33rd European Synchrotron Light Source Workshop (ESLS)

20 and 31 October 2025

SOLEIL Report

Laurent S. Nadolski*
Accelerator Physics Group Leader
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on behalf of the Accelerators and Engineering Division

A. Moutardier
Operation Group

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SOLEIL II
La science éclaire l'avenir
Science lights up the future

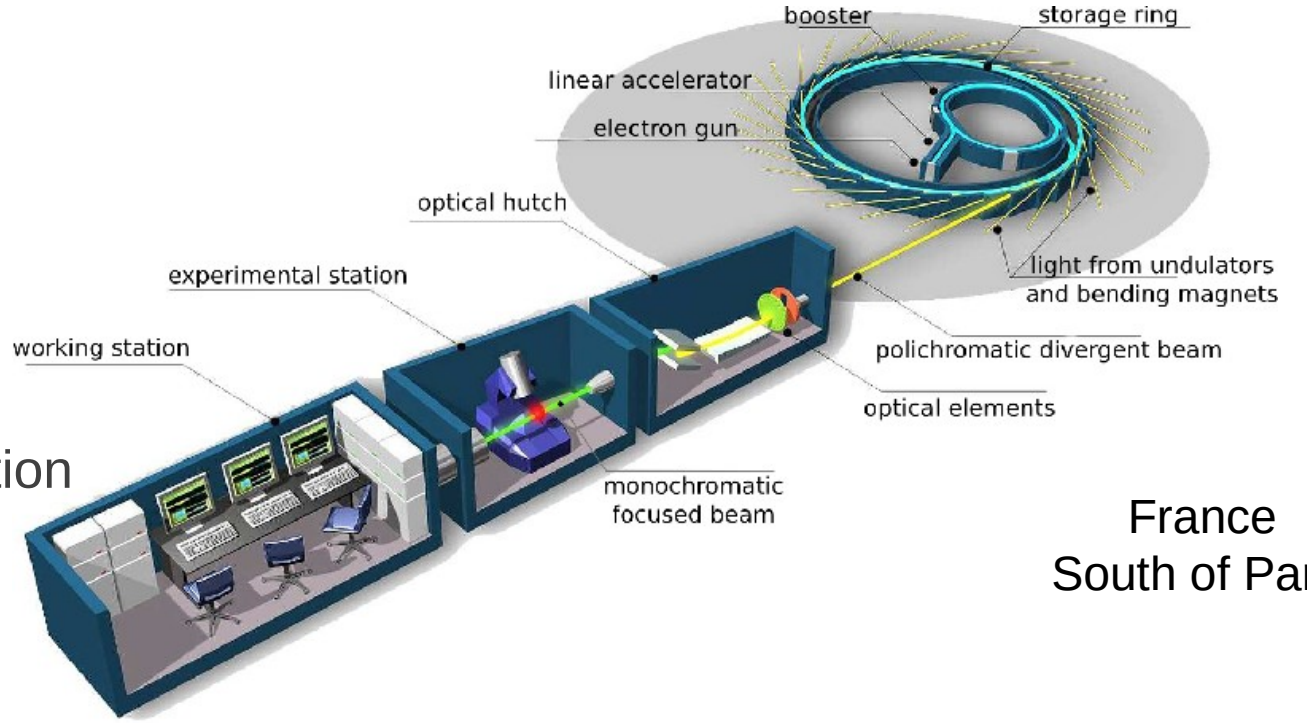
Contents

- **SOLEIL Status Report**
  - Main Statistics
  - Focus on Major Incidents
  - Main Developments

- **SOLEIL II:**
  Entrance in Execution Phase
  - Project Timeline and Funding Situation
  - Freezing the Booster Lattice
  - Freezing the Storage Ring Lattice
  - Launching Major CFTs
  - Personal Selection of Highlights

- **Conclusions and Perspectives**

SR: 354 m
Booster: 157 m



France
South of Paris

29 beamlines
1 CRYO-EM Microscope (French network with ESRF & Strasbourg)

Third Generation Light Source

Location: France, 11 km South of Paris

Circumference: **354 m** **Commissioning: 2026**

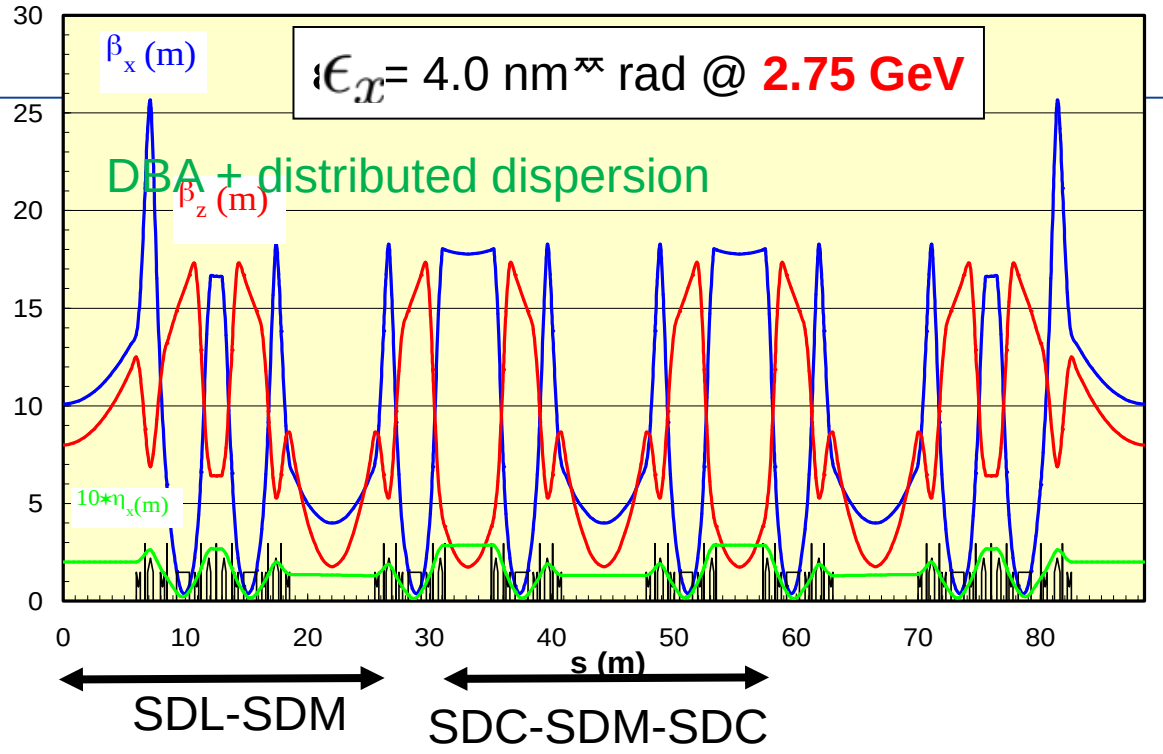
24 straight sections

(variable length)

SDL: 4 x 12 m
SDM: 12 x 7 m
SDC: 8 x 3.6 m

29 beamlines + 1 Cryo-EM

- 2 IR
- 7 on bending magnets
- 20 on insertion devices



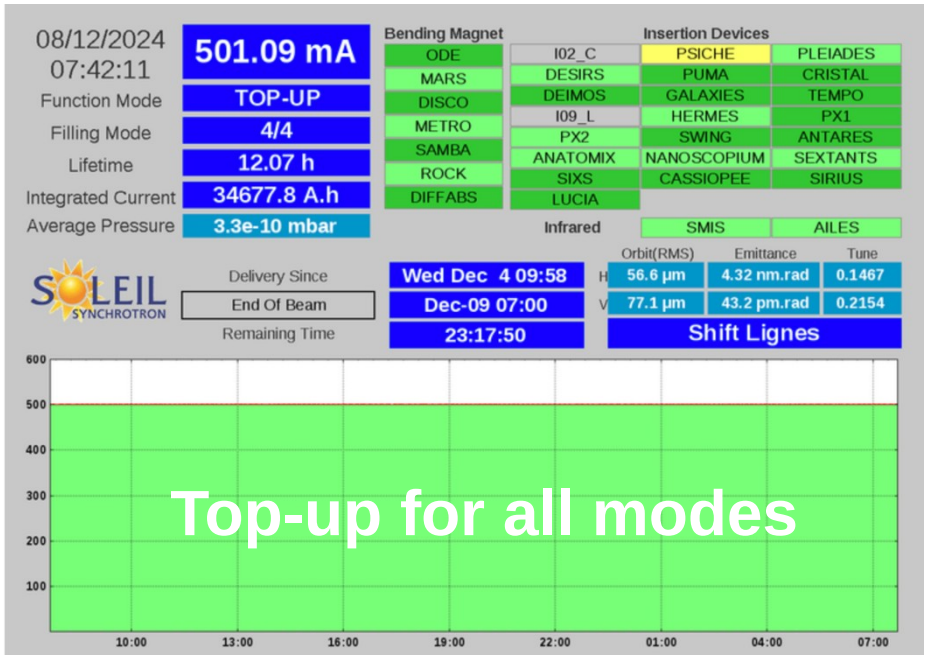
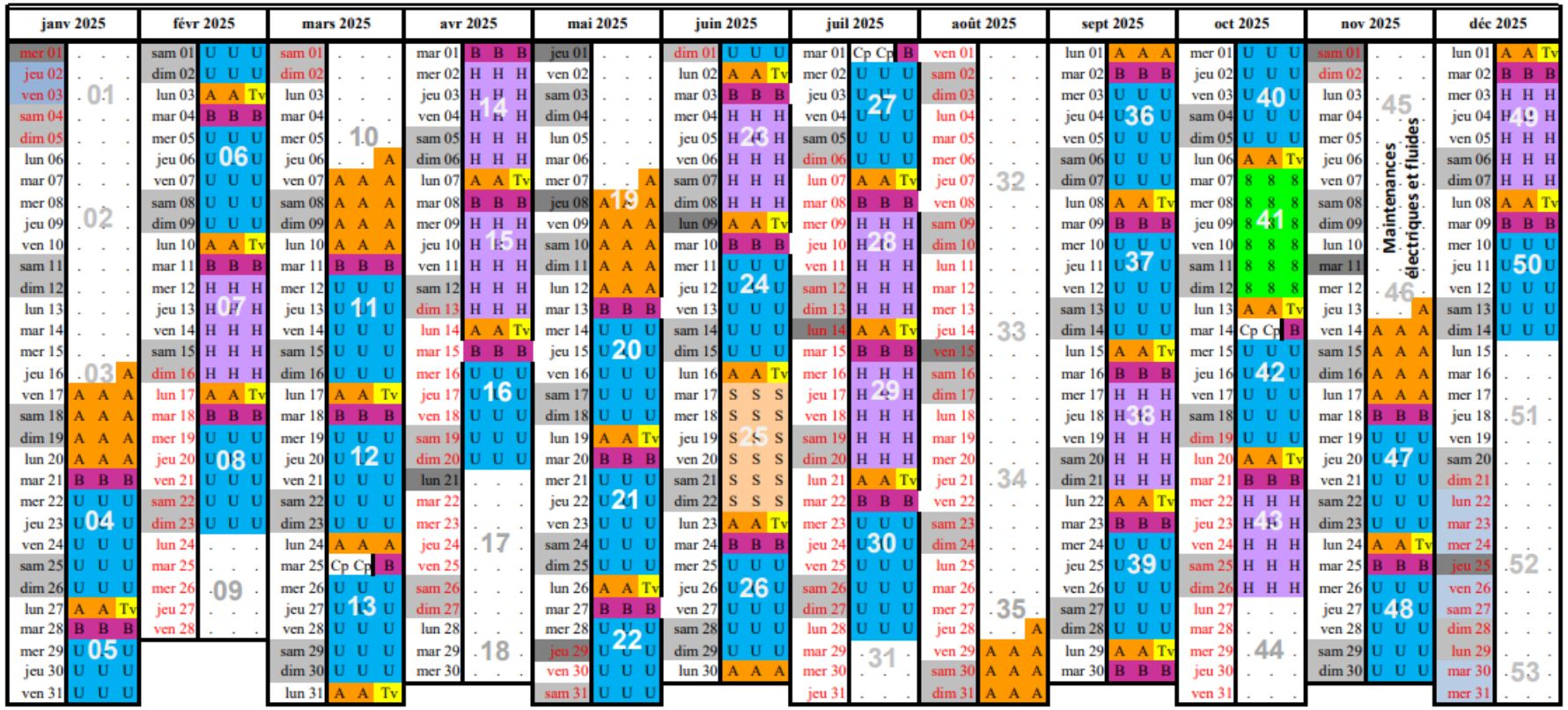


Table 1: Storage Ring Main Parameters

Parameters	Values
Energy	2.75 GeV
Circumference	354.097 m
Natural chromaticities (H/V)	-53/-19
Natural Emittance	4.0 nm · rad
Number of Cells/Symmetry	16/1
Tunes (H/V)	18.155 / 10.229
RF frequency (harmonic number)	352.197 MHz (416)
Total RF Voltage	2.8 MV

