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MINISTÈRE DE LA DÉFENSE

TECHNOLOGIES FOR DISARMAMENT VERIFICATION

IPNDV WG3 meeting,
Ispra, 2016 May 12-13.

<u>**FRANCE**</u>

3 EQUIPMENTS

Within WG3, France promotes <u>3 equipments</u> for further discussions on nuclear materials (NM) or high explosives (HE) detection :

MAIN PART OF THIS PRESENTATION

NM 1 – 'HiSPECT gamma camera'

NM 2 – 'Radiation Detection / Categorization Equipment'

HE 3 – 'Portable neutron device for E detection'

A one-page paper description of each technology is avalaible

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3 TECHNOLOGIES

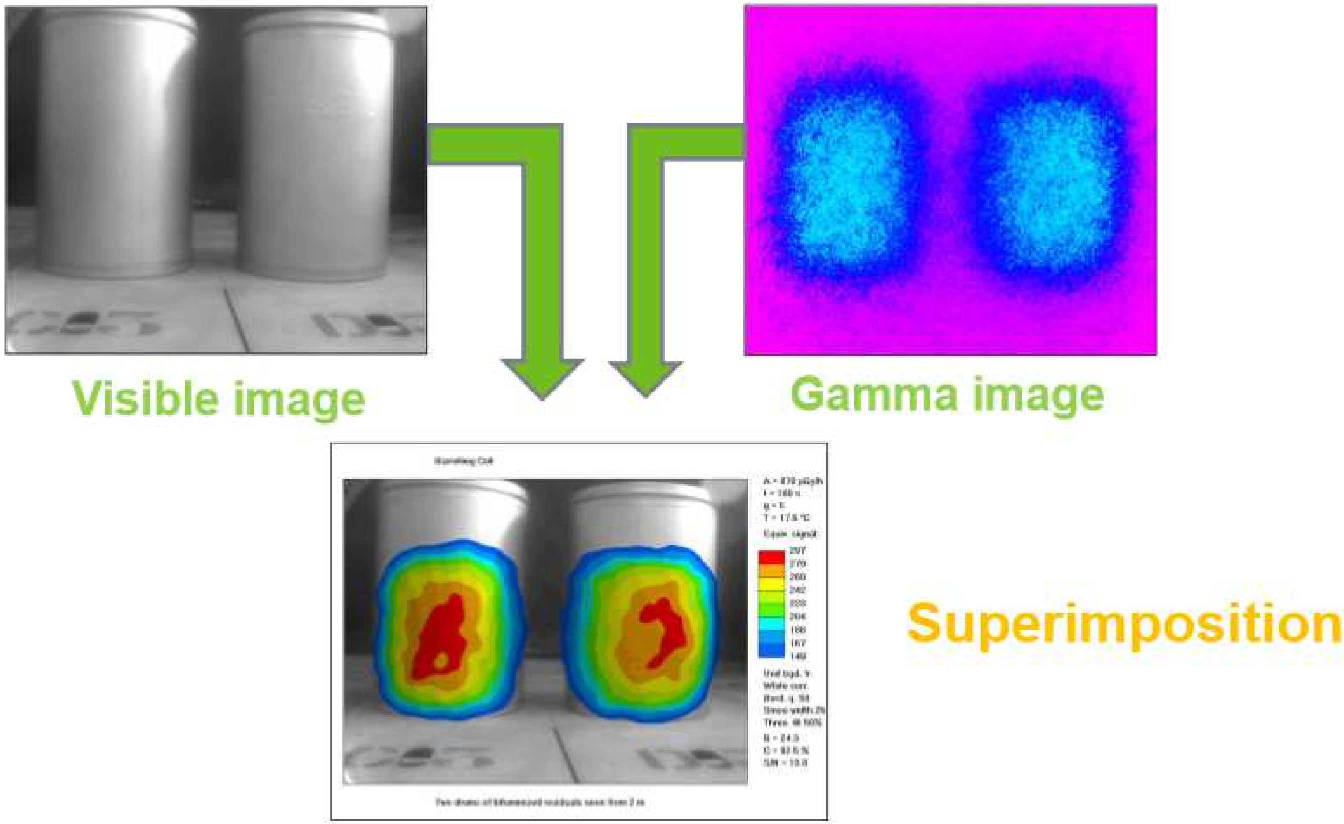
3 equipments based on main technologies using key innovative components :

