

# PET Imaging Innovations

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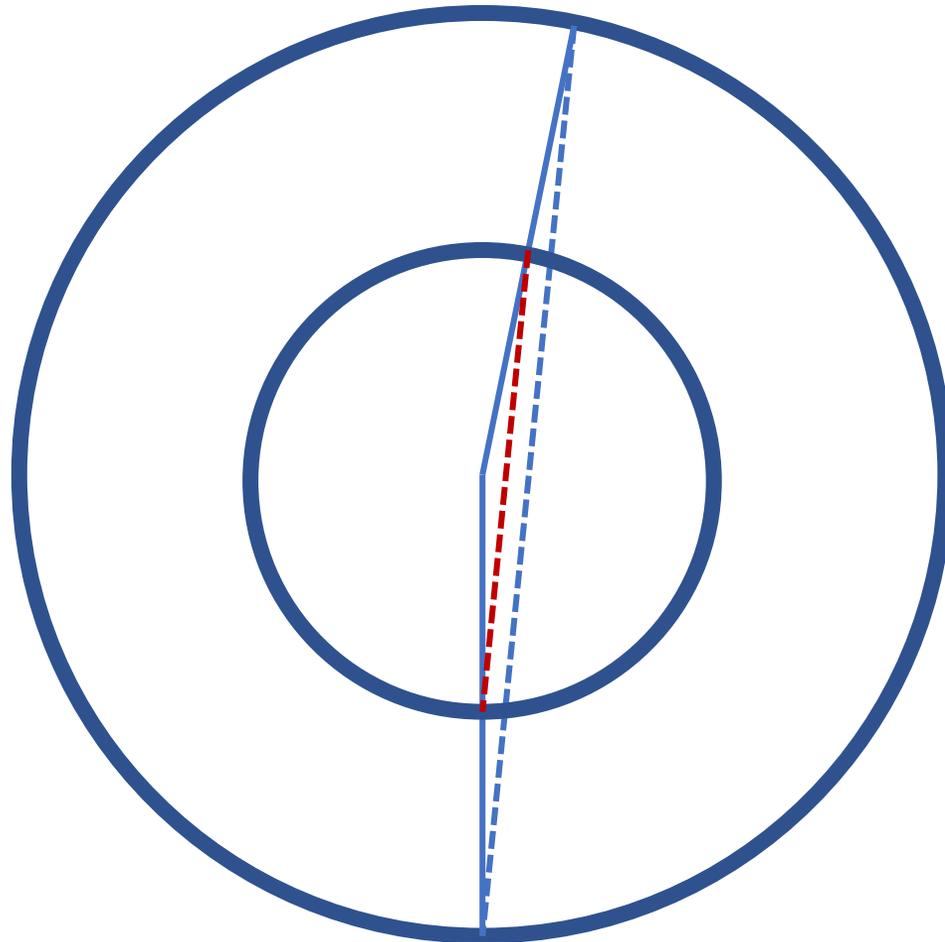
# QST, where?



# Innovations in PET instrumentation

- **Hot topics**
  - Silicon photomultipliers
  - Time-of-flight
  - Total-body PET ...
- **What's next?**
  - Brain-dedicated PET**
  - Whole gamma imaging (WGI)**

# Smaller in ring diameter, better in resolution

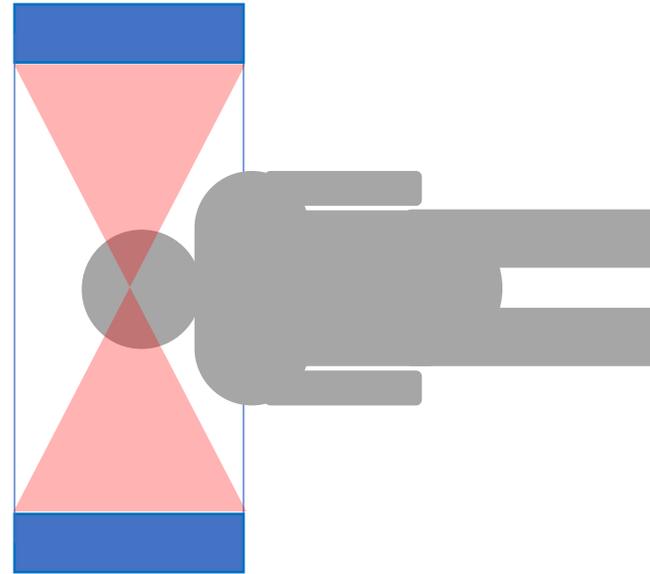
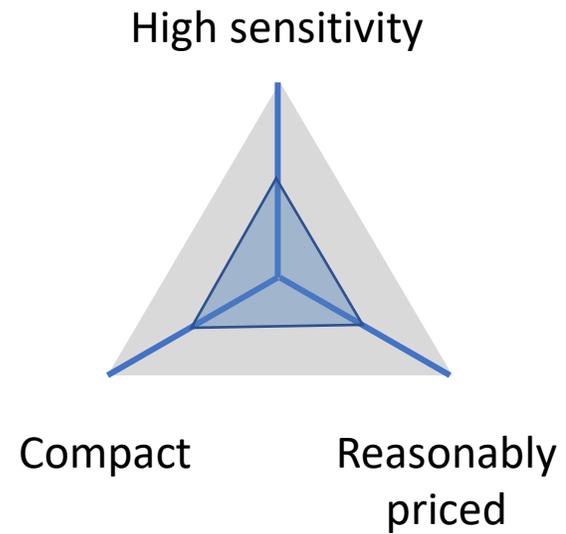


**80 cm** diam. for whole body  
**~2 mm** resolution loss

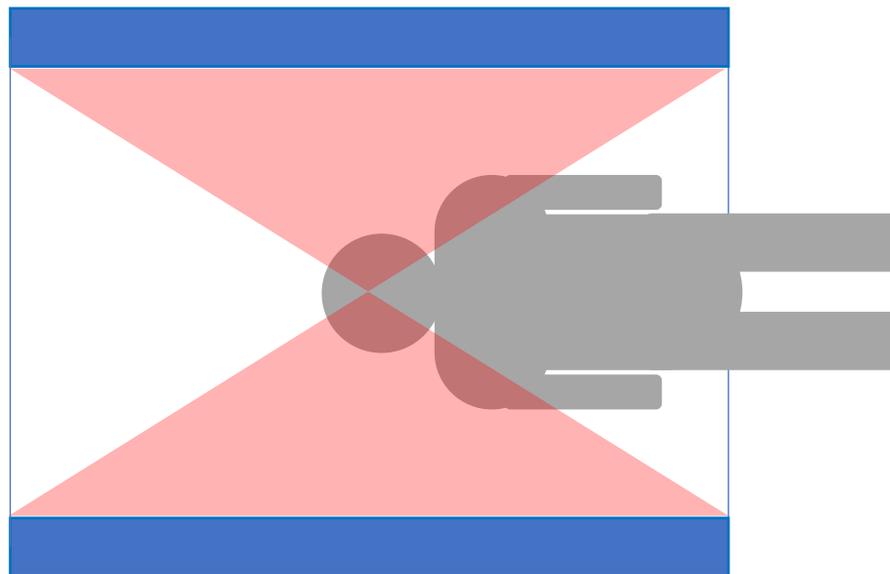
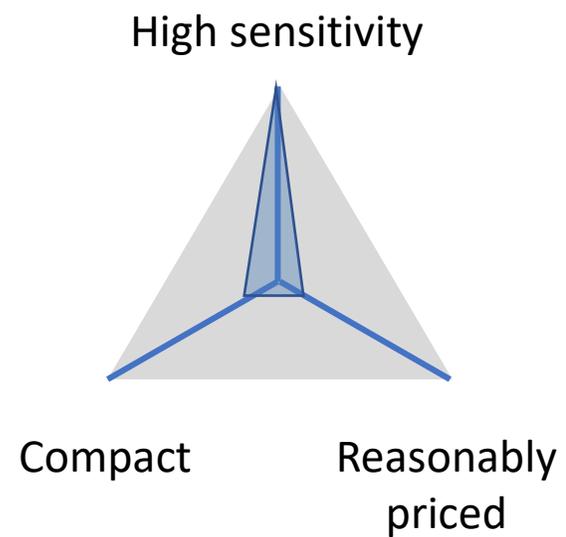


