The European Spallation Source

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Group Leader for Deuteration & Macromolecular Crystallization (DEMAX) Platform

www.europeanspallationsource.se

Outline

EUROPEAN SPALLATION SOURCE

- Overview of the ESS, organization, funding, construction
- Instrument suite
- X-rays vs. neutrons – different properties
- How will we make neutrons at ESS
- What kinds of science can they be used for

ESS is multi-country European collaboration to build the world's brightest neutron source

EUROPEAN SPALLATION SOURCE

Construction investment 1 843 M€$_{(2013)}$

Operations cost ~150 M€/yr

Host countries: Sweden & Denmark

Completion Status: ~60%

Ion source commissioning: 2018

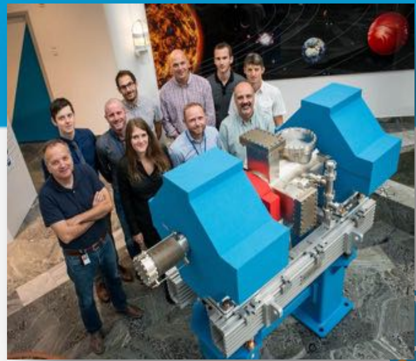
Beam on target: 2022

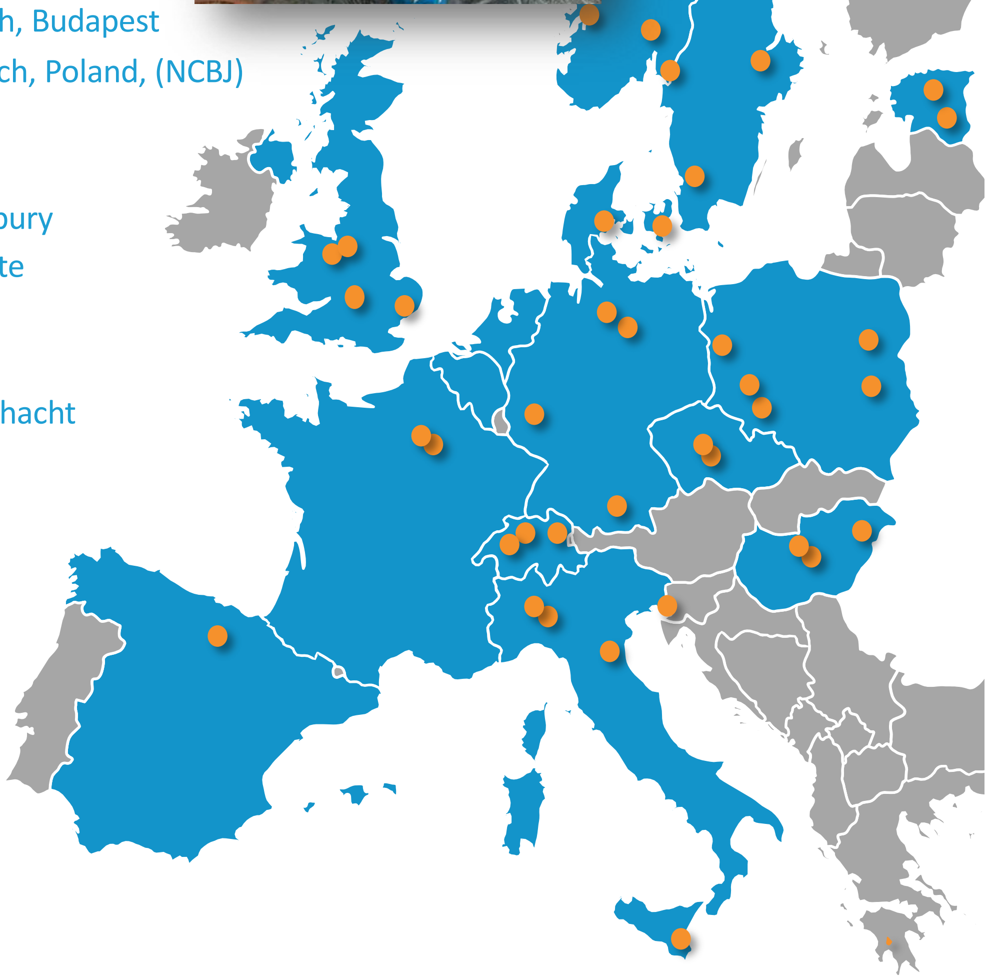
User program: 2023

Neutron instruments: 22

Novel technologies across many areas of the facility (incl. detectors, sample environment)

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)
Kopenhagen University
Laboratoire Léon Brilouin (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)

