Development of a Dual Alpha-Gamma Camera for Radiological Characterization Applications

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DE LA RECHERCHE À L'INDUSTRIE

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Development of a Dual Alpha-Gamma Camera for Radiological Characterization Applications

(NSS) Nuclear instrumentation and Measurement for reactors and related Applications

MAHE Charly, LAFONT Fabien, MITRA Saptarshi, VENARA Julien

HISTORICAL FEEDBACK

In Situ measurement laboratory in Marcoule : ~40 years

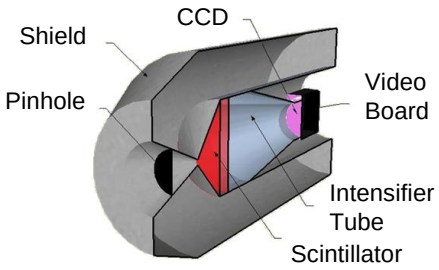
R&D on Nuclear Instrumentation for decommissioning projects

Technical Support and particular operations for CEA, AREVA, EDF, IAEA, CSK-CEN, …

- **CEA Centers :** Saclay, Fontenay-Aux-Roses, Marcoule, Cadarache, Grenoble, Valduc, La Hague
- **AREVA Centers :** Marcoule, Cadarache, La Hague
- **EDF Powerplant :** Tricastin, Cruas, Saint-Laurent, Gravelines, Le Blayais, Dampierre, Chinon, Chooz, Cattenom, Flamanville, …

Part of a laboratory including : virtual reality, robotics (teleoperation) & laser cutting developments

New gamma cameras under development and/or qualification at CEA

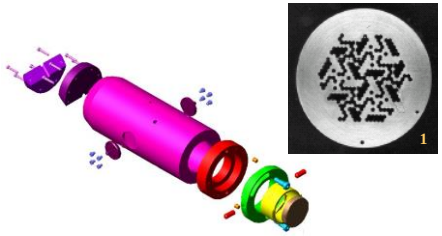


1980

Aladin

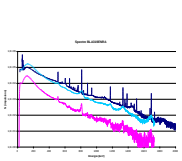
Scintillator

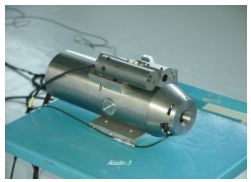
Gamma camera



Coded aperture

Additionnal shutter





CZT Spectrometry

Dose rate

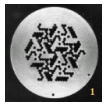
2000

2012

IPix™ (CEA/CANBERRA)

Medipix technology, USB

Coded aperture



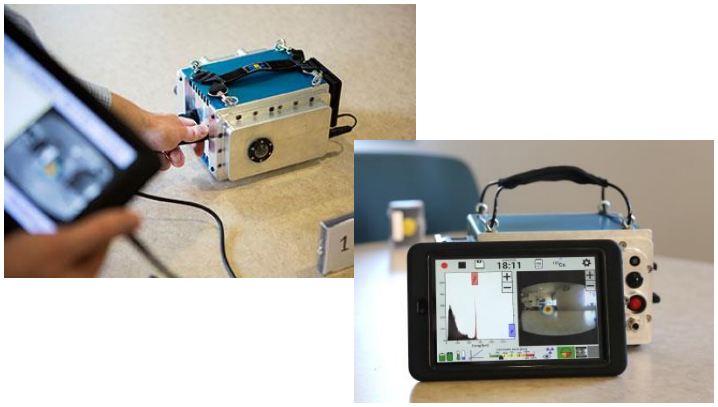
Better performances

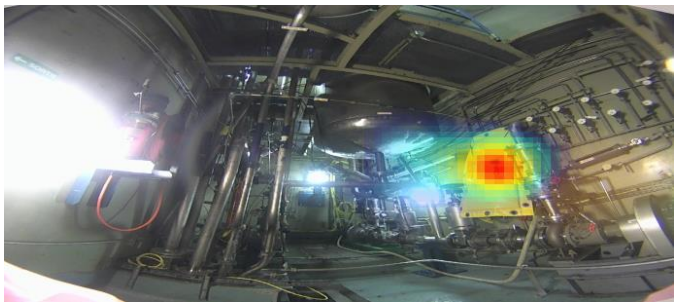
Lower price

More compact & portable device

INTRODUCTION
State Of Development of Gamma Cameras for Nuclear Industry Applications

New gamma cameras under development and/or qualification at CEA





POLARIS (H3D)

CZT Compton camera

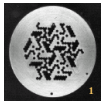
Wireless

Gamma spectrum + gamma image (>250 keV in Compton Mode)

IPix™ (CEA/MIRION)

Medipix technology, USB

Coded aperture



Better performances

Lower price

More compact & portable device

Next generation

?

CZT/Coded Aperture

+

Compton Camera

+

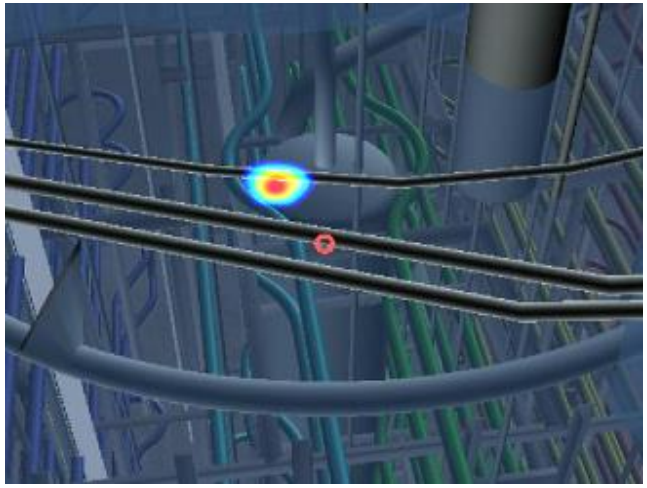
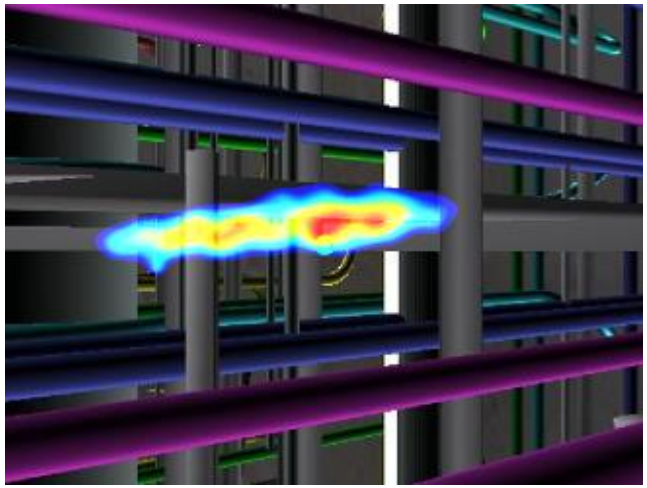
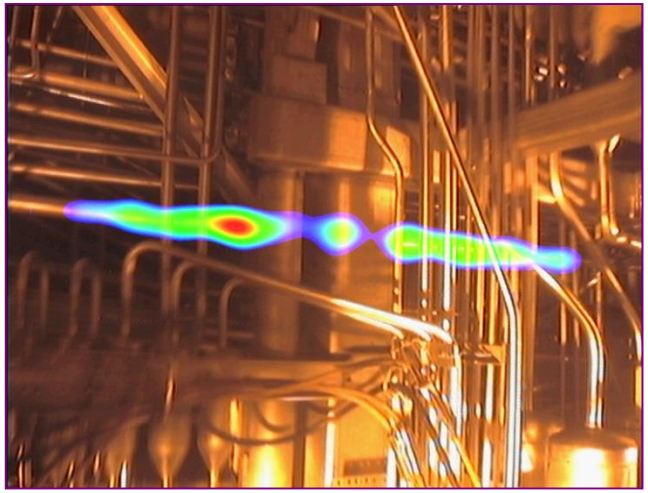
Spectrometric function at any Energy range

