The 2020 Update of the European Particle Physics Strategy

CERN Council meeting – March 2020

Halina Abramowicz
Tel Aviv University
Secretary of the Strategy Update

Outline
- General Introduction
- Preamble
- Short guide to all 20 statements
- Selected Strategy Statements: introduction and formulation

2020 Strategy Update

Reminder - organisation of the Update Process

- Decision making body – CERN Council as coordinating body of European Particle Physics (23 Member States)

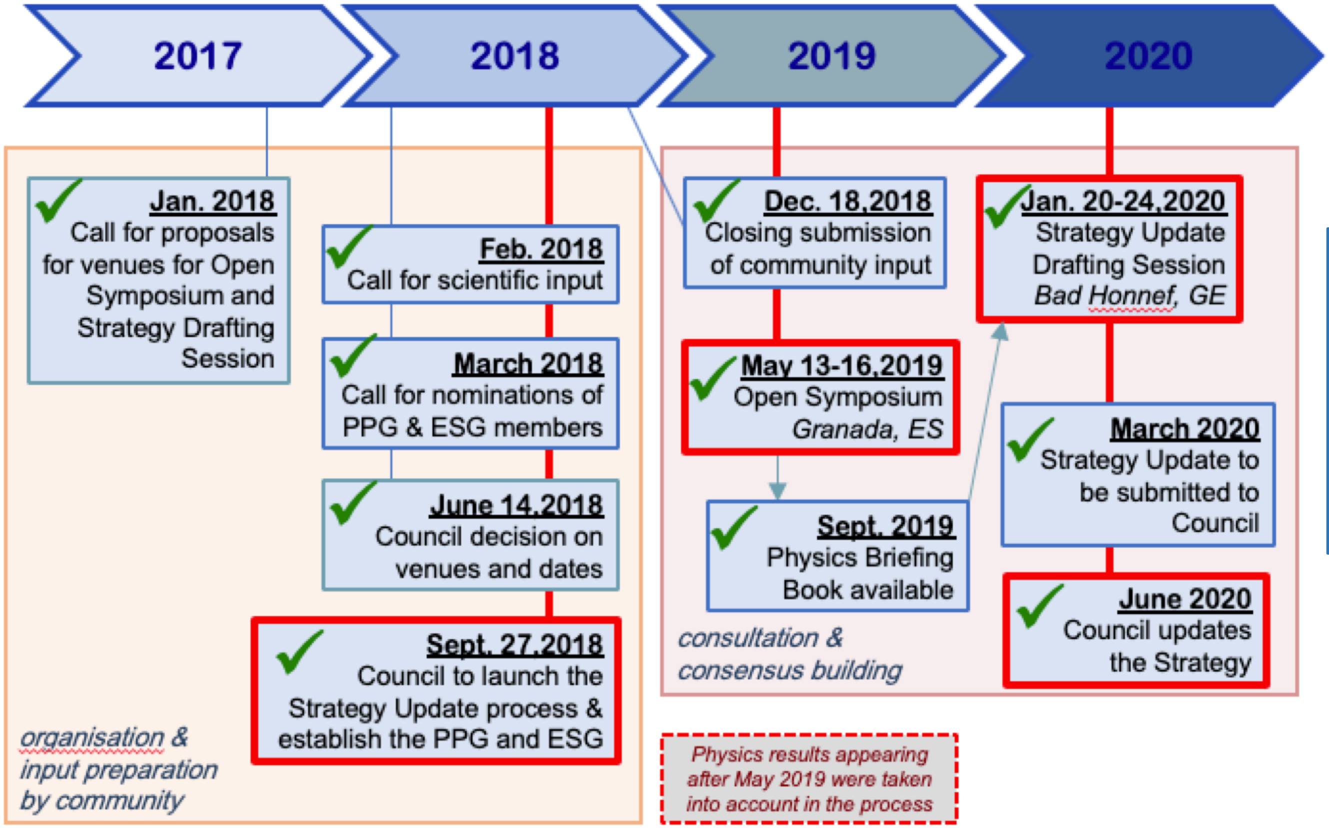
- Drafting of the Strategy Update document – responsibility of the European Strategy Group (ESG) (23 MS representatives, LDG - National Lab's Directors Group, Strategy Secretariat; Invitees: Associate MS, Observer States,… - see backup slide)

- Scientific Input to the Strategy Update – responsibility of the Physics Preparatory Group (PPG) (nominations 4 from ECFA, 4 from SPC, 4 from ICFA, 1 CERN, SUS – see backup slide)
  - Call for input
  - Processing of the input
  - Open Symposium
  - Briefing Book

- Coordinating body – the Strategy Update Secretariat (SUS) (Secretary elected by Council, chairs of SPC, ECFA, LDG)

