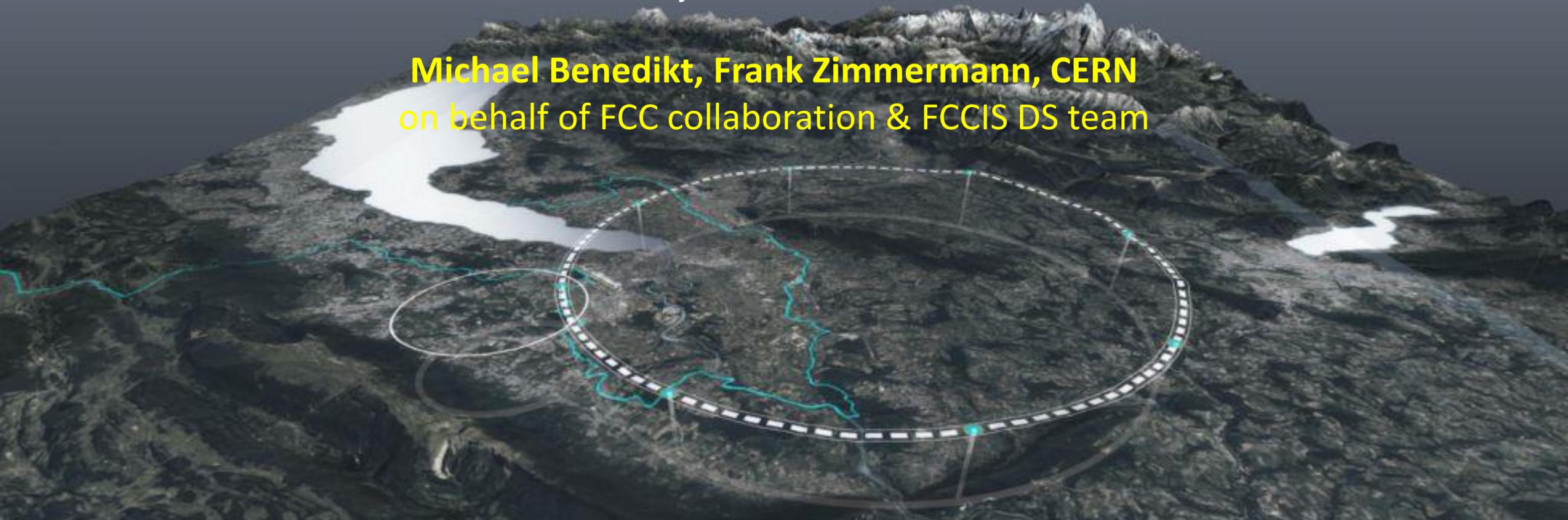


# FCC Feasibility Study Status

SLAC, 14 June 2024

Michael Benedikt, Frank Zimmermann, CERN  
on behalf of FCC collaboration & FCCIS DS team



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

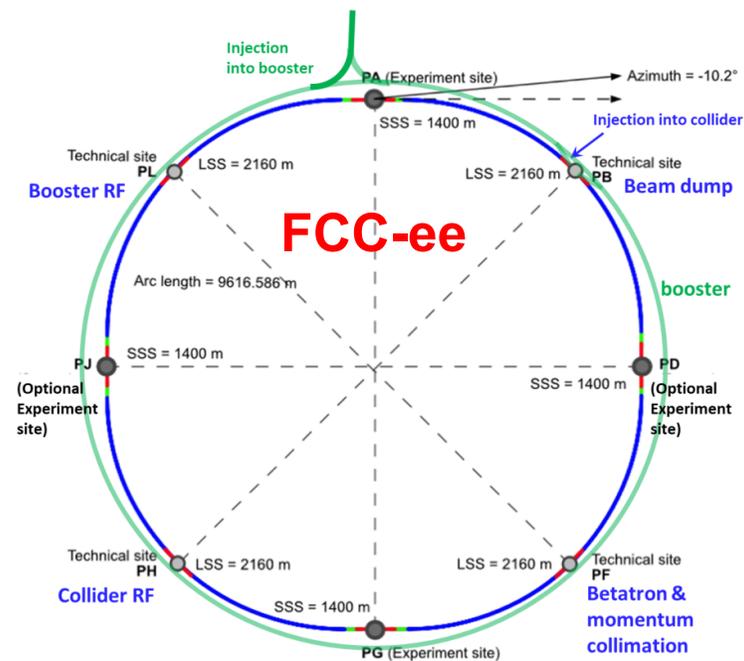
# FCC integrated program

comprehensive long-term program maximizing physics opportunities

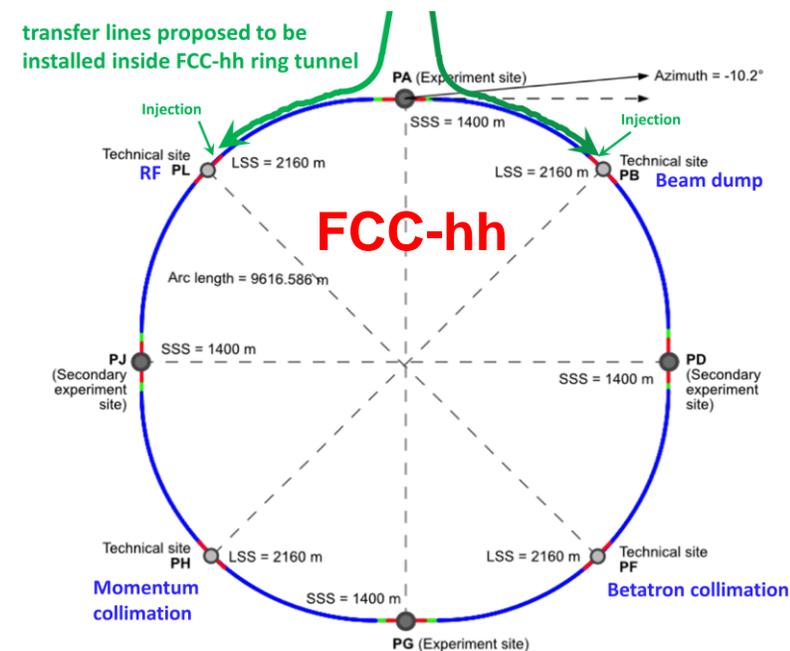
- stage 1: FCC-ee (Z, W, H,  $t\bar{t}$ ) as Higgs factory, electroweak & top factory at highest luminosities
- stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, pp & AA collisions; e-h option
- highly synergetic and complementary programme boosting the physics reach of both colliders
- 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 - 2046



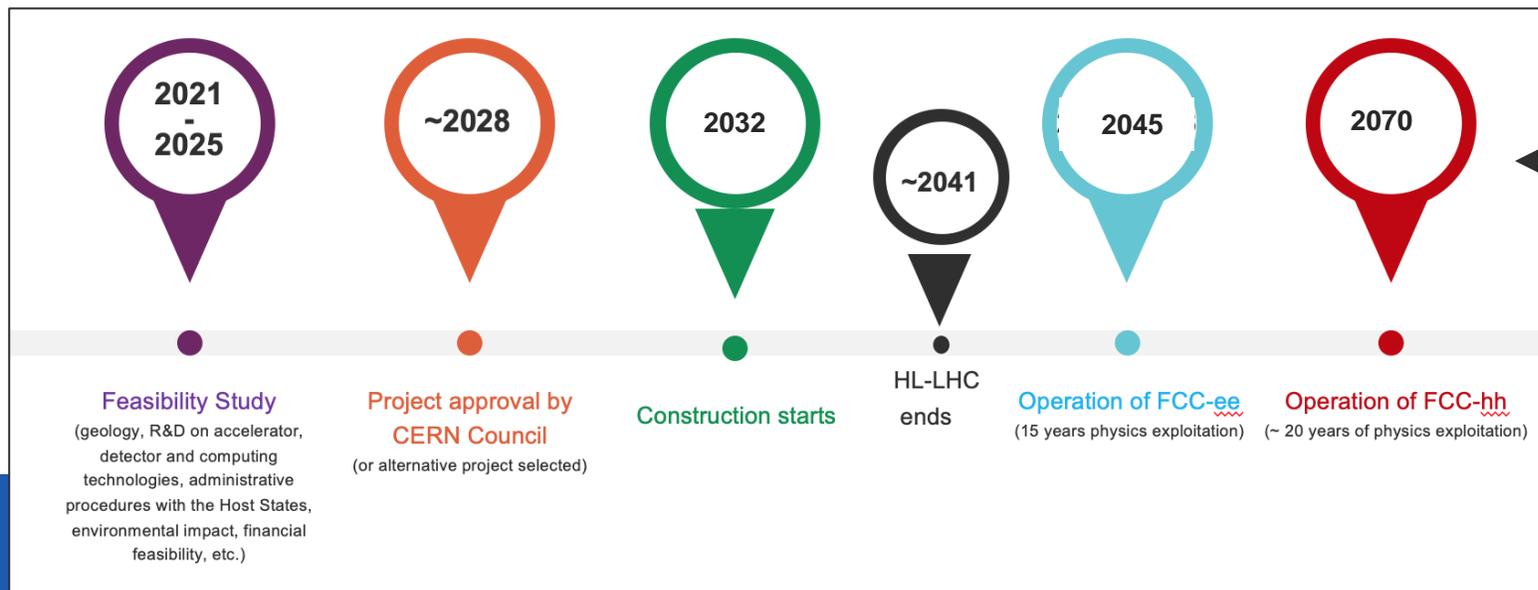
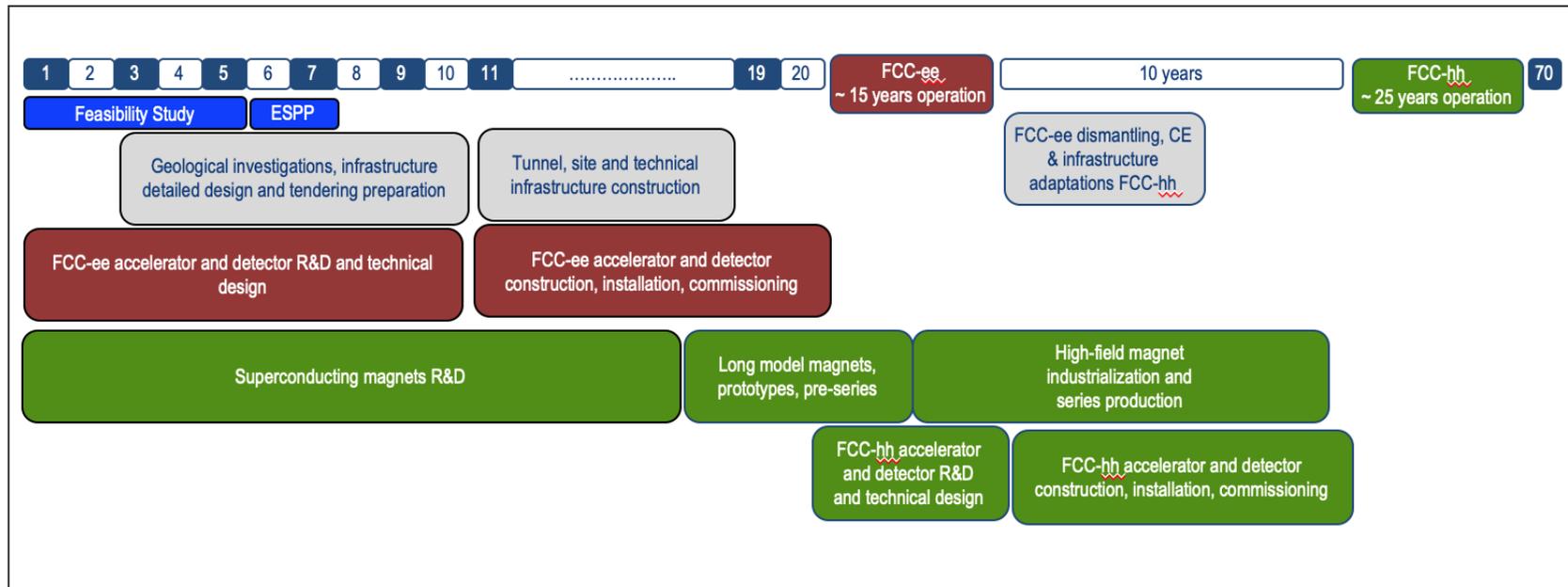
2045 - 2060



2070 -

# FCC integrated program - timeline

Note: FCC Conceptual Design Study started in 2014 leading to CDR in 2018



**“Realistic” schedule** taking into account:

- past experience in building colliders at CERN
- approval timeline: ESPP, Council decision
- that HL-LHC will run until 2041

Can be accelerated if more resources available

## 2013 Update of European Strategy for Particle Physics:

*“CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines.”*

## → FCC Conceptual Design Reports (2018/19)



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)**

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

## 2020 Update of European Strategy for Particle Physics:

*“Europe, together with its international partners, should investigate 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.”*



- ❑ 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

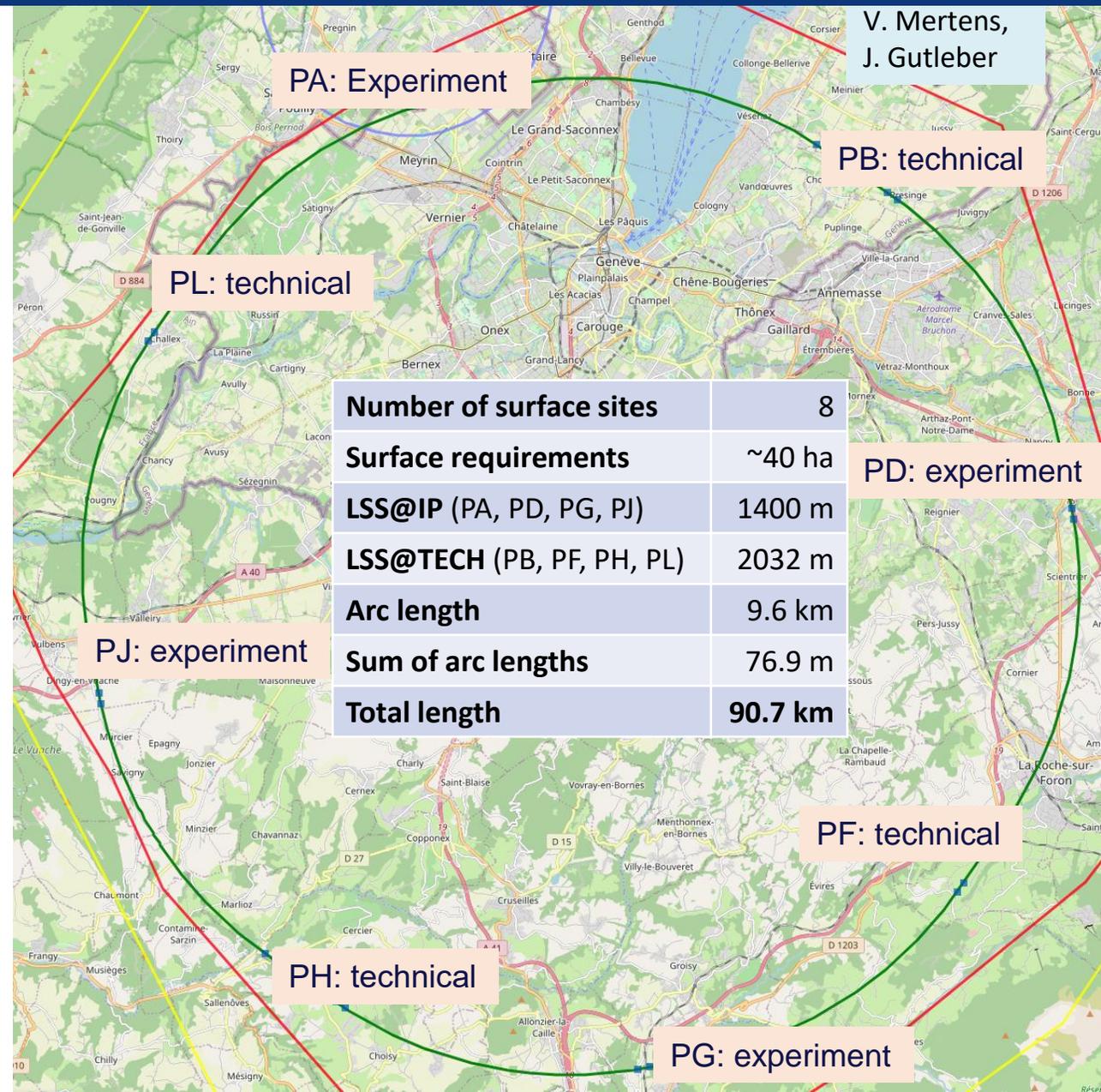
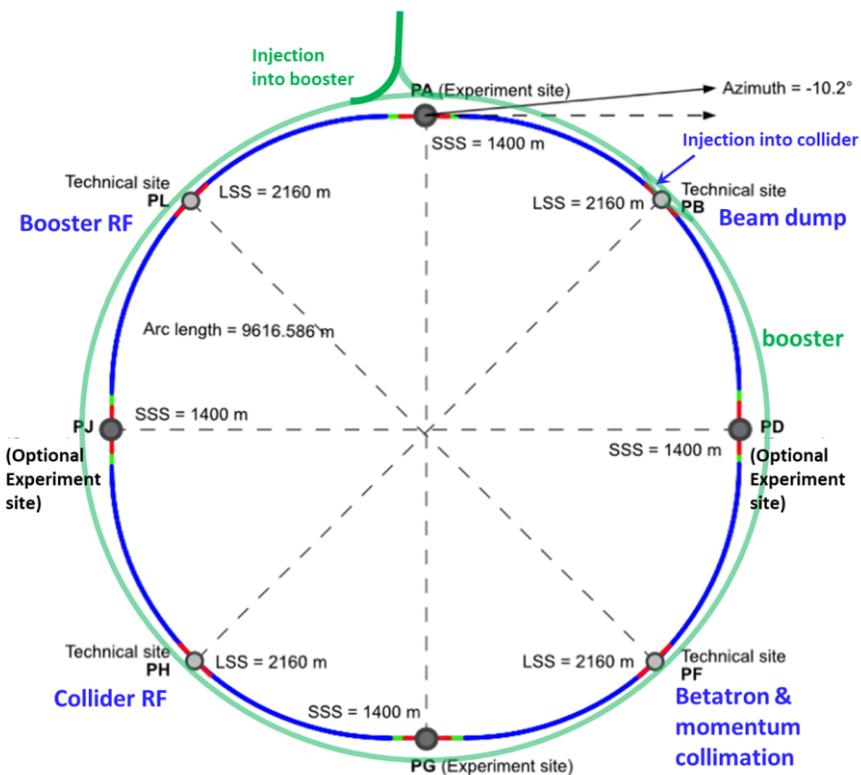
F. Gianotti