Partnership under progress

CEA/DRT, CEA/IRFU, CEA/DEN

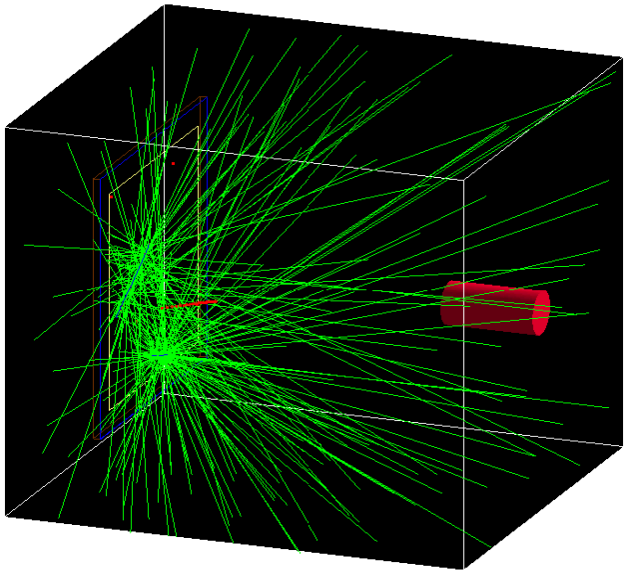
MIRION, GIE INTRA, IRSN, 3D PLUS

GAMMA CAMERA FEEDBACK

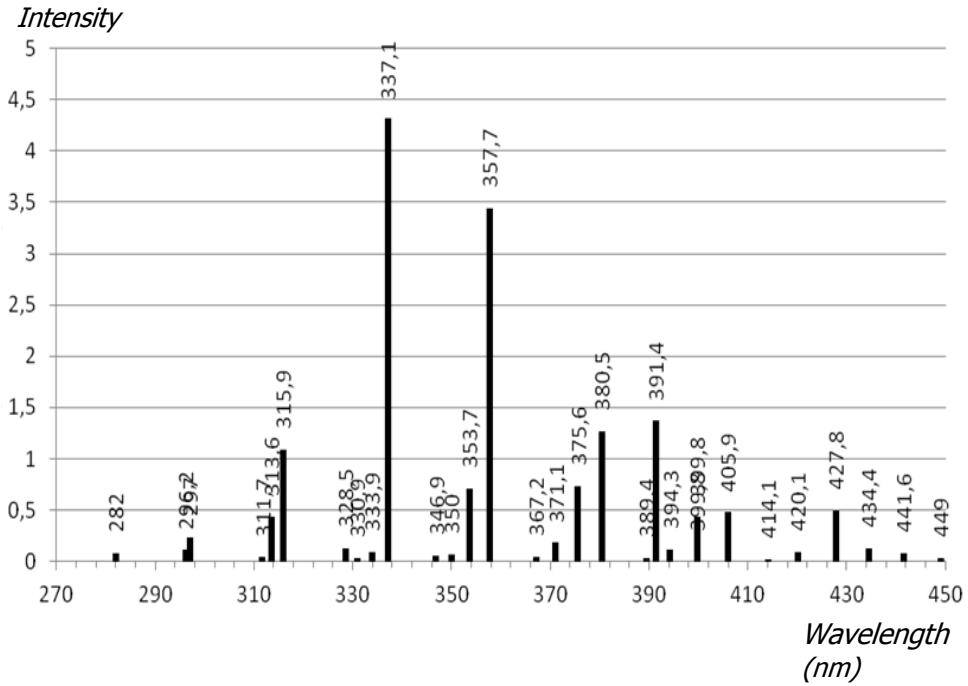
	Used with *3D* view	Used with *real* view
Hot spots localization		
Extended spots localization		

ALPHA CAMERA : A RECENT CAMERA TO LOCALIZE ALPHA CONTAMINATION

Detection of the UV produced by nitrogen molecules under an alpha particle desintegration

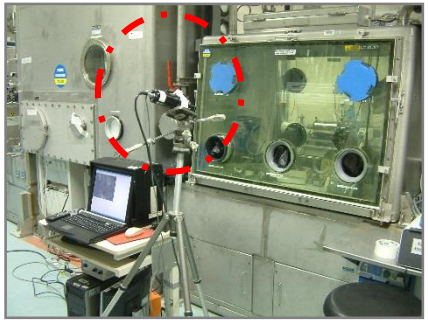


GEANT4 Model of a ^{241}Am source



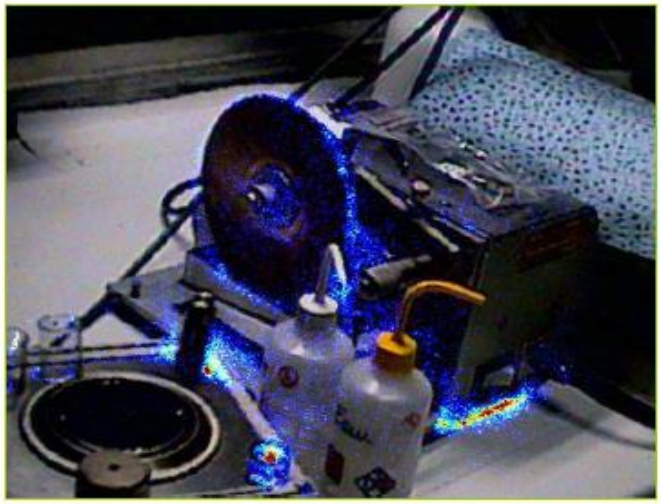
Radio-luminescence of Nitrogen phenomena