MAIN PART OF THIS PRESENTATION

- **NM** 1 - Gamma detection
- **NM** 2 - Gamma & neutron detection
- **HE** 3 - Fast neutron detection

1 – 'HISPECT GAMMA CAMERA'

✓ <u>Purpose</u> : detection, identification and localization of nuclear materials inside a container



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1 – 'HISPECT GAMMA CAMERA'

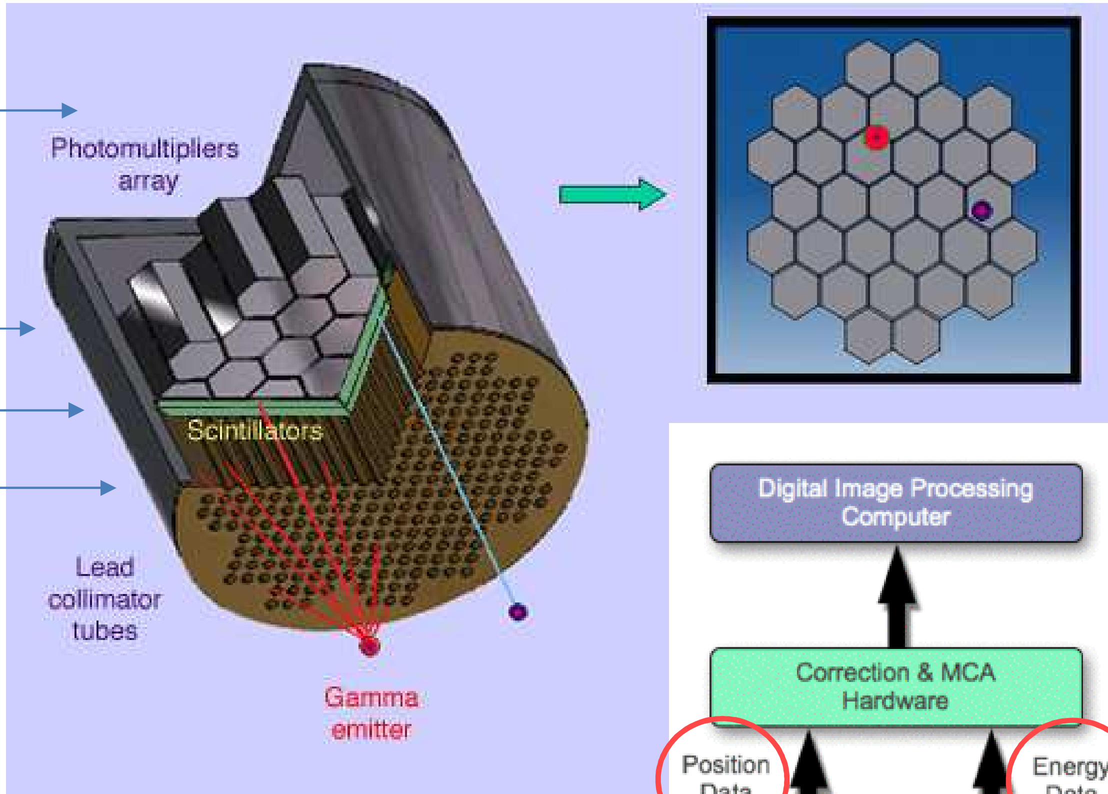
✓ **Principles :**

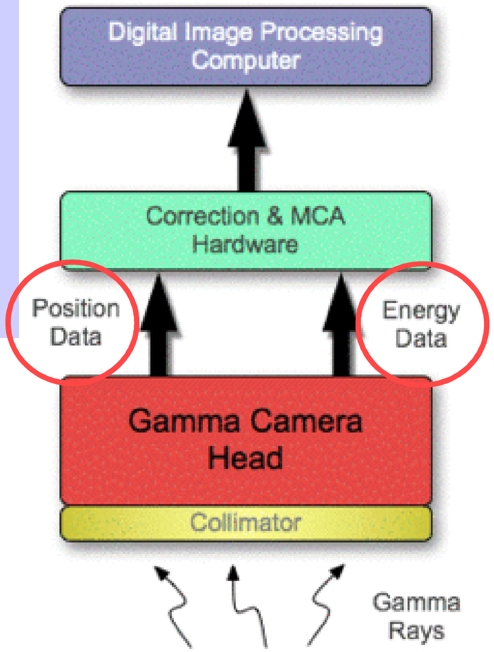
electonic signal amplified by the electronics of the camera

light pulse converted into an electronic signal

brief flash of light

gamma propagation





✓ **Main components :**

- An optical part (a collimator)
- **A detector (a scintillator)**
- An acquisition and processing software

