

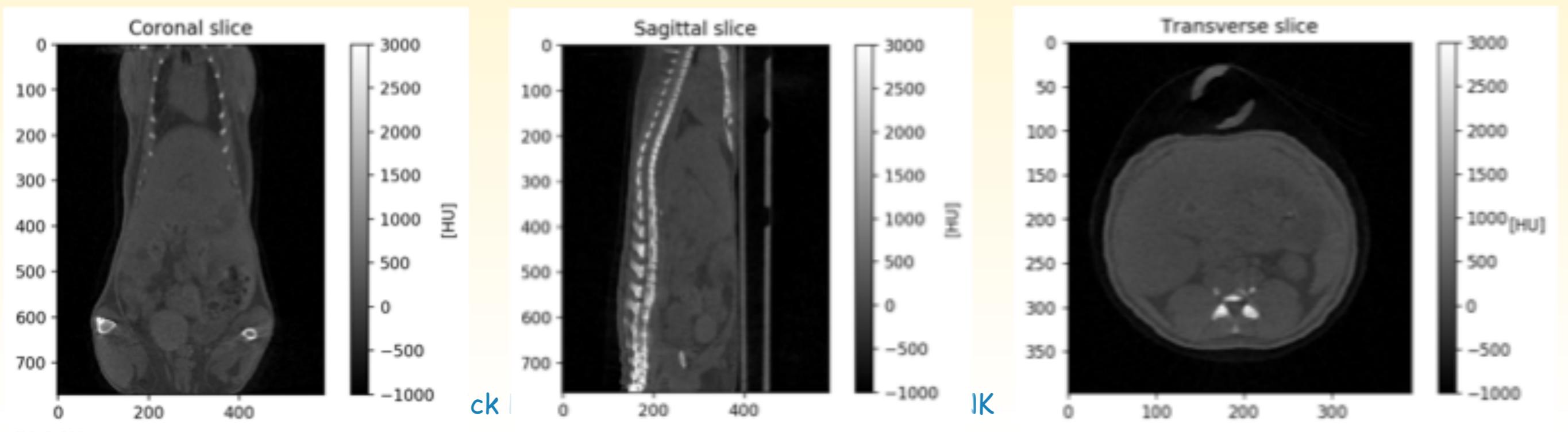
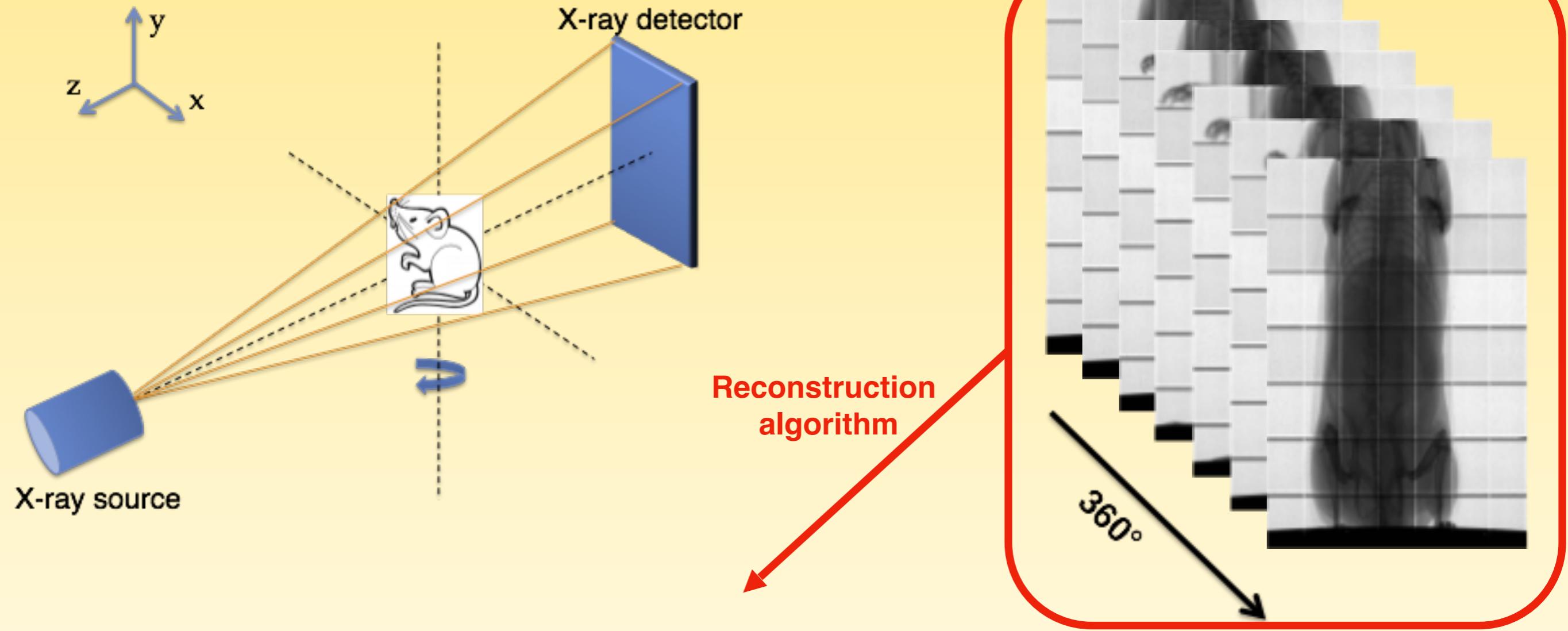
# Besoins en Imagerie médicale: Tomographie spectrale à rayons X (4D CT)



