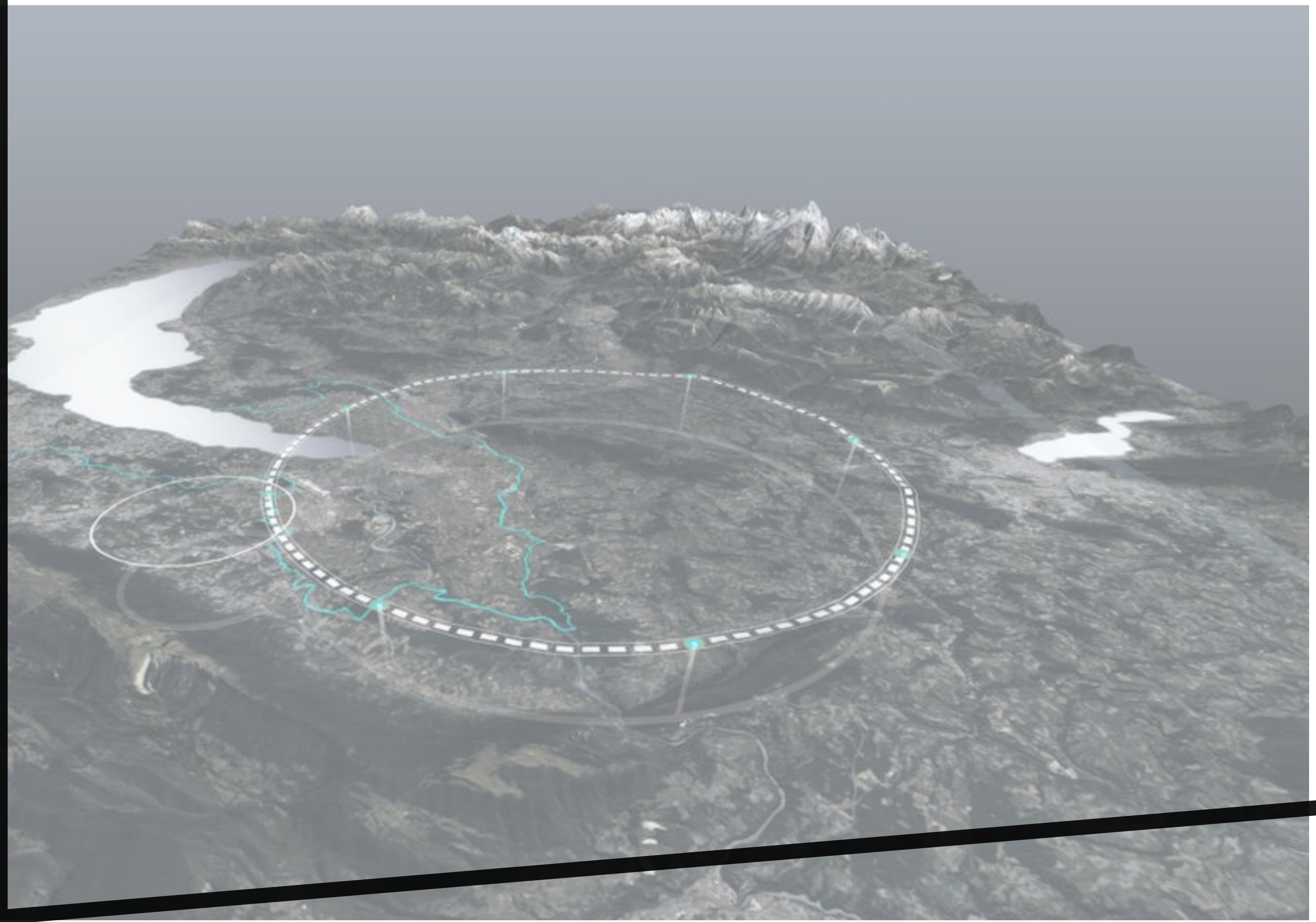
Status of FCC Feasibility Study

FC@DESY, March 15^{th} 2024



Christophe Grojean

DESY (Hamburg)
Humboldt University (Berlin)
CERN
(christophe.grojean@desy.de)

— on behalf of the FCC team—

1.
FCC feasibility study

The launch of the feasibility study.

"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."

— CERN council approved the Strategy and CERN management implemented it —

FCC Feasibility Study (FS) started in 2021 and will be completed in 2025.

Mid-term review in 2023.

Objectives of FCC feasibility study.

- Demonstration of the geological, technical, environmental and administrative feasibility of the tunnel and surface areas and optimisation of placement and layout of the ring and related infrastructure.
- Pursuit, together with the Host States, of the preparatory administrative processes required for a potential project approval to identify and remove any showstopper.
- Optimisation of the design of the colliders and their injector chains, supported by R&D to develop the needed key technologies.
- Elaboration of a sustainable operational model for the colliders and experiments in terms of human and financial resource needs, as well as environmental aspects and energy efficiency.
- Development of a consolidated cost estimate, as well as the funding and organisational models needed to enable the project's technical design completion, implementation and operation.
- Identification of substantial resources from outside CERN's budget for the implementation of the first stage of a possible future project (tunnel and FCC-ee).
- Consolidation of the physics case and detector concepts for both colliders.

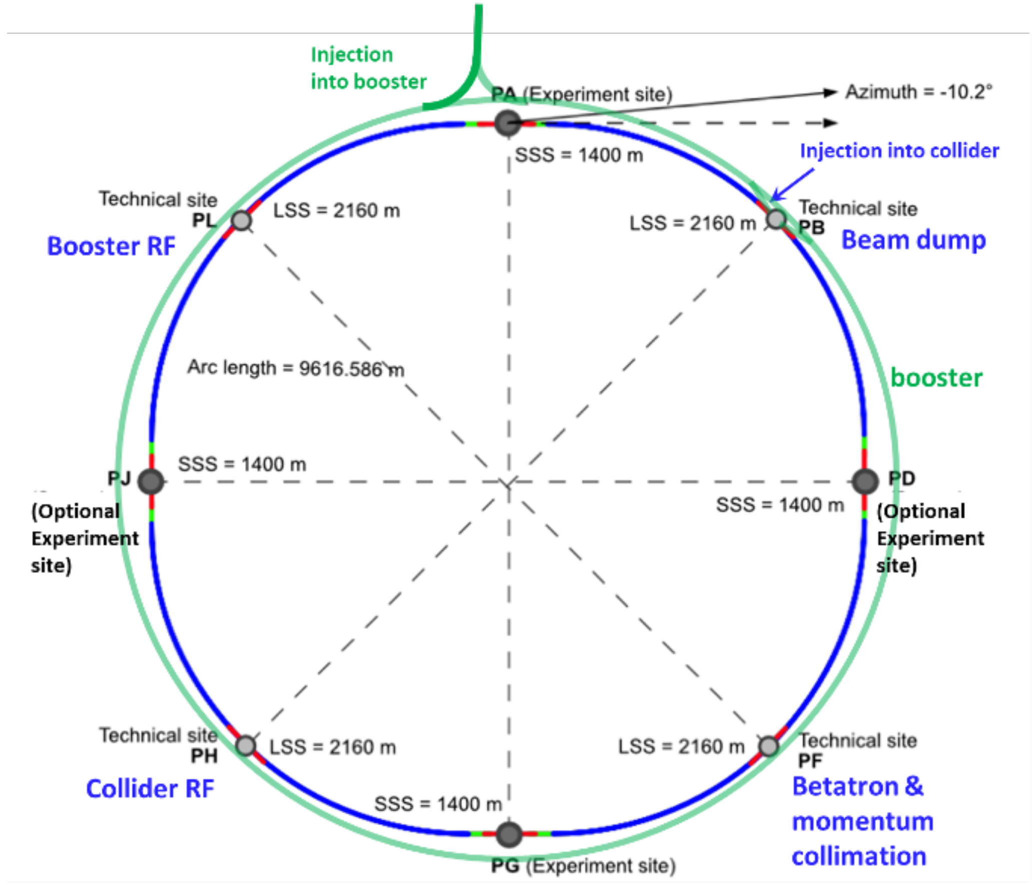
Optimized placement and layout.