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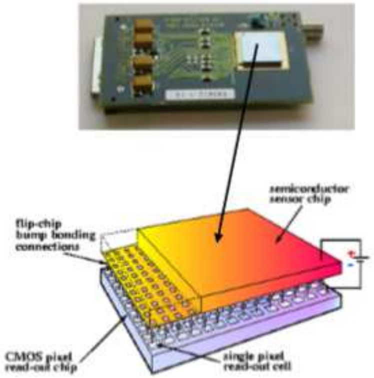
✓ 'GAMPIX' – first generation

3 main components

GAMPIX gamma camera

TimePix/CdTe



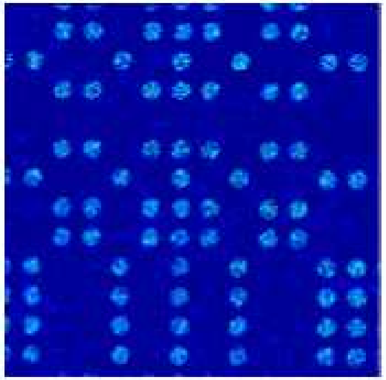
TimePix chip Pixellated chip, hybridized with a 1 mm thick CdTe substrate. The active area is divided into 256 × 256 pixels (55 µm side) working in single photon counting mode (each pixel being an individual detector with its own electronics).

Coded mask A multi-pinhole collimator enables to improve drastically the sensitivity of the camera but requires a decoding step in order to convert the raw image into a decoded gamma image. Several parameters can be adjusted (thickness, rank) according to the need of the end-users (and the nuclear material to be detected)

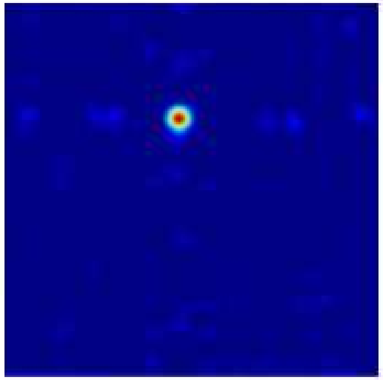
USB interface GAMPIX can be connected in a very easy way to a standard laptop, which greatly simplifies its use (Matlab interface).

✓ ‘GAMPIX’ performances

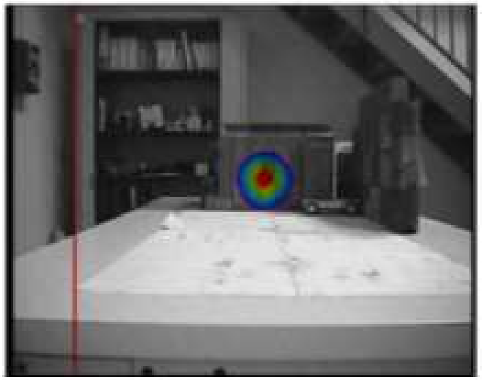
Hot spot localisation



raw gamma image



decoded gamma image



decoded gamma image superimposed with a visible image

Sensitivity

Sources	Dose rate at 1 m ($\mu Sv.h^{-1}$)	Coded mask rank 11	Coded mask rank 13
^{241}Am	0.25	3 s – 5 s	2 s – 4 s
^{137}Cs	2.50	60 s – 100 s	300 s
^{60}Co	3.84	10 min	Undetectable

Angular resolution

		4 mm thick	2 mm thick
Sources	Dose rate at 1 m ($\mu Sv.h^{-1}$)	Coded mask rank 11	Coded mask rank 13
^{241}Am	0.25	2.12°	1.38°
^{137}Cs	2.50	2.06°	1.35°
^{60}Co	3.84	2.57°	Undetectable

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✓ **INDUSTRIAL APPLICATION OF GAMPIX**

