The Wearable PET project for a compact clinical exam for an early diagnosis

#09-235

E.FANCHINI[1]; M.MORICHI[1], J.ALLISON[2,6], P.ANTKOWIAK[3], N. BELLAM[4], F.CASTRO[5,7], L.CHEN[4], P.CORREIA[5,7], P.ENCARNAÇÃO[5,7], J.VELOSO[5,7], C.DA VIA[2], F.GIORDANO[1], A.IOVENE[1], A.KOWALCZYK[3], P.MIĘSAK[3], Z.REN[4], S.SIMPURA[4], E.SUHONEN[4], Y.VENTURINI[1], R.VEPSÄLÄINEN[4], S.WATTS[2]

[1] CAEN s.p.a.

[2] University of Manchester

[3] Warsaw University of Technology

[4] Aalto University

[5] I3N - Universidade de Aveiro

[6] Geant4 Associates International Ltd.

[7] RI-TE Radiation Imaging Technologies

WPET

The **W**earable **P**ositron **E**mission **T**omography **(WPET)**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 777222

2 Partners:

- University of Manchester (UK)
- CAEN s.p.a. (Italy)

Collaborations with:

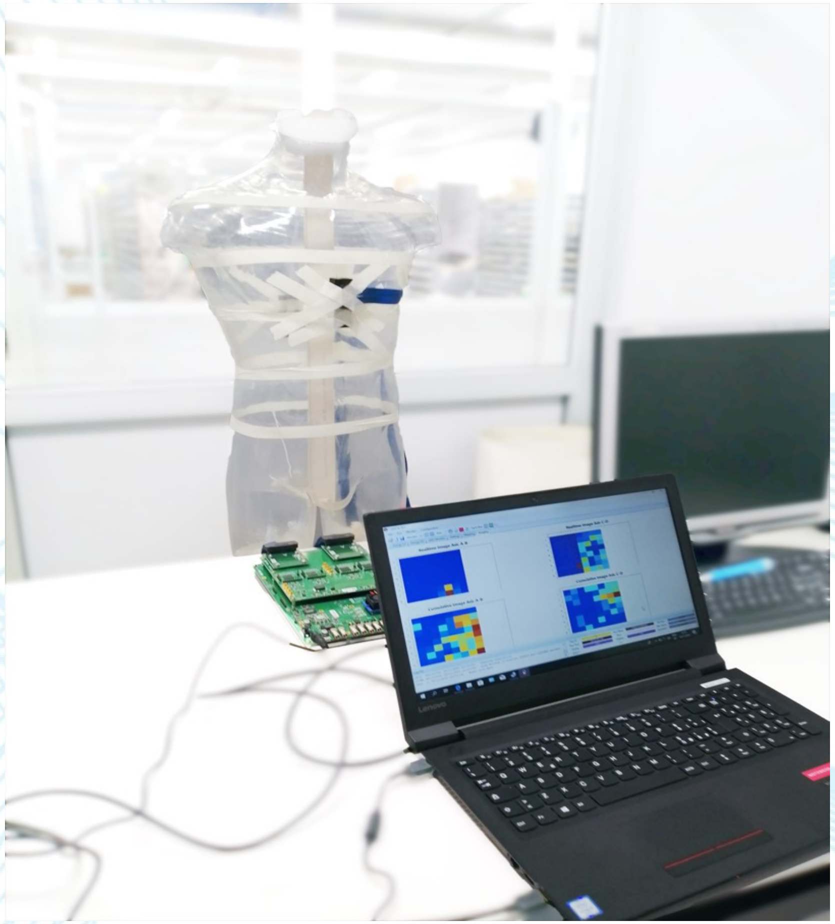
- RI-TE & Universidade de Aveiro (Portugal)
- Geant4 Associates International Ltd (UK)
- Aalto University (Finland) & Warsaw University of Technology (Poland)

