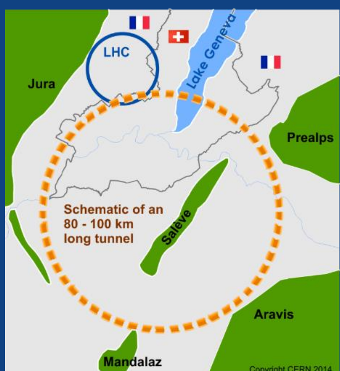
CERN’s vision and goals until the next Strategy update

FCC Innovation Study kick-off meeting



Fabiola Gianotti, CERN, 9 Nov 2020

Introduction

CERN vision and goals for the coming years are based on the 2020 update of the European Strategy for Particle Physics (ESPP)

The 2020 ESPP provides a realistic and prudent approach to visionary and ambitious scientific objectives. It lays the foundations for a bright future for particle physics in Europe, within the global context of the field.

Here: first views on implementation of this scientific vision and objectives

2020 ESPP provides 20 “recommendations”

→ See Ursula Bassler’s talk

2 on Major developments since the 2013 Strategy
HL-LHC; neutrinos

3 on General considerations for the 2020 update
Europe’s leadership role; collaboration CERN-European labs; collaboration with global partners

2 on High-priority future initiatives
Future colliders; accelerator R&D

4 on Other essential scientific activities for particle physics
Scientific diversity programme; theory; detector R&D; SW and computing

2 on Synergies with neighbouring fields
Astroparticle physics; nuclear physics

3 on Organisational issues
Global projects; relations with EC; open science

4 on Environmental and societal impact
Environmental protection; early-career scientists; technology transfer; public engagement

CERN's scientific vision and main goals

- Full exploitation of LHC including high-luminosity upgrade
  - Vast physics reach for **all** experiments
  - Physics and technology milestone towards a future collider

  Note: no future for CERN if HL-LHC is not successful

- Investigation of technical and financial feasibility of FCC

  ESPP gives direction for future collider at CERN*, but prudent approach: feasibility study first

- Reinforced R&D on accelerator technologies: **high-field superconducting magnets**, high-gradient accelerating structures, and plasma wakefield, muon colliders, ERL, etc.

  To prepare a broad and solid future for HEP, including alternatives to FCC if not feasible.

  ESPP recommends development of Accelerator R&D roadmap by European community.

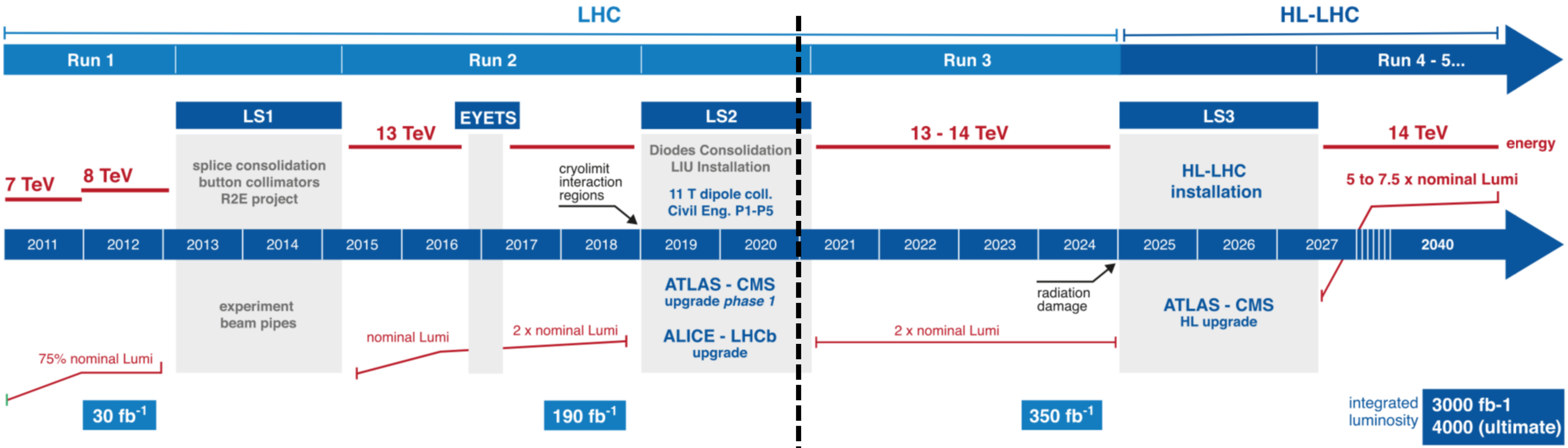
- Support of scientific diversity programme and long-baseline neutrino (in particular LBNF/DUNE)

