Nikhef

EUROPEAN STRATEGY FOR PARTICLE PHYSICS

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Horizons in Particle Accelerators and Laboratory-based Quantum Sensors

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EUROPEAN STRATEGY (UPDATE) PROCESS

- The process by which European PP community, including (but not only) CERN and its MS, determines its strategy
- Very intense, 2-year, well-regulated
- Bottom-up process, all stake holders get to give input
- Not just a nice document to now and then glance at, it is a serious vision,
  - Much quoted in presentations!
- Guide how to spend resources.

GOVERNANCE OF CERN

- To understand the strategy and its implication, it is good to understand CERN governance
- Highest authority: CERN Council
  - Responsible for all major decisions, approves programmes, adopts budgets and reviews expenditures
  - Subcommittees:
    - Scientific Policy Committee
    - Finance Committee
- Director-General (Fabiola Gianotti), with directorate, manages the Lab
  - Formally Council Secretary
- This structure is enshrined in the CERN Convention of 1953
    - Science for Peace!

CERN COUNCIL

- 23 member states
  - Latest new member: Serbia
  - 2 delegates per MS
  - Vote on all key decisions (budget, major new projects, enlargement, DG election etc)
  - Gives guidance on many more
- 10 Associate member states
  - Cyprus, Slovenia, Croatia, India, Lithuania, Pakistan, Turkey, Ukraine, Estonia, Latvia
    - For India: Prof. Ajit Mohanty, director of Bhabha Atomic Research Centre, Mr. Sunil Ganju.
- Observer states: Japan, United States, [suspended: Russian Federation and JINR]
- Meets 4x / year
  - Sept. 2020: 200th Council Meeting

CERN IN SOME NUMBERS

- Annual budget: 1.2 Billion Swiss francs
  - Like medium-sized European University
  - Organizationally like a small city
- Member States pay according to their GDP
  - Associate Member States typically 10% of full Member contribution
  - India: in CMS, Alice, Isolde, … + computing
- CERN is an accelerator and user facility, the experiments are paid by members of the experiments
  - Lots of R&D (accel., detector, ..); not only at CERN, also in national institutes and labs

EUROPEAN STRATEGY FOR PARTICLE PHYSICS

- Initiated by CERN Council in 2005, acting as a council for European Particle Physics (as per CERN Convention)

THE COUNCIL,

WITH REGARD TO

(1) the CERN Convention, dated 1 July 1953 as amended on 17 January 1971, in particular its Article II-2 (b), according to which Organization's mission includes the organisation and sponsoring of international collaboration in nuclear (particle physics) research inside and outside the Laboratory;

- Defined also update mechanism; updated in 2013, and in 2020
- A guide for long-term decision making for the field (scientific priority-setting).
- Not resource-loaded - realising serious items requires separate decisions

2006

- LHC first and foremost
  - + prepare for HL-LHC
- Also R&D for CLIC, and neutrino facilities
- Etc

The European strategy for particle physics

Particle physics stands on the threshold of a new and exciting era of discovery. The next generation of experiments will explore new domains and probe the deep structure of space-time. They will measure the properties of the elementary constituents of matter and their interactions with unprecedented accuracy, and they will uncover new phenomena such as the Higgs boson or new forms of matter. Long-standing puzzles such as the origin of mass, the matter-antimatter asymmetry of the Universe and the mysterious dark matter and energy that permeate the cosmos will soon benefit from the insights that new measurements will bring. Together, the results will have a profound impact on the way we see our Universe; European particle physics should thoroughly exploit its current exciting and diverse research programme. It should position itself to stand ready to address the challenges that will emerge from exploration of the new frontier, and it should participate fully in an increasingly global adventure.

General issues

1. European particle physics is founded on strong national institutes, universities and laboratories and the CERN Organization; Europe should maintain and strengthen its central position in particle physics.

2. Increased globalization, concentration and scale of particle physics make a well coordinated strategy in Europe paramount; this strategy will be defined and updated by CERN Council as outlined below.

Scientific activities

3. The LHC will be the energy frontier machine for the foreseeable future, maintaining European leadership in the field; the highest priority is to fully exploit the physics potential of the LHC, resources for completion of the initial programme have to be secured such that machine and experiments can operate optimally at their design performance. A subsequent major luminosity upgrade (SLHC), motivated by physics results and operation experience, will be enabled by focussed R&D; to this end, R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade by around 2015.

