



Caratterizzazione di fotomoltiplicatori al silicio per una strumentazione tomografica innovativa e a basso costo

Arosio V., Caccia M., Castro F., Mattone C., Moutinho L., Santoro R., Stanizzi A., Veloso J.



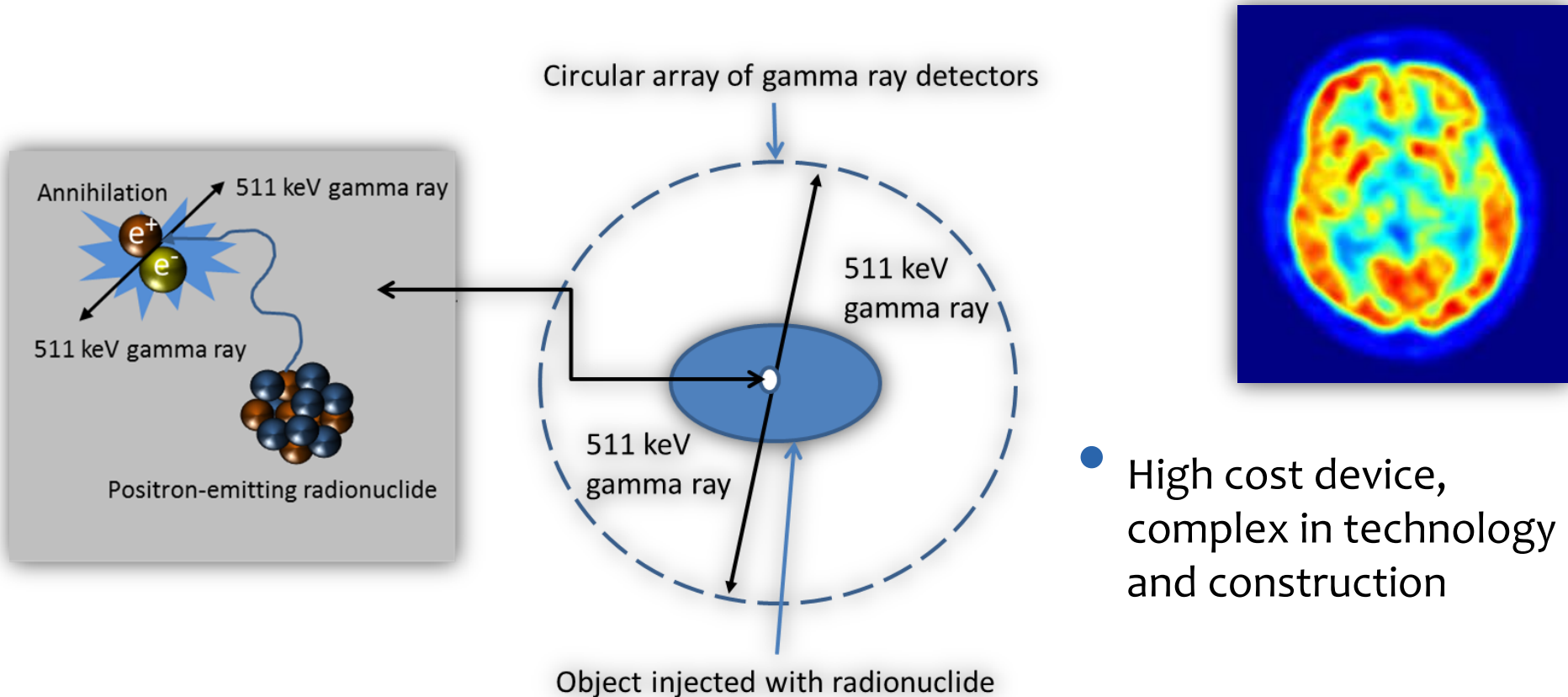
universidade
de aveiro



CAEN
Tools for Discovery

Positron Emission Tomography (PET)

- Non invasive nuclear medicine technique
- Functional 3D imaging for physiological processes investigation and medical diagnosis (oncology, neurology, cardiology)



- High cost device, complex in technology and construction

Small animal PET

Preclinical imaging studies on small animals

Pharmaceutical industry
new drug development
at reduced cost

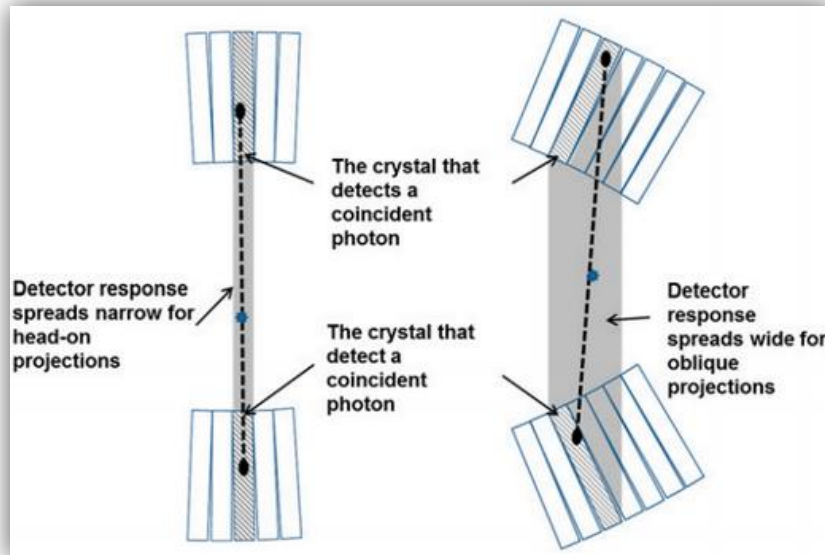
Medical research
study disease progression
and therapeutic response



Major requirement:

