European Strategy for Particle Physics: The Process and Key Recommendations

Paris Sphicas
CERN/NKUA
EUROLABS FINE FINal meeting
KIT, Karlsruhe
June 30, 2026

The European Strategy for Particle Physics: 2026 Update

- ESPP: cornerstone of Europe's strategy-setting process for the long-term future of Particle Physics
  - 2006 (first ESPP); 2013 (HL-LHC decision); 2020 (first post-HL-LHC recommendations)
    - Europe… 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.

      → CERN launched the FCC feasibility study
  - 2024: CERN Council launches current update

- Aim: 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**.

Timeline for the update of the European Strategy for Particle Physics

End September 2024
Council appointment of the members of the **PPG** and decision on the venue for the **Open Symposium**

December 2024
Council decision on the venue for the **ESG Strategy Drafting Session**

31 March 2025
Deadline for the submission of main input from the community

26 May 2025
Deadline for the submission of additional national input in advance of the **Open Symposium**

23-27 June 2025
Open Symposium (in Venice)

End September 2025
Submission of the "Briefing Book" to the **ESG**

14 November 2025
Deadline for the submission of final national input in advance of the **ESG Strategy Drafting Session**

1-5 December 2025
ESG Strategy Drafting Session
(Monte Verita / Ascona, CH)

End January 2026
Submission of the draft strategy document to the Council

March and June 2026
Discussion of the draft strategy document by the Council and **updating of the Strategy**

We are here

Plus de détails sur la page web de l'ESPP: https://europeanstrategyupdate.web.cern.ch

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Open Symposium

23-27 June 2025

Deadline for the submission of final national input in advance of the **ESG Strategy Drafting Session**

14 November 2025

Submission of the draft strategy document to the Council

End January 2026

266 submissions received

- *Major flagship projects*
- *Many projects in other physics areas*
- *National HEP communities*
- *National labs*
- *Early career researchers*
- …
- ...

We are here

March and June 2026

Discussion of the draft strategy document by the Council and **updating of the Strategy**

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

Considerations towards forming the decision on the next CERN flagship project

- **Physics Potential (WG2b report)**
  - → **Assessment of overall physics potential**
    - → **Physics Briefing Book (30 Sept. 2025)**

- **Project assessment (WG2a report)**
  - → **Technical feasibility, required R&D, risks, timeline, costs and human resources (including estimates for the associated detectors), environmental impact**

- **Input by National HEP communities (WG1 report)**
  - → **ESPP requested explicit responses to preferred collider, and alternatives if preferred is not feasible or competitive. Input received March 31, May 26, Nov 14, 2025.**

- **Physics potential and long-term prospects of reaching the 10++ TeV energy scale**
  - **Both precision and energy are required**

https://arxiv.org/abs/2511.03883

CERN Yellow Report

CERN-ESU-2025-001
30 September 2025

Physics Briefing Book

Input for the 2026 update of the European Strategy for Particle Physics

Electroweak Physics: Jorge de Blas[1], Monica Dunford[2] *(Conveners)*, Emanuele Bagnaschi[3] *(Scientific Secretary)*, Ayres Freitas[4], Pier Paolo Giardino[5], Christian Grefe[6], Michele Selvaggi[7], Angela Taliercio[8] *(Contributors)*

Strong Interaction Physics: Andrea Dainese[9], Cristinel Diaconu[10] *(Conveners)*, Chiara Signorile-Signorile[11] *(Scientific Secretary)*, Néstor Armesto[12], Roberta Arnaldi[13], Andy Buckley[14], David d'Enterria[7], Antoine Gérardin[15], Valentina Mantovani Sarti[16], Sven-Olaf Moch[17], Marco Pappagallo[18], Raimond Snellings[19,83], Urs Achim Wiedemann[7] *(Contributors)*

Flavour Physics: Gino Isidori[20], Marie-Hélène Schune[21] *(Conveners)*, Maria Laura Piscopo[83] *(Scientific Secretary)*, Marta Calvi[84], Yuval Grossman[23], Thibaud Humair[24], Andreas Jüttner[7,25], Jernej F. Kamenik[26,65], Matthew Kenzie[27], Patrick Koppenburg[83], Radoslav Marchevski[28], Angela Papa[29], Guillaume Pignol[30], Justine Serrano[10] *(Contributors)*

Neutrino Physics & Cosmic Messengers: Pilar Hernandez[39], Sara Bolognesi[40] *(Conveners)*, Ivan Esteban[41] *(Scientific Secretary)*, Stephen Dolan[7], Valerie Domcke[7], Joseph Formaggio[42], M. C. Gonzalez-Garcia[80,81,82], Aart Heijboer[19], Aldo Ianni[44], Joachim Kopp[7,79], Elisa Resconi[45], Mark Scott[33], Viola Sordini[87] *(Contributors)*

Beyond the Standard Model Physics: Fabio Maltoni[8,31], Rebeca Gonzalez Suarez[32] *(Conveners)*, Benedikt Maier[33] *(Scientific Secretary)*, Timothy Cohen[7,28,78,*], Annapaola de Cosa[34,*], Nathaniel Craig[35], Roberto Franceschini[36], Loukas Gouskos[37], Aurelio Juste[38], Sophie Renner[14], Lesya Shchutska[28] *(Contributors)*

Dark Matter and Dark Sector: Jocelyn Monroe[54,46], Matthew McCullough[7] *(Conveners)*, Yohei Ema[7,†] *(Scientific Secretary)*, Paolo Agnes[47], Francesca Calore[48], Emanuele Castorina[22], Aaron Chou[49], Monica D'Onofrio[50], Maksym Ovchynnikov[7,†], Tina Pollmann[19], Josef Pradler[59,86], Yotam Soreq[52], Julia Katharina Vogel[53] *(Contributors)*

Accelerator Science and Technology: Gianluigi Arduini[7], Philip Burrows[51] *(Conveners)*, Jacqueline Keintzel[7] *(Scientific Secretary)*, Deepa Angal-Kalinin[55], Bernhard Auchmann[76,7], Massimo Ferrario[3], Angeles Faus Golfe[21], Roberto Losito[7], Anke-Susanne Mueller[56], Tor Raubenheimer[57], Marlene Turner[7], Pierre Vedrine[40], Hans Weise[24], Walter Wuensch[7], Chenghui Yu[58] *(Contributors)*

