WELCOME TO THE ILL !

Summary

- ILL – 50 years of neutron science
- The neutron source
- Why neutrons?
- Examples of neutron science and applications
- A look to the future

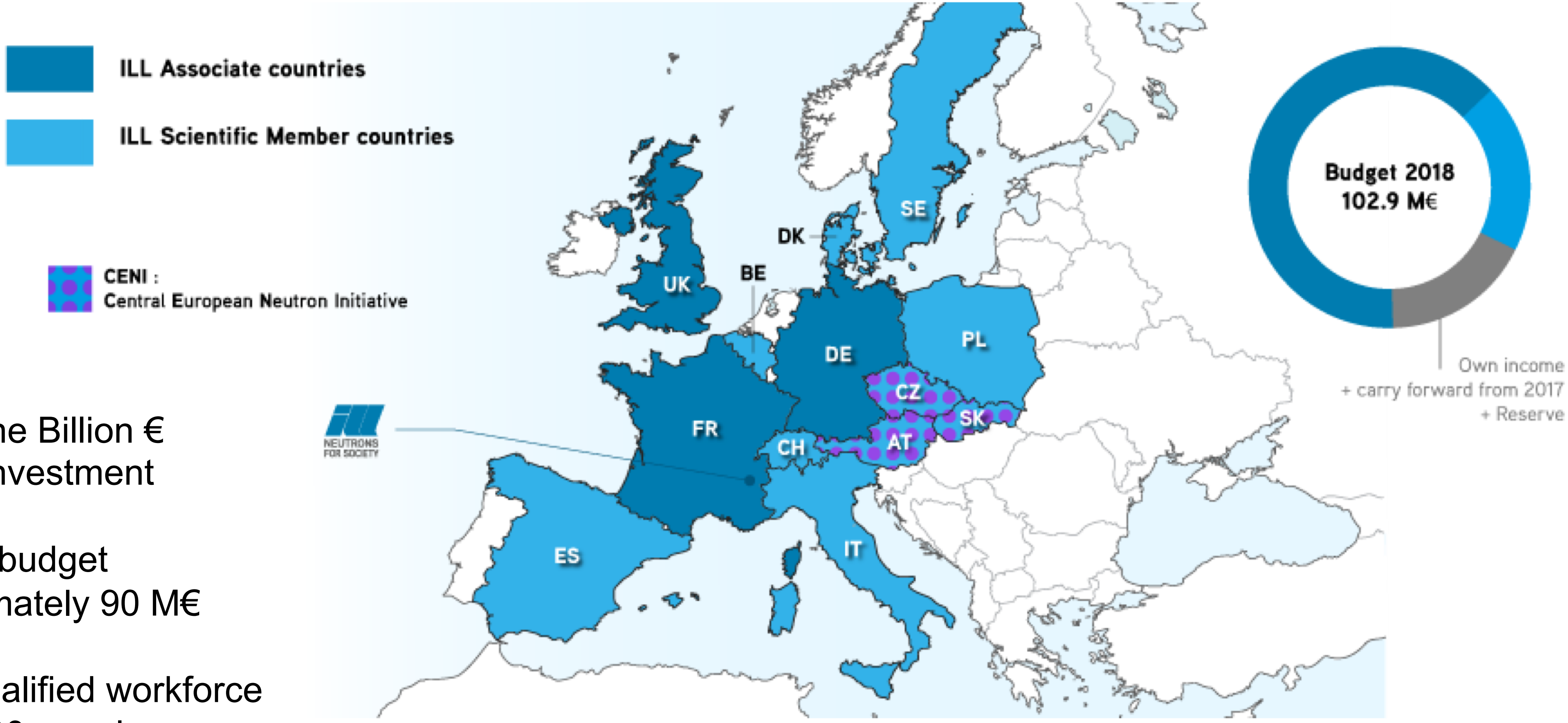
Institut Laue-Langevin – founded in 1967
World leader in neutron science and technology

After more than 40 years, we are still number one

The ILL is the most intense neutron source in the world, at the service of international scientists, to carry out scientific research at the frontiers' of modern science.

The ILL Stakeholders

The advent of the scientific members continues the process.



- Close to one Billion € of capital investment
- An annual budget of approximately 90 M€
- A highly qualified workforce of about 500 people

