Science at ESS
Instruments and Future Users

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www.europeanspallationsource.se

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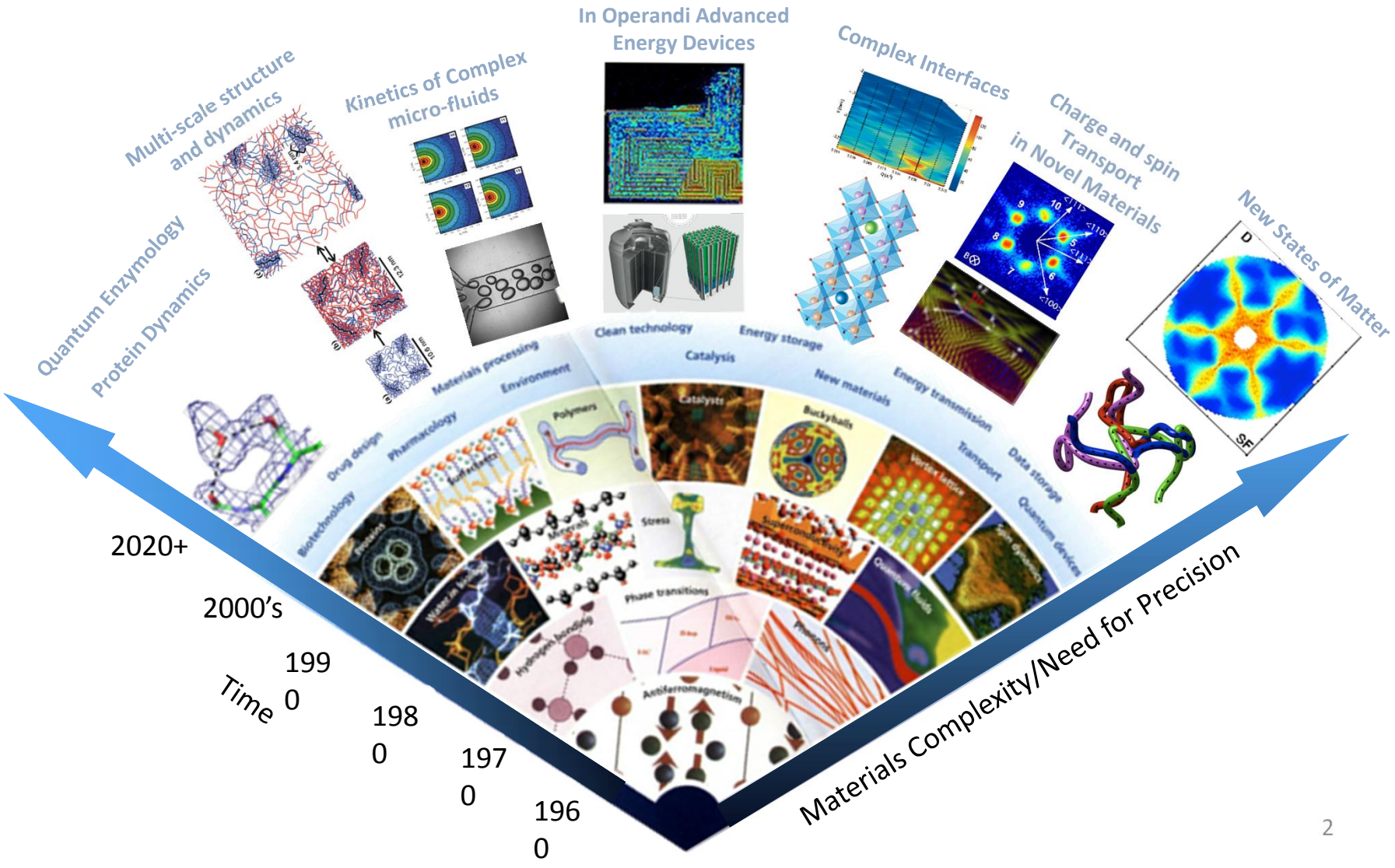
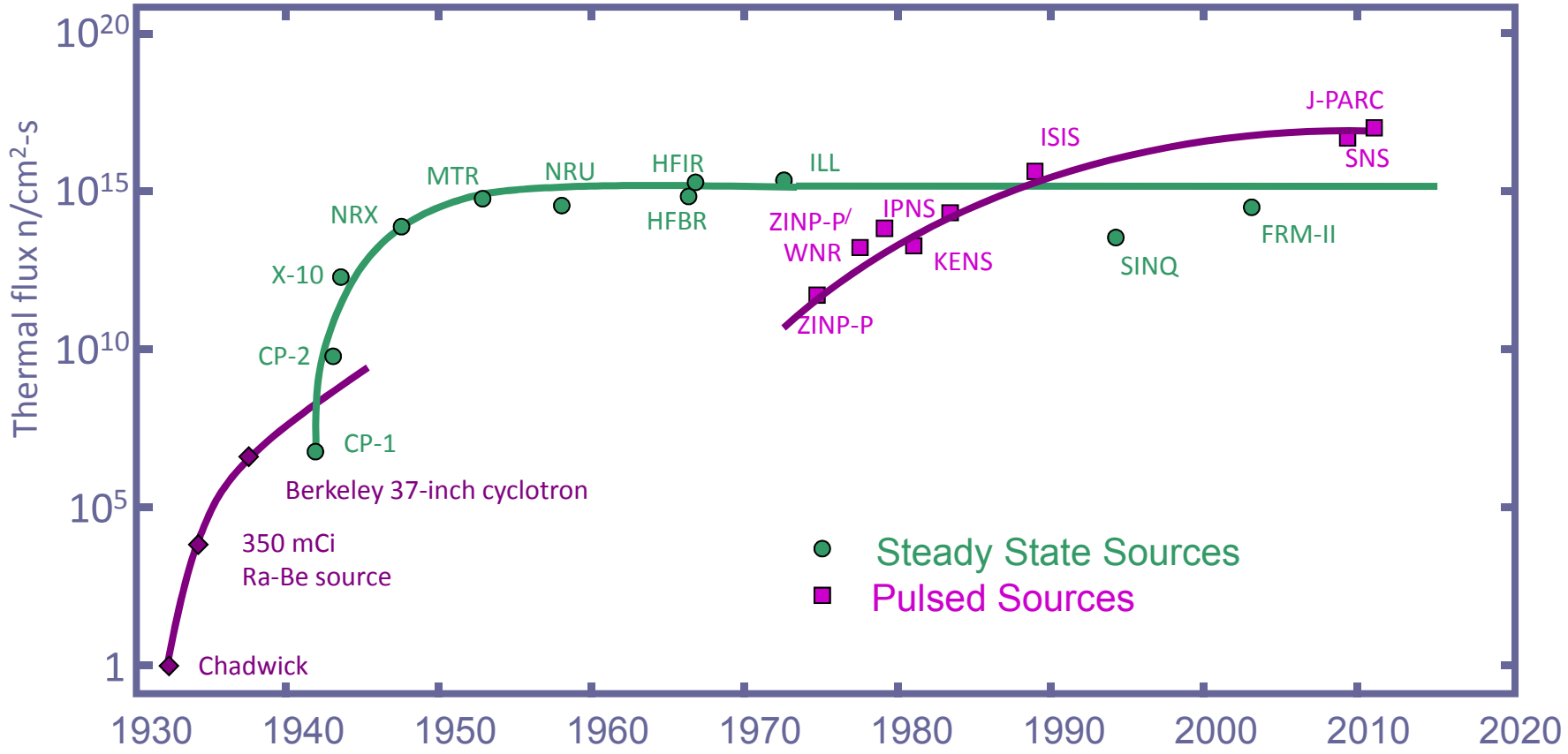
Science with neutrons