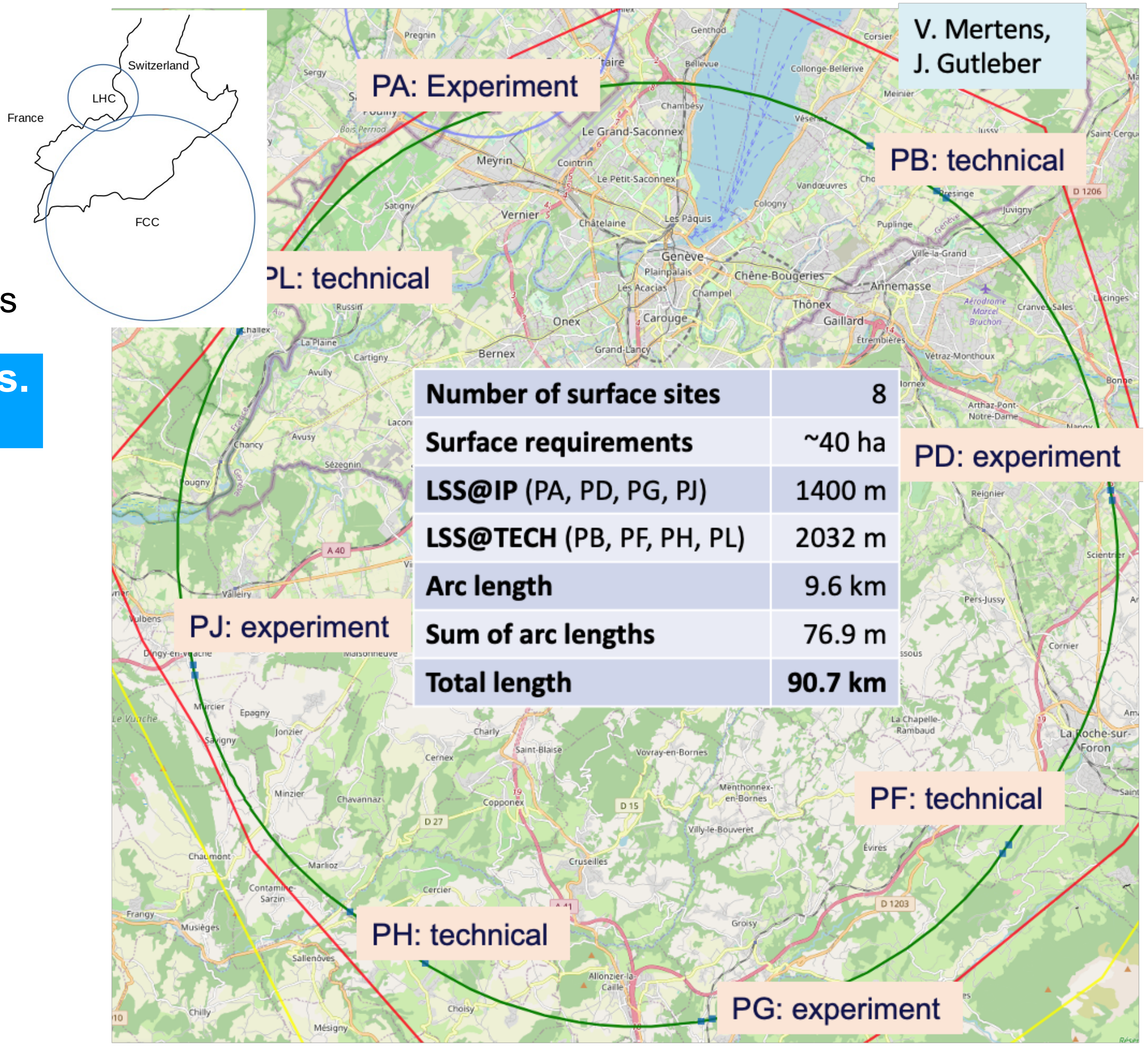
M. Benedikt @ CERN 13.02.24

Layout chosen out of ~ 100 initial variants, based on **geology** and **surface constraints** (land availability, access to roads, etc.), **environment,** (protected zones), **infrastructure** (water, electricity, transport), **machine performance** etc.

“Avoid-reduce-compensate” principle of EU and French regulations

Overall lowest-risk baseline: 90.7 km ring, 8 surface points.
Whole project now adapted to this placement





Number of surface sites	8
Surface requirements	~40 ha
LSS@IP (PA, PD, PG, PJ)	1400 m
LSS@TECH (PB, PF, PH, PL)	2032 m
Arc length	9.6 km
Sum of arc lengths	76.9 m
Total length	**90.7 km**

Optimized placement and layout.

