ESS – Enabling discovery

Mats Lindroos
Head of Accelerator

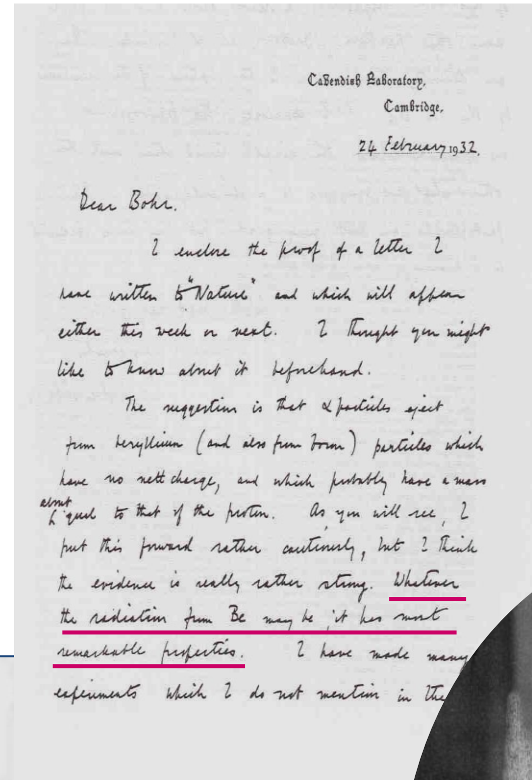
Orsay EURISOL TM October 2014

A European research center

"Whatever the radiation from Be may be, it has most remarkable properties"

Neutrons

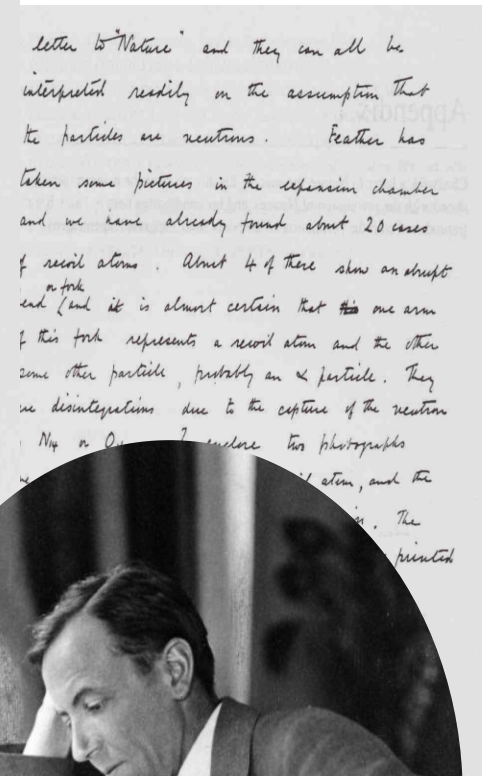
Its discovery
James Chadwick
1932
(α,n) reaction

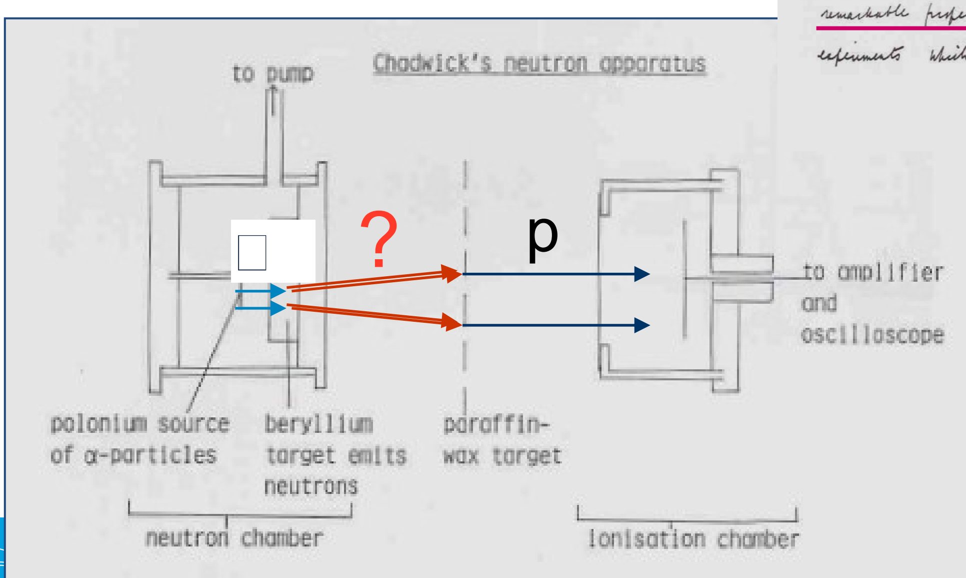

Cavendish Laboratory,
Cambridge.
24 February 1932.

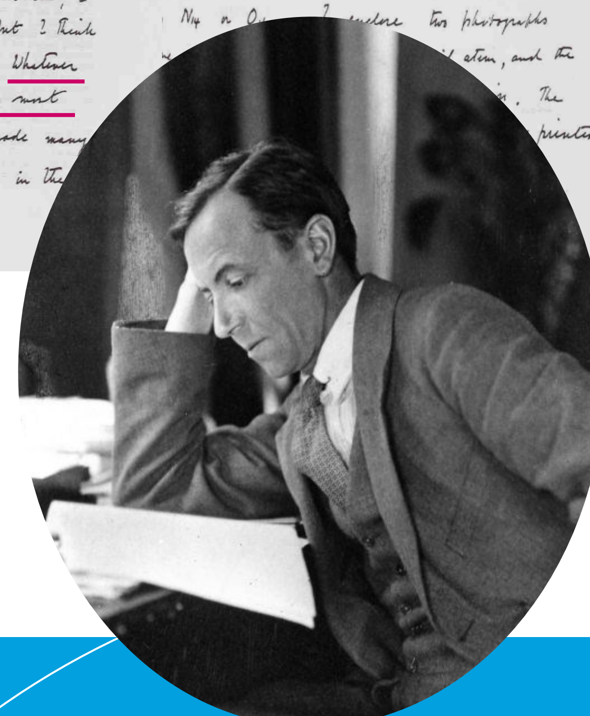
Dear Bohr.

I enclose the proof of a letter I have written to "Nature" and which will appear either this week or next. I thought you might like to know about it beforehand.

The suggestion is that α particles eject from beryllium (and also from boron) particles which have no nett charge, and which probably have a mass about equal to that of the proton. As you will see, I put this forward rather cautiously, but I think the evidence is really rather strong. Whatever the radiation from Be may be, it has most remarkable properties. I have made many experiments which I do not mention in the


letter to "Nature" and they can all be interpreted readily on the assumption that the particles are neutrons. Feather has taken some pictures in the expansion chamber and we have already found about 20 cases of recoil atoms. About 4 of these show an abrupt end (and it is almost certain that one arm of this fork represents a recoil atom and the other some other particle, probably an α particle. They are disintegrations due to the capture of the neutron

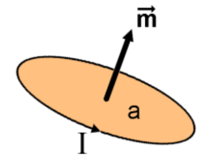




Neutrons are beautiful !

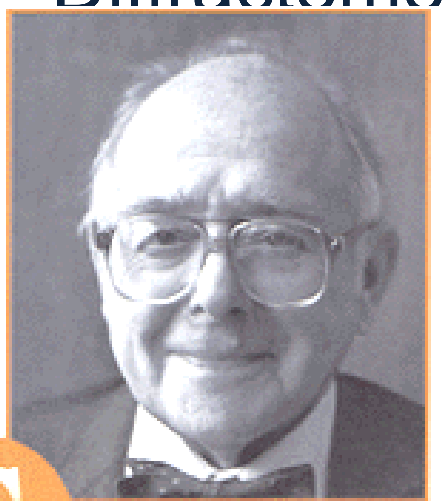
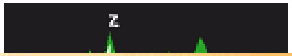
Wave | Particle | Magnetic moment | Neutral





Diffractometers - Measure structures
atoms and molecules

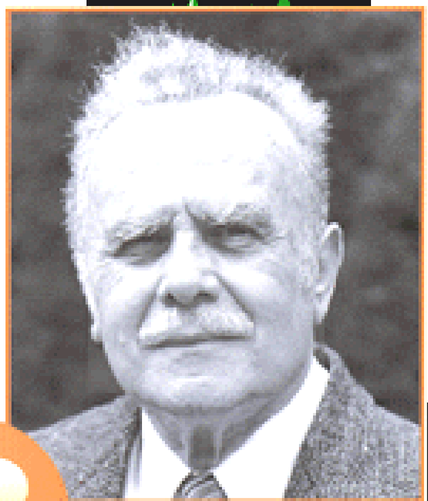
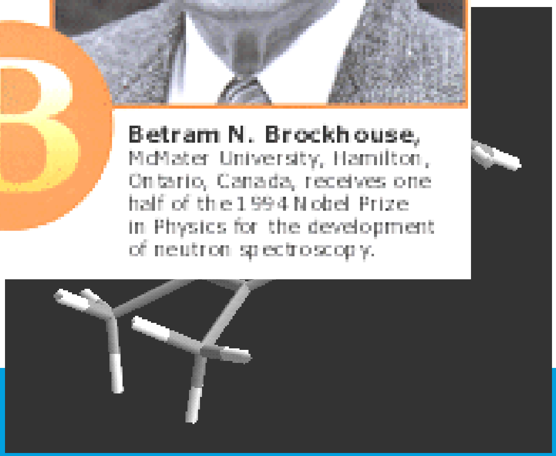
10 Ångström

Clifford G. Shull, MIT, Cambridge, Massachusetts, USA, receives one half of the 1994 Nobel Prize in Physics for development of the neutron diffraction technique.

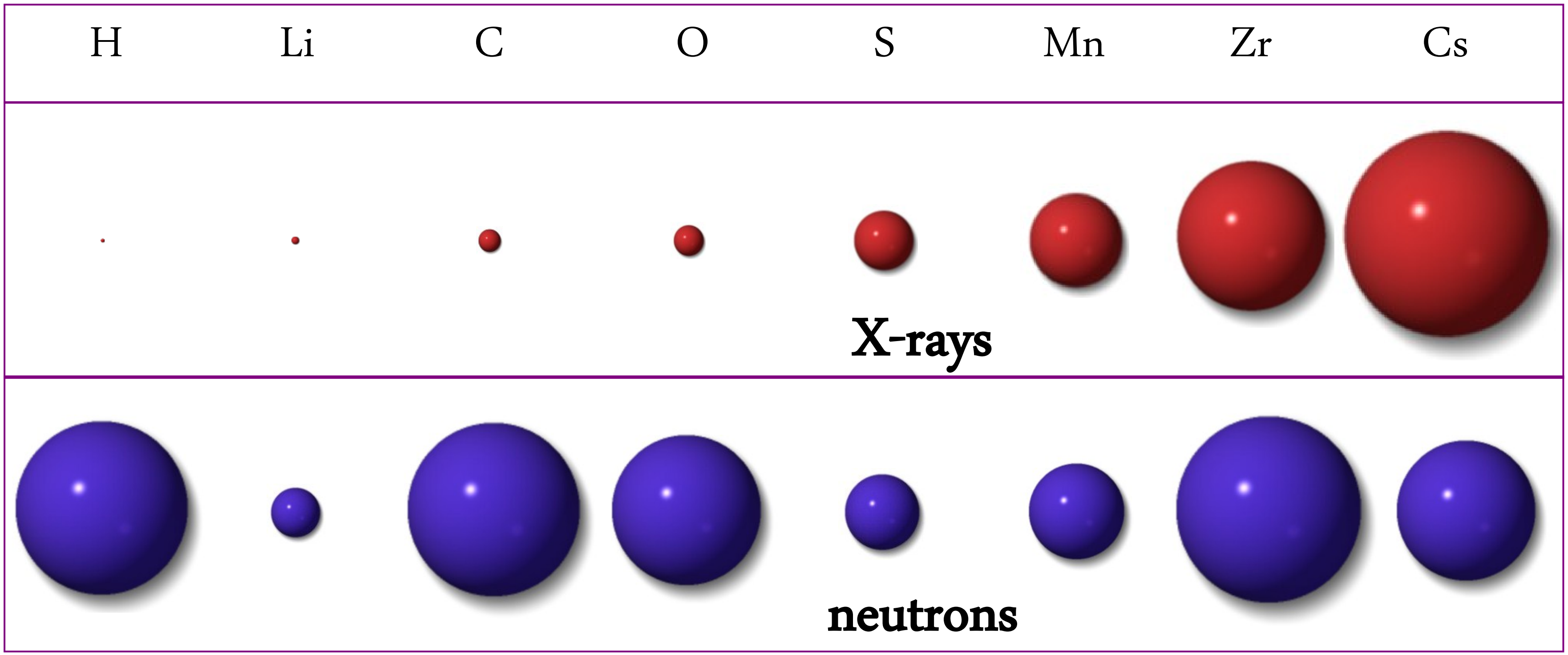
s - Measure dynamics
oms and molecules do

1 - 80 meV

Betram N. Brockhouse, McMaster University, Hamilton, Ontario, Canada, receives one half of the 1994 Nobel Prize in Physics for the development of neutron spectroscopy.

