

Neutron Science at the European Spallation Source

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Associate Adjunct Professor: Copenhagen University

www.europeanspallationsource.se

13th March 2017

The next-generation neutron research facility is taking shape in Lund



2017



2022

Journey to deliver the world's leading facility for research using neutrons



2003
European Design of
ESS Completed

2009
Decision to Site
ESS in Lund

2012
ESS Design Update
Phase Complete

2014
Construction Starts
on Green Field Site

2020
Machine Ready for
1st Beam on Target

2023
ESS Starts
User Program

2025
ESS
Construction
Phase Complete

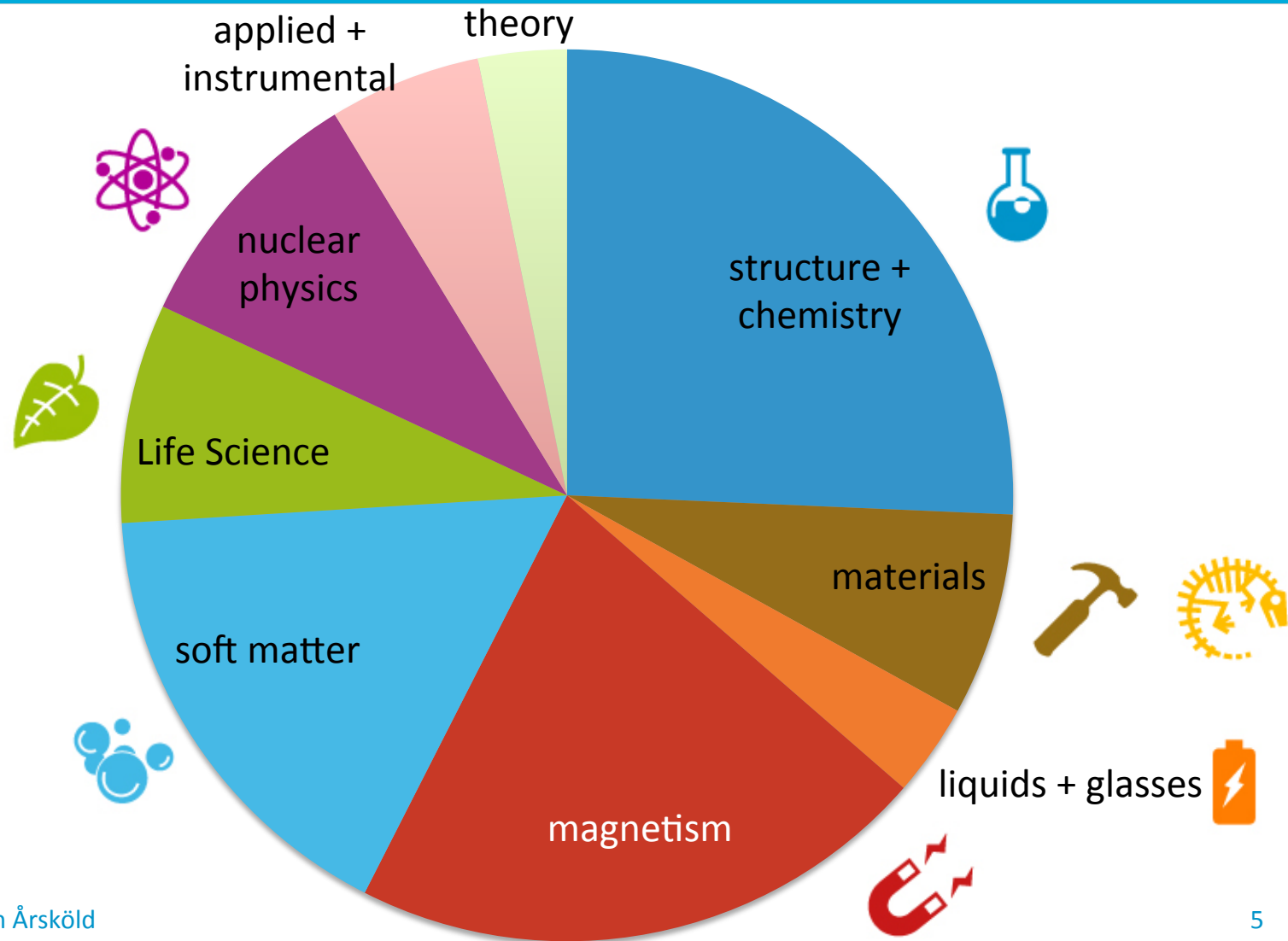
ESS is a user facility



- Researchers who need neutron beams for their experiments.
- From universities, institutes, industry.
- We provide tools & support; they bring their projects and perform the experiments.
- 2000-3000 visiting users/year. A stay can be days or weeks.
- Many different disciplines: materials research, physics, chemistry, life science...



Neutron use per science topic

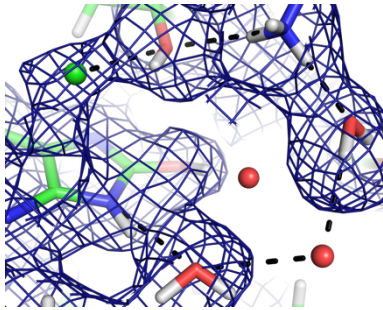


Neutrons are special

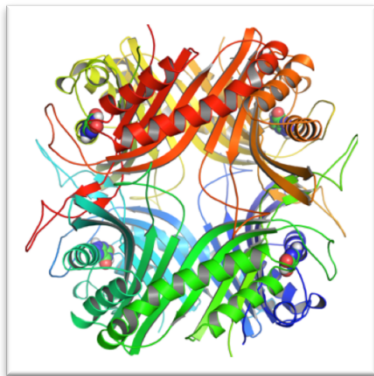
Atomic to micrometer scale

Pico – microsecond dynamics

Nuclear scattering
**Sensitive to light
elements and isotopes**



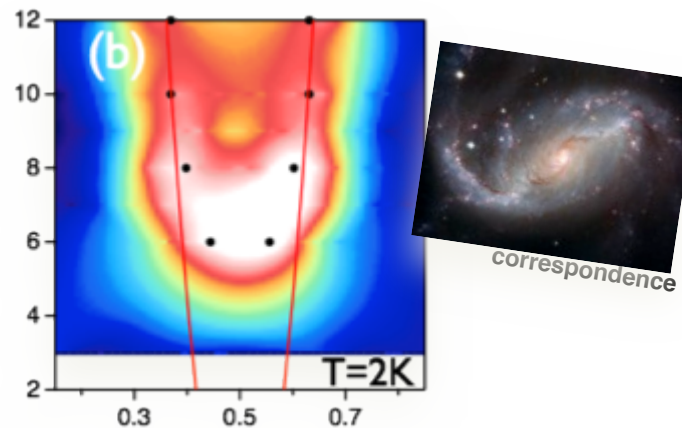
Active sites in proteins



Urate oxidase

Better drugs

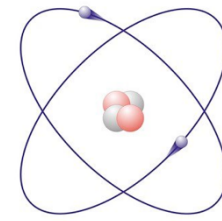
Magnetic moment (spin)
Probe of magnetism



