Determination of the spatial resolution for the J-PET prototype

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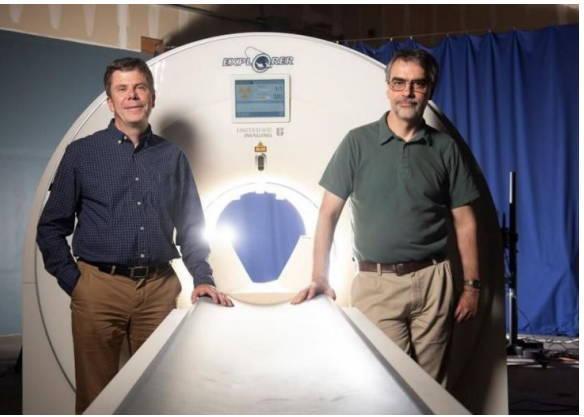
“Is Quantum Theory exact? From quantum foundations to quantum applications” Workshop
Frascati, 23-27 September 2019

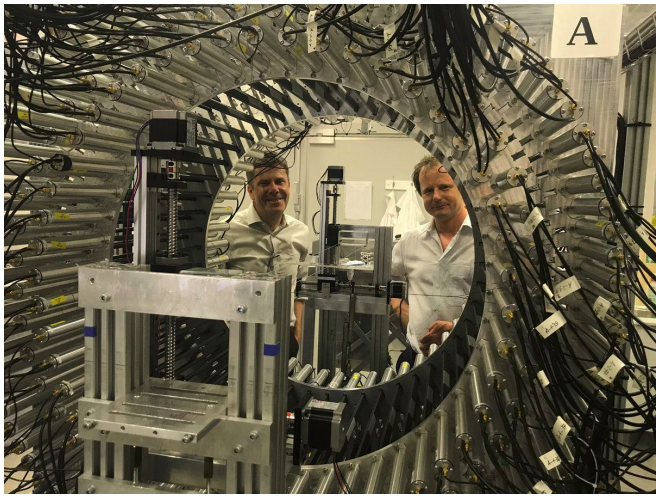
Motivation

NEMA - National Electrical Manufacturers Association → NU 2-1994 → Standards unication necessary due to differences in detectors between different manufacturers.



Comparison between J-PET prototype with other scanners

Required to check possibility of clinical applications



Spatial resolution

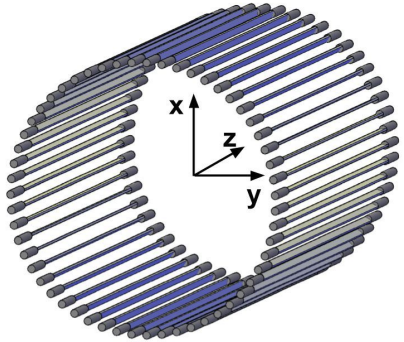
Ability to distinguish small objects

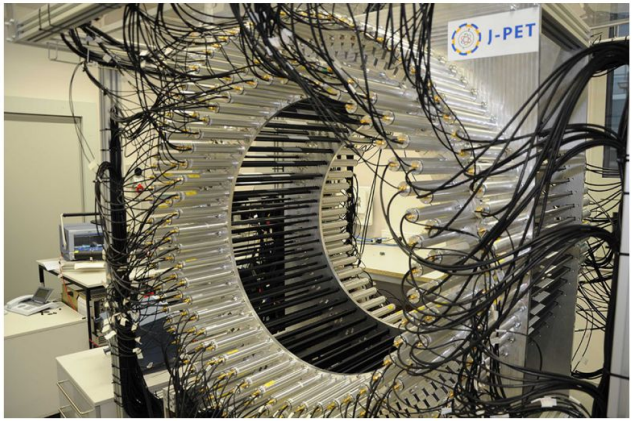
Width of PSF of reconstructed image

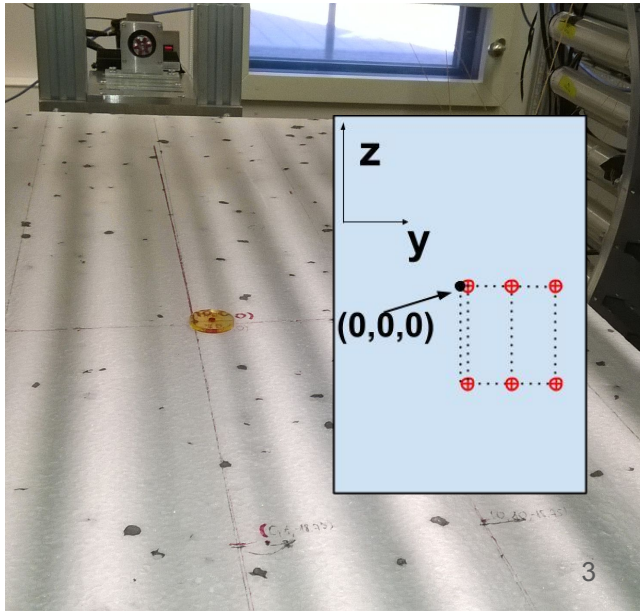
Sources placed in six positions:
- at the center of the axial (FOV) and 3/8 of the axial FOV
- at 1 cm, 10 cm and 20 cm in the transverse direction

(0,1,0)	(0,10,0)	(0,20,0)
(0,1,-18.75)	(0,10,-18.75)	(0,20,-18.75)

One hundred thousand counts per position

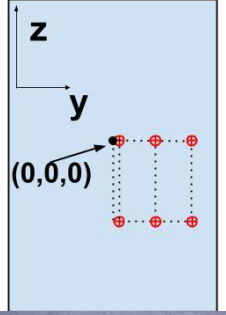


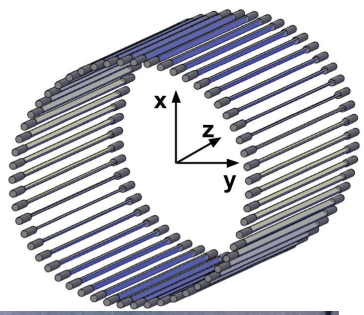


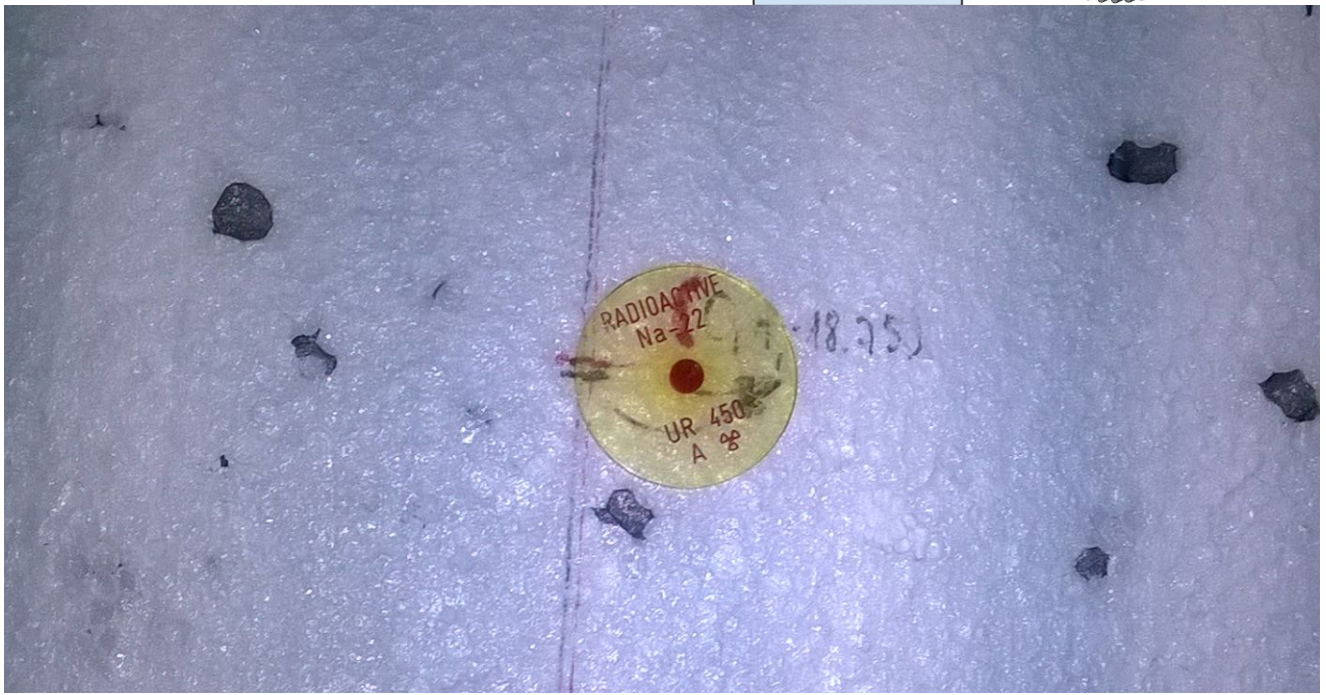


Data selection criteria

Data: single ^{22}Na source, position (0,1,0), activity ~ 1134 kBq, 1 file (measurement time: ~ 5,5 minutes)

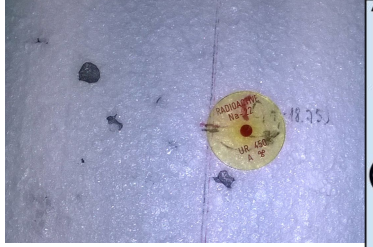


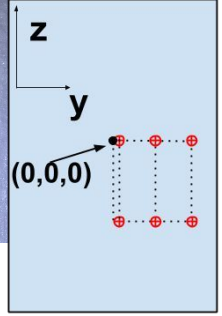


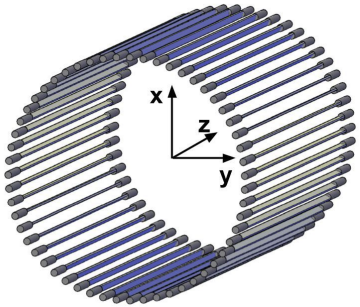


Data selection criteria

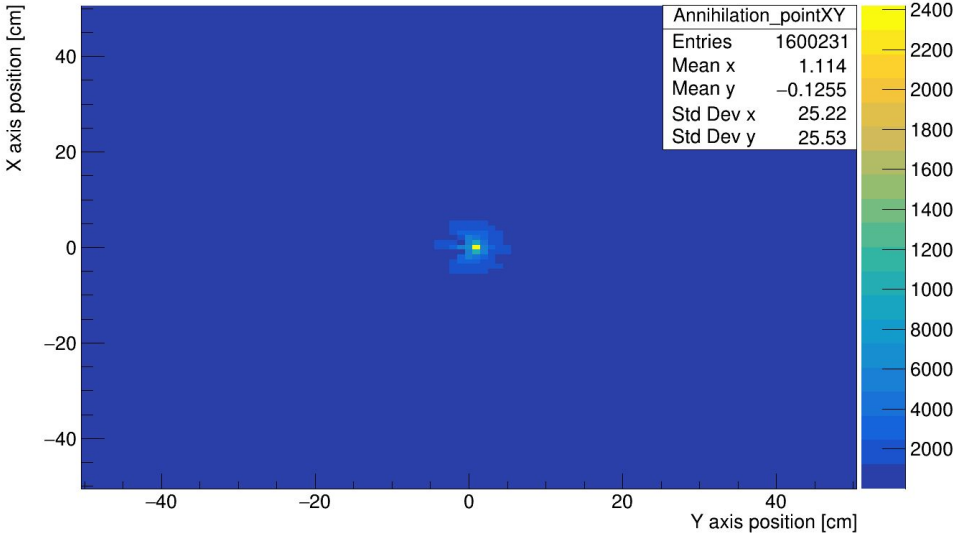
1. always two hits in time window: 4 ns (due to detector diameter)



