
Happy New Year 2024

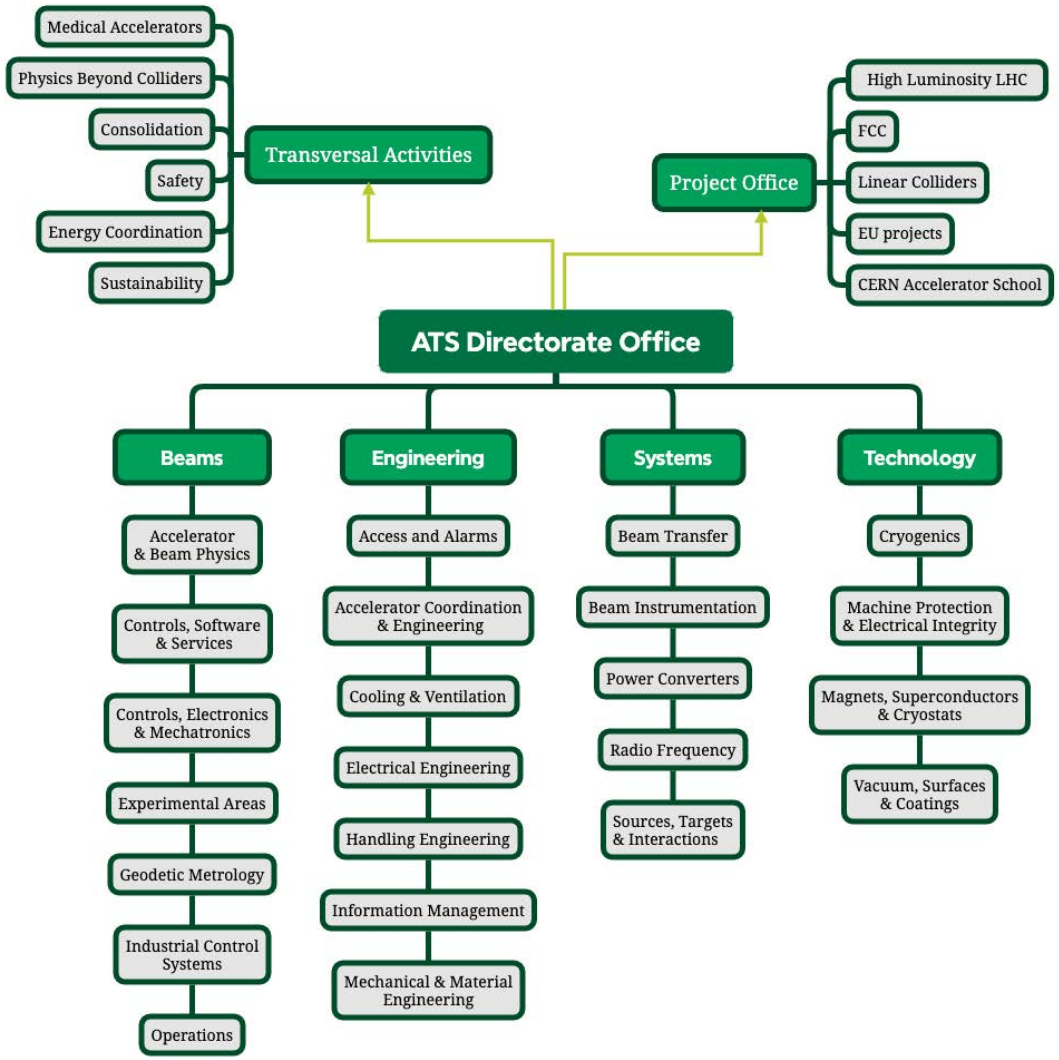
ATS at a glance

Operates, maintains, consolidates, upgrades the world's largest accelerator complex and associated technical infrastructure++

1289 staff (~13% women)
475 fellows/graduates (~26% women)
520 associates (~26% women)
Contract personnel

Annual budget (M+P) ~650 MCHF

Facilities used by 12,000 scientists from around the world



Disclaimer

Big sector!

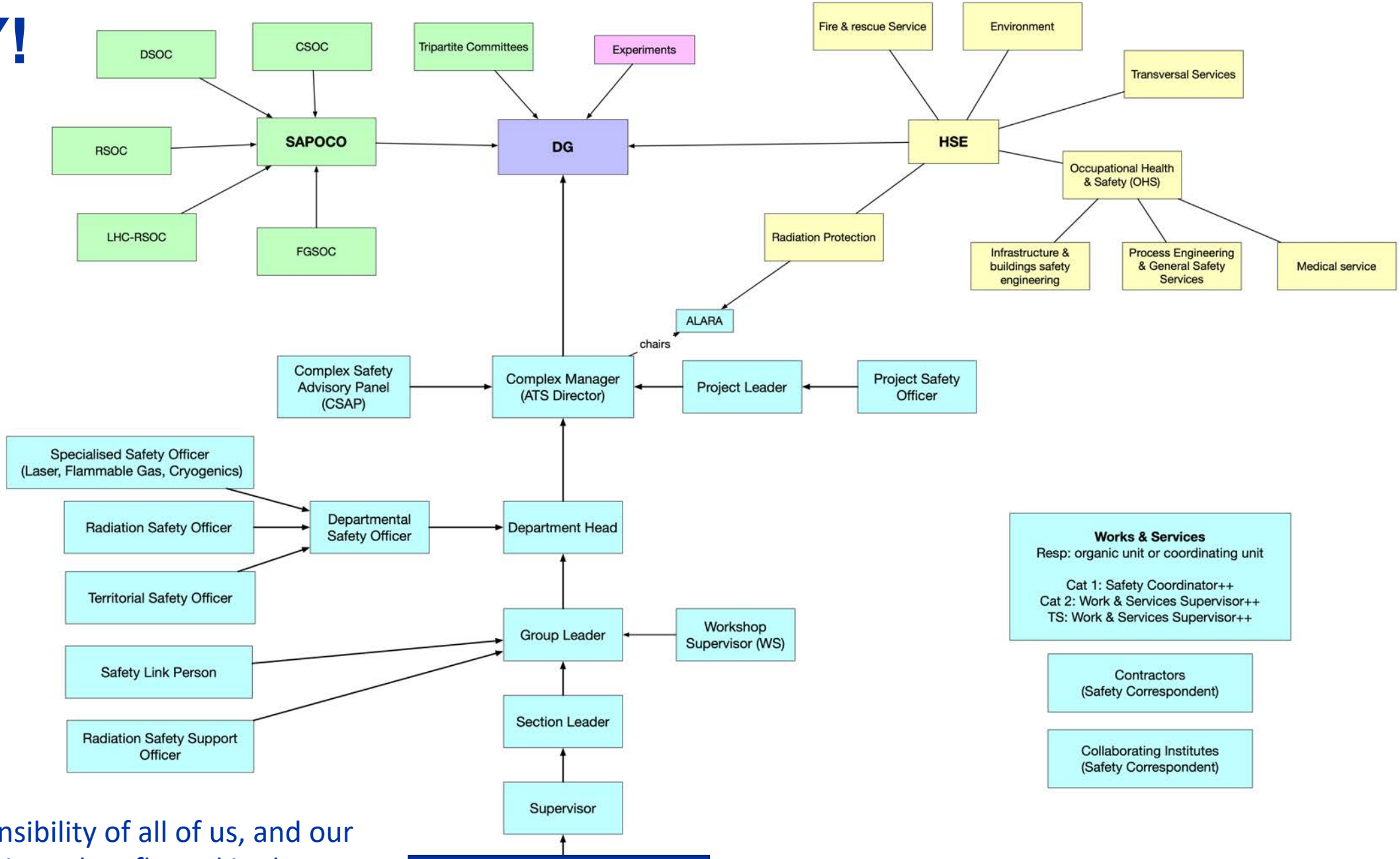
There is a huge amount going on – cannot touch on everything (unless you give me 4 hours)

More details at the departmental plenaries done or incoming

- **TE**: Miguel 155 slides (+99 spares)
- **BE**: Rhodri 106 slides
- **EN**: Katy 99 slides (18th January)
- **SY**: Brennan - a lot as well - 16th January

Names…

SAFETY!



Safety is the responsibility of all of us, and our safety culture is ultimately reflected in the way safety is addressed in our workplaces.

Mandates at:
https://hse.cern/content/general-safety-instructions-gsi

Huge thanks

- **Safety Officers**
  - DSO (4), DDSO (4), Radiation SO (4), Radiation Safety Support (43), TSO (163), DTSO (118), Flammable Gas (1) Cryogenic (2), Experiment(1), DEXSO (1), Laser Safety Support (12), Project (2)
- **Roles**
  - Safety Link Person (40), DSLP (5), DH, GL, SL, Supervisors, Individuals!
- **Committees and Panels**
  - SAPACO, PSO, DSOC, CSOC, RSOC, LHC-RSOC, FGSO, ALARA,
  - PS-CSAP, SPS-CSAP, LHC-CSAP, ATS Safety
- **Work Site**
  - WS (31), DWSS (9), EROS (9)

Individual responsibility

Each person participating in the activities of the Organization or present on its site shall actively contribute to the implementation of the CERN Safety Policy through exemplary conduct and, in particular, compliance with the CERN Safety Rules

2023 - recall

Medium Term Plan - things have settling down following the turmoil of 2022

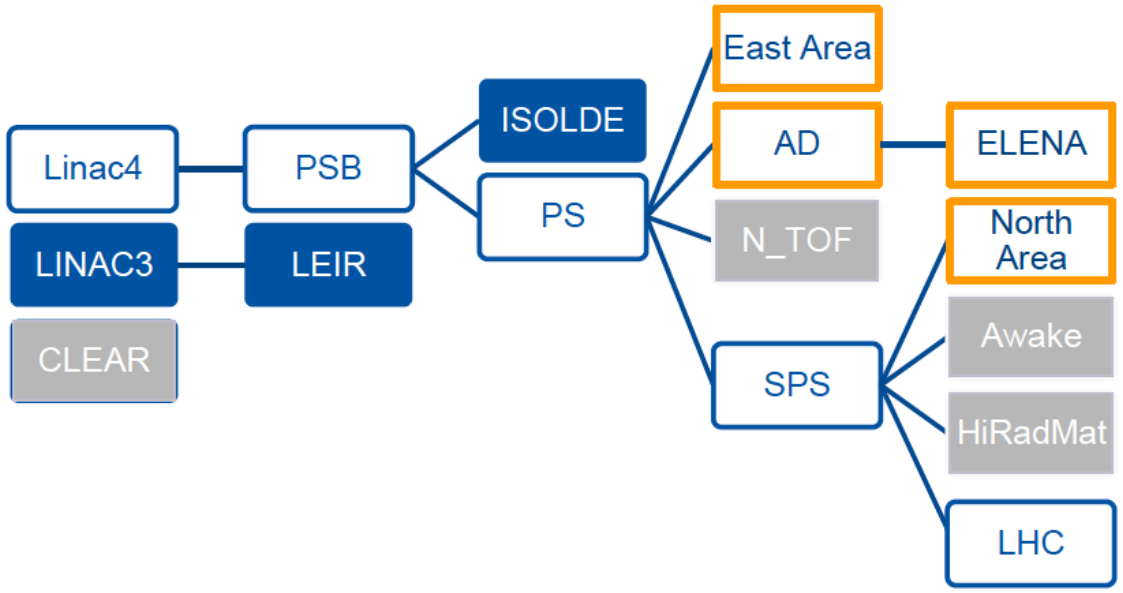
CERN's scientific programme is supported: LHC programme and its upgrade; facilities and experiments at the injectors; accelerator, detector and computing R&D, and design studies for future colliders.

Additional resources allocated to high-priority ATS items: North Area consolidation phase 2, new Superconducting RF building, ISOLDE consolidation, ECN3 upgrade…

These expenses were offset by the personnel contribution, MS additional contribution, reduction in electricity costs, and savings from the overall budget

Cumulative Budget Deficit (CBD) now looking better… heading in the right direction to support an ambitious future for the lab.

Well reflected in the calm end of year close-out at Council – inflation, budget, CBD etc.



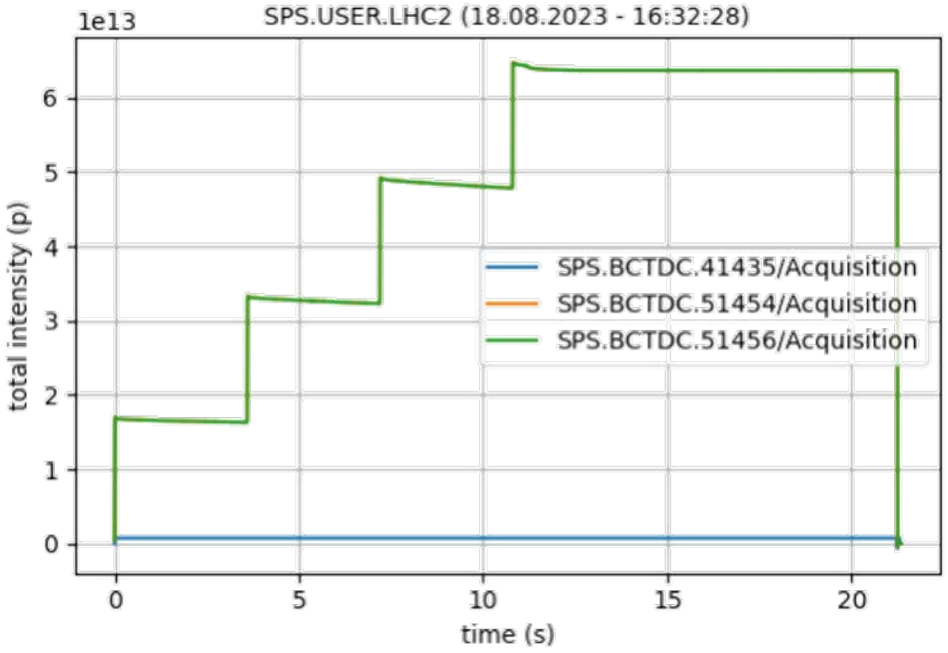
Complex 2023

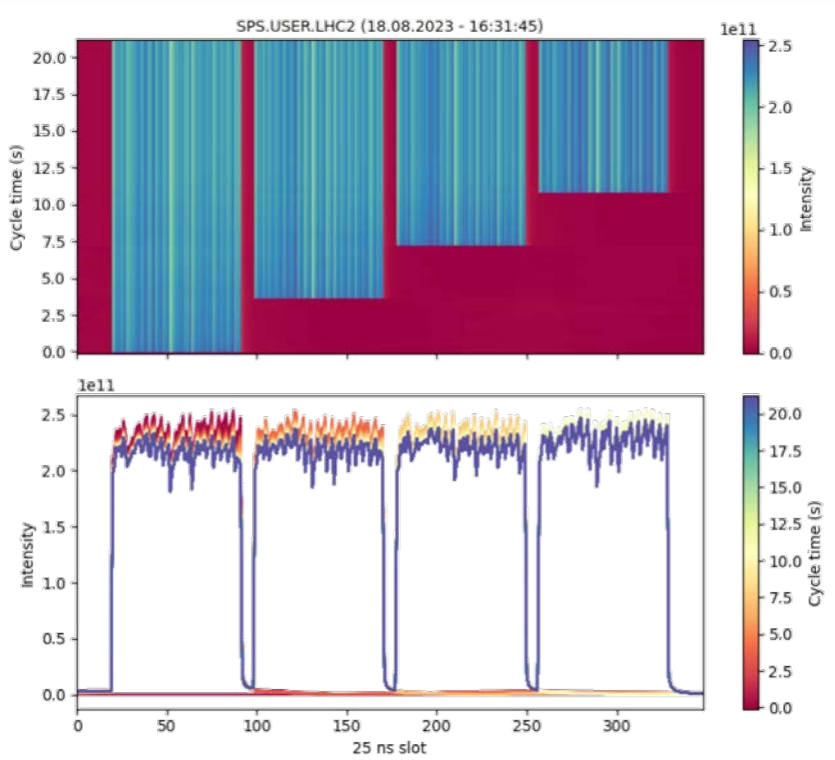
Good year!

Injectors - achieved SPS LIU intensity target

Intensity reach demonstrated on 13.06.23, 18.08.23:
4x72 with 2.2e11 p/b at flat top

- Excellent transmission (~95% without scraping)





ISOLDE

- Operations in 2023
  - In total 59 experiments, 470 shifts, including 3 weeks of „winter" physics
  - HIE-ISOLDE: 10 exp., 122 shifts
  - Most runs fully successful

The INTC congratulated all the technical teams involved for their extraordinary efforts to maintain the scientific activity at ISOLDE almost not affected by the technical troubles.

"We had yet another very successful year, full of the usual issues and problems but with great physics results and lots of happy users!
Erwin Siesling

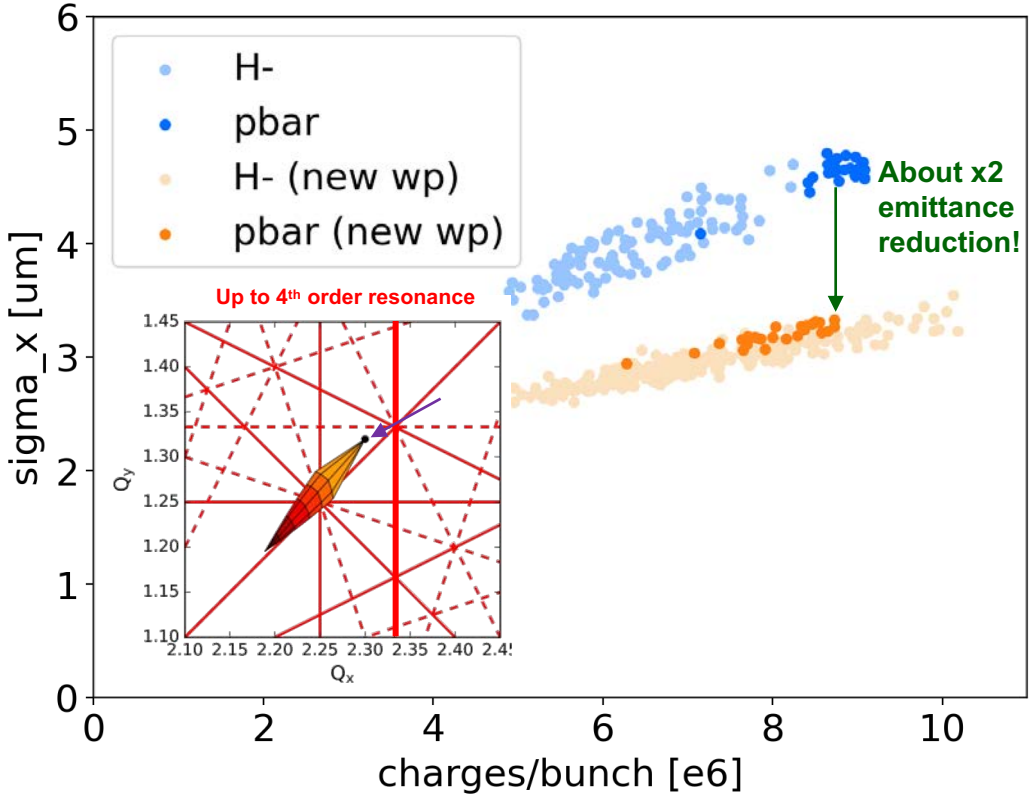
nTOF

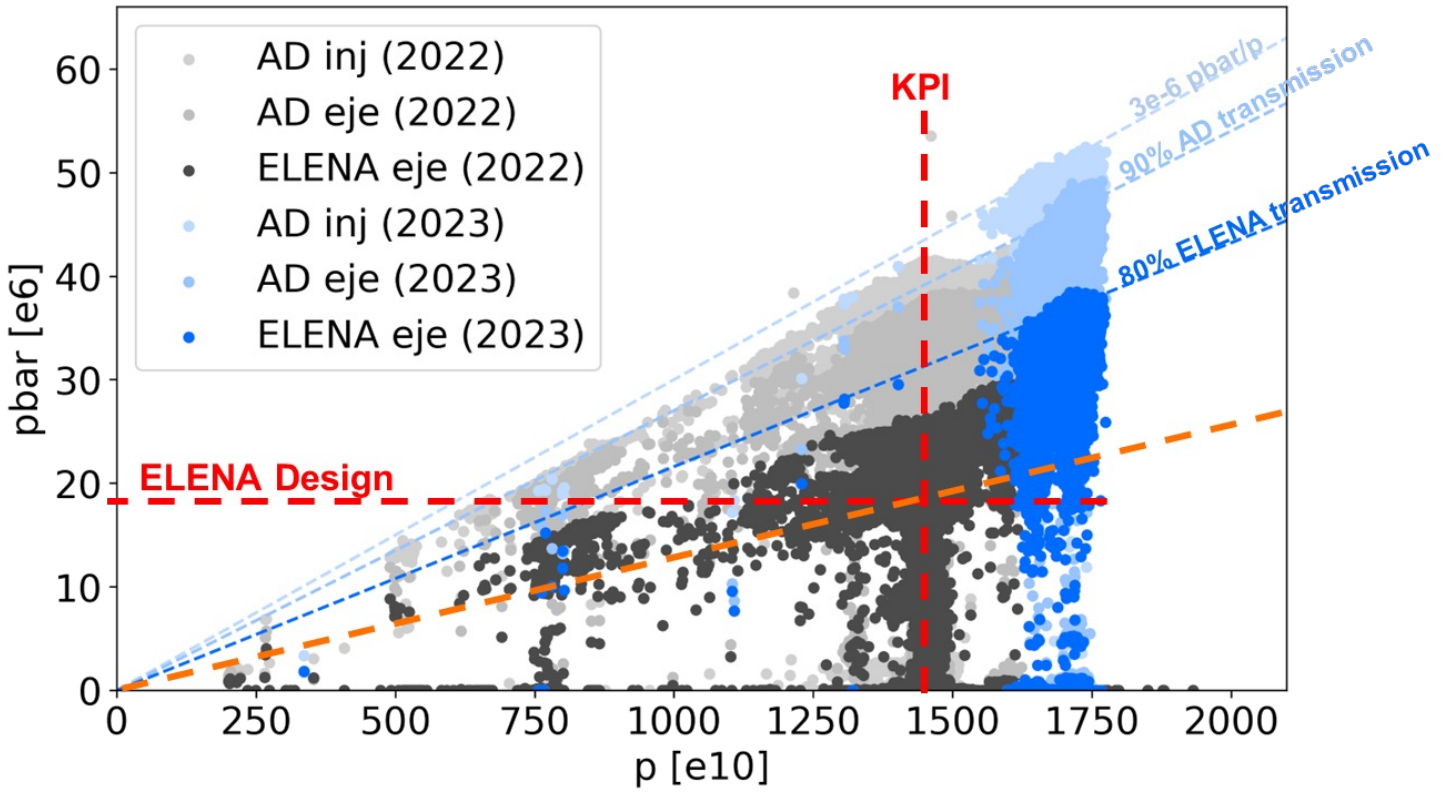
- Operations in 2023
  - → Smooth&productive campaign
  - → First transmission measurement
  - → 9 detector developments successful
  - → Proton intensity limit 30% up
  - → Protons delivery above expectations

The news from n_TOF was positive, too. The 2023 campaign was very smooth and productive. It was confirmed that the present spallation target can accept the average proton-beam intensity increased by about 30% Finally, 14% more than expected protons were delivered in total.

CERN Antiproton Factory Complex (ELENA)

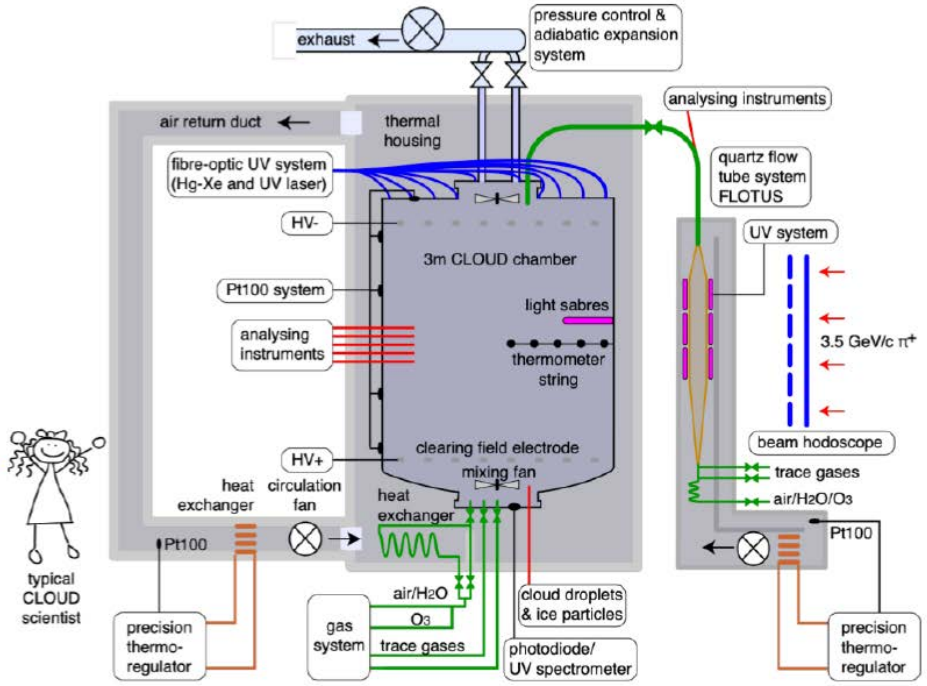
- **New working point avoiding 3rd order resonance resulting in reduction of beam size**
- **Record bunch intensities extracted from ELENA**
  - 1×10^7 antiprotons per bunch extracted towards the experiments



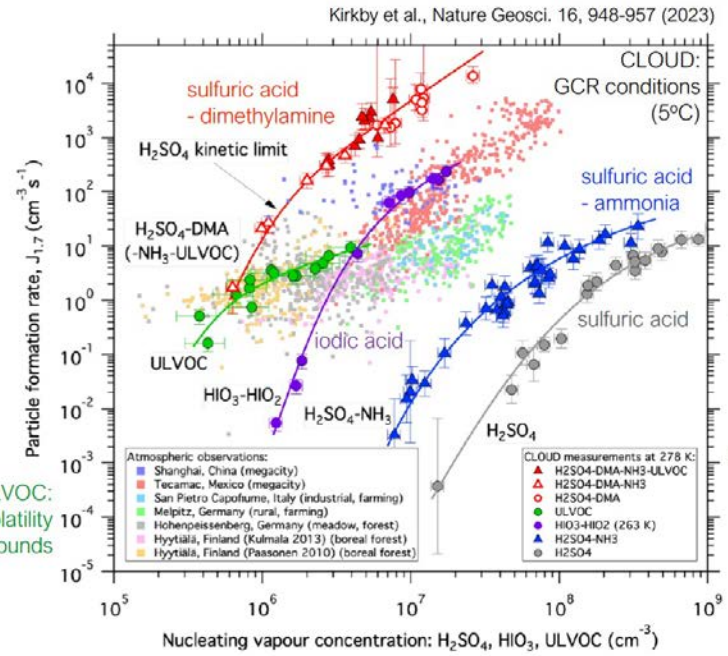


CLOUD – East Area

- Key features:
  - Low contaminants
  - Atmospheric concentrations
  - Precise and steady control of all conditions over long periods:
    - vapours
    - T, UV
    - ionisation (n, gcr, π)
  - Comprehensive analysis instruments
  - FLOTUS (FLOw TUbe System)



New particle formation from CLOUD



ULVOC: Ultra-low-volatility organic compounds

- CLOUD measurements so far indicate that GCR ions account for 27% of global CCN for low clouds
- However GCR variations over solar cycle change CCN by only 0.2%, which is not climatically significant

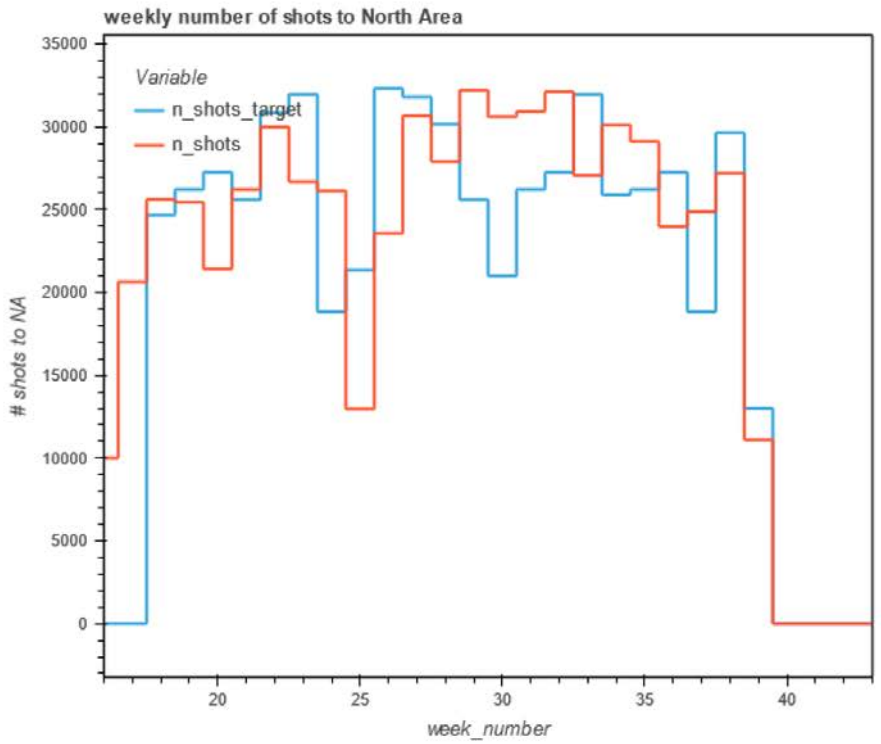
CLOUD aims to help with interpretation of new particle formation in different atmospheric environments, and to provide a mechanistic foundation for air quality and climate models.

The SPSC **congratulates** CLOUD on a series of successful upgrades and measurements, and **acknowledges** the steady stream of publications and continued impact of the experiment.

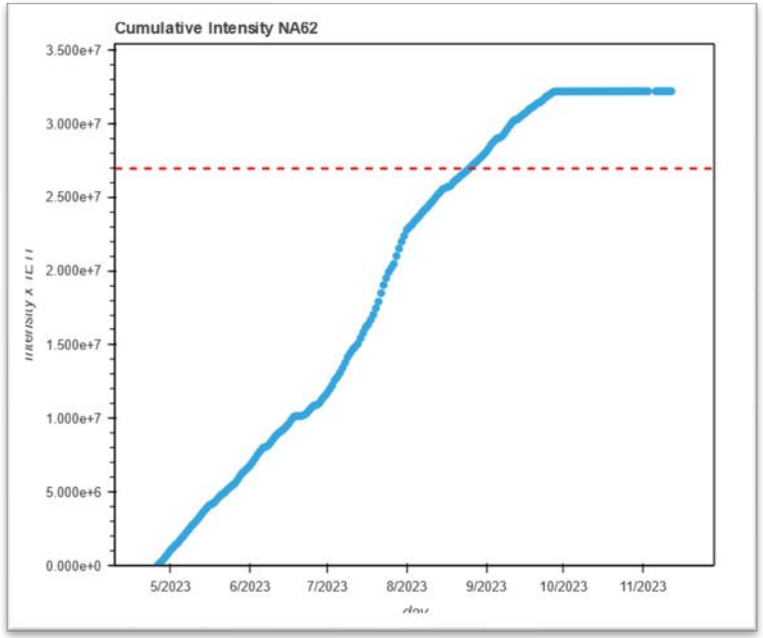
SPS North Area 2023 Proton Spills Delivered

- Projected number of shots (in blue) depend on the program of the SPS
  - AWAKE, HiRadMat, MDs, special beam preparation for LHC, LHC physics,
- → big spread already in the planned number of spills per week
- Very good performance in 2023
  - some weeks below expectation
  - Others above, e.g. LHC not running in the middle of the year

https://bpt.web.cern.ch/sps/sftpro/2023/



NA62



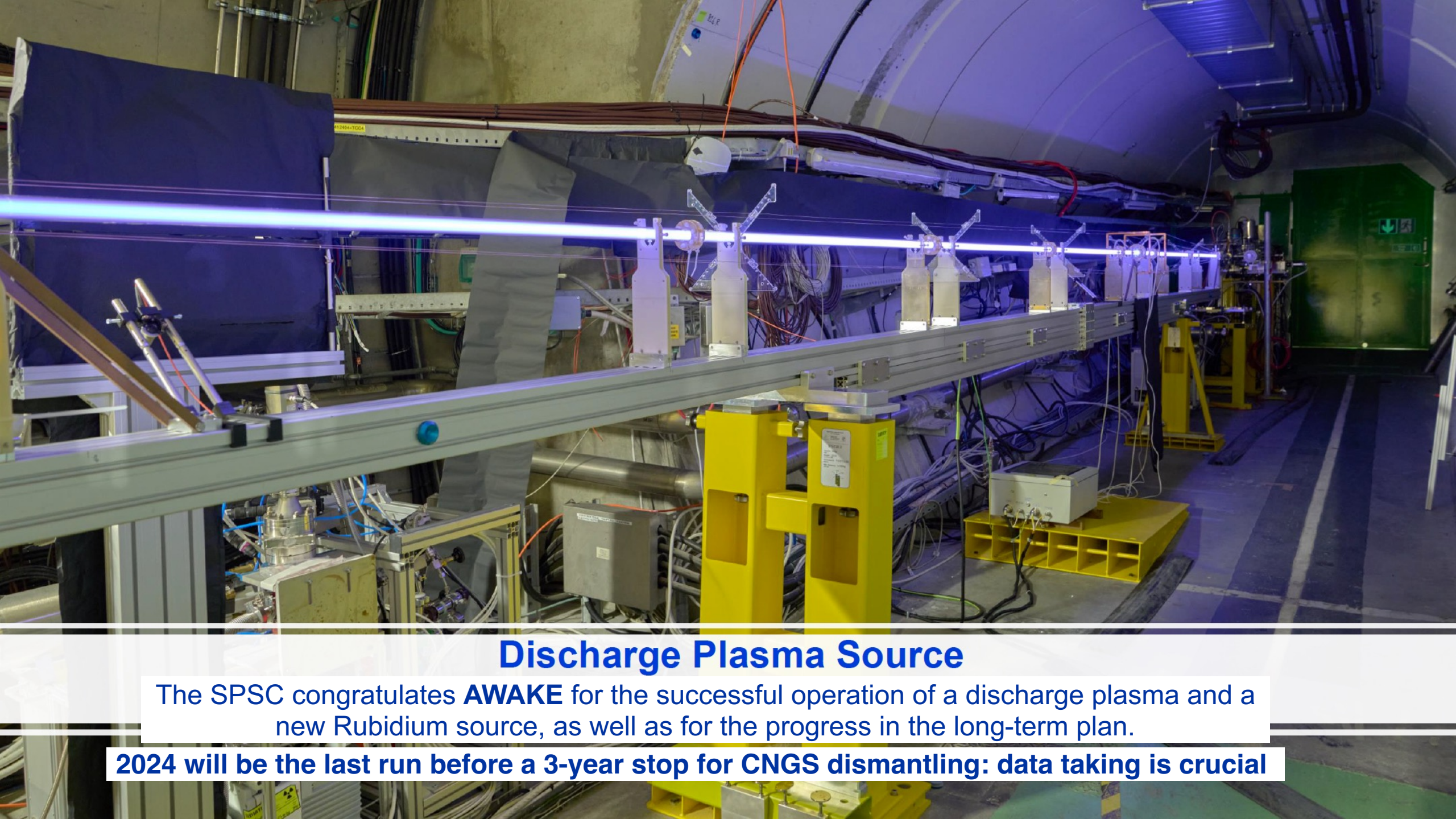
The SPSC **congratulates NA61** for a successful data taking in 2022/23, with increased rate capability, and **takes note of** the very-forward particle production results.

