The Future Circular Collider at CERN

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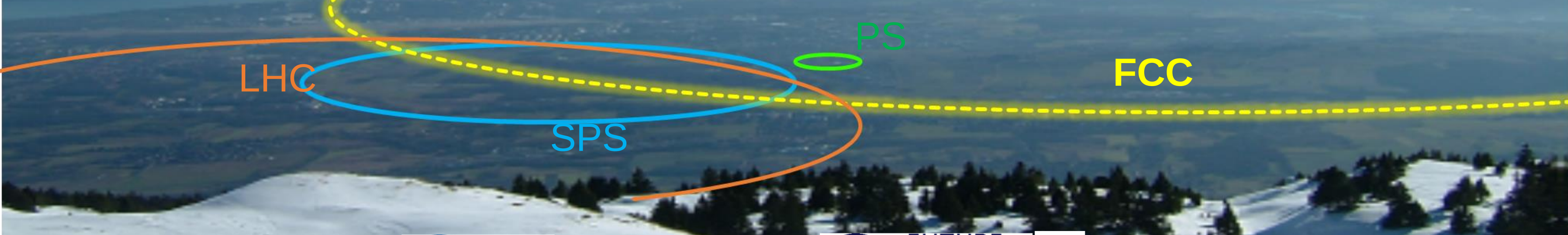

FUTURE CIRCULAR COLLIDER Innovation Study

http://cern.ch/fcc

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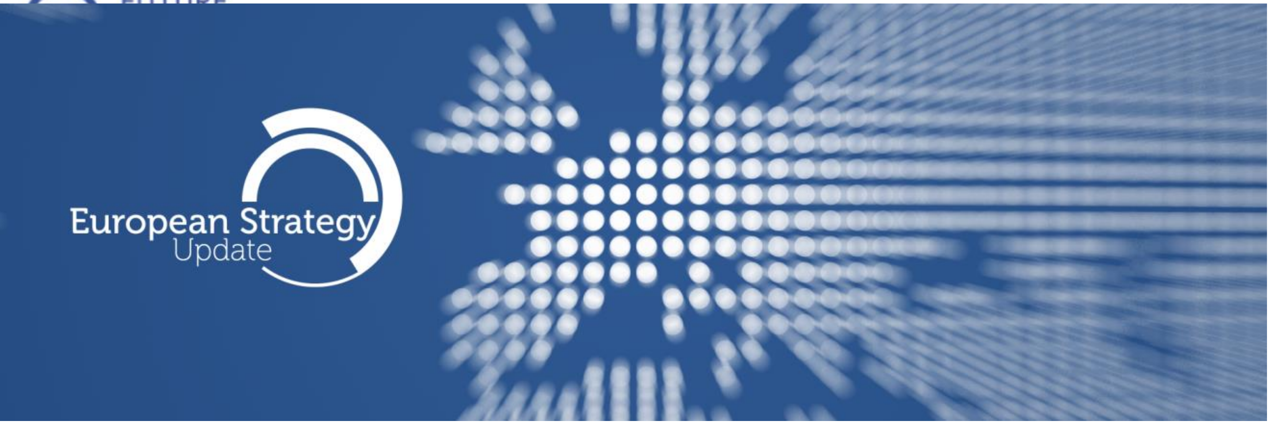
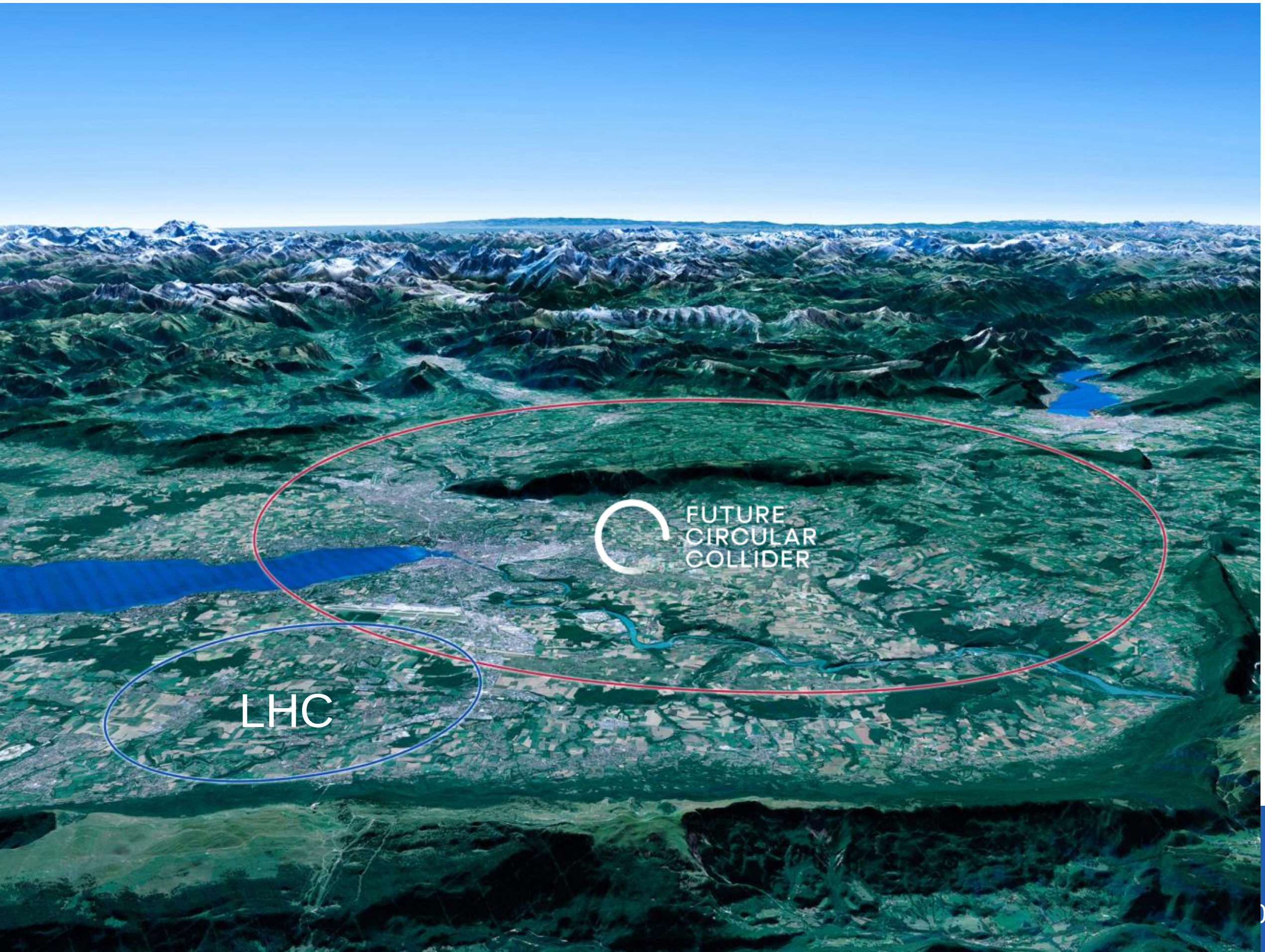
Photo: J. Wenninger





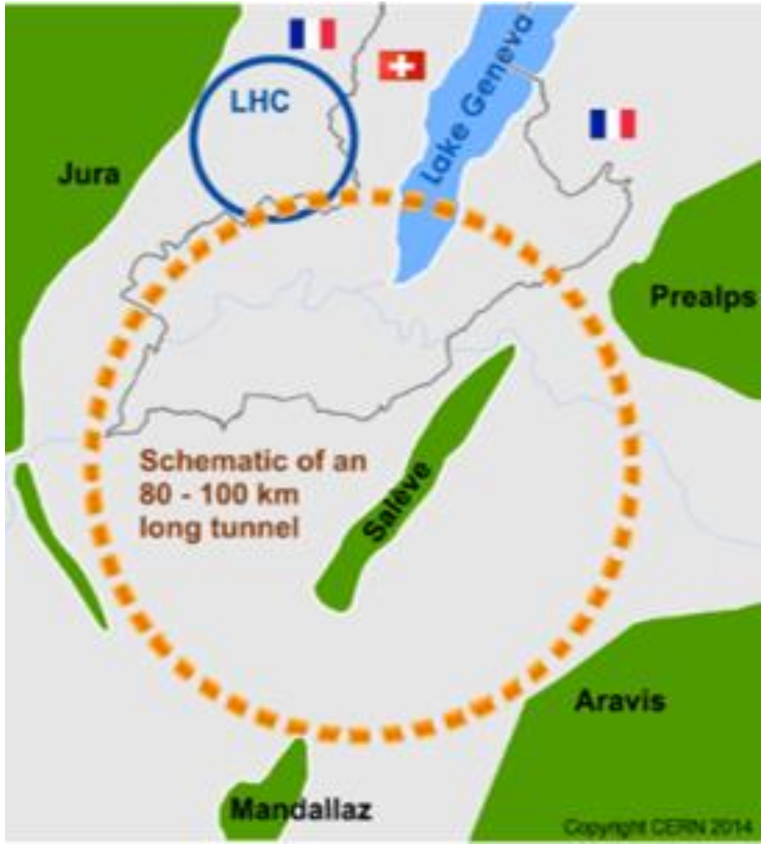
CERN Scientific Priorities for the Future

Implementation of the recommendations of the **2020 Update of the European Strategy for Particle Physics**:

- Fully exploit the LHC & HL-LHC.
- Build a Higgs factory to further understand this unique particle.
- Investigate the technical and financial feasibility of a future energy-frontier 100 km collider at CERN.
- Ramp up relevant R&D.
- Continue supporting other projects around the world.

The FCC Integrated Programme Inspired by successful LEP – LHC Programmes at CERN

Complementary physics, common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure, FCC integrated project allows seamless continuation of HEP after HL-LHC