Light and neutrons

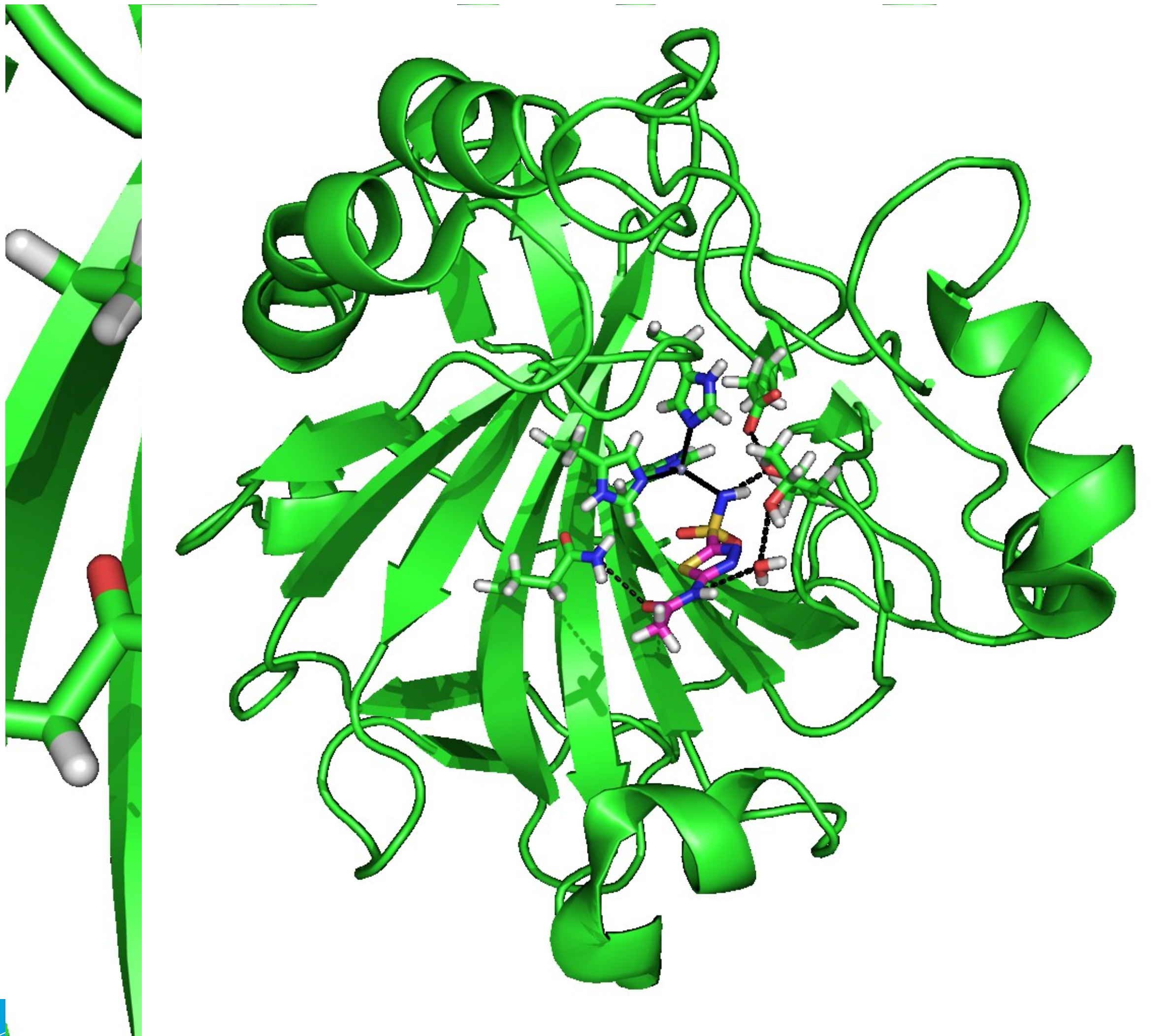


Engineering materials

Non-destructive analysis of a steel armed concrete block with neutron imaging and X-ray tomography.

Source: PSI, CEMNET workshop 2007

Better drugs from detailed protein maps



This enzyme transports CO_2 and regulates blood pH.

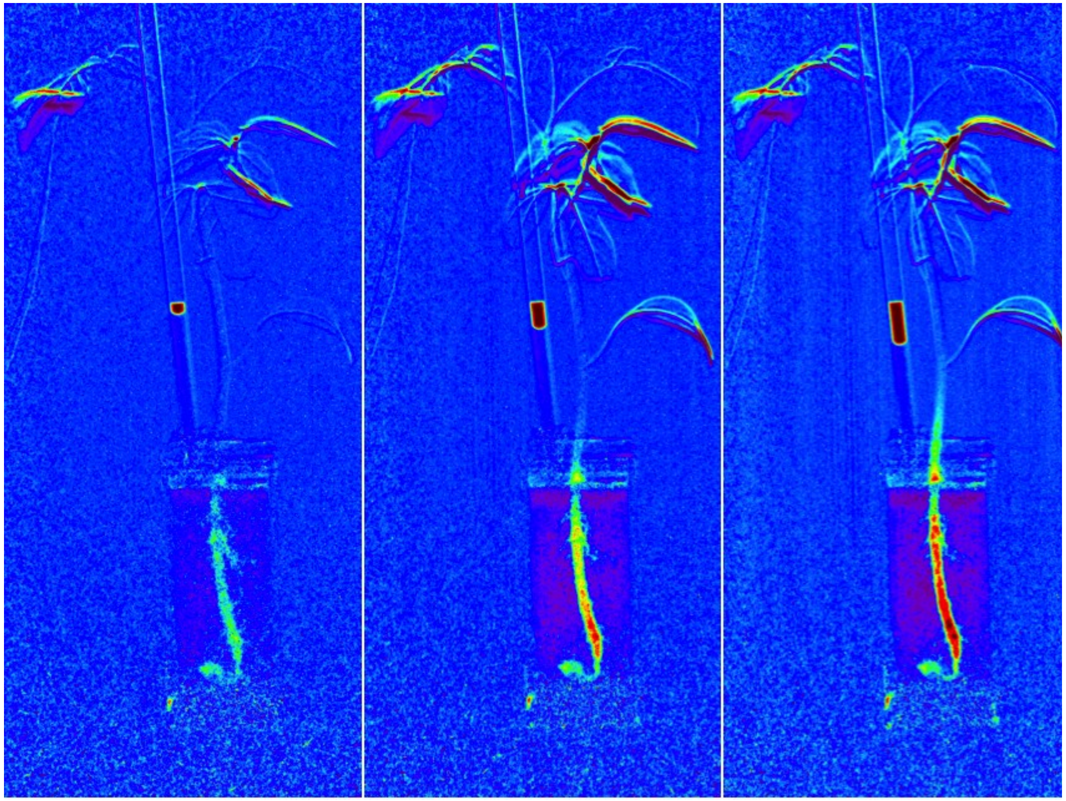
It is a major player in some cancers, glaucoma, obesity and high blood pressure

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

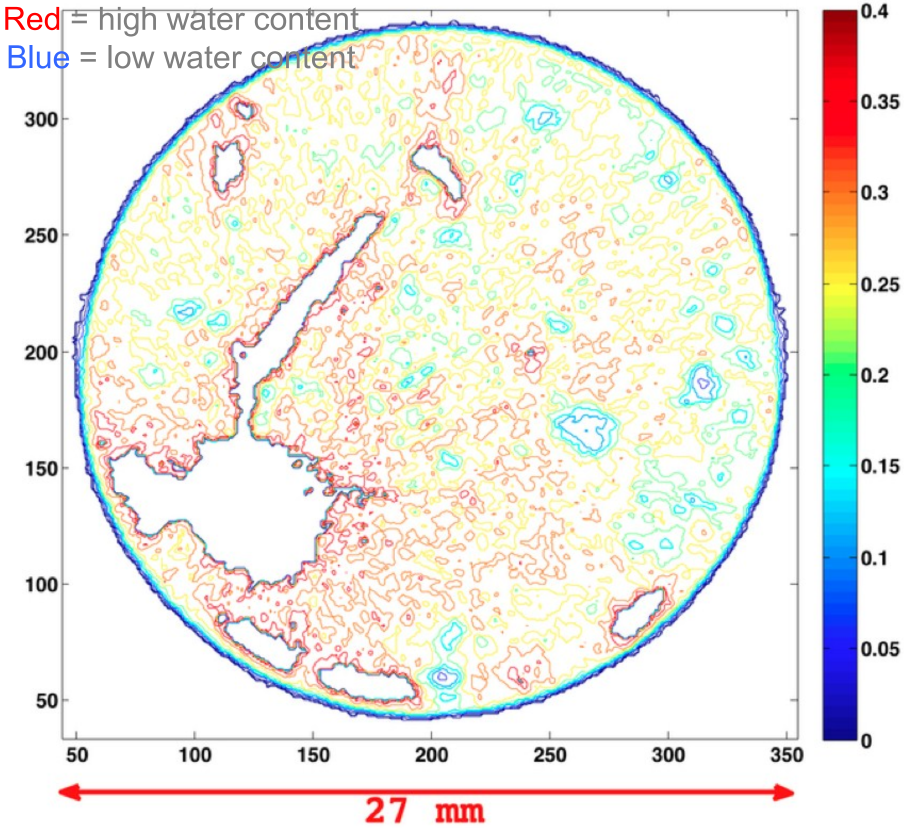
10^{-9} m

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

Whole-organism neutron imaging



Visualising water flow in a tomato seedling with neutron imaging.