NA64

Excellent beam quality in 2023!

Beam halo ~ 3% (5% in 2022)

Hadronic contamination ~ 0.3%



Discharge Plasma Source

The SPSC congratulates **AWAKE** for the successful operation of a discharge plasma and a new Rubidium source, as well as for the progress in the long-term plan.

2024 will be the last run before a 3-year stop for CNGS dismantling: data taking is crucial


Lots of praise from the users for the beam quality and availability and the phantastic responsiveness and support from all the teams!

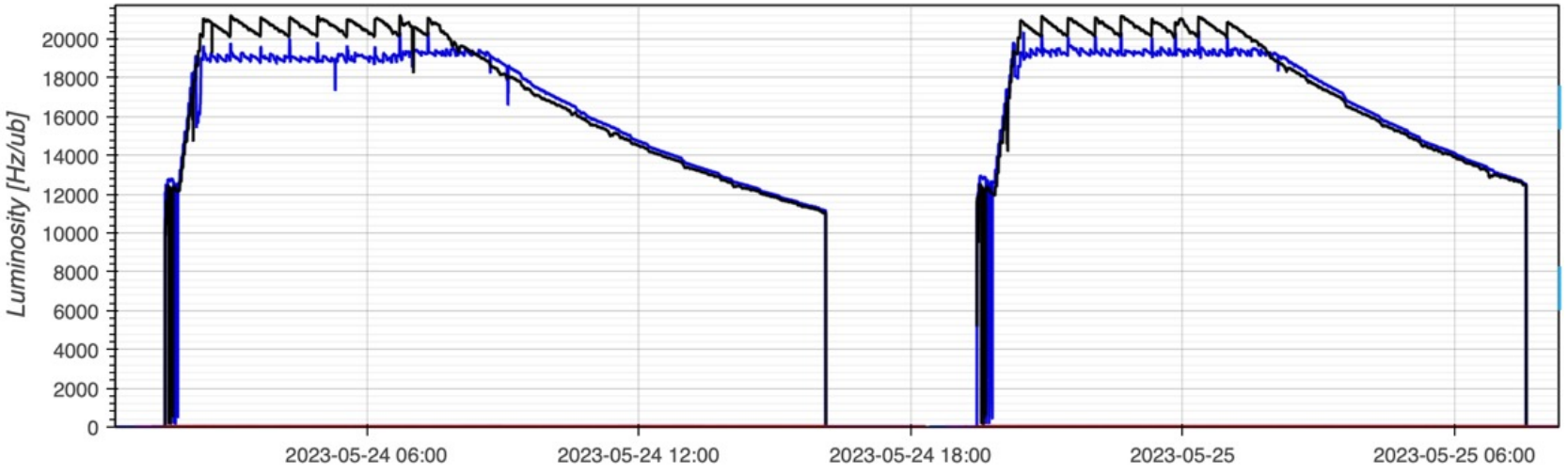
LHC 2023

Record breaking performance
Eventful year – stuff happens.
Expertise, adaptability, commitment & collaboration goes a long way

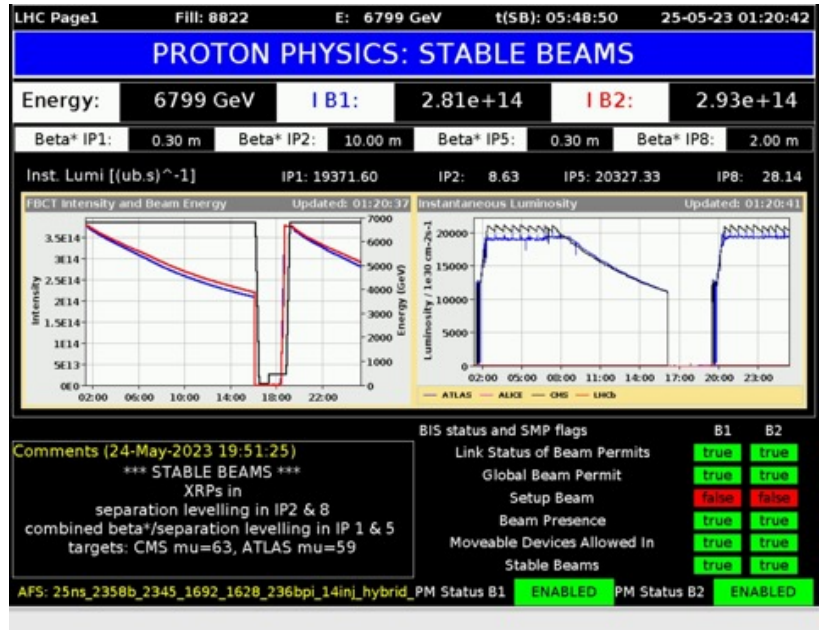
LHC Physics Performance

- **New record: Integrated luminosity of 1.2 fb^{-1} in 24h!**
- **Peak levelling just above 2.0 x 10^{34} $cm^{-2}s^{-1}$**
- **Pileup targets ATLAS/CMS = 59 / 63**
  - Thanks to combined separation β* levelling and separation levelling we can deliver different pile up to ATLAS and CMS

Max energy per beam at start of stable beams: **409 MJ**
1.59 x 10^{11} p/b (Injected: 1.61)



24th to 25th of May 2023

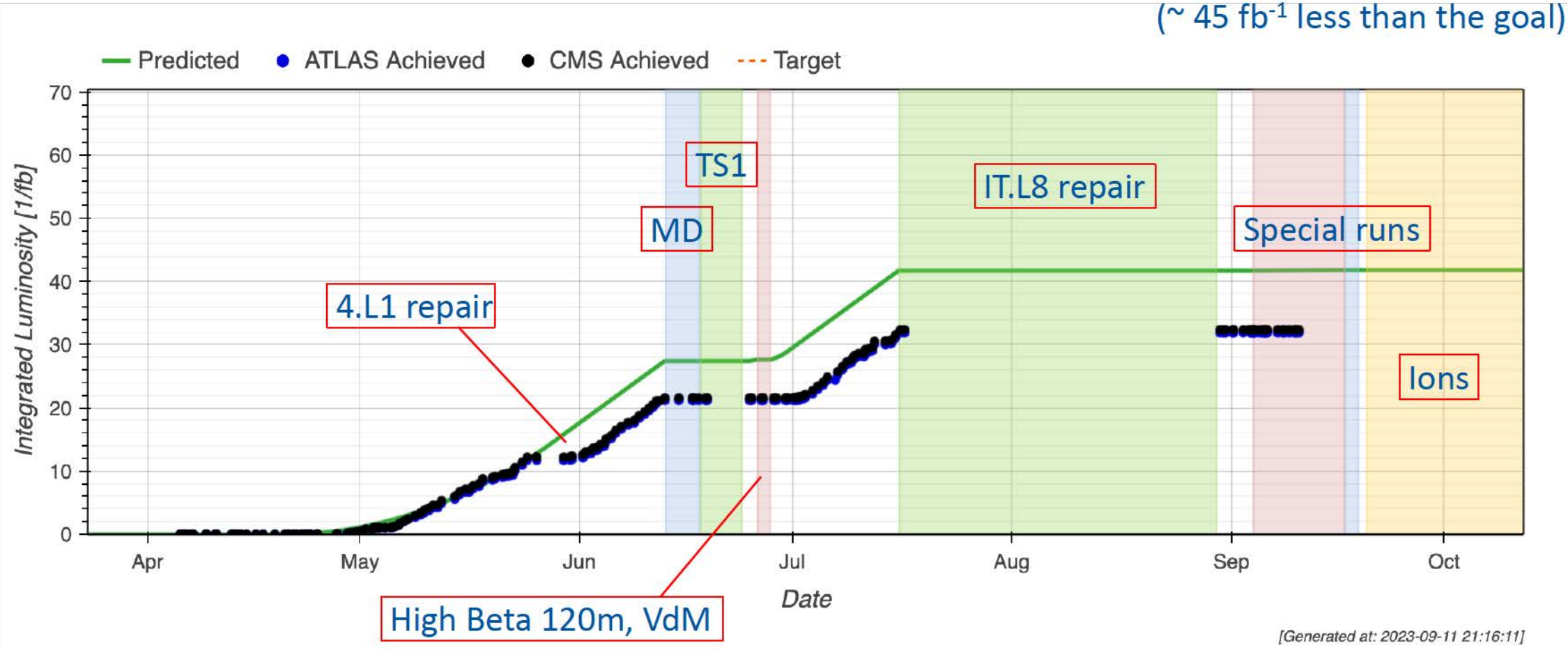


LHC - proton luminosity 2023

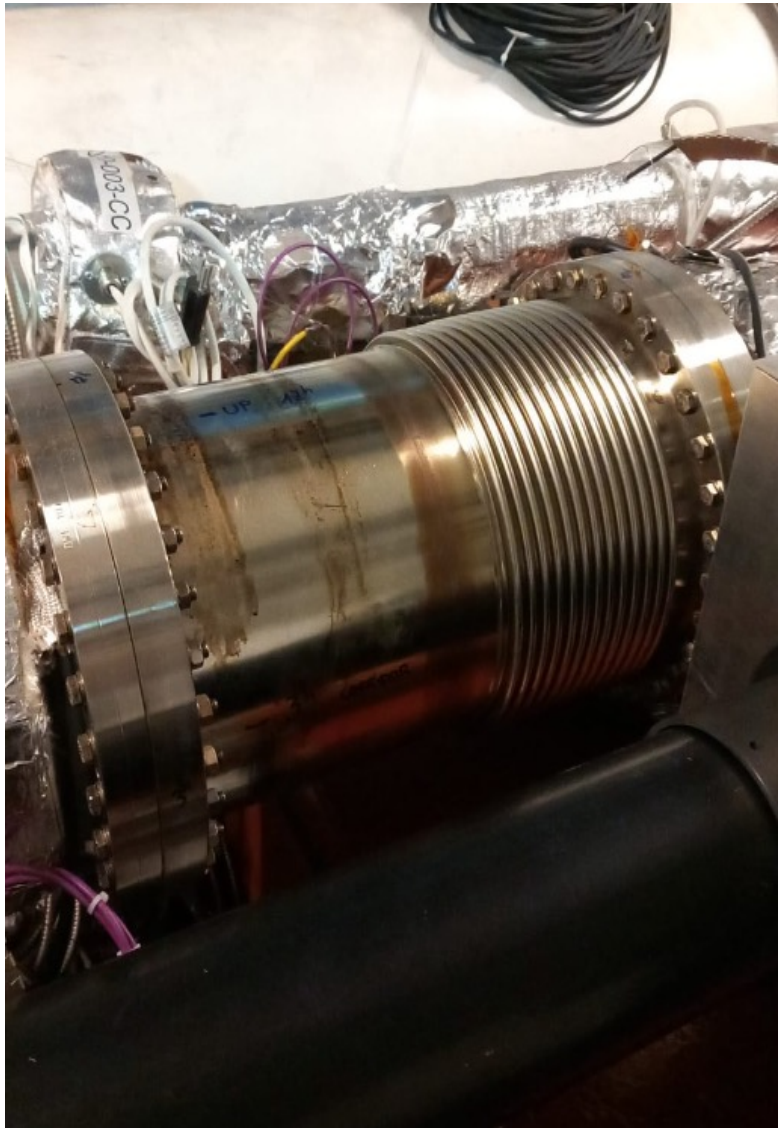
Original goal for 2023: 75 fb^{-1}

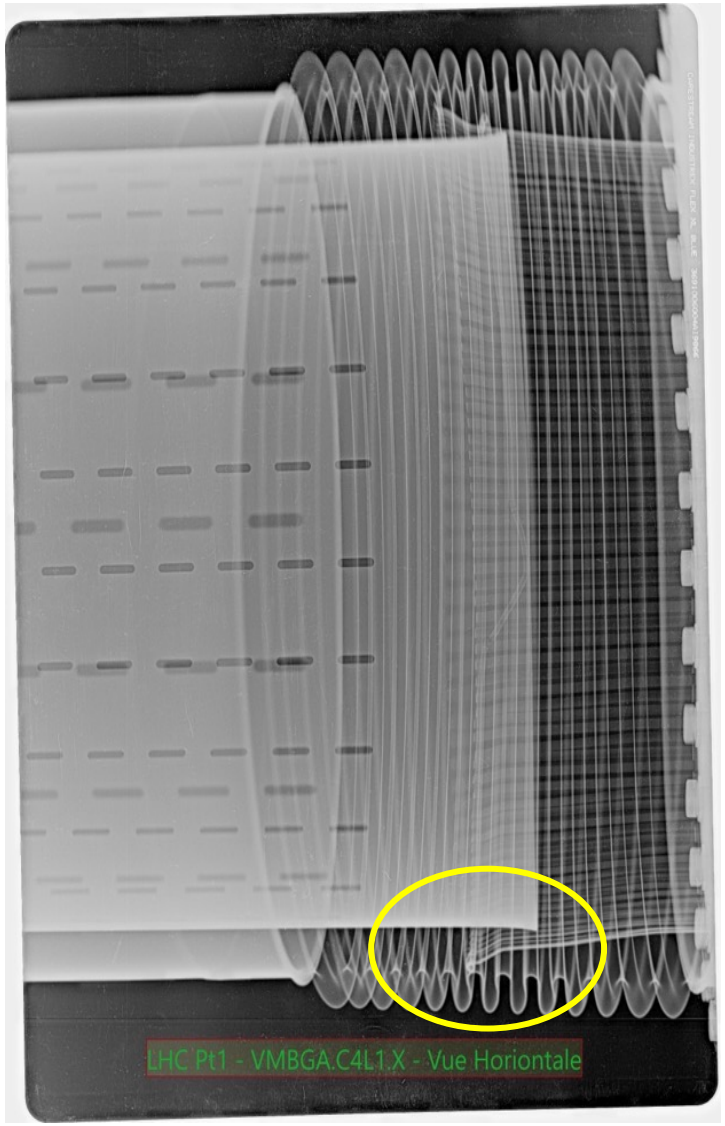
After the IT.L8 repair: no more high intensity proton operation in 2023 → total proton dataset for 2023 is 32 fb^{-1}

(~ 45 fb^{-1} less than the goal)

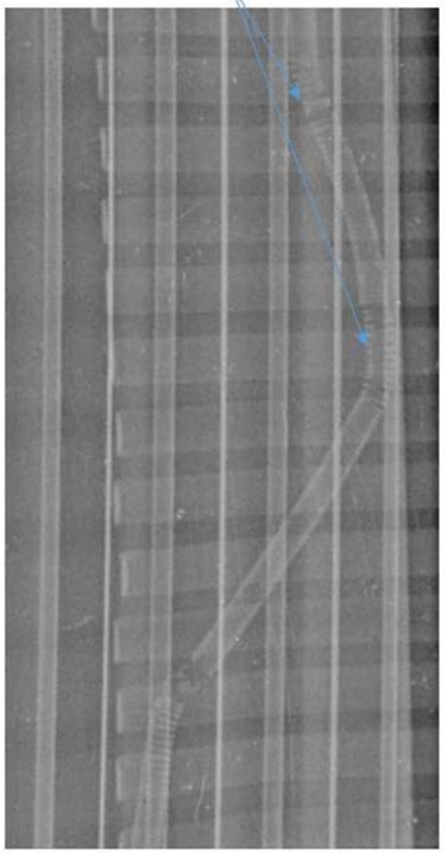


Vacuum Module R1 – May – 5 days lost





Spring disengaged with
RF fingers not touching



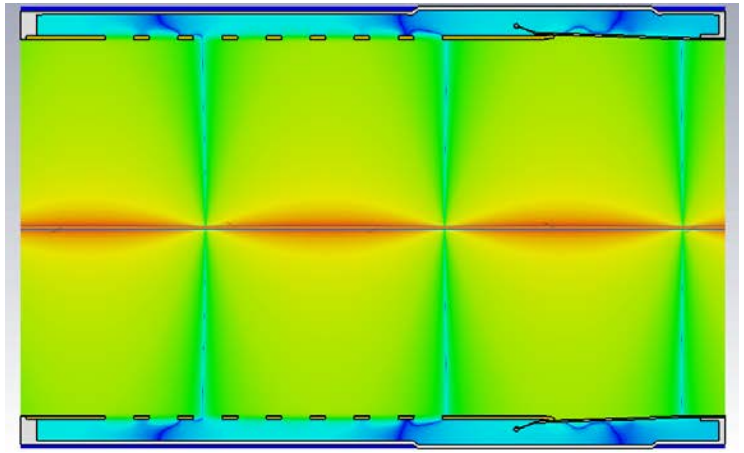
RF Finger faults: analysis of the problem

Taskforce BE-ABP & TE-VSC

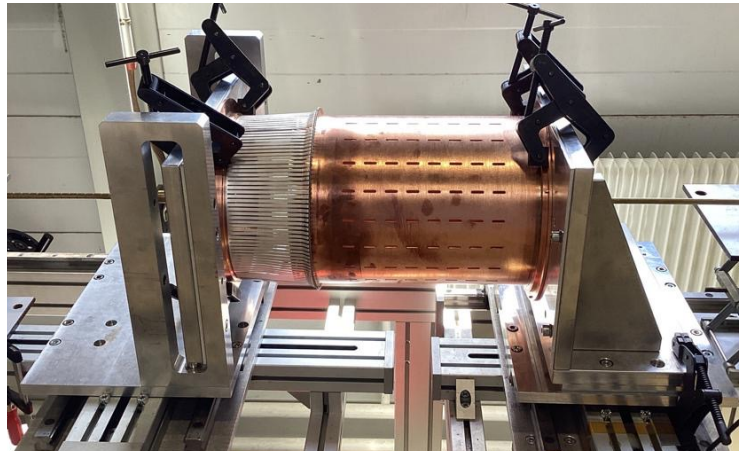
Anomalous heating of a stainless-steel spring

- Impedance matching between simulations and measurements
- Development and testing of consolidation strategies

Heated spring

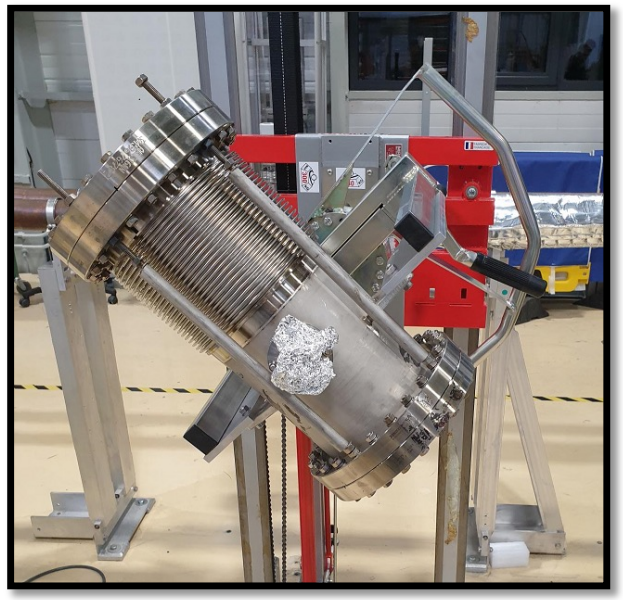


EM field leakage outside the RF fingers

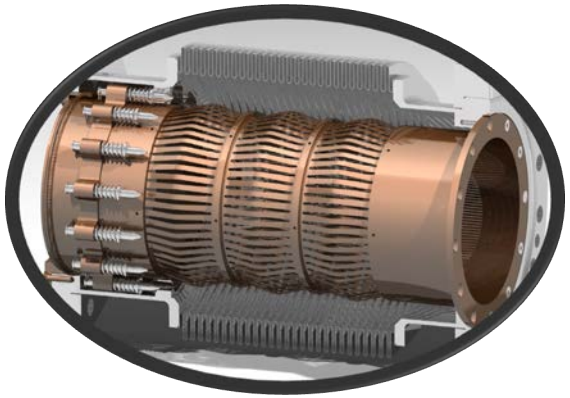


Impedance test bench

RF Finger fault: Mitigation Strategy

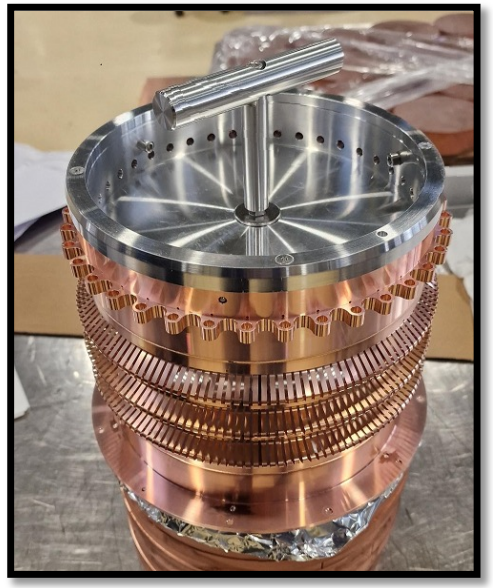


Lifting tooling

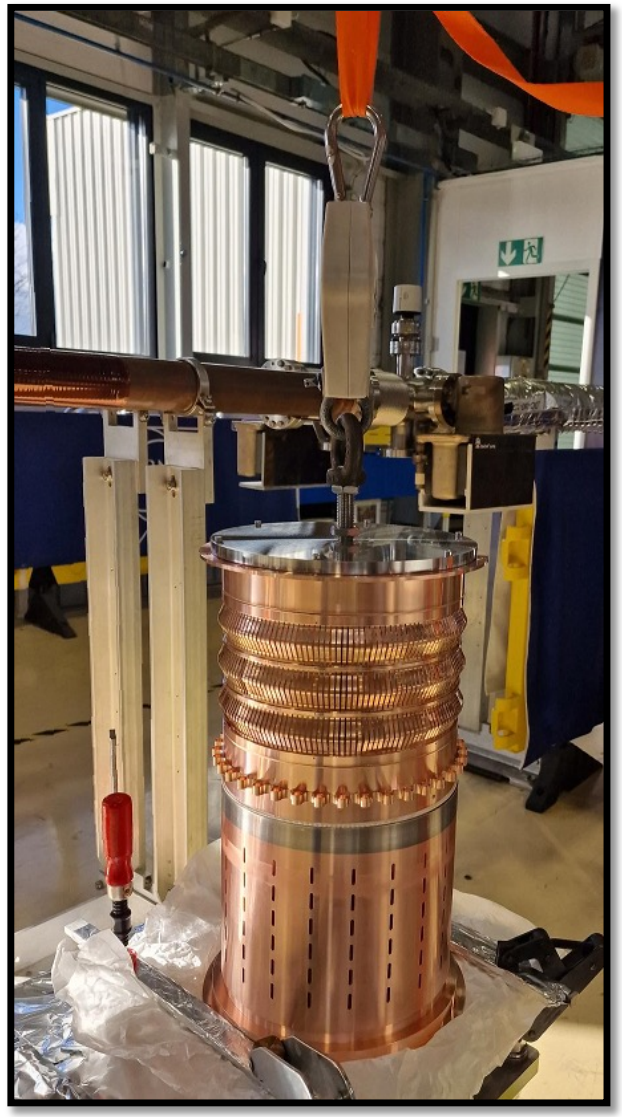


28 modules will be ready for installation
January 2024

Bellows compression tooling



Extension tooling

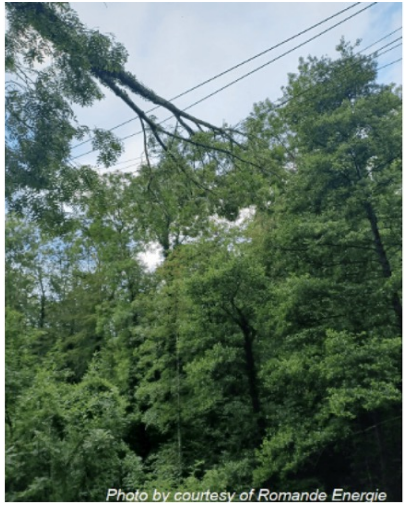


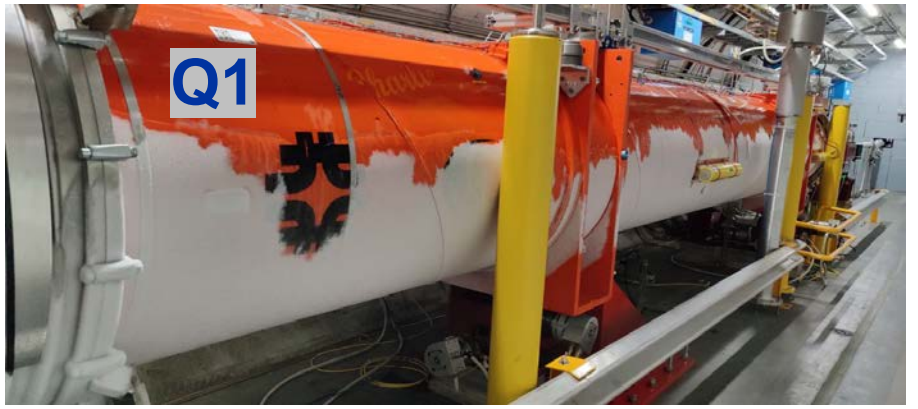
Load and friction test

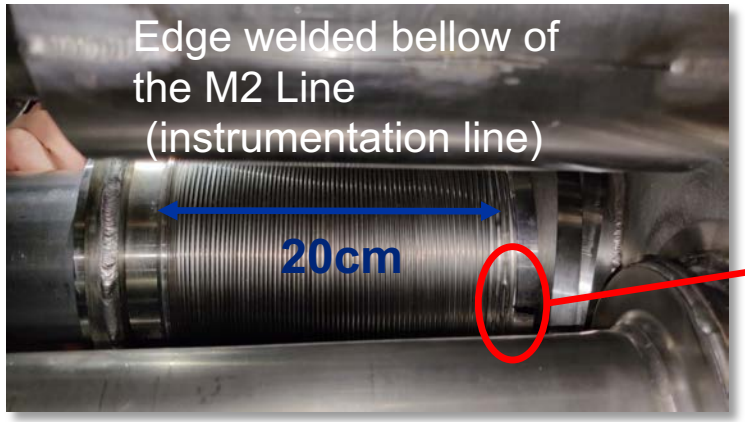
LHC Point 8 Incident – 17 July

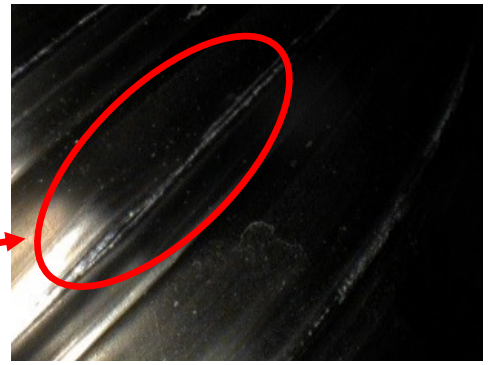
- An **electrical glitch,** caused by the fall of a tree on power lines, triggered the **protection circuit of IT.L8;** 30s after the quench, a **significant leak** appeared in the **magnet vacuum vessels.**
- The **root cause** of the leak was attributed to the **failure of an edge-welded bellow** mounted on the M2 (instrumentation) line between Q1 and Q2.
- The bellow was replaced on **26-27 July** and the interconnection was closed on **Friday 28 July** (a mere **10 days** after the incident; in total, loss of beam physics was limited to 50 days).

Impressive collaborative effort!