Detector Instrumentation: Thomas Bergauer[59], Ulrich Husemann[56] *(Conveners)*, Dorothea vom Bruch[10] *(Scientific Secretary)*, Thea Aarrestad[34], Daniela Bortoletto[54], Shikma Bressler[60], Marcel Demarteau[61], Michael Doser[7], Gabriella Gaudio[62], Inés Gil-Botella[63], Andrea Giuliani[21], Fabrizio Palla[64], Rok Pestotnik[65], Felix Sefkow[24], Frank Simon[56], Maksym Titov[40] *(Contributors)*

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Theoretical Overview: Eric Laenen[19,83,85]
Reviewers: Anadi Canepa[49], Xinchou Lou[58], Rogerio Rosenfeld[72], Yuji Yamazaki[73]
Editors: Roger Forty[7], Karl Jakobs[74], Hugh Montgomery[75], Mike Seidel[28,76], Paris Sphicas[7,77]

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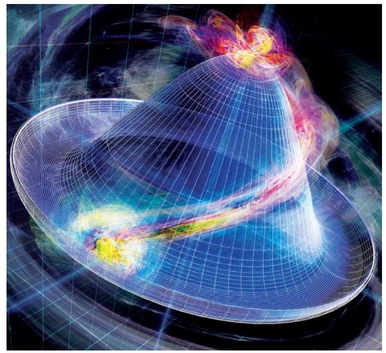
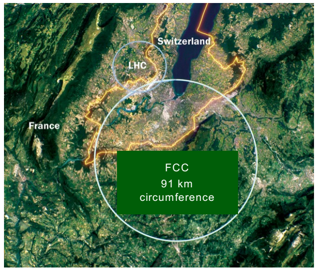


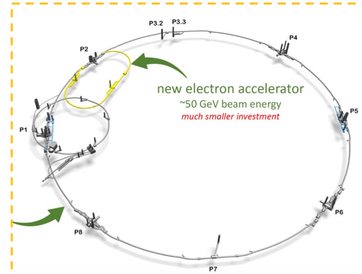
Vision: collider options for ≥10 TeV parton-cm energies

FCC-ee



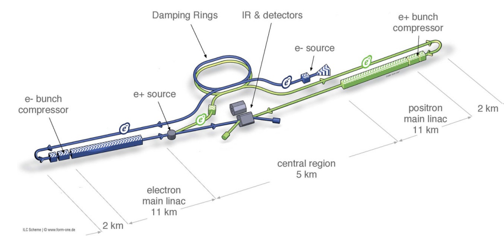
LEP3

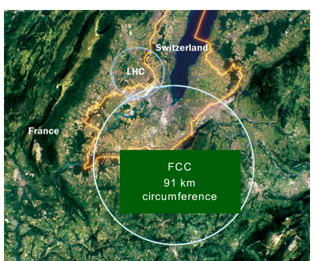
LHeC



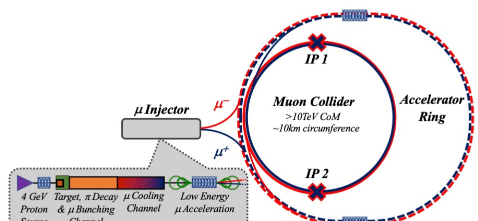
PERLE

LCF, CLIC





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



Muon Collider (3, 10 TeV)

R&D

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?)

Input for the decision making on the next CERN flagship project

Project assessment

ESG Working Group 2a report

Assessment of large-scale accelerator projects at CERN
Report of ESG WG2a

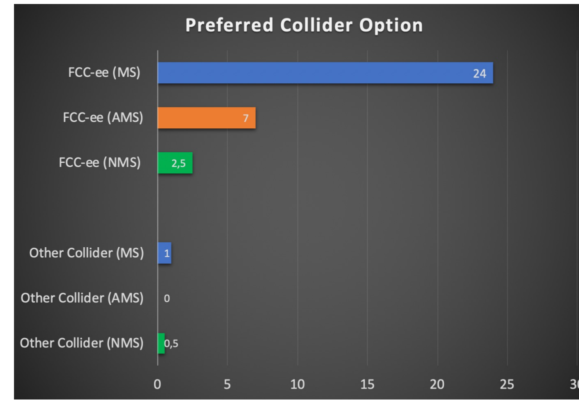
31 October 2025

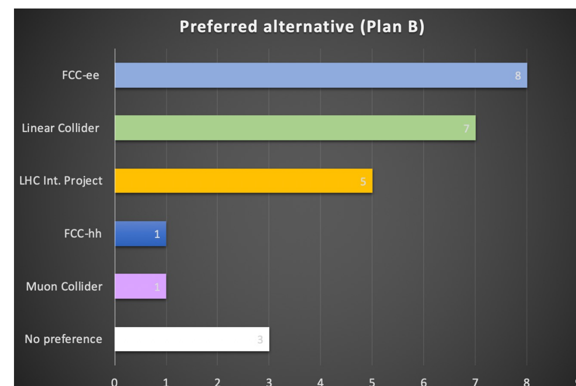
G. Arduini[1,a] (convener), F. Bordry[1] (co-opted accelerator expert), R. Brinkmann[2] (co-opted accelerator expert), P. Burrows[3,b] (convener), K. Desch[4], S. Farrington[5,6], F. Gianotti[1], K. Hanagaki[7], N. Holtkamp[8,9] (co-opted accelerator expert), J. Keintzel[1,c] (scientific secretary), B. Kilminster[10], T. Lesiak[11], L. Rivkin[12,13] (co-opted accelerator expert), F. Sabatié[14], M. Tuts[15], A. Zoccoli[16].

Project	Scope	TRL	R&D	Test facilities	Performance uncertainty	Site preparation	Schedule uncertainty	Cost uncertainty	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							

Final input by the National HEP communities

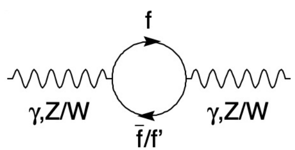
ESG Working Group 1 report



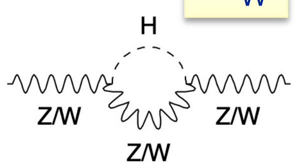


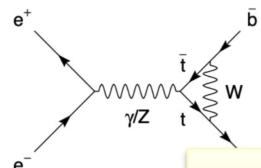
Main conclusion from physics comparisons of candidate colliders

- While the study of the Higgs boson is clearly a very important goal for any future physics program, there is a lot of information in non-Higgs studies – thanks to Quantum Mechanics.
  - Loop processes give access to potential New Physics. Which means that the “old” measurements of W and Z bosons, b-hadron decays etc are very important.

