CPAN Spanish Input to the 2026 European Strategy for Particle Physics Update

Editorial Board
Juan Alcaraz (CIEMAT)
Nestor Arnesto (IGFAE)
Jorge de Blas (UG)
Aurelio Juste (IFAE)
María Martínez (UNIZAR)
Gonzalo Merino (CIEMAT)
Carlos Pena (IFT)
Michel Sorel (IFIC)
Fernando Toral (CIEMAT)
Iván Vila (IFCA)
Luis Mario Fraile (UCM)
Marcel Vos (IFIC)
Contacts: Nicanor Colino (CIEMAT), Maria Jose Costa (IFIC), Pilar Hernández (IFIC), Celso Martínez (IFCA), Carlos Salgado (IGFAE)

María José Costa - IFIC (CSIC-UV) on behalf of the Editorial Board of the Spanish national input
19 November, 2025, Valencia

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 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 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**.
- The ESG should review and update the Strategy and 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.

Timeline for the update of the strategy

- Input from the Spanish community was sent on 31 March (see document here).
- No additional input was sent for the 26 May deadline (not enough time to digest and discuss the input provided by the community).
- Final input sent by 14 November: CERN Collider recommendations, Complete updated national input.

Strategy followed to converge on the first input

- **24 June 2024**: A call for input was launched to the full Spanish community (deadline 5 November)
  The IPs of the various networks led discussions within their communities to provide a collective input, and organised additional discussions in the parallel sessions of the CPAN days (19-20 November).
- **7 October 2024**: National workshop on FCC (CIEMAT, Madrid) to help define the position of Spain towards this project.
- **5 November 2024**: Deadline to send comments to the Editorial Board

CPAN Days 2024

- **19 November 2024**: Future Colliders for Early Career Researchers meeting
- **20 November 2024**: Dedicated discussion on the next collider at CERN during the joint LHC & future colliders parallel session of the CPAN days
- **21 November 2024**: Presentation of the input received and first discussion during the CPAN days plenary session
- **31 January 2025**: First draft of the Spanish CPAN input document ready and distributed to the Spanish community
- **12 March 2025:** Final discussion on the comments received to converge on the final document (meeting in zoom)
- **31 March 2025**: Spanish CPAN input document sent.

Statements from the Spanish input sent on 31 March

- **Preferred large-scale post-LHC accelerator for CERN:**
  - *The FCC (FCC-ee+FCC-hh) project has broad support across the Spanish HEP community as the preferred next flagship facility at CERN, provided its feasibility study establishes that its realisation is technologically and financially achievable within the proposed timescale.*
- **Preferred alternative, if the preferred option is not feasible:**
  - *If the FCC is found not to be feasible, a linear electron-positron collider facility at CERN would be the preferred alternative option, with an initial Higgs factory stage and the possibility of an energy upgrade to the TeV scale.*
- **Preference if other large scale projects proceed outside Europe:**
  - *If Japan proceeds with the International Linear Collider (ILC) or China proceeds with the Circular Electron Positron Collider (CEPC) in a timely way, synergies should be exploited and possible re-optimisations explored, but a flagship collider project at CERN should still be pursued. The timescale for developing a muon collider in the US is expected to be beyond that of a decision on the preferred project at CERN.*

Open Symposium in Venice

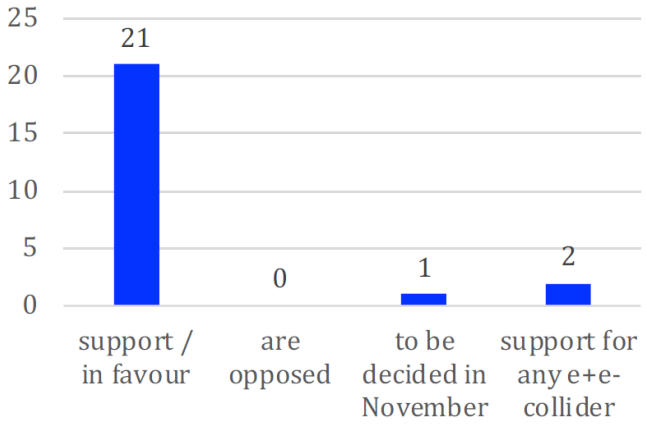
June 23-27: Open Symposium on the European Strategy for Particle Physics (see agenda here)