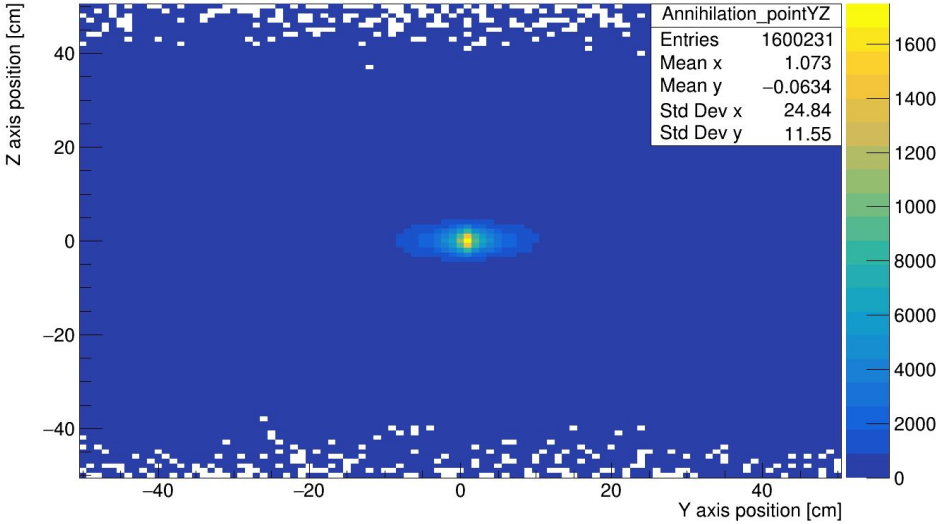




X and Y of Annihilation point

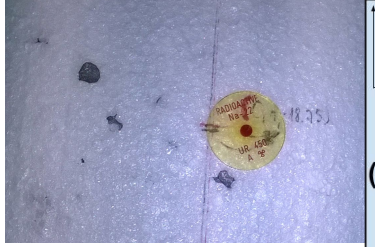


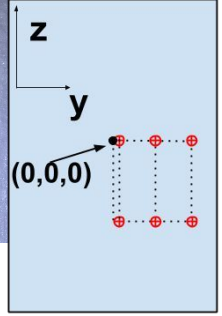
Y and Z of Annihilation point

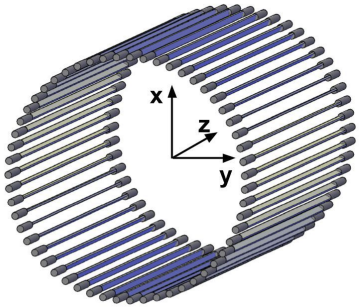


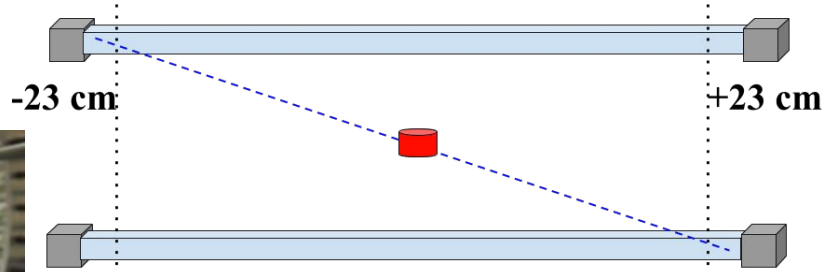
Data selection criteria

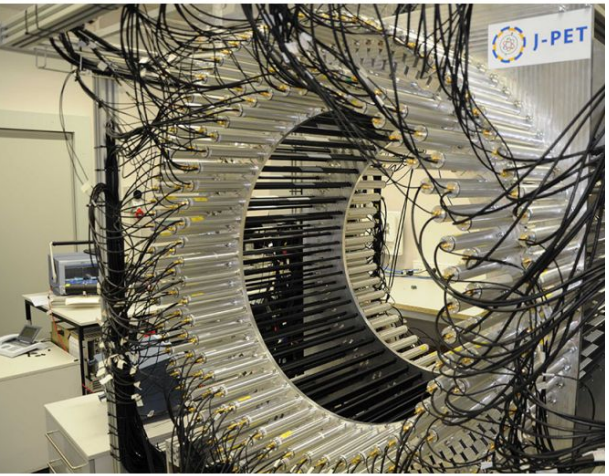
1. always two hits in time window: 4 ns
2. ***z* coordinate** of position of annihilation in range ± 23 cm











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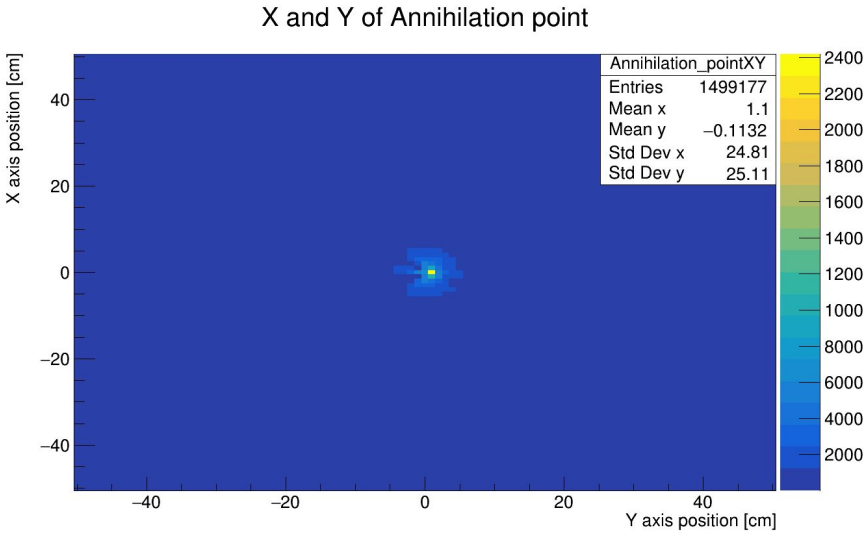

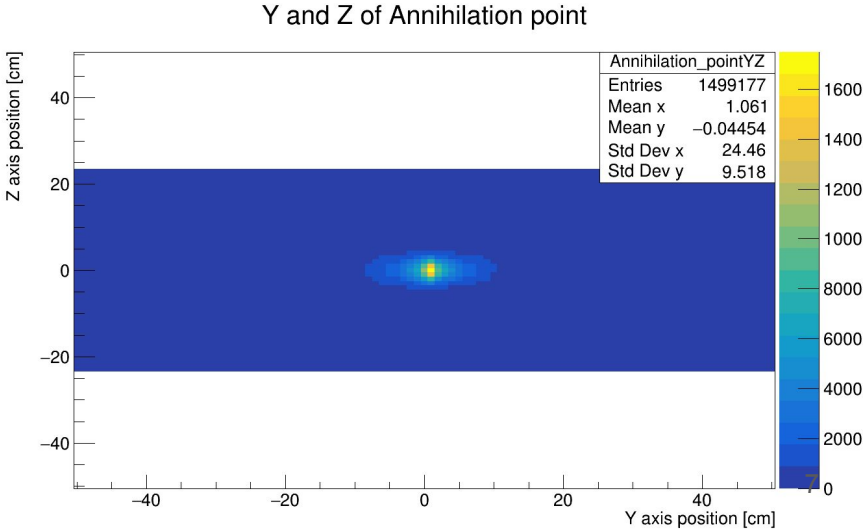

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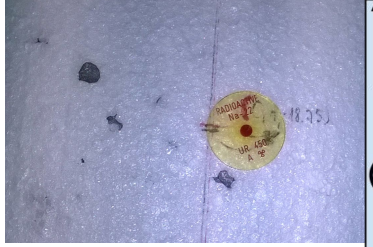

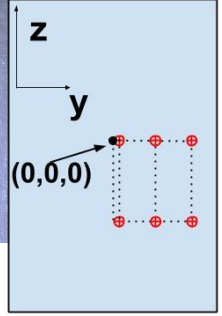

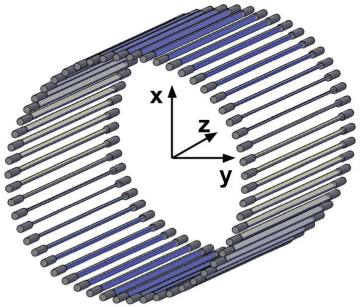

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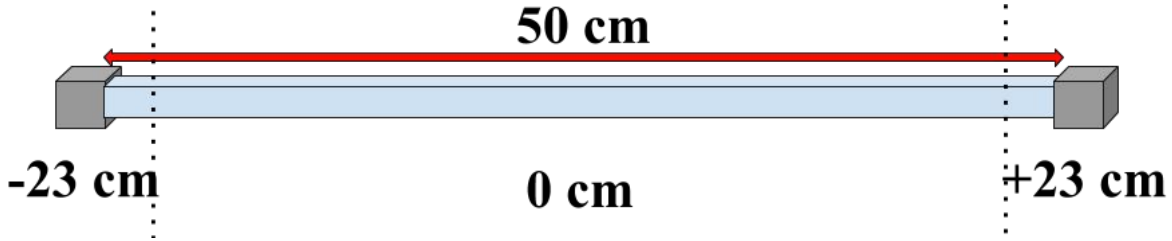

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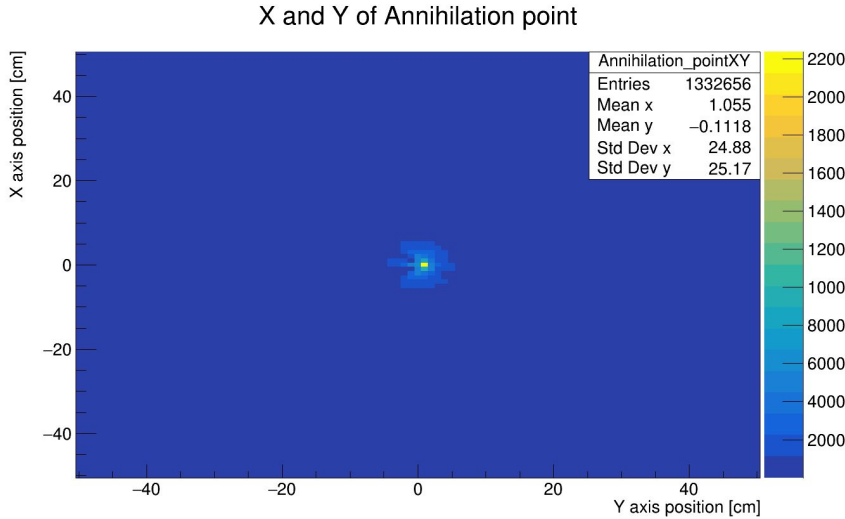

