

# Status of CERN Future Circular Collider

LHC Days Split, 4 October 2024

Frank Zimmermann, CERN  
on behalf of FCC collaboration  
with special thanks to Michael Benedikt



Swiss Accelerator  
Research and  
Technology

<http://cern.ch/fcc>



Work supported by the **European Commission** under the **HORIZON 2020** projects **EuroCirCol**, grant agreement 654305; **EASITrain**, grant agreement no. 764879; **iFAST**, grant agreement 101004730, **FCCIS**, grant agreement 951754; **E-JADE**, contract no. 645479; **EAJADE**, contract number 101086276; and by the Swiss **CHART** program



European  
Commission

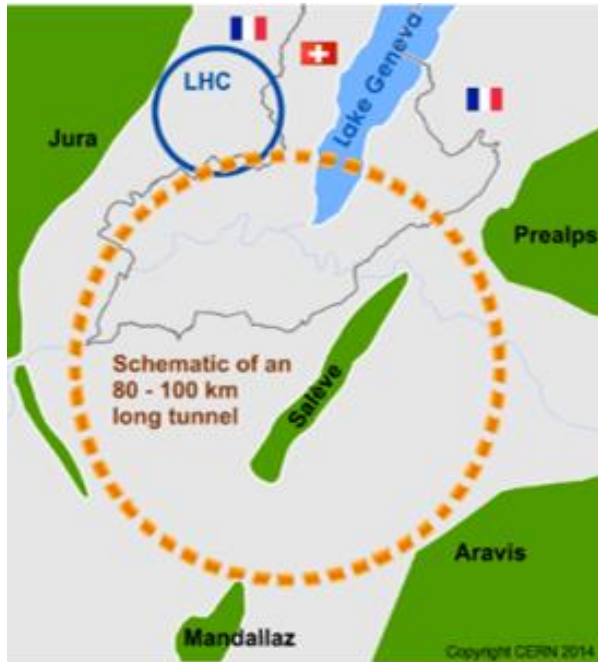
Horizon 2020  
European Union funding  
for Research & Innovation

photo: J. Wenninger

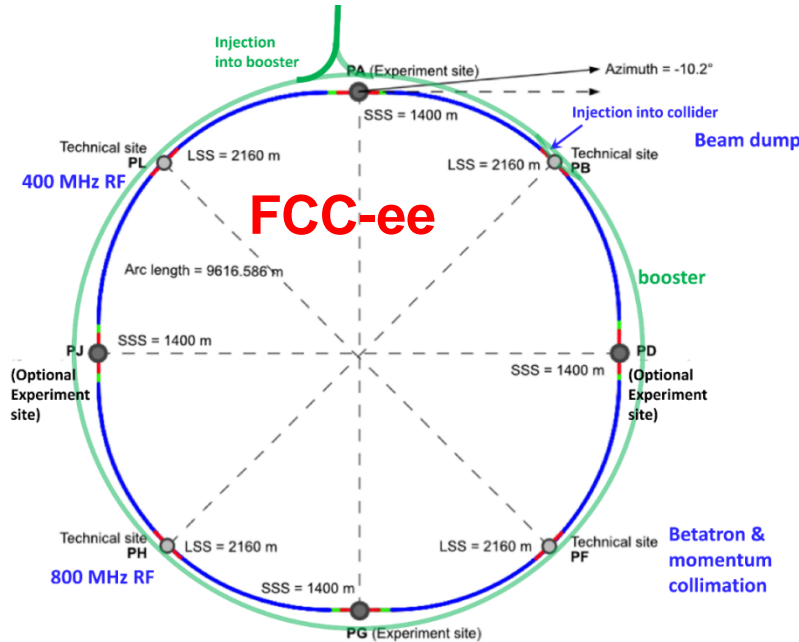
# FCC integrated programme

comprehensive long-term programme maximizing physics opportunities

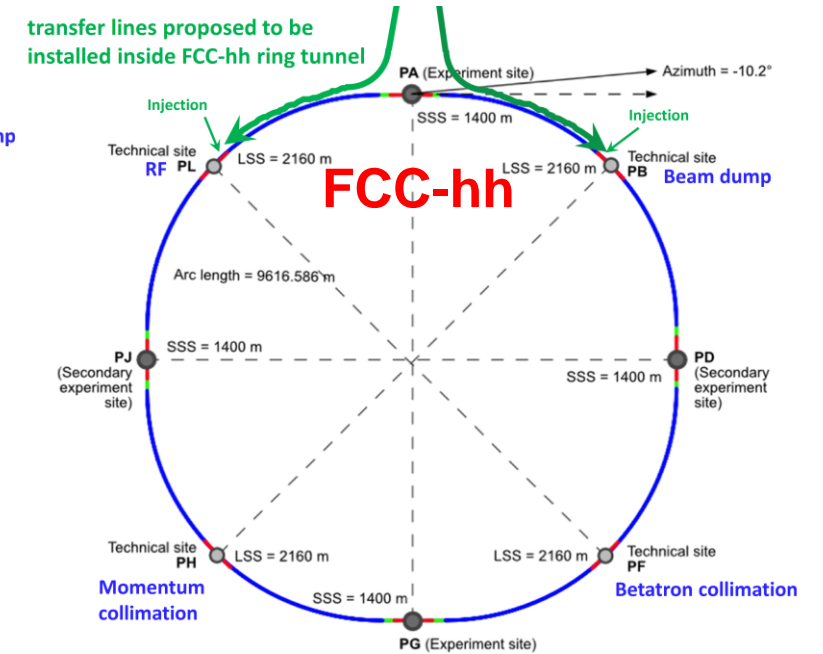
- stage 1: FCC-ee (Z, W, H,  $t\bar{t}$ ) as Higgs factory, electroweak & top factory at highest luminosities
- stage 2: FCC-hh ( $\sim 100$  TeV) as natural continuation at energy frontier, pp & AA collisions; e-h option
- highly synergetic and complementary programme boosting the physics reach of both colliders
- common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure
- FCC integrated project allows the start of a new, major facility at CERN within a few years of the end of HL-LHC



2020 - 2040



2045 - 2060



2065 - 2090



# 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



## FCC Feasibility Study:

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

**~150  
Institutes**

**32  
countries  
+  
CERN**





# FCC Week 2024 – San Francisco – 10 to 14 June



449 participants : 75 remote, 374 on site including, 28 '1-day' passes



# FCC Week 2024 - San Francisco - program

Version: 2.0		Date: 04.06.2024																						
Day	Sunday	Monday		Tuesday					Wednesday					Thursday					Friday	Day				
Time SFO	Front desk	Plenary	Board Room	Parallel 1	Parallel 2	Parallel 3	Parallel 4	Board Room	Plenary	Parallel 1	Parallel 2	Parallel 3	Board Room	Plenary	Parallel 1	Parallel 2	Parallel 3	Parallel 4	Board Room	Plenary	Time SFO			
Room	Georgian	Colonial	Yorkshire	Elizabethan A	Elizabethan B	Elizabethan C	Elizabethan D	Yorkshire	Colonial	Elizabethan A	Elizabethan B	Elizabethan C	Yorkshire	Colonial	Elizabethan A	Elizabethan B	Elizabethan C	Elizabethan D	Yorkshire	Colonial	Room			
08:00-08:30		Welcome coffee (Italian)		Welcome coffee (California East & West)					Welcome coffee (California East & West)					Welcome coffee (California East & West)					Welcome coffee					
08:30-09:00	Registration + as from 07:30am on Monday	1) Welcome remarks 2) CERN plans 3) A view from CERN Council 4+5) NSF and DOE Opening Remarks		Physics Case & Th. Calculations (i)	FCC-ee baseline design & optics, top-up	Safety			Detector Requirements (i)	Collective Effects	Sustainability and impact generation			Detector Requirements (ii)	FCC-ee code development and other themes		RF and Cryo	Governance meeting	Plenary session: summaries	08:30-09:00				
09:00-09:30																						09:00-09:30		
09:30-10:00																							09:30-10:00	
10:00-10:30				Coffee break (Italian)		Coffee Break (California East & West)					Coffee Break (California East & West)					Coffee Break (California East & West)						10:00-10:30		
10:30-11:00				1) Key Note 2) FCC FS status 3) FCC Collaboration status		Physics Case & Th. Calculations (ii)	Optics alternatives & lessons	Transport, logistic and Survey	Synergies and innovation		Software	FCC-ee optics correction & tuning	Sustainability and impact generation			Machine Detector Interface (ii)	FCC-hh design	Injection & instrumentation		Utilities			Plenary session: summaries	10:30-11:00
11:00-11:30																								11:00-11:30
11:30-12:00																								
12:00-12:30				Lunch break (California East & West)		Lunch break (California East & West)					Lunch break (California East & West)					Lunch break (California East & West)						12:00-12:30		
12:30-13:00				Lunch break (California East & West)		Lunch break (California East & West)					Lunch break (California East & West)					Lunch break (California East & West)						12:30-13:00		
13:00-13:30				Lunch break (California East & West)		Lunch break (California East & West)					Lunch break (California East & West)					Lunch break (California East & West)						13:00-13:30		
13:30-14:00		1) Implementation scenario 2) Civil Engineering 3) Accelerator status 4) Technologies & TI		Detector Concepts (i)	FCC-ee injector incl. booster (i)	Civil Engineering	Directions for R&D		Machine Detector Interface (i)	SRF Technology (ii)	Magnets			EPOL (i)	high-field magnets for FCC-hh 1	Vacuum	AIML mini workshop			Governance meeting	13:30-14:00			
14:00-14:30																						14:00-14:30		
14:30-15:00																							14:30-15:00	
15:00-15:30		Coffee break (Italian room)		Coffee Break (California East & West)					Coffee Break (California East & West)					Coffee Break (California East & West)						15:00-15:30				
15:30-16:00		Coffee break (Italian room)		Coffee Break (California East & West)					Coffee Break (California East & West)					Coffee Break (California East & West)						15:30-16:00				
16:00-16:30		1) Super KEKB status and plans 2) The Physics at FCC 3) Detectors requirements and benchmarks 4) Planning for upcoming workshops 5+6) US Plans FCC-PED, FCC-ACC	Governance meeting	Detector Concepts (ii)	FCC-ee injector incl. booster (ii)	Layout optimisation and services	SRF Technology (i)		Plenary: US Session					EPOL (ii)	high-field magnets for FCC-hh 2	Beam Intercepting devices	AIML mini workshop			Governance meeting	16:00-16:30			
16:30-17:00																						16:30-17:00		
17:00-17:30																							17:00-17:30	
17:30-18:00				Detector Concepts (iii)	FCC-ee injector incl. booster (iii)	Finance planning			Governance meeting		Early Career Researchers			Detector Requirements (iii)							17:30-18:00			
18:00-18:30																					18:00-18:30			
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20:30-21:00																					20:30-21:00			
21:00-21:30																					21:00-21:30			