National input as of Venice Open Symposium

Taken from the presentation of Karl Jakobs at the Open Symposium

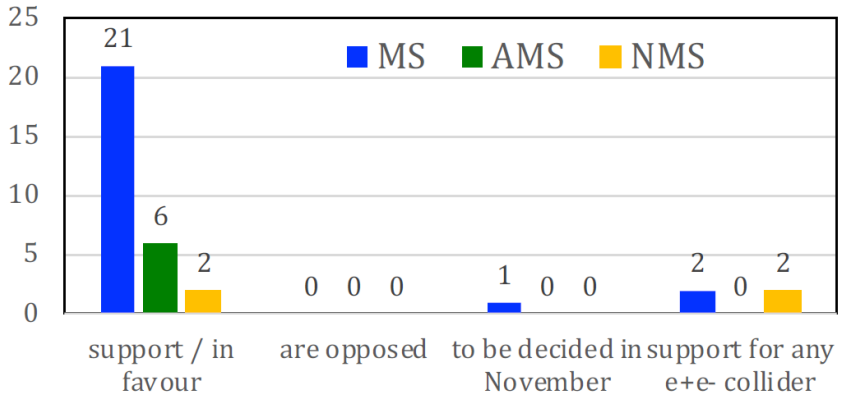
What is the preferred large-scale accelerator for CERN

CERN Member States (MS)



- Overwhelming support (21/24 CERN MS HEP communities) in favour of the integrated FCC-ee/hh programme

… incl. Associate- and Non-Member States (MS)



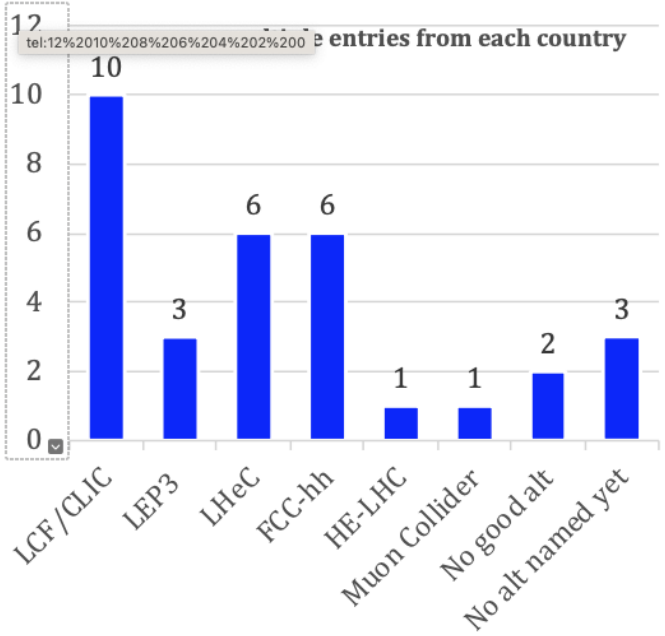
- Support as well from Associate Member states (AMS) and Non-member states (NMS)

Overwhelming support for the integrated FCC-ee/hh programme by the HEP communities in the CERN Member and Associate Member states and beyond

National input as of Venice Open Symposium

Taken from the presentation of Karl Jakobs at the Open Symposium

What is the alternative if the preferred option is not feasible?



CERN Member States (MS) (multiple entries allowed)

- 10 MS HEP communities list a Linear Collider (LCF, CLIC) as second best choice
  (LCF is preferred to be realised with 550 GeV)
- 3 MS HEP mention LEP3 as a genuinely less costly alternative to FCC-ee
- 6 MS HEP communities support LHeC
- 6 MS HEP communities support a lower-energy hadron collider
- 2 MS HEP see no reason for another option, as they would be equally costly.

Not so clear message about the alternative options to be pursued if the chosen preferred plan turns out not to be feasible.

