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PSI

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Monte-Carlo simulations for the PETITION PET scanner

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PETITION

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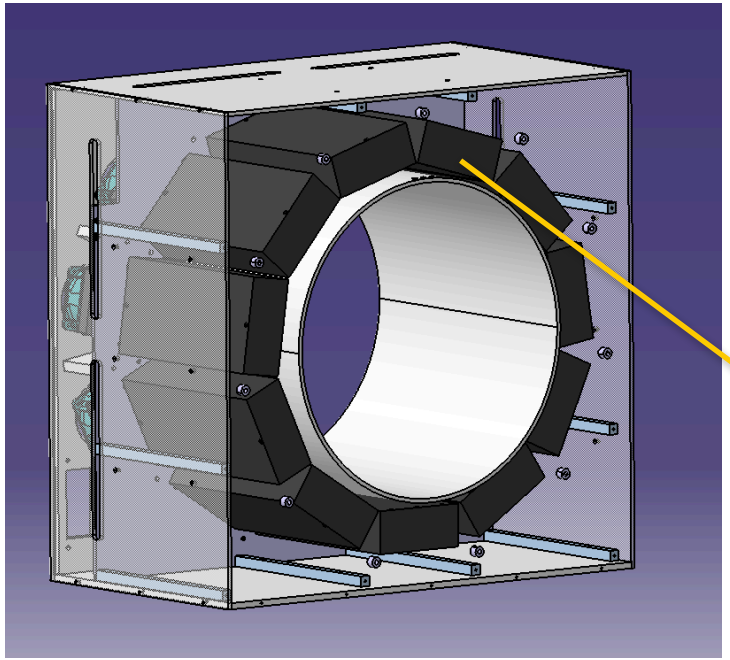
Overview

- What is PETITION?
- PETITION scanner modelling in GATE
- Sensitivity and spatial resolution studies
- Conclusion and outlook

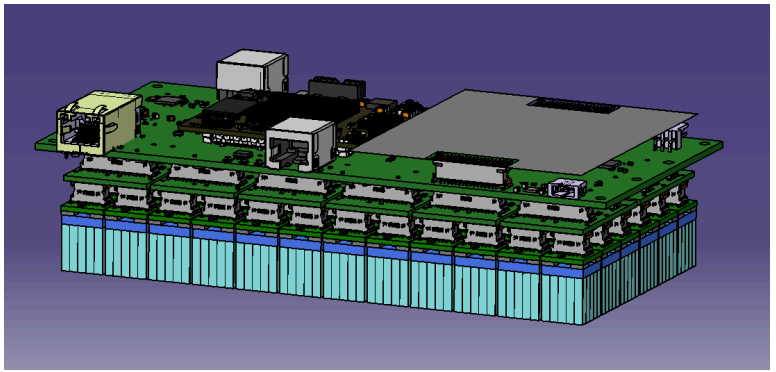
PETITION

- PETITION (PET for InTensive care units and Innovative protON therapy), collaboration between ETH Zürich, CHUV, and PSI



PETITION PET scanner for CHUV

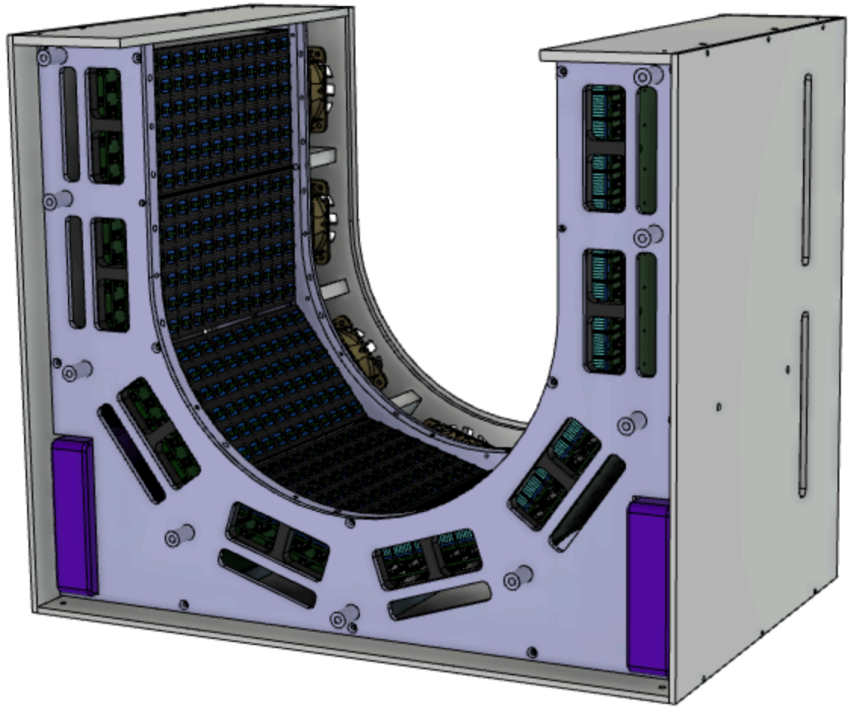
- Design of a modular PET detector by ETH
- For patients under anaesthesia at CHUV
- For range verification and biologically guided proton therapy at PSI