ALPHA CAMERA : A RECENT CAMERA TO LOCALIZE ALPHA CONTAMINATION



Raw α image

Atalante plant (2009)



Results after processing (threshold, colour rendering, superimposition)

- Localisation of α hot spots
- Radionucléides : U / ^{241}Am / Pu
- Quick acquisition times (< 15 minutes)

- Measurements at distance, trought Triplex (1,3 cm) & Leaded glass (1,5 cm à 6 cm)

ALPHA CAMERA FEEDBACK

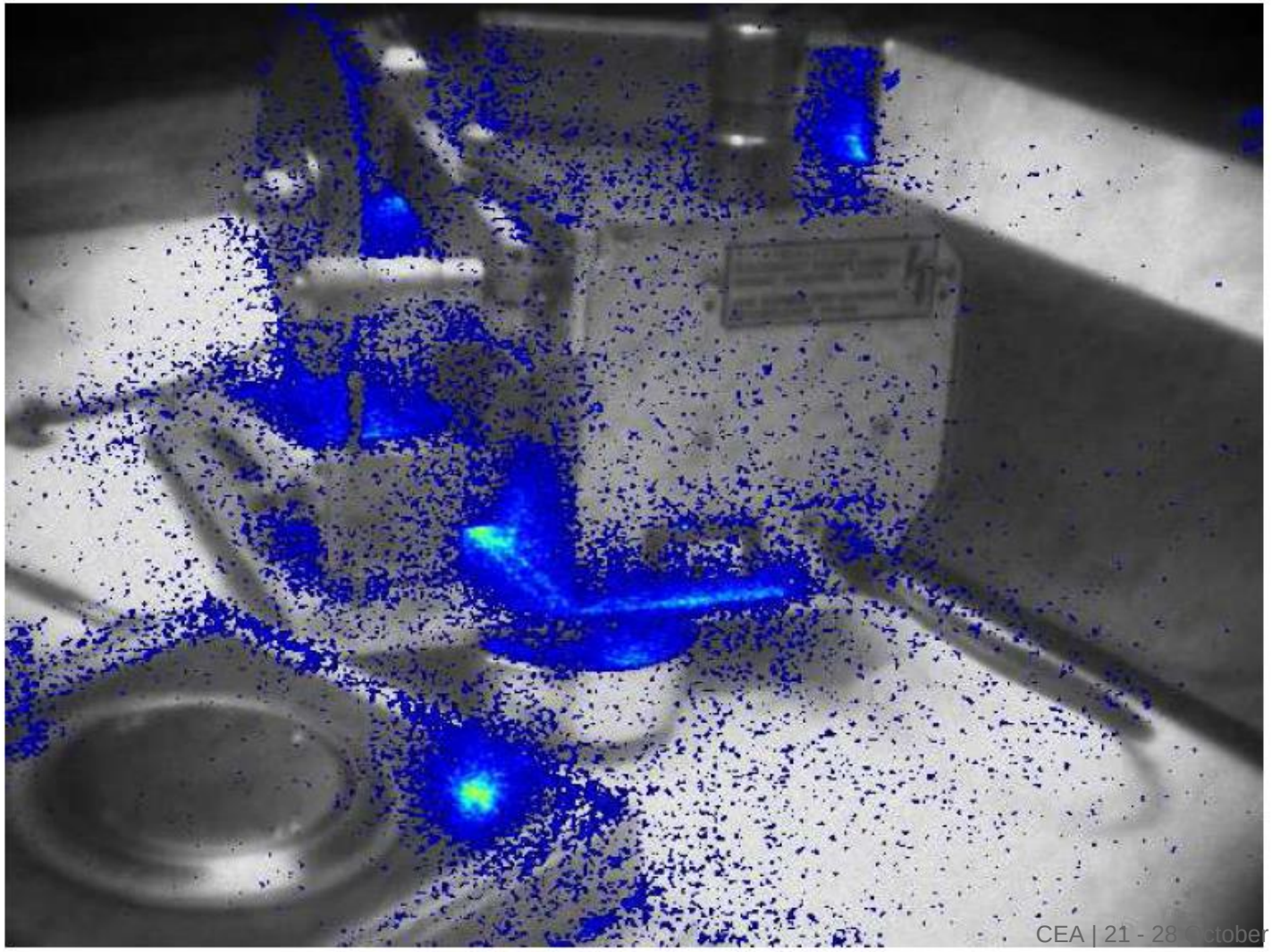
Raw image (without light)

ALPHA CAMERA FEEDBACK

Visible B&W image (with light)

