The European Strategy Update process

Keith Ellis
IPPP, Durham

What are we updating?

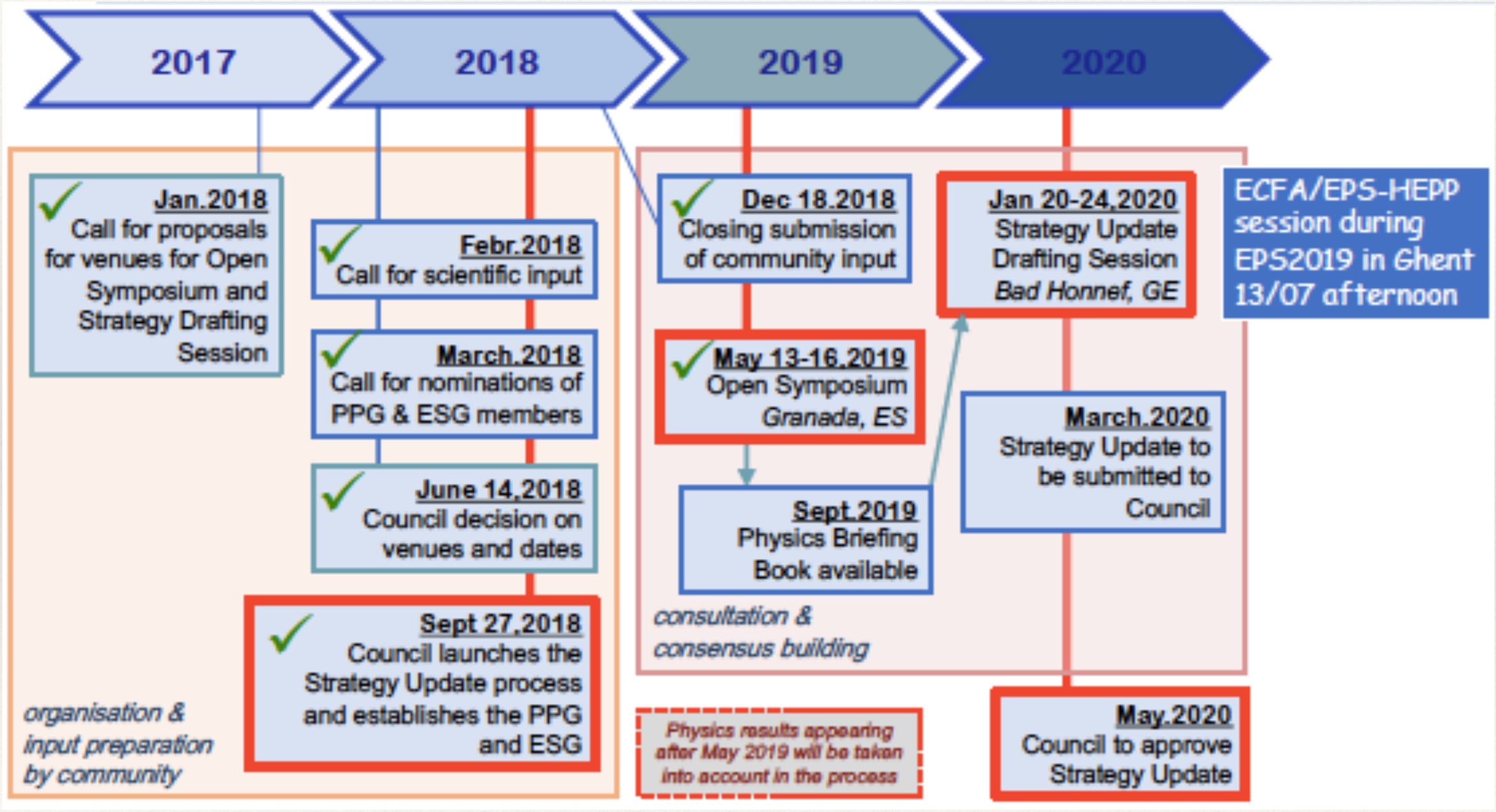
- The European Strategy was last looked at in 2013 — the substance of the document is 3 pages.
- For a description of the process, see Update of the European Strategy for Particle Physics by M. Krammer, Phys.Scripta T158 (2013) 014019.
- **High-priority large-scale scientific activities**
  - ... Europe's 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…..
- …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 accelerator R&D program, including high-field magnets and high-gradient accelerating structures…
- There is a strong scientific case for an electron–positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded….
- ….CERN should develop a neutrino program to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan….

