Imagerie CT spectrale avec le XPAD3.2/AsGa sur le PIXSCAN-FLI

CT Spectral Imaging with the XPAD3.2/GaAs sensor on the PIXSCAN-FLI

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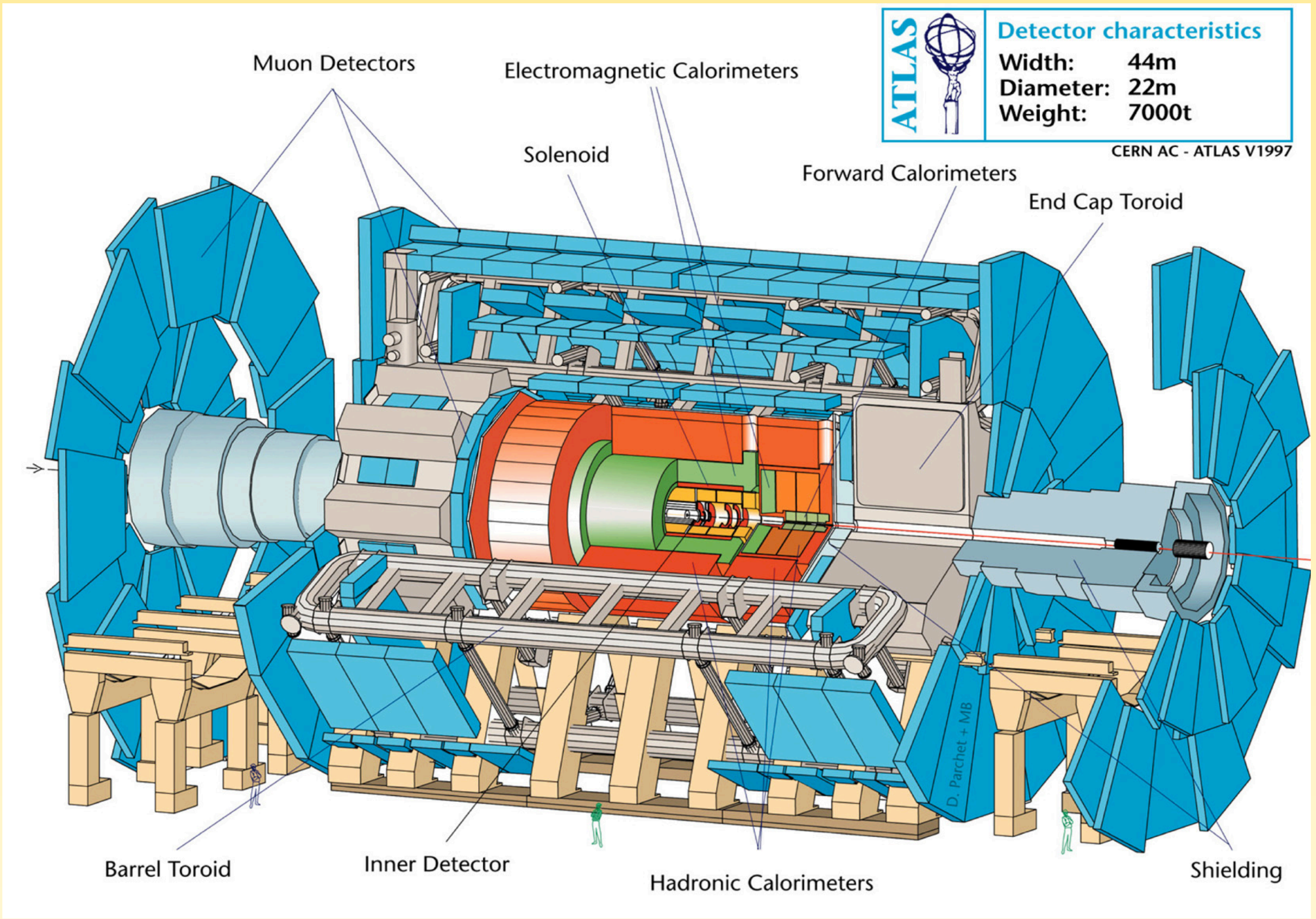
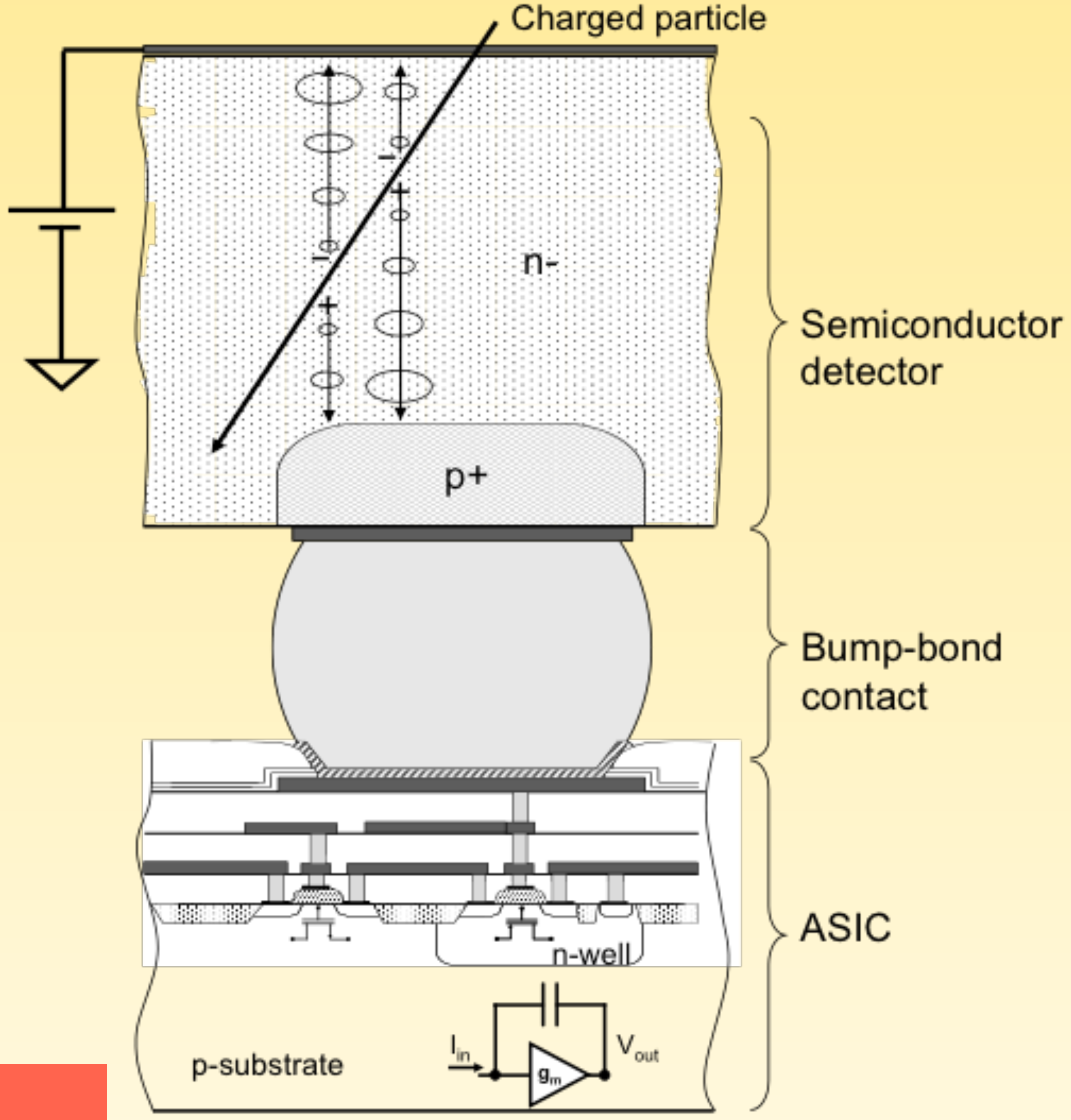
La photodétection avec les semi-conducteurs
LPSC, Grenoble – 4 juin 2024

Hybrid pixel : a technological breakthrough





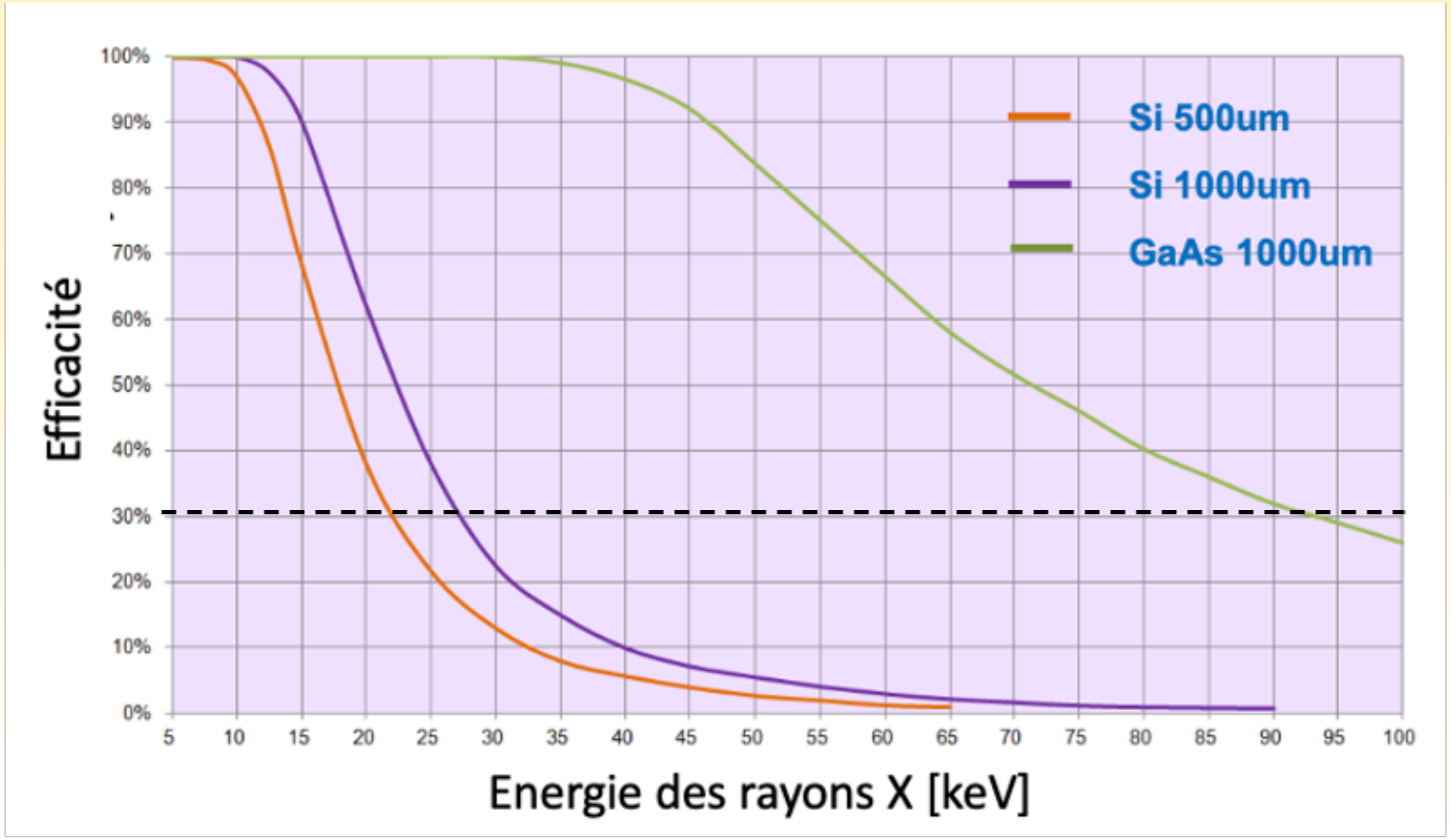
Photon Counting mode

- Dark noise suppression
- Large dynamic range
- Fast acquisition
- Energy selection

