DE LA RECHERCHE À L'INDUSTRIE

APPLICATIONS IN SECURITY AND ENVIRONMENTAL IMAGING

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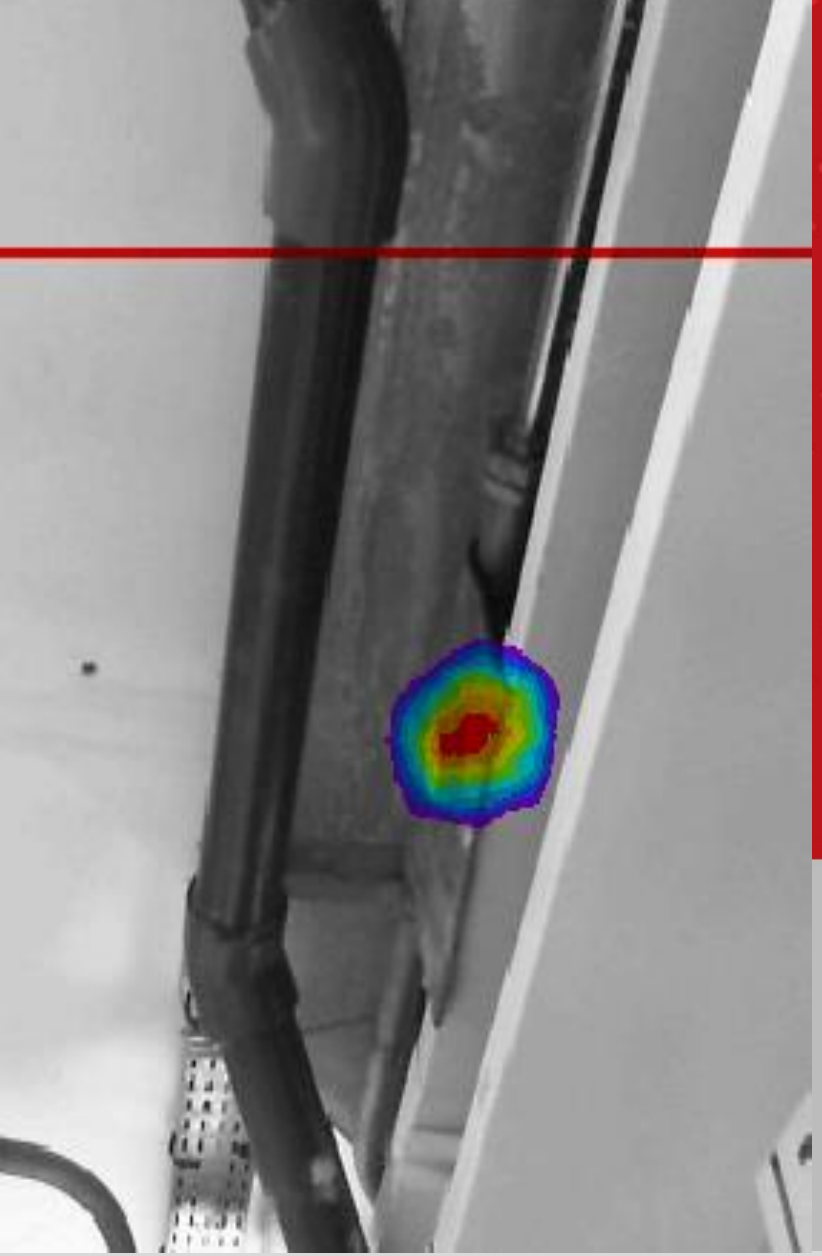
Université Paris-Saclay, CEA, List, F-91191, GIF-SUR-YVETTE Cedex, France

PSD-12 – September 17th 2021



01

VISUALIZE RADIOACTIVITY

RADIATION IMAGING PRINCIPLE

VISUALIZE RADIOACTIVITY…

… A Challenge for Numerous Applications

Operational Radiation Protection

Dismantling & decommissioning

Nuclear waste management

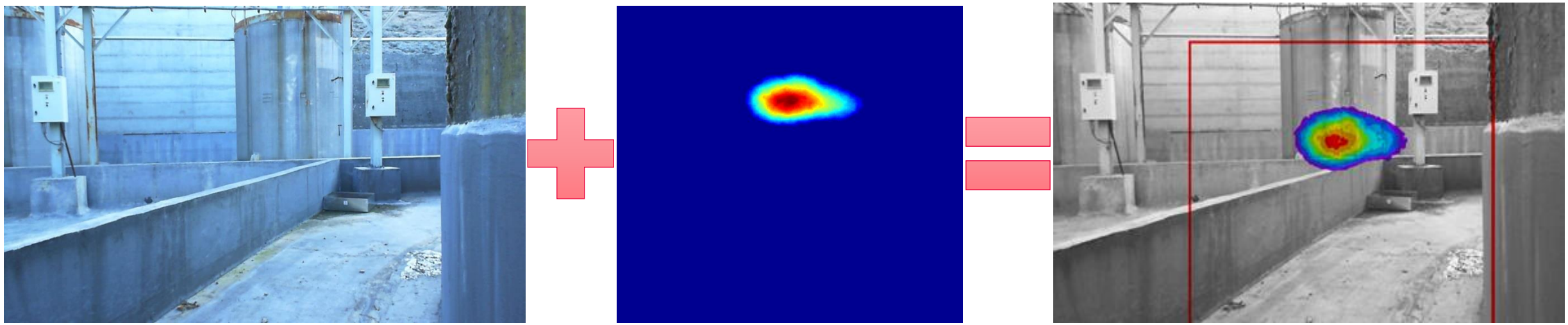
Accidental situations

Homeland Security

Border monitoring

VISUALIZE RADIOACTIVITY…

… THE OBJECTIVE OF GAMMA IMAGING

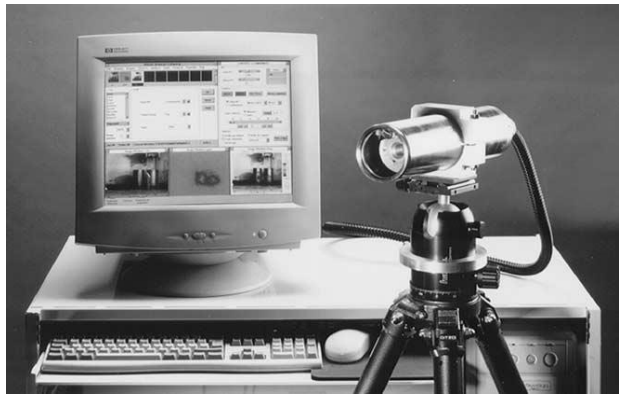


- **Superimposition** of a **radiation** image onto a **visible** image
- **Remote visualization** of hot spots
- Information on **intensity / dose rate**

02

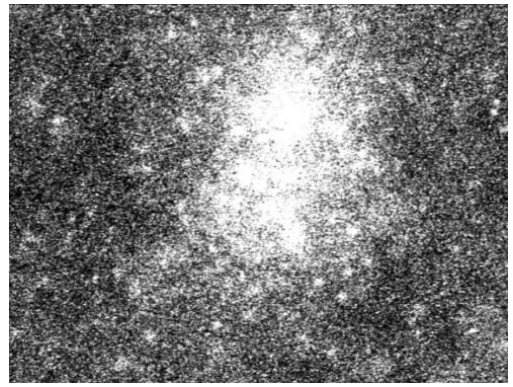
FROM CARTOGAM TO GAMPIX

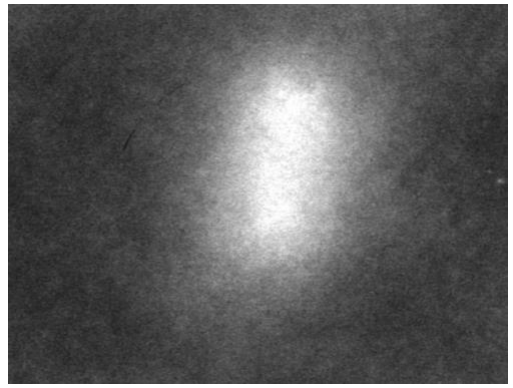
OVER 30 YEARS OF EXPERTISE ON IMAGERS @CEA

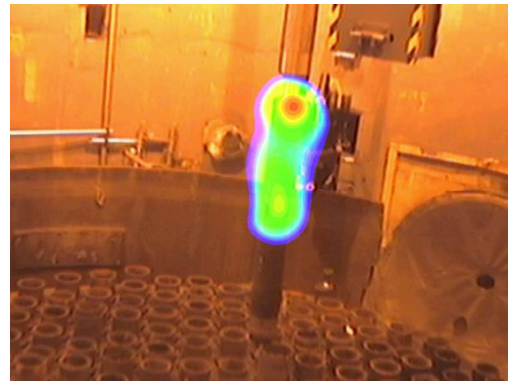


CARTOGAM

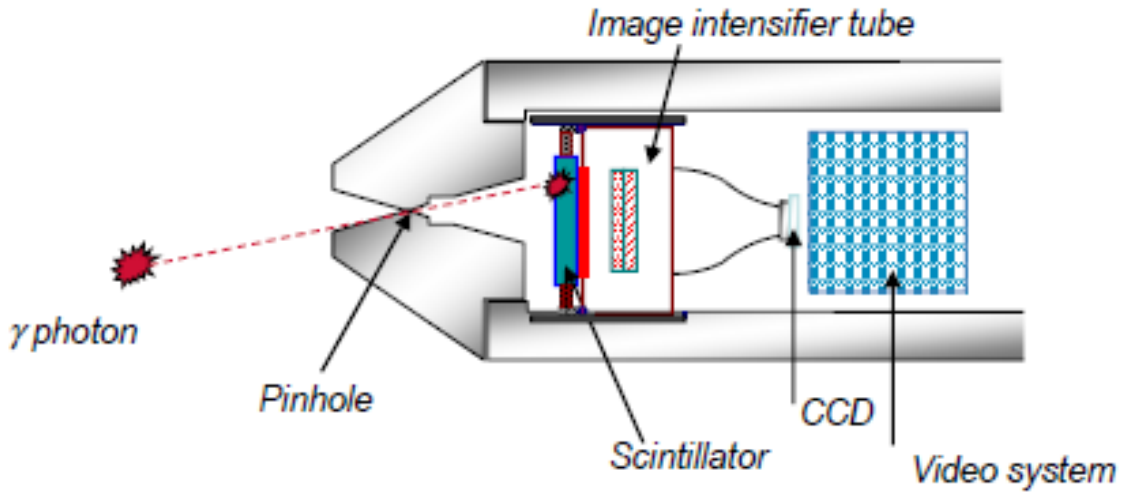
- Pinhole collimator
- Scintillator
- CCD Camera