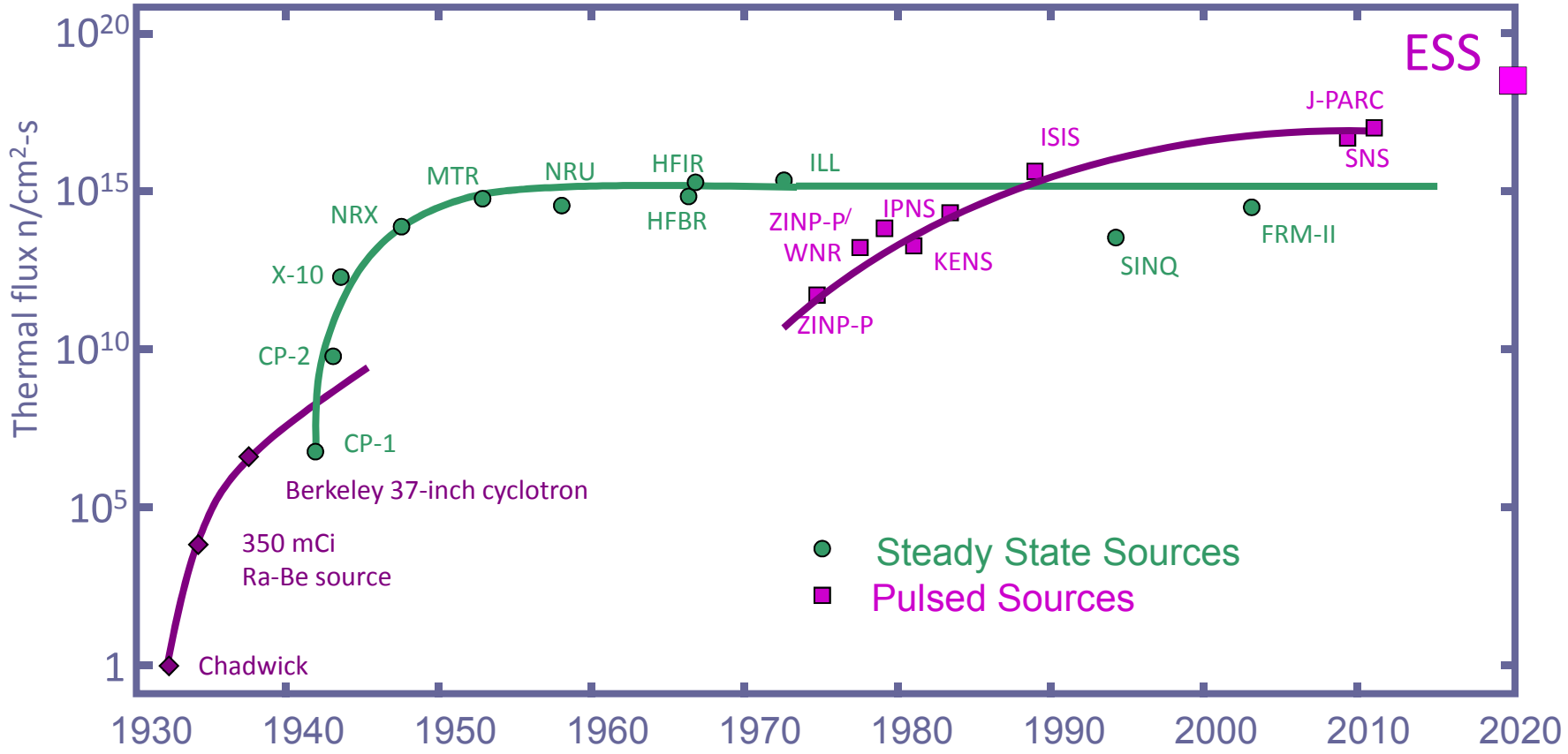


Evolution of neutron sources



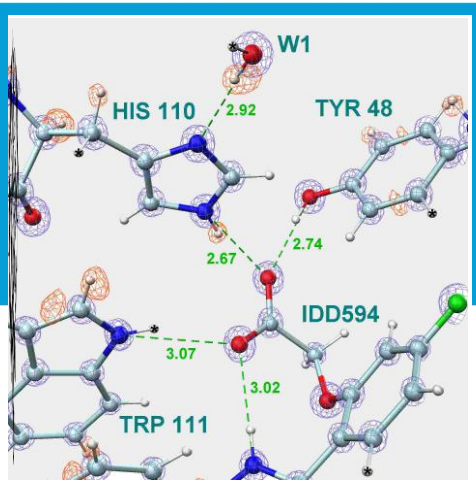
(Updated from *Neutron Scattering*, K. Sköld and D. L. Price, eds., Academic Press, 1986)

Evolution of neutron sources

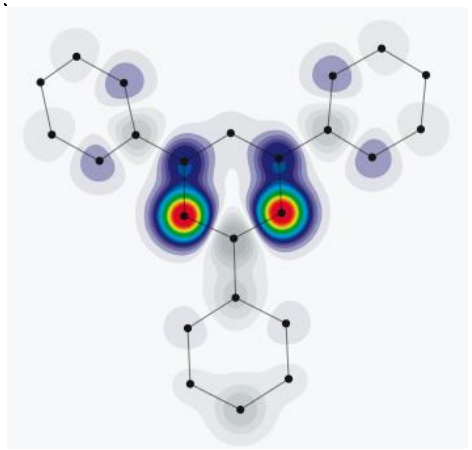


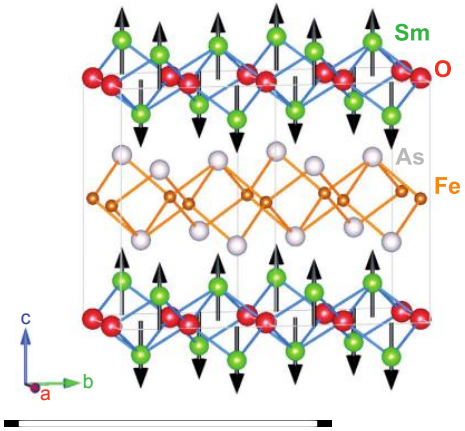
(Updated from *Neutron Scattering*, K. Sköld and D. L. Price, eds., Academic Press, 1986)

