Initial views on the European Strategy implementation

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CERN/3092/RA/Rev., Proposal for a revised procedural framework for the European Strategy for Particle Physics, approved by CERN's Council in March 2014:

"… since the Director-General has the mandate to execute all the Council's decisions, it follows that the Director-General should also be responsible for the implementation of the European Strategy for Particle Physics."

Tools to monitor the ESPP implementation

CERN's Medium-Term Plan

Rolling 5-year plan approved by Council (usually) in June of each year together with the yearly budget
→ allows regular assessment of compliance of CERN's scientific and financial strategy with ESPP recommendations.

Laboratory Directors Group (LDG)

Directors of major European Laboratories: CERN, CIEMAT, DESY, IJCLab-Orsay, IRFU-Saclay, NIKHEF, LNF-Frascati, LNGS-Gran Sasso, PSI, STFC-RAL.
Forum to discuss implementation of ESPP in the laboratories and issues of common interest (e.g. a Muon Collider WG was set up in Sept 2017 to provide input to 2020 ESPP), and for general coordination among European labs in the field (e.g. for joint applications to EU funding).

RECFA visits to countries (3-4 visits/year)

Opportunities to review status of the field and ESPP implementation in the countries, and help the community with recommendations on issues of concern.

ICFA meetings

Discuss regional strategies (ESPP, US P5, etc.) and their implementation in wider worldwide context, promoting coherence of efforts. ICFA panels (Instrumentation, Neutrinos, Advanced and Novel Accelerators, etc.) give opportunities to discuss some of ESPP recommendations in the global context.

FALC = Funding Agencies for Large Colliders

Informal forum to discuss future accelerator projects among major funding agencies worldwide

2020 ESPP provides 20 ”recommendations”

2 : Major developments from the 2013 Strategy
HL-LHC; neutrinos

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

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

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

2 : Synergies with neighbouring fields
Astroparticle physics; nuclear physics

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

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

2020 ESPP provides 20 ”recommendations”

2 : Major developments from the 2013 Strategy
HL-LHC; neutrinos

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

The updated Strategy is visionary and ambitious, but also realistic and prudent.
It lays the foundations for a bright future for particle physics in Europe, within the global context of the field.

19 Jun: CERN’s Council decided unanimously and enthusiastically to update the Strategy

Here: first views on implementation covering mainly scientific aspects;
other aspects mentioned in passing

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

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

Scientific priorities

- Full exploitation of LHC physics potential → successful completion of the high-luminosity upgrade of accelerators and experiments → going well, according to (revised) schedule

- e^+e^- Higgs factory as the highest-priority next collider

- Increased R&D on accelerator technologies: high-field superconducting magnets, high-gradient accelerating structures, plasma wakefield, muon colliders, ERL, etc.
  Develop accelerator R&D roadmap under LDG's supervision → starting

- Investigation of the technical and financial feasibility of a future ≥ 100 TeV hadron collider at CERN, with e^+e^- Higgs and electroweak factory as a possible first stage.
  → to be completed by next Strategy update (~ 2026).

- Support to long-baseline neutrino projects in US and Japan
  → in particular, successful implementation of DUNE at LBNF

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

- Theory, detector R&D (develop roadmap under ECFA's supervision → starting), SW and computing

Preliminary implementation in this year's Medium-Term Plan of CERN
(draft presented in June, final version for approval by the Council in September)

Remarks

- Strategy gives a direction for future collider(s) at CERN: FCC.
  Prudent: feasibility study first.

- Intensified accelerator R&D to prepare more broadly for the future, in particular alternatives if FCC feasibility study is unsuccessful

- No consensus in European community on which type of Higgs factory (linear/circular/where)
  If FCC feasibility successful and project approved → FCC-ee is natural choice at CERN

- ILC
  - compatible with ESPP if **timely** (otherwise conflict of resources with next collider at CERN)
  - are ILC and FCC-ee complementary enough in terms of physics for both to be built?
    No consensus in the community.

