
ess
EUROPEAN
SPALLATION
SOURCE



Bringing ESS to Life – Testing and Commissioning Progress

Superconductivity & Particle Accelerators Conference (SPAS'2026)

IFJ PAN, Krakow, 20-22 Oct 2026

COPIAN-POSTINAR

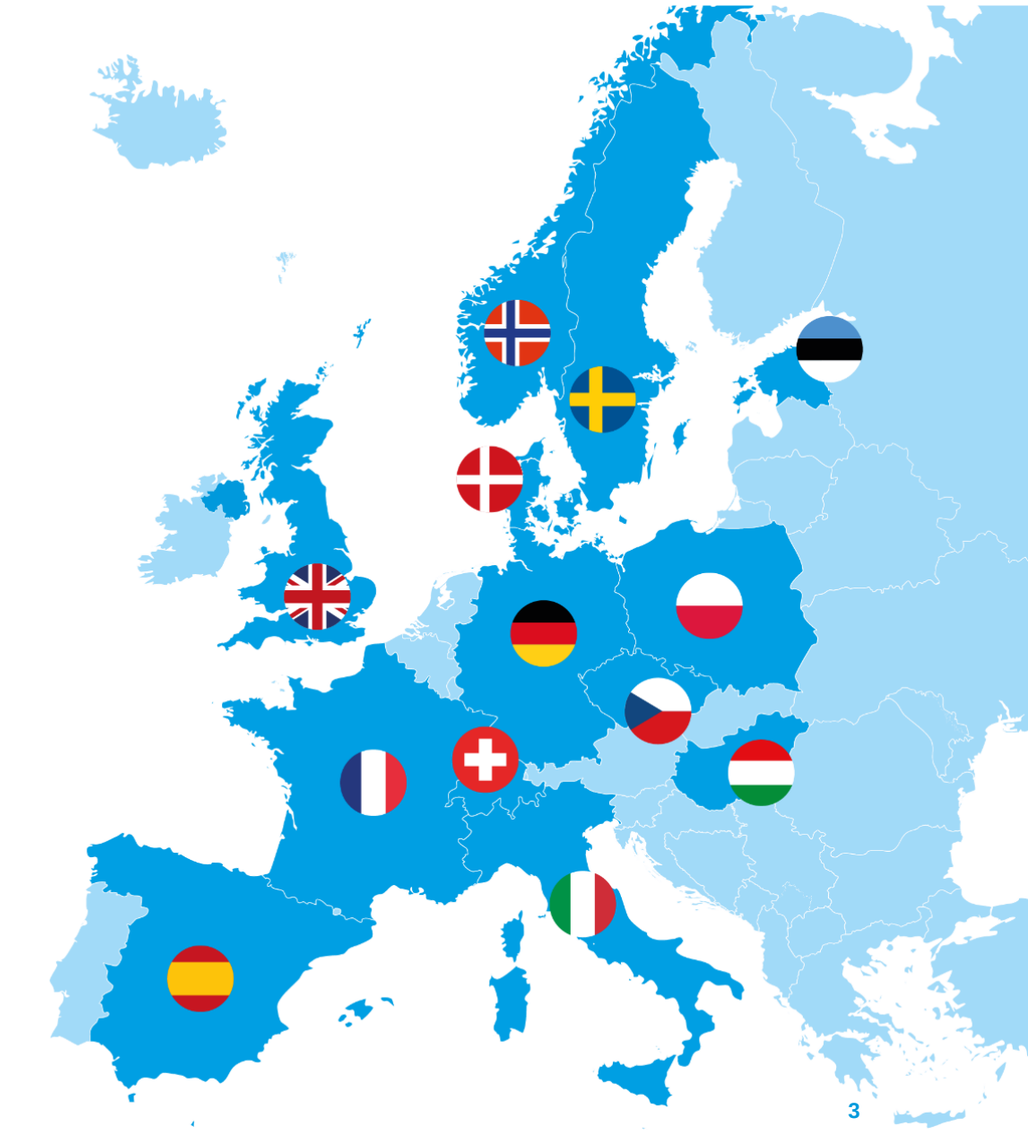
The ESS Project

13 European countries joining forces and sharing a common ambition!

- Host States:
  - Sweden, Denmark

- Member States:
  - Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy, Norway, Poland, Spain, Sweden, Switzerland, United Kingdom.

- A 3.5 B€ project, with an estimated annual operations and development cost of about 180 M€.



The ESS In-Kind Model

A unique international project with over 100 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
Copenhagen University
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)
Laboratoire Léon Brilouin (CEA/CNRS/LLB)
Lund University
Nuclear Physics Institute of the ASCR
Oslo University
Paul Scherrer Institute (PSI)
Polish Electronic Group (PEG)
Roskilde University
Rutherford Appleton Laboratory, Oxford (ISIS)
Tallinn Technical University
Technical University of Denmark
Technical University Munich
Science and Technology Facilities Council
UKAEA Culham
University of Tartu
Uppsala University
WIGNER Research Centre for Physics
Wroclaw University of Technology
Warsaw University of Technology
Zurich University of Applied Sciences (ZHAW)



The ESS Vision

ESS will be a world-leading facility for neutron-based research



How ESS Works

In a Nutshell

1 Protons are generated in the ion source

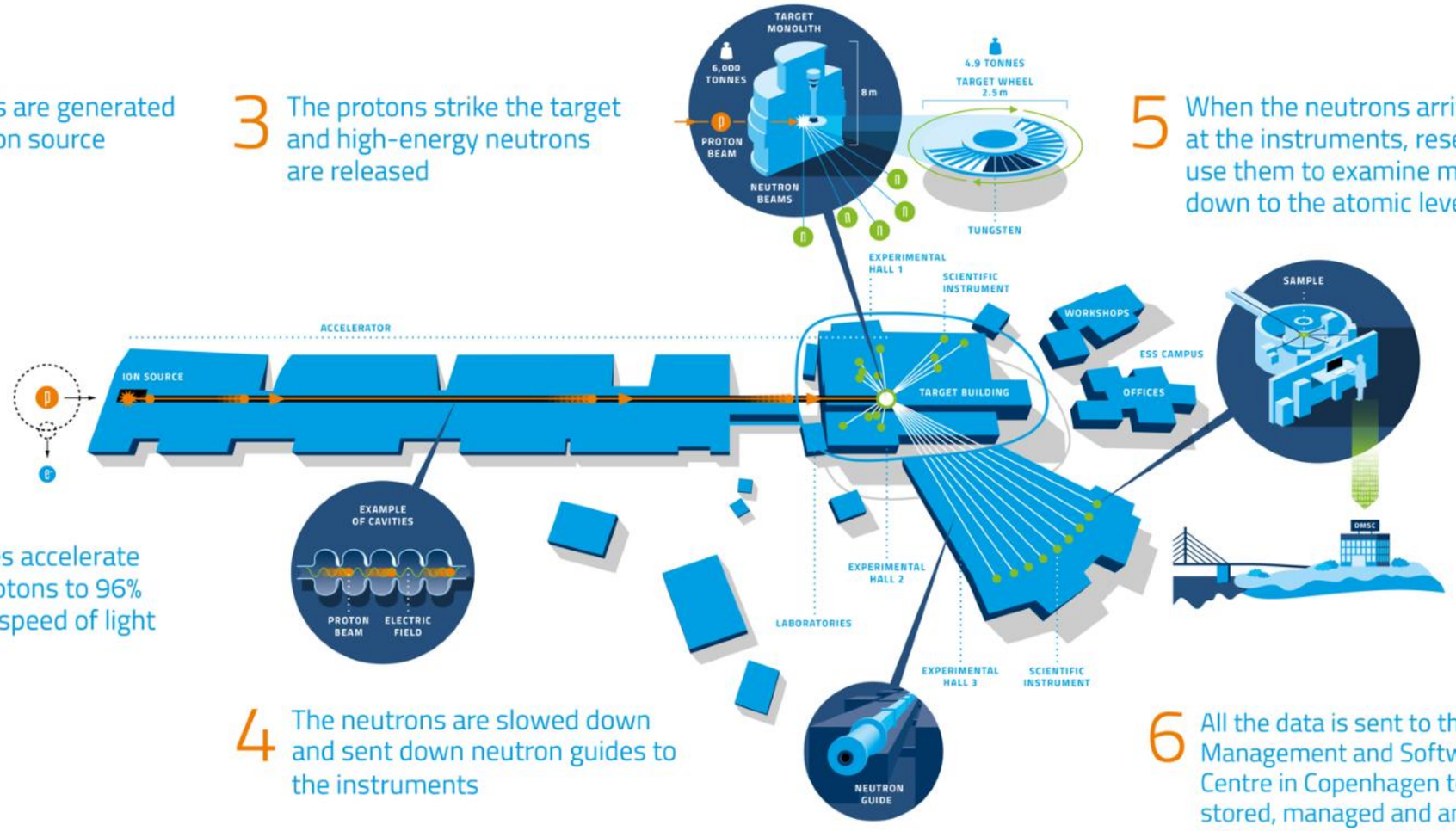
2 Cavities accelerate the protons to 96% of the speed of light

3 The protons strike the target and high-energy neutrons are released

4 The neutrons are slowed down and sent down neutron guides to the instruments

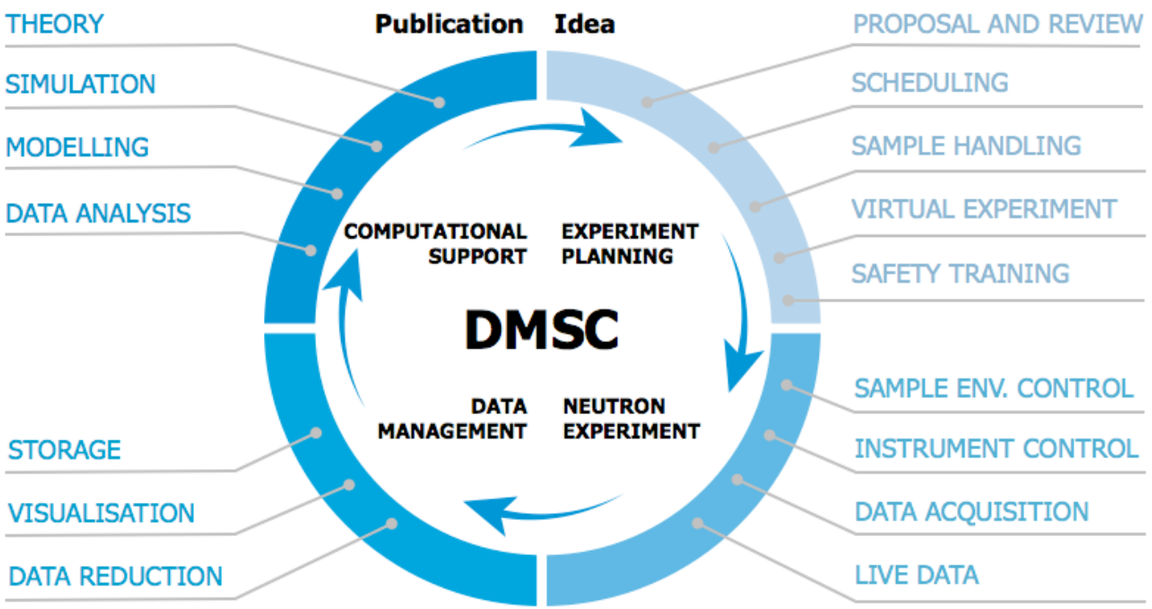
5 When the neutrons arrive at the instruments, researchers use them to examine matter down to the atomic level

6 All the data is sent to the Data Management and Software Centre in Copenhagen to be stored, managed and analysed with the researchers



The Data Management and Scientific Computing Centre (DMSC)

- Located at the Technical University of Denmark in Lyngby.
- Supports users from proposal to publication with scientific computing tools and services
- Actively developing AI-driven tools to automate neutron data analysis, optimise experiment workflows, and enhance real-time decision-making for Users