Key Figures

1400 users from an active community of 12 000 scientists

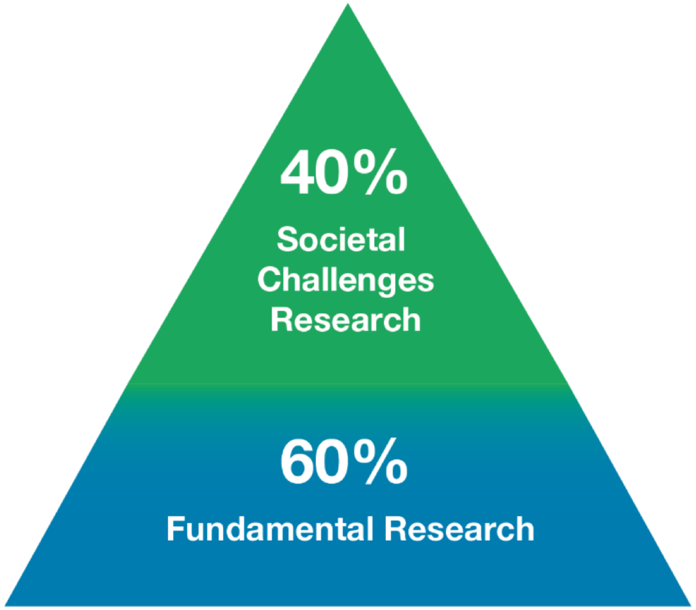
850 experiments/year

650 publications/year

65 countries

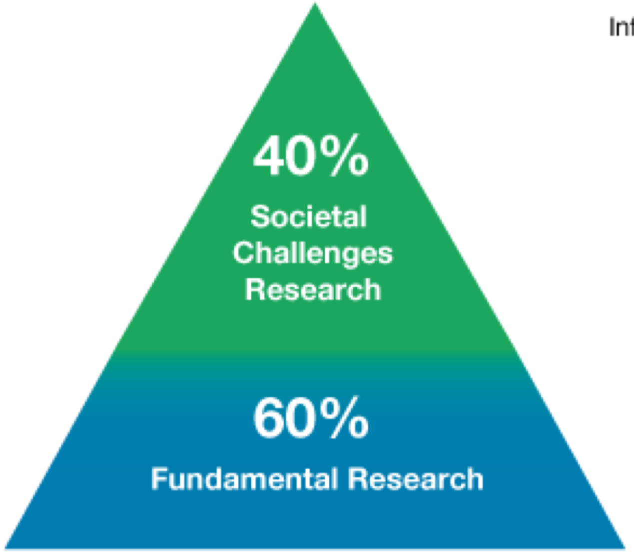
28 instruments + 10 CRG

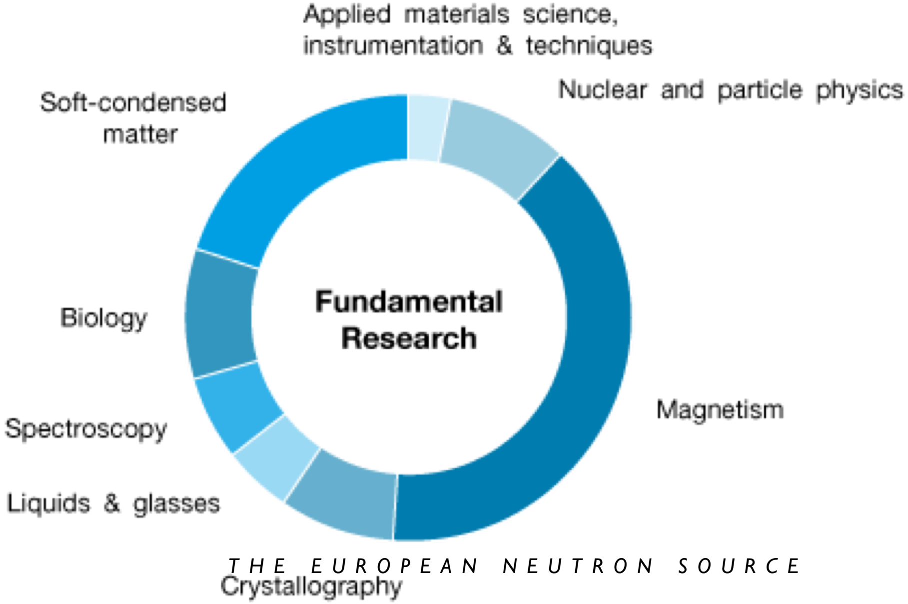
4 cycles of 50 days/year



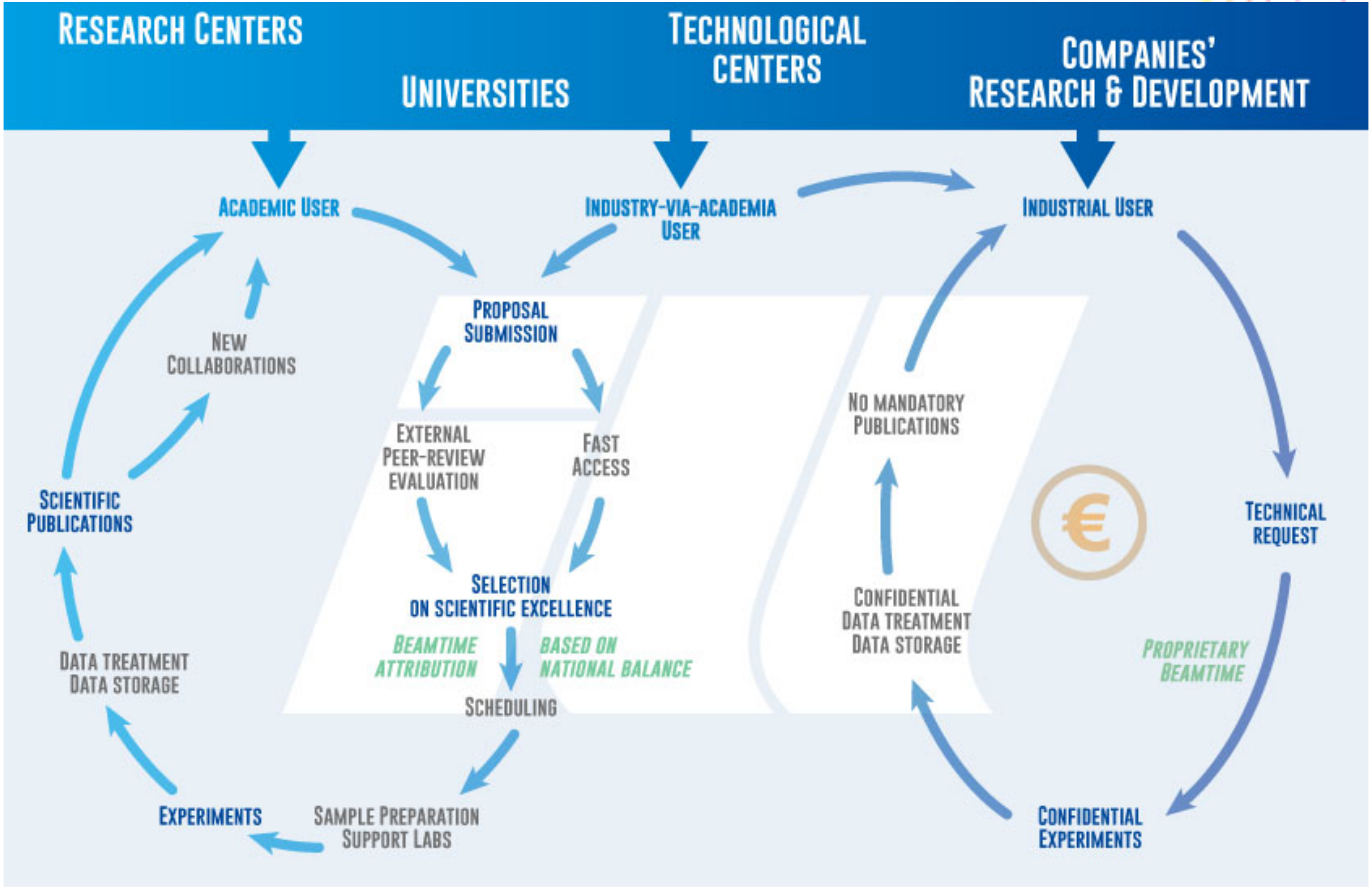
Research Areas

As per accepted proposals





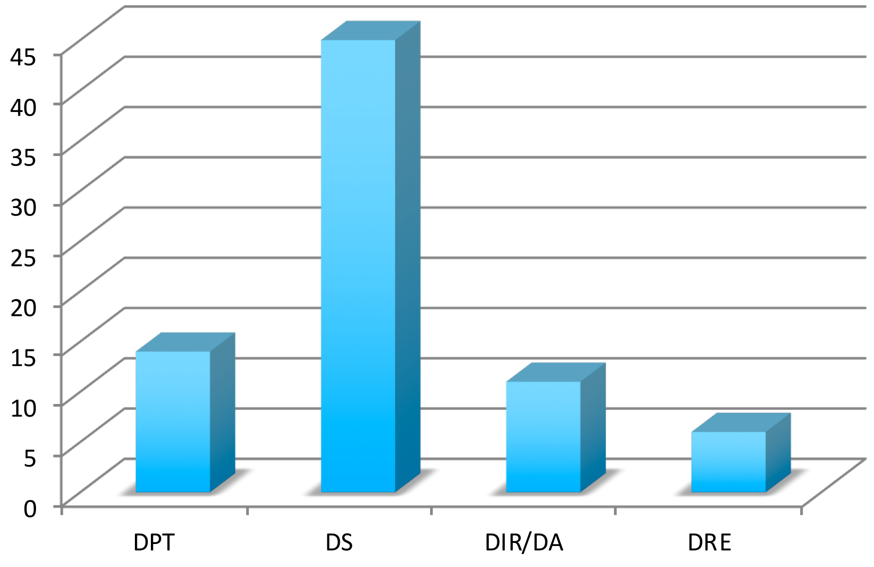
How to Request Beam Time



NEUTRONS FOR SOCIETY

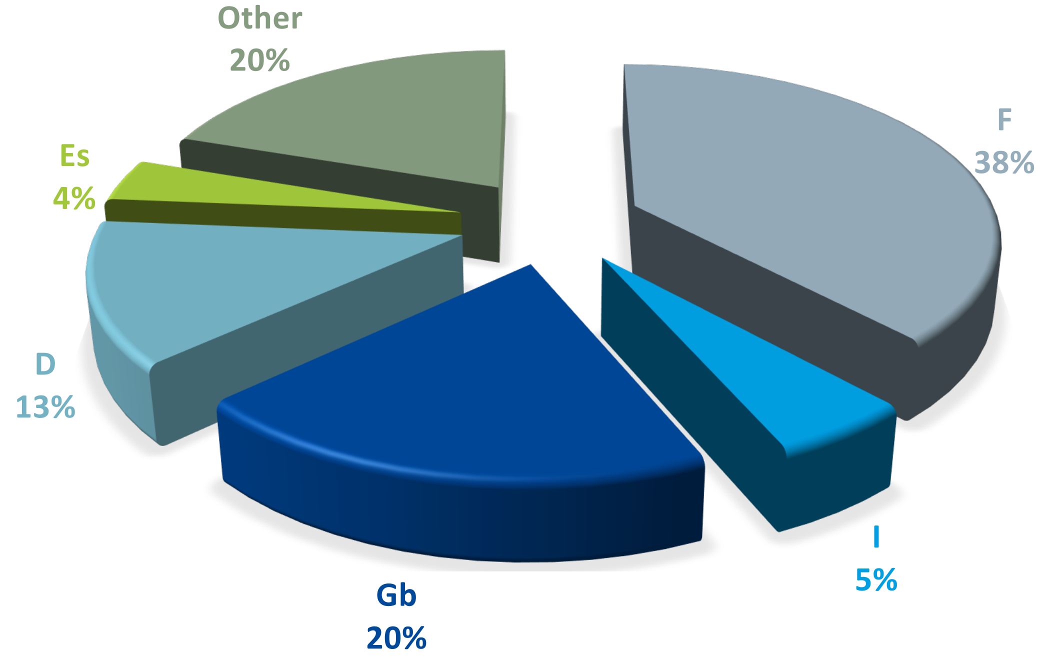
Students @ ILL

- 180 month of traineeship from ILL dedicated budget allocated each year
- Specific external founding
  - Erasmus
  - STFC
  - EU projects



