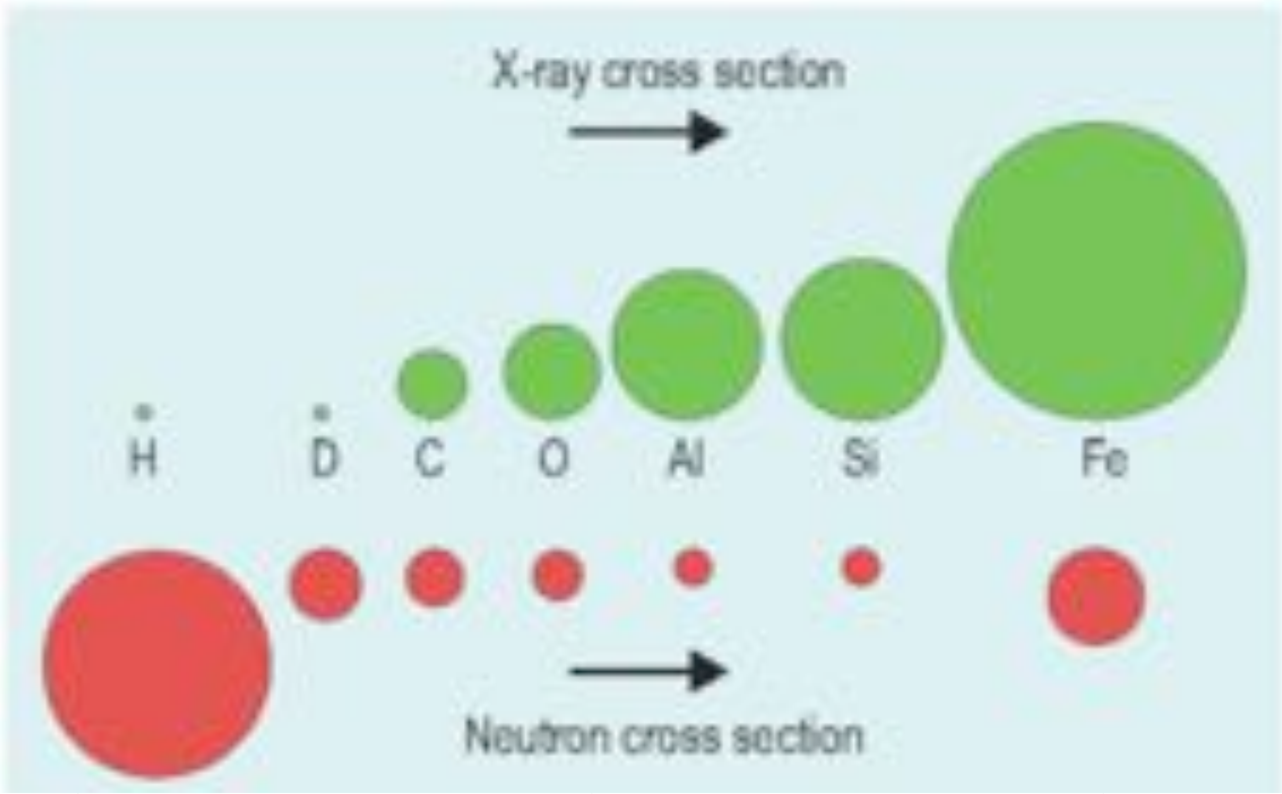
The status of ESS (under construction)

2015

Mats Lindroos
Head of Accelerator

A European research center

Neutrons & x-rays: similar methods, sensitive to different elements.



Neutrons

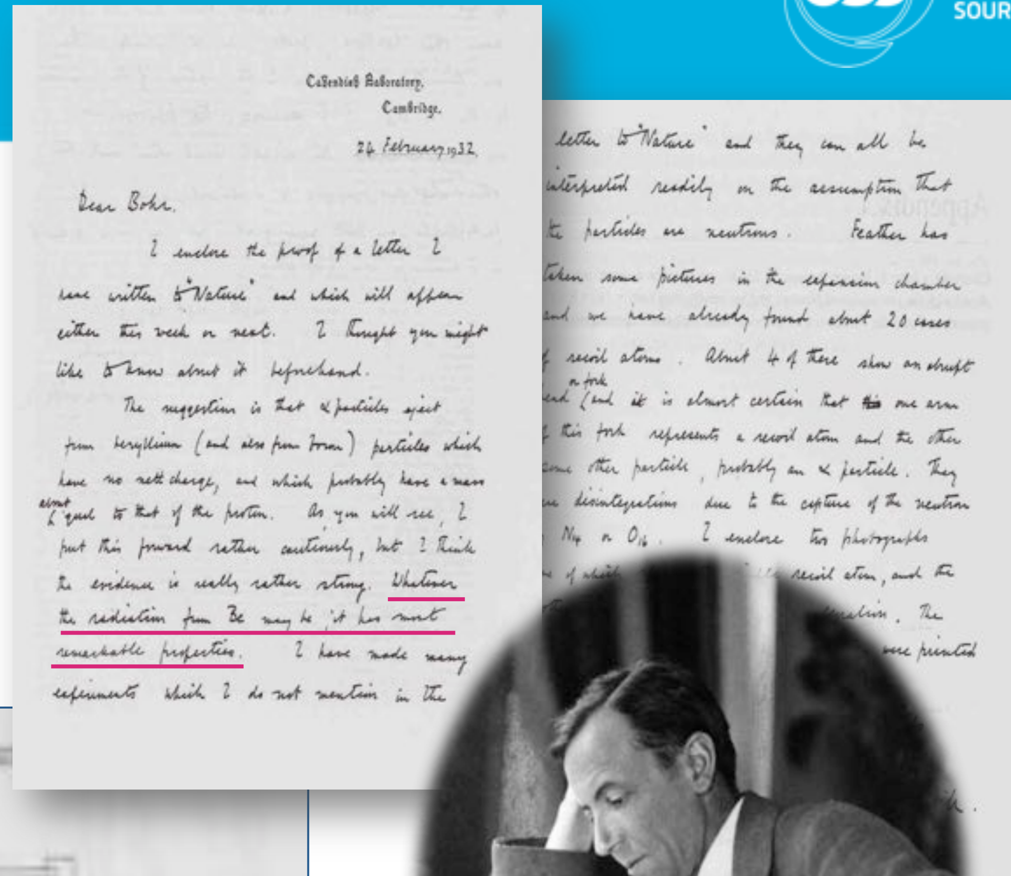
EUROPEAN SPALLATION SOURCE

Its discovery

James Chadwick

1932

(α,n) reaction



Cavendish Laboratory,
Cambridge.

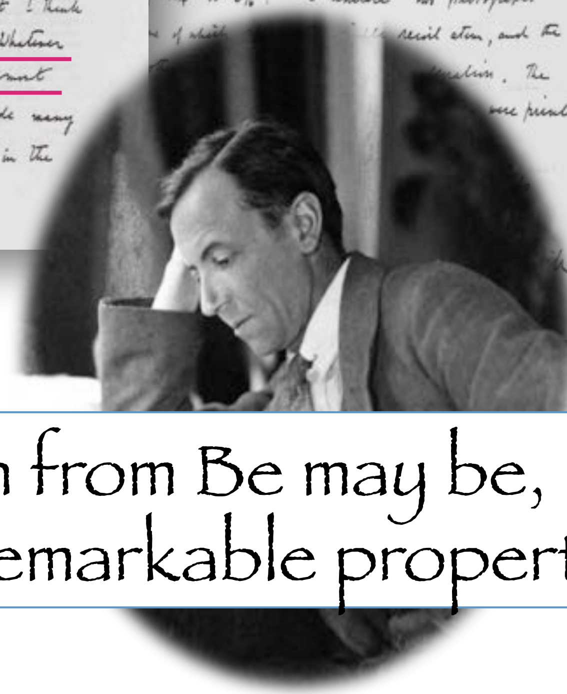
24 February 1932.

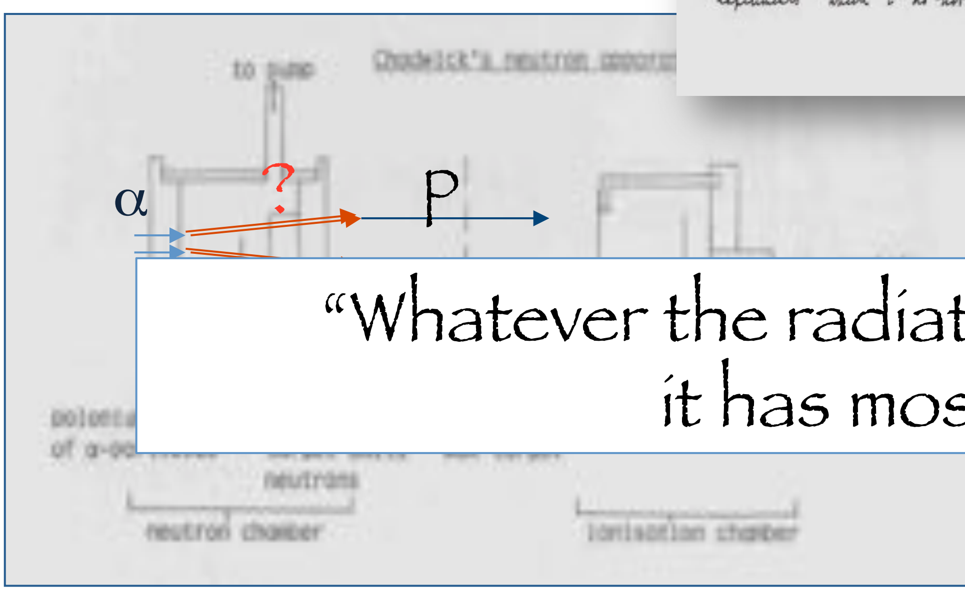
Dear Bohr,

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 fork 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 by N_{14} or O_{16}. I enclose two photographs …

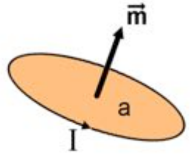




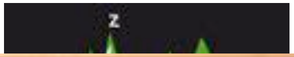
"Whatever the radiation from Be may be,
it has most remarkable properties"

Neutrons are beautiful !

Wave Particle Magnetic moment Neutral



Diffractometers - Measure structures

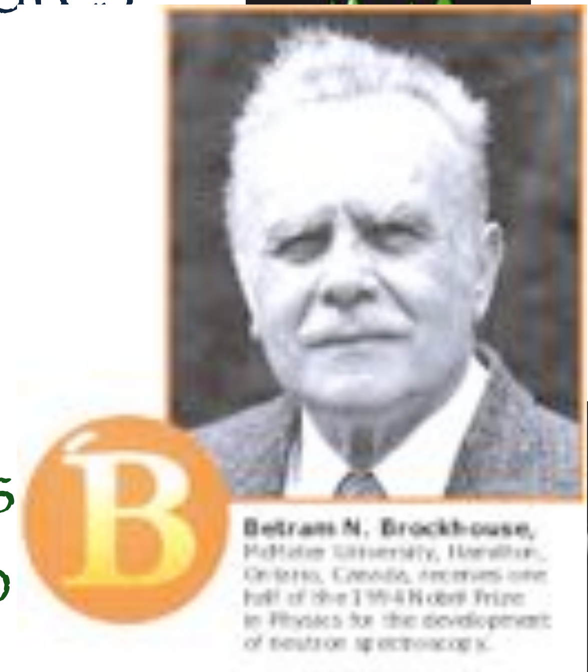


: atoms and molecules

0 Ångström

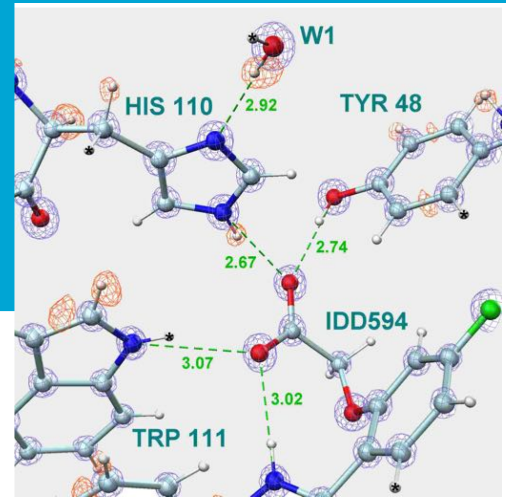
s - Measure dynamics

oms and molecules do

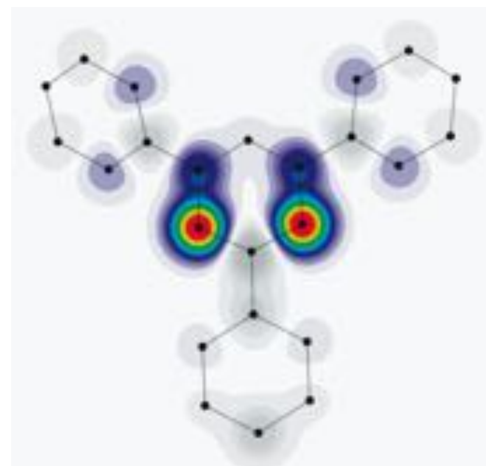


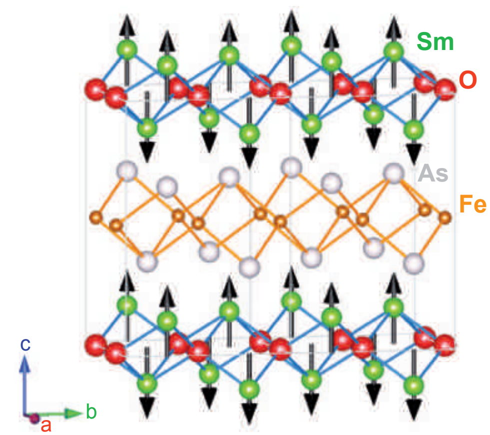
1 - 80 meV

Neutrons are special

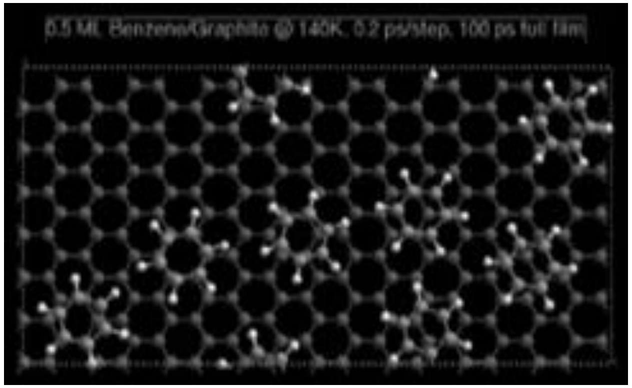


- **charge neutral:** deeply pene- trating ... except for some isotopes
- **nuclear interaction:** cross section depending on isotope (not Z), sensitive to light elements.
- **spin S = 1/2**: probing magnetism
- **unstable** $n \rightarrow p + e + \bar{\nu}_e$ with life time τ ~ 900s , $I = I_0 \, e^{-t/\tau}$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