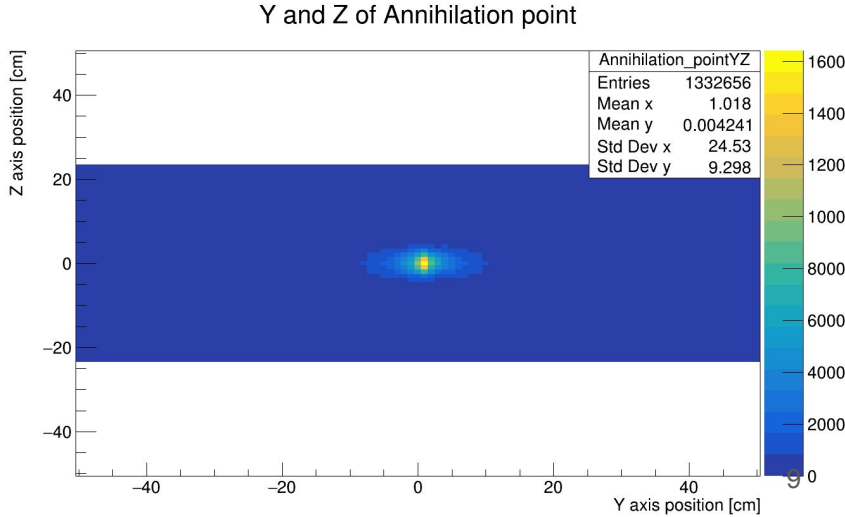

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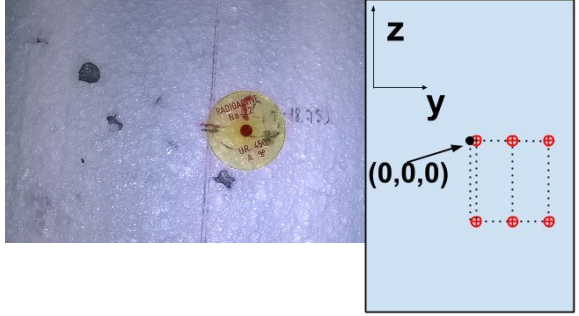

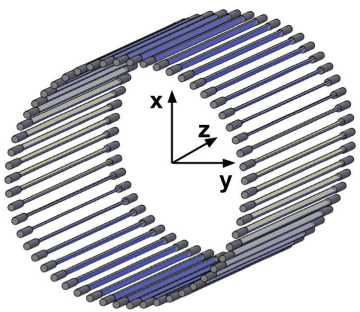

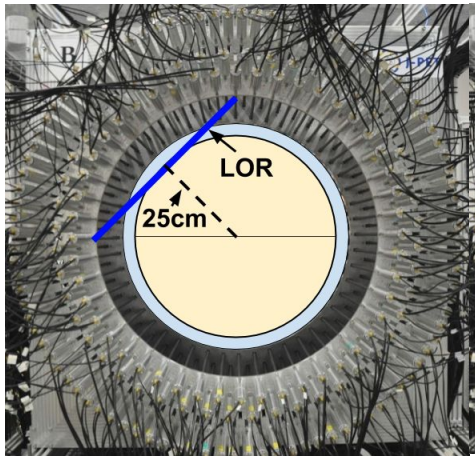

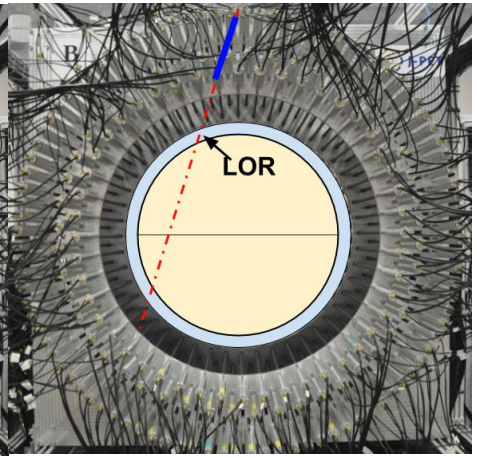

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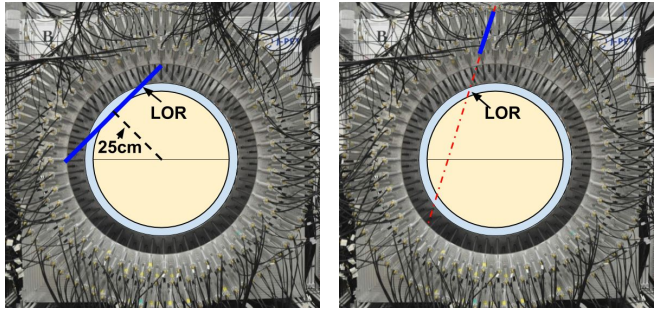

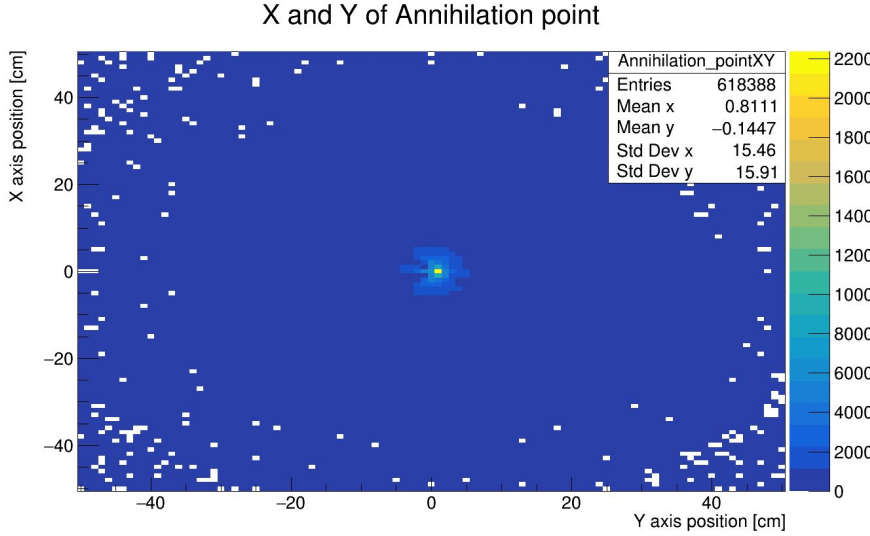

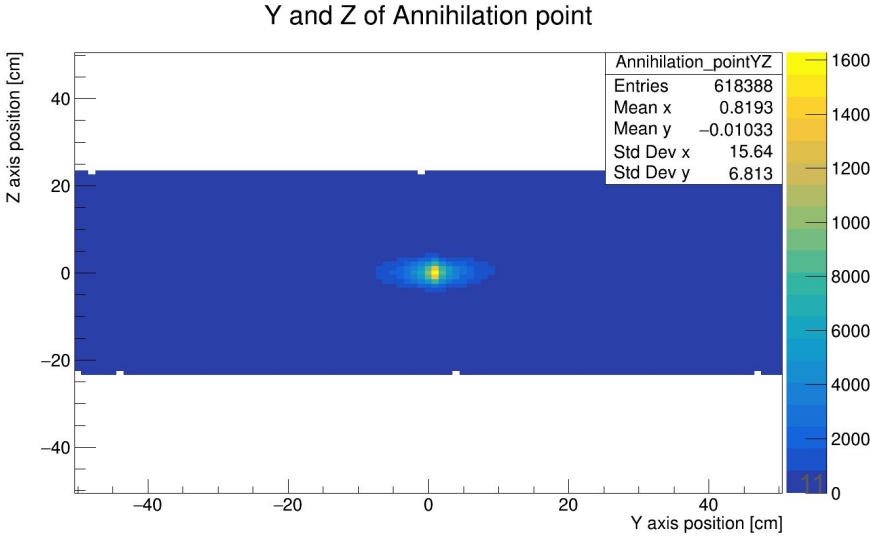

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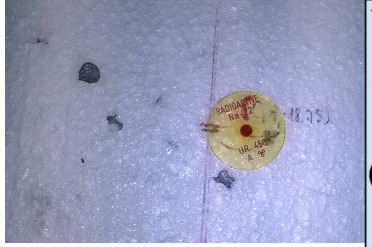
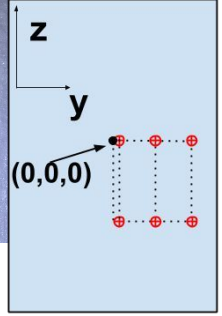
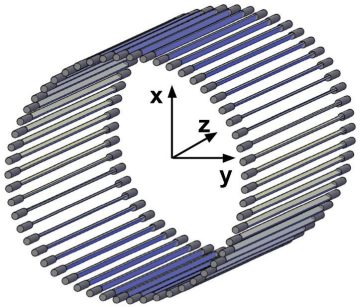
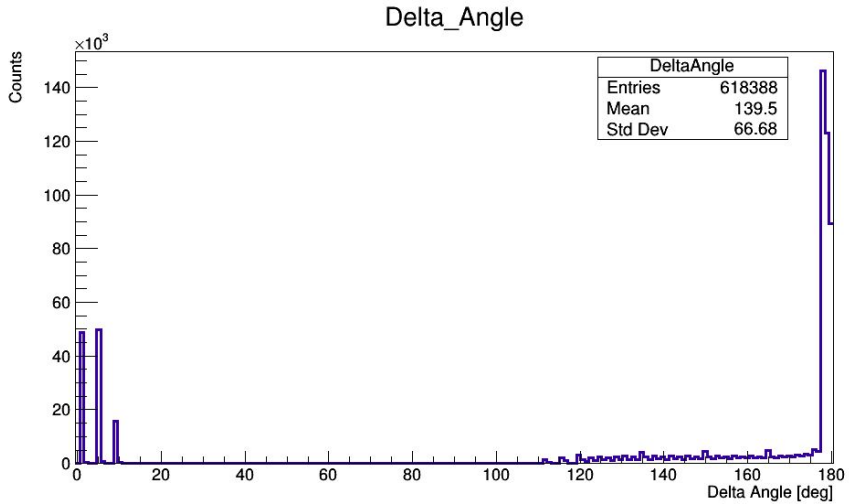
geometrical cuts