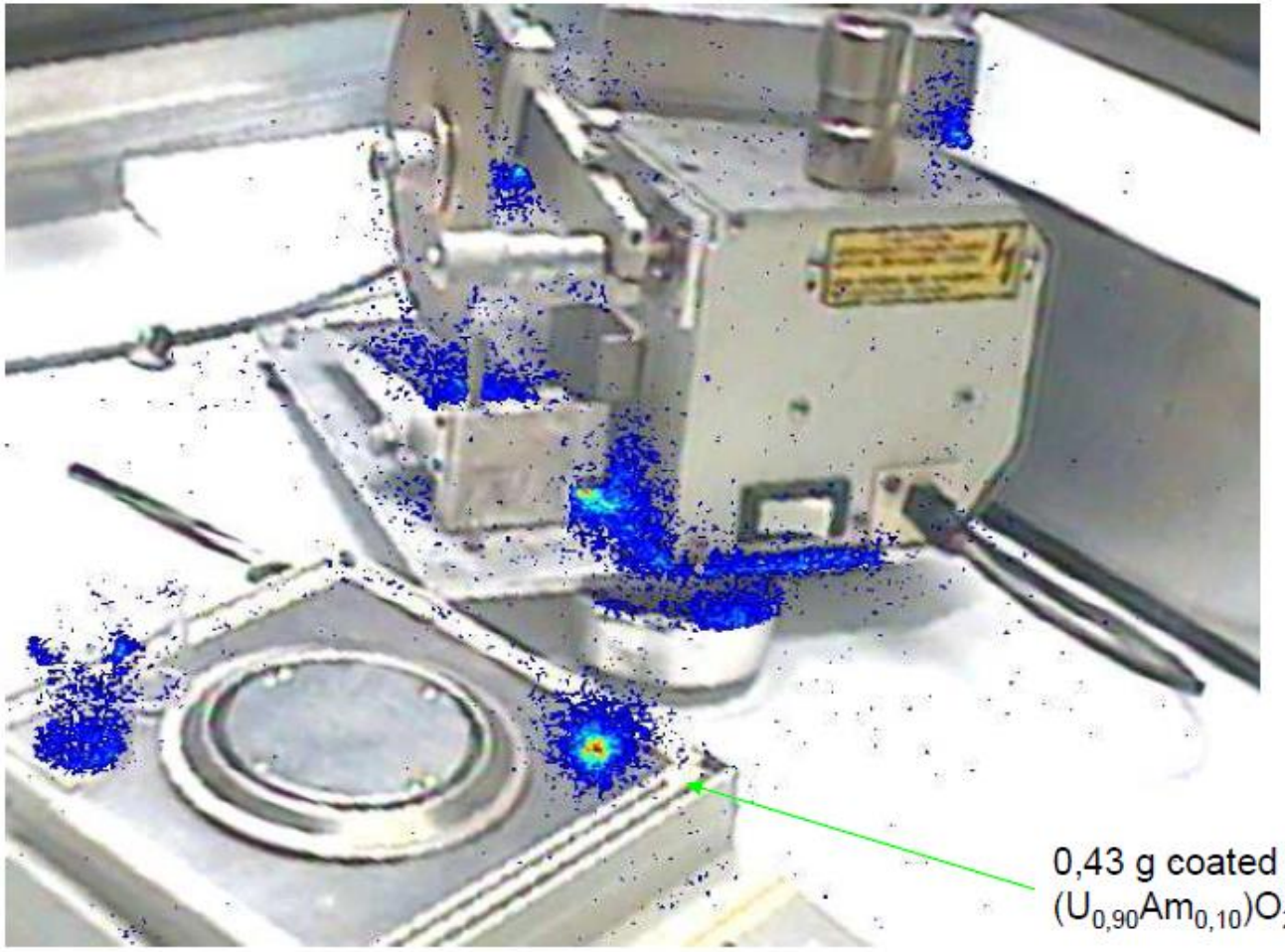
ALPHA CAMERA FEEDBACK

Raw image processed and superimposed on the B&W image



ALPHA CAMERA FEEDBACK

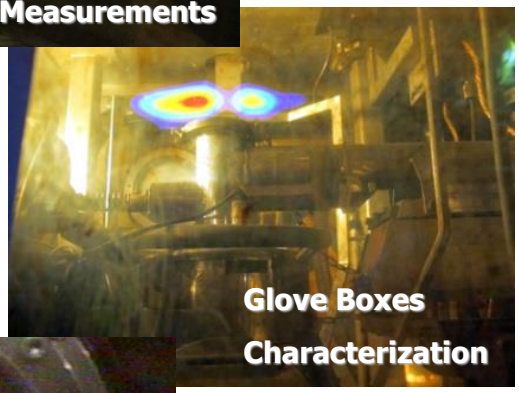
*Raw image processed and superimposed on the **colour** image*

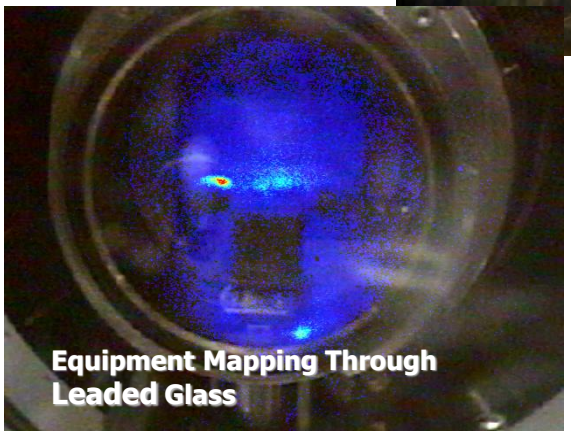


Atalante, 2009, december : Glove box

ALPHA CAMERA : A RECENT CAMERA TO LOCALIZE ALPHA CONTAMINATION

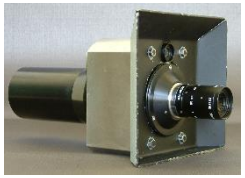
Surface Alpha Contamination Mapping in Darkness Conditions



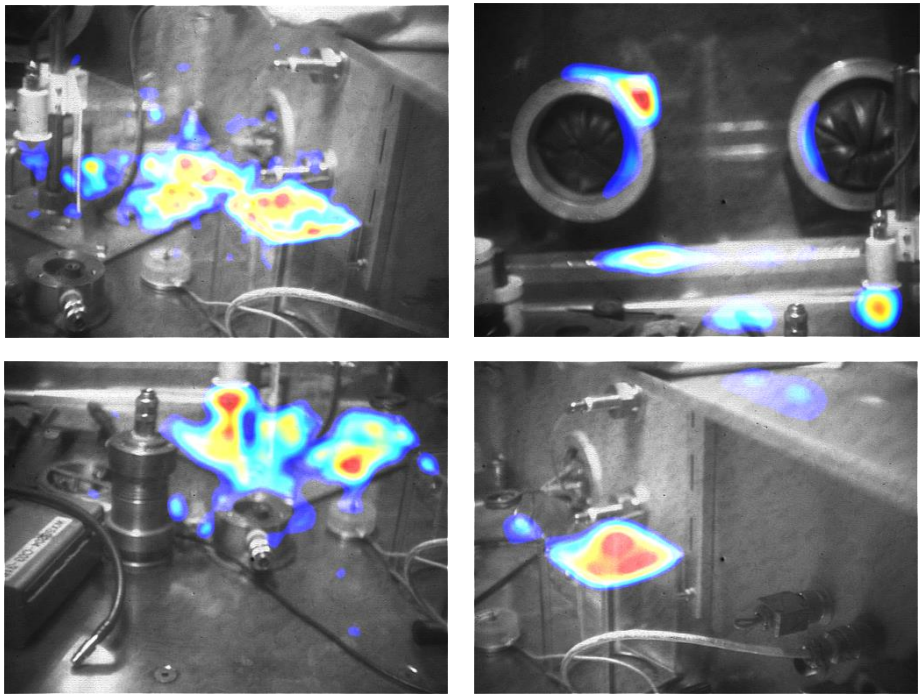


INTEREST OF COUPLING ALPHA AND GAMMA MEASUREMENTS

Example Of A Glove Box Characterization using Alpha Camera and IPIX Gamma Camera, 2016