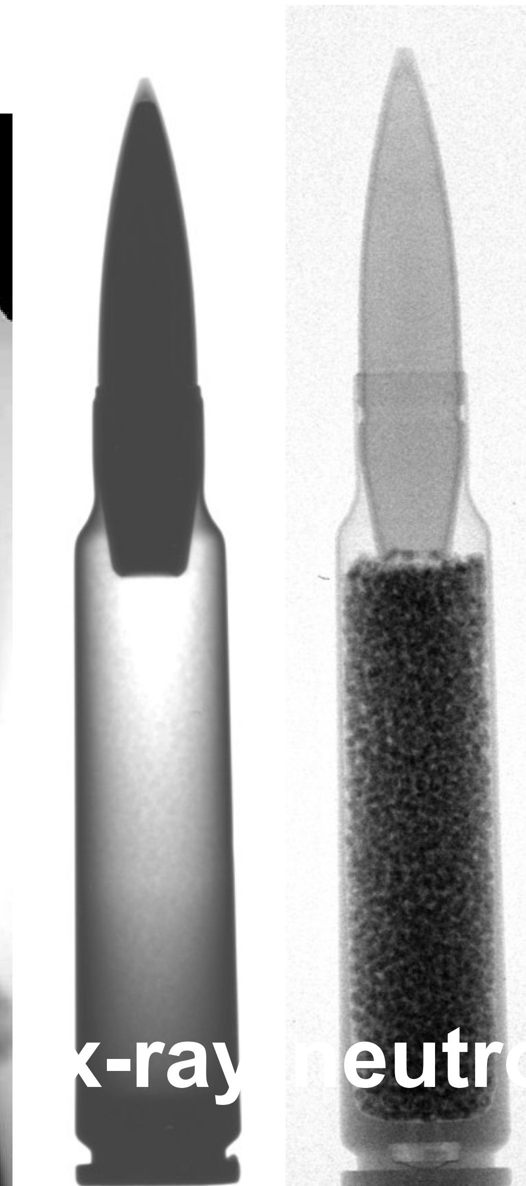


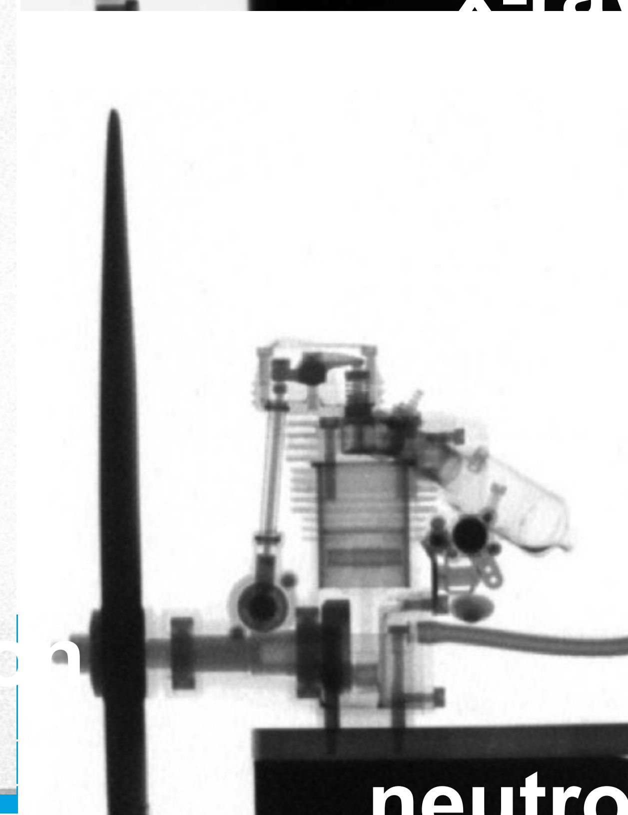
Cross-section of plant roots in soil shows that plants collect

