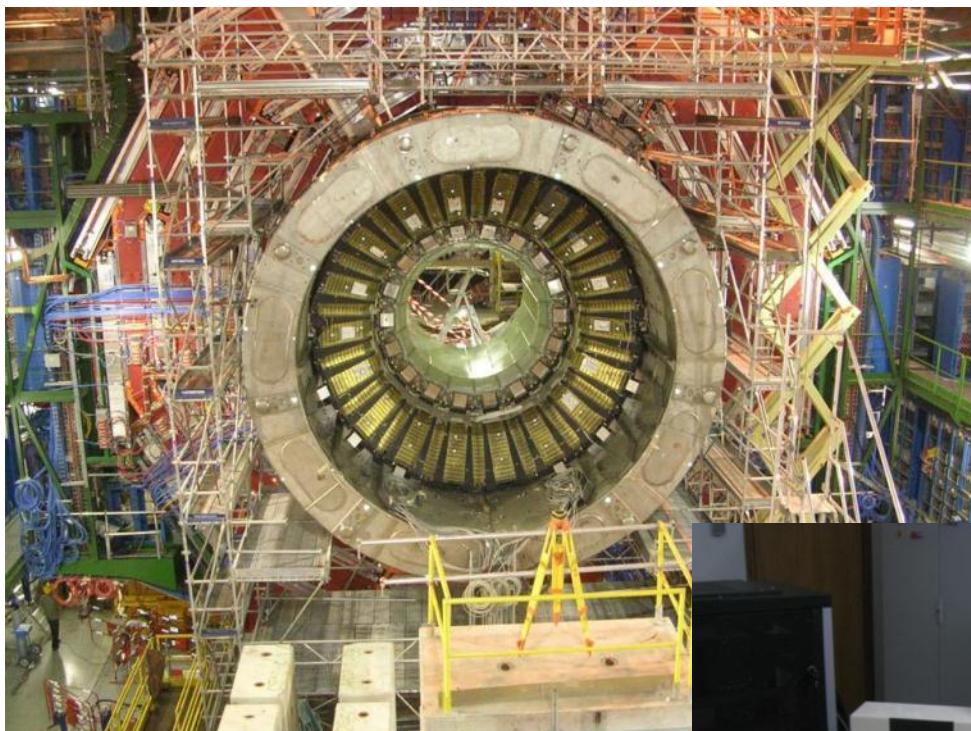


PET Technologies and developments

Jose DA SILVA
LIP-Lisboa

Manaus 07-08-2015

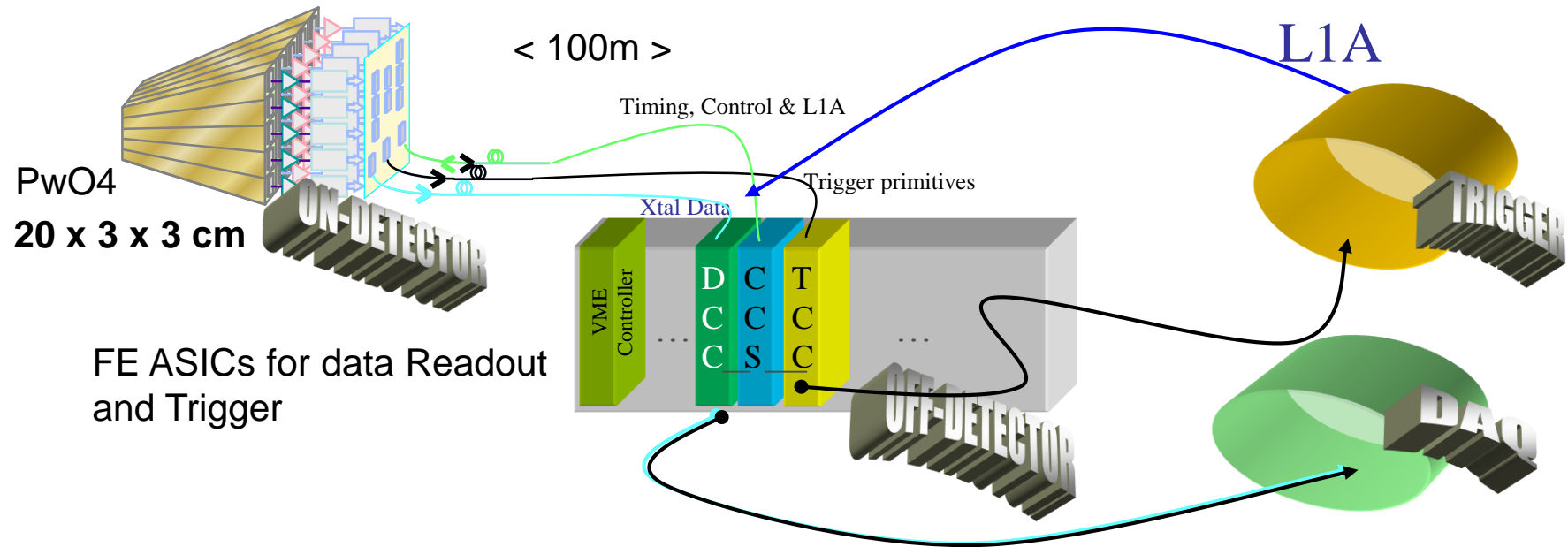
From particle physics to medical applications





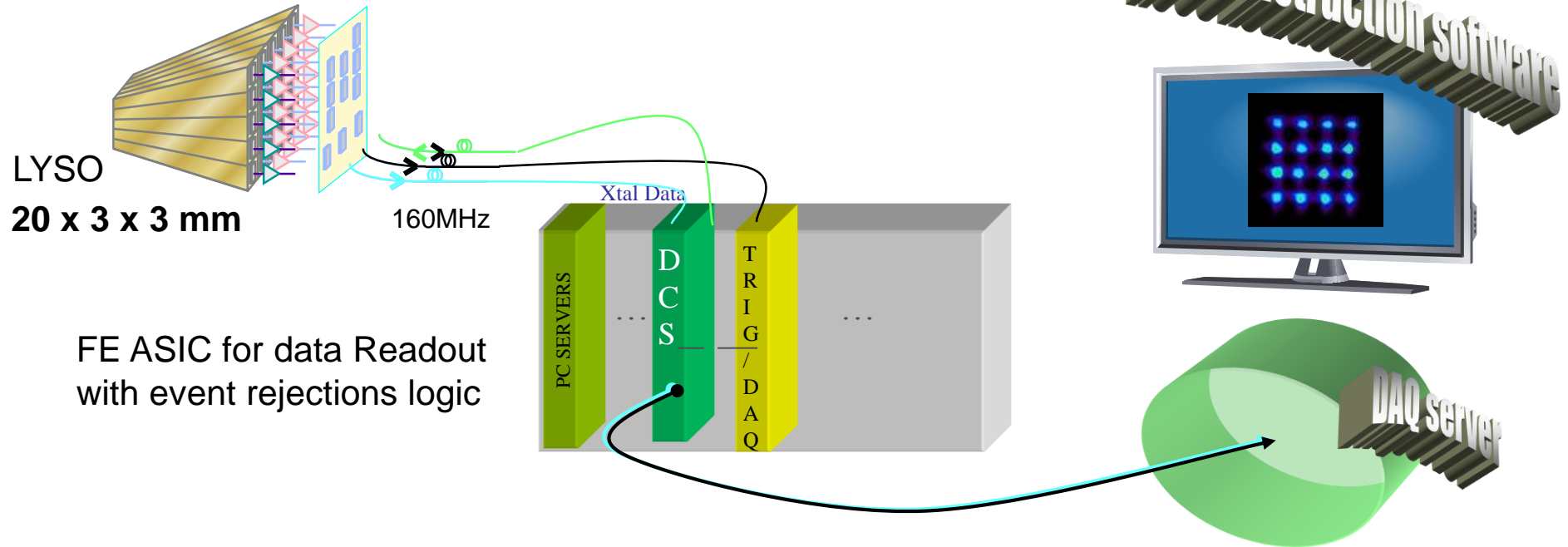
ECAL example:

~76000 channels
68 Trigger Towers modularity



CLEAR PEM example:

6144 channels
32 channels units based





To build an high performance detector for breast cancer detection with unprecedented resolution

- 6 years of I&D
- 6 M€ funding

Supported by:

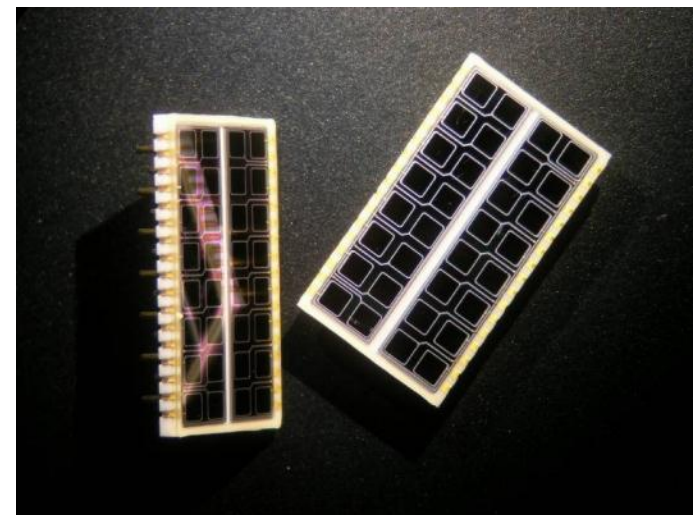
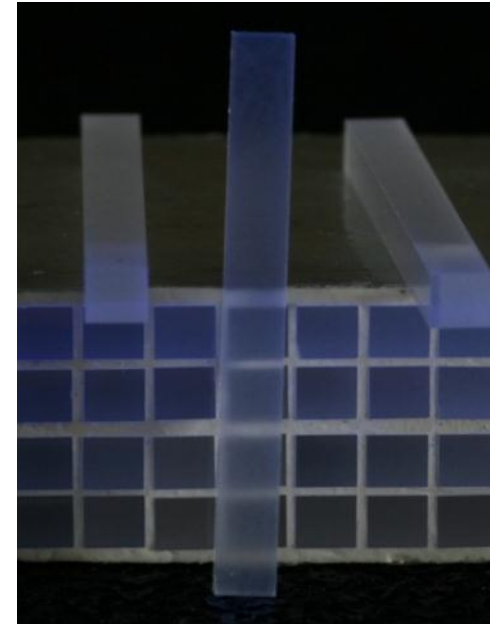


Crystals LYSO:

- Density: $7.4\text{g}\cdot\text{cm}^{-3}$
- Emission Peak: 420nm

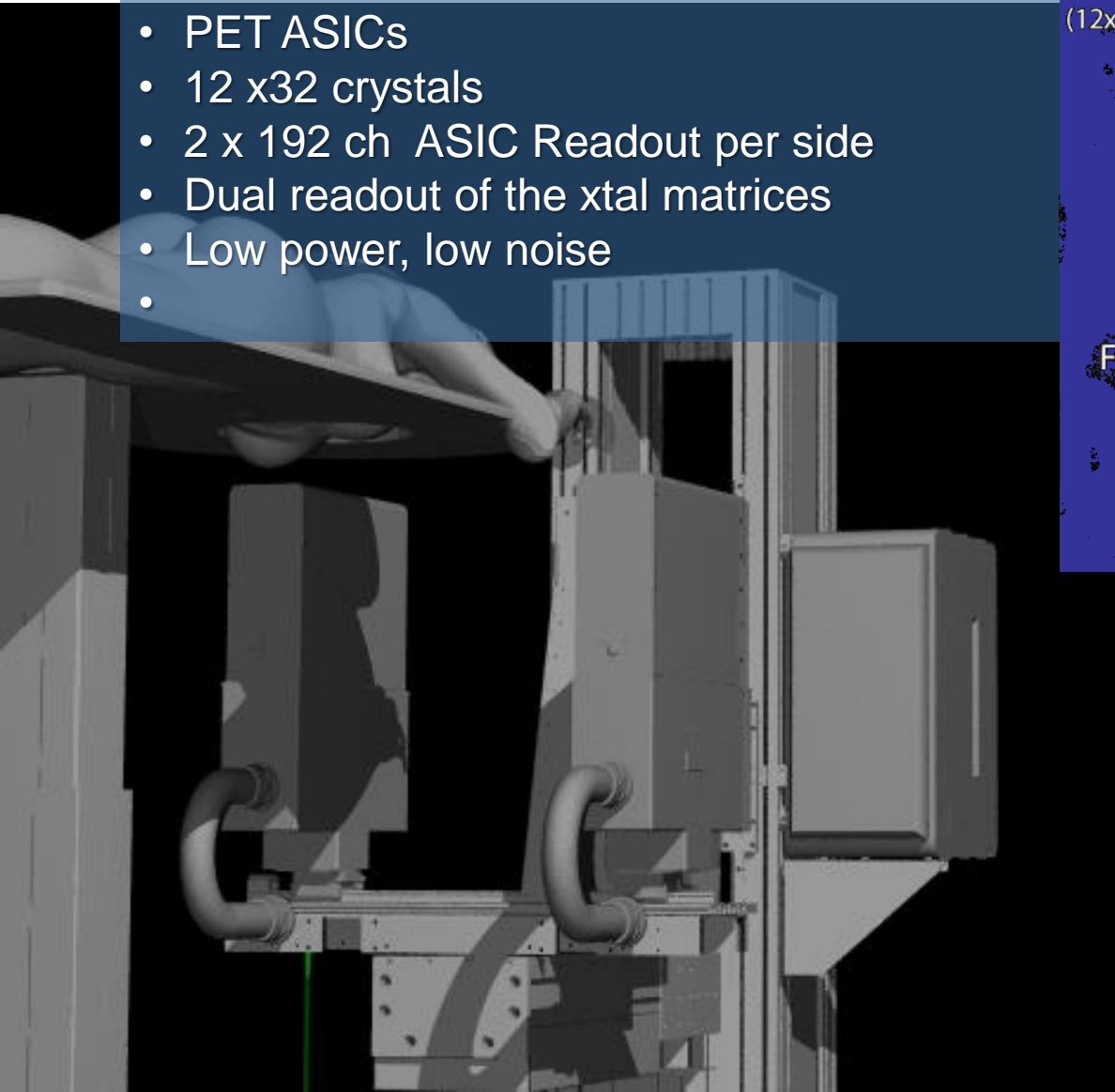
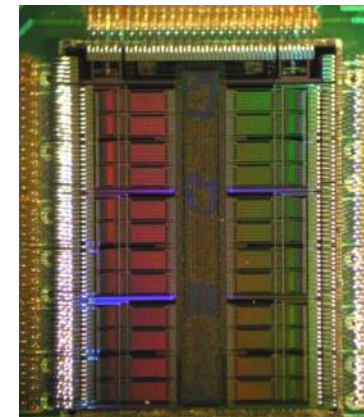
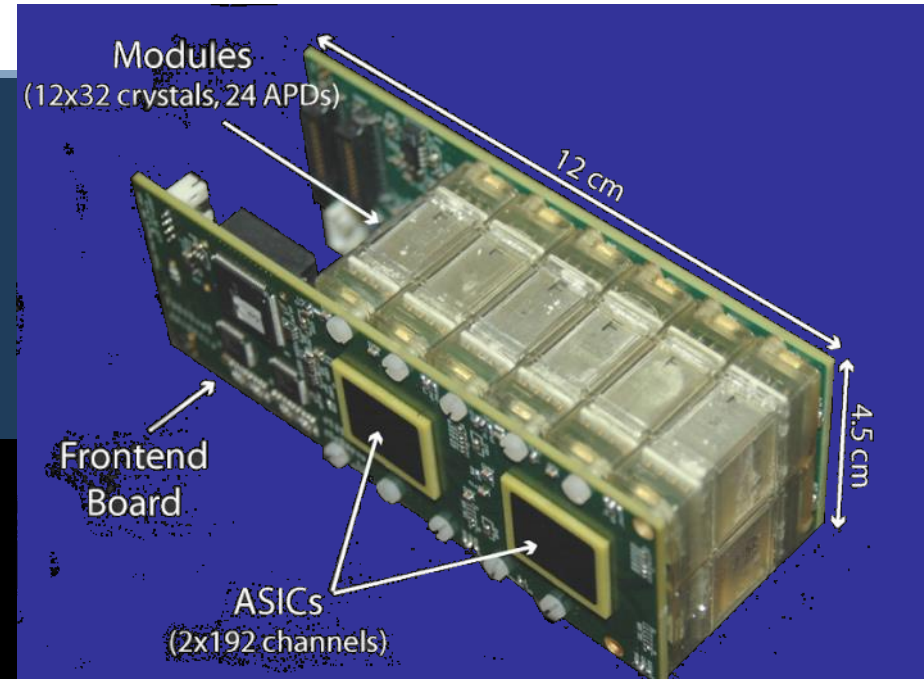
Avalanche Photodiodes (APD): Hamamatsu S8550