Organization and People

56
Nationalities

505
Employees

> 100
Collaborating Institutions

ESS in the European contect of large scale facilities

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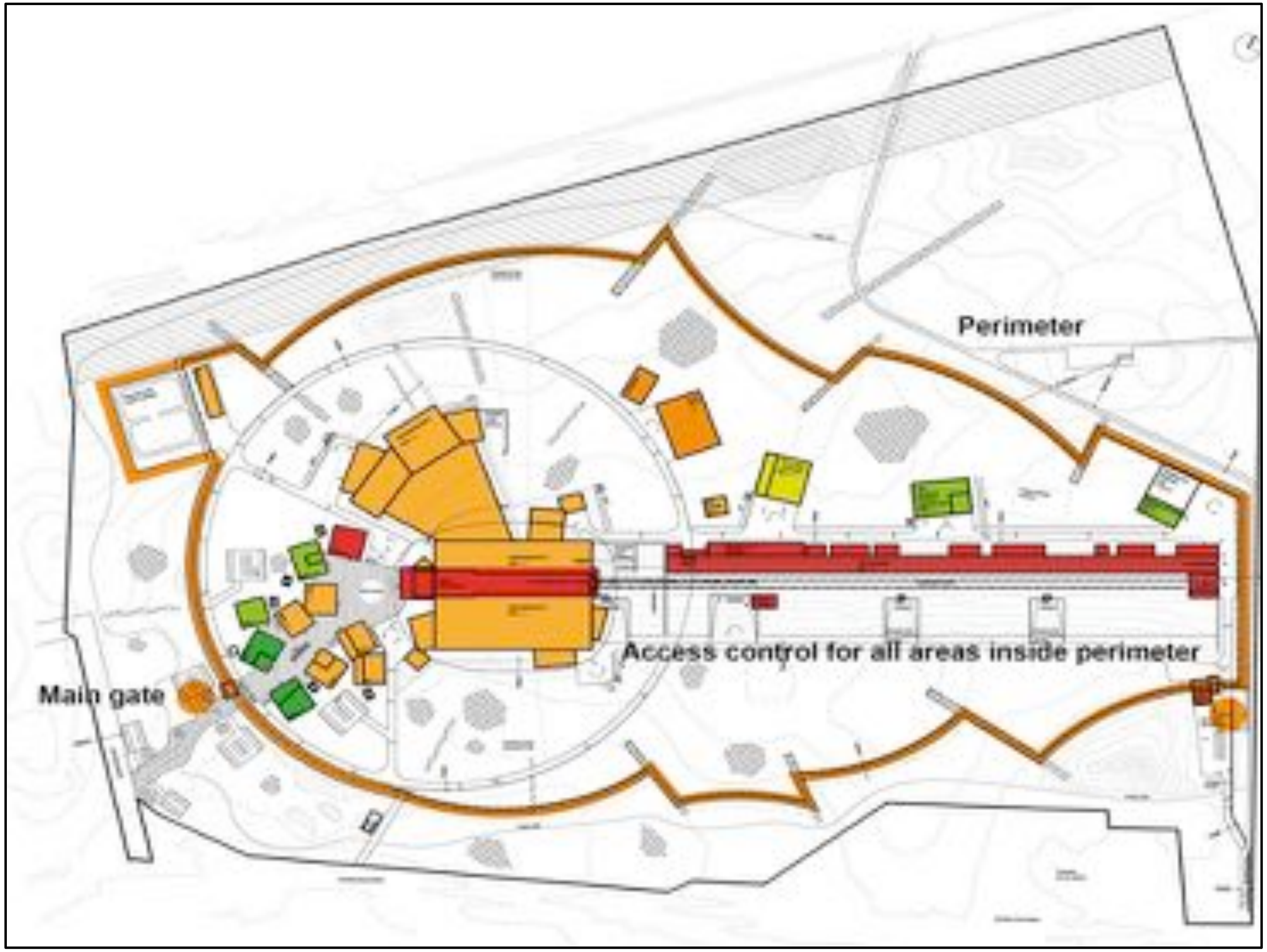
Synchrotron

FEL

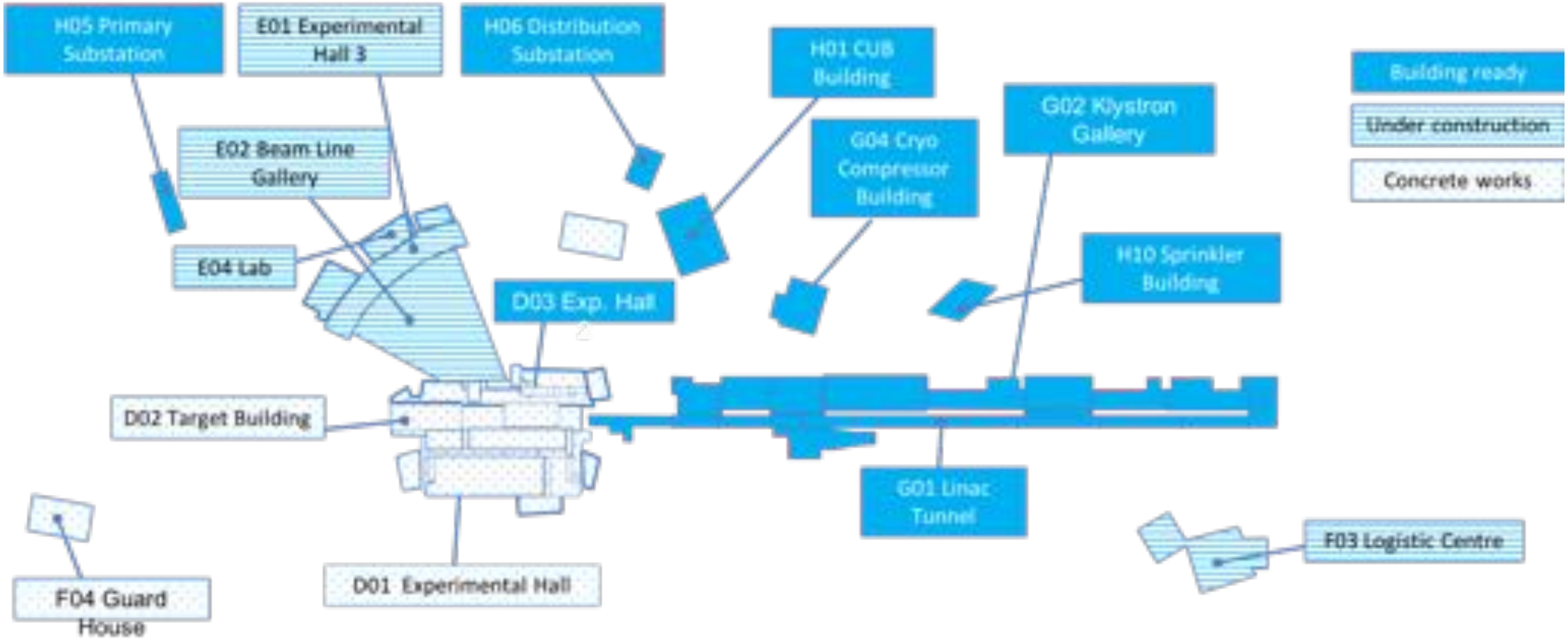
Neutron

For neutrons there are 2 current pulsed sources, ISIS and SINQ, the others are reactors