Surface Alpha Contamination

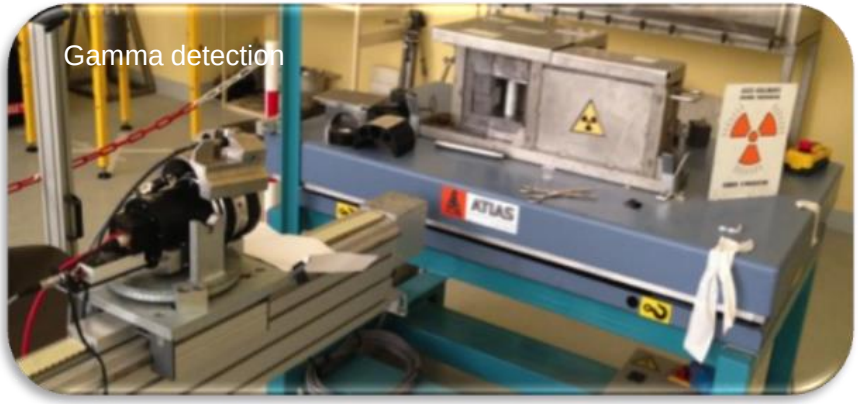


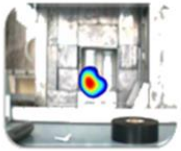
Gamma Main Hot Spot localization (Dose<10μGy.h^{-1})

IPix™

(CEA/MIRION)

DEVELOPMENT OF A DUAL ALPHA / GAMMA CAMERA





2017

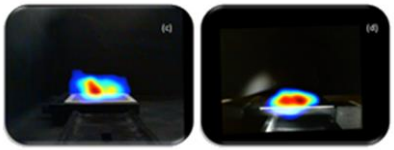
Dual Alpha/Gamma Camera (3rd prototype)

- Still under development and qualification
- Patented still 2015
- Detection of main gamma hot spots

2015

Solar Blind Alpha Camera (2nd prototype)

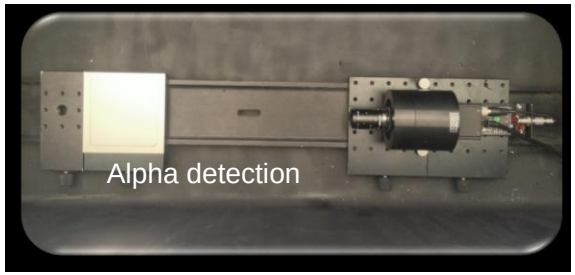
- Reduced influence of the light
- Good sensitivity to UV for high contaminated area
- Enhanced Connectivity (ethernet)



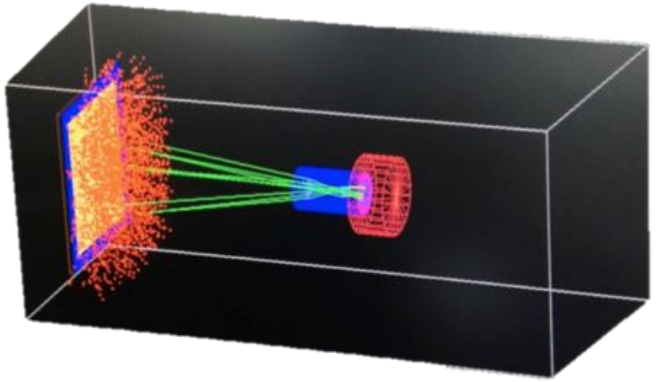
Standard Alpha Camera (1st prototype)

- Darkness condition
- Very good sensitivity to UV
- **Detection Limit : Act > 100 Bq.cm^{-2} (5 min)**

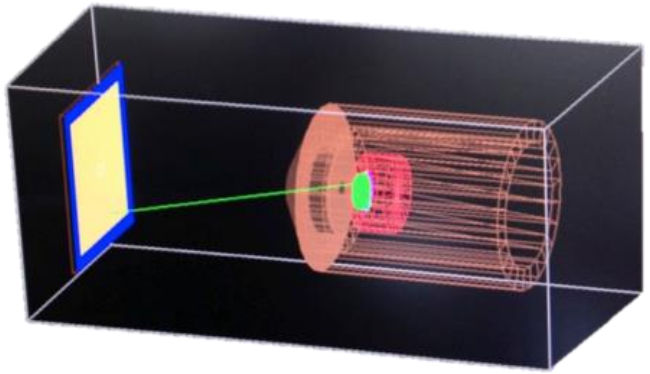
2010



DEVELOPMENT OF A DUAL ALPHA / GAMMA CAMERA

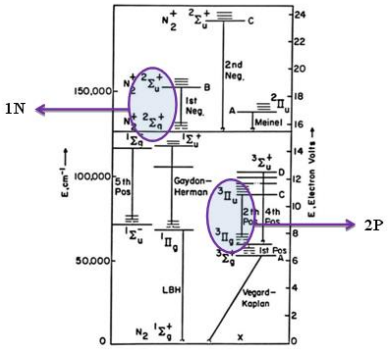


Alpha Camera mode



Gamma Camera mode

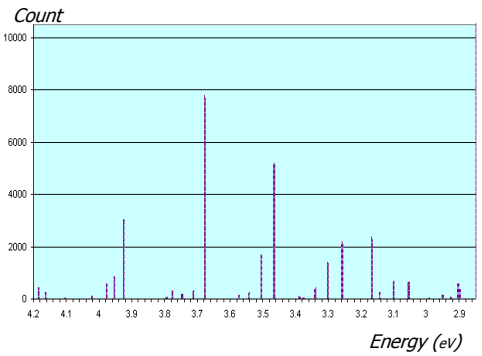
GEANT 4 Modeling of collection of Scintillation Photons from radio-luminescence trhough a UV objectif (left) and scintillations photons from gamma->photons conversion using a CsI scintillator and a pinhole collimator (right)



Direct UV integration

Simulated spectrum of photons

(0.913 bars, T= 20°C)



Scintillator	Density ($g.cm^{-3}$)	λ_{max} (nm)	Ph/keV$_\gamma$
$CdWO_4$	7,9	475	12 – 15
$Bi_4Ge_3O_{12}$	7,13	480	8 – 10
$Lu_{1.8}Y_{0,2}SiO_5$:Ce	7,1	420	32
CsI : Tl	4,51	550	54
BaF_2	4,88	310	10

Scintillation photons integration

DEVELOPMENT OF A DUAL ALPHA / GAMMA CAMERA

Use of the AIRFLY (AIR FLuorescence Yield) collaboration [1]

$$Y_{air}(\lambda,p,T,p_h) = Y_{air}(337nm,p_0,T_0,0).I(\lambda,p_0,T_0) * \frac{1+p_0*(\frac{1}{p'_{air}(\lambda,T_0)}*\left(1-\frac{p_h}{p}\right)+\frac{1}{p'_{H_2O}(\lambda)}*\frac{p_h}{p})}{1+\frac{p}{(\frac{T}{T_0})^{\alpha(\lambda)+0,5}}*(\frac{1}{p'_{air}(\lambda,T_0)}*\left(1-\frac{p_h}{p}\right)+\frac{1}{p'_{H_2O}(\lambda)}*\frac{p_h}{p})}$$

