DEVELOPMENT OF A 3D MULTIMODAL MOBILE IMAGER FOR THE RADIOLOGICAL CHARACTERIZATION OF COMPLEX ENVIRONMENTS

DE LA RECHERCHE À L'INDUSTRIE

19/05/2022

Kamel BENMAHI

Supervisor: Vincent SCHOEPFF

Director: Frédérick CARREL

Plan

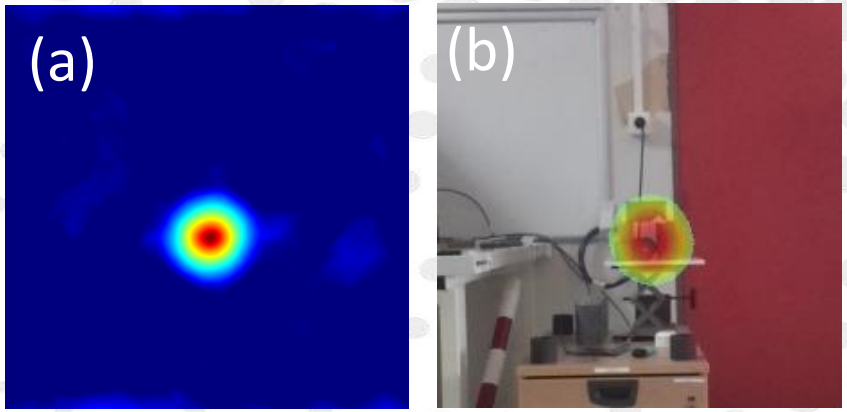
- General context
- Thesis objectives
- Coded-aperture imaging and Compton imaging
- Gamma imaging: 3D localization
- Moving & multimodal imaging
- Conclusion & perspectives

DE LA RECHERCHE À L'INDUSTRIE

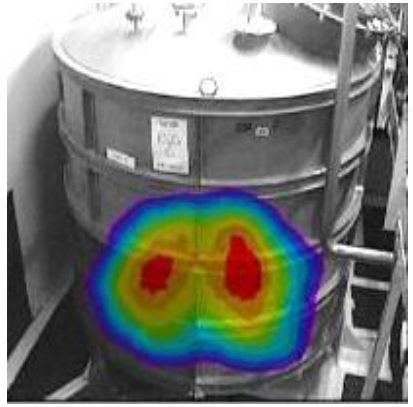
General context

General context

- **Localization of radiological hot spots**
  1. Superimposing a visible image on a gamma image
- **Applications :**
  1. Nuclear decommissioning
  2. Radiation protection
  3. Homeland Security
  4. Nuclear waste management applications



(a): Hot spot reconstruction using the coded-aperture method via Nanopix. (b): Superimposition of a gamma image on a visible image to locate the hot spot.



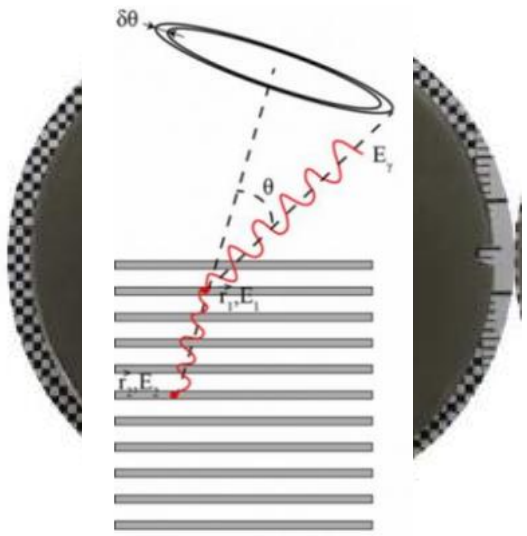
Gamma imagers pictures (a) CARTOGAM. (b) IPIX. (c) Nanopix.

