Positronium Lifetime Imaging by J-PET

KAMIL DULSKI

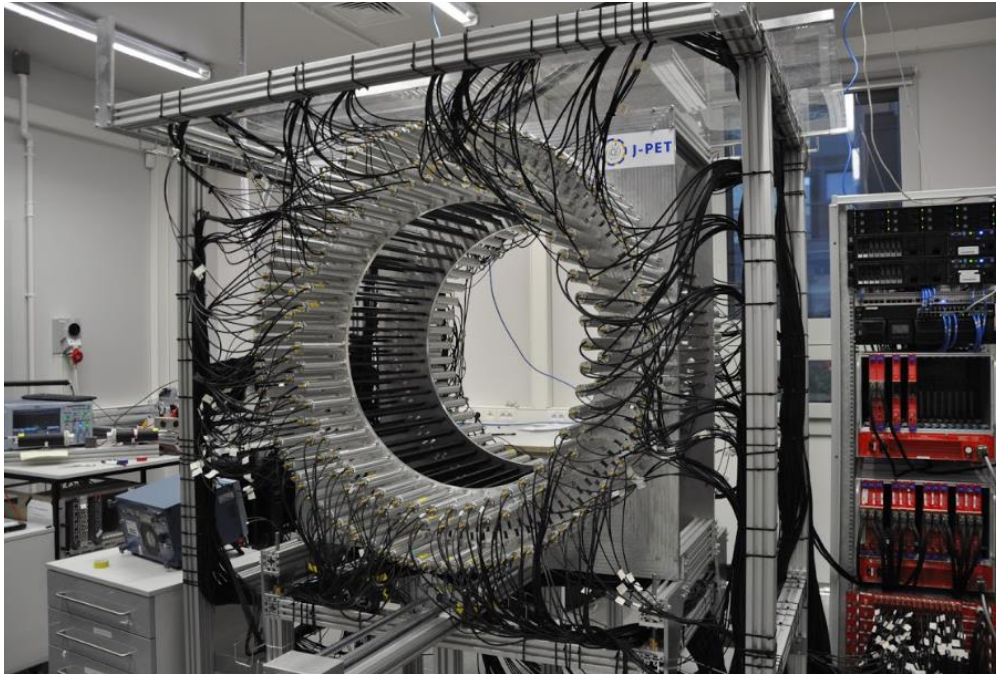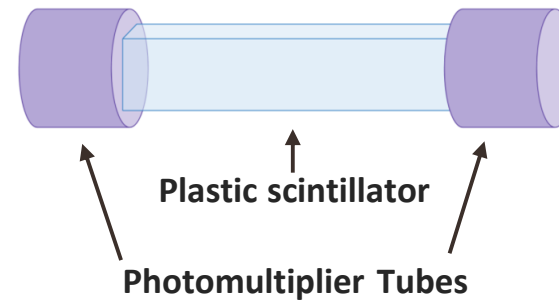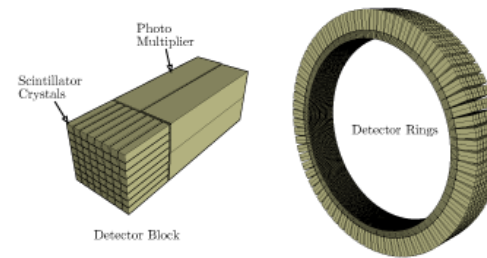on behalf of the J-PET collaboration

IS QUANTUM THEORY EXACT? FROM QUANTUM FOUNDATIONS TO QUANTUM APPLICATIONS
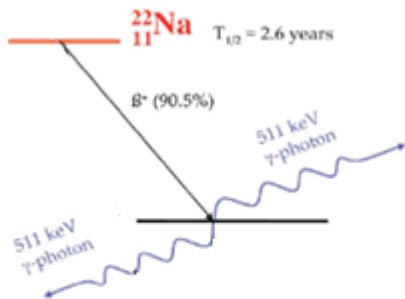
Outline

1. J-PET – novel TOF-PET system

2. Morphometric image

3. Selection criteria for 2γ decay of Positronium

4. Lifetime maps examples
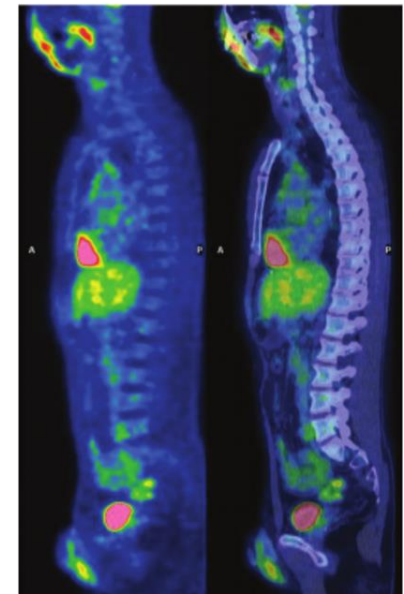
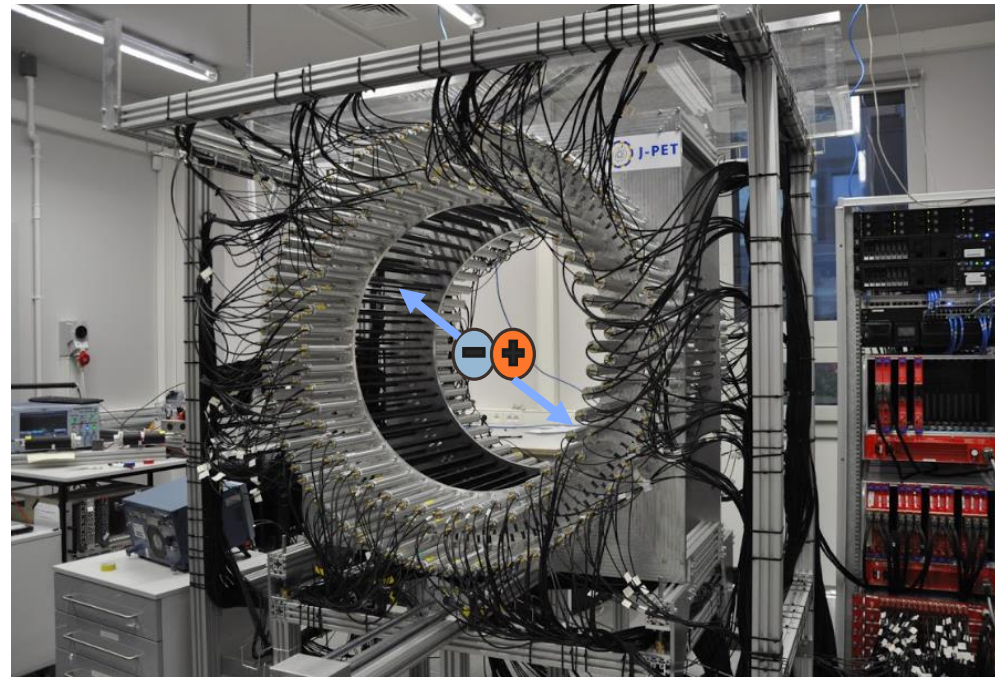# J-PET – novel TOF-PET system

https://psychology.wikia.org/wiki/Positron_emission_tomography

Plastic scintillator

Photomultiplier Tubes
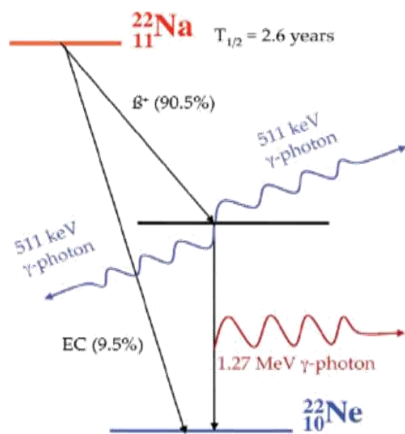
Morphometric image
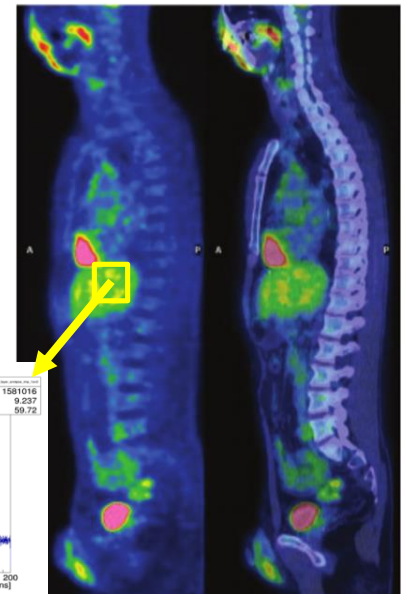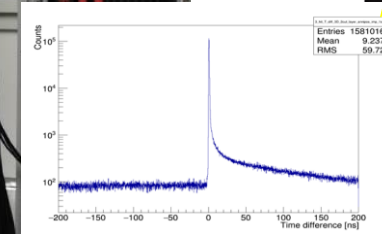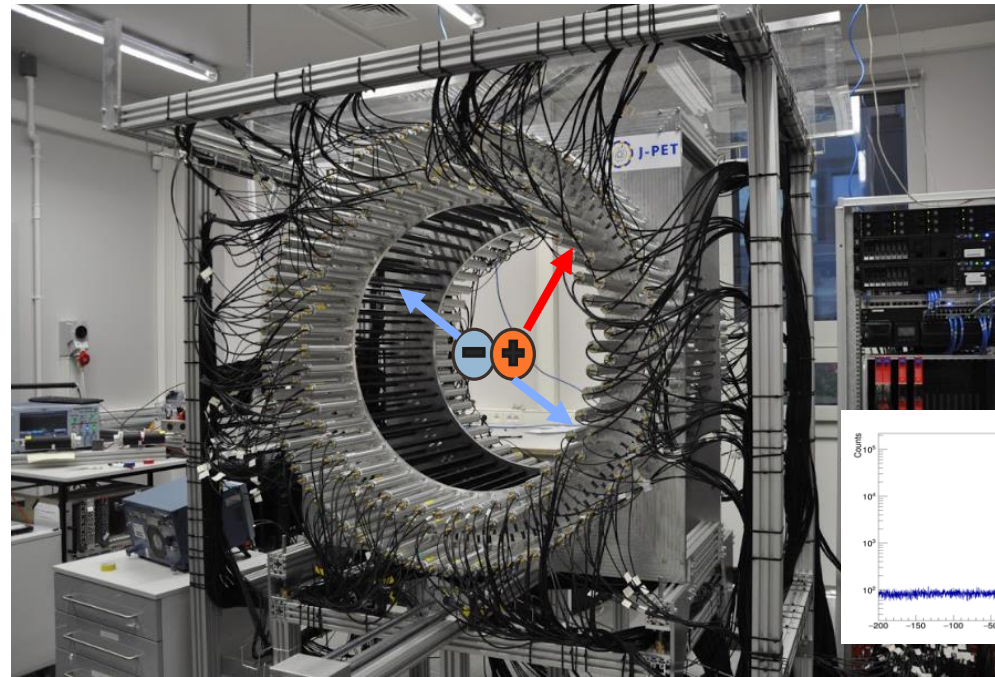

