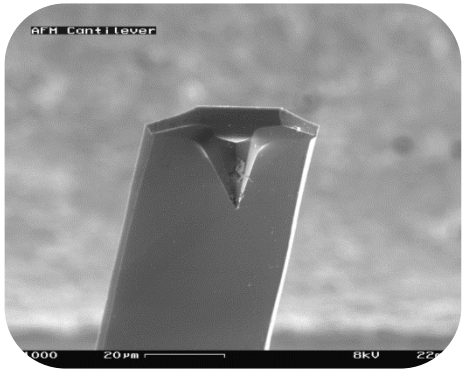
WELCOME TO THE EPN CAMPUS

UNDERSTANDING MATTER NEEDS A RANGE OF ANALYTICAL TECHNIQUES

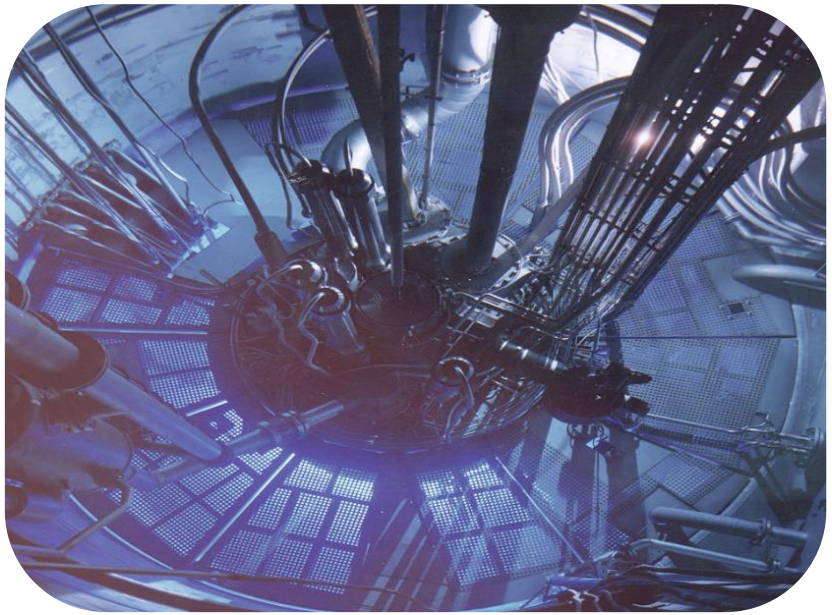
Europe (Grenoble!) has some of the world's leading infrastructure

Microscopy



Nuclear Magnetic Resonance

Neutron scattering



X-rays

Why neutrons?

About the ILL

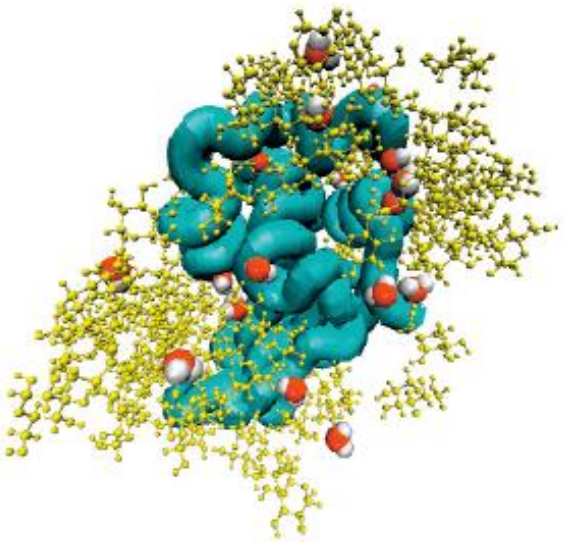
A bit of history

Looking to the future

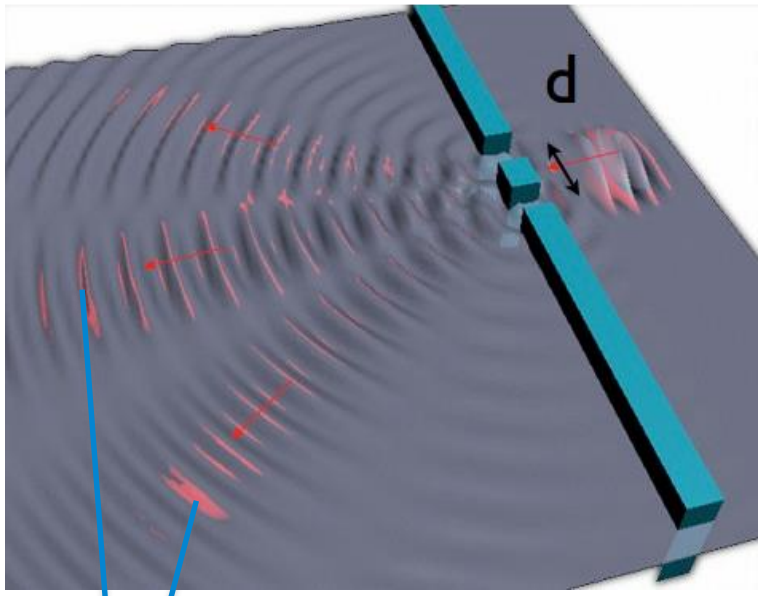
Neutron wavelength is comparable to inter-atomic distances

Wavelengths vary from less than 0.01 nm to more the 1 nm.
Combined with Bragg's Law, distances covering 6 orders of magnitude can be probed.

