PET developments at LIP/Lisbon & PETsys

S. Tavernier, LIP Lisbon

INFRI 7th Workshop, Lisbon, April 14, 2016

Since >10 years there is an active program in LIP-Lisbon developing spin-off from HE physics in medical imaging, mainly PET.

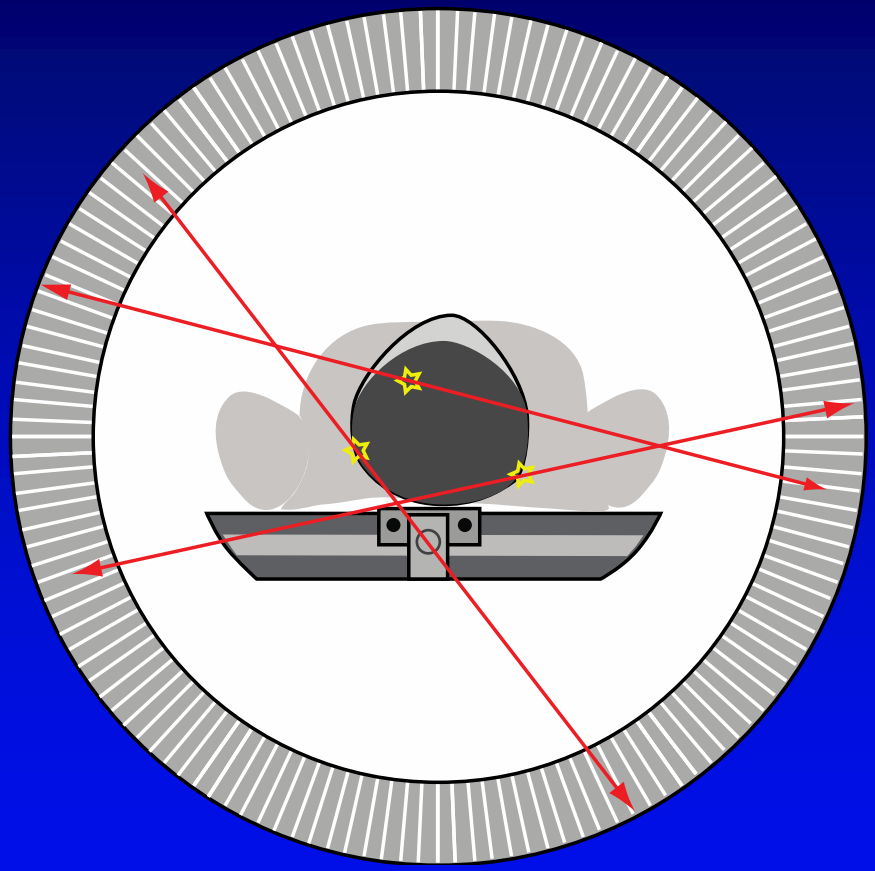
Main activities are
- ClearPEM project
- EndoTOFPET project
- Dedicated readout electronics for TOF-PET

What is PET?

Positron Emission Tomography is a non invasive method for imaging the distribution of a radioactively labelled compounds in the human body.

This is often referred to as “molecular imaging”, or "functional imaging".

Positron Emission Tomography

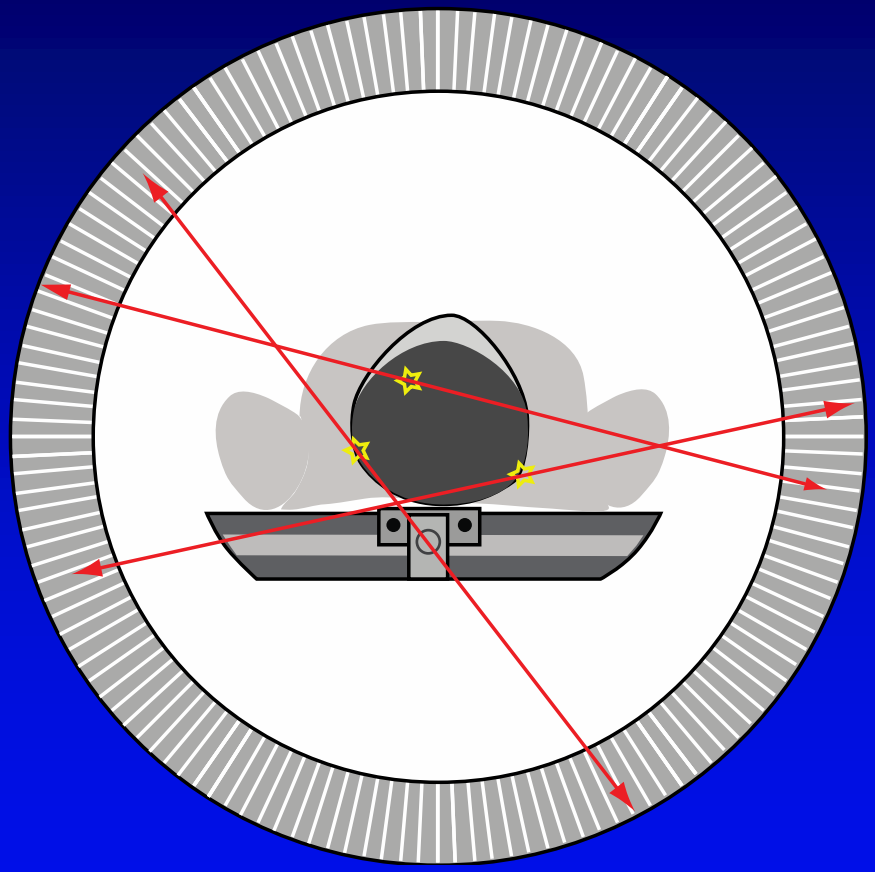


- The patient is injected a drug labeled by a positron emitting isotope

- The positron is emitted and immediately annihilates into two back-to-back gamma rays

- If one detects the gamma rays one knows that the molecule was somewhere on the line joining the two detection points

Positron Emission Tomography



- By far he most commonly used molecule is Fluoro deoxy glucose, one OH^- is replaced by 18F. This isotope has decay time of 109 min.

- The strength of PET compared to other imaging techniques (MRI) is its sensitivity.

- A typical PET-CT whole body scan represents 25 mSv, PET ≈7 mSv, CT 18 mSv.

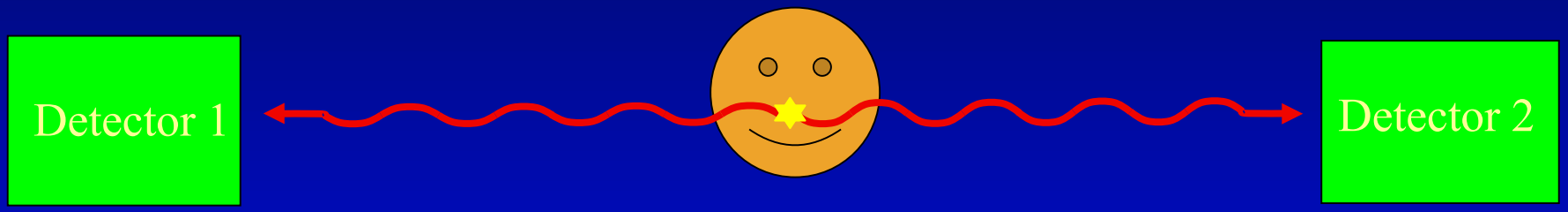
The PET scanner is not observing space points, but lines of response. The positron annihilation occurred somewhere along this line of response.

From a large set of lines of response, covering a sufficient number of directions around the patient, it is possible to reconstruct the 3-dimensional density distribution of the tracer.

This is usually done with an iterative reconstruction algorithm, and is very computer intensive.