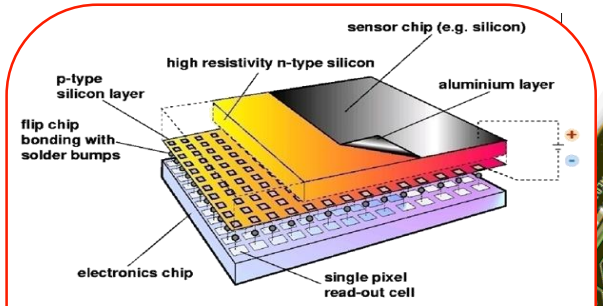
40 cm - 17 kg
(without shielding)

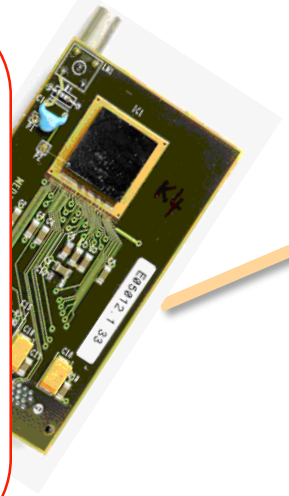


GAMPIX / IPIX

THE BREAKTHROUGH OF PIXELATED SC DETECTORS

Medipix family detectors





256 x 256 pixels (55 µm)

1.4 x 1.4 cm² active zone

1 mm thick CdTe sensor

15 cm - 2 kg

Coded Mask

Multi-pinhole collimator

Improved sensitivity / Improved angular resolution

Visible camera

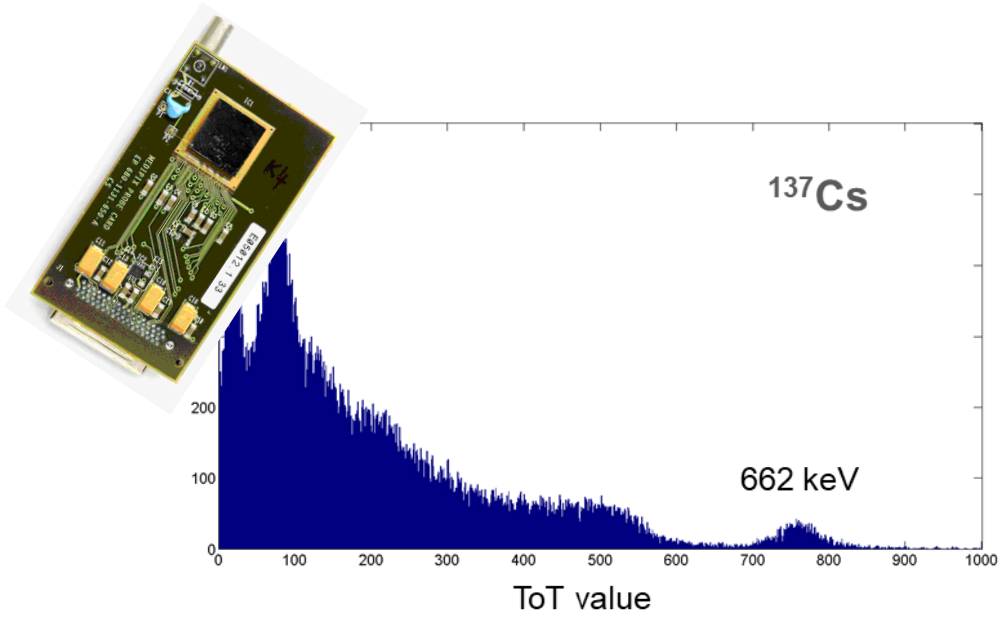
USB Interface

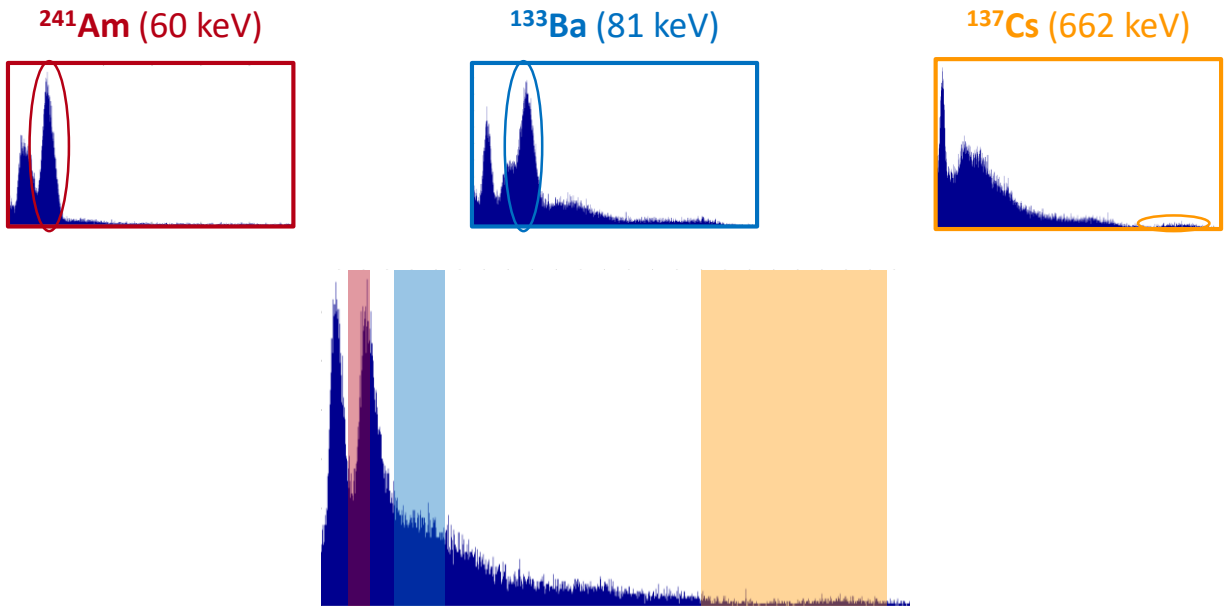
IEAP CTU in Prague

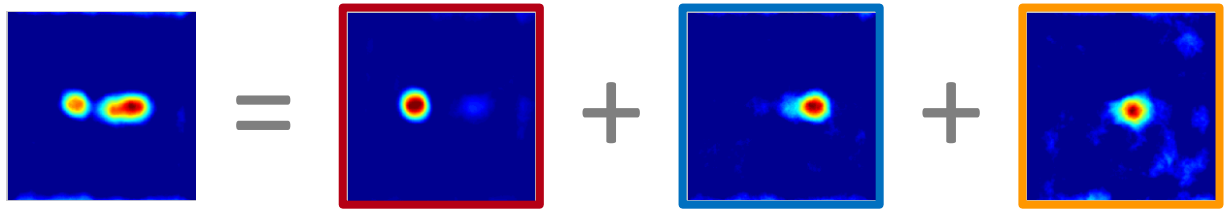
MIRION TECHNOLOGIES

TIMEPIX & SPECTRO-IMAGING

ADDITION OF SPECTROSCOPIC INFORMATION VIA ToT MODE







Capability to discriminate sources by energy in the same field of view

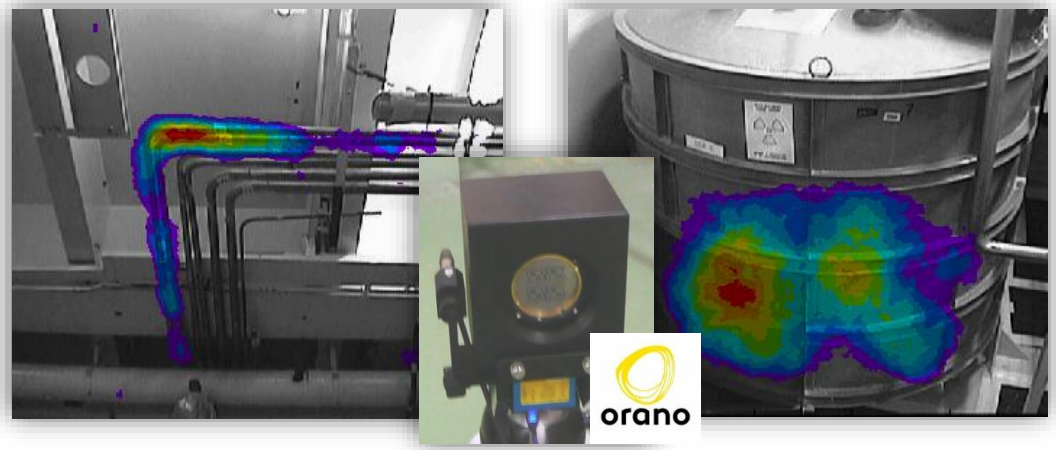
***Hermine Lemaire** – 2015 – Development of third generation gamma imager*