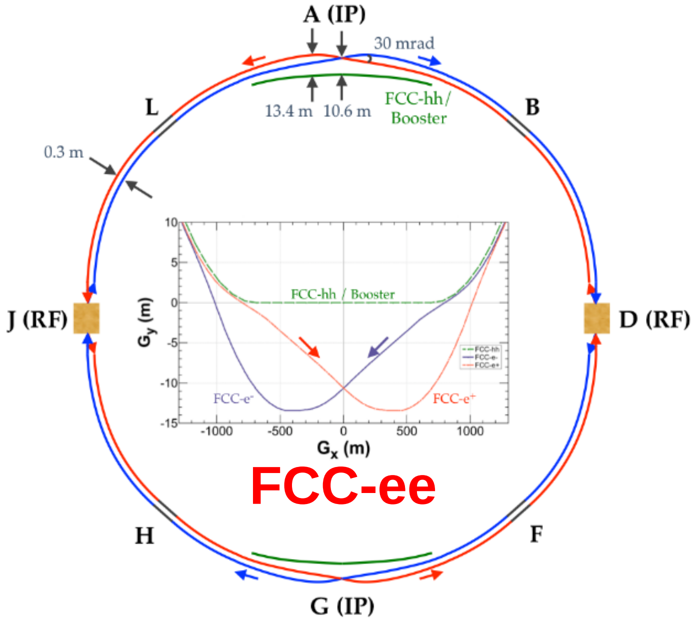


2020 - 2040

Phase 1 : FCC-ee

electron – positron Collider

Higgs, Z, W, ttbar Factory at highest lumi

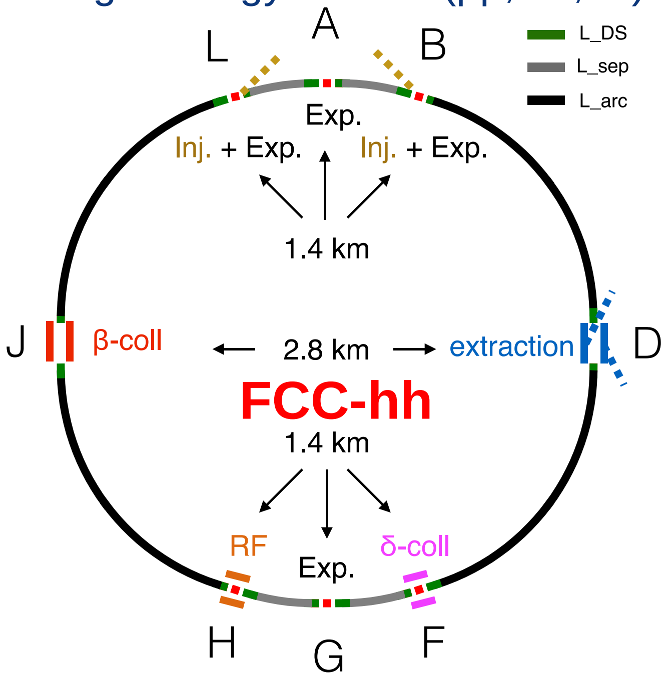


2040 - 2055

Phase 2 : FCC-hh

proton – proton Collider

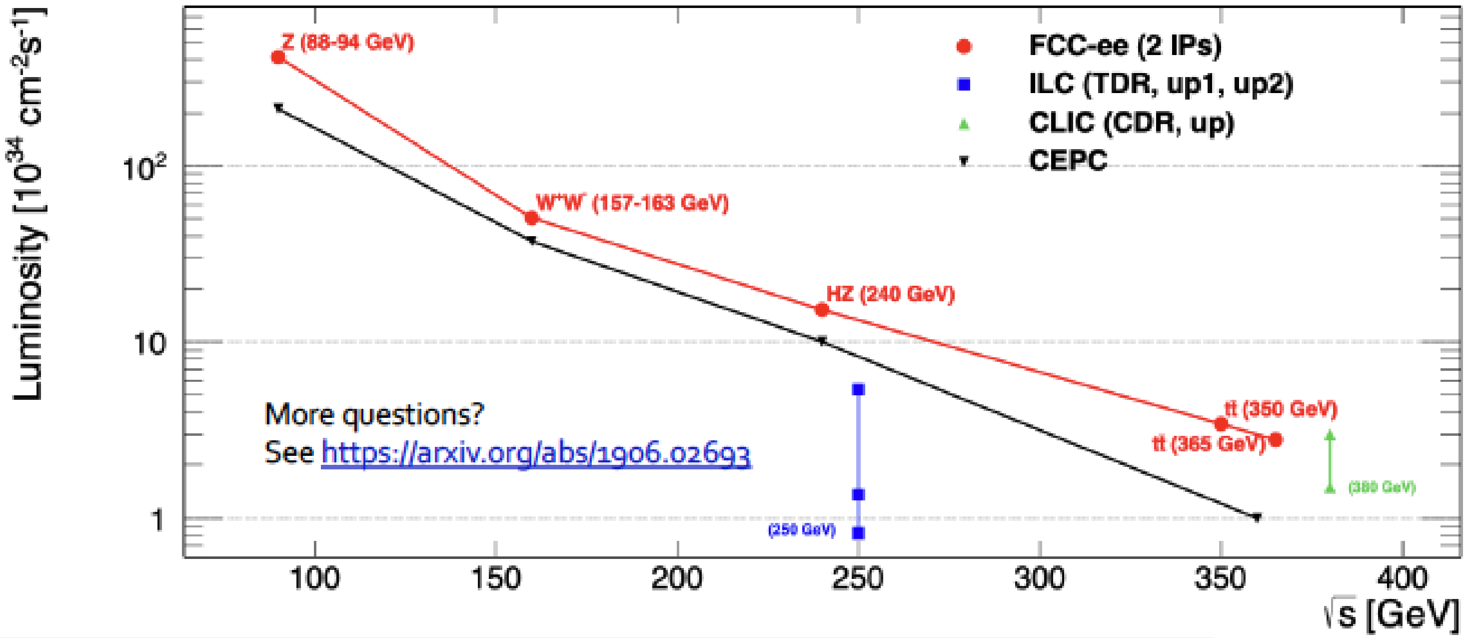
High-energy frontier (pp,ion,eh)



2060 - 2090

FCC-ee Higgs and Electroweak Factory

- Great energy range for the SM heavy particles + highest luminosities + √s precision



				E_{CM} errors:
Z peak	E_{cm} ~ 91 GeV	5×10^{12} e+e- → Z	LEP x 10^5	<100 keV
WW threshold+	$E_{cm} \geq$ 161 GeV	$> 10^8$ e+e- → WW	LEP x 10^3	<300 keV
ZH threshold	E_{cm} : 240 GeV	10^6 e+e- → ZH	Never done	2 MeV
$\bar{t}t$ threshold	E_{cm} ~ 350 GeV	10^6 e+e- → $\bar{t}t$	Never done	5 MeV

P. Janot

Physics Opportunities with FCC-hh

- With 30 ab^{-1} @ 100 TeV in 25 years
  - 2×10^{10} Higgs bosons (180 × HL-LHC)
    - 2×10^{7} Higgs pairs, 10^{8} ttH events
  - 10^{12} top pairs (300 × HL-LHC)
  - 5×10^{13} W, 10^{13} Z (70 × HL-LHC)
  - 10^{5} gluino pairs im m_{gluino} ~ 8 TeV
  - …

- High precision study of H and top
  - Exploration of EWSB in all details
    - Higgs self-coupling to 2-3%
  - Rare or BSM decays
    - BR(H → invisible) to 2.5×10^{-4} (DM!)
    - $g_{H\mu\mu}$, $g_{H\gamma\gamma}$, $g_{HZ\gamma}$ to 0.5%
      - → FCC-ee standard candle essential

- Sensitivity to heavy new physics
  - With indirect precision probes
    - e.g., with cross-section ratios
    - e.g., with high-p_T final states
  - Trade statistics for systematics
    - Further improved by FCC-ee synergies
  - High-energy phenomena (VBS, DY)

- Direct particle observation
  - Mass reach enhanced by ~5 wrt LHC
    - New gauge bosons up to 40 TeV
    - Strongly interacting particles up to 15 TeV
    - Natural SUSY up to 5-20 TeV
    - Dark matter up to 1.5-5 TeV
      - → Possibility to find or rule out thermal WIMPs as Dark Matter candidates

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FCC-ee Basic Design Choices

Double ring e+ e- collider

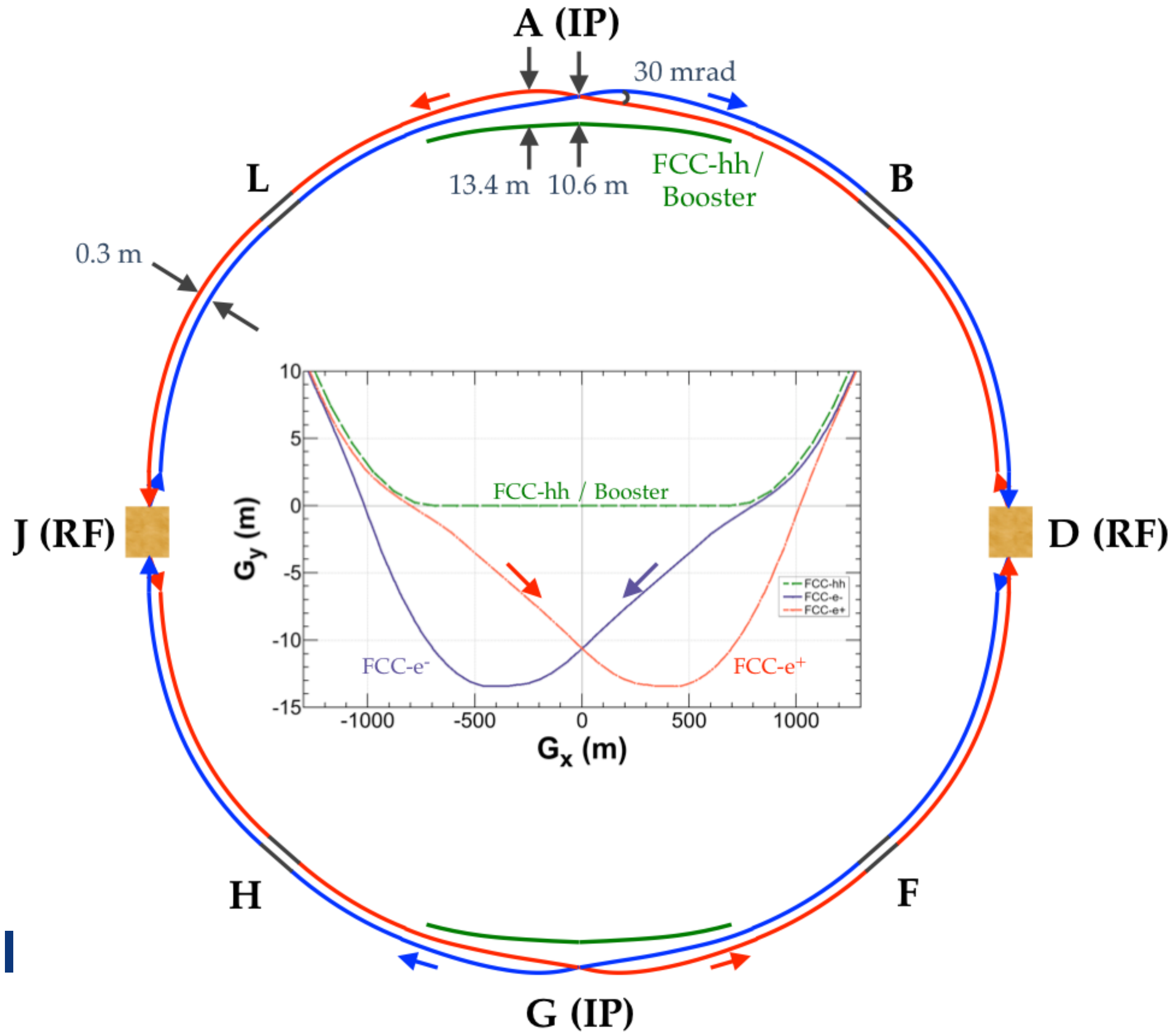
Common footprint with FCC-hh,
except around IPs

Asymmetric IR layout and optics to limit synchrotron radiation towards the detector

2 IPs, large horizontal crossing angle **30 mrad, crab-waist collision optics**
(alternative layouts with 4 IPs under study now)

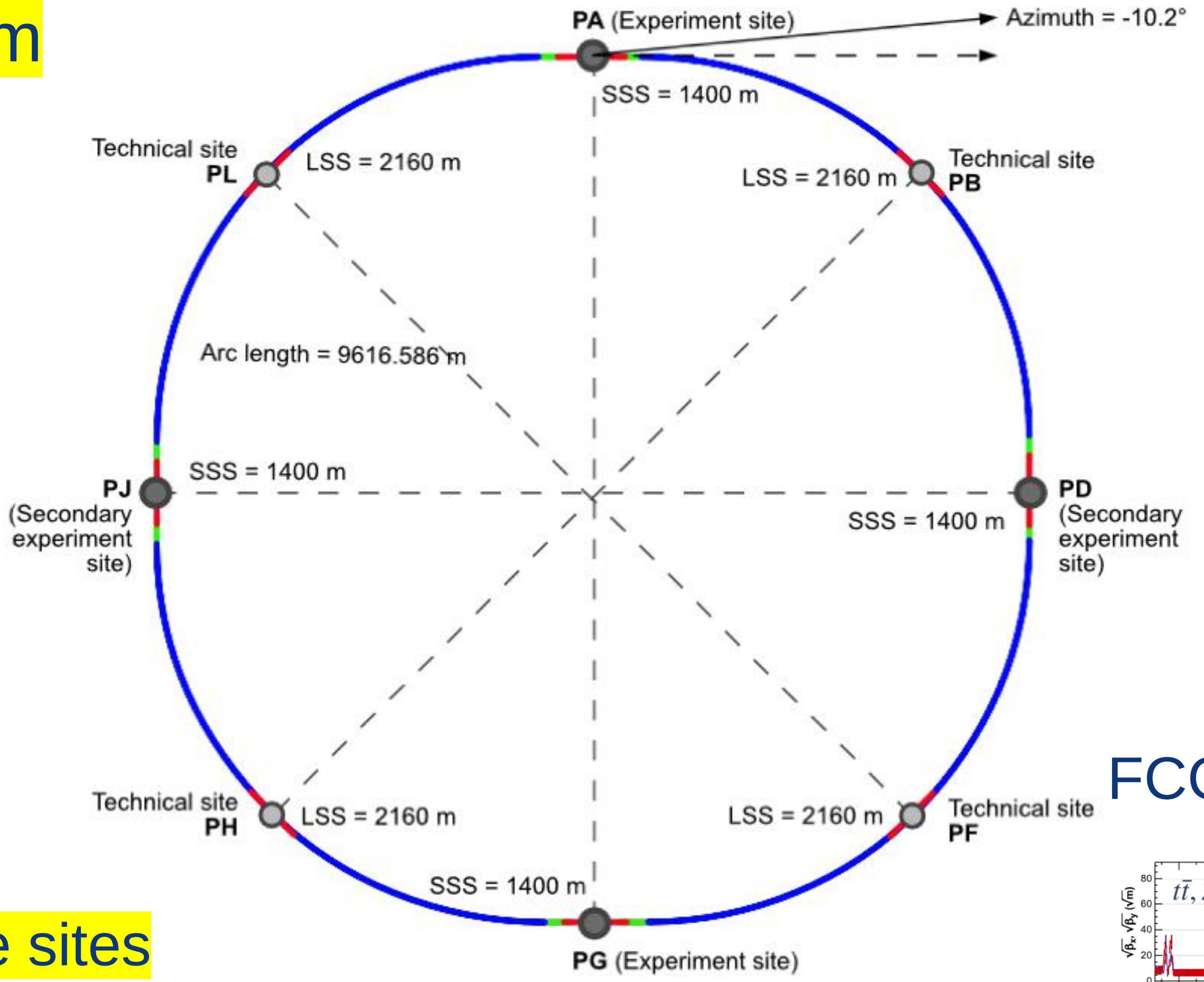
Synchrotron radiation power 50 MW/beam
at all beam energies