* Dose reduction
* Contrast enhancement
* Slow motion
* Spectral CT development

XPAD3 detectors

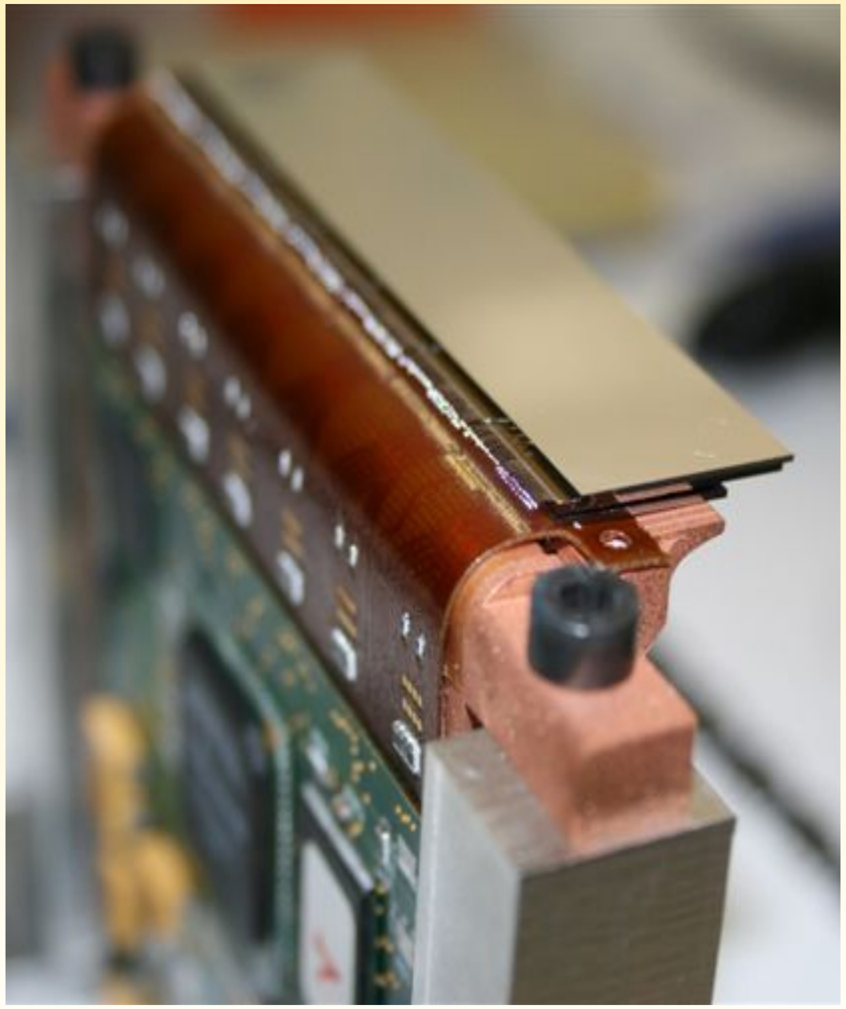
	Silicium Pixels	GaAs Pixels
Sensor thickness	500 µm	1000 µm
Chip	XPAD3.2-S	XPAD3.2-C
Pixel size	130 x 130 µm²	130 x 130 µm²
Pixels per chip	120 x 80	120 x 80
Camera size	8 barrettes of 7 chips	1 chip
Detection surface	124.8 x 72.8 mm²	15.6 x 10.4 mm²
Efficacity > 30 %	Up to 22 keV	Up to 93 keV

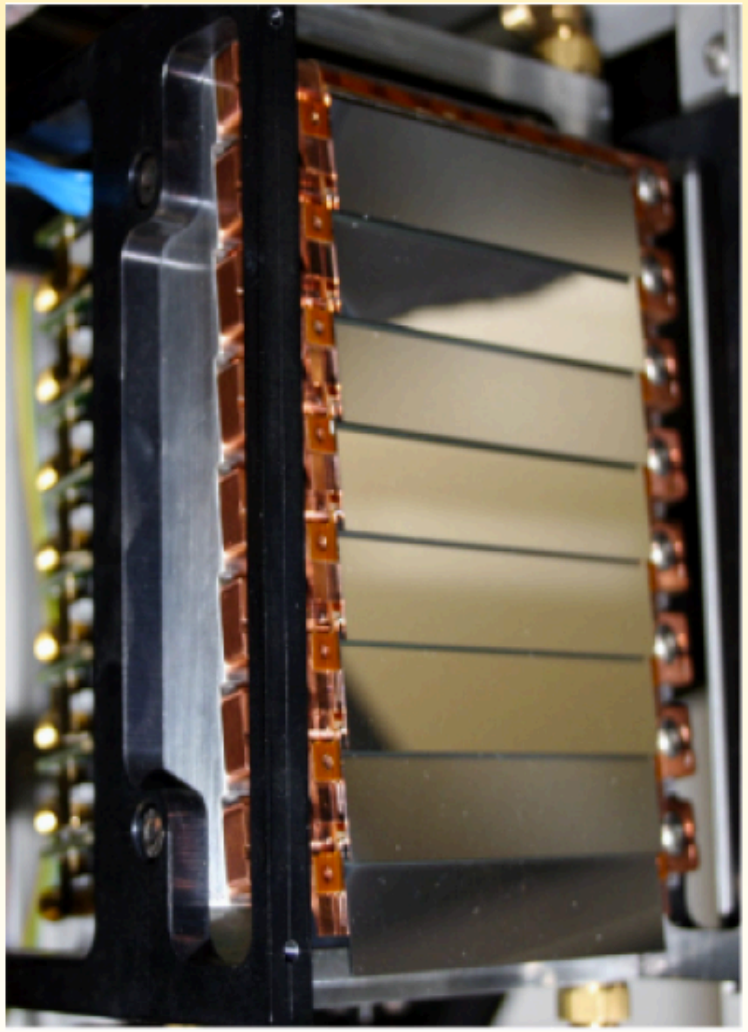


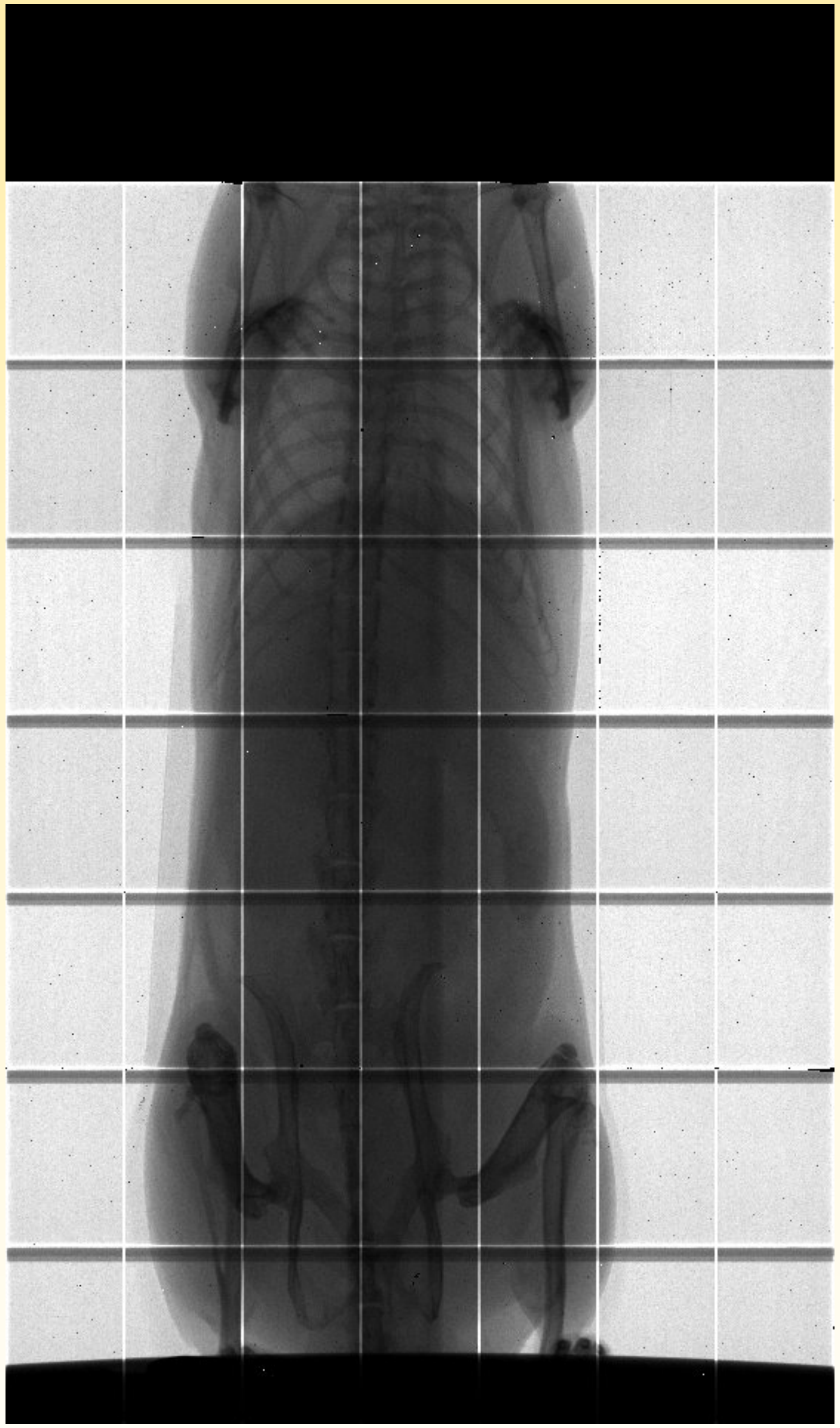
The XPAD3/Si camera

New hybrid pixel camera for X-rays XPAD3/Si designed for in-vivo imaging

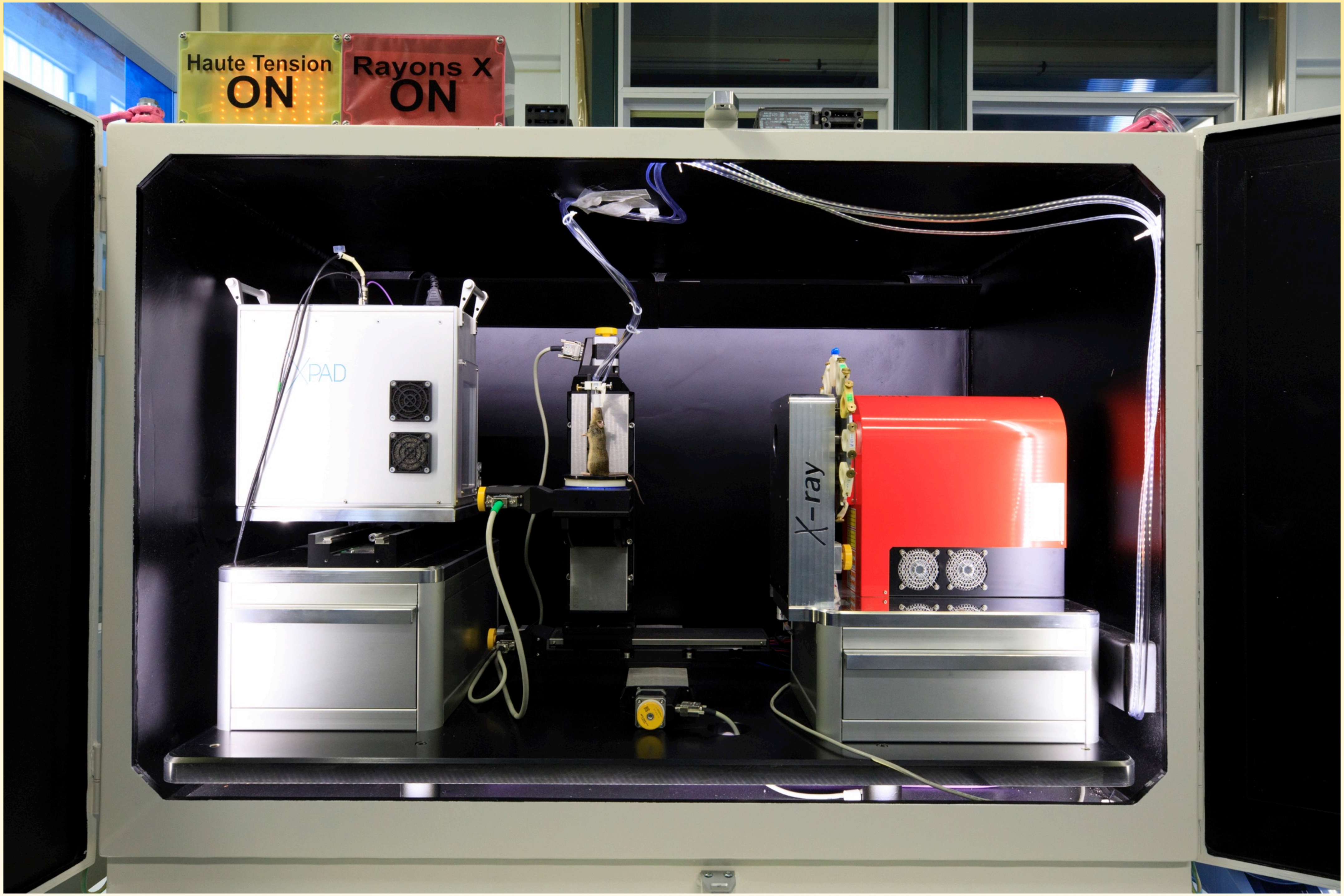
- 125 x 75 mm^2: detector size
- 560 x 960 pixels
- Fast readout and data transfer : up to 240 frames/s (optical fibre and PCIExpress)