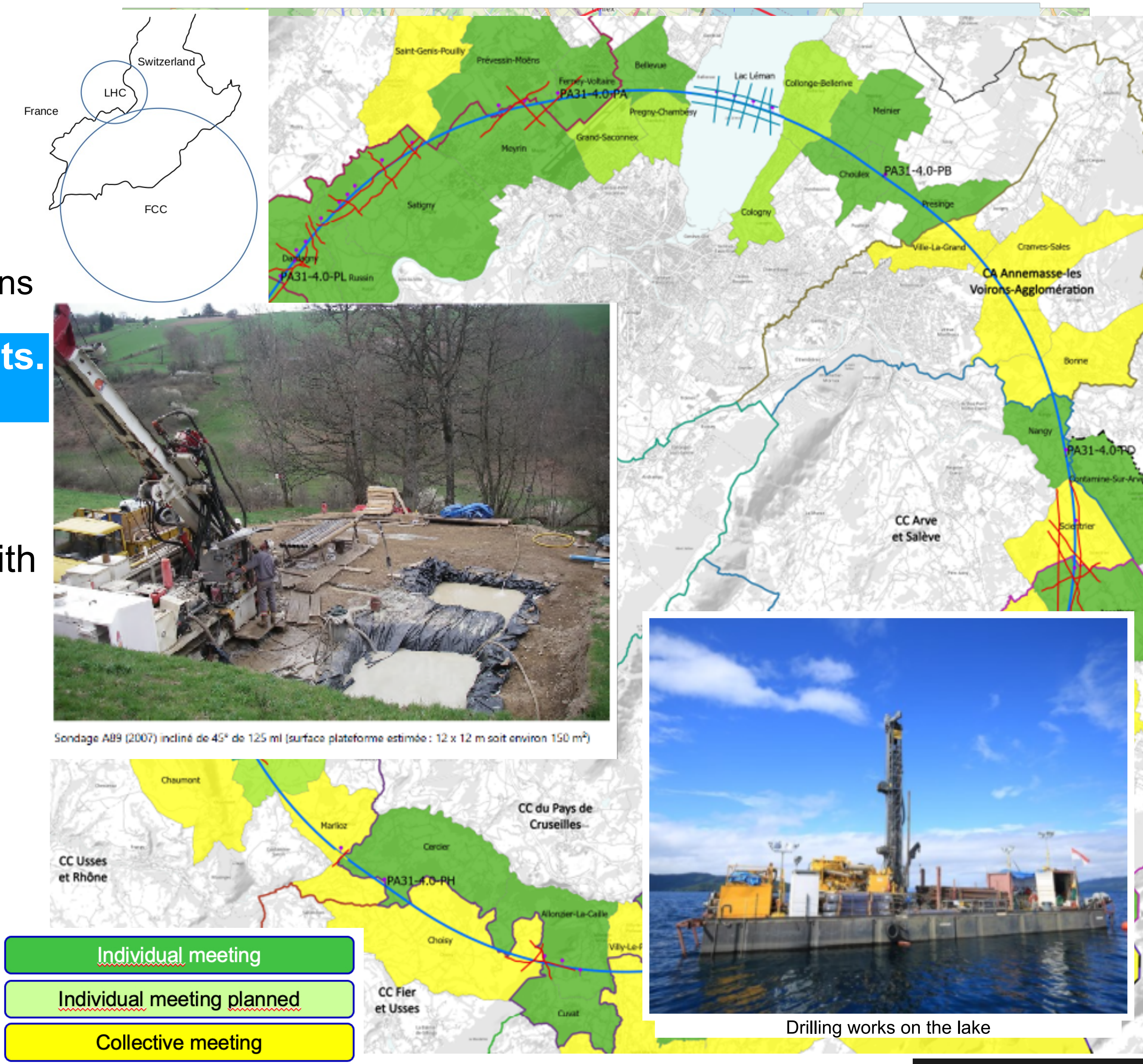
M. Benedikt @ CERN 13.02.24

Layout chosen out of ~ 100 initial variants, based on **geology** and **surface constraints** (land availability, access to roads, etc.), **environment,** (protected zones), **infrastructure** (water, electricity, transport), **machine performance** etc.

"Avoid-reduce-compensate" principle of EU and French regulations

Overall lowest-risk baseline: 90.7 km ring, 8 surface points.
Whole project now adapted to this placement

- **Site investigations in areas with uncertain geological conditions:**
  - Optimisation of localisation of drilling locations ongoing with site visits since end 2022.
  - Alignment with FR and CH on the process for obtaining autorisation procedures. Ongoing for start of drillings in Q2/2024
- **Contracts Status:**
  - Contract for engineering services and role of Engineer during works, active since July 2022
  - Site investigations tendering ongoing towards contract placement in December 2023 and mobilization from January 2024



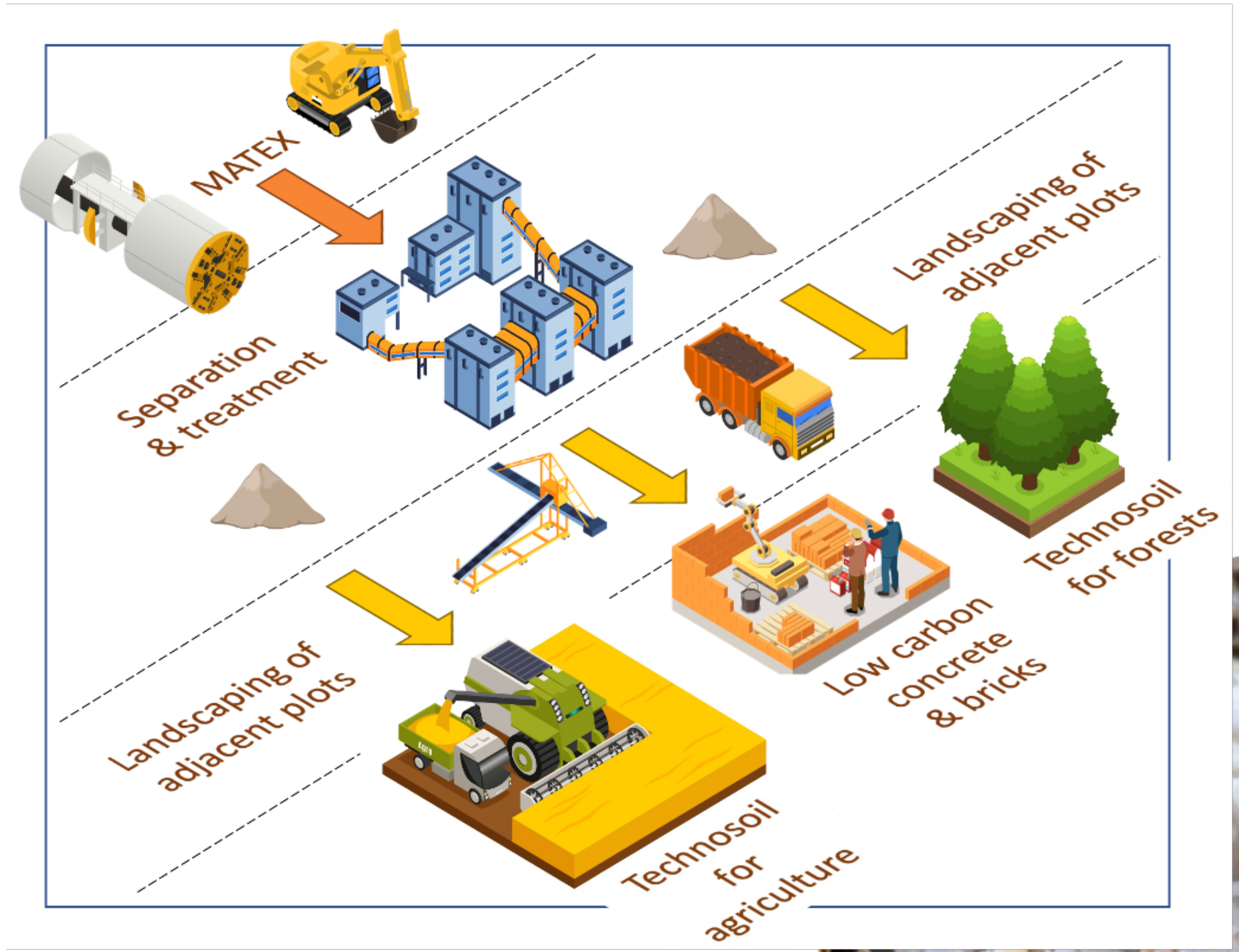
Sondage A89 (2007) incliné de 45° de 125 ml (surface plateforme estimée : 12 x 12 m soit environ 150 m²)

Drilling works on the lake

Environmental considerations.

