CERN: Future Vision and Priorities

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CERN

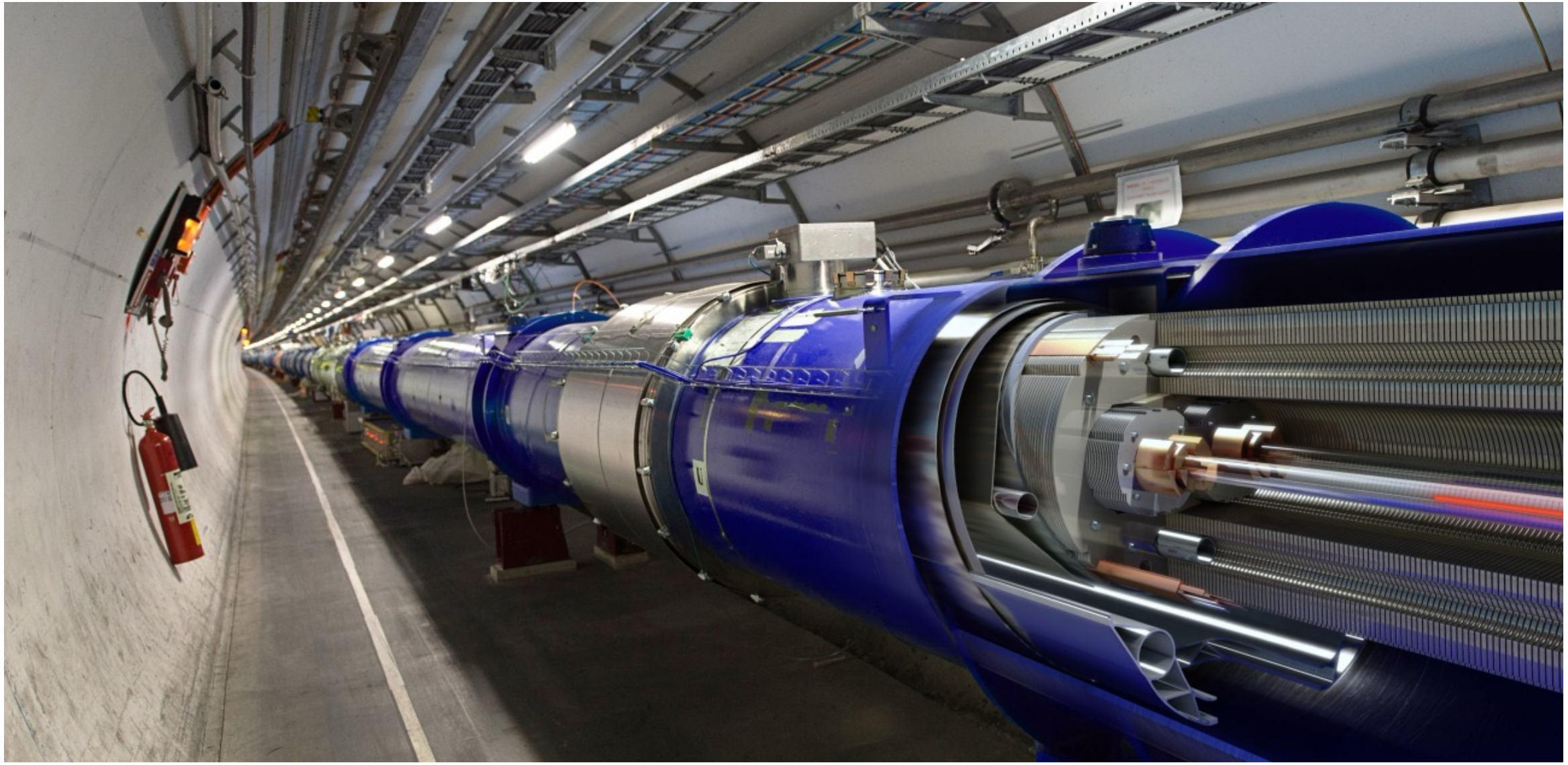
IPAC 26

Deauville

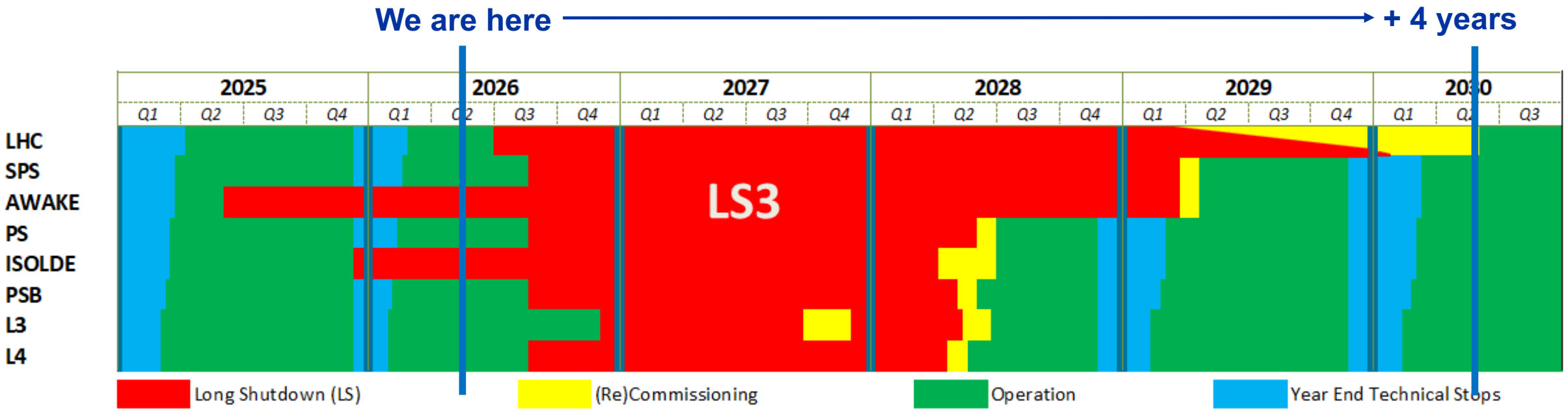
Today's presentation

- 1) Status of the LHC Run 3 and the preparations for HL-LHC
- 2) A few words on the North Area consolidation project
- 3) FCC
- 4) The European Strategy for Particle Physics – the home straight
- 5) Some of the challenges for CERN in the coming years
- 6) CERN's scientific strategy and priorities
  - HL-LHC
  - FCC-ee
  - A roadmap for non-collider physics at CERN
- 7) Concluding remarks

1) Status of the LHC and HL-LHC



Long Shutdown 3 is coming…



LS 3 start

- AWAKE: 02.06.2025
- ISOLDE: 08.12.2025
- LHC: 29.06.2026
- Injectors: 31.08.2026
- L3: 30.11.2026

Inj. Operation restart

- L4 : May 2028
- PSB : May 2028
- PS : July 2028 (*)
- SPS : April/May 2029 (*)

(*) To be optimised

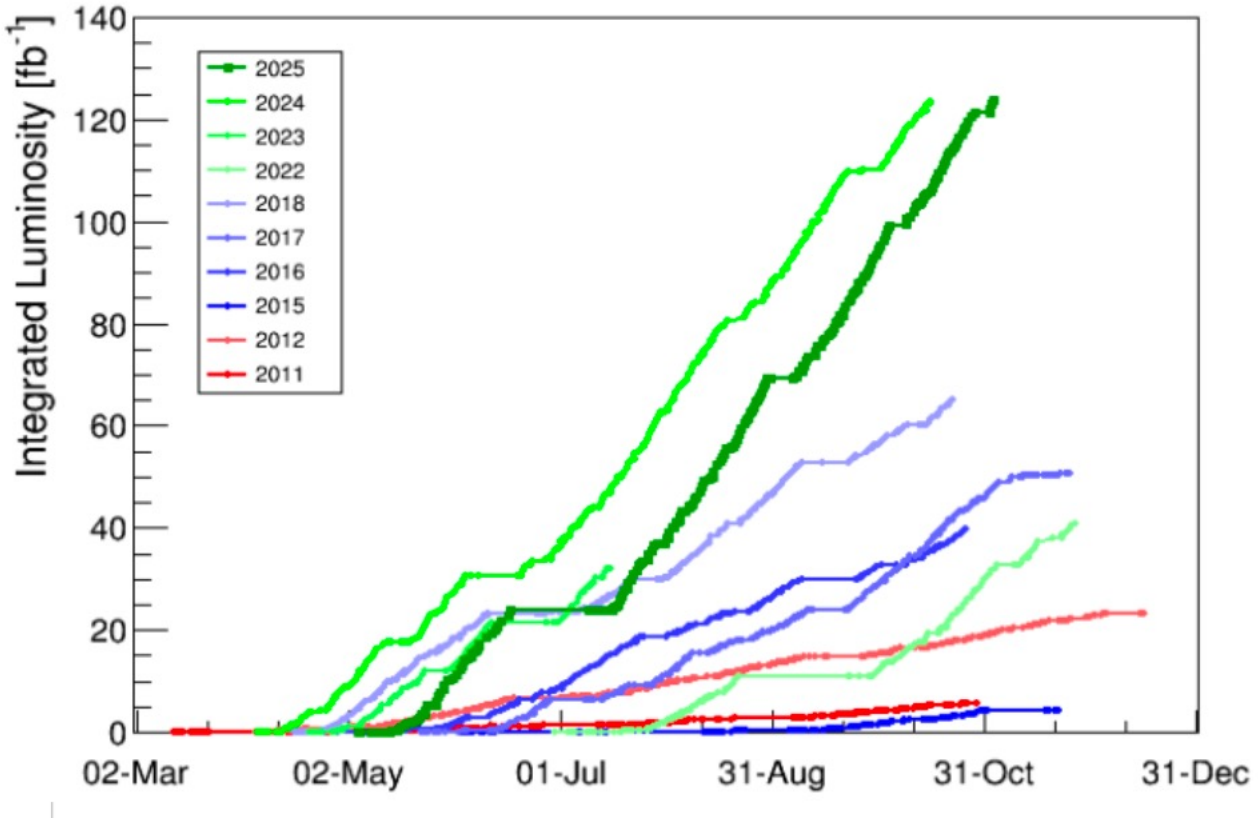
LHC restart

- 1st sectors cooldown : Early 2029
- Final HW Com (P1&5) : January 2030
- Caverns closure : Mid-May 2030
- Beam vac valves op : End-May 2030