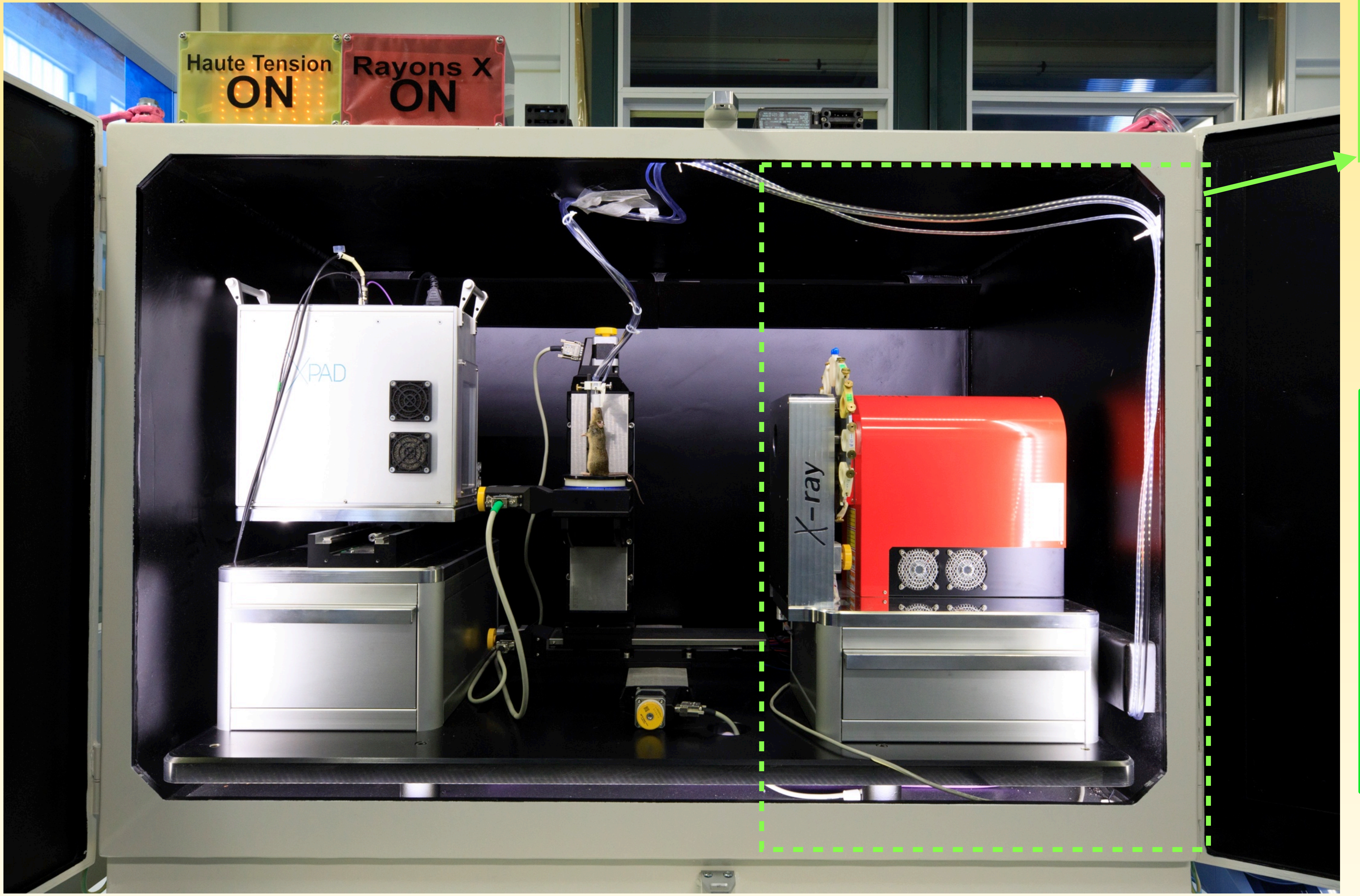
PIXSCAN-FLI



FLi
France Life Imaging

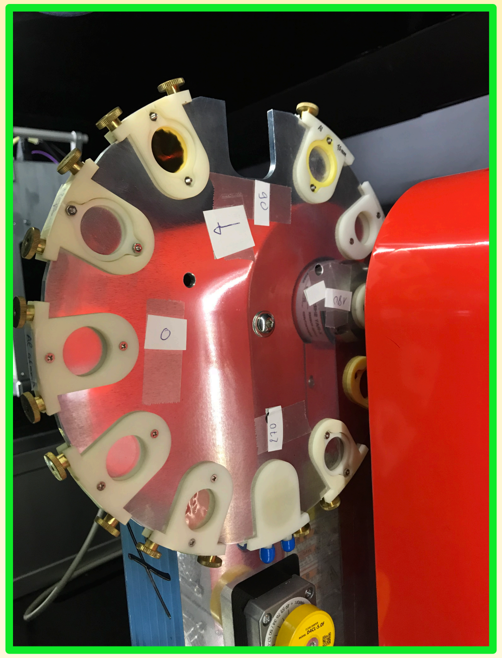
canceropôle
Provence-Alpes-Côte d'azur
le propulseur régional des recherches et innovations anticancers

PIXSCAN-FLI



Source block

W anode (150 kVp)
Wheel filters



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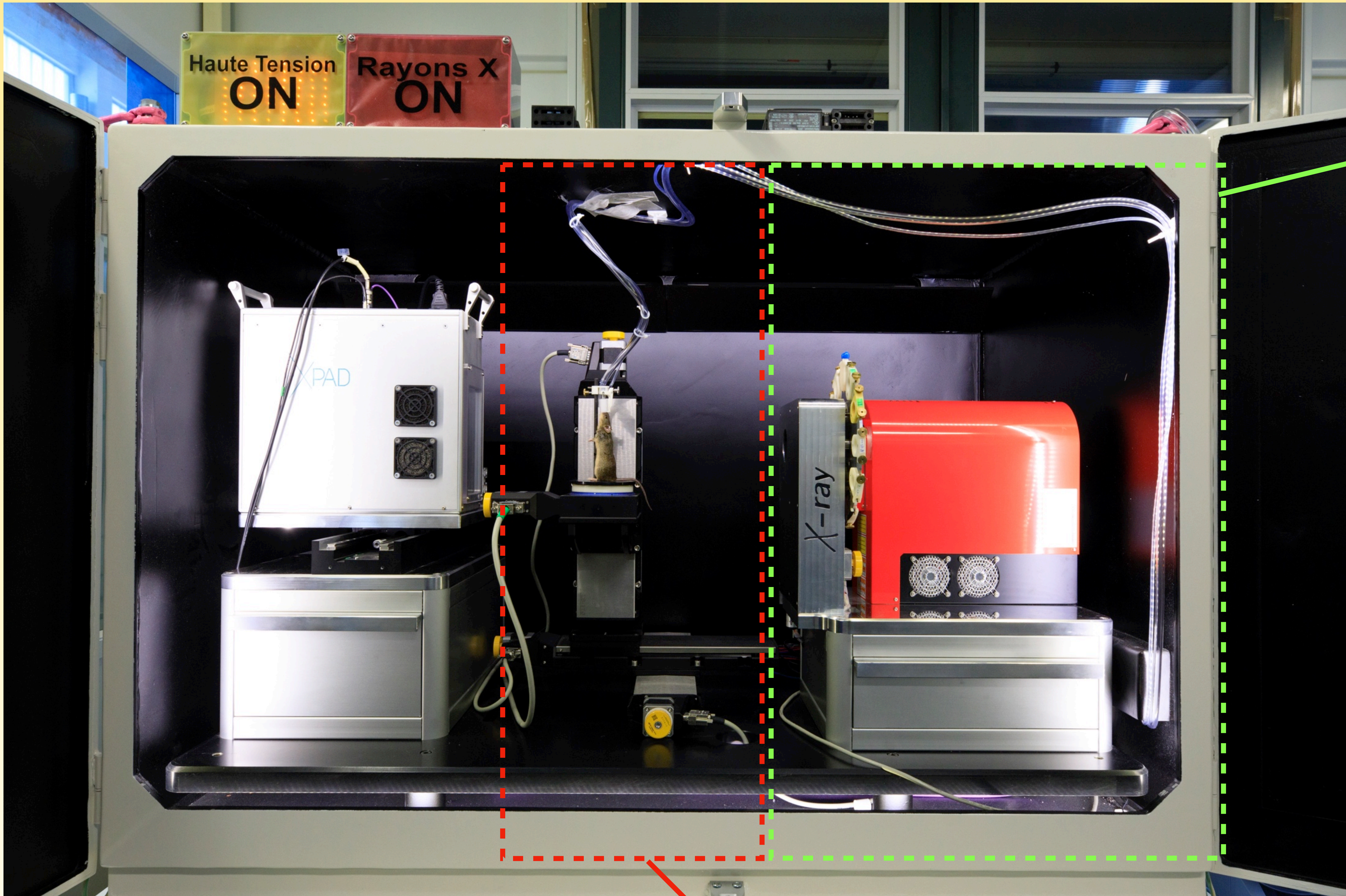


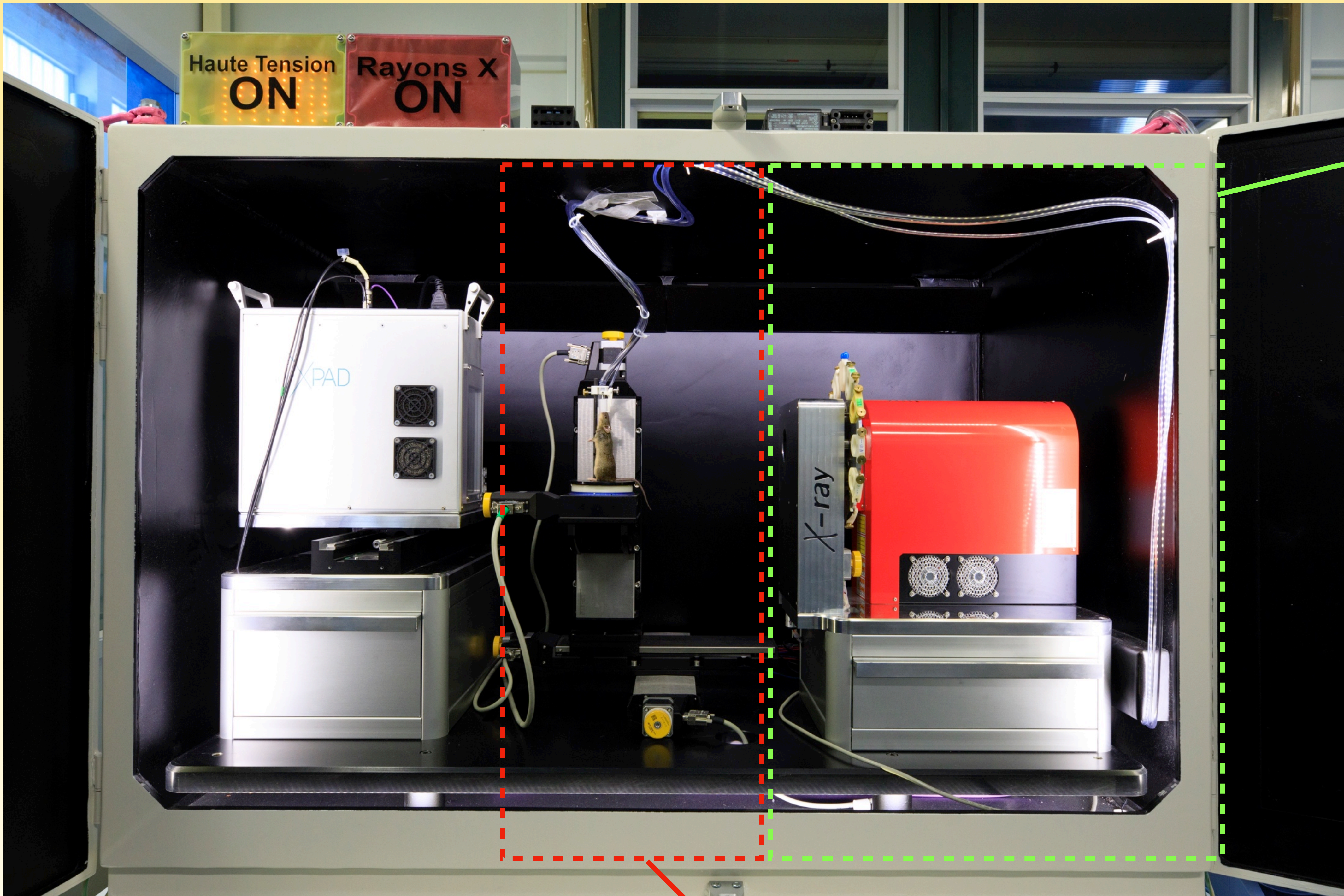
Source block

W anode (150 kVp)
Wheel filters

Animal block

Vertical rotation axis
Acquisition mode: shoot and step or continuous rotation
Gas anesthesia: isoflurane