  Diversity is **keyword** in the absence of clues on E-scale and couplings of new physics

CERN's 2020 Medium-Term Plan (MTP), covering 2021-2025, provides first implementation of this vision → approved with very strong support by Council in Sept

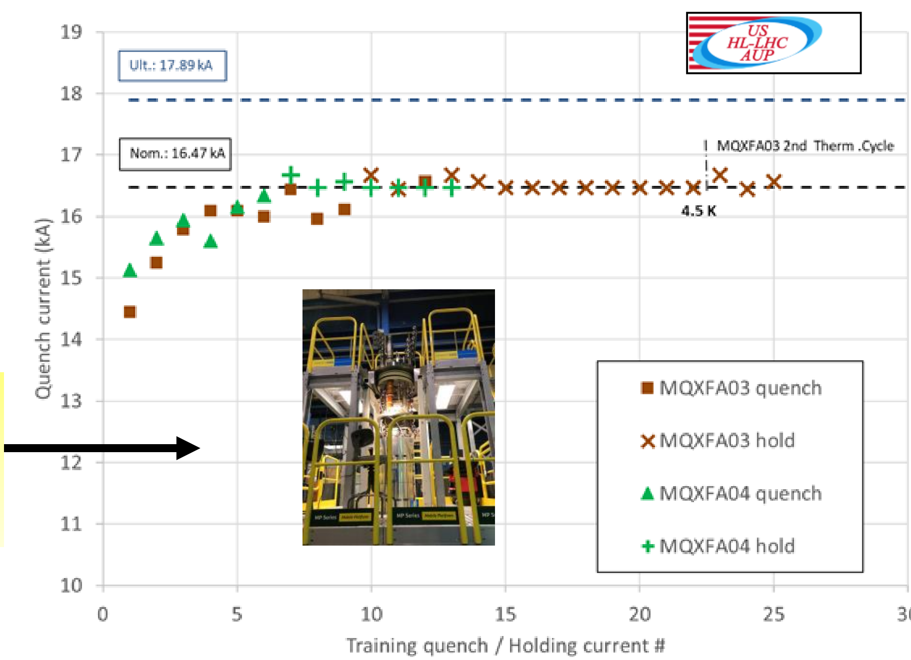
* Strong support in European particle physics community for Higgs factory as next collider and on high-energy pp collider; non consensus, however, on which type of Higgs factory (linear/circular/where)

High-Luminosity LHC



Crucial milestone also for future hadron colliders: 11-12 T Nb_3Sn dipole and inner triplet quadrupoles

Two full-scale (4.2 m) Nb_3Sn quadrupoles for HL-LHC built and successfully tested in the US.



Future colliders in 2020 MTP

FCC

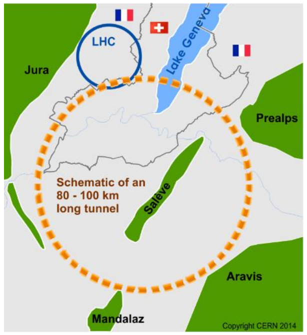
Focus in coming years is feasibility of infrastructure and colliders

Highest priorities:

- ❑ tunnel: high-risk zones, surface areas, admin processes, environment
- ❑ machines: R&D (e.g. SCRF for FCC-ee; magnets for FCC-hh); design optimisation

→ Goal is CDR++ with results of feasibility studies by next ESPP ~ 2026

CERN's budget: ~ 20 MCHF/year (magnets not included)



CLIC

Maintain R&D on key technologies (X-band structure, beam dynamics, etc.)
to keep CLIC as option for future collider (as recommended by ESPP)

CERN's budget: ~ 5.5 MCHF/year

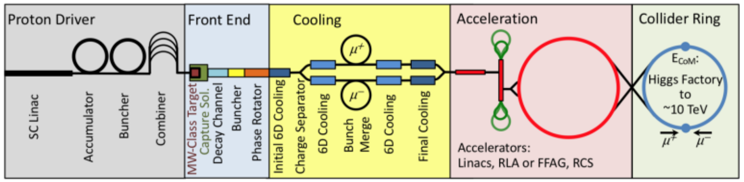
Muon colliders

Effort started at CERN to support European community.

