INNOVATIVE ECONOMY
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Estimation of Point Spread Function of the J-PET detector using different reconstruction methods

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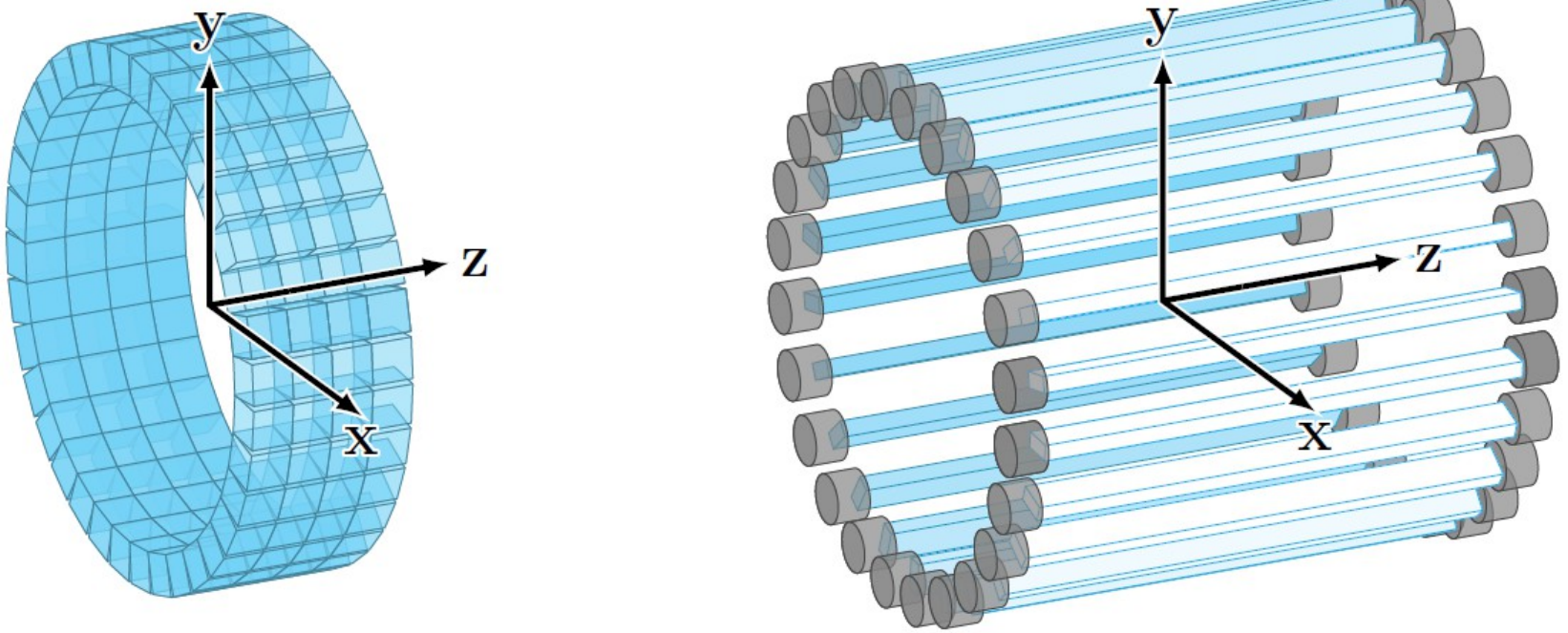
Agenda:

1. Definition of spatial resolution of PET detectors
2. Description of image reconstruction algorithms:
   - Filtered Back Projection (FBP)
   - Back Projection Total Variation (BPTV)
3. Results
4. Summary and further plans

