

LHC au LPC : 30 ans déjà ...
20 ans encore. Et après ?

Stéphane Monteil,
Clermont University, LPC-IN2P3-CNRS.

- Notre Science, la physique des Hautes Energies, réclame des instruments, dont la définition technique et les financements dépassent l'échelle des individus ou des laboratoires nationaux.
- Les acteurs du futur dont nous discuterons dans ces planches:
 - Les machines d'Est en Ouest: ILC, CEPC, FCC, CLIC, C3, mu-collider.
 - Les instances: ESPP (stratégie européenne pour la PP), Snowmass (l'équivalent US), ECFA (une étude a démarré pour comparer les machines en vie de la prochaine ES), ICFA.

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It's a long way to the top if you wanna rock'n'roll — Bon Scott

1964 Electroweak unification

Neutral current discovery in 1973 by Gargamelle (CERN).

1979 Glashow, Salam and Weinberg get the Nobel.

1971 EW loops and RN

Top quark mass predicted by LEP, CERN (from M_Z and other EWPO).

Top quark discovered by CDF, FNAL.

1999 t'Hooft and Veltman get the Nobel.

1973 CP violation

The B -factories establish that the KM paradigm is the dominant source of CP violation in K and B particle systems.

2008 Kobayashi and Maskawa get the Nobel.

1964 Fundamental Scalar

Higgs boson mass cornered by LEP (EWPO) and Tevatron (top and W mass).

An alike Higgs boson discovered where said at LHC.

2013 Englert and Higgs get the Nobel.

- La prochaine machine sera un programme de long terme.
- Est-ce raisonnable ? Ca l'a été !
- La précédente stratégie européenne → 70 ans !