2020 Strategy Update

Timeline

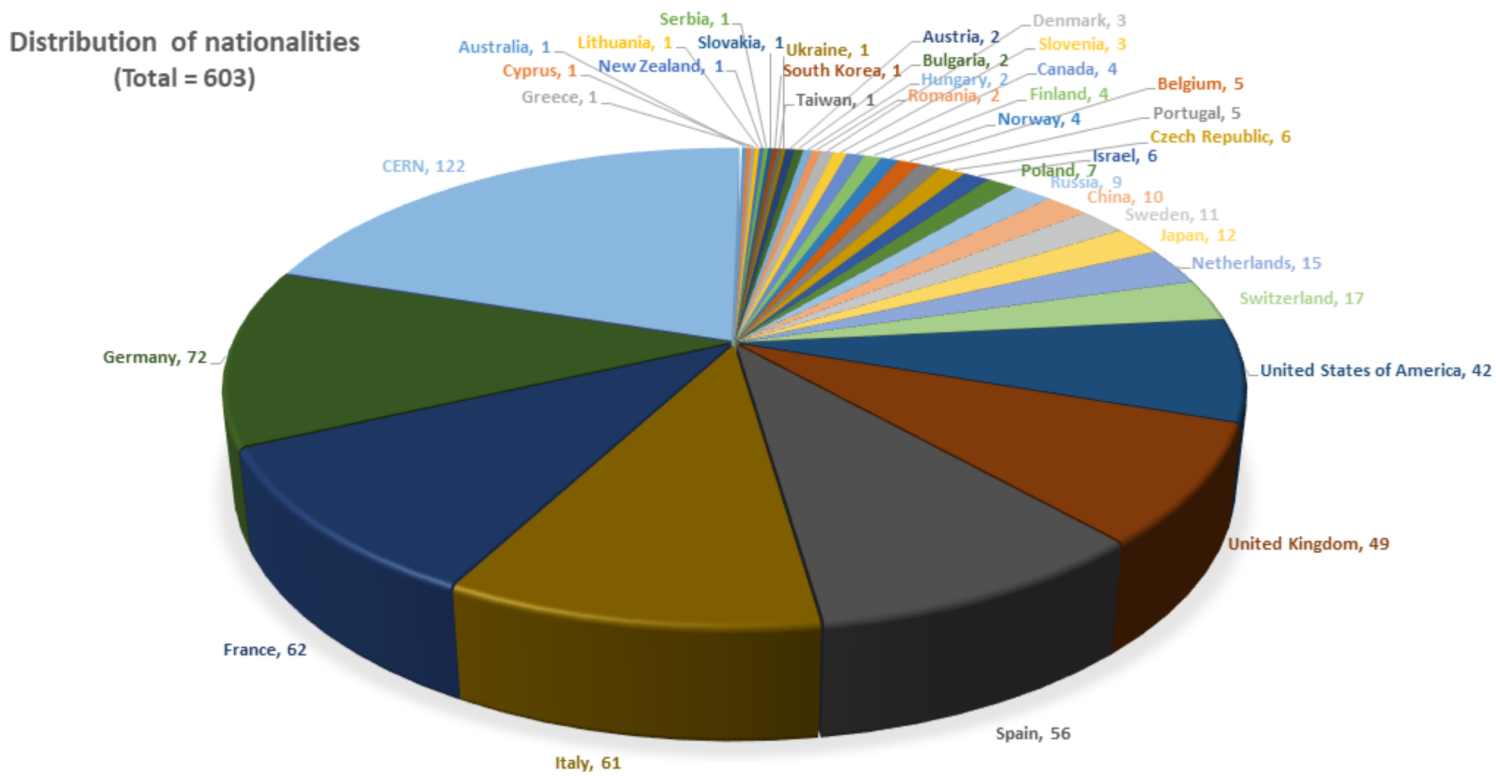


Documents submitted to CERN Council

1. Draft Update of the European Strategy for Particle Physics (with preamble, statements, conclusion) for feedback CERN/SPC/1137/RA CERN/3486/C2

2. Deliberation Document (with in addition rational behind the statements) for information CERN/SPC/1136/RA; CERN/3485/C

Participants in Granada



from Vedrana Zorica

Very well attended
Expected – 500
Registration closed after 600

12% from outside Europe

Outstanding organisation

To Spain

High quality presentations

To PPG

European Strategy Update

2020 Strategy Update

The European Strategy Group

European Strategy Update

Drafting Session – European Particle Physics Strategy Update 2018 - 2020

19-25 January 2020
Bad Honnef, Germany
Europe/Zurich timezone

General Introduction

20 Strategy Statements unanimously adopted by the ESG in Jan.2020

- 2 statements on **Major developments from the 2013 Strategy**
- 3 statements on **General considerations for the 2020 update**
- 2 statements on **High-priority future initiatives**
- 4 statements on **Other essential scientific activities for particle physics**
- 2 statements on **Synergies with neighbouring fields**
- 3 statements on **Organisational issues**
- 4 statements on **Environmental and societal impact**

Derived based on

- Granada Symposium
- National Inputs
- Working Group 1: Social and career aspects for the next generation (chair: Eric Laenen)
- Working Group 2:Issues related to Global Projects hosted by CERN or funded through CERN outside Europe (chair: Mark Thompson)
- Working Group 3: Relations with other groups and organisations (chair: Tatsuya Nakada)
- Working Group 4: Knowledge and Technology Transfer (chair: Leandar Lisov)
- Working Group 5: Public engagement, Education and Communication (chair: Sijbrand de Jong)
- Working Group 6: Sustainability and Environmental impact (chair: Dirk Ryckbosch)

European Strategy Update

2020 Strategy Update

Preamble

- Many mysteries about the universe remain to be explored: **nature of dark matter, preponderance of matter over antimatter, origin and pattern of neutrino masses**
- Nature hides the secrets of the fundamental physical laws in the **tiniest nooks of space and time**
- Particle Physics develops technologies to probe ever smaller distance scales (higher energies)
- **The Higgs** (discovered at the LHC) is a **unique particle** that raises profound questions about the fundamental laws of nature
  - ✓ Higgs properties study is in itself a powerful experimental tool to look for answers
    → **electron-positron collider as Higgs factory**
  - ✓ Higgs boson pair-production study is key to understanding the fabric of the universe
    → **collider with significantly higher energies than Higgs factory**
- New realm of energies is expected to lead to new discoveries and provide answers to existing mysteries
- **The 2020 Strategy update aims to significantly extend knowledge beyond current limits, to drive innovative technological developments, to maintain Europe's leading role**

The European vision is thus to prepare a Higgs factory, followed by a future hadron collider with sensitivity to energy scales an order of magnitude higher than those of the LHC, while addressing the associated technical and environmental challenges.

The 2020 Strategy presents exciting and ambitious scientific goals that will drive technological and scientific exploration into new and uncharted territory for the benefit of the field and of society.

2020 Strategy Statements

Guide through the statements

2 statements on **Major developments from the 2013 Strategy**
a) Focus on successful completion of HL-LHC upgrade remains a priority
b) Continued support for long-baseline ν experiments in Japan and US and the Neutrino Platform

3 statements on **General considerations for the 2020 update**
a) Preserve the leading role of CERN for success of European PP community
b) Strengthen the European PP ecosystem of research centres
c) Acknowledge the global nature of PP research

2 statements on **High-priority future initiatives**
a) Higgs factory as the highest-priority next collider and investigation of the technical and financial feasibility of a future hadron collider at CERN
b) Vigorous R&D on innovative accelerator technologies – through roadmap

4 statements on **Other essential scientific activities**
a) Support for high-impact, financially implementable, experimental initiatives world-wide
b) Acknowledge the essential role of theory
c) Support for instrumentation R&D – through roadmap
d) Support for computing and software infrastructure

2 statements on **Synergies with neighbouring fields**
a) Nuclear physics – cooperation with NuPECC
b) Astroparticle – cooperation with APPEC

3 statements on **Organisational issues**
a) Framework for projects in and out of Europe
b) Strengthen relations with European Commission
c) Support active role in supporting Open Science

4 statements on **Environmental and societal impact**
a) Mitigate environmental impact of particle physics
b) Invest in next generation of researchers
c) Support knowledge and technology transfer
d) Cultural heritage: public engagement, education and communication

Letters for itemizing the statements are introduced for identification, do not imply prioritization

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2020 Strategy Statements

1. Major developments from the 2013 Strategy

2013 Strategy identified 4 high-priority, large-scale scientific activities (2 about future colliders addressed later)
- LHC → upgrade to high luminosity (10 x LHC)
- Neutrino physics → Europe to participate in long-baseline experiments in Japan and the US (Neutrino Platform)

HL-LHC will challenge the understanding of particle physics at around the TeV scale, and indirectly at multi-TeV scales.
- Development of the essential short dipole magnets with Nb_3Sn superconductor ready to be tested in LHC Run3
- Upgrades of ATLAS and CMS documented in TDRs, to be commissioned in 2027; emerging new technologies for trigger systems, computing and management of big data, reconstruction algorithms and analysis methods
- Upgrades considered by LHCb (flavour physics) and ALICE (heavy ion physics)

Deliberation Document

a) Since the recommendation in the 2013 Strategy to proceed with the programme of upgrading the luminosity of the LHC, the **HL-LHC** project was approved by the CERN Council in June 2016 and is proceeding according to plan. In parallel, the LHC has reached a centre-of-mass energy of 13 TeV, exceeded the design luminosity, and produced a wealth of remarkable physics results. Based on this performance, coupled with the innovative experimental techniques developed at the LHC experiments and their planned detector upgrades, a significantly **enhanced physics potential** is expected with the HL-LHC. The required high-field superconducting Nb_3Sn magnets have been developed. *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.*

Strategy Statements

2020 Strategy Statements

1. Major developments from the 2013 Strategy

Neutrino oscillations are a compelling sign of new physics, making neutrinos massive particles