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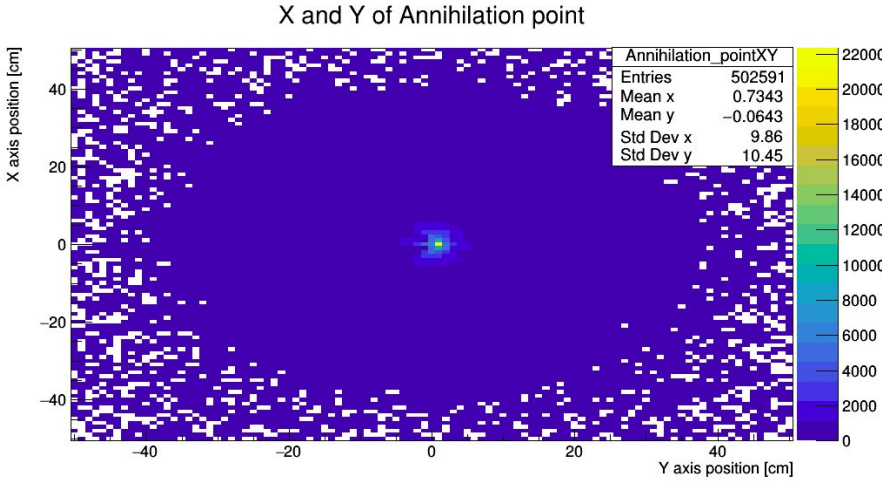
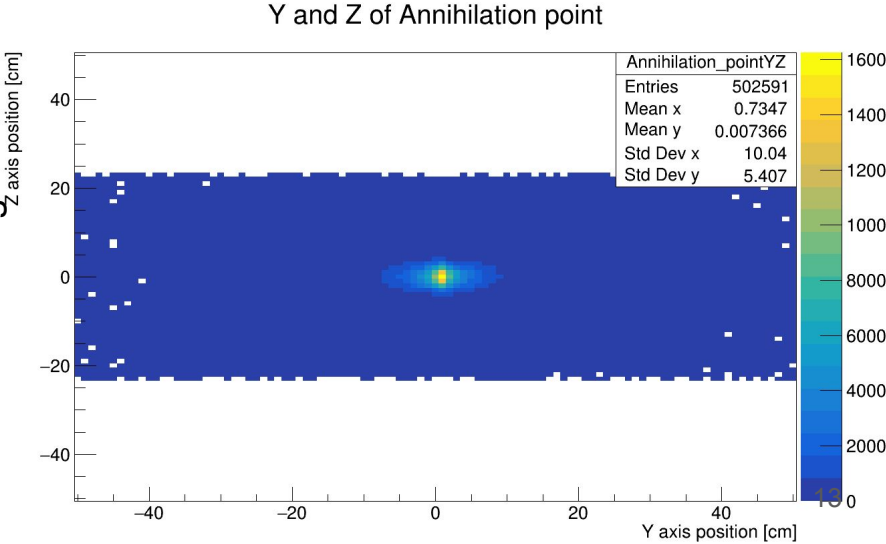
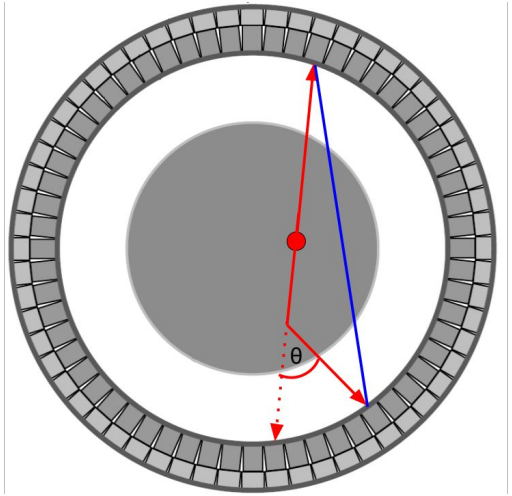
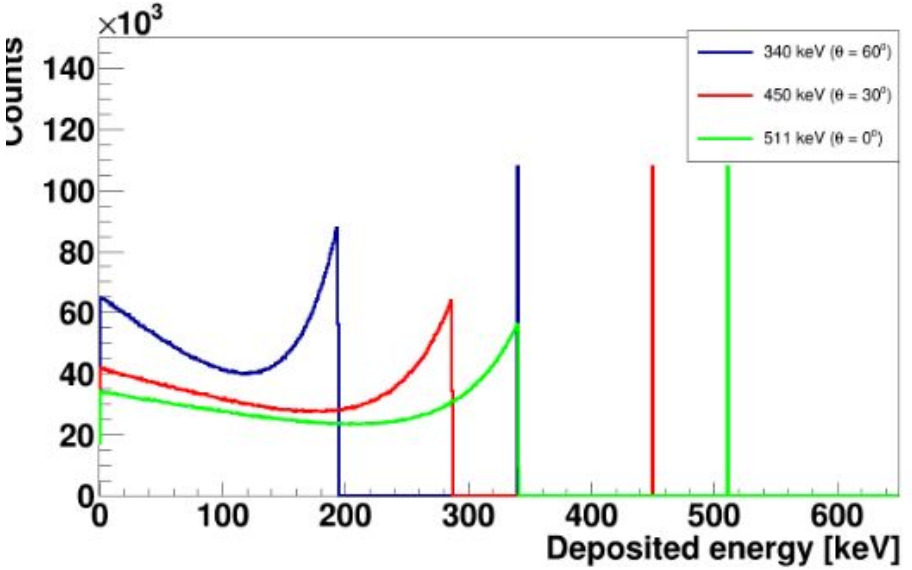


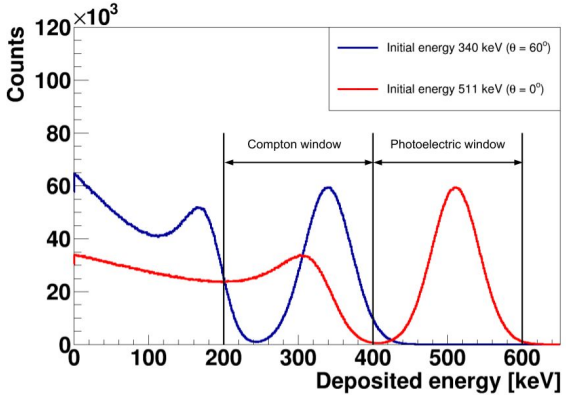


Data selection criteria

1. always two hits in time window: 4 ns
2. - 5. geometrical cuts
6. Energy cuts estimation







Double-strip prototype of polymer time-of-flight positron emission tomograph based on multi-level analog electronics, PhD thesis, Szymon Niedźwiecki, Defence year: 2019

Data selection criteria

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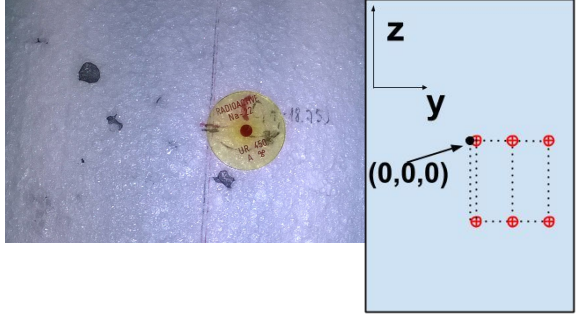
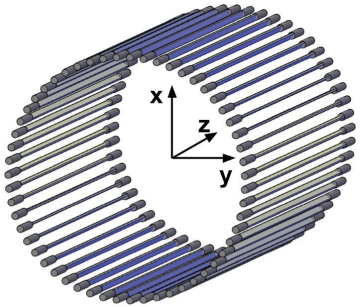
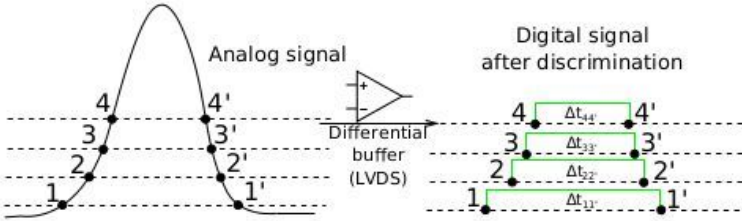
2. - 5. geometrical cuts

6. Energy cuts estimation

done once on data from source inside collimator, measurements done for different positions of collimator along z axis







$$\mathrm{TOT} = \sum_{\mathrm{side=A,B}} \sum_{\mathrm{thr}=1}^{4} \mathrm{TOT}_{\mathrm{side,thr}} ,$$

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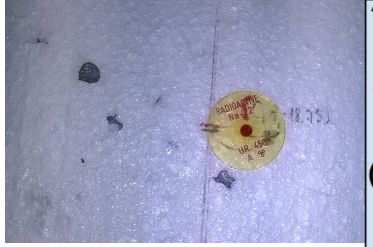