The LHC remains a beautiful machine

2025 was a record-breaking year: delivered over 125 fb^{-1} to ATLAS/CMS

- 2026: a shorter run before start of Long-shutdown 3



By the end of 2025:
ATLAS/CMS had each accumulated **~520 fb^{-1}**

2026 LHC Schedule

Highly compressed startup

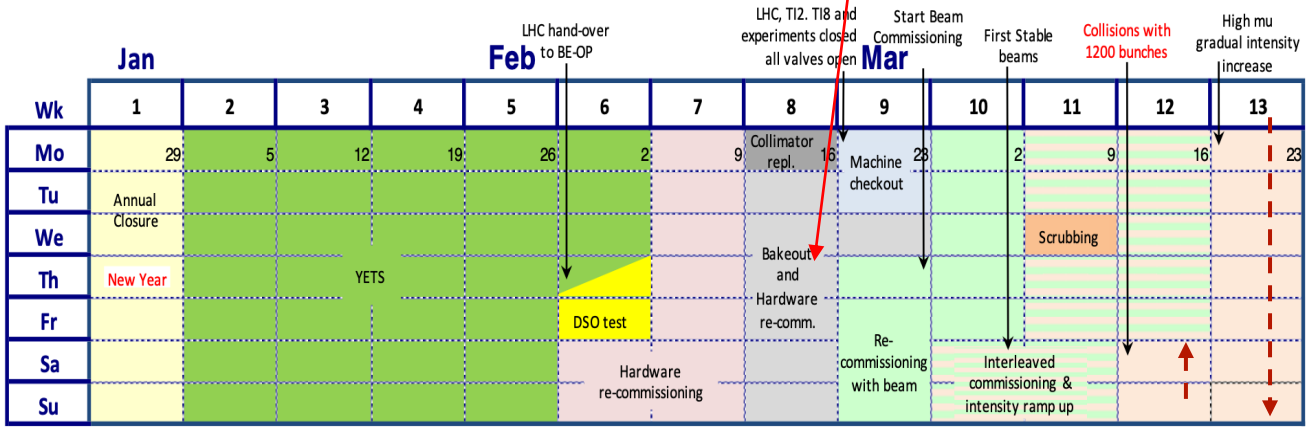
- <11 weeks beam-to-beam YETS
- **< 2 weeks for powering tests**
- 9 days of beam commissioning

Diverse programme:

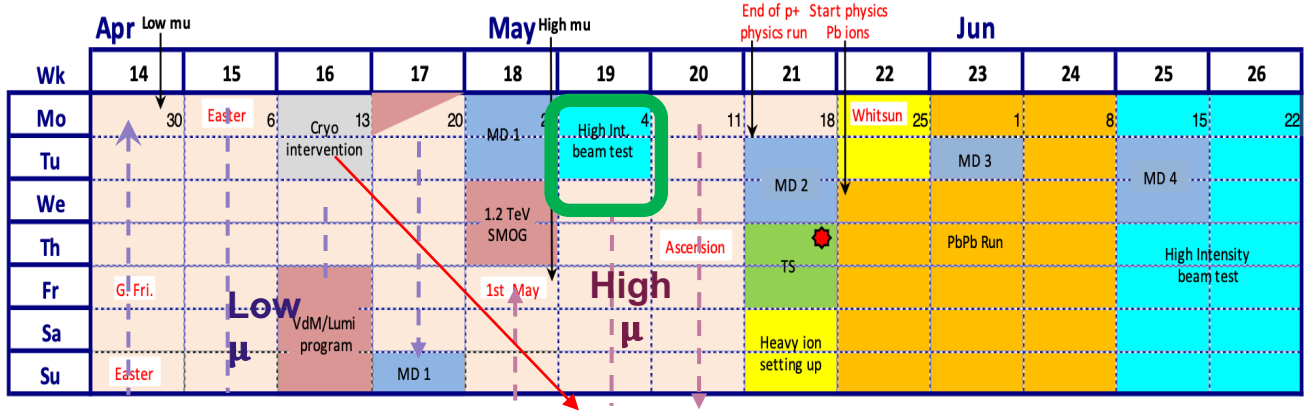
- Intensity ramp up and high-μ run
- Low-μ run
- VdM
- LHCb “1 TeV” run
- MDs
- High intensity tests
- Pb-Pb ion run

Last proton-proton run scheduled for today

Collimator vacuum leak: delay ~5 days



High μ



Warm Compressor exchange: delay 2 days

2026: the machine is running beautifully again

Low pile-up runs for ATLAS (μ=3) and CMS (μ=5) are ahead of schedule – will benefit the precise measurement of W mass

And very long fills are good news for LHCb

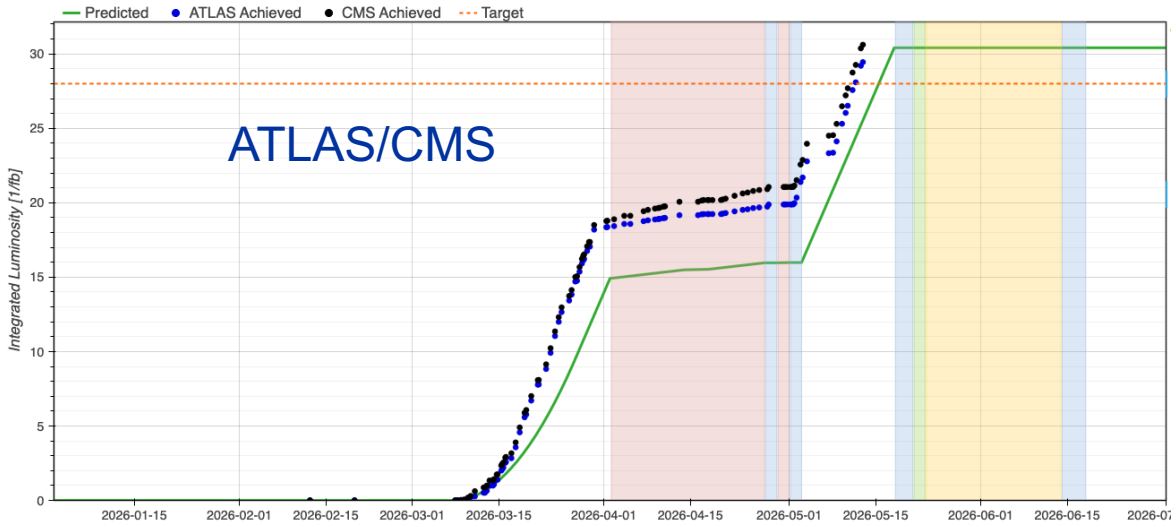
Performance targets (p-p) exceeded:

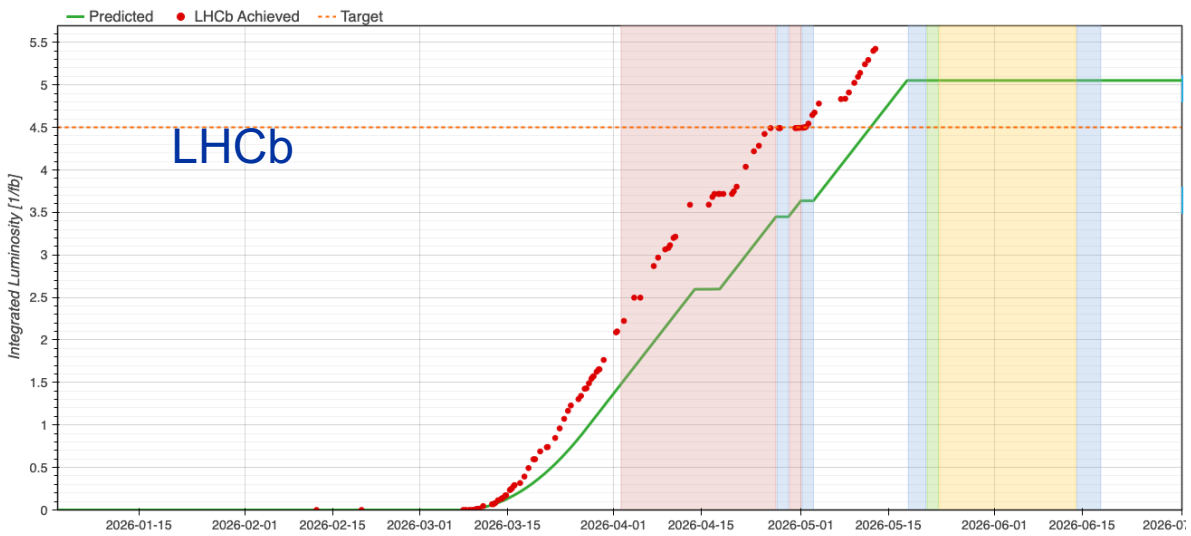
p-p target

- ATLAS/CMS: 28 fb^{-1}
- LHCb: 4.5 fb^{-1}
- ALICE: 28 nb^{-1}

Pb-Pb target

- ATLAS/CMS: 1.8 nb^{-1}
- LHCb: 0.6 nb^{-1}
- ALICE: 1.3 nb^{-1}





Thanks to my CERN colleagues for this spectacular achievement – this doesn't happen by chance

What Next for CERN? HiLumi-LHC (HL-LHC)

The High-Luminosity LHC

- major “upgrade” of the LHC, starting operations ~2030 and running until 2041
- based on cutting-edge Nb_3Sn technology that didn’t exist when the LHC was built

