Preliminary results of determining Modular J-PET spatial resolution

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Outline:

- Modular J-PET
- Experimental results for determine spatial resolution
- Simulation results for determine spatial resolution
- Comparison of experimental results and Simulation results with other available scanners

Jagiellonian - Positron Emission Tomograph (J-PET)

J-PET technology provided the possibility of the development of cost-efficient Total-Body PET which is able to cover all of the patient body. In the J-PET group, we are developing the performance of each single module for the construction of the most optimized TB J-PET.

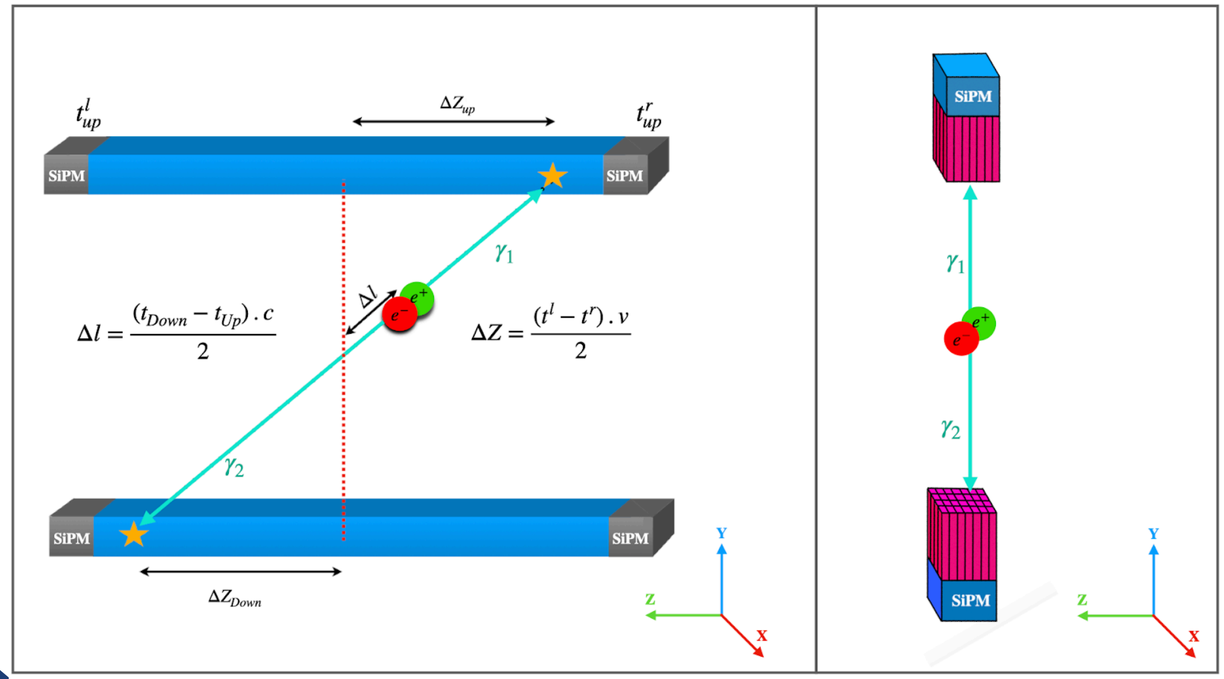


Fig: J-PET technology vs traditional PET scanners (by Meysam Dadgar)

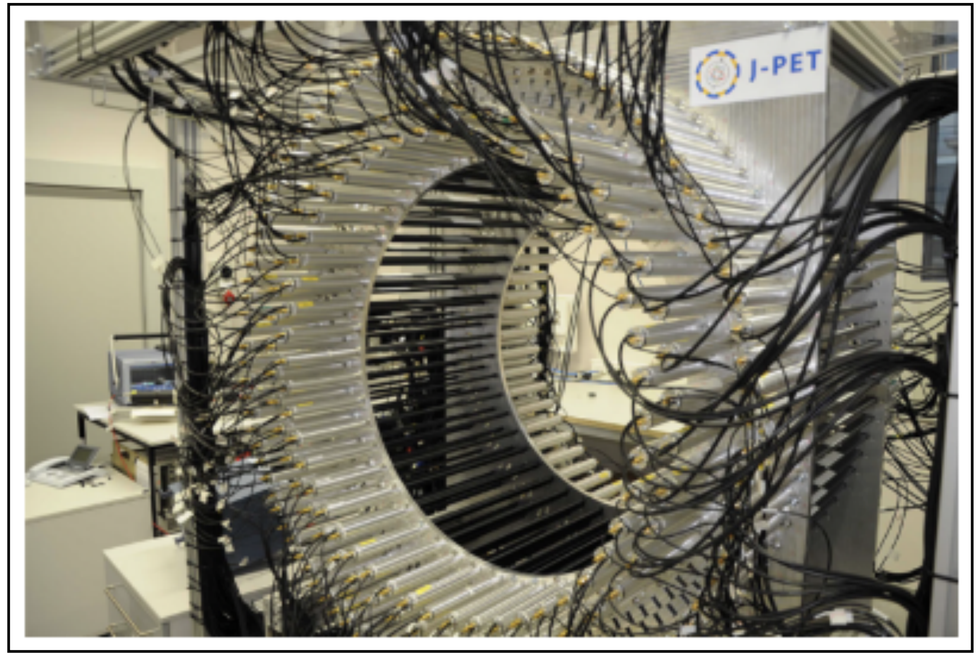


Fig1: 1st generation of J-PET tomography with 50 cm AFOV

Moskal, et al, "Positronium imaging with the novel multiphoton PET scanner", Science Advances, vol. 7, pp. eabh4394 , 2021.

24 Modular prototype

- Second prototype of the J-PET Collaboration.
- Cost-effective enabling of multi photon and positronium imaging.
- Clinical and portability
- Very light ~ 60 Kg
- Consists of 24 modules
- 76.2 cm diameter
- 50 cm FOV
- Each module is built out of 13 scintillator strips
- 6 mm × 24 mm cross-section of each scintillator
- Digital data at the module output
- 34 ^{0} Acceptance angle