50 public sessions, 216 oral presentations, 32 posters

great spirit, much progress, US efforts getting organized

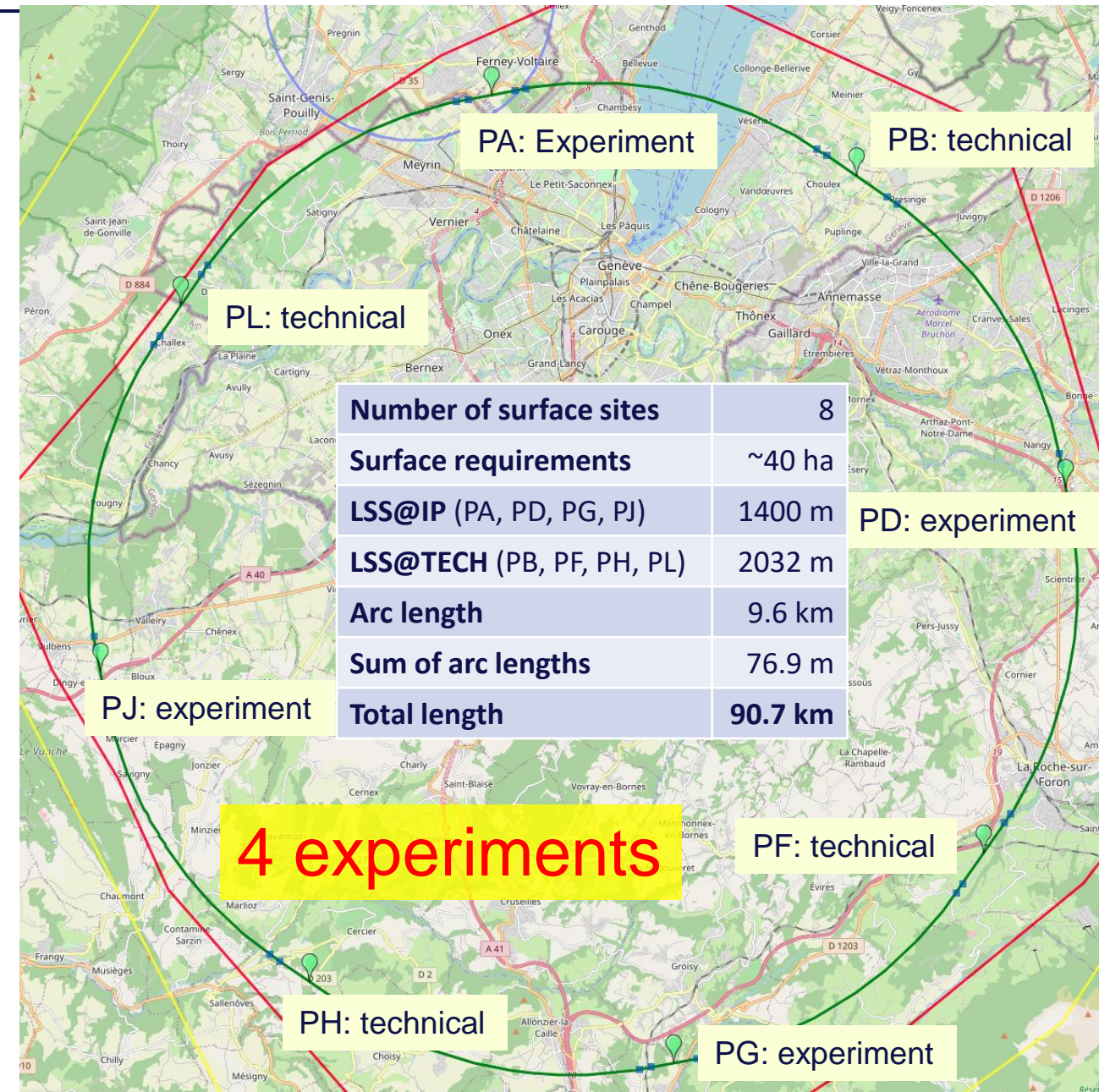
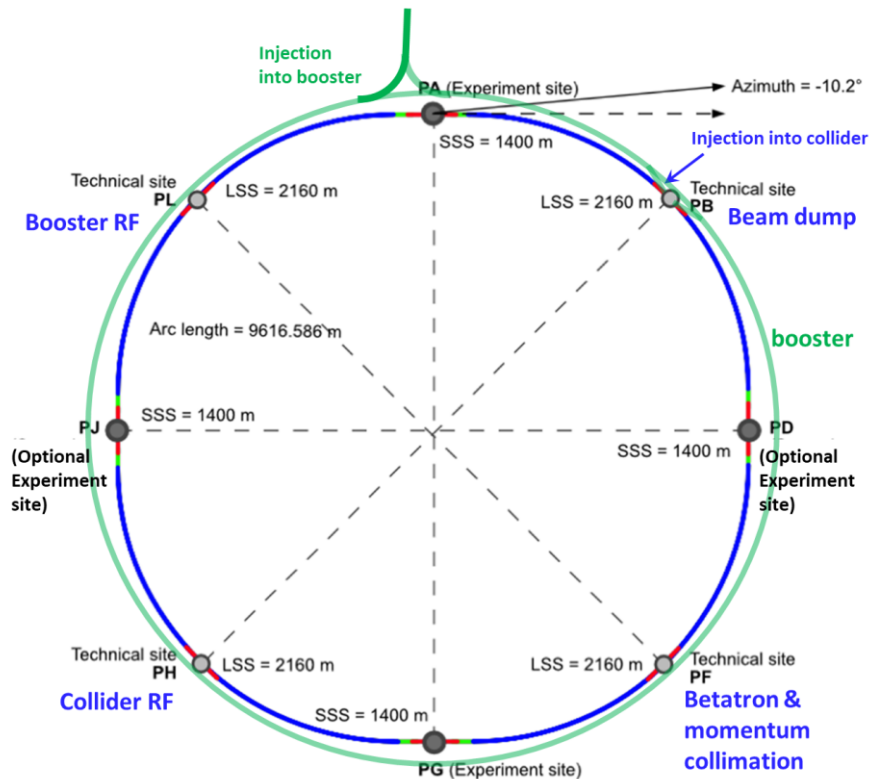
on the best way to completing the Feasibility Study by March 2025

