Preparation of the CPAN Spanish Input to the European Strategy for Particle Physics Update

María José Costa - IFIC (CSIC-UV) on behalf of the Editorial Board of the Spanish national input
21 November, 2024. XVI CPAN Days, Madrid.

The European Strategy for Particle Physics

- The European Strategy for Particle Physics is updated typically every 5 years (see last update in 2020, Strategy and Physics Briefing Book)
- It is prepared by the European Strategy Group (ESG) based on the scientific input from the community summarised by the Physics Preparatory Group (PPG) in a Briefing Book.
- **March 2024 CERN Council**:
  - Decided to anticipate the next update by one year to allow for a timely decision on the CERN future programme and to maintain Europe's world leadership and offer a bright future for young generations.
  - The overall timeline of the Strategy update was approved.
- **June 2024 CERN Council**: Council elected Karl Jakobs (University of Freiburg) as Strategy Secretary Chair and established both the Strategy Secretariat and the European Strategy Group including its remit.
- **September 2024 CERN Council**: Council appointed the Physics Preparatory Group.

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.

Strategy Secretariat

Strategy Secretariat mandate:
Organising and running the ESPP process

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)

Karl Jakobs
Scientific Secreatry Chair

European Strategy Group (ESG)

European Strategy Group mandate:
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.

Spanish members:
Maria Jose Costa (Spain representative)
Nicanor Colino (CIEMAT representative in LDG)
Jose Luis Martínez (invited as Chair of ESFRI)
Pilar Hernández (Invited as part of the PPG)

Physics Preparatory Group (PPG)

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

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SPC Chair	Dr Hugh Montgomery (USA)
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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)	

Physics Preparatory Group (PPG) – Working groups

Working Group		
	Co-convener (PPG member)	Co-convener
Electroweak physics	Monica Dunford (DE, exp)	Jorge de Blas (ES, theory)
Strong interaction	Cristinel Diaconu (FR, exp)	Andrea Dainese (IT, exp, HI)
Flavour physics	Gino Isidori (CH, theory)	Marie-Hélène Schune (FR, exp)
BSM physics	Fabio Maltoni (BE/IT, theory)	Rebeca Gonzalez Suarez (SE, exp)
Neutrino physics and cosmic messengers	Pilar Hernandez (ES, theory)	Sara Bolognesi (FR, exp)
Dark matter and dark sector	Jocelyn Monroe (UK, exp)	Matthew McCullough (CERN, theory)
Accelerator science and technology	Gianluigi Arduini (CERN, acc)	Phil Burrows (UK, exp, acc)
Detector instrumentation	Thomas Bergauer (AT, exp)	Ulrich Husemann (DE, exp)
Computing	Tommaso Boccali (IT, exp, comp)	Borut Kersevan (SL, exp, comp)

Timeline for the update of the strategy

There are three occasions to provide national input.
The process to collect, discuss and document the input from Spain started in June 2024.

Input from the Spanish CPAN community plan

- **24 June 2024**: A call for input was launched to the full Spanish community (deadline 5 November)
  The IPs of the various networks have been leading discussions within their communities to provide a collective input, and organised additional discussions in the parallel sessions of the CPAN days (19-20 November). HUGE THANKS TO ALL OF THEM FOR THIS BIG EFFORT!
- **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
- **19 November**: Future Colliders for Early Career Researchers meeting
- **21 November**: Presentation of the input received and first discussion **(TODAY)**
- **31 January 2025**: First draft of the Spanish CPAN input document ready and distributed to the Spanish community
- **February 2025** (exact date to be confirmed): Final discussion on the document to converge on possible changes.
- **31 March 2025**: Send Spanish CPAN input document.

The following email lists are being used to communicate with the Spanish community:
cpan-investigadores@pegaso.ific.uv.es and gen-fpa@pegaso.ific.uv.es
Please, subscribe to these lists if you have not done it yet!

FCC day – Spain (see agenda here)

Scientific Committee
Juan Alcaraz (CIEMAT)
Nestor Arnesto (IGFAE)
Jorge de Blas (UG)
Mary-Cruz Fouz (CIEMAT)
Isabel Josa (CIEMAT) – Chair of LOC
Aurelio Juste (IFAE)
Marcel Vos (IFIC)
Contacts: Nicanor Colino (CIEMAT), Maria Jose Costa (IFIC), **Pilar Hernández (IFIC) - Chair**, Celso Martínez (IFCA), Carlos Salgado (IGFAE)

Many thanks to the CIEMAT group for hosting us and to the scientific committee for setting up an excellent program!

Input received from the various groups/networks/ICTS

A total of **15** documents of very high quality were received from:

Networks:
- **LHC** (sent by Salvador Martí, Isabel Josa, Miguel Ullán, Isidro González, José Hernández, Sven Heinemeyer, Ricardo Vázquez)
- **Future Colliders** (sent by Mary Cruz Fouz, Marcel Vos)
- **RENATA, Multidark, REDONGRA** (Miguel Angel Sánchez, Carmen Palomares, Carlos Sopuerta, Michel Sorel, Maria Martínez)
- **FNUC** (sent by Teresa Kurtukian, Jose Enrique Ramos)
- **WLCG** (sent by Jose Hernández, Jose Salt, Santiago González, Gonzalo Merino, Josep Flix, Antonio Pérez, Andreu Pacheco, Jose Del Peso, Jose Enrique García)
- **COMCHA** (sent by Luca Fiorini, Arantza Oyanguren)
- **LATTICENET** (sent by Carlos Pena)
- **Hadrons** (sent by Nestor Armesto)
- **Instrumentation** (sent by Iván Vila, Inés Gil, César Domingo)

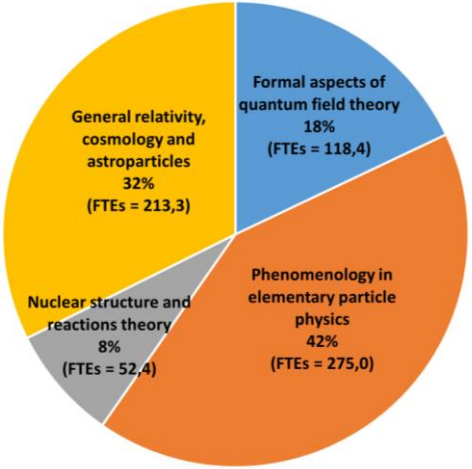
Experiments
Na64 (sent by Laura Molina)
NEXT (sent by Juan José Gómez)
Belle-II (sent by Carlos Mariñas)