- Chinese colliders (CepC, SppC)
  It's in direct competition with ESPP → if CepC goes ahead faster than FCC feasibility study, Europe would go directly to FCC-hh (if feasible)

Future colliders

FCC

Focus on feasibility study of infrastrutcure and colliders (as recommended by ESPP).
Highest priorities:

- tunnel: high-risk zones, surface areas, administrative processes, environment
- machines: R&D (e.g. superconducting RF for FCC-ee; magnets for FCC-hh); design

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

CLIC

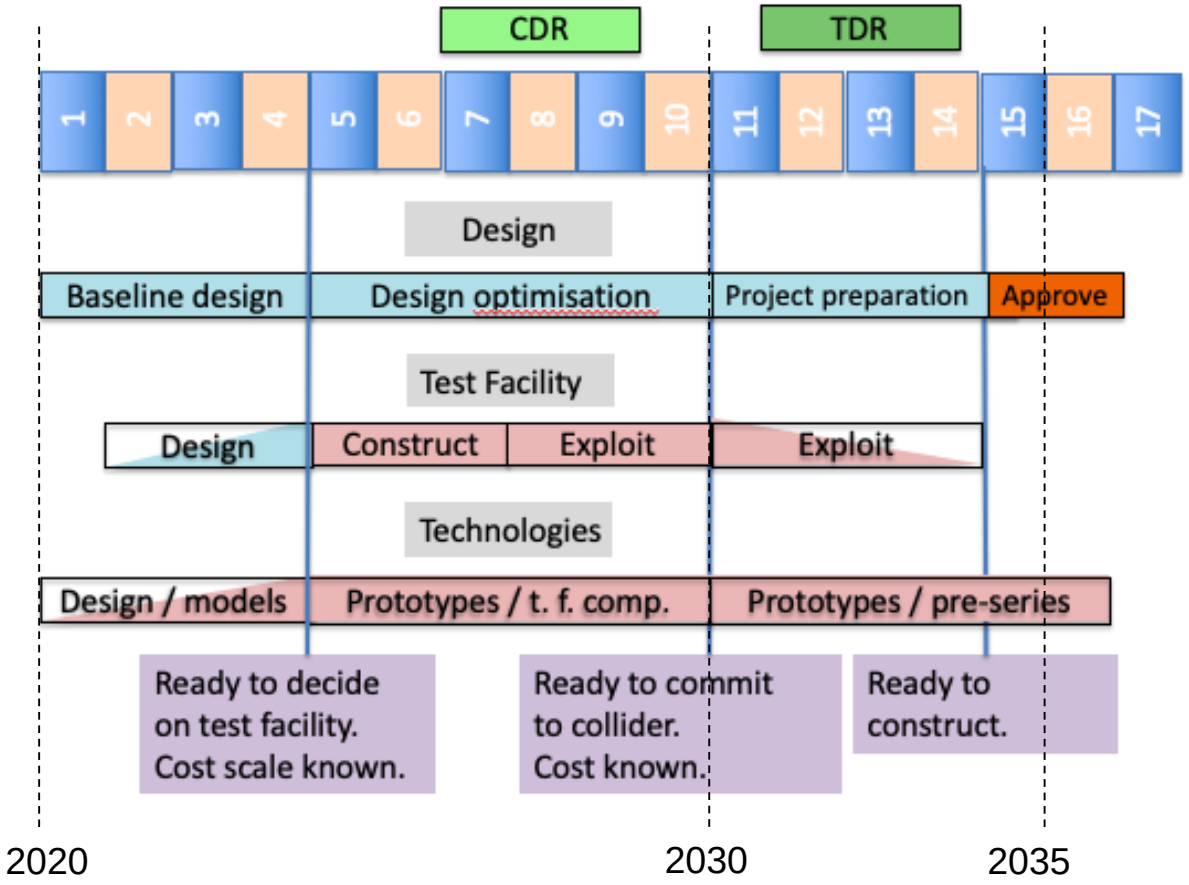
Continue R&D on key technology (X-band structure, beam dynamic, etc.) to maintain CLIC as option for a future collider (as recommended by ESPP).

Muon colliders

Effort started at CERN to support European community.
Main challenges: accelerator and collider rings, design of interaction region, muon source and cooling, fast-ramping magnets and power converters, neutrino radiation and civil engineering.