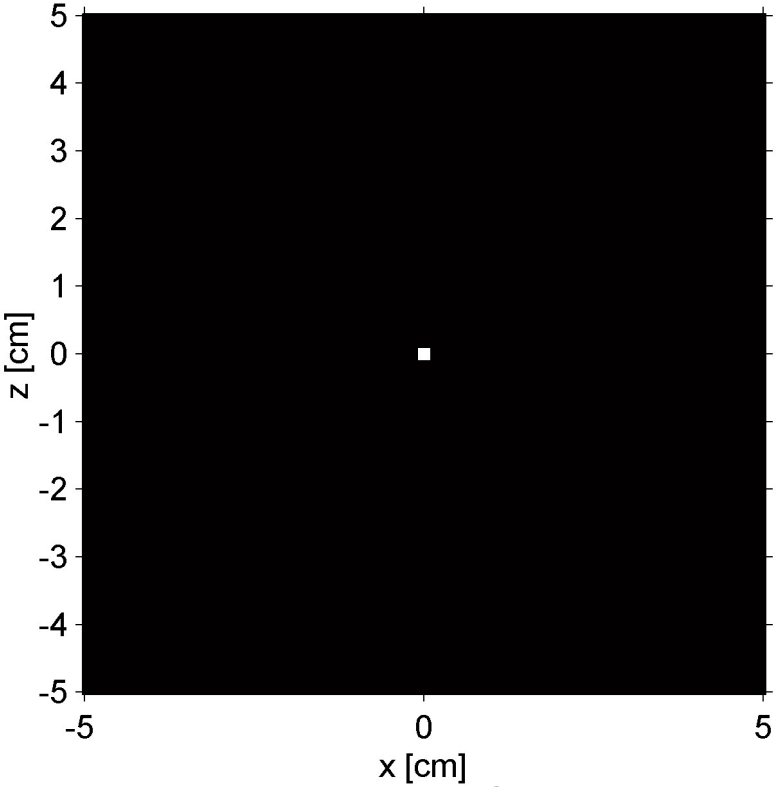
1. Spatial resolution of PET detectors



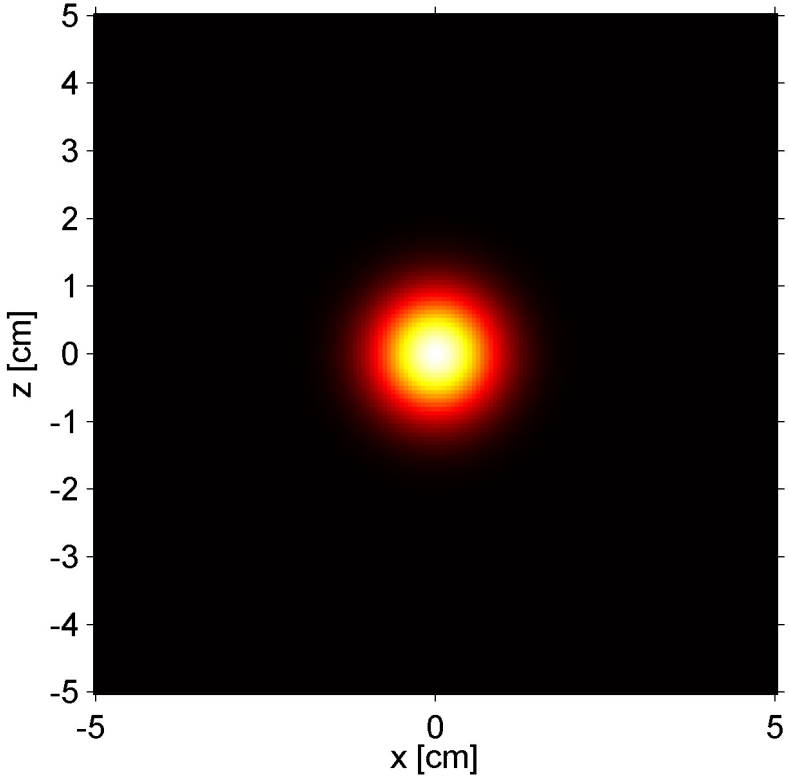
- Comparison of the concepts of classical PET scanner based on crystal scintillators (left part) and the J-PET scanner (right part)
- Reconstruction of the three-dimensional (3D) image of the point source is crucial for the estimation of spatial resolution of PET detectors.

