FAST ADVANCED SCINTILLATION TIMING (2014-2018): http://www.cern.ch/FAST-COST

TD1401 EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Strasbourg 2016 NSS/MIC

Jagiellonian Positron Emission Tomograph – TOF-PET based on plastic scintillators

L. Raczyński[1], D. Alfs[2], T. Bednarski[2], P. Białas[2], C. Curceanu[3], E. Czerwiński[2], K. Dulski[2], A. Gajos[2], B. Głowacz[2], M. Gorgol[4], B. Hiesmayr[5], B. Jasińska[4], D. Kamińska[2], G. Korcyl[2], P. Kowalski[1], T. Kozik[2], W. Krzemień[1], E. Kubicz[2], M. Mohammed[2], M. Pawlik-Niedźwiecka[2], Sz. Niedźwiecki[2], M. Pałka[2], Z. Rudy[2], O. Rundel[2], N. Sharma[2], M. Silarski[2], J. Smyrski[2], A. Strzelecki[2], A. Wieczorek[2], W. Wiślicki[1], B. Zgardzińska[4], M. Zieliński[2], P. Moskal[2]

[1]National Centre for Nuclear Research, Poland; [2]Jagiellonian University, Poland; [3]LNF INFN, Italy; [4]Maria Curie-Skłodowska University, Poland; [5]University of Vienna, Austria;

Aim:

- Cost effective whole-body PET
- MR and CT compatible PET insert

J-PET

Presentation #: M17-1, Nov. 5, 08:30, Schweitzer
and poster #: M04B-5, Nov. 2, 16:30, Etoile

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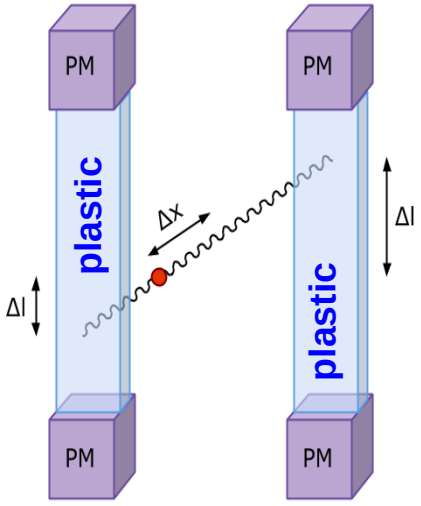
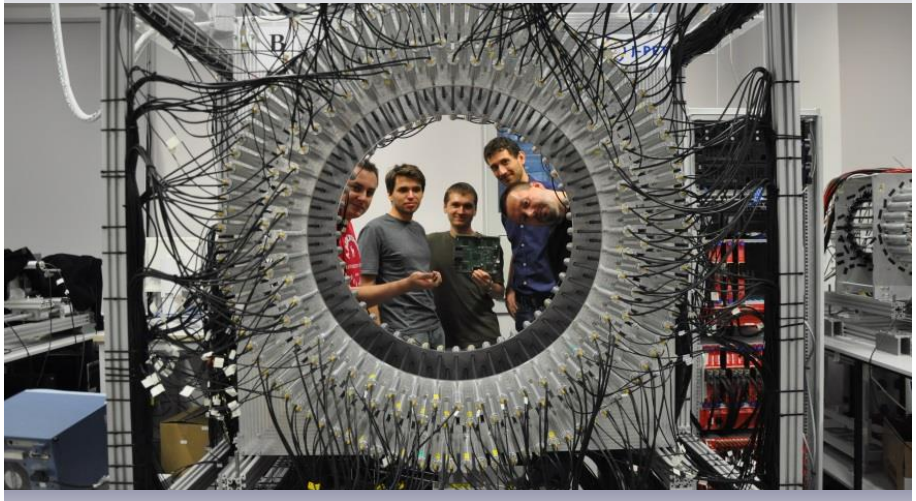
- Axially arranged plastic strips instead of radially arranged crystals.
- Axial position of the interaction of gamma quantum in the detector (ΔL) and the position of annihilation point along line-of-response (Δx) are determined solely based on the time measurement.
- Timing of signals is used not only for the determination of hit-position and TOF, but also for suppression of scatterings via time-over-threshold (TOT) method or via recovery of the signal waveform based on the compressing sensing (see poster M04B-5)



