TWEPP-23

Contribution ID :173

Proof of principle for a novel PET detector

Andrej Seljak on behalf of PetVision Consortium

Calaserena Cagliari, Sardegna, Italy 1st to 6th October 2023

Motivation

Positron emission tomography (PET) method is based on detecting two gamma rays originating from the point of annihilation of the positron emitted being by radio-labelled agent, and used to follow the human's physiological processes.

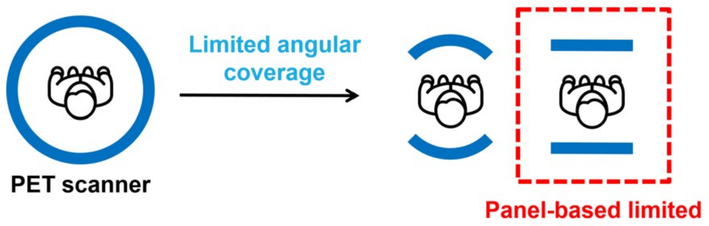
In Time-Of-Flight PET gamma rays' arrival time is measured in addition to their position. The coincidence timing resolution (CTR) of state-of-the art scanners is between 200 ps and 500 ps FWHM, which can already significantly improve the contrast in imaging large objects. To increase the sensitivity of the next-generation PET scanners timing accuracy should be substantially increased. By using latest advances multichannel system with improved CTR is becoming technologically possible. Generally 3D images from limited angle PET scanners are distorted and have artifacts. Fortunately, with improving timing resolution of PET gamma detectors, artifact free images can be obtained even by a very simplified detector.

With this new concept, the price of PET scanners for imaging single or multiple organs can be drastically decreased. We found comparable image quality parameters of both systems when the CTR approaches 50ps FWHM and also that good CTR can partially compensate for smaller gamma detection efficiency. A new planar detector is under construction by the consortium, named PETVISION, and funded by the European Union.

Funded by the European Union

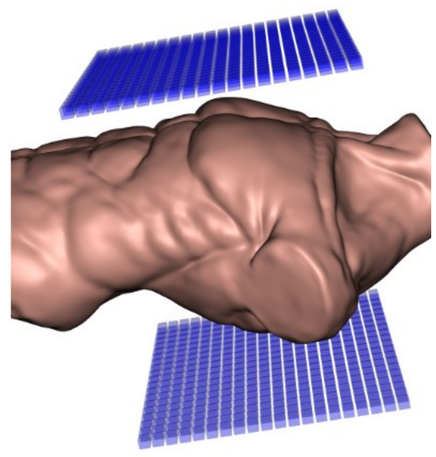
This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101099896

Limited Angle PET scanner



Our goals:

- Development of an ultra fast gamma-ray detector
- Construction of a prototype PET imager
- Evaluation and validation of imager performance



Advantages

Portable or bedside PET imaging

Flexibility

Adjustable FOV and sensitivity

Modularity

Combining multiple panels → multi-organ/total-body PET scanner

Accessibility

Reduced manufacturing cost and complexity

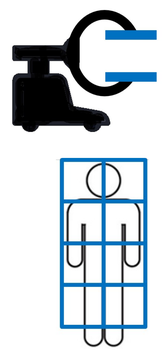
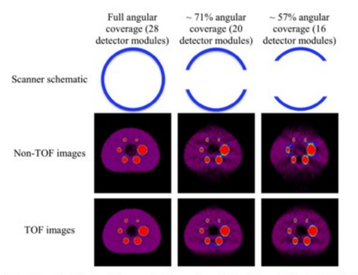
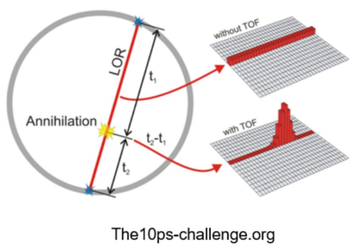


Image quality



S. Surti, J. S. Karp, Physica Medica 32 (2016)



The10ps-challenge.org

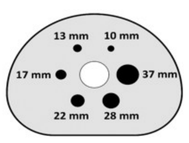
NEMA NU 2-2018 image quality phantom

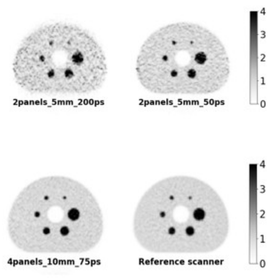
4:1 hot sphere to background activity ratio