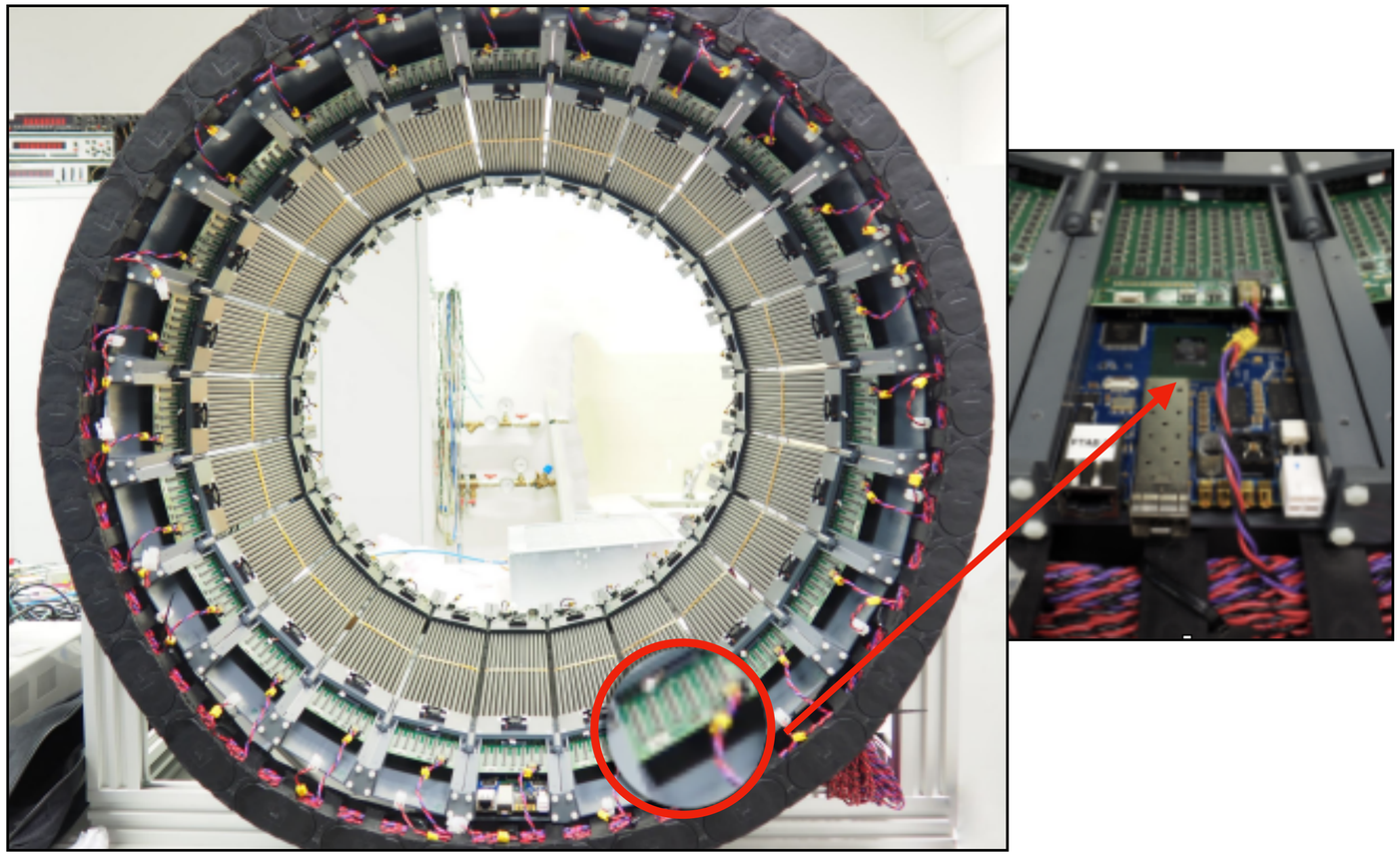


Fig: (Left)Modular J-PET after mechanical assembly, (Right) Power supply board (green) providing voltage to each SiPM separately and TDC board (blue) converting analog signals to digital ones, by measuring the Time of analog signal crossing at two selected constant thresholds.

Spatial resolution

Spatial resolution: system ability to distinguish two points after image reconstruction.

Experimental measurement:

- ^{22} Na Point source
- Activity of source: 10 MBq
- Threshold in both side : 30 mV & 70 mV
- Analysing experimental Dada: J-PET framework
- Position of source (cm) is

  (0,0,0), (0,0,10), (10,0,0),(10,0,10)

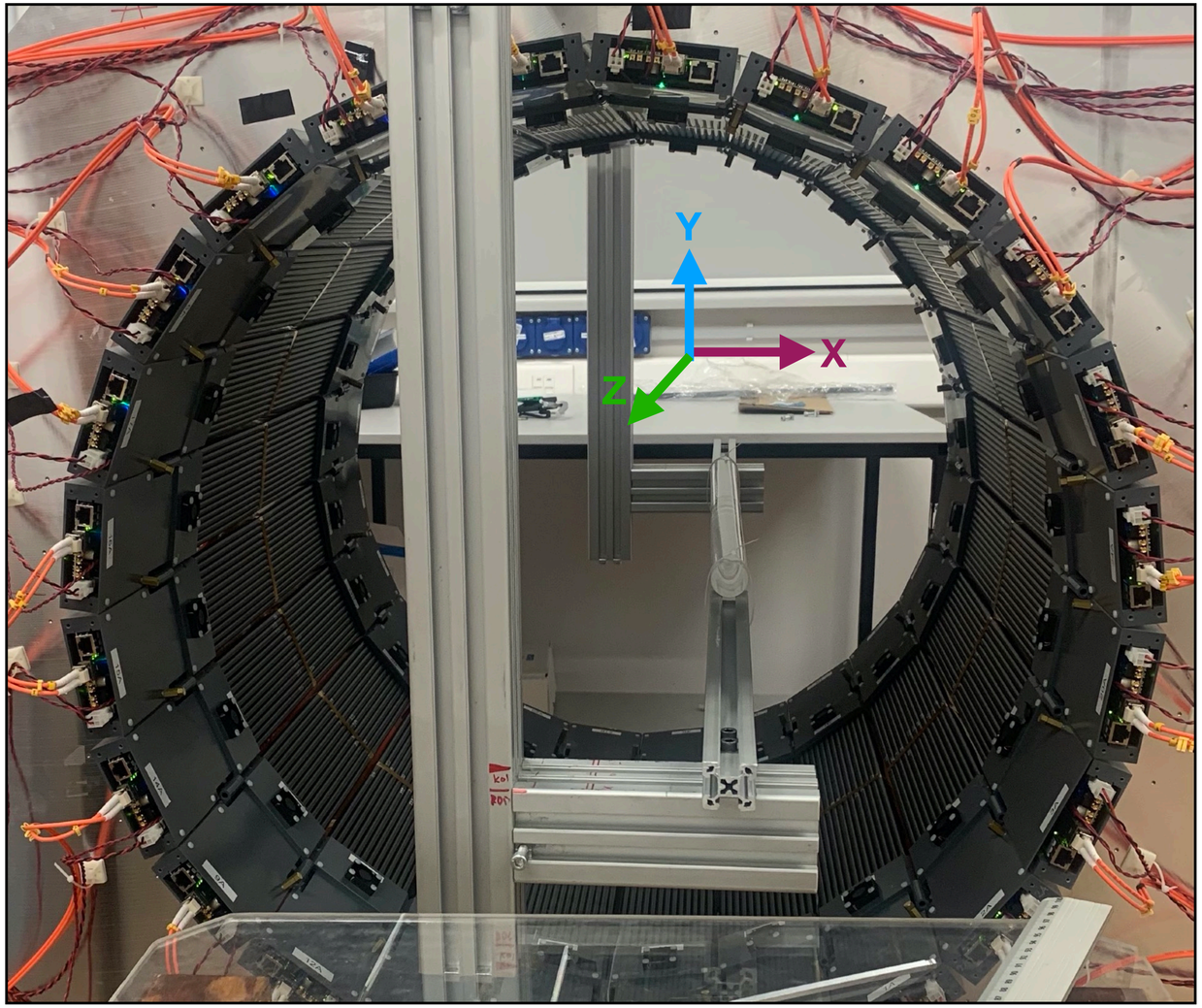


Fig : Experimental setup, Point like source inside the detector at position (10,0,0)

W. Krzemień, A. Gajos, K. Kacprzak, K. Rakoczy, G. Korcyl, J-PET Framework: Software platform for PET tomography data reconstruction and analysis. SoftwareX 11, 100487 (2020).

Time Over Threshold (TOT)Vs scintillator ID for position (0,0,0)