Main challenges: accelerator and collider rings, interaction region, muon source and cooling, fast-ramping magnets and power converters, neutrino radiation and civil engineering.

International collaboration being put in place, initially hosted at CERN

CERN's budget: 2 MCHF/year



FCC feasibility study: main challenges

Financial feasibility

Cost of tunnel: ~5.5 BCHF; FCC-ee: ~5-6 BCHF; FCC-hh: ~17 BCHF (if after FCC-ee)

→ cannot be funded only from CERN's (constant) budget + "one-off" contributions from non-Member States → need new mechanisms (global project funding model; EC? private?)

First priority of feasibility study: find ~ 5 BCHF for the tunnel from outside CERN's budget

Technical and administrative feasibility of tunnel

- highly-populated area; two countries with different legislative frameworks
- land expropriation and reclassification
- high-risk zones
- environmental aspects

First priority of feasibility study: no show-stopper for ~100 km tunnel in Geneva region

Technologies of machine and experiments

- huge challenges, but under control of our scientific community
- pressing environmental aspects: energy, cooling, gases, etc.

First priority of feasibility study: magnets; minimise environmental impact; energy efficiency and recovery

Gathering scientific, political, societal and other support

→ requires "political work" and communication campaign for "consensus building" with governments and other authorities, scientists from other fields, industry, general public, etc.

→ can FCC be a facility also for other disciplines (nuclear science, photon science, etc.)?

→ creative and proactive ideas for technology transfer from FCC to society

Accelerator R&D: superconducting magnets

2020 MTP implements a reinforced R&D programme for superconducting high-field magnets, as key technology for future accelerators (hadron colliders, muon colliders, neutrino beams, etc.) and detectors, with great potential for wider societal applications.
Budget ~ doubled (~ 190 MCHF in 10 years)

Strong partnership with industry and with labs and universities in Europe, US and beyond

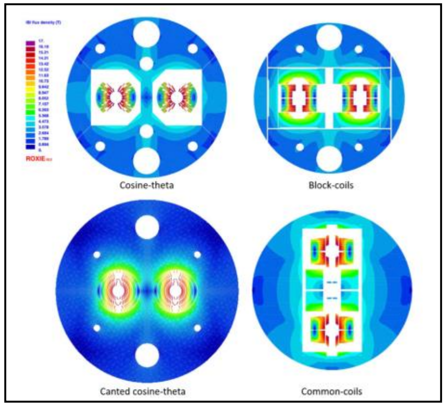
Main activities:

- materials: LTS (Nb_3Sn) and HTS → goal: 16 T for LTS, at least 20 T for HTS inserts
- magnet technology: engineering, mechanical robustness, insulating materials, field quality
- production of models and prototypes to demonstrate material, design and engineering choices, industrialisation and costs
- infrastructure and test stations for tests up to ~ 20 T and 20-50 kA

Goals (ambitious) for next ESPP ~ 2026:

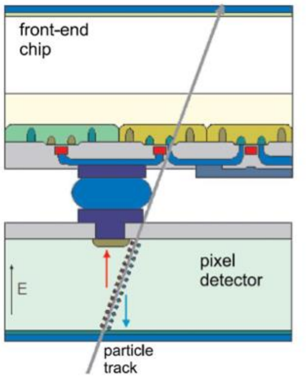
- Nb_3Sn: demonstrate technology for large-scale accelerator deployment
- HTS: demonstrate suitability for accelerator magnet applications

Stepwise approach, building on experience gained with operation at LHC and HL-LHC



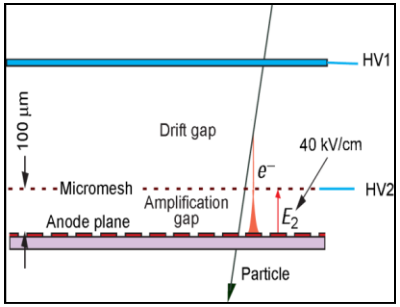
Detector R&D

Great technical and performance challenges for FCC detectors



CERN: initiative launched in Experimental Physics department in 2017 on strategic R&D for detectors at future collider and non-collider projects
Main goals: define main needs and requirements; identify and develop most promising technologies; foster synergies across projects.