4. In order to be in the position to push the energy and luminosity frontier even further it is vital to strengthen the advanced accelerator R&D programme; a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.

5. It is fundamental to complement the results of the LHC with measurements at a linear collider. In the energy range of 0.5 to 1 TeV, the ILC, based on superconducting technology, will provide a unique scientific opportunity at the precision frontier; there should be a strong well-coordinated European activity, including CERN, through the Global Design Effort, for its design and technical preparation towards the construction decision, to be ready for a new assessment by Council around 2010.

6. Studies of the scientific case for future neutrino facilities and the R&D into associated technologies are required to be in a position to define the optimal neutrino programme based on the information available in around 2012; Council will play an active role in promoting a coordinated European participation in a global neutrino programme.

7. A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest.

2013

- Exploit LHC to the fullest, including HL-LHC
- Design studies for next collider at CERN (pp + ee)
- Europe looks forward to ILC proposal from Japan
- Develop long-baseline neutrino programme (with US and Japan)

The European Strategy for Particle Physics
Update 2013

Preamble

Since the adoption of the European Strategy for Particle Physics in 2006, the field has made impressive progress in the pursuit of its core mission, elucidating the laws of nature at the most fundamental level. A giant leap, the discovery of the Higgs boson, has been accompanied by many experimental results confirming the Standard Model beyond the previously explored energy scales. These results raise further questions on the origin of elementary particle masses and on the role of the Higgs boson in the more fundamental theory underlying the Standard Model, which may involve additional particles to be discovered around the TeV scale. Significant progress is being made towards solving long-standing puzzles such as the matter-antimatter asymmetry of the Universe and the nature of the mysterious dark matter. The observation of a new type of neutrino oscillation has opened the way for future investigations of matter-antimatter asymmetry in the neutrino sector. Intriguing prospects are emerging for experiments at the overlap with astroparticle physics and cosmology. Against the backdrop of dramatic developments in our understanding of the science landscape, Europe is updating its Strategy for Particle Physics in order to define the community's direction for the coming years and to prepare for the long-term future of the field.

General issues

a) The success of the LHC is proof of the effectiveness of the European organisational model for particle physics, founded on the sustained long-term commitment of the CERN Member States and of the national institutes, laboratories and universities closely collaborating with CERN. *Europe should preserve this model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.*

b) The scale of the facilities required by particle physics is resulting in the globalisation of the field. *The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.*

High-priority large-scale scientific activities

After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority.

c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

d) To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available. *CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous*

FRIDAY JUNE 19 2020: A NEW STRATEGY UPDATE

- Location: ~~Budapest~~ Online
- Unanimously decided in Open Session of CERN Council
- Culmination of two years of compilation, discussion, deliberation…

WHO

- European Strategy Group (ESG)
  - 1 member per (A)MS (often Council delegate)
  - CERN Director General
  - 9 Lab. directors (LDG)
  - 5 from observer states (Japan, US, Russia, ..)
  - Chairs of APPEC, NuPECC, FALC, ESFRI
- Strategy Secretariat
  - Halina Abramowicz, Keith Ellis, Jorgen D'Hondt, Leonid Rivkin
  - Excellent support team
- Physics Preparatory Group (PPG)
  - SPC, ECFA members, CERN member, 2 from Asia, 2 from Americas

INPUTS FOR STRATEGY

- From Sept. 2018 to Dec. 2018, call for contributions, each maximum 10 pages
  - 160 inputs received
    - National inputs
    - Inputs from sub-fields
    - Inputs from neighbouring fields etc etc
  - Important step in reaching consensus..