- They are much lighter than charged leptons
- Not all oscillation parameters are yet fully known (observed very different mixing patter from quarks)
- Essential to pursue the exploration of the neutrino sector with accelerator, reactor, solar, atmospheric and cosmic neutrino experiments
- Two complementary approved programmes are in preparation with the DUNE (US) and Hyper-Kamiokande (Japan) experiments - strong participation of European physicists with CERN support through notably the Neutrino Platform
- The community is very keen for the Neutrino Platform to continue operation at CERN
- Balanced European support for this worldwide effort important to secure the determination of neutrino properties

b) The existence of non-zero neutrino masses is a compelling sign of new physics. The **worldwide neutrino physics programme** explores the full scope of the rich neutrino sector and commands strong support in Europe. Within that programme, the Neutrino Platform was established by CERN in response to the recommendation in the 2013 Strategy and has successfully acted as a hub for European neutrino research at accelerator-based projects outside Europe. *Europe, and CERN through the Neutrino Platform, should continue to support long baseline experiments in Japan and the United States. In particular, they should continue to collaborate with the United States and other international partners towards the successful implementation of the Long-Baseline Neutrino Facility (LBNF) and the Deep Underground Neutrino Experiment (DUNE).*

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2020 Strategy Statements

2. General considerations for the 2020 update

Global nature of particle physics research

- The increase in scale of the leading particle physics facilities and the resulting decrease in their number worldwide has led to the globalisation of the field
- The timely realisation of complementary, large-scale projects in different regions of the world, each of them unique in pushing further the frontiers of particle physics, remains essential for the progress of the field, as well as for the development of the key technologies
- With the neutrino programme, Europe has chosen to participate in the long-baseline programmes in Japan and the US rather than building its own facility. Instead, it has secured reciprocal support for the timely realisation of the HL-LHC project.
- Europe's long-term vision is to maintain its leadership in pushing the exploration of the energy frontier, and this vision is supported by the other regions

c) The broad range of fundamental questions in particle physics and the complexity of the diverse facilities required to address them, together with the need for an efficient use of resources, have resulted in the establishment of a global particle physics community with common interests and goals. This Strategy takes into account the rich and complementary physics programmes being undertaken by Europe's partners across the globe and of scientific and technological developments in neighbouring fields. *The implementation of the Strategy should proceed in strong collaboration with global partners and neighbouring fields.*

2020 Strategy Statements

European Strategy Update

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Strategy Update

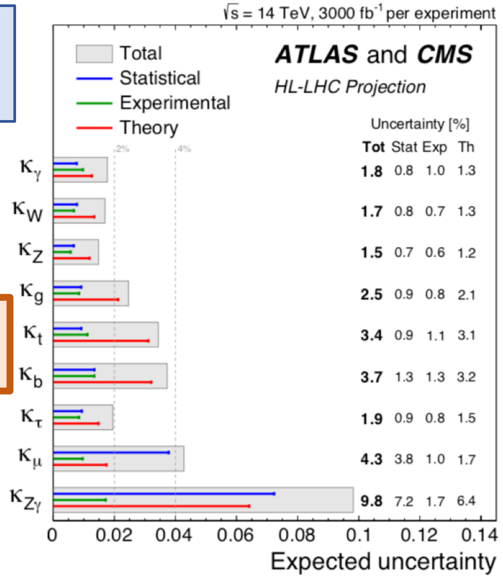
What has changed since the 2013 Strategy Update?

- ➢ The HL-LHC was approved in 2016
- ➢ The expected reach of HL-LHC has been substantially updated

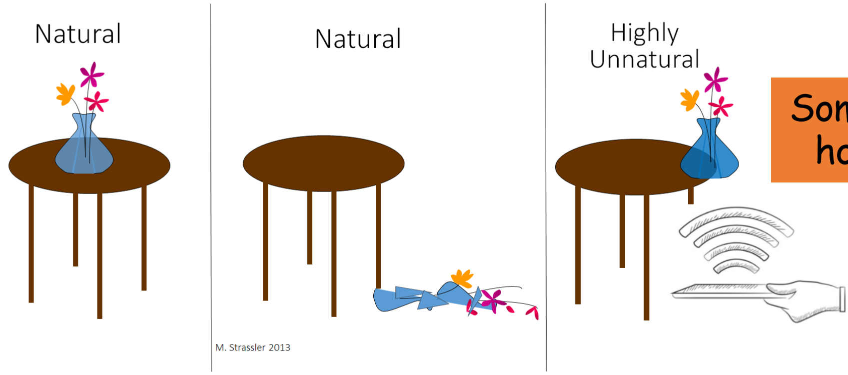
What did not change since the 2013 Strategy Update?

- No signs of BSM physics
- *Neutrinos have masses – not acquired in the SM*
- *There is dark matter in the Universe with no candidates within the SM*
- *Prevalence of matter over anti-matter*
- ➢ *Theorists believe that the theory is not complete*