DEPLOYMENT FOR RADIOLOGICAL AND SECURITY APPLICATIONS

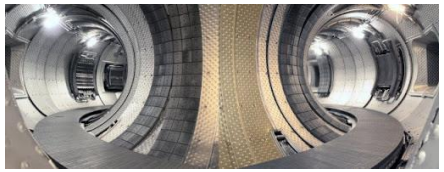
SOME EXAMPLES…

Radiation Protection Applications

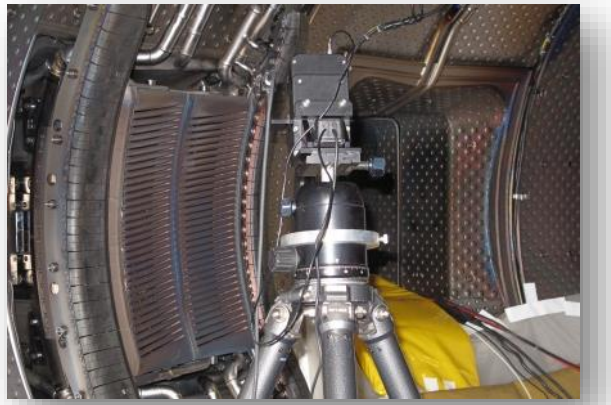
Dismantling and Decomissionning



Homeland Security Applications

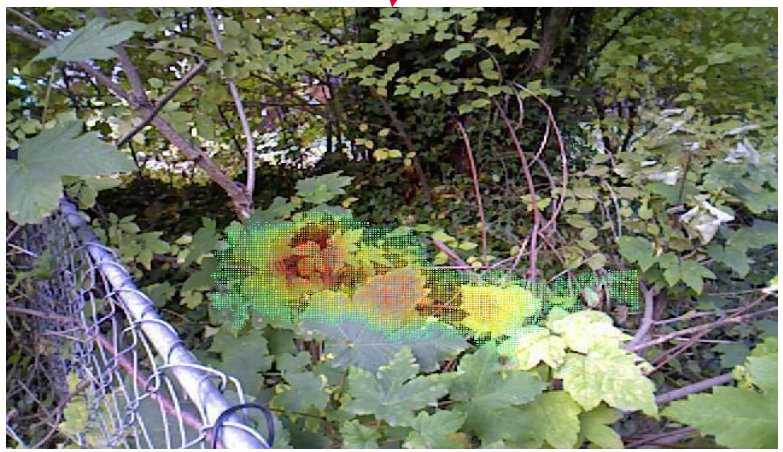


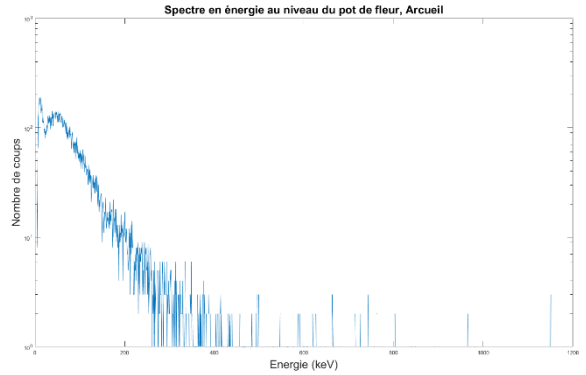
Large research equipments diagnosis (ToreSupra – WEST – Tokamak)



ENVIRONMENTAL MEASUREMENTS

A FEW VIEW OF AN HISTORICAL AREA …





This research program was funded by *French Research Agency* under grant agreement number *ANR-11-RSNR-0016 - ORIGAMIX*

03

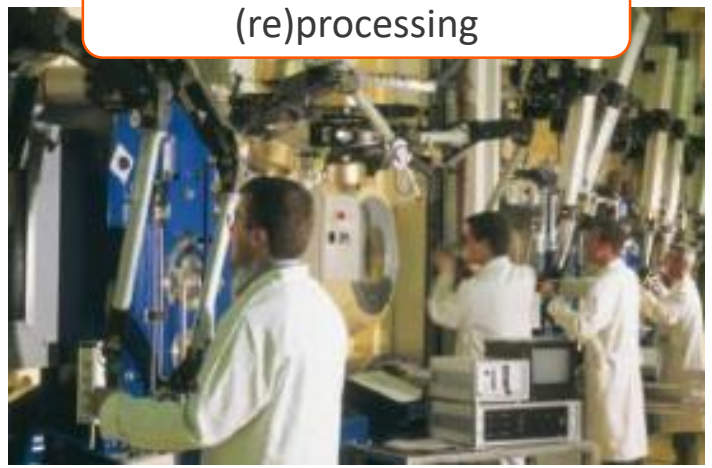
NANOPIX

PUSHING COMPACTNESS TO THE LIMITS

FROM GAMPIX / IPIX TO NANOPIX

A Form Factor Problem!

ORANO La Hague
Fuel processing plant

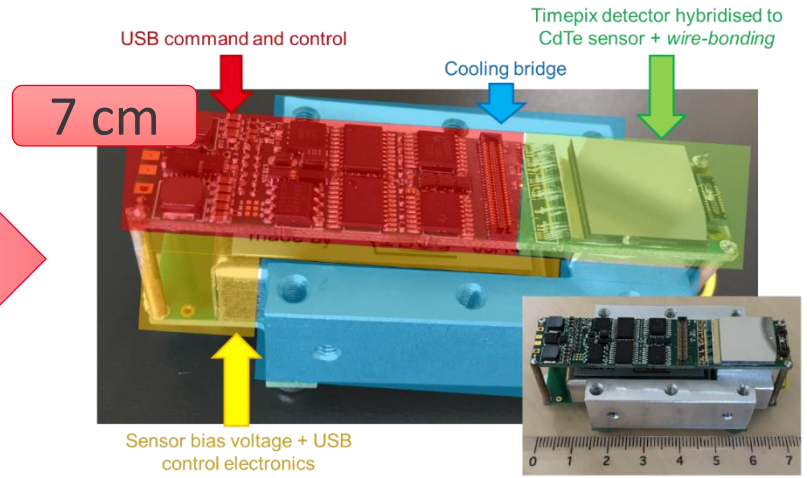


Hot cells for fuel rods (re)processing

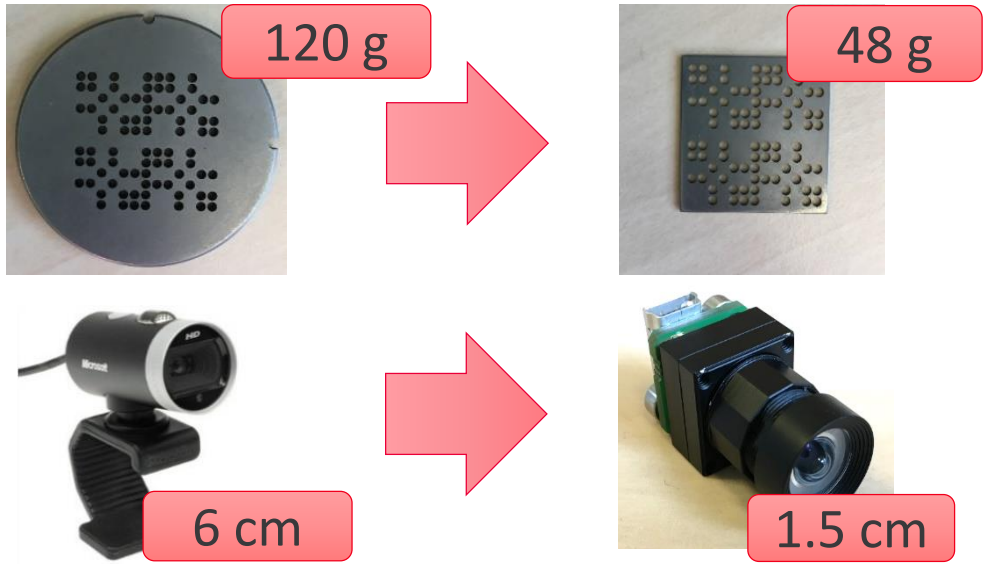
ϕ 8 cm holes for instrumentation

Needs for the development of a miniaturized gamma camera

- **Miniaturization of detector**



- **Miniaturization of other building blocks**



NANOPIX

Innovation Award

World Nuclear Exhibition
Paris - 2018

orano

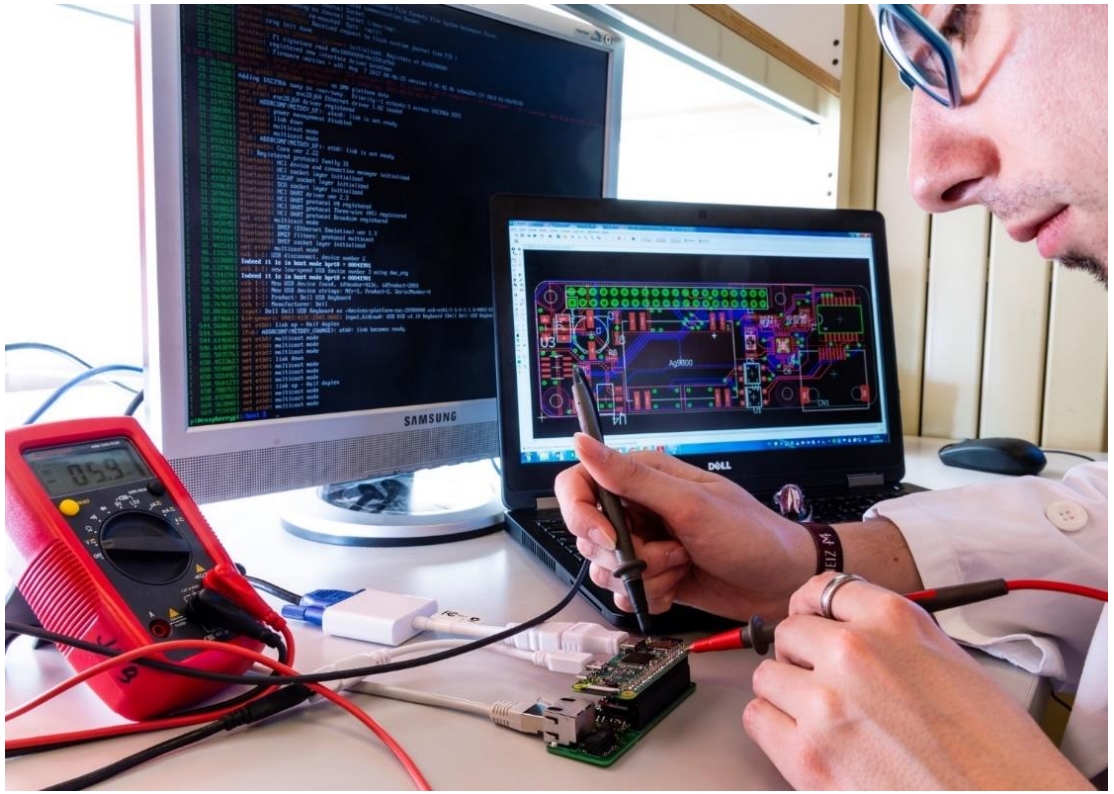
list
ceatech

INTERFACING AND SUPERVISION

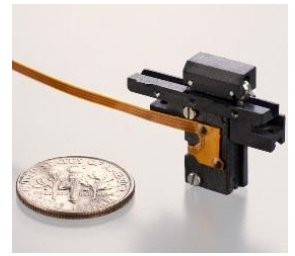
Integration of onboard intelligence

CONNEXION AND POWER SUPPLY

Improvement of connexion (PoE)

