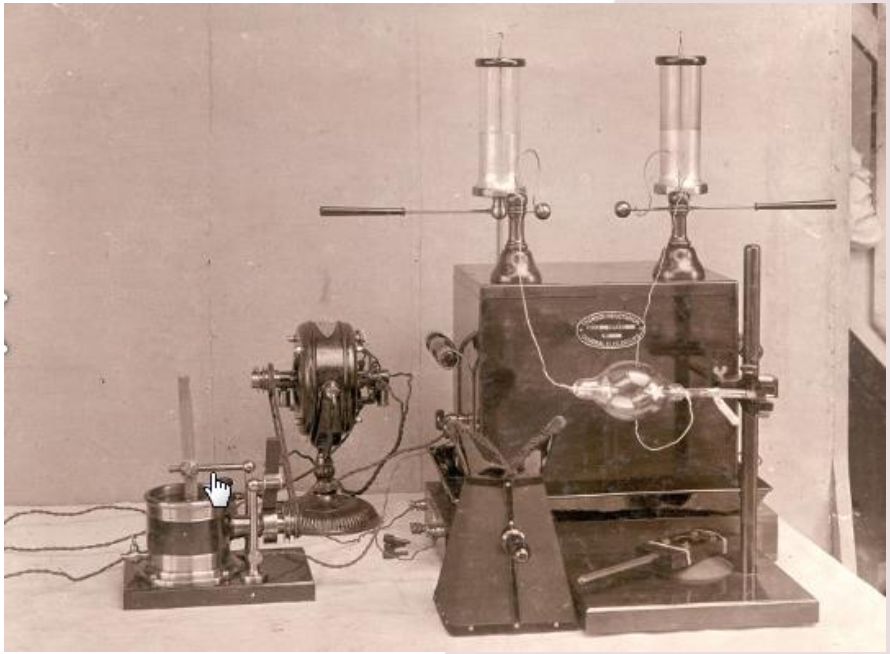
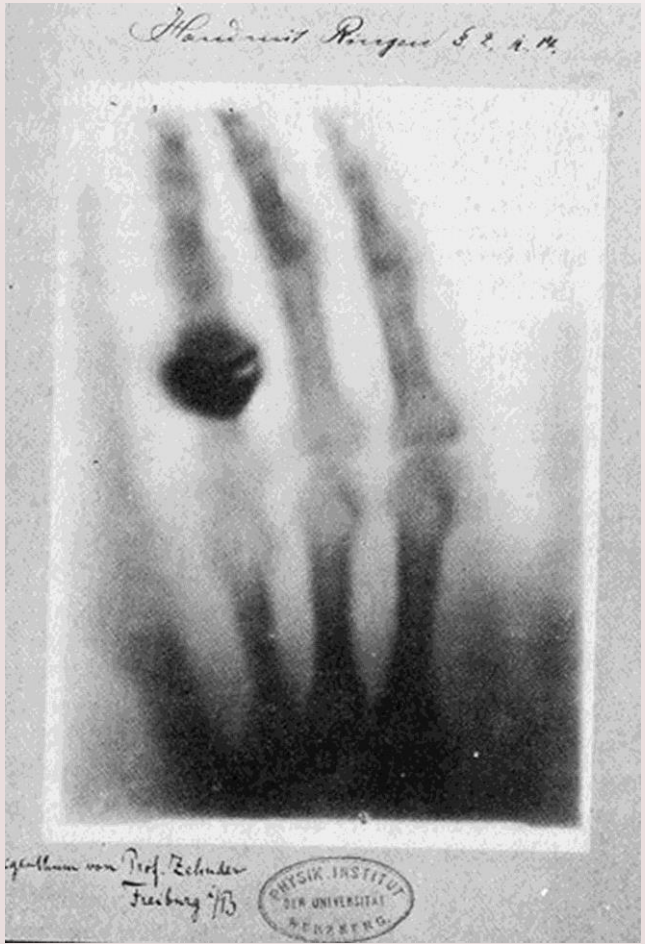
The potential use of fast neutrons to perform computed tomographic imaging