M. Benedikt @ CERN 13.02.24

- **Excavated material** from FCC subsurface infrastructures: 6.5 Mm^3 in situ, 8.4 Mm^3 excavated
- **Priority : reuse, minimize disposal**
- 2021-2022: International competition **"Mining the Future"**, launched with the support of the EU Horizon 2020 grant, to find innovative and realistic ideas for the reuse of molasse (96% of excavated materials)
- 2023: **"OpenSky Laboratory"** project: Objective - Develop and test an innovative process to transform sterile "molasse" into fertile soil for agricultural use and afforestation. launched in Jan. 2024: 5500m^2 near LHC P5 in Cessy (FR). Trial with 5 000t of excavated local molasse → convert it to arable soil (agricultural/forestry)

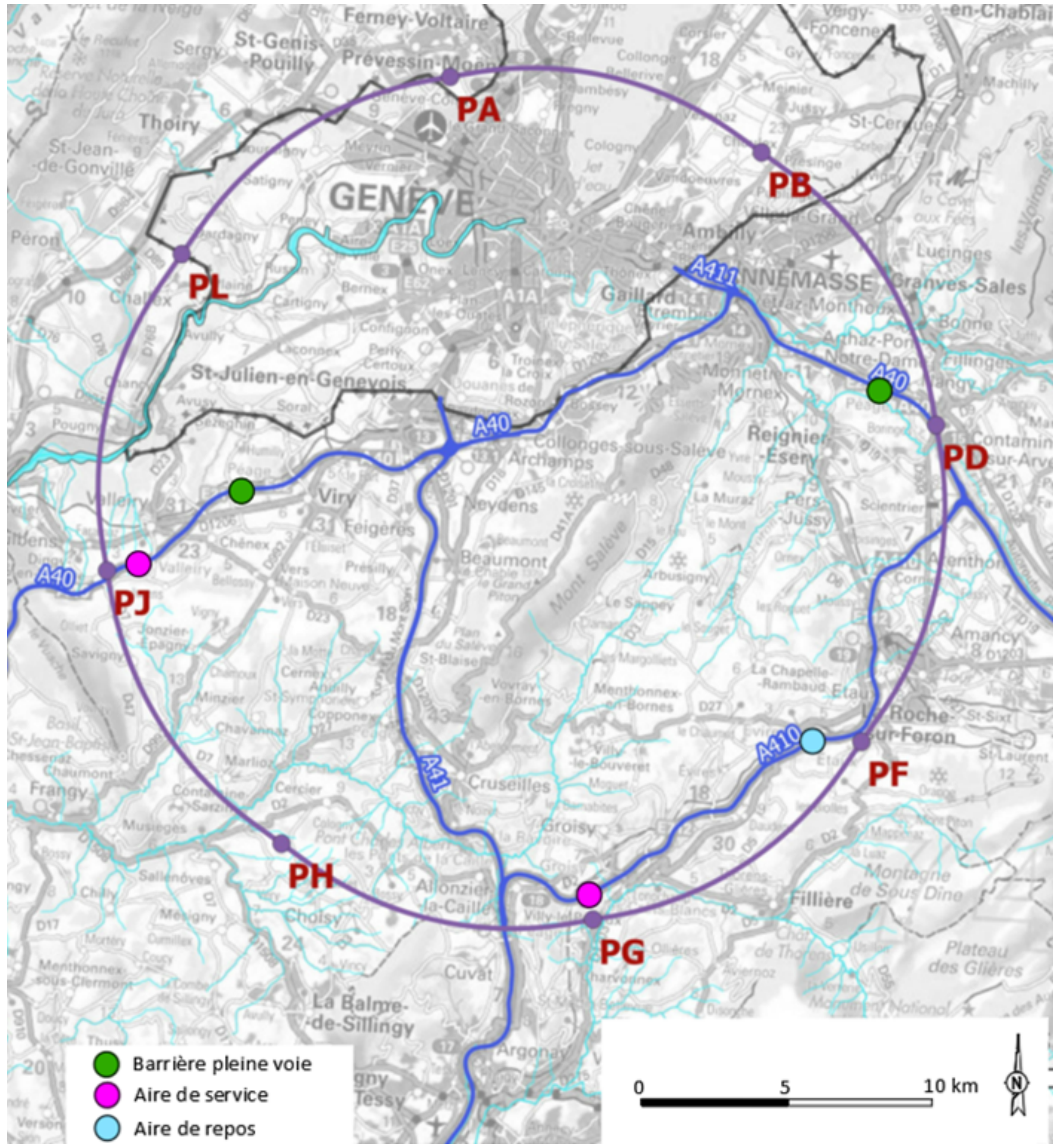


- **Heat:**
  - heating for local houses
  - cheese factories in Jura and Haute-Savoie expressed special interest

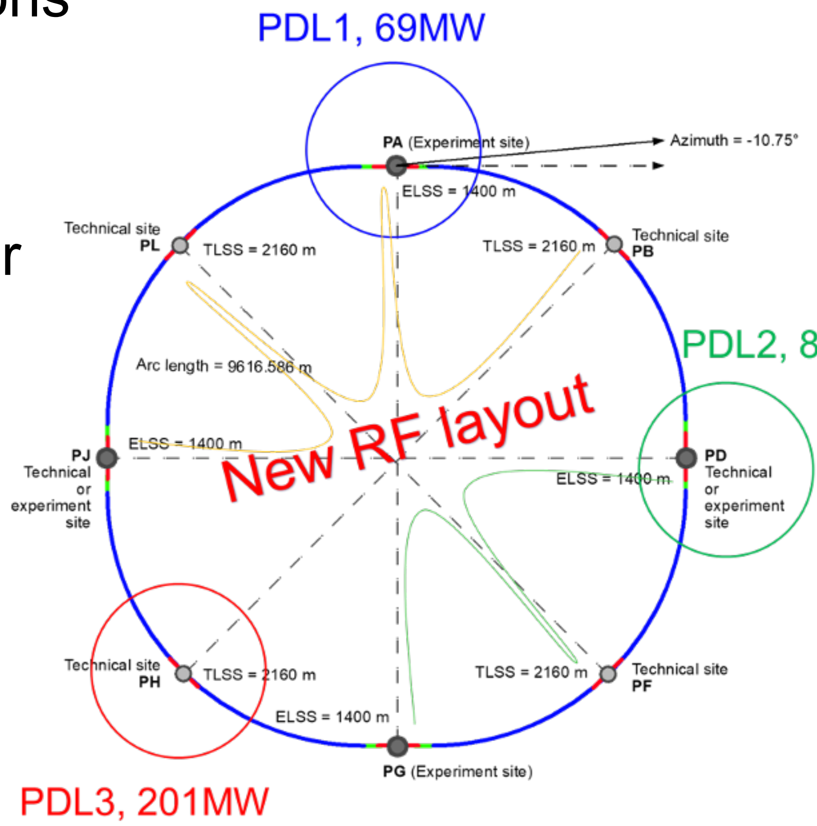
Connections with local infrastructre.

M. Benedikt @ CERN 13.02.24

- **Road accesses** developed for all 8 surface sites
  - Four possible highway connections defined
  - Less than 4 km new departmental roads required