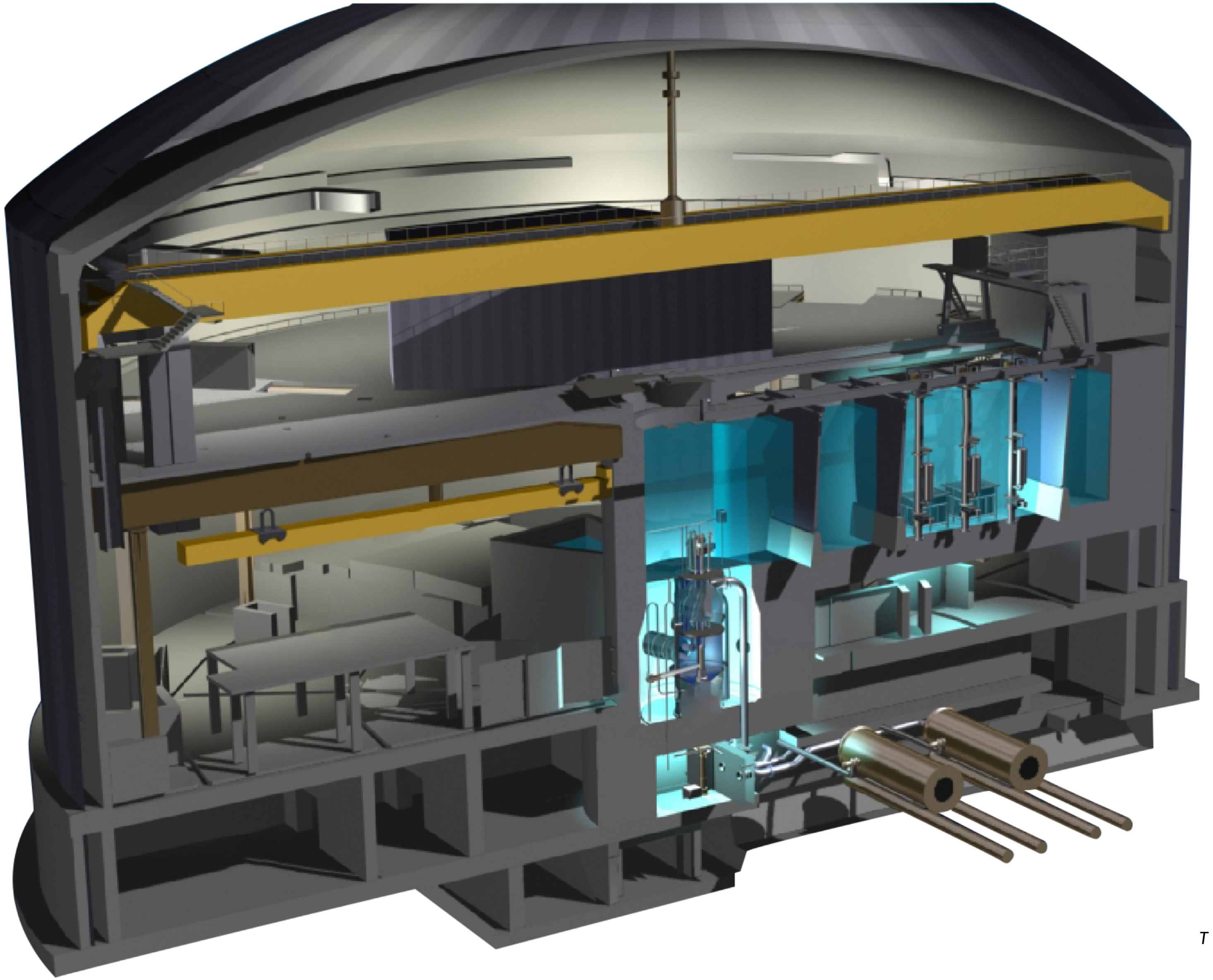
Students distribution per division

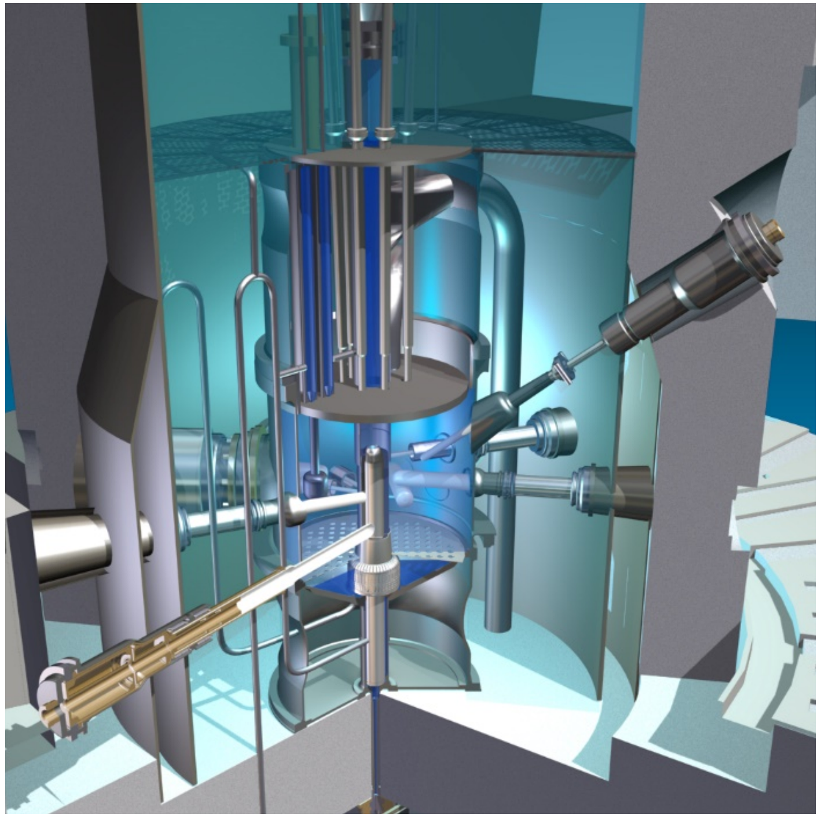
National balance



Average of about 10 new PhD students/year

The ILL Reactor



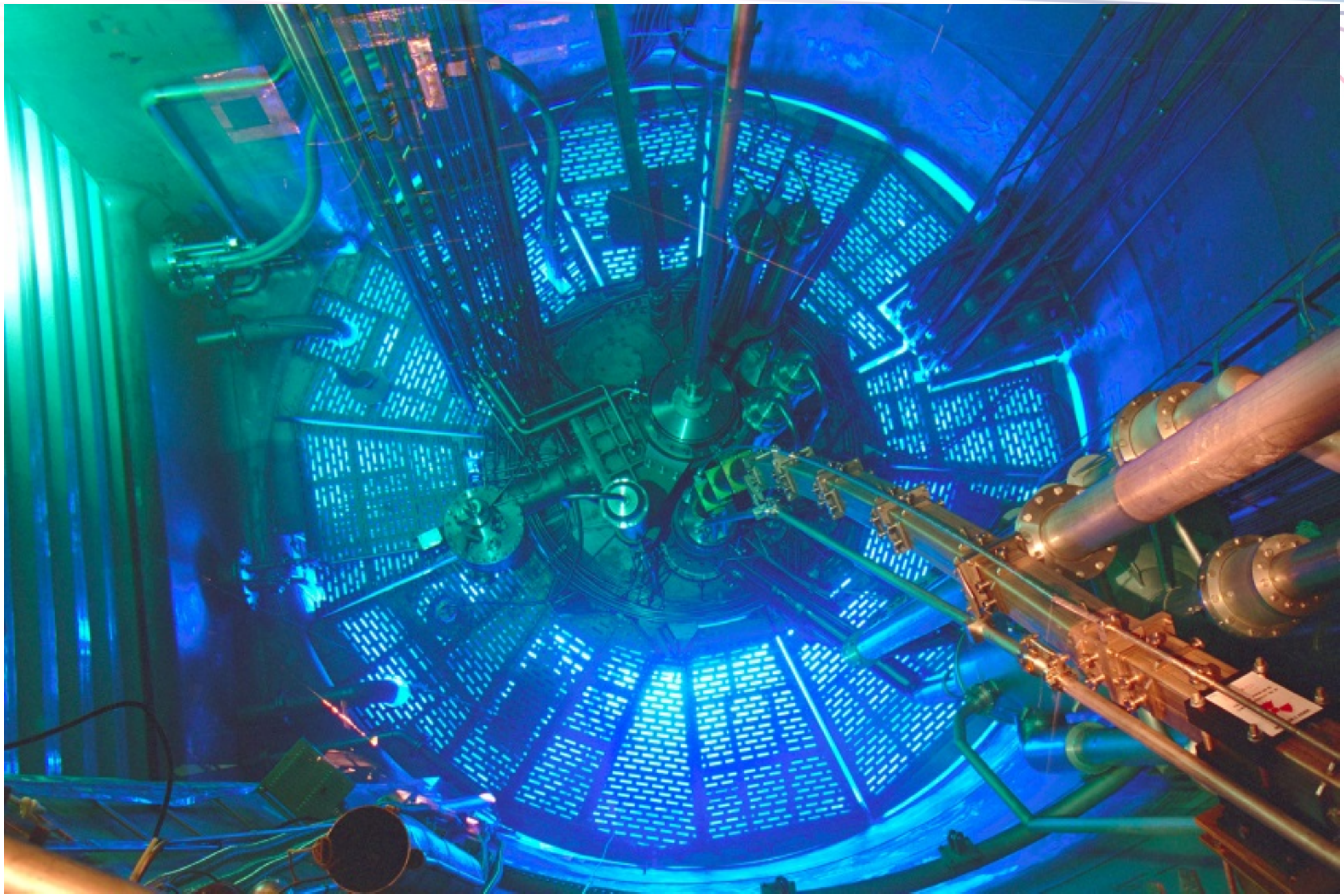


A neutron source generating

5 x 10^{18} fast neutrons/sec

at a max power of 58 MW

The ILL Reactor



Neutron Production

Fission Reaction

$n^1 + U^{235} \longrightarrow$ 2 fission fragments + 2.5 n^1 + 200 MeV

Thermal

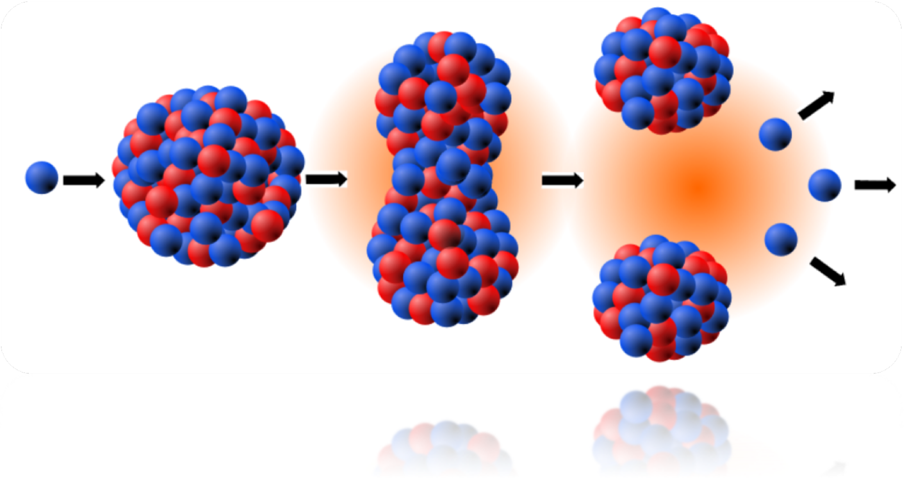
1 neutron to maintain chain reaction

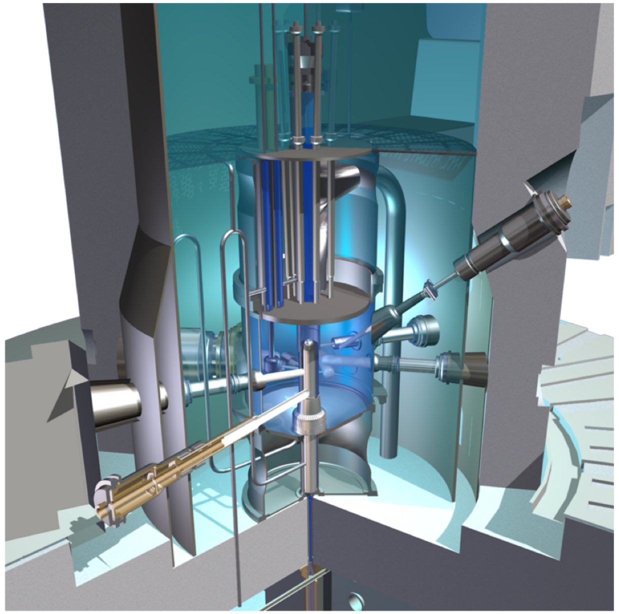
1 neutron escapes & is available for use

0.5 neutrons absorbed

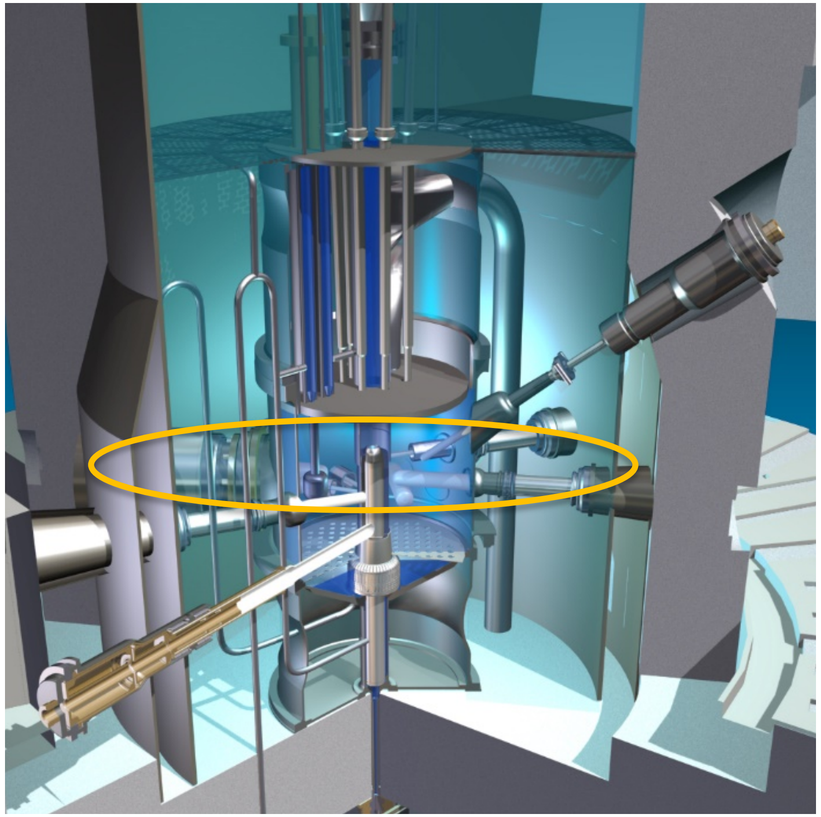
2 to 3 neutrons

No. of fissions/sec $= \dfrac{20 \times 10^6 \text{ watts}}{200 \text{ MeV/fission}}$





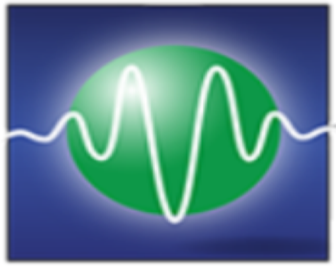
How Neutrons Are Extracted



Neutrons: A Powerful Probe

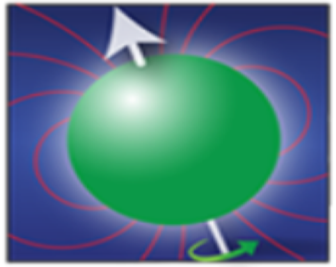
No electric charge

It therefore has an excellent penetration depth for most materials.



Associated wave

Neutron beams can be reflected, refracted, diffracted, just like any other wave.

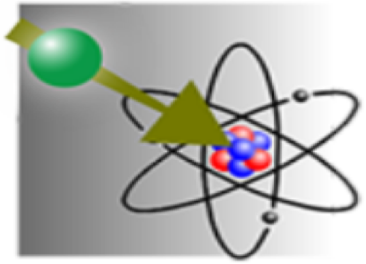


Spin + associated magnetic moment

It therefore behaves like a tiny compass needle able to probe magnetism at the atomic scale.

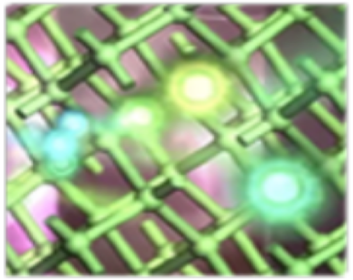
Interacts with the nucleus of atoms

Whereas X-rays and electrons interact with the electron cloud.



Energy range

It is similar to the energy of atomic and molecular motions in matter, making the neutron very sensitive to these motions.



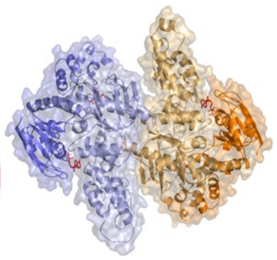
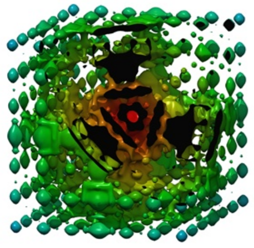
Neutrons: A Powerful Probe

The properties of matter and materials are largely determined by their structure and dynamics at the atomic scale - *distance between atoms ~ 1 Å = 1/100 000 000 cm*

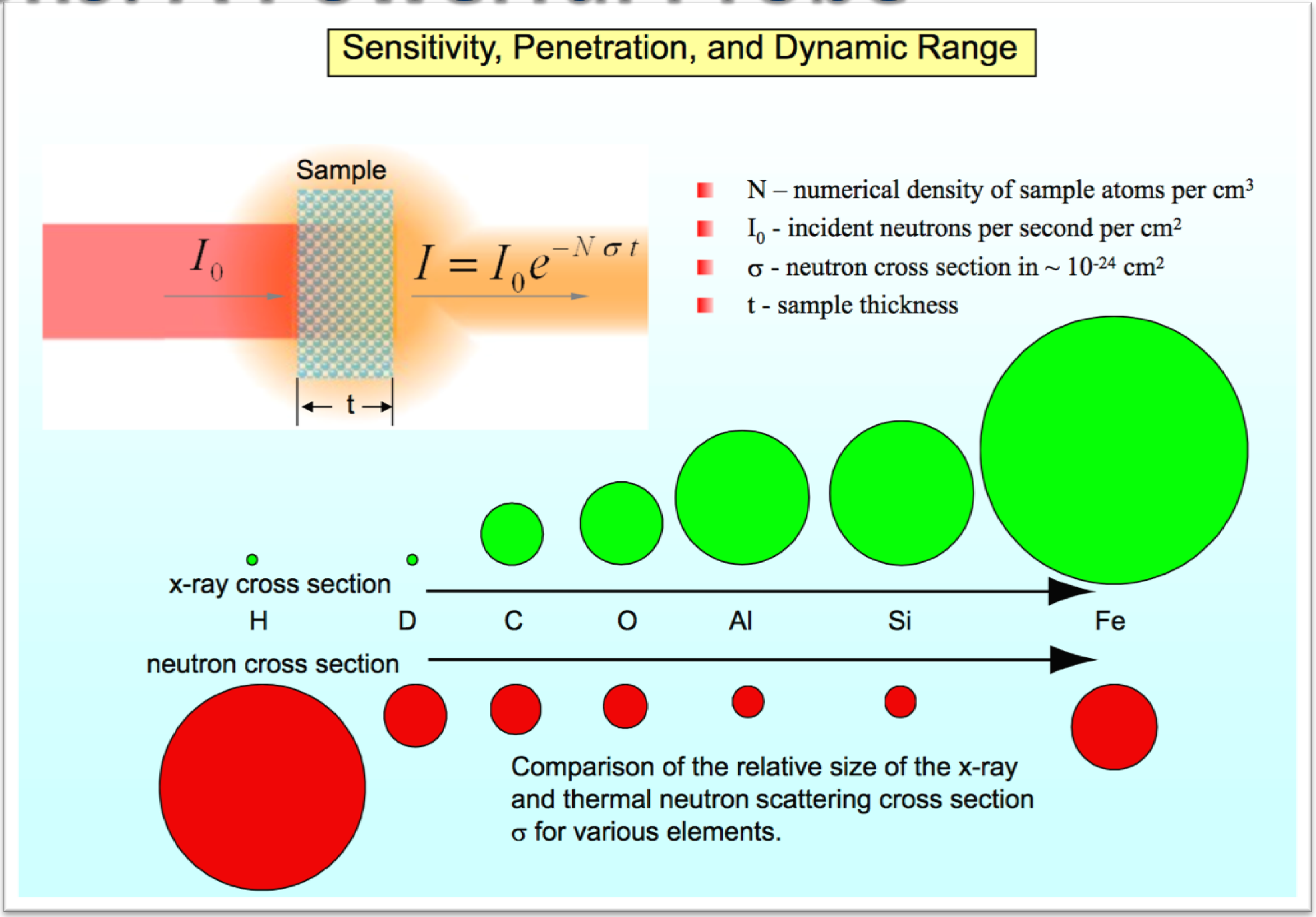
The wavelength of the neutron is comparable to atomic sizes and the dimensions of atomic structures, which explains why neutrons can « see » atoms.

Therefore neutrons are an ideal tool to understand the world around us, telling scientists:

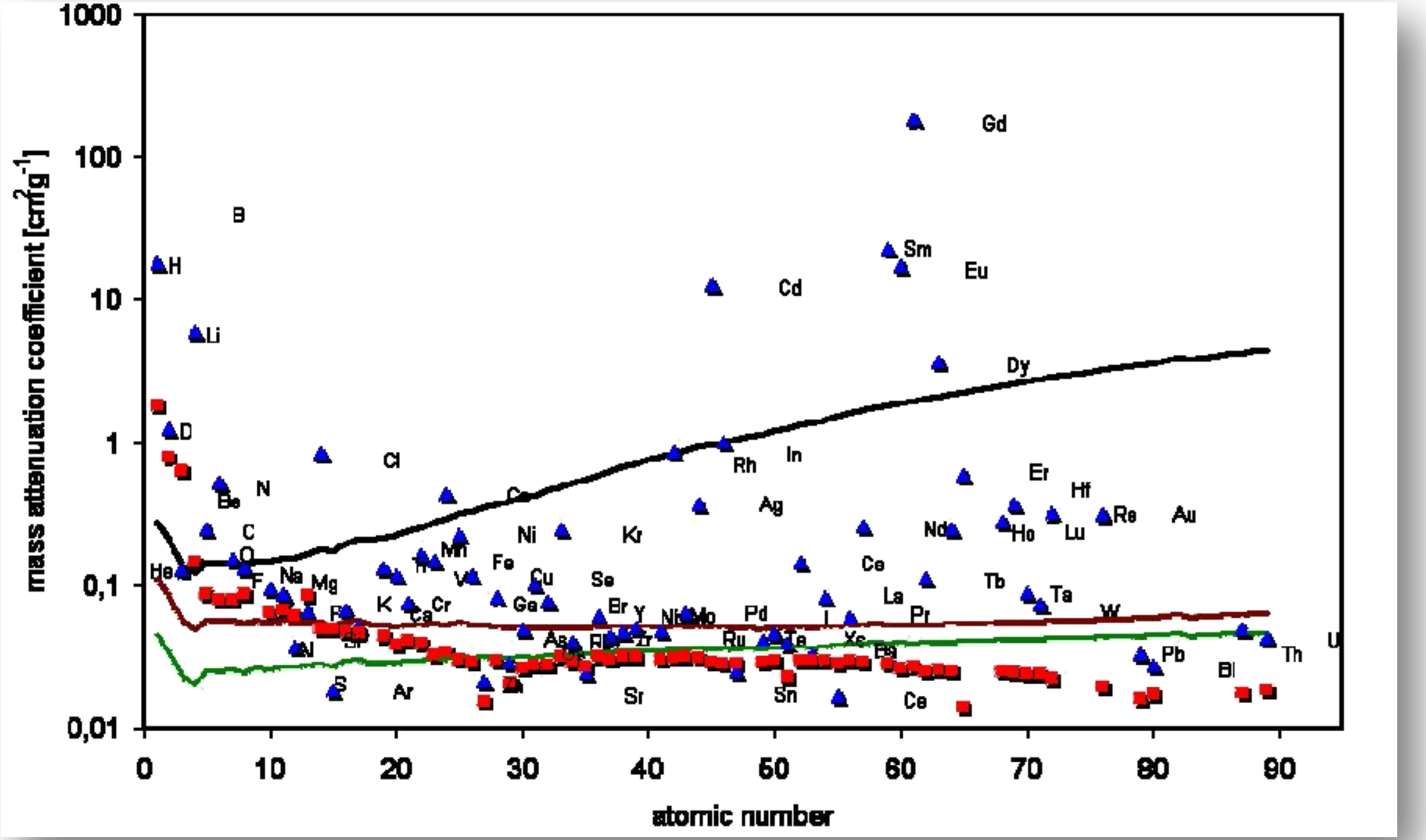
Where is which atom?
How does it bind?
How does it move?
What surrounds it?