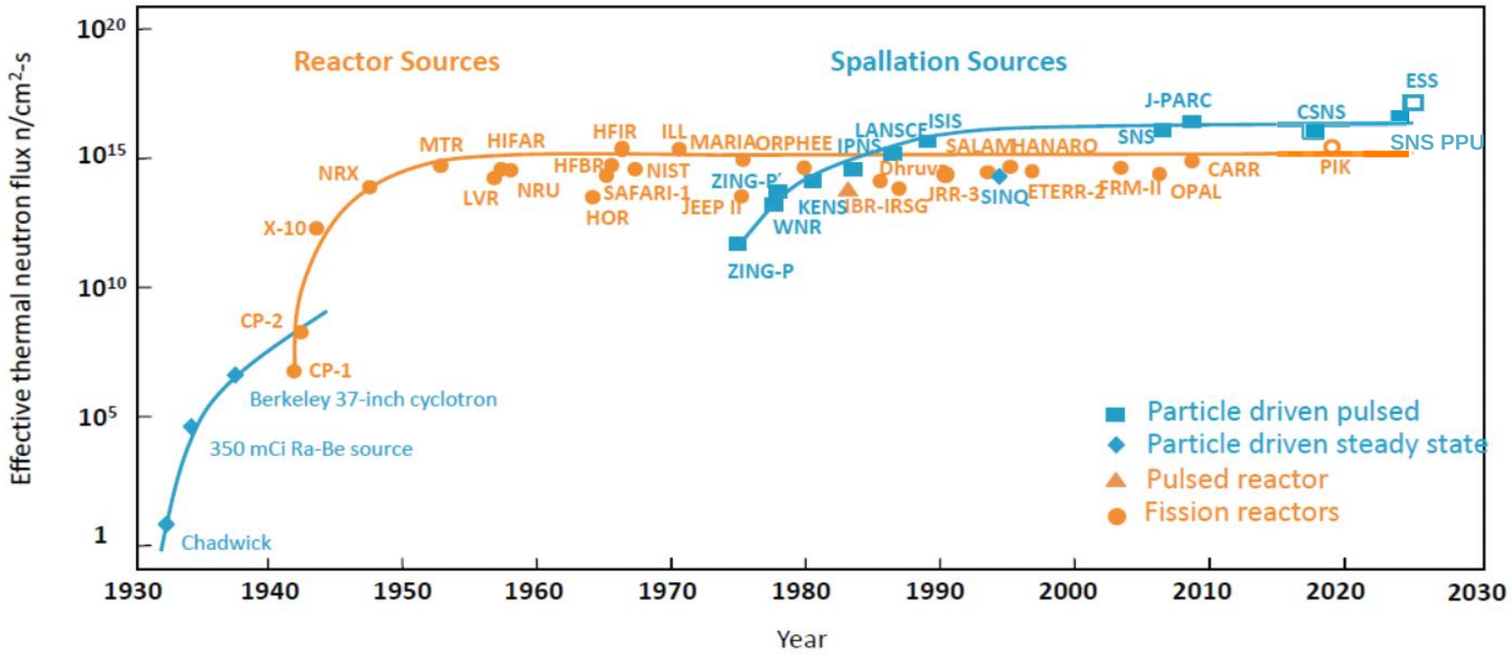


Neutron Science

ESS is positioned to take its intended place as a cutting-edge neutron source

- ESS bridges the worlds of continuous neutron sources (reactors and cyclotrons) and short-pulsed neutron sources (rapid-cycling synchrotrons or linear accelerators with accumulator rings) to enable new experimental techniques

- Major national and international facilities strive to schedule neutron delivery for ~200 days/year



Continuous Sources	Long-Pulse Source (2.86 ms)	Short-Pulse Sources (< 1 us)
Fission Reactors: ILL (France) - 58 MWth HFIR (USA) - 83 MWth Accelerator – Cyclotron: SINQ (Switzerland) - ~1MW	Accelerator – Linear: ESS (SE/DK) - 14 Hz, 2-5 MW	Accelerator – RCS: J-PARC MLF (Japan) - 25 Hz, 1 MW ISIS/RAL (UK) - 40/10 Hz, 160/40 kW CSNS (China) - 25 Hz, < 500 kW Accelerator – Linear/Accumulator Ring: LANSCE (USA) - 20 Hz, 80 kW SNS (USA) - 60 Hz, 2 MW

ESS Instruments

Each instrument designed to be world-leading at 2MW

- 15 instruments in baseline budget and currently in development
- Each instrument designed to be world-leading at 2MW
- A total of 42 beam ports
- Next phase: Up to 22 instruments

Life sciences

Soft condensed matter

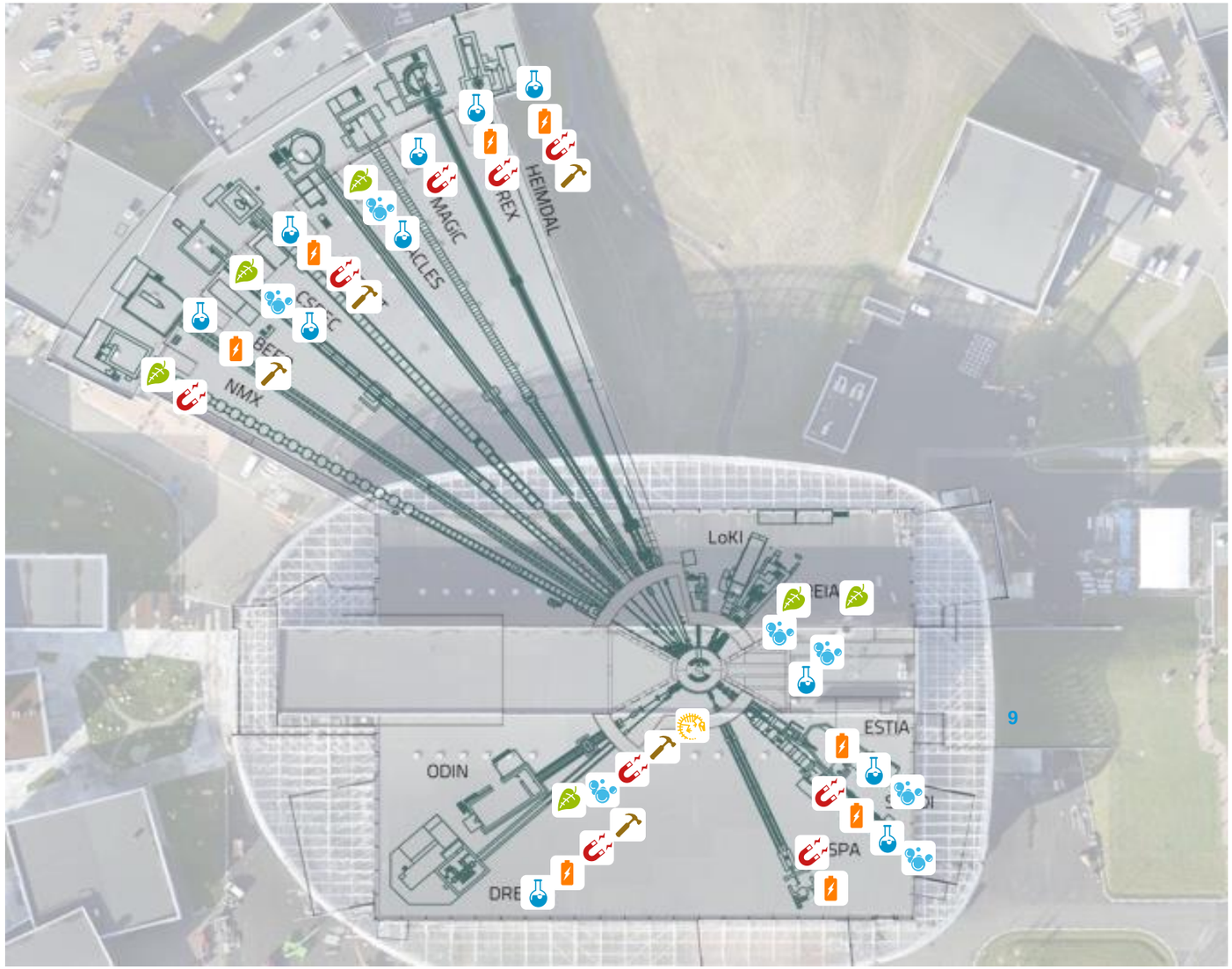
Chemistry of materials

Energy research

Magnetism & superconductivity

Engineering & Geo-sciences

Archeology & Heritage conservation

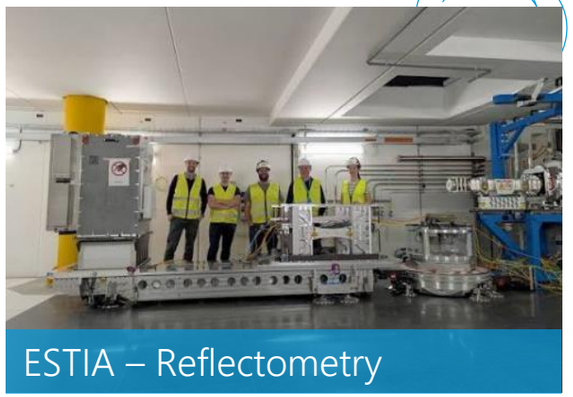


ESS Instruments

Instruments

- 6 instruments + Test Beam Line (TBL) will be ready for first neutrons at BOT
  - LOKI, BIFROST, ODIN, DREAM, ESTIA, NMX
- Outreach to the scientific and industry user community, and readying support laboratories
- Major steps towards readiness for operations across the whole organisation
- Significant effort on all remaining instruments

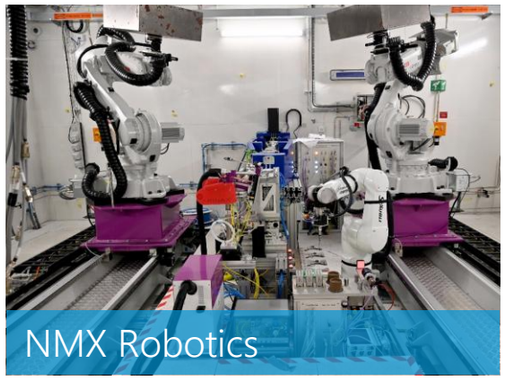

DREAM – Diffraction

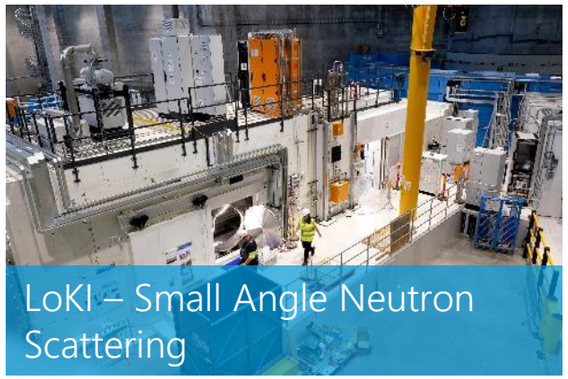

ESTIA – Reflectometry


TBL - Test Beamline


BIFROST – Spectroscopy


E02 Beamline Gallery


NMX Robotics

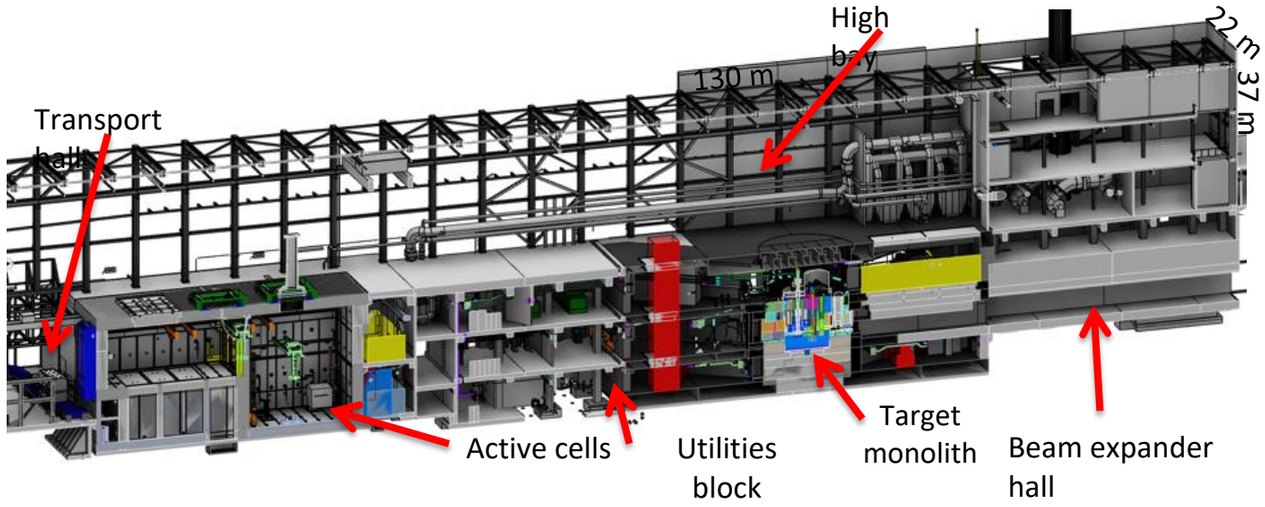

LoKI – Small Angle Neutron Scattering

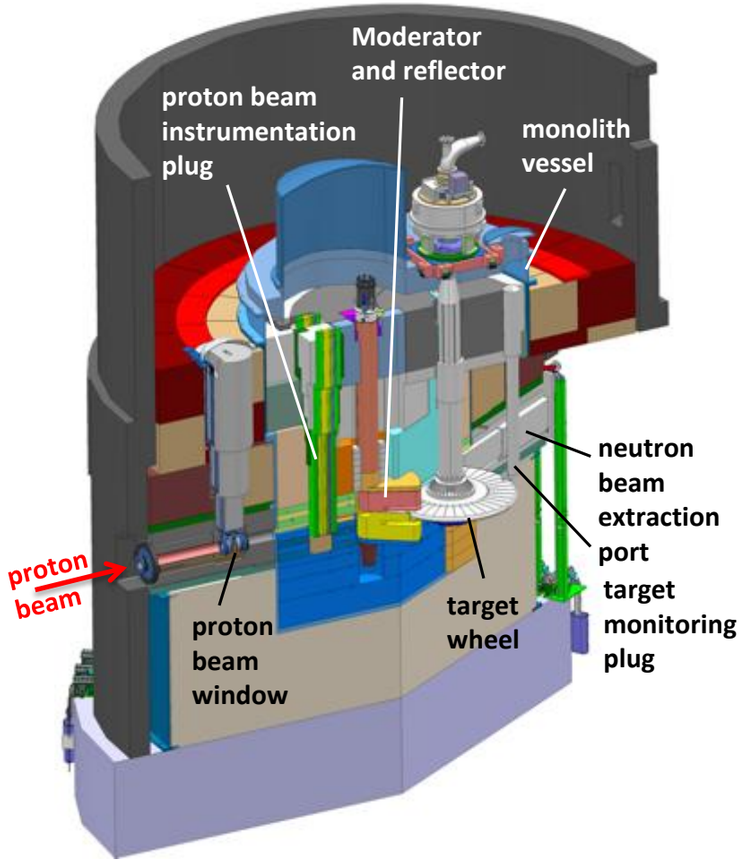

ODIN – Multi-purpose Imaging

Towards Beam on Target (BOT)