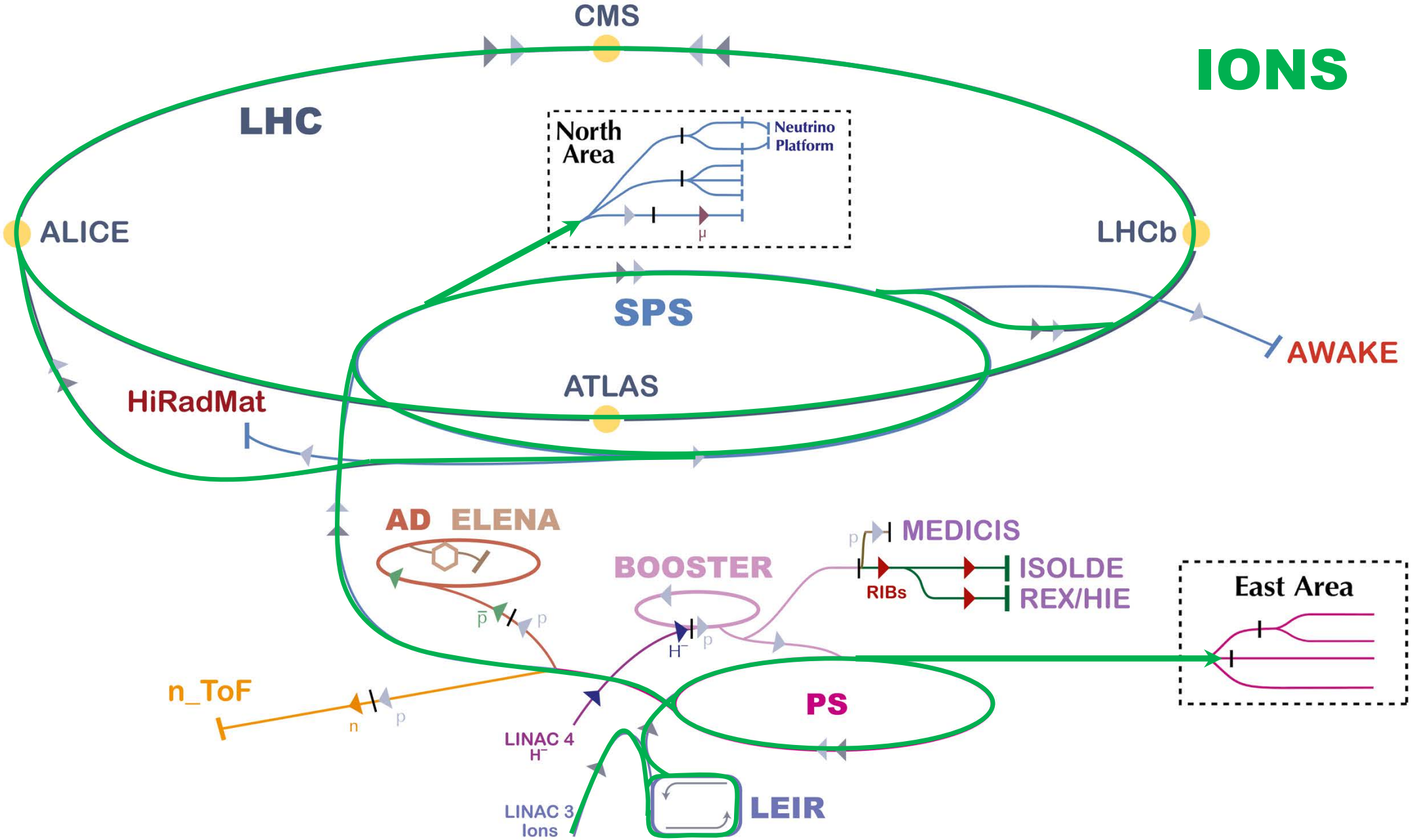








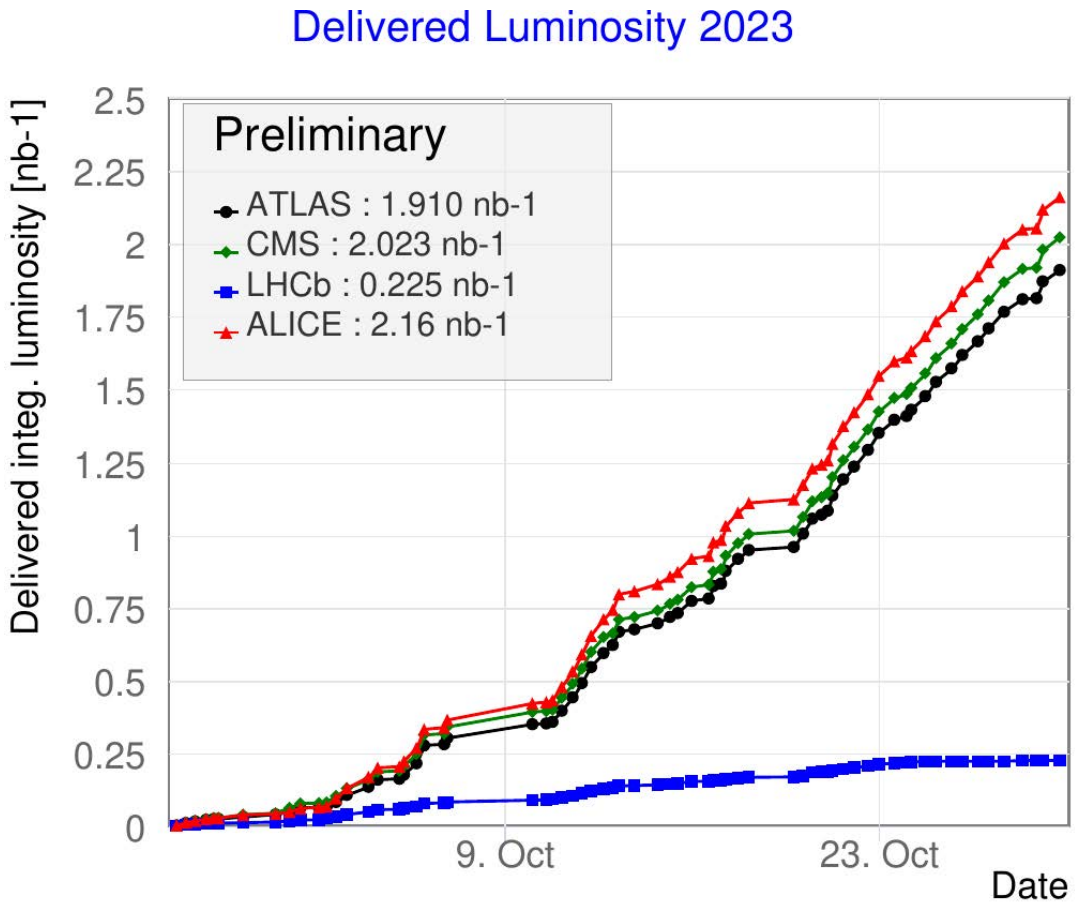
IONS



H⁻ (hydrogen anion) | p (protons) | ions | RIBs (Radioactive Ion Beams) | n (neutrons) | p̄ (antiprotons) | e⁻ (electrons)

CMS Experiment at the LHC, CERN
Data recorded: 2023-Sep-26 17:59:51.672000 GMT
Run / Event / LS: 374288 / 9272477 / 82

LHC ions – despite some challenges



2023 ion run: a lot of new concepts (slip stacking, crystal collimation, new IP2 collimators, …). These new concepts worked very well, but we encountered some other issues such as SEUs in QPS electronics

Lot learnt - should be well placed for the remaining ion runs in Run 3

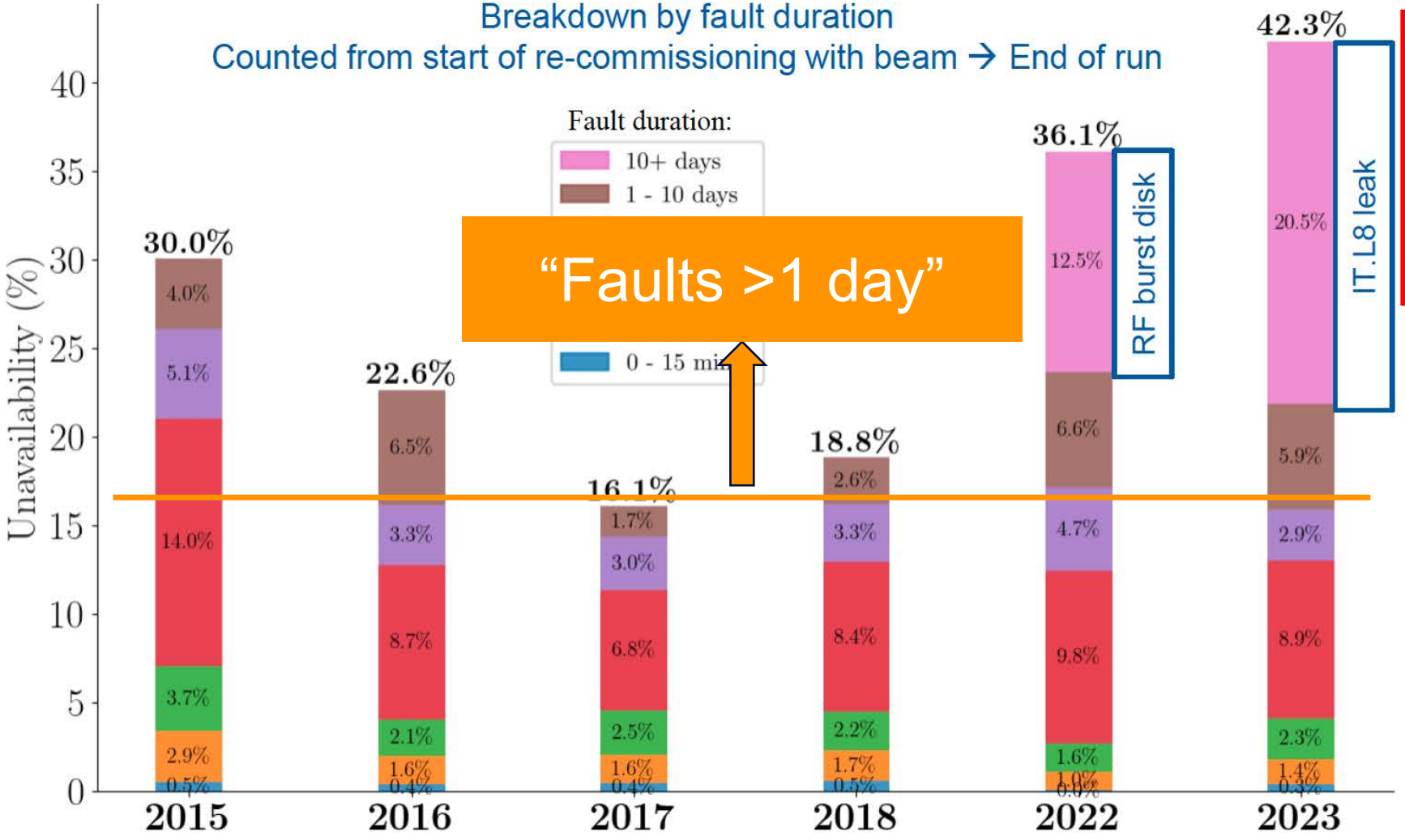
2023 Overall Availability - Injectors

Facility	Destination	'21/'22 Overall [%]	Achieved 2023		Period
			Overall [%]	Per destination [%]	
LINAC4	PSB	97.3/96.8	**97.9**	**97.9**	03.03.2023 – 12.11.2023
PSB	PS	94.5/94.8	**96.1**	**96.4**	10.03.2023 – 12.11.2023
	ISOLDE			**96.6**	17.03.2023 – 30.10.2023
PS	SPS	88.1/89.6	**91.7**	**92.7**	17.03.2023 – 30.10.2023
	East Area			**93.5**	27.03.2023 – 01.11.2023
	n_TOF			**92.8**	03.04.2023 – 30.10.2023
	AD			**93.9**	12.06.2023* – 12.10.2023
SPS	LHC	73.4/74.1	**86.6**	**94.8**	27.03.2023 – 30.10.2023
	North Area			**87.3**	24.04.2023 – 30.10.2023
	AWAKE			**98.4**	01.05.2023 – 22.10.2023
	HiRadMat			**99.0**	22.05.2023 – 27.08.2023

**Revised AD start date following quadrupole water leak*

In the injectors, overall, very good availability.
Productive physics programmes for all users.

LHC - Distribution of Fault Durations over Years



LHC downtime in 2022 and 2023 is dominated by long faults

- Faults > 10 days start to appear during run in 2022
- Faults < 1 day fairly stable

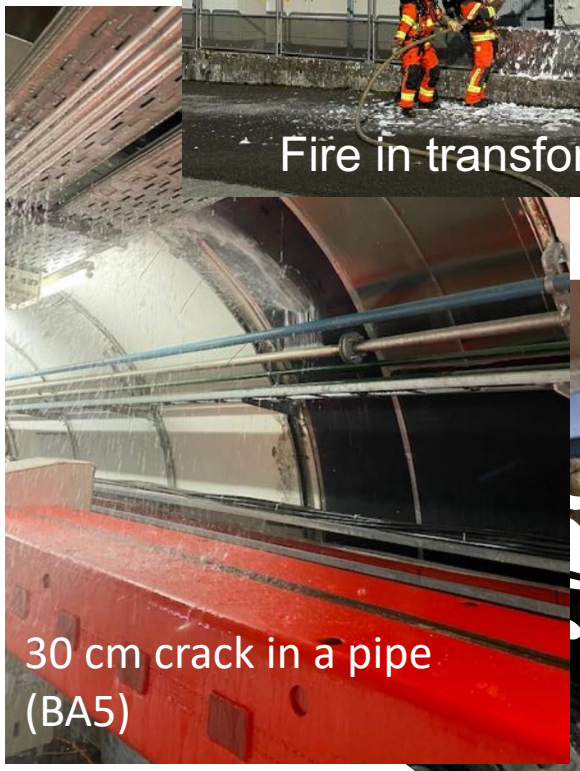
→ Split analysis in faults shorter and longer than 1 day

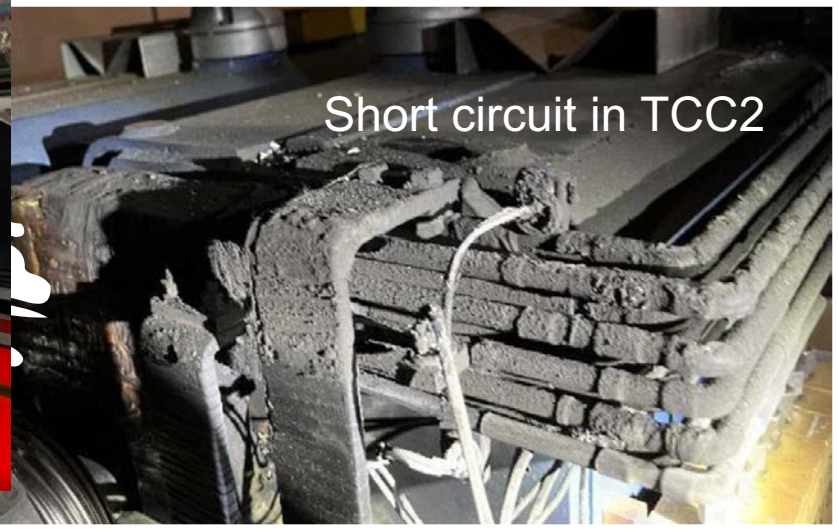
Faults > 1 day are rare:
→ qualitative analysis

Faults < 1 day are frequent:
→ statistical analysis

Technical Infrastructure – stuff happens


Fire in transformer in BA2


30 cm crack in a pipe (BA5)

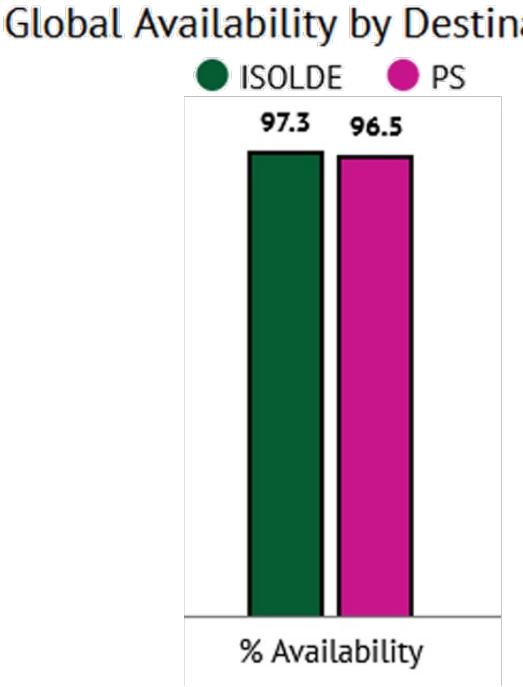

Short circuit in TCC2

Electrical glitches:

- 22 glitches recorded so far in 2023
- 15 glitches recorded in 2022
- Some were impressive….

PS Booster

- **Good availability at > 96%**
- **In 50 years of the PSB there have been no water leaks on the main quadrupole magnets**
  - Since LS2 leaks have appeared with several magnets exchanged during the YETS
  - One new small leak has appeared since and is being closely monitored



~50 YEARS OF RELIABLE OPERATION,
ZERO LEAKS UNTIL 2021 AND SIX SINCE!

Task Force established – mitigation plan established

Commonalty of phenomena

What was observed?

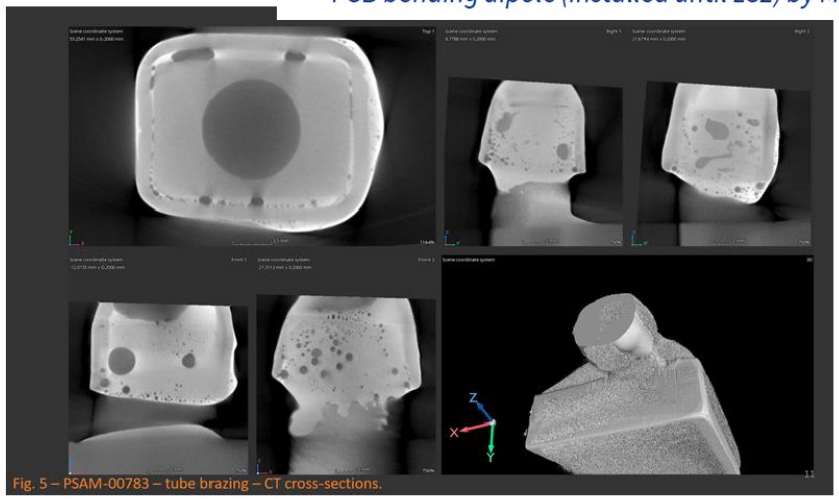
Poor brazing interfaces presenting numerous discontinuities

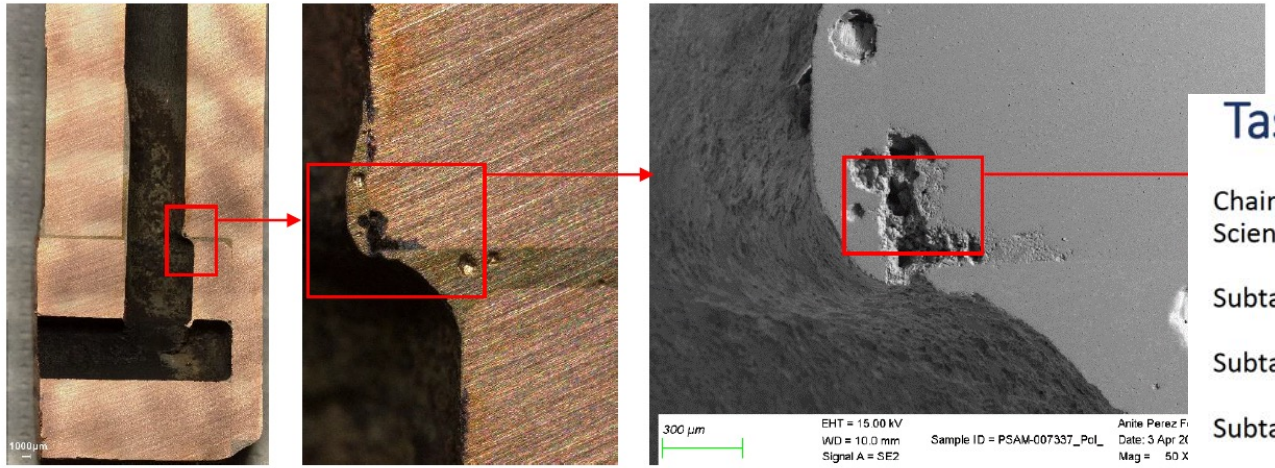
Corrosion selectively attacks Cu at the interface with the Sil-Fos braze (Cu-Ag-P) and the Cu phase within the braze metal

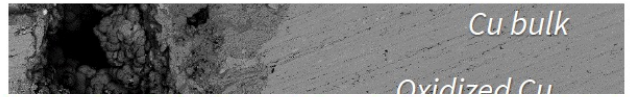
As corrosion progresses, the Cu grain structure is revealed and, in some sites, a large gap is formed

"S" detected in the conduct surface (up to 5.5 wt. %)

PSB bending dipole (installed until LS2) by M. Celuch







Task Force Members *& expert support*

Chair: Ralf Trant (TE)
Scientific secretary: Luigi Scibile (TE)

Subtask 1: Anthony Newborough (TE-MSC)

Subtask 2: Stefano Sgobba (EN-MME), Ana Teresa Perez Fontenla (EN-MME)

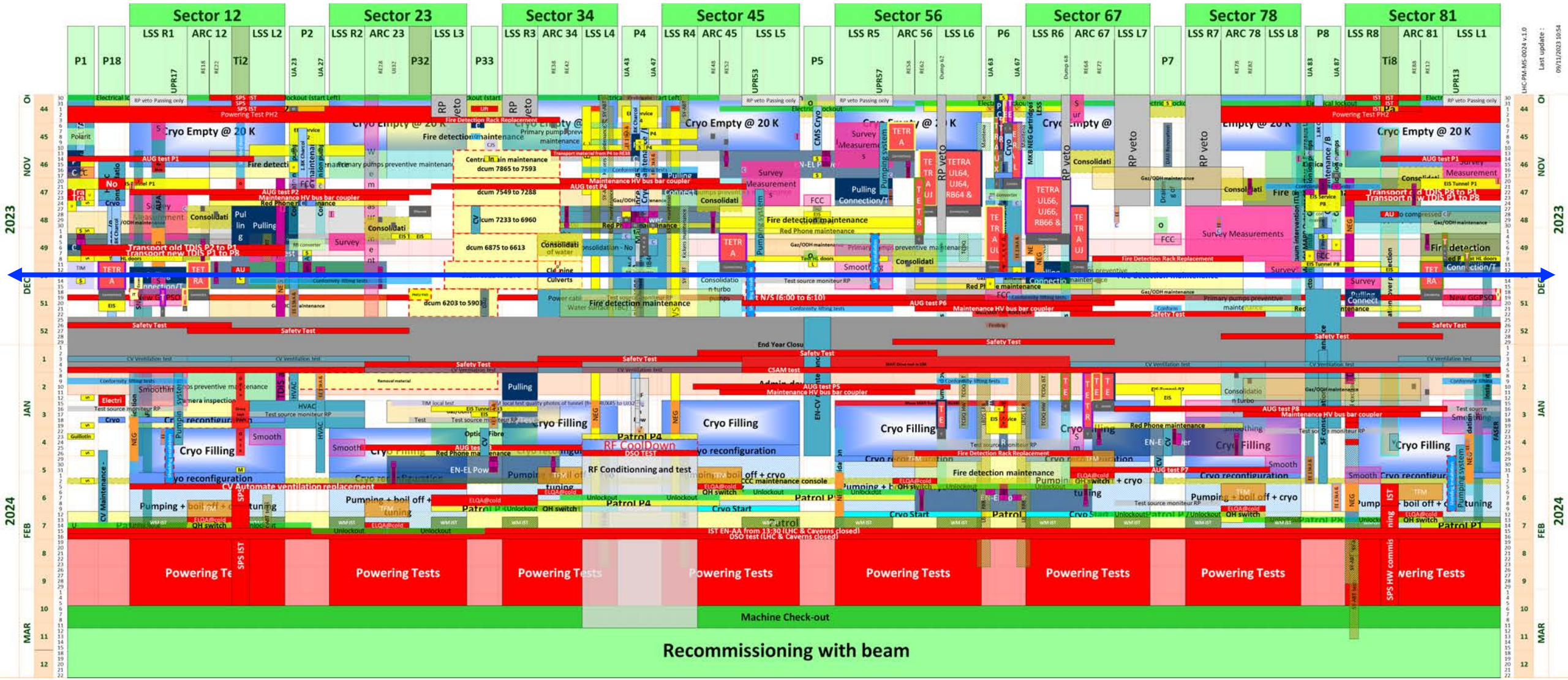
Subtask 3: Gilles Favre, Serge Mathot (EN-MME), Antony Newborough (TE-MSC)

Subtask 4: Gian Piero di Giovanni (BE-OP), *Foteini Asvesta (BE-ABP)*

Subtask 5: Mikko Karppinen (TE-MSC), Anthony Newborough (TE-MSC)

EN-CV: Serge Deleval, EN-ACE: Markus Albert, TE-VSC: J.A. Ferreira Somoza

EYETS 2023-24 Global Schedule LHC-PM-MS-0024



Plus similar for injectors and facilities

Cryo maintenance activities

Intensive year for the maintenance team

- **2’300 Work Order** on the maintenance contract so far

Shutdown Activities

- **LHC Machine YETS 22-23**
- ATLAS & CMS maintenance in January 2023
- HIE Isolde maintenance in January 2023
- SPS maintenance in February 2023
- NA maintenance in Feb/March 2023
- B165 maintenance March 2023
- SM18 maintenance March 2023
- P1 ANRS in June 2023
- WAT in June 2023
- LHC TS September *Cancelled*
- LHC anticipated task during summer
- **LHC Machine eYETS 23-24**

Outdoor storage summer cleaning and painting campaign

Revision of STAL pumps

Calibration with BEAMEX device

Water/Oil exchanger cleaning

Activated charcoal replacement

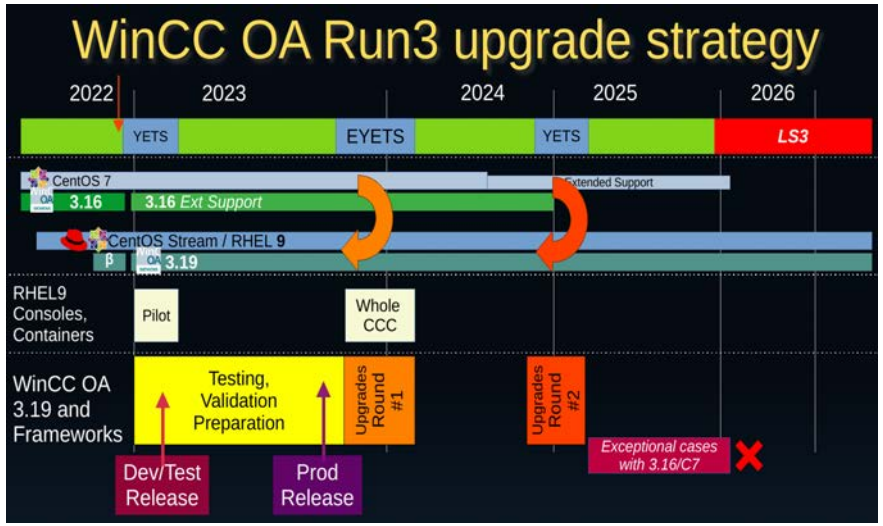
Updating our Industrial Control Systems

- **Major Industrial Controls upgrades Underway**
  - WinCC OA 3.19, RHEL9 and Windows 2022
- **SCADA Application Service (SAS)**
  - Operating system upgrade from CentOS7 to RedHat 9
  - Phase out of old installation & management software in CCR servers
  - LASER alarms migration to new infrastructure
  - New WinCC OA licensing scheme
  - New Windows Terminal Servers (Windows Server 2022)

CentOS → Red Hat

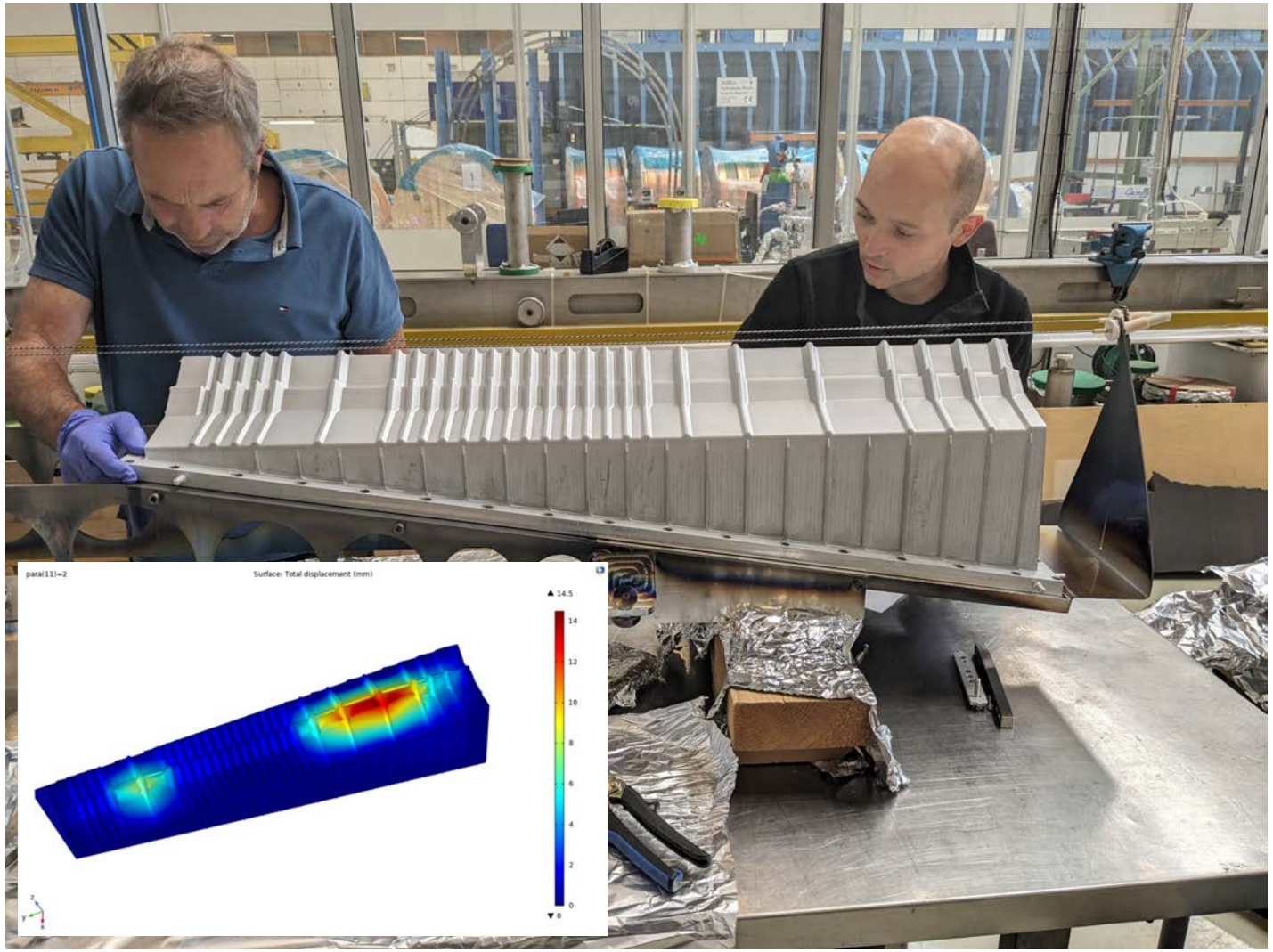
Windows Server 2016 → Windows Server 2022

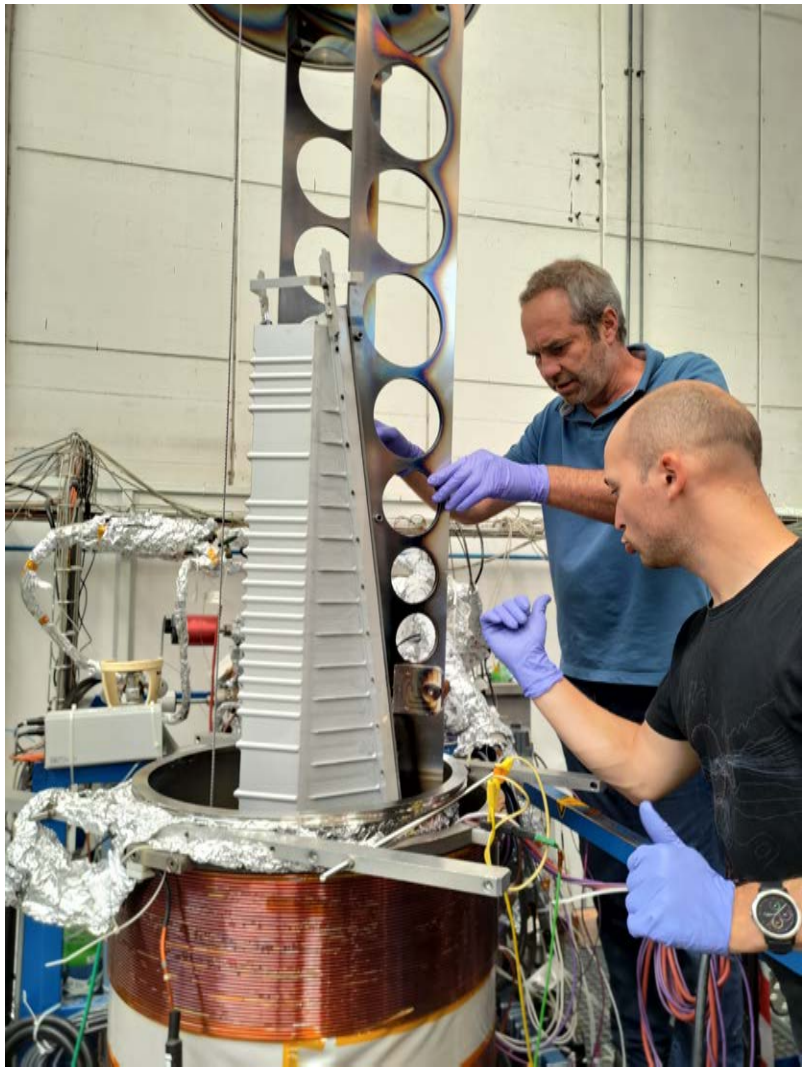
On time, reliable, low profile



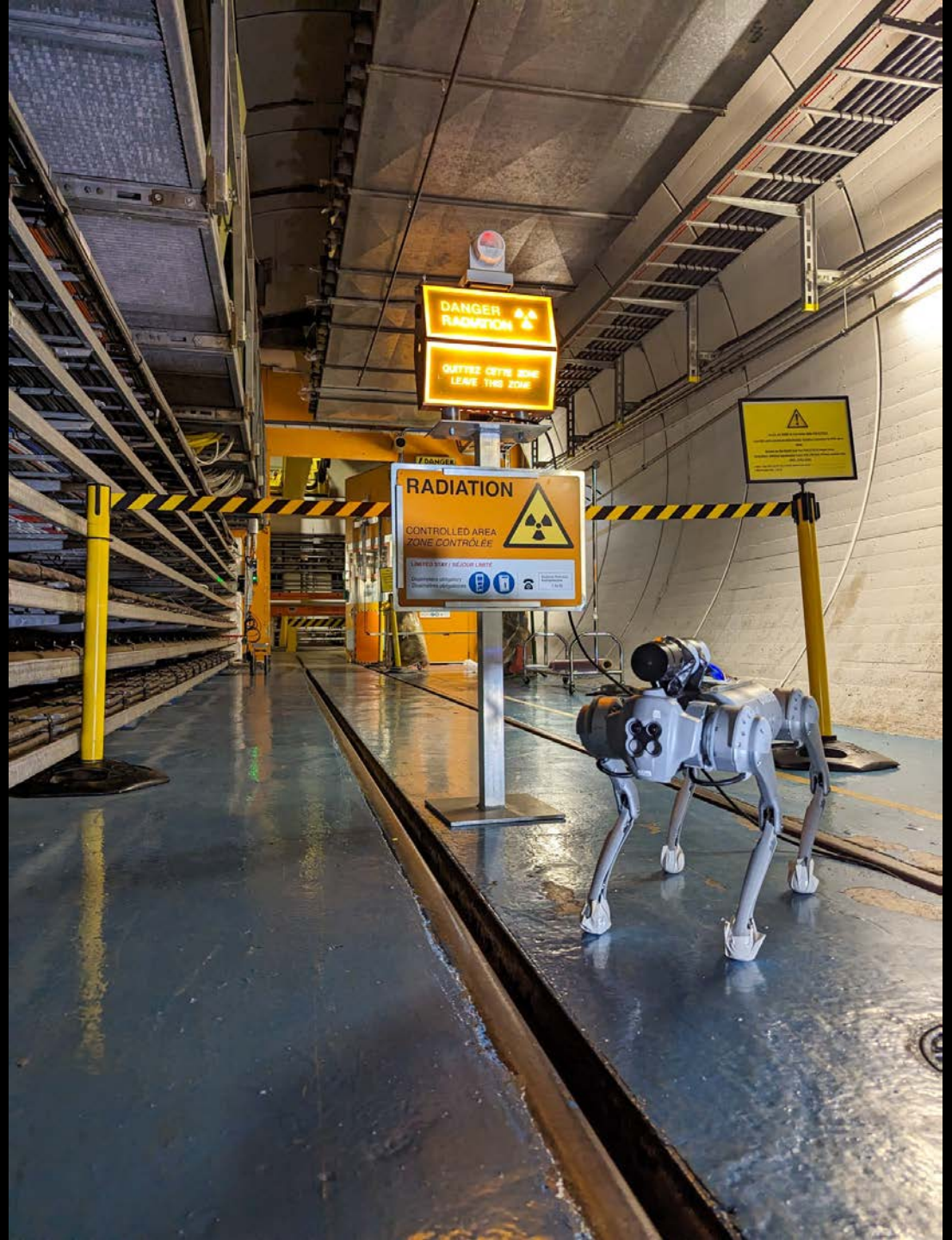
- **Industrial Controls Framework Upgrades**
  - Development and pre-upgrade validation
    - JCOP Framework 9.0.0 — 4 April 2023
    - UNICOS Framework 9.0.0 — 4 April 2023
  - Production-ready releases
    - JCOP Framework 9.1.0 — 31 October 2023
    - UNICOS Framework 9.1.0 — 2 November 2023