Neutrons: A Powerful Probe



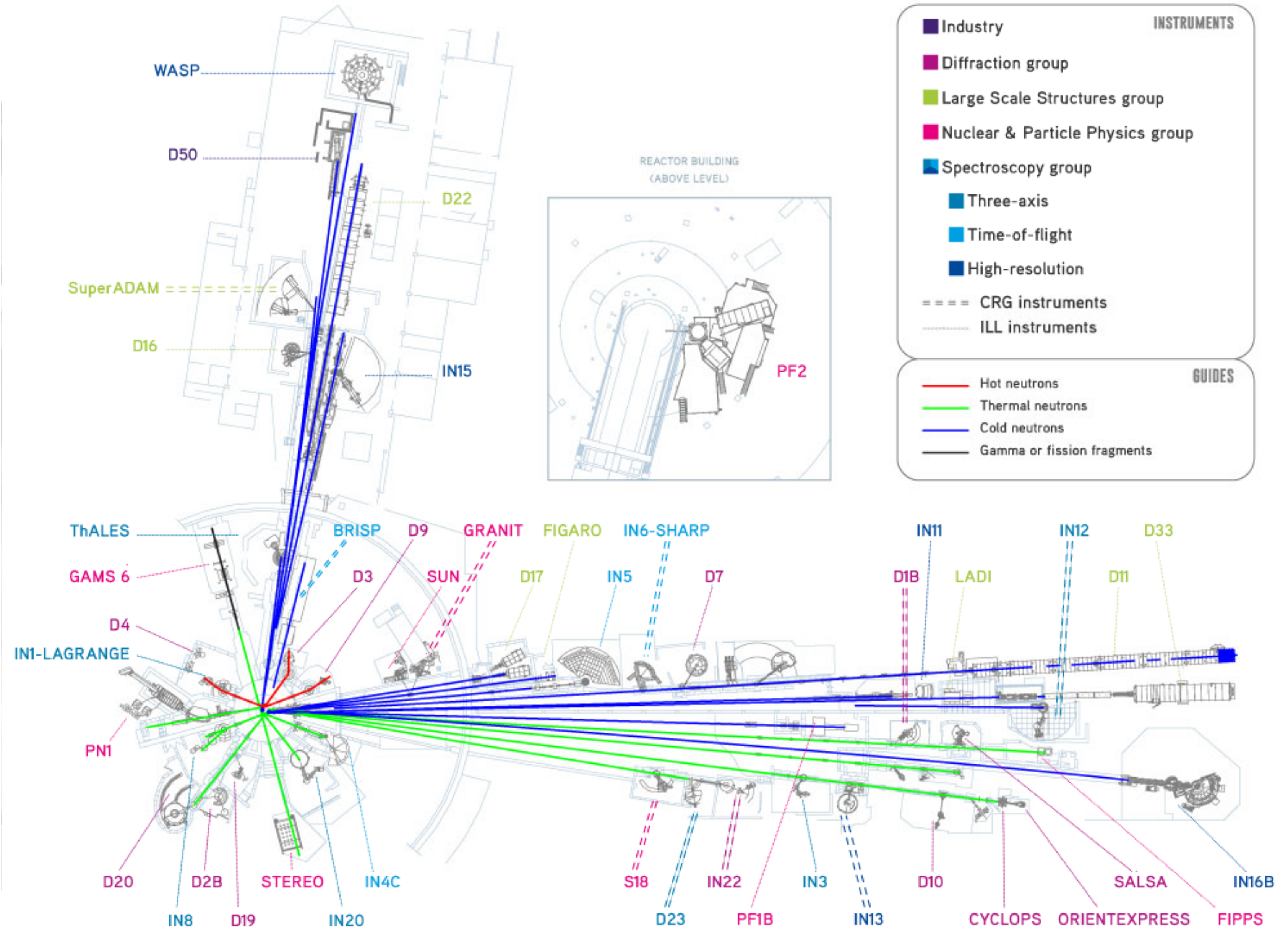
Neutrons: A Powerful Probe



Attenuation coefficient

- 120 keV X-ray
- 1,25 MeV Gamma-ray
- 8 MeV Gamma-ray
- 25 meV neutrons
- 1.7MeV neutrons

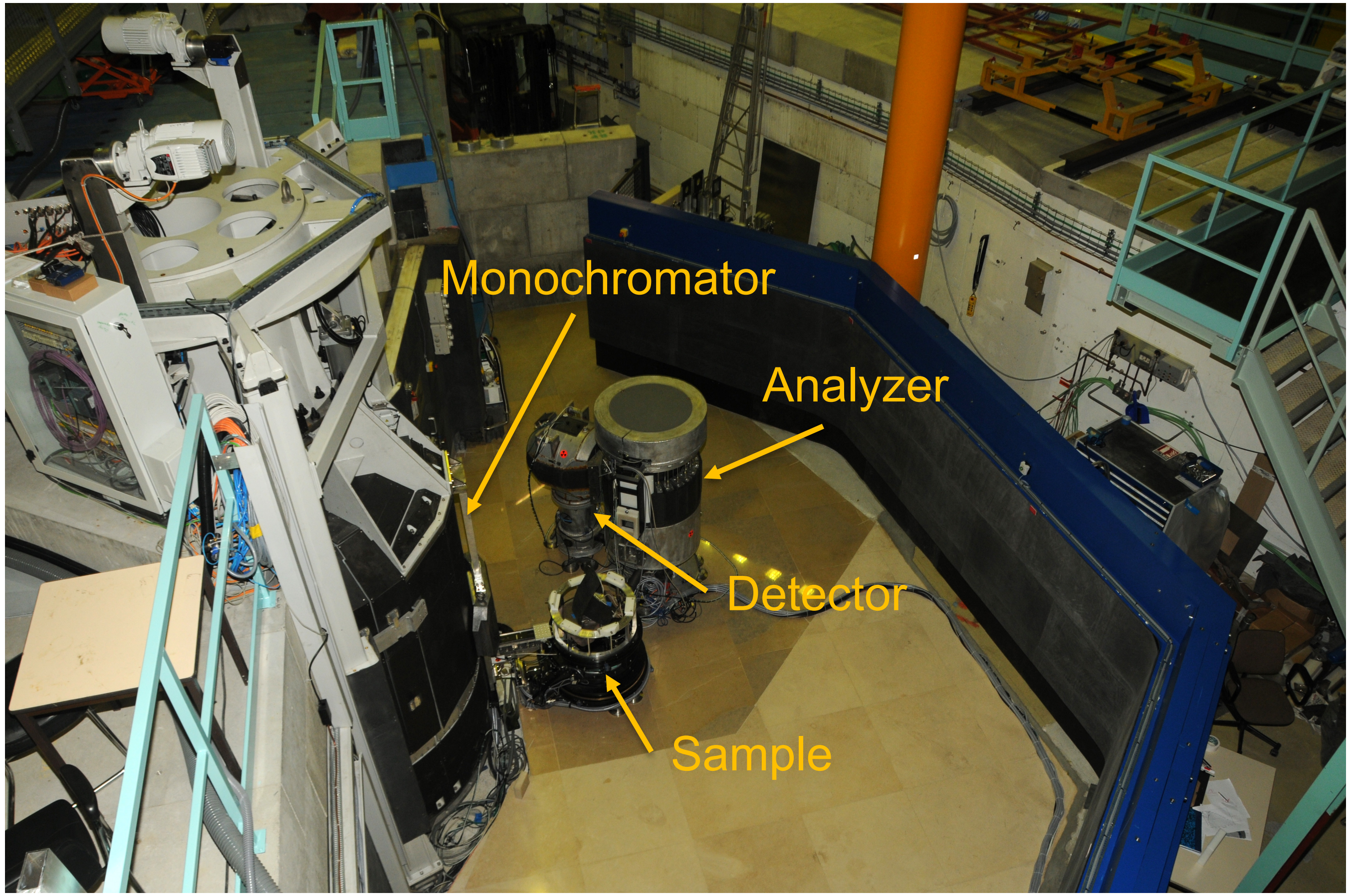
The Instrument Suite

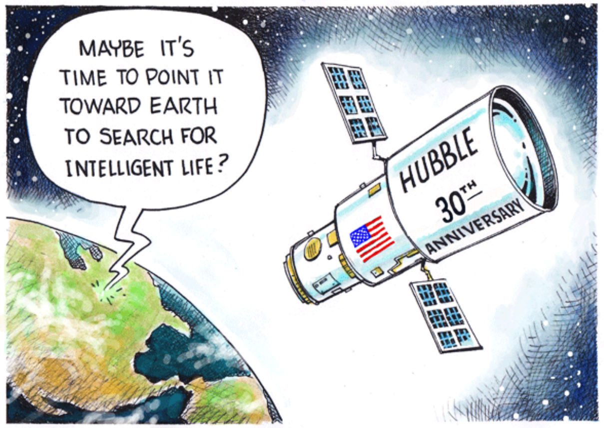


NEUTRONS FOR SOCIETY

Autonomous Measurements on ThALES

ThALES: Three Axis Neutron Spectrometer





Incoming flus:
10^7 to 10^9 n/cm^2/s

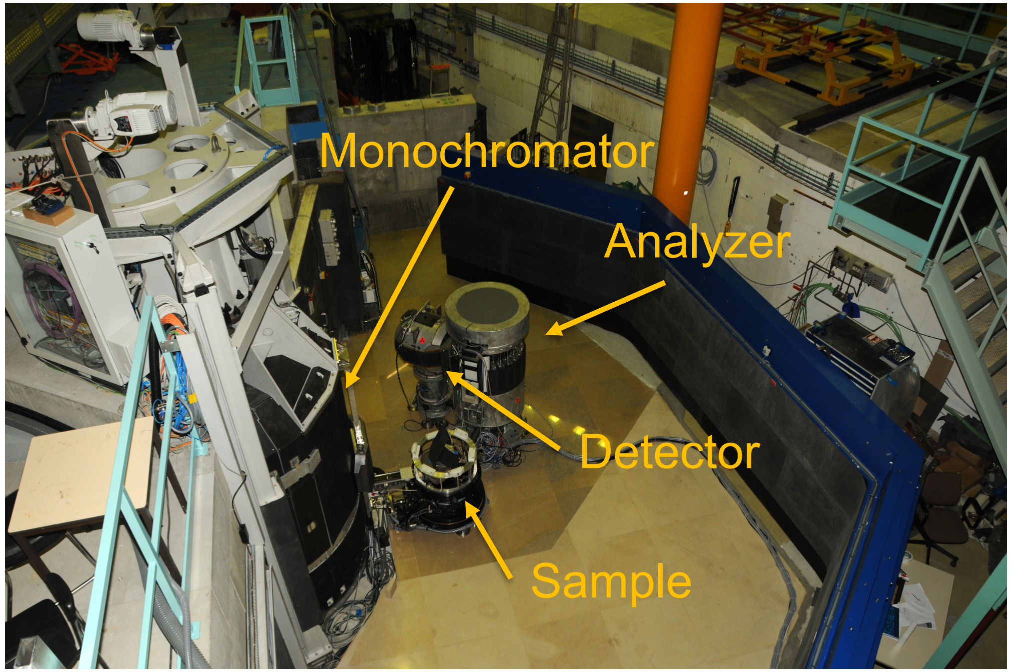
Nr of analyzing channels:
Classical TAS: 1
FlatCone: 31