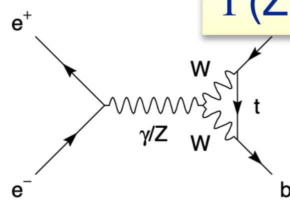


M_W

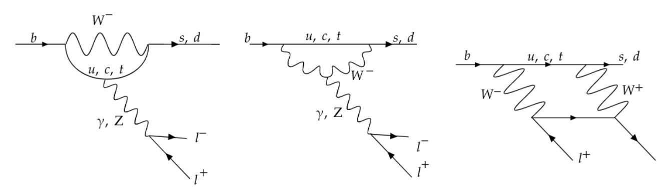




Γ(Z→bb)

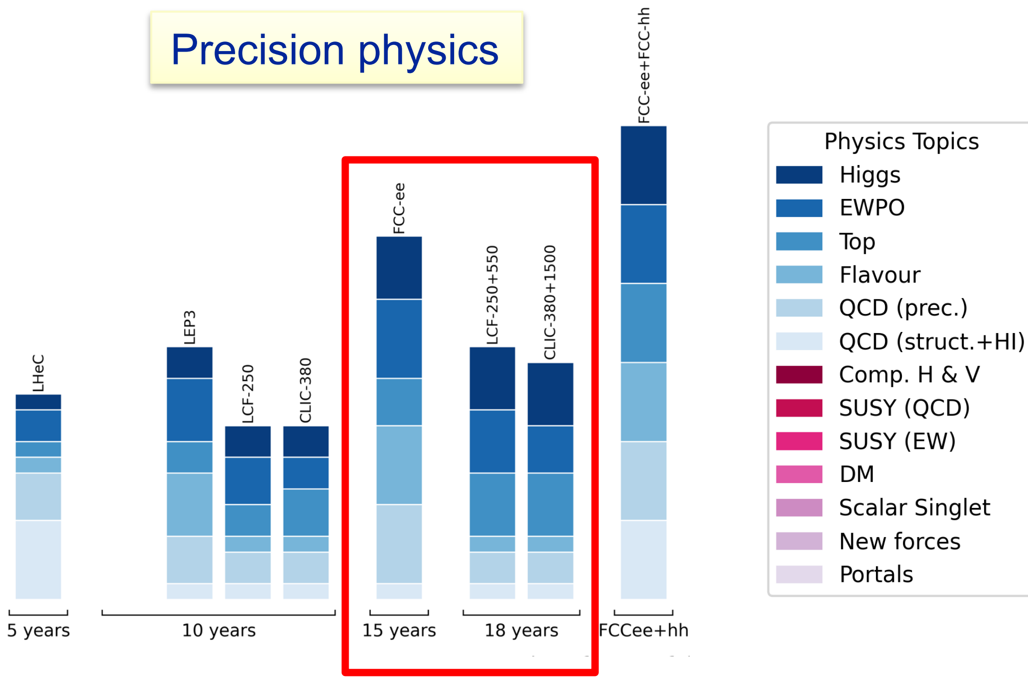


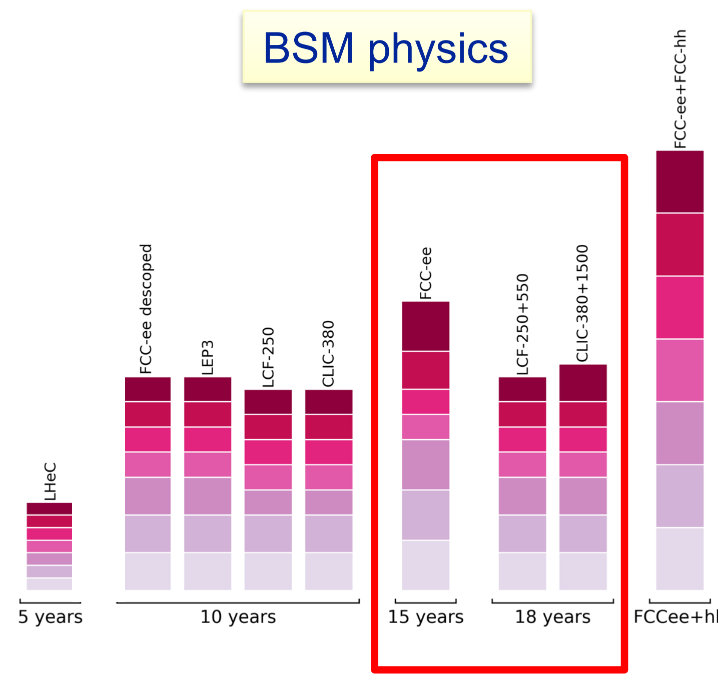
Rare b decays



  - Loops → small effects/rare processes → need highest possible precision.
- To estimate true physics reach: combine all measurements in EFT analysis
  - For the highest possible physics reach: need a Higgs-EWK-Top-Flavor factory
  - And: Optimal exploration of the BSM landscape needs both Precision and Energy

Overall Physics Assessment





CERN-ESU-2026-006

Can we improve on the Figure of Merit – beyond a scalar sum?

Summary I

Machine	Precision Physics	BSM physics	Physics vs CEPC	Technical readiness	Constr. cost (BCHF)	Time scale	Path to ≥10 TeV
FCC-ee	22	23			15.3	2046-2060	
LCF550	15	17			14.8	2045-2065	
CLIC1500	14	18			14.6	2045-2066	