From 1000 nm

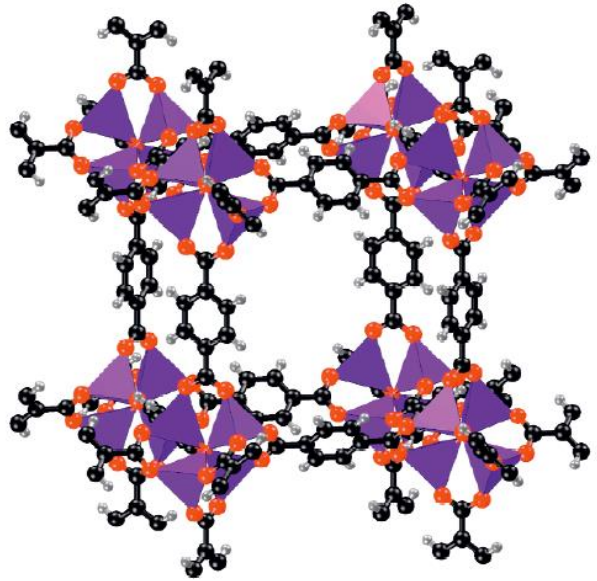


Cold neutrons



$$\Delta\phi = \frac{\Delta y}{D} = \frac{\lambda}{d}$$

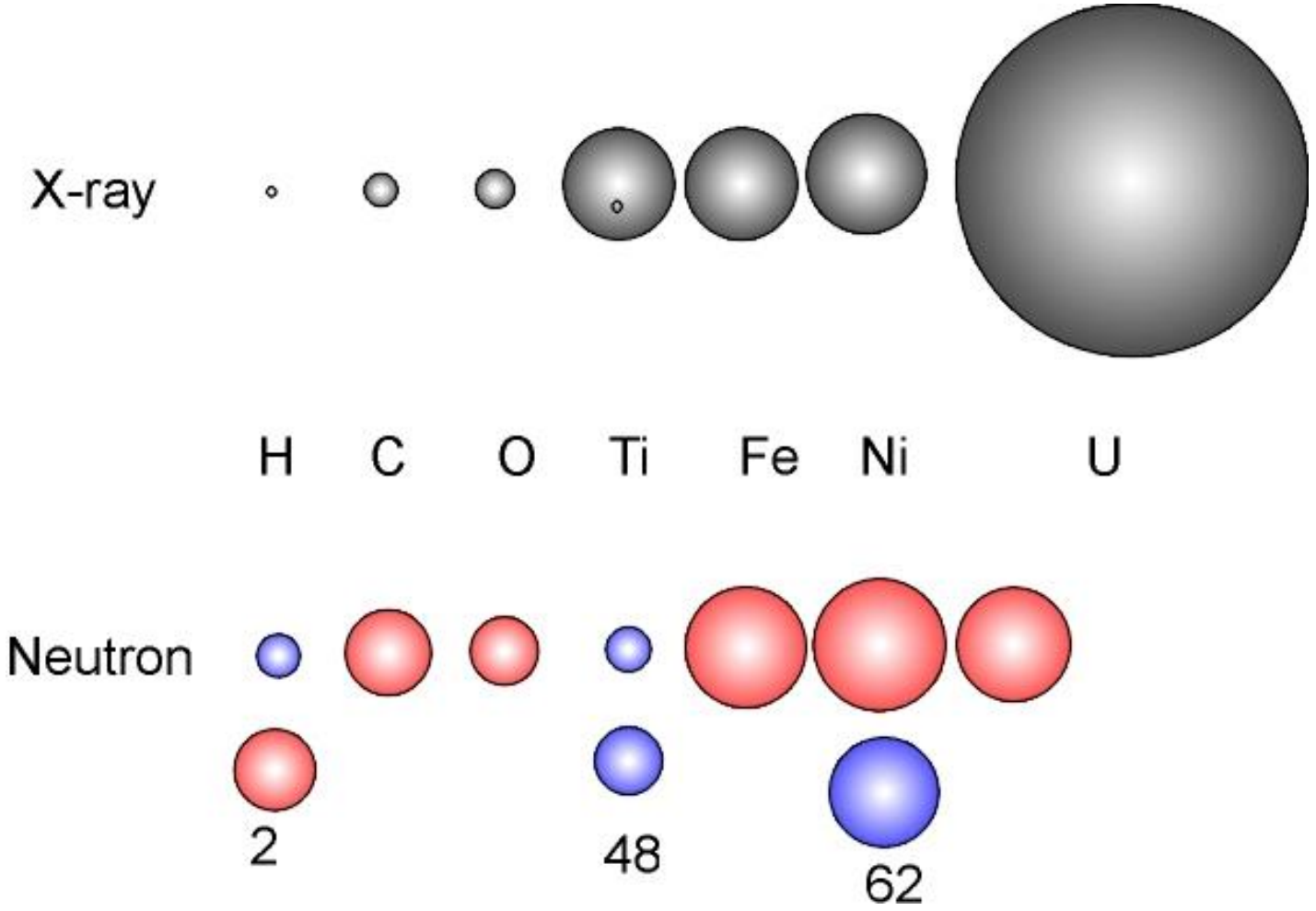
To 0.001 nm



Hot neutrons

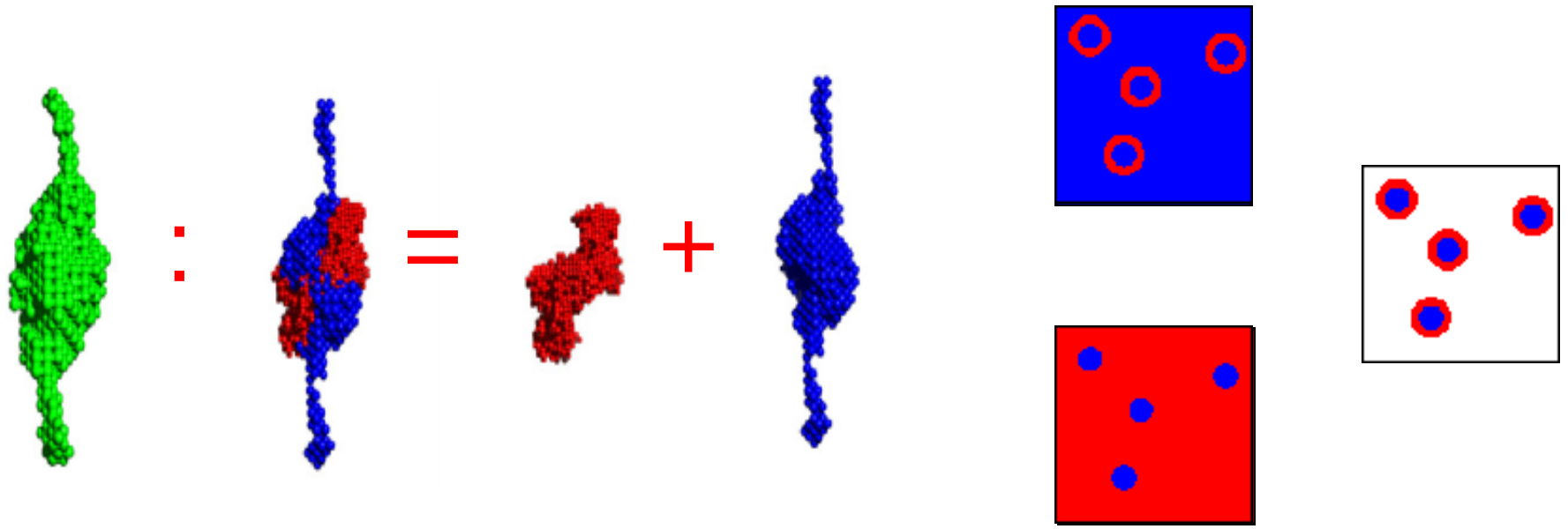
NEUTRONS ARE SCATTERED BY NUCLEI

With no charge, neutrons penetrate the electronic cloud of materials and are scattered by nuclei – this depends on nuclear spin and isotope



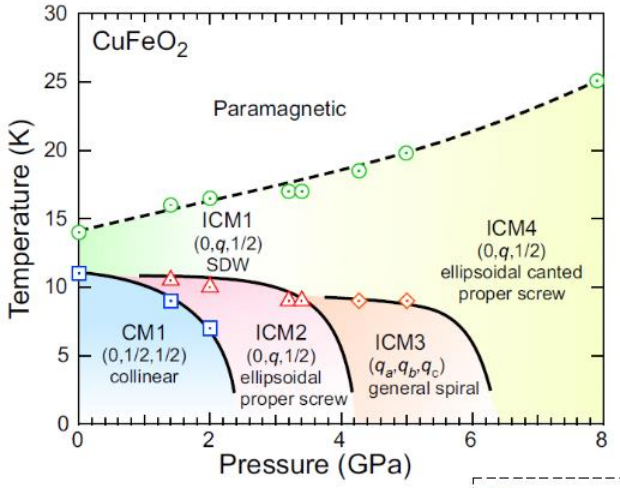
NEUTRONS ARE SCATTERED BY NUCLEI → CONTRAST VARIATION

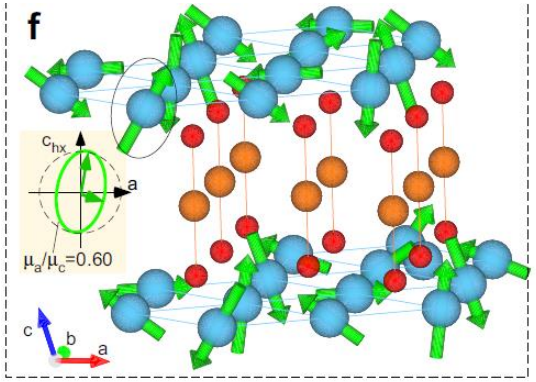
H_2O/D_2O solutions can have zero scattering length or they can be matched to the scattering power of individual components

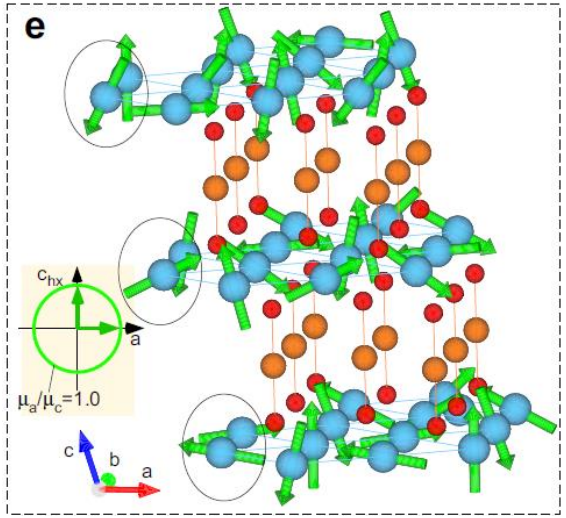


NEUTRON SPIN INTERACTS WITH UNPAIRED ELECTRONS → MAGNETISM

Neutrons probe directly the complex magnetic structure and excitations of materials – polarized neutron beams and magnetic fields facilitate these investigations

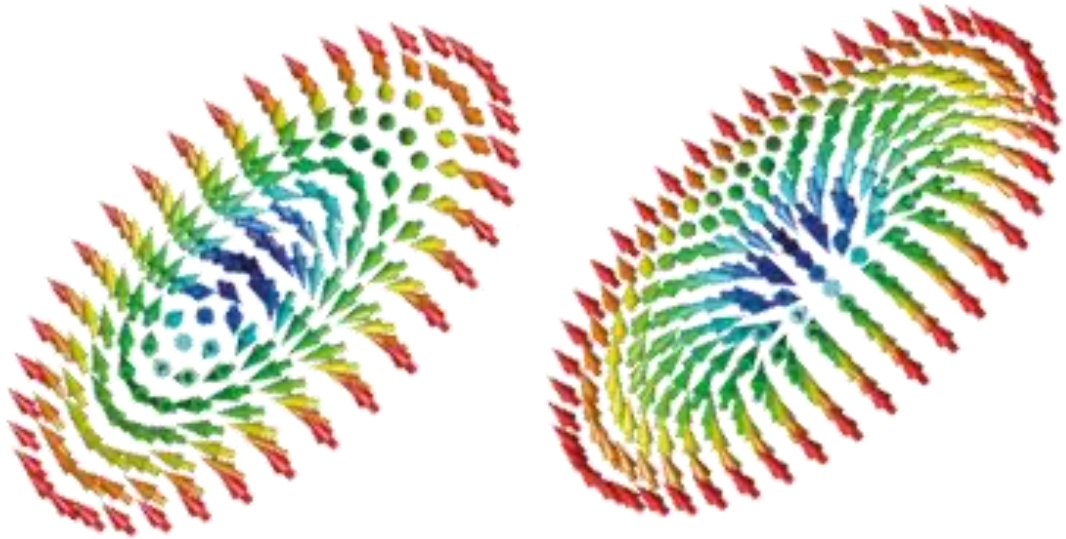






Complex spin structures in multiferroics

Arrangement of spins in two skyrmion structures



I. Kezsmarki et al., Nature Materials, 2015, **14**, 1116; DOI: 10.1038/nmat4402ptions.

NEUTRON IMAGING – DEPENDS ON ABSORPTION AND SCATTERING (NUCLEAR AND MAGNETIC)

An engine in action

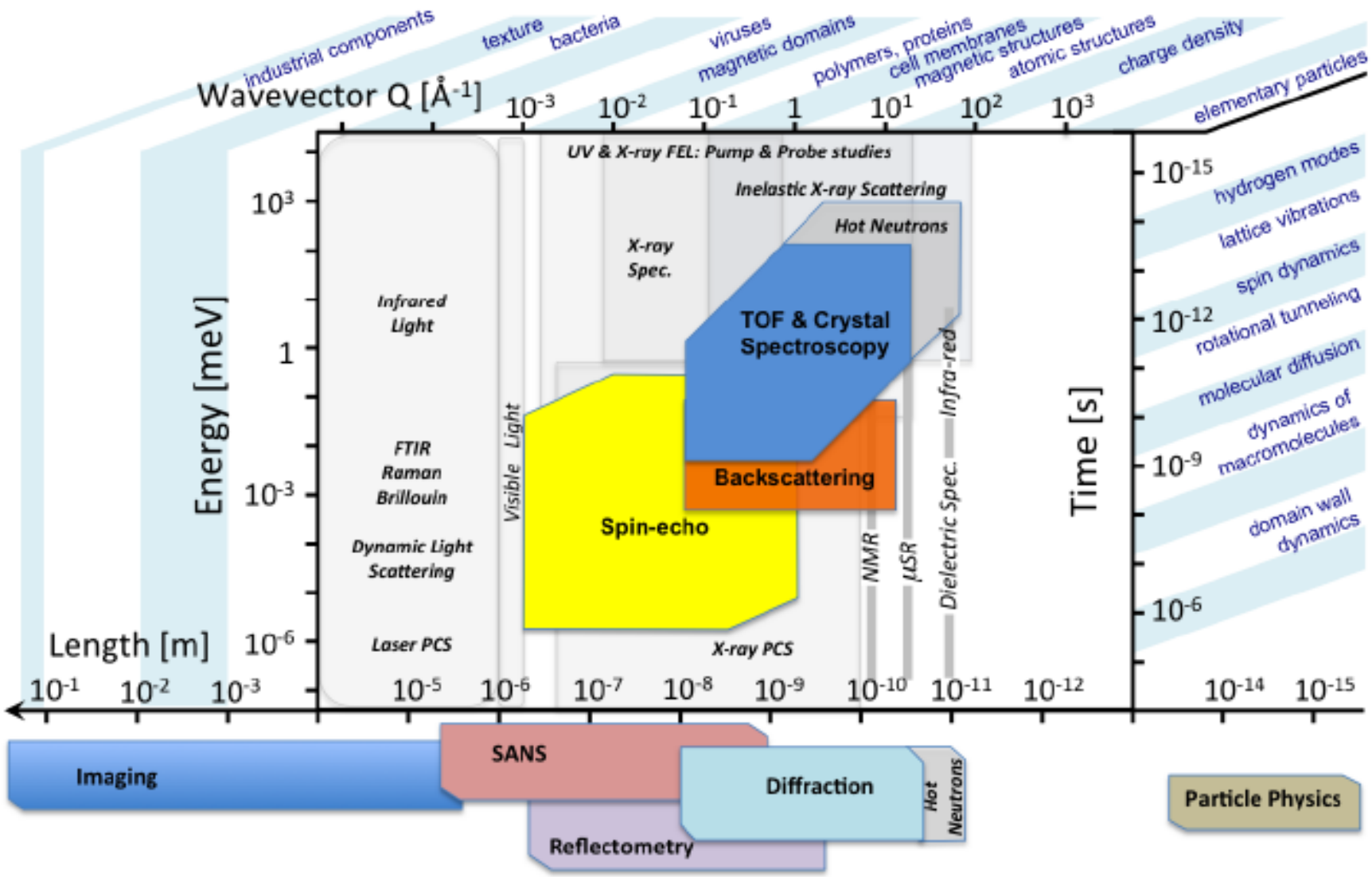
Jeremy H. Lakey J. R. Soc. Interface 2009;6:S567-S573

Plastic components are well resolved by neutrons owing to their hydrogen content while the metallic body is penetrated easily