Jagiellonian-PET



AFOV = 50 cm CRT < 500 ps (FWHM)

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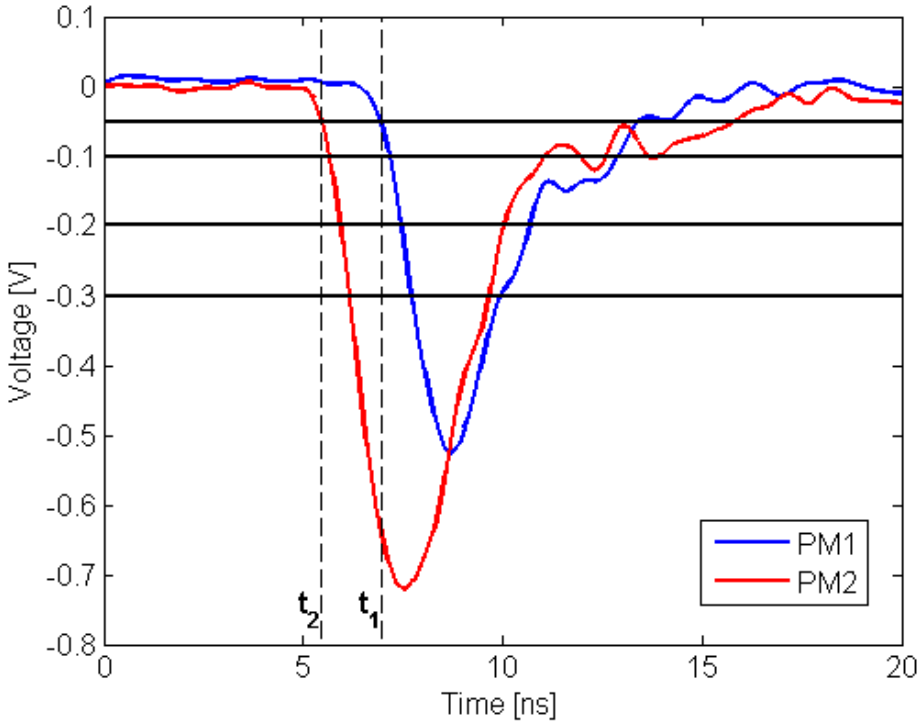
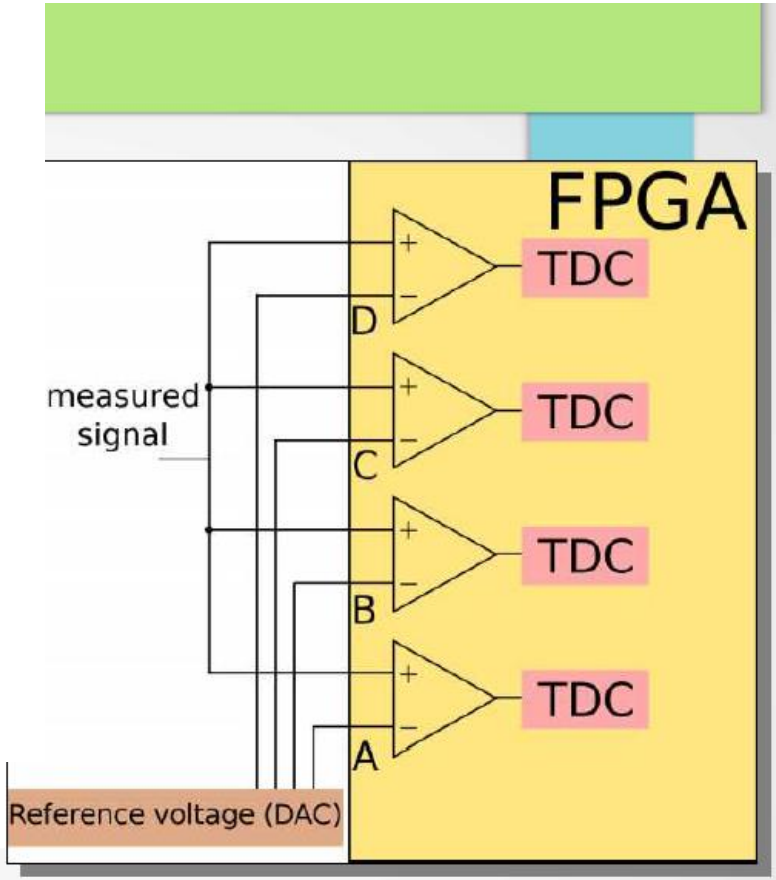
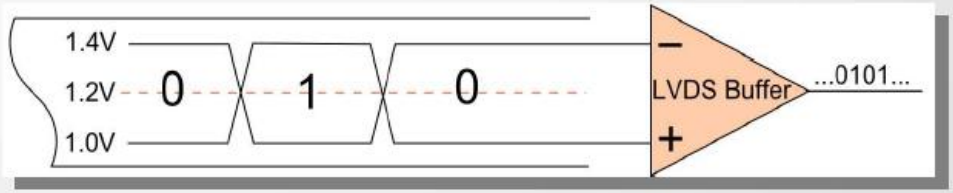


