

PAUL SCHERRER INSTITUT



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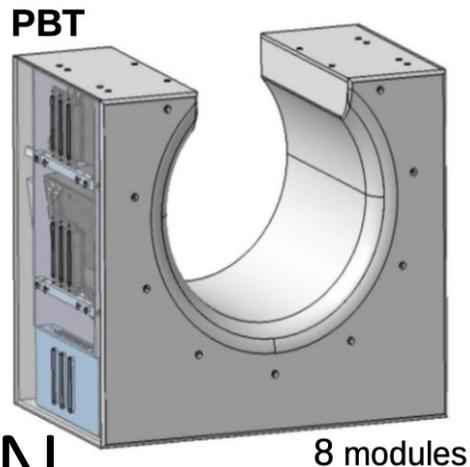
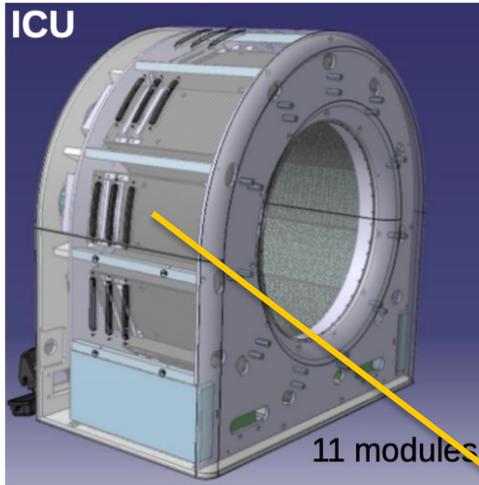
Monte-Carlo simulations for the in-beam PETITION PET scanner