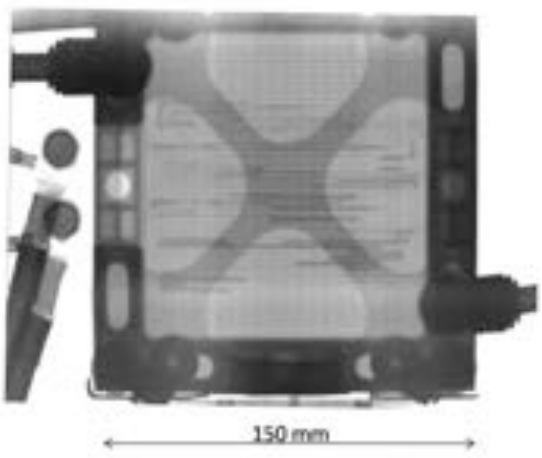




WHERE ARE THE ATOMS AND WHAT DO THEY DO?



Neutron Imaging - Examples

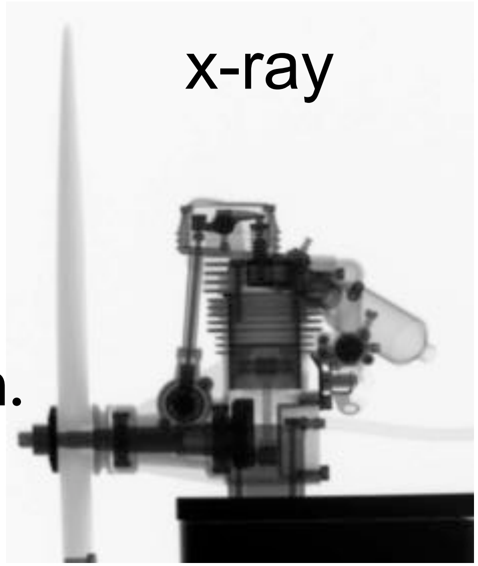


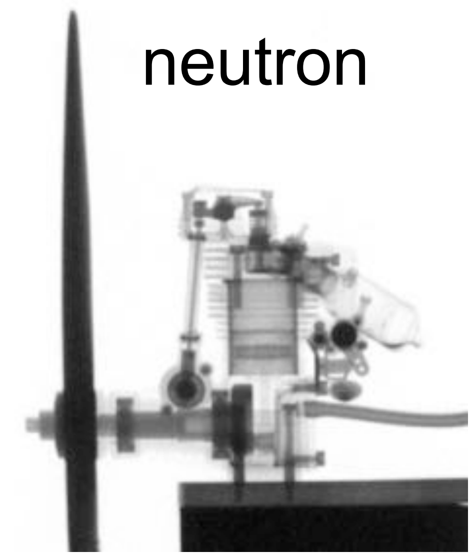
$I = I_0 \ e^{-\mu.d}$

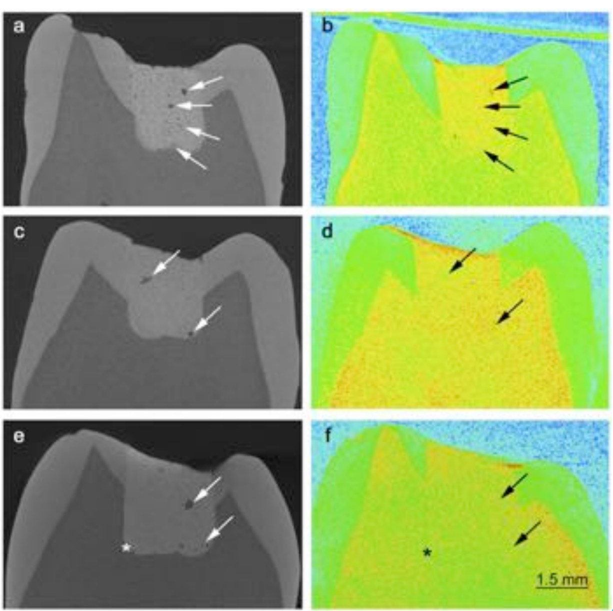
neutron μ different to x-ray

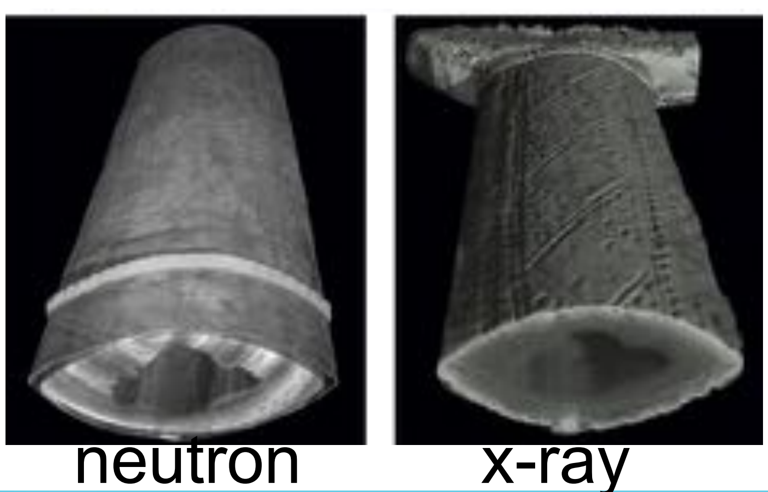
contrast hydrogen / deuterium.