NB: Birth of neutrino platform

Organization of the strategy process

- Coordinating body: Strategy Update Secretariat (SUS: Abramowitz, D'Hondt, Ellis, Rivkin)
- Scientific input to the strategy update - responsibility of the Physics preparatory group (PPG ~ 17 people, including from UK:Ellis)
  - Call for input
  - Open symposium Granada
  - Briefing book
- Drafting of the Strategy Update document - European Strategy Group (ESG, about ~70 people,(including from UK: Butterworth, Ellis, Thomson) in January 2020.
- The CERN Council ultimately has to approve the update of the Strategy.

EPPSU Timeline



Scientific Input to Strategy Update

- Calls for input issued February 28, 2018 with deadline for submission December 18, 2018
- 160 submissions received

Track ID	Granada sessions	Description	Conveners		
1		Large experiments and projects	PPG/ESG		40
2		National road maps	ESG		42
7	B1	Electroweak Physics (physics of the W, Z, H bosons, of the top quark, and QED)	Keith Ellis	Beate Heinemann	21
8	B2	Flavour Physics and CP violation (quarks, charged leptons and rare processes)	Belen Gavela	Antonio Zoccoli	27
5	B3	Dark matter and Dark Sector (accelerator and non-accelerator dark matter, dark photons, hidden sector, axions)	Marcela Carena	Shoji Asai	27
3	B4	Accelerator Science and Technology	Caterina Biscari	Lenny Rivkin	51
4	B5	Beyond the Standard Model at colliders (present and future)	Gian Giudice	Paris Sphicas	20
10	B6	Strong Interactions (perturbative and non-perturbative QCD, DIS, heavy ions)	Krzysztof Redlich	Jorgen D'Hondt	31
9	B7	Neutrino Physics (accelerator and non-accelerator)	Stan Bentvelsen	Marco Zito	23
6	B8	Instrumentation and Computing	Xinchou Lou	Brigitte Vachon	35
11		Other (communication, outreach, strategy process, technology transfer, individual contributions,...)	ESG		

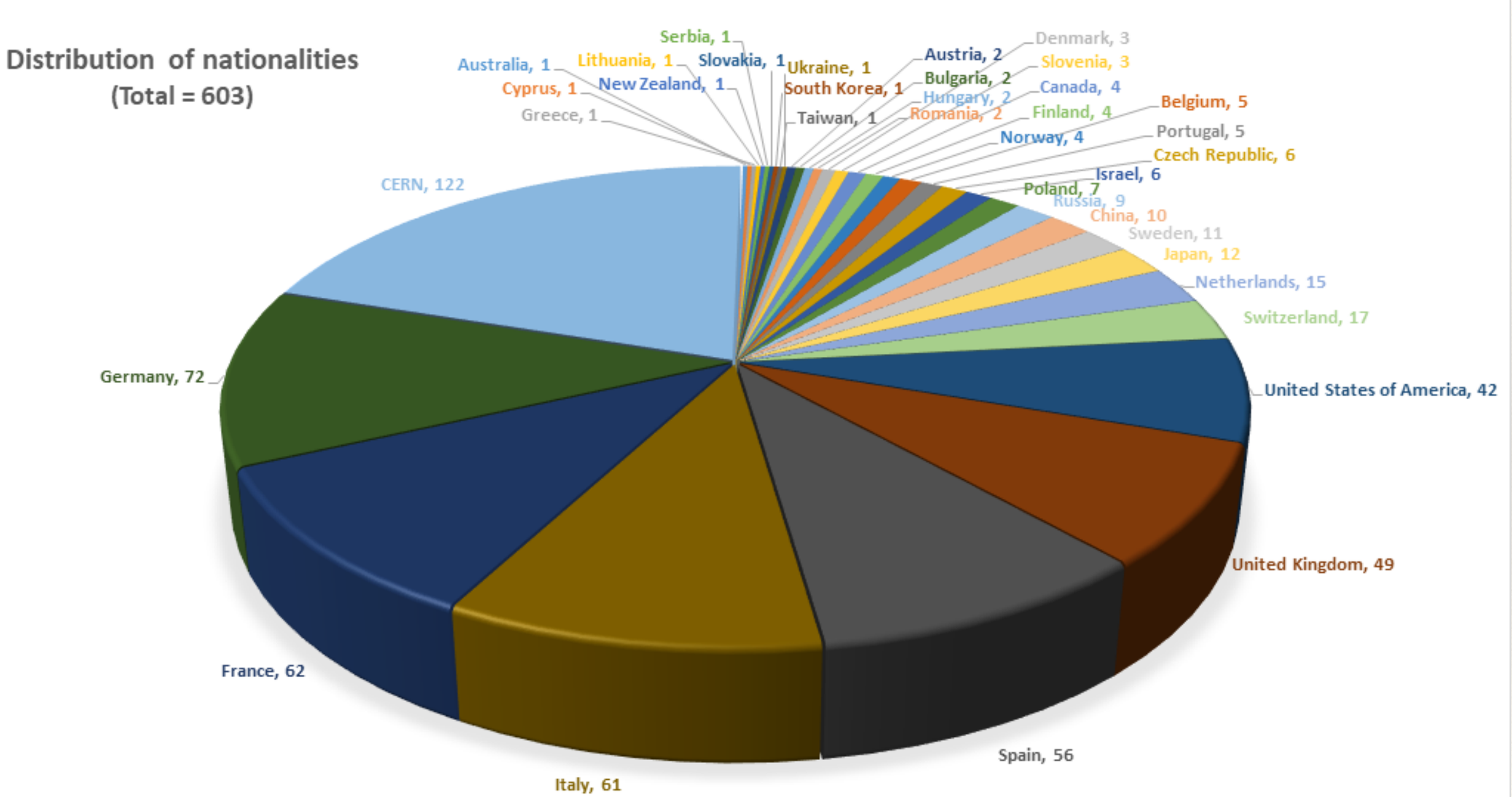
- The Open Symposium aimed to reach a consensus on the scientific goals of the community, based on the provided input, and to assess the proposed projects and technologies to achieve these goals.
- The ESG needs all this input to propose a realistic update of the Strategy.