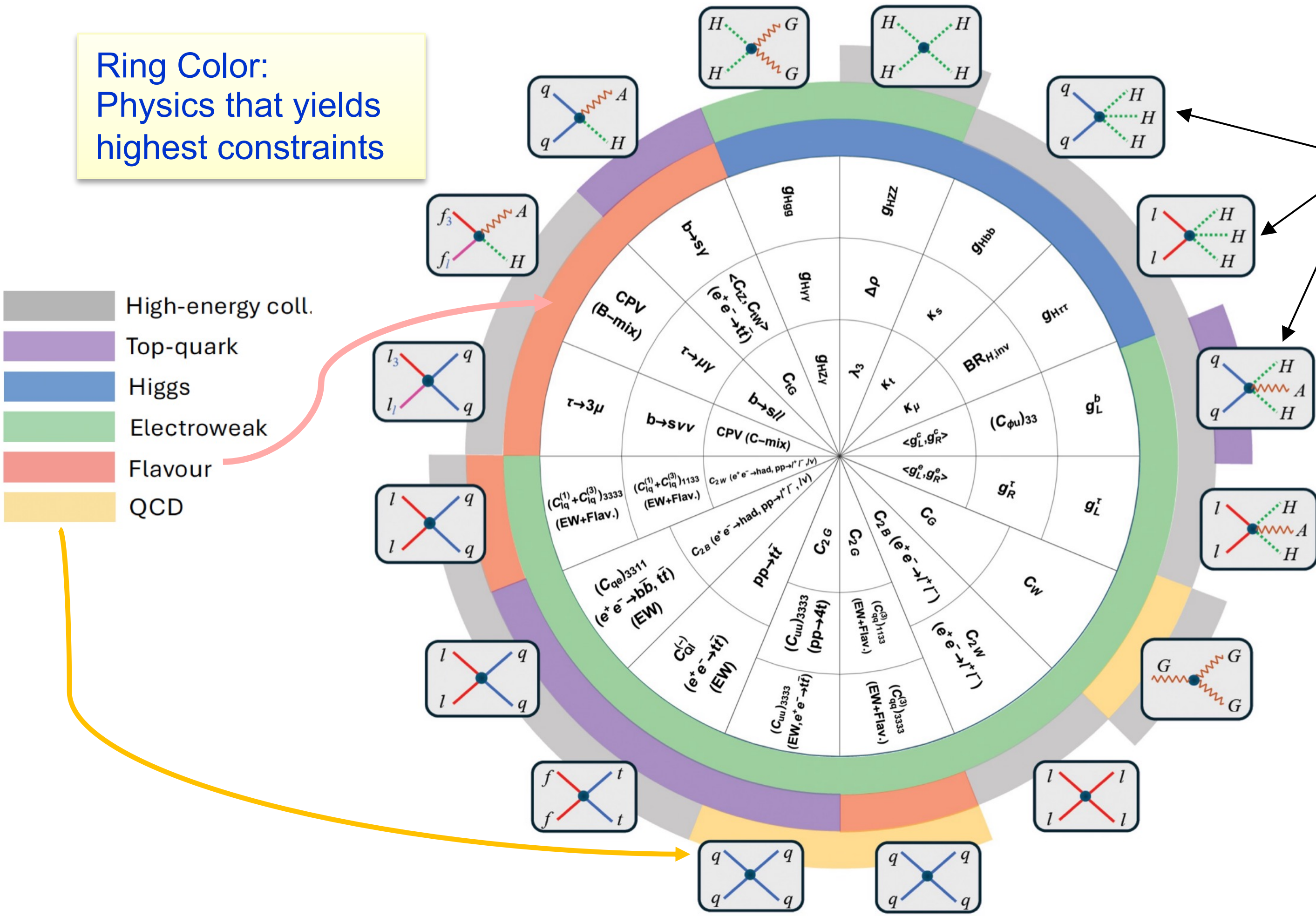
Physics: from WG2b (sum of precision/BSM physics)
Phys vs CEPC: competitiveness, assuming CEPC is running in parallel
Tech readiness: from WG2a
Construction cost: from proponents + exp. (CERN part)

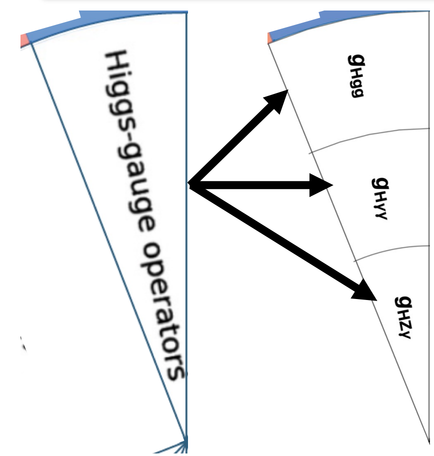
Coverage of the Physics Landscape

Ring Color:
Physics that yields highest constraints

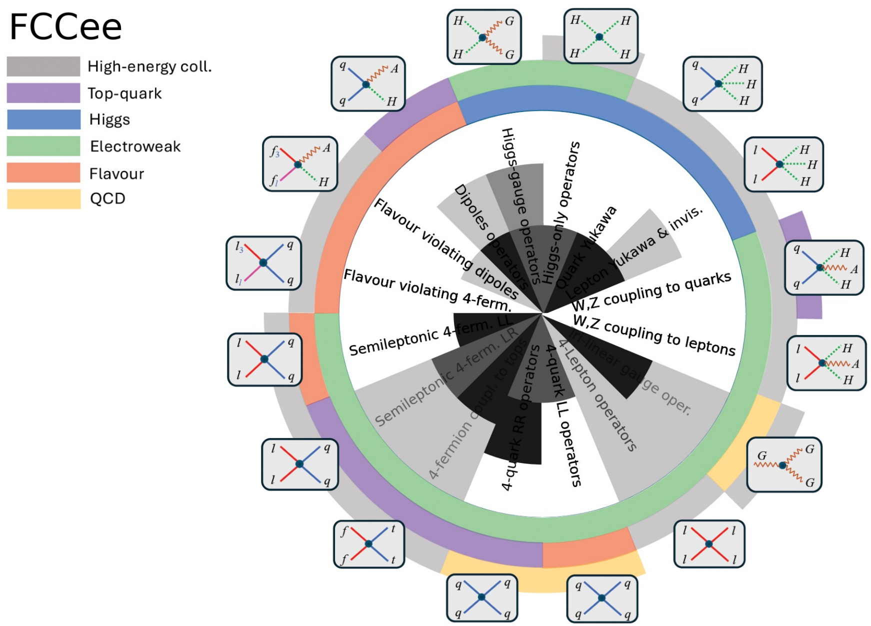
Physics areas (SMEFT inspired): 16 sectors with possible BSM physics