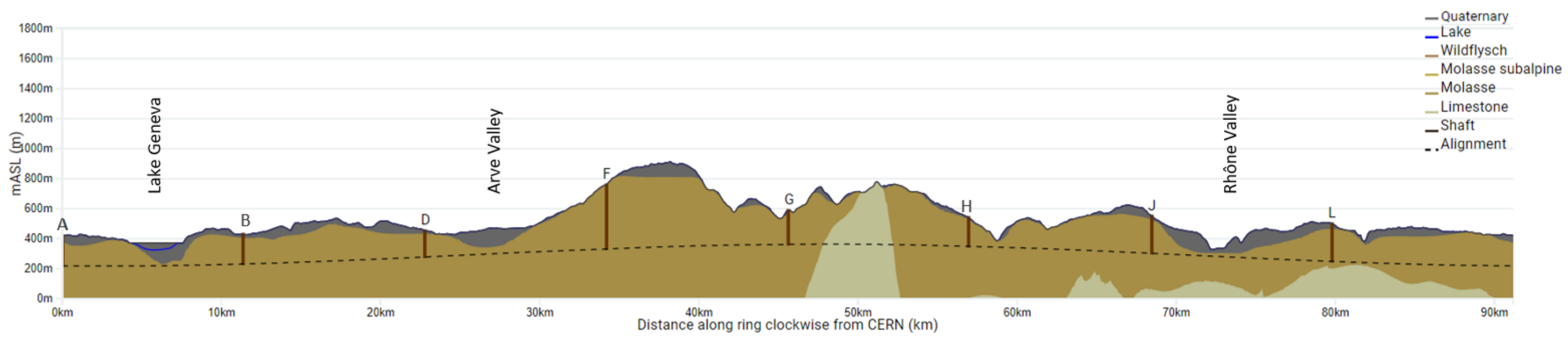


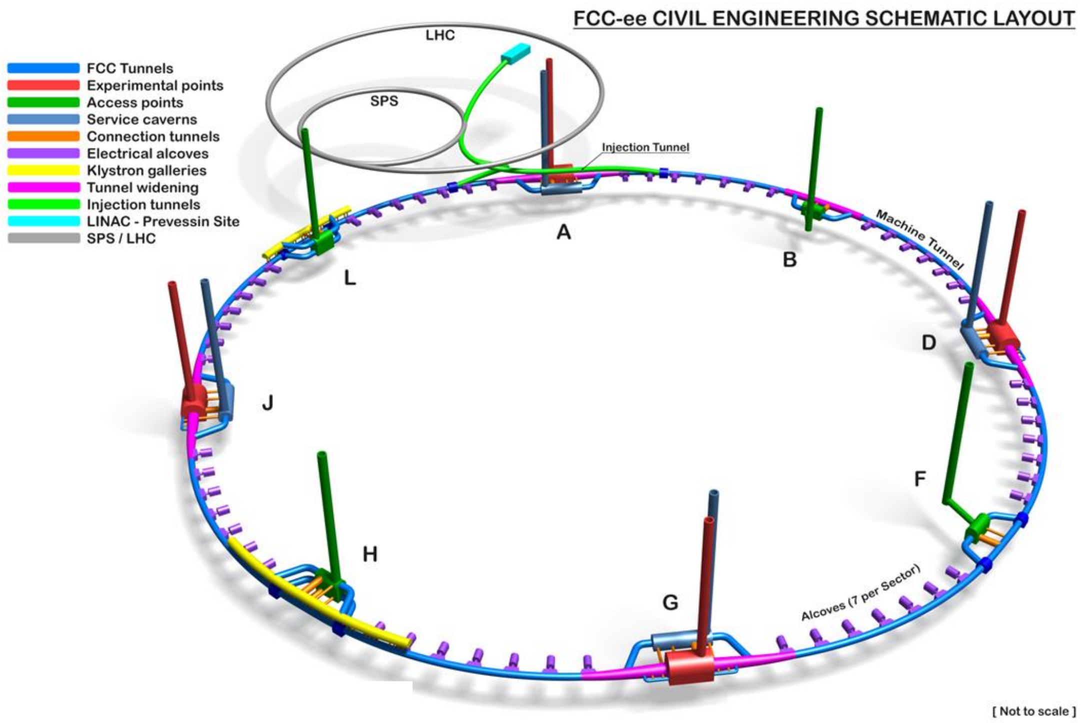
- **Connections to electrical grid**
  - Electrical connection concept studied by RTE (French electrical grid operator) → requested loads have no significant impact on grid
  - Powering concept and power rating of the three sub-stations compatible with FCC-hh
  - R&D efforts aiming at further reduction of the energy consumption of FCC-ee and FCC-hh



Civil engineering

T. Watson @ Annecy FCC Physics '24



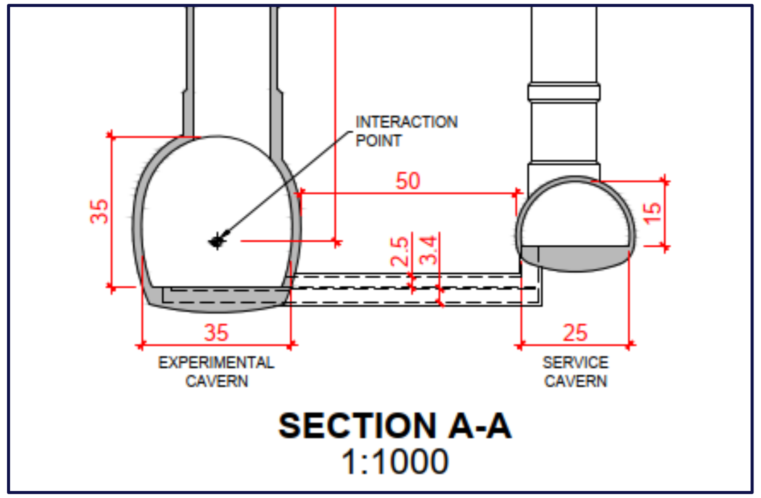


Shaft depths:

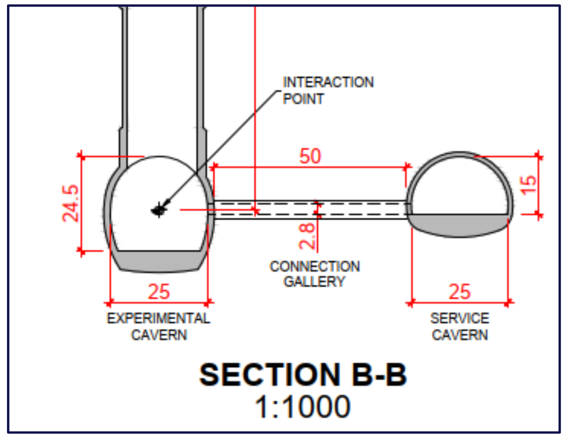
A: 201 m B: 201 m D: 181 m F: 400 m G: 226 m H: 235 m J: 253 m L: 250 m

Tunnel Boring Machine (TBM)

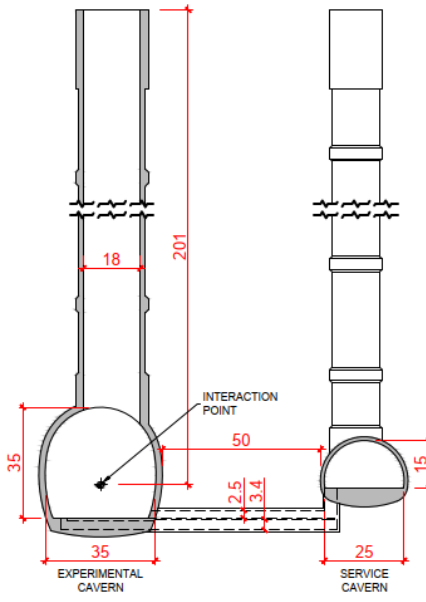
- Tunnel Boring Machines are designed to work almost continuously 24/7 other than periodic maintenance. Rate of 18m/day in the Molasse. 21-27 months to complete one sector → 8 years with two TBMs .
- 13 shafts
- 2/2 large/small caverns