A. Skandani DOI:10.1080/10420150.2011.569720

R. Gorla DOI:10.1155/2012/751761

Morphometric image

A. Skandani DOI:10.1080/10420150.2011.569720

R. Gorla DOI:10.1155/2012/751761

Measurement details

Samples in mini-chambers
Radius ~3cm
Height ~4cm

Nr	Sample	Activity	Longest Mean Lifetime
1.	IC3100	0.42 MBq	140 ns
2.	XAD4	0.28 MBq	90 ns
3.	PVT	0.35 MBq	2 ns

1.
(6.5, -9.5)

2.
(6.5, 9.5)

3. (0, -10.5)

Measurement details

Samples in mini-chambers
Radius ~3cm
Height ~4cm

Nr	Sample	Activity	Longest Mean Lifetime
1.	IC3100	0.42 MBq	140 ns
2.	XAD4	0.28 MBq	90 ns
3.	PVT	0.35 MBq	2 ns

1. (6.5, -9.5)

2. (6.5, 9.5)

3. (0, -10.5)

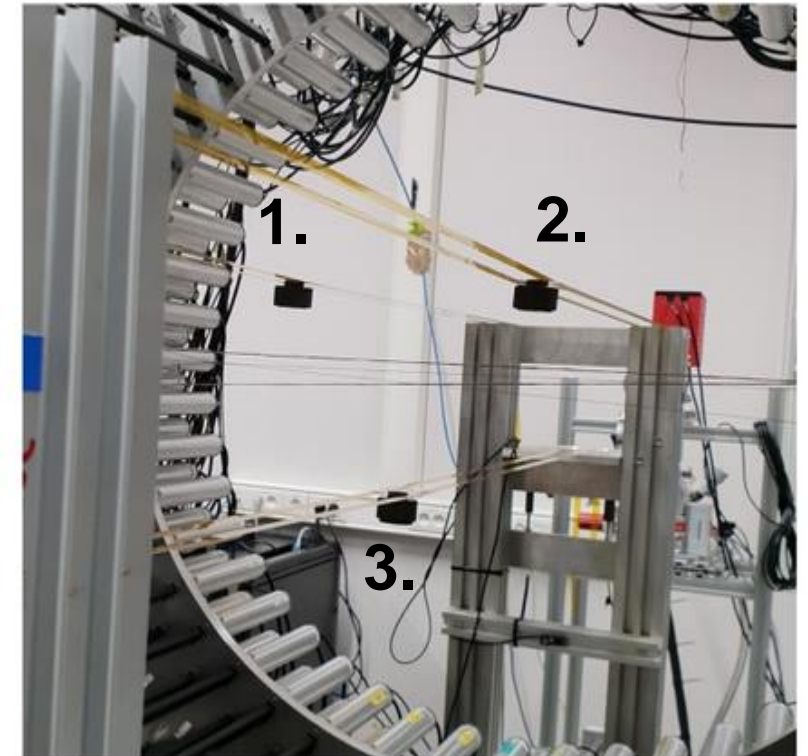# Measurement details

Samples in mini-chambers
Radius ~3cm
Height ~4cm

Nr	Sample	Activity	Longest Mean Lifetime
1.	IC3100	0.42 MBq	140 ns
2.	XAD4	0.28 MBq	90 ns
3.	PVT	0.35 MBq	2 ns

1.
(6.5, -9.5)

2.
(6.5, 9.5)

3. (0, -10.5)
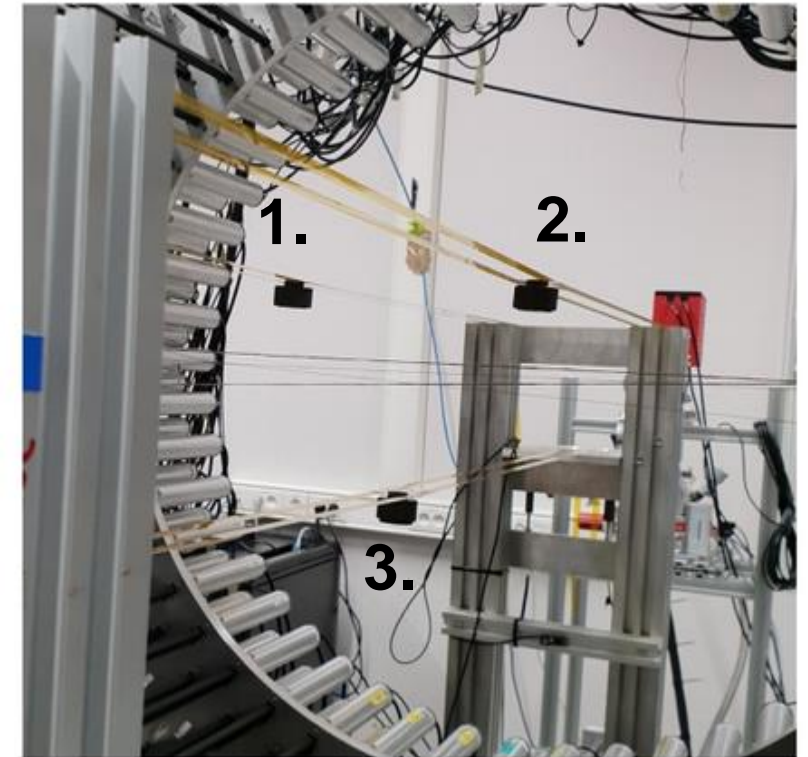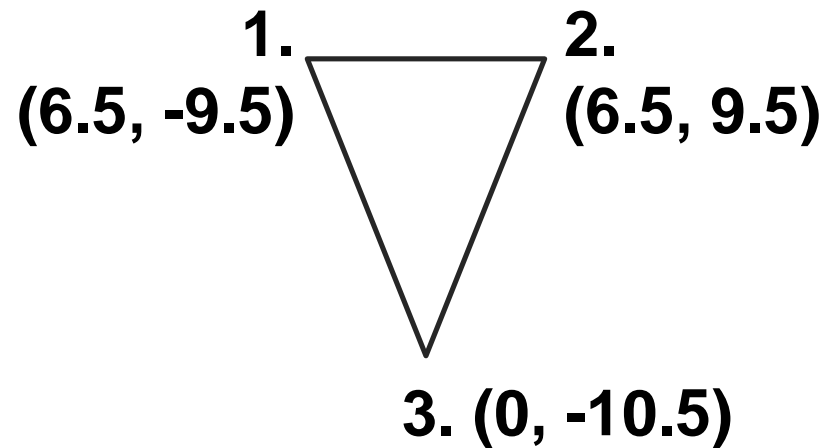
Results – Annihilation points no criteria
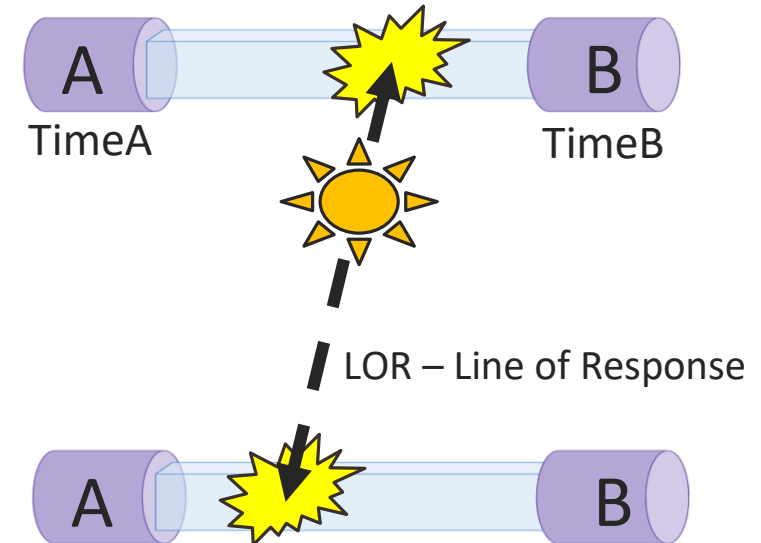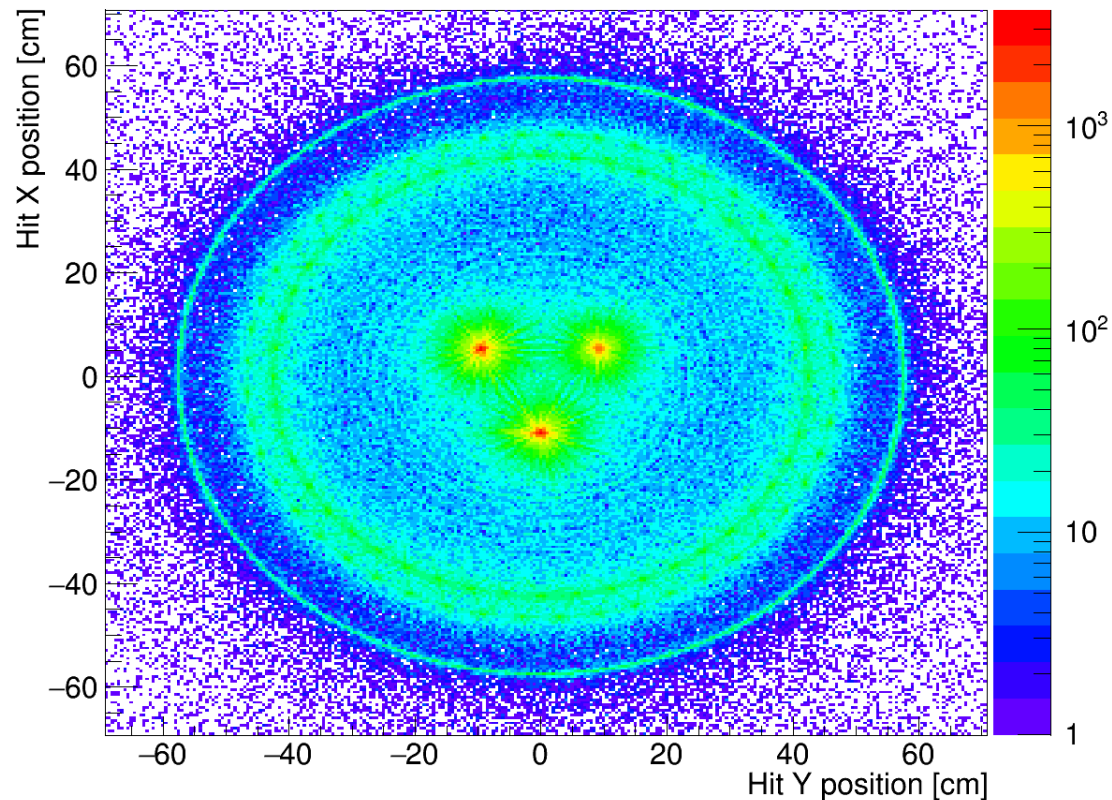
Position along the strip = 1/2 · (TimeA − TimeB) · V_{scint}
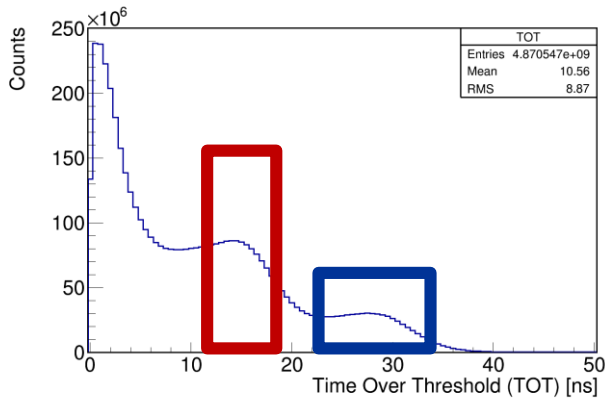
$T_i = 1/2 \cdot (TimeA + TimeB)$