Target

- 5 tonnes rotating tungsten target (~3T tungsten), He cooled
- Suspended by a 5m long shaft
- 36 sectors, rotates @23.3 rpm, synchronised with 14 Hz proton beam
- Expected 5 year lifetime (at 5 MW)



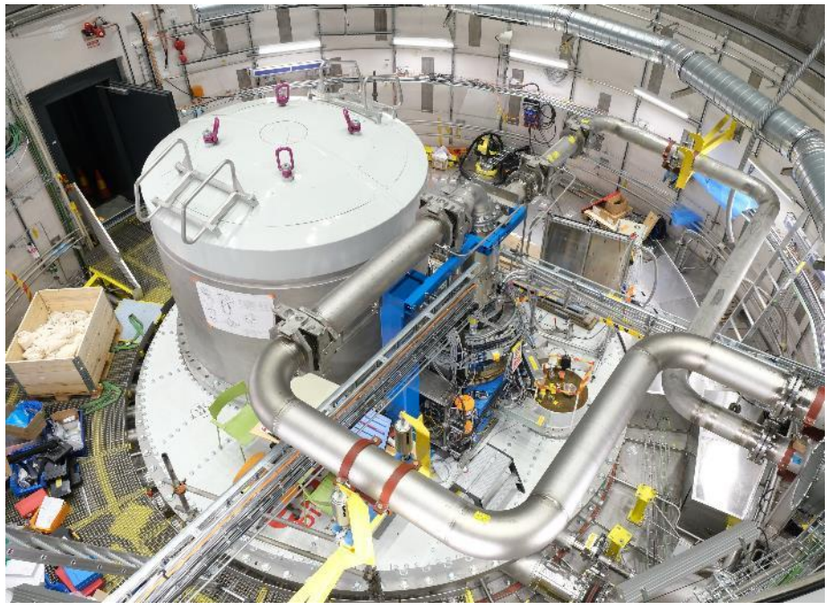


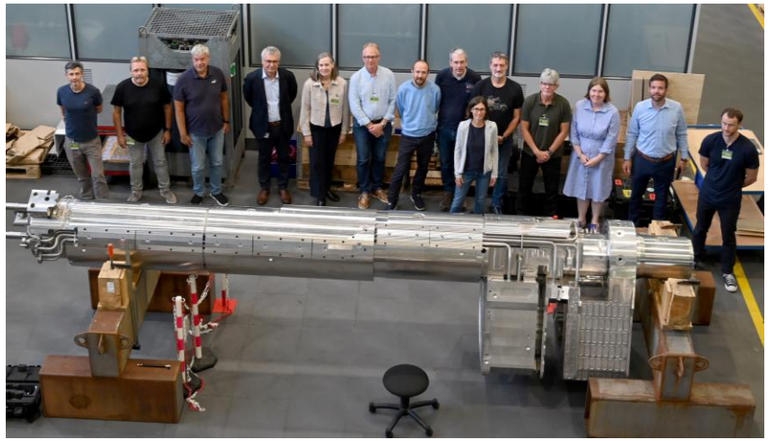
Towards Beam on Target

Target

- The majority of systems and components for the Neutron Factory have been installed
- An incident in Nov. 2025 delayed completion, as MRP1 was damaged
- Testing of individual systems and commissioning of systems groups is largely completed.
- Integrated tests and commissioning of system groups are mostly completed.
- Commissioning without beam ongoing.
- Full integrated commissioning of the Neutron Factory to be completed by the end of 2026.
- MRP2 arrived at ESS, in September!!!



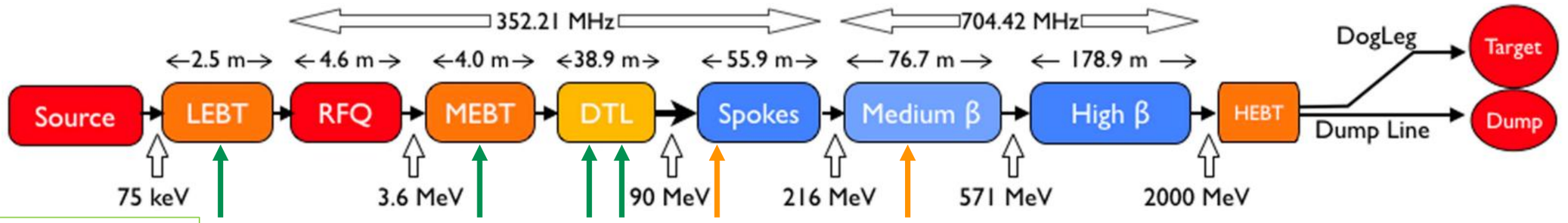






Towards Beam on Target

Accelerator



Intermediate beam stops

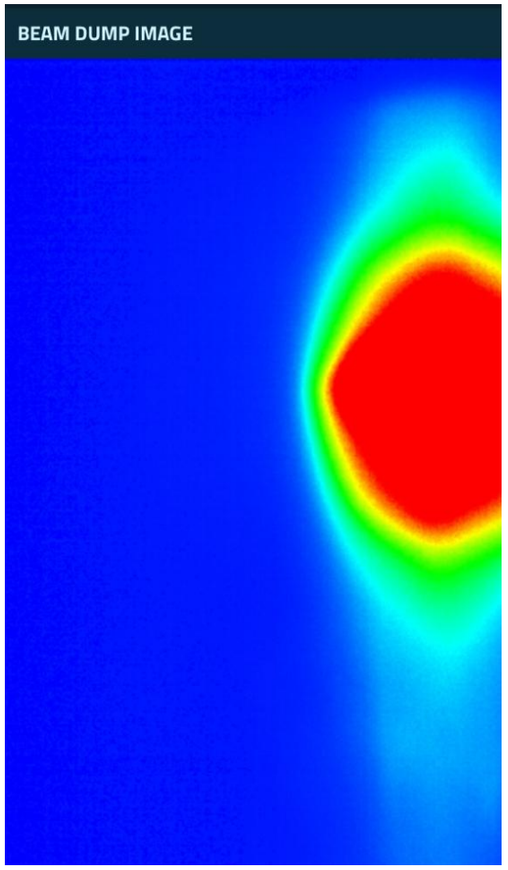
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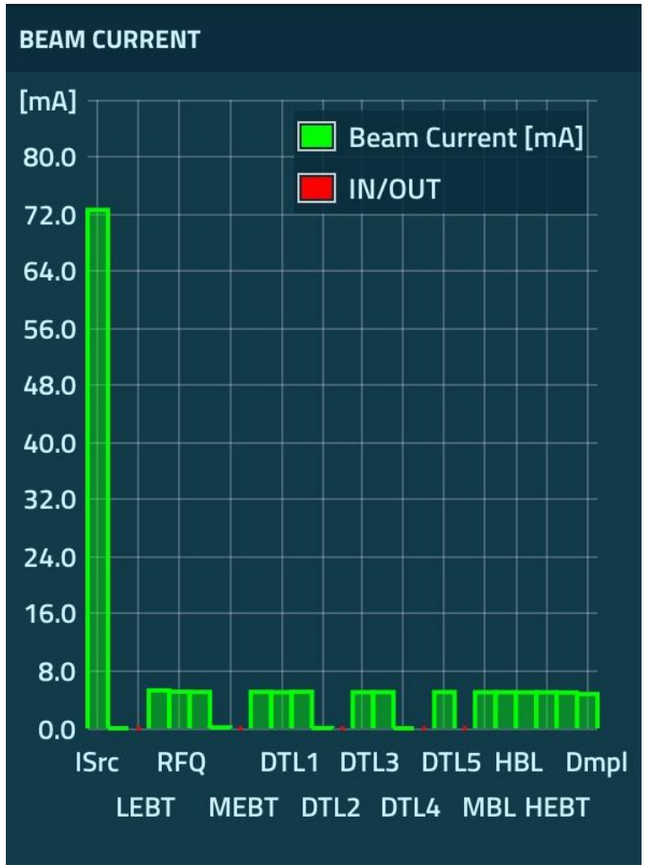
Parameter	Value
Avg. power (design/today) [MW]	5/2
Max. energy (design/today) [MeV]	2000/870
Peak current [mA]	62.5
Pulse length [ms]	2.86
Rep. rate [Hz]	14
Duty Factor [%]	4
RF Freq. [MHz]	352.21/704.42

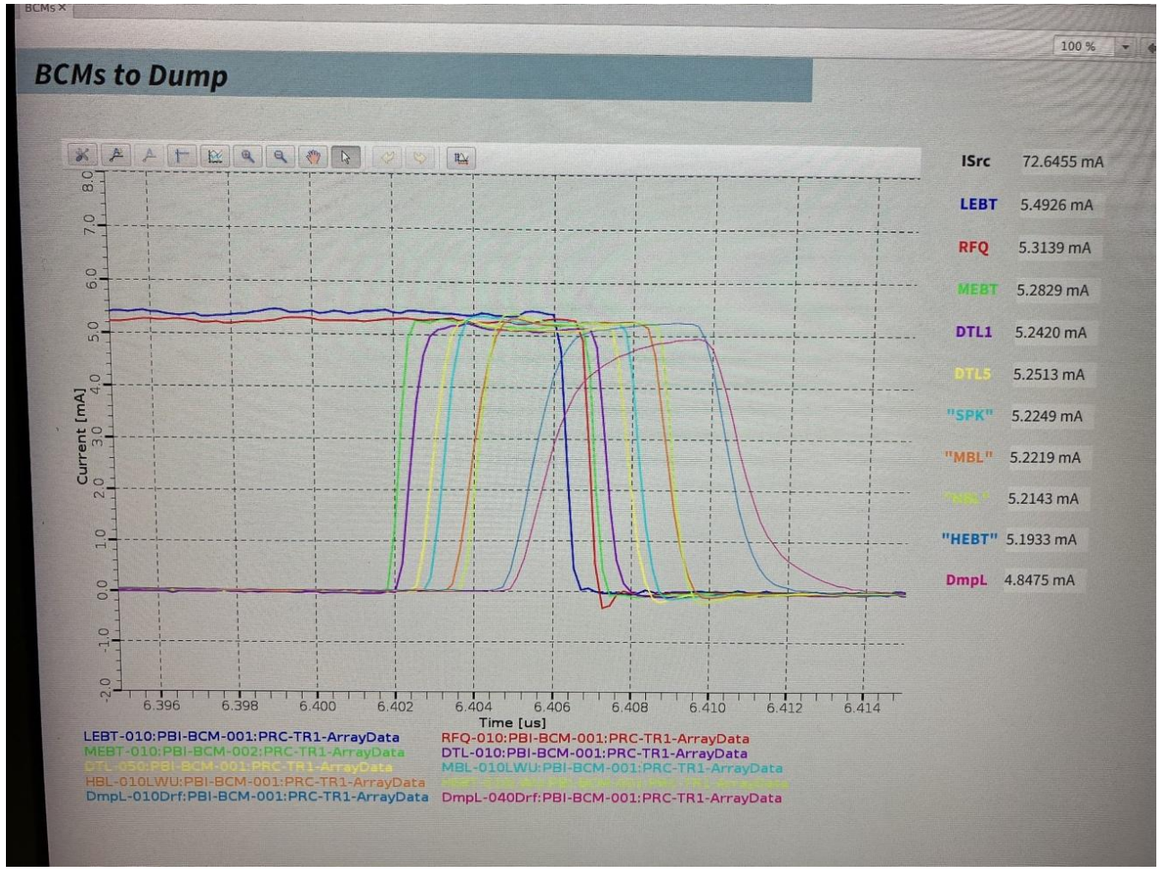
	Length	No. Magnet	#Cav x $\beta_{g/(Opt)}$	No. Sections	Power (kW)	IK partner
LEBT (from Plasma)	2.7	2 Solenoids	—	1	—	INFN-LNS
RFQ	4.5	—	1	1	1600	CEA Saclay
MEBT	4.0	11 Quads	3	1	15	ESS-Bilbao
DTL	38.9		5	5	2200	INFN-LNL
LEDP + Spoke	55.9	26 Quads	26 x (0.50)	13	330	IPNO
Medium Beta	76.7	18 Quads	36 x 0.67	9	870	LASA / CEA
High Beta I (~1.3 GeV)	93.7	22 Quads	44 x 0.86	11	1100	STFC / CEA
High Beta II	85.2	20 Quads	40 x 0.86	10	1100	STFC / CEA
Contingency + HEDP	132.3	32 Quads	—	15	—	Elettra
DogLeg	64.4	12 Quads + 2	—	1	—	Elettra
A2T	44.7	6 Quads + 8 Raster	—	1		Aarhus Uni
	603.0					

