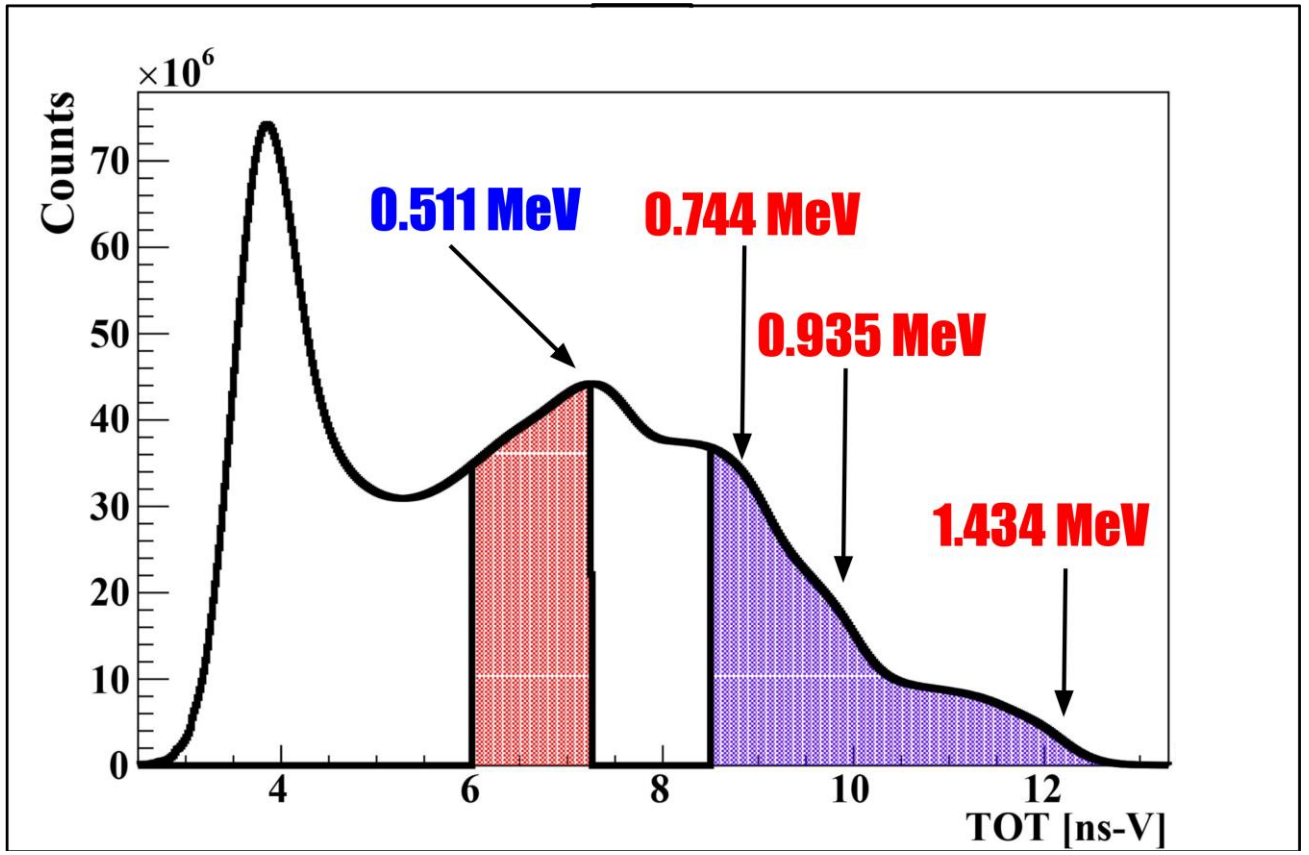


$$\Delta T_{\text{mean}} = \sum_{i=-0.1\ \text{ns}}^{9\,\text{ns}} (N_i - N_b)\Delta T_i \Big/ \sum_{i=-0.1\ \text{ns}}^{9\,\text{ns}} (N_i - N_b)$$

