A DUMMIES GUIDE TO ...

FCC

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CROHEP Meeting
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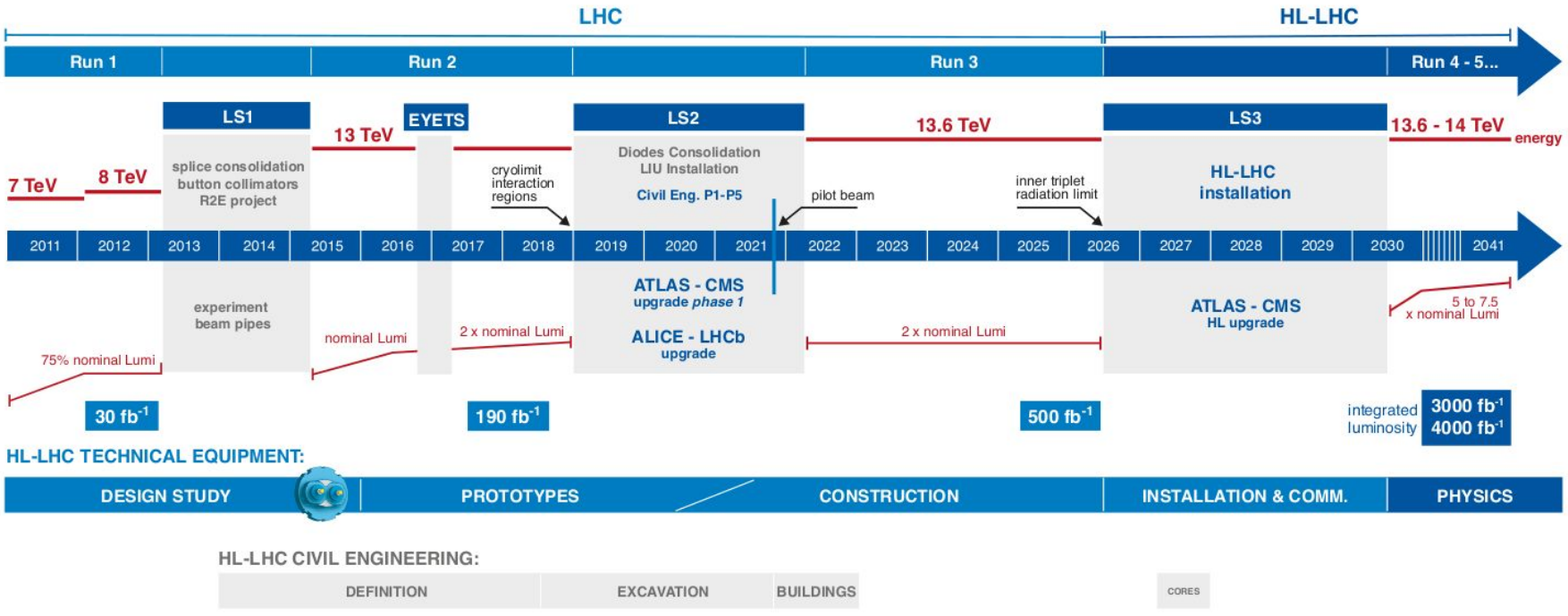
Disclaimer

- By no means an exhaustive overview of the subject
- Presenting only basic outlines and key features
- See references at the end for more details on physics goals and opportunities as well as hardware design choices and parameters