Open Symposium in Granada

- **Parallel sessions** (convened by members of the PPG)
  - Themes for parallel sessions given on previous slide.
  - Experts invited to summarize submitted input
  - Two sessions per theme, separated by half a day
    - Focus on a few fundamental questions (posted on Granada website under "Organisation of the Symposium")
    - Plenty of time for discussions
- **Plenary Sessions**
  - Two half-days to review where we stand and what is expected of the European community, also by communities outside Europe
  - Full day of summaries from the parallel session discussions

End product of the Symposium → Briefing Book based on the summaries, compiled by the PPG, assisted by scientific secretaries (aim at about 100 pages).

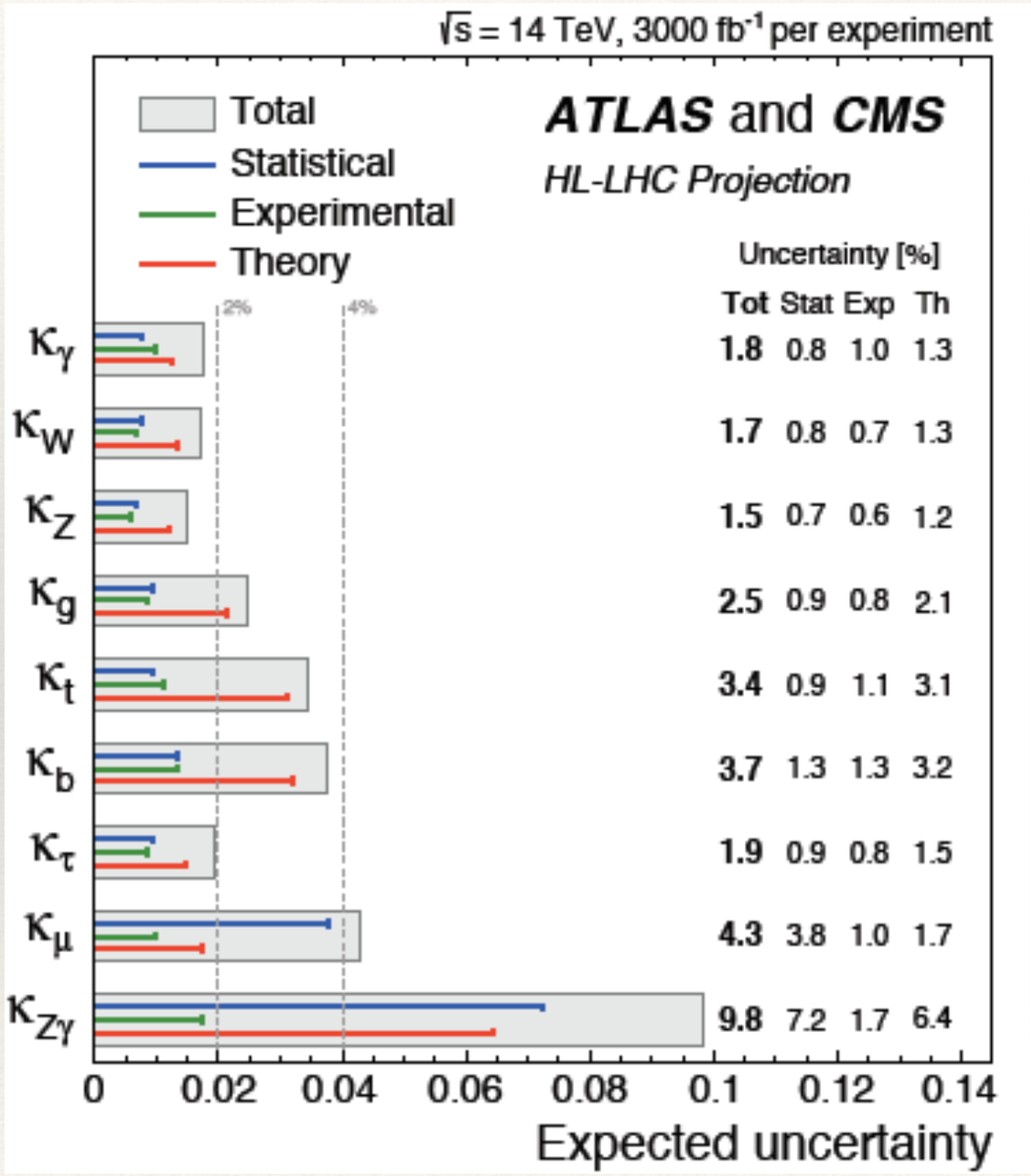
Broad participation in Granada



Selected observations on physics

Higgs Physics

- Precision Higgs Physics is a key deliverable for a future facility.
- Bear in mind that YR studies for HL-LHC have demonstrated impressive improvement from HL-LHC, especially κ_t, κ_b
- Reach depends on theory progress.



For all the modes that are not statistically limited, dominant error is theoretical

Higgs @ future colliders

- Compare and contrast of various future facilities taking HL-LHC as a baseline.
- Based on input submitted.

arXiv:1905.03764

Higgs Boson studies at future particle colliders

- Preliminary Version -

J. de Blas[1,2], M. Cepeda[3], J. D'Hondt[4], R. K. Ellis[5], C. Grojean[6,7], B. Heinemann[6,8], F. Maltoni[9,10], A. Nisati[11,*], E. Petit[12], R. Rattazzi[13], and W. Verkerke[14]

[1]Dipartimento di Fisica e Astronomia Galileo Galilei, Universita di Padova, Via Marzolo 8, I-35131 Padova, Italy
[2]Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Padova,Via Marzolo 8, I-35131 Padova, Italy