Yannick Boursier



# Snapshot of standard tomography (CT)



# Why Deep Learning in CT Reconstruction ?

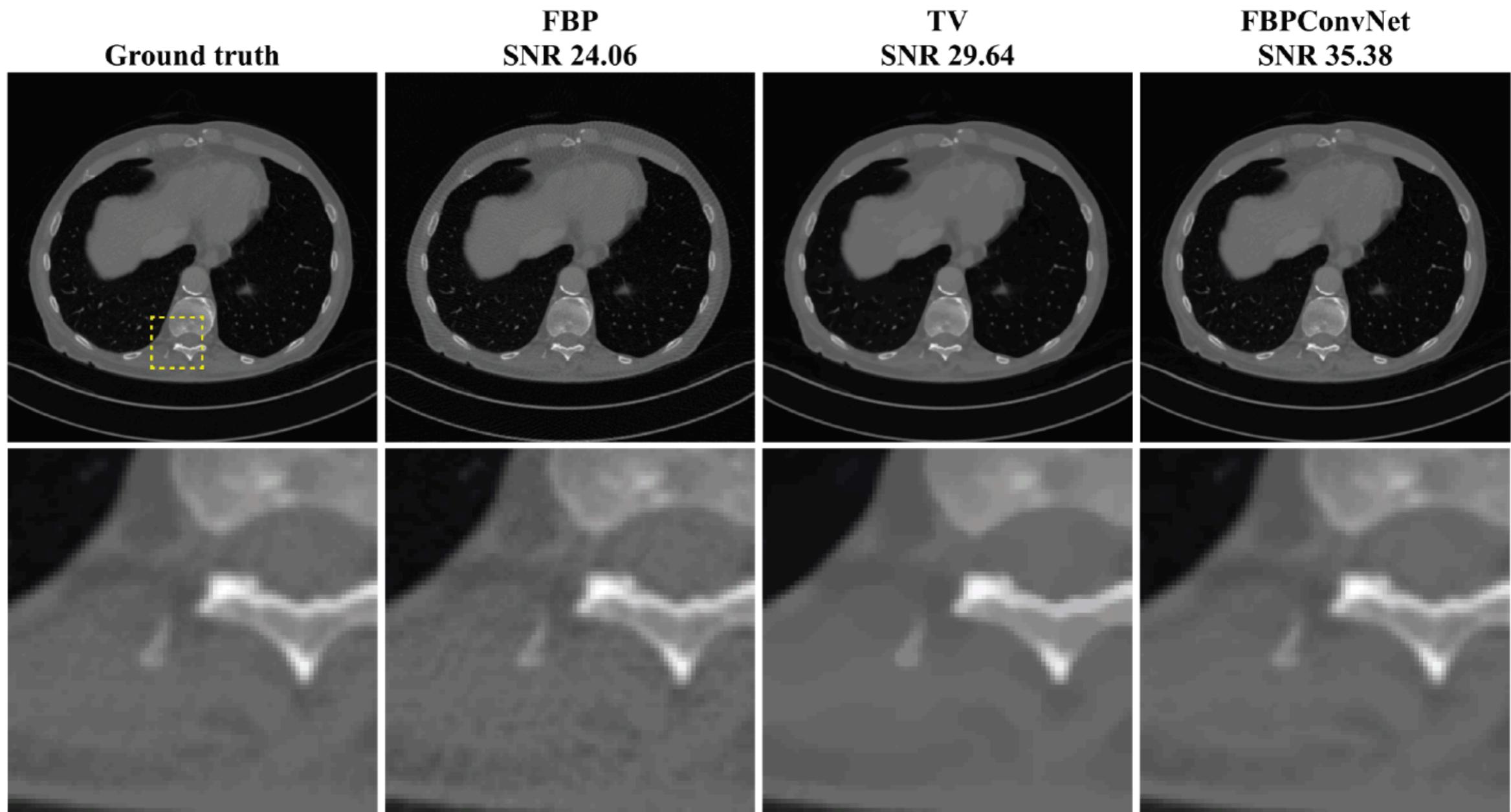


Fig. 5. Reconstructed images of biomedical dataset from 143 views using FBP, TV regularized convex optimization [14], and the FBPConvNet.

[Jin et al., June 2017]

# Why Deep Learning in CT Reconstruction ?

Reference



SAFIRE (Siemens)



Variational Network



[Hammernik et al., Nov 2017]

# Physics of spectral tomography

In the polychromatic real life, for a pixel p:

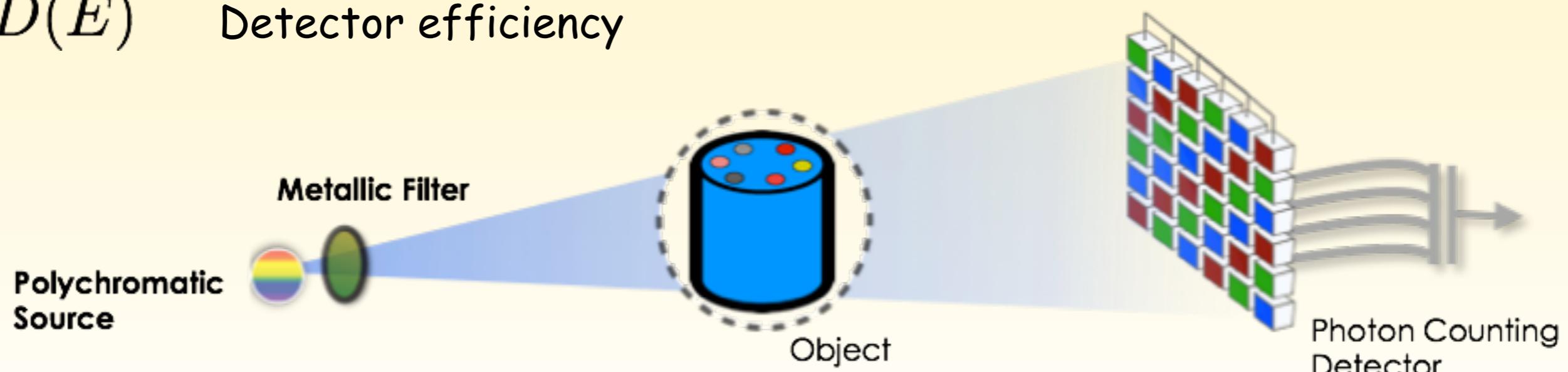
$$I_p = \int_0^{\infty} I_0(E) F(E) D(E) e^{-\int_{\mathcal{L}_p} \mu(E, l) dl} dE$$