New VELO RF box: NEG coating





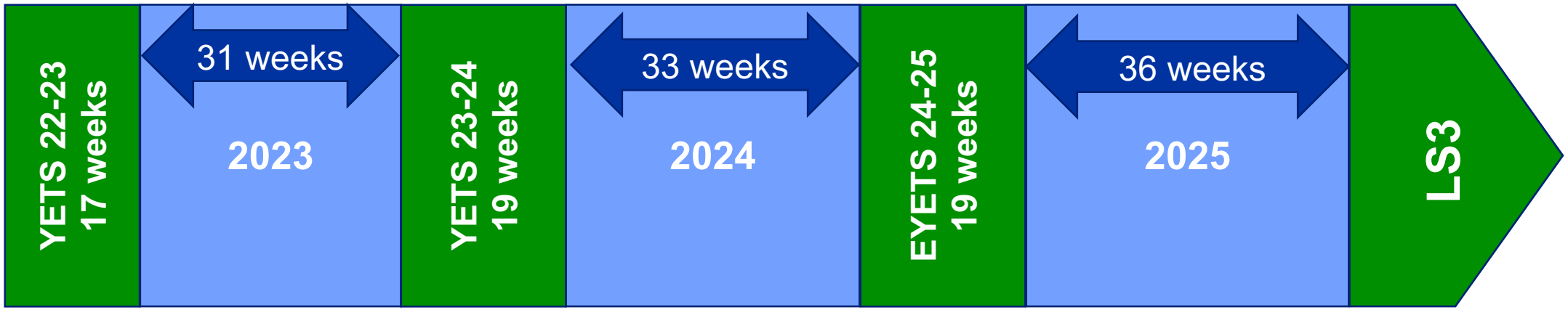
VELO RF foils exchange intervention



Robodog doing radiation measurements in BA80

Run 3 Schedule

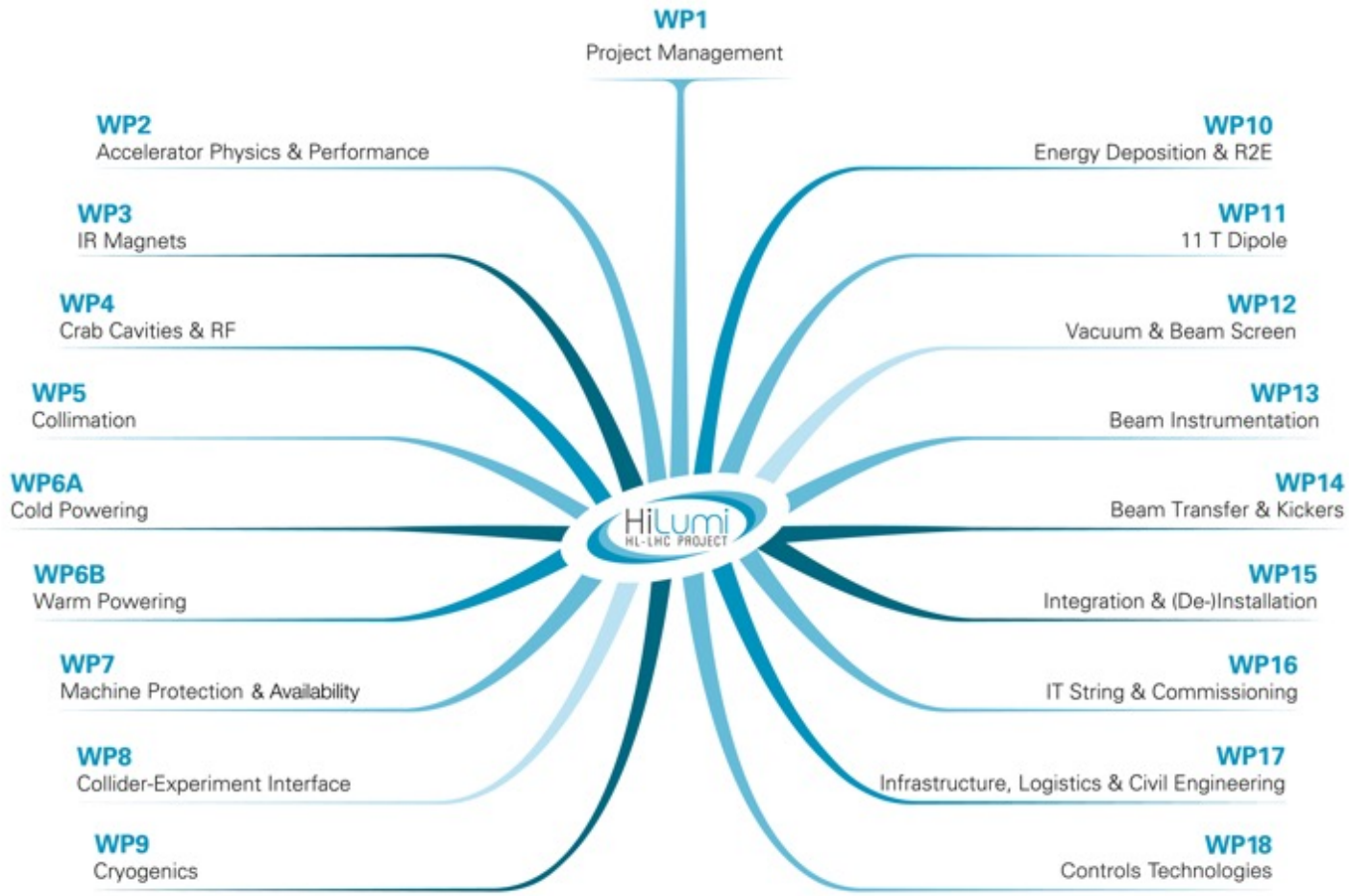
- **Reduced operation in 2023 but total for 2024/2025 remains unchanged**
- **Optimised the running time to adapt to energy costs to bring significant savings without impacting overall physics time beyond that introduced with 2022 & 2023 measures**



Baseline start of LS3 is 17 November 2025

HL-LHC

Lots going on
Good progress
Getting to the sharp end



HL-LHC technology landmarks

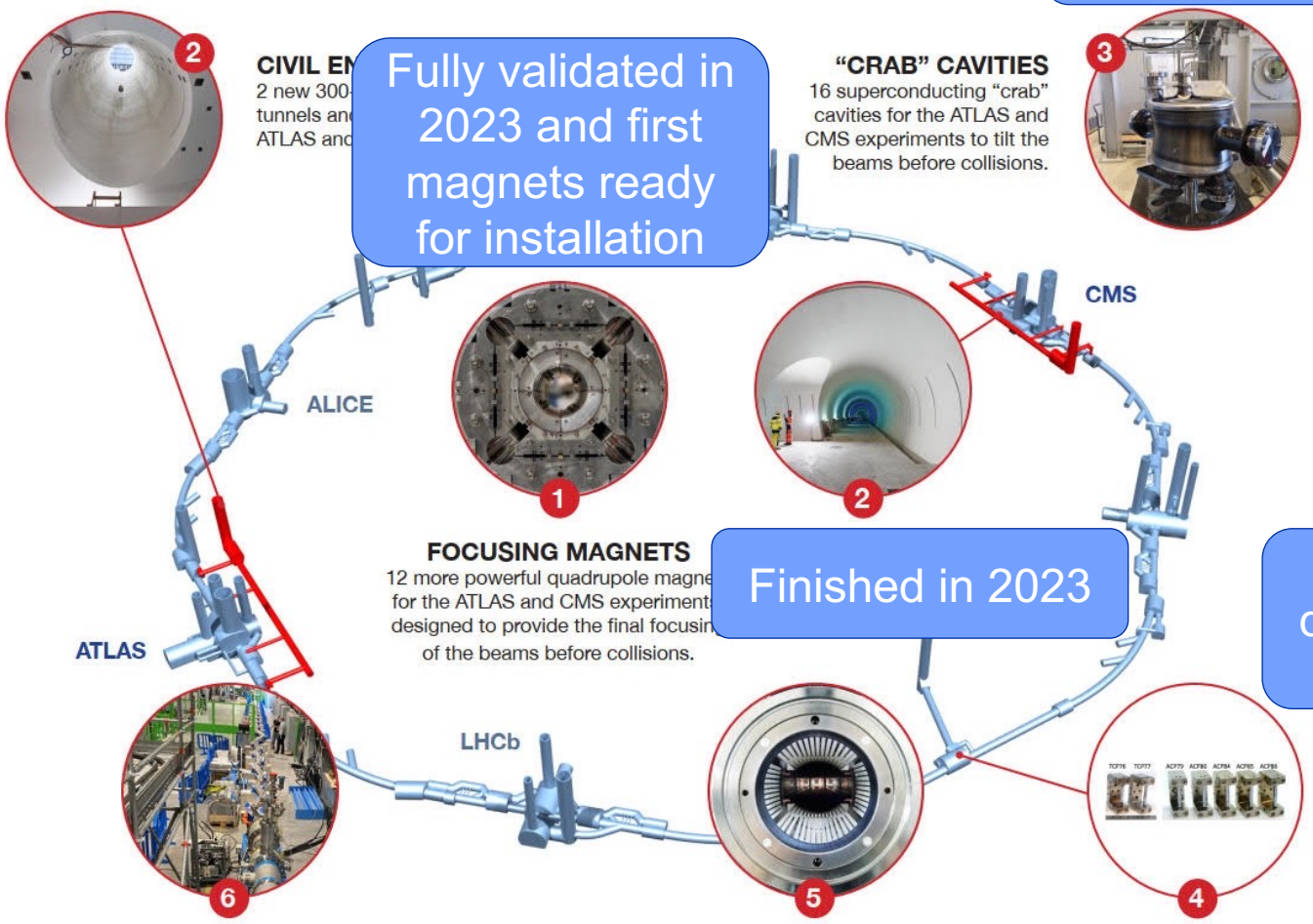
Series production in Industry well underway

Finished in 2023

Fully validated in 2023 and first magnets ready for installation

HL-LHC has many challenging novelties covering a broad technology spectrum

Technology intensive project!



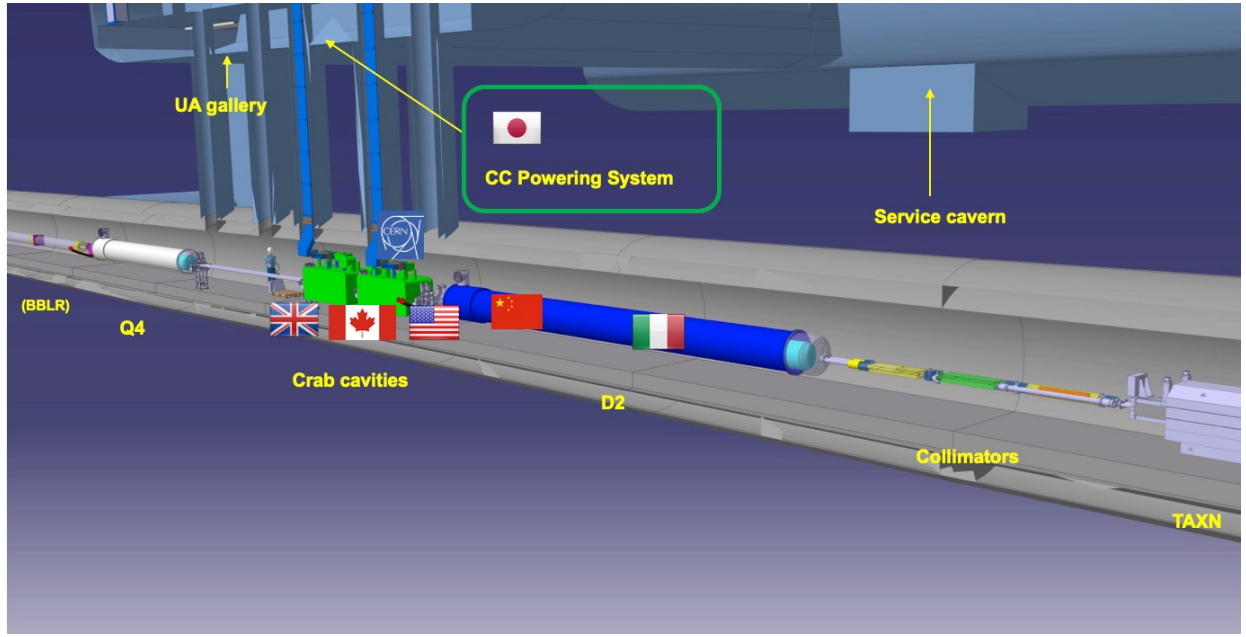
Finished in 2023

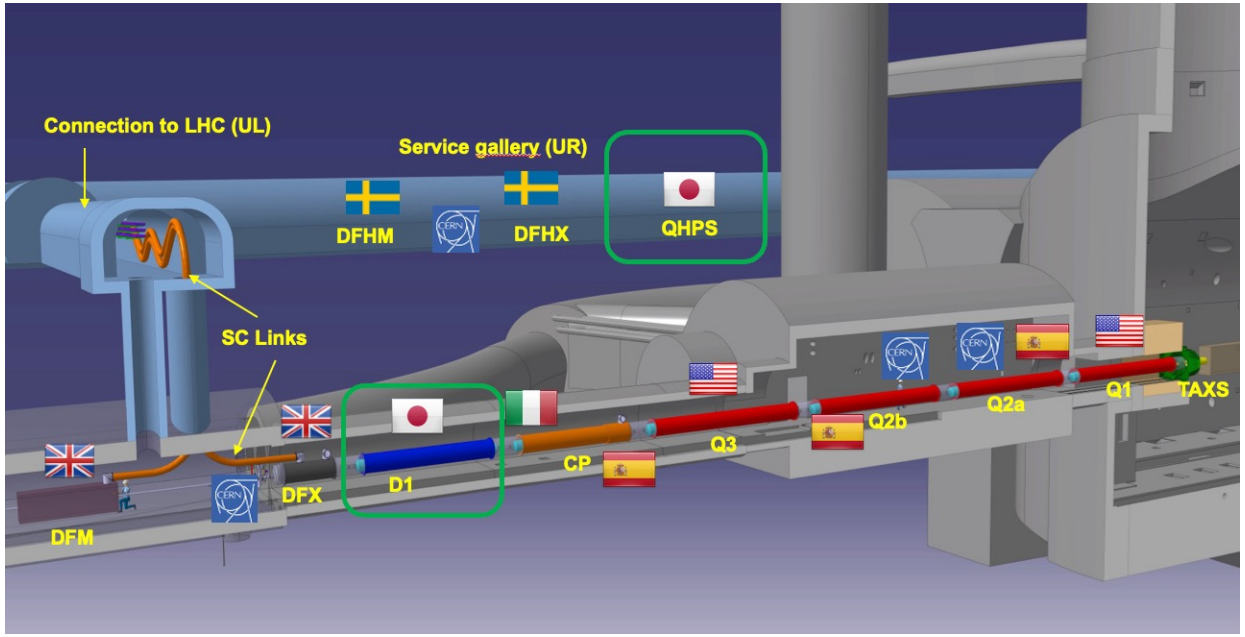
Successfully deployed in 2023 Pb-Pb run

Complete Prototype System installed in SM18 and under test

½ system already installed for Run 3

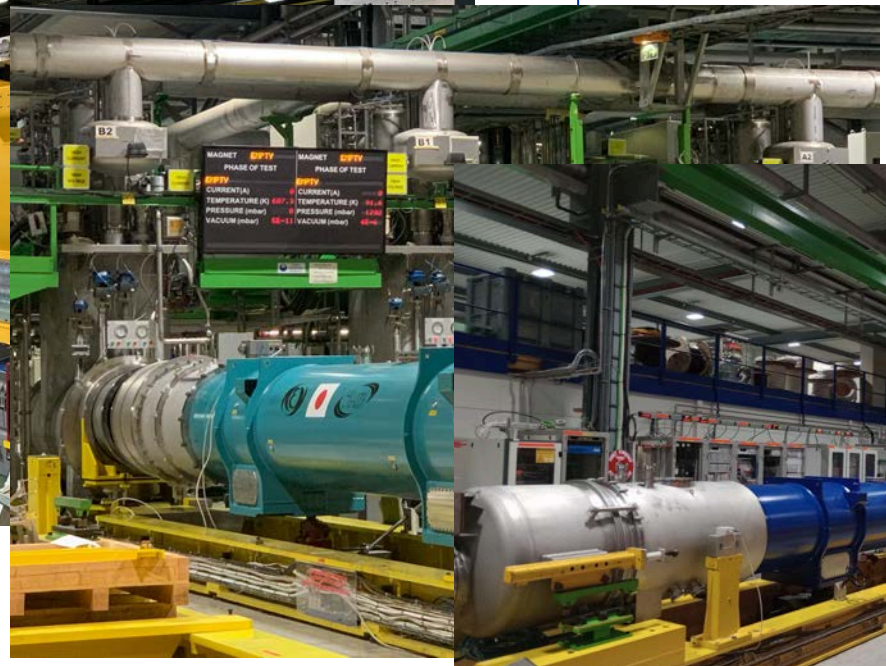
International Collaboration

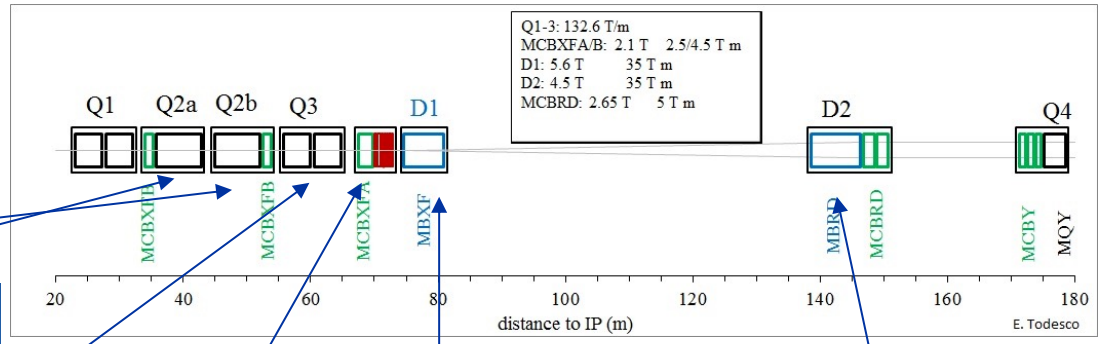




Currently pursuing additional contributions with Japan for QHPS and the Crab Cavity powering system **- both are well advanced**

Ten years…





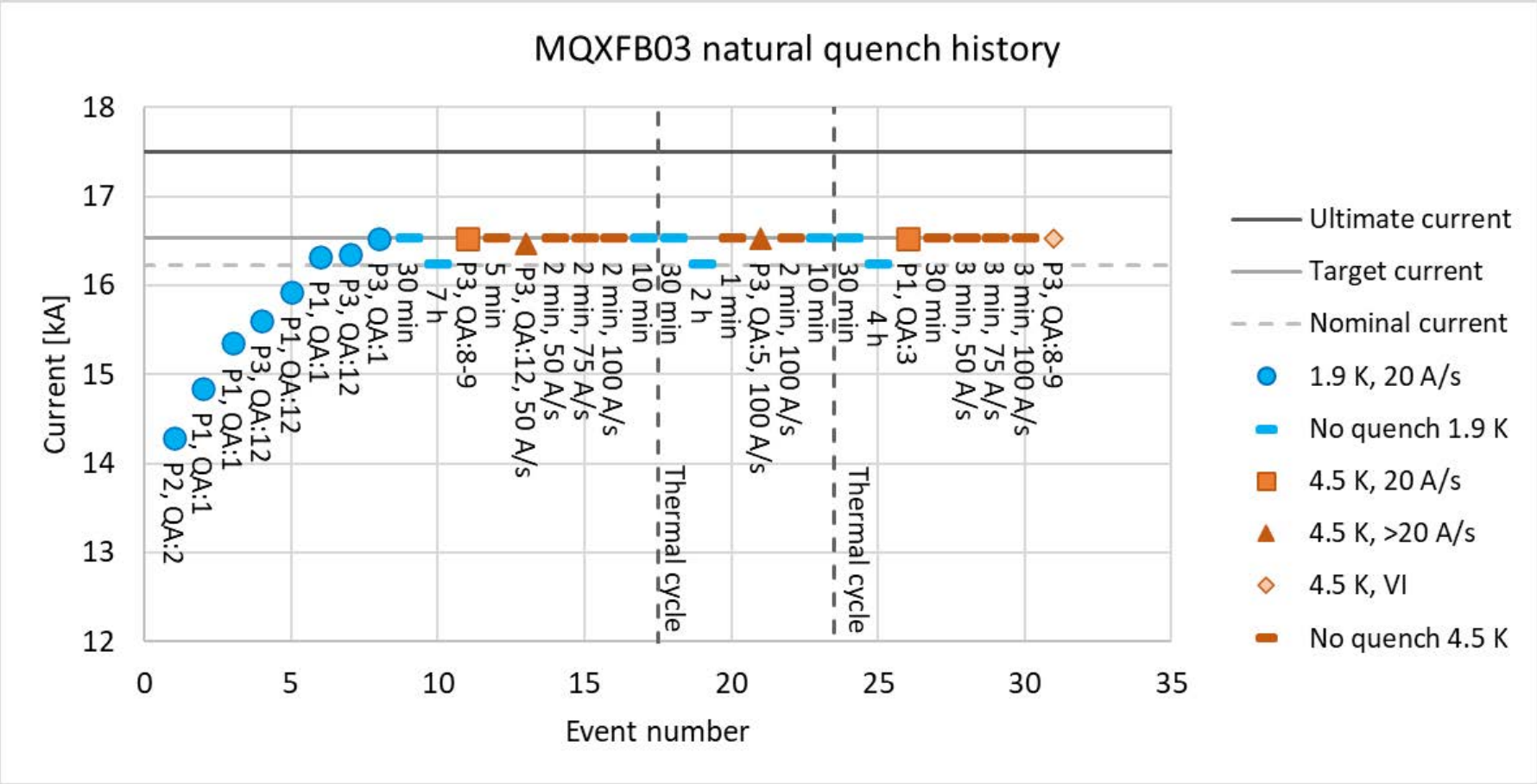
Ezio


Brookhaven
BERKELEY LAB
Fermilab

#2 Series Nb_3Sn Inner Triplet Quadrupole

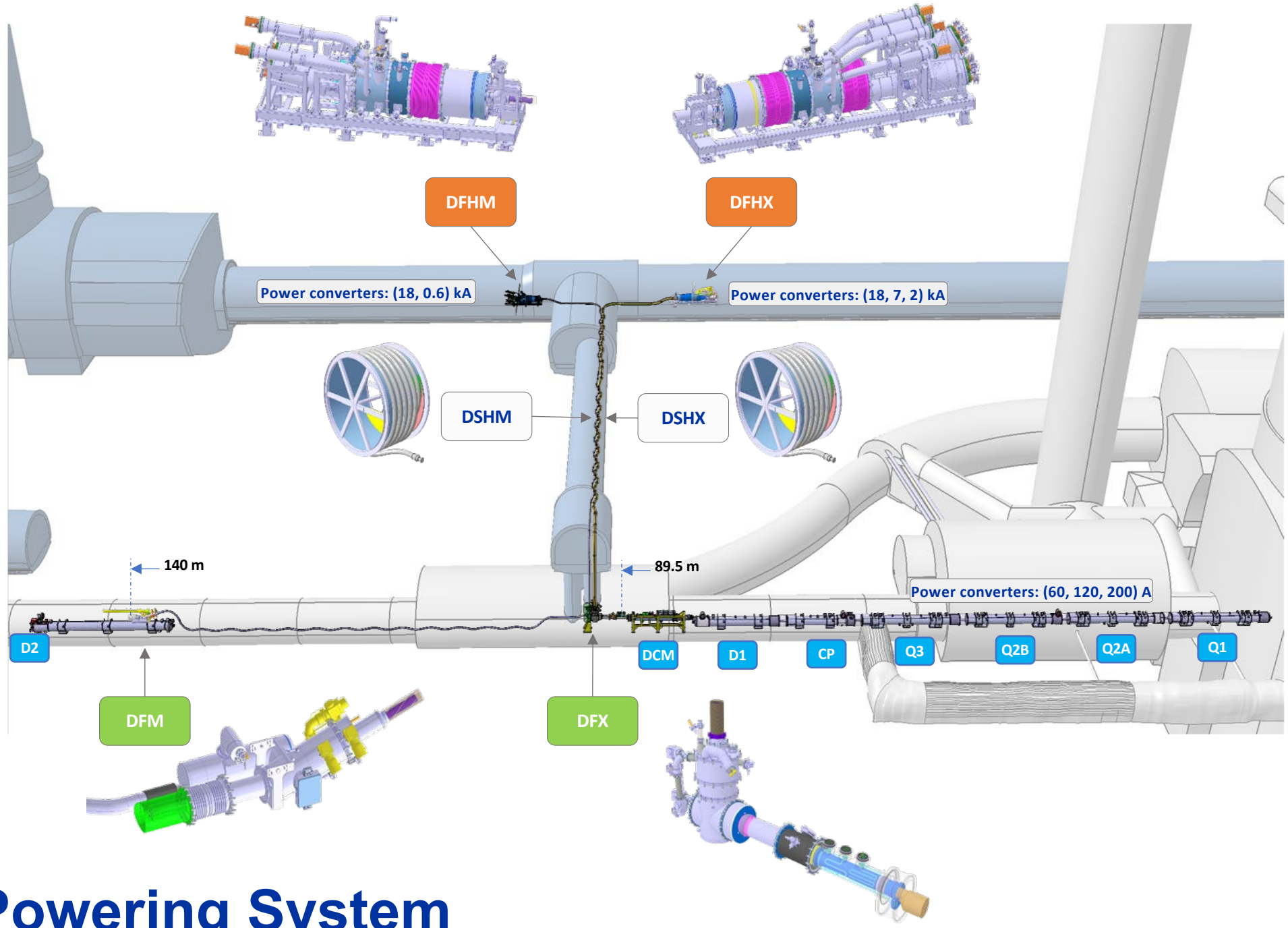
- New welding/fixed point procedures
- New loading procedure
- Coil process optimization

First magnet with full complement of measures



HL-LHC 2023 HIGHLIGHTS

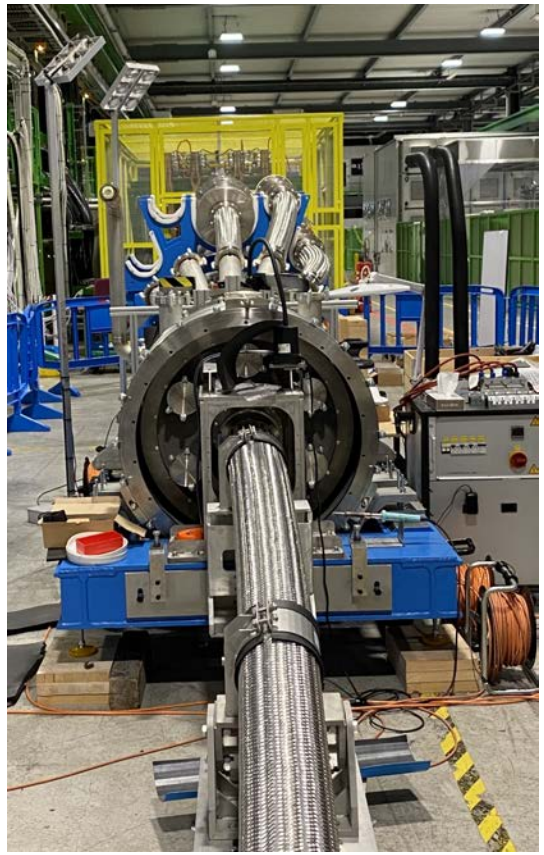
HL-LHC 2023 HIGHLIGHTS
HL-LHC 2023 HIGHLIGHTS



Cold Powering System

Full S/C link

Pressure and leak tests, followed by cool-down, will take place in January. This is a great achievement of the WP6a team, who have made every effort to achieve this important milestone.



