European Spallation Source update

GIOVANNA FRAGNETO, SCIENCE DIRECTOR

2003
European design of ESS completed

2009
Decision to site ESS in Lund

2012
ESS design update phase complete

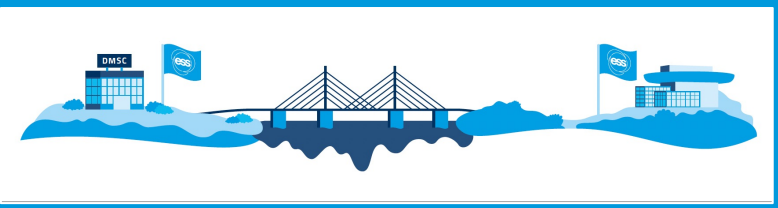
2014
Construction starts on green field site

2019
Start of initial operations phase

2025
Beam on target

2026–2027
Early Science

2027–2028
User program

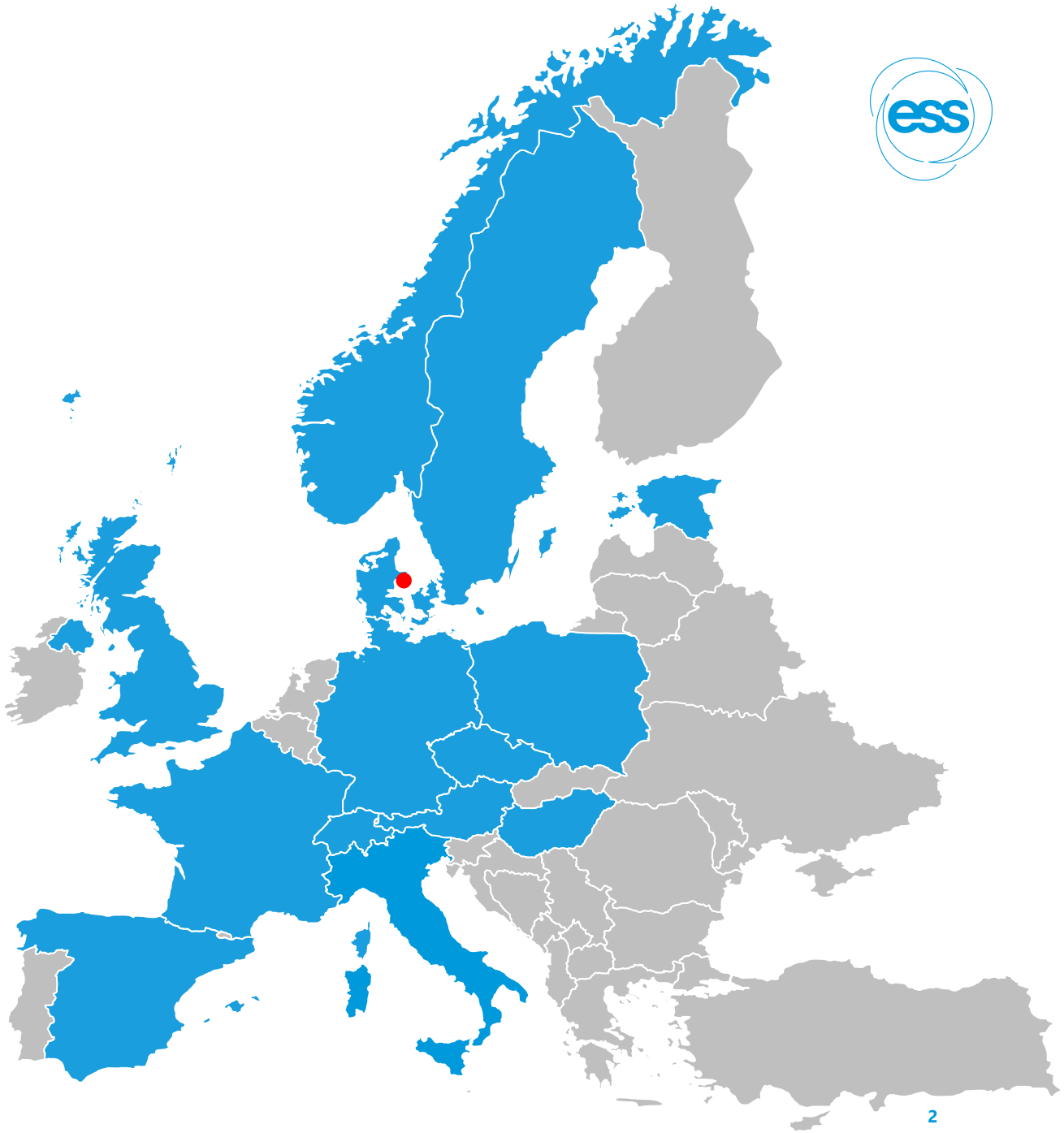


The ESS Project

European Research Infrastructure Consortium
13 founding countries
More than 40 partner institutions
More than 130 collaborating institutions
In kind model