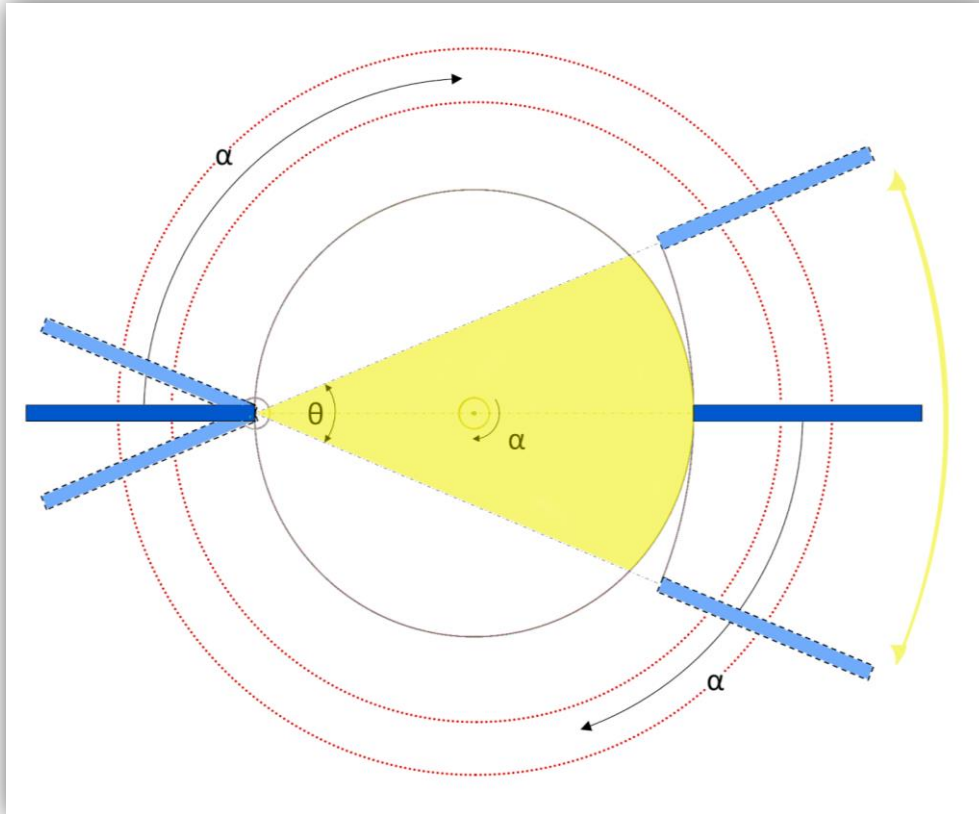
spatial resolution < 1 mm FWHM

- small scintillator crystals cross-section
 - ↳ parallax error due to photons obliquely incident on the crystal
- depth of interaction to obtain spatial resolution uniform over the field of view