1. Spatial resolution of PET detectors

Radioactive point source



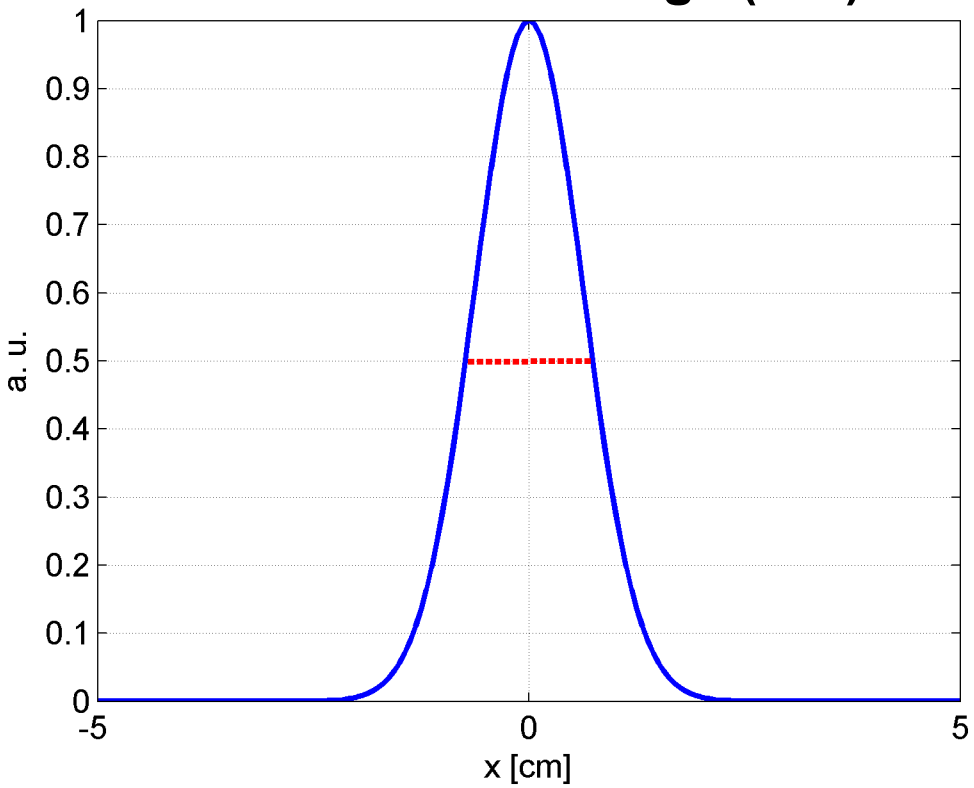
Reconstructed image



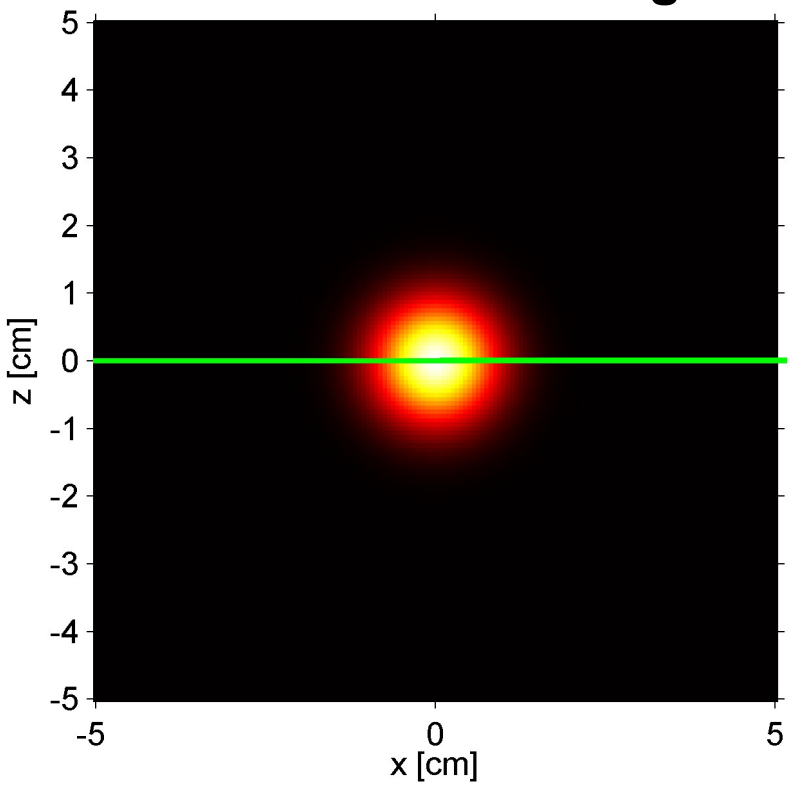
- The spatial resolution of a PET scanner is evaluated based on reconstructed images (right part)
- NEMA norm requires Filtered Back Projection reconstruction algorithm

1. Spatial resolution of PET detectors

Reconstructed image (z=0)