J.N. Wilson, IPN Orsay

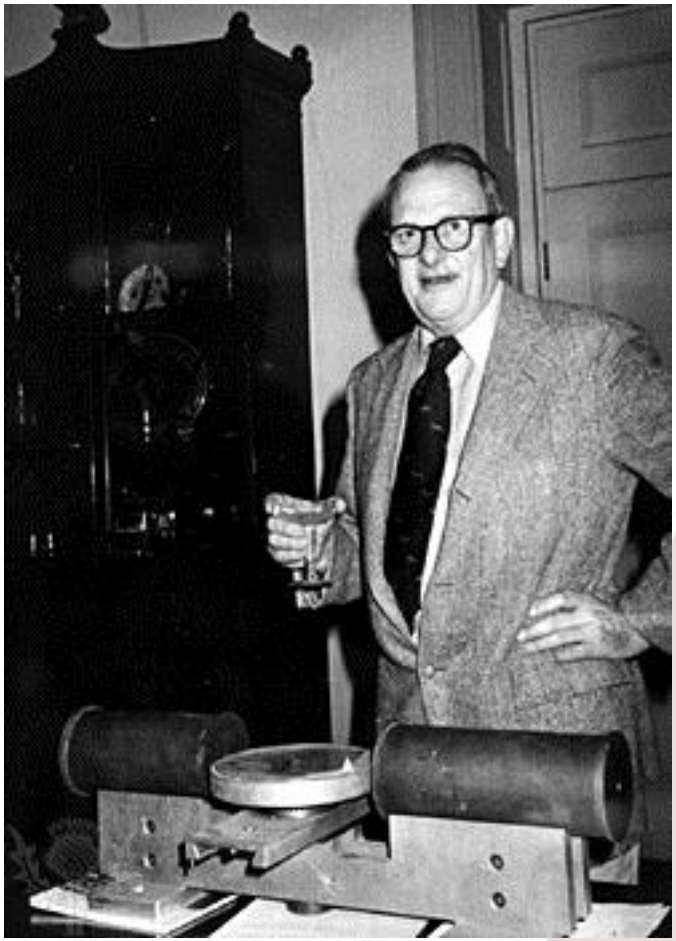
The first x-ray image

Willhelm Röntgen - 1895



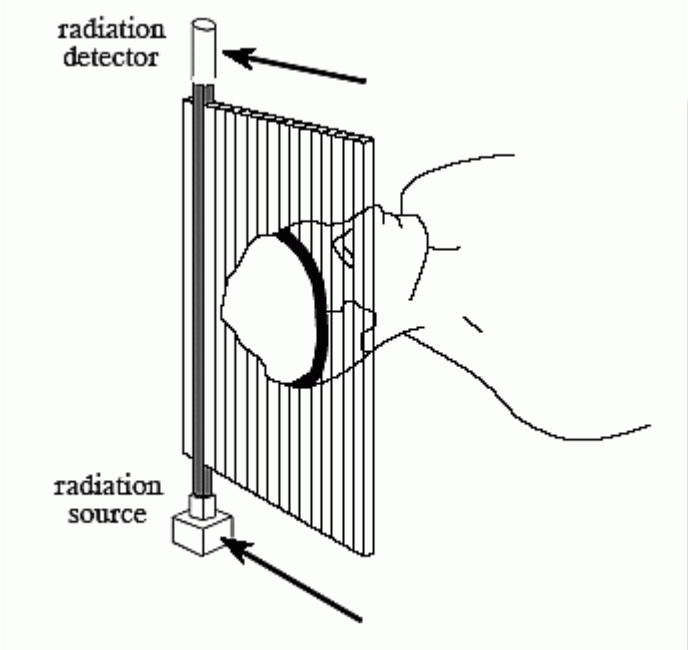


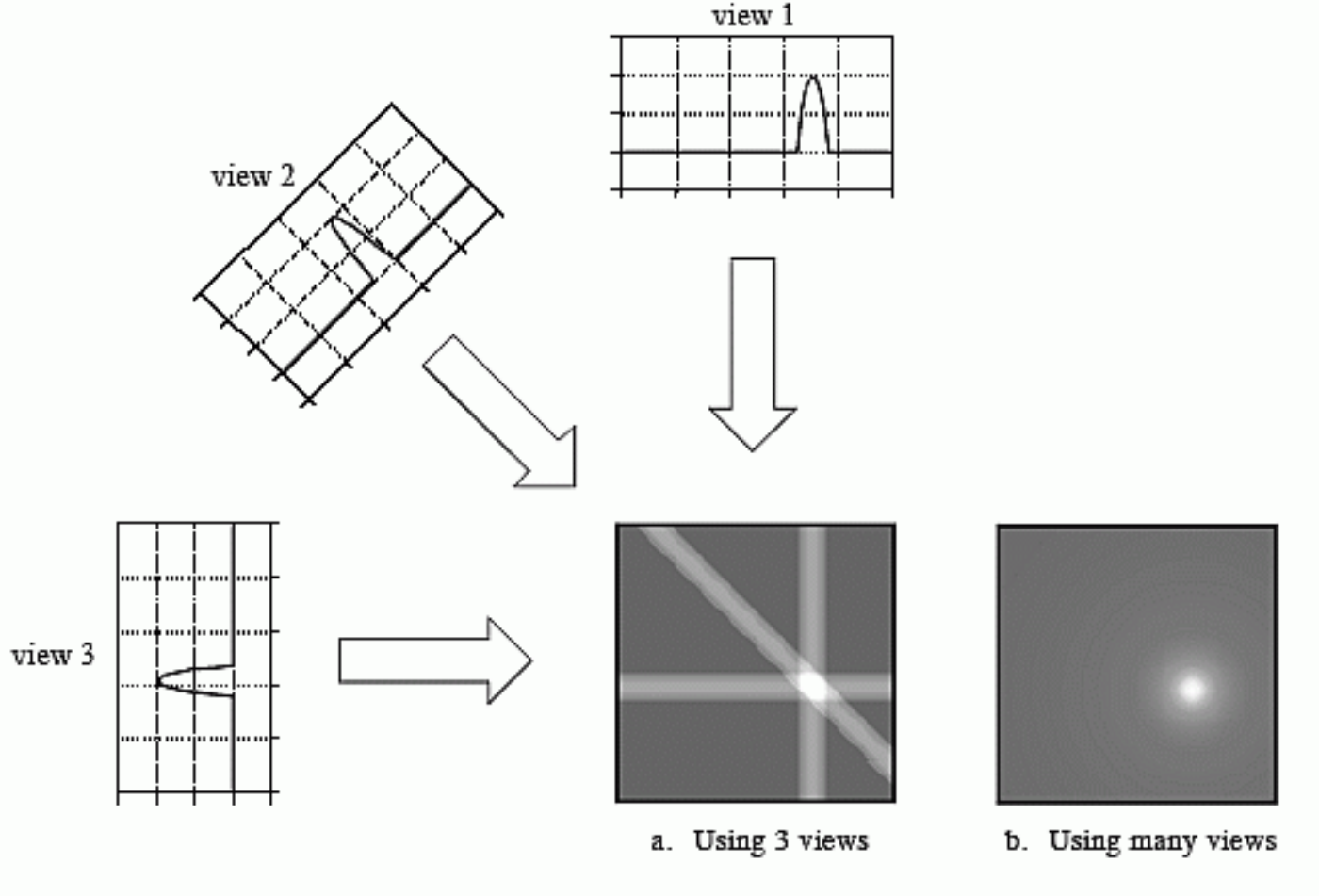
x-ray computed tomography



Allan M. Cormack & Godfrey N. Hounsfield
Nobel Prize in Medicine 1979

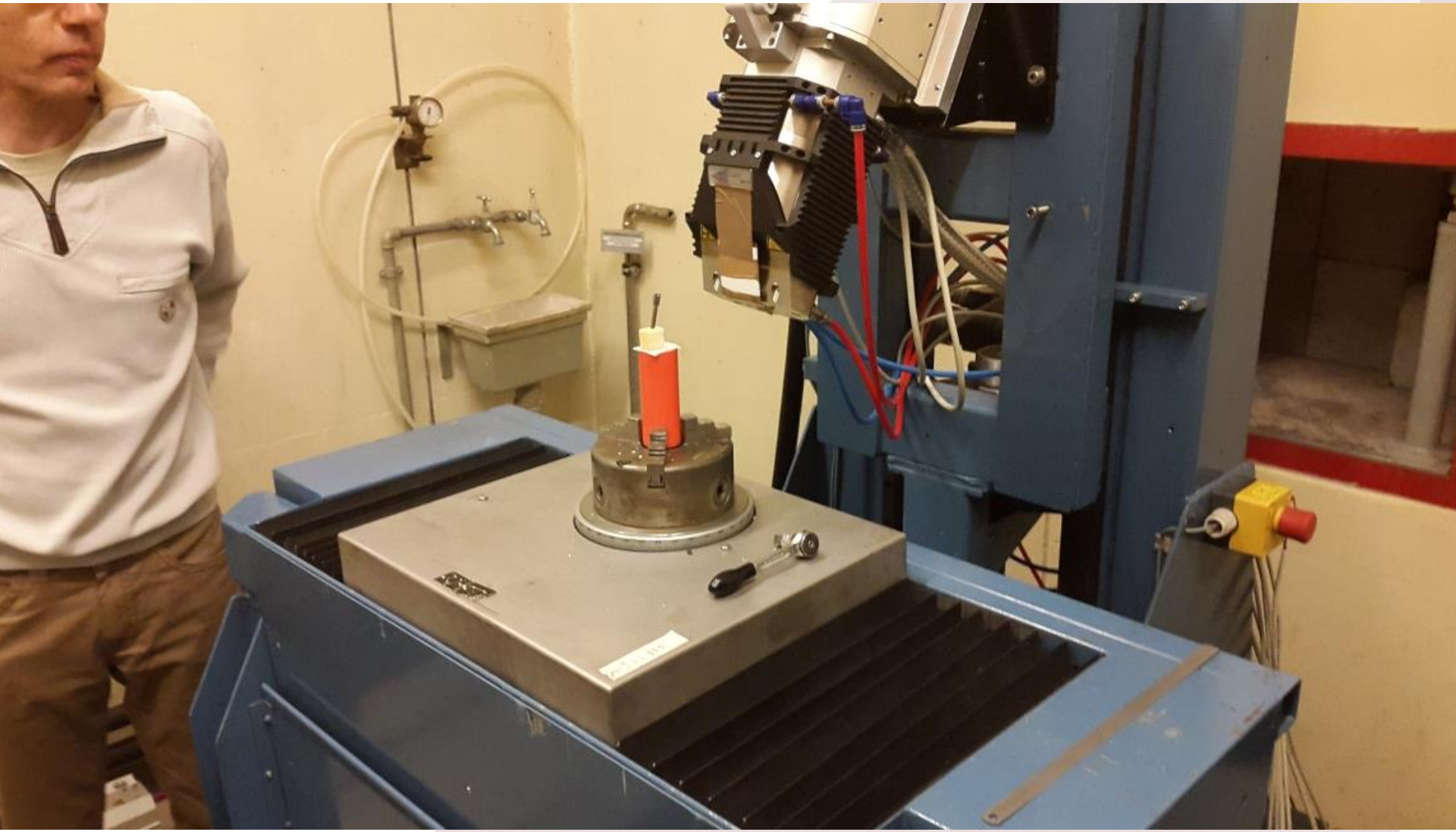
