The FCC Feasibility Study

Michael Benedikt, CERN

on behalf of the FCC collaboration and FCCIS

http://cern.ch/fcc

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European Commission

Horizon 2020
European Union funding
for Research & Innovation

photo: J. Wenninger

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**..”

→ launch of Future Circular Collider Feasibility Study in summer 2021

FCC FS Council Documents, June '21

Organisational Structure of the FCC Feasibility Study

http://cds.cern.ch/record/2774006/files/English.pdf

CERN/SPC/1155/Rev.2
CERN/3566/Rev.2
Original: English
21 June 2021

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken		*Voting Procedure*
For decision	**RESTRICTED COUNCIL** 203rd Session **17 June 2021**	Simple majority of Member States represented and voting

FUTURE CIRCULAR COLLIDER FEASIBILITY STUDY:

PROPOSED ORGANISATIONAL STRUCTURE

This document sets out the proposed organisational structure for the Feasibility Study of the Future Circular Collider, to be carried out in line with the recommendations of the European Strategy for Particle Physics updated by the CERN Council in June 2020. It reflects discussion at, and feedback received from, the Council in March 2021 and is now submitted for the latter's approval.

Main Deliverables and Timeline of the FCC Feasibility Study

http://cds.cern.ch/record/2774007/files/English.pdf

CERN/SPC/1161
CERN/3588
Original: English
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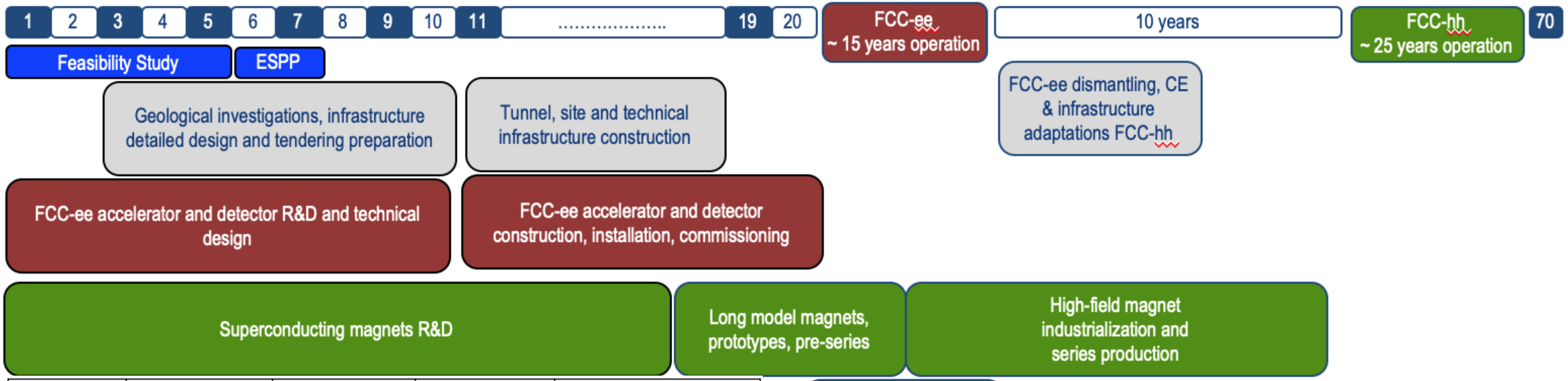
FUTURE CIRCULAR COLLIDER FEASIBILITY STUDY:

MAIN DELIVERABLES AND MILESTONES

This document describes the main deliverables and milestones of the study being carried out to assess the technical and financial feasibility of a Future Circular Collider at CERN. The results of this study will be summarised in a Feasibility Study Report to be completed by the end of 2025.

Timeline of the FCC integrated programme

Technical schedule



	√s	L /IP ($cm^{-2}\,s^{-1}$)	Int. L /IP(ab^{-1})	Comments
e^+e^- **FCC-ee**	~90 GeV Z 160 WW 240 H ~365 top	230 x10^{34} 28 8.5 1.5	75 5 2.5 0.8	2-4 experiments Total ~ 15 years of operation
pp **FCC-hh**	100 TeV	5 x 10^{34} 30	20-30	2+2 experiments Total ~ 25 years of operation
PbPb **FCC-hh**	$\sqrt{s_{NN}}$ = 39TeV	3 x 10^{29}	100 nb^{-1}/run	1 run = 1 month operation
ep **Fcc-eh**	3.5 TeV	1.5 10^{34}	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb **Fcc-eh**	$\sqrt{s_{eN}}$ = 2.2 TeV	0.5 10^{34}	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb

- Feasibility Study: 2021-2025
- If project approved before end of decade → construction can start beginning 2030s
- FCC-ee operation ~2045-2060
- FCC-hh operation 2070-2090++