Complex and expensive

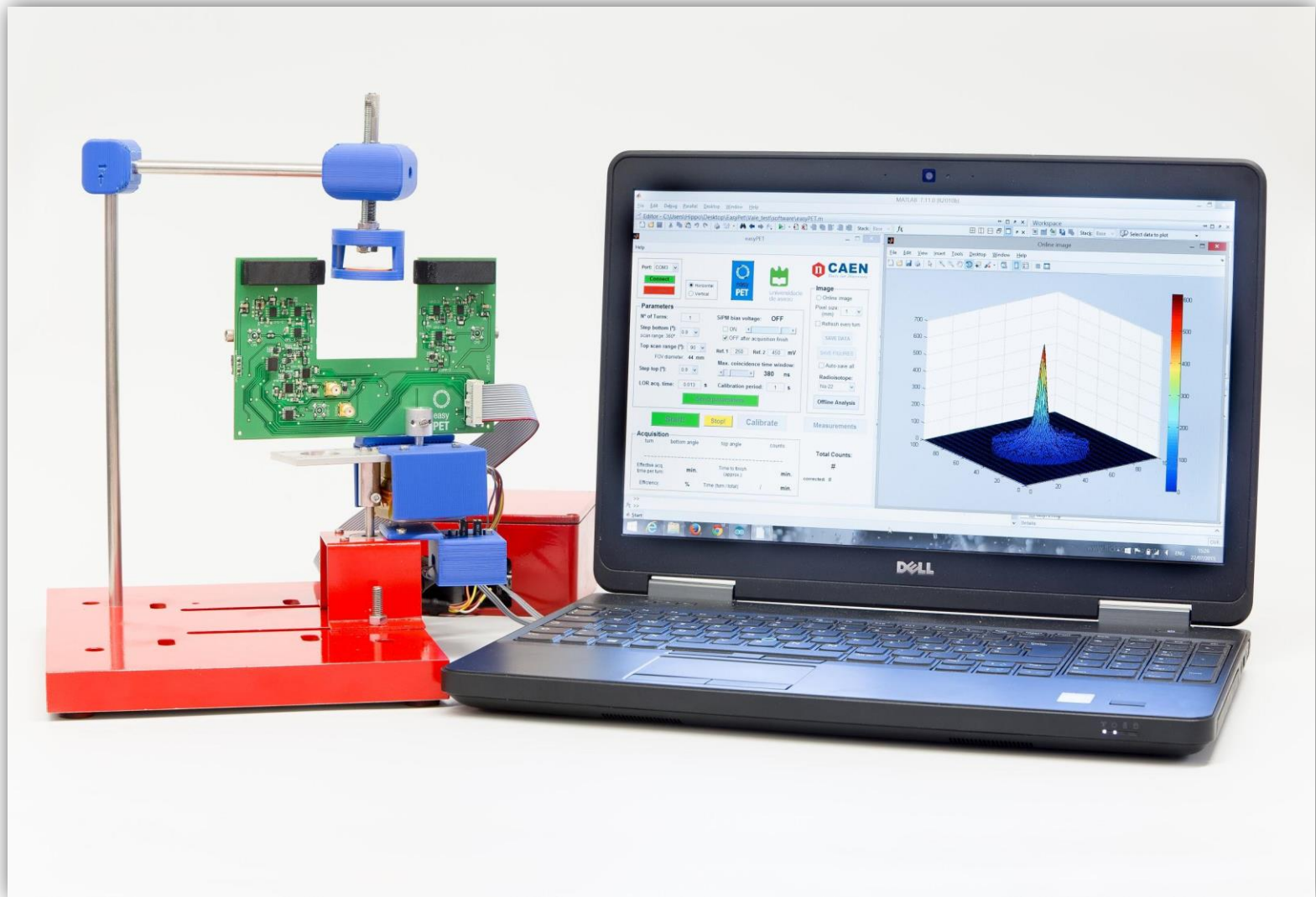
easyPET operating principle



- Single pair of detectors oppositely aligned
 - **Parallax error is eliminated**
- Mechanical rotating system executing two types of independent movements to simulate the entire PET ring
 - **360° rotation (axis ≡ center)**
 - **θ scan (axis ≡ one detector)**
 - **High spatial resolution uniform over the field of view**

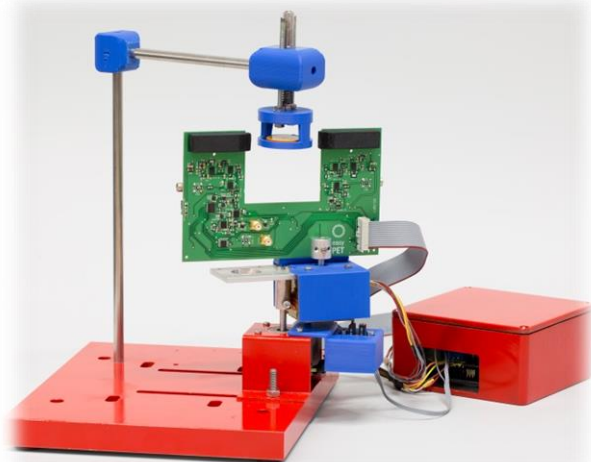
easyPET provides a very cost-effective solution

the complexity of the apparatus is reduced without affecting the performances



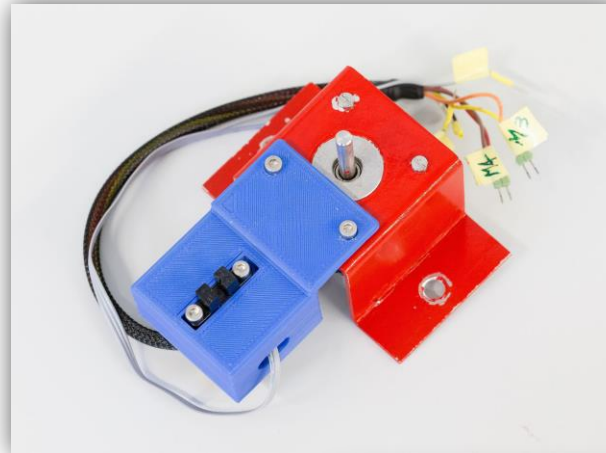
Basement

Source holder

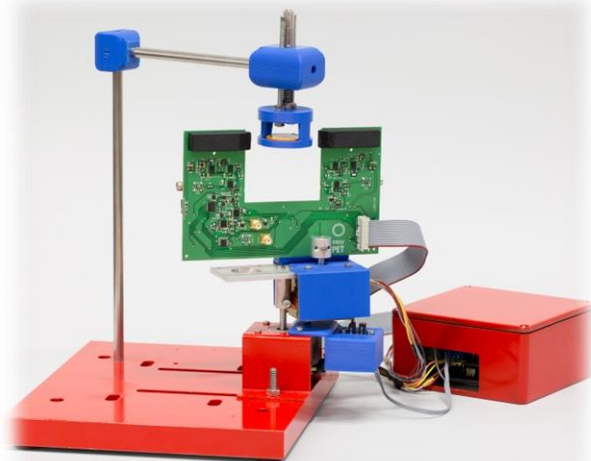
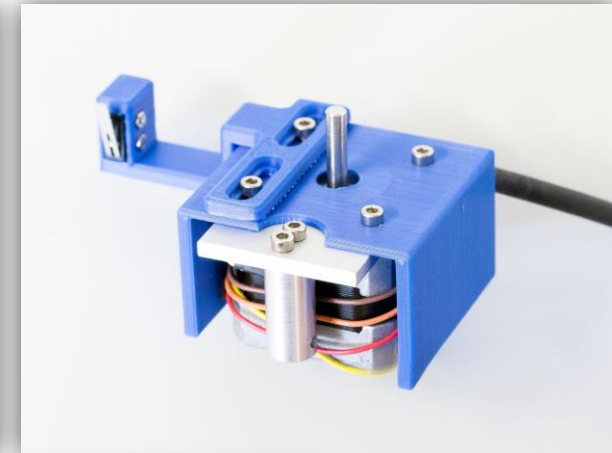