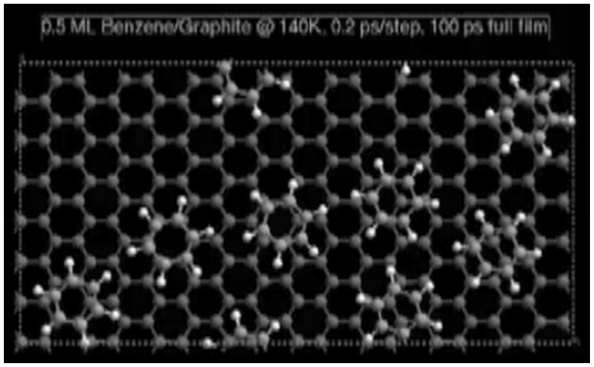
Neutrons are special



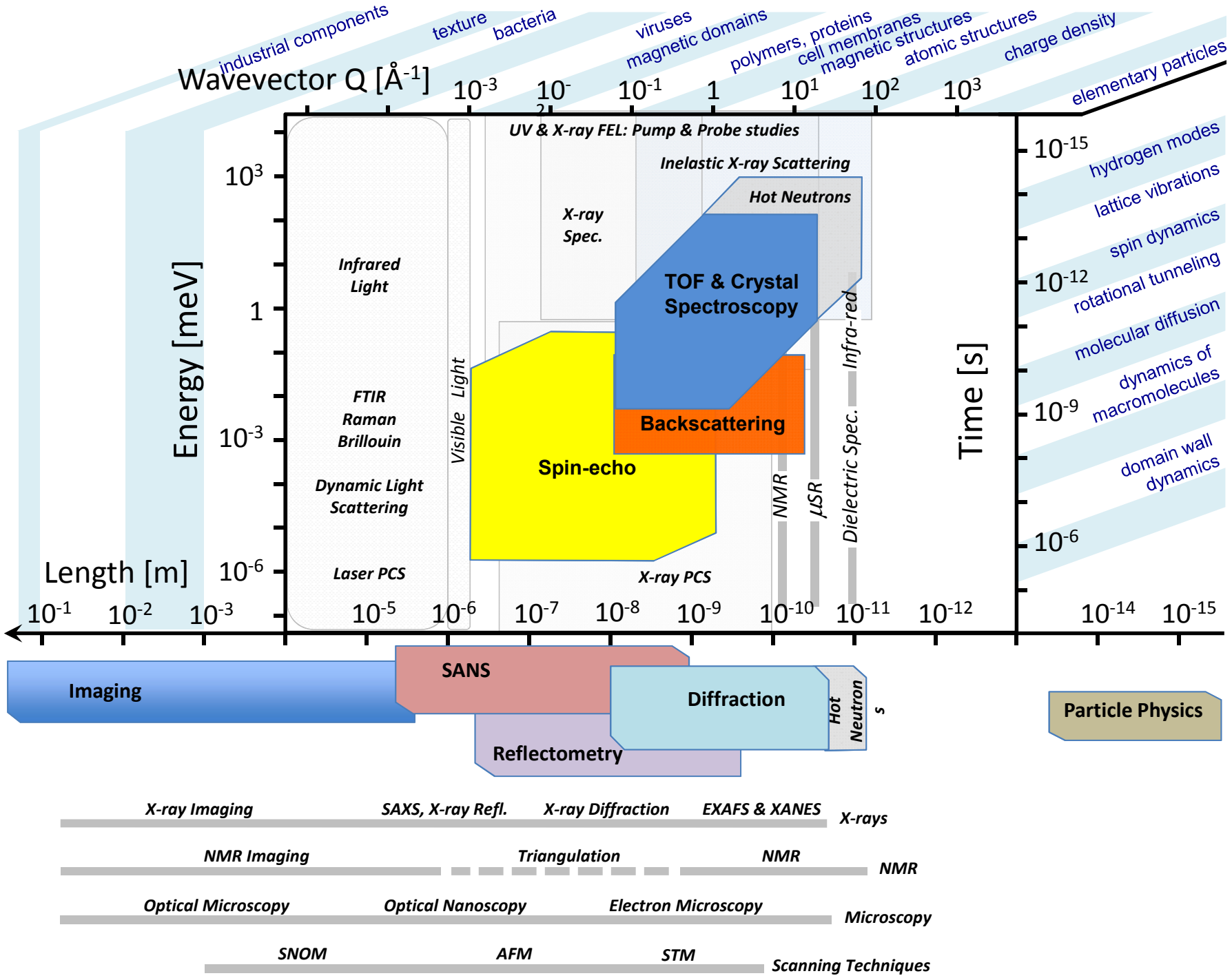
- **charge neutral:** deeply penetrating … except for some isotopes
- **nuclear interaction:** cross section depending on isotope (not Z), sensitive to light elements.
- **spin S = 1/2**: probing magnetism
- **unstable** $n \rightarrow p + e + \underline{\nu}_e$ with life time $\tau \sim 900s$, $I = I_0 \ e^{-t/\tau}$
- **mass**: n ~p; thermal energies result in non-relativistic velocities.
  E = 293 K = 25 meV,
  v = 2196 m/s , λ = 1.8 Å



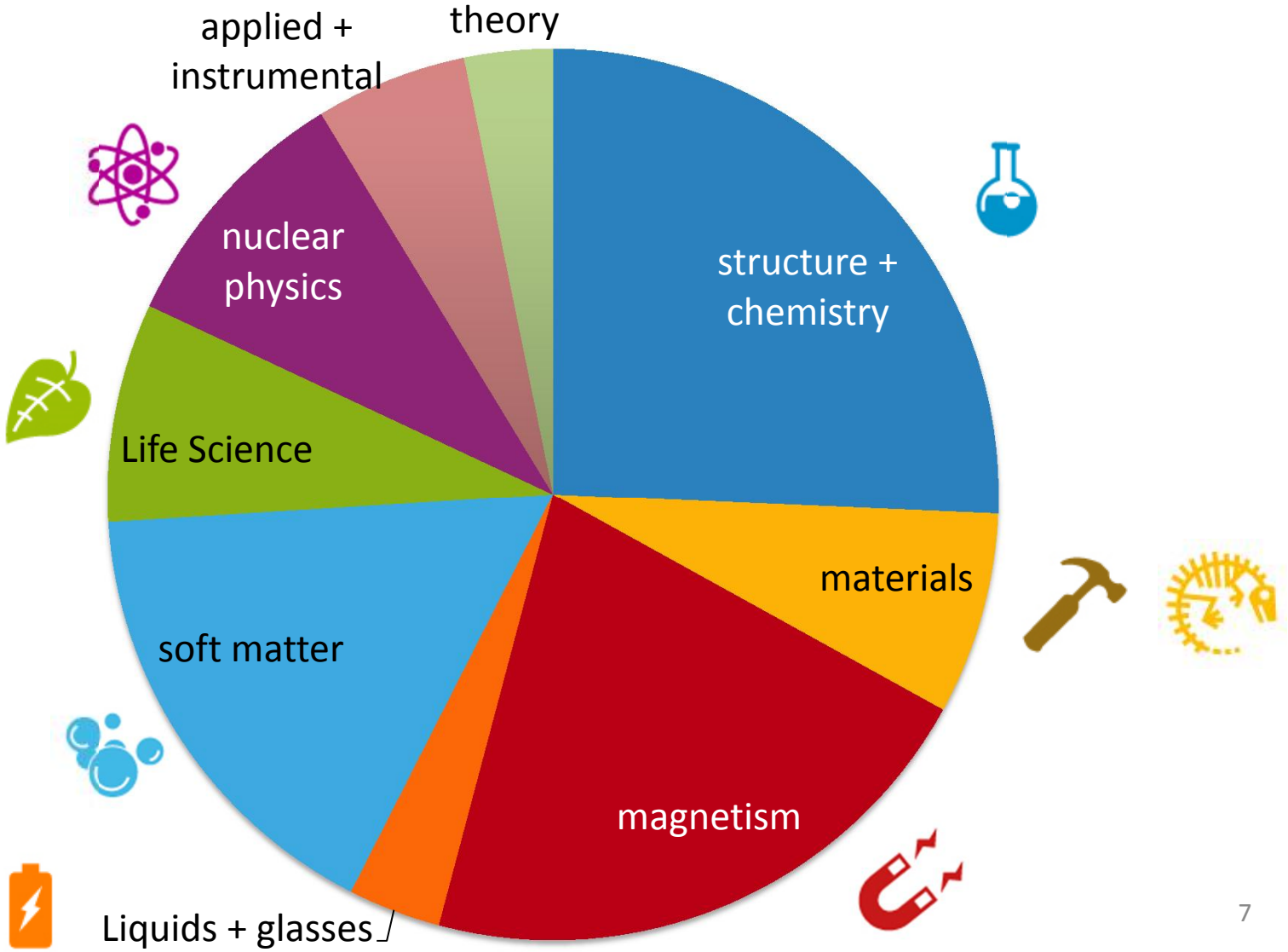




WHERE ARE THE ATOMS AND WHAT DO THEY DO?