ICTS:
CNA (sent by Jose Maria López – CNA Director)
LSC (sent by Carlos Peña – Director)

ECR (sent by Lourdes Urda, Carla Marín)

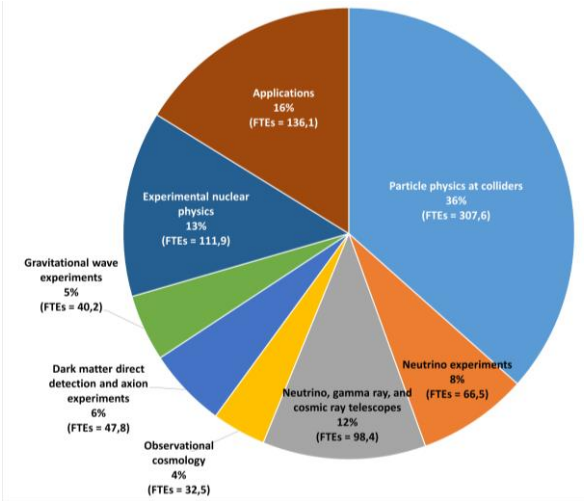
We are extremely grateful for the good response and thank you all for your participation in this process, and in particular the IPs of the various networks who have organised meetings within their communities to come up with collective based recommendations.

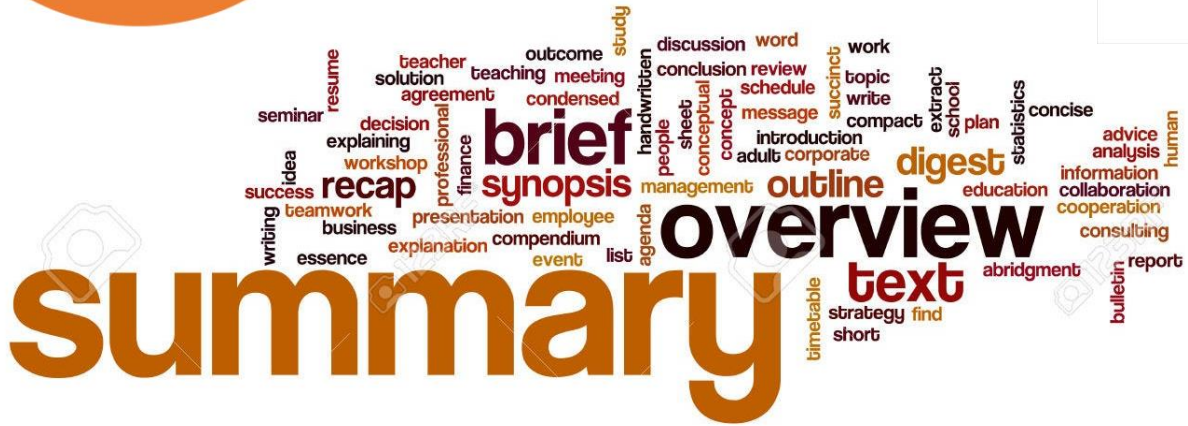
Attempt to summarise the input received so far



Input received from the Spanish community which includes **around 1500 physicists, engineers and technicians distributed in the 28 CPAN nodes.**

The received input will be shared with the community once the final versions are available.





Part 1: National input on the next Collider at CERN

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.

Guidelines for questions to be answered

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. 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 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).

Reminder: 2020 ESPP update

***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;

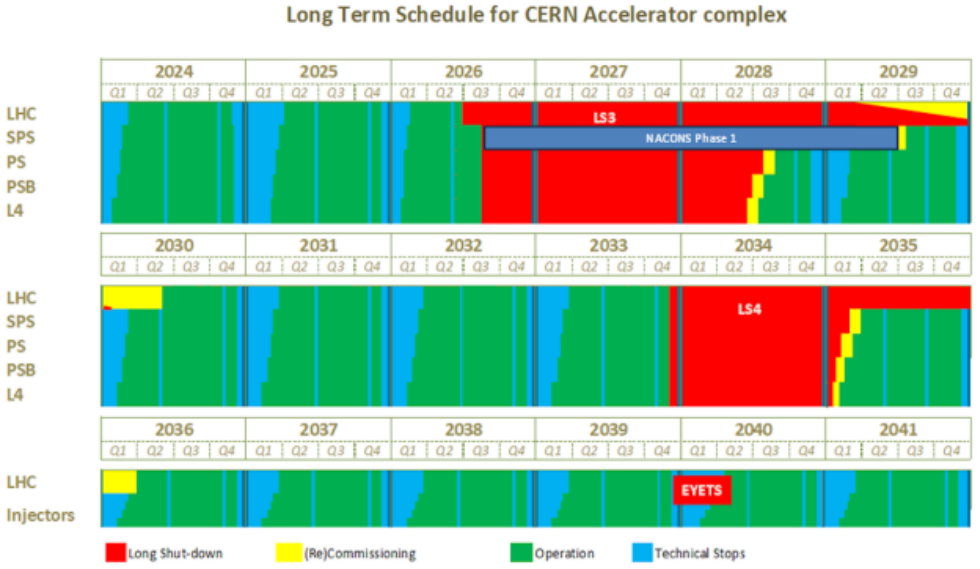
• Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility 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.