easyPET components

Bottom motor



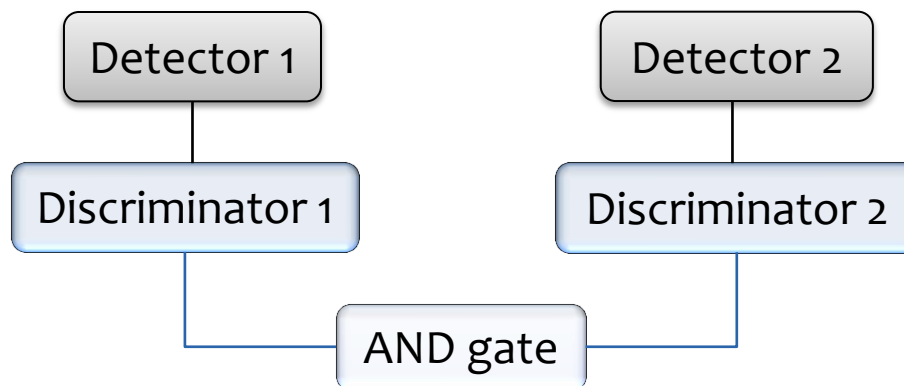
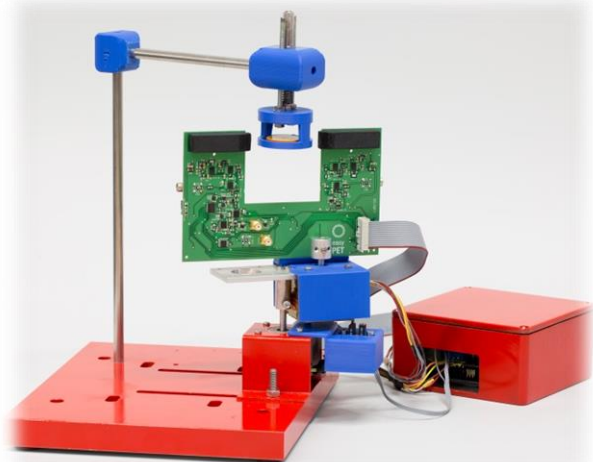
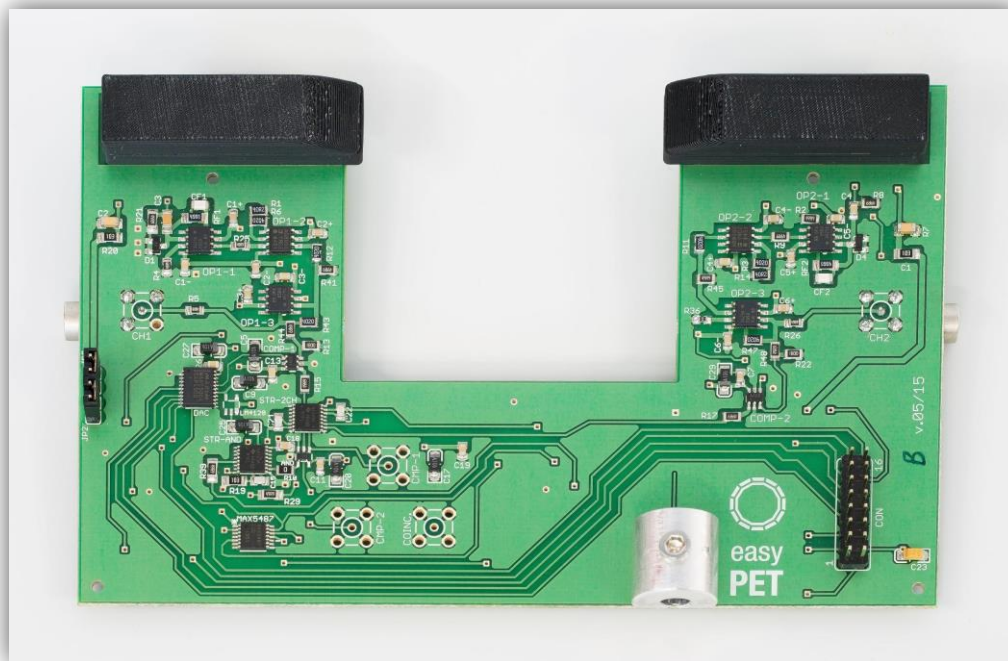
Top motor



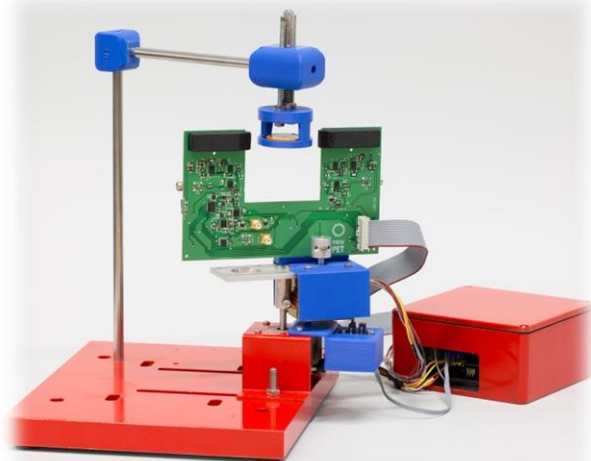
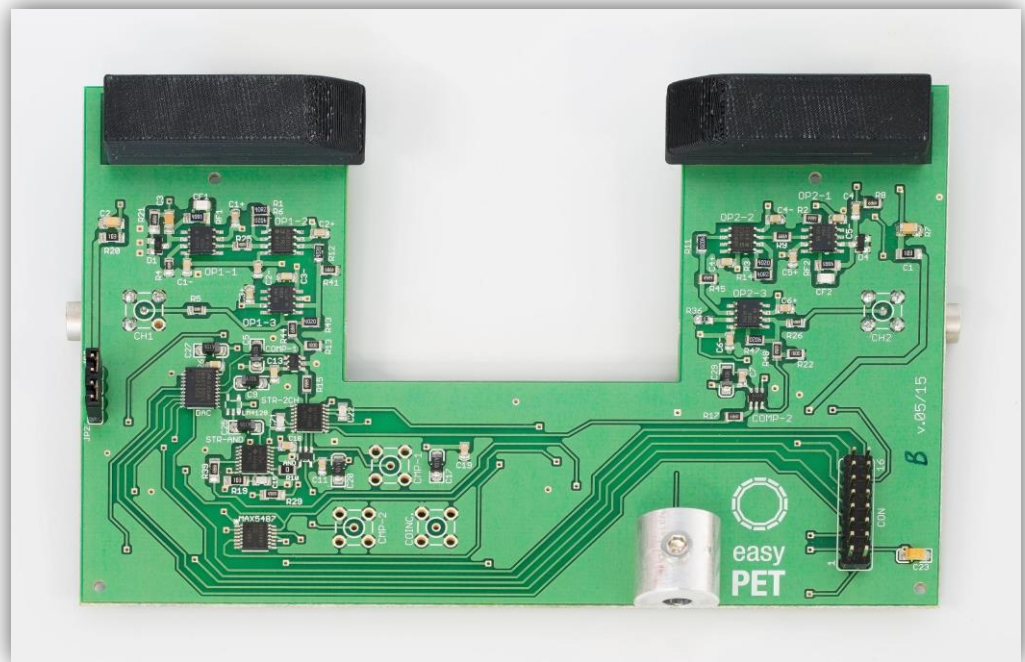
Arduino
controller