Geant4 International User Conference, October 25, 2022

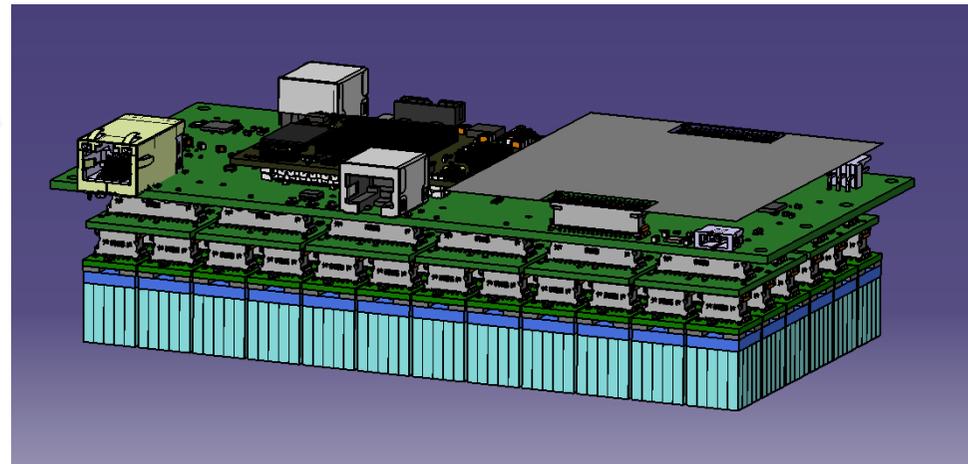


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PETITION



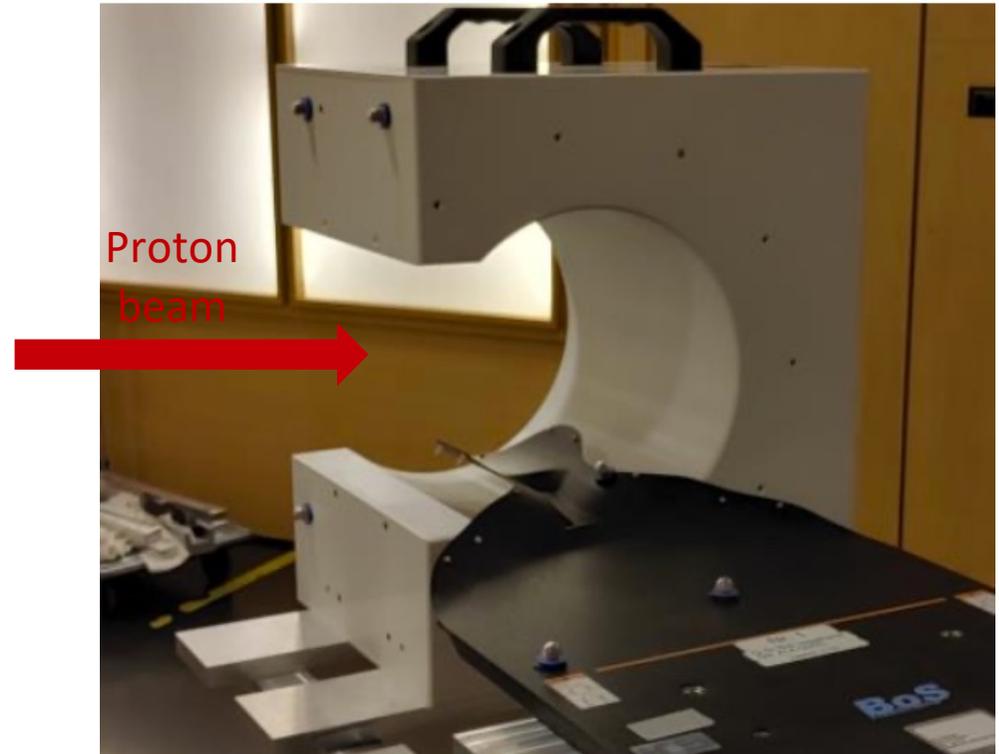
- PETITION (PET for InTensive care units and Innovative protON therapy), collaboration between ETH Zürich, CHUV, and PSI.
- Design of a modular PET detector by ETHZ.
- For patients under anaesthesia at CHUV.
- **For range verification and biologically guided proton therapy at PSI.**



Module of the PETITION scanner

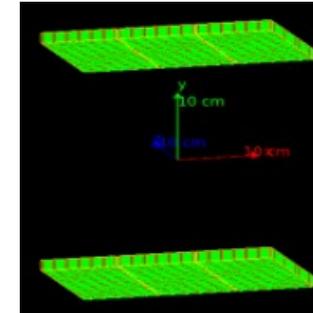
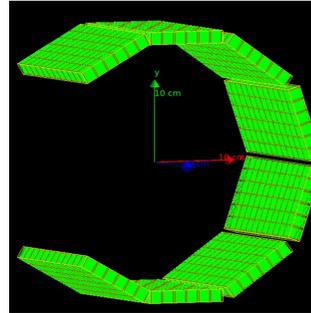
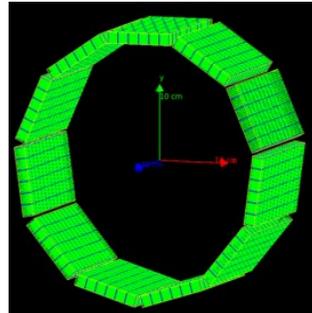
PETITION project at PSI