M. Palka, et al., Bio-Algorithms and Med-Systems 10 (2014) 41.



Discrimination of the signal is done with LVDS buffer which acts as a comparator. This innovative approach is the subject of **patent application**



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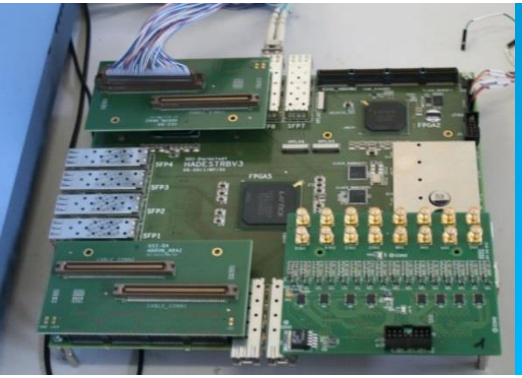


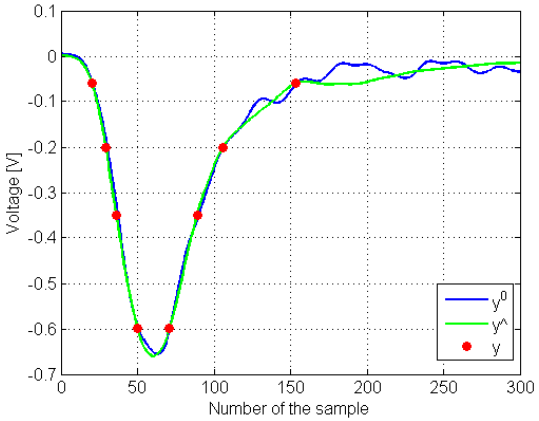
ONLY DIGITAL in triggerless mode

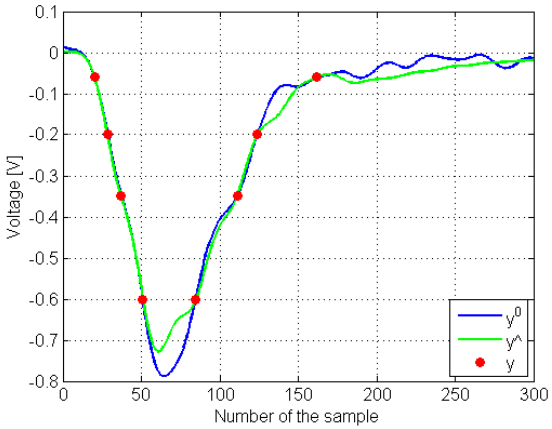
FFE sampling & Readout electronics

precision of 21ps for 10 Euro per sample

M.Pałka, P.M., **PCT/EP2014/068367**

G. Korcyl, P. M., M. Kajetanowicz, M. Pałka, **PCT/EP2014/068352**





- Signals are sampled at four voltage levels at the leading and at the trailing edges with the newly developed digital multi-voltage-threshold electronics.
- It is shown that using the recovered waveform of the signals, instead of samples at four voltage levels alone, improves the time and spatial resolution of the hit position reconstruction of about 10%.