x-ray computed tomography principle




view 1
view 2
view 3
a. Using 3 views
b. Using many views

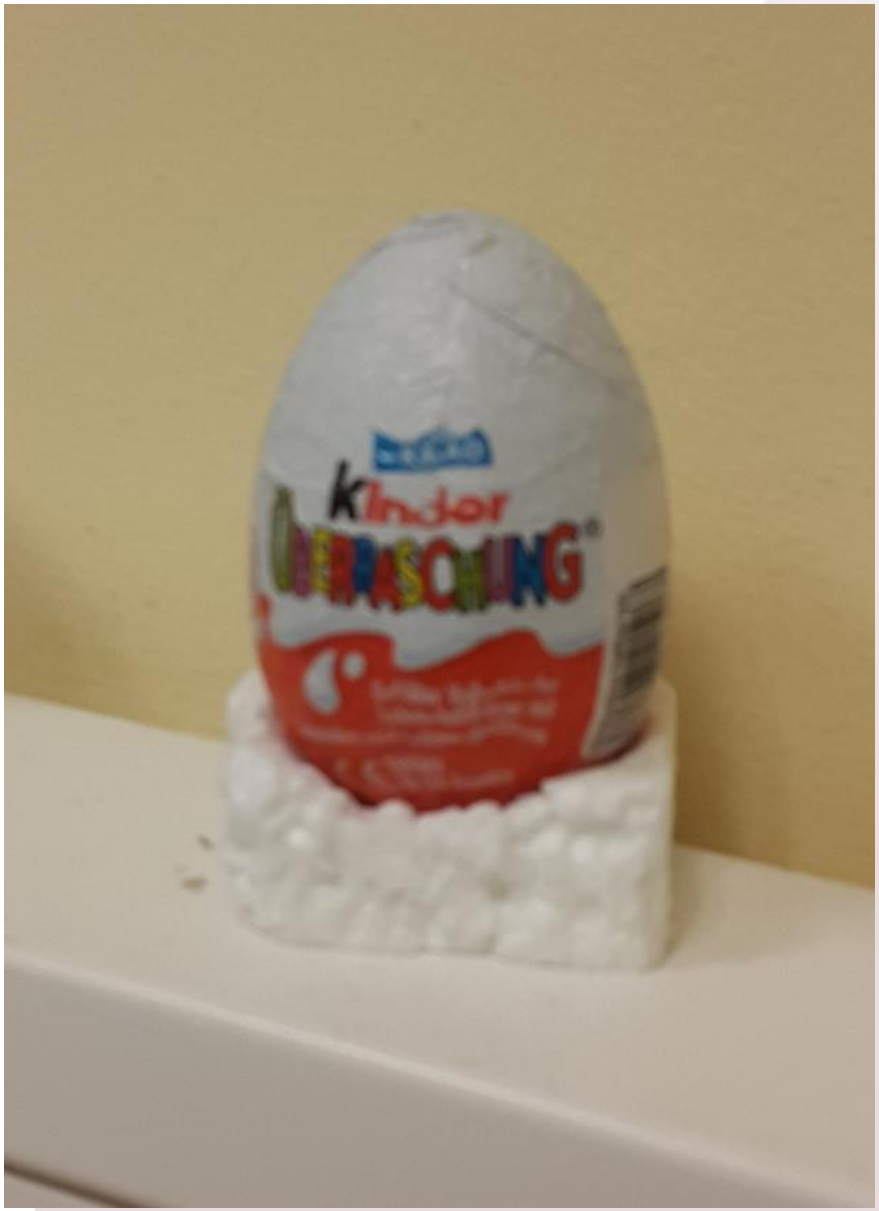
BAM x-ray CT setup

Bundesanstalt für Materialforschung und prüfung, Berlin, Germany



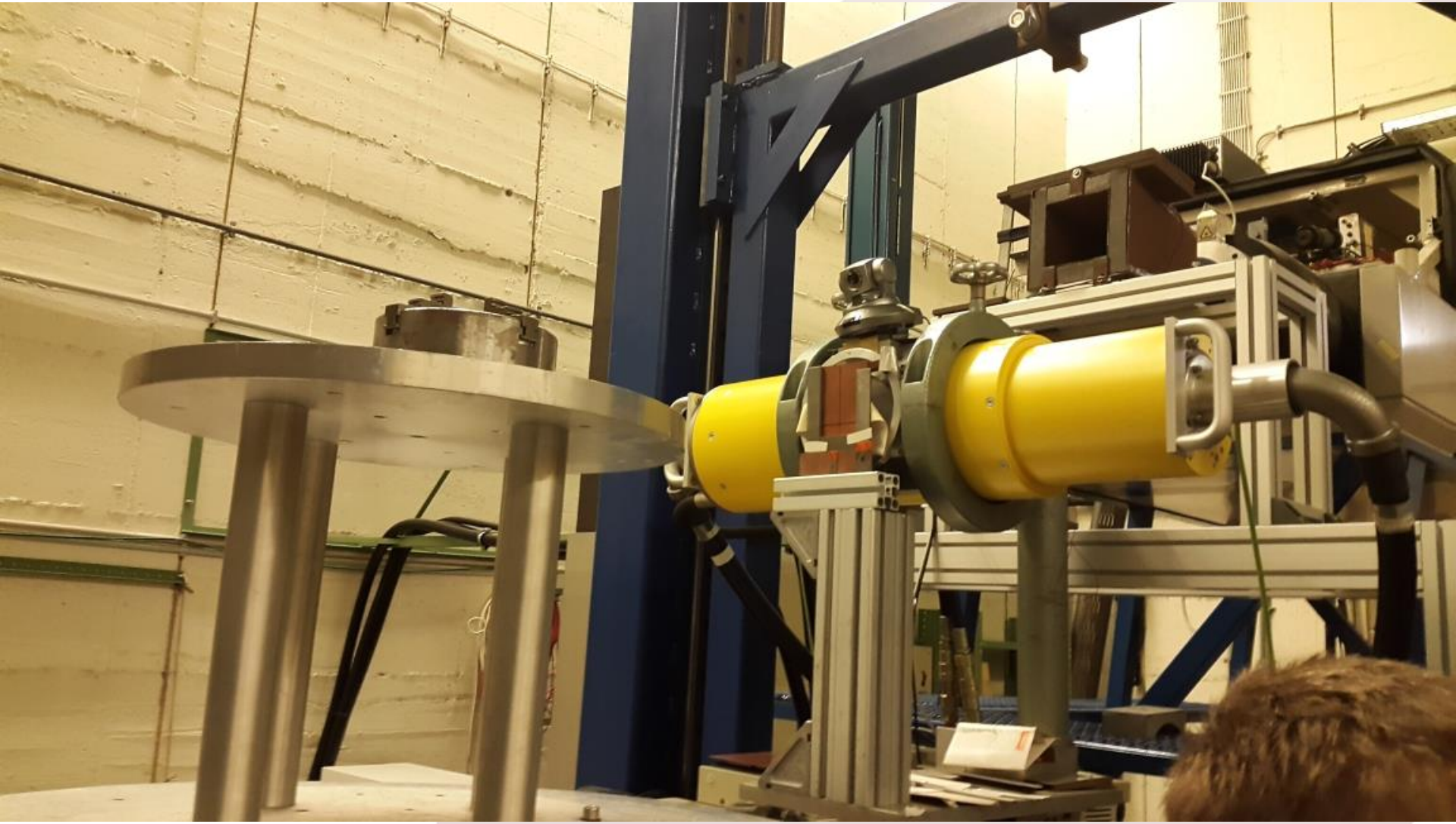
CCD Detection System (2000x2000 pixels)