Towards Beam on Target

16 May 2025 - Beam on Dump (BOD)



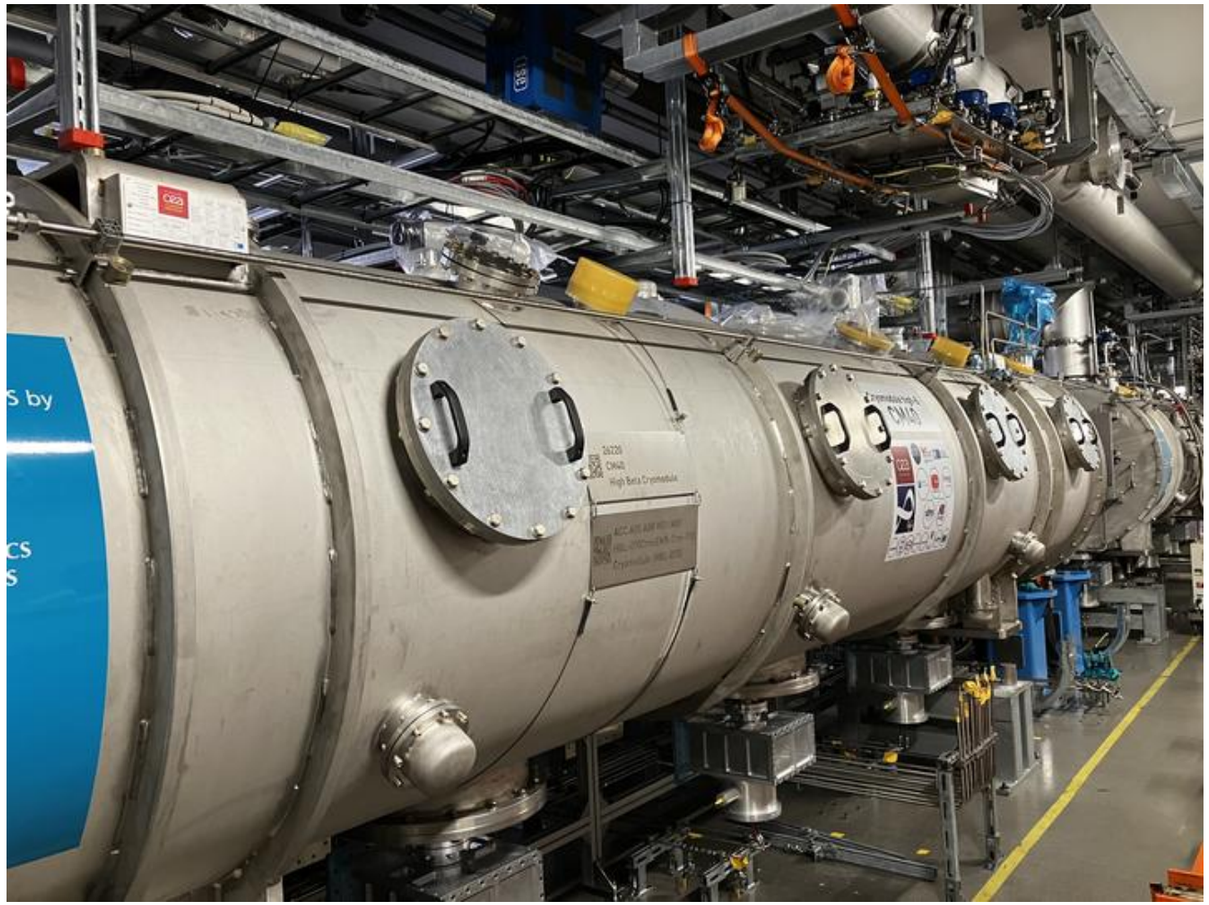




Towards Beam on Target

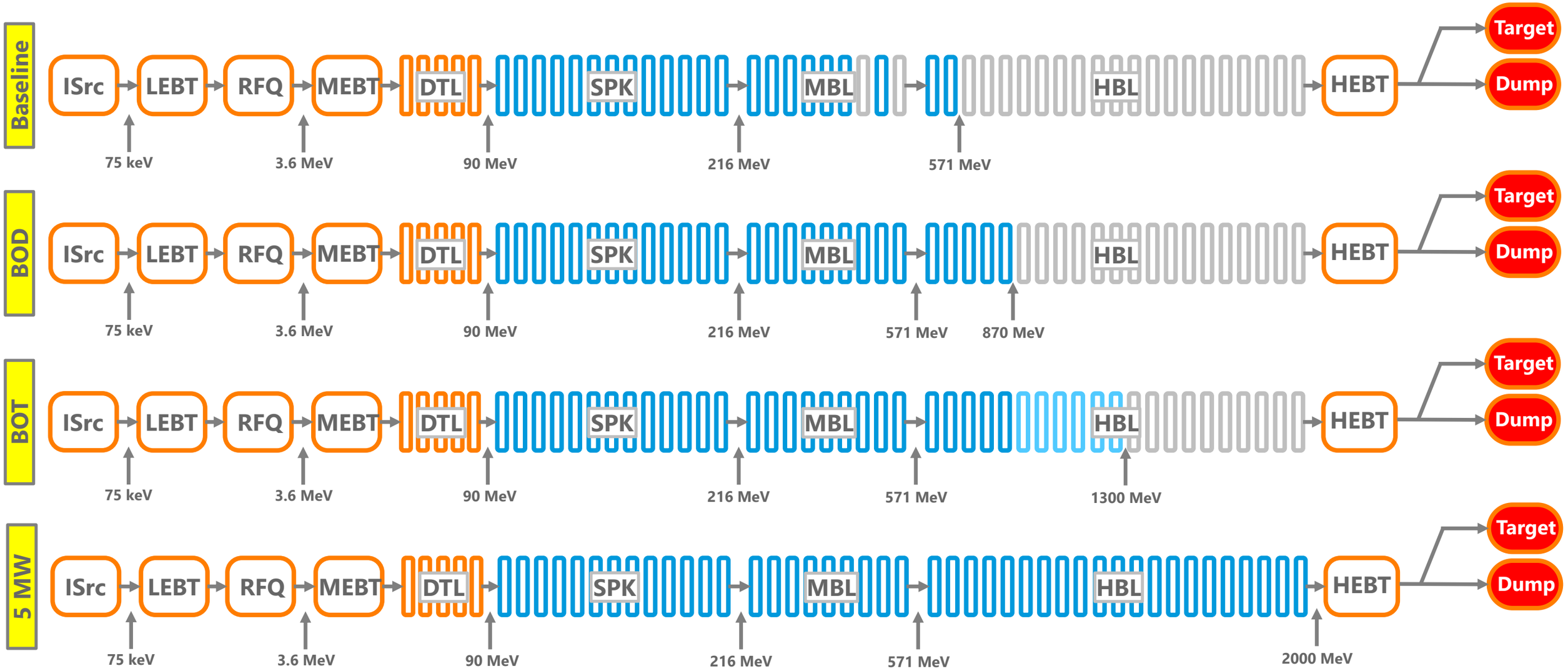
6 Additional HB CMs Installed

- Very successful summer/autumn installation campaign in 2025
- 6 additional HB CMs installed
- Averaged ~1 week per cryomodule, which is an impressive installation rate
- Significant effort from the TS2 team to prepare the cryomodules for installation
- Strong delivery from the installation and support teams
- Valuable learning opportunity for planning future shutdowns and installation campaigns for the remaining 10 CMs required to reach the full 2 GeV scope