Solve the high-temperature
Superconductivity puzzle

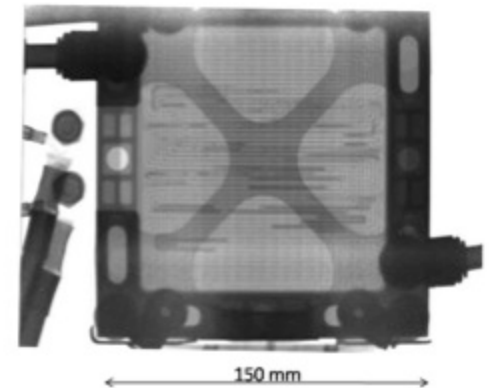


Efficient high-speed trains



SCIENCEPHOTOLIBRARY

Charge neutral
Deeply penetrating



Li motion in fuel cells

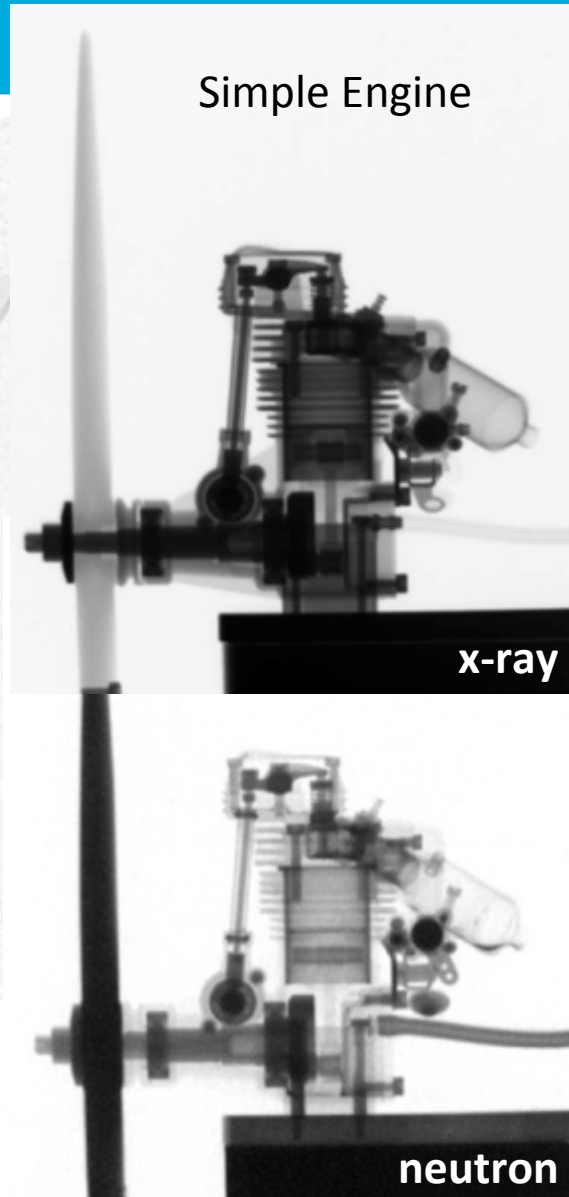


Improve electric cars

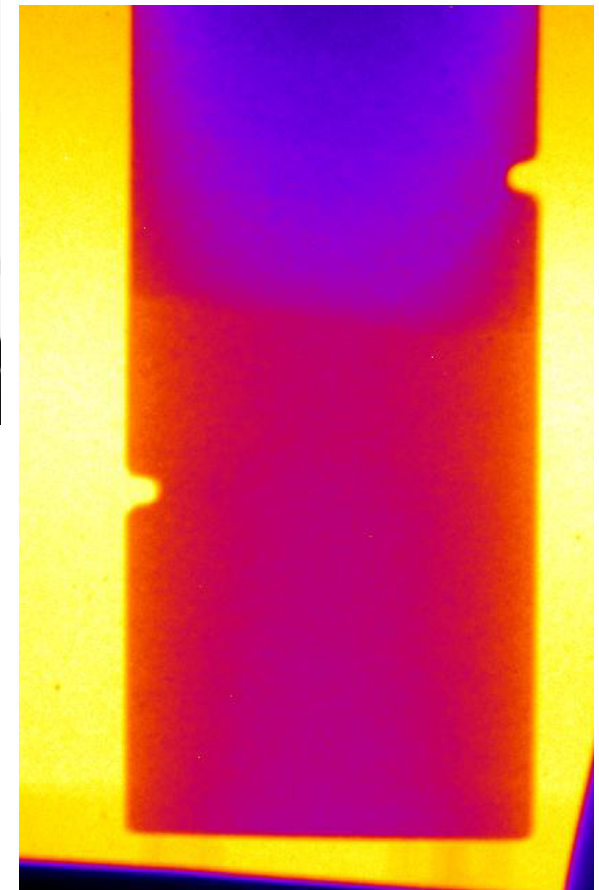
Neutrons See the Light Elements



Courtesy of the NIAG group, PSI, Switzerland.

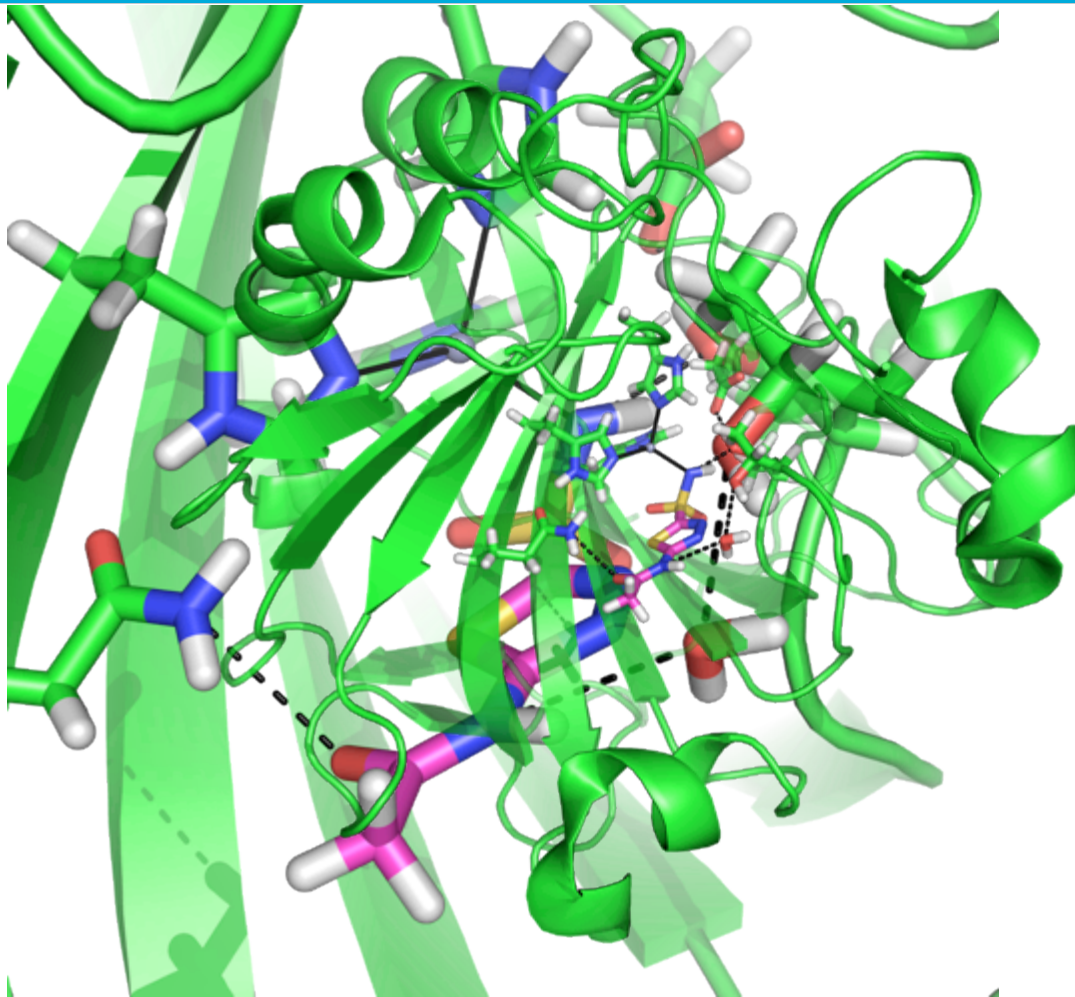


Co2 sequestration
Fracking



Courtesy of S. Hall, Lund Uni

Neutrons reveal how drugs interact with drug targets



The enzyme carbonic anhydrase transports CO_2 and regulates blood acidity. It is a major player in some cancers, glaucoma, obesity and high blood pressure

