Spatial resolution of a flat panel limited angle TOF-PET scanner

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INTRODUCTION

- **Excellent coincidence timing resolution** (CTR) in positron emission tomography (PET) enables new detector geometries such as flat panel and open geometry. [1]
- **Flat panel** scanners can be cheaper, lighter and modular
- New possibilities in medical imaging (personalization and combination of imaging techniques.
- **Purpose** of this work: to develop a new method to estimate spatial resolution as established methods don't consider limited angle coverage. [2] [3]

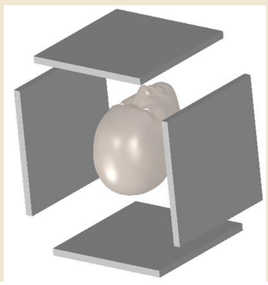

***Figure 1**: Flat panel scanner with 4 panels and a model of patient's head.*

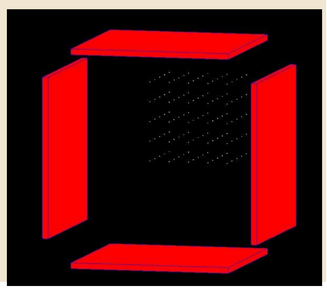

***Figure 2**: Simulated scanner geometry - 4 panels of LSO crystals. Simulated sources presented as small white dots.*

METHODS

- Simulations performed with GATE.
- Grid of 5x5x5 sources was simulated.
- Images reconstructed using CaSToR, voxel size 0.8 mm, performed with 20 iterations.
- **Spatial resolution estimation method**: 3D Gaussian fit performed on each image. Full width at half maximum (FWHM) obtained from each standard deviation is the reported result.

$$f(x,y,z) = A \cdot \mathrm{e}^{\frac{(z-z_0)^2}{2\sigma_z^2}+\frac{(y-y_0)^2}{2\sigma_y^2}+\frac{(x-x_0)^2}{2\sigma_x^2}}$$

- The developed method allows for easy modification of any parameters.
- The method will be tested on simulations of Siemens Biograph Vision, a scanner used in clinical practice.
- For qualitative evaluation, a brain phantom was used. [4]

***Table 1**: Simulated scanner geometry. Crystal width was reduced while keeping spacing the same to examine a sparse configuration.*

Number of panels	Panel size	Scintillator	Crystal thickness	Crystal width	Crystal pitch	CTR
4	30x30 cm^2	LSO	10 mm	3 mm	3.01 mm	75 ps
4	30x30 cm^2	LSO	10 mm	2.5 mm	3.01 mm	75 ps
4	30x30 cm^2	LSO	10 mm	2 mm	3.01 mm	75 ps
4	30x30 cm^2	LSO	10 mm	1.5 mm	3.01 mm	75 ps
4	30x30 cm^2	LSO	10 mm	1.5 mm	2.01 mm	75 ps

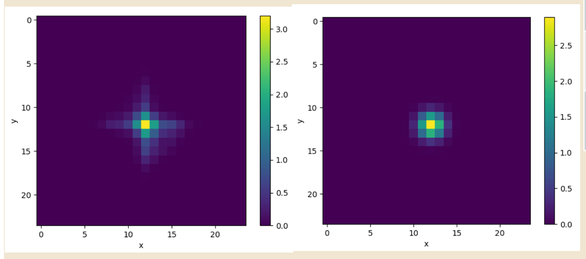

***Figure 3**: Image of a reconstructed source on the left and the result of the fitting on the right.*

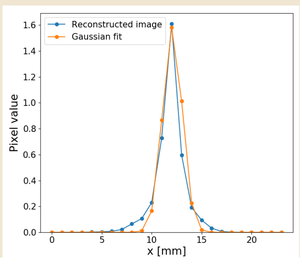

***Figure 4**: Line profiles of the two images from figure 3.*

RESULTS

- The result of the method are 125 values for FWHM in mm in the first octant of the field of view (FOV) of the scanner (symmetry is assumed).
- In the direction of x and y axis the resulting spatial resolution for a scanner with 3 mm wide crystals ranges from 1.3 mm to 5.3 mm at the very edges of the FOV. Axial resolution ranges from 0.7 to 1.5 mm. In most of the FOV the value is around 0.9 mm.

***Figure 5**: Representation of how results match the scanner geometry. In this case resolution in direction of x axis is shown.*

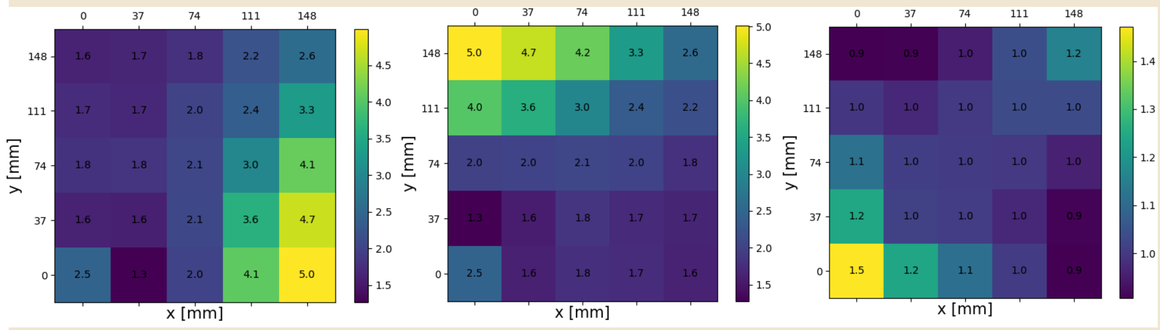

***Figure 6**: Spatial resolution results for a slice at the centre of the FOV for crystal width of 3 mm. Left image shows FWHM in x axis, middle in y axis and right in z axis. All values are in mm.*