- Gain ~ 150
- Dark Current: $\leq 10\text{nA} / \text{pixel}$



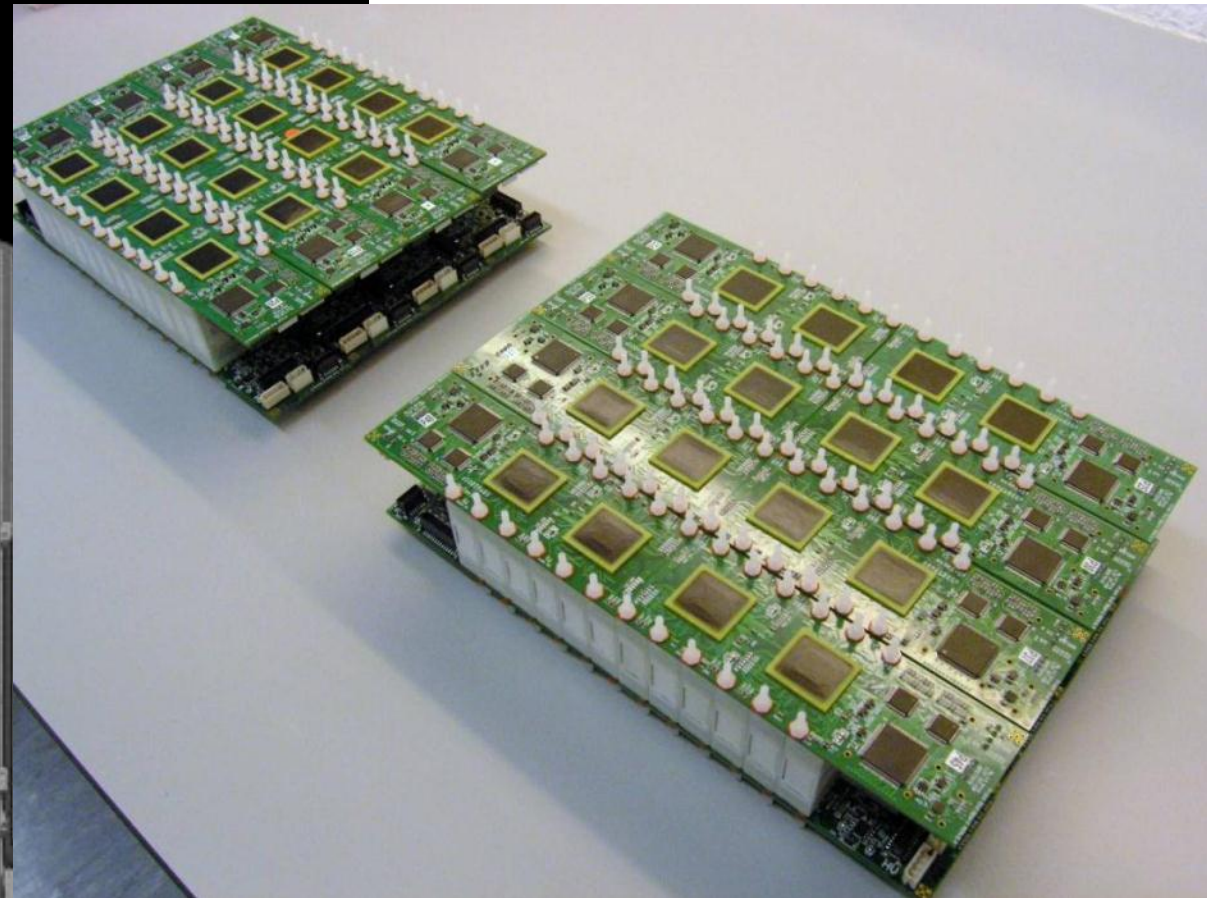
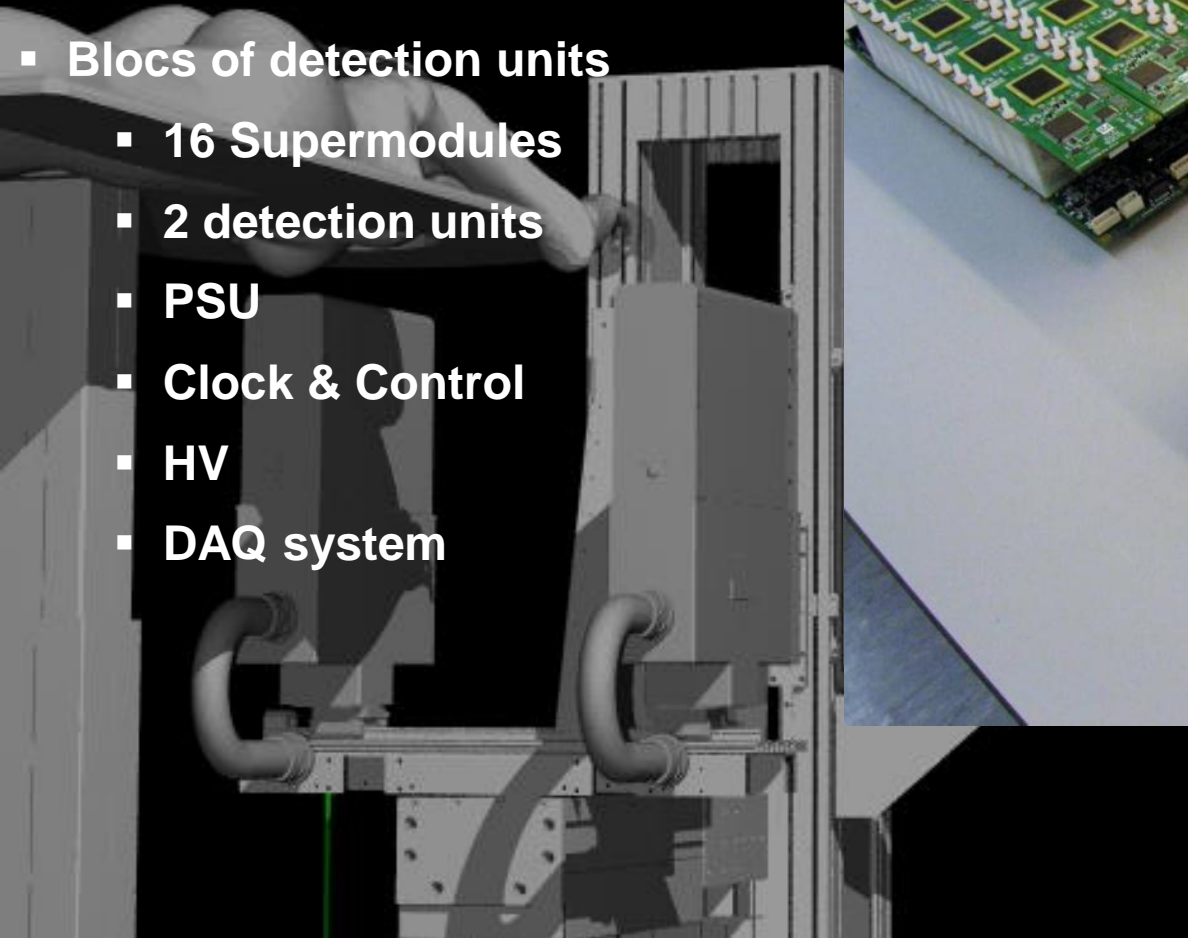
Basic detector module : a Supermodule

- PET ASICs
- 12 x32 crystals
- 2 x 192 ch ASIC Readout per side
- Dual readout of the xtal matrices
- Low power, low noise
-



