

Richard Hawkings (CERN, EP dept)

Future colliders and ESPP for CERN ECRs event , 25/11/24

- The European Strategy for Particle Physics (ESPP)
 - Some historical context
- The 2026 update
 - Organisation of the strategy committees/groups
 - Timeline
 - Expected inputs from the community
 - Collider scenarios
- The ECFA Higgs/Electroweak/Top study
- Discussions at CERN
- Conclusions



ESPP update [website](#)

- Much material drawn from PECFA meeting at CERN, [14-15/11/24](#)
 - In particular from the talk of Karl Jakobs



Introduction – the European Strategy for Particle Physics



- The cornerstone of Europe's strategy-setting process for the long-term future of the field
 - Mandated by the CERN Council
 - Taking into account international physics landscape, and results from CERN and other facilities
- Original strategy from 2006, updated in 2013 and 2020
- Contributed to significant decisions in the CERN programme
 - 2013 strategy recommended to proceed with the LHC luminosity upgrade
 - HL-LHC project approved by CERN council in 2016
 - 2013 strategy recommended that CERN should develop a neutrino programme to pave the way for European involvement in future long-baseline experiments
 - Neutrino Platform at CERN to support European participation in expts. in Japan and US
- 2020 strategy key recommendations:
 - An e^+e^- Higgs factory is the highest-priority next collider
 - For the longer term, Europe has ambition for a pp collider at highest possible \sqrt{s}

- Full exploitation of the LHC:
 - *The successful completion of the high-luminosity upgrade of the machine and detectors should remain the focal point of European particle physics, together with continued innovation in experimental techniques. The full physics potential of the LHC and the HL-LHC, including the study of flavour physics and the quark-gluon plasma, should be exploited.*
- High-priority future initiatives:
 - *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.*

- CERN Council approved timeline in March 2024 – completion in June 2026
- Timeline determined by physics landscape:
 - e.g. results from LHC and elsewhere, HL-LHC upgrades ongoing
 - Central focus on the Higgs sector
- But also on on strategic considerations:
 - FCC feasibility study at CERN to be completed in March 2025
 - Positive mid-term report presented in early 2024: no technical showstoppers for FCC-ee as the first stage of an integrated FCC programme
 - Developments in the international landscape for future colliders
 - ILC in Japan as a global project: no commitments so far
 - P5 process in the US recommended participation in an 'off-shore' Higgs factory
 - Technical Design report for CEPC in China released in December 2023 – aiming for adoption in next Chinese 5-year funding cycle in 2025
- Also, need long-term planning to maintain community engagement / expertise
 - Minimise gap between end of HL-LHC and exploitation of next project
 - Young physicists look for a clear vision with credible timelines
 - Strategy is also important for planning complementary facilities and programmes

- Remit for European Strategy Group (ESG) approved by Council in June 2024
 - *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.*
- ESG should take into account
 - Input from the particle physics community
 - Status of implementation of the 2020 strategy update
 - Accomplishments over recent years, including recent results, progress on HL-LHC construction, outcome of FCC Feasibility Study and recent technical developments in accelerators, detectors and computing
 - The international landscape of the field
- Update should include
 - The **preferred option** for the next collider at CERN
 - **Prioritised alternative options** to be pursued if the chosen preferred plan turns out not to be feasible or competitive

Strategy secretariat and ESG members

- Strategy secretariat leads the process

STRATEGY SECRETARIAT	
Strategy Secretary (Chair)	Prof. Karl Jakobs
SPC Chair	Dr Hugh Montgomery
LDG Chair	Prof. Dave Newbold → Mike Seidel from Jan 2025
ECFA Chair	Prof. Paris Sphicas

- European Strategy Group (ESG) responsible for Strategy document
 - Chaired by Strategy Secretary
 - One representative for each CERN member state
 - One representative from each of the large particle physics labs in LDG
 - CERN DG and DG-elect
 - Chairs of SPC, ECFA
 - Various invitees, e.g. Council president, associate member states & observers
 - Members of the Physics Preparatory Group (PPG)



Physics preparatory group (PPG)



- PPG collects community input, organises the Open Symposium and prepares the Briefing Book
- Composition (appointed by Council)
 - Strategy secretariat
 - Four members recommended by SPC
 - Four members recommended by ECFA
 - One representative from CERN
 - Gianluigi Arduini (BE dept)
 - Representatives from Asia and Americas

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

PPG working groups and conveners

- Work organised into 9 working groups with two conveners each
 - One from PPG central group, one other (from SPC and ECFA nominations)

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)

- Each working group will have an ECR as scientific secretary (being finalised)

Work sharing between the PPG and ESG

■ Complementary areas of activity

[Karl Jakobs]

