EUROPEAN
SPALLATION
SOURCE

The European Spallation source
A giant microscope for a more sustainable future

Jo Lewis

2023-09-08

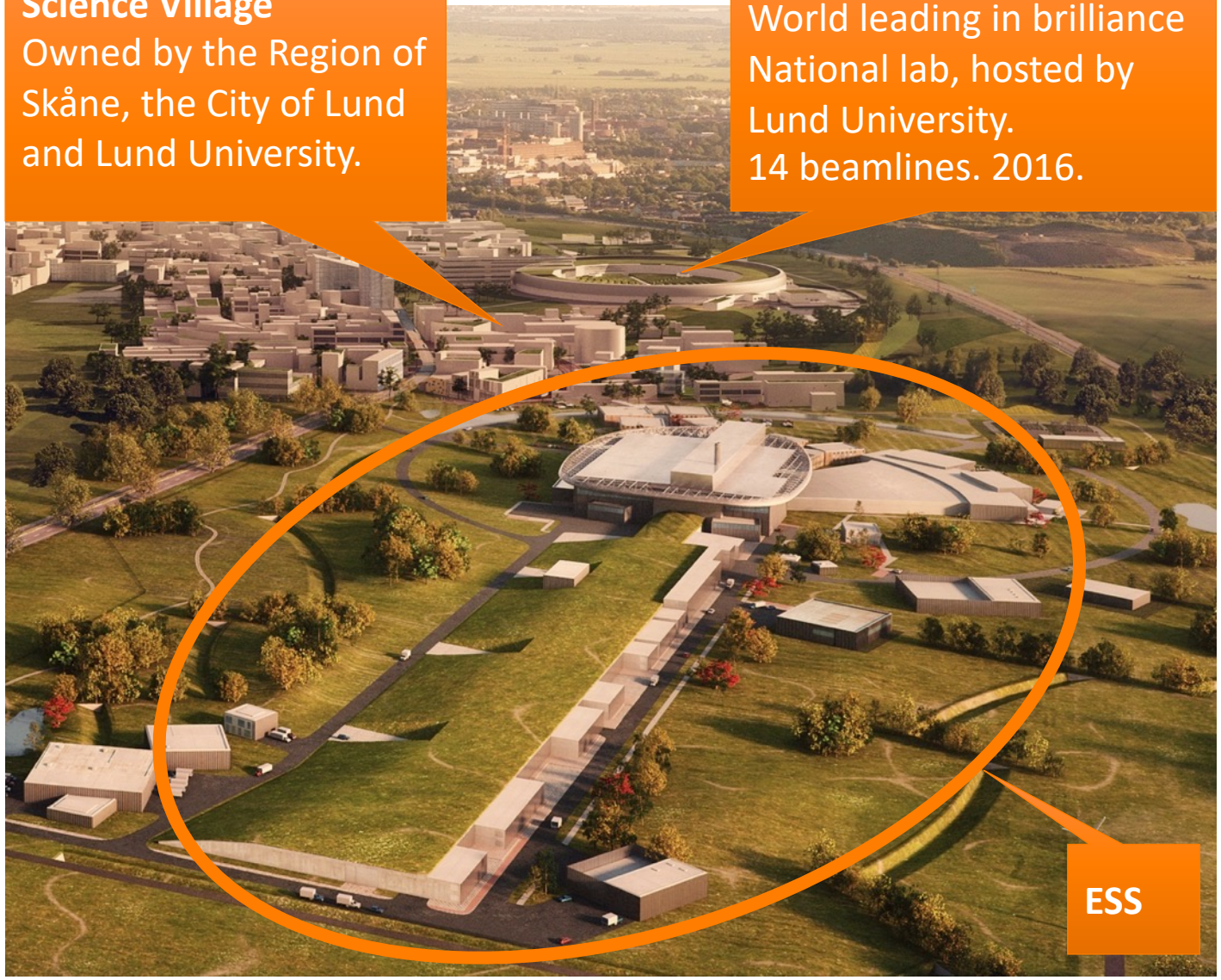
In 2009 Sweden and Denmark won the bid to be home to a new giant microscope

We’re building a global science hub in Lund

ESS, MAX IV, Science Village Scandinavia

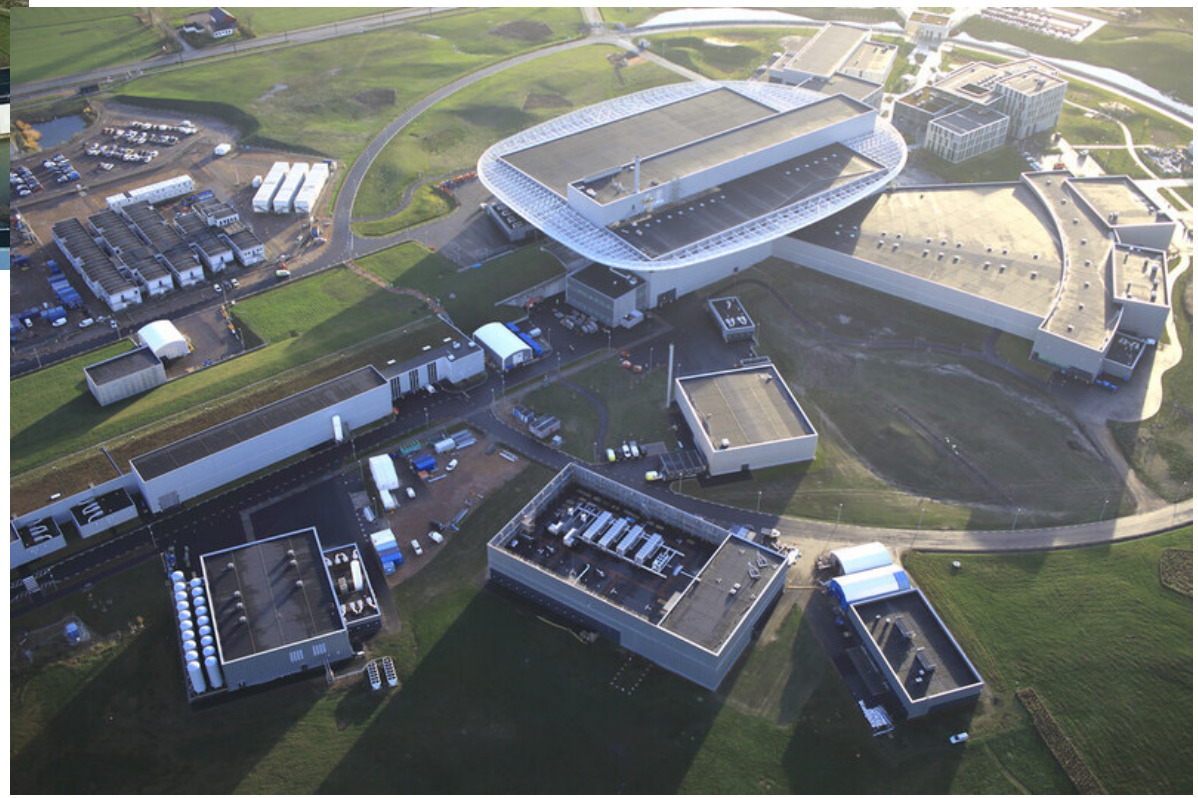
Science Village
Owned by the Region of Skåne, the City of Lund and Lund University.

MAX IV
World leading in brilliance National lab, hosted by Lund University.
14 beamlines. 2016.



ESS today

Photo taken
Feb 2022



ESS is owned and being built by 13 member countries and partners

Organisation and People

519
Employees

56
Nationalities

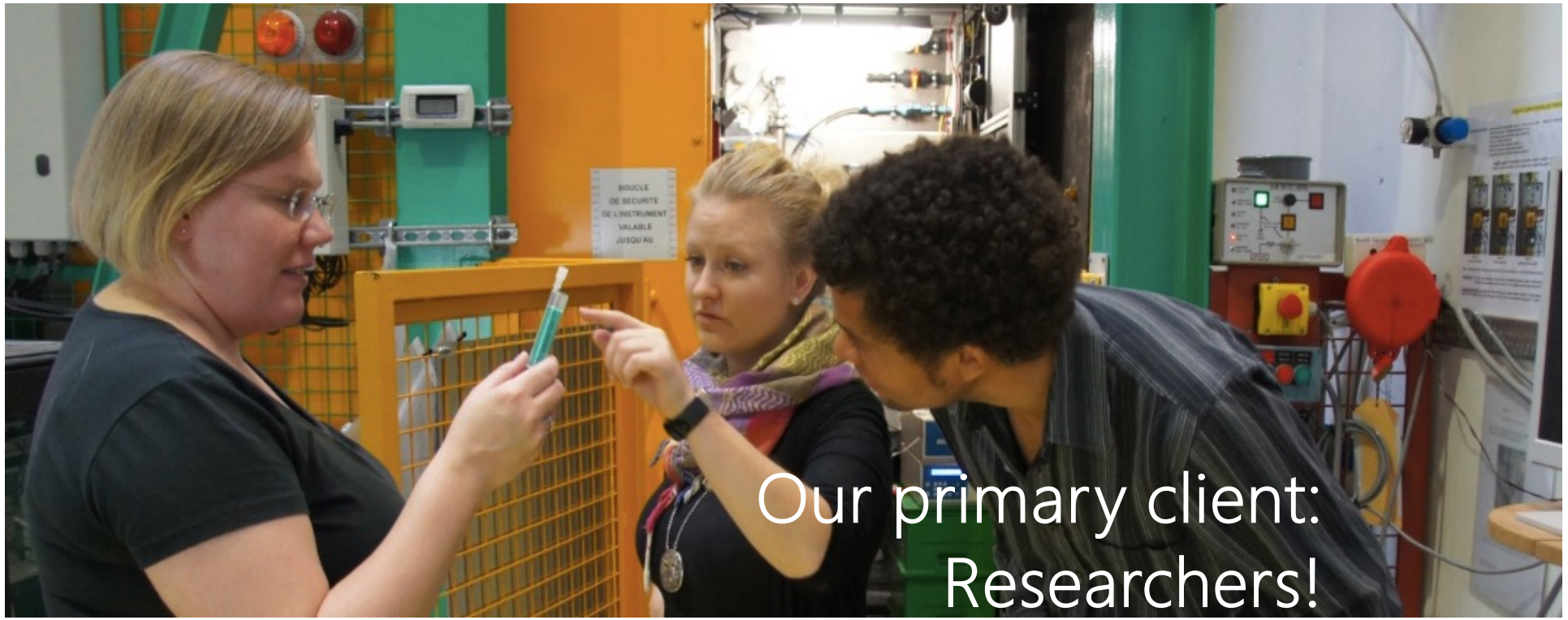
> 100
Collaborating Institutions

What is it for?