Taken from slides from Karl Jakobs ECFA open plenary session

→ **Current baseline**: FCC integrated programme (FCC-ee followed by a hadron collider of at least 100 TeV)
→ **Possible alternative scenarios**:
- Realisation of a lower-energy hadron collider (50 – 80 TeV) on an earlier timescale (2050 – 2055)
- Linear Collider at CERN
- Muon Collider at CERN
- Further exploitation of the LHC physics programme, eventually with the addition of e-h collisions
- …

Short-term/medium priorities

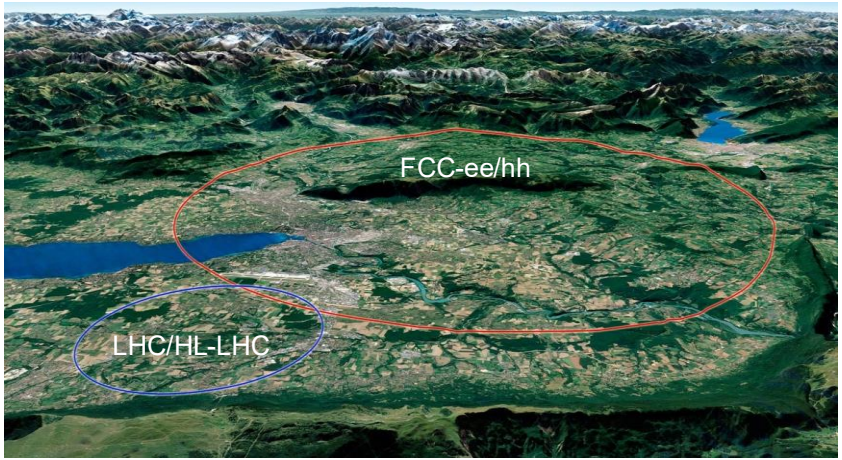
- **Spanish institutes are deeply involved in the LHC experiments**: **ATLAS, CMS, LHCb and MoEDAL**, as well as in the high-luminosity upgrade of the collider and associated detectors.
- The LHC+HL-LHC program is the flagship of HEP for the next 15-20 years. **Adequate completion of the HL-LHC program - exceeding an integrated luminosity of 3 ab^{-1} - is a priority**

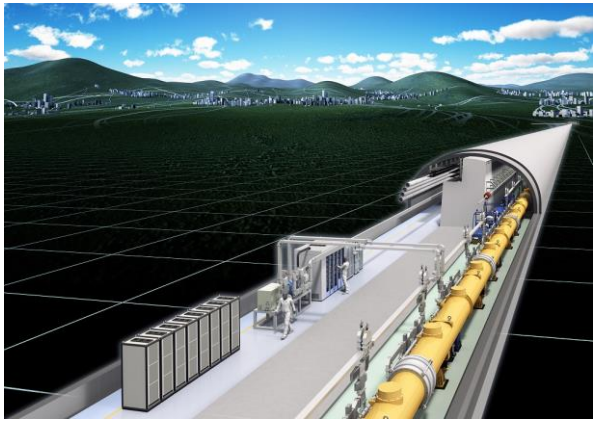


- **Diversity in physics interests should reflect in different experimental programs** (e.g., lattice and hadron networks interested in heavy ions and hadronic structure - EIC, FAIR,...; lattice on flavour - Belle-II, FCCee,...; sub-GeV dark sector - NA64;...). Diverse experimental programs, e.g., LHeC, could fill time gaps between major projects.

Preferred option for CERN's next flagship facility

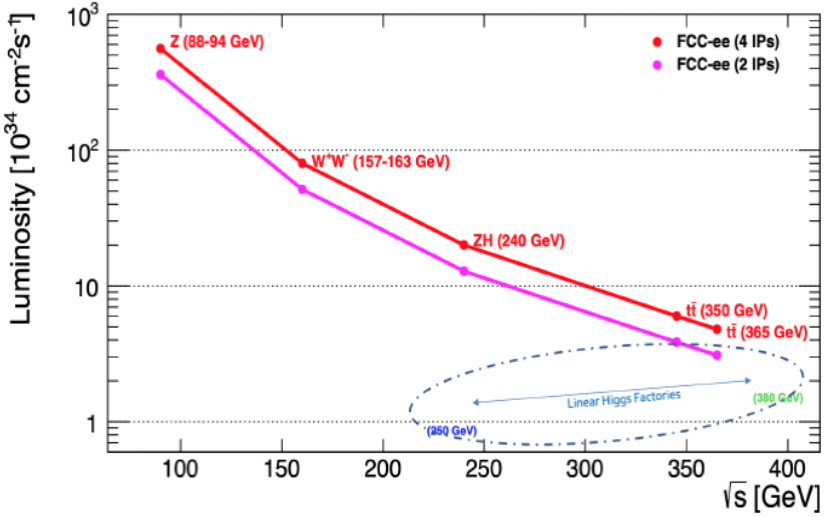
- The Spanish HEP community:
  - **supports a Higgs/top/EW factory electron-positron collider** that can characterize Higgs, top and EW interactions at exquisite precision;
  - insists that a positive **decision should be reached as soon as possible** to guarantee a timely start of the construction of this facility;
  - is **involved in the FCCee project and proposals for a linear collider**, as well as the ECFA Higgs/top/EW factory studies;
  - **will contribute to the electron-positron collider that is selected by the European strategy process**, whether it is circular or linear



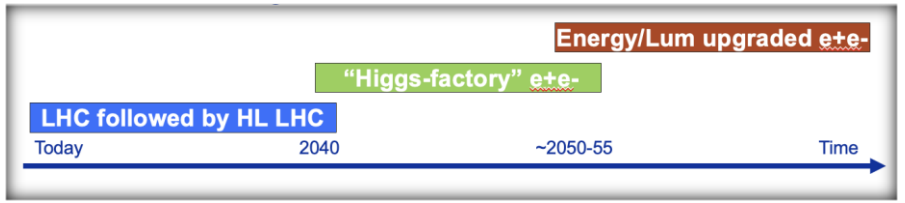


Higgs factory electron-positron collider science case

- **Higgs factory**:
  - Higgs program at the per mile level of precision for couplings to fermions and bosons
  - More than “just” Higgs: top and EW physics, QCD and flavour studies
- **Complementary (circular/linear)**:
  - **Circular colliders** excel at the Z-pole: access to new effects at several 10’s of TeV scale via precision physics, flavour/rare process factories, possibility to re-use the infrastructure for a 100 TeV hadron collider.
  - **Linear colliders** open up energy range above top quark pair threshold: ttH, di-Higgs production. Possibility for luminosity upgrade using ERL and further increase of energy with eventually with plasma wakefield acceleration.