FUTURE CIRCULAR COLLIDER

FCC Feasibility Study (2021-205): high-level objectives

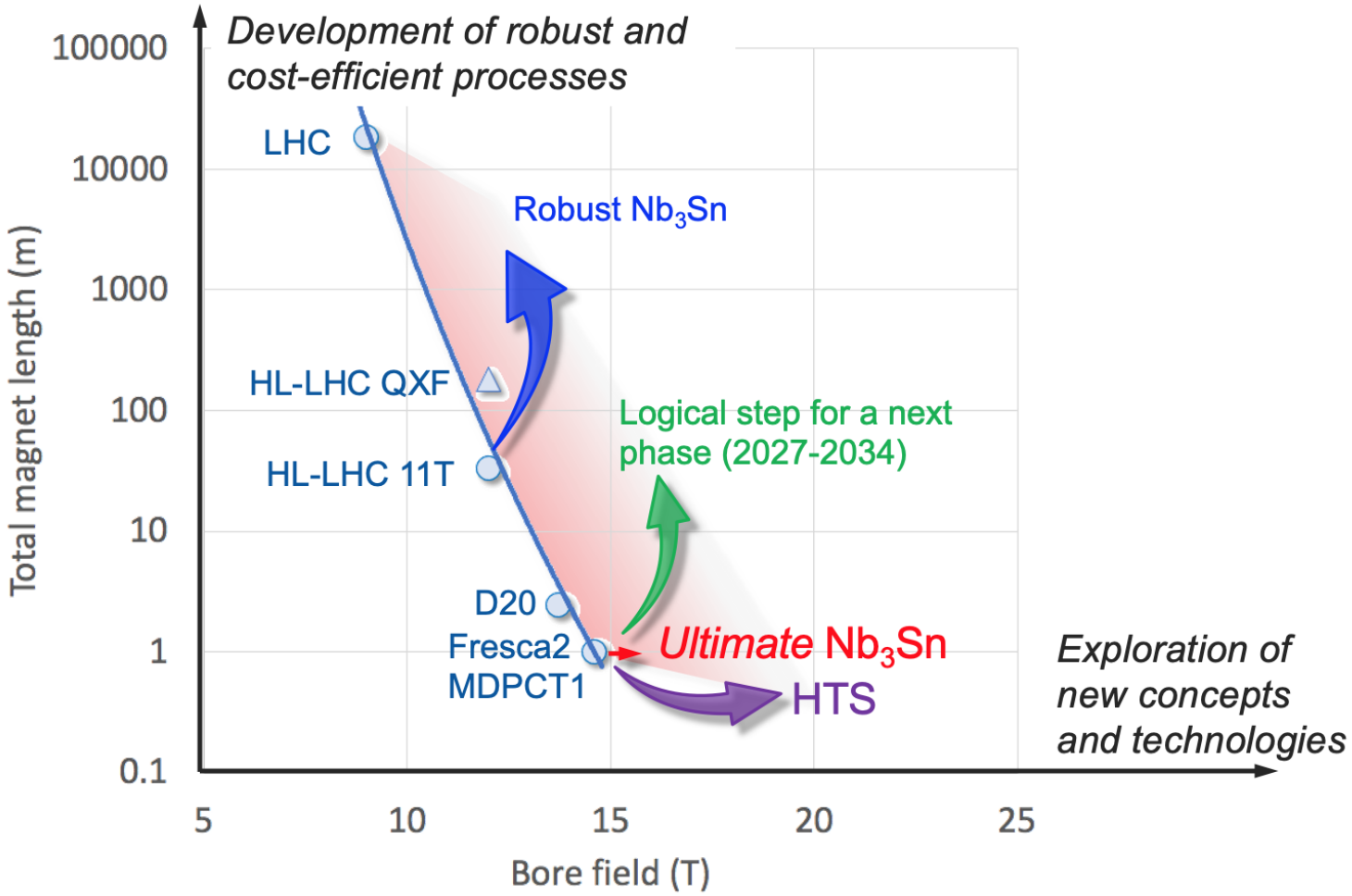
- demonstration of the geological, technical, environmental and administrative feasibility of the tunnel and surface areas and optimisation of placement and layout of the ring and related infrastructure;
- pursuit, together with the Host States, of the preparatory administrative processes required for 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.