PIXSCAN-FLI



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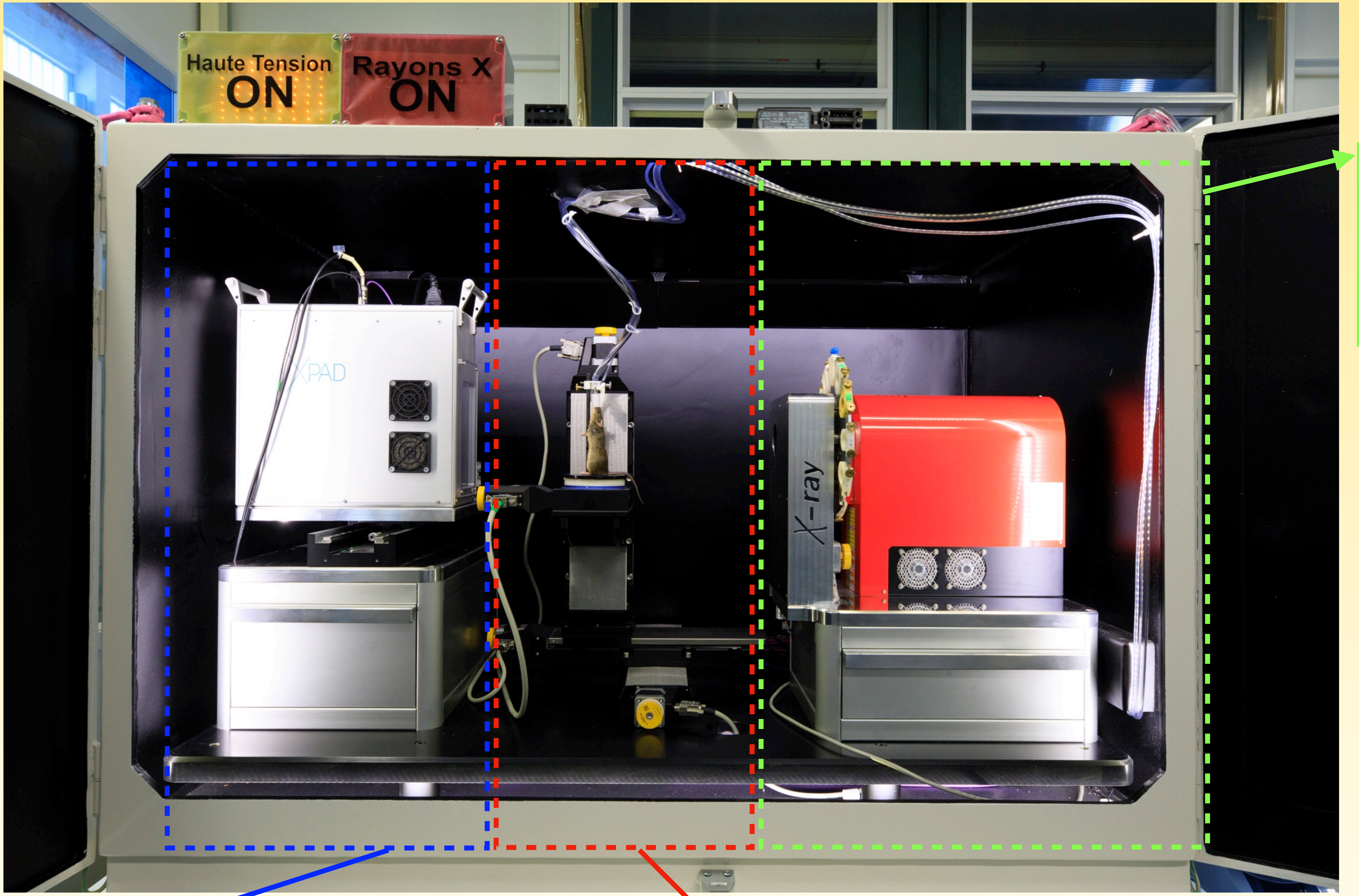

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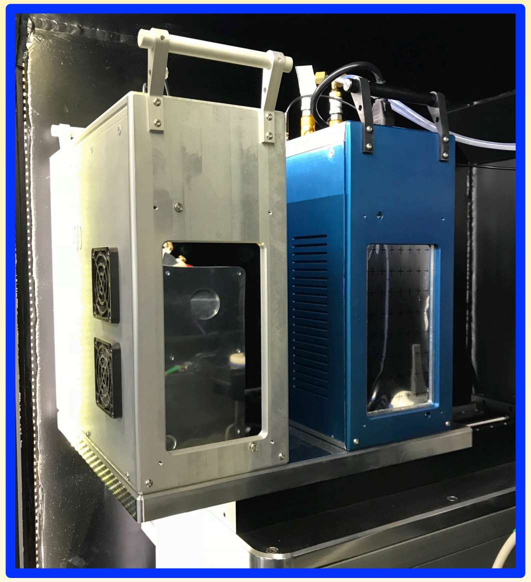


Detector block

Two cameras
Resolution of 50 - 85 µm/voxel

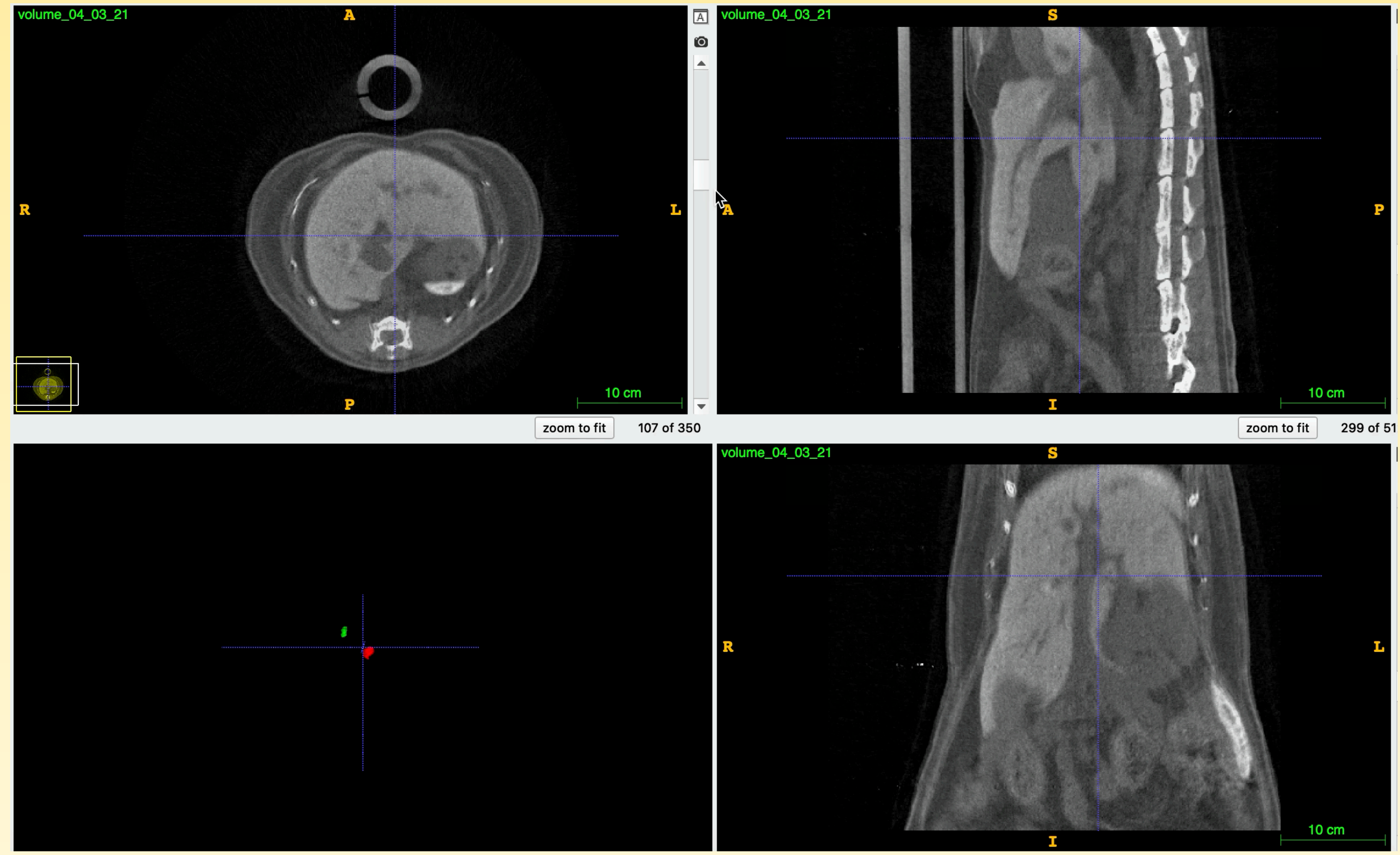
Animal block

Vertical rotation axis
Acquisition mode: shoot and step or continuous rotation
Gas anesthesia: isoflurane

XPAD3 detectors for in vivo imaging

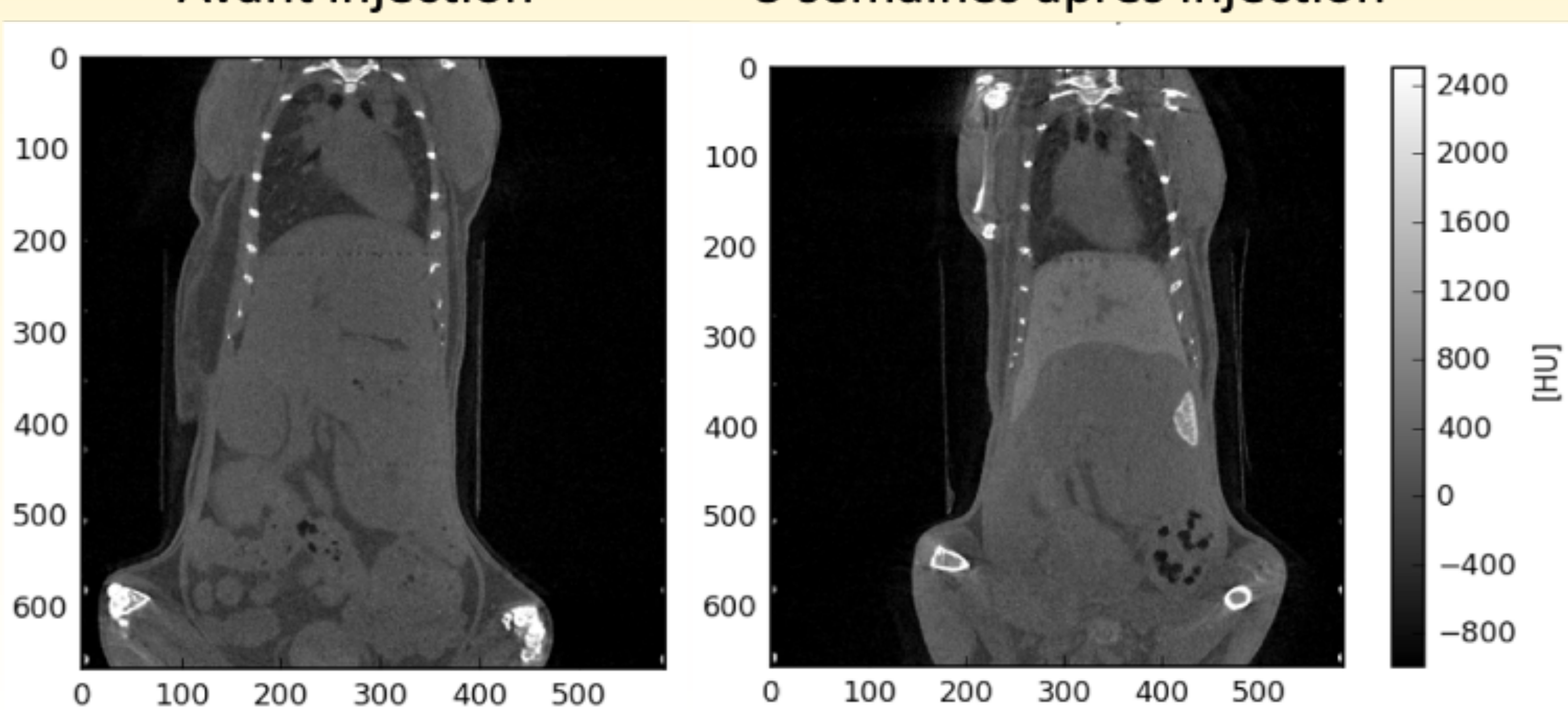
Photon Couting CT (PC-CT) imaging

- 50 kVp / 500 µA / 0.6 mm Al
- Exposure time per projection : 198 ms
- 1440 projections
- 110 mGy/scan
- Hepato-specific contrast agent (ExiTron nano 12000®, Barium nanoparticules)