Time Of Flight > TOF

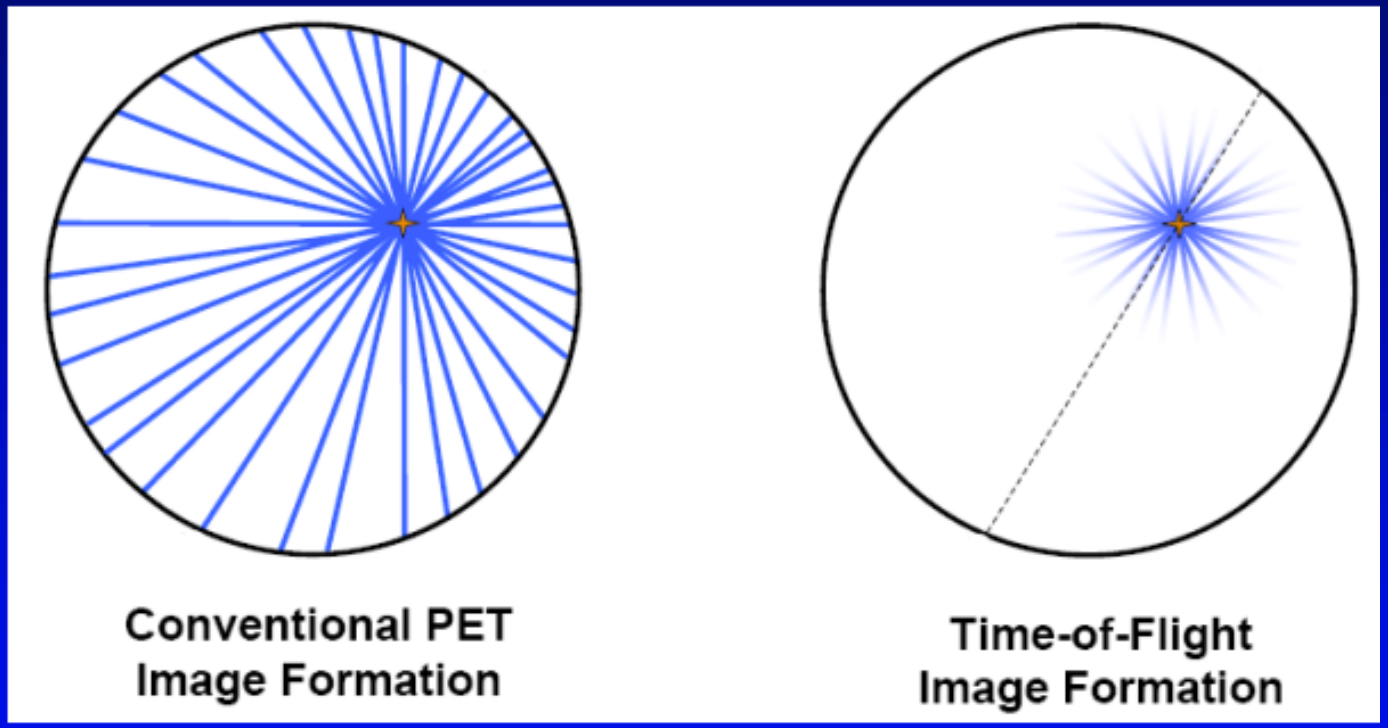
What if we could measure the time difference very accurately $\Delta t = 100$ ps >>> $\Delta x = 1.5$ cm !



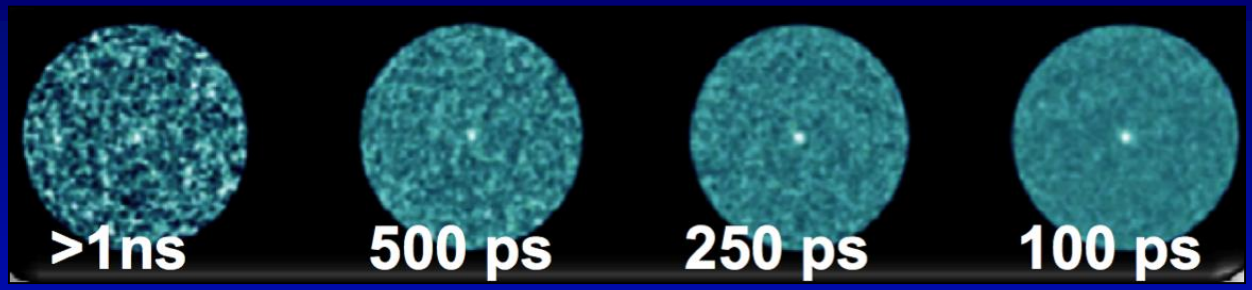
If $\Delta t \approx 10$ ps events would be space points !

Time of Flight (TOF) in PET

100 ps = 1.5 cm



TOF in PET results in a increase of effective sensitivity $\approx$ 2 ns /(TOF time resolution)



Also with good TOF it is no longer necessary to have a full detector ring surrounding the patient.

The ClearPEM project

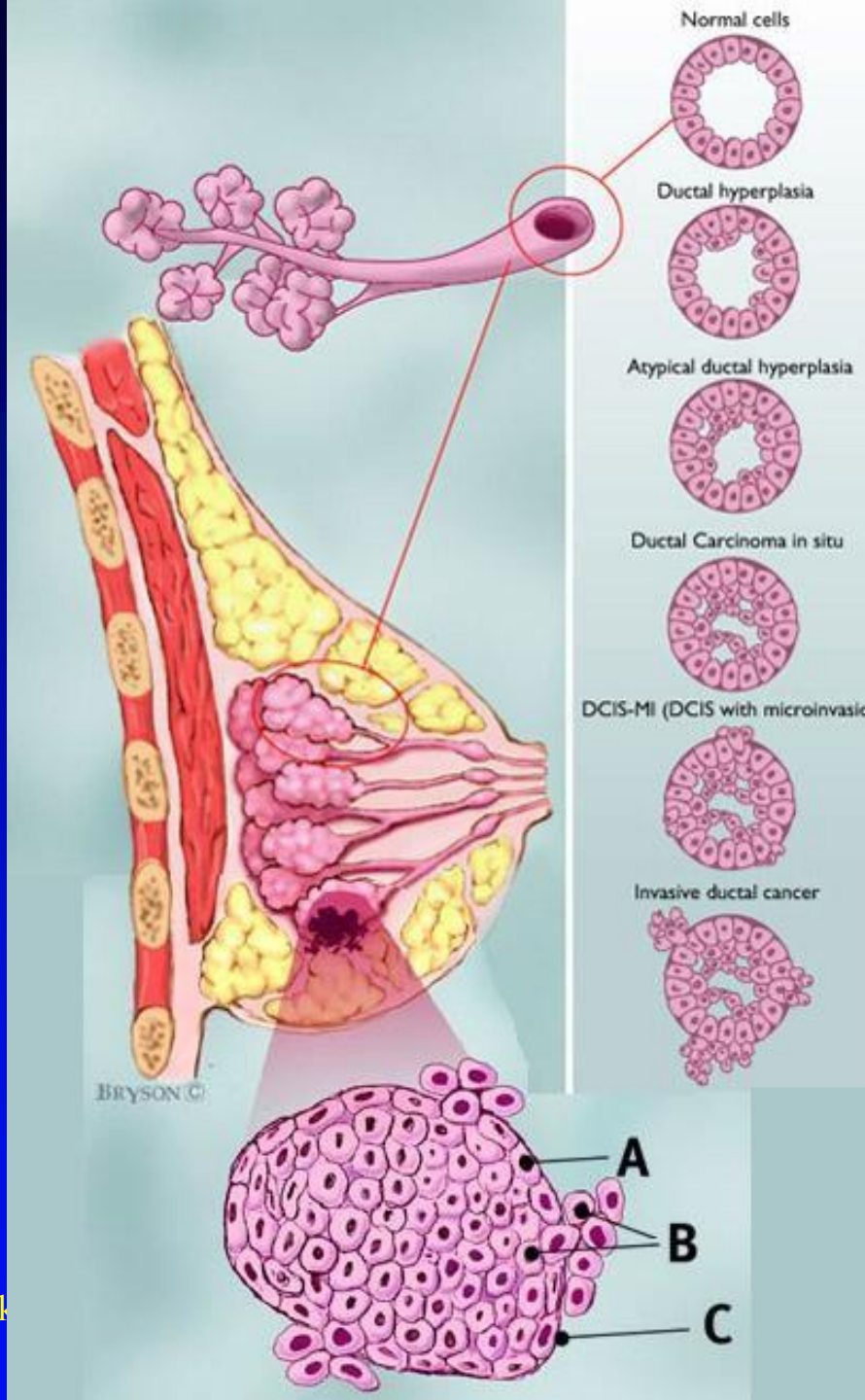
A dedicated PET scanner for breast imaging

Why?