large cavern complex



small cavern complex



shaft @ exp. site

Civil engineering

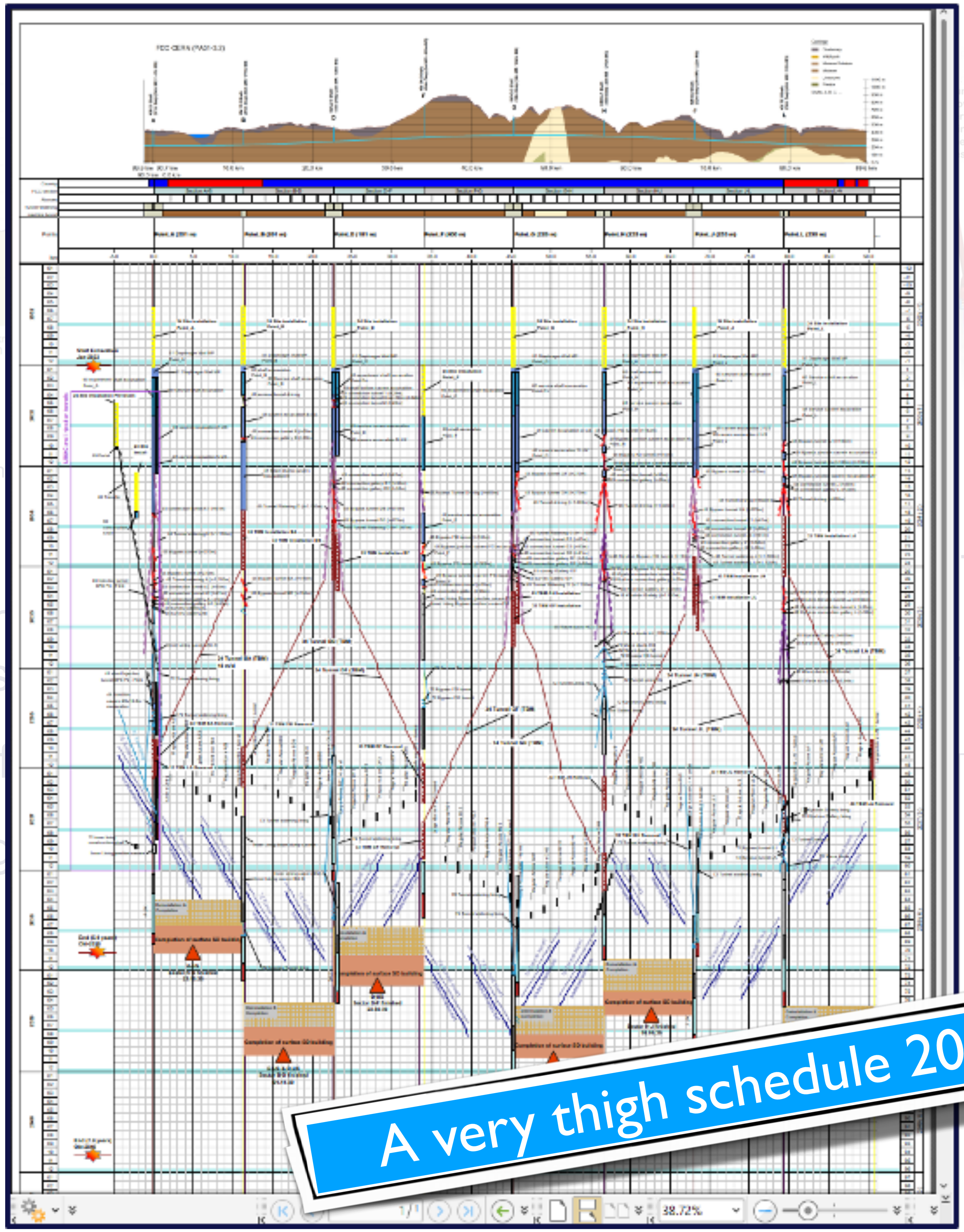
T. Watson @ Annecy FCC Physics ‘24

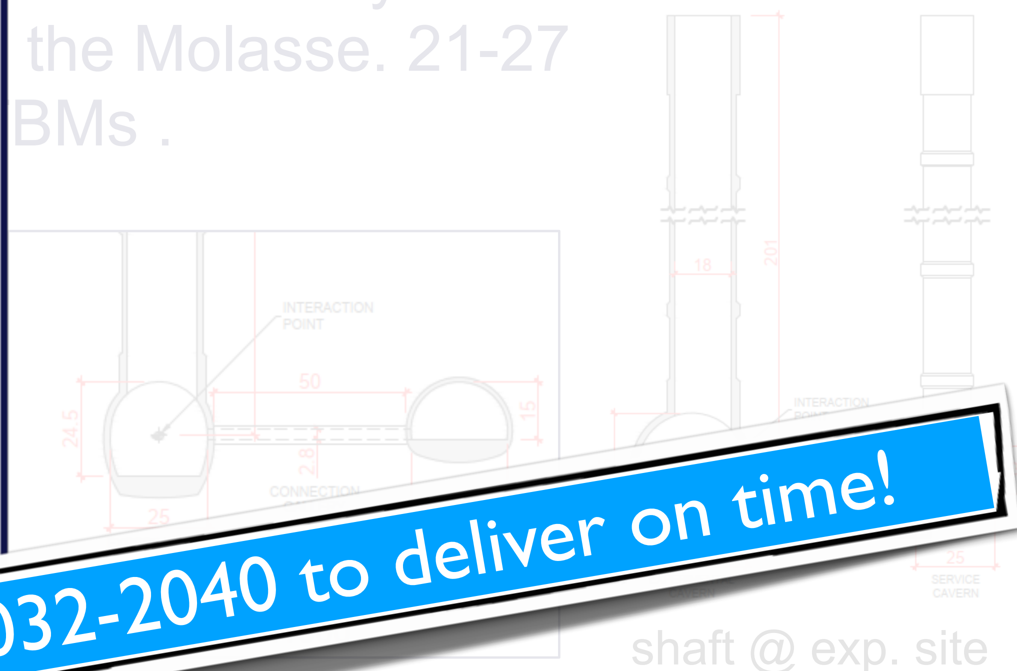
Shaft depths:

A: 201 m B: 201 m D: 181 m F: 400 m G: 226 m

Tunnel Boring Machine (TBM)

- Tunnel … t continuously 24/7 other th… the Molasse. 21-27 months… BMs .
- 13 shaf…
- 2/2 larg…

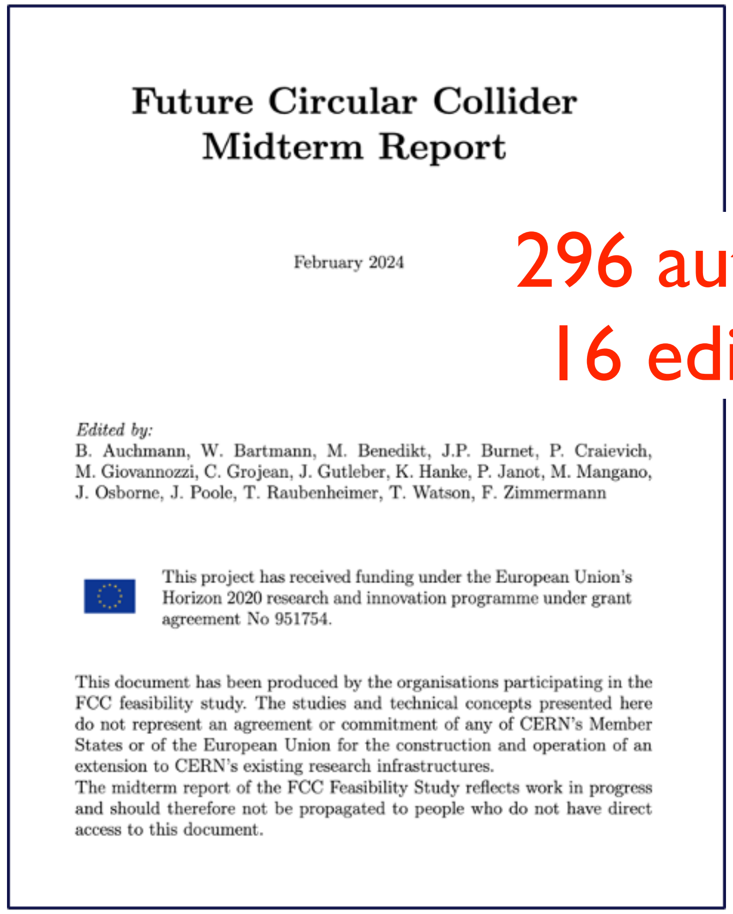




A very thigh schedule 2032-2040 to deliver on time!