TOT provides a measure of energy deposited in Compton scattering

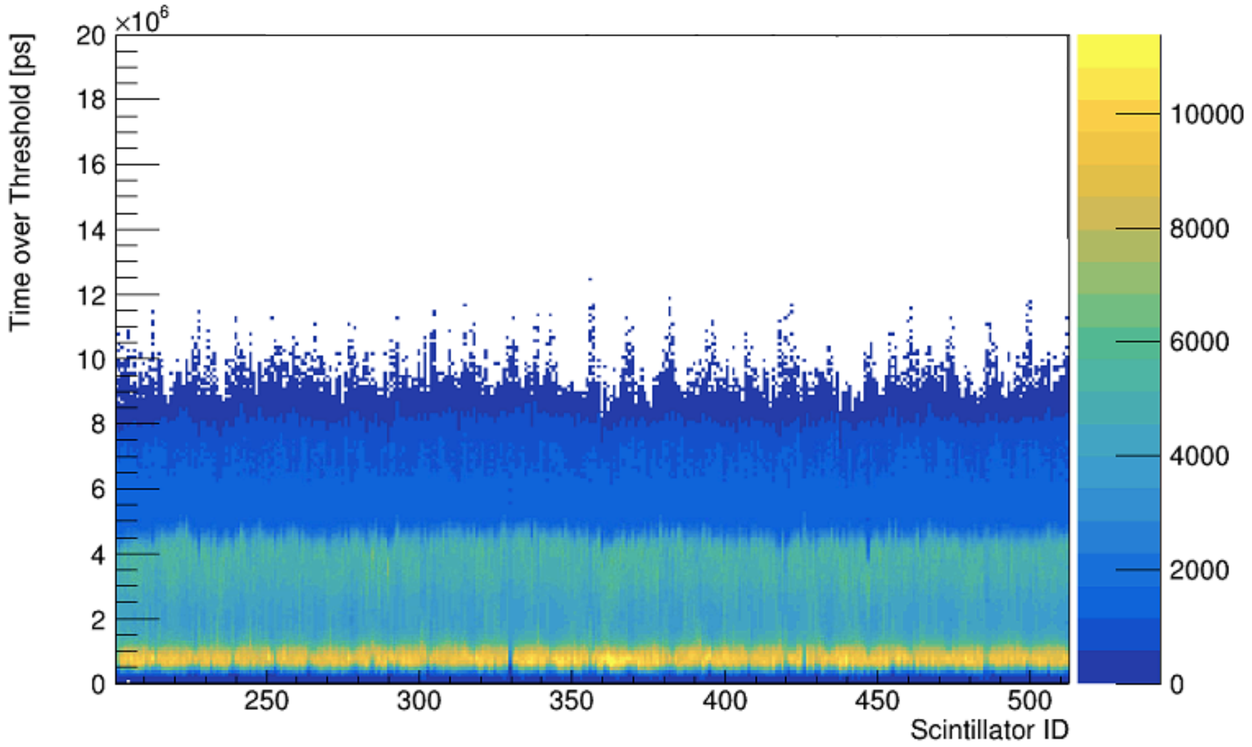


Fig: Hit TOT divided by multiplicity, all hits

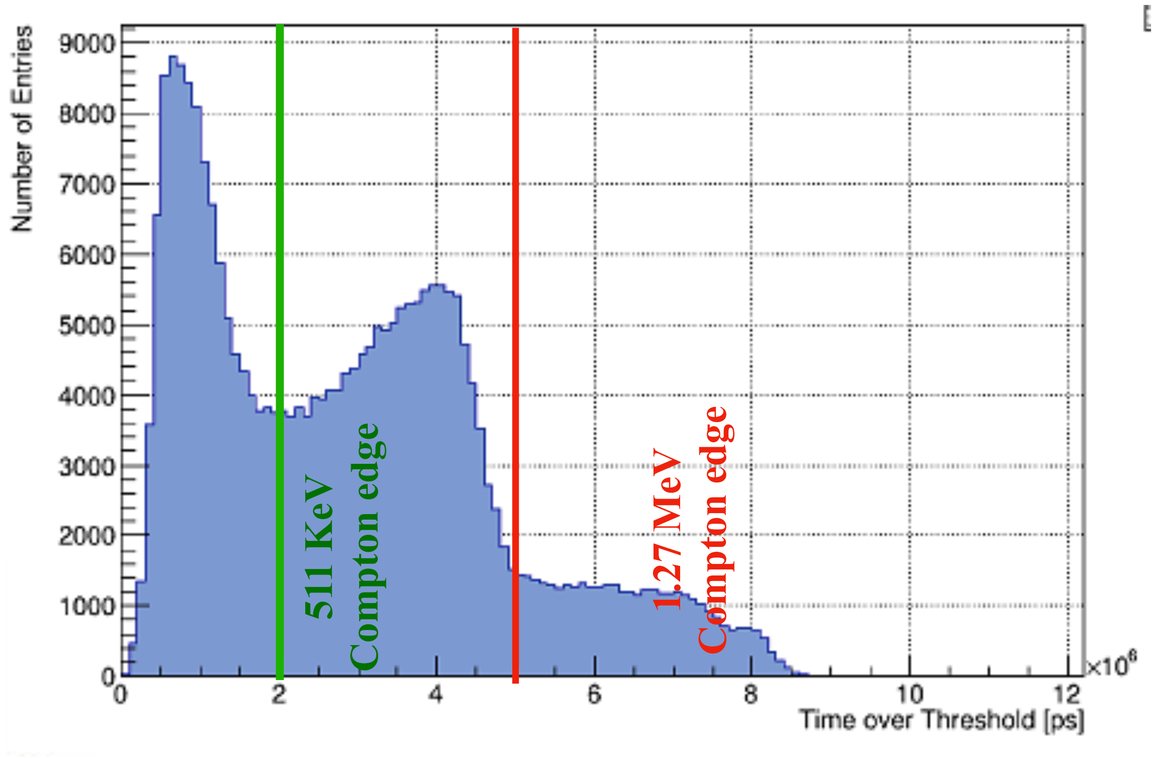
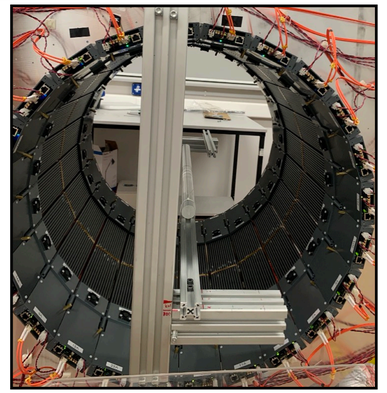


Fig. Exemplary histogram of the sum of TOT for all scintillators for source placed in position (0, 0, 0). Applied cuts are marked with lines.



XZ and XY position of annihilation for position (0,0,0)

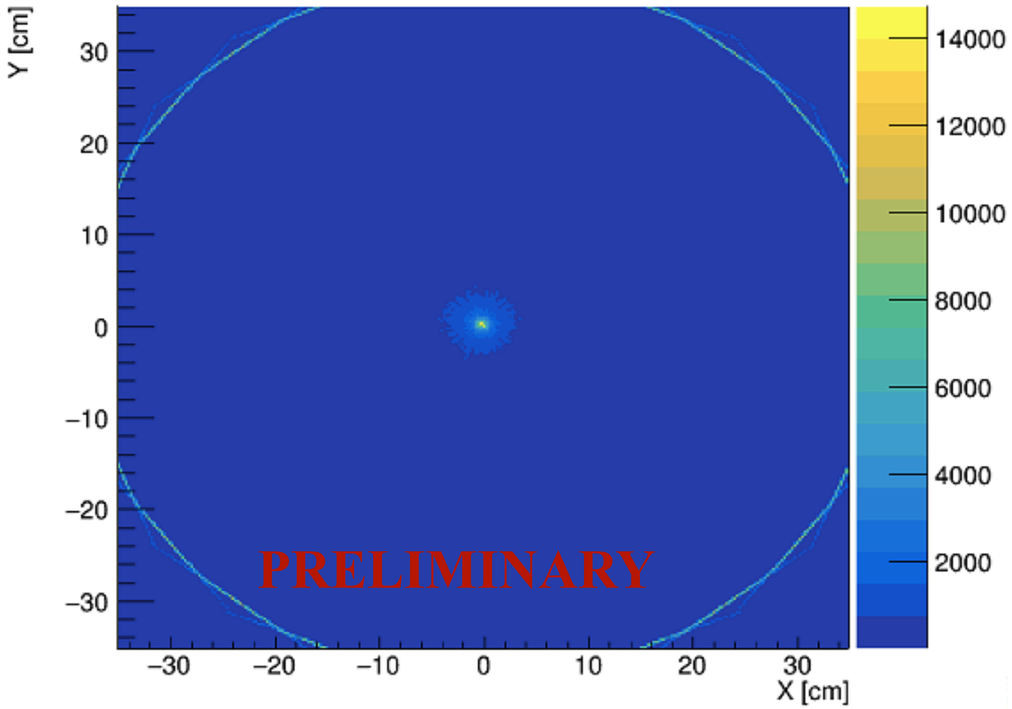


Fig: XY position of annihilation points before application of selection criteria.