Linear Collider

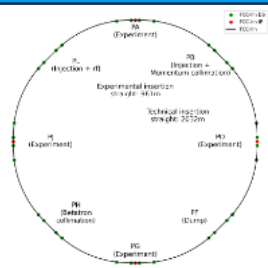


Multi-TeV energy frontier

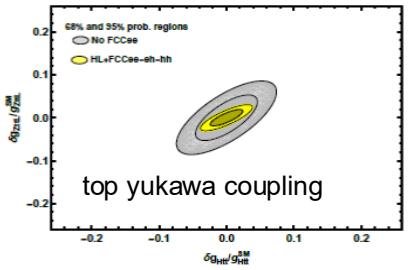
- **Exploration of the multi-TeV energy frontier**
  - Direct discovery of new resonances and effects at the 10 TeV scale
  - Deeper study of the Higgs potential (<5% precision in the triple Higgs coupling)
  - Many SM and QCD studies at high Q^2, low x, high p_T particle production, PDFs, final states with ≥3 massive bosons/tops, quartic couplings, …
  - Final word on WIMP dark matter
- **Hadron collider**: addition of heavy-ion, flavour physics, low-angle dedicated experiments, as well as an ep mode concurrent with pp
- **Muon collider**: neutrino physics, at ≥ 10 TeV running: deeper studies of boson-boson scattering, the Higgs potential and indirect sensitivity to new physics above its CM energy

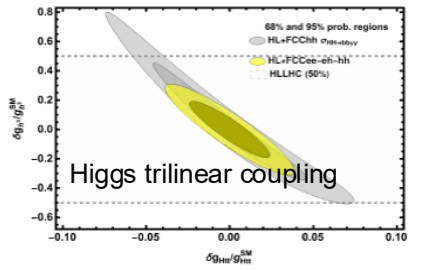
FUTURE CIRCULAR COLLIDER

Feasibility study expected to be completed in March 2025



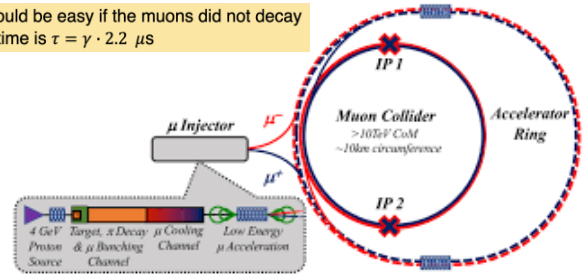
FCC-ee/hh together 2-3 times better than FCC-hh alone





International MUON Collider Collaboration

It would be easy if the muons did not decay
Lifetime is $\tau = \gamma \cdot 2.2\ \mu s$



After-LHC scenarios

- Different opinions expressed on the preferred next major collider project at CERN and no unanimous consensus reached.
- If the FCCee is feasible (and later ultimately approved), the Spanish community will support and wishes to participate in the FCC-ee project as the next flagship project at CERN.
- If the FCCee proves not to be feasible or is not approved, Spanish groups have expressed a preference for a linear electron-positron collider as the next flagship project at CERN.
- A lower-energy hadron collider with $\sqrt{s}$ = 50 – 80 TeV should also be considered: the feasibility, timeline and cost of such a machine should be assessed.
- If the CEPC is approved early, there is limited interest in participating.
- If a linear collider is approved in Japan, Spanish institutes that gave a long-standing participation in linear collider activities will be interested to participate.

Part 2: National input on non-collider projects

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.

Guidelines for questions to be answered

It would thus be most useful if the national inputs explicitly included the **preferred 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)? (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.

Neutrino physics and astroparticles: General Input to the ESPP

- The scientific objectives and technological approaches are very diverse, with **Spanish participation spanning more than 30 experimental projects**.
- CERN should continue to support astroparticle and neutrino physics projects not based at CERN through **Recognized Experiment status**. Among those, **particularly strategic for us are the projects and infrastructures with Spanish participation** included in the European Strategy Forum on Research Infrastructures (ESFRI) Landmarks and Projects, and in the Spanish Unique Science and Technology Infrastructures (ICTS).

Neutrino Physics
T2K
NEXT
Hyper-Kamiokande

Dark Matter Direct Detection
DarkSide-20k
DAMIC-M

Multi-Messenger Astrophysics
AMS
Auger
ANTARES
FERMI
MAGIC
CTA
KM3NeT
HERD

Gravitational Waves
LISA
Advanced Virgo
LIGO
Einstein Telescope

Observational Cosmology
Euclid

CERN Recognised experiments with Spanish participation

General input to the ESPP

- **CERN should continue to support neutrino physics based at CERN**, both theory and experiments, through its **Neutrino Platform**. Among neutrino experiments with Spanish participation, Neutrino Platform is supporting Hyper-K and DUNE.
- **International collaboration agreements between CERN and other particle physics laboratories** around the world **should continue and be strengthened**, as we believe that they are beneficial not only for the current and future collider projects at CERN, but also for astroparticle and neutrino physics projects based elsewhere.
- GW science has a significant potential to explore the early stages of the Universe with implications in fundamental physics. CERN technologies could play a key role in this field and synergies should be exploited. **The GW Spanish community (in particular from the ET) considers that GW research should be included as one of CERN's missions in the next ESPP update**.
- Specific recommendations have also been received for the various research lines in which Spain has a strong participation and commitments (not possible to cover them all in this talk).