Printed Circuit Board



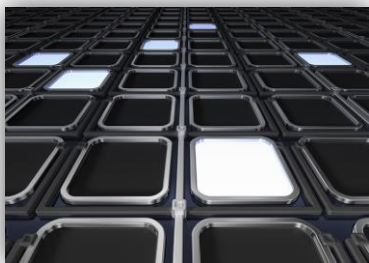
Printed Circuit Board



LYSO
Crystal
& Light
detector

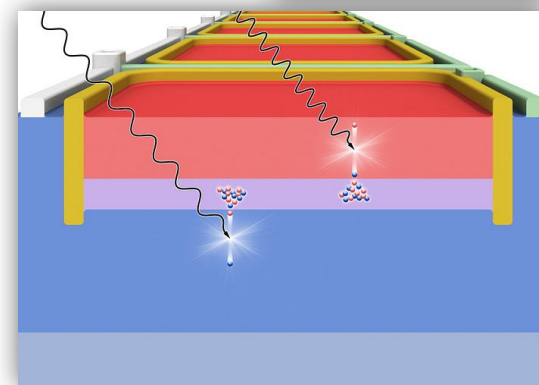
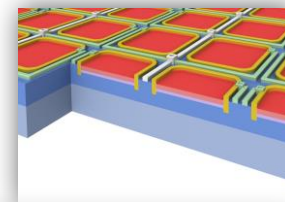
Silicon Photomultipliers (SiPM)

- High density ($\sim 10^4/\text{mm}^2$) matrix of photodiodes working in Geiger-Müller regime with 10^6 gain

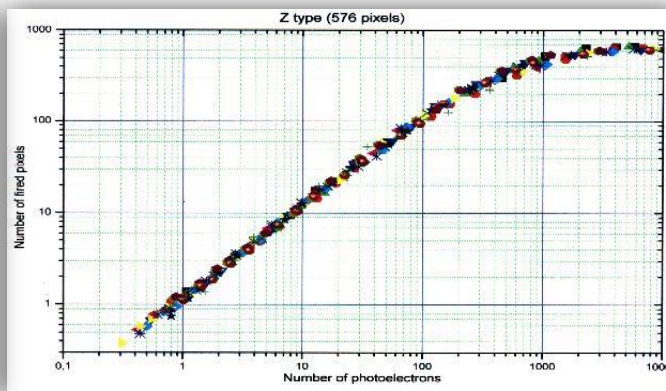
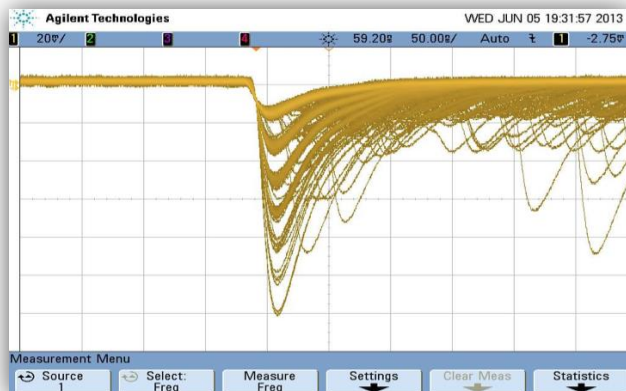


binary information

High gain
Low voltage



- Photodiodes connected in parallel to a single output



analog information

High photon number resolving power
Wide dynamic range

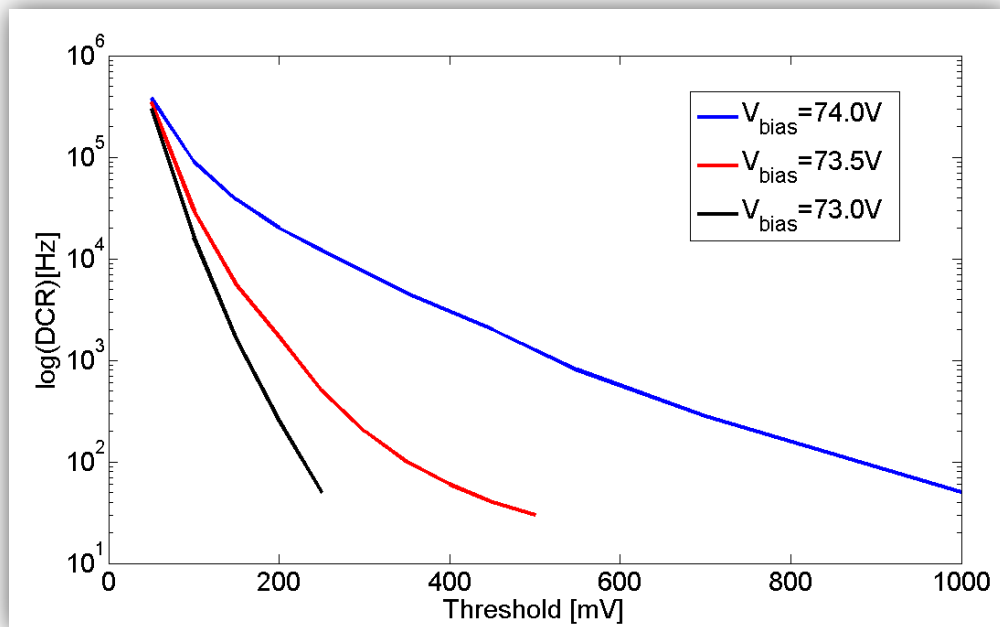
Good timing capability

Low cost
Withstanding to magnetic field

Dark Count Rate (DCR)