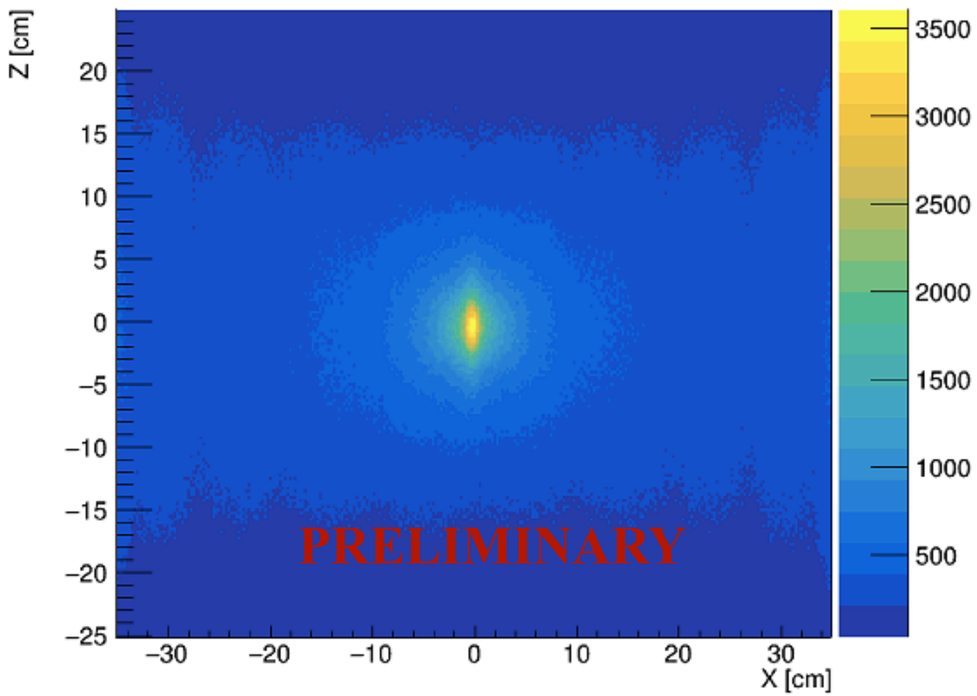
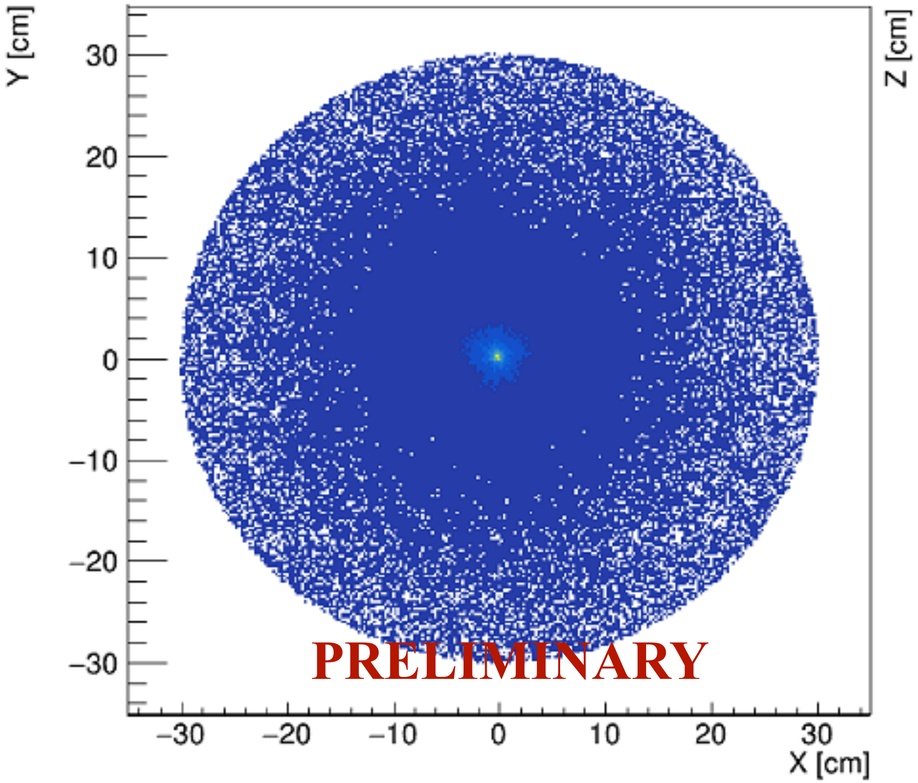


Fig: XZ position of annihilation points before application of selection criteria.

XZ and XY position of annihilation for position (0,0,0)

- 2 interactions in 4 ns time window;
- each interaction is in different head;
- $2 * 10^6 < TOT < 5 * 10^6$ (ps* mV)

  (X*X + Y*Y) < 30*30
- |Z|<25 cm;
- SiPM multiplicity = 8;



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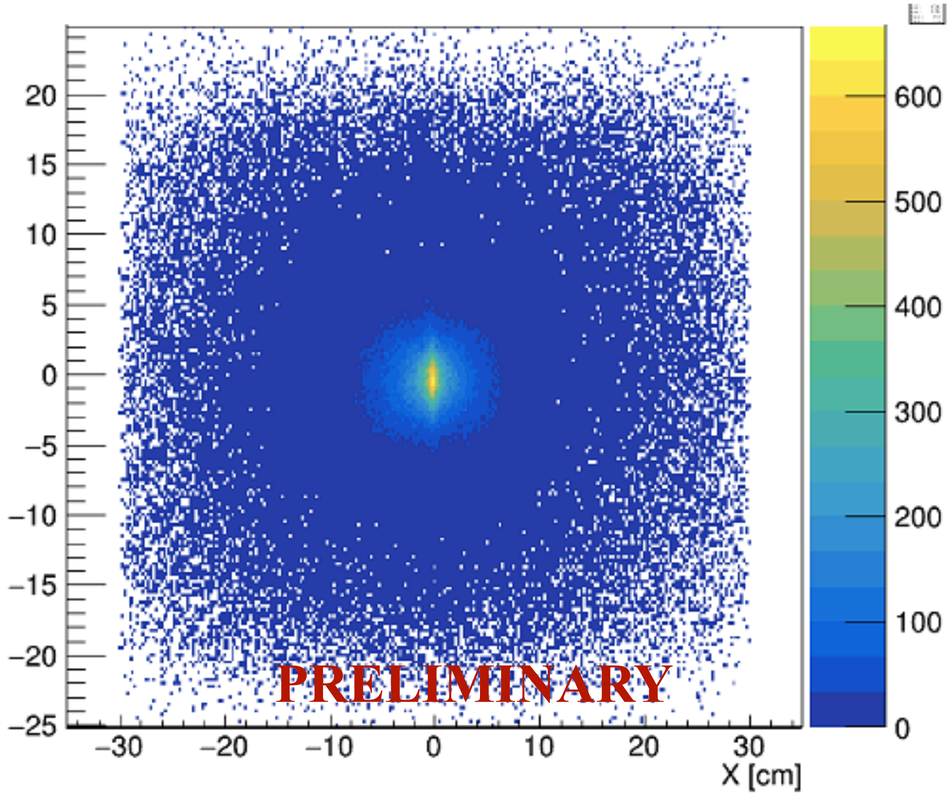


Fig: XZ position of annihilation points after application of selection criteria.