Fully closed Dec 2024

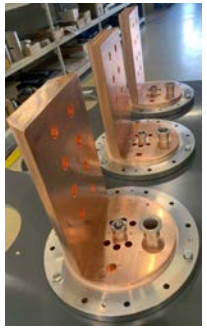
Total:120 kA

HL-LHC fabrication

Vessel series on mannufacturing

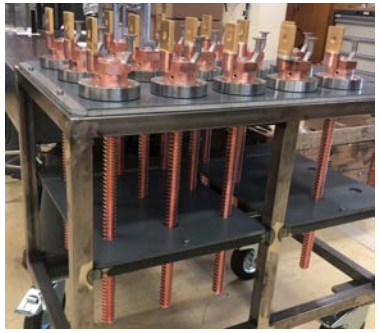
Lower exchangers CL 7kA & 600A

Copper Head 18kA



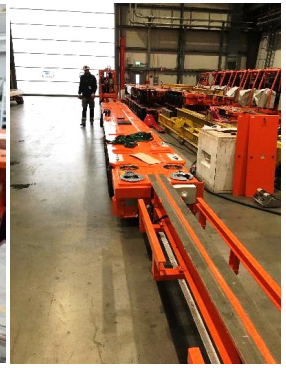
Heat exchangers 18kA CU RRR

EB welding CL 600A



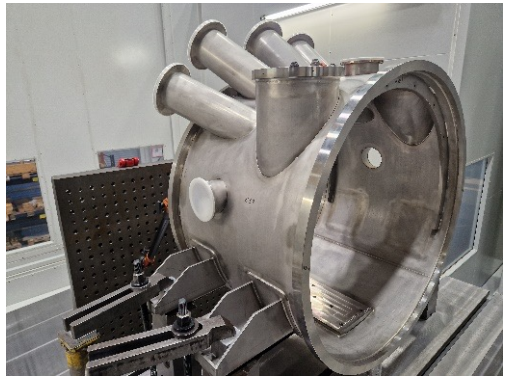
Assembly and storage of cryostats

CL 2kA Complete



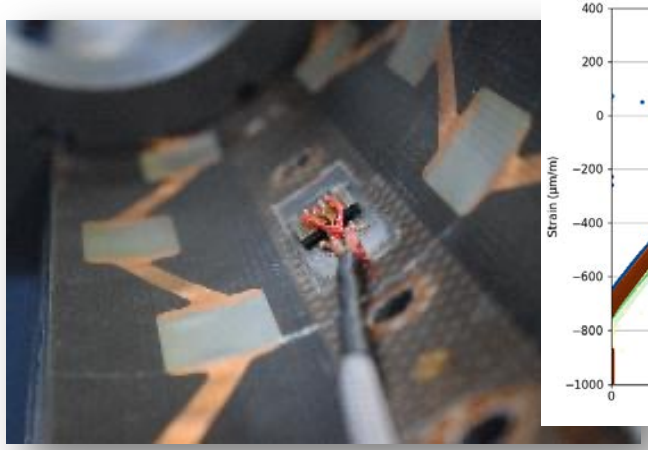
MAFI: manufacturing and commissioning (ongoing) of 1st refurbished convoy

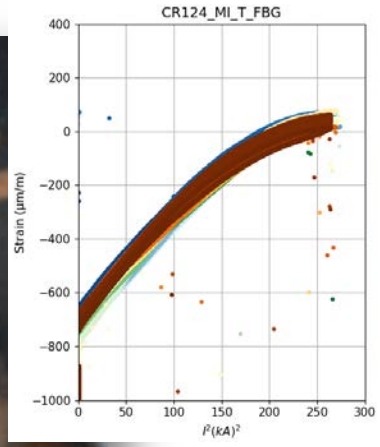
HL-WP3 : DFHX



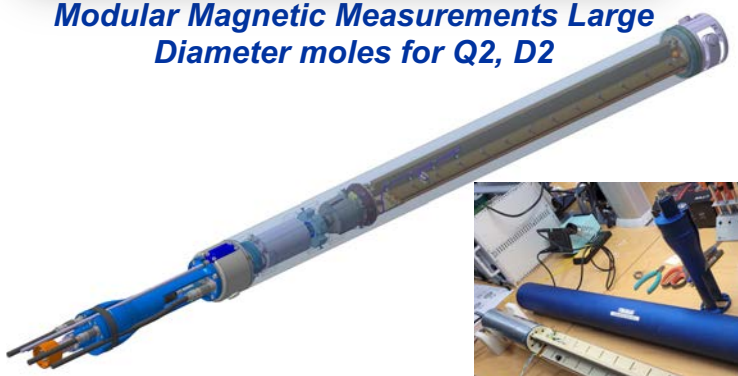
HL-LHC fabrication

Optical Mechanical measurements in MQXFB magnets

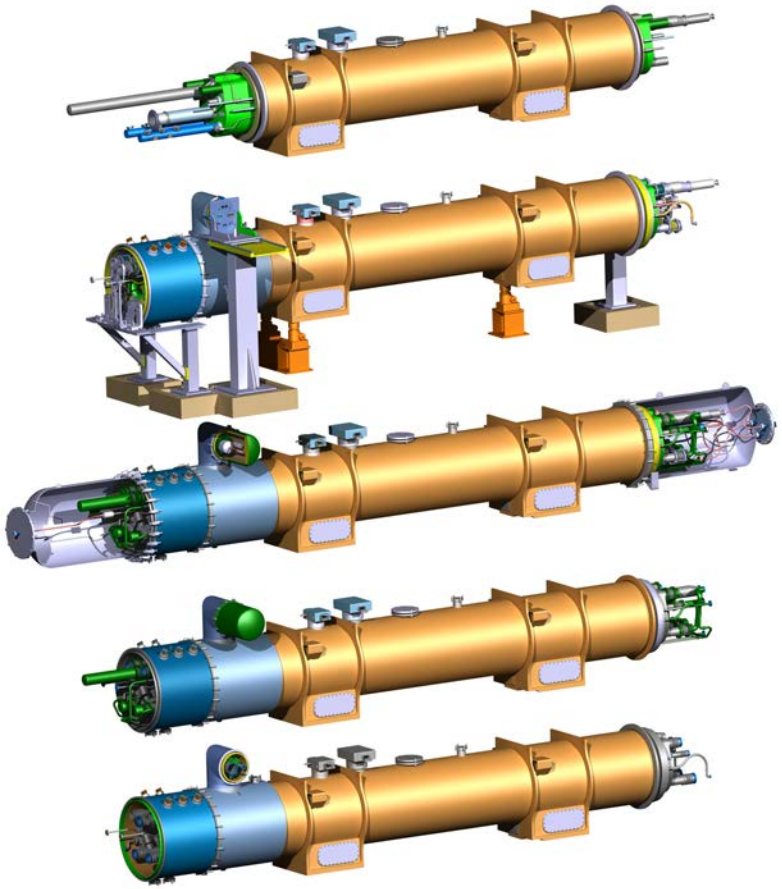




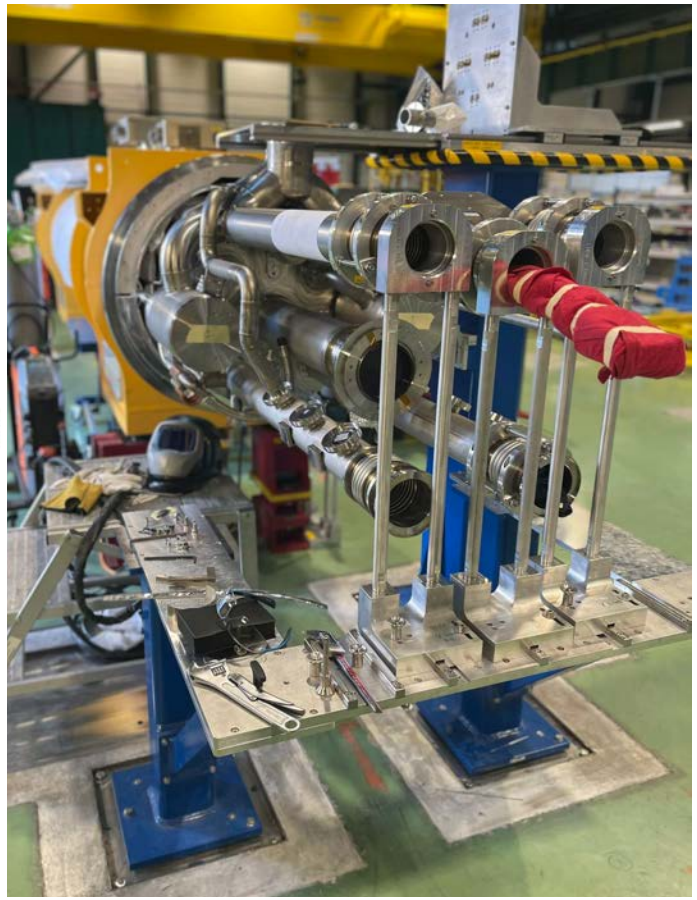
Modular Magnetic Measurements Large Diameter moles for Q2, D2



HL-LHC WP3 INNER TRIPLETS – STRING CONFIGURATION DESIGN FINALISED



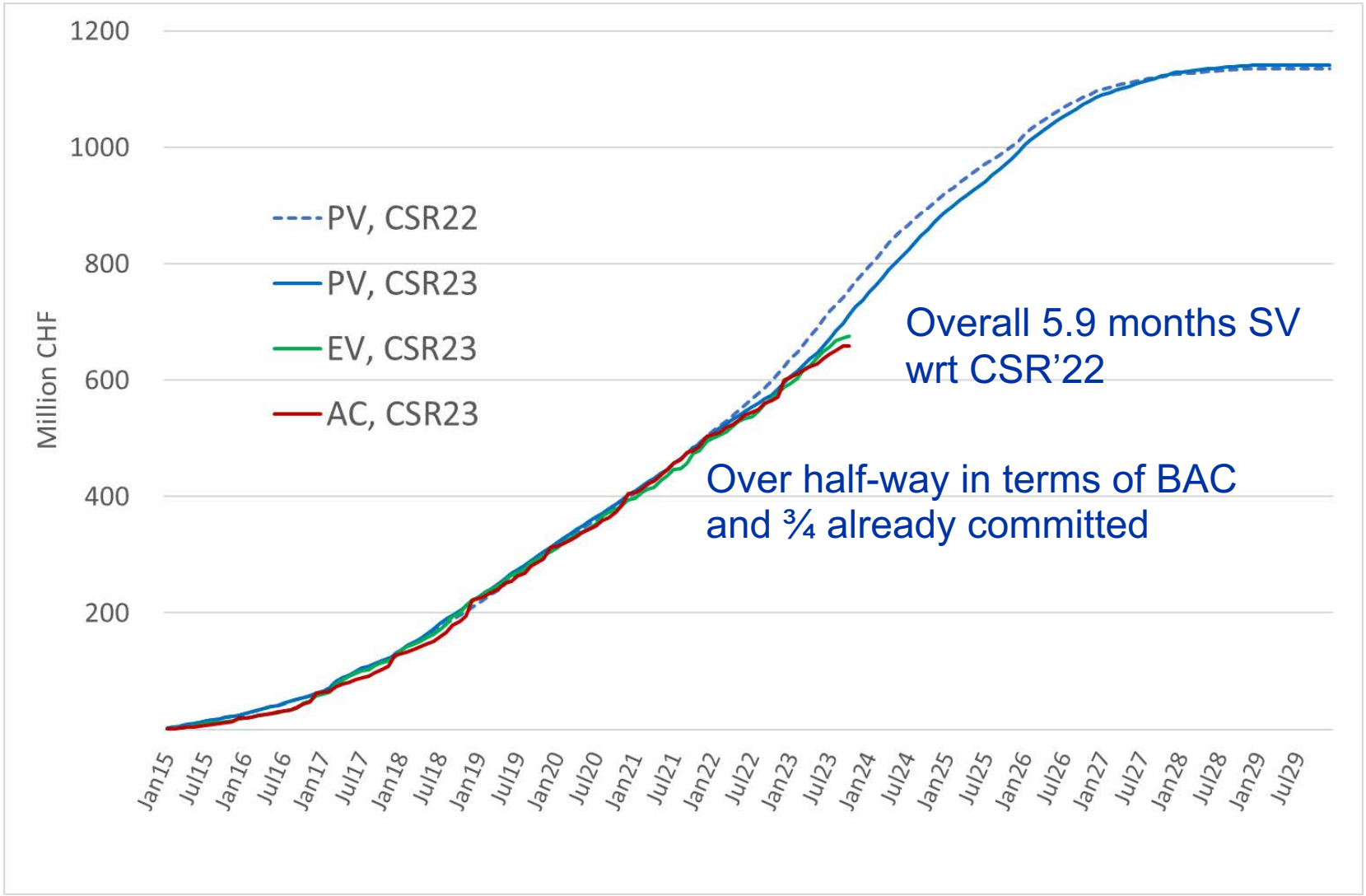
Corrector package assembled in SMI2. Magnet ready to be tested.



HL-LHC Cost & Schedule Review 13-16 November

Visits Workshops, Magnets, String Test, Crab Cavities …

EVM full project



PV Planned Value
EV Earned Value
AC Actual Cost
BAC Budget at Completion

CSR Executive Summary - extract

The HL-LHC project team is congratulated for overall excellent progress.

- The HL-LHC project is now in an advanced stage **with 3/4 of the budget committed**. Although schedule risks remain in several areas, the CMAC is convinced that **the project will be ready for implementation in LS3.**

- For the **Nb_3Sn superconducting IR quadrupoles manufactured at CERN significant advances were achieved**, including the demonstration of first full performance of the 7.15-m-long magnets, as previously achieved by the AUP 4.2-m-long magnets.

- **Large volume procurement played a crucial role** in advancing the project since the last CSR.

- The losses from **in-kind Russian contributions are now fully mitigated**.

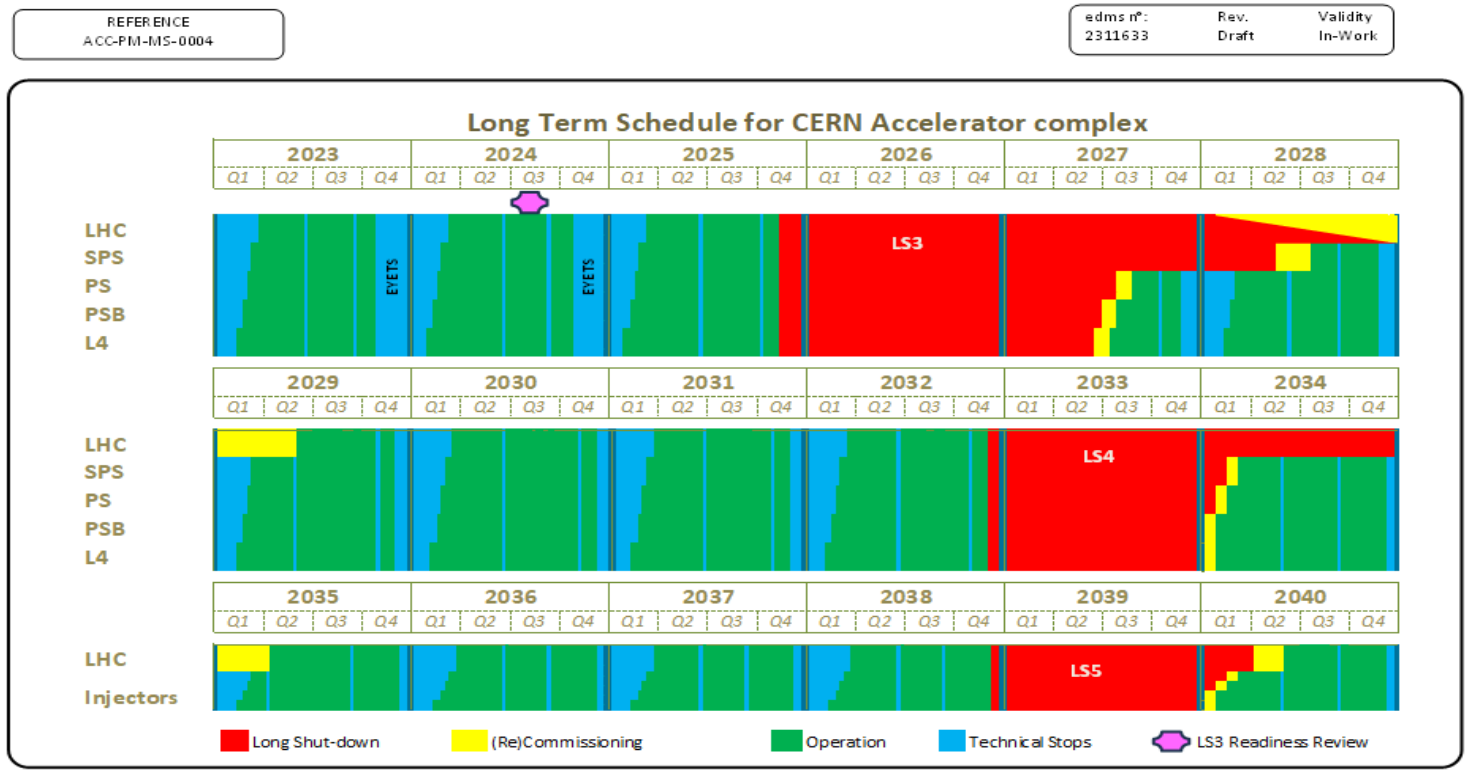
- **The focus must now shift to manage the complexity of the work during LS3.** Challenges include complex installation, potential overload of technical groups, compatibility of parallel activities, radiation dose, work safety in a dense program.

LS3

Incoming!

Complex, NA-CONS, HL-LHC, Experiments (inc. CO2)…

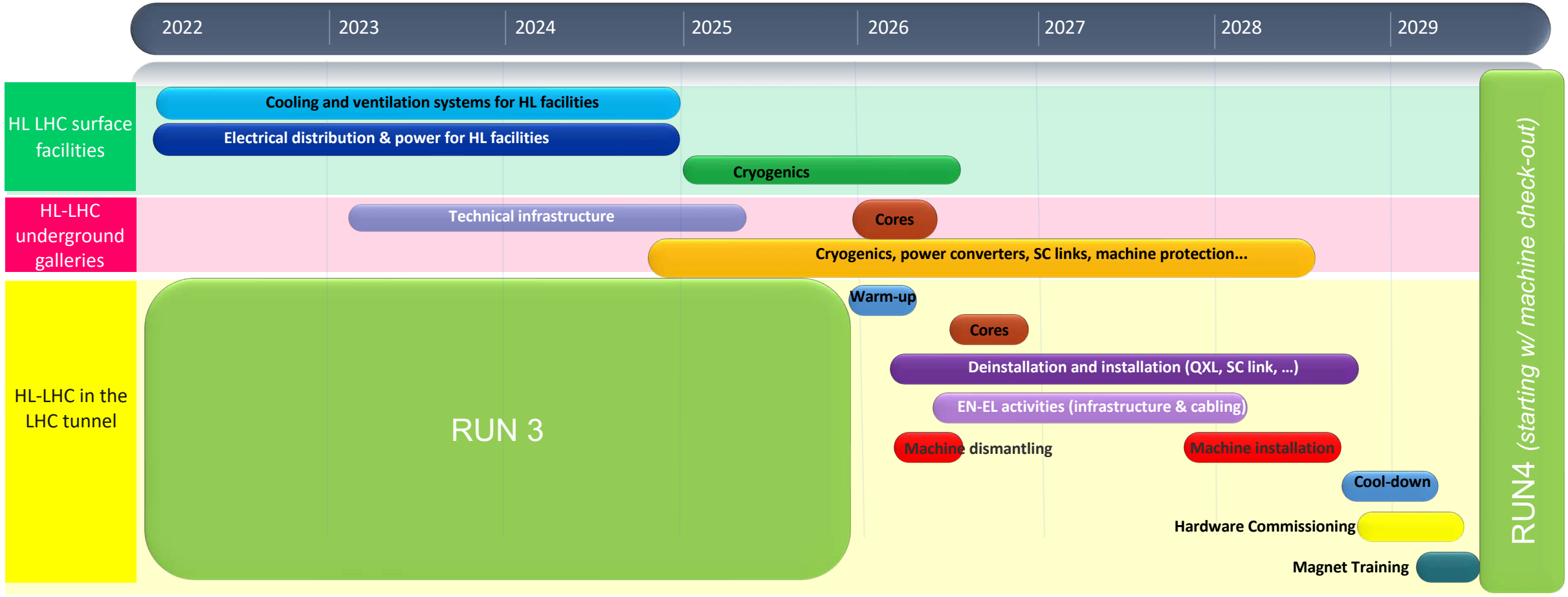
LHC/HL-LHC Timeline to 2041



- EYETS 2023-24
- LS3 readiness review in Q3 2024
- 30 months for intervention in the SPS i.e. NA CONS
- Progressive commissioning of LHC
  - First sectors recommissioning i.e. leak tests after pressure test in January 2028 (S23 & S34)
  - First sectors cooldown in March 2028 (S23&34)

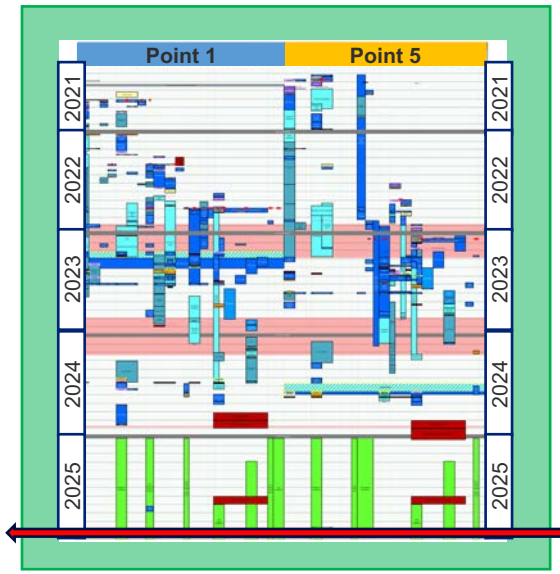
J.-Ph. Tock

HL Installation during Run 3 & LS3

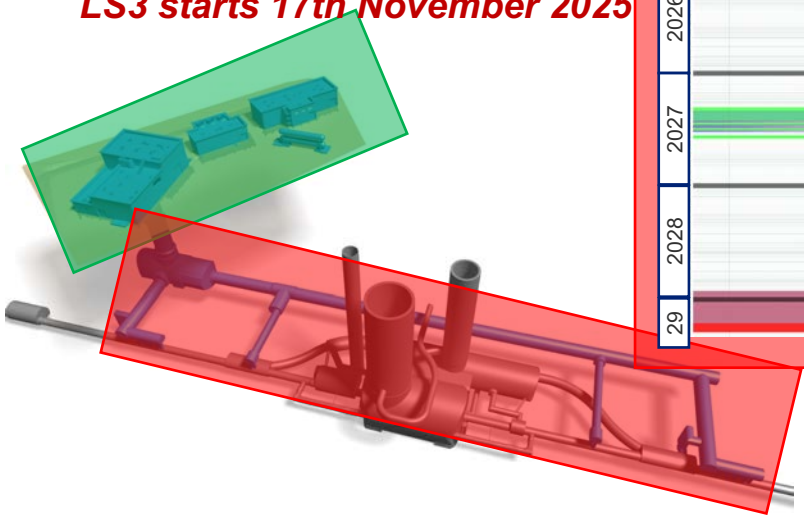


HL Installation during Run 3 & LS3

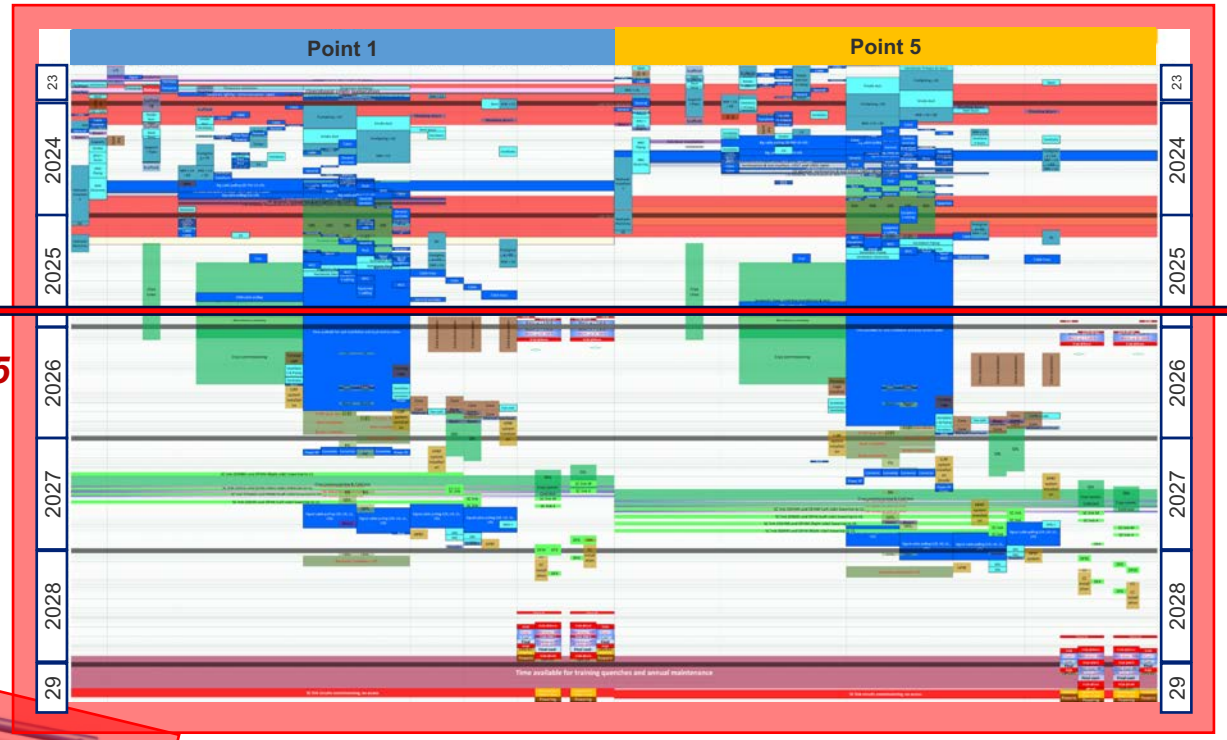
HL-LHC surface facilities

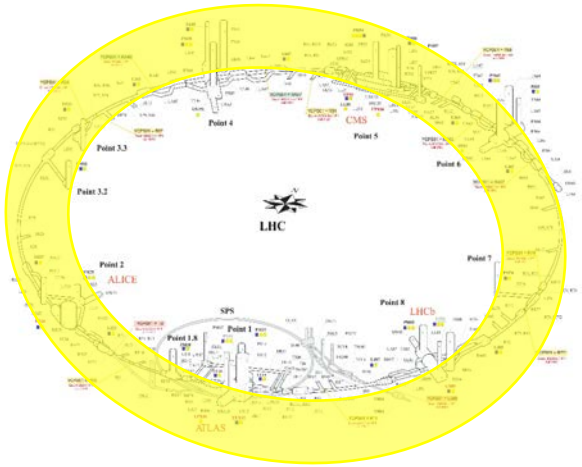


LS3 starts 17th November 2025

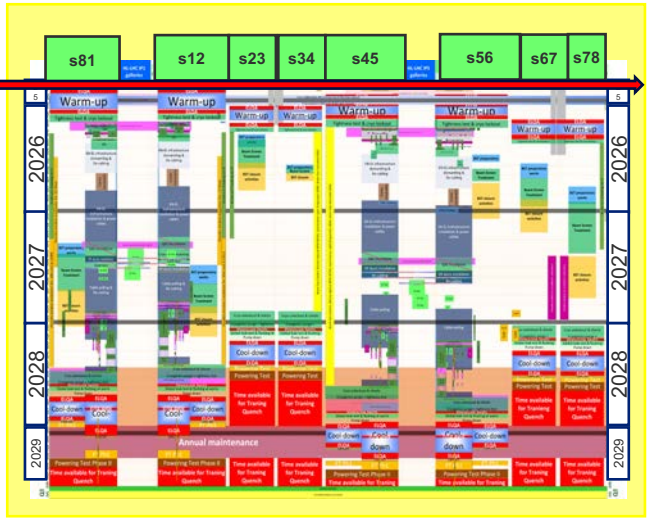


HL-LHC underground galleries





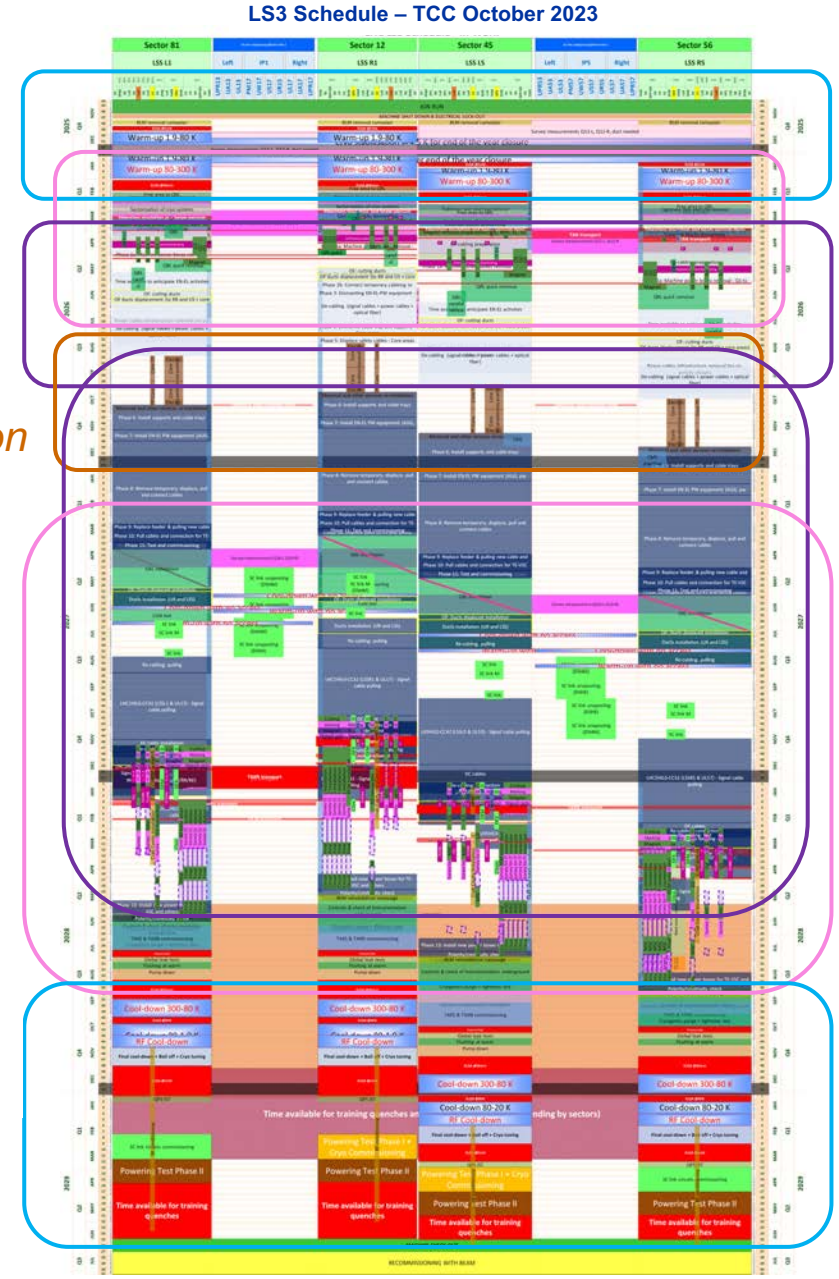
LHC LS3 schedule



181st HL-LHC TCC 20th July 2023→ EDMS LHC-PM-MS-0020 v.3.0
→ Baseline for Installation surface facilities and underground galleries

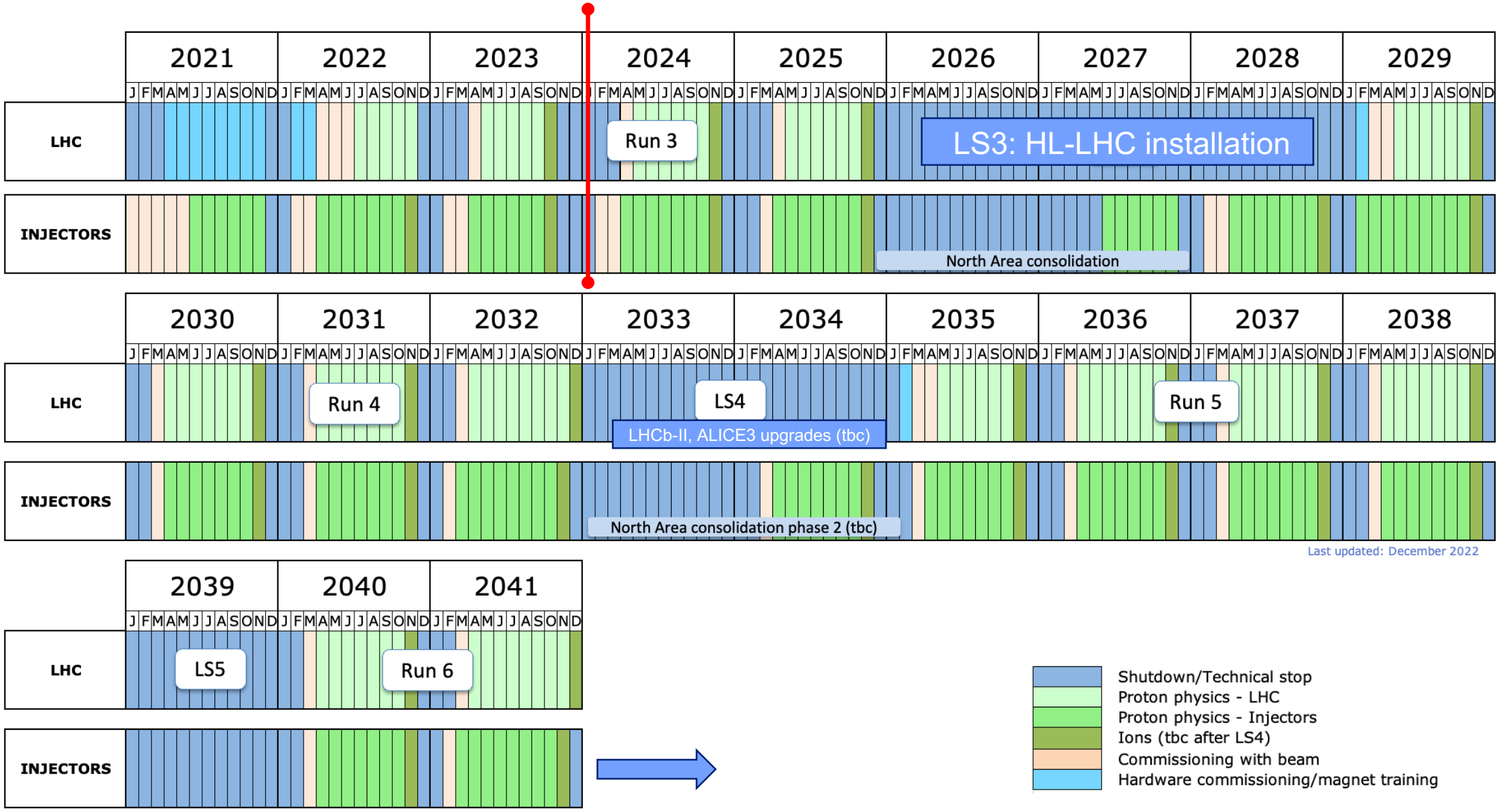
184th HL-LHC TCC 5th October 2023 → EDMS 2400939 v.2.0 → HL WORKING BASELINE

CSR 2023: HL-LHC LS3 Schedule Ver-2.0



- *HL Schedule Ver-2 in circulation since 5 October 2023 (TCC)*
- *HL De-&Installation phases duration inside the LS3 3 years "red phase" (ref. to Long Term Schedule for CERN Accelerator complex ACC-PM-MS-0004)*
- *Considering (re)commissioning "yellow phase", HL-LS3 slightly longer of baseline duration (by 3 months, depending on (re)commissioning duration)*
- *Assumed that Project installation activities end with completion of HWC (done with/by BE-OP)*
- *Planned de-cabling and cabling mostly in double-shift, in agreement with EN-EL. Resources identified and financed*
- *Still ongoing discussion to improve and optimize activities in "parallelism or cohabitation"*
- *Provided margin for 1st units installation (learning curves)*
- *Still missing some key tech. decisions/details (ex. cores excavation, where IT is expected in Nov23)*
- *Resources evaluation & smoothing requested now to all HL WPs and Groups*

Indicative timeline - full and diverse physics programme



Complex – full and diverse physics programme

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
L4, PSB, PS						LS3							LS4			
L3, LEIR						LS3							LS4			
SPS						LS3							LS4			
LHC		Run 3				LS3			Run 4				LS4			
CLEAR	Review			Review												
ISOLDE						BD							LS4			
HIE-ISOLDE													LS4			
MEDICIS			Review													
n_TOF													LS4			
EAST AREA													LS4			
ELENA													LS4			
AWAKE		AWAKE Run 2a,b		Review	CNGS			Run 2c		Run 2d						
North Area						NA-CONS Ph1							NA-CONS Ph2			
ECN3																

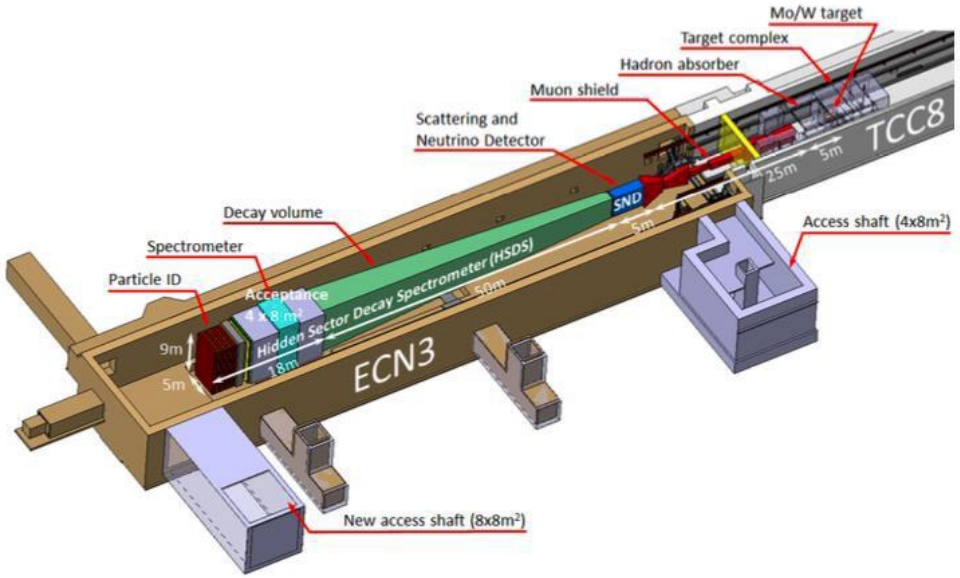
ECN3 upgrade

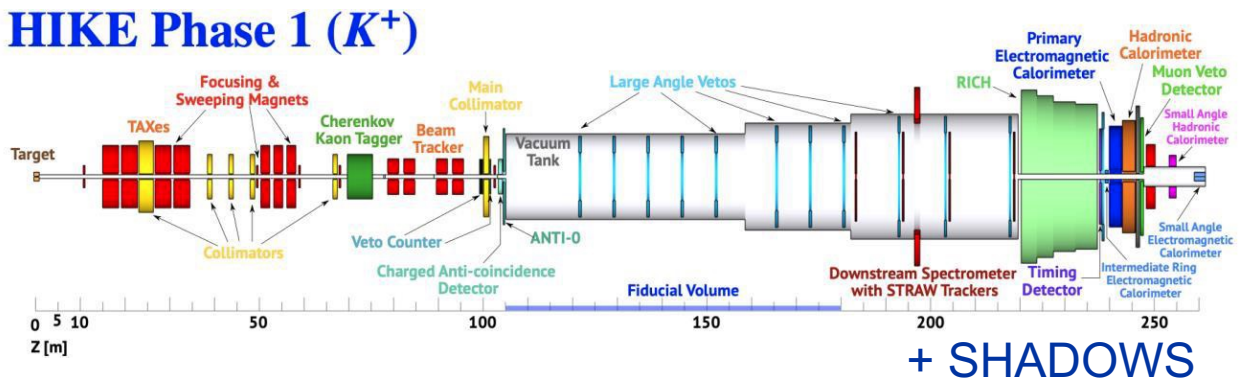
A new high intensity facility in ECN3 is technically feasible and can be implemented in synergy with NA-CONS for operation in Run 4

First funding envelope approved in 23 for essential studies required for timely deployment

An experiment-specific decision was foreseen by the Research Board at end of 2023 to start experiment specific detailed TDR phase in 2024

SPSC reporting into RB did not down-select between options, decision pushed to March.





