

# Update of the European Strategy for Particle Physics

IPHC contribution to the  
French HEP community submission

27 November 2024

# Strategy set up in 2018 (updated in 2020)

From <https://cds.cern.ch/record/2720129/files/CERN-ESU-013.pdf>

## Main strategy:

- Exploit HL-LHC (also flavour and QGP),
- Support long baseline neutrino experiments in USA and Japan via neutrino platform
- Future: e+e- Higgs factory is the highest-priority, pp collider with  $E > 100$  TeV on the longer term  
→ Launched FCC feasibility studies (2021-2025),
- In parallel, support for smaller experiments (EDM, CLFV, DM & axion,...).

## But also:

- Importance of adequate support for theory,
- Importance of adequate detector, computing, software and infrastructure R&D,
- Continue synergy with nuclear and astroparticle physics
- Importance to minimise environmental impact.

# Strategy update: objectives and calendar

- **Gianotti:** CERN leading role [...] will NOT survive without a flagship project, strongly motivated by physics, following the LHC within a short time (<10 years). A first-stage future collider running in the mid 2040's is crucial [...]. [[reference](#)]
- **Desired timeline:** recommendation by **next ESPP ~ 2026**, approval by CERN's Council by end of the decade, start of construction early- 2030's, start of operation mid 2040's. Realistic for FCC-ee and CLIC, difficult for FCC-hh (magnet technology, cost).
  - Call for individual contributions (10 pages), to be sent by **March 2025**.

# Mandate for the strategy update

- 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**.
- It 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.
- It 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 should add **other items identified as relevant to the field**, including accelerator, detector and computing R&D, the theory frontier, actions to minimise the environmental impact and to improve the sustainability of accelerator-based particle physics, the strategy and initiatives to attract, train and retain the young generations, public engagement and outreach.

See [mandate](#) and [Paris SpHicas presentation](#) (Restricted ECFA chair)

# French contribution to ESPPU

National HEP communities encouraged to participate. For France, IN2P3 & Irfu take charge, and rely on the GDRs to prepare a 10 page contribution. 4 working groups:

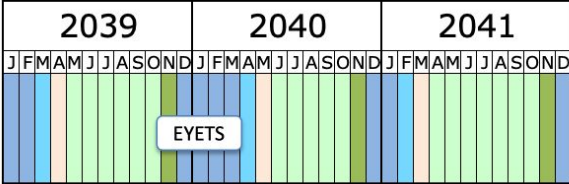
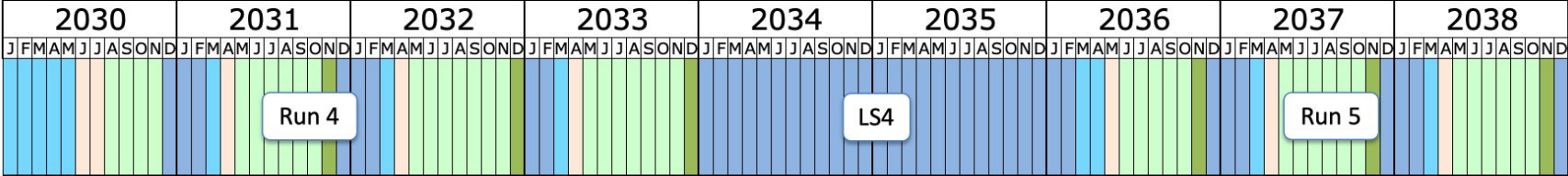
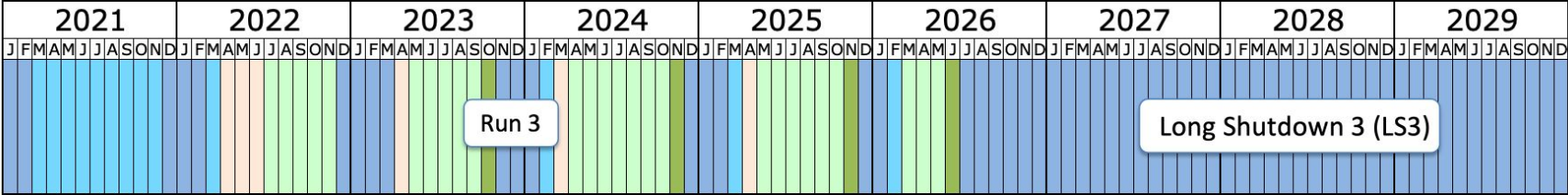
- GT1 : [Standard Model and beyond](#) [IRN Terascale] – Steering group: Fabrice Couderc, Marie-Hélène Genest, Ana Teixeira (meetings: [04/10/2024](#) and [13/11/2024](#))
- GT2 : [Flavour physics and tests of fundamental interactions](#) [GDR Intensity Frontier] – Steering group: Yasmine Amhis, **Giulio Dujany**, Christopher Smith (meeting: [06/11/2024](#))
- GT3 : [Neutrinos \(Long-baseline\)](#) [IRN Neutrinos] – Steering group: Sara Bolognesi, Stéphane Lavignac, Anselmo Mereaglia (meeting [09/10/2024](#))
- GT4 : [QCD and heavy ions colliders](#) [GDR QCD] – Steering group: Cyrille Marquet, Carlos Munoz Camacho, Michael Winn (meeting [19/09/2024](#))
- GTS : [Future colliders - Steering group](#): Cristinel Diaconu, **Jeremy Andrea**, Maarten Boonekamp, Stéphane Monteil (meeting [18/12/2024](#))

