First images from the next-generation UHR human brain PET scanner

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Mediterranean Thematic Workshops in Advanced Molecular Imaging

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IR&T Imaging Research and Technology

Introduction

Background: Little progress was made during the last decades to improve the spatial resolution of brain PET scanners, even though the achieved state-of-the-art is far worse than the theoretical limit.

Aim: Develop an ultra-high-resolution (UHR) PET scanner for human brain imaging at the physical spatial resolution limit.

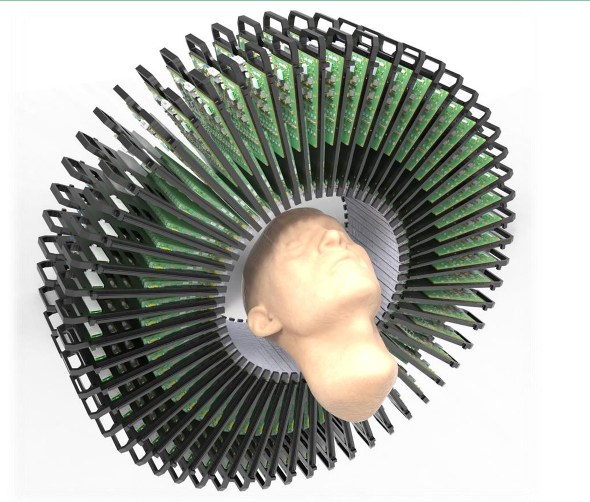
Method:

- ✓ Field-proven LabPET-II technology platform
- ✓ Truly pixelated detectors featuring 1:1:1 coupling of scintillator, photodetector, and electronic readout
- ✓ Single events data acquisition via Gigabit Ethernet links
- ✓ Software flexible real-time coincidence engine to sort list-mode data
- ✓ 3D-OSEM reconstruction with precomputed polar system matrix

System Description

Design parameters

Ring diameter	398 mm
Axial length	235 mm
Patient opening	355 mm
Transaxial FOV	300 mm
Detectors per ring	896
Nb of rings	144
Nb of pixels & channels	129,024
Nb of coincidence LORs	~16×10⁹