DE LA RECHERCHE À L'INDUSTRIE

Thesis objectives

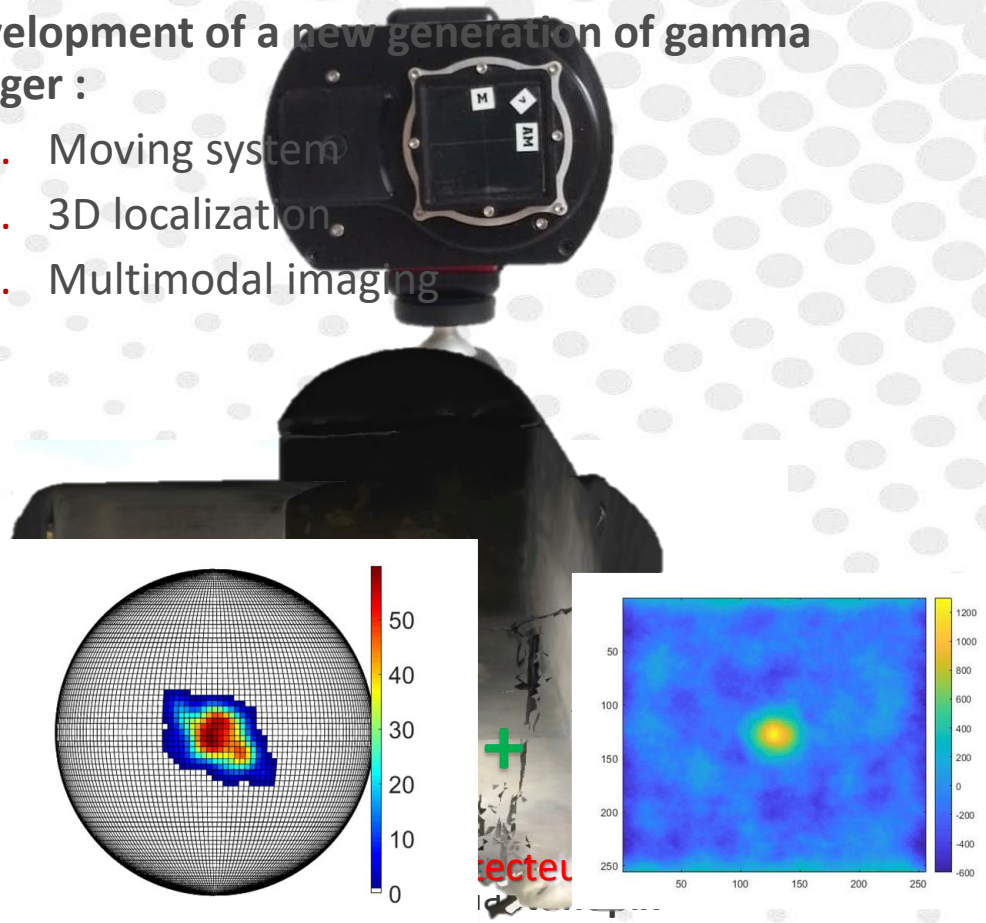
Thesis objectives

- **Localization in current systems :**
  1. Stationary measurements;
  2. Two distinct 2D localization techniques.
     - Coded-aperture;
     - Compton scattering.



Extracted from: http://www.univearths.fr/

- **Development of a new generation of gamma imager :**
  1. Moving system
  2. 3D localization
  3. Multimodal imaging