- 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°



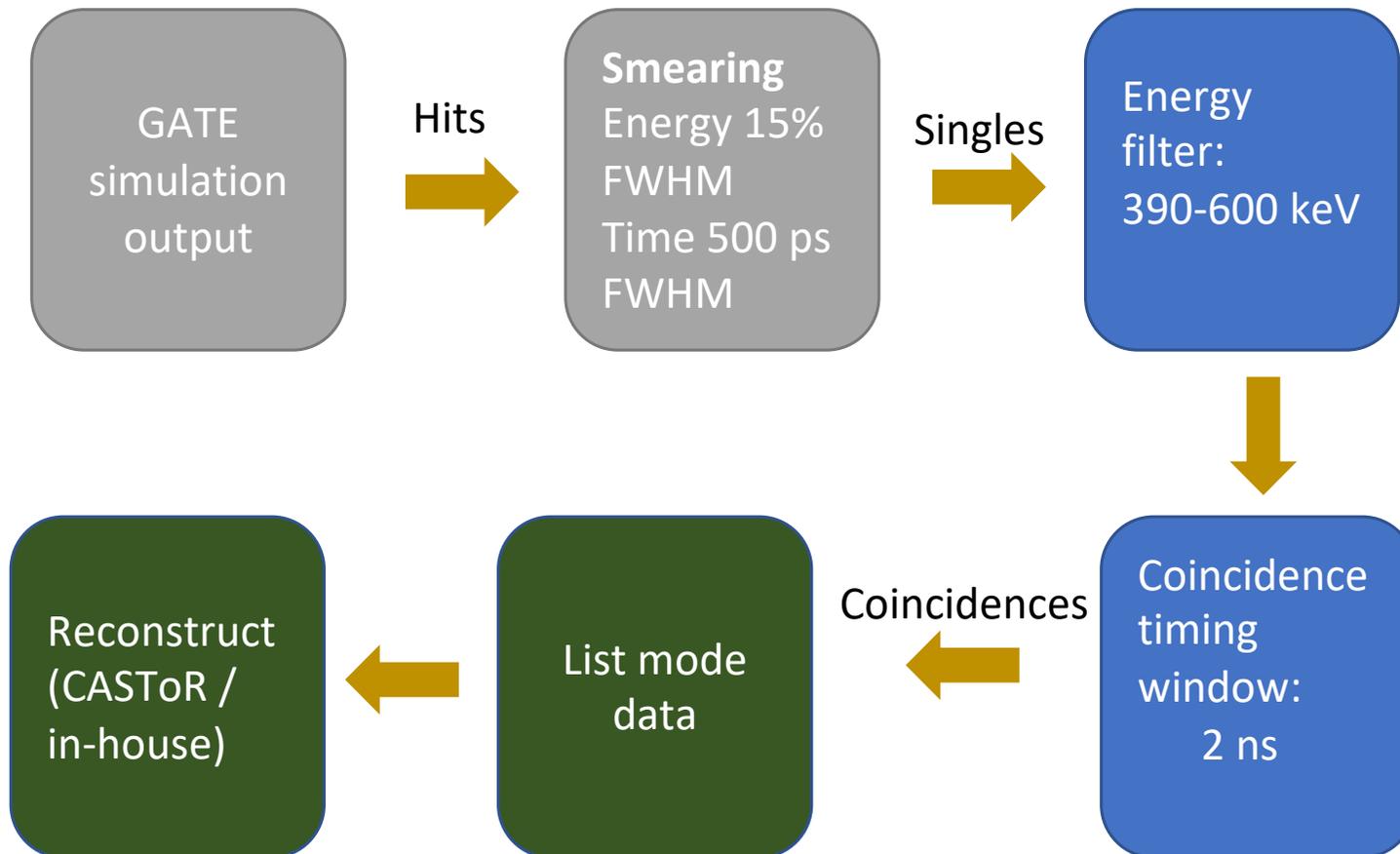
Mock-up of the PETITION scanner for PSI

Scanner modelling in GATE (v8.2)



Geometry	Ring PETITION (CHUV)	PETITION	DUAL HEAD PETITION
Number of modules	11	8	6
Crystal per module	1800	1800	1800
Crystal dimensions	$2.74 \times 2.74 \times 15 \text{ mm}^3$	$2.74 \times 2.74 \times 15 \text{ mm}^3$	$2.74 \times 2.74 \times 15 \text{ mm}^3$
Scanner opening	0 mm	256 mm	322 mm
Radial extent	161.3 mm	161.3 mm	161.3 mm
Axial FOV	179 mm	179 mm	179 mm

