Studies performed on previous J-PET prototypes

Szymon Niedźwiecki
on behalf of the J-PET collaboration

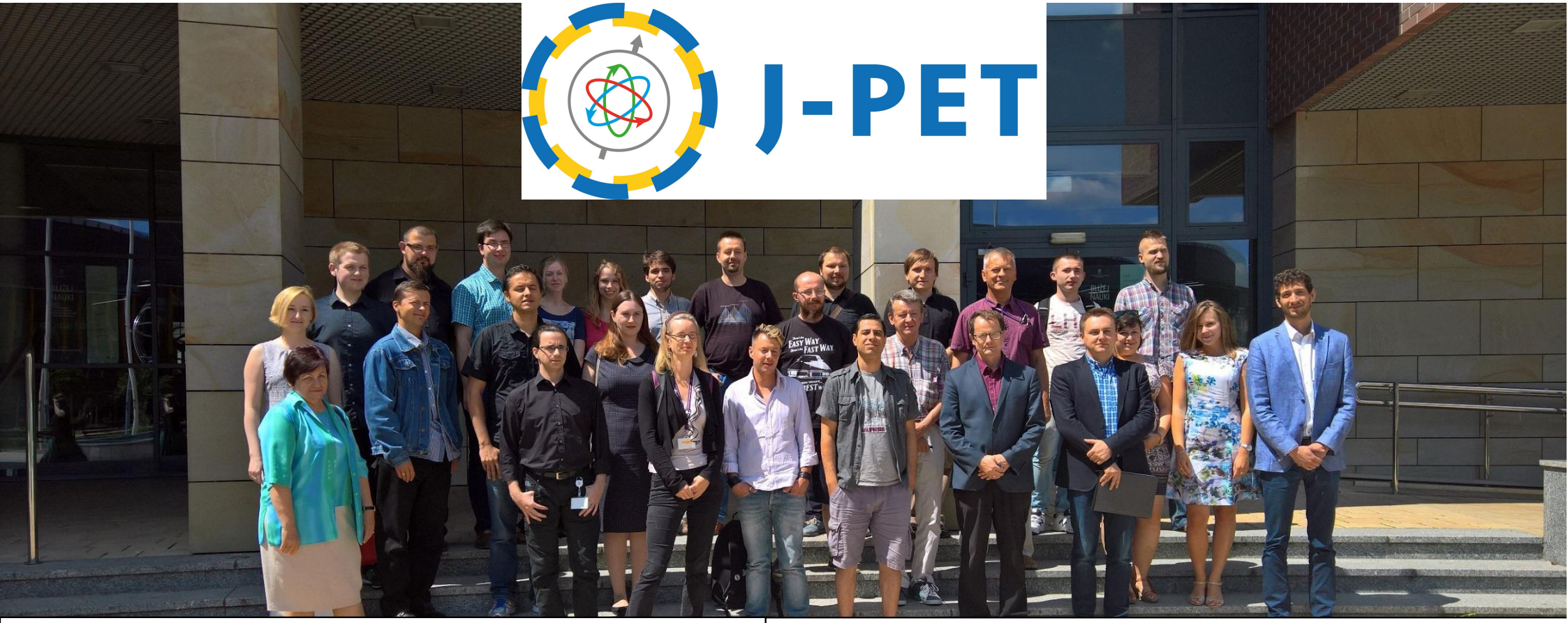
Plan of presentation

Introduction:

1. Goal of the J-PET collaboration
2. Positron-Emission Tomography (PET)
3. Different approach to the PET

Prototypes:

4. 2 module
5. 24 module
6. First tests of the new scanner prototype
7. Summary and future plans



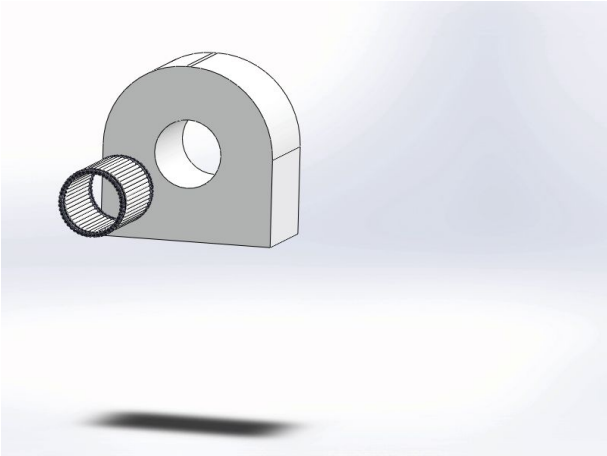
Detectors: T. Kozik, A. Heczko, W. Migdał, B. Korzeniak
PALS: B. Jasińska, B. Zgardzińska M. Gorgol, K. Wysogląd
Bio-physics: E. Kubicz, A. Wieczorek, M. Zieliński, B. Głowacz
Simulations: W. Wiślicki, P. Kowalski, D. Kisielewska, R. Shopa
Software: W. Krzemień, A. Gajos, K. Kacprzak, K. Rakoczy, K. Muzalewska

Physics: E. Czerwiński, N. Krawczyk, M. Pawlik - Niedźwiecka, J. Gnatek, D. Alfs, Sz. Niedźwiecki, M. Mohamed, O. Rundel, J. Raj, S. Choudhary, N. Sharma, S. Sharma, M. Skurzok, M. Silarski
Electronics: M. Kajetanowicz, M. Pałka, G. Korcyl, P. Strzempek
Reconstruction: P. Białas, Z. Rudy, L. Raczyński, A. Strzelecki

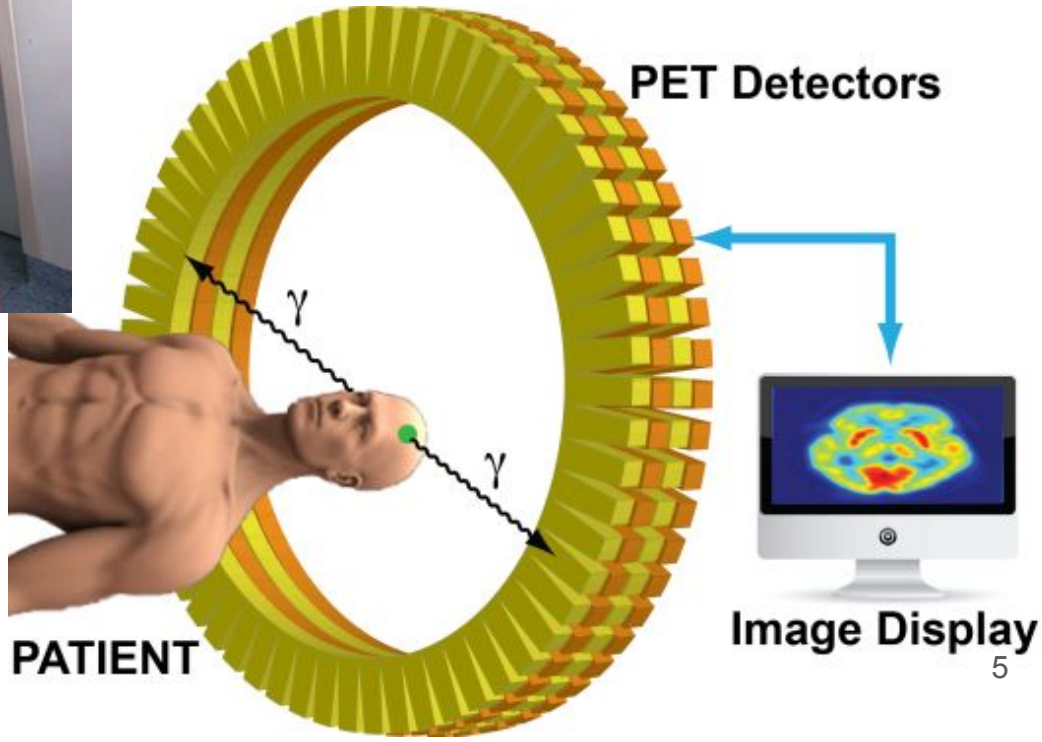
Our goal:

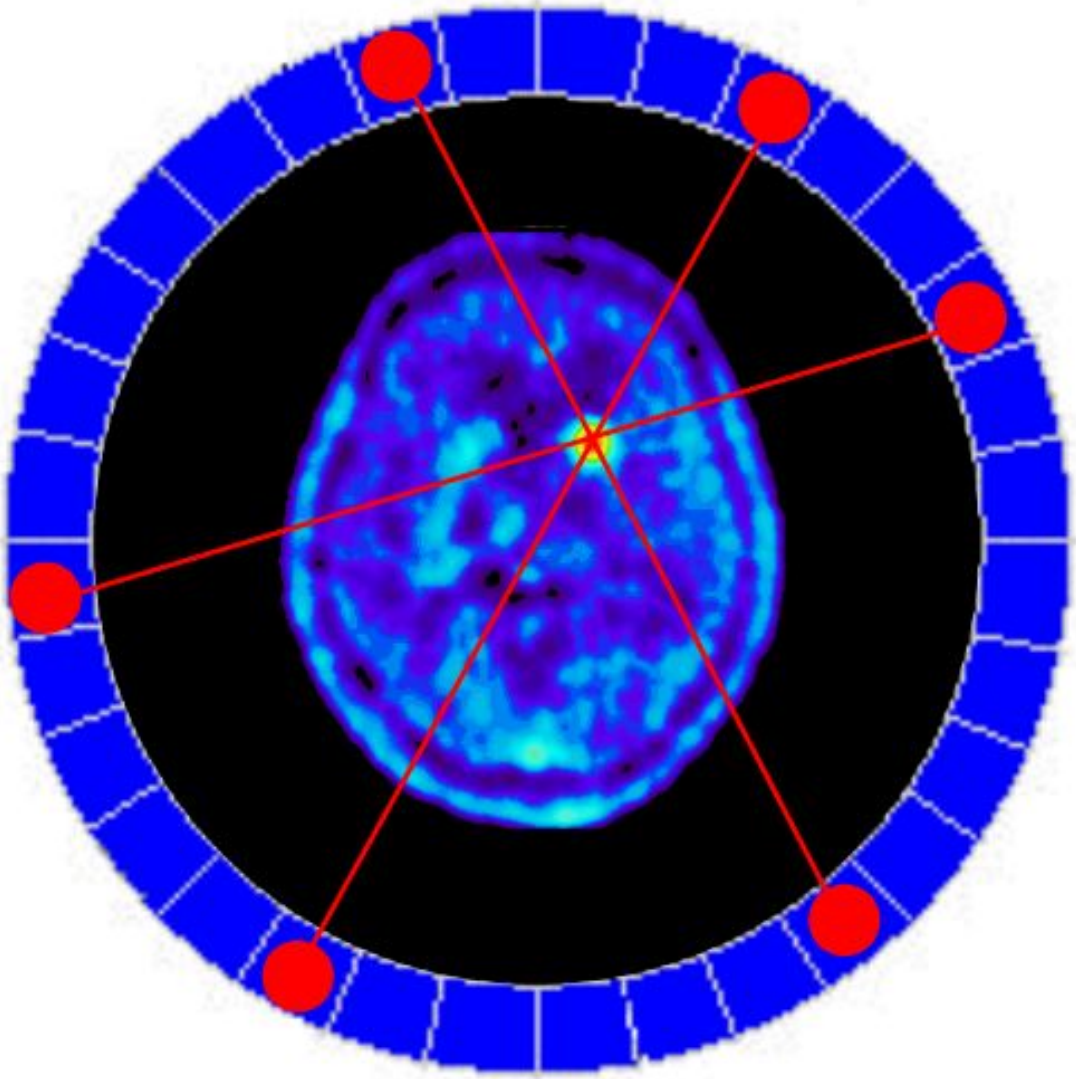
Cost effective whole-body PET scanner

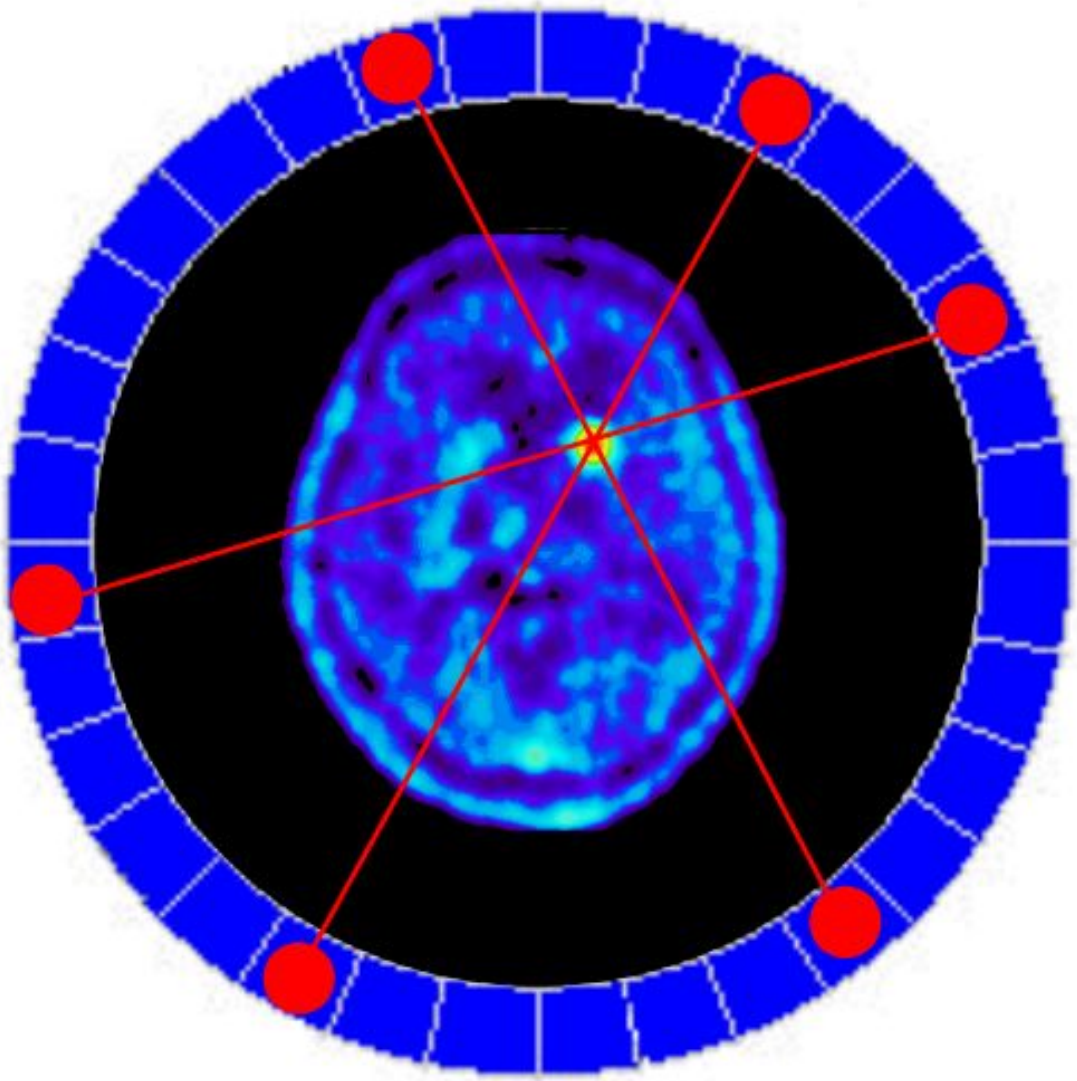
Usable as PET insert compatible with MRI and CT