Future colliders: muon colliders

Preliminary, optimistic schedule for p-driven muon collider as presented to ESPP



Goal of R&D and desing studies in 2021-2025: develop design and features of test facility in time for next ESPP ~ 2026

Note: test facility would need strong endorsement by ESPP and CERN's Council approval as estimated cost is ~ 500 MCHF

Future colliders: FCC's 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 + additional "*ad hoc*" contributions from Member and other States → need innovative mechanisms: EC? private funds? donations?

First priority of feasibility study: find funds for the tunnel

Governance model for an unprecedented, global project

To be developed with international partners from the outset

Technical and administrative feasibility of tunnel

- ❑ highly-populated area; two countries with different legislative frameworks
- ❑ land expropriation and reclassification
- ❑ need to gain support of local populations (with a view to public surveys and debates)
- ❑ environmental aspects

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

Technologies of machine and experiments

- ❑ huge challenges, but under control of our scientific community → "easier"
- ❑ environmental aspects (aim at "green collider"): power, energy, cooling, gases, etc.

First priority of feasibility study: magnet technology; how to minimise environmental impact

Gathering political and societal support

→ requires "political work" and vast communication campaign for "consensus building" with governments and other authorities, scientists from other fields, general public (Science Gateway,…)

Accelerator R&D: super-conducting magnets

CERN is implementing 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.

Main activities:

- ❑ materials: LTS (Nb_3Sn) and HTS → goal: 16 T for LTS, at least 20 T for HTS
- ❑ 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

Strong partnership with industry and European national labs and universities

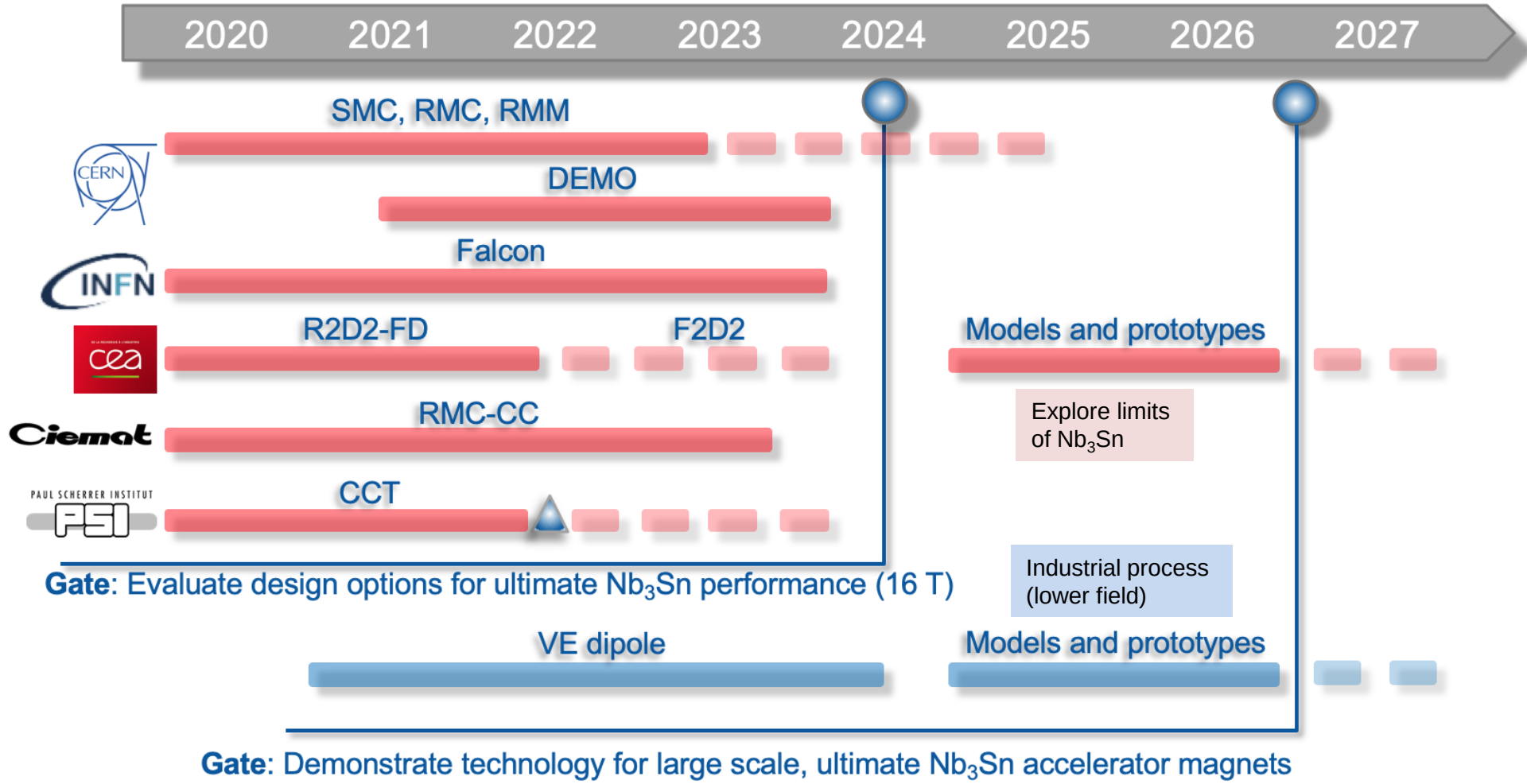
Goals (ambitious) for next ESPP ~ 2026:

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

Crucial milestone: first Nb_3Sn dipole (left) and inner triplet quadrupole (right) for HL-LHC built and qualified for installation at CERN and in the US. Field: 11-12 T

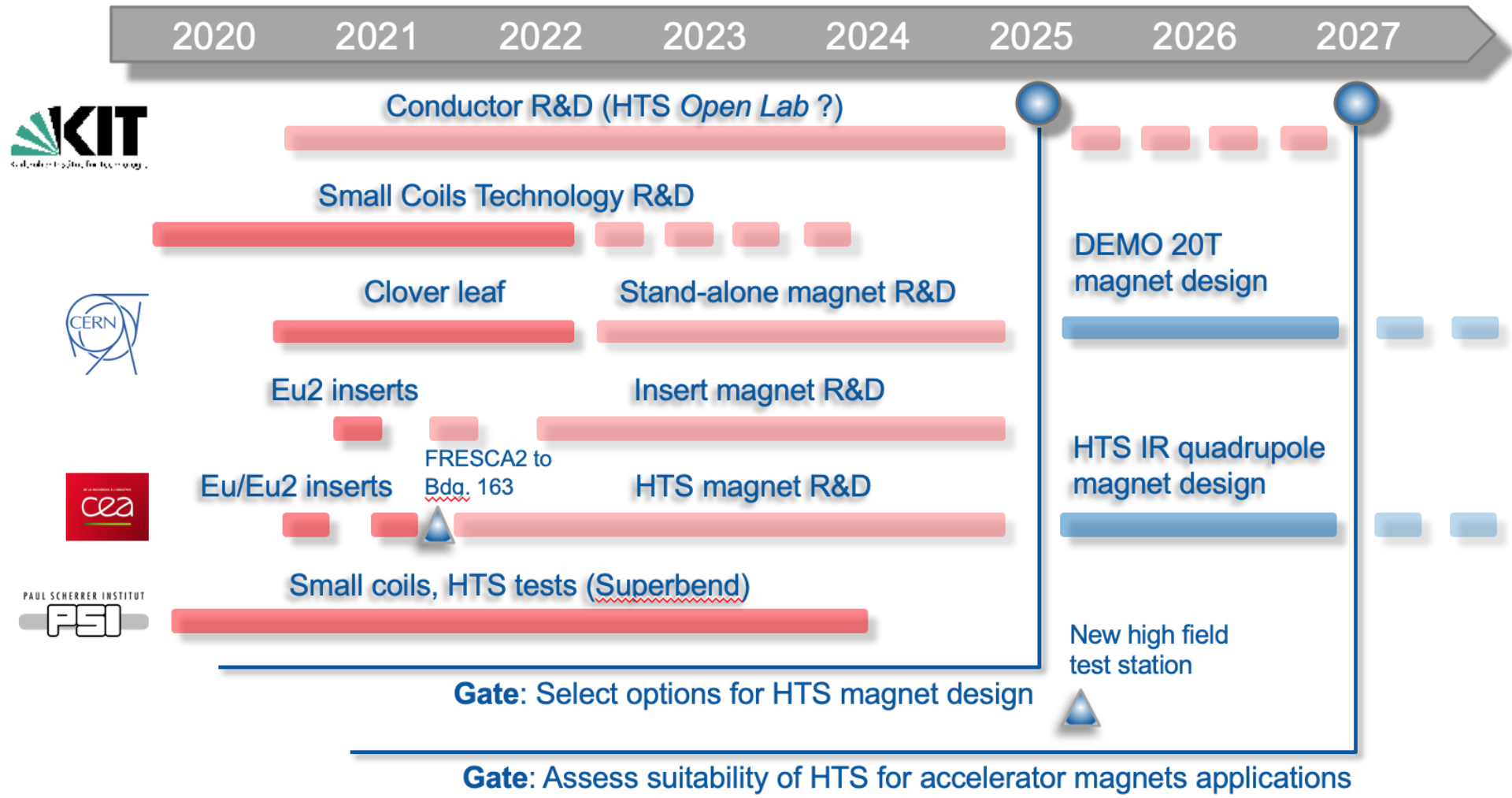
Accelerator R&D: super-conducting magnets