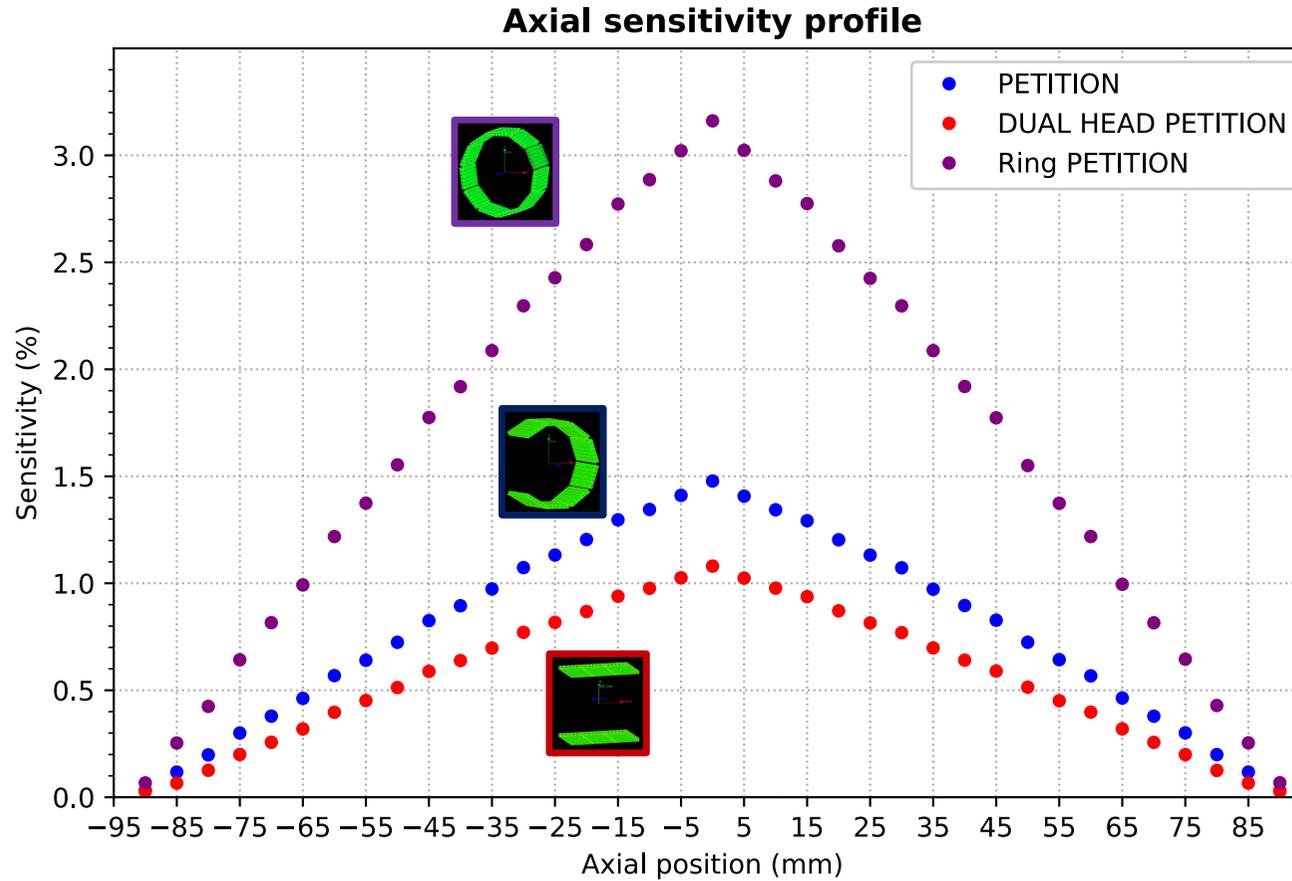
Data Processing Chain



Performance parameter: Sensitivity

- Detected count rate per unit of activity.
- Practical limitations on injected activity and acquisition time.
- Source: Point Na^{22} ($r = 0.3 \text{ mm}$)
- Phantom: An acrylic cube of dimensions $10 \times 10 \times 10 \text{ mm}^3$
- Source activity: 1 MBq
- Acquisition time: 50 seconds at each axial position

Axial sensitivity profile comparison



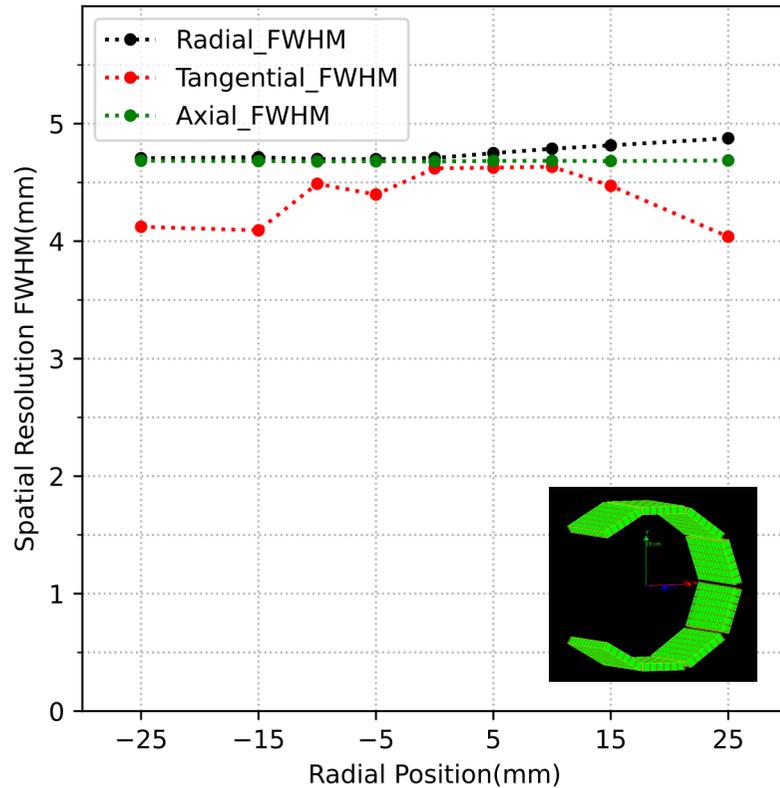
Performance parameter: Spatial Resolution

