The Future Circular Collider Feasibility Study

Michael Benedikt, CERN

Austrian FCC Meeting,
11 October 2021

photo: J. Wenninger

FCC hh ee he | EuroCirCol A key to New Physics | EASITrain | ARIES | FUTURE CIRCULAR COLLIDER Innovation Study | E-JADE | http://cern.ch/fcc | CERN

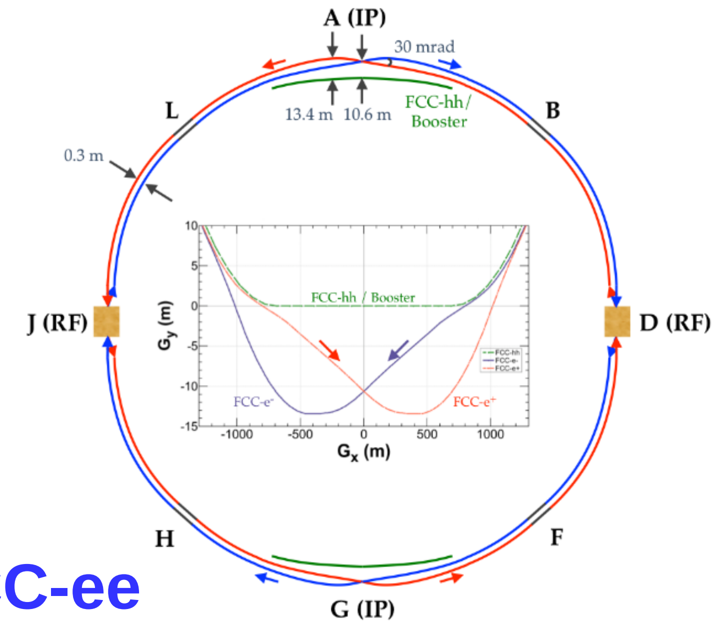
Work supported by the ***European Commission*** *under the* ***HORIZON 2020 projects EuroCirCol****, grant agreement 654305;* ***EASITrain,*** *grant agreement no. 764879;* ***ARIES****, grant agreement 730871,* ***FCCIS****, grant agreement 951754, and* ***E-JADE,*** *contract no. 645479*

European Commission | Horizon 2020 European Union funding for Research & Innovation

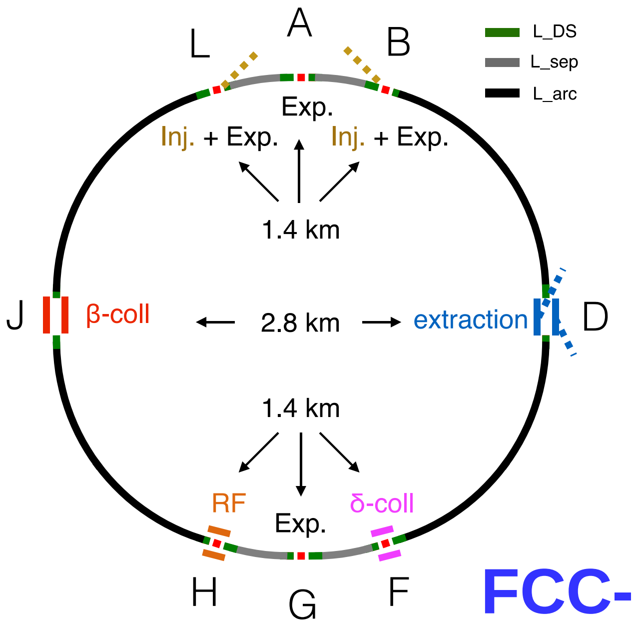
The FCC integrated program inspired by successful LEP – LHC programs at CERN

comprehensive long-term program maximizing physics opportunities

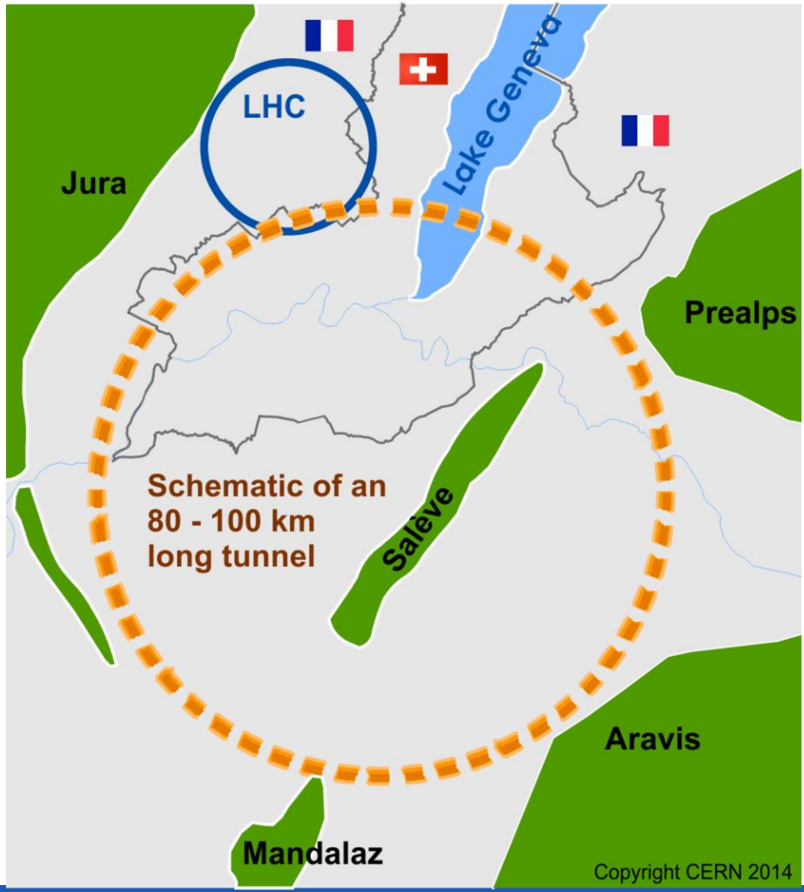
- **stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & top factory at highest luminosities**
- **stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options**
- complementary physics
- common civil engineering and technical infrastructures
- building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