Post-LHC flagship accelerator at CERN

Three important ingredients will be taken into account by the European Strategy Group in concluding on the final recommendations for the proposed post-LHC flagship accelerator project at CERN

- (1) **Physics Potential**: The Briefing book, circulated on **1 October,** presents an assessment of the European particle physics, and compares the physics potential of the various flagship proposals in the different physics areas.
- (2) **Assessment of the proposed flagship projects**: A working group of the ESG together with external accelerator experts are carrying out a comparison of the proposed projects. The evaluation focuses on the technical readiness, the time and cost estimates, R&D needs, as well as on the performance parameters. Preliminary Executive Summary shared on **21 October**, and full report sent on **4 November**.
- (3) **Input from the national HEP communities**: Considering (1) and (2), the final national inputs on the questions below were provided by **14 November**:
  - **What is the preferred large-scale post-LHC accelerator for CERN?**
  - **What is the preferred alternative, if the preferred option is not feasible?**
  - **What is the preferred alternative, if the preferred option would not be competitive?**

Strategy followed to converge on the Spanish final input

- **7 October**: ESPP session at the LII International Meeting on Fundamental Physics in Santiago.
- **14 October**: Deadline to send suggestions of possible updates to the Editorial Board
- **28 October**: Circulation of first draft to the Spanish community.
- **4 November**: Deadline to send comments to the Editorial Board.
- **11 November**: Circulation of a second draft incorporating the comments received.
- **13 November**: Final Spanish input documents sent (within the 14 November deadline).

We were asked to focus on the post-LHC flagship accelerator at CERN, providing answer to the following questions:

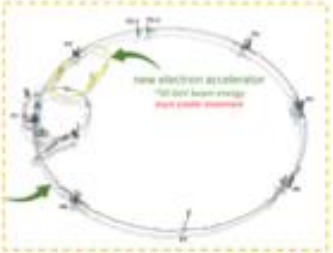
- What is the preferred large-scale post-LHC accelerator for CERN?
- What is the preferred alternative, if the preferred option is not feasible?
- What is the preferred alternative, if the preferred option would not be competitive?

Potential for development: future 10 TeV parton-scale collider options

FCC-ee

LEP3

LHeC



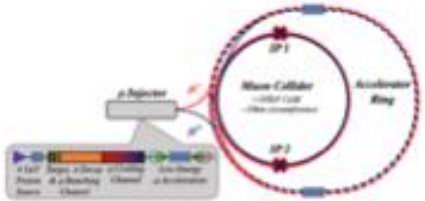
PERLE

LCF, CLIC

Taken from the presentation of Karl Jakobs at the Open Symposium

R&D

FCC-hh,
baseline 85 TeV (→ 120 TeV)
+ possibility for HI collisions



Muon Collider (3, 10 TeV)

e^+e^- with improved acceleration technologies
LCF, C^3 (→ 1 TeV), CLIC (1.5 TeV), HALHF, …
→ plasma acceleration for higher energies
(can $\mathcal{O}(10)$ TeV be reached? on what timescale?)

Information available: Assessment of the projects

Parameters considered

	CLIC			FCC-ee				FCC-hh	LCF				LEP3			LHeC	MC	
									LP	FP								
Particles colliding [-]	e^+/e^-			e^+/e^-				p/p	e^+/e^-				e^+/e^-			e^-/p	μ^+/μ^-	
C.o.m. energy [GeV]	380	550	1500	91.2	160	240	365	84600	250	91.2	250	550	91.2	160	230	1180	3200	7600
Length [km]	12.1	15	29.6	90.7				90.7	33.5				27.6			9.2/27.6	11/4.8	11/8.7
#IPs [-]	2	2	1	4				4	2				2			1	2	
Peak inst. lumi/IP [$10^{34}cm^{-2}s^{-1}$]	2.2	3.2	3.7	140	20	7.5	1.4	30	1.35	0.28	2.7	3.85	40	6.2	1.6	2.3	0.9/2	7.9/10.1
Peak power consumption [MW]	166	210	287	251	276	297	381	355	143	123	182	322	200	226	250	220	117	182
Cost [BCHF][a]	7.2	+30%[b]	+7.1	15				+19[c]	8.3	+0.8		+5.5	3.9			2	12	17

[a] Total installation and construction cost quoted by the proponents of the projects in 2024 prices. The cost includes the technical components, materials, contracts, services, civil construction and conventional systems and associated implicit labour such as that provided by a company to produce components. It does not include labour provided by the host institution and the collaborating laboratories, contingency, any potential future inflation, the costs prior to project approval (construction and R&D), off-line computing, spares, maintenance, beam commissioning. The cost of the experiments is not included. The cost of land acquisition, site activation (e.g. external roads, water supplies, power lines) and spoil removal are not included for CLIC and LCF though they are expected to represent a minor contribution to the total cost (at the percent level). The additional cost of each individual upgrade is indicated.