PHYSICS WITH VERY HIGH ENERGY

e^+e^- COLLIDING BEAMS

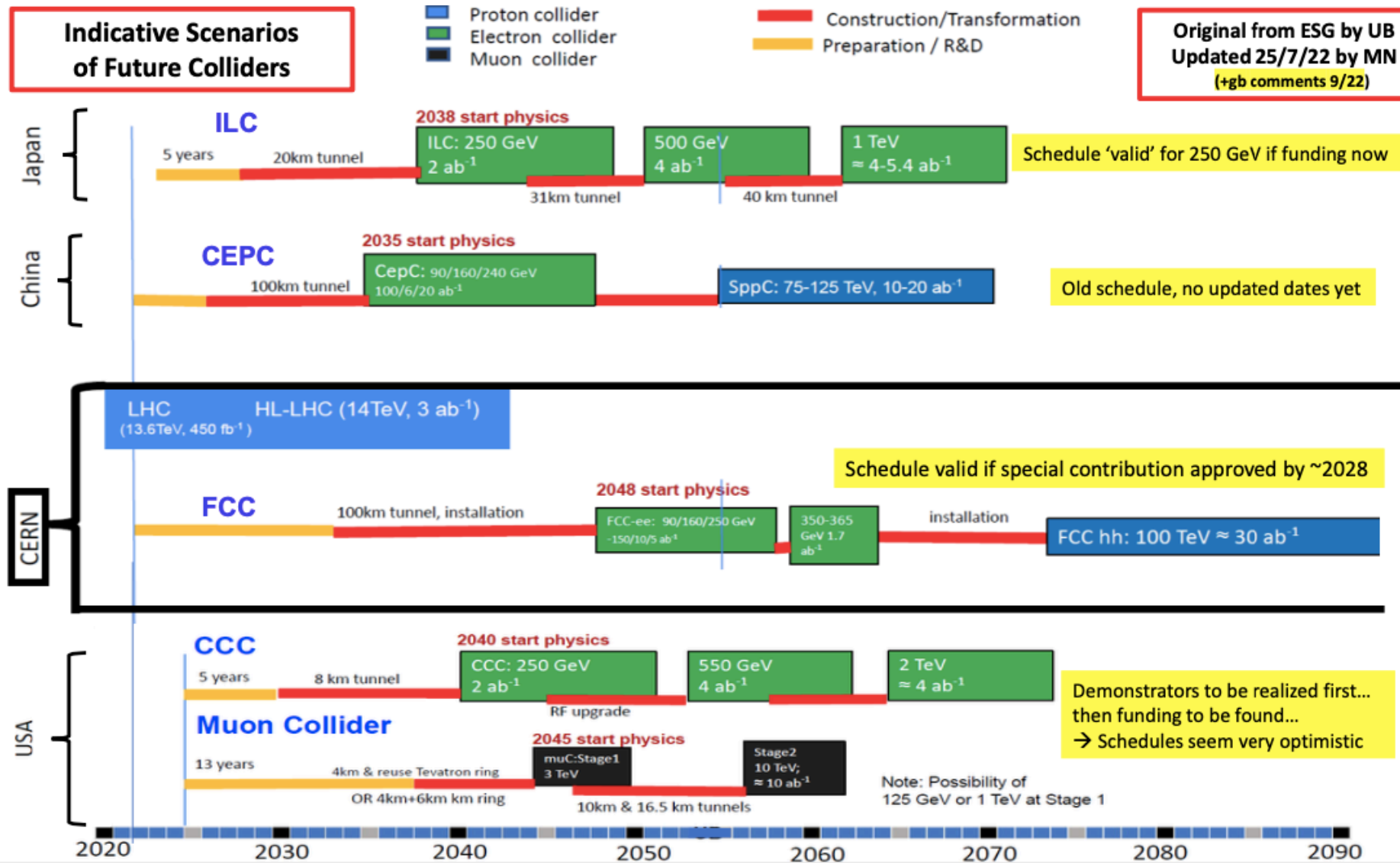
CERN 76-18
8 November 1976

L. Camilleri, D. Cundy, P. Darriulat, J. Ellis, J. Field,
H. Fischer, E. Gabathuler, M.K. Gaillard, H. Hoffmann,
K. Johnsen, E. Keil, F. Palmonari, G. Preparata, B. Richter,
C. Rubbia, J. Steinberger, B. Wiik, W. Willis and K. Winter

ABSTRACT

This report consists of a collection of documents produced by a Study Group on Large Electron-Positron Storage Rings (LEP). The reactions of

Les machines



- Celle de 2013:

Summary: European Strategy Update 2013 *Design studies and R&D at the energy frontier*

....“to propose an ambitious **post-LHC accelerator project at CERN** by the time of the next Strategy update”:

- d) **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 programme, including high-field magnets and high-gradient accelerating structures,***
 - **in collaboration with national institutes, laboratories and universities worldwide.**
 - <http://cds.cern.ch/record/1567258/files/esc-e-106.pdf>



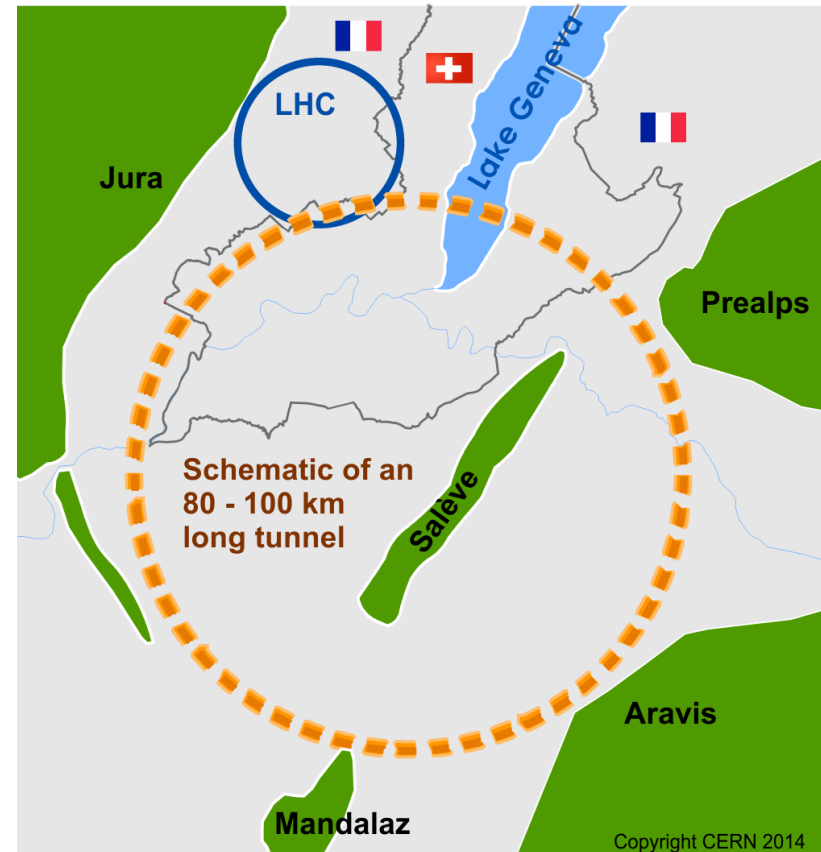
Future Circular Collider Study
Michael Benedikt
FCC Kick-Off 2014