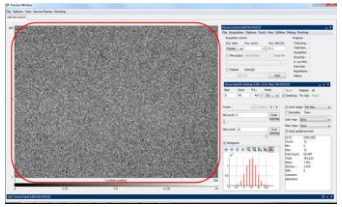


AUTOMATION



Integration of nanomotor for remote control

ACQUISITION AND TREATMENT



Improvement of software for embedded application

SMART-NANOPIX

INNOVATION CONCENTRATED IN A COMPACT GAMMA IMAGER

100 x 70 x 55 mm³

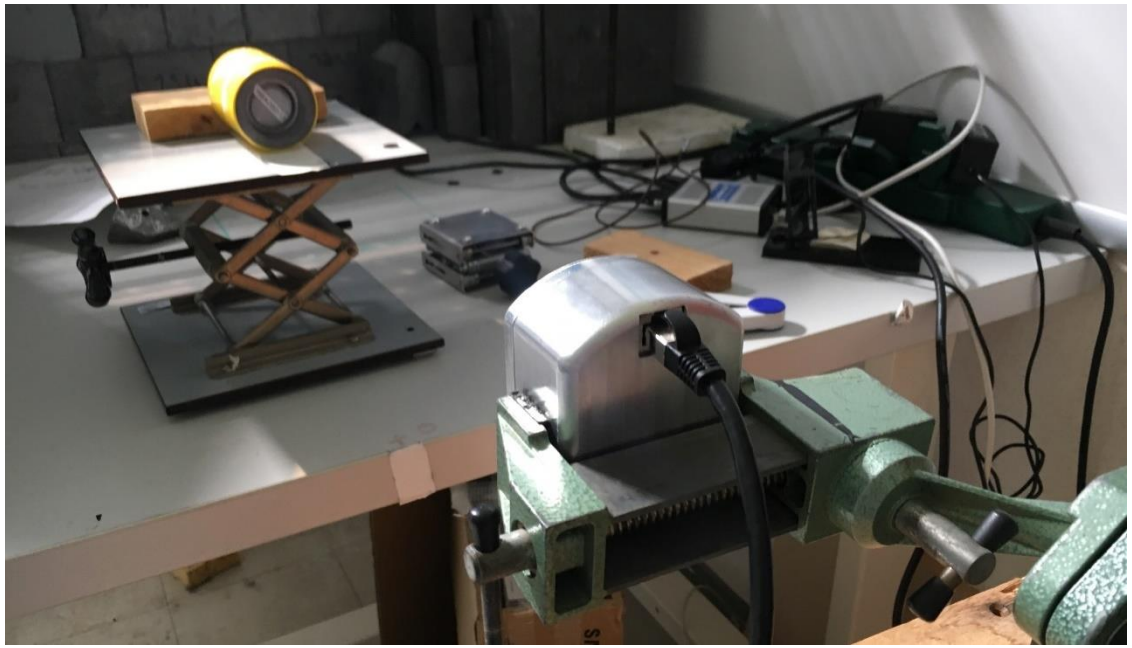
450 g

list
cea tech

orano

NANOPIX

In-Lab Performances



Angular Resolution: from 1.5 to 6°

Field of View: 50°

Dose rate range: 25 nGy.h^{-1} to > 50 Gy.h^{-1} (irradiator limit)

Energy range: 8 keV to 1.5 MeV

RN	Activity	Sensitivity @ 1 m
^{241}Am	74 MBq	< 1s
^{137}Cs	33 MBq	60 s
^{60}Co	4,6 MBq	1200 s

Background rejection: Yes

Spectroscopy capability: Yes

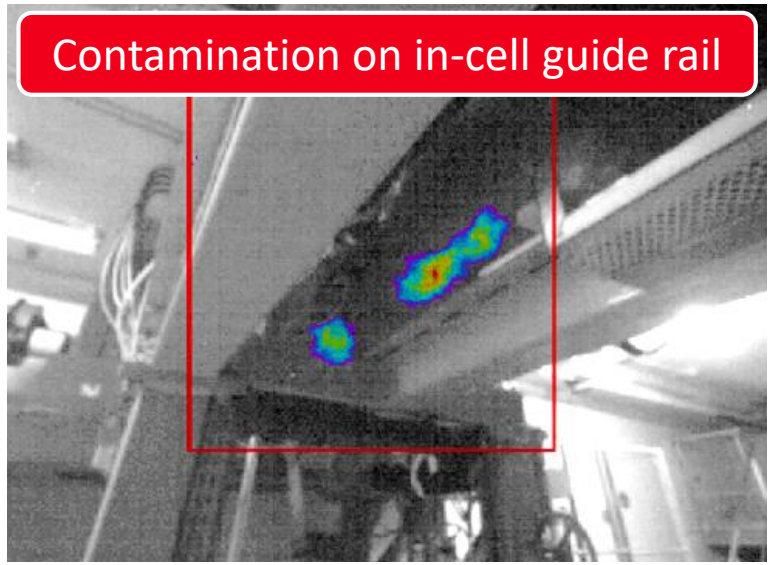
Dose Rate info possible: Yes

NANOPIX

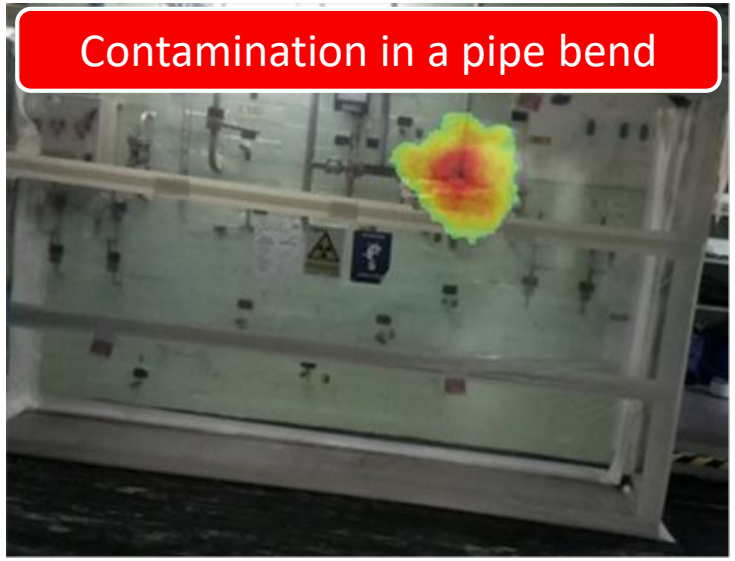
On Site Performances

Remote hot spot location after fuel decladding operation

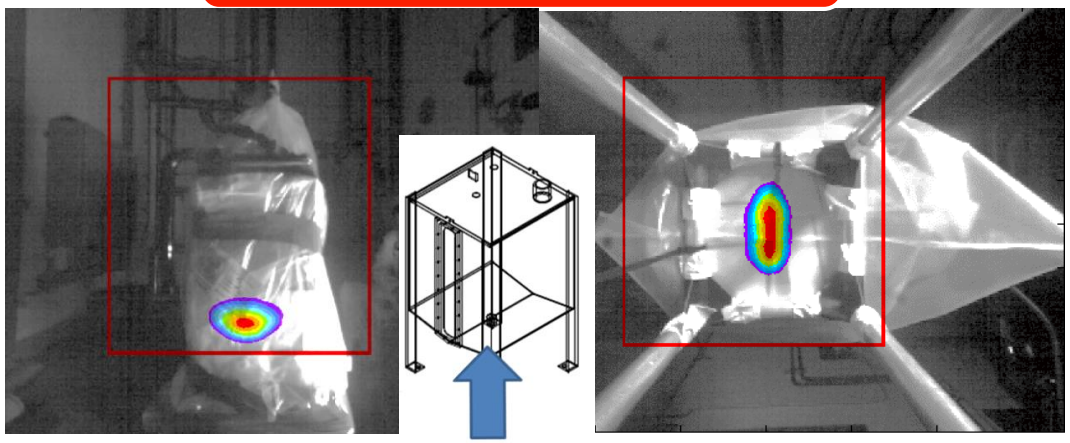
Contamination on in-cell guide rail



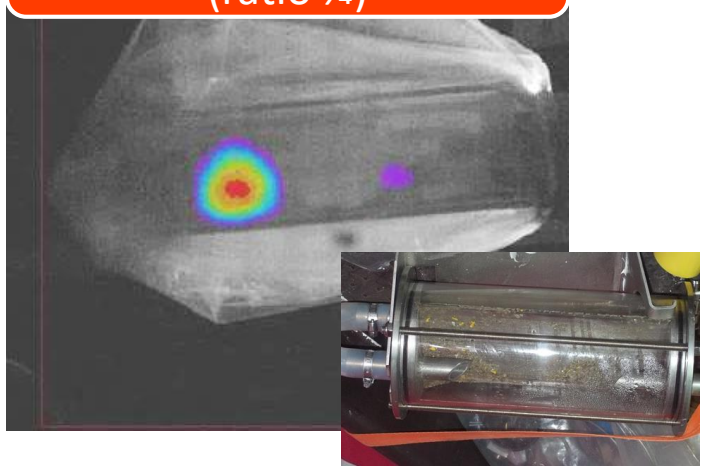
Contamination in a pipe bend



Liquid effluent contamination under a decomissioned tank



Contaminated filter (ratio ¼)