Wavevector Q [Å^{-1}]
industrial components
texture
bacteria
viruses
magnetic domains
polymers, proteins
cell membranes
magnetic structures
atomic structures
charge density
elementary particles
10^{-3}
10^{-2}
10^{-1}
1
10^{1}
10^{2}
10^{3}
UV & X-ray FEL: Pump & Probe studies
Inelastic X-ray Scattering
Hot Neutrons
X-ray Spec.
Infrared Light
TOF & Crystal Spectroscopy
Backscattering
Spin-echo
FTIR
Raman
Brillouin
Dynamic Light Scattering
Laser PCS
X-ray PCS
Visible Light
NMR
μSR
Dielectric Spec.
Infra-red
Energy [meV]
10^{3}
1
10^{-3}
10^{-6}
Time [s]
10^{-15}
10^{-12}
10^{-9}
10^{-6}
hydrogen modes
lattice vibrations
spin dynamics
rotational tunneling
molecular diffusion
dynamics of macromolecules
domain wall dynamics
Length [m]
10^{-1}
10^{-2}
10^{-3}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-14}
10^{-15}
Imaging
SANS
Diffraction
Hot Neutrons
Reflectometry
Particle Physics
X-ray Imaging
SAXS, X-ray Refl.
X-ray Diffraction
EXAFS & XANES
X-rays
NMR Imaging
Triangulation
NMR
NMR
Optical Microscopy
Optical Nanoscopy
Electron Microscopy
Microscopy
SNOM
AFM
STM
Scanning Techniques

Neutron use per science topic



Neutrons for Energy Research

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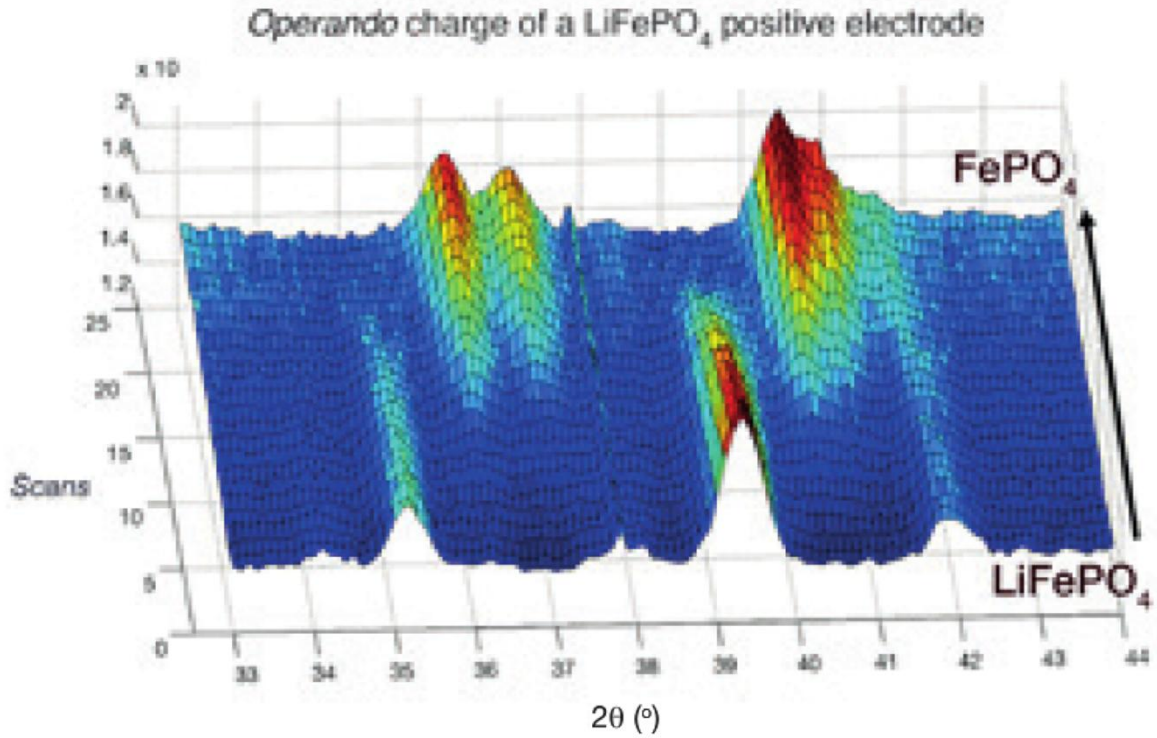
energy

Real-time neutron diffraction studies of electrode materials for Li-ion batteries.

Neutrons are sensitive to light elements light lithium.

High intensity powder diffraction reveals lithium extraction / insertion in electrode material.



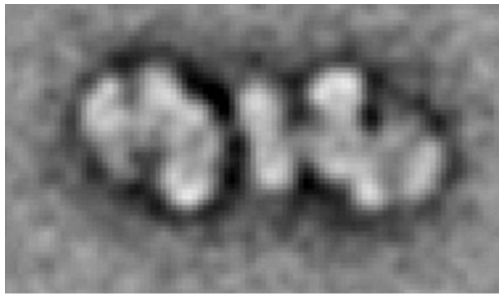
Bianchini and Suard (ILL 2014)

Neutrons solved structure enigma of DNA-restriction enzyme type I

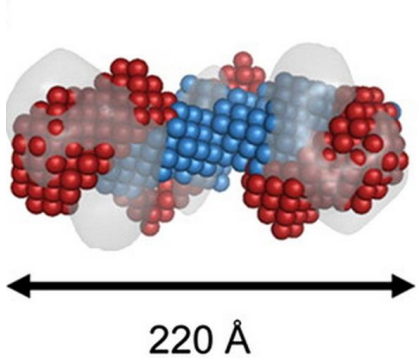
EUROPEAN SPALLATION SOURCE

health

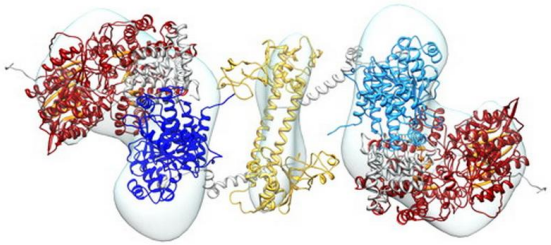
2D difference EM image of EcoRI24l



Protein structure prediction modeled from EM map of EcoRI24l



EcoR124I+DNA model, SANS data, and 2D difference imaging



Restriction enzymes cut pieces of DNA at specific sites.
Used to cut and paste genes for different purposes.

EcoRI24l is a bacterial restriction enzyme that controls the influx of foreign genes into the genome of many bacteria.