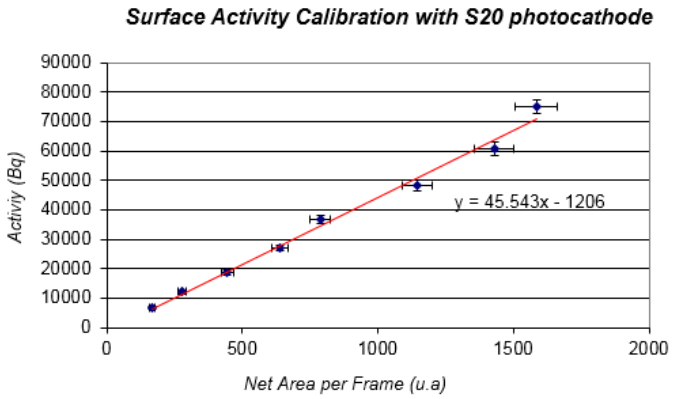
Parametric study (température, pression, humidity in air, …)

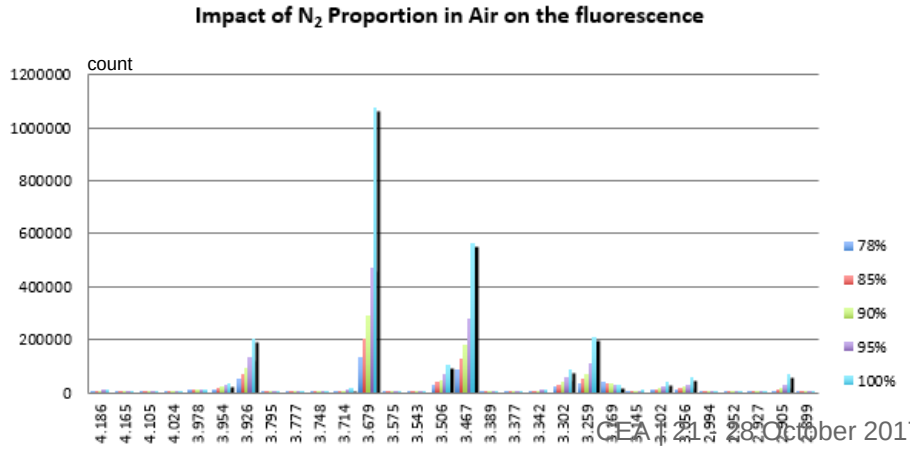
Simulation of fluorescence photons spectrum

Geometrical Efficiency

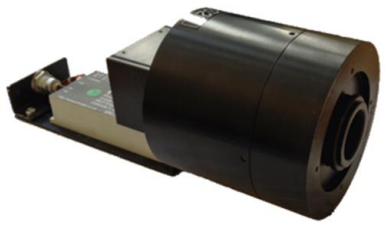
Calibration Factors

Y : Champ de scintillation
I : Intensité relative
p_0 : Pression de référence (1 bar)
T_0 : Température de référence (273°K)
p : Pression de l'environnement
T : Température de l'environnement
p_h : Pression partielle en eau
λ : Longueur d'onde de la raie d'émission
p'_{air} (λ) : paramètre de pression lié à la raie λ
p'_{H20} (λ) : paramètre de pression en eau lié à la raie λ
α(λ) : paramètre de température lié à la raie λ





DEVELOPMENT OF A DUAL ALPHA / GAMMA CAMERA



Common Architecture

Intensifier tube (optimized)