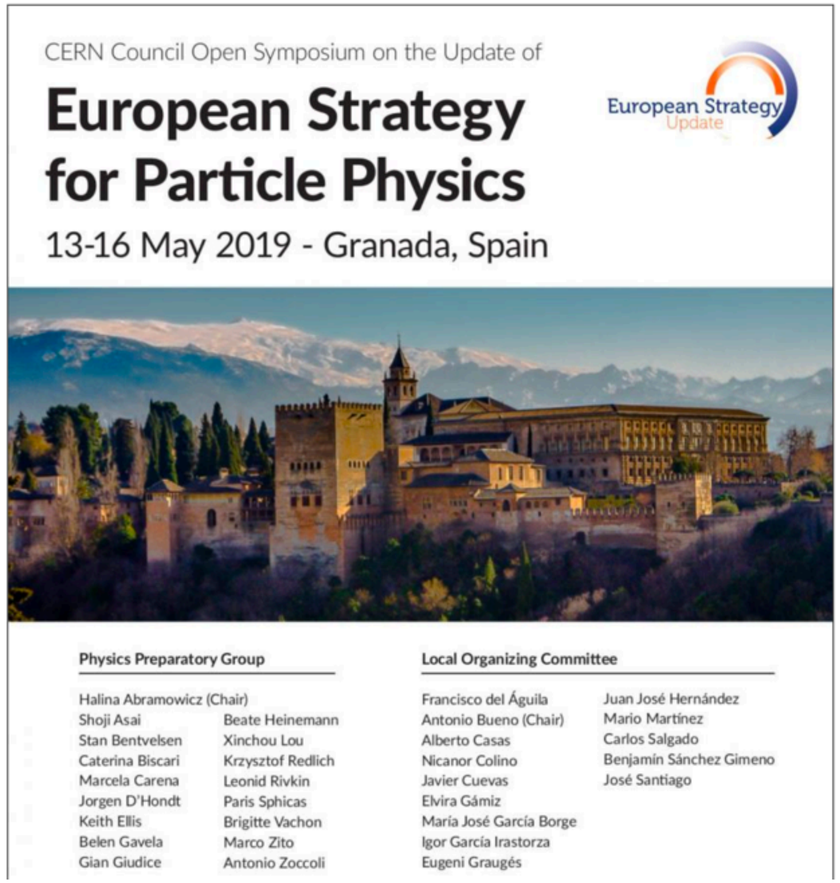
WORKING GROUPS

1. Social and career aspects of the next generation
2. Issues related to global projects hosted by CERN or funded through CERN outside Europe
3. Relations with other groups and organisations
4. Knowledge and Technology Transfer
5. Public engagement, Education and Communication
6. Sustainability and environmental impact

Each has written a separate, public report

OPEN SYMPOSIUM IN GRANADA, MAY 2019

- About 600 participants
- Overview talks
  - Lots of parallel talks
- Ample time for discussion
  - + Working group meetings



CERN Council Open Symposium on the Update of

European Strategy for Particle Physics

13-16 May 2019 - Granada, Spain

European Strategy Update

Physics Preparatory Group

Halina Abramowicz (Chair)
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Eugeni Graugés
Juan José Hernández
Mario Martínez
Carlos Salgado
Benjamín Sánchez Gimeno
José Santiago

PHYSICS BRIEFING BOOK

- Prepared by Physics Preparatory Group, 254 pages
- On basis of inputs and Granada Open Symposium

CERN-ESU-004
10 January 2020

Physics Briefing Book

Input for the European Strategy for Particle Physics Update 2020

Electroweak Physics: Richard Keith Ellis[1], Beate Heinemann[2,3] *(Conveners)*
Jorge de Blas[4,5], Maria Cepeda[6], Christophe Grojean[2,7], Fabio Maltoni[8,9], Aleandro Nisati[10],
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Strong Interactions: Jorgen D'Hondt[14], Krzysztof Redlich[15] *(Conveners)*
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Nestor Armesto[18], Daniël Boer[19], David d'Enterria[20], Tetyana Galatyuk[21], Thomas Gehrmann [22],
Klaus Kirch[23], Uta Klein[24], Jean-Philippe Lansberg[25], Gavin P. Salam[26], Gunar Schnell[27],
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Flavour Physics: Belen Gavela[31], Antonio Zoccoli[32] *(Conveners)*
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Daniel Aloni[36], Augusto Ceccucci[20], Avital Dery[36], Michael Dine[37], Svetlana Fajfer[38], Stefania Gori[37],
Gudrun Hiller[39], Gino Isidori[22], Yoshikata Kuno[40], Alberto Lusiani[41], Yosef Nir[36],
Marie-Helene Schune[42], Marco Sozzi[43], Stephan Paul[44], Carlos Pena[31] *(Contributors)*