Simulated 1 min scans

MLEM: 50 iterations, 3 x 3 x 3 mm³ voxels

Gaussian post filter: 5 mm FWHM





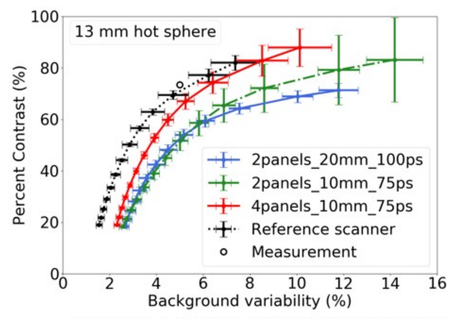
Quantitative measures used to evaluate the image quality

Percent contrast

$$Q_{H,j} = \frac{\frac{C_{H,j}}{C_{B,j}} - 1}{\frac{a_H}{a_B} - 1}$$

Backgroud variability

$$N_j = \frac{\sigma_j}{C_{B,j}}$$



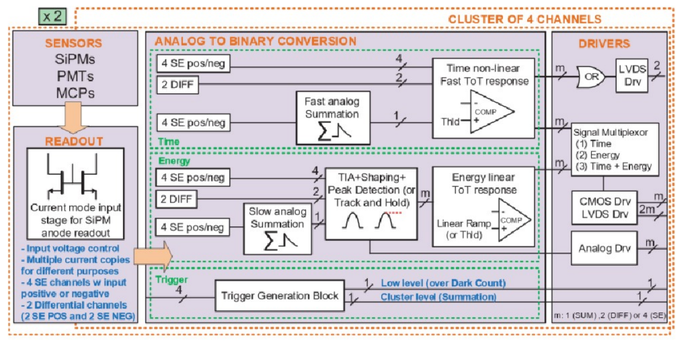
Measurement → J. van Sluis, J Nucl Med 2019 60(7) 1031-1036

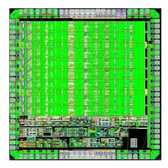
Reference article

Front-end

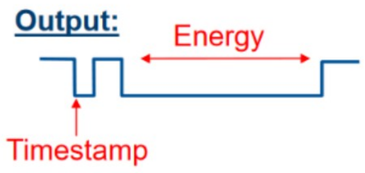
FastIC readout chip

Parameter	Value
Technology	65 nm CMOS
Power consumption	~12mW/ch in SE mode (V_{DD} = 1.2 V), depends on operation mode (~ 3 mW/Input Stage)
Number of channels	8 SE / 4 DIFF
Connection Type	Configurable SE (Pos/Neg polarity), DIFF, Sum of 4 (Pos/Neg polarity)
Electronics Time Jitter	~ 25 ps_{rms} SPTR (330 pF 3x3 SiPM, LCT5 S13360 SiPM, Vov = 4.5 V, L = 1.2 nH)
Energy Resolution	Linear (~ 2.5 % Linearity error)
Dynamic Range	5 uA - 20 mA
Maximum Rate	~ 2 MHz (Linear ToT readout), > 50 MHz (Non-linear ToT. Pulse-shape-dependent)
Testing and Calibration	Yes
Interface	I2C (compatible with picoTDC)
Output	Configurable Digital (single-ended CMOS or differential SLVS) or Analog output (10 pF load).