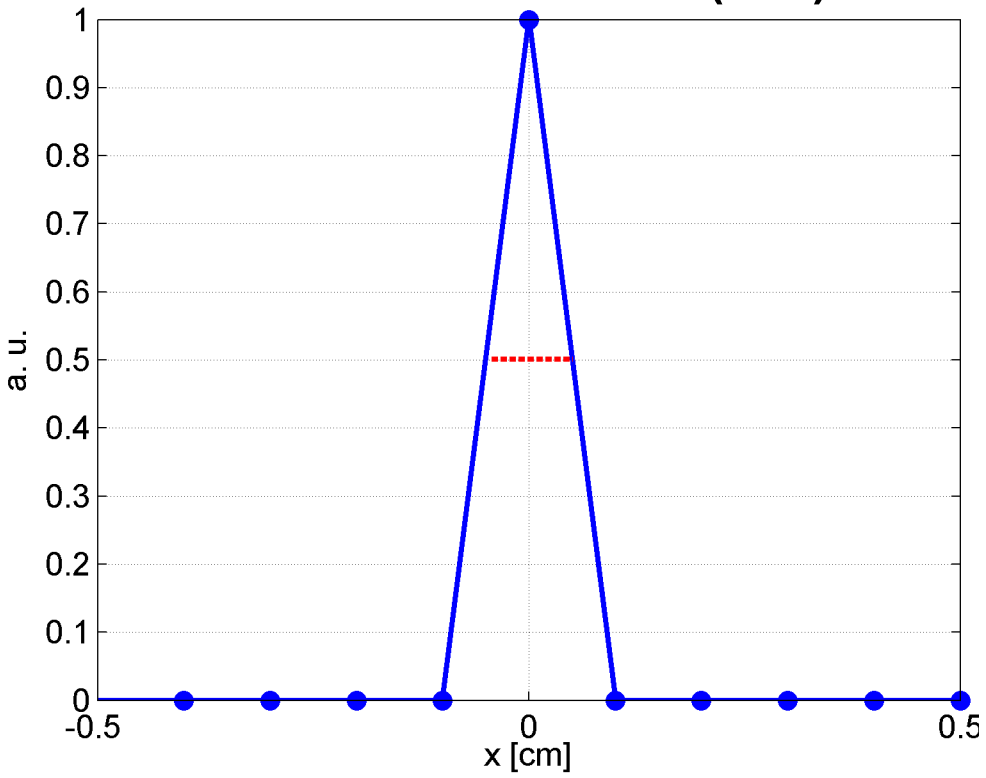
Reconstructed image



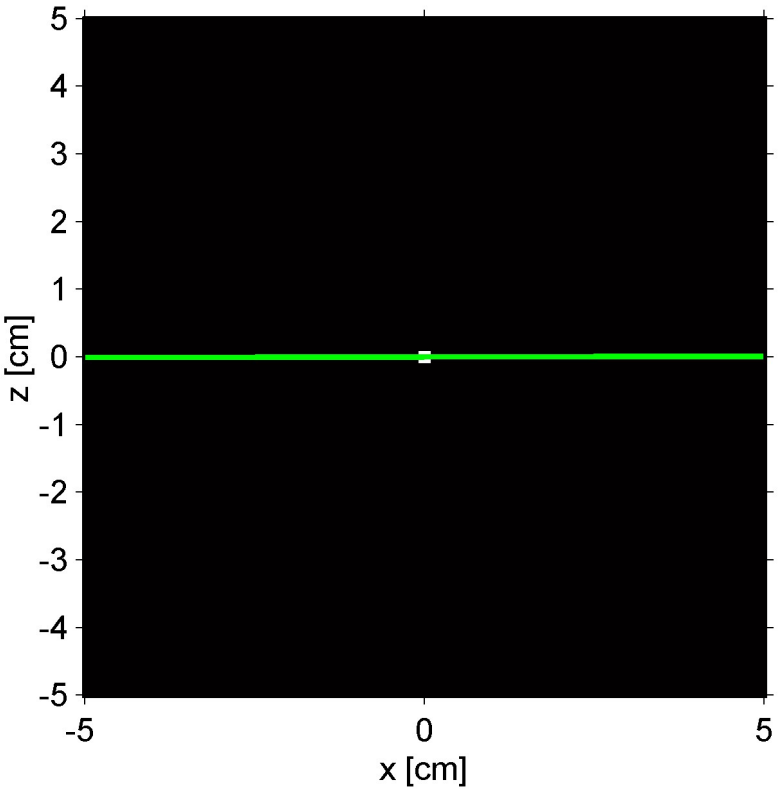
- The spatial resolution (in each direction – here along „***x***” axis) is defined as the width of the reconstructed profile of a point source, measured similarly to FWHM (marked with red dotted line); here PSF is about 1.5 cm