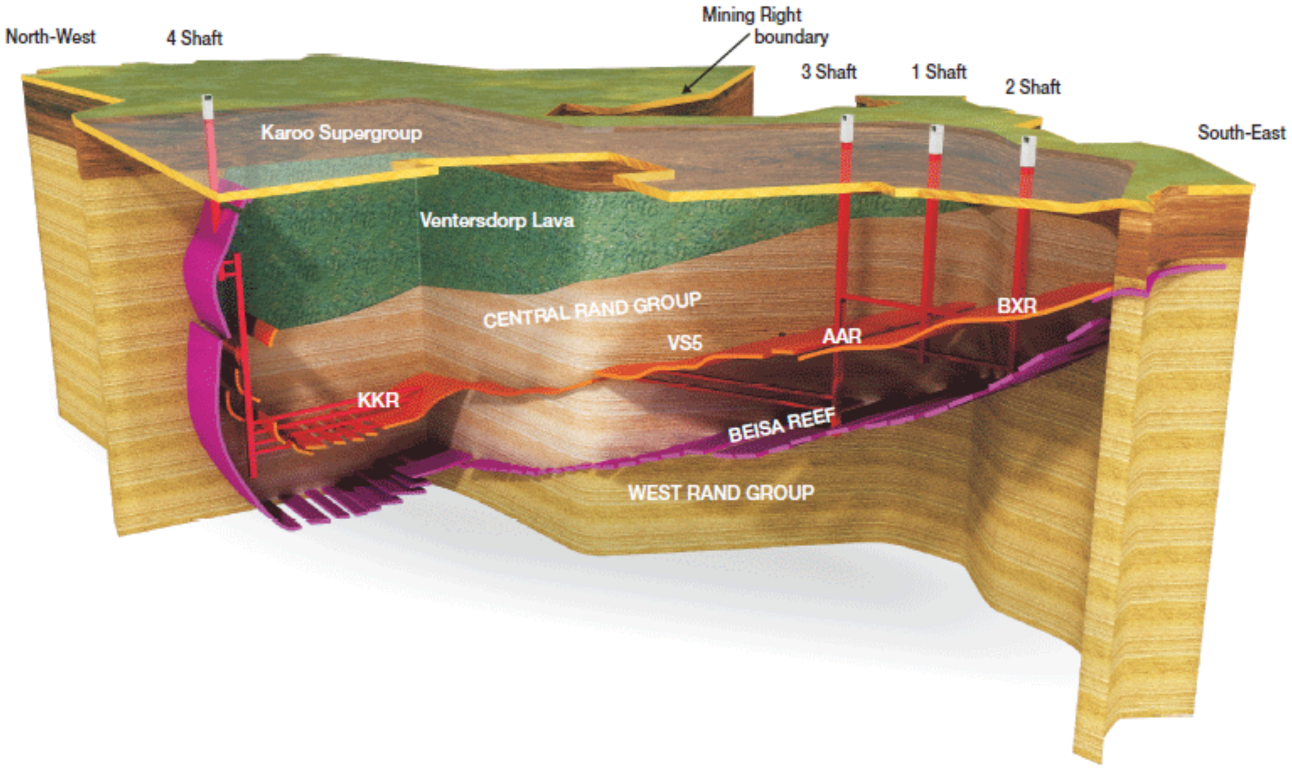
Efficiency depends on **interactivity**

gpCAM - Autonomous Measurements

Inspired by the Kriging regression model

ThALES: three Axis Neutron Spectrometer





Danie G. Krige: distance-weighted average gold grades at the Witwatersrand reef (South Africa).

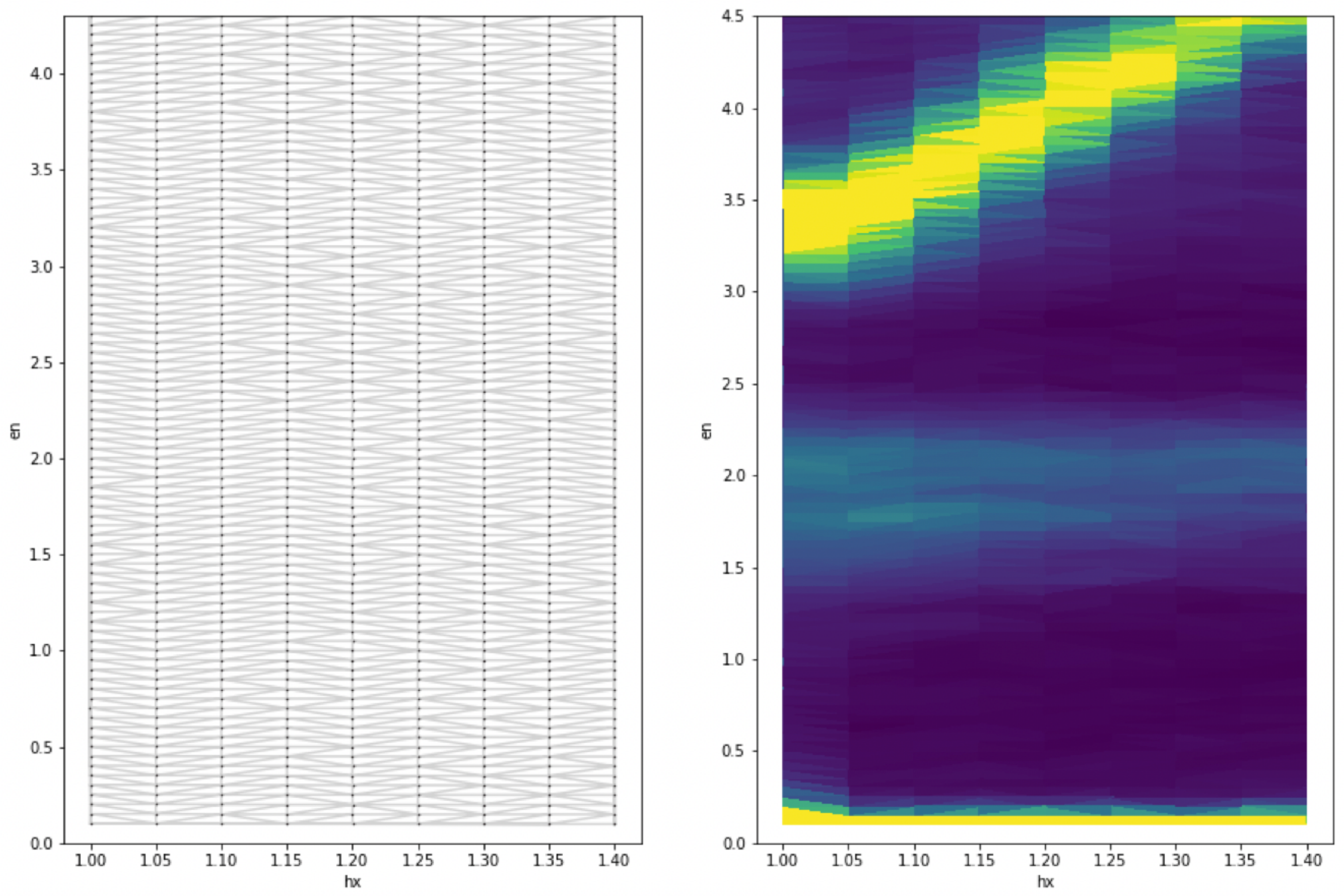
Georges Matheron: mathematical/ theoretical basis 1960

Grid Measurement

Step in hx = 0.05 A^{-1}

Step in EN = 0.05 meV

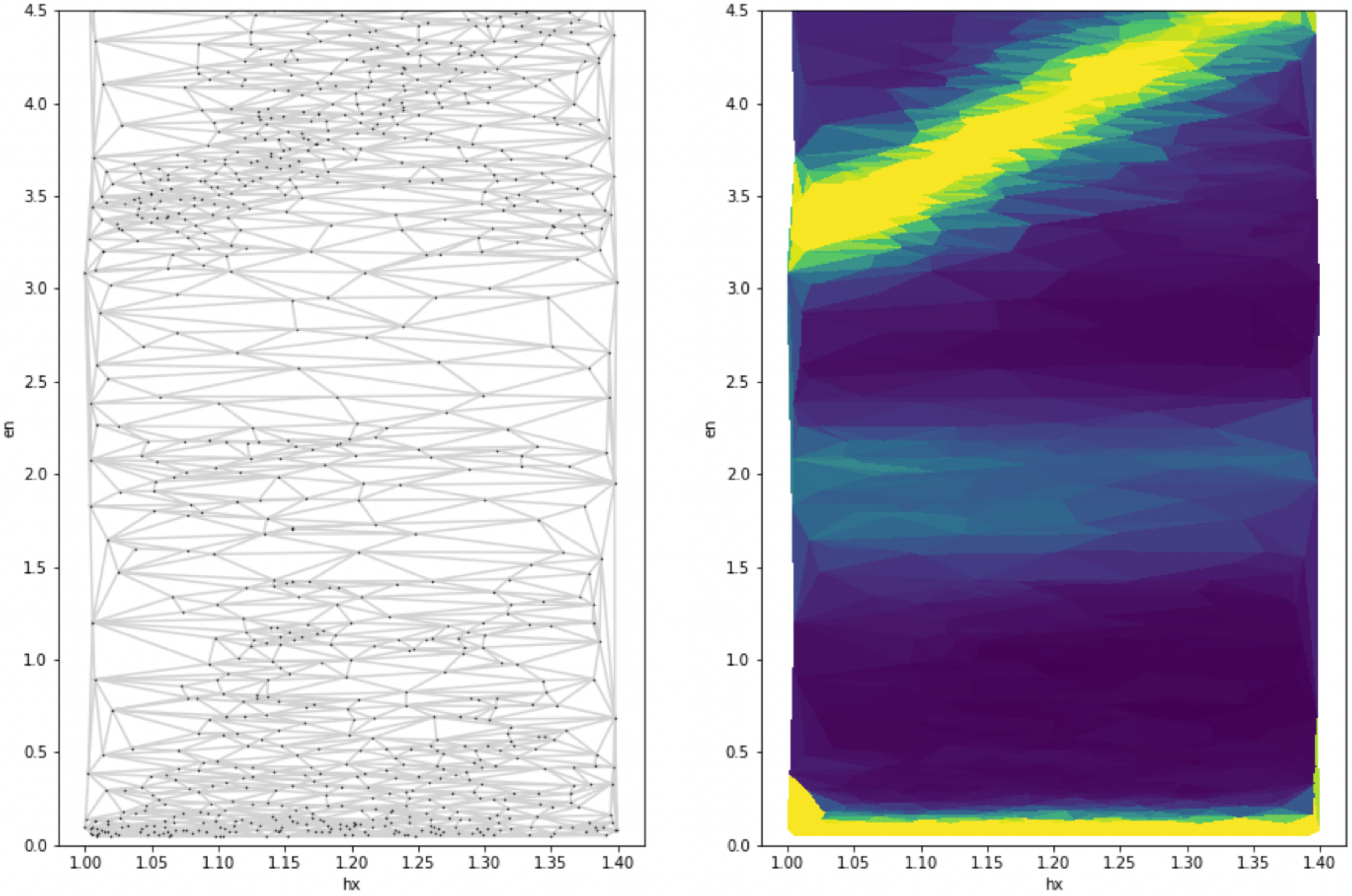
Number of points: 801



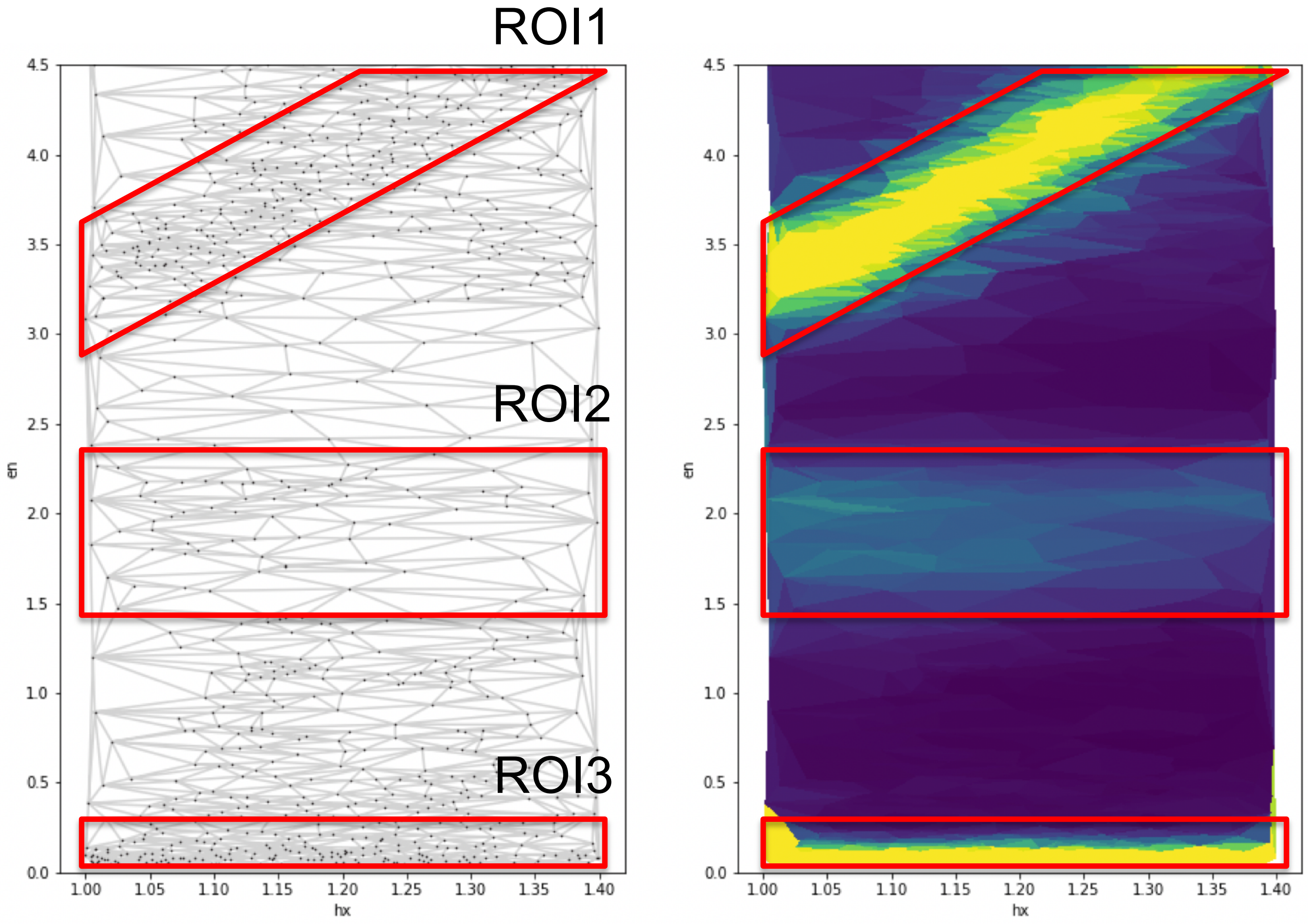
Measuring magnetic excitations along [110]

