Commissioning of 50 cm AFOV modular plastic J-PET scanner

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Abstract

PET imagining community is in progress of developing total-body PET systems in order to increase the sensitivity of detection system by enlarging the axial field-of-view (AFOV). Achieving higher sensitivity can decrease the time of scan or the injected dose. One of the approaches to increase AFOV is to increase the amount of detection rings while another, cost-effective possibility is to detect gamma quanta by means of plastic scintillators, oriented along the patients body [1, 2]. Such solution maintains the size of readout system, independently on AFOV. Here a prototype with 50 cm AFOV is be presented, which is the first step towards the total-body PET based on plastic strips. The prototype is also a first test of multi photon (multi gamma) [3] and positronium imaging methods [4] on patients.

Materials and methods

A mobile, modular prototype of the J-PET detector, a PET scanner based on plastic scintillators, is being commissioned at the Jagiellonian University this year. The system is built out of 24 modules, composed of 50 cm long 13 scintillator strips, read out by a SiPMs (Fig. 1). Each module converts an analogue response to the digital data independently. Acquisition system is based on trigger-less FPGA technology divided into few steps, maintaining the modularity of the system: TDC conversion based on MVT by means of LVDS buffers [5], concentration of signals from each end of the module and final aggregation of data streams with possibility to produce initial image in real-time [6].