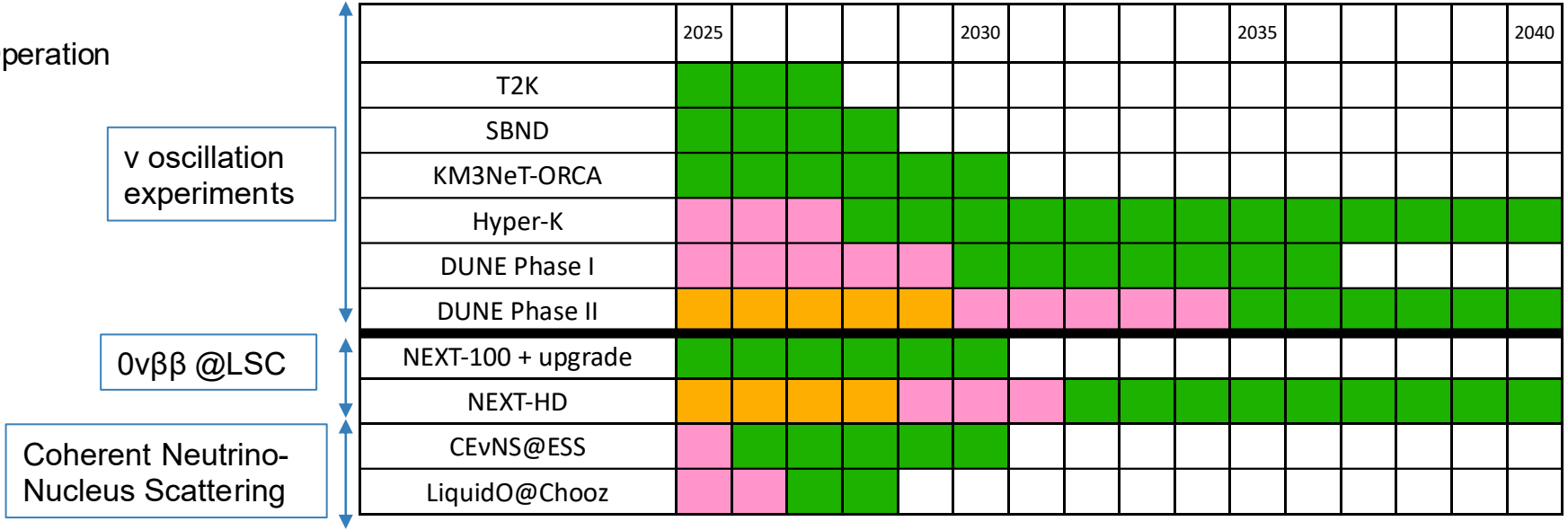
Neutrino Physics

R&D

Construction

Operation

Neutrino experiments with Spanish participation



Note: CERN is a member of SBND and DUNE Collaborations

- In addition, high-impact **neutrino theory and phenomenology** in Spain, particularly ν oscillation global fits, ν interaction modelling, BSM searches in ν experiments, and nuclear matrix elements for 0νββ decay.

Multi-messenger astrophysics

Charged particles

Participation focused in:

- **AMS** @ ISS (until 2030, upgrade in 2026): technical and scientific
- **AUGER** (2004-2024), **'AugerPrime' Phase II** (2025-2035): science, data processing, analysis

Interest:

- **HERD** at the China Space Station (>2027).

Gamma rays

Participation focused in:

- **CTAO:** construction and science
- **Fermi-LAT:** operations and science

First telescope (LST-1) already producing scientific results. LSTs 2 to 4 ready by the end of 2025.

In orbit since 2008. No successor at sight.

Gravitational waves

Participation focused in:

- **LIGO-VIRGO:** instrumentation, data analysis and theoretical studies
- **Einstein Telescope:** instrumentation, science
- **LISA:** analysis and HPC

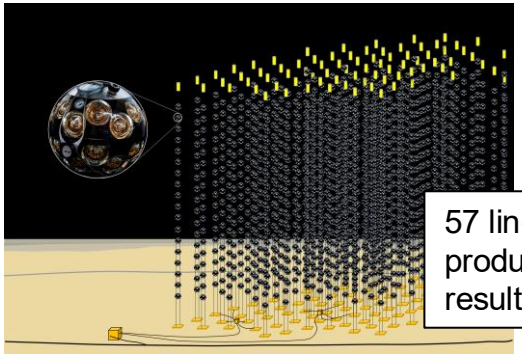
Interest:

- Development of quantum technologies (deciHerz band), Pulsar Timing Arrays and CMB polarization detectors (low frequency band)

Neutrinos

Participation focused in:

- **KM3NeT:** Hardware and science.



57 lines already producing competitive results.

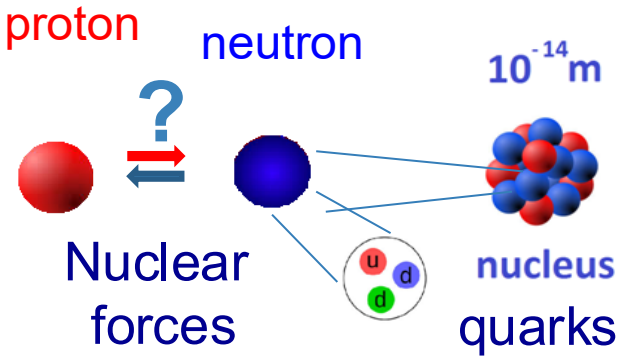
Dark matter direct detection

- **Heavy WIMPs**: **Participation in the 2nd generation experiment DarkSide-20k, and interest in 3rd generation ARGO, using Ar technology**. Critical to maintain the underground production and control chain for Ar. Ar technology complementary to the Xe one.
- **Light DM, axions/ALPs**: **Participation in the development of small initiatives to explore novel concepts and detection methods, in particular those using quantum sensors** (**SuperCDMS, DAMIC-M/OSCURA, TREX, ANAIS+ ,CADEx, RADES, QRADES**).
- **ANAIS-112** will test the **DAMA anomaly** with 5σ significance by late 2025, but further work on systematics is needed. With DAMA/LIBRA ending data collection in 2024. **Interest to participate in the independent operation of the DAMA crystals**.
- The **International Axion Observatory (IAXO)** is the largest European collaboration in search for **axions**. **Participation in the completion and scientific exploitation of the pathfinder BabyIAXO and the preparations towards the future full-scale IAXO.**

Nuclear physics: Key topics and facilities

- Nuclei provide a unique laboratory for studying the strong, weak, and electromagnetic interactions. Complementary approach to particle and astroparticle physics.