Neutrino Physics & Cosmic Messengers: Stan Bentvelsen[45], Marco Zito[46,47] *(Conveners)*
Albert De Roeck [20], Thomas Schwetz[29] *(Scientific Secretaries)*
Bonnie Fleming[48], Francis Halzen[49], Andreas Haungs[29], Marek Kowalski[2], Susanne Mertens[44],
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Beyond the Standard Model: Gian F. Giudice[20], Paris Sphicas[20,52] *(Conveners)*
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Matthew McCullough[20], Gilad Perez[36], Philipp Roloff[20], Veronica Sanz[55], Andreas Weiler[44],
Andrea Wulzer[4,12,20] *(Contributors)*

Dark Matter and Dark Sector: Shoji Asai[56], Marcela Carena[57] *(Conveners)*
Babette Döbrich[20], Caterina Doglioni[53], Joerg Jaeckel[28], Gordan Krnjaic[57], Jocelyn Monroe[58],
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Accelerator Science and Technology: Caterina Biscari[61], Leonid Rivkin[62] *(Conveners)*
Philip Burrows[26], Frank Zimmermann[20] *(Scientific Secretaries)*
Michael Benedikt[20], Pierluigi Campana[54], Edda Gschwendtner[20], Erk Jensen[20], Mike Lamont[20],
Wim Leemans[2], Lucio Rossi[20], Daniel Schulte[20], Mike Seidel[62], Vladimir Shiltsev[63],
Steinar Stapnes[20], Akira Yamamoto[20,64] *(Contributors)*

Instrumentation and Computing: Xinchou Lou[65], Brigitte Vachon[66] *(Conveners)*
Roger Jones[67], Emilia Leogrande[20] *(Scientific Secretaries)*
Ian Bird[20], Simone Campana[20], Ariella Cattai[20], Didier Contardo[68], Cinzia Da Via[69], Francesco Forti[70],
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Editors: Halina Abramowicz[71], Roger Forty[20], and the Conveners

DRAFTING@BAD HONNEF 19-25 JANUARY 2020

- About 60 participants
  - ESG + PPG + Secretariat + support
- Brief presentations, discussions, formulations..
- Drafting sessions by Strategy Secretariat
- Sessions often until 22.00 and beyond
- Finished after lunch on Saturday
- Final roll call a special moment..