[3]Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Avda. Complutense 40, 28040, Madrid, Spain
[4]Inter-University Institute for High Energies (IIHE), Vrije Universiteit Brussel, Brussels, 1050, Belgium
[5]IPPP, University of Durham, Durham DH1 3LE, UK
[6]Deutsches Elektronen-Synchrotron (DESY), Hamburg, 22607, Germany
[7]Institut für Physik, Humboldt-Universität, Berlin, 12489, Germany
[8]Albert-Ludwigs-Universität Freiburg, Freiburg, 79104, Germany
[9]Centre for Cosmology, Particle Physics and Phenomenology, Université catholique de Louvain, Louvain-la-Neuve,1348, Belgium
[10]Dipartimento di Fisica e Astronomia, Università di Bologna and INFN, Sezione di Bologna, via Irnerio 46, 40126 Bologna, Italy
[11]Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Roma, P.le A. Moro 2, I-00185 Roma, Italy
[12]Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France
[13]Theoretical Particle Physics Laboratory (LPTP),EPFL, Lausanne, Switzerland
[14]Nikhef and University of Amsterdam, Science Park 105, 1098XG Amsterdam, the Netherlands

*Corresponding author

ABSTRACT

This document aims to provide an assessment of the potential of future colliding beam facilities to perform Higgs boson studies. The analysis builds on the submissions made by the proponents of future colliders to the European Strategy Update process, and takes as its point of departure the results expected at the completion of the HL-LHC program. This report presents quantitative results on many aspects of Higgs physics for future collider projects using uniform methodologies for all proposed machine projects of sufficient maturity. This report is still preliminary and is distributed for the purposes of discussion at the Open Symposium in Granada (13-16/05/2019).