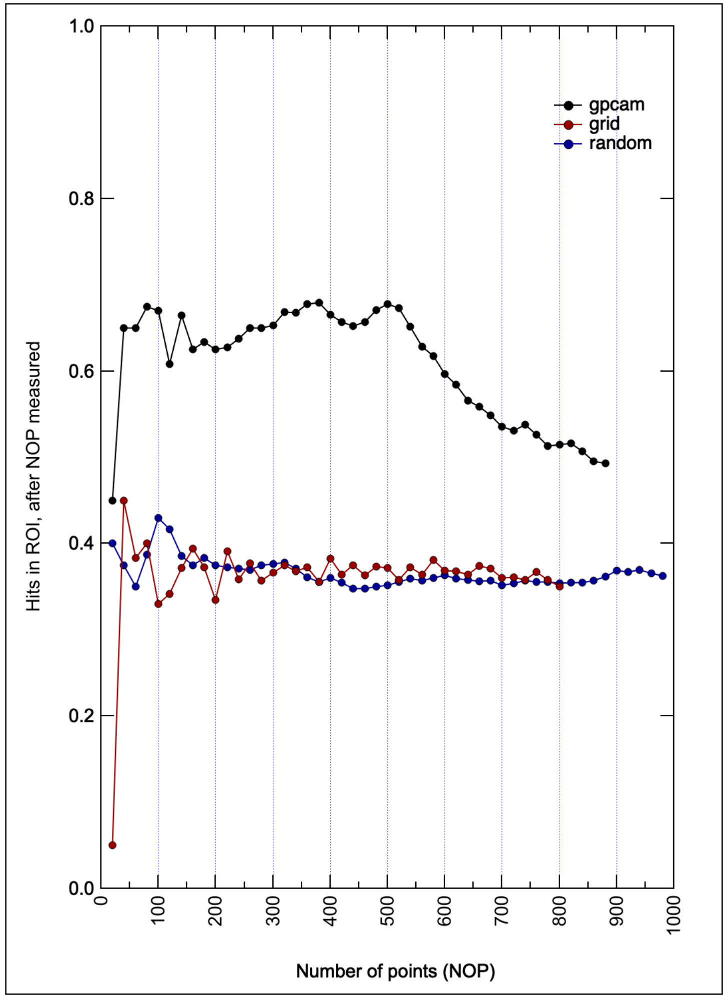
gpCAM Driven Measurement

Number of points: 899

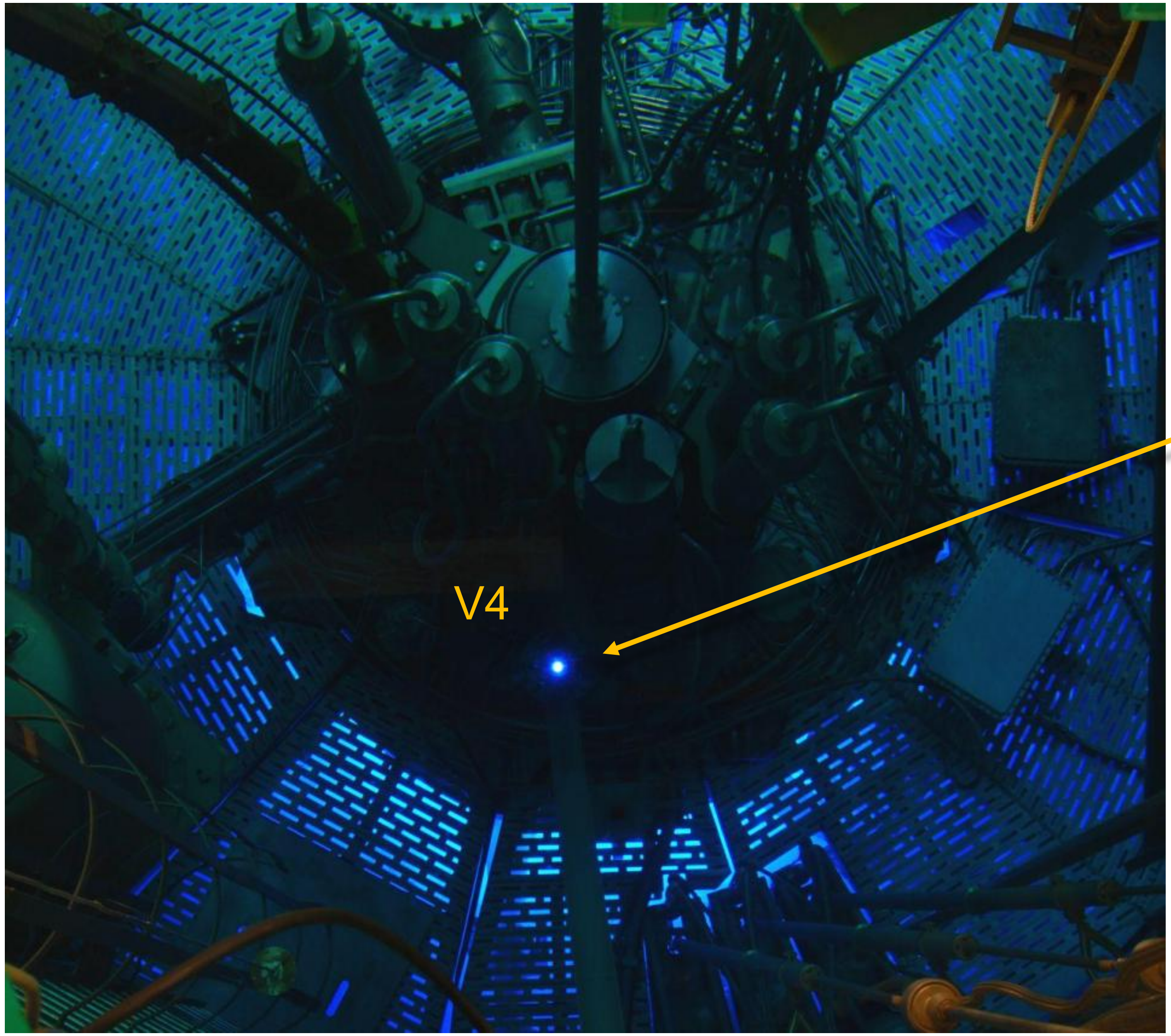


Hits Within Region Of Interest





Radio Isotope "Made in Grenoble"

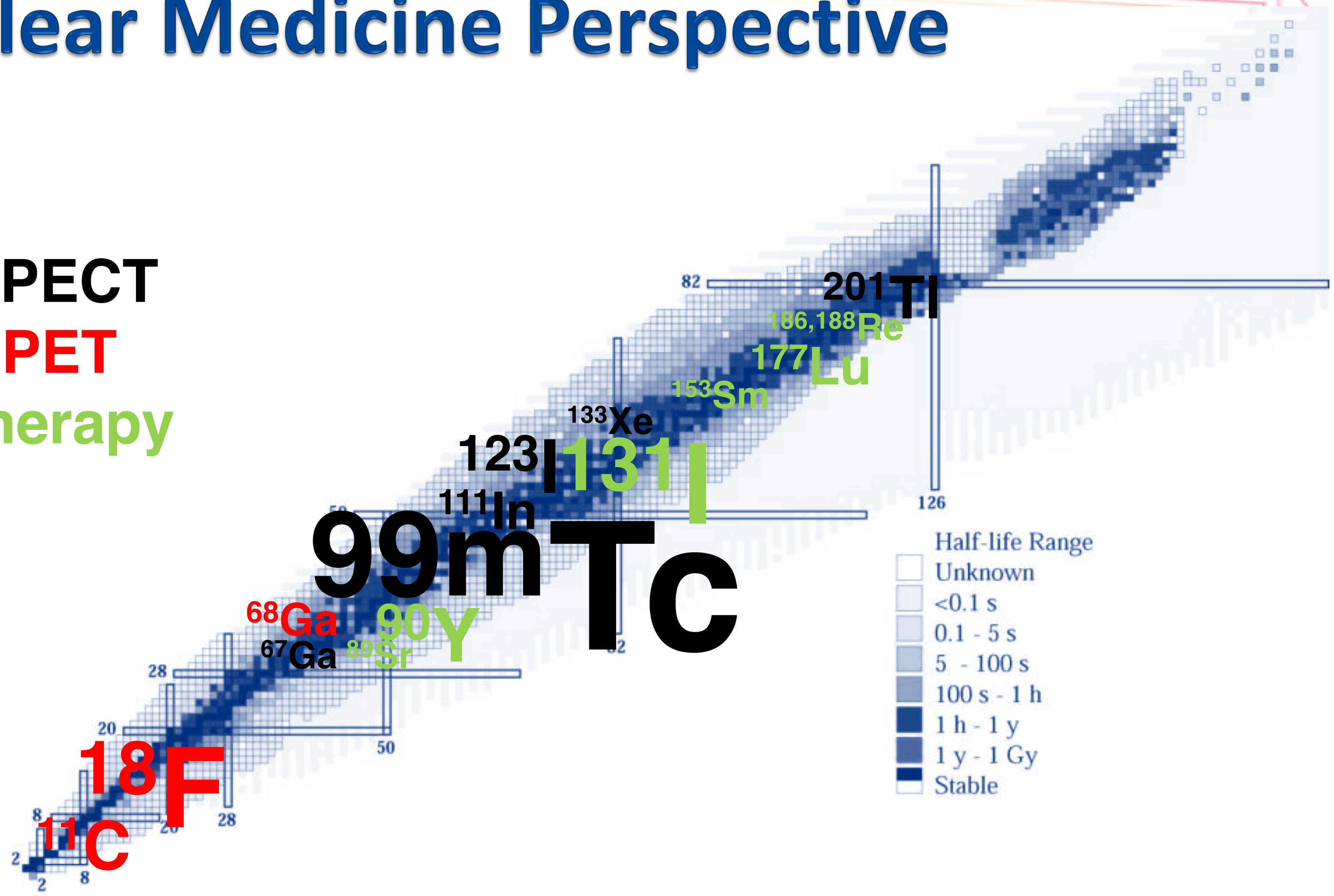


The highest neutron flux in Western Europe

$1.5\ 10^{15}$ n cm^{-2} s^{-1}

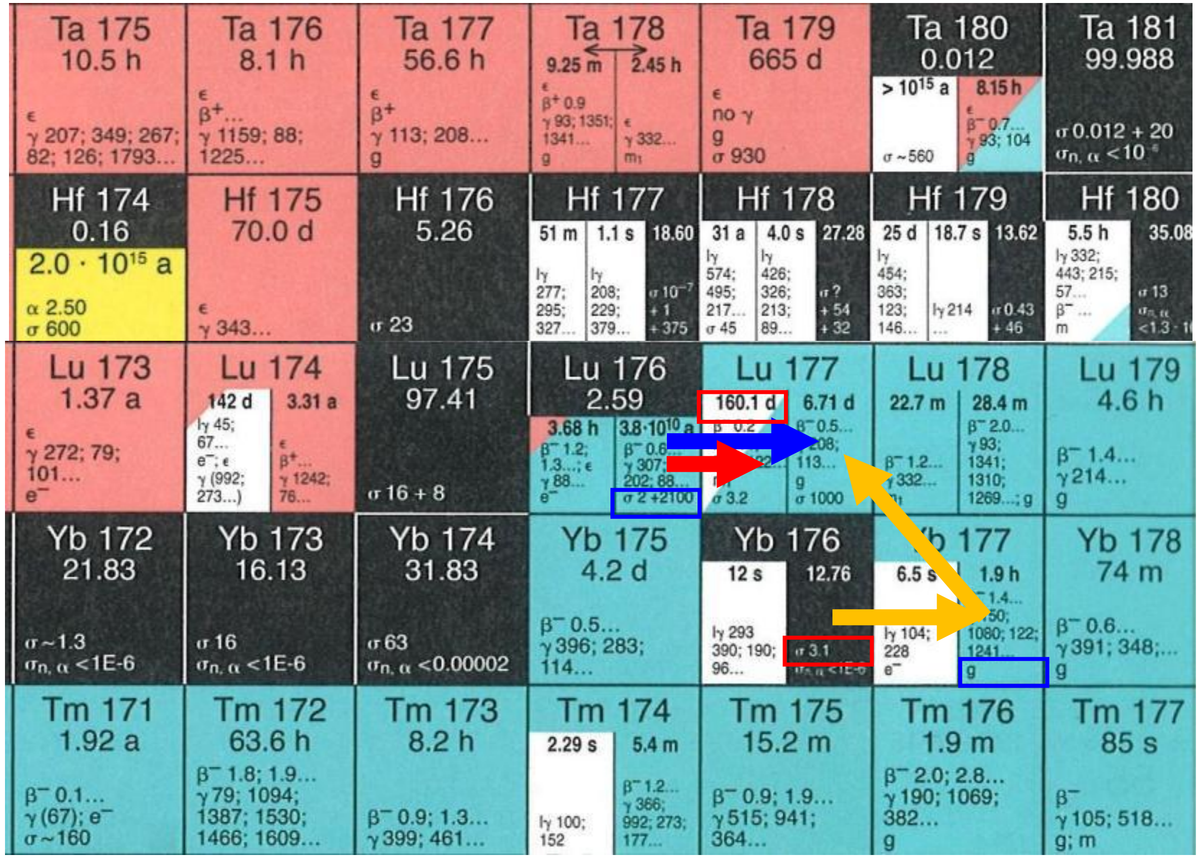
Nuclear Medicine Perspective

SPECT
PET
Therapy



NEUTRONS FOR SOCIETY

^{177}Lu a Showcase for Nuclear Physics



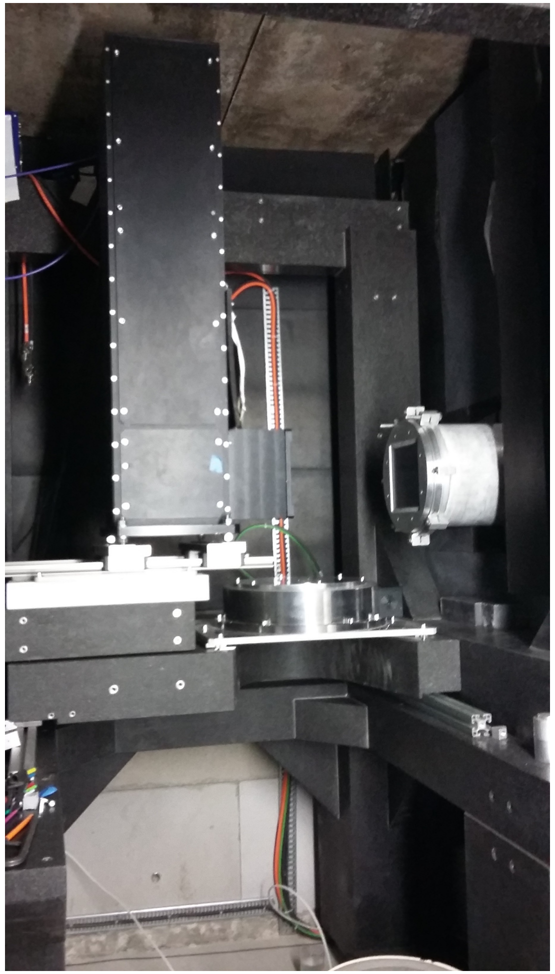
- n-capture on ^{176}Lu
- Production of the long-lived ^{177}Lu isomer

