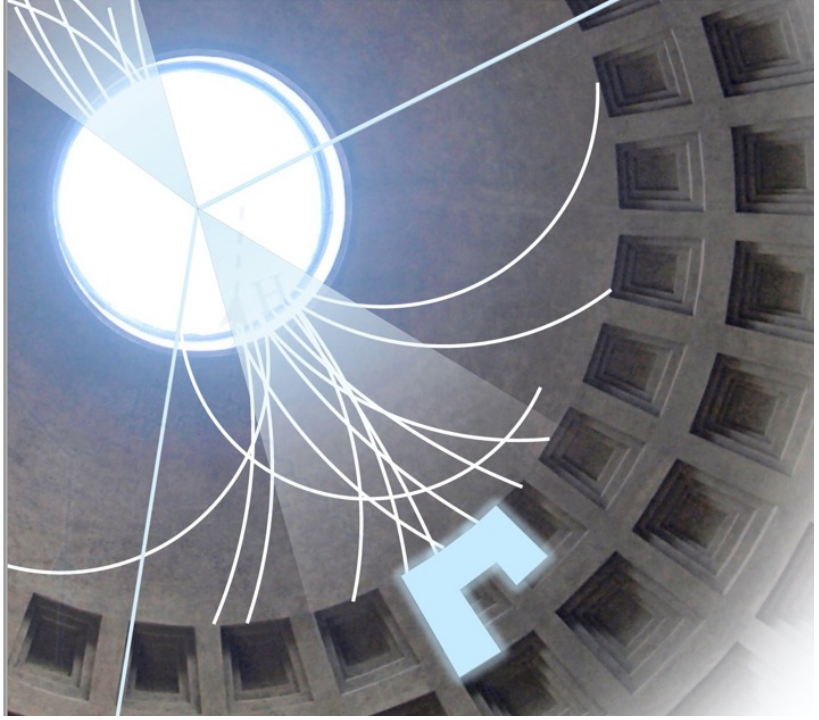


Importance of FCC for INFN scientific program

A. Zoccoli (INFN & UniBO)

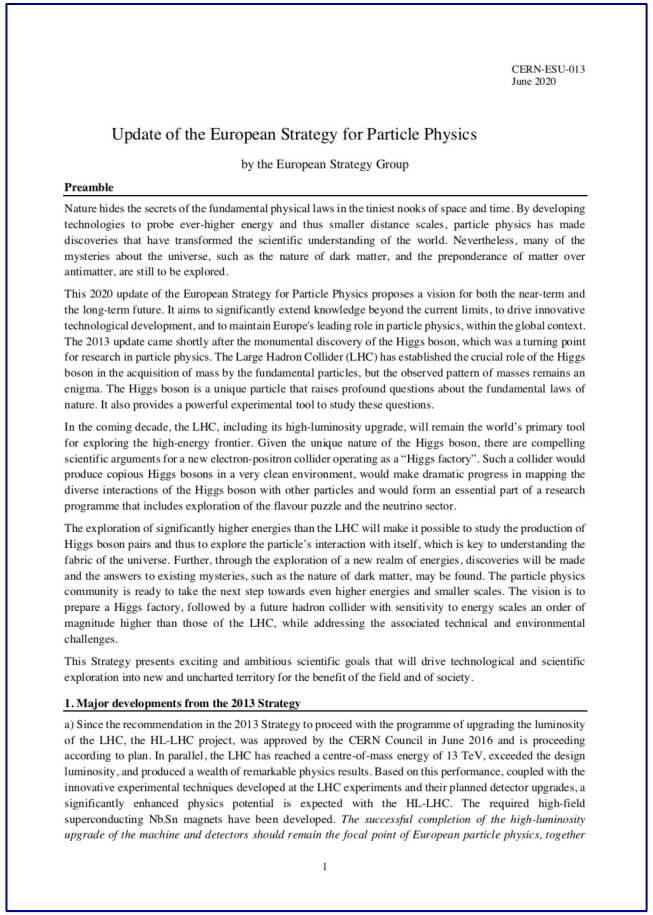
1° FCC Italy, Roma 21-22 marzo 2022

The ESPP

The European Strategy for Particle Physics is the cornerstone of Europe's decision-making process for the long-term future of the field. Mandated by the CERN Council, it is formed through a broad consultation of the grass-roots particle physics community, it actively solicits the opinions of physicists from around the world, and it is developed in close coordination with similar processes in the US and Japan in order to ensure coordination between regions and optimal use of resources globally.