NEUTRON SCATTERING COVERS MANY ORDERS OF MAGNITUDE

15 ORDERS OF MAGNITUDE IN LENGTH

10 ORDERS OF MAGNITUDE IN TIME



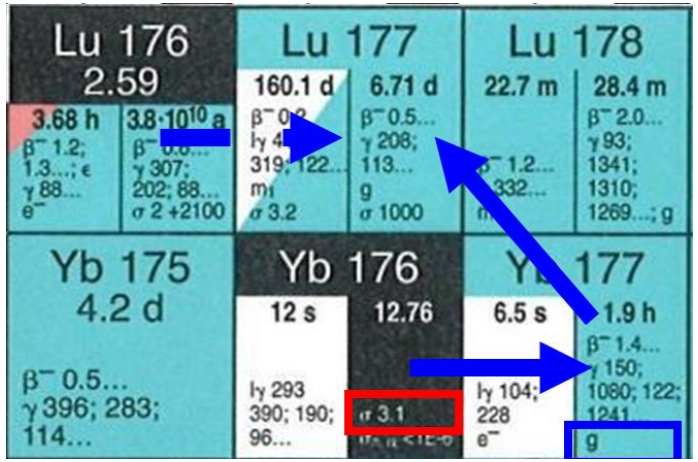
Neutrons as "objects" – particle physics

The neutron

- Lives for ~15 minutes
- Has an electric dipole moment of (almost) zero
- Has quantised states in the earth's gravitational field (*micron* spatial separation → *peV* energy separation → ultra cold neutrons)

NEUTRON RICH NUCLEI – NUCLEAR PHYSICS

Understand and produce, pure short-lived (~weeks) isotopes for therapeutic applications



Thyroid: $^{131}I^-$

Lymphoma:
Zevalin® (^{90}Y-mab)
Bexxar® (^{131}I-mab)
^{131}I/^{177}Lu-mabs (I/II)

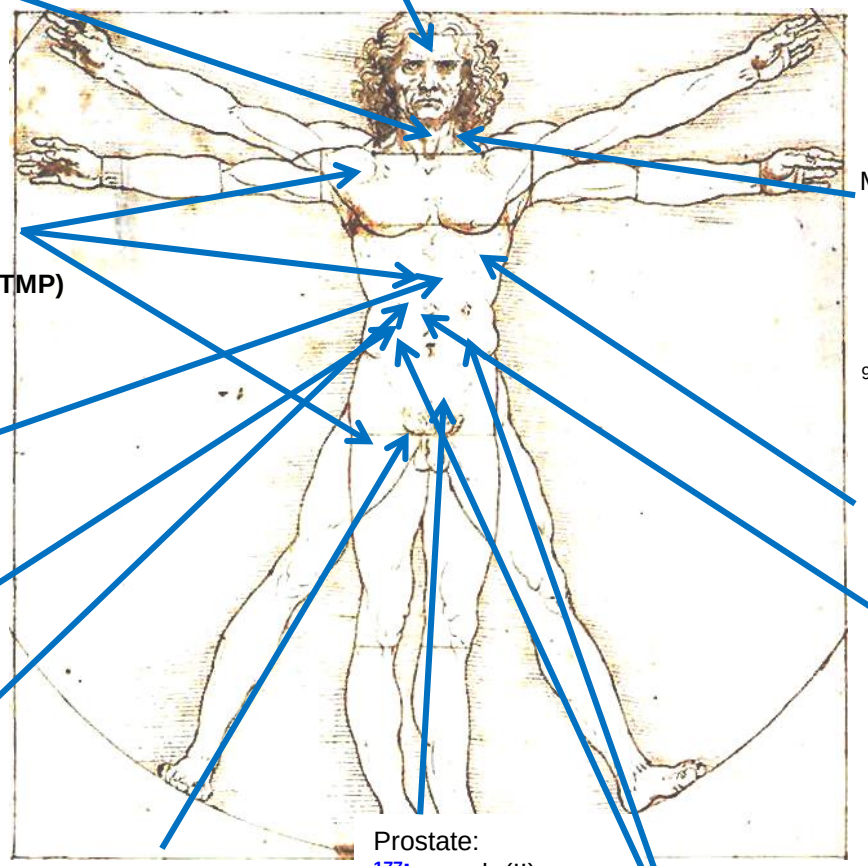
Bone metastases:
Metastron® ($^{90}SrCl_2$)
Quadramet® (^{153}Sm-EDTMP)
Xofigo® ($^{223}RaCl_2$)

Neuroblastoma:
^{131}I-MIBG

Neuroendocrine (GEP-NET):
^{177}Lu-peptides (III)

Liver (HCC):
Theraspheres® & SIRspheres® (^{90}Y)
^{188}Re-Lipiodol (II)
^{166}Ho-microspheres

Brain: ^{90}Y-mab ,^{131}I-mab (I/II), ^{211}At-mab (I), ^{213}Bi-pept.(I)



Leukemia, myeloma:
^{131}Y-mab (III),
^{213}Bi/^{225}Ac-mab (II)

Medullary Thyroid: ^{131}I-mab (II)
^{90}Y/^{177}Lu-pept.

Breast:
^{90}Y-mab, $^{131}I^-$ (II), ^{212}P-mab (I)

Lung (SCLC):
^{177}Lu-mab (II)

Pancreas:
^{90}Y-mab (III)

Ovary:
^{212}Pb-mab (I)
^{90}Y/^{177}Lu-mab

Melanoma:
^{213}Bi-mab(I)

Colon & rectum:
^{131}I-mab (II)

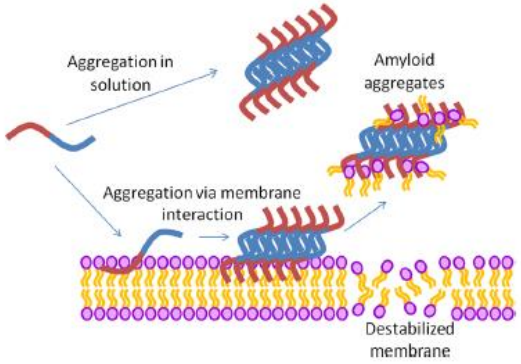
Prostate:
^{177}Lu-mab (II)
^{177}Lu-PSMA (I)

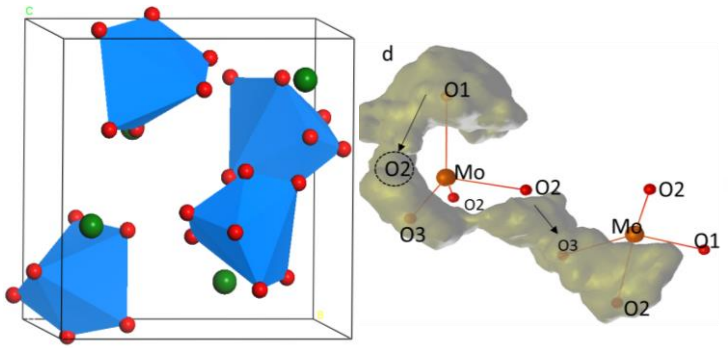
Kidneys (RCC):
^{90}Y/^{177}Lu-mab (II)

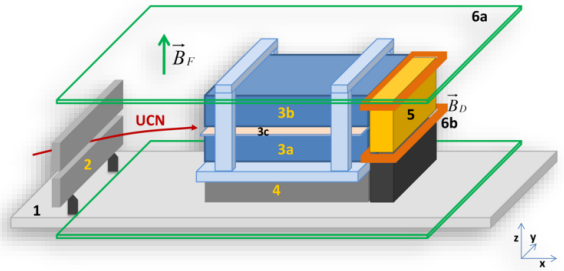
The brightest neutron spot in Europe

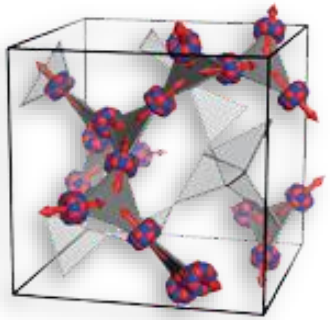
CONDENSED MATTER (AND MORE) CAN BE STUDIED WITH NEUTRONS

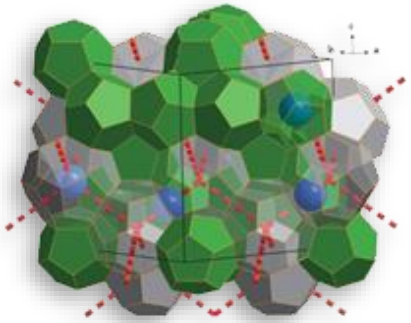
Much of this research addresses today's societal challenges