Top-up injection scheme for high luminosity
Requires **booster synchrotron in collider tunnel**



New "lowest risk" Placement/Optics Allows 4 Experiments

C=91 km



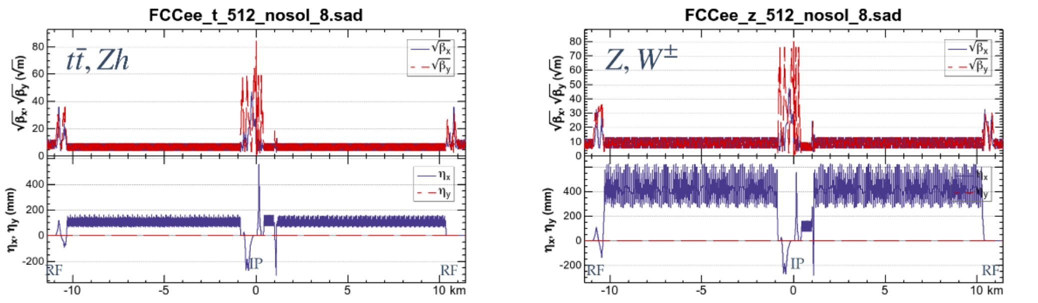
8 surface sites

J. Gutleber

perfect symmetry and **perfect 4-fold superperiodicity**

FCC-ee beam optics for ¼ ring

K. Oide



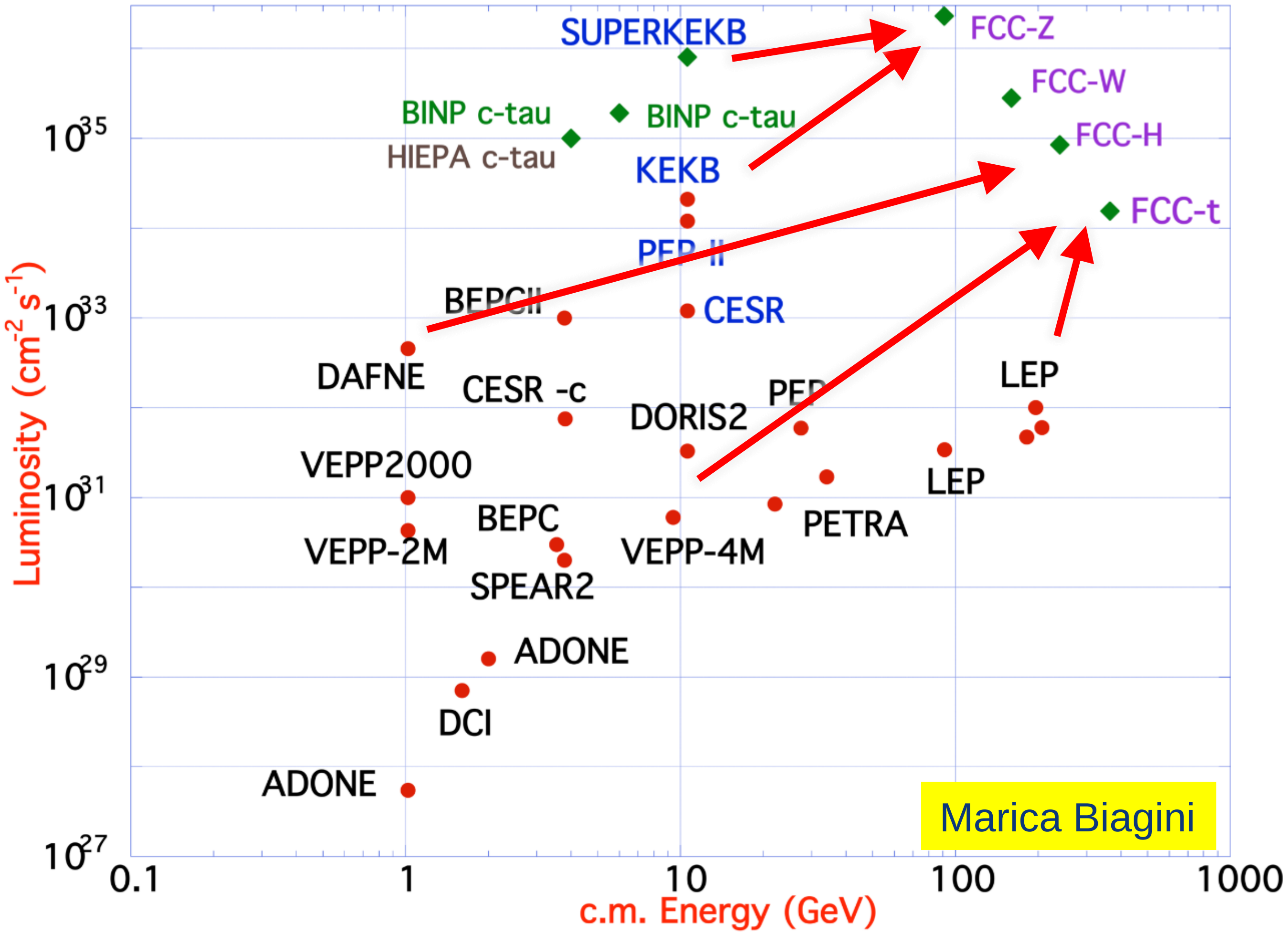
FCC-ee Collider Parameters (Stage 1)

Parameter [4 IPs, 91.2 km circumference]	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45	80	120	182.5
beam current [mA]	1400	135	26.7	5.0
no. bunches/beam	8800	1120	336	42
bunch intensity [10^{11}]	2.76	2.29	1.51	2.26
SR energy loss / turn [GeV]	0.0391	0.37	1.869	10.0
total RF voltage 400/800 MHz [GV]	0.120/0	1.0/0	2.48/0	4.0/7.67
long. damping time [turns]	1170	216	64.5	18.5
horizontal beta* [m]	0.15	0.2	0.3	1
vertical beta* [mm]	0.8	1	1	1.6
horiz. geometric emittance [nm]	0.71	0.28	0.64	1.49
vert. geom. emittance [pm]	1.42	4.34	1.29	2.98
bunch length with SR / BS [mm]	4.32 / 15.2	3.55 / 7.02	2.5 / 4.45	1.67 / 2.54
luminosity per IP [10^{34} cm^{-2}s^{-1}]	181	17.3	7.2	1.25
beam lifetime rad Bhabha / BS [min]	19 / -	20 / -	10 / 19	12 / 46

Preliminary - for new layout & with 4 IPs

FCC-ee Design Concept

based on lessons and techniques from past colliders (last 40 years)



B-factories: **KEKB & PEP-II:**
- double-ring lepton colliders,
- high beam currents,
- top-up injection

DAFNE: crab waist, double ring

S-KEKB: low β_y*, crab waist

LEP: high energy, SR effects

VEPP-4M, LEP: precision E calibration

KEKB: e^+ source

HERA, LEP, RHIC: spin gymnastics

combining successful ingredients of several recent colliders → highest luminosities & energies

FCC-ee RF Staging Scenario

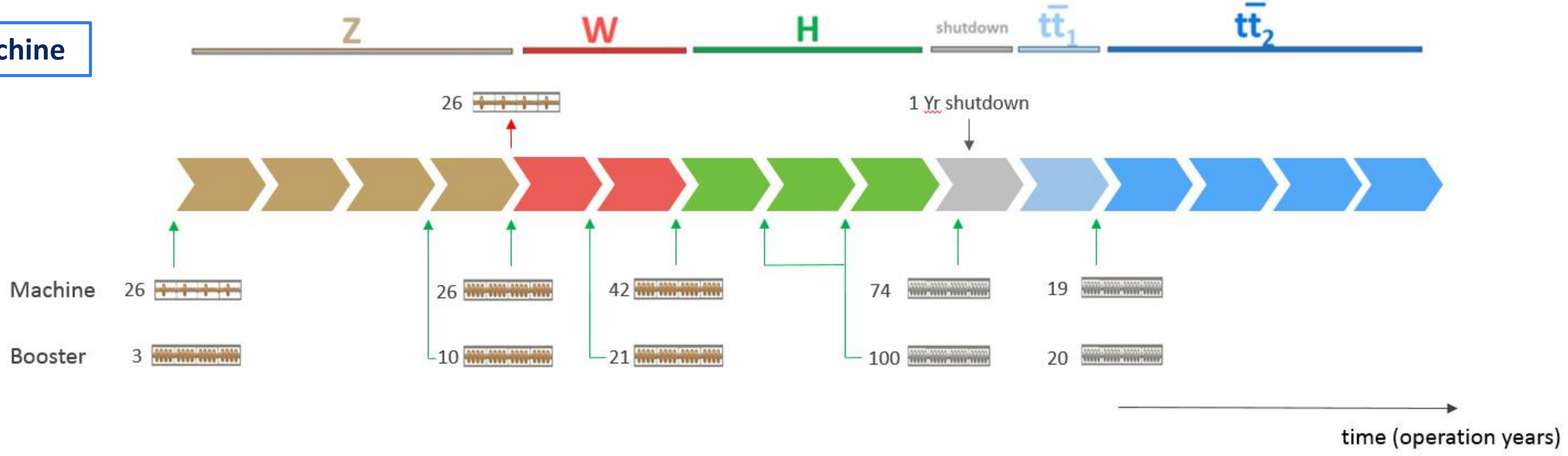
"Ampere-class" machine

WP	V_{rf} [GV]	#bunches	I_{beam} [mA]
Z	0.1	16640	1390
W	0.44	2000	147
H	2.0	393	29
ttbar	10.9	48	5.4

"high-gradient" machine

three sets of RF cavities to cover all options for FCC-ee & booster:

- **high intensity (Z, FCC-hh): 400 MHz mono-cell cavities (4/cryom.)**
- **higher energy (W, H, t): 400 MHz four-cell cavities (4/cryomodule)**
- **ttbar machine complement: 800 MHz five-cell cavities (4/cryom.)**
- **installation sequence comparable to LEP (≈ 30 CM/shutdown)**