Module of the PETITION scanner

PETITION project at PSI

- Opening for proton beam
- Mounted on patient table in Gantry 2
- On-line imaging of patient activation
- Phantom and head rest have to fit
- Can be rotated in steps of 90°

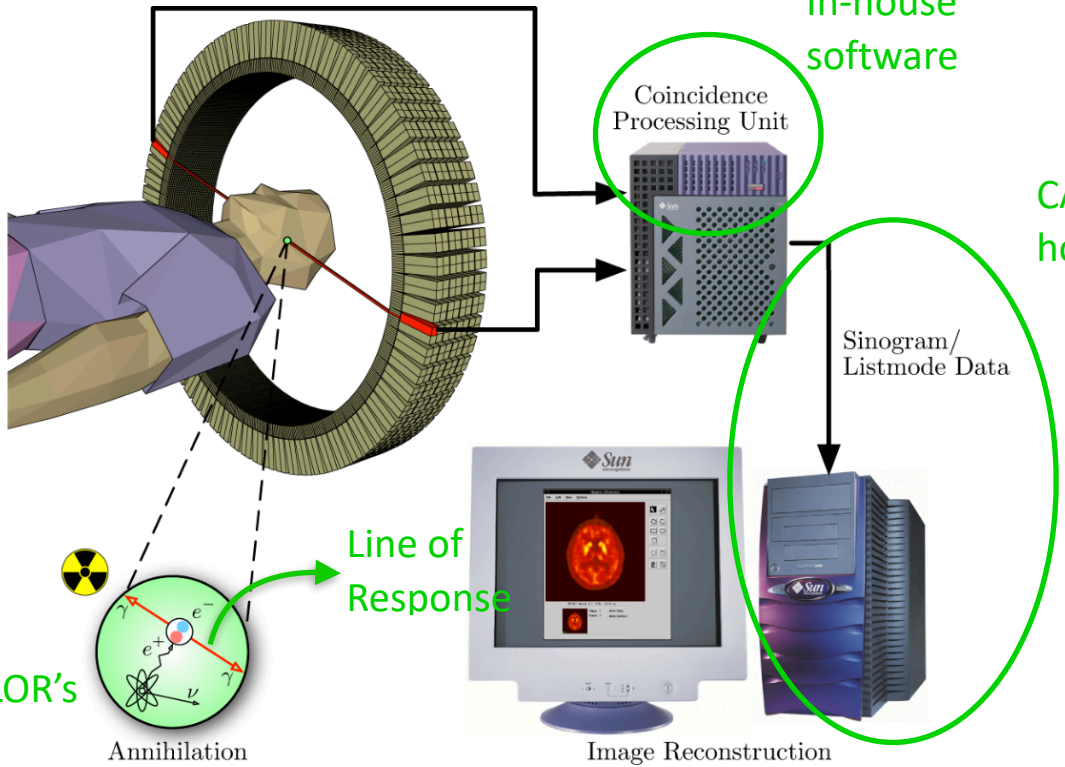


PETITION scanner for PSI

Motivation for PETITION scanner

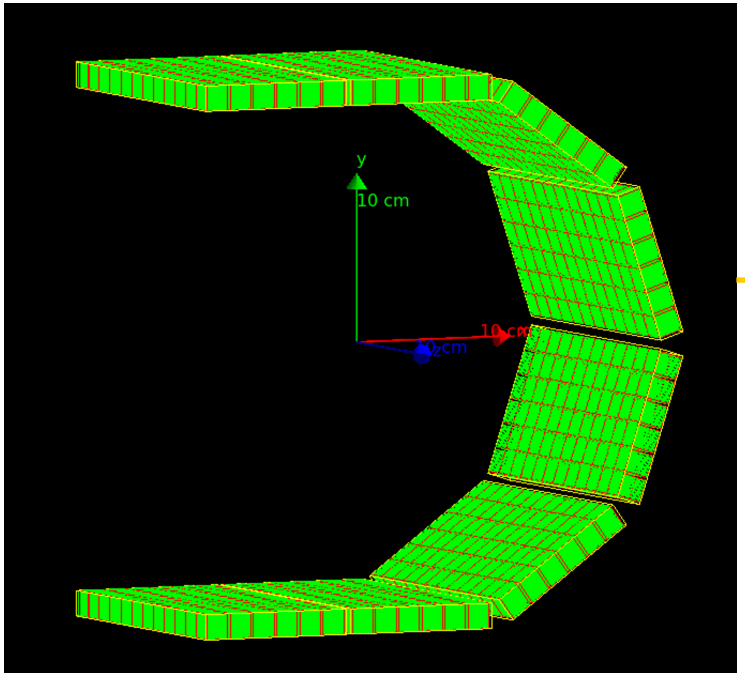
- CT & MRI are used for anatomical imaging in radiotherapy.