Contaminated part in a waste package

*© Pictures are courtesy of **ORANO La Hague***

04

ROBOTIC VECTOR EMBEDMENT

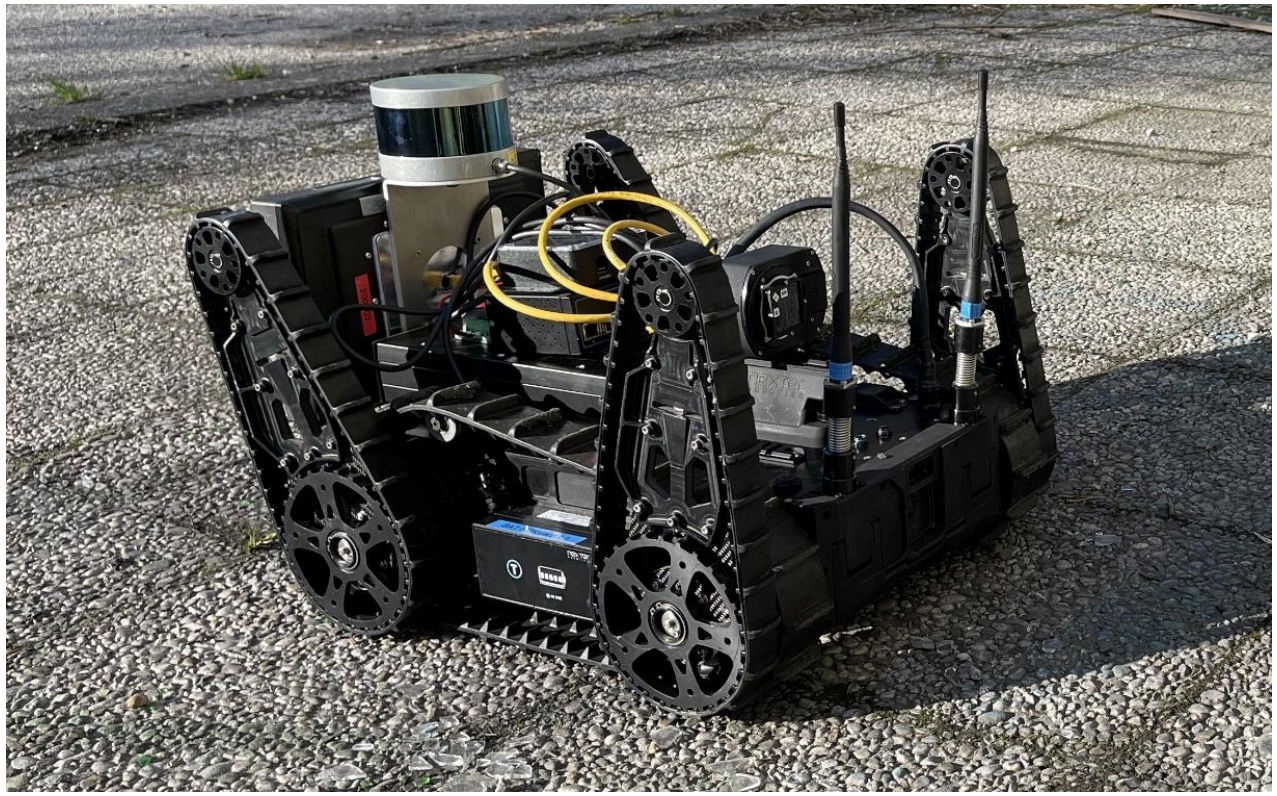
REDUCE OPERATORS EXPOSURE
WITH UNMANNED VEHICLES

Embedment of Nanopix imager on **UGV / UAV for remote unmanned assessment** in the frame of H2020 TERRIFFIC Project

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 786729 (TERRIFFIC)

ROBOTIC VECTOR EMBEDMENT

UGV Mission for Location of a Hidden Source



Results acquired during TERRIFFIC trials with French Firefighters in Chambéry (March 2021)

Location of a **300 MBq Cs-137 Source** @**5m** in **20 seconds**

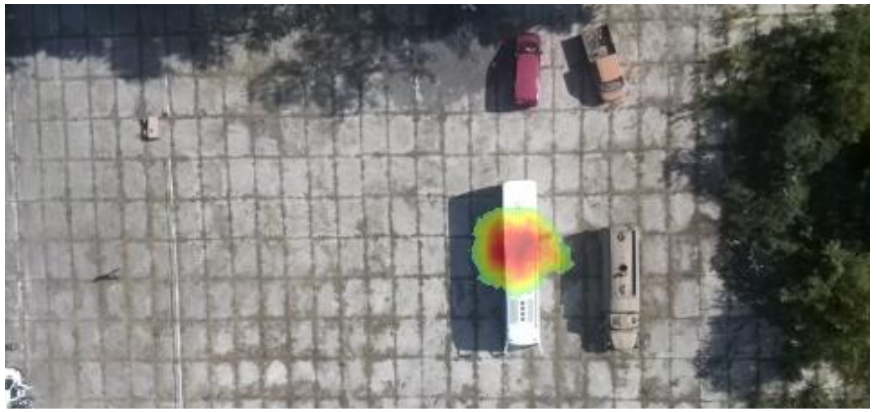
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 786729 (TERRIFFIC)

ROBOTIC VECTOR EMBEDMENT

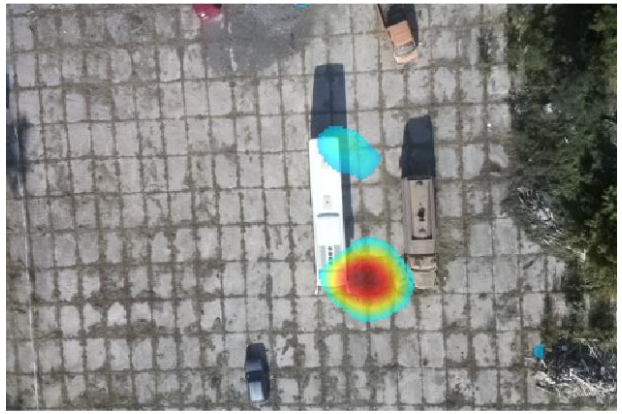
UAV Mission for Location of Highly Irradiating Hotspots

Results acquired during TERRIFFIC trials with Slovak and Czech Firefighters in Bratislava (September 2021)

Ir-192 (50.68 GBq) from 50m in 6 min



Se-75 (79.15 GBq) from 60m in 2 min



Ir-192 & Se-75 in 90 sec, from 50m and 90 m

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 786729 (TERRIFFIC)