Spurious **random** avalanches initiated by **thermal emission**

DCR measurement
rate of **signals** exceeding the **threshold**



DCR decreasing
low bias (less avalanche probability)
high threshold

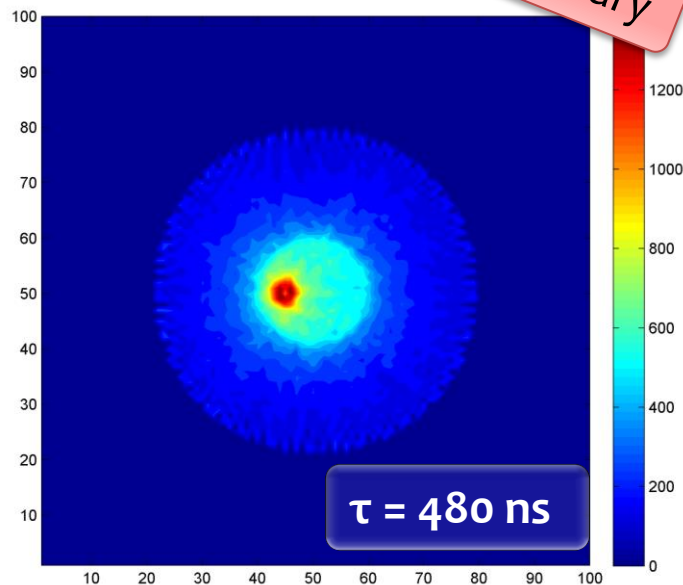
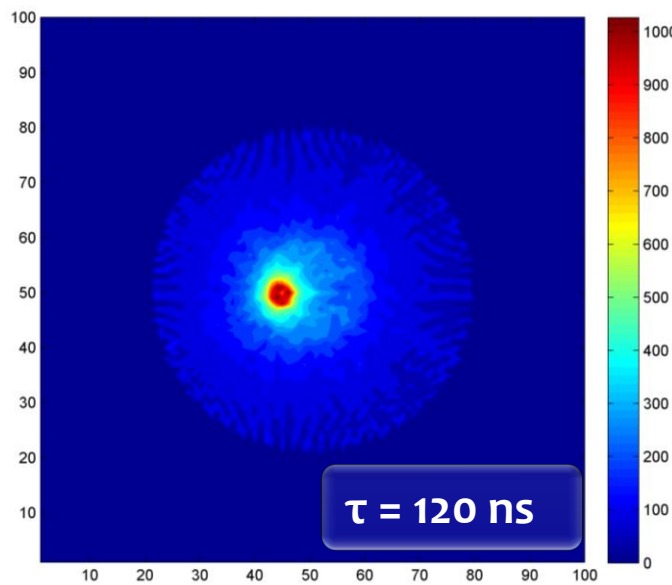
less efficiency ✗

Exploit coincidences! ✓

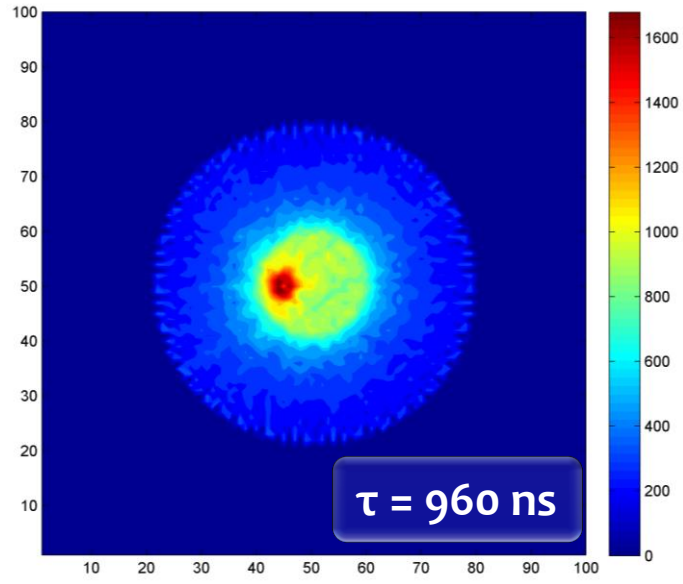
Coincidence gate (τ)

Preliminary

$V_{\text{bias}} = 73.5 \text{ V}$
 Threshold = 200 mV



τ [ns]	B [Hz]	S [Hz]	(S-B)/ \sqrt{B}
120	3	42	22.5
240	9	46	12.3
360	11	48	11.2
480	12	53	11.8
600	17	57	9.7
720	21	60	8.5
840	23	60	7.7
960	23	61	7.9