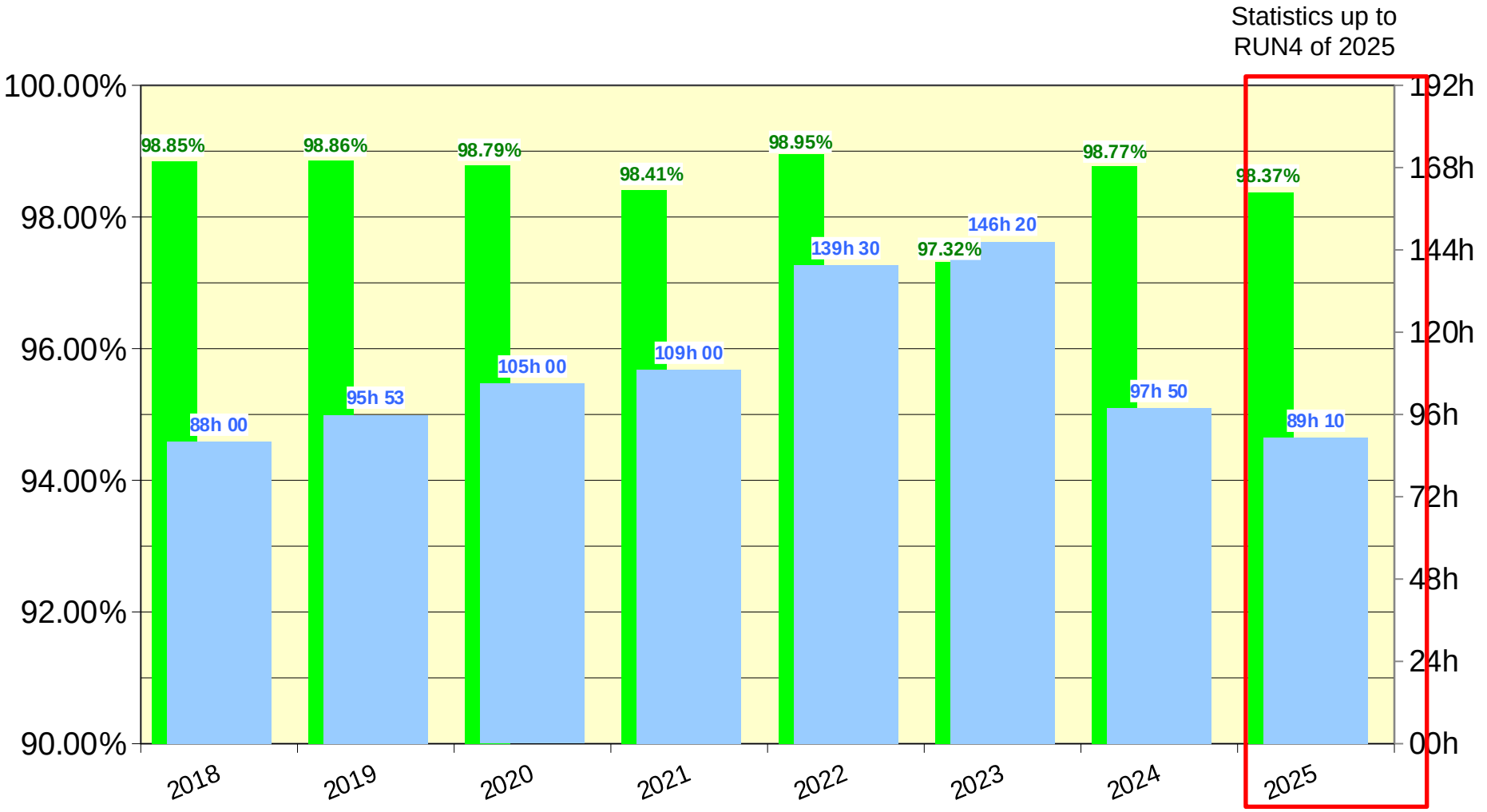
SOLEIL Major Statistics

2025 Beam Calendar: 5 RUNs

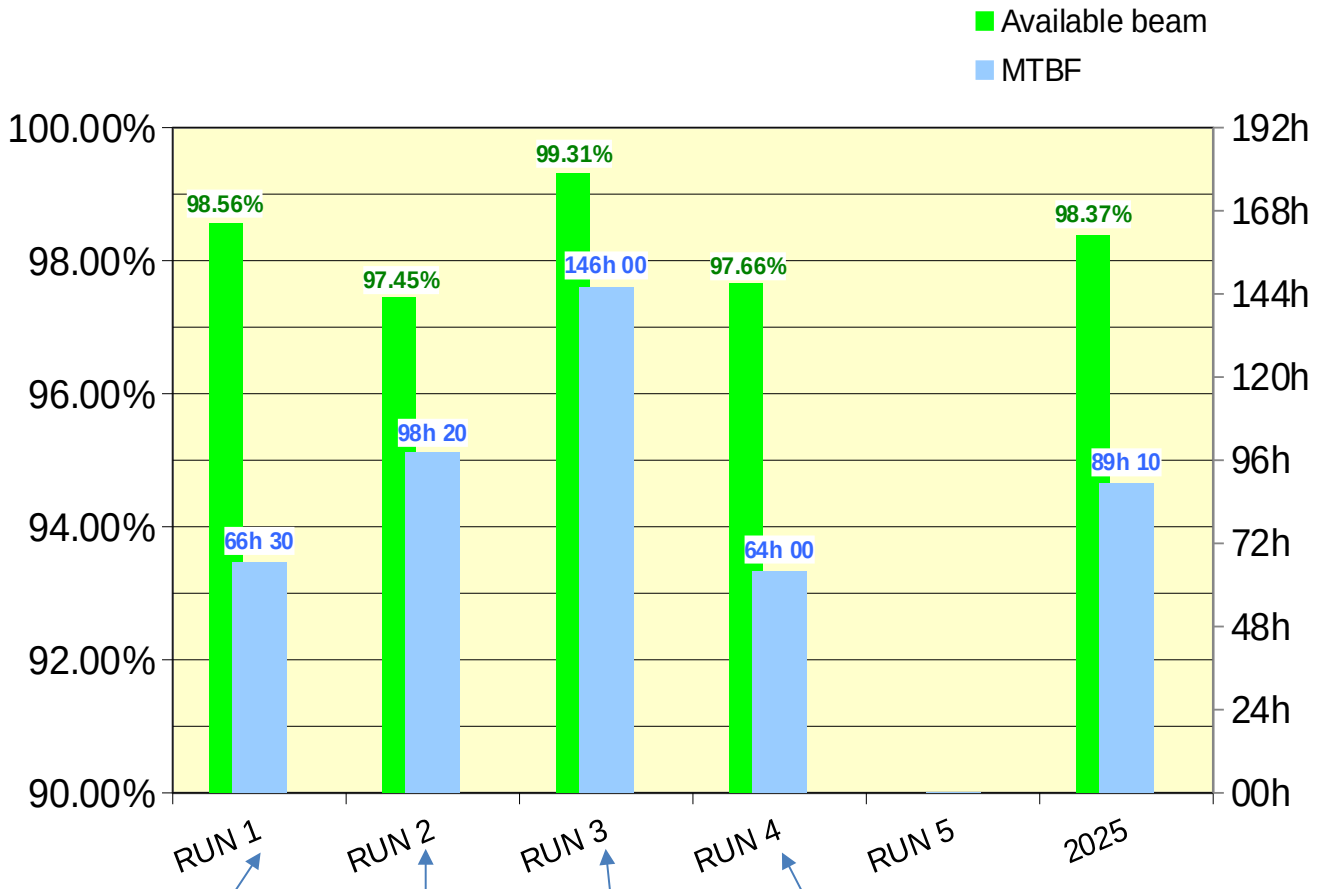


4905 hours, divided into five RUNs are scheduled for the Beamlines in 2025.

USERS Photon Beam Availability



Performance Details in 2025 (up to RUN4)

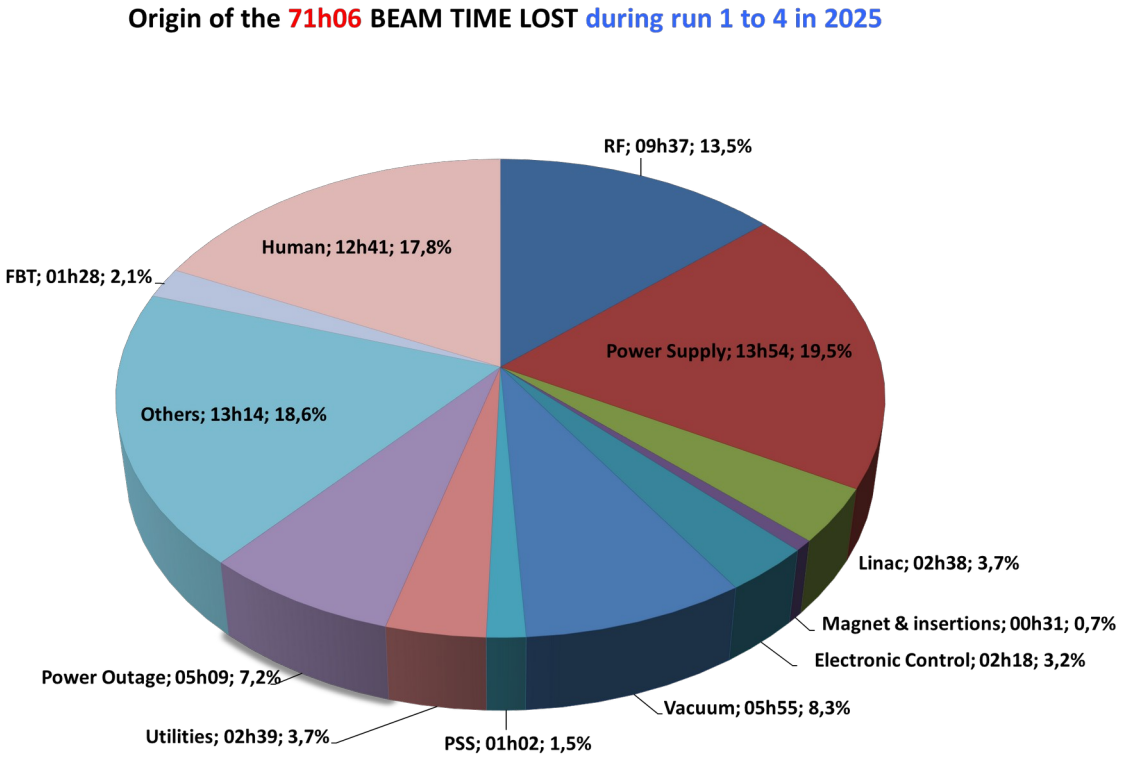


Several beam excitations due to CPMU18 Cristal installation (high vacuum)

One long failure on TL1 dipole power supply

The longest RUN of the year (11 weeks)

Many beam losses due to ring RF failure, one human mistake and an electrical issue (Stop of cryo compressor)

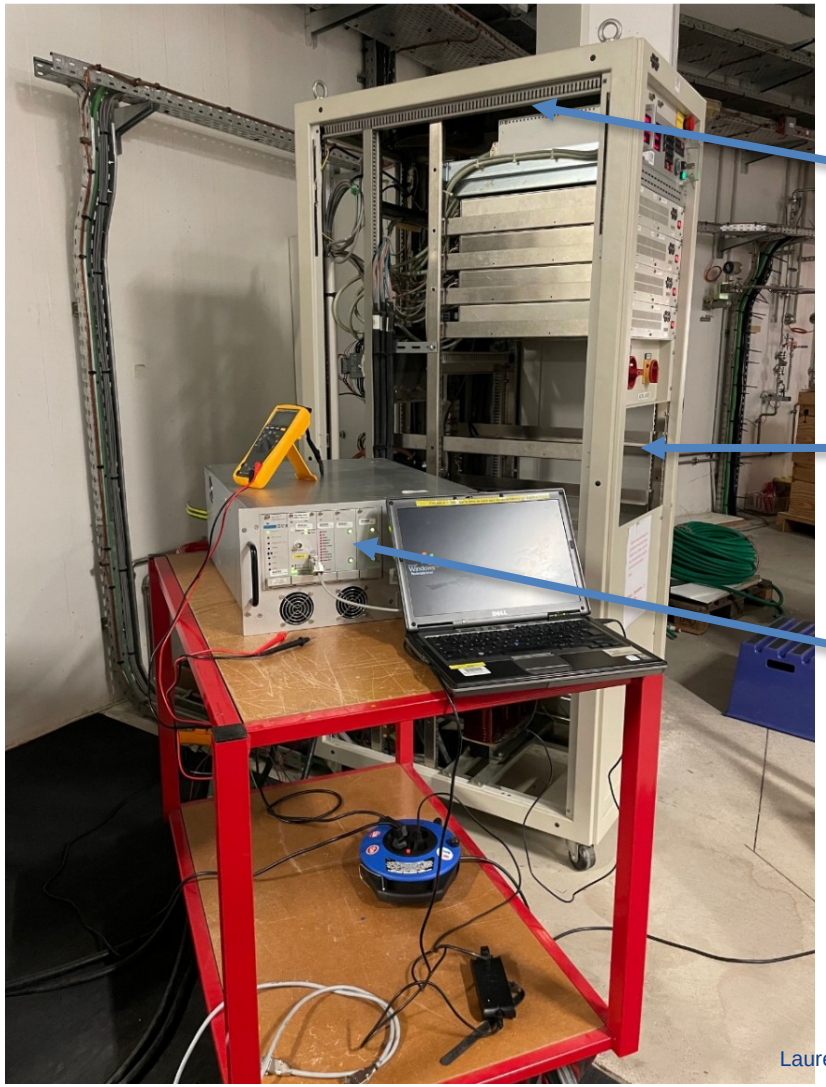


- Breakdown distribution in 2025 (until RUN4).
- Total of 53 failures (until RUN4).
- 5 power outages (until RUN4).

Major Incidents

Issue: Failure of TL1 dipole power supply and inability to find the issue.
Temporary solution: Adaptation and installation of a quadrupole ring power supply
Reason: Fan rack failure (misconception of electrical circuit provide false error)
Impact: Beam interruption (10h17)

March 16th, 2025



Issue: Water leak on LINAC Klystron 2

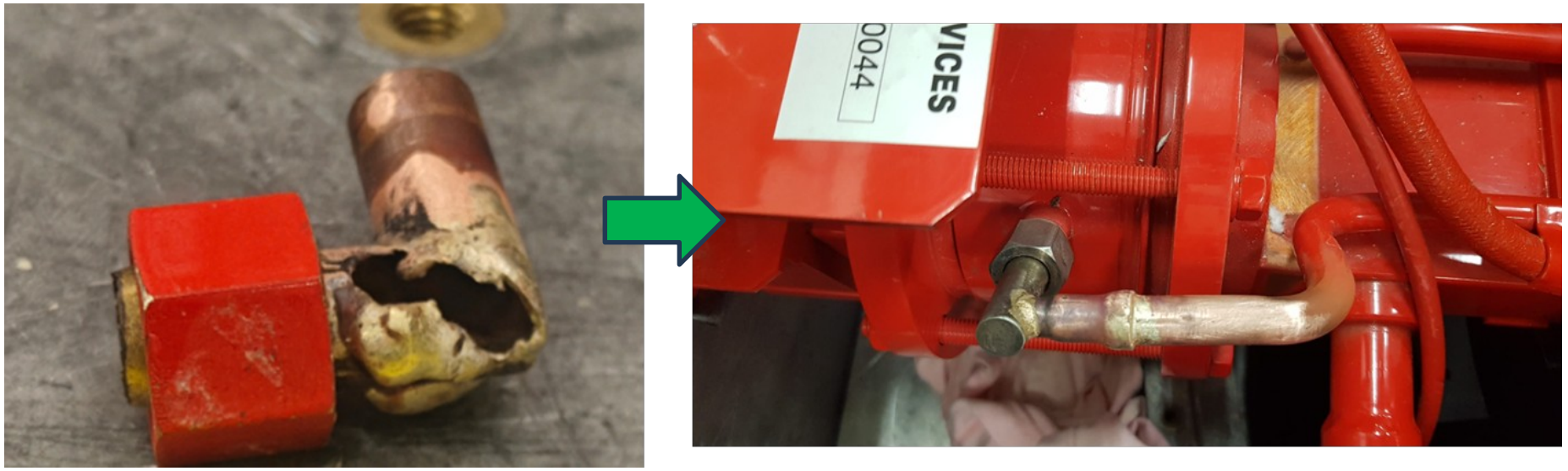
Temporary solution: Isolation of Klystron 2 and switch to LINAC degraded mode

Reason: A connector was severely damaged by water flow.

Solution: Joint brazed attempt leads to cave in => it has been replaced.

Impact: Beam interruption (2h36)

July 28, 2025



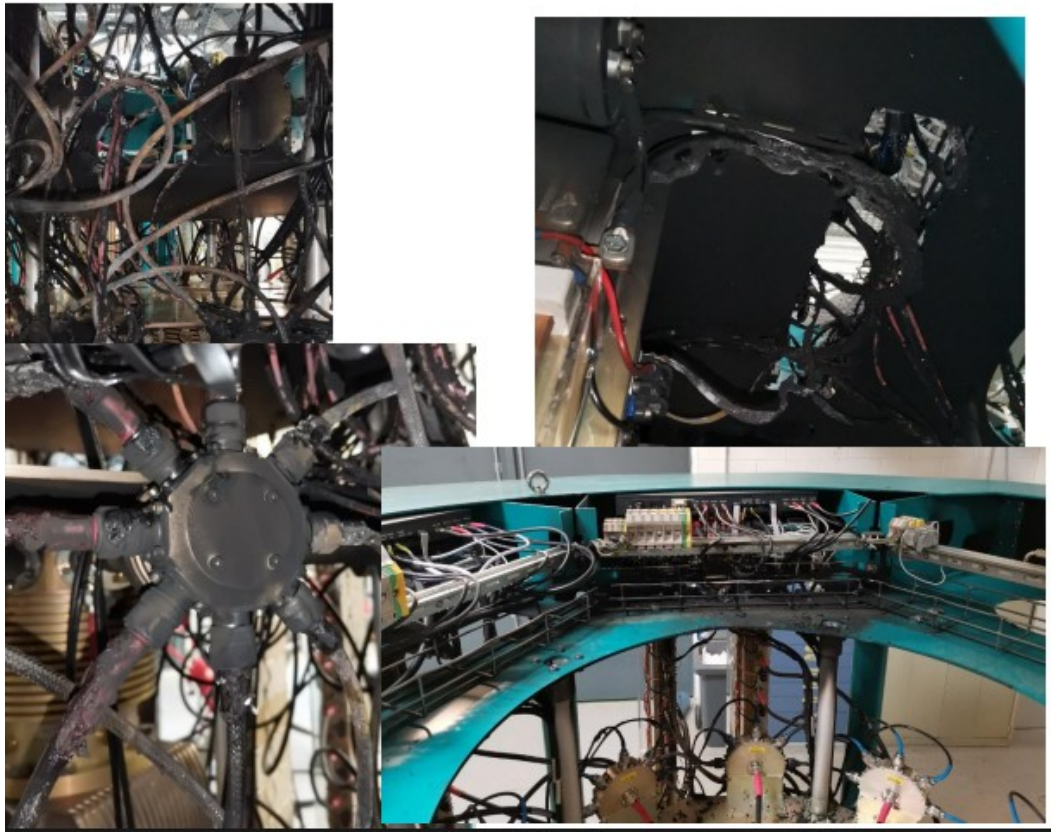
Issue: Cable fire in a RF SSPA tower of the second RF cavity

Reason: Lose grip on at least 3 cables on a combiner

Solution: Tightening all cables (add fireproof insulator around cables in progress too)

Impact: Beam interruption (2h13)