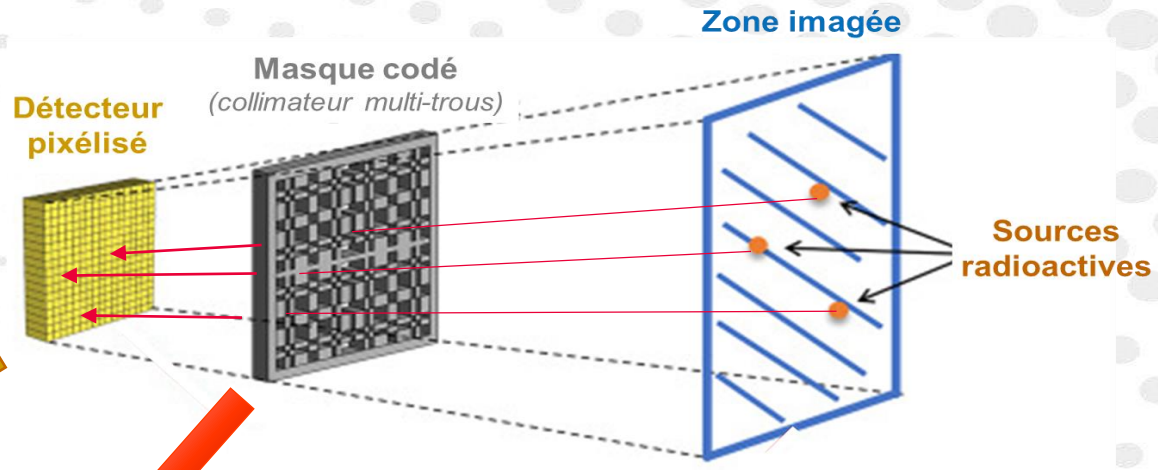


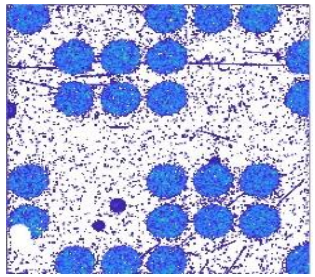
DE LA RECHERCHE À L'INDUSTRIE

Coded-aperture imaging and Compton imaging

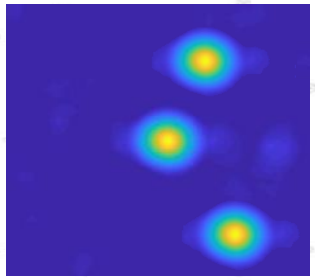
Coded-aperture imaging and Compton imaging

- **Coded-aperture imaging:**
  1. Spatial modulation of the incoming flux of γ-ray and x-ray
  2. Masks: multi-holes collimators
  3. Decoding



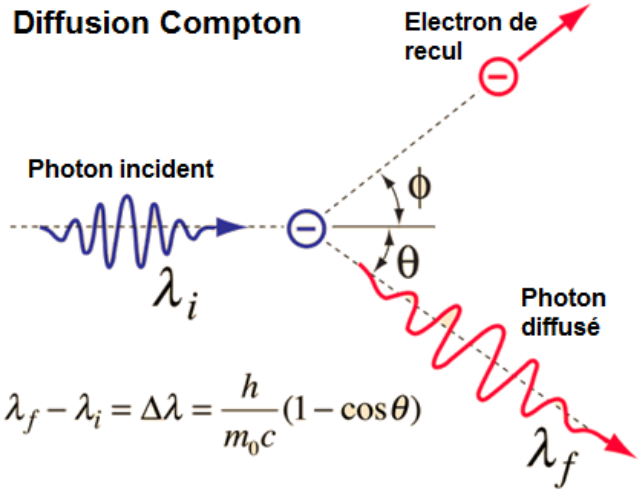


Decoding



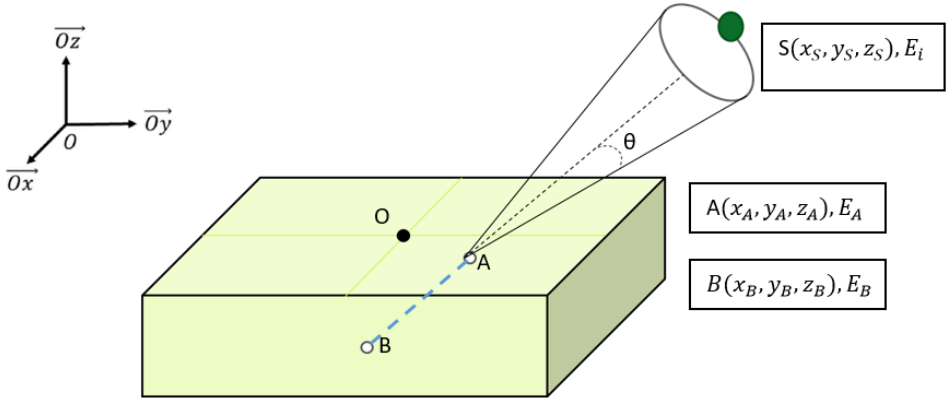
Coded-aperture imaging and Compton imaging