**40 cm** for brain  
**~1 mm** resolution loss

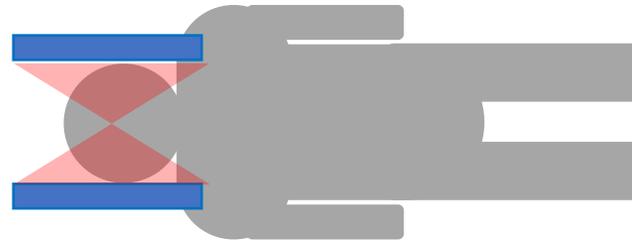
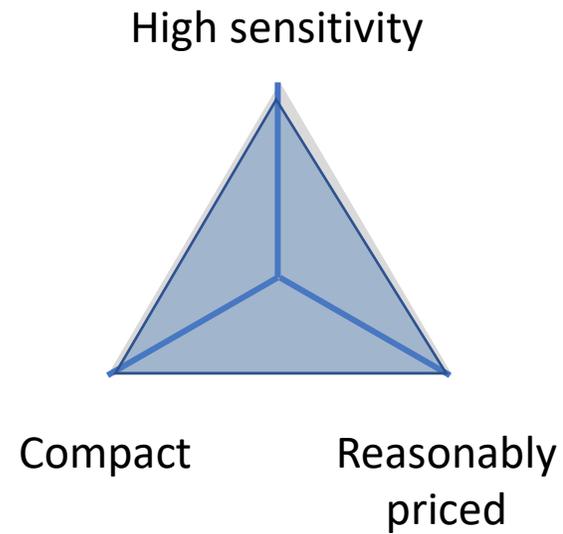
# Conventional PET



# Total-body PET



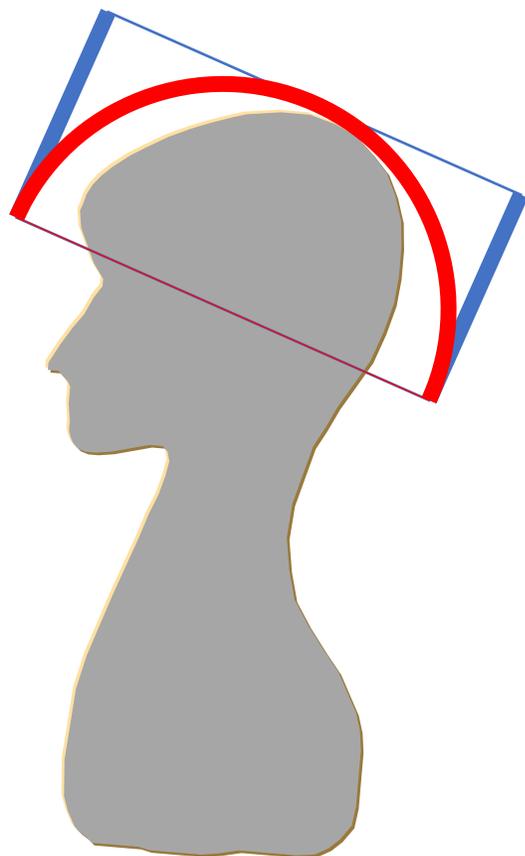
# Brain-dedicated PET



# Cylinder vs. Hemisphere

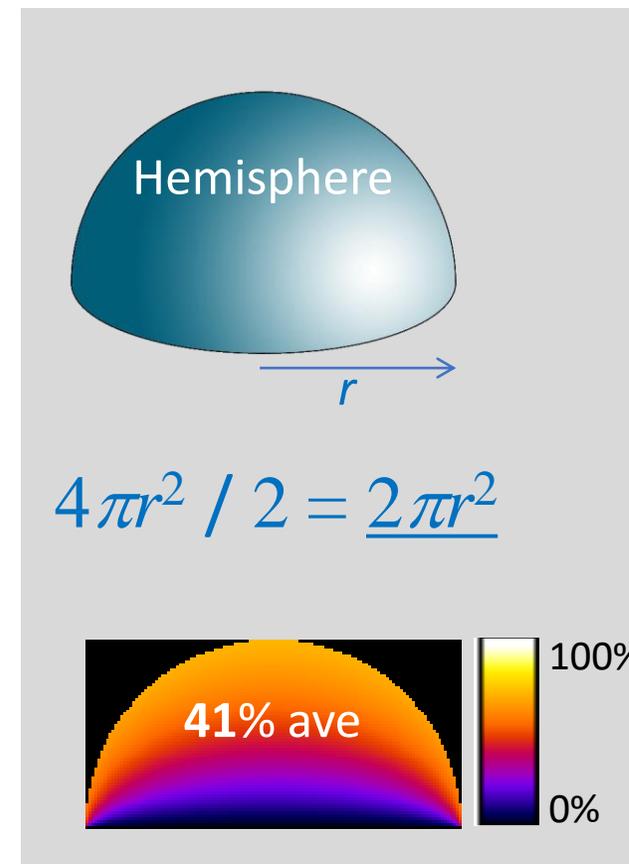
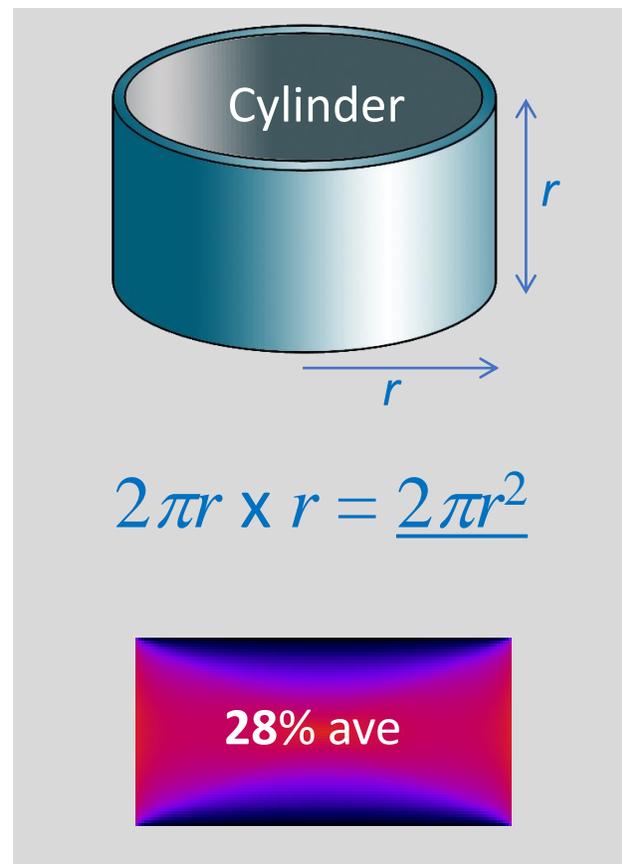
H Tashima,..., T Yamaya, SNMMI2013

H Tashima & T Yamaya, PMB, p7205, 2016



Surface area  
(Relative num.  
of detectors)

PET  
geometrical  
sensitivity



1.5x sensitivity gain with the same num. of detectors

# Has anybody ever built a hemispherical PET?



Biograph Vision  
(Siemens)



Cartesion Prime  
(Cannon)



Verens

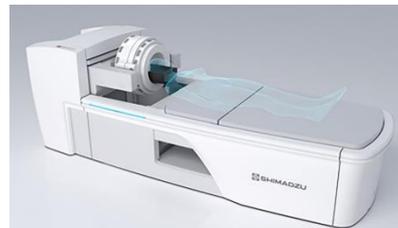


Discovery MI



ClariTom uMI 780  
(Siemens imaging)

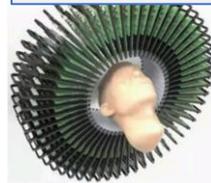
**All cylinders**



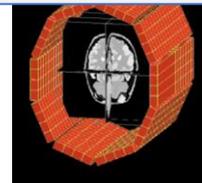
BresTome<sup>1</sup>  
(Shimadzu)



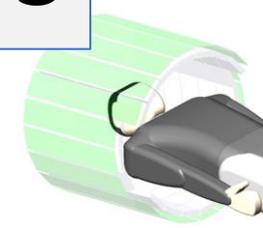
CareMiBrain<sup>2,3</sup>  
(OncoVision)