Fundamental science and research are crucial for improved quality of life

ESS will be a user facility

- Researchers who need neutrons 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…



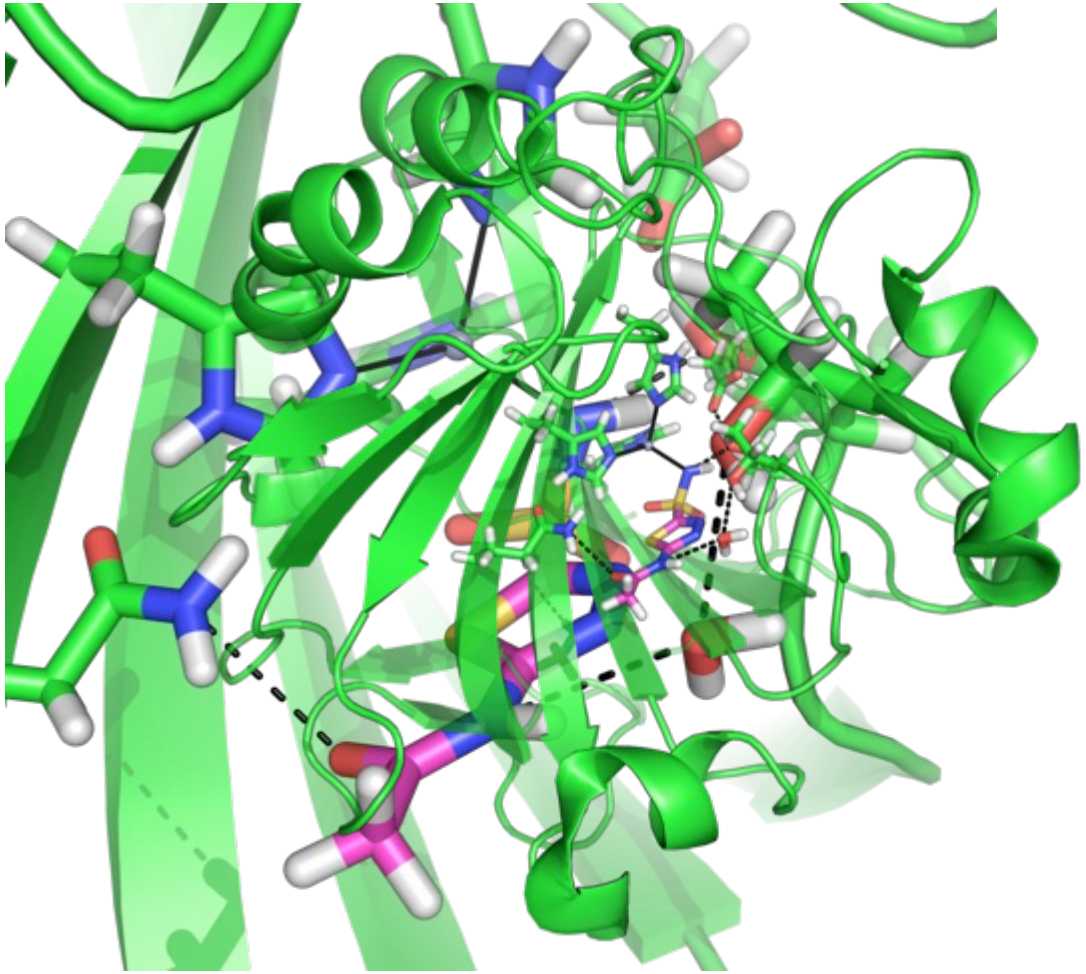
We are creating…

…KNOWLEDGE

- life sciences
- soft condensed matter
- chemistry of materials
- energy research
- magnetism & superconductivity
- engineering & geo-sciences
- archeology & heritage conservation
- fundamental & particle physics

Neutrons reveal how drugs interact with drug targets

Life sciences



Carbonic anhydrase

- Enzyme
- Transports CO_2
- Regulates blood acidity

Scientists are studying its role 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 to this enzyme

Image: Fisher, S. Z. *et al.* 2012 JACS

Neutrons for a sustainable energy economy

Energy research

Wind turbines:
- strong, light, flexible materials
- better magnets

Solar panels:
- Economically feasible, robust solutions
- Neutron reflectivity probes surface action

Cars:
- Fuel cells
- Long-range batteries
- Lighter materials

Energy research

How do we store the renewable energy?

The Royal Swedish Academy of Sciences awarded the Nobel Prize in Chemistry 2019 to
John B. Goodenough
M. Stanley Whittingham
Akira Yoshino

"for the development of lithium-ion batteries"

By increasing the Li^+ content, the energy density can be improved

BUT this affects cost and safety.

Use neutrons to monitor Li^+ directly in battery systems during charge and discharge.

Li-ion battery during discharge. Li^+ ions move from anode to cathode inside the battery while electrons move through a wire.

“Machine forensics” using neutrons

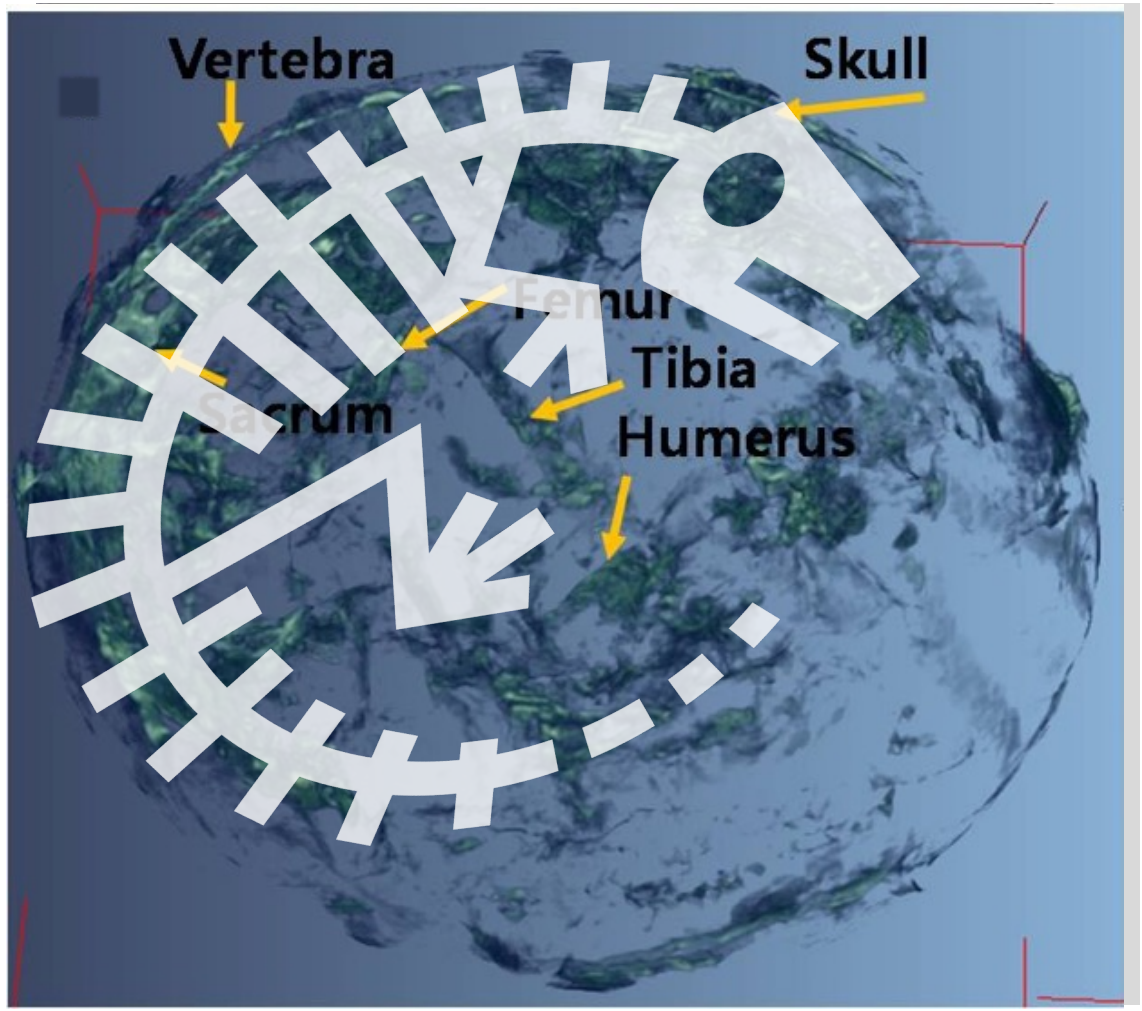
Engineering & geo-sciences

Neutrons can penetrate massive metal parts easily.
Neutrons see the hydrogen-rich soot
The technical problem was understood using neutron tomography.

Archeology & heritage conservation

Neutrons for Archaeology

Looking inside a dinosaur egg



Gondwana Research 20 (2011), 621-629

Sindra Petersson Årsköld

How does it work?

How does a giant microscope work?