6th juin 2025



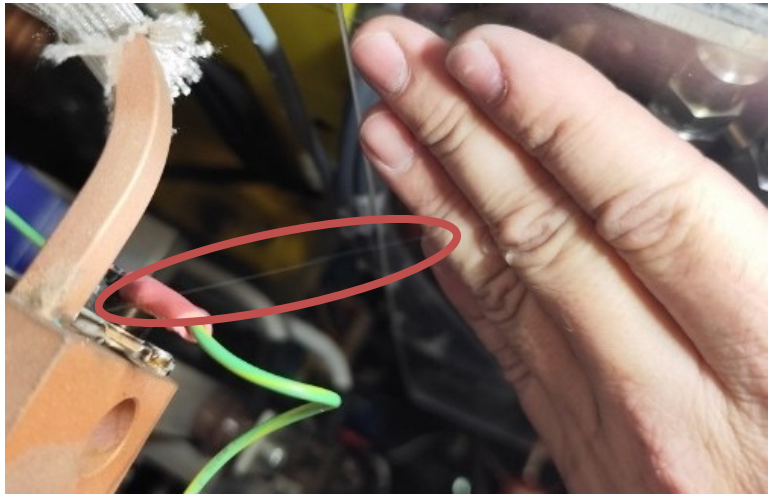
Issue: Abnormal value on an ion pump

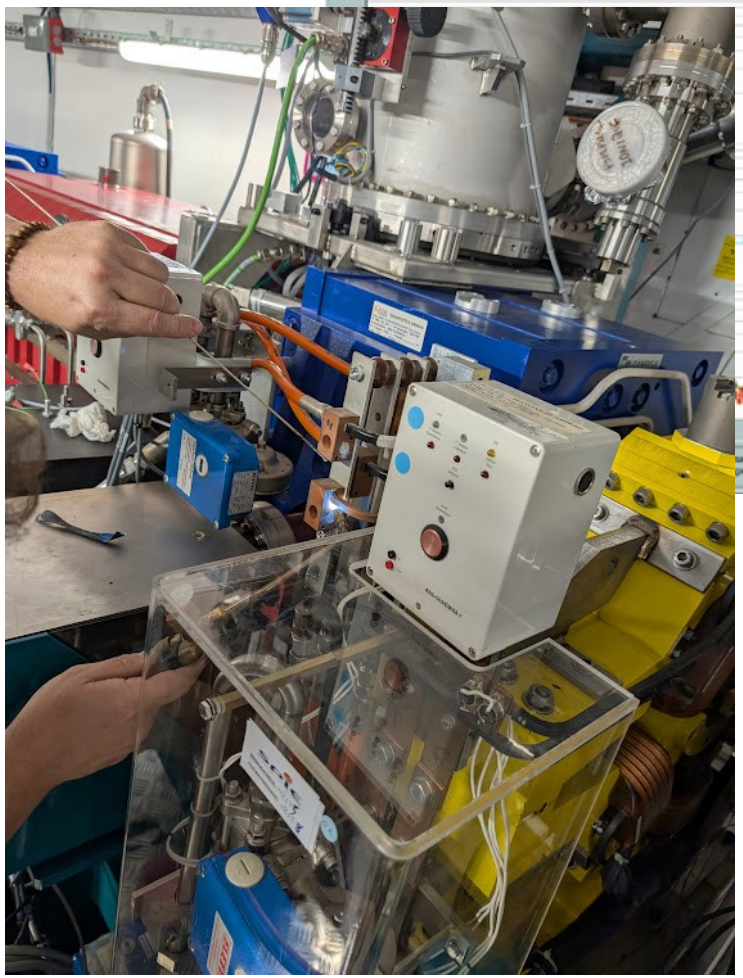
Reason: water leak on a nearby quadrupole spraying the ion pump connector.

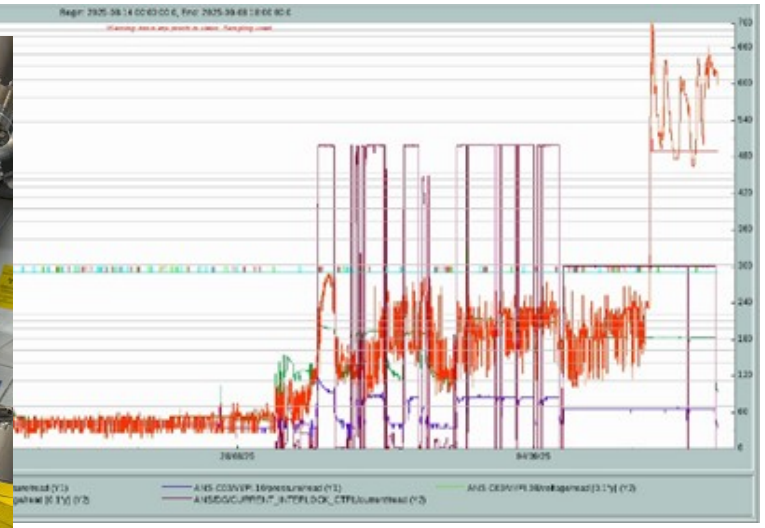
Solution: Soldering the Qpole leak

Impact: Ion pump out of order

August 30, 2025





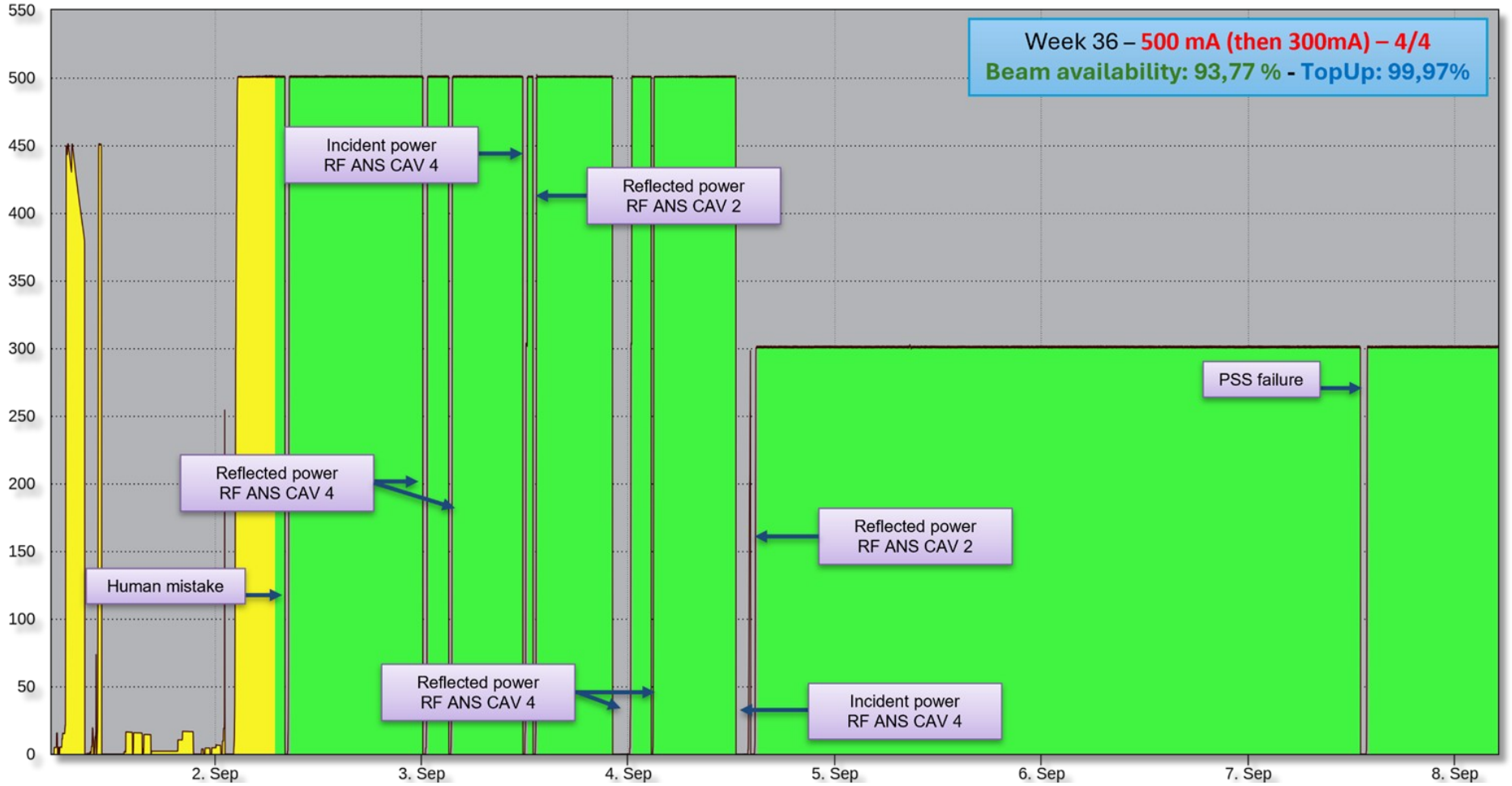


Issue: Several failure on 2 RF power tower leading to 8 beam loss in 2 days

Reason: Failure due to the switch used to pass from operation to test mode

Impact: After the 7th lost: Decision to isolate the 4th cavity power supply and lower beam current at 300 mA

First RUN week in September, 2025

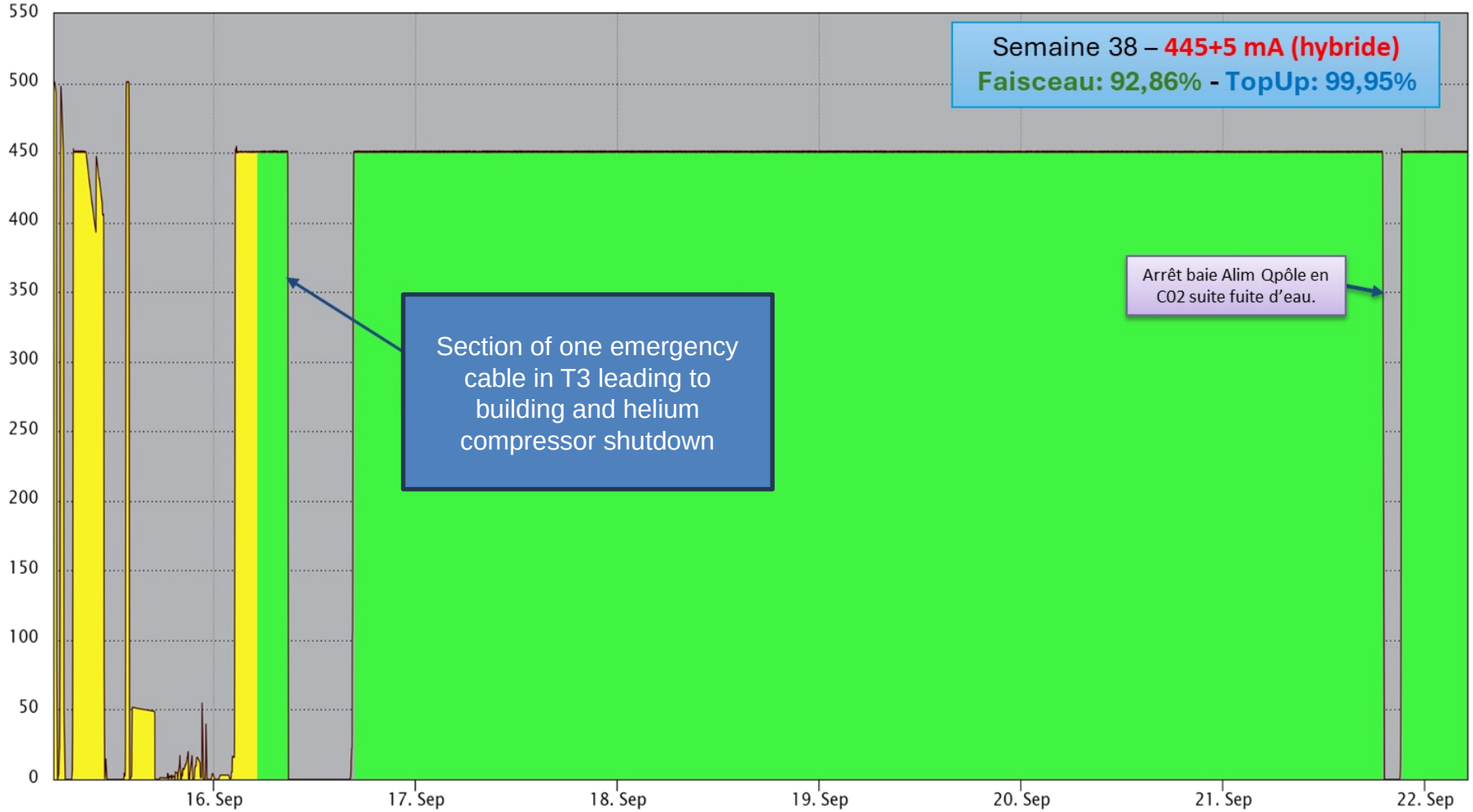


Issue: Cryomodule stop and issues to restart

Reason: Shutdown of helium compressors due to an emergency cable sectioned in the technical building T3 and succession of failure during restart

Impact: Beam interruption (7h58)

September 16, 2025



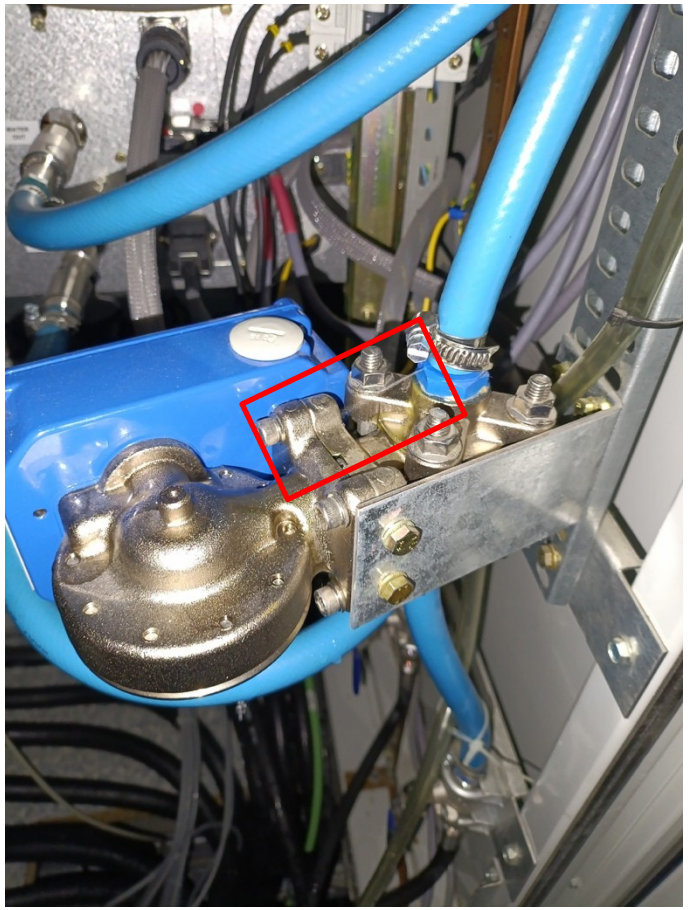
Issue: Water leak in the power supply of a ring quadrupole

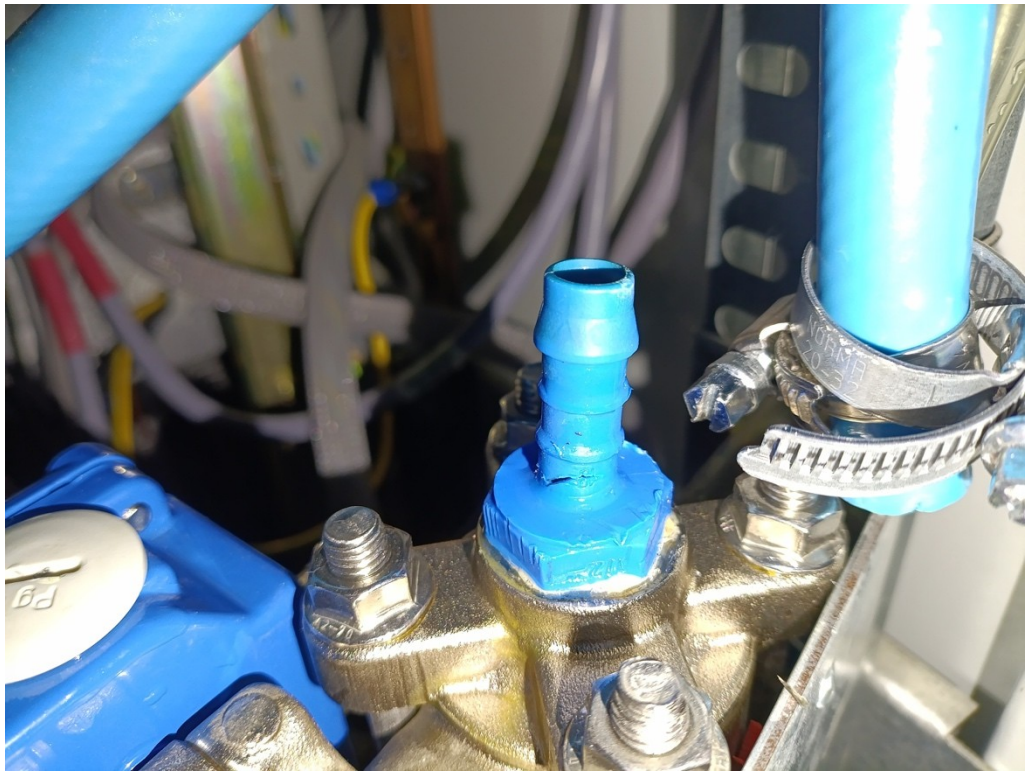
Reason: Perforation of a flowmeter connector due to ageing with mechanical stress