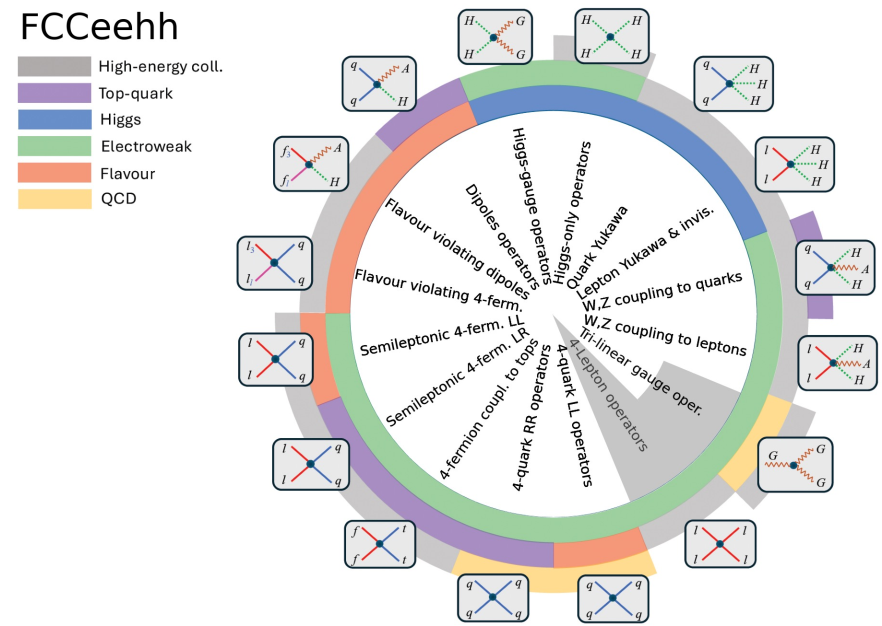
Further: 2-3 sub-sections (more detailed view; total: 44)





Coverage of the FCC integrated programme





Improvement factors in precision w.r.t. HL-LHC are evaluated and mapped on a log-scale covering the range 1 to 5

HL-LHC: 1 (gray scale 1 = black)

Best collider: 5 (gray scale 5 = white)

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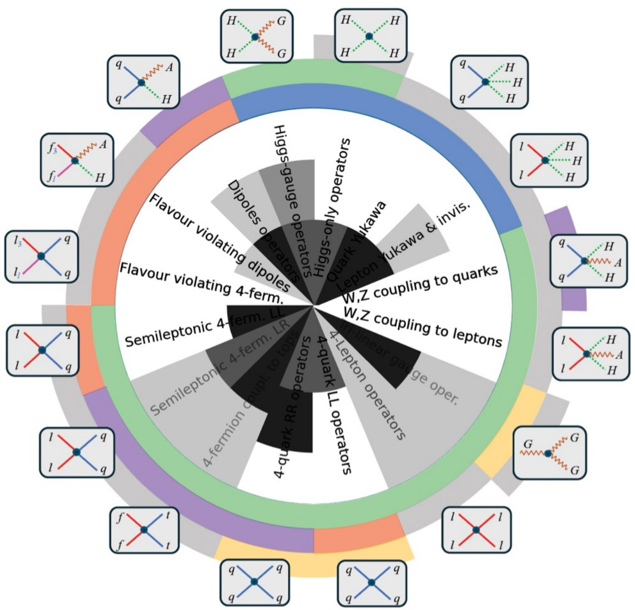
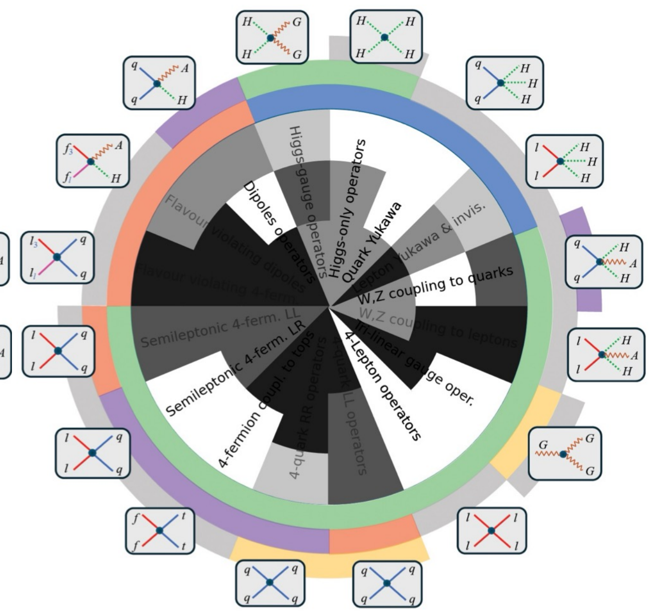
FCC-ee versus high-energy e⁺e⁻ colliders

FCC-ee
Technical Readiness
Cost: 15.3 BCHF
Vision to 10++ TeV

LCF550
Technical Readiness
Cost: 14.8 BCHF
Vision to 10++ TeV

CLIC1500
Technical Readiness
Cost: 14.6 BCHF
Vision to 10++ TeV





The preferred next flagship collider: FCC-ee

- **The FCC-ee would deliver the world’s broadest high-precision particle physics programme**
  - **Outstanding discovery potential through the Higgs, electroweak, flavour and top sectors, as well as advances in QCD**
  - **Its technical feasibility is demonstrated via the FCC feasibility study**
  - **Scope and costs are well defined, plausible funding models exist**

- **The FCC-ee would maintain European leadership in high-energy particle physics, also advancing technology and providing societal benefits**

- **The FCC-ee would also pave the way towards a hadron collider reusing the tunnel and much of the infrastructure, providing a direct discovery reach well beyond the 10 TeV parton energy scale**

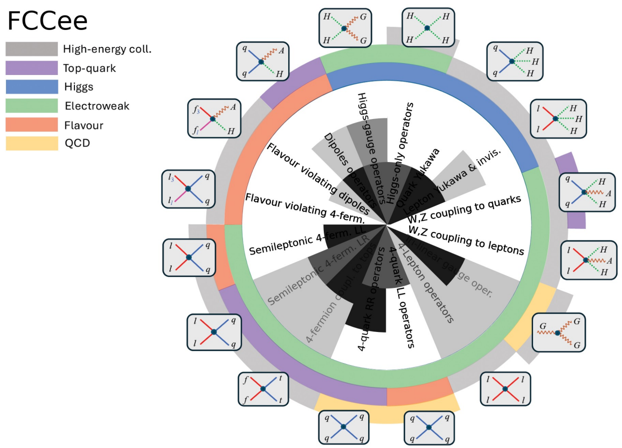
- **Remaining question: what if this “plan A” is not feasible?**
  - **Financial viability & potential emergence of unforeseen challenges, notably those associated with tunnel construction**