Higgs couplings @ Future colliders

of "largely" improved H couplings (EFT)

		Factor ≥2	Factor ≥5	Factor ≥10	Years from T_0
Initial run	CLIC380	9	6	4	7
	FCC-ee240	10	8	3	9
	CEPC	10	8	3	10
	ILC250	10	7	3	11
2^{nd}/3rd Run ee	FCC-ee365	10	8	6	15
	CLIC1500	10	7	7	17
hh	HE-LHC	1	0	0	20
2^{nd}/3rd Run ee	ILC500	10	8	6	22
	CLIC3000	11	7	7	28
ee,eh & hh	FCC-ee/eh/hh	12	11	10	>50

13 quantities in total

NB: number of seconds/year differs: ILC 1.6×10^7, FCC-ee & CLIC: 1.2×10^7, CEPC: 1.3×10^7

Comparisons

Project	Type	Energy [TeV]	Int. Lumi. [a^{-1}]	Oper. Time [y]	Power [MW]	Cost
ILC	ee	0.25	2	11	129 (upgr. 150-200)	4.8-5.3 GILCU + upgrade
		0.5	4	10	163 (204)	7.8 GILCU
		1.0			300	?
CLIC	ee	0.38	1	8	168	5.9 GCHF
		1.5	2.5	7	(370)	+5.1 GCHF
		3	5	8	(590)	+7.3 GCHF
CEPC	ee	0.091+0.16	16+2.6		149	5 G$
		0.24	5.6	7	266	
FCC-ee	ee	0.091+0.16	150+10	4+1	259	10.5 GCHF
		0.24	5	3	282	
		0.365 (+0.35)	1.5 (+0.2)	4 (+1)	340	+1.1 GCHF
LHeC	ep	60 / 7000	1	12	(+100)	1.75 GCHF
FCC-hh	pp	100	30	25	580 (550)	17 GCHF (+7 GCHF)
LE,FCC hh	pp	37.5	20	20		
HE-LHC	pp	27	20	20		7.2 GCHF