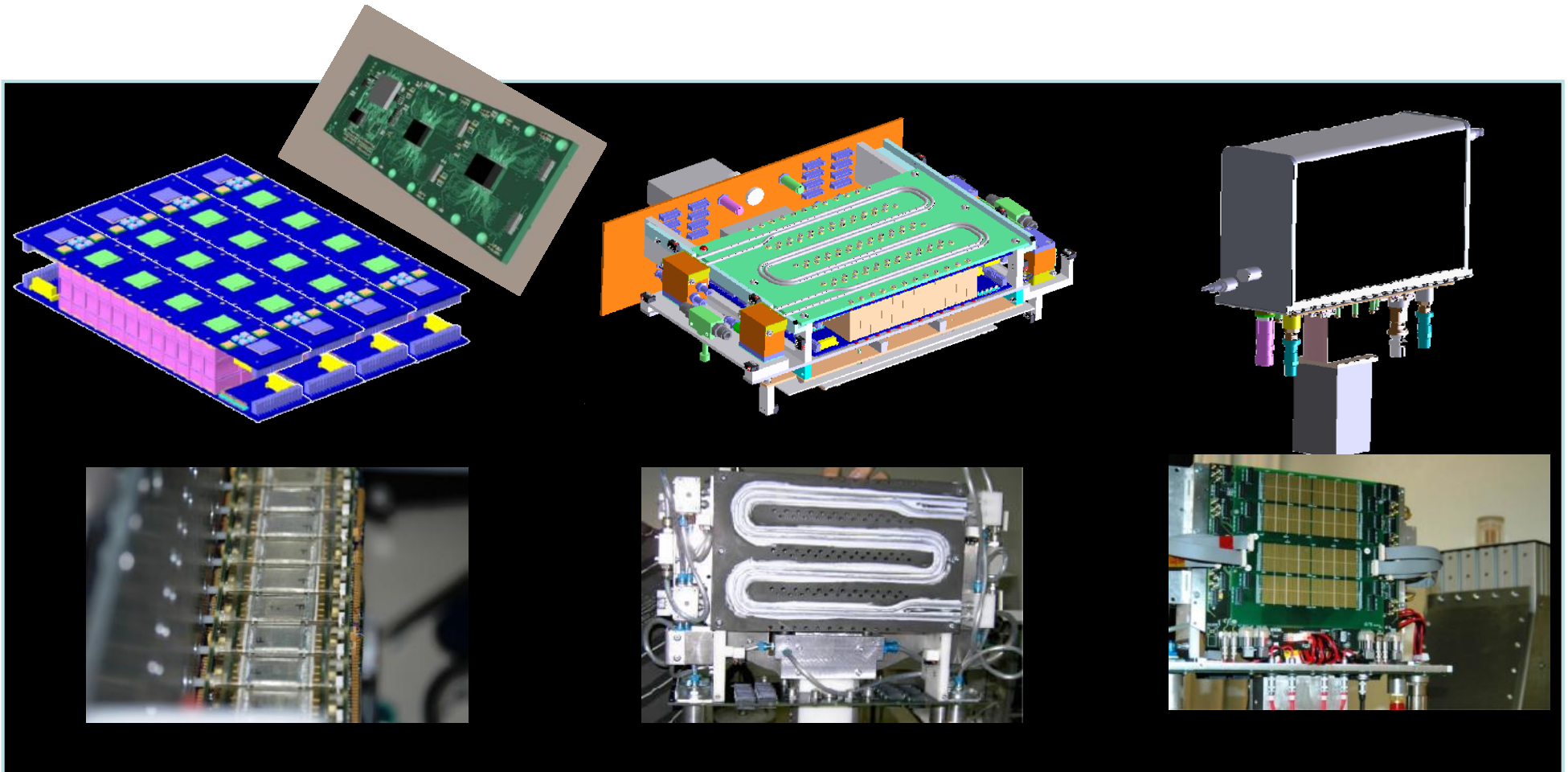
Modular compact system

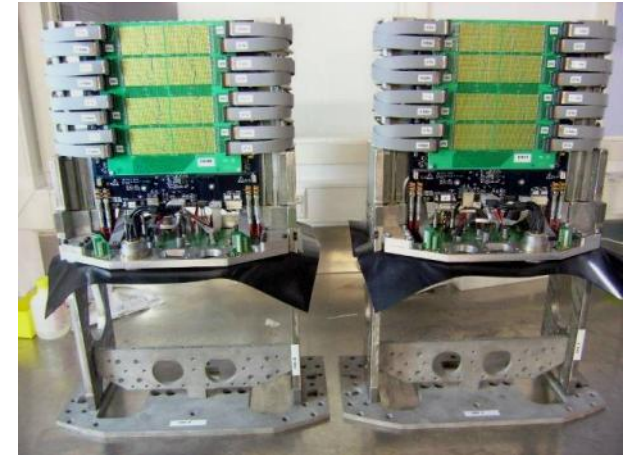
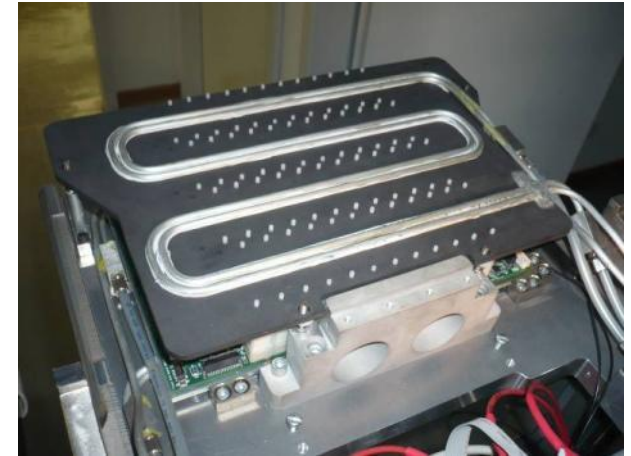
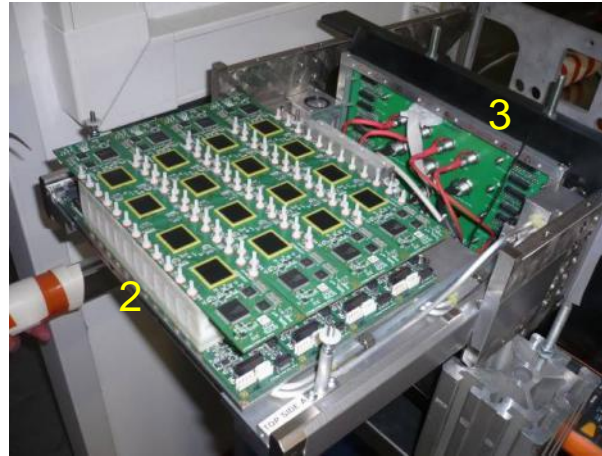
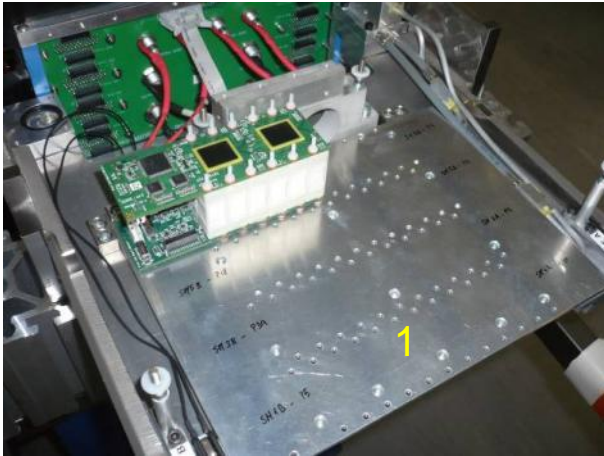
- Blocs of detection units
 - 16 Supermodules
 - 2 detection units
 - PSU
 - Clock & Control
 - HV
 - DAQ system



Da Modelização à Realização

The full project , from electronics to mechanics, was first emulated with 3D CAD/CAE systems , and manufactured only after.





1. Water cooling plates

2. Supermodulos

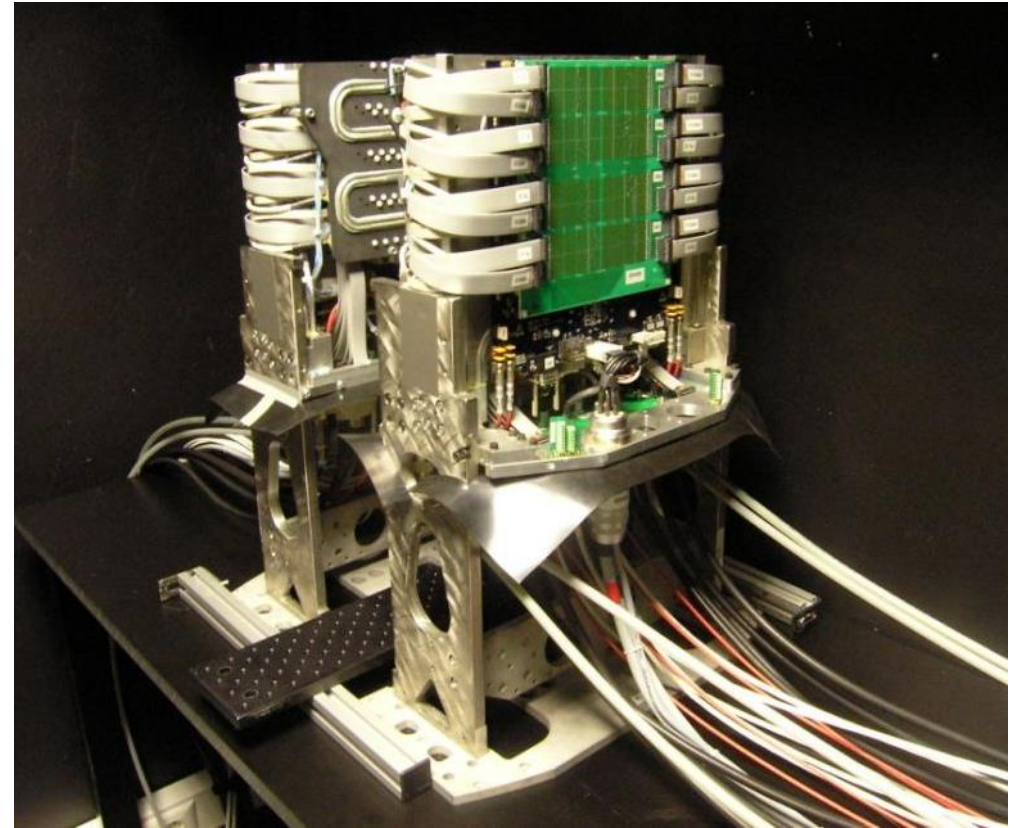
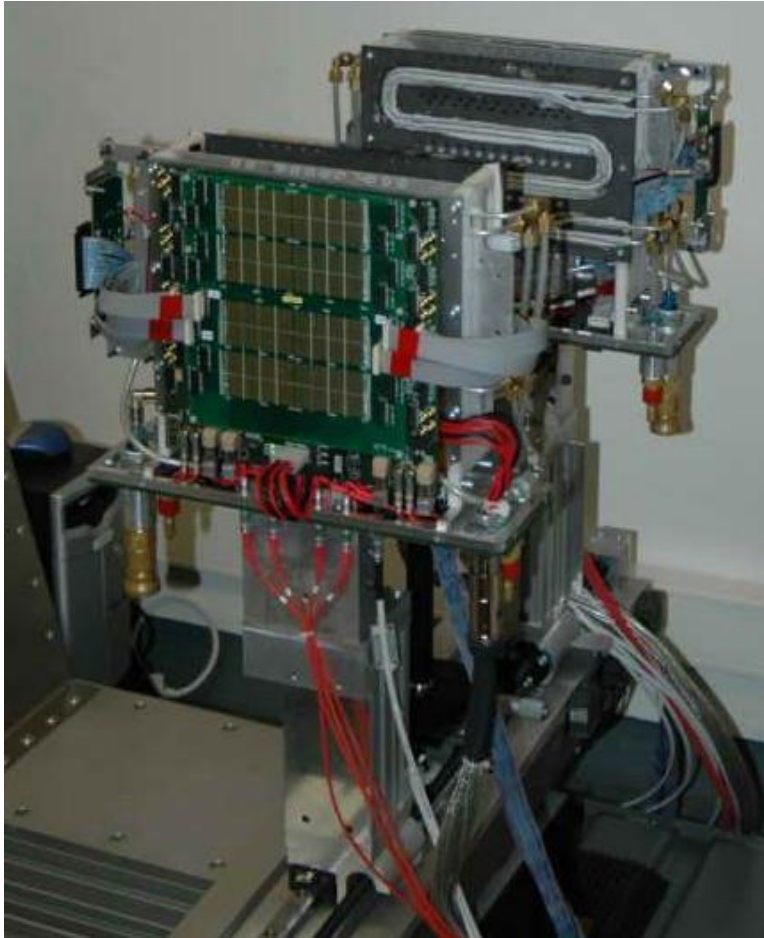
3. connexion panel)

4. Cables assembly

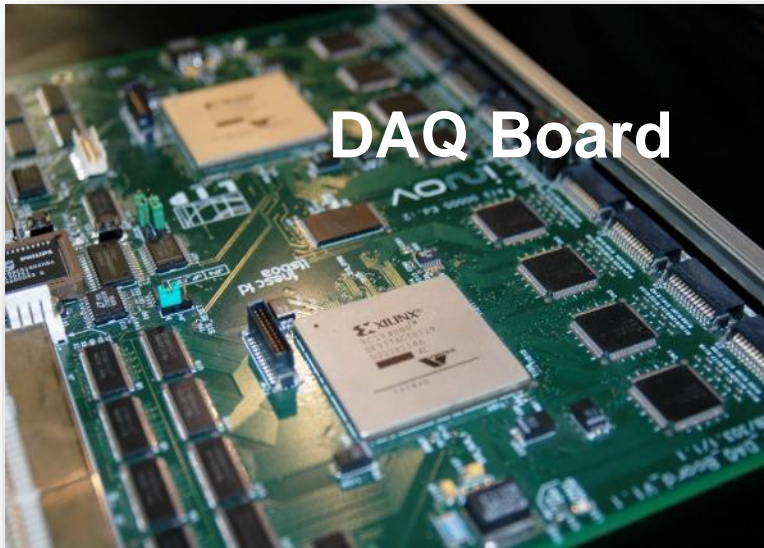
5 : Service Board (LV , HV, CLOCK, DATA)

6. HV Matrix (HV distribution)

Detector Heads Final



DAQ and Trigger units



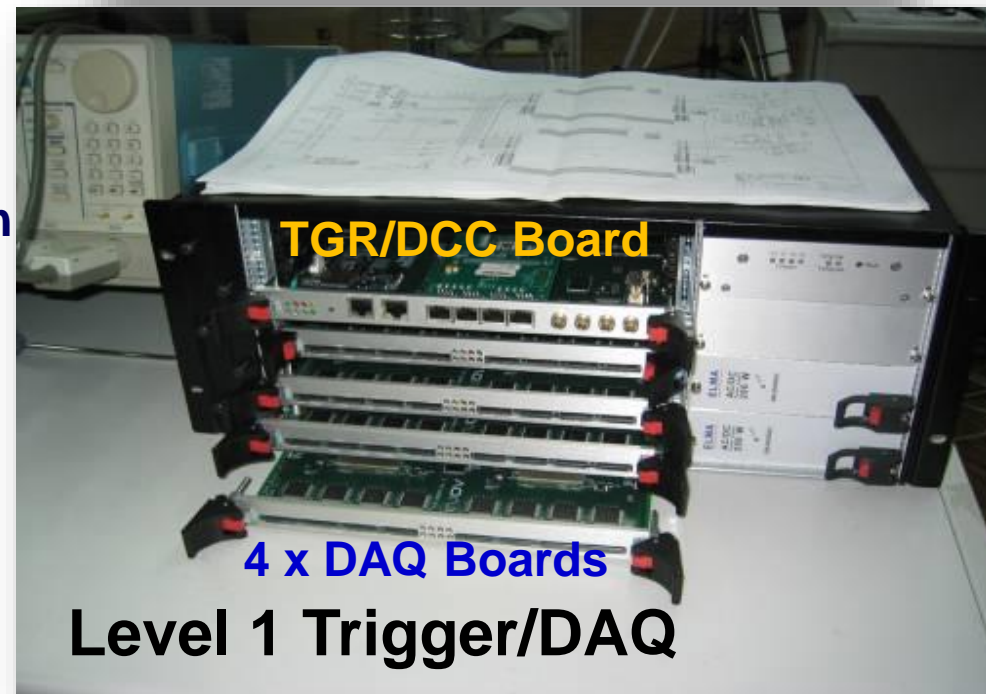
DAQ Board



**New Data link:
S-link 64**

TRG/DCC Board

- The L1 trigger and DAQ boards are assembled in one external crate
- Complex trigger algorithm (36K calibration constants)
- Frontend - L1 Trigger - at 156 Gb/s
- Level 2 DAQ: Servidor high-end
- L1-L2 bandwidth up to 800 MB/s



TRG/DCC Board

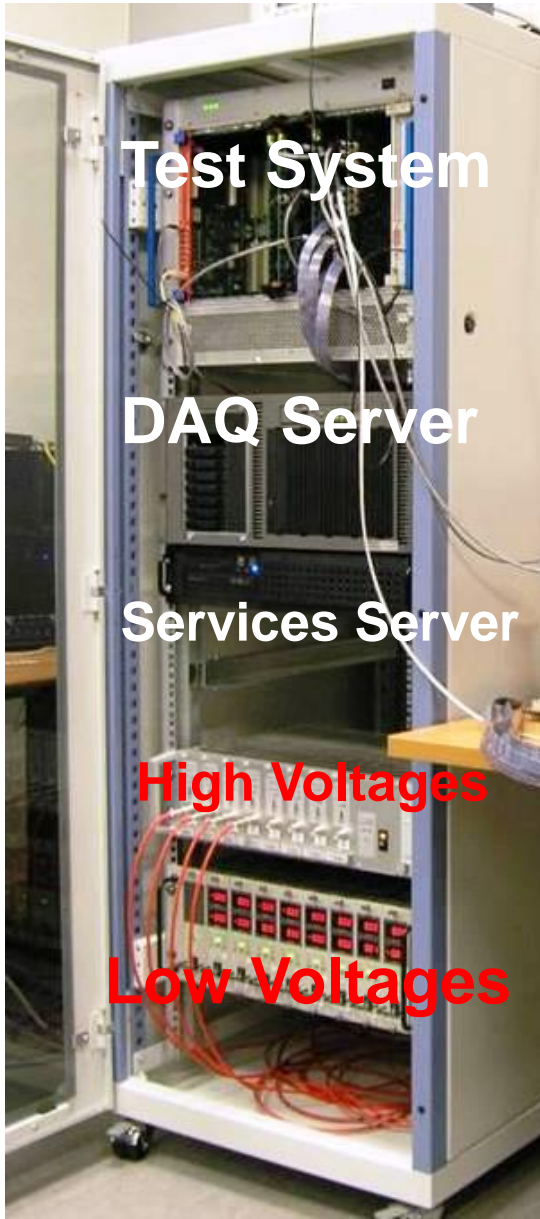
4 x DAQ Boards

Level 1 Trigger/DAQ



Data Acquisition System

Acquisition Manager



Applications Actions Fri Oct 6, 4:34 PM

Applications Actions Fri Oct 6, 4:32 PM

Applications Actions Fri Oct 6, 4:36 PM

AcqTool

Acquisition Tools

Data Manager

File Process Display Volumes Volume Measurements

Image
File creation time: 2006-09-28 13:12
File Size: 9MB

One Volume Overview developed by Quasi-Software Company@IBEB.pt

Options Save

	49	52	71
YZ view			
1	1	1	1
SliderX	<input type="text"/>	<input type="text"/>	<input type="text"/>
1	1	1	1
SliderY	<input type="text"/>	<input type="text"/>	<input type="text"/>

Current Color Table:

File: 21.cimg

Direct Fourier reconstruction with projection and PET.pdf

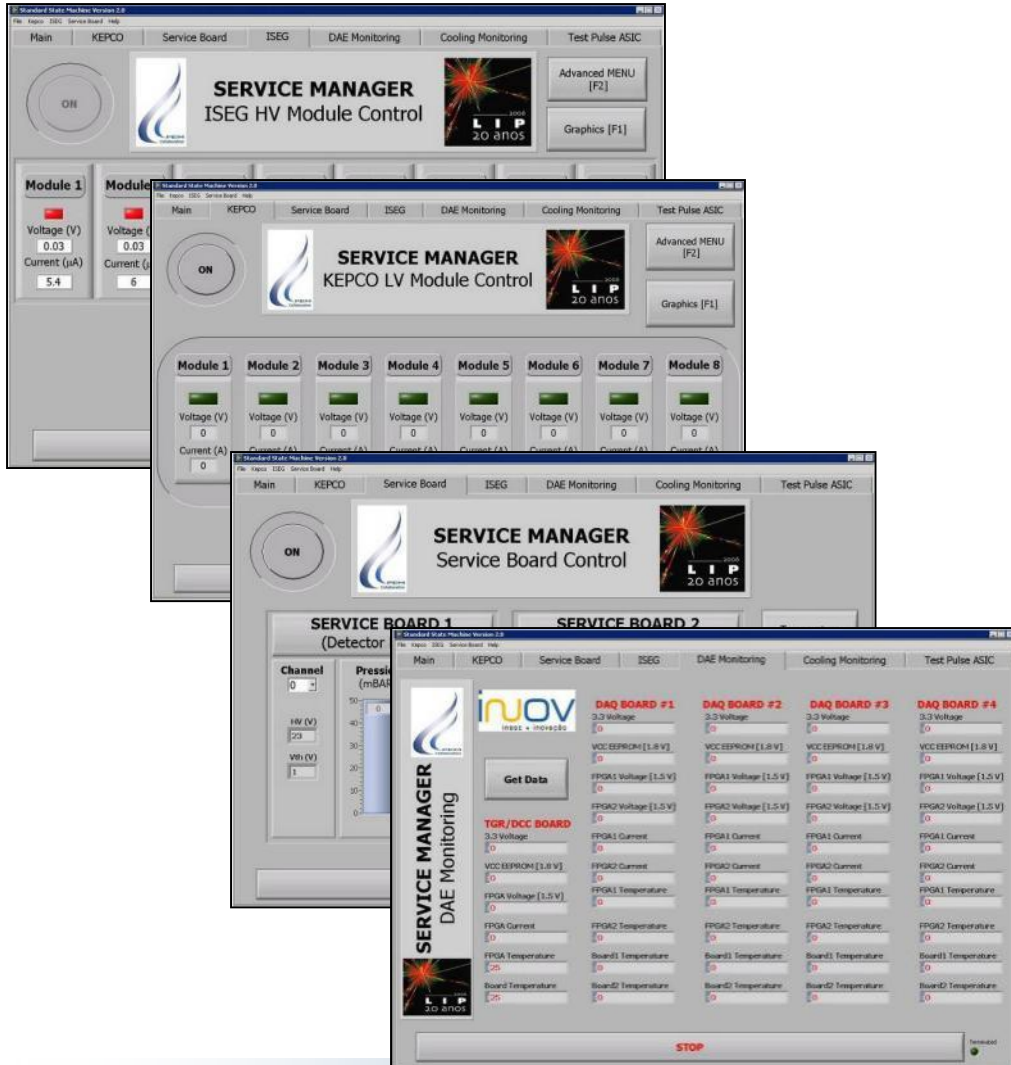
Trash

[rbugalho@porthos:~/work/trunk-vi] AcqTool File Browser: rbugalho Data Manager One Volume Overview developed i



DCS software

Control panels



DAQ test system

DAQ Server

8 cores, 2 TB disk array

Service Manager

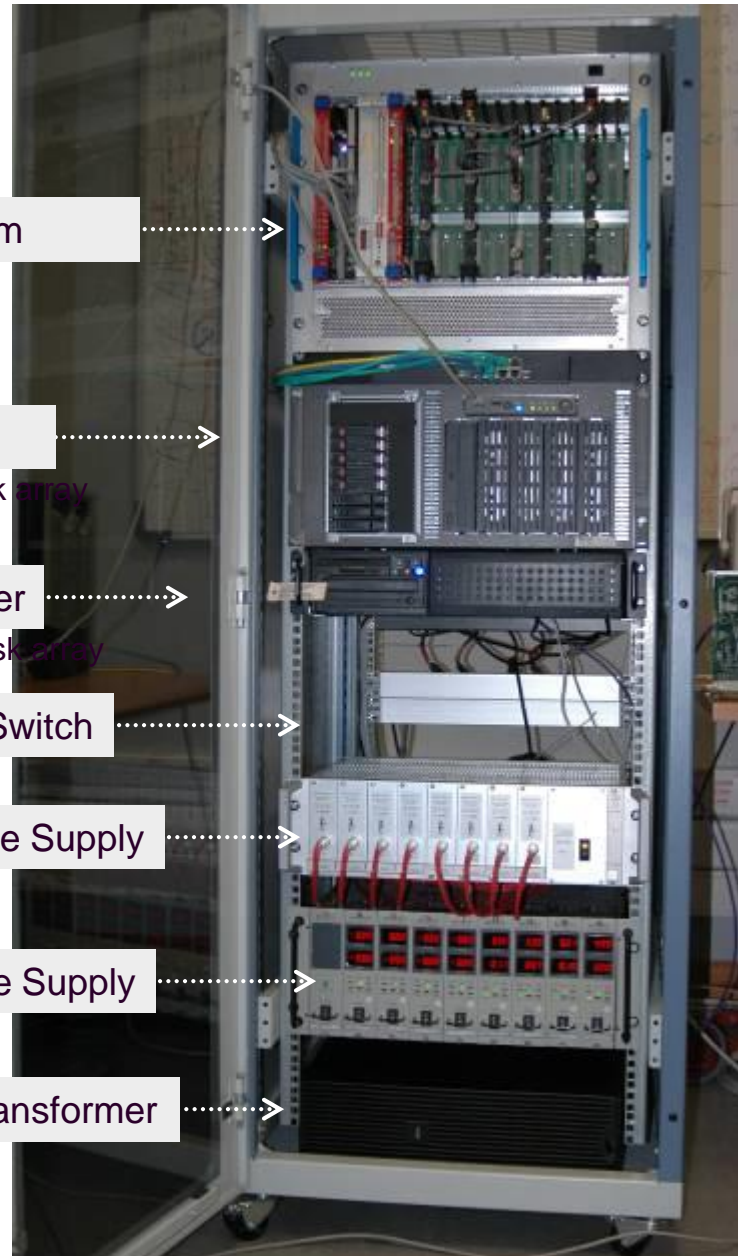
2 cores, 0.5 TB disk array

Gigabit Switch

High Voltage Supply

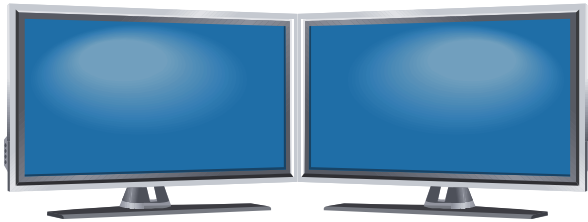
Low Voltage Supply

Isolation Transformer

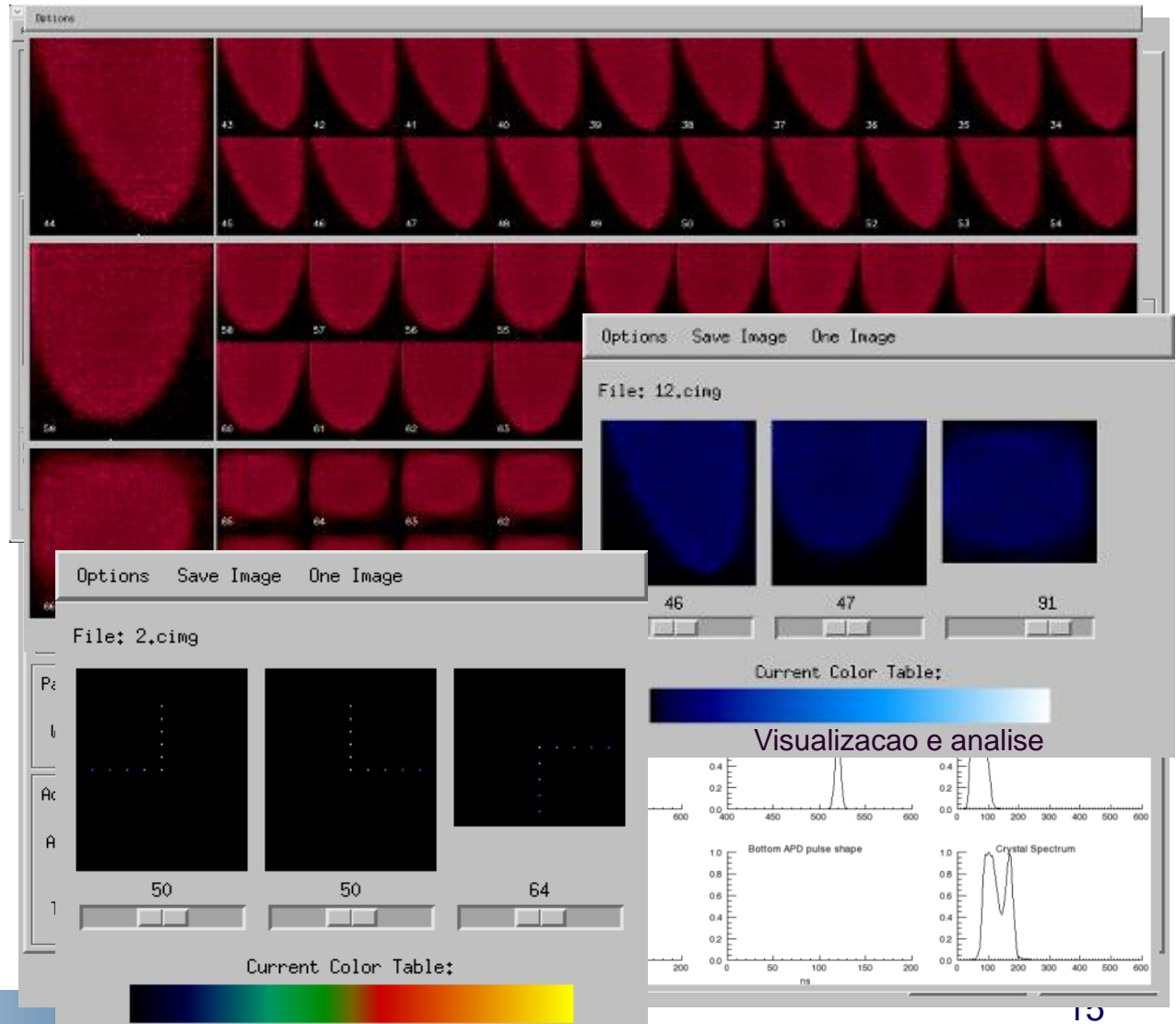


DATA Server

Operation, Monitoring, Reconstruction and visualisation software

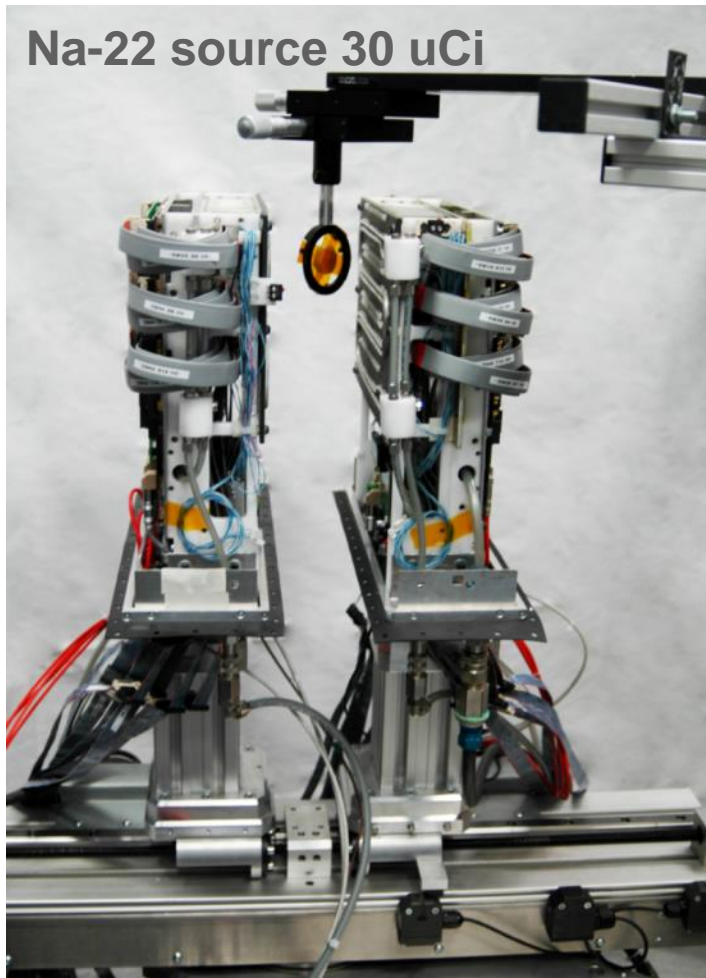


4 cores, 4 GB RAM, 1 TB disk array

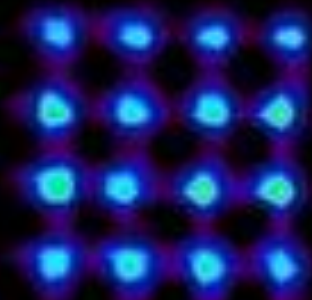


ClearPEM Images

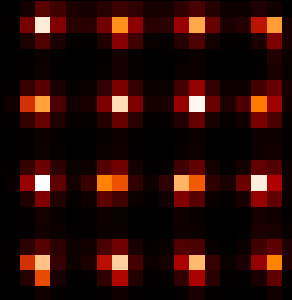
- Two acquisition per position
- (400-600 keV)
- Simultaneous reconstruction with 16 acquisition points



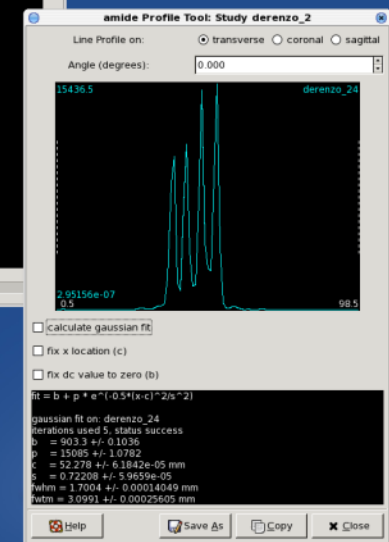
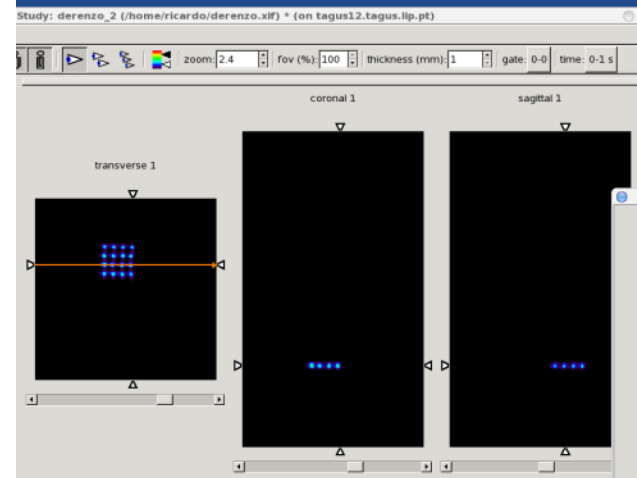
OSEM-3D