not increasing with Z^2



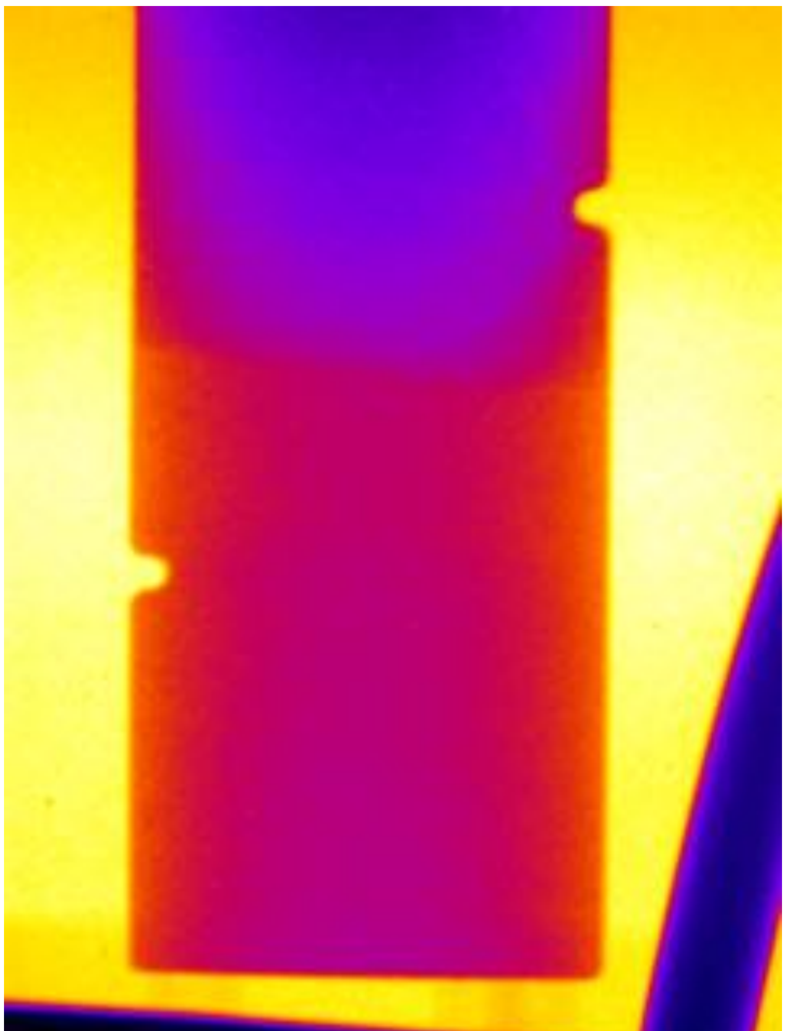




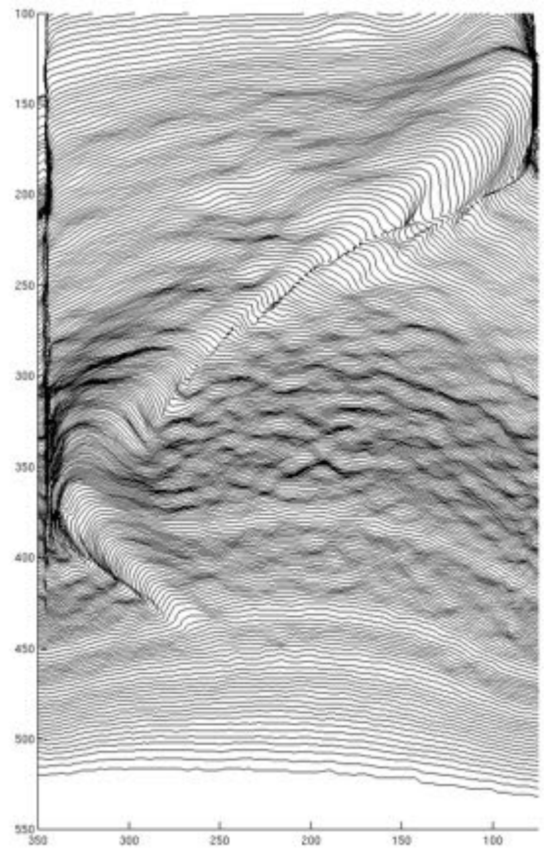


Fluid Flow in Sandstone with localized deformation

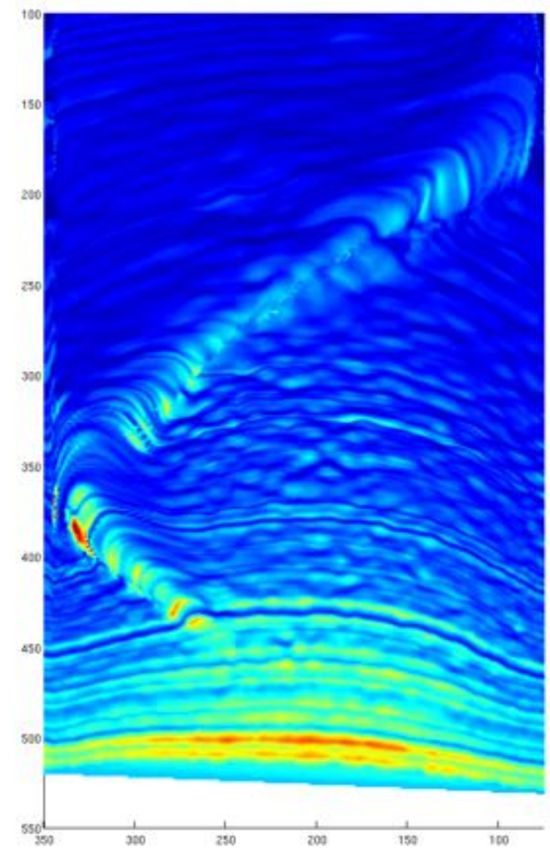
Time-lapse neutron radiography…



Flow-fronts



Flow-velocities

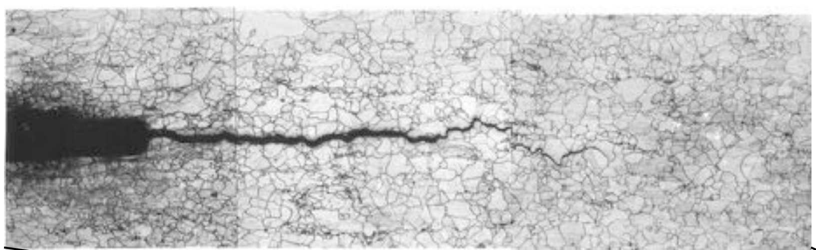


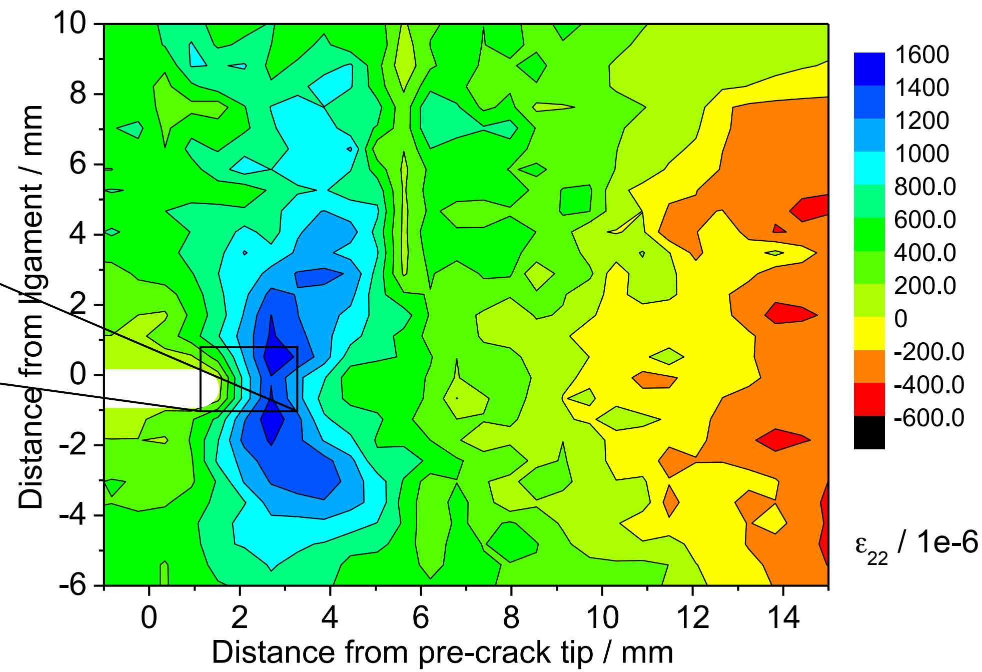
Pixel width = 0.124 mm

S. Hall

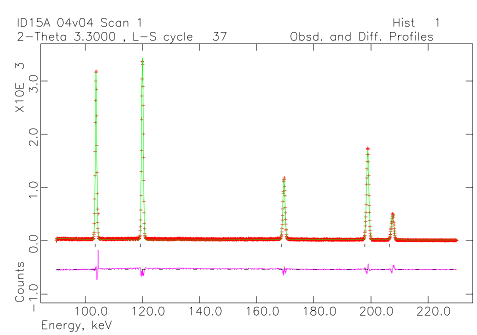
Stress around fatigue cracks

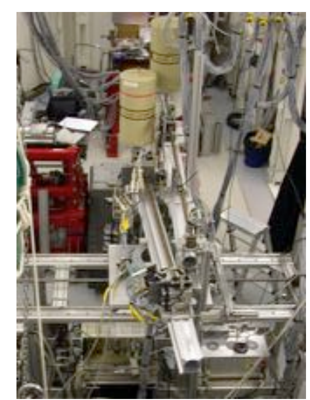
Fatigue + Creep Crack in **25mm** Austenitic steel





Aim: 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…





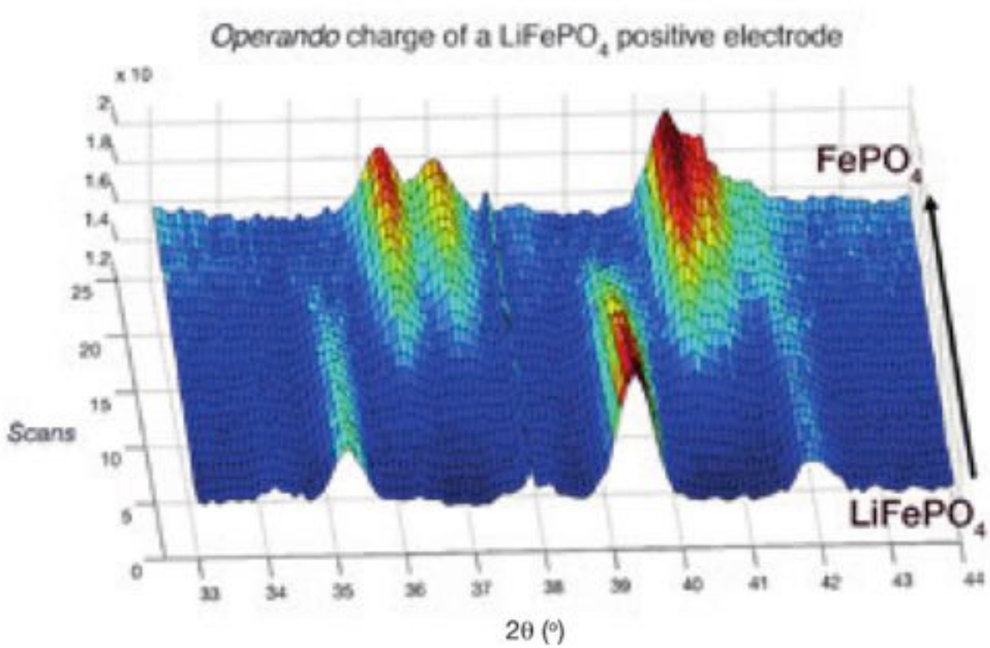
A Steuwer et al, J Appl Crysts (2004)

Neutrons for Energy Research

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

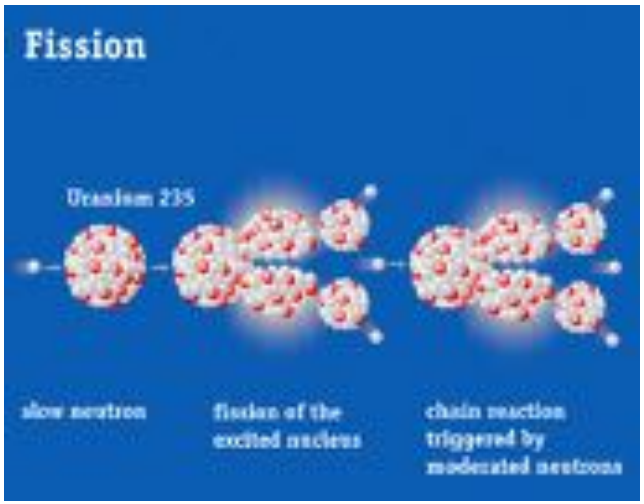
Neutrons are sensitive to light elements light lithium.

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



Bianchini and Suard (ILL 2014)

Why Spallation?