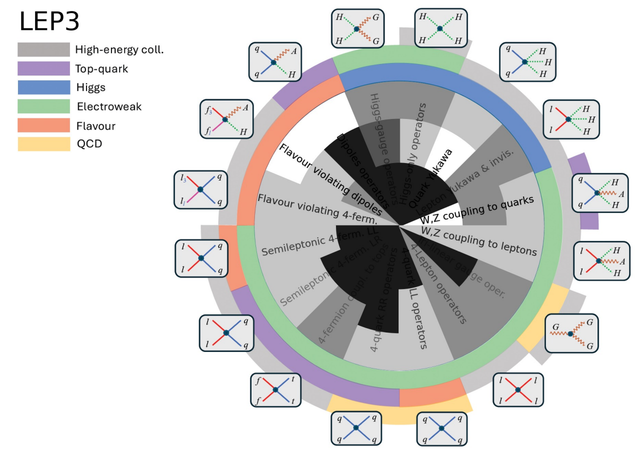
Summary II

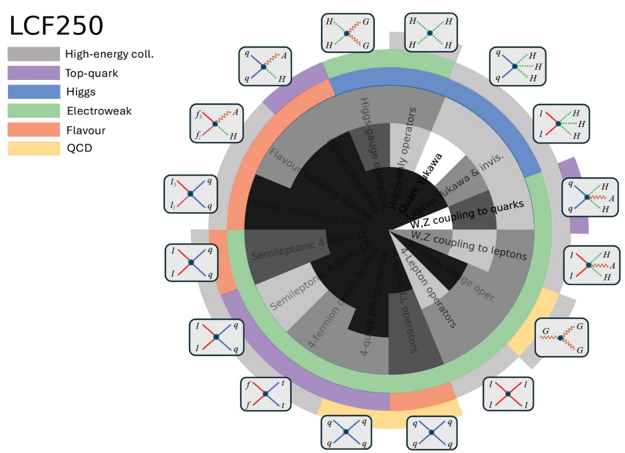
Machine	Precision Physics	BSM physics	Physics vs CEPC	Technical readiness	Constr. cost (BCHF)	Time scale	Path to ≥10 TeV
FCC-ee	22	23			15.3	2046-2060	
LCF550	15	17			14.8	2045-2065	
CLIC1500	14	18			14.6	2045-2066	
LCF250	10	16			9.4	2045-2053	
CLIC380	10	16			7.5	2045-2054	
LEP3	15	17			4.1	2047-2062	
LHeC	8	7			2.1	2044-2051	

Physics: from WG2b (sum of precision/BSM physics)
Phys vs CEPC: competitiveness, assuming CEPC is running in parallel
Tech readiness: from WG2a
Construction cost: from proponents + exp. (CERN part)

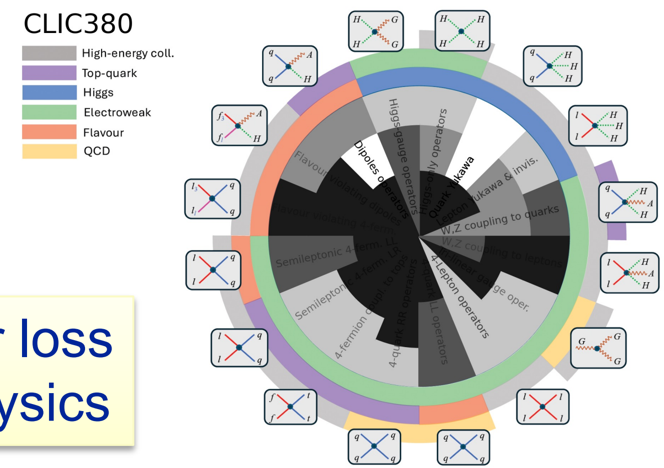
Coverage of first-stage e^+e^- colliders







Major loss of physics



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Towards identifying a plan B

- **All other collider options (i.e. not the FCC-ee) are considered as potential alternatives if the FCC-ee is not feasible.**
  - **All these alternatives do not present a concrete and visionary plan, by failing one or more of the requirements for the next flagship collider at CERN:**
    - **providing sufficient precision in the electron-positron collider program so as to be competitive with an FCC-ee-like machine running concurrently,**
    - **providing a sufficiently concrete plan due to pending demonstrations of key technology elements, or**
    - **providing a convincing vision for exploration of the highest achievable energies**

- **Given this analysis and the coherence of the input from the national HEP communities, ESPP update also considered possibility of a collider based on the FCC-ee concept but at a lower cost**
  - **Albeit with reduced physics capability.**

→ **An alternate option: a descoped FCC-ee has been investigated.**

→ **Removing top-quark run (1.26 BCHF); two rather than four IPs/ experiments (0.80 BCHF); lower RF system power 50 MW ® 30 MW (0.35 BCHF); Luminosity: x0.36.**

Overall Summary

	Machine	Precision Physics	BSM physics	Physics vs CEPC	Technical readiness	Constr. cost (BCHF)	Time scale	Path to ≥10 TeV	
Plan A	FCC-ee	22	23			15.3	2046-2060		Plan A
Plan B	Descoped FCC-ee	15	17			12.9	2046-2055		Plan B
	LCF550	15	17			14.8	2045-2065		
	CLIC1500	14	18			14.6	2045-2066		
	LCF250	10	16			9.4	2045-2053		
	CLIC380	10	16			7.5	2045-2054		
	LEP3	15	17			4.1	2047-2062		
	LHeC	8	7			2.1	2044-2051		

Physics: from WG2b (sum of precision/BSM physics)
Phys vs CEPC: competitiveness, assuming CEPC is running in parallel
Tech readiness: from WG2a
Construction cost: from proponents + exp. (CERN part)

Conclusion: next flagship collider

The electron–positron Future Circular Collider (FCC-ee) is recommended as the preferred option for the next flagship collider at CERN.