OSEM-2D



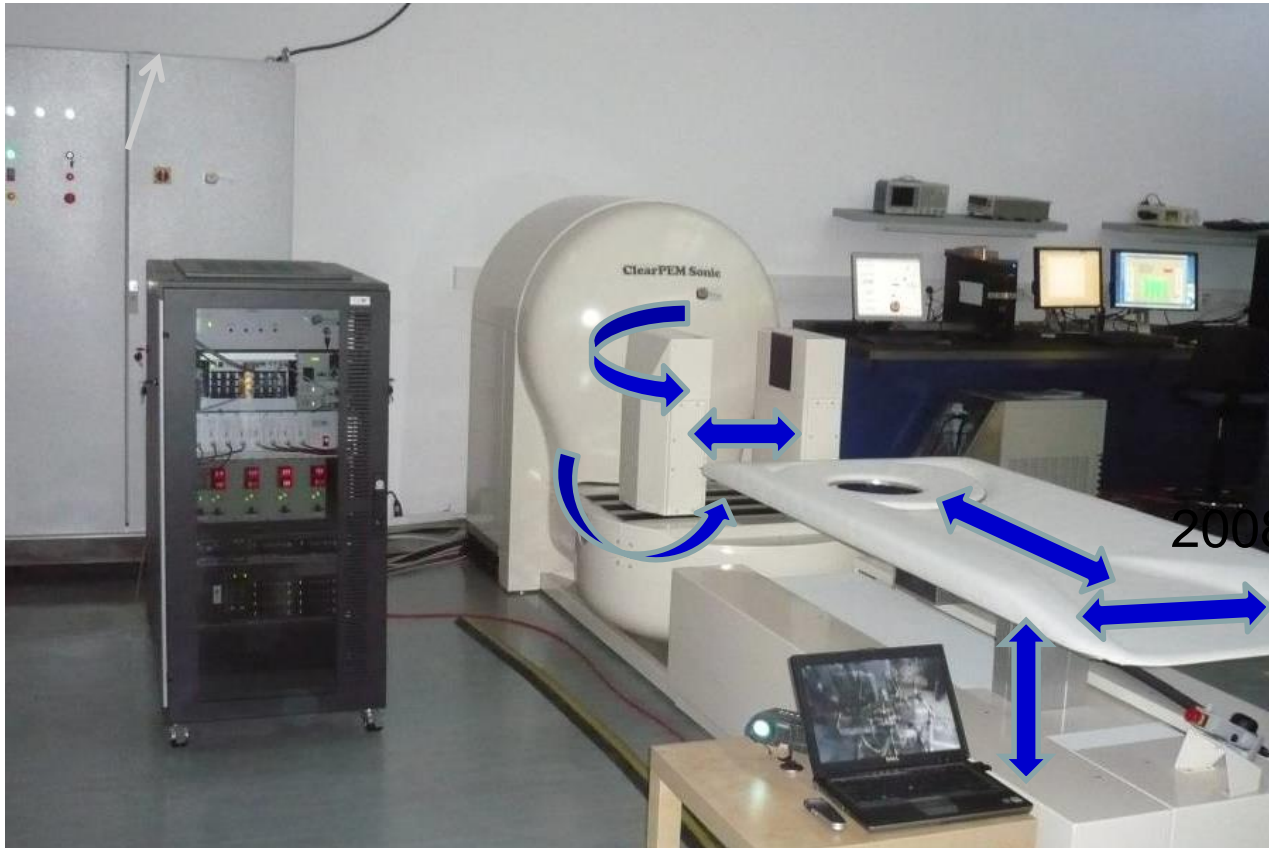
FWHM (deconvoluted of source size) = 1,2 mm



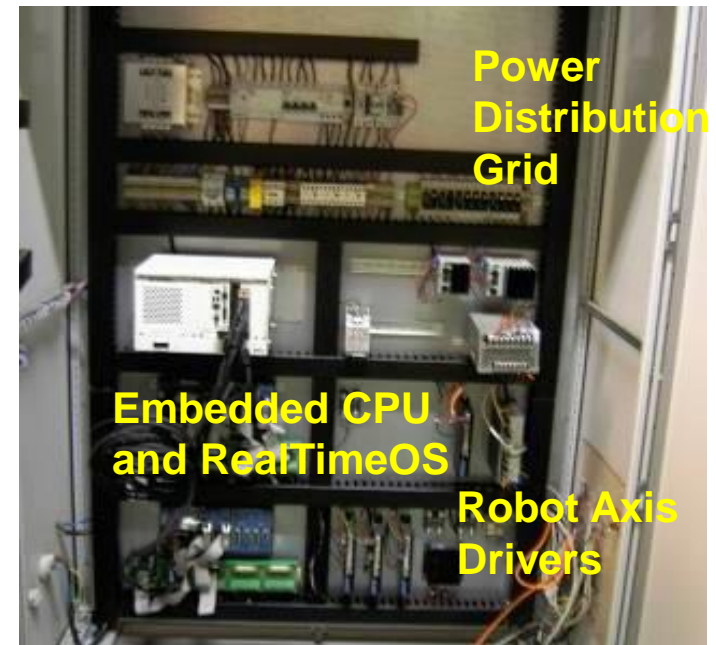
Grid with 5 mm pitch
1 mm Na-22 source

ClearPEM robot

Robot : 6 axes

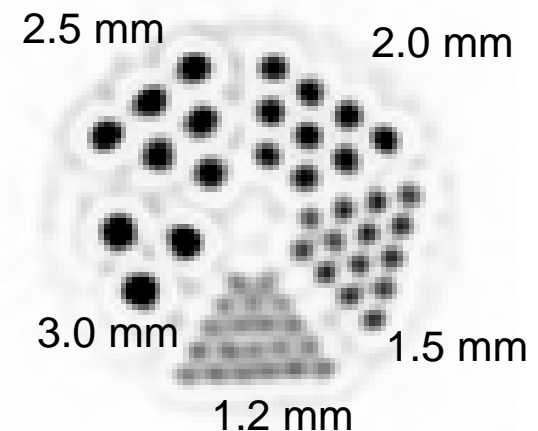
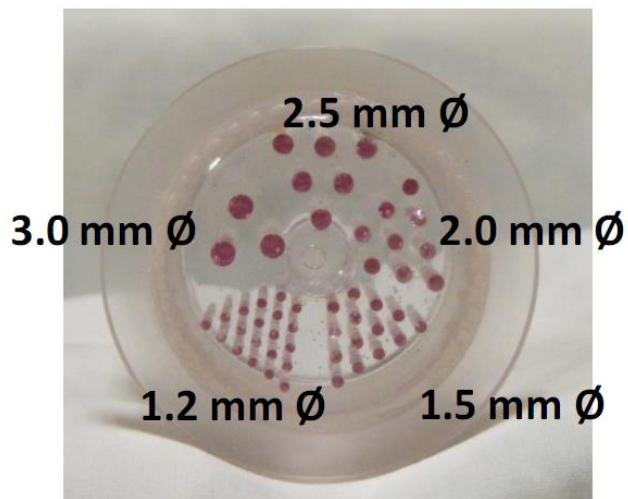


Robot Control

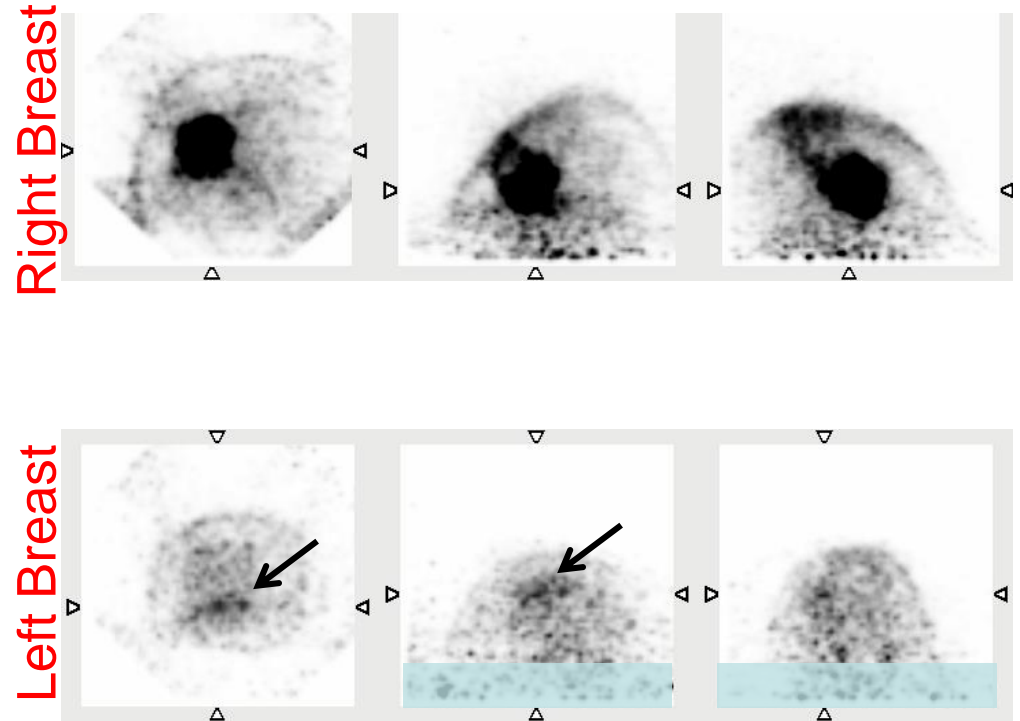
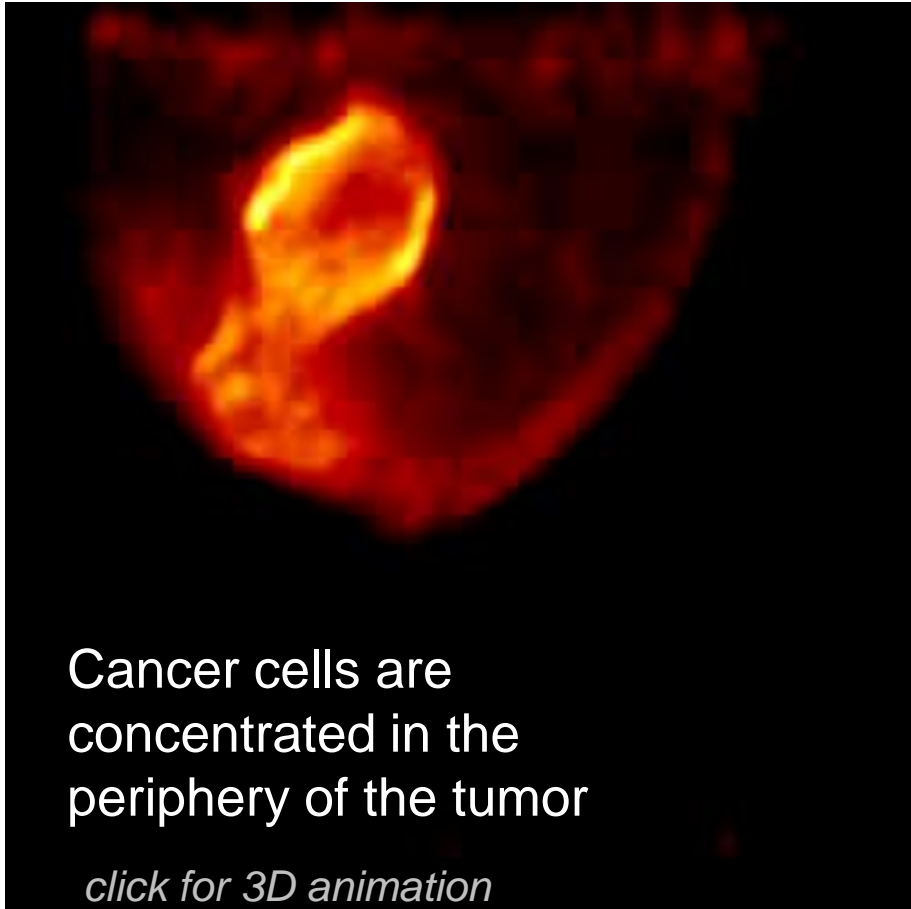


Development concluded in 2008

- The PET Scanner with the best spacial resolution (1.3mm)
- The only PET in the market with DOI measurement and without paralax
- The highest density of integration



- We have fully developed two PET scanners
 - CLEAR PEM and CLEAR PEM SONIC
- The validity of the results was demonstrated on clinical trials in Coimbra (Portugal) and in the Hopital Nord, in Marseilles (France)
- We have identified several cases of cancers that were invisible in the full body PET scanners.
- Still ongoing:
 - Clinical trials at Hospital San Gerardo, Monza, Italy
 - PET Markers studies (ICNAS, Coimbra)



Patient with breast cancer tumors imaged both with whole-body PET and with ClearPEM

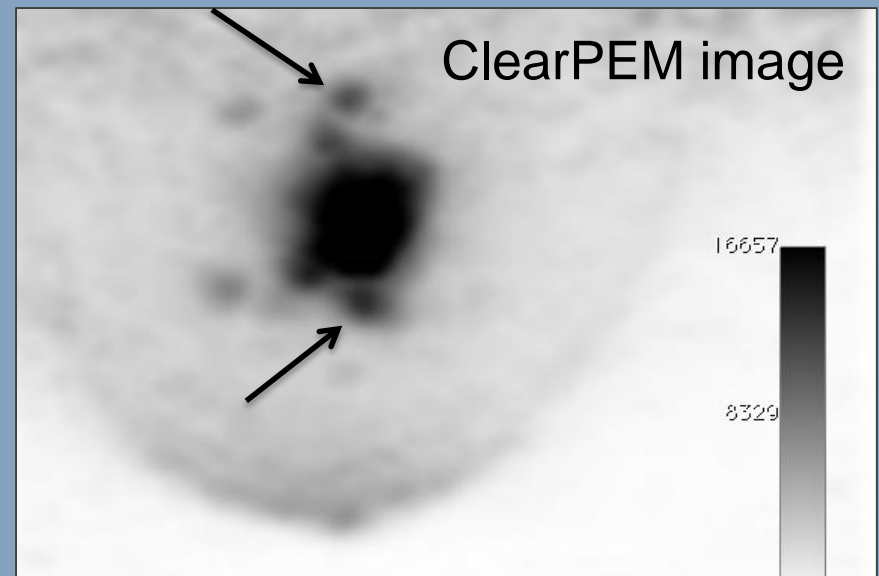
PET/CT exam:
Resolution is insufficient to identify multiple focus