+ SHADOWS

Thanks to ECN3 beam delivery task force, BDF WG, and Conventional Beams WG for bringing it this far

Beyond the end of HL-LHC?

The vision is for another major project commensurate with the laboratory's capabilities, communities, and resources to assure the future of CERN for the next 50+ years

- Engine for continued investment, innovation, R&D and scientific engagement
- CERN remains a world leading Research Infrastructure
- CERN remains a prestigious symbol of worldwide collaboration, scientific excellence at the leading edge
- Geopolitical implications!

The preferred direction for a future collider at CERN is the FCC

- As mandated by the European Strategy for Particle Physics
- Feasibility study to be delivered end 2025 – expect full and detailed scrutiny
- This a big, hairy, audacious goal – but then so was LEP, so was the LHC

Alternatives to be pursued as plan B (CLIC, ILC, Muon Collider)

Future Collider Options

Within specified timeframe (start ops. ~2045)

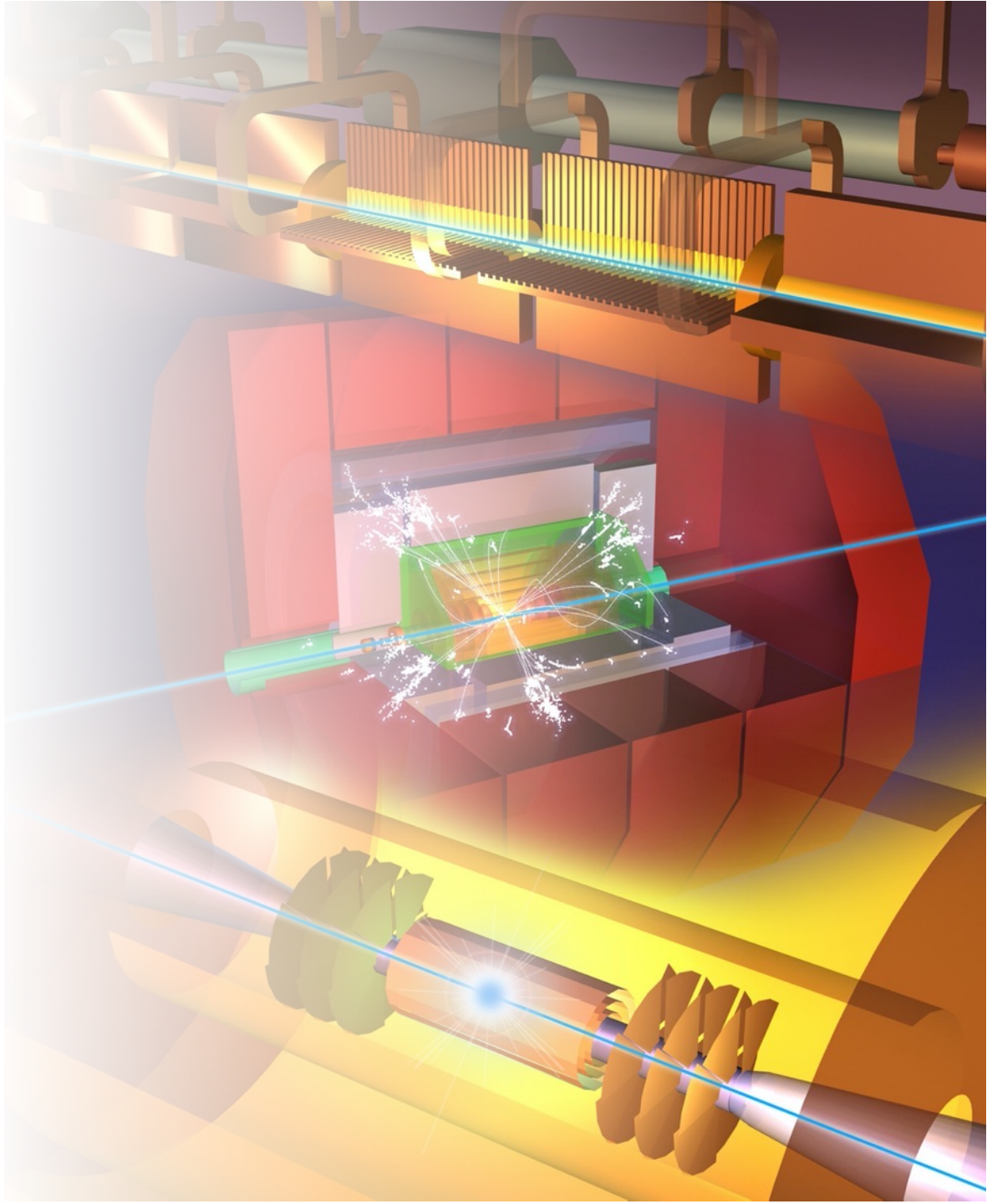
- FCC-ee
- CLIC-380
- (ILC-250, LEP3, LHeC, HE-LHC)

Outside specified timeframe

- FCC-hh (natural follow-on to FCC-ee)
- Muon Collider

Options possibly in timeframe not at CERN: ILC, CEPC, C^3

CEPC has just released their TDR!



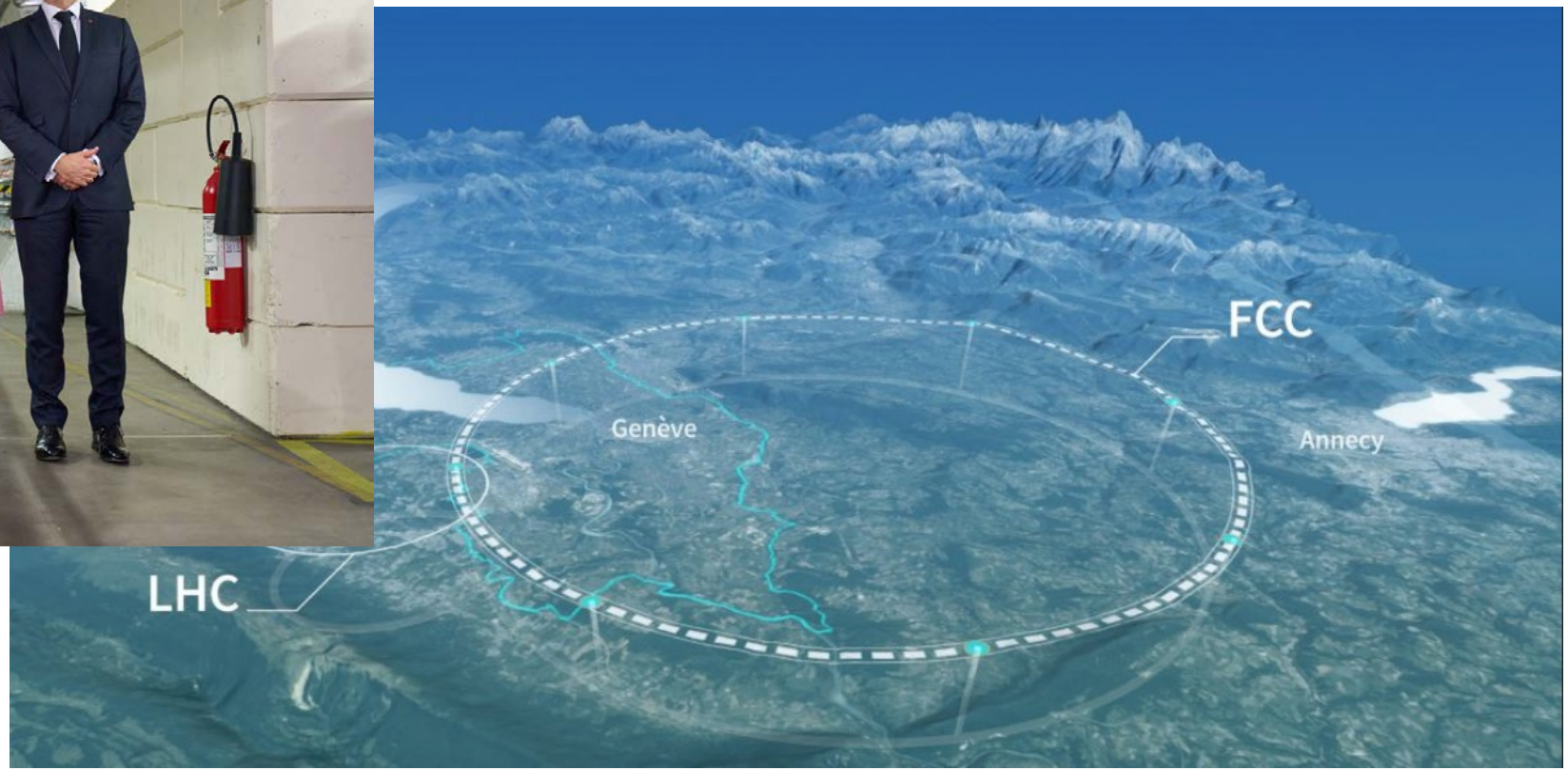
Future Colliders - in brief…

Future collider study	Status
FCC feasibility study	Great progress – delivery foreseen end 2025 Serious mid–term review complete, closeout Feb. 2024
Linear collider - ILC	Mature design, slow progress in moving to pre-lab phase in Japan Targeted R&D phase as a bridge (ITN launched), not going away
Linear collider - CLIC	Mature design, X-band, luminosity optimization, sustainability Project Readiness Report as a step toward a TDR for next ESPPU
Muon collider	International Study established, collaboration up and running Successful INFRA-DEV bid, lots of interest, strong HTS synergies

Accelerator R&D

Accelerator technologies and R&D	Total 2023-2028 M+P [MCHF]
RF technologies R&D	55.2
High-field superconducting accelerator magnets R&D	136.2
Proton-driven plasma wakefield acceleration (AWAKE)	34.1
CERN Linear Electron Accelerator for Research (CLEAR)	9.2
Other accelerator R&D	19.1

RF technologies	Future for SRF should be secure with the new building
HFM	Up and running – interesting!
Proton WFA (AWAKE)	Run 2 ongoing, review incoming, choices clear…
CLEAR	Firm foundations, review in 2024, hopefully good for another 5 years to 2030
Other accelerator R&D	Diverse – good links out



FCC

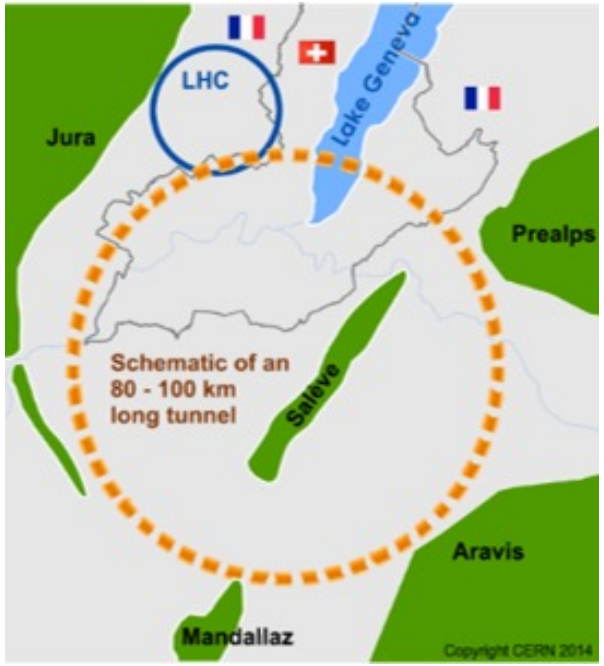
Feasibility study - good progress, mid-term review just gone
High-level interest building

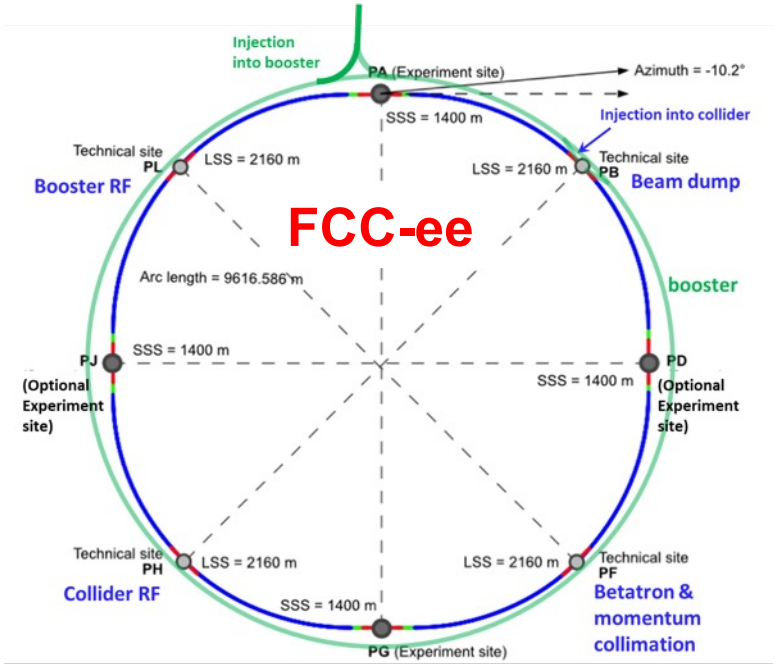
FUTURE CIRCULAR COLLIDER

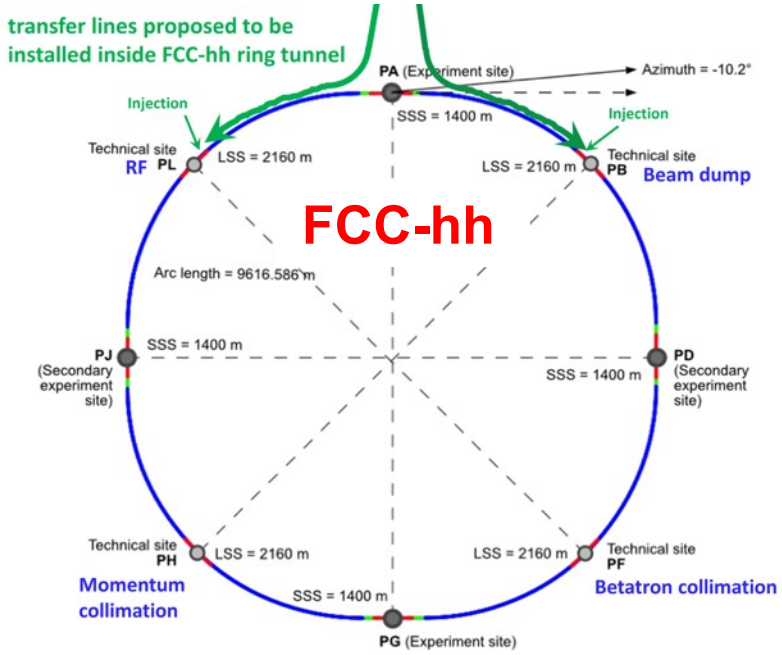
FCC integrated program

Comprehensive long-term program maximizing physics opportunities:

- Stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & top factory at highest luminosities
- Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options







2020 - 2040 | 2045 - 2063 | 2070 - 2095

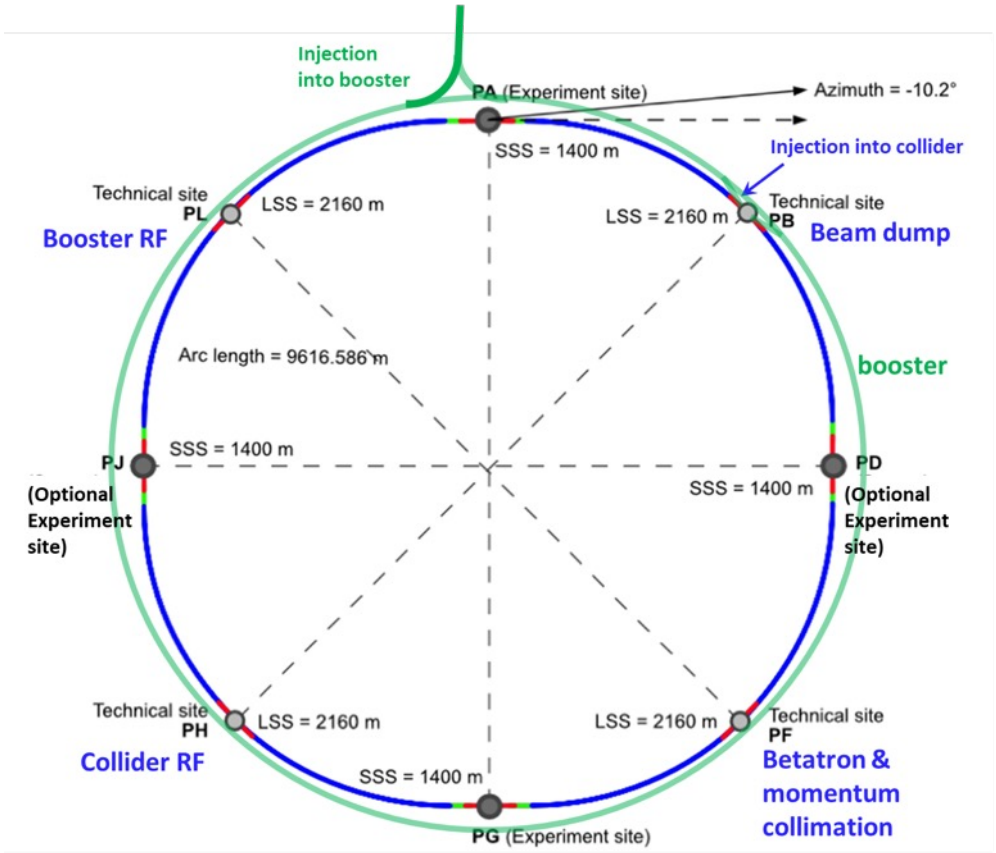
FUTURE CIRCULAR COLLIDER

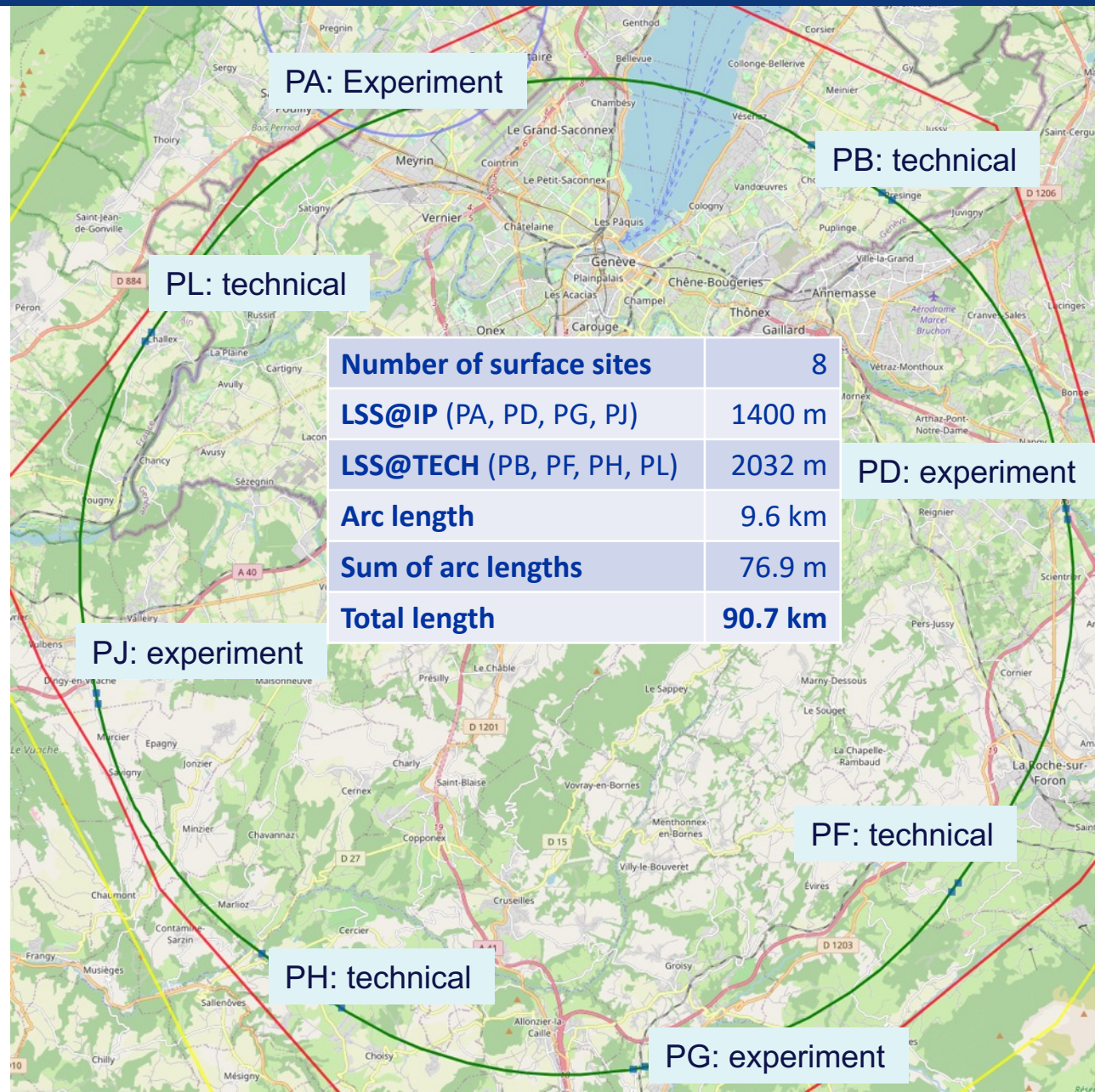
Feasibility study (2021 – 2025) ongoing

Major achievement: optimization of the ring placement
Layout chosen out of ~100 initial variants, based on geological, urban, environmental & infrastructure constraints.

Lowest-risk baseline: 90.7 km ring, 8 surface points

Whole project now adapted to this placement





Number of surface sites	8
LSS@IP (PA, PD, PG, PJ)	1400 m
LSS@TECH (PB, PF, PH, PL)	2032 m
Arc length	9.6 km
Sum of arc lengths	76.9 m
Total length	**90.7 km**

FCC Underground Civil Engineering Schematic

Tunnel Circumference: 90.7 km

Excavated vol: 6.2 Mm^3 (in the ground)

Access shafts: 12

Construction shafts: 1

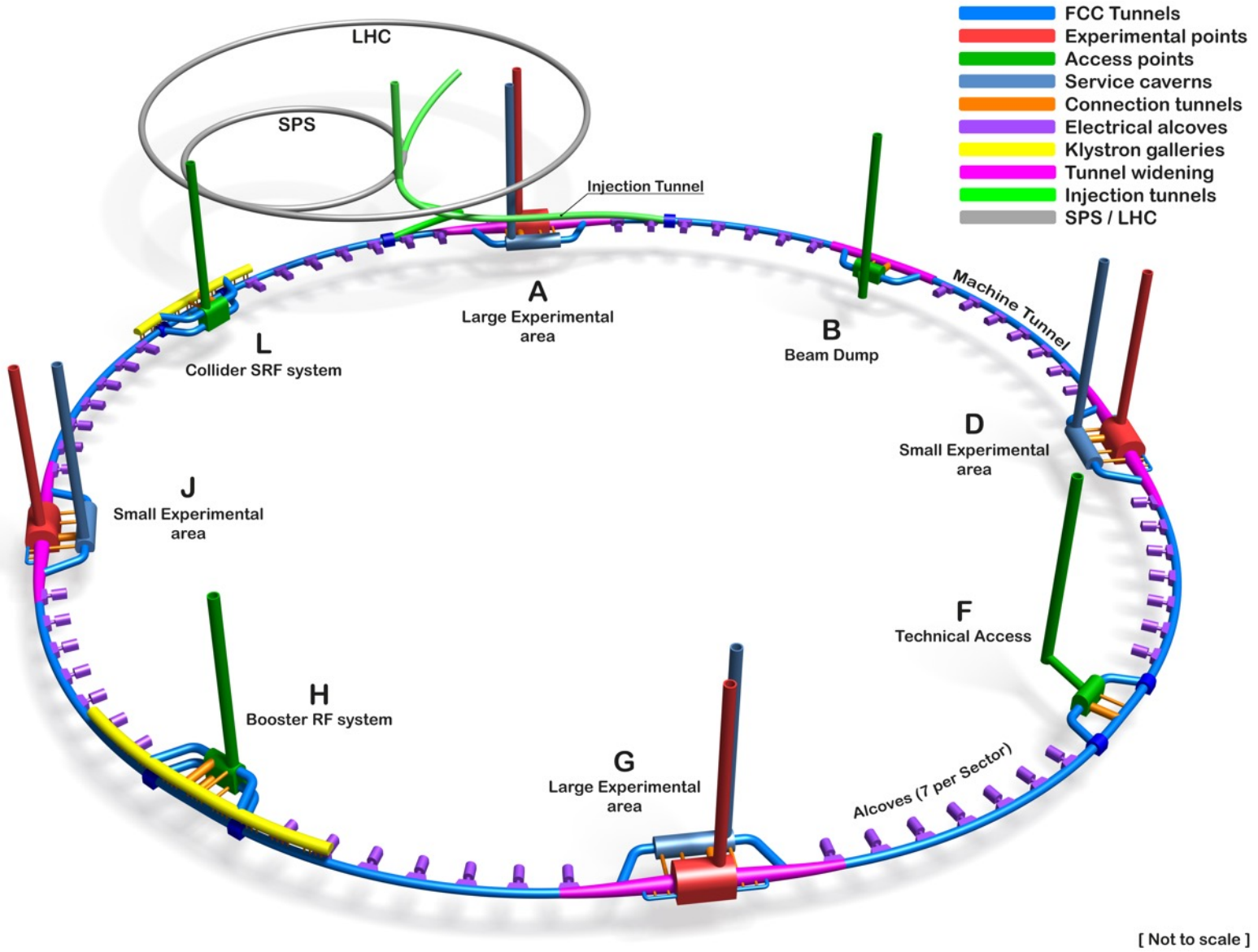
Large experiment areas: 2

Small experiment areas: 2

Technical points: 4

Deepest shaft: 400 m

Average shaft depth: 243 m



2023 Process – FCC mid-term review

Intense preparation

- FCC Feasibility Study mid-term review report (~800 pages) plus a lot of presentations

FCC Mid-Term Review

- 16 Oct 2023 → 18 Oct 2023
- Scientific Advisory Committee (SAC) and Cost Review Panel (CRP) did their stuff

Joint SPC and FC Normal Sessions

- 20 Nov 2023 → 22 Nov 2023
- Summaries and recommendations presented

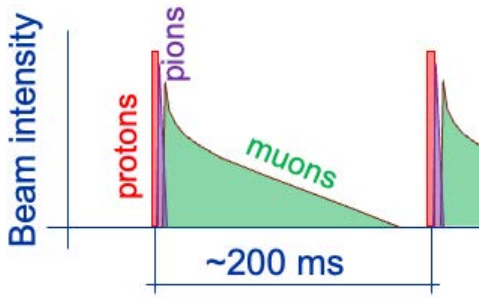
SPC and FC reported into December's Restricted Council

Final deliberations at Restricted Council - Friday 2 Feb 2024

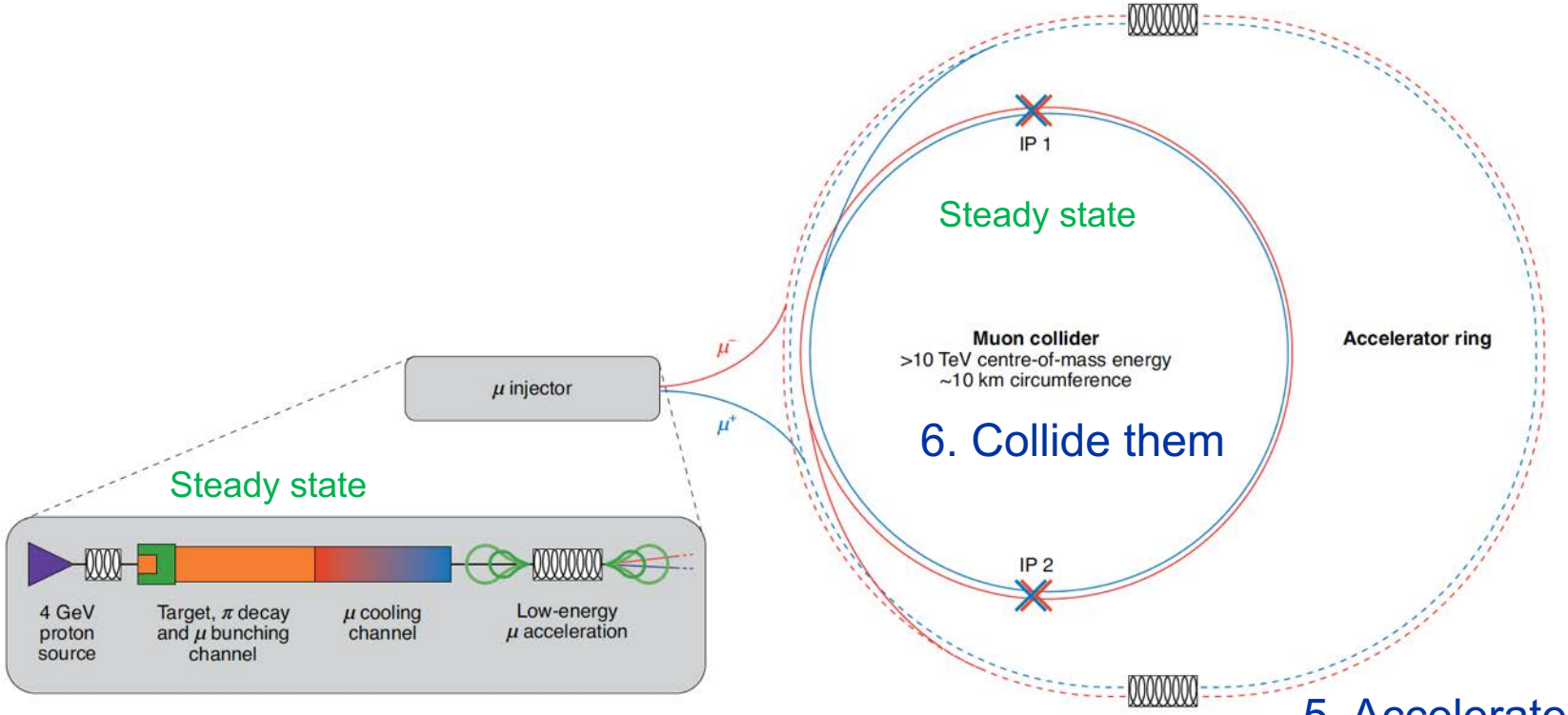
Mid-Term review well received by SAC and CRP
Encouraging high level support, understandable reservations

Muon Collider

Large mass (207 m_e) suppresses synchrotron radiation => circular collider
Fundamental particle yields clean collisions & requires less energy than protons
But lifetime at rest is only 2.2 μs (fortunately increases with energy)!