FCC-ee Figures of Merit

FUTURE CIRCULAR COLLIDER

Luminosity vs. capital cost

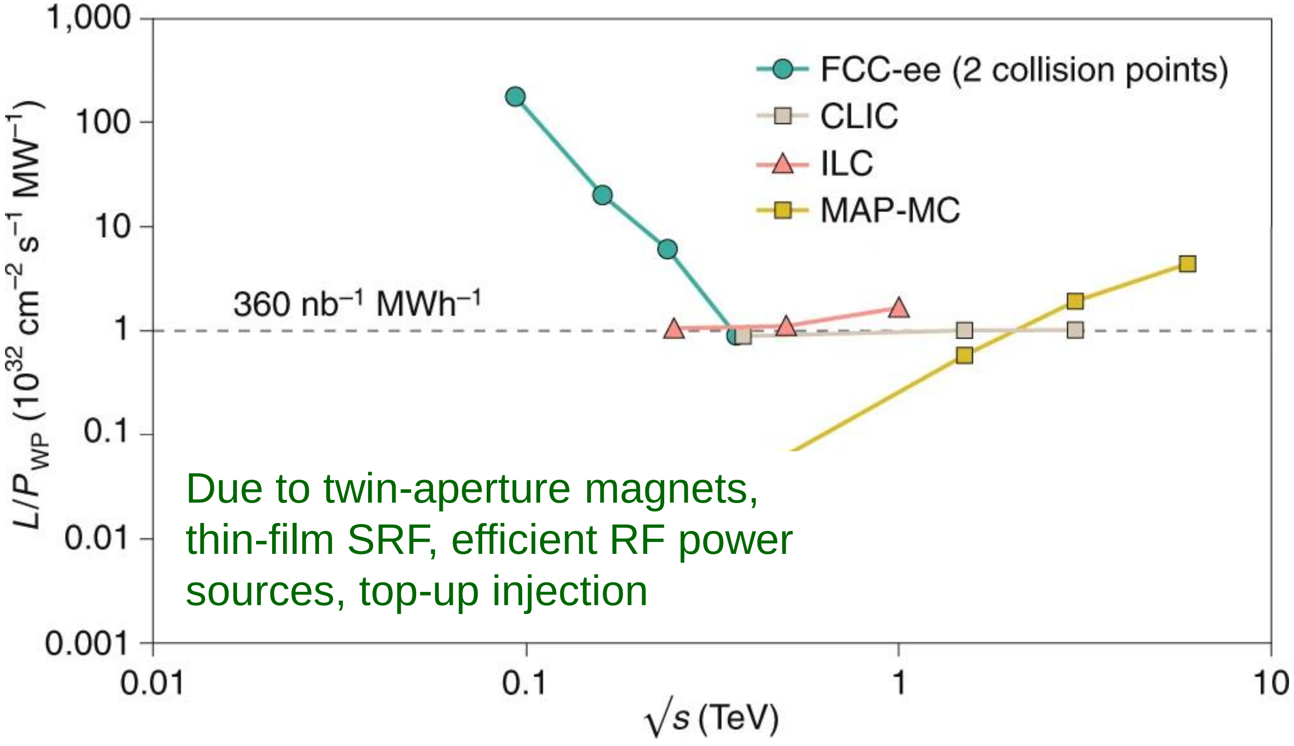
- for the H running, **with 5 ab^{-1} accumulated over 3 years and 10^{6} H produced**, the total investment cost (~10 BCHF) corresponds to
  → **10 kCHF per produced Higgs boson**

- for the Z running with **150 ab^{-1} accumulated over 4 years and 5x10^{12} Z produced,** the total investment cost corresponds to
  → **10 kCHF per 5×10^{6} Z bosons**

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

Capital cost per luminosity dramatically decreased compared with LEP !

Luminosity vs. electricity consumption

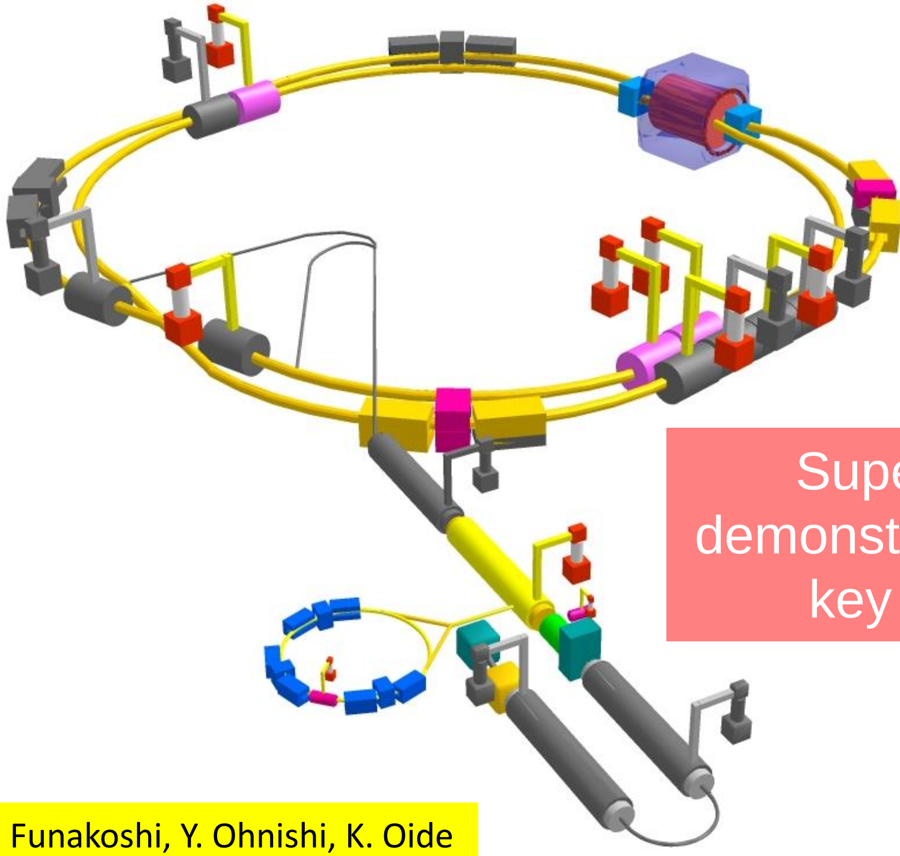


Due to twin-aperture magnets, thin-film SRF, efficient RF power sources, top-up injection

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

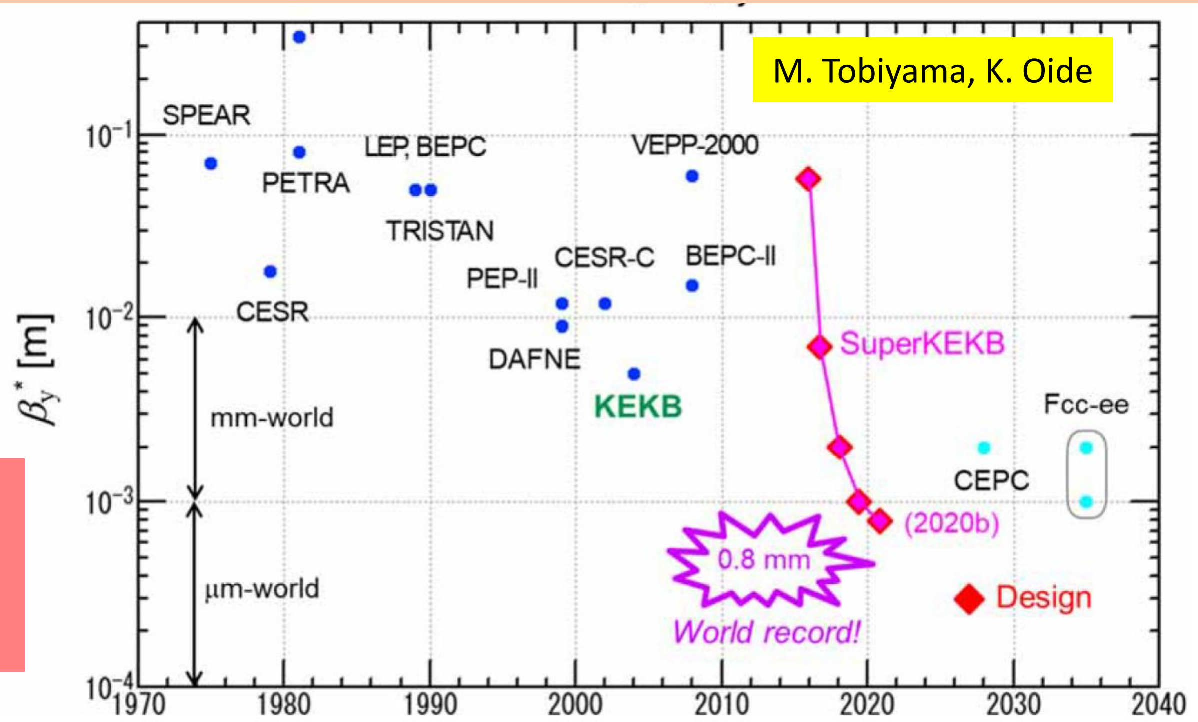
SuperKEKB – Pushing Luminosity and β*

Design: double ring e^+e^- collider as *B*-factory at 7(e^-) & 4(e^+) GeV; **design luminosity ~8 x 10^{35} $cm^{-2}s^{-1}$; β_y^* ~ 0.3 mm; nano-beam – large crossing angle** collision scheme **(crab waist w/o sextupoles)**; **beam lifetime ~5 minutes**; **top-up** injection; **e^+ rate up to ~ 2.5 10^{12} /s**



Y. Funakoshi, Y. Ohnishi, K. Oide

SuperKEKB is demonstrating FCC-ee key concepts



β_y^* = 0.8 mm achieved in both rings – using the FCC-ee-style "virtual" crab-waist collision scheme

Potential EIC – FCC collaboration

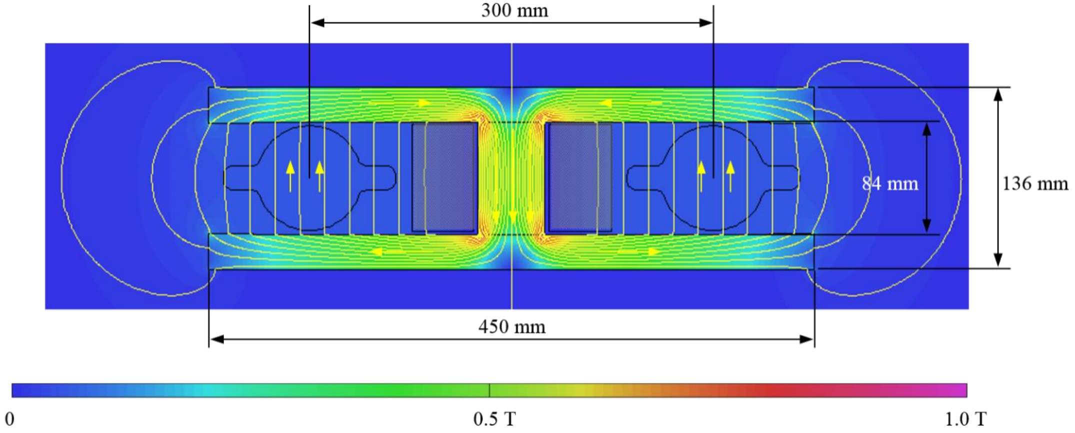
NSLS-II, EIC & FCC-ee beam parameters

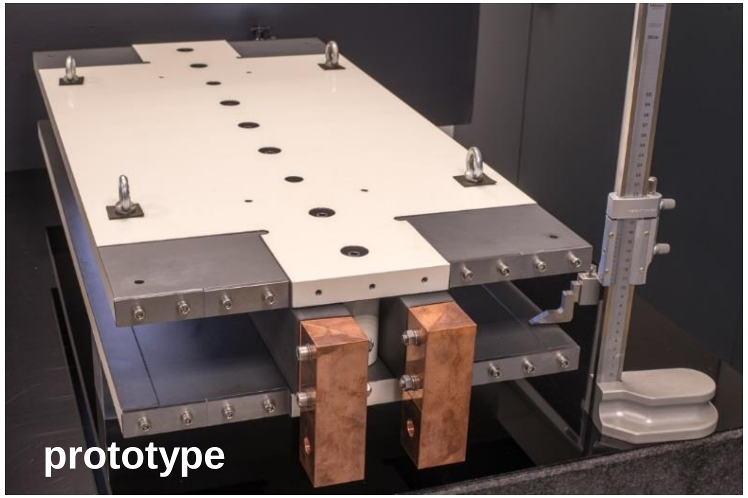
	NSLS-II	EIC	FCC-ee-Z
Beam energy [GeV]	3	10 (20)	45.6
Bunch population [10^{11}]	0.08	1.7	1.7
Bunch spacing [ns]	2	10	15, 17.5 or 20
Rms bunch length [mm]	4.5 - 9	2	3.5 (SR)
Beam current [A]	0.5	2.5 (0.27)	1.39
RF frequency [MHz]	500	591	400

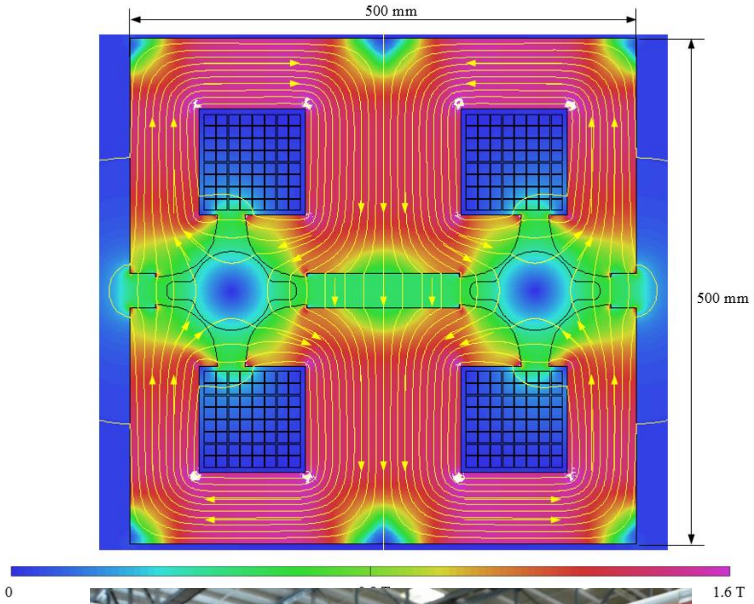
Similarity of several parameters strongly suggests collaboration to exploit synergies in areas such as beam instrumentation, SRF, vacuum system with SR handling, etc.