Optical fiber

CCD

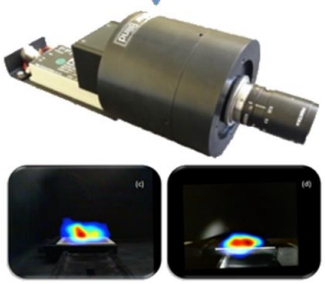
Dual α/γ Detection Head

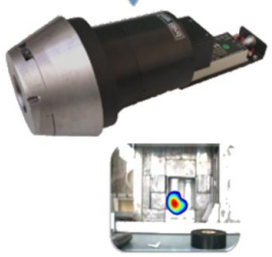
Scintillator + pinhole

Or

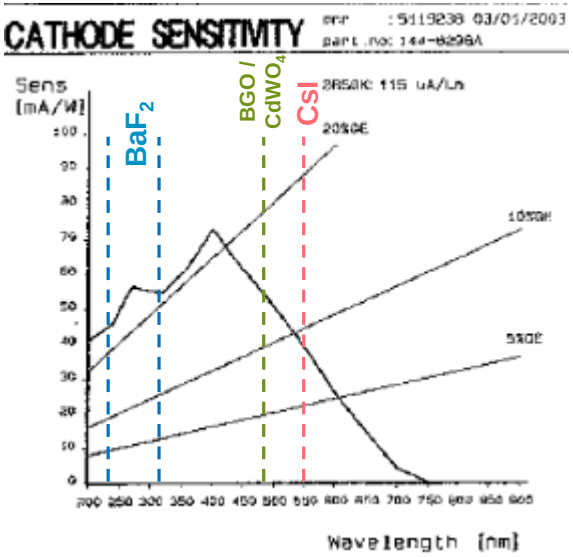
Scintillator + coded mask

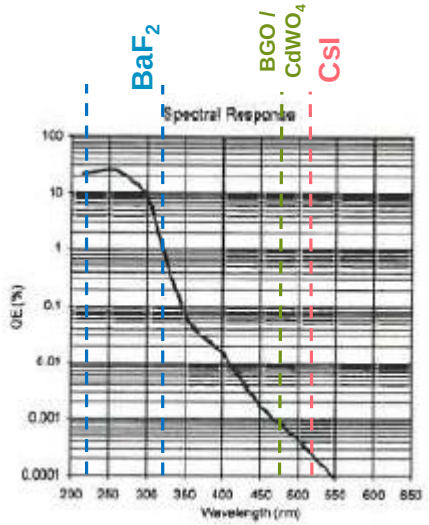
UV lens



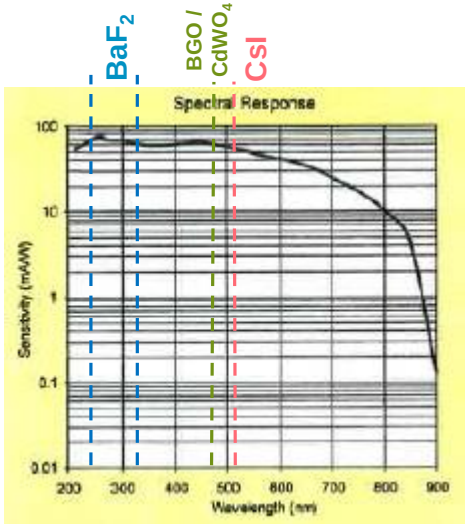


S20





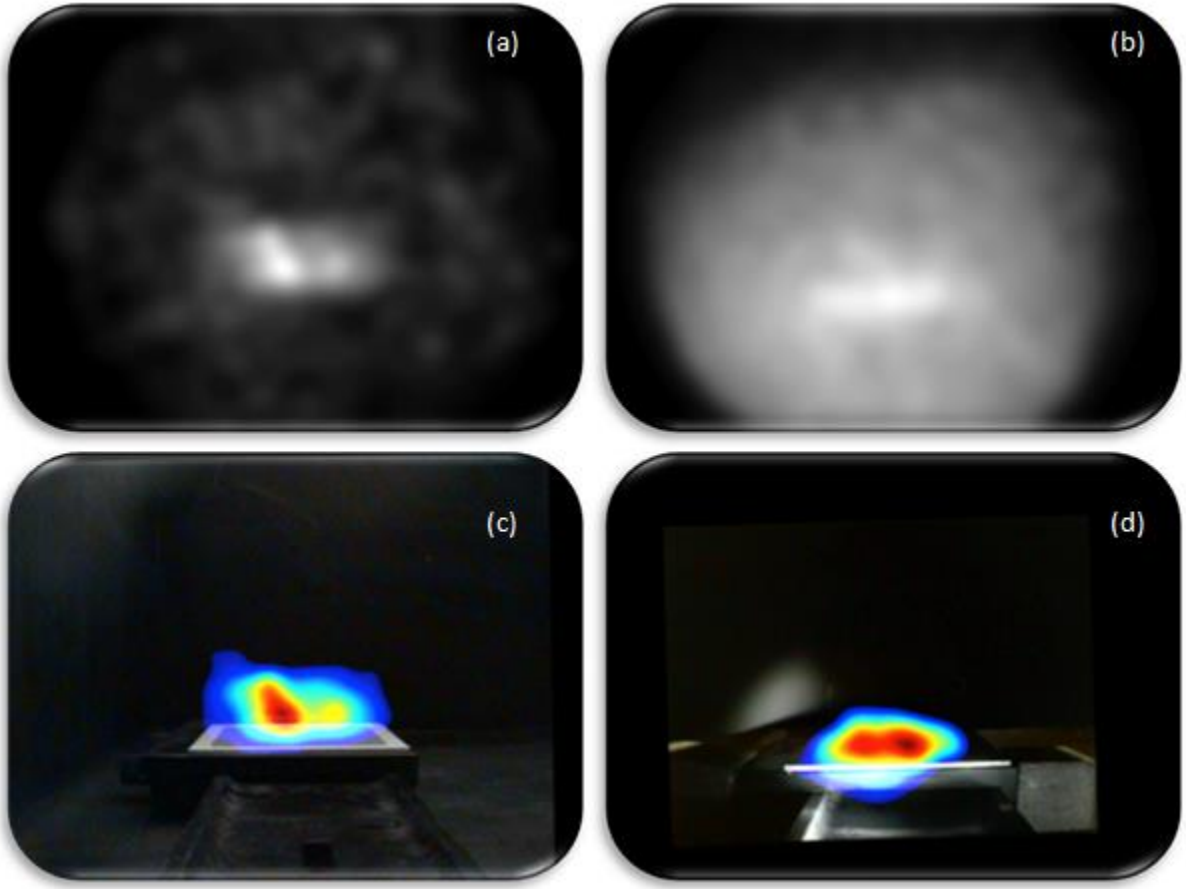
Solar Blind



S20 « Low-Noise »

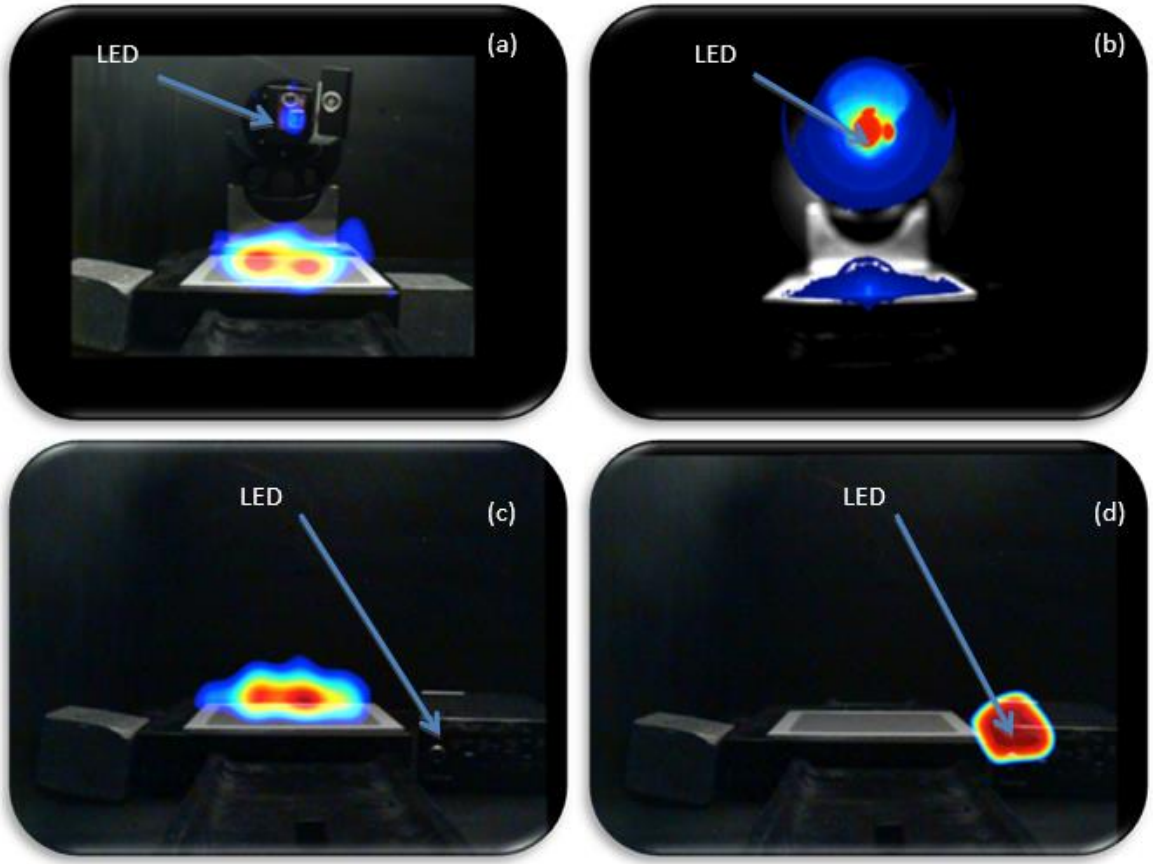
Image Intensifier Tubes Comparison

Alpha / UV Mode



(a, b) Raw Alpha/UV Images with FFT filtering (a : Solar Blind, b : Low-Noise S20)
(c, d) Final superimposition on visble image (c : Solar Blind, d : Low-Noise S20)