Solution: It has been replaced

Impact: Beam interruption (2h18)

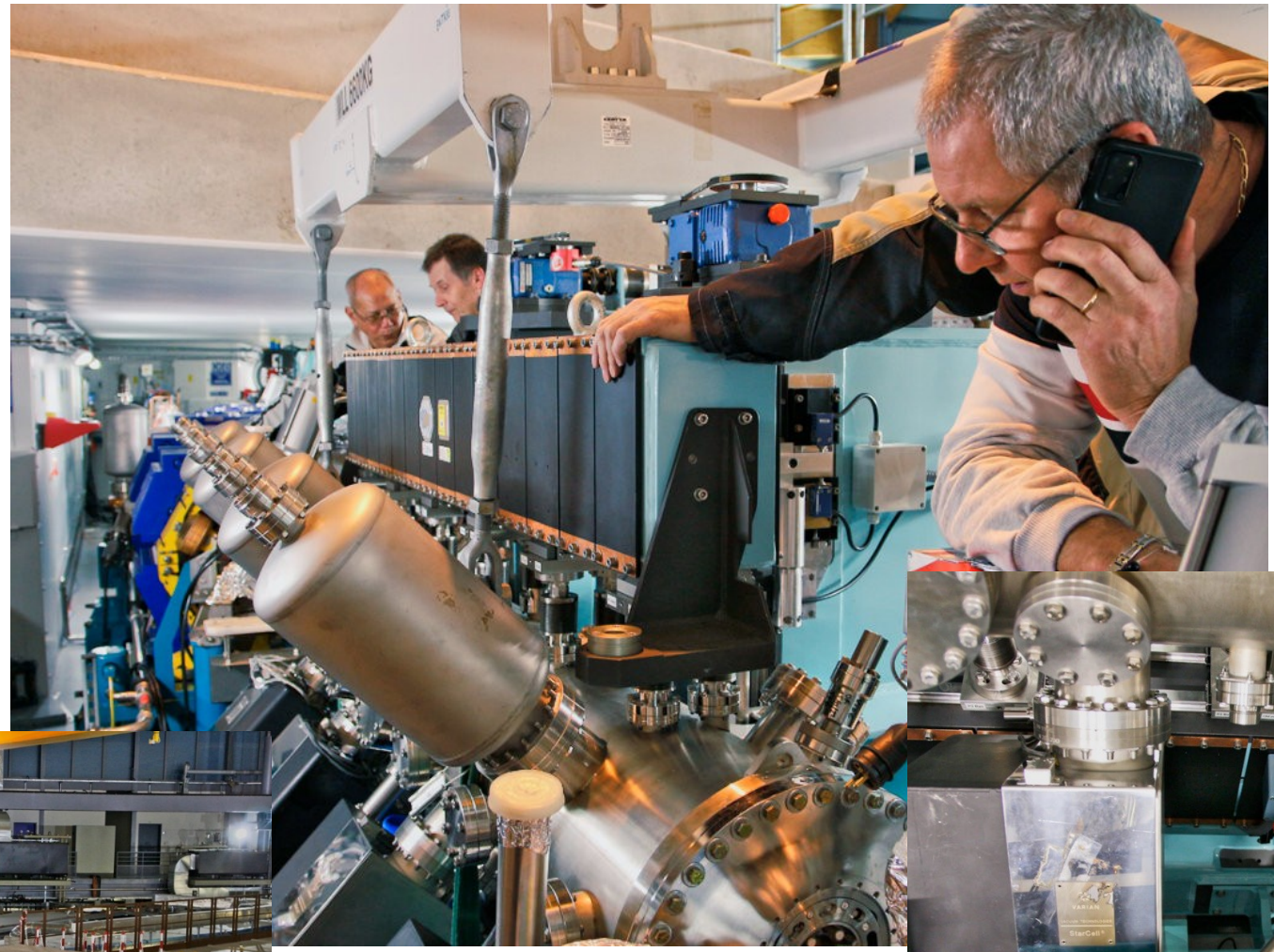
September 21, 2025

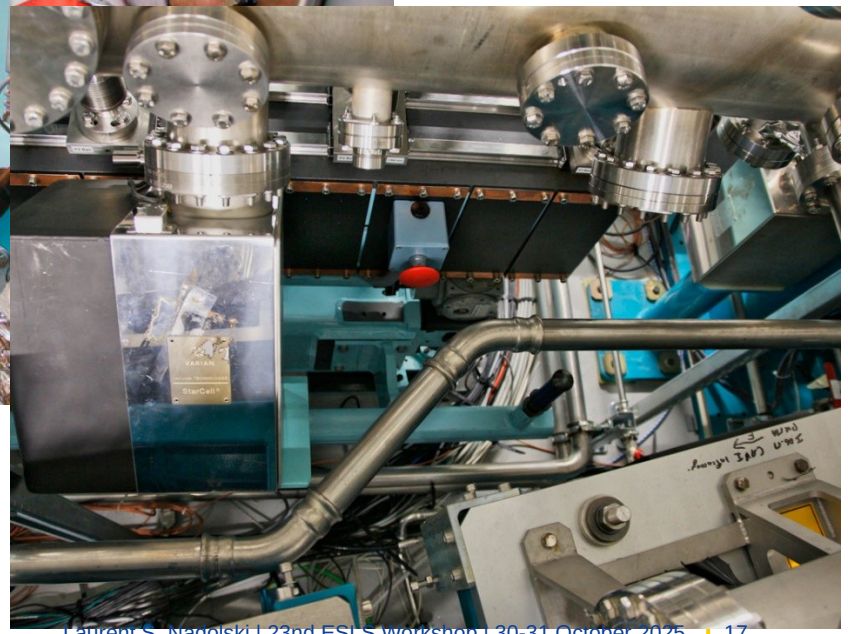




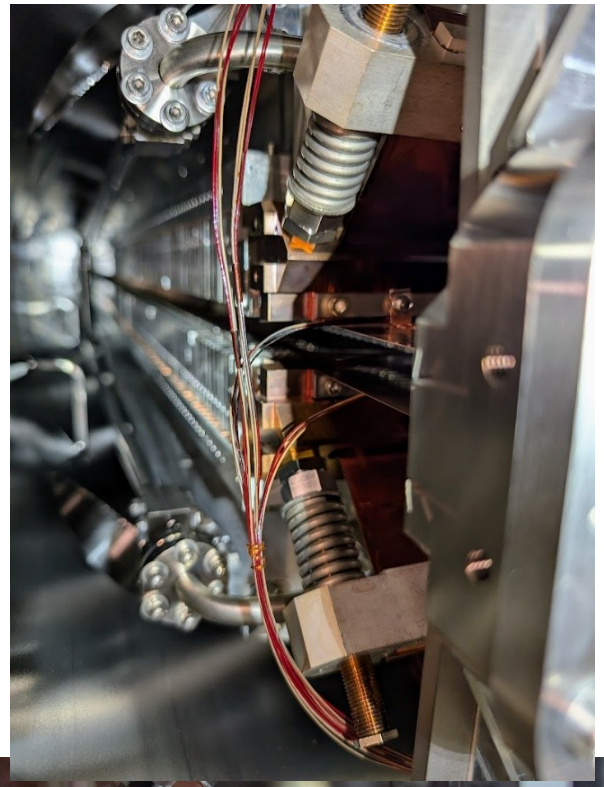
R&D at SOLEIL

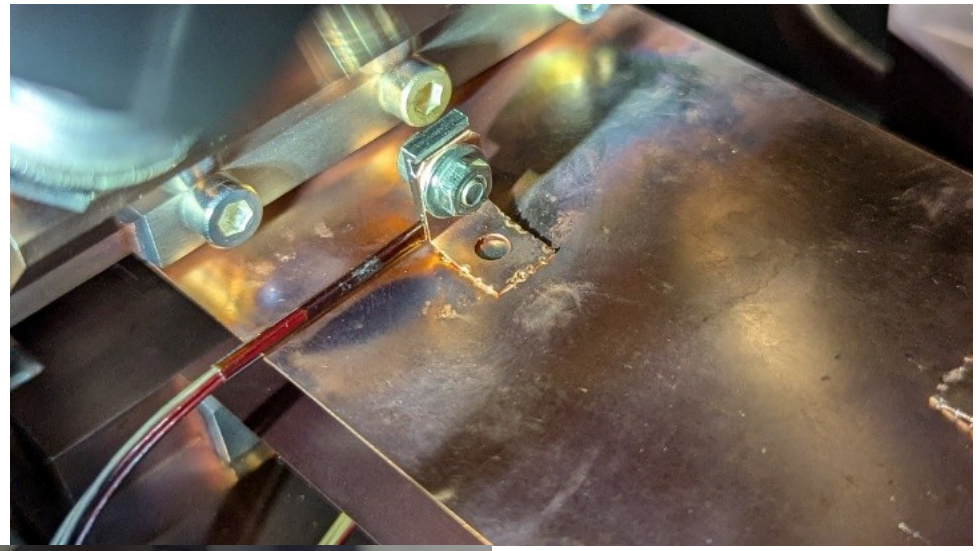
CRISTAL IVU (U20) undulator substitute by a CPMU18

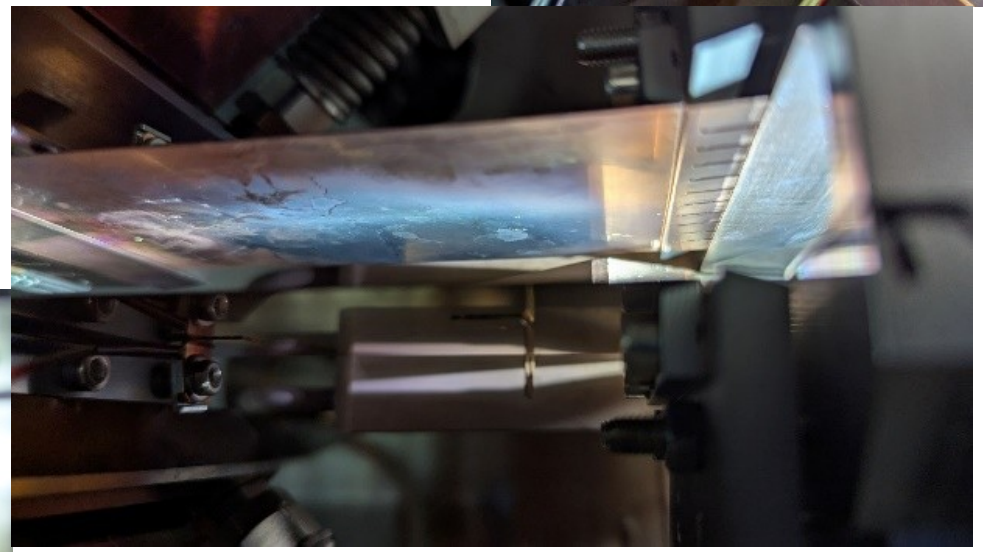


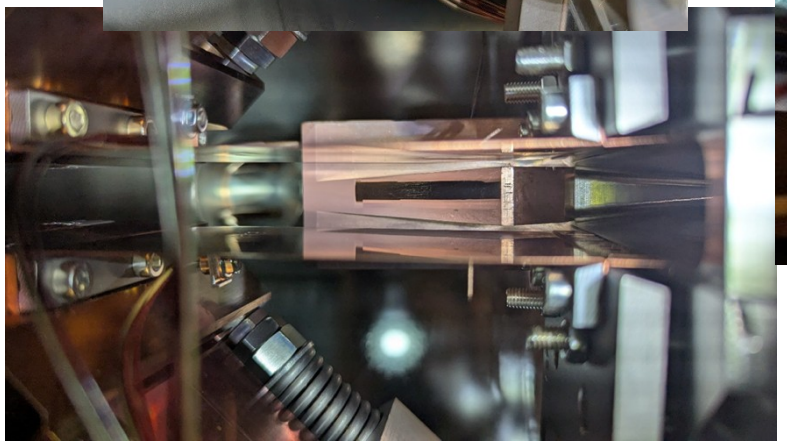


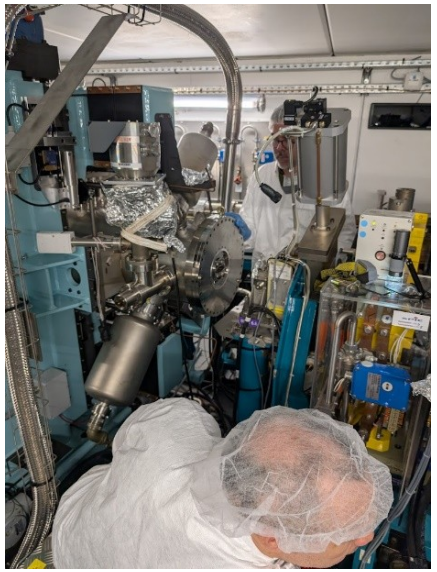
Replacement of the upper exit transition of the CPMU18 undulator and setup of the 4th vacuum pump removed during undulator installation