3

- Au moment des résultats de LHC Run II, produire une vision éduquée pour le prochain tour de la stratégie **en 2020.**

Former une coll. international
(hébergée par le CERN) pour étudier:

- 100 TeV pp -collider (FCC- hh) as long term goal, defining infrastructure requirements.
- e^+e^- collider (FCC- ee) as potential first step.
- $p-e$ (FCC- he) as an option.
- 80-100 km infrastructure in Geneva area.
- Conceptual design report and cost review for the next european strategy → 2020.



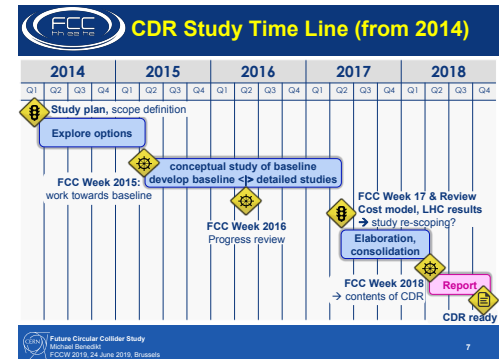
C'est fait !

Status of global FCC Collaboration

136 Institutes
32 Companies
34 Countries

EC H2020

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Results of FCC Conceptual Design Study

EPJ C Particles and Fields
EPJ ST Special Topics

FCC-ee: The Lepton Collider
Future Circular Collider Conceptual Design Report Volume 2
Michael Benedikt et al. (Eds.)

FCC Physics Opportunities
Future Circular Collider Conceptual Design Report Volume 1
Michael Benedikt et al. (Eds.)

FCC-hh: The Hadron Collider
Future Circular Collider Conceptual Design Report Volume 3
Michael Benedikt et al. (Eds.)

High Energy Large Hadron Collider
Future Circular Collider Conceptual Design Report Volume 4
Frank Zimmermann et al. (Eds.)

more than 1350 contributors from 350 institutes, a truly global collaboration and effort as suggested by the EPPSU 2013

Study Documentation:

4 CDR volumes submitted to EPJ in December 2018.

- FCC Physics Opportunities
- FCC-ee
- FCC-hh
- HE-LHC

Preprints available since 15 January 2019
<http://fcc-cdr.web.cern.ch/>

CDR presentation during welcome event this evening.

Paper copies can be requested at
<http://get-fcc-cdr.web.cern.ch>

Next stages (CDR+, TDR) are subjected to the ESPP update outcome.

Three recommendations:

- *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;*
 - To realize a machine at the energy frontier, high field magnets with at least 16T are mandatory and far from industrialisation, development of HTS magnets reaching higher fields should be pursued
- *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.*
 - Feasibility study should be carried out before the next Strategy Update to allow for decision to be taken
 - technical feasibility, administrative implications and questions of implementation in the Geneva area including tunnelling and environmental impact)
 - financial feasibility for construction and operation, including additional resources from international partners and start establishing the global frame for the project.
- *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.*