Until 2012, the exact molecular structure was unknown. Here, the authors have combined EM, SAXS and SANS to determine the structure of this enzyme

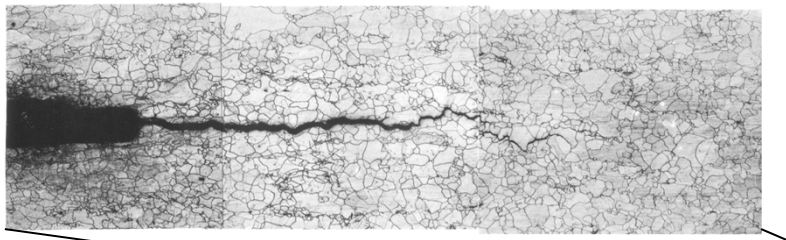
Kennaway, C.K. *et al.* Genes Development *(*2012) p. 92-104

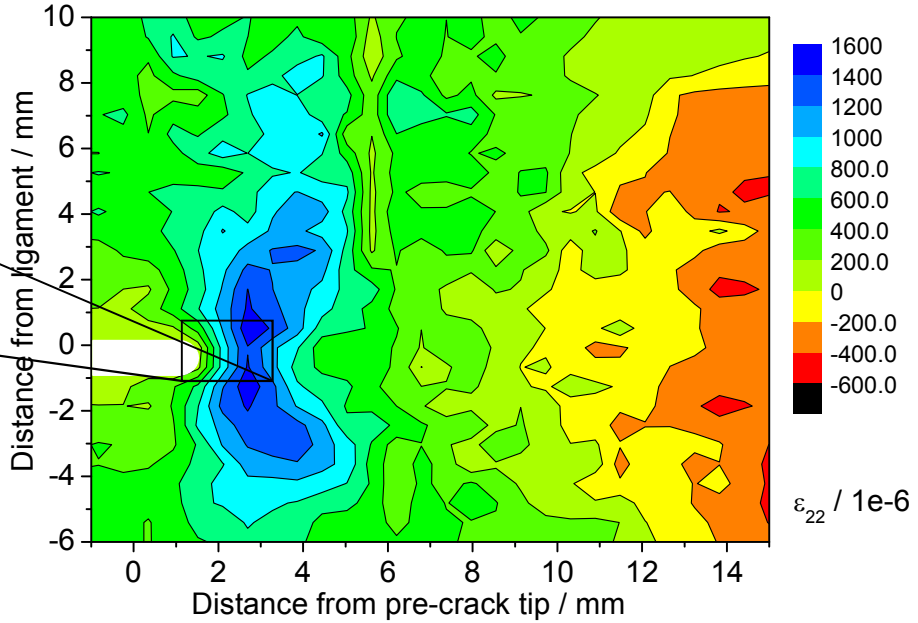
Stress around fatigue cracks

EUROPEAN SPALLATION SOURCE

new materials, mobility

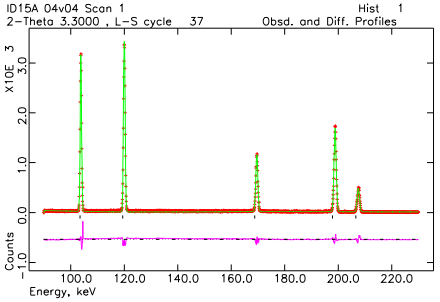
Fatigue + Creep Crack in **25mm** Austenitic steel

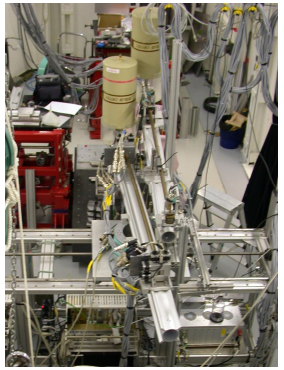




Exploring the boundaries of spatial resolution achievable in real materials engineering components.

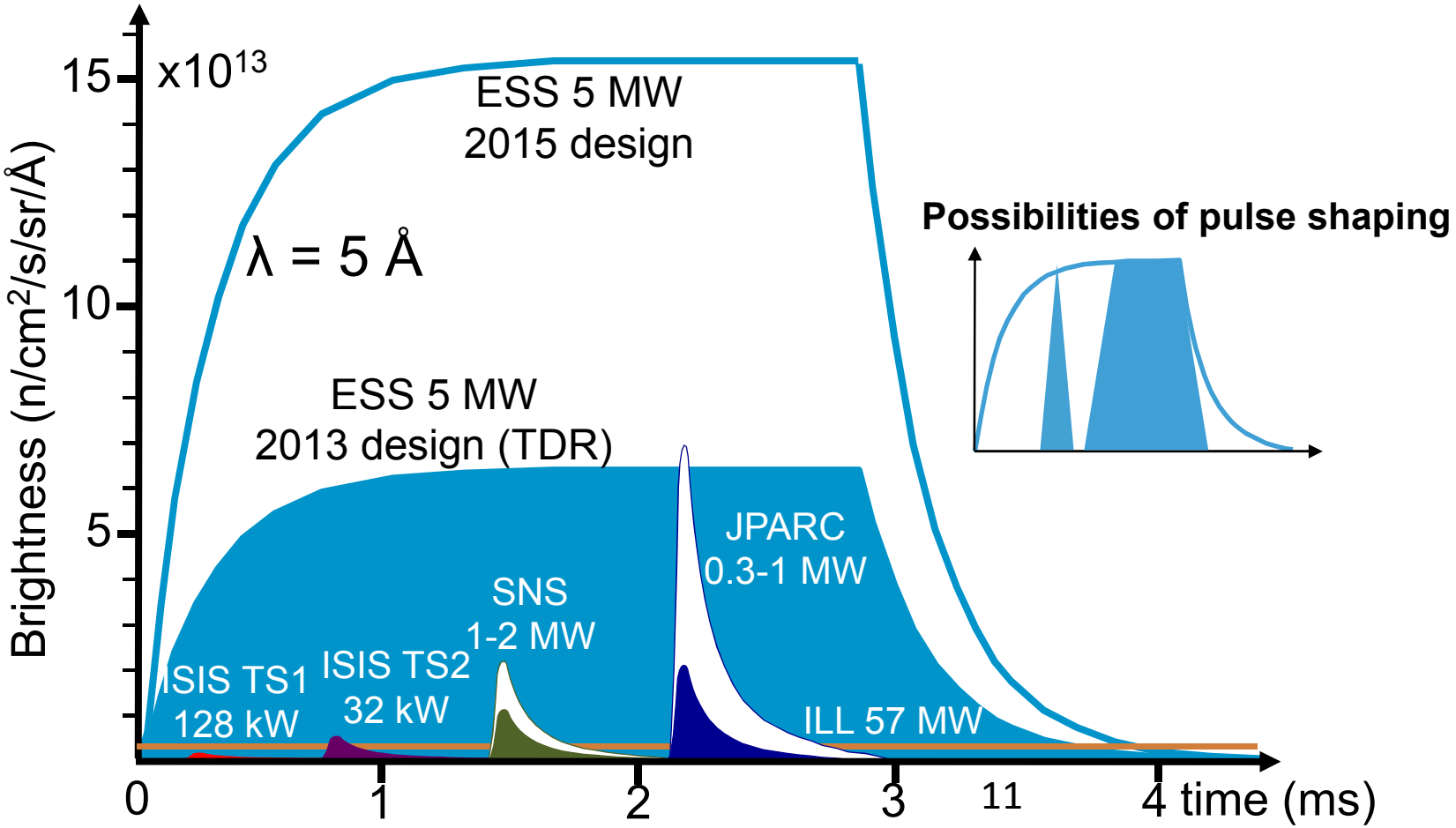
Using combinations of in-situ techniques: imaging & diffraction, in-situ loading, high-temperature…





A Steuwer et al, J Appl Crysts (2004)