Matsushima U. *et al.* 2008 (WCNR-8), Gaithersburg, USA

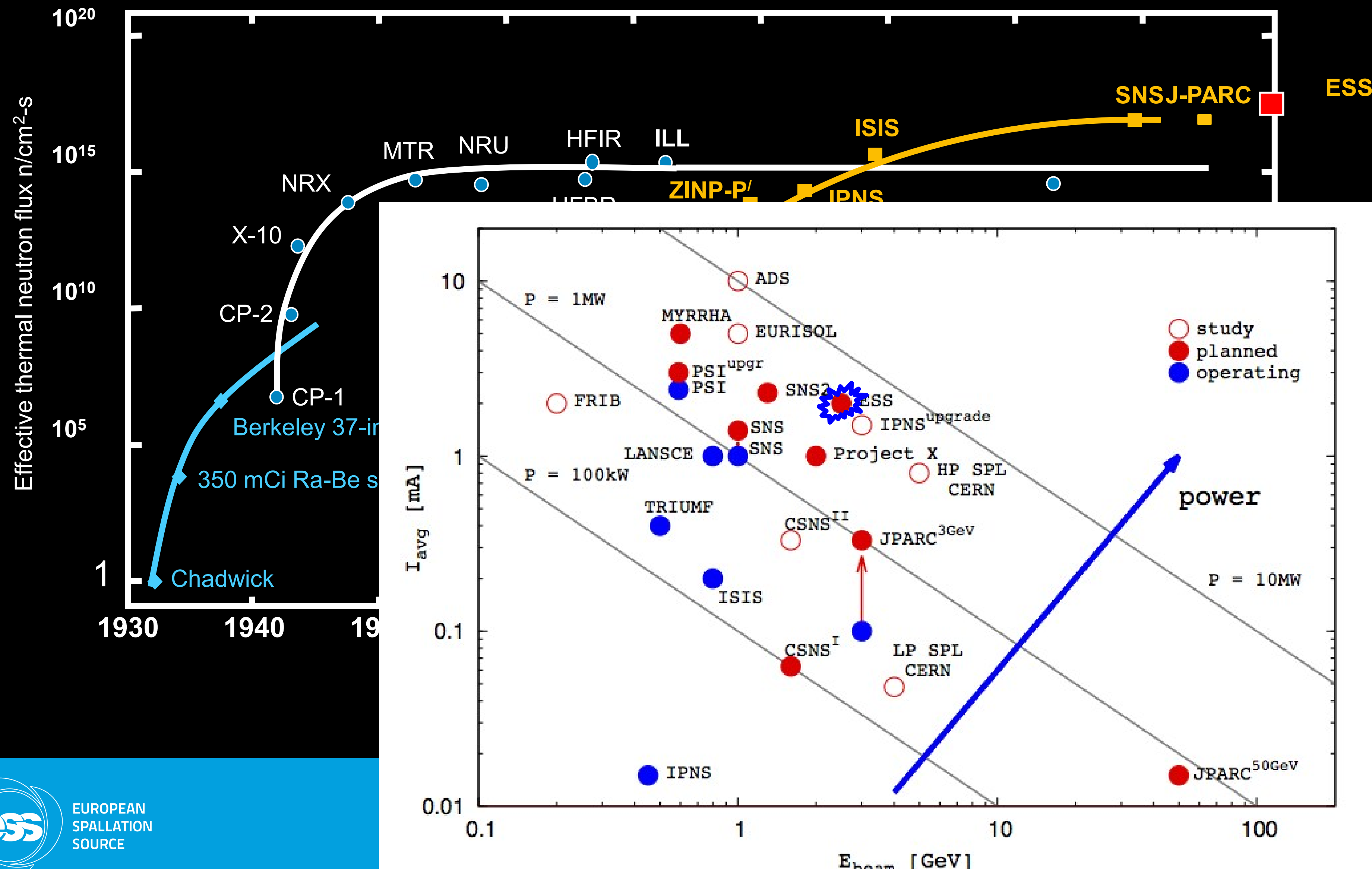
Paul Scherrer Institute

Neutrons See the Light



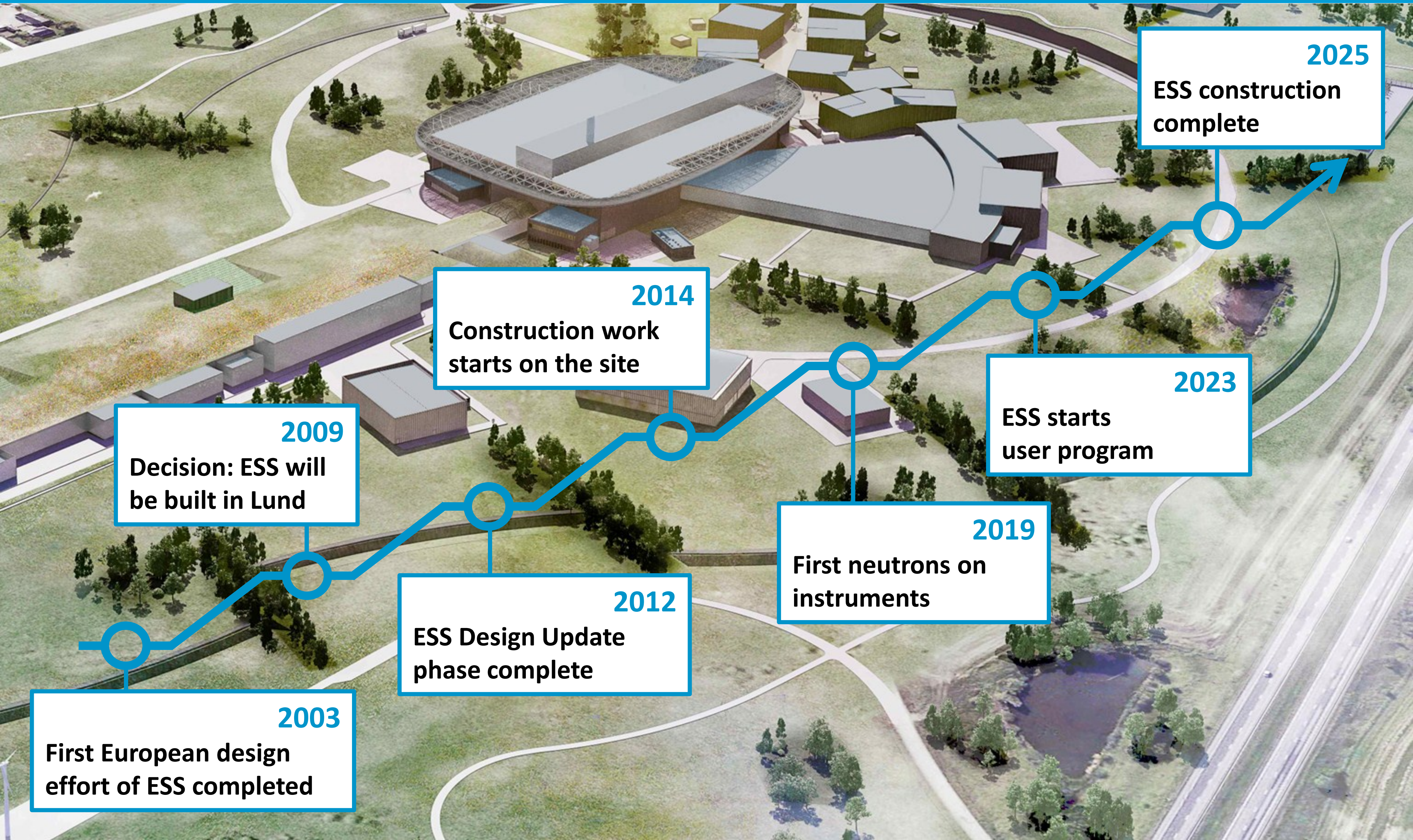


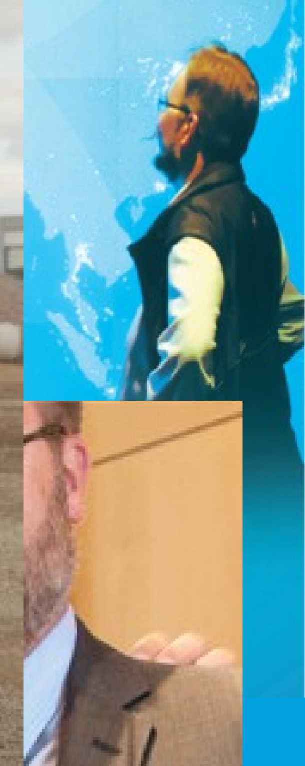
ESS - Bridging the neutron gap



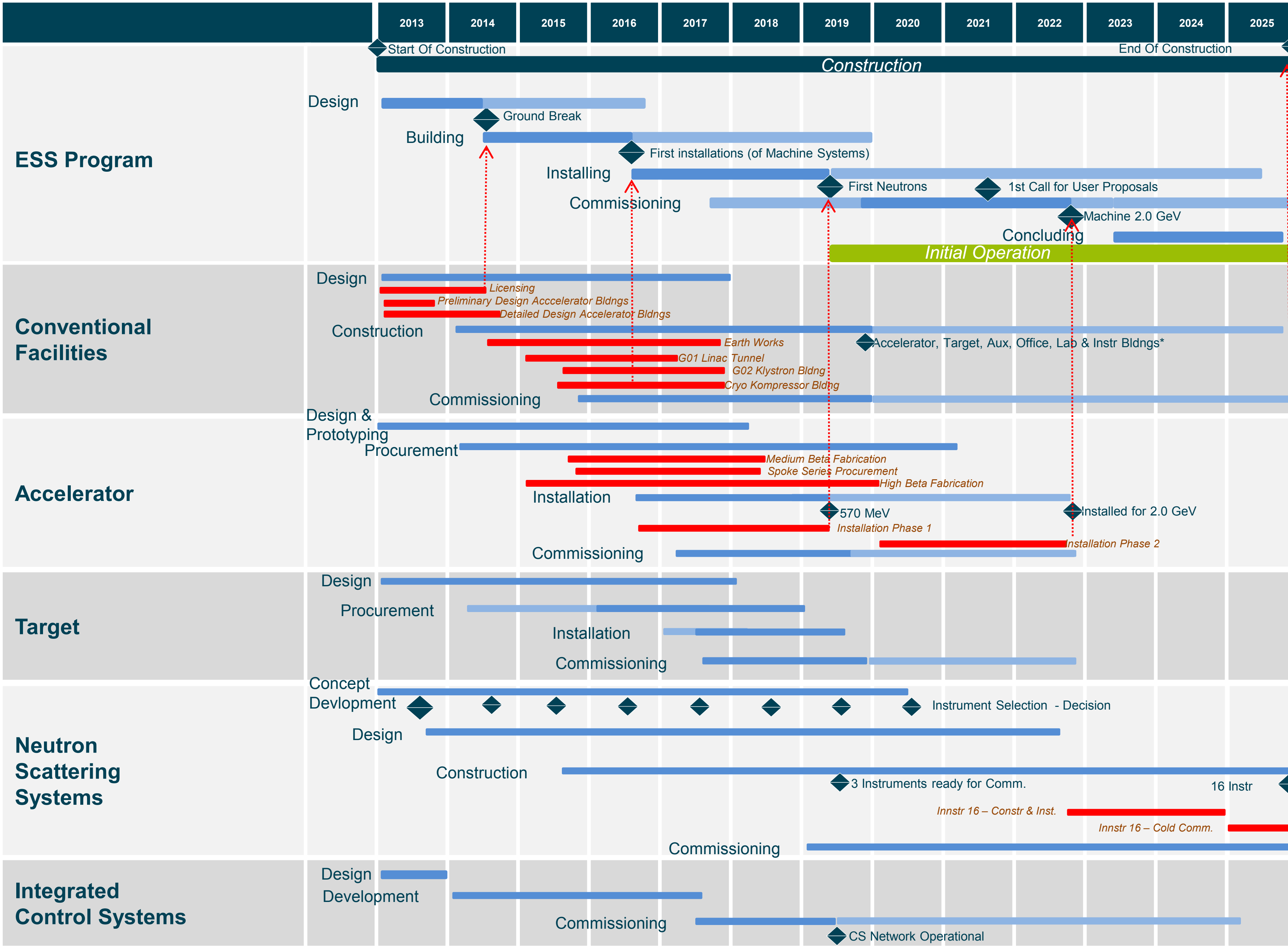
EUROPEAN
SPALLATION
SOURCE

The road to realizing the world's leading facility for research using neutrons



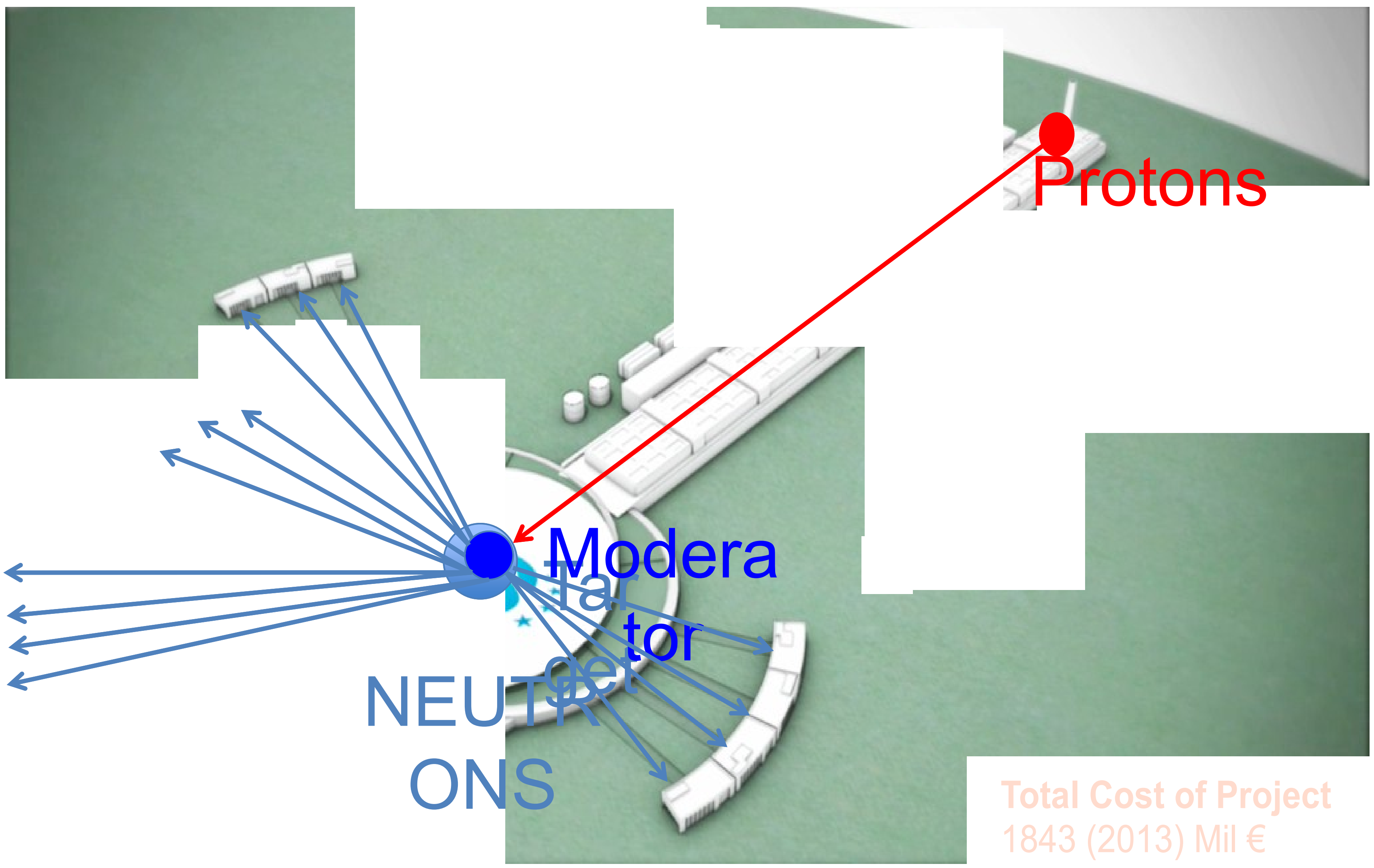


Top-Level ESS Project Schedule



Update from site

Helicopter view of ESS



Build and operate a 5 MW SCRF linac

Design Drivers:

High Average Beam Power

5 MW

High Peak Beam Power

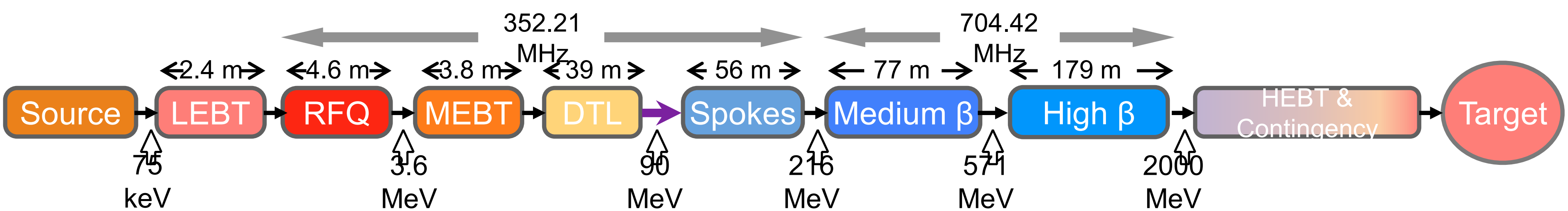
125 MW

High Availability

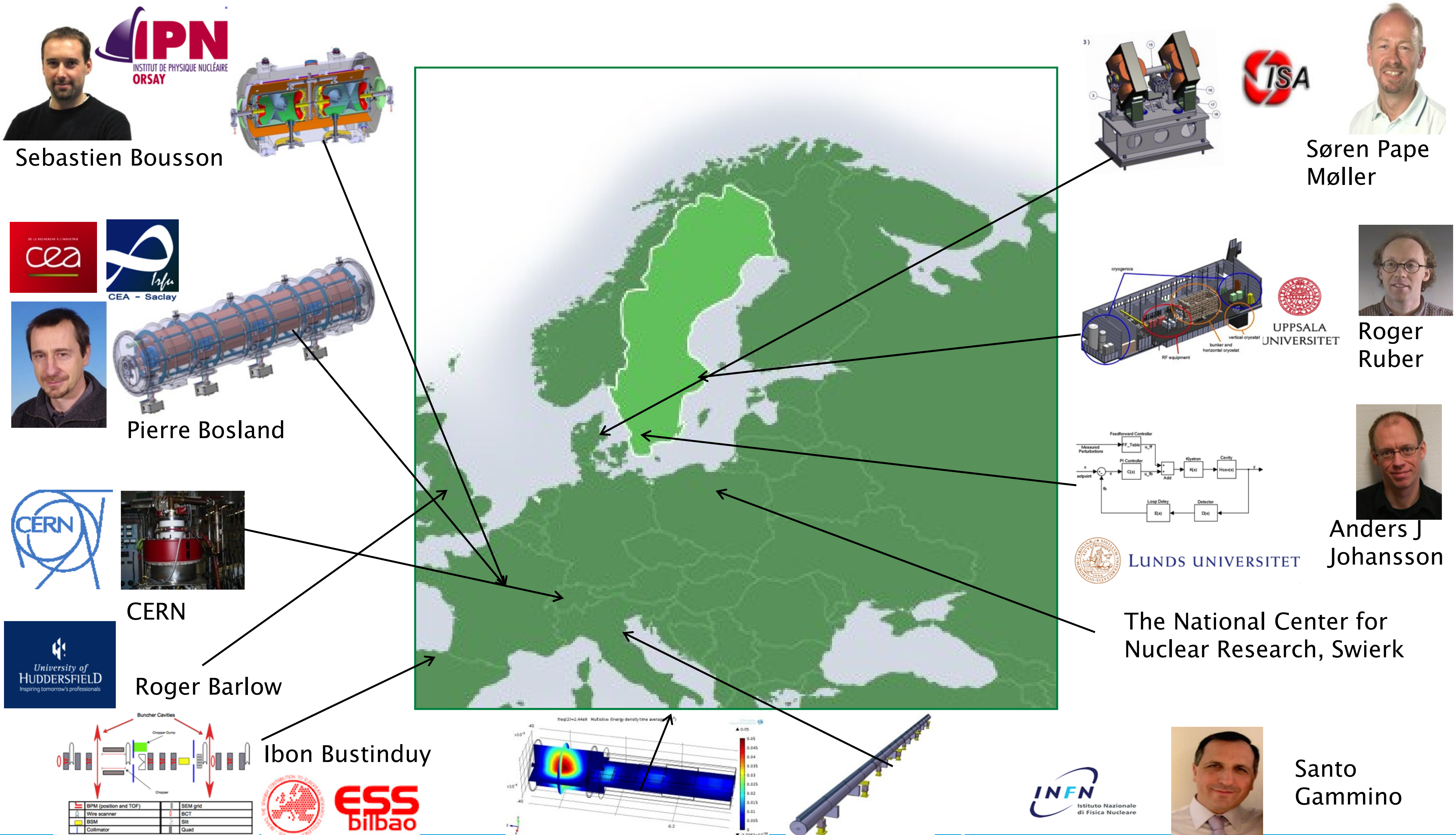
> 95%

Key parameters:

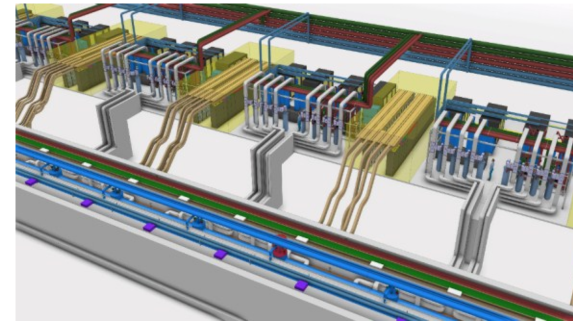
- -2.86 ms pulses
- -2 GeV
- -62.5 mA peak
- -14 Hz
- -Protons (H+)
- -Low losses
- -Minimize energy use
- -Flexible design for future upgrades

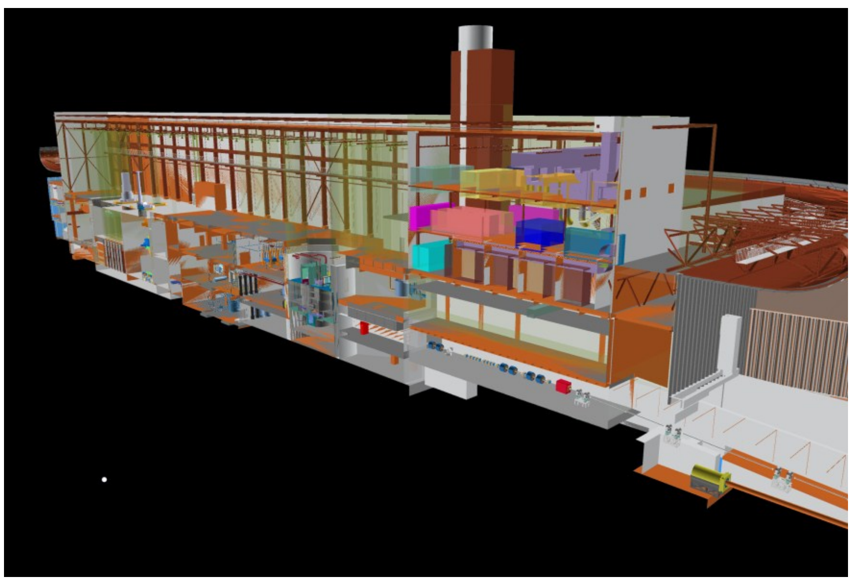


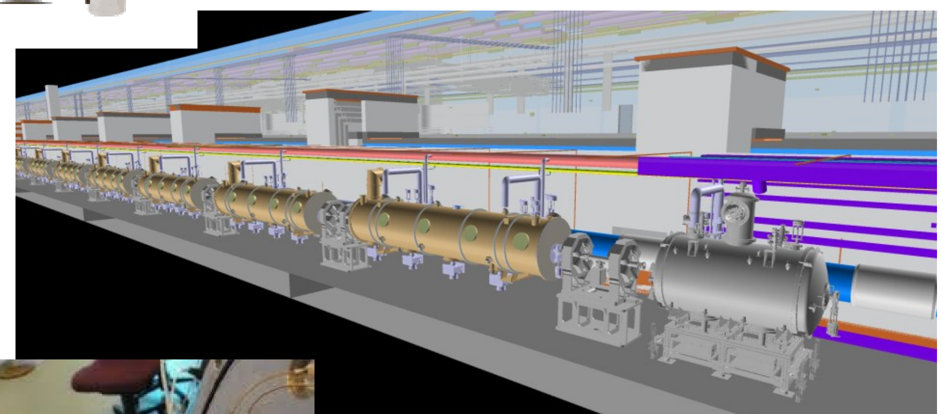
Collaboration During Pre-Construction



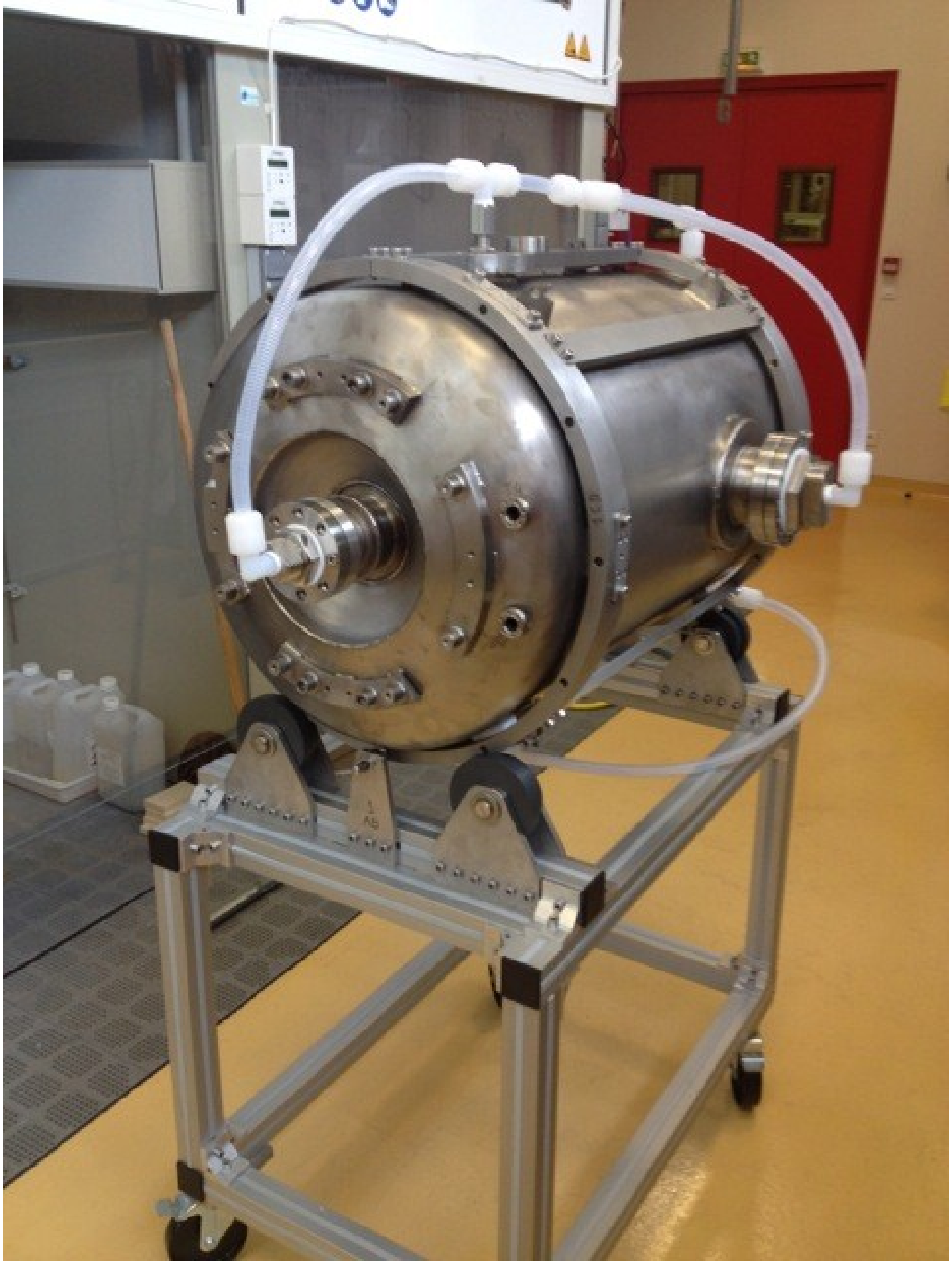
And not to forget…



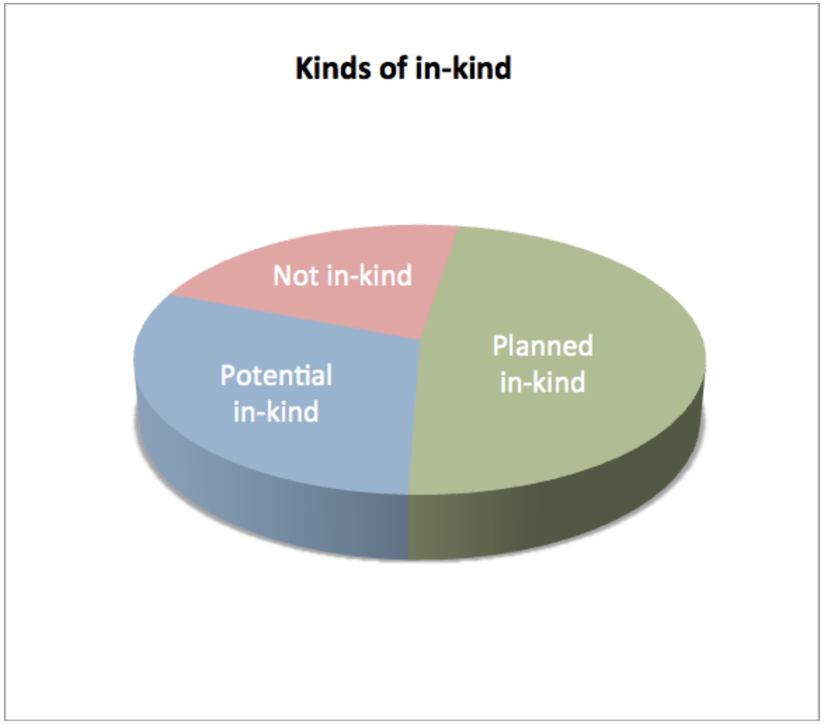




Many opportunities for new IK partners!