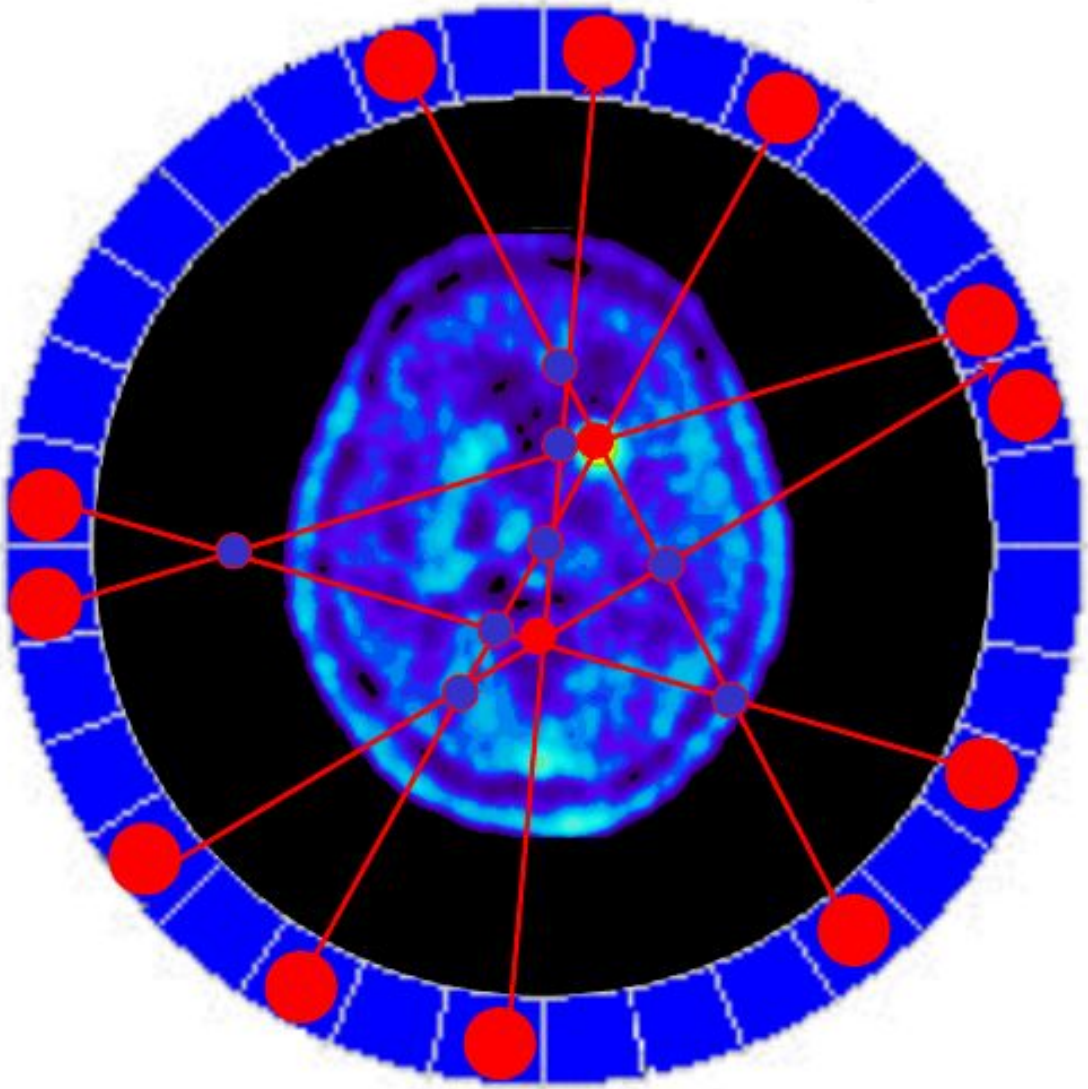


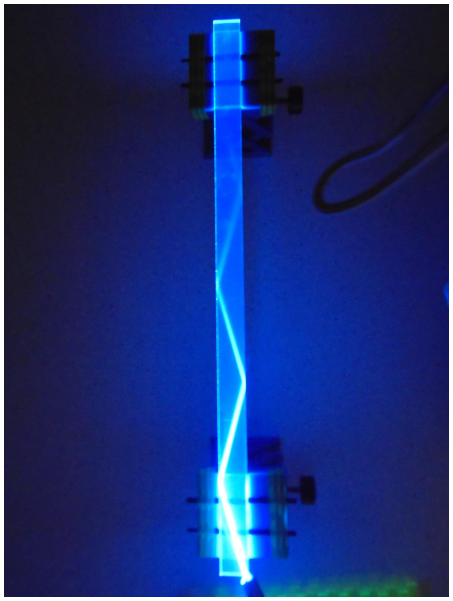
$$^{18}F \rightarrow {}^{18}O + e^{+} + \nu_e$$