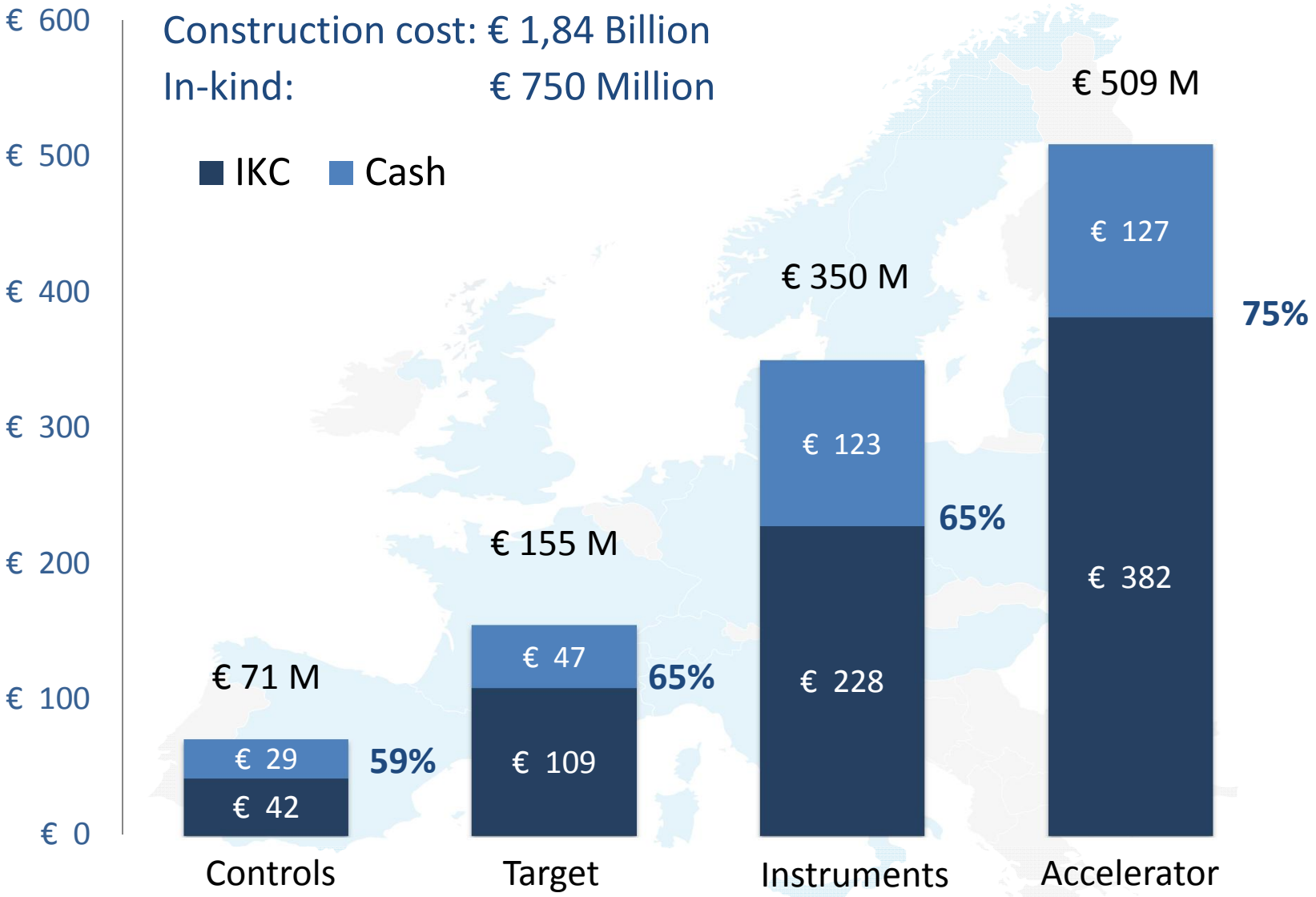
The unique ESS long pulse



more neutrons per second than any steady state source …

… with higher brightness than any other spallation source

ESS In-kind Goals



Neutron Scattering Systems Project

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Construct 22 world-leading neutron beam instruments

Build the technical and scientific support infrastructure needed for delivering world-leading science