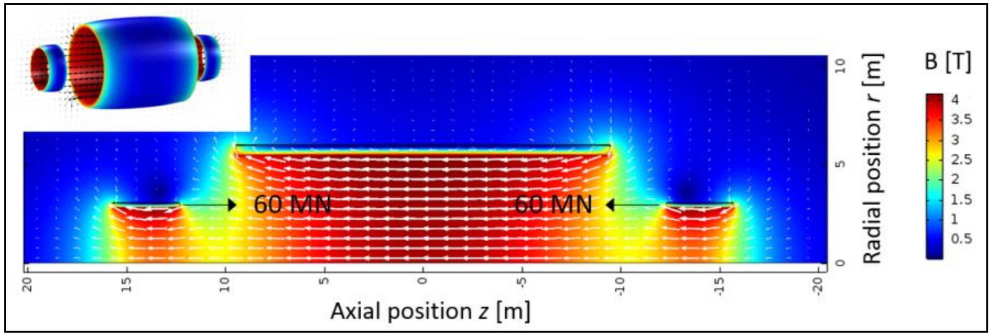
Emphasis on areas where CERN has significant expertise and infrastructure.
Close cooperation with interested Institutes and similar activities in Europe.



8 Work Packages - silicon detectors for vertexing and tracking, micropattern gas detectors, calorimetry and light-based detectors, detector mechanics and cooling, integrated circuit technologies, radiation-hard optical links, simulation and analysis software, detector magnets.

As of 2020: new budget line in CERN's MTP (~ 90 MCHF in 11 years) grouping all detector R&D activities across projects → increase synergies and optimise resources

Detector R&D roadmap being developed (ECFA), as recommended by ESPP



Additional remarks

Physics at FCC

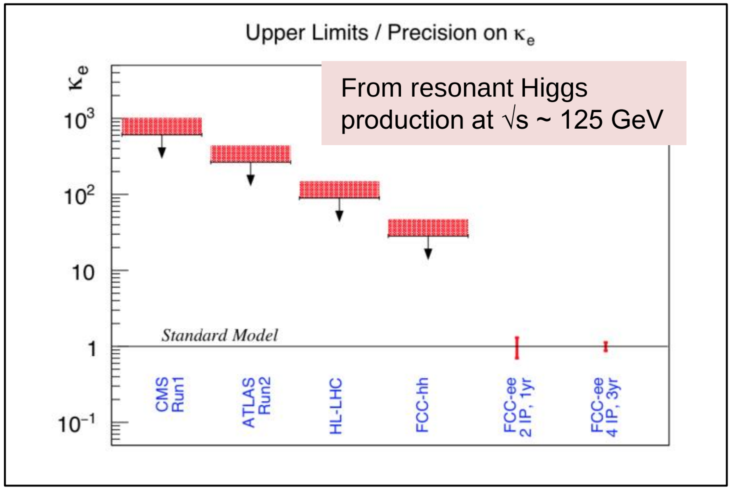
Important to continue to expand the already compelling programme and reach
→ essential component of feasibility study (to gather scientific, political and societal support).
CERN will put in place dedicated effort in experimental and theoretical physics

Timeline

- Operation of next big collider before ~ 2045 (i.e. < 10 years from end of HL-LHC) is crucial to keep our community motivated and engaged (young people!) and maintain expertise.
  Easier for FCC-ee; technically and financially harder for FCC-hh.
- Best scenario: recommendation of ESPP in ~ 2026 → project approval by Council and start of construction by end of the decade.

Global collaboration and perspective

- Implementation of FCC will require worldwide scientific, technological and financial cooperation
  → challenging also in terms of governance
- Need to pursue studies of complementarity between FCC-ee and ILC, to inform decision on FCC-ee if ILC goes ahead → see initial work by Blondel and Janot: https://arxiv.org/pdf/1912.11871.pdf



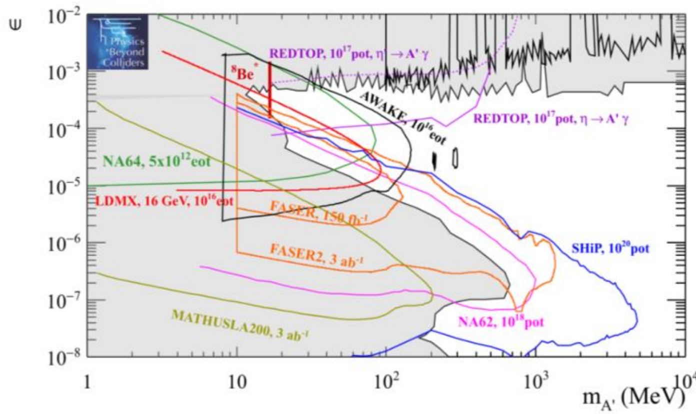
Scientific diversity programme

ESPP supports high-impact scientific diversity programme complementary to high-E colliders (role of national labs emphasised, as well as participation in experiments outside Europe)