ESPP published on 19/6/2020

Strategy statements



CERN-ESU-013
June 2020

Update of the European Strategy for Particle Physics

by the European Strategy Group

Preamble

Nature hides the secrets of the fundamental physical laws in the tiniest nooks of space and time. By developing technologies to probe ever-higher energy and thus smaller distance scales, particle physics has made discoveries that have transformed the scientific understanding of the world. Nevertheless, many of the mysteries about the universe, such as the nature of dark matter, and the preponderance of matter over antimatter, are still to be explored.

This 2020 update of the European Strategy for Particle Physics proposes a vision for both the near-term and the long-term future. It aims to significantly extend knowledge beyond the current limits, to drive innovative technological development, and to maintain Europe's leading role in particle physics, within the global context. The 2013 update came shortly after the monumental discovery of the Higgs boson, which was a turning point for research in particle physics. The Large Hadron Collider (LHC) has established the crucial role of the Higgs boson in the acquisition of mass by the fundamental particles, but the observed pattern of masses remains an enigma. The Higgs boson is a unique particle that raises profound questions about the fundamental laws of nature. It also provides a powerful experimental tool to study these questions.

In the coming decade, the LHC, including its high-luminosity upgrade, will remain the world's primary tool for exploring the high-energy frontier. Given the unique nature of the Higgs boson, there are compelling scientific arguments for a new electron-positron collider operating as a "Higgs factory". Such a collider would produce copious Higgs bosons in a very clean environment, would make dramatic progress in mapping the diverse interactions of the Higgs boson with other particles and would form an essential part of a research programme that includes exploration of the flavour puzzle and the neutrino sector.

The exploration of significantly higher energies than the LHC will make it possible to study the production of Higgs boson pairs and thus to explore the particle's interaction with itself, which is key to understanding the fabric of the universe. Further, through the exploration of a new realm of energies, discoveries will be made and the answers to existing mysteries, such as the nature of dark matter, may be found. The particle physics community is ready to take the next step towards even higher energies and smaller scales. The vision is to prepare a Higgs factory, followed by a future hadron collider with sensitivity to energy scales an order of magnitude higher than those of the LHC, while addressing the associated technical and environmental challenges.

This Strategy presents exciting and ambitious scientific goals that will drive technological and scientific exploration into new and uncharted territory for the benefit of the field and of society.

1. Major developments from the 2013 Strategy

a) Since the recommendation in the 2013 Strategy to proceed with the programme of upgrading the luminosity of the LHC, the HL-LHC project, was approved by the CERN Council in June 2016 and is proceeding according to plan. In parallel, the LHC has reached a centre-of-mass energy of 13 TeV, exceeded the design luminosity, and produced a wealth of remarkable physics results. Based on this performance, coupled with the innovative experimental techniques developed at the LHC experiments and their planned detector upgrades, a significantly enhanced physics potential is expected with the HL-LHC. The required high-field superconducting Nb$_3$Sn magnets have been developed. *The successful completion of the high-luminosity upgrade of the machine and detectors should remain the focal point of European particle physics, together*

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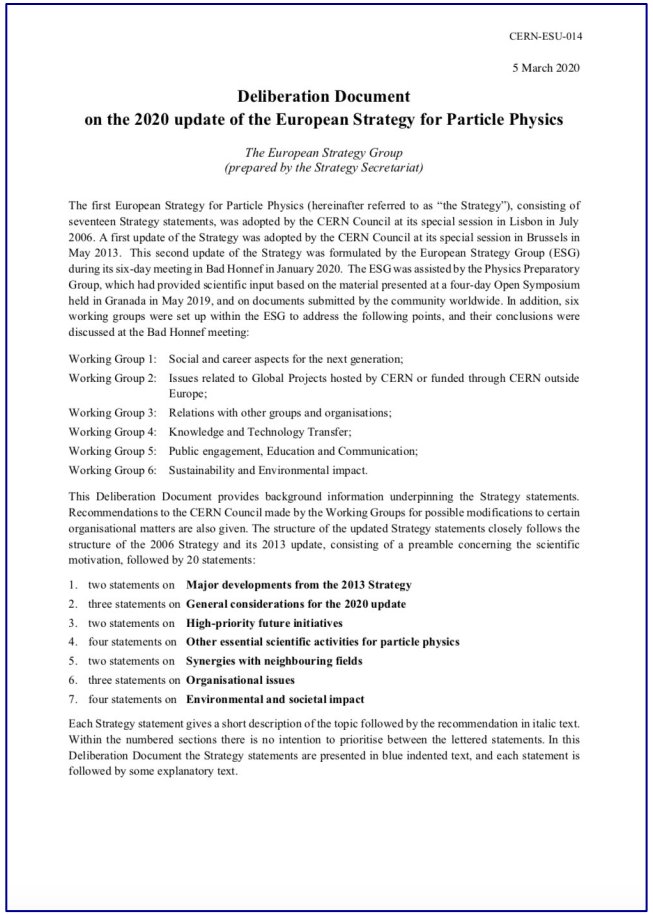
Deliberation document