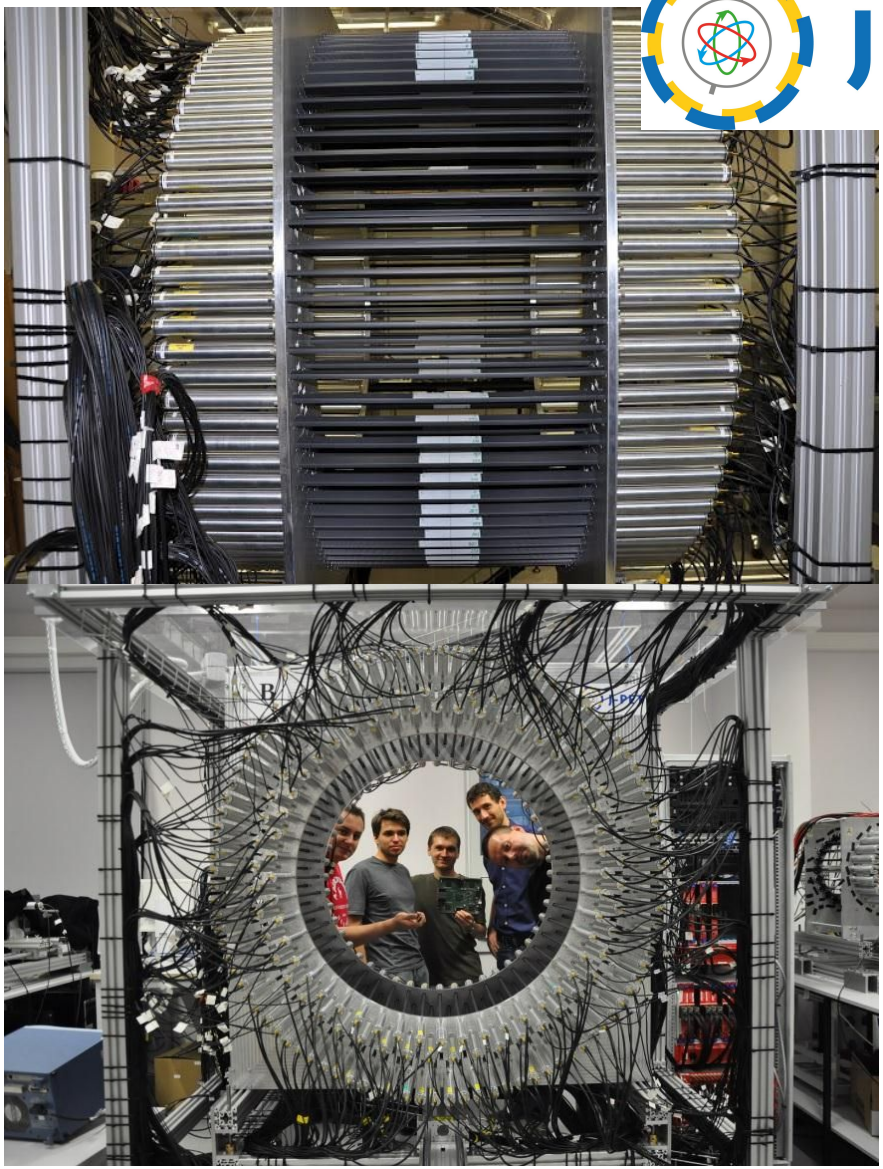




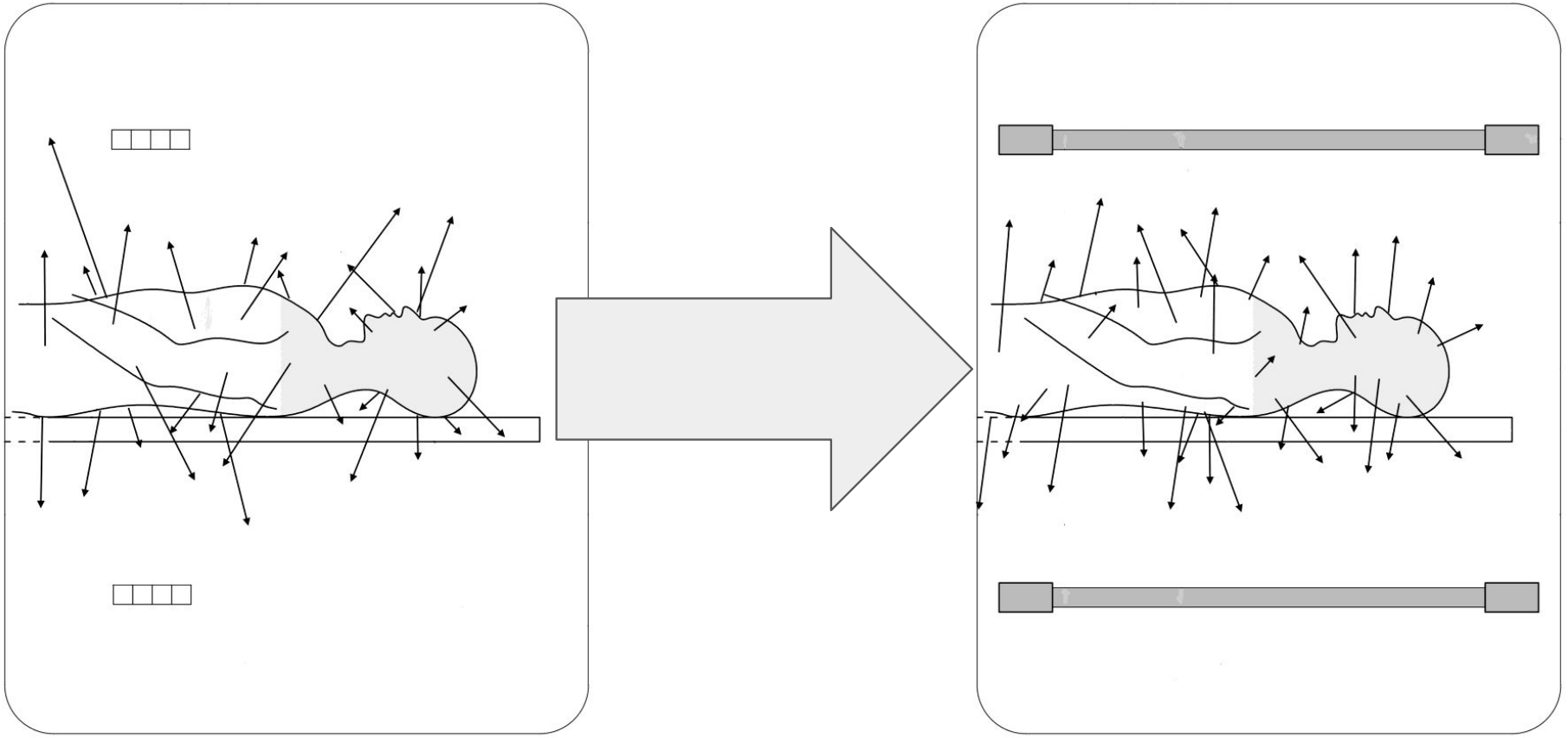








- Long **plastic** scintillators instead of crystals with **low attenuation** coefficient
- **Axial** alignment of detection modules

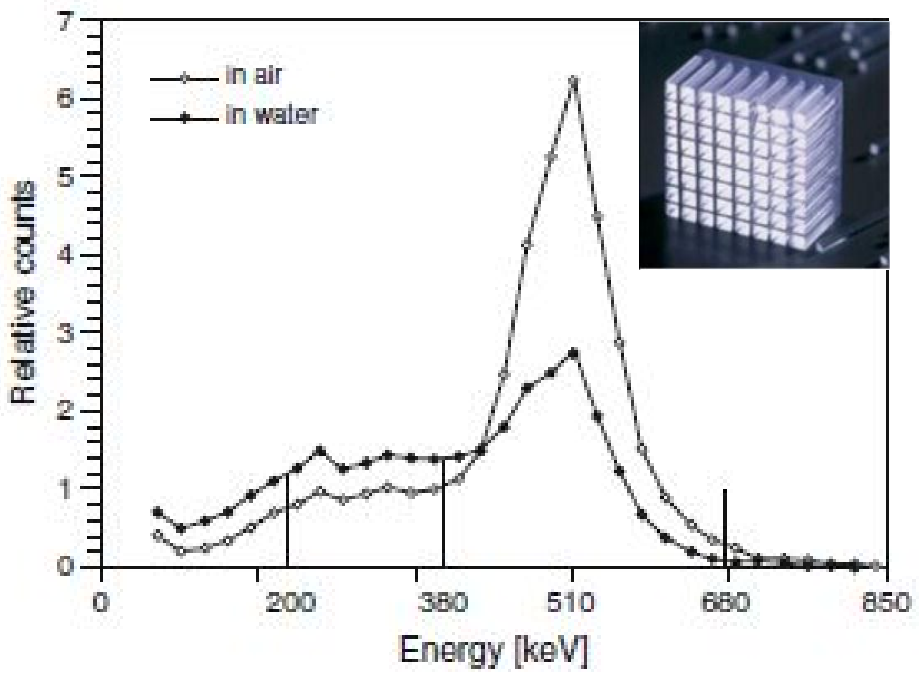


20 cm Field of View

100 cm Field of View

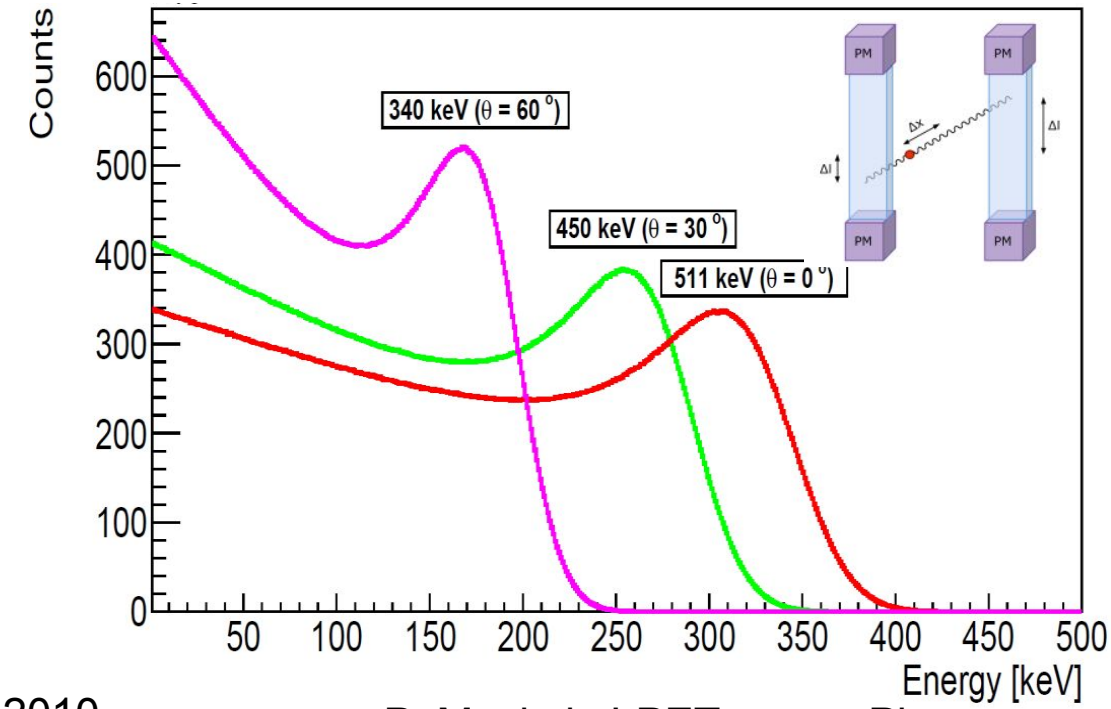
Detection of 511 keV gamma quanta

Crystals



Saha G, Basics of PET imaging. Springer New York 2010

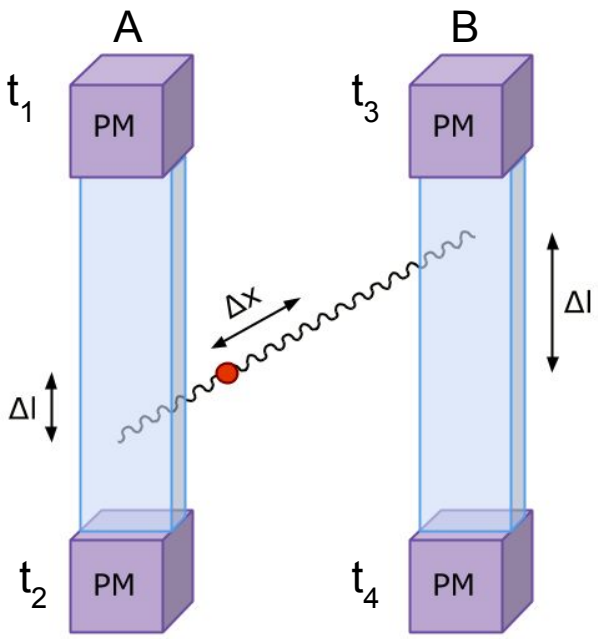
Plastics



P. Moskal, J-PET group, Phys. Med. Biol. 61:2025-2047 (2016)

Feature	ALLEGRO (Philips-ADAC)	ECAT ACCEL (CTI-Siemens)	ADVANCE/ADVANCE Nxi (General Electric)
Energy window width [keV]	435-590	350-650	300-650