16 Instruments

+

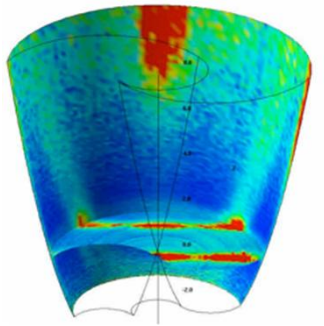
Sample Environment

+

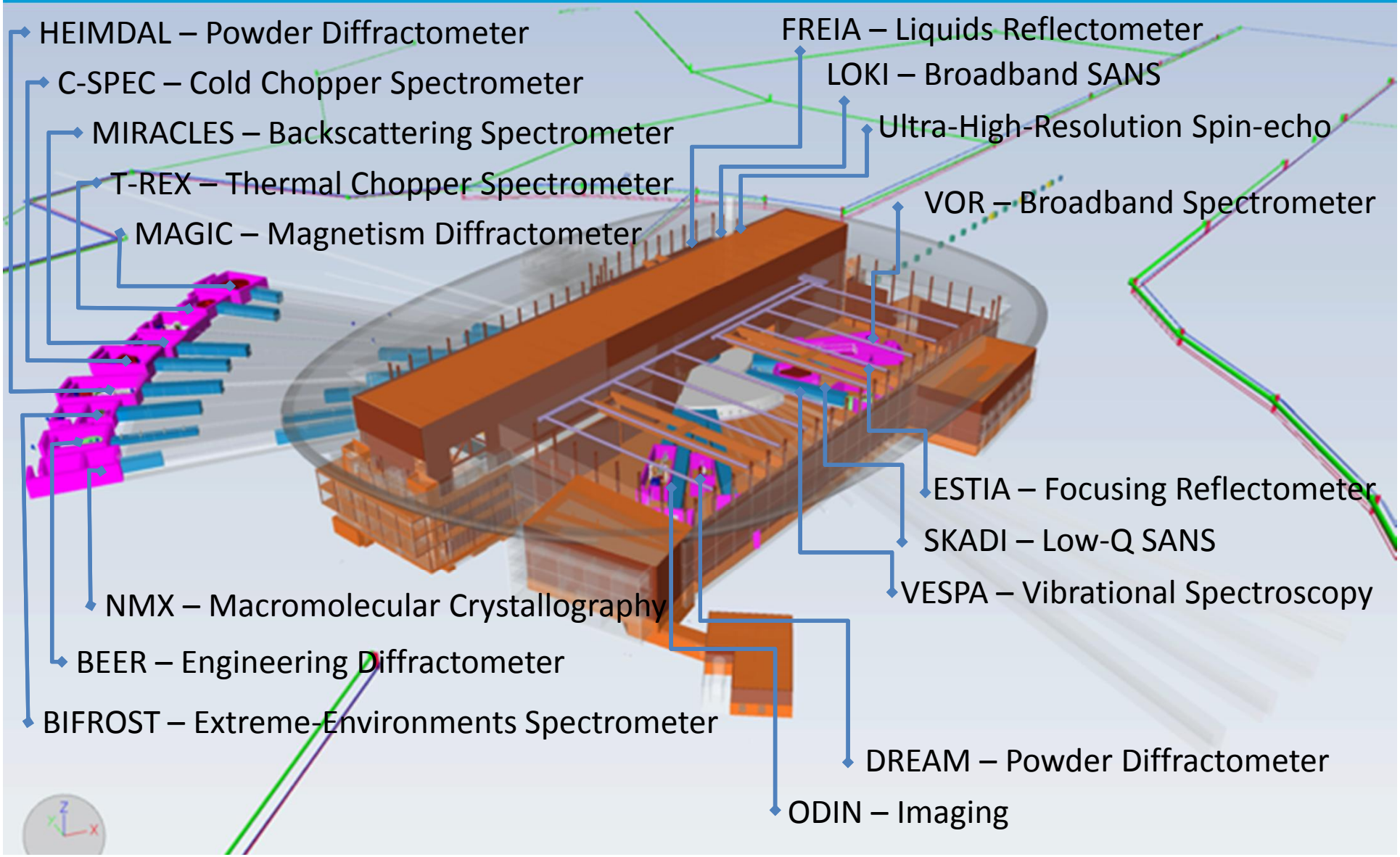
Science Support Laboratories

+

Analysis and Visualisation Software



Instrument Suite is taking shape



Current status of Instrument delivery

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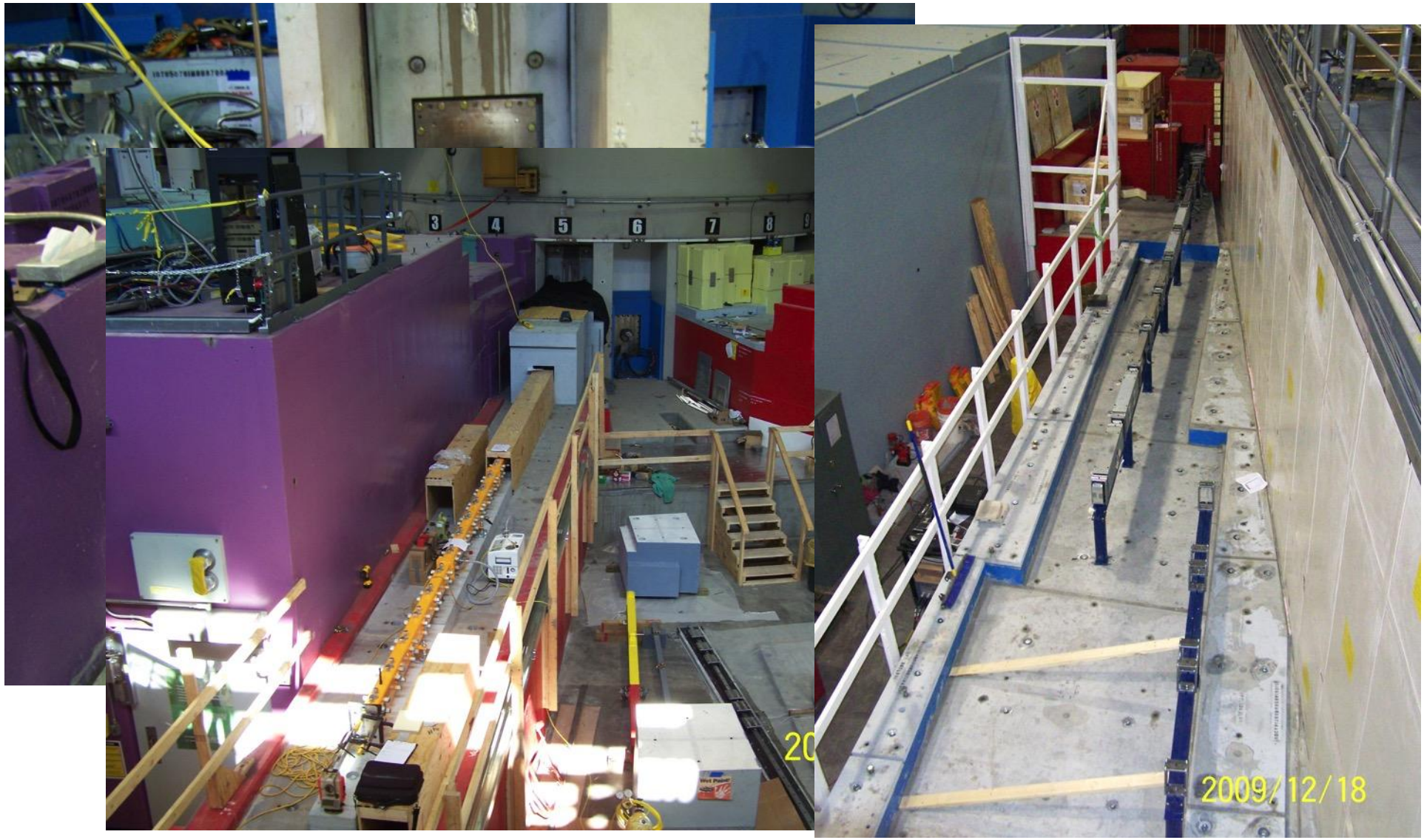
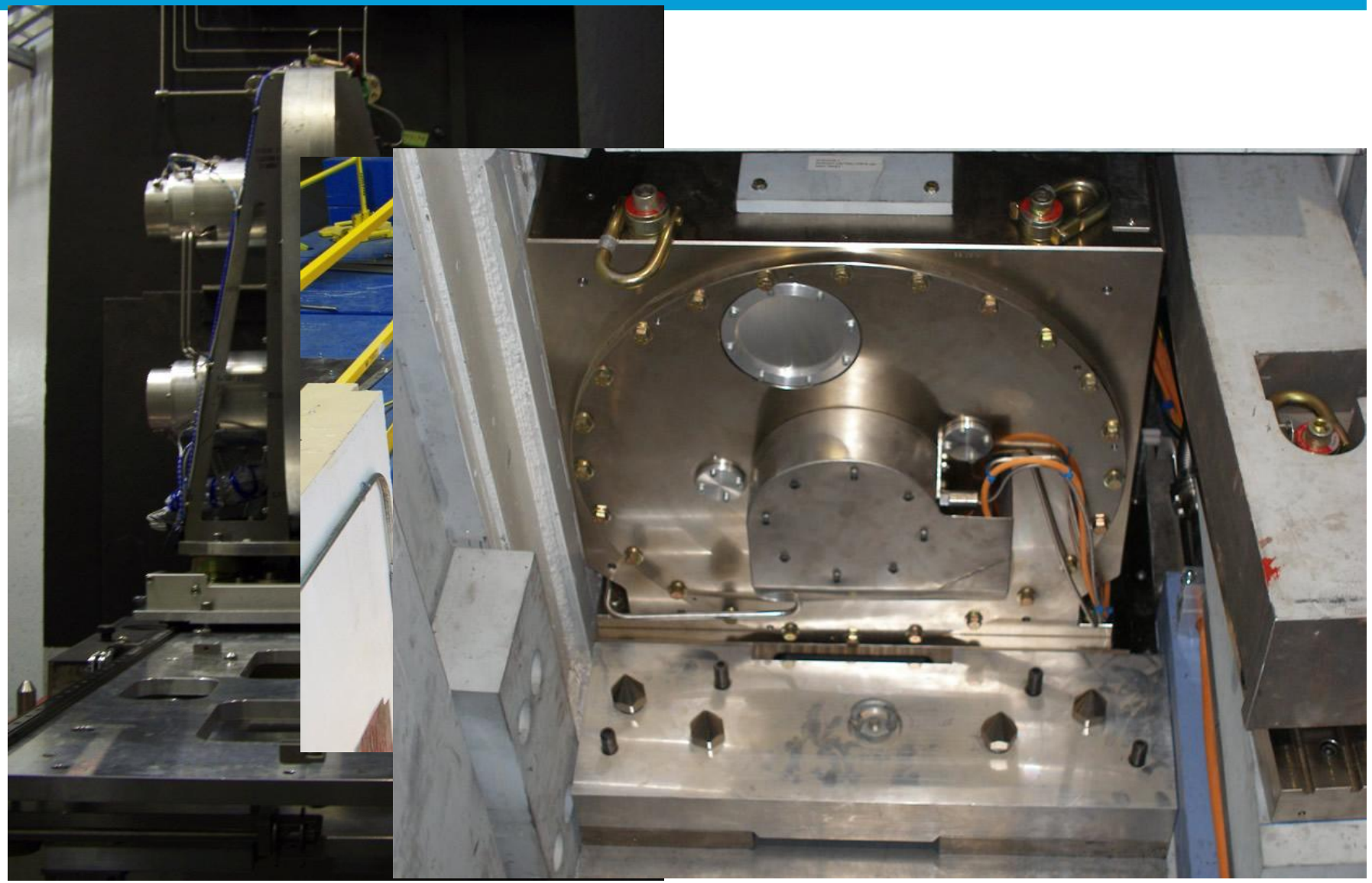
class	Instrument	cost category	In-kind Partners	Cost (M€)	% IK
Large scale structures	LOKI broadband SANS		**ESS (30%) +** ES (Bilbao ~32%), IT (CNR ~24%), UK (STFC ~8%), CH (PSI ~3%), HU (Wigner ~1%)	12.1	**68%**
	SKADI general-purpose SANS (note 1)	B	**DE(FZJ 50%) + FR(LLB 50%)**	12	95%
	ESTIA focusing reflectometer	A	**CH(PSI)**	9	95%
	FREIA liquids reflectometer	A	**ESS (<30%) -> UK (ISIS)? or DE(FZJ) ?**	9	90%
Diffraction	NMX macromolecular crystallography		**ESS (<30%) +** HU (Wigner 16%) + FR (LLB ~4%) + NO (~17%) + IT/UK (~15%)	11.7	**52%**
	DREAM powder diffractometer (bispectral)	B	**DE(FZJ 75%) +** FR(LLB 25%)	12	95%
	HEIMDAL hybrid diffractometer	B	**DK(AU <30%)** +CH(PSI ~ 30%) + HU (~5%) +UK? (~20%) + ?	12	**70%**
	MAGIC magnetism single-crystal diffractometer	B	**FR (LLB 75%)** + DE (FZJ 25%)	12	100%
Engineering	BEER engineering diffractometer	B	**DE (HZG 50%), CZ (NPI 50%)**	12	100%
	ODIN multi-purpose imaging	A	**ESS** -> DE(TUM 50%) +CH (PSI 50%)	9	95%
Spectroscopy	C-SPEC cold chopper spectrometer	C	**DE(TUM 50%) +FR(LLB 50%)**	15	100%
	BIFROST extreme-environments spectrometer	B	**DK(DTU/KU <30%)** +CH(PSI ~ 20%) + HU (~20%) +NO (~15%) + ?	12	**70%**
	T-REX bispectral chopper spectrometer	C	**DE (FZJ 75%)** + IT (Perugia) -25%	15	95%
	VESPA vibrational spectroscopy	B	**IT** (CNR) **+ UK (ISIS)?**	12	100%
	MIRACLES backscattering spectrometer	B	**DK (KU) ->** ES(Bilbao ~70%?) +FR(LLB ~20%?) +HU (Wigner~5%?) + ESS (~5%)	12	95%
	6th Spectrometer (unassigned)	B		12	90%
	16 instruments		**cost**	**188.77**	**88.1%**
	neutron guide bunker		CZ (Skoda?, Envinet?)	14	**80.0%**
			total cost (with bunker)	**202.77**	**87.7%**