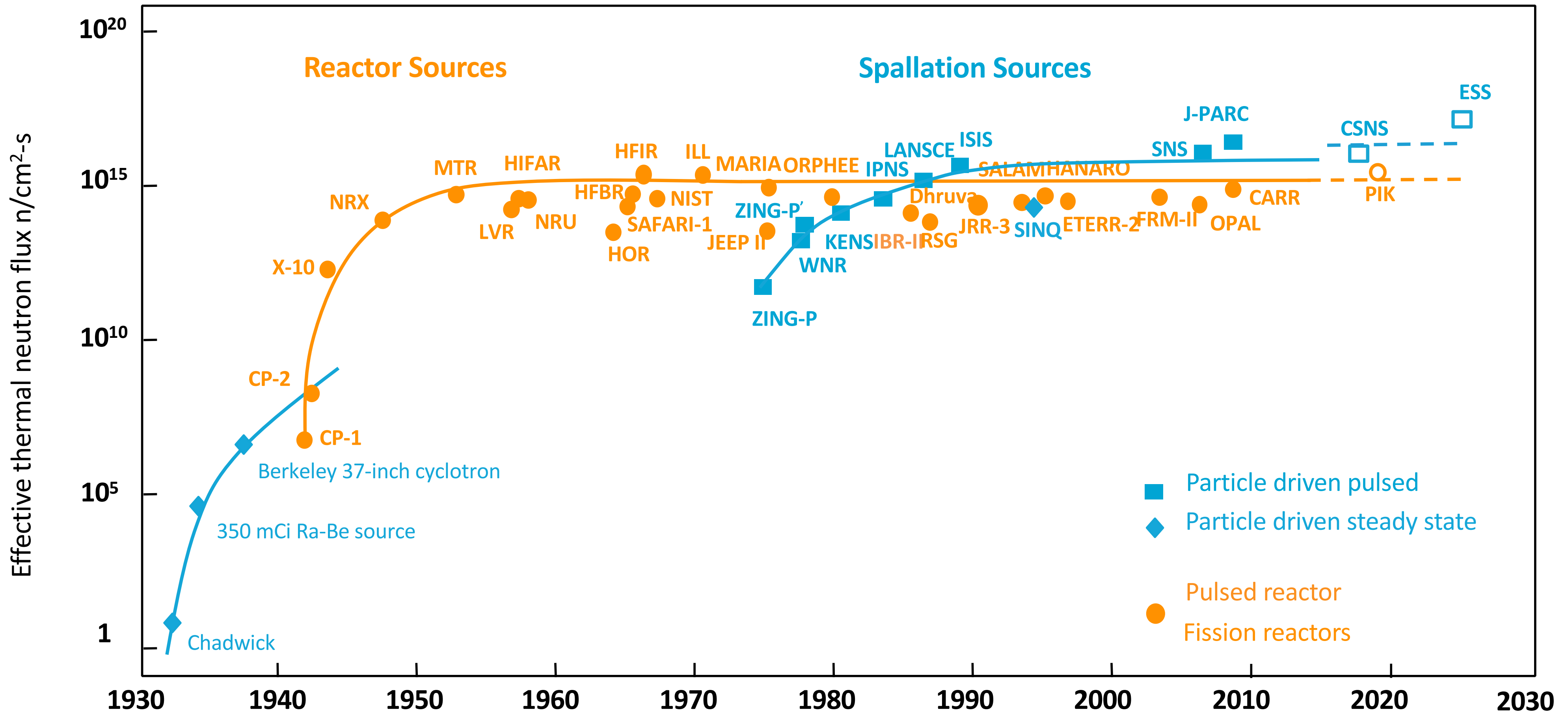

Perimeter
Access control for all areas inside perimeter
Main gate

Construction progress: taken April 2019

Facility outline – SKANSKA & ESS working together



Neutron facilities – reactors and particle driven



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

World-leading instrument suite (15 of 22 shown)
Support labs, workshops, technical groups