Supine position

PEM:

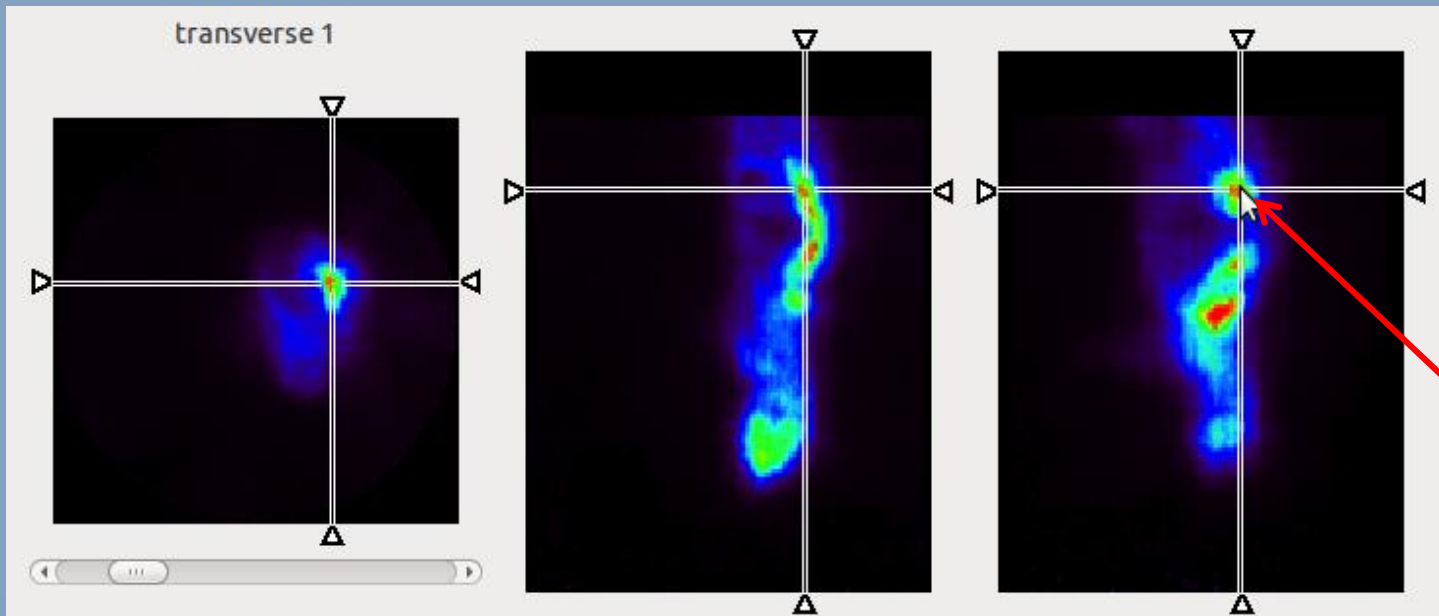
- Multifocal Lesions are observed
- Strong impact on surgery planning



Prone position

Images obtained at Hospital Université de la Méditerranée

Image obtained with PETsys scanner installed at ICNAS, Faculdade de Medicina, Coimbra



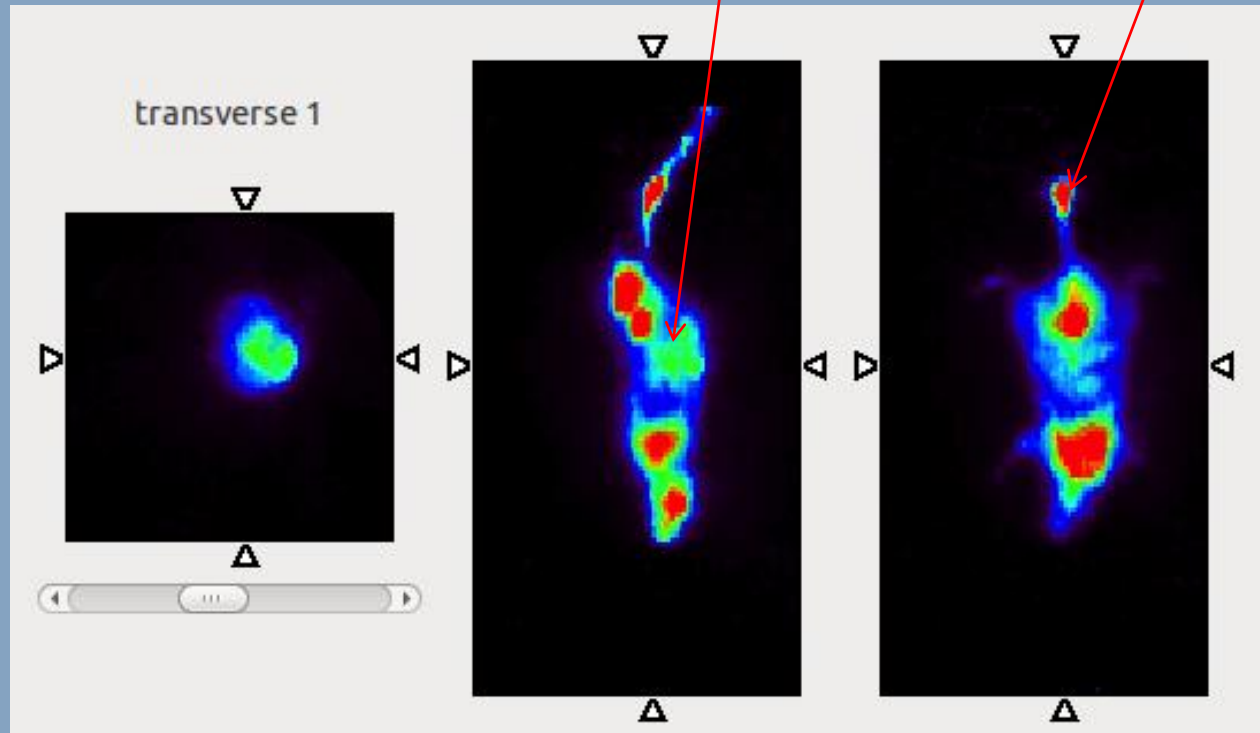
FDG scan
 A = 1,2 mCi
 Weight = 180g
 Colon tumor

Colon tumor

Image obtained with PETsys scanner installed at ICNAS, Faculdade de Medicina, Coimbra

Melanoma

Injection in the tail



FDG scan
 A = 170 μ Ci
 Weight = 18g
 Melanoma



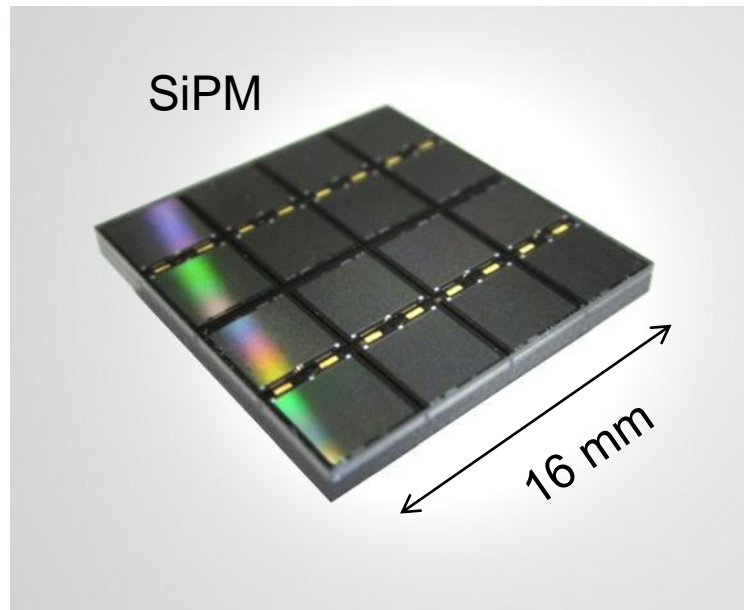
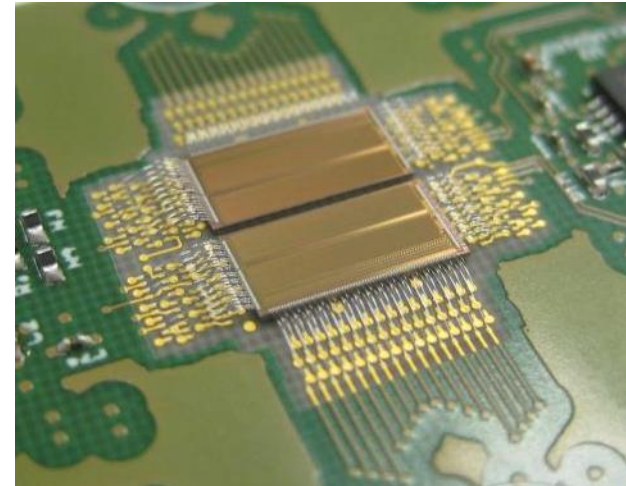


Installed at Hopital
Nord Marseille ...



...and moved to
Monza

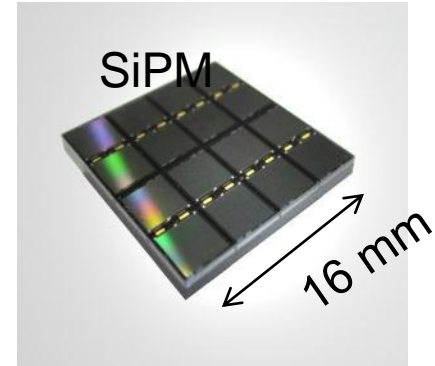
Novas tecnologias
Novos detectores
Novas aplicações



New technologies
New detectors
New applications

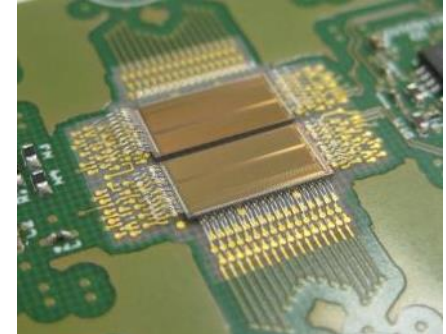
High sensitivity:

- New PET modules with higher sensitivity
- New photodetectors (APDs->SiPM)



PET Time-of-Flight

- New time-of-flight PET detectors, SiPM (Silicon Photomultipliers)
- New ASIC for time-of-flight PET detectors



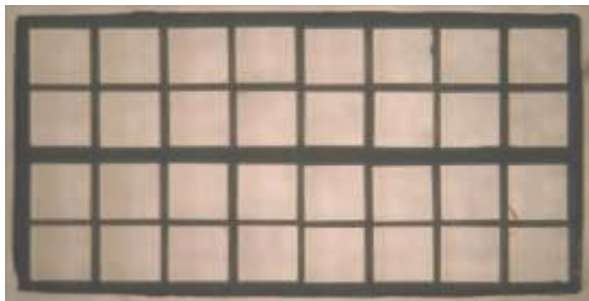
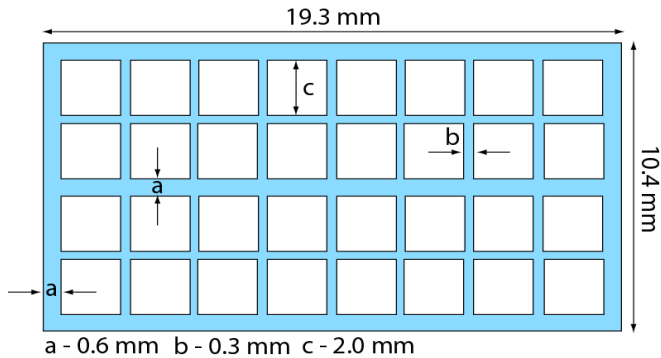
Trigger/DAQ for large scanner systems

- New DAQ high performance system
 . (for brain abd full body PET)
- New DAQ formats from market(uTCA)
- DAQ goes optical



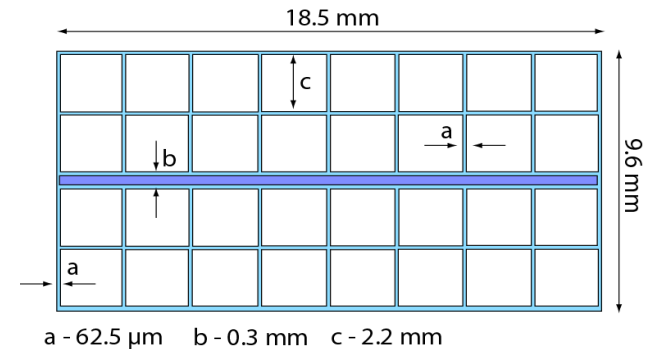
New Crystal Detector Matrices

Sinocera Matrix



64% packing fraction
82% 511 keV interaction probability
(20 mm crystals)