Neutron crystallography pinpoints protons and waters in the active site, showing how the drug Acetazolamide binds

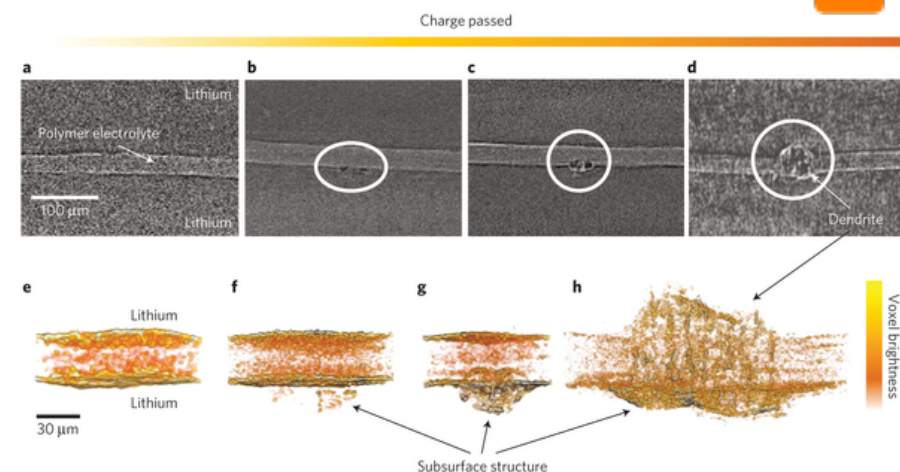
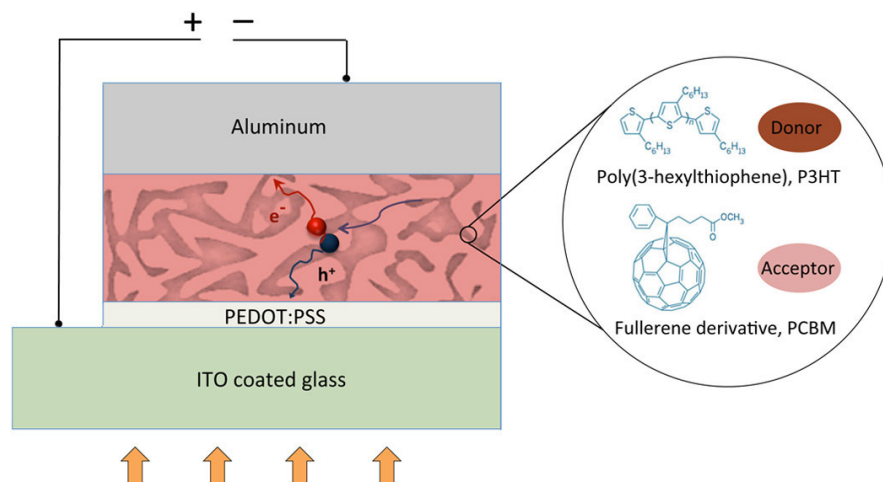
Neutrons for Clean Energy Technology



Lithium Ion Batteries are a crucial technology for the expansion of electric vehicle use and for mobile computing.

Higher energy densities could be achieved with **alternative anode materials** and **new electrolytes**.

Analysis of **operating devices** allows the monitoring of **nano- and micro-structural change**.



Dendrite growth in lithium metal anode batteries observed by x-ray microtomography. (Harry et al. (2013) Nature Materials 13, 69)

Organic Solar Cells promise to provide cheap and accessible solar energy.

The **lifespan** and **efficiency** of the devices depends on the **nano-structure** of the bulk heterojunction polymer mixture.

Understanding the **structural evolution** under operation guides development of new devices.

Understanding protein structure in milk.

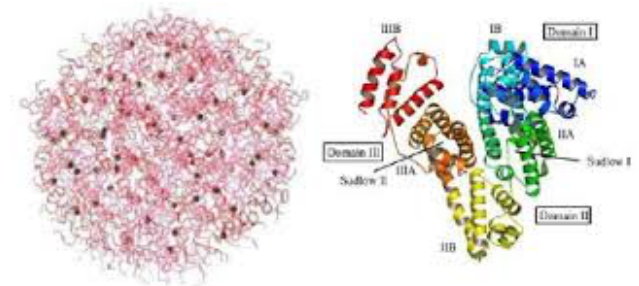


Casein micelles, a family of related phosphorus-containing proteins, make up 80% of the protein in cow milk. Casein micelles building blocks of cheese, yoghurt and supplying amino acids, calcium, and phosphorus to the body.

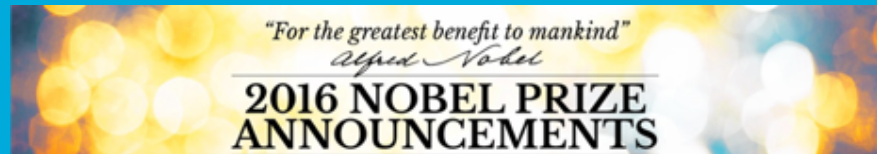
Small angle neutron scattering unravelled the structure & characterised composite particles of milk. Protein's matrix has fluctuations in density that are attributable to the hydrophobic interactions of the casein proteins.



University of Utrecht &
Source: Oak Ridge National
Laboratory (2012)



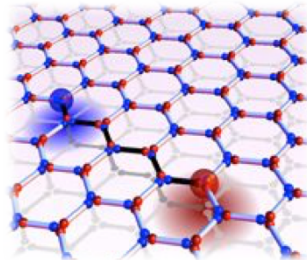
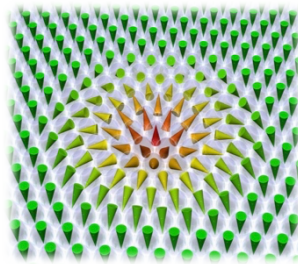
Neutrons for magnetic and electronic phenomena