Results will be summarised in a Feasibility Study Report to be released at end 2025

F. Gianotti

High-field magnets R&D: 1st steps towards FCC-hh

In parallel to FCC studies, HFM development program as long-term separate R&D project



CERN budget for high-field magnets doubled in 2020 Medium-Term Plan (~ 200 MCHF over ten years)

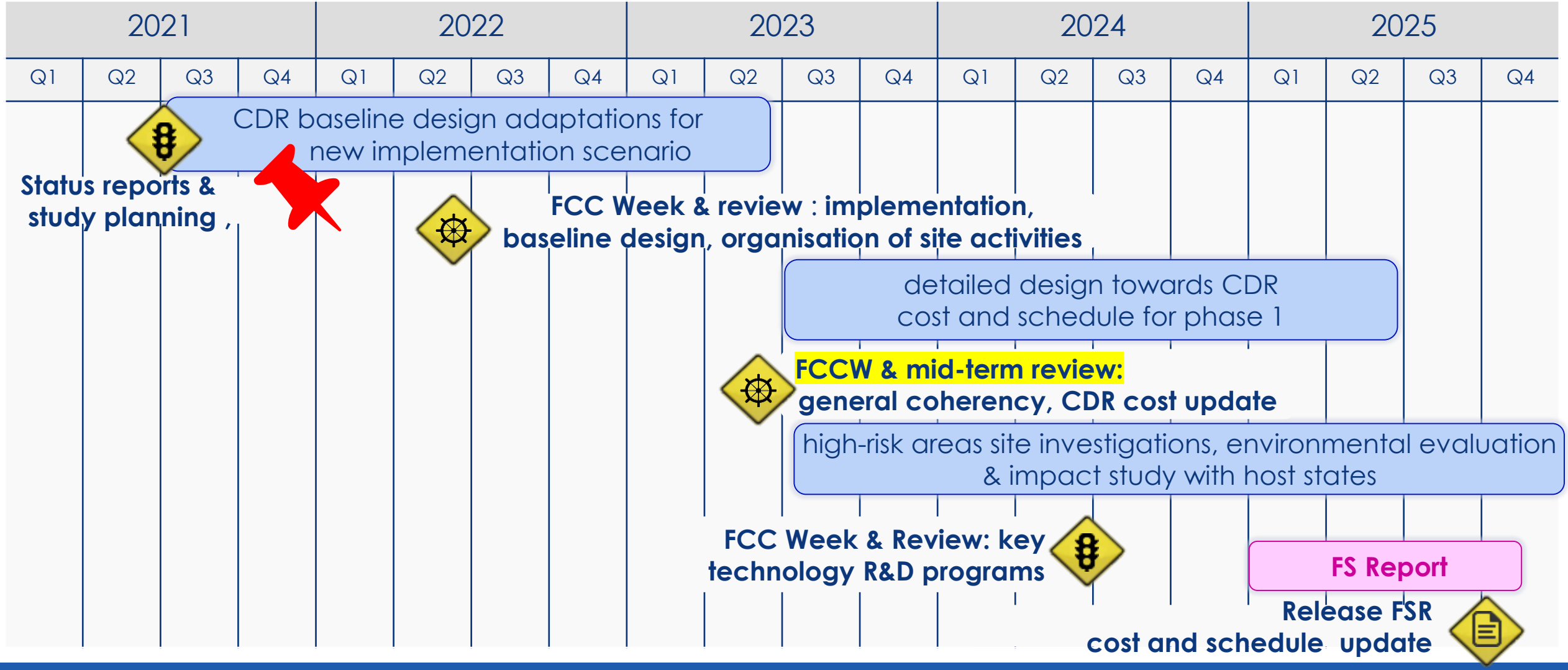
Main R&D activities:

- ❑ materials: goal is ~16 T for Nb_3Sn, at least ~20 T for HTS inserts
- ❑ magnet technology: engineering, mechanical robustness, insulating materials, field quality
- ❑ production of models and prototypes: to demonstrate material, design and engineering choices,
  industrialisation and costs
- ❑ infrastructure and test stations: for tests up to ~ 20 T and 20-50 kA

Detailed deliverables and timescale being defined through Accelerator R&D roadmap under development