PPG: Physics + Technology working groups

- Electroweak physics (including Higgs physics)
- Strong interaction
- Flavour physics
- Beyond the Standard Model physics
- Neutrino physics and cosmic messengers
- Dark matter and dark sector
- Accelerator science and technology
- Detector instrumentation
- Computing

→ **Physics Briefing Book**

ESG: Overarching topics

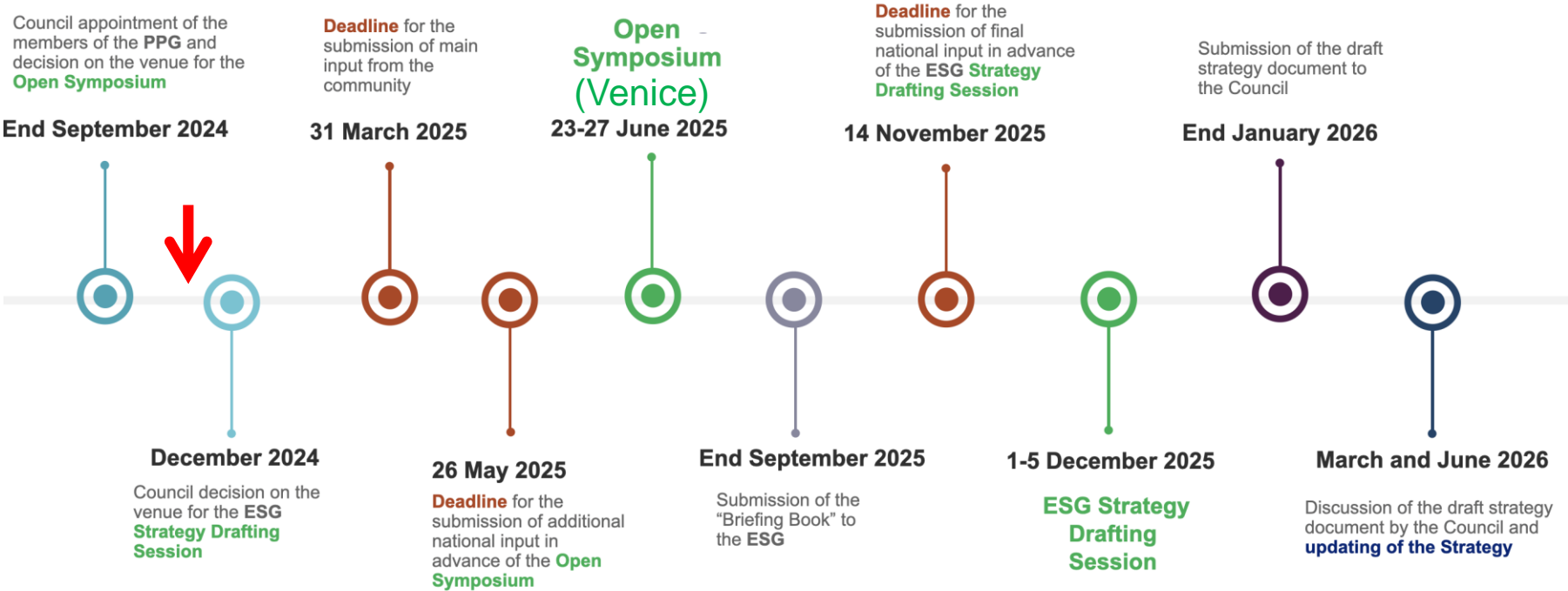
- **National input / roadmaps (→ strategic)**
- **Projects (FCC, LC/C³, LE-FCC-hh, MC, ..)**
(timeline, costs, (physics → PPG))
- Comparisons across proposed projects
- Relations with other fields of physics
- Implementation of the Strategy
(role of CERN and National Labs, coordination of European participation in projects sited outside Europe, ...)
- Knowledge and Technology transfer
- Sustainability, environmental impact
- Public engagement, education, communication
- ...

- PPG will define benchmark physics processes/measurements, and make comparative assessments of the potential of the various projects (in the WGs)
- More global comparisons across physics topics will be done by the ESG

Timeline

- Major milestones: community inputs, open symposium, drafting session

Timeline for the update of the European Strategy for Particle Physics



Community involvement

- Input from the community is important and expected
 - Need to reach a consensus within the field
- 1) Submission of inputs from the community by 31/3/25 (submission [portal](#))
 - Self-contained documents of max 10 pages (see [guidelines](#))
 - Additional details can be submitted in longer back-up documents
- 2) Input from projects (e.g. FCC, linear collider, muon collider, theory, ...)
- 3) Inputs from national HEP communities
 - Meetings are taking place or planned in many countries

- Much key input will only be available at end of March 2025
 - Final report of FCC feasibility study (including progress on financial aspects)
 - Input from alternative projects
 - Reports on accelerator and detector R&D
- ⇒ Foreesee further input from national HEP communities at later stages
 - Before the open symposium and the drafting session