- PET (functional imaging) is used for molecular imaging and quantification.
- PETITION scanner for guiding proton therapy treatment.
    1. For range verification using the proton beam activation.
    2. For hypoxia guided treatment by imaging hypoxia using the PET scanner.

Positron Emission Tomography



Source: [1]

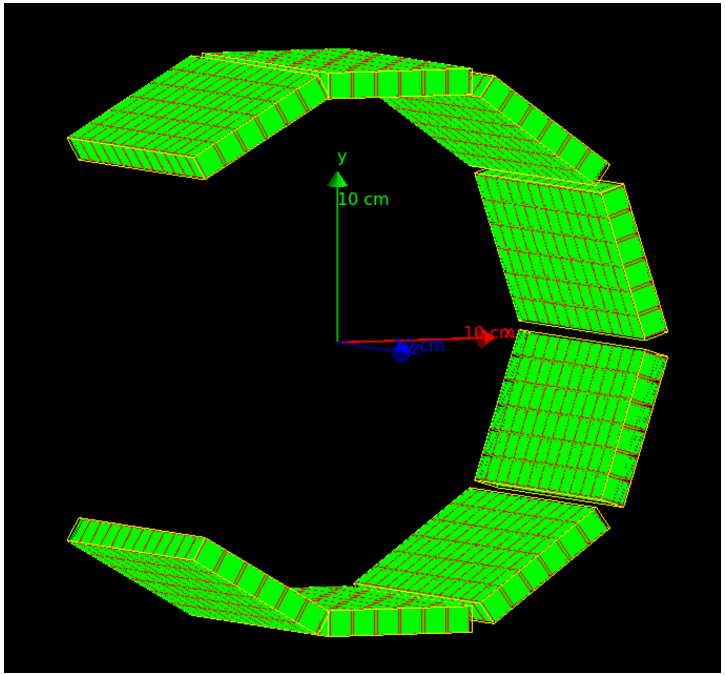
Scanner modelling in GATE (v8.2)