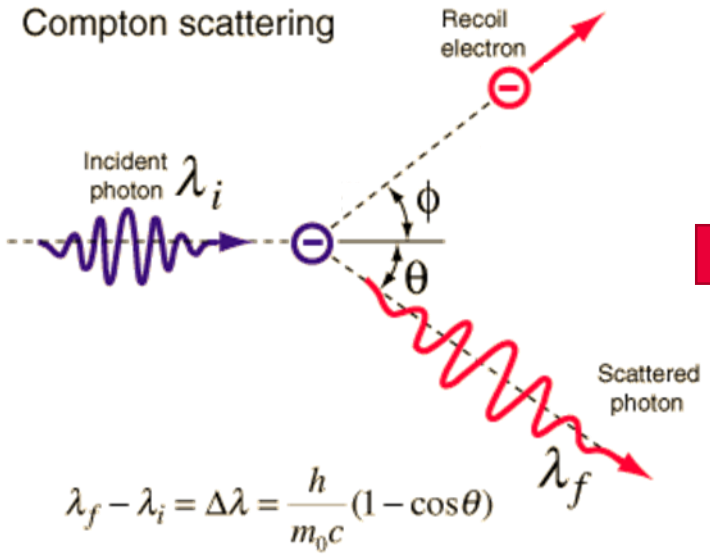
05

GOING FURTHER…

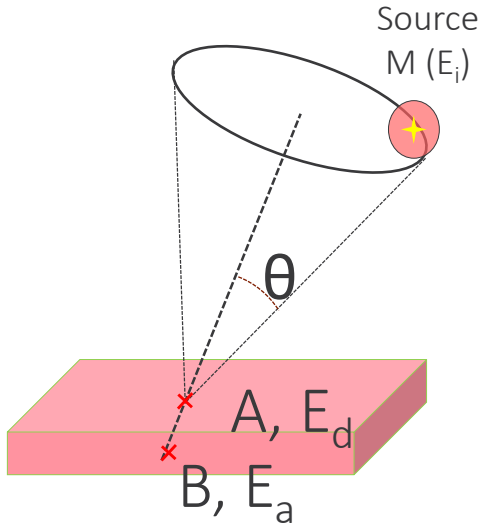
NEW DEVELOPMENTS FOR FUTURE CHALLENGES

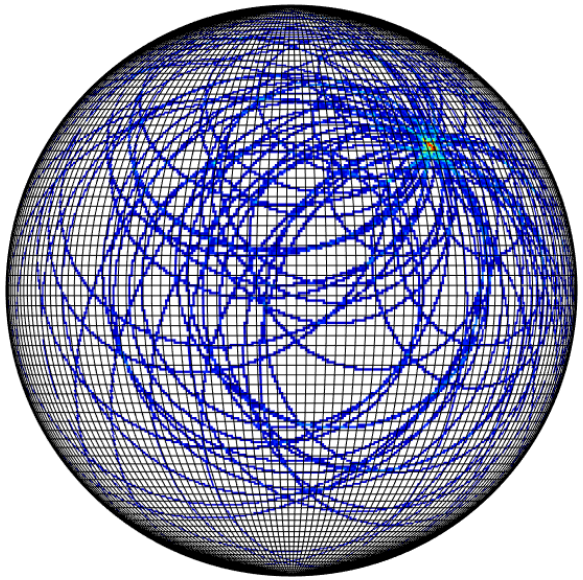
Simultaneous ToT & ToA

Carry out **Hybrid Imaging** (Compton and Coded Aperture) with a single detector



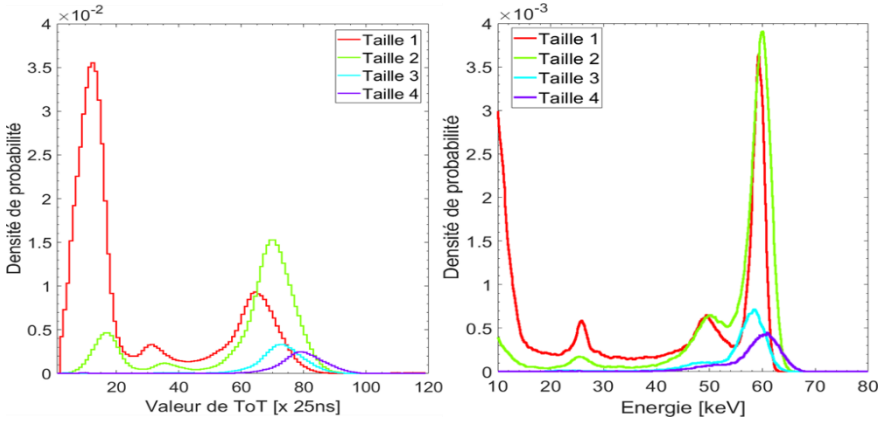
Source: hyperphysics.phy-astr.gsu.edu



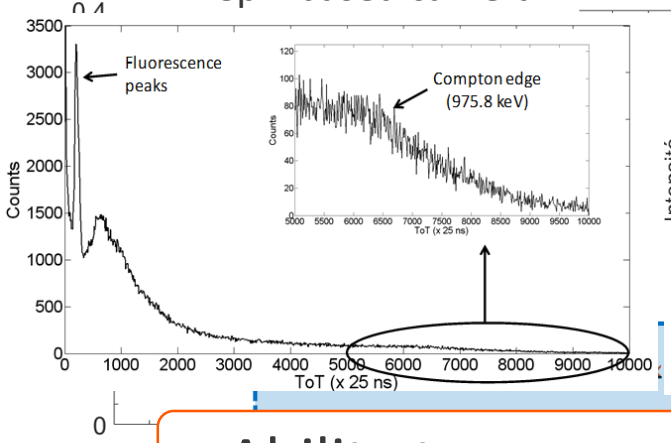


Guillaume Amoyal – 2019 – *Development of an hybrid gamma camera*

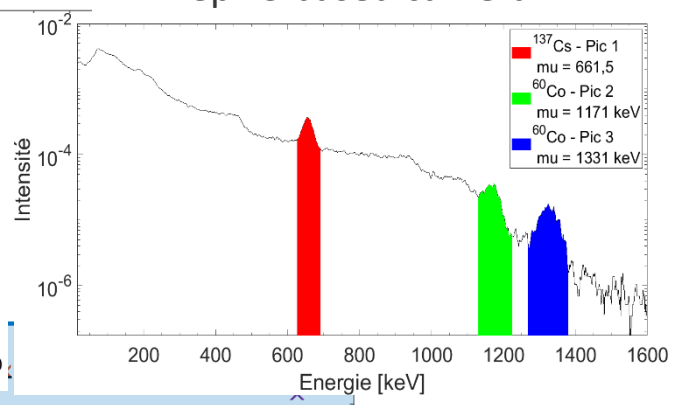
Fine energy calibration of Timepix3



Timepix based camera

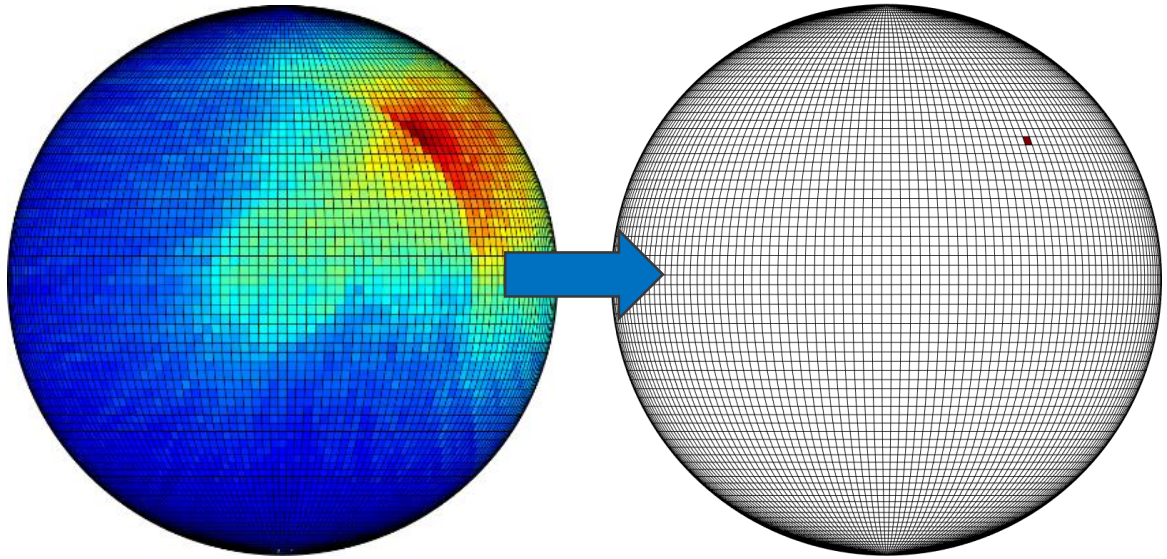


Timepix3 based camera



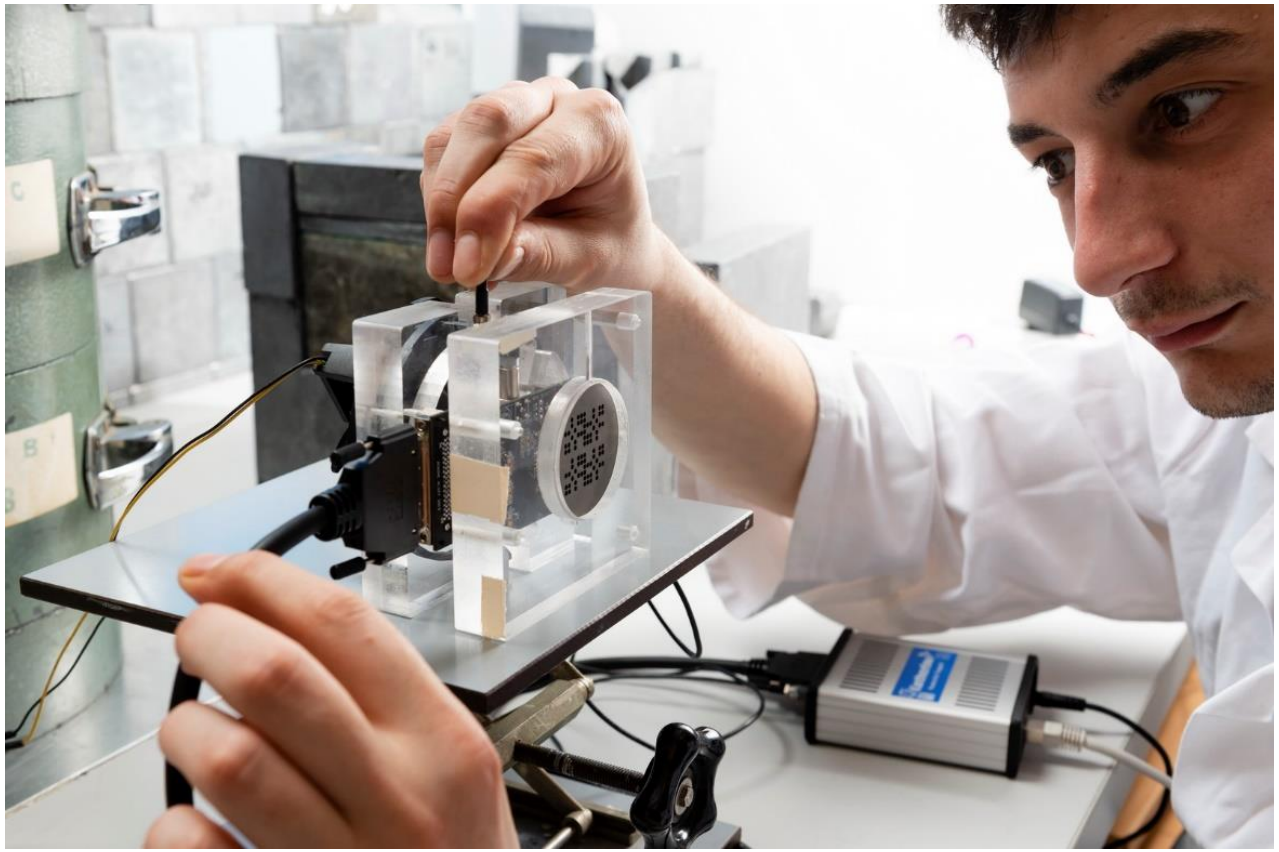
Ability to reconstruct 60-Co peaks!

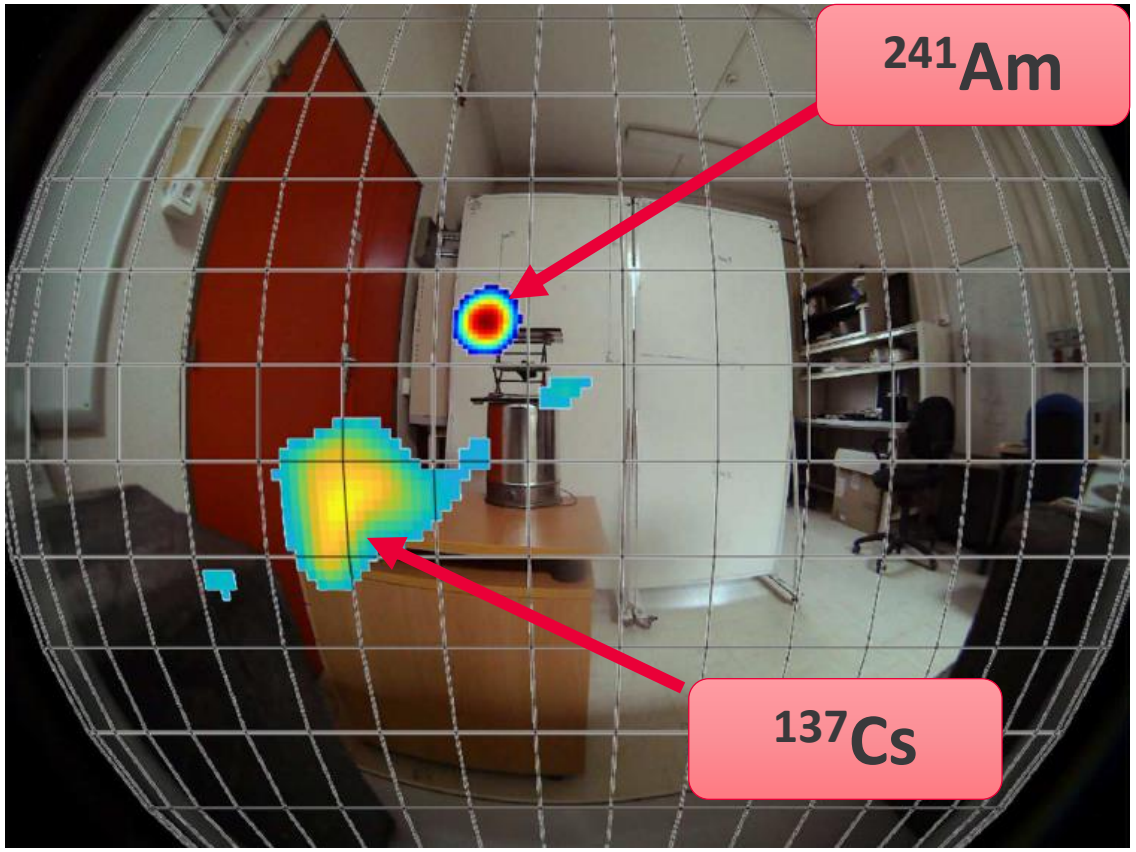
Development of advanced iterative algorithms