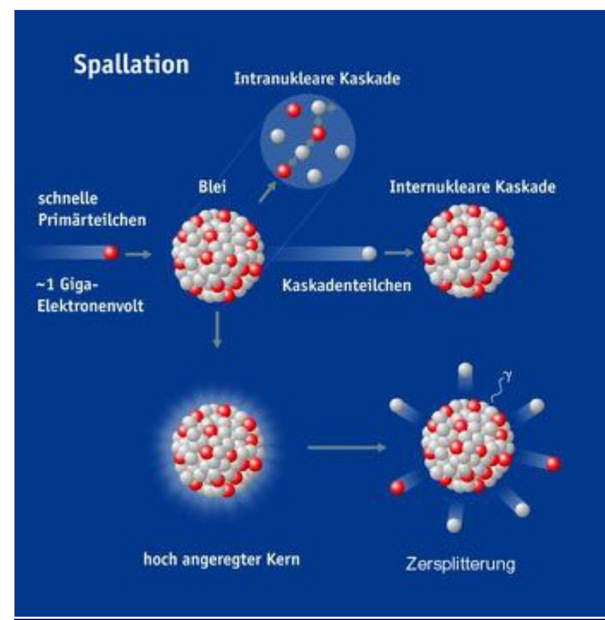


Fission of uranium
in nuclear reactor

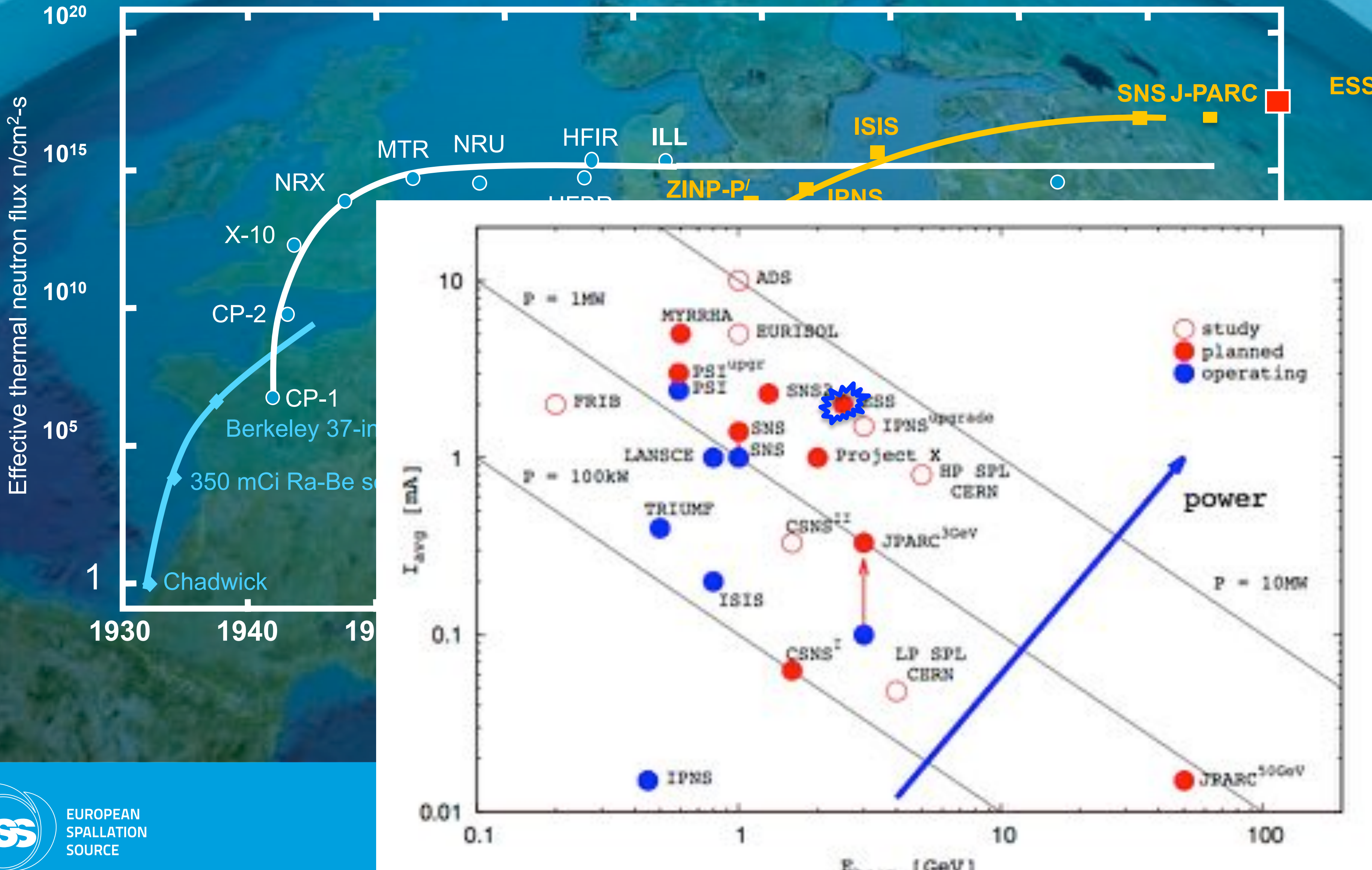
2-3 neutrons per process

Spallation on target
using proton accelerator

30+ neutrons per process



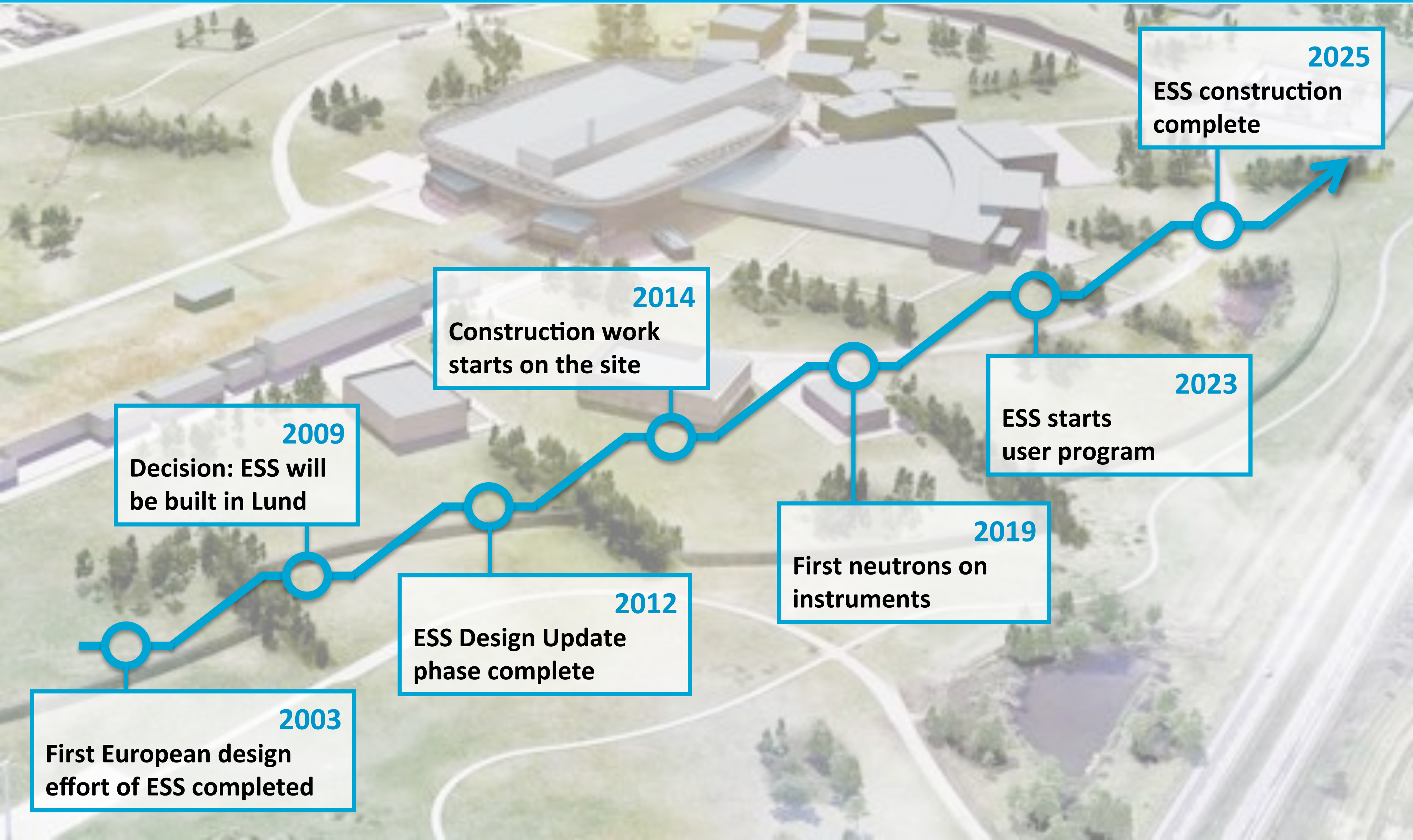
ESS - Bridging the neutron gap



EUROPEAN
SPALLATION
SOURCE

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

EUROPEAN SPALLATION SOURCE



Financing includes cash and deliverables

EUROPEAN SPALLATION SOURCE

Host Countries of Sweden and Denmark

47,5% Construction

15% Operations

In-kind Deliverables ~ 3%

Cash Investment ~ 97%

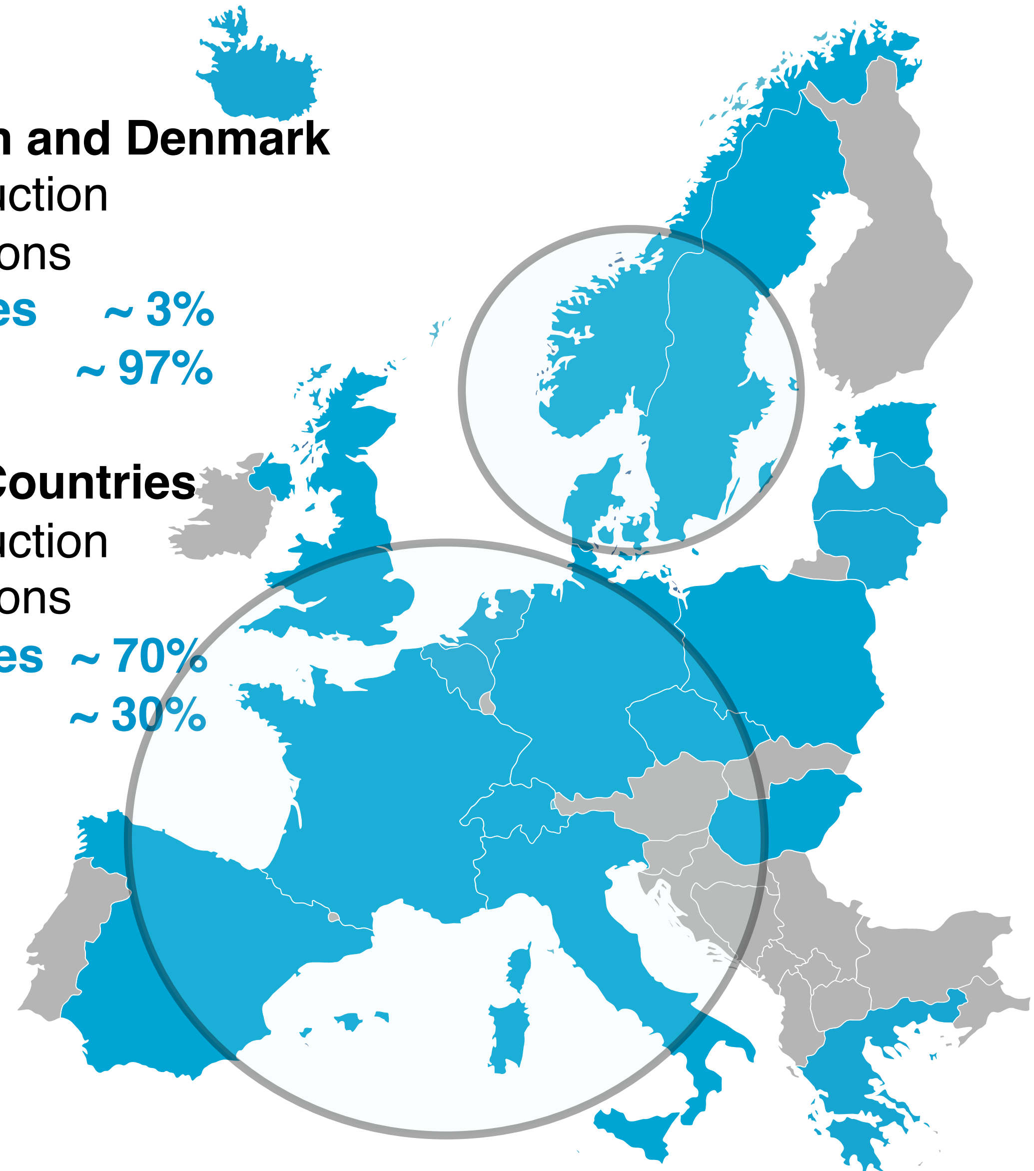
Non Host Member Countries

52,5% Construction

85% Operations

In-kind Deliverables ~ 70%

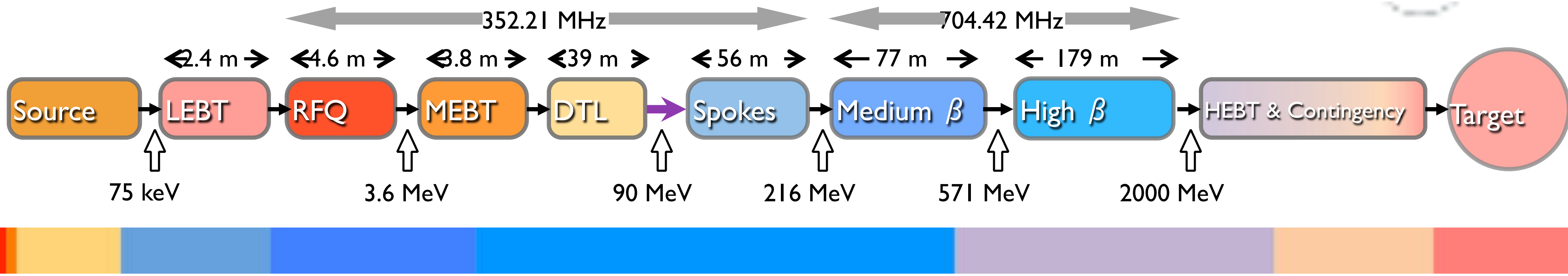
Cash Investment ~ 30%



Start Civil Construction

EUROPEAN SPALLATION SOURCE

High power 5MW proton accelerator

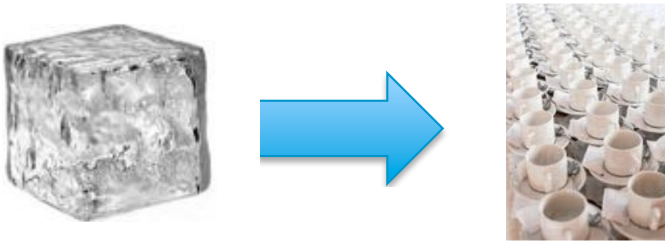


Accelerating protons to almost the speed of light
in pulses hitting the target 14 times per second.

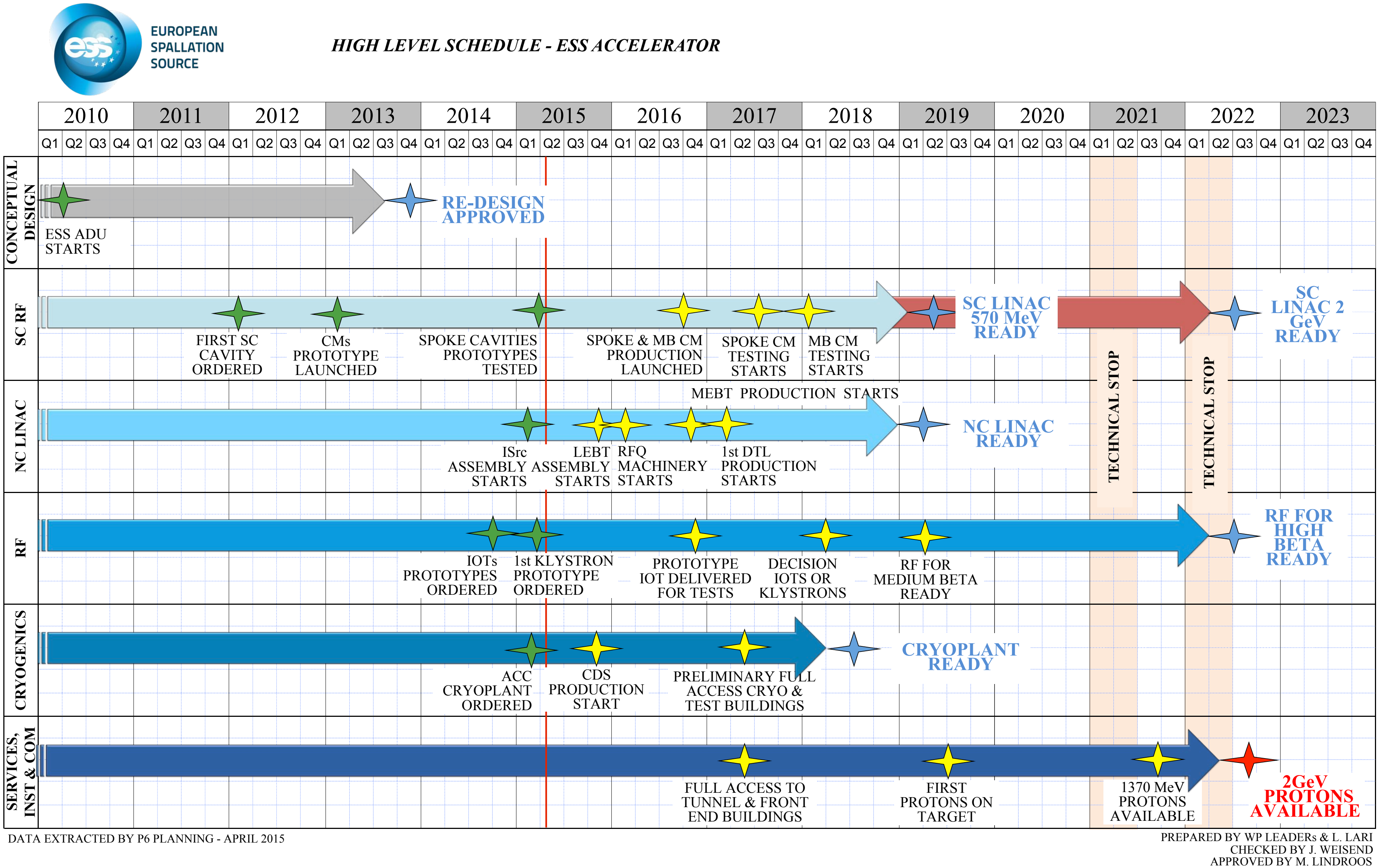
Energy per pulse equals to

- 16lb (7,2kg) shot travelling with 1100 km/h.
- melting approx. 1 kg (1 liter) of ice …