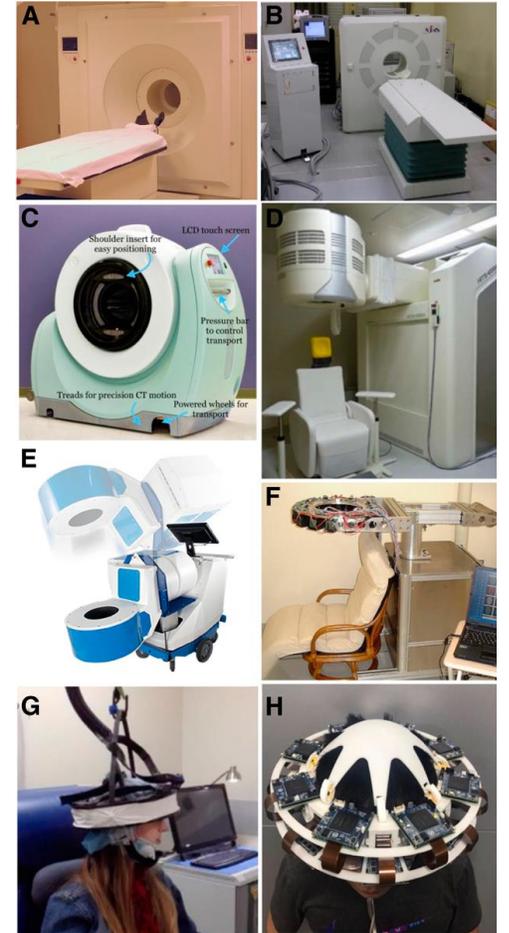
SAVANT<sup>3,4</sup>  
(under research)



Prism-PET<sup>5</sup>  
(under research)



NeuroExplorer<sup>3,6</sup>  
(under research)



Catana, J Nucl Med, p. 1044, 2019

1. Mizuta, et al. Ann Nucl Med. 2022.
2. Moliner, et al. Sci Rep. 2019.
3. Majewski. Bio-Algorithms and Med-Systems. 2021.
4. Gaudin, et al. IEEE TRPMS. 2019.
5. Wang, et al. Med Phys. 2022.
6. Yale University Website: <https://medicine.yale.edu/news-article/yale-pet-center-receives-102m-brain-initiative-grant-to-build-new-scanner/>