FCC feasibility mid-term report.

- **703 pages**: 7 chapters (cost and financial feasibility is a separate document) + refs.
  - Placement scenario (75 pages)
  - Civil engineering (50 pages)
  - Implementation with the host states (45 pages)
  - Technical infrastructure (110 pages)
  - FCC-ee collider design and performance (170 pages)
  - FCC-hh accelerator (60 pages)
  - (Cost and financial feasibility)
  - Physics and experiments (110 pages)
  - References (70 pages)
- **Executive summary**: 44 pages
- Reviewed by
  - Scientific Advisory Committee and Cost Review Panel on Oct. 16-18
  - Scientific Policy Committee and Financial Committee on Nov. 21-22
  - CERN Council Feb. 2


Future Circular Collider
Midterm Report

February 2024

Edited by:
B. Auchmann, W. Bartmann, M. Benedikt, J.P. Burnet, P. Craievich, M. Giovannozzi, C. Grojean, J. Gutleber, K. Hanke, P. Janot, M. Mangano, J. Osborne, J. Poole, T. Raubenheimer, T. Watson, F. Zimmermann

This project has received funding under the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754.

This document has been produced by the organisations participating in the FCC feasibility study. The studies and technical concepts presented here do not represent an agreement or commitment of any of CERN's Member States or of the European Union for the construction and operation of an extension to CERN's existing research infrastructures.
The midterm report of the FCC Feasibility Study reflects work in progress and should therefore not be propagated to people who do not have direct access to this document.

296 authors
16 editors

confidential documents (work in progress) available to CERN personnel

Physics, Experiments, Detectors.

- FCC Feasibility Study PED deliverables for mid-term review

8. Physics & Experiments	C. Grojean, P. Janot, M. Mangano	8.1 Overview
		8.2. Documentation of the specificities of the FCC-ee and FCC-hh physics cases.
		8.3 Strategic plans for the improved theoretical calculations.
		8.4 FCC-ee Detector Requirements.

deliverables explicitly requested from SPC & Council (8.2–8.4)

- Content of the mid-term PED chapter (60 pages were expected → 110 pages delivered)

Physics, Experiments, Detectors.

- FCC Feasibility Study PED deliverables for mid-term review

8. Physics & Experiments	C. Grojean, P. Janot, M. Mangano	8.1 Overview
		8.2. Documentation of the specificities of the FCC-ee and FCC-hh physics cases.
		8.3 Strategic plans for the improved theoretical calculations.
		8.4 FCC-ee Detector Requirements.

deliverables explicitly requested from SPC & Council

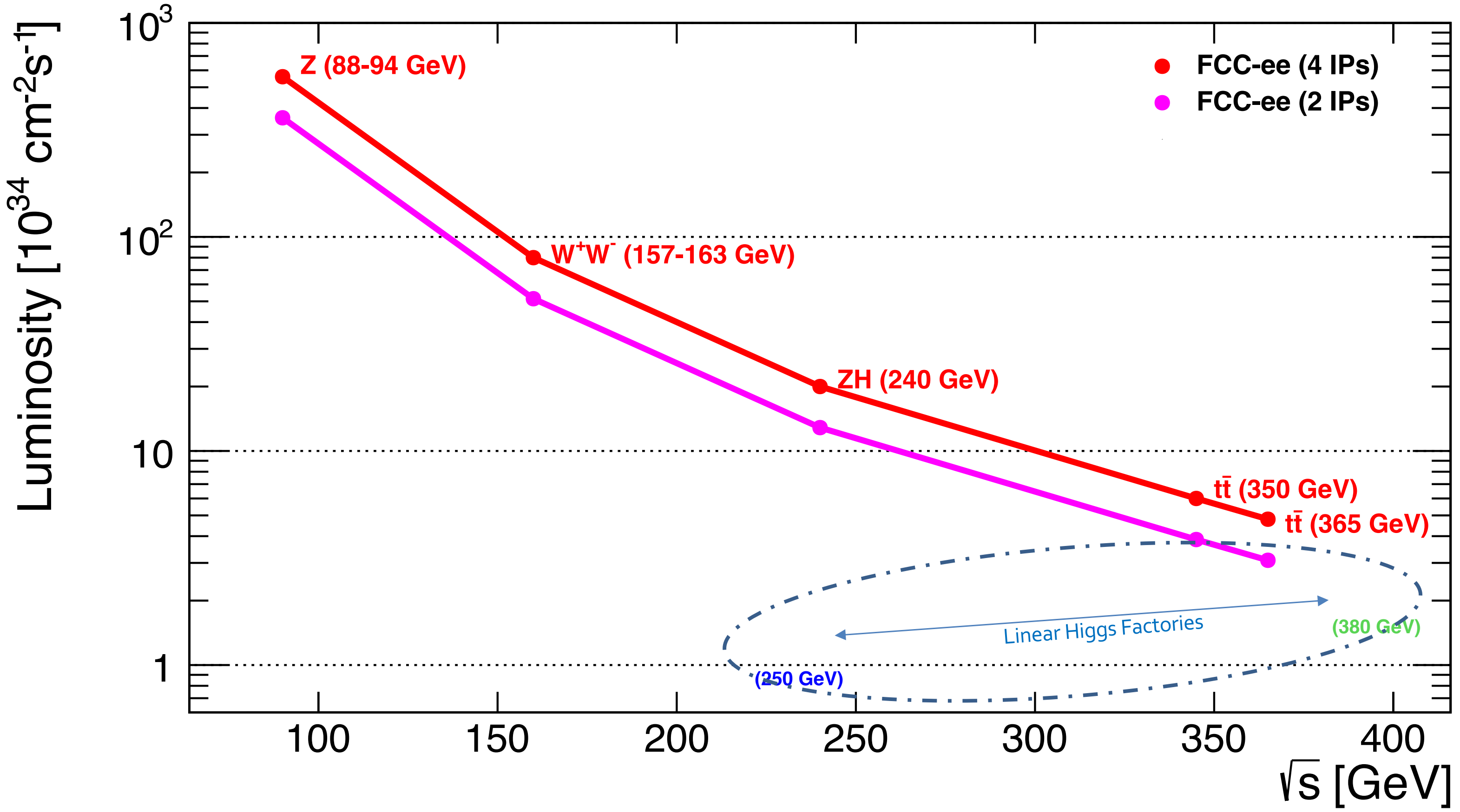
- Content of the mid-term PED chapter (… 0 pages delivered)