CANBERRA

Features

- Complete tool for *in situ* gamma imaging, saving time, cost and dose
- Real-time acquisition and immediate display
- 2.35 kg/5.5 lb camera
- Excellent spatial resolution for localization of gamma-ray emitters
- High detection sensitivity even at low energies
- IP65 rated, fully decontaminable
- Battery, POE or direct powered
- Remote control and operation
- Single Ethernet cable between tablet PC and camera (up to 80 m long)
- Three coded masks available for optimized response (optional)
- Fully rugged convertible notebook
- User-friendly software

iPIX
Ultra Portable Gamma-Ray Imaging System

Description

iPIX is a unique gamma imager that quickly locates and identifies low level radioactive sources from a distance while estimating the dose rate at the measurement point in real time. It is the ideal tool to map a radioactive area before entering the zone, thus reducing the dose exposure (ALARA) during standard operation or decommissioning. iPIX is also the appropriate instrument to detect any suspicious radioactivity in security and safeguard applications, as well as for emergency situations such as Fukushima.

Technology

iPIX integrates the GAMPIX technology developed by the Atomic Energy Commission (CEA) in France. It is based on a 1 mm CdTe detector bonded to a pixilated CMOS chip – the Timepix sensor developed at the CERN research center – a coded mask and mini optical-camera.

The coded mask aperture allows for background noise subtraction by means of a technique called mask/anti-mask differentiation. This greatly contributes to the reduced size and weight of the gamma imager. The mask automatically rotates to the anti-mask position based on the measurement conditions (background and source activity).

The radioactivity mapping is automatically superimposed onto the visible image of the scene of interest.

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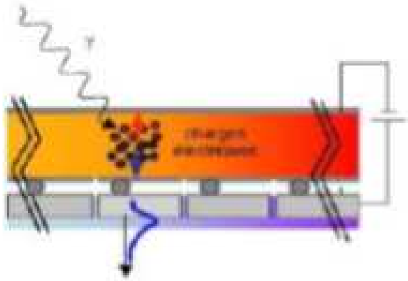
1 – ‘HISPECT GAMMA CAMERA’

✓ ‘HiSPECT’ – new generation : spectro imager

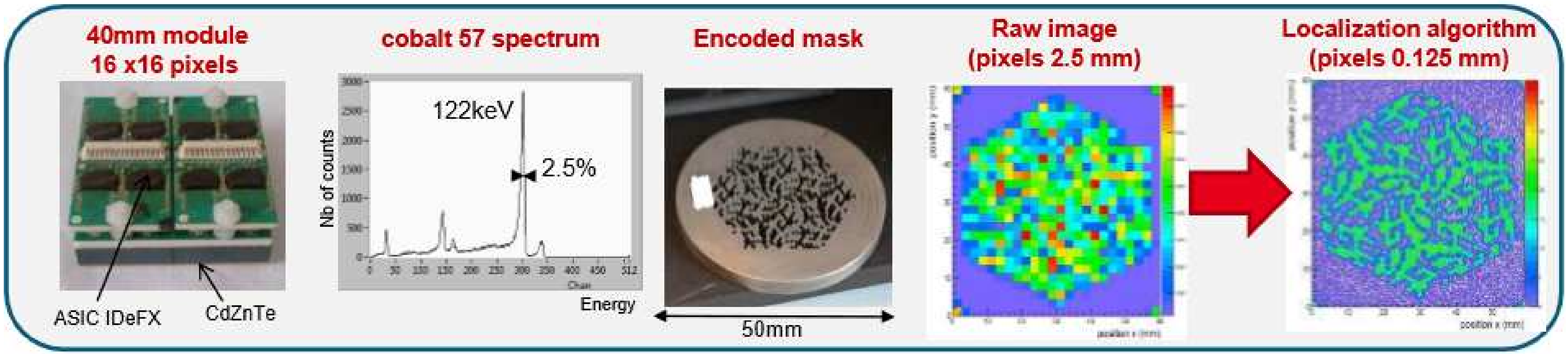


CdZnTe based gamma imaging module with a standard dimensioning (40x40x5mm)

Essential brick to build a camera, with enhanced performance:

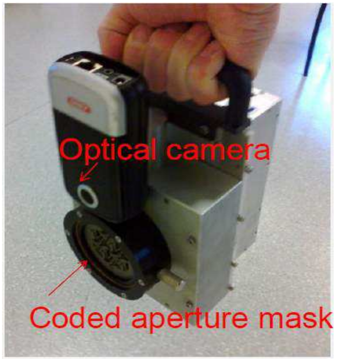
- **High energy resolution: average of 2.5% at 122keV**
- **Submillimeter spatial resolution: 0.3 mm using a dedicated localization algorithm**

The usual trade-off between energy and spatial resolution is avoided by this design. This also allows to envision new camera architectures enabling sensitivity gains.