- From basic constituents to nuclei, QCD
- Structure of nuclear matter, collective vs. individual nucleon behaviour
- Role of nuclei in the evolution of the universe, stellar nucleosynthesis
- Weak interaction, neutrino and dark matter physics, symmetries
- Physics beyond the Standard Model?
- Diagnosis, therapy, condensed matter, energy, life sciences



- Experimental nuclear physics research is multisite, based on the complementarity of different state-of-the-art research infrastructures:
  - Unstable radioisotopes, particle beams, electromagnetic probes, neutron sources
- Focus on discovery potential, match of facility capabilities and experimental tools
- Role of advanced instrumentation and theory

Nuclear physics: Input to the ESPP

- Spanish community aligned with NuPECC, sent key input to Long Range Plan 2024
- Most top international facilities based on **hadron drivers** (proton, light & heavy ion)
  - **CERN** unique facilities (ISOLDE, n_TOF) at the forefront of research worldwide
  - Strong effort for **ESFRI** facilities: FAIR (DE), Spiral2 (FR), future IFMIF-DONES (ES)
  - Medium and small facilities (including national ICTS CNA) have a relevant impact and it is important to foster collaboration with major facilities.

Summary:
- Important to keep European leading role linked to particle physics strategy beyond LHC.
- Ensure the diversity in the physics program in a future collider era.
- Strategy to secure long-term opportunities for continuing world-leading nuclear-physics programmes, using proton injector chain unique to CERN, and elsewhere.
- Future plans for hadron collider to include nuclear physics and QCD research.
- Exploit synergies in instrumentation, computing and related areas.

Part 3: National input on other fields

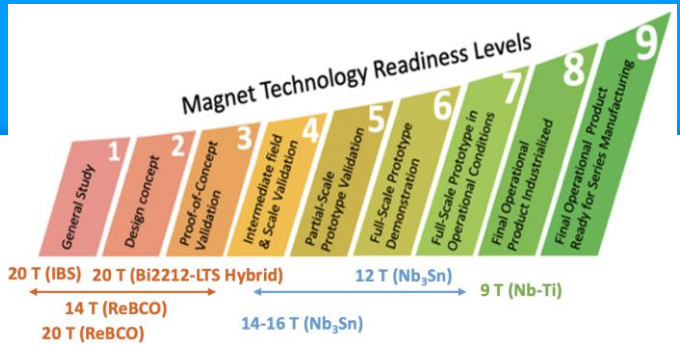
The ESG should review and update the Strategy and add other items identified as relevant to the field, including **accelerator**, **detector** and **computing R&D**, the **theory frontier**, actions to minimise the **environmental impact** and to improve the **sustainability** of accelerator-based particle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

The theory frontier: For the future

- Precision in the theoretical calculations matching that in the experimental results is essential for the interpretation of the measurements.

- Ensuring sufficient person and computer power is required by the complexity of such precise calculations.

Accelerators R&D



- Vigorous R&D of key accelerator technologies is crucial for the long-term future of High Energy Physics: **high-field magnets for hadron colliders** (14 T with Nb_3Sn, 20 T with HTS), **high-gradient RF cavities**, **recirculating LINACs**, and novel collider schemes based on **muon beams** or **plasma/wakefield acceleration** are important parts of the current roadmap.

- The **sustainability** of collider projects (CO_2 footprint of construction and operation) and **synergies with other fields and industry** are key considerations
- **Spanish institutes** are involved in **high-field magnets** (CIEMAT, ALBA), **high-gradient cavities** (CIEMAT, ALBA, IFIC) and **Energy Recovery LINACs** (ESS-Bilbao), as well as **beam dynamics** and **instrumentation**. **Experience covers both future linear or circular colliders**.
- Strong involvement of **Spanish industry** in accelerator development in close collaboration with research centers.

Detectors R&D – Current context

- The 2020 European Strategy for Particle Physics (ESPP) identified the need for advanced detector R&D to support future experimental goals.
- In response, the European Committee for Future Accelerators (ECFA) developed the **ECFA Detector R&D Roadmap**.
- The Roadmap defined the **General Strategic Recommendations** (GSRs):
  - Infrastructure for test facilities and resources; engineering support, especially in electronics and microelectronics; specialized software for design and data processing; International coordination to avoid redundancy; a balance between centralized and distributed R&D; sustainable funding for long-term projects; encouragement of exploratory "blue-sky" research; R&D career support; industrial partnerships; open data and knowledge sharing.
- Most of the GSRs implemented by the CERN anchored **Detector R&D (DRD) Collaborations**:
- The DRD collaborations address specific technologies like gaseous, liquid, and semiconductor detectors, photon and particle ID, calorimetry, quantum sensors, and electronics.

- Spanish institutions play a key role in many DRD activities, the **CPAN Network of Instrumentation and Detectors (CNID)** enhance the collaboration among Spanish teams for greater impact.