LHC / HL-LHC Plan

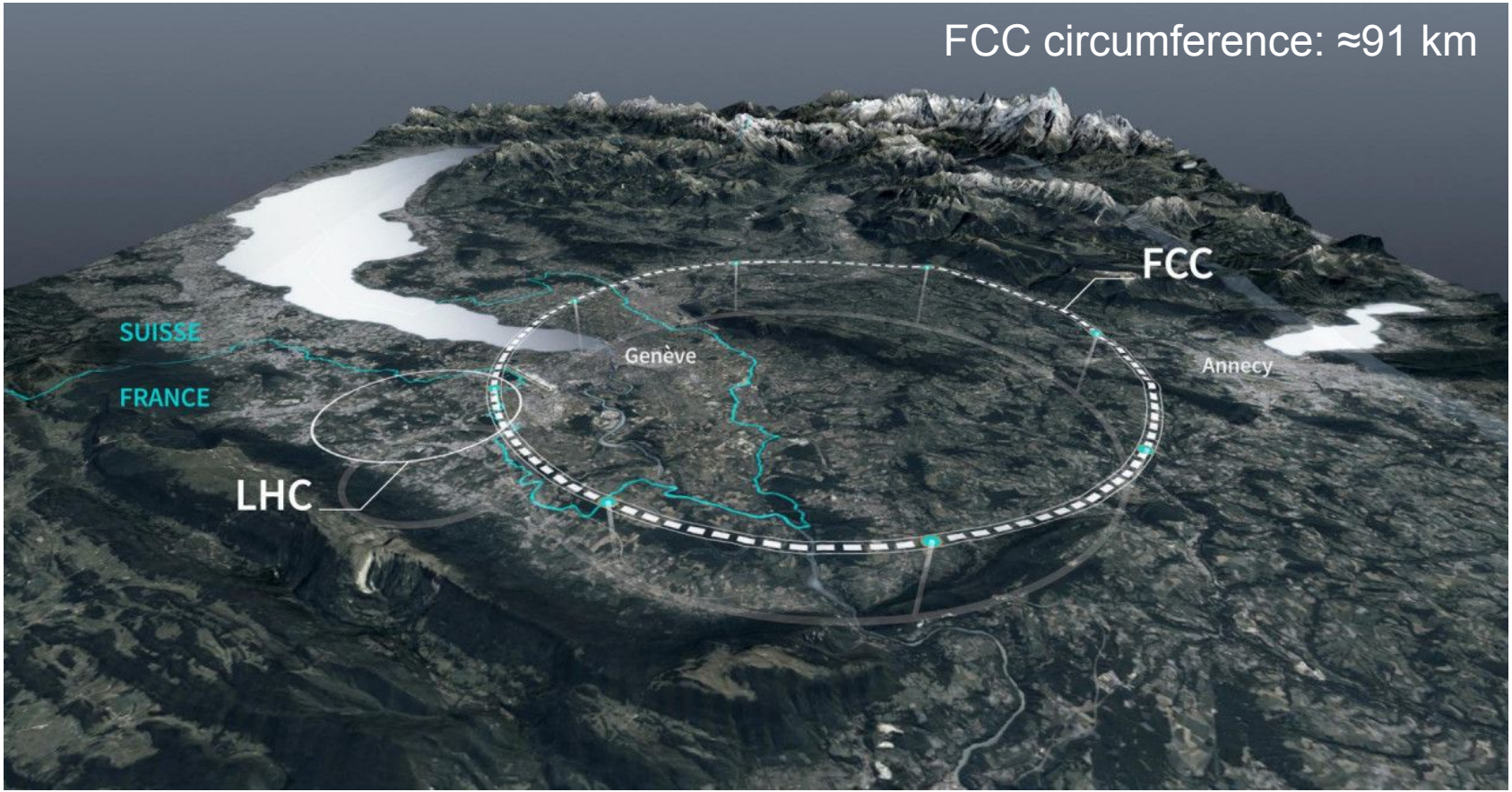


What is FCC?

FCC = Future Circular Collider

- Proposed next-generation particle collider at CERN aimed at exploring fundamental physics beyond the capabilities of the LHC
- Significantly larger and more powerful than the LHC
- Represents CERN's long-term vision for advancing our understanding of the universe and pushing the boundaries of human knowledge in particle physics