Initially proposed PETITION design

Opening: 29.5 cm

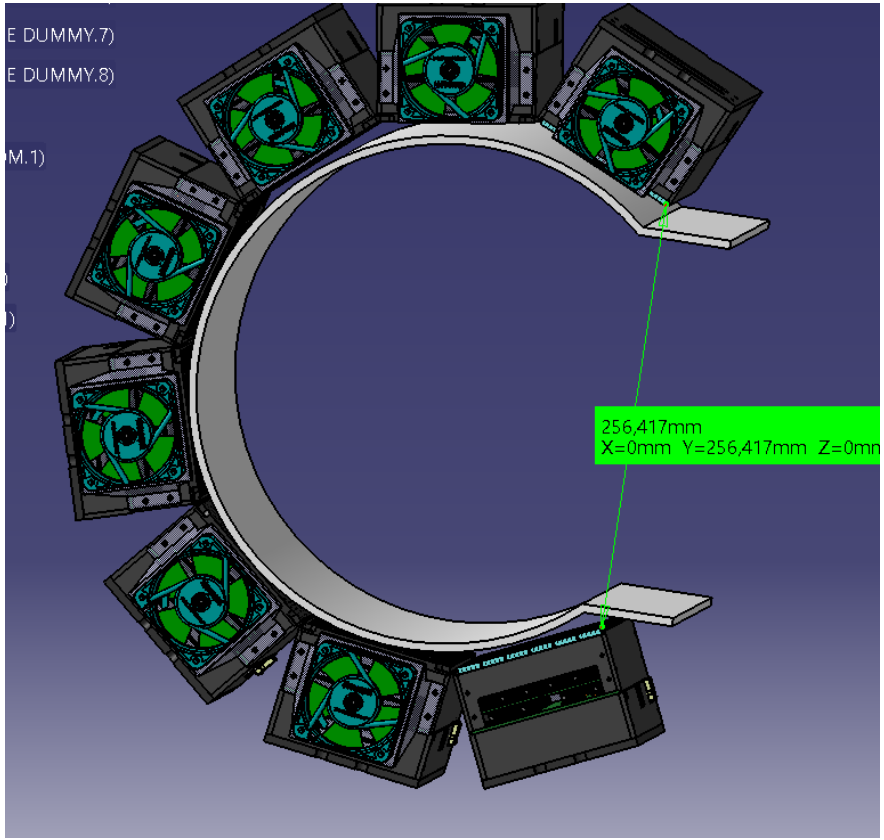
Tilted outer modules



PETITION new design

Opening: 25.6 cm

PETITION new design parameters



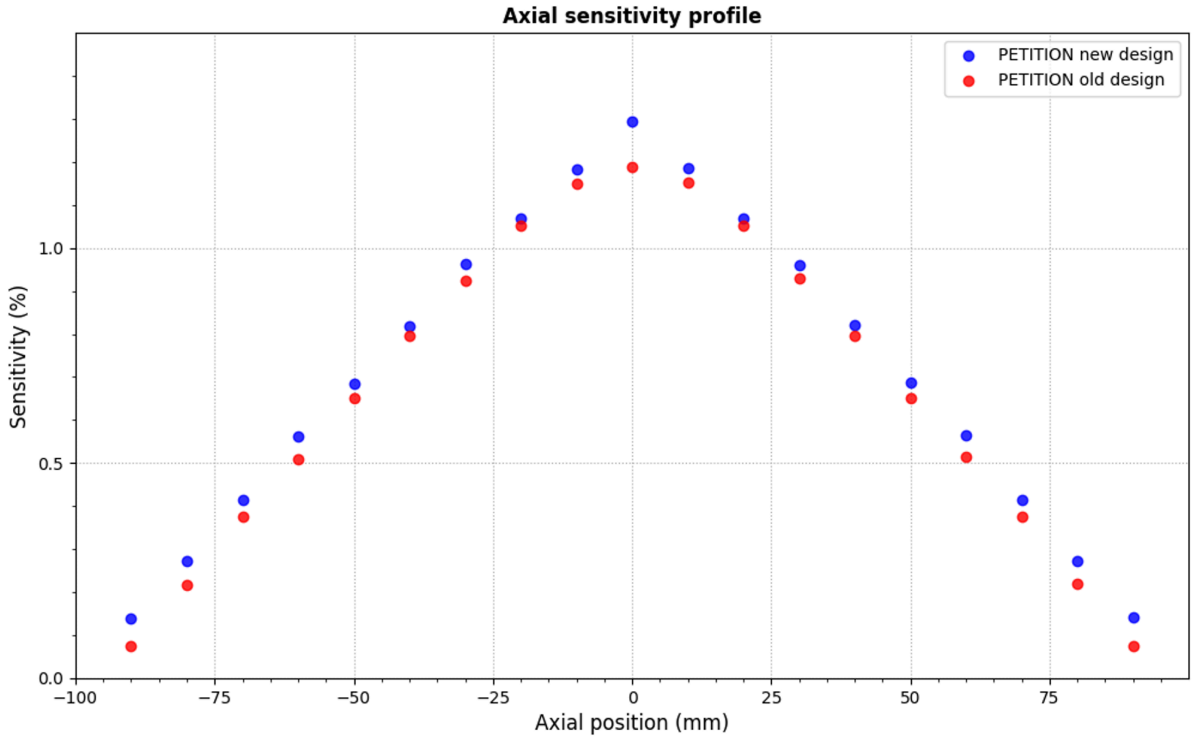
Opening: 25.6 cm

- 32.3 cm crystal-to-crystal distance
- 8 modules
- Crystal dimensions: 2.73 x 2.73 x 15 mm^3
- 17.9 cm Axial Field of View (FOV)
- Aimed for the Head and Neck region

Performance parameter: Sensitivity

- Detected count rate per unit of activity.
- Practical limitations on injected activity and acquisition time.
- Source : Point Na^{22} (r = 0.3 mm)
- Phantom: Plastic cube of dimensions 10 x 10 x 10 mm^3
- 1 MBq source activity and acquired for 50 seconds at each axial position
- Energy Window: 391-601 KeV, Coincidence Timing Window: 2 ns