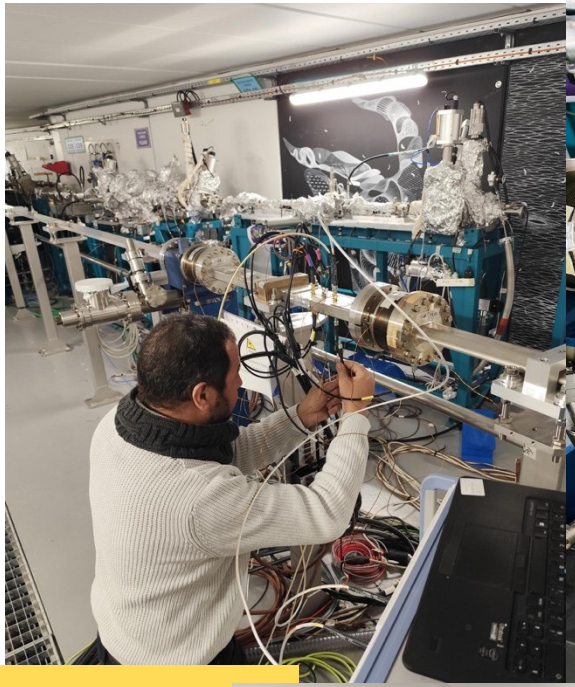


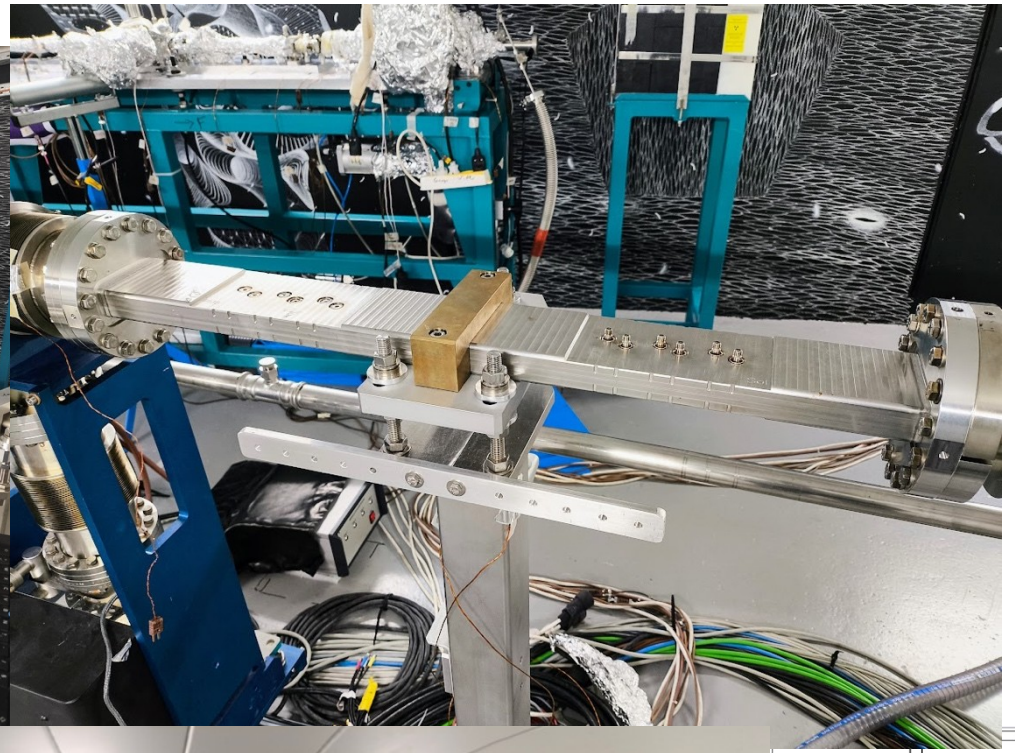


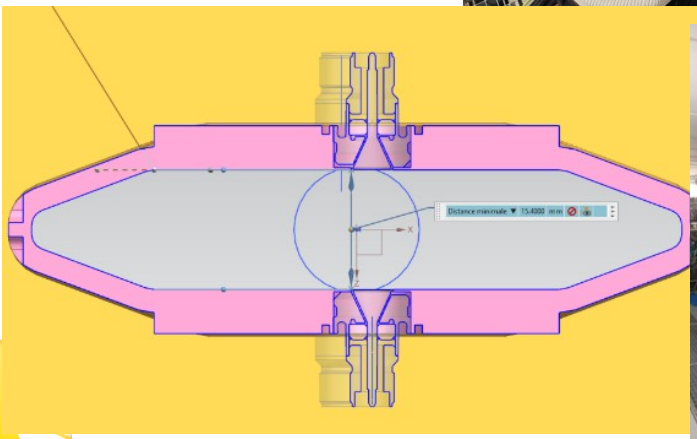


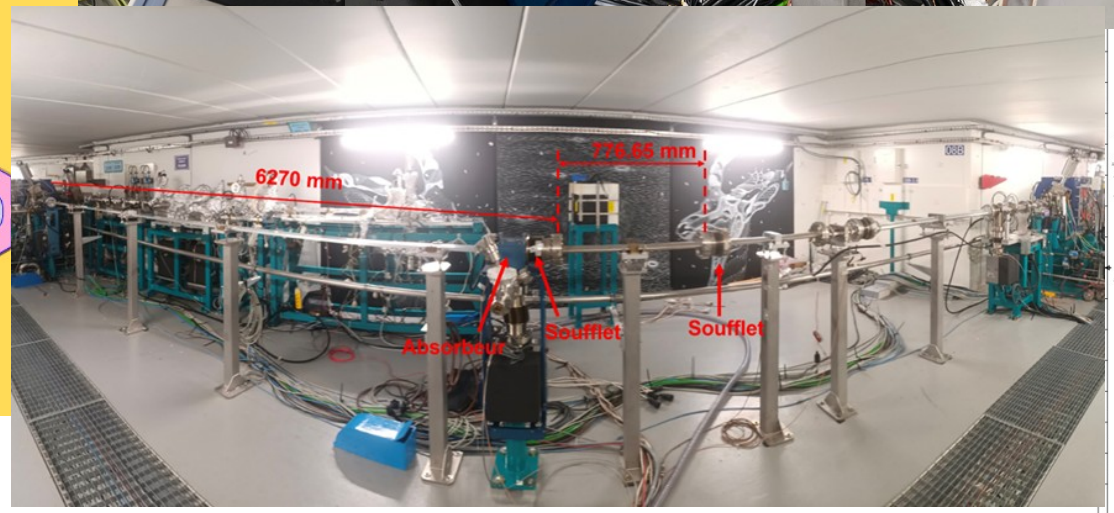


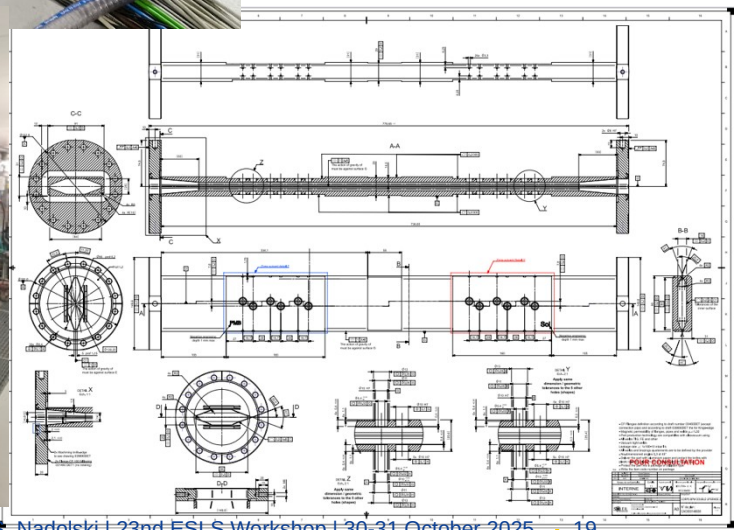
Installation of prototype vacuum chamber with SOLEIL II BPM electrodes



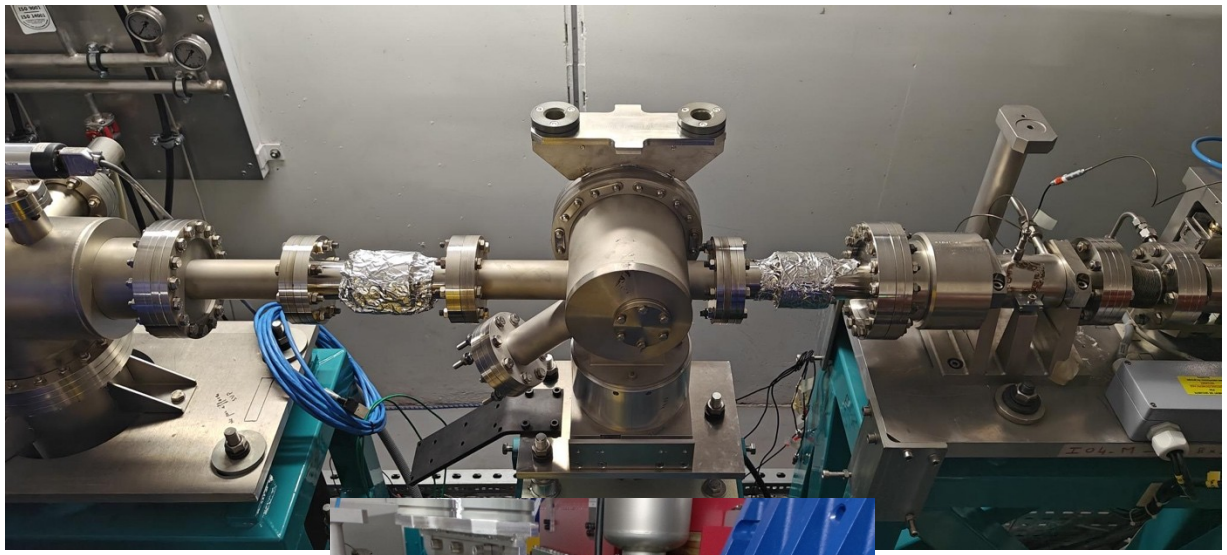






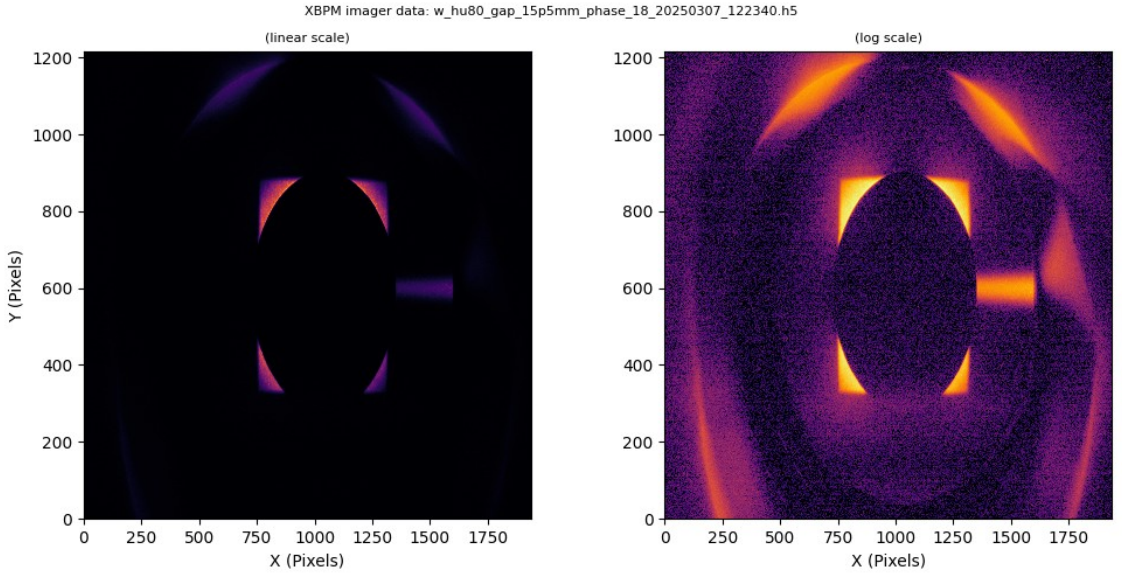


TDL I04-M PLEIADES: Installation of Diamand XBPM imager

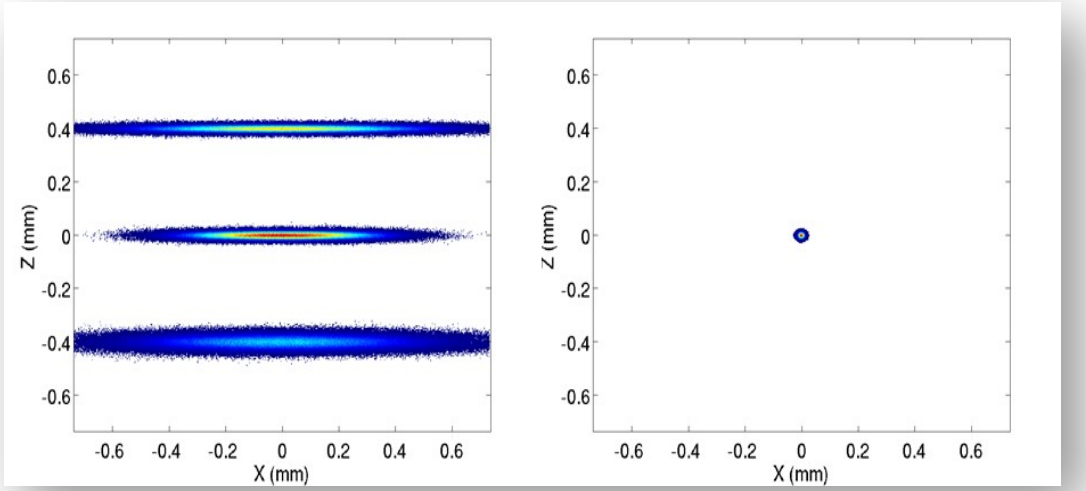


Classical 4-blade X-ray Beam Position Monitors (XBPMs) are not suitable for helicoidal undulators.

Diamond XBPM imager aimed to visualize the outer part of the photon beam using an annular piece of diamond, thus leading to a better shape reconstruction than with a 4-point measurement.

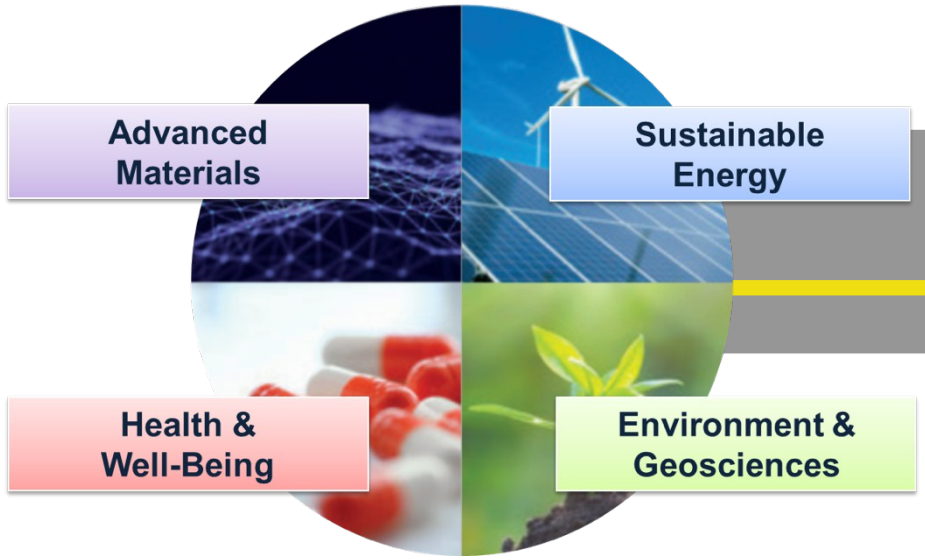


Third Generation



Fourth Generation

SOLEIL → SOLEIL II



Upgrade

SOLEIL II Project Phase : A New Organization

Budget: See A. Nadji Introduction

Steering Committee
SOLEIL II

1. SOLEIL II Project Phase 1

Project Leader: Amor Nadji

Deputy: Javier Perez

Project Management Office
Administrative support
Planning
Resources
Budget
Purchasing
Risks
Quality
Safety
Change Management

Hélène Rozelot

1.1 Construction of Accelerators	1.2 Relocation and adaptation of Beamlines	1.3 Overhaul of the information system	1.4 Infrastructure & Logistics
Laurent Nadolski Patrick Alexandre	Kewin Desjardins Stephanie Blanchandin	Yves-Marie Abiven Emiliano Fonda	Christian Herbeaux Mohamed Nouna

Deliverables for SOLEIL II Phase 1 Project

- 28 out of 29 beamlines reconducted + 1 Cryo-EM
- Upgrade of LINAC and TL1 @150 MeV before shutdown.
- Construction of a new low-emittance Booster.
- Construction of a new ultra-low emittance Storage Ring (SR).
- Construction of the first three new Insertion Devices.
- Relocation of 6 Beamlines (4 IDs + 2 BMs).
- Adaptation and alignment of other Beamlines.
- Modernization of IT systems.
- Installation of the necessary infrastructure and buildings.
- Commissioning of accelerators: restart of the LINAC, commissioning of the new Booster, and the new Storage Ring.
- Commissioning of ready beamlines and restart of laboratories.
- Opening of beamlines to users.

SOLEIL II Progress Report: Selection

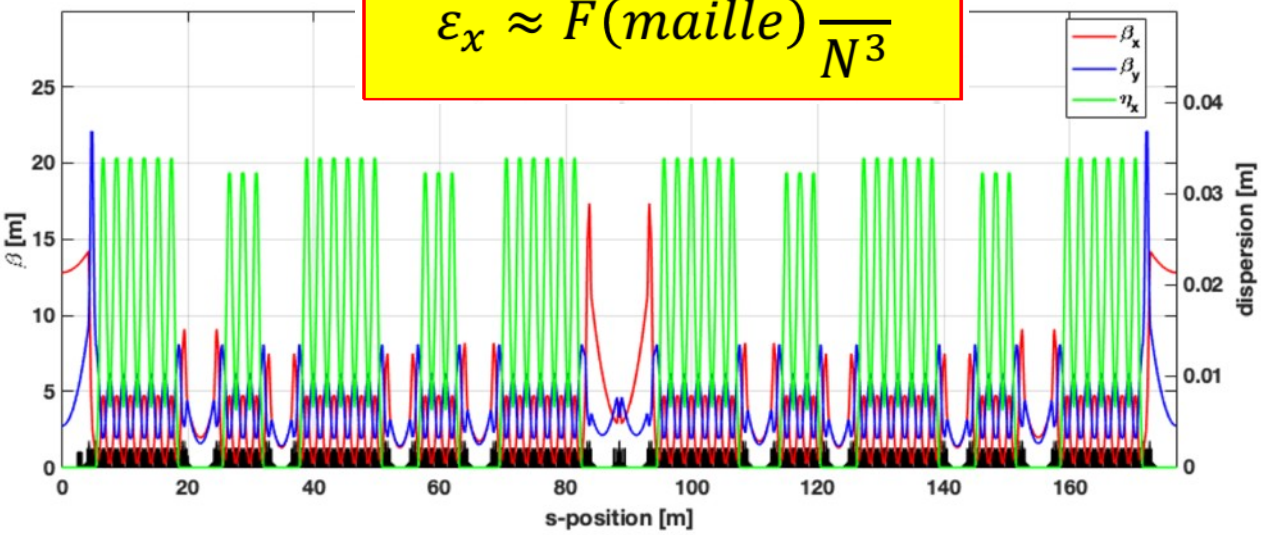
A New Storage Ring for SOLEIL II

Lattice V3633

Upgrade Project of the SOLEIL Accelerator Complex, SRN, 2023
https://doi.org/10.1080/08940886.2023.2186661
A brief introduction to the Synchrotron SOLEIL and its upgrade programme. *Eur. Phys. J. Plus* **139**, 80 (2024).
https://doi.org/10.1140/epjp/s13360-024-04872-2

28 beamlines **1 CRYO-EM microscope**

$$\varepsilon_x \approx F(maille)\frac{E^2}{N^3}$$



Twiss functions (horizontal and vertical beta function in red and blue. horizontal dispersion in green) along half of the SOLEIL II storage ring circumference.