Higgs couplings after HL-LHC



Largest contribution to the uncertainty from theory



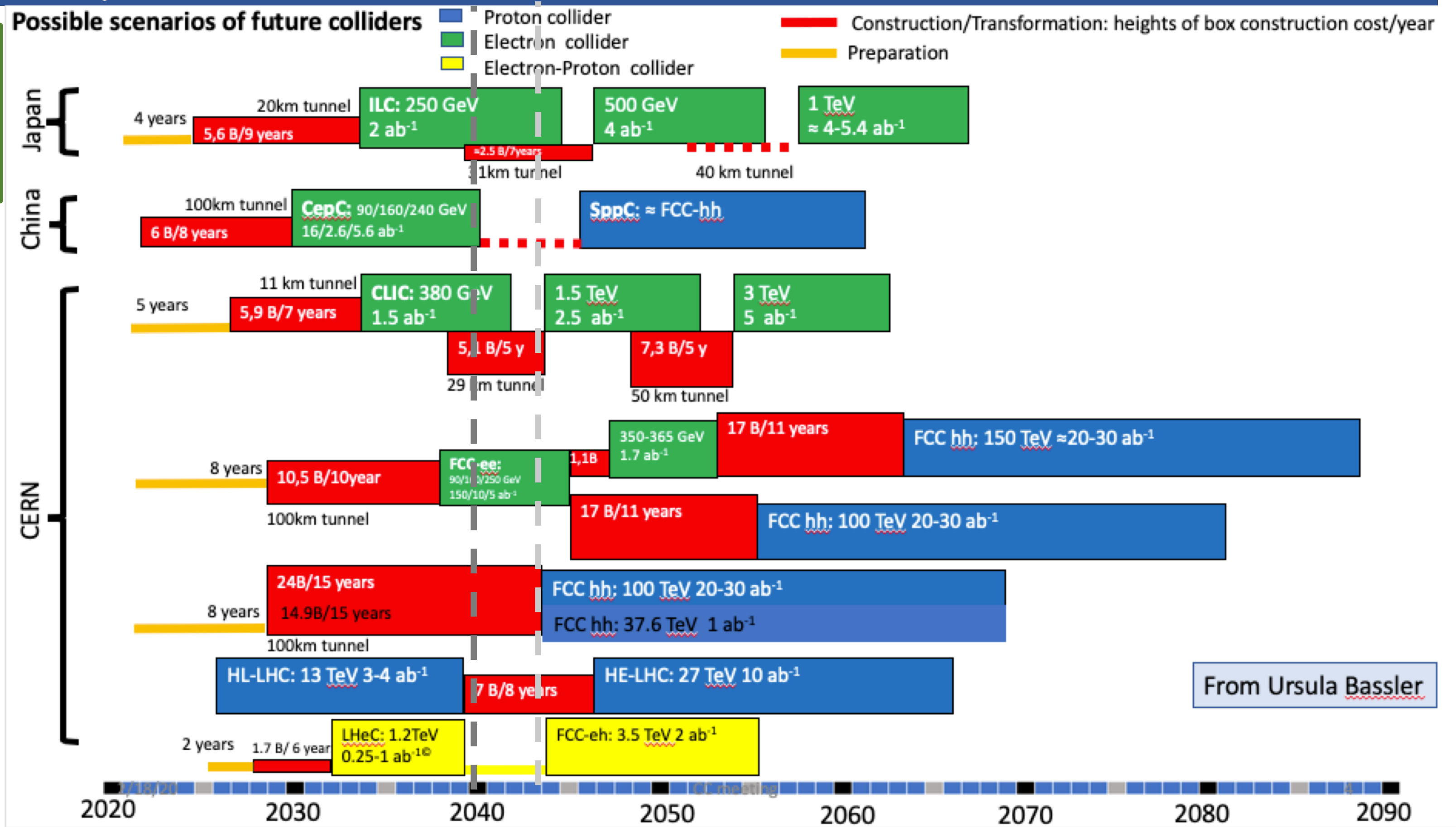
Something must be holding the vase

From Matt Strassler

2020 Strategy Update

3. High-priority future initiatives

Map of possible future facilities submitted as input to the Strategy Update



Report from Open Symposium in Granada

Precision physics with the Higgs

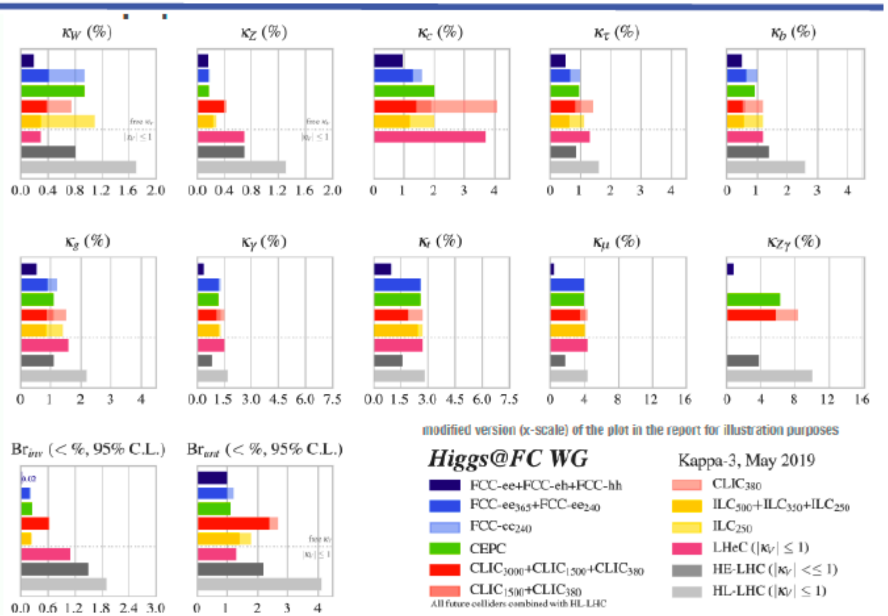
H as a scalar couples to all the fundamental particles

Comparison of Colliders: kappa-framework

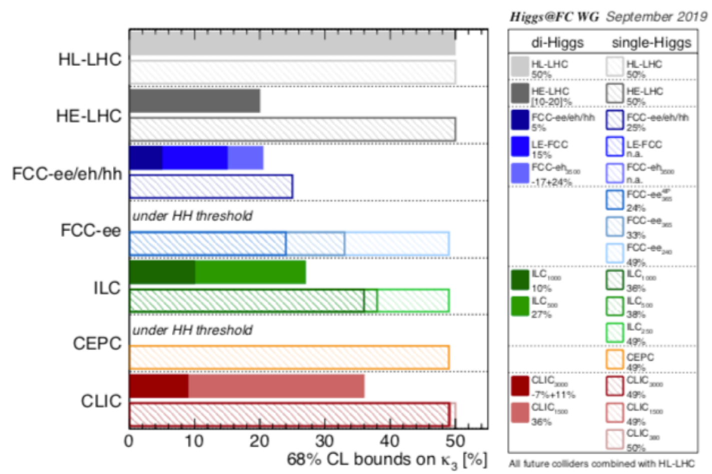
Some observations:

- **HL-LHC achieves precision of ~1-3% in most cases**
  - In some cases model-dependent
- **Proposed e^+e^- and ep colliders improve w.r.t. HL-LHC by factors of ~2 to 10**
- **Initial stages of e^+e^- colliders have comparable sensitivities (within factors of 2)**
- **ee colliders constrain $BR \rightarrow$ *untagged* w/o assumptions**
- **Access to κ_c at ee and eh**

arXiv:1905.03764



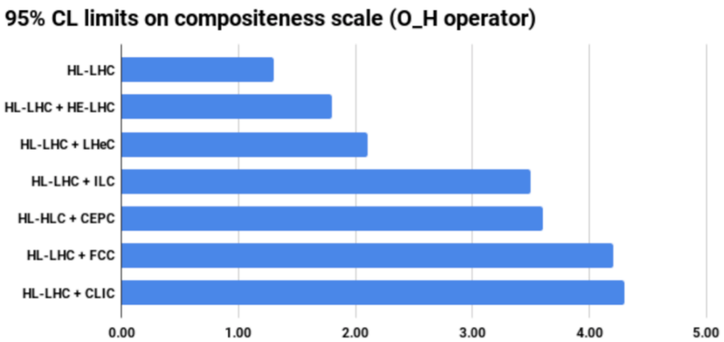
Higgs self-coupling



Report from Open Symposium in Granada

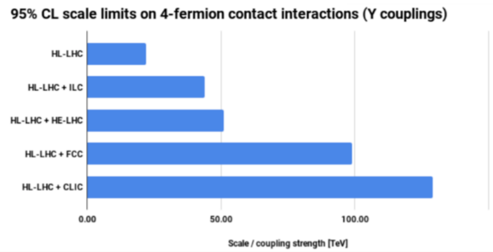
BSM at colliders

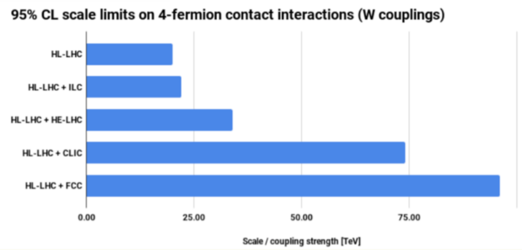
Higgs compositeness scale



Maximum sensitivities from CLIC and FCC(ee+eh+hh)

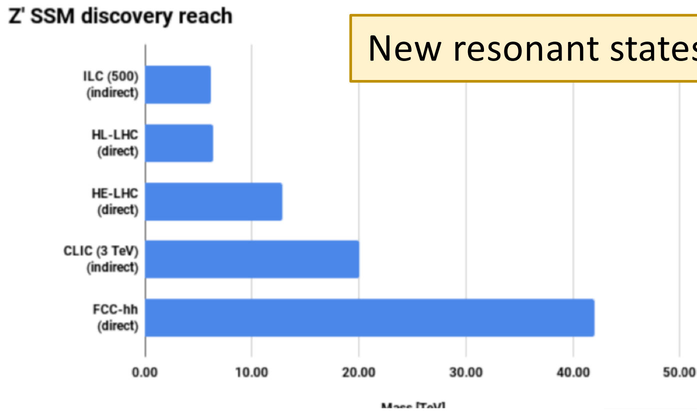
Contact Interactions





Sensitivity for ee colliders enhanced for couplings ≳ 1
(weak couplings → direct searches become more sensitive)
Searches for W' & charged fermion currents more effective at hadron colliders