WPET

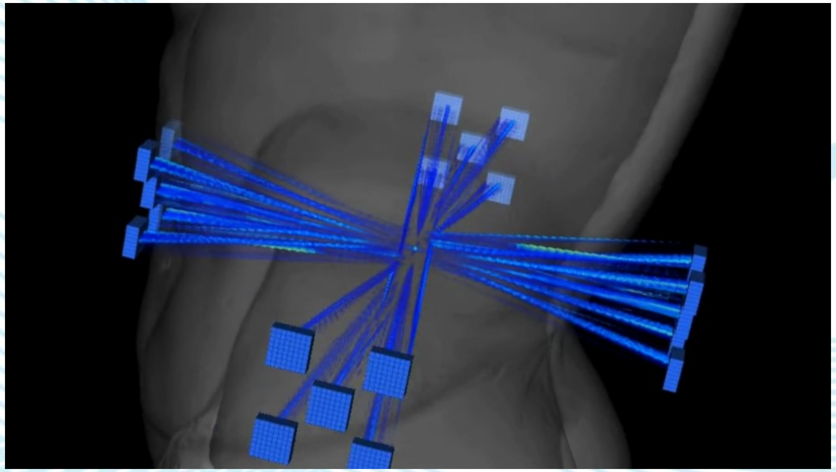
The WPET project studied the manufacturing feasibility of a modular PET system.

The idea was to have a device that is:

- **Portable** to be integrated for example into a jacket
- **Low cost** compared to tradicional systems
- **Flexible** or adaptable to specific needs and body parts
- **Real time** analysis and reconstruction
- Widely **accessible** for an early cancer screening



Proof of concept test set-up in the lab



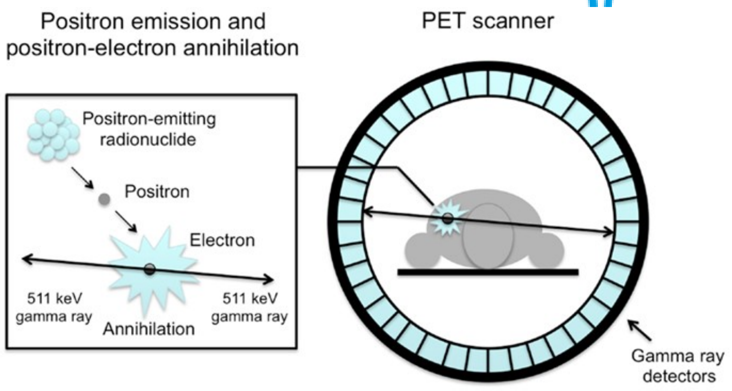
Data reconstruction of the lab tests

ANIMMA 2021

The PET technique

Positron Emission Tomography or PET is a precise imaging technique used in hospital oncology units to test patients with cancer to establish and locate possible metastasis and better define the treatment plan.
The exam foresees a radioactive positron emitter sugar solution is injected into the patient's body, the sugar reaches cancer cells where it is absorbed. It is here where the positrons annihilate producing two high energy gamma rays back to back that can be detected outside the human body.
Tracking back both gammas it can be reconstructed the location of an high activity group of cancer cells

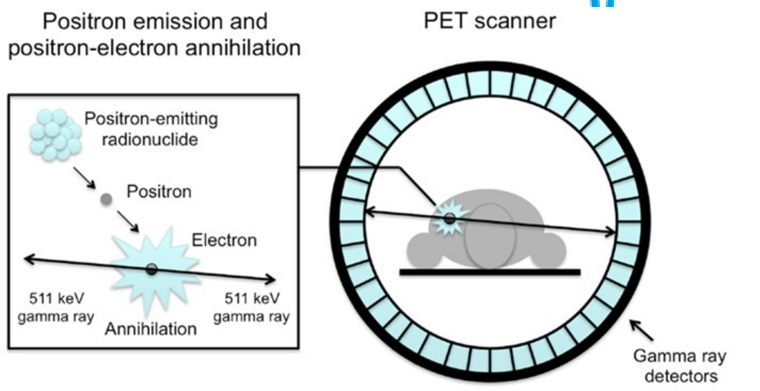
There is a trend to reduce costs, increase mobility and image specific organs with dedicated scanners (e.g. breast, brain)