$\sqrt{s}$	$\int \mathcal{L}dt$
3 TeV	1 ab^{-1}
10 TeV	10 ab^{-1}
14 TeV	20 ab^{-1}



1. Produce muons

2. Capture them

3. Cool them

4. Accelerate them

5. Accelerate them

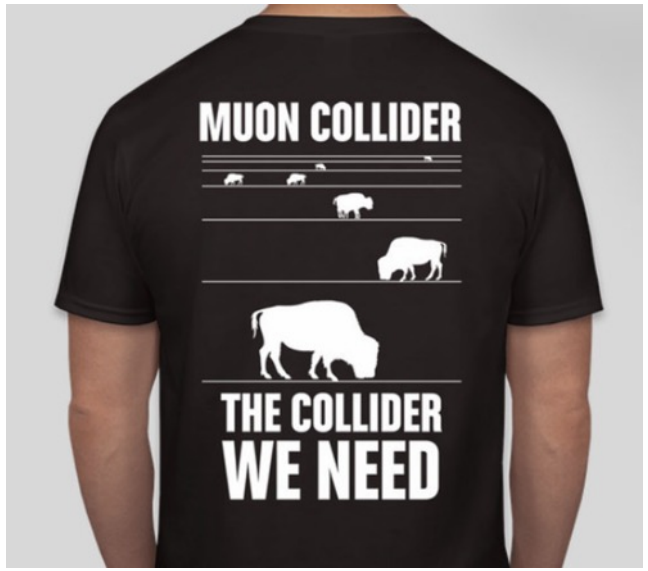
Muon Collider

Very challenging - but significant, long-term, worldwide interest

Part of the European Accelerator R&D roadmap

- Resources allocated at CERN to host an **International Muon Collider** study
- **MuCol** - Horizon INFRADEV - Development of novel technologies for the Muon Collider Study – up and running

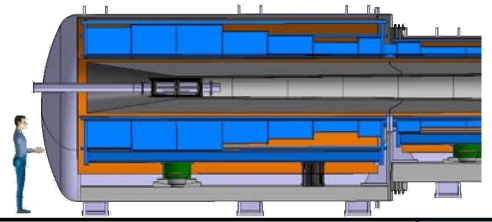
Now back on in the US following the recent Particle Physics Project Prioritization Panel (P5) 10-year roadmap



Muon Collider magnets

Target

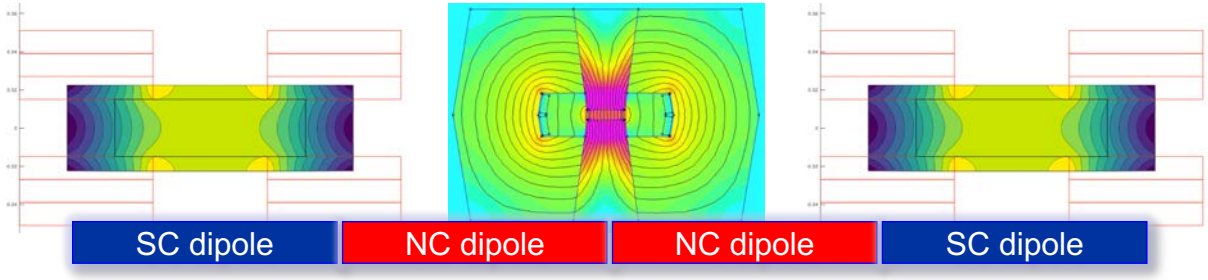
20 T, 200 mm
Heat: 5…10 kW
Dose: 80 MGy

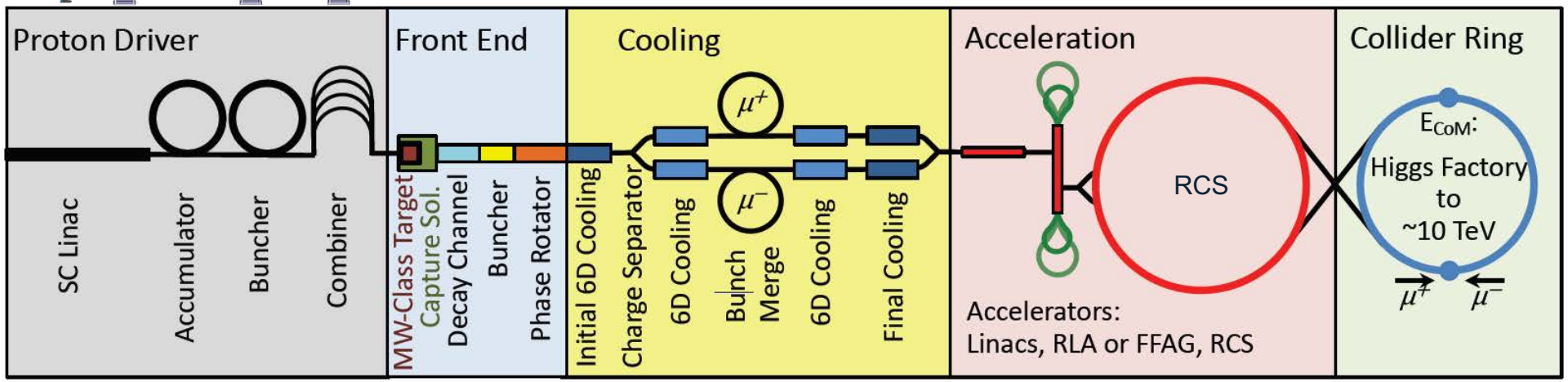


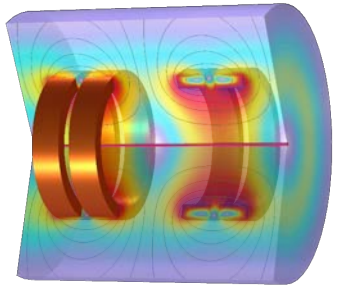
Accelerator

NC ±1.8 T, 400 Hz
100 mm x 30 mm

SC < 10T
100 mm x 30 mm





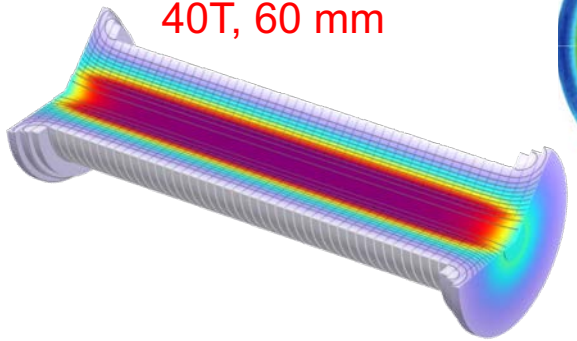


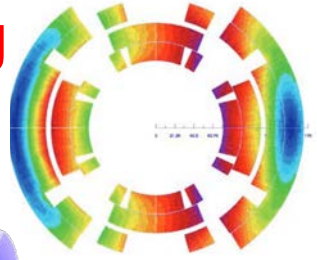
6D cooling

2…14T
100…900 mm

Final cooling

40T, 60 mm





Collider

16T peak, 150 mm
Heat: 5 W/m
Dose: 20…40 MGy

Luca Bottura

Strong connection to HTS magnets for fusion

Energy

Costs are down, European market reform unfolding

Pursuing long term supply - renewables and potentially nuclear

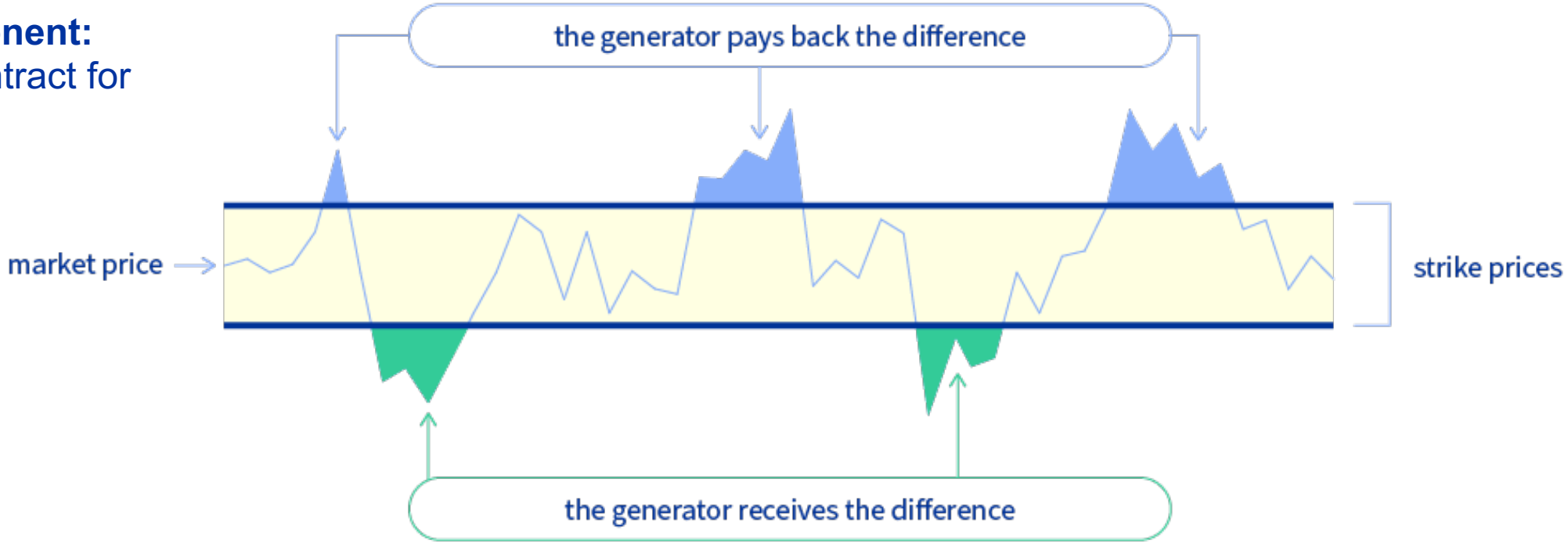
Our supply is low carbon

Energy Management/Coordination, ISO 50001

Electricity market reform

EU's long-term response to the energy crisis experienced in 2022.

One component:
two-way contract for difference



The French government and state-owned utility EDF reached an agreement on 14 November 2023 to regulate the selling price of nuclear power at an average of €70 per Megawatt-hour, with a CfD-like mechanism applying when prices rise above €78-€80/MWh.

https://www.consilium.europa.eu/en/policies/electricity-market-reform/

Power Purchase Agreements

Long term agreements (~15 years) based on renewables at agreed prices

Two photovoltaic PPA agreements being pursued at CERN

First PPA provider: ~45 GWh per year for a start in 2027.

Second PPA provider: ~89 GWh per year for a start in 2027.

Positive adjudication for both contracts at Finance Committee in Oct. 2023

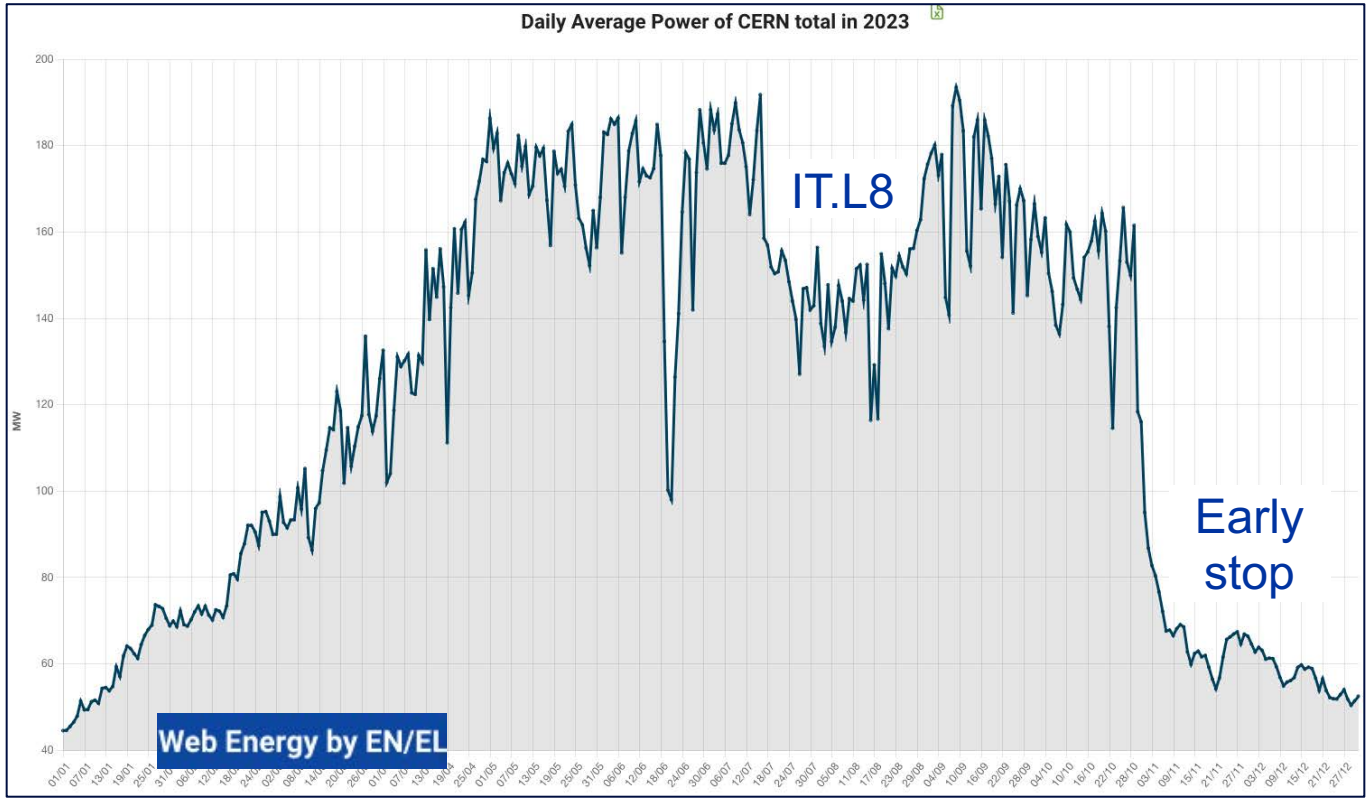
Nuclear power "PPA" also under discussion – waiting for Energy Market Reform to settle down

- **Greens our supply**
- **Secures part of our supply at reasonable cost**

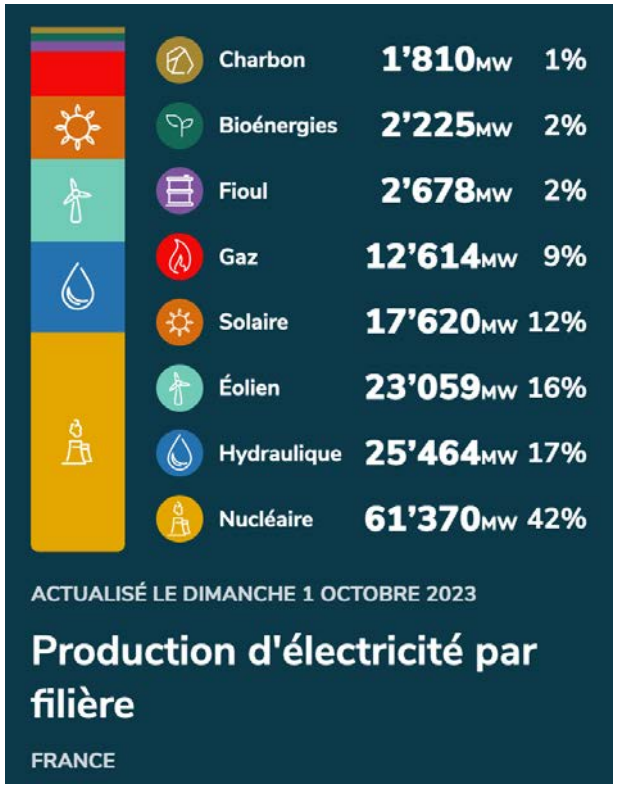
https://www.rte-france.com/en/home

CERN electricity consumption 2023

Total 1,080 GWh **LHC ~55% inc. experiments**



All pulled from the French Grid



Energy Pathways to 2050 →

Achieving carbon neutrality will require transforming the economy and lifestyles, and restructuring the power system in such a way as to allow electricity to replace fossil fuels as the country's leading energy source

BETTER: ISO 50001 certification

- CERN is the first Laboratory ISO 50001 certified.
- Certification implies the establishment of improvement goals, and of continuous monitoring.
- The process is not limited to the experts on the field: the line and top management have to be continuously informed of the status of the KPIs and take action.
- The Energy Management Panel (standard and Enlarged) are the bodies used to manage and control Electricity Consumption.

afaq
AFNOR CERTIFICATION

Certificat
Certificate

N° 2023/103380.1 Page 1 / 1

AFNOR Certification certifie que le système de management mis en place par :
AFNOR Certification certifies that the management system implemented by:

Organisation européenne pour la Recherche nucléaire (CERN)
European Organization for Nuclear Research (CERN)

pour les activités suivantes :
for the following activities:

RECHERCHE FONDAMENTALE EN PHYSIQUE DES PARTICULES.

FUNDAMENTAL RESEARCH IN PARTICLE PHYSICS.

a été évalué et jugé conforme aux exigences requises par :
has been assessed and found to meet the requirements of:

ISO 50001 : 2018

et est déployé sur les sites suivants :
and is developed on the following locations:

Adresse	N° SIREN
Esplanade des Particules 1 CH-1211 GENÈVE 23	
9001, route de Saint-Genis FR-01280 PREVESSIN MOENS	445403488

(L'ensemble des activités de l'entreprise sur les sites donnés est couvert par la certification)
(The scope of certification covers all activities carried out on the above-mentioned locations)

Ce certificat est valable à compter du (année/mois/jour) 2023-02-02 Jusqu'au 2026-02-01
This certificate is valid from (year/month/day) *until*

Julien NIZRI
Directeur Général d'AFNOR Certification
Managing Director of AFNOR Certification

Flashez ce QR Code pour vérifier la validité du certificat

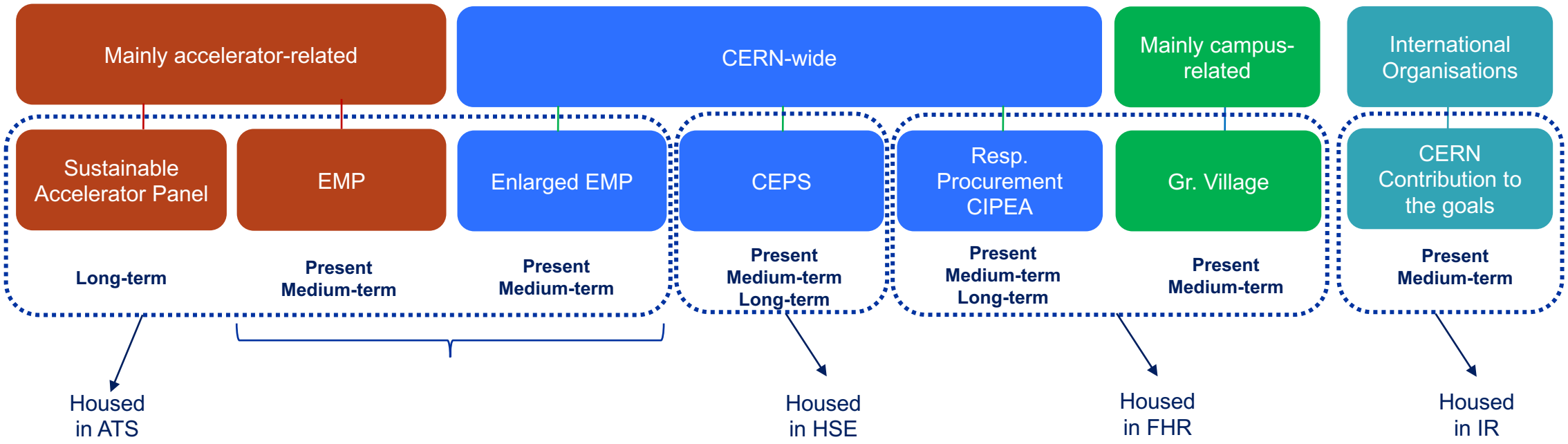
BETTER: Energy performance plan (2023-2027)

- **Main technical document together with the « energy review » including the:**
  - Retained perimeter
  - Energy baseline
  - Summary of actions carried out in the past
  - Energy performance indicators
  - Objectives and targets for the next 5 years
  - Action plan for the next 5 years
  - Benchmark against other research institutes
- **Definition of 8 Significant Energy Uses (SEUs)**
  - Energy use accounting for substantial energy consumption and/or offering considerable potential for energy performance improvement

Action Plan (selection)

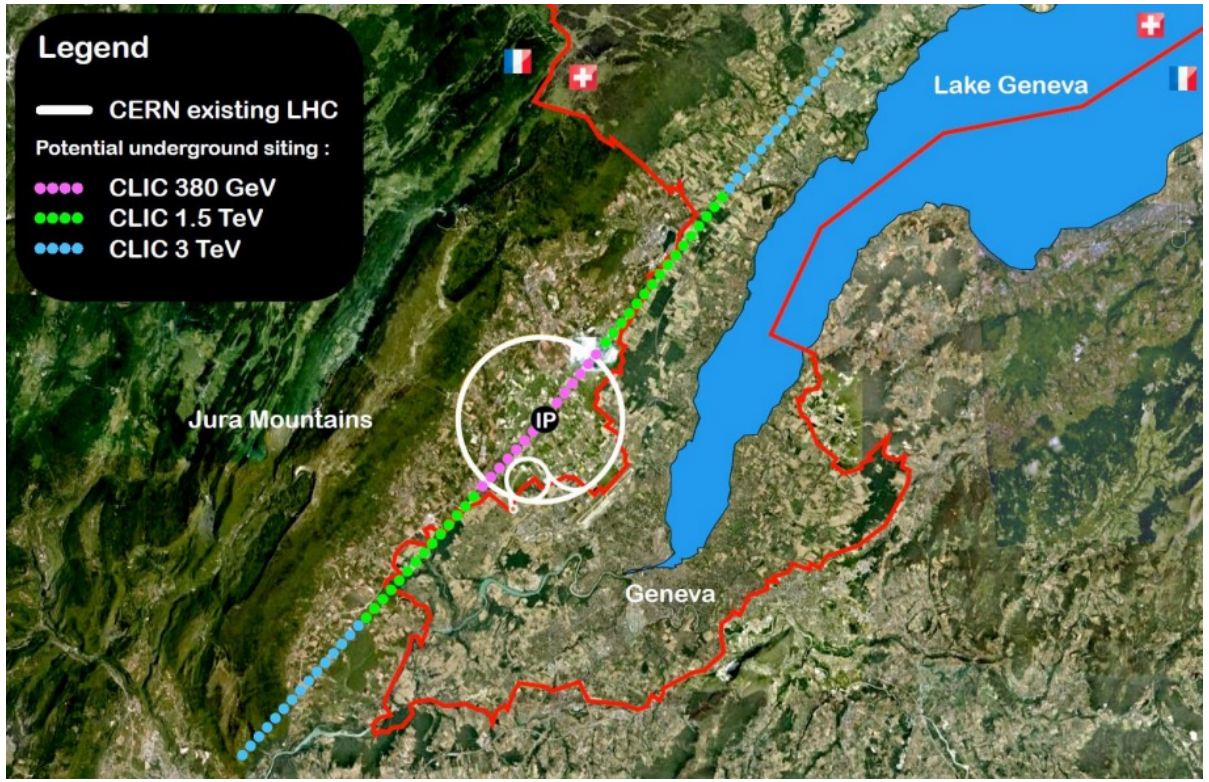
	Energy saved
Cooling and ventilation consolidation	6 GWh/year
75 consolidation projects for buildings	10+ GWh/year
Science Gateway	200+ MWh/year
Optimisation of Cryo operations mode	25 GWh/year
Heat recovery projects	
Meyrin and Prévessin	30+ GWh/year
Ferney-Voltaire	20 GWh/year

Sustainability related panels/activities at CERN



SCE Technical Seminar
Lifecycle Assessments

Future Projects - Linear Colliders

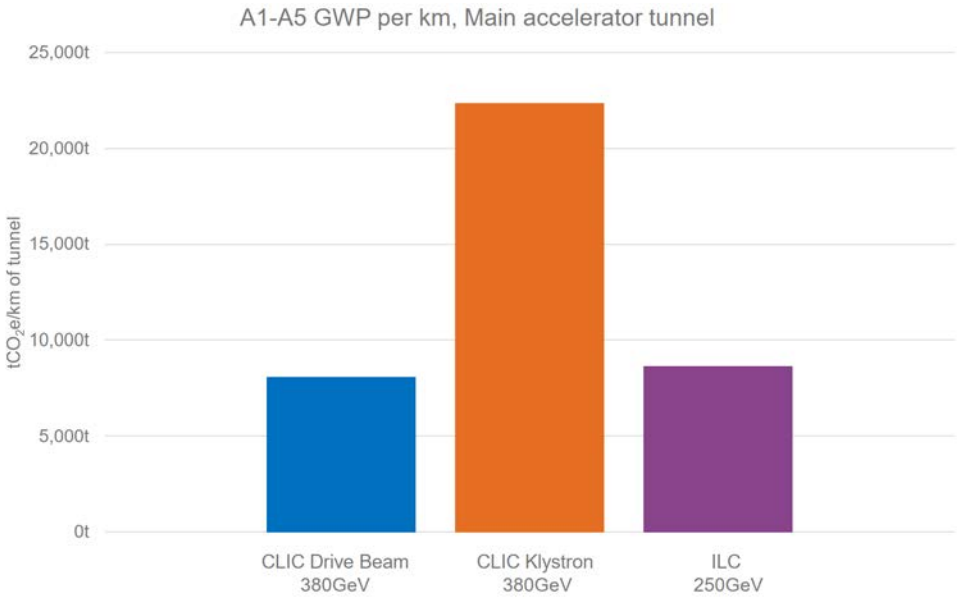


Introduction to Linear Colliders
Steinar Stapnes, CERN

Lifecycle Assessment of Linear Colliders
Suzanne Evans, ARUP

Key topics

- Embodied CO_2
- Lifecycle assessment framework
- Construction energy consumption
- Benchmarking, comparisons to other projects
- Carbon reduction opportunities



ARUP

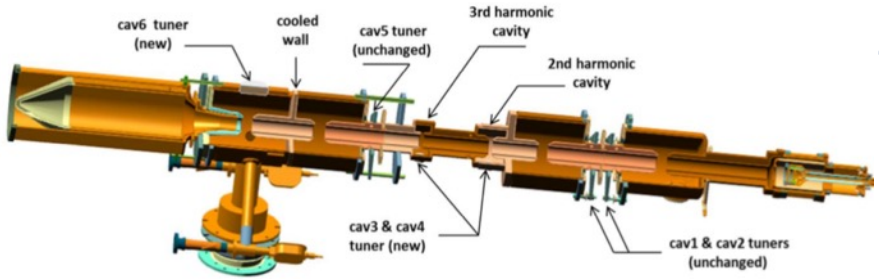
CERN

FUTURE CIRCULAR COLLIDER

FCC-ee R&D Examples

Efficient RF power sources

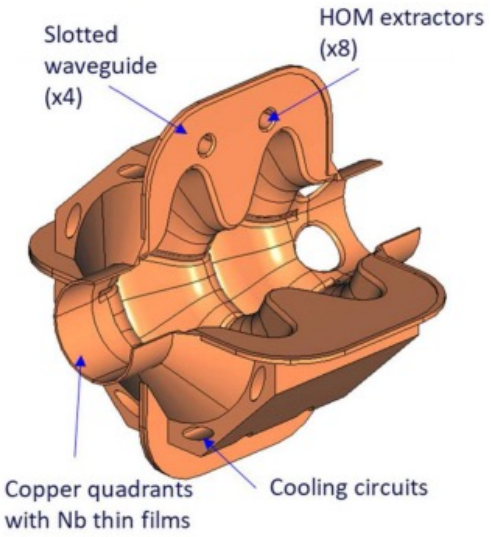
(400 & 800 MHz)



High efficiency klystrons & scalable solid-state amplifiers, FPC & HOM coupler, cryomodule, thin-film coatings

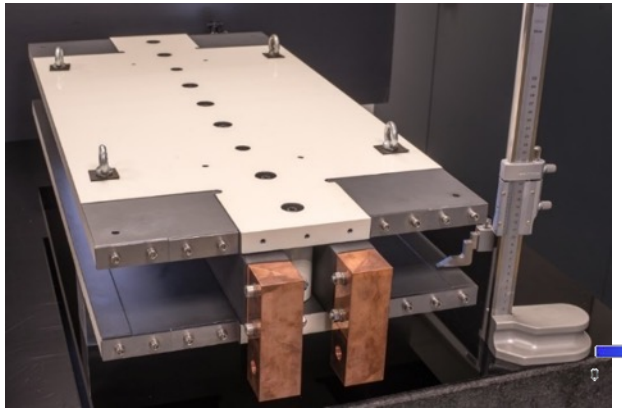
Efficient high-Q SC cavities

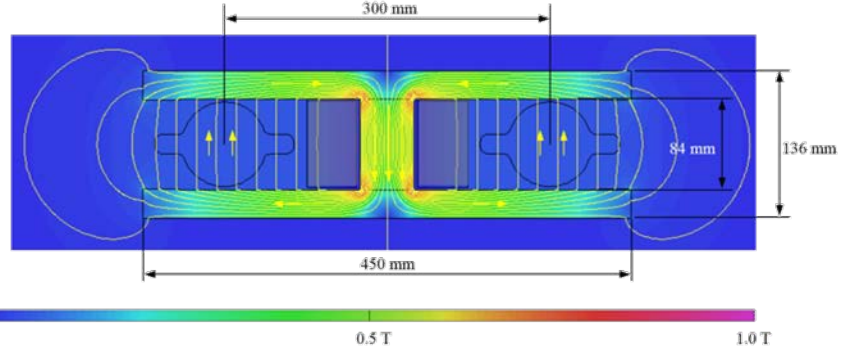
400 MHz 1 & 2 cell Nb/Cu, 4.5 K



Slotted Waveguide Elliptical cavity (SWELL) for high beam current & for high gradient

Energy **efficient** twin aperture **arc dipoles**





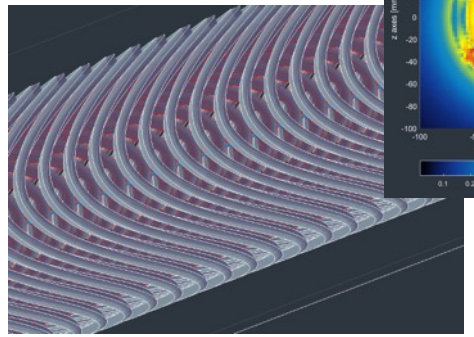
2840 x ~21 m -> 60 km

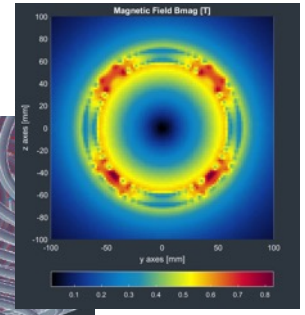
Under study: **CCT HTS quads & sexts for arcs**

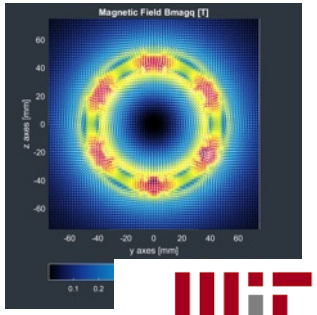
- **reduce energy consumption** by O(50 MW)