FCC-ee



FCC-hh



FCC-ee figures of merit

Luminosity vs. capital cost

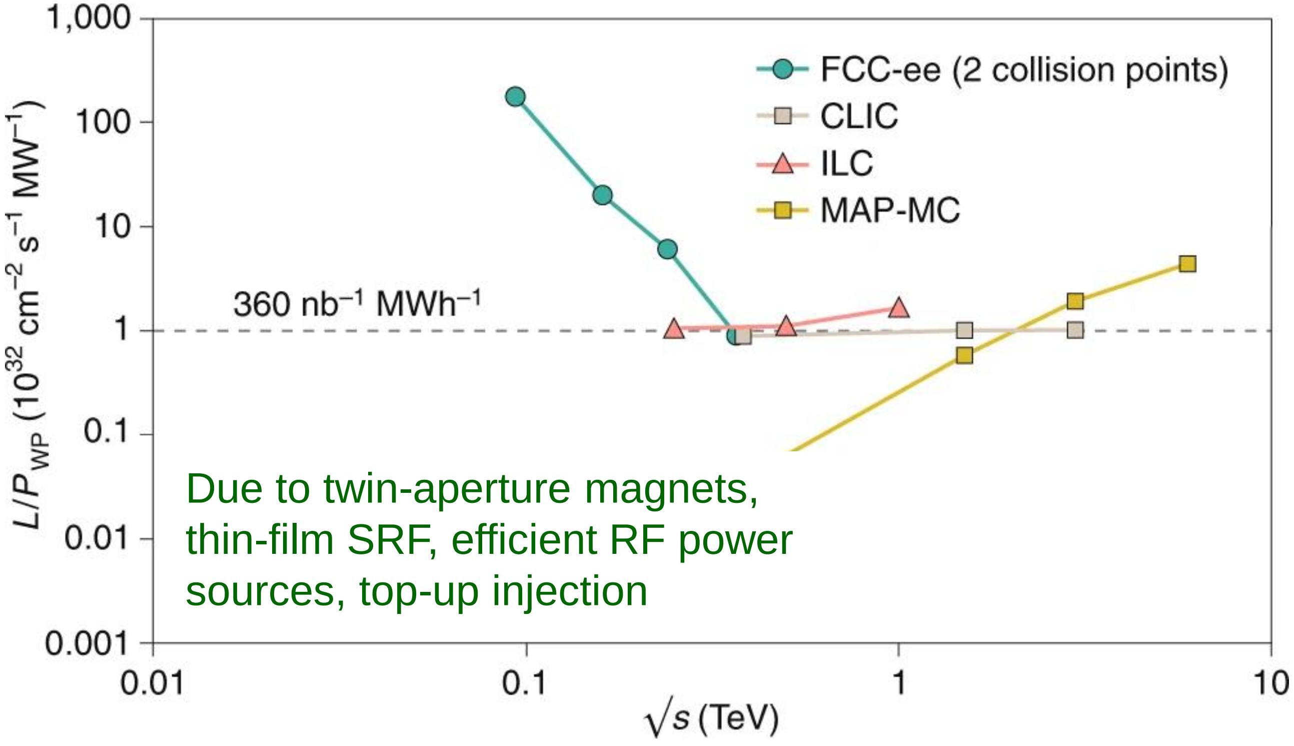
- for the H running, **with 5 ab^{-1} accumulated over 3 years and 10^6 H produced**, the total investment cost (~10 BCHF) corresponds to
  → **10 kCHF per produced Higgs boson**

- for the Z running with **150 ab^{-1} accumulated over 4 years and 5×10^{12} Z produced,** the total investment cost corresponds to
  → **10 kCHF per 5×10^6 Z bosons**

This is the number of Z bosons collected by each experiment during the entire LEP programme !

Capital cost per luminosity dramatically decreased compared with LEP !