- Current baseline is FCC integrated programme (ee followed by ≥ 100 TeV hh)
 - Follows from the conclusion of the 2020 strategy
- Potential alternative scenarios
 - Lower-energy hadron collider (e.g. 50-80 TeV) on an earlier timescale (2050—55)
 - Linear collider (e.g. CLIC) or muon collider at CERN
 - Further exploitation of the LHC, perhaps also with e-h collisions
 - Other possibilities to be proposed by the community
- Input is expected on these scenarios
 - FCC feasibility study report (technical, physics, environmental, financial)
 - Input from review committees is expected later in 2025
 - Lower-energy hadron collider inputs:
 - Accelerator magnets with 12-14 T – R&D, technology, timescale, price
 - Physics potential of a 91km collider with such magnets
 - Input from the linear, muon and e-h collider communities
- Strategy secretariat is preparing guidelines for such ‘project’ input

- ECFA prepared list of standard questions to be addressed by national inputs
 - Hope to make the inputs as coherent as possible for informing the strategy
 - Especially wrt the key questions of preferred collider and prioritisation of alternatives
 - Can be viewed here: [ECFA guidelines for national inputs](#)
- Key aspects for future colliders:
 - What is the preferred next/major flagship collider project for CERN?
 - Key elements in decision? E.g. physics potential, long-term perspective, resource requirements, timing, careers/training, sustainability
 - Should alternative options be considered, if other projects proceed in other regions (ILC, CEPC, muon collider), or major new unexpected results appear?
 - What accelerator R&D topics should be pursued in addition to preferred option?
 - What is the prioritised list of alternative colliders if preferred is not feasible?
- What complementary non-collider projects should be pursued?
 - At CERN, in Europe, elsewhere? With what relative priority?
 - What are the key elements in this decision?
 - To what extent should CERN participate in nuclear, astroparticle or other physics areas, relative to the current level of involvement?

- ECFA organised a dedicated activity on physics studies, experiment design and detector studies for a future high-energy e^+e^- collider
 - Aiming to build synergies between the different e^+e^- projects
 - Workshops held in 2022, 2023, and finally in Paris in November 2024
 - Three main working groups on physics performance, analysis methods and detector technologies, organised around 14 focus topics

- HtoSS: $e^+e^- \rightarrow Zh: h \rightarrow ss$
- ZHang: ZH angular distributions and CP studies
- Hself: Determination of the Higgs self-coupling
- Wmass: Mass and width of the W boson
- WWdiff: Full studies of WW and $e\nu W$
- TTthresh: Top threshold - detector-level studies of $e^+e^- \rightarrow t\bar{t}$
- LUMI: Precision luminosity measurement
- EXscalar: New exotic scalars
- LLPs: Long-lived particles
- EXtt: Exotic top decays
- CKMWW: CKM matrix elements with on-shell and boosted W decays
- BKtautau: $B^0 \rightarrow K^{0*}\tau^+\tau^-$
- TwoF: EW precision - 2-fermion final states
- BCfrag/Gsplit: Measurement of b - and c -fragmentation functions and hadronisation rates and measurement of gluon splitting to $b\bar{b} / c\bar{c}$

- Working to produce a final report as input to the ESPP process
 - To be submitted to arXiv in March 2024

- CERN has a ‘special’ status in the ESPP discussions
 - The process is focussed on the future of this laboratory
 - CERN is sometimes treated as a ‘national community’ or funding agency, but we are not expected to produce a ‘national input’ to the ESPP
 - But ... we have a representative on the ESG (Gianluigi Arduini)
 - Many CERN scientists (including ECRs) are involved in preparing inputs for submissions to the ESPP, e.g. the physics studies and project studies
 - Some are involved in their national community discussions
 - CERN ECRs should be involved in preparing the ECR input to the ESPP
- Specific discussions for the CERN staff/fellow/student community
 - Today’s workshop for ECRs
 - EP/TH faculty meeting on physics and detector studies for FCC, 27/9/24
 - Further discussions are planned in the new year, e.g. a RCS sector meeting

- The ESPP update process has started
 - A dense programme of community activities planned for 2025, culminating in the submission of a draft strategy document to council in early 2026
 - Impressive progress in understanding the physics potential, technical feasibility, cost and wider implications of proposed future colliders
 - Plenty of opportunities to get involved, help shape the future of our field
 - First stage is the submission of inputs by 31/3/25
- Some final remarks paraphrased from Karl Jakobs and Paris Sphicas
 - Vital to reach a consensus on the next large collider project in this strategy update
 - Given the scale of the project and long timescales, the decision cannot be postponed – will define the future of the field
 - ECRs are urging the community to make a decision
 - To maximise the chances of a project being approved, we must reach consensus, and then support the final plan
 - The fastest way to no new collider is non-convergence of the community
- Get involved ... 😊