For a 2D CCD detector arrays, scattering into other pixels is a big issue. Many of the counts in a pixel do not come from direct paths but from scattered paths.

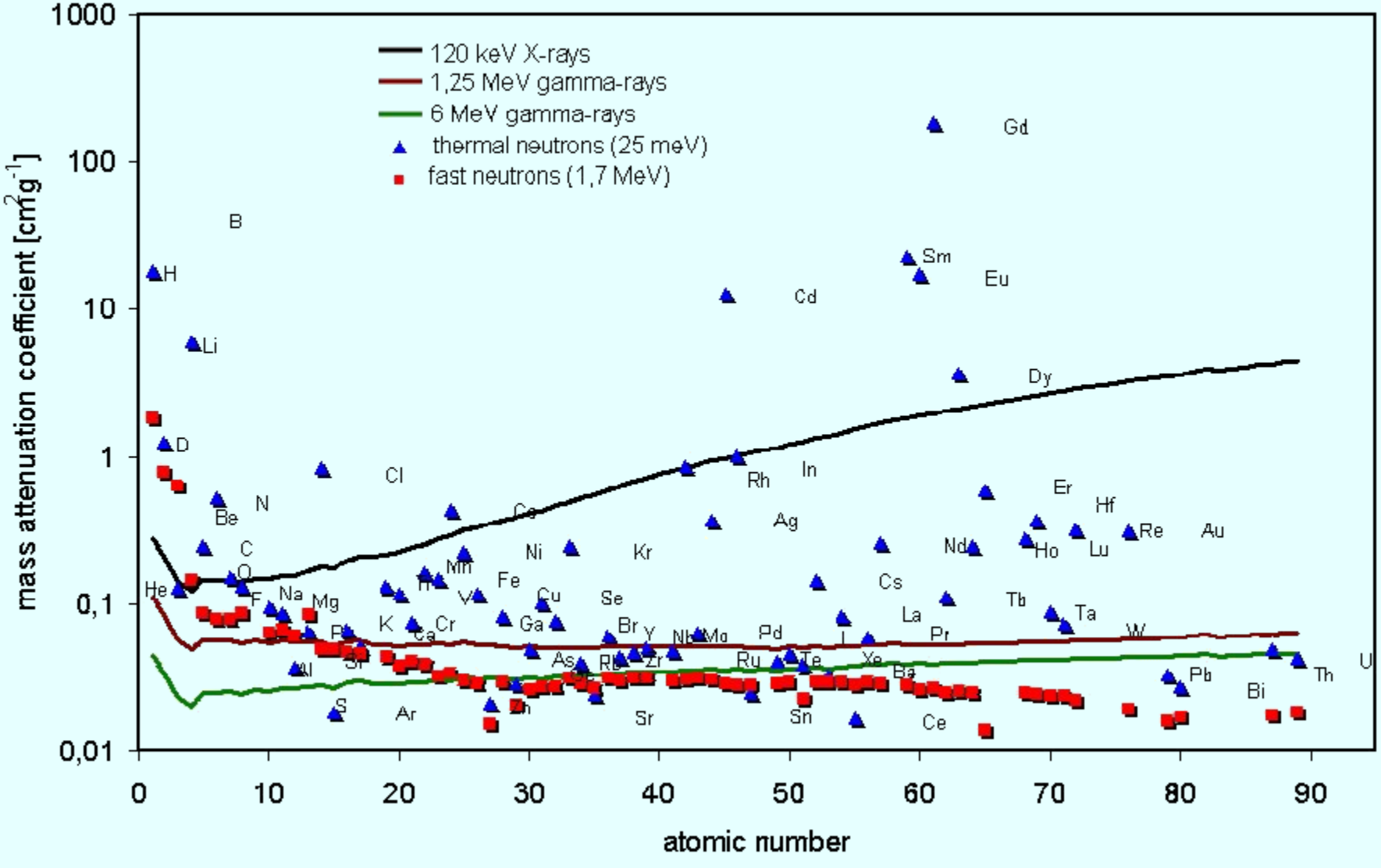

Kinder
ÜBERRASCHUNG

Large Object x-ray CT

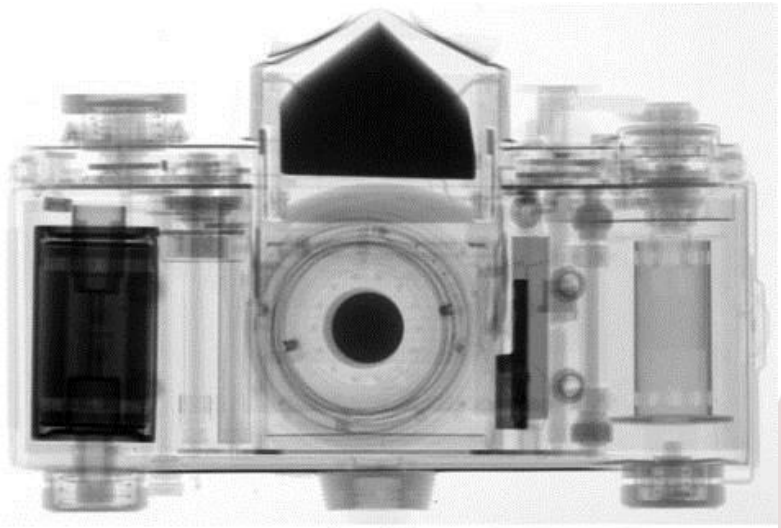
LINAC: 500 keV electrons

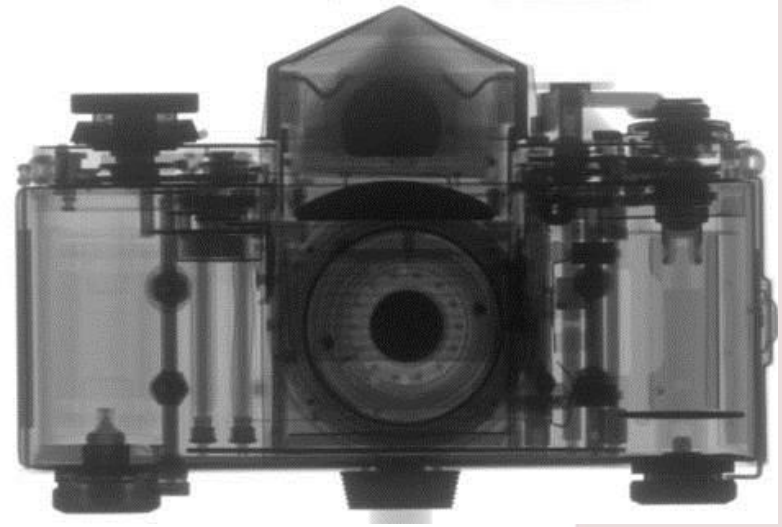


Mass attenuation coefficients



Thermal neutron imaging facilities





ORPHEE/ISIS (CEA Saclay, France)
Helmholtz Zentrum (Berlin, Germany)
MLZ (Munich, Germany)
PSI (Switzerland)