1 – 'HISPECT GAMMA CAMERA'

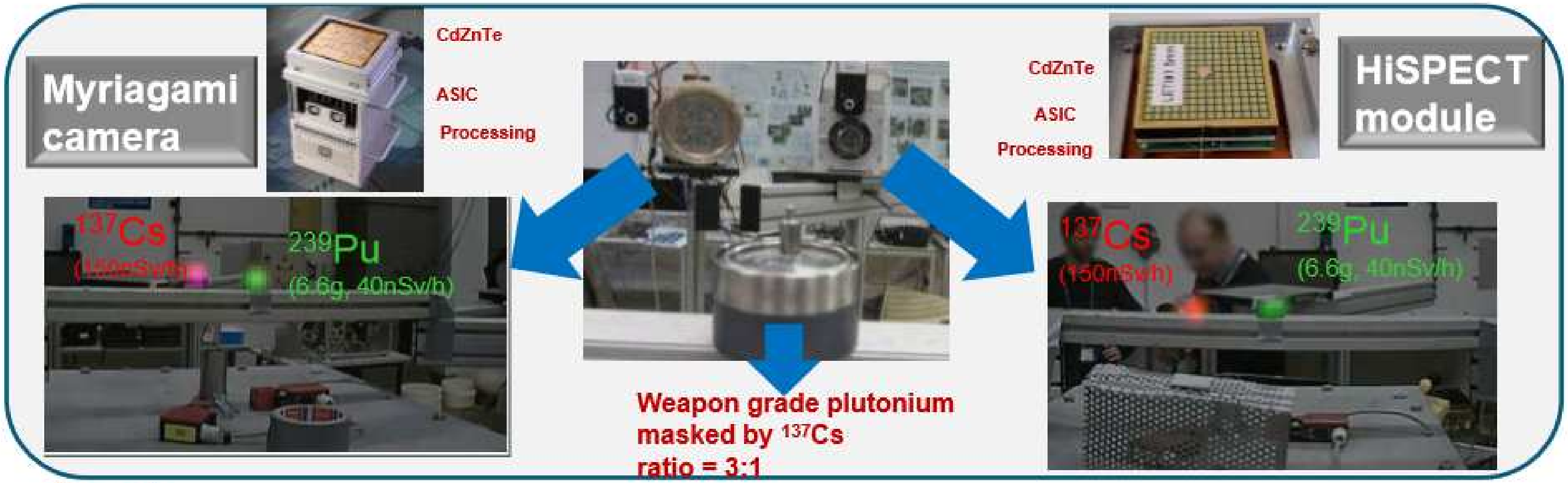
HiSPECT : application for nuclear control



Two portable CdZnTe gamma camera based on the coded aperture mask method.
Simultaneously source and nuclear material detection, identification and imaging.

Applications :

- Struggle against nuclear material trafficking and radio-terrorism.
- Environment decontamination.
- Nuclear industry and decommissioning.



Results

Evaluation of the two systems at JRC European research center (Ispra, Italy).

→ Detection and identification are very good at low energy - below search device norm but correct at high energy. Localization of a 22nSv/h of ^{137}Cs in 1 minute inside 70nSv/h background.

→ Interest of spectral imaging with multiple isotopes and of course when source distribution matters.

3 simultaneous functionalities detection-identification-imaging are the main strength of these system.

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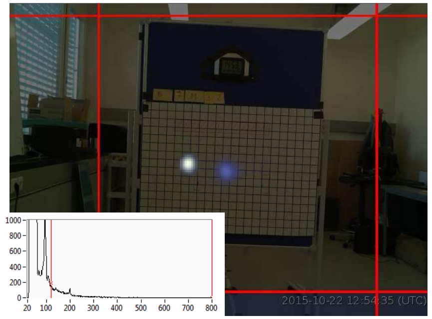
1 – 'HISPECT GAMMA CAMERA'

9 gamma-imaging systems tested for 4 days with various configurations

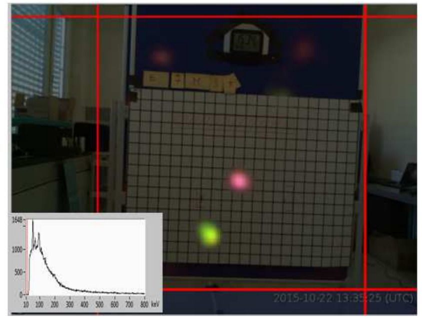
Technology demonstration workshop at IAEA (Oct. 2015)
Test for safeguards application