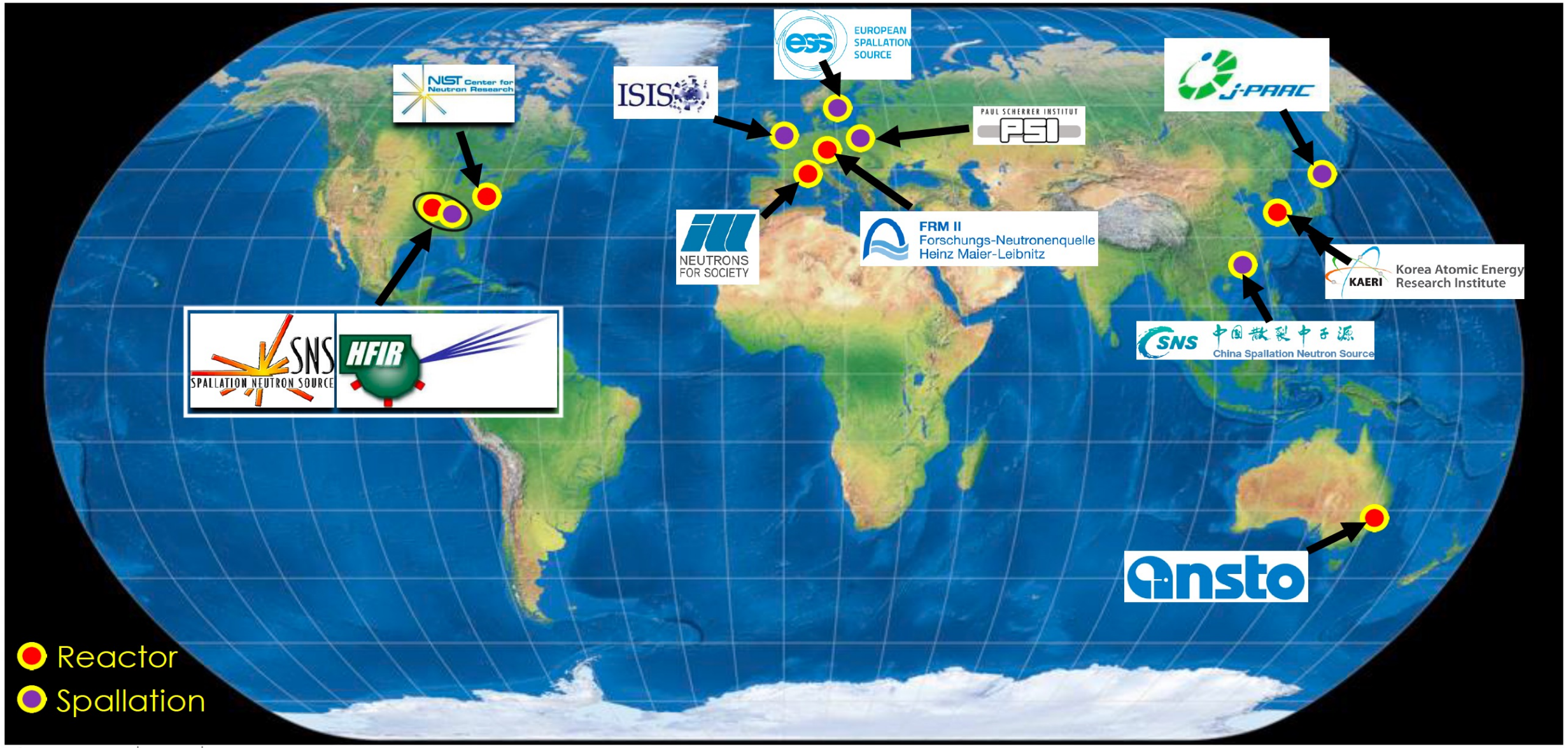
Host Countries
Sweden and Denmark

Member Countries



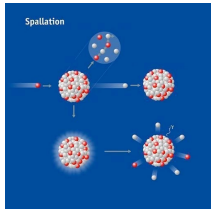
Generating neutrons

Neutron Sources around the world

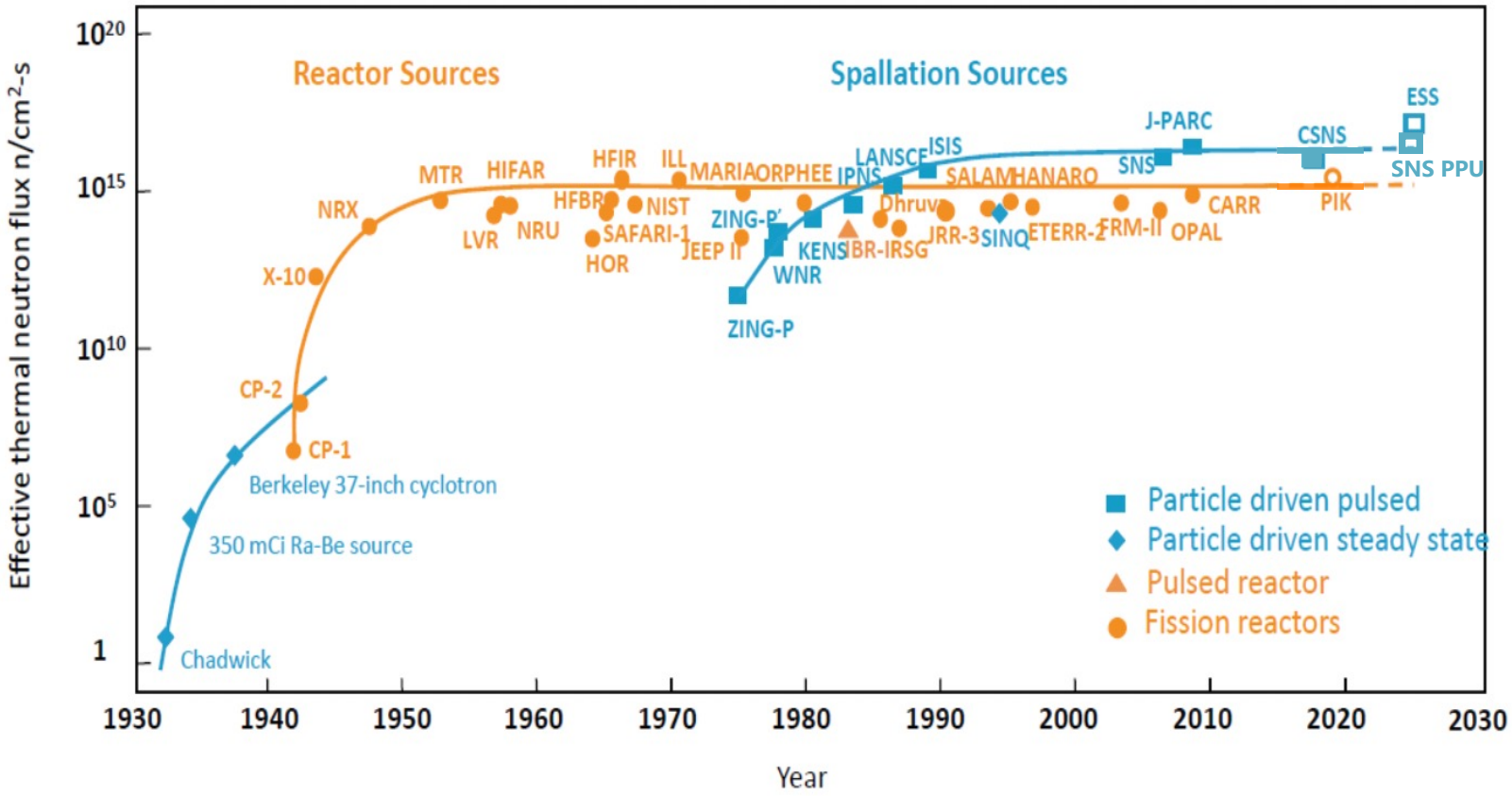


ESS peak flux 20 (2MW)–50 (5MW) brighter than the ILL

ESS mission



Long pulse (2.86ms) spallation neutron source fed by a linear proton accelerator (870MeV 2MW) and rotating Tungsten target



To build and operate the world most intense neutron source that will enable scientific breakthroughs in research relating to materials, energy, health and environment and address some of the most important challenges of our time

ESS in the global neutron source landscape

Continuous Sources

Fission reactors :

ILL (France) – 58 MW thermal, 50-day fuel cycle, 4 cycles / year

HFIR (USA) – 83 MW thermal, 23-day fuel cycle, 6-7 cycles / year

Cyclotron *accelerator-based*:

SINQ (PSI/Switzerland) – 1,4 MW proton beam power producing muons and spallation neutrons

Pulsed Sources

Long-pulse driven by linear accelerator *pulse length 2,86* ***milli****seconds*

ESS (SE/DK) – 14 Hz, 0,8 – 2 GeV, 2-5 MW proton beam power

ESS bridges the space between continuous and short-pulsed sources and opens up new techniques and opportunities

Short-pulse driven by rapid-cycling synchrotron accelerators (RCS)*, all beam structures less than 1* ***micro****second*

J-PARC MLF (Japan) – 25 Hz, 3 GeV RCS up to 1 MW proton beam power – **Hg** target

ISIS (RAL/UK) – 50 Hz, 0,8 GeV RCS up to 200 kW proton beam power providing muons and spallation neutrons divided between TS-1 (40 Hz) and TS-2 (10 Hz) – **W** target

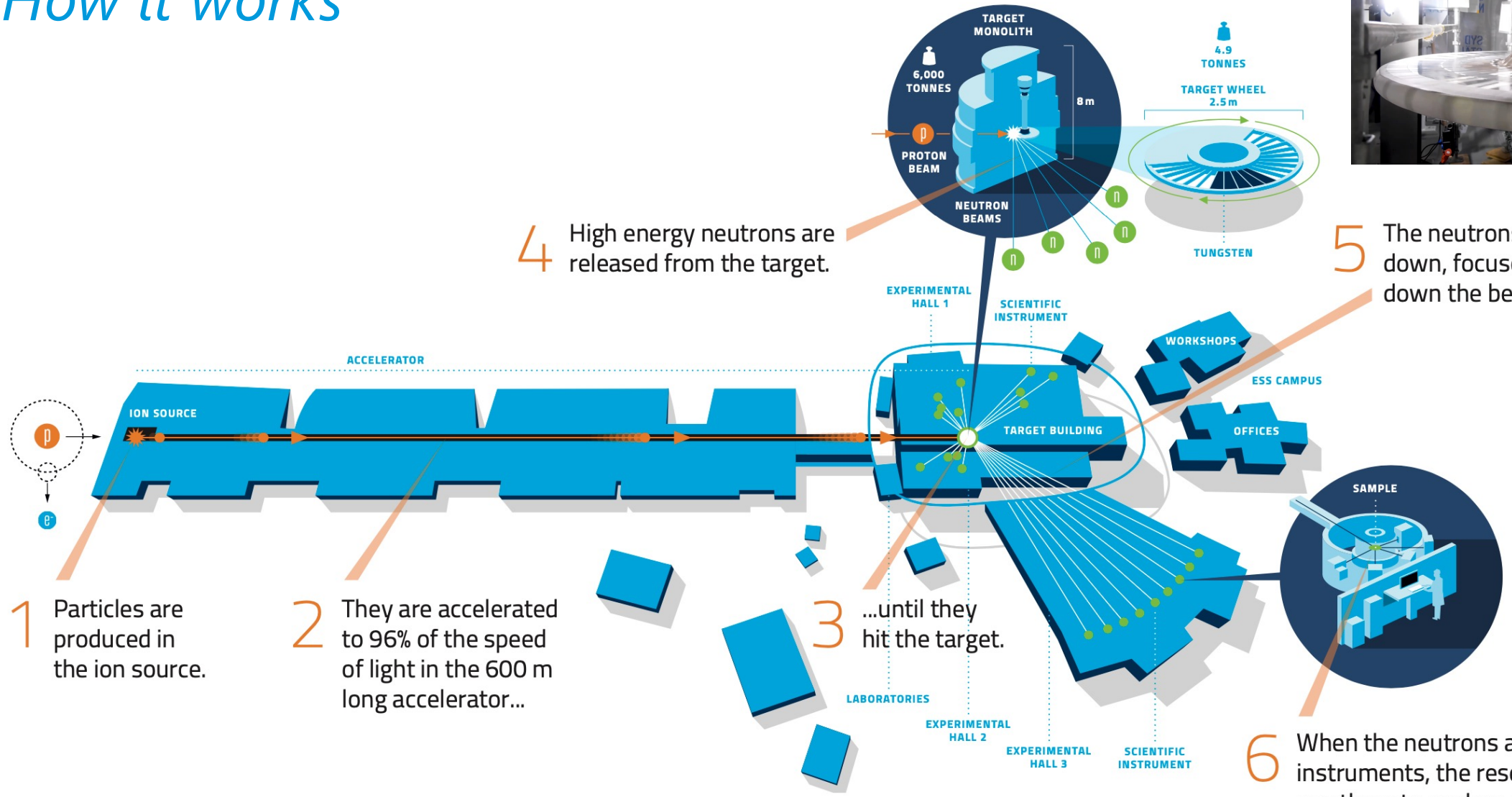
CSNS (China) – 25 Hz, 1,6 GeV RCS up to 100 kw proton beam power **– W** target

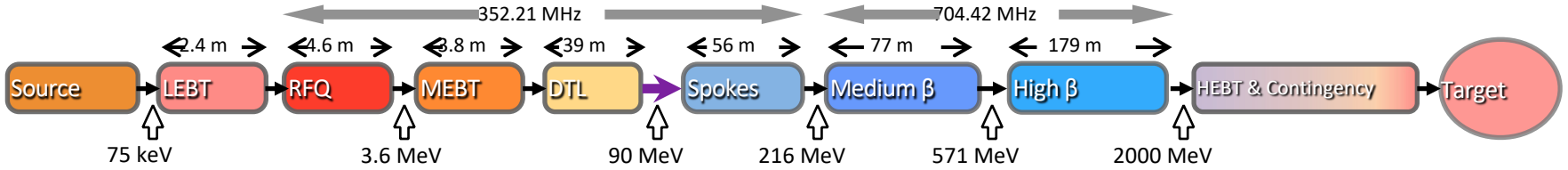
Short-pulse driven by linear accelerators and accumulator rings*, all beam structures less than 1* ***micro****second*

SNS (USA) – 60 Hz, 1,05 GeV 1,7 MW proton beam power - **Hg** target

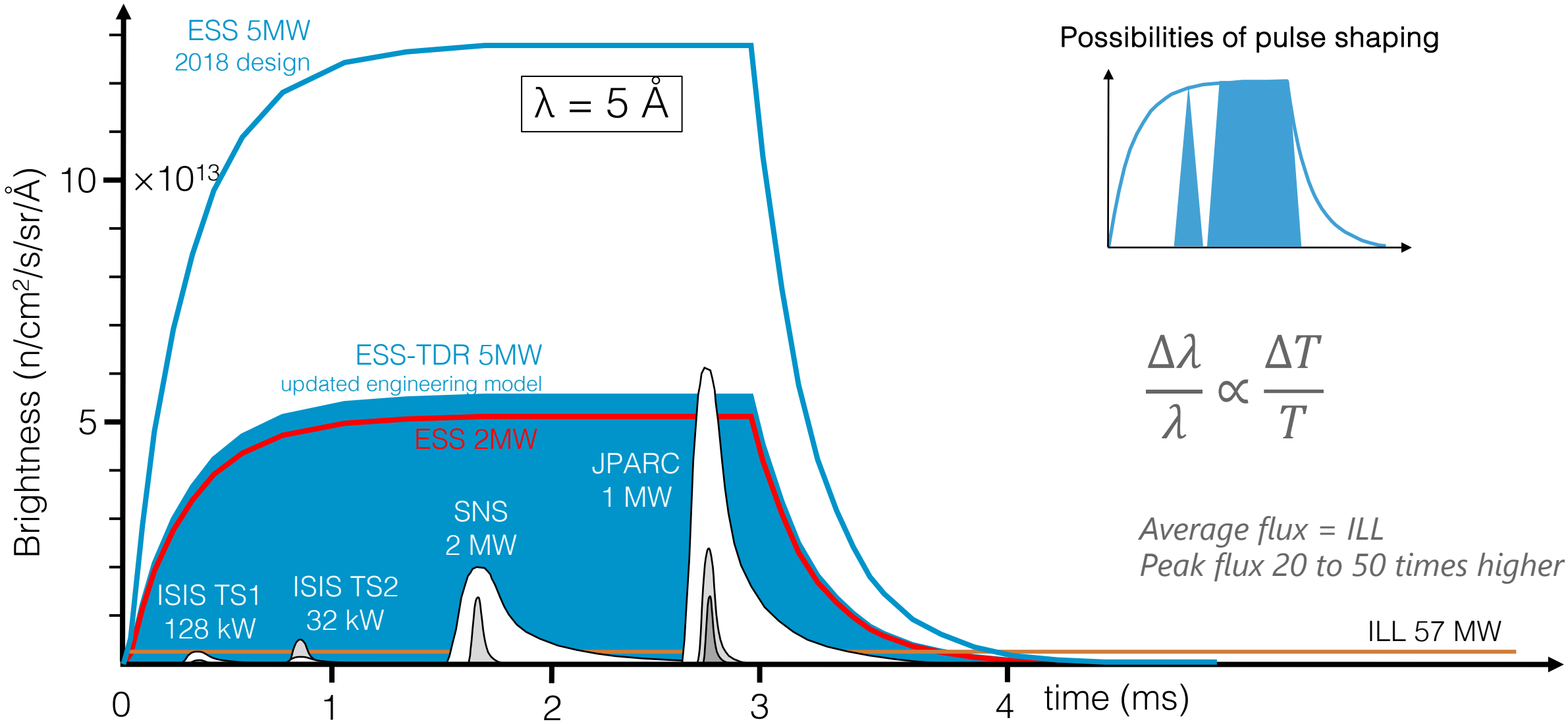
LANSCE (USA) – 20 Hz, 0,8 GeV 80 kW proton beam power – **W** target