- Ability of a PET scanner to distinguish the fine details.
- Source: Point Na^{22} ($r = 0.3 \text{ mm}$)
- Phantom: An acrylic cube of dimensions $10 \times 10 \times 10 \text{ mm}^3$
- Axial positions: $[-45, 0, 45] \text{ mm}$
- Radial positions: -50 to 50 mm
- Source activity: 1 MBq and acquisition time: 50 seconds
- Reconstructed PET image: OSEM algorithm (12 iterations, 4 subsets, no filtering)

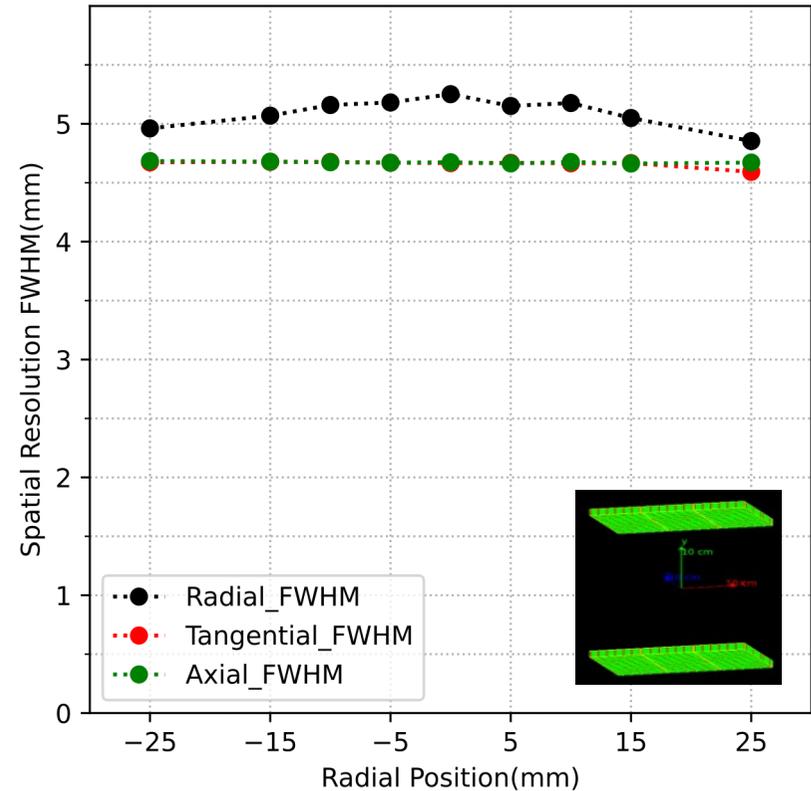


Spatial Resolution comparison at axial center