Position along the LOR = $1/2 \cdot (T_1 − T_2) \cdot c$

Selection criteria for 2γ decay of Positronium
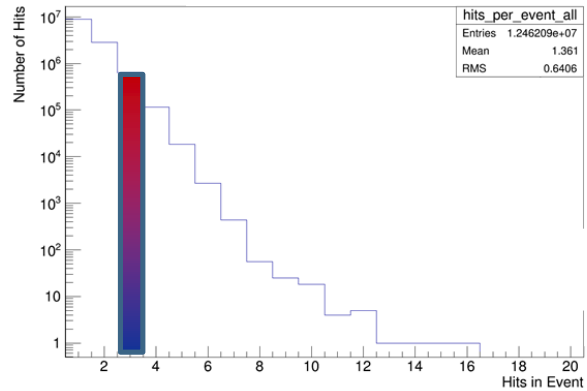
Number of Hits in Event

Minimal angle between any hits

Energy/TOT

Minimal angle between Annihilation Hits

Scatter test for Annihilation Hits

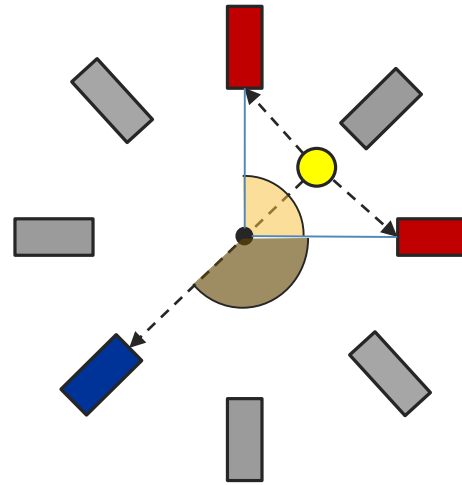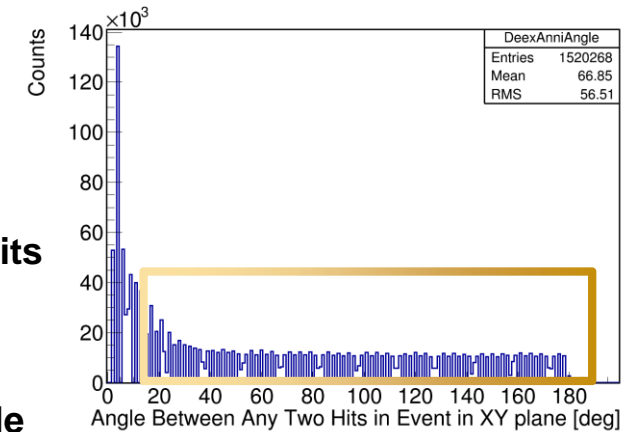# Selection criteria for 2γ decay of Positronium
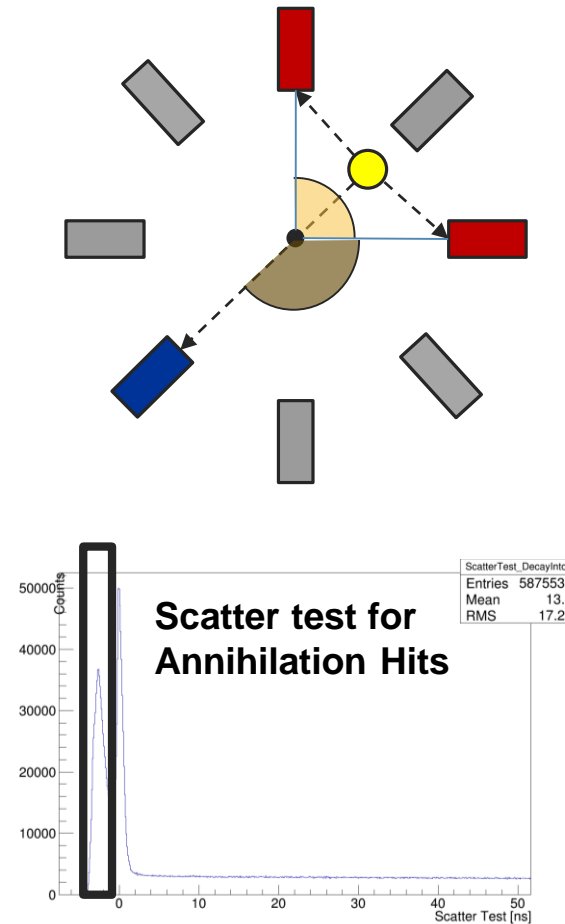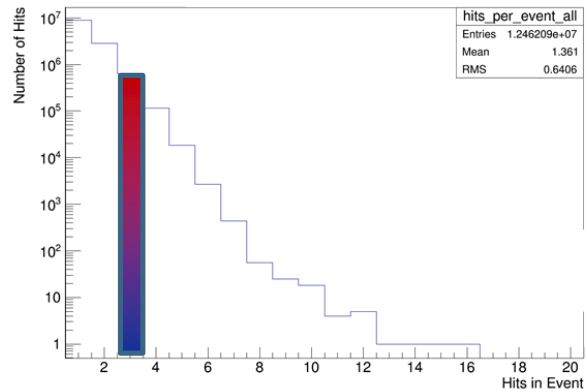
Number of Hits in Event
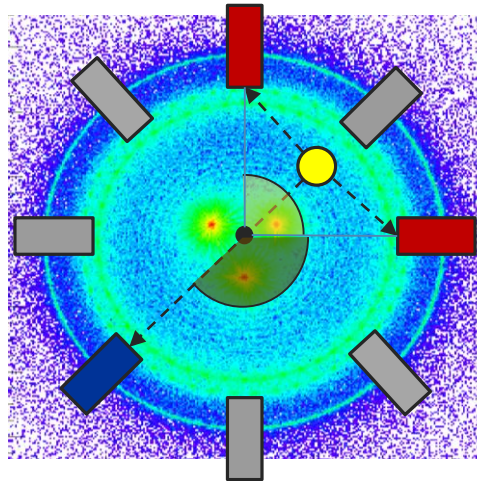
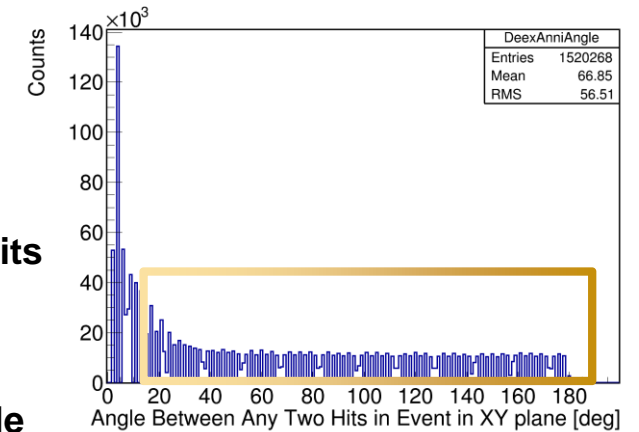**Minimal angle between any hits**