From web

The PET technique

Positron Emission Tomography or PET is a precise imaging technique used in hospital oncology units to test patients with cancer to establish and locate possible metastasis and better define the treatment plan.
The exam foresees a radioactive positron emitter sugar solution is injected into the patient's body, the sugar reaches cancer cells where it is absorbed. It is here where the positrons annihilate producing two high energy gamma rays back to back that can be detected outside the human body.
Tracking back both gammas it can be reconstructed the location of an high activit group of cancer cells



	PET	WPET
Result	3D cancer localization & dimensioning	3D cancer localization & dimensioning
Size	Fixed 2 x 4 m2	Human torso 90 x 50 x 30 cm^3
Crystals Weight	>200 kg and a complex infrastructure	About 10 kg and a small support
Measurement time	~ 45 min for a full body scanner	few hours for a specific zone
Spatial resolution	1/1.5 mm	few mm level
Potential issue	Claustrophobia	Weight of the detector, reliability of the detector to tumor location

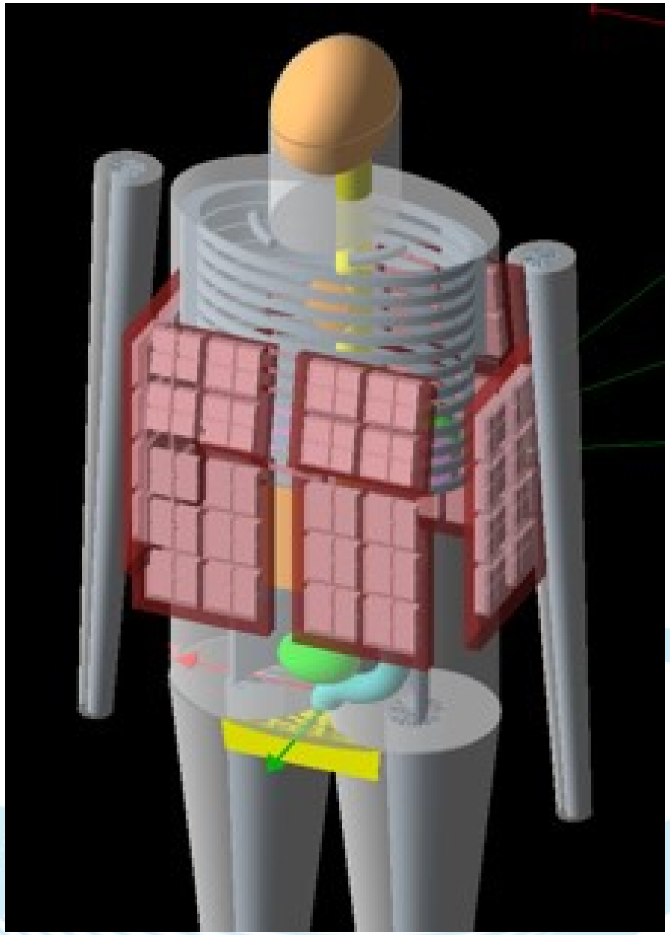
From web

G4 Simulation

- **Modular** element that can be adapted to different situations or conditions (ex. Children, male and female or animal dimensions or standing or in a seated position) and must be made of a group of detectors
- **Light** enough to be worn
- **Precision** measurements allowing the correct particle detection and identification
- **Power dissipation**: low power consumption to avoid dissipation on the patient

These are the requirements used to develop the Geant4 simulation package

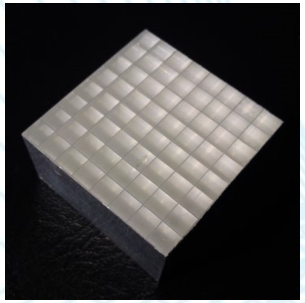
We assumed detector positions surveyed to a precision better than a millimetre.