FCC layout

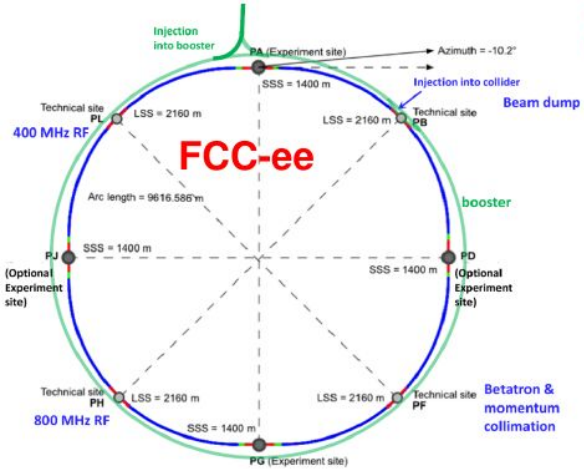

FCC circumference: ≈91 km
FCC
SUISSE
FRANCE
Genève
Annecy
LHC

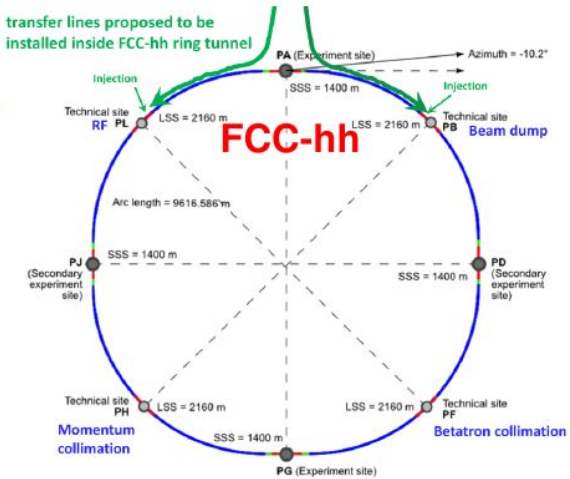
FCC-ee and FCC-hh

Integrated FCC plan consists of 2 stages:

Stage 1: **FCC-ee** as a high luminosity Higgs, electroweak and top factory with center-of-mass energies in the 88–365 GeV range. Technologically ready

Stage 2: **FCC-hh** as an energy frontier (~100 TeV) proton-proton collider. Also capable of providing heavy ion collisions. Technologically not yet ready





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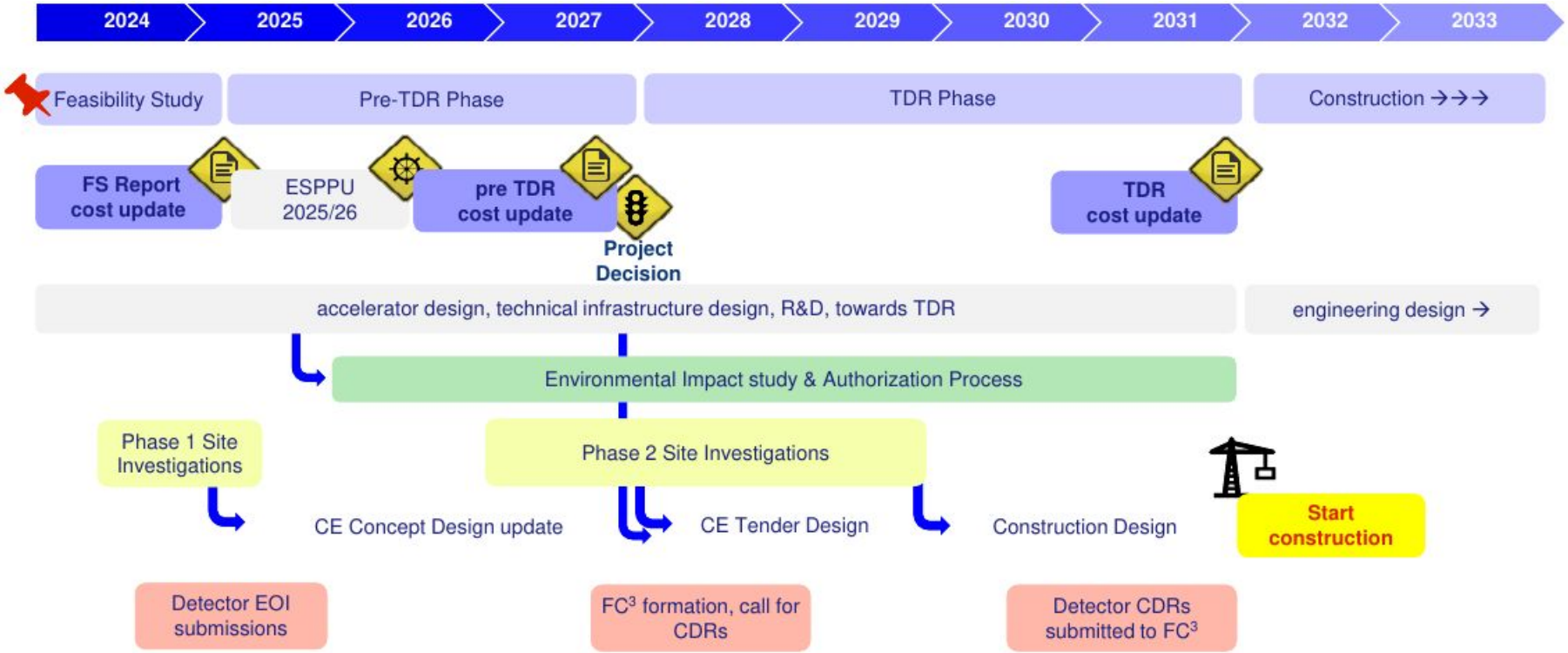
- Complementary and synergetic physics programs
- Common civil engineering and technical infrastructure, building on and reusing existing infrastructure at CERN
- Integrates well with the HL-LHC timeline