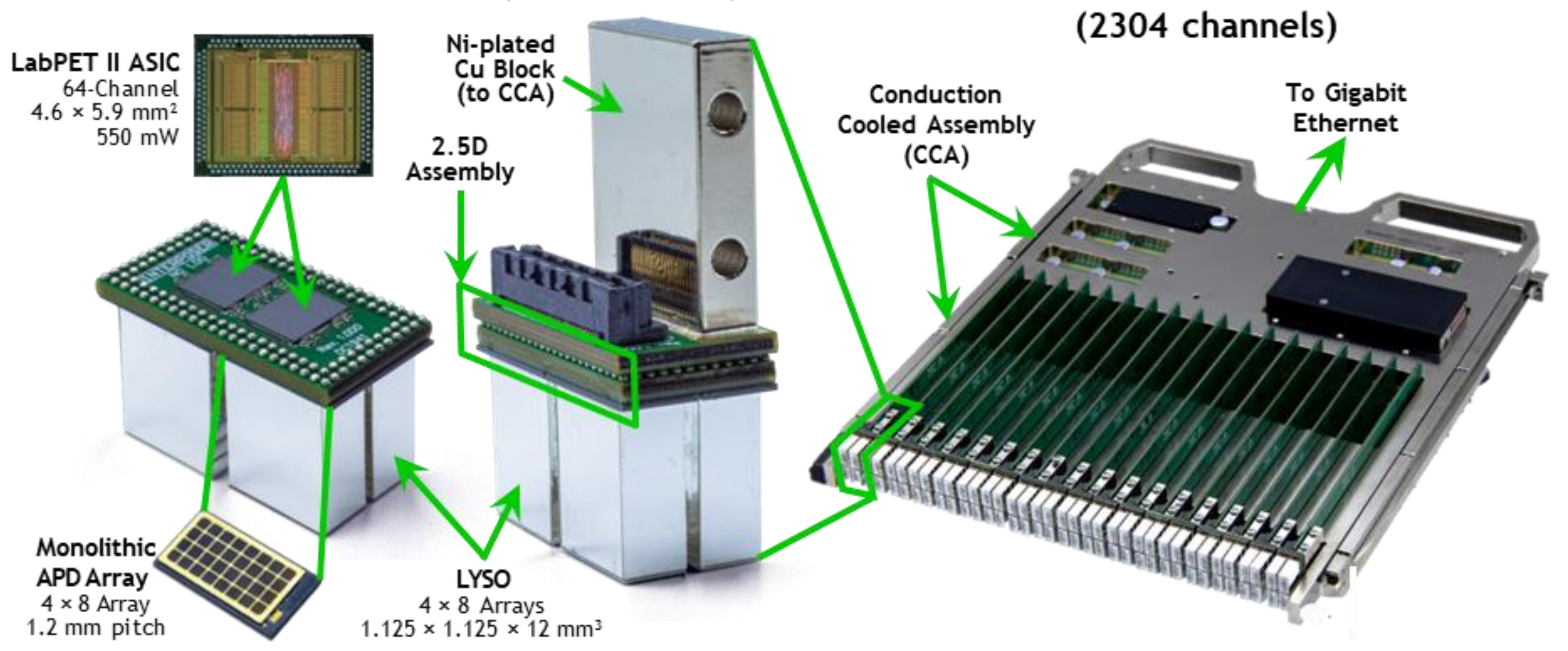


Target Performance

Spatial resolution (250-650 keV)	
Center	1.25 mm
10 cm offset	< 2.5 mm
Absolute sensitivity	> 3.5%
Time resolution	< 3 ns
Time window	< 6 ns
Energy resolution	< 25%
Dead time	490 ns

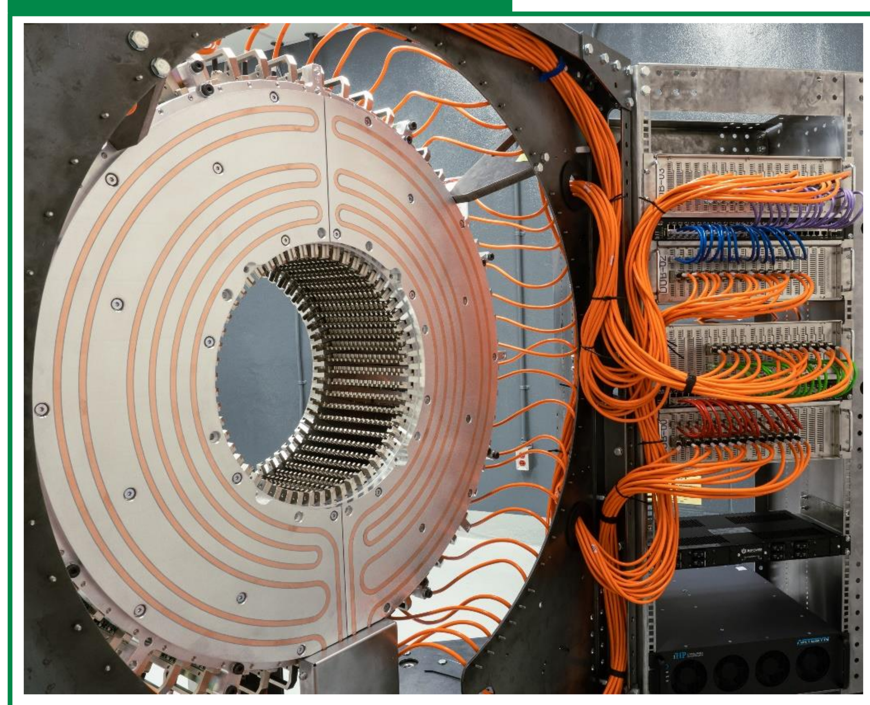
Detection Front-End

UHR Detection Module (128 channels) **UHR Detection Cassette** (2304 channels)



Details of the UHR detection module and cassette showing the basic components for fully parallel signal processing and heat extraction by conduction cooling.