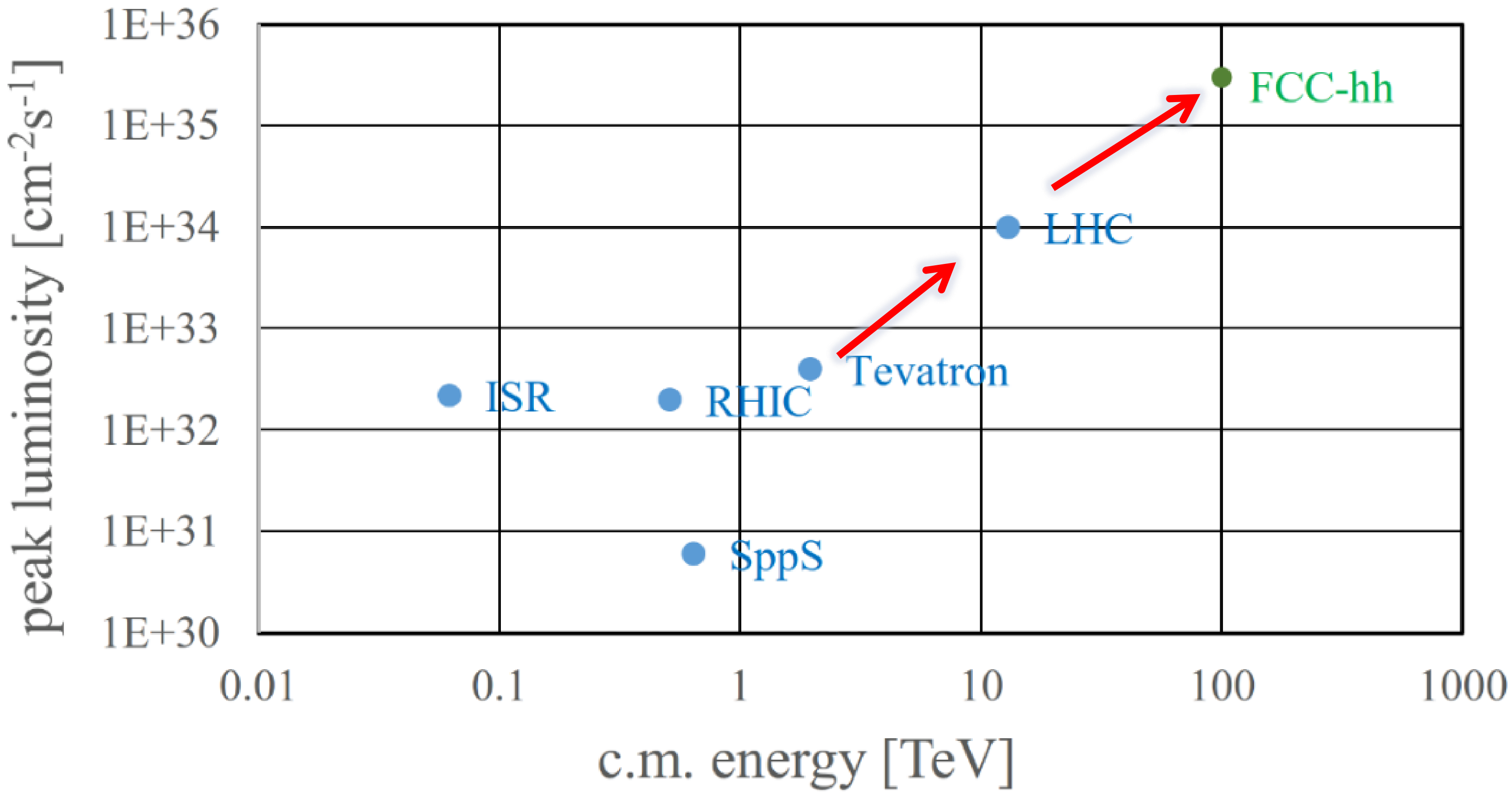
Luminosity vs. electricity consumption



Due to twin-aperture magnets, thin-film SRF, efficient RF power sources, top-up injection

Highest lumi/power of all H fact proposals
Electricity cost ~200 CHF per Higgs boson

FCC-hh: performance



order of magnitude performance increase in **energy & luminosity**

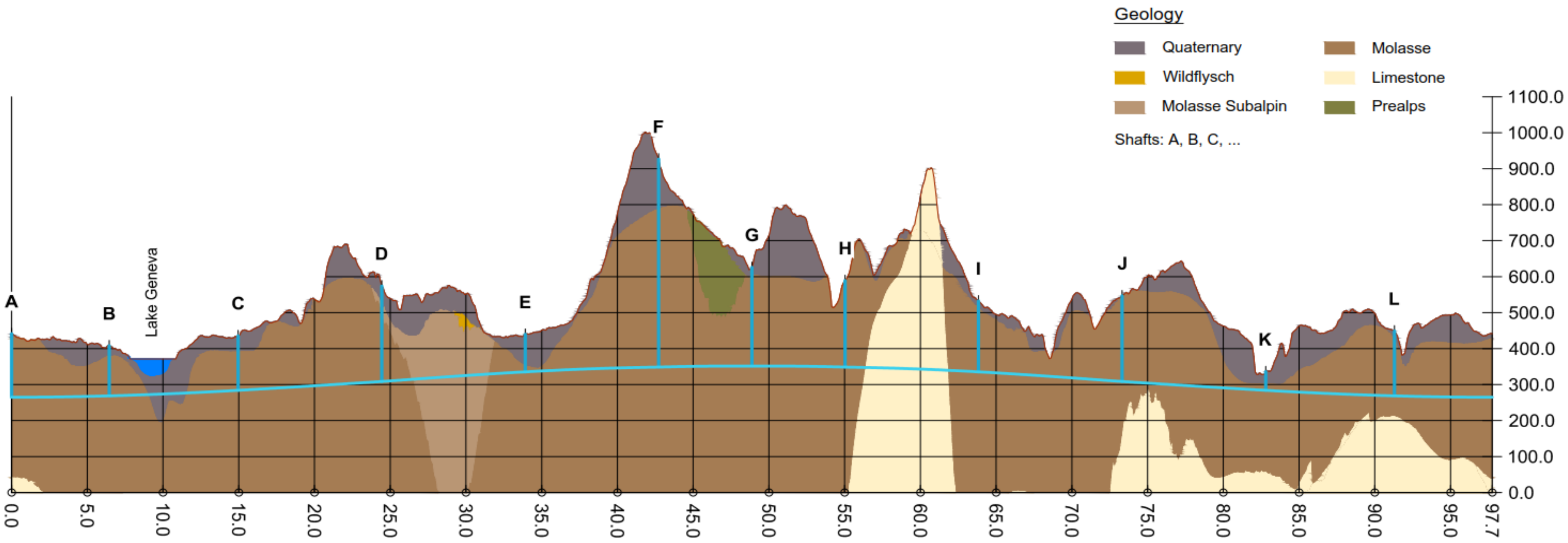
100 TeV cm collision energy (vs 14 TeV for LHC)