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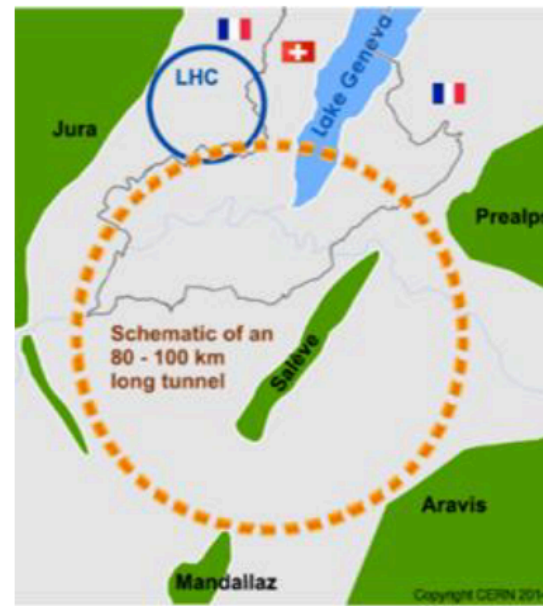
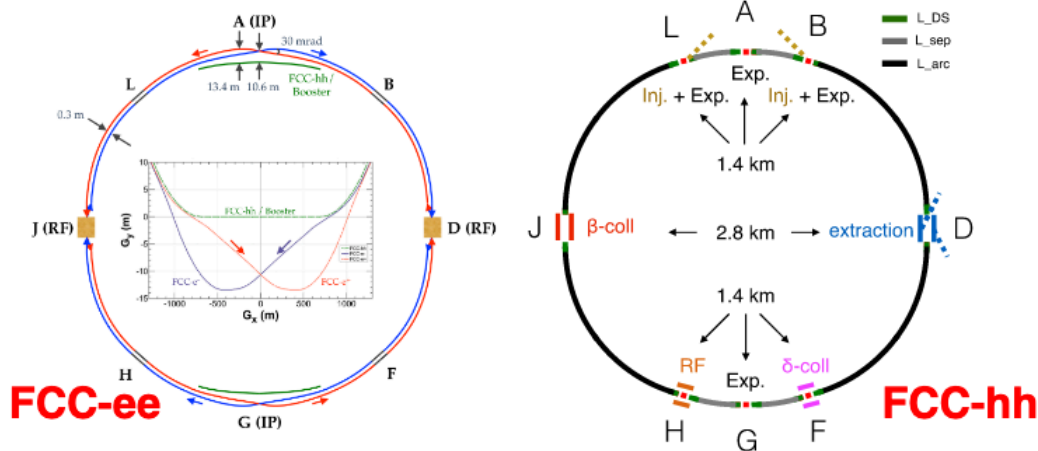
“the vision is to prepare a Higgs factory, followed by a future hadron collider with sensitivity to energy scales an order of magnitude higher than those of the LHC ” ESPP 2020 d’après d’Hondt (ECFA).



The FCC integrated program inspired by successful LEP – LHC programs at CERN

Comprehensive cost-effective program maximizing physics opportunities

- Stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & top factory at highest luminosities
- Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options
- Complementary physics
- Common civil engineering and technical infrastructures
- Building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of HEP after HL-LHC



Future Circular Collider Study
Michael Benedikt
FCCIS kick-off meeting, 9 November 2020