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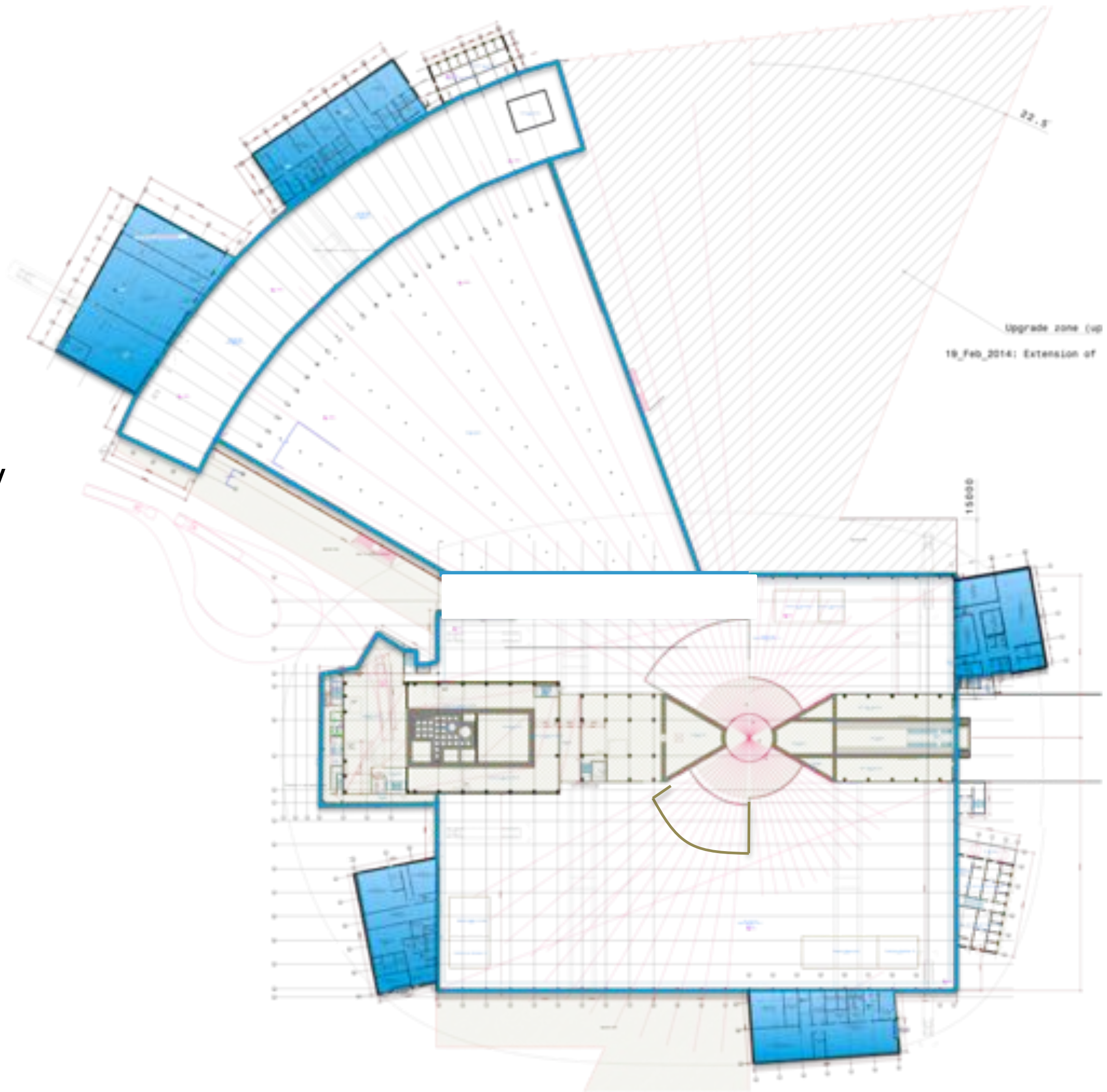
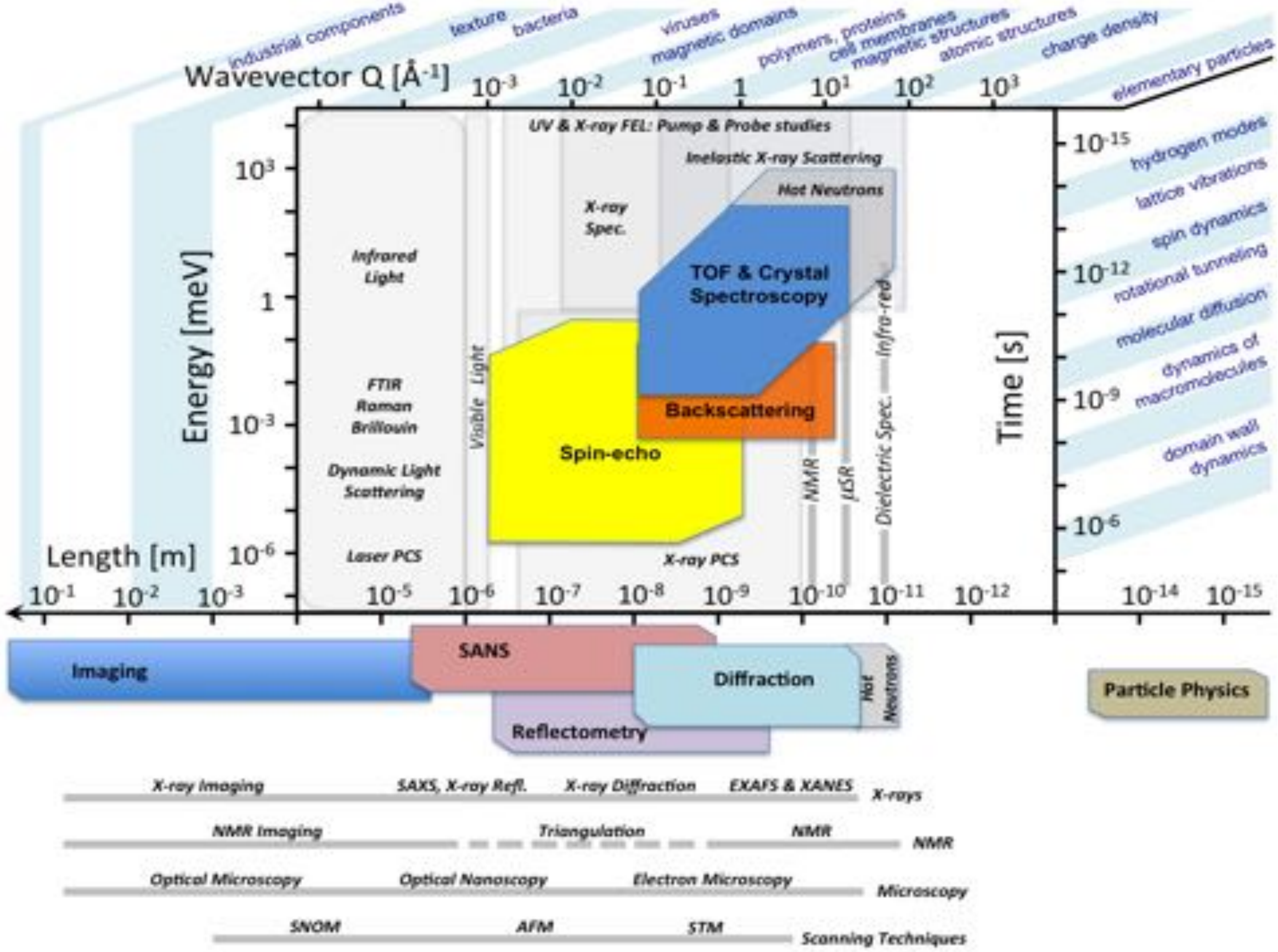
LoKI—Small-Angle Neutron Scattering
NMX—Macromolecular Diffraction
ODIN—Imaging
BEER—Materials and Engineering Diffraction
ESTIA—Reflectometry
DREAM—Powder Diffraction
C-SPEC—Direct Geometry Spectroscopy
SKADI—Small-Angle Neutron Scattering
BIFROST—Indirect Geometry Spectroscopy
FREIA—Horizontal Reflectometry
HEIMDAL—Powder Diffraction
MAGiC—Single Crystal Diffraction
MIRACLES—Backscattering Spectroscopy
T-REX—Time-of-Flight Spectroscopy
VESPA—Vibrational Spectroscopy





industrial components
texture
bacteria
viruses
magnetic domains
polymers, proteins
cell membranes
magnetic structures
atomic structures
charge density
elementary particles
Wavevector Q [Å-1]
10-3 10-2 10-1 1 101 102 103
UV & X-ray FEL: Pump & Probe studies
Inelastic X-ray Scattering
Hot Neutrons
X-ray Spec.
Infrared Light
TOF & Crystal Spectroscopy
FTIR Raman Brillouin
Dynamic Light Scattering
Laser PCS
Visible Light
Spin-echo
Backscattering
X-ray PCS
NMR
µSR
Dielectric Spec.
Infra-red
Energy [meV]
103 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