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



Accelerator R&D: super-conducting magnets

Ambitious, preliminary roadmap for high-T superconducting magnets

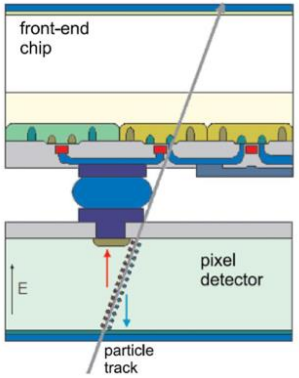


R&D for future detectors

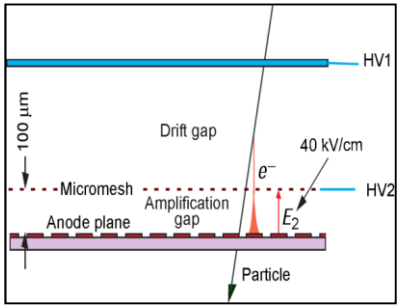
2017: initiative launched by CERN's EP department on strategic R&D for detectors at future collider and non-collider projects.

Main goals: define main needs and requirements; identify and develop most promising technologies; foster synergies across projects.

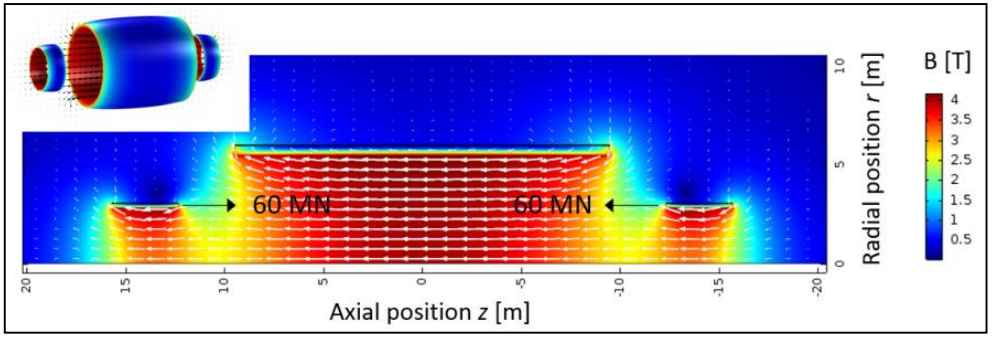
Emphasis on areas where CERN has significant expertise and infrastructure. Close cooperation with interested Institutes and similar activities in Europe.



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.
→ status and plans summarised in report submitted to ESPP



As of 2020, new budget line in CERN's MTP grouping all detector R&D activities across projects (residual Phase-2 upgrade work, Linear Collider, FCC, PBC) → increase synergies and optimise resources.