# First prototyping in 2015

H. Tashima, ..., T. Yamaya, PMB, 64 (2019) 065004



# 高画質省スペースを実現した 頭部専用PET装置

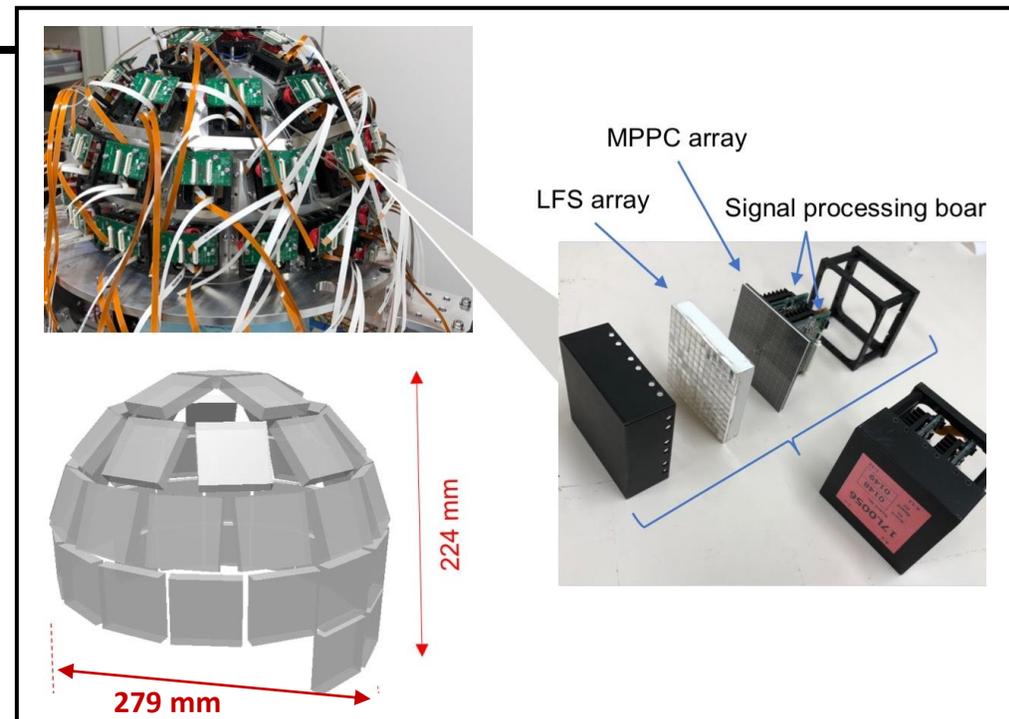
Vrain *Vision+Brain*

高画質の画像を提供する  
世界初のヘルメット型PET装置



# Commercialized as VRAIN by ATOX Corp. in Jan 2022

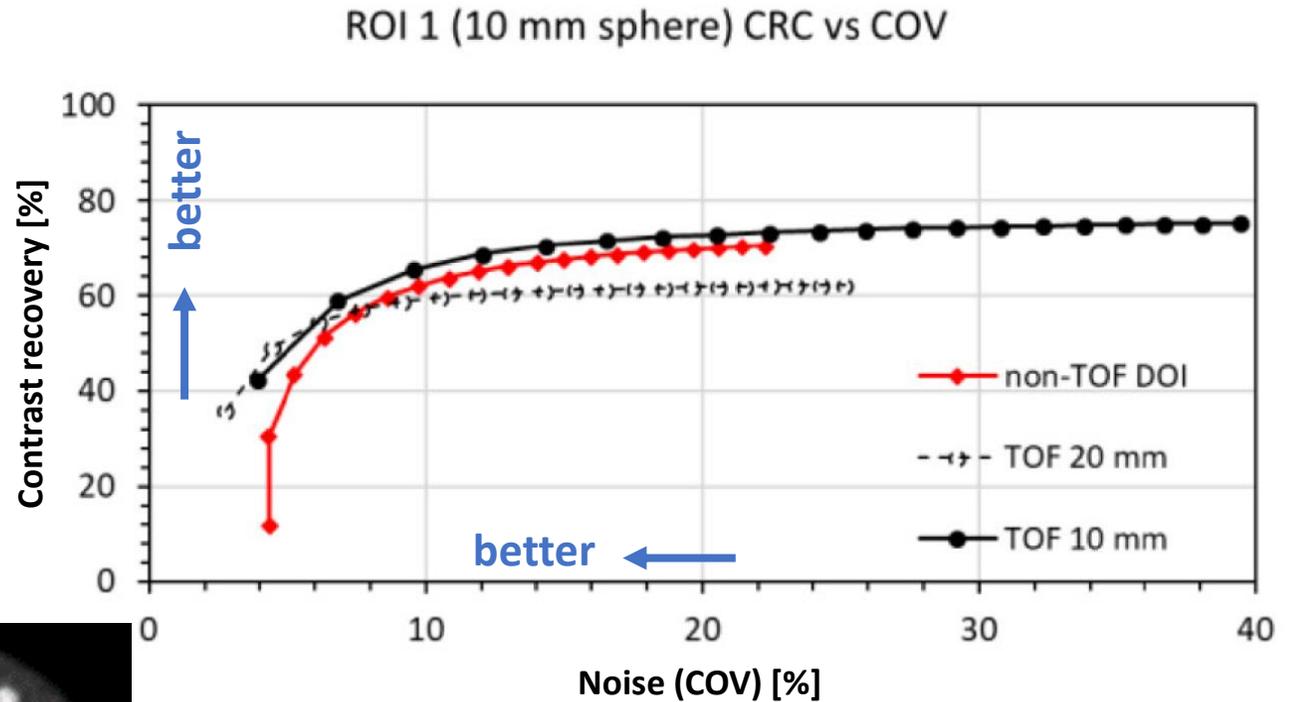
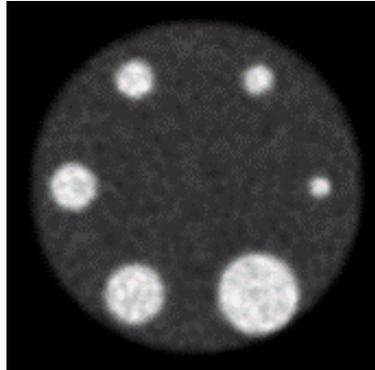
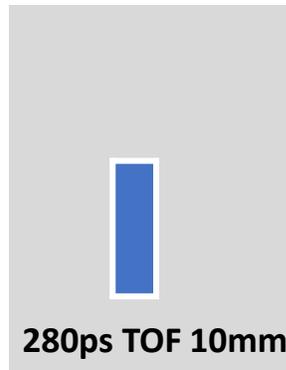
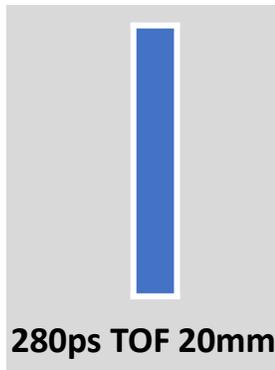
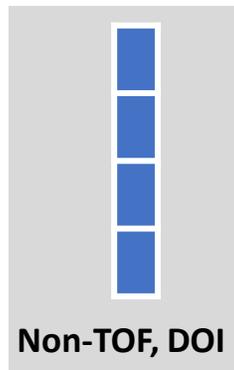
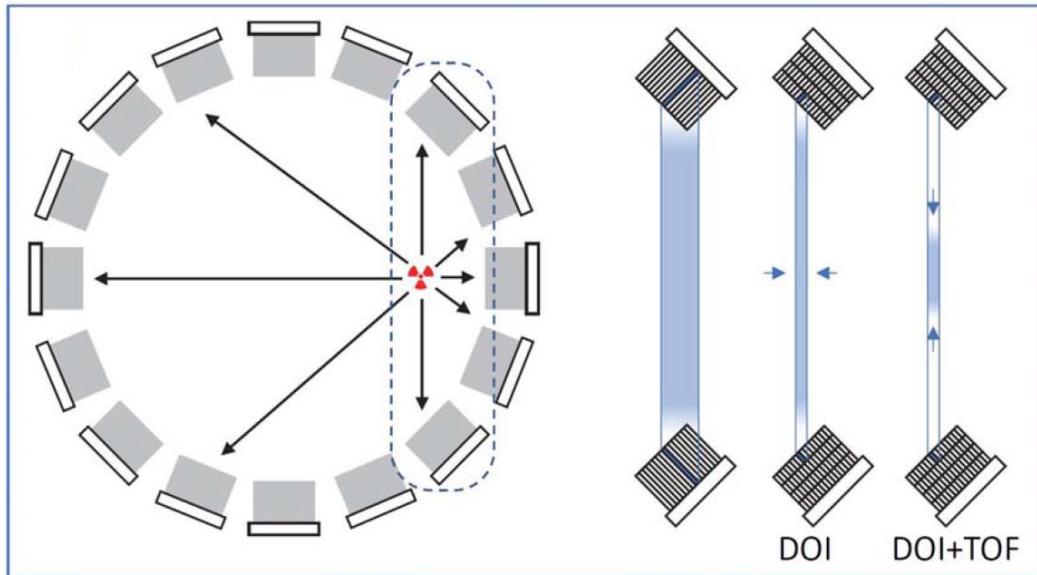
E. Yoshida, et al., PMB, 145008, 2020



- LFS 4.1 mm x 4.1 mm x 10 mm L
- MPPC 4.0 mm x 4.0 mm (1:1 coupling)
- 54 detectors
- TOF, non-DOI

# Depth-of-interaction (DOI) OR time-of-flight (TOF)?

S. Takyu, et al., PMB 035012, 2020



GEANT4 simulation

**TOF + nonDOI + 10 mm thickness was the best among three settings.**

# World's fastest class TOF resolution in clinical PET



Biograph Vision  
214 ps



Cartesion Prime  
280 ps



Vereos  
325 ps



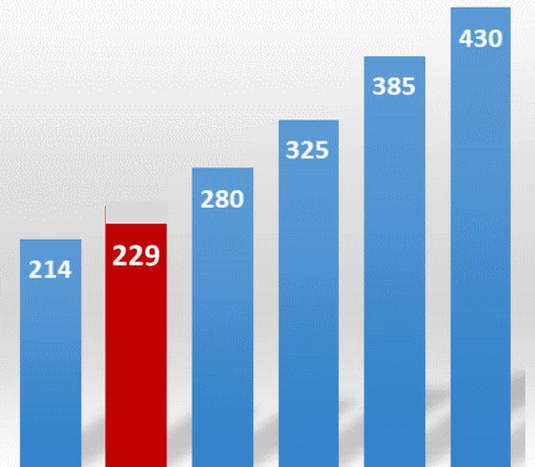
Discovery MI  
385 ps



ClariTom uMI 780  
430 ps



TOF resolution ranking



Vrain

# VRAIN vs. Discovery MI 5-ring

(Paper in prep.)