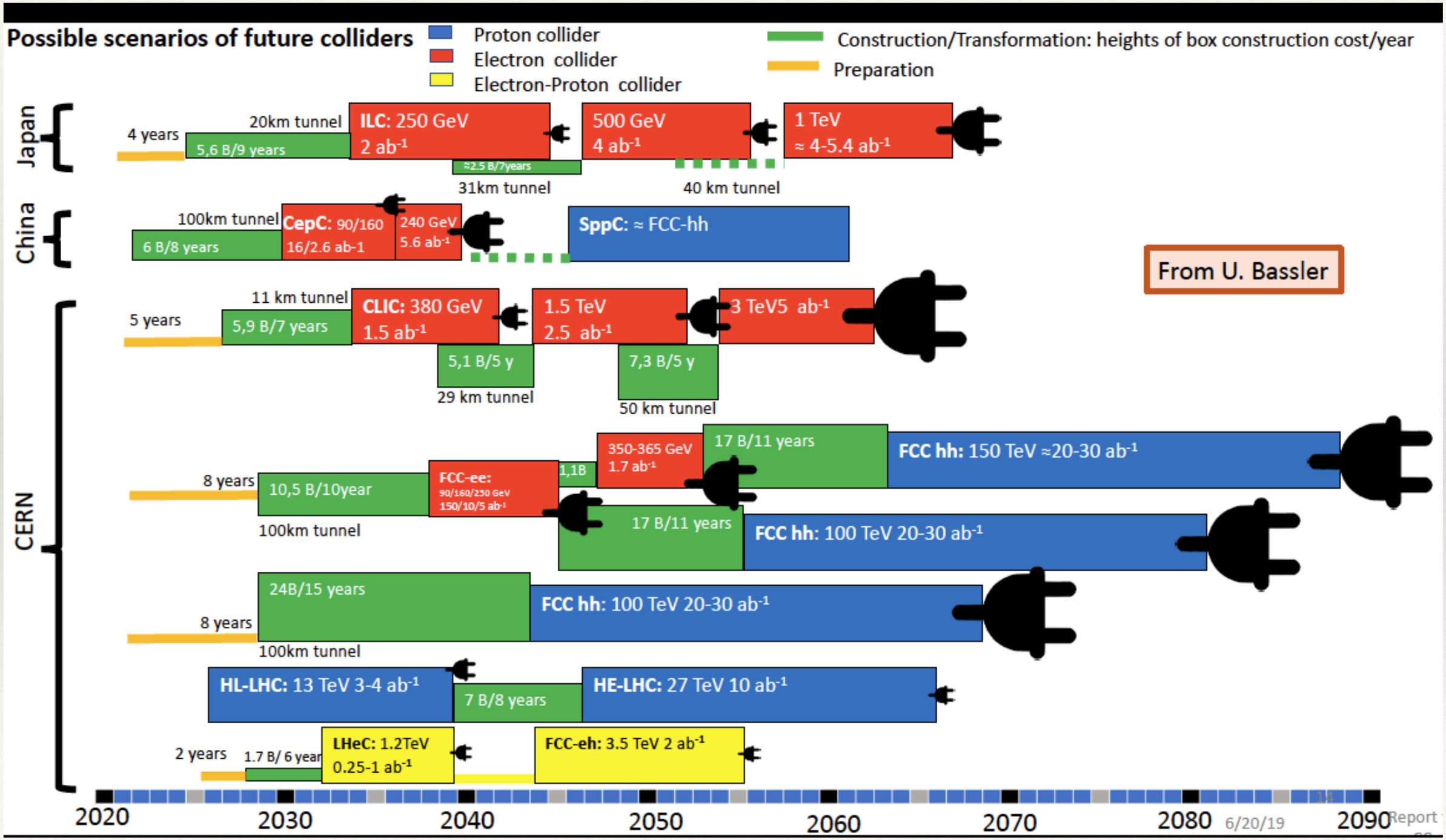
1 ILCU=1 2012 US$

Collider Schedules: starting from T_0

	T_0	+5	+10	+15	+20	...	+26
ILC	0.5/ab 250 GeV		1.5/ab 250 GeV	1.0/ab 500 GeV	0.2/ab $2m_{top}$	3/ab 500 GeV	
CEPC	5.6/ab 240 GeV		16/ab M_Z	2.6 /ab $2M_W$			SppC =>
CLIC	1.0/ab 380 GeV			2.5/ab 1.5 TeV		5.0/ab => until +28 3.0 TeV	
FCC	150/ab ee, M_Z	10/ab ee, $2M_W$	5/ab ee, 240 GeV	1.7/ab ee, $2m_{top}$			hh,eh =>
LHeC	0.06/ab		0.2/ab	0.72/ab			
HE-LHC	10/ab per experiment in 20y						
FCC eh/hh	20/ab per experiment in 25y						

NB: number of seconds/year differs: ILC 1.6×10^7, FCC-ee & CLIC: 1.2×10^7, CEPC: 1.3×10^7