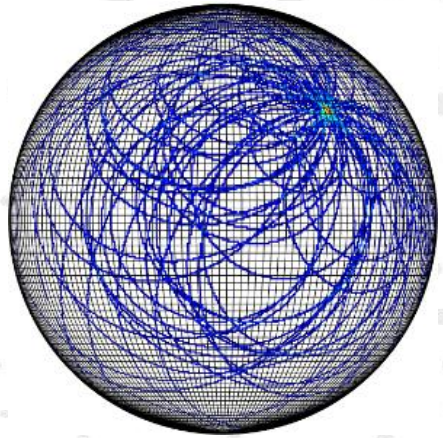
- **Compton imaging:**
  1. Compton scattering
  2. Information preserved: energy and direction of the γ-ray.
  3. Calculation of scattering angle
  4. Intersection of cones



$$\cos(\theta) = 1 + \frac{m_e c^2}{E_i} - \frac{m_e c^2}{E_a}$$

Extracted from: hyperphysics.phy-astr.gsu.edu



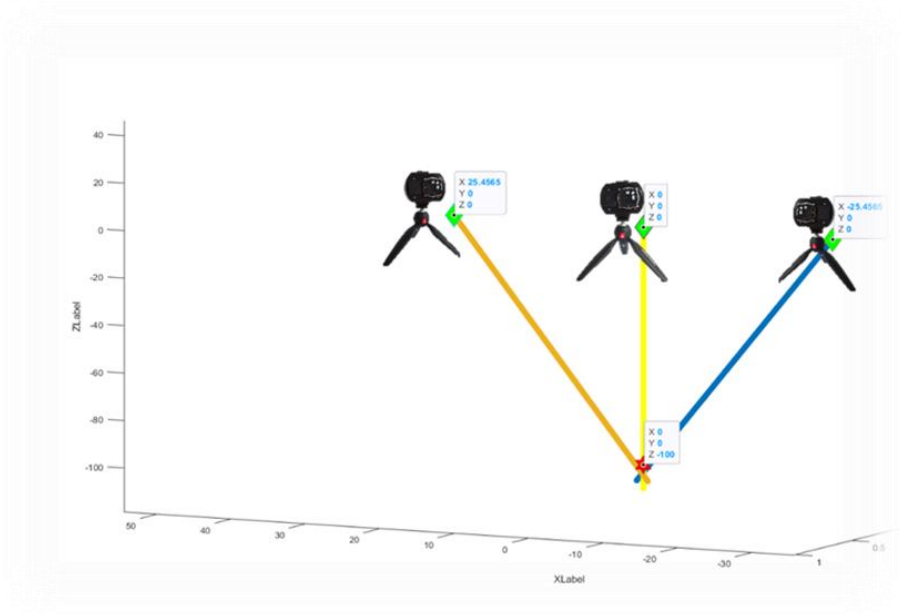


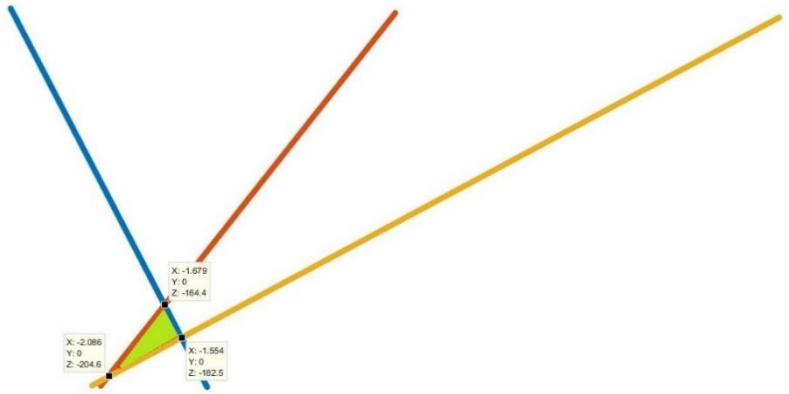
DE LA RECHERCHE À L'INDUSTRIE

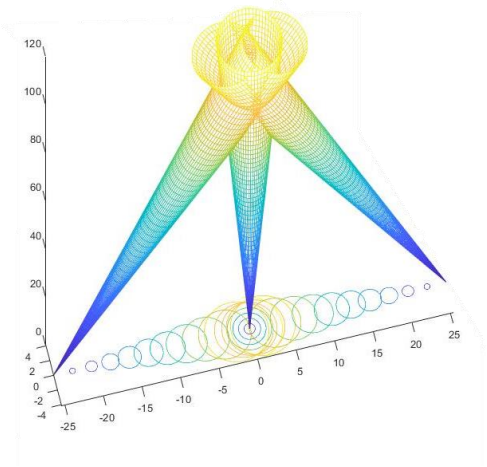
Gamma imaging: 3D localization