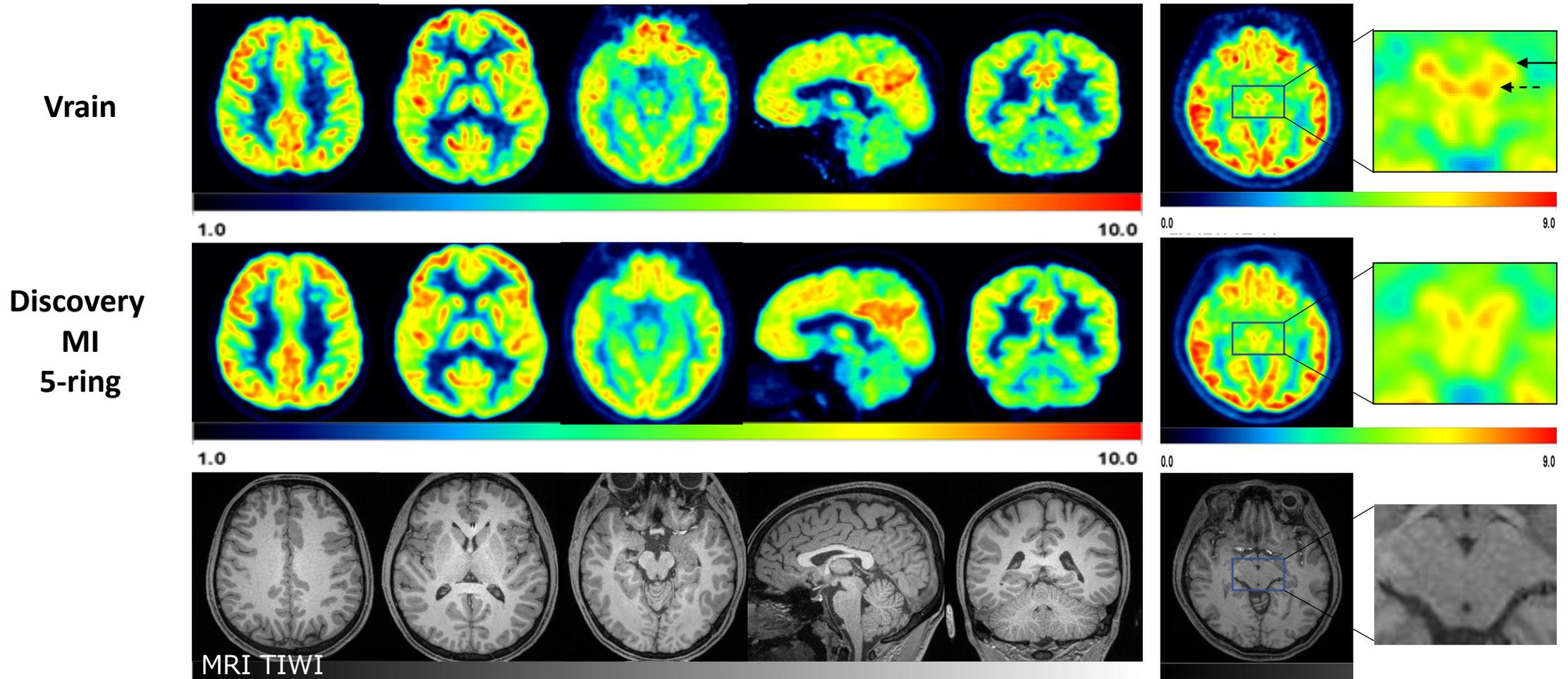
**Vrain  
(10 min)**



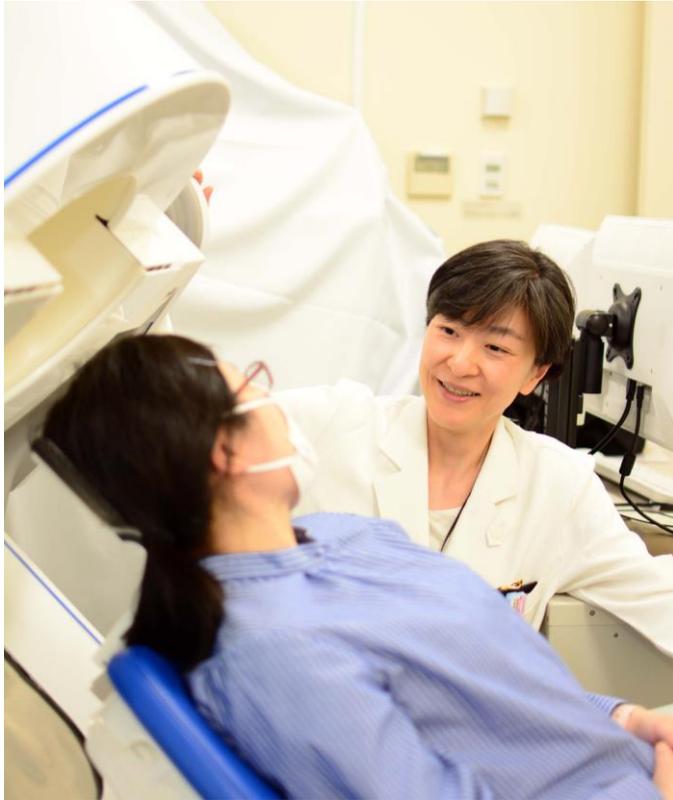
**GE Discovery MI 5-ring  
(10 min)**

# VRAIN vs. Discovery MI 5-ring

M. Takahashi, 2021 Report on PET Imaging Physics Research, p. 26, 2022



# Brain-dedicated PET VRAIN: Summary



World's fastest  
class detector

High image quality

World's first  
hemispherical PET

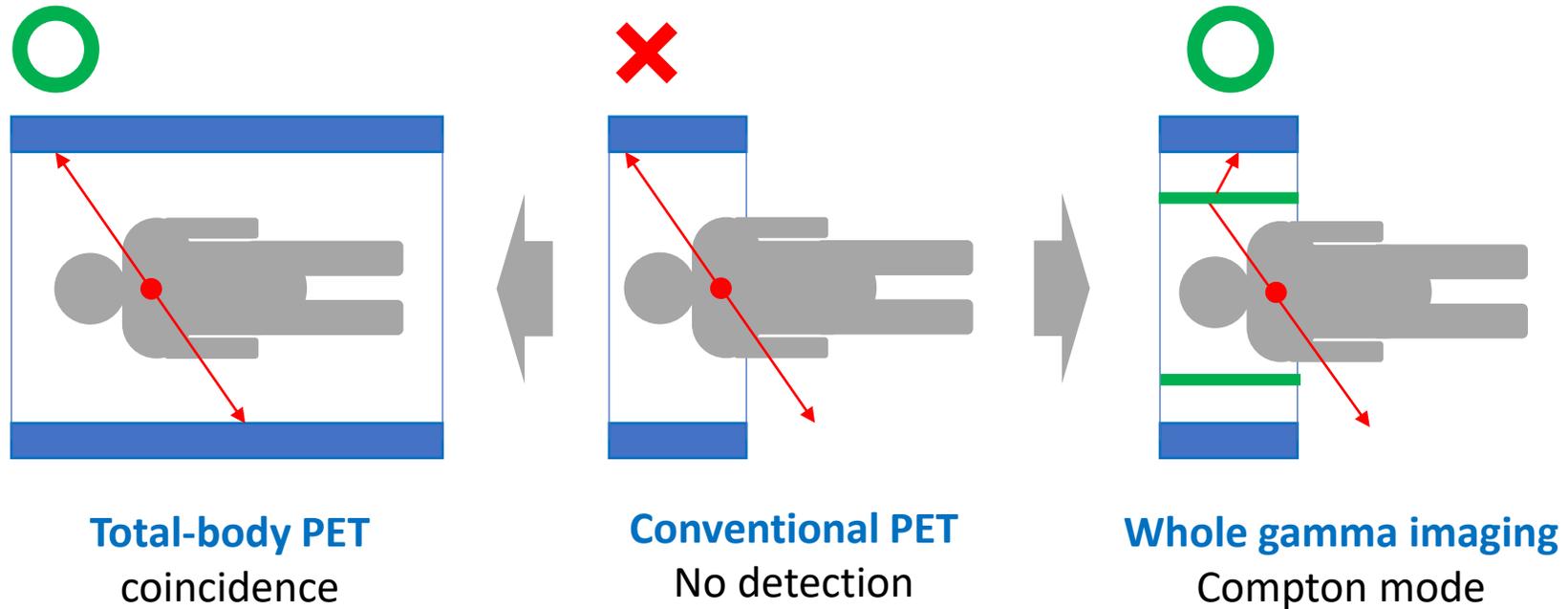
World's least  
amount of detectors

Unusual seated PET

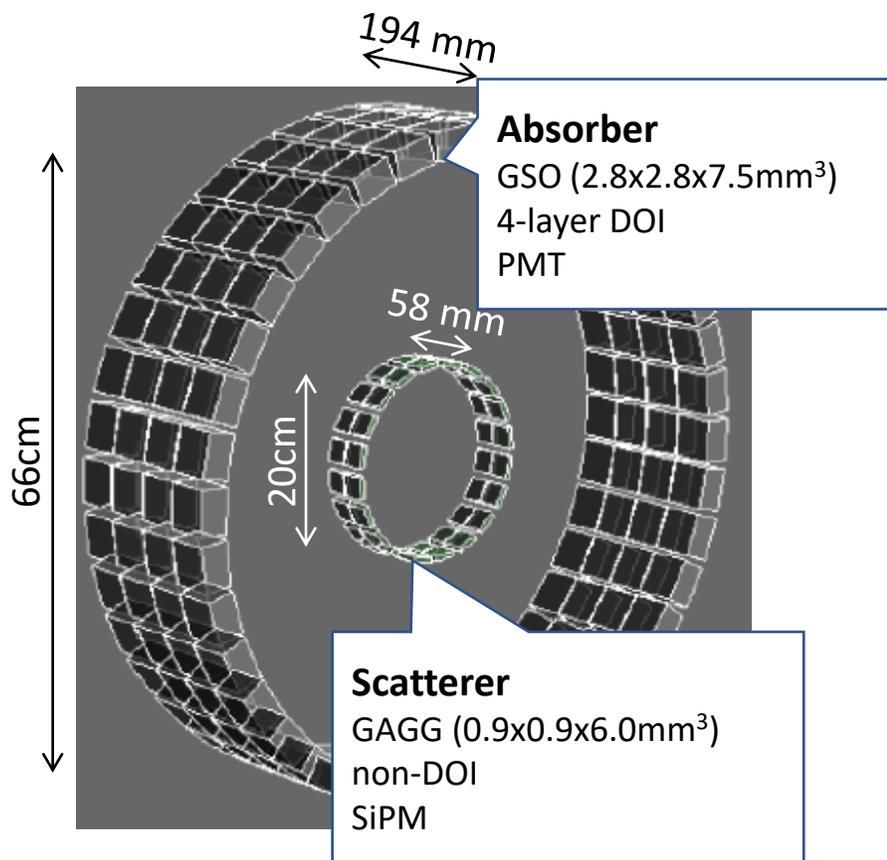
Patient-friendly,  
world's smallest PET