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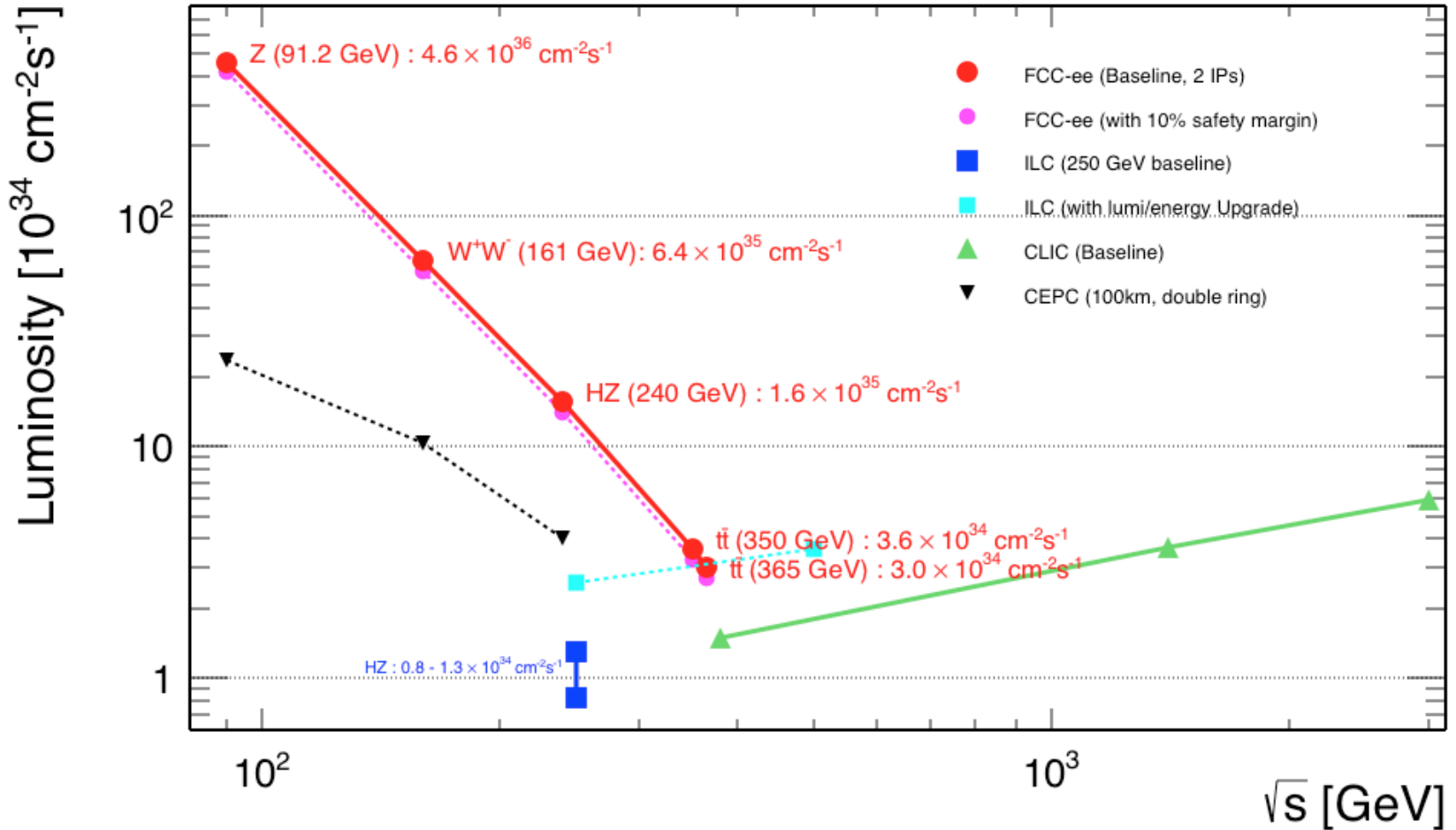
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L’étude de faisabilité est en route pour la prochaine stratégie.

- FCC-*ee* can’t happen before the completion of the HL-LHC program.
- FCC-*ee* shall happen seamlessly after HL-LHC.
- FCC-*hh* is foreseen after FCC-*ee*. The Higgs Physics program is inclusive (FCC-*hh* invincible for trilinear H couplings).



- Snowmass process was very productive
 - Despite of COVID
- 2014 P5 continuing construction projects are strongly supported
 - And will require substantial funding for the coming 5+ years
- Higgs factory is considered as the next preferred option for the energy frontier collider
 - 10 options are presented with FCCee among mostly discussed
- We expect no “decision” about next Higgs factory during this P5 process
 - Rather to emphasize the importance of R&D for accelerators, detectors, physics
- Next Snowmass/P5 might be sooner vs 8-10 years from now
 - Depends on new scientific results, convergence with existing projects (funding) and interest around the world to host Higgs factory
- If CERN will decide to build FCCee US will participate and contribute



- Note that you do the LEP in a minute at FCC-ee!

- 1) Find a new heavy particle at the Run III of LHC:
 - HL-LHC can study it to a certain extent.
 - If mass is small enough (and couples to electrons), CLIC can be the way.
 - Larger energies are needed to study (find) the whole spectrum.
 - The underlying quantum structure must be studied.

- 2) Find no new particle, but non-standard H properties
 - HL-LHC can study it to a certain extent.
 - Higgs factory.
 - Z , W , top factories for the quantum structure.
 - Energy frontier (also for precision measurements)

- 3) Find no new particle, standard H properties but flavour observables departing from SM:
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- 4) Find no new particle, standard H properties and flavour observables in SM:
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- Une longue tradition de physique e^+e^- avec LEP en point d'orgue.
- Des développements de détecteurs, calorimétrie en premier lieu, depuis 1999, à destination de l'ILC. Participation à CALICE.
- Le LPC est impliqué depuis 2014 dans le programme FCC du CERN. Edition du chapitre Flavours (parmi 6 chapitres de Physique) du Conceptual Design Report.
- Toujours à l'action dans la nouvelle phase de *Feasibility Study*. Avec une activité détecteur émergente. Avec un groupe de qqs physiciens et ITA.
- On a réussi le LHC et construit des compétences. Il faut en même temps que réussir HL-LHC préparer un futur désirable en Europe. Allons-y!