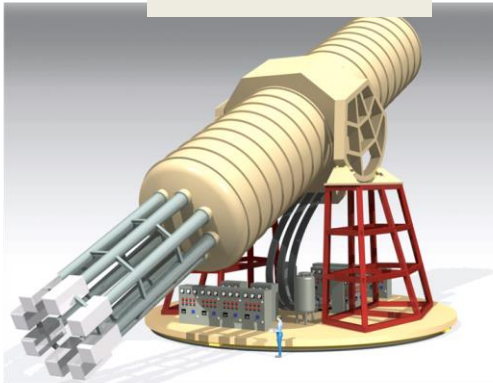
Since 2016: CERN has hosted Physics Beyond Colliders Study group.
Unique role in promoting and channelling new research initiatives at CERN and European labs.
Several experiments examined by PBC now being carried out.
→ CERN budget for PBC activities increased from 1 MCHF/year to 3 MCHF/year.
Will also allows continuation of key R&D for beam dump facility at SPS North Area
→ can start construction after next ESPP if project recommended and then approved by Council

FASER's trench in LHC tunnel,
480 m downstream of IP1
→ detector installation in LS2

Dark photon searches



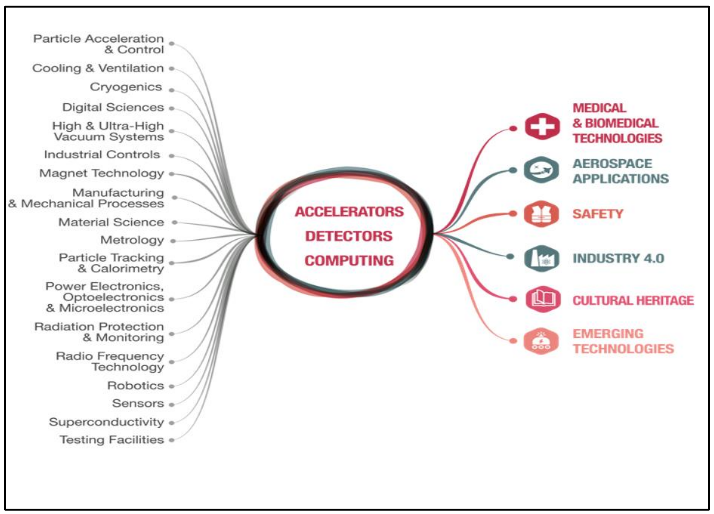
IAXO at DESY

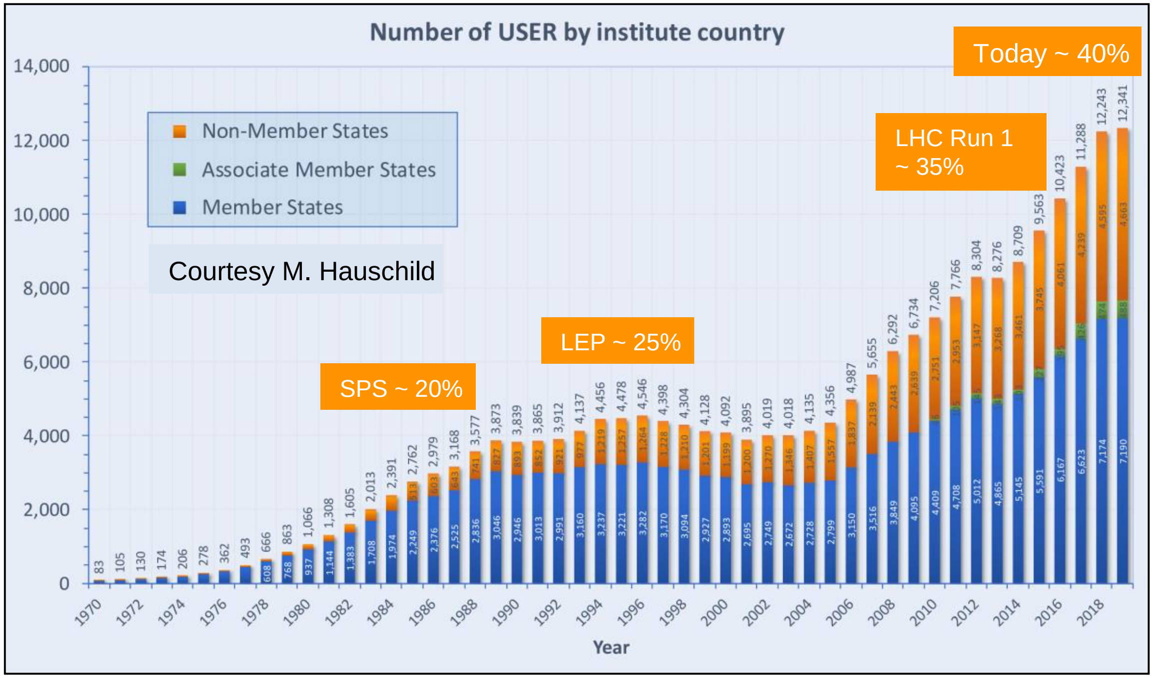


Conclusions

CERN' plays a leading role in particle physics → a long-term perspective for the laboratory is crucial for the future of the field worldwide

CERN's scientific standing, its innovative wide-ranging technologies, and its large community (> 18000 people) come today primarily from its "flagship" project: **LHC**