$\mu(E, l)$  Unknown linear attenuation coefficient

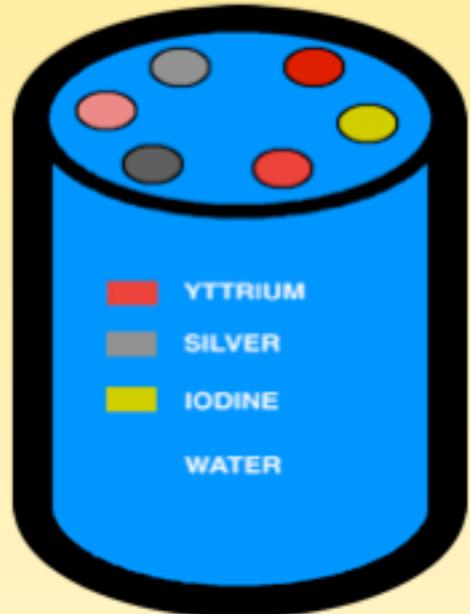
$I_0(E)$  Source spectrum

$F(E)$  Linear attenuation coefficient of a metallic filter

$D(E)$  Detector efficiency

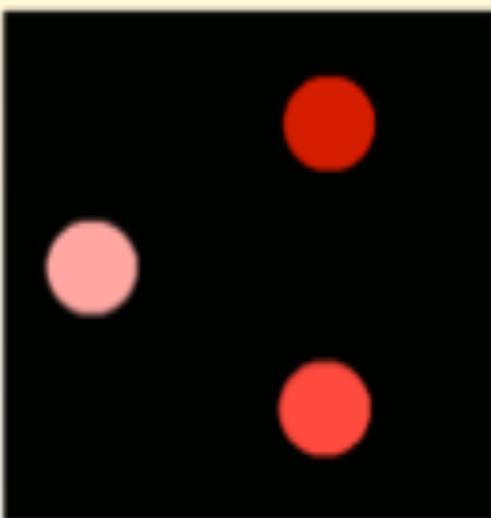


# Expectation and benefits

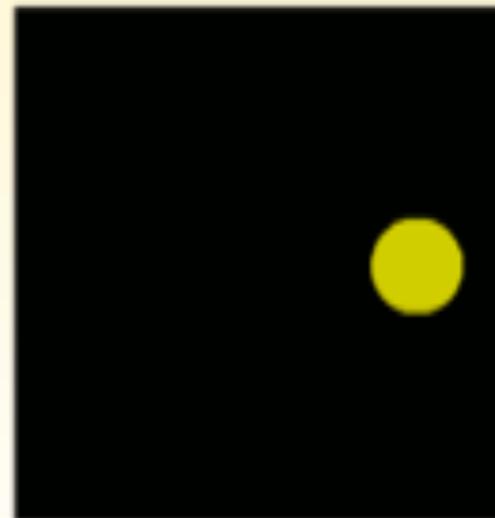


Standard CT:  
Low contrast  
No identification

Yttrium



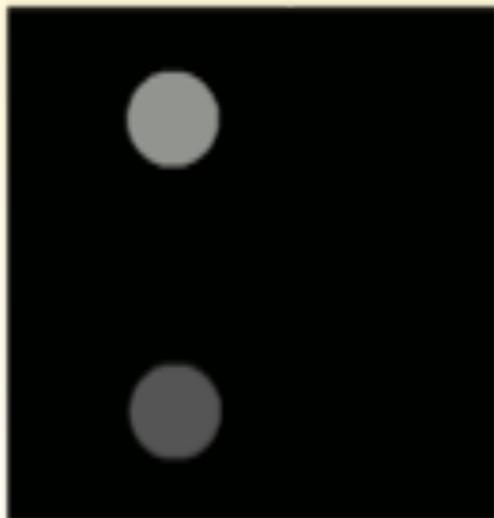
Iodine



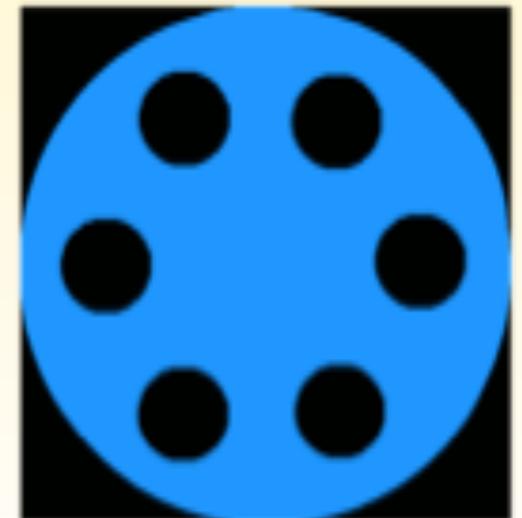
Spectral CT:

- Identification of components of interest
- Quantification

Silver



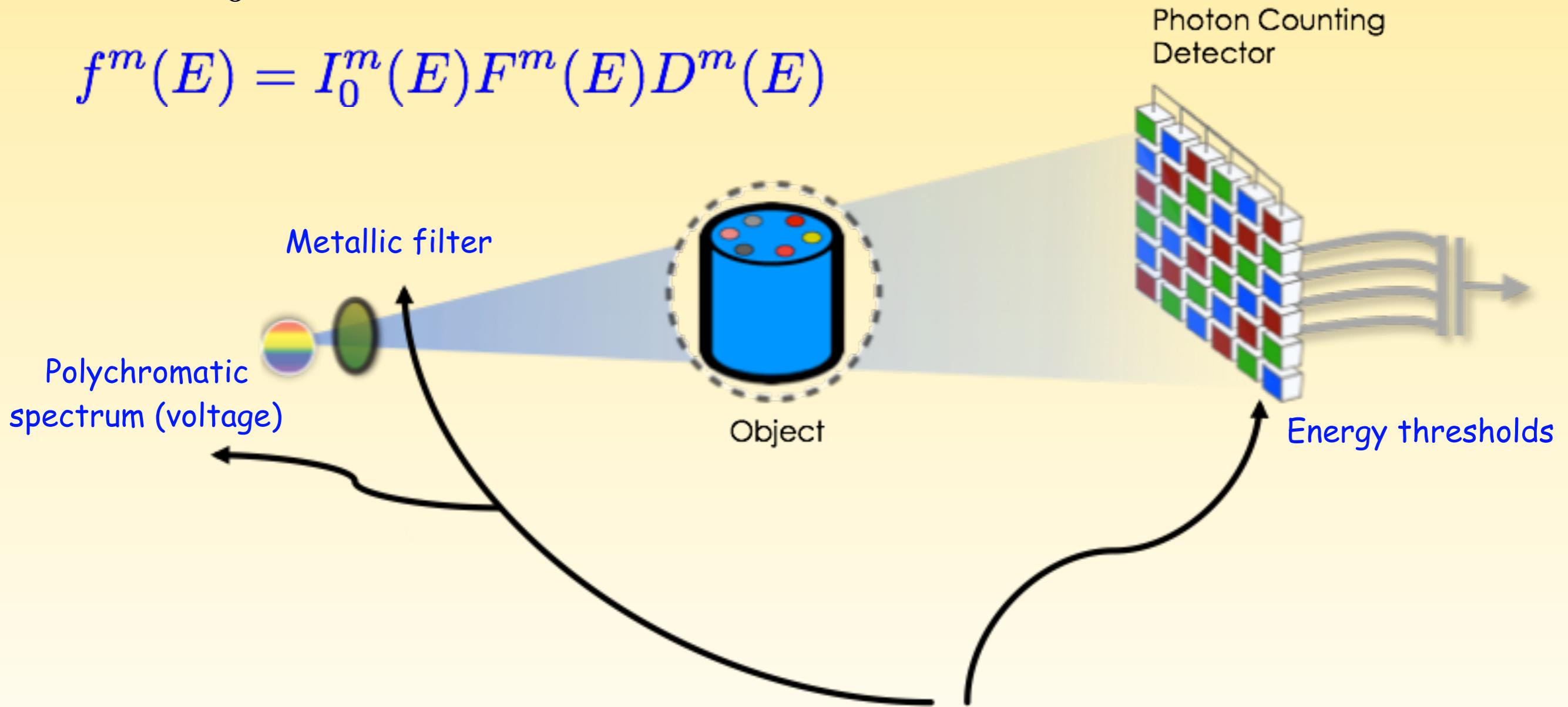
Water



# How to get spectral data ?

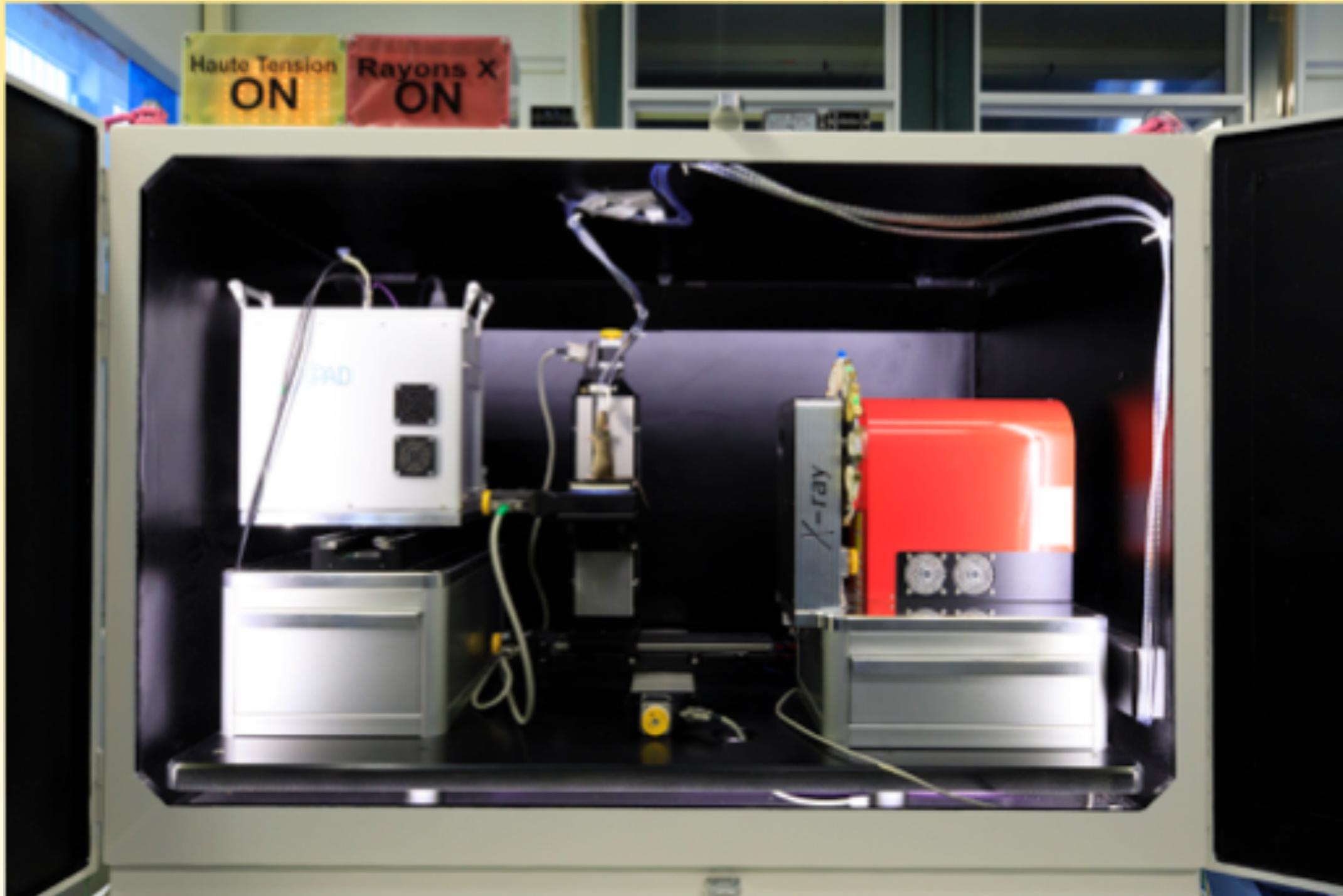
$$I_m^p = \int_0^\infty f^m(E) e^{-\int_{\mathcal{L}_p} \sum_k a_k(l) \sigma_k(E)} dE$$

$$f^m(E) = I_0^m(E) F^m(E) D^m(E)$$