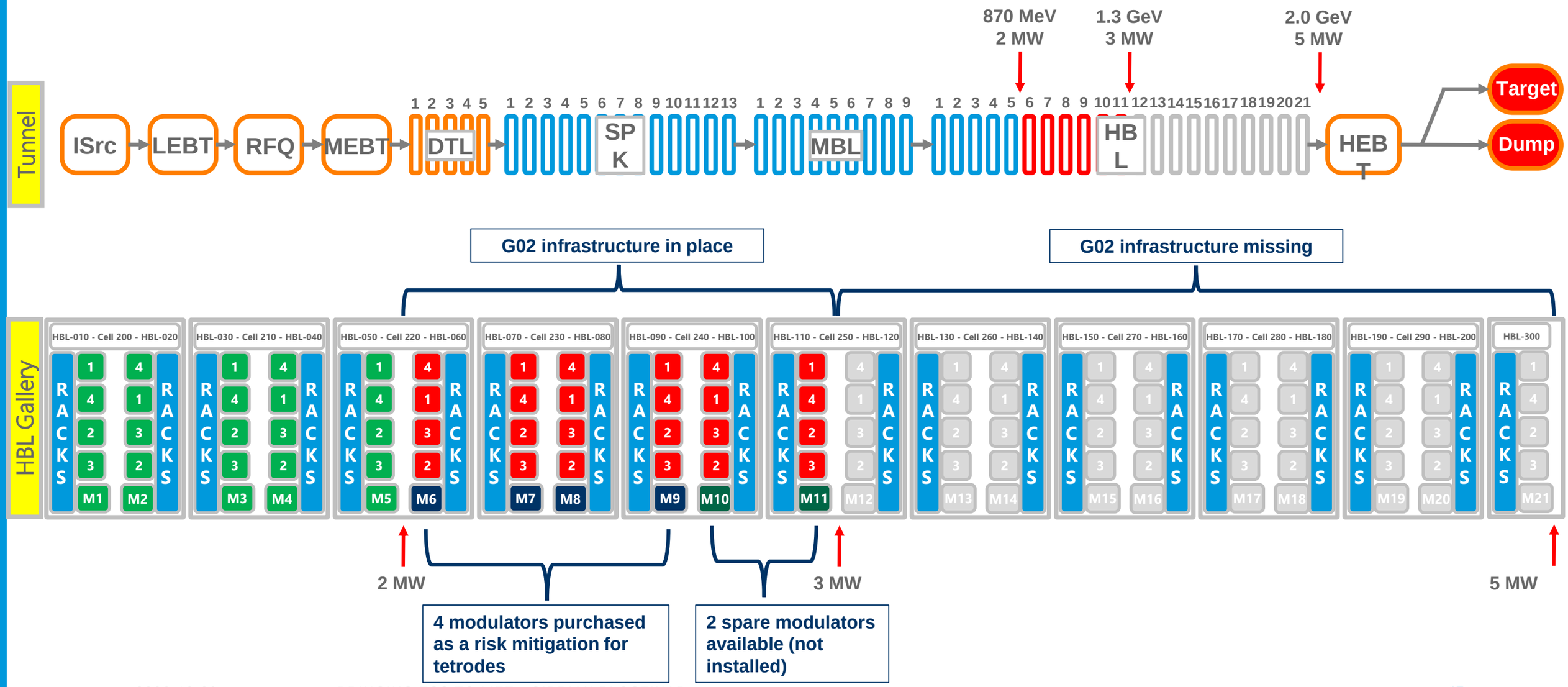
Towards Beam on Target

Accelerator Configuration



Towards Beam on Target

RF Installation for 1.3 GeV/3 MW – 24 RF Systems

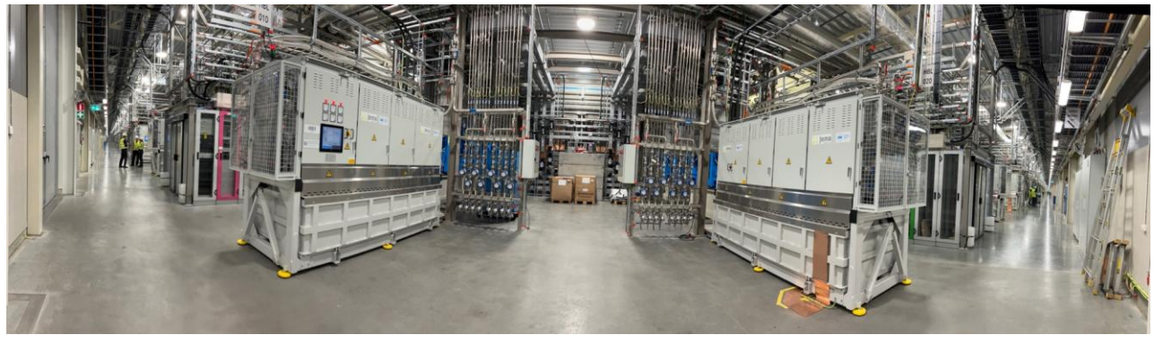


Towards Beam on Target

RF Installation for 1.3 GeV/3 MW – 24 RF Systems

- 24 High Power RF Systems
- Spare klystrons being used while new klystrons are being delivered. Order for 24 additional klystrons placed, delivery ongoing
  - **HBL-060:** 4 Systems high power tested - Being re-configured as a 704 MHz TS for component and klystron testing of new deliveries.
  - **HBL-070:** 4 Lower power tested
  - **HBL-080, 090, 100:** 12 in progress
  - **HBL-110:** 4 on hold while dedicated to test stand
- High Power Loads:
  - Order for 84 High power loads placed.
  - First deliver of 8 pre-series delivered
- Cooling configuration to put loads and klystrons in series will be tested. Will enable improved energy recovery.





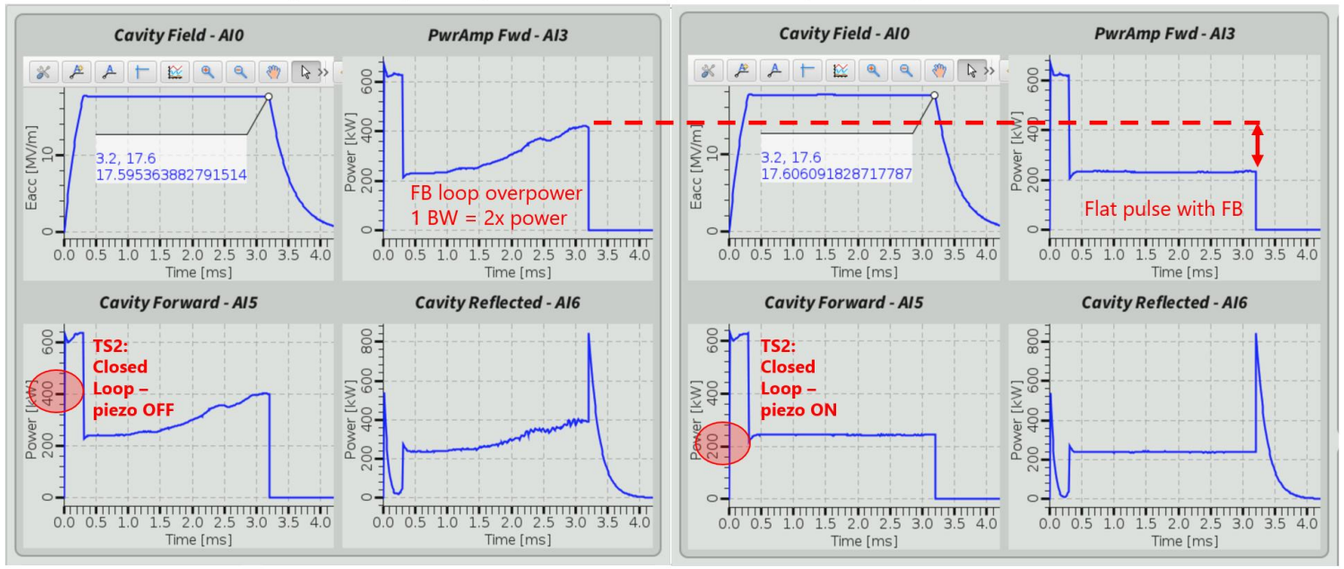
Towards Beam on Target

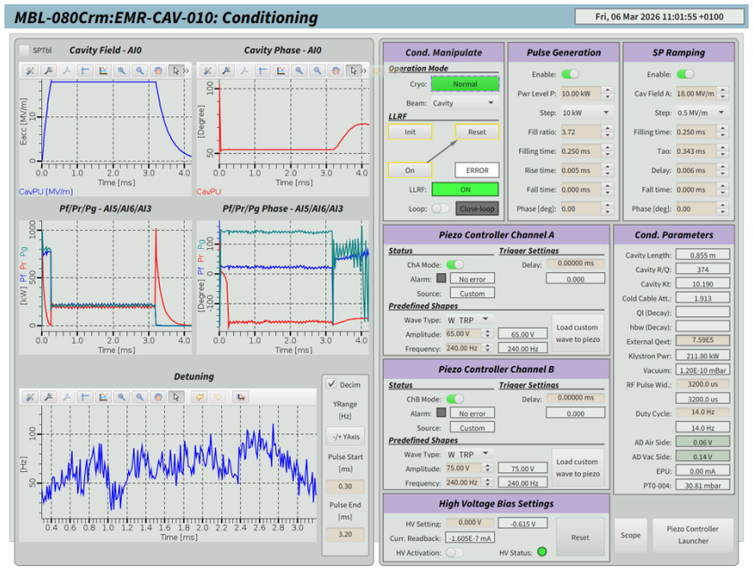
Long RF Pulses with Piezo Compensation

- To compensate the LFD a piezo algorithm was developed, tested and deployed
  - ACC & ICS Teams
- Demonstrate stable operation with the nominal RF pulses (3ms) in closed loop at 14 Hz, using piezo compensation -

Parameters	BOD	BOD2
Rep. Rate	1 Hz	14 Hz
Pulse Length	1 ms	3.2 ms
Piezo	OFF	ON

Piezo OFF Cavity detuning at high field (LFD) requires extra power at pulse end! **Piezo ON**

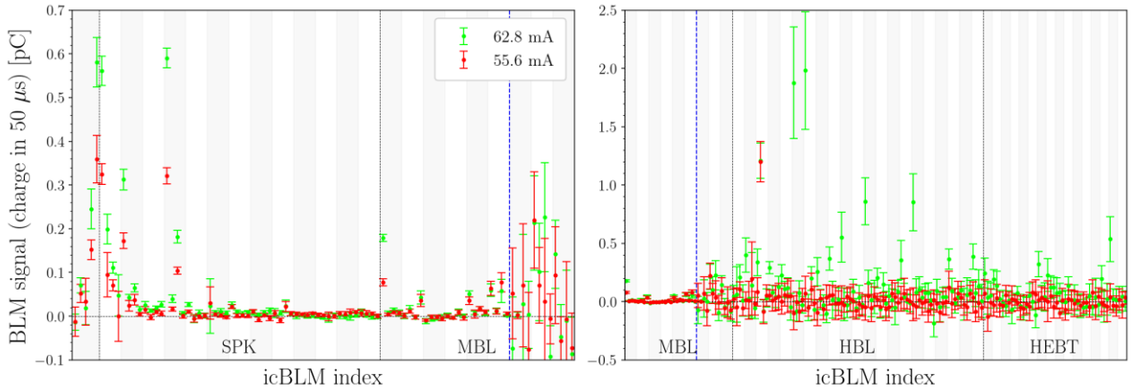


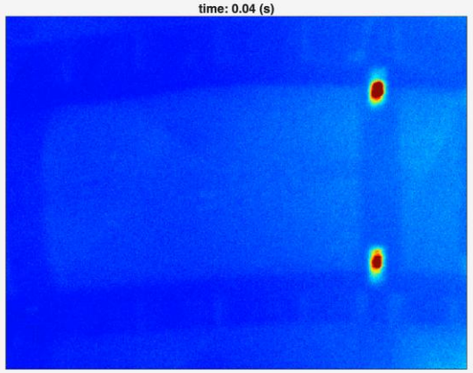


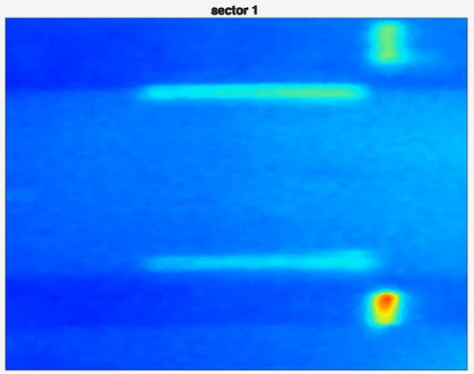
Towards Beam on Target

Critical Beam Instrumentation Delivery and Commissioning (Over 500 Devices)

- **BLMs**
  - All 266 ICBLMs detectors are installed.
  - All but 3 of the 82 nBLM detectors installed (spare shortage, procurement underway)
  - System tested with beam during BOD2
  - Goal to set thresholds and activate protection function before BOT
- **IMG**
  - There are four imaging systems. Two in the DmpL and two in the Target area
  - The DmpL IMG systems were commissioned during BOD2 and the protection functions are active. The target IMG systems will be commissioned during BOT. Fantastic effort from ACC and ICS



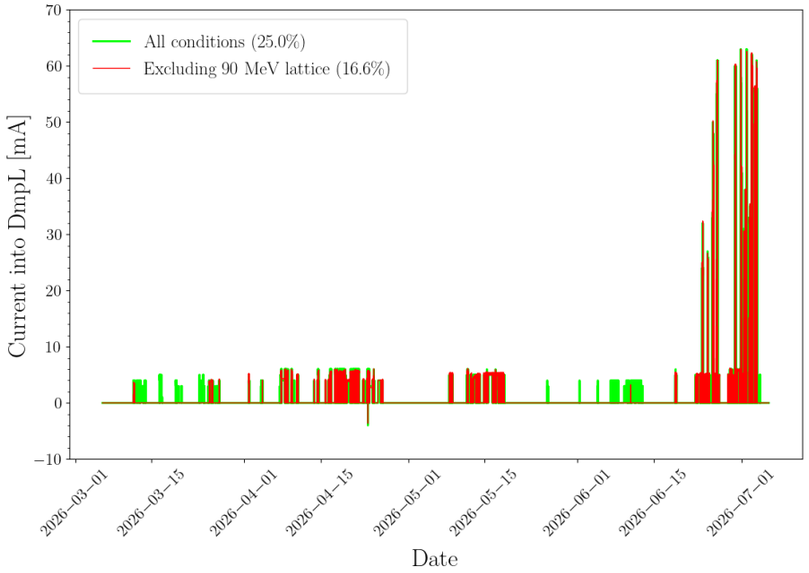


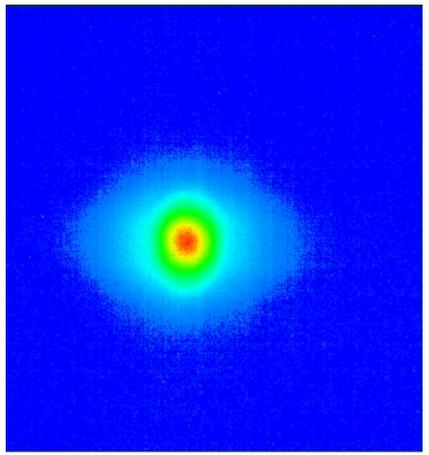


Towards Beam on Target

Beam on Dump 2 (BOD2)

- Demonstrate readiness for Beam on Target (BOT) and First Science by delivering all relevant scope and validating all critical systems, interfaces, and operational capabilities during Beam on Dump 2 commissioning (BOD2).