With ~10 times increased luminosity compared to the LHC

- in many ways, we are just at the start of the LHC/HL-LHC journey

Meanwhile the detectors and triggers will become ever more capable

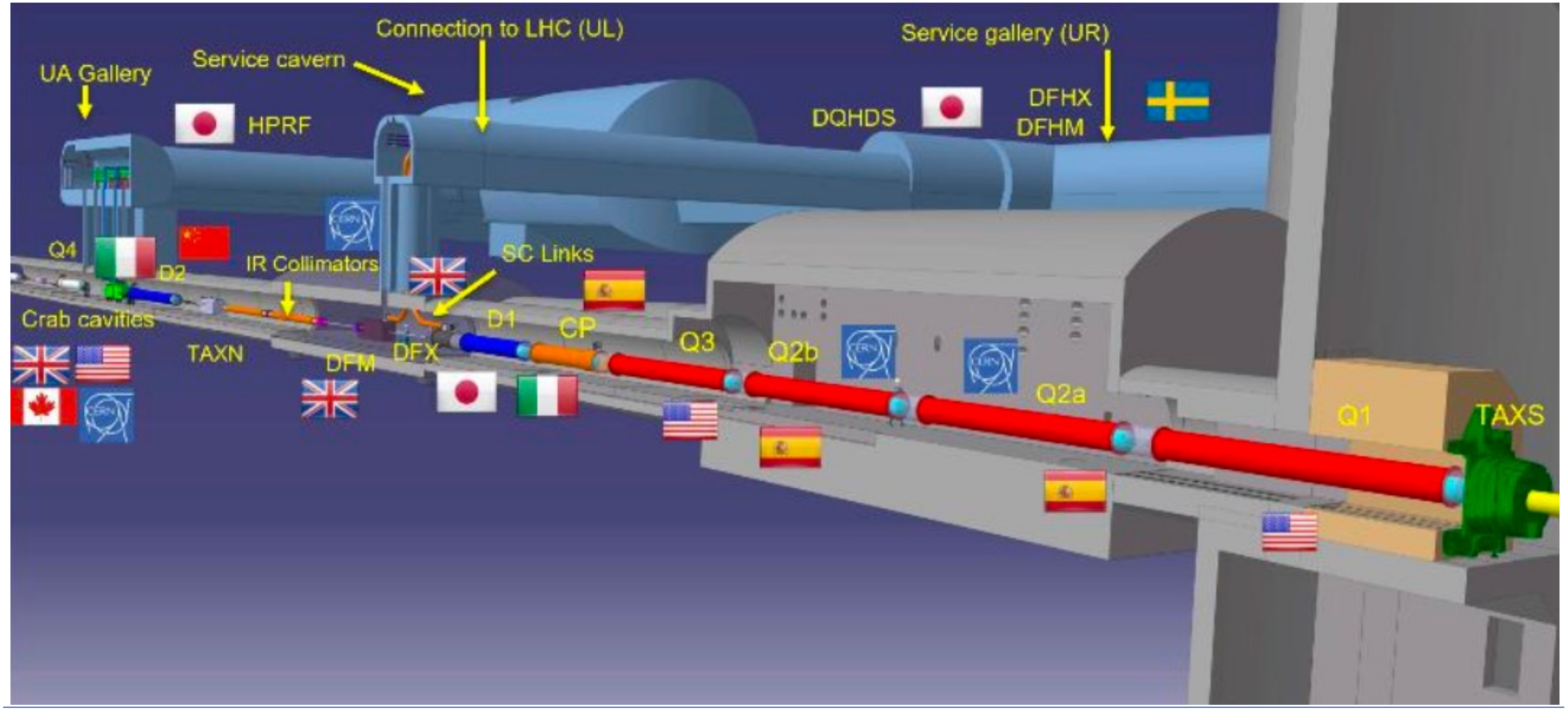
- the upgrades of ATLAS and CMS are central to the HL-LHC programme

And never forget the people

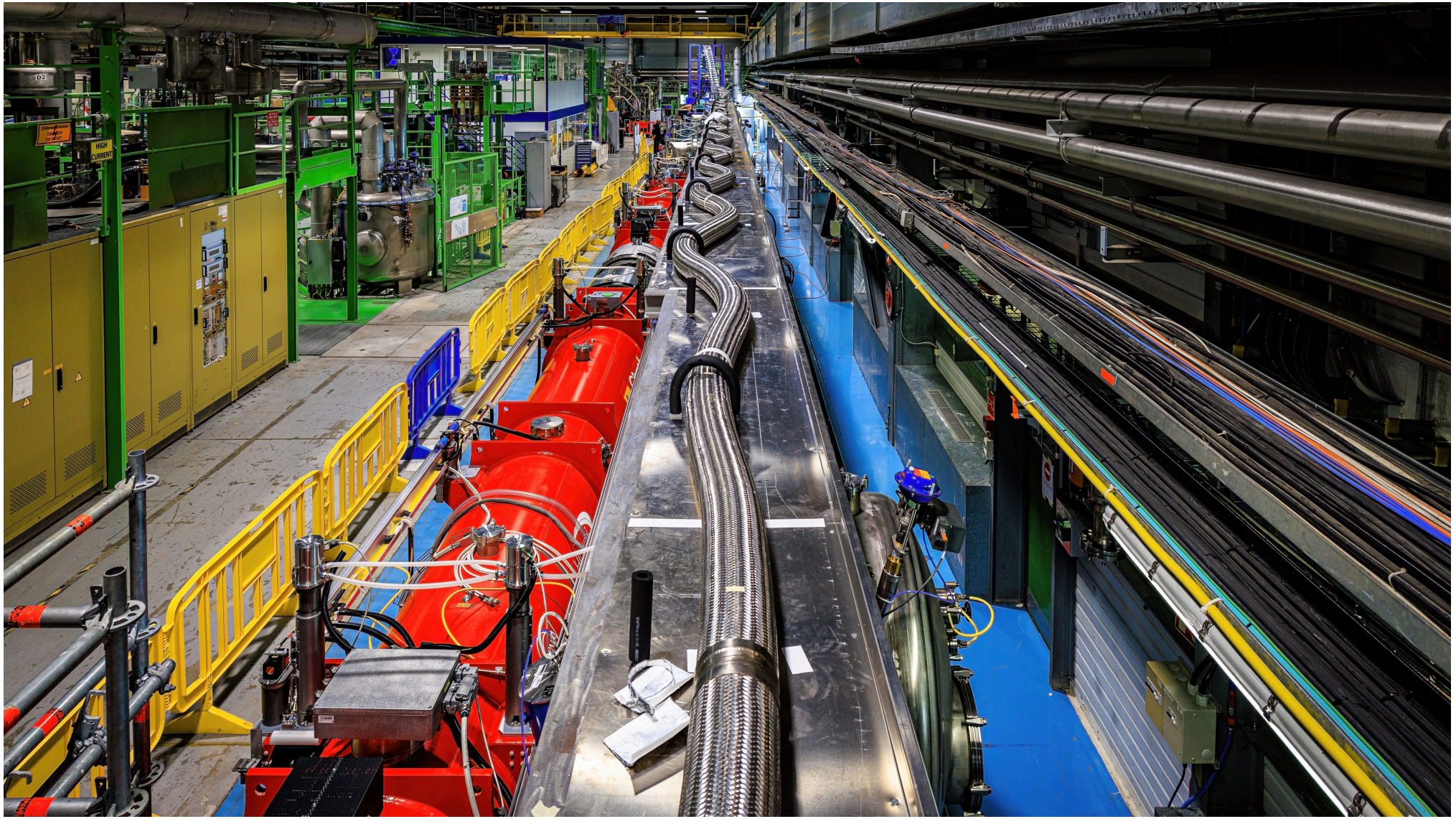
- Brilliant young researchers, aided by AI tools, will give ever greater power

The HL-LHC is an incredible scientific opportunity
- a lot more data, even better detectors, new techniques
- **real discovery potential!**

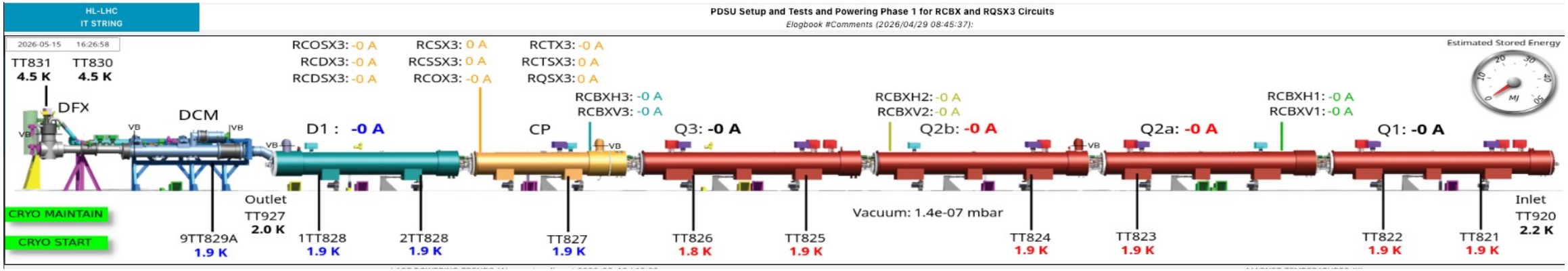
It is also a major international collaboration