Bottom-up approach: contributions collected at <https://esppu.in2p3.fr> (deadline 18/11 but still accepting contributions) general symposium Jan 20-21, 2025 <https://indico.in2p3.fr/e/esppu-symposium-fr>

# Timeline for the update of the European Strategy for Particle Physics



# Up to date LHC schedule (Oct 2024)



- Shutdown/Technical stop
- Protons physics
- Ions
- Commissioning with beam
- Hardware commissioning

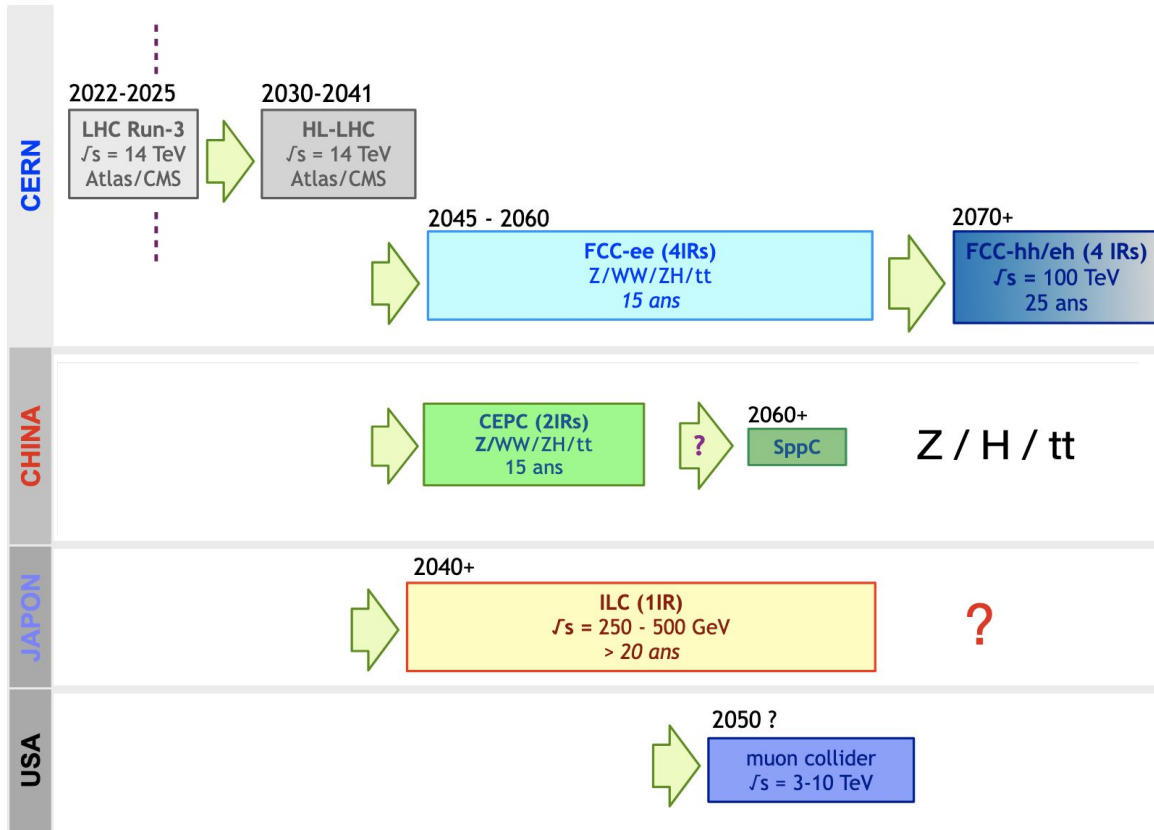
Last update: November 24

# IPHC projects

Projet	2024	2024	2025	2025	2026	2026	2027	2027	2028	2028	2029	2029	2030	2030	2031	2031	2032	2032	2033	2033	2034	2034	2035	2035	2036	2036	2037	2037	2038	2038	2039	2039	2040	2040	2041	2041	2042	2042
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
LHC	Run 3		Long shutdown 3 (LS 3)											Run 4		LS 4		Run 5																				
CMS	Tracker upgrade											HL-LHC		LS 4		HL-LHC																						
ALICE	ITS-3 upgrade											Run 4		LS 4		ALICE 3 ?																						
Belle -2	Prise de données											shutdown											Run 3		...													
Belle-2 VTX upgrade ?	R & D Obelix											Run 3		Run 3																								
	ESPPU																																					
PICSEL/FCce	MIMOSIS															FCce (2045)																						
	DRD3 R&D -> VTX demonstrator																																					
Neutrino: JUNO TT	TT installation				Maintenance + prise de données											...																						
ESSnuSB	ESSnuSB+ -> CDR				R & D -> TDR											...																						