A descoped FCC-ee is the preferred alternative option for the next flagship collider at CERN

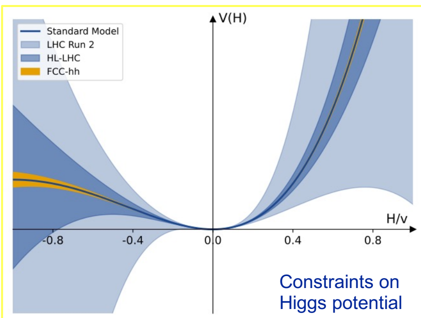
At this stage, without knowing the reasons for which the FCC-ee would not be feasible, other alternative options are not ranked.

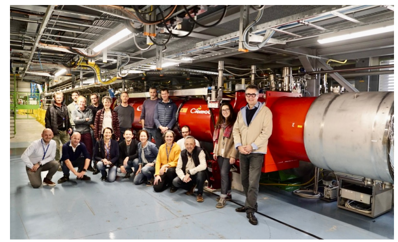
This was a conscious decision and reflects the large gap in the overall physics reach and path to the future between the FCC-ee and the other options. Should the descoped FCC-ee turn out to be necessary: we can still get to the full FCC-ee if more resources are secured at a later stage.

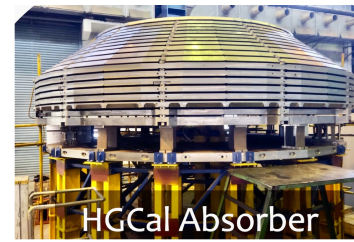
Other recommendations

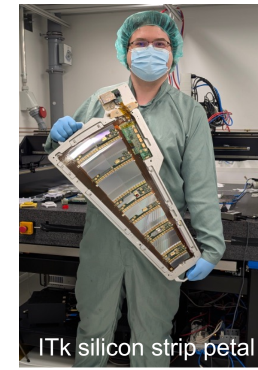
General Recommendations

1. **The full exploitation of the physics potential of the LHC and the HL-LHC and the completion of the high-luminosity upgrade remain the highest priorities of European particle physics.**
    1. **Every effort must be made to complete the HL-LHC upgrade within the current schedule.**









2. **The unique ecosystem of particle physics research centres and universities in Europe should be further strengthened in order to address the objectives set out in this Strategy.**
3. **The implementation of the Strategy should be pursued in strong collaboration with global partners and neighbouring fields.**
4. **The relationship between the particle physics community and the European Commission should be further strengthened, exploring funding opportunities for the realisation of infrastructure projects and R&D programmes in cooperation with other fields of science and industry.**

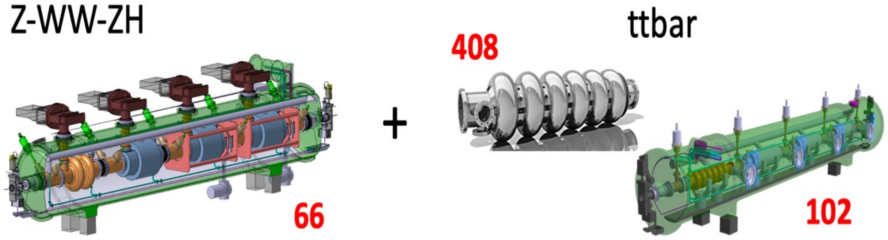
To ensure that Europe remains at the forefront of technologies for particle physics, R&D in collaboration with international partners and industry must continue to be supported with high priority, thereby enhancing sustainability and societal impact.

Technologies: Accelerator science and technology (I)

- … highest priority … development and industrialisation of key technologies:
  - advanced superconducting and normal-conducting RF structures
  - efficient RF power sources and
  - accelerator-quality magnets in the 14–20 T range, including those based on high-temperature superconductors.

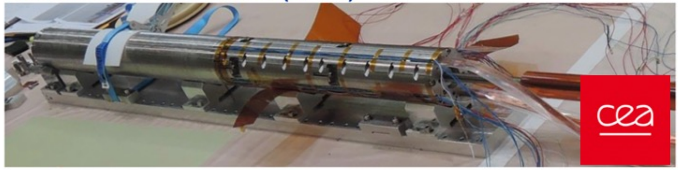
ReBCO Racetracks, CERN

FCCee Collider RF system (400 MHz and 800 MHz)



EUCARD2 Feather M2 (CERN)

EUCARD2 Cos Theta (CEA)



Technologies: Accelerator science and technology (II)

- **Demonstration of high-current multi-turn energy recovery in linacs constitutes an important step towards power-efficient lepton accelerators for a broad range of applications and should be pursued.**

- **The longer-term development of advanced technologies, such as high-gradient wakefield acceleration and those underpinning bright muon beams, should be supported at an appropriate level.**

→ Synergies with the US initiative on muon collider R&D should be exploited.

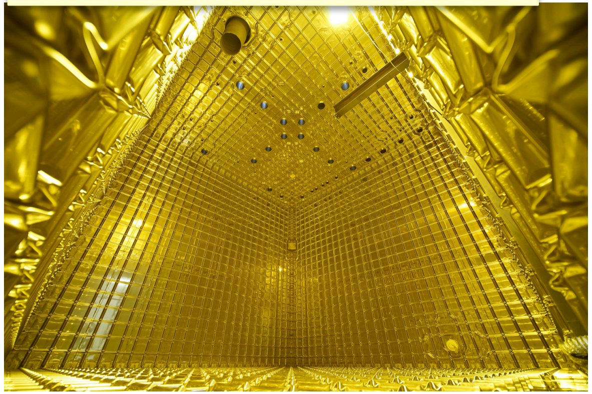
Other research directions in particle physics

- European contributions to both accelerator-based and non-accelerator neutrino and dark matter experiments are essential and should be supported.

- CERN should continue to provide support to the global long-baseline neutrino programme via the Neutrino Platform. The collaboration between CERN and non-accelerator-based experiments on technologies of mutual benefit should be continued.

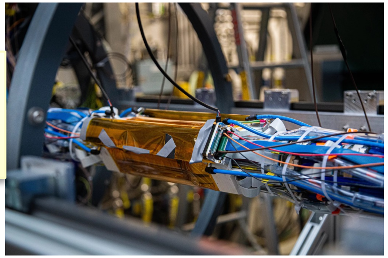
- The ecosystem of European particle physics laboratories should continue to support a broad, diverse spectrum of key precision experiments in particle physics.