- breast cancer is 3rd most frequent cancer in humans

- one in 10 women eventually develops breast cancer

- good survival rate if detected at an early stage

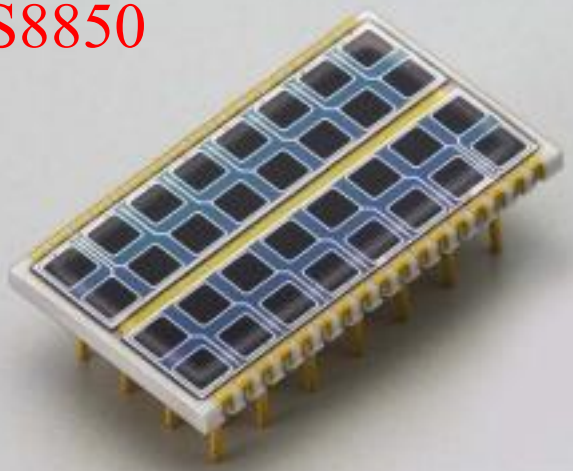


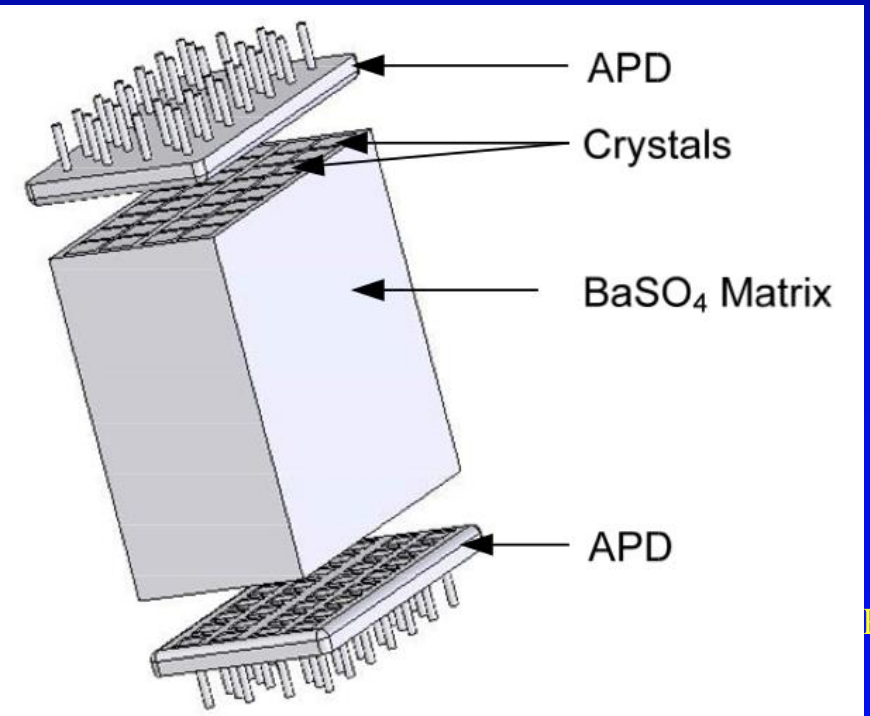
How?

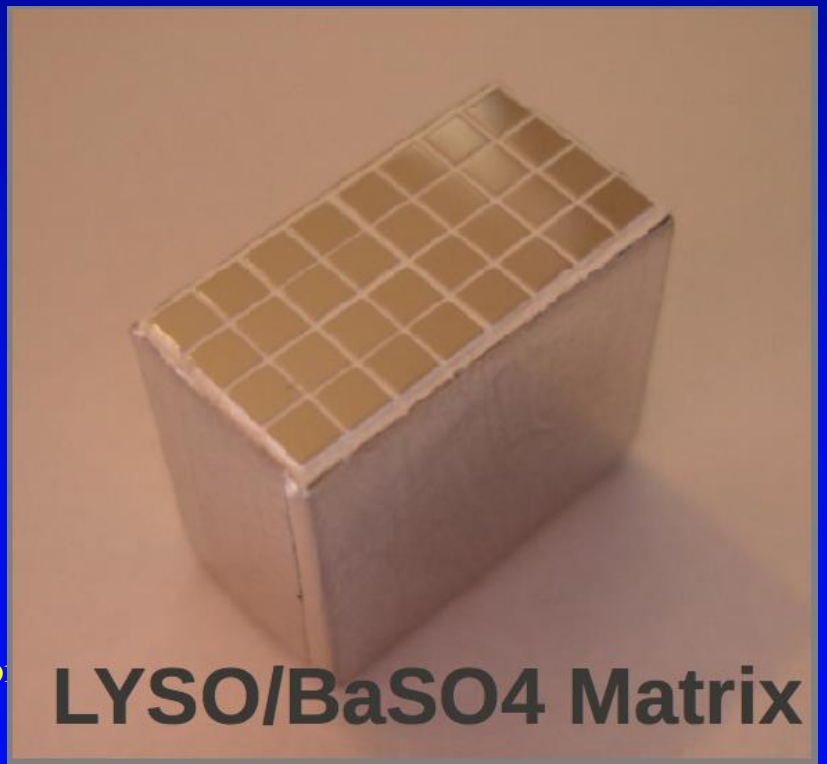
- take advantage of the (at that time) new APD photodectors

- Use our expertise in using APDs acquired in CMS

Hamamatsu APD array S8850







The ClearPEM scanners

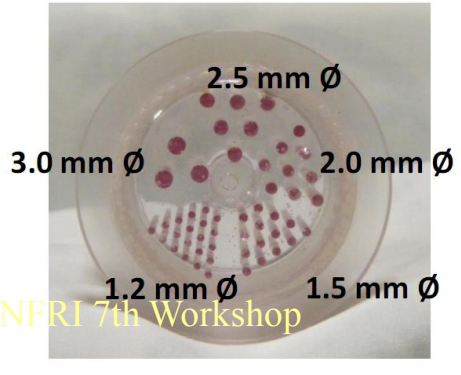
ClearPEM (prototype) in Coimbra

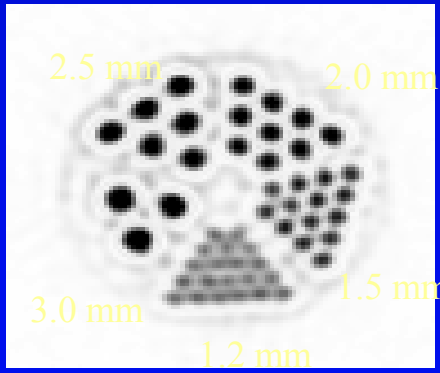
ClearPEM-II in Monza (Italy)

- Spatial resolution : 1.3 mm

Obtained with Derenzo phantom (Na22 rods)

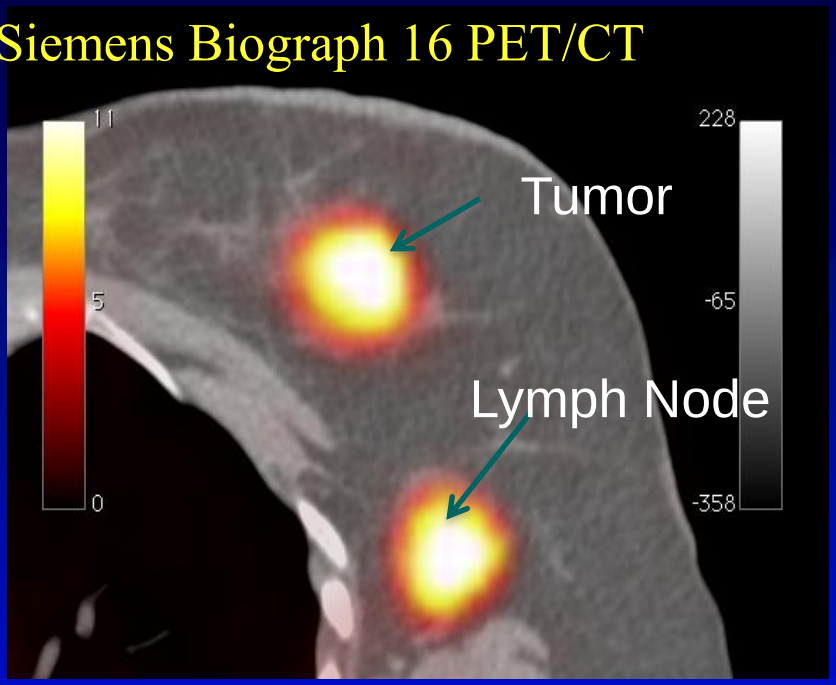
- Sensitivity: 2 to 5%, depending on the configuration