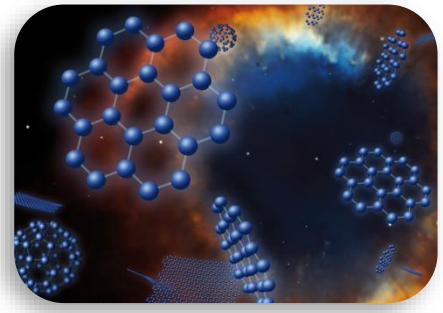


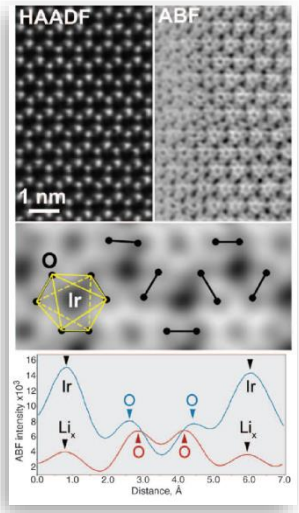


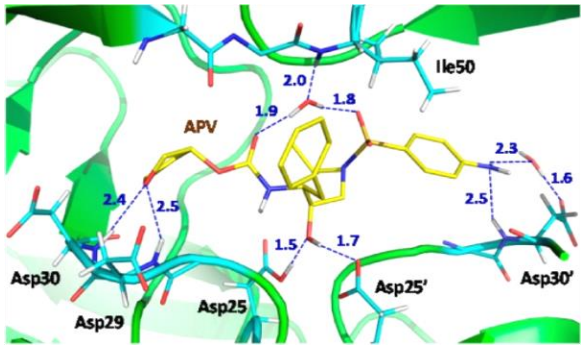


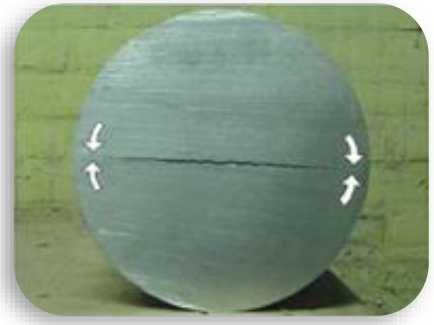


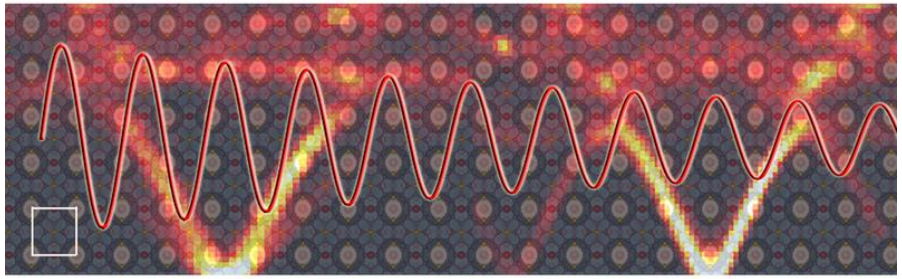


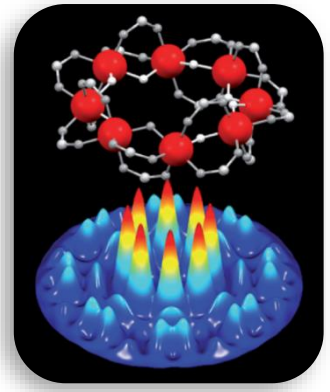












WE ARE THE WORLD'S FLAGSHIP FACILITY

AFTER ALMOST 50 YEARS OF OPERATION, WE ARE STILL NUMBER ONE

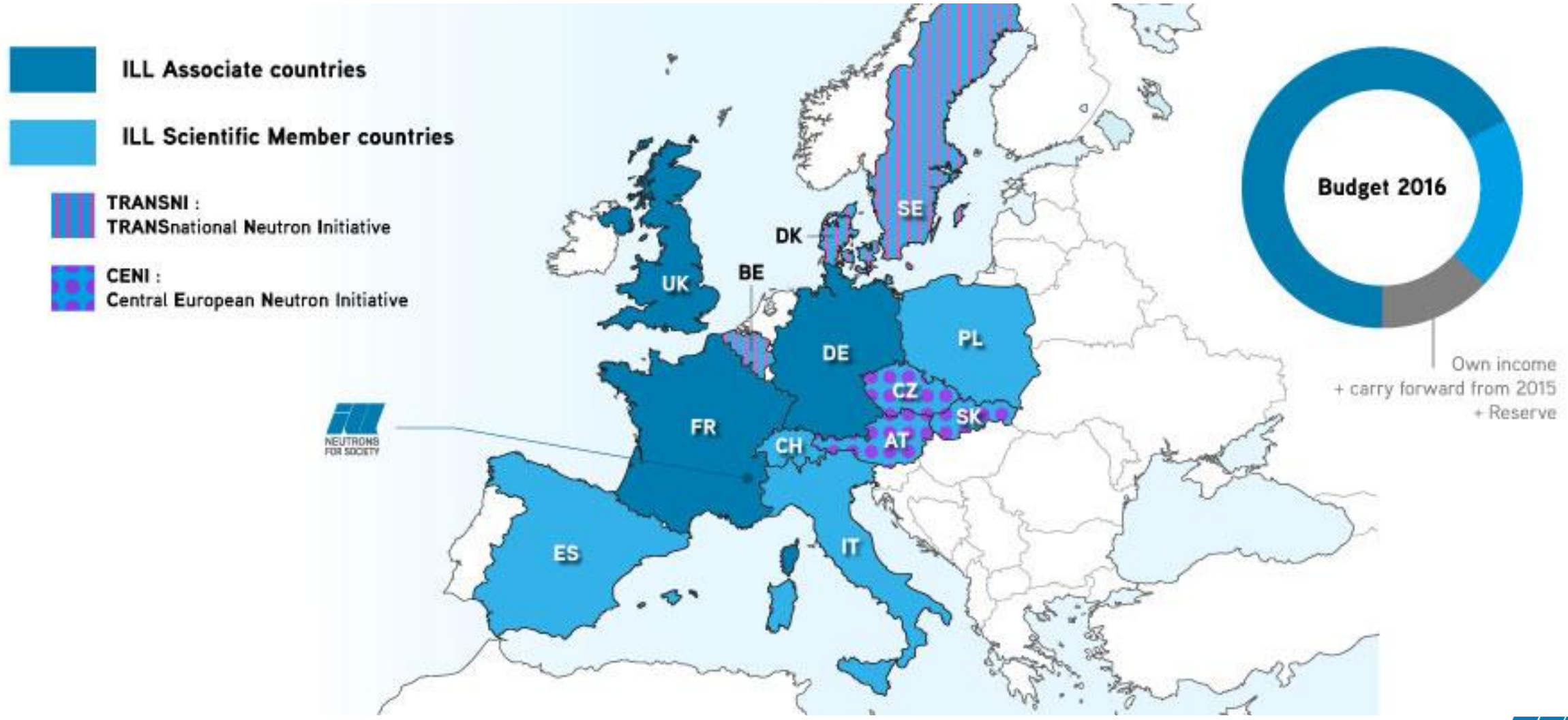
Because the ILL:

- Is the **most intense** continuous neutron source in the world
- Adapts to **scientific trends** and the needs of the **user community**
- Offers the best **cutting-edge instrumentation**
- Attracts and benefits from the **best researchers** on the international stage