J-PET

FAST ADVANCED SCINTILLATION TIMING (2014-2018): http://www.cern.ch/FAST-COST

cost TD1401 EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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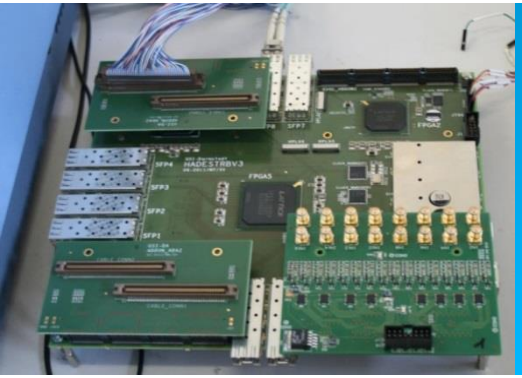

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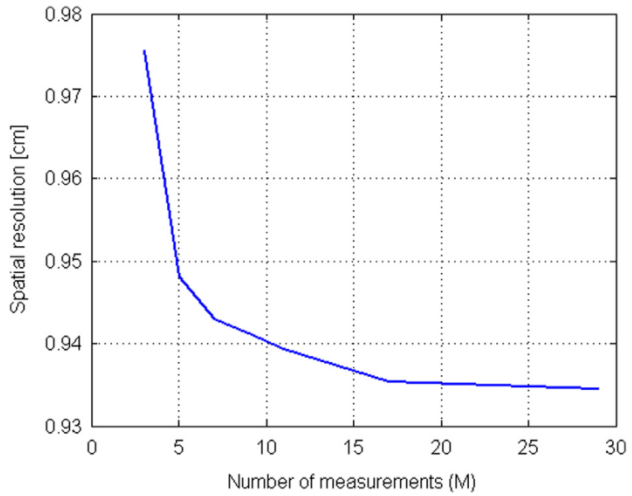


IDEAS :

Library of signals;
Principal Component Analysis;
Compressive Sensing;

- **L. Raczyński et al., Nucl. Instr. Meth. A 786 (2015) 105**
- **P. Moskal et al., Nucl. Instr. Meth. A 775 (2015) 54**
- **L. Raczyński et al., Nucl. Instr. Meth. A 764 (2014) 186**

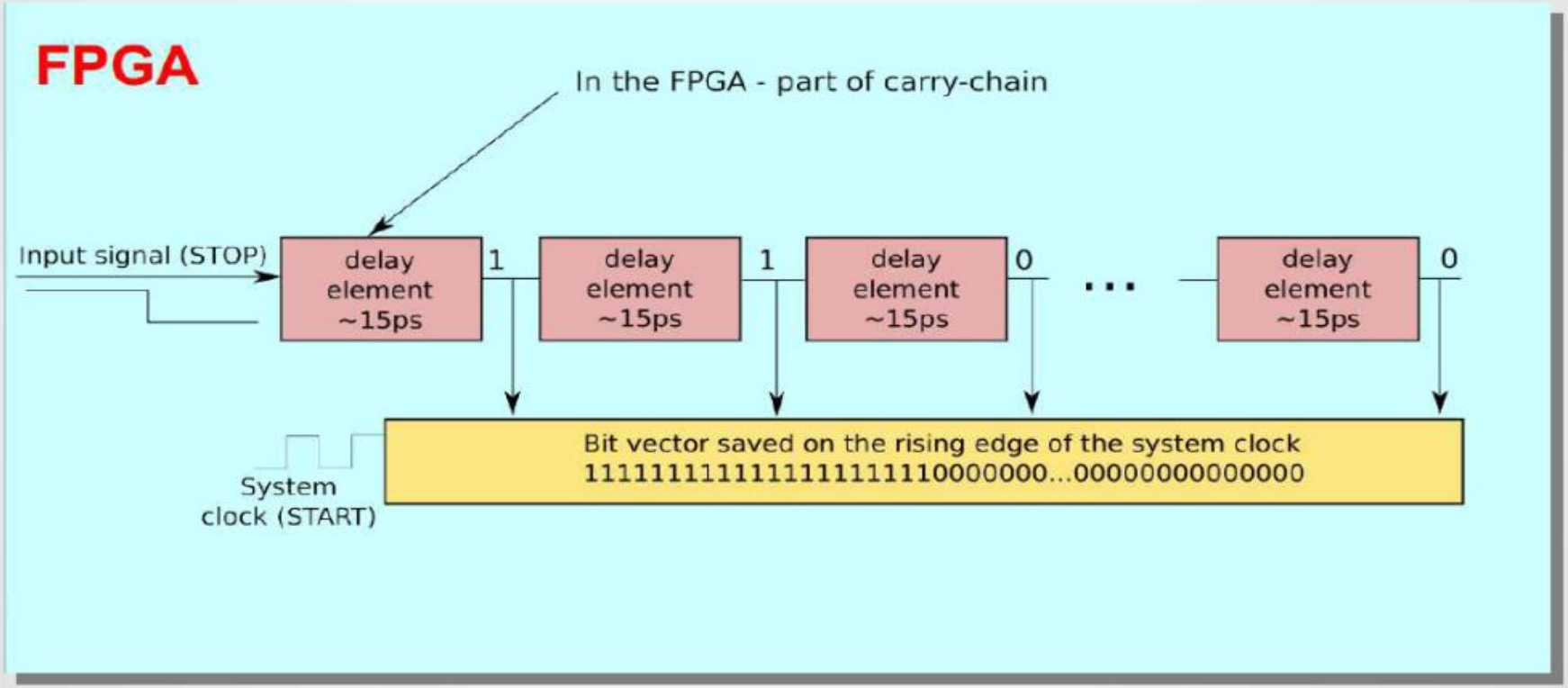
Detector | **FrontEnd electronics** | **Electronics controller**