# FCC baseline placement and layout for feasibility study

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

**4 experiments**

PF: technical

PH: technical

PG: experiment

PA: Experiment

PB: technical

PL: technical

PD: experiment

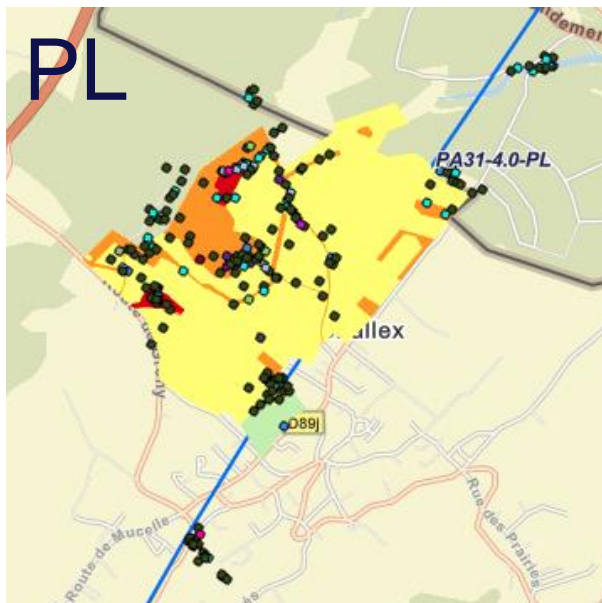
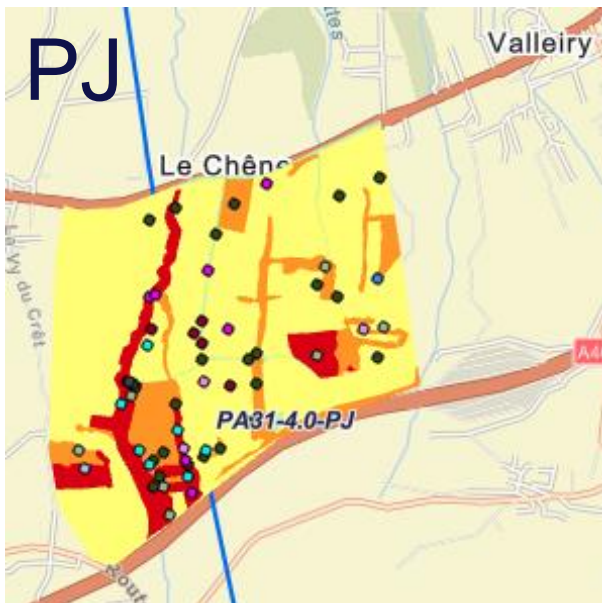
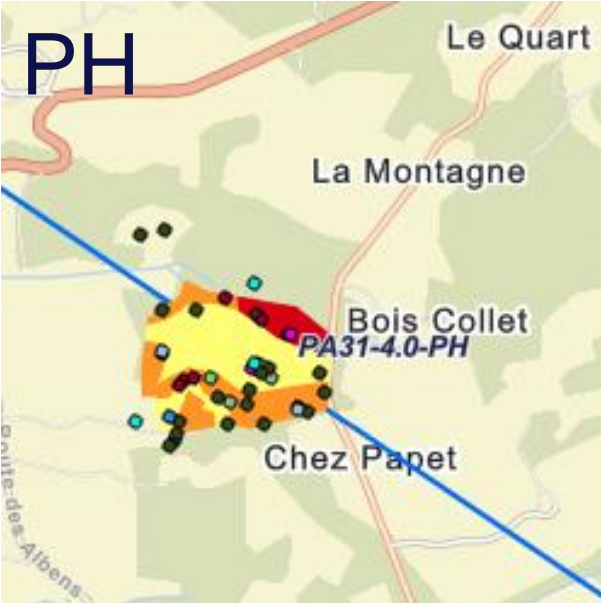
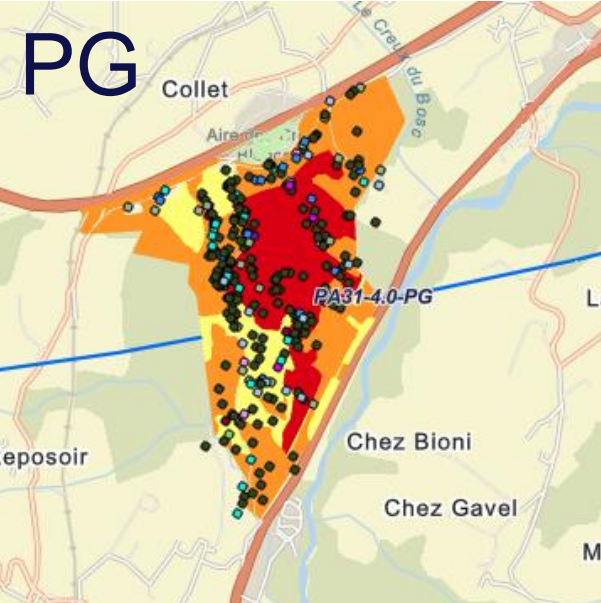
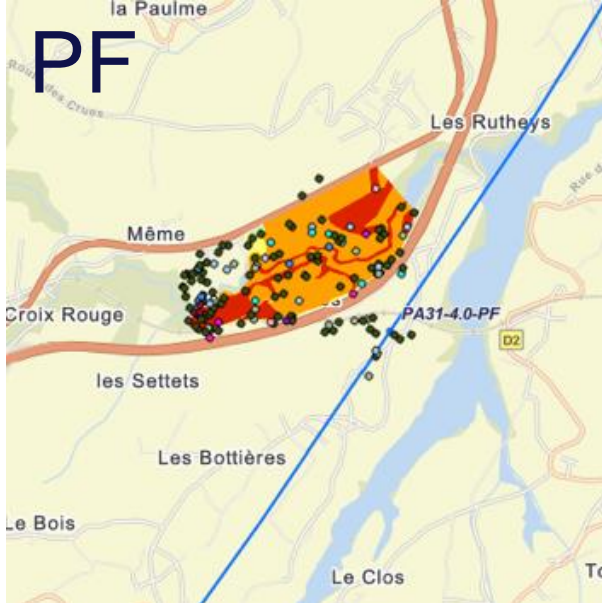
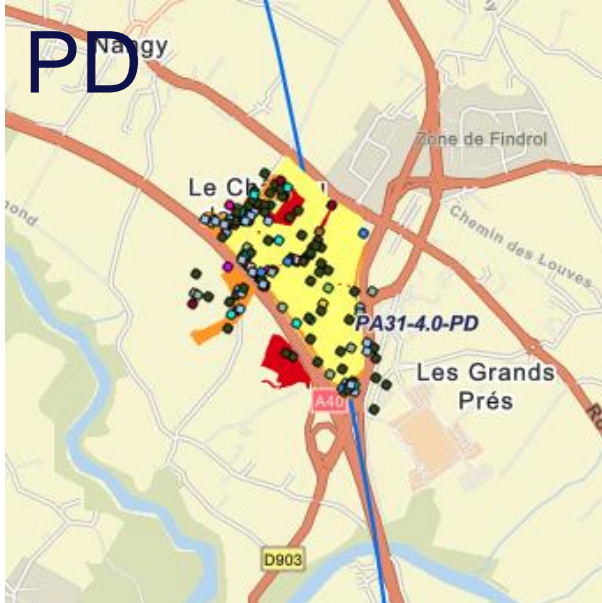
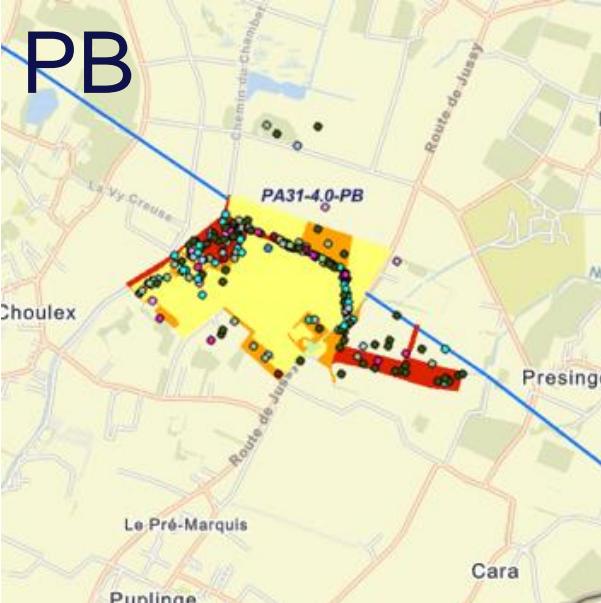
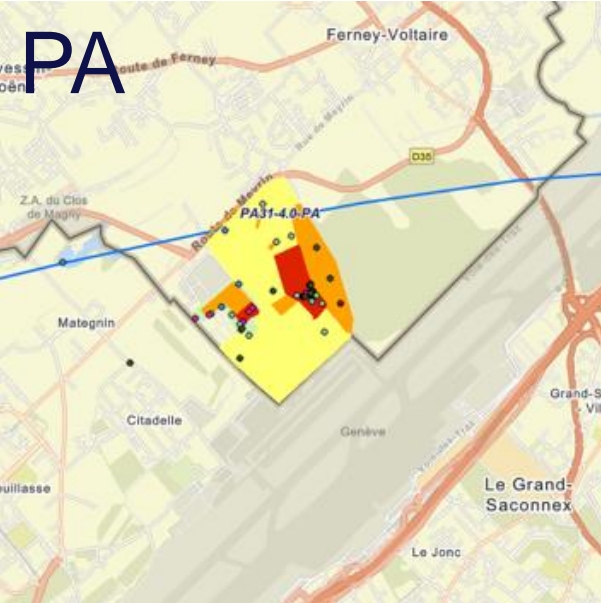
PJ: experiment







# Total area investigated in 2023/24: 585 ha over 4 seasons





# Environment report in progress: 2 volumes

**Non-technical presentation of the FCC and the environment it would be embedded in. In french for administrative services, the public and as basis for pre-project phase activities.**

## Volume 1: Environmental initial state

**Environmental analysis** of perimeter:

- Climate, air, water, soil, geology, biodiversity, habitats, urbanism, mobility, economic activities, patrimony (cultural, architectural, archeological, natural), landscape, noise, vibration, artificial light pollution, radiation, natural risks, technical risks, potentially conflicting and synergetic projects.
- **Evolution of the territory without FCC.**

Non-technical presentation of **the FCC motivation**, study and a potential project.

**Environmental strategy and guiding principles** for Ecodesign to be considered by infrastructure and equipment designers in pre-TDR phase.

## Volume 2: Environmental aspects

**High level descriptions** of all infrastructures, collider and experiment subsystems.

**Identification of aspects** that may lead to noteworthy environmental impacts as far as the current level of concepts allow (**prioritisation**).