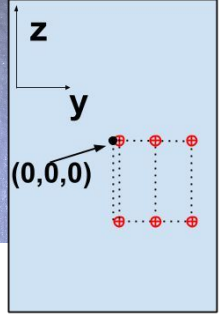

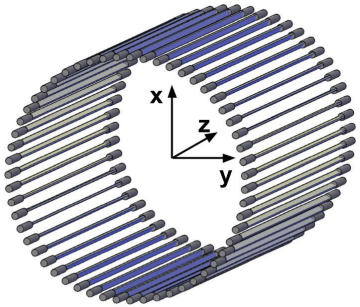

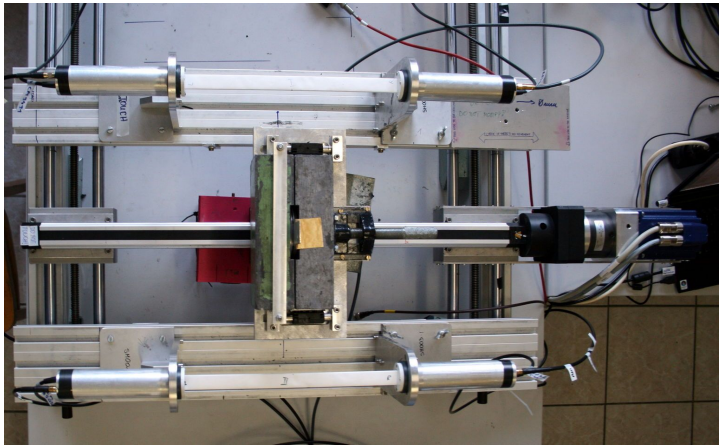

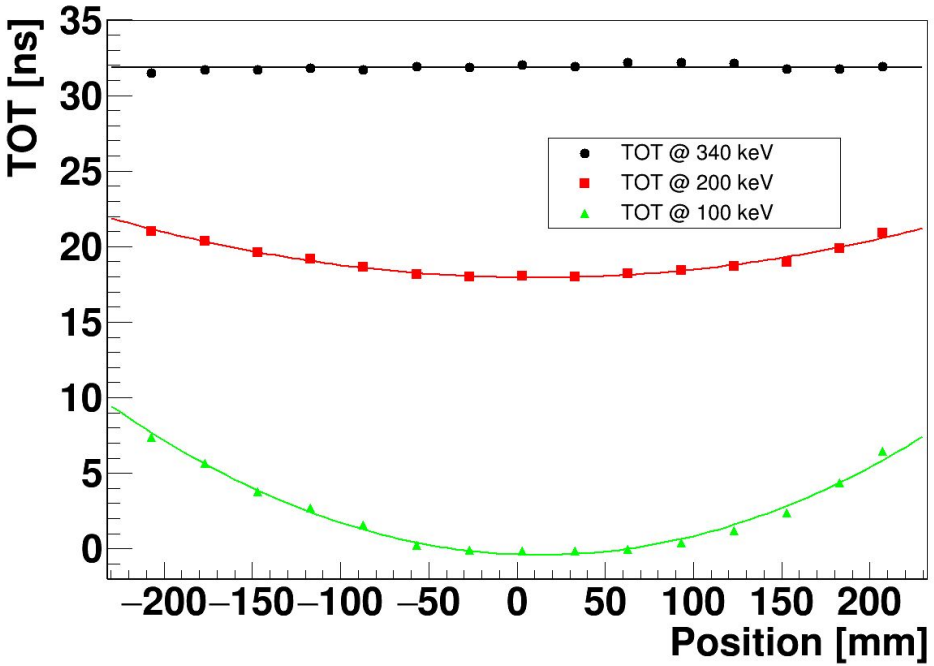

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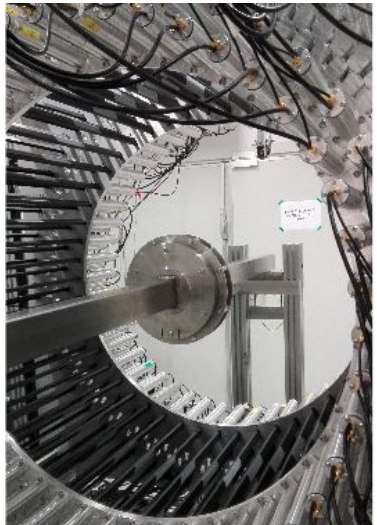
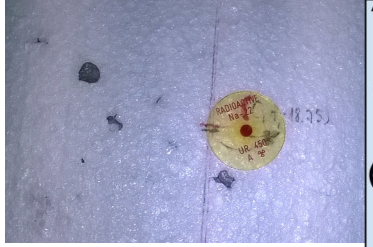
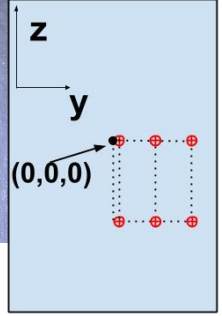
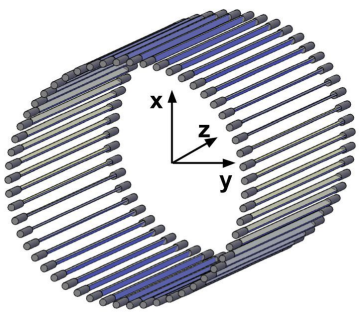
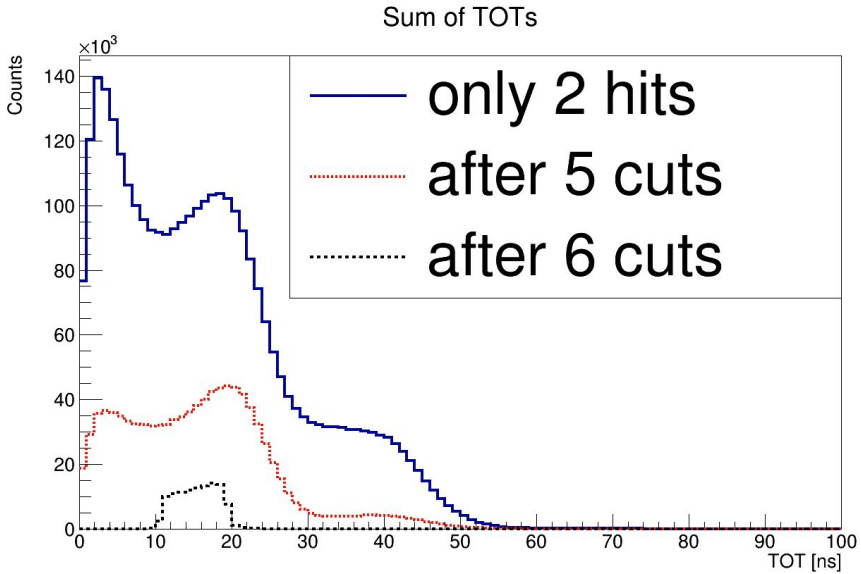
6. Energy cuts estimation











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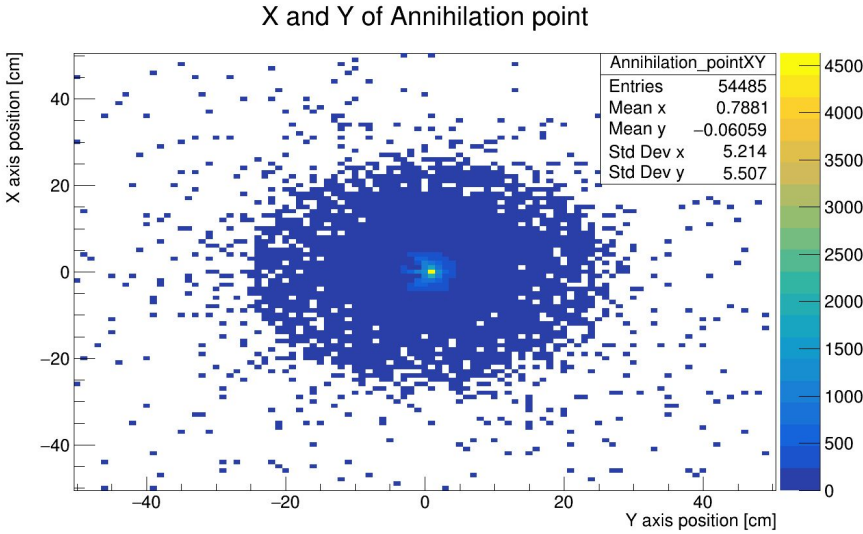
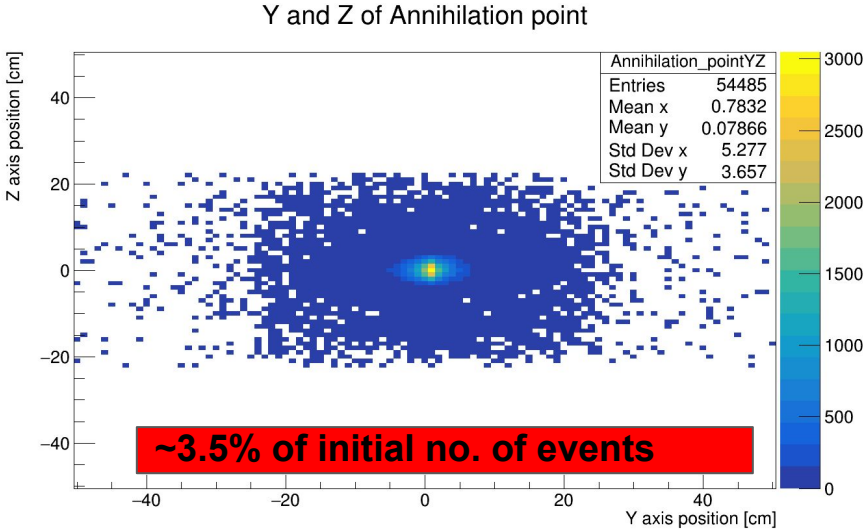
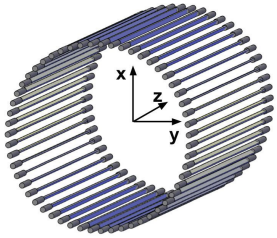
2. - 5. geometrical cuts
6. Energy cuts estimation





Reconstruction algorithms



Maximum Likelihood Expectation Maximization (MLEM)

iteration no. = 20

pixel size = 4 mm

Z (sigma) = 0.0185 [m]

LOR (sigma) = 0.228 [m]

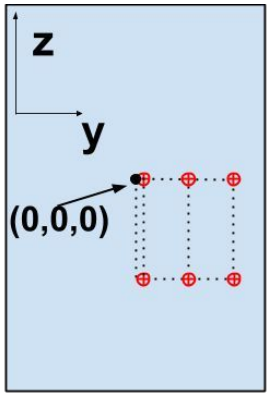
input file: x, y, z and t of both hits

Filtered Back-Projection (FBP)

Reconstruction distance accuracy: 4 mm

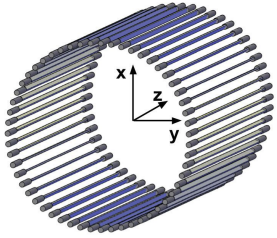
Sinogram no. of slices: 25

Sinogram and reconstruction done directly on data



(0,1,0)	(0,10,0)	(0,20,0)
(0,1,-18.75)	(0,10,-18.75)	(0,20,-18.75)

Reconstruction algorithms

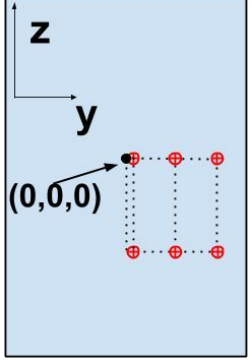


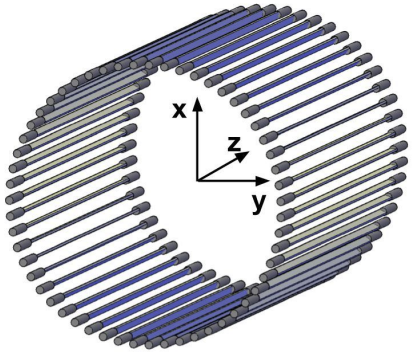
Maximum Likelihood Expectation Maximization (MLEM)

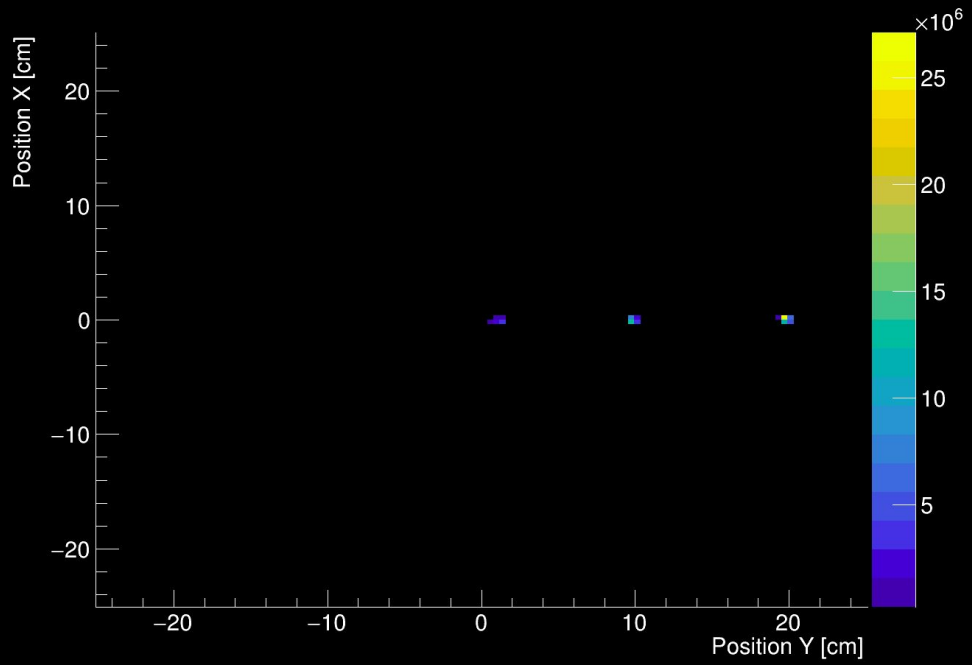
Filtered Back-Projection (FBP)