…. *and next pulse boils it.*

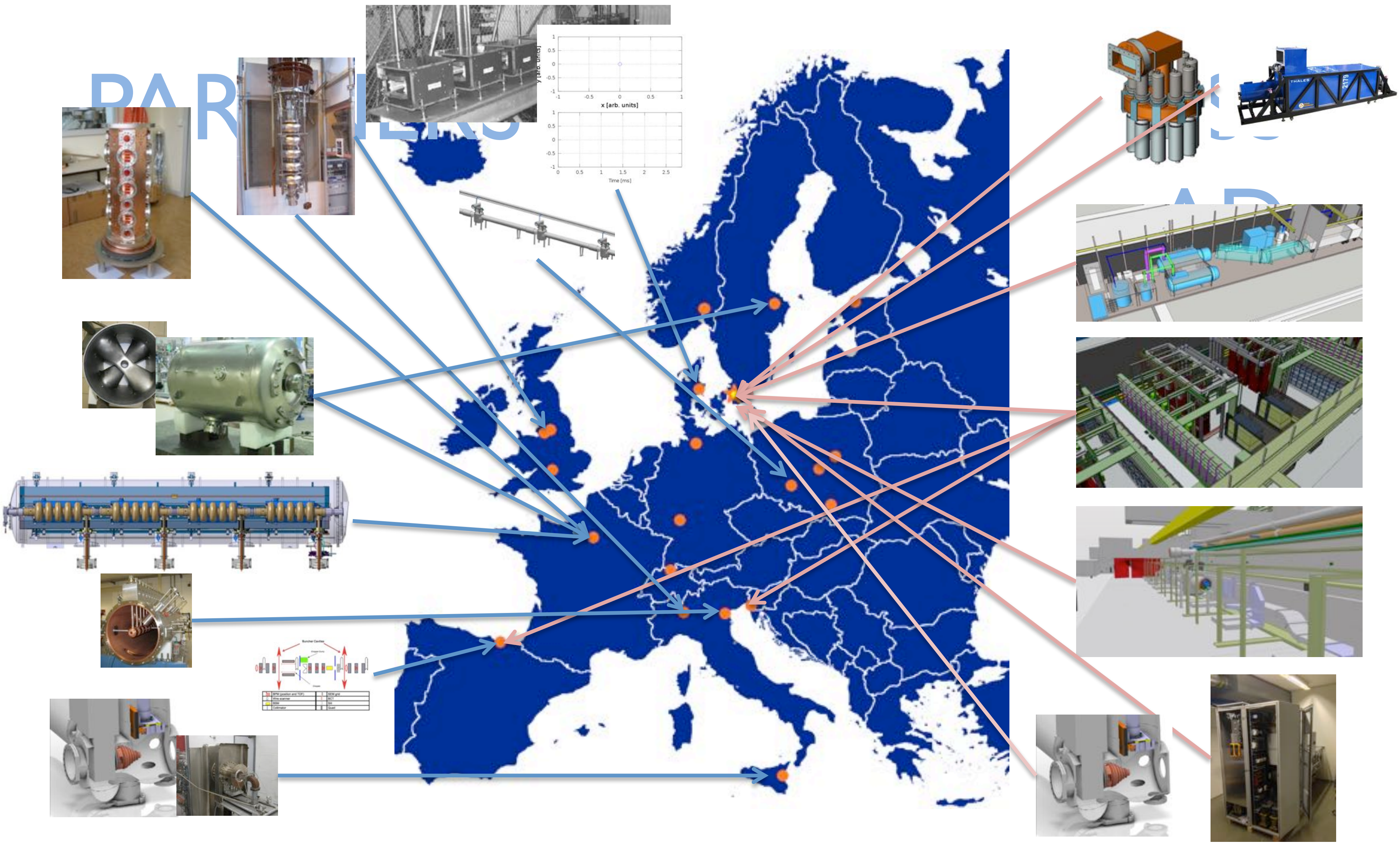


High Level Master Schedule



Accelerator Selected technologies

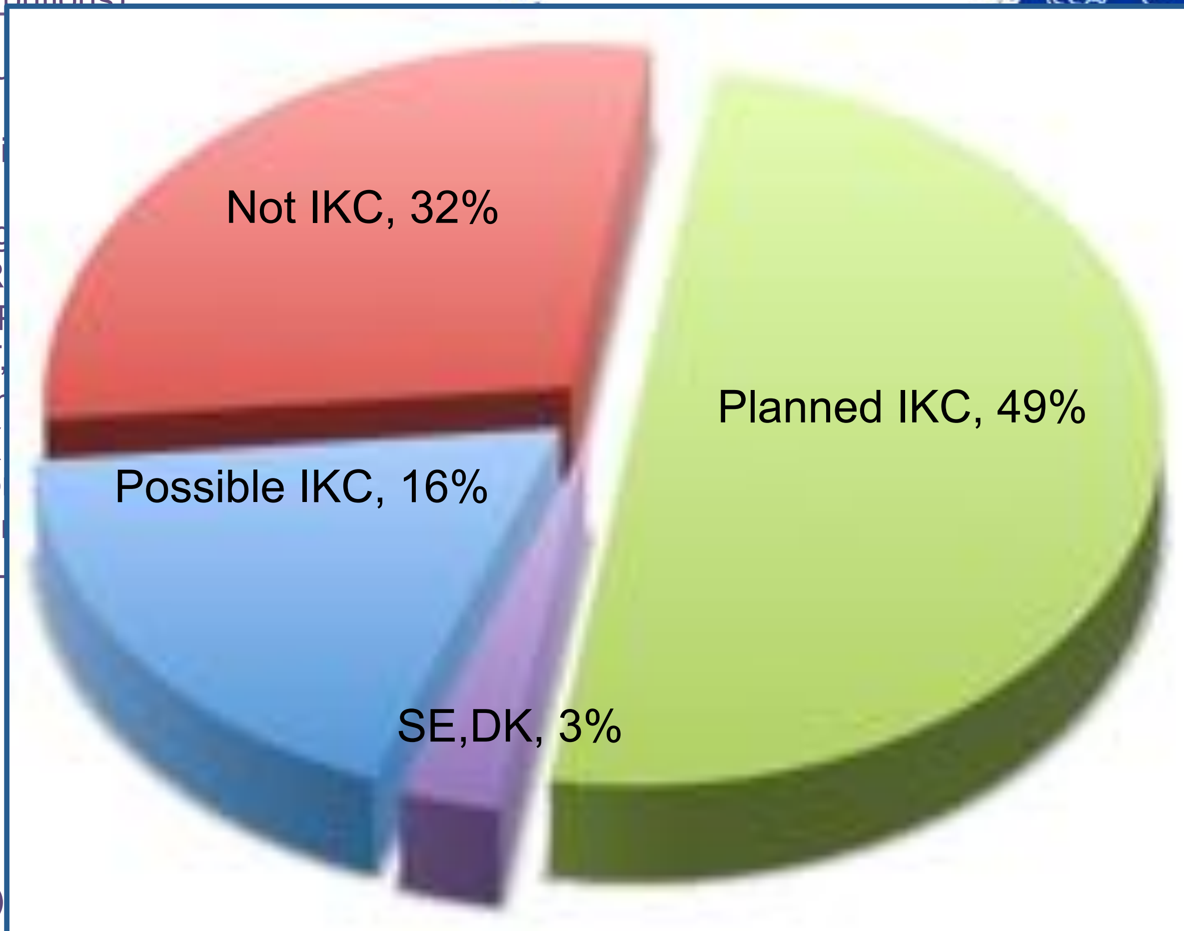
EUROPEAN SPALLATION SOURCE



Partner Institutions

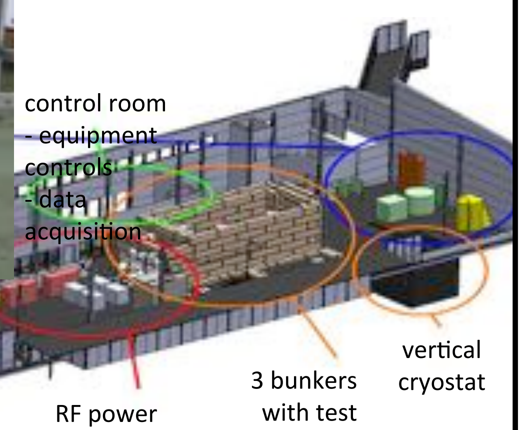
In-kind (main contributions)

Univ Agder (Ion sou
ATOMKI (RF-LPS)
CEA (RFQ, SRF, Di
CNRS (SRF, Cryo)
Cockcroft Inst (Diag
Daresbury Lab (SR
Elettra (RF, Magn, P
ESS-Bilbao (MEBT,
GSI (Diagn, Vacuu
Huddersfield Univ (
IFJ PAN (Installatio
INFN Catania (Sou
INFN Legnaro (DTL
INFN Milan (SRF)
NCBJ (LLRF)
RAL (Diagn)
RHUL (Diagn)
Tallinn UT (RF)
TU Lodz (LLRF)
Univ Oslo (Diagn)
Warsaw UT (LLRF)
Wroclaw UT (Cryo)



ESS Linac RF System

Integration test at LTH



In-kind RF:

- Sweden, Uppsala University (FREIA) and Lund University
- Polen, tri-uni
- Italy, Elettre
- Spain, ESS Bilbao
- Hungary, Atomki
- Estonia, TU Tallin

R&D on High Voltage and High Power Klystron Modulators for the ESS accelerator

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

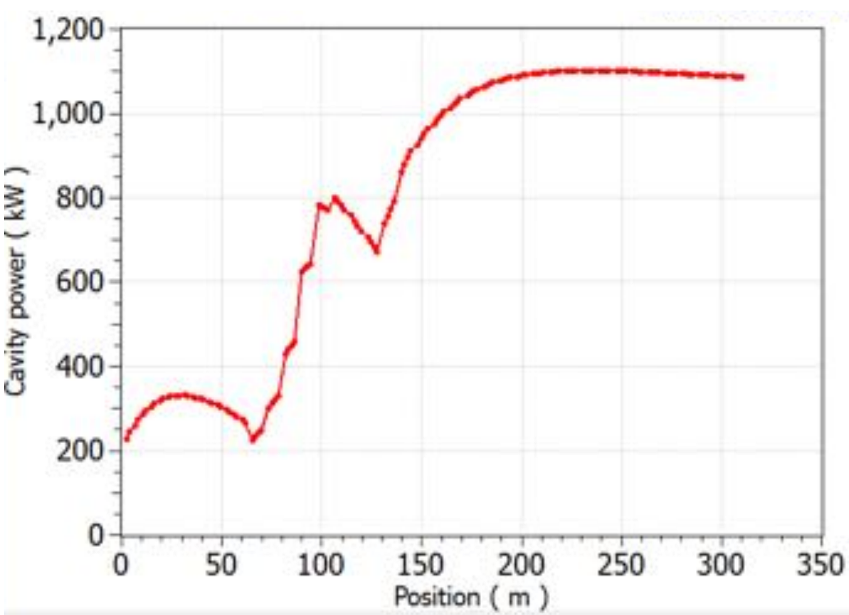
LU INNOVATION SYSTEM

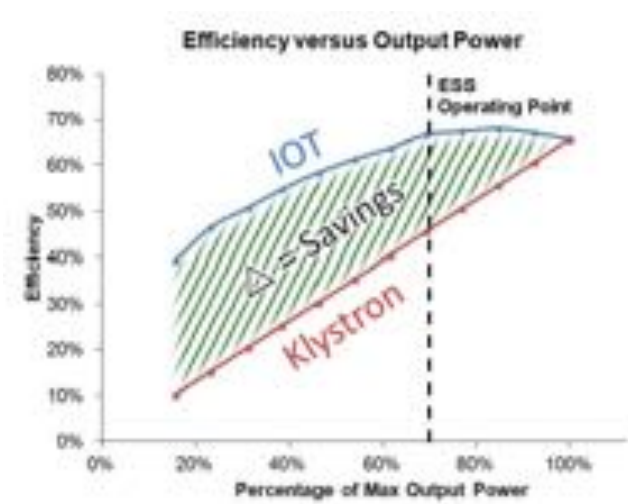
1994-2014 40 years aq

WE ARE RELIABLE

RF power sources: IOT progress

- 2 prototypes ordered
  - Good progress with both vendors with L3 being 4-6 months ahead of schedule
- Delivery in September 2016 to CERN test stand
- 84 tubes needed for high beta
- Decision and tender early 2018 for 84 tubes - possible In-kind

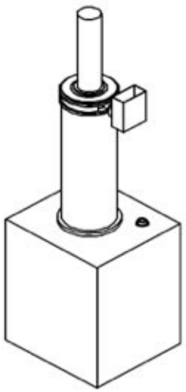




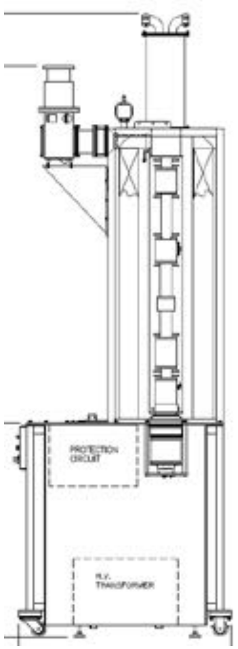
L3 Electron Devices CPI THALES

WP 8 Medium beta klystrons

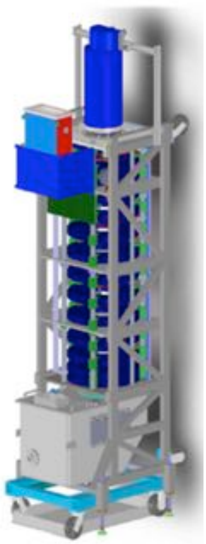
- 3 prototypes ordered
- Delivery Q2-Q3 2016
  - To be tested at ESS
- 36 tubes needed for medium beta
- Tender in the end of 2016 for 36 tubes - possible In-kind



Toshiba E37504



CPI

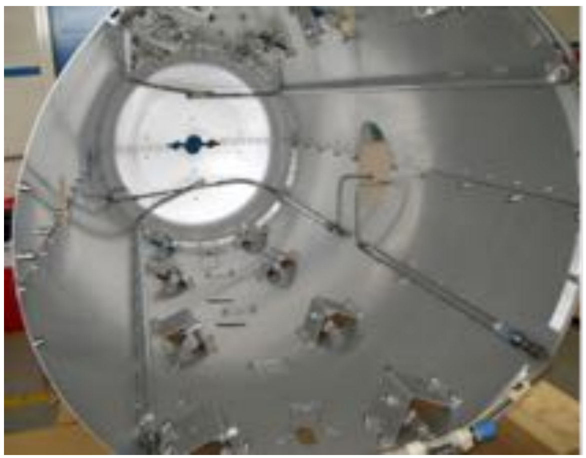


Thales TH 2180

Spoke Cryomodule fabrication - CNRS

EUROPEAN SPALLATION SOURCE

Thermal shield



Vacuum vessel & Mechanical support

Cold/warm transition

Gate valves

Inter-cavity belows

First blank assembly of some parts

Six beta0.67 prototype cavities – CEA (@ZANON)

- All **Dumbbells** completed and frequency measurements performed
- **End groups** completed by end of September
- **Helium tank** prepared for welding

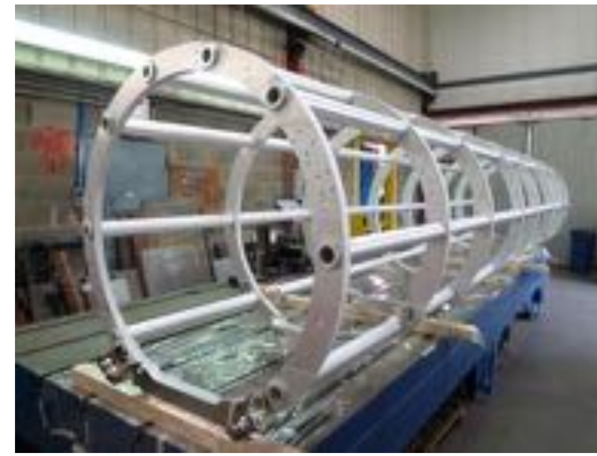
- **First cavity** delivered to CEA by **end of October**
- Once the 1st cavity is approved by CEA, Zanon can deliver **one bare cavity every 2-3 weeks**.