Need several measurements that are discriminant

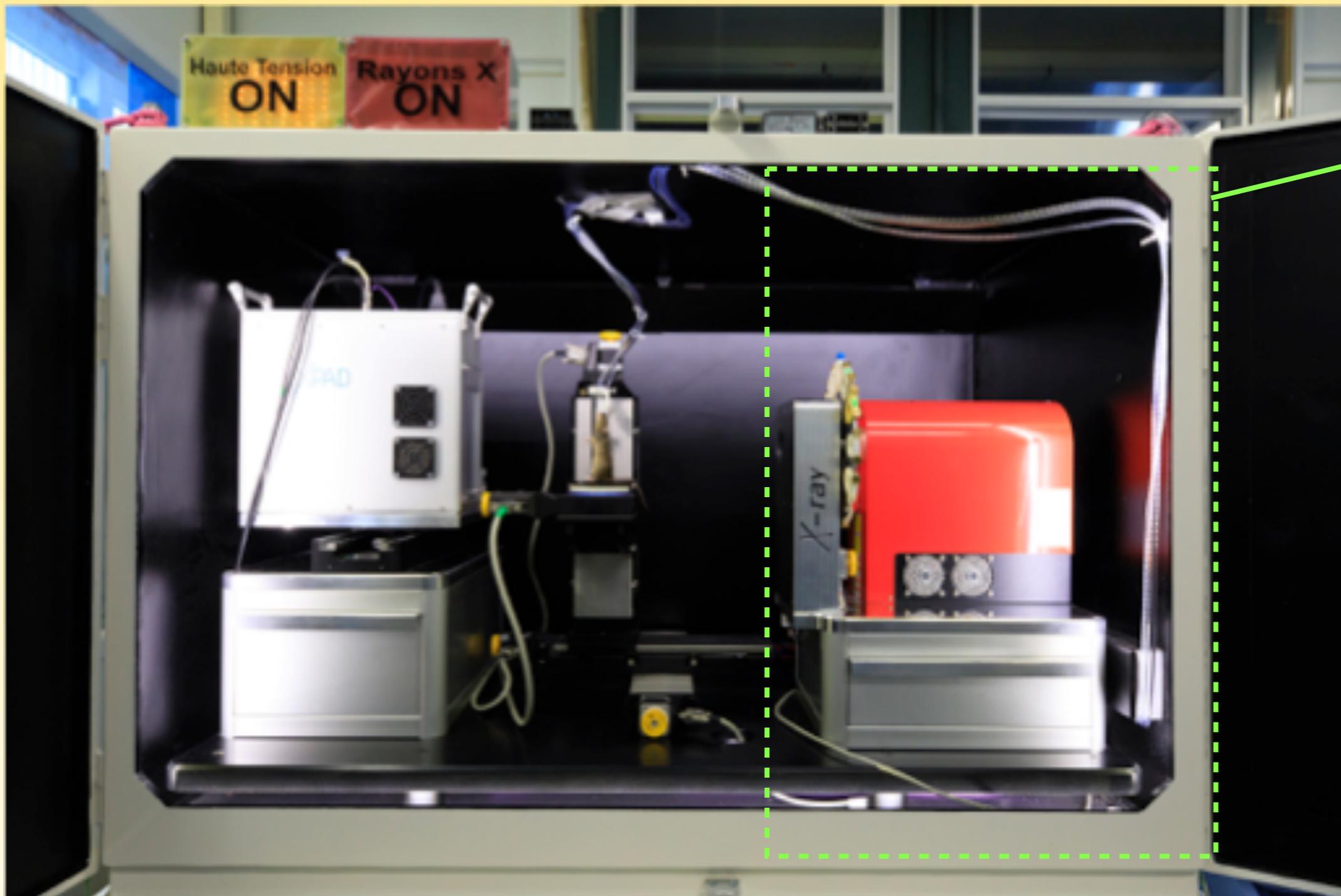
# PIXSCAN-FLI



FLi  
France Life Imaging

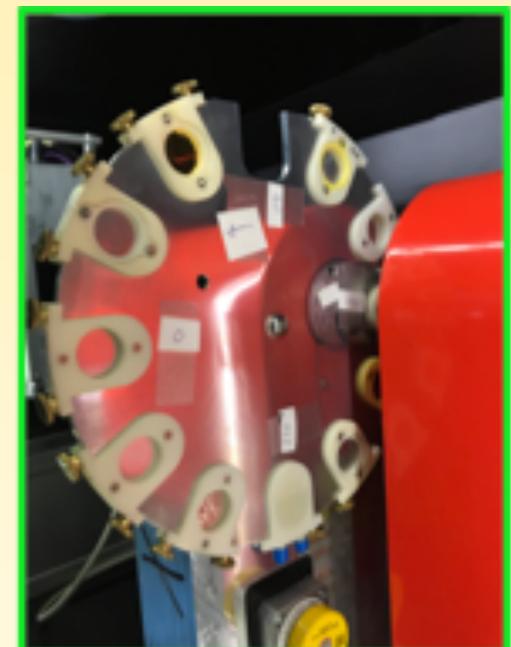
canceropôle  
Provence-Alpes-Côte d'azur  
le propulseur régional des recherches  
et innovations anticancéreuses