Positronium imaging with ^{52}Mn

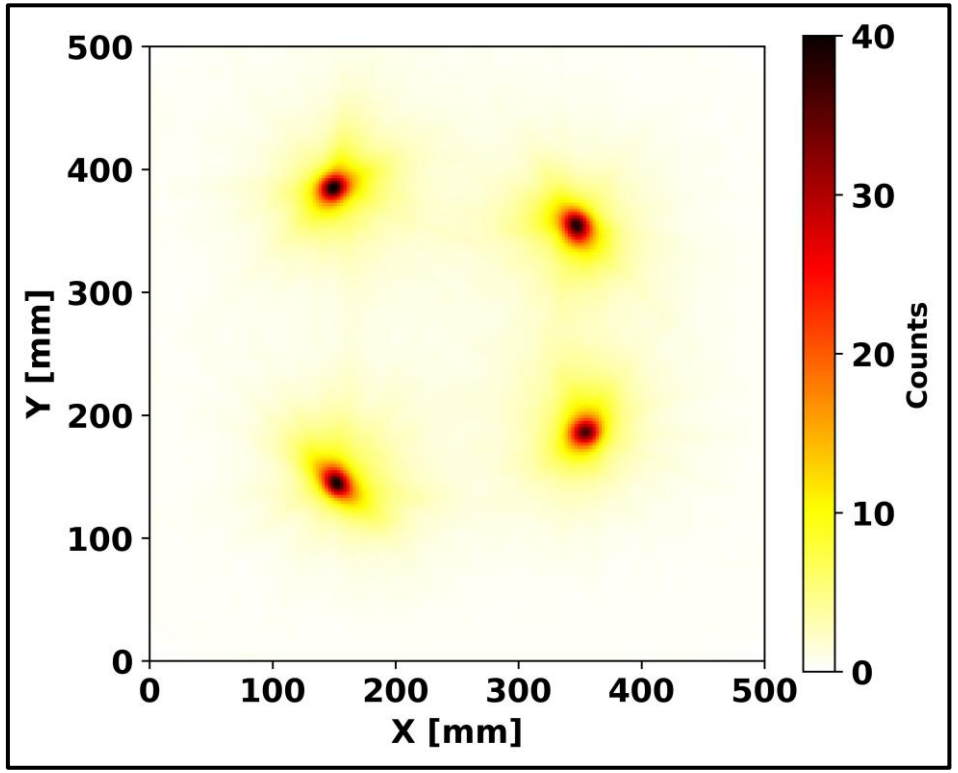


TOT as a measure of the **Energy**