**Any other method  
to increase sensitivity more?**

# Boosted PET sensitivity by WGI



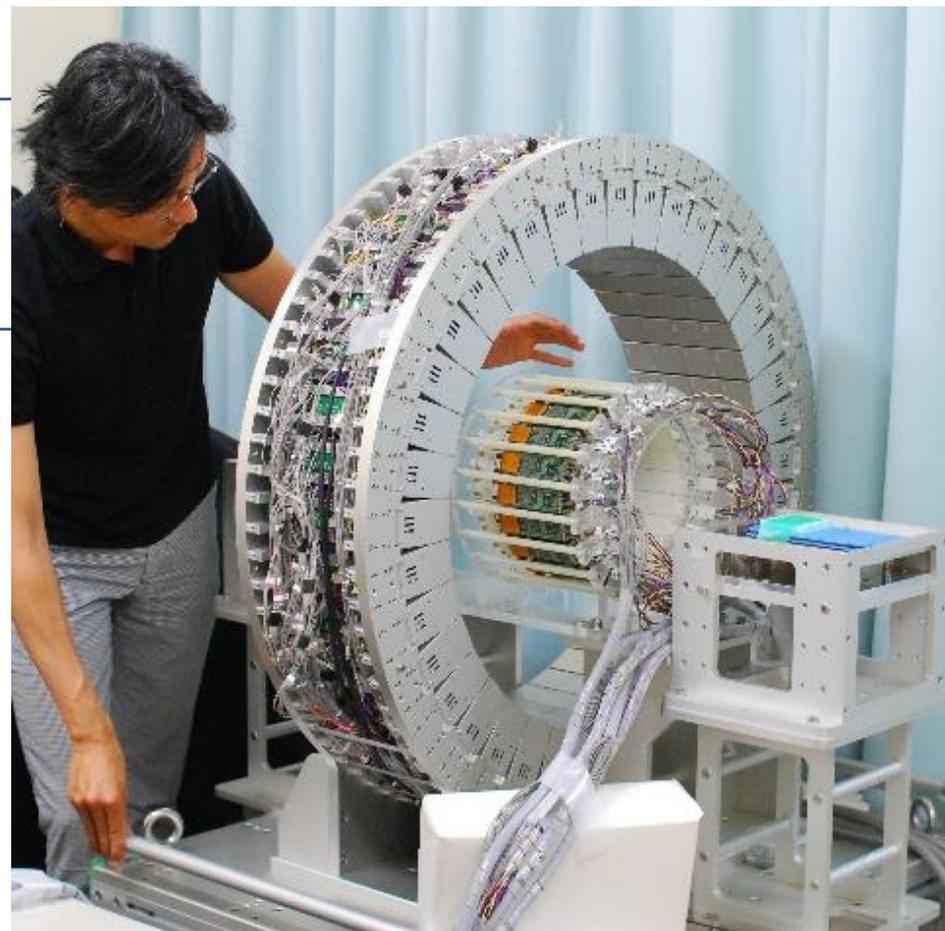
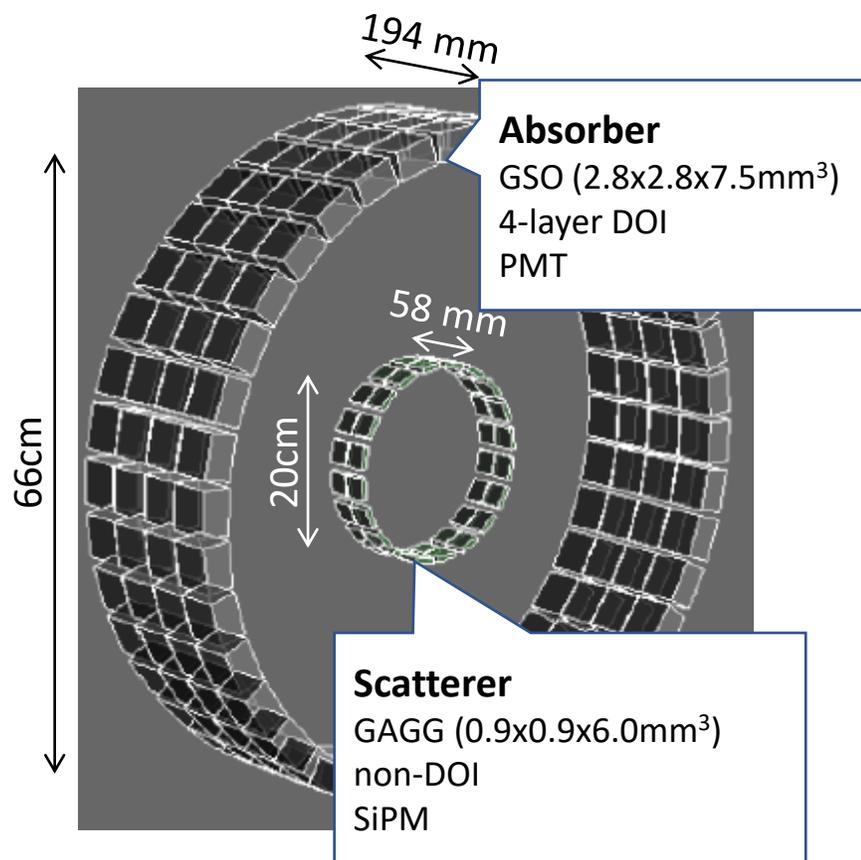
# WGI prototyping