1. Protons are generated at the ion source

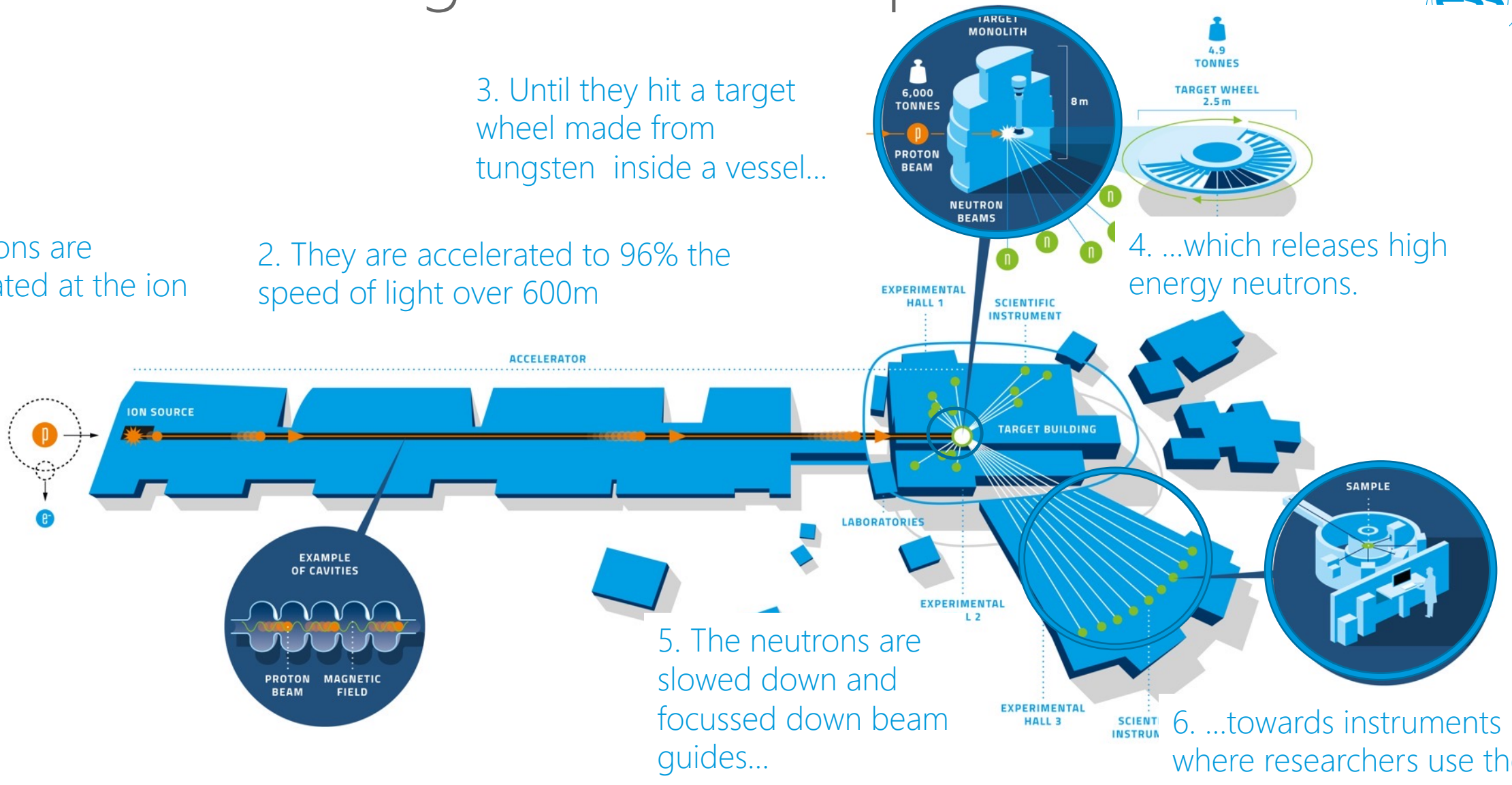
2. They are accelerated to 96% the speed of light over 600m

3. Until they hit a target wheel made from tungsten inside a vessel…

4. …which releases high energy neutrons.

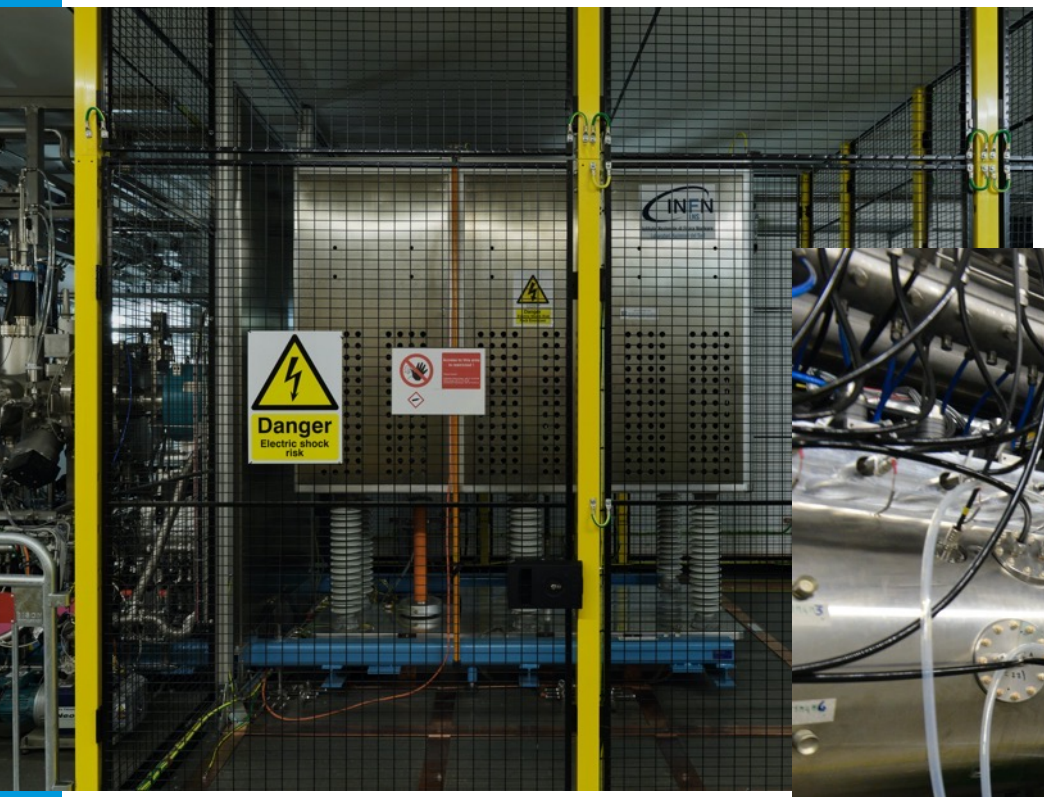
5. The neutrons are slowed down and focussed down beam guides…

6. …towards instruments where researchers use the neutrons to explore materials down to an atomic level.