Axial sensitivity profiles



Sensitivity comparison

Geometry	Absolute Sensitivity (%)	
	Z = 0 mm	Z = 50 mm
PETITION initial design	1.15	0.65
PETITION new design	1.3	0.69

Performance parameter: Spatial Resolution

- Ability of a PET scanner to distinguish the fine details.
- Source : Point Na^{22} (r = 0.3 mm)
- Phantom: Plastic cube of dimensions 10 x 10 x 10 mm^3
- 1 MBq source activity and acquired for 50 seconds at the center of the FOV
- Reconstructed PET image in CASToR, OSEM algorithm (12 iterations, 4 subsets, no filtering)

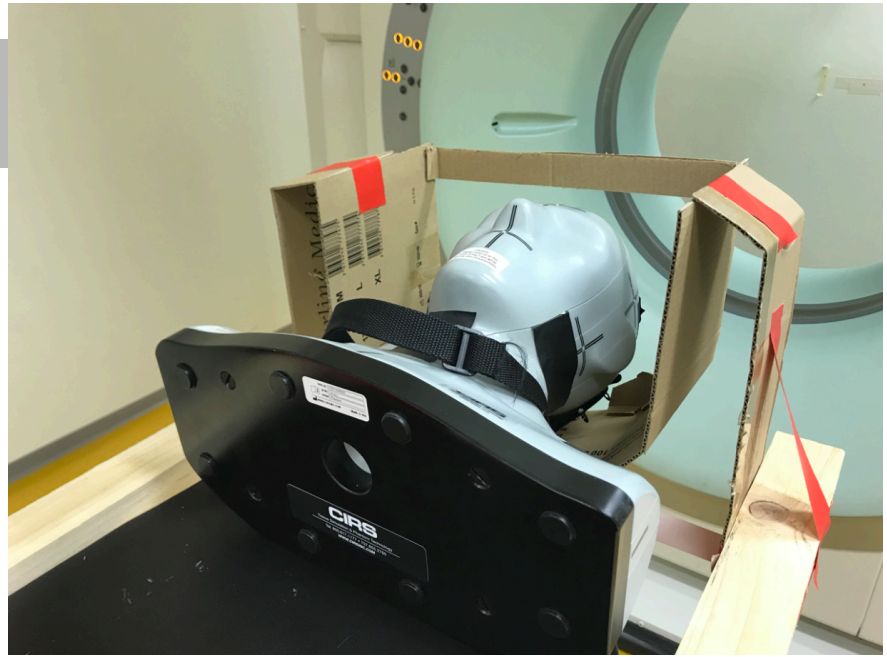
Spatial Resolution comparison

Geometry	Spatial Resolution FWHM (mm) r=0		
	Radial	Tangential	Axial
PETITION initial design	2.39	3.33	2.65
PETITION new design	1.95	2.70	2.71