FWHM for three direction in different position

PRELIMINARY

MLEM Castor

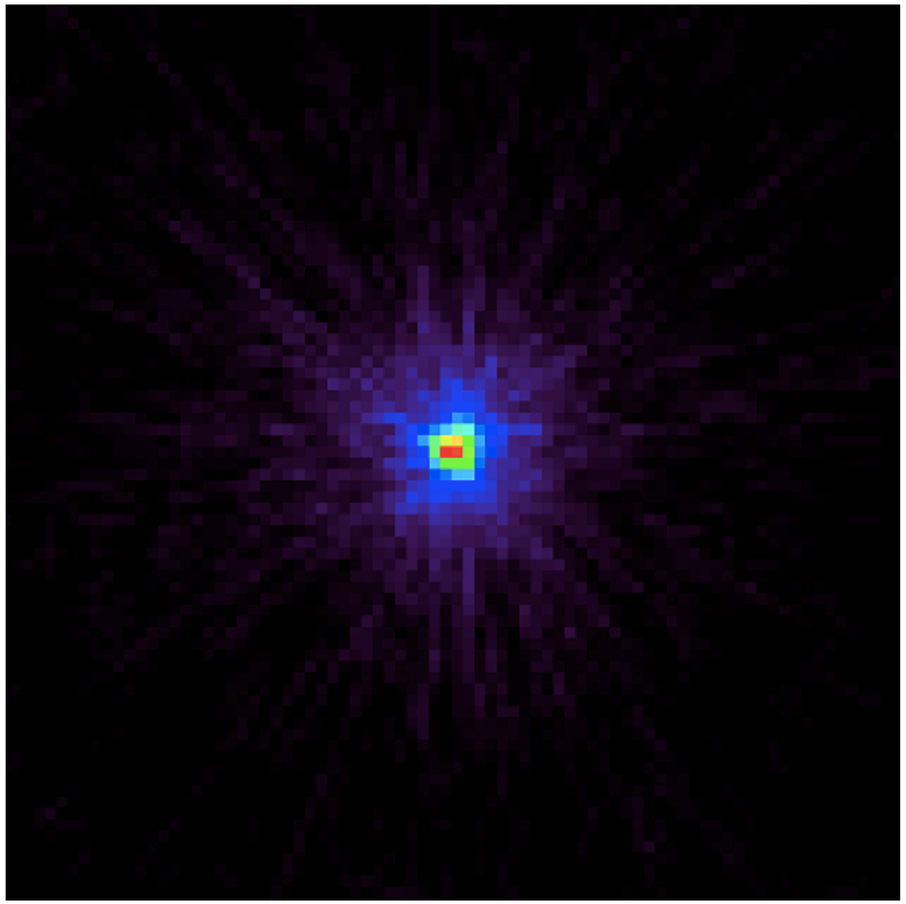
TOF resolution: 600 ps

Voxel size:
$2.5 \times 2.5 \times 2.5\ mm^3$

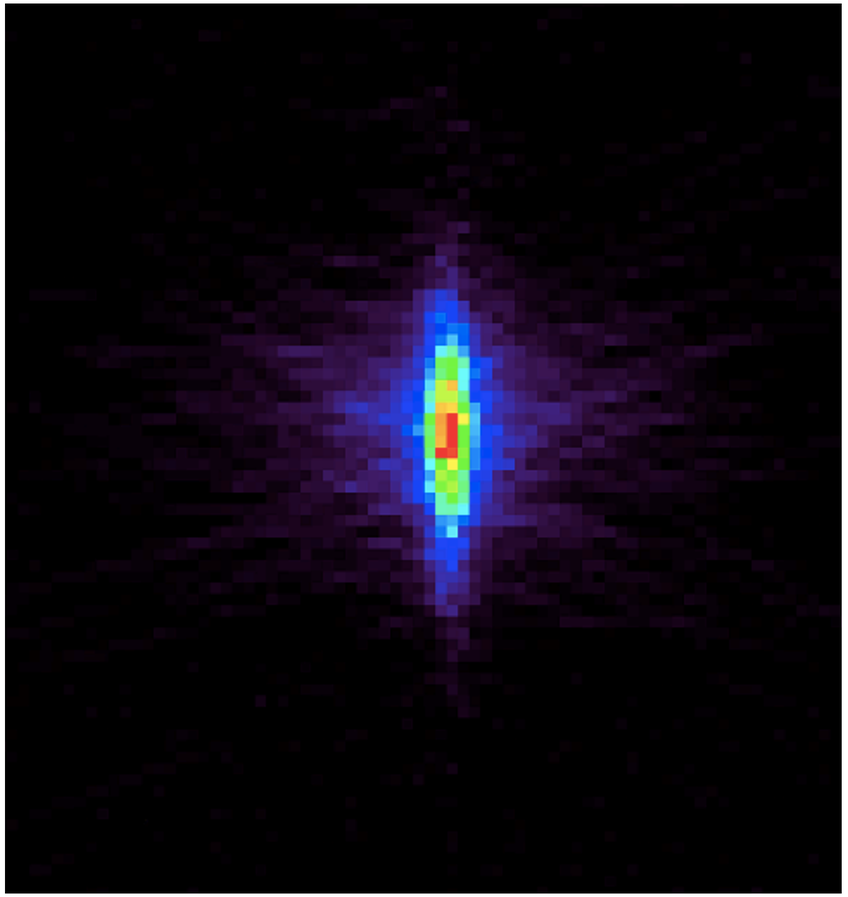
Image size:
$200 \times 200 \times 200\ mm^3$

20 iteration (1 Subsets)

Amide



Transverse plane

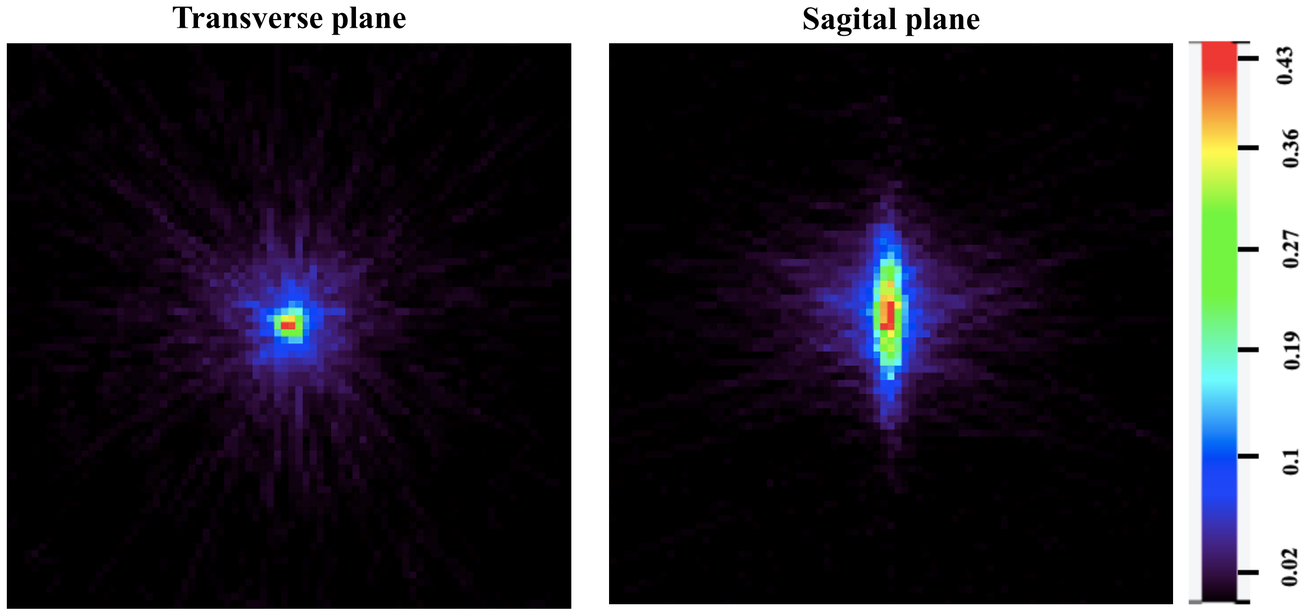


Sagital plane

Experimental results

FWHM for three direction in different position

MLEM Castor
TOF resolution: 600 ps
Voxel size: $2.5 \times 2.5 \times 2.5$ mm^3
Image size: $200\times 200 \times 200$ mm^3
20 iteration (1 Subsets)



PRELIMINARY

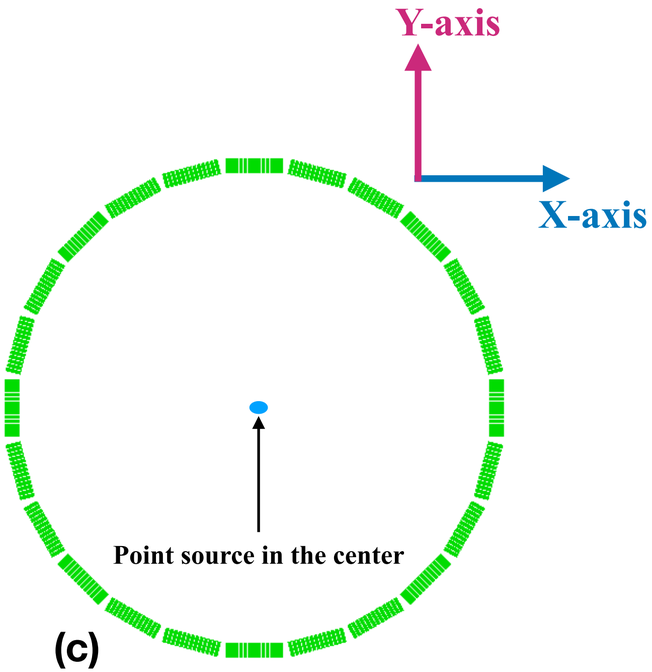
Position (cm)	FWHM radial (mm)	FWHM tangential (mm)	FWHM axial (mm)
(0,0,0)	5	5	12.5
(0,0,10)	5	5	12.5
(10, 0, 0)	7.5	7.5	12.5
(10, 0, 10)	5	5	12.5