Tentative timeline to construction



Price tag*

- **7.6 GCHF** for the common civil engineering and technical infrastructure
- **4 GCHF** for the FCC-ee collider and injector
- **17 GCHF** for the FCC-hh collider and injector (of which 9.4 GCHF for the magnets)

*Numbers taken from Ref. [1]

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Some numbers for comparison:

- Cost of LHC construction: 4.3 GCHF
- Estimated cost of ILC (without site construction): 6.5 GCHF
- Estimated cost of the first stage of CLIC: ~6 GCHF

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FCC experiments would be an extra cost. For comparison, the total cost of all LHC detectors was ~1.5 GCHF

*Numbers taken from Ref. [1]

Physics goals

- Precision Higgs, electroweak and top measurements
- Investigation of electroweak symmetry breaking mechanism
  - Including the nature of electroweak phase transition with possible implications on the observed baryon asymmetry
- Searches for new physics beyond the standard model
  - Including the nature of dark matter, the origin of neutrino masses, the hierarchy problem, etc.
- Exploration of flavor physics
- Investigation of QCD at the energy frontier
- Exploration of quark-gluon plasma

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Energy scale of new particles or phenomena largely unknown → achieving greater sensitivity, higher precision, and increased energy reach offered by FCC essential

Status of FCC global collaboration

Increasing international collaboration as a prerequisite for success:
→links with **science, research & development** and **high-tech industry** will be essential to further advance and prepare the implementation of FCC

141 Institutes

32 countries + CERN

FUTURE CIRCULAR COLLIDER
Feasibility Study

FCC Feasibility Study:
Aim is to further increase the collaboration, on all aspects, in particular on Accelerator and Particle/Experiments/Detectors

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Croatia currently not participating

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CEPC/SppC

CEPC = Circular Electron Positron Collider
SppC = Super proton-proton Collider

- FCC-like collider proposal by the Chinese HEP community
- ~100 km circumference
- Estimated cost: 5 GCHF
- At an advanced planning stage
- Approval by Chinese government expected by the end of 2025 (FCC approval by ~2028)