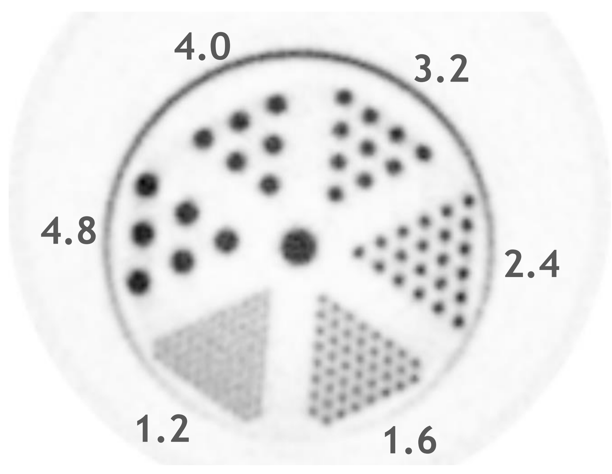
Current Status



11/18 rings of detector modules
→ 143 mm axial FOV
→ 78,848 pixel detectors
→ Absolute sensitivity: 1.2%

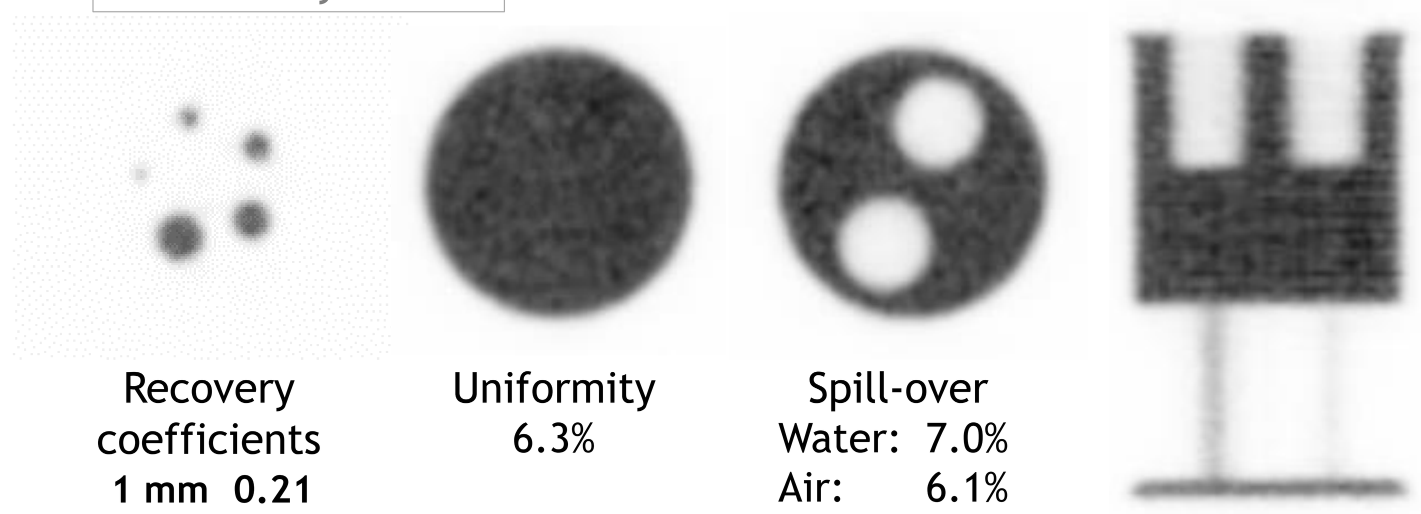
UHR scanner during assembly showing the water-cooled cold plates for heat extraction (*left*), the Gigabit Ethernet links for single events data acquisition and the partially populated detector rings (*right*).