Masking scenarios
→ *Weak SNM (Special Nuclear Materials) sample with high background from an industrial radionuclide*

Am (white)/Pu (blue)

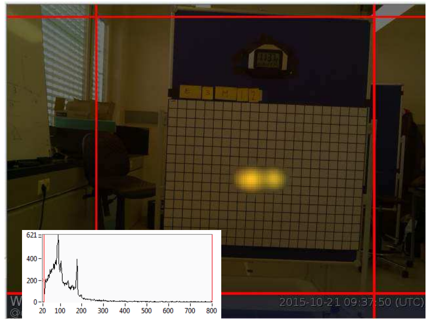


Co60 (green)/Pu (red)

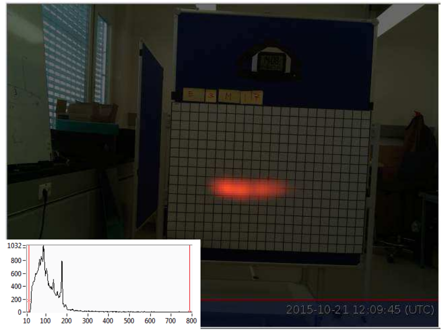


Extended sources
→ *SNM samples with shape delineation*

Uranium containers

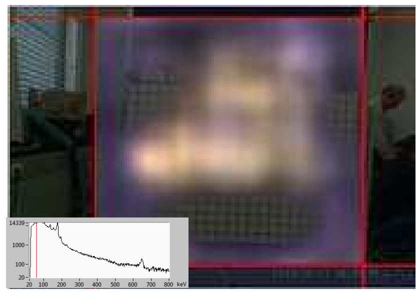


Uranium bar

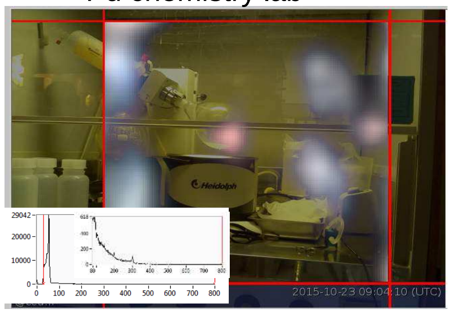


Complex scenes
→ *(near) real life cases with complex distributions and parasitic activity outside field of view*