Tarantola G. et al, Journal of Nuclear Medicine, 44, No.5 May 2003



$\Delta t^{12} = t_1 - t_2$

$\Delta l^{12} = \Delta t^{12} * v / 2$

$\Delta T^{AB} = (t_1 + t_2) /2 - (t_3 + t_4) /2$

$\Delta x^{AB} = \Delta T^{AB} * c / 2$

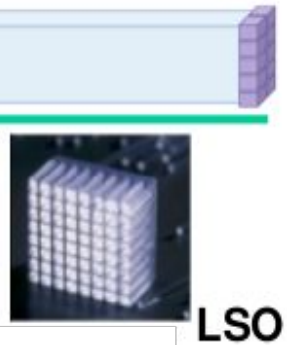
- Readout from **both** sides of each module
- Annihilation point determined based on **time information**

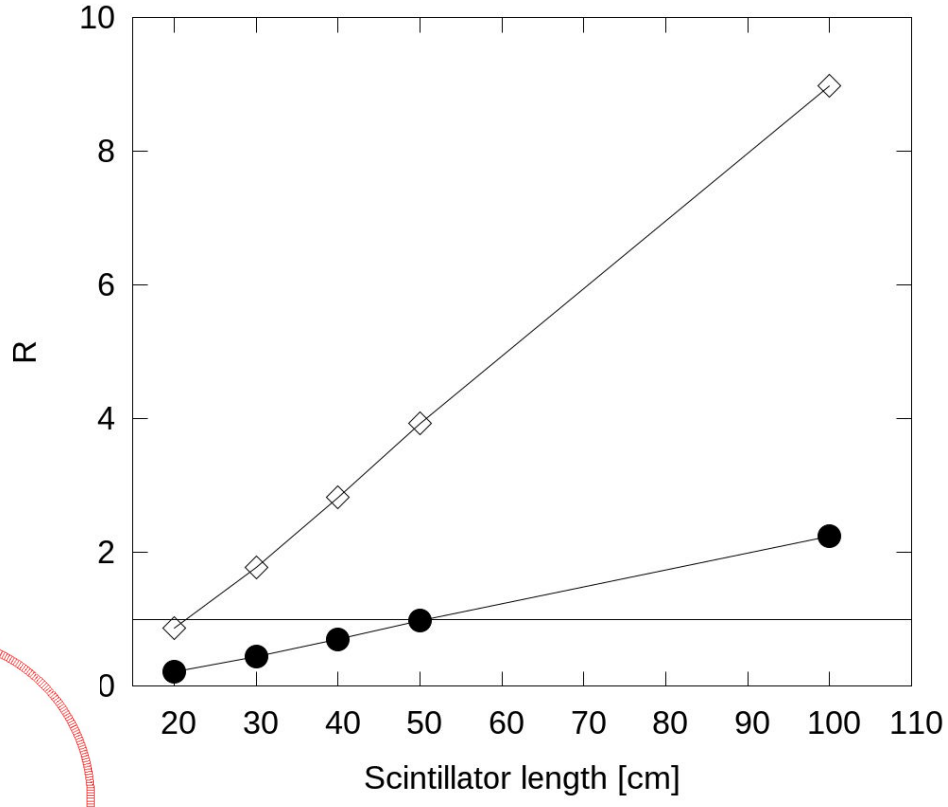
Extending Field of View does not increase readout cost

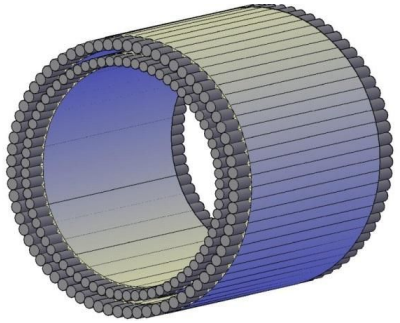
Figure of Merit for whole body imaging (FOM):

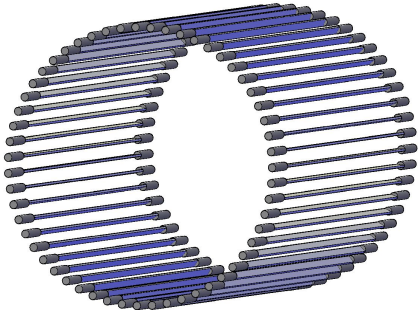
$$FOM \cong \frac{(\text{detection effi.})^2 \cdot (\text{selection effi.})^2 \cdot \text{acceptance}}{CRT \cdot \text{Number\_of\_bed\_positions}}$$

$$R = \frac{FOM\_JPET}{FOM\_LSO}$$

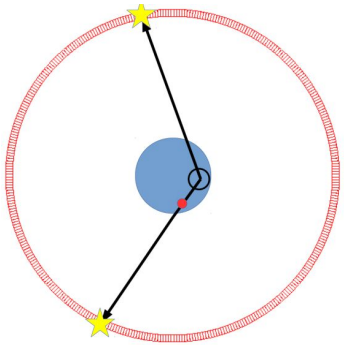








Diameter 80 cm
LSO AFOV = 20 cm
J-PET AFOV = 50 cm
LSO CRT = 0.400 ns
J-PET CRT = 0.240 ns
Deposited energy threshold = 0.2 MeV



P. Moskal, J-PET group, Phys. Med. Biol. 61:2025-2047 (2016)

1. Long **plastic** scintillators instead of crystals with **low attenuation** coefficient
2. **Axial** alignment of detection modules
3. Detection based only on **Compton scattering**
4. Readout from **both** sides of each module
5. Annihilation point determined based on **time information**
6. Width of signal measured at **fourth** constant thresholds
7. Energy deposition estimated using **TOT**
8. **Triggerless** data acquisition and digital front-end boards
9. Initial **online** reconstruction, based on **FPGA** instead PC

Can be used not only for standard medical examination!