# Optimized 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

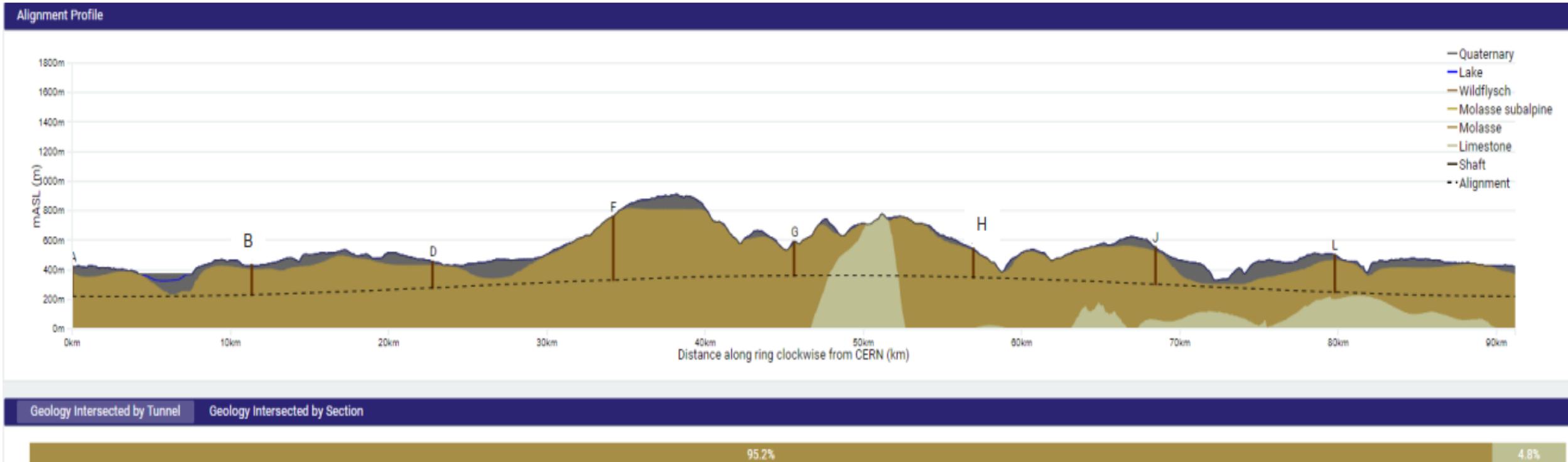
**Overall lowest-risk baseline: 90.7 km ring, 8 surface points,**  
Whole project now adapted to this placement



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

V. Mertens,  
J. Gutleber

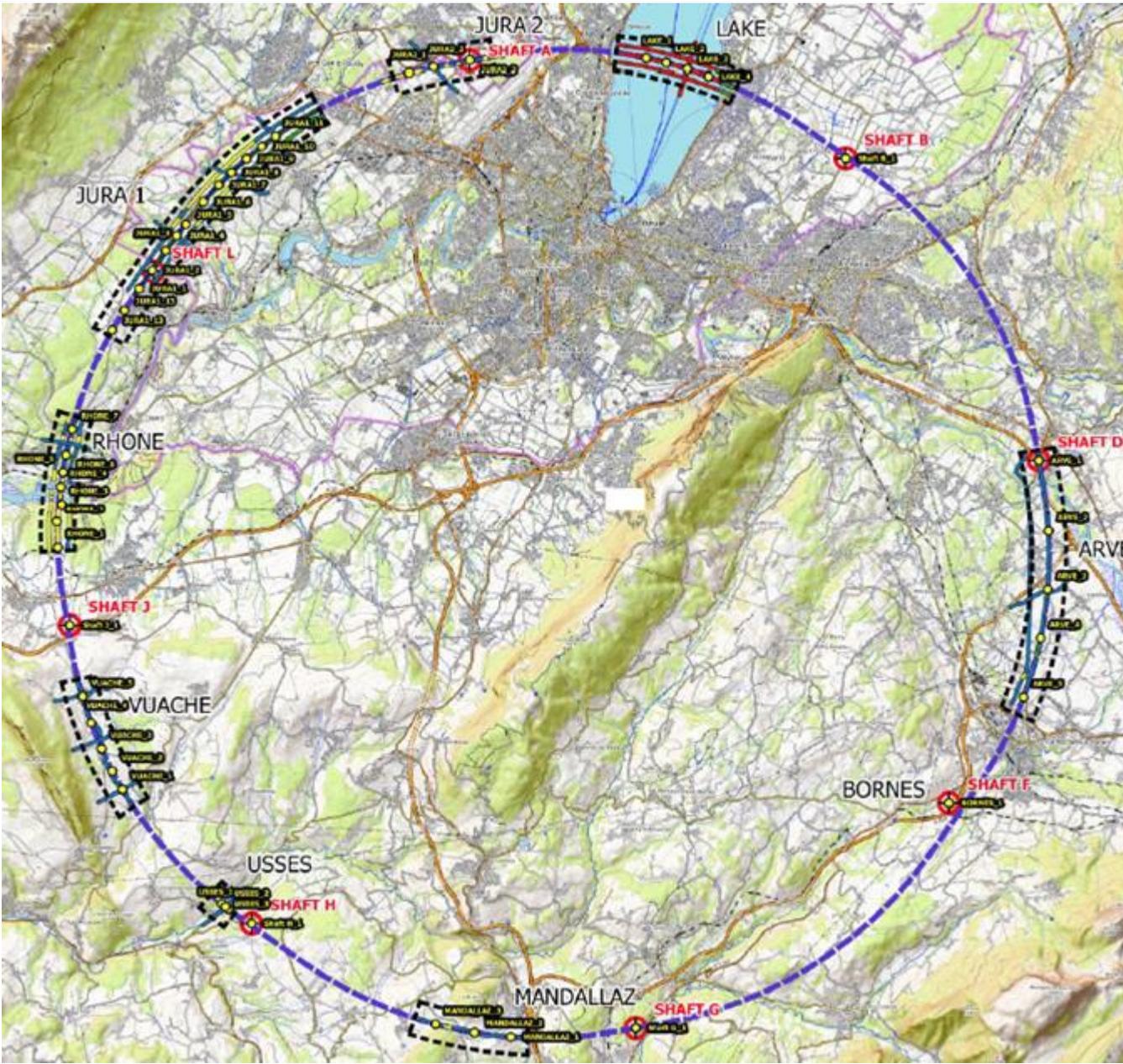




## Tunnel implementation summary

- 91 km circumference
- 95% in molasse geology for minimising tunnel construction risks
- Site investigations in zones where tunnel is close to geological interfaces: moraines-molasse-limestone

# Status site investigations



Site investigations to identify exact location of geological interfaces:

- Molasse layer vs moraines/limestone
- ~30 drillings and
- ~100 km seismic lines
- Start in July 2024

→ Vertical position and inclination of tunnel



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

# Start of public information & engagement sessions

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

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

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



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.

## Unveiling the science of tomorrow: FCC Study takes centre stage at La Roche-sur-Foron exhibition

The Future Circular Collider team discussed the project's status and aspirations with a large number of attendees

15 MAY, 2024 | By Zoe Nikolaidou



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.

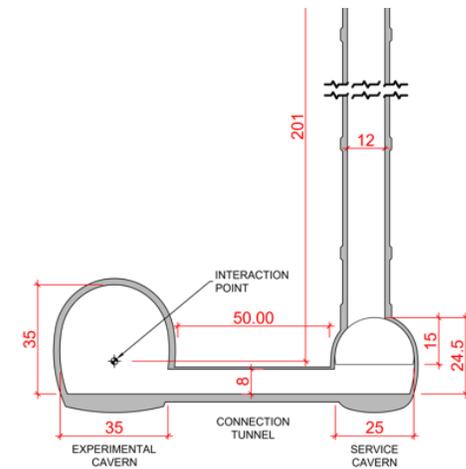
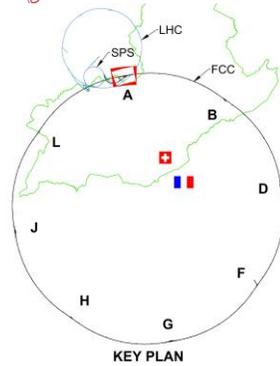
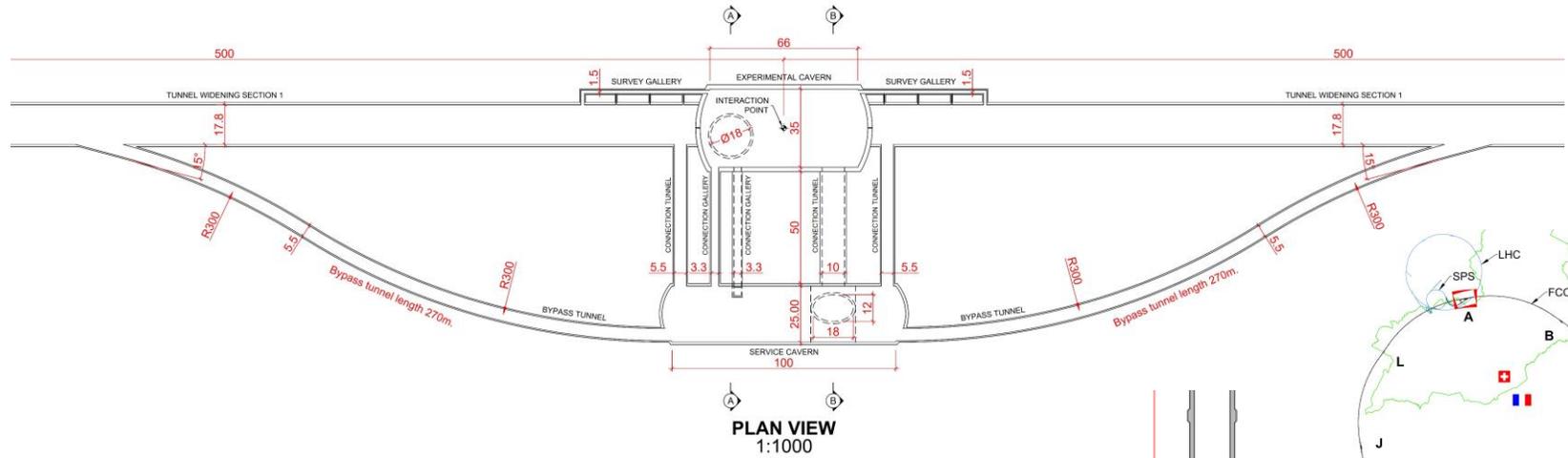


The event featured a comprehensive look at CERN's illustrious history, groundbreaking achievements, and future ambitions, including the prominently featured Future Circular Collider (FCC) project with study experts interacting with the audience.

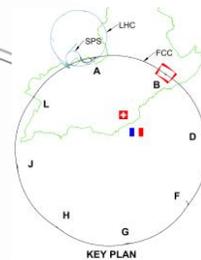
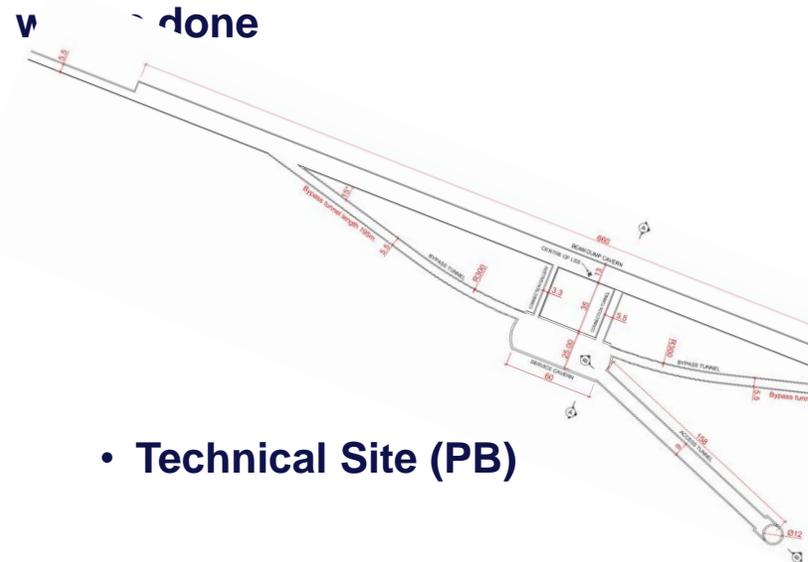
# CE underground progress

- Full 3D model of underground structures as basis for costing exercises
- Update of scheduling and costing with external consultant ongoing
- Independent second costing exercise based on same bill of quantities **not done**

## • Experiment Site (PA)



## • Technical Site (PB)

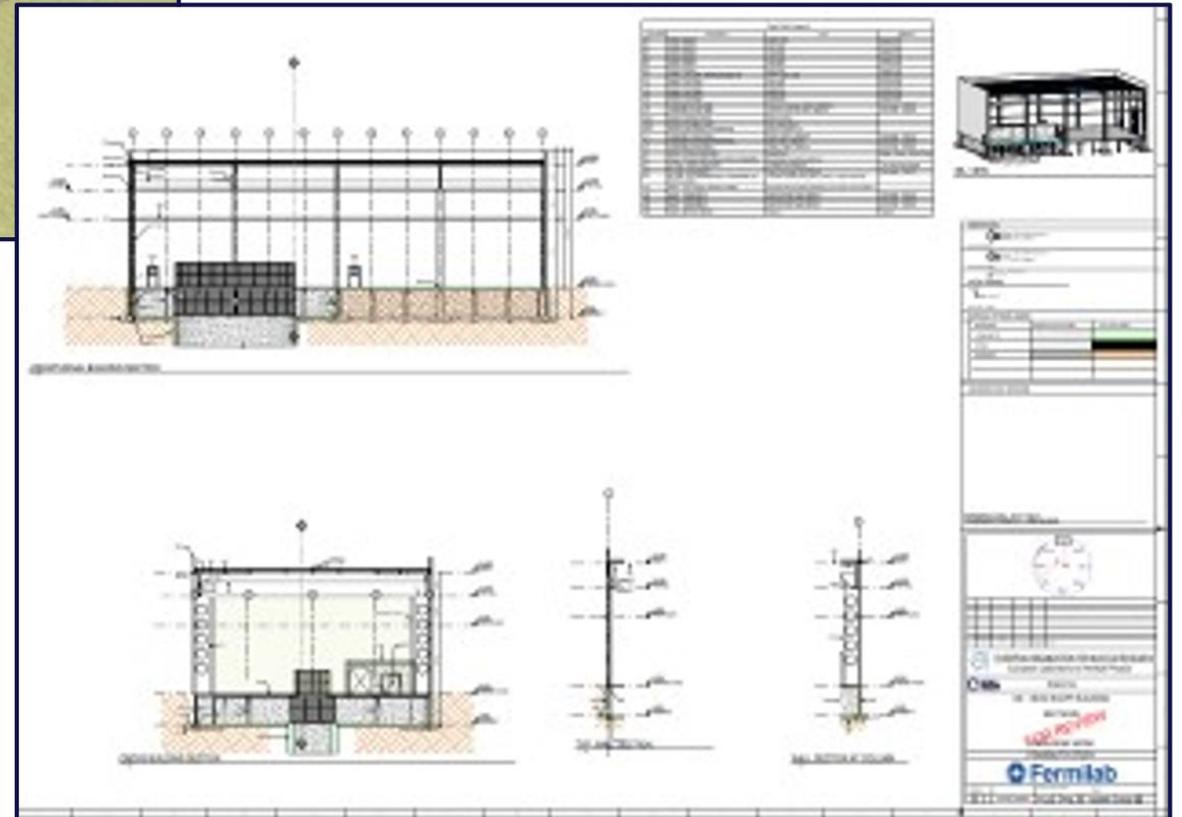




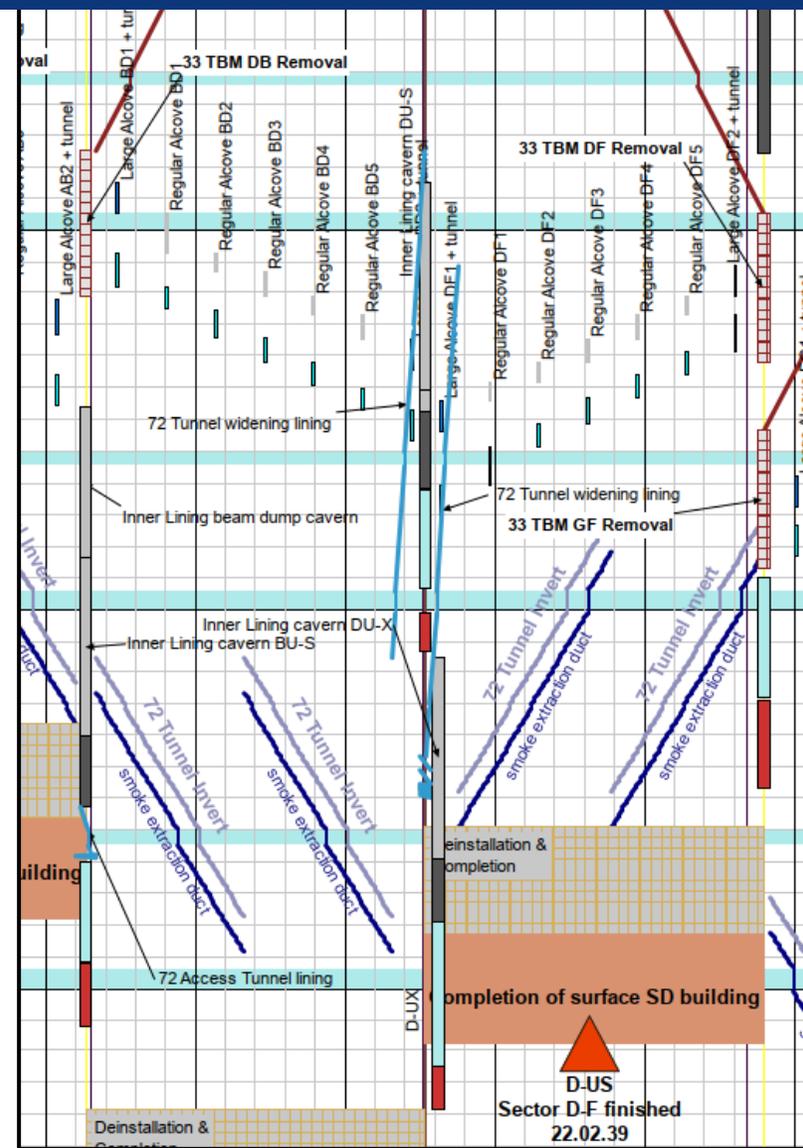
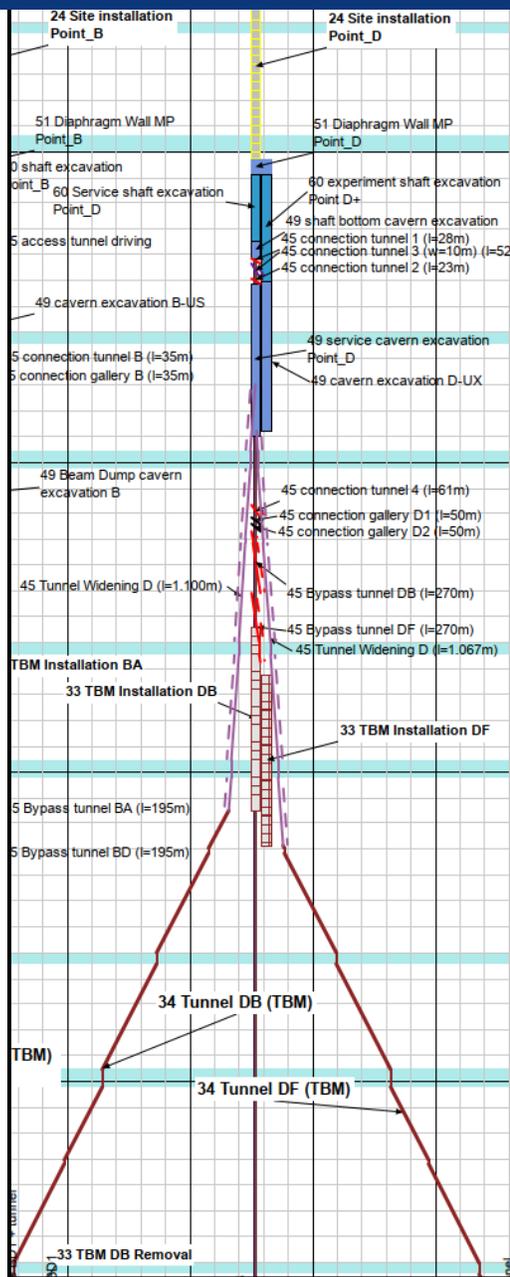
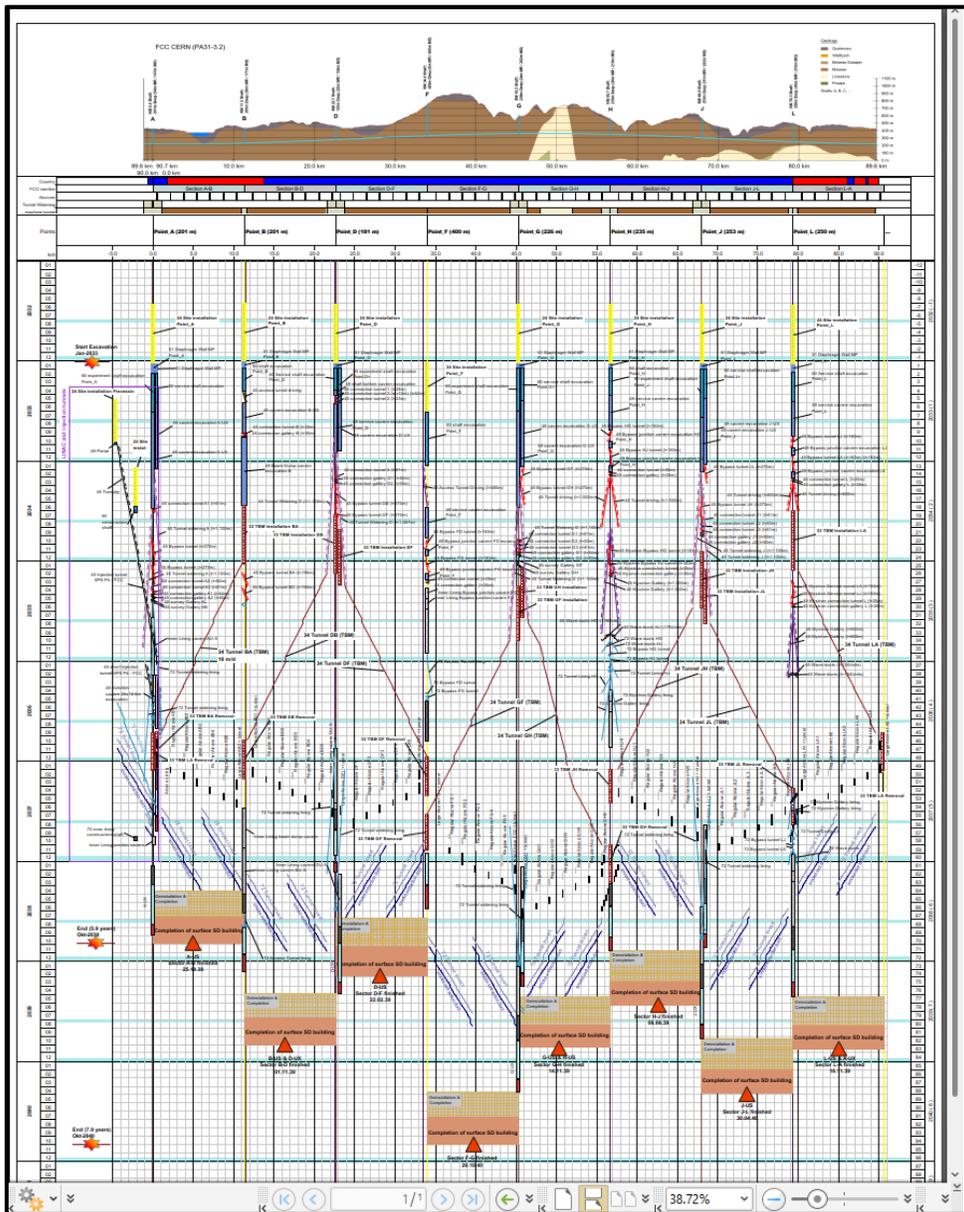
**Generic study of experiment site and technical site by FNAL**