1. Spatial resolution of PET detectors

Ideal reconstruction (z=0)



Ideal reconstruction



- The smallest value of the spatial resolution is equal to the pixel size along given direction (we use linear interpolation of the profile function); here PSF limit is 0.1 cm

2. Image reconstruction algorithms

Filtered Back Projection (FBP)

- Registration of sinogram

↓

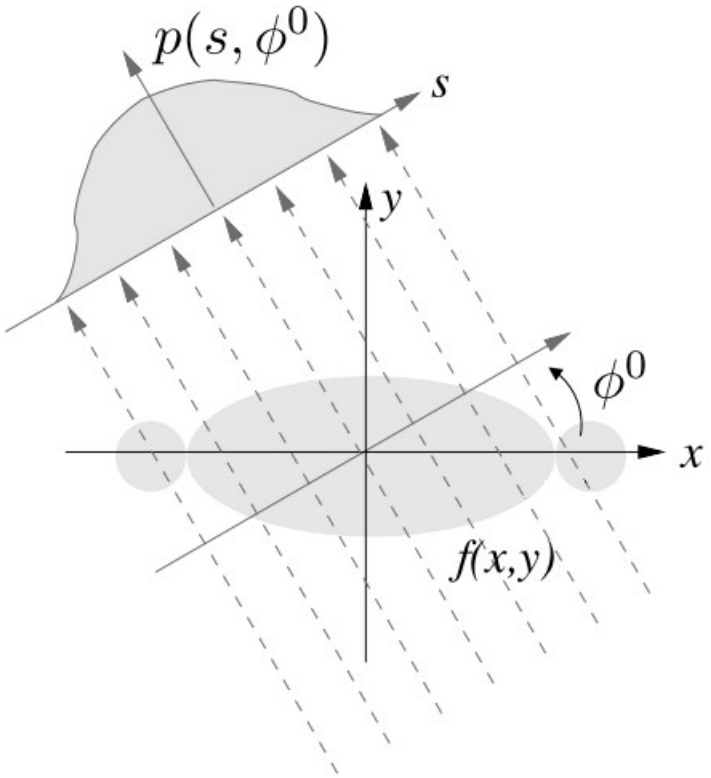
- Filtration (in projection space)

$$p^{\mathrm{F}}(s,\phi) = \mathcal{F}^{-1}\left(W(v_s)|v_s|\mathcal{F}\left(p(s,\phi)\right)\right)$$

↓

- Back-projection to image space

$$f(x,y) = \int_0^{\pi} p^{\mathrm{F}}(s = x\cos\phi + y\sin\phi, \phi)\mathrm{d}\phi$$



2. Image reconstruction algorithms

Filtered Back Projection (FBP)

- Registration of sinogram

↓

- Filtration (in projection space)

$$p^{\mathrm{F}}(s,\phi) = \mathcal{F}^{-1}\left(W(v_s)|v_s|\mathcal{F}\left(p(s,\phi)\right)\right)$$

↓

- Back-projection to image space

$$f(x,y) = \int_0^{\pi} p^{\mathrm{F}}(s = x\cos\phi + y\sin\phi, \phi)\mathrm{d}\phi$$

Back Projection TV (BPTV)

- Registration of sinogram

↓

- Back-projection to image space

$$b(x,y) = \int_0^{\pi} p(s = x\cos\phi + y\sin\phi, \phi)\mathrm{d}\phi$$

↓

- Filtration (in image space)

$$\min_f \left(\mathrm{TV}(f) + \frac{\mu}{2}\|A\boldsymbol{f} - \boldsymbol{b}\|_2^2\right)$$

3. Results

Reconstruction of point source:

x: 1 cm, y: 0 cm, z: 0 cm

Simulation setup:

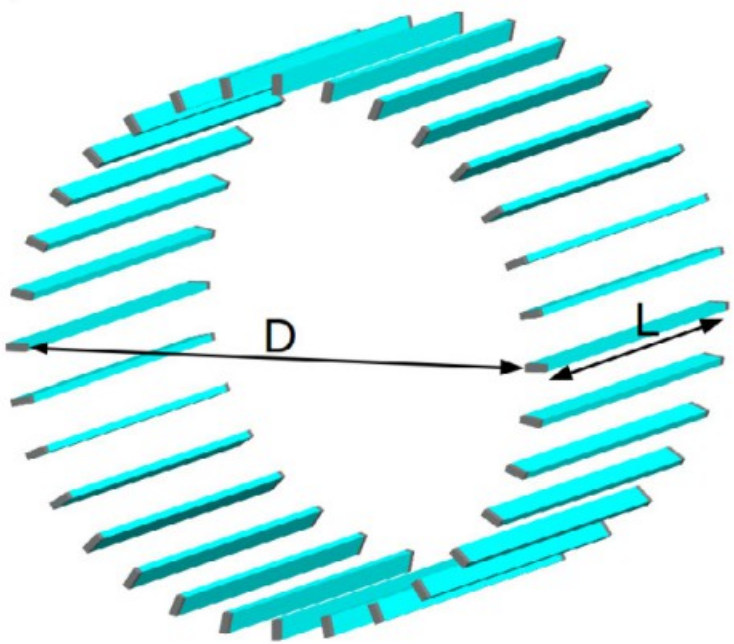
Number of layers:

Number of rings: 384

Number of events: 150 000

Detector diameter (D): 87.46 cm

Detector length (L): 50.00 cm



Voxel size*:

x: 1.8 mm, y: 1.8 mm, z: 3.9 mm

*size is the same as in experiments with STIR software:
Shopa R.Y. et al. Acta Physica Polonica B, vol. 47, pp. 1757 (2017)

3. Results

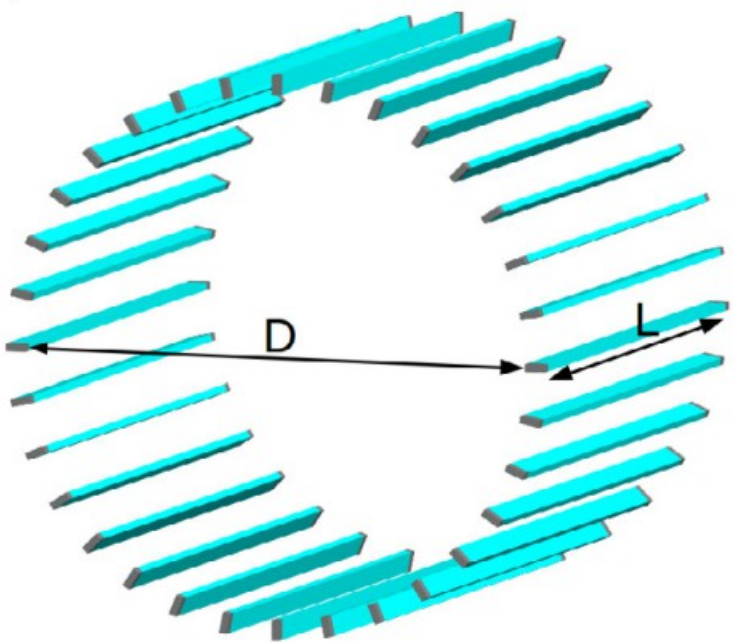
Investigated parameters:

Spatial resolution of hit position along strip (standard deviation):