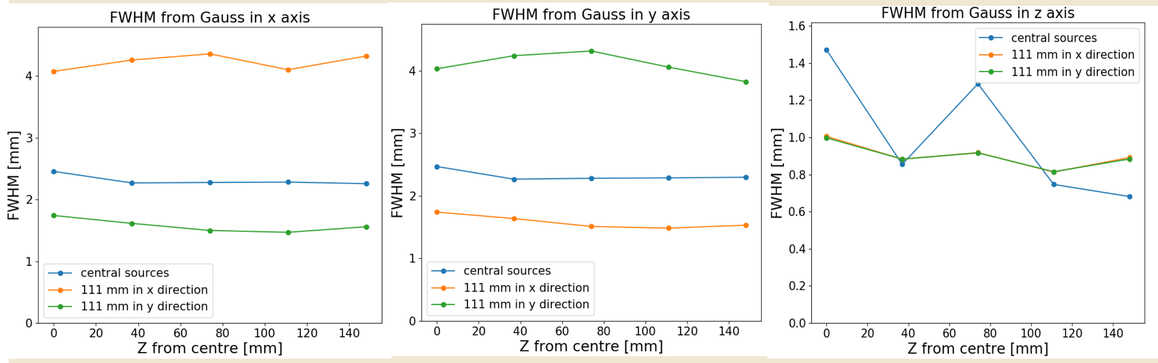

***Figure 7**: Spatial resolution dependence on axial position at set x and y values.*

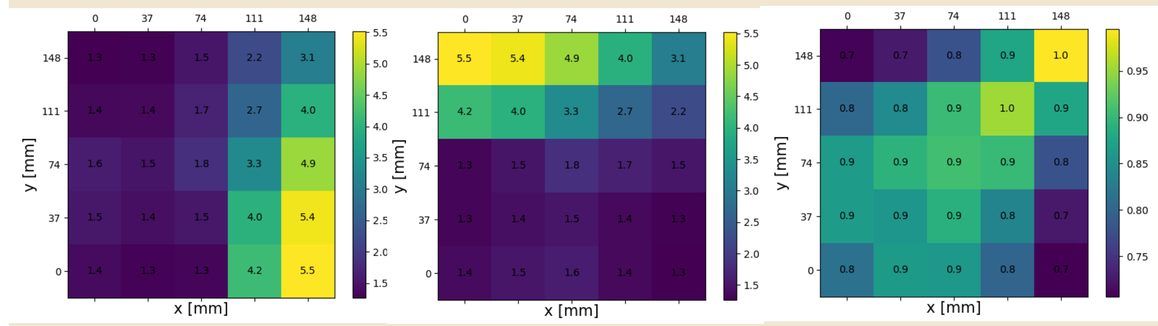

***Figure 8**: Spatial resolution results like on figure 6, but in this case for crystal width 1.5 mm and crystal pitch 2 mm.*

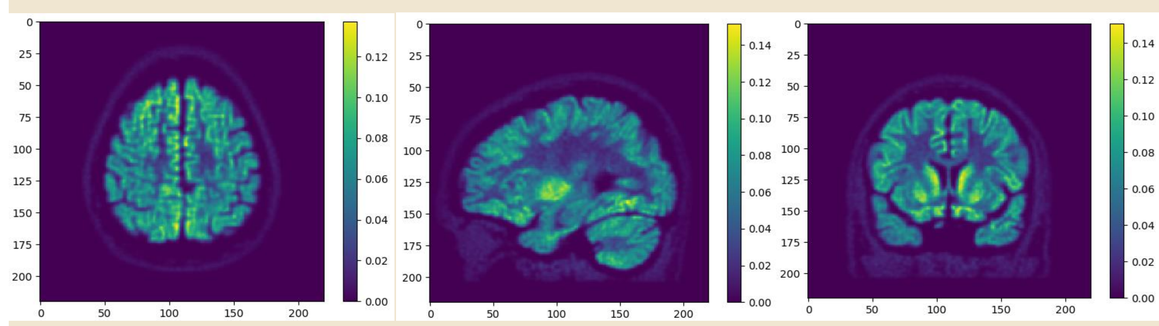

***Figure 9**: Images of a brain phantom [4], obtained using the scanner with 3 mm wide crystals with a 1 mm filter.*

CONCLUSIONS

- A method to estimate the spatial resolution of flat panel, open geometry PET scanner was developed.
- For a scanner with 3 mm wide crystals resolution of 1.3 to 5.3 mm in x and y direction was obtained. It degraded towards the edges of the scanner, but also at the very centre. In the axial direction the resolution ranged from 0.7 to 1.5 mm with the biggest degradation in the centre of the FOV.
- The method will be further developed and verified with simulations of a clinical scanner.
- Scanner performance will be evaluated with the image quality metric as specified by the NEMA standard. [3]

REFERENCES

*[1] **Razdevsek, G., et al.** (2021). Multi-panel limited angle PET system with 50 ps FWHM coincidence time resolution: a simulation study. In IEEE Transactions on Radiation and Plasma Medical Sciences.*
*[2] **Surti, S., et al.** (2008). Design considerations for a limited angle, dedicated breast, TOF PET scanner. In Physics in Medicine and Biology (Vol. 53, Issue 11, pp. 2911–2921). IOP Publishing.*
[3] Performance Measurements of Positron Emission Tomographs (PET). NEMA Standards Publication NU 2-2018
*[4] **Belzunce, M. A., et al.** (2020). Technical Note: Ultra high-resolution radiotracer-specific digital pet brain phantoms based on the BigBrain atlas. In Medical Physics*

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