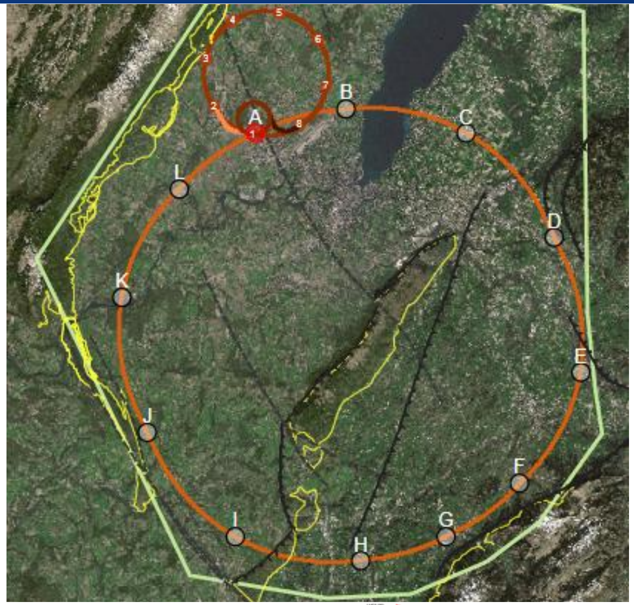
20 ab^{-1} per experiment collected over 25 years of operation (vs 3 ab^{-1} for LHC)

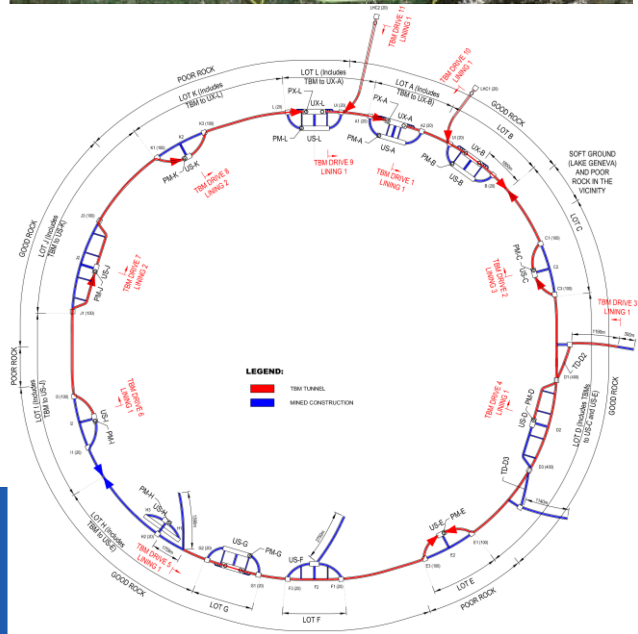
similar performance increase as from Tevatron to LHC