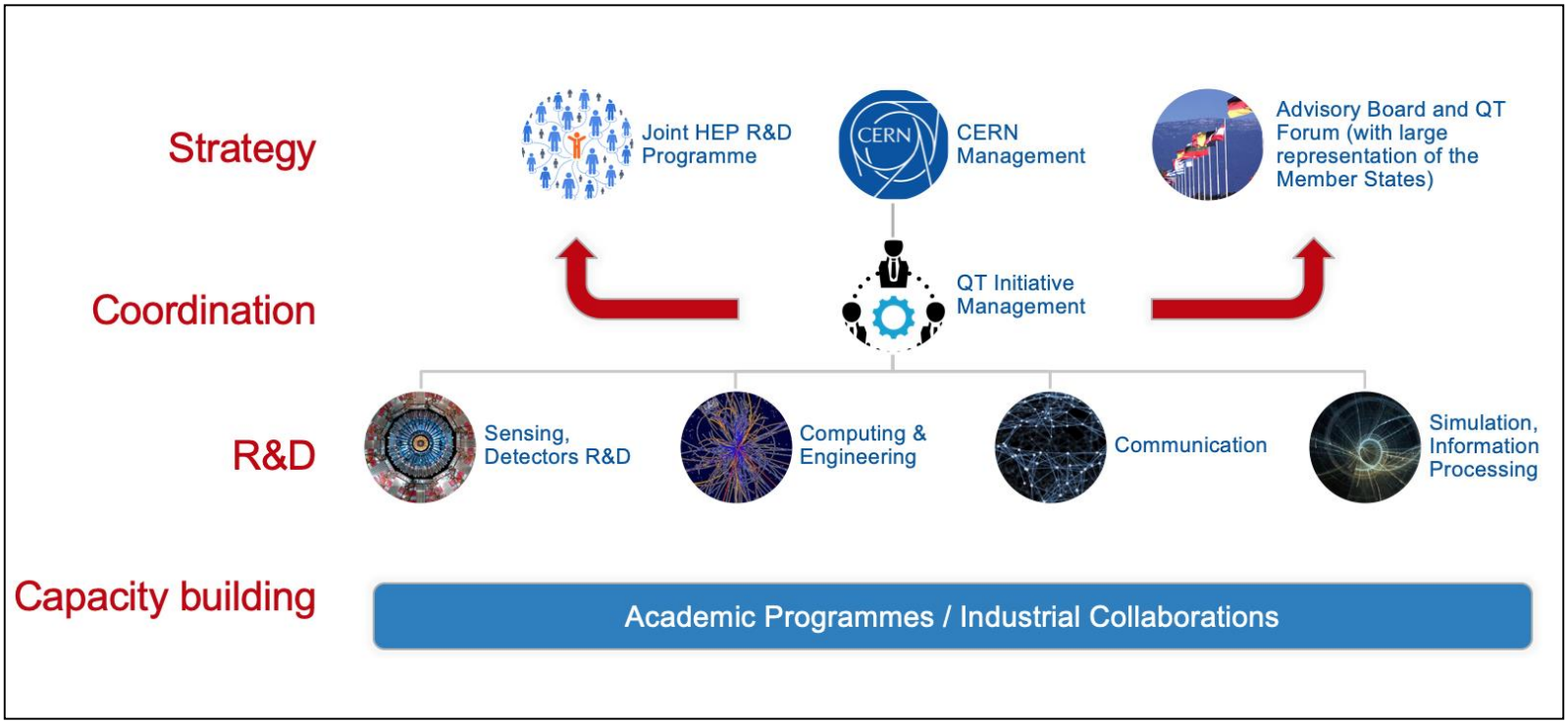
These activities will be revised and adapted as soon as detector R&D roadmap available.

Software and Computing: CERN Quantum Technology Initiative

Quantum technologies developing fast, with high-potential impact on science and society
→ significant resources invested in CERN's Member States and beyond.

CERN and its community are in a unique position to make significant contributions:

- ❑ diverse set of skills and technologies: SW, computing, theory, engineering, cryogenics, electronics, etc.
- ❑ compelling use cases from our scientific work that are attractive to industry and other stakeholders
- ❑ rich network of academy and industry relations and collaboration models like Openlab (https://openlab.cern)



Received support from Council

Initiative discussed with LHC experiments, WLCG, Scientific Computing Forum, HEP Software Foundation and representatives of similar projects in Member States and beyond.