VIRGO	Maintenance/dvpt Ncal																																					
	O4				O5 ?																																	
Einstein	construction											Ouverture telescope Einstein																										
km3net	DOM prod				...																																	



# Schedules of various colliders (GT1 [link](#))



# Questions for IPHC

Starting from the set of questions proposed in

ECFA guidelines for inputs from national  
HEP communities to the European  
Strategy for Particle Physics

<https://ecfa.web.cern.ch/ecfa-guidelines-inputs-national-hep-communities-european-strategy-particle-physics-0>

Adapted to our lab let us discuss what IPHC could say...

# Questions for IPHC

- What's the next general-purpose collider we'd like to see (at CERN in particular)? What alternative scenarios (Plan B) do we recommend?
- What is our long-term neutrino physics strategy and program?
- What is our long-term flavor physics strategy and program?
- What is our long-term strategy and program for strong interaction physics?
- Overall, what is our vision for European strategy, including in relation to other themes (nuclear physics, astroparticles, physics not at colliders, etc.)?
- We should also address how to take sustainable development into account in our strategy.
- Our instrumental and computing strategy in the broadest sense also needs to be debated.
- Are the resources of IPHC (Expertises, technical resources, Computing, Person Power, etc.) in adequation with our strategy ? What are the critical aspects ?