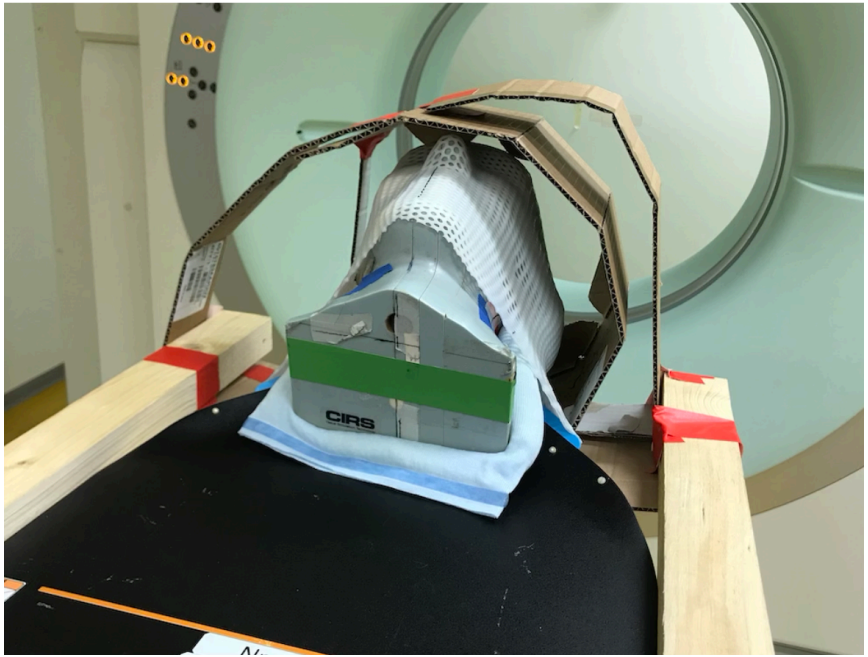
Clinical studies for the scanner design

- To verify the feasibility of the detector design in the clinics.
- Recalculate clinical treatment plans with surrounding mock-up of the scanner.
- Generate such a mock-up in GATE.
- Determine the required opening and diameter.