## Examples of Fermilab Deliverables

- bills of quantities extracted from FNAL designs
- basis for cost estimate by consultant with experience on industrial constructions in CH-FR area.



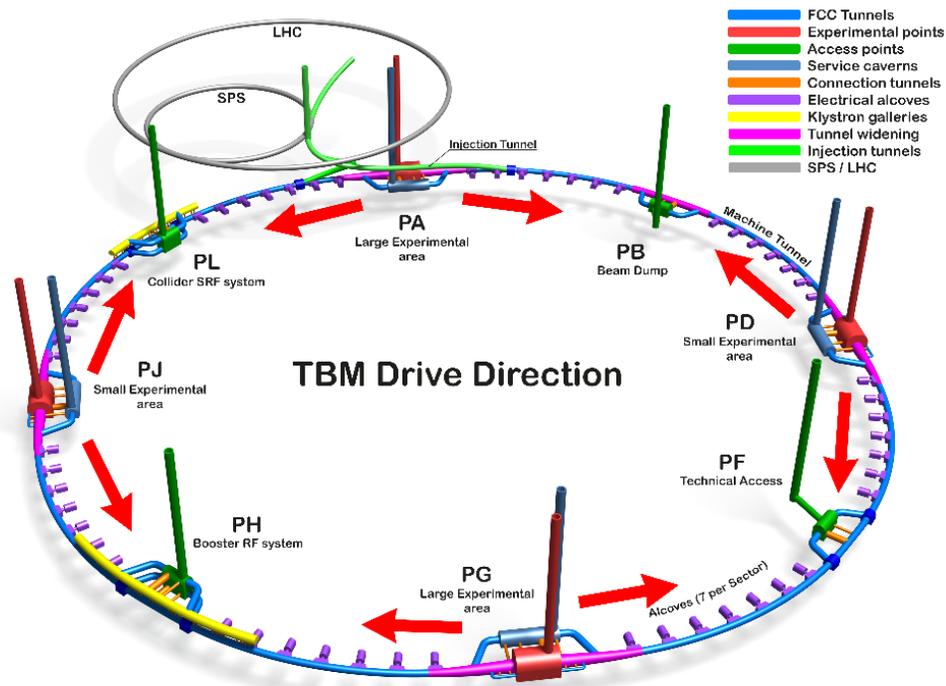
## CE linear construction schedule



Point D – Example of linear schedule

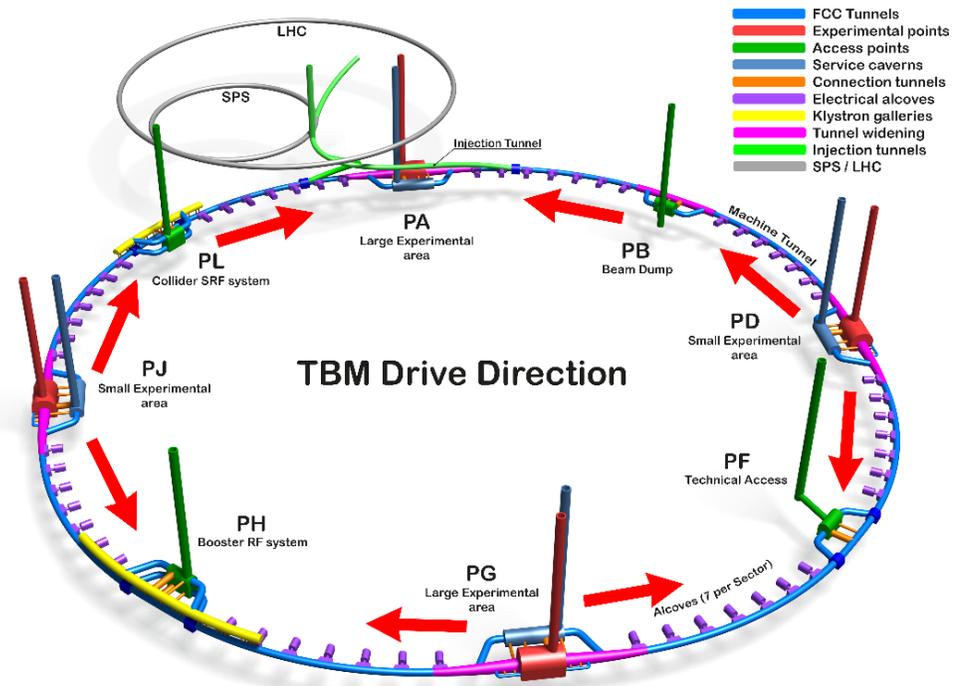


## 2 TBMs from each experimental point



[ Not to scale ]

## Alternative with no TBMs from PA

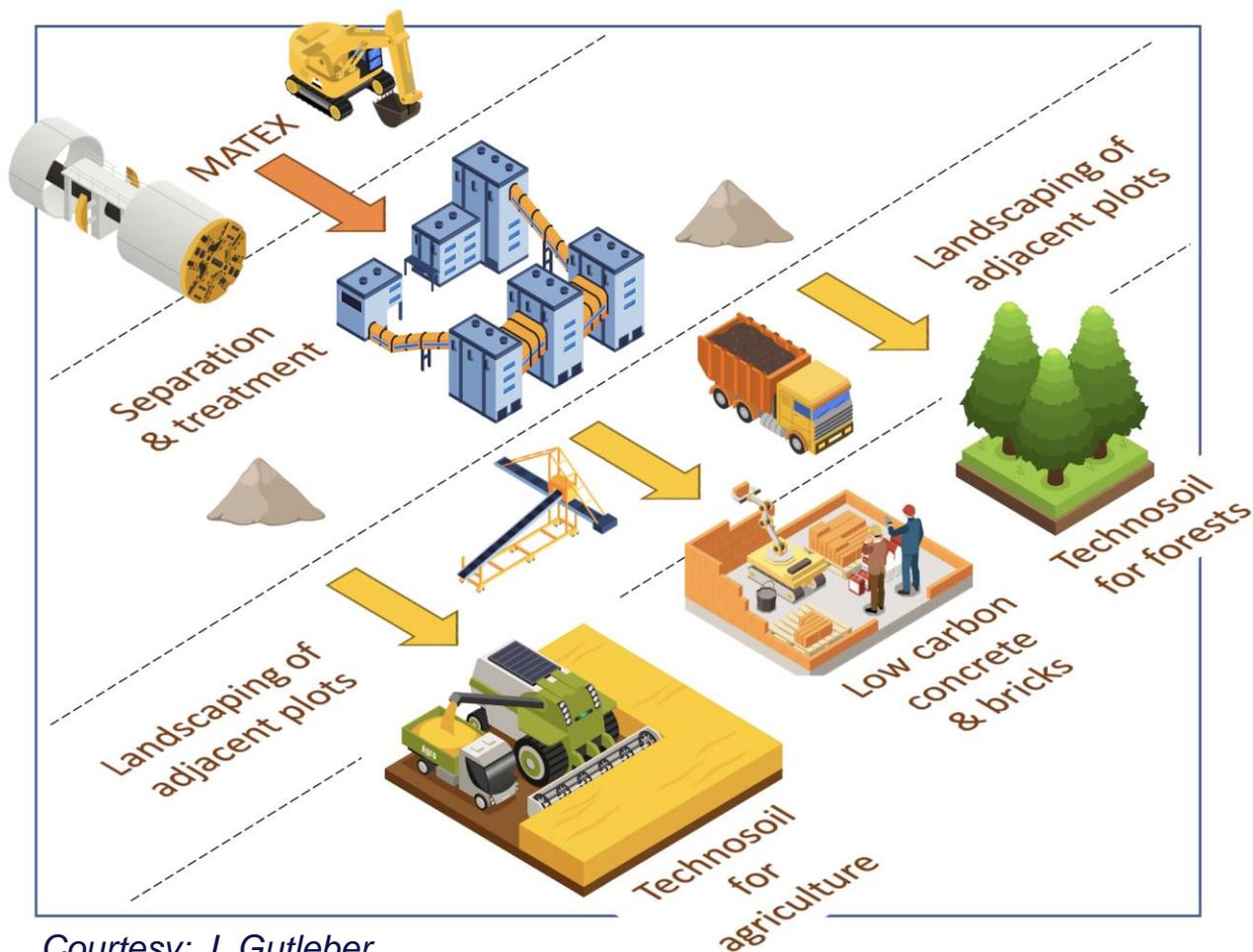


[ Not to scale ]

	Limestone (m3)	Molasse (m3)	Moraine (m3)	Total (in-situ) (m3)	Total (Bulk factor 1.3) (m3)	%	Start Excavation	End Excavation
PA	-	1,315,336	62,721	1,378,058	1,791,475	22%	Jan-33	Jun-38
PB	-	137,379	10,473	147,852	192,207	2%	Jan-33	Jul-35
PD	-	1,248,824	24,925	1,273,749	1,655,874	20%	Jan-33	Jun-37
PF	-	165,213	-	165,213	214,777	3%	Jan-33	Apr-35
PG	141,175	1,193,094	30,829	1,365,098	1,774,628	22%	Jan-33	Jun-38
PH	-	304,083	7,482	311,565	405,034	5%	Jan-33	Dec-35
PJ	-	1,258,608	29,910	1,288,518	1,675,073	20%	Jan-33	Sep-37
PL	-	227,088	13,468	240,556	312,723	4%	Jan-33	Dec-35
Inj	-	122,329	-	122,329	159,028	2%	Jan-33	Jun-36
<b>Total</b>	<b>141,175</b>	<b>5,971,954</b>	<b>179,808</b>	<b>6,292,937</b>	<b>8,180,819</b>	<b>100%</b>		

	Limestone (m3)	Molasse (m3)	Moraine (m3)	Total (in-situ) (m3)	Total (Bulk factor 1.3) (m3)	%	Start Excavation	End Excavation
PA	-	562,457	62,721	625,178	812,731	10%	Jan-33	Jun-38
PB	-	499,592	10,473	510,066	663,085	8%	Jan-33	Jul-35
PD	-	1,248,824	24,925	1,273,749	1,655,874	20%	Jan-33	Jun-37
PF	-	165,213	-	165,213	214,777	3%	Jan-33	Apr-35
PG	141,175	1,193,094	30,829	1,365,098	1,774,628	22%	Jan-33	Jun-38
PH	-	304,083	7,482	311,565	405,034	5%	Jan-33	Dec-35
PJ	-	1,258,608	29,910	1,288,518	1,675,073	20%	Jan-33	Sep-37
PL	-	617,754	13,468	631,222	820,589	10%	Jan-33	Dec-35
Inj	-	122,329	-	122,329	159,028	2%	Jan-33	Jun-36
<b>Total</b>	<b>141,175</b>	<b>5,971,954</b>	<b>179,808</b>	<b>6,292,937</b>	<b>8,180,819</b>	<b>100%</b>		

An innovative local approach for excavated materials:



Courtesy: J. Gutleber

Excavated material from FCC subsurface infrastructures:  $6.5 \text{ Mm}^3$  in situ,  $8.4 \text{ Mm}^3$  excavated (bulk factor 1.3)

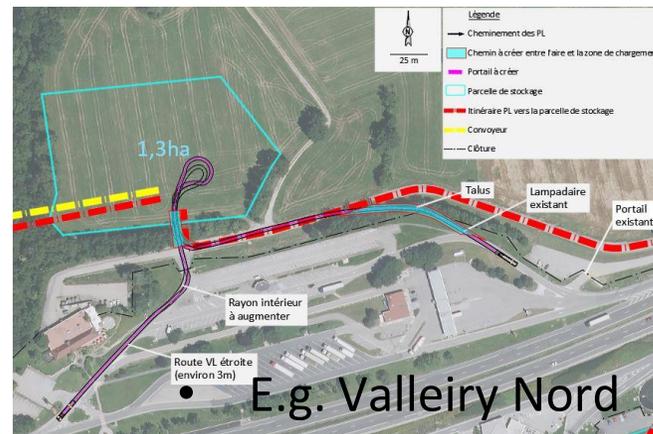
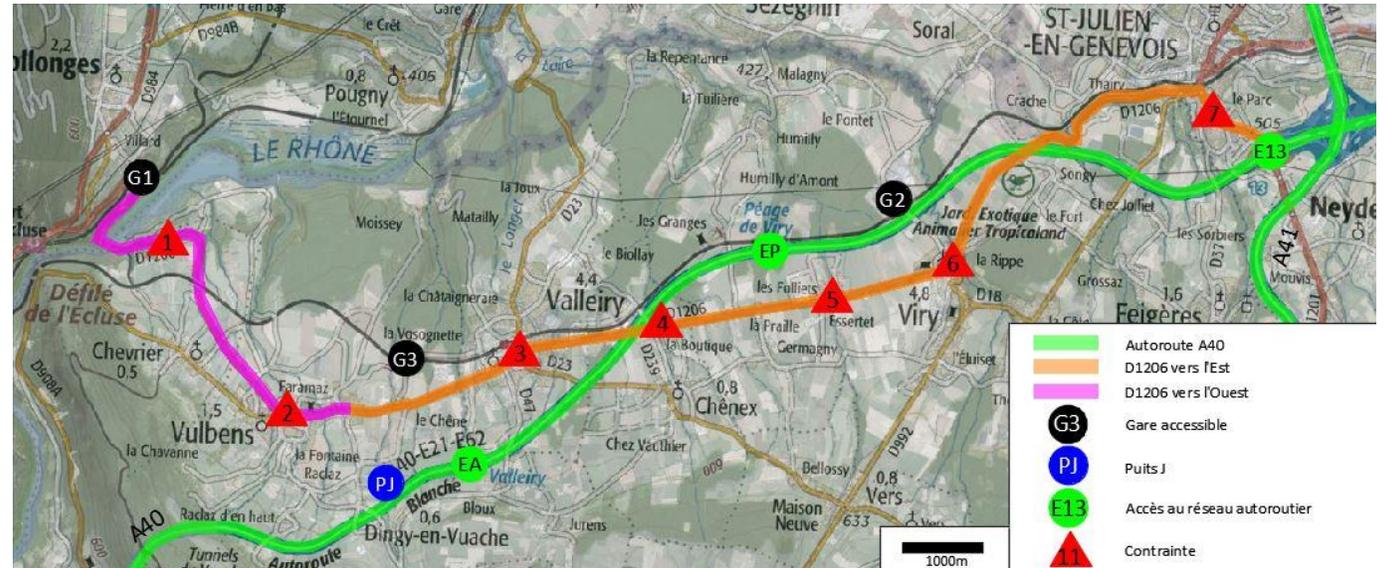
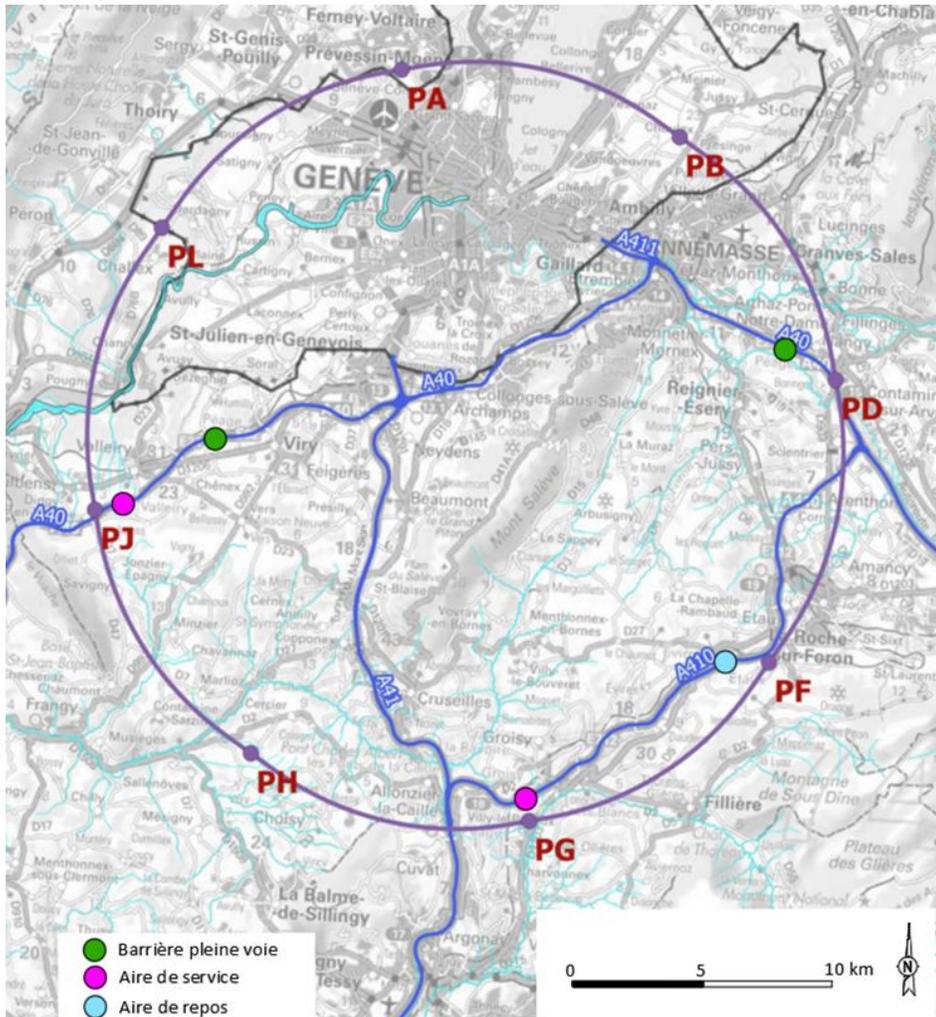
2021-2022: International competition “**Mining the Future**”, launched with the support of the EU Horizon 2020 grant agreement 951754, to find innovative and realistic ideas for the reuse of Molasse (95% of excavated materials)