Hunting for materials that make our technology smarter



Understanding quantum phenomena and novel states of matter in detail

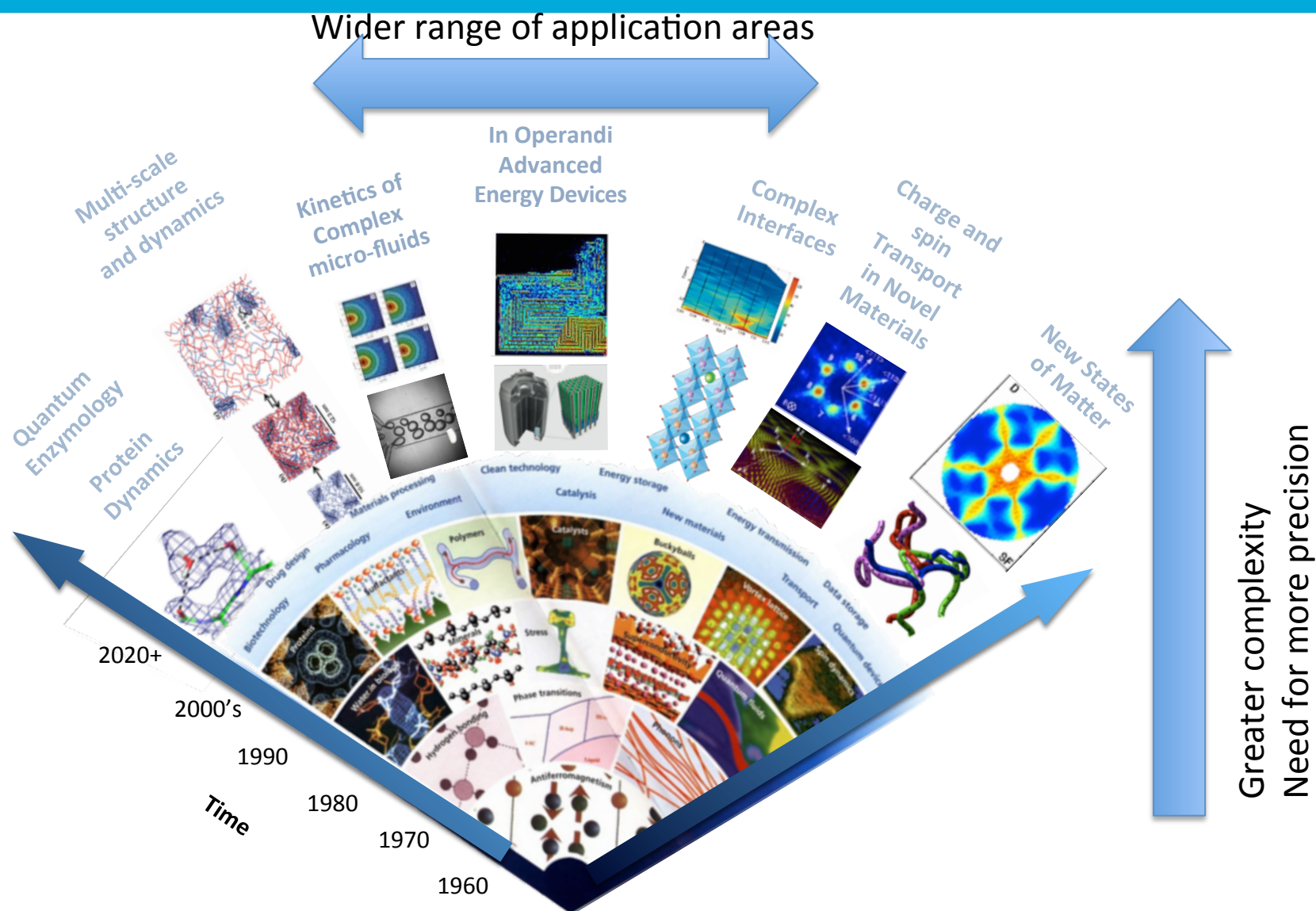


Improving electronic properties and exploiting quantum phenomena

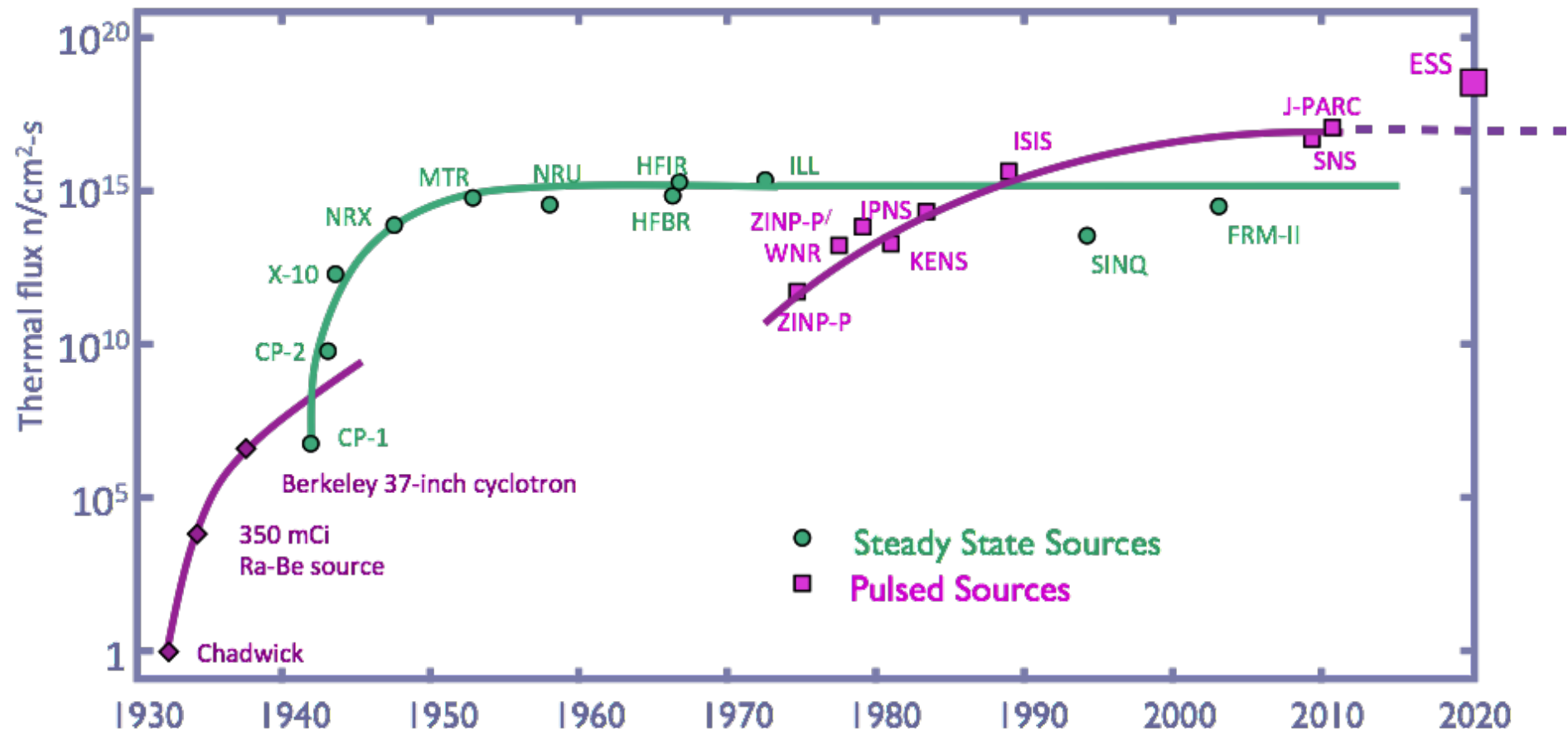


The sensitivity of neutrons to magnetism and the unique ESS neutron flux makes it possible to study quantum materials & understand them at a microscopic level.