2020 UPDATE

2020 UPDATE OF THE EUROPEAN STRATEGY
FOR PARTICLE PHYSICS

by the European Strategy Group

European Strategy
Update

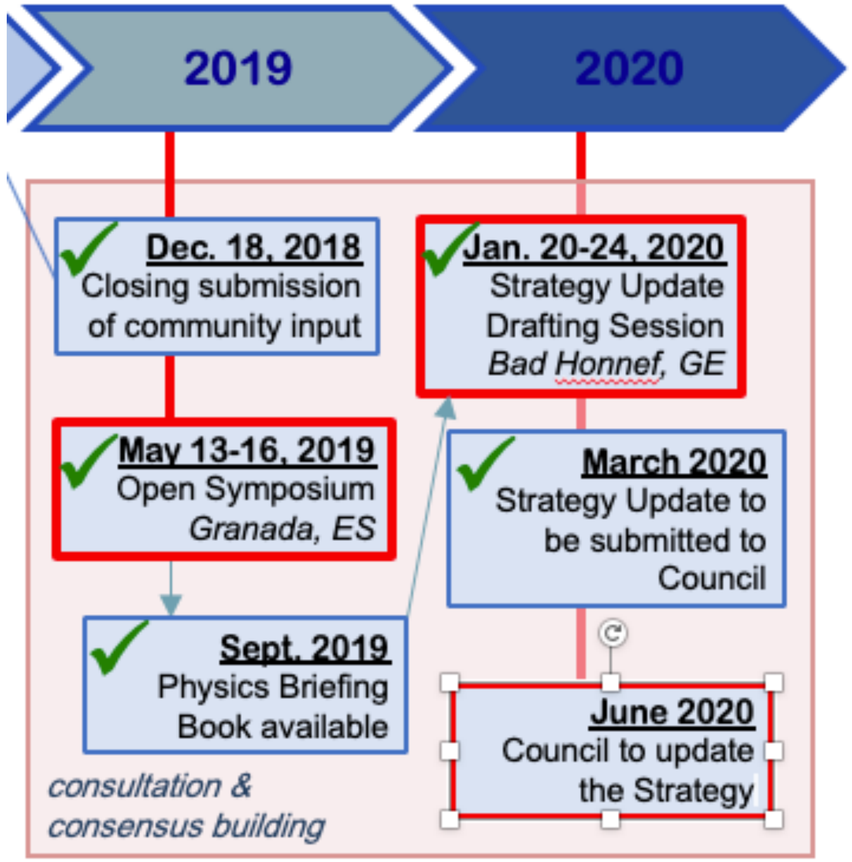
DELIBERATION DOCUMENT

DELIBERATION DOCUMENT
ON THE 2020 UPDATE OF THE EUROPEAN STRATEGY
FOR PARTICLE PHYSICS

The European Strategy Group

European Strategy
Update

EPSSU 2020



- 20 Strategy statements
- 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

PREAMBLE

Following slides adapted from presentation by Halina Abramowicz in Open Session of Council

- Many unsolved mysteries about the universe: **dark matter, 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**
- **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

Prepare a Higgs factory, followed by a future hadron collider with sensitivity to scales an order of magnitude higher than those of the LHC, while addressing the associated technical and environmental challenges.

MAJOR DEVELOPMENTS FROM 2013 STRATEGY

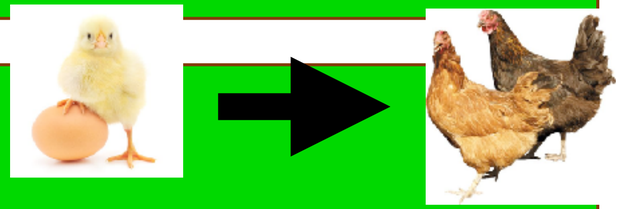
2013 Strategy: Two high-priority, large-scale scientific activities
- LHC -> HL-LHC
- Neutrino physics -> Europe links up with Japan and the US (Neutrino Platform)

2013 Strategy: Two more high-priority activities
- R&D for post-LHC acceleration. -> CLIC (CDR + PIP); FCC (CDR)
- ILC: *"Europe looks forward to a proposal from Japan.."*

- LHC running well (after some Covid delays); HL - LHC construction well underway

- CERN participates through Neutrino Platform in DUNE in US,
- 2021: CERN also will construct and pay for 2nd cryostat
- CERN, also through NP, participates in T2K experiment in Japan

- ILC: no further positive news on decision
- CDRs done



GENERAL CONSIDERATIONS FOR 2020 UPDATE

- CERN (with LHC) is the world's premier particle physics laboratory
- Cooperation between the Member, Associate Member and non-Member States and the concentration of the European particle-physics effort at CERN have created a unique resource in scientific accomplishments, human capital, international collaboration, technical expertise, and research infrastructure
- CERN and other laboratories use cutting-edge technologies shared throughout Europe for the benefit of the Member and Associate Member States

a) Europe, through CERN, has world leadership in accelerator-based particle physics and related technologies. The future of the field in Europe and beyond depends on the continuing ability of CERN and its community to realise compelling scientific projects. *This Strategy update should be implemented to ensure Europe's continued scientific and technological leadership.*

GENERAL CONSIDERATIONS FOR 2020 UPDATE

European ecosystem for research in particles physics

- European National Laboratories collaborate, together with research institutes and universities, in large programmes at CERN, in local activities and at other large laboratories
- European research centres provide a variety of large technical platforms for development, testing and production of accelerator and detector components
- European research centres have synergies with other communities that go well beyond particle physics
- High visibility of European research centres in supranational large projects is essential for their sustainability

b) The European organisational model centred on close collaboration between CERN and the national institutes, laboratories and universities in its Member and Associate Member States is essential to the enduring success of the field. This has proven highly effective in harnessing the collective resources and expertise of the particle, astroparticle and nuclear physics communities, and of many interdisciplinary research fields. Another manifestation of the success of this model is the collaboration with non-Member States and their substantial contribution. *The particle physics community must further strengthen the unique ecosystem of research centres in Europe. In particular, cooperative programmes between CERN and these research centres should be expanded and sustained with adequate resources in order to address the objectives set out in the Strategy update.*