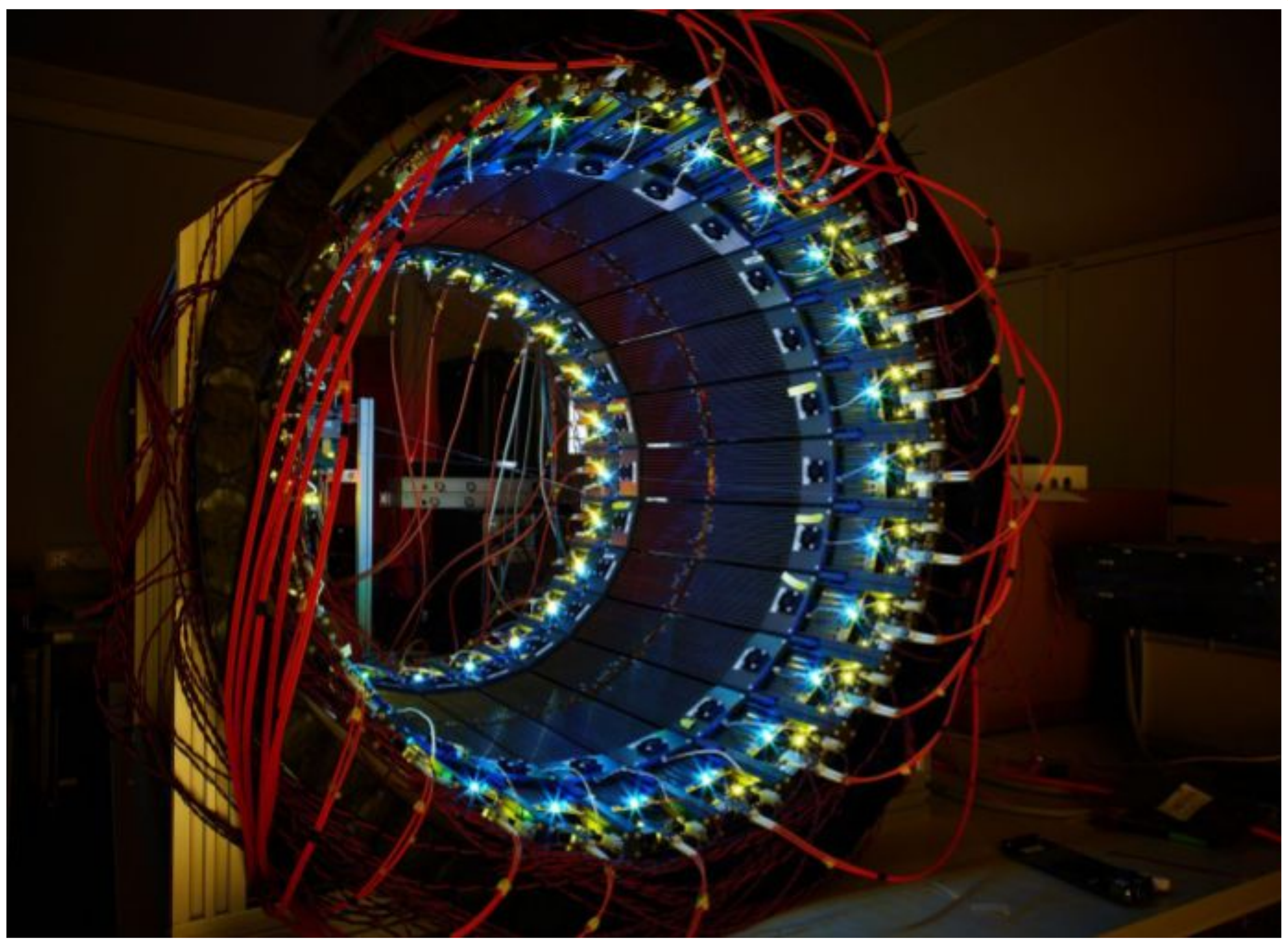

Fig 1. Mobile, modular J-PET prototype, built out of 24 modules. Each module is composed of 13 scintillator strips, read out by a SiPM array from both sides.

System performance with point-like source

Preliminary results acquired with point-like ^{22}Na source placed at center of FOV are presented in Figs 2 and 3. System resolutions are satisfactory apart from spatial resolution along Z axis.

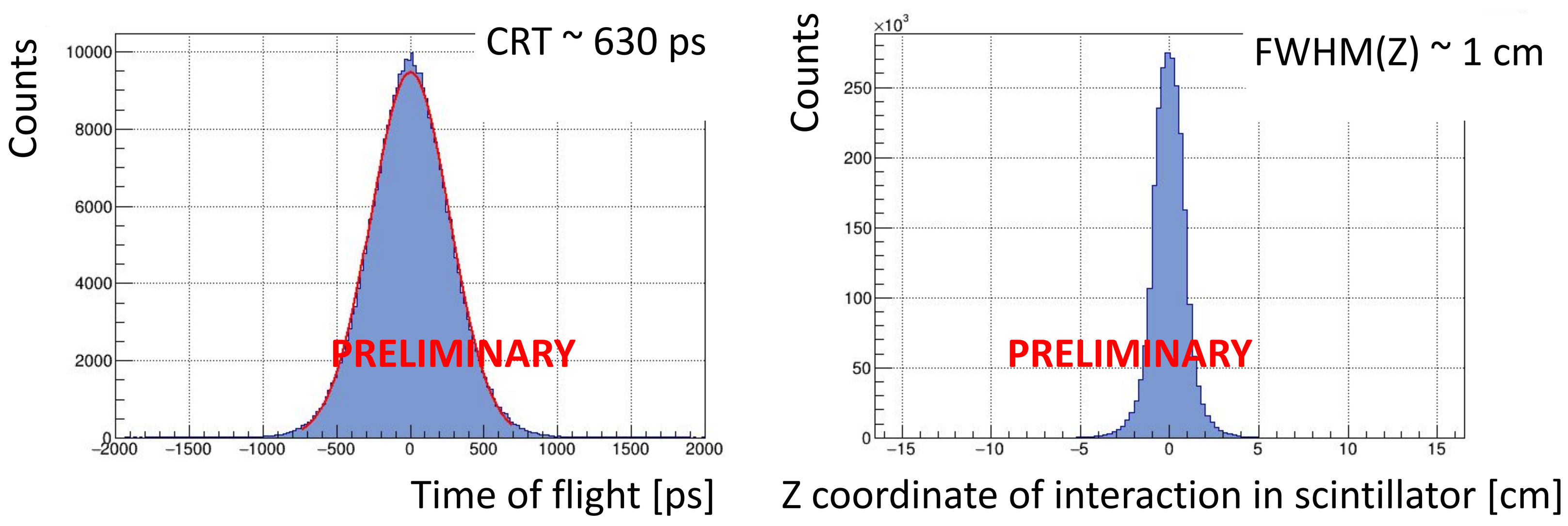

Fig 2. (left) Time of flight spectrum after first two iterative walk corrections. (right) Distribution of Z coordinates of interaction position inside scintillator.