Result: Positronium imaging with ^{52}Mn

2+1 gamma image



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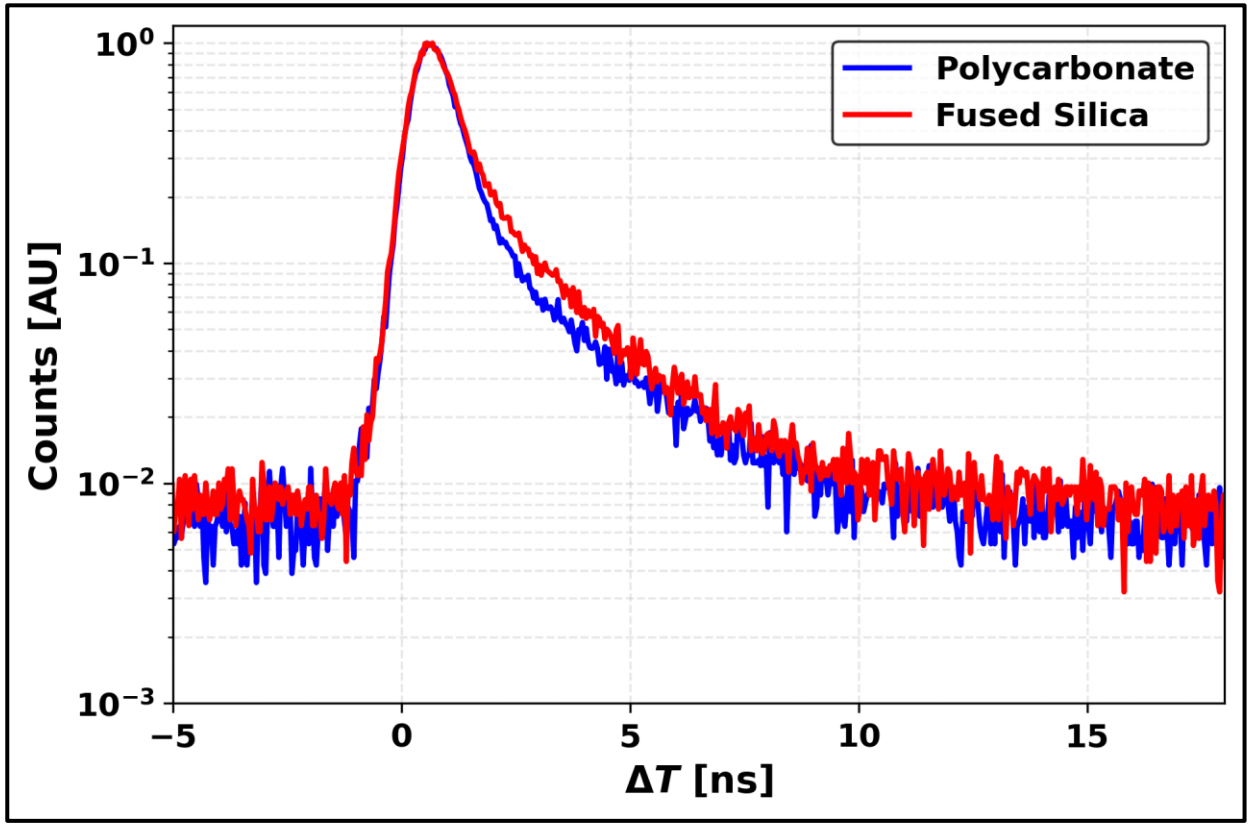
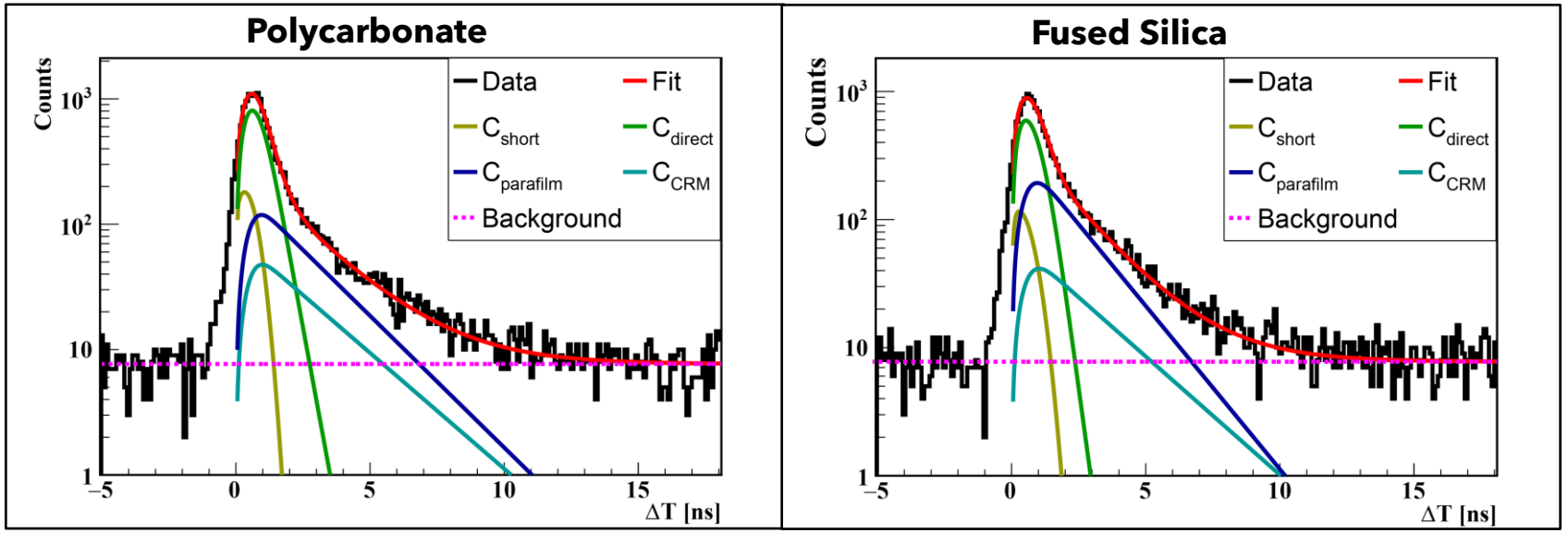
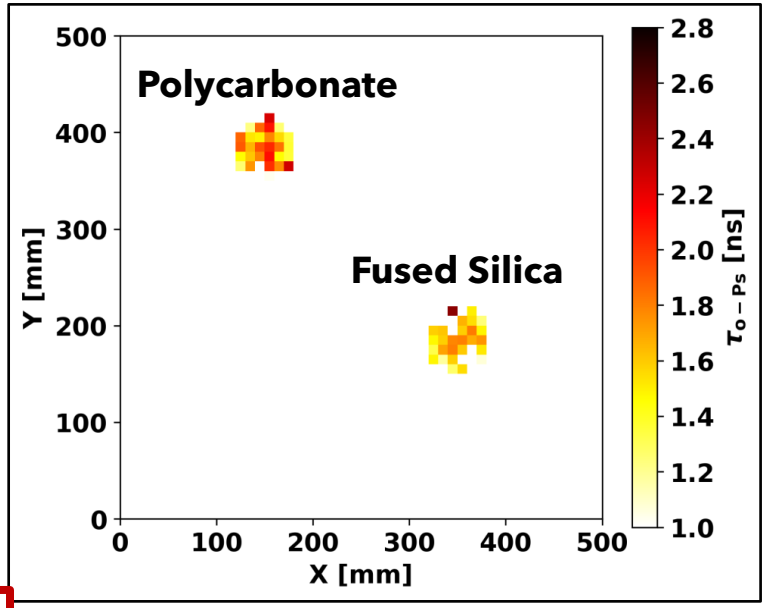