ACCSYS update in-kind discussions

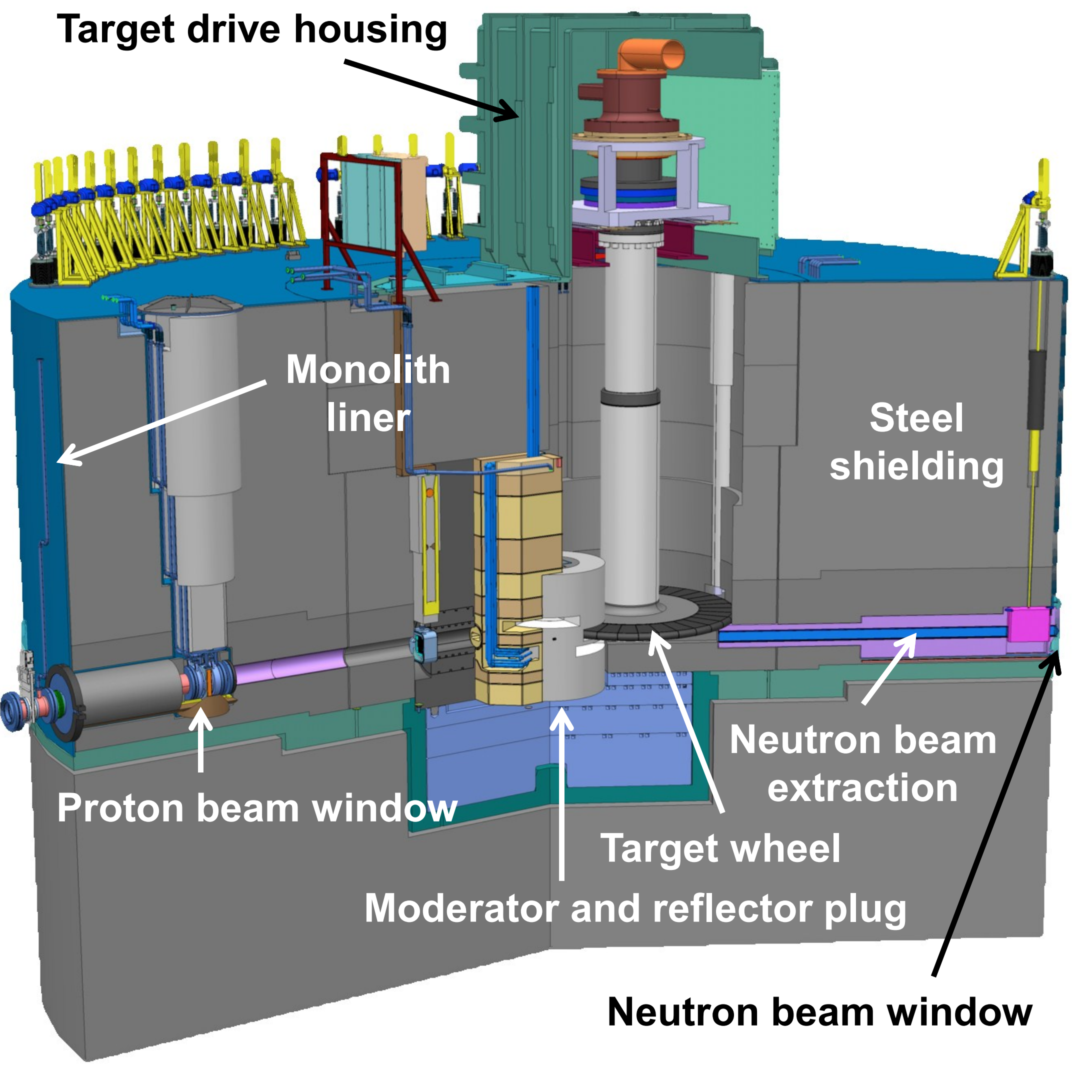


- Potential partners identified for 46% of the total planned/potential in-kind value
- Planned/potential in-kind is 78% of accelerator budget
- Many activities start 2014, reflecting the importance of reaching agreements soon
- New ACCSYS collaboration members soon: STFC (UK), Wroclaw (PL), Elettra (IT), LASA-INFN (IT)

Håkan Danared, ACCSYS in-kind manager

Target station converts protons to "slow" neutrons

- Diameter ~ 11 m; Height ~ 8 m
- Mass ~ 7000 tonnes (mainly steel)



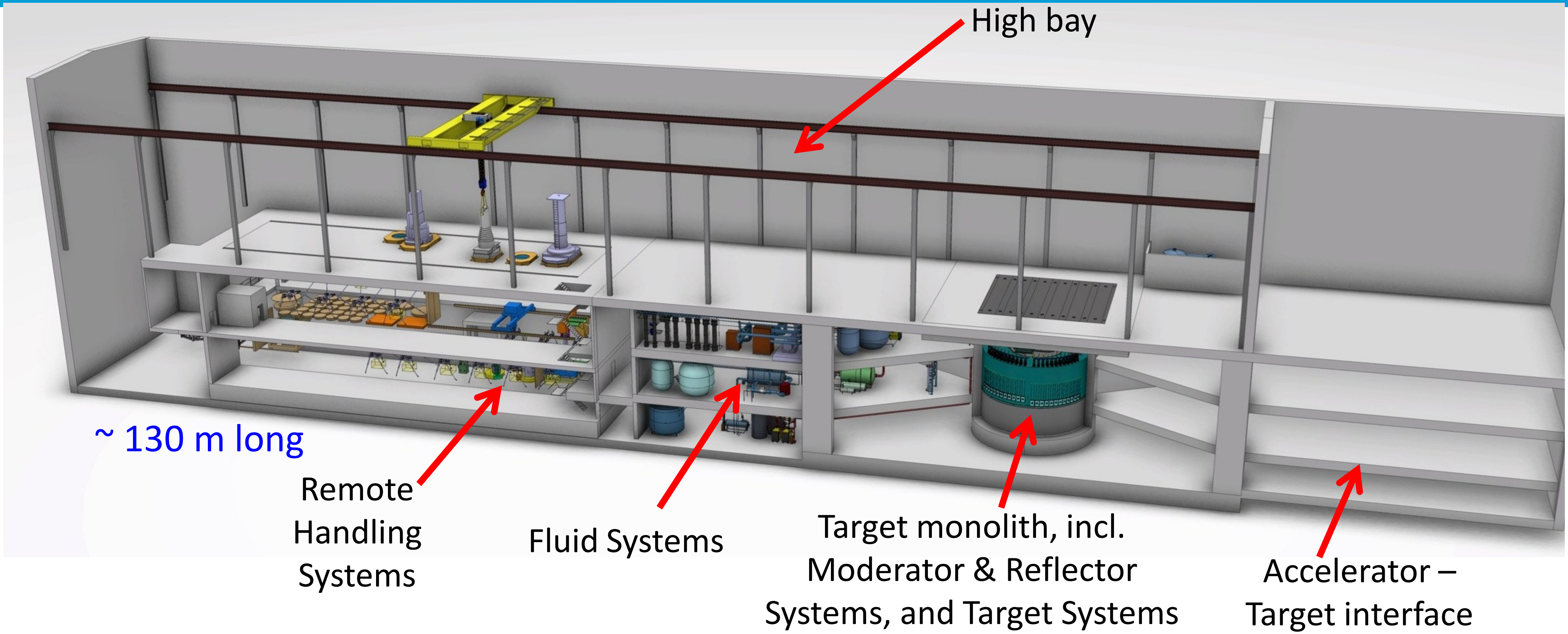
Functions:

- Convert protons to usable neutrons
- Heat removal
- Confinement and shielding

Unique features:

- Rotating target
- He-cooled W target
- High brightness moderators

Target Station includes systems that address nuclear hazards



- Remote Handling Systems including hot cells and associated equipment for maintenance and storage of irradiated components
- Target Safety System including credited controls to protect public and environment from radioactive hazard
- Fluid Systems including He and H_2O coolant loops, ventilation, filtering, etc.

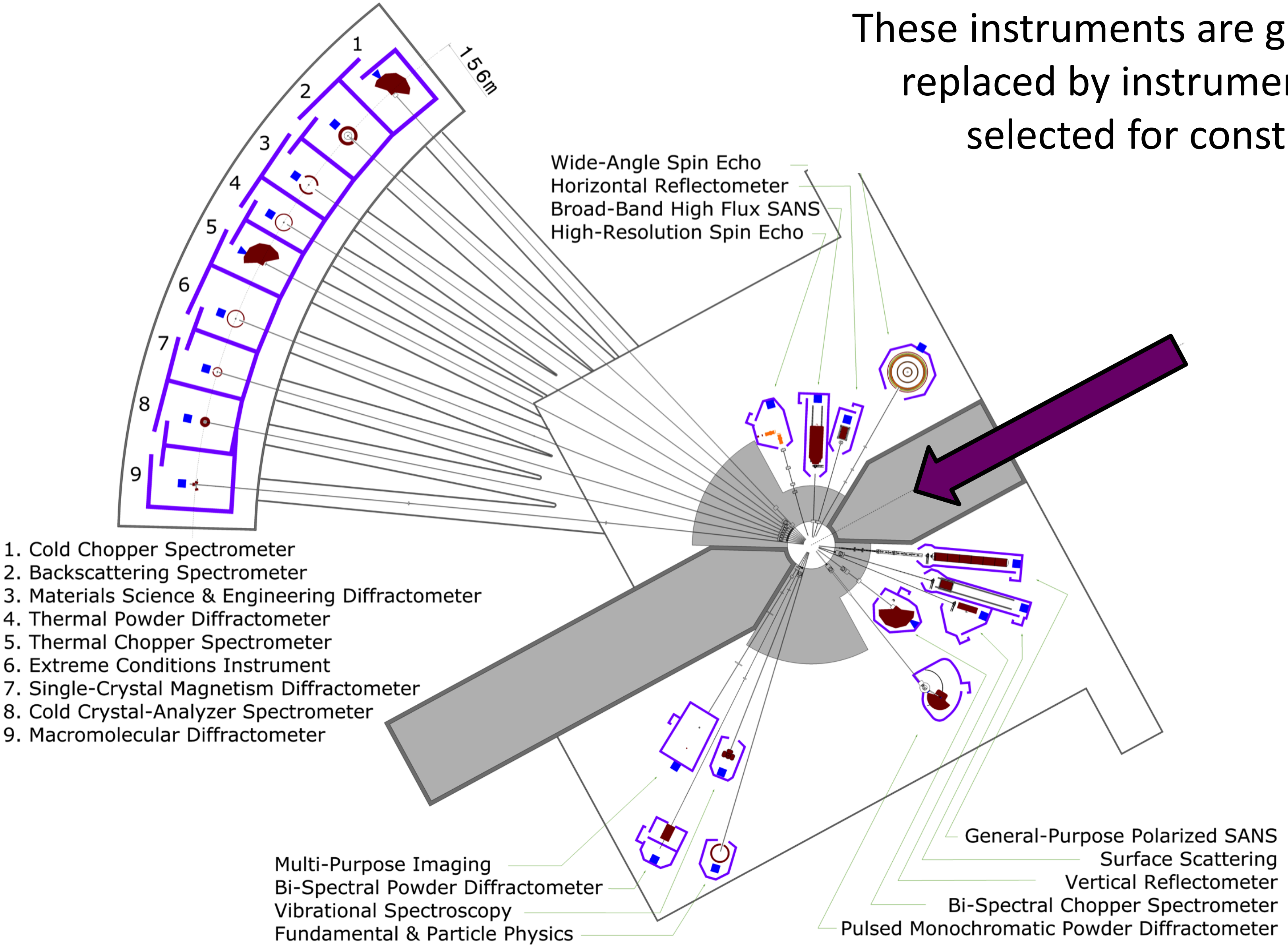
Science Drivers for the Reference Instrument Suite

Multi-Purpose Imaging	life sciences; soft condensed matter; magnetism & superconductivity; engineering & geo-sciences; archeology & heritage conservation
General-Purpose SANS	magnetism & superconductivity; soft condensed matter; chemistry of materials; energy research
Broadband SANS	soft condensed matter; life sciences
Surface Scattering	soft condensed matter; life sciences; chemistry of materials; magnetism & superconductivity
Horizontal Reflectometer	soft condensed matter; life sciences; chemistry of materials
Vertical Reflectometer	magnetism & superconductivity; chemistry of materials; energy research; soft condensed matter
Thermal Powder Diffractometer	chemistry of materials; energy research; engineering & geo-sciences; magnetism & superconductivity
Bispectral Power Diffractometer	magnetism & superconductivity; chemistry of materials; energy research; engineering & geo-sciences
Pulsed Monochromatic Powder Diffractometer	chemistry of materials; energy research; magnetism & superconductivity
Materials Science Diffractometer	engineering & geo-sciences; chemistry of materials
Extreme Conditions Instrument	energy research; magnetism & superconductivity; chemistry of materials
Single-Crystal Magnetism Diffractometer	magnetism & superconductivity; chemistry of materials
Macromolecular Diffractometer	life sciences
Cold Chopper Spectrometer	life sciences; chemistry of materials; magnetism & superconductivity
Bispectral Chopper Spectrometer	life sciences; soft condensed matter; chemistry of materials; magnetism & superconductivity
Thermal Chopper Spectrometer	chemistry of materials; energy research; magnetism & superconductivity
Cold Crystal-Analyser Spectrometer	chemistry of materials; energy research; magnetism & superconductivity; engineering & geo-sciences
Vibrational Spectroscopy	chemistry of materials; energy research; magnetism & superconductivity
Backscattering Spectrometer	life sciences; soft condensed matter; chemistry of materials
High-Resolution Spin-Echo	life sciences; soft condensed matter; chemistry of materials; energy research
Wide-Angle Spin-Echo	energy research; magnetism & superconductivity; life sciences; soft condensed matter
Fundamental & Particle Physics	fundamental & particle physics