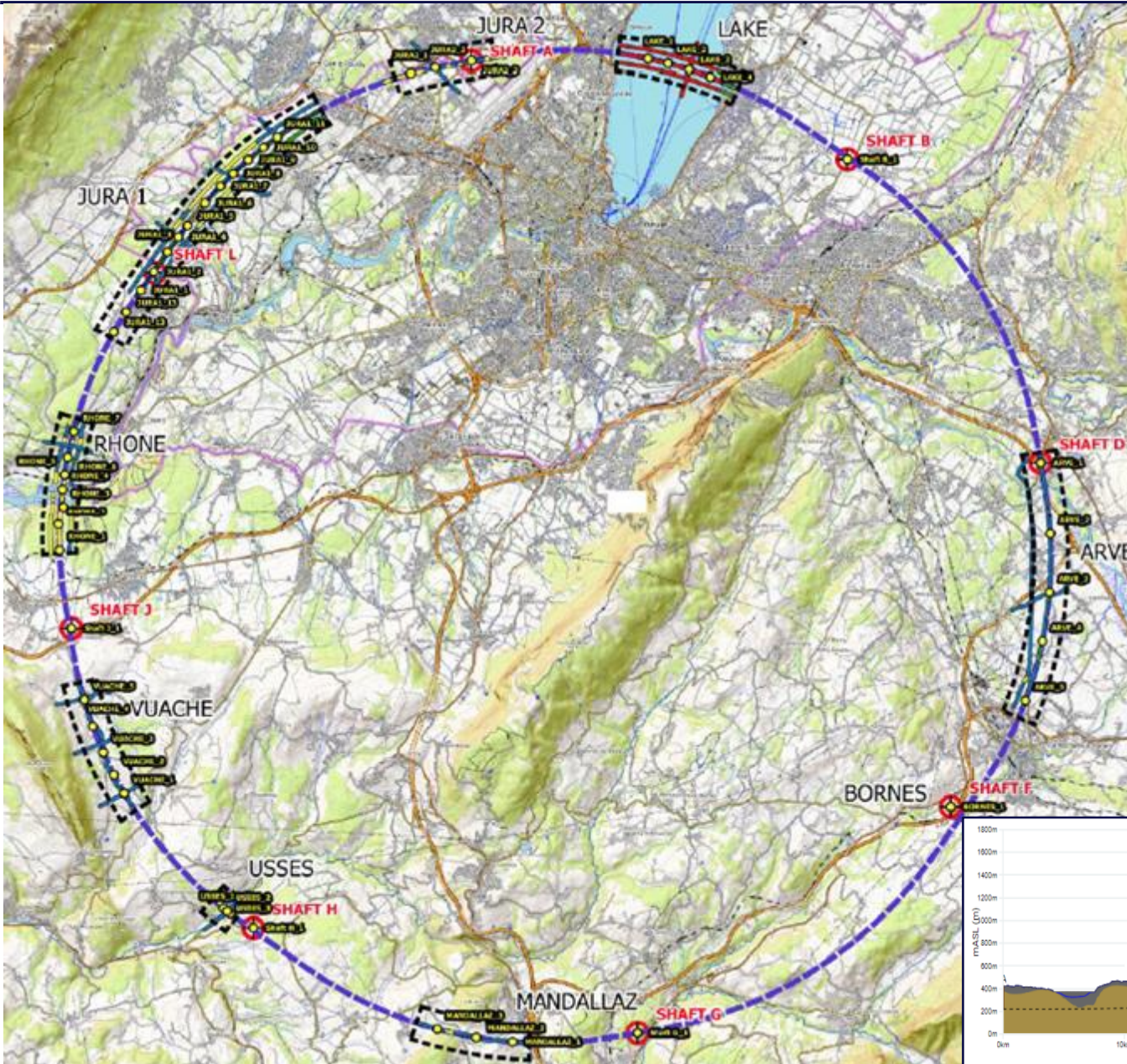
**Functional descriptions** of surface sites and needed territorial developments.

**Description of the construction** activities.

**Description of the installation** activities.



# First series of site investigations



## Site investigations to identify exact location of geological interfaces:

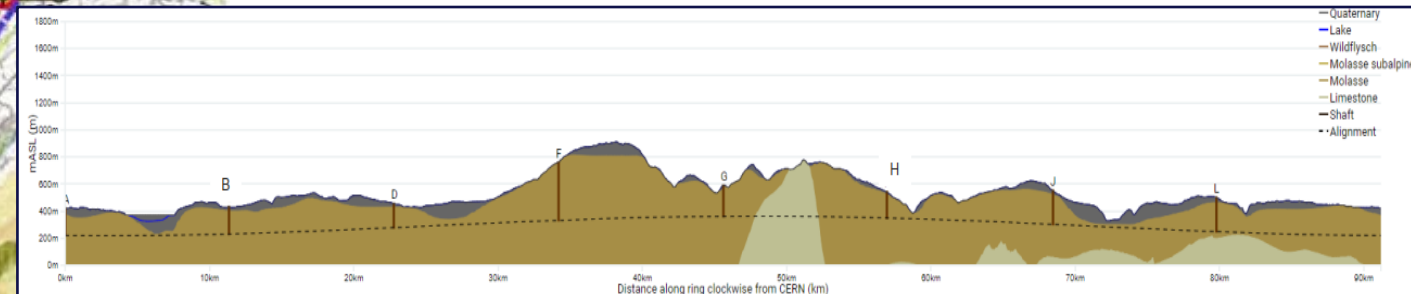
- Molasse layer vs moraines/limestone
- ~30 drillings and ~100 km seismic lines



Sondage A89 (2007) incliné de 45° de 125 ml (surface plateforme estimée : 12 x 12 m soit environ 150 m<sup>2</sup>)



Drilling works on the lake





# Status of site investigations – permitting

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## Permitting France

- Authorizations and permits are in place for the seismic investigations.
- All dossiers for drillings submitted and approval is expected by 27 September 2024.

## Permitting Switzerland

- Permitting ongoing and completion expected in autumn 2024.

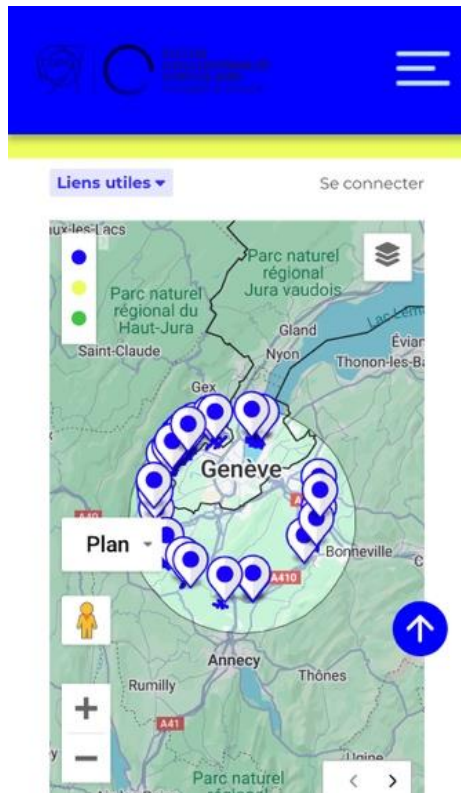
## Contracts

- One of the two contracts for the drilling and seismic investigations has been signed. This covers 80% of the works to be done in France.
- The second contract is currently with the contractor. This contract covers the remaining 20% of work in France and 100% of the work to be done in Switzerland. (The works in the lake represent almost 50% of this contract.)

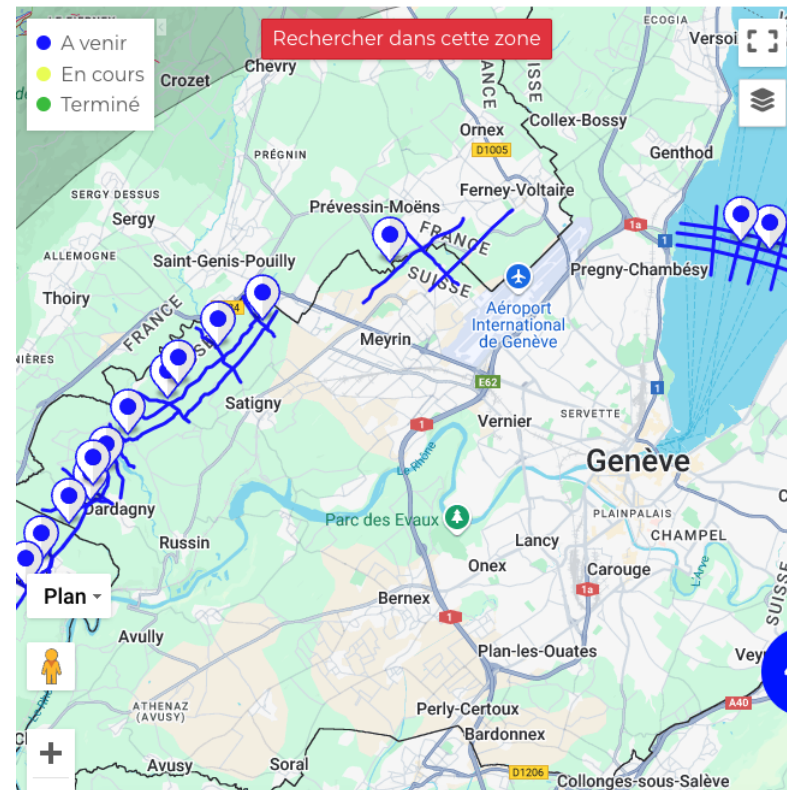


# Site investigations – information of local stakeholders

- Meetings with mayors and city councils of municipalities concerned
- Flyers distributed at a large scale; personal letters sent to private landowners
- On-site face to face encounters with CERN when needed or required by landowners or users
- Dedicated website with:
  - interactive map showing up-to-date schedule & weekly progress of geophysics and geotechnical activities
  - information and videos to better understand the works required