2023: Definition of the “**OpenSky Laboratory**” project:

- **Objective:** Develop and test an innovative process to transform sterile “molasse” into fertile soil for agricultural use and afforestation.
- Duration: **4 years (2024-2027)**
- **CERN LHC point 5 CMS**

# Connections to transport infrastructure

- Road accesses identified and documented for all 8 surface sites
- Four possible highway connections defined (materials transport)
- Total amount of new roads required < 4 km (at departmental road level)

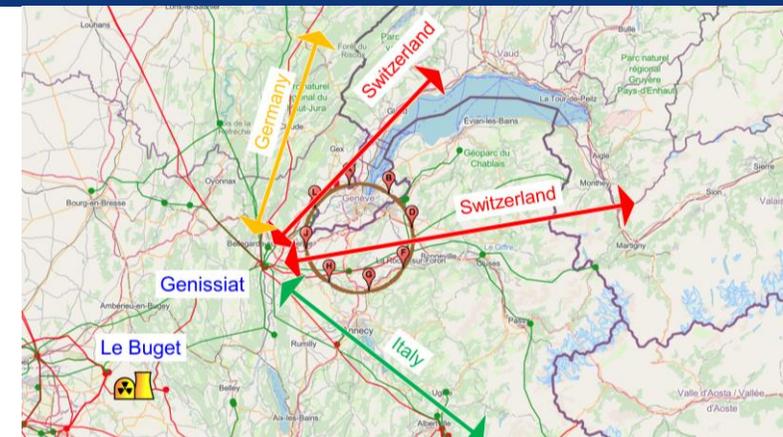


Detailed road access scenarios & highway access creation study carried out by Cerema, including regulatory requirements in France

E.g. Valleiry Nord

## Updated FCC-ee energy consumption

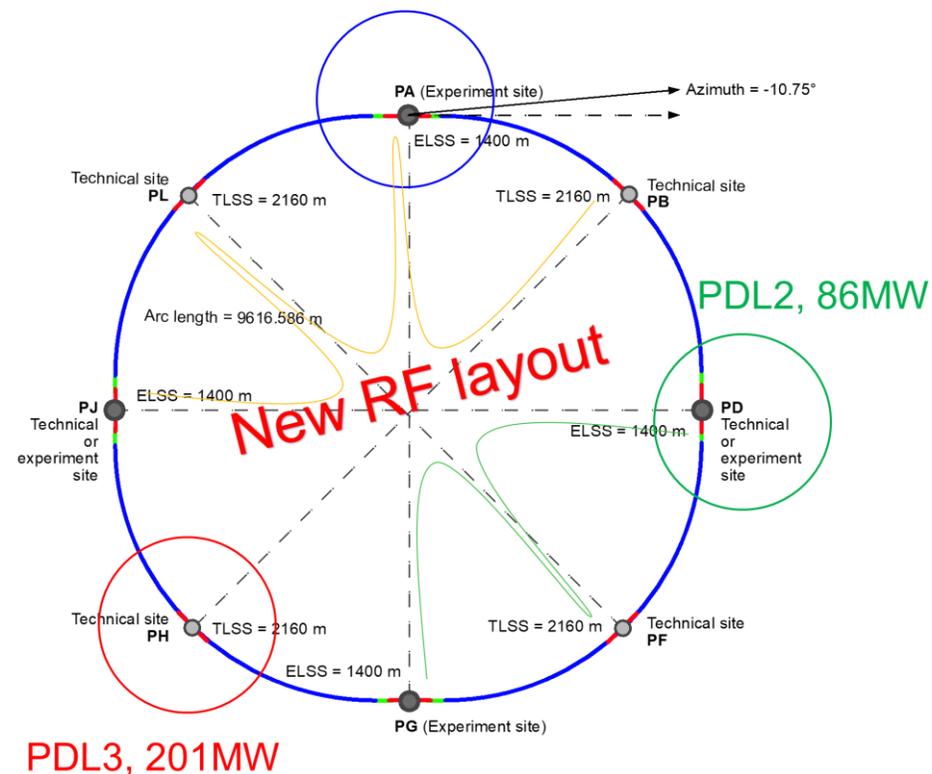
	Z	W	H	TT
Beam energy (GeV)	45.6	80	120	182.5
Max. Power during beam operation (MW)	222	247	273	357
Average power / year (MW)	122	138	152	202
<b>Total FCC-ee yearly consumption (TWh)</b>	<b>1.07</b>	<b>1.2</b>	<b>1.33</b>	<b>1.77</b>
Yearly consumption CERN & SPS (TWh)	0.70	0.70	0.70	0.70
<b>Total yearly consumpt. CERN &amp; SPS &amp; FCC-ee (TWh)</b>	<b>1.77</b>	<b>1.90</b>	<b>2.03</b>	<b>2.47</b>



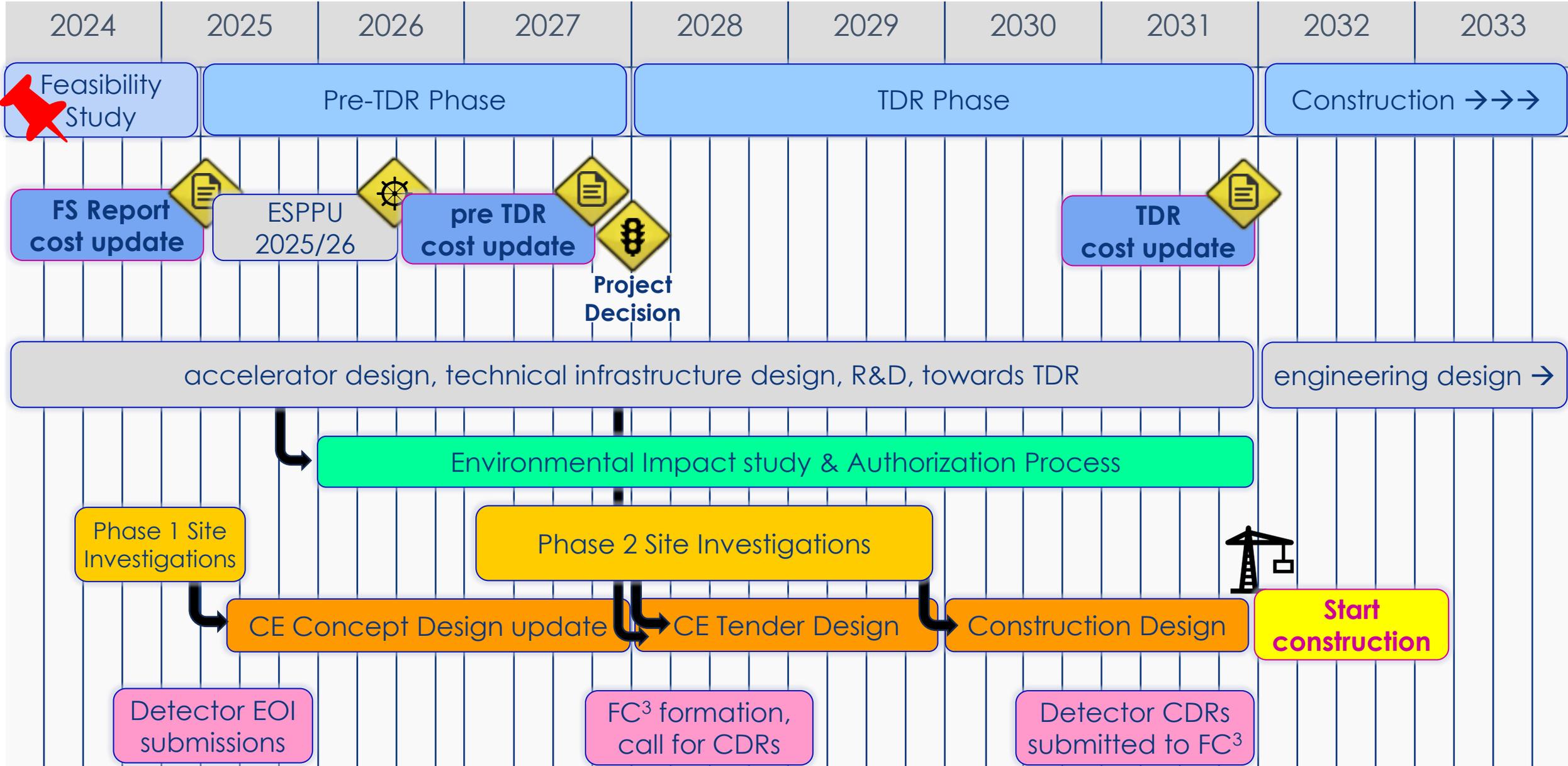
The loads could be distributed on three main sub-stations (optimally connected to existing regional HV grid):

- **Point D with a new sub-station covering PB – PD – PF – PG**
- **Point H with a new dedicated sub-station for collider RF**
- **Point A with existing CERN station covering PB – PL – PJ**
- **Connection concept was studied and confirmed 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**

PDL1, 69MW

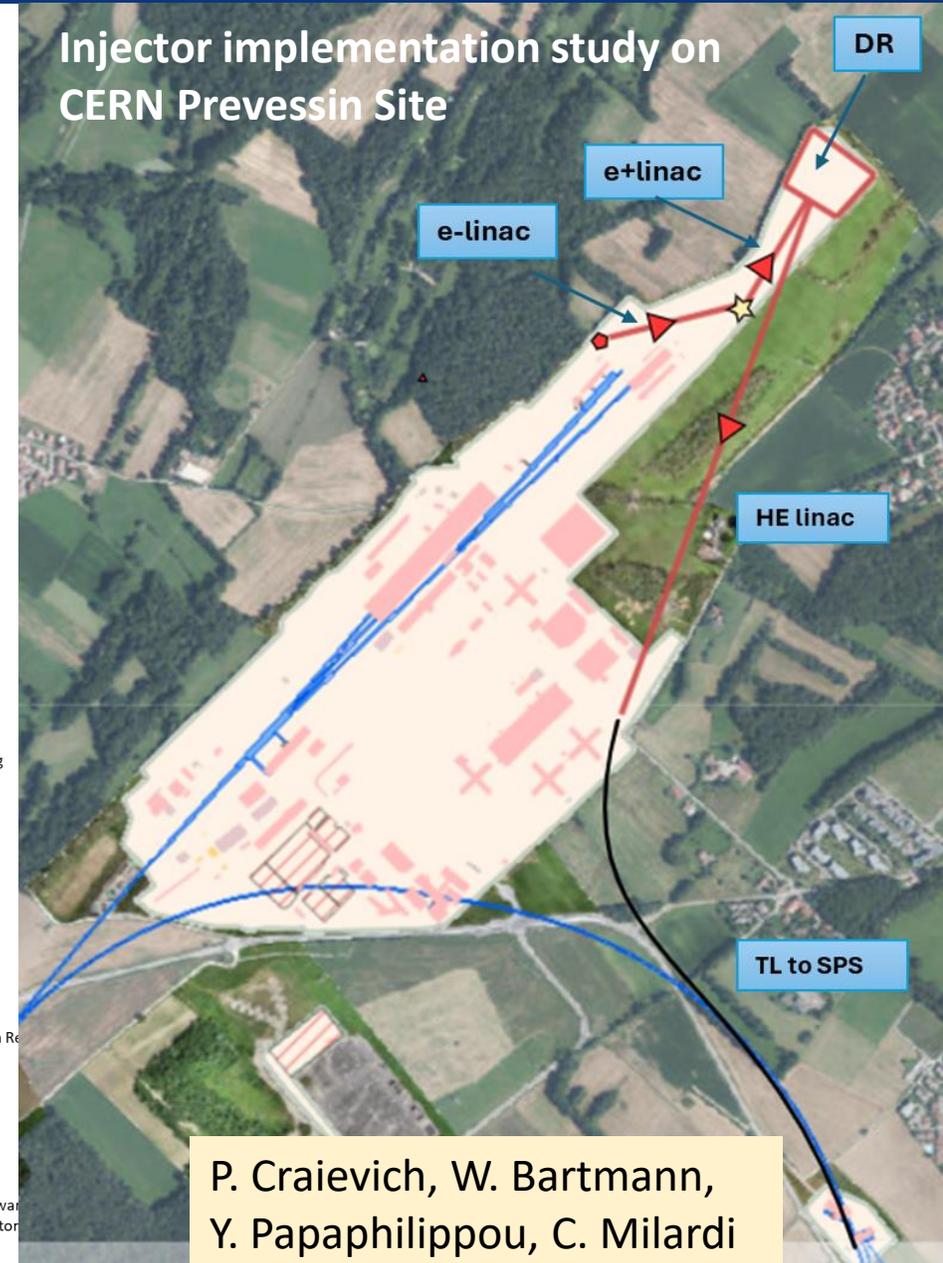
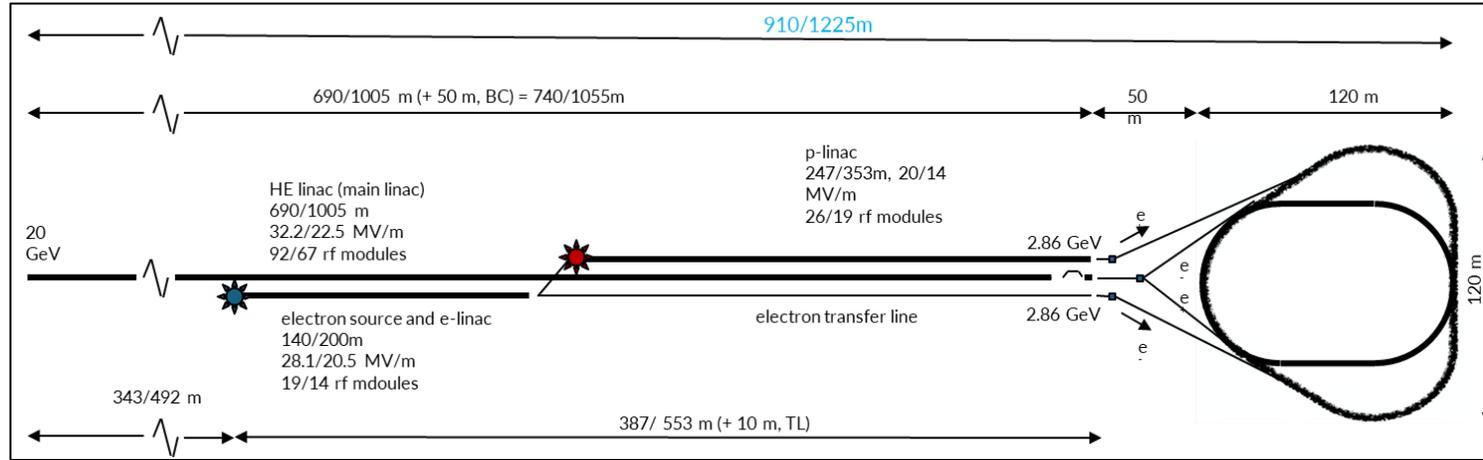


# Expected time line till start of construction

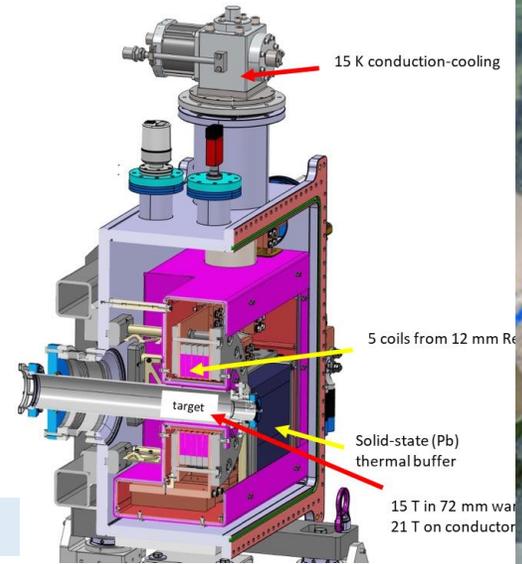
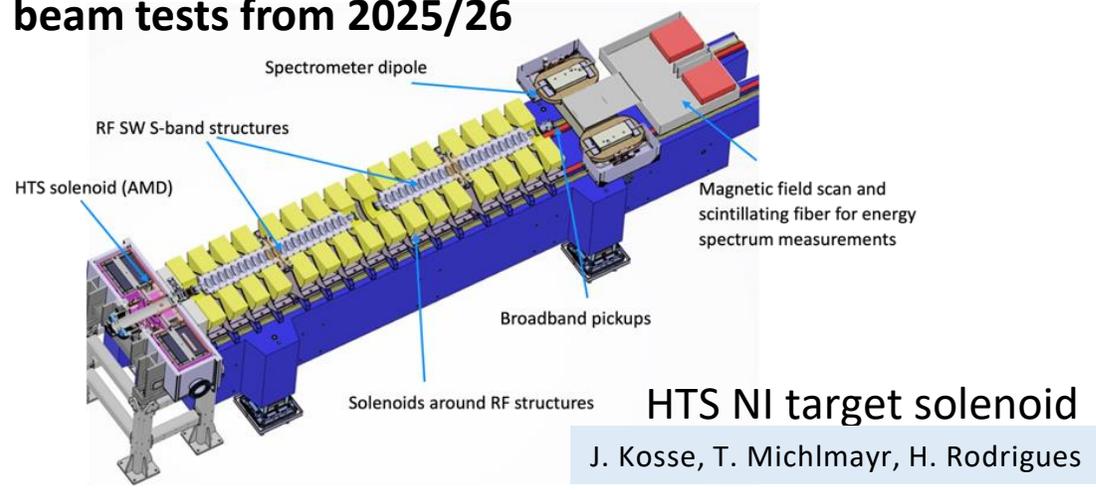