# PIXSCAN-FLI

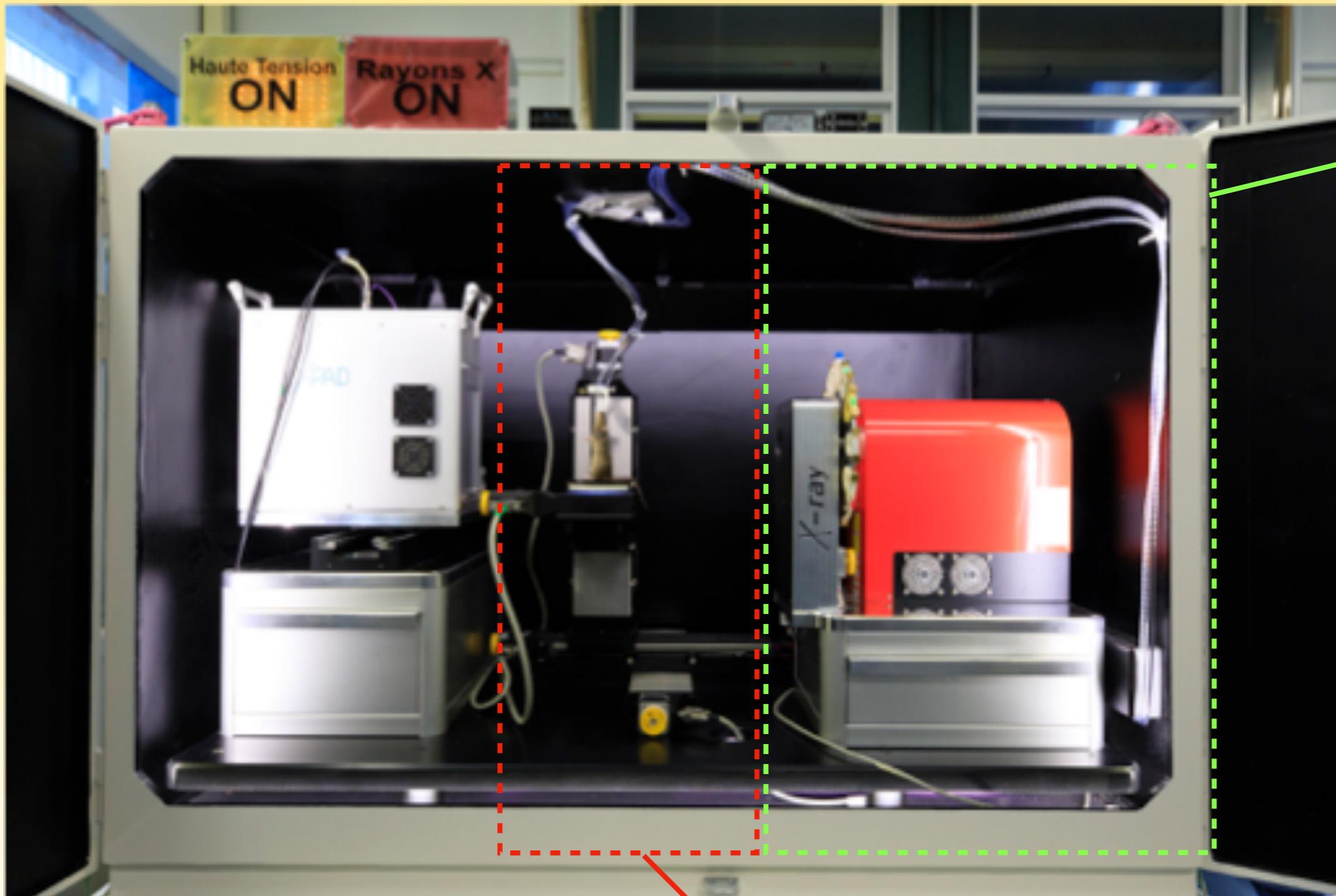


Source block

W anode (150 kVp)  
Wheel filters



# PIXSCAN-FLI



**Source block**

W anode (150 kVp)  
Wheel filters

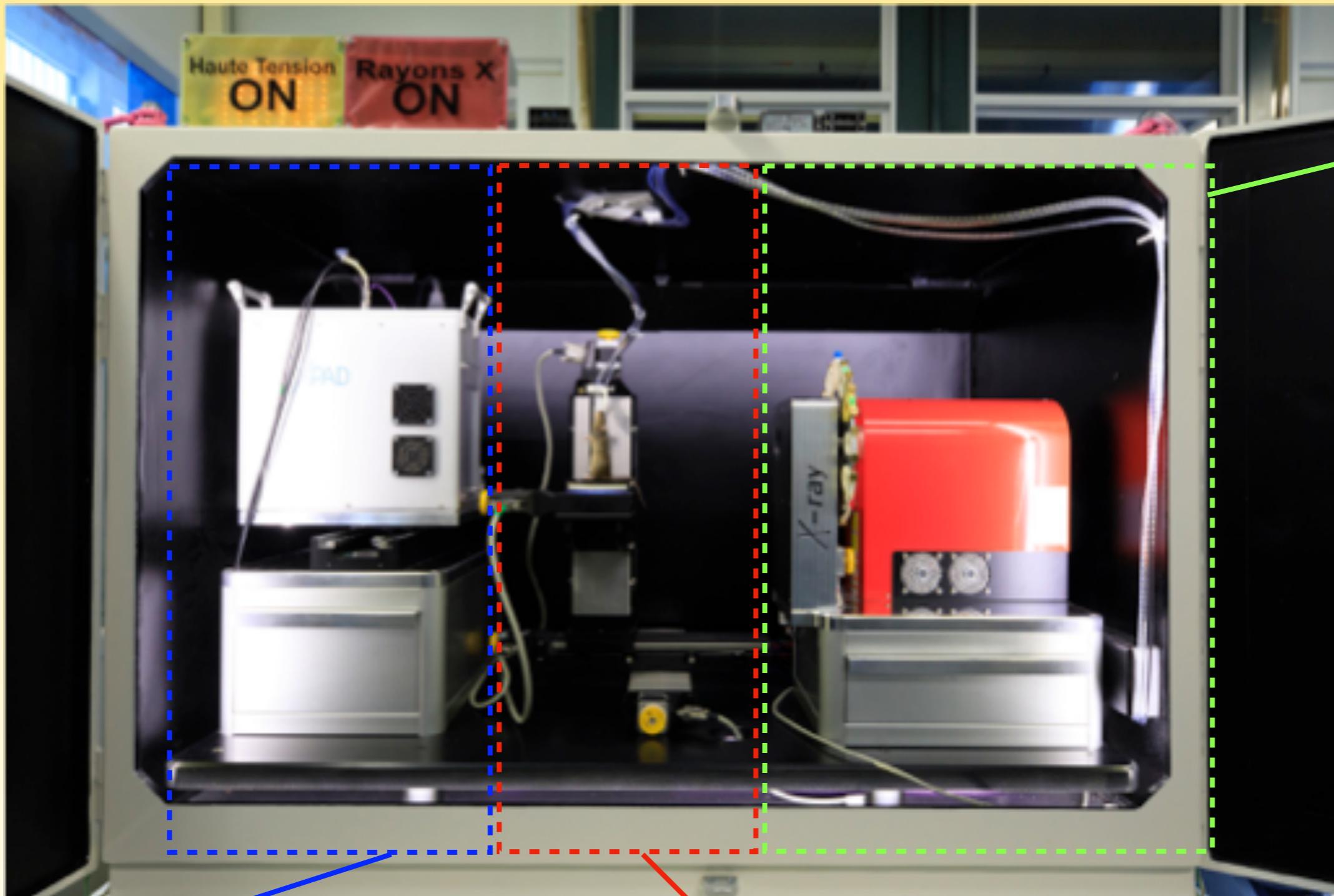
**Animal block**

Vertical rotation axis

Acquisition mode: shoot and step or continuous rotation

Gas anesthesia: isoflurane

# PIXSCAN-FLI



## Detector block

Two cameras

Resolution of 85  $\mu\text{m}/\text{voxel}$

## Animal block

Vertical rotation axis