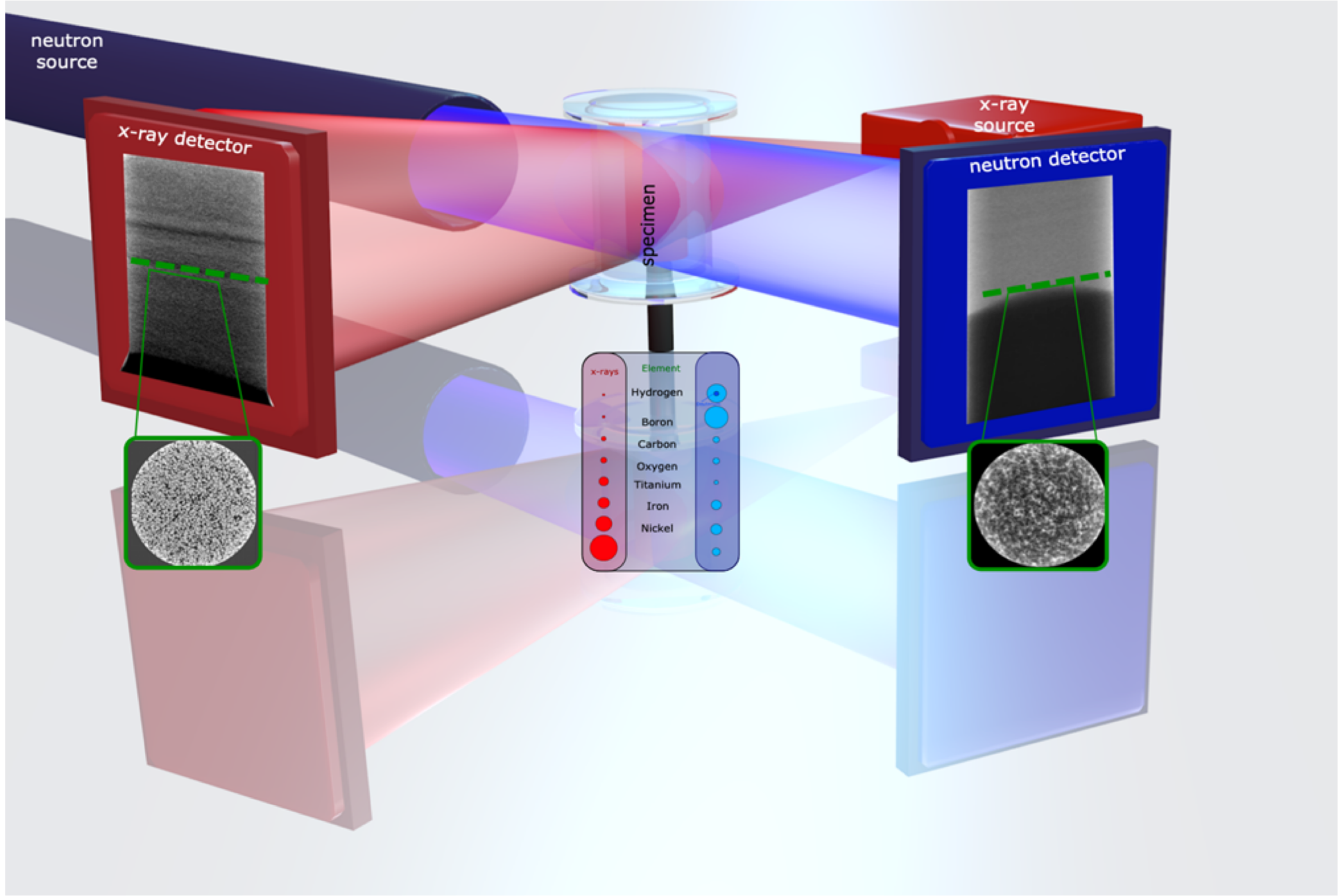
Waste problem for hospitals!

- n-capture on ^{176}Yb followed by β-decay
- Free from long-lived isomers

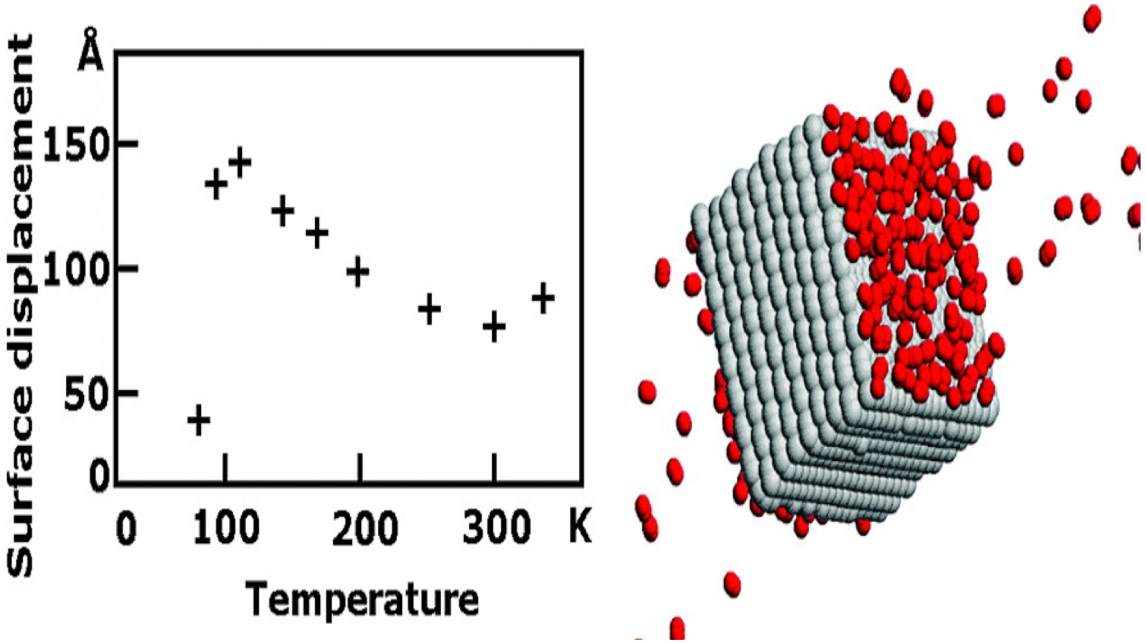
Requires high flux reactor !

NEXT: Neutron and X-Ray Tomography

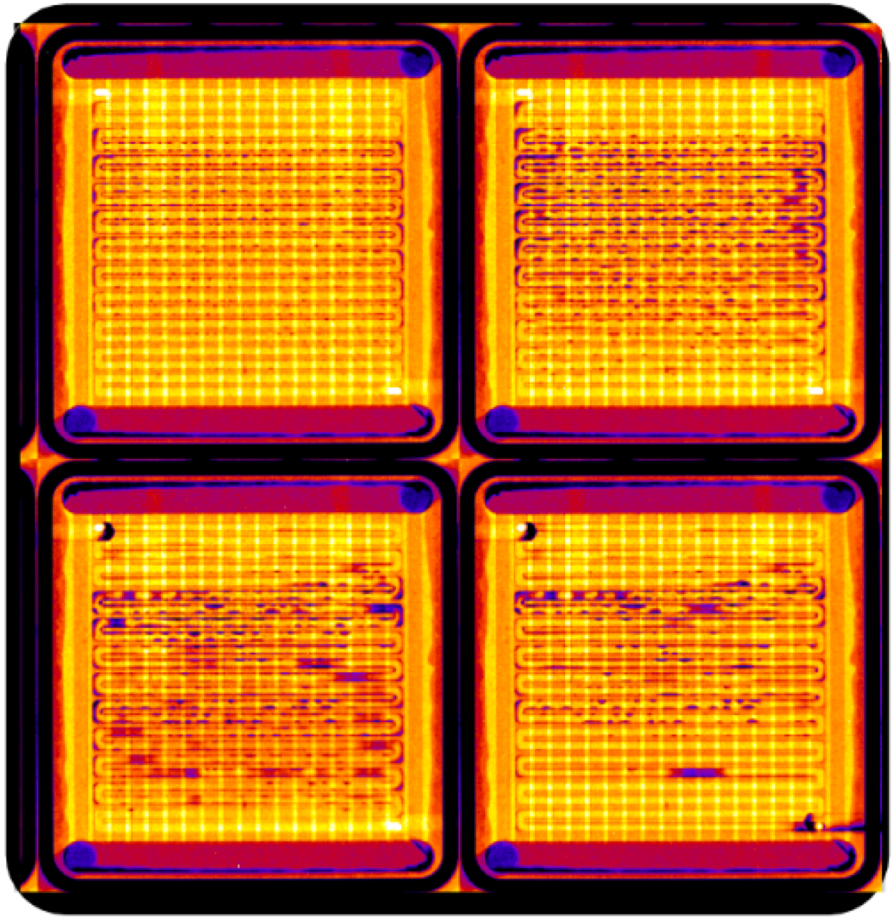




H_2 Storage in Fuel Cells

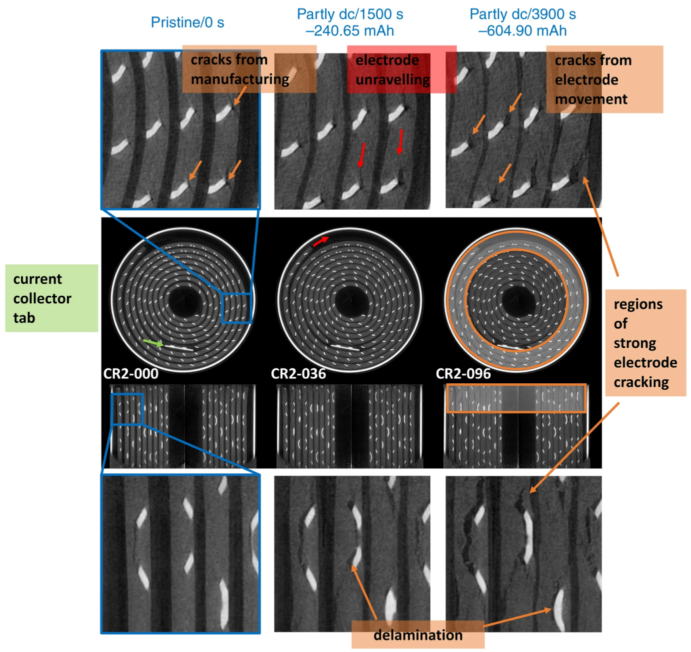


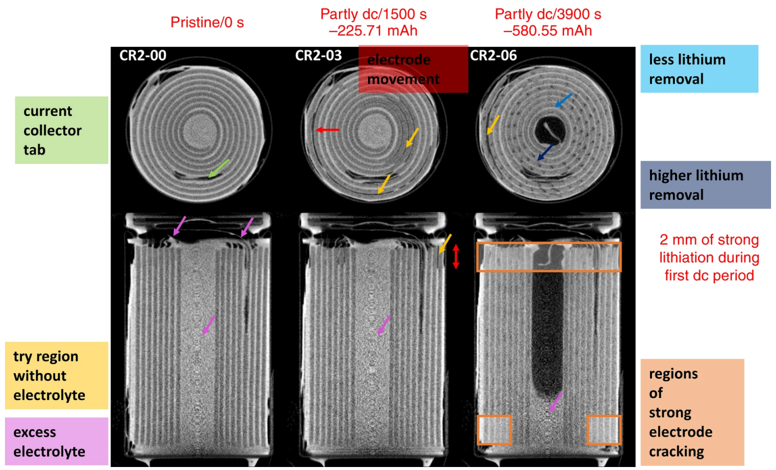
H_2 flow through a membrane



Dynamic water formation in a H_2 fuel cell

Understanding Ageing of Li Batteries





X-ray tomography

In total, 103 tomograms were recorded labelled from CR2-000 to CR2-102. One tomogram was recorded every 40 s with a total acquisition period of 2.8 s. Here the pristine state and two partly discharged states are presented. The images show the cracking and volume expansion of the MnO_2 electrode during cell discharging. The highly absorbing steel casing is visible as very bright ring around the wounded membrane–electrode ensemble

Neutron tomography

Captured during the discharge over a 4.7 Ω resistor, where the lithium electrode and the excess of electrolyte in the middle of the cell are clearly visible. Lithium intercalation and electrolyte consumption are observed, as well as electrode cracking and electrolyte consumption. In total, eight neutron tomograms were collected with an acquisition period of about 8 h.