Uranium bars + parasitic sources



Pu chemistry lab



2 – RADIATION DETECTION / CATEGORIZATION EQUIPMENT

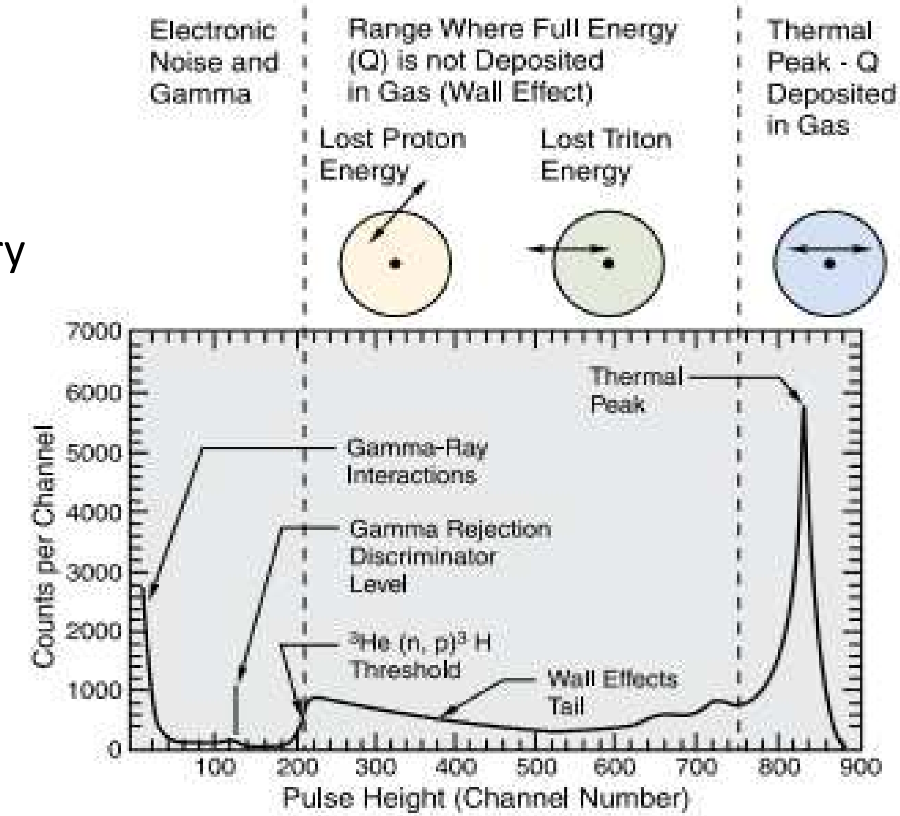
✓ Neutrons detection

Neutrons dectectors must rely upon a conversion process where an incident neutron interacts with a nucleus to produce a secondary charged particule which is directly detected.

The most common reaction for thermal (low energy) neutron detection is :

$$n + {}^{3}He \rightarrow p + {}^{3}H + 765\ keV$$

where both the proton and the triton are detected by a gas filled proportional counters using ^{3}He fill gas.



Thermal Neutron Induced Pulse Height Spectrum from a Moderated ^{3}He Detector

Because all of the neutrons which are detected have been moderated to reduce their energy to the thermal level, all neutron energy is lost (only one peak which is the reaction energy (765 ke V)).

➡ **High neutrons detection efficiency with/but excellent gamma discrimination !**

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2 – RADIATION DETECTION / CATEGORIZATION EQUIPMENT

✓ Innovative scintillators

Alternative to Helium-3 technology (huge problems in matching supply -> price) ?

The SCINTILLA European project has involved a consortium of 9 partners, including 5 research groups and 4 companies, providing 9 detector prototypes (based on 6 different technologies).

SEVENTH FRAMEWORK PROGRAMME

Parameters of the technologies under development.

Detector	Sensitivity	Usage case	Developer
Gd–lined plastic scintillator	$n + \gamma$	container, vehicle	INFN/ANN
LiZnS detector	n	container, vehicle, luggage, people	Symetrica
NaI(Tl) spectrometer	γ spectroscopy	luggage, people	Symetrica
2 PVT spectrometers	γ spectroscopy	container, vehicle, luggage, people	Symetrica
2 PSD Plastic scintillators[a]	$n + \gamma$	container, vehicle, luggage, people	CEA and Saphymo
CZT gamma camera	γ	portable device	CEA
Mini–CZT	γ	miniature device	CEA

[a]PSD: pulse shape discrimination

<u>Plastic scintillator</u> : only one detector for neutron detection and for gamma detection (and identification)

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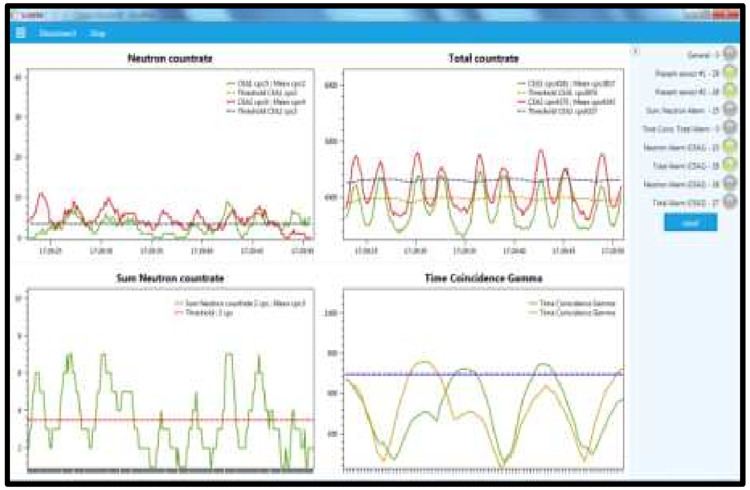
2 – RADIATION DETECTION / CATEGORIZATION EQUIPMENT

✓ <u>CEA plastic scintillators</u>

<u>Key developments</u> : - instrinsic signal processing.
- thermal stabilization methods of photomultiplier tubes.
- undoped plastic scintillator (containing fluorescent complexes)



- New electronic hardware and algortihms enabling discrimination between neutron and gamma in plastic scintillators together, even for low energy neutrons (less than 10 Mev) ; exploitation of coincidence of events.
- The electronic platform in mainly based onto a quad 200 MHz ADCs.
- Using phase rotating, it is possible to sampling the signal up to 800 MHz, with 8 bits precision.