Minimal angle between Annihilation Hits

Scatter test for Annihilation Hits

$$Scatter\ test =$$
$$|Time_{Anni1} - Time_{Anni2}| - \frac{Distance(HitPos_{Anni1}, HitPos_{Anni2})}{Speed\ of\ Light}$$
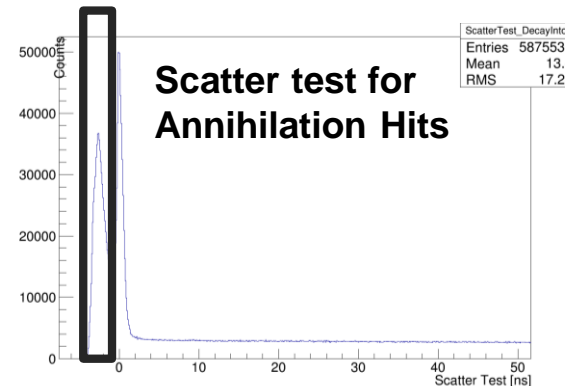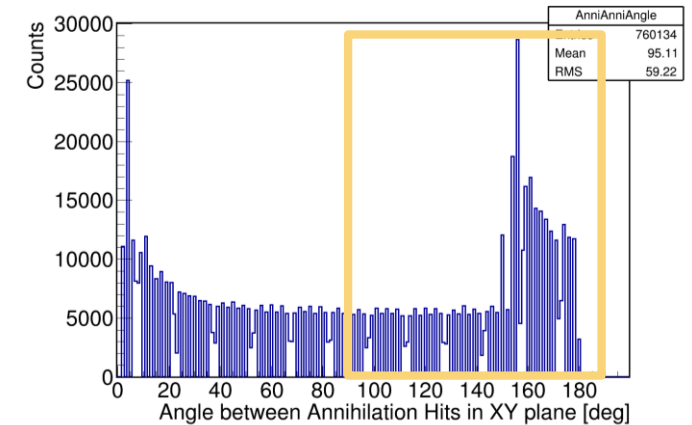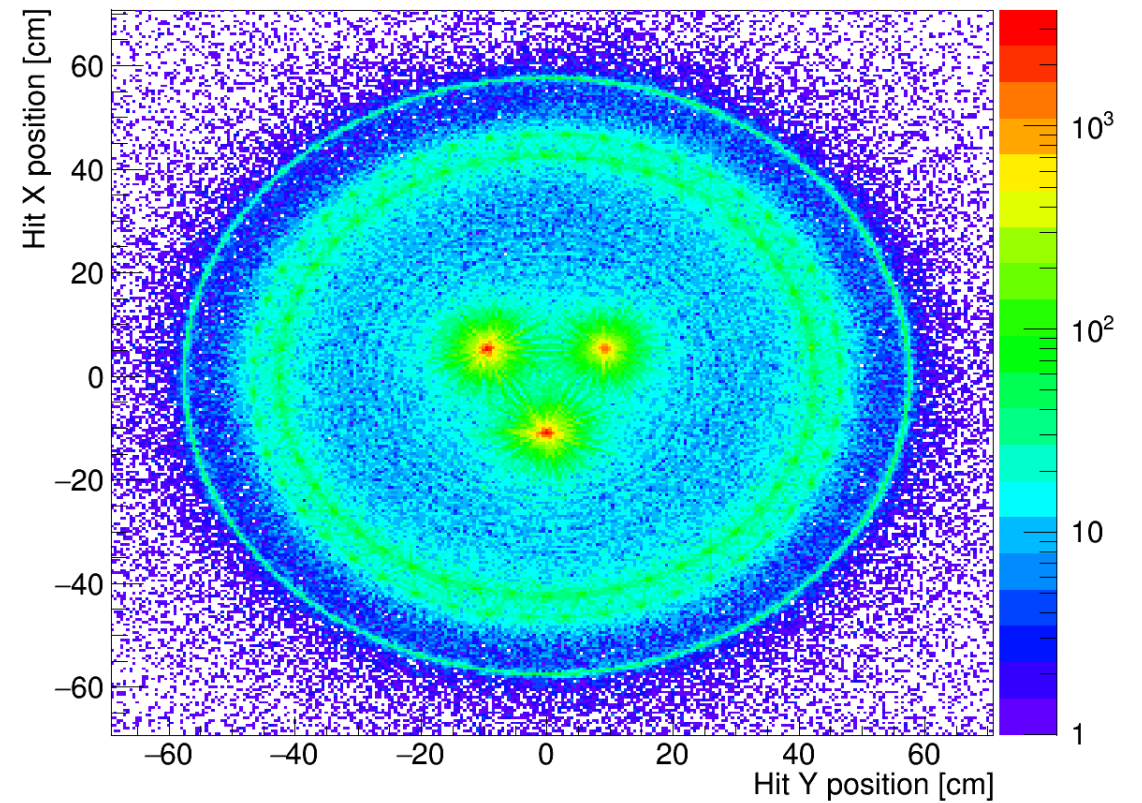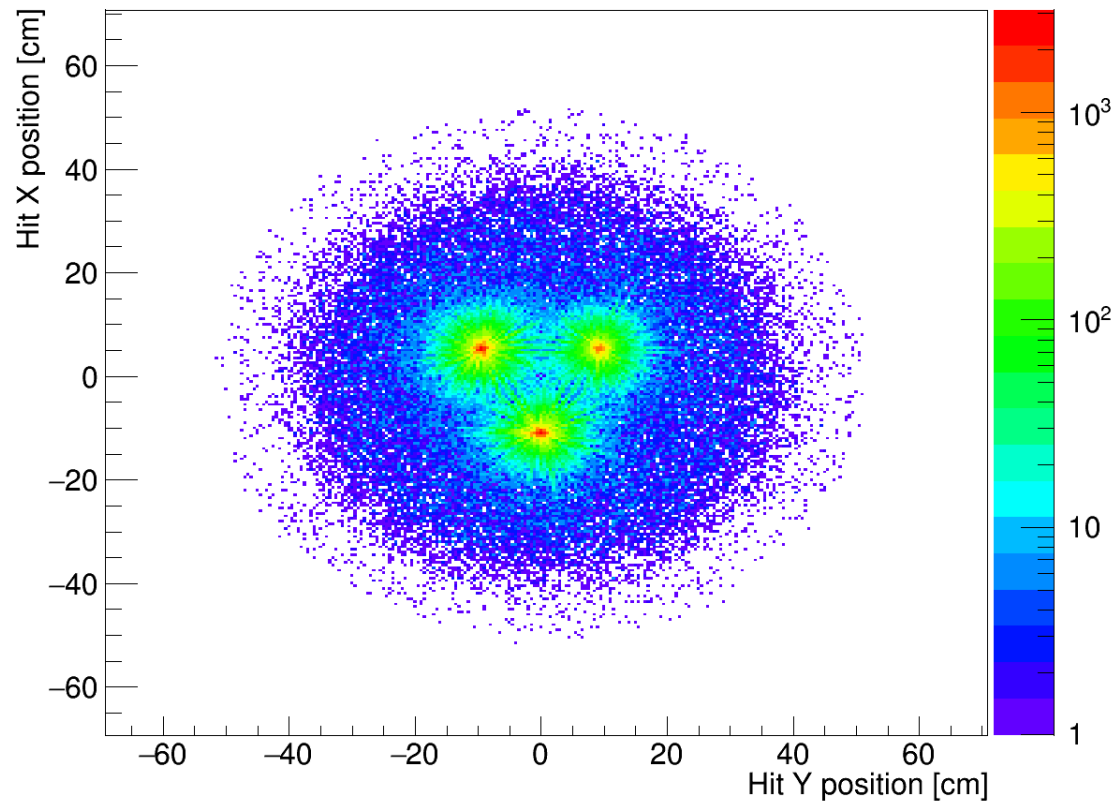
Results – Annihilation points

Results – Annihilation points

Results – Annihilation points + lifetime

IC3100 – longest mean lifetime 140 ns in vacuum

Hit X position [cm] vs Hit Y position [cm]

Counts vs Lifetime of Positronium [ns]

Lifetime_STPlus_CutOnPos_X5_25_Y-9_5

Entries	50088
Mean	7.525
RMS	71.71

$0.5 \cdot (Time_{Anni1} + Time_{Anni2}) - Time_{Deex}$

Results – Annihilation points + lifetime

**XAD4 – longest mean lifetime 90 ns
In vacuum**

$0.5 \cdot (\text{Time}_{\text{Anni1}} + \text{Time}_{\text{Anni2}}) - \text{Time}_{\text{Deex}}$