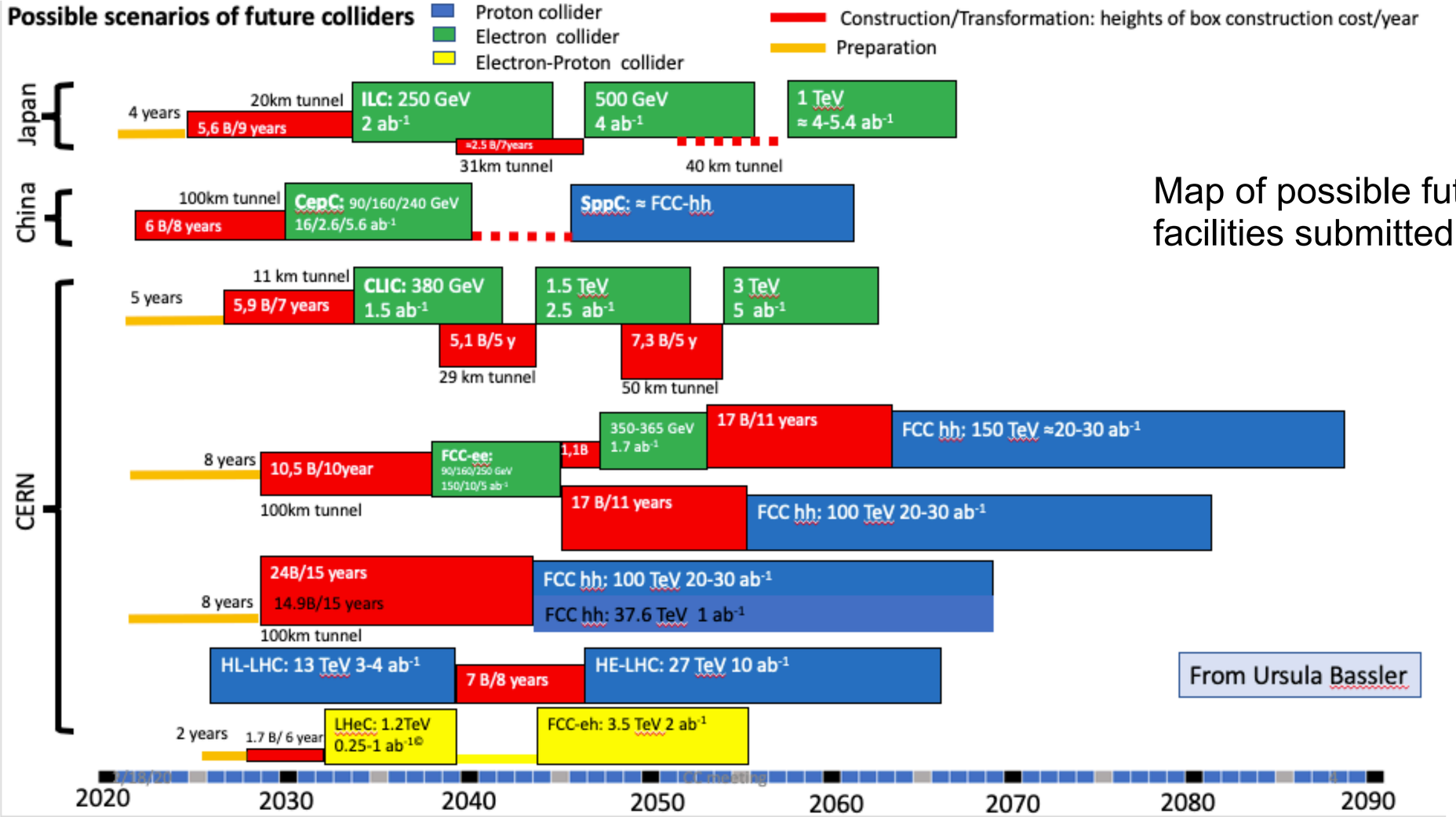
GENERAL CONSIDERATIONS FOR 2020 UPDATE

Global nature of particle physics research

- The increase in scale of the leading particle physics facilities 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
- Europe's long-term vision is to maintain its leadership at 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.*

HIGH-PRIORITY FUTURE INITIATIVES



Map of possible future facilities submitted as input

From Ursula Bassler

HIGH-PRIORITY FUTURE INITIATIVES

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

- Two ways: Higgs factory and exploration of the energy frontier
- Europe is 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 make this the most promising 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, for a decision