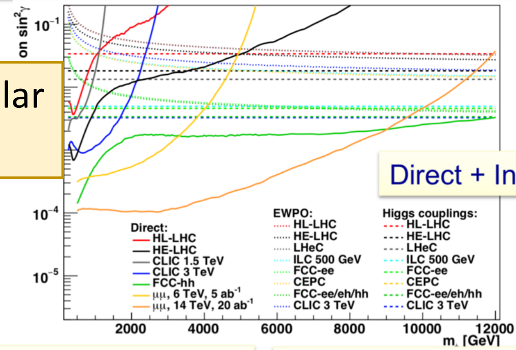
New resonant states



Direct searches: pp: main LHC result ZZ; hadron colliders: extrap in $\sqrt{s}$; $e^+e^- \to \nu\nu\varphi$; $\varphi \to hh \to bbbb$

Extended scalar sector

Direct + Indirect



And much more

European Strategy Update

2020 Strategy Statements

3. High-priority future initiatives

It is essential for particle physics in Europe and for CERN to be able to propose a new facility after the LHC

- There are two clear ways to address the remaining mysteries: Higgs factory and exploration of the energy frontier
- Europe is in the privileged position to be able to propose both: CLIC or FCCee as Higgs factory, CLIC (3 TeV) or FCChh (100 TeV) for the energy frontier
- The dramatic increase in energy possible with FCChh leads to this technology being considered as the most promising for a future facility at the energy frontier.
- It is important therefore to launch a feasibility study for such a collider to be completed in time for the next Strategy update, so that a decision as to whether this project can be implemented can be taken on that timescale.

a) 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.*

The timely realisation of the electron-positron International Linear Collider (ILC) in Japan would be compatible with this strategy and, in that case, the European particle physics community would wish to collaborate.

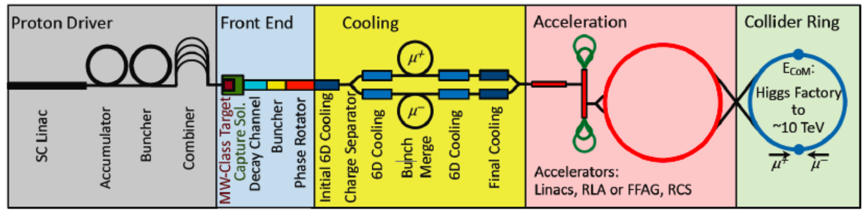
Report from Open Symposium in Granada

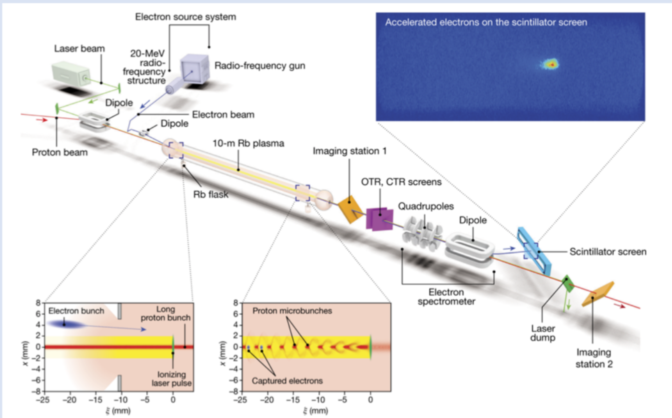
Future developments

Very interesting R&D projects

- Muon collider:
  - from proton beam (rcooling success: MICE)
  - from e+e- production (LEMMA)
- Plasma wakefield acceleration:
  - High gradients possible: ~100 GV/m
  - R&D progressing well but many challenges

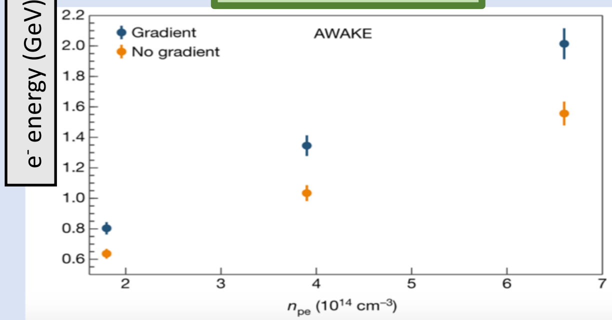
Muon-based technology represents a unique opportunity for the future of high energy physics research: the multi-TeV energy domain exploration.





AWAKE@CERN

e⁻ energy (GeV)



Plasma density

Achieved 2 GeV over 10m
Gradient 200 MV/m

European Strategy Update

2020 Strategy Statements

3. High-priority future initiatives

Accelerator R&D is crucial to prepare the future collider programme

- The European particle physics community should develop an accelerator R&D roadmap focused on the critical technologies needed for future colliders, maintaining a beneficial link with other communities such as photon or neutron sources and fusion energy
- The roadmap should be established as soon as possible in close coordination between the National Laboratories and CERN
- A focused, mission-style approach should be launched for R&D on high-field magnets (16 T and beyond) including high-temperature superconductor (HTS) option to reach 20 T. CERN's engagement in this process would have a catalysing effect on related work being performed in the National Laboratories and research institutions
- The roadmap should also consider: R&D for an effective breakthrough in plasma acceleration schemes, an international design study for a muon collider and R&D on high-intensity, multi-turn energy-recovery linac (ERL) machines

b) Innovative accelerator technology underpins the physics reach of high-energy and high-intensity colliders. It is also a powerful driver for many accelerator-based fields of science and industry. The technologies under consideration include high-field magnets, high-temperature superconductors, plasma wakefield acceleration and other high-gradient accelerating structures, bright muon beams, energy recovery linacs. *The European particle physics community must intensify accelerator R&D and sustain it with adequate resources. A roadmap should prioritise the technology, taking into account synergies with international partners and other communities such as photon and neutron sources, fusion energy and industry. Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.*

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Report from Open Symposium in Granada

Flavour Physics and CP

- Study processes very unlikely or impossible in the SM
- Great sensitivity to Physics Beyond the Standard Model – scale beyond 10^2 – 10^5 TeV
- Complementarity of low energy high-precision and high energy frontier