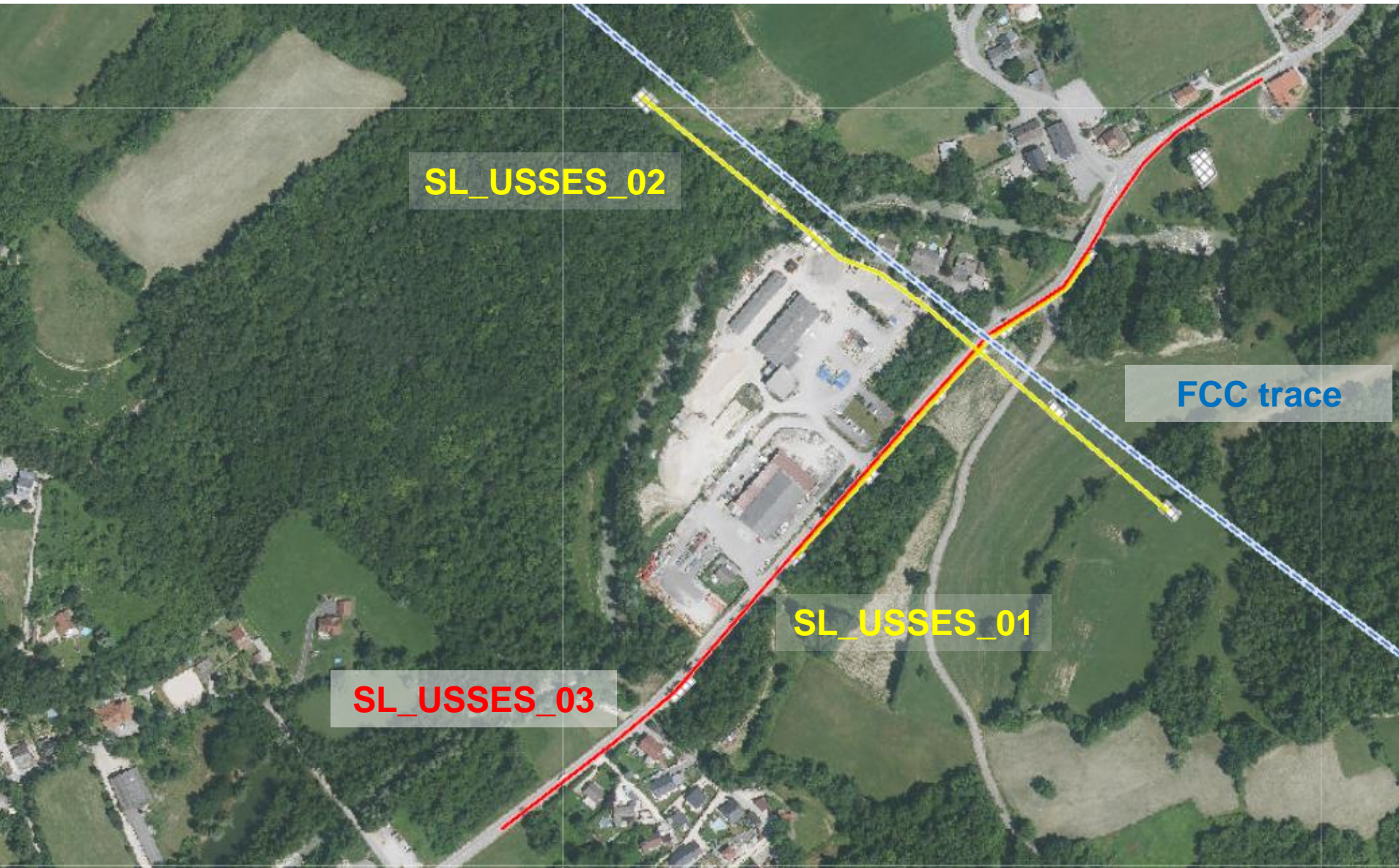
Interactive map on a dedicated website



Flyer



# Start of site investigations – field work planning



## First seismic line

### Seismic line SL\_USSES\_02 :

Acquisition date : 01/10/2024

Length : 480 meters

Method(s) : Explosive and Seismic gun

Geophones : 96 units (5 meters of spacing)

Shot points : 13 shot points in total



## Second seismic line

### Seismic line SL\_USSES\_01 :

Acquisition date : 02/10/2024

Length : 300 meters

Method(s) : Weight drop

Geophones : 60 units (5 meters of spacing)

Shot points : 15 shot points in total

100 m

Extract from the FCC GIS – 20/09/2024



# Start of site investigations – this week !

## DL Des études géologiques ont débuté sur le projet d'accélérateur du Cern

Des employés du Cern et d'autres entreprises étaient sur le terrain pour rassurer les riverains dans le cadre du chantier du futur collisionneur circulaire (FCC). Des investigations géologiques sont en cours pour vérifier la faisabilité du projet.

Patrick Roubian – Aujourd'hui à 16:06 | mis à jour aujourd'hui à 16:13 – Temps de lecture : 3 min



Une moitié de représentants du Cern et de l'entreprise qui va réaliser les investigations géologiques. Photo Le DL/P.R.



seismic vibration truck



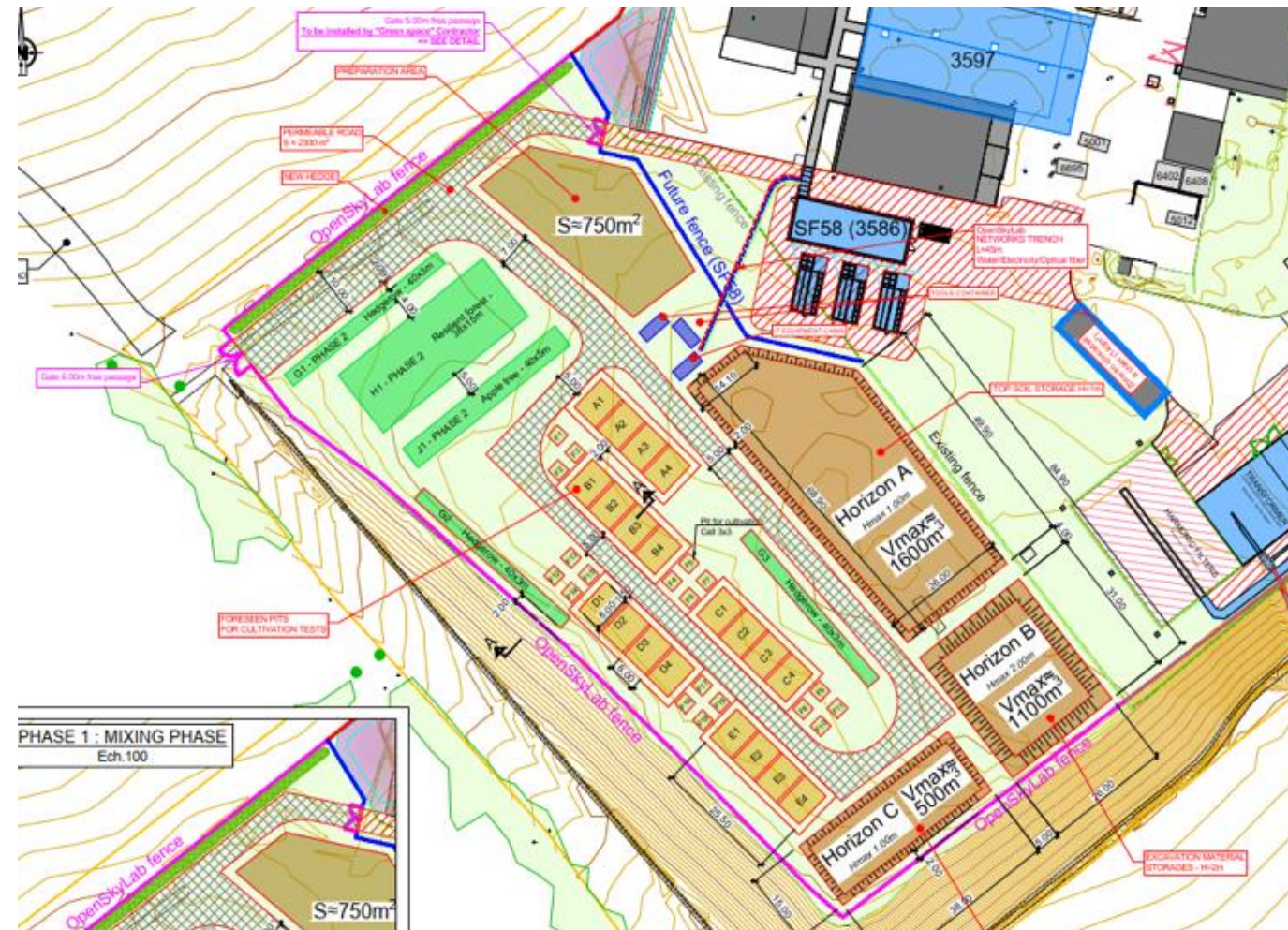
drilling rig waiting to start work



# Excavation material re-use opportunities: OpenSkyLab@LHC P5 CMS

## Academic and industrial collaboration

- Transformation of Molasse (FCC ~8 Mm<sup>3</sup> volume) into fertile soil for agricultural and other uses
- Materials: Molasse from the HL-LHC construction
- Duration: 4+ years (2024 - )
- Trials with 5 000 t molasse
  - Soil fertilisation process (micro-organisms, mixing with fertile soil, etc.)
  - Development of fertilisation mix products
  - Development of quality managed processes
  - Experimental phase with scientific protocol and field monitoring and control





# OpenSkyLab status and progress





# Start of public information & engagement sessions

First public information and discussion meeting at the Science Gateway on the 24th April at CERN.



The meeting was organised for the **local community of our Host States, France and Switzerland**, in the Science Gateway.

The "**Progress of the feasibility study of the Future FCC circular collider**" was followed by a discussion with the participants.

La Roche-sur-Foron - Haute Savoie international fair April 27 to May 6



CERN's participation in the **International Fair of Haute-Savoie/Mont Blanc**, enhanced by the valuable help of volunteers from the FCC team, resulted in meaningful **discussions with more than 2000 members of the local community** on topics ranging from the required technological advancements to sustainability measures.