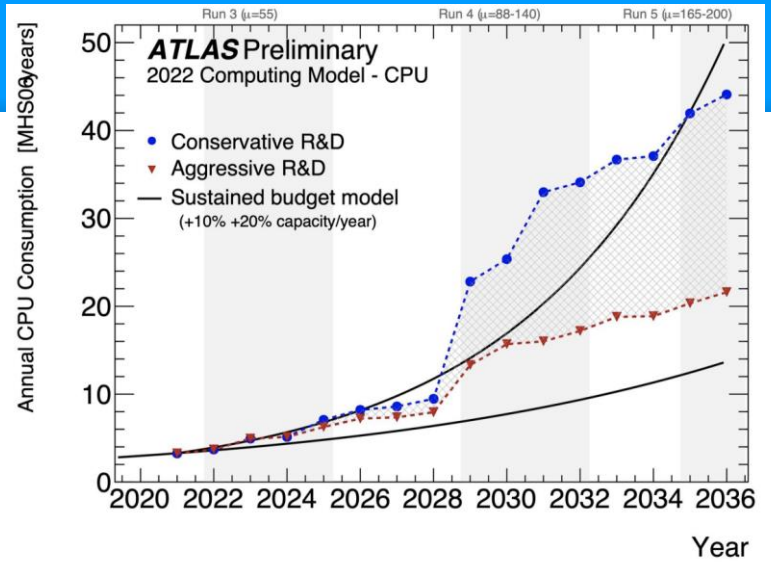
CPAN NETWORK ON INSTRUMENTATION AND DETECTORS

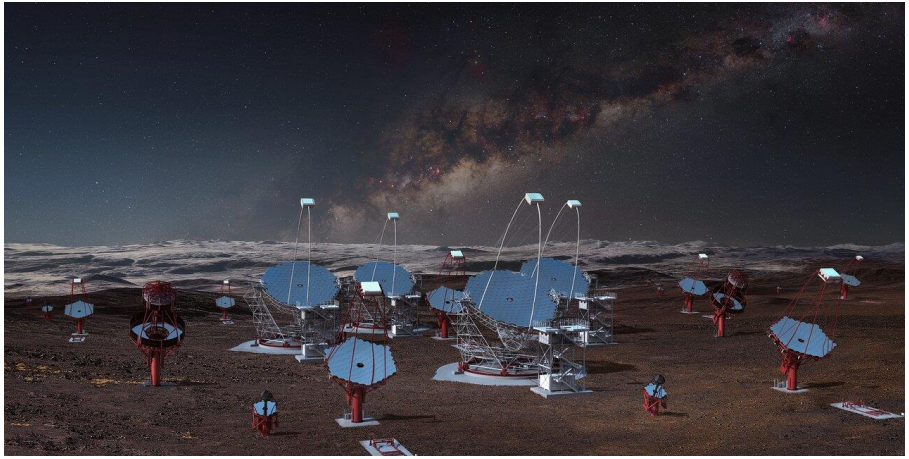
Detectors R&D – Input to the ESPP

- **Priority for Full Implementation**:
  - The 2025 ESPP Update should emphasize the **need to implement the ECFA Detector R&D Roadmap fully**, with focus on sustainable funding and formal agreements for the DRD collaborations.
- **Recommendations for Future Colliders and Experiments**:
  - Detector-Concept Collaborations: ECFA should **promote proto-collaborations for new collider detectors**: System design optimization, physics benchmarking and system integration at both sub-detector and full-detector levels.
- **Beyond Colliders**:
  - **Support for accelerator and non-accelerator experiments**, like neutrino physics and dark matter searches, should continue.
  - **Enhance the CERN Neutrino Platform** by utilizing shared resources and expertise from various neutrino experiments to accelerate advancements in neutrino detector technology and strengthen ties with relevant DRD collaborations.

Computing R&D

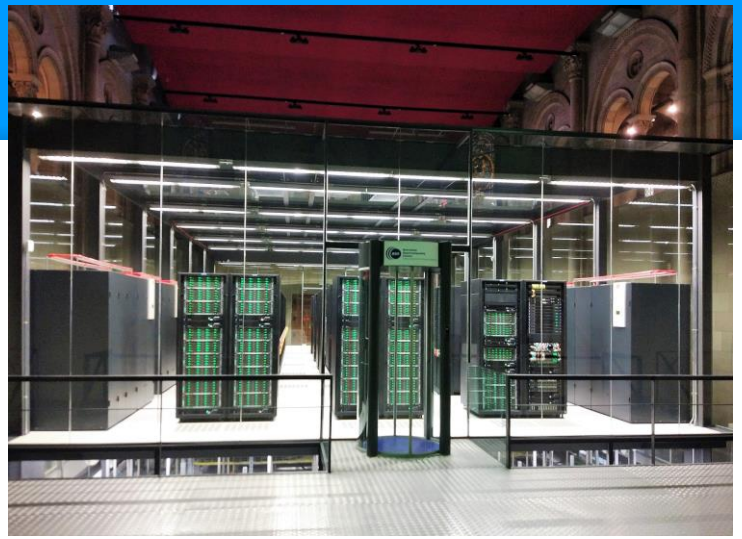
- **The HL-LHC phase will require nearly ten times more computing resources:**
  - Crucial to invest in **R&D to reduce CPU and storage needs**.
  - To **support analysis**, need dedicated infrastructures to provide **efficient and interactive access to very large datasets**.
- **This trend extends across the field to future experiments**, including colliders, fixed targets, and astroparticle research, which will all **depend heavily on advanced computing technologies** to reach their scientific objectives.

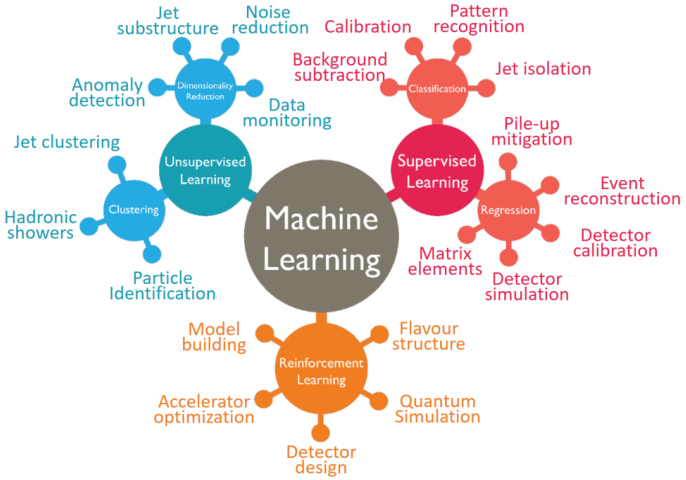




Computing R&D

- **HPC systems** have been instrumental for a long time in parts of the field such as Lattice. As they concentrate growing amounts of computing power, **they are becoming increasingly important for experimental HEP computing**.
  - Their **integration into experiments workflows should be a strategic priority**.
  - Due to their heterogeneous nature, significant investment will be required to **optimise HEP software**.
  - **Political support** needed to continue advancing large-scale computing infrastructures across Europe and to ensure reliable **access for the HEP community.**
- Important for experiment frameworks to be able to provide **seamless access to large-scale Cloud resources.**
- **Artificial intelligence (AI)**, especially machine learning (ML), is playing a **growing role** in the field, transforming data analysis workflows. AI hardware trends, driven by the commercial sector, are shaping scientific computing, **requiring adoption of ML-optimized infrastructures and optimisation of software for these architectures**.





Computing R&D

- **Environmental sustainability should be a key focus**. New developments in software and computing have to be aimed at reducing the carbon footprint of computing activities.
- **The integration of GPUs and FPGAs is essential**, enabling more energy-efficient computations.
  - In the longer term, **emerging technologies like quantum computing and neuromorphic chips** might be vital for future energy-efficient experiments.
- The **WLCG** is widely regarded as a model for large-scale distributed scientific computing. It should **position itself strategically as a science-driven organization** that not only provides essential services **for HEP** but also develops an ecosystem of tools, services, and capabilities that benefit a **wider range of scientific disciplines**.