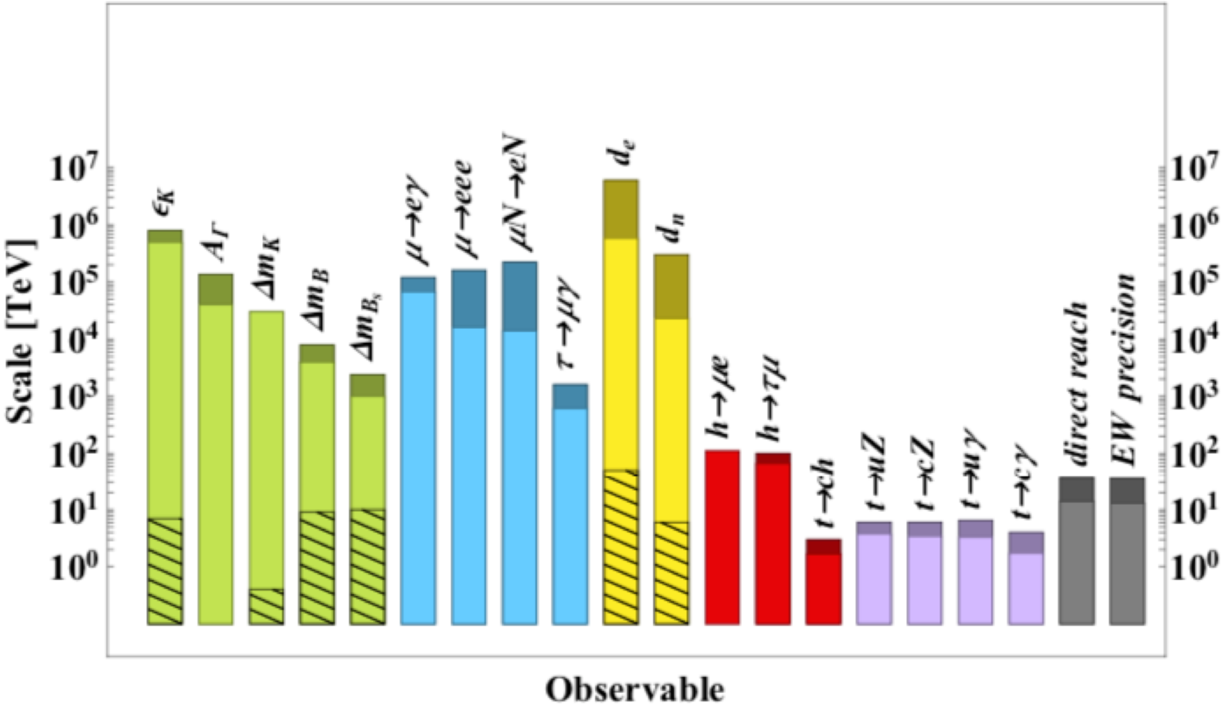
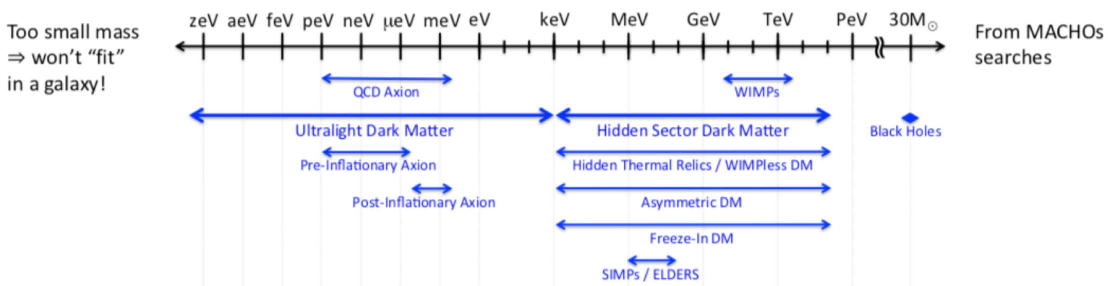


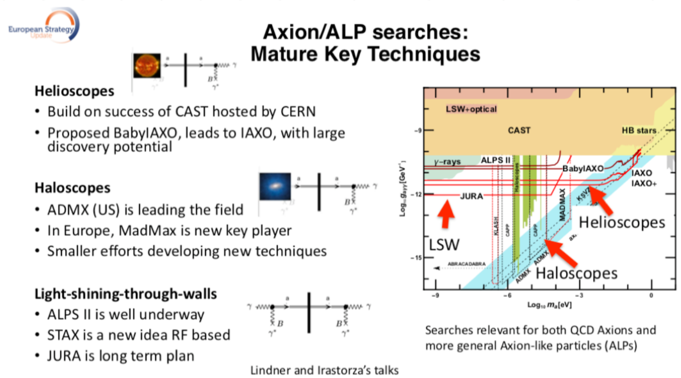
Fig. 5.1: Reach in new physics scale of present and future facilities, from generic dimension six operators. Colour coding of observables is: green for mesons, blue for leptons, yellow for EDMs, red for Higgs flavoured couplings and purple for the top quark. The grey columns illustrate the reach of direct flavour-blind searches and EW precision measurements. The operator coefficients are taken to be either ~ 1 (plain coloured columns) or suppressed by MFV factors (hatch filled surfaces). Light (dark) colours correspond to present data (mid-term prospects, including HL-LHC, Belle II, MEG II, Mu3e, Mu2e, COMET, ACME, PIK and SNS).

Report from Open Symposium in Granada

Dark matter/Dark sector

- Dark Matter
  - ➢ What if dark matter is light?





- Dark Sector
  - ➢ Search for dark photon

BEAM DUMP PROJECTS AT CERN

DP = Dark Photon
DS = Dark Scalar
HNL = Heavy Neutral Lepton
ALP = Axion-Like Particle

EXPERIMENT	PERIOD	BEAM	PARTICLES ON TARGET	SIGNATURE	MODELS
NA64++(e)	2015-24	e 100 GeV	~5 10^{12}	invisible & visible e^+e^-	DP, ALPs
eSPS/LDMX	> 2026	e 16 GeV	10^{16}	invisible	DP, ALPs
AWAKE++	> 2026	e ~50 GeV	~10^{15}	visible e^+e^-	DP, ALPs
NA62++	> 2022	p 400 GeV	10^{18}	visible	DP, DS, HNL, ALPs
SHiP	> 2026	p 400 GeV	2 10^{20}	recoil & visible	DP, DS, HNL, ALPs
NA64++(μ)	> 2022	μ 160 GeV	5 10^{13}	invisible	DZ_{μ}, ALPs

NB: CERN offers unique opportunities with both lepton and hadron beams

LHCb and LHC-LLP dedicated projects (FASER, milliQan, CODEX-b, MATHUSLA) have also sensitivity in similar mass range

2020 Strategy Update

4. Other essential scientific activities for particle physics

Summary of "Physics Beyond Colliders" (PBC) study – aimed at exploring opportunities offered by the accelerator infrastructure of CERN and European research centres