On 15 May, RTS (Radio Télévision Suisse) broadcasted a special program celebrating CERN's 70th anniversary and hosted at CERN's Science Gateway.



The event featured a comprehensive look at **CERN's illustrious history, groundbreaking achievements, and future ambitions**, including the prominently featured Future Circular Collider (FCC) project with **study experts interacting with the audience**.



# Commission Nationale de Débat Public (CNDP) - mission & public information

The **CNDP**, created in 1995, is an **independent French authority that ensures public participation in the definition and decision process of major projects in France**, impacting the environment by providing a neutral and transparent framework for discussions between decision-makers and citizens.

On July 2, 2024, the **CERN DG requested the CNDP to undertake an advisory mission** on public participation for the FCC. On July 3, the president of the CNDP appointed two guarantors to:

- **Assist CERN in preparing the first information meetings** on the ongoing studies in the region.
- **Provide non-binding advice to CERN** on the next steps for **public participation regarding the FCC**.

## Present status:

- The FCC team, with the advice of the guarantors, is preparing the launch of information meetings on site investigations that are starting in the region.
- Discussions regarding the legal framework of CERN, as International Organisation, and its compatibility with CNDP procedures are ongoing with the guarantors.

**RÉPUBLIQUE FRANÇAISE**  
Commission nationale  
du débat public

**Décision n° 2023 / 109 / CERN / 1 du 3 juillet 2024 relative au projet FCC de futur collisionneur circulaire d'accélérateur de particules du CERN (74)**

La Commission nationale du débat public,

Vu le code de l'environnement en ses articles L.121-1 et suivants ;  
Vu le courrier du 2 juillet 2024 et le dossier annexé de Mme Fabiola GIANOTTI, représentant le CERN, sollicitant une mission de conseil afin de préparer la saisine à venir sur le projet FCC de futur collisionneur circulaire d'accélérateur de particules du CERN et d'accompagner les premières démarches d'information du public menées par le maître d'ouvrage ;

Après en avoir délibéré,


Décide :

**Article 1er**  
Mme Brigitte FARGEVIEILLE et M. Jonas FROSSARD sont désignés pour assurer une mission de conseil relative à la préparation de la saisine à venir sur le projet FCC d'accélérateur de particules du CERN et à l'accompagnement des premières démarches d'information du public menées par le maître d'ouvrage.

**Article 2**  
A l'issue de leur mission, Mme Brigitte FARGEVIEILLE et M. Jonas FROSSARD, produiront un bilan de leur mission relative à la préparation de la saisine à venir sur le projet d'accélérateur de particules du CERN et à l'accompagnement des premières démarches d'information du public menées par le maître d'ouvrage.

**Article 3**  
La présente décision sera publiée au *Journal officiel* de la République française.

Fait le 3 juillet 2024

Le Président  


Signature numérique de Marc  
PAPINUTTI marc.papinutti  
Date : 2024.07.03 16:30:58  
+02'00'

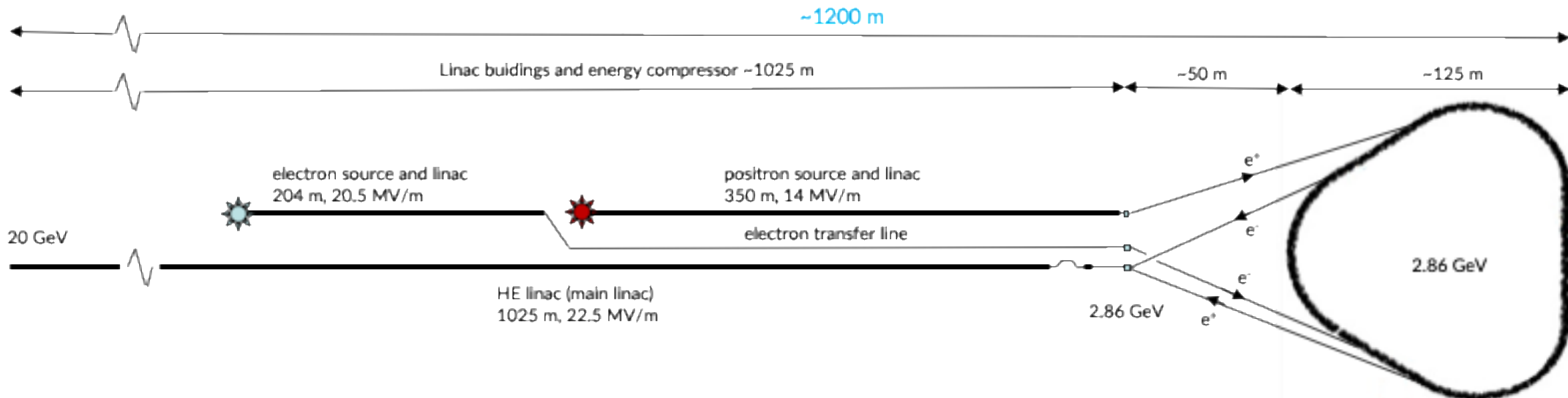
Le président  
M. Papinutti

CNDP decision for the Advisory Mission



# Optimized injector concept and parameters

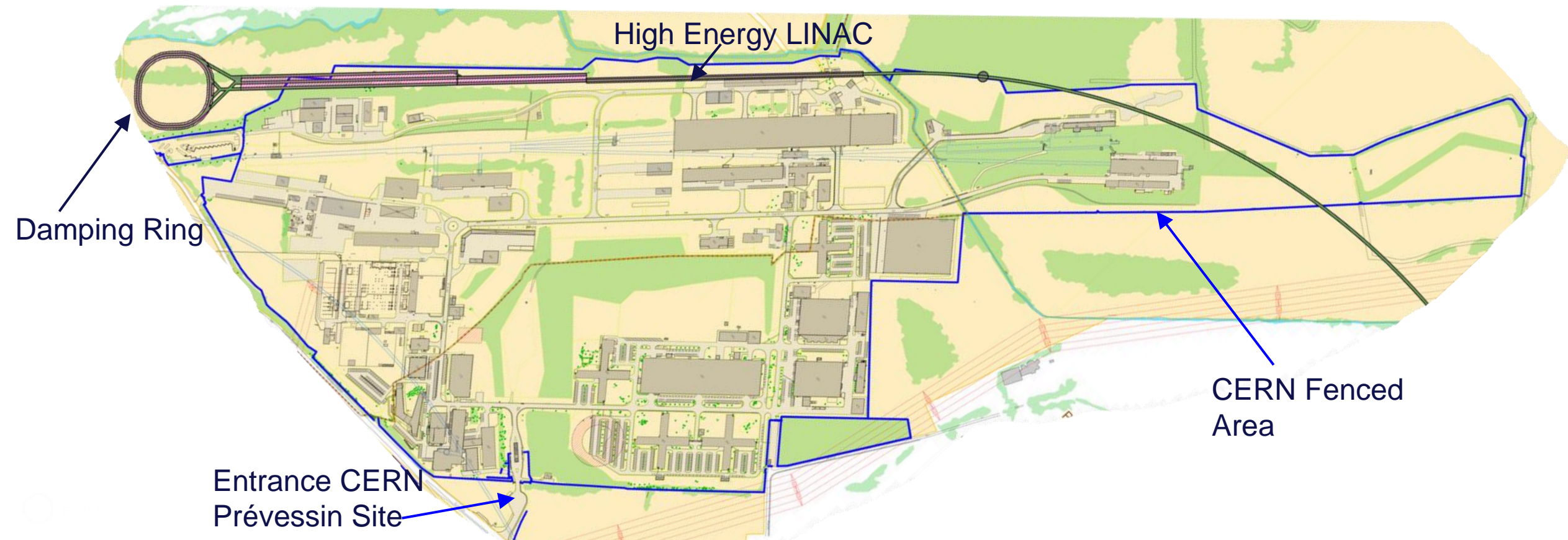
- **Mid-term review recommendations to reduce gradients and repetition rate → new linac optimization in terms of cost and power density**
  - Overall power consumption (for linacs) is reduced by **more than a factor 3** by means of:
    - new accelerating structures with higher shunt impedance;
    - lower gradient (29.5 MV/m → 22.5/20.5 MV/m);
    - lower repetition rate (200/400 Hz → 100 Hz).
  - Repetition rate of **100 Hz with 4 bunches** per rf pulse
  - New layout: **Damping Ring at higher energy 2.86 GeV**, no common linac with 2x repetition rate.