EUROPE HAS THE HIGHEST CONCENTRATION OF NEUTRON SOURCES

Neutrons are a unique analytical probe, only available at large scale facilities

THE ILL MEMBER COUNTRIES AND THEIR FINANCIAL PARTICIPATION



KEY FIGURES ABOUT THE ILL

1400 users/year from an active community of 12 000 scientists

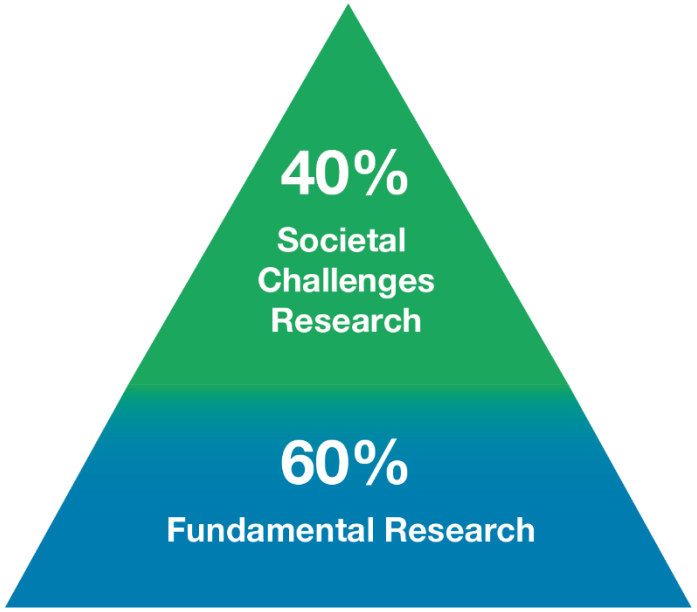
850 experiments/year

600 publications/year

38 countries

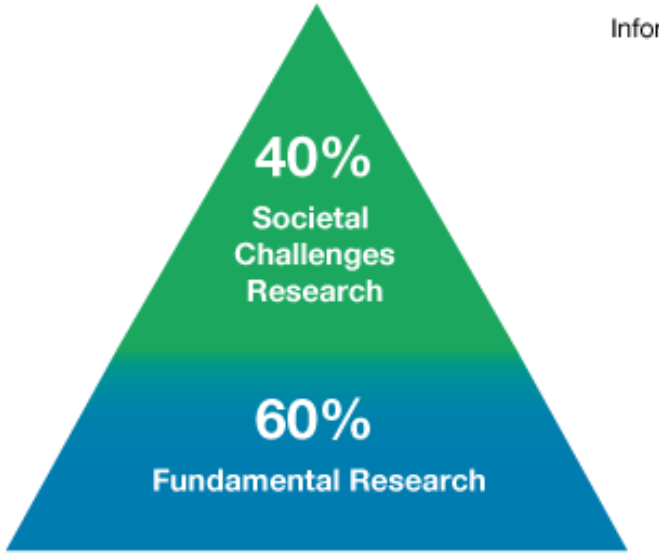
28 instruments + 10 CRG

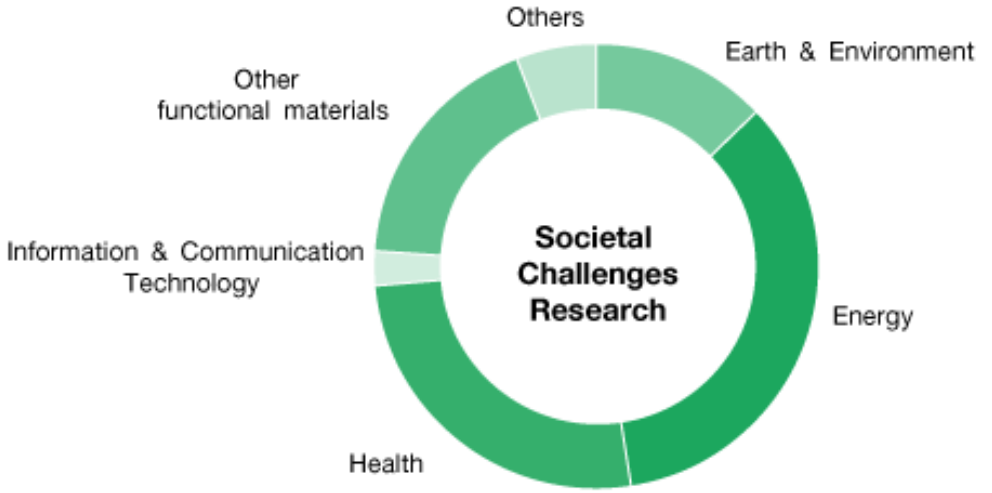
150 - 200 days operation/year

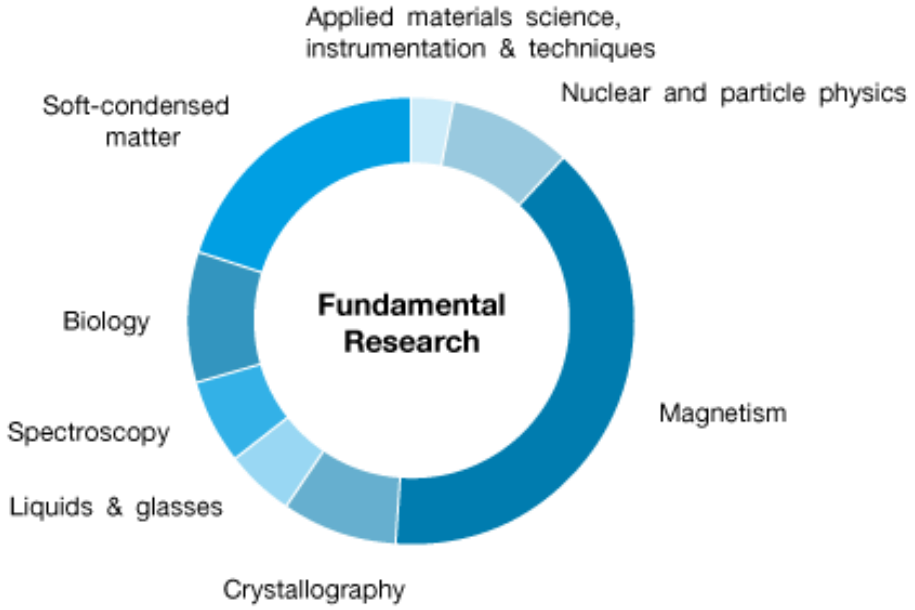


Research areas covered by the ILL

As per accepted proposals

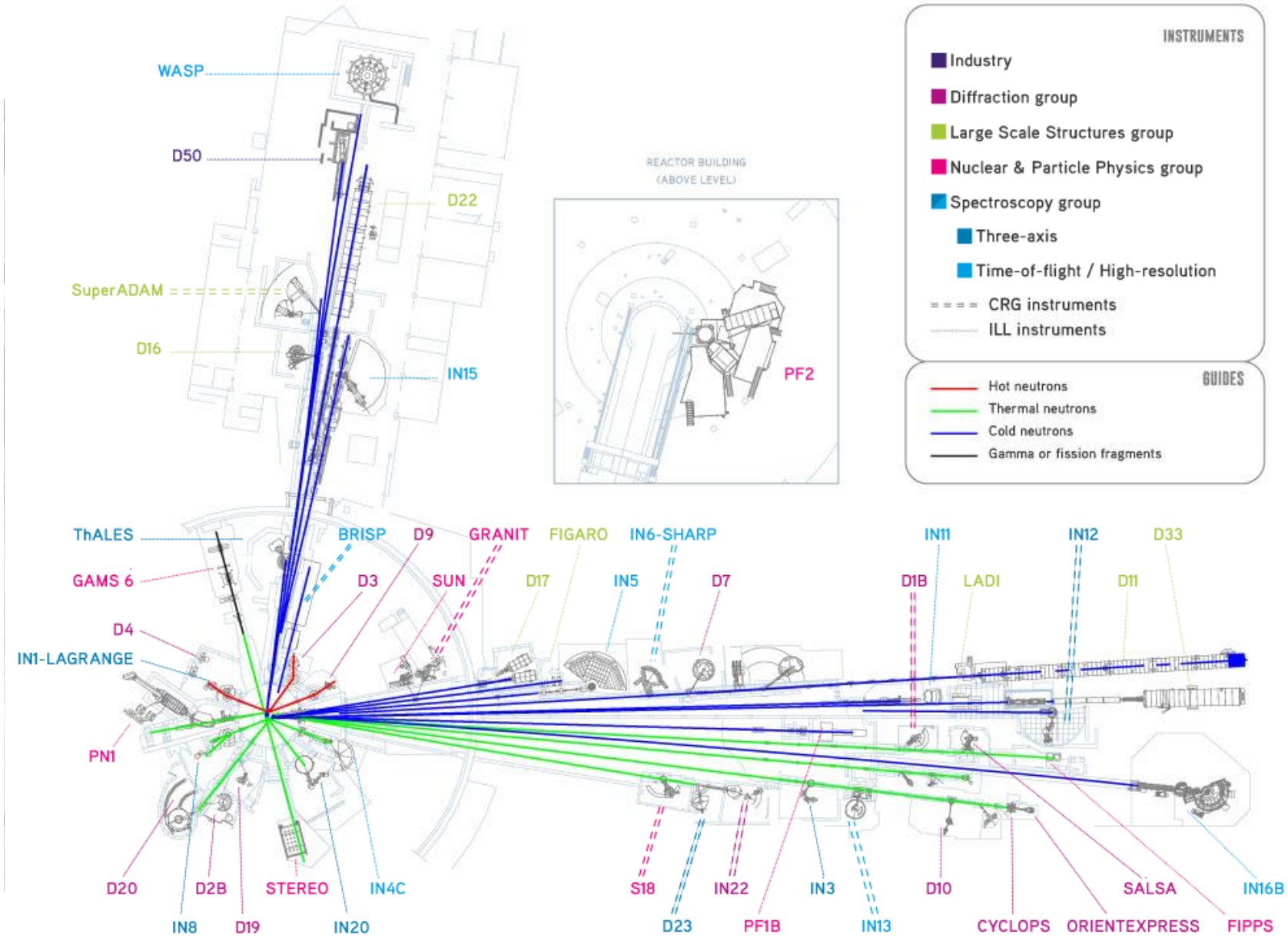




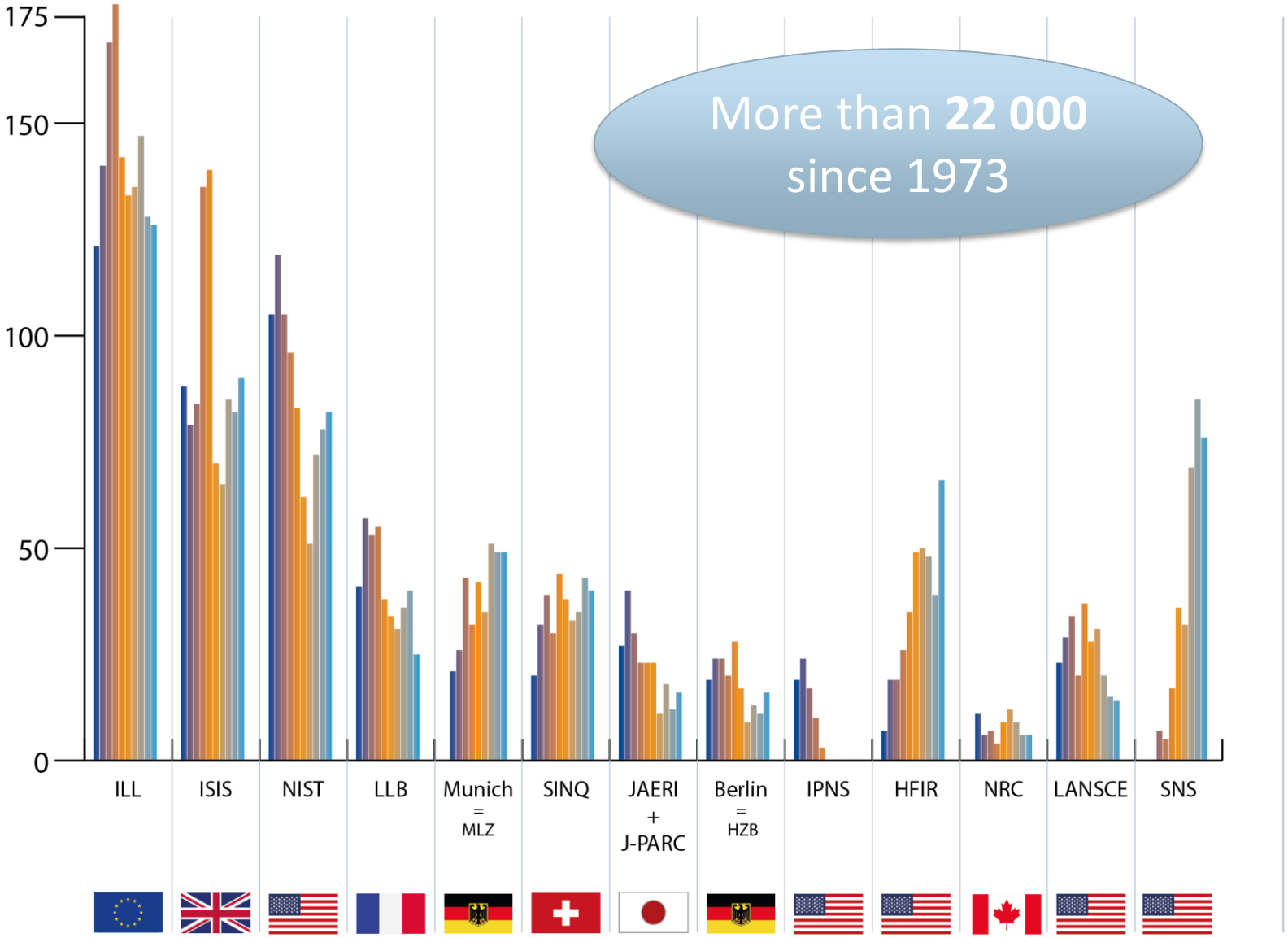


NEUTRONS FOR SOCIETY

THE ILL'S INSTRUMENT SUITE