Acquisition mode: shoot and step or continuous rotation

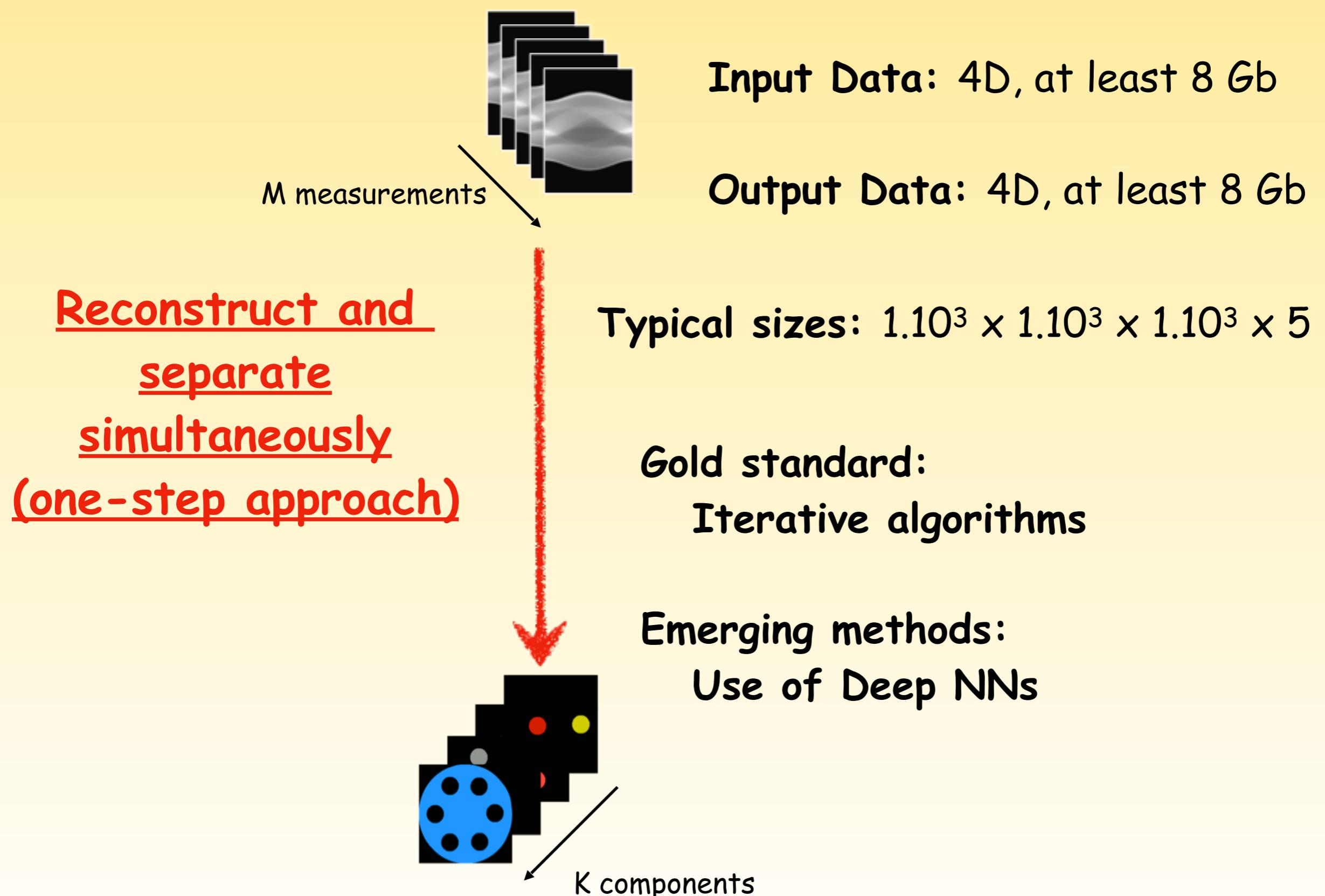
Gas anesthesia: isoflurane

## Source block

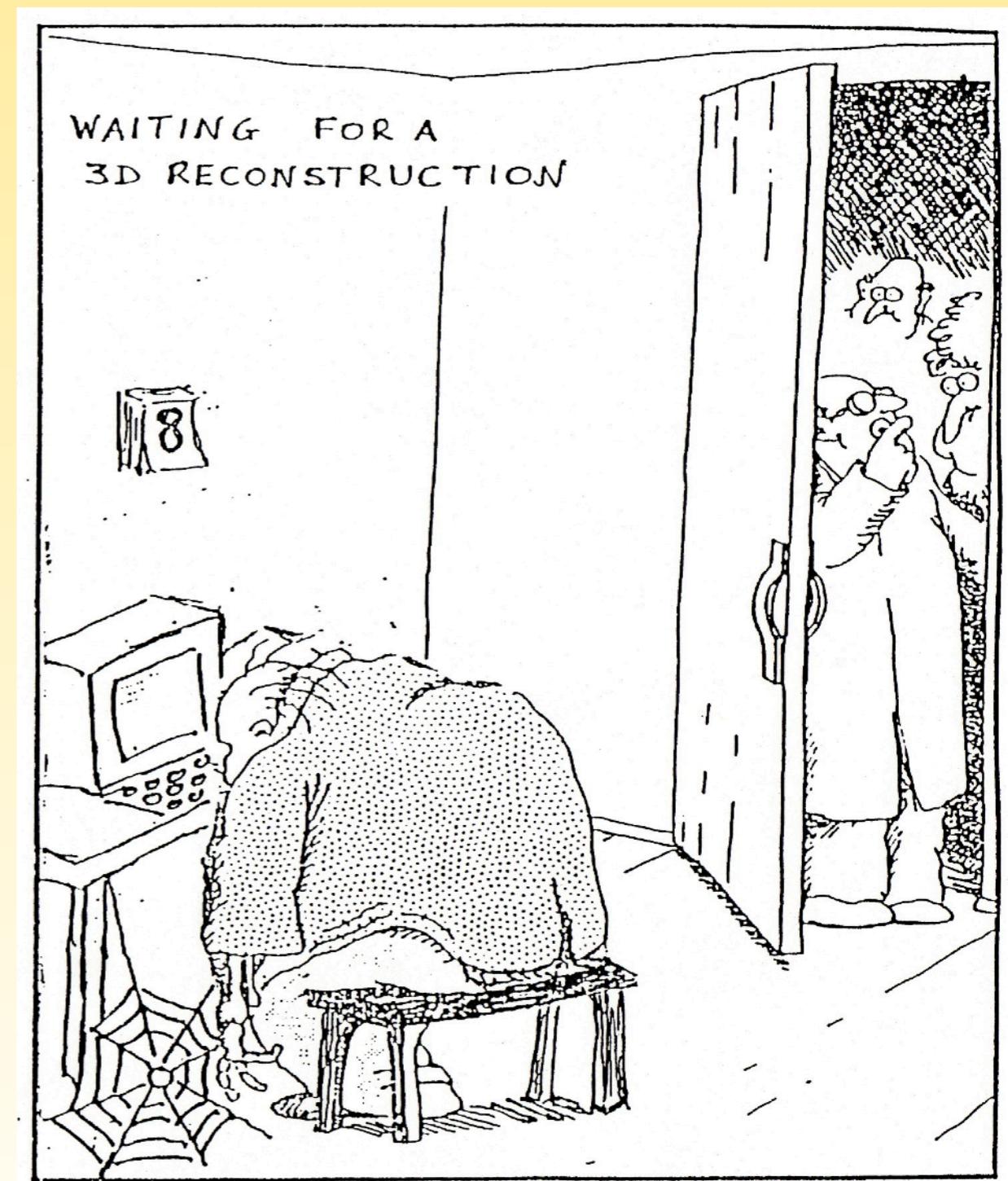
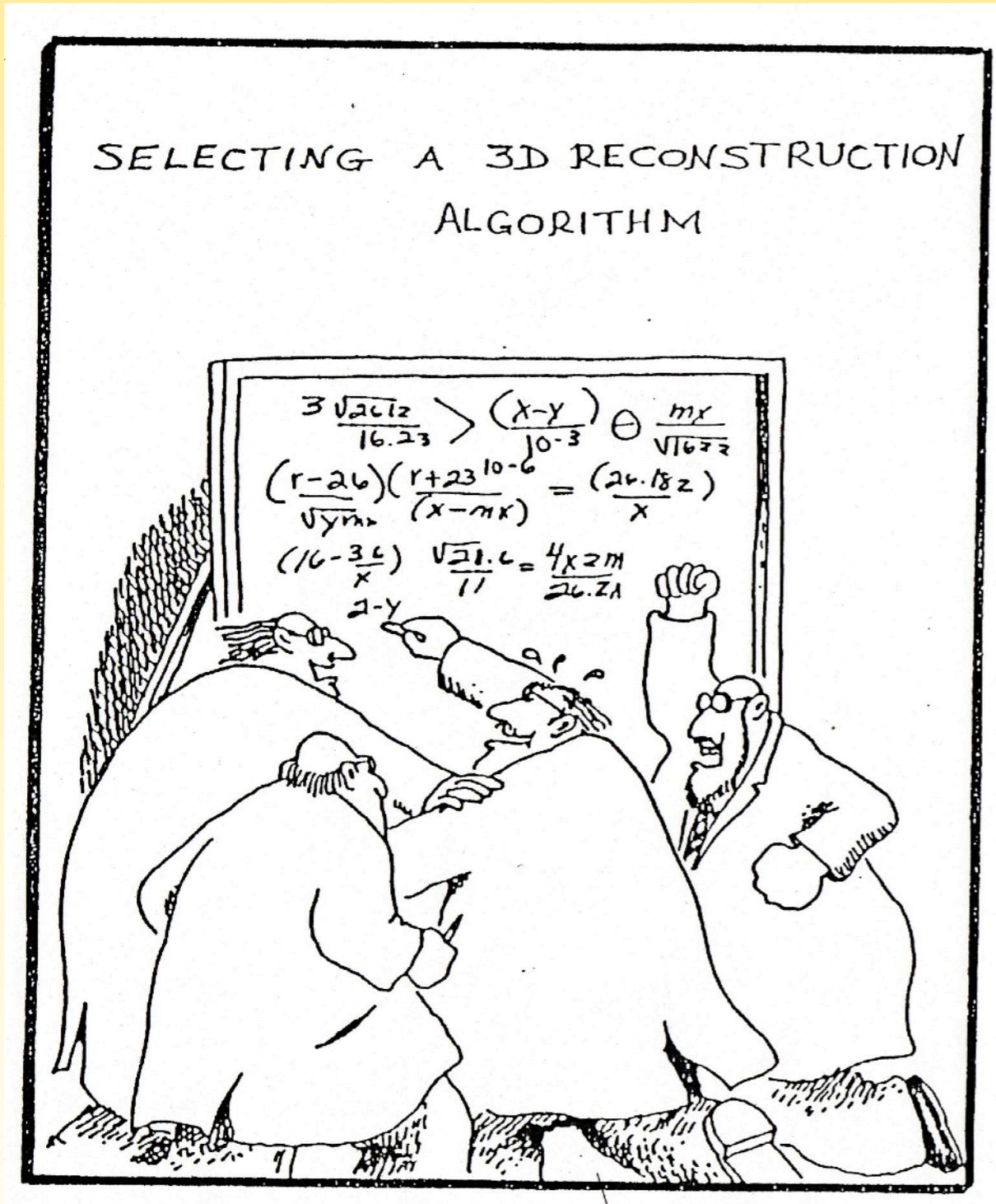
W anode (150 kVp)

Wheel filters

# How to deal with spectral data ?



# Separate and reconstruct simultaneously The curse of dimensionality



What is expensive is to apply the X-ray projection and the X-ray back projection !