# Optimised injector implementation at Préveessin site

- Better integration with existing CERN Préveessin Site & strongly reduced visible impact from outside.
- Ideal connection to existing experimental halls.
- Good conditions for construction (see next slide).
- CERN dedicated land, small part outside fenced area but with same urbanistic classification as enclosed Preveessin Site (UAcern)

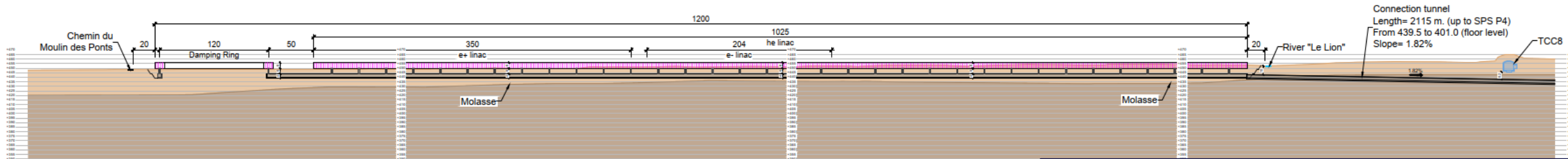




# Injector construction concept

## OPTION 9

### DAMPING RING NEXT TO "DECHETERIE"

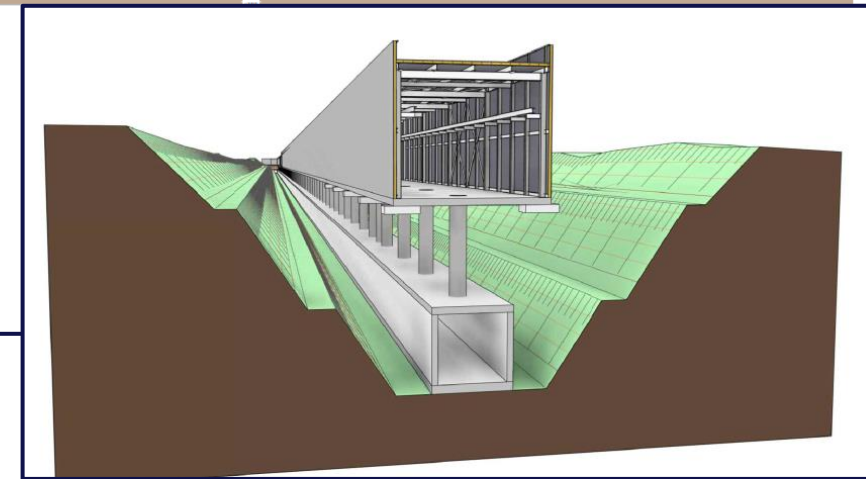
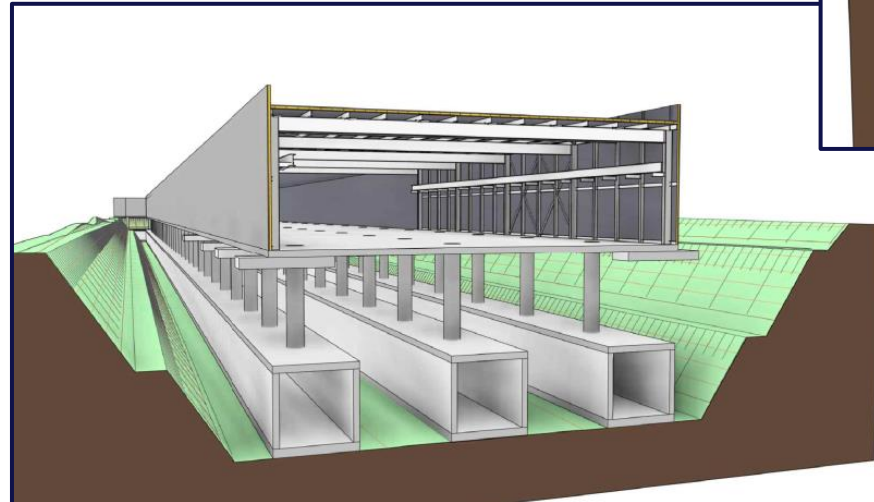


LONGITUDINAL PROFILE

## Longitudinal Section

- Less than 5 m elevation change over the 1200 m of terrain provides **ideal conditions for "cut and cover" technique**
- Most efficient and cheapest way of building shallow underground construction
- Excavated material largely re-used as backfill above the tunnel
- Accounts also for radio-protection requirements

HE LINAC Line +  
Electron and Positron Lines



HE LINAC Line

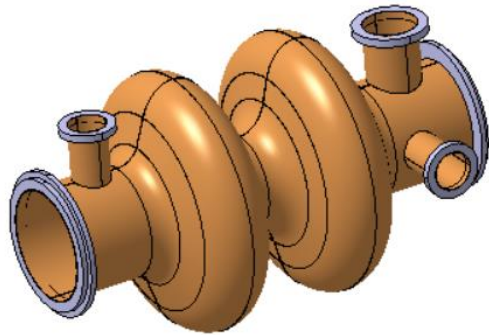


# 400 MHz SRF progress – one system for 3 energies

Same two-cell RF cavities for Z, WW and ZH operation with constant cavity coupling thanks to **reverse phase operation**: (1) experimentally verified w high beam loading at KEKB (*Y. Morita et al., 2009*), (2) Baseline solution US EIC

- No longer any 1-cell 400 MHz cavities
- Reduced installation time
- Reduced commissioning effort
- Fast switching between Z, WW and ZH operation