			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
		SPS	LS2						LS3						LS4				
		LHC	LS2		Run 3				LS3			Run 4			LS4				
North Area	NA64-electron	Operational	LS2		Data Taking										LS4				
	NA64-mu	< 1 MCHF	Studies		Test	Pilot	Phase 1												
	NA61/Shine	< 2 MCHF	Detector upgrade		Data Taking					Data Taking									
	MUonE	< 2 MCHF	Preparation		Pilot	Run 1	Data Taking												
	NA62-beamdump	< 1 MCHF	Studies		1e18 PoT in Run 3														
	KLEVER	~40 MCHF	EoI/proposal		R&D/Construction				Installation	Data Taking									
	COMPASS++	~10 MCHF	Studies/proposal		Phase1 Data Taking/Studies/R&D				Installation	Data Taking									
LHC	ALICE fixed target	<5 MCHF			Design/tests				Preparation/Construction			Data Taking							
	LHCb fixed target	<5 MCHF		Design	Construction and testing			Data	LS3			Data Taking							
	LHC Spin	~5 MCHF	Study		R&D				Production/Installation			Data Taking							
	FASER	~5 MCHF	Installation		Data Taking				Upgrade - phase 2			Data Taking							
	MATHUSLA	<100 MCHF		Funding to test design			Construction					Data Taking							
	CODEX-b	<5 MCHF	EoI		Beta		Beta data taking		Production/Installation			Data Taking							
	MilliQan	<5 MCHF	Demonstrator		Funding/Construction				Upgrade			Data Taking							
SPS	LDMX/eSPS	<10 MCHF			Studies		Production/Installation			Data Taking									
	SHiP	~70 MCHF	CDR		TDR/Prototypes			Production/construction			Installation		Data Taking						
	TauFV	tbc	Design		CDR	TDR/Prototypes		Production/construction			Installation		Data Taking						
	BabyIAXO (DE)	<5 MCHF		Production/construction			Commission	Data Taking											
	IAXO	~60 MCHF					Design, prototyping, construction, integration and commissioning (start tbc)												
	AWAKE	~15 MCHF	Prep/construction		AWAKE Run 2				LS3	AWAKE++?									
	eSPS	~80 MCHF	CDR		TDR		Preparation/Construction			Data Taking									
	Beam Dump Facility	~160 MCHF	CDR	TDR			Construction/Installation						Operation						
	Gamma Factory	~2 MCHF		CDR	SPS Proof of Principle/TDR				Preparation			LHC demo							
	nuSTORM	>160 MCHF	Study	CDR		TDR/Prototyping						Approval							
	CPEDM prototype (DE)	~20 MCHF	Study	CDR		TDR		Construction		Data Taking									

Other activities essential for the field
- Diverse scientific programme – dark sector; flavour and CP violation; axions;
- Theory (formal, phenomenology, computational, MC)
- Detector R&D

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4. Other essential scientific activities for particle physics

Diverse science at low energy: exploration of dark matter and flavour puzzle

- Change of paradigm for dark matter particles - could be as light as 10^{-22} eV to as heavy as primordial black holes of $10 \times M_{\odot}$
- Observed pattern of masses and mixings of quarks and leptons, remains a puzzle
- Physics Beyond Colliders study identified many high impact options with modest investment
- Larger scale new facilities such a the Beam Dump Facility, and later LHeC option at CERN, difficult to resource within the CERN budget, considering the other recommendations of this Strategy
- Improvements in the knowledge of the proton structure needed to fully exploit the potential of present and future hadron colliders - added value from fixed target experiments and from Electron Ion Collider (CD0) in BNL
- Given the challenges faced by CERN in preparing for the future collider, the role of the National Laboratories in advancing the exploration of the lower energy regime cannot be over-emphasised (ex. axions at DESY, rare muon decays in PSI, dark photon in Frascati)

a) The quest for dark matter and the exploration of flavour and fundamental symmetries are crucial components of the search for new physics. This search can be done in many ways, for example through precision measurements of flavour physics and electric or magnetic dipole moments, and searches for axions, dark sector candidates and feebly interacting particles. There are many options to address such physics topics including energy-frontier colliders, accelerator and non-accelerator experiments. A diverse programme that is complementary to the energy frontier is an essential part of the European particle physics Strategy. *Experiments in such diverse areas that offer potential high-impact particle physics programmes at laboratories in Europe should be supported, as well as participation in such experiments in other regions of the world.*

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Guide through the statements

2 statements on **Major developments from the 2013 Strategy**

a) Focus on successful completion of HL-LHC upgrade remains a priority
b) Continued support for long-baseline experiments in Japan and US and the Neutrino Platform

3 statements on **General considerations for the 2020 update**

a) Preserve the leading role of CERN for success of European PP community
b) Strengthen the European PP ecosystem of research centres
c) Acknowledge the global nature of PP research

2 statements on **High-priority future initiatives**

a) Higgs factory as the highest-priority next collider and investigation of the technical and financial feasibility of a future hadron collider at CERN
b) Vigorous R&D on innovative accelerator technologies

4 statements on **Other essential scientific activities**

a) Support for high-impact, financially implementable, experimental initiatives world-wide
b) Acknowledge the essential role of theory
c) Support for instrumentation R&D
d) Support for computing and software infrastructure

2 statements on **Synergies with neighbouring fields**

a) Nuclear physics – cooperation with NuPECC
b) Astroparticle – cooperation with APPEC

3 statements on **Organisational issues**

a) Global collaboration on projects in and out of Europe
b) Relations with European Commission
c) Open science

4 statements on **Environmental and societal impact**

a) Mitigate environmental impact of particle physics
b) Investment in next generation of researchers
c) Knowledge and technology transfer
d) Cultural heritage: public engagement, education and communication

7. Environmental and societal impact

Climate change and particle physics

- In a world with increasing demand on limited resources and undergoing climate change it is crucial to keep energy consumption, sustainability and efficiency in mind when discussing the future of particle physics
- In the discussion of the optimal choice for a new facility, the energy efficiency of the accelerator should be considered alongside factors such as cost, timescale and physics reach
- Research into environmentally-friendly alternatives for materials with high global warming potential for use in particle physics detectors should be strongly stimulated and supported
- The community should invest in both hardware and software efforts to improve the energy efficiency of its computing infrastructures
- The community is expected to be in the vanguard of alternatives to physical travel such as virtual meeting rooms. and should support low-carbon forms of travel and carbon offsetting, whenever travel is unavoidable

a) The energy efficiency of present and future accelerators, and of computing facilities, is and should remain an area requiring constant attention. Travel also represents an environmental challenge, due to the international nature of the field. *The environmental impact of particle physics activities should continue to be carefully studied and minimised. A detailed plan for the minimisation of environmental impact and for the saving and re-use of energy should be part of the approval process for any major project. Alternatives to travel should be explored and encouraged.*

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7. Environmental and societal impact

Next generations of particle physicists

- The exploratory nature of particle physics and its fundamental questions about the universe fascinates many inside and outside the field and draws in talented students
- National laboratories, research institutes and universities worldwide provide the training ground of future young scientists. Education and training in key technologies are crucial for the needs of the field and society at large
- It is essential to make the research environment in particle physics as attractive as possible and in particular to consider the worries expressed by the early career researchers (document under the auspices of ECFA)
- The principles of equality, diversity and inclusion should be clearly and recognisably present in all of the field's activities

b) Particle physics, with its fundamental questions and technological innovations, attracts bright young minds. Their education and training are crucial for the needs of the field and of society at large. *For early-career researchers to thrive, the particle physics community should place strong emphasis on their supervision and training. Additional measures should be taken in large collaborations to increase the recognition of individuals developing and maintaining experiments, computing and software. The particle physics community commits to placing the principles of equality, diversity and inclusion at the heart of all its activities.*

7. Environmental and societal impact

Knowledge and technology transfer

- A large number of technologies developed or under development by the particle physics community exist with excellent potential to be transferred to other fields of science and industry
- It is important to recognise the potential impact of technological developments in accelerators and associated fields on progress in other branches of science, such as astroparticle physics, cosmology and nuclear physics
- Joint developments with applied fields in academia and industry have brought benefits to fundamental research and may become indispensable for the progress in the field, demonstrating that knowledge and technology transfer is not a one-way street

c) Particle physics has contributed to advances in many fields that have brought great benefits to society. Awareness of knowledge and technology transfer and the associated societal impact is important at all phases of particle physics projects. *Particle physics research centres should promote knowledge and technology transfer and support their researchers in enabling it. The particle physics community should engage with industry to facilitate knowledge transfer and technological development.*