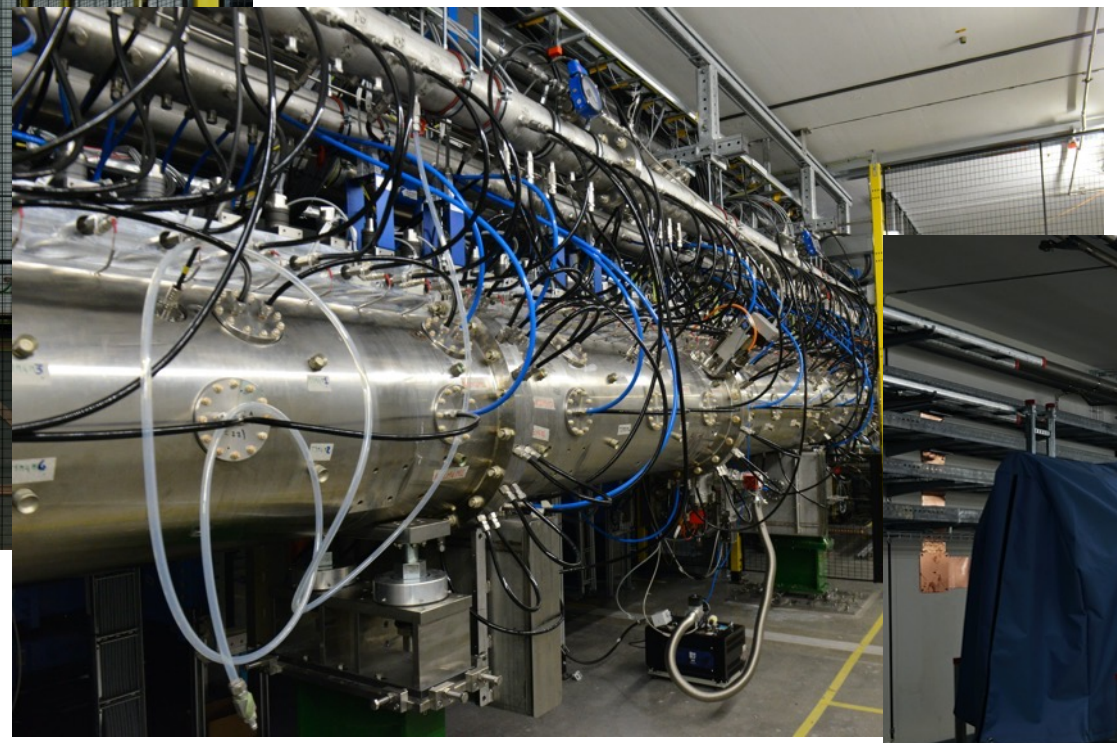


Accelerator

Ion source



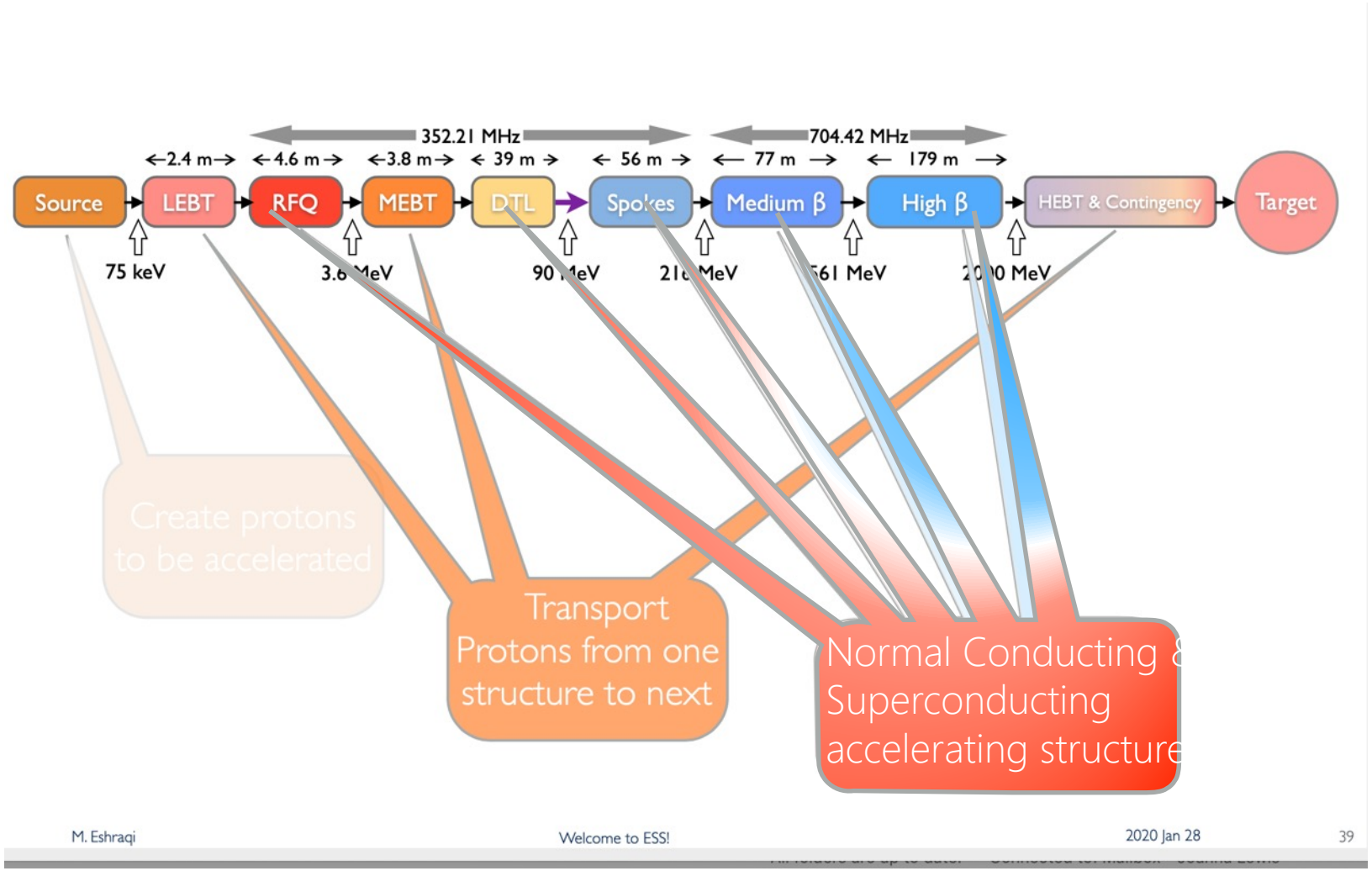
Normal conducting linac



Super conducting linac

A Linear Accelerator has many components

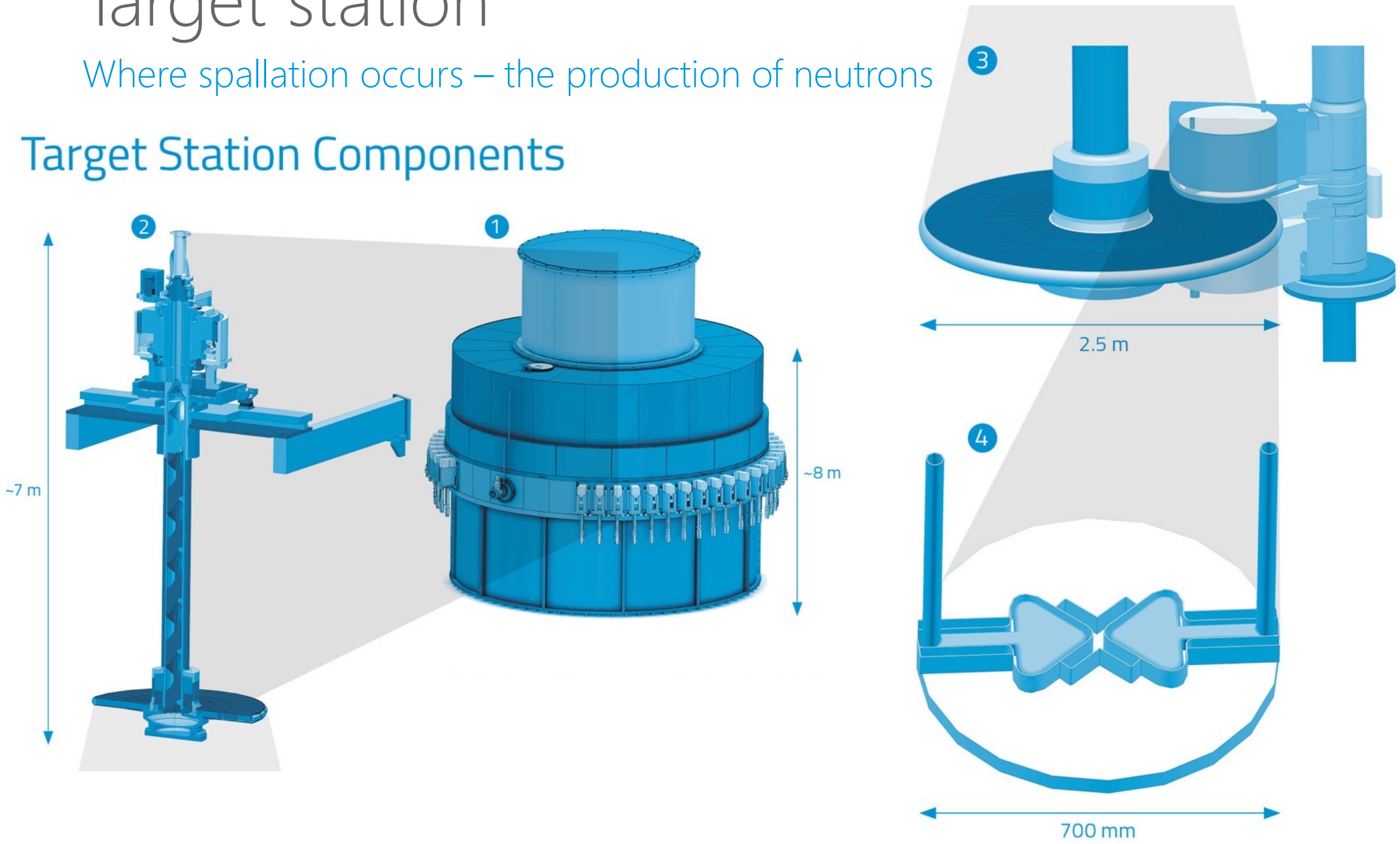
Protons are guided, focussed and accelerated down a 600m tunnel



- Ion source
- Normal conducting and superconducting accelerating structures
- Beam Transport Units
- Vacuum
- Cryogenics
- Monitoring & control systems