[b] Cost of the upgrade from 380 GeV.

[c] Cost estimated if FCC-hh follows FCC-ee. The cost for standalone FCC-hh is given as 28.4 BCHF.

Table 1: Overview of the main parameters submitted to the ESPP2026 and considered for this assessment. Data compiled from Refs. [ID40, ID78, ID188, ID207, ID214, ID233, ID247,1,2,3,4]. LP=Low Power, FP=Full Power.

Information available: Assessment of the projects

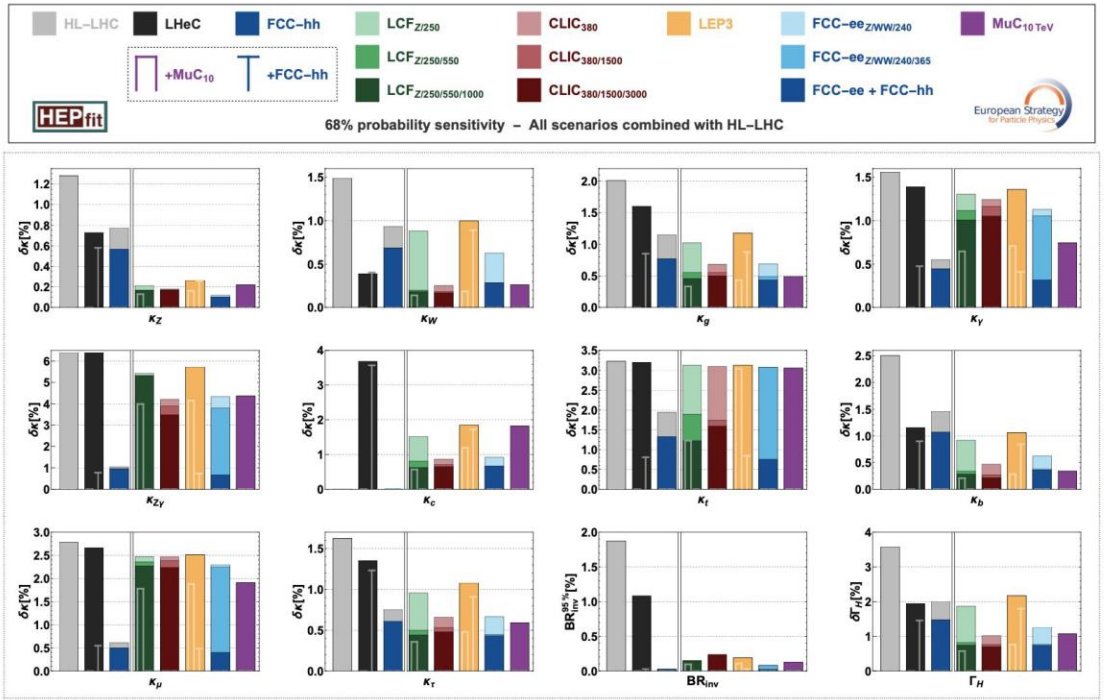
Summary of the key findings

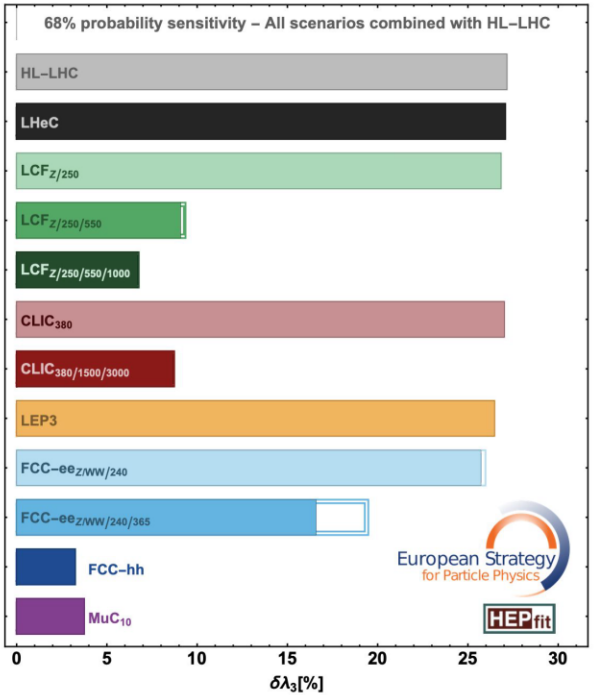
Project	Scope	TRL	R&D	Test facilities	Performance	Site preparation	Schedule	Cost	Risk
CLIC 380 GeV, 1.5 TeV		4 - 6 / 5.2							
FCC-ee 91-365 GeV		4 - 7 / 6.0							
FCC-hh 85 TeV		4 - 7 (Nb_3Sn) / 4.3 2 - 7 (HTS) / 3.2							
FCC-hh - SA 85 TeV		4 - 7 (Nb_3Sn) / 5					Nb_3Sn		
LCF 250 - 550 GeV		5 - 7 / 5.5							
LEP3 91 - 230 GeV		3 - 6 / 4.0							
LHeC: HL-LHC + 50 GeV ERL		3 - 6 / 4.5							
MC 3.2 TeV, 7.6 TeV		3.2 TeV: 3 - 5 7.6 TeV: 2 - 5							

Table 16: Summary table schematically representing the key findings of the WG according to the assessment criteria and based on the present status of the large-scale collider project proposals as submitted to the ESPP2026. Scope=Scope