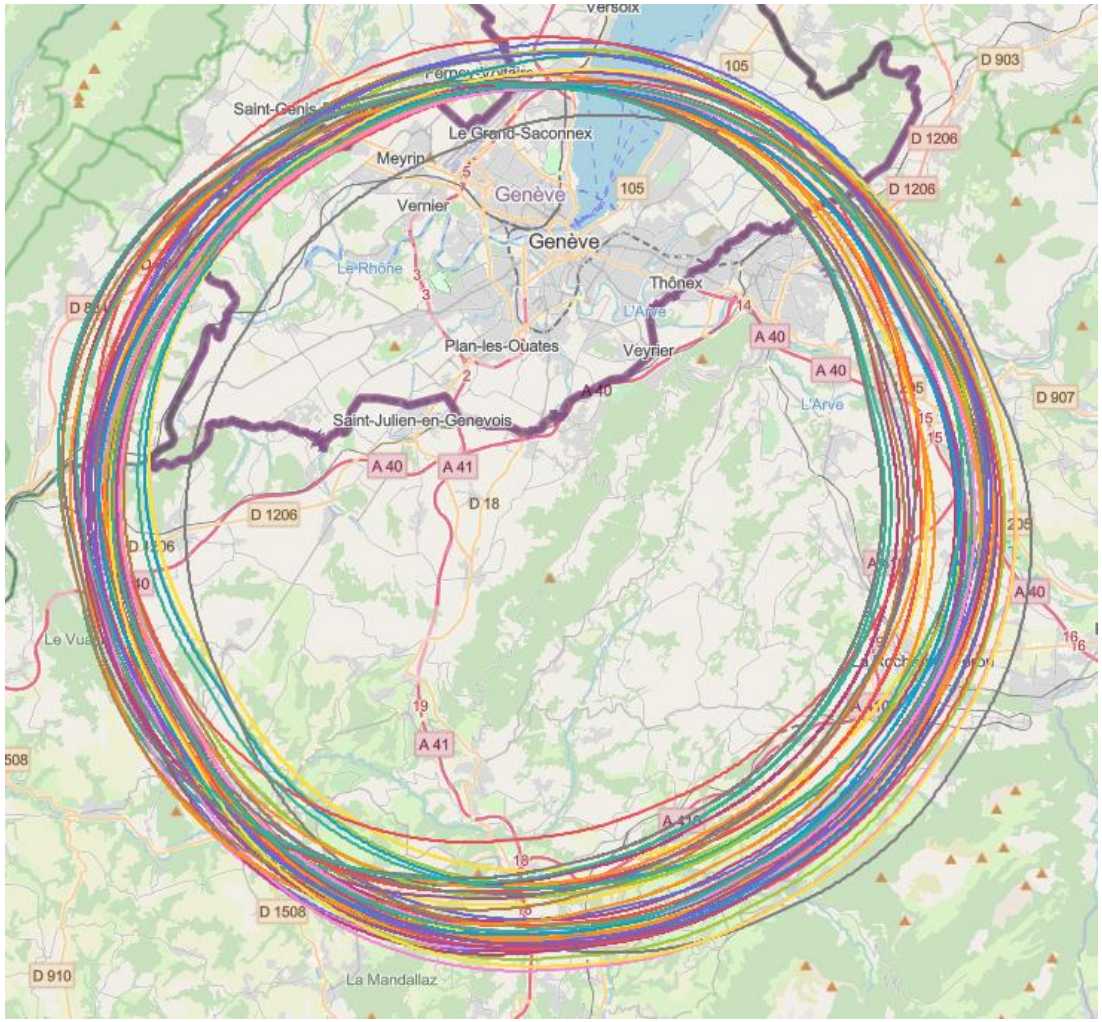
L. Bottura, F. Gianotti

Feasibility Study Timeline



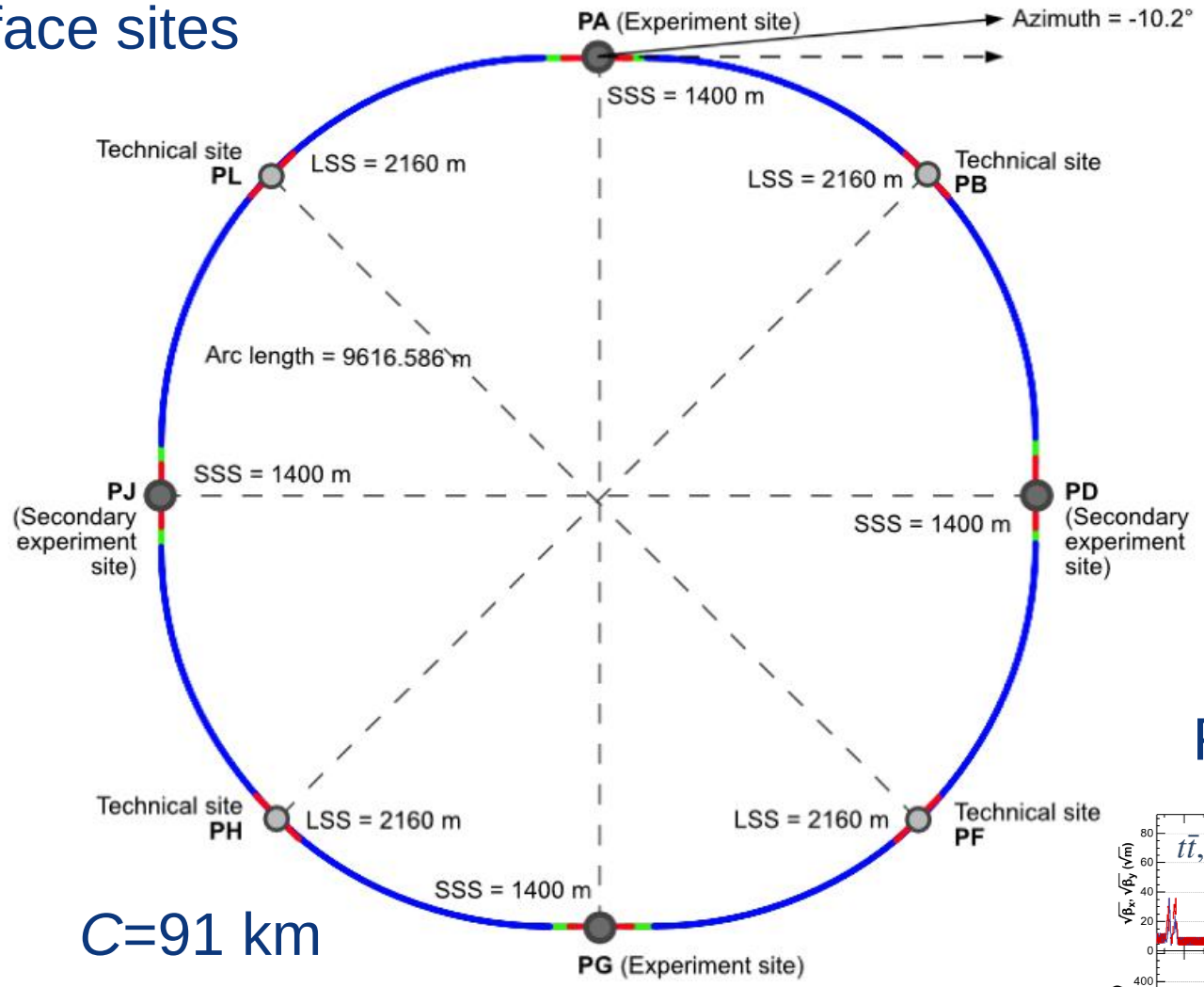
Implementation studies with host states

- 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



new “lowest risk” placement/optics allows 4 exp’s

8 surface sites

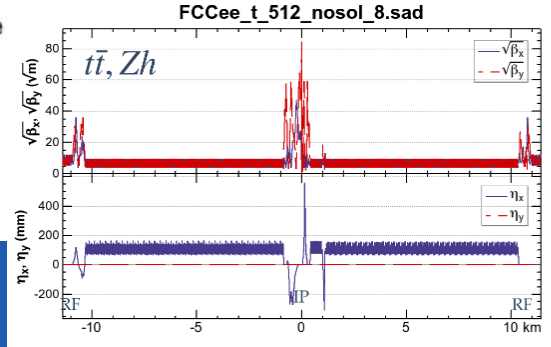


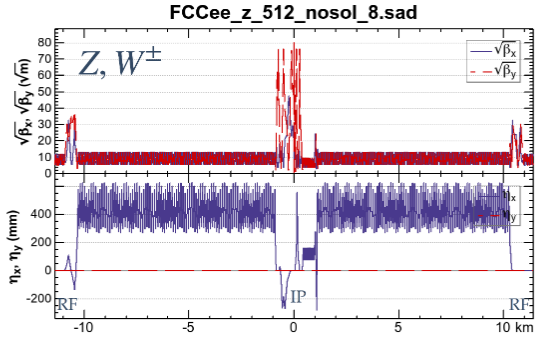
C=91 km

4-fold symmetry
and
4-fold superperiodicity