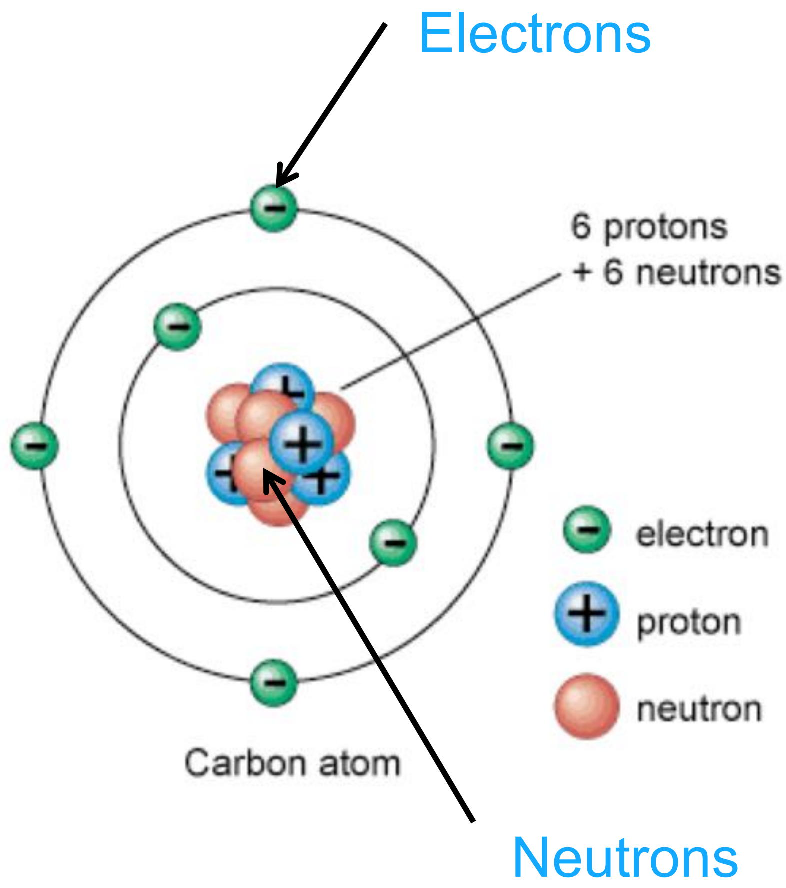
Complementary probes

X-rays:

- EM radiation (also known as photons)
- No mass or magnetic dipole moment
- Cause ionizing radiation damage
- Scatter from electron clouds
- *Easy to detect, readily available*
- *Small samples*

Neutrons:

- Neutral subatomic particles
- Mass & magnetic dipole moment
- No charge, great penetrating depth
- No radiation damage (thermal)
- Scatter from atomic nucleus
- *Difficult to make & detect*
- *Large samples*



Neutrons are sensitive to Isotopes

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Element	Atomic number	Atomic weight of natural element	Specific nucleus	Nuclear spin	Neutrons b (10^{-12} cm.)	Neutrons $\mathcal{S}$ (barns)	Neutrons σ (barns)	X-rays f_x, 10^{-12} cm. sin θ = 0	X-rays f_x, 10^{-12} cm. (sin θ)/λ = 0·5 Å^{-1}
H	1	..	H^1	½	−0·378	1·79	81·5	0·28	0·02
			H^2	1	0·65	5·4	7·6	0·28	0·02
He	2	..	He^4	0	0·30	1·1	1·1	0·56	0·15
Li	3	6·94	..	..	−0·18	0·47	1·2	0·84	0·28
			Li^6	1	0·18(a)	0·4	..	0·84	0·28
			Li^7	$\frac{3}{2}$	−0·21(a)	0·6	1·4	0·84	0·28
Be	4	..	Be^9	$\frac{3}{2}$	0·774	7·53	7·54	1·13	0·39
B	5	..	..	..	..	..	4·4	1·41	0·42
C	6	..	C^{12}	0	0·661	5·50	5·51	1·69	0·48
			C^{13}	½	0·60	4·5	5·5	1·69	0·48
N	7	..	N^{14}	1	0·940	11·0	11·4	1·97	0·53
O	8	..	O^{16}	0	0·577	4·2	4·24	2·25	0·62

How do you make neutrons?

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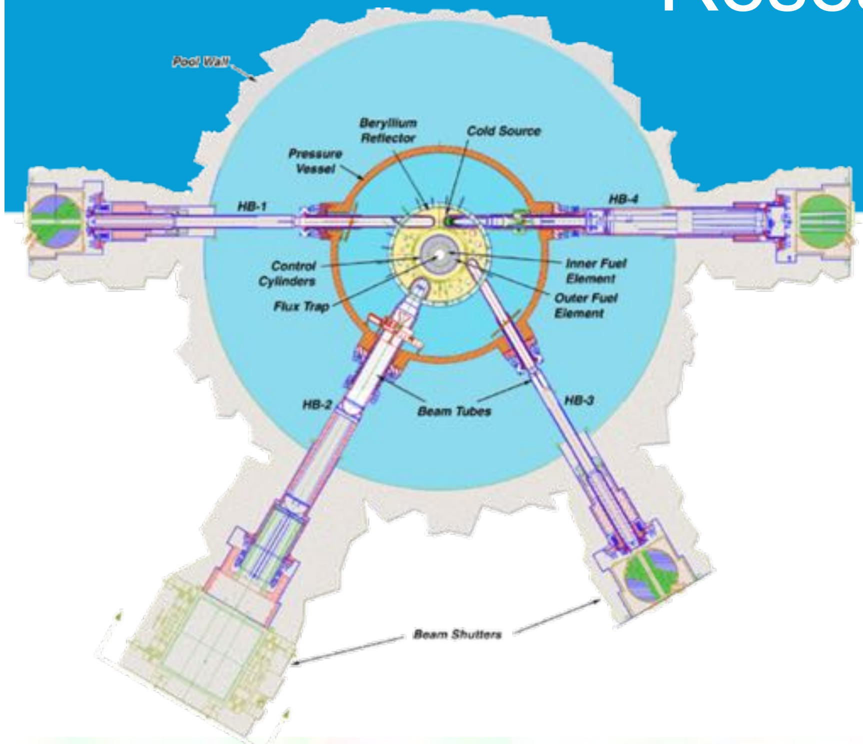
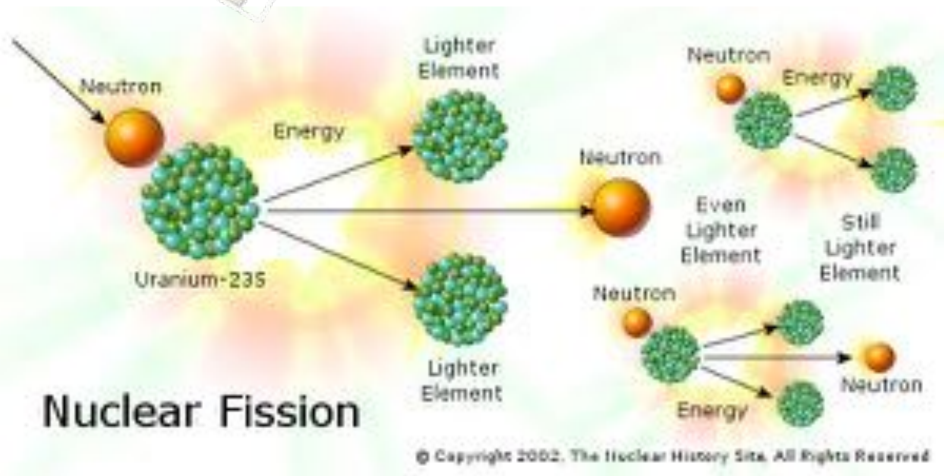
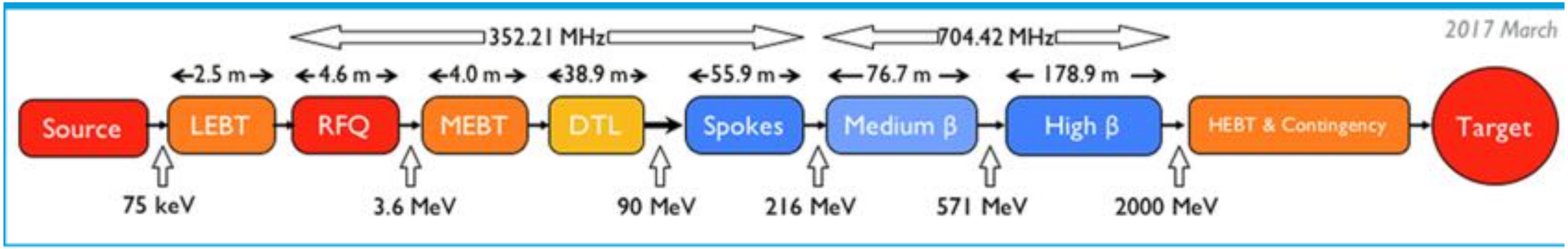
Reactors vs. spallation sources