## Overall injector parameter optimisation

- Operation frequency, gradient, etc...
- Positron production energy, damping ring energy



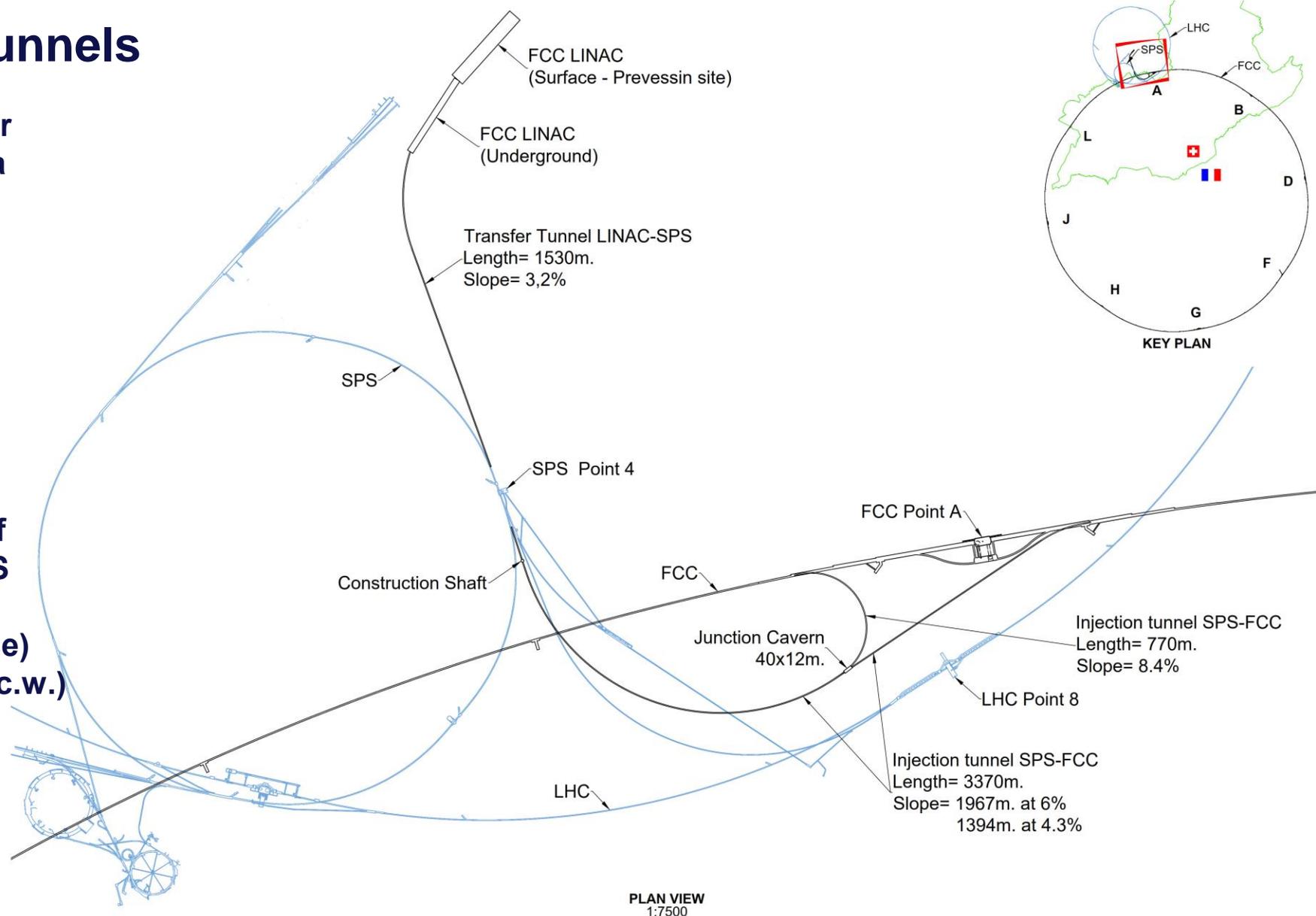
## “Positron production experiment” at PSI’s SwissFEL, beam tests from 2025/26



P. Craievich, W. Bartmann,  
Y. Papaphilippou, C. Milardi

## LINAC and Injection Tunnels

- Designed to enable injection either from SPS as pre-booster or from a new HE Linac sited at Preveessin
- Single tunnel with spur to enable anti-clockwise injection
- Design allows re-use for FCC-hh if injector in the SPS tunnel (SC-SPS option)
  - SPS Point 4 to FCC (clockwise)
  - SPS Point 6 to FCC (counter-c.w.)



# FCC-ee main machine parameters

Parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45.6	80	120	182.5
beam current [mA]	1270	137	26.7	4.9
number bunches/beam	11200	1780	440	60
bunch intensity [ $10^{11}$ ]	2.14	1.45	1.15	1.55
SR energy loss / turn [GeV]	0.0394	0.374	1.89	10.4
total RF voltage 400/800 MHz [GV]	0.120/0	1.0/0	2.1/0	2.1/9.4
long. damping time [turns]	1158	215	64	18
horizontal beta* [m]	0.11	0.2	0.24	1.0
vertical beta* [mm]	0.7	1.0	1.0	1.6
horizontal geometric emittance [nm]	0.71	2.17	0.71	1.59
vertical geom. emittance [pm]	1.9	2.2	1.4	1.6
vertical rms IP spot size [nm]	36	47	40	51
beam-beam parameter $\xi_x / \xi_y$	0.002/0.0973	0.013/0.128	0.010/0.088	0.073/0.134
rms bunch length with SR / BS [mm]	5.6 / 15.5	3.5 / 5.4	3.4 / 4.7	1.8 / 2.2
luminosity per IP [ $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ ]	140	20	$\geq 5.0$	1.25
total integrated luminosity / IP / year [ $\text{ab}^{-1}/\text{yr}$ ]	17	2.4	0.6	0.15
beam lifetime rad Bhabha + BS [min]	15	12	12	11

4 years  
 $5 \times 10^{12} \text{ Z}$   
 $\text{LEP} \times 10^5$

2 years  
 $> 10^8 \text{ WW}$   
 $\text{LEP} \times 10^4$

3 years  
 $2 \times 10^6 \text{ H}$

5 years  
 $2 \times 10^6 \text{ tt pairs}$

## Design and parameters to maximise luminosity at all working points:

- allow for 50 MW synchrotron radiation per beam.
- Independent vacuum systems for electrons and positrons
- full energy booster ring with top-up injection, collider permanent in collision mode

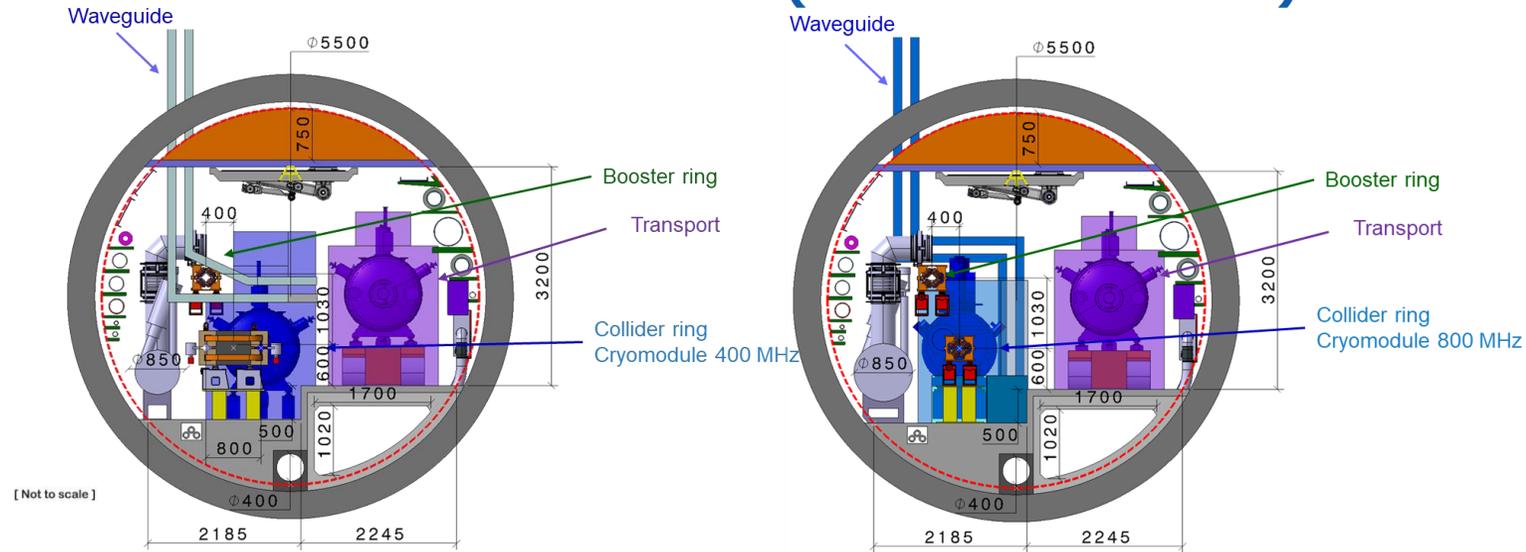
- x 10-50 improvements on all EW observables
- up to x 10 improvement on Higgs coupling (model-indep.) measurements over HL-LHC
- x10 Belle II statistics for b, c,  $\tau$
- indirect discovery potential up to  $\sim 70 \text{ TeV}$
- direct discovery potential for feebly-interacting particles over 5-100 GeV mass range

Up to 4 interaction points  $\rightarrow$  robustness, statistics, possibility of specialised detectors to maximise physics output

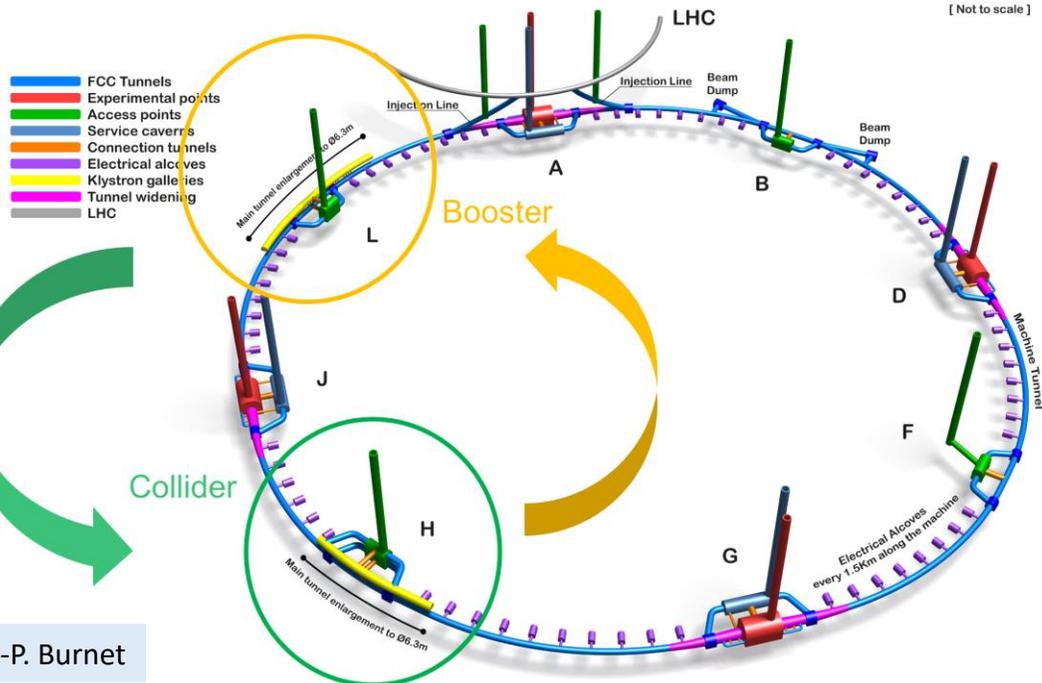
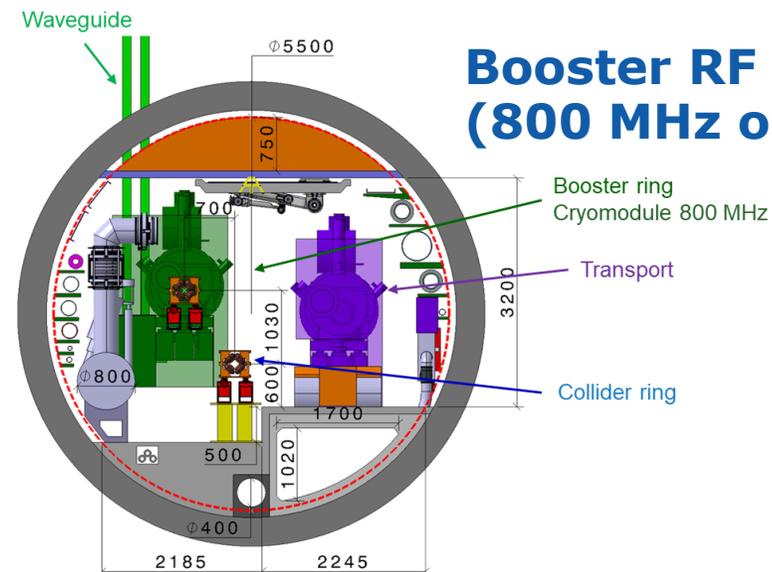
# modified FCC-ee RF layout

- RF for collider and booster in separate straight sections H and L.
- fully separated technical infrastructure systems (cryogenics)
- collider RF (highest power demand) in point H with optimum connection to existing 400 kV grid line and better suited surface site

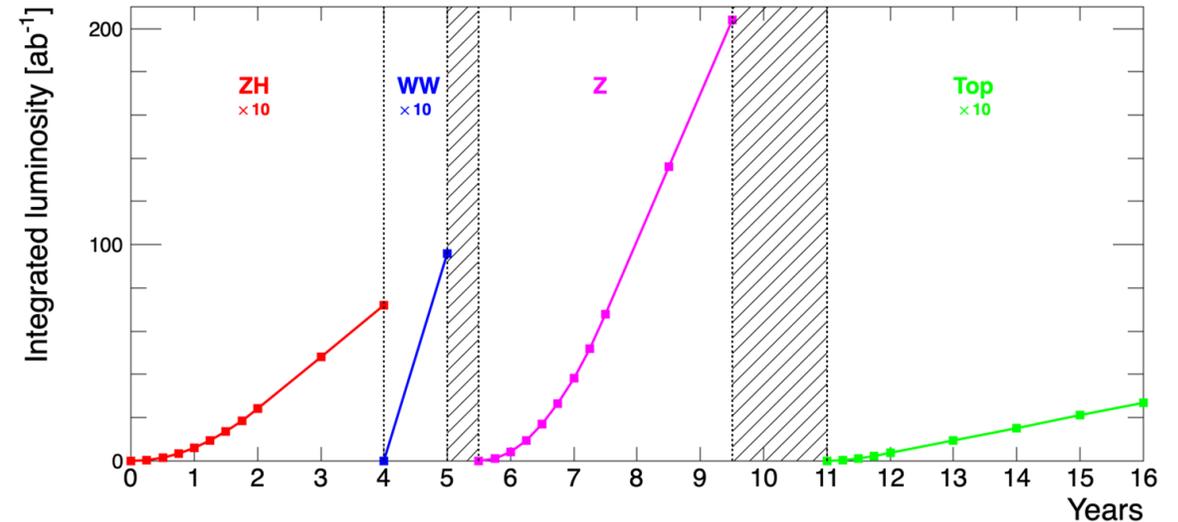
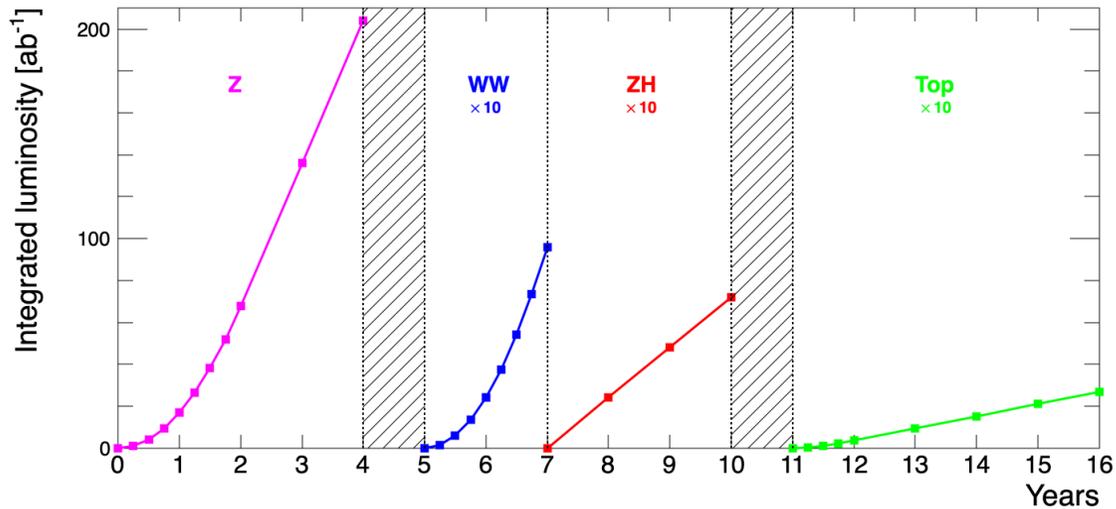
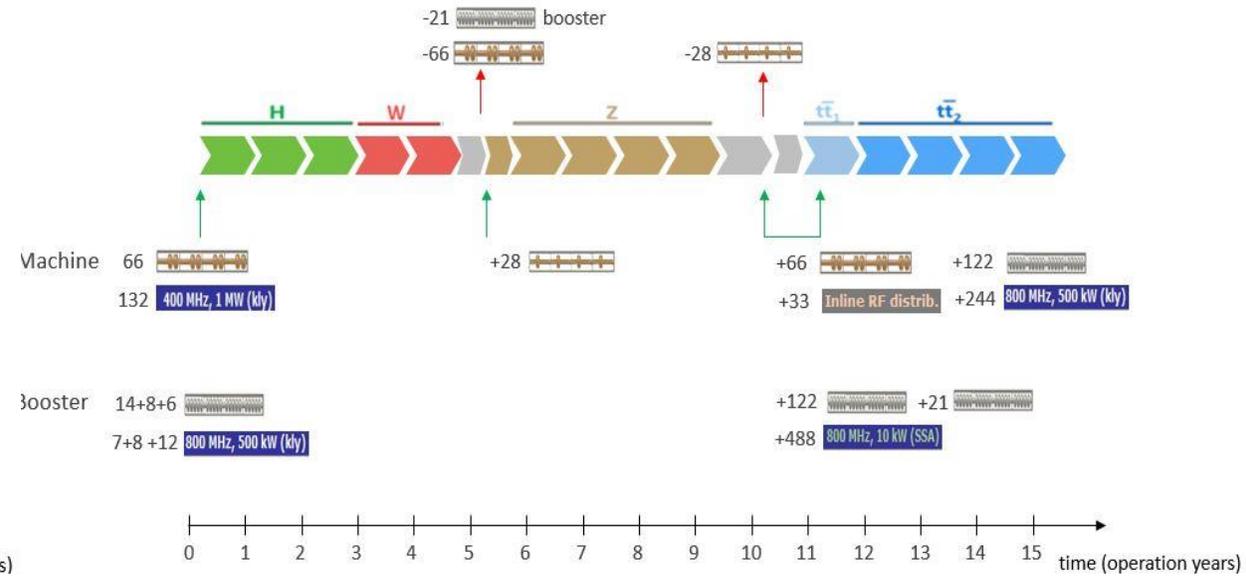
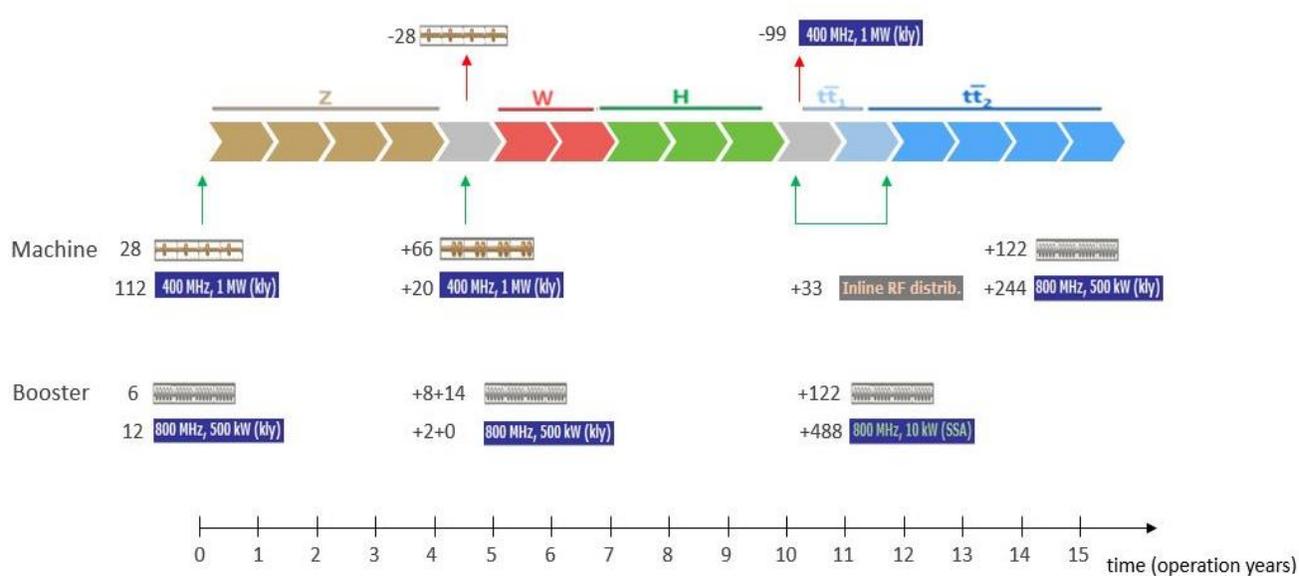
## Collider RF - Point H (400 and 800 MHz)