Avant injection

3 semaines après injection



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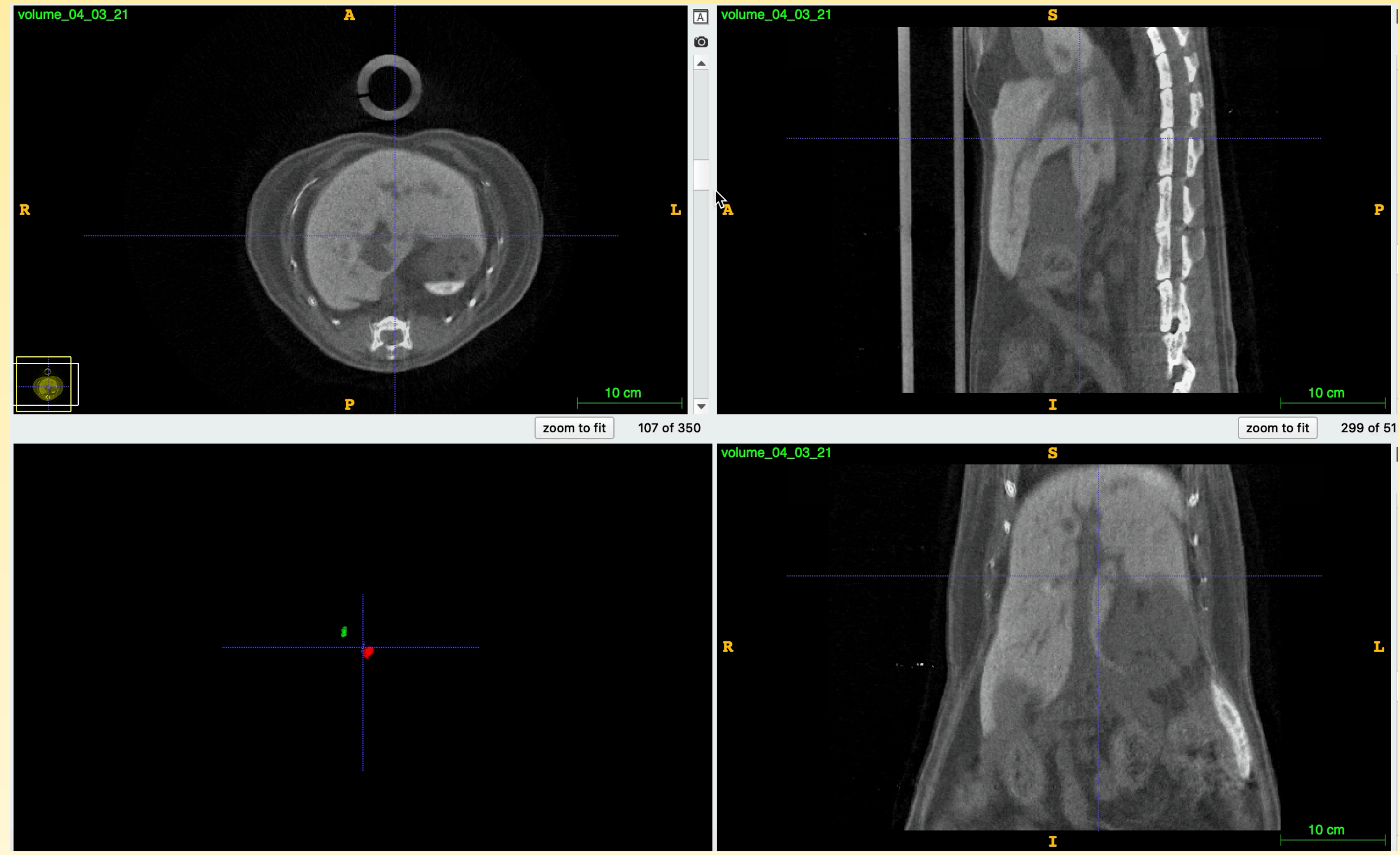

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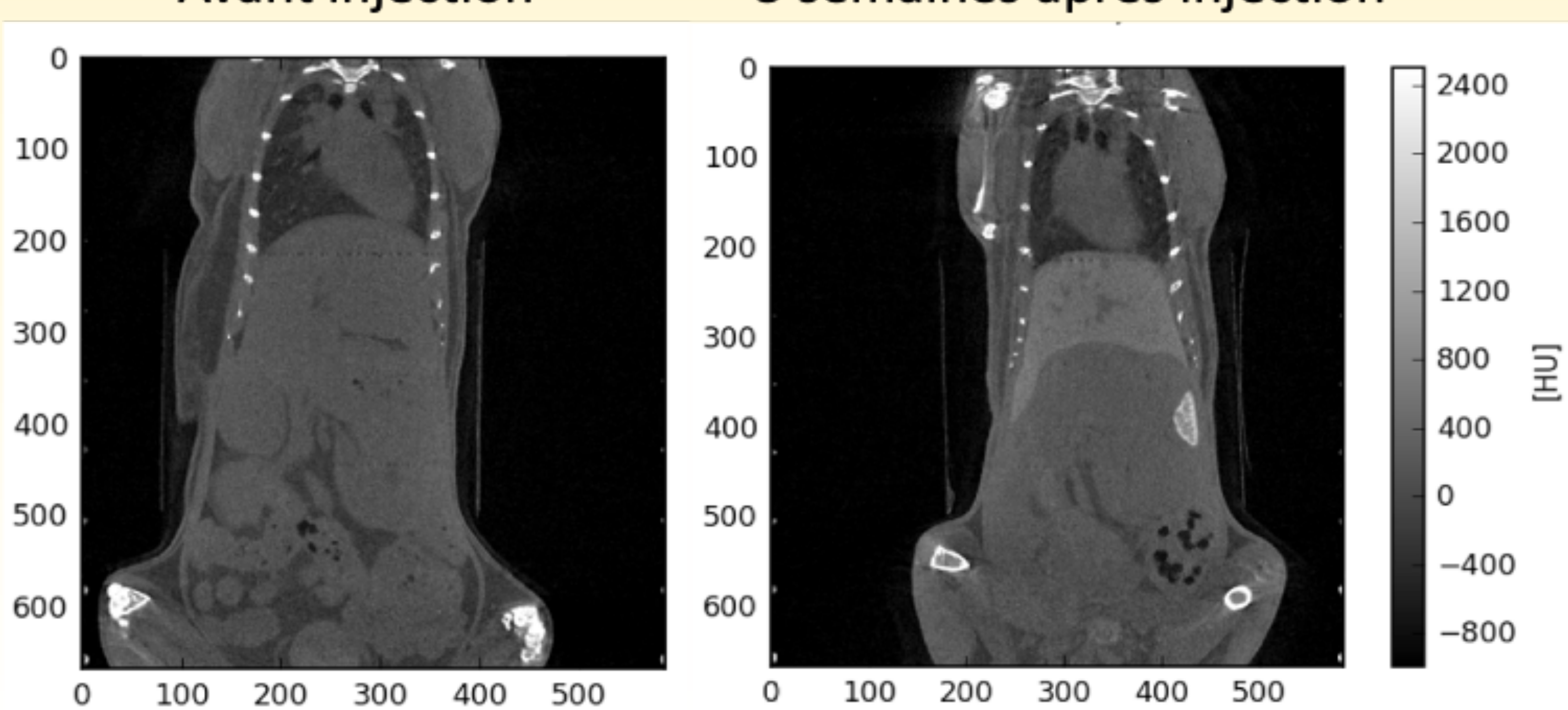

Objectives of the development of spectral imaging

New XPAD3.2-C/AsGa detector:

- Better detection efficiency than silicon
- High-energy operation possible

Contribution to in vivo imaging:

- Functional imaging
- Imaging with multiple contrast agents

Objectives:

Characterizing the detector

Proof of concept for spectral tomography at high energy K-edges

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K-edge: abrupt transition from attenuation coefficient to binding energy of K-layer electron

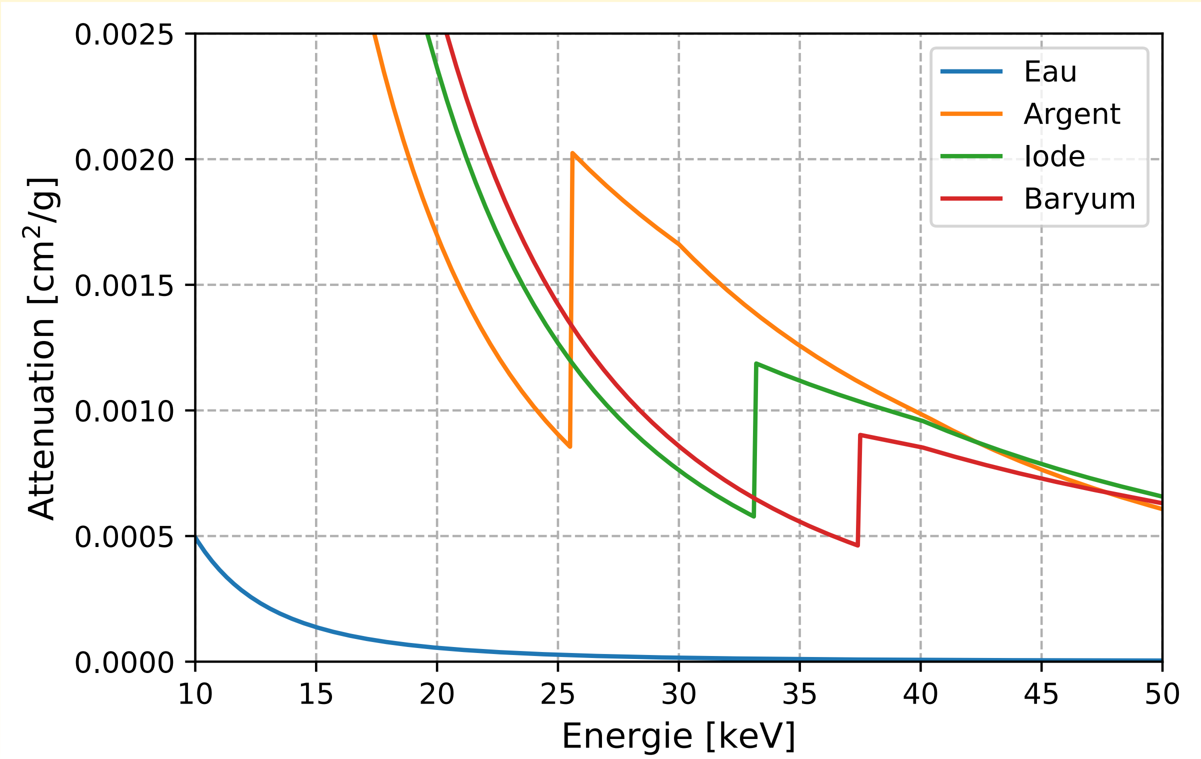
Energy specific to each material

Material	K-edge energy
Silver	25.5 keV
Iodine	33.2 keV
Barium	37.4 keV
Gold	80.7 keV

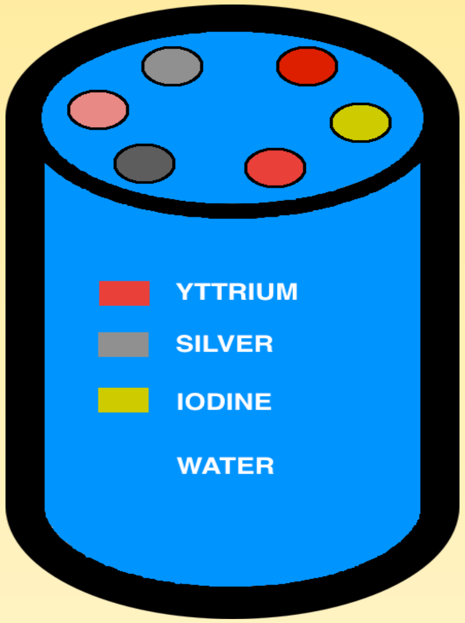
Objectives:

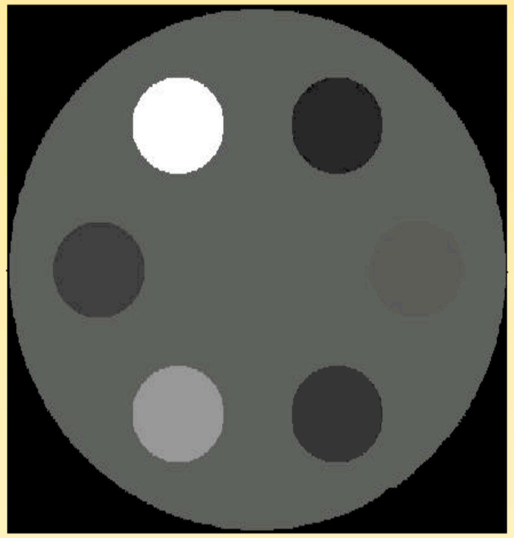
Characterizing the detector

Proof of concept for spectral tomography at high energy K-edges



Expectation and benefits

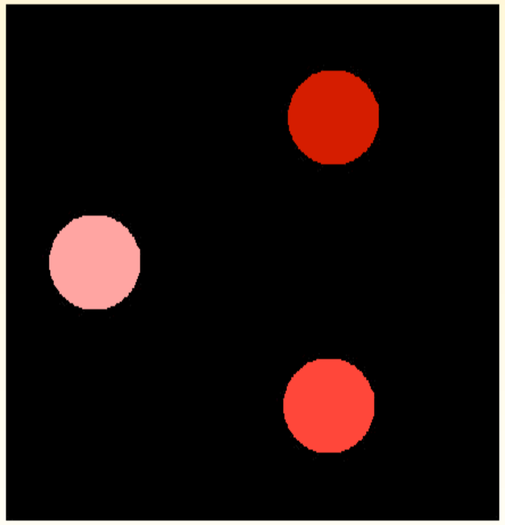




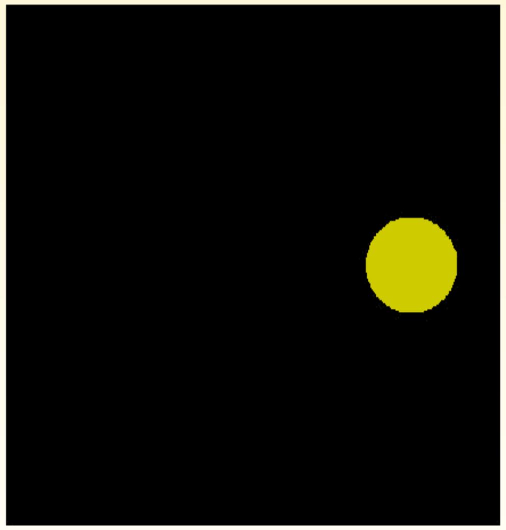
Standard CT:
Low contrast
No identification

Spectral CT:
- Identification of components of interest
- Quantification

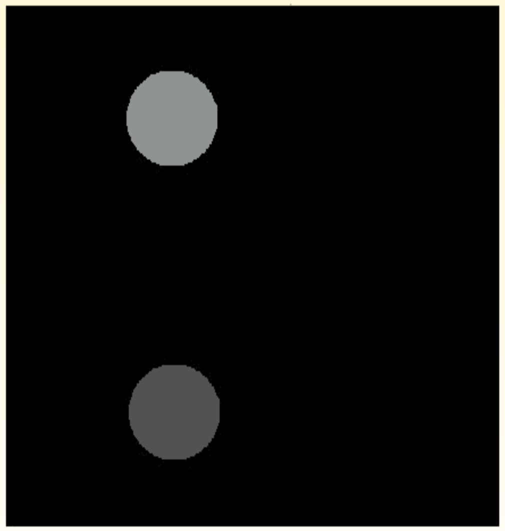
Yttrium



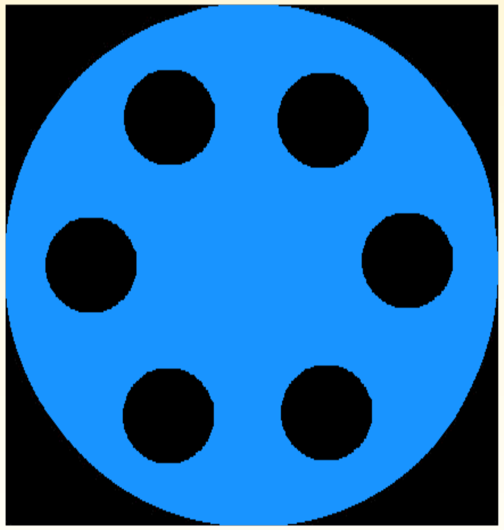
Iodine



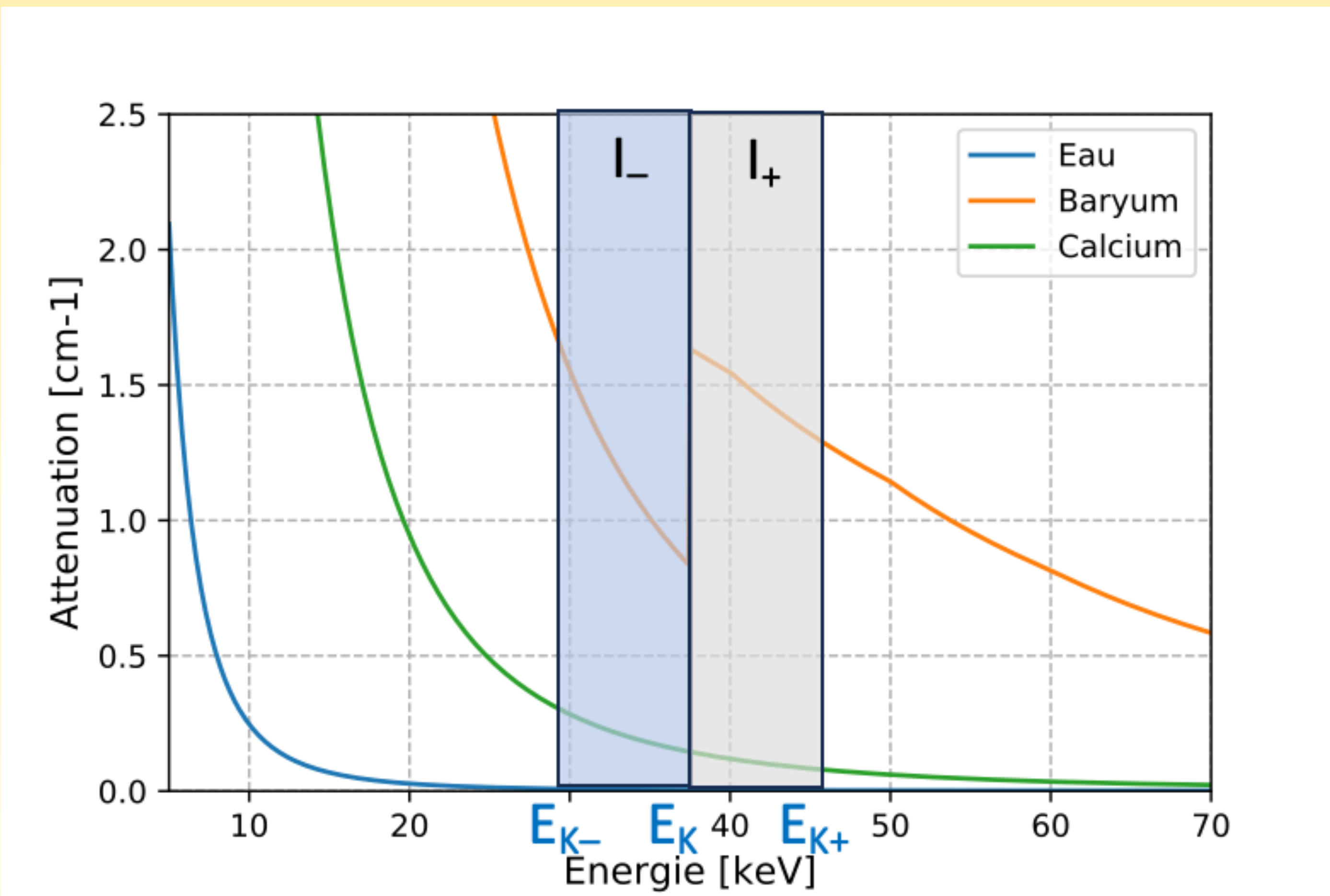
Silver



Water



Development of spectral imaging



Acquisition of images :

- at the energy of K-edge : E_K
- at the energy of K-edge + ΔE : E_{K+}
- at the energy of K-edge – ΔE : E_{K-}

Two energy windows in which photon flux can be estimated:

- $I_- = I[E_{K-}] - I[E_K]$
- $I_+ = I[E_K] - I[E_{K+}]$

$\mu_{spectral}(x) = \mu_+(x) - \mu_-(x)$

➢ $\mu_+(x) > \mu_-(x)$ if it is the material of interest,

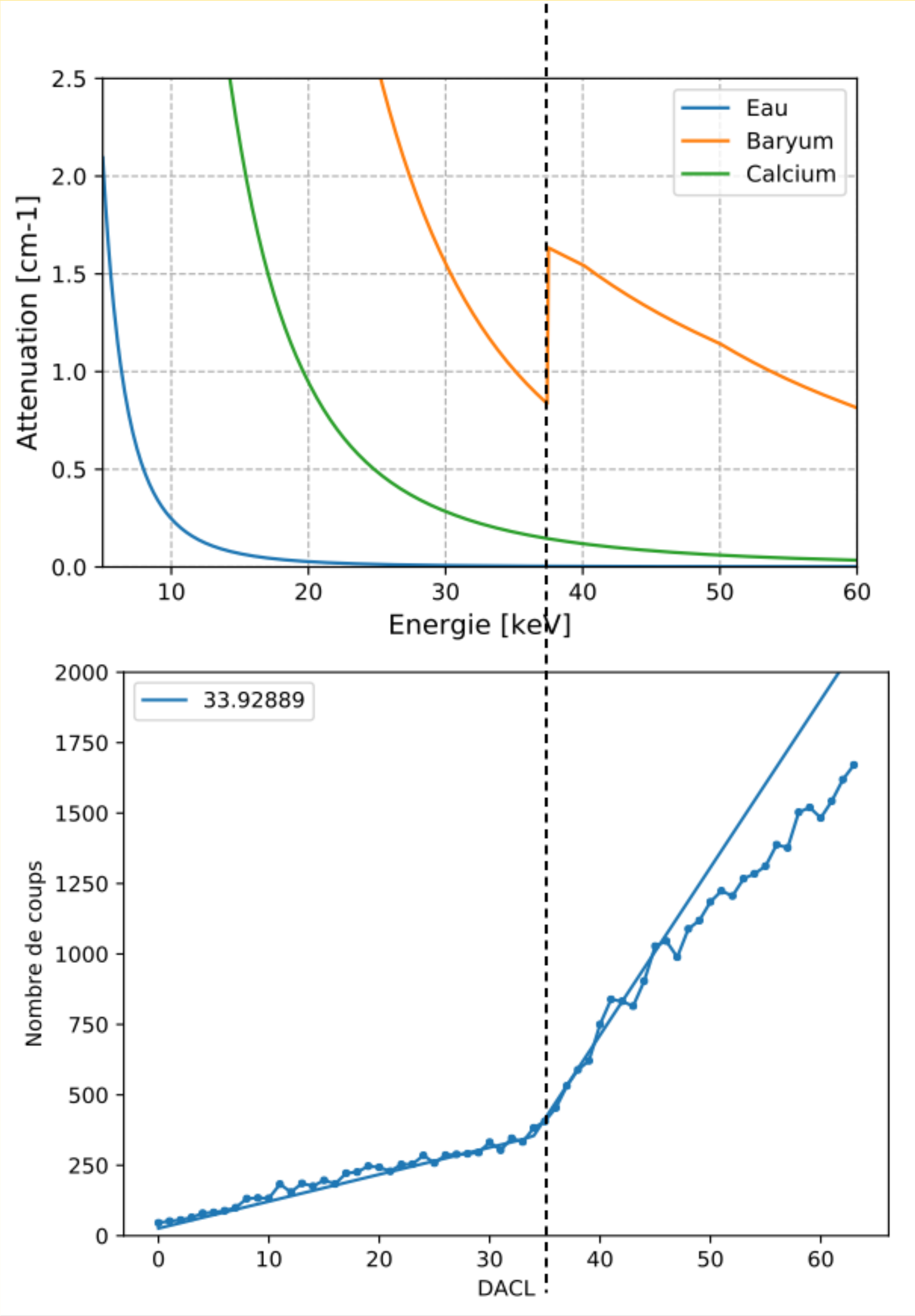
➢ $\mu_+(x) < \mu_-(x)$ otherwise

Development of spectral imaging

Parameters to set the energy threshold :