Research Reactors

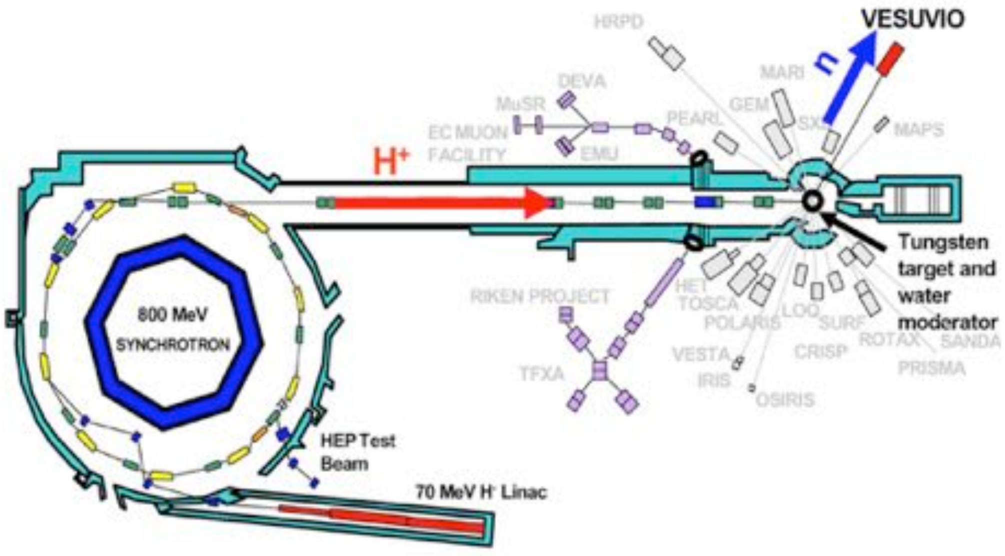


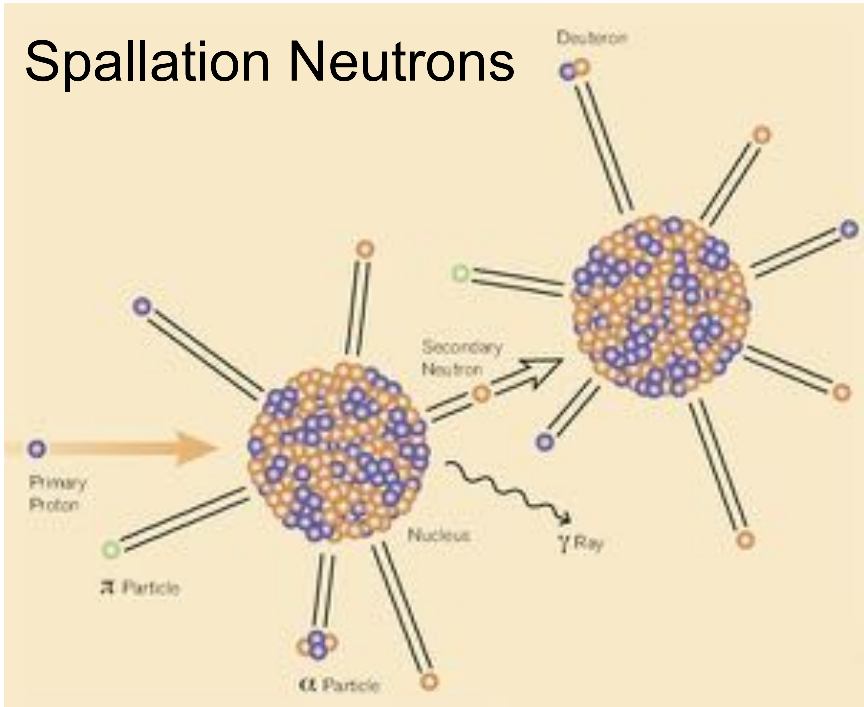


- Core of enriched ^{235}U rod cooled with light or heavy water (8-10 kg)
- ^{235}U undergoes fission to lighter atoms with release of neutrons
- Moderators slow neutrons down to useable energies (wavelength), monochromators select appropriate wavelength for appropriate length scale
- Around core there are beam guides that take neutrons to instruments