## Booster RF - Point L (800 MHz only)



# Operation sequences for FCC-ee and RF configuration



- Evolution of RF configuration of collider and booster with beam energies and physics operation points
- Long-term R&D for SRF, 400 MHz Nb on Cu, 800 MHz bulk Nb system

# RF R&D activities

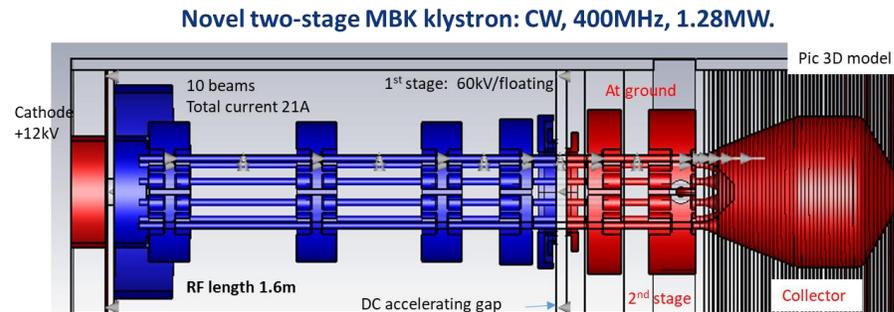
## RF system R&D is key for increasing energy efficiency of FCC-ee

- Nb on Cu 400 MHz cavities, seamless cavity production, coating techniques
- Bulk Nb 800 MHz cavities, surface treatment techniques, cryomodule design
- RF power source R&D in synergy with HL-LHC.

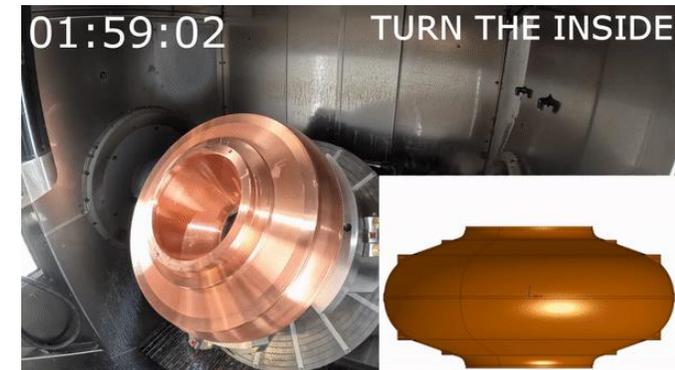
### 800 MHz cavity and CM design collaborations with JLAB and FNAL



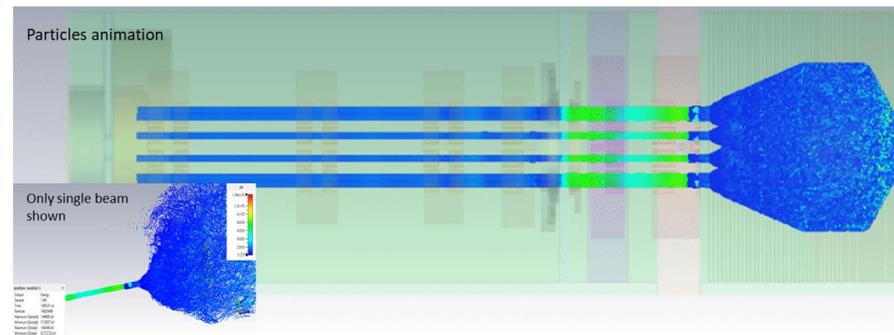
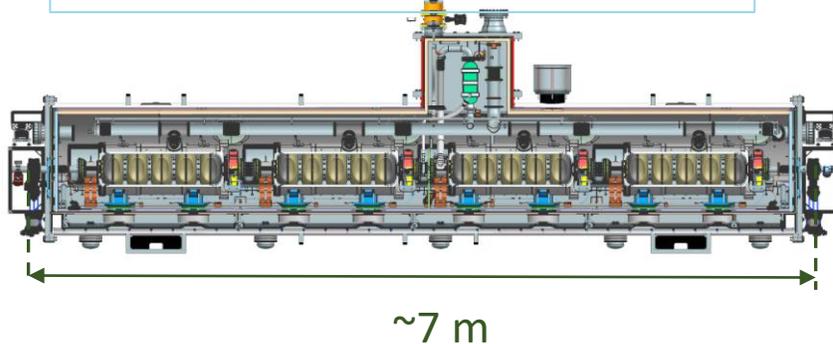
### high-efficiency klystron R&D in collaborations with THALES & CANON



### 400 MHz cavity production in collaboration with KEK



### 800 MHz segmented design, based on PIP-II



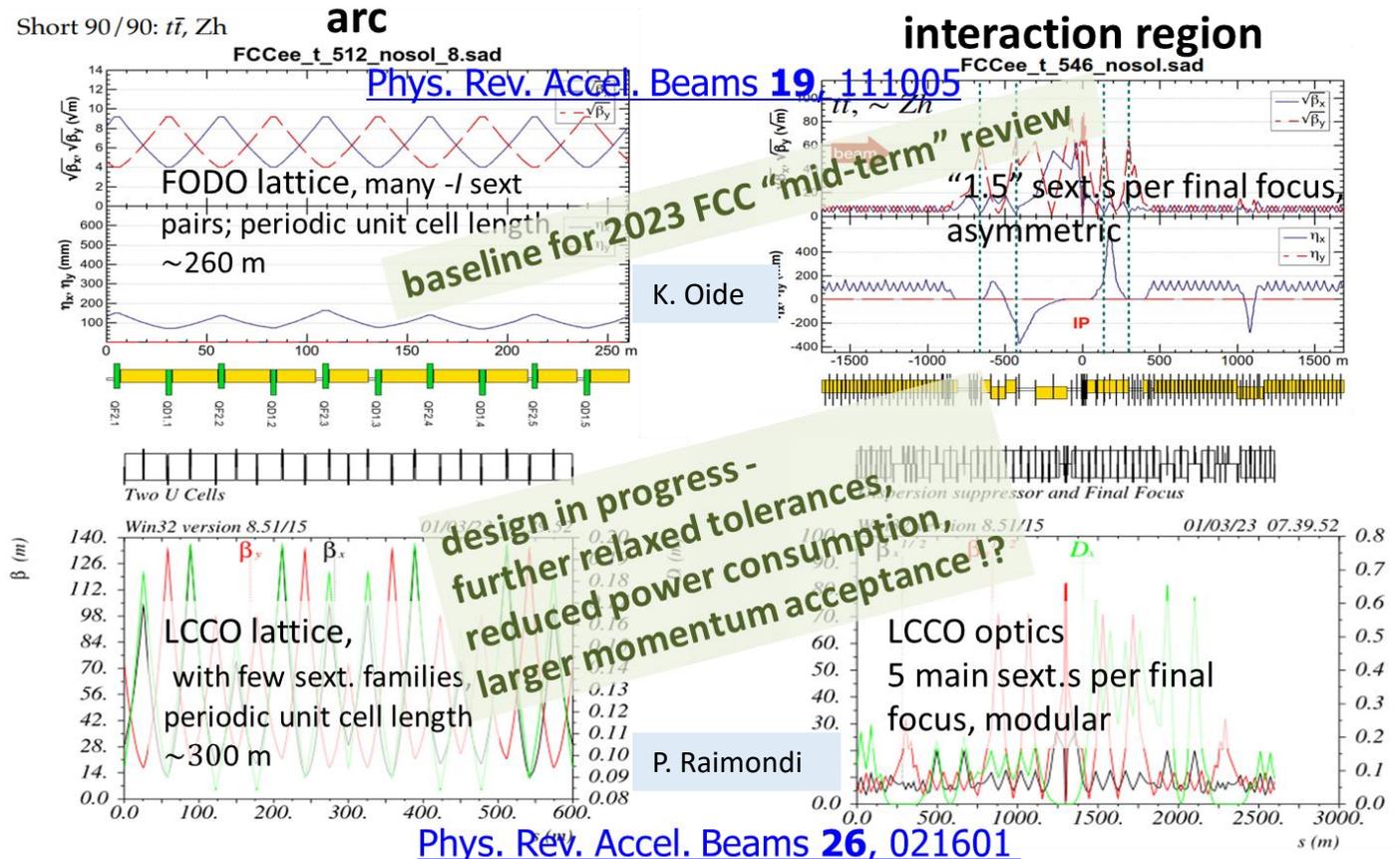
# Collider and Booster design

## Complete accelerator design and layout

- consolidated beam parameters throughout entire chain & different operation modes
- definitive collider and booster and optics and layout
- beam-based alignment procedures, tolerances and requirements
- complete impedance models for booster and collider rings

→ specifications for design of components and technical infrastructure

→ full inventory for integration studies and requirements for civil engineering



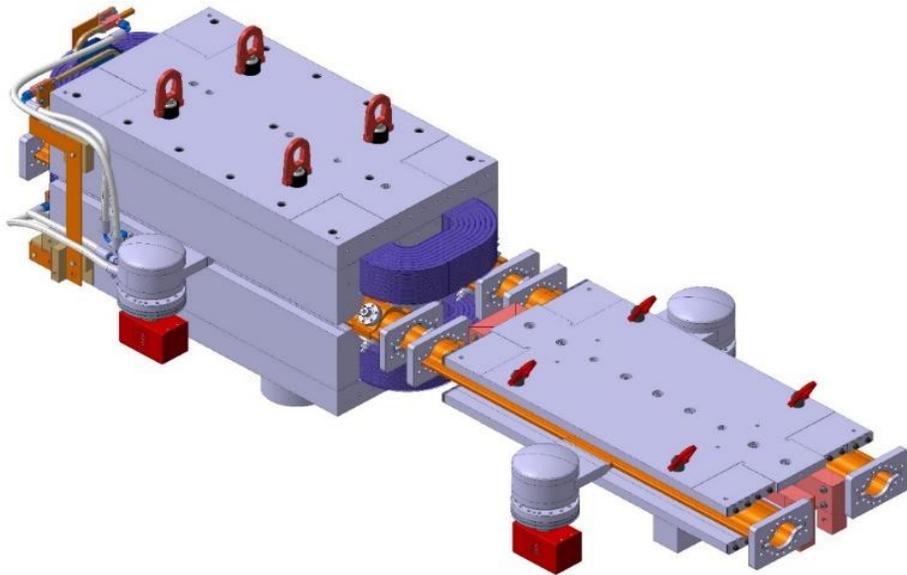
# Arc layout and integration optimization

## Arc cell optimisation – 80 km total length, dedicated working group active.

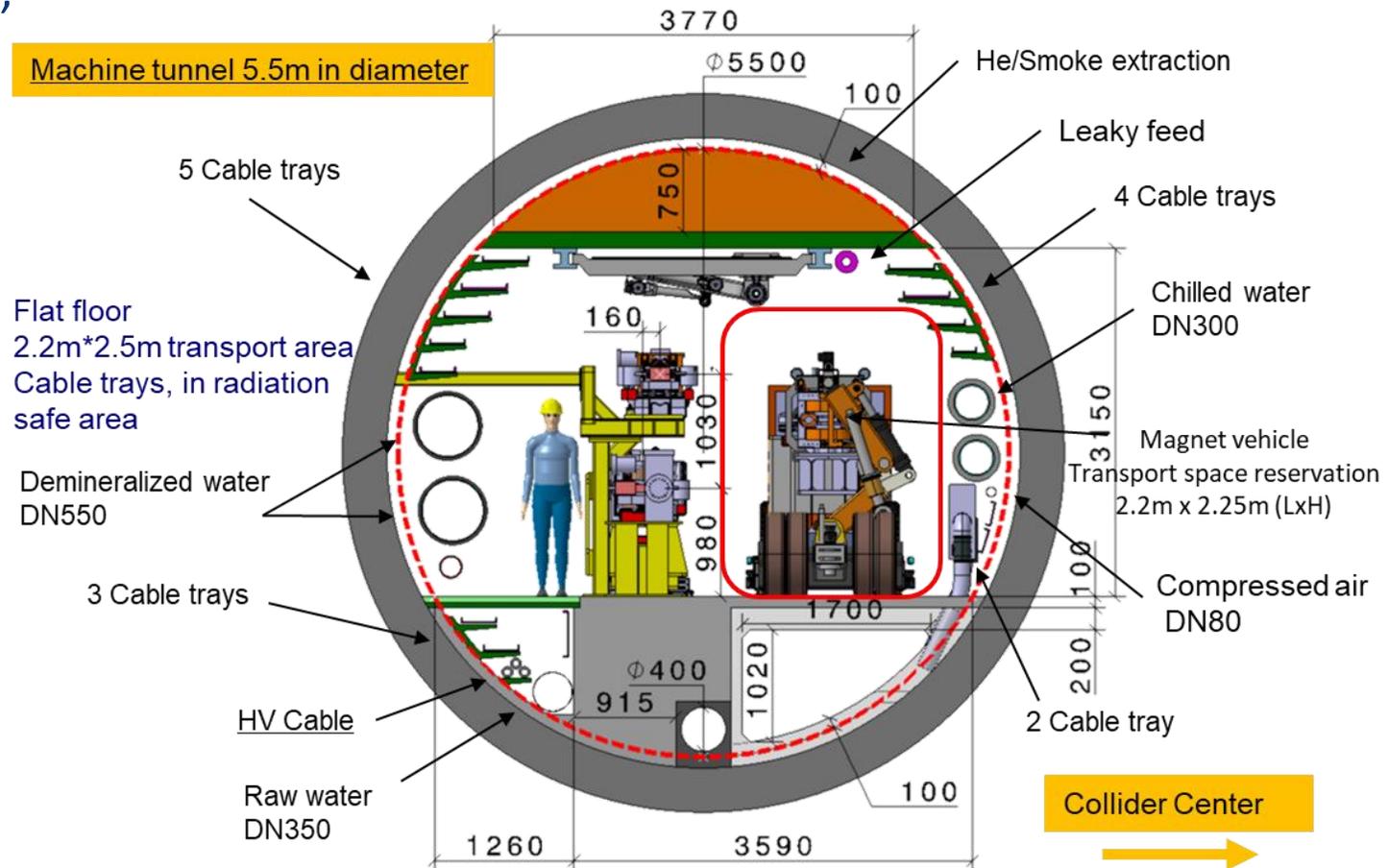
- Including support, girder and alignment systems, shielding systems
- vacuum system with antechamber + pumps, dipole, quadrupole + sext. magnets, BPMs,
- cabling, cooling & technical infrastructure interfaces.
- Safety aspects, access and transport concept,

→ Confirmation of tunnel diameter

## FCC-ee arc half-cell mock up

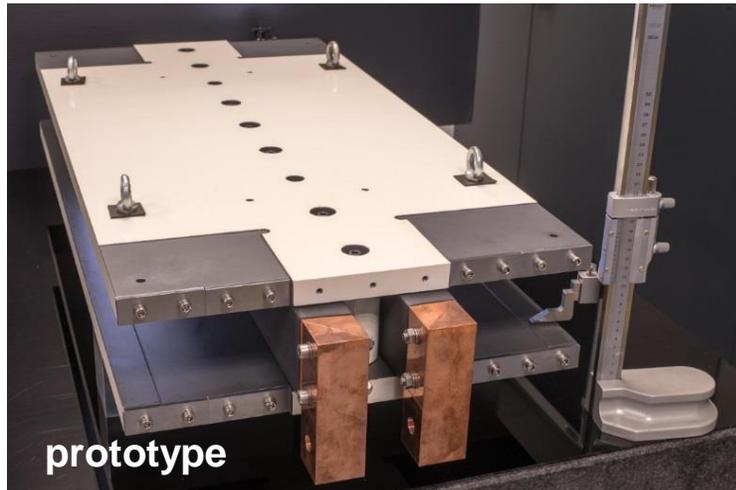
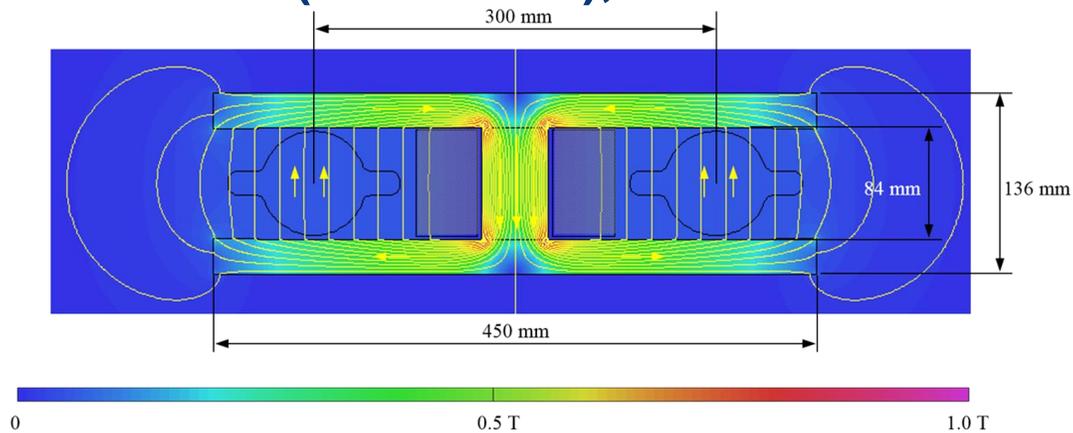