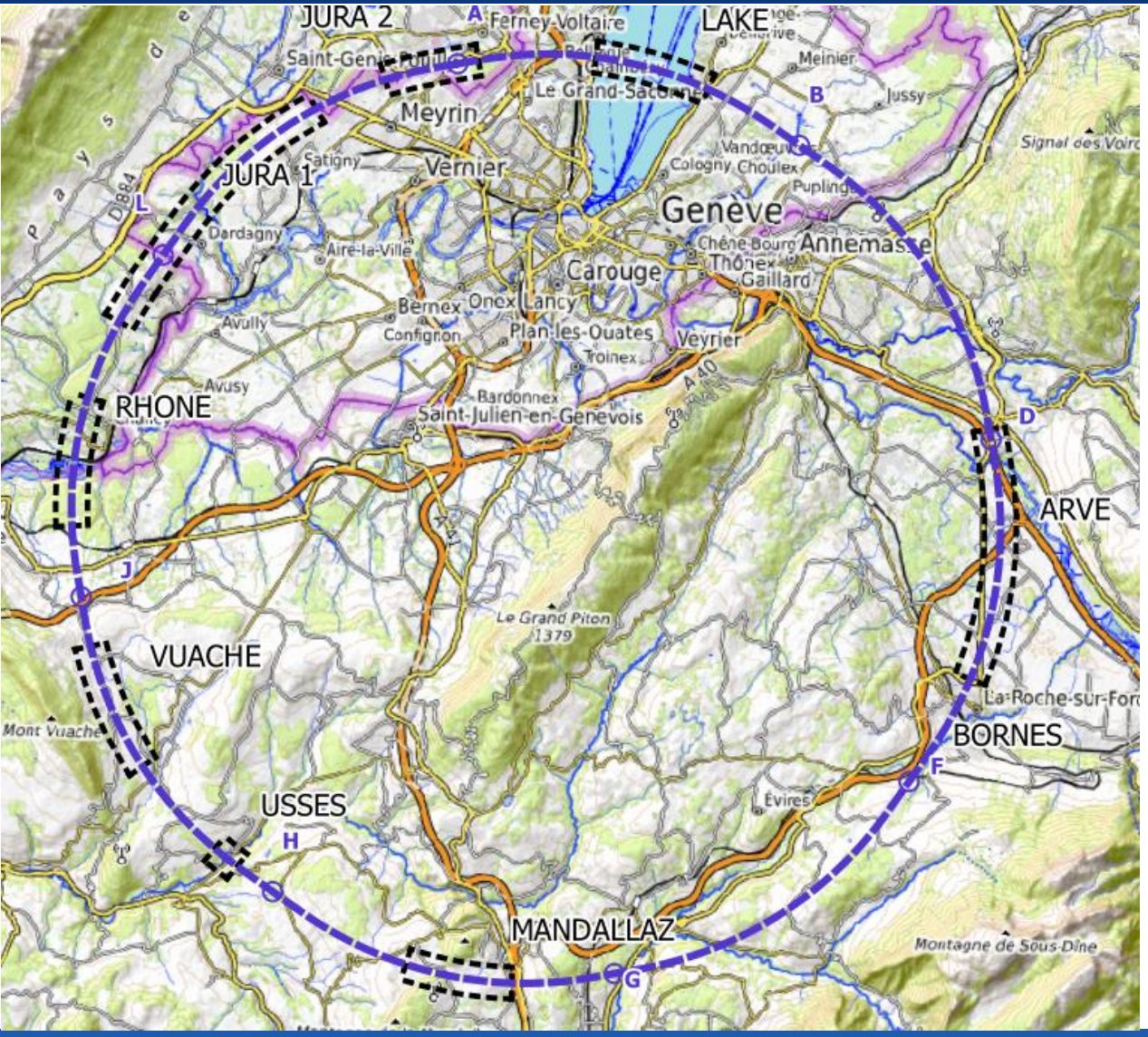
FCC-ee 2 or 4 Ips
FCC-hh 4 IPs

FCC-ee beam optics for ¼ ring K. Oide





Plans for high-risk area site investigations



JURA, VUACHE (3 AREAS)
Top of limestone
Karstification and filling-in at the tunnel depth
Water pressure

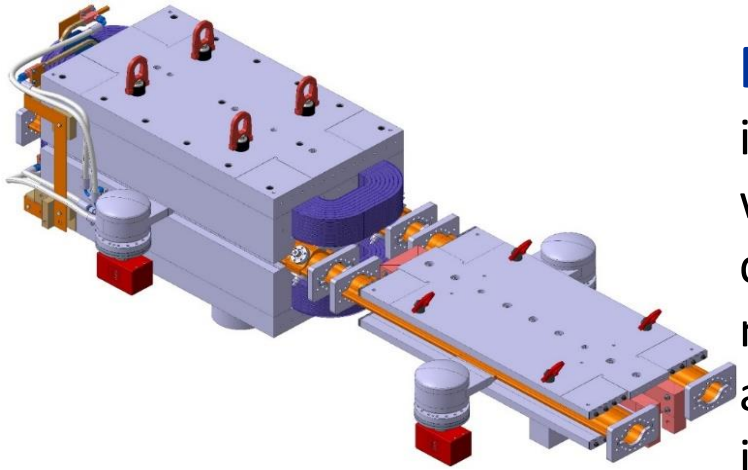
LAKE, RHÔNE, ARVE AND USSES VALLEY (4 AREAS)
Top of the molasse
Quaternary soft grounds, water bearing layers

MANDALLAZ (1 AREAS)
Water pressure at the tunnel level
Karstification

BORNES (1 AREA)
High overburden molasse properties
Thrust zones

Site investigations planned for mid 2023 – mid 2025:
~40-50 drillings, 100 km of seismic lines

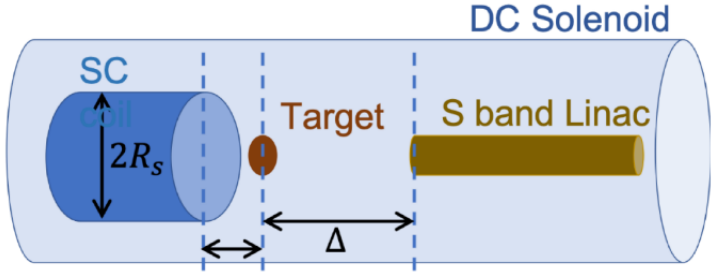
FCC key deliverables: prototypes by 2025



FCC-ee arc half-cell mock up
including girder, vacuum system with antechamber + pumps, dipole, quadrupole + sext. magnets, BPMs, cooling + alignment systems, technical infrastructure interfaces.