- ITH
- DACL
- ITUNE

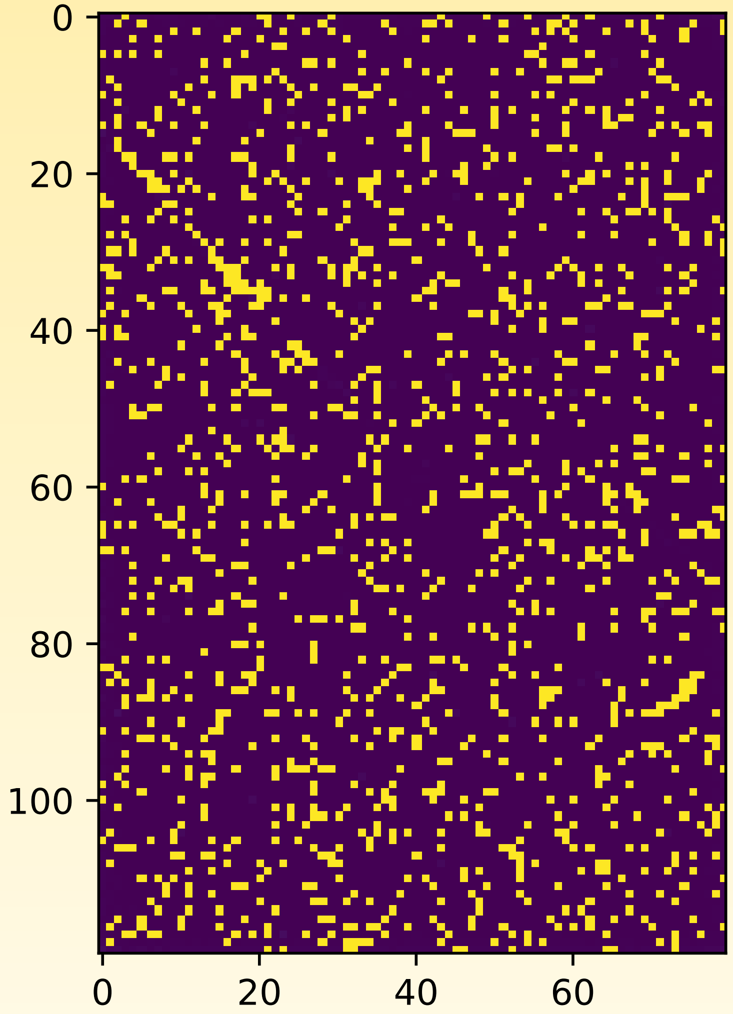
Threshold = (ITH−DACL) × ITUNE

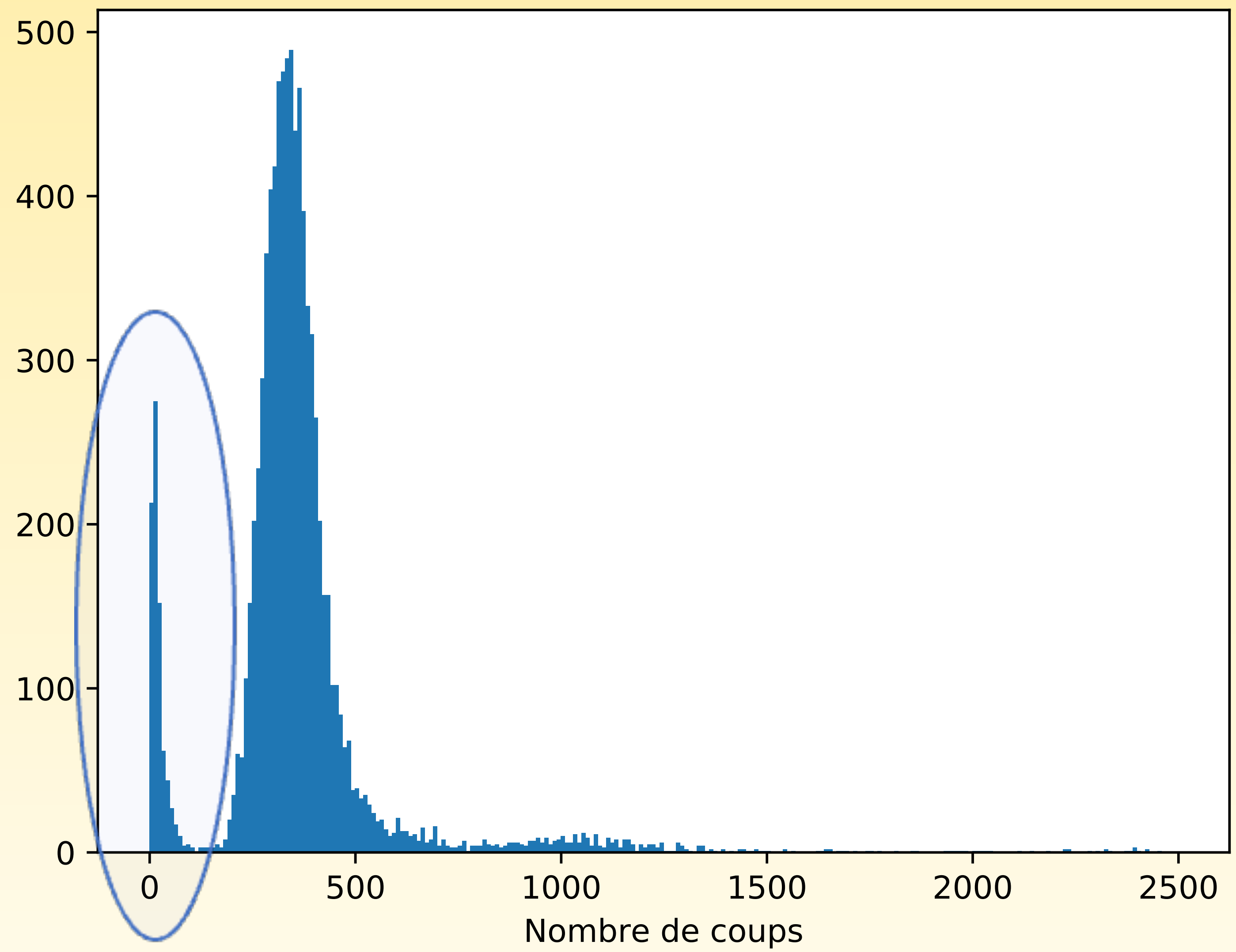


K-edge calibration of a material :

- Using a filter composed of the material to be calibrated
- ITUNE and ITH are set
- Perform DACL scan
- Break = DACL value corresponding to the material's K-edge energy
- Calibrate all pixels
- Take into account uncalibrated or poorly calibrated pixels

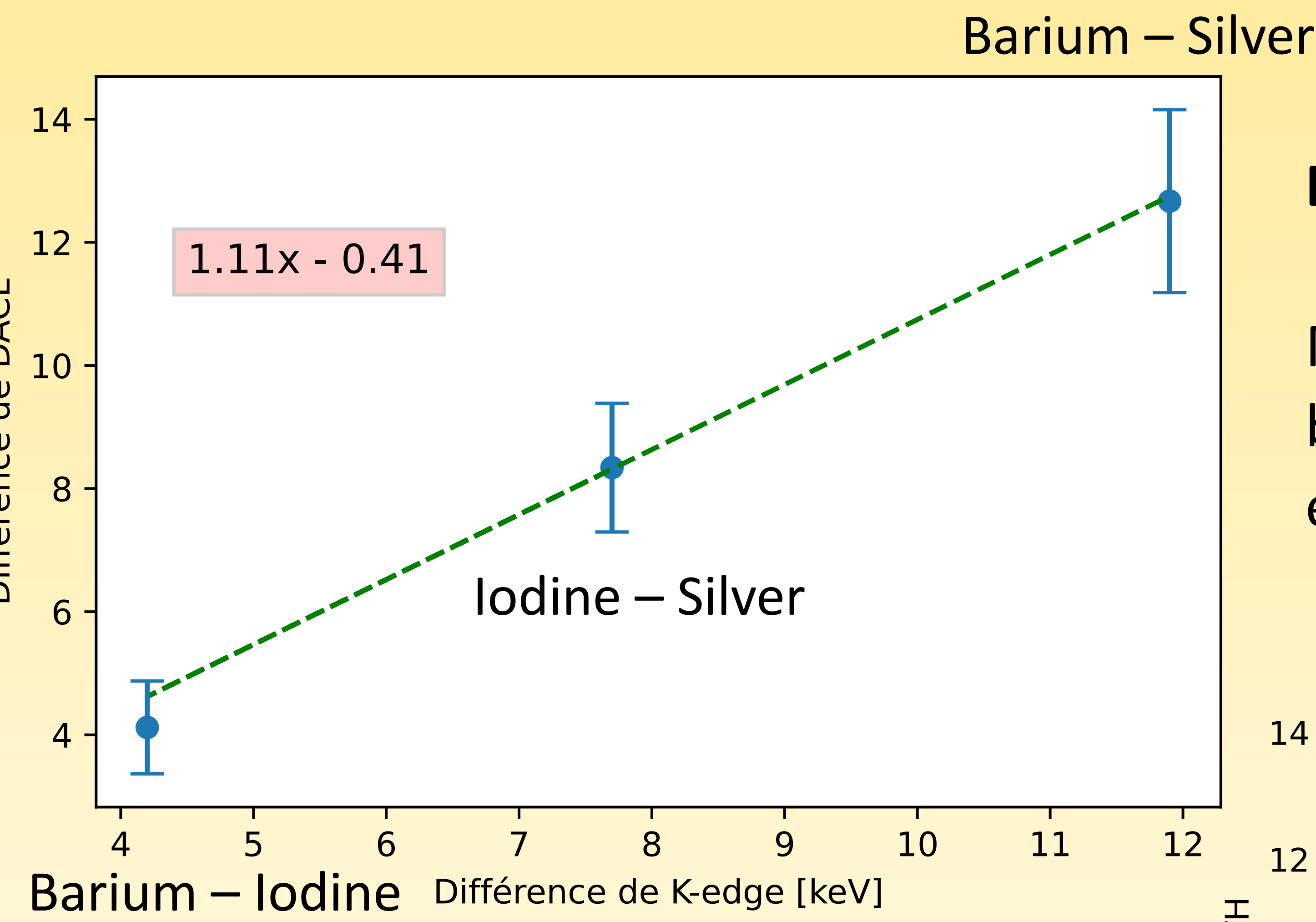
Maps of calibrated pixels





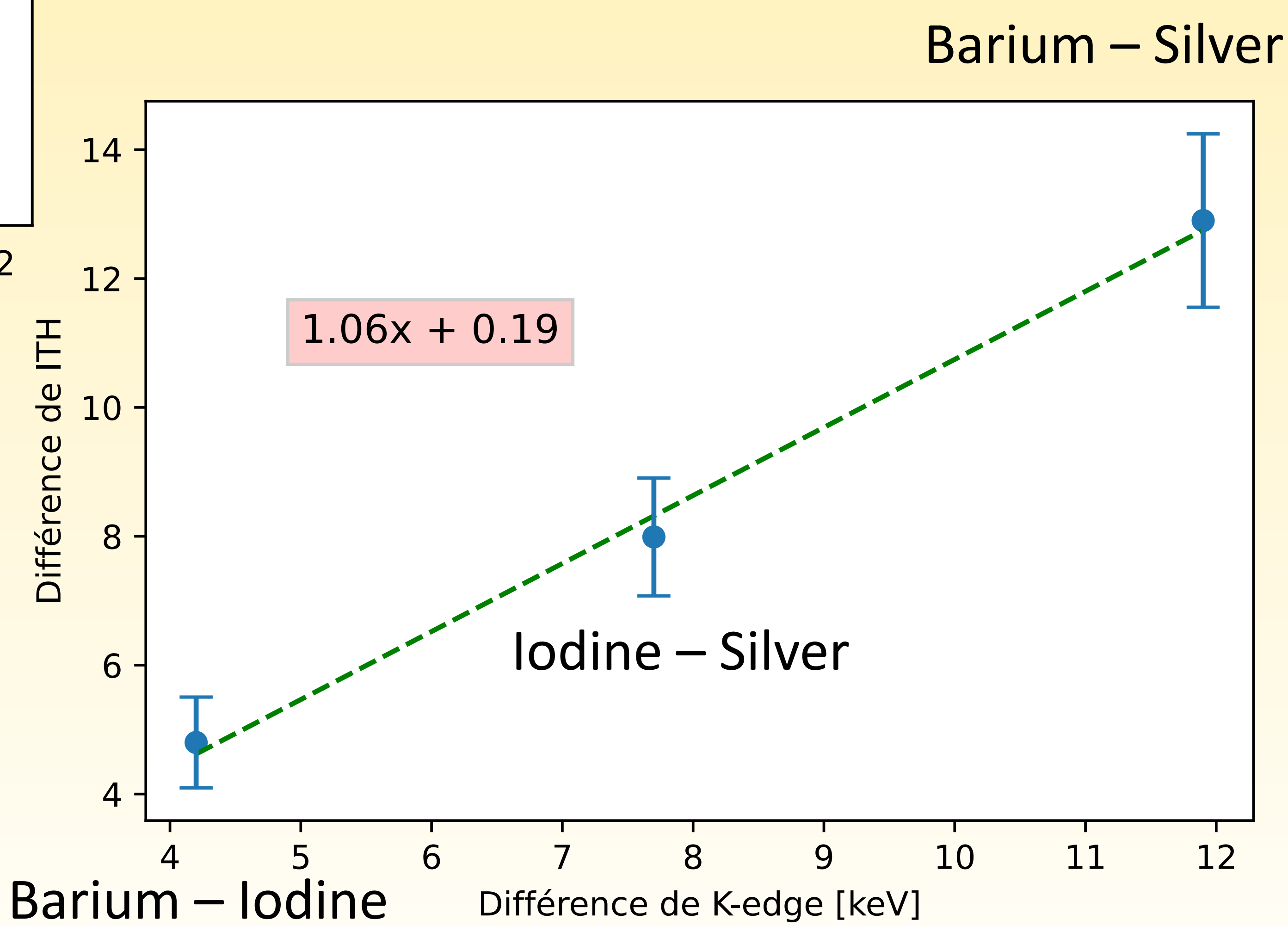
Takes into account uncalibrated pixels and poorly calibrated pixels