How it works


TARGET MONOLITH
6,000 TONNES
8 m
PROTON BEAM
NEUTRON BEAMS
4.9 TONNES
TARGET WHEEL 2.5 m
TUNGSTEN
4 High energy neutrons are released from the target.
5 The neutrons are slowed down, focused and sent down the beamlines.
EXPERIMENTAL HALL 1
SCIENTIFIC INSTRUMENT
WORKSHOPS
ESS CAMPUS
ACCELERATOR
ION SOURCE
TARGET BUILDING
OFFICES
SAMPLE
1 Particles are produced in the ion source.
2 They are accelerated to 96% of the speed of light in the 600 m long accelerator...
3 ...until they hit the target.
LABORATORIES
EXPERIMENTAL HALL 2
EXPERIMENTAL HALL 3
SCIENTIFIC INSTRUMENT
6 When the neutrons arrive at the instruments, the researchers can use them to explore materials down to an atomic level.


352.21 MHz
704.42 MHz
2.4 m
4.6 m
3.8 m
39 m
56 m
77 m
179 m
Source
LEBT
RFQ
MEBT
DTL
Spokes
Medium β
High β
HEBT & Contingency
Target
75 keV
3.6 MeV
90 MeV
216 MeV
571 MeV
2000 MeV

Long-pulse Performance and Flexibility



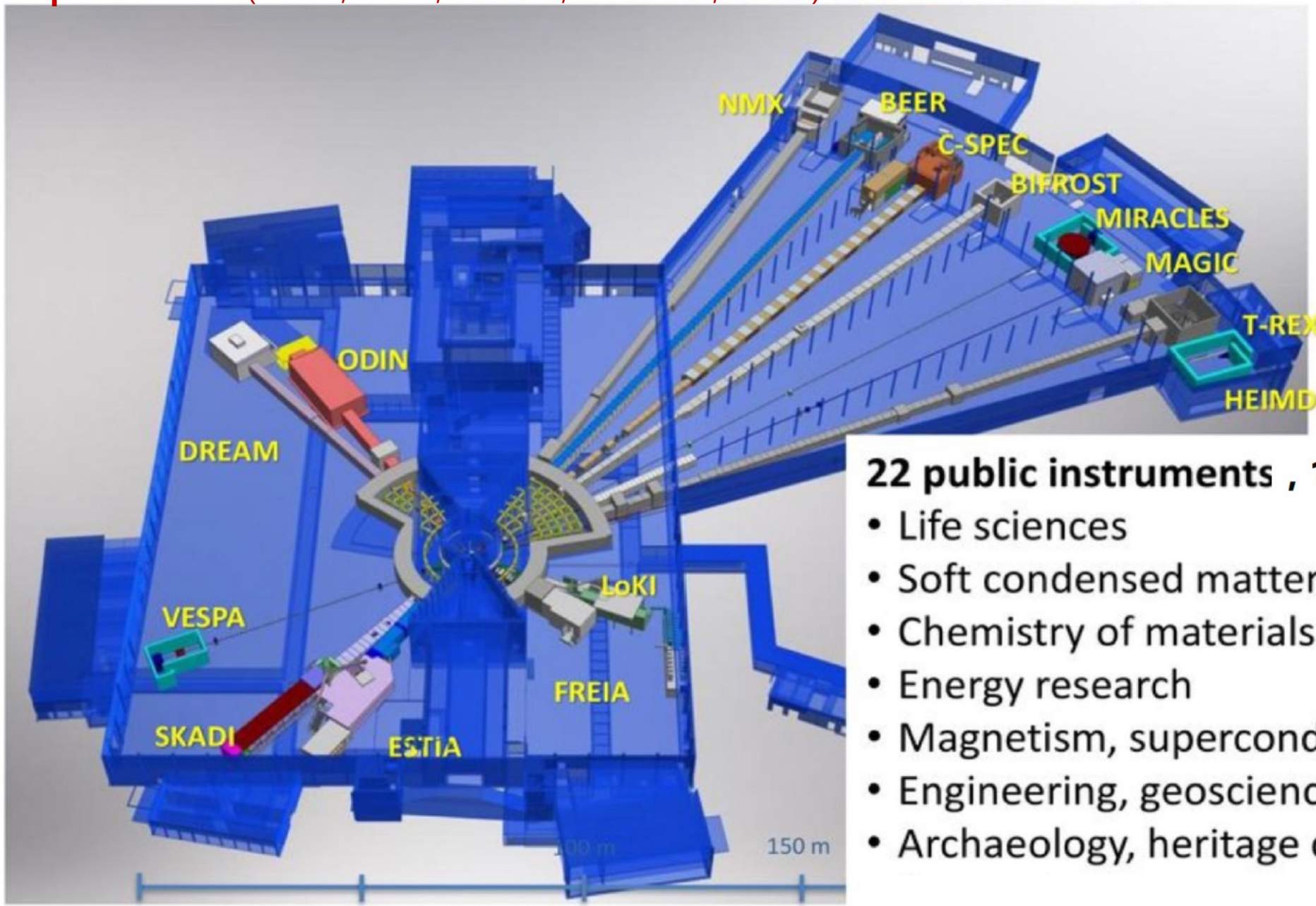
Possibilities of pulse shaping

$$\frac{\Delta\lambda}{\lambda} \propto \frac{\Delta T}{T}$$

Average flux = ILL
Peak flux 20 to 50 times higher

Diffractometers (DREAM, MAGiC, HEIMDAL, BEER) - **Imaging** (ODIN)
SANS (LoKI, SKADI) - **Reflectometers** (Estia, FREIA) - **Macromolecular Crystallography** (NMX)
Spectrometers (CSPEC, T-REX, BIFROST, MIRACLES, VESPA)

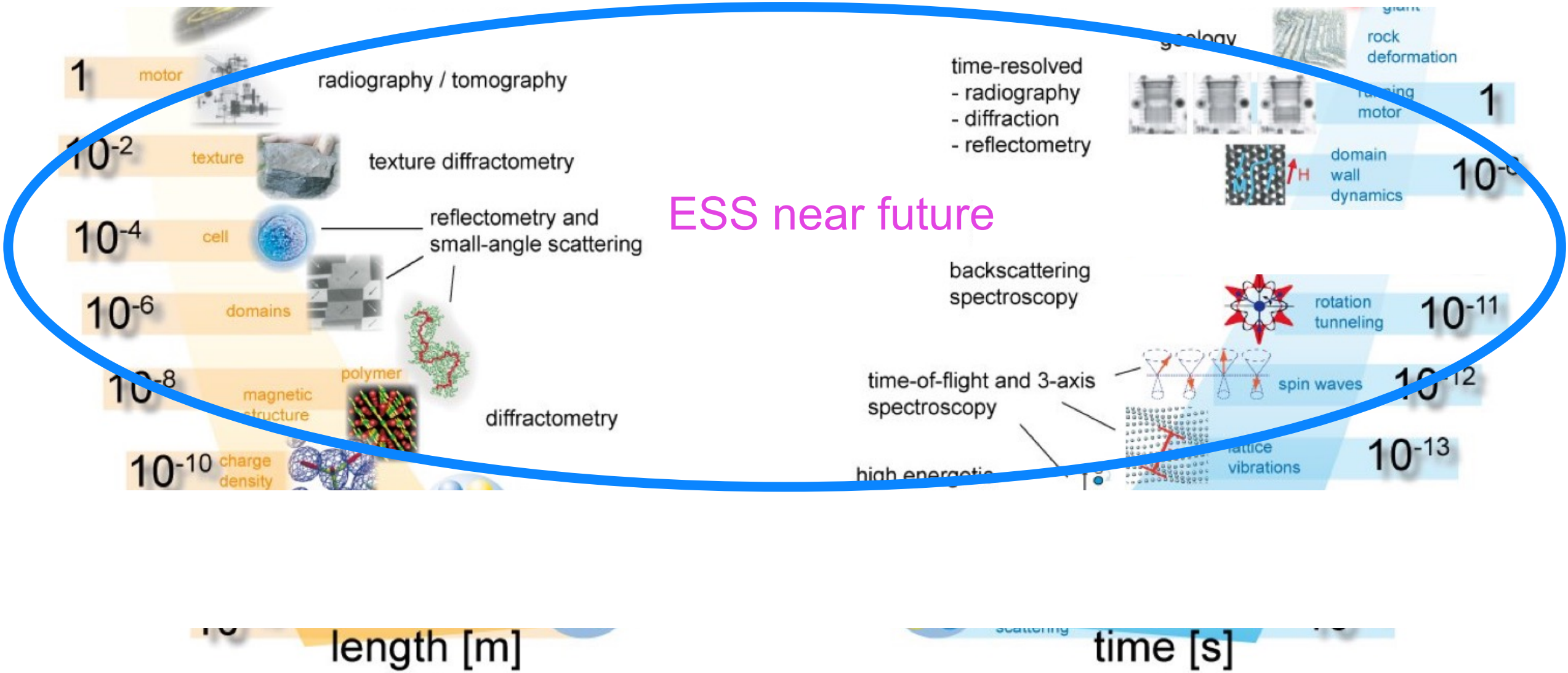
In-kind model for instrument design and construction



22 public instruments , 15 selected to date

- Life sciences
- Soft condensed matter
- Chemistry of materials
- Energy research
- Magnetism, superconductivity
- Engineering, geosciences
- Archaeology, heritage conservation