Prototypes of FCC-ee Low-power Magnets

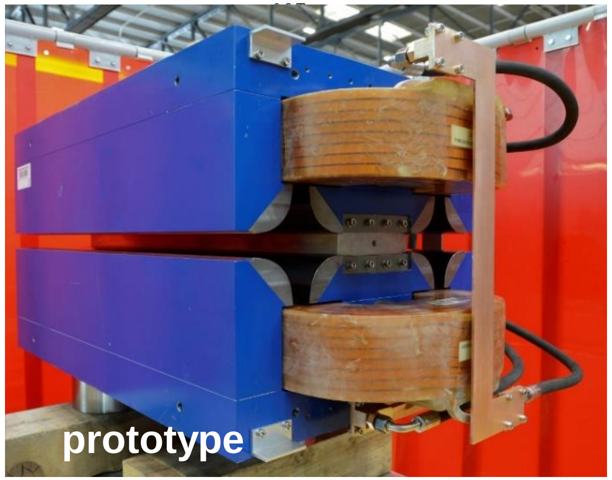
Twin-dipole design with 2× power saving
16 MW (at 175 GeV), with Al busbars



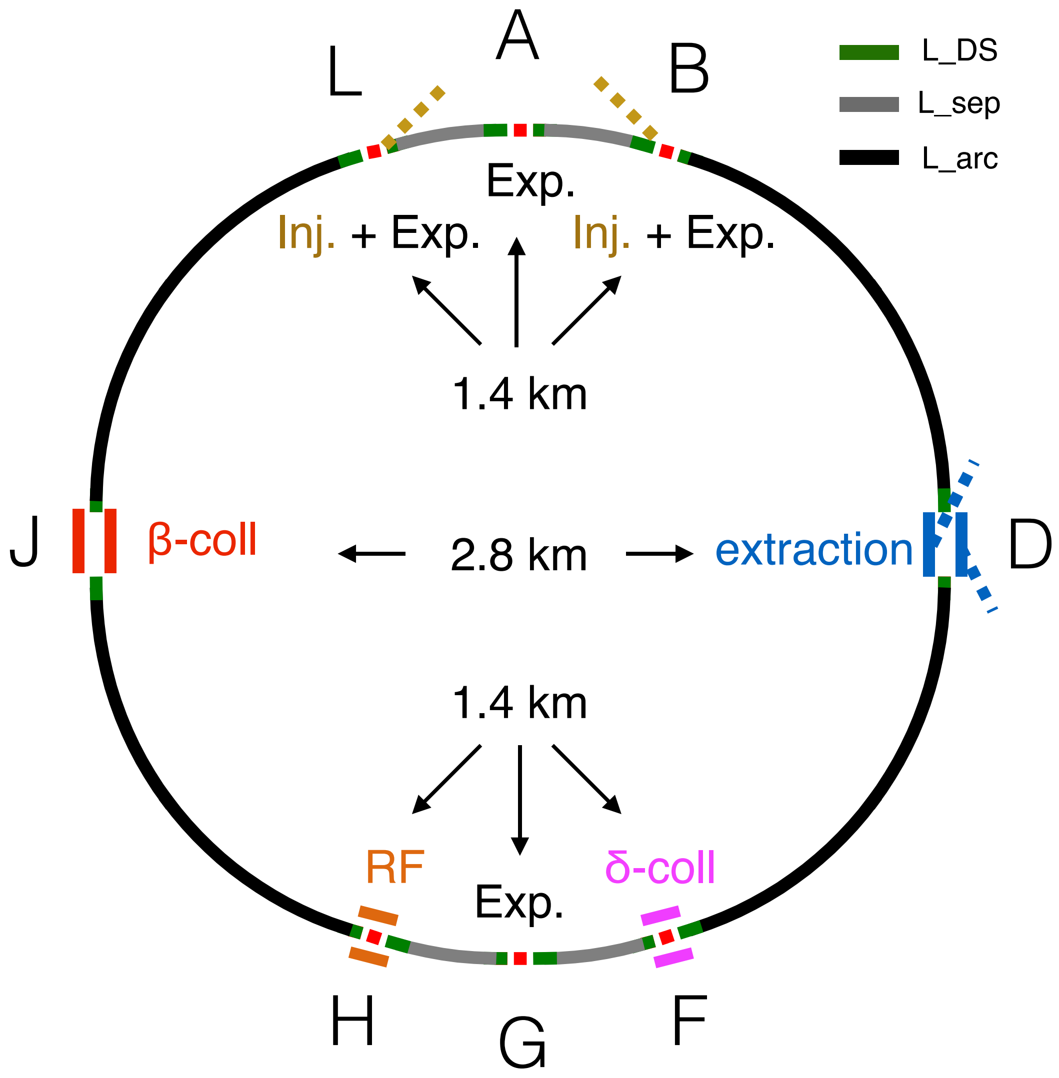




Twin F/D arc quad design with 2× power saving 25 MW (at 175 GeV), with Cu conductor



FCC-hh Basic Design Choices



- **dual aperture superconducting magnets**
- **two high-luminosity experiments (A & G)**
- **two other experiments (L & B)** combined with **injection upstream** of experiments
- **two collimation insertions**
  - betatron cleaning (J)
  - momentum cleaning (F)
- **extraction/dump insertion (D)**
- **RF insertion (H)**
- **Injection from LHC (~3 TeV) or scSPS (~1.2 TeV)**
- **Alternative layouts under study**

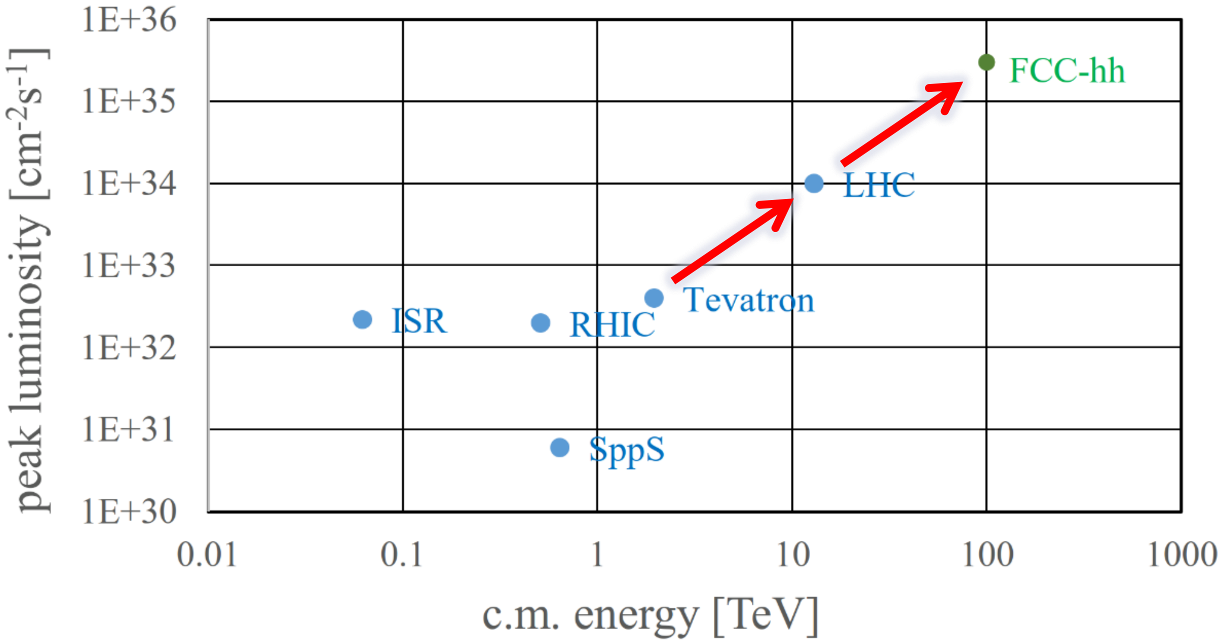
FCC-hh (pp) Collider Parameters (Stage 2)

FUTURE CIRCULAR COLLIDER

parameter	FCC-hh		HL-LHC	LHC
collision energy cms [TeV]	100		14	14
dipole field [T]	16-17		8.33	8.33
circumference [km]	91.2		26.7	26.7
beam current [A]	0.5		1.1	0.58
bunch intensity [10^{11}]	1	1	2.2	1.15
bunch spacing [ns]	25	25	25	25
synchr. rad. power / ring [kW]	2700		7.3	3.6
SR power / length [W/m/ap.]	32.1		0.33	0.17
long. emit. damping time [h]	0.45		12.9	12.9
beta* [m]	1.1	0.3	0.15 (min.)	0.55
normalized emittance [μm]	2.2		2.5	3.75
peak luminosity [10^{34} $cm^{-2}s^{-1}$]	5	30	5 (lev.)	1
events/bunch crossing	170	1000	132	27
stored energy/beam [GJ]	7.8		0.7	0.36