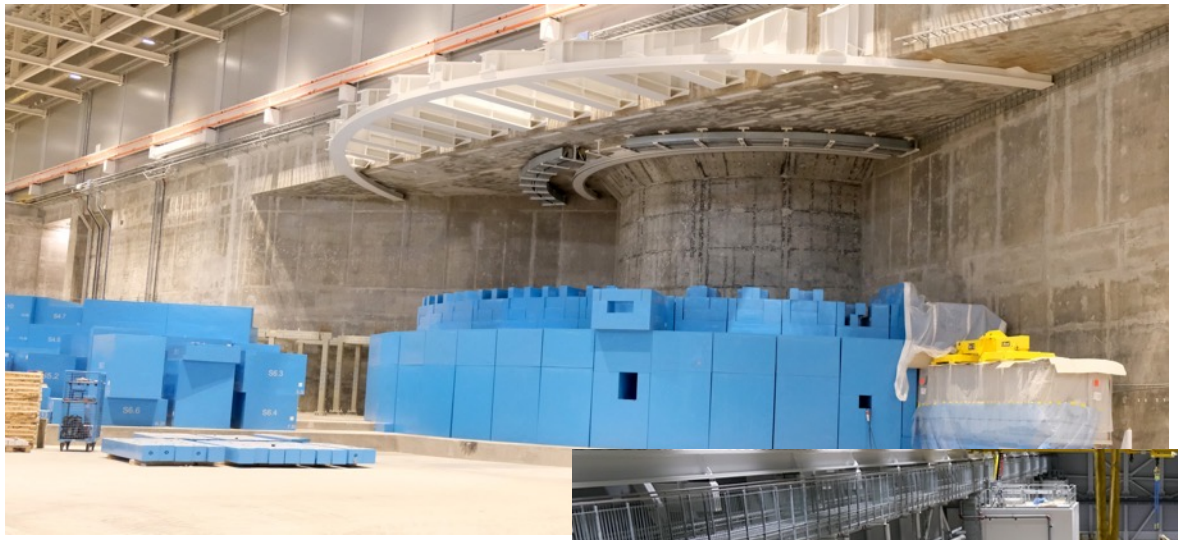
Target station

Where spallation occurs – the production of neutrons



Target

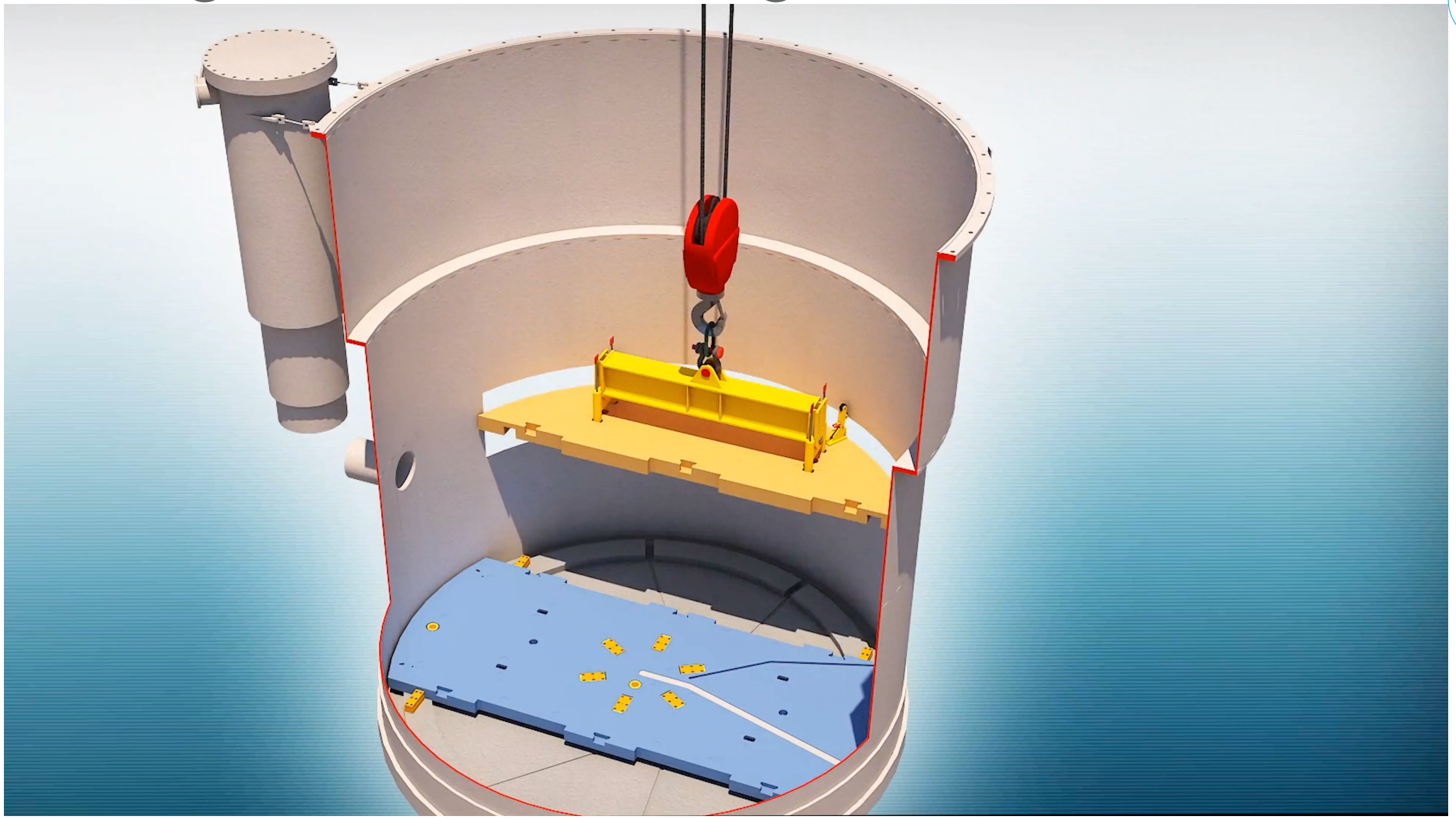
Bunker



Monolith

Target Wheel

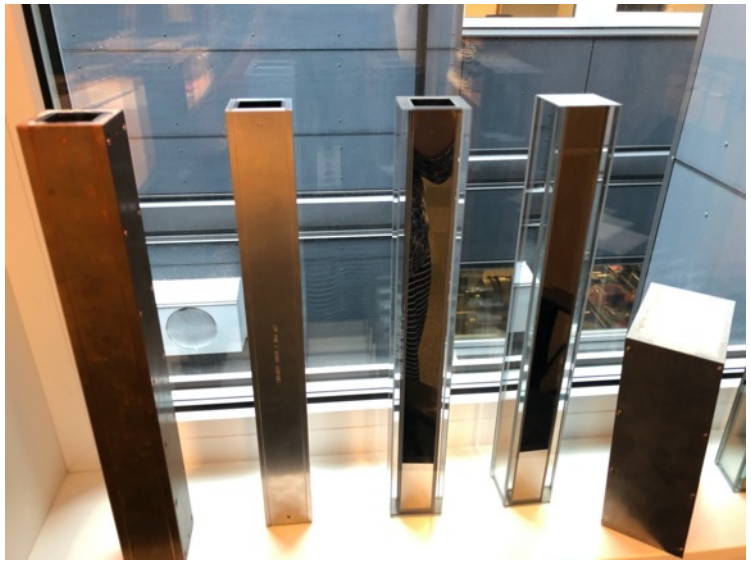
Target station shielding

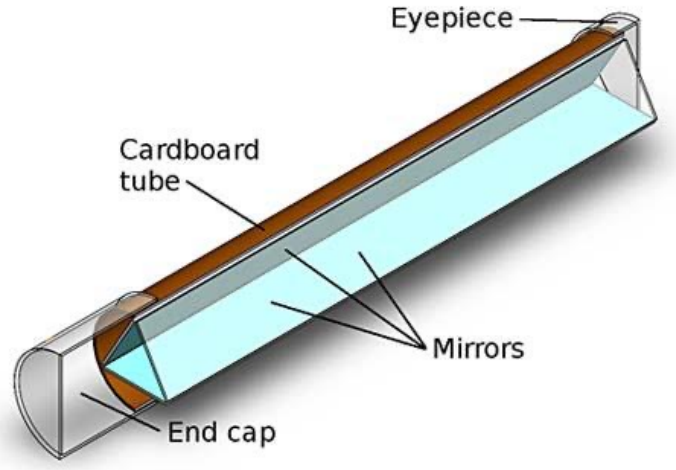


Neutrons are guided down beamlines

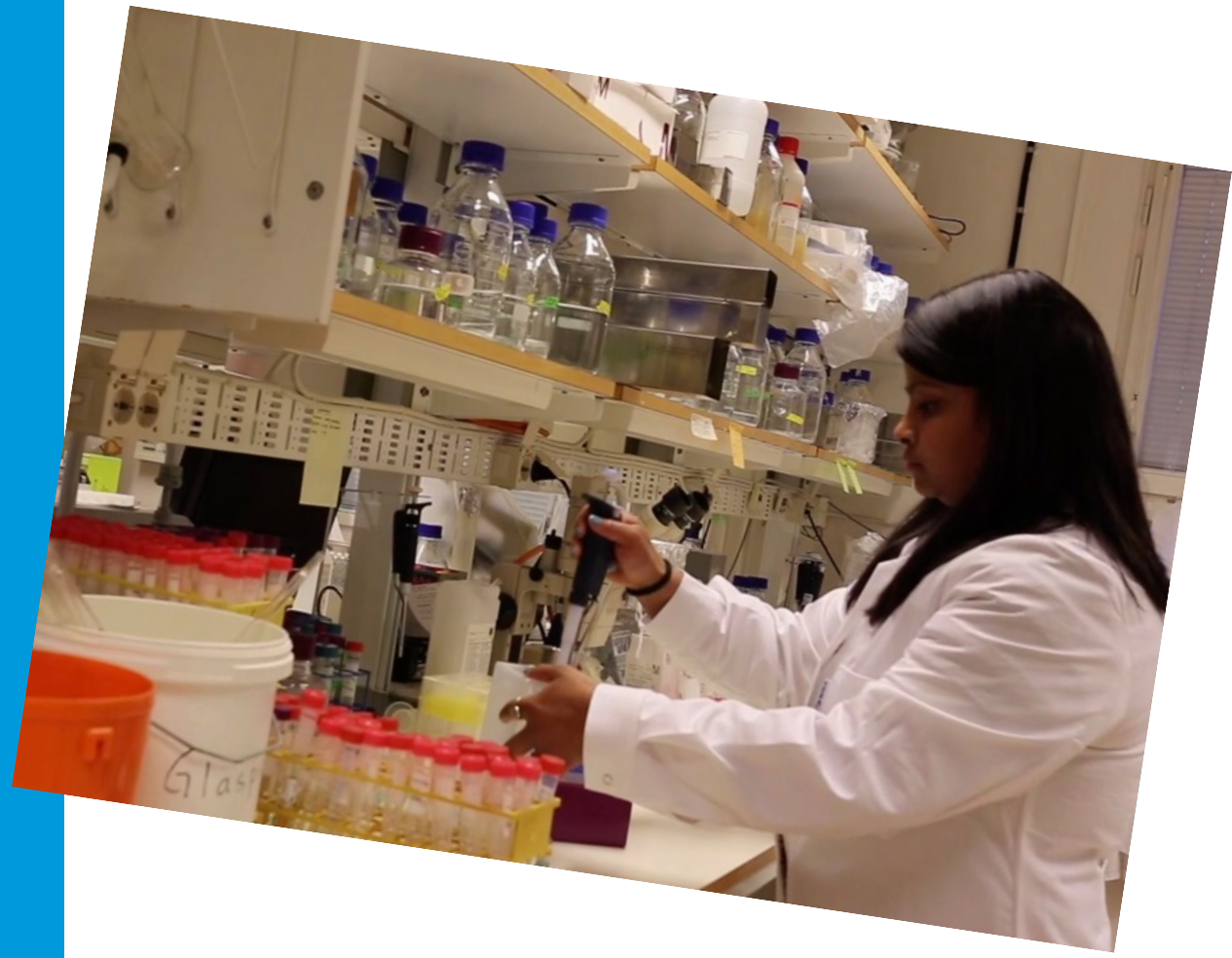
Until they interact with the sample in a particular instrument

Beamguides are a bit like very long, highly reflective, kaleidoscopes



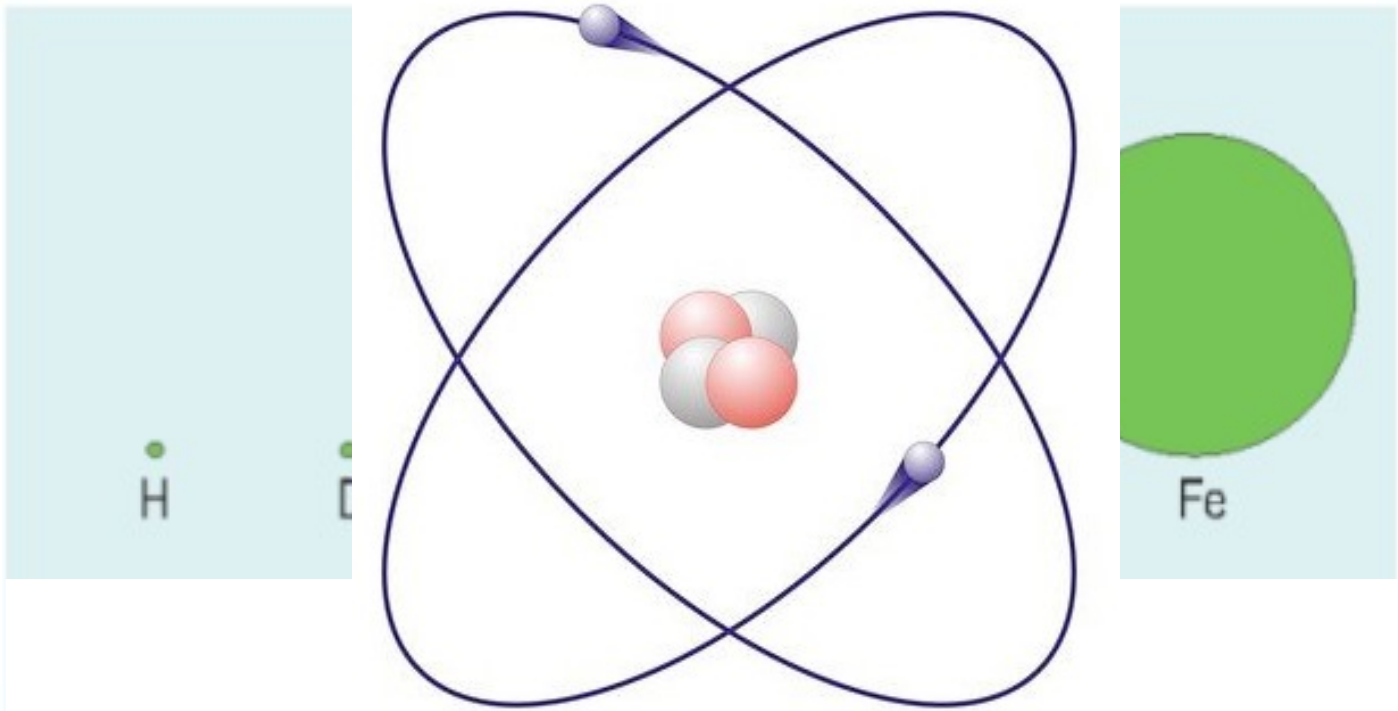


How do neutrons help researchers see inside stuff?