Neutron Science: Pushing the Boundaries



Neutron Facilities



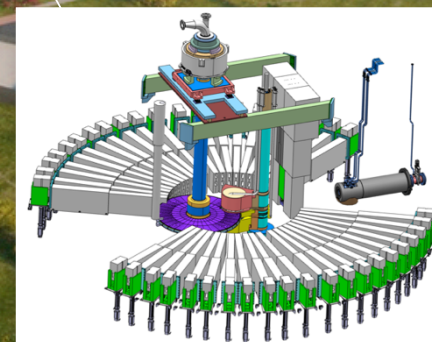
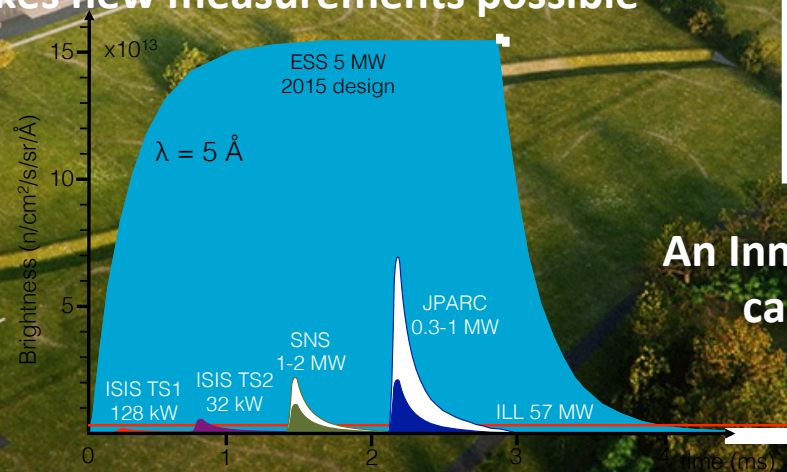
(Updated from *Neutron Scattering*, K. Sköld and D. L. Price, eds., Academic Press, 1986)

The European Spallation Source



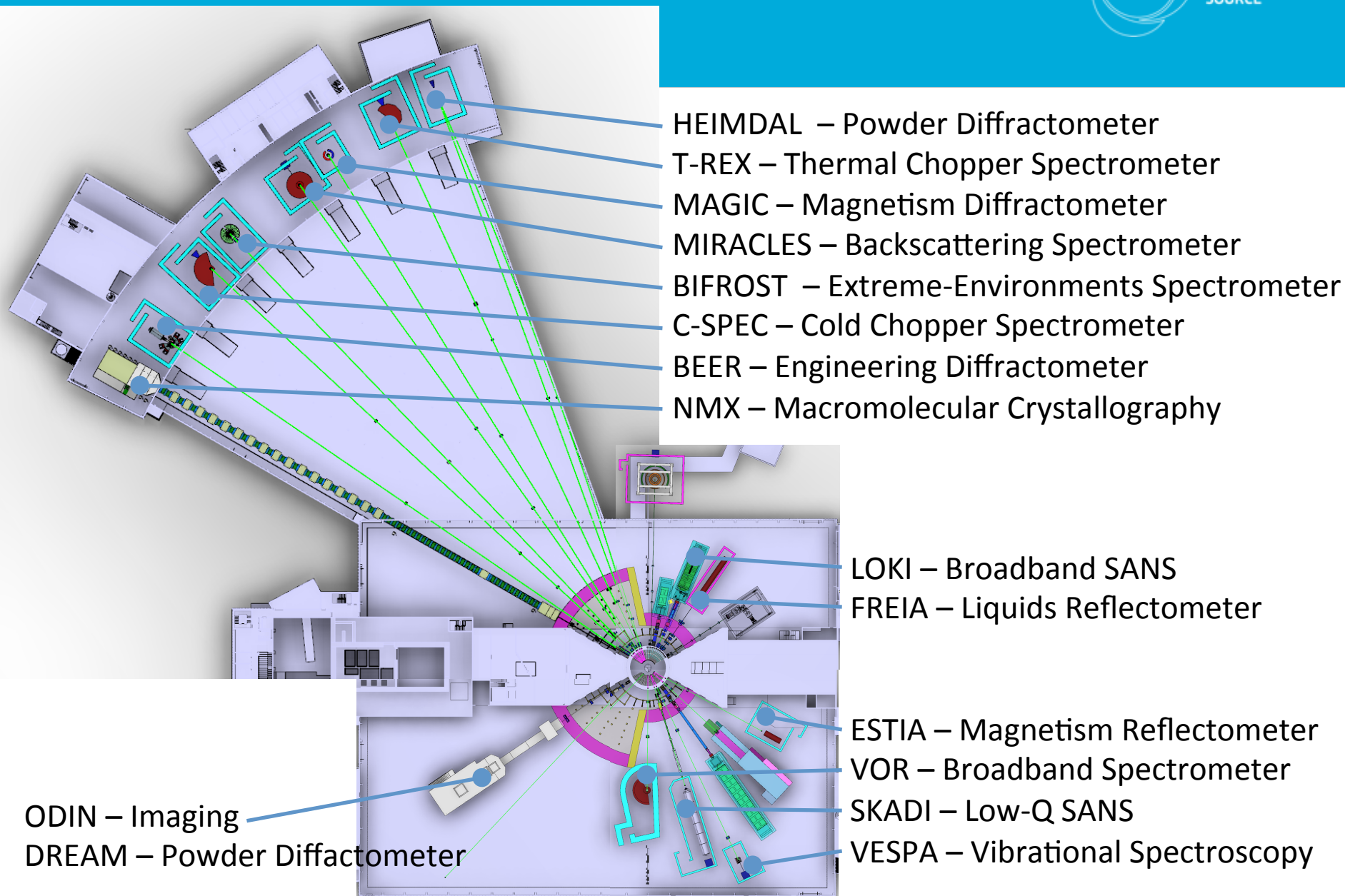
Most powerful
linear proton
accelerator

High brightness and tunable resolution
makes new measurements possible



An Innovative Target Station that
can host >30 instruments

ESS first 15 instruments



ESTIA: Polarised focussing reflectometer for small samples



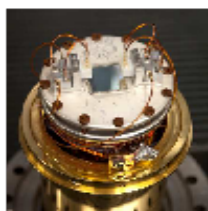
Estia a polarised focusing reflectometer for small samples

for the investigation of the chemical and magnetic depth-profile near surfaces and of lateral correlations and structures

Paul Scherrer Institut
Switzerland
Jochen Stahn



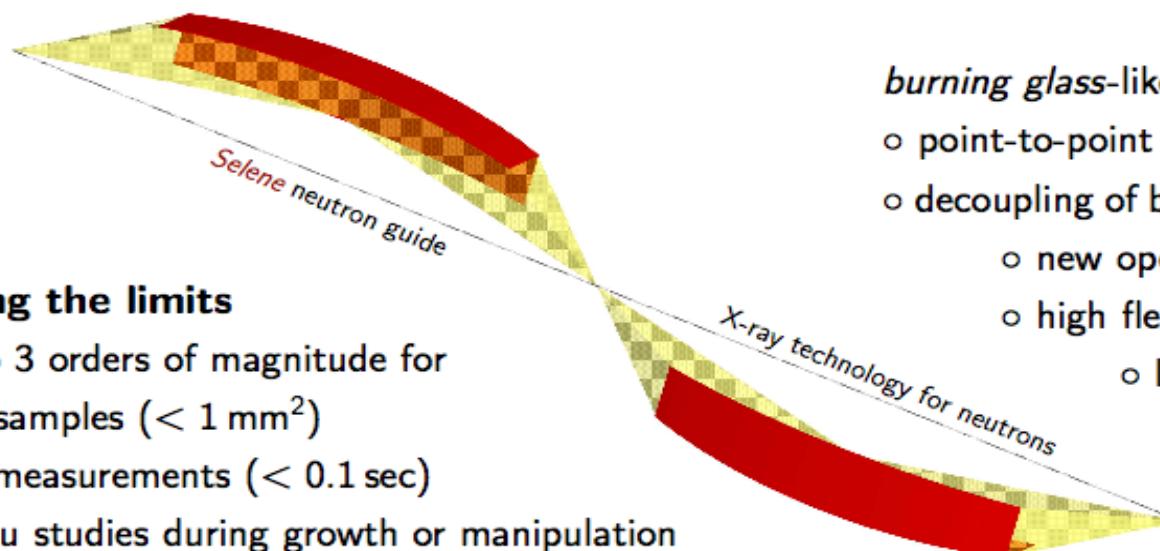
University of Copenhagen
Denmark
Marité Cardenas



functional devices: *spin-valves, spintronics*
diffusion processes: *Li batteries, corrosion protection*
multifunctional materials: *interface-coupled electric and magnetic properties*
towards real materials: *raster-scanning of bent, faceted or multi-domain surfaces*