This leading role, technological innovation capability and large community will NOT survive without a flagship project (strongly motivated by physics*) following the LHC within a short time (<10 years).

* High-energy colliders are indispensable and irreplacable tools for exploration of fundamental physics

Conclusions

This is recognised by the 2020 Strategy update, which provides a realistic and prudent approach to ambitious and visionary scientific objectives → it lays the foundations for a bright future of the field at CERN and in Europe, within the global context.

CERN's vision and goals in the coming years are shaped accordingly
→ full exploitation of LHC/HL-LHC; reinforced and broad accelerator R&D programme; feasibilty study of FCC; scientific diversity

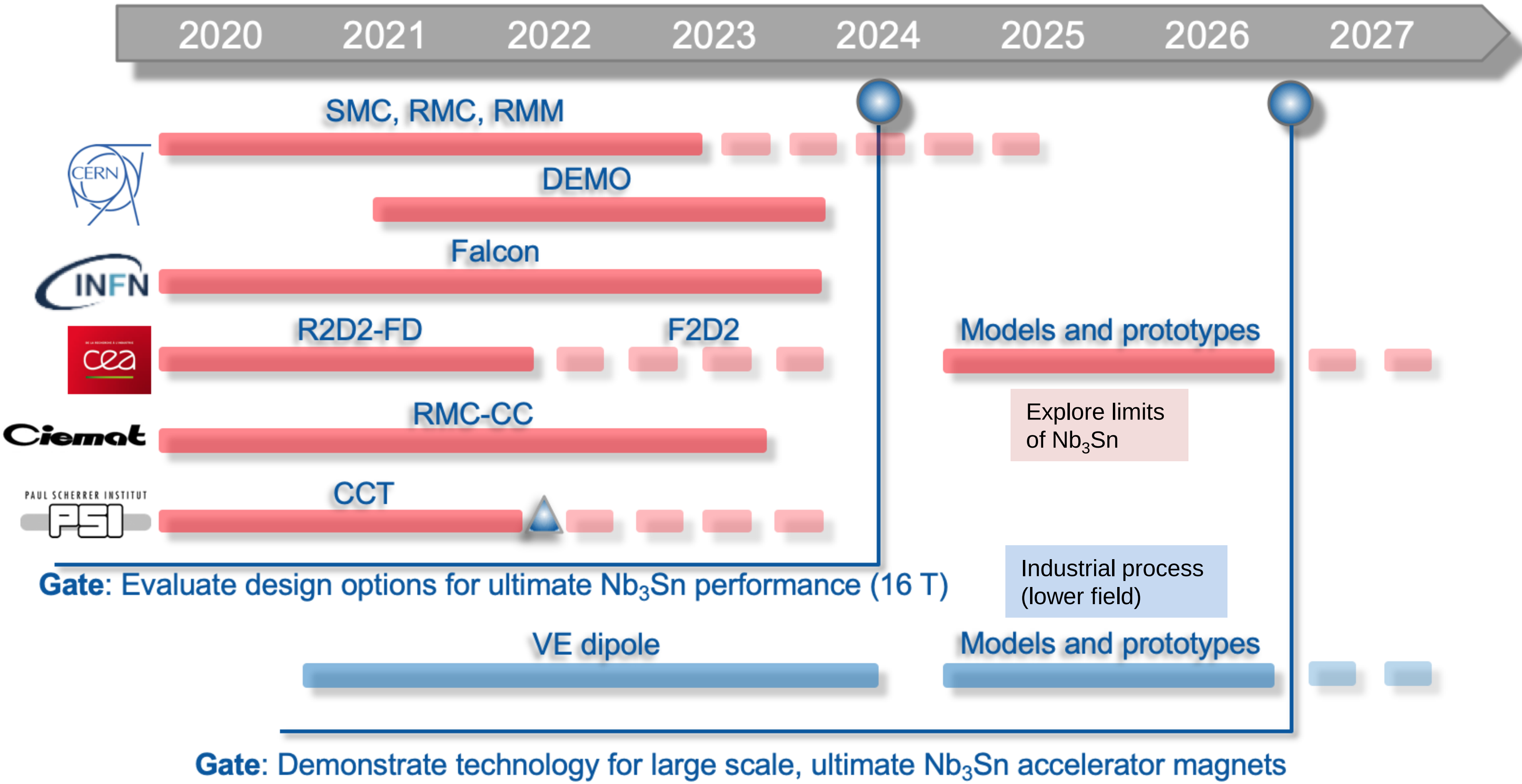
The programme of work until the next update (~ 2026) is vast and demanding.