CERN-ESU-014

5 March 2020

Deliberation Document
on the 2020 update of the European Strategy for Particle Physics

The European Strategy Group
(prepared by the Strategy Secretariat)

The first European Strategy for Particle Physics (hereinafter referred to as "the Strategy"), consisting of seventeen Strategy statements, was adopted by the CERN Council at its special session in Lisbon in July 2006. A first update of the Strategy was adopted by the CERN Council at its special session in Brussels in May 2013. This second update of the Strategy was formulated by the European Strategy Group (ESG) during its six-day meeting in Bad Honnef in January 2020. The ESG was assisted by the Physics Preparatory Group, which had provided scientific input based on the material presented at a four-day Open Symposium held in Granada in May 2019, and on documents submitted by the community worldwide. In addition, six working groups were set up within the ESG to address the following points, and their conclusions were discussed at the Bad Honnef meeting:

Working Group 1: Social and career aspects for the next generation;
Working Group 2: Issues related to Global Projects hosted by CERN or funded through CERN outside Europe;
Working Group 3: Relations with other groups and organisations;
Working Group 4: Knowledge and Technology Transfer;
Working Group 5: Public engagement, Education and Communication;
Working Group 6: Sustainability and Environmental impact.

This Deliberation Document provides background information underpinning the Strategy statements. Recommendations to the CERN Council made by the Working Groups for possible modifications to certain organisational matters are also given. The structure of the updated Strategy statements closely follows the structure of the 2006 Strategy and its 2013 update, consisting of a preamble concerning the scientific motivation, followed by 20 statements:

1. two statements on **Major developments from the 2013 Strategy**
2. three statements on **General considerations for the 2020 update**
3. two statements on **High-priority future initiatives**
4. four statements on **Other essential scientific activities for particle physics**
5. two statements on **Synergies with neighbouring fields**
6. three statements on **Organisational issues**
7. four statements on **Environmental and societal impact**

Each Strategy statement gives a short description of the topic followed by the recommendation in italic text. Within the numbered sections there is no intention to prioritise between the lettered statements. In this Deliberation Document the Strategy statements are presented in blue indented text, and each statement is followed by some explanatory text.

Higgs studies and FCC next priorities (feasibility study)

A. An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy. Accomplishing these compelling goals will require innovation and cutting-edge technology:

• the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature superconductors;

• Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update.

Accelerator and detector R&D among the priorities of CERN and Member States throughthe collaboration with national infrastructures

B. Innovative accelerator technology underpins the physics reach of high-energy and high-intensity colliders. It is also a powerful driver for many accelerator-based fields of science and industry. The technologies under consideration include high-field magnets, high-temperature superconductors, plasma wakefield acceleration and other high-gradient accelerating structures, bright muon beams, energy recovery linacs. ***The European particle physics community must intensify accelerator R&D and sustain it with adequate resources. A roadmap should prioritise the technology, taking into account synergies with international partners and other communities such as photon and neutron sources, fusion energy and industry. Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.***

C. The success of particle physics experiments relies on innovative instrumentation and state-of-the-art infrastructures. To prepare and realise future experimental research programmes, the community must maintain a strong focus on instrumentation. ***Detector R&D programmes and associated infrastructures should be supported at CERN, national institutes, laboratories and universities. Synergies between the needs of different scientific fields and industry should be identified and exploited to boost efficiency in the development process and increase opportunities for more technology transfer benefiting society at large. Collaborative platforms and consortia must be adequately supported to provide coherence in these R&D activities. The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels.***

Addressing coordination, governance and promote political consensus

A. An ambitious next-generation collider project will require global collaboration and a long-term commitment to construction and operations by all parties. ***CERN should initiate discussions with potential major partners as part of the feasibility study for such a project being hosted at CERN. In the case of a global facility outside Europe in which CERN participates, CERN should act as the European regional hub, providing strategic coordination and technical support. Individual Member States could provide resources to the new global facility either through additional contributions made via CERN or directly through bilateral and multilateral arrangements with the host organisation.***