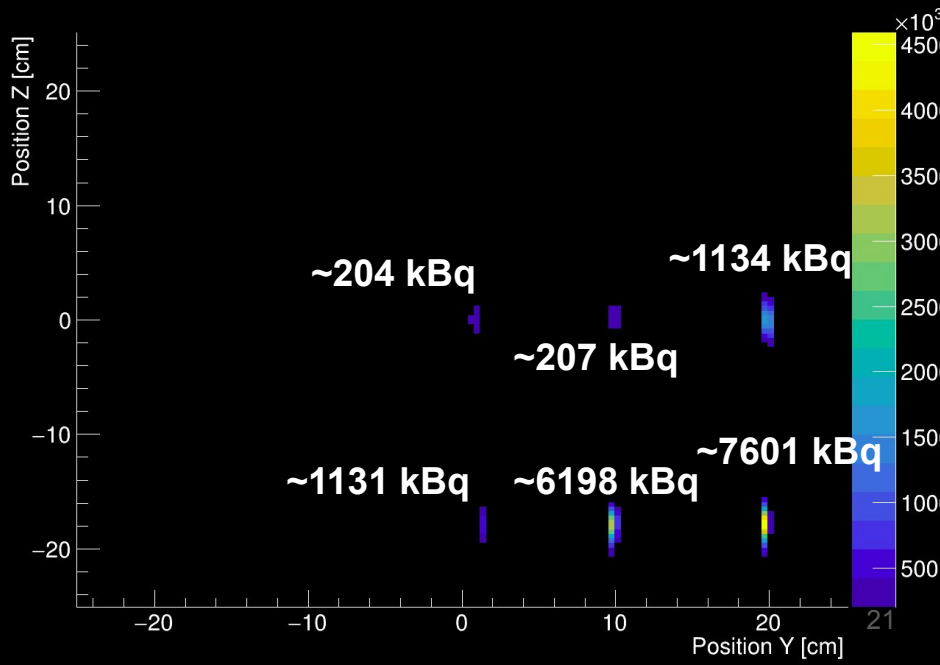
Results for 6 sources (MLEM)

~130 000 events, ~ 4,5 minutes of measurement







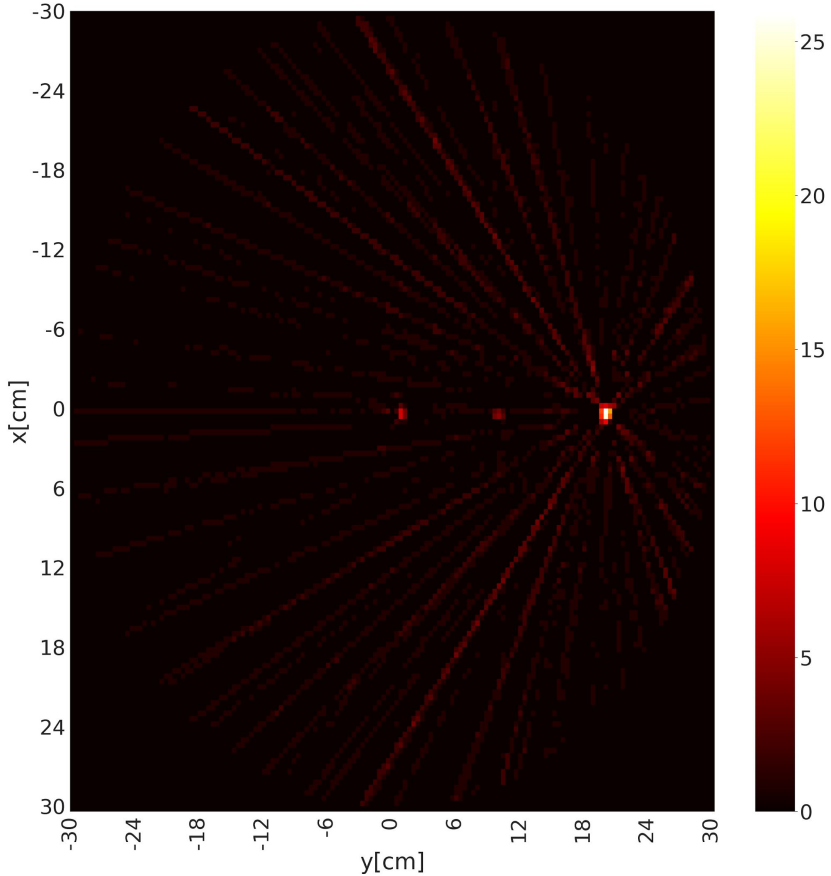


Results for 6 sources (FBP)

slice size = 2 cm

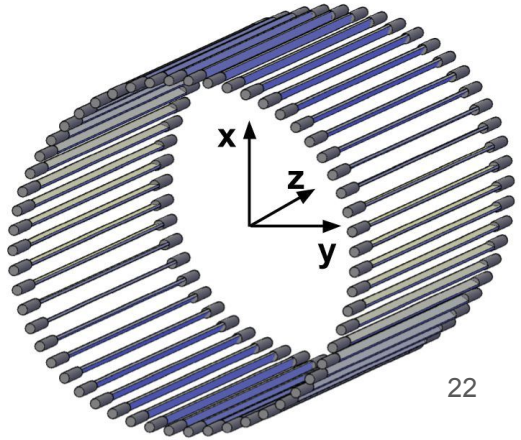
Filter name: Hann

pixel size = 4 mm

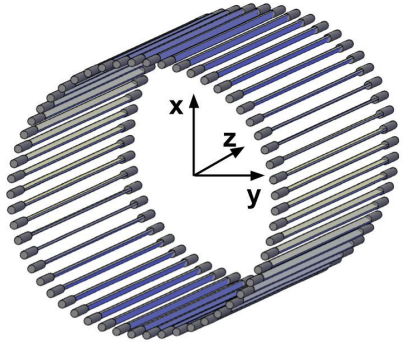


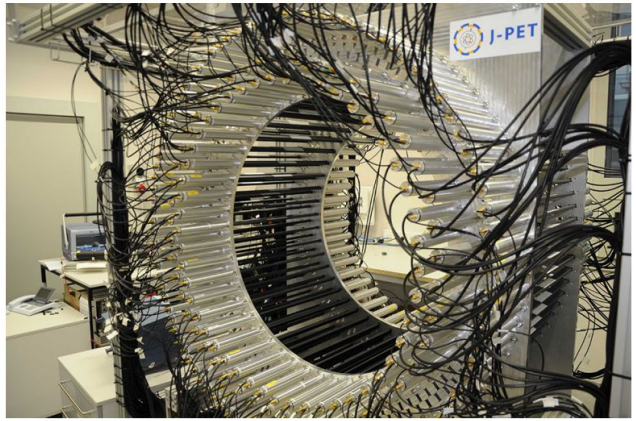
slice number: 0 (-1 cm,1 cm)

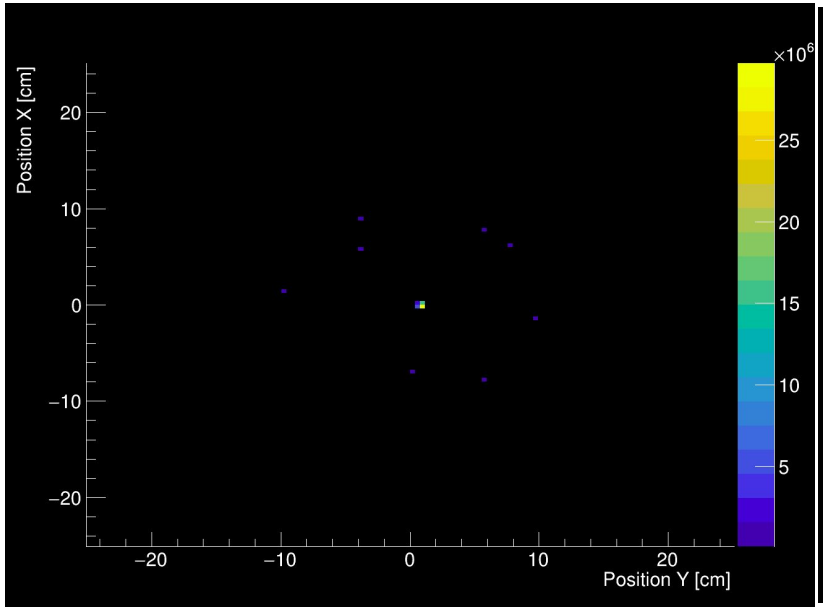
~130 000 events, ~ 4,5 minutes of measurement

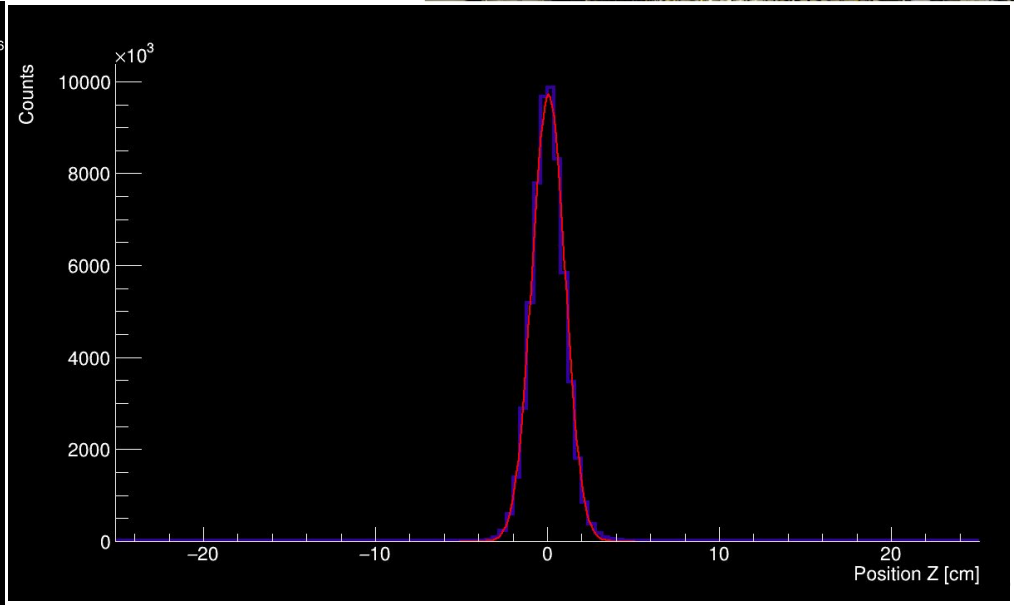


PSF (Point Spread Function)