Parameters	SOLEIL	SOLEIL II
Energy [GeV]	2.75	2.75
Circumference [m]	354.10	353.98
Maximum Beam Current [mA]	500	500
Lattice Type	DBA	**7BA-4BA**
Cell Number	24	20
Natural Emittance [pm.rad] Round beam (100% coupling)	**3 900** **-**	**90** **54**
Energy Spread	1.02 E-3	0.93 E-3
Natural RMS Bunch Length [ps]	16.1	9.0
Transverse Damping Times, $\tau_x/\tau_y/\tau_s$ [ms]	6.9 / 6.9 / 3.5	7.7 / 13.7/ 11.5
Momentum Compaction Factor	4.2 E-4	1.06 E-4
Energy Loss per Turn [keV]	917	471
Overall RF Voltage [MV]	2.6	1.7
RF Frequency [MHz]	352.20	352.31
Synchrotron Frequency [kHz]	4.2	1.7

Parameters without insertion devices nor harmonic cavities
7 superbend at 2.92 T and 5 at 1.7 T

Roadmap: LINAC UPGRADE TO 150 MeV

Oct/Nov. 25

Controls Migration

LINAC **3rd Modulator Commissioning**

Dec. 25 / Jan. 26

New LINAC **buncher** installation & commissioning

LINAC AC system installation

(1st phase)

March 26

LINAC accelerating section conditioning @ 20 MW

Preparations for PS cable trays

Back up for controls migration

(May 26)

Back up for controls migration & LINAC conditioning

Mid June – End Aug. 26**

Beam stopper installation

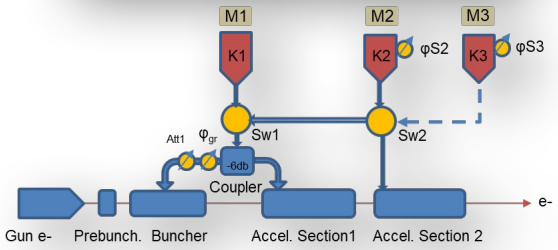
TL1 Power supply & control installation

TL1 Quadrupole cooling installation

LINAC AC system installation (2nd phase)

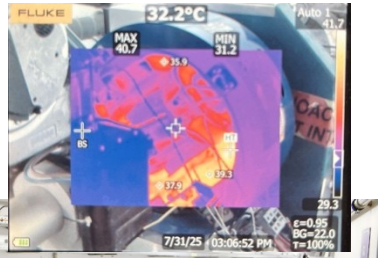
Shielding installation

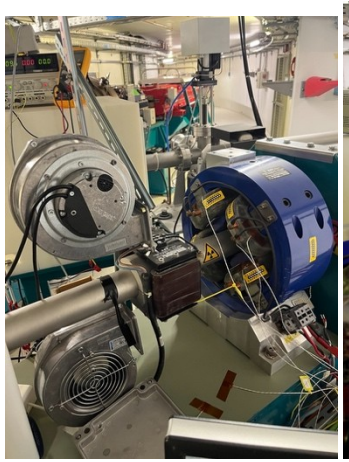
Commissioning (110 MeV up to 150 MeV)

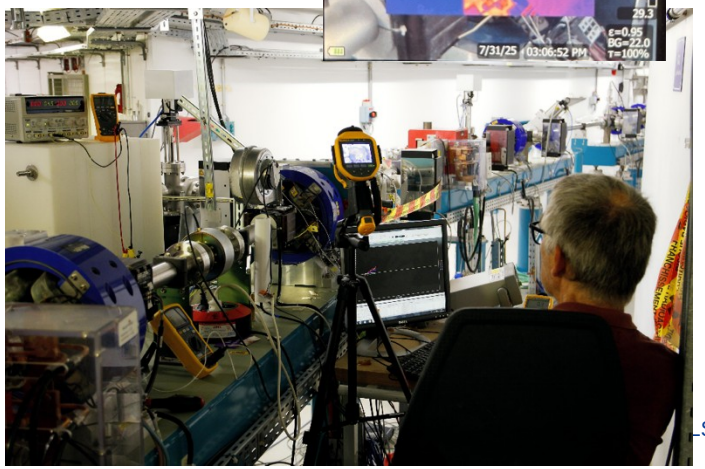


Setup of a 3rd RF modulator

Temperature measurement of quadrupoles under fan airflow with nominal current set point at 150 MeV







Build of the new direct beam stop.

End 2026 Injection into the booster at 150 MeV **Followed by daily operation**

SOLEIL II
La science éclaire l'avenir
Science lights up the future

A Multiyear RF-Roadmap

- A multi-year RF roadmap, with specific construction milestones
  - RF conditioning: August 2026-Shutdown
  - MC (main cavity) and HC (harmonic cavity) testing in the present storage ring + DLLRF

Aug. 26
RF Bunker ready

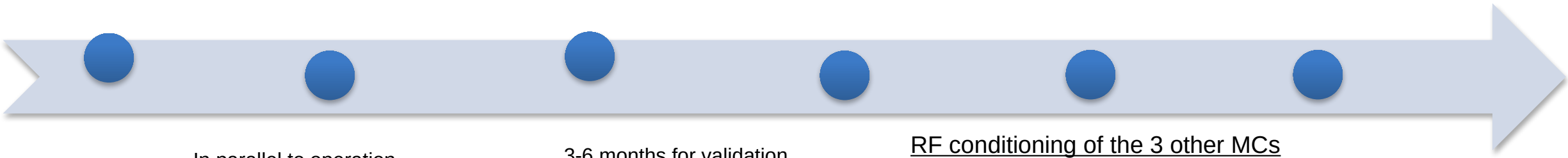
Aug 26 / Dec. 26
RF Conditioning
-300 kW Coupler
- First 2 RI 352 MHz Cavities

July-August 27
Installation in SOLEIL SR of the 2 first RI 352 MHz Cavities

Fall 2027
RF Conditioning
-1st HC cavity
- Cont. of RF systems

January 2028
1st 1.4 GHz HC installed into SOLEIL

October 2028
Shutdown of SOLEIL



In parallel to operation
Stored Beam reduced to **450 mA**

3-6 months for validation
3 more cavities to manufacture

RF conditioning of the 3 other MCs

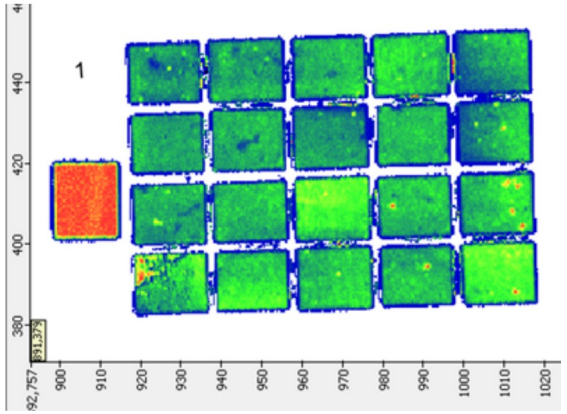
Construction, then RF conditioning of the 2 other HCs

Fall 2025
New DLLRF in operation for Booster

Summer 2026
New DLLRF in operation for SR

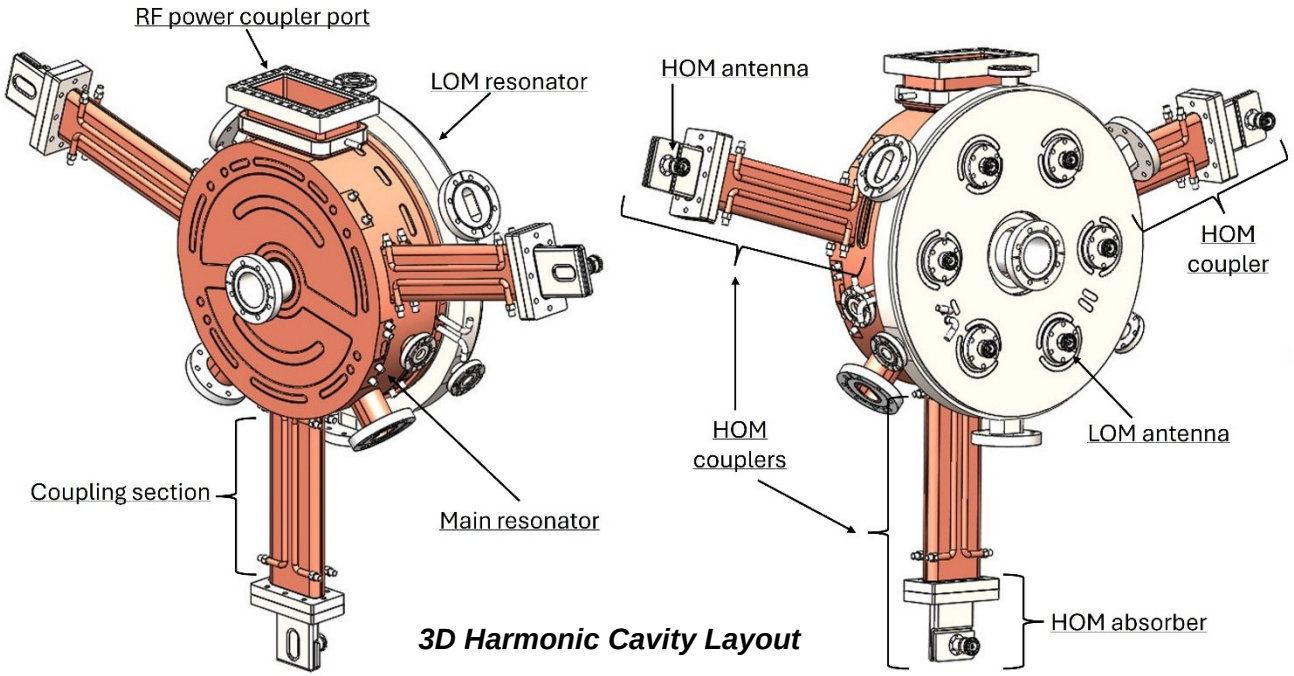
RF System Status

- **Fundamental system - *5 x 352 MHz HOM-damped cavities***
  - Final Design Review last summer with latest improvements
  - Ongoing studies with Institut de Soudure to test brazing samples of absorber ferrite and define the acceptance criteria
  - **Tuner CFT launched in mid-September** (8 tuners expected by **May 2026**)
  - 250 kW FPC's: built in the framework of a collaboration with CERN
  - Ancillaries CFT's (pick-ups, support frame…) to be launched by **November 2025**
  - Home-made DLLRF prototype ready to be tested in the Booster ring in **November 2025**
  - SSPA upgrade with 9 x new 50 kW towers



Microsonic scan of a ferrite plate sample

- **Harmonic system - 3 x 4th harmonic mono-cell cavities**
  - Design made **in collaboration with ESRF**
  - Cavity CFT launched last July, contract signature expected before the end of this year for a **delivery mid 2027**



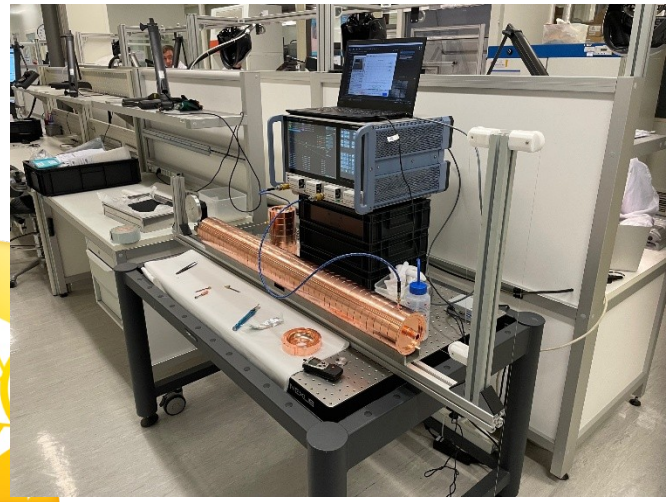
3D Harmonic Cavity Layout

RF and LINAC System Status

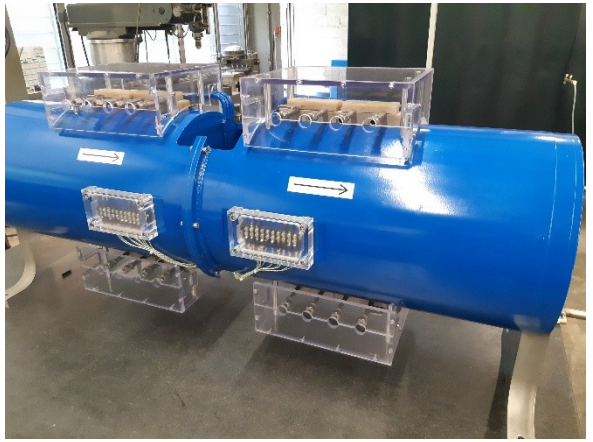
- **Test area for RF conditioning**
  - **RF bunker** will be adapted by April 2026
  - Test area to be completed by the end of August 2026
  - Heavy power components located on the **LINAC roof** will allow cavity and coupler conditioning for both Booster and SR (MC + HC) **from September 2026 onwards.**

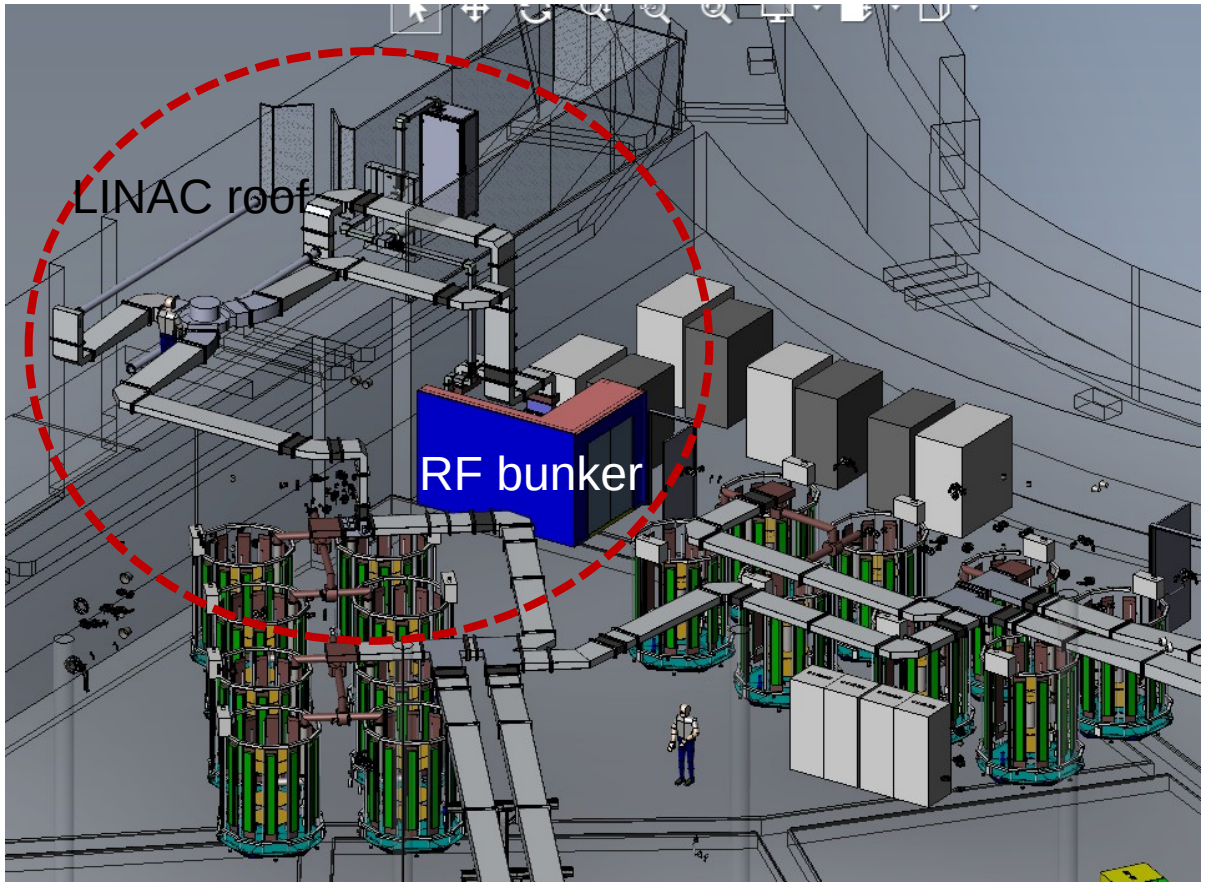
- **LINAC status**
  - 3rd Modulator (SSA based) to be installed in November 2025 to provide **full energy redundancy**
  - New buncher section as a spare part → delivery **end 2025**