✓ INDUSTRIAL APPLICATION

SaphyGate GN

SNM Portal Monitor

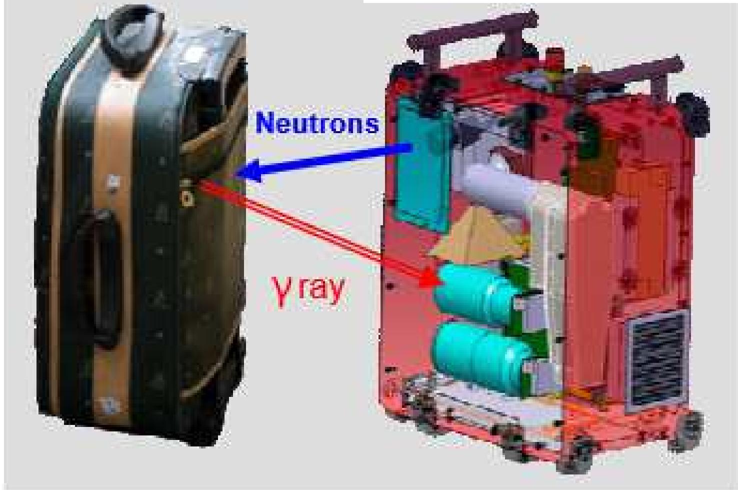
- Sensitive and accurate: SaphyGate-GN combines very large PVT detector, sophisticated electronics and algorithm to exceed the challenging IAEA, IEC and ANSI standards
- Background noise shielding automatically taken into account
- Automatic scan: no intervention by control personnel
- 100 ms fast and real-time count rate analysis during measurement
- Rugged material designed for all weather conditions
- Easy to install and to operate
- Modular architecture allows easy upgrade
- CEA license

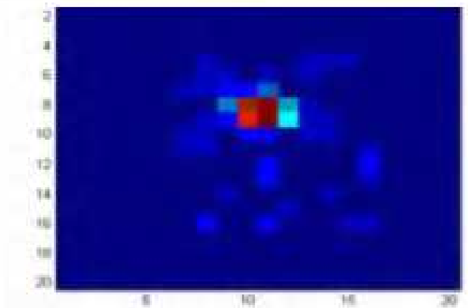
Illicit trafficking of nuclear and other radioactive material has become a growing concern since the first seizures in the early 1990s. SNM (Special Nuclear Material) can be used to create nuclear weapons whereas radioactive material can be used to produce dirty bomb (RDD).

Each state has the responsibility for combating illicit trafficking and the inadvertent movements of radioactive material. SNM portal Monitors are therefore installed in strategic locations such as borders, air terminals, ports, nuclear facilities and critical buildings.

3 – PORTABLE NEUTRON DEVICE FOR E DETECTION

ULIS
Unattended Luggage Inspection System
for Homeland Security and Defense





The location of the suspect material is computed by using directional information from the associated particle detector and time-of-flight measurements of the neutrons. Material composition is derived from comparing the detected gamma ray energy spectra with a database (library) in the electronics module.

Fast neutron interrogation and associated particle detection offer the ability to accurately obtain the chemical composition and the mass estimation of any kind of material inside an object. Neutrons are emitted toward the object. As a result, the atomic interactions produce element-specific gamma ray emission which allows to determine the stoechiometry of analyzed matter.

Computation provides a 3D-image, allowing the mapping of the location of the suspect material. An optional X-ray detector can supplement the neutron interrogation result with a conventional X-ray image.

ULIS combines neutron technology and image processing to automatically determine whether an object is dangerous or not, and to provide identification and localization of the threat.

3 – PORTABLE NEUTRON DEVICE FOR E DETECTION

-THE ULIS EXCLUSION ZONE IS INCLUDED IN (USUAL) PYROTECHNIC EXCLUSION ZONE IN CASE OF SUSPICIOUS ITEM INSPECTION

-THE RESTRICTED AREA SIZE DEPENDS ON ALLOWED DOSERATE ON OPERATORS (10 m means about 10 µSv/h)

3 – PORTABLE NEUTRON DEVICE FOR E DETECTION