F. Carra, CERN; F. Valchkova

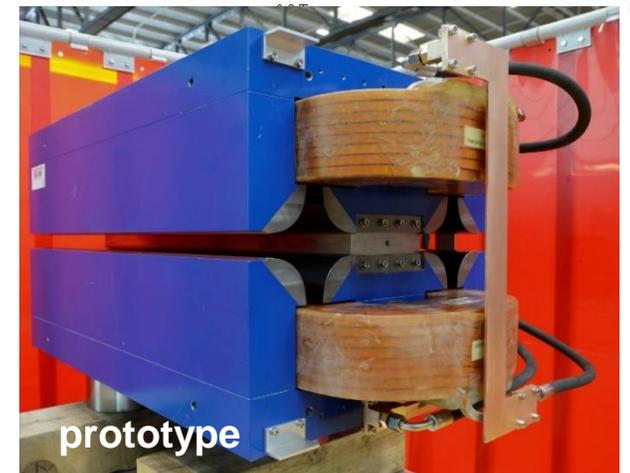
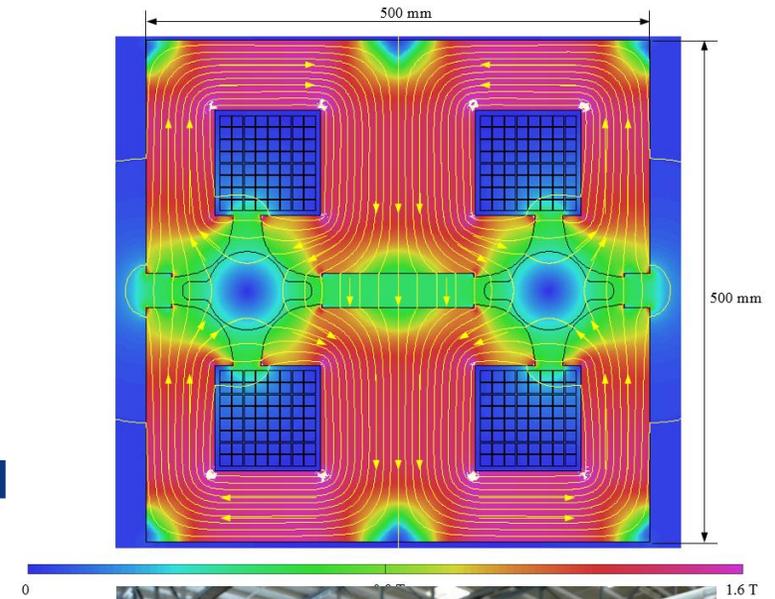


# prototypes of FCC-ee low-power magnets

**Twin-dipole design with 2× power saving  
16 MW (at 175 GeV), with Al busbars**



**Twin F/D arc quad  
design with  
2× power saving  
25 MW (at 175 GeV),  
with Cu conductor**

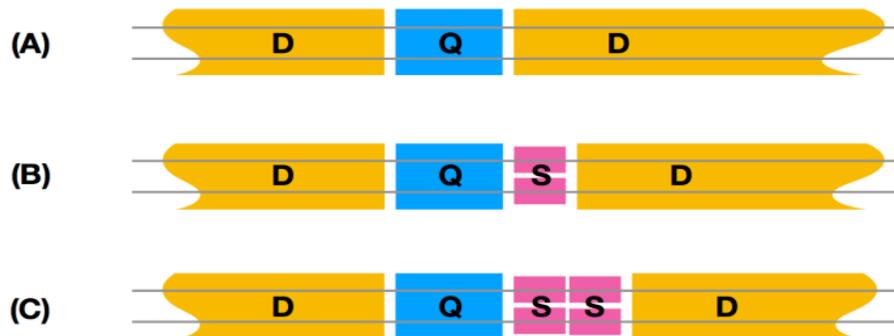


even more efficient alternative magnet designs are being explored

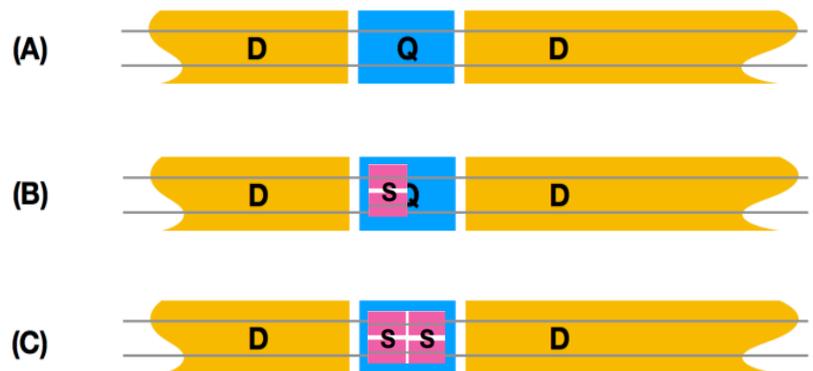
## CDR: 2900 quads & 4700 sextupoles

- Normal conducting, ~50 MW @ ttbar
- 3 different types of short straight sections

### CDR arc lattice



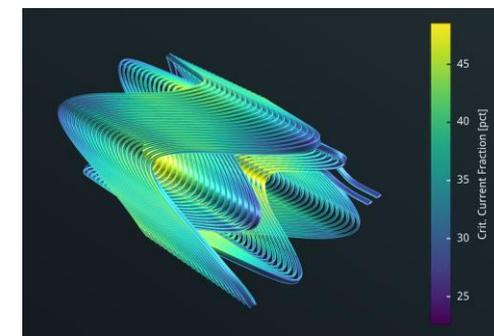
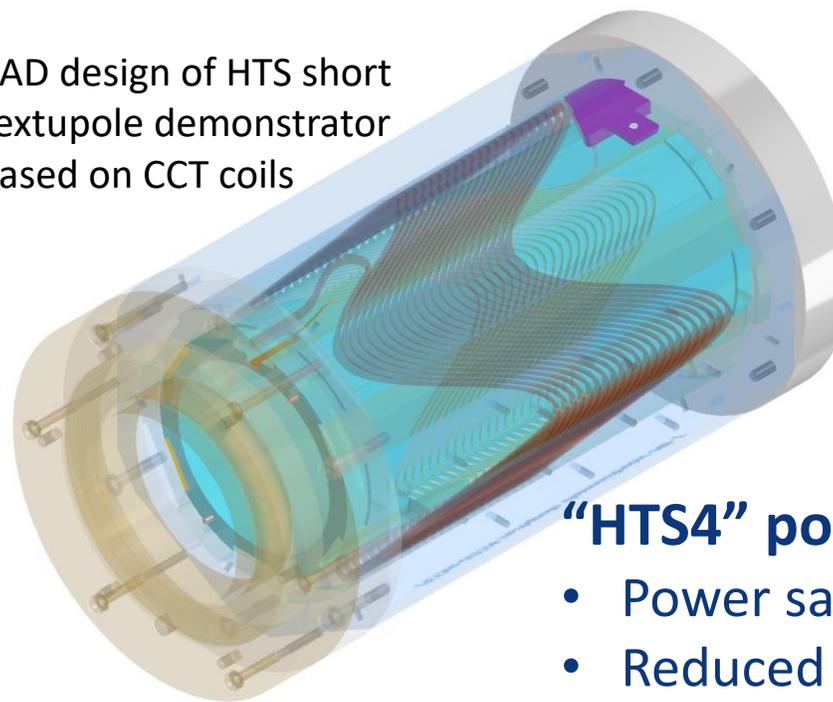
### HTS option



## “HTS4” project within CHART collaboration

- Nested SC sextupole and quadrupole.
- HTS conductors operating at around 40K.
- Cryo-cooler supplied cryostat
- Produce a ~1m prototype by 2026

CAD design of HTS short sextupole demonstrator based on CCT coils



## “HTS4” potential

- Power saving
- Reduced length and increased dipole filling factor
- Optics flexibility

# Synchrotron radiation in tunnel

	LEP-II (1999-2000)	FCC-ee Z	FCC-ee W	FCC-ee ZH	FCC-ee ttbar
Beam energy	98-104.5 GeV	45.6 GeV	80 GeV	120 GeV	182.5 GeV
Bending radius	3.1 km	10 km			
Beam current	6.2 mA (@98 GeV)	2 x 1270 mA	2 x 137 mA	2 x 26.7 mA	2 x 4.86 mA
Energy loss/turn (arcs)	2.6 GeV (@98 GeV) 3.4 GeV (@104.5 GeV)	0.04 GeV	0.37 GeV	1.9 GeV	10.3 GeV
Power loss (arcs)	16 MW (@98 GeV)*	100 MW			
Total arc length	23 km	77 km			
Power loss/unit length (arcs)	0.7 kW/m (@98 GeV)*	1.3 kW/m			
Critical energy	0.7 MeV – 0.8 MeV	0.02 MeV	0.1 MeV	0.4 MeV	1.3 MeV

\*Indicative value (beam current decreased from 98 GeV to 104.5 GeV)

A. Lechner et al.

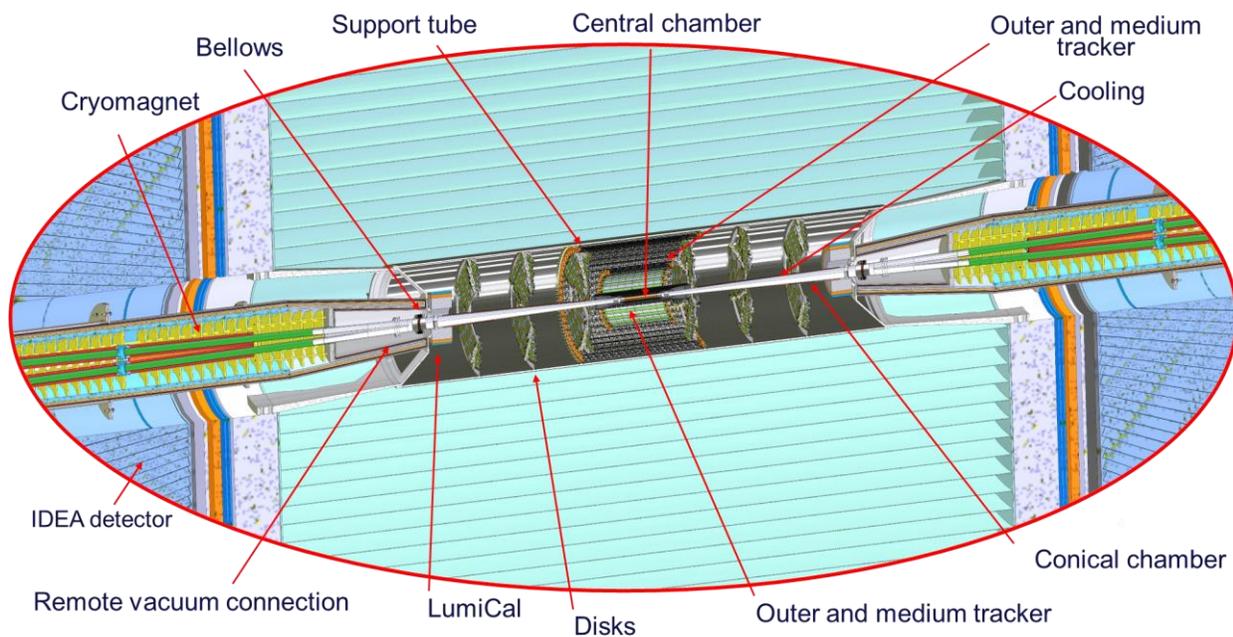
- **Source term comparable to LEP operation, higher critical energy for ttbar run.**
- **Baseline with distributed (water cooled) photon stops every ~6 m.**
- **Different shielding strategies for (Z, W, ZH) vs ttbar?**

# Machine detector interface

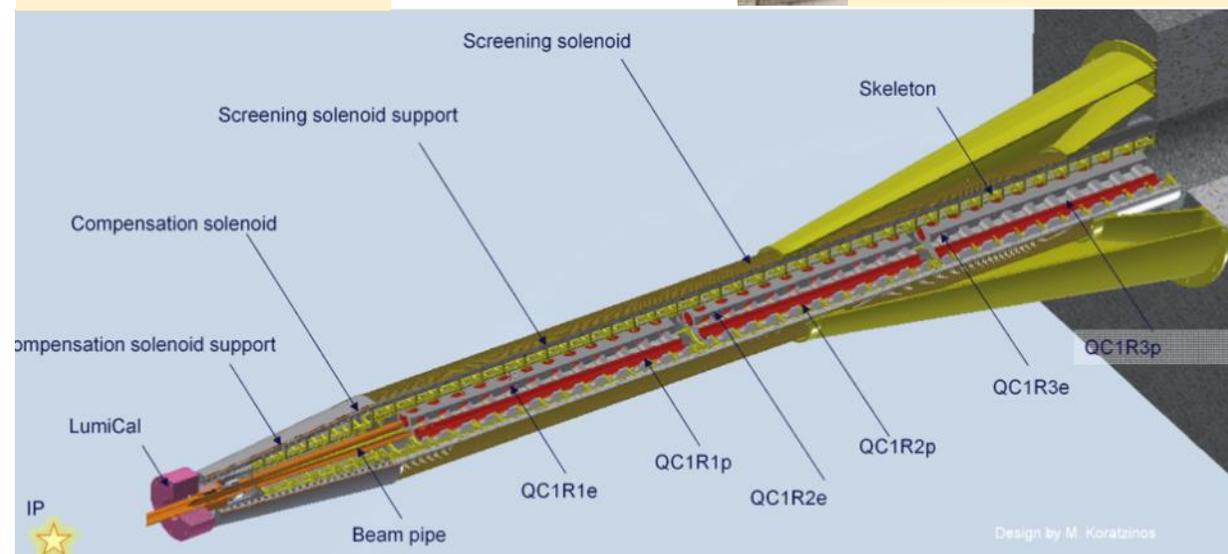
## Key topics:

- SC IR magnet system & Cryostat design
- 3D integration
- IR mock-up / INFN

Machine		FCCee	CEPC	ILC	SuperKEKB
Crossing-angle	mrad	30	33	14	83
$L^*$	m	2.2	1.9	3.5	0.935
Vertical $\beta_y^*$ at IP	mm	0.7-1.6	0.9-2.7	0.4	0.3
Detector soln field	T	2/3	3	3.5/5	1.5
Detector stay clear	mrad	100	118/141	90	350/436
Two beam $\Delta X$ at $L^*$	mm	66	62.7	49	77.6
He temperature	K	1.9	4.2	4.5	4.5



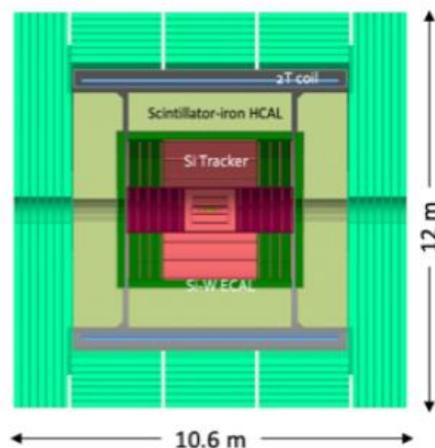
J. Seeman, SLAC  
P. Tavares, CERN



M. Boscolo, F. Palla, INFN

# FCC-ee detector concepts under study

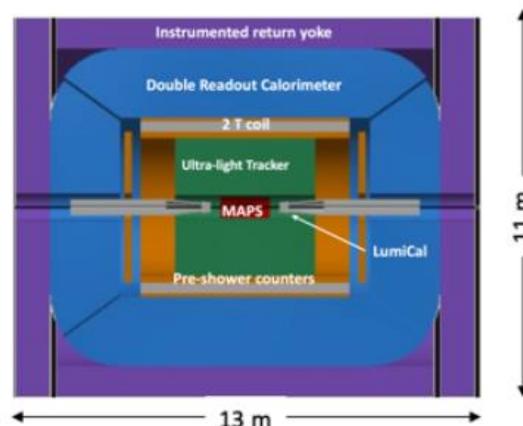
CLD



- Well established design
  - ILC -> CLIC detector -> CLD
- Full Si vtx + tracker; CALICE-like calorimetry; large coil, muon system
- Engineering and R&D needed for
  - reduction of tracker material budget
  - operation with continuous beam (no power pulsing: cooling of Si sensors for tracking + calorimetry)
- Possible detector optimizations
  - Improved  $\sigma_p/p$ ,  $\sigma_E/E$
  - PID: timing and/or RICH?

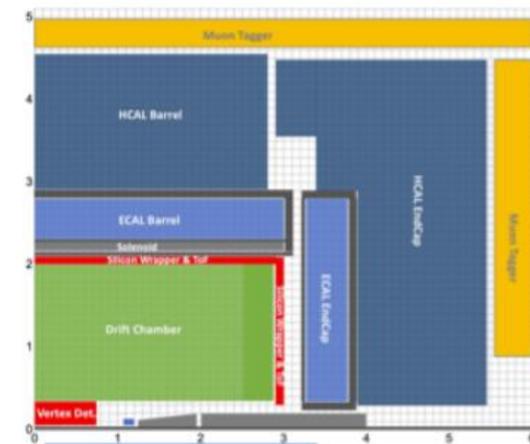


IDEA



- Less established design
  - But still ~15y history: ILC 4<sup>th</sup> Concept
- Si vtx detector; ultra light drift chamber w powerful PID; compact, light coil; monolithic dual readout calorimeter; muon system
  - Possibly augmented by crystal ECAL
- Active community
  - Prototype designs, test beam campaigns, ...