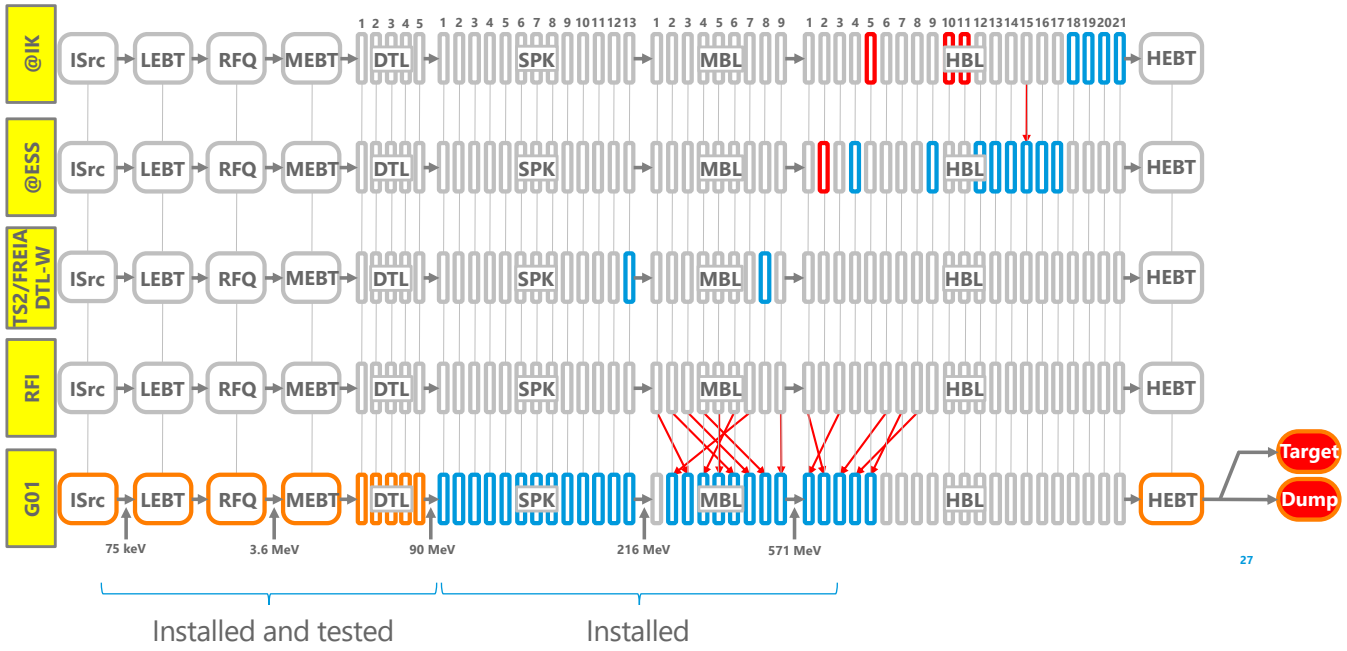
Exploring wide length and time-scales with neutrons



Accelerator

Installations progressing

- Normal Conducting Linac installation completed *(proton beam successfully transported to the DTL4 FC, achieving nominal current)*
- *Almost* a full compliment of CMs ready for BOD/BOT (*2K operation achieved*)
- Gallery support systems are in good shape. All RF racks needed for BoT have been energized, now being soak tested.
- A2T region nearing completion



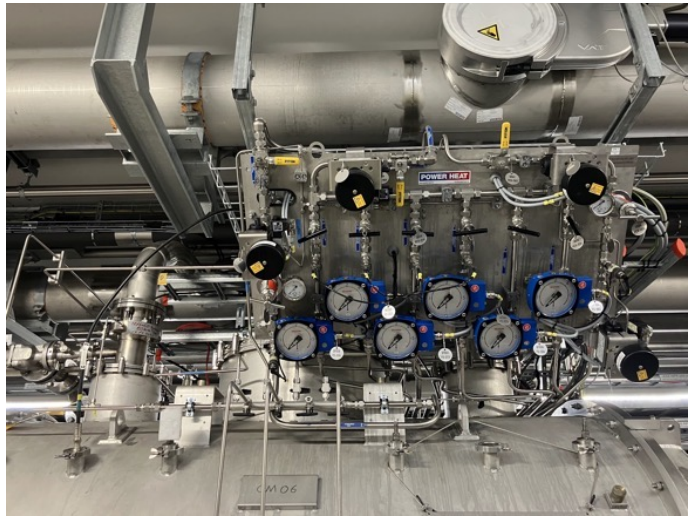
Week 5: The French state visit to the Accelerator tunnel celebrating the recent achievements leading up to beam operations at the end of 2024