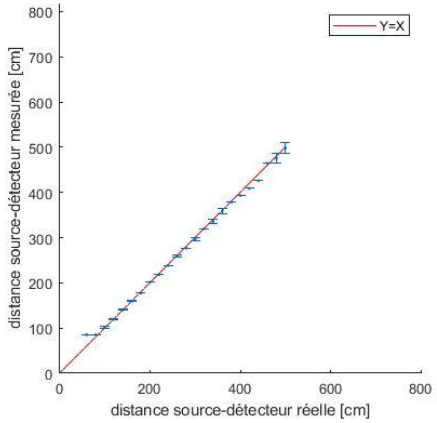
Gamma imaging: 3D localization

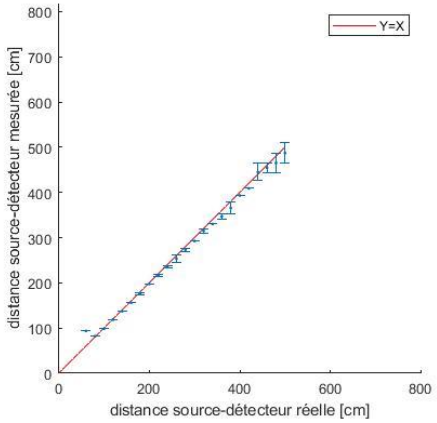
- **Coded-aperture imaging:**
  1. Moving the detector
  2. Performing several projections
  3. Recording all the detector's positions
  4. Applying triangulation method
  5. Forming the region of uncertainty

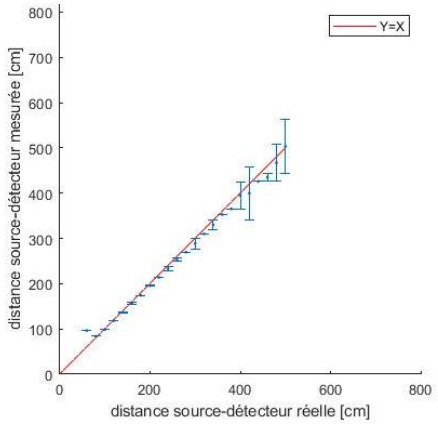


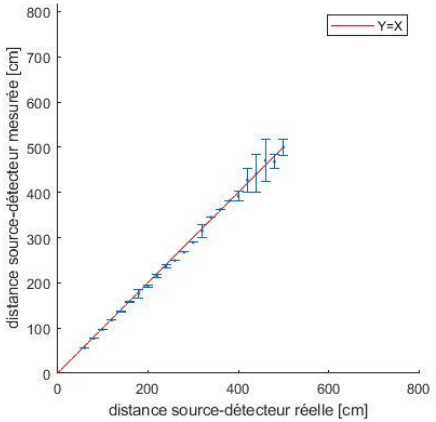


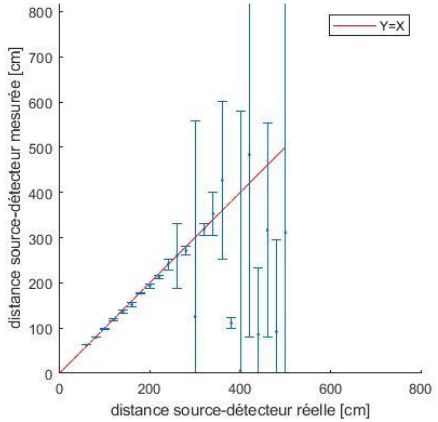












Gamma imaging: 3D localization

- **Coded-aperture imaging:**

^{241}Am (59,6 keV)