J-PET

But also for studies of:

- **additional diagnostic parameters**

More details in
P. Moskal talk on Friday

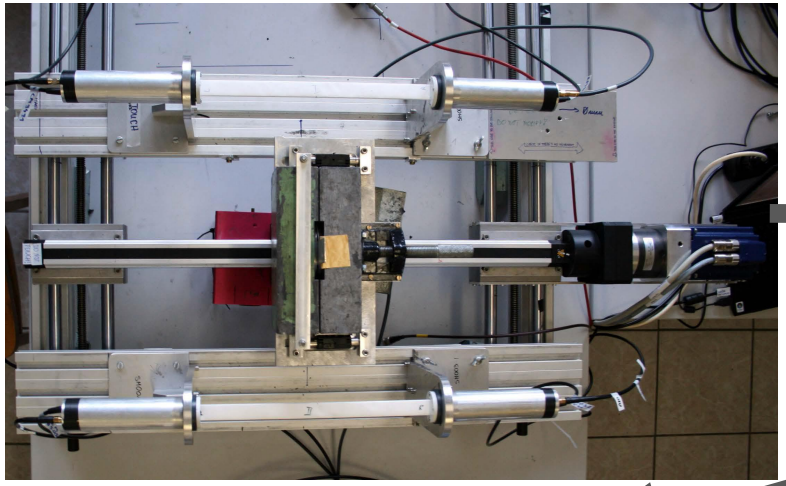
- **discrete symmetries breaking**

More details in
M. Silarski talk today

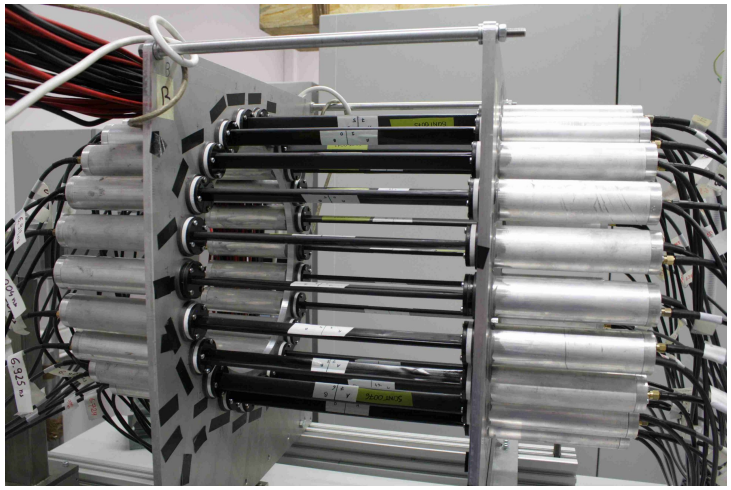
- **quantum entanglement**

Prototypes presentation

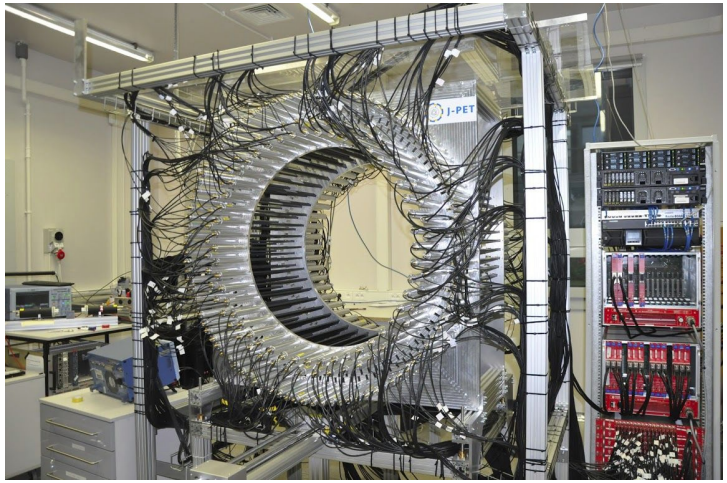
2 modules



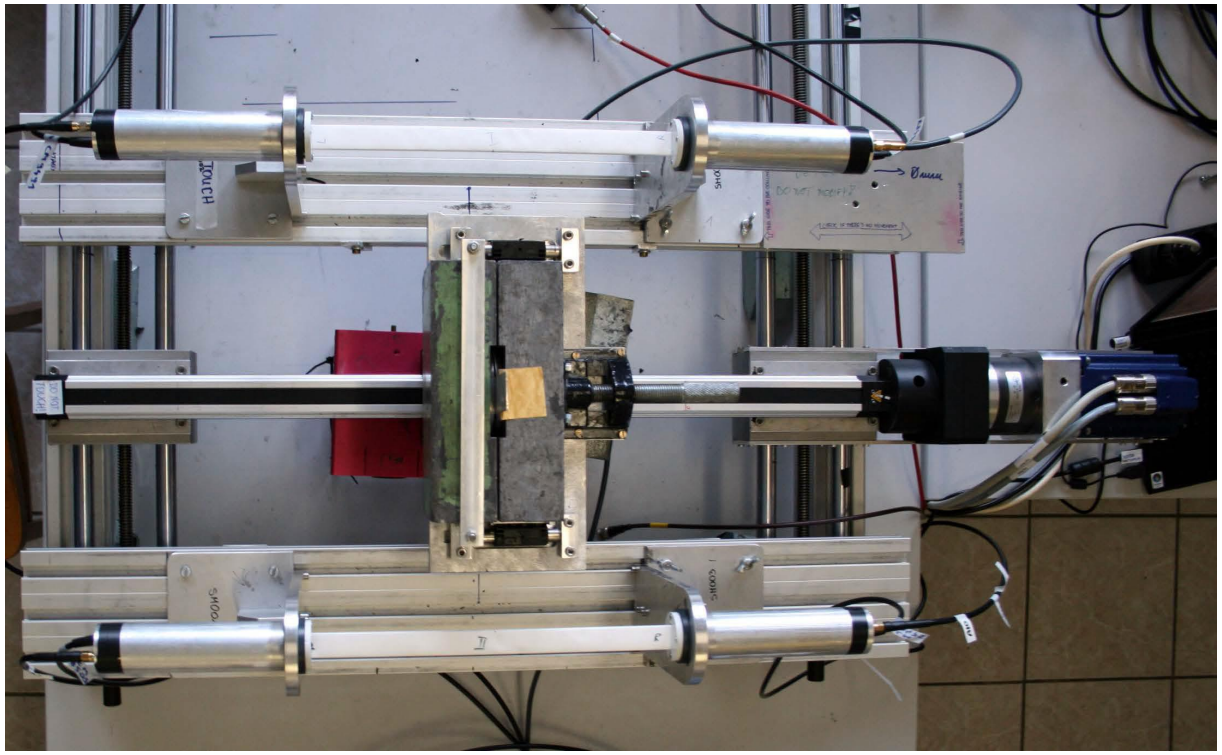