Possible timelines



A. Yamamoto view on relative timelines

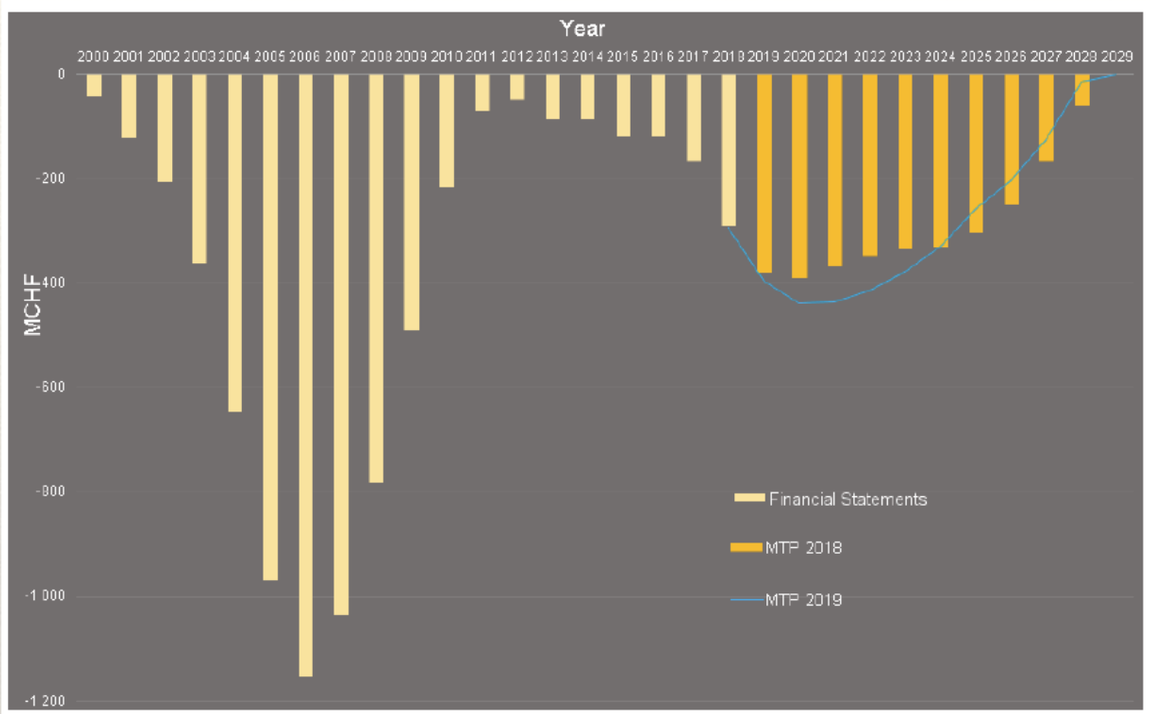
Timeline	~ 5	~ 10	~ 15	~ 20	~ 25	~ 30	~ 35
Lepton Colliders							
SRF-LC/CC	Proto/pre-series	Construction		Operation		Upgrade	
NRF—LC	Proto/pre-series	Construction		Operation		Upgrade	
Hadron Collider (CC)							
8~(11)T NbTi /(Nb3Sn)	Proto/pre-series	Construction		Operation		Upgrade	
12~14T Nb_3Sn	Short-model R&D	Proto/Pre-series		Construction		Operation	
14~16T Nb_3Sn	Short-model R&D		Prototype/Pre-series		Construction		

Note: **LHC experience**: **NbTi (10 T)** R&D started in 1980's --> **(8.3 T)** Production started in late 1990's, in **~ 15 years**