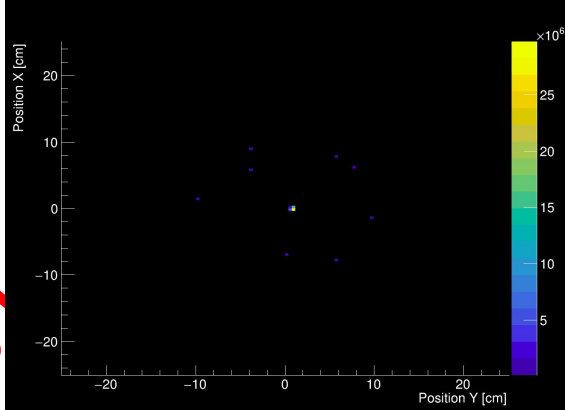


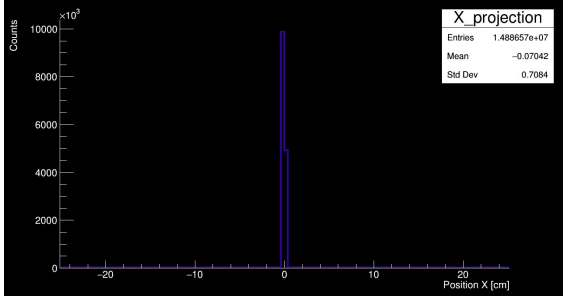


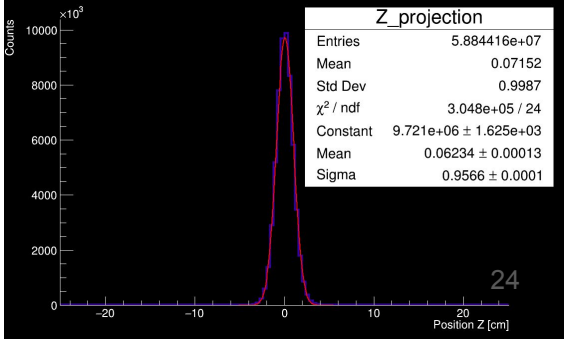
PSF estimation

Source position [cm]	FWHM (MLEM) [cm]	FWHM (FBP)
(0,1,0)	0,4 (x) 0,4 (y) 2,24±0,1 (z)	
(0,1,-18.75)	0,4 (x) 0,8 (y) 2,31±0,01 (z)	
(0,10,0)	0,8 (x) 0,4 (y) 2,28±0,01	
(0,10,-18.75)	0,4 (x) 0,8 (y) 2,56±0,01 (z)	
(0,20,0)	0,8 (x) 0,4 (y) 2,40±0,01 (z)	
(0,20,-18.75)	0,8 (x) 0,8 (y) 2,35 ±0,01 (z)	

IN PROGRESS
~ 2 pixels (x & y)

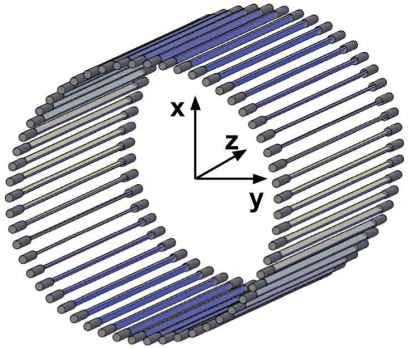






Thank you for your attention

MLEM reconstruction



iteration no. = 20

pixel size = 4 mm

Z (sigma) = 0.0185 [m]

LOR (sigma) = 0.228 [m]

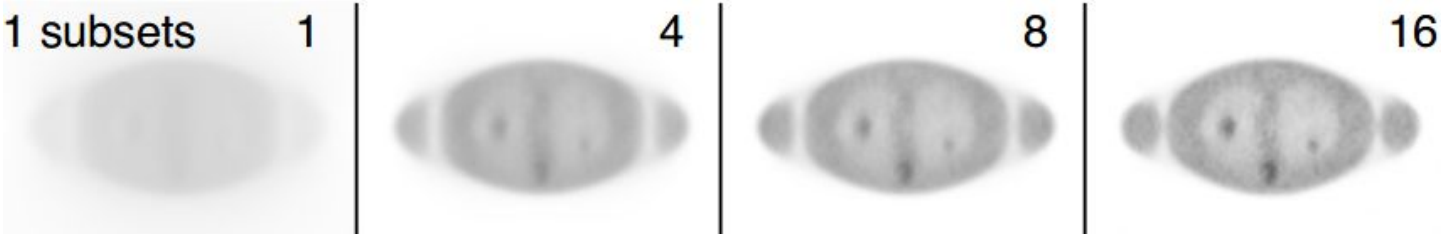
Maximum Likelihood Expectation Maximization (MLEM)

Density of emission for pixel for t iteration $l = (x, y)$

$$\rho(l)^{t+1} = \sum_{j=1}^{N} \frac{P(e_j|l)\rho(l)^{(t)}}{\sum_{i=1}^{M} P(e_j|i)s(i)\rho(i)^{(t)}}$$

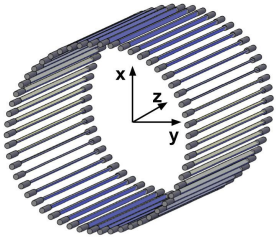
$P(e_j|l)$ probability that emission event originating from pixel l is detected as e_j

$s(i)$ probability to detect event from pixel i

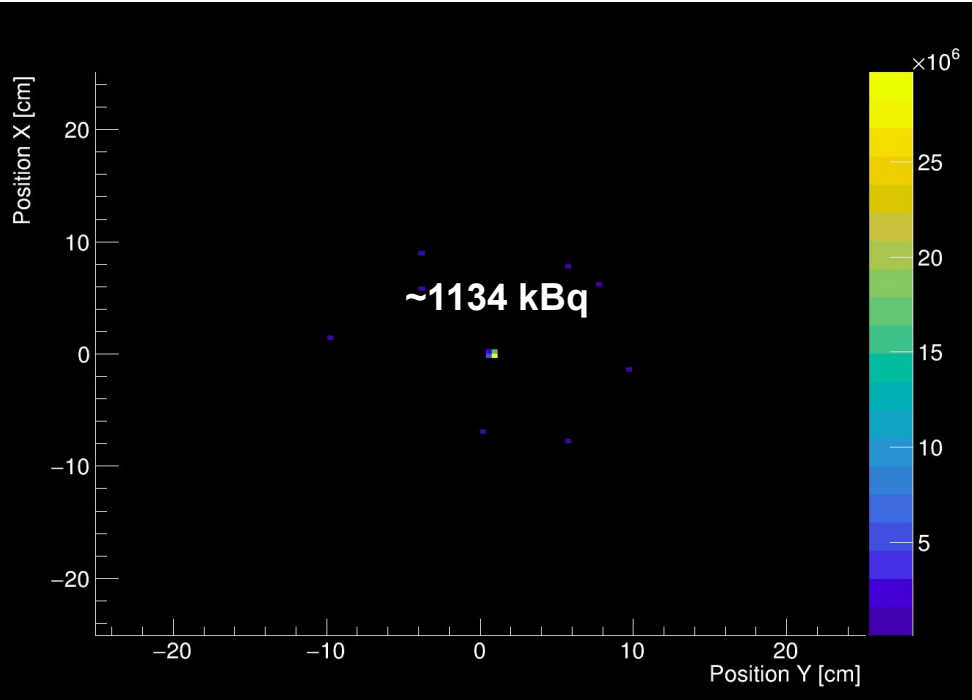


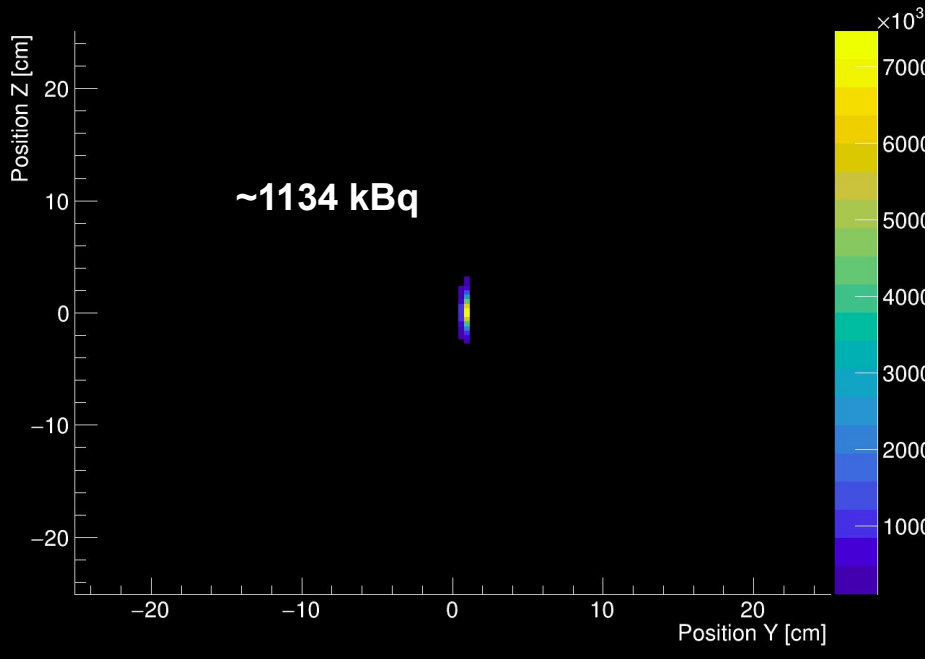
PET Image Reconstruction Adam Alessio, PhD and Paul Kinahan, PhD

MLEM reconstruction

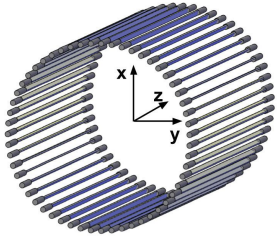


Maximum Likelihood Expectation Maximization (MLEM)