- Feasibility study well underway; large set of topics to be addressed
- Governance is set up, and links to and between host states
- Important: Midterm review end of 2023, with special Council session early in 2024

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.
- 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 a breakthrough in plasma acceleration, design study for a muon collider, R&D energy-recovery linac (ERL) machines

- Accelerator R&D roadmap complete
- Compiled by Laboratory Directors Group (LDG)
- Now starting implementation phase; long R&D time needed for HFM
- Heard already about IMCC, Plasma acceleration, ERL, HTS etc

OTHER ESSENTIAL ACTIVITIES: DARK MATTER & FLAVOUR

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

- Dark matter particles -could be as light as 10^{-22} eV to as heavy as black holes of $10xM_{\odot}$
- 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 as the Beam Dump Facility, and LHeC option at CERN, difficult to resource within the CERN budget*
- Knowledge of the proton structure needed to fully exploit hadron colliders - added value from fixed target experiments and from Electron Ion Collider (CD0) in BNL
- 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)

- Vigorous effects ongoing in flavour physics, also in Physics Beyond Colliders, DM detection
- EIC will have impact for PDF's, hence for much of hadron collider physics
- Funding for lower energy national lab expts seems healthy

OTHER ESSENTIAL ACTIVITIES: THEORY

Essential role of theory for advancement in particle physics

- European theoretical research ranges from abstract ideas of string theory to the detailed simulation of collider physics processes
- Neighbouring fields enrich the scientific dialogue (cosmology, nuclear physics and astrophysics, condensed matter and atomic physics, computation and quantum information)
- Theory plays an essential role in assessing the strategic importance for future investments in accelerators
- Calculation-intensive areas such as precision phenomenology at colliders, lattice field theory or the development of Monte-Carlo event generators and other software tools <u>require long time scales to yield results</u>
- Outreach activities benefit from the special perspective that theoretical physicists bring

- Significant activities in precision techniques and calculations methods
- But also in formal developments, with increasing cross-talk
- Already global collaboration, certainly also with India theorists
  - Formal, QCD, SM, BSM, etc etc
- Source of inspiration for many students

OTHER ESSENTIAL ACTIVITIES: DETECTOR R&D

Instrumentation R&D critical for present and future endeavours

- Delivering future research programme requires advances in instrumentation through transformational R&D
- Existing R&D collaborative structures should be strengthened and new ones created. An environment is needed that stimulates innovation and collaboration with industry
- The National Laboratories and research institutes in Europe provide access to dedicated infrastructures and test facilities, specialised expertise and user support
- A roadmap should be developed by the community (ECFA's role) taking into account progress with emerging technologies in adjacent fields

- Detector R&D roadmap is complete
- Compiled by European Committee for Future Accelerators (ECFA)
- Now starting implementation phase; large variety of detection techniques to be pursued.
- New collaboration structure: DRD's
  - Quantum sensing, etc
  - Possibilities for India R&D for DRDs

OTHER ESSENTIAL ACTIVITIES: COMPUTING

Computing and software infrastructure

- There is a need for strong community-wide coordination for computing and software R&D activities, and for common coordinating structures promoting coherence in these activities, long-term planning and effective means of exploiting synergies with other disciplines and industry
- A significant role for artificial intelligence is emerging in detector design, detector operation, online data processing and data analysis
- Computing and software are profound R&D topics in their own right and are essential to sustain and enhance particle physics research capabilities
- More experts need to be trained to address the essential needs, especially with the increased data volume and complexity in the upcoming HL-LHC era, and will also help in experiments in adjacent fields.

- Progress here by-and-large self-propelled:
- AI is finding its way into PP research, other computing R&D
- Quantum Computing for PP already considerable effort

SYNERGIES WITH NEIGHBOURS: NUCLEAR PHYSICS

Particle and Nuclear Physics

- The synergies are driven by the ambition to achieve first-principle understanding of strong dynamics based on QCD
- They share similar experimental tools
- The CERN baseline programme includes ISOLDE and n_TOF facilities and the heavy-ion programme at SPS and LHC
- Future European facilities such as FAIR, NICA and ESS or EIC in the US envisage research programmes that are of interest to particle physics
- The nuclear physics roadmap in Europe is coordinated by the Nuclear Physics European Collaboration Committee (NuPECC) and there are well established communication lines between the two communities
- NuPECC has expressed strong support for the extension of the heavy-ion programme into the HL-LHC era and beyond