level-of-definition; TDR=Technical Readiness Level score - the range of values and the cost-weighted average for the baseline scenarios are listed; the colour code is selected based on on the cost-weighted average TRL score (TRL≥ 6 - green, 4≤TRL<6 - yellow, TRL<4 - red); R&D=R&D requirements, R&D plan level-of-definition, R&D funding status; Test facilities=need of test facilities or demonstrators and (if needed) level-of-definition of their scope; Performance=Performance uncertainty; Site preparation=Site preparation status; Schedule=Schedule uncertainty; Cost=Cost uncertainty; Risk=Risk level-of-definition. The cost-weighted average TRL score could not be estimated for the MC project as there is no detailed cost breakdown by sub-system. The colour code for the various criteria is defined according to the summary assessment in the Tables A.1 to A.8.

Information available: The briefing book

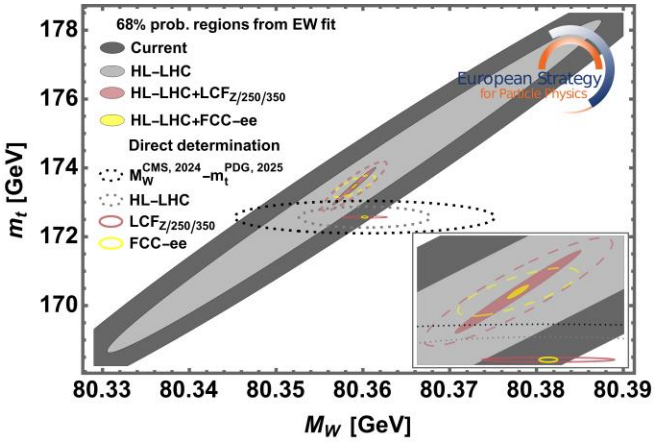
- Each chapter of the briefing book was presented and discussed to the Spanish Community during the ESPP session at the [LII International Meeting on Fundamental Physics] in Santiago.
- **The results will be summarised by Jorge de Blas in the plenary session on Thursday.**