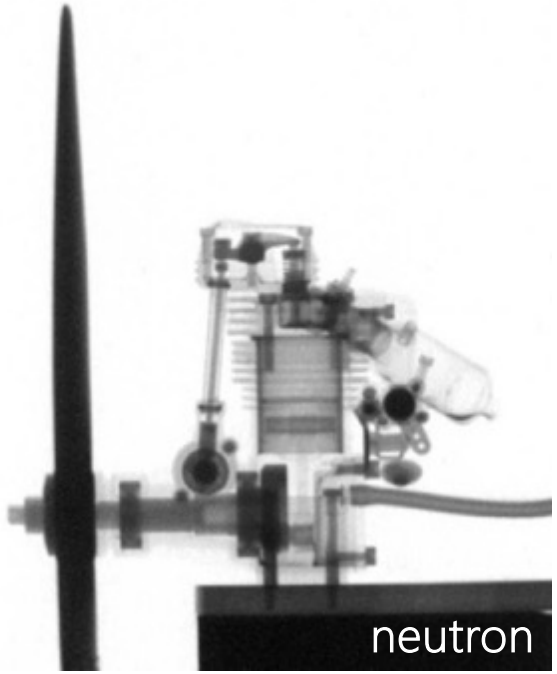
What's special about Neutrons?

1. Neutral charge
2. Interact with the nucleus
3. Wavelengths are similar to atomic distances
4. Energies are similar to atomic and electronic processes
5. Have a magnetic moment



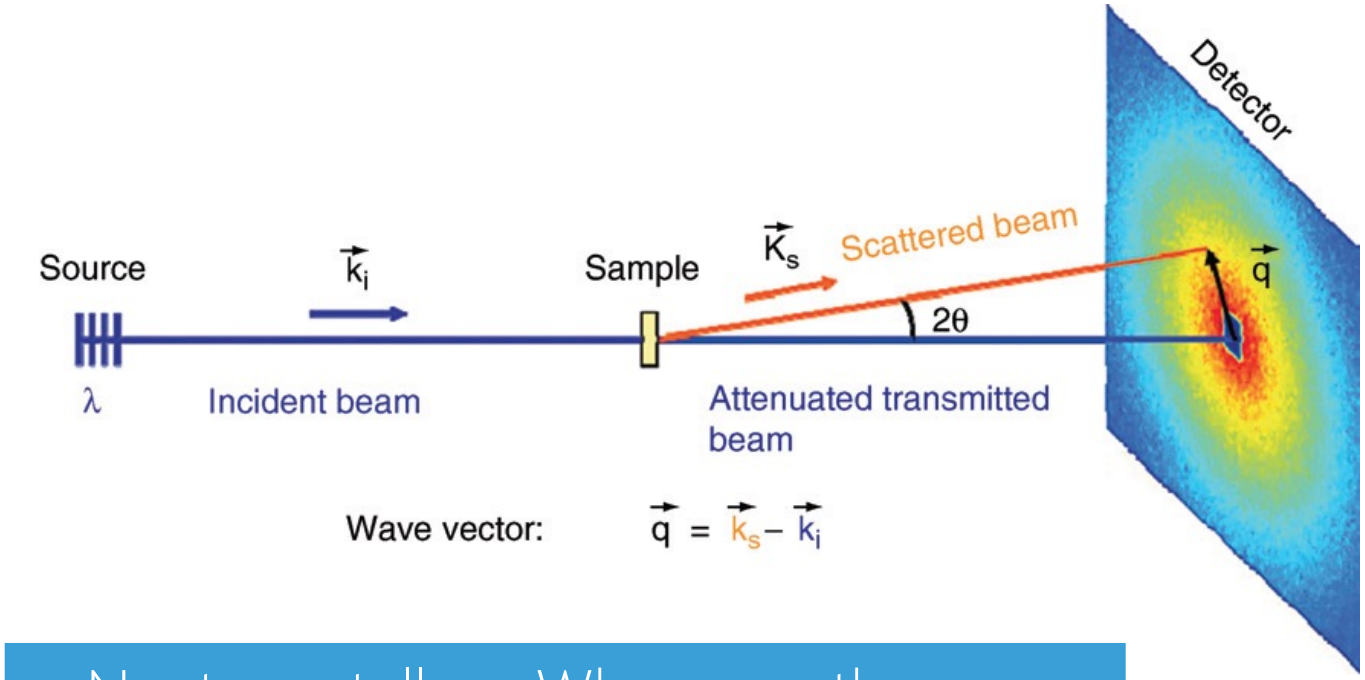
Neutrons See the Light Elements

Courtesy of the NIAG group, PSI, Switzerland.



Neutron scattering shows the molecules and atoms inside a sample

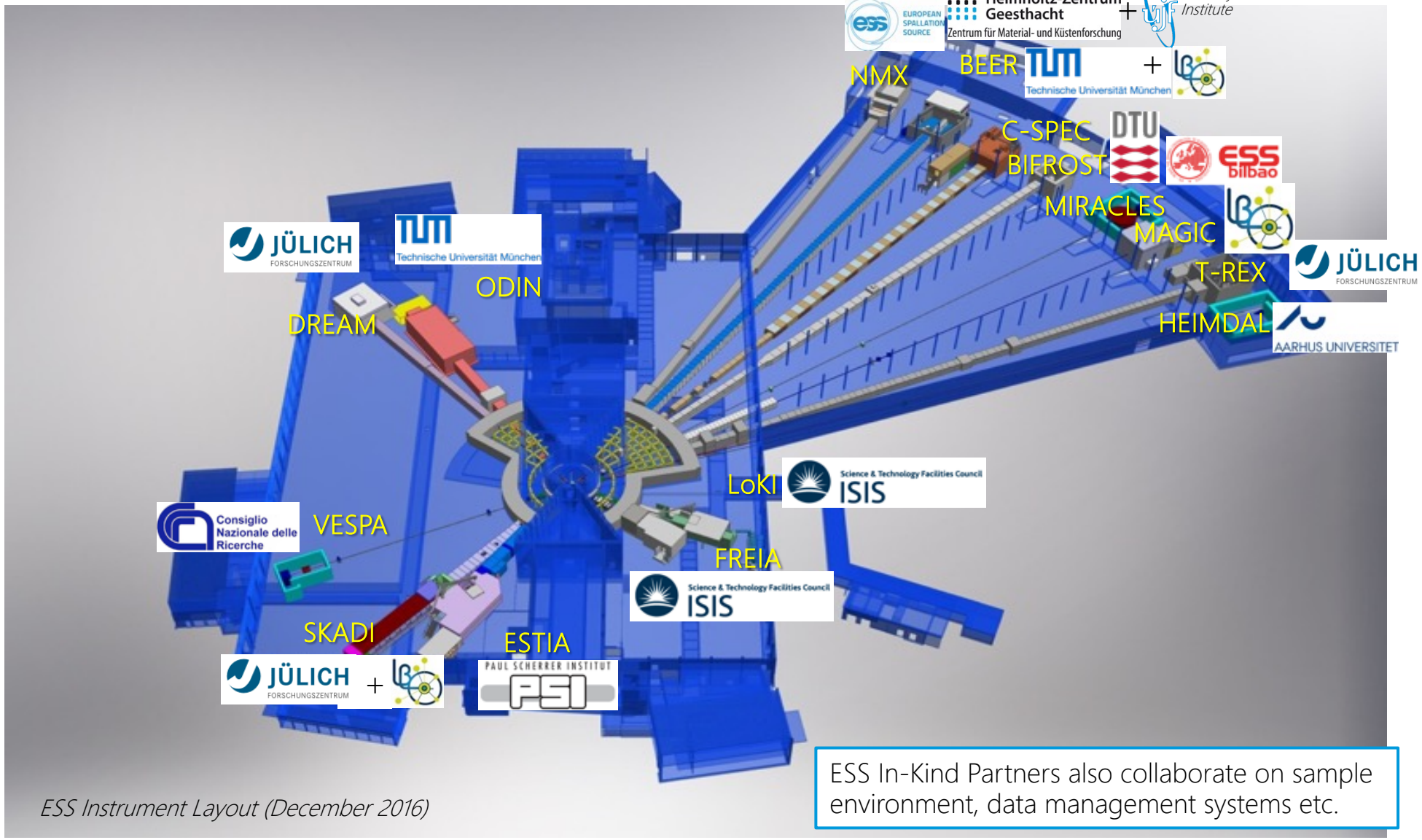
Wavelength of a neutron = distance between atoms in a material
This produces a diffraction pattern



Neutrons tell us: Where are the atoms, and what are they doing?