**3) Questions to be considered by countries/regions when forming and submitting their “national input” to the ESPP:**

- a) Which is the preferred next major/flagship collider project for CERN?
- b) What are the most important elements in the response to 3a)?
  - 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 3a) 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 3a), what other accelerator R&D topics (e.g. highfield magnets, RF technology, alternative accelerators/colliders) should be pursued in parallel?
- e) What is the prioritised list of alternative options if the preferred option set out in 3a) is not feasible (due to cost, timing, international developments, or for other reasons)?
- f) What are the most important elements in the response to 3e)? (The set of considerations in 3b should be used).

**4) The remit given to the ESG also specifies that “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 4a)? (The set of considerations in 3b 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.

BACK UP

# Scenario summary

- A. European only and/or preferred option
  - 1. FCC
  - 2. ILC
  - 3. CLIC
- B. In CEPC gets confirmed soonish and/or fall-back plan if A is not competitive or feasible
  - 1. (FCC not really a fallback plan)
  - 2. HE-LHC + LHeC
  - 3. High energy Linear collider facility
  - 4. Muon Collider + LHeC (high risk)
  - 5. Fast FCC-hh at xx TeV (only in the advent of CEPC)
- C. New physics (HL-)LHC in tails of distributions
  - 1. (FCC full program)
  - 2. HE-LHC + LHeC
  - 3. Something else ?

Bill

FCC ee: 15 GCHF [7\*]

FCC hh: + 20-25 GCHF [7\*]

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ILC  $\leq 500\text{GeV}$ : 12 GCHF [5]

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CLIC (0.4TeV): 7 GCHF

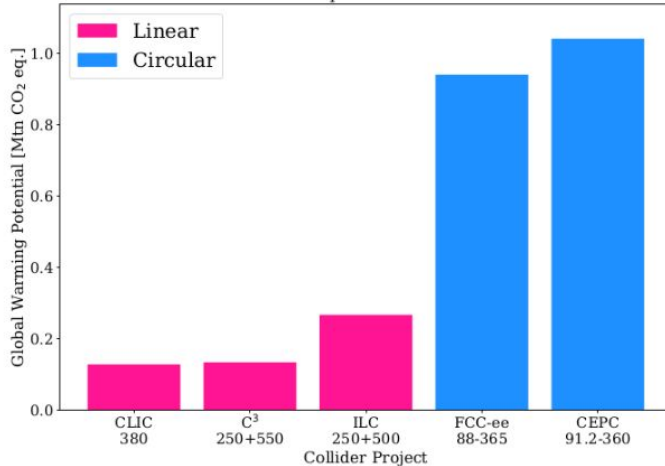
CLIC (1.5TeV): +5 GCHF

Bill

LHeC: 1-2 GCHF ?

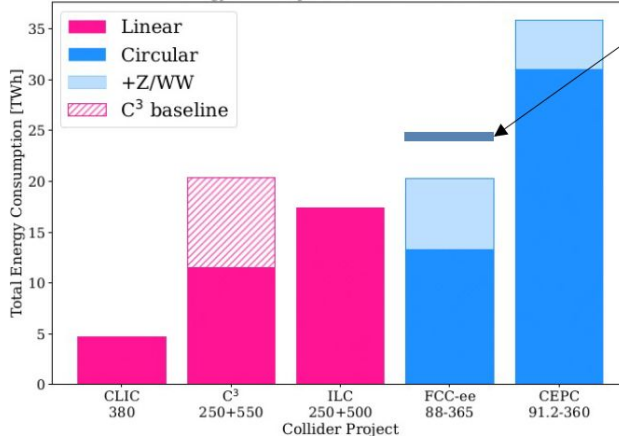
HE-LHC: 9 GCHF [7\*]

Carbon Footprint of Construction



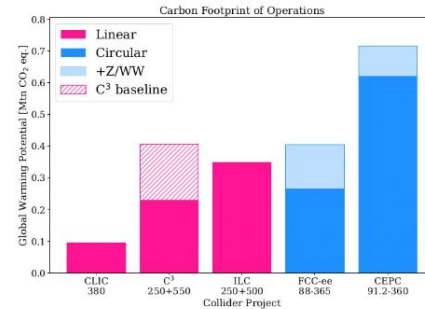
# Accelerator operations

Energy Consumption of Different Colliders



From J.P Burnet (sept 2024)  
[https://agenda.ciemat.es/event/4431/timetable/#20240926\\_detailed](https://agenda.ciemat.es/event/4431/timetable/#20240926_detailed)