Scanner modelling- clinical studies

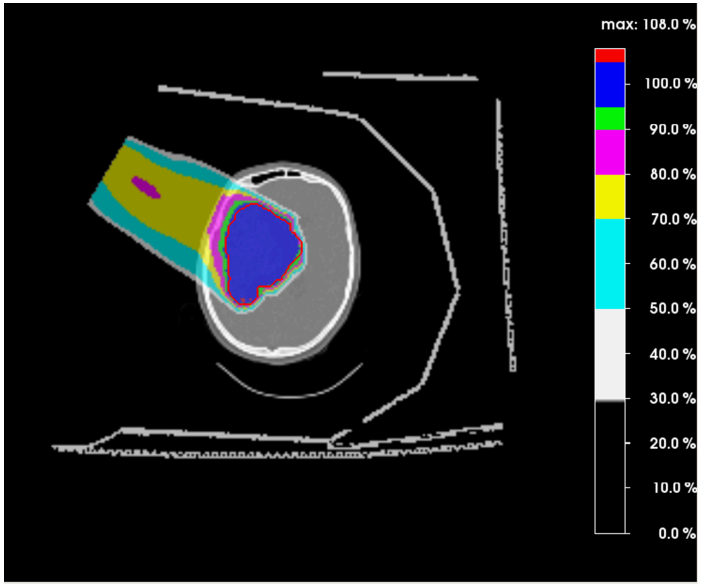


Cardboard mock-up of the U-geometry

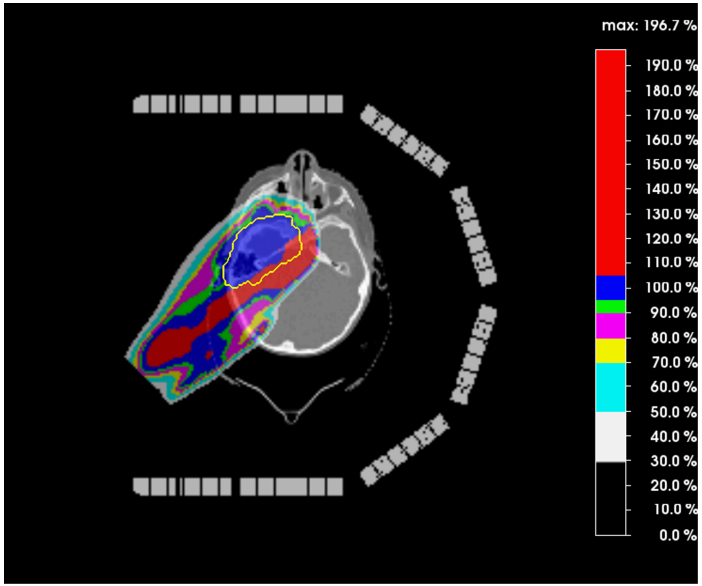


Cardboard mock-up of the new geometry

Clinical studies: results



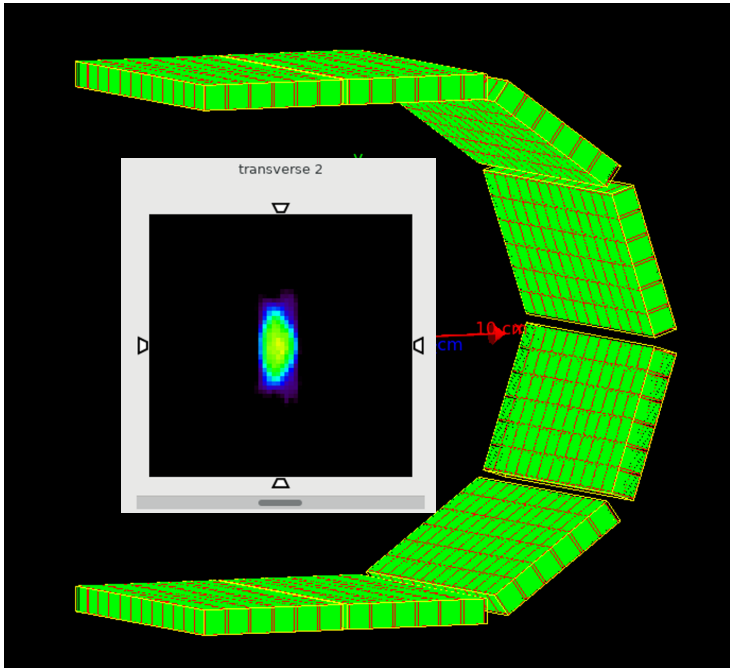
U-design of the PETITION scanner (CT)



U-design of the PETITION scanner (Mu-Map actor in GATE)

PETITION image reconstruction

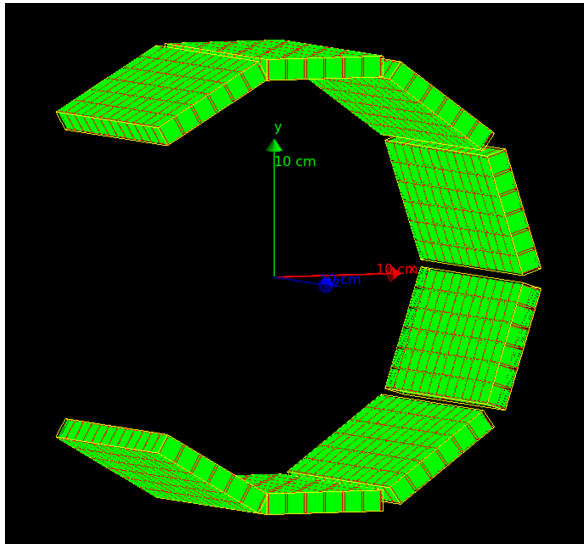
- Simulated water cylinder in GATE for 40 seconds
- Water cylinder filled with uniform activity
- Reconstructed in CASToR
- OSEM algorithm (4 subsets, 12 iterations, no filtering)
- Deep Learning based methods to improve the reconstructed image



Reconstructed water cylinder

Conclusion and outlook

- The simulation to reconstruction workflow has been setup using GATE, CASToR/in-house reconstruction software.
- Performance characteristics have been studied for different modelled geometries to finalise the design.
- Peak sensitivity of 1.3 % and spatial resolution ~ 2.5 mm FWHM at the center of FOV.
- Further improvement in image reconstruction using Deep Learning methods for such scanners.



Finalised PETITION design

Thank you

- Questions/Comments/ Feedback?

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References

[1] J. Langner, “Development of a parallel computing optimized head movement correction method in positron emission tomography,” Master’s thesis, University of Applied Sciences Dresden and Forschungszentrum Dresden-Rossendorf, 2003.