key technology: high-field magnets

FCC implementation - footprint baseline





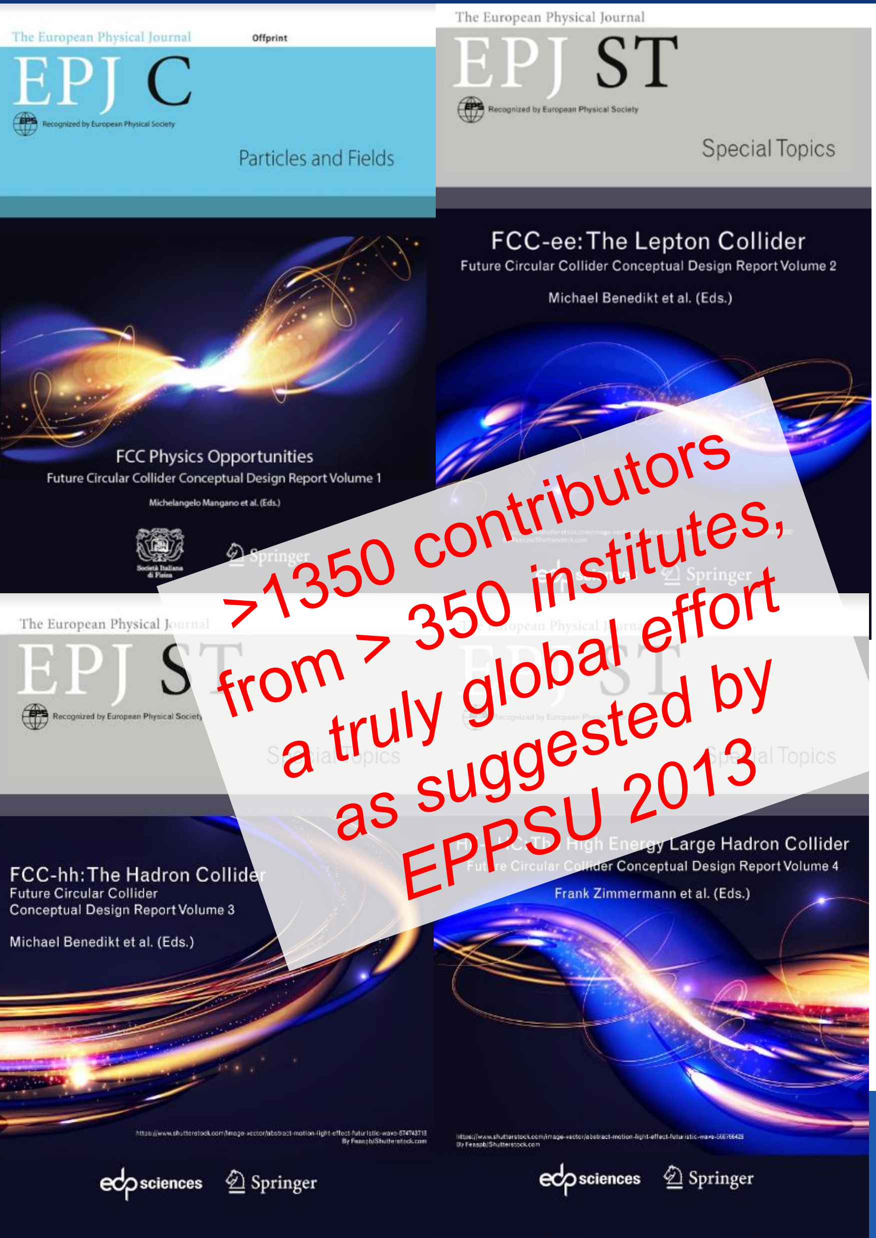


present baseline position was established considering:

- lowest risk for construction, fastest and cheapest construction
- feasible positions for large span caverns (most challenging structures)

- **90 – 100 km circumference**
- **12 surface sites with ~5 ha area each → recent studies on 8 surface s.**

FCC CDR & Study Documentation



- **FCC-Conceptual Design Reports:**
  - **Vol 1 Physics, Vol 2 FCC-ee, Vol 3 FCC-hh, Vol 4 HE-LHC**
  - CDRs published in **European Physical Journal C (Vol 1) and ST (Vol 2 – 4) [Springer]**

    EPJ C 79, 6 (2019) 474 , EPJ ST 228, 2 (2019) 261-623 ,

    EPJ ST 228, 4 (2019) 755-1107 , EPJ ST 228, 5 (2019) 1109-1382

- EPJ is a merger and continuation of *Acta Physica Hungarica, Anales de Fisica, Czechoslovak Journal of Physics, Fizika A, Il Nuovo Cimento, Journal de Physique, Portugaliae Physica* and ***Zeitschrift für Physik***. 25 European Physical Societies are represented in EPJ, including the DPG.
- **Summary documents provided to EPPSU 2019/20**
  - **FCC-integral, FCC-ee, FCC-hh, HE-LHC**
  - Accessible on http://fcc-cdr.web.cern.ch/

from ESPP Update 2020

High-priority future initiatives:

- 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**.

- "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**.."

FCC feasibility study 2021 – 25 & roadmap

Fabiola Gianotti: “CERN vision and goals until next strategy update” FCCIS Kick-Off, 9 Nov. 2020

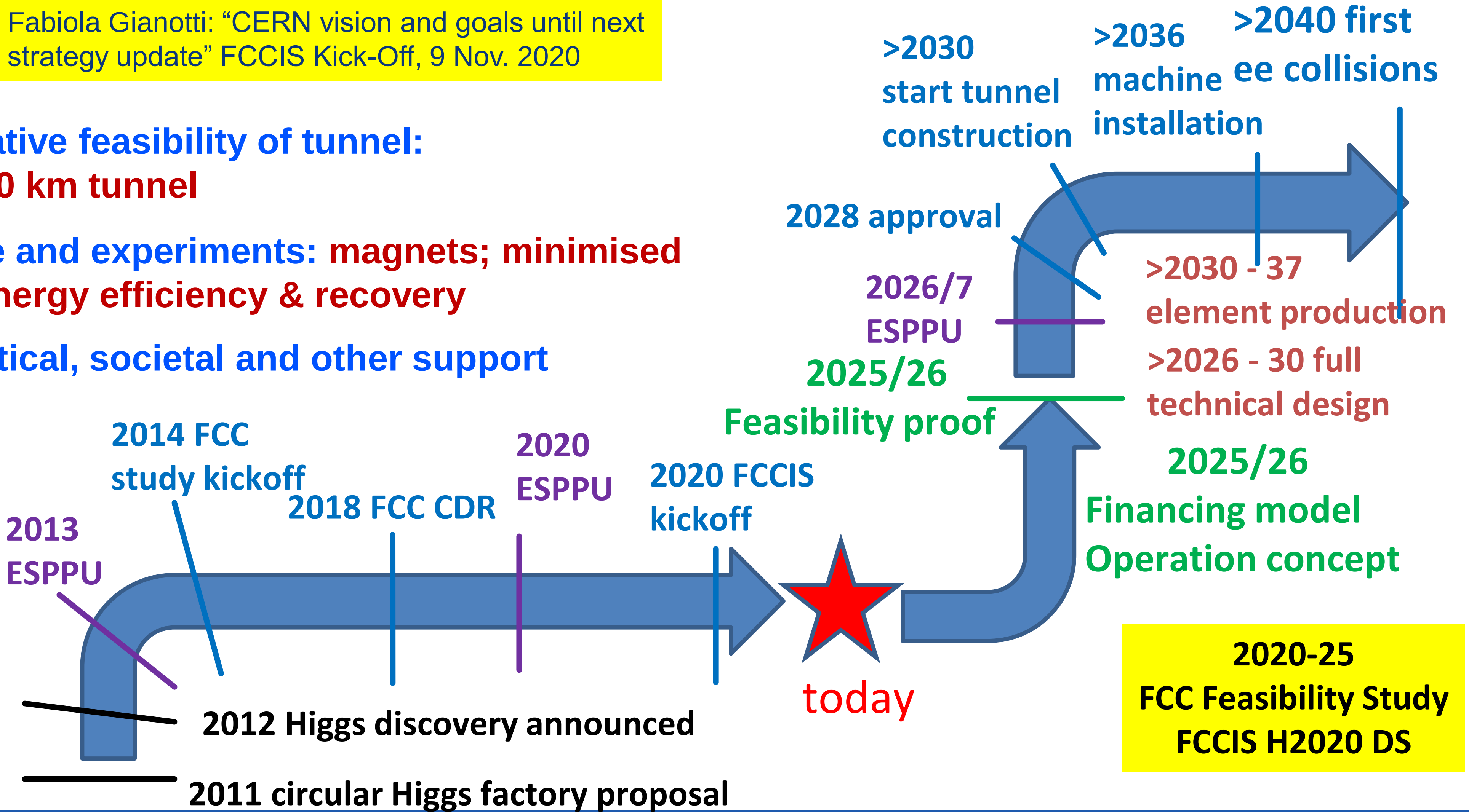
Highest priority goals:

Financial feasibility

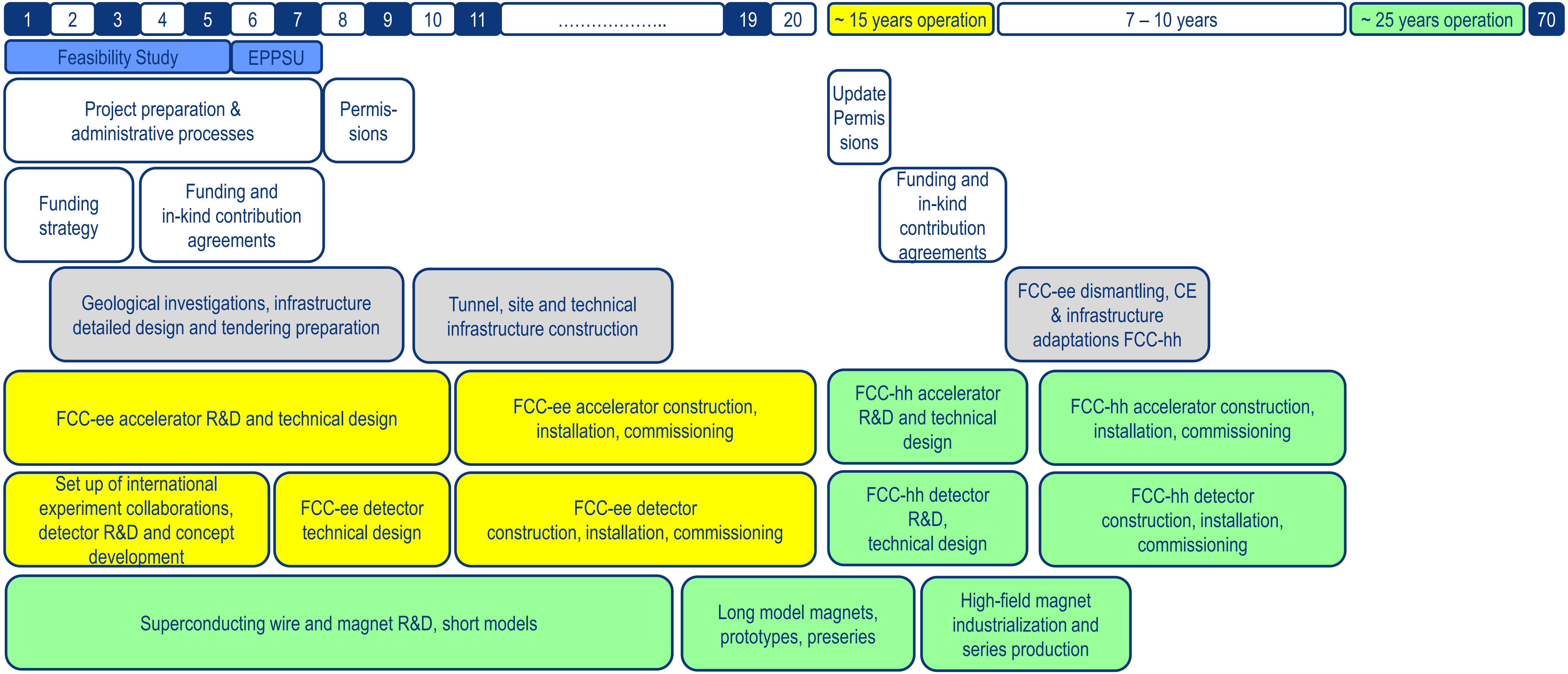
Technical and administrative feasibility of tunnel: no show-stopper for ~100 km tunnel

Technologies of machine and experiments: magnets; minimised environmental impact; energy efficiency & recovery