PUBLICATIONS IN HIGH-IMPACT SCIENTIFIC JOURNALS AT THE ILL

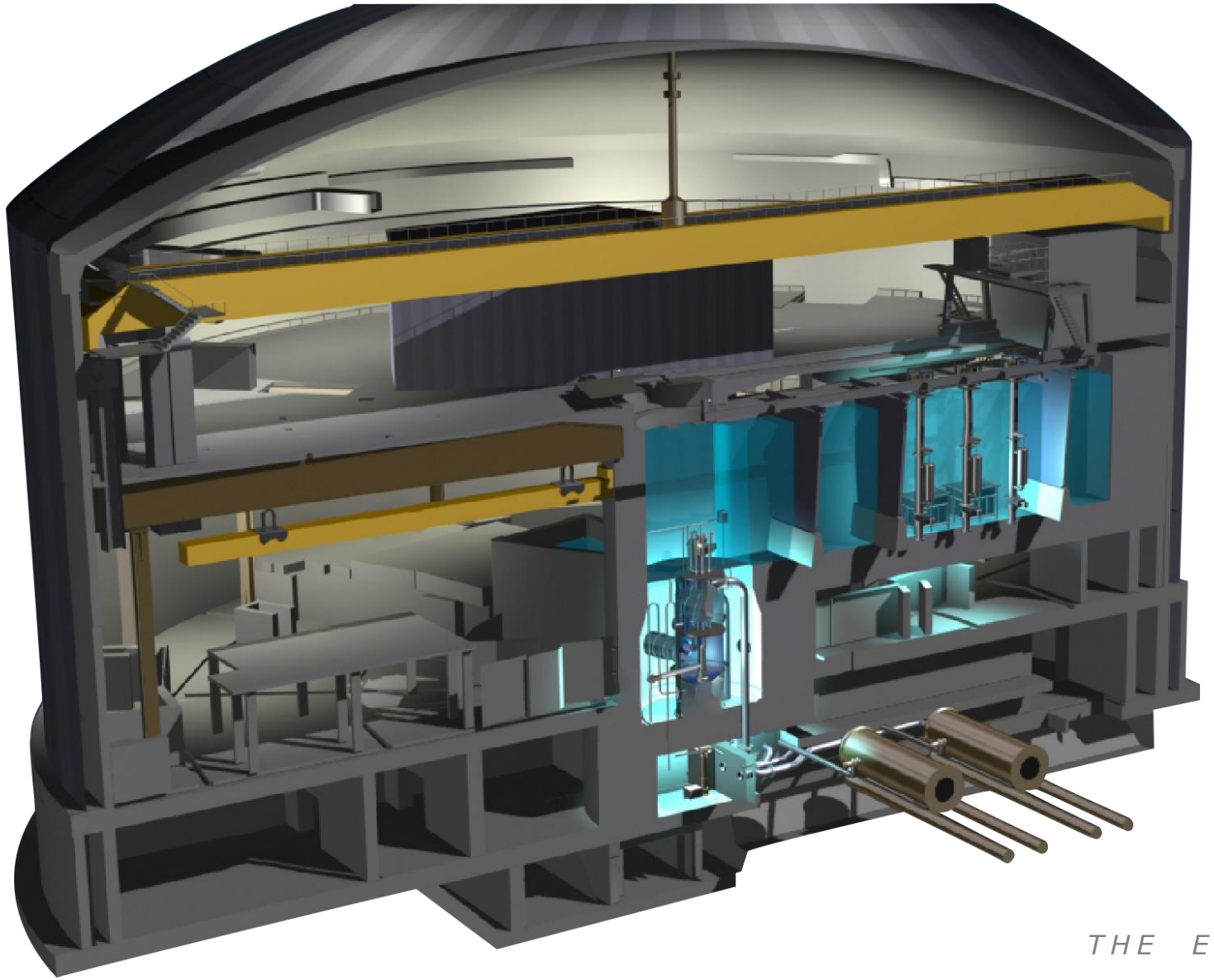


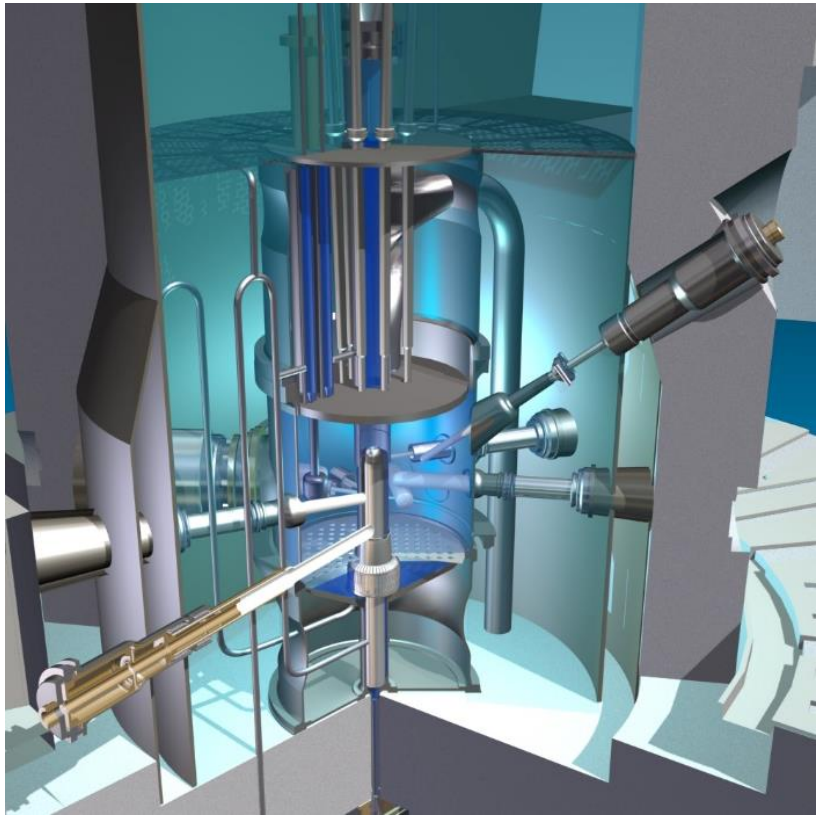
Chemistry of Materials
Europhysics Letters
J. Molecular Biology
JACS
Langmuir
Macromolecules
Nature
Nature Materials
Nature Physics
Phys. Rev. B
Phys. Rev. C
Phys. Rev. E
Phys. Rev. Lett.
Science

2007 — 2016

NEUTRONS FOR SOCIETY

The ILL Reactor



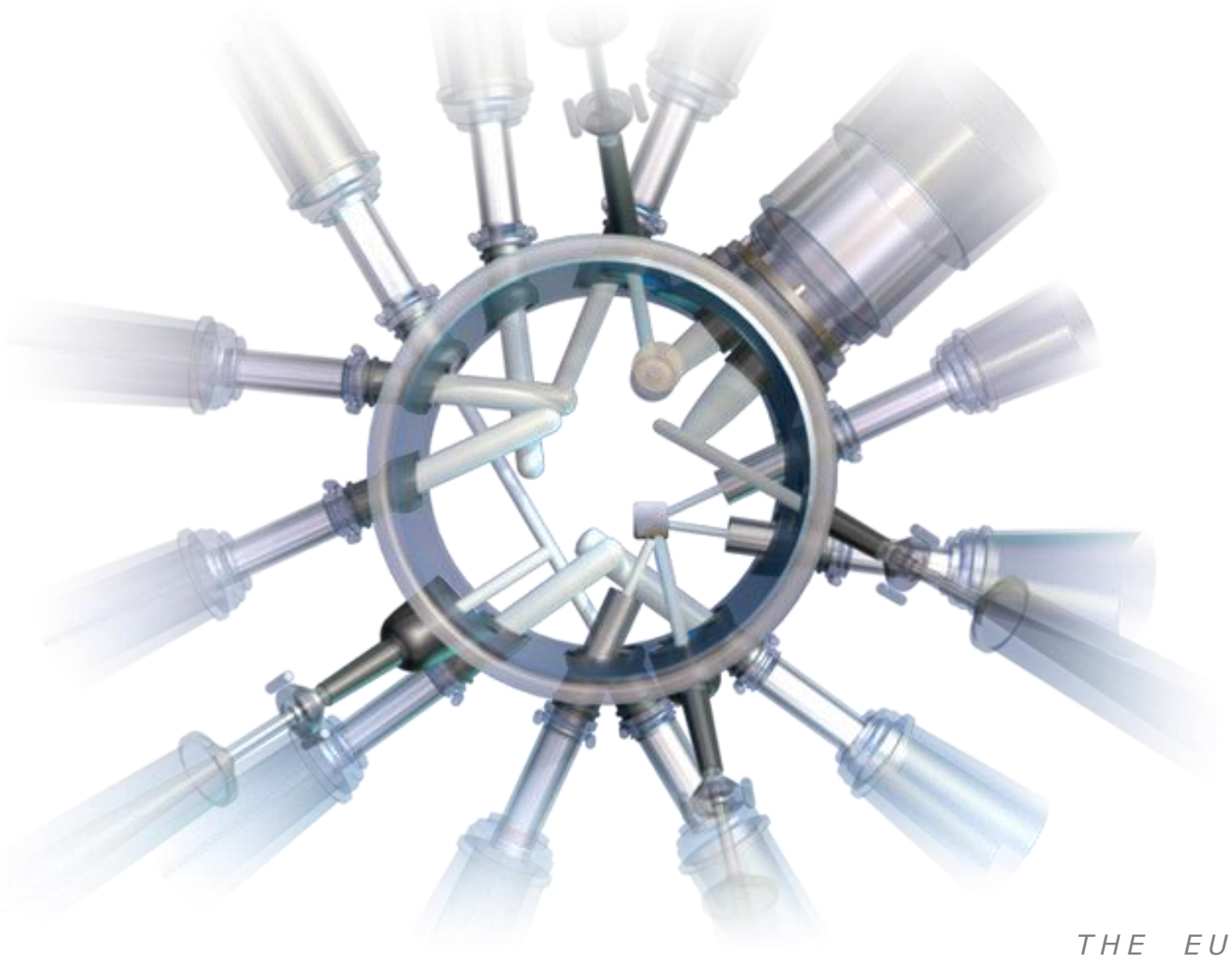


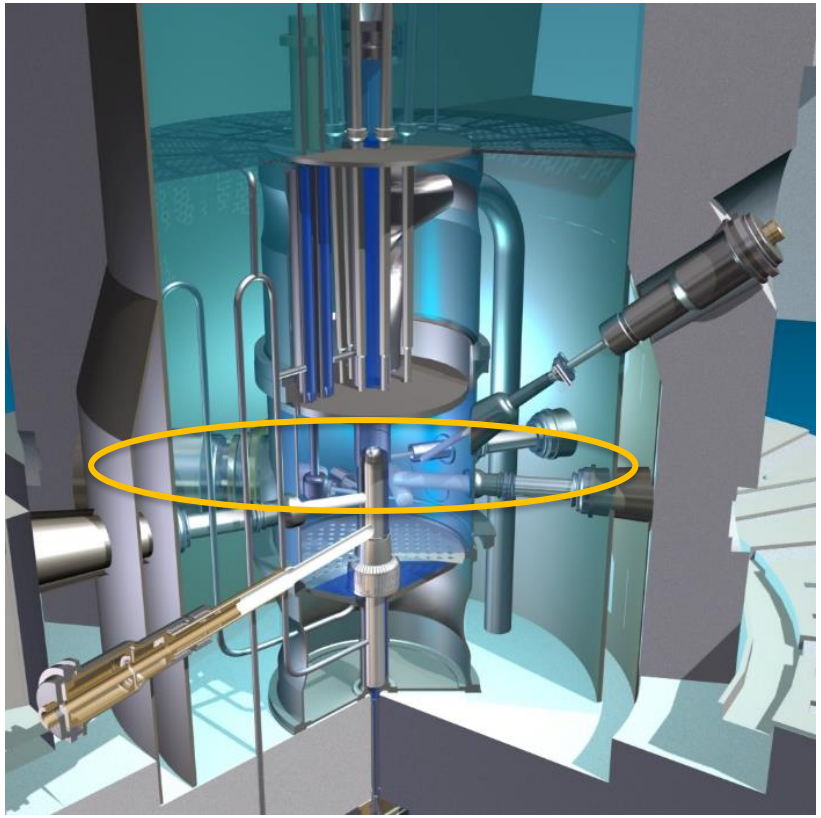
A neutron source generating

$\sim 10^{15}$ neutrons/cm^2/sec

at a max power of 57 MW

How neutrons are extracted and guided





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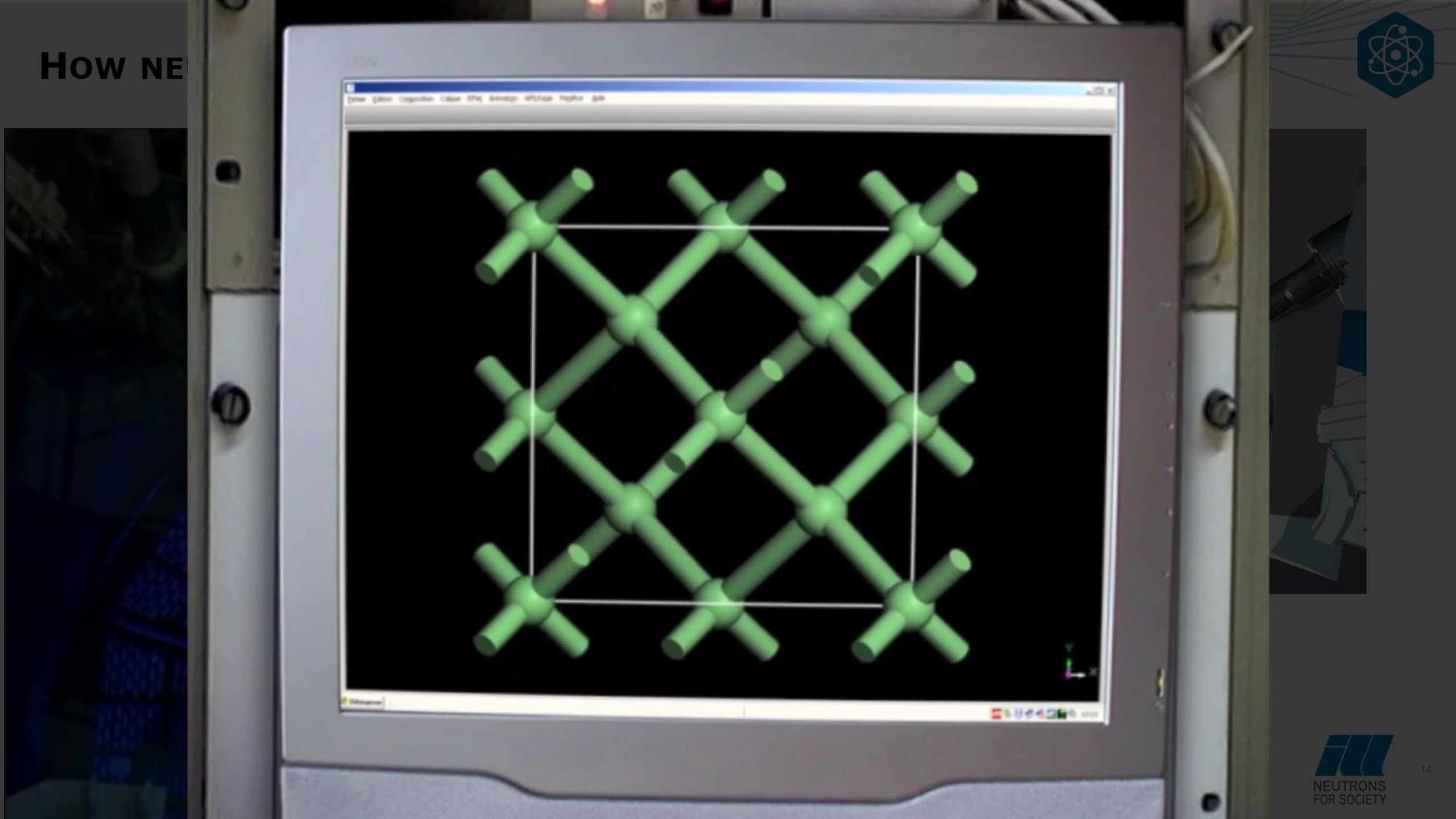
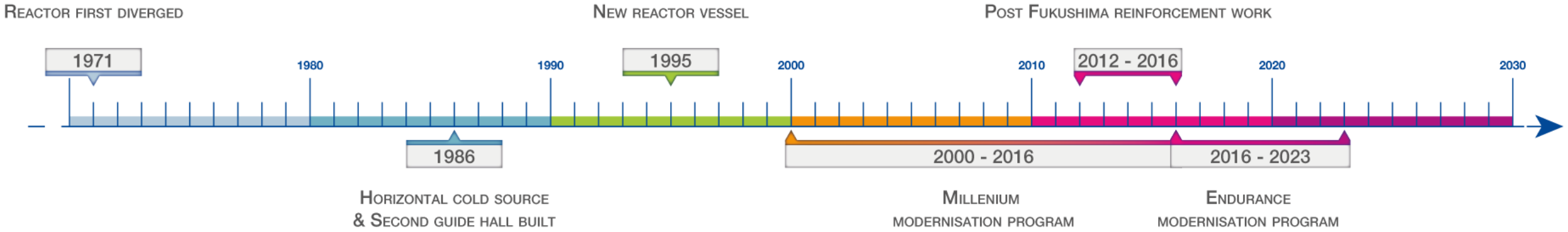