Current view at CERN, 16T with Nb_3Sn extremely challenging

Financial Environment

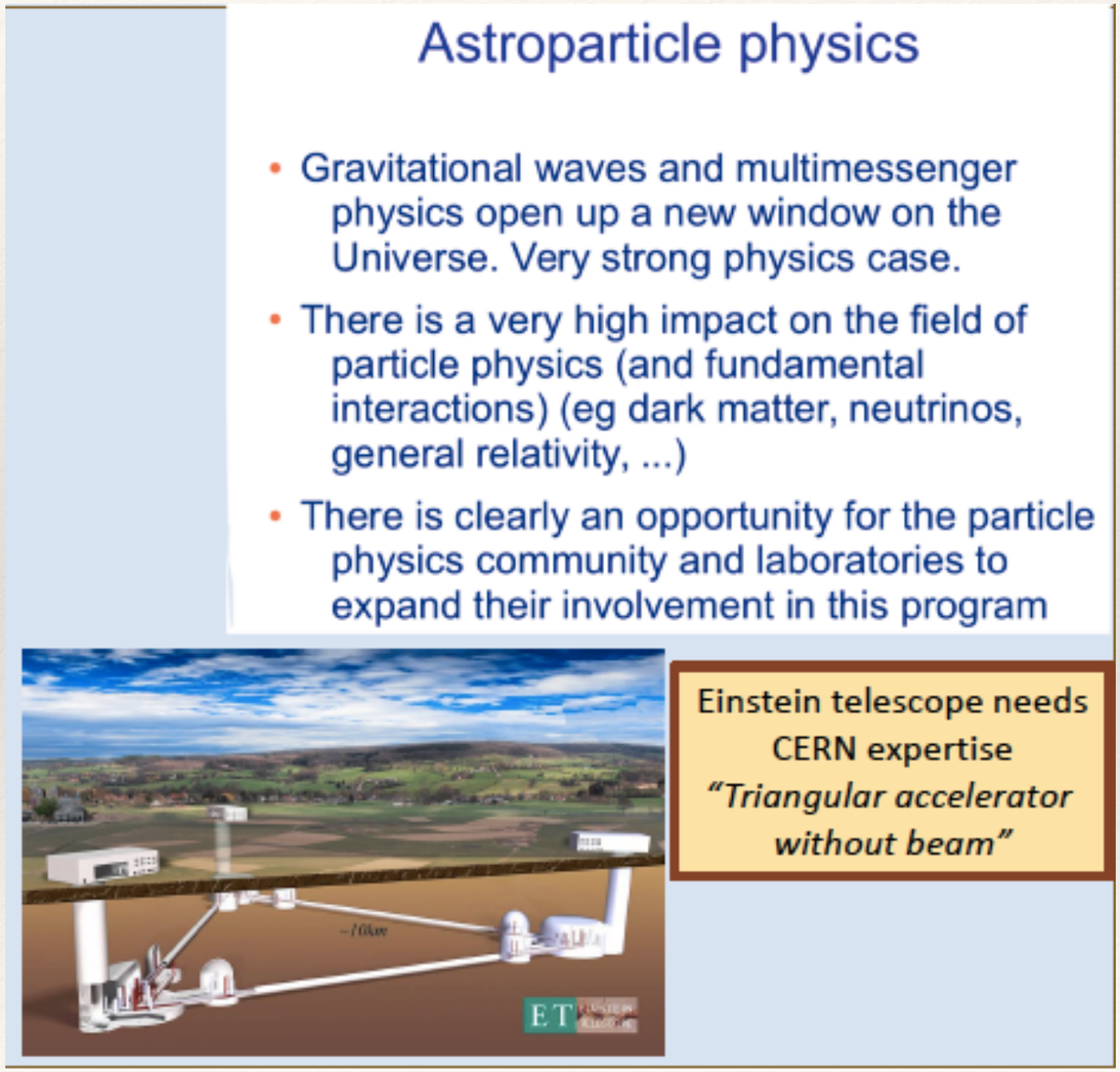
- CERN's 2019 Medium Term Plan, contains extended period of budget deficit
- "In the current financial situation: not possible, before 2026, to finance any new projects recommended by the 2020 ESPP update (e.g. in the area of Physics Beyond Colliders) nor to support both CLIC and FCC at level needed to prepare TDRs by next ESPP update(~ 2026)" (F. Gianotti)
- Hence choices need to be made.



- Foreseen expenditure in High-Energy Frontier ~CHF30M/year until 2026 when it can grow to ~CHF90M/year.

Relationship to astroparticle

- 2013 recommendation "In the coming years, CERN should seek a closer collaboration with ApPEC on detector R&D with a view to maintaining the community's capability for unique projects in this field."



Physics potential of a LE-FCC-hh

- Cost minimization of hadron machine in 100 km tunnel.
- Magnetic field 6T, 1.9K, s=37.5TeV, integrated luminosity $10ab^{-1}$ in 20 years.
- Rough estimate of physics reach
- e.g. Higgs physics (assume e+e- collider elsewhere in the world).
- Higgs self-coupling measured to 15% (c.f. 27TeV, 20%,100TeV, 6.5%)

Mangano

Ratios of cross sections

	$gg \to H$	VBF	WH	ZH	ttH	HH
σ(37.5 TeV) (pb)	230	19	5	3	5.8	0.26
27/14	2.7	2.7	2.3	2.4	4.8	3.8
37.5/14	4.2	4.4	3.3	3.5	9.5	7.0
100/14	15	16	10	13	53	34
37.5/27	1.6	1.6	1.5	1.5	2.0	1.8

Target precisions for Higgs processes that are complementary to measurements at e+e- machines

$\delta R/R$	HE-LHC	LE-FCC	FCC-hh
$R = B(H\to\gamma\gamma)/B(H\to 2e2\mu)$	1.7%	1.5%	0.8%
$R = B(H\to\mu\mu)/B(H\to 4\mu)$	3.6%	2.9%	1.3%
$R = B(H\to\mu\mu\gamma)/B(H\to\mu\mu)$	8.4%	6%	1.8%
$R = B(H\to\gamma\gamma)/B(H\to 2\mu)$	3.5 %	2.8%	1.4%