European Strategy for Particle Physics: 2026 Update

Hungarian Roadmap
2024/12/16 → → → 2025/03/31

Péter Lévai, 16 December 2024, Budapest, Hungary

ESPP: European Strategy for Particle Physics

https://europeanstrategy.cern/european-strategy-for-particle-physics

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.

The European Strategy process was initiated by the CERN Council in 2005, resulting in a document being adopted by the Council in 2006. This document placed the LHC at the top of European particle physics' scientific priorities, …

The first update was prepared in 2012 and adopted in 2013. By this time, the LHC had proved its capacity with the discovery of the long-sought Higgs boson, …

The second update of the European Strategy got underway in 2018:
Open Symposium in Granada (2019); Drafting Session in Bad Honnef (2020) [→ Budapest]
Post-LHC facilities: CLIC &/or FCC at CERN; ILC in Japan; CEPC in China

The third update of the European Strategy was launched by the CERN Council in 2024/06.
HU-delegate: Dezső Varga

Timeline for the update of the European Strategy for Particle Physics

More details on ESPP web page: https://europeanstrategyupdate.web.cern.ch/

Organisation of the work in PPG

The Strategy Secretariat has set up **nine working groups** to cover the full range of physics topics as well as the technology areas of accelerators, detector technologies and computing.

Working Group			
	Co-convener (PPG member)	Co-convener	Scientific Secretary
Electroweak physics	Monica Dunford (DE, exp)	Jorge de Blas (ES, theory)	Emanuele Bagnaschi (IT)
Strong interaction	Cristinel Diaconu (FR, exp)	Andrea Dainese (IT, exp, HI)	Chiara Signorile-Signorile (DE)
Flavour physics	Gino Isidori (CH, theory)	Marie-Hélène Schune (FR, exp)	Maria Piscopo (NL)
BSM physics	Fabio Maltoni (BE/IT, theory)	Rebeca Gonzalez Suarez (SE, exp)	Benedikt Maier (UK)
Neutrino physics and cosmic messengers	Pilar Hernandez (ES, theory)	Sara Bolognesi (FR, exp)	Ivan Esteban (ES)
Dark matter and dark sector	Jocelyn Monroe (UK, exp)	Matthew McCullough (CERN, theory)	Yohei Ema (CERN)
Accelerator science and technology	Gianluigi Arduini (CERN, acc)	Phil Burrows (UK, exp, acc)	Jacqueline Keintzel (CERN)
Detector instrumentation	Thomas Bergauer (AT, exp)	Ulrich Husemann (DE, exp)	Dorothea vom Bruch (FR)
Computing	Tommaso Boccali (IT, exp, comp)	Borut Kersevan (SL, exp, comp)	Daniel Thomas Murnane (DK)

Physics Preparatory Group

- Each group has **two co-conveners** and one Early-Career Researcher (ECR) as **Scientific Secretary** to organise the work
- ECRs have been appointed by the co-conveners, in consultation with the Strategy Secretariat
  (partially based on nominations via ECFA)

Short summary of the charge to the co-conveners

- Selection of Early Career Researchers (✔)
- Definition of sub-topics and appointment of additional working group members (ongoing)
- Definition of benchmark processes / measurements (ongoing, will be shared with project groups)
- Organisation of working-group meetings
- Writing of the Physics Briefing Book
  (will be supported by Roger Forty, who has agreed to be Scientific Secretary of the Strategy update)

It is expected that for each physics area comparative assessments on the physics potential of various proposed projects for the defined benchmark are made. By construction this comparison should be made at the working group level;

A more global comparison across various physics areas is the responsibility of the ESG.

Benchmark measurements / processes for PPG Groups

- A set of benchmark measurements / processes has been defined by the co-conveners;
  It is expected that they are addressed in the March 2025 submission

- Benchmarks have been shared with the large projects for feedback, iterations will follow

- Examples (preliminary):

Electroweak physics, incl. Higgs

- Higgs (m_H, single-Higgs couplings via SMEFT and kappas)
- HH and Higgs potential (Higgs self-coupling)
- Precision EW (m_W, Z width, $\sin^2\theta_W$; EW couplings via SMEFT)
- Longitudinal scattering
- Top benchmarks: top mass and SMEFT

BSM Physics

- New gauge forces (Z', W'...)
- Compositeness (indirectly from EFT fits)
- Extension of the minimal real scalar sector giving 1st order electroweak phase transition and possibly stability.
- Minimal dark matter (WIMP) global
- High-energy aspects of flavour, e.g. exotic top decays
- SUSY (direct only collider)
- Portals (dark photon, dark Higgs, HNLs, axions, ALPs)

- See slides in backup for more details

- Detector instrumentation: will look at requirements from projects and whether they are covered by the R&D activities as carried out in the DRD activities;
- Accelerator technologies: similar, check on requirements of projects and whether they are properly addressed by the corresponding R&D activities
- Computing: what will be the computing needs for new projects, how can they be covered, R&D lines

Community Involvement

Input and involvement of the community is important!
(… and explicitly asked for in the remit of the Strategy Process)

Goal must be to reach a consensus in the community on the way forward for our field!