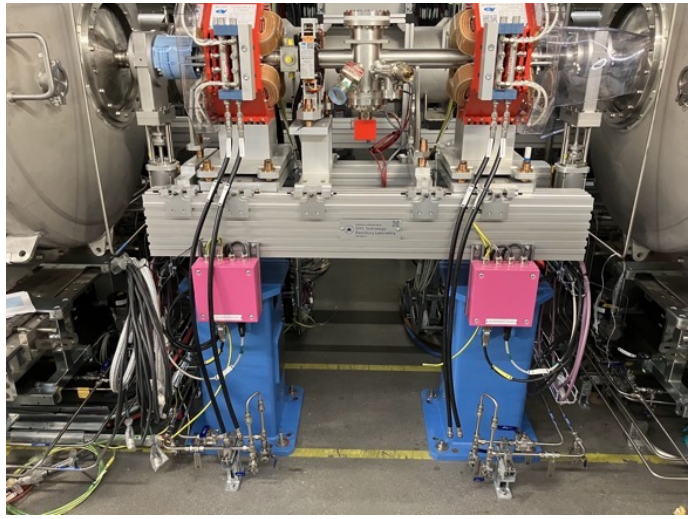
DTL installation complete by INFN team

All spoke cryomodules installed

But one was vented

Pipework at SPK030 completed

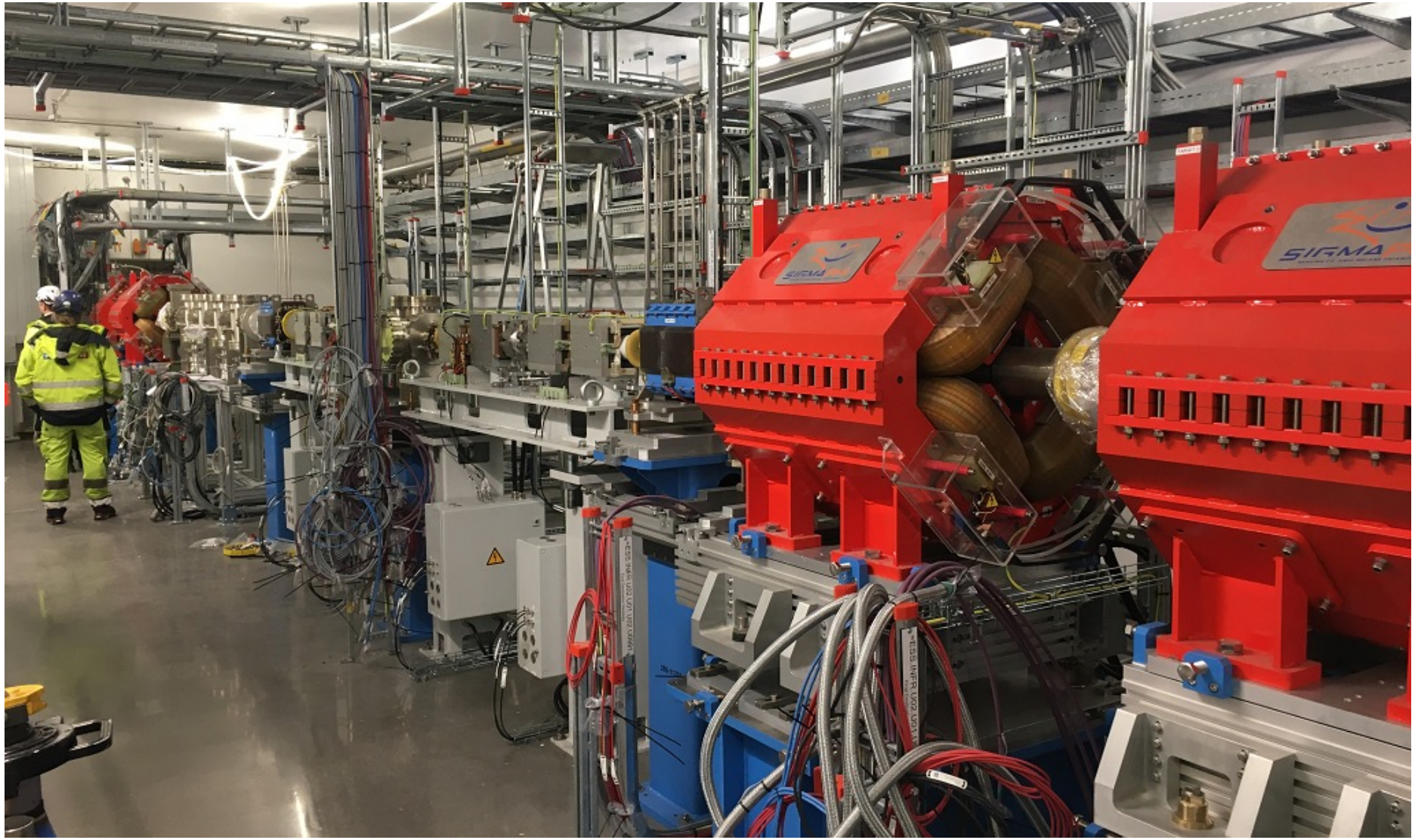




Medium and high-beta cryomodules installed

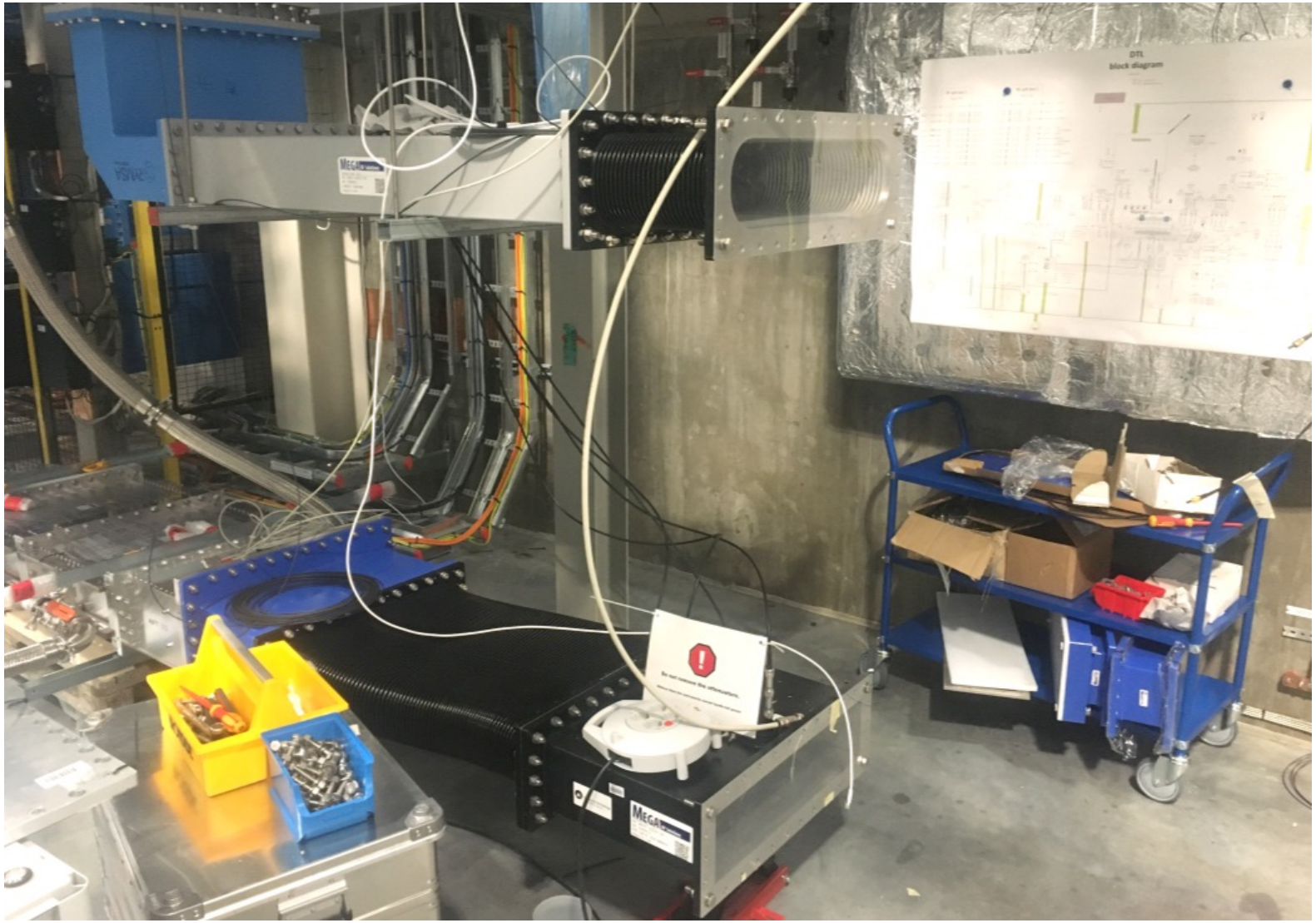
“Dogleg”, from tunnel to surface level

Beam-delivery system, rastering magnets

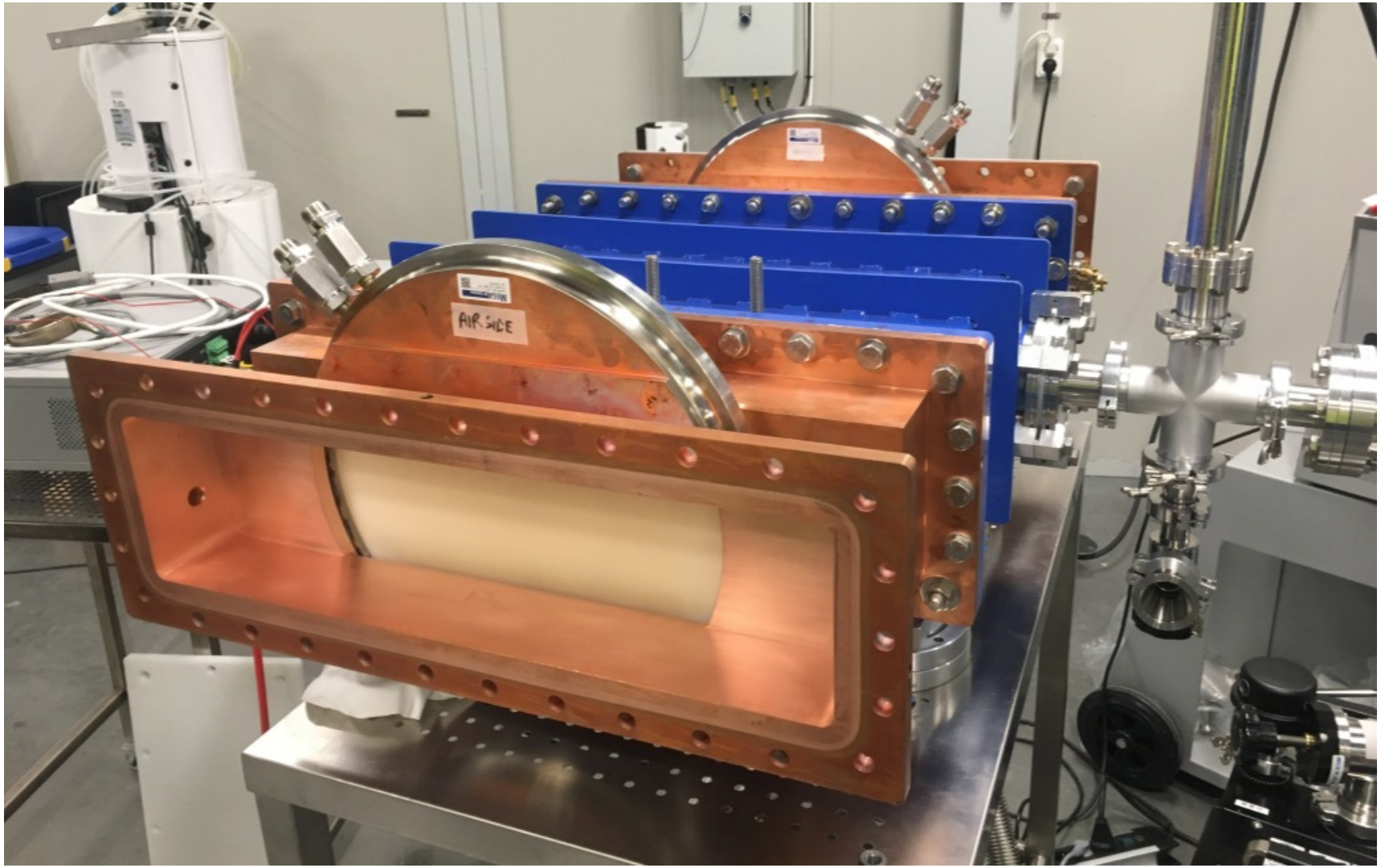


Gamma blocker, end of accelerator tunnel

DTL window test setup



DTL windows with test box



2024

A crucial year for the project

Finish installation of CMs, RF, BI, Magnets
Conditioning of CMs and DTLs
Shielding and fire sealing
Backup compressor, H20 upgrade
MPS, PSS for BoD
Cryo cooldown with 27 CMs
SAR4/SRR4

Beam on Dump
~Nov

A2T region

2024

2025

Last deliveries of Target components (e.g. He circ. A&B)
Target installation -> testing & commissioning

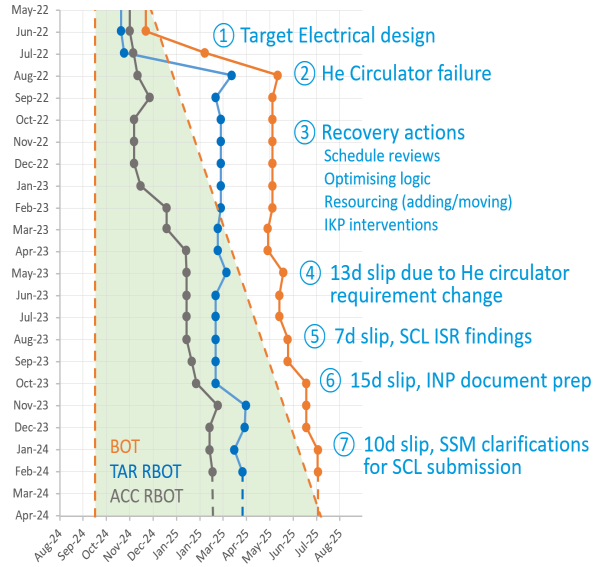
INP ref doc complete, receive SCL permit, submit INP permit

DMSC systems ready for Tranche 1
LOKI, ODIN, DREAM, BIFROST, TBL TG5/SAR

Integrated testing

Beam on Target
~Aug

Post-BoT activities



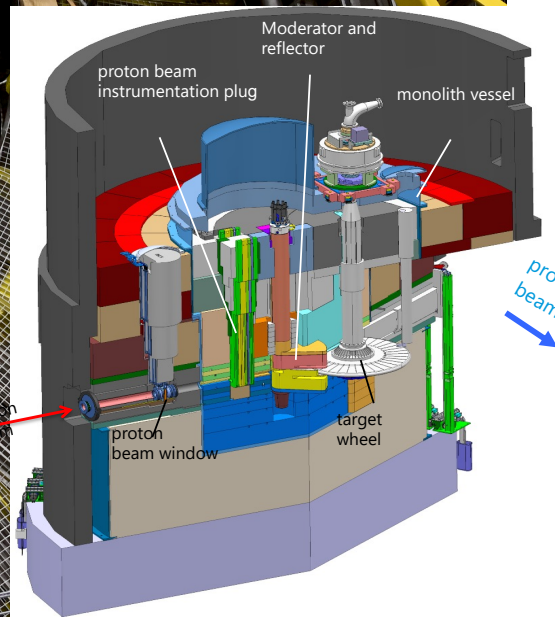
Target

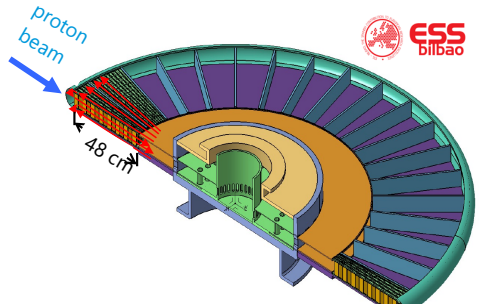
Monolith systems

The connection cell and monolith area has been a hive of activity.

The monolith cap installed on 22 May is the last piece of the puzzle to seal the Target Monolith vessel and will enable extensive pressure and leak tests of the entire volume.