- Actively pursue the following key performance objectives:
  - Demonstrate stable operation with the nominal RF pulses (3ms) in closed loop at 14 Hz, using piezo compensation

    ✓ Achieved
  - Demonstrate long beam pulses of (>1ms) at low current (6mA) using adaptive feed-forward

    ✓ Achieved 20 mA, 1.5 ms, 1/30 Hz
  - Demonstrate longer beam pulses (50us) to dump at nominal current using adaptive feed-forward
    - Achieved 30 mA, 50 µs, 1 Hz (peak power limited in SPK-020-1)
  - Demonstrate 80% availability of the accelerator

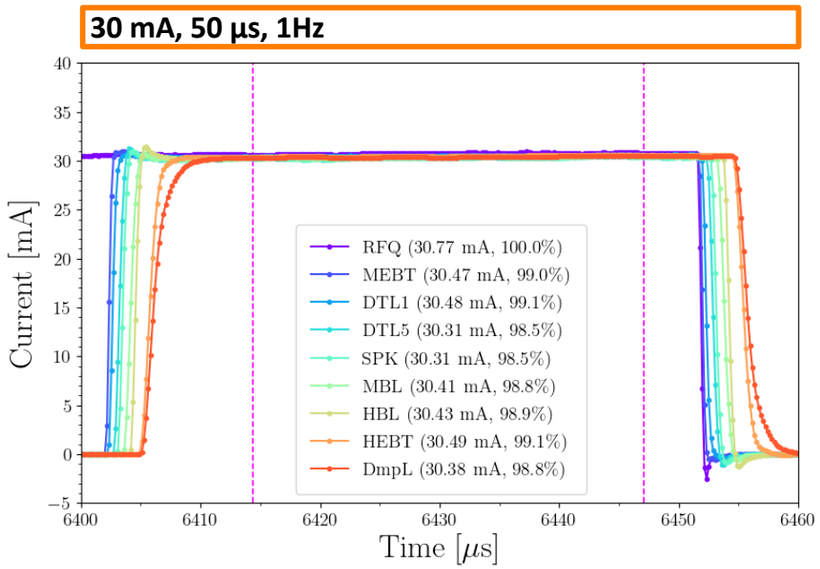
    ✓ Achieved

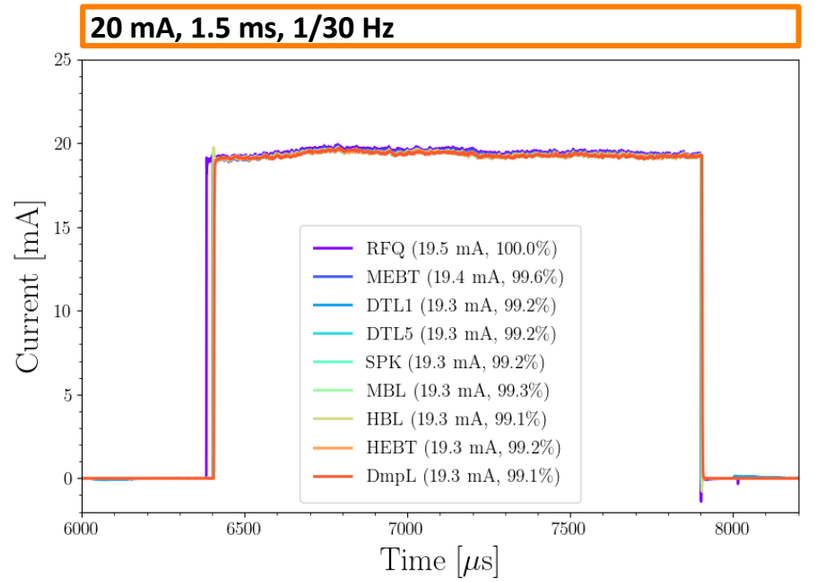
Sofia Johannesson et al., "Beam Commissioning of the ESS Accelerator: Results and Challenges", Proc. of LINAC'26, Daejeon, South Korea

Towards Beam on Target

Beam on Dump 2 (BOD2)

- Significant improvements between BOD and BOD2
  - Expanded the operational envelope
    - 30 mA, 50 µs, 1 Hz
    - 62.5 mA, 5 µs, 1 Hz
    - 20 mA, 1.5 ms, 1/30 Hz
  - Better phase scans
    - 856 MeV vs 861 MeV from the model
    - (813 MeV vs 877 MeV for BOD)
  - Very encouraging results of very low beam-transport losses
  - Invaluable operational experience ahead of BOT



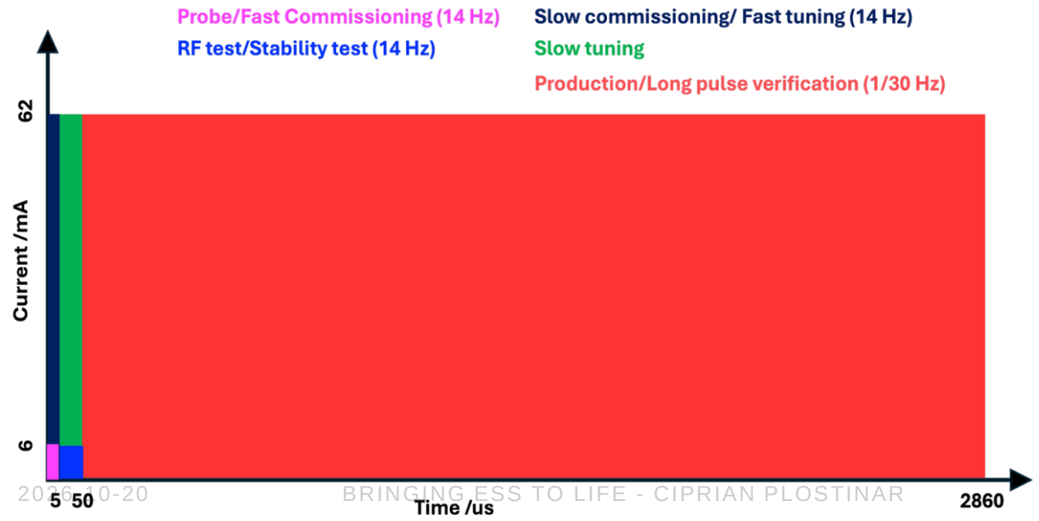


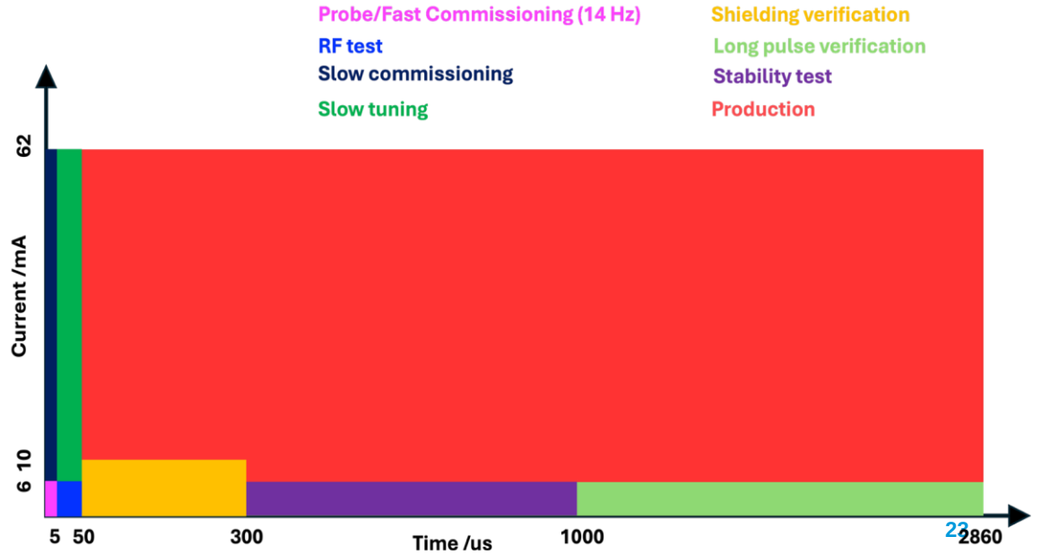
Towards Beam on Target

New Beam Modes

- Old beam modes:
  - Limited flexibility
  - Not practical for commissioning goals
  - Difficult to commission certain systems
- New beam modes:
  - Added flexibility
  - Easier commissioning with long pulse
  - Easier to commission certain systems

Mode	I [mA]	T [us]	F [Hz]	Average Power (2/0.88 GeV) [kW]
Probe	6	5	1	0.06/0.026
Fast commissioning	6	5	14	0.84/0.37
RF test	6	50	1	0.6/0.264
Stability test	6	50 1000	14 1	8.4/3.7 12/5.28
Slow commissioning	62.5	5	1	0.625/0.275
Fast tuning	62.5	5	14	8.75/3.85
Slow tuning	62.5	50	1	6.25/2.72
Long pulse verification	62.5 6	2860	1/30 1/3	11.92/5.24 11.44/5.03
Shielding verification	- 10	- 300	- 1	- 6/2.64
Production	62.5	2860	14	5005/2202.2





Towards Beam on Target

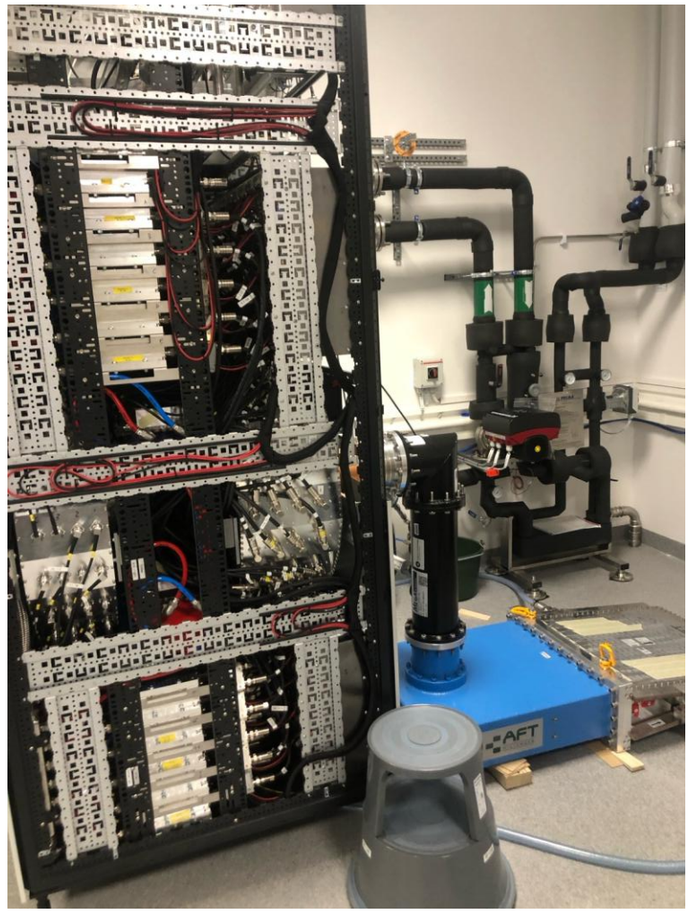
Consolidation Projects

- **Accelerator Maintenance and Test Facility**
  - Project gaining momentum. Current focus on functional requirements.
- **400 kW SSPA project**
  - Developed after a TAC recommendation as a robust alternative to the current tetrode-based SPK RFPS to eliminate a significant single-point-of-failure and supply-chain risk.
  - First 1 kW rack operational at full duty cycle (14Hz 3.5ms). Three more racks in construction.
- **352 MHz/704 MHz Test Stands**
  - Developed in G02, but will have to be relocated as the 3 MW project advances.
  - Essential capability, used for RF window, coupler, klystron, and RF components testing.
- **Test Stand 4**
  - Low priority, but excellent execution. Will provide much needed beam testing capabilities.
  - First beam extracted this year
- **SPK Tuner Motors Solution Development**
  - Testing underway at ESS
  - Expecting a solution to be validated in 2027
- **Accelerator Workshop in G02**
  - Under Development
- **Cryogenics**
  - ACCP Backup Compressor completed.
  - ACCP Cold Compressors AMB tech project ongoing
- **Procurement of Spares**
  - Strong technical ownership and collaboration

Towards Beam on Target

Consolidation Projects

SSPA

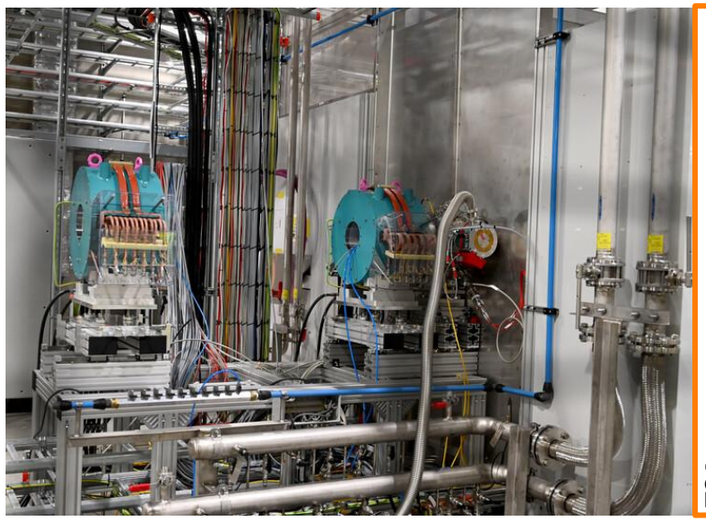


B02 SRF Lab





RF TS



TS4

Some Lessons Learned

Technical Challenges

- **SPK CM02 venting event during installation.**
- “Race” to prepare the spare SPK CM14 for substitution.
- Significant installation effort.
- SPK CM02 repair

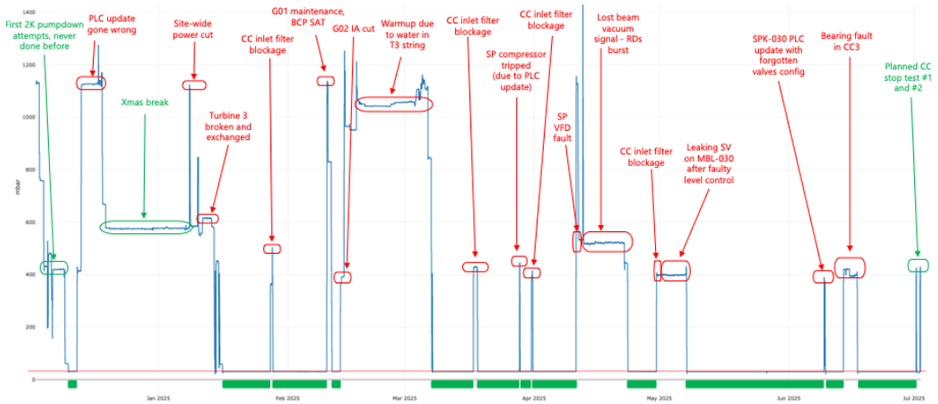
- **Water leak in the tunnel in the HEBT area over the weekend.**
- Over 5000L of water spilled.
- Highlighted improvements we needed to make in preparation for operation.