Results – Annihilation points + lifetime

PVT – mean lifetime 2 ns

$0.5 \cdot (\text{Time}_{Anni1} + \text{Time}_{Anni2}) - \text{Time}_{Deex}$
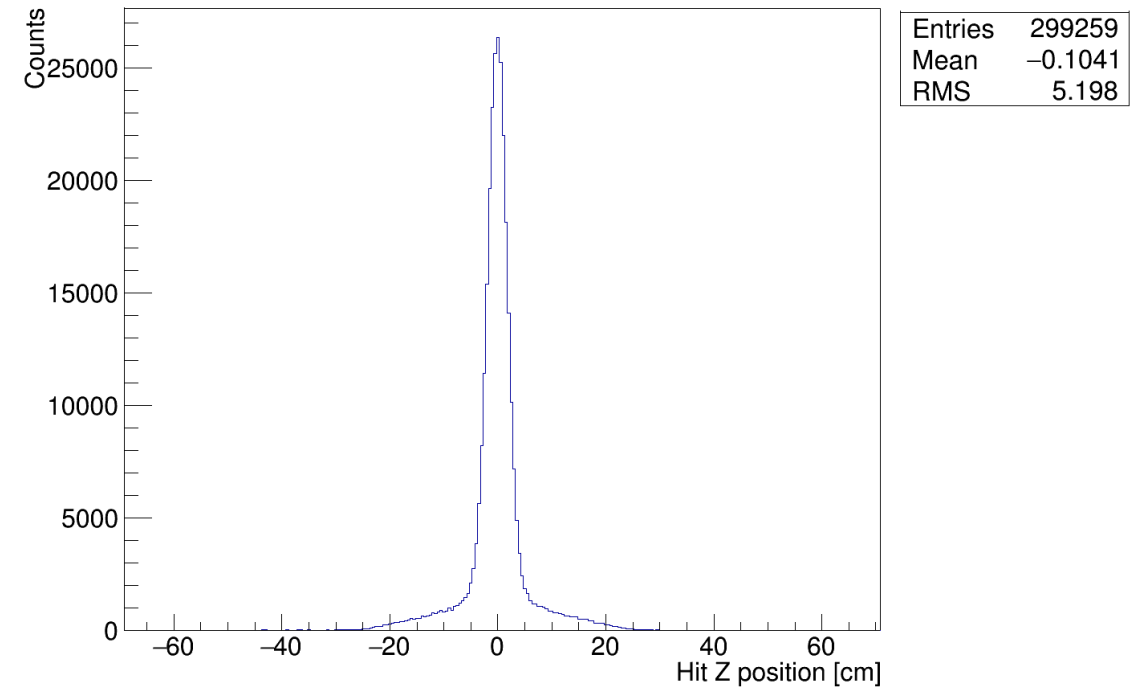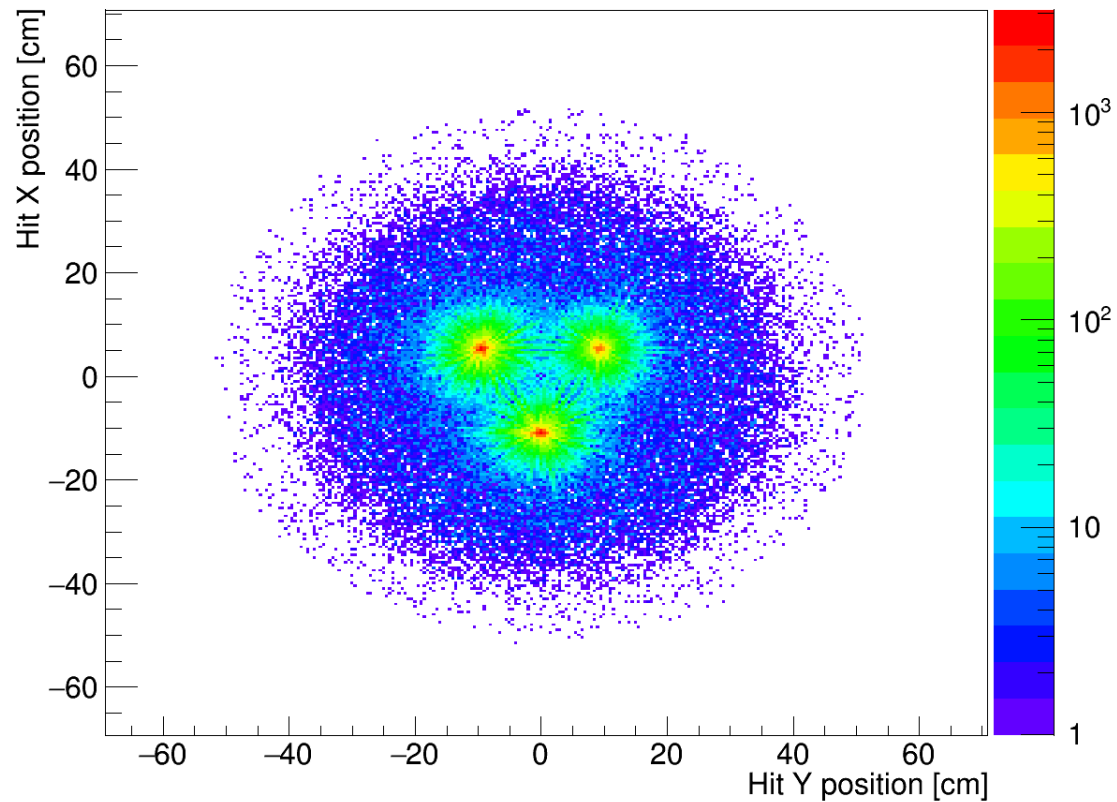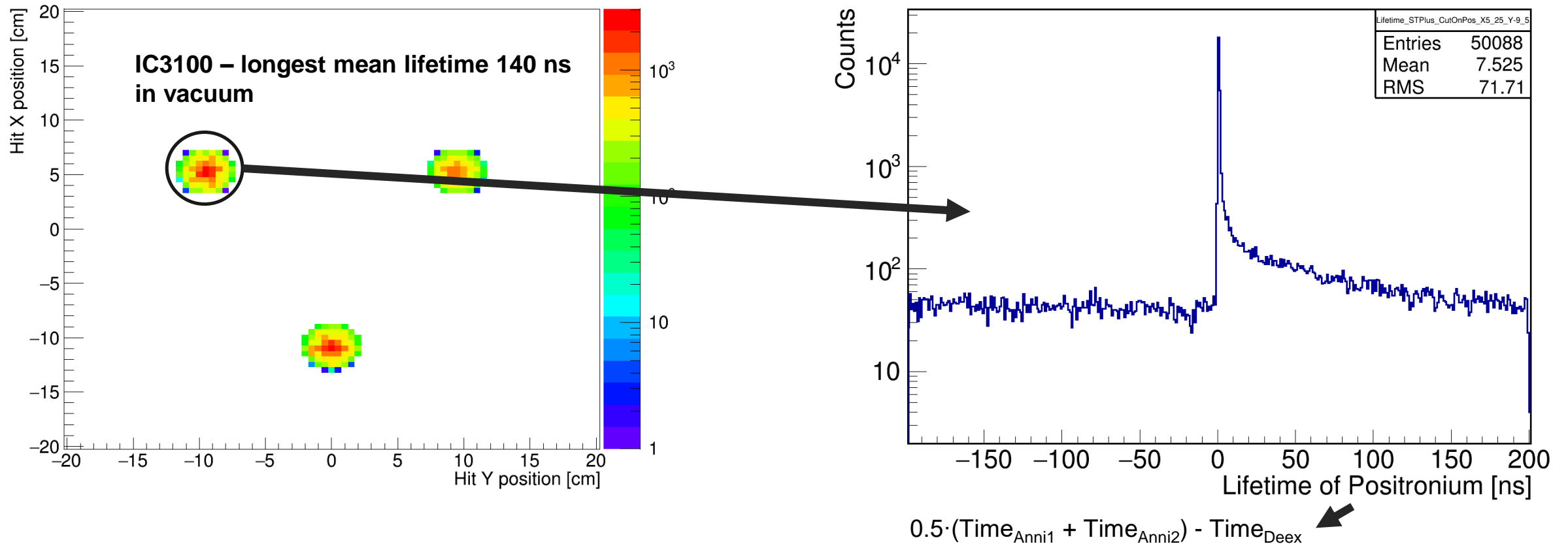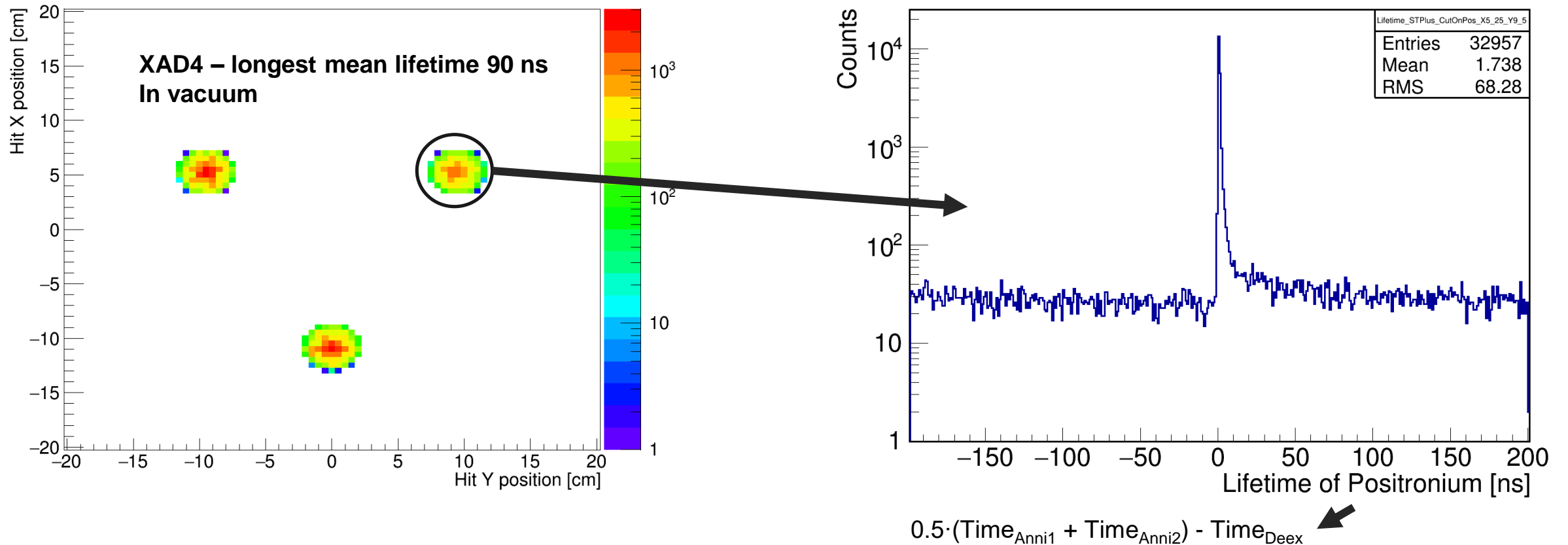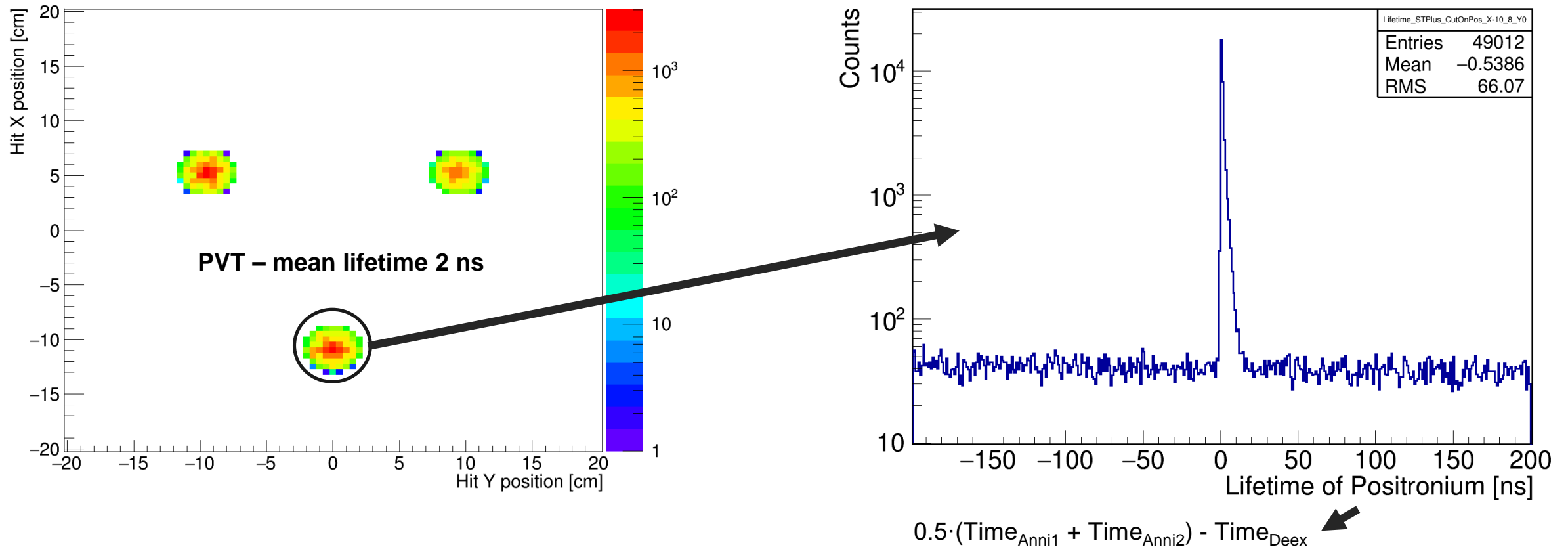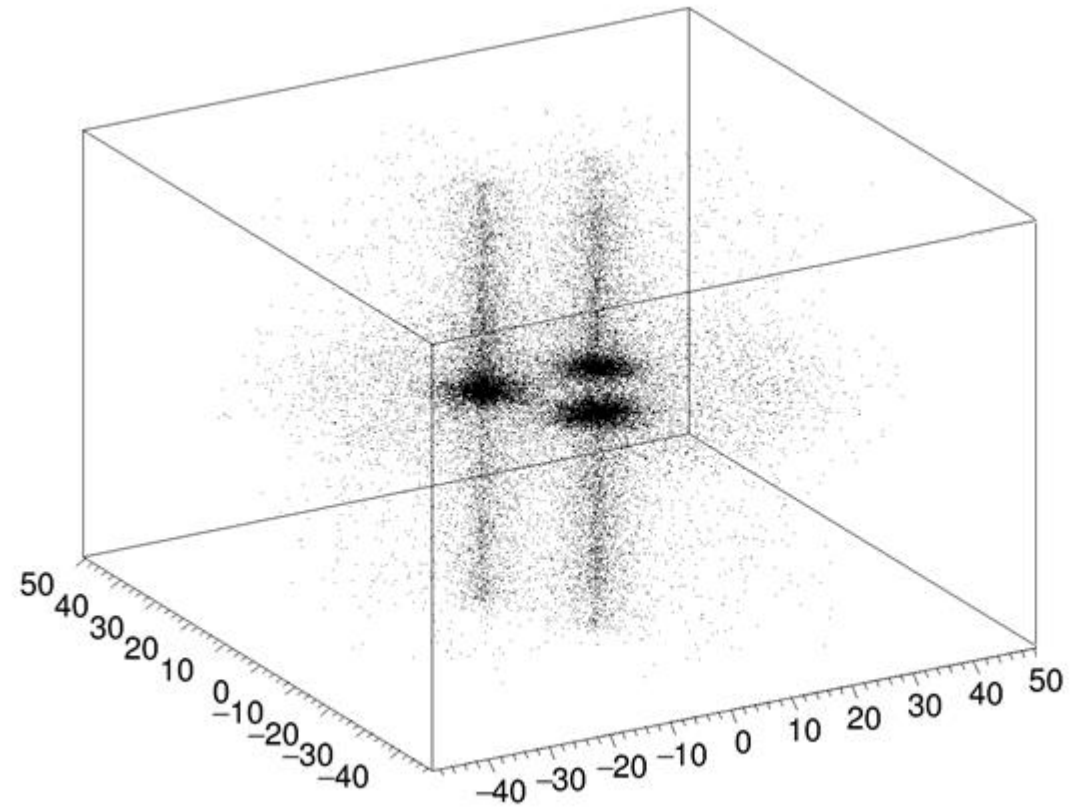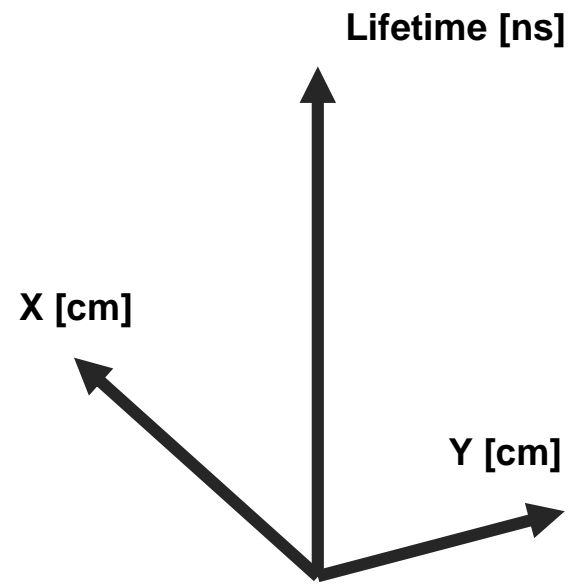
Lifetime map