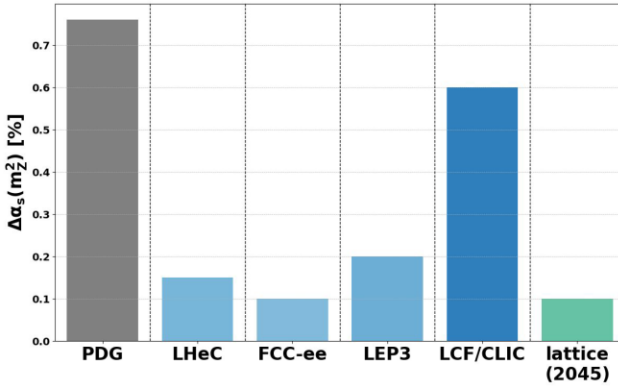


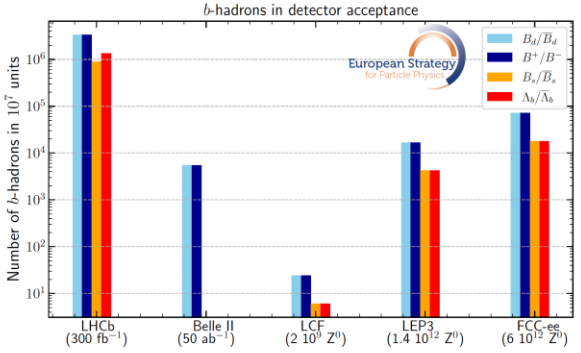


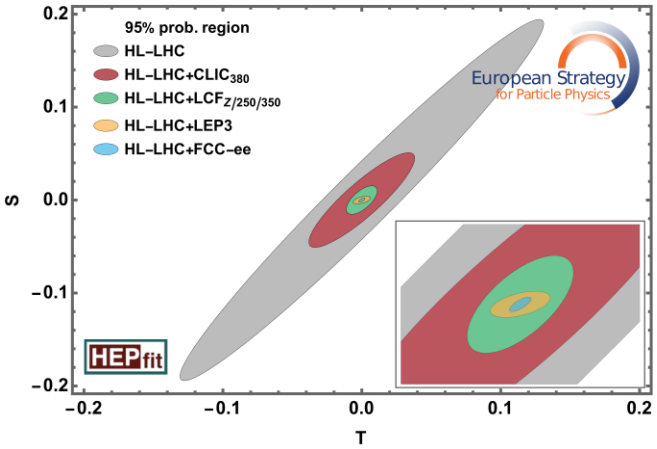
Information available: The briefing book

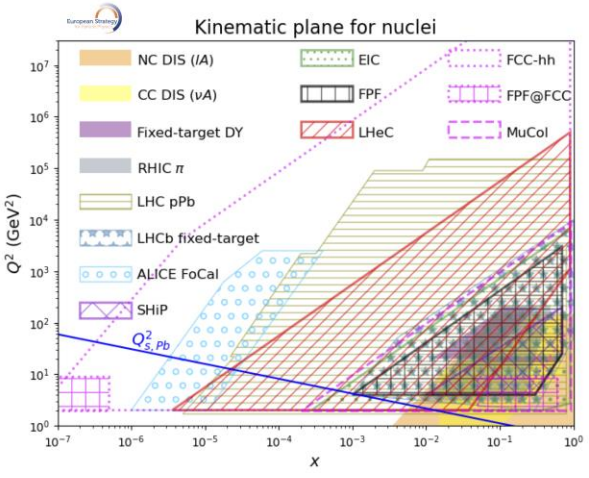
See talks from Jorge de Blas (EW), Nestor Armesto (strong) and Marie-Helene Schune (flavour)