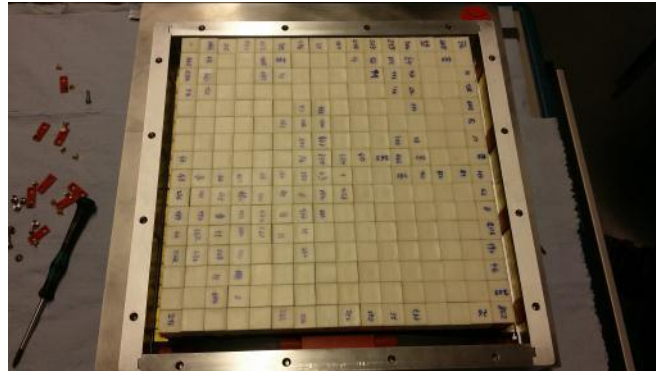
Proteus Matrix

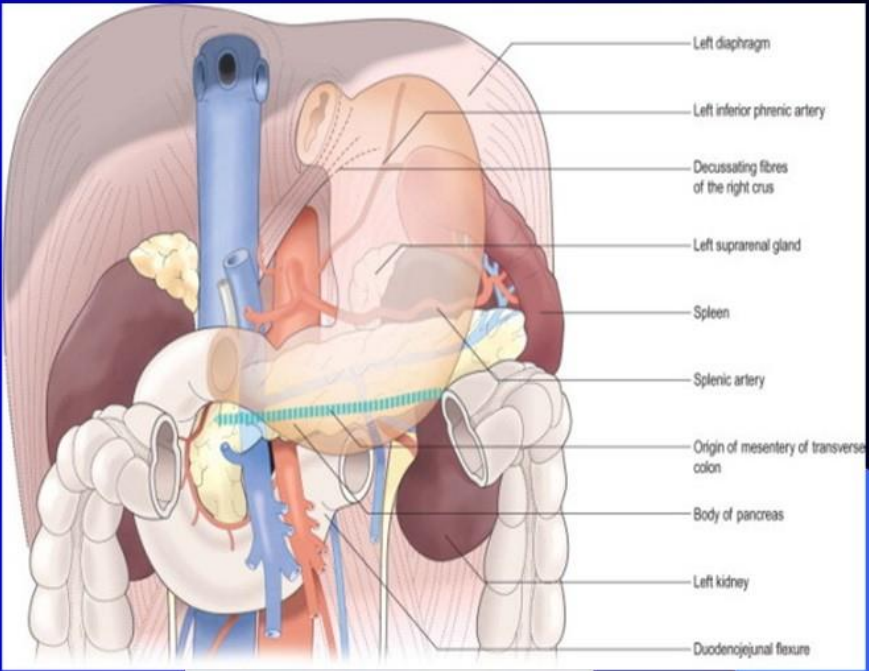
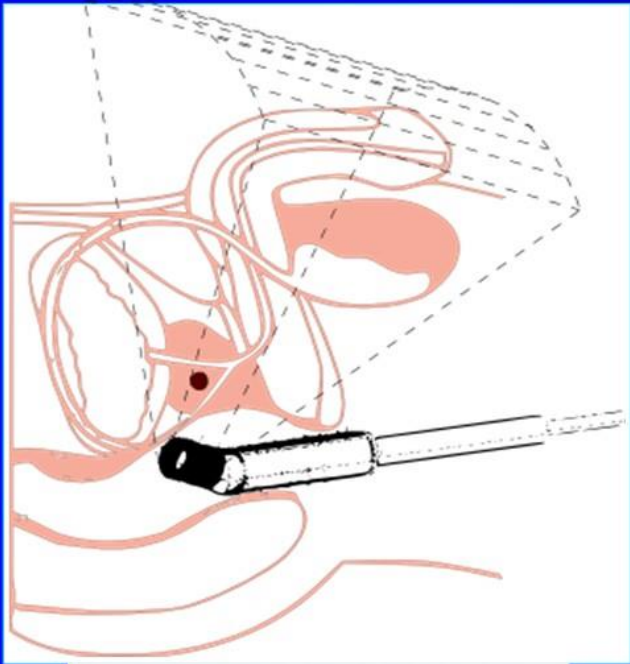


88% packing fraction
92% 511 keV interaction probability
(30 mm crystals)

Better xtal matrices , with reduced gaps, from a direct interaction with manufacturers

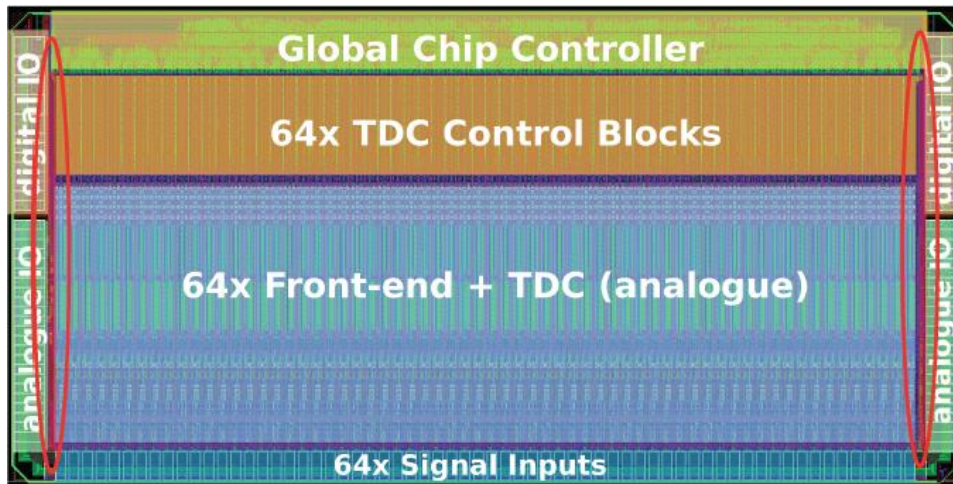
The purpose: create an Endoscopic PET based detector For pancreatic and prostate cancer detection





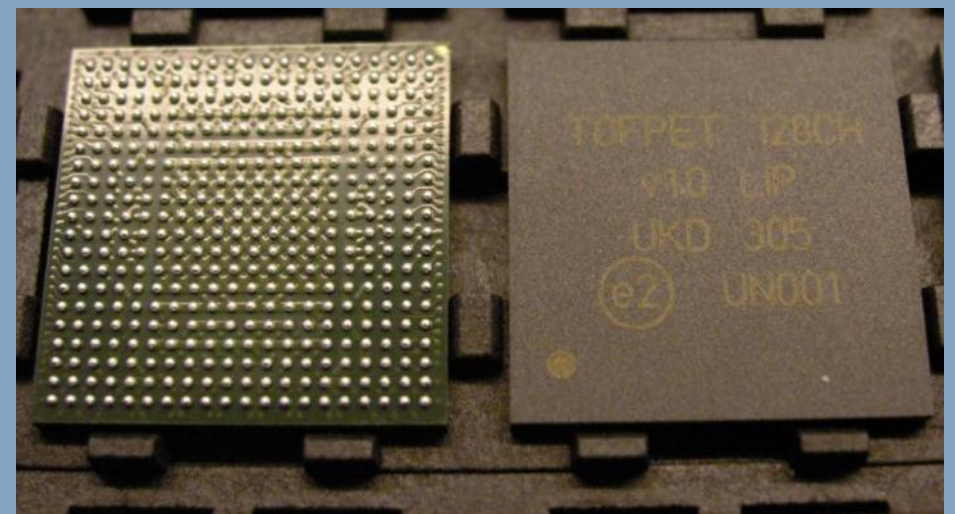
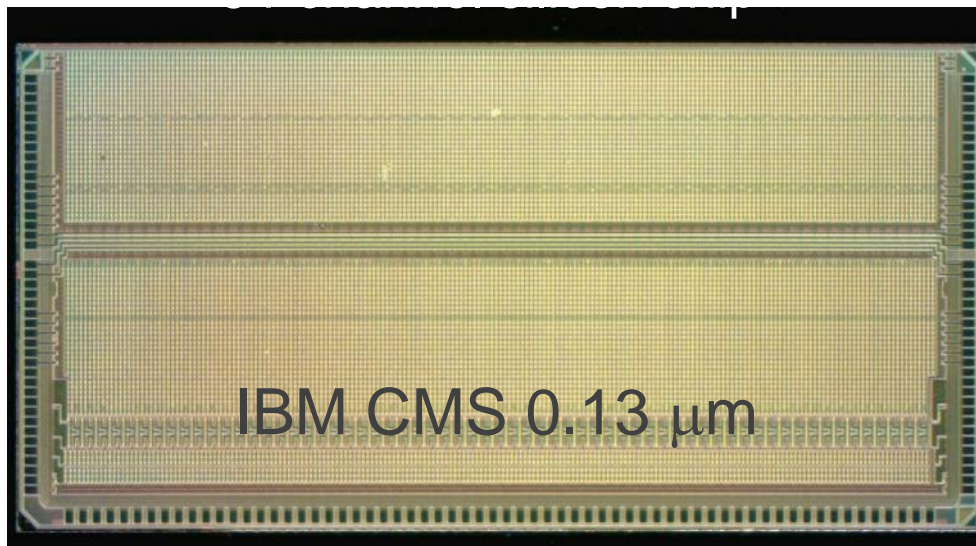
TOFPETASIC for Time of Flight PET

- Benefiting from the experience with APDs, LIP and PETsys has developed microelectronics and detectors based on SiPMs.

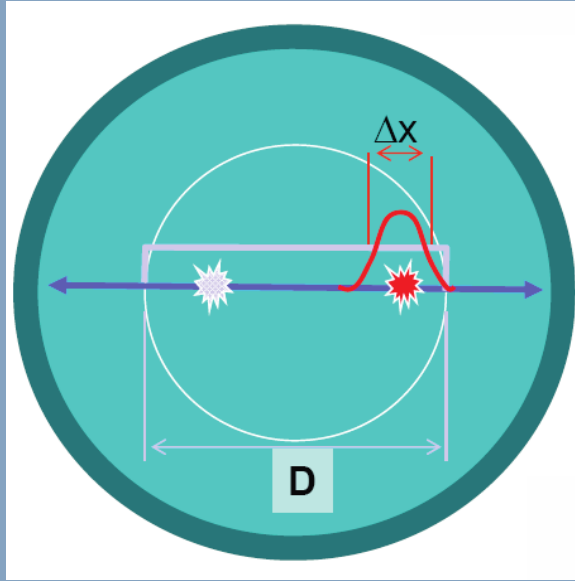


TOFPET microelectronics ASIC

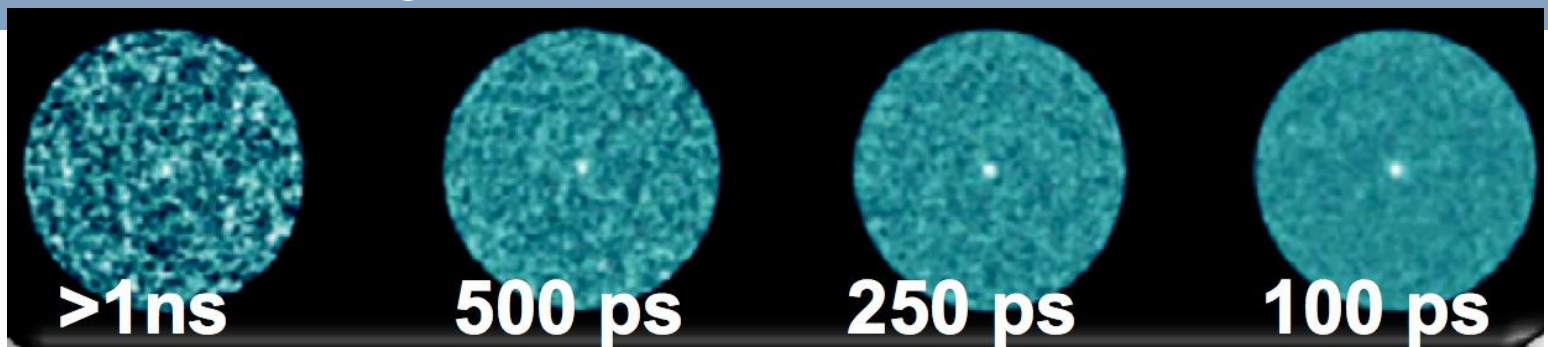
- Clock frequency 160 MHz
 - TDC time binning 50 ps
 - Power per channel 7 mW
 - SNR for single photoelectron 23.5 dB
- 128-channel dual-die BGA package



Better time resolution will dramatically improve the PET image quality

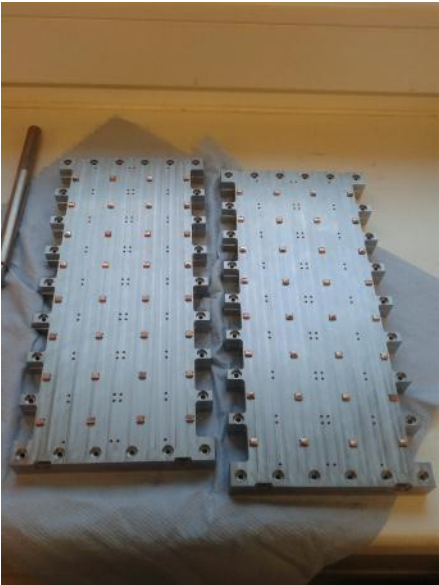


- The accuracy of the source localization depends on the coincidence time resolution (CTR)
- $\Delta x = (\text{speed of light}) \times \text{CTR} / 2$
- The TOF benefit is proportional to $D / \Delta x$
- With PMTs $\text{CTR} \geq 500 \text{ ps}$ if great care is taken to get the best CTR

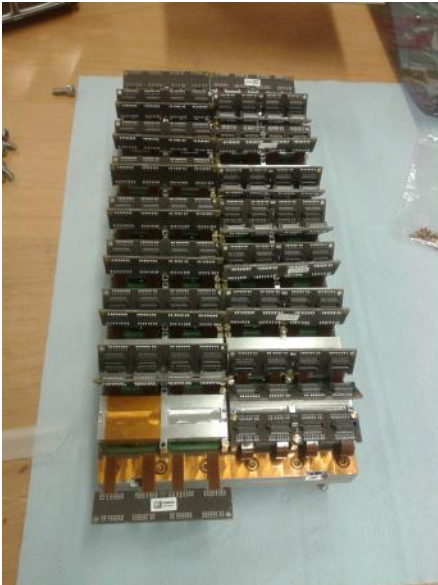


PETsys Detector Modules have CTR ~250 ps

DESY

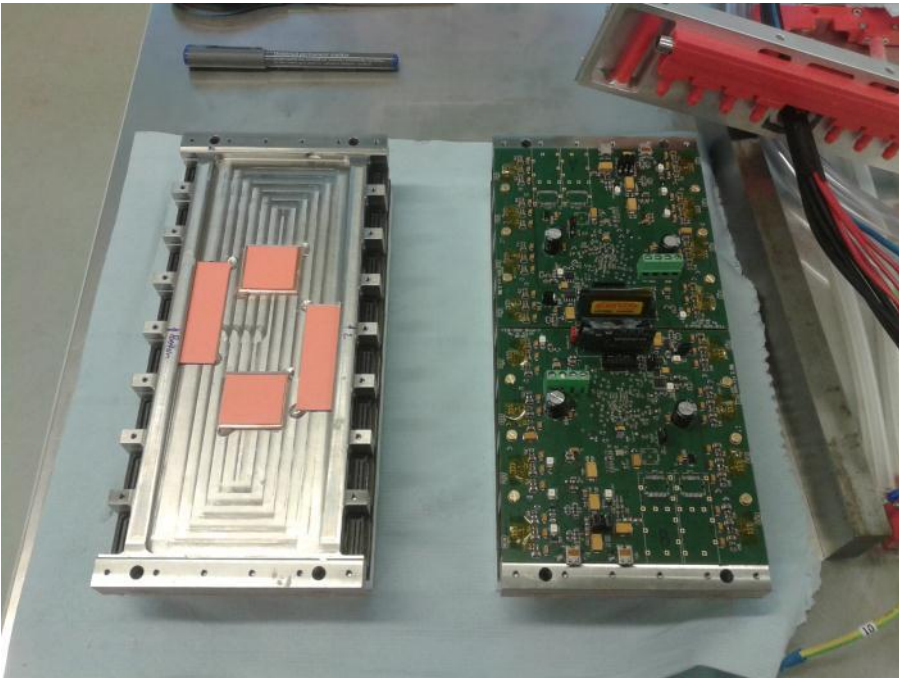


HEIDELBERG

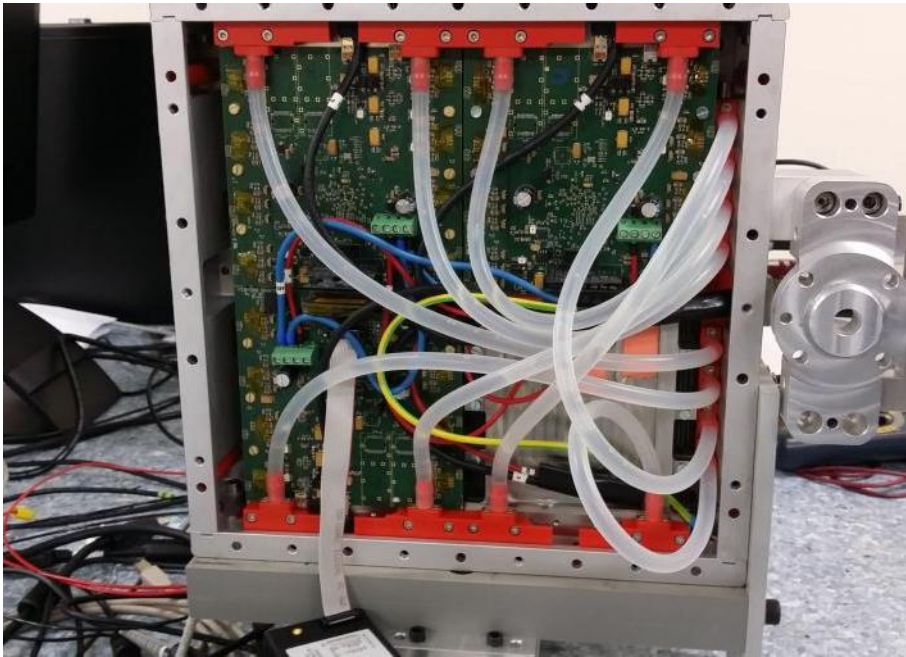


After the production of the individual components from each workpackage we bring it all together