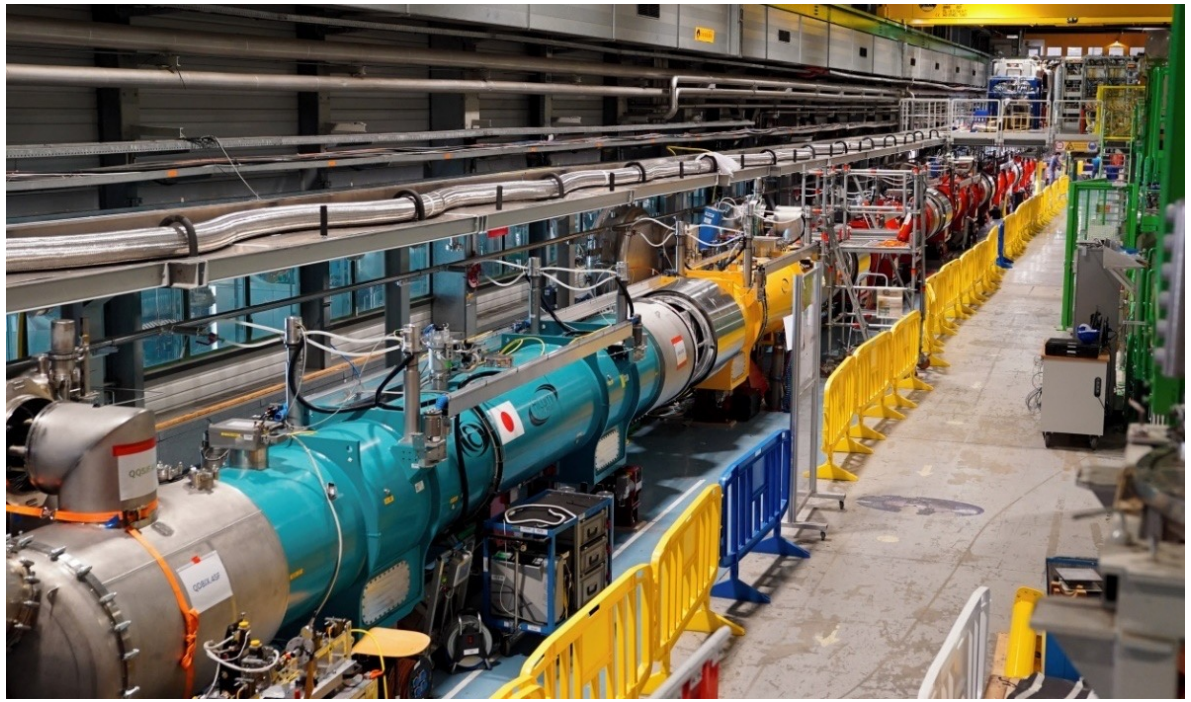


HL-LHC today in SM18: the Inner Triplet String



Making great progress with the Inner Triplet String





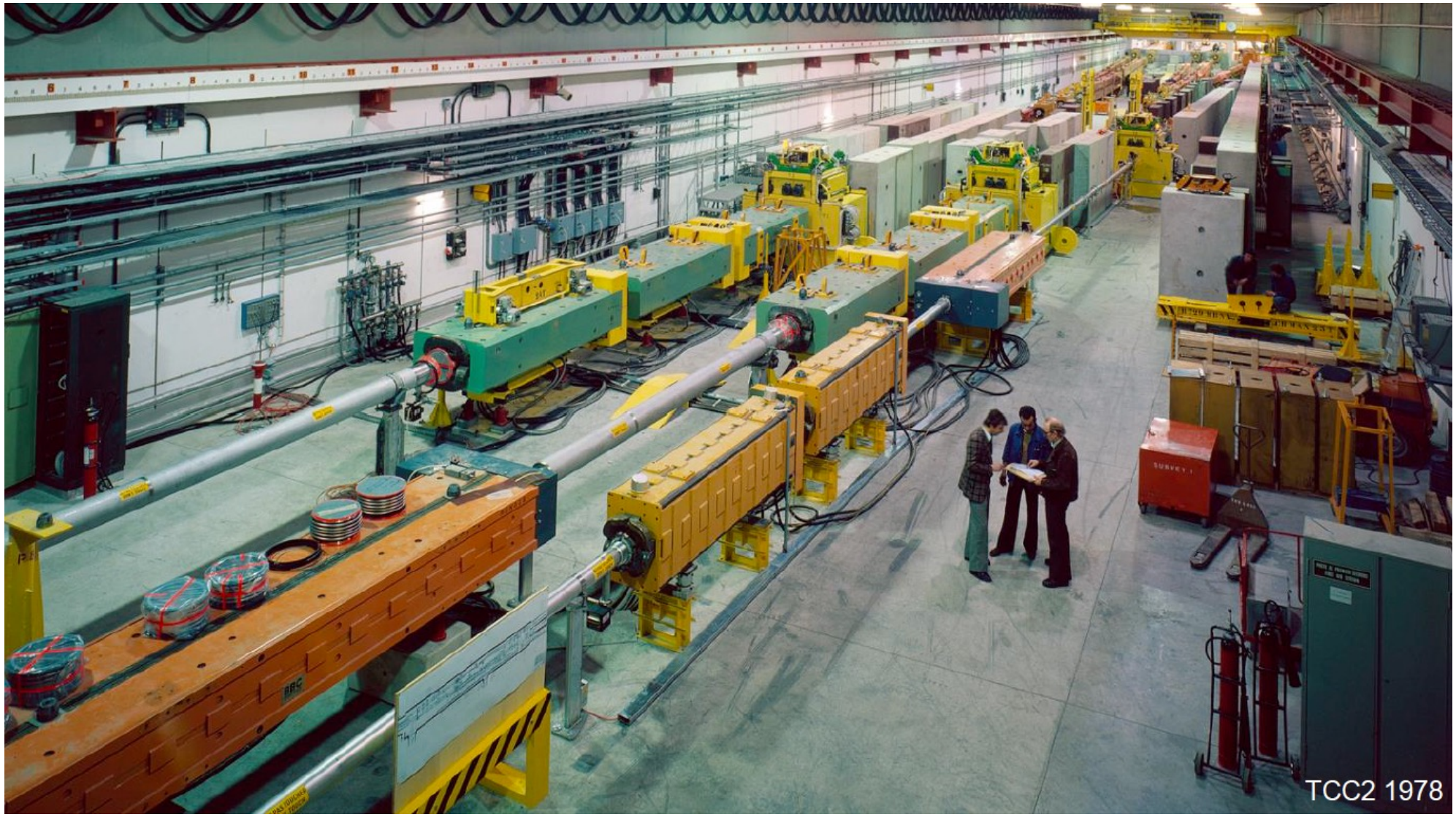
- IT-String Reached 1.9K on March 17th
- Corrector magnet powering tests complete
- Main circuit powering tests in progress
- All powering tests will be complete by the end of Summer 2026
- Run 2 of Inner Triplet String in 2027

HL-LHC: progress with cryogenic infrastructure

Cold Box (QURCG) handling and installation completed in Point 5

Lowering and temporary storage of first spools for connection to QPLG in Pt5

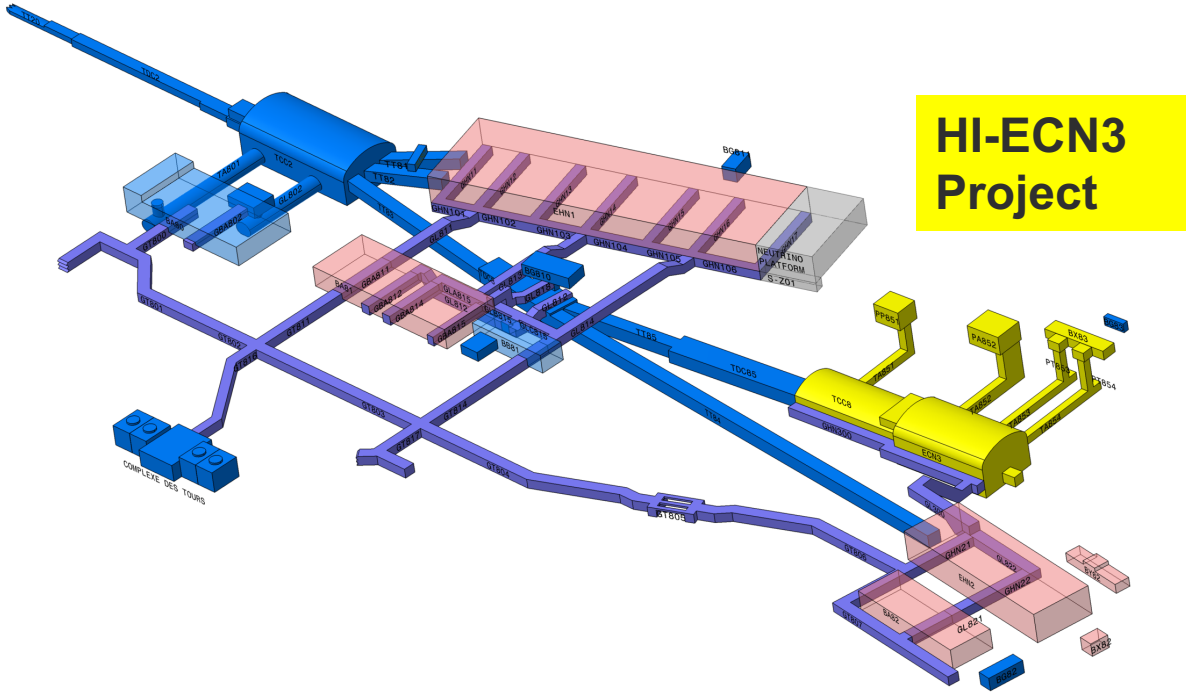
2) North Area consolidation (NA-CONS)