Biology: Extreme Conditions

Halomonas is a microorganisms destroying the wreck of the Titanic

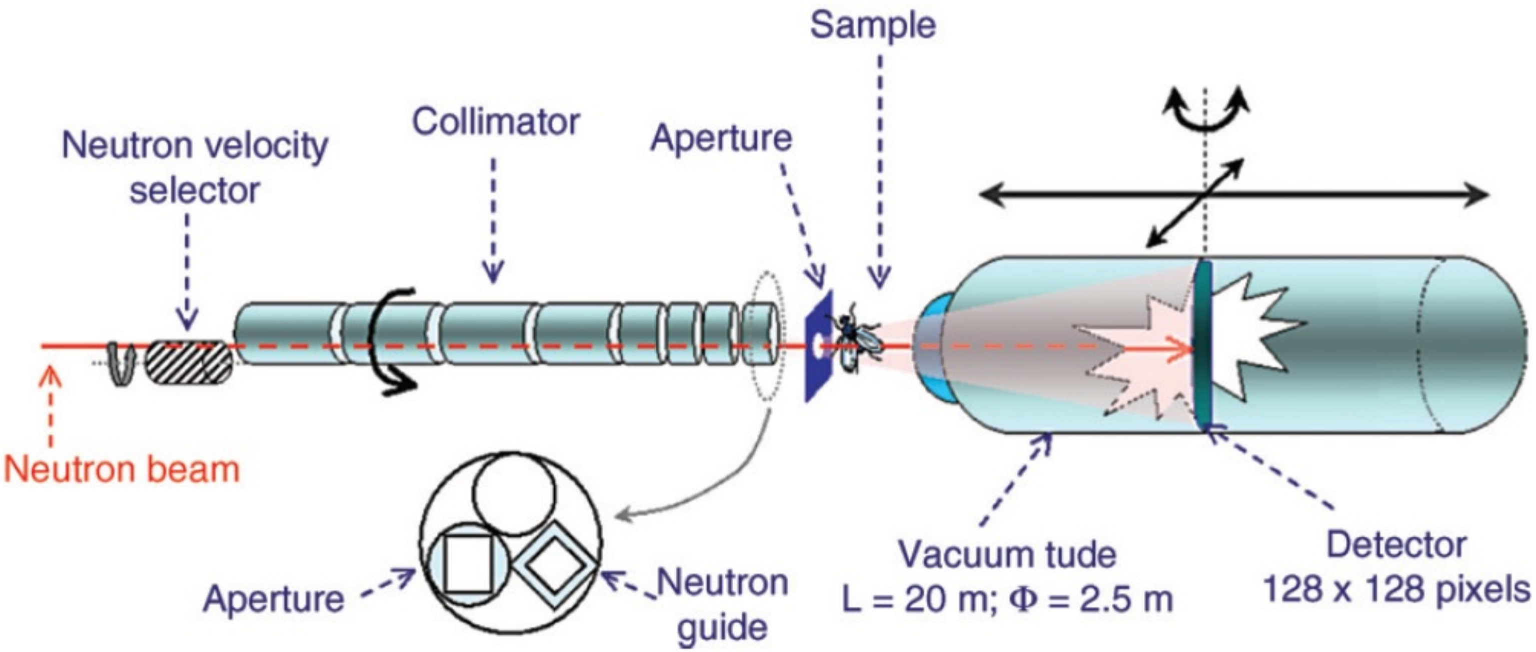
It survives at a depth of ~3800 m

Neutron scattering experiments were designed in order to understand how ectoine permits Halomonas to survive in their extreme environment.

Understanding microbe adaptation to extreme environments remains a challenge of high biotechnological potential—in bioremediation and waste management.

Small Angle Neutron Scattering

The Swiss knife of material science: can deliver information on hard and soft matter, from crystals to biological structures



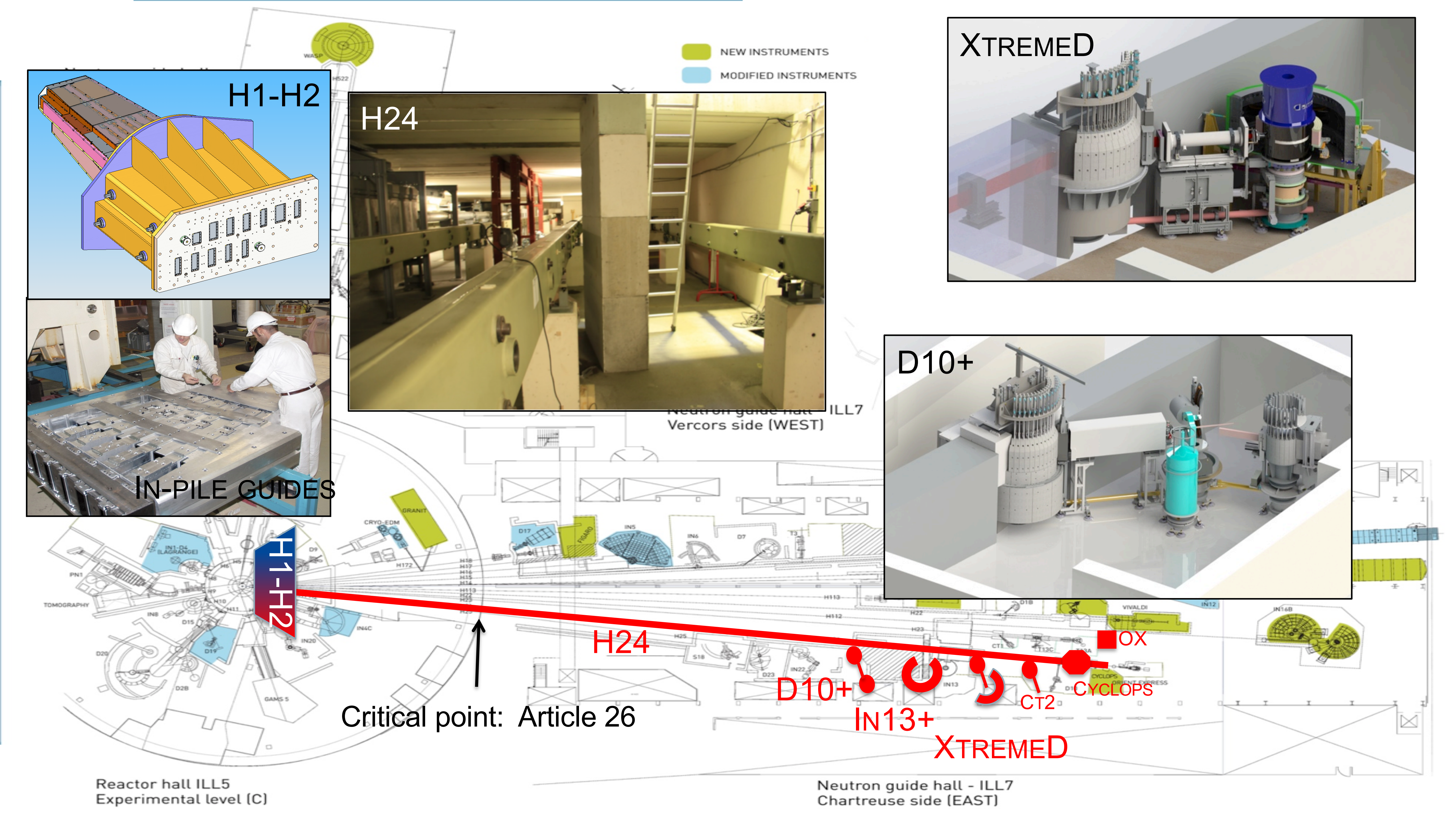
Neutrons Unlock The Secret of Limoncello

The key is the mix of alcohol, oil and water. Alcohol inhibits the repulsion of oil and water

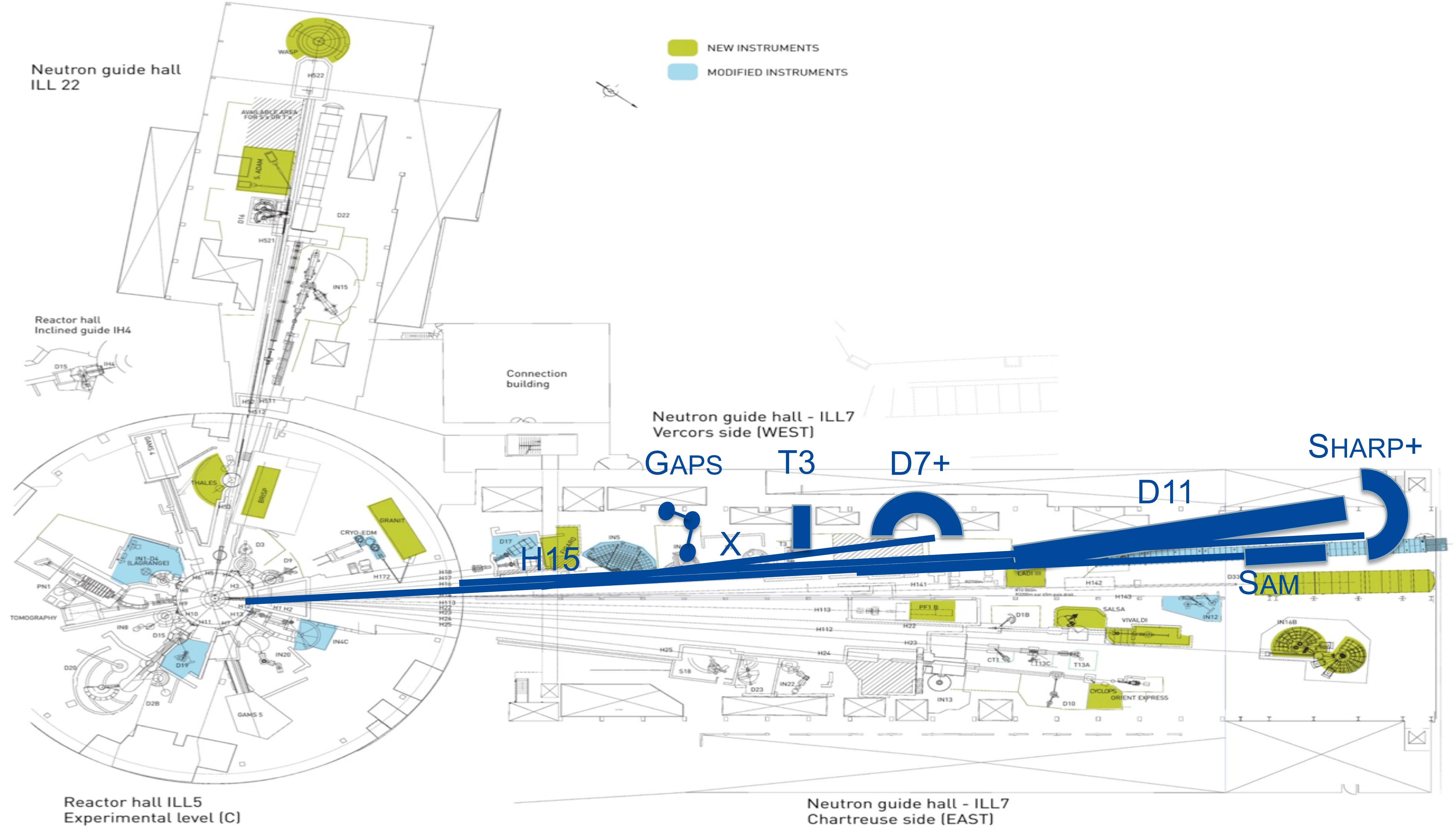
Replacing the H of water and alcohol with D allows to increase contrast on the lemon oil component

Neither sugar content nor temperature affects the appearance of limoncello at a microscope scale. However, varying the oil and water content did change how much oil was dissolved in the alcohol-water mix rather than locked up in droplets

Studying limoncello could help the growing industry in citrus oils for green solvents, environmentally-friendly plastics and insect repellent



XTREMED
H1-H2
H24
D10+
IN-PILE GUIDES
NEW INSTRUMENTS
MODIFIED INSTRUMENTS
Neutron guide hall - ILL7
Vercors side (WEST)
H1-H2
H24
OX
D10+
IN13+
CT2
CYCLOPS
XTREMED
Critical point: Article 26
Reactor hall ILL5
Experimental level (C)
Neutron guide hall - ILL7
Chartreuse side (EAST)


NEW INSTRUMENTS
MODIFIED INSTRUMENTS
Neutron guide hall
ILL 22
Reactor hall
Inclined guide IH4
Connection
building
Neutron guide hall - ILL7
Vercors side (WEST)
GAPS
T3
D7+
SHARP+
D11
H15
X
SAM
Reactor hall ILL5
Experimental level (C)
Neutron guide hall - ILL7
Chartreuse side (EAST)
WASP
S. ADAM
D22
IN15
THALES
BRISP
GRANIT
CRYO-EDM
TOMOGRAPHY
GAMS 5
SALSA
VIVALDI
CYCLOPS
ORIENT EXPRESS
IN16B

The EPN Science Campus