Reconstruction

Hit along strip | **Annihilation point** | **Image**

J-PET: W. Krzemień et al., Acta Phys. Pol. B47 (2016) 561

TDC in FPGA


FPGA
In the FPGA - part of carry-chain
Input signal (STOP)
delay element ~15ps
1
delay element ~15ps
1
delay element ~15ps
0
...
delay element ~15ps
0
System clock (START)
Bit vector saved on the rising edge of the system clock
11111111111111111111110000000...00000000000000

cost TD1401 EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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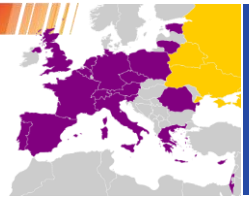
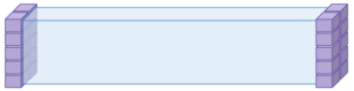
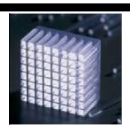


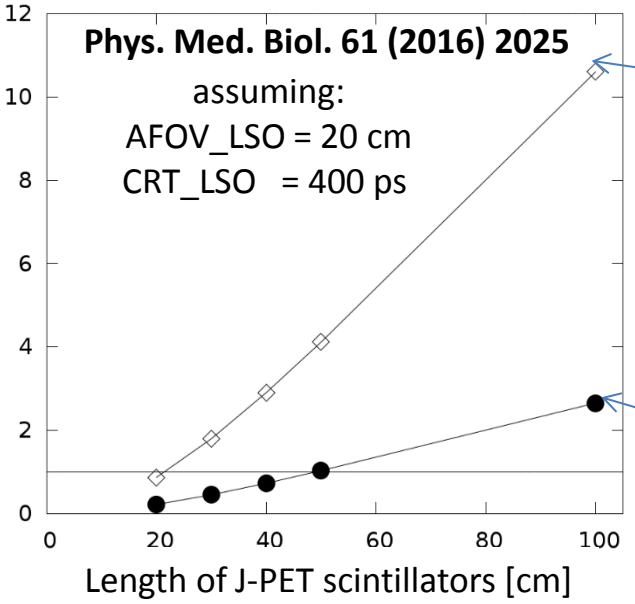
Figure of merit for whole body imaging (FOM)

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

$$\mathbf{R} = \frac{\text{FOM\_SiPM\_JPET}}{\text{FOM\_LSO\_crystals}}$$







J-PET

CONCLUSIONS:

- A full scale prototype of PET from the axially arranged plastic scintillators was built by the Jagiellonian-PET group.
- In order to compensate for the lower efficiency of plastic scintillators and thus to obtain figure-of-merit of the J-PET comparable to the LSO crystal based scanners it is required to use either two detection layers or to increase the J-PET axial field-of-view to about 50 cm.
- Plastic scintillators and their large light attenuation length (larger than 100 cm) enables construction of tomograph with a large axial field-of-view in a cost effective way.
- J-PET detector is built from non-magnetic and low-Z material strips. Therefore, it is possible to combine J-PET with CT and J-PET with MR, so that the same part of the body can be scanned simultaneously with both methods.