Medium β cryomodule fabrication – CNRS and CEA

EUROPEAN SPALLATION SOURCE

Production of the main components and the toolings has been launched

Vacuum vessel & space frame delivered

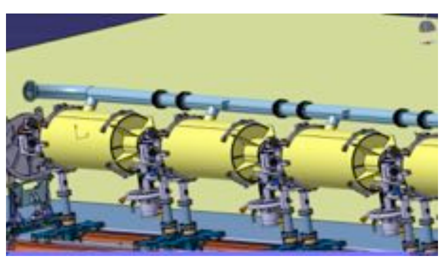


The detailed study of the assembling procedures is in progress.

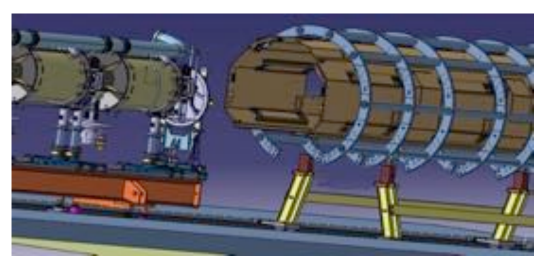
XFEL cryomodules assembly lessons learned applied to ESS, QA process

(N_2)

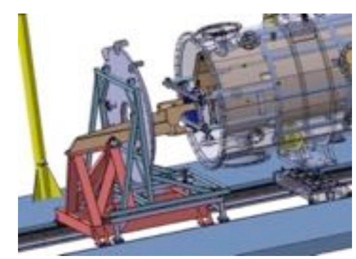
Assembling of the cavity string with a N2 flow for protection against dust particles



Welding the titanium diphasic tubes



The cavity string is inserted in the spaceframe already equiped with the thermal shield

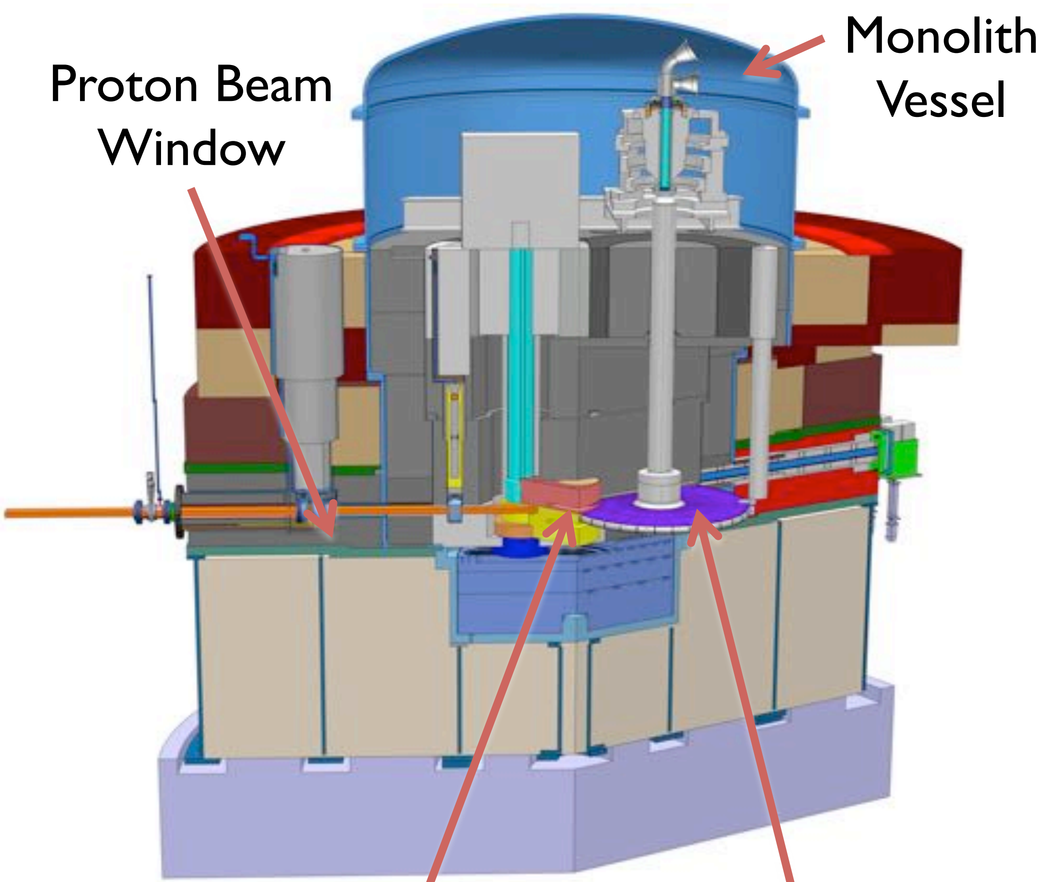


Closing the vacuum

…

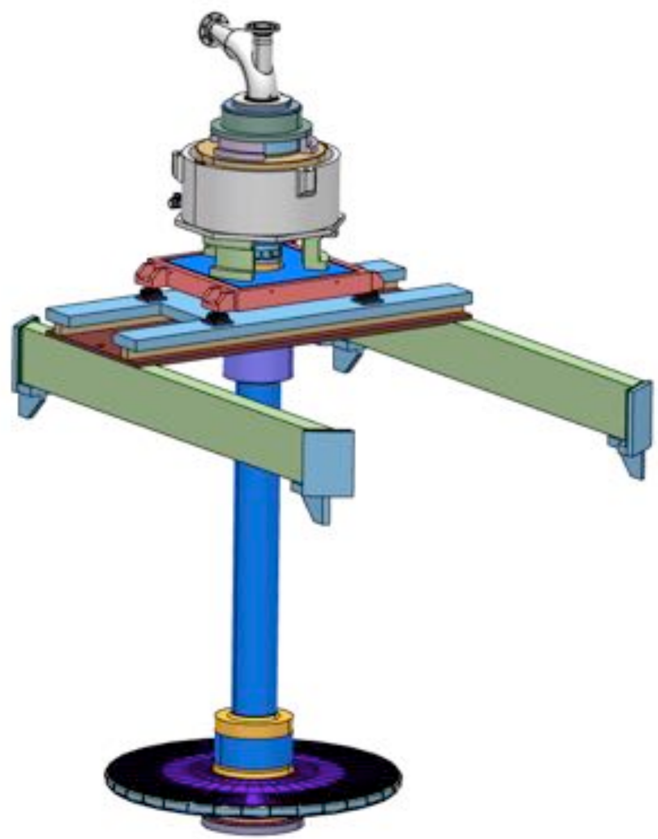
Target Station incorporates unique features

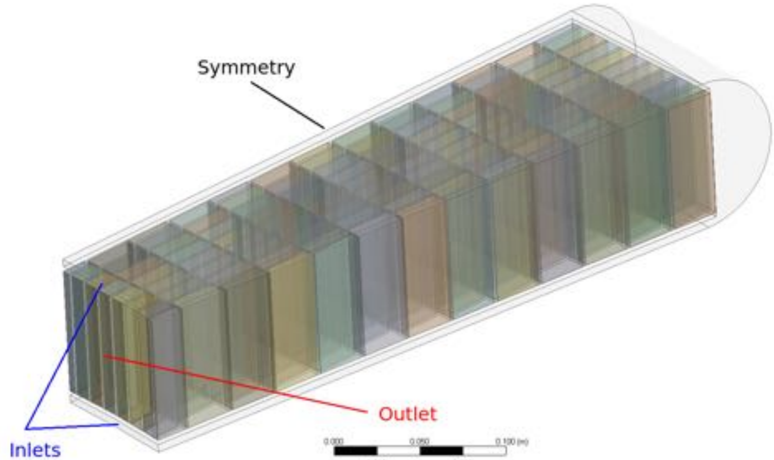
- Rotating W target
- He cooling for target
- High brightness neutron moderators



Target Systems

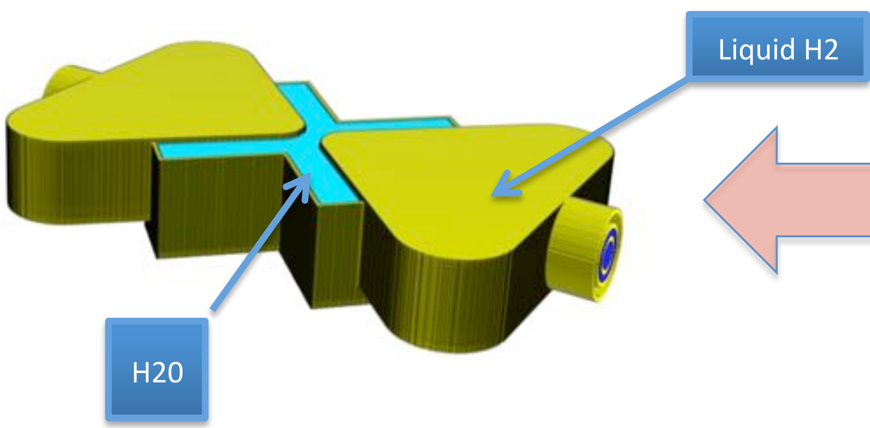
- Features:
  - He-cooled tungsten plates integrated in a wheel
    - ~ 60 n/p for 2 GeV p on W
  - 2.5 m diameter wheel on 5 m long shaft with rotational speed ~ 0.4 Hz
    - Lifetime ~ 5 years (@ 5 MW)

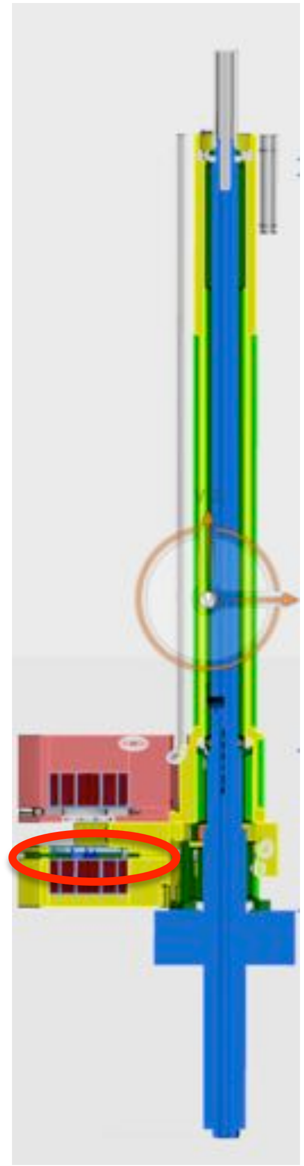


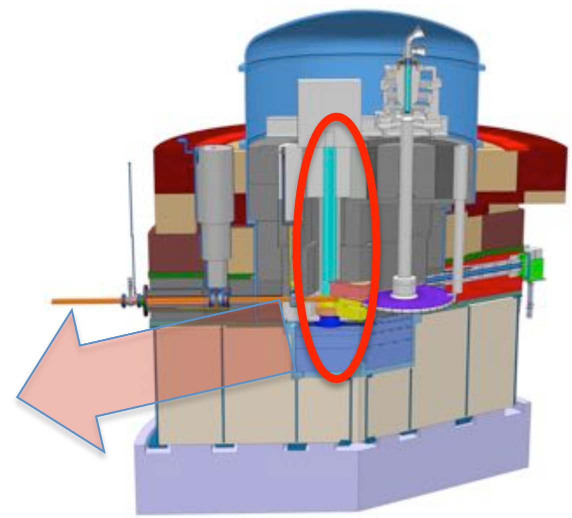


Moderator and Reflector Systems

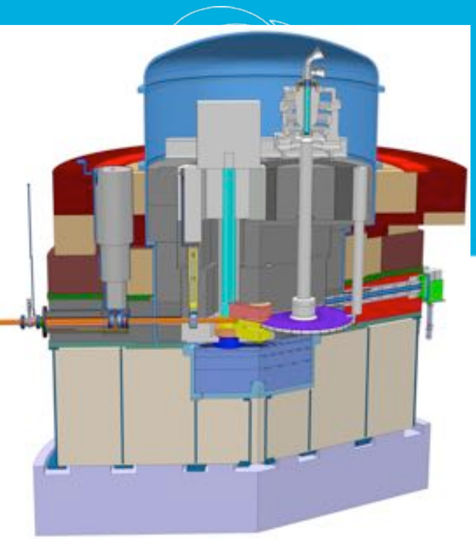
- Features:
  - Cold moderators - Supercritical hydrogen at 20 K
  - Thermal moderators – water
  - Al alloy vessels with beryllium reflector
  - New moderator concepts increase cold and thermal neutron source brightness by > 2x
  - Radiation damage limits lifetime to ~ 1 year at 5 MW