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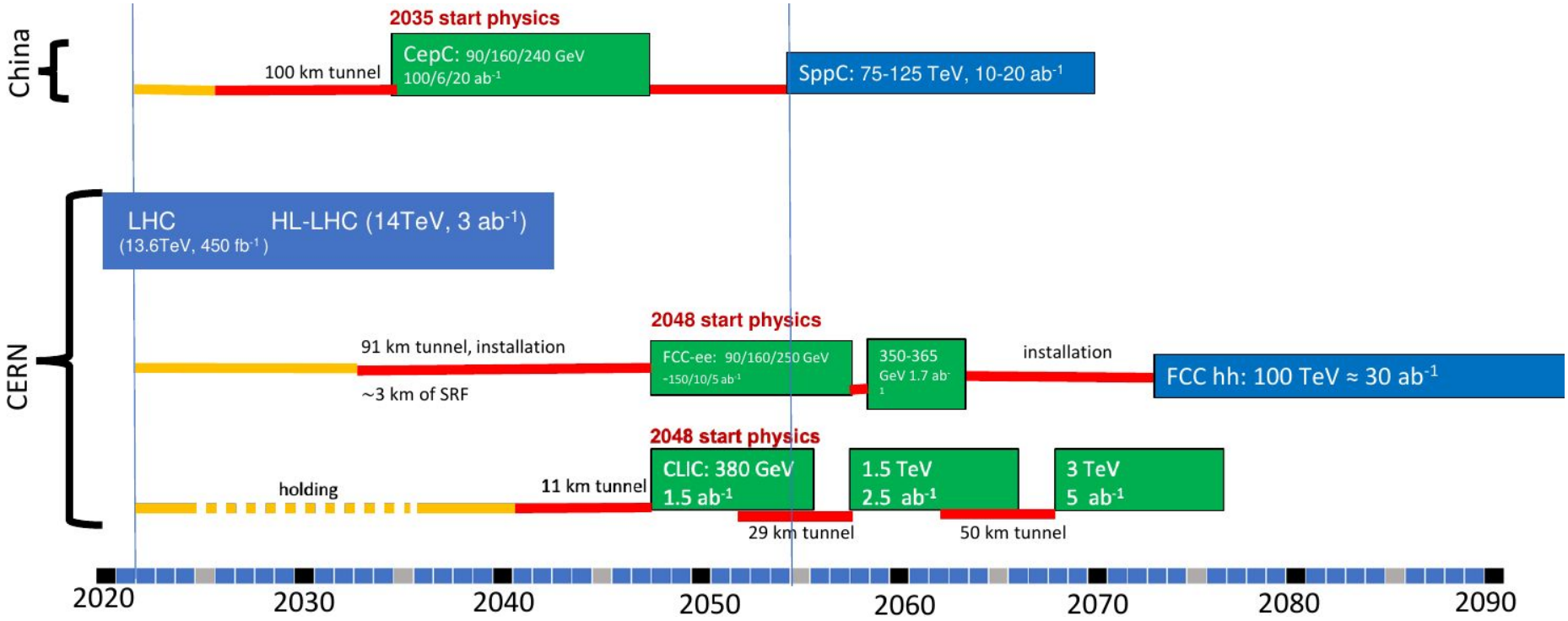
NEWS | 17 June 2024 | Correction 18 June 2024

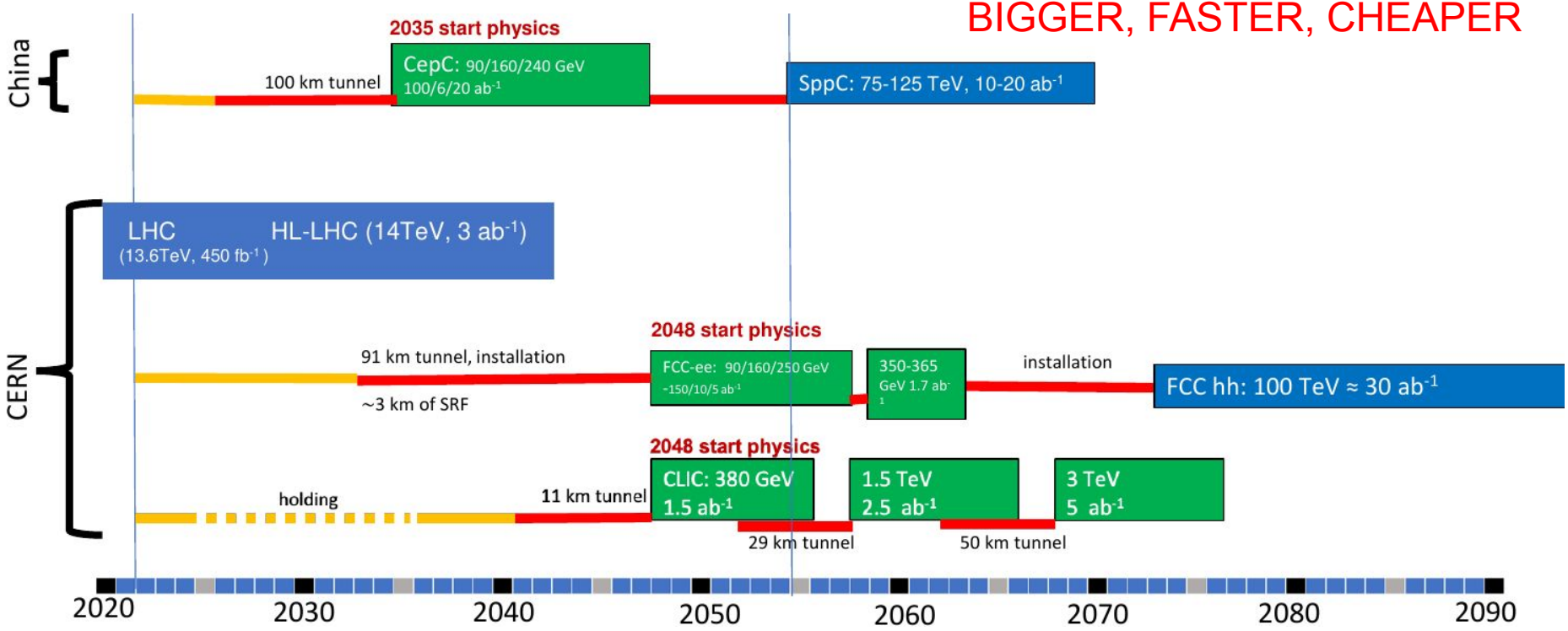
China could start building world's biggest particle collider in 2027