Spatial Resolution for PETITION

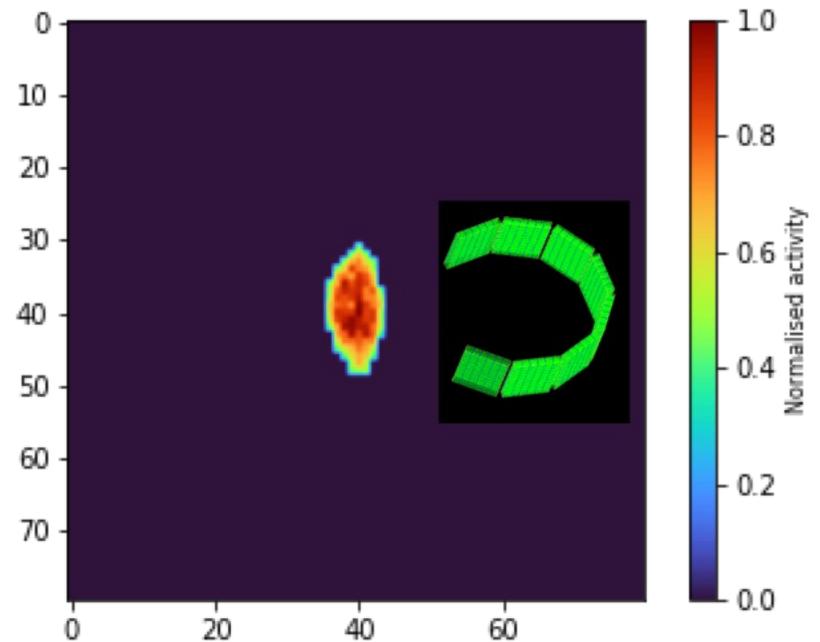


Spatial Resolution for DUAL HEAD PETITION



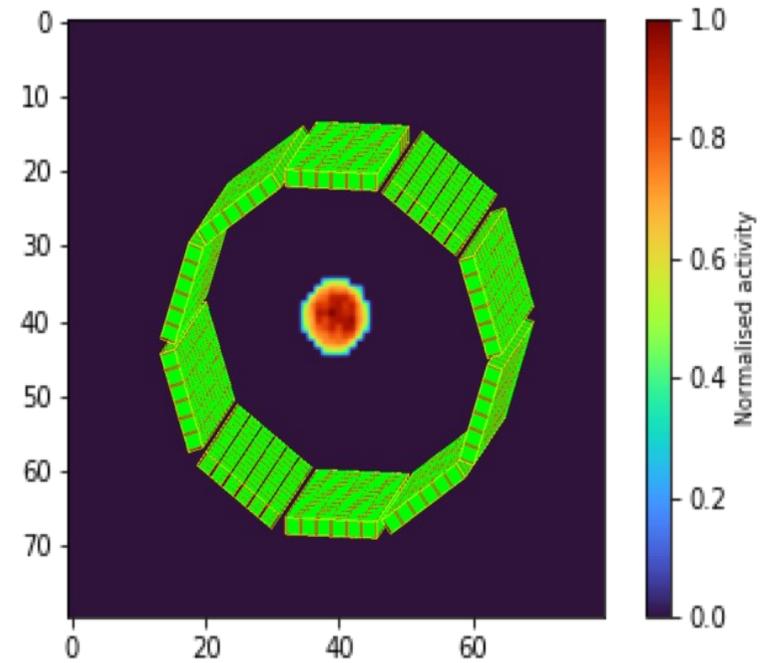
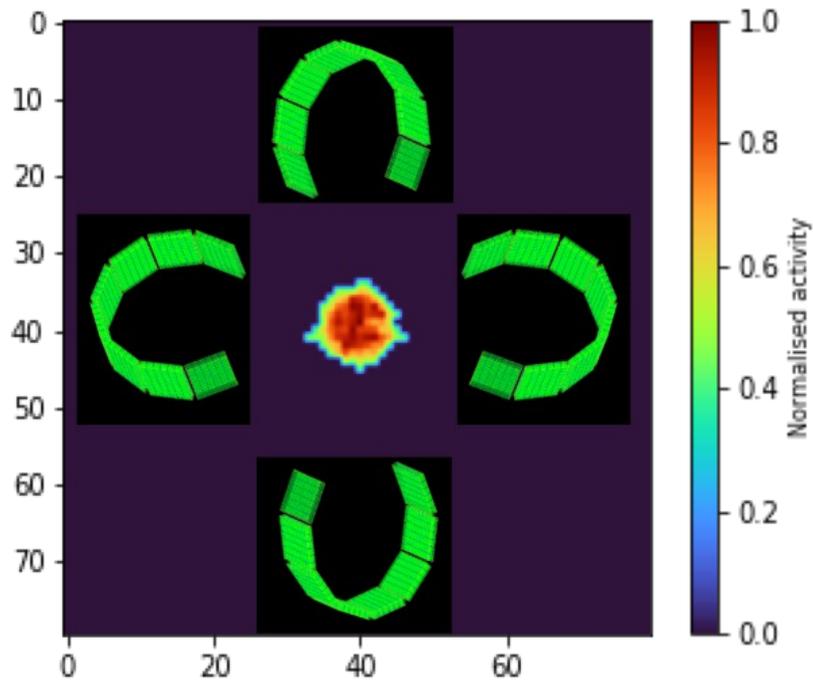
PETITION image reconstruction

- Simulated water cylinder in GATE for 40 seconds.
- Water cylinder filled with uniform 1 MBq activity.
- Placed at the axial center.
- Reconstructed PET image: OSEM algorithm (4 subsets, 12 iterations, no filtering)