Conclusions

The 2020 Strategy is visionary and ambitious, but also realistic and prudent.

It lays the foundations for a bright future for the field at CERN and in Europe
→ maintain a scientific and technical leading role in particle physics

It should be implemented in collaboration with worldwide partners

The Strategy update is the result of two years of intense and successful efforts of the community to prepare and discuss excellent scientific and other input.

Examples of key objectives for next ESPP update ~ 2026:

- ❑ Successful completion of Run 3, HL-LHC construction and ATLAS and CMS Phase-2 upgrades (installation in LS3: 2025-2027)
- ❑ Start of installation of first detector of DUNE experiment at LBNF (strong contributions of CERN and Europe to detector, PIP-II accelerator, cryogenics)
- ❑ Feasibilty study for FCC (succesfully) completed
- ❑ Accelerator R&D: LTS/HTS magnet feasibilty; AWAKE Run 2 completed; muon collider ready to build facility; etc.

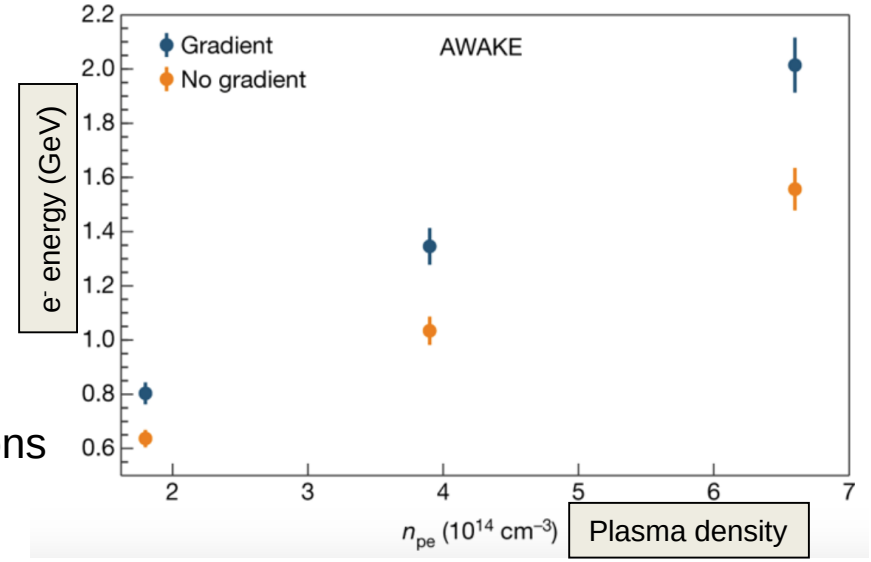
Implementation started → it will require work, dedication and enthusiasm of the full community

EXTRAs

AWAKE

Advanced Proton Driven Plasma Wakefield Acceleration Experiment

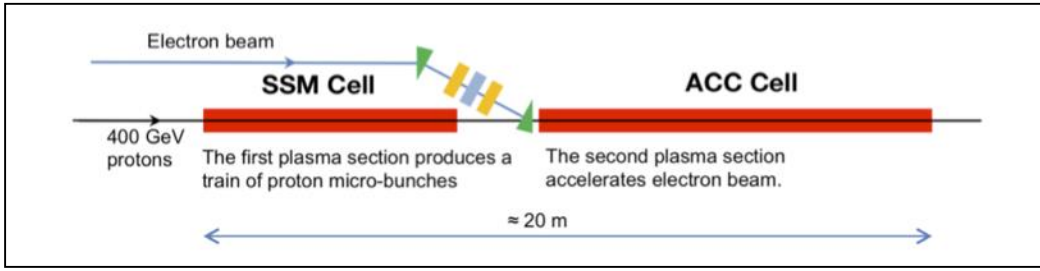
Run 1 (2016-2018): first demonstration of p-driven e⁻ acceleration over 10 m plasma cell: 20 MeV → 2 GeV (200 MV/m gradient)



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



10 M (16 M) materials budget allocated over 2020-2024 (2020-2029) for design studies and implementation of Run 2 programme