The US$5 billion facility would be cheaper, bigger and faster to build than a similar one proposed by European scientists.

FCC vs CEPC/SppC timeline



FCC vs CEPC/SppC timeline



Concluding remarks

- High energy physics is one of few areas where Europe is the global leader. FCC at CERN would secure European leadership for the foreseeable future
- FCC is a large and ambitious project that offers extraordinary possibilities for investigating the key open questions in particle physics
- The studies done so far have shown that FCC is the best and most cost effective future project on a path toward a 100-TeV hadron collider in Europe
- CERN has a proven track record of running large scientific projects
- It goes without saying that for our local HEP community having the next big collider in Europe would be a preferred option

Some personal thoughts

- Projects like FCC require a global effort. Current geopolitical landscape certainly not making global collaboration easier
- We have to be honest and admit that golden days of particle physics are over
  - There are other cool kids on the block. Is our story inspiring enough to attract the best and brightest young minds?
  - Used to be at the forefront of technological development but now often catching up with developments outside our field
- Tax payers and policy makers do not care about measuring this or that coupling to a sub-percent precision. They care about return on their investment. We have a lot to offer (human capital, technology, innovation) but this needs to be better quantified and communicated
- If approved, CEPS will likely have a major impact on the future of CERN (we don't need two FCCs!)
- Unfavorable demographic outlook in the coming decades in most developed countries. Will the global HEP community be able to sustain projects like FCC? Perhaps AI developments will come to the rescue

“Progress in knowledge has no price”

Alain Blondel

References

[1] FCC-ee: Your Questions Answered, arXiv:1906.02693

[2] FCC Physics Opportunities : Future Circular Collider Conceptual Design Report Volume 1, DOI:10.1140/epjc/s10052-019-6904-3

[3] FCC-ee: The Lepton Collider : Future Circular Collider Conceptual Design Report Volume 2, DOI:10.1140/epjst/e2019-900045-4

[4] FCC-hh: The Hadron Collider : Future Circular Collider Conceptual Design Report Volume 3, DOI:10.1140/epjst/e2019-900087-0

[5] F. Zimmermann, Future Circular Colliders (FCC) – Status, Seminar at CERN

[6] F. Zimmermann, FCC feasibility study: current update, Presentation at the 114th Plenary ECFA Meeting

[7] K. Andre, FCC-ee Collider Design Overview, Talk at ICHEP 2024

[8] H. Yang, Status of the CEPC Project, Talk at ICHEP 2024

[9] X. Lou, CEPC-SppC general status and perspectives, Talk at 2024 LHC Days