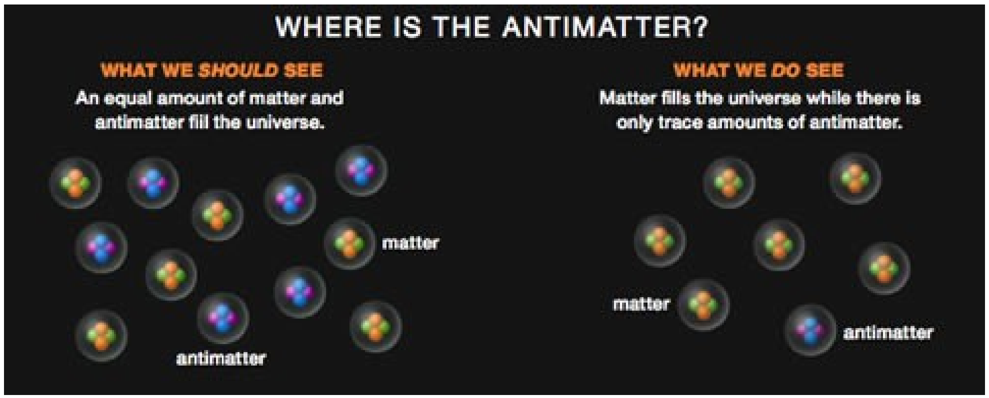
- life sciences
- magnetism & superconductivity
- soft condensed matter
- engineering & geo-sciences
- chemistry of materials
- archeology & heritage conservation
- energy research
- fundamental & particle physics

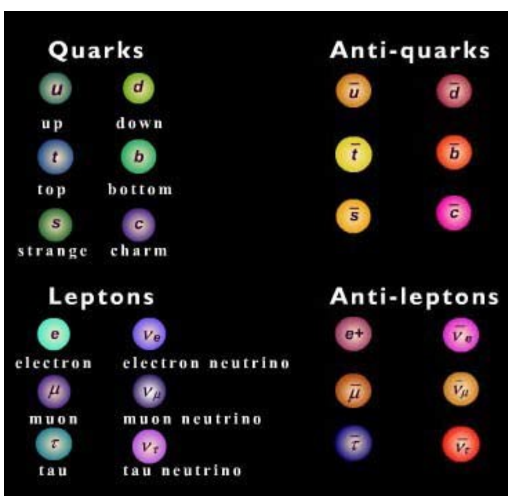
The reference suite – a guide

These instruments are gradually being replaced by instrument concepts selected for construction.



Finding the anti-neutron will help explain matter/anti-matter imbalance





ESS will enable

- Reliable production of many cold (slow neutrons)
- Unprecedented ability to find the anti-neutron
- State-of-the-art neutron optics technology instrument development for oscillation experiments

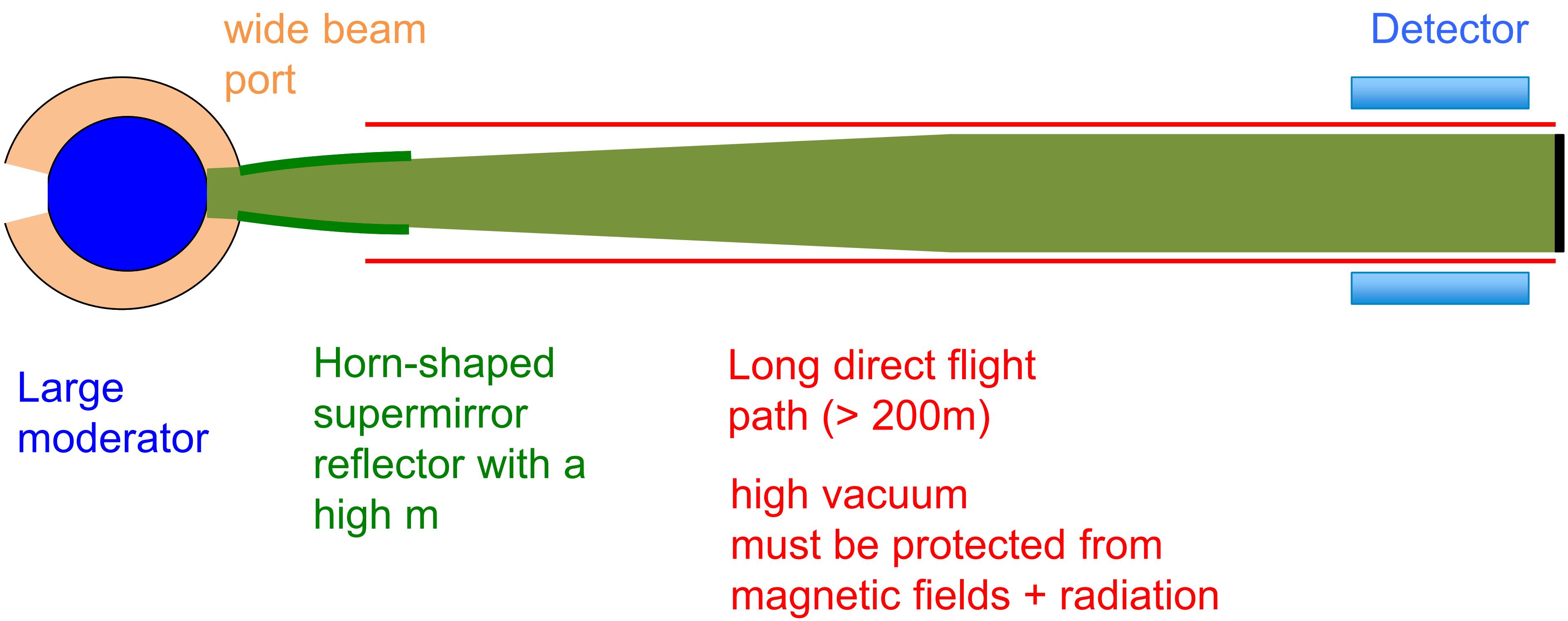
Neutron - antiNeutron oscillations

- Provided new physics occurs beyond the Standard Model at the mass scale of the order of 10^2 to 10^3 TeV the oscillation time could be in the region of $\mathbf{10^8}$ **s**

- The experimental search for neutron-antineutron oscillations was done at the ILL high flux reactor at Grenoble (1994). No antineutron was detected in $2.4.10^7$ s running time.

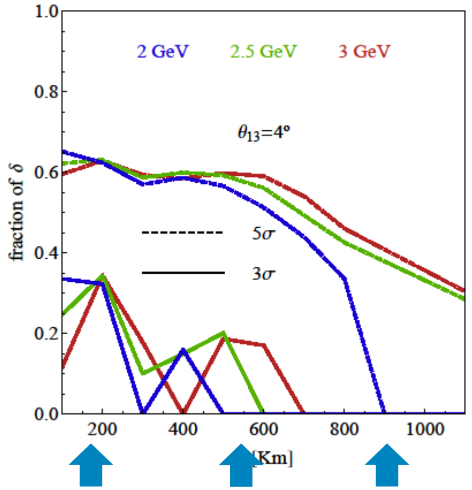
nnbar experiment @ ESS ?

observe neutrons propagating in free space for a maximum of time without wall collisions