(i) Submission of input from the community by **31 March 2025**

Guidelines for documents to be submitted have been defined
→ **Comprehensive and self-contained summary of 10 pages (max)**

Additional information and details can be submitted in a **separate back-up document**, which can be consulted by the Physics Preparatory Group (PPG) if clarification on any aspects is required.
But the back-up document is not a mandatory component of the submission.

(ii) Input from **projects** (FCC, Linear Collider, …, Muon Collider, …, theory, …) is expected
In addition, input on technical data expected (→ slides 8 and 9)

(iii) Input from **national HEP communities** is a vital component of the Strategy Process
(ECFA guidelines, already discussed in September SPC/Council meetings)

Guidelines for documents to be submitted on 31 March

July 2024

European Strategy Update

Contact:
eppsu2024-strategy-secretariat@cern.ch

Guidelines for submitting input for the 2026 update of the European Strategy for Particle Physics

Cover page (1 page)
Each document submitted should carry a single cover page containing no more than the title, the contact person(s) and an abstract.

Comprehensive summary (maximum 10 pages)
The submitted document must be no more than 10 pages long (excluding the cover page) and must provide a comprehensive and self-contained summary of the input. It should address:

- scientific context,
- objectives,
- methodology,
- readiness and expected challenges,
- timeline,
- construction and operational costs (if applicable).

Back-up document
Additional information and details can be submitted in a separate back-up document, which can be consulted by the Physics Preparatory Group (PPG) if clarification on any aspects is required. But the back-up document is not a mandatory component of the submission.

Format and deadline for submission
The cover page and the comprehensive summary are to be submitted in portable document format (pdf) by 31 March 2025. The back-up document should have a cover page with the same title and contact persons and with the words "Back-up Document" added. A dedicated submission portal for both documents will be made available via the ESPPU website.

Distribution
All the documents submitted will be forwarded to the PPG and the European Strategy Group (ESG). Unless explicitly requested otherwise, they will also be made public. The option not to make a given document public will be available upon submission via the dedicated portal.

https://europeanstrategy.cern/

Klick on *"Information for the physics community"*

→ *2026 update;*
direct link: 2026 update

All inputs shall be submitted via this portal

Large-Scale Projects: Guidelines for Input

- It is anticipated that a number of proposals for large-scale research projects (capital investment of at least 250 MCHF) – including, but not limited to, particle colliders and collider detectors – will be submitted as input to the strategy process.
- In addition to studying the scientific potential of these projects, the ESG wishes to evaluate the sequence of delivery steps and the challenges associated with delivery, and to understand how each project could fit into the wider roadmap for European particle physics.
- In order to allow a straightforward comparison of projects, we therefore request that all large-scale projects submit – in addition to their physics case and technical description – a standardised set of technical data.

1. Stages and parameters

a. The main stages of the project and the key scientific goals of each
b. Whether the ordering of stages is fixed or whether there is flexibility
c. For each stage, the main technical parameters
d. The number of independent experimental activities and the number of scientists expected to be engaged in each.

2. Timeline

a. The technically-limited timeline for construction of each stage
b. The anticipated operational (running) time at each stage, and the expected operational duty cycle

Large-Scale Projects: Questions

3. Resource requirements

a. The capital cost of each stage in 2024 CHF
b. The annual cost of operations of each stage
c. The human resources (in FTE) needed to deliver or operate each stage over its lifetime, expressed as an annual profile
d. Commentary on the basis-of-estimate of the resource requirements

4. Environmental impact

a. The peak (MW) and integrated (TWh) energy consumption during operation of each stage
b. The integrated carbon-equivalent energy cost of construction
c. Any other significant expected environmental impacts

5. Technology and delivery

a. The key technologies needed for delivery that are still under development in 2024, and the targeted performance parameters
b. The critical path for technology development or design
c. A concise assessment of the key technical risks to the delivery of the project

6. Dependencies

a. Whether a specific host site is foreseen, or whether options are available
b. The dependencies on existing or required infrastructure
c. The technical effects of project execution on the operations of existing infrastructures at the host site