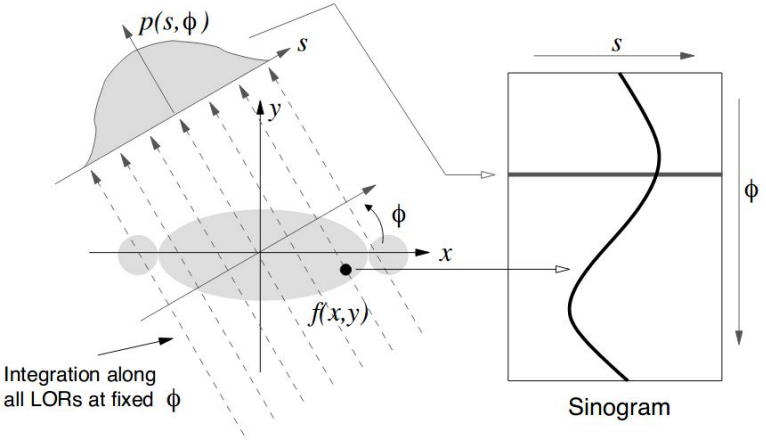


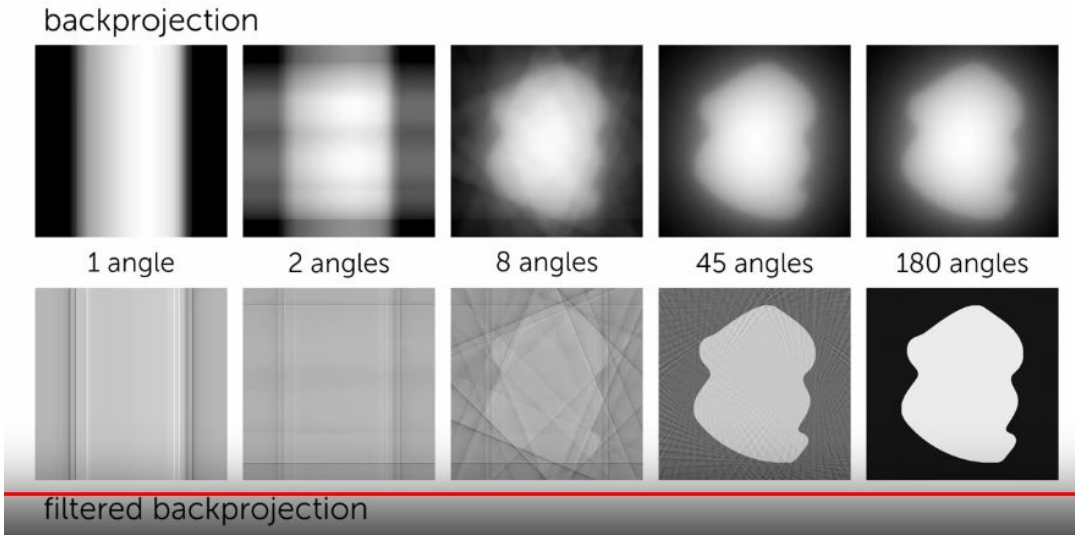


FBP reconstruction



each complete projection fills a single row of ϕ in the sinogram

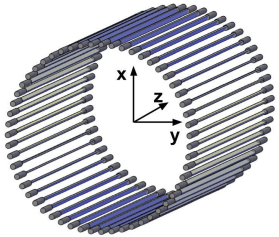




PET Image Reconstruction
Adam Alessio, PhD and Paul Kinahan, PhD

source: ASTRA Toolbox

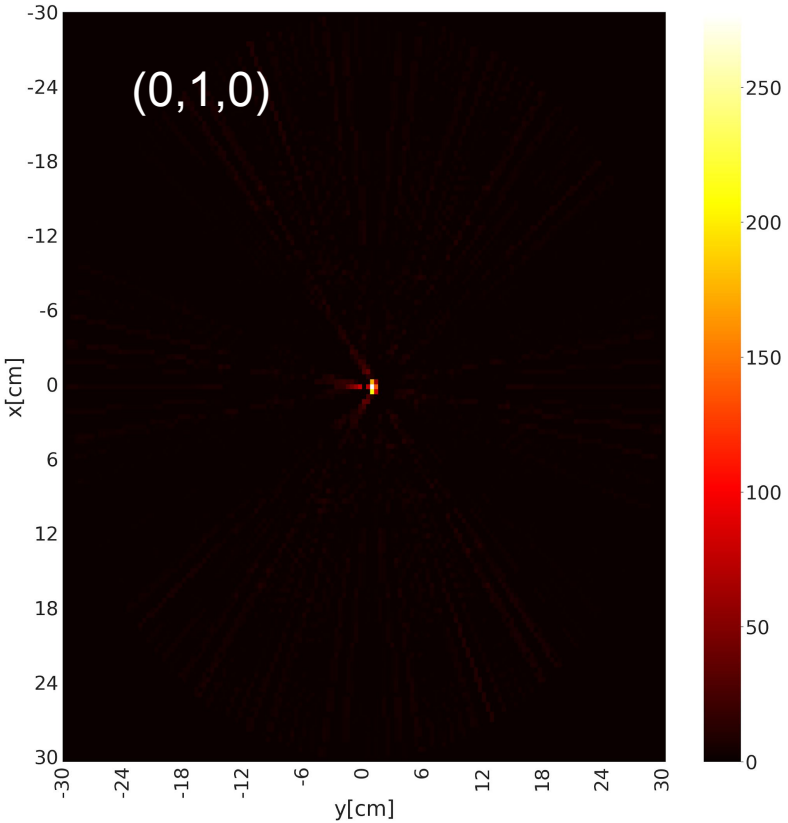
FBP reconstruction

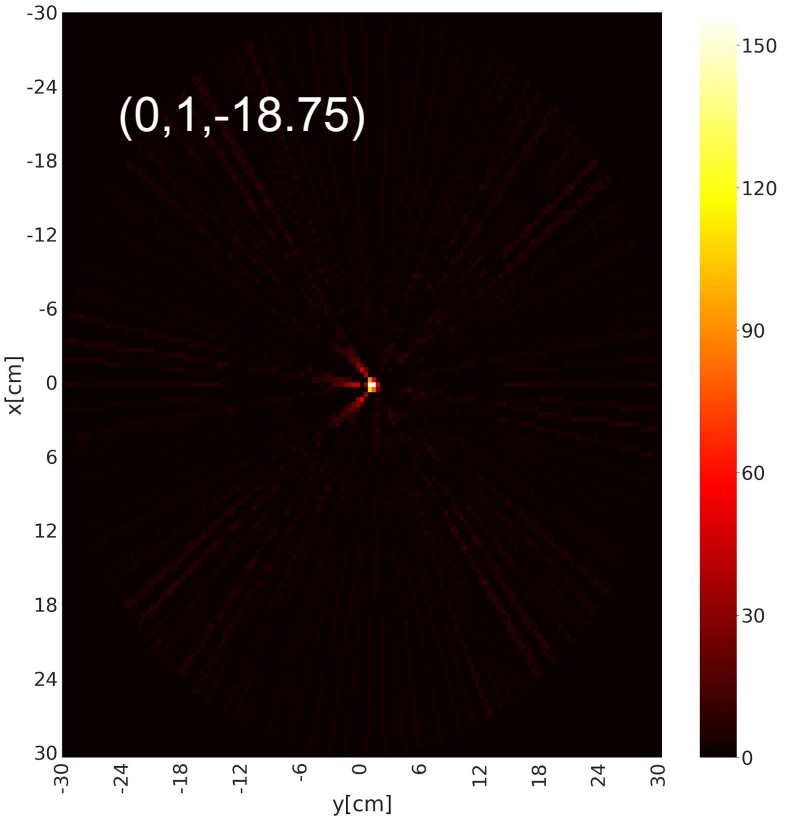


slice size = 2 cm

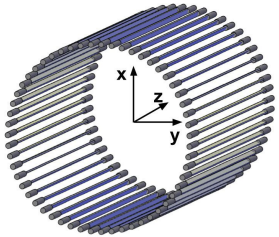
Filter name: Hann

pixel size = 4 mm





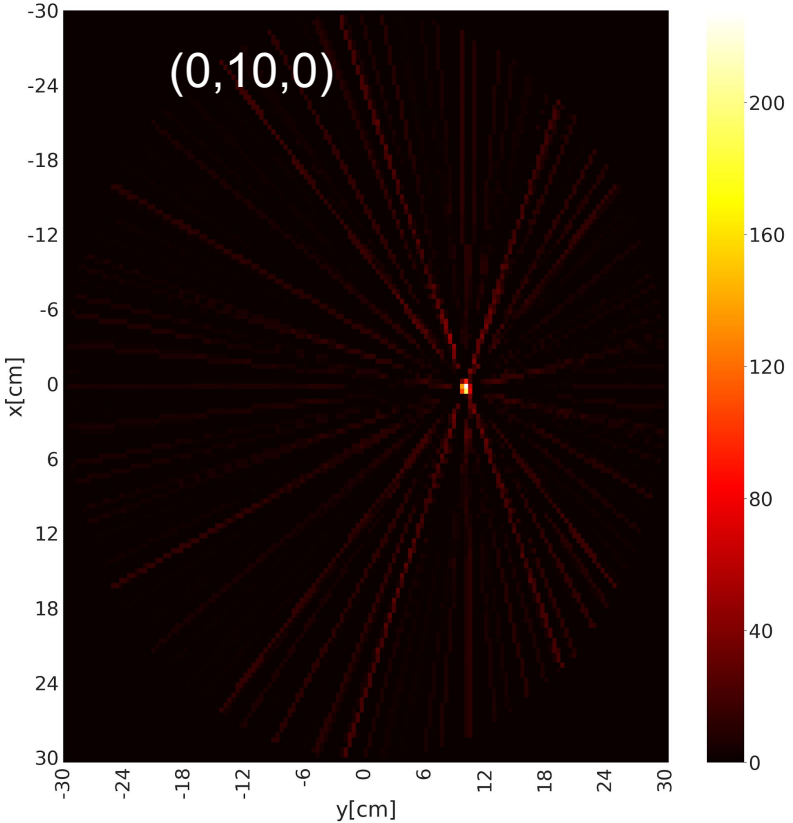
FBP reconstruction

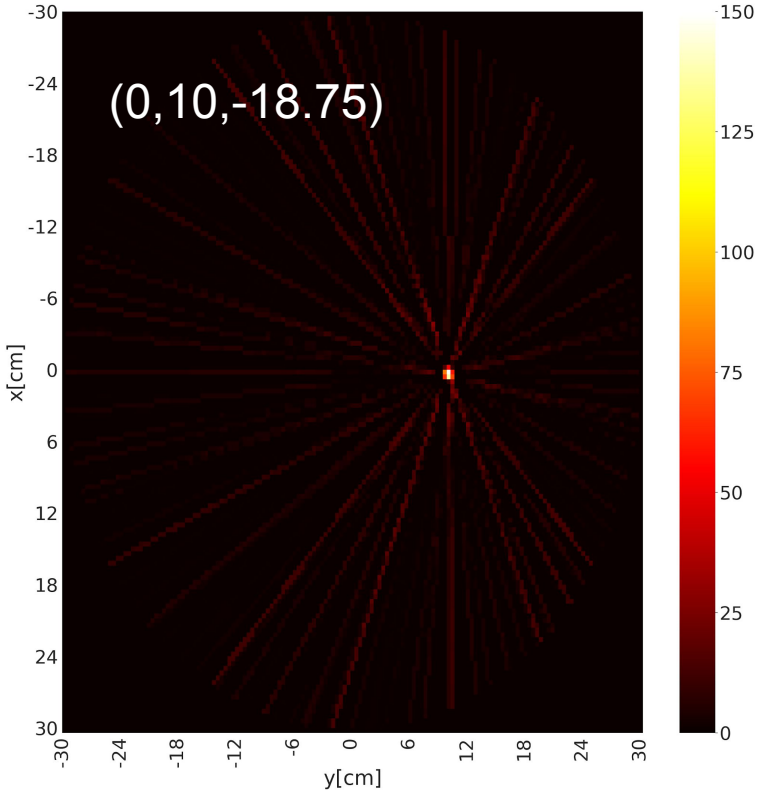


slice size = 2 cm

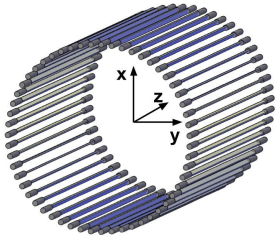
Filter name: Hann

pixel size = 4 mm





FBP reconstruction



slice size = 2 cm

Filter name: Hann

pixel size = 4 mm