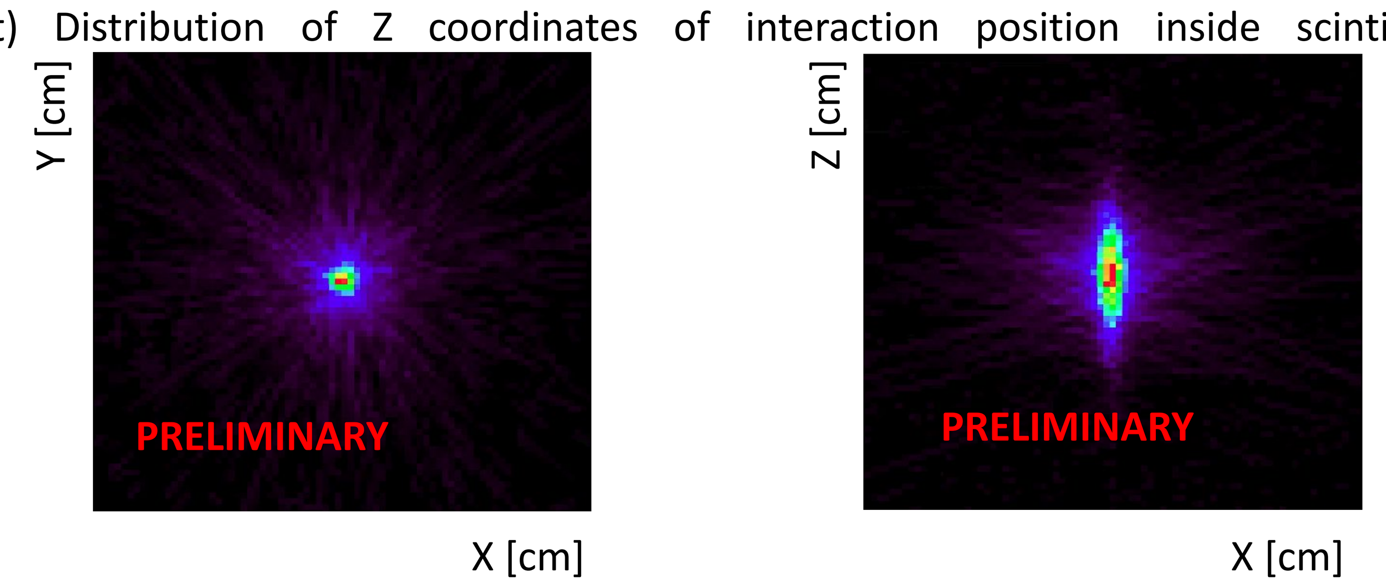

Fig 3. Point-like source image reconstructed with CASTOR software on (left) from the front view (XY plane) and (right) from the top (ZX plane).