The feasibility study of FCC is particularly challenging and will require the hard work, dedication and enthusiasm of the full FCC community.
If successful, the impact on the future of CERN and the field will be IMMENSE.

EXTRAs

Accelerator R&D: super-conducting magnets

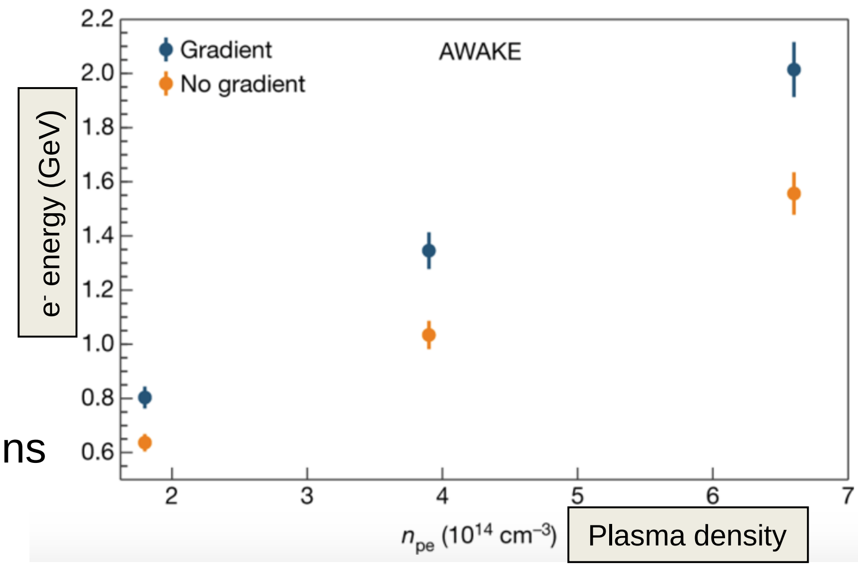
Ambitious, preliminary roadmap for low-T superconducting magnets (Nb_3Sn)



AWAKE

Advanced Proton Driven Plasma Wakefield Acceleration Experiment

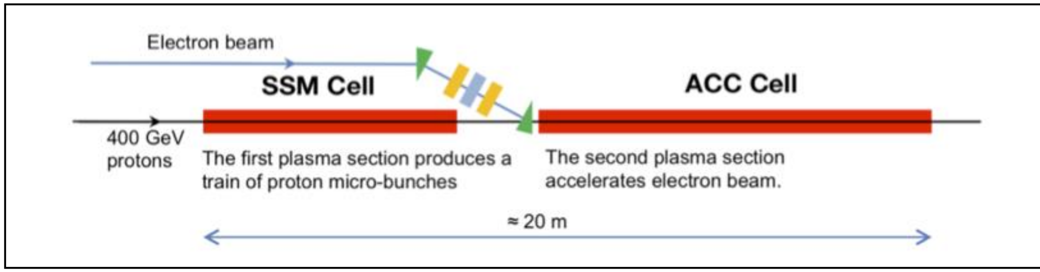
Run 1 (2016-2018): first demonstration of p-driven e^- acceleration over 10 m plasma cell: 20 MeV → 2 GeV (200 MV/m gradient)



Run 2 (after LS2): goal is to demonstrate ~1 GV/m , e^- beam emittance preservation
→ AWAKE beams can be used for physics applications