## 400 MHz cavities



**Z, W, ZH**

**X 264**

400 MHz 2-cell cavity

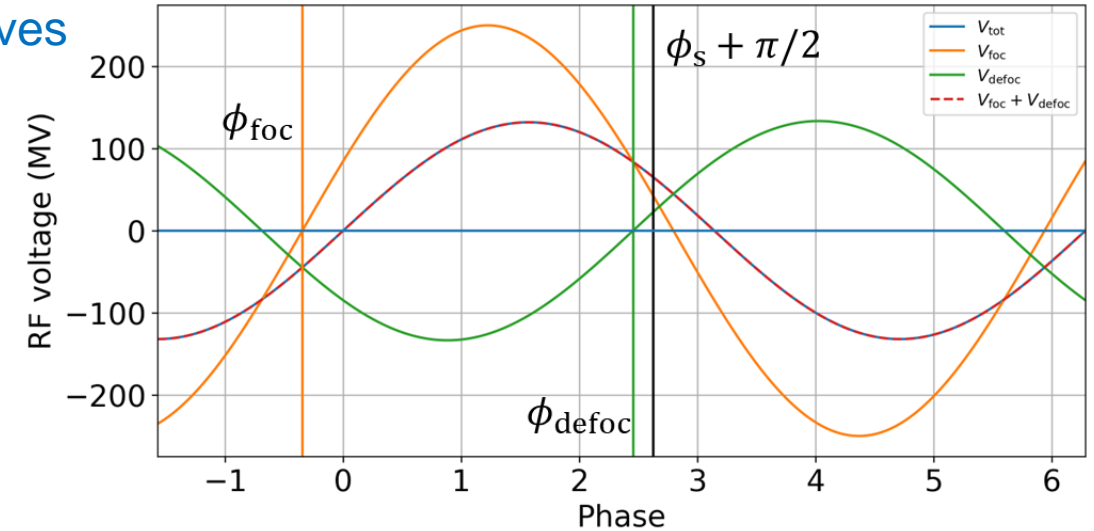
Niobium thin film on Copper,

Operation at 4.5 Kelvin

Max. accel. gradient  $E_{acc} = 13 \text{ MV/m}$

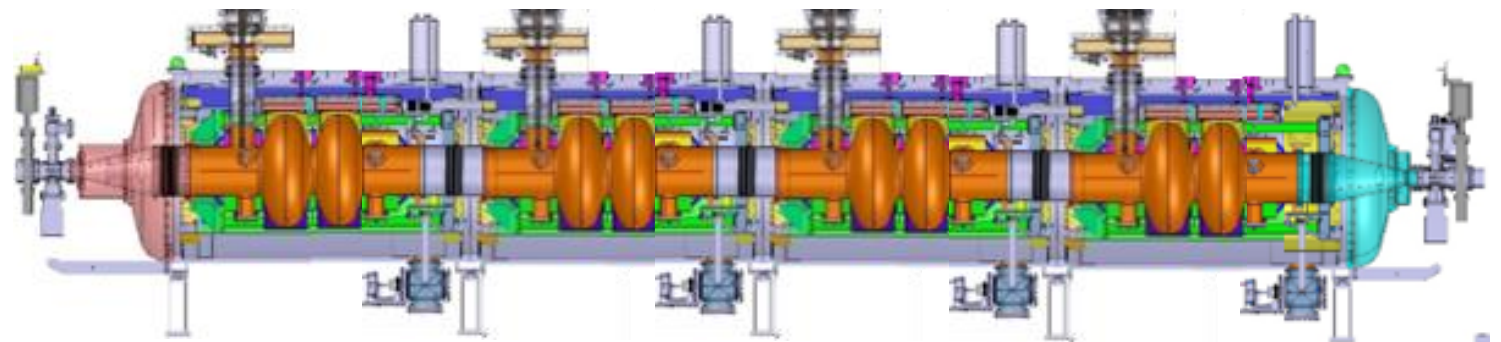
Quality factor  $Q_0 = 3.3 \times 10^9$

RF waves



cryomodule

**X 66**



400 MHz cryomodule, ~12 m long

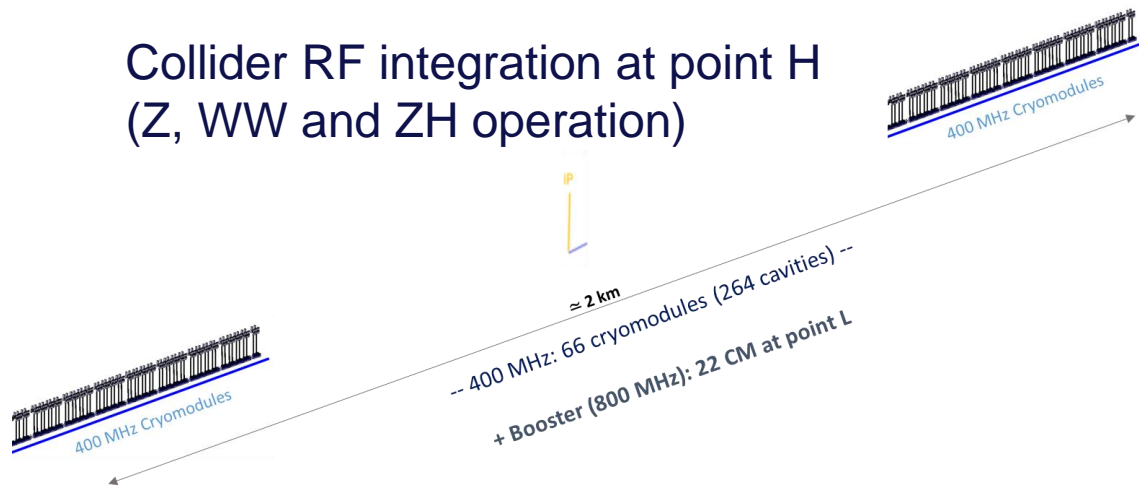


# SRF integration and beam switchyard

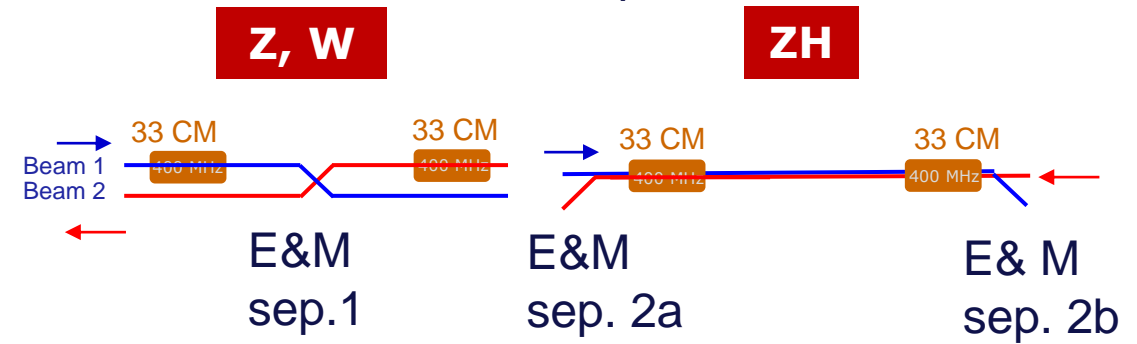
## Beam switching between (Z, W) and ZH operation

- RF section: ES separators + magnetic field to not emit SR towards RF cavities
- Allows quasi “instantaneous” switching between Z, W, ZH

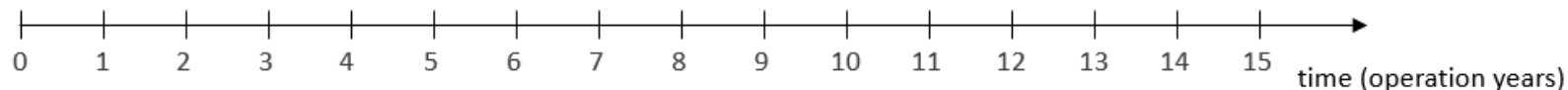
Collider RF integration at point H  
(Z, WW and ZH operation)



Beam crossing and combination  
at RF section in point H



extra year of operation thanks to single RF system





# other FCC science applications under study

for example:

**FCC-ee booster as diffraction limited storage ring** with coherent synchrotron radiation down to 0.1 Å

FCC-ee injector as the world's **ultimate positron source** for material studies and paving a path towards the first **Bose-Einstein condensation of Ps** (511-keV gamma-ray laser)

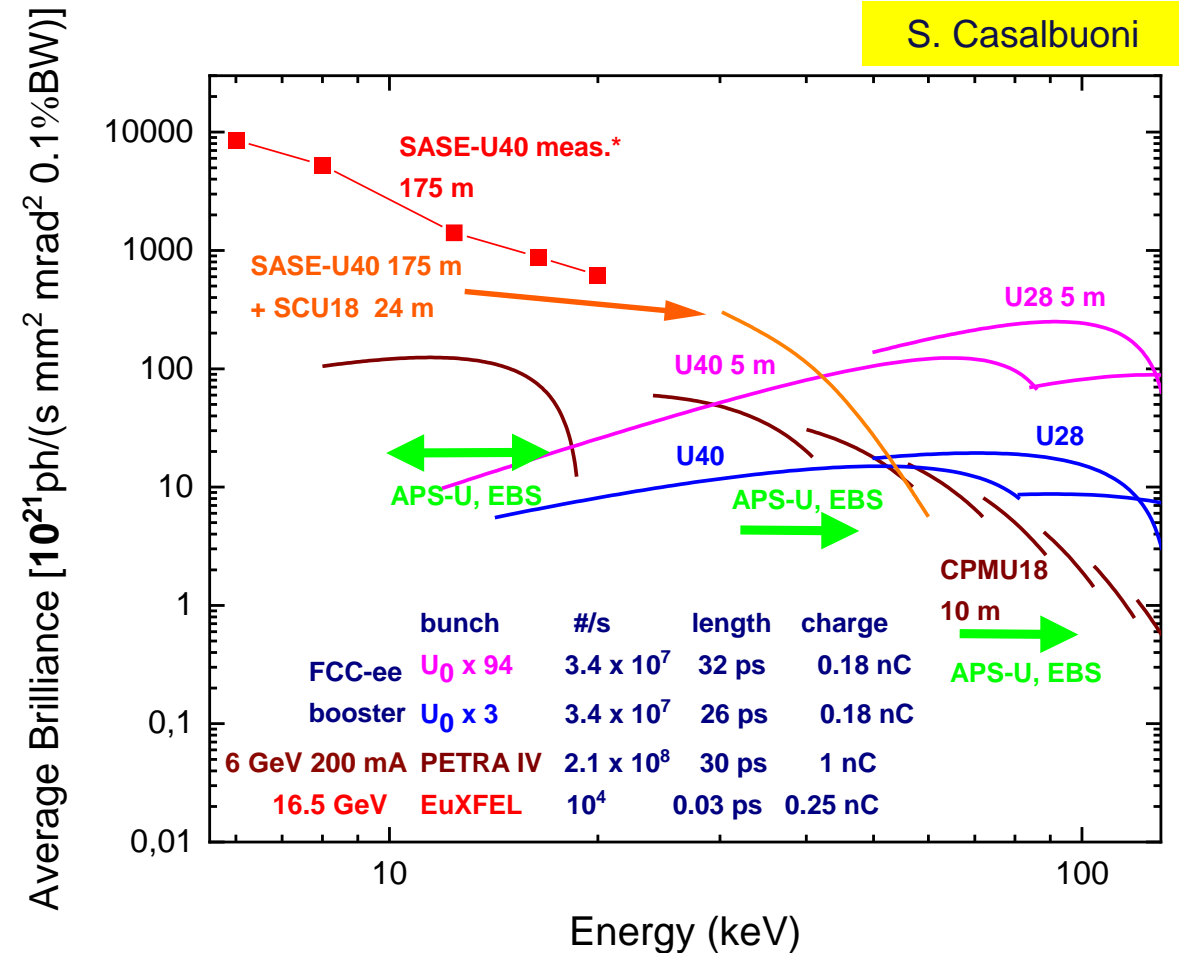
M. Doser,  
B. Rienäcker

using beamstrahlung for **radionuclide production**

e<sup>-</sup> beam driven **neutron source**

M. Calviani,  
C. Duchemin

etc.



# Feasibility Study Report for March 2025

## Structure: Three Volumes

- **Vol. 1: Physics, Experiments and Detectors (~200 pages)**
- **Vol. 2: Accelerators, Technical Infrastructures, Safety Concepts (~400 pages)**
- **Vol. 3: Civil Engineering, Implementation & Sustainability (~200 pages)**
- **Executive Summary of the FCC Feasibility Study: ~40 pages**

## **Input for Update of European Strategy for Particle Physics**

to be prepared with Overleaf & published by EPJ (Springer-Nature) – FCCIS members



### In addition:

- Documentation on Cost Estimate – Funding Models**
- Environmental Report**



## The future of European competitiveness

Part B | In-depth analysis and recommendations

SEPTEMBER 2024

[https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead\\_en](https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en)

***“One of CERN’s most promising current projects, with significant scientific potential, is the construction of the Future Circular Collider (FCC): a 90-km ring designed initially for an electron collider and later for a hadron collider..***

***Refinancing CERN and ensuring its continued global leadership in frontier research should be regarded as a top EU priority, given the objective of maintaining European prominence in this critical area of fundamental research, which is expected to generate significant business spillovers in the coming years.”***

# CERN 70th anniversary, 1 October 2024

## DL Le Cern soude l'Europe autour de l'accélérateur de 91 kilomètres

**LE DAUPHINÉ**  
libéré

Si le Centre européen de recherche nucléaire craignait une crise des 70 ans, les chefs d'États européens et la présidente de la Commission Européenne Ursula Von der Leyen l'ont écartée ce mardi, apportant un soutien franc.

Sébastien Colson – Hier à 19:25 | mis à jour hier à 19:41 – Temps de lecture : 4 min



President Ursula von der LEYEN @ the Official Ceremony for CERN's 70th anniversary

1.7K views · Streamed 22 hours ago ...more

European Commission 187K

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Autour de la directrice générale du Cern, Fabiola Gianotti (au centre en blanc), des personnalités comme la présidente de la Confédération suisse, Viola Amherd, la Princesse Astrid de Belgique, ou les présidents de l'Italie ou la Serbie, Sergio Mattarella et Aleksandar Vucic, ont dit leur soutien comme la présidente de la Commission européenne, Ursula Von der Leyen (à droite en rose). Photo Le DL /Greg Yetchmeniza



# FCC Week 2025 - Vienna



## Event Overview

- **Venue: Hofburg Palace**, a historical and cultural landmark in **Vienna, Austria**.
- **Dates: Monday 19 to Friday 23 May 2025**
- **Presentation of the Feasibility Study Report and review of its findings and opportunities for future R&D projects**
- **Please save the date and join us in Vienna**



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