Lifetime maps examples
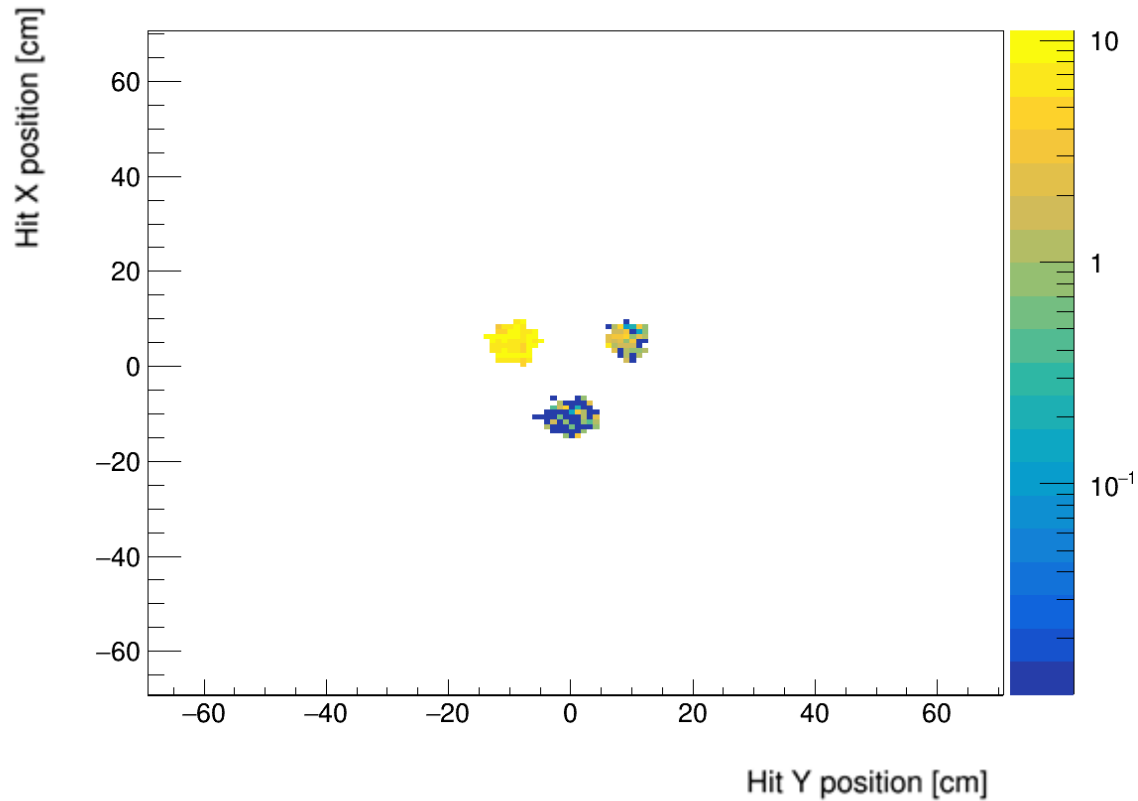
- **1 cm x 1 cm** voxel
- Shown only for voxels for which total number of counts is higher than **5%** of **maximal number of counts**
- **Lifetime estimate** – **Mean** of histogram

Lifetime maps examples

- **1 cm x 1 cm** voxel
- Shown only for voxels for which total number of counts is higher than **5%** of **maximal number of counts**
- **Lifetime estimate** – **Width** at 10% of Max of histogram

Lifetime maps examples

- **1 cm x 1 cm** voxel
- Shown only for voxels for which total number of counts is higher than **5%** of **maximal number of counts**
- **Lifetime estimate** – **Mean** decreased by Background estimate