7. Commentary on current project status

a. A concise description of the current design / R&D / simulation activities leading to the project, and the community pursuing these
b. A statement of any major in-kind deliverables already negotiated
c. Any other key technical information points in addition to those captured above, including references to additional public documents

Work / topics covered and shared among PPG and ESG

PPG:
Physics + Technology working groups

- Electroweak physics (including Higgs physics)
- Strong interaction
- Flavour physics
- Beyond the Standard Model physics
- Neutrino physics and cosmic messengers
- Dark matter and dark sector
- Accelerator science and technology
- Detector instrumentation
- Computing

→ **Physics Briefing Book**

ESG: Overarching topics

- **National input / roadmaps (→ strategic)**
- **Projects (FCC, LC, LE-FCC-hh, MC, ..)**
  (timeline, costs, …. (physics → PPG))
- Comparisons across proposed projects
- Relations with other fields of physics
- …

ESG working groups need to be set up;
→ *First proposal has been prepared by Strategy Secretariat (to be discussed and finalised at an in-person ESG meeting at CERN on 15th January 2025)*

Proposed ESG Working Groups (preliminary, discussion within ESG)

(1) National Input, Diversity in European Particle Physics

- Analyse and summarise the input that will be submitted by the national HEP communities.
- Discuss constraints imposed by a large accelerator project at CERN. What fraction of the CERN and European research budget should be put on a single flagship project?
- Discuss the level of European participation in projects outside Europe

(2) Project Comparison Group

(a) Project assessment (technical feasibility, timeline, risks, cost and human resources, environmental impact)
(b) Physics potential
(c) Development of international landscape of the field

(3) Implementation of the Strategy / Deliverability of larger projects

Main purpose: assess how European National Laboratories and institutes can best work together with CERN to deliver large scale accelerator and detector projects.

("Distributed delivery model" for CERN's next major infrastructure? New management practices and tools?
What lessons can be learnt from the recent major projects (e.g. ATLAS and CMS upgrades)?
What could be a model for international participation (beyond CERN Member and Associate Member States)?)

(4) Relations with other fields of physics

Evaluate to what extent CERN should participate in nuclear physics, astroparticle physics or other areas of science.
CERN has unique capabilities in e.g. accelerators, particle detectors and information technology, which can be of use for other fields of physics.

Proposed ESG Working Groups (preliminary, discussion within ESG)

(5) Sustainability and environmental impact

Crucial to consider energy consumption, sustainability, and efficiency of future projects.
It is essential that also the HEP community is seen to be contributing to reducing or offsetting our environmental impact

(6) Public Engagement, Education, Communication

- It is both an obligation and an incentive to share our results and insights with the stakeholders supporting the research.
- The viability of particle physics in the long term relies heavily on the proper education and training of the next generation of particle physicists and engineers

(7) Social and career aspects for the next generation

- How to maintain the attractiveness of the field of particle physics and preserve expertise in view of the lengthening timescales of projects.
- How to improve the recognition of individuals in large collaborations
- Reward of technical work on accelerator and detector development, software and computing, as well as code support and technical aspects for the highly involved theory calculations.

(8) Knowledge and Technology Transfer

Knowledge transfer (KT) from fundamental research to society is of very high importance to demonstrate the impact of basic science on everyday life. Although particle physics addresses basic science issues, the cutting-edge technologies developed in the fields of accelerators, detectors and IT to permit ground-breaking scientific results that have the potential to generate important spin-offs, as has been demonstrated in the past in several domains.

Next steps

- PPG: Finalise benchmarks (incorporate feedback from large projects, state some benchmarks more precisely)
  Working Group structure and WG participants

- ESG: 1st in-person meeting on 15th January at CERN
  → discuss and finalise ESG Working Groups and participation of ESG members in these groups

- Start discussion on layout of the Venice Open Symposium

23-27 June 2025, Venice

Special Session of the CERn Council: 28-29 May 2026
Headquarter of the Hungarian Academy of Sciences

Venue: Gala Hall of the HAS
300-350 persons in „theather mode”
100-120 persons in U-shape „Council-mode”
Sound system, projectors, monitors, internet

9 Széchenyi István Square
Budapest, 1051 Hungary

ECFA for ESPP

HU-Delegate: Ferenc Siklér

ECFA guidelines for national HEP community inputs: Questions to address

a) Which is the preferred next major/flagship collider project for CERN?

b) What are the most important elements in the response to (a)?