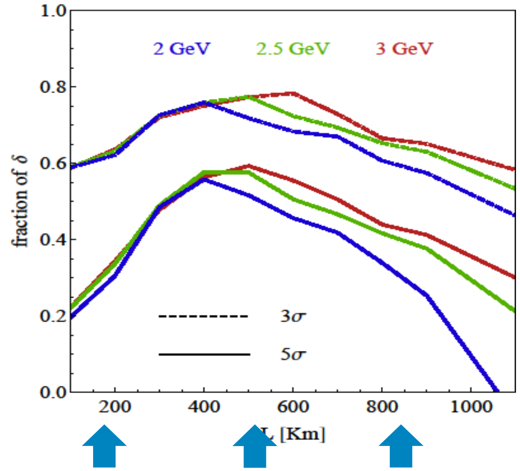
ESSnuSB

Before spring 2012 Θ_{13}=4°

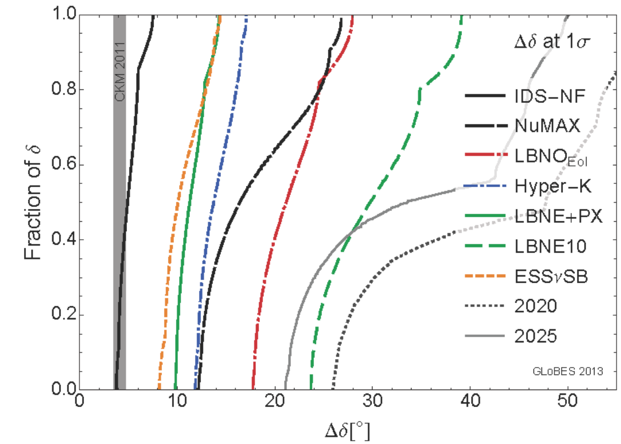


1st osc. max 2nd osc. max 3rd osc. max

After spring 2012 Θ_{13}=8.73°

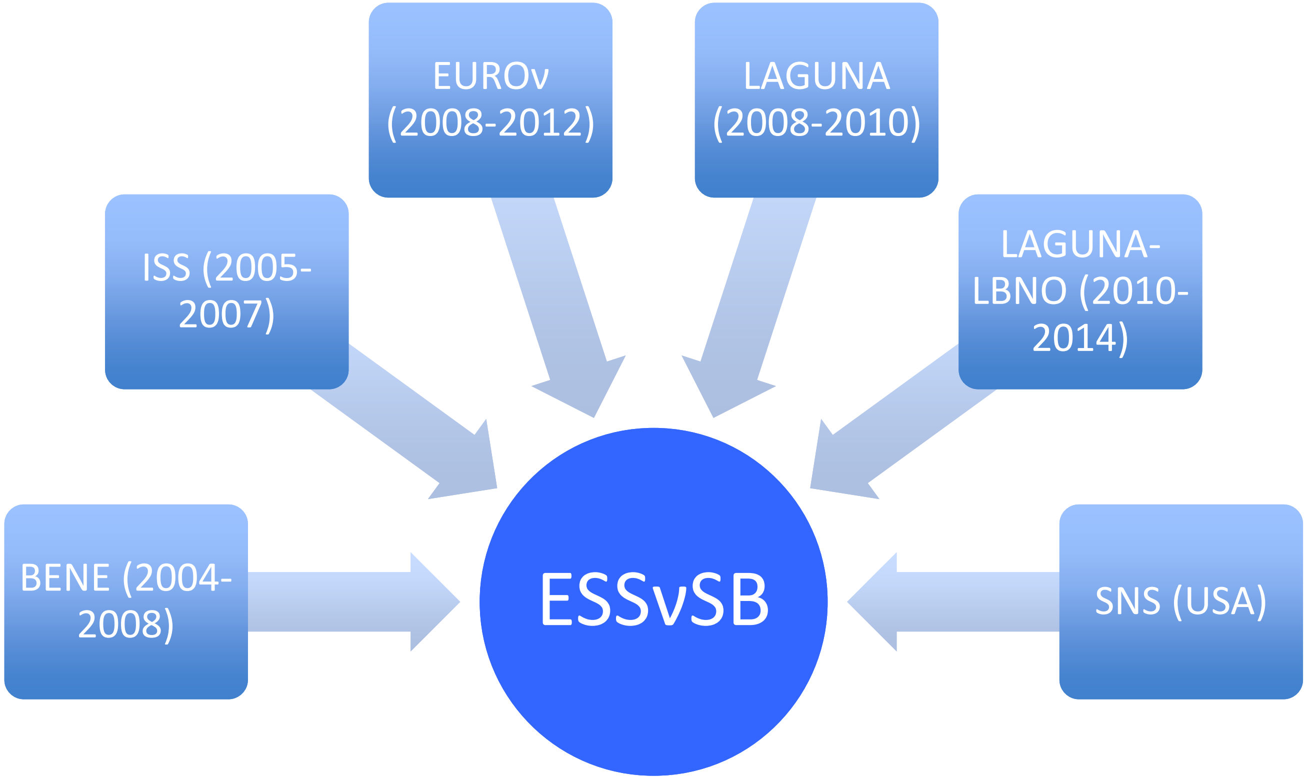


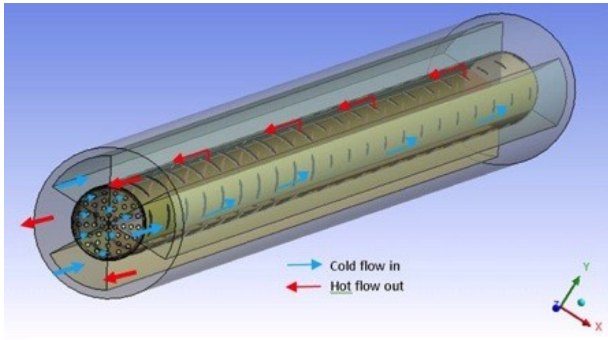
1st osc. max 2nd osc. max 3rd osc. max

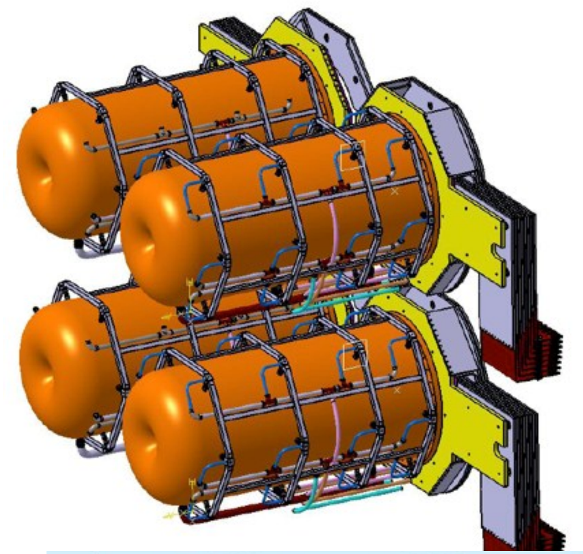


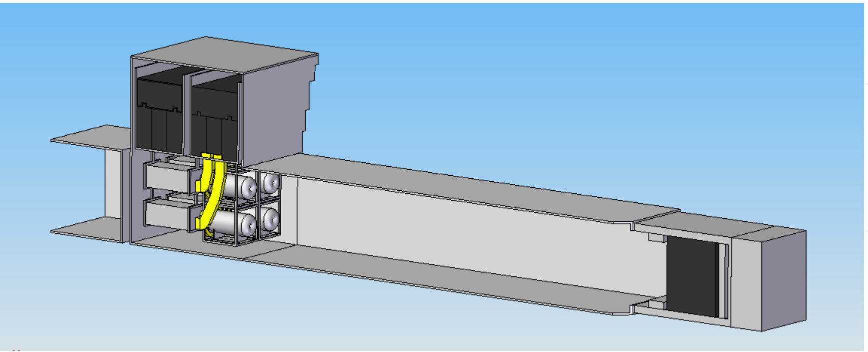
- New accumulation ring with staggered beam extraction using solid state switch driven ILC like strip line kickers of up to 100 pulses to match pulse length to moderators and simplify target design
- Linac operated with H- and at 28 Hz to keep both target station operating at 5 MW
- Support (refunded) from ESS for Design study proposal

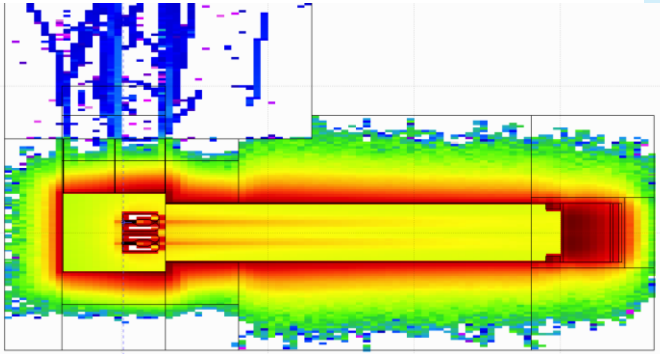
Previous Expertise

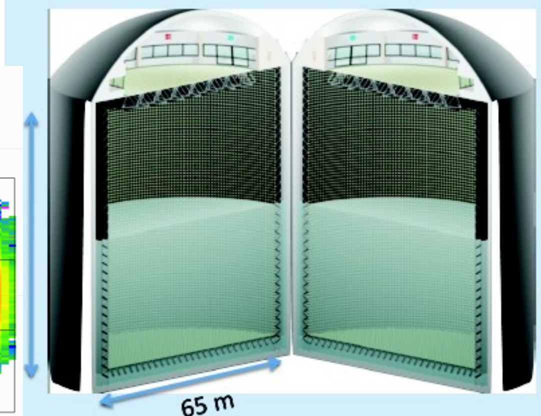








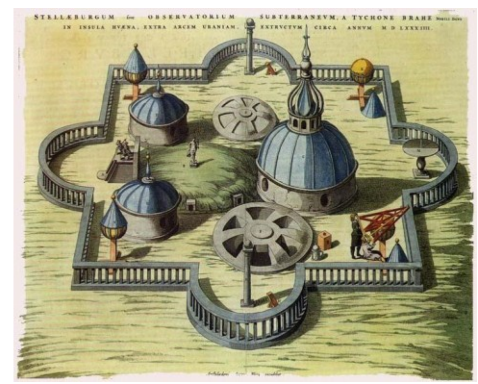




1.8 Billion Euros:
Biggest investment in Science ever in Scandinavia?

In modern time, definitely YES!

However, Tycho Brahe's Stjärneborg costed the Danish king 1% of the state budget in 1580.



"With better measurements of the stars positions and movements I can make much better horoscopes for you, your majesty!"

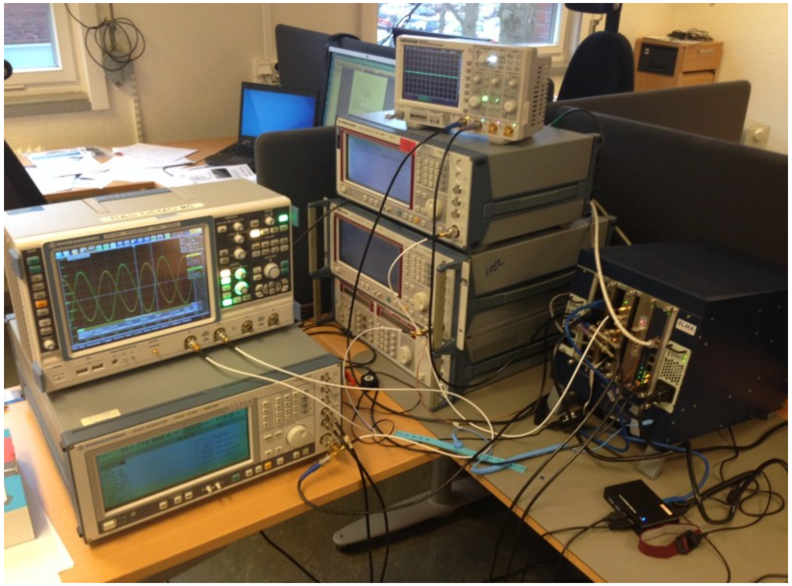
EURISOL and ESS

- What has ESS got from EURISOL
  - Trained people
  - Spoke cavities and other equipment design
  - Collaboration model including accelerator
  - And much more
- What can EURISOL learn from ESS
  - A new major European facility can be built at an existing lab (FAIR at GSI) or at a Green field site (ESS)
  - Rigid industrial or DOE style project organization and execution is necessary to build trust in a European collaboration
  - Dreams come true but it requires a lot of work by persistent and visionary people!

EUROPEAN SPALLATION SOURCE

Welcome!

Lund University Activities in Accelerator Development for ESS



LLRF system test bench and prototype.

- Development of the low level RF system for the ESS linear accelerator.
- Development of prototypes for high power high voltage pulsed modulators.
- Participates in cavity development for normal conducting accelerator.
- Total: 40 MSEK
- ESS AB: 27.5 MSEK

- Discussing future in-kind contributions for e.g. LLRF

From a conceptual design to reality…

Design and specifications:

- ESS and LTH;

R&D and training of Highly Qualified Personnel:

- LTH (3 MSc thesis, 5 Research associate,
  1 PhD thesis starting Jan 2015);

Control system hardware :

- National Instruments AB, Skåne business center;

Control system software :

- Lund University Innovation System (LUIS) AB;

Construction (Low Voltage part):

- AQ Elautomatik AB, in Lund;

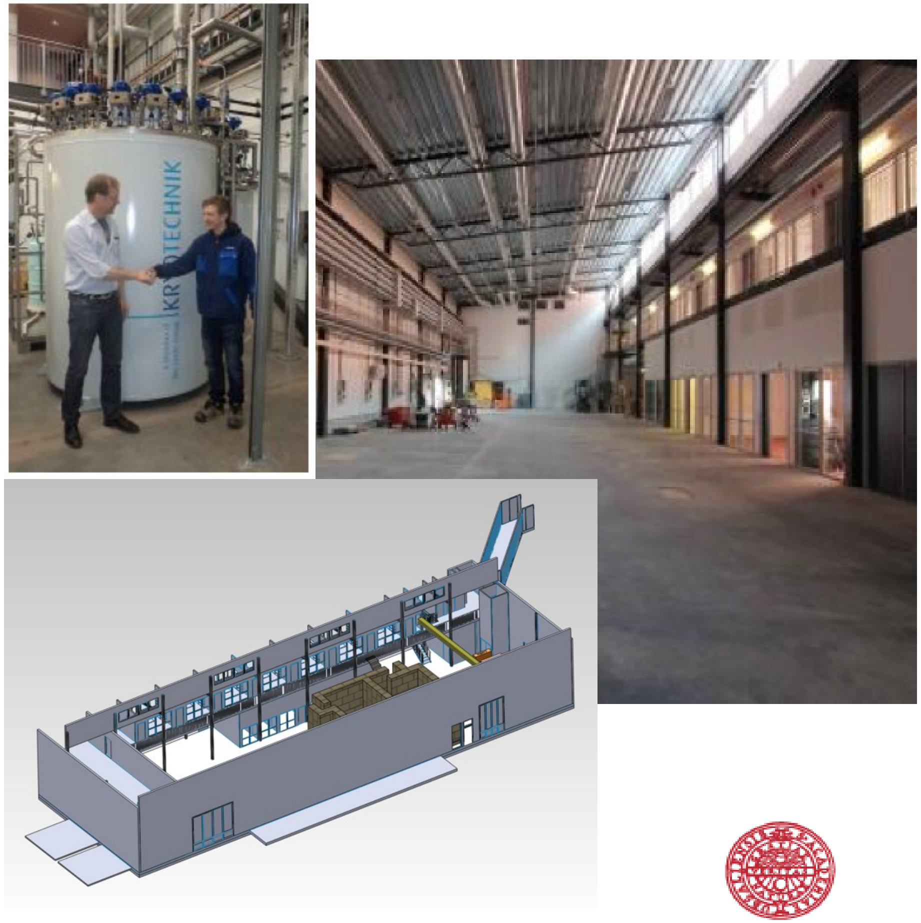
LUND UNIVERSITY

NATIONAL INSTRUMENTS

LU INNOVATION SYSTEM

1994-2014 20 years aq WE ARE RELIABLE

FREIA at Uppsala University



UPPSALA
UNIVERSITET

Existing contract:

- RF Design and FREIA SRF Test Facility — Total: 177 MSEK; ESS AB: 60 MSEK

Proposed new contract:

- Detailed report on spoke cryomodule prototype tests
- Spoke cryomodule acceptance tests
- Spoke valvebox prototype tests
- Contributions to control system
- UU personnel working at ESS, Lund
- Test stand for klystrons and high power modulators.