Different instruments for different science

ESS Lead Partners for instrument construction

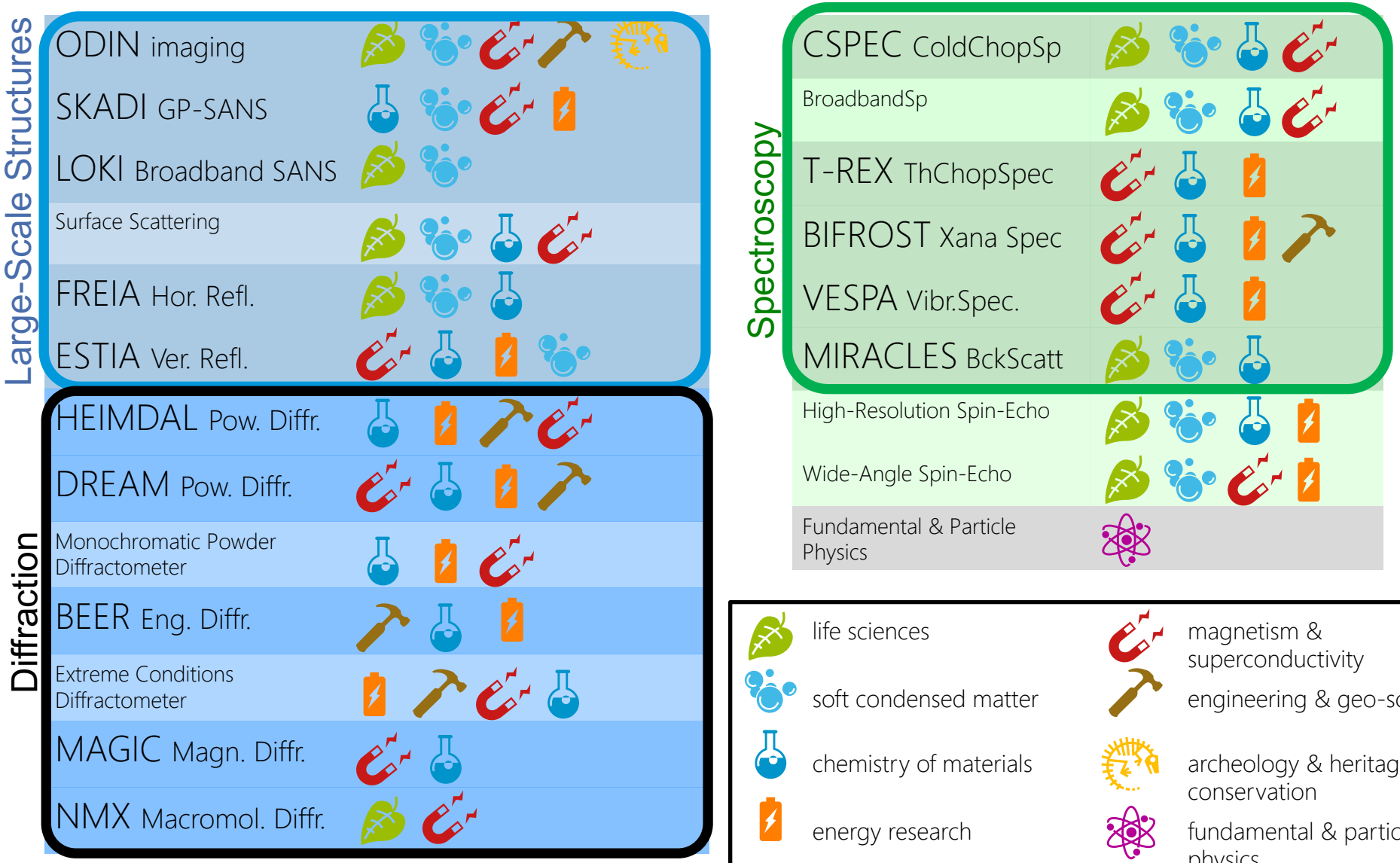


ESS Instrument Layout (December 2016)

ESS In-Kind Partners also collaborate on sample environment, data management systems etc.

Different instruments for different areas of science

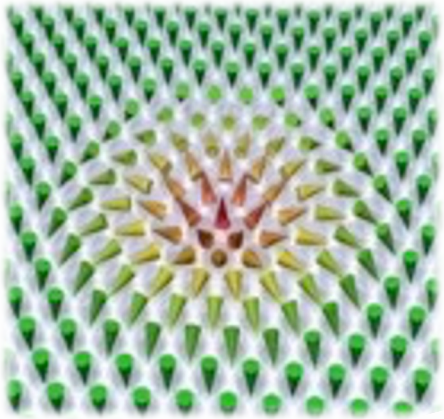
15 Instruments funded. Space for at least 7 more in the future



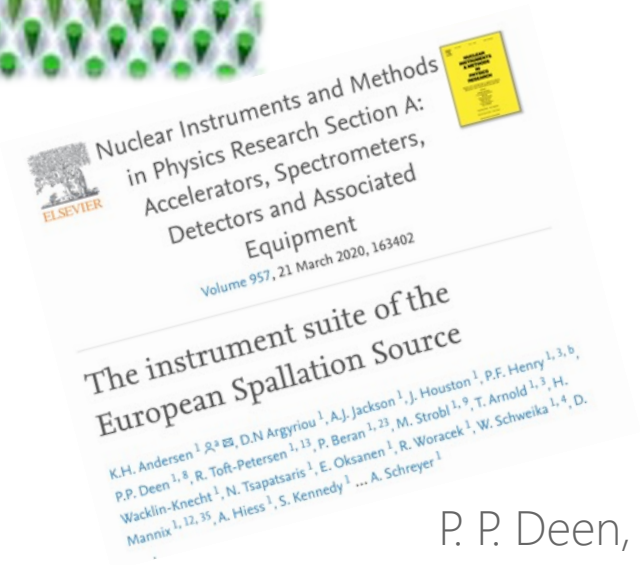
Then we turn all that data into meaningful results to share

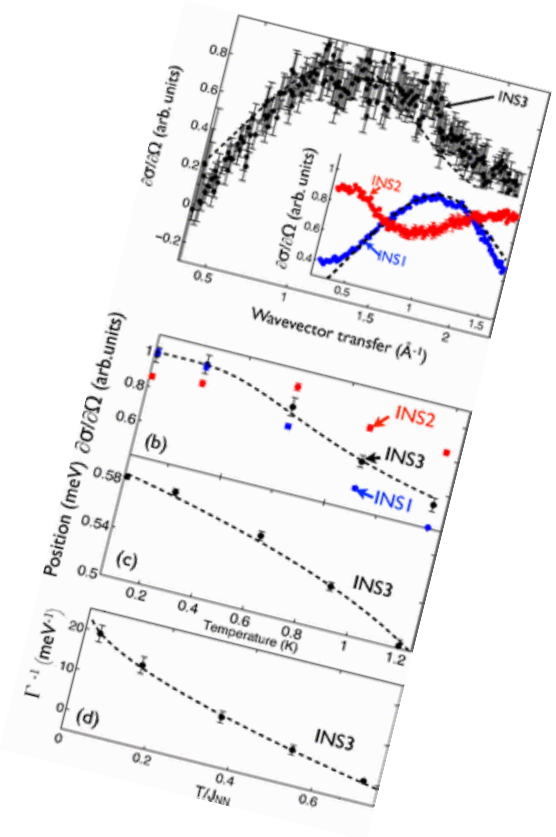
About 500 hours of movies!