400 MHz SRF cryomodule,
with prototypes of multi-cell cavities
High-efficiency RF power sources

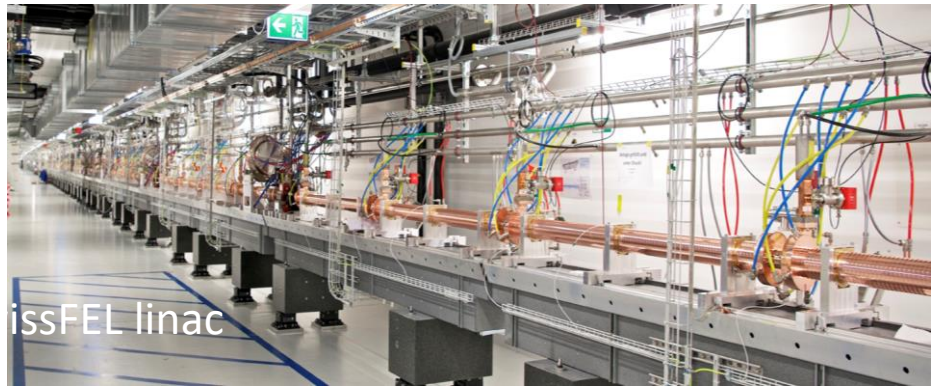
high-yield positron source
target with DC SC solenoid or flux concentrator



positron capture linac
large aperture S-band linac

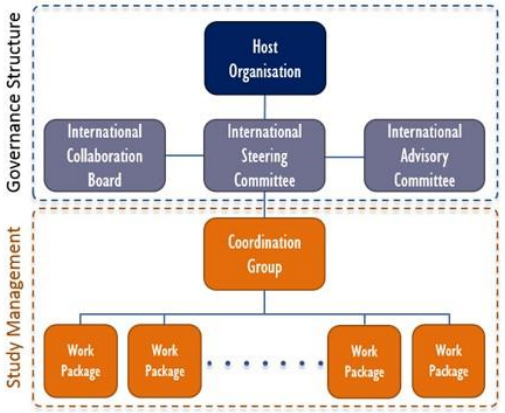
- Freq ： 2.856 GHz
- 90 cells per structure
- Length: 3.254 m
- Distance between two TWs: 45 cm
- Gradient: 20 MV/m
- Aperture: 30 mm