Characterization of the GaAs detector



Estimation of the DACL step in energy:

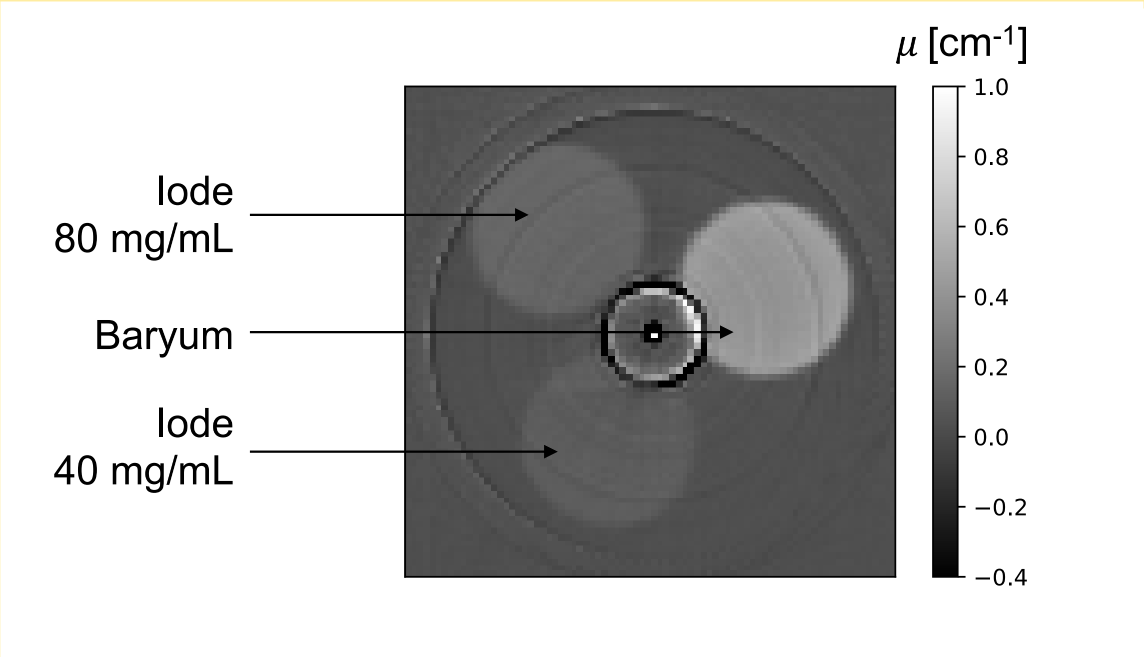
Measurement of DACL and ITH steps between different materials at different energies



Acquisition of 3 images :

- Threshold set at K-edge energy
- Threshold set at K-edge energy + ΔE
- Threshold set at K-edge energy – ΔE

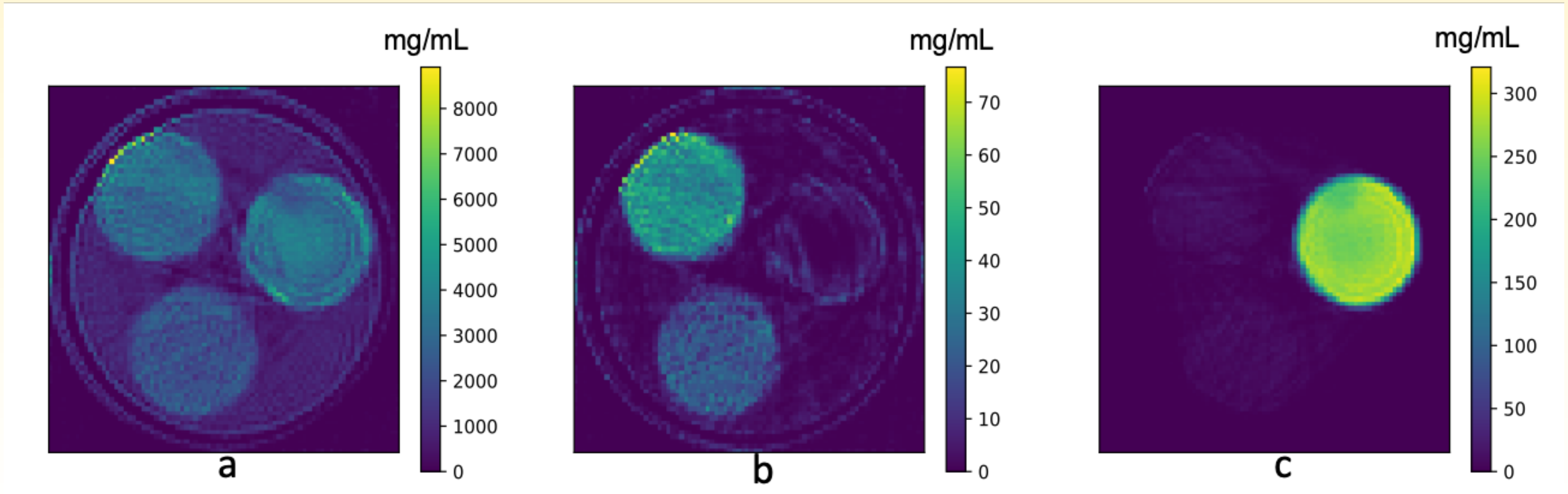
Results on Iodine / Barium phantom



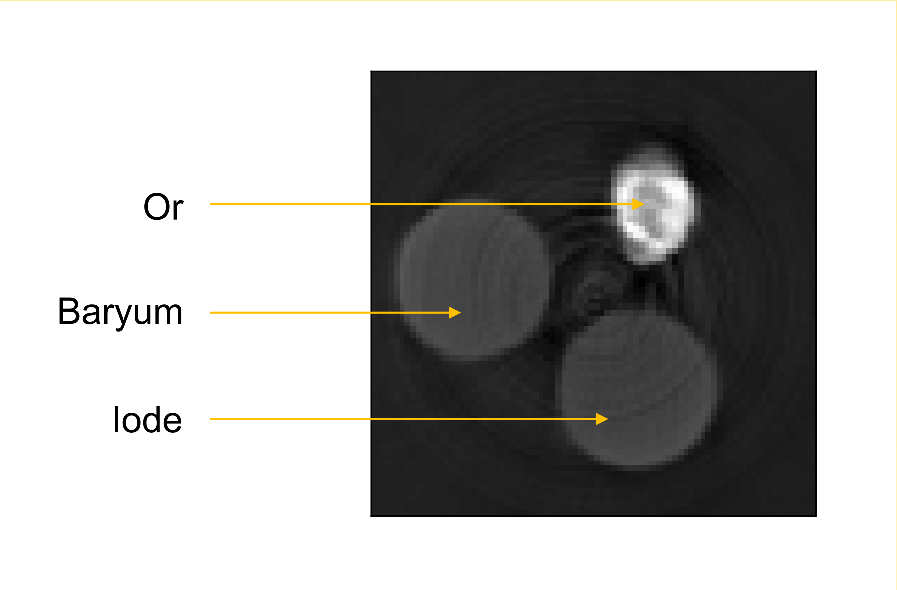
Phantom with 3 inserts :

- 40 mg/mL iodine solution
- 80 mg/mL iodine solution
- Barium nanoparticle solution

- Separation of different materials in their respective channels
- ProMeSCT algorithm quantification biased by partial knowledge of AsGa detector response

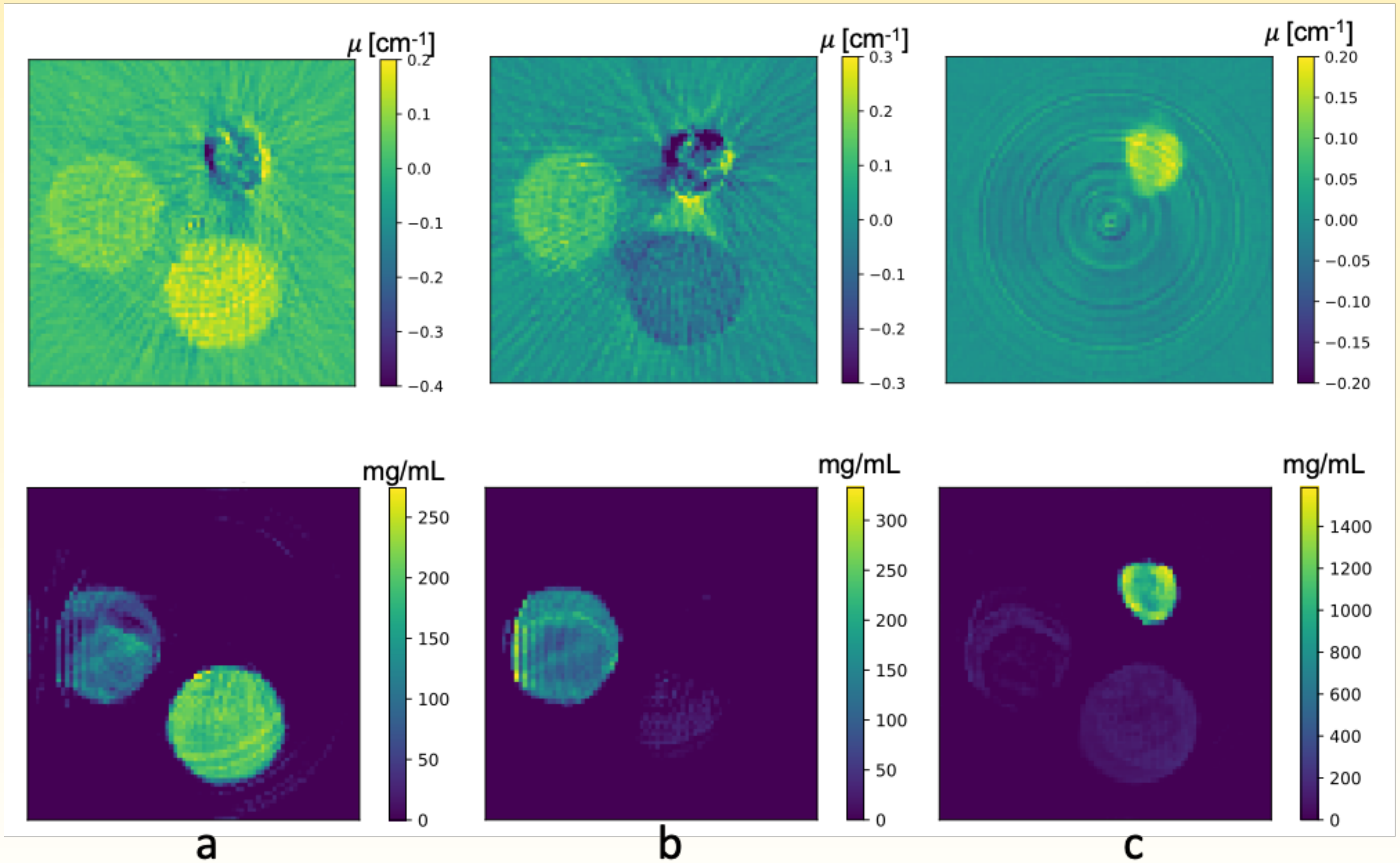


Results on Iodine / Barium /Gold phantom



Phantom with 3 inserts :

- Iodine solution 350 mg/mL
- Barium nanoparticle solution
- Rolled gold foil



Soustraction au K-edge

ProMeSCT

Résultats des séparations de (a) l'iode, (b) du baryum et (c) de l'or

Conclusion and future challenges

Preliminary results of spectral CT with XPAD3.2/GaAs

- High K-edge energy reachable
- Need for a Monte Carlo simulation of the spectral response of the detector for an accurate quantification

Spectral CT promises

- Quite mature technology
- Growing number of clinical applications
- Emergence of nanotechnologies exciting for spectral CT

Thank you for your attention

Questions ?