2 mm
5 mm
10 mm

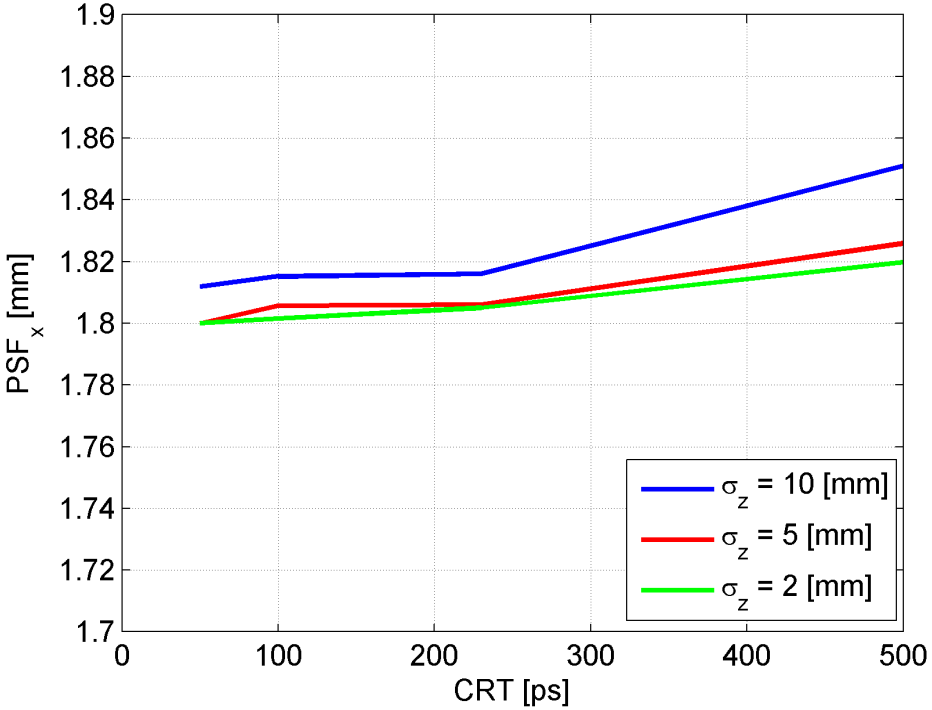
Coincidence Resolving Time (CRT):