NEUTRONS FOR SOCIETY

MODERNISATION PROGRAMMES

A constant upgrade of our facilities and instruments :
the secret of our excellent, modern and highly efficient instrumentation



MODERNISATION PROGRAMMES

A constant upgrade of our facilities and instruments :
the secret to our 45-year long record of world leadership in neutron science

First phase : 2001-2008

- 14 new or upgraded instruments
  - ➢ 42 M€ invested

Second phase : 2009-2016

- 4 new instruments + 3 instruments CRG
- 4 instrument upgrades
  - ➢ 43 M€ invested

- ✓ 'twice as bright' replaced or renewed neutron guides
- ✓ technical devices improved, from cryostats to magnets
- ✓ new polarised optics
- ✓ new electronic instrument control system…

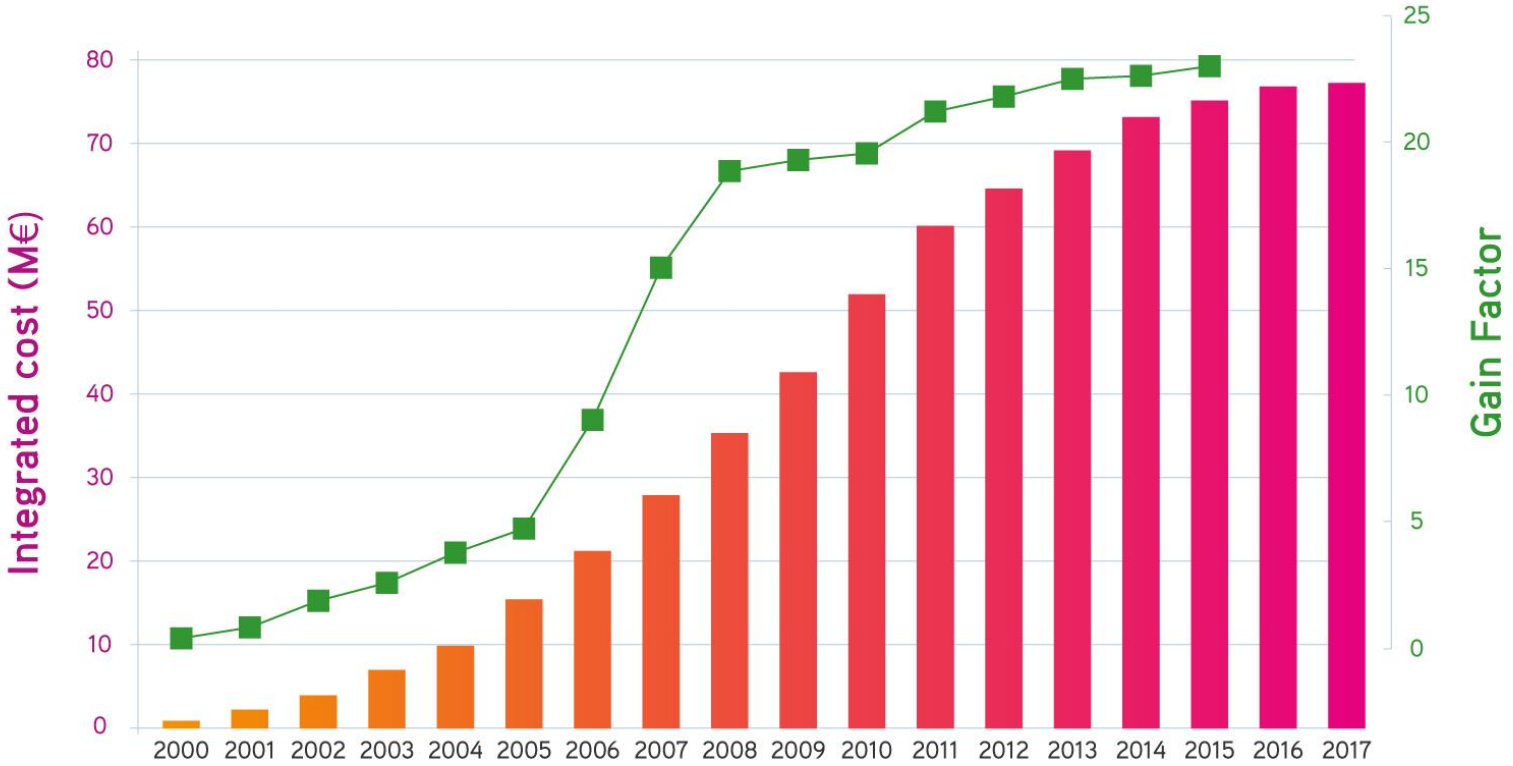
MODERNISATION PROGRAMMES

2000 - 2016

MILLENIUM

MODERNISATION PROGRAM

The resulting average neutron detection rate on the instruments is almost improved by a factor of 25!



NEUTRONS FOR SOCIETY

MODERNISATION PROGRAMMES

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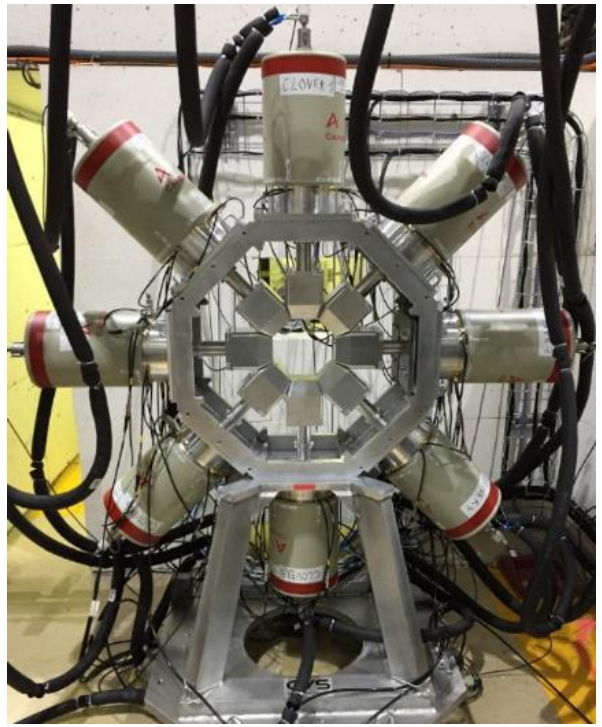