# Scheme of an iterative algorithm

$$\hat{A} = \arg \min_A G(A) + R(A)$$

How to accelerate the convergence rate ? **metric strategy (Newton-like)**

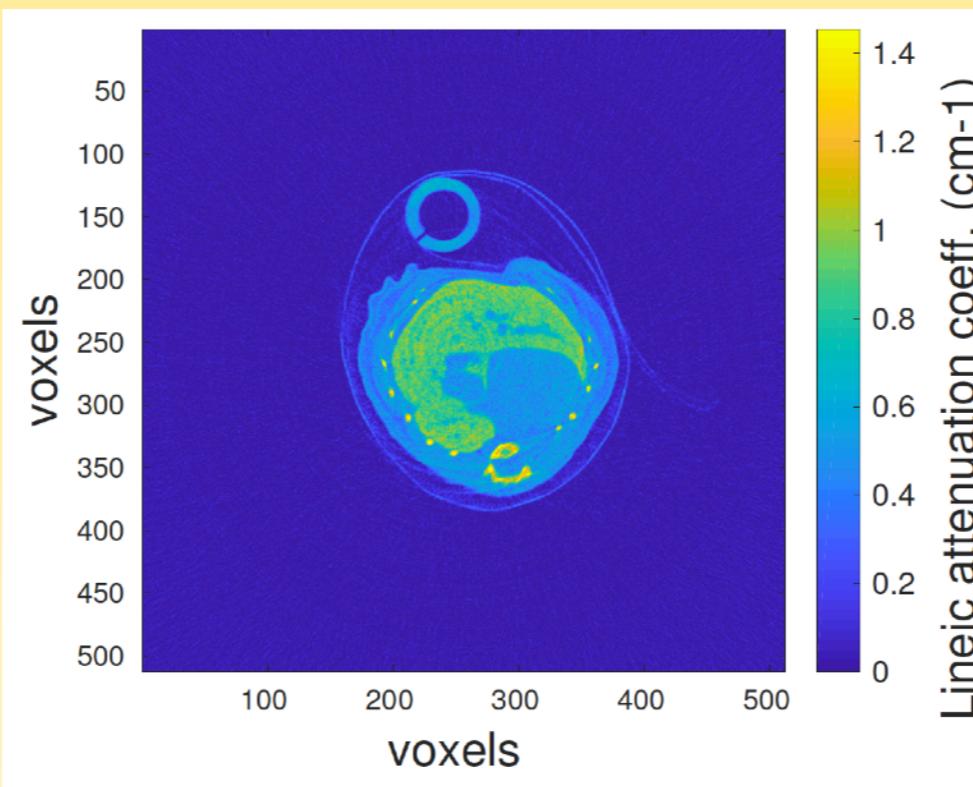
**Forward step:**  $x^{i+1/2} = x^i - \gamma_i \mathbf{M}_i^{-1} \nabla G(x^i)$

**Backward step:**  $x^{i+1} = \text{prox}_{\mathbf{M}_i, R}(x^{i+1/2})$

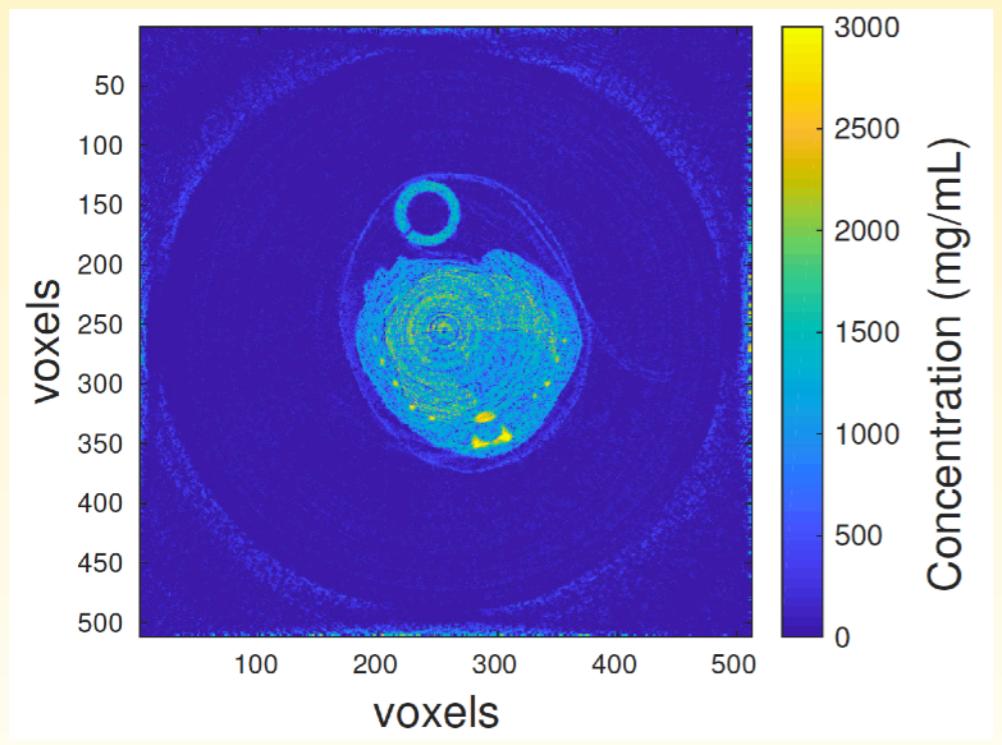
with  $\text{prox}_{\mathbf{M}, R}(x) = \arg \min_z \frac{1}{2} \|z - x\|_{\mathbf{M}}^2 + R(z)$

$$= \arg \min_z \frac{1}{2} \langle z - x, \mathbf{M}(z - x) \rangle + R(z)$$

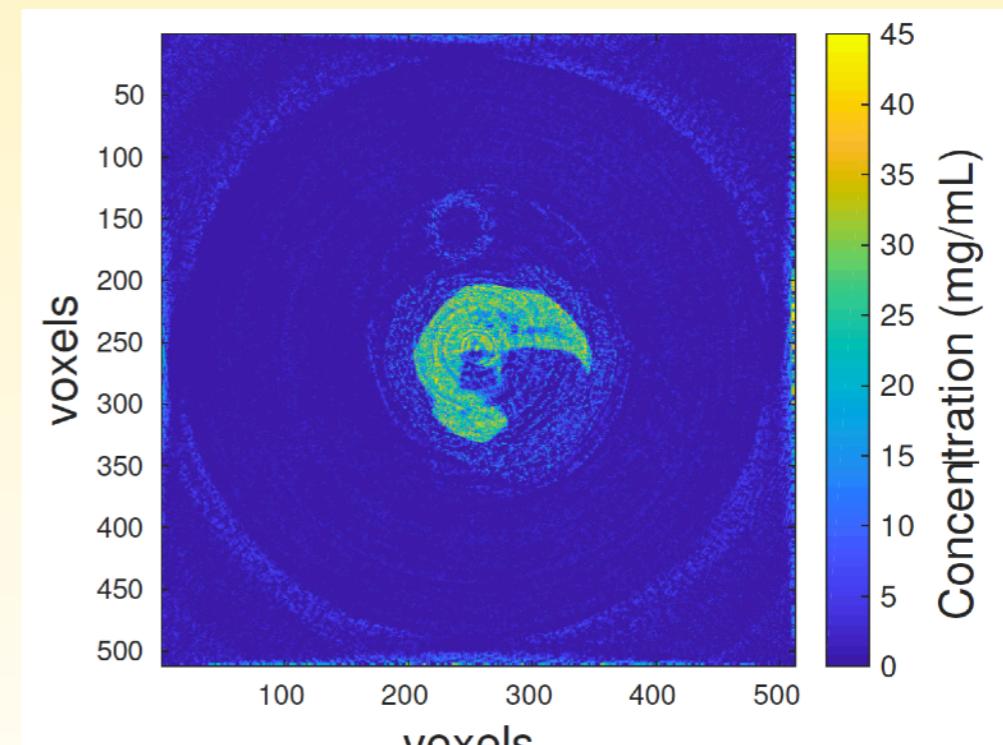
# Outlook of results



FDK



Water-like map



Barium map

# THINK challenges:

How to fasten data processing with (Deep) Neural Networks ?

Can be data processing incorporated in electronics ?