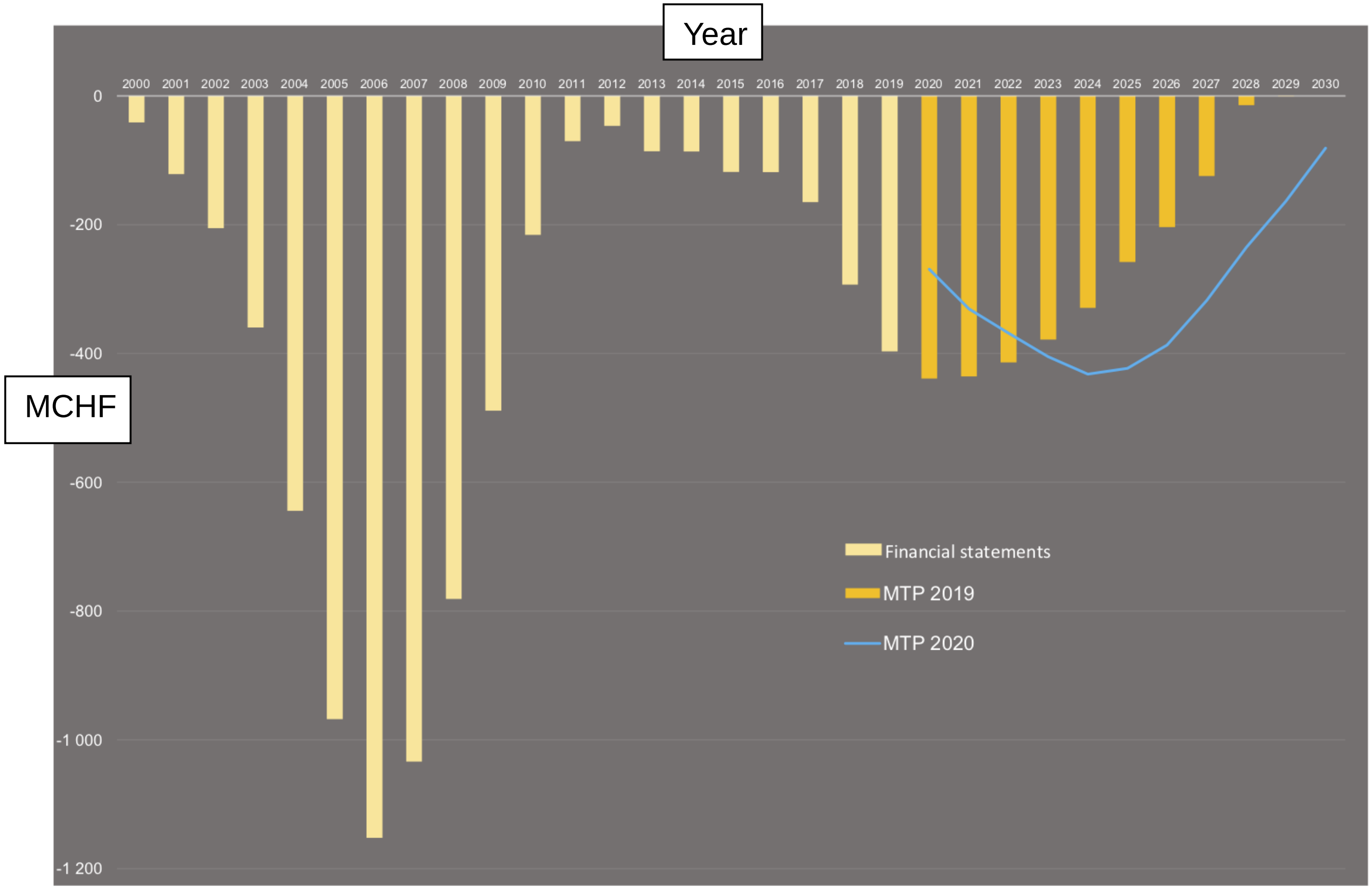
Run 2 set-up:

- 2 x 10 m plasma cells to separate proton SSM from e^- acceleration
- new electron source: 165 MeV, 200 fs pulses → use CLIC high-gradient X-band technology (limited space)
- civil engineering work and modification to p beam line to gain space
- additional beam diagnostics



Needed resources allocated over 2020-2029 for design studies and implementation of Run 2

Cumulative Budget Deficit vs time



As of ~ 2028, CERN's financial situation allows significant investment in new projects