A single set of experiments could produce a terabyte of data



1. Sorted
2. Visualised
3. Analysed by the researchers



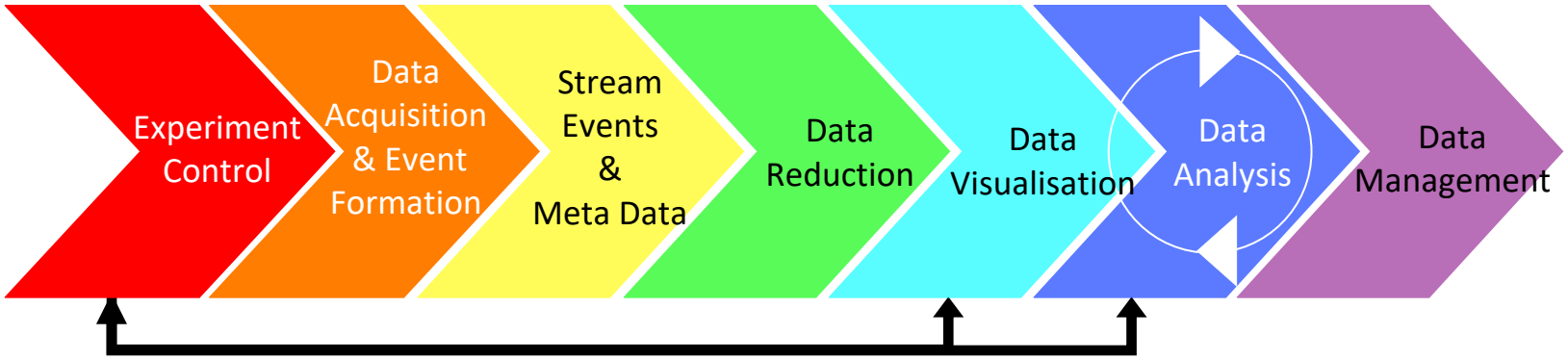


P. P. Deen, Phys Rev B ,ASP

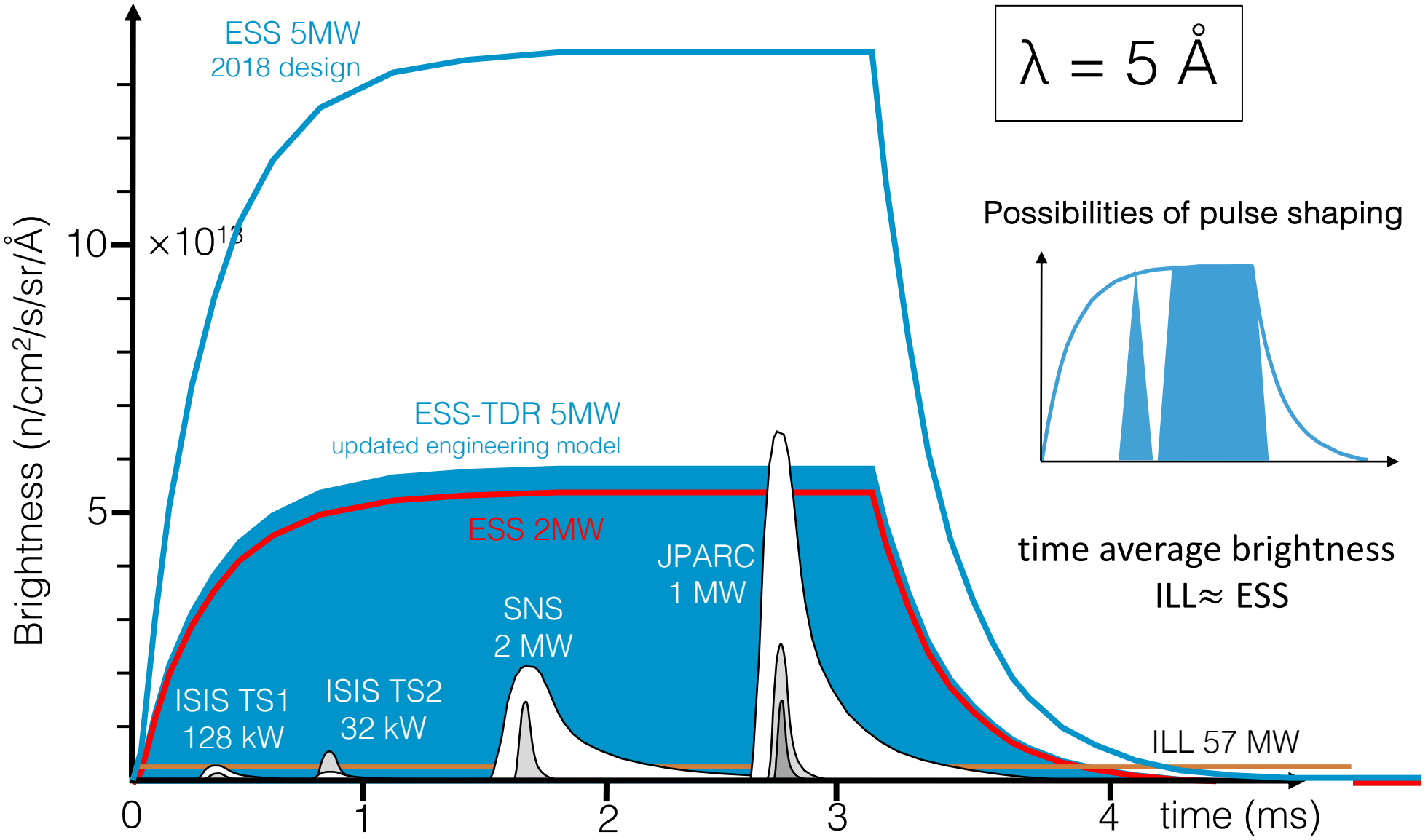
Data Management and Software Centre

Based at Copenhagen University

Provide scientific software and computing support for researchers doing neutron scattering at ESS



Long-pulse performance



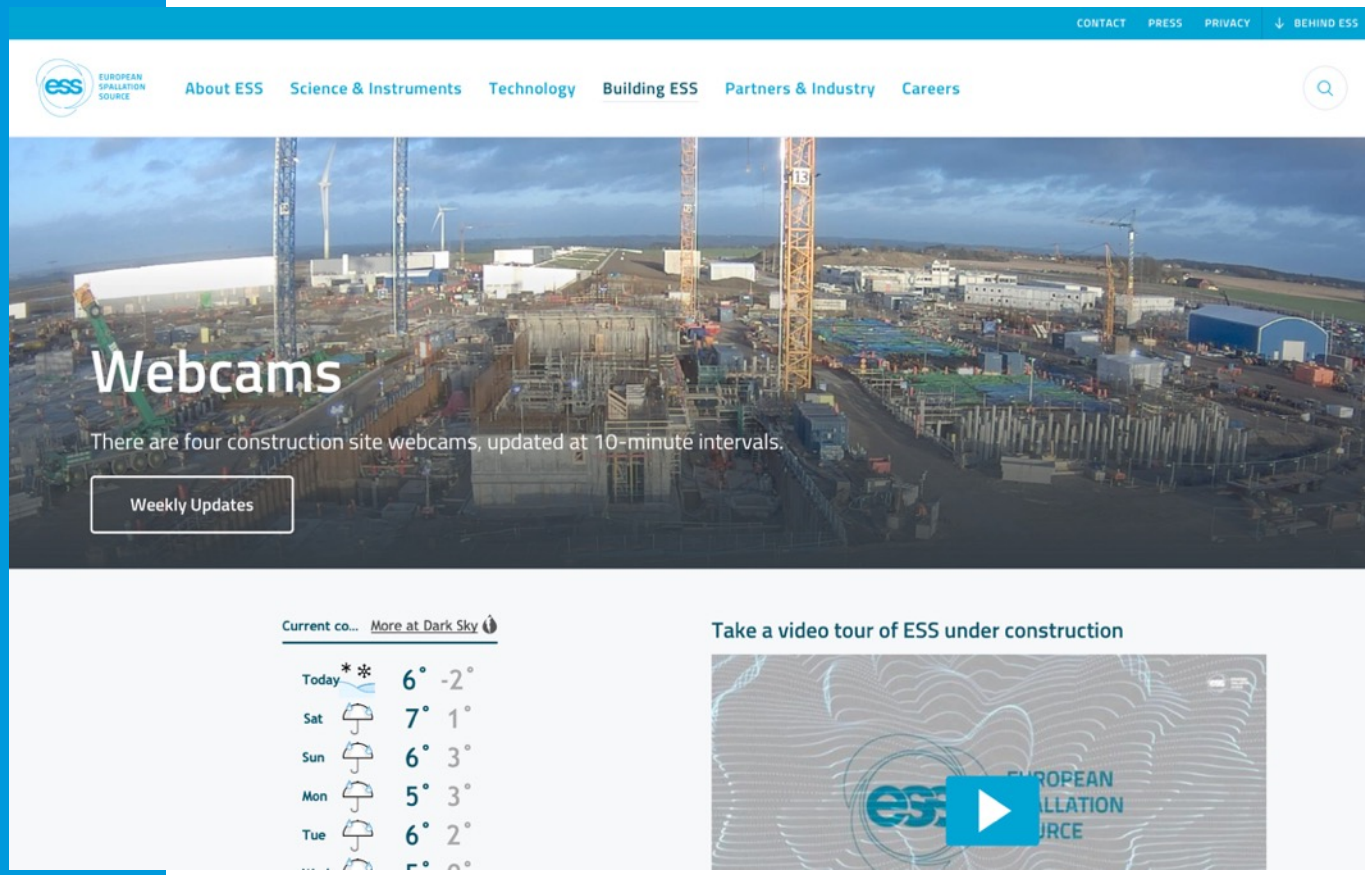
$\lambda = 5$ Å

Possibilities of pulse shaping

time average brightness
ILL≈ ESS

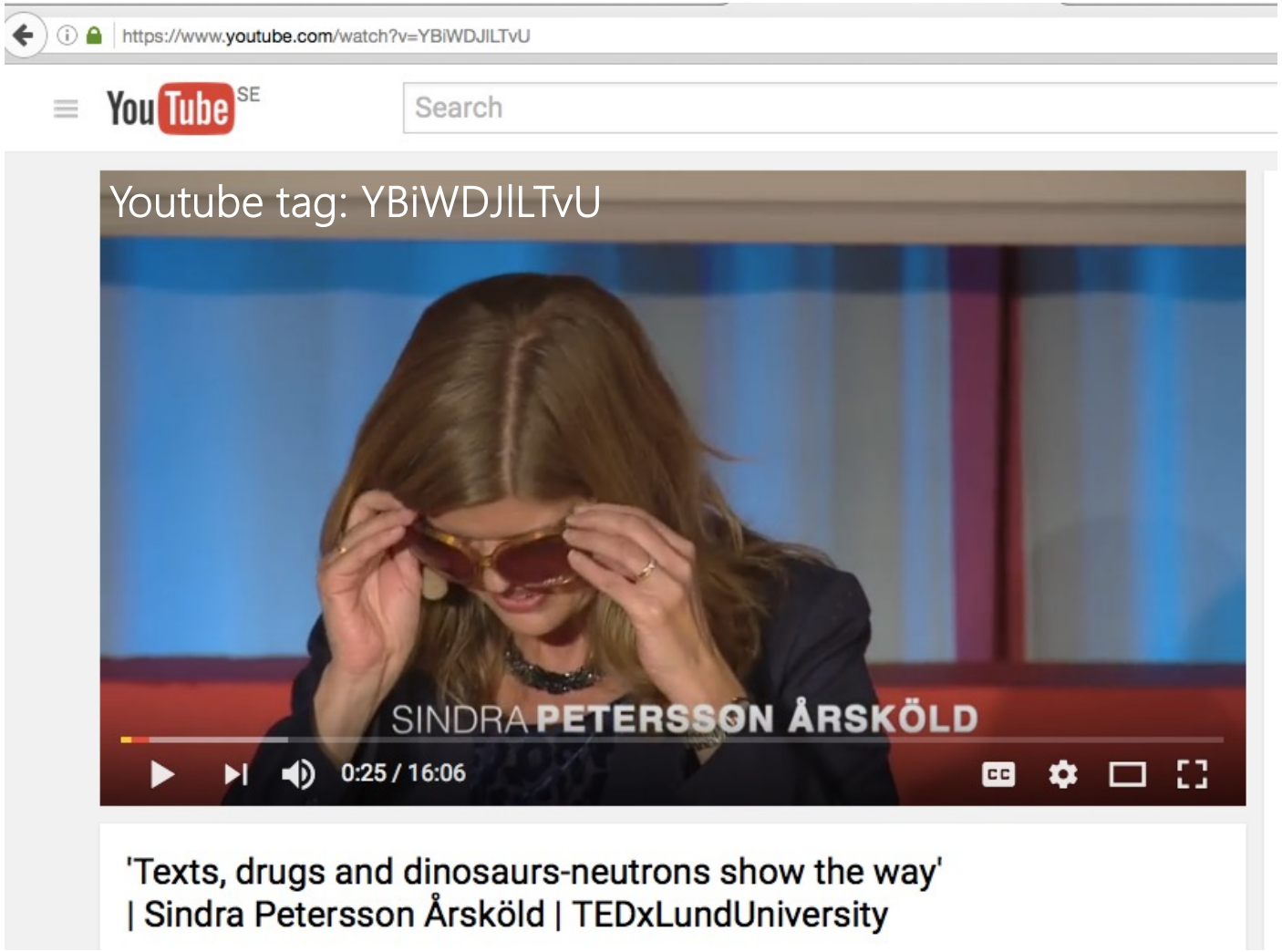
Everybody can have a virtual look

ess.eu/explore



Information
Videos
Photos

Take a look at one our scientist's TEDx Talks



https://youtu.be/YBiWDJlLTvU

Thank you

Joanna.Lewis@ess.eu