European Strategy for Particle Physics: 2026 update

- Status and Plans -

Karl Jakobs (Strategy Secretary)

FCC Early Career Forum

CERN, 13 January 2025

Remit of the European Strategy Group (ESG)

- *In June 2024, the CERN Council established and approved the **remit of the European Strategy Group***

  *"The aim of the Strategy update should be to develop a **visionary and concrete plan** that greatly advances human knowledge in fundamental physics through the **realisation of the next flagship project at CERN**. This plan should attract and value **international collaboration** and should **allow Europe to continue to play a leading role in the field."***

- The ESG should take into consideration:
  - The **input of the particle physics community;**
  - The **status of implementation of the 2020 Strategy update**;
  - The **accomplishments over recent years**, including the results from the LHC and other experiments and facilities worldwide, the progress in the construction of the High-Luminosity LHC, the outcome of the Future Circular Collider Feasibility Study, and recent technological developments in accelerator, detector and computing;
  - **The international landscape of the field**

- *The Strategy update should include the **preferred option** for the next collider at CERN and **prioritised alternative options** to be pursued if the chosen preferred plan turns out not to be feasible or competitive.*

The Strategy Secretariat and European Strategy Group (ESG)

Strategy Secretariat: Organising and running the ESPP process

Karl Jakobs (Strategy Secretary, Chair)
Hugh Montgomery (SPC Chair)
Mike Seidel (LDG Chair) (→ has replaced Dave Newbold (STFC) as new LDG Chair on 1st Jan. 2025)
Paris Sphicas (ECFA Chair)

European Strategy Group (ESG) Preparation of the Strategy Document

- The Strategy Secretary (acting as Chair)
- **One representative appointed by each CERN Member State**
- **One representative appointed by each of the laboratories represented in the Large Particle Physics Laboratory Directors Group (LDG), including its Chair**
- **The CERN Director-General**
- **The CERN Director-General elect**
- The SPC Chair
- The ECFA Chair
- Invitees: President of CERN Council, one representative from each of the Associate Member and Observer States, one representative from the European Commission, the Chairs of APPEC, NuPECC and ESFRI, the members of the Physics Preparatory Group.

The Physics Preparatory Group (PPG)

Physics Preparatory Group collects input from the community, organises the Open Symposium, prepares the Briefing Book

- Strategy Secretary (acting as Chair)
- **Four members appointed by Council on the recommendation of the SPC**
- **Four members appointed by Council on the recommendation of ECFA**
- **One representative appointed by CERN**
- **Two representatives from the Americas**
- **Two representatives from Asia**
- The SPC Chair
- The ECFA Chair
- The LDG Chair

PPG MEMBERS	
Strategy Secretariat	
Scientific Secretary (Chair)	Prof. Karl Jakobs (DE)
SPC Chair	Dr Hugh Montgomery (USA)
ECFA Chair	Prof. Pareskevas Sphicas(GR)
LDG Chair	Prof. Dave Newbold (UK)
SPC	
Prof. Pilar Hernandez (ES)	
Prof. Gino Isidori (CH)	
Prof. Fabio Maltoni (BE/IT)	
Prof. Jocelyn Monroe (UK	
ECFA	
Dr Tommaso Boccali (IT)	
Dr Thomas Bergauer (AT)	
Dr Cristinel Diaconu (FR)	
Prof. Monica Dunford (DE)	
CERN	
Dr Gianluigi Arduini (CERN)	
ASIA/AMERICAS	
Dr Anadi Canepa (USA)	
Prof. Xinchou Lou (China)	
Prof. Rogerio Rosenfeld (Brazil)	
Prof. Yuji Yamazaki (Japan)	

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 as Scientific Secretaries for all working groups (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
  (essentially done, few names t.b.c.; information will be communicated via the web pages soon)
- Definition of benchmark processes / measurements
  (ongoing, an iteration with the large-scale projects done)
- 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;
- Benchmarks have been shared with the large projects for feedback, iterations ongoing, some of the points accepted
- Examples (preliminary, present status) in backup slides

- We plan to summarize the full set in a document that will be shared with you and become publicly available via the Strategy web pages (discussions in some PPG groups still ongoing, hope to converge next week)

- 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; establish the R&D needs, timeline, resources for future projects
- Computing: what will be the computing needs for new projects, how can they be covered, what R&D lines are needed

Timeline for the update of the European Strategy for Particle Physics

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

Community Involvement

Input and involvement of the community is important!

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 11 and 12)

(iii) Input from **national HEP communities** is a vital component of the Strategy Process
(ECFA guidelines, already discussed in Plenary ECFA meetings and in many national meetings)
Details can be found here: ECFA guidelines for national HEP community input

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

ECFA guidelines / questions

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 the preferred option in (a), 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)? (The set of considerations in (b) should be used).

Paris Sphicas

National HEP input on non-collider projects and other fields

Paris Sphicas

Remit to ESG also specifies:

> **"The Strategy update should also indicate areas of priority for exploration complementary to colliders and for other experiments to be considered at CERN and at other laboratories in Europe, as well as for participation in projects outside Europe."**

It would thus be most useful if the national inputs explicitly included the preferred prioritisation for non-collider projects. Specific questions to address:

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)? (The set of considerations as for the "next collider" should be used).