- **Cryogenic Operation**
  - Failed PLC update
  - Power glitch
  - Loss of water cooling
  - Network issues, PLC network glitch
  - Loss of instrument air
  - Cold compressor inlet filter clogging









Some Lessons Learned

Technical Challenges

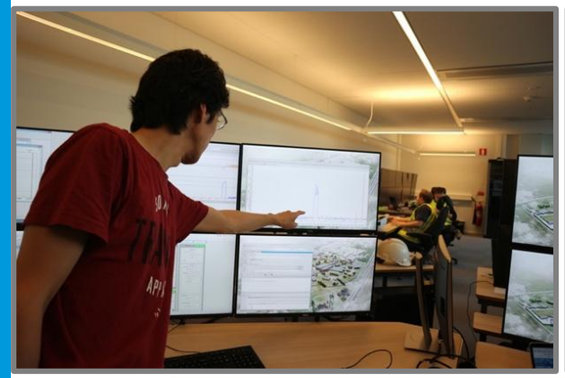
- The power dip incident also affected the ACC.
  - It took around **10 days to fully reestablish operation**.
  - The incident highlighted several **opportunities for improvement**.
- What are we doing on the ACC side?
  - Controls and Integration Improvements
  - Hardware resilience
  - Operations
  - “Class A” Technical Risks

- SPK-070-S1 tuner motor stuck
  - Discovered during setting up the machine for BOD2. Not possible to arrange an intervention at this stage.
  - Machine rephased for beam operation.
  - New technical solution currently under development at ESS.
  - Need repair plan

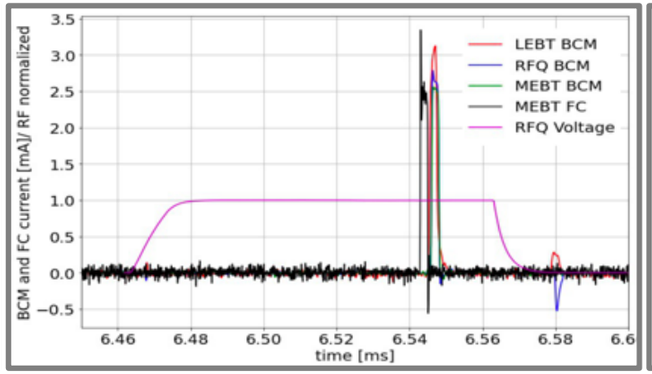
- ACCP cold compressor CC3 suffered a bearing failure.
  - Repair took ~one month during BOD2 under a lot of pressure. Technical improvements highlighted.
  - New AMB solution planned for 2027.
  - 4K operation tested.
  - 90 MeV lattice used for commissioning.

ESS ACC Commissioning History

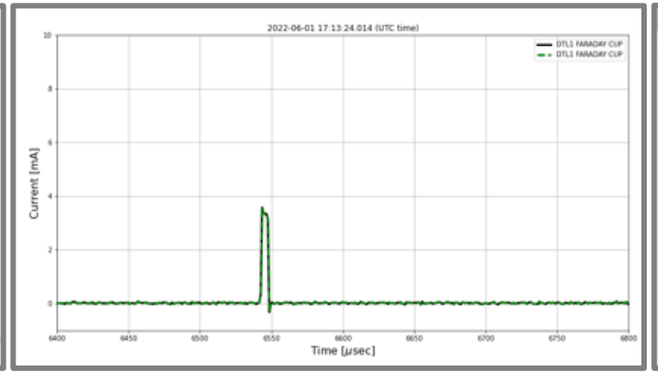
Beam: ISrc->LEBT - 19 Sep, 2018



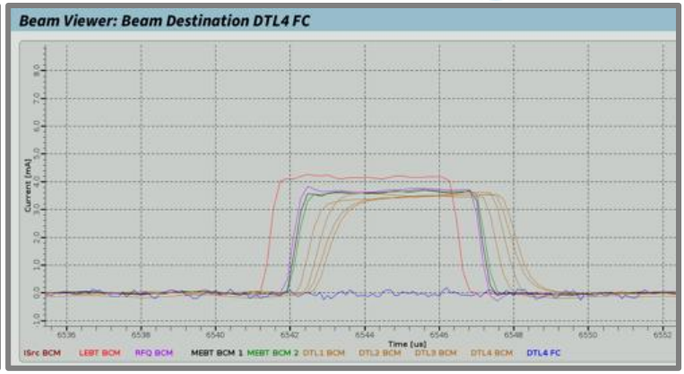
Beam: ISrc->MEBT - 26 Nov, 2021



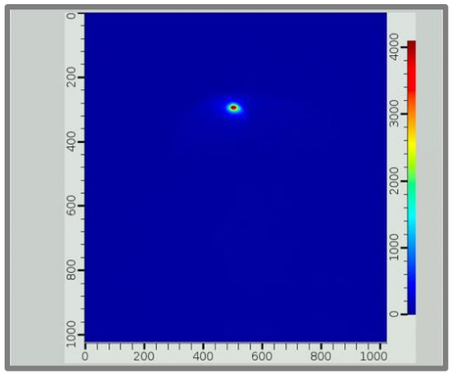
Beam: ISrc->DTL1 - 1 Jun, 2022



Beam: ISrc->DTL4 - 20 Apr, 2023



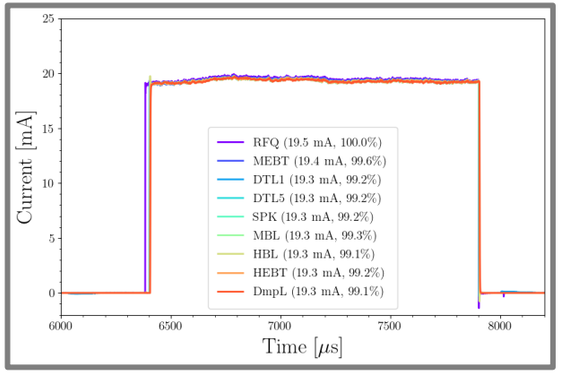
Beam: ISrc->TBD - 09 Apr, 2025



BOD - 16 May, 2025



350 kW Beam Equivalent - 03 Jul. 2025



SRR1 17 Jul, 2018

SRR2A 7 Sep, 2021

SRR2B 4 May, 2022

SRR3 22 Mar, 2023

SRR4 24 Feb, 2025

First kW Beam 30 Jun, 2026

SRR5 9 Nov, 2026

EOC 31 Dec, 2027

2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027

19 Sep, 2018 **First LEBT Beam**

26 Nov, 2021 **First RFQ Beam**

1 Jun, 2022 **First DTL1 Beam**

20 Apr, 2023 **First DTL4 Beam**

9 Apr, 2025 **First Protons on Dump**

16 May, 2025 **BOD**

3 Jul, 2026 **350 kW Beam Equivalent**

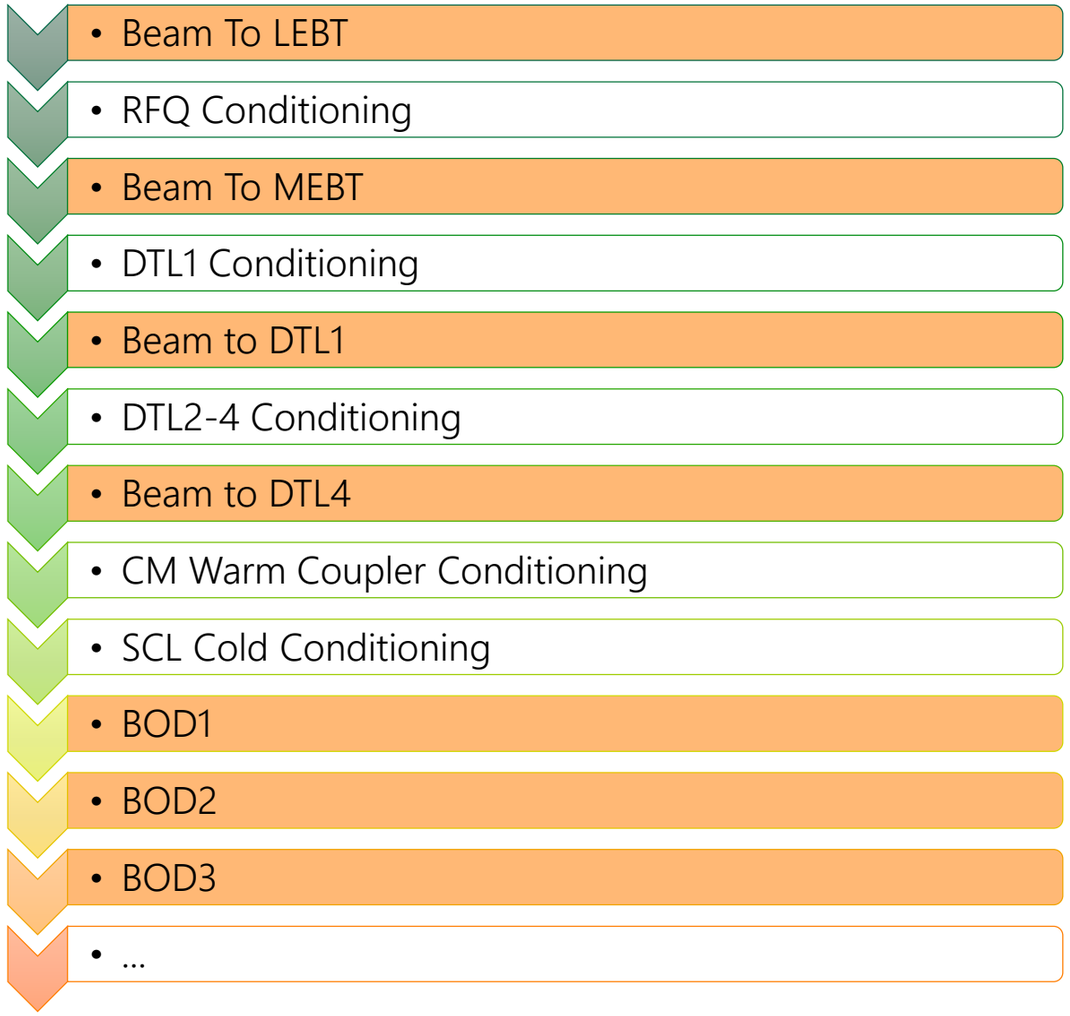
18 Jan, 2027 **BOT**

Readiness for BOT

BOD3 Objectives

BOD3 objectives:

- Complete remaining critical systems for BOT
- Focus on operational improvements
  - Maintain nominal RF duty cycle
  - Steady run to the tuning beam dump
- Continue to expand the technical envelope
  - Beam studies
- Continue machine consolidation efforts that will strengthen the machine performance after BOT:



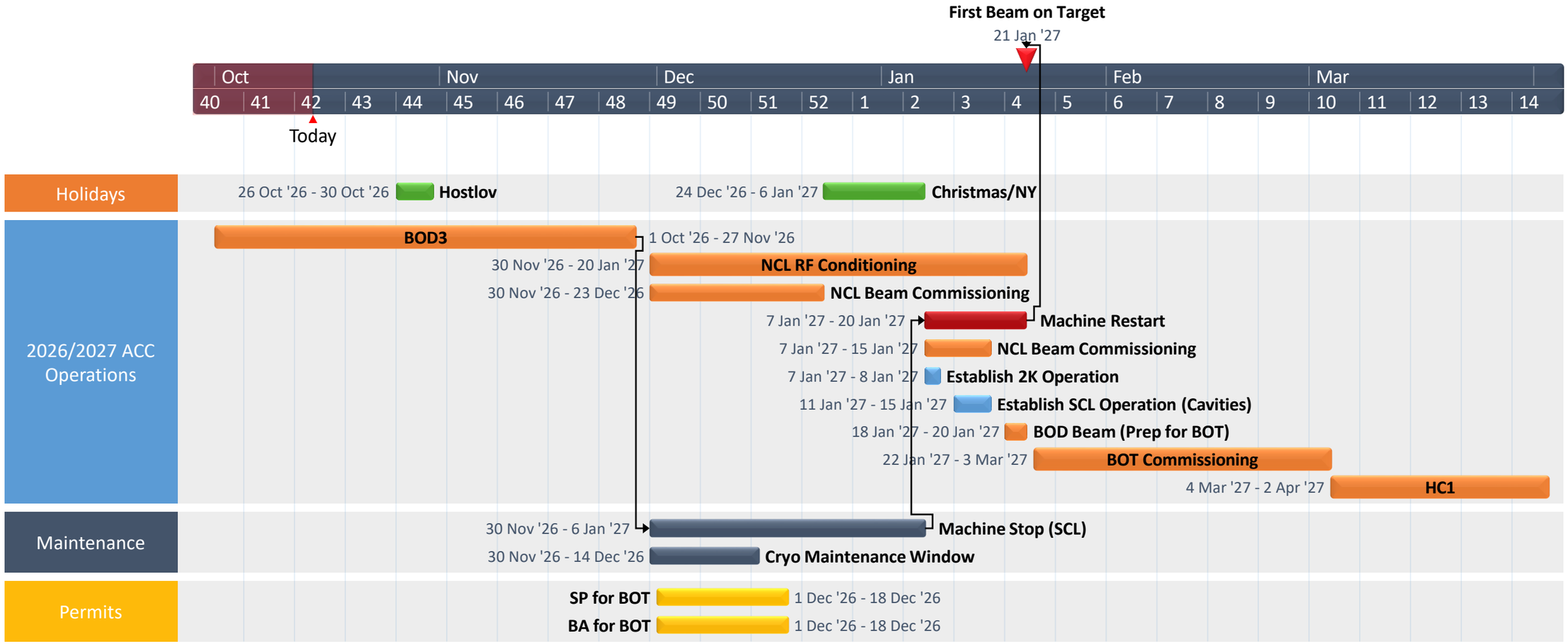
Getting Ready for Operations

From construction to start of operations

2009	2013	2014	2022	2025	2026	2027	2028	2030s onwards
Decision to site ESS in Lund (SE), with the Data Management & Software Centre in Copenhagen (DK)	Technical Design Report completed	Start of construction	Civil construction completed	Accelerator commissioned (Beam on Dump) Call for input to instrument roadmap, beyond the 15 currently under construction	Six instruments ready for neutrons	First neutrons – the proton beam strikes the target for the first time First science experiments Accelerator upgrade to 3MW	Start of User Programme Start of steady state operations	Upgrade accelerator to 5MW New instruments (for suite of 22) >800 experiments/year >500 publications/year

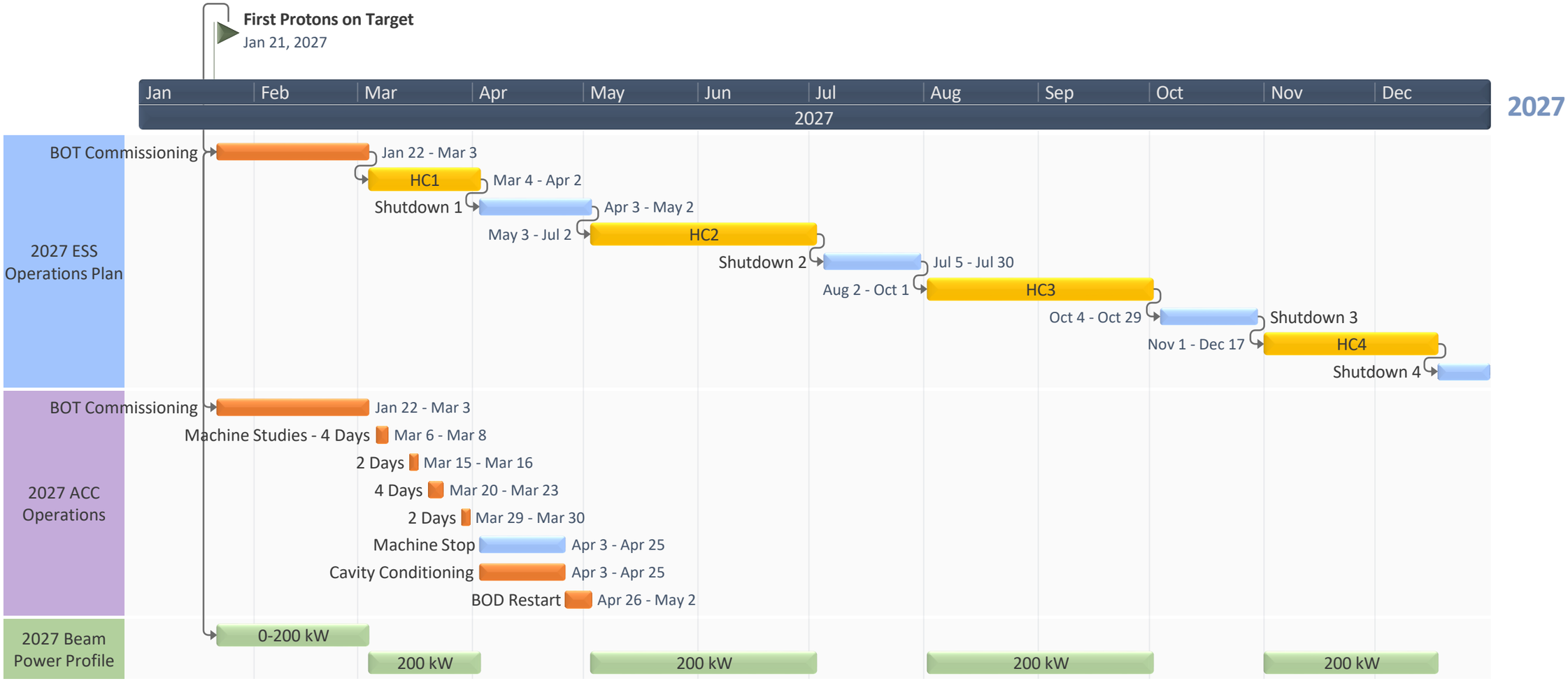
Readiness for BOT

Timeline - ACC Autumn Plans



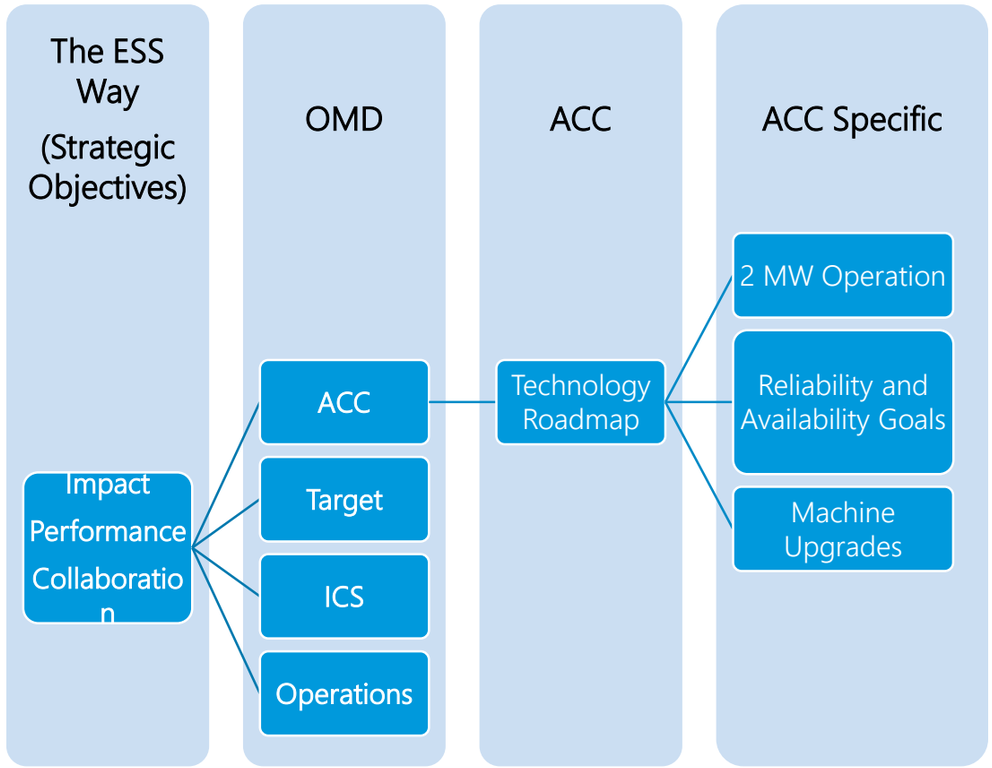
Beyond BOT

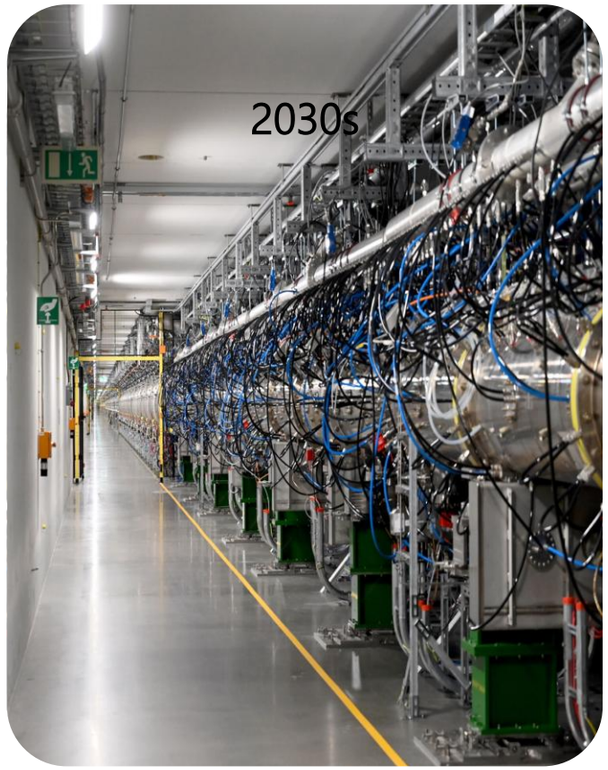
2027 Plans

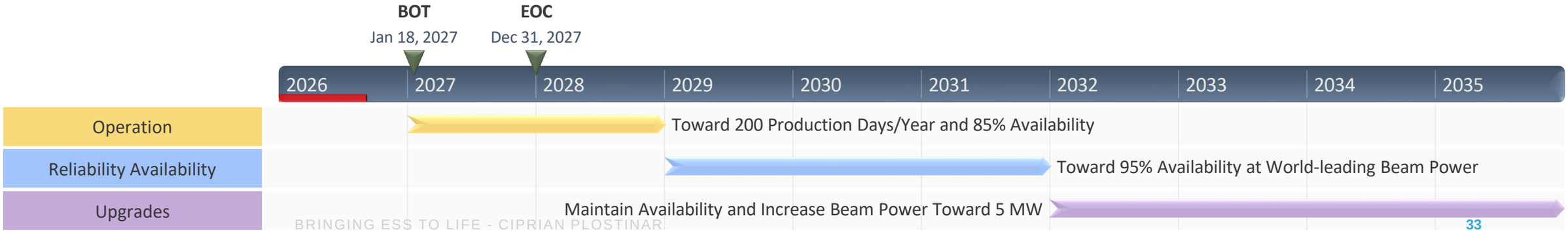


Beyond BOT

Technology Roadmap for Sustainable Operation







Lund Science Village

ESS and Max IV – A Unique Hub

- Max IV is Swedish national laboratory providing scientists with brilliant X-rays for research. Lund University is the host.
- LINXS was set up to promote science and education focusing on the use of neutrons and X-rays


ESS


MAX IV

ESS in Europe

ESS joins the array of accomplished European neutron science facilities

- Europe has a unique set of neutron facilities with a highly diverse and dynamic user community
- ESS is an integral member of European and international neutron and accelerator-based research facilities.
- In 2026, ESS also joined EIROforum



A Long Journey

From an idea to a neutron facility









The Journey Continues

Next: Beam on Target




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@ess-neutron
@essneutron