3rd klystron-modulator in LINAC room



New buncher section



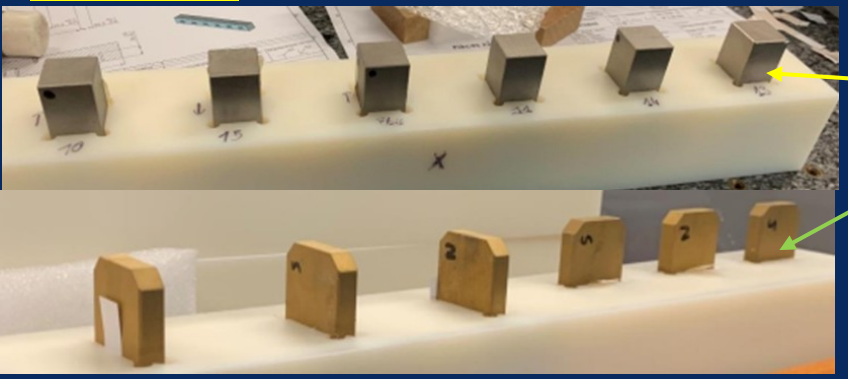


Test area plotted in red

110 to 150 MeV injector upgrade scheduled during mid-June-August 2026 extended shutdown

MAGNET IRRADIATION TESTS AT CERN: CHARM FACILITY

Reminder



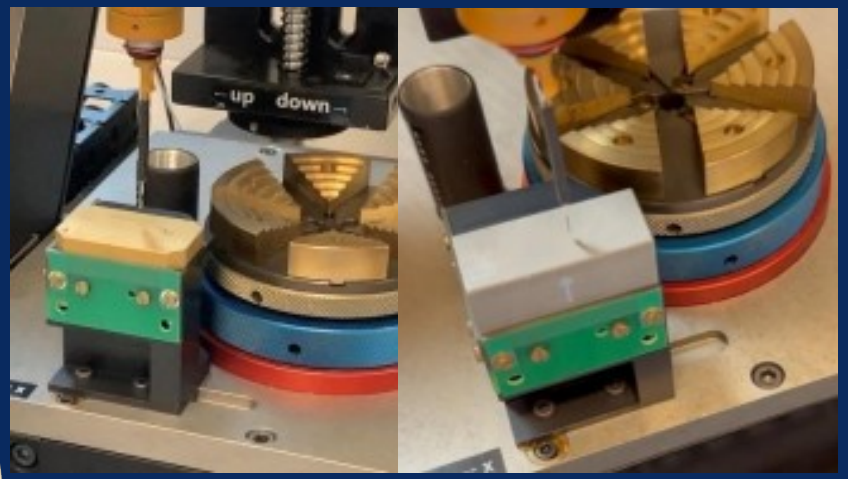
2 sets of Permanent Magnets irradiated at CHARM for each PM grade
Sm_2Co_{17}
and
$Nd_2Fe_{14}B$

[NEW] 2 new sets in May 2025

Nylon boxes with the magnetic field of permanent magnets arranged in different orientations (N/S & // or ⊥)

SOLEIL Permanent Magnet Samples in nylon boxes at CHARM

- The two boxes were irradiated at 1.9×10^{12} Si 1 MeV Eq n^- (electronic radiation damage quantity measured at the sample position), corresponding to approximately 5×10^{12} $n \cdot cm^{-2}$ in terms of neutron fluence.



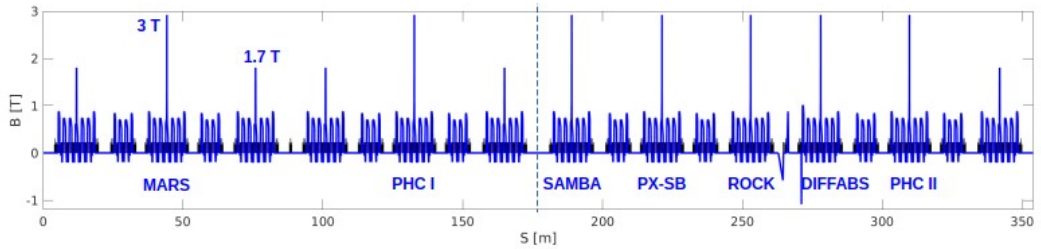
All magnets were measured at SOLEIL using a 2D Hall probe before and after irradiation.
Both faces of each magnet were thus characterized.

- For the Sm_2Co_{17} magnets, **no significant variation in the magnetic field was observed (± 0.2%)** according to the measurements, with a bench reproducibility of about ± 0.1%.
- For the $Nd_2Fe_{14}B$ magnets, the measured field decreased by approximately 2%.

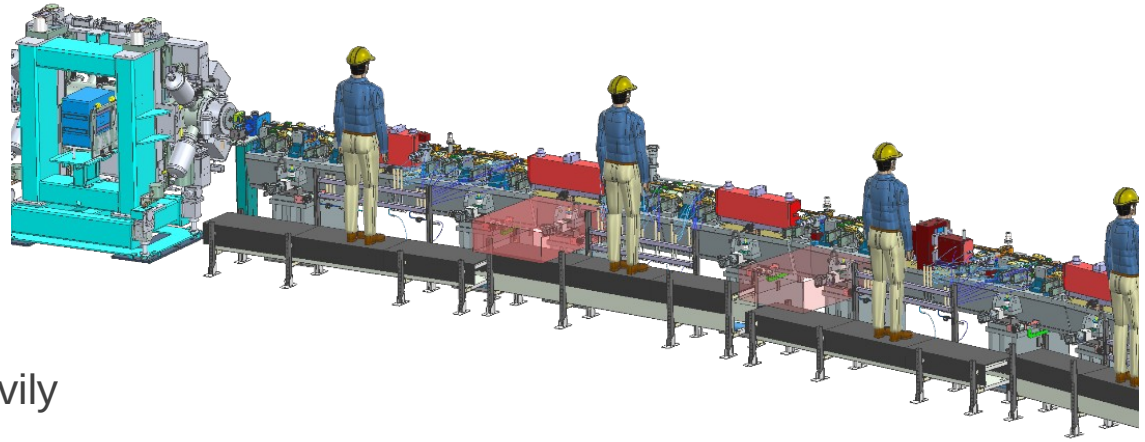
Work Progress

- Consolidation of the Storage Ring Lattice

New V3633

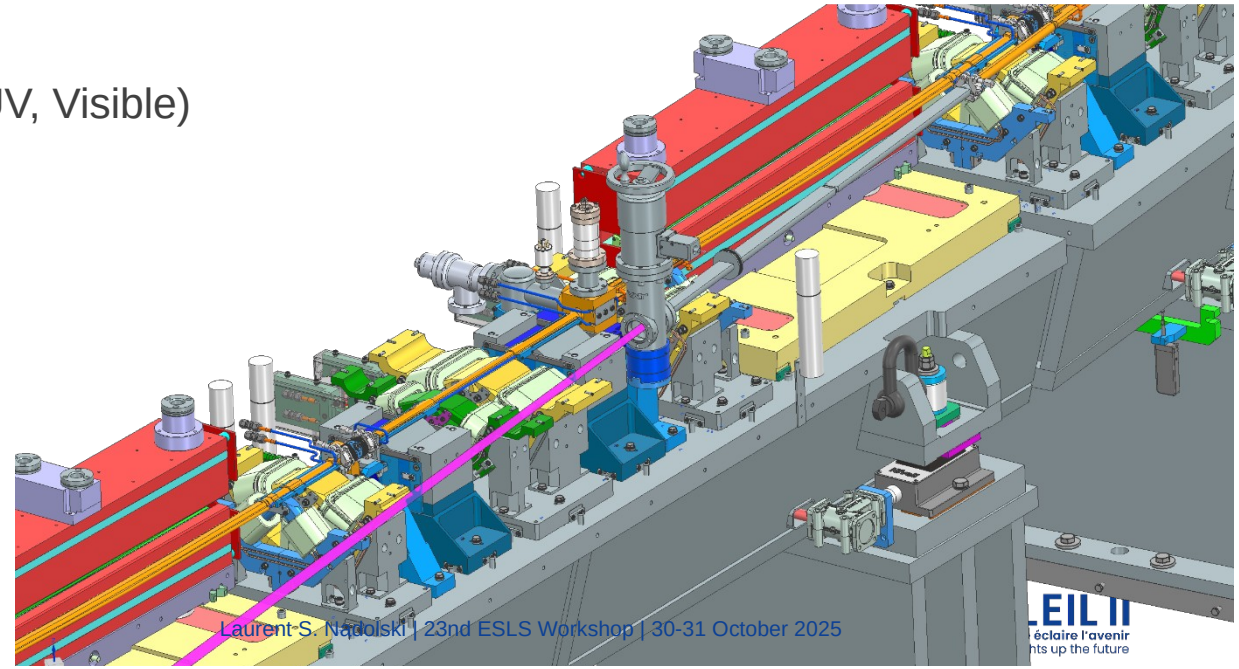


The 3D model is mature: **about 80% for the lattice V3631**



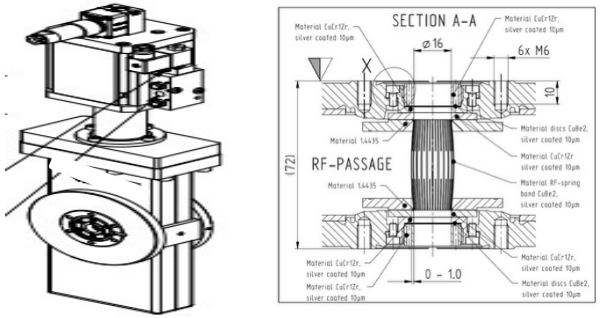
- Final adjustments for Beamline performance optimization are made during this very fall
  - Complex and interleaved projects have been discussed heavily over the last year with new proposed solutions.
    - Opportunity for THz-IR beamlines
    - [NEW] Low-energy photon extractions (IR, UV, VUV, Visible)
    - [PROGRESS] MARS beamline

- All sources for beamlines are identified for Phase 1



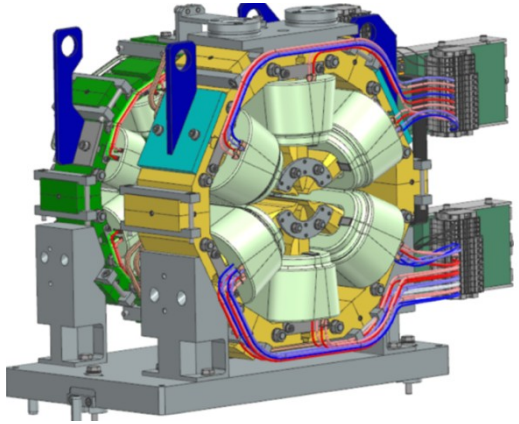
Calls for Tender 2025

First Batch: BPM LIBERA Brilliance+

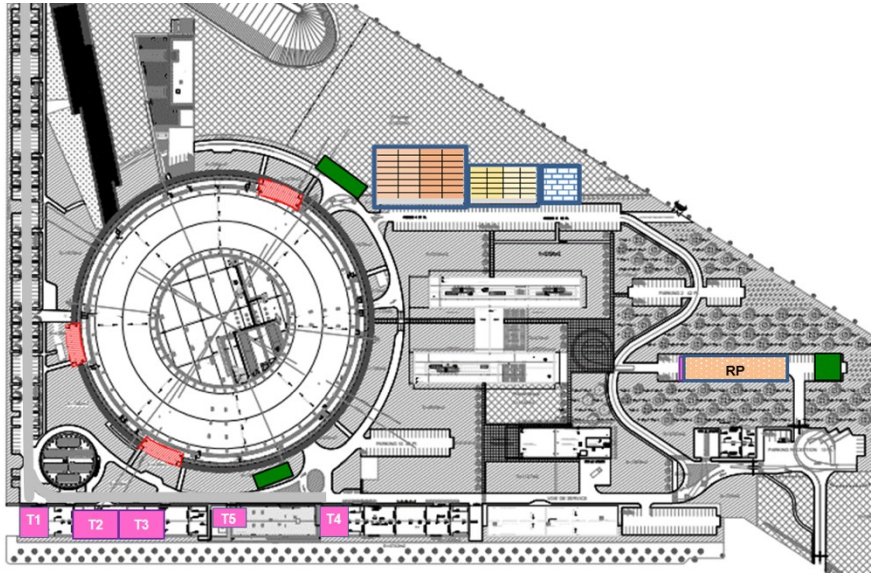


RF-Short Circuit valves

Getter / Ion Pumps



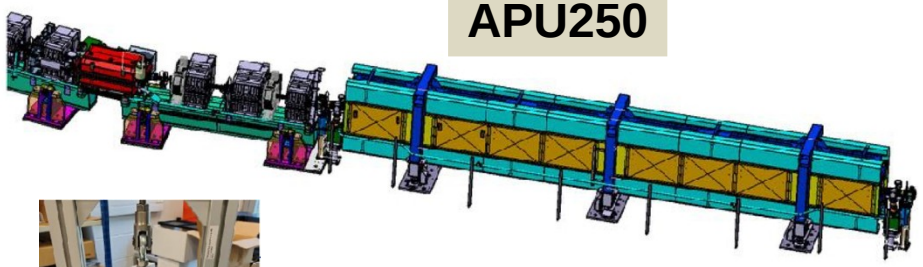
Doublet (octupole/sextupole)

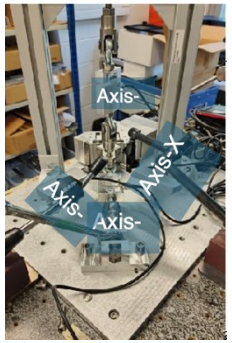


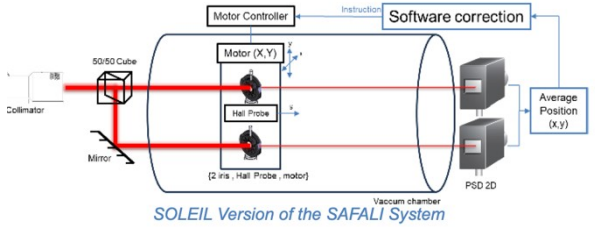
Building Progress

Prototypes and Photon Sources

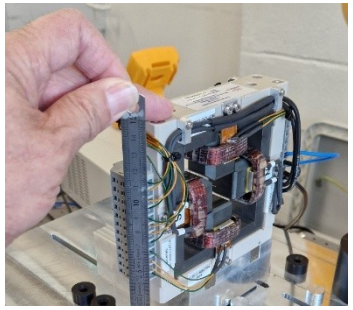
APU250



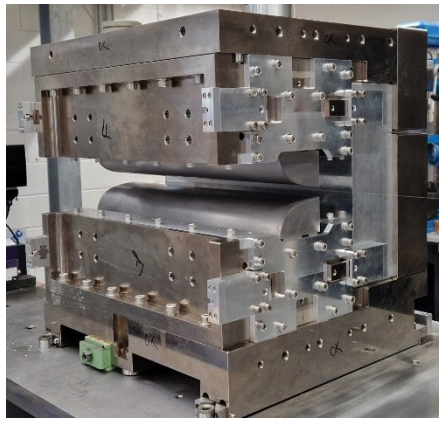




SOLEIL Version of the SAFALI System



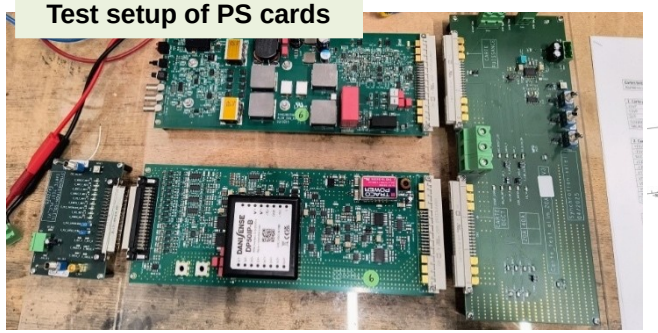
Fast FOFB Steerer (SigmaPhi)

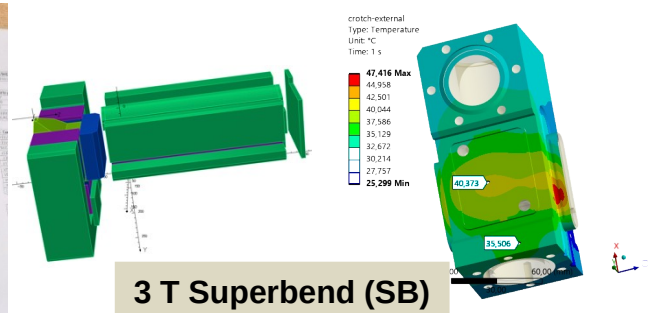


The assembling of the DNC prototype took place in August 2025.