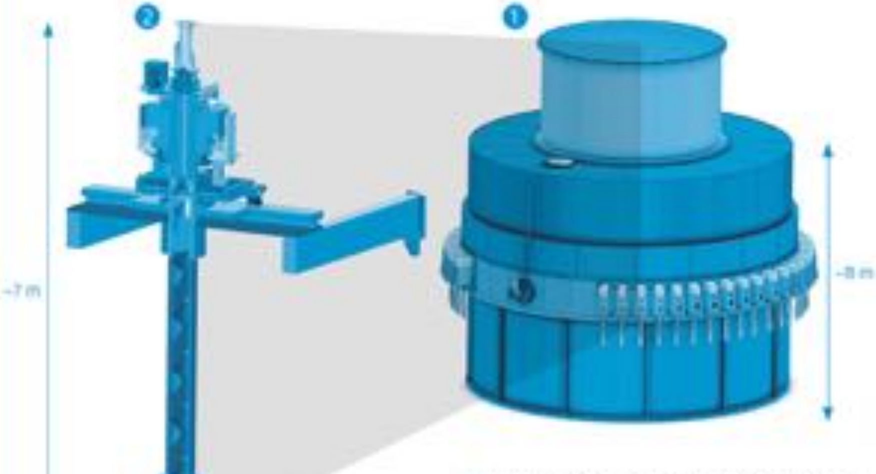
- Ion source produces H^+ plasma (electrons are boiled off)
- Pulsed proton beam accelerated to ~96% speed of light
- He-cooled, rotating W-target wheel – 2.6m diameter, 11 tons
- ***Spallation neutrons*** are produced at ~10% speed of light
- Further slowed down by moderators (speed of sound)
- Neutrons directed into beam ports where they are shaped and chopped to appropriate wavelengths for use
- Beamlines & instruments

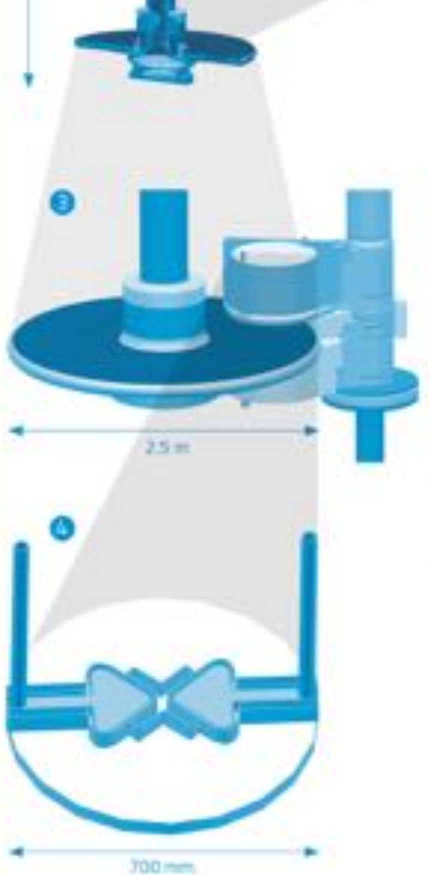




Accelerator

Target Station Components



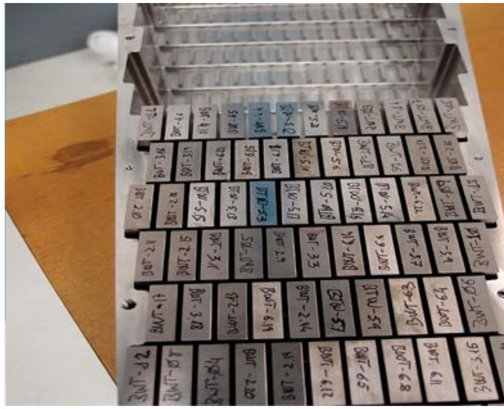


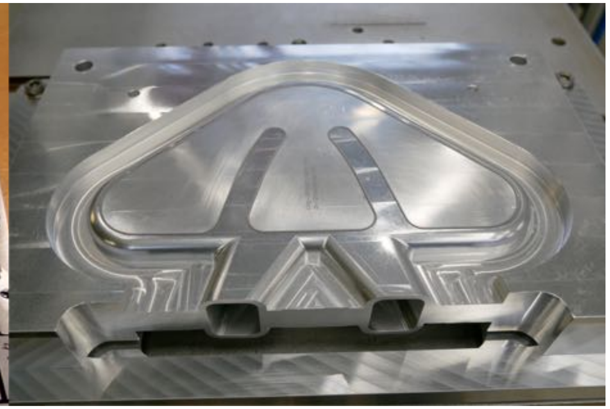
1. The Target Station monolith, including 6,000 tonnes of steel shielding. The view shows the aperture where the proton beam enters the monolith horizontally, as well as some of the 42 double-decker neutron beam line penetrations.