Table: Tranaxial and axial resolution at four position

Simulation results

Description of the simulation Modular J-PET

- GATE software
- Point - like -source
- Diameter of source is 1 mm
- The activity of source is 10 MBq
- Back to back gamma photons
- Position of source (cm) is
- (0,0,0), (0,0,10), (10,0,0),(10,0,10)
- Collected data analyzed with GOJA software
- Time window is 3 ns



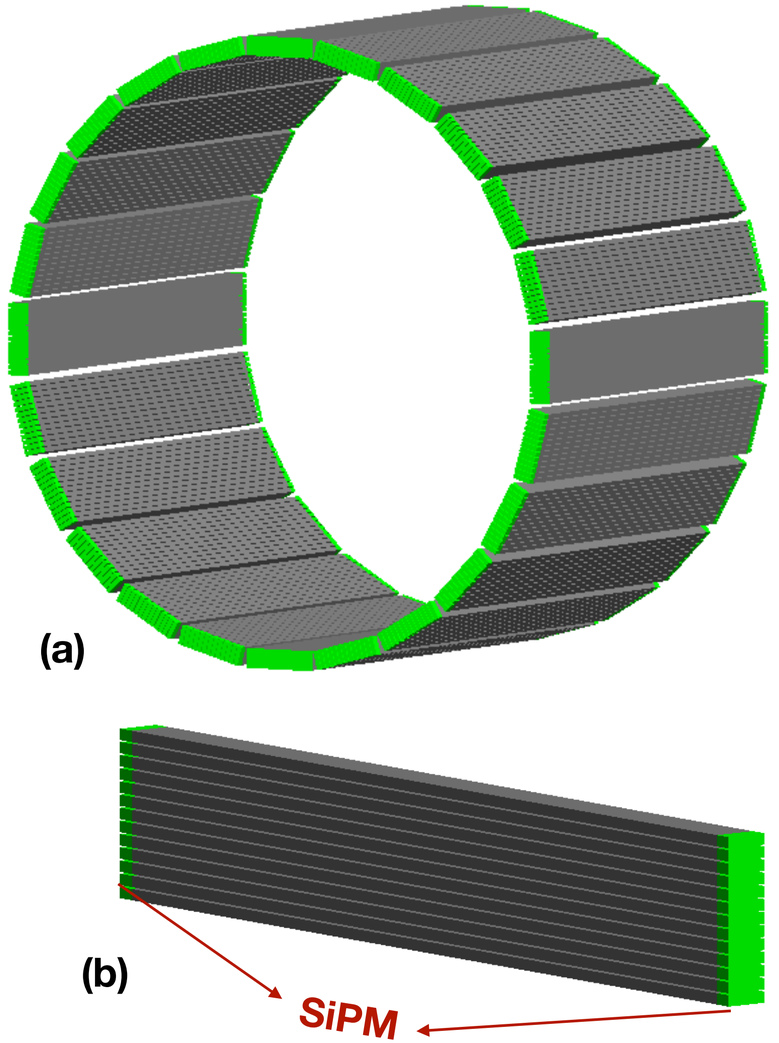
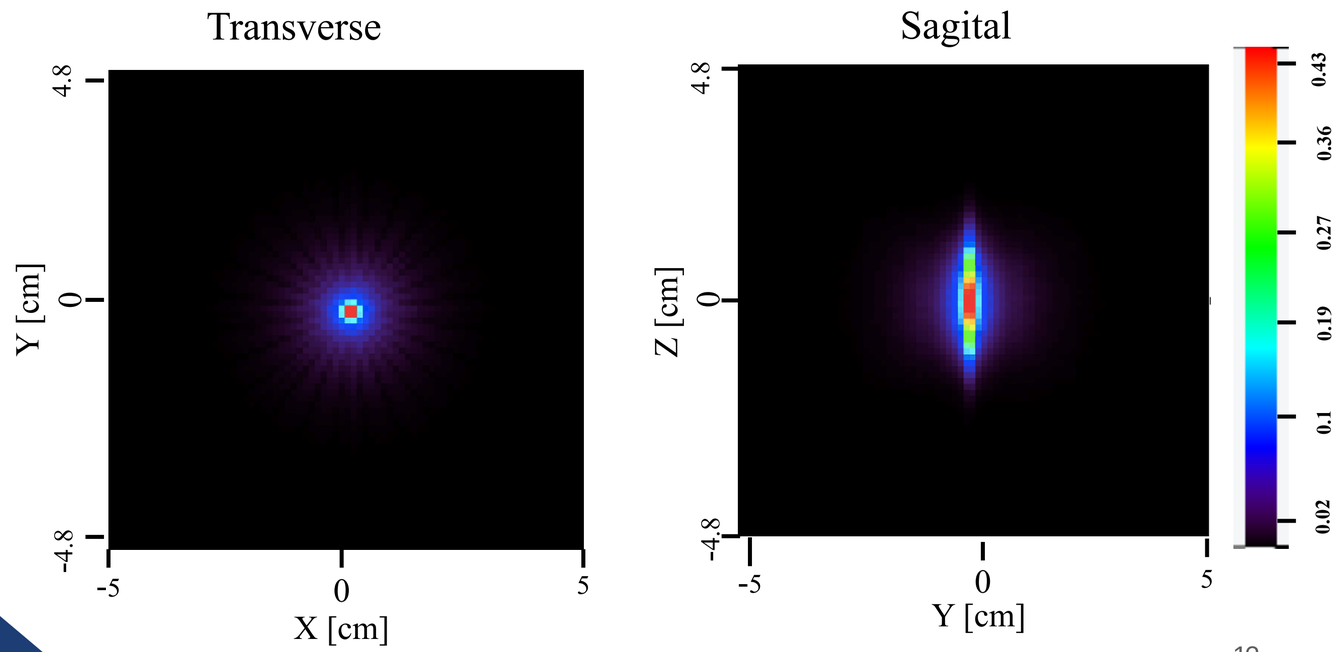


Fig: Schematic of 24 Modular J-PET(a), One Modur which is built of 13 plastics scintillator and read out by analog sim in the both side(b), Front view of the Modular J-PET with the point like source in the center(c)

Simulation results

Image reconstruction by QETIR for the simulated source in the (0 cm, 0 cm, 0 cm)

- Voxel size: $2.5 \times 2.5 \times 2.5$ mm^3
- Image size: $160 \times 160 \times 200$ mm^3
- 10 iteration (1 Subsets)
- TOF resolution: 230 ps