^{133}Ba ([81, 276, 302 ,356, 383] keV)

^{137}Cs (662 keV)

NPS = **2.10^6**, displacement of the detector = **35 cm**

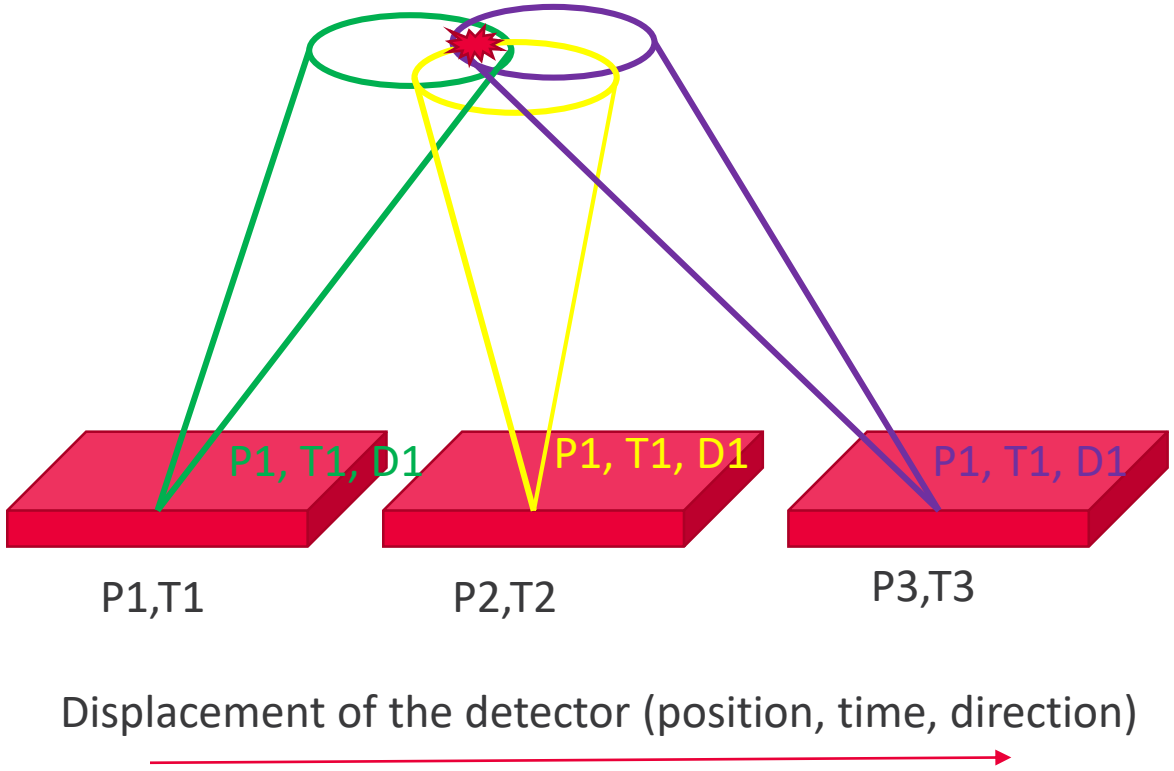
NPS = **10^5**, displacement of the detector= **25 cm**

✗

Gamma imaging: 3D localization

- **3D localization for Compton imaging:**
  1. Detector displacement
  2. Compton cones reconstruction
  3. Associating to each Compton event the following parameters: position, time and direction
  4. Projection of cones according to their positions in space and time