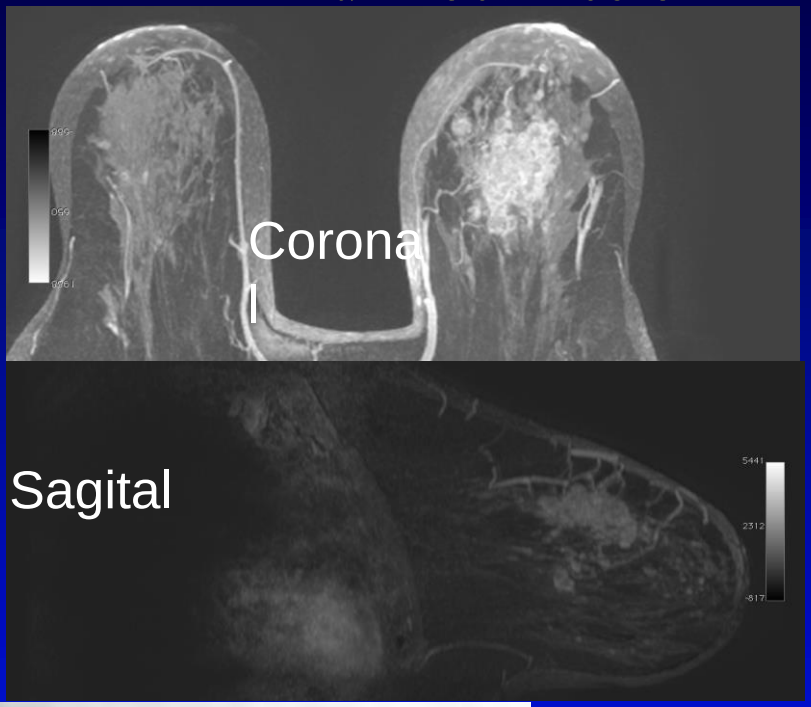


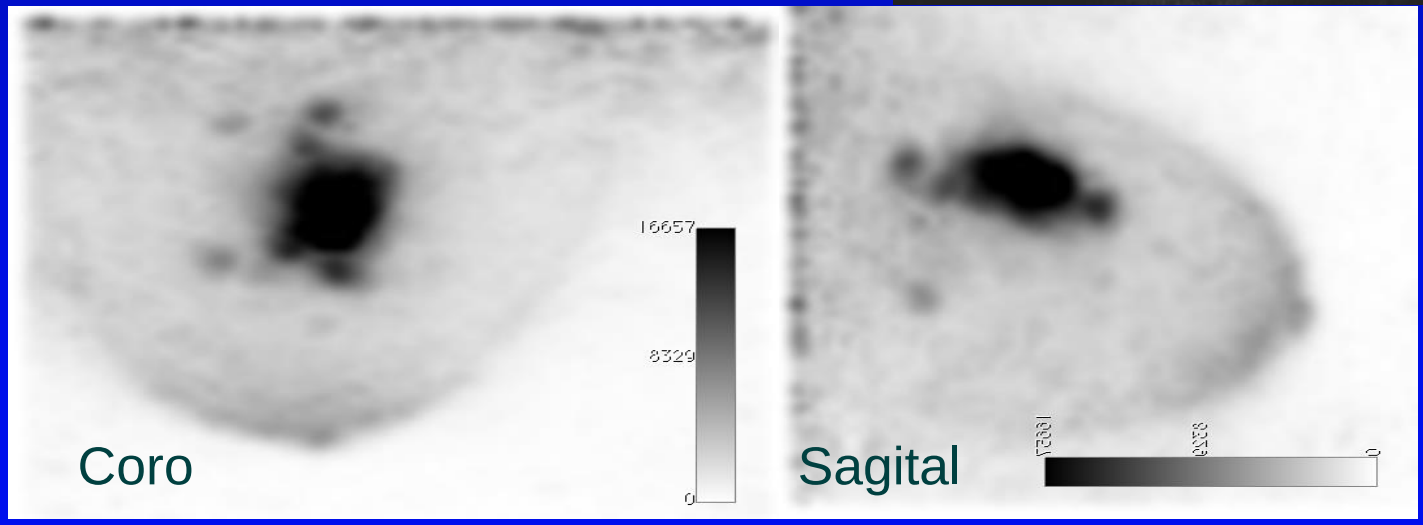
Phase one clinical trials: example patient image

Siemens Biograph 16 PET/CT



MRI-Multifocal lesion

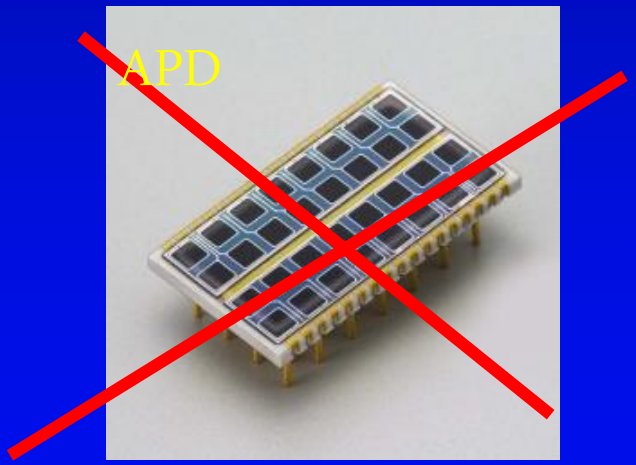


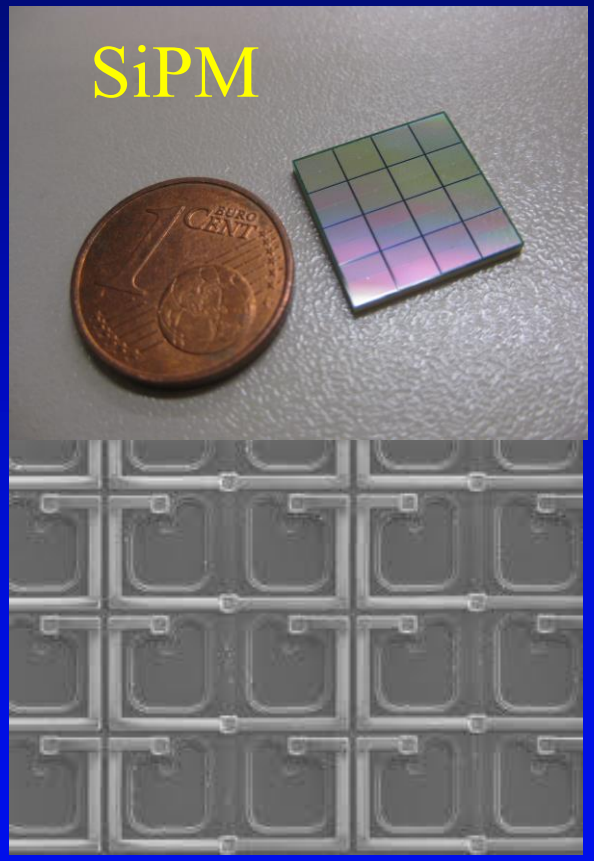


In Monza (Italy), after some difficulties with calibration issues ClearPEM operation has recently resumed.

A clinical study (200 patients) will evaluate if FLT (3-deoxy-3-[^{18}F]fluorothymidine) can be used to monitor the stage of the disease reducing the need to perform a biopsies. The performance of ClearPEM will be compared the one of the standard whole-body PET.

But we have been overtaken by technological progres





The EndoTOFPET-US project

EU FP7 project

The EndoTOFPET-US project

The tool

- Endo = Endoscopic
- TOF = Time of Flight
- PET = Positron Emission Tomography
- US = Ultrasound

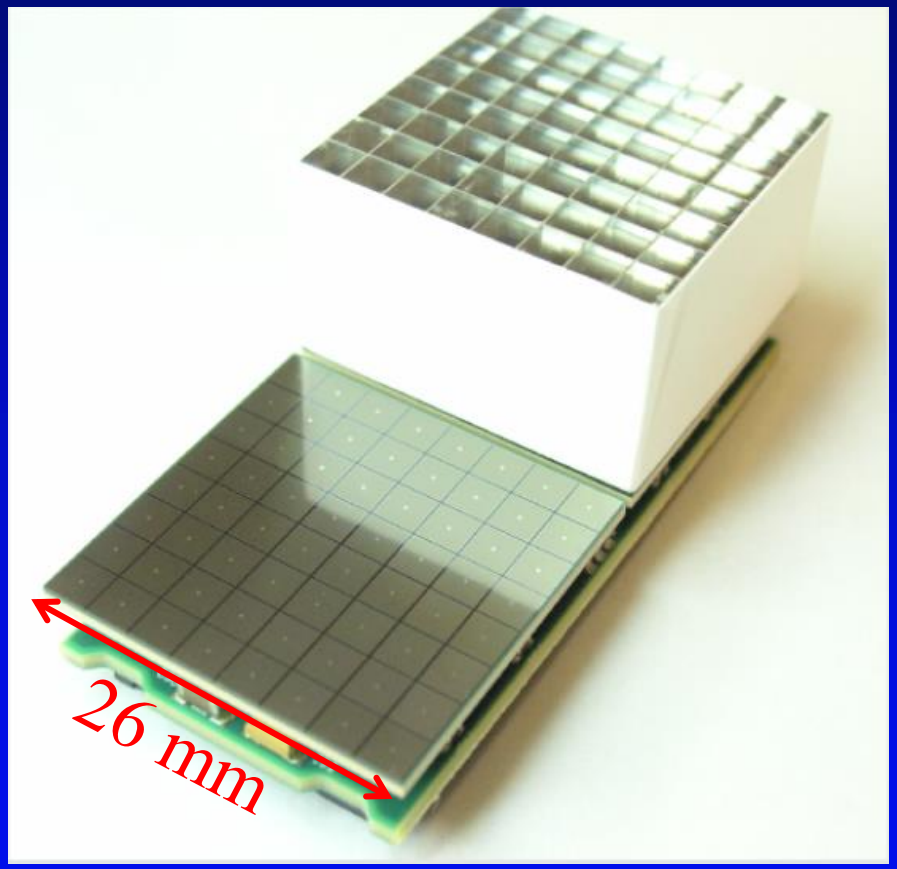
The goals:

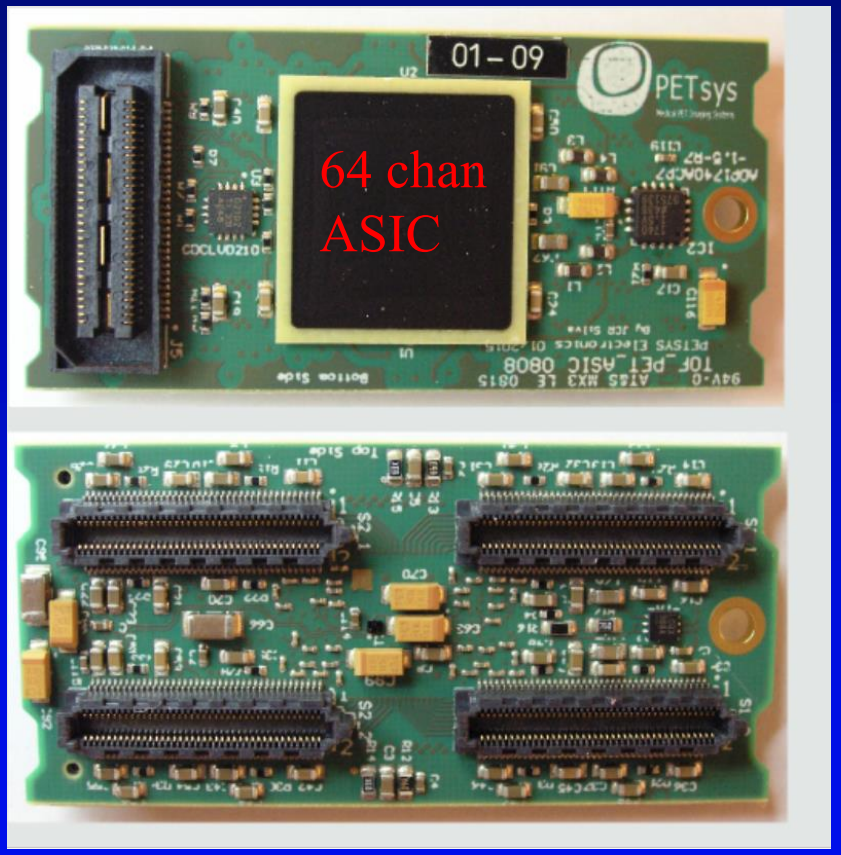
1) development of biomarkers for prostate and pancreas tumor
2) intra-operative imaging of prostatic and pancreatic lesions (guided surgery / biopsy)

The role of LIP in the EndoTOFPET-US project was to develop the readout electronics for a PET system using SiPMs for treading the scintillator light.

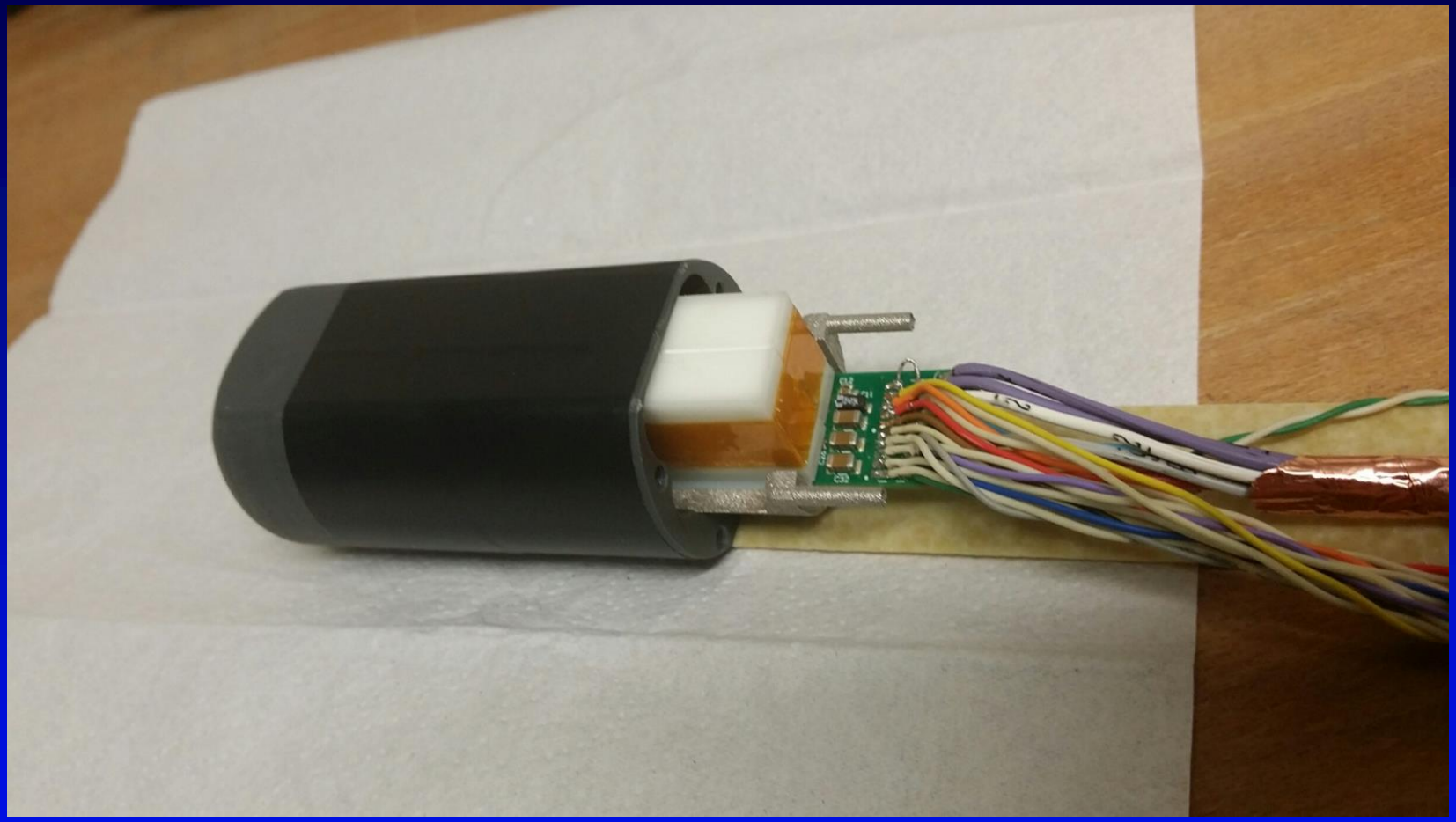
The challenge is to have a highly integrated electronics with low power consumption and the best possible time resolution (≈ 200 ps).

Our new, SiPM based, front end PET detector based on the TOF PET ASIC allows building the most compact PET detector ever.





And the internal probe ..



We decided to commercialise the readout electronics developed in the academic project.

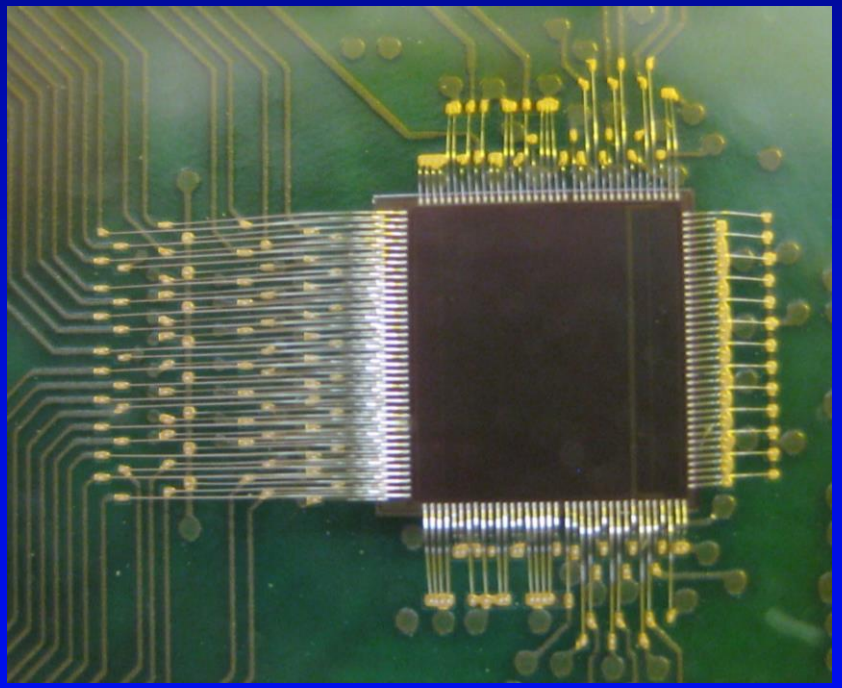
We founded a company PETsys electronics, a spin-off from LIP Lisbon.

Starting from the electronics developed in the ENDOTOFPET project we developed a versatile readout electronics for SiPM based PET. The readout is scalable to several 10'000 channels.