Result: Positronium imaging with ^{52}Mn

Fit Results from Polycarbonate and fused silica



Voxel wise mean o-Ps lifetime ($\tau_{o\text{-}Ps}$)



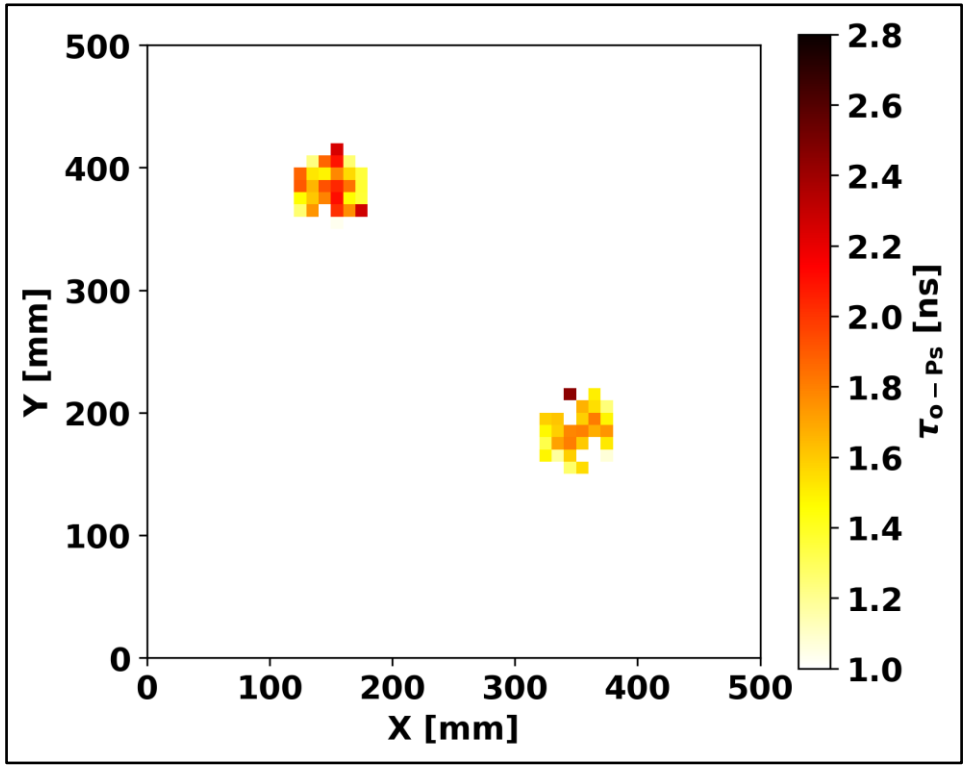
Certified lifetime: Polycarbonate: **2.10 ± 0.05 ns** Fused silica: **1.62±0.05 ns**

^{52}Mn

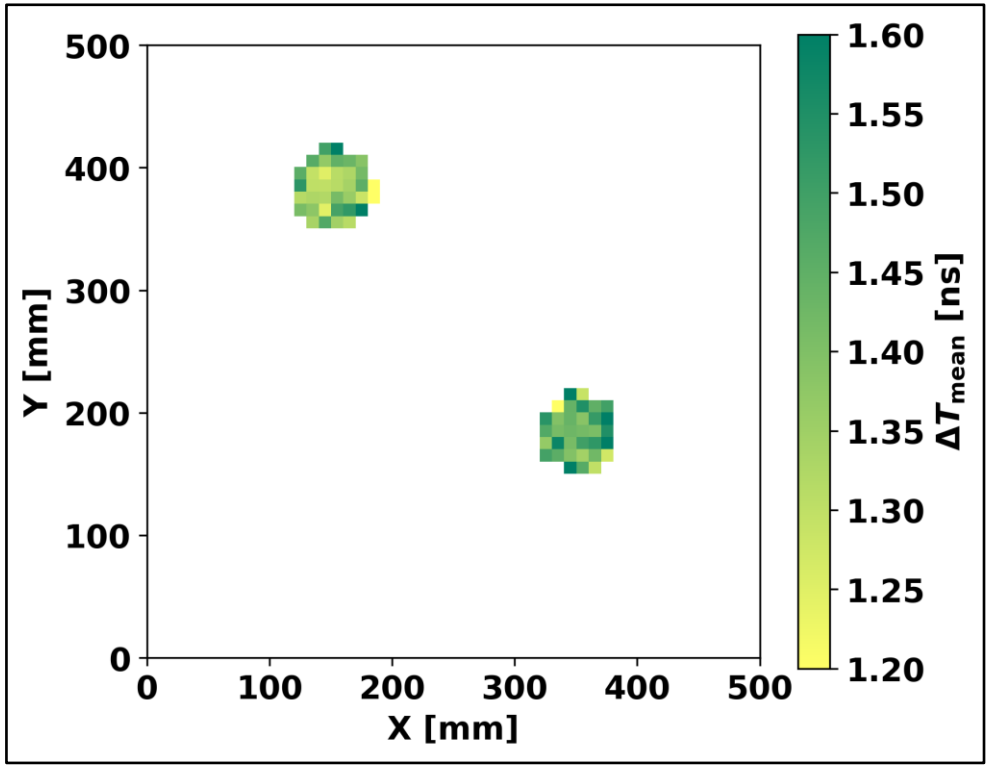
Sample Name	τ_{oPs} [ns]	I_{oPs} [%]	I_{direct} [%]	I_{pPs} [%]	ΔT_{mean} [ns]
Polycarbonate	2.066 ± 0.071	22.40 ± 0.65	58.02 ± 0.75	9.57 ± 0.61	1.304 ± 0.011
Fused Silica	1.703 ± 0.041	37.82 ± 0.77	43.63 ± 0.76	8.54 ± 0.62	1.416 ± 0.012