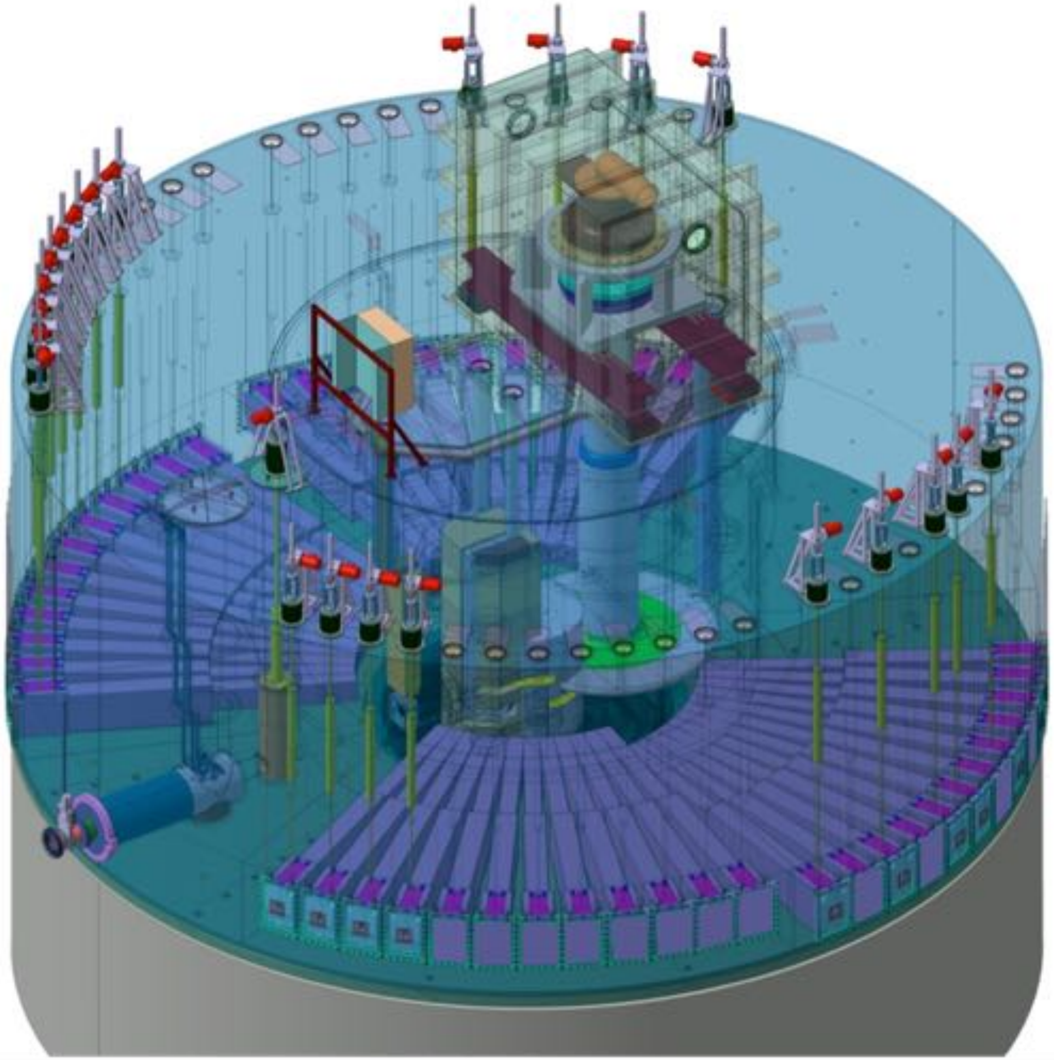
2. A cut-away view of the target wheel shaft assembly and target wheel. The 4-tonne, 2.5-meter-diameter target wheel is divided into 36 radial segments containing around 7,000 tungsten blocks. It is cooled via helium and rotates such that one proton beam pulse will strike each segment of the wheel over the course of a single rotation. The helium coolant passages are integrated into the shaft, as is the drive motor and support bearing for the wheel.

3. The moderator-reflector systems adjacent to the target wheel, one above the wheel and one below it. They can be rotated on their shaft and removed from the monolith for service or replacement.

4. The ESS "butterfly" moderator design. This is the low-profile (3-cm-high) moderator enclosed within the reflector situated just above the target wheel. To a large extent, this small device will determine how many neutrons the ESS target station will produce. Two hydrogen moderator cans, arranged as opposing "arrows", and one water moderator can, the "x" in the centre, contain the hydrogen and water media that "moderate" or slow down the neutrons released from the target. The neutrons then enter the beam lines at a speed suitable for experiments.



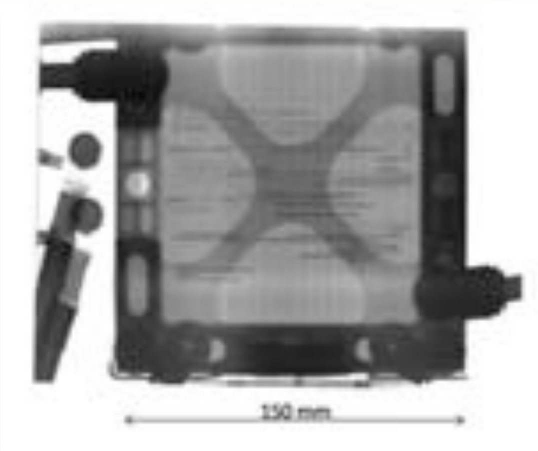




Target monolith building

Neutrons are useful

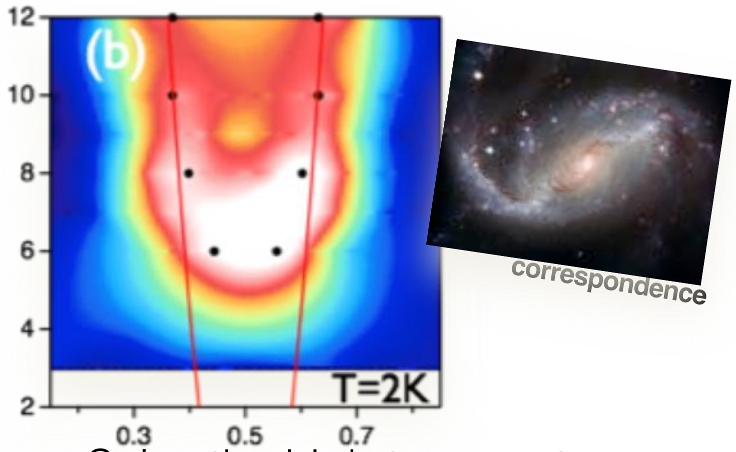
Charge neutral
Deeply penetrating



Li motion in fuel cells

Improve electric cars

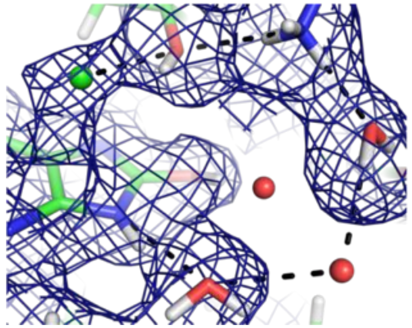
Magnetic moment (spin)
Probe of magnetism



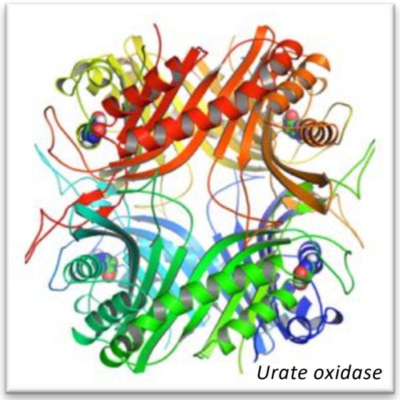
Solve the high-temperature Superconductivity puzzle

Efficient high-speed trains

Nuclear scattering
Sensitive to light elements and isotopes



Active sites in proteins



Better drugs

Thank you for your interest!

Questions?