Based on a highly integrated ASIC 64 channels
Each channel with amplifier, discriminator, time and amplitude digitisation

After the ASIC everything
Output is only digital

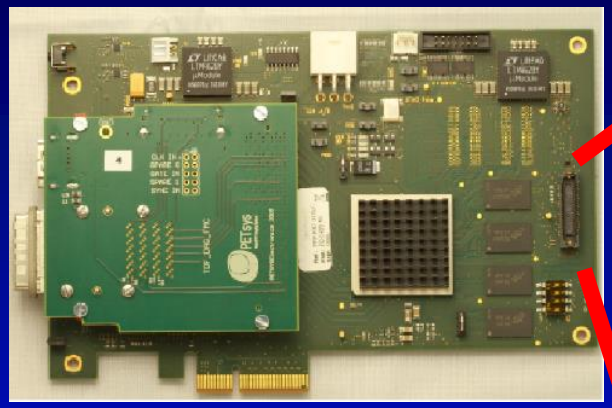
TOFPET2 ASIC



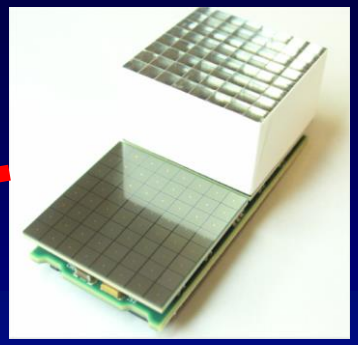
FE board with ASICs

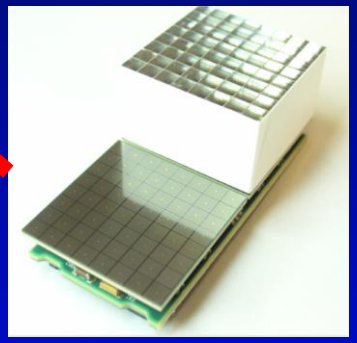
FPGA board

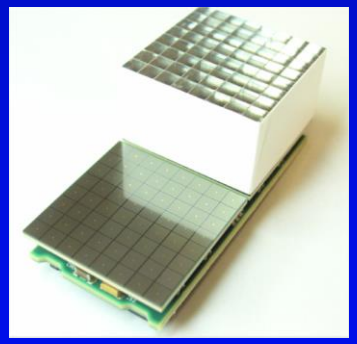
DAQ board

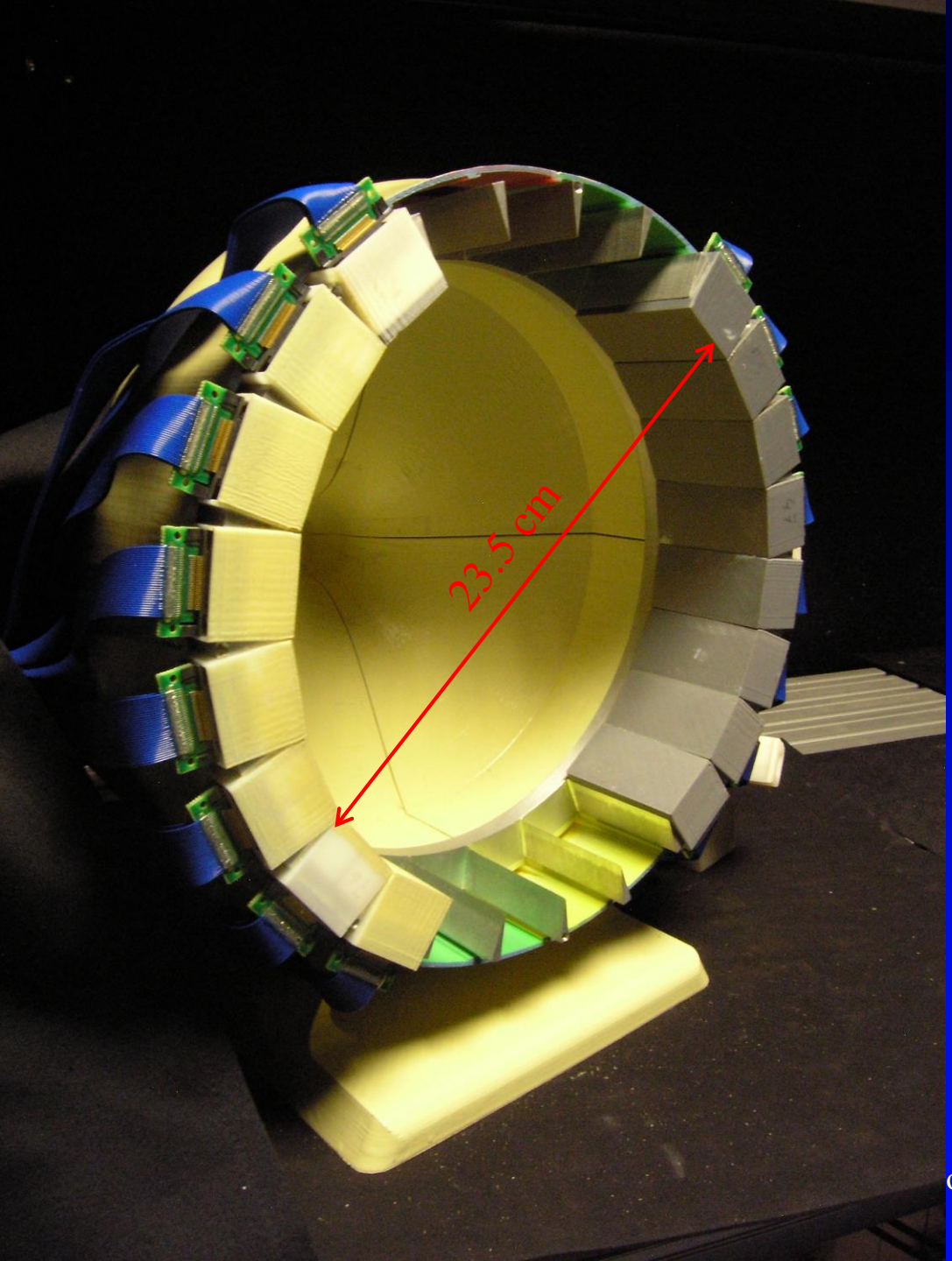


Coincidence sorting
in firmware



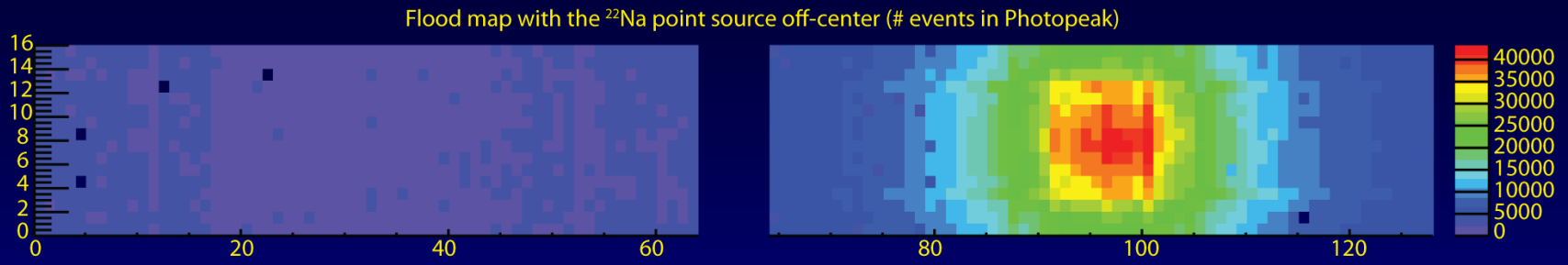


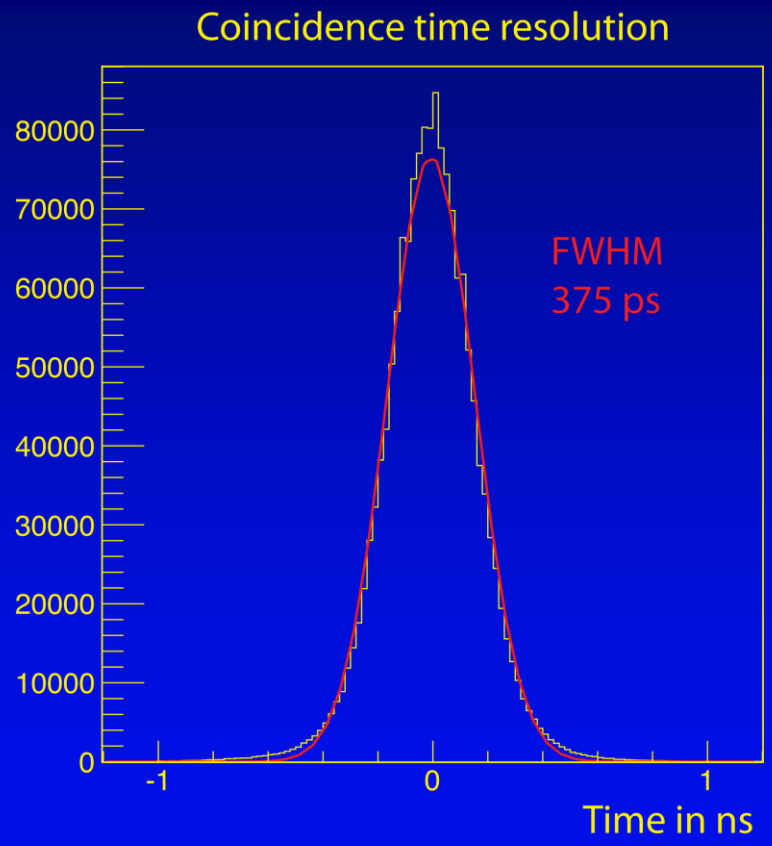


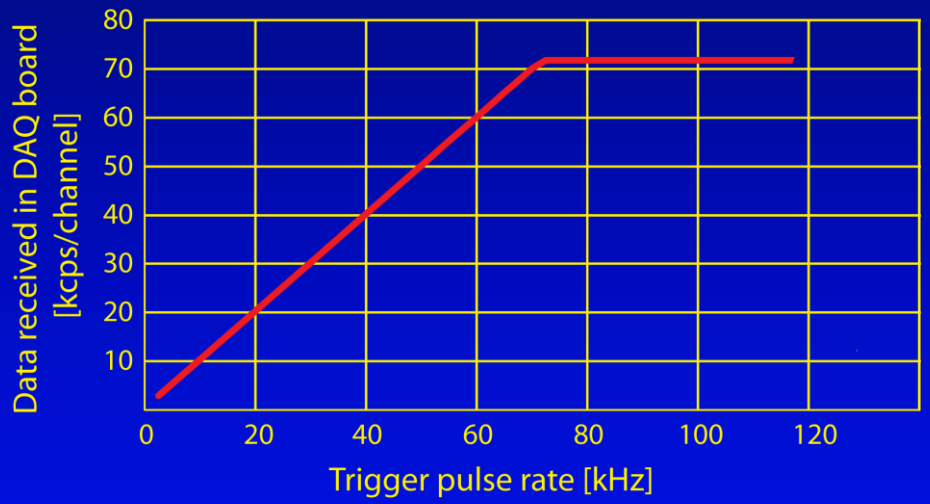


Demonstrator
PET scanner
with 2048 channels

Based on TOFPET1
ASIC







Based on TOFPET1 ASIC

Next ASIC2 is now under test

- Expect time resolution 200 ps FWHM real system
- Linear energy determination limited by scintillator
- Rate up to 600 kcps/channel

Summary and conclusion