Schedule for Instrument construction

Neutron beam guides

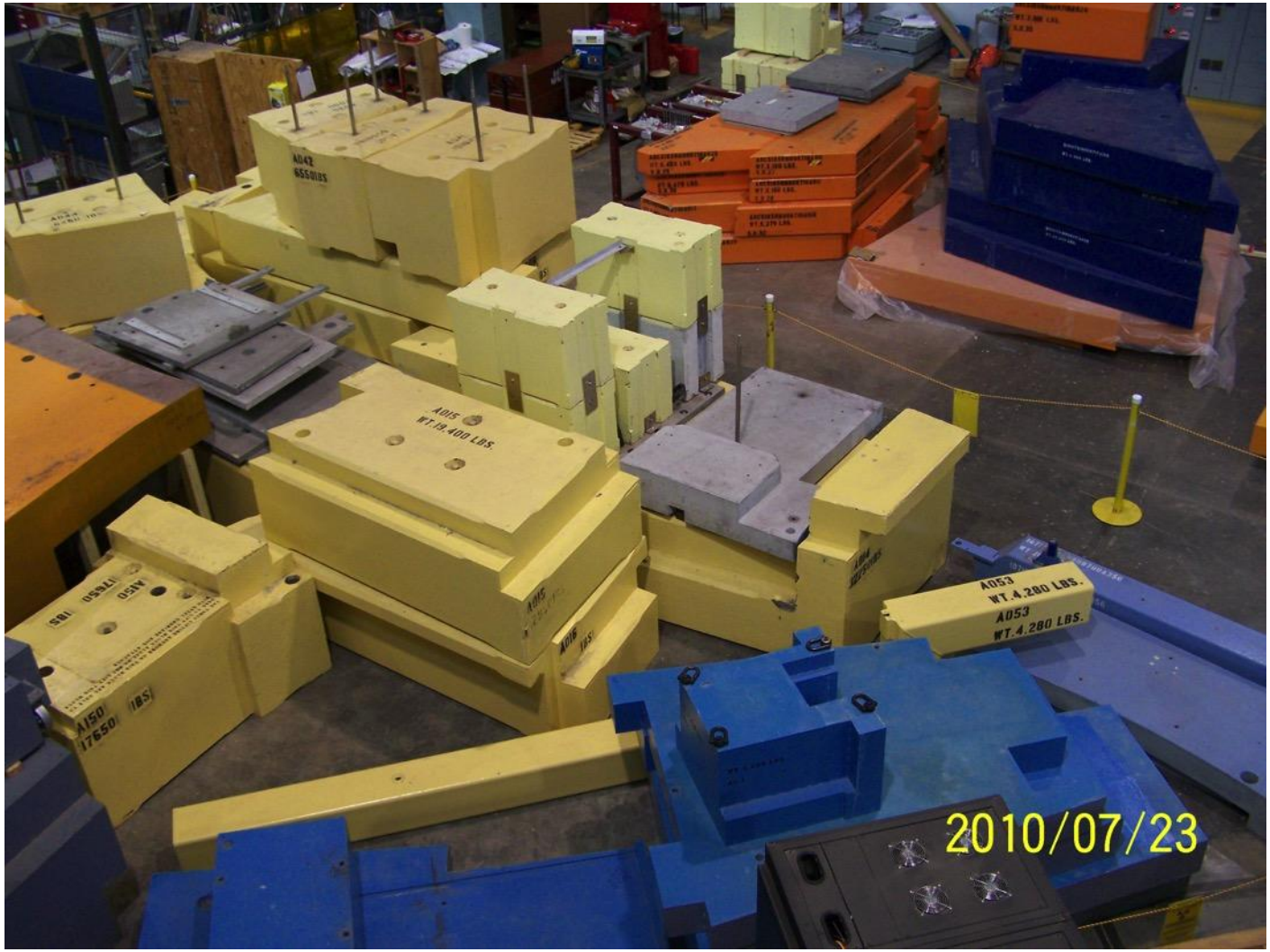


Disc choppers



Instrument cave and detector tank

Stackable Shielding



Shielding

Conclusion

- Opportunity for academia and industry to contribute to construction
  - Instruments
  - Support infrastructure: sample environment, labs, software
- Opportunity for academia and industry to perform science at ESS
  - World-leading user facility
  - Understanding materials for a knowledge-based economy