- To support the R&D program required to address the challenges faced by the field and to make use of the opportunities arising from global trends, **increased investment in training and retaining scientific software and computing specialists will be crucial, alongside providing clear career paths and proper recognition for their work**.

Early Carer Researchers (ECR)

- In 2020, ECFA established an ECR Panel to discuss factors impacting the future of particle physics.
- Carla Marin and Lourdes Urda, as Spanish representatives in this Panel, took the initiative to collect information from the ECR Spanish community regarding the ESPP upgrade.
  - Conducted a survey: The survey is still open at this link.
  - Organised national session on "Future colliders for Early Career Researchers" on Tuesday morning (as recommended by ECFA)

If you are an ECR (i.e. PhD students and postdocs, either with a non-permanent contract
or with up to 8 years after obtaining the PhD), please register to the CERN e-group: ecr-ecfa-spain

You are welcome to fill in the Survey at this link.

ECFA SPAIN 2024

In 2020, the latest update of the European Strategy for Particle Physics was approved by the CERN Council. One of its twenty strategy statements emphasizes that an electron-positron Higgs factory is the highest-priority next collider. Studies on this and other colliders are in full swing worldwide. Moreover, the next update of the European Strategy is expected for 2026-2027, and the update has been moved up, with the Spanish input needing to be submitted by early 2025. Given the long timelines of these projects, we believe it is of paramount importance for Early Career Researchers (ECRs) to participate in an informed way in the many discussions currently taking place about the future of our field. The aim of this survey is to poll the Spanish High-Energy Physics community on this subject. An initial overview of the results will be presented at the Spanish network for future colliders meeting in Valencia (1-2 July, 2024), and ultimately, the final outcomes and conclusions will be shown at the XVI CPAN in Madrid (19-21 November, 2024), where we especially encourage ECRs to attend and participate in the discussions.

There are 29 questions in this survey.

THIS SURVEY IS ANONYMOUS.

Early Carer Researchers (ECR)

- Based on the results of the survey from **23 ECRs**, the following conclusions were reached:
  - Strong endorsement **CERN's longer-term focus on collider-based research**, fully supporting the HL-LHC exploitation and advocating for Europe to pursue at least one major new collider.
  - An **e+e- collider is identified as the highest priority** (divided opinions between FCCee and CLIC/ILC, important to take into account the international panorama to ensure complementarity).
  - For the **high-energy frontier**, similar levels of support for hadron collider, muon collider and plasma wakefield accelerator.
  - Important to **engage ECR in these R&D projects** to gain experience and so that their insights are integrated into the planning of these facilities.
  - **Economic, environmental and societal** are important aspects to consider.
  - **Concerns about career paths and job security are prevalent**, significantly influencing their motivation to remain in the field.
  - The **necessity to migrate to other countries for career advancements** adds complexity and should be reconsidered in today's globalised world.
  - Desire of an **early decision the next facility**, which would help to attract and retain talent.

Next steps

- The goal is to have a first draft of the Spanish input for the ESPP document by the end of January.
- The input received so far is extremely valuable, thank you very much!
- However, additional separate discussions with the different communities (colliders, astroparticles, nuclear, accelerators, computing, detectors, theory) will be needed to converge on statements which have an ample support of the community and to give as clear as possible answers to the suggested challenging questions (if at all possible).
- The draft document will be circulated to the CPAN community to collect additional comments.
- A meeting will take place in February (date to be defined) for a final discussion on possible changes before submission by the end of March.

Final words (quoting Karl Jakobs):
Reaching a consensus on the next large collider project at CERN in this Strategy Update is vital!
- Given the scale of the project, large timescales, … the decision cannot be postponed.
- It will define the path to the future of our field
→ ***Get engaged in the discussions*** *(at national level, projects, Open Symposium in Venice, etc)*
In order to maximise the chances to get the next collider approved, we must reach consensus, and support the final plan, whatever it will turn out to be!

Acnowledgements

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- Project CNS2024-154901 funded by MCIN/AEI

Backup

FCC “physics features”

- Main objectives: comprehensive search for deviations from the SM at the intensity (FCC-ee) and energy (FCC-hh) frontiers. FCC-ee and FCC-hh are complementary to reach these objectives
- **FCC-ee** (up to 4 detectors in ring, no longitudinal polarization in baseline, exquisite beam energy precision):
  - Provides largest statistics in e+e- collisions up to the top-pair production threshold; aims for ultimate precision on fundamental masses and couplings of the SM
  - Higgs program at the per mille level of precision for couplings to fermions and bosons (after combination with FCC-hh for some channels with low branching ratios)
  - Access to new effects at the 10 TeV scale via precision physics (Tera-Z running)
  - Unique factory for the study of flavour physics (b, c, tau) and QCD/hadrons in e^+e^- collisions
  - Optimal machine for the direct discovery of feebly interacting particles up to m~100 GeV
- **FCC-hh**:
  - Direct discovery of new resonances and effects at the 10 TeV scale
  - Deeper study of the Higgs potential (<5% precision in the triple Higgs coupling)
  - Many SM and QCD studies at high Q2, low x, high pT particle production, PDFs, final states with ≥3 massive bosons/tops, quartic couplings, …
  - Natural addition of heavy-ion, flavour physics, low-angle dedicated experiments, as well as an ep mode concurrent with pp

Linear collider “physics features”

- Main objective: comprehensive study of fundamental parameters and deviations from the SM in e^+e^- collisions up to $\sqrt{s}$ = 3 TeV (1 TeV at ILC, 3 TeV at CLIC)
- Baseline program includes longitudinal polarization for the colliding beams
- Comprehensive Higgs physics program, with unique capabilities, particularly at high center-of-mass energies: vector boson fusion production and measurement of the triple Higgs coupling via HH production
- Precise measurement of fundamental SM masses and couplings, including high precision physics at the Z pole (Giga-Z option)
- High sensitivity to new physics effects that grow fast with $\sqrt{s}$: top physics well above the top-pair threshold, direct ttH production, HZ final state, high-mass dilepton final states, …
- Direct search for feebly interacting particles, particularly at masses above the Z pole