Gathering scientific, political, societal and other support

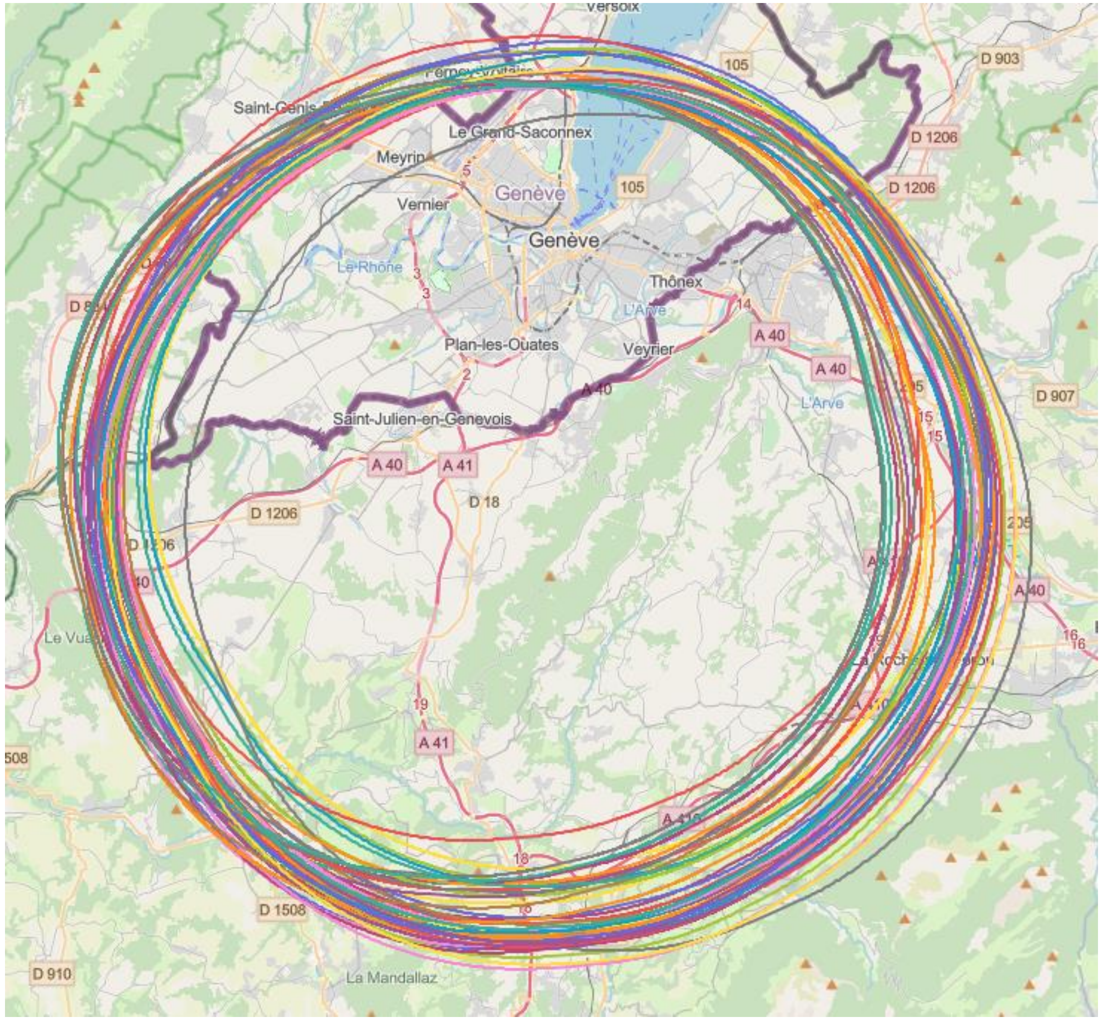


FCC integrated project technical schedule



Implementation studies with host states

- layout & placement optimisation across both host states, Switzerland and France;
- following "avoid-reduce-compensate" directive of European & French regulatory frameworks;
- diverse requirements and constraints:
  - **technical feasibility of civil engineering** and subsurface geological constraints
  - **territorial constraints on surface** and subsurface
  - **nature, accessibility**, technical infrastructure, resource needs & constraints
  - **optimum machine performance and efficiency**
  - economic factors including benefits for, and synergies, with the **regional developments**
  - …
- collaborative effort: FCC technical experts, consulting companies, government-notified bodies



FCC FS Placement Review - Conclusion

FUTURE CIRCULAR COLLIDER

Future Circular Collider

REPORT

FCC PLACEMENT STUDY REVIEW

Document identifier:	FCC-2106080000-GDI
Date:	08/06/2021
Work package/unit:	FCC Advisory Committee
Version:	V1.0
Status:	Final
Domain:	Accelerators
Keywords:	FCC

Abstract:

The FCC infrastructure is based on a 90 to 100 km circumference tunnel, accessed via more or less regularly spaced shafts with up to 12 surface sites. Placement of this infrastructure needs to take into account the underground geological conditions, territorial and environmental constraints as well as the physics performance that can be reached with the proposed colliders. Further optimisation must also balance cost, risk and other aspects. Placement studies already started during the conceptual design phase and were refined in cooperation with host state authorities. They were supported by civil engineering studies and the development of a geological model for the Geneva basin. Starting from a baseline layout, various geometries and placement scenarios have been developed. A down-selection through more detailed analysis of these variants is the next logical step towards identification of a preferred placement scenario that should then serve as reference for further studies on the feasibility of the entire FCC.