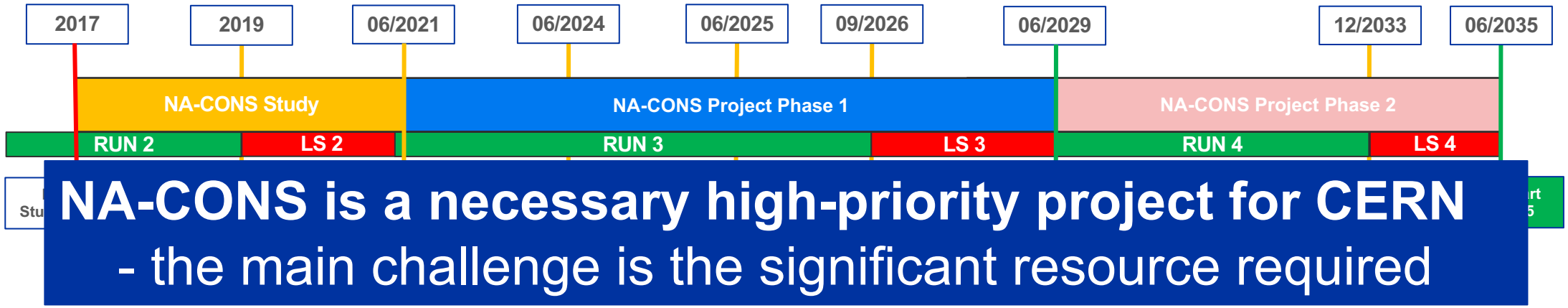


NA-CONS

Renovation of the Fixed Target Experimental Area site after 47 years

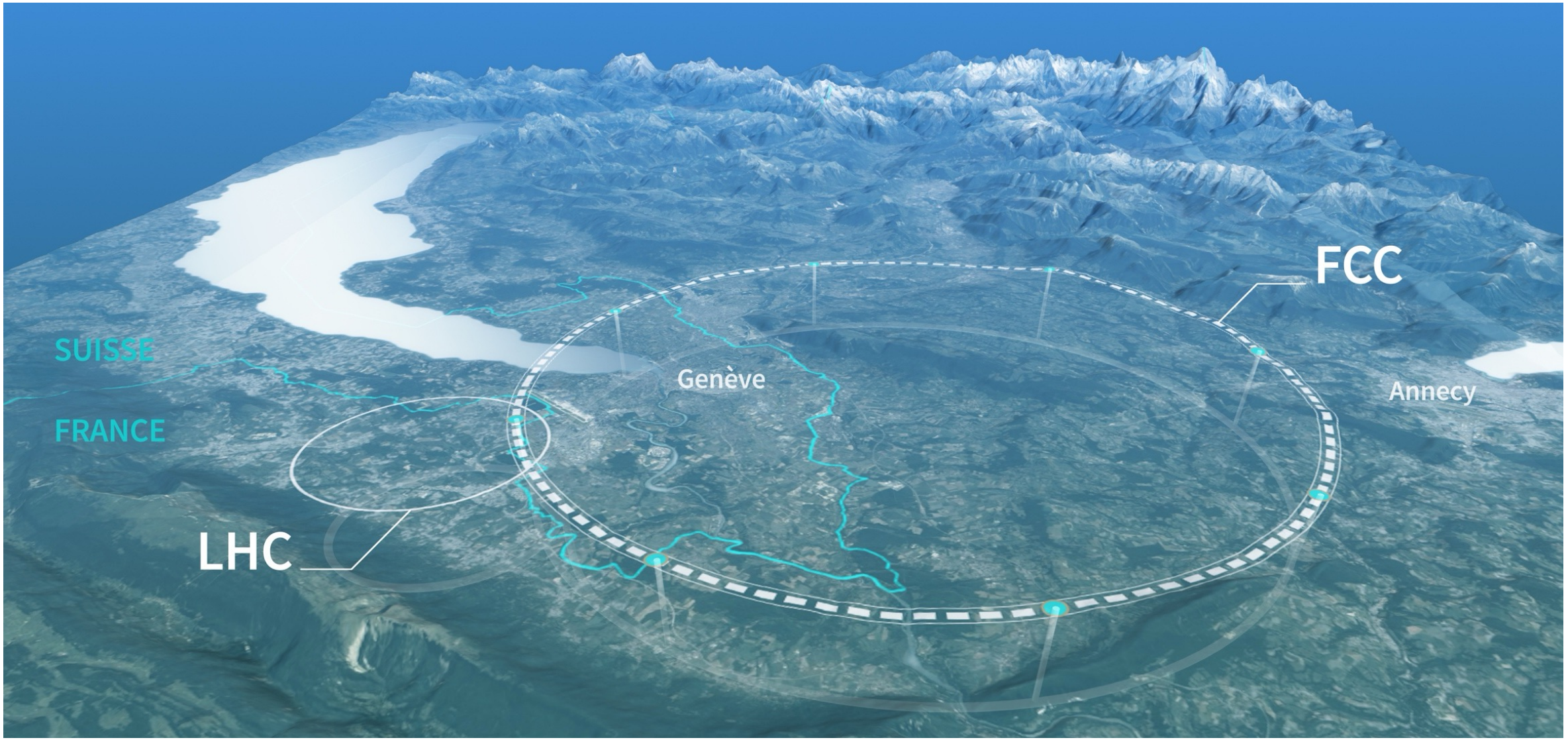
- This is a **major** and **necessary** project
  - Recover the availability and reliability
  - Correct safety concerns and non-conformities
  - Ready for new experiments/test beam





NA-CONS is a necessary high-priority project for CERN
- the main challenge is the significant resource required

3) The Future Circular Collider



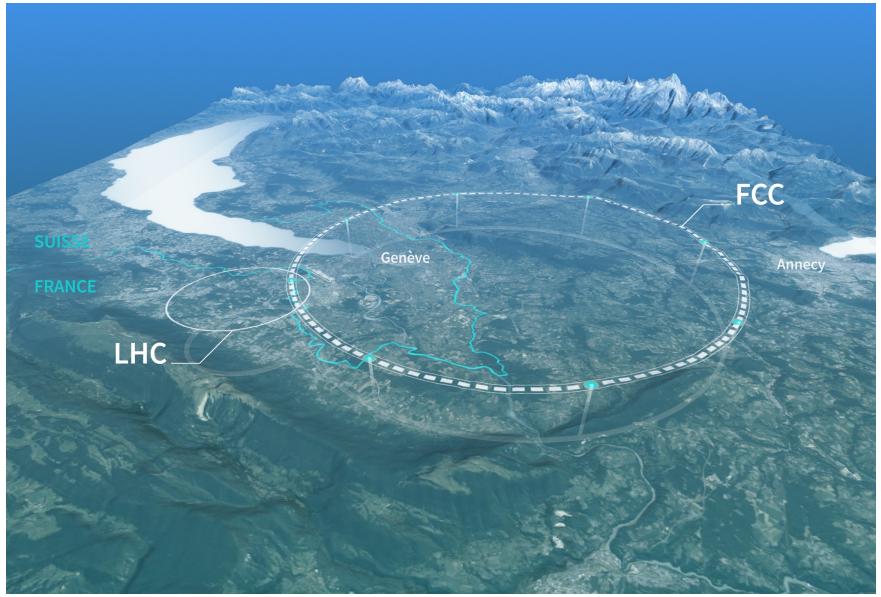
Why the FCC?

The Higgs Boson is a genuinely new and unique type of matter

- It is also very “strange” – and may well provide a new window for discovery
- A strong scientific case for a new “Higgs Factory” machine to study it in fine detail

The “Future Circular Collider” (FCC)

- A new 91km ring
- First stage collides electrons & positrons: **FCC-ee**
- An ambitious and exciting scientific programme
  - Higgs and **much more (Z, flavour, …)**
- Targeting start of operations in ~2045-2048
- Total cost over ~15 years of about 15 BCHF…



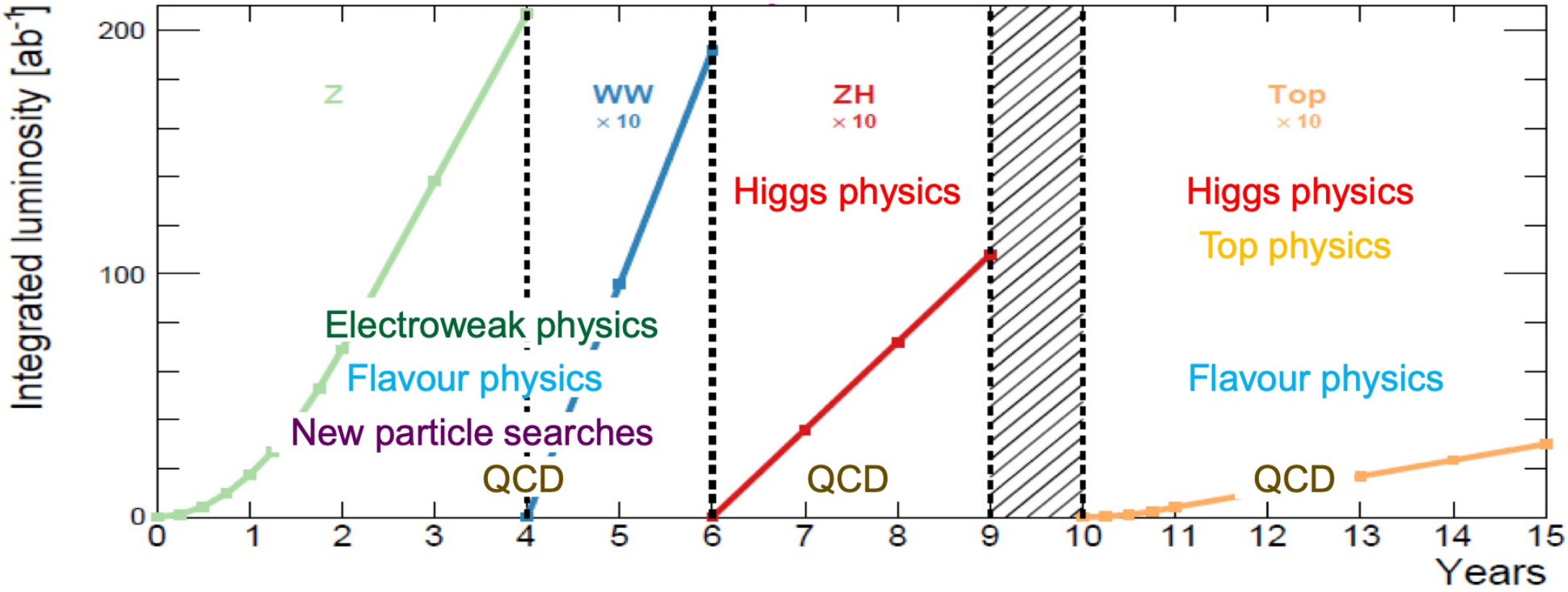
It is incredibly exciting and is a suitably ambitious next project for CERN

- Scientific case studied by European Strategy Group (ESG)

FCC-ee Physics

Flexible exploration of the Higgs and the wider electro-weak sector

- Flexibility to run at Z, WW and ZH and subsequently top-pair production
- Huge event samples for incredible precision – e.g. 10^{12} Z bosons = 1,000,000 x LEP