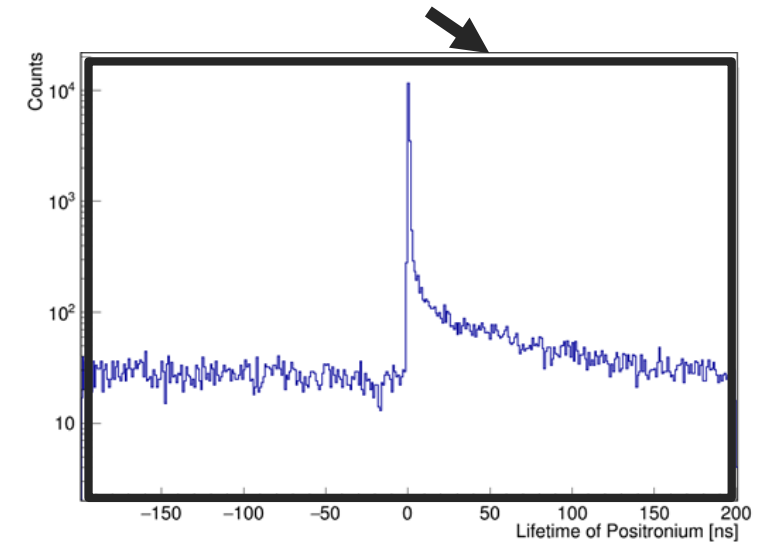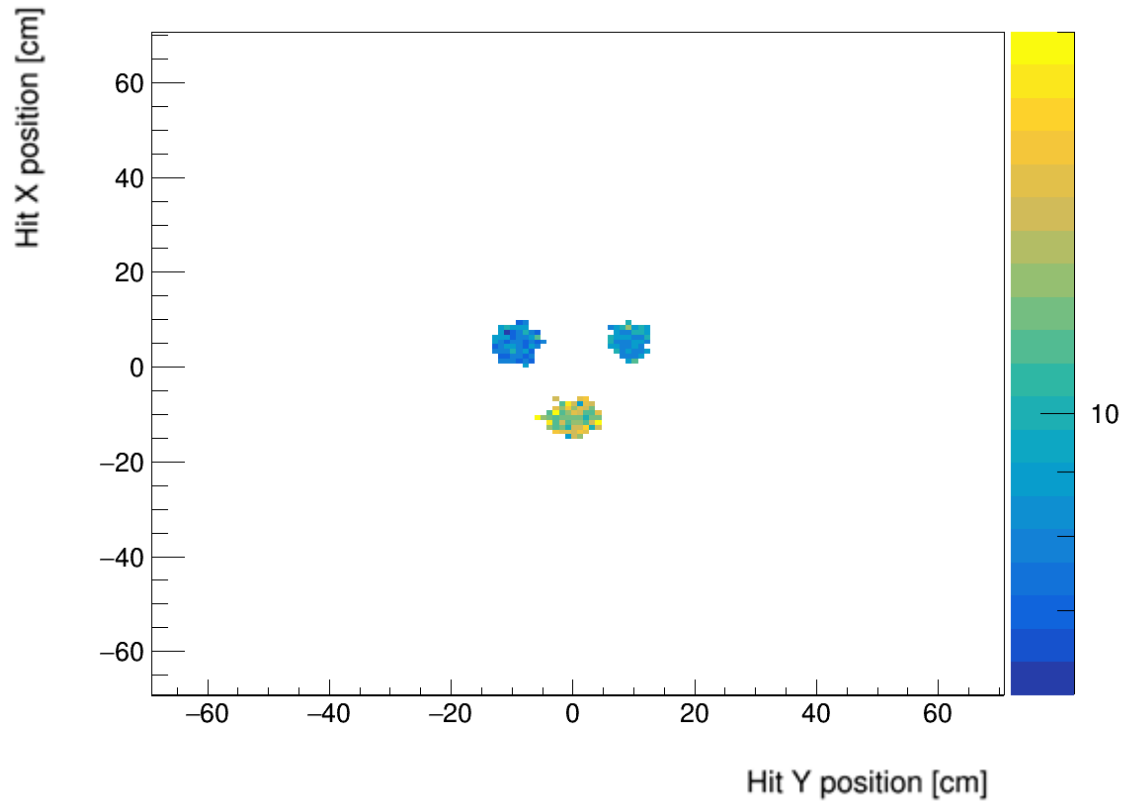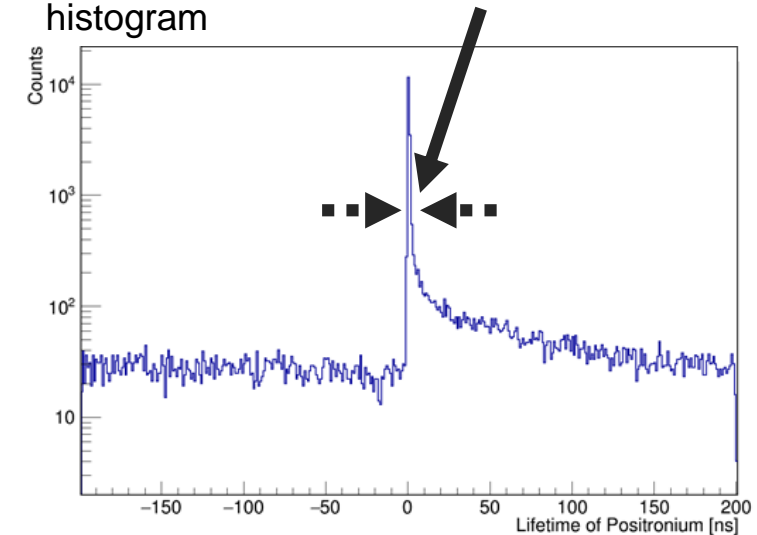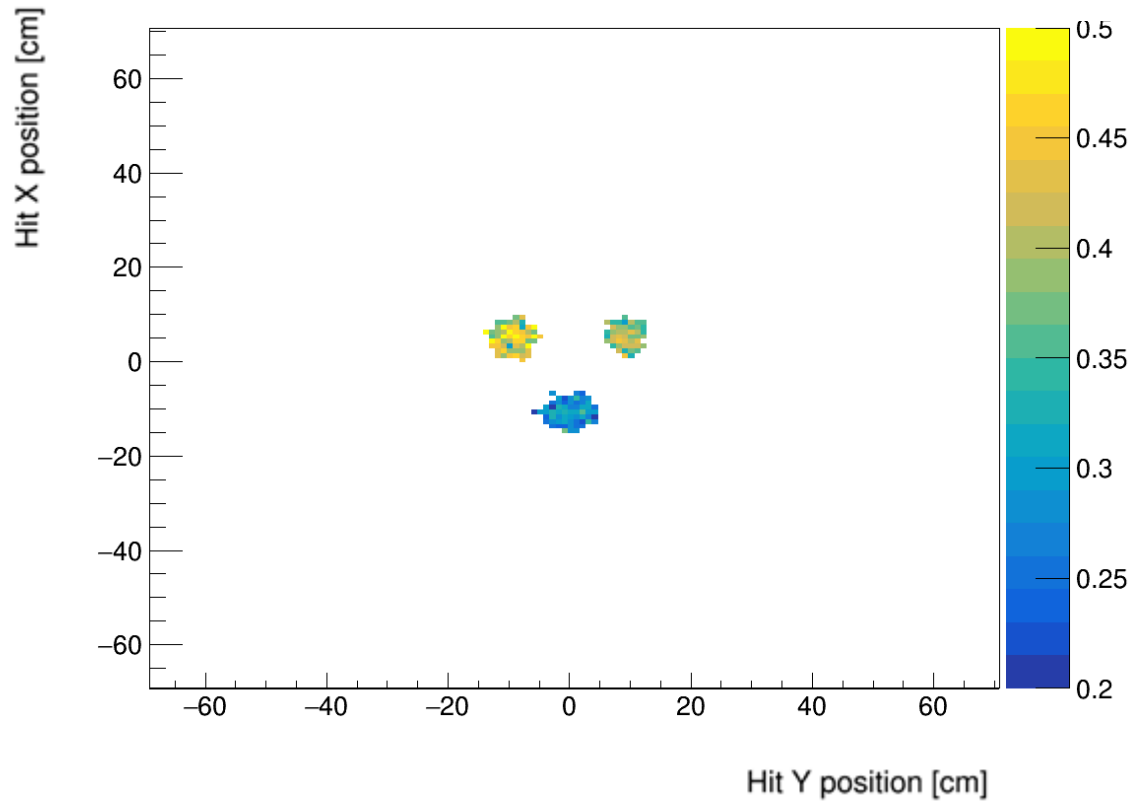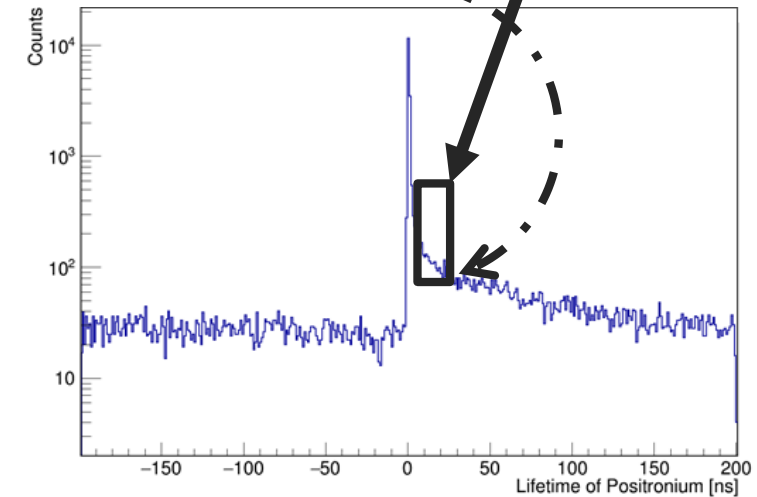# Morphometric image example
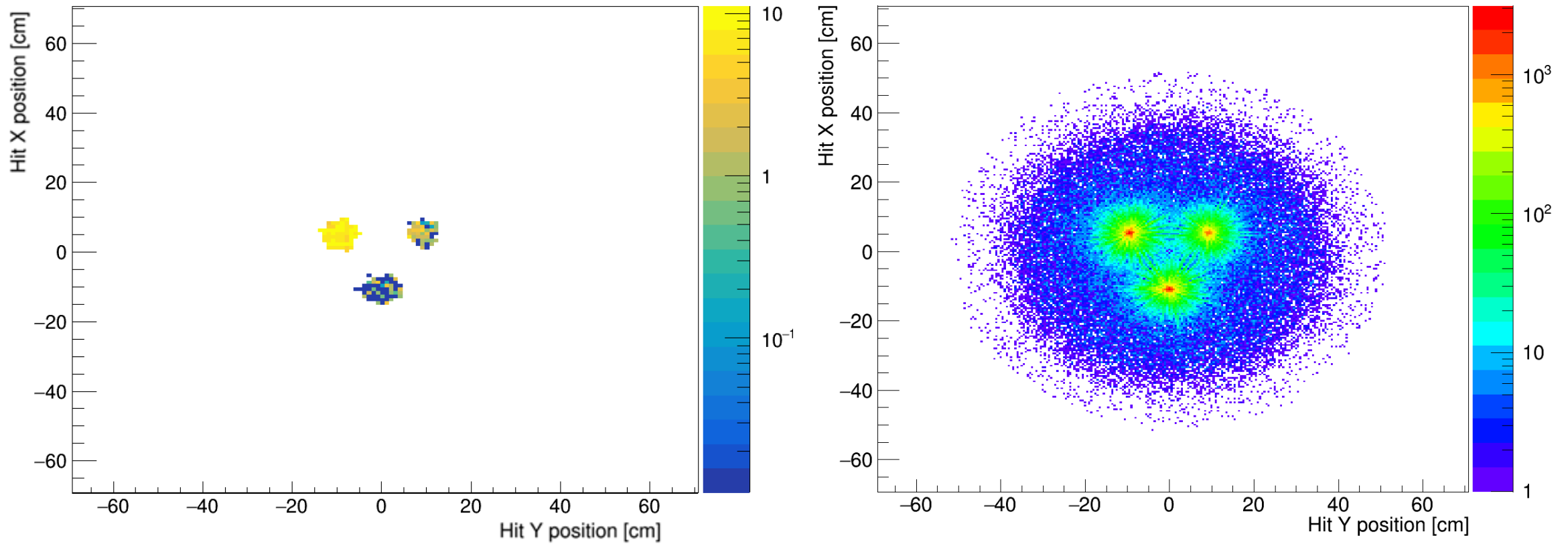
Conclusions

J-PET detector can succesfully work as a PET detector creating images of radioisotope distribution in measured setup.

By using specific selection criteria, it is possible to study different types of decay of Positronium in J-PET detector.

Radioisotope distribution with information about mean lifetime of positronium (or its estimate) in each voxel, allows to obtain new quality in imaging – morphometric image. J-PET is the first PET detector able to obtain such images.

Some tests still needed to find an optimal measure of mean lifetime for lifetime image.