Result: Positronium imaging with ^{52}Mn

Voxel wise mean o-Ps lifetime ($\tau_{o\text{-}Ps}$)



Voxel wise mean positron lifetime (ΔT_{mean})



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Result: ^{52}Mn and ^{55}Co

^{55}Co					
Sample Name	τ_{oPs} [ns]	I_{oPs} [%]	I_{direct} [%]	I_{pPs} [%]	ΔT_{mean} [ns]
Polycarbonate	2.174 ± 0.024	20.34 ± 0.21	59.76 ± 0.24	9.90 ± 0.19	1.303 ± 0.003
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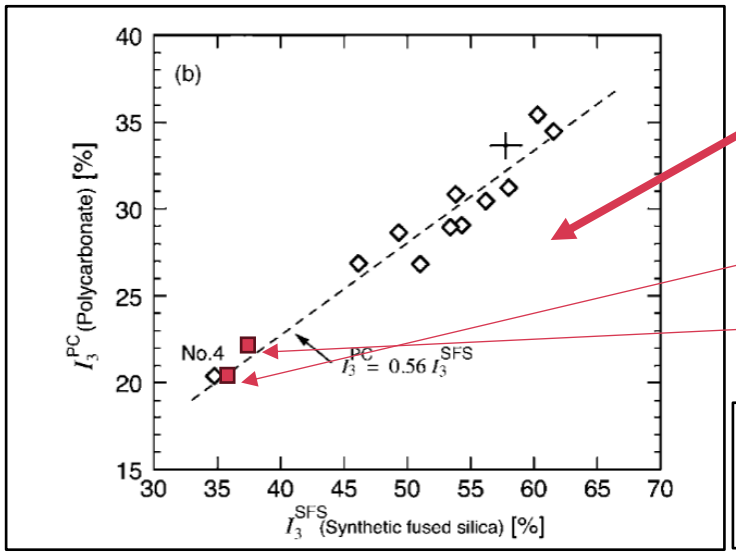

$I_{poly} = (0.56)\, I_{silica}$

^{55}Co:
$I_{poly} = (0.560 \pm 0.006)\, I_{silica}$

^{52}Mn:
$I_{poly} = (0.592 \pm 0.021)\, I_{silica}$

Ito, K., et al (2008). Interlaboratory comparison of positron annihilation lifetime measurements for synthetic fused silica and polycarbonate. Journal of Applied Physics, 104(2). https://doi.org/10.1063/1.2957074

Conclusion

- The preliminary results from the **^{52}Mn and ^{55}Co** are **promising.**
- The **mean o-Ps lifetime** in the **CRMs** are in **excellent agreement** with the certified lifetime.
- The mean positron lifetime is **consistent** for **CRMs** in both isotope.
- The **intensity ratio** of the **mean o-Ps lifetime** is **consistent** with the **previous reported result.**

Acknowledgement

NATIONAL SCIENCE CENTRE POLAND

2021/42/A/ST2/00423

2021/43/B/ST2/02150

2022/47/I/NZ7/03112

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Thank You