ESS (Lund, Sweden)

- **Complementary to x-ray CT**
- **High penetration for high-Z materials**

- **Potential activation of the sample**
- **No information on isotopic composition**
- **Attenuation coefficients vary wildly with material type**
- **High efficiency detection system is difficult to build**

Potential applications of Fast Neutron Tomography

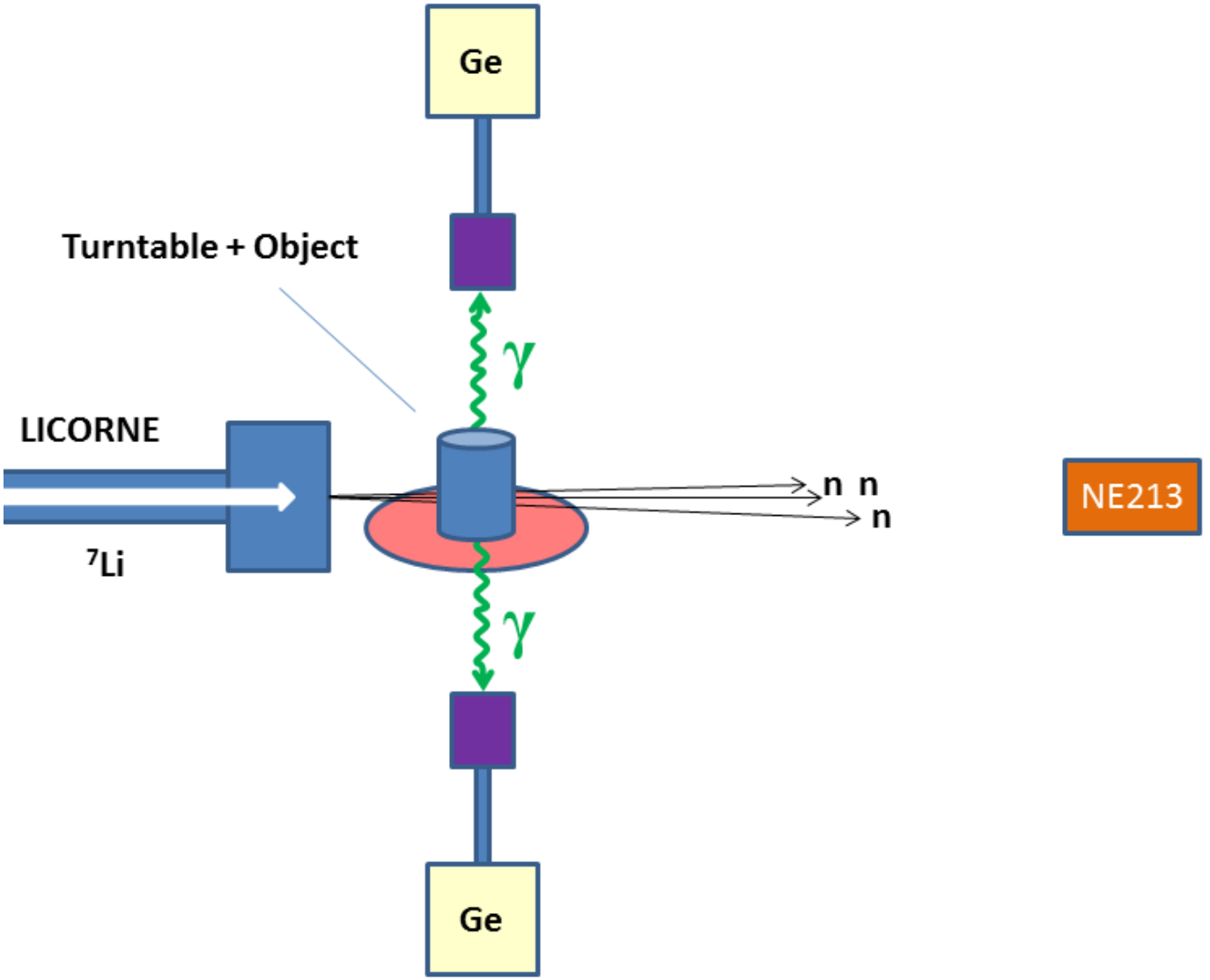
- Border/airport security (e.g. detection of explosives in suitcases)
- Nuclear Industry: Characterisation of nuclear waste packages
- Cultural Heritage: Imaging inside precious artifacts and objects
- Precision quality control for industry
- Non destructive characterization of geological samples (e.g. Metorites)