Preliminary - for new layout

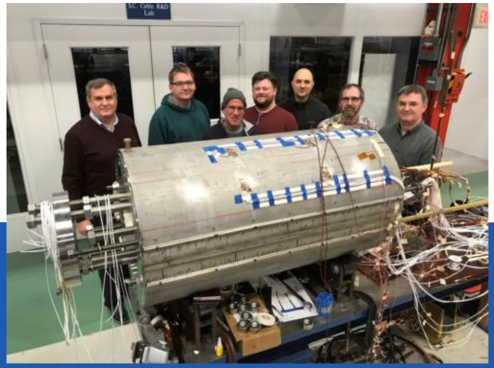
FCC-hh: Highest Collision Energies



- **order of magnitude performance increase** in both **energy & luminosity**
- **100 TeV cm collision energy** (vs 14 TeV for LHC)
- **20 ab^{-1} per experiment collected over 25 years** of operation (vs 3 ab^{-1} for LHC)
- similar performance increase as from Tevatron to LHC
- **key technology: high-field magnets**

from
LHC technology
8.3 T NbTi dipole

via
HL-LHC technology
12 T Nb_3Sn quadrupole



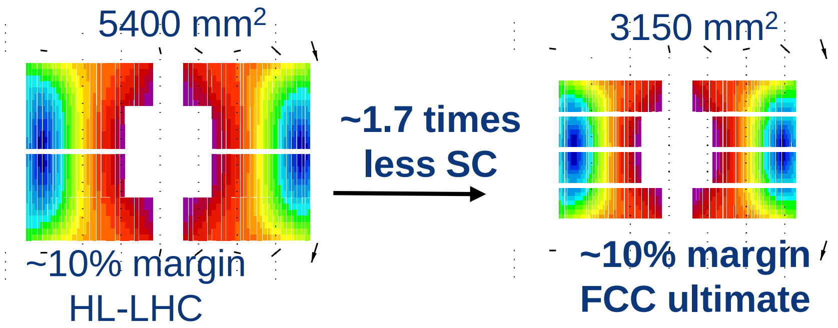
FNAL dipole demonstrator
14.5 T Nb_3Sn

World-wide FCC Nb_3Sn Programme

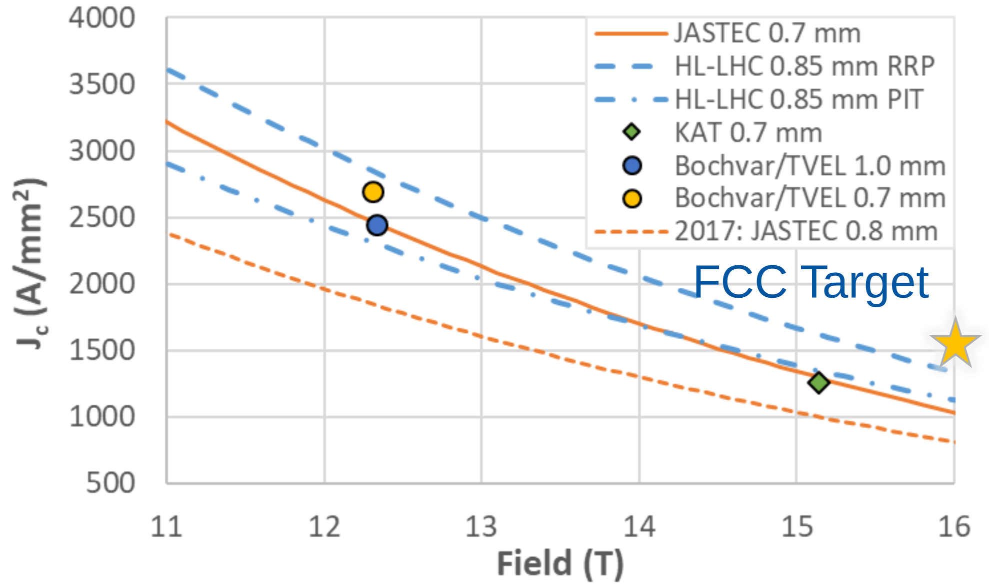
FUTURE CIRCULAR COLLIDER

Main development goal is wire performance increase:

- **J_c (16T, 4.2K) > 1500 A/mm² →50% increase wrt HL-LHC wire**
- **Reduction of coil & magnet cross-section**



After 1-2 years development, **prototype Nb_3Sn wires from several new industrial FCC partners already achieve HL-LHC J_c performance**



FCC conductor development collaboration:

- **Bochvar Institute** (production at **TVEL**), **Russia**
- **Bruker, Germany, Luvata Pori, Finland**
- **KEK** (**Jastec** and **Furukawa**), **Japan**
- **KAT**, **Korea, Columbus, Italy**
- **University of Geneva**, **Switzerland**
- **Technical University of Vienna**, **Austria**
- **SPIN**, **Italy, University of Freiberg, Germany**

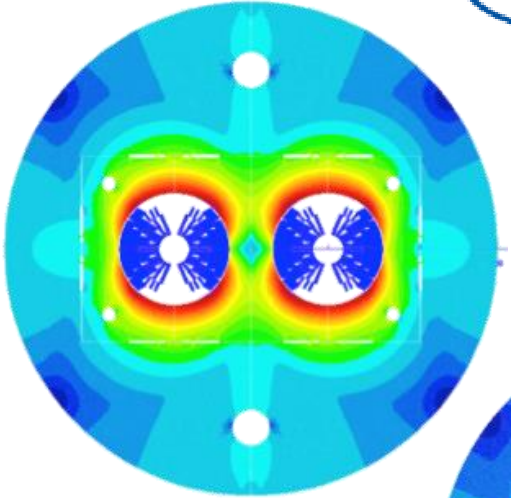
2019/20 results from US, meeting FCC J_c specs:

- **Florida State University:** high-J_c Nb_3Sn via Hf addition
- **Hyper Tech /Ohio SU/FNAL**: high-J_c Nb_3Sn via artificial pinning centres based on Zr oxide.

16 T Dipole Design Activities and Options

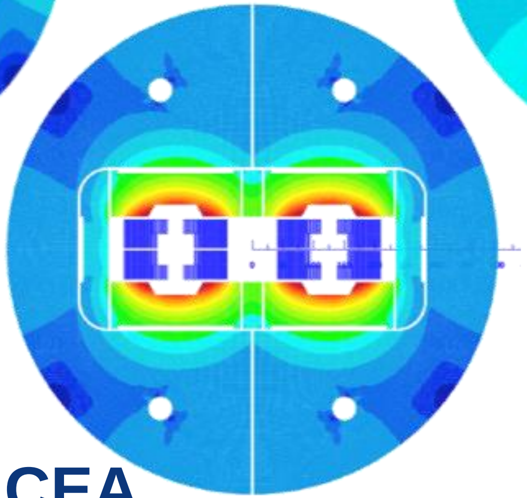
H2020

Cos-theta



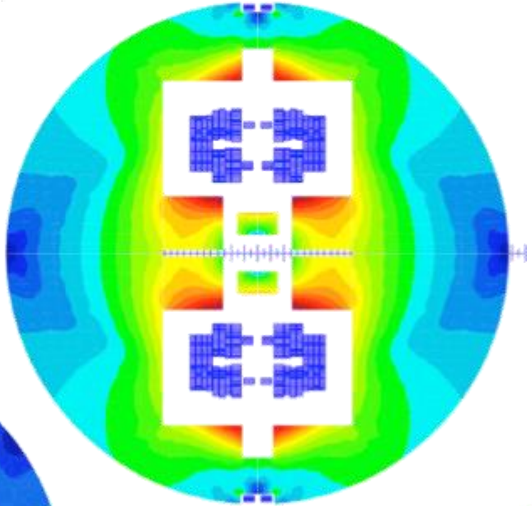
INFN

Blocks



CEA

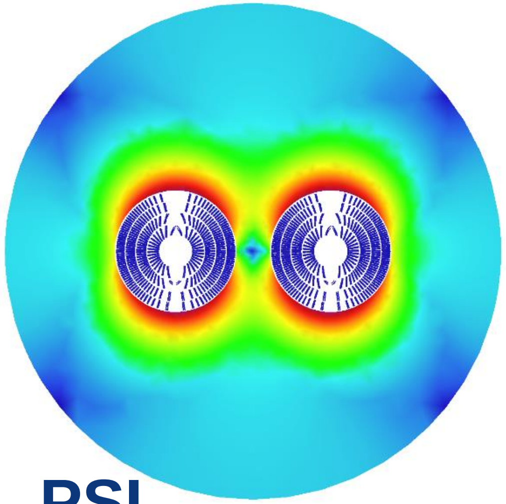
Common coils



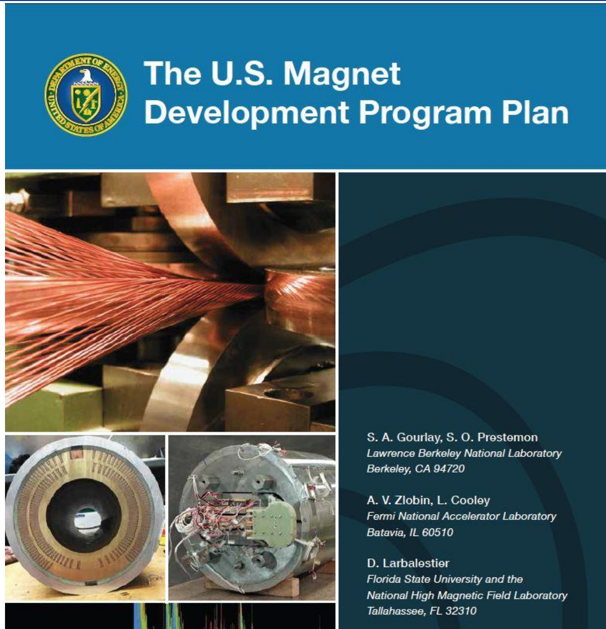
CIEMAT

Swiss contribution

Canted Cos-theta



PSI


The U.S. Magnet Development Program Plan

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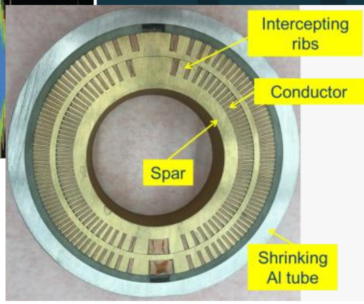
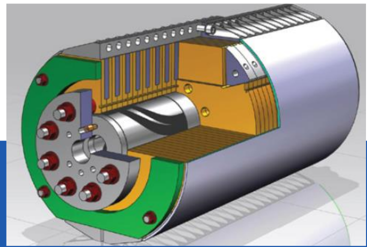