Large TPC, CERN Neutrino Platform



DM Xenon experiment at Gran Sasso

Mu3e integration run at PSI

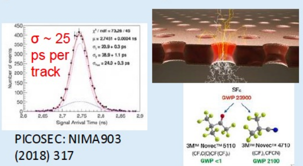


ALPS experiment at DESY

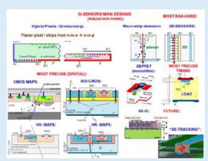
Technologies: Detector development

- For the DRD collaborations … must receive adequate funding. New R&D topics and initiatives should be integrated in the DRD scheme. **The General Strategic Recommendations in the roadmap must be fully addressed by dedicated initiatives coordinated across the DRD collaborations.**
- A coherent, strategic approach and sufficient resources to support **close cooperation with industry are required to address the rising costs and growing complexity in engineering, particularly in microelectronics.**
- To enhance efficiency and align developments with global technology trends in other fields, standardised, **off-the-shelf solutions should be prioritised over custom designs**, where applicable.

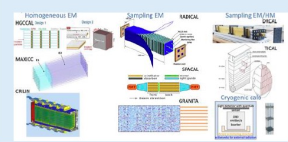
DRD1: Gaseous Detectors
Large · Fast · eco-friendly gases · MPGD, e.g. GEMs



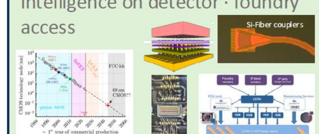
DRD3: Semiconductor Det.
Monolithic CMOS · LGADs · radiation hardness · interconns.



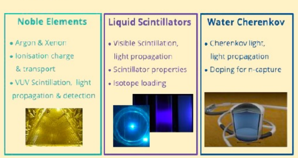
DRD6: Calorimetry
Energy resolution · High granularity · dual readout · particle flow · sandwich · optical



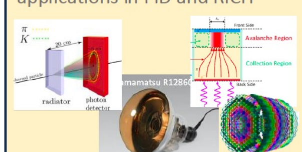
DRD7: Electronics
ADC/TDC IP Blocks · Opto-electronics · packaging · power · extreme environments · COTS · intelligence on detector · foundry access



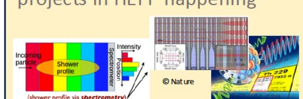
DRD2: Liquid Detectors
for Neutrinos · Dark Matter · 0vbb



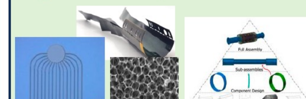
DRD4: Photon detectors
vacuum, solid-state (SiPM), hybrid single-photon and SciFi detectors · applications in PID and RICH

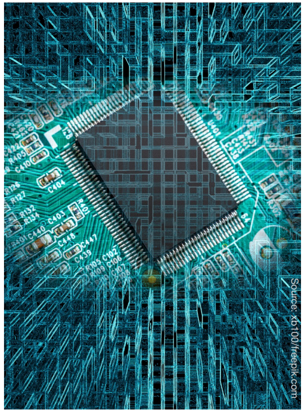


DRD5: Quantum Sensors
Quantum dots · superconduct. nanowires · bolometers · TES · MMC · nuclear clocks
Applications in LEPP, first projects in HEPP happening



DRD8: Mechanics
Ultra-thin beam pipes · CF foam and new materials · curved, retractable sensors · air & micro-channel cooling · eco-friendly ccoling fluids · robots · augmented reality





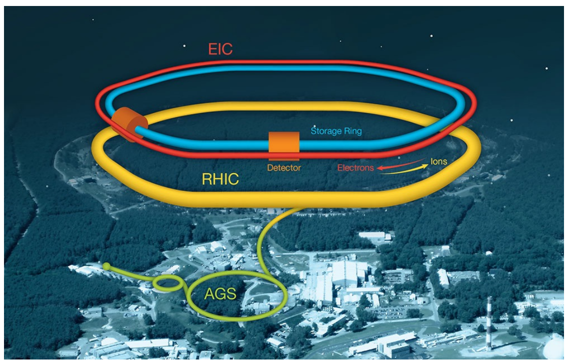
Synergies with neighbouring fields

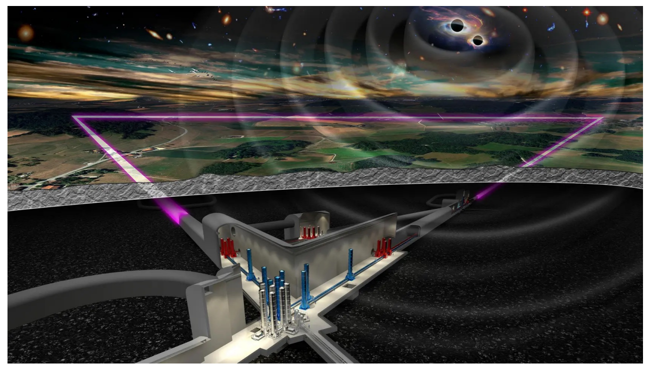
- European contributions to both accelerator-based and non-accelerator **neutrino and dark matter experiments are essential and should be supported.**

- **CERN should continue to provide support to the global long-baseline neutrino programme via the Neutrino Platform.** The collaboration between CERN and non-accelerator-based experiments on technologies of mutual benefit should be continued.

- The ecosystem of European particle physics laboratories should continue to support a broad, diverse spectrum of key precision experiments in particle physics.

ESG Working Group 4 report





Other recommendations

- Technologies: Computing
- Technologies: Knowledge Transfer
- Theory
- Project Implementation, cooperation with large Particle Physics Laboratories (PPLs) in Europe
- Sustainability and environmental impact
- Public engagement, education, communication, social and career aspects

Pseudo–summary

Two top strategic priorities:
1. The full exploitation of the physics potential of the LHC and the HL-LHC and the completion of the high-luminosity upgrade. Every effort must be made to complete the HL-LHC upgrade within the current schedule.
2. The implementation of the Strategy should be pursued in strong collaboration with global partners and neighbouring fields.

A very clear and strong message from the European Strategy Group: All efforts (by Council and CERN management) should be made to make FCC a reality. The baton is now with CERN management and Council

European contributions to both accelerator-based and non-accelerator neutrino and dark matter experiments are essential and should be supported. CERN: continue support to the global long-baseline neutrino programme via the Neutrino Platform. Also, on technologies of mutual benefit.

European particle physics laboratories should continue to support a broad, diverse spectrum of key precision experiments in particle physics.