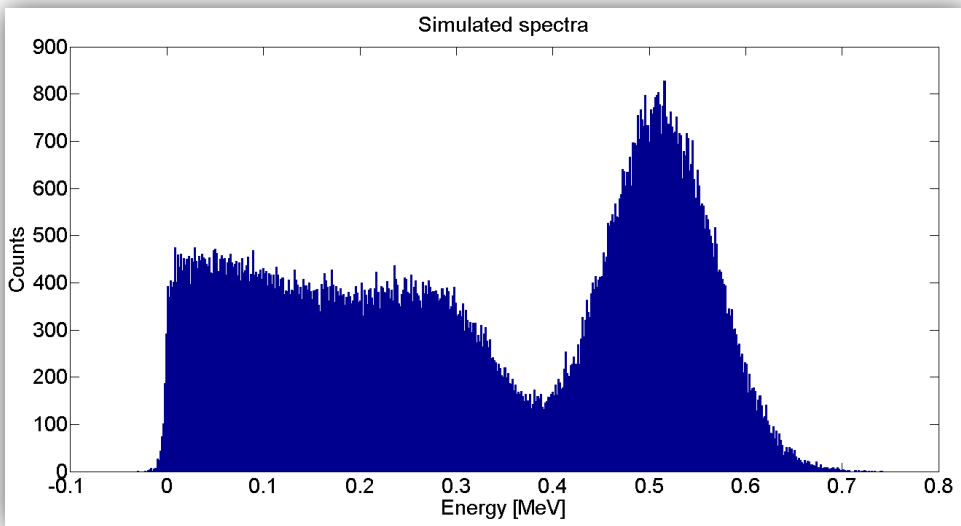
Relative efficiency (ϵ_r)

Preliminary

Threshold [mV]	Coincidence DCR [HZ]
100	194
120	272
140	60
160	15
180	6
200	3

Energy calibration

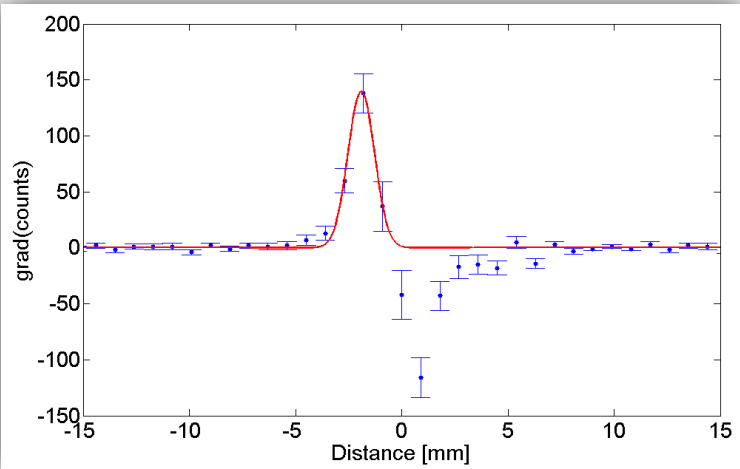
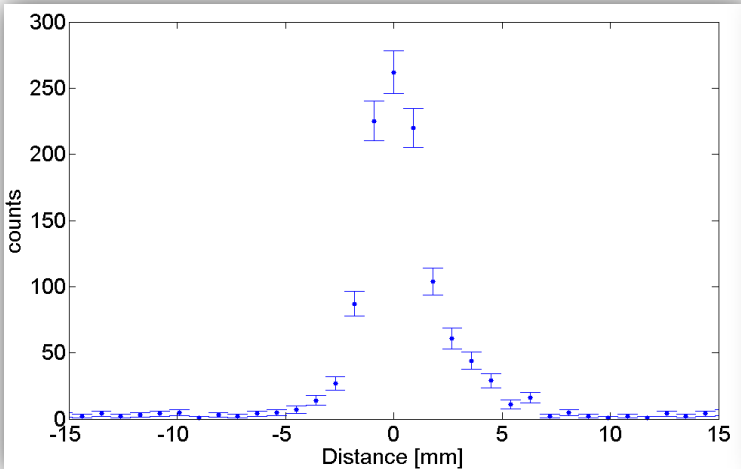
Threshold [KeV]	E_r [%]
0	100
50	91
100	83
200	67
250	59



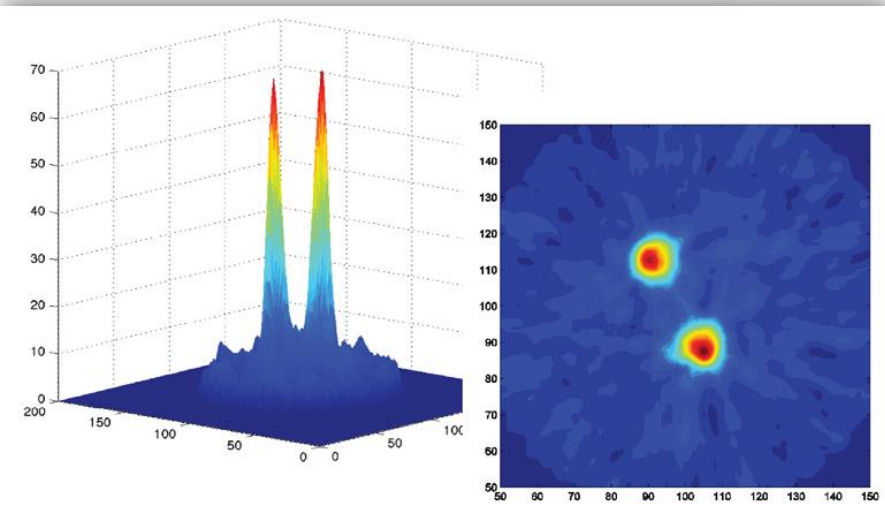
Manufacturer	Energy (keV)
Bioscan/Mediso	250–750
Carestream	Not available
Gamma Medica/GE Healthcare	250–650
Philips	410–665
Raytest Isotopenmessgeräte GmbH	250–750
Sedecal, S.A.	250–650
Siemens Preclinical Solutions	250–750

$$\text{Step} \times \text{Gaussian} = \text{Sigmoid}$$

Edge-response function



**1.45 ± 0.4 mm
FWHM**



^{22}Na sources
 5 μCi
 2.7 mm \varnothing
 9 mm apart

Manufacturer	FWHM (mm)
Bioscan/Mediso	1.2
Carestream	<1.3
Gamma Medica/GE Healthcare	1.3
Philips	2.7
Raytest Isotopenmessgeräte GmbH	1.5
Sedecal, S.A.	1.5
Siemens Preclinical Solutions	1.3