Alpha / UV Mode with 550 nm LED-Light Pollution

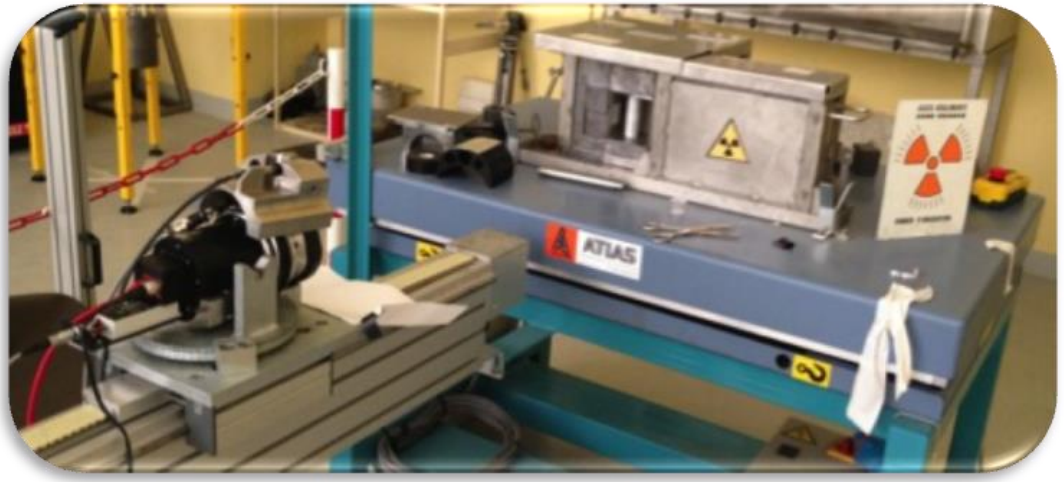


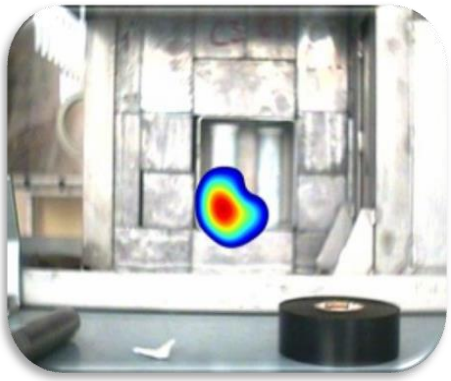
(a, b) Raw Alpha/UV Images with FFT filtering (a : Solar Blind, b : Low-Noise S20)
(c, d) Final superimposition on visible image (c : Solar Blind, d : Low-Noise S20)

Gamma Mode with ^{137}Cs and ^{60}Co sources

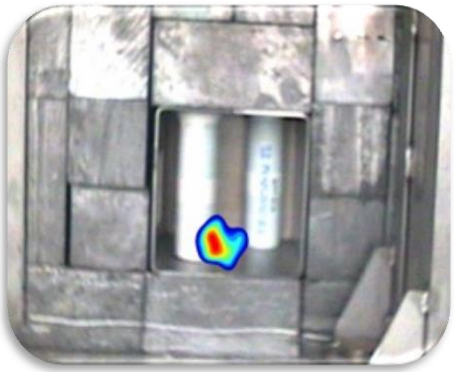
Distance between cameras and gamma sources : 1 meter

Several configurations tested with S20/SB intensifier tubes, scintillators and existing pinholes in DENAL®





Low-Noise S20 + BGO
1000 frames



Solar Blind + BaF2 (λ=220 nm & 310 nm)
1000 frames

View of tubes equiped with ALADIN pinhole and 25 mm diameter scintillator

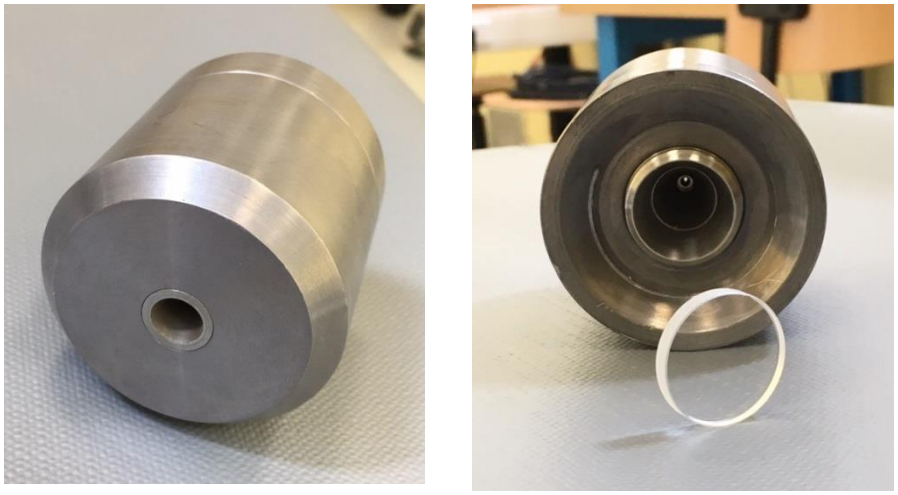
Scintillators : summary of results

Gamma Detection and localization				
Scintillator	**Density ($g.cm^{-3}$)**	**Scintillation Wavelenght (nm)**	**LNS20**	**SB**
$CdWO_4$	7,9	475	✓	✗
BGO	7,13	480	✓	✗
LYSO	7,1	420	✗	✗
CsI : Tl	4,51	550	✓	✗
BaF_2	4,88	220, 310	✓	✓

Gamma Sensitivity	
Scintillator & tube	**Relative Sensitivity (%)**
LNS20+$CdWO_4$	100
SB+BaF_2	72
LNS20+BaF_2	38
BGO+LNS20	32
CsI+LNS20	8,5

CONCLUSION

- **Alpha Camera** based on a S20 photocathode (25 mm) is under industrialization process
- A new pinhole has been designed to fit with the S20 (25 mm) tube
- Scintillators (d=25 mm, e=4mm) of $CdWO_4$, BGO and BaF_2 are considered
- The design of the peripheral shielding is under progress



View of the scintillator and the new pinhole design

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Thanks for your attention

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