Reconstructed water cylinder
with one position of PETITION
scanner

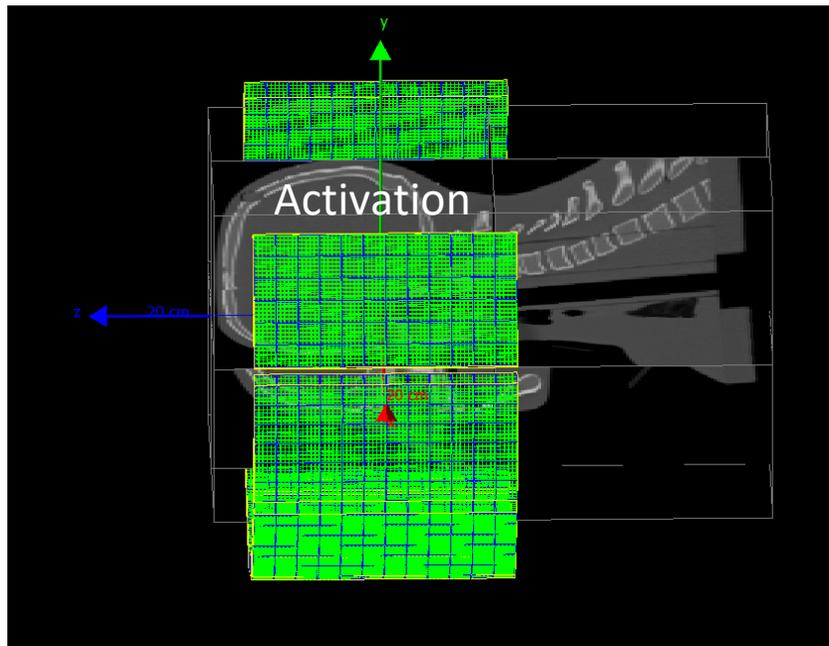
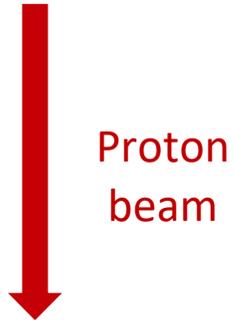
PETITION image reconstruction



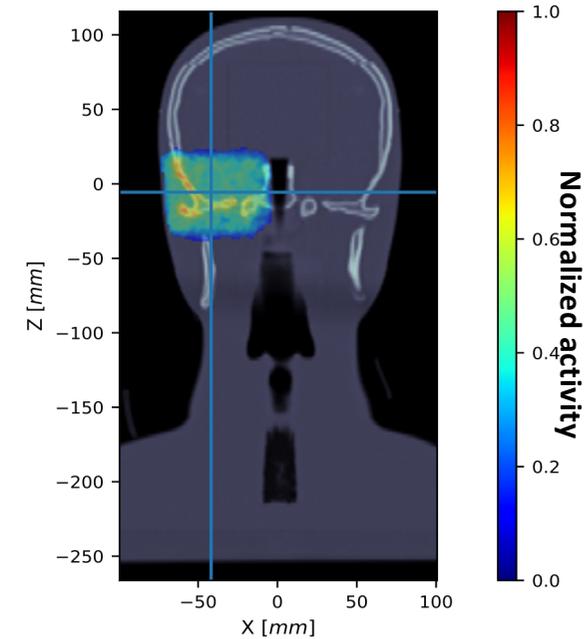
SSIM : 0.97

(Structural Similarity Index Measure)