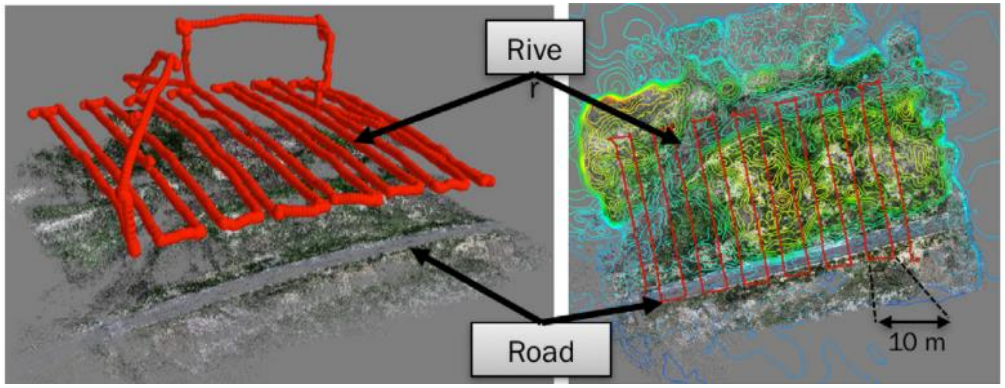
Photo credit : ADVACAM



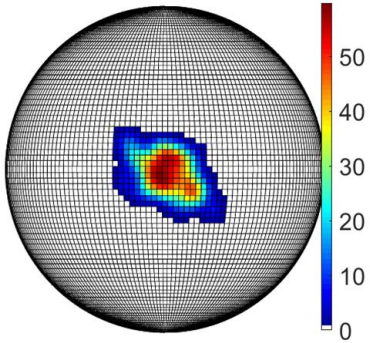
DE LA RECHERCHE À L'INDUSTRIE

Moving & multimodal imaging

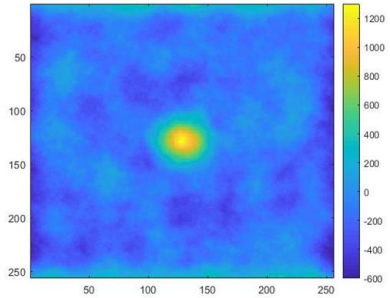
Moving & multimodal imaging



Vetter K, "*Gamma-Ray imaging for nuclear security and safety: Towards 3-D gamma-ray vision,*" *Nucl. Instruments Methods Phys,* 2017.



+

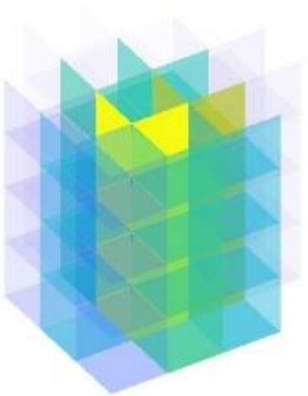


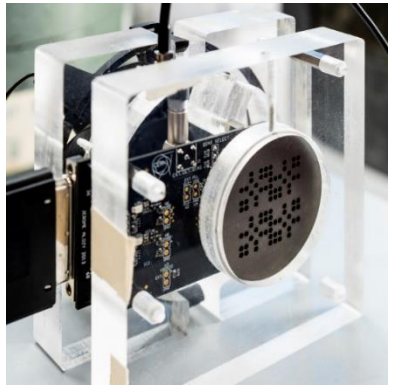
DE LA RECHERCHE À L'INDUSTRIE

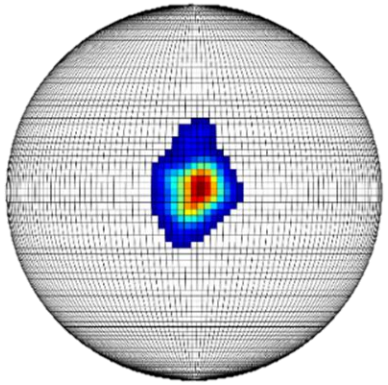
Conclusion and perspectives

Conclusion & perspectives

- **Conclusions :**
  - ✓ 3D imaging
  - ✓ Moving & multimodal imaging
- **Perspectives :**
  - Multimodal imaging development
  - 3D reconstruction of hot spots
    - Analytical algorithms
    - Iterative algorithms : 3D-ML-EM …
  - Hot spot localization in 3D, and in real time







Thank you !

19/05/2022

Kamel BENMAHI