24 modules



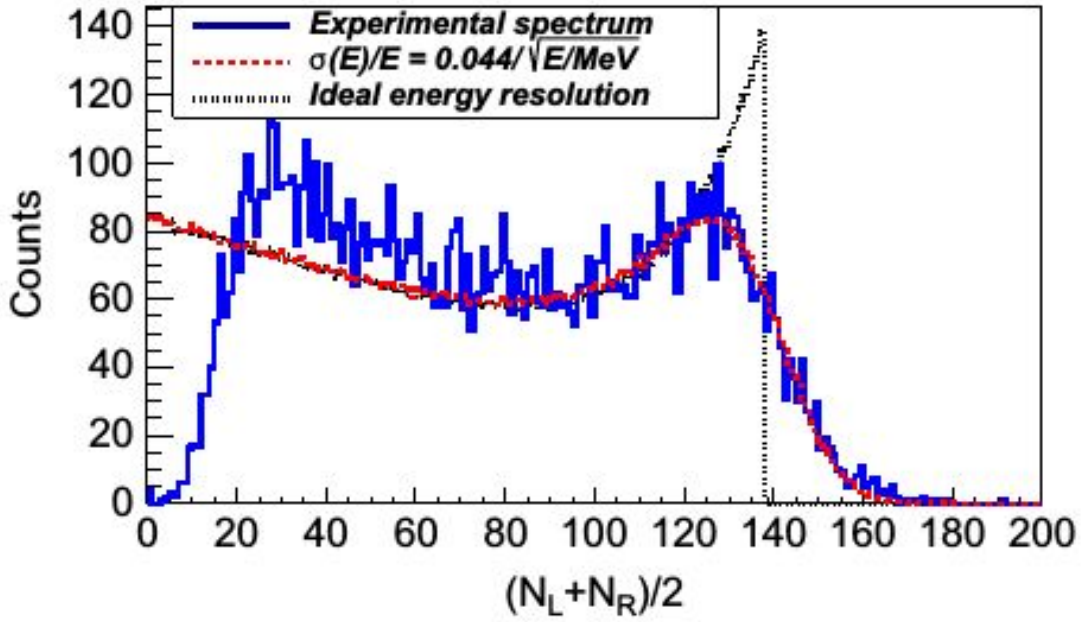
192 modules

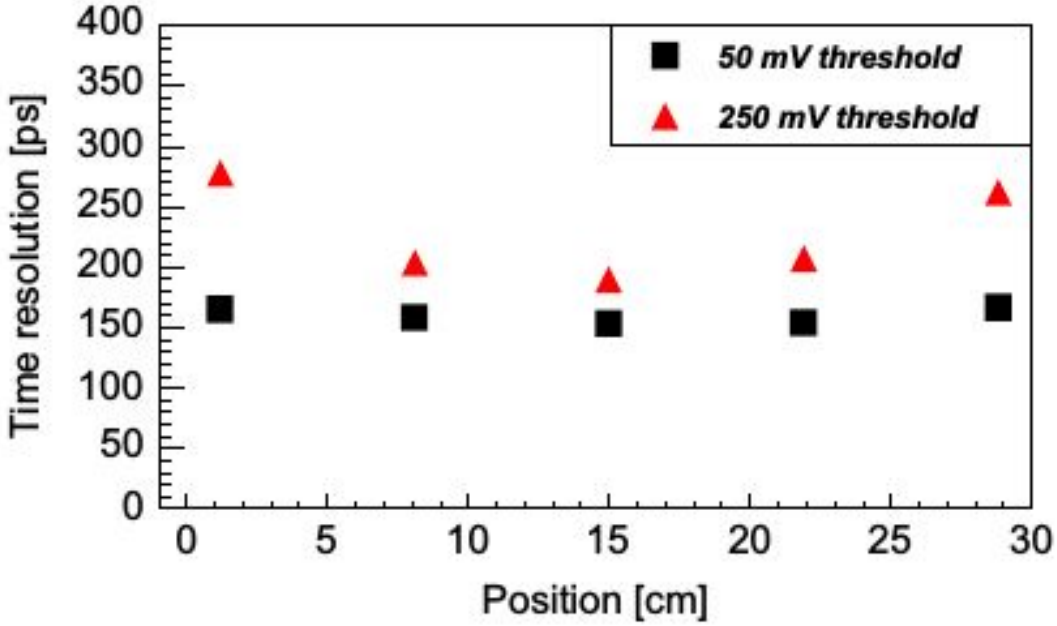


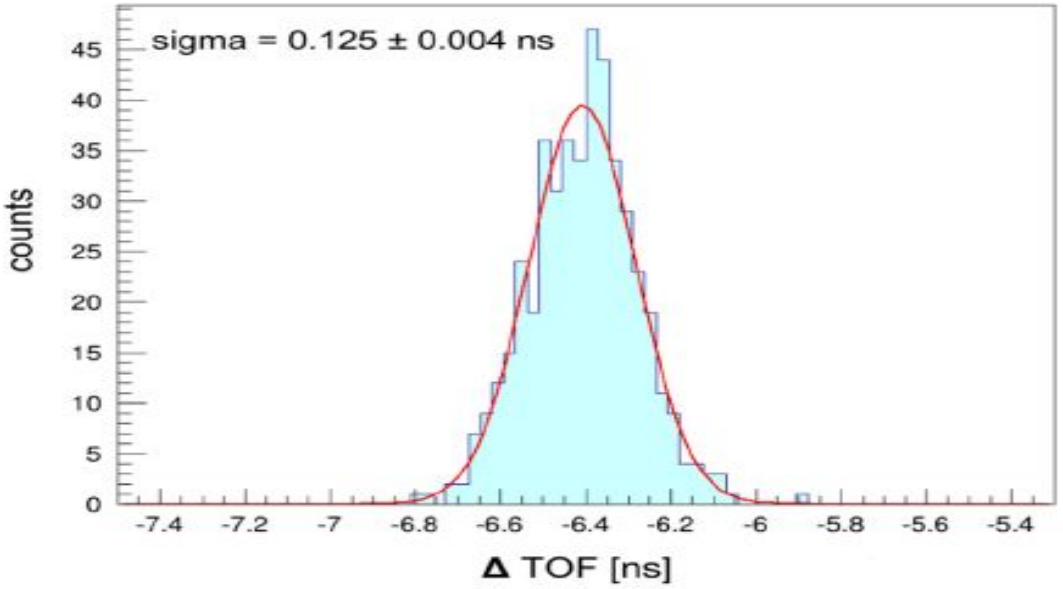
2 module prototype



30 cm diameter, 30 and 50 cm AFOV
signals probed every 100 ps



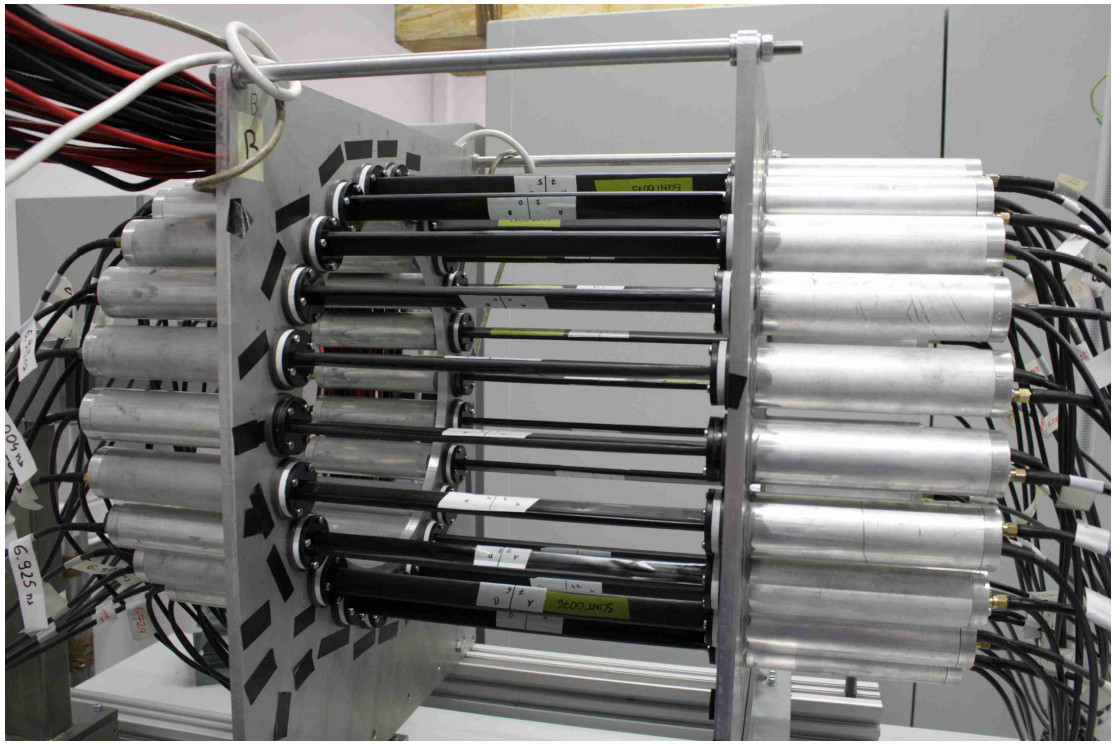




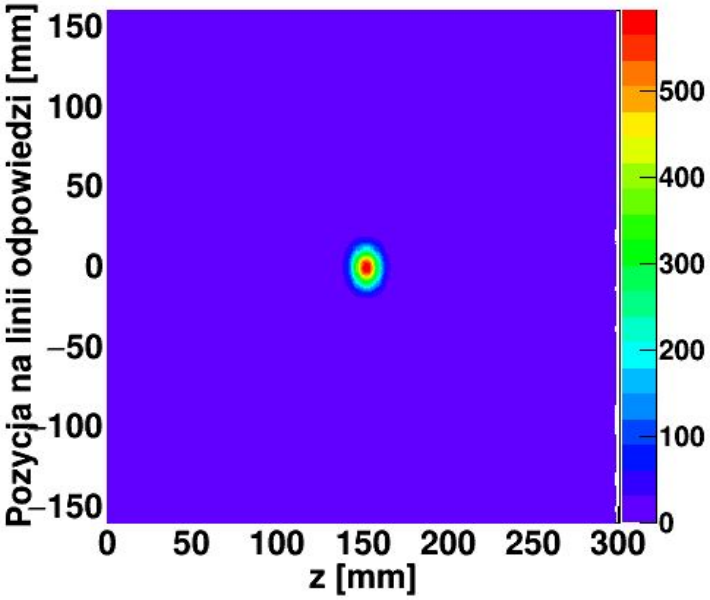
Energy resolution = 17.5%
Time resolution = 160 ps
Hit position (Z-axis) = 0.93 cm
TOF resolution = 125 ps