Physical Performance



Raw image of Mini Deluxe resolution phantom at the FOV center (no normalization for detector efficiency and no corrections)

Preliminary results



Recovery coefficients	
1 mm	0.21
2 mm	0.56
3 mm	0.70
4 mm	0.80
5 mm	0.84

Uniformity 6.3%

Spill-over Water: 7.0% Air: 6.1%

Image of NEMA Image Quality phantom at the FOV center, all corrections applied (8 subsets, 8 iterations, 0.6 mm voxels)

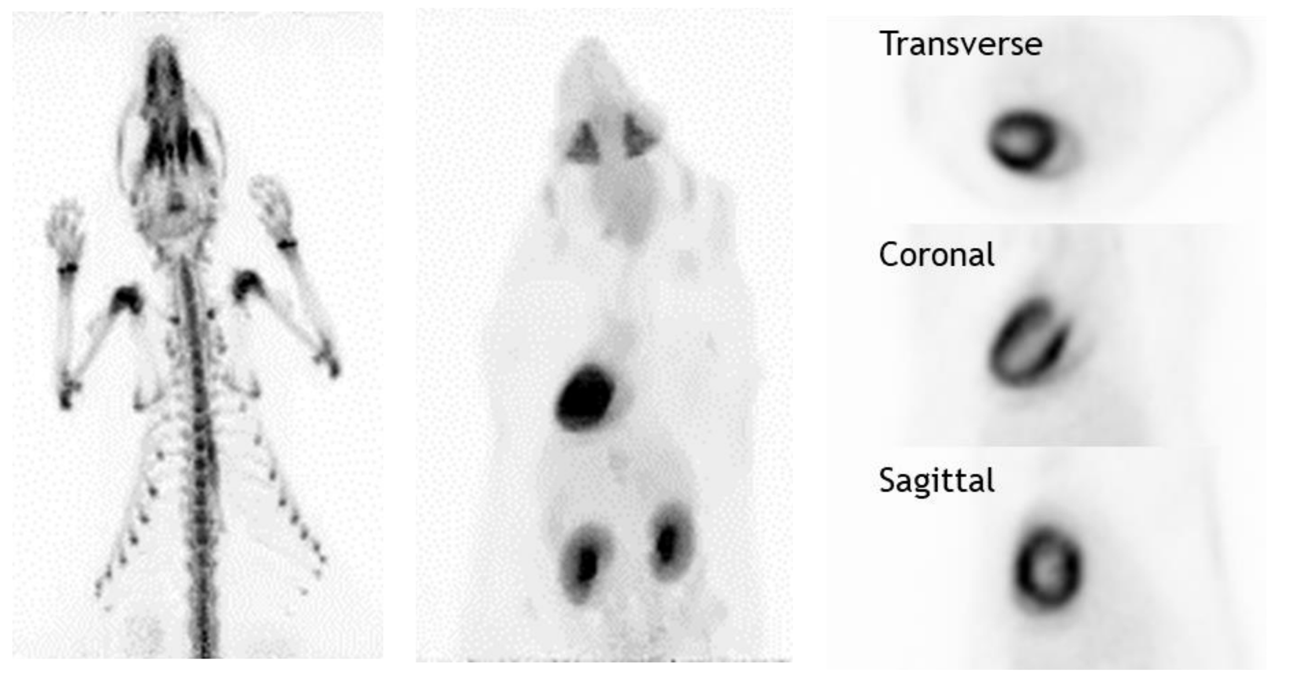
Preclinical Imaging

MIP images of rats injected with 36 MBq Na[18]F (*left*) and 20 MBq [18]F-FDG (*middle & right*), both acquired for 60 min at 40 min p.i.