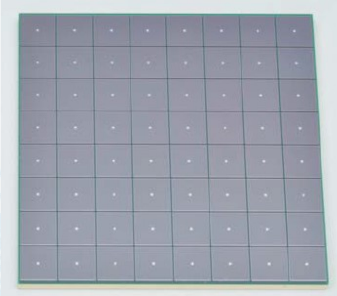


Modular system

Crystal assembly

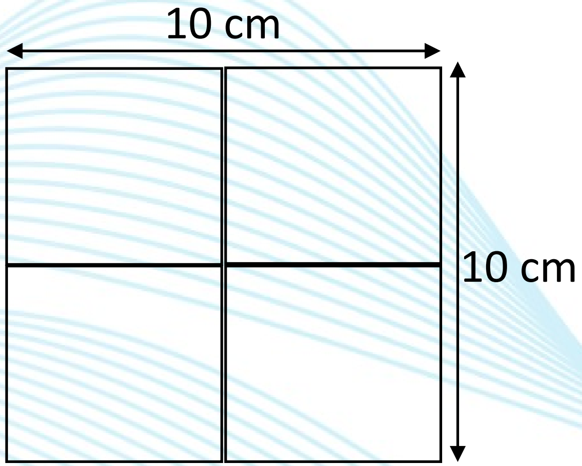
- LYSO Scintillator matrix $3x3x1\ cm^3$
- SiPM Matrix



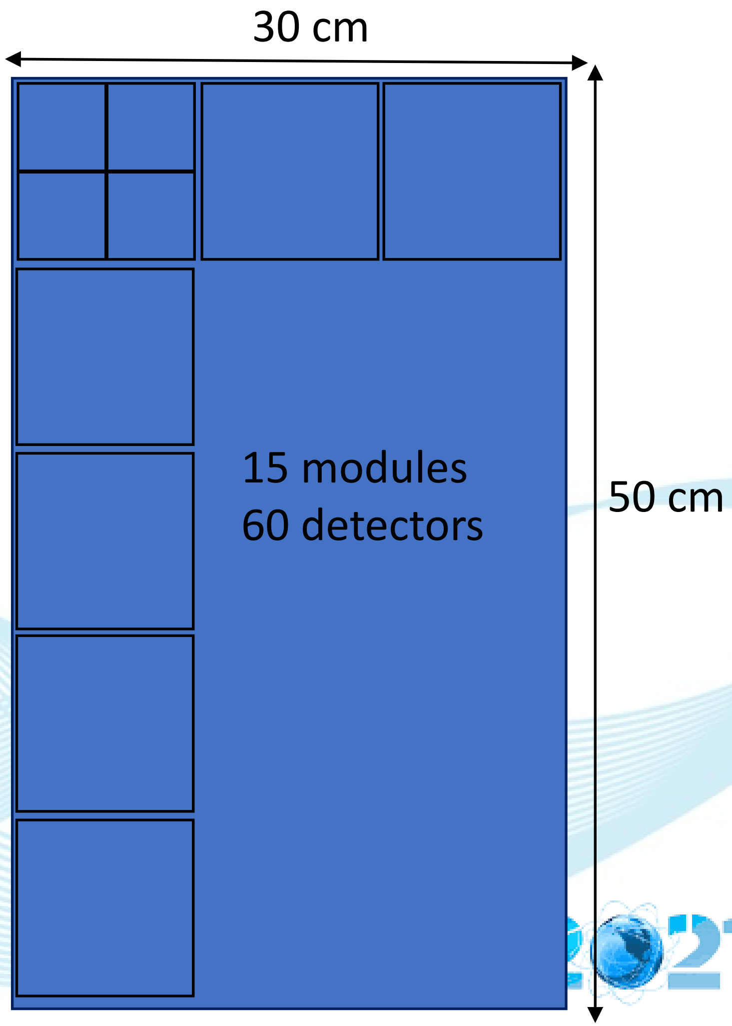


Module

Module = 4assemblies



Modularity (ex. Torso)



Each module is independent from the others and can be used in multiple configurations