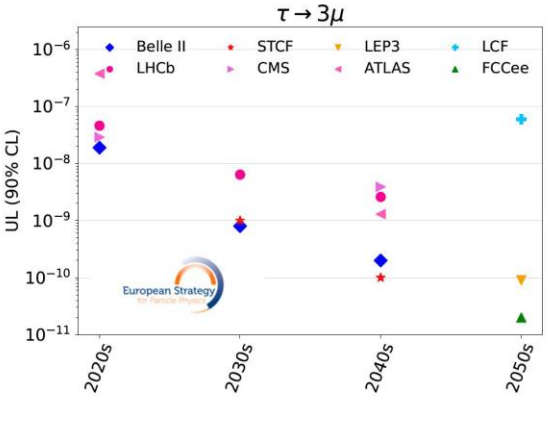






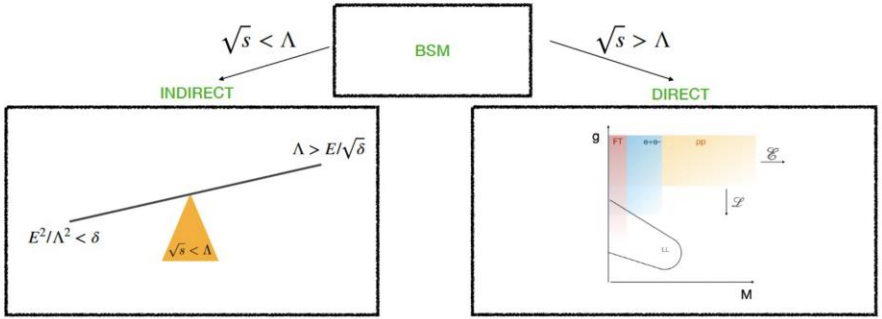






Information available: The briefing book

Summary on BSM results presented by Aurelio Juste

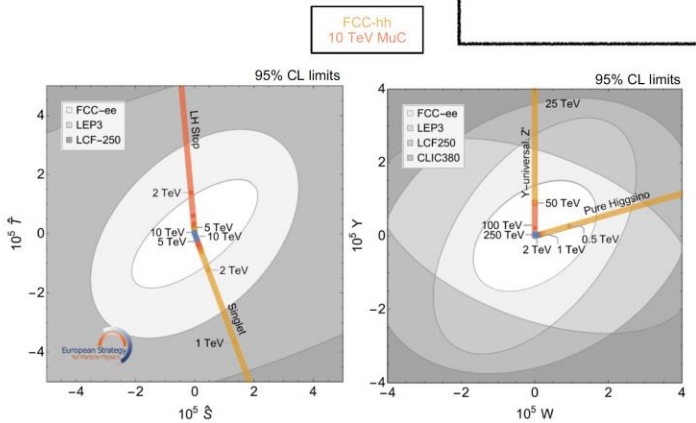


Conclusions

- We don't yet know how Nature solves the SM puzzles, so a broad experimental program is essential to uncover new physics and study its properties.
- Exploring selected models highlights the strengths and limitations of different collider options.

- FCC-ee (and, to a lesser extent, LEP3), followed by FCC-hh or a 10 TeV muon collider, appear most powerful.
- In the scenarios presented here, a LCF with runs between 250–1500 GeV offers less reach than the integrated FCC program or a 10 TeV muon collider.

- Precision measurements and direct searches should be regarded as independent probes, and they are both essential to robustly probe BSM scenarios at scales of ~10 TeV and beyond.



"Can new physics still be discovered at high-energy colliders (FCC-hh, MuC) if precision measurements at e^+e^- colliders turn out to be compatible with the SM?"

YES

Spanish community conclusions

- From the discussion, based on the physics results and large project assessments, we concluded:
  - There were no new scientific or technological ingredients to change the view expressed by Spain in March.
  - It was also considered important to recognise the interest of other more cost-effective projects, and the need to be more specific on the question to remain competitive.

Spanish final input

- **What is the preferred large-scale post-LHC accelerator for CERN?**
  - *The **FCC** (FCC-ee+FCC-hh) project has broad support across the Spanish HEP community as the preferred next flagship facility at CERN, provided its feasibility study establishes that its realisation is technologically and financially achievable within the proposed timescale.*

Spanish national input to the European Strategy for Particle Physics

The Spanish particle, astroparticle and nuclear physics community

Editorial team: J. Alcaraz Maestre (CIEMAT), N. Armesto (IGFAE), J. de Blas (UGR), L.M. Fraile (UCM), A. Juste (IFAE), M. Martínez (UZ), G. Merino (CIEMAT), C. Pena (IFT, UAM-CSIC), M. Sorel (IFIC, CSIC-UV), F. Toral (CIEMAT), I. Vila (IFCA, CSIC-UC), M. Vos (IFIC, CSIC-UV)

Contacts: N. Colino (CIEMAT), M.J. Costa (IFIC, CSIC-UV), P. Hernández (IFIC, CSIC-UV), C. Martínez (IFCA, CSIC-UC), C.A. Salgado (IGFAE)

Abstract

This document summarises the final input from the Spanish particle physics community regarding the next collider at CERN. The statements supersede those provided in March 2025. They reflect the outcome of discussions within the community, and are based on the overall assessment of the large-scale projects prepared by the European Strategy Group Working Group 2a, as well as on the physics potential studies summarised in the Briefing Book.