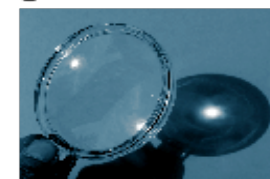
pushing the limits

- by 2 to 3 orders of magnitude for
 - tiny samples ($< 1 \text{ mm}^2$)
 - fast measurements ($< 0.1 \text{ sec}$)
 - in-situ studies during growth or manipulation



burning glass-like neutron guide

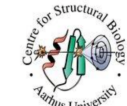
- point-to-point imaging
- decoupling of beam size and divergence
 - new operation modes
 - high flexibility
 - low background



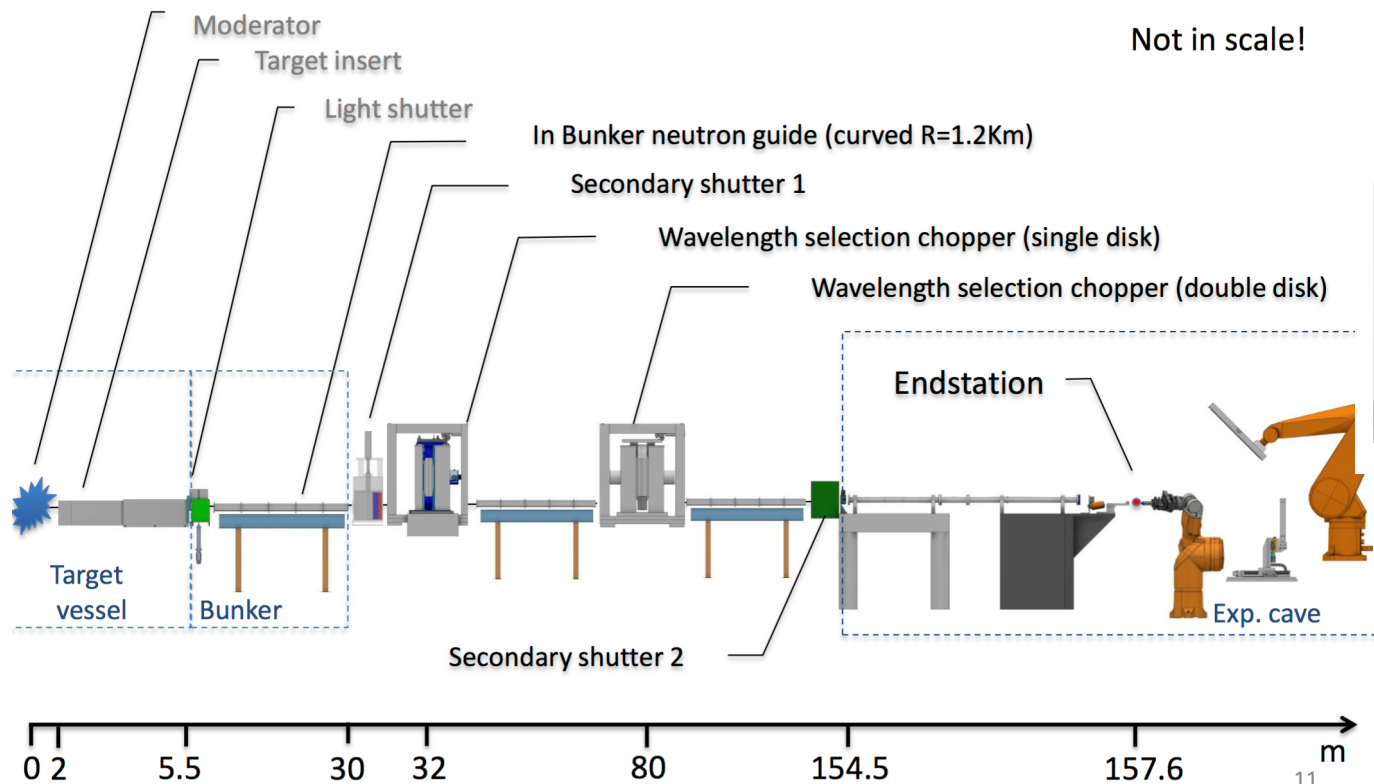
NMX: diffractometer for macromolecular samples



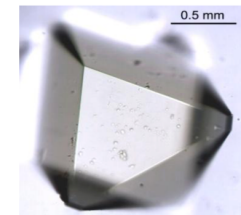
EUROPEAN
SPALLATION
SOURCE



3



“Small” crystals : 0.2mm to 5mm



Oksanen, E et al. *J. R. Soc. Interface* **2009**, *6* Suppl 5, S599-610.

Macromolecular
crystallography

Enzyme mechanisms
Protein-ligand
interactions
Proton transport
across membranes

BEER: Beamline for European Materials Engineering Research.

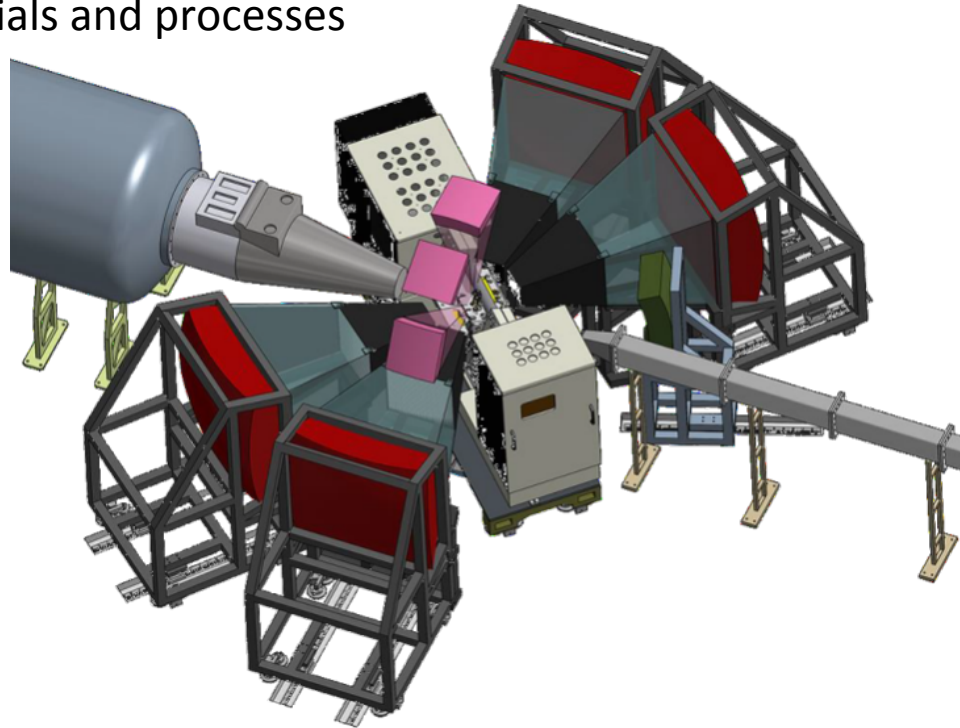


Scientific case:

In operando and in-situ investigation of material properties of technologically important materials during fabrication, processing or operations

New materials for transport, energy, medical applications

Optimization of industrial materials and processes



ESS-SAC:BEER has potential to take engineering science with neutrons to a new level.