LICORNE II

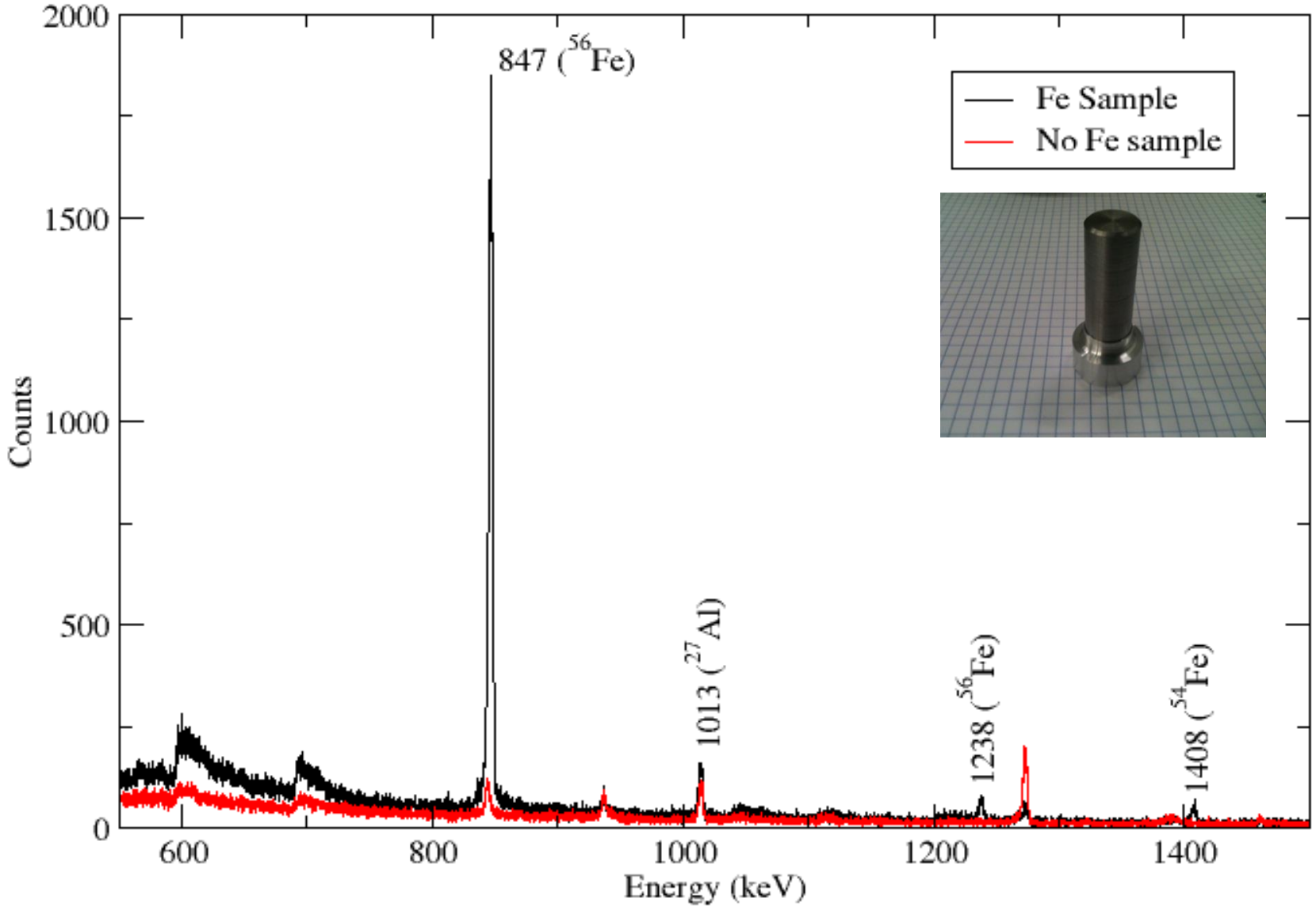
H_2 pressure and low control system

Hydrogen gas cells

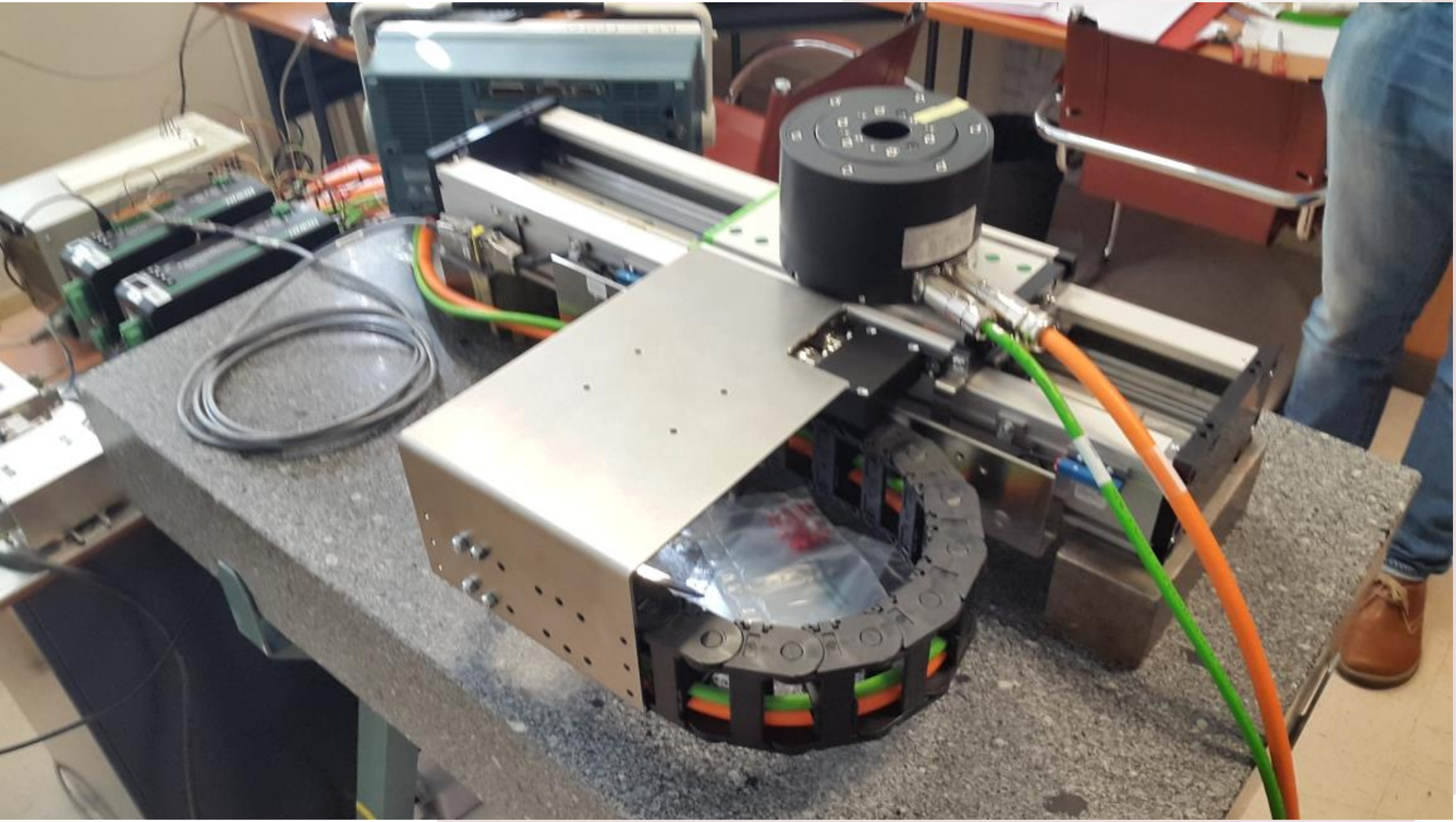
Experimental Setup



Non-destructive, penetrating probes of sample compositions
A new application for directional fast neutrons