- We have developed a few years ago a very successful dedicated dedicated PET scanner for breast imaging. However, the design is based on the APD technology and therefore no longer up to date.

- We developed an SiPM based PET readout electronics in the framework of the ENDOTOFPET project.

- the spin-off company PETsys Electronics is presently continuing to develop this readout electronics, and commercialising it.

Thank you for your attention

Backup slides

The situation to avoid ...

Make sure to keep the physician involved from the design phase

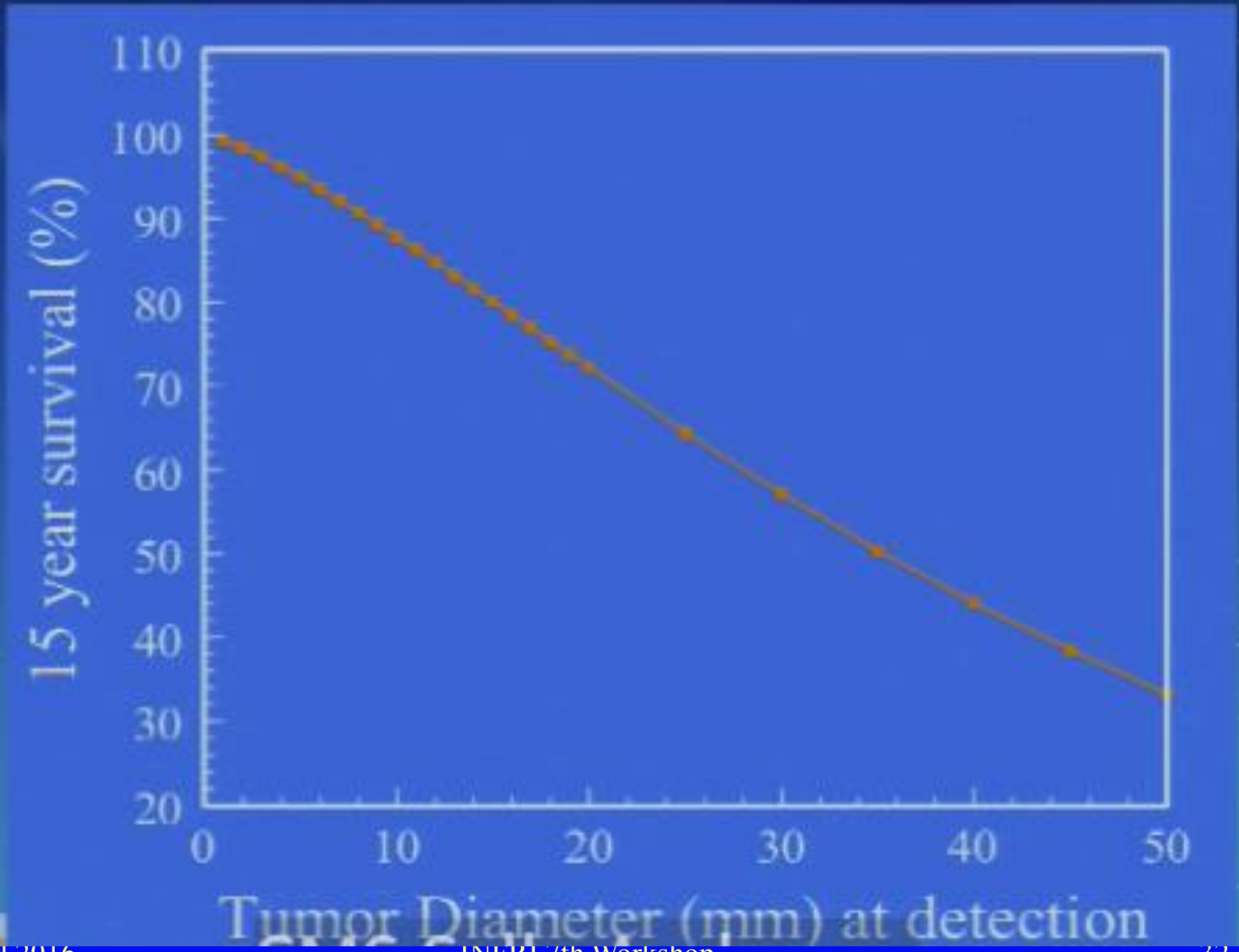
Hey, I've solved your clinical problem

Physicist

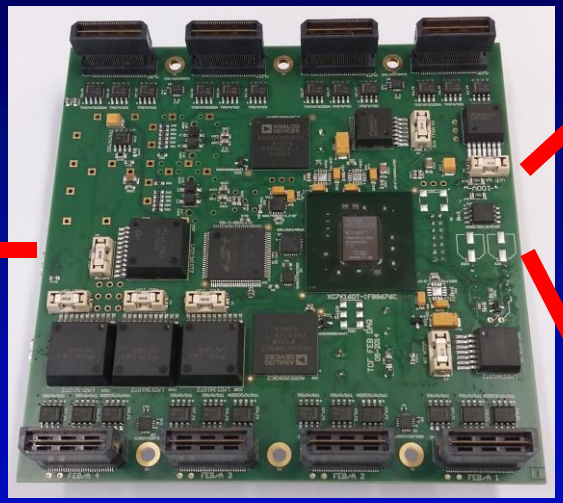
I didn't know I had a problem

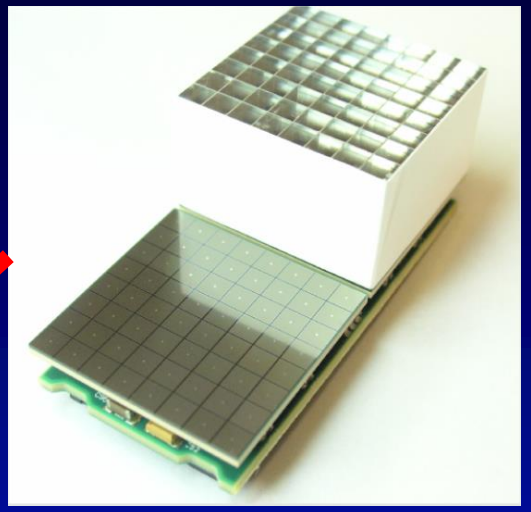
Physician

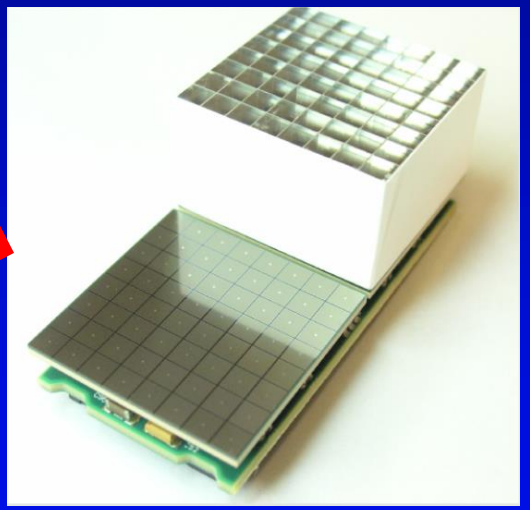
Predicting the survival of patients with breast carcinoma using tumor size,
JS Michaelson, M Silverstein, J Wyatt, et. al. *Cancer* 2002; 95: 713-723