First phase : 2016-2019

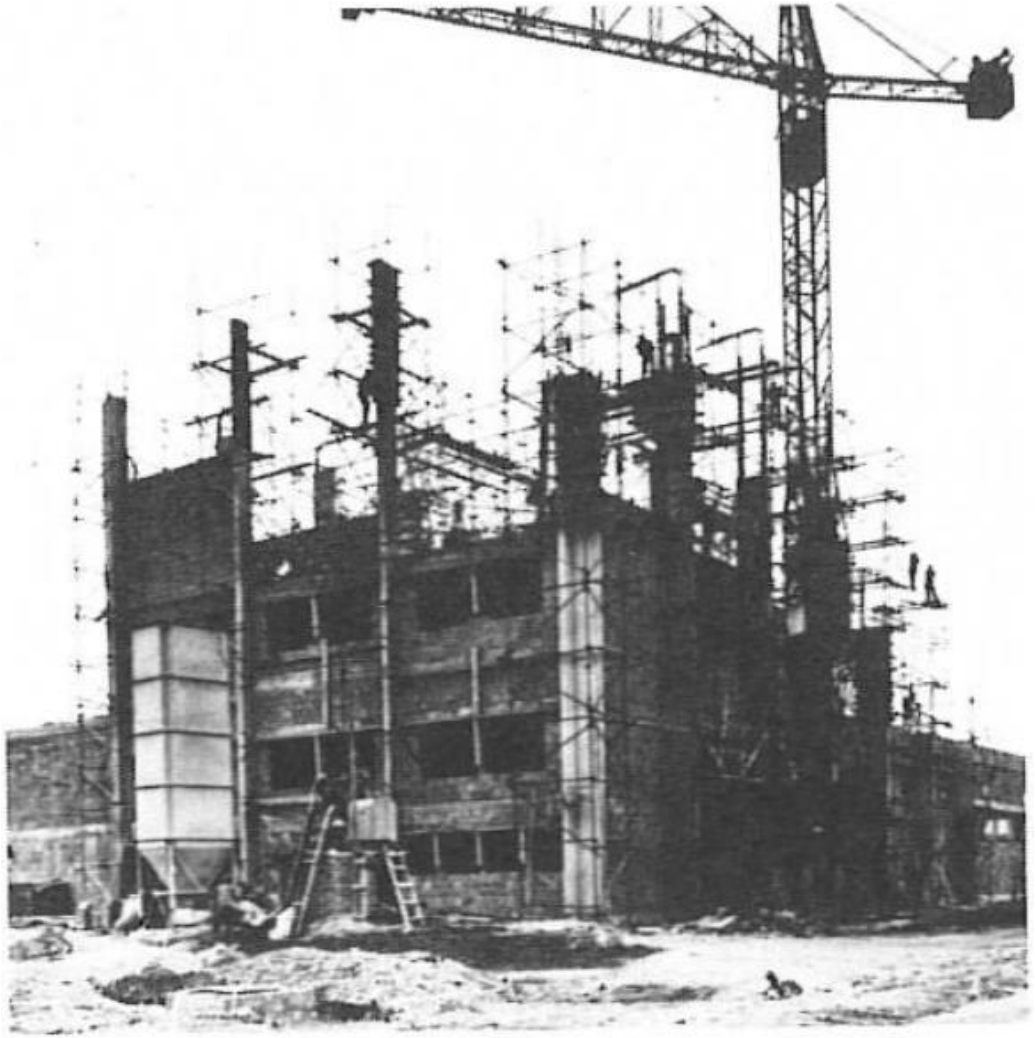
Second phase : 2020-2023

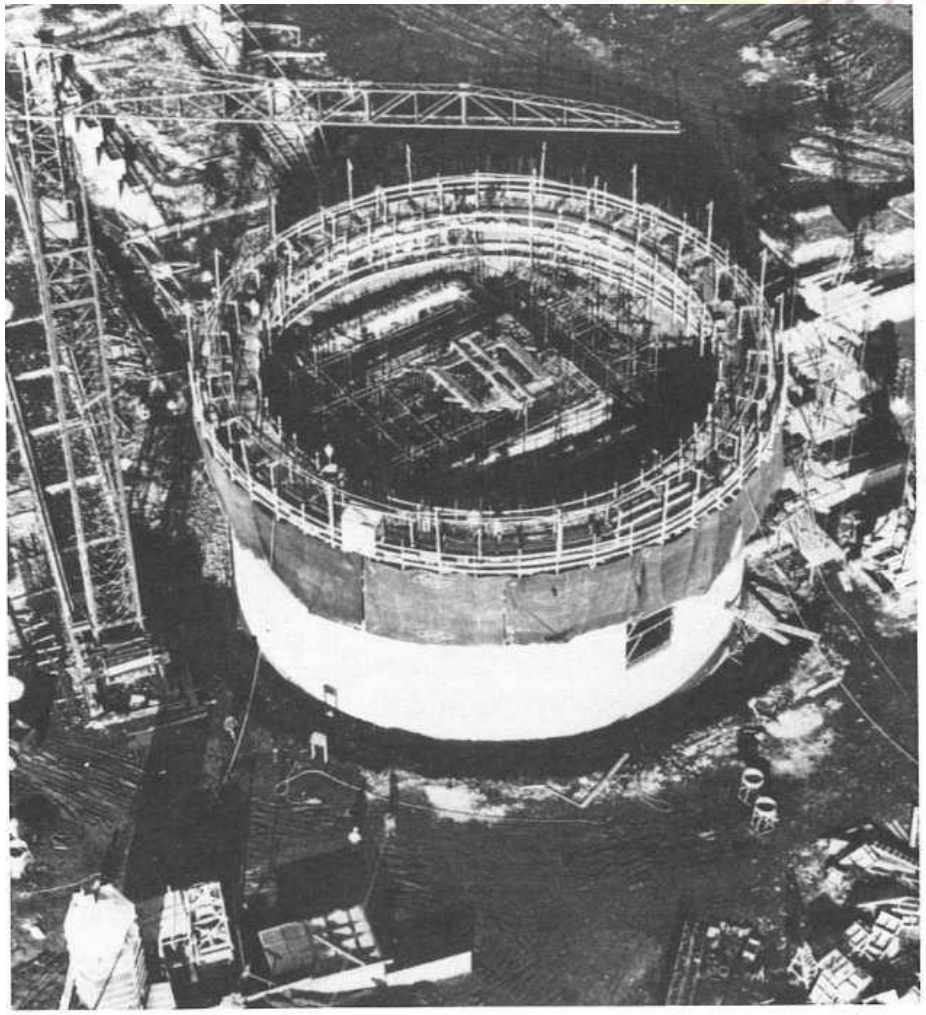
- 9 instrument projects
- Creation or refurbishment of neutron guides
- 2 infrastructure projects:
  - sample environment
  - data analysis software

✓ preserve our position of leadership by drawing on our strengths
✓ offer new possibilities in the fields of magnetism, materials science, soft matter, biology and particle physics

A LITTLE BIT OF HISTORY

A LITTLE BIT OF HISTORY





Le réacteur Siloé en construction.

A LITTLE BIT OF HISTORY

A LITTLE BIT OF HISTORY: 19 JANUARY 1967

A LITTLE BIT OF HISTORY

A LITTLE BIT OF HISTORY: 1971 - 1973

1971:

→ Divergence (Aug 31) and full power (Dec 21)

1973:

→ start of user programme

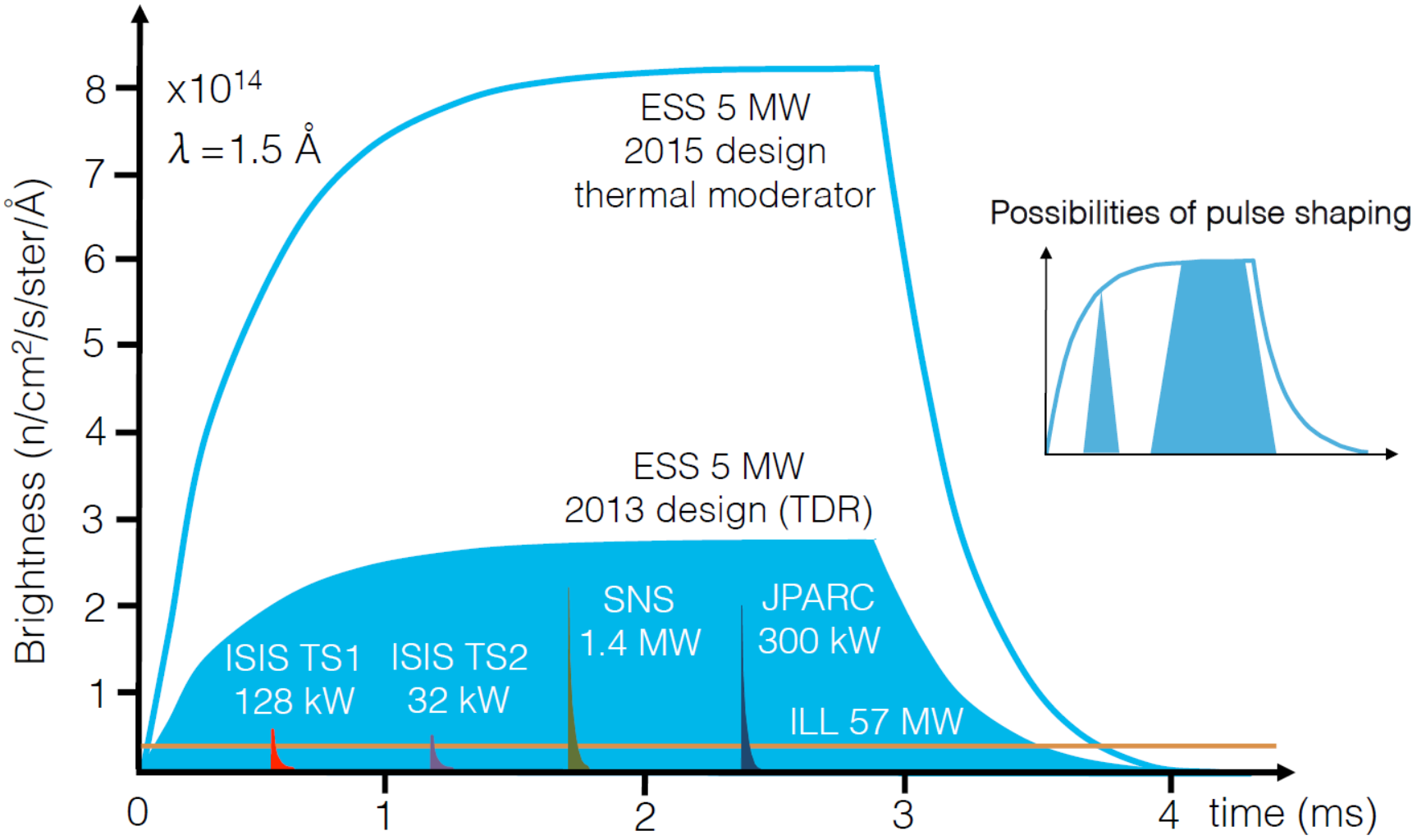
→ UK joins ILL

→ UK joins EU!

→ (1975: referendum on UK remaining in EU – 67% YES!)

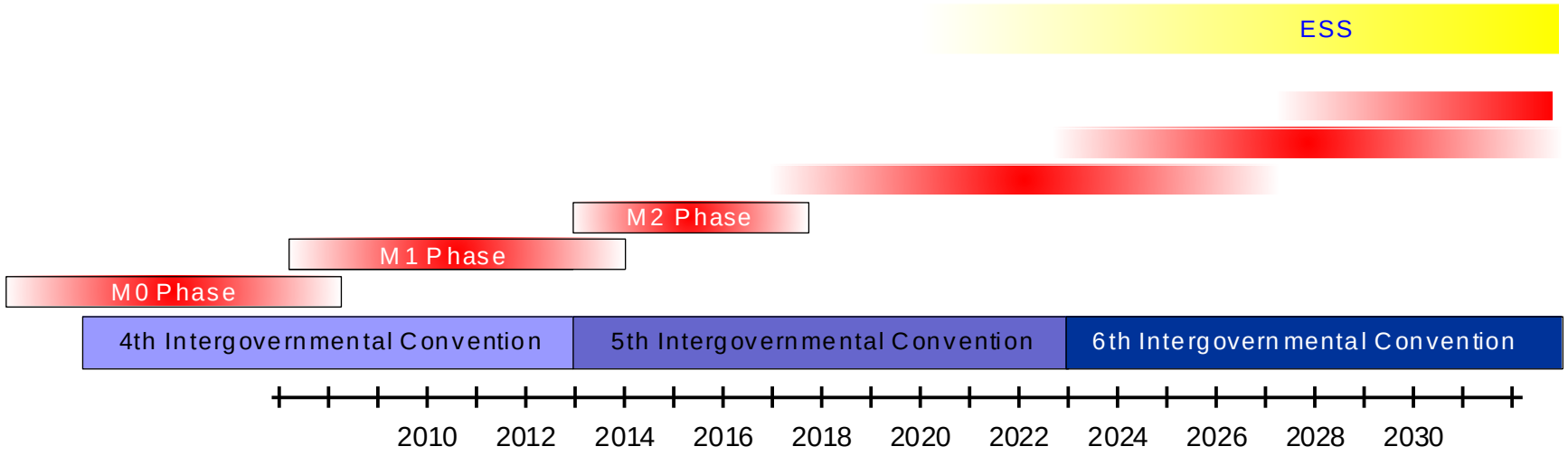
LOOKING TO THE FUTURE: REACTORS AND/OR SPALLATION SOURCES

LOOKING TO THE FUTURE: REACTORS AND/OR SPALLATION SOURCES



Looking to the future: a European strategy

- ESS: Construction ends 2020 – first neutrons, one test beam line. User programme starts 2023. Instrument suite of 15 instruments by 2026, 22 by 2028, etc. Cost ~3B€. 10-year ramp-up to significant scientific output → 2033
- Reactors at LLB, Paris and HZB, Berlin closing by 2020 – 20% loss in capacity in Europe (17% loss in scientific output)
- ILL beyond 2023: 30% of beam time → 40% of science



Welcome to the summer school, the EPN campus, Grenoble – enjoy yourselves