Reconstruction

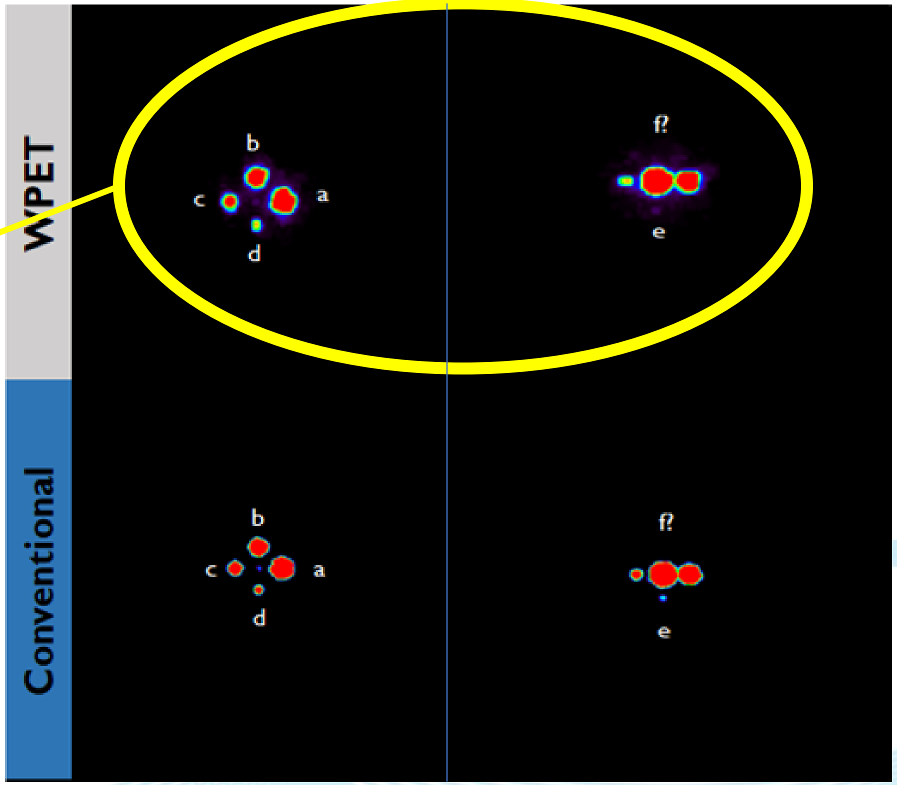
To determine the spatial sensitivity a source of ^{18}F fluorodeoxyglucose (FDG) uniform over the torso was simulated in Geant4 for the conventional system and our chosen WPET modular jacket

Six "test" with 3D sources, spheres of radius 10, 8, 6, 4, 2 and 1 mm

Five of the six sources are clearly visible for both configurations, the 1 mm source escaping detection with our statistics

The spatial resolution of hotspots is then limited by detector element size, positron range and positron annihilation non-collinearity