- Natural link to research in India (talk by Vandana Nanal)
- India involved in ISOLDE and ALICE
- Much interest by QCD theorists in EIC

SYNERGIES WITH NEIGHBOURS: ASTROPARTICLE PHYSICS

Particle and Astroparticle Physics

- Synergies exist at the level of infrastructure, detectors, computing, interaction models and physics goals (ex.: neutrinos, dark matter, cosmic rays and gravitational waves)
- *The need to foster these synergies has been clearly identified in the national inputs*
- The astroparticle physics roadmap in Europe is coordinated by the Astroparticle Physics European Consortium (APPEC); APPEC seeks strong cooperation with CERN
- The APPEC theory centre for astroparticle physics, EuCAPT, was established recently with CERN chosen as its first hosting hub
- It would be appropriate to establish a new procedure (like "Recognised Experiments") for collaborations seeking CERN's technical support, which should be limited to providing technical expertise and infrastructure services <u>in a cost-neutral way</u> for CERN

- A lot of effort in APP, and natural links to PP. E.g. Einstein Telescope office at CERN, which helps with governance, civil engineering, vacuum technology etc

ORGANISATIONAL ISSUES: GLOBAL PROJECTS

Global projects, Europe and CERN

- Large future projects, because of their size, complexity, duration and cost, will need to be planned on a global scale
- Need to consider governance and funding around either CERN hosting a next-generation collider as a globally funded project or a European contribution to a next-generation collider constructed outside Europe, and specifically the role that CERN would play
- *For the case of a new global facility hosted at CERN, long-term commitments are needed from non-European states and must take account of both construction and operating costs and must be compatible with the provisions of the CERN Convention, amendment of which is not desirable*
- For the case of a European contribution to a new global facility outside Europe, CERN should, if so decided by the CERN Council, provide strategic coordination and technical support for European contributions
- The modalities of European participation in a global facility outside Europe remain to be decided, as and when the need occurs

- Working group report part of Strategy
- Current Council has a Working Group on Governance, including as charge: "Governance of Future Global Projects".

ORGANISATIONAL ISSUES: OPEN SCIENCE

Open Science

- Open science comprises open access to scientific publications and research data, preservation and reuse of research outcomes, sharing of infrastructures, as well as participation in the research process
- Open Science promotes the sharing of research-based knowledge and facilitates the wide use of research findings, data, methods and infrastructures in the research community and in society at large
- Open science policies are formed and implemented at the national and international levels by governments, international institutions, and research funders
- The particle physics community in Europe and CERN have been pioneers in several aspects of open science, such as the open-access publishing initiative SCOAP3, the Zenodo archive and, not least, by establishing the worldwide web

- Demanded now by funding agencies; SCOAP3 makes it easy for PP

ENVIRONMENTAL AND SOCIETAL IMPACT: CLIMATE CHANGE

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

- Travel reduction happened very quickly after drafting session…
- Significant efforts at CERN towards sustainability (see Environmental Reports)
- Energy now a major (cost) factor, also here efforts to improve carbon footprint

ENVIRONMENTAL AND SOCIETAL IMPACT: NEXT GENERATION

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

- Involving next generation is crucial, and very challenging given long timescales
- Equality, diversity and inclusion should be visible
- Make careers possible and visible, besides science also in R&D, computing, engineering, acelerator technology etc.

ENVIRONMENTAL AND SOCIETAL IMPACT: KNOWLEDGE TRANSFER

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

- Also important, there is much to be gained both ways
- Important to have good relations with Industry (Industrial Liaison Offices are key)
- Business Incubator Center?

ENVIRONMENTAL AND SOCIETAL IMPACT: PUBLIC ENGAGEMENT

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 <u>should become part of the regular school curriculum</u>

- Here PP is already doing very well, and ahead

NEXT STEPS

- CERN uses the strategy to allocate its resources, via the Medium Term Plan (now+5 years)
- Complete LHC programme, ready the HL-LHC upgrade
- Complete FCC feasibility midterm review
- [Deal with energy crisis]
- [Deal with crisis due to Russian agression]
- R&D roadmaps implementation
- Progress on other goals (sustainability, next generation scientists etc)
- Next update start: 2026-2027 (?), should then reach a decision on FCC