Phantom activation

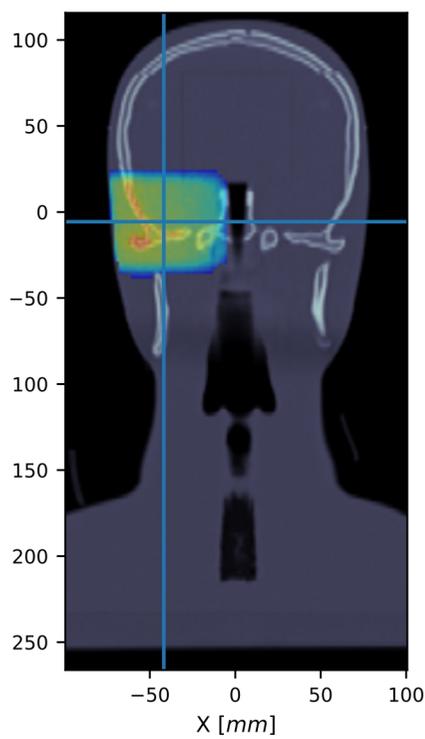


Istopes scored:
 ^{10}C , ^{11}C ,
 ^{38}K , ^{13}N ,
 ^{15}O , ^{30}P ,
 ^{14}O

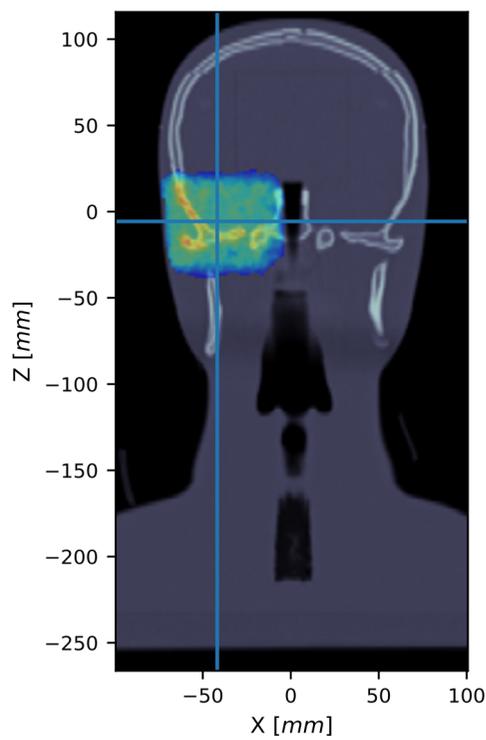


Reconstructed image

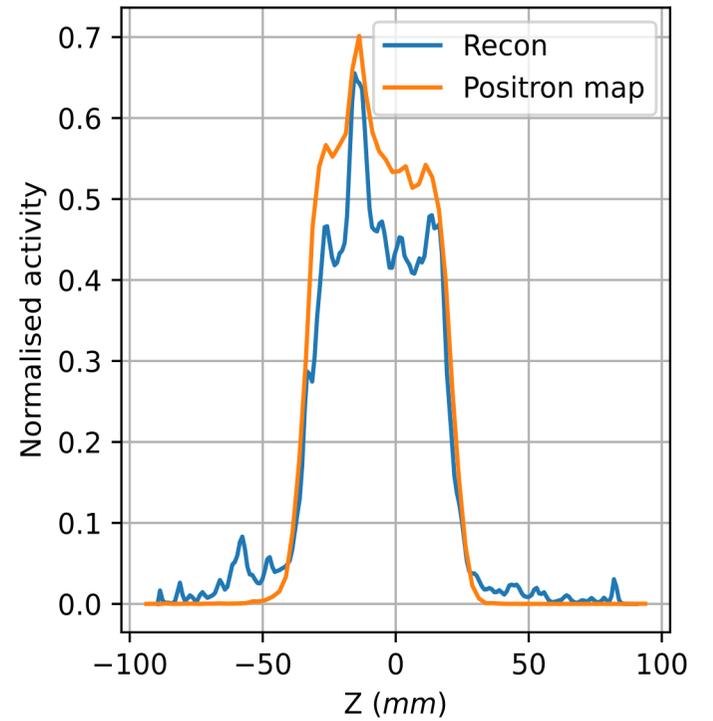
Phantom activation reconstruction



Positron stopping map



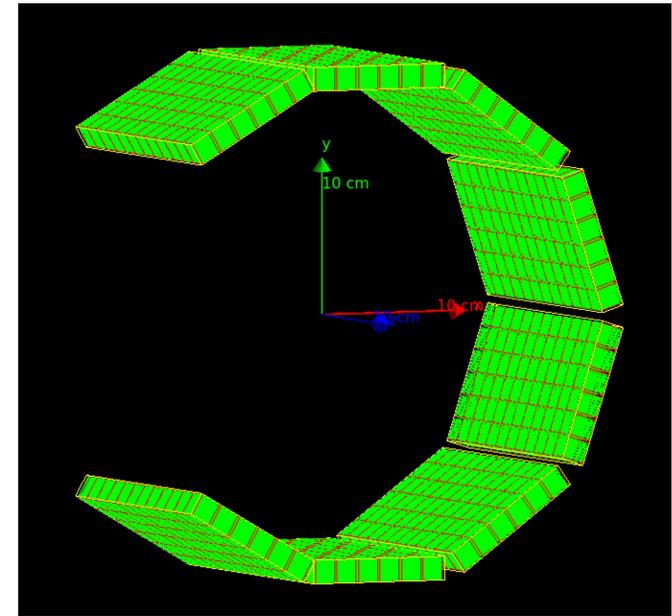
Reconstructed image



Activity profile comparison

Conclusion and outlook

- The simulation to reconstruction workflow for the open ring geometry has been setup using GATE, CASToR.
- Performance characteristics have been studied and compared against conventional dual head geometry.
- Simulation to activation reconstruction workflow has been simulated.
- Further improvement in image reconstruction using Deep Learning methods for non-conventional PET scanners.



Thank you

- Questions/Comments/
Feedback?

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