Guillaume Amoyal – 2019 – *Development of an hybrid gamma camera*

Coupling **coded aperture AND Compton Imaging** in a single camera

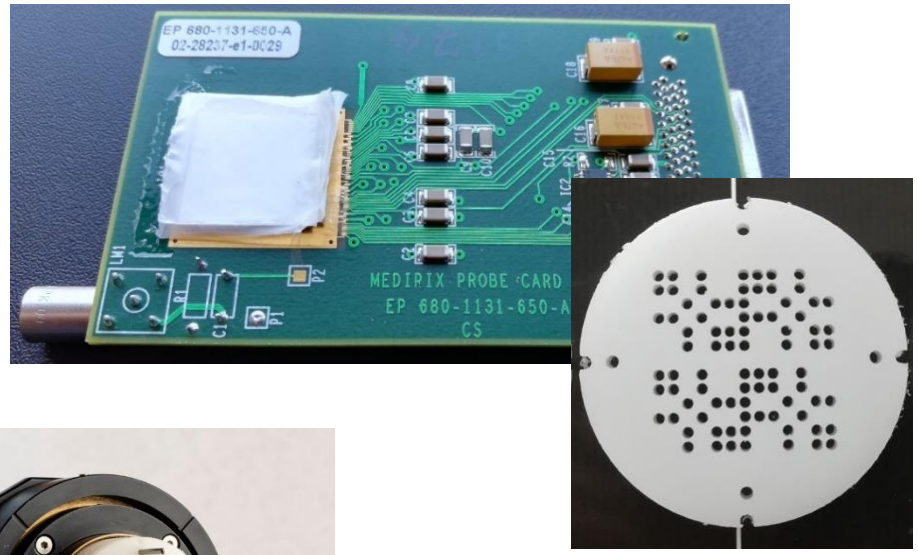




Guillaume Amoyal – 2019 – *Development of an hybrid gamma camera*

TIMEPIX & NEUTRONS

VISUALIZE MORE THAN GAMMA RAYS



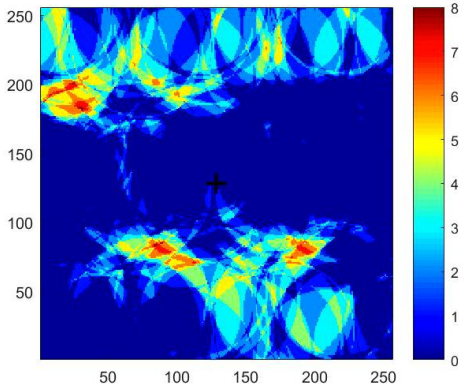
Converted Timepix for Neutron

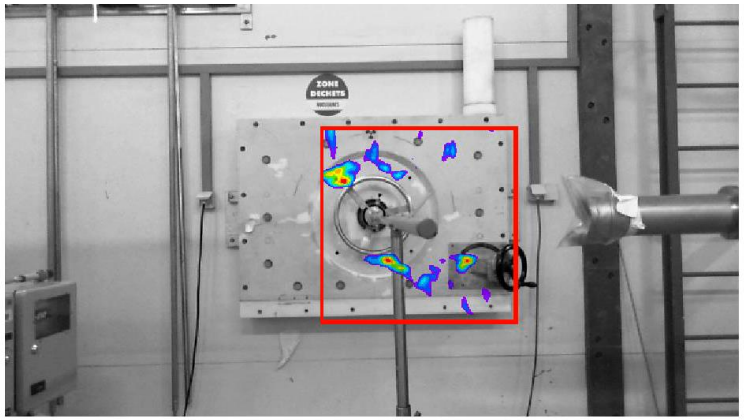
+

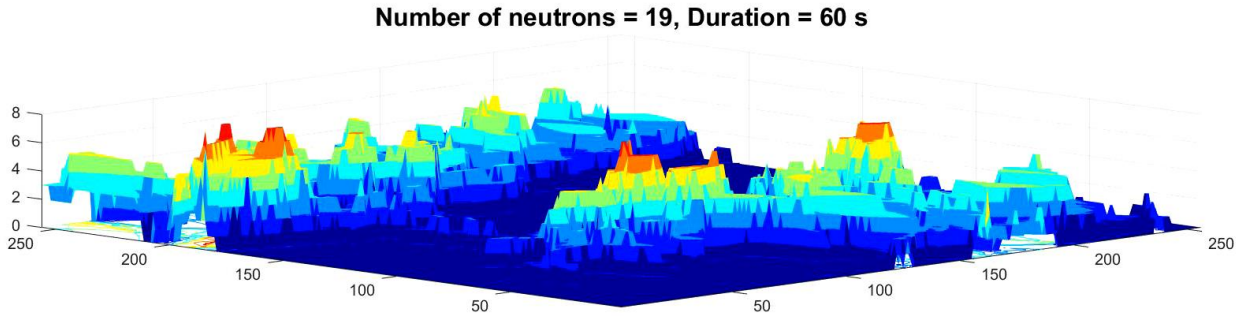
Specific Coded Masks

+

Processing algorithms

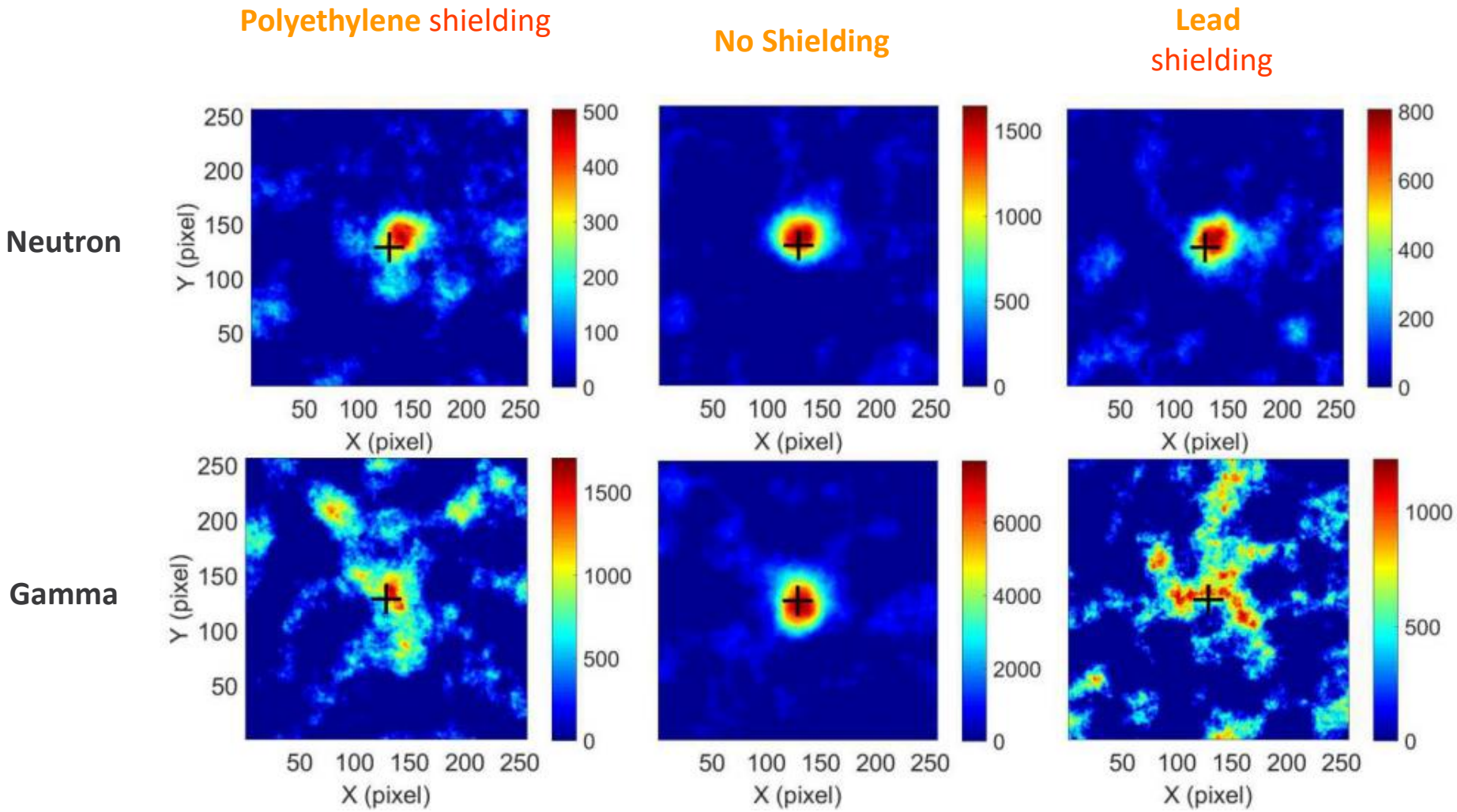






First Prototype of Compact Neutron Imager

Clément Lynde – 2019 – *Development of portable neutron camera*



Clément Lynde – 2019 – *Development of portable neutron camera*

06

MIXING ALL TOGETHER

COLLABORATIVE WORKS FOR ULTIMATE TOOL

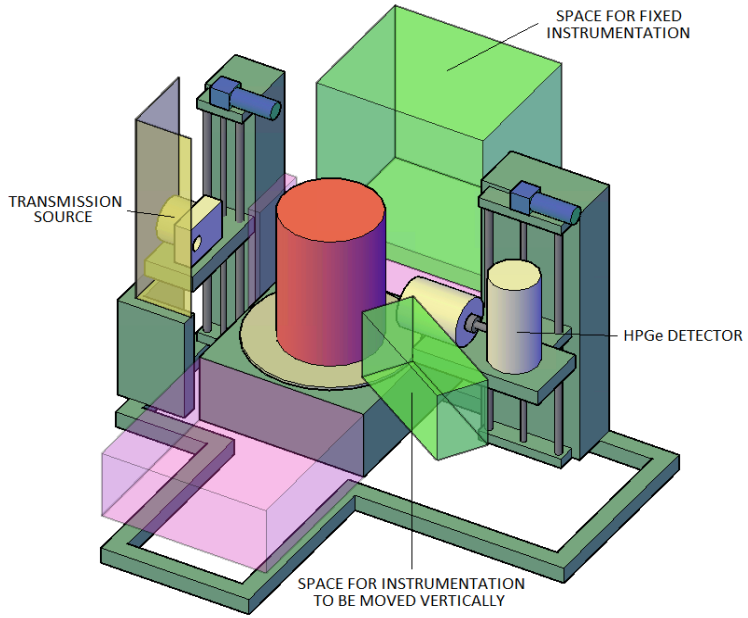
MICADO EURATOM PROJECT

PUSH NANOPIX TO THE NEXT STEP

micado

Develop a complete set of tool for

Radiological Waste Characterization Plateform



- Move Nanopix to Timepix3 ASIC
- Enhance CdTe Crystal

for ***improved spectrometry and sensitivity*** performances

list cea tech

orano

IEAP CTU in Prague

XIE X-RAY IMAGING EUROPE

RICE

ZÁPADOČESKÁ UNIVERZITA V PLZNI

UNI FREIBURG

CAEN Tools for Discovery

ENEA

This project has received funding from the European Union's Euratom programme under grant agreement N° 847641 (MICADO)

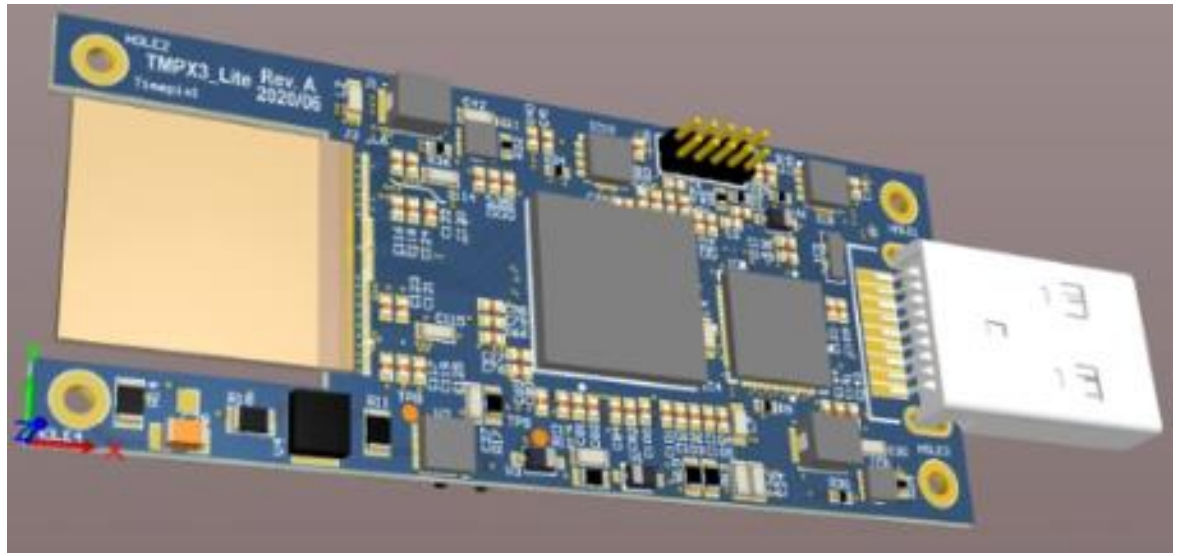
Inspired by 2 prequel systems

Katherine System for TPX3

FITPixLite for TPX

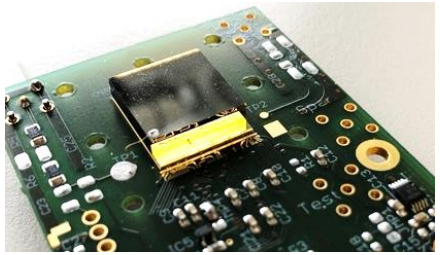
IEAP CTU in Prague

RICE
ZÁPADOČESKÁ UNIVERZITA V PLZNI

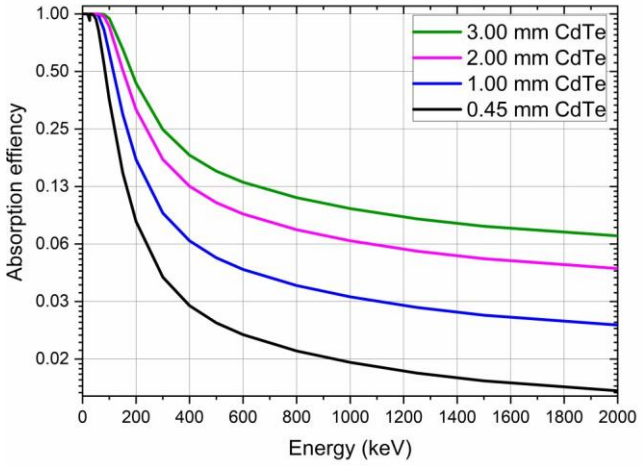