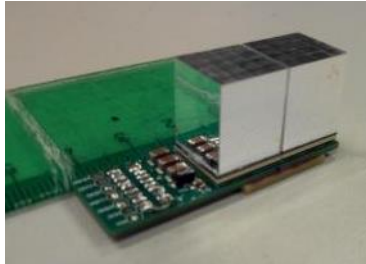
LIP



Integration@CERN



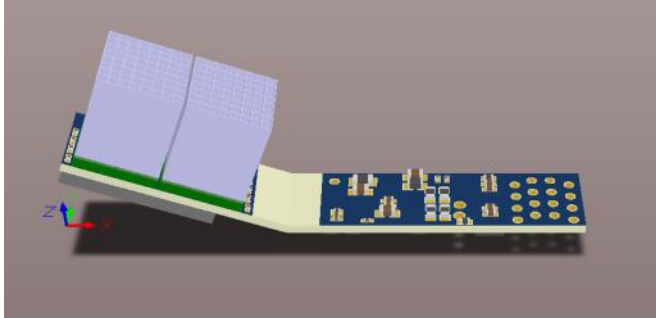
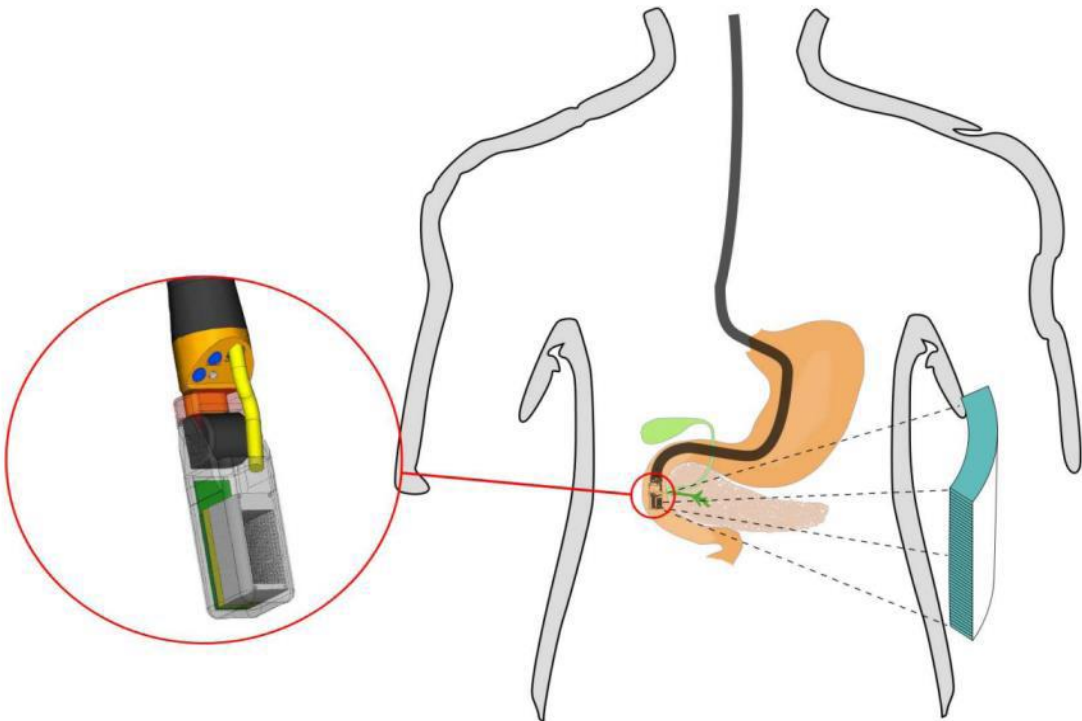
ENDOTOFPET project



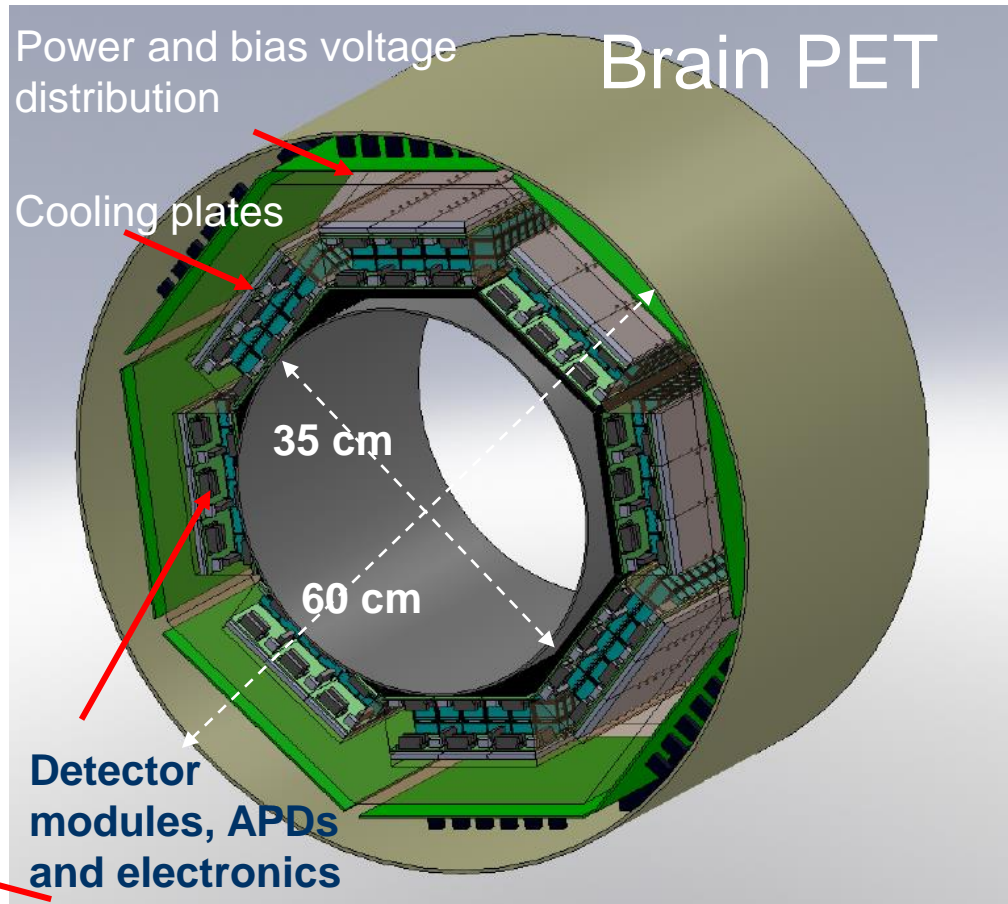
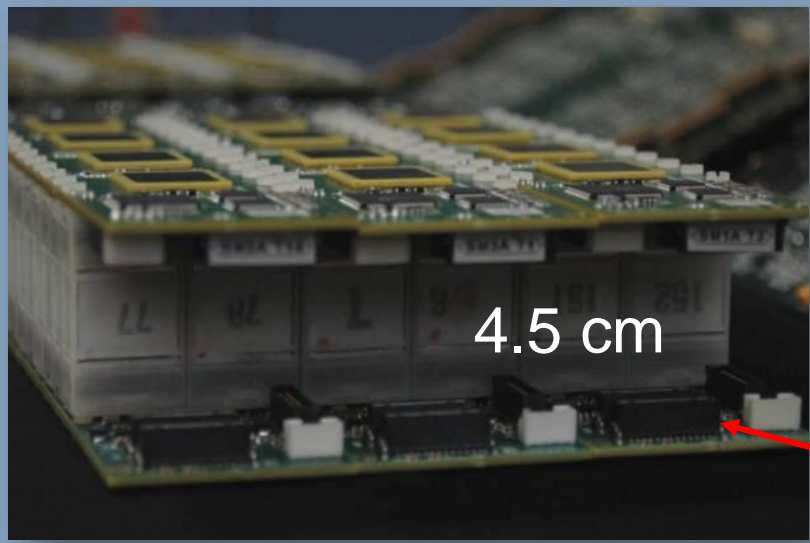
**PET HEAD
Using SIPM and
LIP TOFPET ASIC
Prostate version**



**Pancreas PET HEAD
Using SIPM and
LIP TOFPET ASIC
(Under development)**



Technology using SiPMs

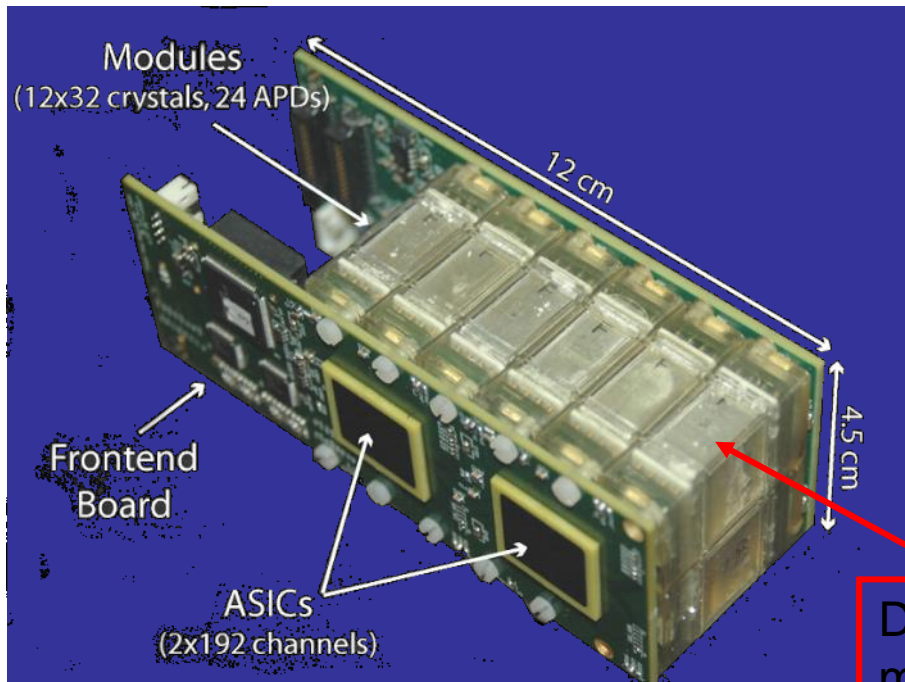


Brain PET-MR Insert

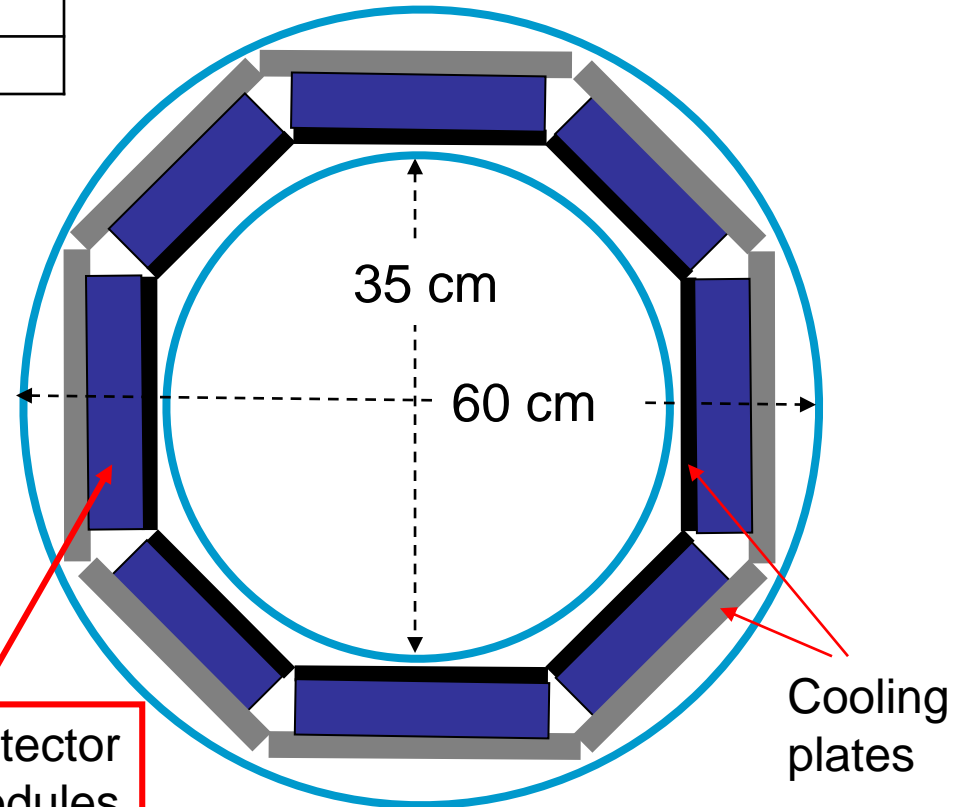
PERFORMANCE PARAMETERS

Parameter	Value
Spatial resolution	1.3 mm FWHM
Energy resolution (511 keV)	15% FWHM
Time resolution (coincidence)	4 ns FWHM
Dol resolution	2 mm FWHM

Ressonancia Magnetica Leitura com Dol



Detector modules



Obrigado Manaus