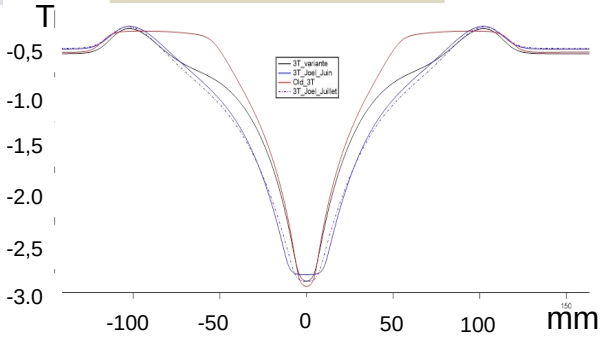
BPM prototype before welding (@RIAL).

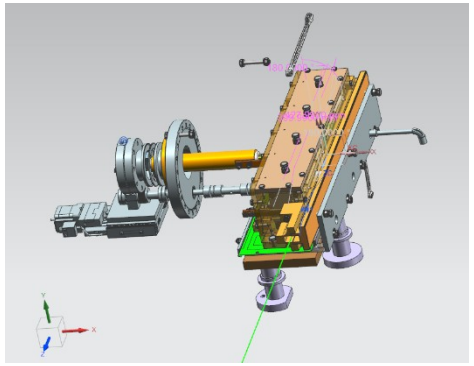
Test setup of PS cards



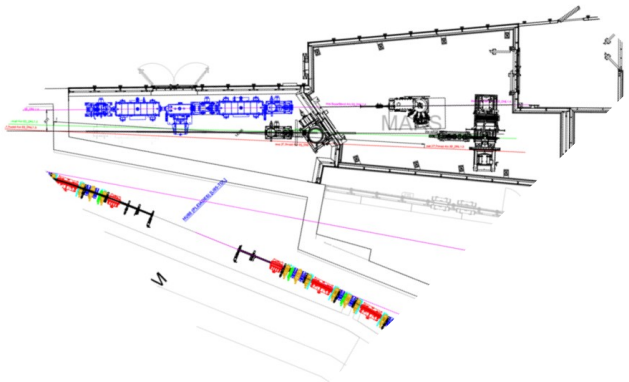


3 T Superbend (SB)





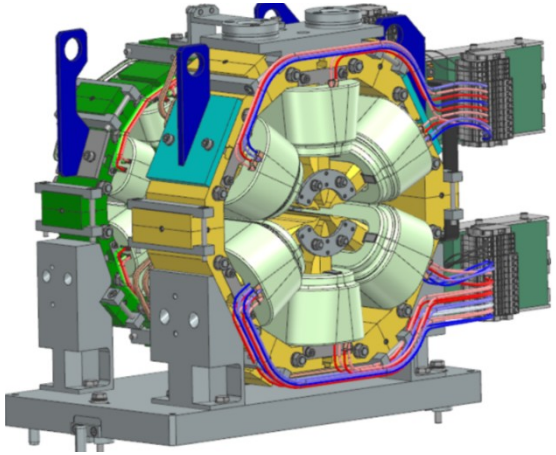
SR thin septum magnet *(magnet / stored beam pipe / electrical connection / transverse translation) – S. Thoraud – J. Da Silva Castro.*



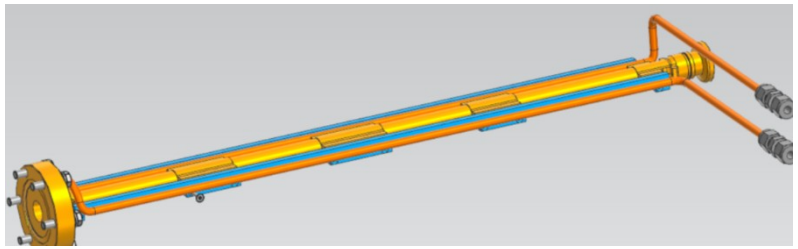
MARS Beamline Source Point

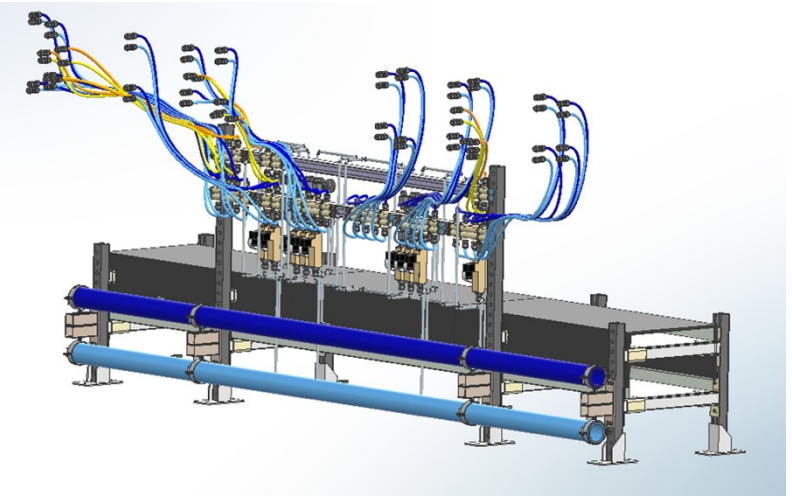
New direct beam stopper (ARDI)

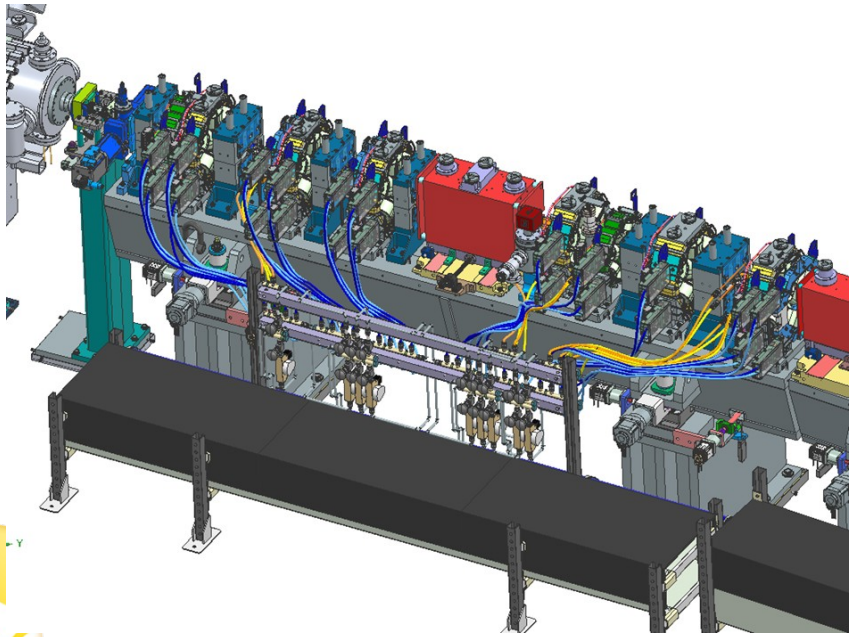
Electrical and Water Cooling Distribution Units



Present electromagnet configuration:
The coils are independently water-connected

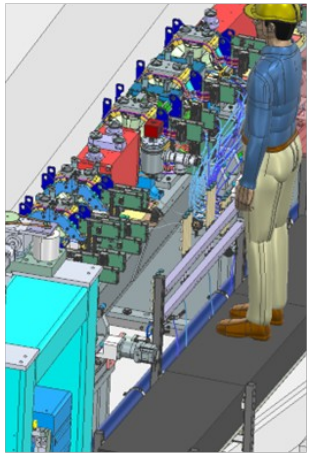


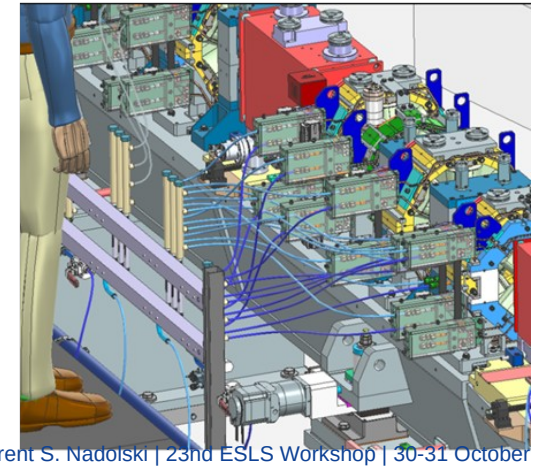




Define standard configurations of pre-assembly for water distribution of magnets and vacuum chambers (reduce the number or types).

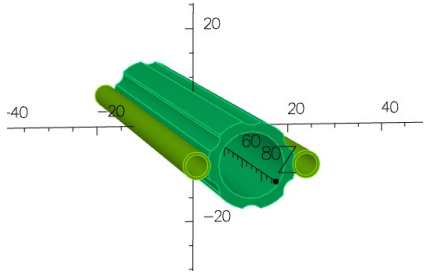
Cable trays will be designed for supporting workers

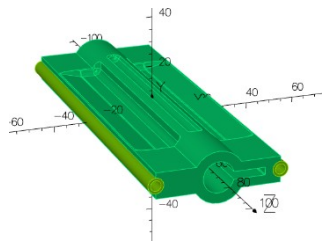




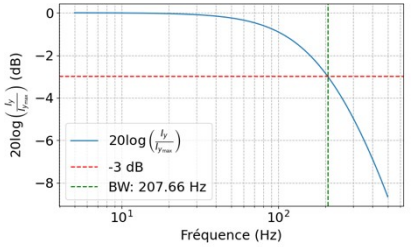
CDR Requirement: Pushing the FB Bandwidths, and FFWD Correction Frequencies

- Cut-off frequencies of the final design of the chambers were revealed (late identification in the project) to be very heterogeneous and low in some places (VC shape, VC with antechamber, cooling circuit, photon absorbers)

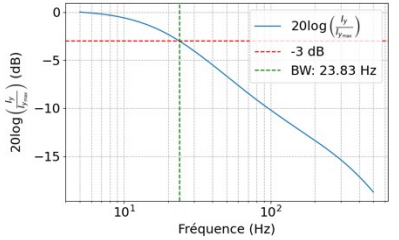




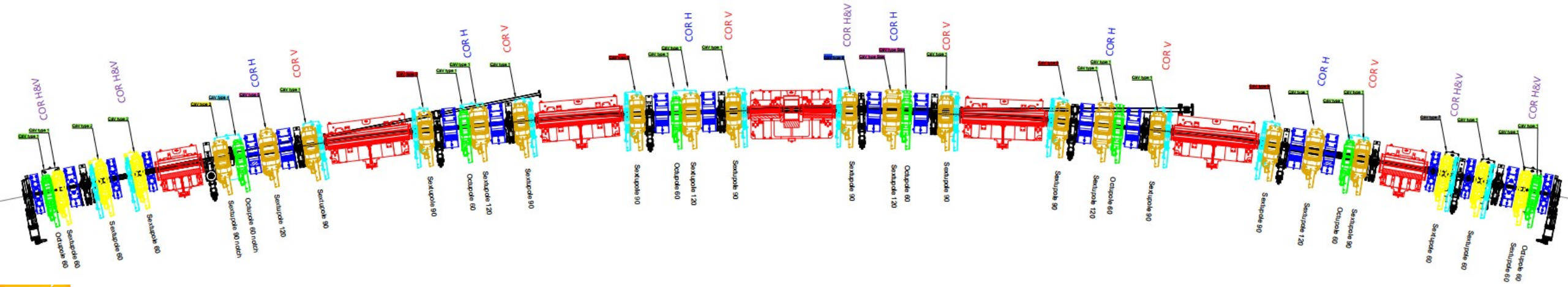
- Challenging
  - Risk assessment to meet the specification
  - Are the CDR specifications over-specified?
  - Avoid, at all costs, putting the project at risk and keeping the current VC designs.



THE BANDWIDTH: 208 Hz



THE BANDWIDTH: 24 Hz



Conclusions and Perspectives

- **SOLEIL II: a highly ambitious upgrade**
  - **A new SOLEIL for tomorrow's science**
  - The highest brilliance in its class is not the result of a quest for performance at any price, but a **guarantee of adaptability to the future**.

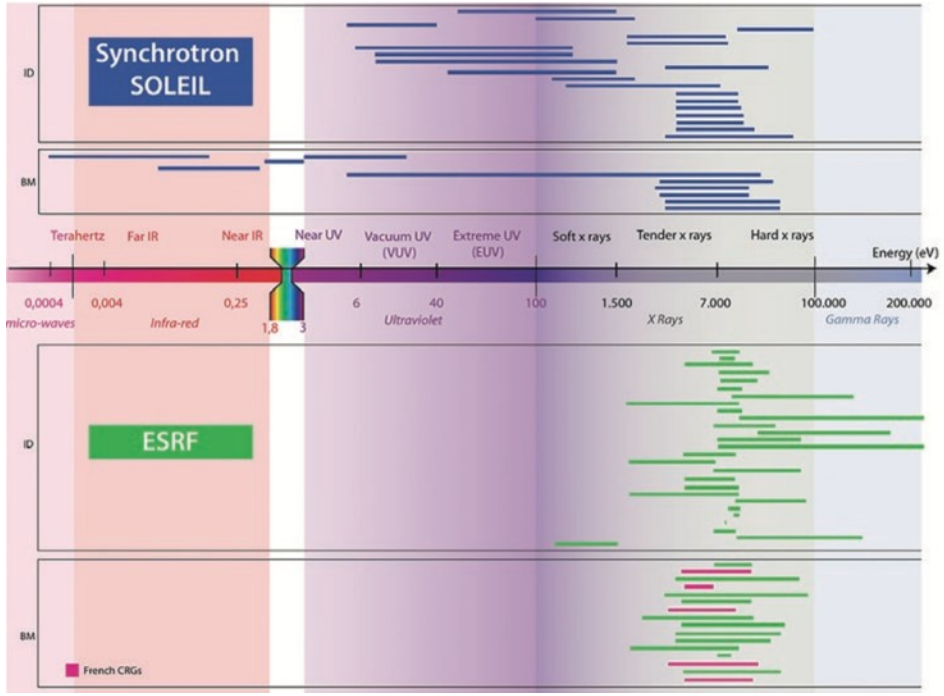
- **Upgrade Budget Spending**
  - The call for tenders for SOLEIL II has been launched, with **several major contracts already signed** — including BPM systems, RF components, and vacuum equipment.

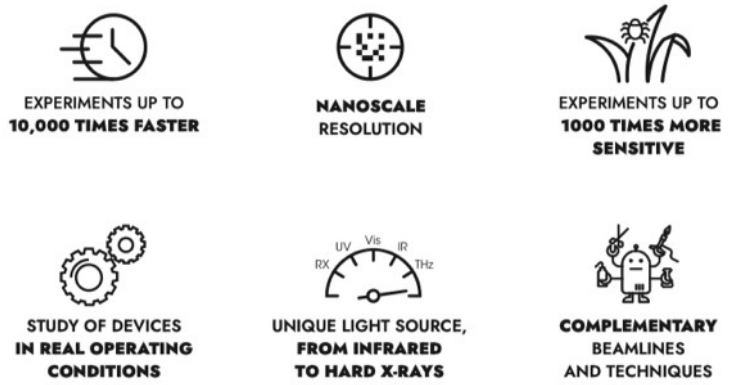
- **Ensuring technical feasibility through**
  - **Innovative partnerships** established with multiple industrial players
  - An **intensive R&D phase underway**, involving the development and testing of several prototypes
  - Main chamber and magnet tenders (CFTs) planned for 2026

- **Mechanical Integration to freeze the SR Lattice by late 2025**

- **Organization**
  - A new project structure has been implemented to strengthen coordination and clarity of responsibilities.
  - Active work is ongoing to define and manage interfaces across systems and teams.
  - The objective is to deliver an updated and consolidated schedule by the end of the year.
  - At the IT level, agile working methods have been introduced in collaboration with all stakeholders, including the four main programs, to improve responsiveness and cross-functional alignment.
  - The integration of cybersecurity within the IT architecture (including controls) remains a demanding but essential task to ensure system robustness and long-term reliability..

- **Collaboration**
  - In parallel**, collaborative development initiatives** are being pursued with sister facilities and partner companies to foster innovation, share expertise, and strengthen industrial engagement.





La science éclaire l'avenir
Science lights up the future

SOLEIL SYNCHROTRON

Many thanks to everyone involved in the project

THANK YOU FOR YOUR ATTENTION

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