1.2. REVIEWERS

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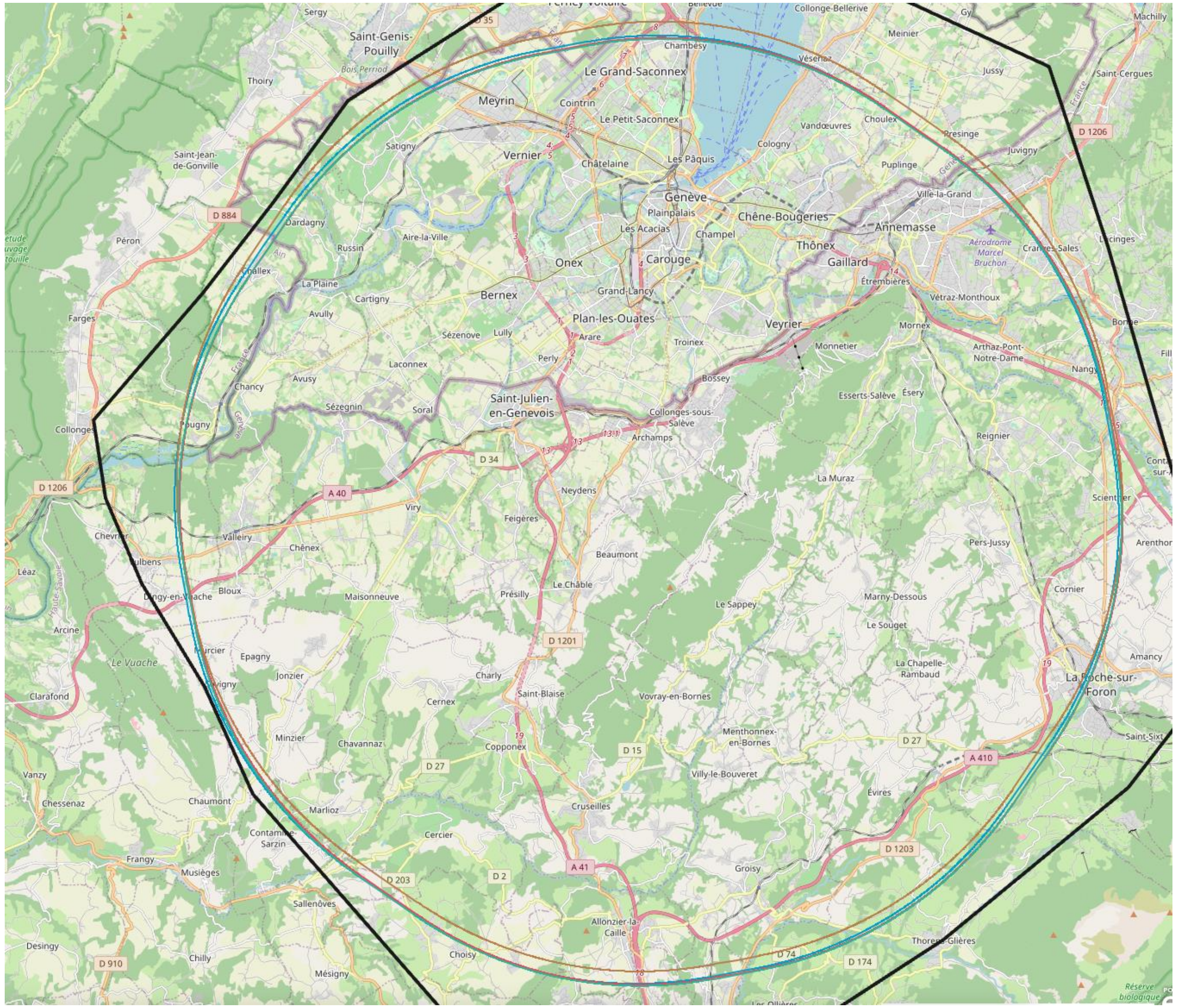
Main recommendations:

A. Given the limited resources, the FCC team needs to base future detailed studies on one concrete placement option. The lowest-risk 8-point option PA31-0.4 should be chosen as the preferred variant for carrying out the next concrete steps towards understanding the FCC feasibility.

B. In order to avoid the bias in favor of novelty, further work is needed in order to bring the study of the PA31-0.4 8-point option to the same level and even beyond as formerly achieved for the 12-point CDR footprint.

Detailed implementation studies

- Analysis of baseline scenario from review PA31-1.0 with automated search tool with enlarged perimeters around target areas for surface sites.
- More than 3’000’000 iterations on PA31-1.0 with different starting conditions revealed no better ranked scenarios in geological boundary area.
- Presently three scenarios maintained, optimised fallback scenarios 1.1 and 1.6 in addition to a baseline 1.0 scenario that will only be considered if 1.0 turns out to be incompatible from a territorial point of view.



Status of Global FCC Collaboration

increasing international collaboration as a prerequisite for success

34 Countries

EC H2020

30 Companies

147 Institutes

93 member states
16 associate member states
21 non-member states with observer status
17 other non-member states

Summary

- The European Strategy Update 2019/20 issued the **request for a feasibility study of the FCC integrated programme to be delivered by end 2025.**
- **The main activities of the FCC Feasibility Study are:**
  - **concrete local/regional implementation scenario** in collaboration **with host state authorities**,
  - accompanied by **machine optimization, physics studies and technology R&D**,
  - performed **via global collaboration** and supported by **EC H2020 Design Study FCCIS,**
  - in parallel **High Field Magnet R&D program** as separate line, to prepare for FCC-hh.
- Long term goal: **world-leading HEP infrastructure for 21st century** to push the particle-physics **precision and energy frontiers** far beyond present limits.
- **Success of FCC relies on strong global participation. Everybody interested is warmly welcome to join the effort!**