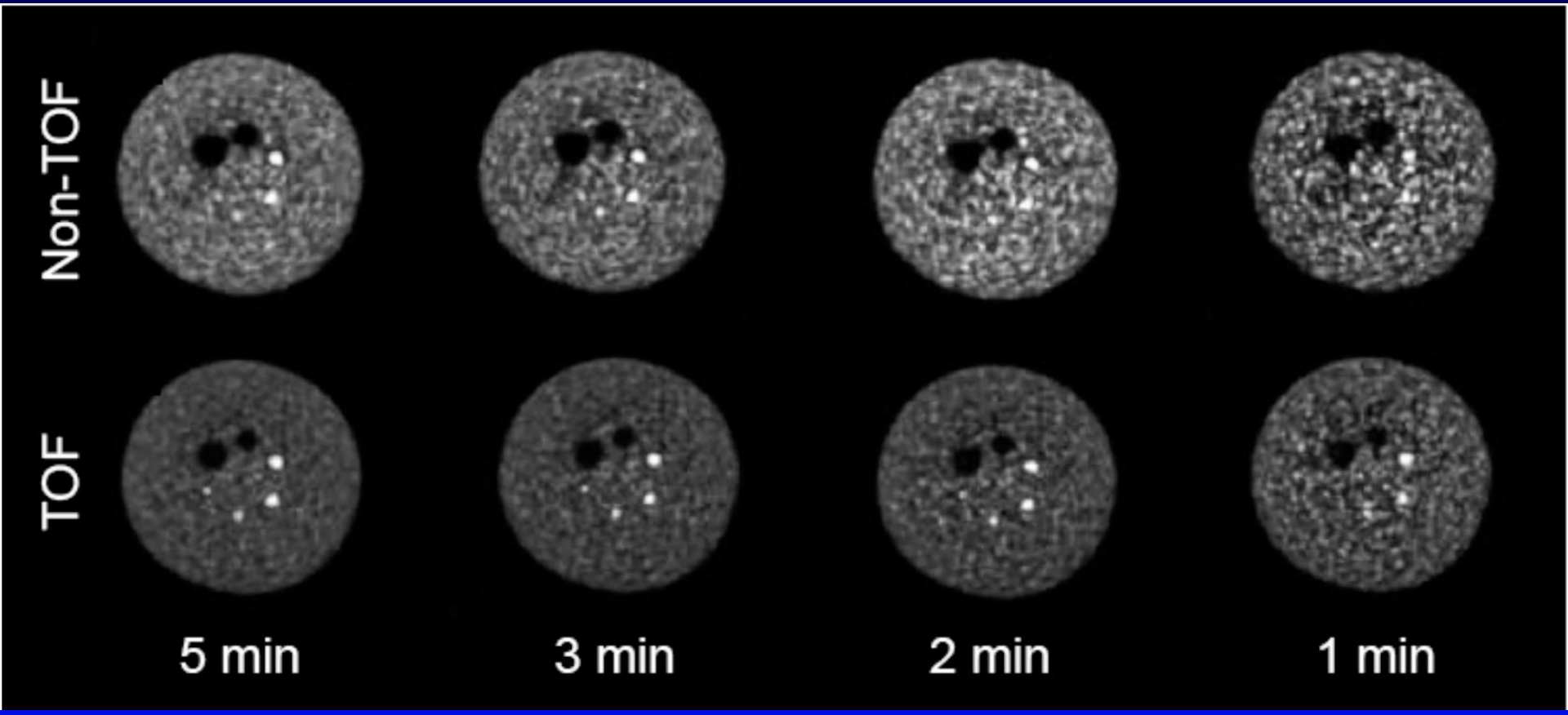
And allows building a PET scanner with many 10'000 channels







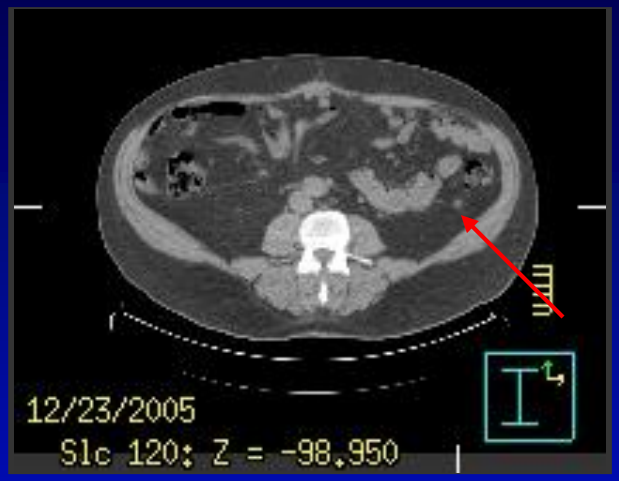
Simulation: object D=35 cm, TOF=600 ps, Sensitivity gain factor 3.9

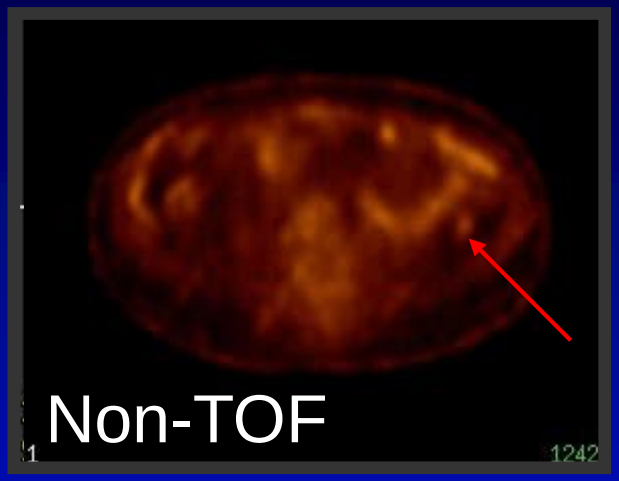


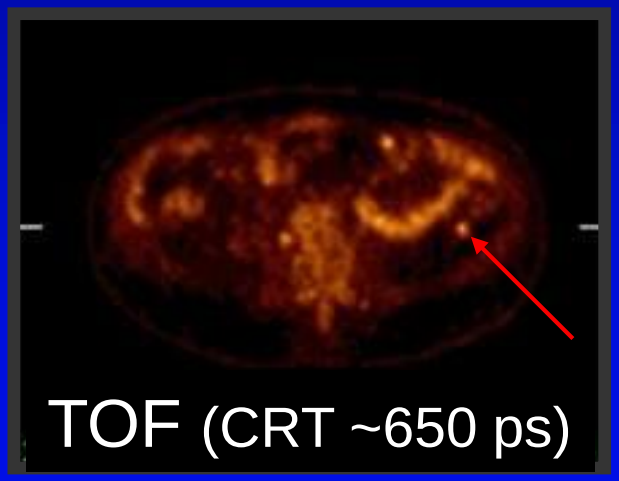
Karp JS, Surti S, Daube-Witherspoon ME, Muehllehner G. Benefit of time-of-flight in PET, experimental and clinical results: . J Nucl Med 2008; 49(3):462-70.

Colon cancer, left upper quadrant peritoneal node

114 kg; BMI=32.2 ; 13.4 mCi; 2 hr post-inj



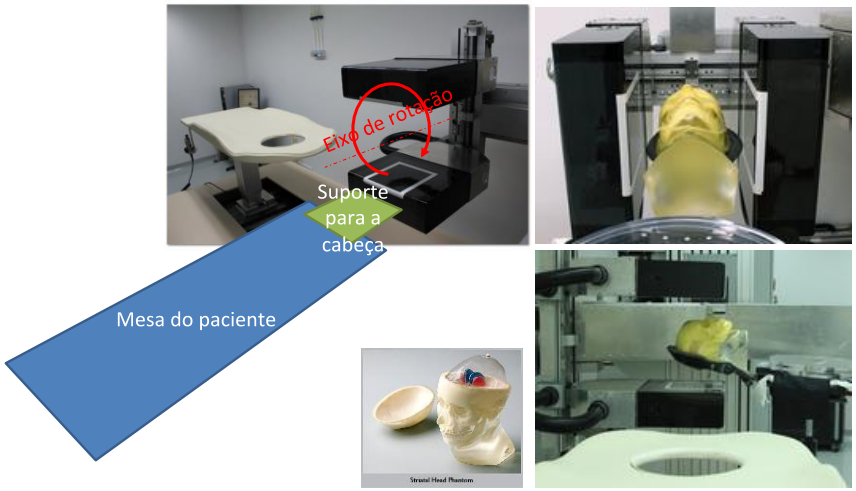




Images J. Karp, University of Pennsylvania

In Coimbra, the team has mainly been using the ClearPEM as a small animal PET, and evaluating the possibility to use it as a brainPET.

ClearPEM – exames cerebrais (humanos)



Fantoma antropomórfico de cérebro

ClearPEM – estudos pré-clínicos

Rato injectado com ^{11}C-Raclopride