— Main physics topics covered/discussed in the report —

1. FCC-ee: much more than a Higgs factory:
   - precision for discovery
   - tera-Z direct discovery potential
2. FCC-ee/hh as a Higgs/electroweak factory
3. FCC-ee as a flavour factory
4. FCC-hh: the broadest exploration potential at high-energy
5. FCC-ee↔FCC-hh: complementarity and synergy

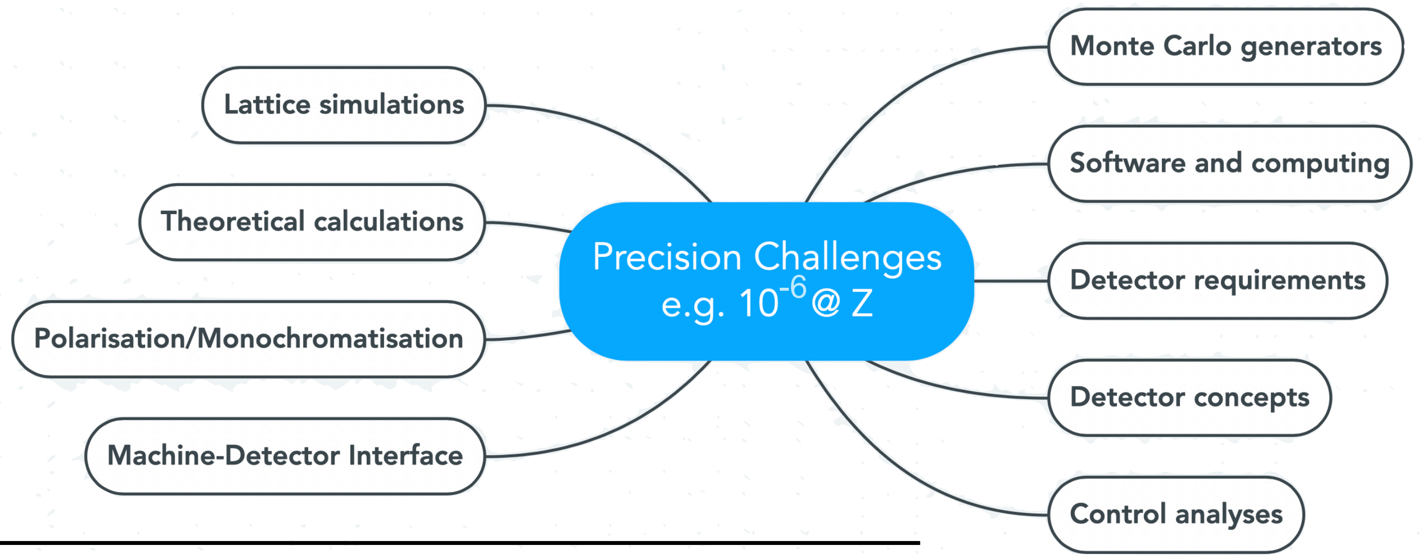
FCC-ee Run Plan.

LEP1 data accumulated in **every 2 mn**. Exciting & diverse programme with different priorities every few years.
(order of the different stages still subject to discussion/optimisation)



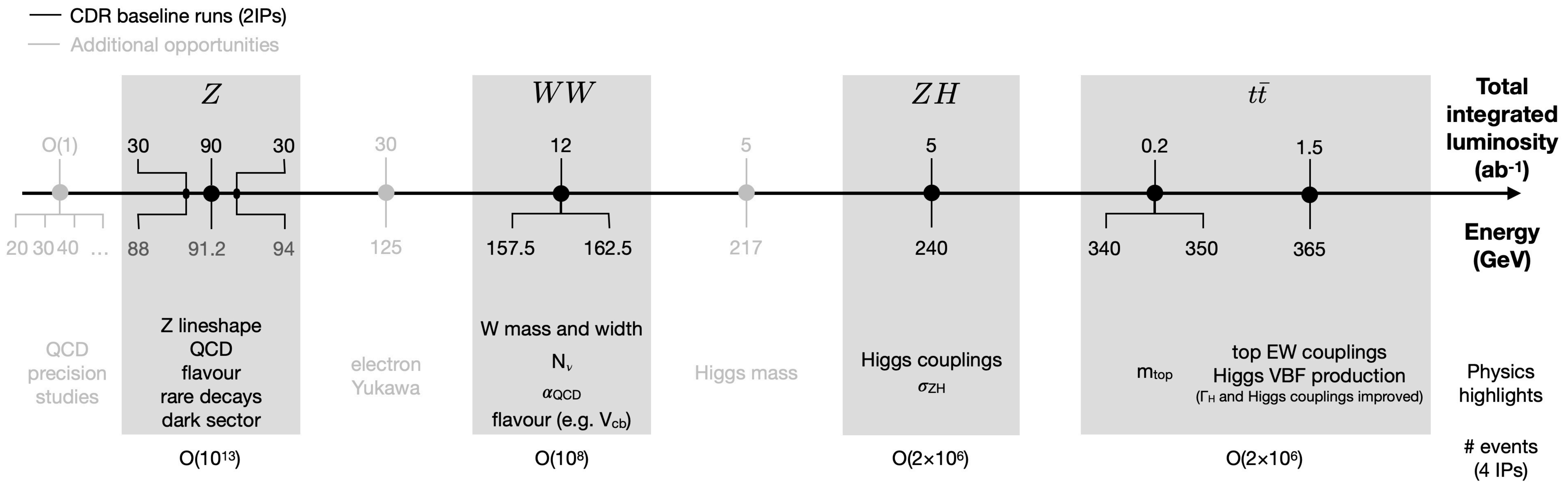
— Superb statistics achieved in only 15 years —

in each detector:
10^5 Z/sec, 10^4 W/hour,
1500 Higgs/day, 1500 top/day



Working point	Z, years 1-2	Z, later	WW, years 1-2	WW, later	ZH	$t\bar{t}$	
$\sqrt{s}$ (GeV)	88, 91, 94		157, 163		240	340–350	365
Lumi/IP (10^{34} cm^{-2}s^{-1})	70	140	10	20	5.0	0.75	1.20
Lumi/year (ab^{-1})	34	68	4.8	9.6	2.4	0.36	0.58
Run time (year)	2	2	2	–	3	1	4
Number of events	6×10^{12} Z		2.4×10^8 WW		1.45×10^6 ZH + 45k WW $\to$ H	1.9×10^6 $t\bar{t}$ +330k ZH +80k WW $\to$ H	

Collider Programme (and beyond).



- **Opportunities** beyond the baseline plan (√s below Z, 125GeV, 217GeV; larger integrated lumi…)
- **Opportunities** to exploit FCC facility differently (to be studied more carefully):
  - using the electrons from the injectors for beam-dump experiments,
  - extracting electron beams from the booster,
  - reusing the synchrotron radiation photons.

Feedback.

Andy **Parker** (SAC chair), Norbert **Holtkamp** (CRP chair), Hugh **Montgomery** (SPC chair), Laurent **Salzarulo** (FC chair), Eliezer **Rabinovici** (Council president)

"many thanks for the work done, congratulations for the results, impressive quality of the study…"

"Financial Committee underlines the need to make the project attractive from the physics viewpoint and takes the view that it would be unfortunate to sacrifice the attractiveness of the physics for the sake of reducing costs."

"Si j'ai voulu venir là aujourd'hui c'est pour témoigner ma confiance aux équipes et notre volonté, notre ambition de conserver la première place dans ce domaine."

["My visit here bears witness to my trust in CERN personnel and France's will and ambition to keep the leadership in this domain."]

E. Macron, CERN 16.11.2023