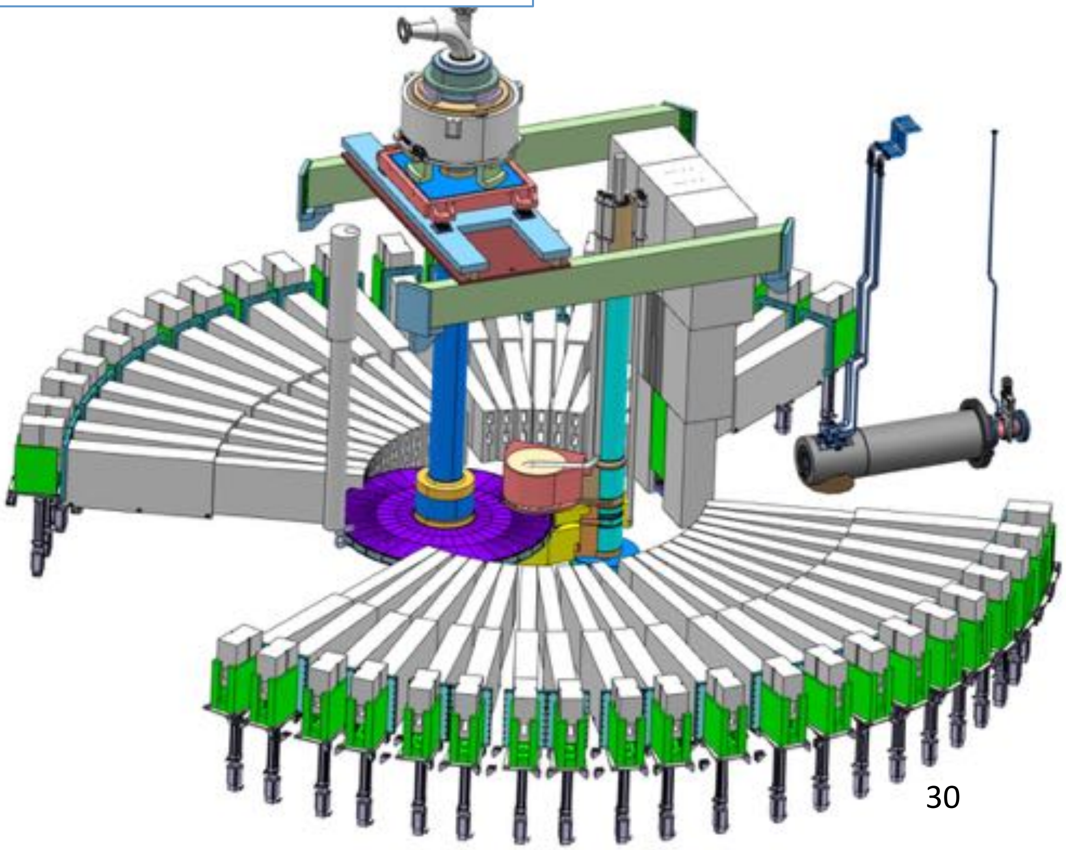


Monolith Systems

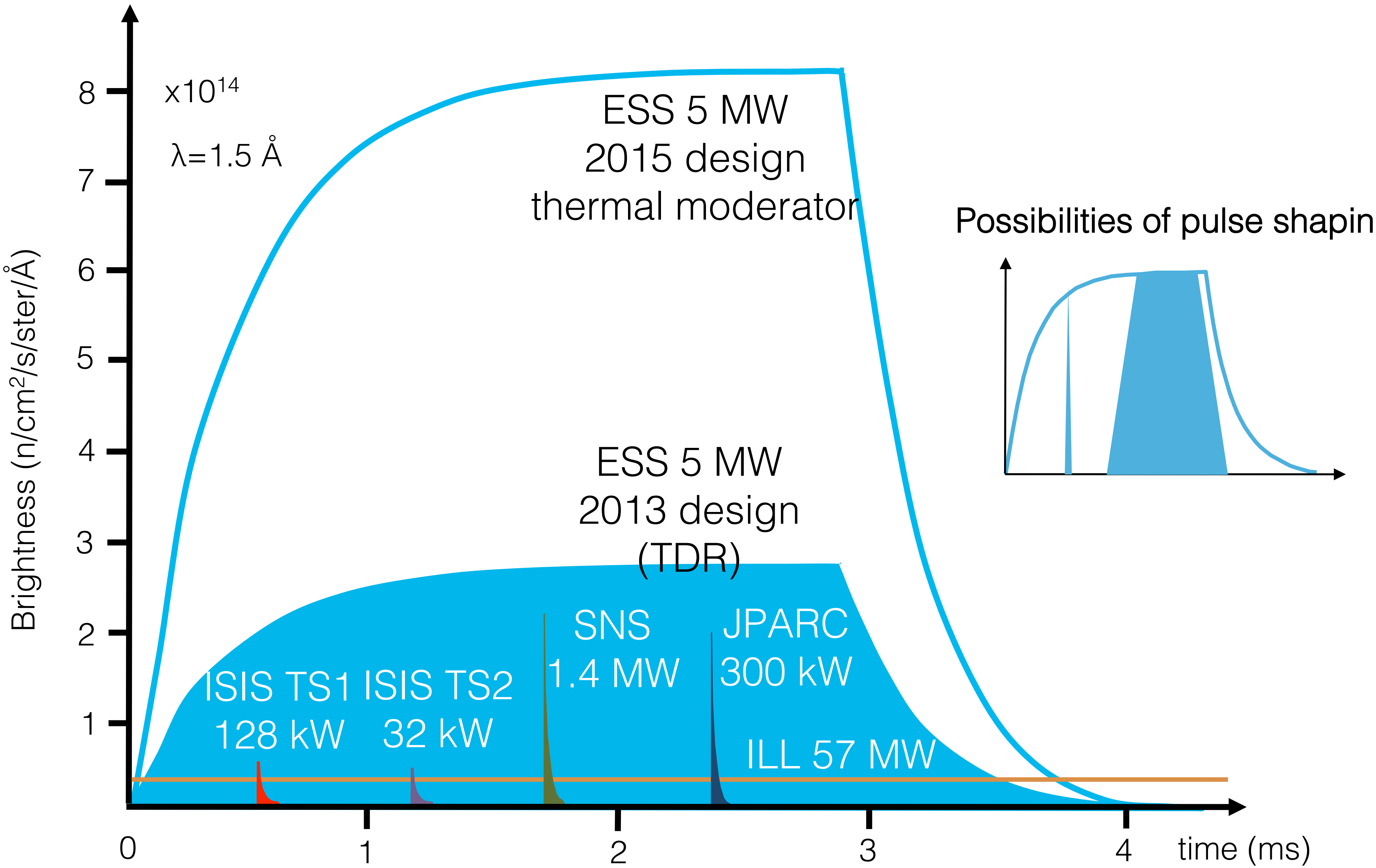


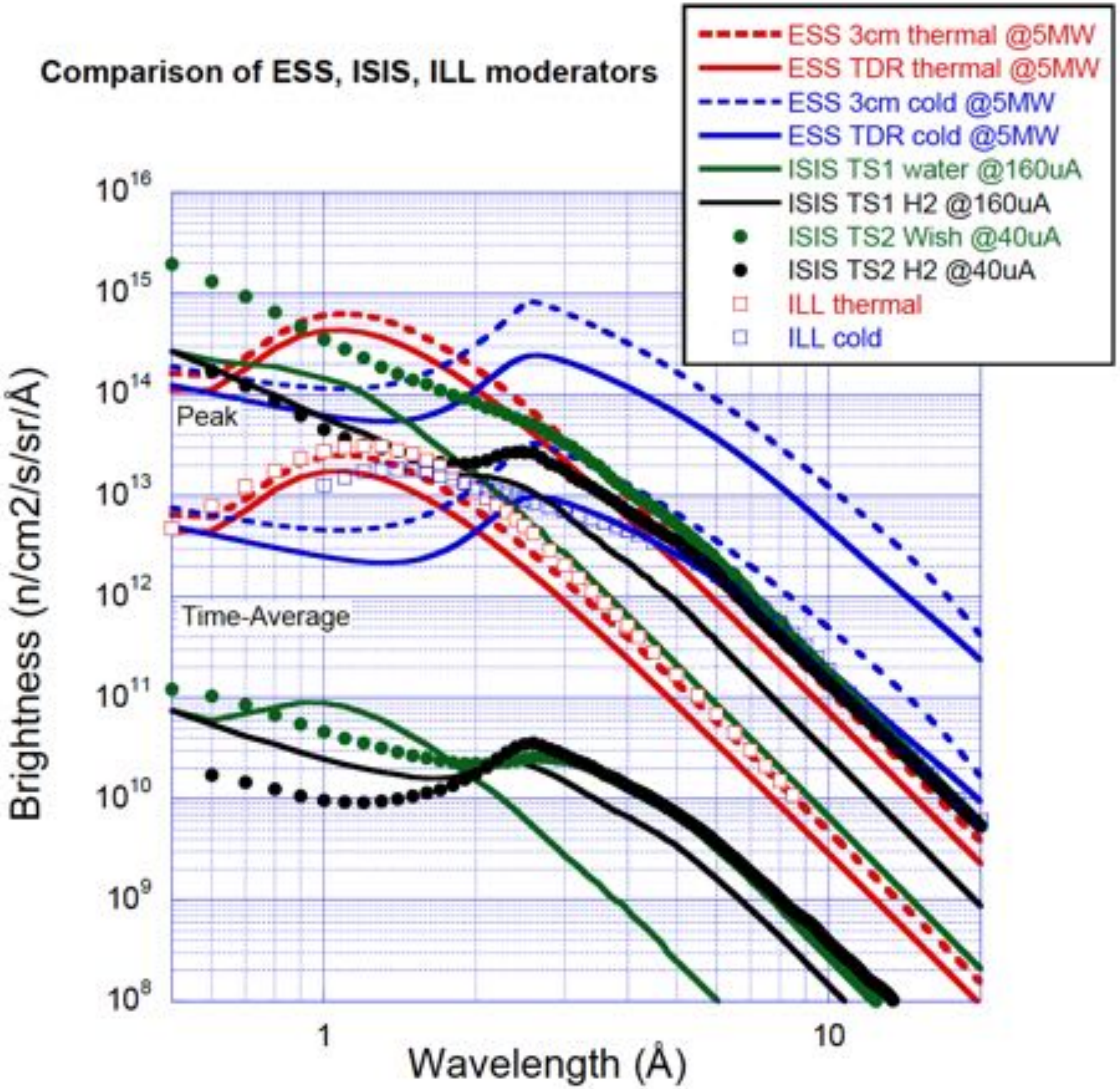
- 11 m diameter
- 6,000 tonnes of steel shielding
- 42 neutron beam ports

- Features:
  - Monolith internals:
    - Proton beam window (PBW)
    - Diagnostics inserts
    - Neutron extraction system
    - Shutters
    - Monolith vessel
    - He atmosphere in vessel
    - Shielding
  - Tuning beam dump



ESS long pulse potential




Comparison of ESS, ISIS, ILL moderators
ESS 3cm thermal @5MW
ESS TDR thermal @5MW
ESS 3cm cold @5MW
ESS TDR cold @5MW
ISIS TS1 water @160uA
ISIS TS1 H2 @160uA
ISIS TS2 Wish @40uA
ISIS TS2 H2 @40uA
ILL thermal
ILL cold
Peak
Time-Average
Brightness (n/cm2/s/sr/Å)
Wavelength (Å)
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
1
10

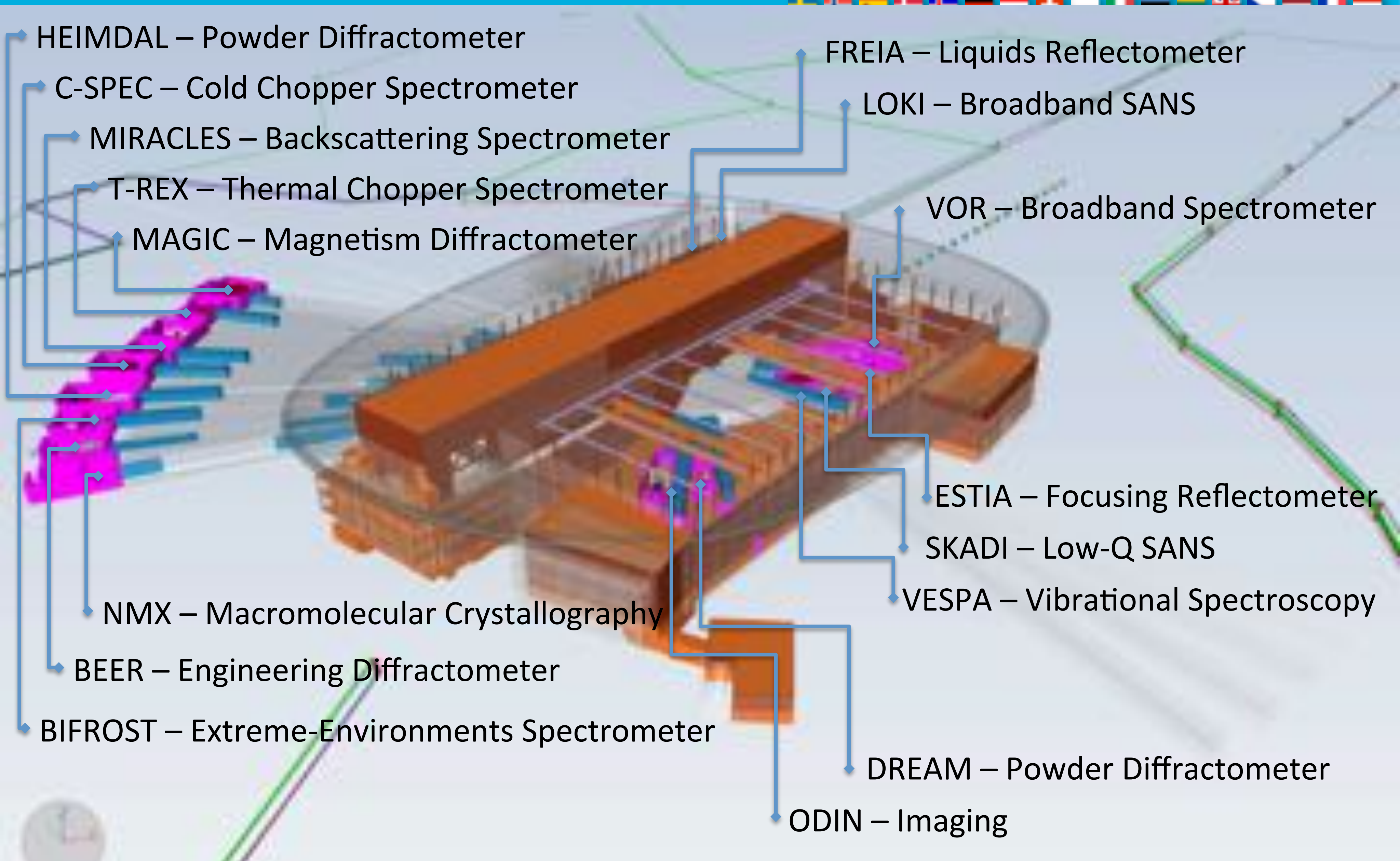
Science Drivers for the Reference Instrument Suite