B. The particle physics community and the European Commission have a strong record of collaboration. ***The relationship between the particle physics community and the European Commission should be further strengthened, exploring funding-mechanism opportunities for the realisation of infrastructure projects and R&D programmes in cooperation with other fields of science and industry.***

C. European science policy is quickly moving towards Open Science, which promotes and accelerates the sharing of scientific knowledge with the community at large. Particle physics has been a pioneer in several aspects of Open Science. ***The particle physics community should work with the relevant authorities to help shape the emerging consensus on Open Science to be adopted for publicly-funded research, and should then implement a policy of Open Science for the field.***

ESPP 2020 Roadmap: current status

- Budget allocated in the CERN mid-term plan for feasibility studies and TDR preparation
  → First review foreseen in mid 2023

- Two Working Groups on Accelerators R&D and Detectors R&D concluded the preparatory work and prepared detailed reports

- Laboratory Directors Group (LDG) and CERN Council are defining the ESPP implementation roadmap

- Proposal on how to implement the two Roadmaps, under scrutiny at LDG and to be discussed at Council

ESUPP 2020 Roadmap: current status

- Detectors R&D: "traditional approach" in which INFN researchers develp frontier technologies (for FCC-ee or FCC-hh,)
  → CERN *uno inter pares*

- Accelerators R&D:implementation phase more complex:
  - participation definition to FCC feasibility study
  - current and future governance for FCC studies (MoU, etc…)
  - financial coordination for FCC.

  Strategic role for CERN: coordination hub, technology developer, support to regional Member state activities

The role of INFN (researchers/ engineers)

- INFN is willing to play a major role in this scenario
- If FCC approved → relevant contribution from Italy (10% ? O(100 ME) ?) both on experiments and detectors
- INFN must ready putting in place a program for technology development, know-how consolidation and for the involvement of the high tech industrial system
- INFN has to Identify specific activities on accelerator and detector where to focalize its main contributions and to build-up the necessary critical mass
- 1st FCC Italy workshop is a step in this direction

Some actions in place

- Participation on the different activities on detector and accelerator R&D (superconductivity, magnets, accelerator, muon collider….)
- IRIS: PNRR project on superconductivity submitted by iNFN
- Bilatreal agreement with CERN for common activities on FCC
- Organization of the INF community to play a primary role in the FCC endeavour (1° FCC Italy workshop ……)

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IRIS

Innovative Research Infrastructure on applied Superconductivity

Research Infrastructure for the development of superconducting technologies

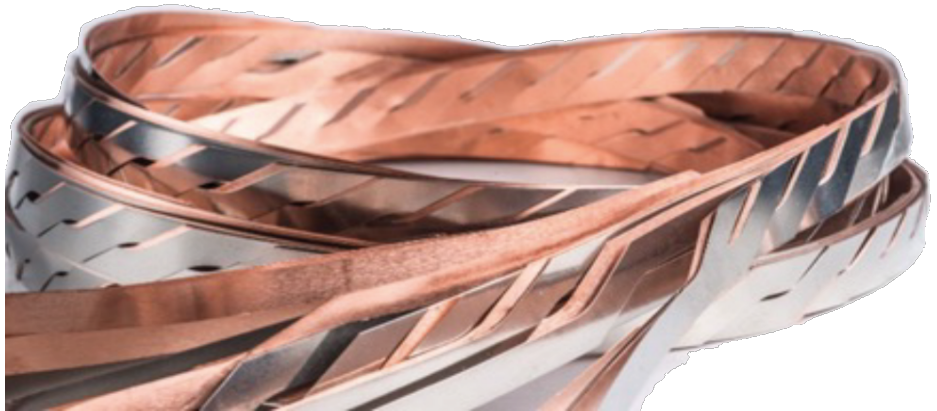
Including high temperatures

Industrial spin-offs:

- Superconducting magnets → CERN/Medicine
- Low-dispersion superconducting cables

Budget: 75 M€ (50% in Southern Regions):

- **40 M€** to upgrade infrastructures, laboratories, cutting-edge technologies
- **25 M€** for electric power line prototypes and magnets



Piano Nazionale di Ripresa e Resilienza

MUR

INFN

Istituto Nazionale di Fisica Nucleare

Conclusions

- The future of European (and INFN) particle physics community is tightly related to the next accelerator machine after LHC
- FCC is the principal option in this scenario and its feasibility must be investigated and verified within the current ESPP time frame (before 2027)
- INFN is and will be deeply involved in alle the FCC activities in the next years

Thank you for the attention