ESS : a truly international venture



Construction investment 1 912 M€

Operations cost ~150 M€/yr

Host Countries Sweden and Denmark

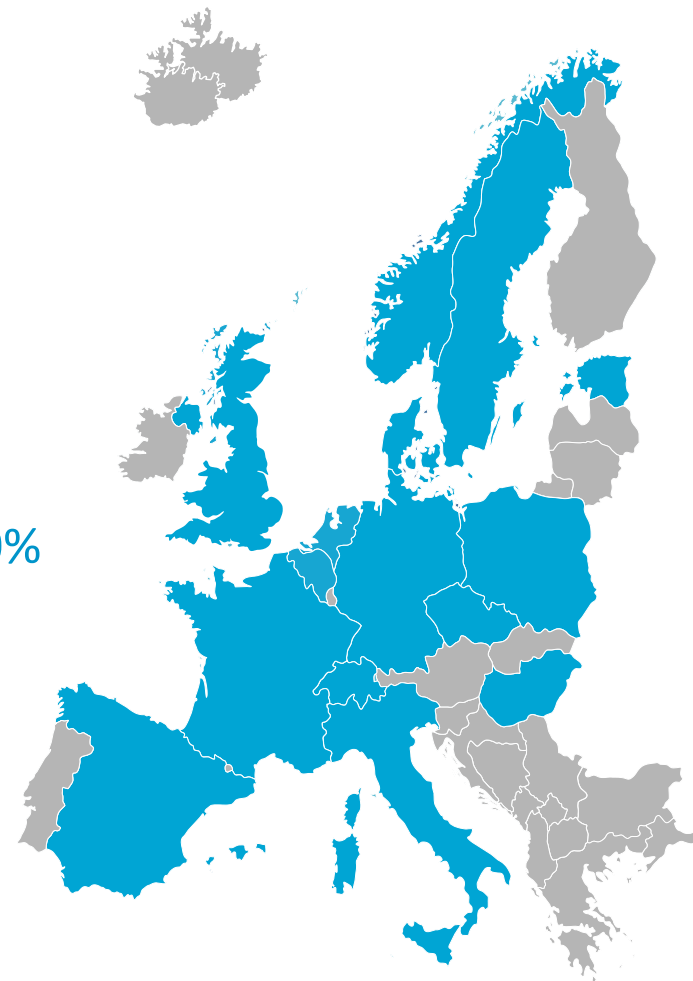
Construction 47.5% Cash Investment ~ 97%

Operations 15%

Non-host Member Countries

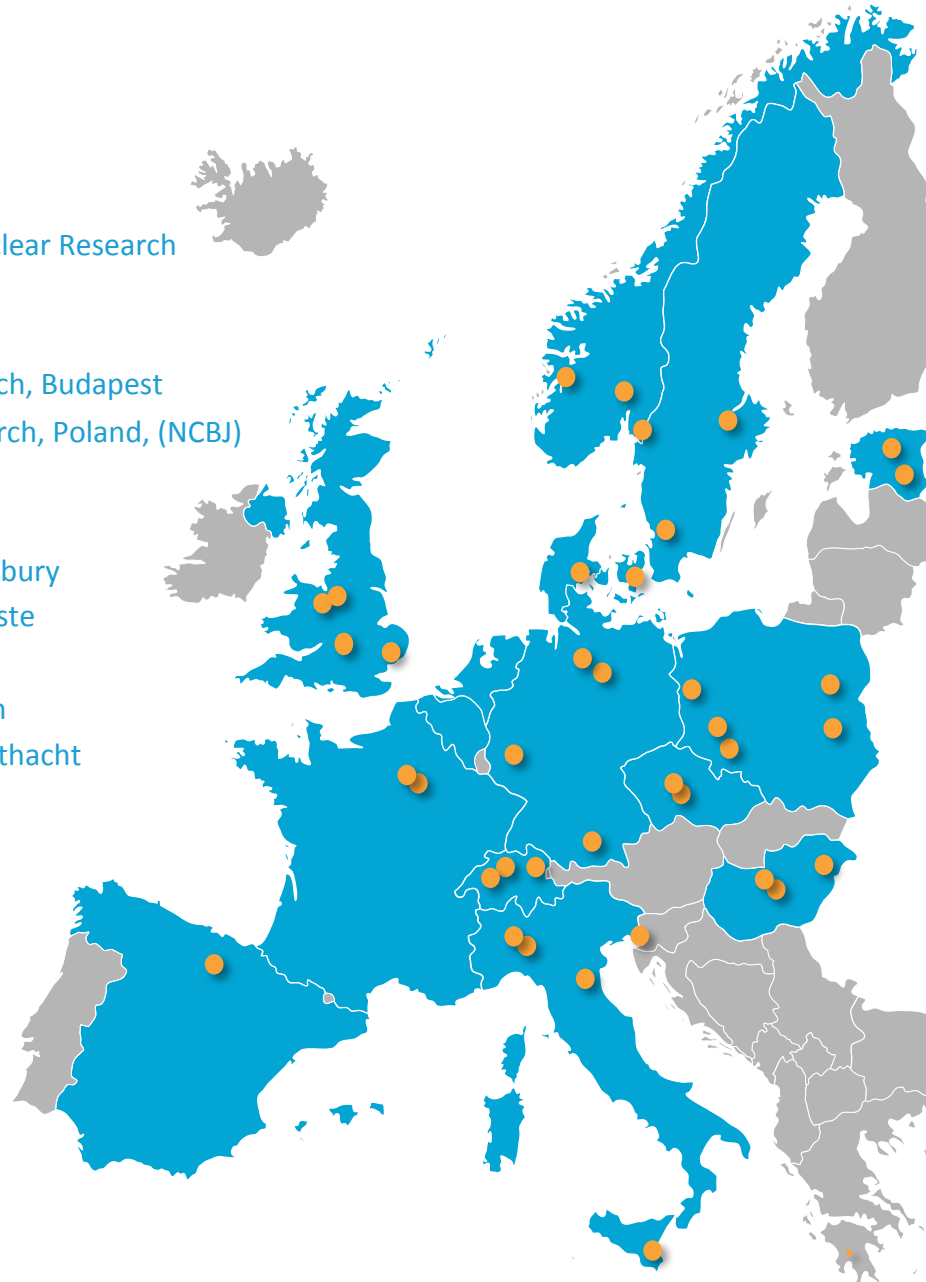
Construction 52.5% In-kind Deliverables ~ 70%

Operations 85%



ESS In-kind Partners

Aarhus University
 Atomki - Institute for Nuclear Research
 Bergen University
 CEA Saclay, Paris
 Centre for Energy Research, Budapest
 Centre for Nuclear Research, Poland, (NCBJ)
 CNR, Rome
 CNRS Orsay, Paris
 Cockcroft Institute, Daresbury
 Elettra – Sincrotrone Trieste
 ESS Bilbao
 Forschungszentrum Jülich
 Helmholtz-Zentrum Geesthacht
 Huddersfield University
 IFJ PAN, Krakow
 INFN, Catania
 INFN, Legnaro
 INFN, Milan
 Institute for Energy
 Research (IFE)



Rutherford-Appleton Laboratory, Oxford(ISIS)
 Copenhagen University
 Laboratoire Léon Brillouin (LLB)
 Lund University
 Nuclear Physics Institute of the ASCR
 Oslo University
 Paul Scherrer Institute (PSI)
 Polska Grupa Energetyczna - PGE
 Roskilde University
 Tallinn Technical University
 Technical University of Denmark
 Technical University Munich
 Science and Technology Facilities Council
 University of Tartu
 Uppsala University
 WIGNER Research Centre for Physics
 Wroclaw University of technology
 Warsaw University of Technology
 Zurich University of Applied Sciences (ZHAW)

Lately at ESS



- New Director General: John Womersley.
- Operations cost review successfully completed.
- SSM licensing process on-going.
- EIB “cash facility” in place to ensure liquidity through construction.
- Scope-setting of instrument projects completed. 15 instruments in construction budget; upgrades planned for operations budget.
- Construction of the buildings approx. 30% complete. Accelerator installations just starting in the tunnel.