Front End Boards performance

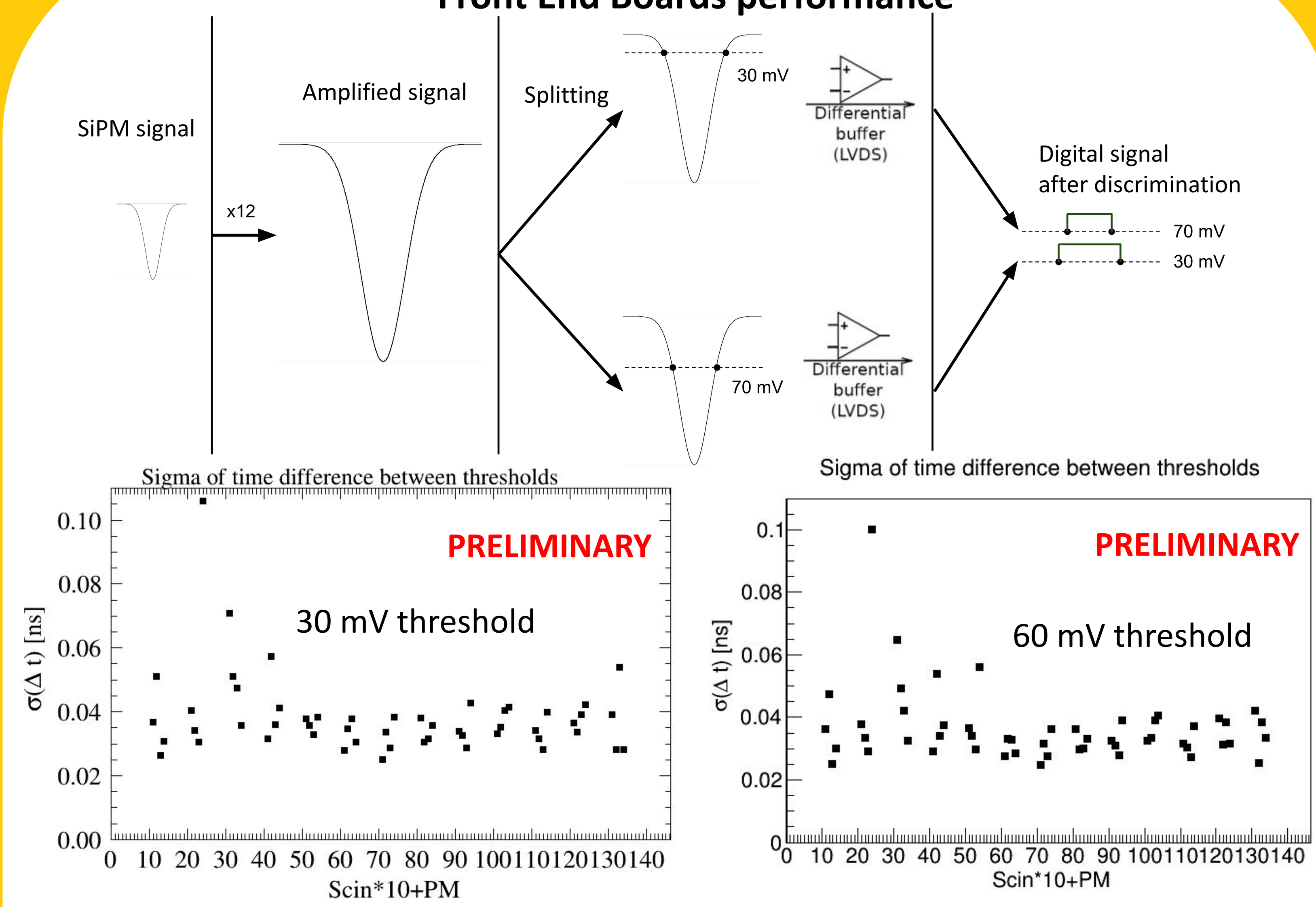

Fig 4. (top) Signal processing scheme. Each SiPM signal is amplified, then split into two and then converted with TDC unit on FPGA chip. (bottom) Time difference between two thresholds set on the same value for each SiPM.

Conclusions and Perspectives for TB J-PET

Commissioning of the 50 cm FOV modular plastic J-PET scanner has been completed at the Jagiellonian University and preliminary checks show that it is ready to perform tests on clinical patients. First ex-vivo images using the J-PET prototype have been recently demonstrated [3, 4]. Moreover first in-vivo images with patients were taken in March (Fig. 5), results of which are also presented in this conference.

Total Body scanner based on plastic scintillators is under development. It will possess high sensitivity and improved resolution along Z axis due to application of WLS readout [7] improving spatial resolution of the system to < 5 mm.

Fig 5. Modular J-PET a moment before data taking from patients torso.

Tab 1. Comparison of selected features of Modular and Total Body J-PET scanners with other, crystal based PET devices.

Feature	Modular J-PET	Total Body J-PET	Philips Biograph mCT Flow	GE Discovery 710	uExplorer
Detector material	BC404	BC408	LSO	LYSO	LYSO
Transaxial resolution @ 1 cm [mm]	5 PRELIMINARY	5.5 SIMULATION	4.4	4.9	3.0
Axial resolution @ 1 cm [mm]	12.5 PRELIMINARY	4.5 SIMULATION	4.5	5.6	2.8
CRT [ps]	630 PRELIMINARY	140 SIMULATION	540	544	505
Energy resolution FWHM [%]	21	NA	NA	12	12
Energy window [keV]	200-380	200-380	435-650	425-650	430-645
AFOV [cm]	50	>200	21.8	15.7	194

References

1. P. Moskal, et al. "Simulating NEMA characteristics of the modular total-body J-PET scanner - an economic total-body PET from plastic scintillators", Phys. Med. Biol. 66 (2021) 175015.
2. S. Niedźwiecki, et al., "J-PET: A New Technology for the Whole-body PET Imaging", Acta Phys. Polon. 2017; B48 10: 1567-1576.
3. P. Moskal, et al., "Positronium imaging with the novel multiphoton PET scanner", Science Advances 7 (2021) eabh4394.
4. P. Moskal, et al., "Testing CPT symmetry in ortho-positronium decays with positronium annihilation tomography", Nature Communications 12 (2021) 5658.
5. M. Pałka, et al., "Multichannel FPGA based MVT system for high precision time (20 ps RMS) and charge measurement". JINST; 2017: 12 P08001.
6. G. Korcyl, et al. "Evaluation of Single-Chip, Real-Time Tomographic Data Processing on FPGA - SoC Devices". IEEE Transactions On Medical Imaging. 2018; Vol. 37, No. 11: 2526 - 2535.
7. J. Smyrski, et al. "Measurement of gamma quantum interaction point in plastic scintillator with WLS strips" NIM. in Physics Research A 851 (2017) 39-42.

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