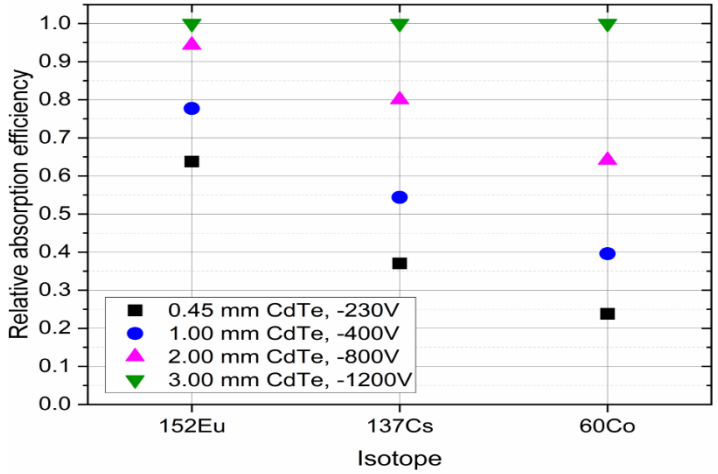
This project has received funding from the European Union's Euratom programme under grant agreement N° 847641 (MICADO)

Improve detection efficiency through sensor tickness

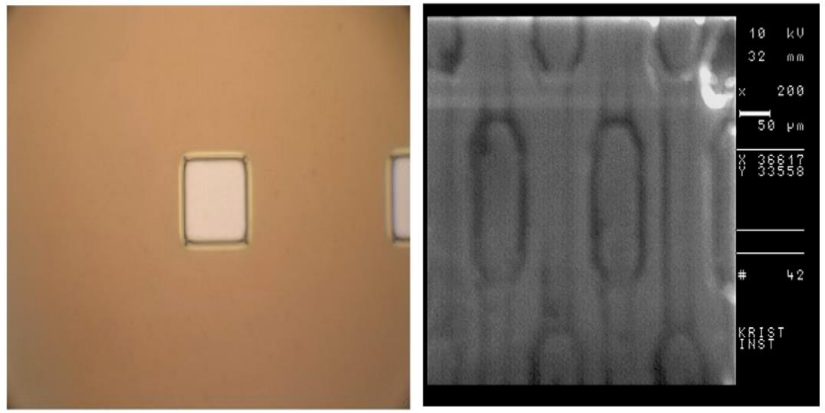


- ***Detection efficiency*** linked with sensor thickness
- ***Prototype realised and tested*** for 0.45, 1, 2 and 3 mm thickness
- Has to take into account the ***leakage current*** (impact on angular resolution)





Improve passivation layer



- Extends ***working temperatures*** and avoids ***chemical reaction*** on CdTe
- Method developed for ***deposition below 200 °C*** (less defects in cristal)

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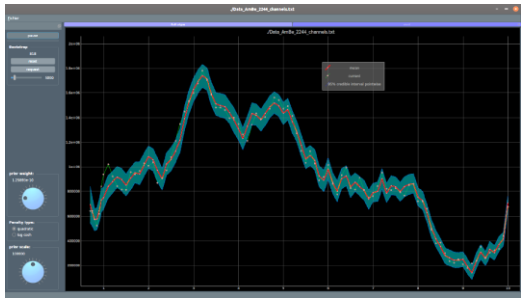
ONE FINAL WORD

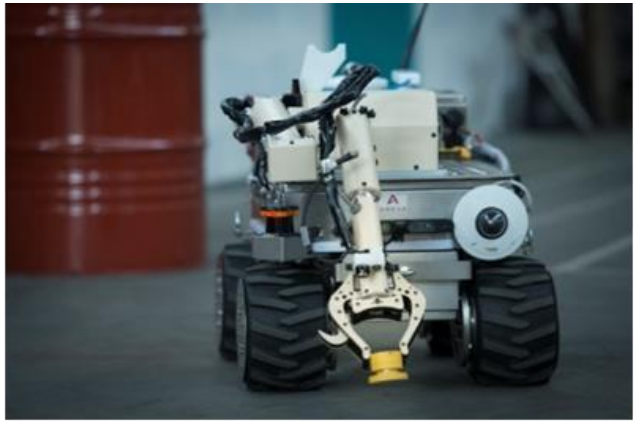
CLEANDEM EURATOM PROJECT (MARCH 2021)

Make this new generation autonomous:

- New generation electronics & embedded processing
- Enhanced algorithms supported by AI

for ***automated remote measurements***





Integration of the gamma camera onto
rugged UGV plateform
for D&D and post accidental remediation

This project has received funding from the European Union's Euratom programme under grant agreement N° 945335 (CLEANDEM)

Thank you for your attention

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Special Acknowledgments to:

- *Medipix Collaboration Members and especially CERN team colleagues ☺*
- *ORANO for supporting Nanopix development and its on-site deployment*
- *French CBRN-e interministerial program for financial support*
- *H2020 TERRIFFIC, EURATOM MICADO and EURATOM CLEANDEM consortiums*