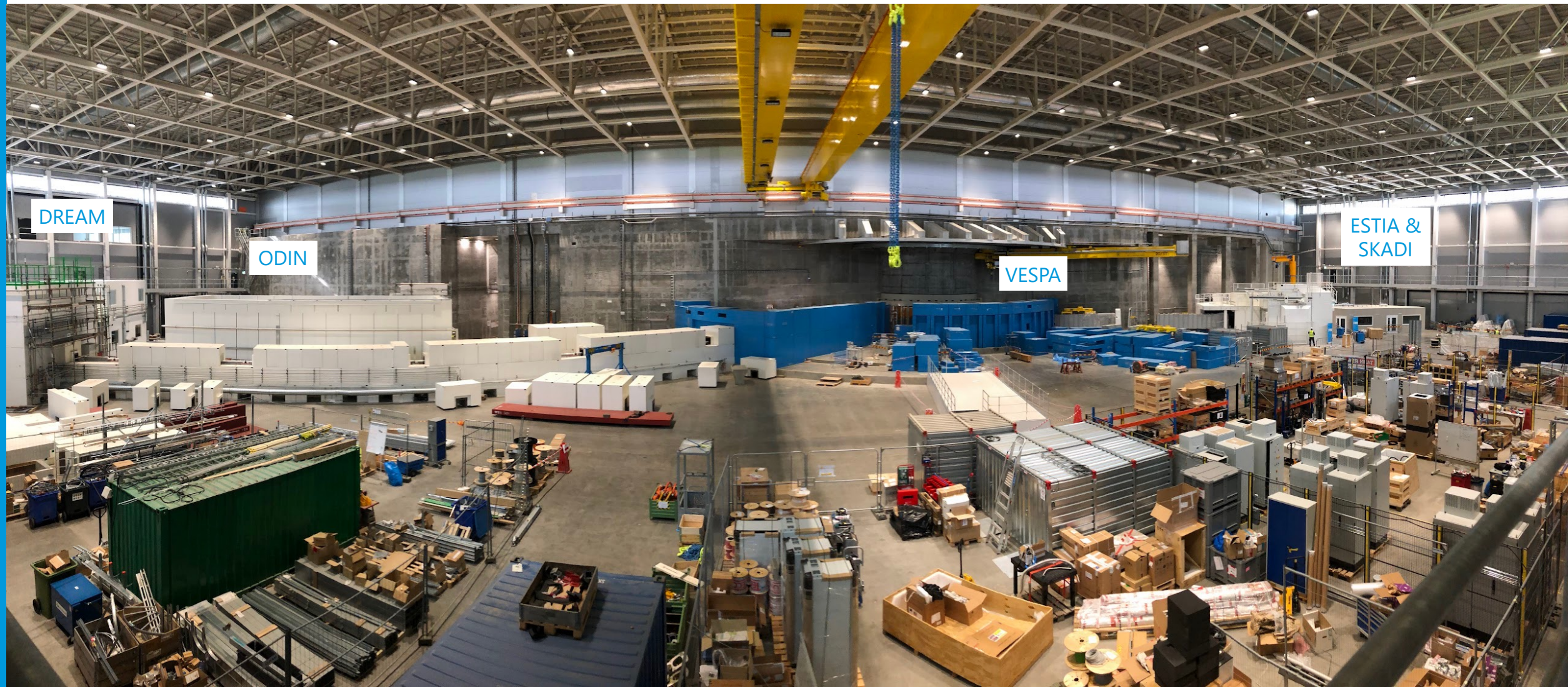
Installation is rapidly turning to testing and commissioning leading up to TAR RBOT





Neutron Instruments

D01 side



Neutron Instruments

D03 side

Neutron Instruments

Week 6: The in-bunker neutron guide section for LOKI is being assembled and aligned in an area next to the cave.

Tranche 1 is progressing:

The current focus is getting LOKI, BIFROST, ODIN, DREAM, NMX and TBL ready for BOT

In bunker components for later instruments are also being prioritized to limit future bunker work

Cave installations for ESTIA, SKADI and MAGIC ongoing

ESS Ramp up

BOT 5 August 2025

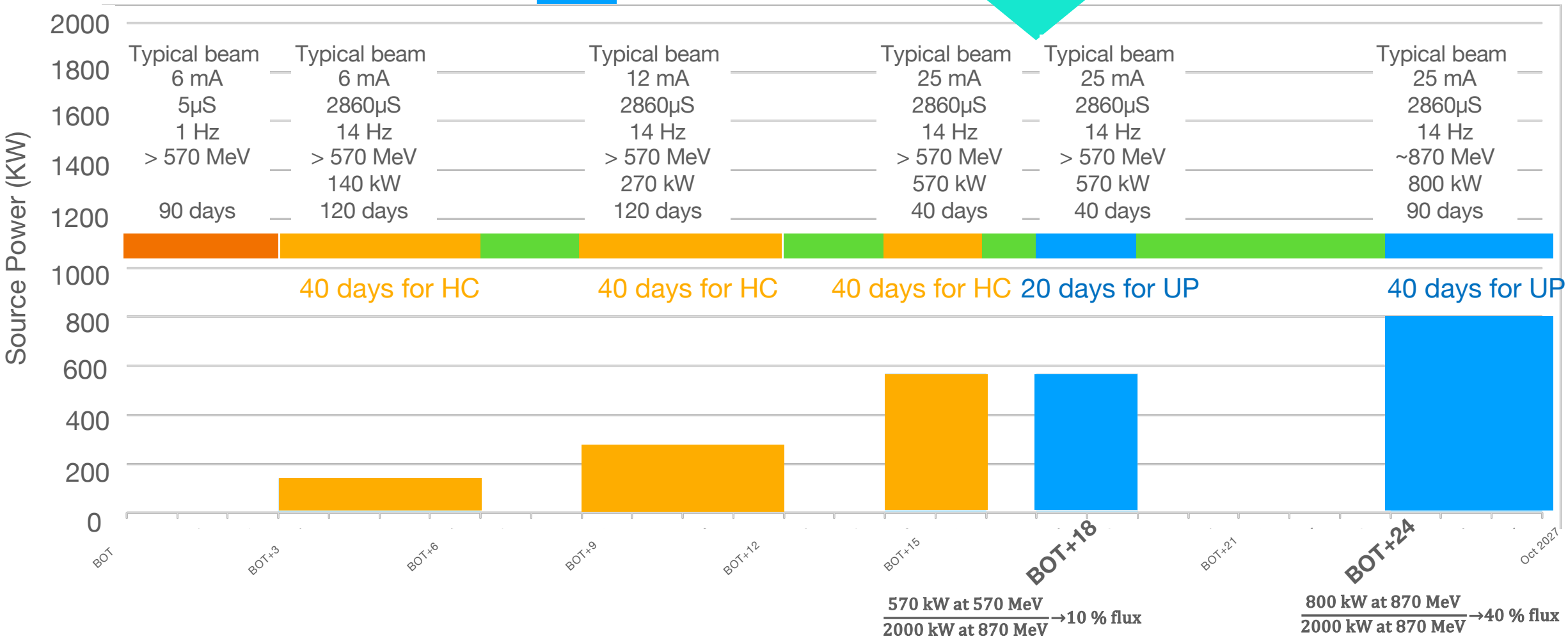
Accelerator commissioning & TBL

Hot commissioning

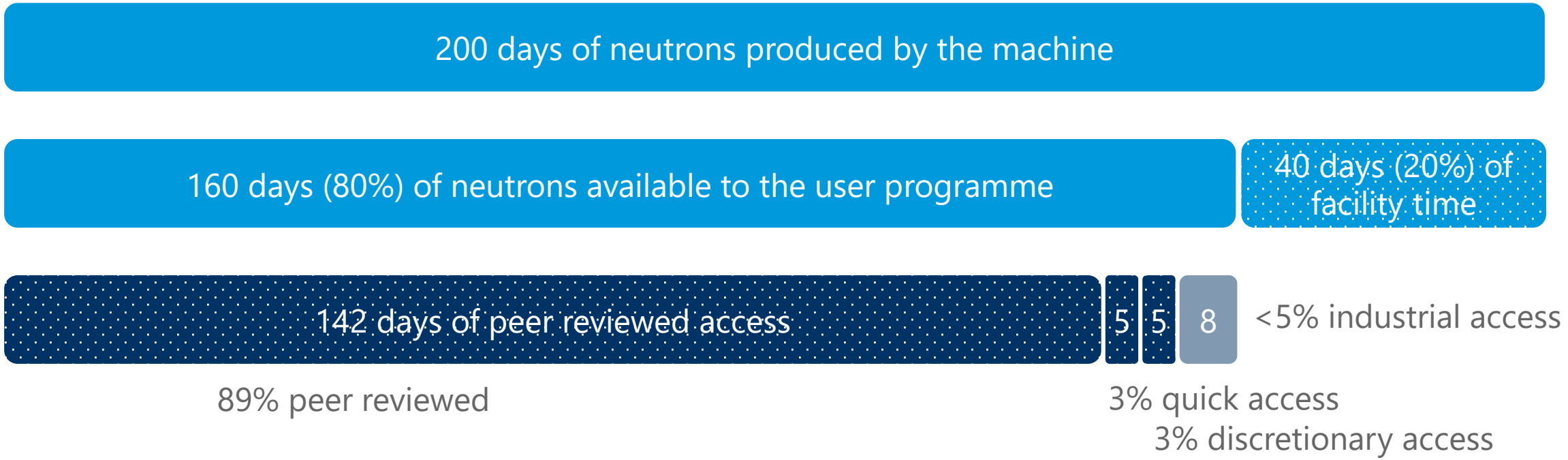
Shutdown

Users

First users 18 months after BOT



ESS proposal for Access to Neutron Instruments: work in progress



- **User programme to be offered to member countries proportionally to their financial contribution to the facility**
- Excellent science from non member countries will be possible via discretionary access
- ESS staff are invited to use the peer review process

ESS meetings organisation & first science brainstorm

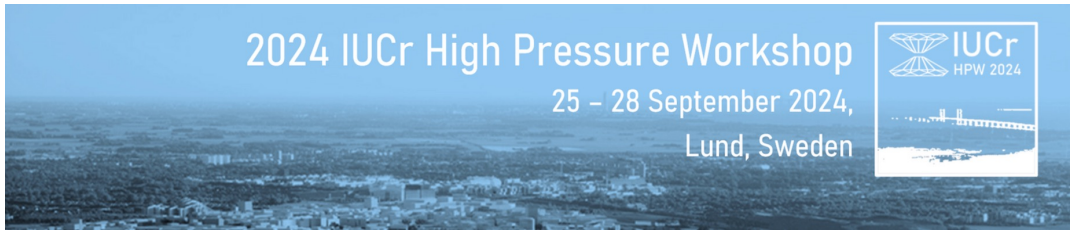
REFLECTOMETRY – SXNS & ORSO (Grenoble - Jul)

NMX – ECM 34 – (Padova - Aug)

SANS - ECIS 2024 satellite – (Copenhagen - Sep)

IMAGING – NEUWAVE 12 (Lund – Sep)

DIFFRACTION - IUCr High Pressure (Lund - Sep)



FUNDAMENTAL & PARTICLE PHYSICS (Lund – Oct)

Brainstorm of the community in view of next call for instruments)

ILL/ESS USER MEETING (Grenoble – Dec)

Mats Lindroos (1961-2024)

An invaluable member of our organisation, contributing heavily to its establishment and development with his knowledge and kindness towards everyone.