PAUL SCHERRER INSTITUT

PSI



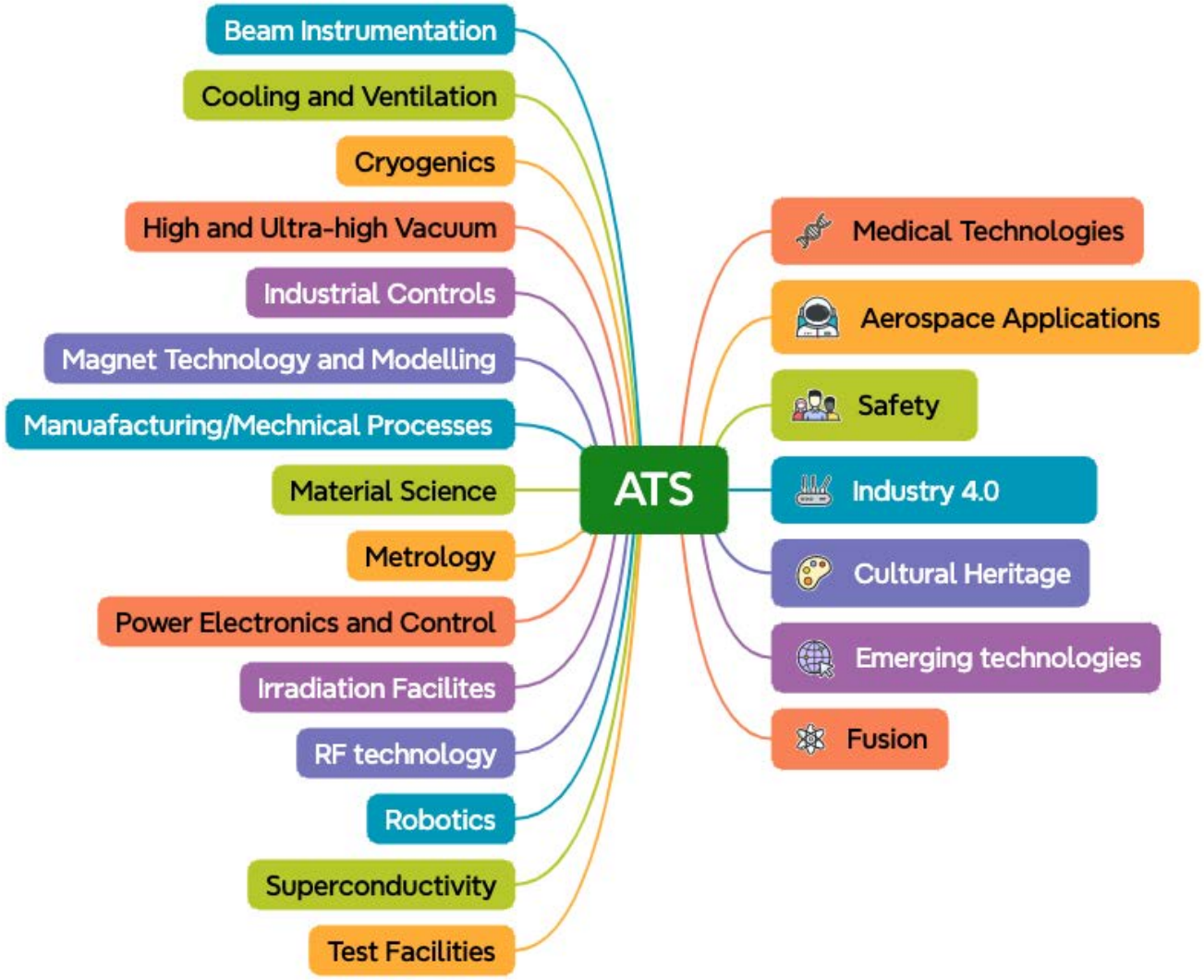




Massachusetts Institute of Technology

Knowledge Transfer

Lots going on…



CIPEA – Flagship Projects under Implementation

RENEWABLE AND LOW-CARBON ENERGY

Agreement with **GTT** to support the design of large cryostats for the maritime transportation of liquid hydrogen

GTT
Technology for a Sustainable World

CLEAN TRANSPORTATION AND FUTURE MOBILITY

Partnership with **Airbus** to assess SC power distribution options for future electric/hybrid airplanes using liquid hydrogen

AIRBUS

CLIMATE CHANGE AND POLLUTION CONTROL

Collaboration with **ESA** Phi-lab to develop AI algorithms to analyse Earth Observation space images for climate monitoring

esa

SUSTAINABILITY AND GREEN SCIENCE

Project with **ABB** to improve energy efficiency of CERN cooling and ventilation with smart sensors and digital twins

ABB

ATS Fusion Technology Coordination Unit

M. Battistin, B. Bordini, L. Bottura, E. Chesta L. Scibile, J.P. Tock, R. Veness

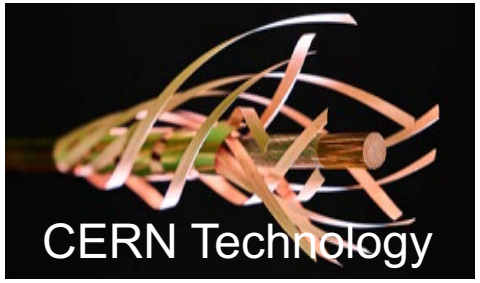
KT initiatives

Advise, coordinate, facilitate

Public sector:
ITER
EUROFusion
F4E
UKAEA
…

CERN

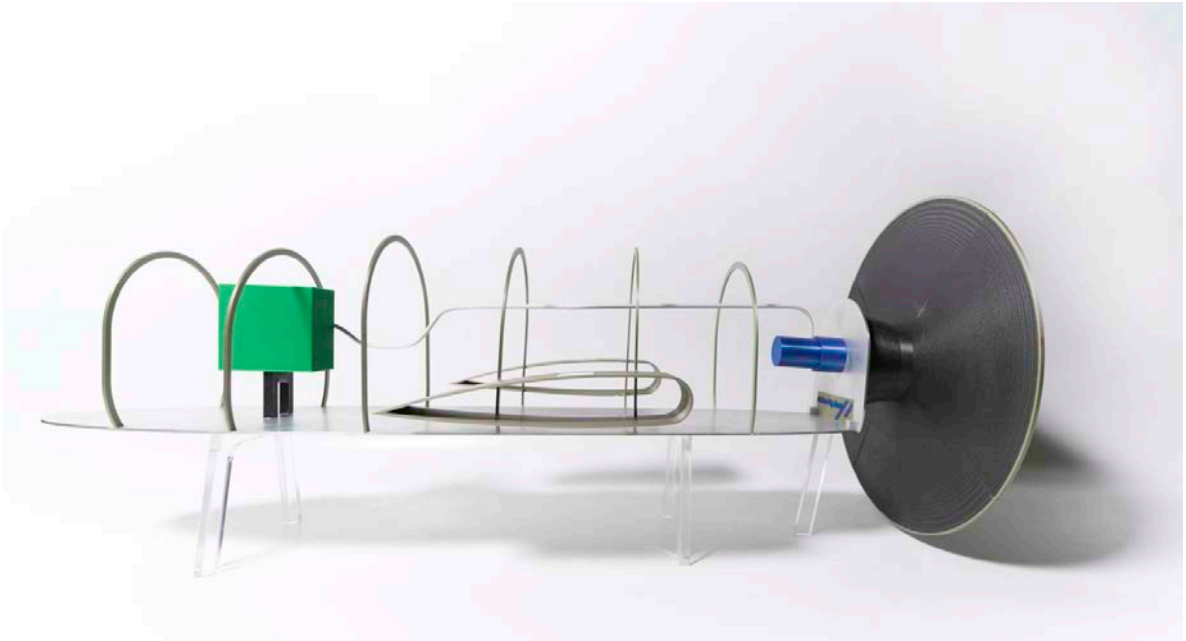
Private sector:
Gauss Fusion
Tokamak Energy
Rolf Kind
…



This is coordination, FTCU not necessarily owners of agreements (ATS or KT activities)

Partnership with AIRBUS on superconductivity

In 2022, CERN and Airbus UpNext started an innovation partnership to evaluate how superconductivity can be useful in future zero-emission aircraft.
In 2023, a superconductive demonstrator has been built at CERN, and first results of the tests came end 2023.



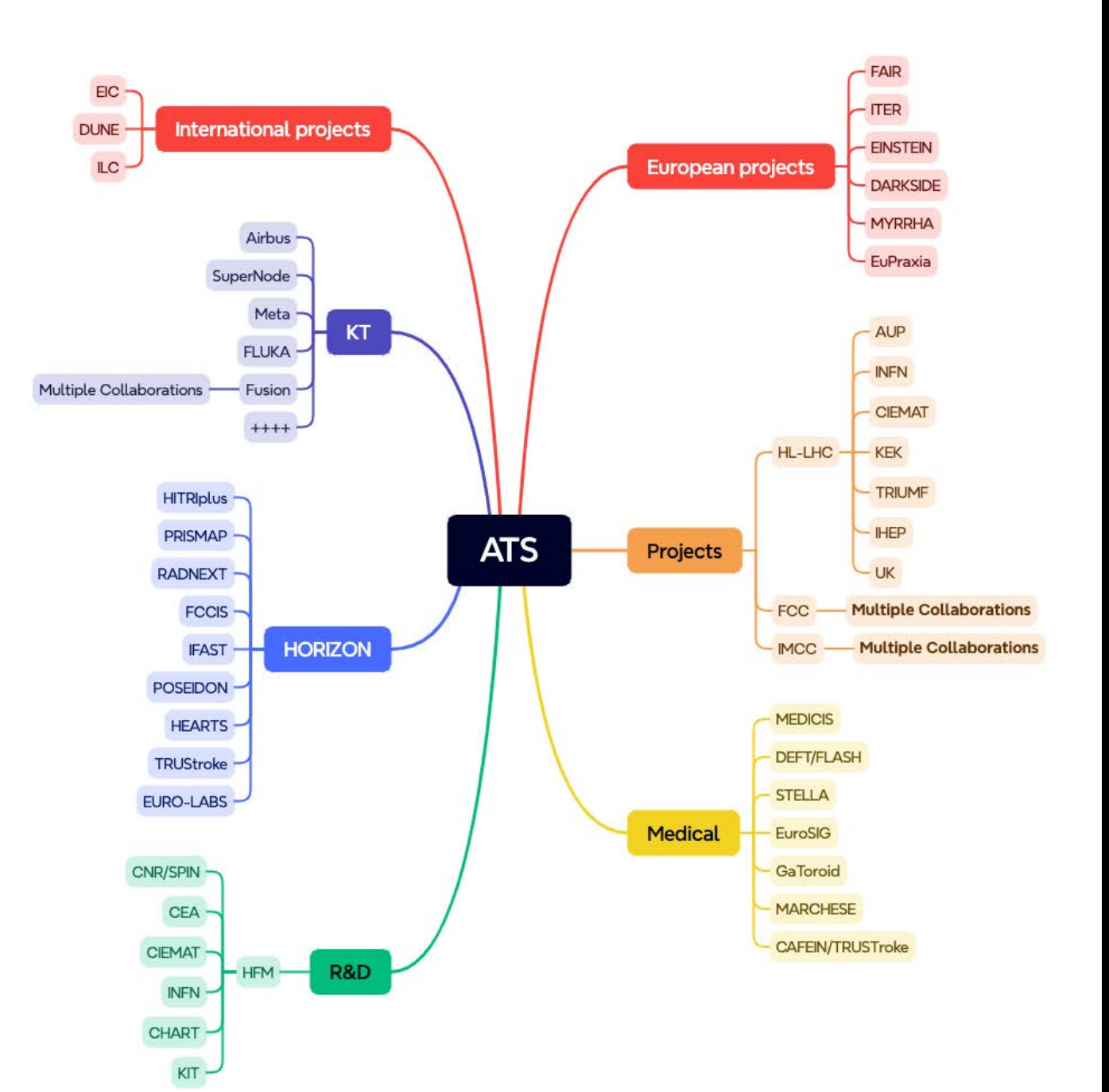
We are also happy to conclude the year with the successful test of the SCALE system that we have conceived and built for Airbus: a novel light (< 300 g/m) REBCO cable operated in DC mode at 4 kA (+/- 2 kA) at up to 68 K. This measurement relied on the 600 A HTS REBCO HL-LHC current leads, also successfully qualified during the test campaign.

A. Ballarino, *et al.*

Collaboration with META

Agreement signed to investigate a possibility of using superconducting links for the power distribution in META's data center.

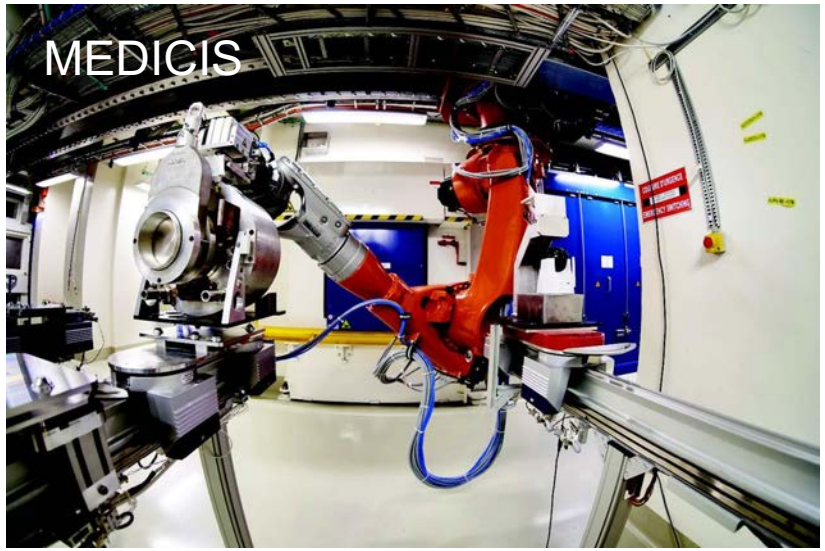
Rich Collaborative Ecosystem

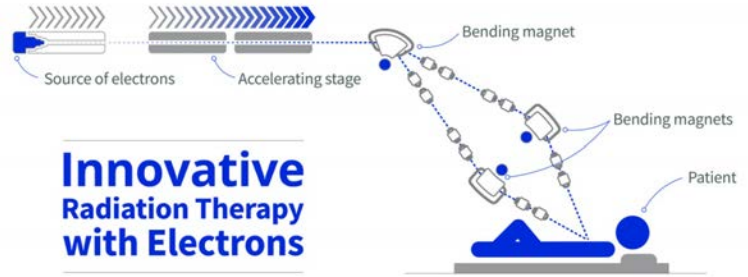


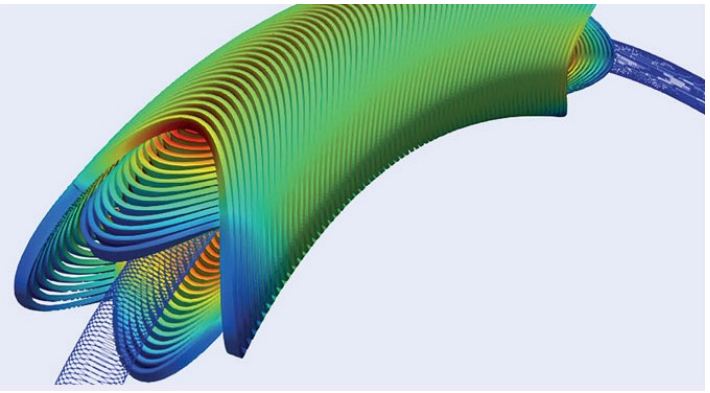
ATS – significant engagement in HORIZON

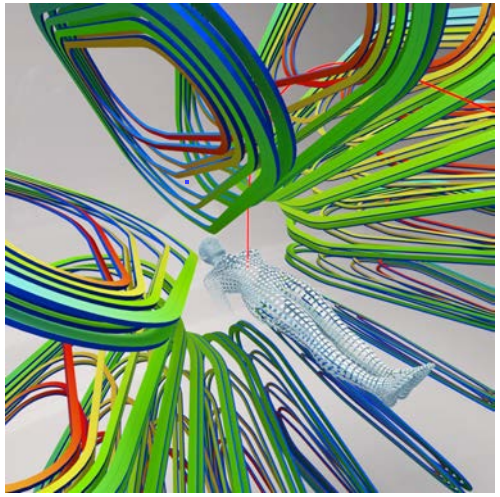
All of these projects back by European wide collaboration

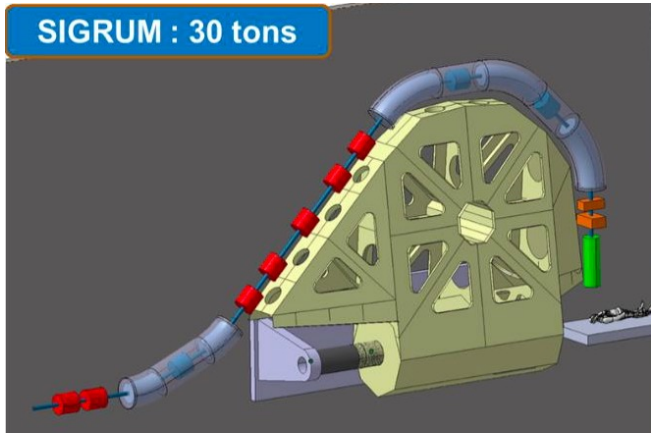
HORIZON		
	CALL	SUBJECT
PRISMAP	INFRAIA-2020	European medical isotope programme: Production of high purity isotopes by mass separation
HITRIplus	INFRAIA-2020	Heavy Ion Therapy Research Integration plus
POSEIDON	CL5 CLIMATE	POwer StoragE In D OceaN
HEARTS	CL4 SPACE	High-Energy Accelerators for Radiation Testing and Shielding
TRUSTroke	HLTH-2022-STAYHLTH	TRUSTWORTHY AI FOR IMPROVEMENT OF STROKE OUTCOMES
LISA	H2020-MSCA-ITN	Laser Ionization and Spectroscopy of Actinide elements
FCCIS	INFRADEV-2019	Future Circular Collider Innovation Study
RADNEXT	INFRAIA-2020	RADiation facility Network for the EXploration of effects for indusTry and research
I.FAST	INFRAINNOV-2020	Innovation Fostering in Accelerator Science and Technology
EURO-LABS	INFRA-2021-SERV	EUROpean Laboratories for Accelerator Based Science
MuCol	INFRA-2022-DEV	Design Study for a Muon Collider complex at 10+ TeV center of mass











Medical

Wide range of initiatives!

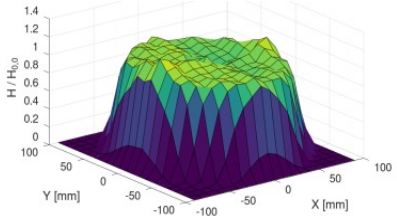
MARCHESE
Machine learning based human recognition and health monitoring system

An innovative FLASH VHEE radiotherapy facility

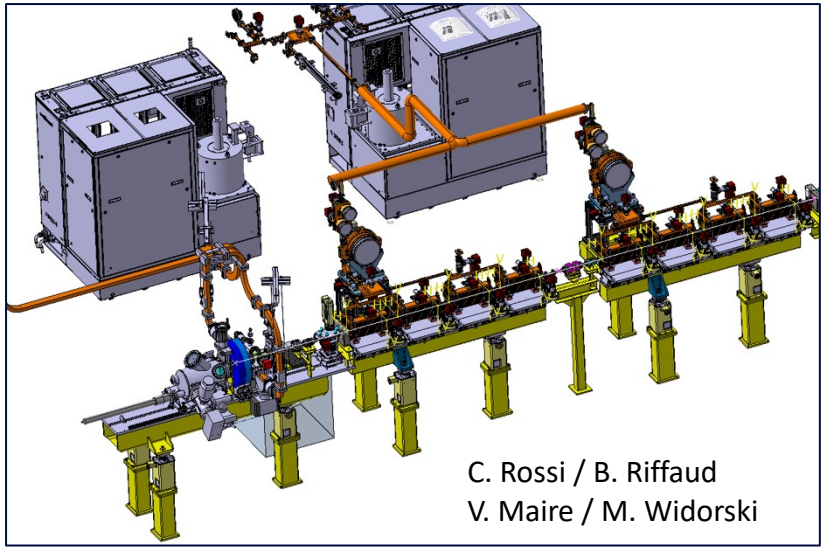
Ongoing collaboration between CERN, CHUV and THERYQ for the design and construction of a radiotherapy facility using a unique accelerator based on CLIC technology (DEFT).

A. Latina / A. Malyzhenkov / A. Grudiev

New accelerating cell design to compensate octupolar effect



The RF design and beam dynamics for DEFT are <u>VERY</u> challenging -> uniformity with the large required field



C. Rossi / B. Riffaud
V. Maire / M. Widorski

Confidential

Construction site of the future bunker, CHUV, Lausanne.

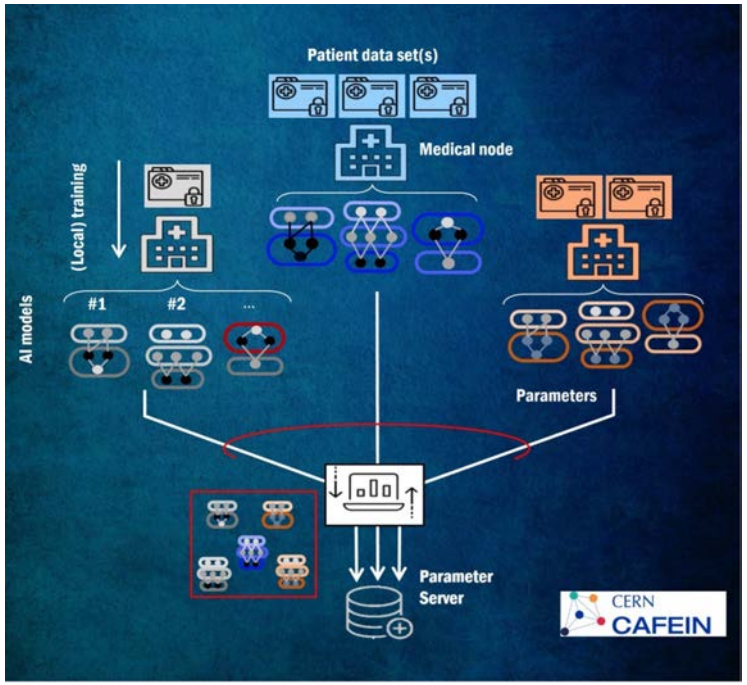
First clinical trials ~2027

Acknowledgments – Walter Wuensch, Olivier Brunner

AI and federated learning for healthcare

CAFEIN is an AI-based tool deployed via a federated learning platform, finds application in several health domains.

1. A project with IARC (WHO's International Agency for Research on Cancer) was started, with the goal of assisting in the screening, diagnosis, prevention and therapy evaluation of breast and prostate cancer. The project is supported by the Medical Applications budget.



TRUSTroke meeting at CERN in September 2023.

2. The EC-funded project TRUSTroke started (1M€ for CERN), aiming at trustworthy assessment of stroke progression and risk of recurrence on a federated learning platform.

Knowledge Transfer seminar (recording available) : https://indico.cern.ch/e/trustroke

Luigi Serio, *et al.*

NIMMS (Next Ion Medical Machine Study)

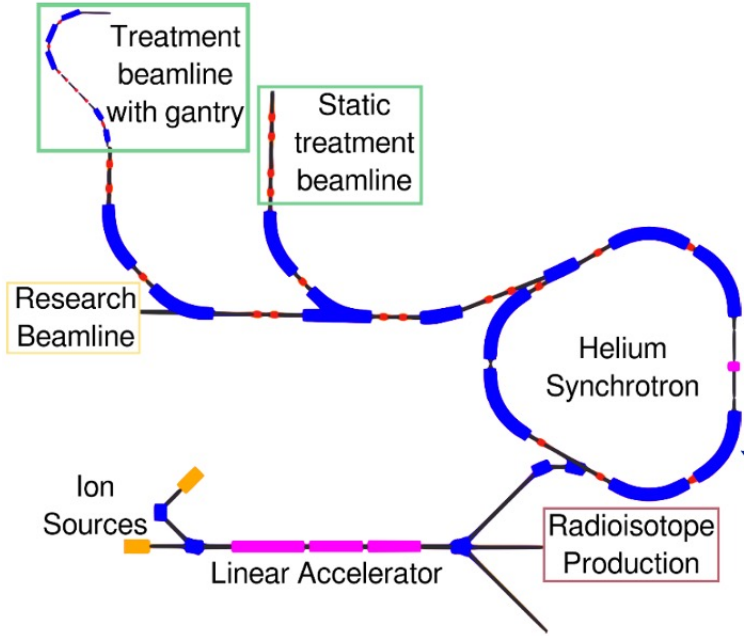
Building on CERN expertise to develop **a portfolio of technologies** that can be used in a next generation facility

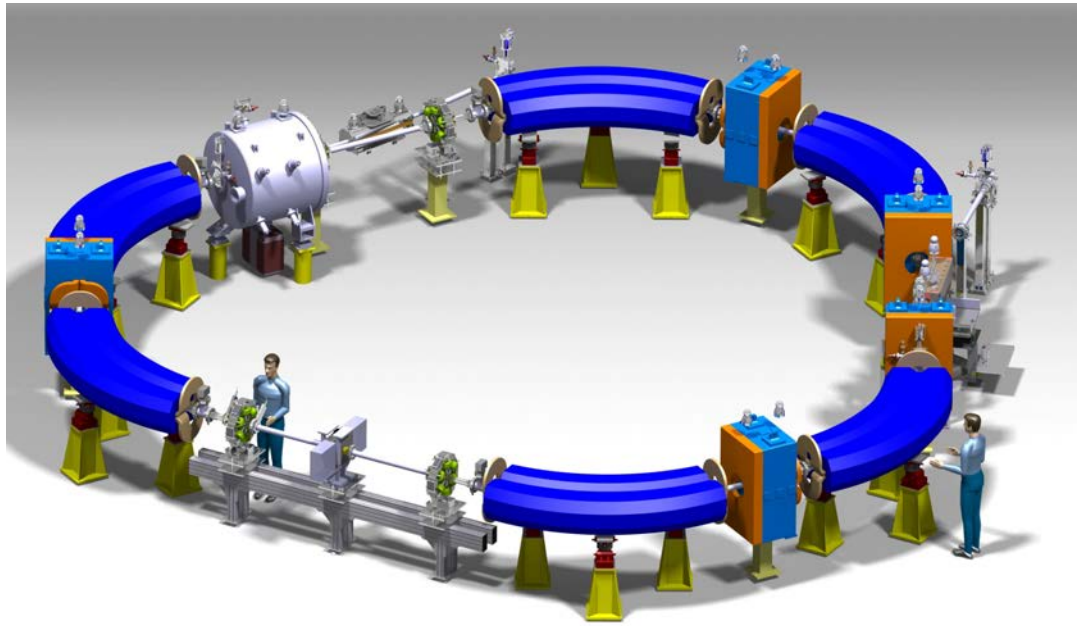
Multi-ion synchrotron (beyond p and C-ions)
Compact and cheaper superconducting synchrotron
Compact ion linac
Superconducting gantries
Higher beam intensity, faster extraction; real time imaging

Interest in the Baltic States for an Advanced Particle Therapy Centre

CERN Baltic Group

Draft concept paper
Advanced Particle Therapy Center for the Baltic States





Staff Survey response

86.2% enjoy their work
91.2% are proud to work at CERN
91.4% care about the future of CERN
but…!

Development Opportunities

- Career development
- Internal mobility
- Training

Work Environment and Culture

- Workload, resources, resources, resources
- Retention of expertise
- State of offices and catering facilities

Vision

- Communications
- Uncertainty about post HL-LHC era
- Prioritization of activities and resources

Five CERN-wide recommendations for action presented at end 2023

In addition to global ATS actions, each department is now working to towards implementing their own adapted actions following the surveys – more from your DHs

GENDER target
(aspirational)

GOAL

With a particular focus on **women in STEM:**

from 21% in 2020 → 25% in 2025

OUR VISION

scientific excellence through diversity and inclusion

OUR GOAL

to increase the nationality and gender diversity of Staff & Fellows (MPE) population by 2025

25 by '25

Accelerating diversity at CERN

NATIONALITY indicator
(not a cap, not a quota)

GOAL

With a particular focus on under-represented MS and a **more balanced return** by 2025:

address nationality clusters **> 25%**

and increase our conscious efforts toward nationality diversity in recruitment & retention

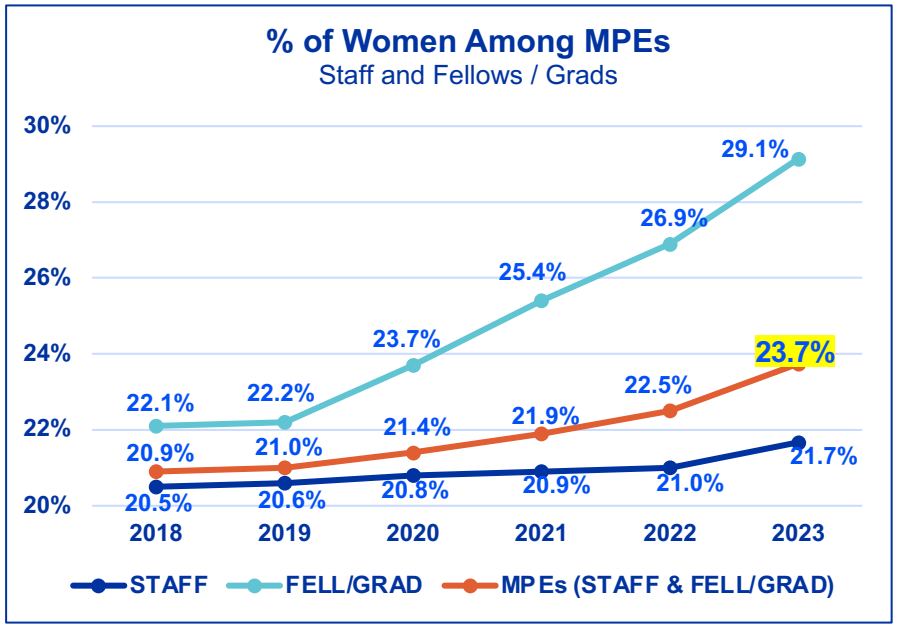
25 by '25 Periodic Update: 01 Dec 2023

2020
- Strategy Paper submitted to Director-General

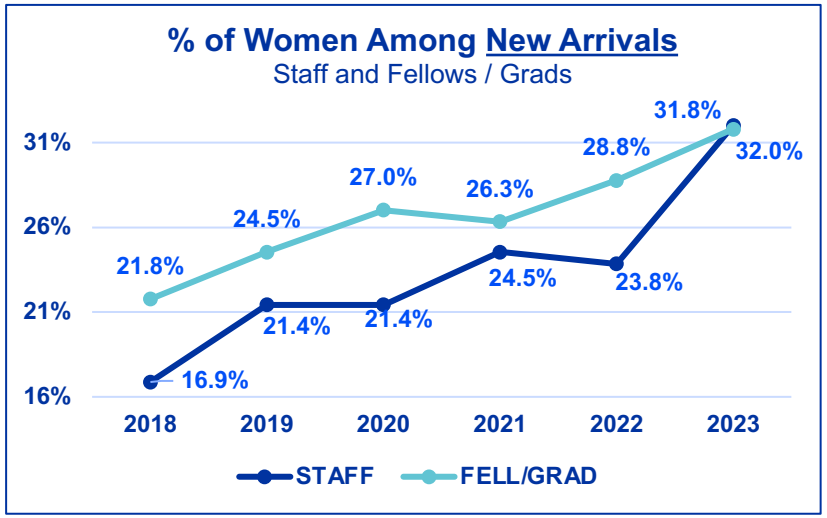
2021
- Enlarged Directorate endorses Strategy
- Department Heads appoint 33 Focal Points
- Focal Points create & consult Focus Groups
- HR implements Nat / Gen Population Dashboards

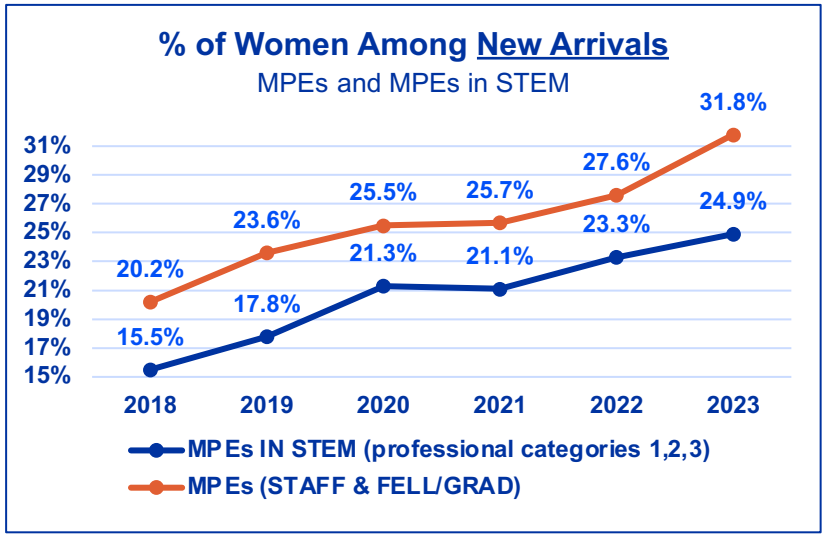
2022
- 1st D&I Review Exercise
- Action Menu + Fitness Plans approved
- Dept Heads appoint 18 D&I Officers (DIOs)
- DIOs establish a Community of Practice

2023
- Transforming Bias Workshop
- Theatre Forum on sexism
- HR implements Nat / Gen Recruitment Dashboard
- 1st Departmental Fitness Plan checkpoint



Women MPEs = **23.7%**
only 1.3% away from our 25% target!





Report from the SPC

We live in interesting times.