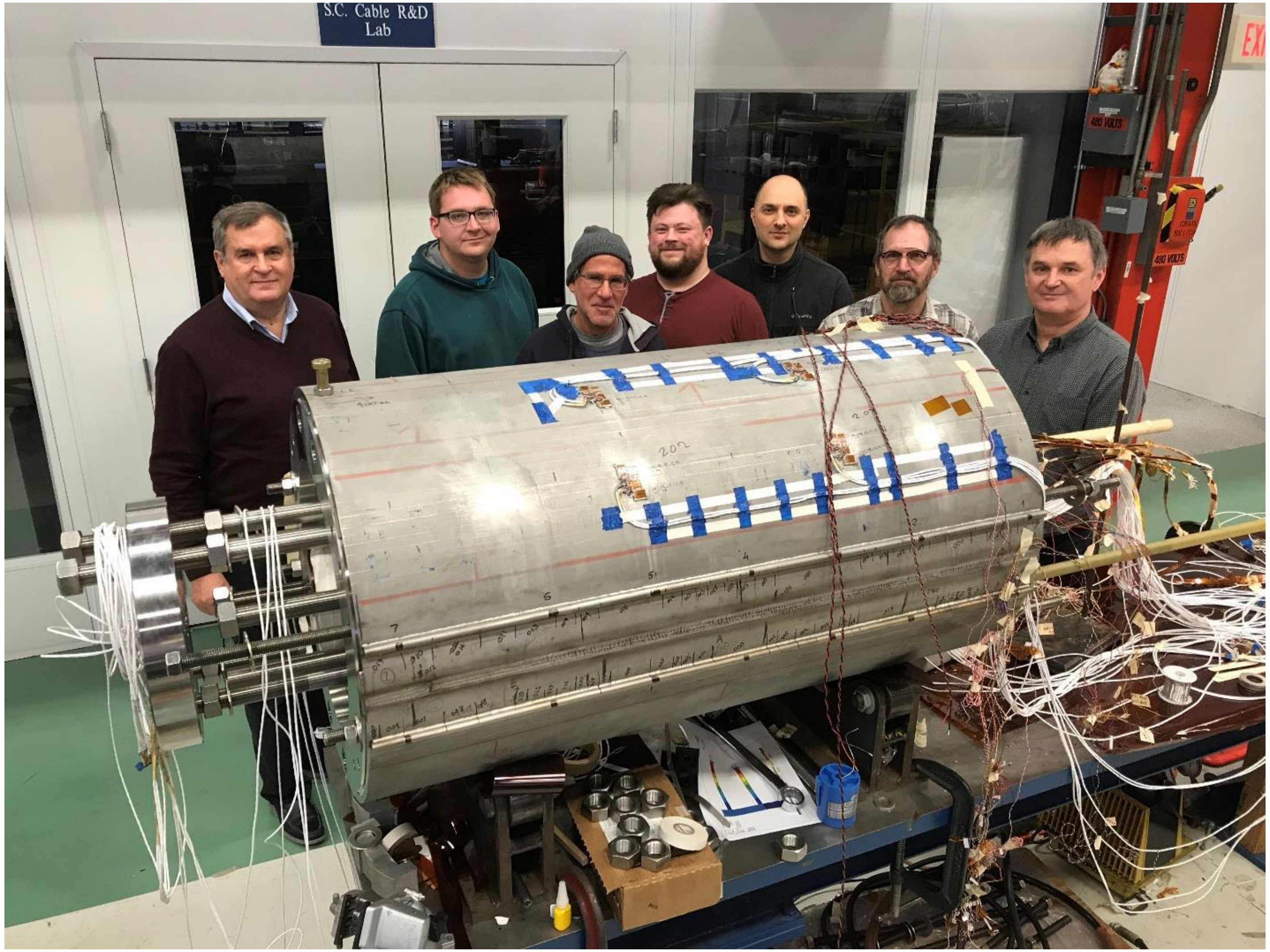
LBNL

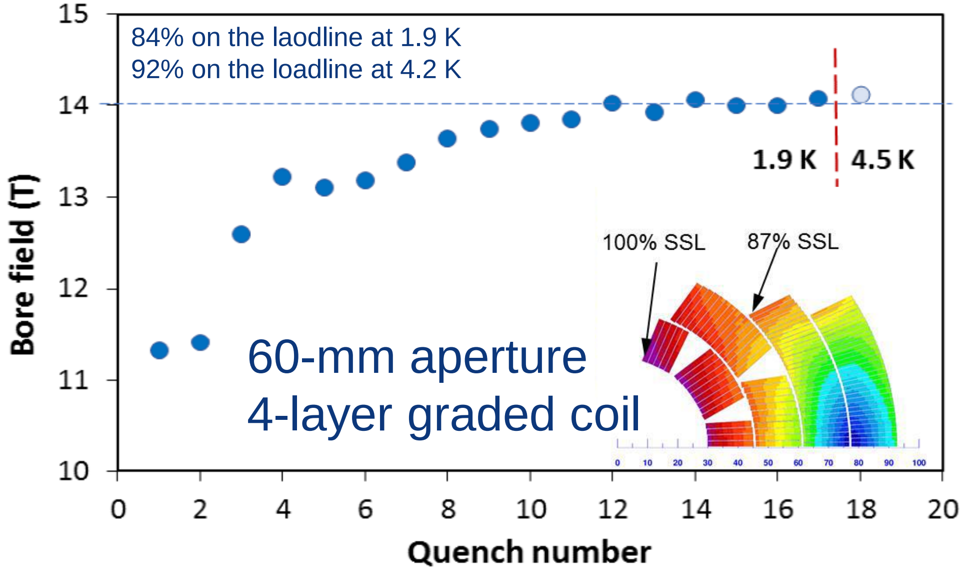


FNAL

Short model magnets (1.5 m lengths) will be built until 2025

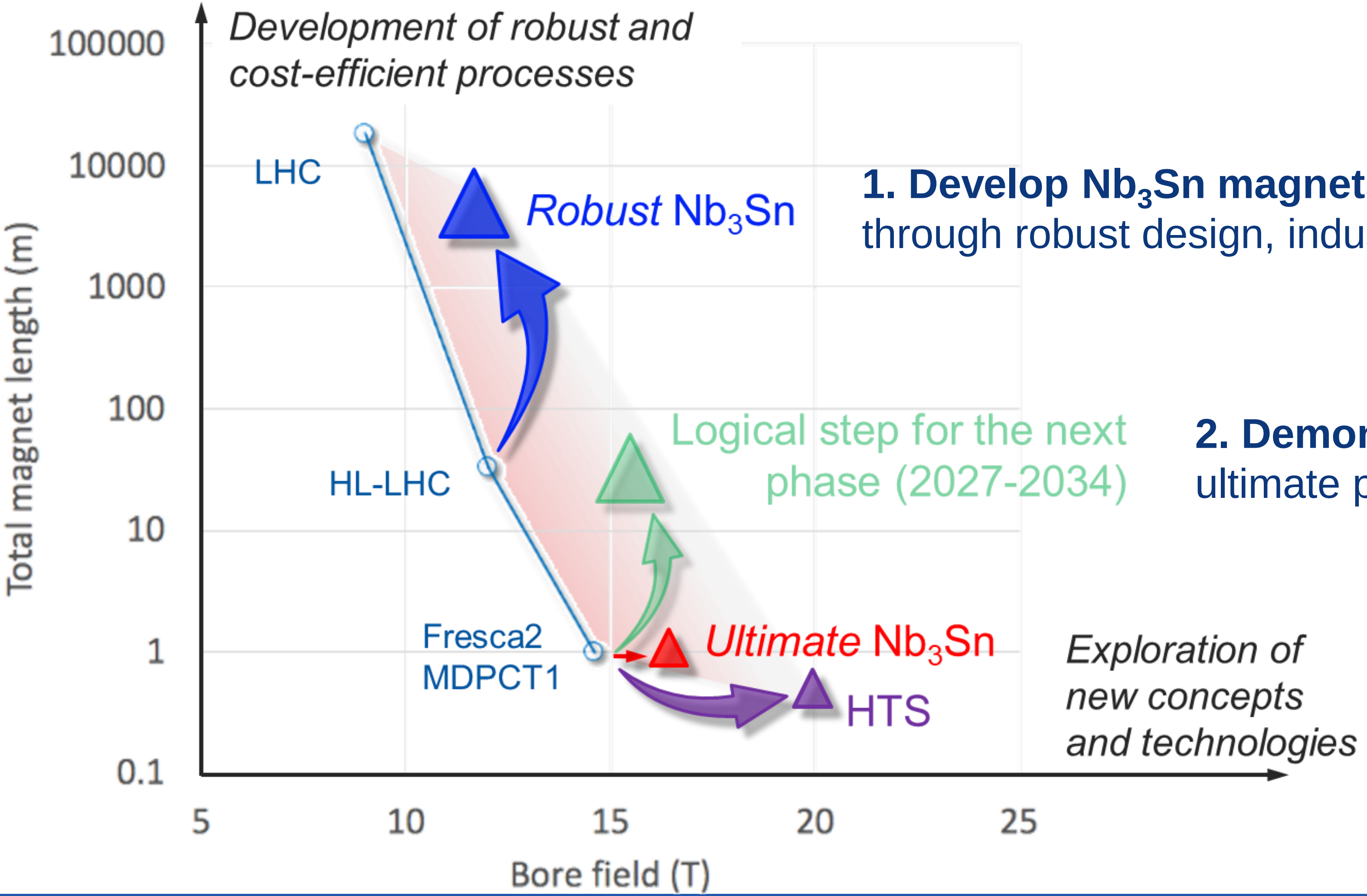
US – MDP: 14.5 T Magnet Tested at FNAL





- 15 T dipole demonstrator
- Staged approach: In first step pre-stressed for 14 T
- Second test in June 2020 with additional pre-stress reached 14.5 T

High Field Magnet Programme Goals until 2027



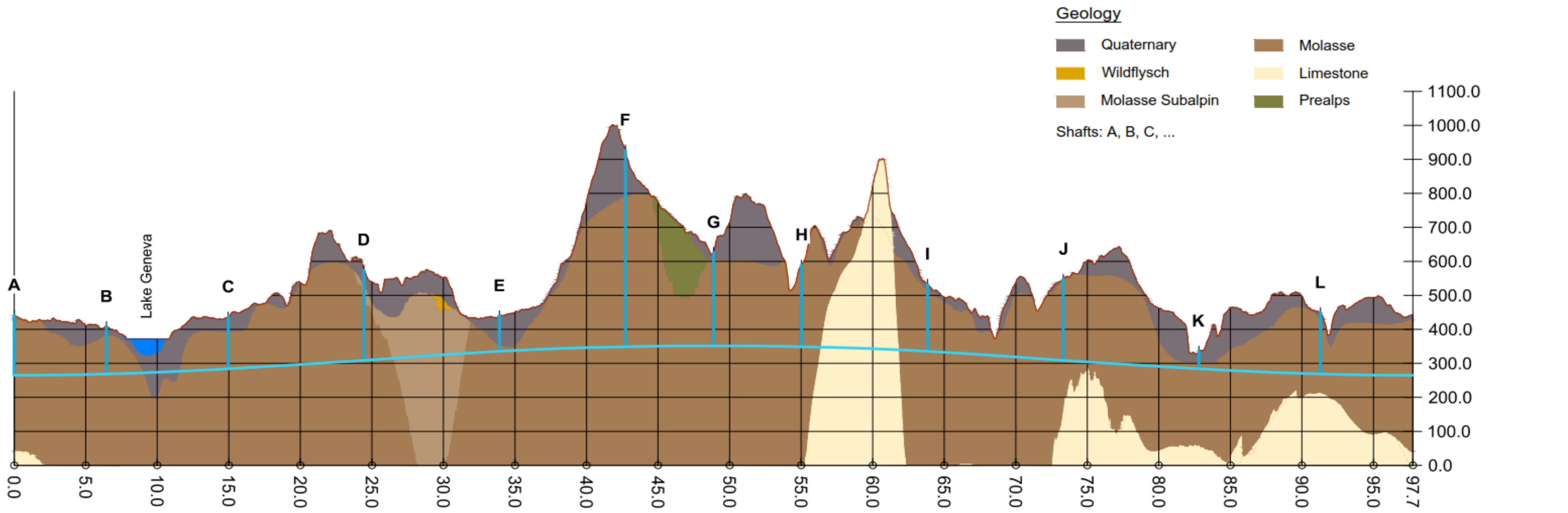
L. Bottura

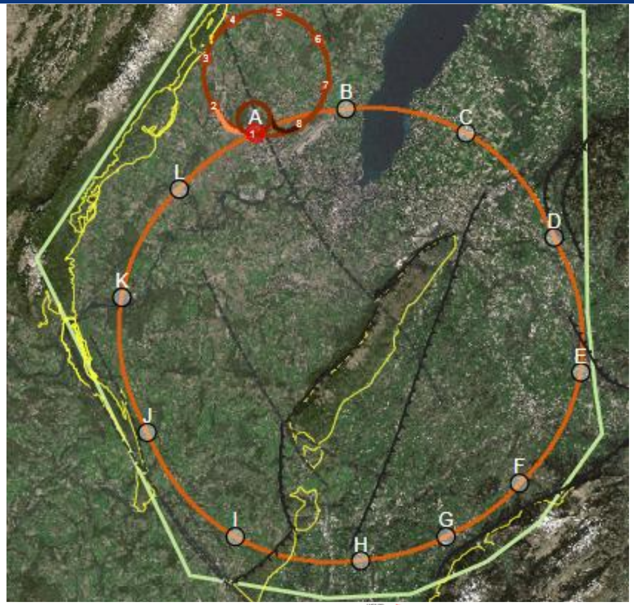
1. Develop Nb_3Sn magnets for collider-scale production, through robust design, industrial processes and cost reduction