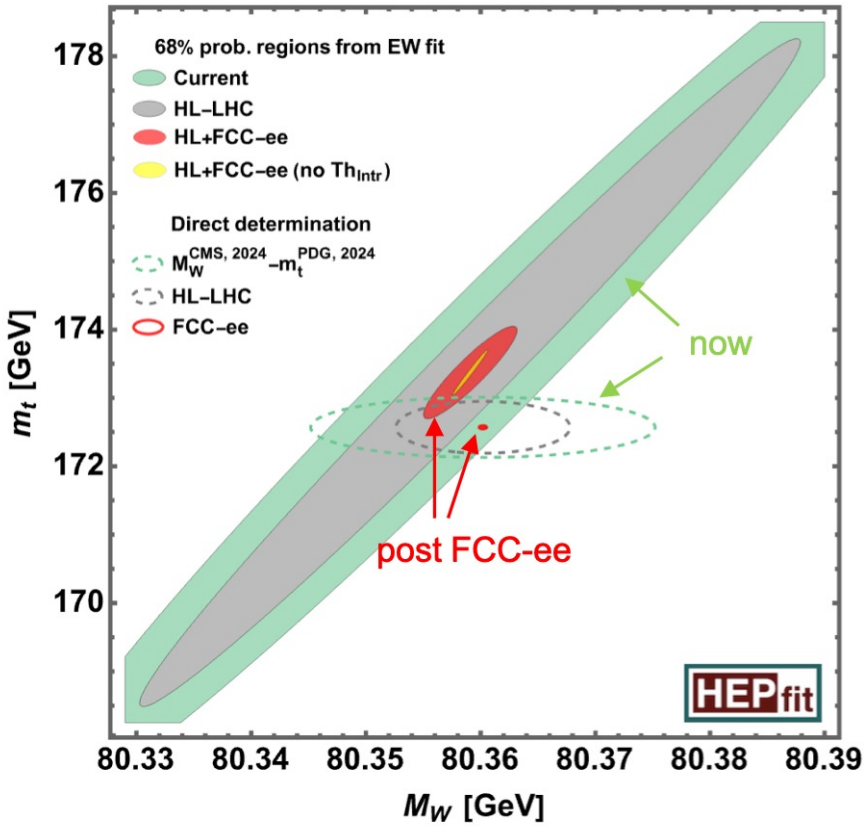
FCC-ee Physics

Step-change in precision!

- e.g. Model-independent Higgs couplings at the sub-1% level
- e.g. Three-orders of magnitude improvement c.f. LEP – this is a paradigm change

Coupling	HL-LHC	FCC-ee
κ_Z (%)	1.3*	0.10
κ_W (%)	1.5*	0.29
κ_b (%)	2.5*	0.49
κ_g (%)	2*	0.54
κ_τ (%)	1.6*	0.46
κ_c (%)	–	0.87
κ_γ (%)	1.6*	1.1
$\kappa_{Z\gamma}$ (%)	10*	4.3
κ_t (%)	3.2*	3.1
κ_μ (%)	4.4*	3.3
$\lvert\kappa_s\rvert$ (%)	–	$^{+29}_{-67}$
Γ_H (%)	–	0.78
$\mathcal{B}_{inv}$ (<, 95% CL)	1.9×10^{-2} *	5×10^{-4}
$\mathcal{B}_{unt}$ (<, 95% CL)	4×10^{-2} *	6.8×10^{-3}

* next to HL-LHC numbers → not model independent



4) The European Strategy for Particle Physics: the home straight

We are coming to the end of a roughly 18-month process:

- Hope that the European Strategy for Particle Physics will be **updated** on 22nd May at a dedicated Council meeting in Budapest **later this week**

ESG Main Recommendations

General Recommendations

i. *The **full exploitation of the physics potential of the LHC and the HL-LHC and the completion of the high-luminosity upgrade remain the highest priorities** of European particle physics.*
Every effort must be made to complete the HL-LHC upgrade within the current schedule.

CERN's future vision and strategy is completely aligned with this recommendation:

- **HL-LHC machine *and* detectors are CERN's highest priorities**
- **Full exploitation of HL-LHC including LHCb and ALICE upgrades**
- **Importance of maintaining the current schedule**

Recommendations on the next collider at CERN

I. The *next CERN flagship collider project*

i. The electron–positron Future Circular Collider (FCC-ee) is recommended as the preferred option for the next flagship collider at CERN.

ii. A descoped FCC-ee is the preferred alternative option for the next flagship collider at CERN

At this stage, without knowing the reasons for which the FCC-ee would not be feasible, other alternative options are not ranked.

Very clear preference with respect to other options

The strong preference for FCC-ee with respect to other collider options considered is based on the detailed scientific assessment of the ESG

- A simple summary below (there is a lot more in the ESG deliberation documents)

Machine	Precision Physics	BSM physics	Physics vs CEPC	Technical readiness	Constr. cost (BCHF)	Time scale	Path to ≥10 TeV
FCC-ee	22	23			15.3	2046-2060	
Descoped FCC-ee	15	17			12.9	2046-2055	
LCF550	15	17			14.8	2045-2065	
CLIC1500	14	18			14.6	2045-2066	
LCF250	10	16			9.4	2045-2053	
CLIC380	10	16			7.5	2045-2054	
LEP3	15	17			4.1	2047-2062	
LHeC	8	7			2.1	2044-2051	

Physics: from WG2b: sum of precision/BSM physics

Phys vs CEPC: competitiveness, assuming CEPC is running in parallel

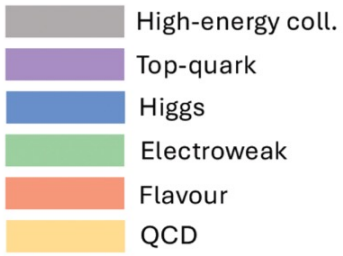
Tech readiness: from WG2a

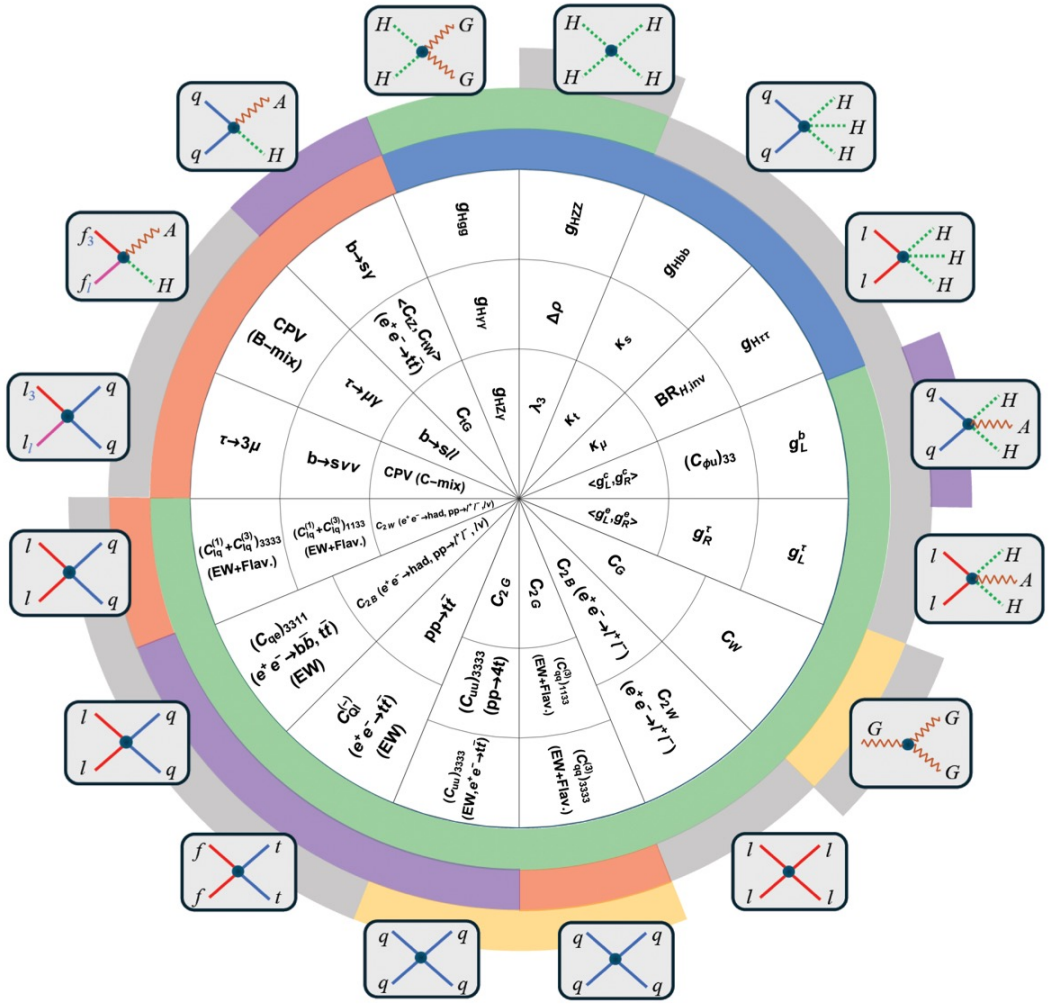
Construction cost: from proponents + exp. (CERN part)

Coverage of the physics landscape

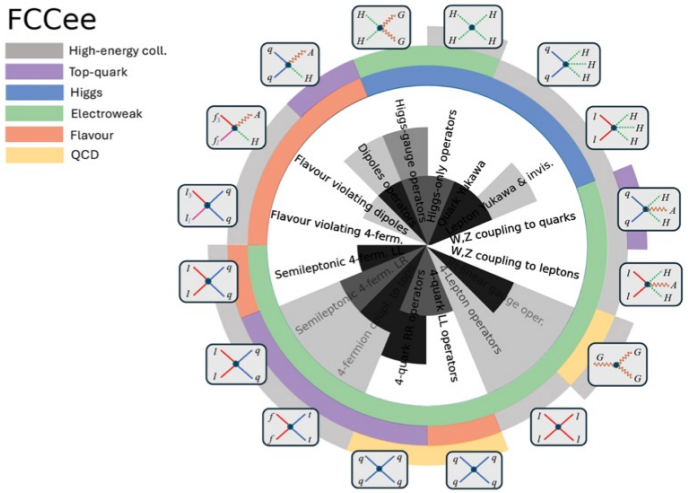
This is a very nice study from ESG WG 2b:

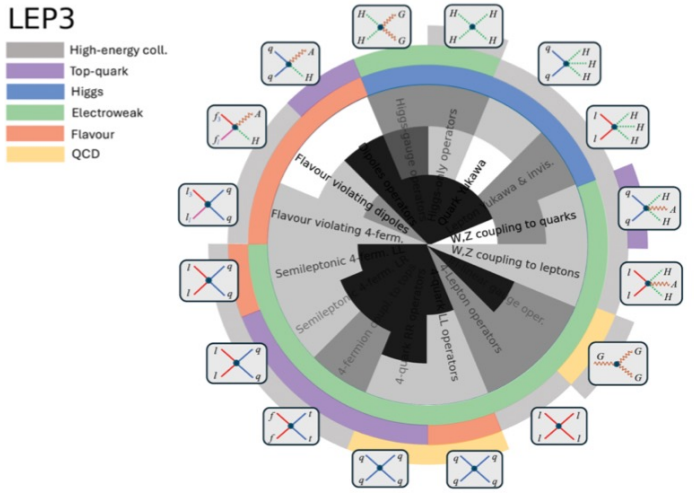
- map improvements in effective couplings relative to HL-LHC
- logarithmic scale 1 – 5
- colour-coded:
  - black = 1
  - white = 5

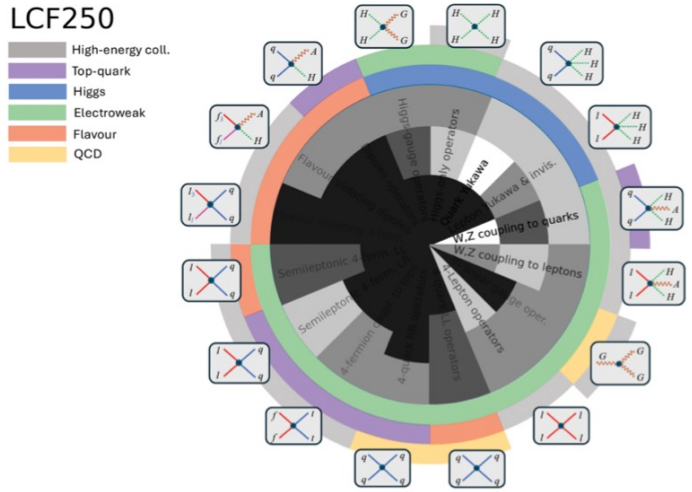


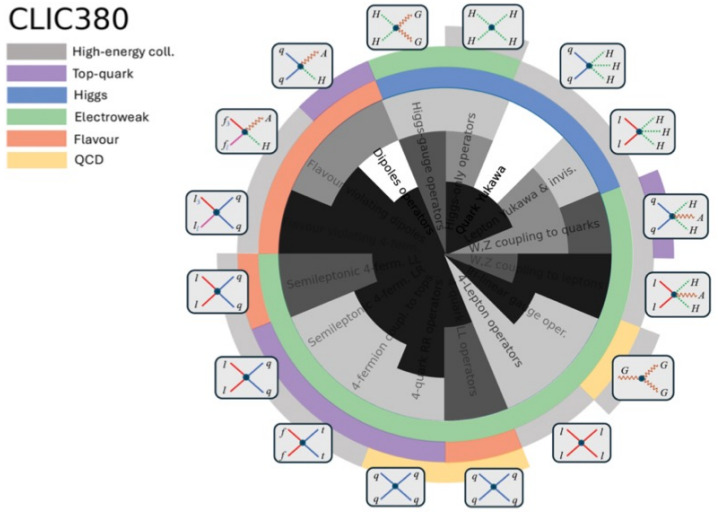


Coverage of FCC-ee with first stage e^+e^- colliders

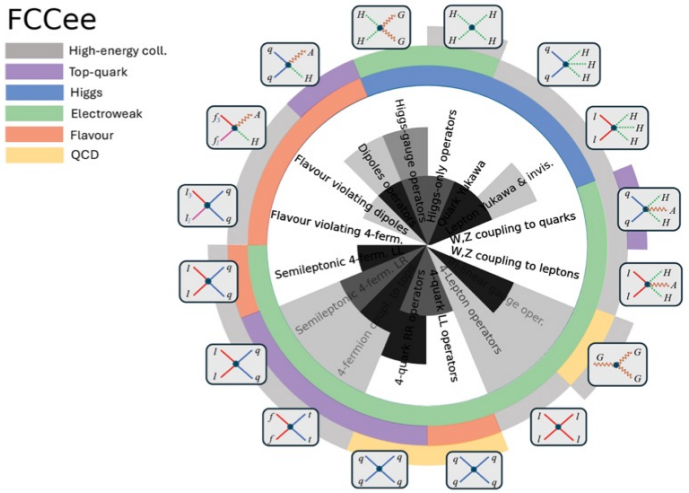


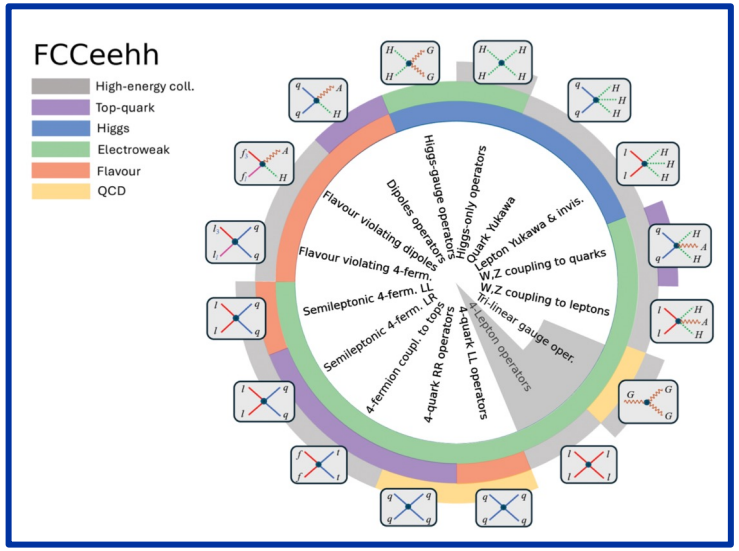


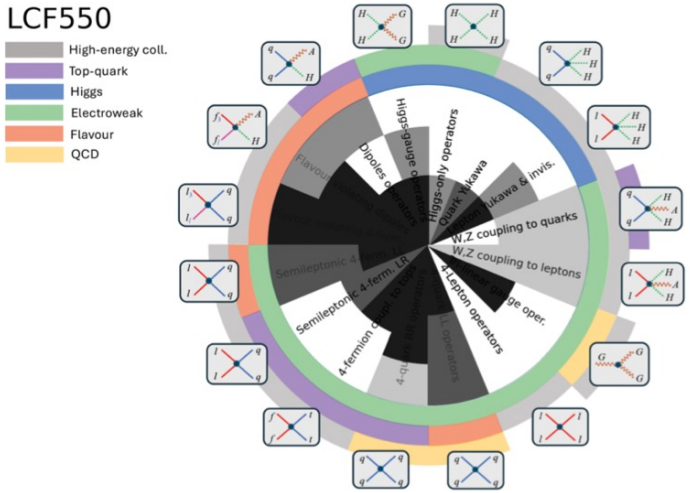


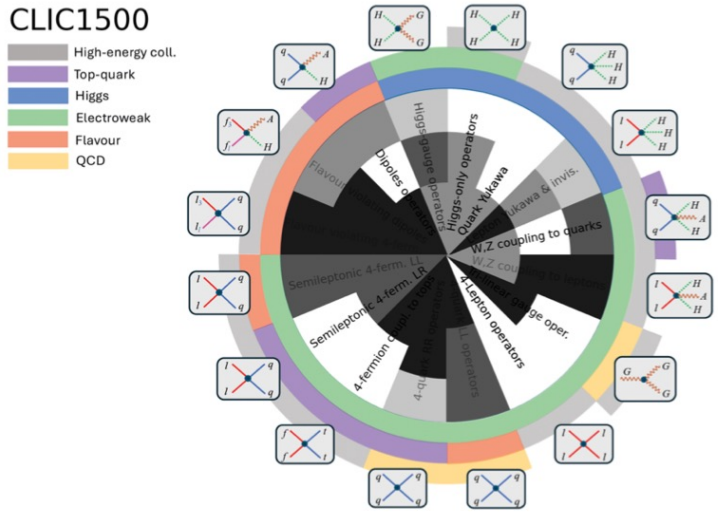


FCC-ee vs. second stage colliders









What does all this mean for CERN?

The key points from the European Strategy Group (ESG) report regarding FCC:

- Strong endorsement of the physics and strategic case for FCC-ee as the next flagship collider at CERN
  - Near consensus within the particle physics communities in CERN's Member States
- A descoped/staged FCC is preferred to other options as the alternative
- No explicit prioritization of LEP 3, LHeC, LCF, CLiC. Concluded that **FCC is far ahead**

Assuming this update of the ESPP, FCC-ee is CERN's vision for the future:

- ***Our clear aim is to be ready* for a decision on FCC-ee in 2028**
- CERN's highest long-term objective is to be in a position in 2028 to propose to Council FCC-ee as CERN's next flagship collider
  - Seeking a go/no-go decision
- We will make the case based on FCC-ee alone
  - noting that it provides a potential future pathway to a very-high energy hadron collider

Progressing FCC-ee to a decision point is CERN highest long-term scientific priority

The European Strategy underpins CERN's strategy

Top Priority – full exploitation of the LHC and HL-LHC

- HL-LHC and ATLAS and CMS upgrades are CERN's top priority
- Full exploitation of HL-LHC includes the ALICE and LHCb upgrades during LS4

Highest long-term priority – FCC-ee as CERN's next flagship collider

- Our aim is to be in the position for CERN Council to be able to take a decision on FCC-ee from June 2028 onwards

Non-collider physics at CERN will remains an important part of the programme

- Our aim is to develop a new roadmap for the future of the non-collider physics programme at CERN by early 2027

Accelerator R&D – top priorities as recommended by the ESG:

- Advanced superconducting and normal-conducting Radio Frequency (RF) technology
- Efficient RF power supplies
- Accelerator quality magnets (14-20T), including High-Temperature Super-conductors (HTS)

The Importance of HL-LHC

The construction of the HL-LHC and the ATLAS/CMS upgrades will dominate the next four years at CERN

- Long Shutdown 3 (LS3) for the LHC commences on 29 June 2026
- The plan and **clear intent** is to be commissioning the machine and detectors in 2030

This is a major task

- The HL-LHC installation will be the largest project undertaken by CERN in around 20 years
- The Phase 2 detector upgrades, are the largest projects undertaken by ATLAS and CMS since the construction of the original detectors

The HL-LHC *and* the detector upgrades represent *by far* the highest priority for CERN in the coming years

- Meeting the current schedule, which is our intention, will require **laser focus**
- Accordingly, CERN is prioritising resources to during LS3 maximize the likelihood of success

HL-LHC and the Phase 2 upgrades are CERN's highest priorities

5) The challenges for CERN in the coming years

Challenges in the coming years

The HL-LHC programme (machine and detectors) and LS3 consolidation

- Represent a **major shift from operation to construction**
- The work involved is exciting and also extremely technically and logistically challenging

At CERN

- There are also other major activities during for LS3, including consolidation of the North Area
- Resources (people) are stretched with many activities running in parallel

In the wider scientific community

- Resources (people) are already stretched
- And today, the economic situation across Europe is not easy – stiff competition for funding

Geopolitically

- We live in interesting times. There is increased risk of supply chain disruption and inflation

We can succeed, but it will require real focus at CERN and in the wider community

- this means being willing to delay/pause other activities to free up resources

6) CERN’s Scientific Strategy and Priorities

Accelerator programme

Main priorities

- **Completion of the HL-LHC with commissioning in 2030**
  - This is the top priority by far and this degree of priority is being reflected in our financial and personnel planning
  - Colleagues in ATS are developing a globally resource-loaded plan for all activities within LS3, with break points for non-HL-LHC activities that could be delayed to maintain the HL-LHC schedule
- **Bringing the FCC-ee to a decision point in 2028**
  - **FCC-ee** is **the** highest long-term priority
  - If the “answer” is “no”, then foresee a likely new targeted European Strategy update
- **Consolidation of CERN’s injector complex**
  - With a view to the long-term PS and SPS based non-collider physics programmes, e.g. NA-CONS, HI-ECN3 and ongoing consolidation of the PS and SPS

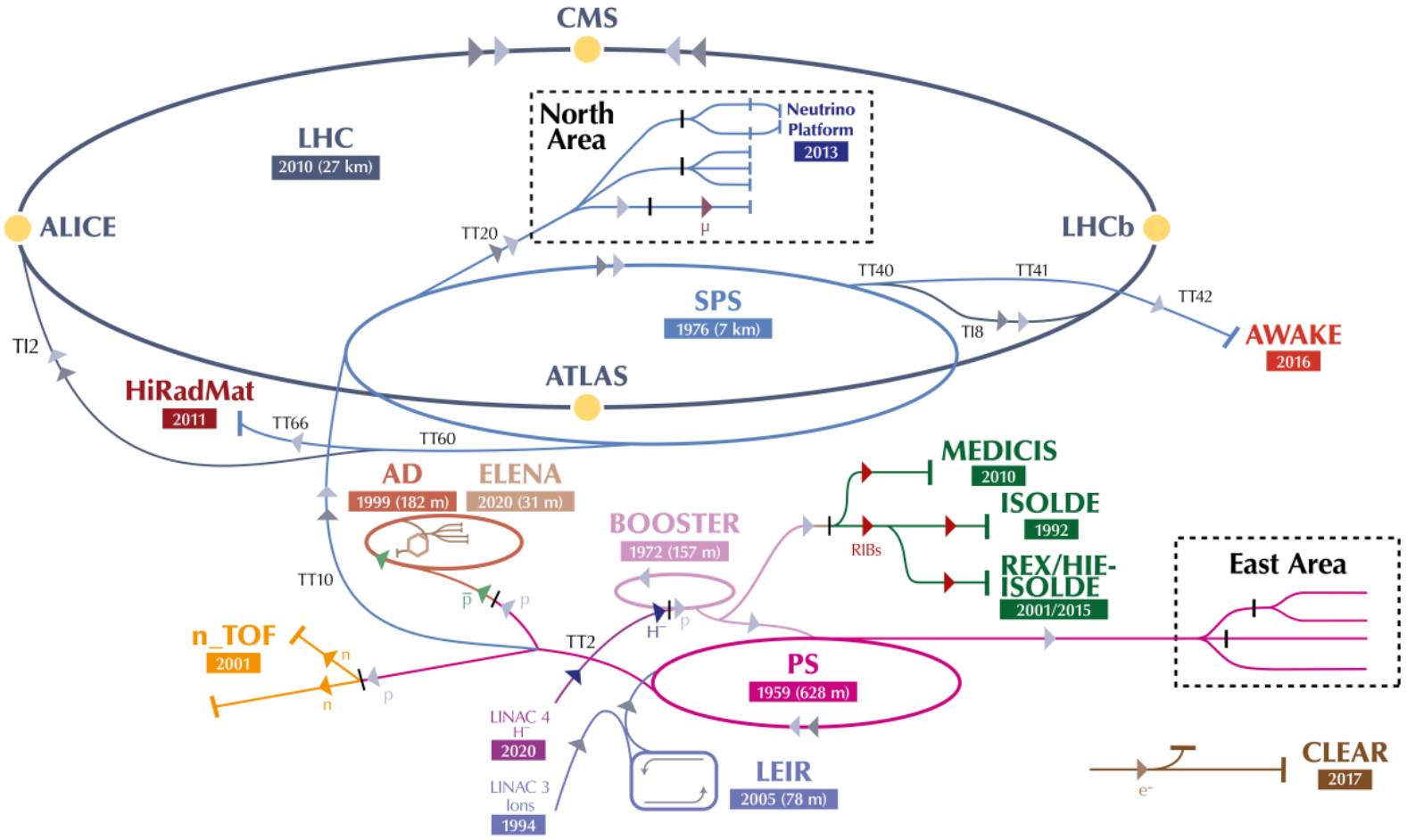
Scientific research

Main priorities

- **Completion of the ATLAS and CMS upgrades by 2030**
  - Alongside the HL-LHC, this is the top priority
  - CERN will strengthen the host-laboratory programme to maximise the likelihood of success
- **Fully exploit the HL-LHC**
  - Progress the TDRs of the LS4 ALICE and LHCb upgrades and associated funding model
  - Need a plan compatible with the current LS4 schedule (2034-2035) and available funding
  - CERN has committed to investing in the Phase 2b ALICE and LHCb upgrades
- **Evolve the computing for the HL-LHC operation**
  - Working with the LHC collaborations and the WLCG to evolve the computing model for HL-LHC operation within the likely available resources

Non-Collider Physics at CERN

There's more to CERN than the LHC…



Non-Collider Physics at CERN

The non-collider physics programme at CERN

- An essential part of the attractiveness of the laboratory and its scientific output
- Supports a large scientific user community of ~3,000 users
- The Physics Beyond Colliders programme has developed ideas for options for new projects, using CERN's unique infrastructure
- And potential future developments elsewhere: ISOLDE, AD/ELENA, AICE, …

Main priorities for non-collider physics at CERN

- **Develop a long-term roadmap for non-collider physics at CERN**
  - Embed a long-term investment line in CERN's financial planning
  - Prioritise potential new experimental activities taking a holistic view
    - **this work has already started**
  - SHiP remains a scientific priority, but we still need to have clarity on the scope, schedule and funding model

Concluding Remarks

Concluding remarks

Our mission and our challenge

- **The next five years will be a critical period for CERN**
  - We are moving from a period dominated by operations of the LHC, to the HL-LHC machine and detector construction, **both of which are at the scale not seen at CERN for the last 20 years**
  - At the same time, we are aiming to progress FCC-ee, as CERN's next flagship project after HL-LHC, to approval and then to project implementation
  - An amazing and **incredibly exciting opportunity**, but it will not be easy – far from it…
    - HL-LHC construction, detector upgrades, LS3 consolidation and FCC-ee development all running in parallel
  - And all in the context of an ever more uncertain economic and geopolitical background
- **I am confident that we can succeed, but during LS3 we will need to focus on these very top priorities for the future of CERN**

Thank you

home.cern

Evaluation by the European Strategy Group

Project	Scope	TRL	R&D	Test facilities	Performance uncertainty	Site preparation	Schedule uncertainty	Cost uncertainty	Risk
CLIC 380 GeV, 1.5 TeV		4 - 6 / 5.2							
FCC-ee 91-365 GeV		4 - 7 / 6.0							
FCC-hh 85 TeV		4 - 7 (Nb_3Sn) / 4.3 2 - 7 (HTS) / 3.2							
FCC-hh - SA 85 TeV		4 - 7 (Nb_3Sn) / 5					Nb_3Sn		
LCF 250 - 550 GeV		5 - 7 / 5.5							
LEP3 91 - 230 GeV		3 - 6 / 4.0							
LHeC: HL-LHC + 50 GeV ERL		3 - 6 / 4.5							
MC 3.2 TeV, 7.6 TeV		3.2 TeV: 3 - 5 7.6 TeV: 2 - 5							

- Muon Collider: The technologies underpinning the MC design are in the early phases of exploration;
  Comprehensive R&D programme defined (300 MCHF, 1800 FTEy);
  Demonstrator need to be built.

- FCC-hh: Further R&D and industrialisation of high-field magnets (Nb_3Sn 15 - 20 y);
  Costs of HFM, further developments of high-temperature superconducting (HTS) magnets

- LEP3: Absence of a detailed lattice design and full-scale simulation → uncertainties on projected luminosity;
  Proposed baseline HTS nested quadrupoles/sextupoles represent the lowest TRL (luminosity, power)

- LHeC: Performance critically depends on a very high-current Energy-Recovery Linac (ERL);
  Uncertainty on luminosity of an order of magnitude;
  Successful demonstration of the PERLE programme at IJCLab is vital