- **What is the preferred alternative, if the preferred option is not feasible?**
  - *If the FCC is found not to be feasible, **a linear electron-positron collider** at CERN would be the preferred alternative option. The initial project should envisage a first stage running from the Z pole to the optimal Higgs-strahlung energy, and a second stage reaching energies beyond the ttH and HH production thresholds.*
  - *If the linear collider should also prove unfeasible, the **LHeC and LEP3** projects offer interesting but more limited scientific programs with a significantly lower investment, and may provide bridges towards an earlier high-energy proton collider. …. The possibility of starting with a **high-energy hadron collider** should also be considered.*
- **What is the preferred alternative, if the preferred option would not be competitive?**
  - *If a competitive electron-positron collider proceeds outside Europe in a shorter time scale than the proposed FCC-ee project, **a competitive and complementary flagship project at CERN to reach higher energies and ultimate precision on the Higgs properties** should be pursued.*

Spanish final input

Spanish national input to the European Strategy for Particle Physics

The Spanish particle, astroparticle and nuclear physics community

Editorial team: J. Alcaraz Maestre (CIEMAT), N. Armesto (IGFAE), J. de Blas (UGR), L.M. Fraile (UCM), A. Juste (IFAE), M. Martínez (UZ), G. Merino (CIEMAT), C. Pena (IFT, UAM-CSIC), M. Sorel (IFIC, CSIC-UV), F. Toral (CIEMAT), I. Vila (IFCA, CSIC-UC), M. Vos (IFIC, CSIC-UV)

Contacts: N. Colino (CIEMAT), M.J. Costa (IFIC, CSIC-UV), P. Hernández (IFIC, CSIC-UV), C. Martínez (IFCA, CSIC-UC), C.A. Salgado (IGFAE)

Executive summary

The LHC will continue to be the world's leading project in particle physics for the next two decades. Therefore, completing its high-luminosity upgrade and fully exploiting its physics programme must remain the top medium-term priority. The FCC project, including the initial electron-positron and subsequent hadron-hadron phases, has broad support across the Spanish community as the preferred next flagship facility at CERN. The community is committed to participating at all levels. This ambitious project, with its large overall physics potential, would strengthen Europe's leadership in the field, with CERN as the global reference laboratory. Should the FCC be unfeasible, the preferred alternative would be a linear electron-positron collider at CERN, whose initial project should envisage a first stage running from the Z pole to the optimal Higgs-strahlung energy, and a second stage reaching energies beyond the ttH and HH production thresholds.

Ensuring a diverse and comprehensive physics programme is crucial for addressing fundamental physics questions, including fixed-target, neutrino, flavour, astroparticle and nuclear physics experiments. CERN should continue supporting leading-edge projects through the Recognized Experiment status and international collaboration agreements.

A strong investment in accelerator R&D, along with the necessary advancements in detectors and computing, is essential for the success of future endeavours. Full implementation of the corresponding ECFA R&D roadmaps, prioritizing the required FCC developments and including environmental sustainability considerations, must be achieved. Additionally, continued theoretical advancements, particularly in high-order perturbative computations, non-perturbative studies and model-building, are crucial for future discoveries, with CERN remaining a key hub for collaboration and support.

An early decision on CERN's next flagship project is critical for our young researchers, and their involvement in the early stages would be highly beneficial. Effective communication and outreach will be essential for such an unprecedented endeavour as the FCC.

- The complete final input from Spain covering also other areas was amended as supplementary material, highlighting in red the changes with respect to the document submitted in March 2025

Topics covered (12 pages)

Executive summary

1. Introduction
2. Particle physics at colliders
3. Non-collider physics projects
4. Accelerators R&D
5. Detector R&D
6. Computing R&D
7. The theory frontier
8. Early Career Researchers
9. Communication and outreach

Next steps

- The updated documents from the national HEP communities are now available at this link.
- Summary report on the new submissions as well as reports from working groups of the European Strategy Group (ESG) will be presented in the Open ECFA Plenary meeting this Friday, 21 November.

Spanish members in ESG
M.J. Costa (Spain representative)
N. Colino (CIEMAT representative in LDG)
J.L. Martínez (invited as Chair of ESFRI)
P. Hernández (Invited as part of the PPG)
C. Peña (Invited as Chair of APPEC)

It is a pleasure and an honour to represent Spain in the European Strategy group and, in particular in the upcoming the drafting session. Many thanks for your participation throughout this process.