EUROPEAN SPALLATION SOURCE

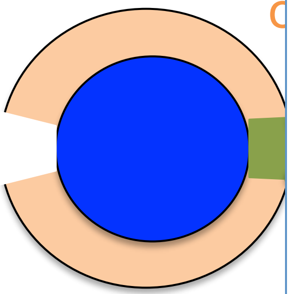
Instrument	Science drivers
Multi-Purpose Imaging	life sciences; soft condensed matter; magnetism & superconductivity; engineering & geo-sciences; archeology & heritage conservation
General-Purpose SANS	magnetism & superconductivity; soft condensed matter; chemistry of materials; energy research
Broadband 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

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

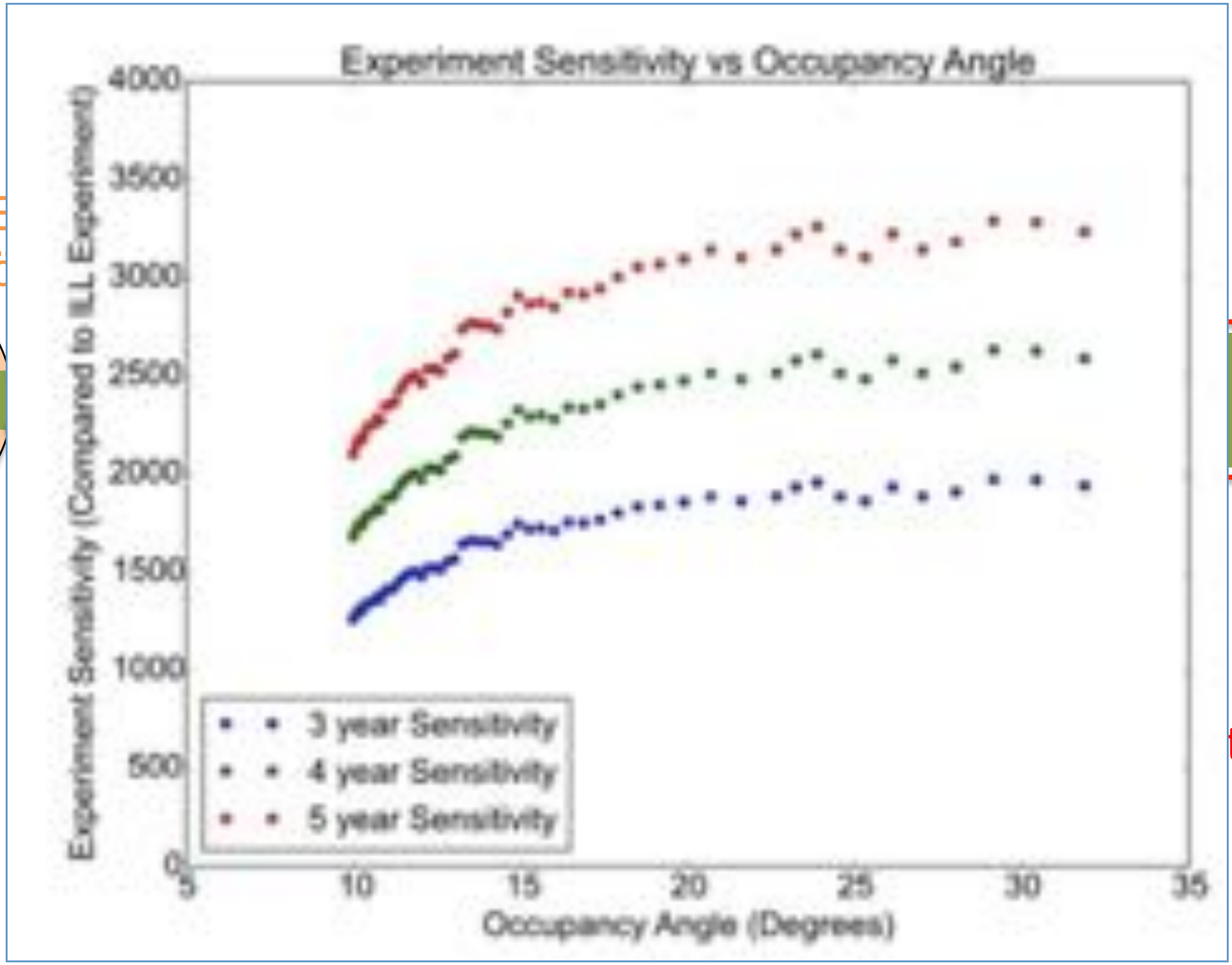
Instrument Suite is taking shape



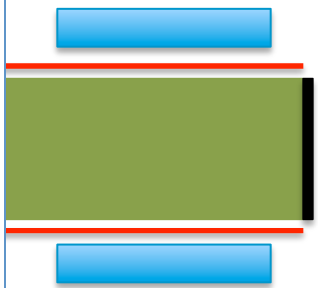
nnbar experiment @ ESS ?



En stor moderator



Detector



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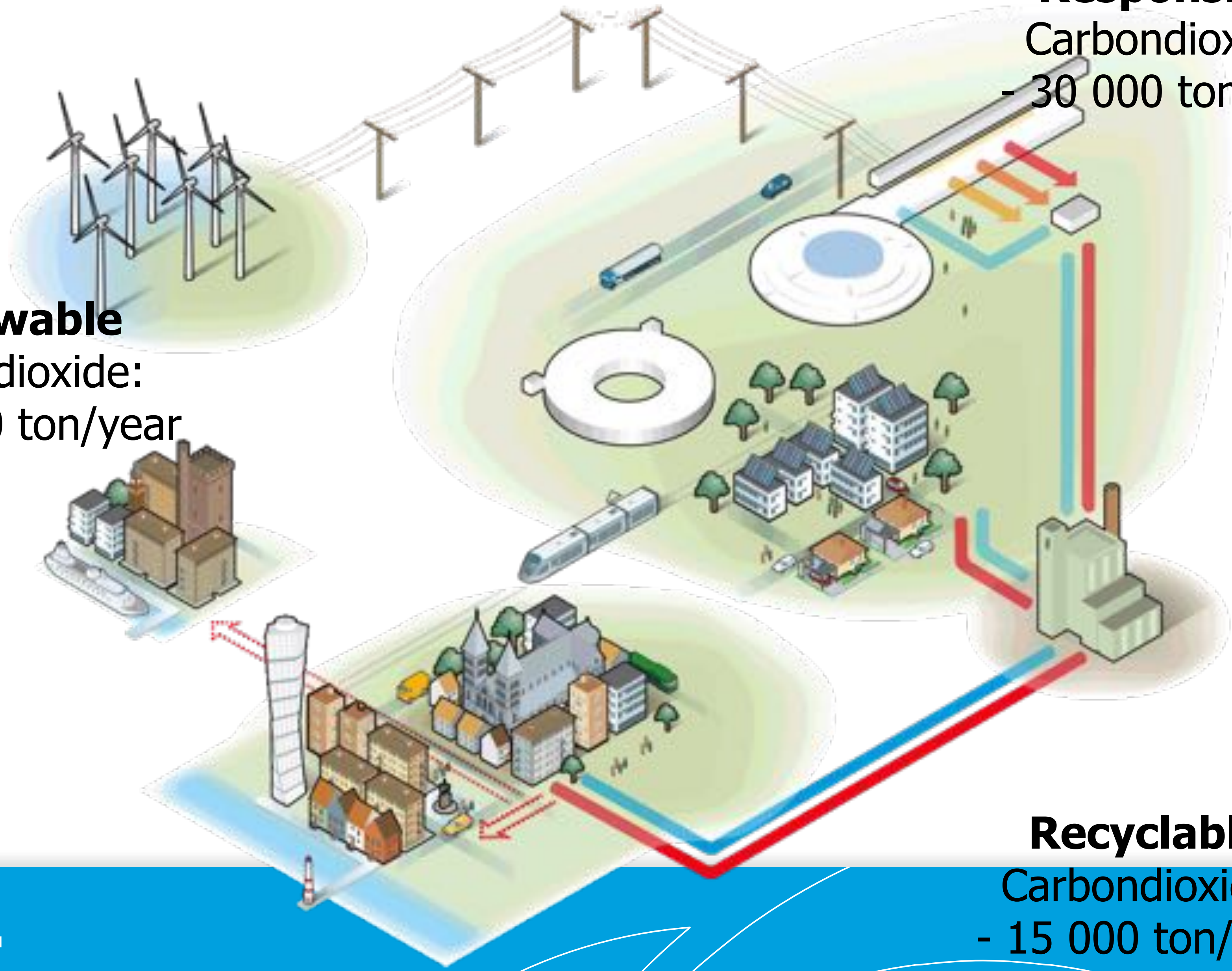
A sustainable research facility

Responsible
Carbondioxide:
- 30 000 ton/year



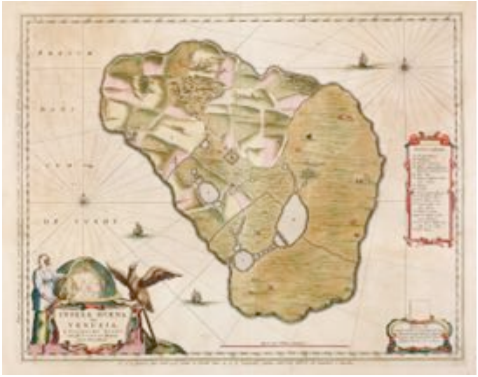
Renewable
Carbondioxide:
- 120 000 ton/year

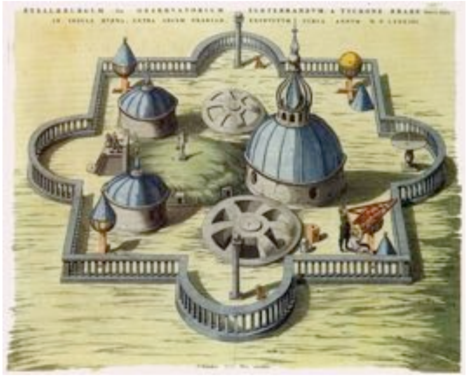
Recyclable
Carbondioxide:
- 15 000 ton/year

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!”

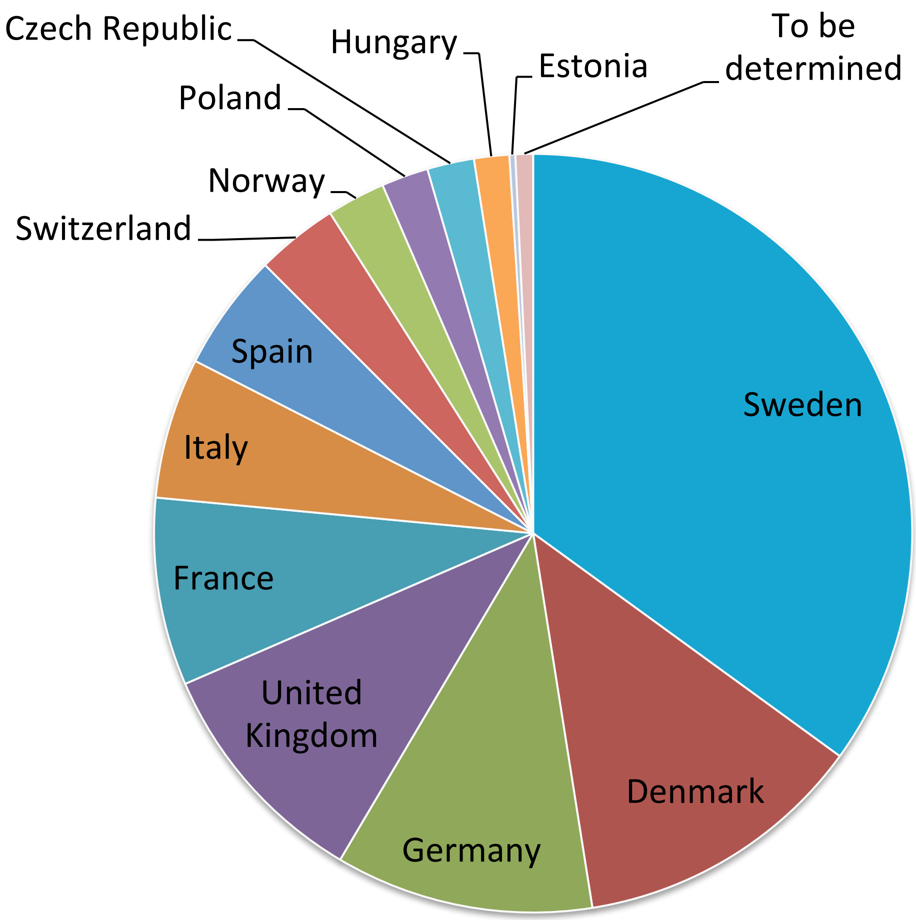
Welcome to ESS!

ESS, Science village and MAX-IV

Partners contributions

EUROPEAN SPALLATION SOURCE

Sweden	**35.0 %**
Denmark *	**12.5 %**
Germany *	**11.0 %**
United Kingdom	**10.0 %**
France	**8.0 %**
Italy	**6.0 %**
Spain *	**5.0 %**
Switzerland	**3.5 %**
Norway	**2.5 %**
Poland	**2.0 %**
Czech Republic	**2.0 %**
Hungary	**1.5 %**
Lithuania	**0.45 %**
Estonia	**0.25 %**
Total	**99.70 %**
Iceland	*tbd (~0.25)*
Latvia	*tbd ~(0.25)*
Netherlands	*tbd (~2.0)*
Belgium (observer)	*tbd (~2.0)*
Greece (observer)	*tbd (~1.0)*



* Includes Pre-construction Costs

Discussions: Finland, Portugal, and Turkey