IPN Orsay scanning table

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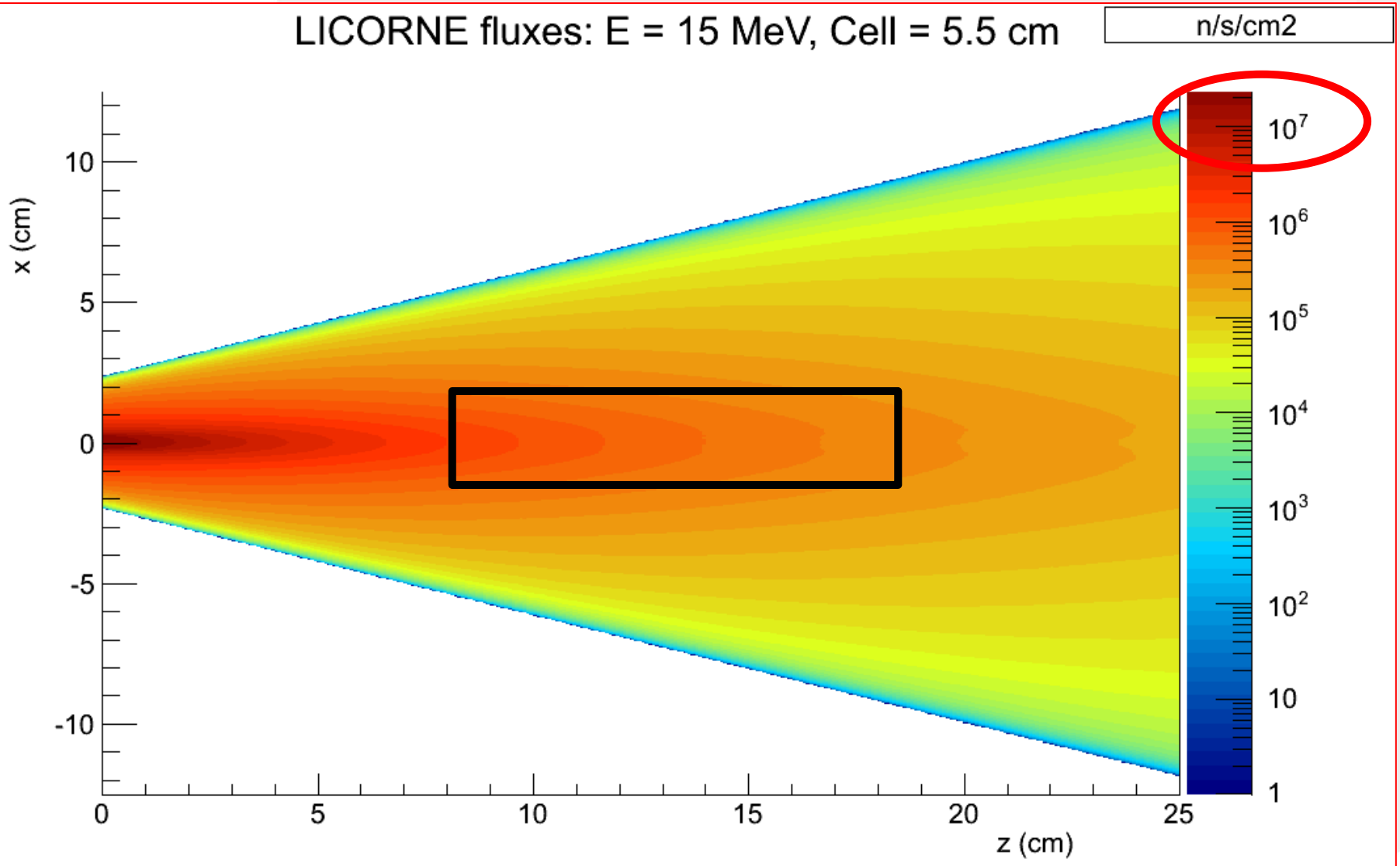
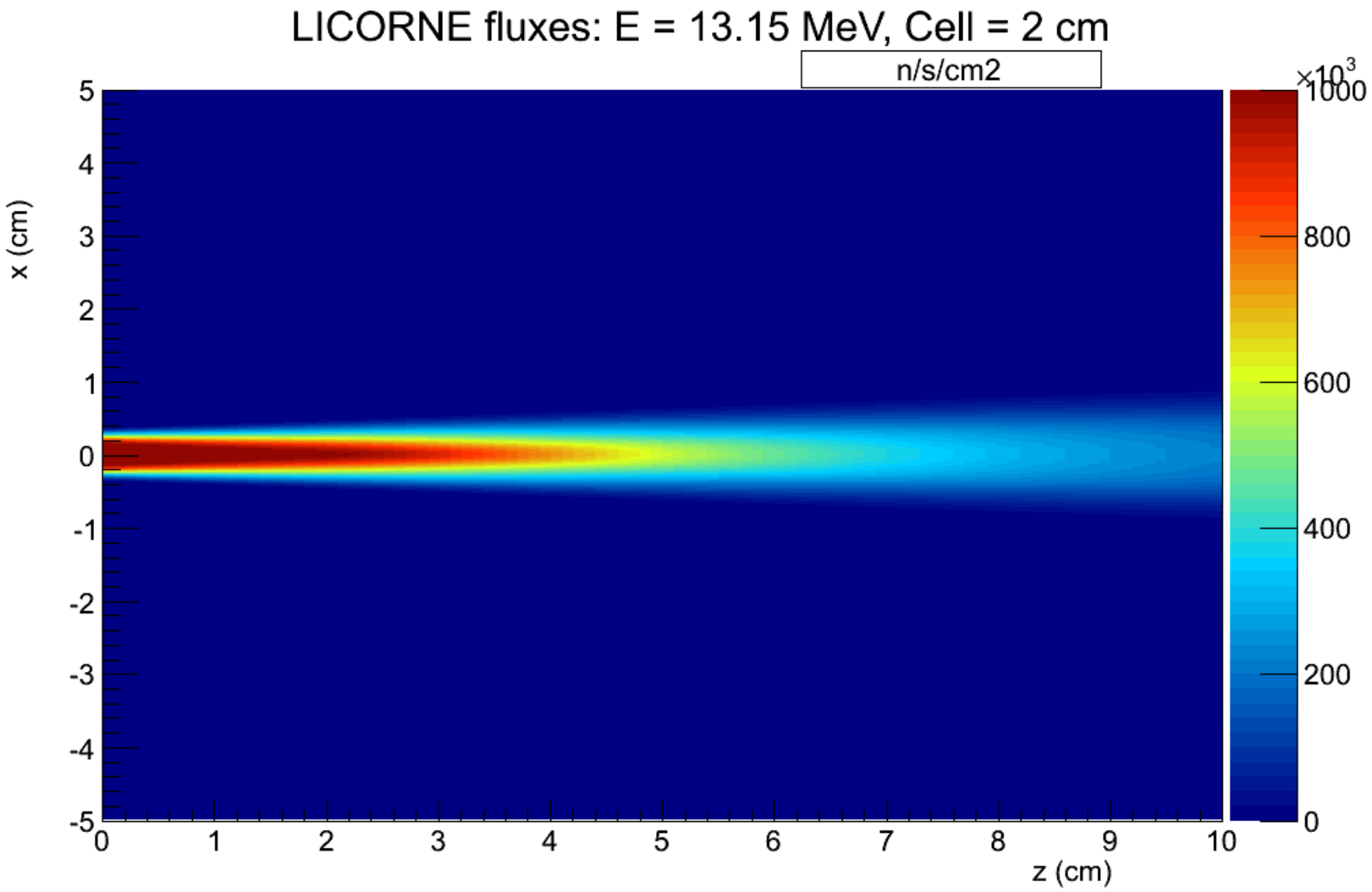
RESTAURIERUNG AM OBERBA

Conclusions/Summary

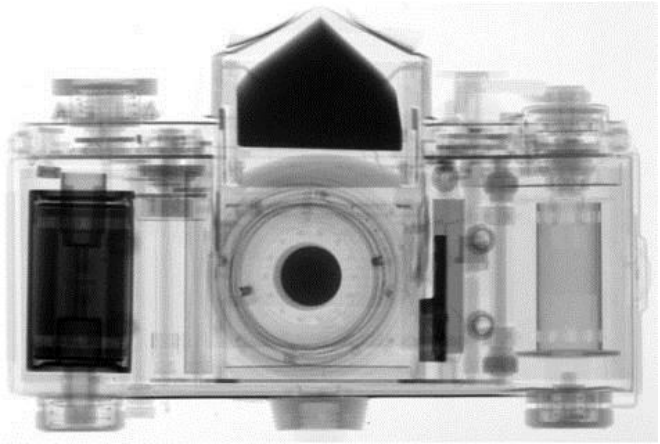
- Fast neutron imaging would be an interesting potential application for IFMIF/DONES
- Look for special niche applications which are complementary to x-ray or thermal neutron CT
- Requires very well collimated neutron beam + fast neutron detection system (e.g. highly segmented 1D or 2D liquid scintillator array)
- Production and ejection of secondary particles (gammas, neutrons) gives important additional information on the object internal structure
- Secondary particles are produced with 14 MeV neutrons mainly via (n,n'γ) and (n,2n) reactions
- Detection of emitted gamma rays will require additional gamma ray array detection system