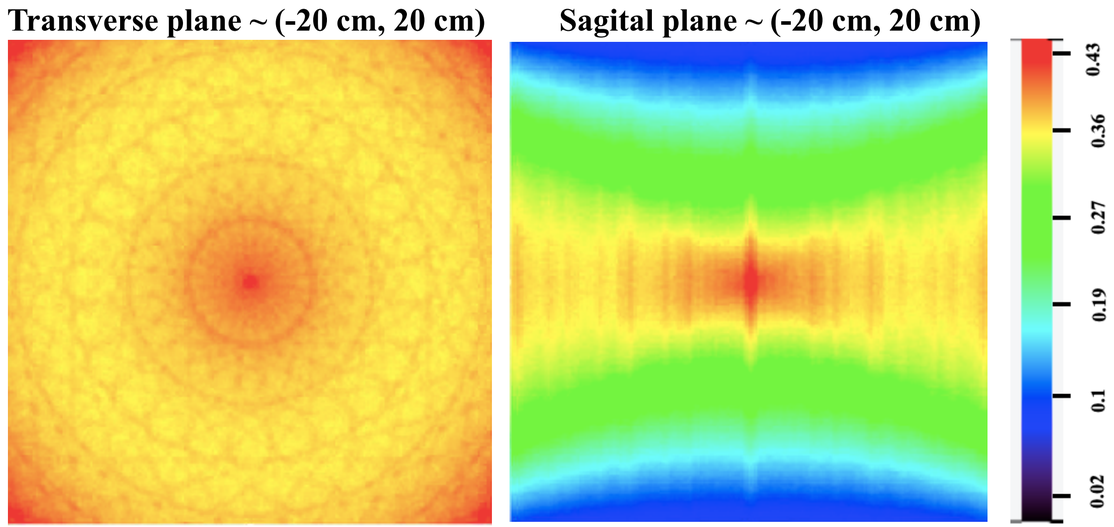


Fig : Sensitivity map

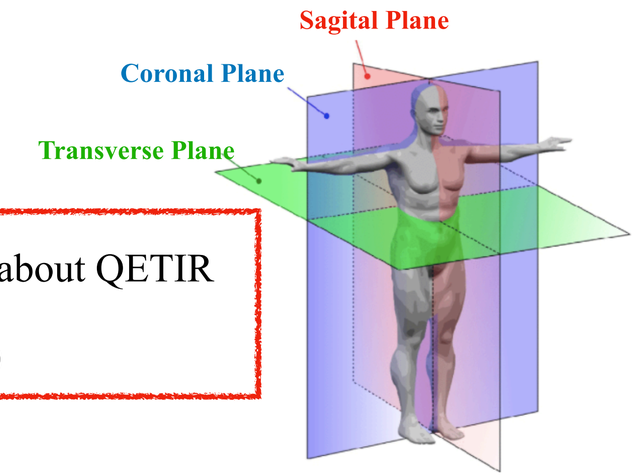
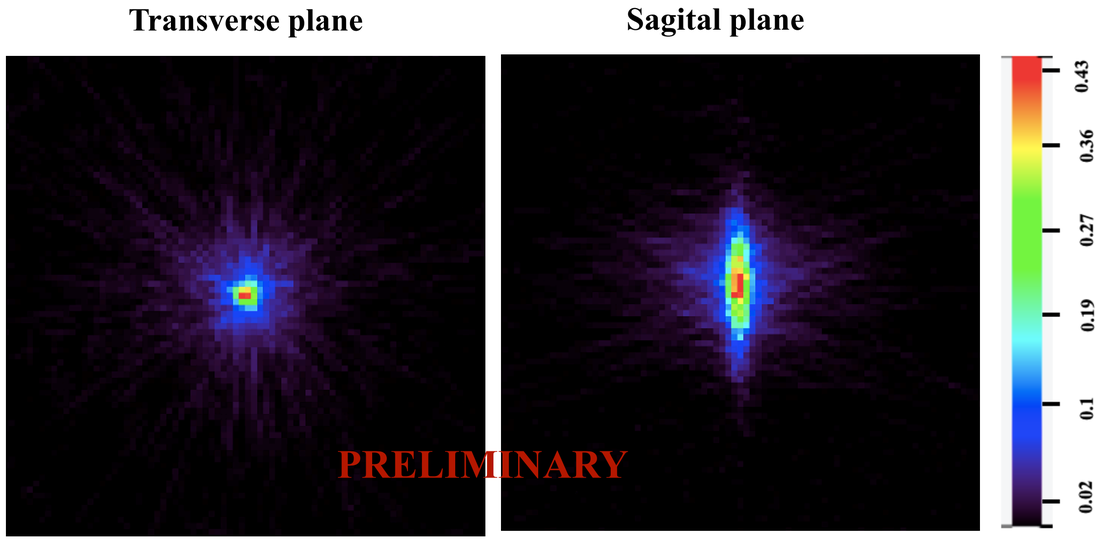


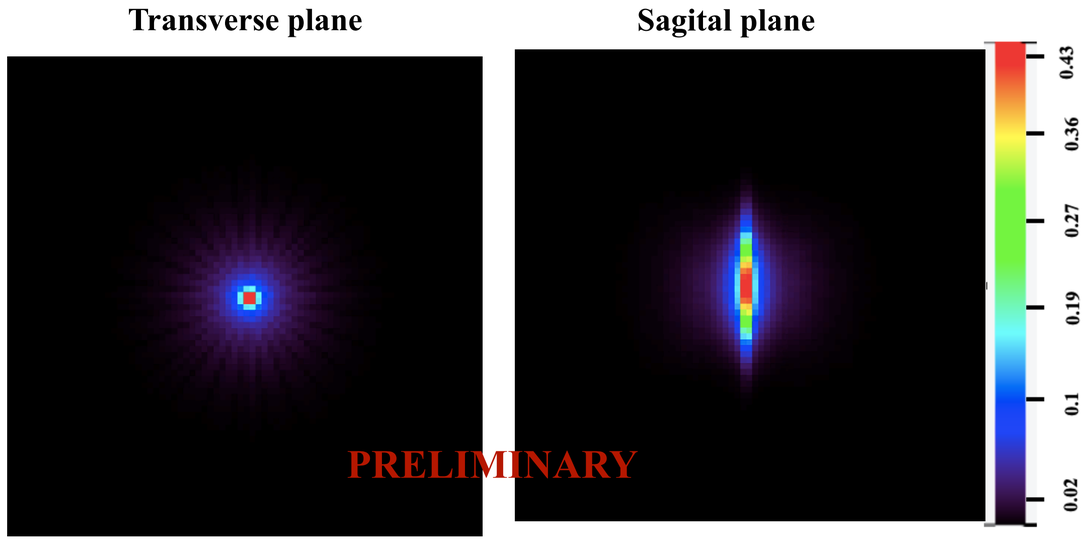
Fig: Anatomical planes that divides the body

More information about QETIR
Meysam Dadgar
Thursday at 17:10

Simulation results



Experimental results



Simulation results

Position (Cm)	FWHM radial experimental	FWHM radial simulation	FWHM tangential experimental	FWHM tangential simulation	FWHM axial experimental	FWHM axial simulation
(0,0,0)	5	3.10	5	3.13	12.5	4.87
(0,0,10)	5	3.11	5	3.03	12.5	4.63
(10, 0, 0)	7.5	3.03	7.5	4.3	12.5	4.28
(10 , 0, 10)	5	3.03	5	4.28	12.5	4.30

All units for FWHM is **mm**

Table: Comparison tranaxial and axial resolution at four position for simulation and experimental results

Conclusion

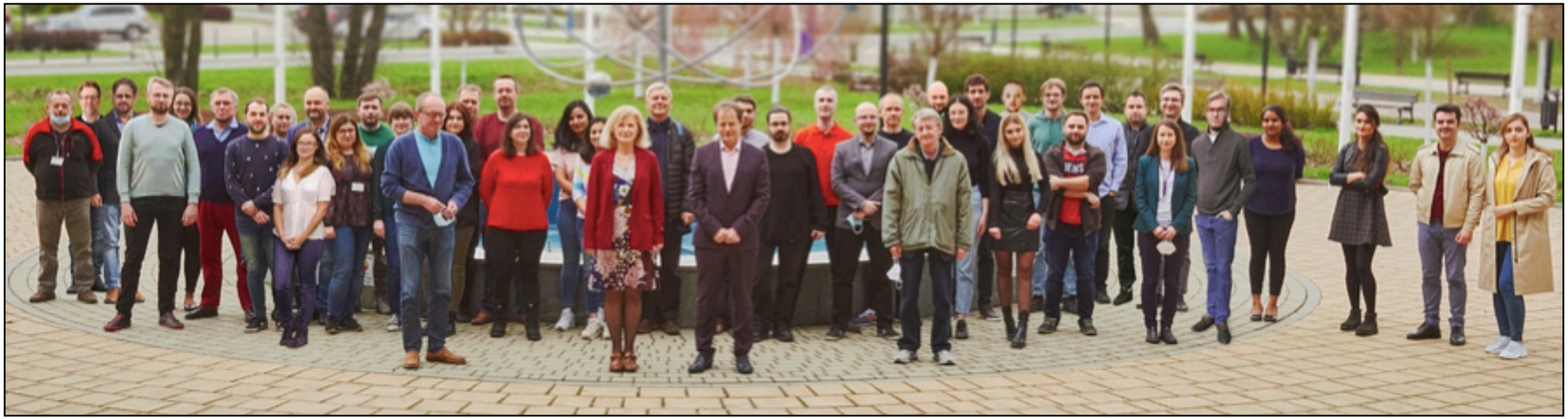
	PennPET explorer	Mini Explorer II	Phillips Biograph MCT Flow	Modular J-PET
Scintillator	LYSO	LYSO	LSO	BC404
Number of modules	18	24	-	24
Number of ring	3	2	1	1
Ring diameter (cm)	76.4	52	84.2	76.2
Axial field of view (cm)	64	48.3	21.8	50
Timing window (ns)	4	2.7	-	4
Energy window (KeV)	440–660	430-1000	435-650	~ 200-380
Axial resolution at center (mm)	4.1	2.61	4.5	12.5
Transaxial resolution at center (mm)	3.9	2.88	4.4	5

Karp JS et al. J Nucl Med. 2020;61(1):136– 143.