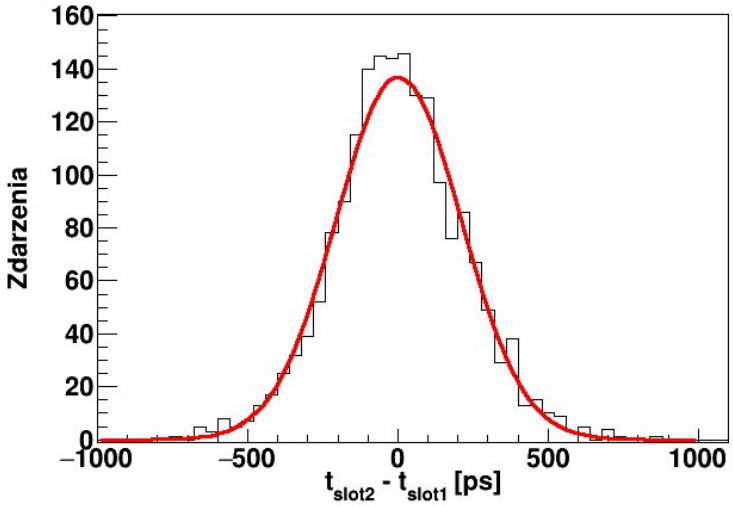
P. Moskal et al., Nucl. Inst. and Meth. (2014) A764 317-321
P. Moskal et al., Nucl. Inst. and Meth. in Phys. Res. A (2015) A775 54-6 2

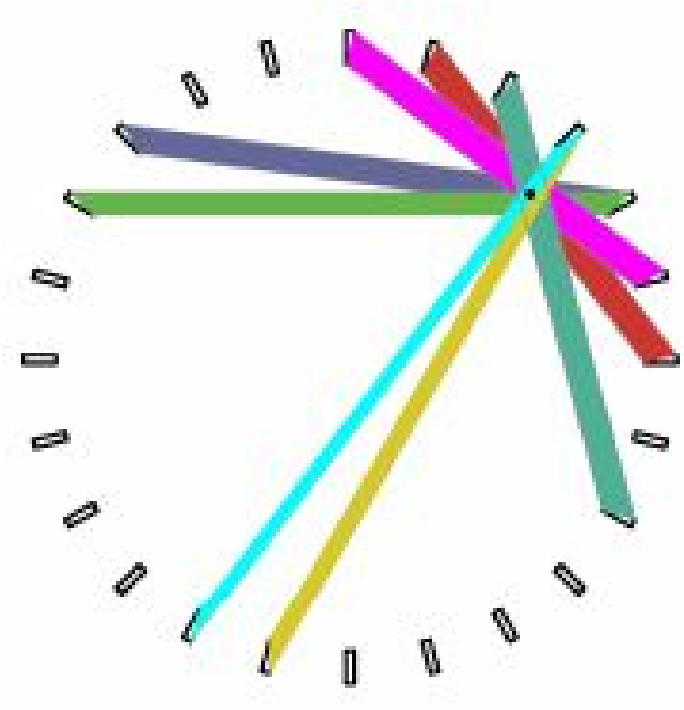
24 module prototype



36 cm diameter, 30 cm AFOV
4 constant threshold readout at both sides



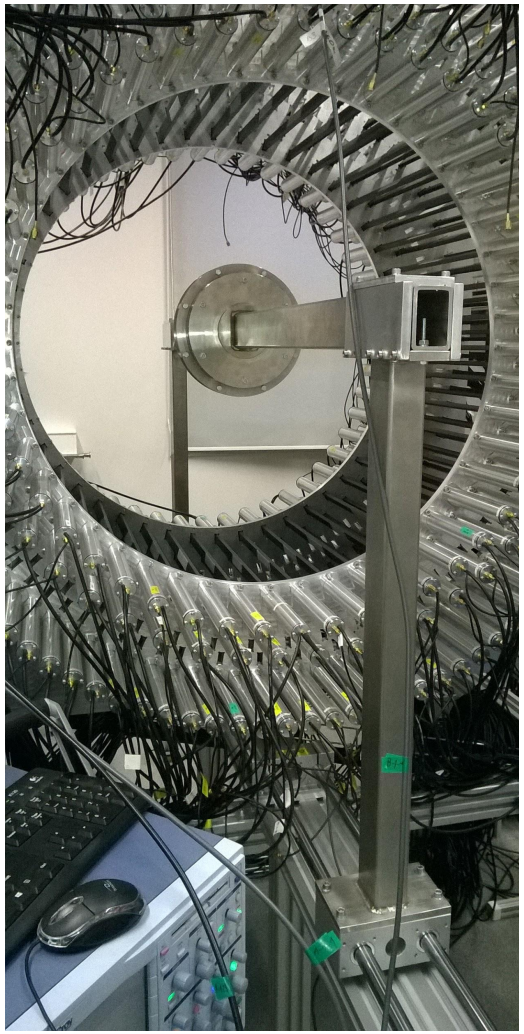


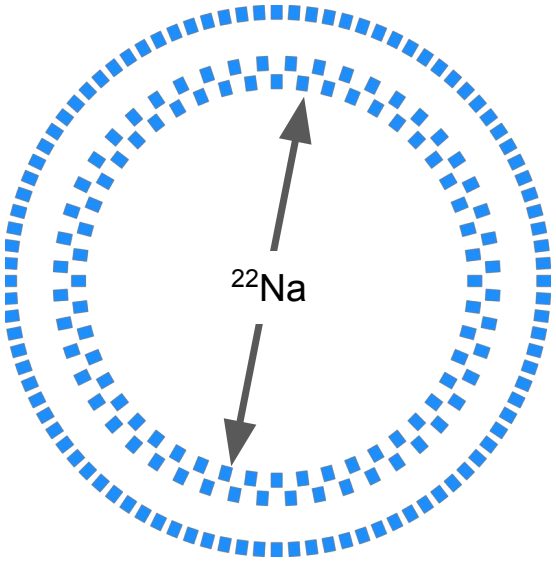


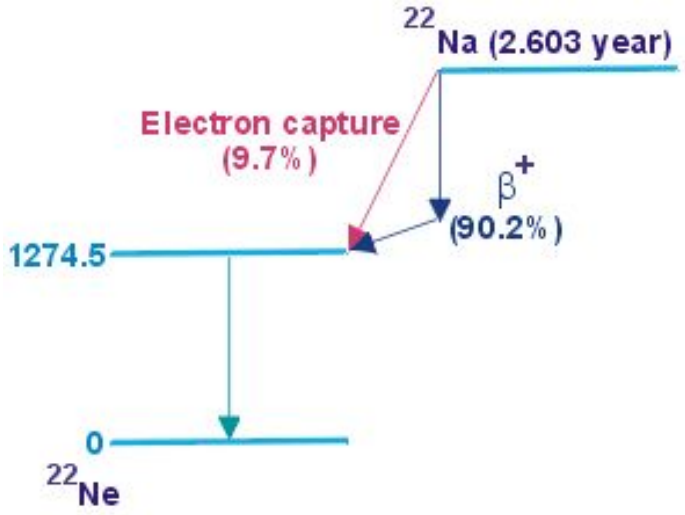
Time resolution = 214 ps
Hit position (Z-axis) = 1.35 cm
TOF resolution = 208 ps
Spatial transverse resolution = 7.6 mm
Spatial axial resolution = 11.5 mm

T. Bednarski PhD Thesis

192 module prototype







85 cm diameter, 50 cm AFOV
4 constant threshold readout at both sides

Comparison between J-PET prototypes

Parameter	2 modules	24 modules	192 modules **PRELIMINARY**	GE Discovery 710
Energy resolution [%]	17.5 %	---	---	~10-25%
TOF resolution [ps]	125	208	220	230
Spatial transverse resolution [mm]	---	7.6	8.0	4.9
Spatial axial resolution [mm]	---	11.5	11.7	5.6

Summary

- J-PET group is working on scanner for whole body examination based on plastic scintillators and multi-threshold readout
- First whole body prototype of J-PET scanner was constructed and is operational
- Preliminary experimental results are very promising
- Second prototype construction based on SiPM readout is under way