AVAILABLE FLUXES

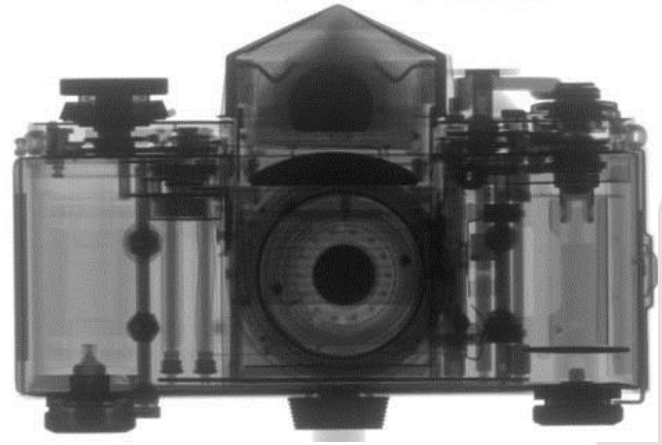



LICORNE fluxes: E = 13.15 MeV, Cell = 2 cm
n/s/cm2
×10^3
1000
800
600
400
200
0
x (cm)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
z (cm)

Complementarity neutrons/photons



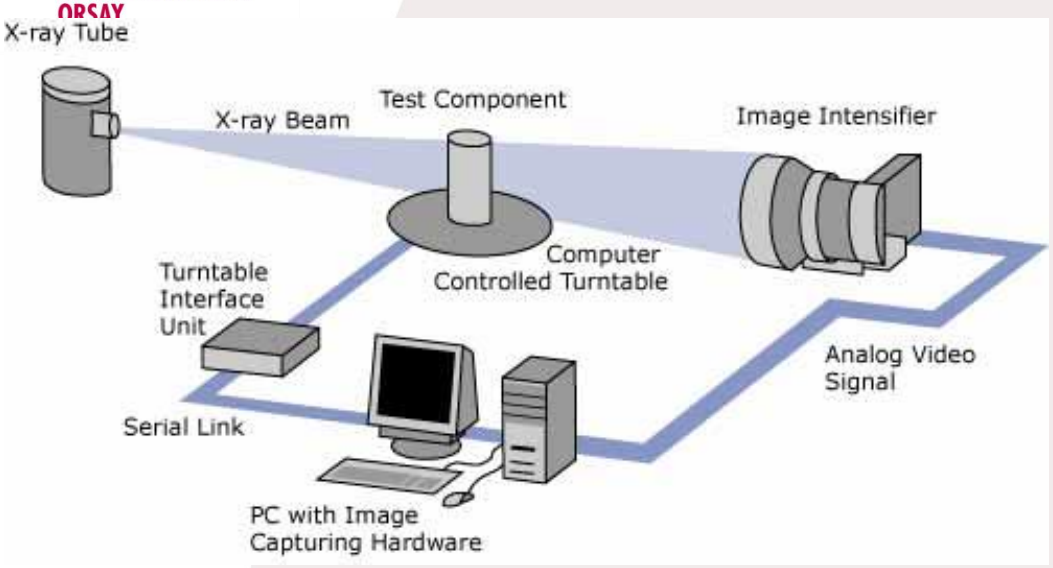
Thermal neutrons



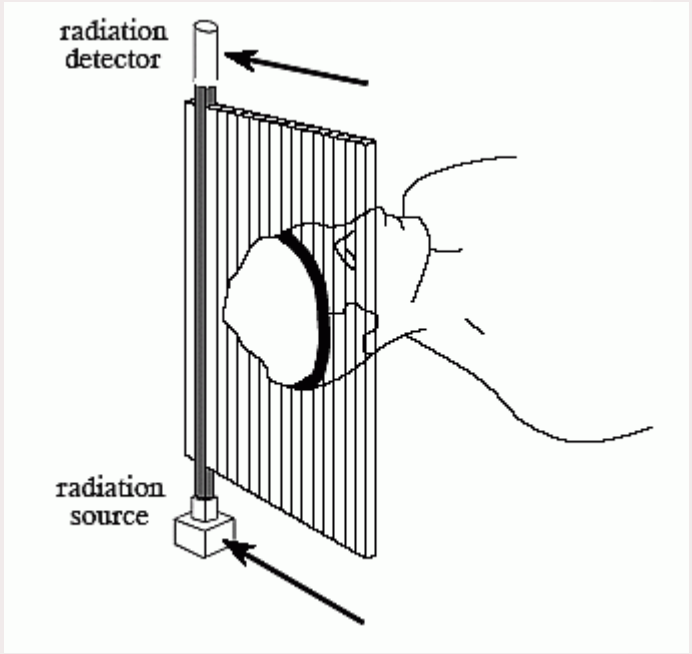
X-rays

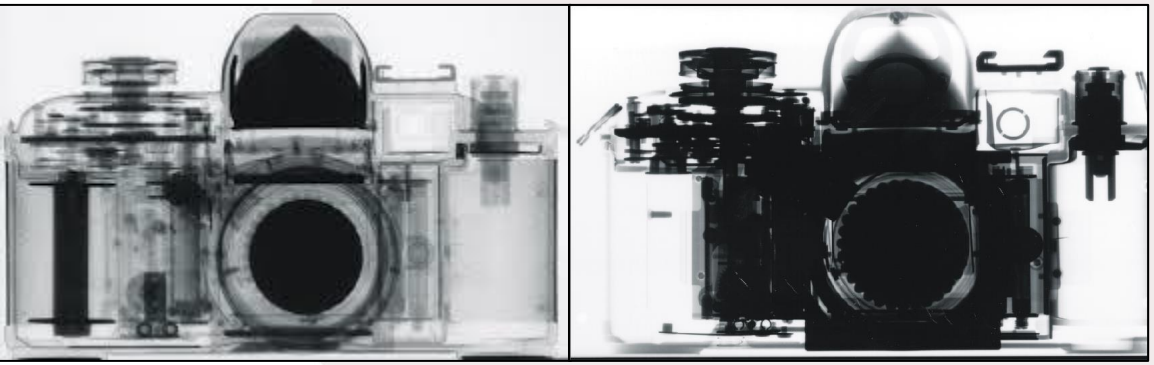
Radiograph of an analog camera: by neutrons (top) by X-rays (bottom). While X-rays are attenuated more effectively by heavier materials like metals, neutrons make it possible to image some light materials such as hydrogenous substances with high contrast: in the X-ray image, the metal parts of the photo apparatus are seen clearly, while the neutron radiograph shows details of the plastic parts.

IMAGING APPLICATIONS



Neutron radiography/ tomography





Laboratoire d'Archéologie Moléculaire et Structurale

LAMS