# WGI prototyping

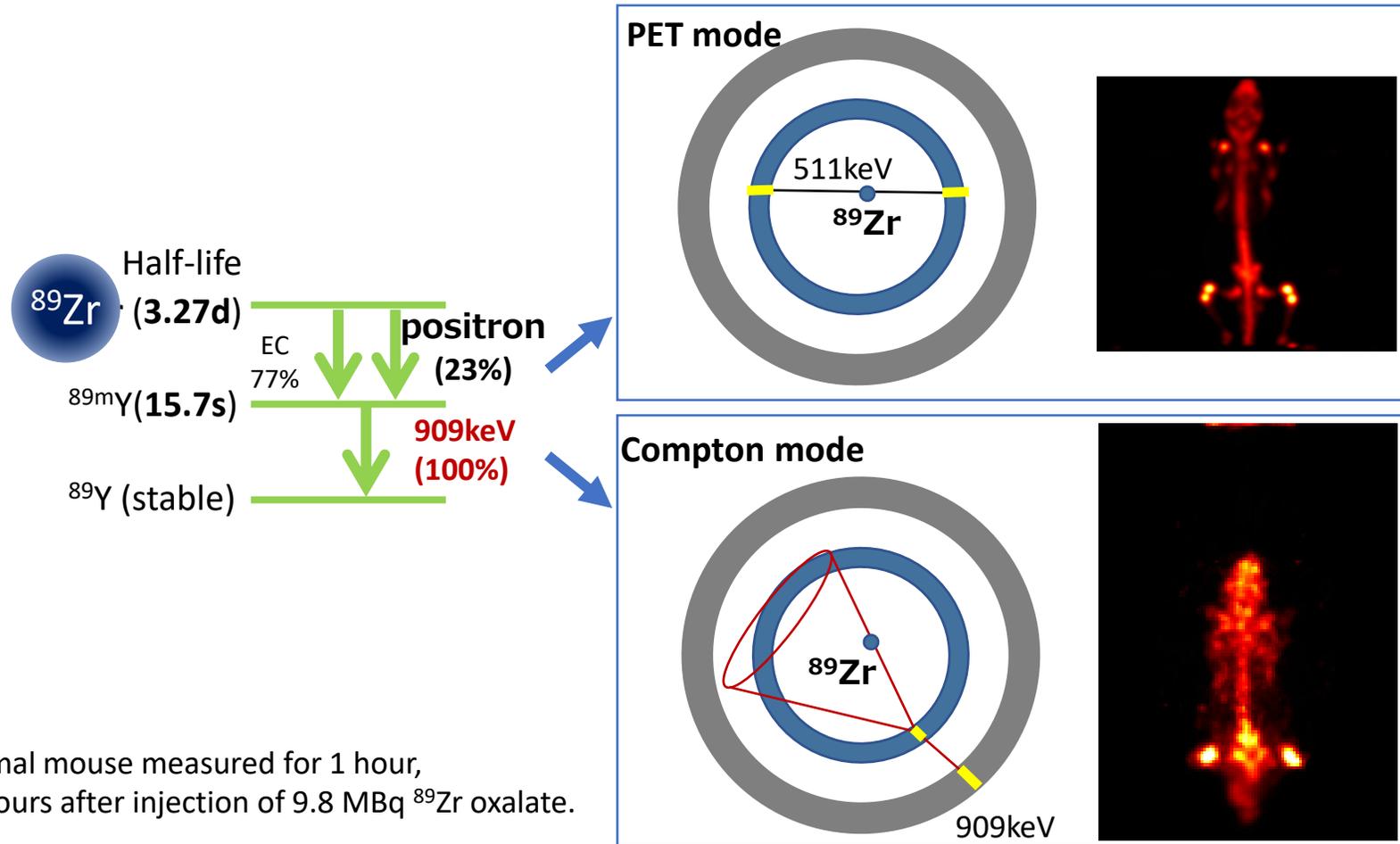
*T Yamaya, et al, SNMMI2017, No.152*

*E Yoshida,..., T Yamaya, et al, PMB, 125013, 2020*



# $^{89}\text{Zr}$ -WGI

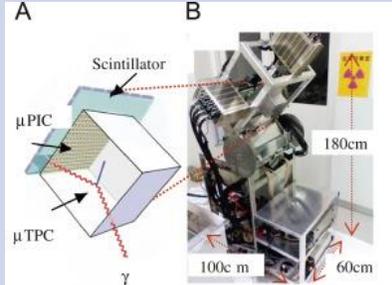
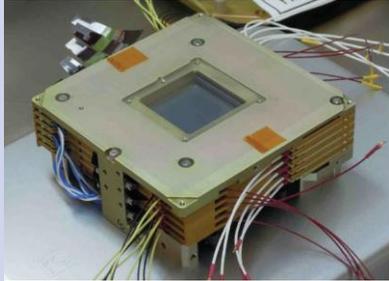
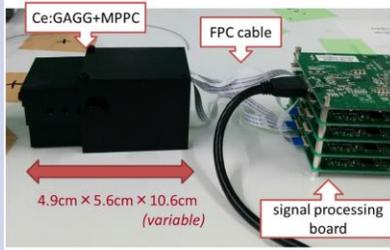
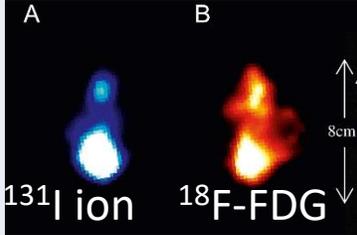
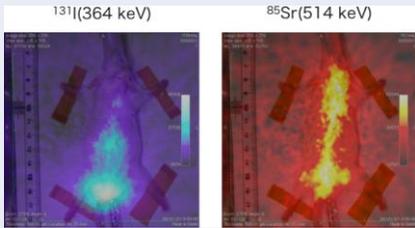
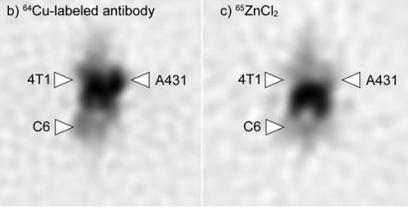
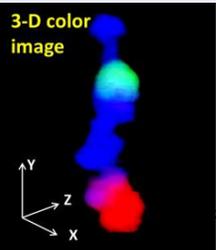
H Tashima,..., T Yamaya, PMB, 225038, 2020



Normal mouse measured for 1 hour,  
22 hours after injection of 9.8 MBq  $^{89}\text{Zr}$  oxalate.

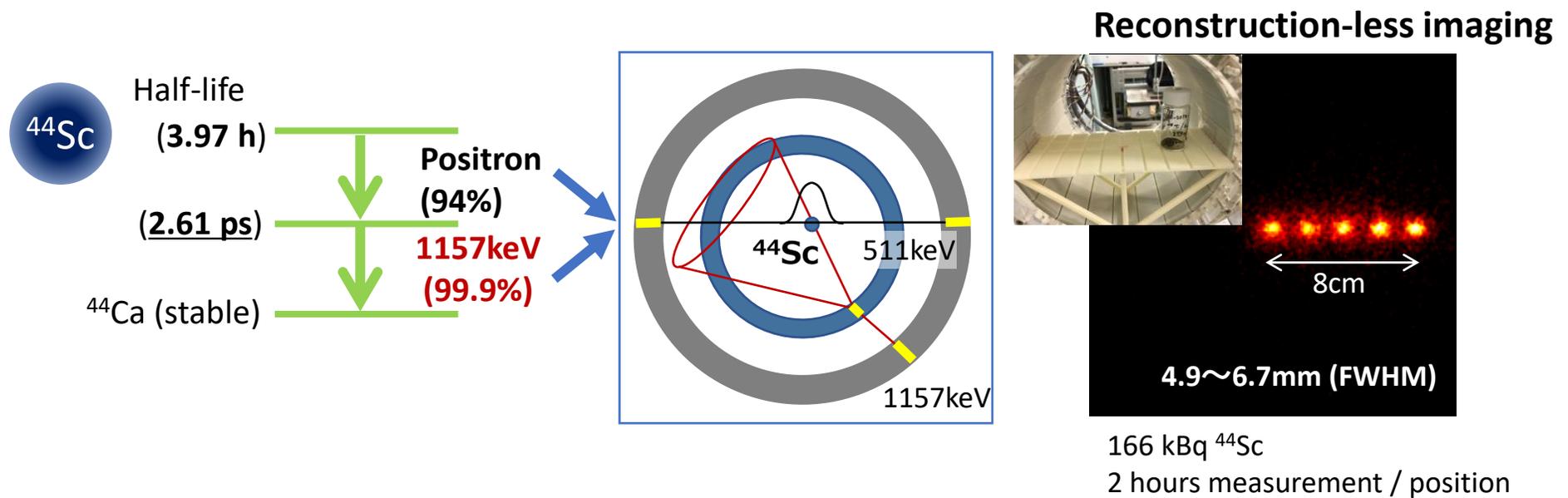
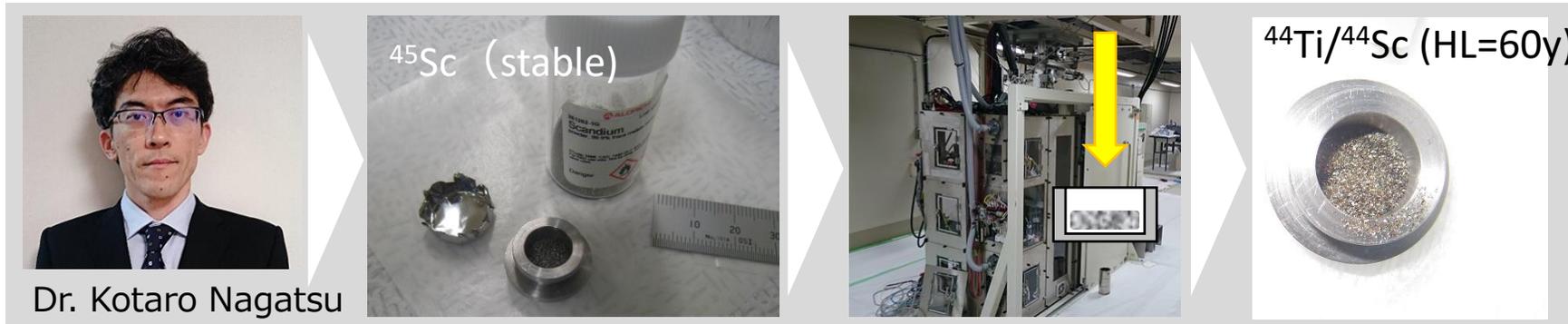
As of Jun 01 2019

# Compton imaging of mice

<p><b>Kyoto U</b> S. Kabuki et al NIMA p606, 2010</p>	<p><b>JAXA</b> S. Takeda et al IEEE TNS p70, 2012</p>	<p><b>Riken</b> S. Motomura et al J. Anal. At. Spe. 934 2013</p>	<p><b>Waseda U</b> A. Kishimoto et al NIMA p656, 2017</p>
<p>Gas + GSO</p> 	<p>Si + CdTe</p> 	<p>Ge + Ge</p> 	<p>GAGG-GAGG</p> 
			 <p>3-D color image</p> <p><math>^{131}\text{I-NaOH}</math> <math>^{85}\text{SrCl}_2\text{-HCL}</math> <math>^{87}\text{SrCl}_2\text{-saline}</math></p>