Noble Liquid ECAL based



new

- A design in its infancy
- High granularity Noble Liquid ECAL is core
  - Pb+LAr (or denser W+LCr)
- Drift chamber; CALICE-like HCAL; muon system.
- Coil inside same cryostat as LAr, possibly outside ECAL
- Active Noble Liquid R&D team
  - Readout electrodes, feed-throughs, electronics, light cryostat, ...
  - Software & performance studies

# FCC-hh main machine parameters

parameter	FCC-hh	HL-LHC	LHC
collision energy cms [TeV]	<b>84 – 120</b>		14
dipole field [T]	<b>14 – 20</b>		8.33
circumference [km]	<b>90.7</b>		26.7
arc length [km]	<b>76.9</b>		22.5
beam current [A]	<b>0.5</b>	1.1	<b>0.58</b>
bunch intensity [ $10^{11}$ ]	<b>1</b>	2.2	1.15
bunch spacing [ns]	<b>25</b>		<b>25</b>
synchr. rad. power / ring [kW]	<b>1020 - 4250</b>	7.3	3.6
SR power / length [W/m/ap.]	<b>13 - 54</b>	0.33	0.17
long. emit. damping time [h]	<b>0.77 – 0.26</b>		<b>12.9</b>
peak luminosity [ $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ ]	<b>~30</b>	5 (lev.)	1
events/bunch crossing	<b>~1000</b>	132	27
stored energy/beam [GJ]	<b>6.1 - 8.9</b>	0.7	0.36
Integrated luminosity/main IP [ $\text{fb}^{-1}$ ]	<b>20000</b>	3000	300

**With FCC-hh after FCC-ee: significant amount of time for high-field magnet R&D, aiming at highest possible collision energies**

- Target field range for cryo-magnet R&D

Formidable challenges:

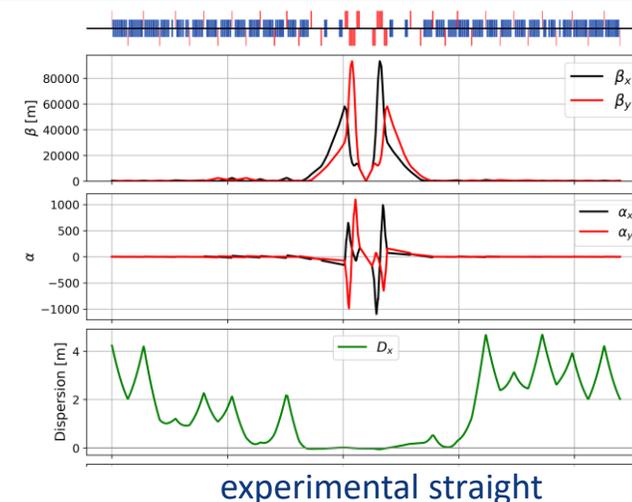
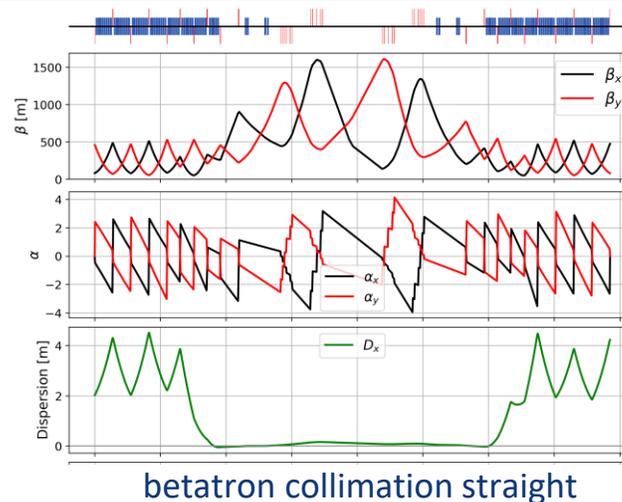
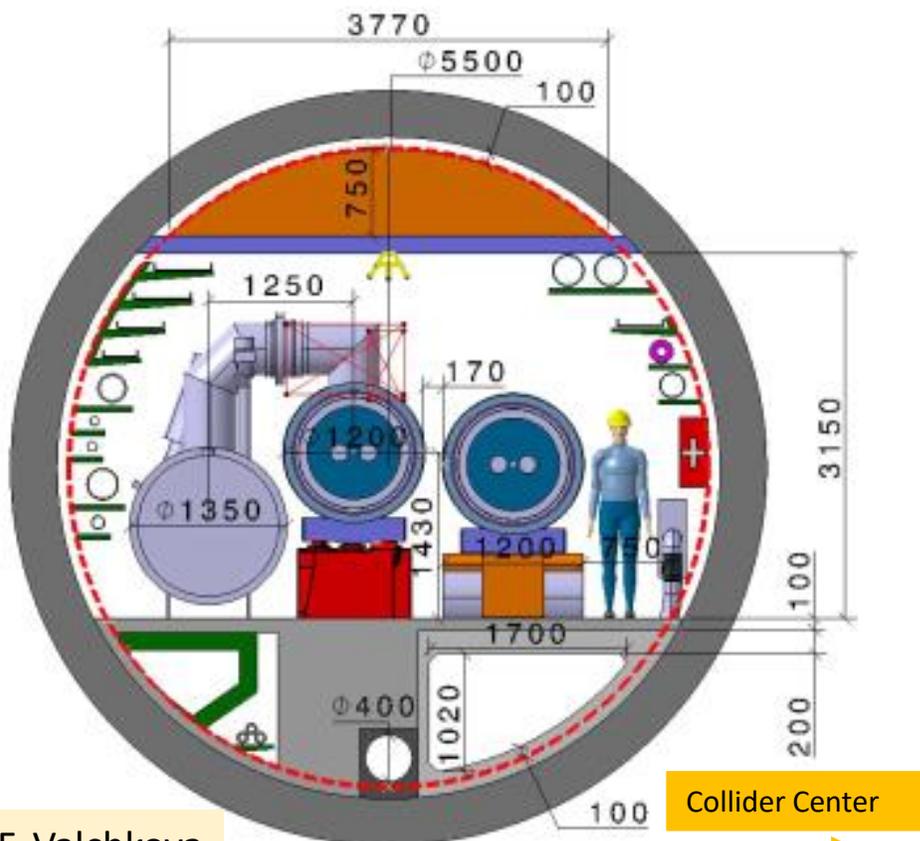
- ❑ high-field superconducting magnets: 14 - 20 T
- ❑ power load in arcs from synchrotron radiation: 4 MW → cryogenics, vacuum
- ❑ stored beam energy: ~ 9 GJ → machine protection
- ❑ pile-up in the detectors: ~1000 events/xing
- ❑ optimization of energy consumption: → R&D on cryo, HTS, beam current, ...

Formidable physics reach, including:

- ❑ Direct discovery potential up to ~ 40 TeV
- ❑ Measurement of Higgs self to ~ 5% and ttH to ~ 1%
- ❑ High-precision and model-indep (with FCC-ee input) measurements of rare Higgs decays ( $\gamma\gamma$ ,  $Z\gamma$ ,  $\mu\mu$ )
- ❑ Final word about WIMP dark matter

## Optics design activities:

- adaptation to new layout and geometry
- shrink  $\beta$  collimation & extraction by  $\sim 30\%$
- optics optimisation (filling factor etc.)



M. Giovannozzi. G. Perez, T. Risselada

## High-field cryo-magnet system design

- Conceptual study of cryogenics concept and temperature layout for LTS and HTS based magnets, in view of electrical consumption.
- Update of integration study for the ongoing HFM designs and scaling to preliminary HTS design.

**→ Confirmation of tunnel diameter!**

- HFM R&D (LTS and HTS) on technology and magnet design, aiming also at bridging the TRL gap between LTS and Nb-Sn

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

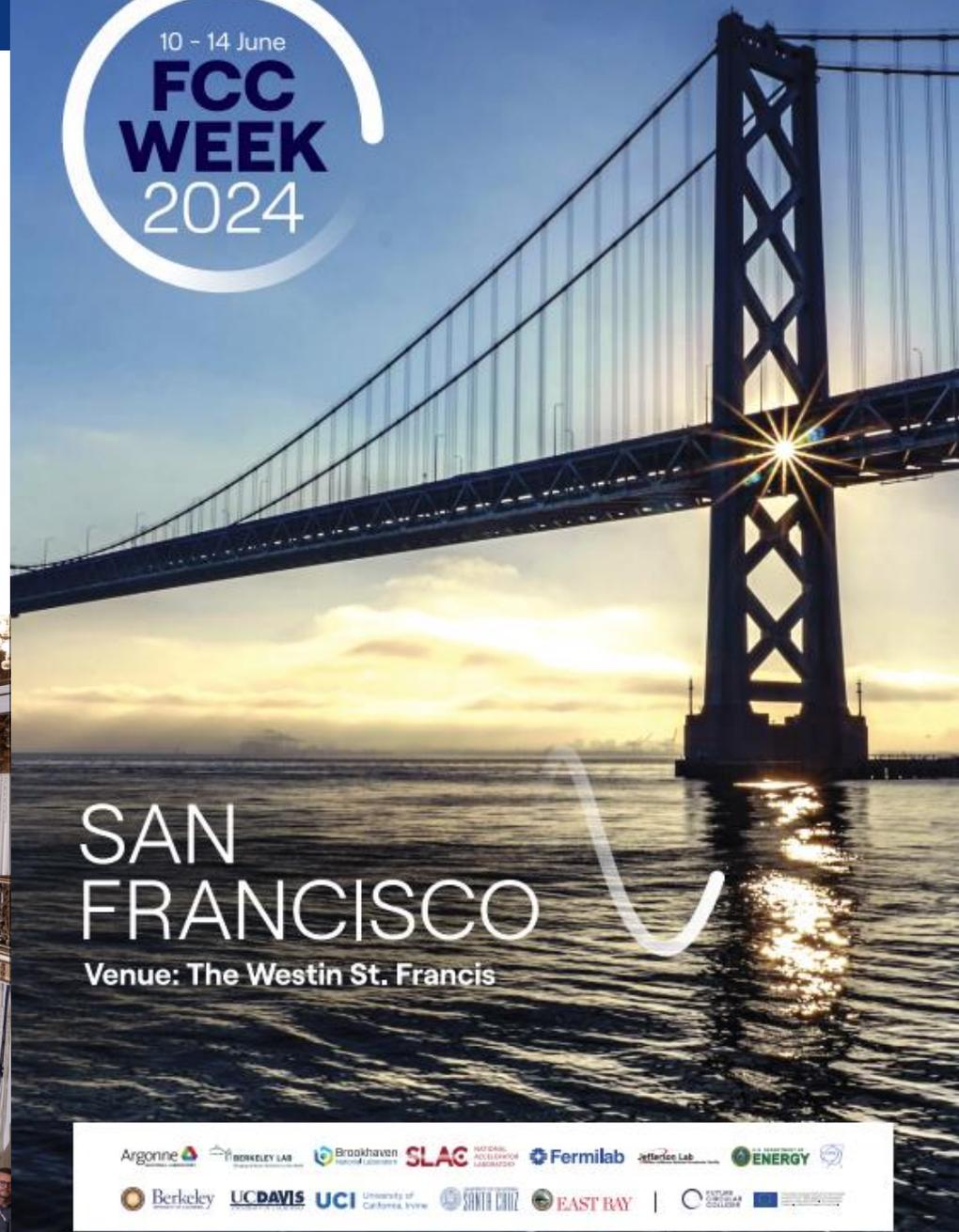
141  
Institutes

32  
countries  
+  
CERN



The complete status of the FCC and all the latest advancements were presented at the Future Circular Collider (FCC) Week 2024, in San Francisco:

<https://fccweek2024.web.cern.ch>



# SAN FRANCISCO

Venue: The Westin St. Francis



\*\*\*

## Joint Statement of Intent between The United States of America and The European Organization for Nuclear Research concerning Future Planning for Large Research Infrastructure Facilities, Advanced Scientific Computing, and Open Science

The United States and CERN intend to:

- ◆ Enhance collaboration in future planning activities for large-scale, resource-intensive facilities with the goal of providing a sustainable and responsible pathway for the peaceful use of future accelerator technologies;
- ◆ Continue to collaborate in the feasibility study of the Future Circular Collider Higgs Factory (FCC-ee), the proposed major research facility planned to be hosted in Europe by CERN with international participation, with the intent of strengthening the global scientific enterprise and providing a clear pathway for future activities in open and trusted research environments; and
- ◆ Discuss potential collaboration on pilot projects on incorporating new analytics techniques and tools such as artificial intelligence (AI) into particle physics research at scale.

Should the CERN Member States determine the FCC-ee is likely to be CERN's next world-leading research facility following the high-luminosity Large Hadron Collider, the United States intends to collaborate on its construction and physics exploitation, subject to appropriate domestic approvals.

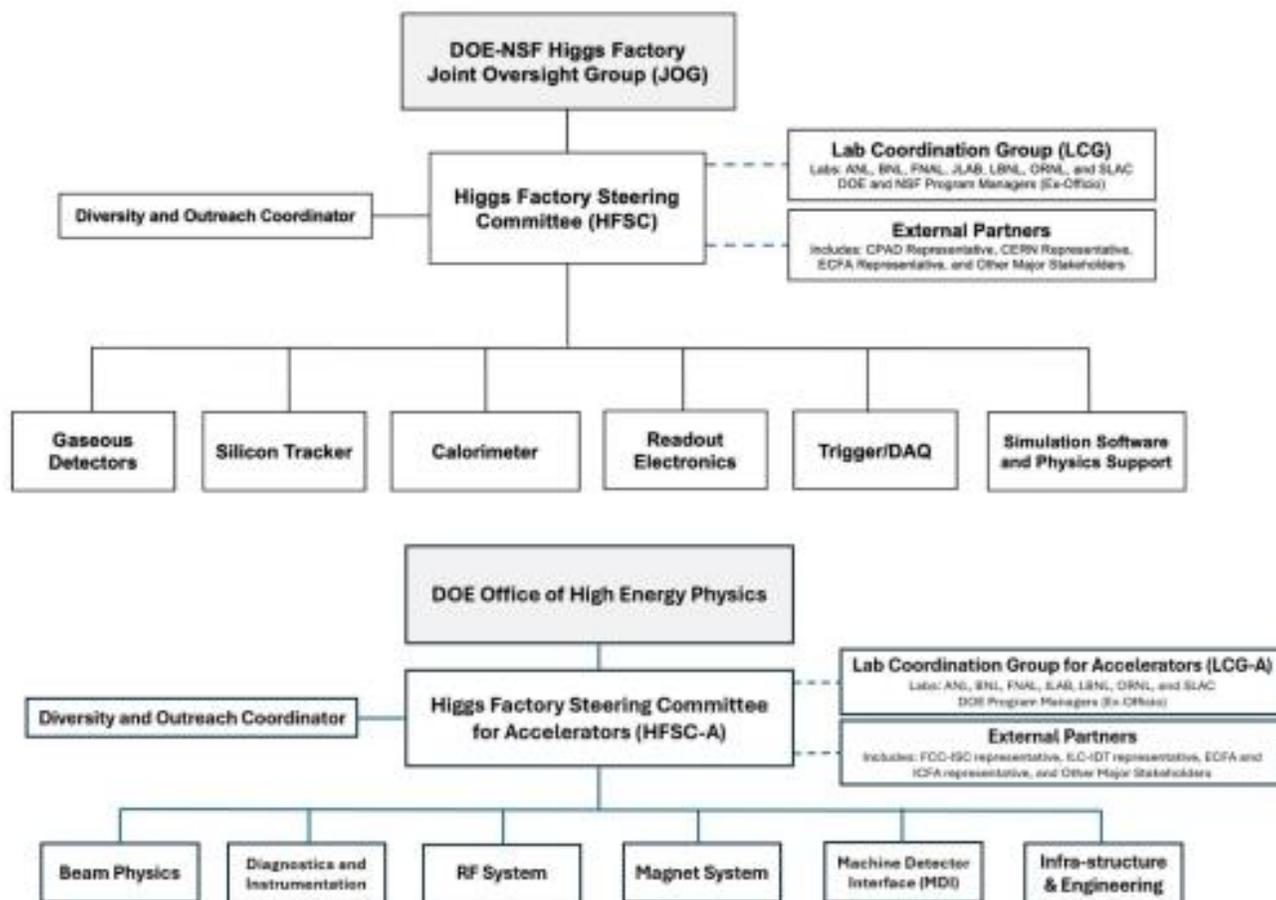
26 April 2024

White House Office of Science and Technology Policy Principal Deputy U.S. Chief Technology Officer Deirdre Mulligan signed for the United States while Director-General Fabiola Gianotti signed for CERN.



## DOE and NSF Higgs factory organization

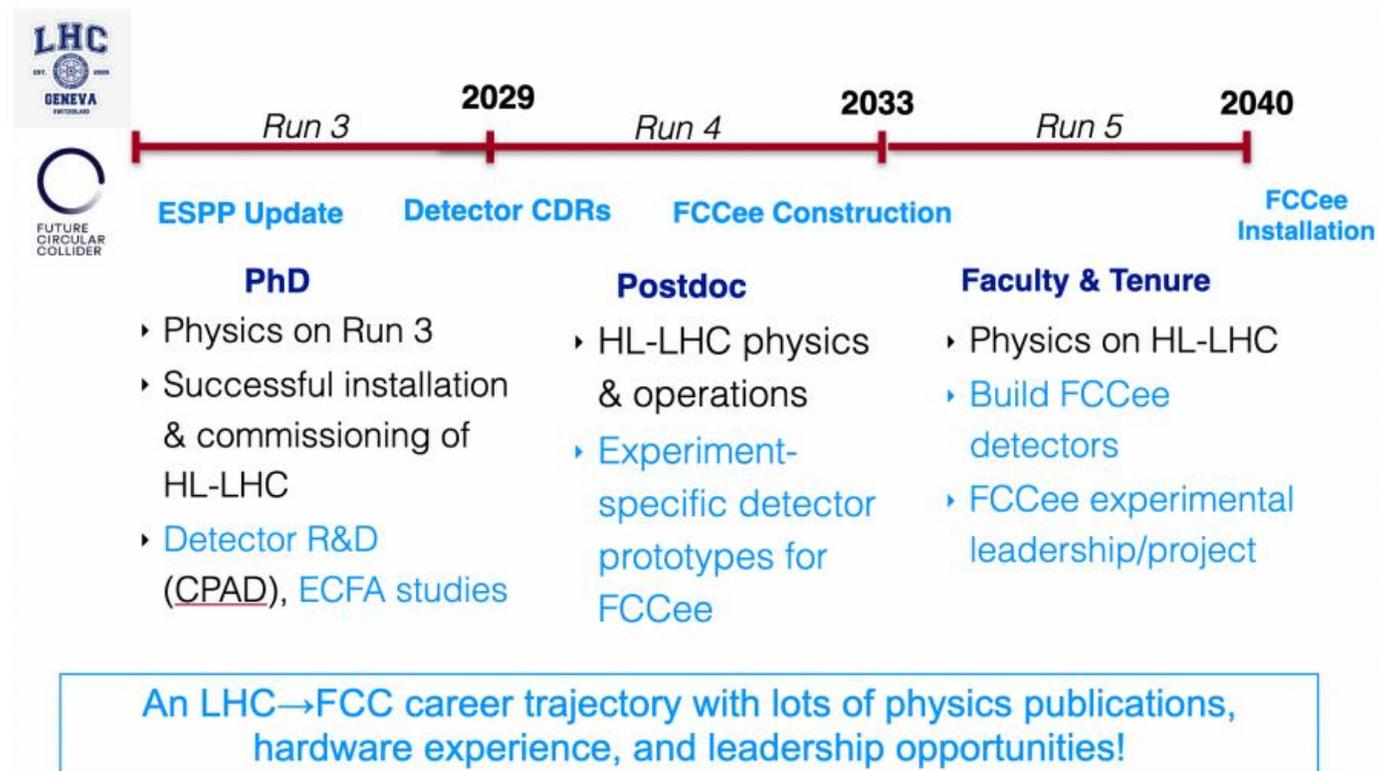
(organizations will evolve to follow the needs of the community)



### Charge

1. Physics and technical feasibility studies, including any associated design and R&D efforts, to advance various experiment detector concepts at a future Higgs factory;
  2. Prioritization and stewardship of the national R&D efforts should funds be identified by DOE and/or NSF;
  3. Development of the pre-project detector R&D scope that will be required prior to DOE and/or NSF initiating any detector project at a future e+e- collider;
  4. Conceptualization of the software and computing framework that will be needed to advance physics studies and R&D efforts; and to collect, store, and analyze the large volumes of physics data at future collider experiments;
  5. In consultation with DOE and NSF program managers, develop various funding models that will be required to support the R&D efforts described in items (3) and (4) above; and
  6. Ensure collaborations by the U.S. with our partners are cost-effectively carried out to advance the future Higgs factory initiatives. (CPAD, ECFA, DRD, others).
- Prepare the groundwork to respond to the P5 Recommendation 5: "[Convene a targeted panel to review] the level and nature of US contribution in a specific Higgs factory including an evaluation of the associated schedule, budget, and risks once crucial information becomes available"

## A possible FCC career



- **Next milestone: completion of the FCC Feasibility Study by March 2025**
- **By 2027-2028, possible FCC project approval, start of CE design contract:**
  - specifications to enable CE tender design by 2028
  - refined input for environmental evaluation and project authorisation process
  - requires overall integration study and designs based on technical pre-design of accelerators, technical infrastructure and detectors
- **By 2031-32, possible start of CE construction:**
  - CE groundbreaking
  - TDR to enable prototyping, industrialization towards component production
- **Strong collaboration with US and further international partners is essential for success!**



# VIENNA

HOFBURG

19-23 MAY  
**FCC**  
**WEEK**  
2025

Save the date: 19 – 23 May 2025



[home.cern](https://home.cern)