- i) Physics potential
- ii) Long-term perspective
- iii) Financial and human resources: requirements and effect on other projects
- iv) Timing
- v) Careers and training
- vi) Sustainability

c) Should CERN/Europe proceed with the preferred option set out in (a) or should alternative options be considered:

- i) if Japan proceeds with the ILC in a timely way?
- ii) if China proceeds with the CEPC on the announced timescale?
- iii) if the US proceeds with a muon collider?
- iv) if there are major new (unexpected) results from the HL-LHC or other HEP experiments?

d) Beyond preferred option, what other accelerator R&D topics (e.g. high-field magnets, RF technology, alternative accelerators/colliders) should be pursued in parallel?

e) What is the prioritised list of alternative options if the preferred option is not feasible (due to cost, timing, international developments, or for other reasons)?

f) What are the most important elements in the response to (e)?

Prioritisation for non-collider projects:

- a) What other areas of physics should be pursued, and with what relative priority?
- b) What are the most important elements in the response to (a)?
- c) To what extent should CERN participate in nuclear physics, astroparticle physics or other areas of science, while keeping in mind and adhering to the CERN Convention? Please use the current level and form of activity as the baseline for comparisons.

Rich, excellent physics program → challenging detectors

F. Sefkow (ECFA HET Wkshp 2024)

Higgs Factory Program
- 2M ZH events at $\sqrt{s}$=240 GeV
- 75k WW→H events at $\sqrt{s}$=365 GeV
- Higgs Couplings
- Higgs self-couplings (2-4σ) via loop diagrams
- Unique: $e^+e^- \rightarrow H$ at $\sqrt{s}$ = 125 GeV

→
- **Momentum Resolution $\sigma(p_T)/p_T \simeq 10^{-3}$ @ $p_T \sim$ 50 GeV**
- **Jet $\sigma(E)/E \approx$ 3-4% in multi-jets for Z/W separation**
- **Impact parameter resolution for b, c tagging**

Precision EW and QCD Program
- 6 x 10^{12} Z and 10^8 WW events
- m_Z, Γ_Z, Γ_{inv}, $\sin^2\theta_W$, m_W, Γ_W, …
- 2 x 10^6 tt events
- m_{top}, Γ_{top}, EW couplings
- Indirect sensitivity to new physics

→
- **Absolute normalisation of luminosity to 10^{-4}**
- **Relative normalisation to 10^{-5} (eg Γ_{had}/Γ_l)**
- **σ(p)/p limited by multiple scattering → minimise material.**
- **Track angular resolution < 0.1 mrad**
- **Stability of B-field to 10^{-6}.**

Heavy Flavor Program
- 10^{12} bb, cc; 1.7 x 10^{11} ττ (all clean): 10x Belle
- CKM matrix, CP measurements,
- rare decays, CLFV searches, lepton universality

→
- **Superior impact parameter resolution**
- **Precisely identify secondary vertices and measure lifetimes**
- **ECAL resolution at few %/$\sqrt{E}$**
- **Excellent π^0/γ separation for tau identification**
- **PID: K/π separation over wide p range → e.g. timing, …**

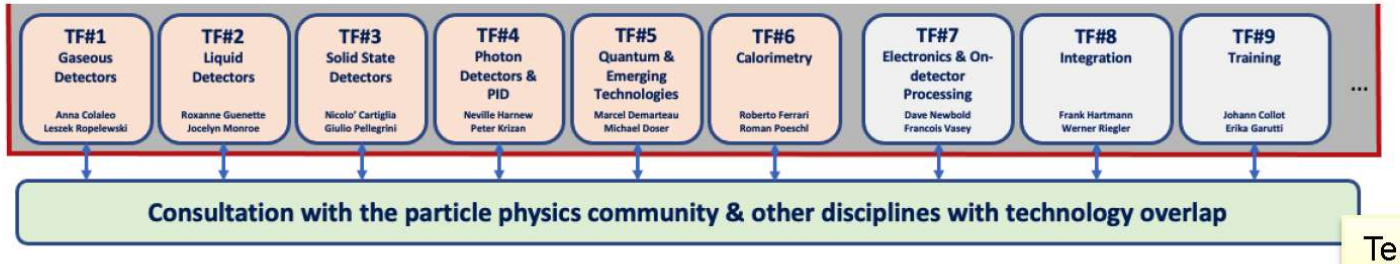
Feebly coupled particles Beyond SM
- Opportunity to directly observe new feebly interacting particles with masses below m_Z
- Axion-like particles, dark photons, Heavy neutral leptons
- Long-lifetime LLPs

→
- **Sensitivity to (significantly) detached vertices**
- **Tracking: more layers, "continuous" tracking**
- **Calorimeter: granularity, tracking capability**
- **Large decay length → extended decay volume**
- **Precise timing**
- **Hermeticity**