State-of-the-art & Outlook

2D imaging

Simple, low-cost, user friendly and portable **didactic PET system** for high-level education



↓

Electronics re-design
Mechanics optimization
Multi-pair detectors
Image analysis algorithms



3D imaging

Pre-clinical small animal PET



BACKUP

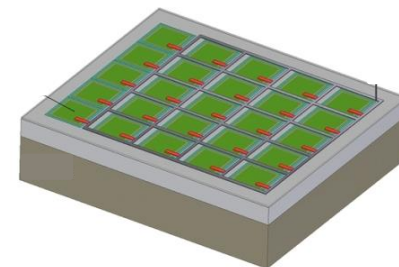
HILGER LYSO CRYSTAL



2x2x30 mm

Density (g/cm ³)	7.1
Decay Time (ns)	40
Light Yield (ph./MeV)	32000
Peak emission (nm)	420
Radiation length (cm)	1.15
Reflective index	1.81

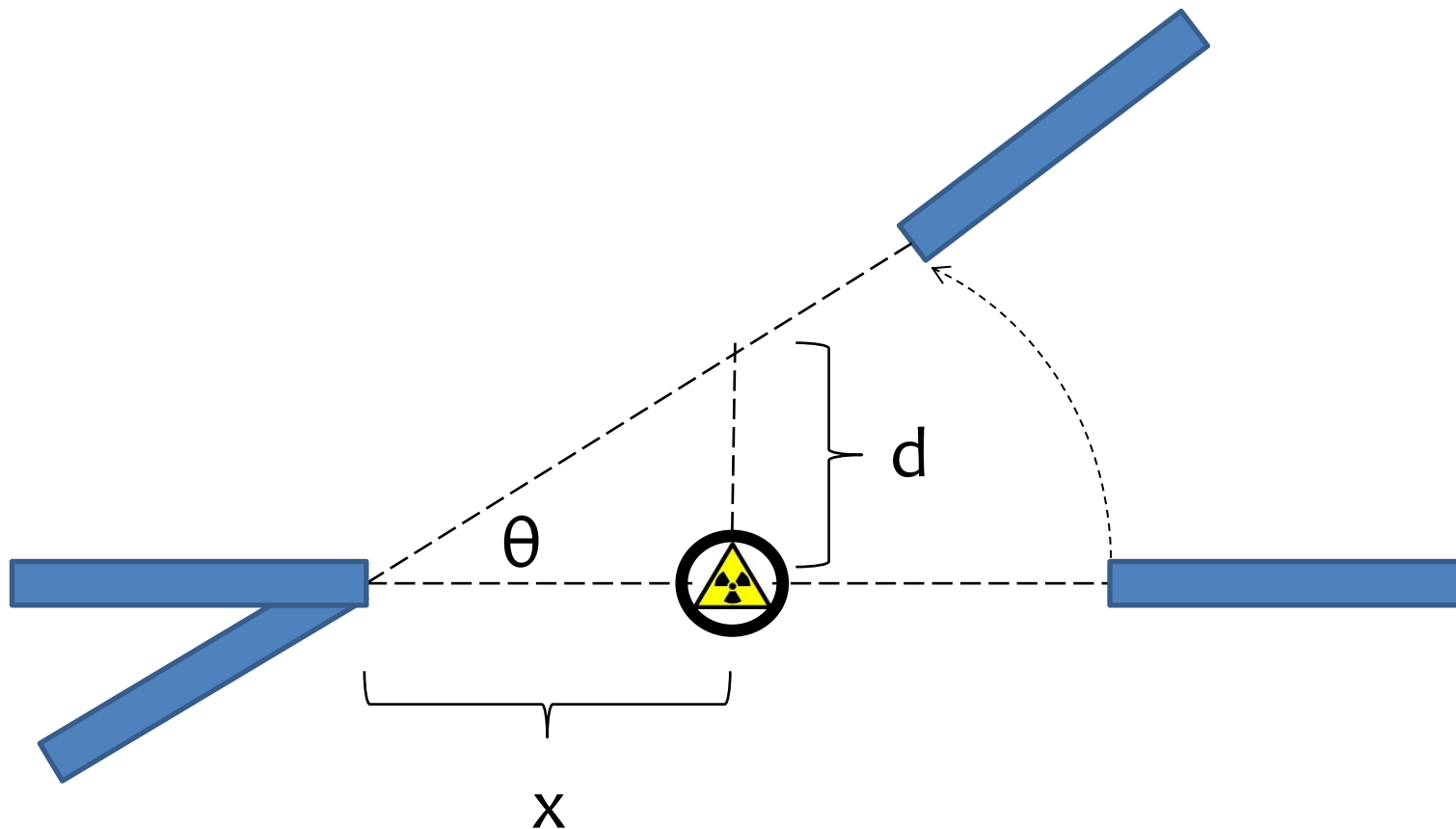
HAMAMATSU MPPC



1x1 mm

Effective active area (mm ²)	1 x 1
Number of pixel	400
Pixel size (μm)	50x50
Peak sensitivity wavelength (nm)	440
Photon Detection Efficiency (%)	50
Operating voltage (V)	73
Dark Count Rate (KHz)	100
Gain	7.5x10 ⁵

Spatial resolution



$$d = x \cdot \tan\theta$$