Thank You for Your attention

Files analyzed

~4000 files analyzed from the morphometric image measurement from the October 28th - 30th -> 45 h minutes of measurement
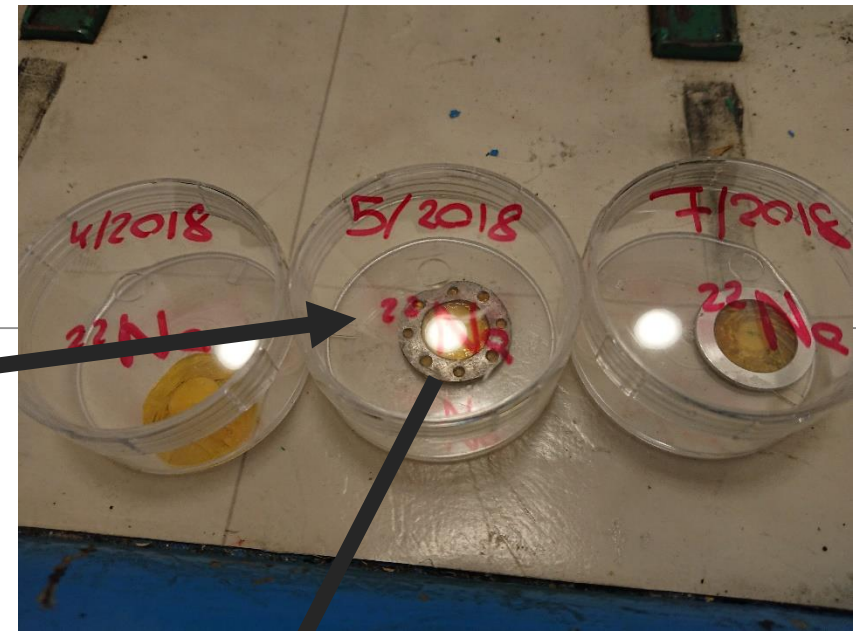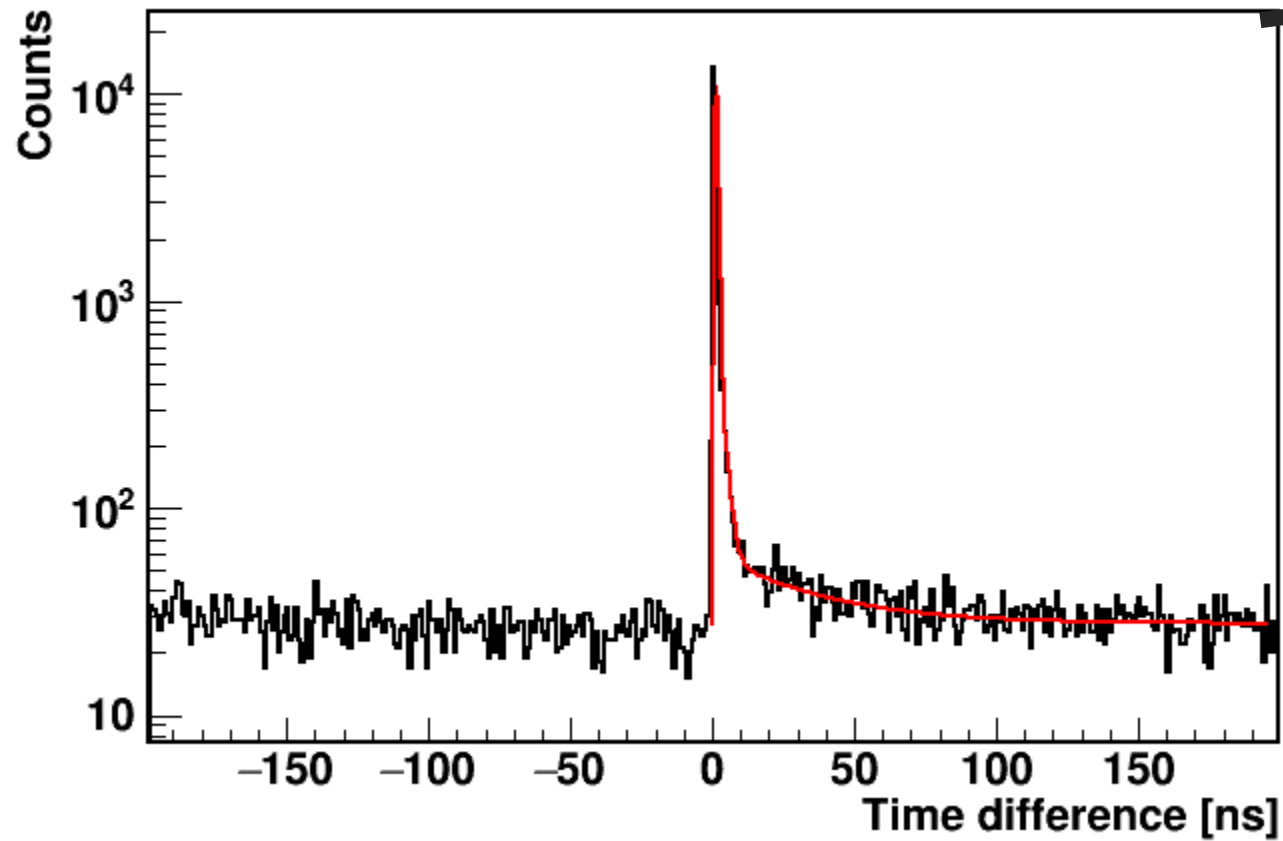
Time windows:

    Signal Lead Trail Time Window – 30 ns

    Signal Lead Time Window – 4 ns

    Hit Time Window – 50 ns

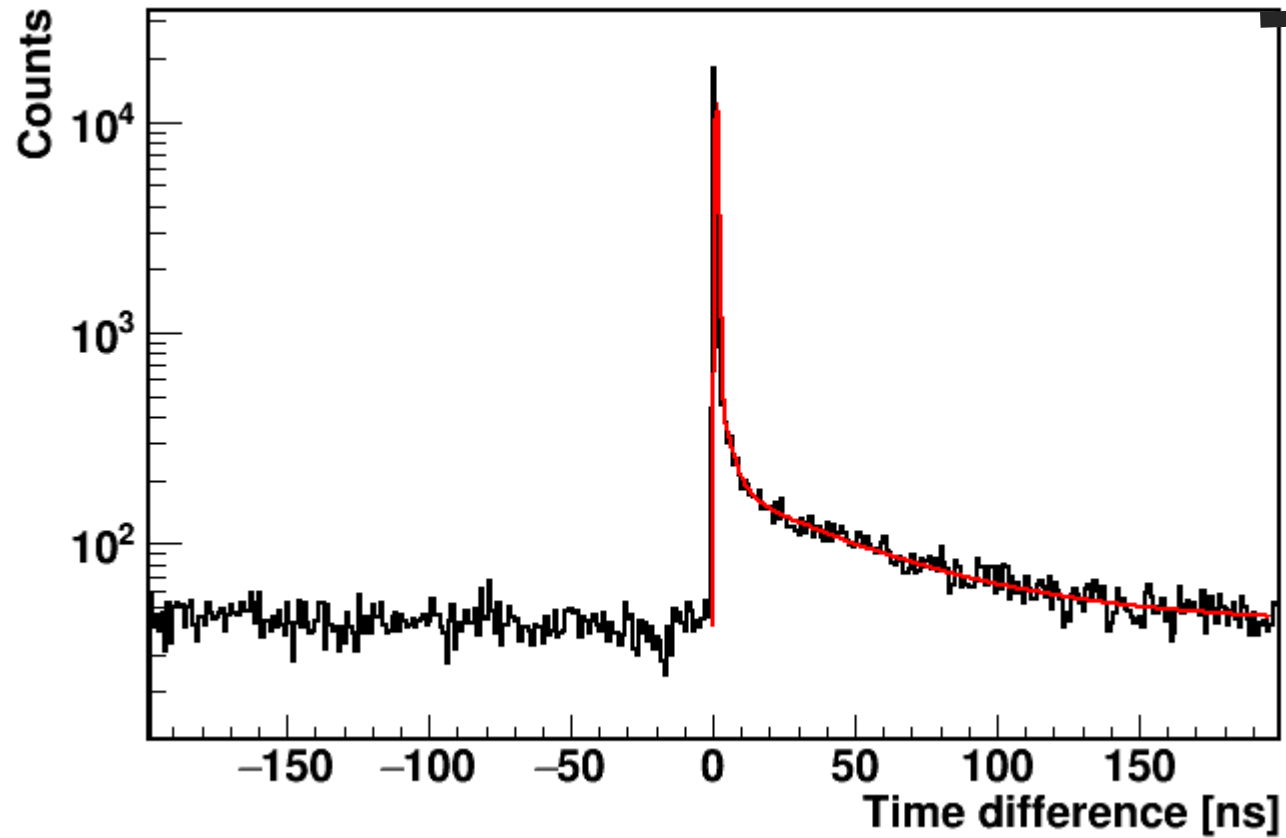   Event Time Window – 200 ns

Fits – XAD4

Components
Lifetime [ns]   Intensity [%]
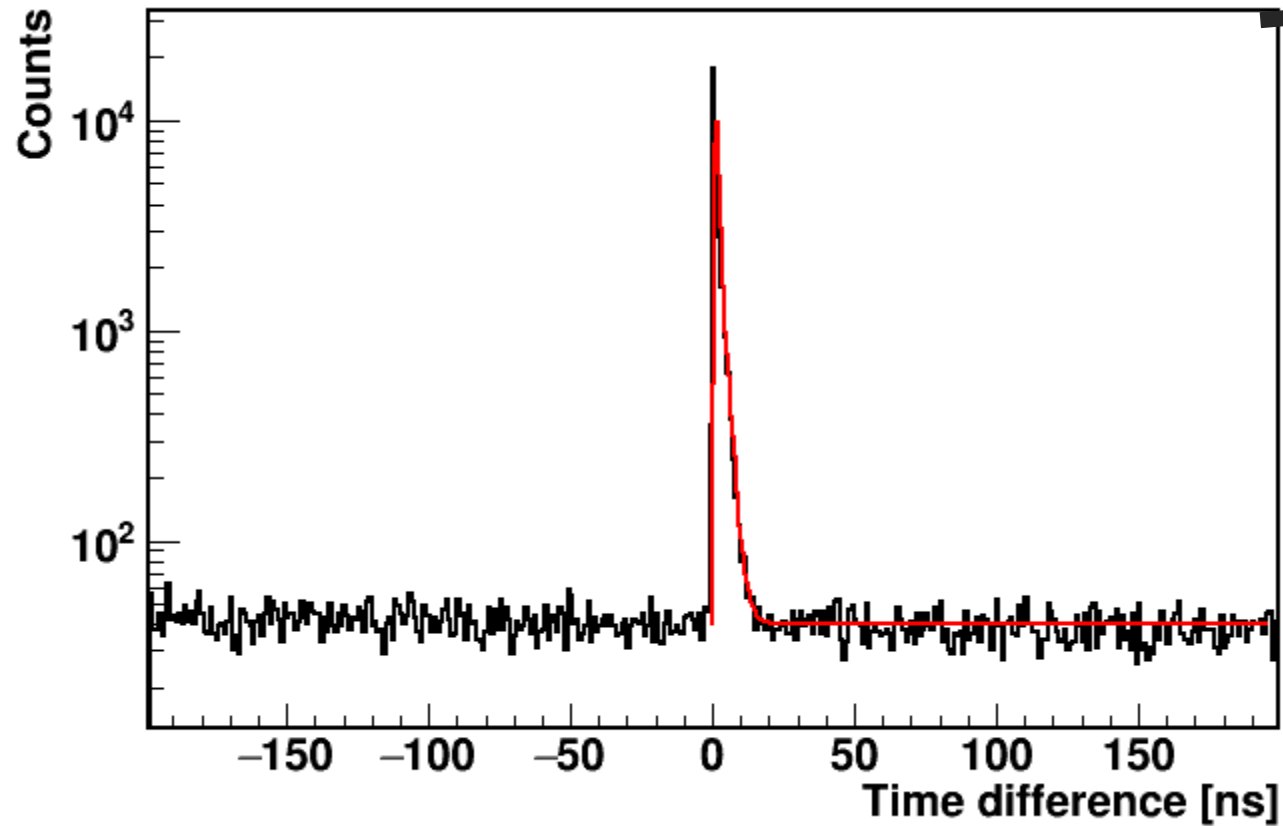
0.374   fixed (source)   10   fixed

0.22   fixed (metal)   11.89 (48)
0.125   fixed (p-Ps)   16.29 (35)
0.442 (26)   51.05 (64)
1.84 (07)   16.36 (42)
33.1 (3.3)   7.41 (42)

Fits – IC3100

Components Lifetime [ns]		Intensity [%]	
0.374	fixed (source)	10	fixed
0.125	fixed (p-Ps)	17.28 (26)	
0.384 (05)		41.71 (41)	
3.70 (31)		8.18 (35)	
53.2 (1.3)		32.83 (35)	

Fits – PVT

Components

Lifetime [ns]		Intensity [%]	
0.374	fixed (source)	10	fixed
0.22	fixed (metal)	23.27 (46)	
0.125	fixed (p-Ps)	13.24 (33)	
0.579 (64)		7.78 (73)	
2.01 (02)		55.70 (73)	