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.

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
(5) Sustainability and environmental impact
(6) Public Engagement, Education, Communication
(7) Social and career aspects for the next generation
(8) Knowledge and Technology Transfer

Next steps

- PPG: Finalise benchmarks (incorporate feedback from large projects, state some benchmarks more precisely)

- ESG: 1st in-person meeting on 15th January at CERN

  → Discuss and finalise ESG Working Groups and participation of ESG members in these groups

  → Converge on the layout of the Venice Open Symposium

We are looking forward to receive your input!

In case of any questions, please contact us: eppsu2024-strategy-secretariat@cern.ch

Backup Slides

Benchmark example: Higgs / Electroweak / Top

J. De Blas, M. Dunford

Benchmark Processes: Higgs Properties (I)

1) Higgs mass precision
2) Single Higgs couplings: sensitivity to BSM in Higgs couplings to SM particles

From Kappa fits:
- In combination with HL-LHC
- Two possible versions:
  - All SM coupling modifiers AND non-SM Higgs decays
  - All SM coupling modifiers WITHOUT non-SM Higgs decays

From SMEFT fits: Separate email, prepared together with Fabio (BSM) and Gino (Flavor), was sent to the different projects with the scope/baseline assumptions of the SMEFT fits.

The projected uncertainties (and correlations) on the corresponding Higgs observables are requested, e.g.
$\sigma_{ee->ZH}$ (incl.), $\sigma_{ee->ZH}$ x BR(H->bb, cc, ss, gg, ττ, μμ, WW*, ZZ*, γγ, Zγ)
$\sigma_{ee->Hνν\ (WBF)}$ x BR(H->bb, cc, ss, gg, ττ, μμ, WW*, ZZ*, γγ, Zγ)

3

Benchmark Processes: Precision EW

1) Projected uncertainties on Electroweak precision observables (without imposing any assumption about fermion universality):
   a) On-shell Z measurements: M_Z, Γ_Z, σ_{had}, R_f, Asymmetries (A_{FB}, A_f),... with f=e,μ,τ,b,c,s,...
   b) On-shell W measurements: M_W, Γ_W, BR(W->eν , μν, τν),...
   c) Other Observables/Pseudo-Observables. E.g. definitions and expected precision in observables used for determination of anomalous triple gauge couplings (aTGC) from Di-boson production.

When reporting the uncertainties of these or any other observables where systematics are expected to be important, it is requested to indicate explicitly any relevant assumptions made in the estimations of such systematics, and in particular those related to assumed improvement in the theory side.

2) EW couplings: sensitivity to BSM in Z and W couplings to SM fermions
From SMEFT fits: Same setup used in "Higgs properties"

Benchmark Processes: Higgs Properties (II)

1) Shape of the Higgs potential:
   - Precision on Higgs self-coupling:
     - From HH production
     - From single-Higgs measurement, via SMEFT fit
     - In both cases, inclusive and exclusive (only κ_λ) determinations

Benchmark Processes: Top-quark

1) Top-quark mass precision

2) Top-quark properties from SMEFT fits:
   a) Top-quark EW couplings (Ztt, Wtb)
   b) Top-quark Yukawa coupling
   c) Other interactions entering in Top processes, depending on assumptions chosen in SMEFT fit, e.g. four-fermion interactions, Top-dipole operators

As in the EW and Higgs part, it is requested to have the definitions and projected uncertainties of the observables used in the interpretation.

EFT Interpretations

PPG conveners / F. Maltoni

- The **PPG will perform a comparison of the future sensitivity of different project proposals via appropriate EFT analyses**, using the projected sensitivities on different observables provided by the collaborations.

- This does not mean that specific EFT analyses provided by the collaborations are not welcome. However, in such case we encourage the proponents to provide to the PPG all the information on the experimental pseudo-data (list of observables, expected uncertainties and correlations) and also on the definition/assumptions (and motivations) of the EFT they have adopted, so that the results can be reproduced in principle.

- One of the goals of the EFT analyses to be performed by the PPG, is to establish the reach for specific UV models. In this context, it is important to make specific assumptions about the flavour structure of the underlying theory. As a baseline, for collider and EW observables, we propose to adopt the flavour symmetry

  $U(2)_{qL} \times U(2)_{uR} \times U(2)_{dR} \times U(1)_e \times U(1)_\mu \times U(1)_\tau$

  i.e. to consider the first two quark generations “equivalent”, single out the third quark generation, and treat separately each lepton flavour (requiring individual lepton flavour conservation).

- We stress that the most useful input for the PPG will be in terms of observables and their precision, in a manner that can be interpreted (at least) within the above flavour assumptions. (e.g. electroweak precision observables)

- Finally, in those cases where some interpretation is done by the collaborations exclusively in terms of a single parameter of interest (i.e. assuming everything else to be SM like) and this is suggested as input for the EFT fit, the precise definition of the observable used in such analyses would be required in order to perform a global interpretation.