Maximum Intensity Projection of the FoV

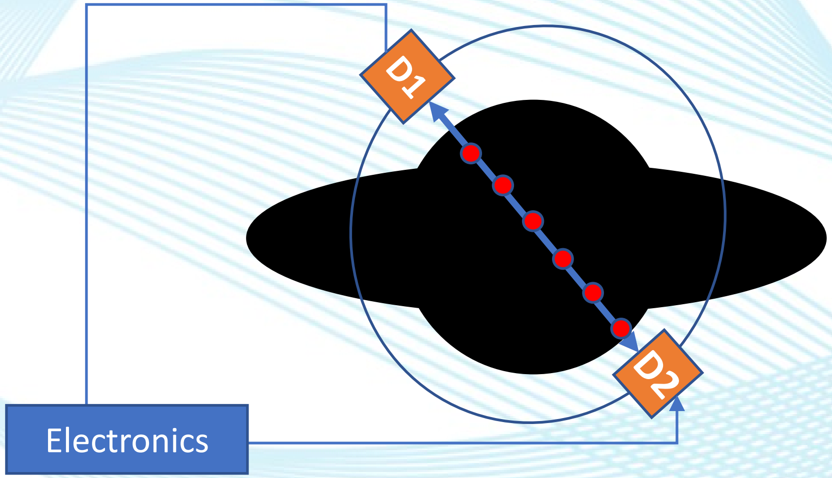


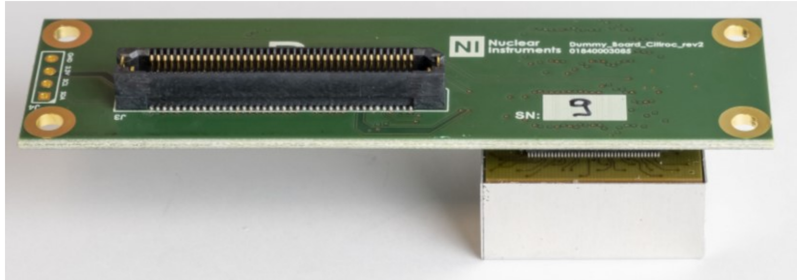
Transverse projection

Coronal projection

The proof of concept

- Two light tight detector assemblies placed in opposite position
- A cabled electronic board acquires signals from 2 crystals
- A laptop running the acquisition software
- Offline data reconstruction based on timing and position information
- Test performed in laboratory to verify performances

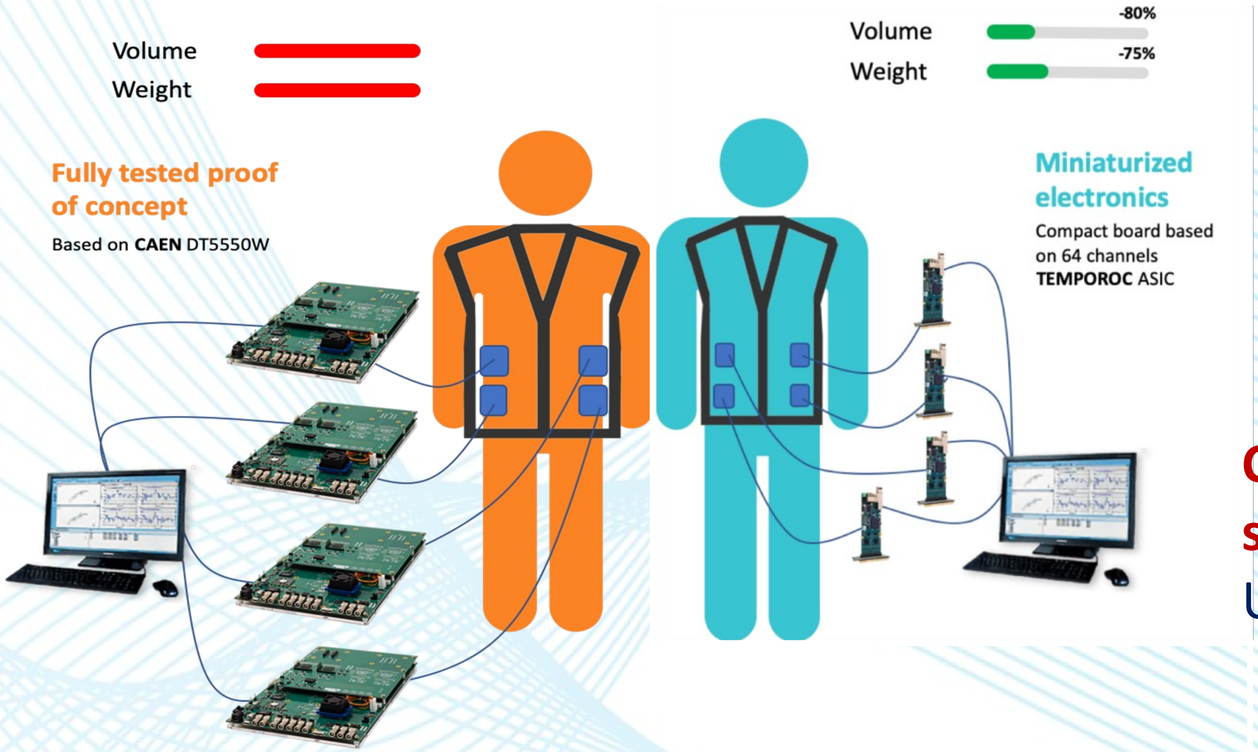




Detector assembly (LYSO + SiPM matrix) & patch panel

Light tight assembly

The Electronics setup



Fully operational prototype tested.