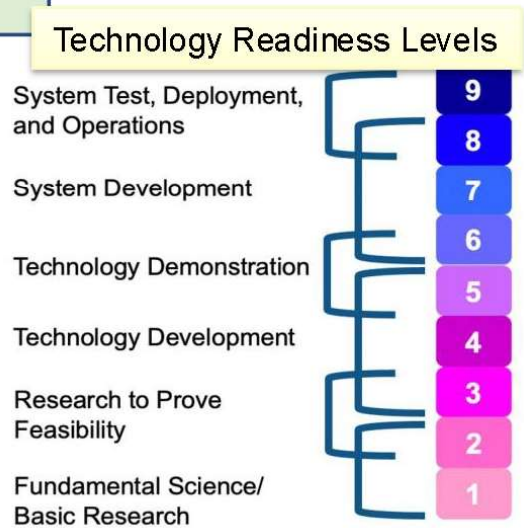
ECFA Detector R&D Roadmap & Implementation plan

2021: ECFA released full roadmap (200 pages) and synopsis (~10 pages) based on a community-driven effort DOI: 10.17181/CERN.XDPL.W2EX

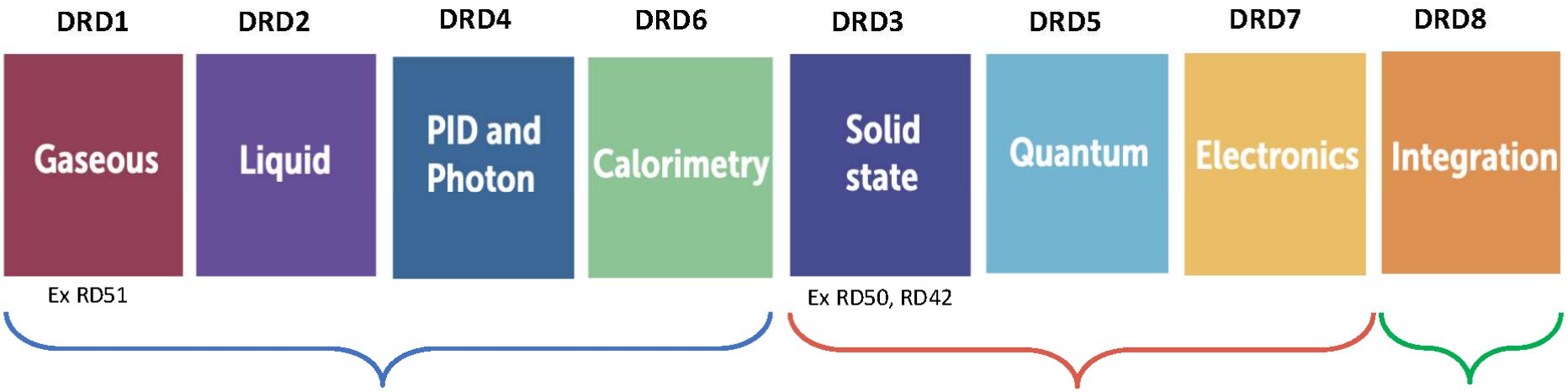
- Ten "General Strategic Recommendations"; Nine Technology domains with Task Force areas; Most urgent R&D topics in each domain: Detector R&D Themes (DRDTs)



- **Implementation plan: Approved by CERN SPC and Council in Fall 2022 (CERN/SPC/1190 ; CERN/3679)**
  - CERN to host DRD collaborations; DRD interface to CERN: DRDC
- **Strategic R&D bridges the gap between the idea ("blue sky research", TRL 1-3) and the deployment and use in a HEP experiment (TRL 8-9)**
  - Detector R&D Collaborations should address TRLs from 3 to 7, before experiment-specific engineering takes over
  - DRD interface to ECFA via ECFA Detector panel (web page)



Status of DRD collaborations



- **DRD reports at open sessions of DRDC meetingsg**
  - **Indico category: Category "Experiments / R&D"**
- **Full DRD proposals in CERN CDS**
  - **Contents: strategic R&D needs and definition of work packages, milestones & deliverables**
  - **Strategic funding to be agreed with funding agencies/institutions**
  - **Preparing DRD MoUs**

MoU Drafts → DRD Collaborations

Mission: National Roadmap for ESPP

Deadline: 31 March 2025

Request: HU-Roadmap → → → CERN ESPP, NRDIO, HUN-REN, …

Impact:

CERN ESPP:	**Input for the PPG and ESG of ESPP**
NRDIO:	**Input for the next years Activity Plan**
HUN-REN:	**6/25 years plan of R&D activities at HUN-REN Institutes**
Universities:	**Programs for the next years**