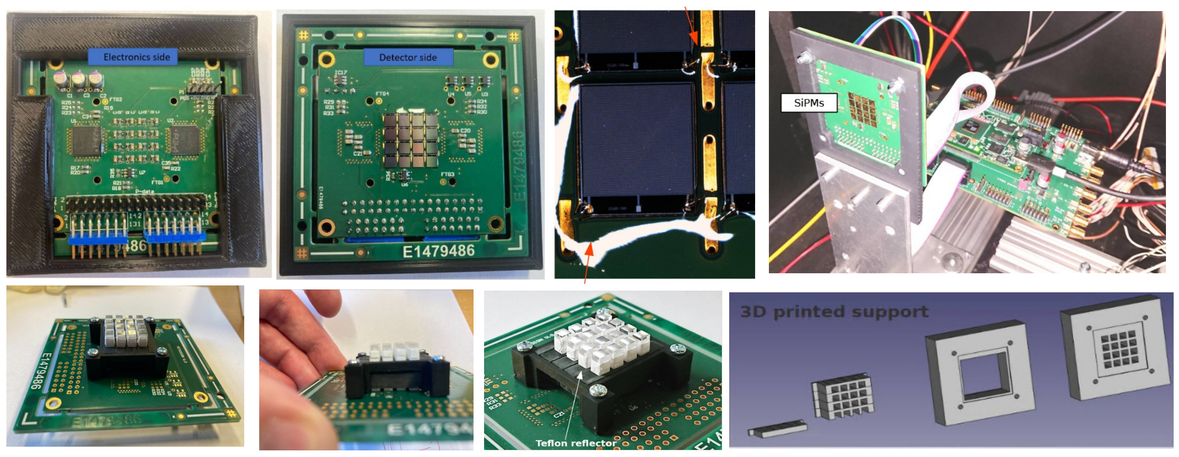


LSO:Ca:Ce 2x2x3mm
FBK NUV-HD-LF v2



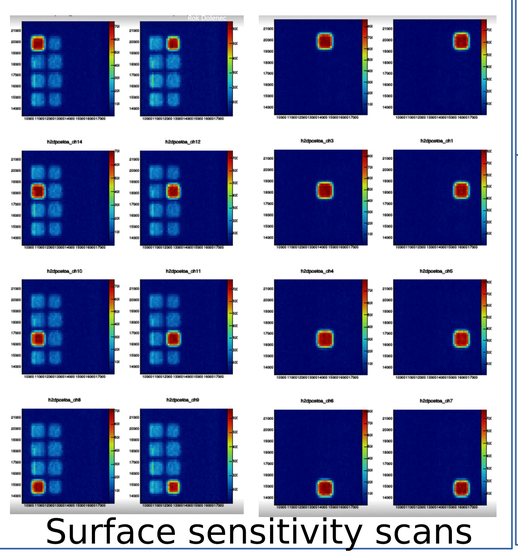
CTR 76ps FWHM
SPTR 151ps FWHM

Prototype



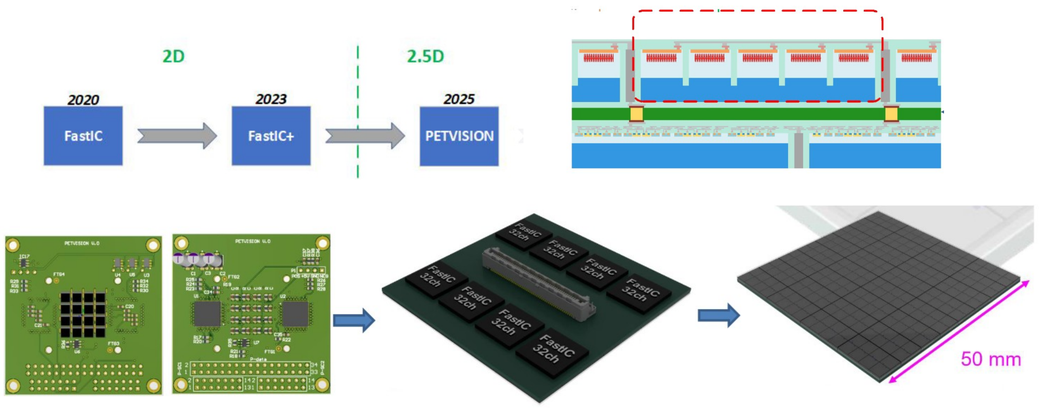
AIM:

- Characterize System performance using CAEN V1290 HPTDC 25ps, 32 channels
- Mostly single photon illumination, focused laser spot, 405nm, 20ps
- Scan over the module surface
- SiPM bias = 38.5 V (6V over voltage)



Surface sensitivity scans

The future



Develop 30 x 30 cm panel:

- New ASIC FastIC+(TDC inside)
- Next evolution FastIC-PET (Optimized for PET)
- 2.5D SiPMs by FBK
- From 2 panel to total body PET

SCAN ME

Communication and Exploitation

- **PetVision started in 2023**
- Project and collaboration details
- Technology development
- Commercialization
- **Interesting positions at various locations**