Vanessa Nadig1, European Journal of Nuclear Medicine and Molecular Imaging (2022) 49:445–459.

Lv Y, et al, Phys Med Biol. 2019;64(7):075004.

Thank you for your attention

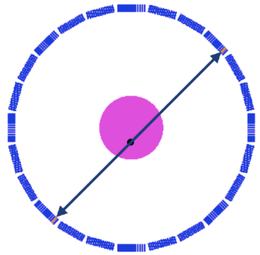


Description of the simulation Modular J-PET

For Analysis — GATE Output J-PET Analyzer (GOJA)

- prepare List_Mode for image reconstruction.
- Categorizing events as true scatter or randoms

For reconstruction — Quantitative Emission Tomography Iterative Reconstruction (QETIR)

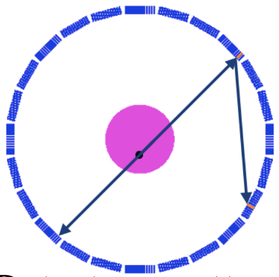


True Coincidence

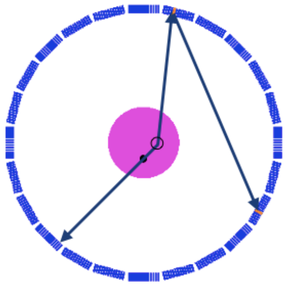
selection of events

- Two hits in 3 ns coincidence time window.
- Two scatterings with deposited energy bigger than fixed energy threshold: 200 keV.

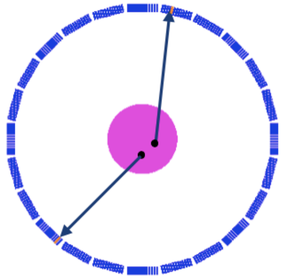
M. Dadgar, P. Kowalski, ``GATE Simulation Study of the 24-Module J-PET Scanner: Data Analysis and Image Reconstruction," Acta Physica Polonica B, vol. 51, pp. 309--311, 2020.



Detector_scattered Coincidence



Phantom_scattered Coincidence



Random Coincidence

Fig: Different types of coincidences

contribute to the background
leads to decrease reconstructed image quality

Simulation results

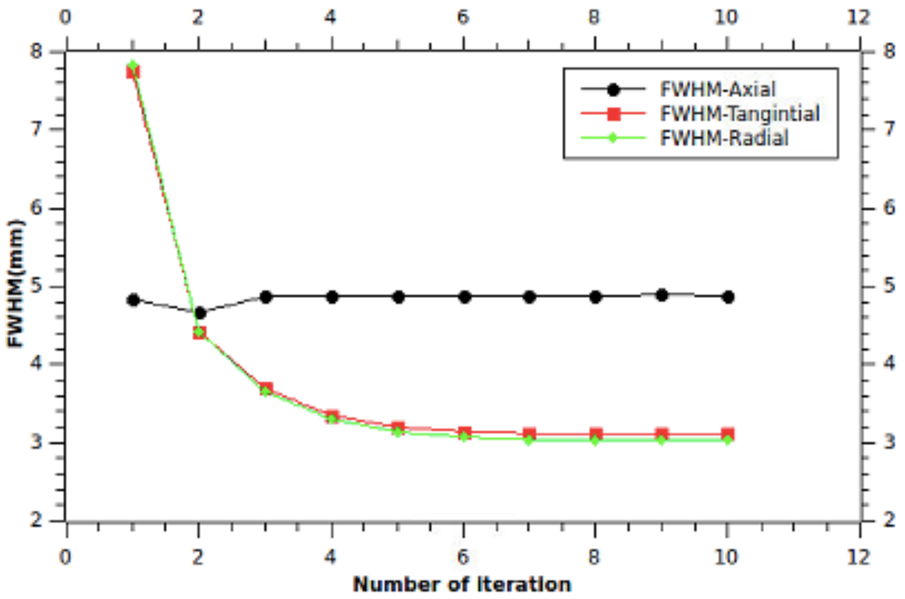
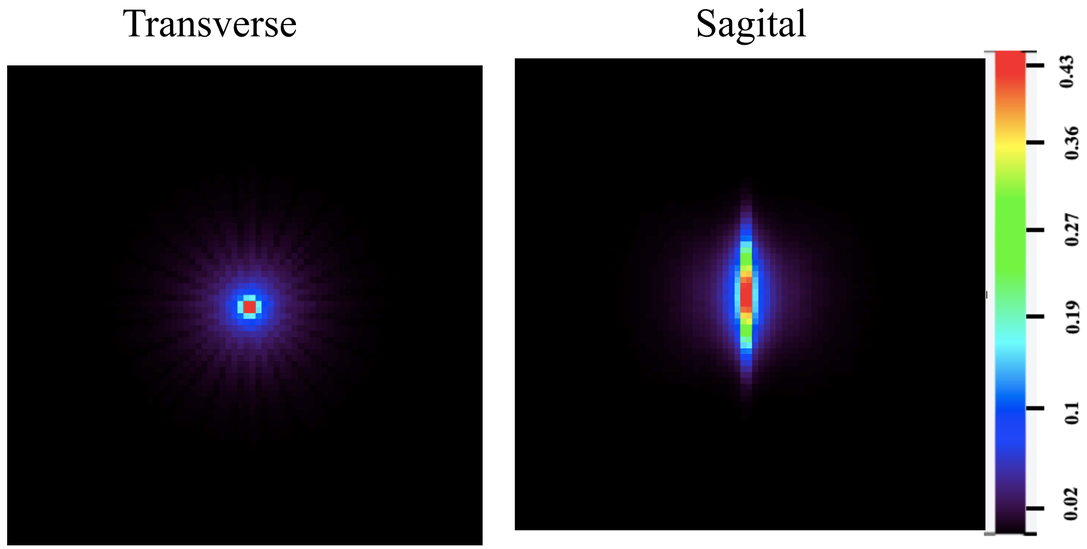


Fig: tranaxial and axial resolution at center for different iteration



Position	FWHM radial experimental	FWHM radial simulation	FWHM tangential experimental	FWHM tangential simulation	FWHM axial experimental	FWHM axial simulation
(0,0,0)	5	3.10	5	3.13	12.5	4.87
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(10 , 0, 10)	5	3.03	5	4.28	12.5	4.30

Table: Comparison tranaxial and axial resolution at four position for simulation and experimental results

Conclusion

	Experimental results				Simulation results	
	PennPET explore	Mini Explorer II	Phillips Biograph MCT	Modular J-PET	First J-PET prototype	Modular J-PET
Scintillator	LYSO	LYSO	LSO	BC404	BC420	BC404
Number of modules	18	24		24	-	24
Number of ring	3	2		1	1	1
Ring diameter (cm)	76.4	52	84.2	76.2	85	76.2
Axial field of view (cm)	64	48.3	21.8	50	50	50
Timing window (ns)	4	2.7		4	3	3
Energy window (KeV)	440–660	430-1000	435-650	~ 200-380	200-380	>200
Axial resolution at center (mm)	4.1	2.61	4.5	12.5	11.4	30
Transaxial resolution at center (mm)	3.9	2.88	4.4	5	~3	3

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