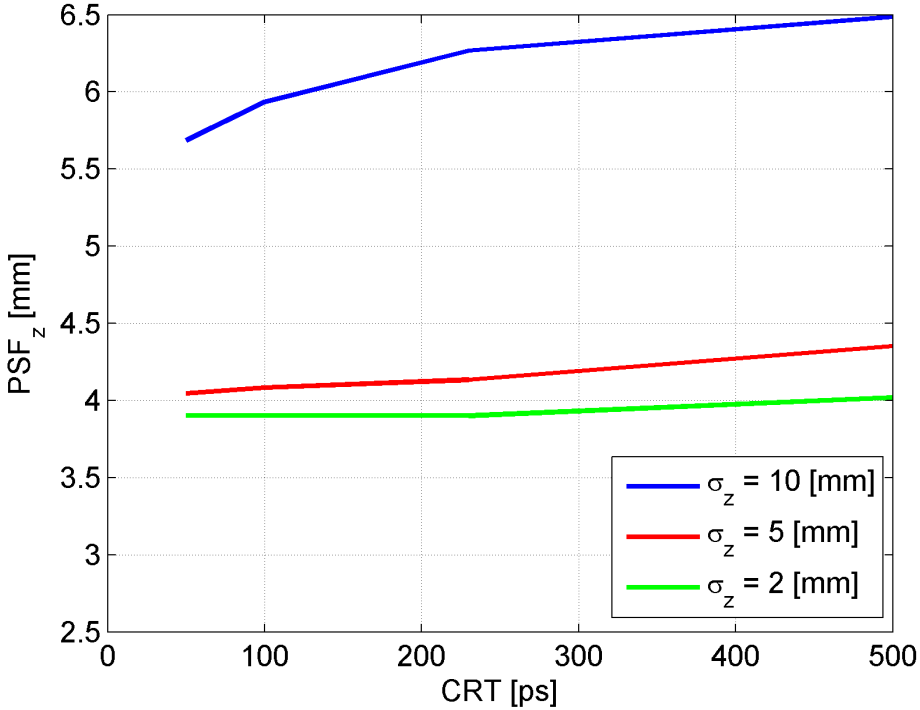
50 ps
100 ps
230 ps
500 ps



In total 12 different simulation scenarios

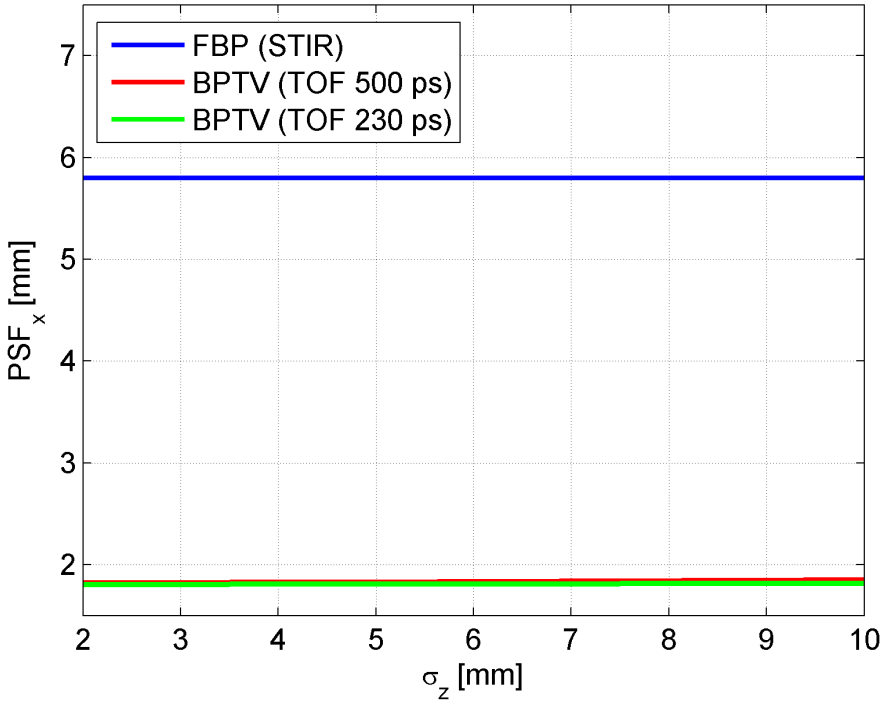
3. Results

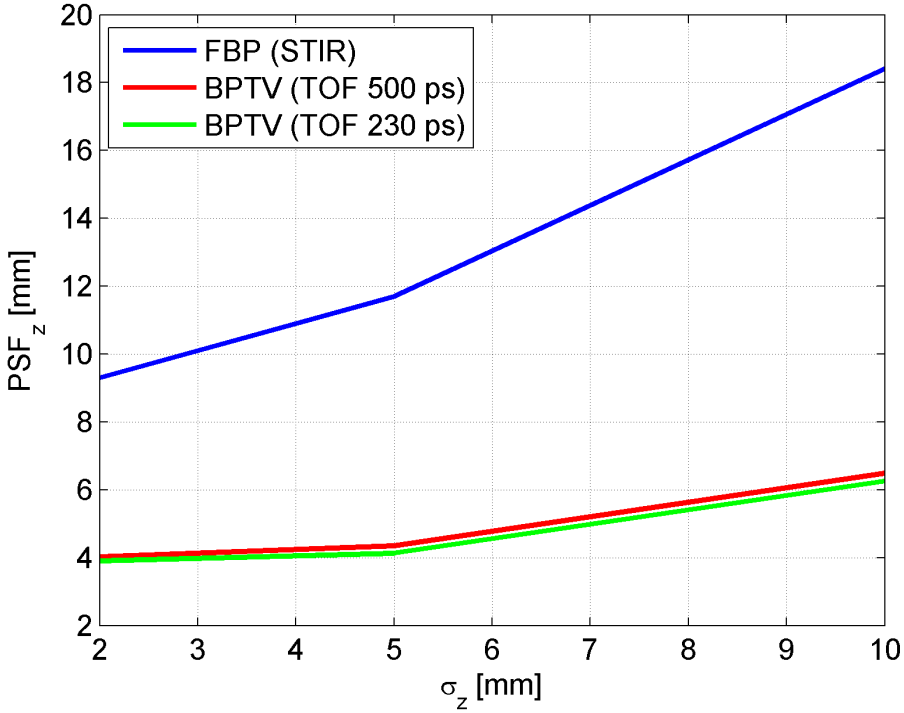




- Results obtained with BPTV (Back-projection Total Variation) method
- PSF's are limited by the voxel size: 1.8 mm in „x" direction – left part
  3.9 mm in „z" direction – right part.
- The influence of CRT is quite moderate

3. Results





- Comparison of the performance of the FBP and BPTV algorithms
- BPTV performs much better than FBP in all cases
- The most significant is the improvement of the hit position axial resolution

4. Summary

It was demonstrated that using the Total Variation regularization improves the spatial resolution of reconstructed image.

The spatial resolution of hit position along strip is the crucial parameter of J-PET scanner. On the other hand the influence of CRT is quite moderate.

Further analysis will consider the image reconstruction of phantoms, e.g. NEMA IEC phantom, with both FBP and BPTV algorithms.