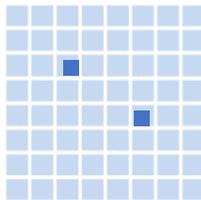
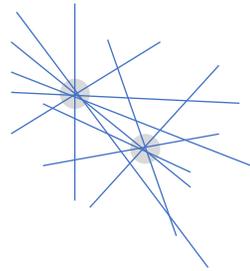
# $^{44}\text{Sc}$ -WGI

*E Yoshida, ..., T Yamaya, et al, PMB, 125013, 2020*

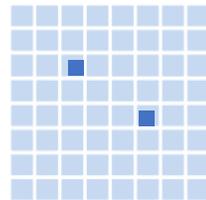
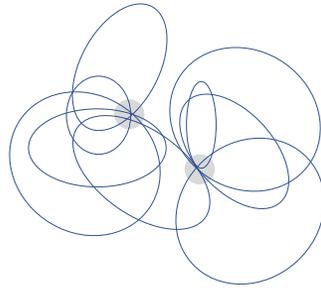


# New imaging principles

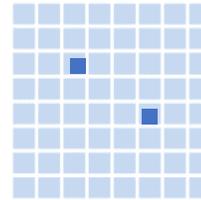
**PET**  
lines-of-response



**Compton camera**  
surfaces of cone



**$^{44}\text{Sc}$ -WGI**  
spots



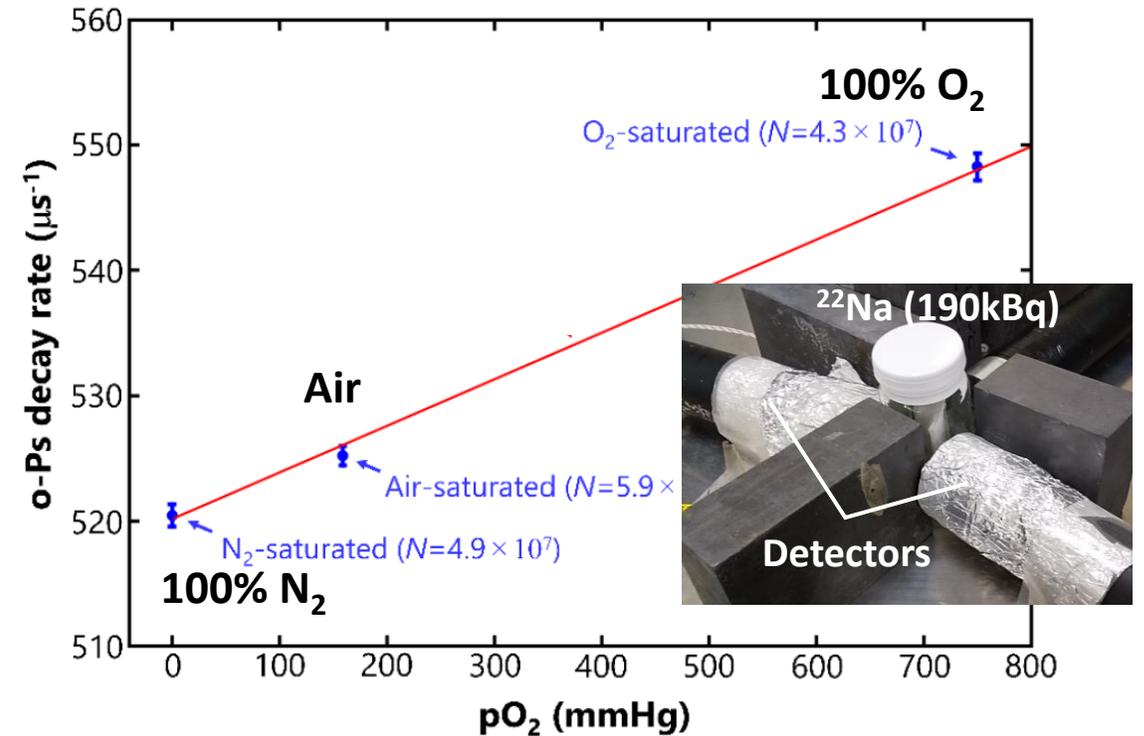
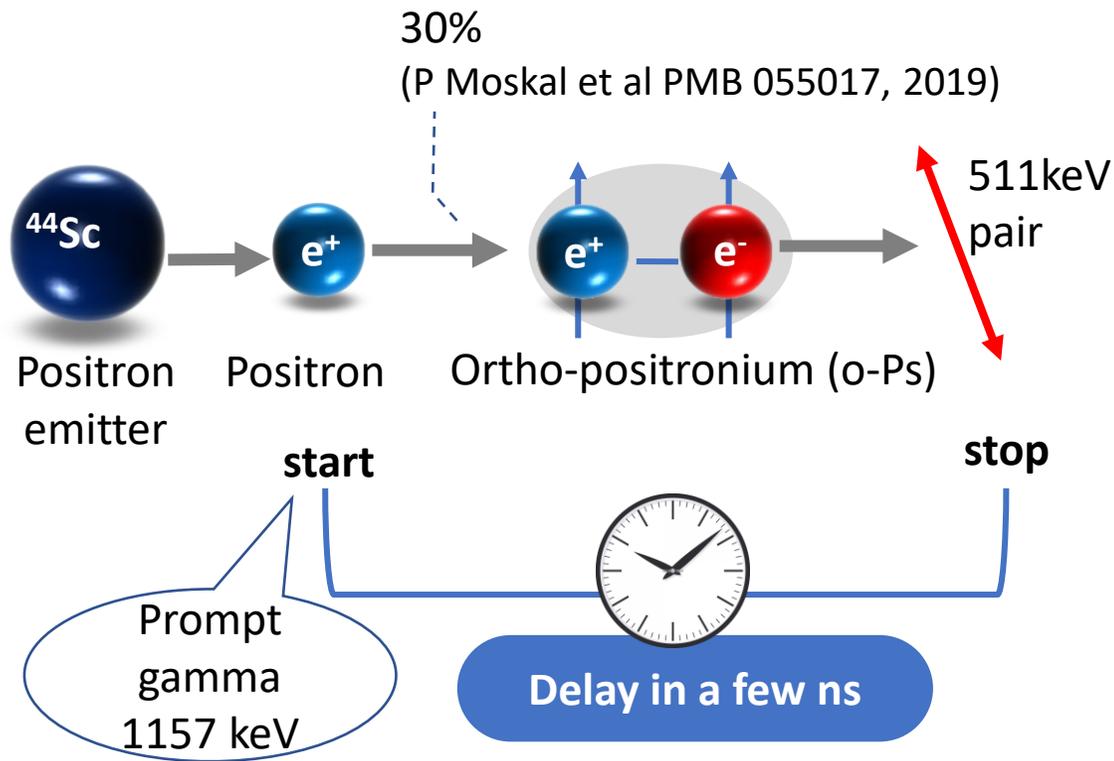
~~Time integration~~

~~Reconstruction~~

Realtime imaging?

# “Quantum PET” ?

K Shibuya, ..., T Yamaya, Commun. Phys., 2020



O-Ps life time can be a biomarker for hypoxia imaging, which is necessary for selecting an optimal cancer treatment method.

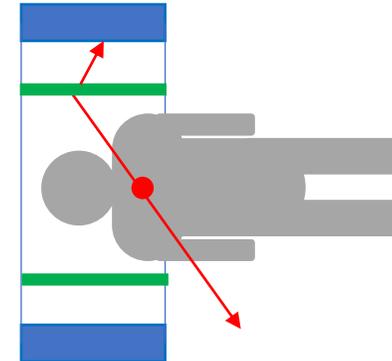
# PET Imaging Innovations - Summary

## Methods to acquire more gamma-rays from patients for better diagnosis

- Increasing **solid angle** (detector coverage)
- Minimizing **photon non-collinearity**
- Combination with **Compton imaging**
- Use of **third gamma-ray** (choice of non-pure positron emitters)



Hemispherical brain PET (VRAIN)



Whole gamma imaging (WGI)

# More info.

## 次世代PET研究報告書

Reports on PET Imaging Physics Research  
(JPN/ENG in reports in 2016 and later)