In 2015 Mats formally joined ESS and led the Accelerator Division and sub-project since its inception before stepping down earlier this year due to his illness.

His visionary, collaborative approach led to the establishment of strong and enduring In-Kind partnerships with many institutions that have worked together to build the elements of the machine now being installed and tested in Lund.

The energy and passion that he devoted to the ESS and the accelerator sub-project will be realised towards the end of the year when the accelerator construction will be finalised and commissioning begins.

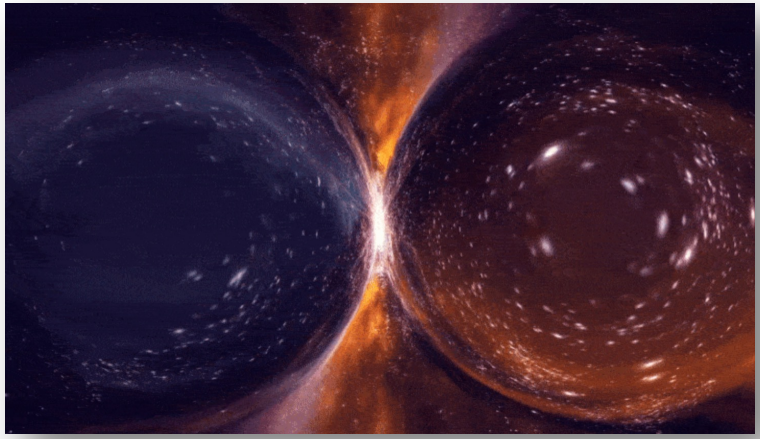
Mats was a strong advocate for other novel and scientifically important potential future uses for the capabilities that ESS will deliver, engaging and connecting those interested in these initiatives to the last.

Mats will be greatly missed by all of us who had the privilege to work alongside him.

Additional slides

- The ESS will be the brightest neutron source in the world enabling new opportunities for many different scientific fields, including materials and life sciences, energy, environmental technology, cultural heritage and fundamental physics

- User community is developing a broad fundamental physics program



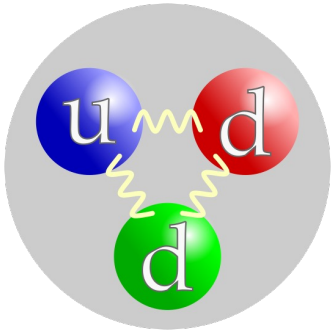
- This includes mainly
  - Physics with neutrons
  - Physics with neutrinos

Fundamental physics possibilities with **neutrons**

Standard Model of particle physics (SM)

Precision experiments

Beyond SM
New interactions



HIBEAM Beamline
Search for neutron oscillations
Search for Axion-like particle
Hadronic parity violation
Electromagnetic properties of the neutron

Search for Neutron antineutron oscillation (NNBAR)

Matter –Antimatter asymmetry of the Universe

ANNI Beamline
Neutron Beta Decay
Hadronic parity violation
Electromagnetic properties of the neutron

Ultra Cold Neutron

Electric Dipole moment of the neutron (EDM)

Gravity resonance spectroscopy

Neutron beta decay

Fundamental physics possibilities with **neutrinos**

Standard Model of particle physics (SM)

Precision experiments

Beyond SM
New interactions

ESSν
Coherent Elastic Neutrino-Nucleus Scattering at the ESS
High-statistics, precision CEνNS measurements

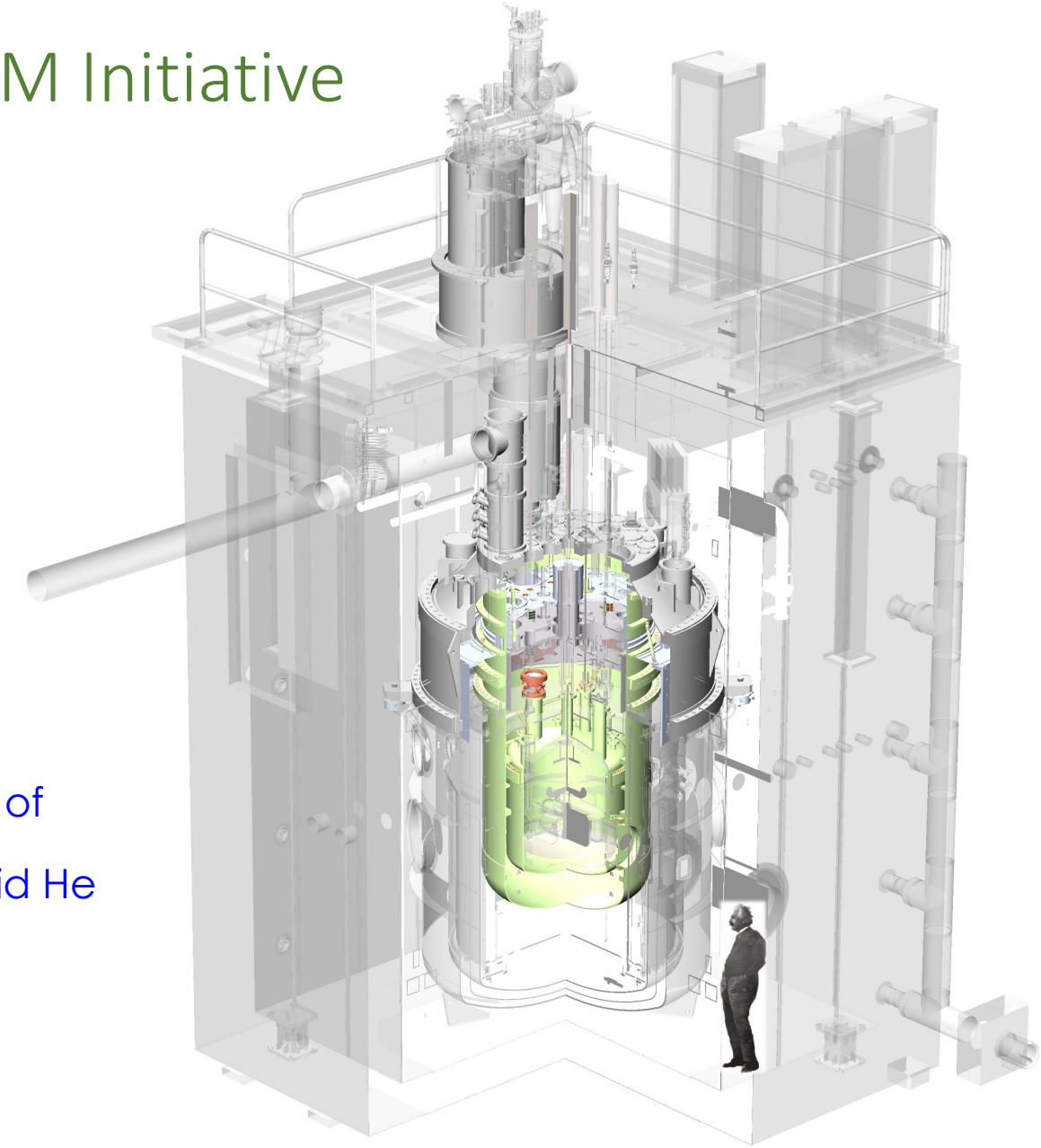
ESSnuSB
Discover and measure neutrino CPV

U.S./European Cryogenic Neutron EDM Initiative

- A large scale cryogenic experiment to measure the neutron EDM at a sensitivity below 3e-28 e-cm.
- Mostly developed by US Department of Energy and National Science Foundation, but funding terminated in 2023 with construction underway.

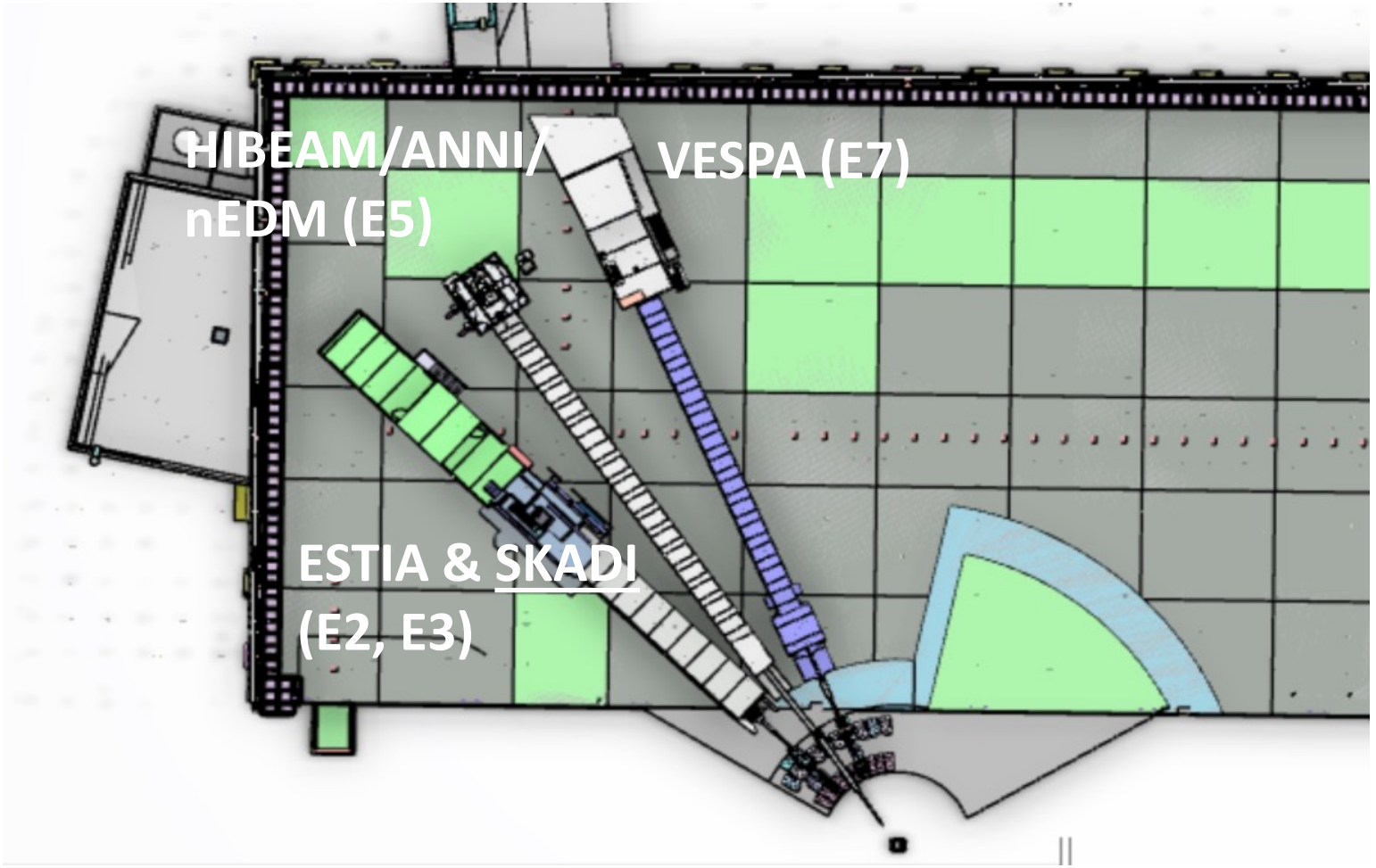
New Effort

- Planning a sequence of preparatory demonstration measurements at ILL
- Experiment could be installed at ESS for improved precision beyond goals at Oak Ridge's Spallation Neutron Source
    - Uses cryogenic techniques to improve all aspects of the experiment
    - Production of ultra-cold neutrons in situ in superfluid He provides high density in measurement cell
    - Same He serves as insulator for high voltage, permitting higher electric field than at room temperature
    - Same He serves as scintillator to detect light from absorption of neutrons on ^{3}He spin analyzer
    - Cryogenic experiment allows precise control of magnetic field conditions