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7. Environmental and societal impact

Public engagement, education and communication

- The particle physics community is highly active and effective in public engagement. European funding agencies are urged to explicitly accompany research funding with resources for public engagement activities
- Good contacts between particle physicists and other research disciplines will lead to better mutual understanding of the importance and urgency of the open scientific research
- The International Particle Physics Outreach Group (IPPOG) has been established to streamline particle physics education at the high-school level and its mission could be expanded to provide public engagement material
- The well established effectiveness of the European Particle Physics Communication Network (EPPCN) would be further improved if the vacancies for EPPCN representatives for all Member and Associate Member States were filled
- The basic picture of fundamental constituents of matter and their interactions should become part of the regular school curriculum

d) Exploring the fundamental properties of nature inspires and excites. It is part of the duty of researchers to share the excitement of scientific achievements with all stakeholders and the public. The concepts of the Standard Model, a well-established theory for elementary particles, are an integral part of culture. *Public engagement, education and communication in particle physics should continue to be recognised as important components of the scientific activity and receive adequate support. Particle physicists should work with the broad community of scientists to intensify engagement between scientific disciplines. The particle physics community should work with educators and relevant authorities to explore the adoption of basic knowledge of elementary particles and their interactions in the regular school curriculum.*

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Concluding remarks

This 2020 update of the European Strategy for Particle Physics has focussed on both near and long-term priorities for the field. Given the scale of our long-term ambition, the European plan needs to be coordinated with other regions of the world. A further update of the Strategy should be foreseen in the second half of this decade when the results of the feasibility study for the future hadron collider are available and ready for decision.

Back-up slides

EPPSU 2020/backup

Strategy Secretariat

- H. Abramowicz (Chairperson)
- J. D'Hondt (ECFA Chairperson, *ECFA: European Committee for Future Accelerators*)
- K. Ellis (SPC Chairperson, *SPC: Science Policy Committee @ CERN*)
- L. Rivkin (European LDG Chairperson, *LDG: Lab Directors Group*)

Contact: EPPSU-Strategy-Secretariat@cern.ch

EPPSU 2020

Physics Peparatory Group

- *Strategy Secretariat*
- Caterina Biscari (ES), Belen Gavela (ES), Beate Heinemann (DE), Krzysztof Redlich (PL) – *delegates nominated by SPC*
- Stan Bentvelsen (NL), Paris Sphicas (GR), Marco Zito (FR), Antonio Zoccoli (IT) – *delegates nominated by ECFA*
- Gian Giudice (*CERN*) – *nominated by CERN*
- Shoji Asai (Japan) and Xinchou Lou (China) - *delegates from Asia nominated by ICFA*
- Marcela Carena (US) and Brigitte Vachon (Canada) - *delegates from the Americas nominated by ICFA*

Responsible to organize the Open Symposium and to deliver to the European Strategy Group (ESG) a Briefing Book.

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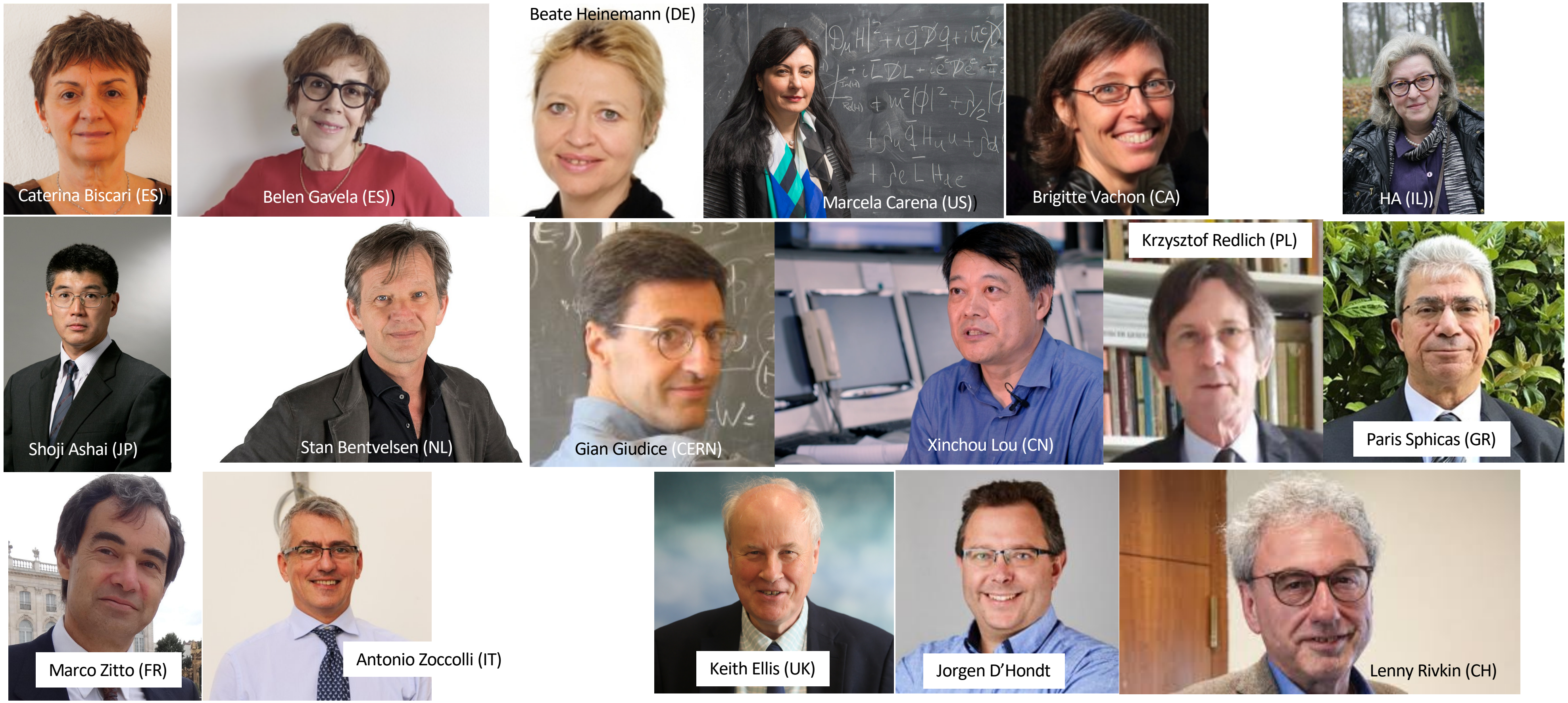
Faces behind the Strategy science - Physics Preparatory Group



Names at
http://europeanstrategyupdate.web.cern.ch/composition-esg

EPPSU 2020

Composition of the ESG

European Strategy Group (ESG) composition, adopted by Council, December 2013:

- the Strategy Secretary (acting as Chairperson),
- one representative appointed by each CERN Member State,
- one representative for each of the Laboratories participating in the major European Laboratory Directors' meeting, including its Chairperson,
- the CERN Director-General,
- the SPC Chairperson,
- the ECFA Chairperson.

Responsible to deliver a draft Strategy Update to Council.

Invitees

- the President of the CERN Council,
- one representative from each of the Associate Member States,
- one representative from each Observer State,
- one representative from the European Commission and JINR,
- the Chairpersons of ApPEC, FALC, ESFRI, and NuPECC,
- the members of the Physics Preparatory Group.

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Timeline for non-collider projects

PBC

Accelerator R&D

Neutrino