Industry Access to and Benefit from Neutron Sources



- Development & delivery of specialized equipment during construction & maintenance.
- **Use neutrons for R&D**

Standard access :

- Open to all, selection by scientific excellence of the project.
- Free of charge
- Publication required

Proprietary access:

- Pay for access
- Keep project & results confidential

ILL estimates that 15-30% or more of their beam time is used for academic/industrial collaborations.

Grenoble estimates that for every € invested into the facilities, =>3€ appear in the regional economy.



Welcoming industry use of ESS neutrons

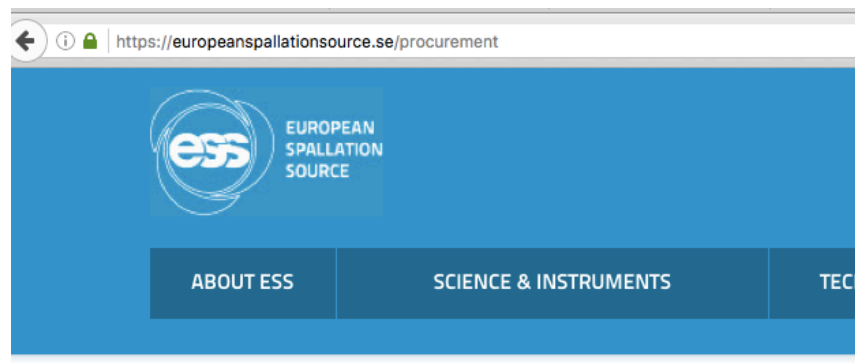


- We have a strong expectation on us to facilitate industry usage of ESS.
We want this!
- Current ESS ILO function is focused on the delivery of components to the construction. *Collaborations on neutron use is currently handled on a peer-to-peer level – more to come!*
- The ESS access policy is not yet set. *Focus on the open proposal system – but needs to enable many ways in.*
- An ESS innovation policy is being drafted. *Needs to enable many ways in.*
- University/industry collaborations are key to enabling industry usage of ESS neutrons.

Procuring components and services



- ESS in Lund
- Skanska
- ESS in-kind partners across Europe



Procurement

CURRENT

MARKET SURVEYS

To create your Business Profile, please click [here](#).

Ongoing Procurement

1.

Title: Call for Expression of Interest: Research Grant Experts

PARTNERS & INDUSTRY

IN-KIND CONTRIBUTIONS

INDUSTRIAL SUPPLIERS

PROCUREMENT

Business Profile

Procurement Rules

Guidelines for Suppliers

Contract Award Notices

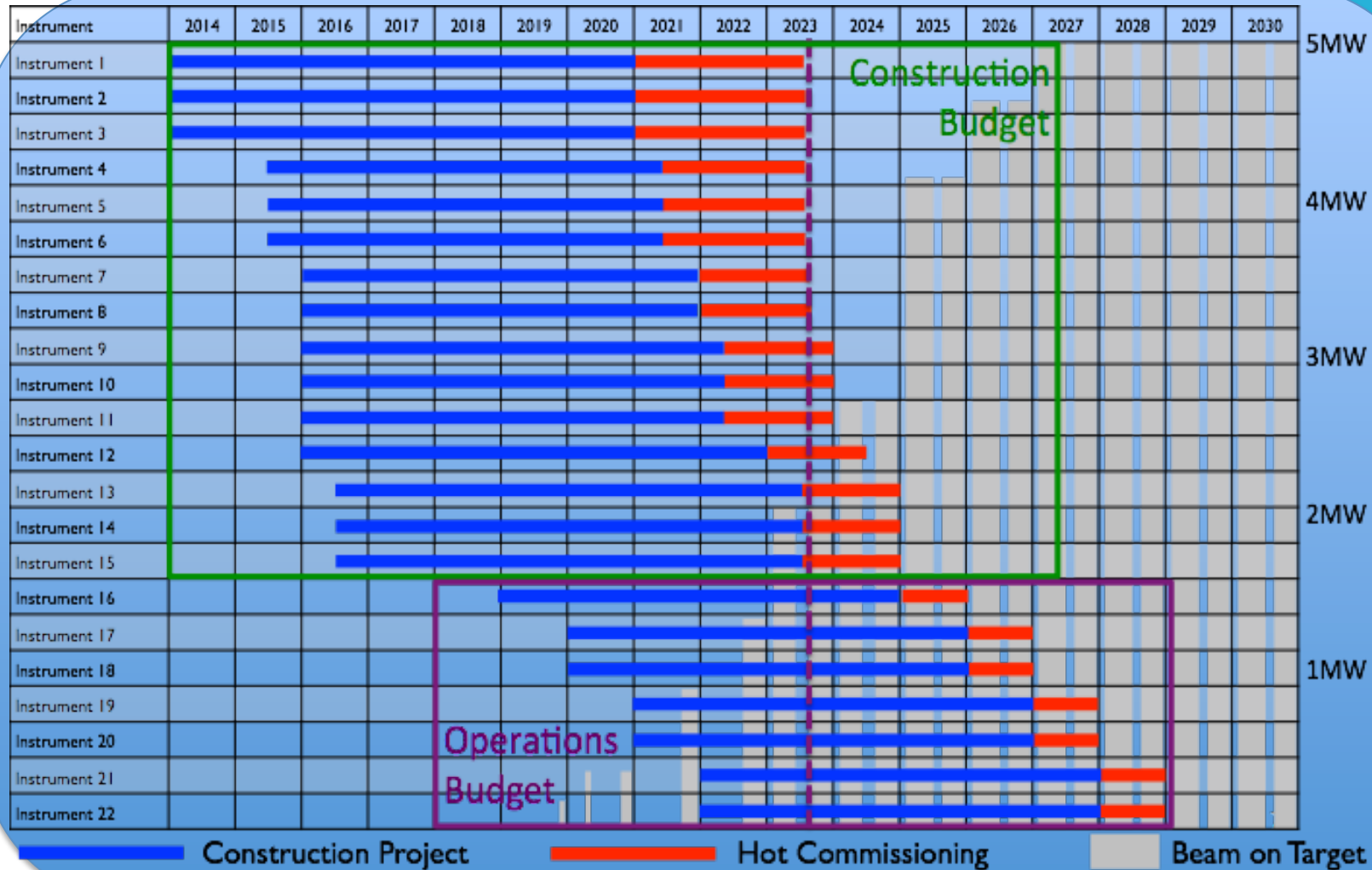
ILO NETWORK

GRANT INVOLVEMENT

PARTNERS & INDUSTRY EVENTS

The ESS Project

Instrument number 2017 2020



Try neutrons in your R&D project free of charge



SINE2020 is an EU-funded project, running from 2015-2019.

The Industry Consultancy initiative of SINE2020 invites **applications from industry** for the use of European neutron sources for **test measurements or feasibility studies for free.**

3rd call later this year.

For more information visit:

<http://sine2020.eu/industry.html>

RAPID ACCESS

Fast-stream processing for industrial applications, optimising result lead times.

CONFIDENTIALITY

Activity covered by non-disclosure agreements. Only company name and measurement type to be published.

FLEXIBLE SERVICES

In many cases industrial processes and conditions can be re-created in the test laboratory. Final data analysis and reporting are provided.



EXPERT CONSULTANCY

Industrial R&D professionals in collaboration with experienced specialists from European neutron centres.

Thank you!