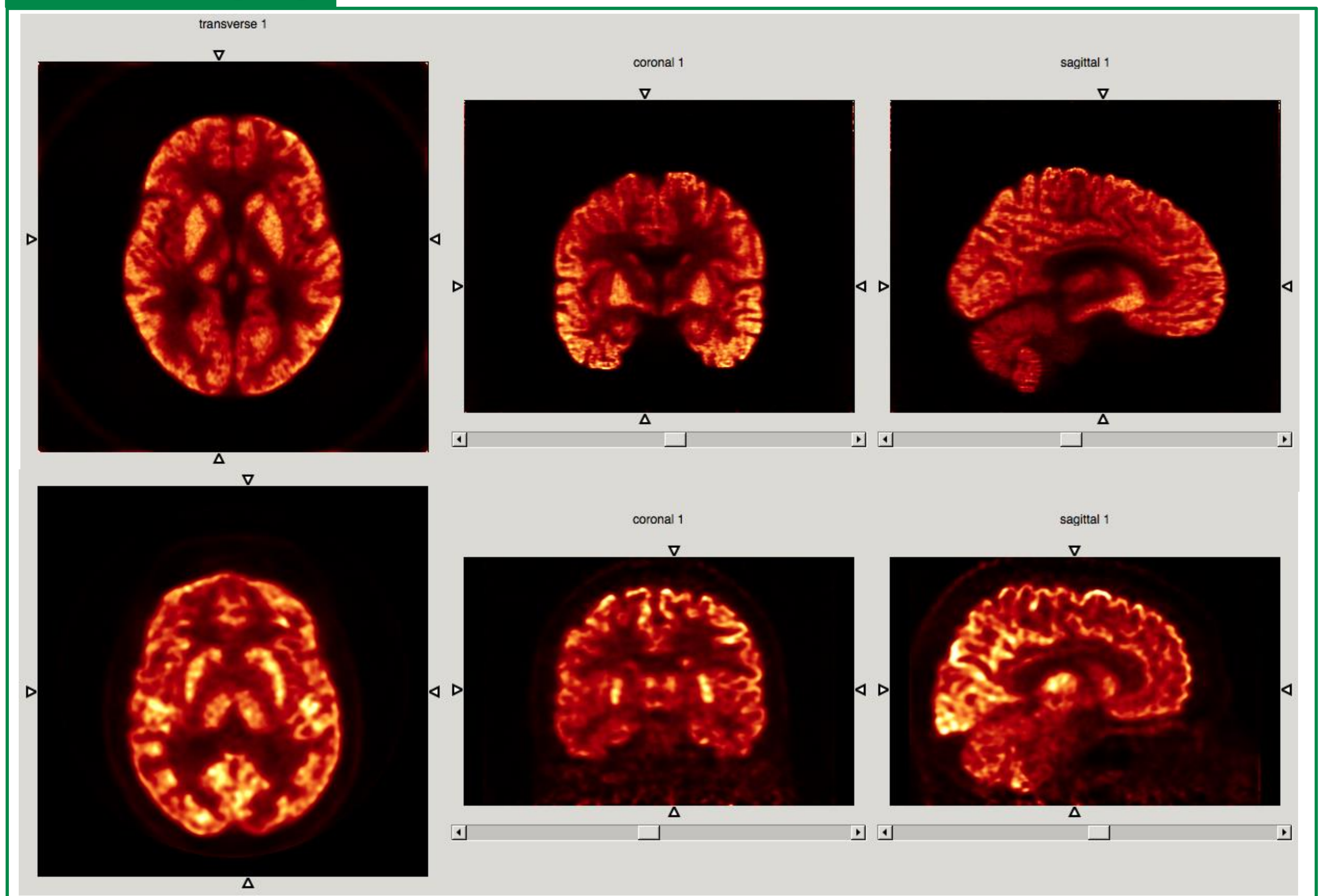
The right panel shows orthogonal planes through the heart of the rat injected with [18]F-FDG.

Highlights:

- Clearly resolved bone structures
- Differentiation of medullary and cortical kidney
- Clearly resolved non-gated left/right myocardium and ventricles



Brain Imaging



Top: GATE simulation of [18]F-FDG brain uptake using the histology-based BigBrain atlas (596 × 10⁶ events, CASToR 3D-MLEM reconstruction, 0.4 mm voxels, positron range and acolinearity not simulated).
Bottom: [18]F-FDG image of the brain of a 59-year-old woman (injected dose: 192 MBq, 60 min acquisition time starting 94 min p.i., 271 × 10⁶ events, 0.6 mm voxels). Image obtained with the partial UHR scanner.

Conclusion

The preliminary imaging performance of the partial UHR brain scanner is promising in spite of the limited sensitivity and the not fully optimized reconstruction and correction software used at this stage. We are currently working to complete the 18 rings of detector modules, which will increase sensitivity by extending the axial FOV to 235 mm. Recovery of triple events due to inter-crystal scatter is also being investigated. Further improvement of image accuracy is also expected by implementing real-time tracking and correction for patient motion.

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