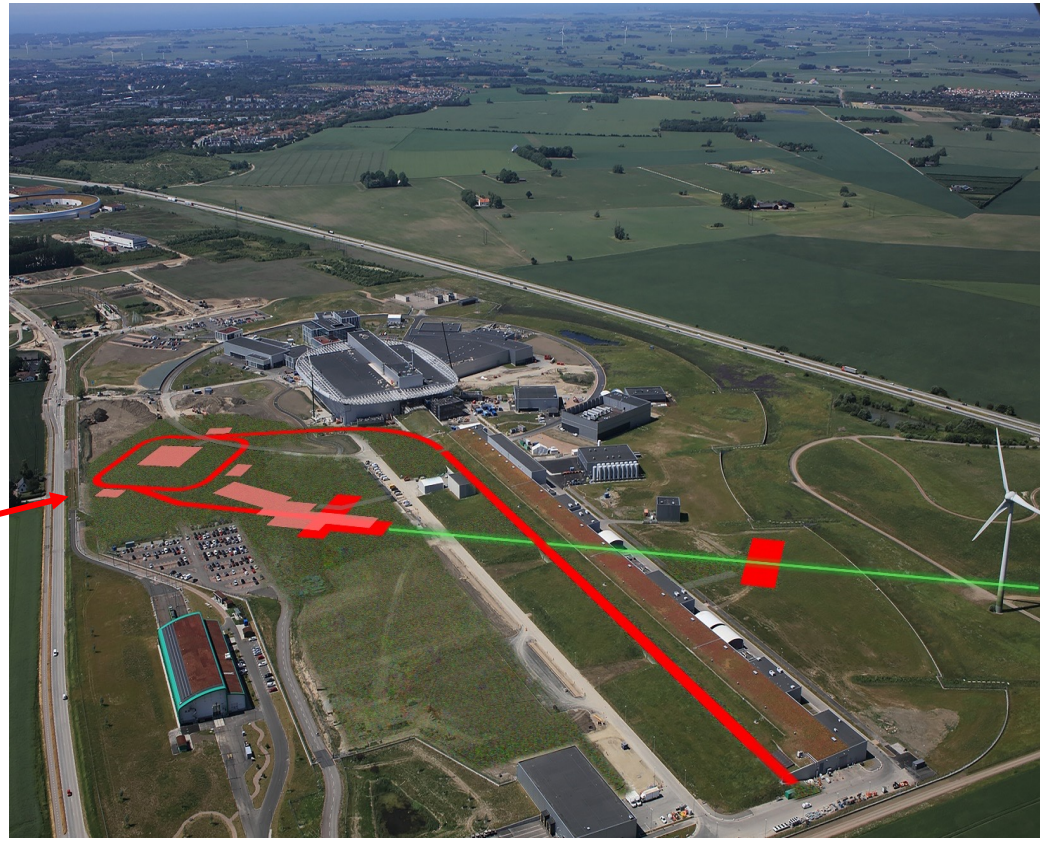
Relocating the nEDM Experiment to ESS is under discussion

- The nEDM experiment could be installed on the E5 beamline at ESS, to run as part of general purpose particle physics beamline
- Initial investigations show that the experiment is technically compatible with ESS site with minor modifications
- Seeking to collaborate with Europe-based scientists to complete R&D at ILL and obtain future funding

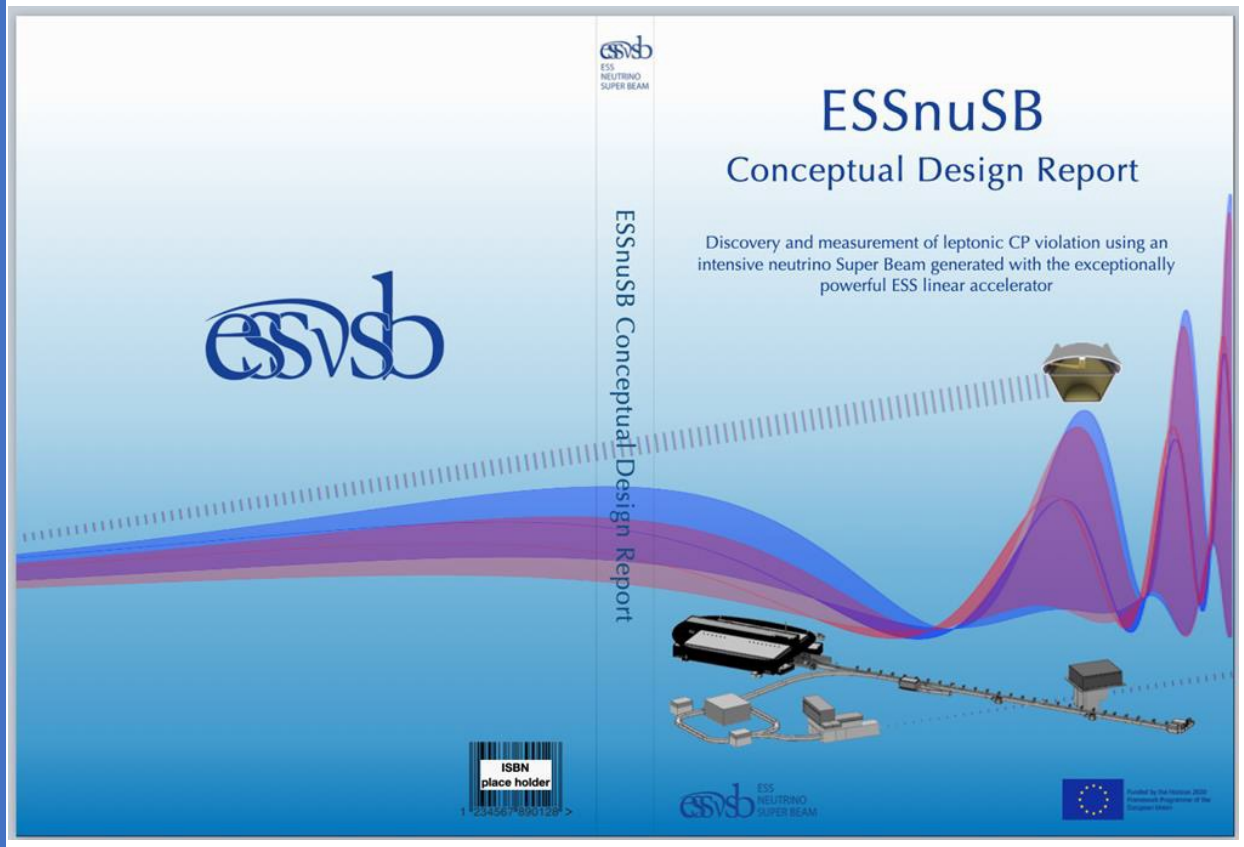


The ESS neutrino Super Beam (ESSnuSB)

- The ESSnuSB is a proposed accelerator long baseline neutrino experiment at ESS
- The ESSnuSB will search for CP violation in the leptonic sector with higher precision
- The ESS accelerator needs to be upgraded
- A neutrino production target station will be built
- There will be a near detector close to the neutrino target station and a far detector in the north of Sweden
- They are supported by 2 European INFRADEV grants



ESSnuSB Conceptual Design Report



Published on arXive 6June 2022:
https://arxiv.org/abs/2206.01208
and in European Physical Journal 6 Nov 2022
Eur. Phys. J. Spec. Top .(3955-3779 :**231** (2022))
https://link.springer.com/article/10.1140/epjs/s11734-00664-022-w

CDR outline:

1 Linac upgrade

2 An accumulator ring

3 A target station and 50 m decay tunnel

4 A near detector placed in the neutrino beam
Some 250m downstream of the target station

5 A far detector 360 km from the target station
consisting of two large underground tanks filled each with 24000m^3 of water

6 Physics performance

The ESSnuSB+ Collaboration

1	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR
2	UNIVERSITE DE STRASBOURG	FR
3	RUDER BOSKOVIC INSTITUTE	HR
4	TOKAI NATIONAL HIGHER EDUCATION ANDRESEARCH SYSTEM, NATIONAL UNIVERSITY CORPORATION	JP
5	UPPSALA UNIVERSITET	SE
6	LUNDS UNIVERSITET	SE
7	EUROPEAN SPALLATION SOURCE ERIC	SE
8	KUNGLIGA TEKNISKA HOEGSKOLAN	SE
9	UNIVERSITAET HAMBURG	DE
10	UNIVERSITY OF CUKUROVA	TR
11	NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	EL
12	ARISTOTELIO PANEPISTIMIO THESSALONIKIS	EL
13	SOFIA UNIVERSITY ST KLIMENT OHRIDSKI	BG
14	LULEA TEKNISKA UNIVERSITET	SE
15	ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE	CH
16	UNIVERSITA DEGLI STUDI ROMA TRE	IT
17	UNIVERSITA' DEGLI STUDI DI MILANO-BICOCCA	IT
18	ISTITUTO NAZIONALE DI FISICA NUCLEARE	IT
19	UNIVERSITA DEGLI STUDI DI PADOVA	IT
20	CONSORCIO PARA LA CONSTRUCCION, EQUIPAMIENTO Y EXPLOTACION DE LA SEDE ESPANOLA DE LA FUENTE EUROPEA DE NEUTRONES POR ESPALACION	ES

The ESSnuSB Collaboration, currently consisting of ca 80 members from 20 universities and laboratories in 11 European countries has had and has strong support from the European Commission, from ESS and from Zinkgruvan Mining.