To compare with 1.2TWh/year  
 (present total CERN consumption)



From <https://arxiv.org/abs/2307.04084>

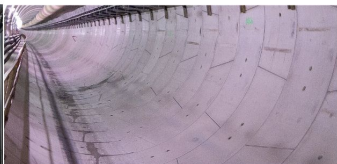
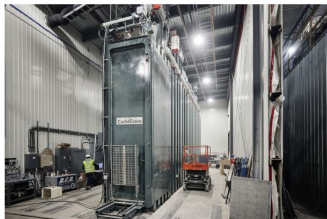
## Toward a 0-net CO<sub>2</sub> emission tunnel ?

Industry is elaborating cement free concrete

- cement fully replaced by steel slag
- CO<sub>2</sub> captured from a plant
- CO<sub>2</sub> injected into the slag+gravel to produce concrete
- **negative CO<sub>2</sub>eq concrete !** (but only prefab)

<https://carbocrete.com/specify-carbocrete/>

Needs to certify the concrete for tunnel usage  
**Usual scaling-up issue, but would help the civil society**



Idea submitted to CERN last week

$$\begin{aligned} & \text{Higgs} \\ & \sqrt{s} \left( \frac{P}{\Gamma} \right) \\ & T_{\text{collisions}} \left( \frac{T_{\text{run}}}{\mathcal{L}_{\text{inst}} / \text{IP}} \cdot 10 \right) \\ & \mathcal{L}_{\text{int}} \left( \frac{\mathcal{L}_{\text{int}}}{\mathcal{L}_{\text{int}}} \right) \end{aligned}$$

	# Higgs Boson / h	Electricity TWh / year [1]	Electricity tCO <sub>2</sub> eq for 20 years (1)	Tunnel construction tCO <sub>2</sub> eq (2)
FCC-ee (2IPs) - 240GeV	71.6	1.5	875'000	900'000
CEPC (2IPs) - 240GeV	71.6	0.9	525'000	1'000'000
ILC - 250 GeV	15.2	0.8	467'000	200'000
CLIC - 380GeV	12.3	0.6	350'000	110'000
LEP3	15.7			Existing tunnel





# Output “perspectives” French particle physics 2020

Project	Science Driver		SD1	SD2	SD3	SD4	SD5	SD6
	project scale	interest in FR						
			Higgs sector	Higgs imprint	direct searches	quark flavors and CP	charged lepton flavors	cosmology
<b>Energy frontier</b>								
ATLAS&CMS@LHC/HL-LHC	€€€	★★★	***	***	***	*	*	-
ILC	€€	★★	***	***	*	-	-	*
CLIC	€€	★★	***	***	***	-	-	*
FCCee	€€	★★	***	**	*	***	***	*
CEPC	€€	★★	***	**	*	***	***	*
High-energy pp	€€€	★★	***	***	***	**	**	-
<b>Intensity frontier</b>								
Belle-II	€	★	-	-	-	***	***	-
LHCb Ia	€€	★★	-	-	-	***	***	*
LHCb Ib	€	★★	-	-	-	***	***	*
LHCb II	€€	★★	*	-	-	***	***	*
<b>Dedicated experiments</b>								
n2EDM	€	★	-	-	-	***	-	-
COMET	€	★	-	-	-	-	***	-
OSQAR/VMB	<€	★	-	-	**	-	-	*
GBAR/AEGIS	<€	☆	-	-	-	-	-	**
CODEX-b	<€	★	-	-	**	-	-	*
SHIP	€	☆	-	-	**	-	-	*



⚠ Out of date but good for context