beam test of e^+ source & capture linac at SwissFEL – yield measurement

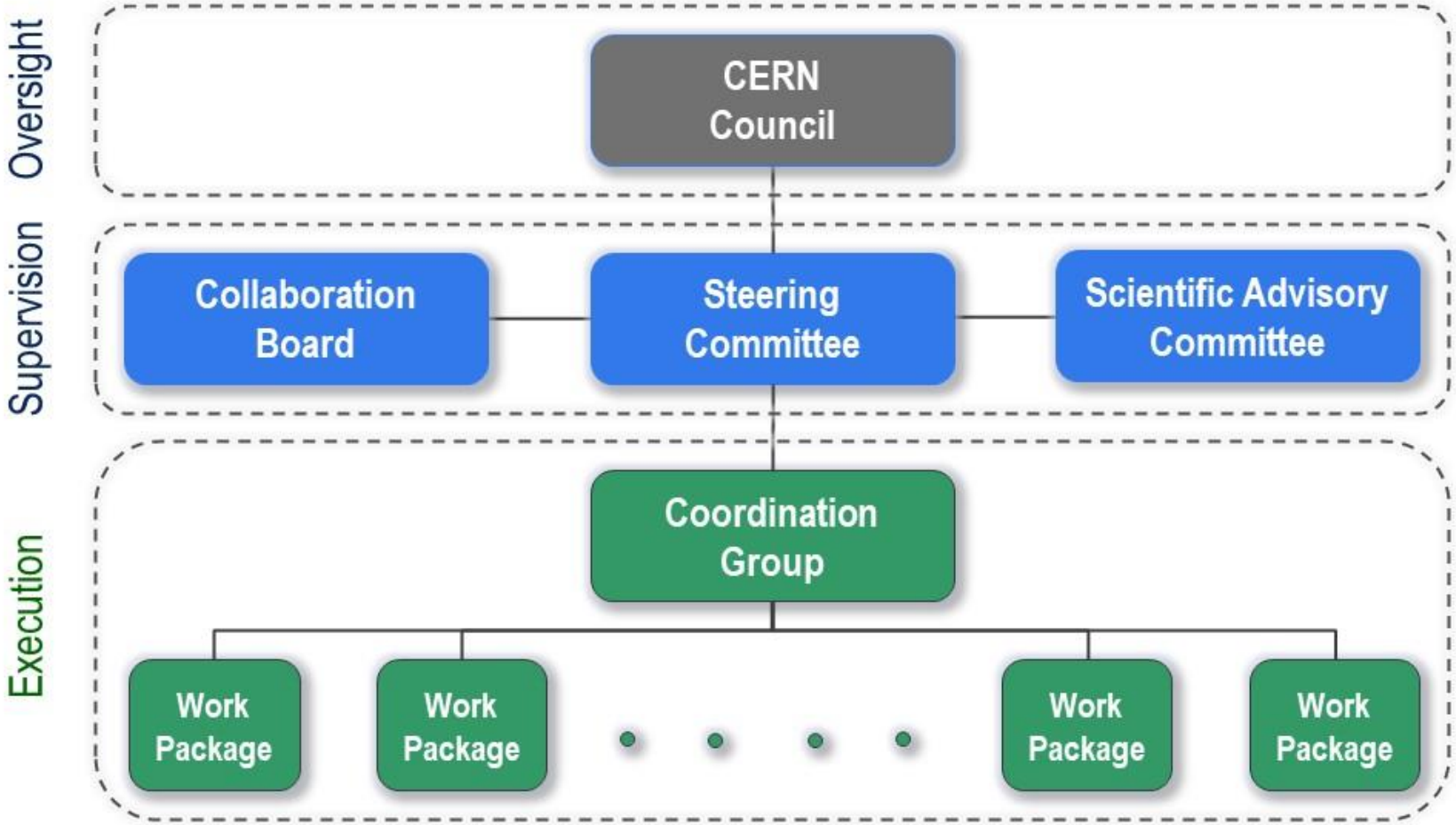


FCC Feasibility Study - organisational structure

- New structure very similar to the first phase of the FCC Study (2014-2020), leading to the Conceptual Design Report as input to the ESPPU.



- Classical structure common to CERN projects.



Status of Global FCC 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

147 Institutes

30 Companies

34 Countries

EC H2020

FCC Feasibility Study – coordination team and contact persons

EU Projects
NN

Collaboration building
Emmanuel Tsesmelis

Communications
Panagiotis Charitos, James Gillies

Study Support and Coordination
Study Leader: Michael Benedikt
Deputy Study Leader: Frank Zimmermann

Study Support Unit
IT: Sylvain Girod
Procurement: Adam Horridge
Quality control: NN
Resources: Sylvie Prodon
Scheduling, quality mangement: NN
Secretariat: Julie Hadre

Physics, Experiments and Detectors
Patrick Janot
Christophe Grojean

- **Physics programme**
  Matthew McCullough, Frank Simon
- **Detector concept**
  Mogens Dam
- **Physics performance**
  Patrizia Azzi, Emmanuel Perez
- **Software and computing**
  Gerardo Ganis, Clément Helsens

Accelerators
Tor Raubenheimer
Frank Zimmermann

- **FCC-ee collider design**
  Katsunobu Oide
- **FCC-hh design**
  Massimo Giovannozzi
- **Technology R&D**
  Roberto Losito
- **FCC-ee booster design**
  Antoine Chancé
- **FCC-ee injector**
  Paolo Craievich, Alexej Grudiev
- **FCC-ee energy calibration polarization**
  Alain Blondel, Jorg Wenninger
- **FCC-ee MDI**
  Manuela Boscolo, Mike Sullivan

Technical Infrastructures
Klaus Hanke

- **Integration**
  Jean-Pierre Corso
- **Geodesy & survey**
  Hélène Mainaud Durand
- **Electricity and energy management**
  Jean-Paul Burnet
- **Cooling and ventilation**
  Guillermo Peon
- **Cryogenics systems**
  Laurent Delprat
- **Computing and controls infrastructure, communication and network**
  Dirk Duellmann
- **Safety**
  Thomas Otto
- **Operation, maintenance, availability, reliability**
  Jesper Nielsen
- **Transport, installation concepts**
  Cristiana Colloca

Host State processes and civil engineering
Timothy Watson

- **Administrative processes**
  Friedemann Eder
- **Placement studies**
  Johannes Gutleber, Volker Mertens
- **Environmental evaluation**
  Johannes Gutleber
- **Tunnel, subsurface design**
  John Osborne
- **Surface sites layout, access and building design**

Organisation and financing models
Paul Collier (interim)

- **Project organisation model**
- **Financing model**
  Florian Sonnemann
- **Procurement strategy and rules**
- **In-kind contributions**
- **Operation model**
  Paul Collier, Jorg Wenninger

FCC Week 2022

In Paris 30 May to 3 June 2022

Planning for a hybrid event.

We are looking forward

to seeing you there !

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,**
  - **cost estimate and schedules for both construction and operation periods** with **funding concept**
  - 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 in all domains. Everybody interested is warmly welcome to join the effort!**