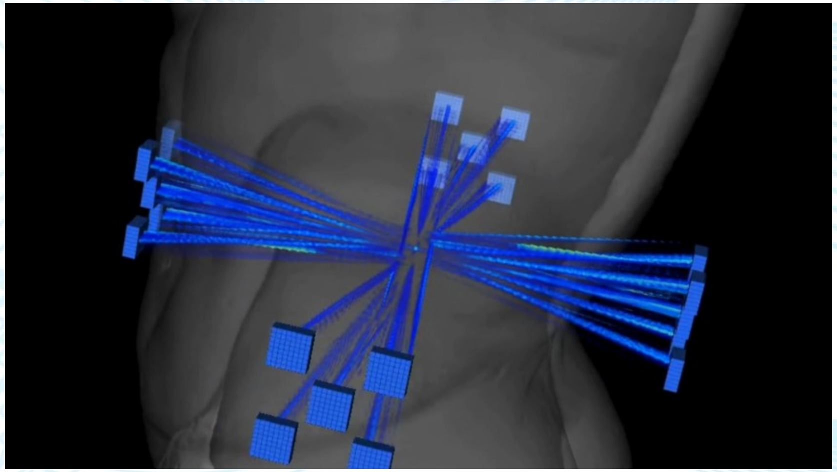
- Two LYSO matrixes of 3 x 3 x 1 cm^3 coupled to a 64 channels SiPM readout, light tight assembly, and one DT5550W board used as front end electronics and a first signal selection (timing and energy cuts) was used to validate the principles.
- Tests demonstrated the system operability but also the necessity to modify the electronics to be more compact and scalable

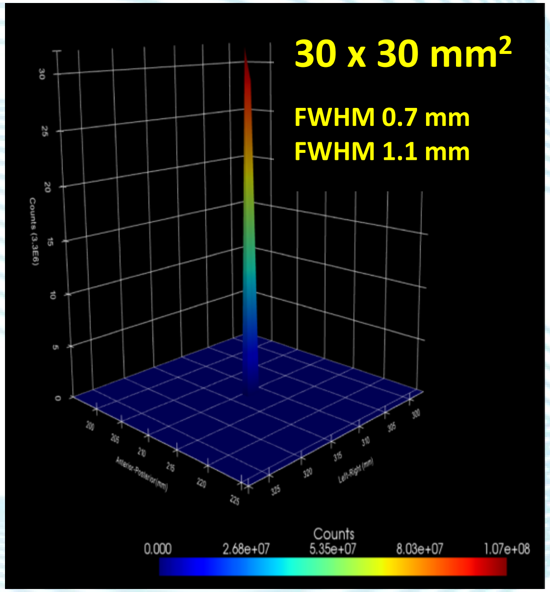
Completed pre-design of a scaled-up full modular system layout with miniaturized electronic boards. Uses TEMPOROC 64 channel ASIC for SiPM readout.

The laboratory tests

Test performed in laboratory with a ^{22}Na source placed in a fixed location and crystals moved in 5 different positions, always facing each other to verify the source position reconstruction

- Front-end electronics acquires in real time events in coincidence
- List mode event saving used for the reconstruction algorithm
- Laboratory source of ^{22}Na source of 0.13 uCi
- Acquisition time from 1 to 3 hours
- Acquisitions with source located in the center and detector at 40 cm (front/back torso) & 60 cm (right/left torso) far apart





Other applications

The identified modular element structure has the flexibility to be adapted in different configurations.

This is important for the possibility to use its modularity not only in a jacket configuration, but in other TOF applications.

We have identified other field of interest:

- **Science:** Dynamical Radio-Tracing, X-ray Imaging, SPECT, Dosimetry in harsh environments, COVID-19 portable lung test, Space Missions, **prompt gamma detection in proton therapy.**
- **Industry**: Medicine, Homeland Security, High Energy and Nuclear, Space and Aviation.
- **Health: Life saving early cancer routine screening (breast, prostate, liver, pancreas, etc.) missed by traditional methods for a population at risk.**

Summary

- WPET Phase 1 Attract project concluded
- Proof of concept tested demonstrating of few mm resolution achieved with point like source in laboratory
- Reconstruction algorithm developed based on Maximum Likelihood Expectation Maximization taking advantages from time coincidence events and TOF information
- Simulations used for the optimization of the modular design
- Work on the modular prototype