2. Demonstrate Nb_3Sn full potential in terms of ultimate performance

3. Provide a proof-of-principle for HTS magnet technology

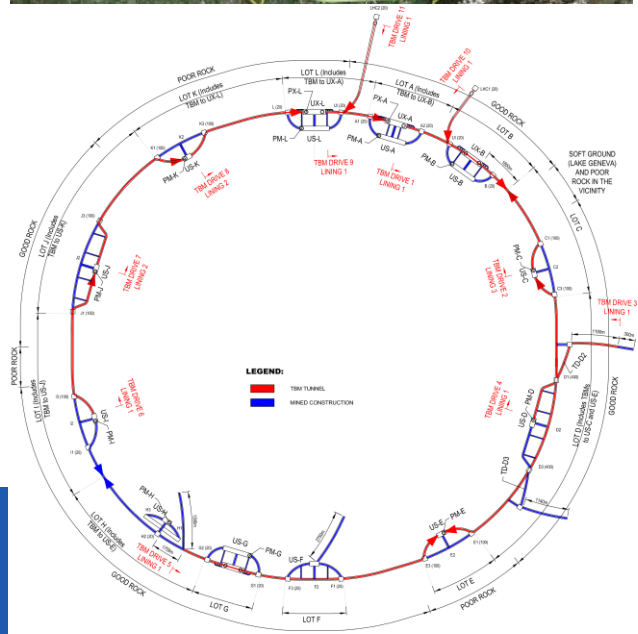
FCC Implementation - Footprint Baseline



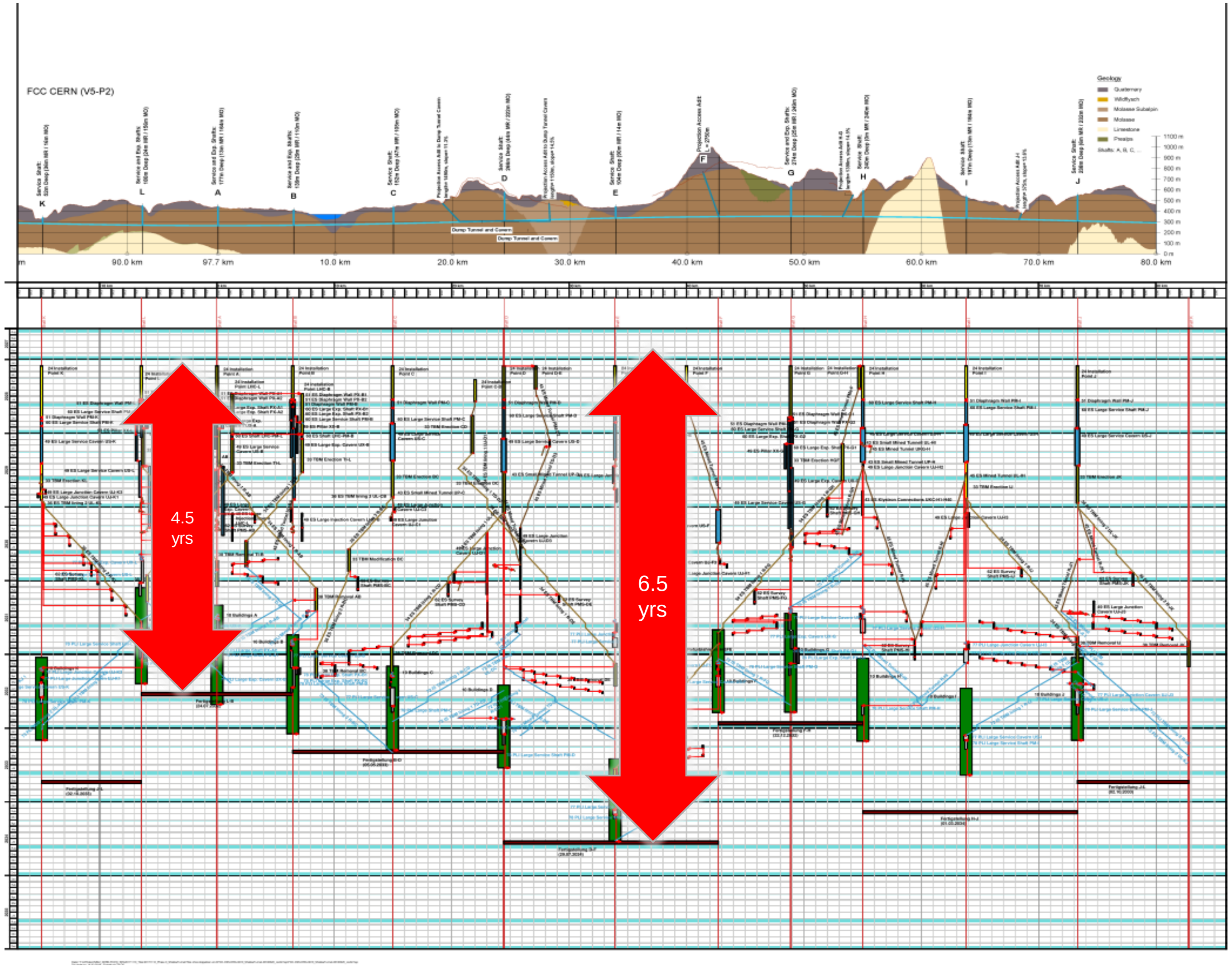


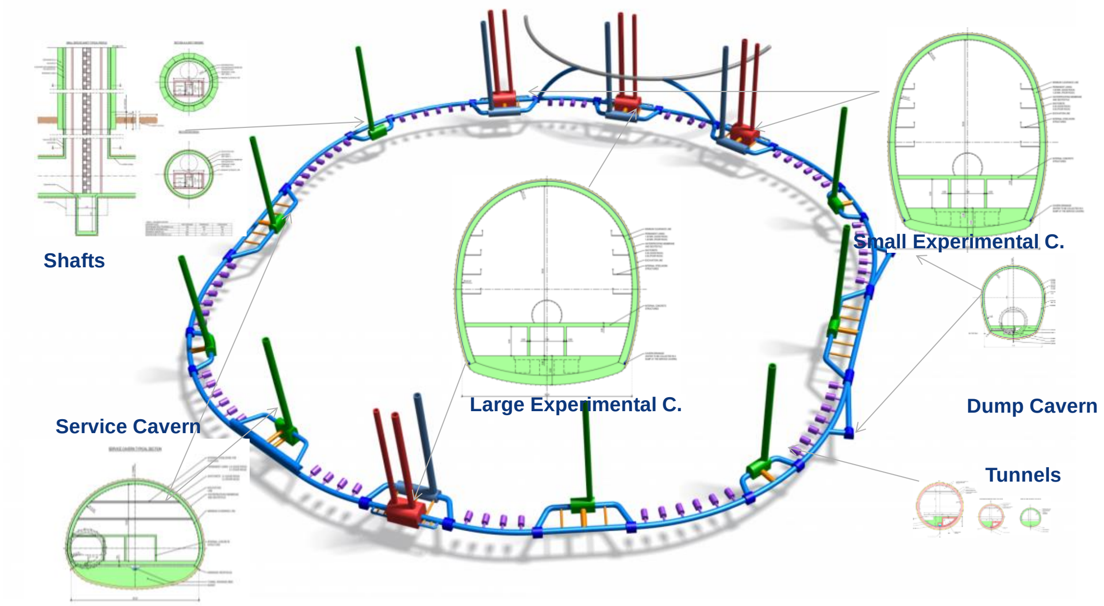
- **Present baseline position was established considering:**
- lowest risk for construction, fastest and cheapest construction
- Molasse rock preferred for tunnelling, avoid limestone with karstic structures

- **90 – 100 km circumference**
- **12 surface sites with few ha area each**



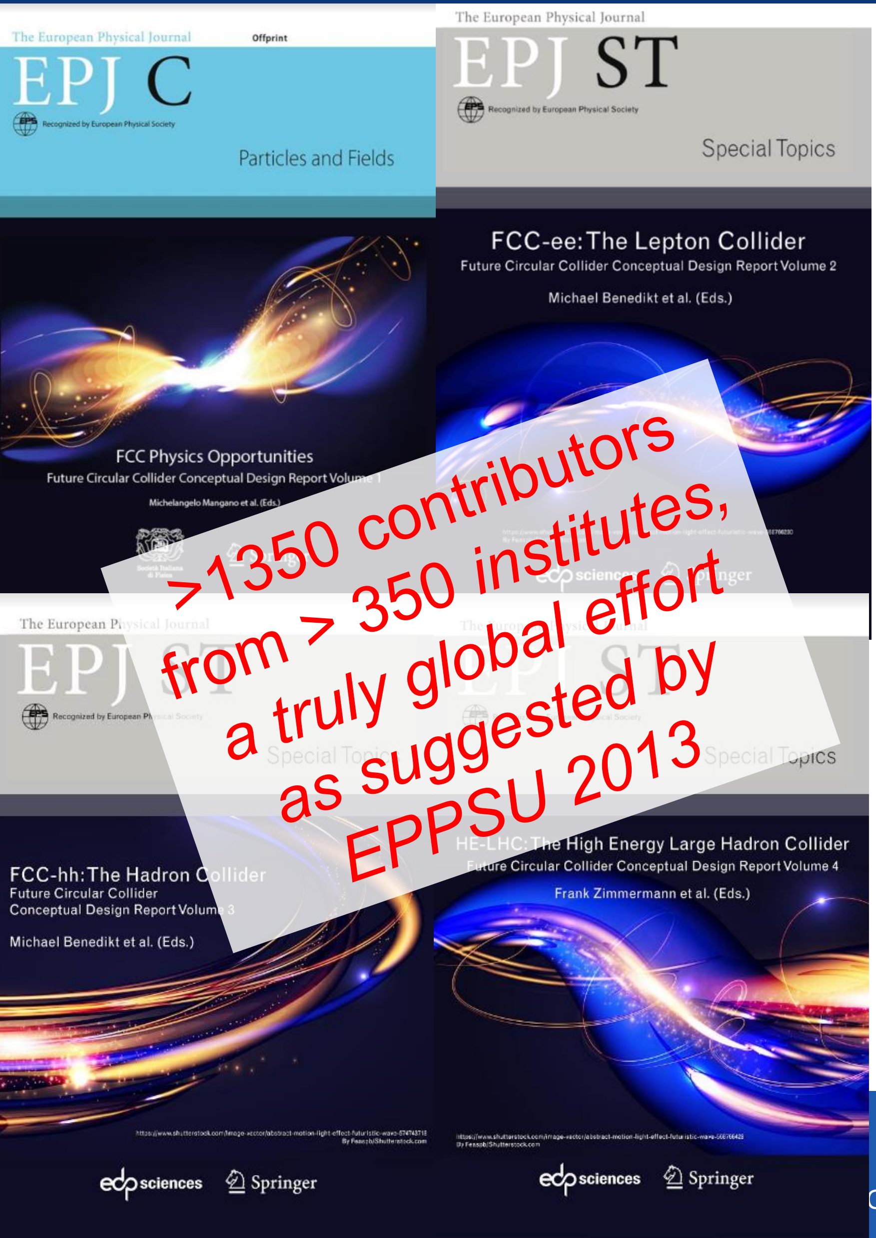
Civil Engineering Construction Schedule





- **Total construction duration 7 years**
- **First sectors ready after 4.5 years**

FCC CDR and Study Documentation



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

    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

- **Summary documents provided to EPPSU SG**
  - **FCC-integral, FCC-ee, FCC-hh, HE-LHC**
  - Accessible on http://fcc-cdr.web.cern.ch/

FCC Feasibility Study

FCC Feasibility Study

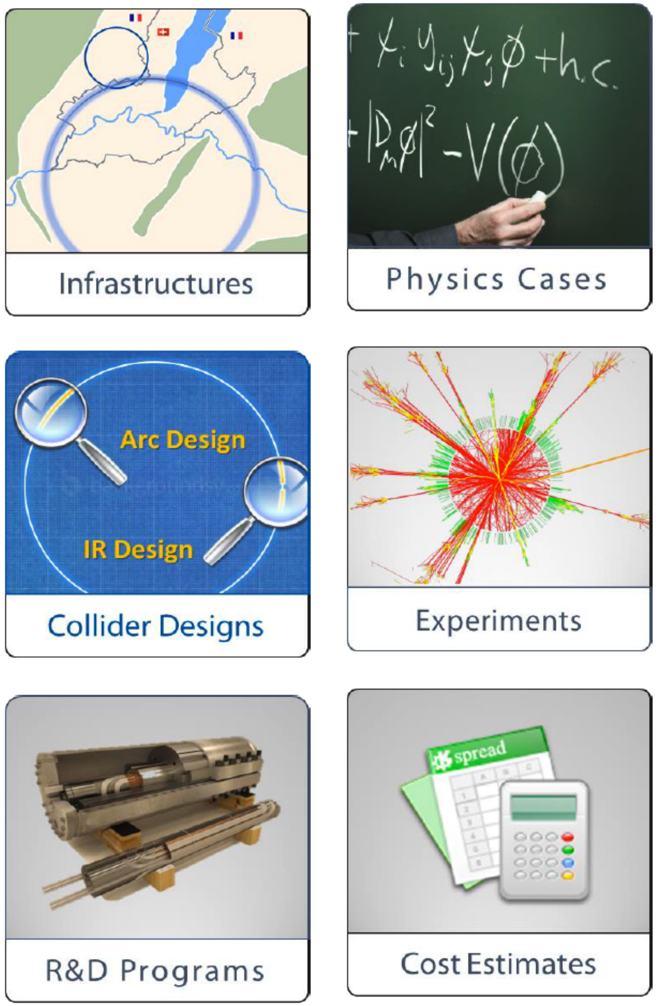
FCC Feasibility Study (FS) will address a recommendation of the 2020 update of the European Strategy for Particle Physics (ESPP):

- "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."

High-level Goals of Feasibility Study

High-level goals of Feasibility Study

- optimisation of placement and layout of the ring and related infrastructure, and demonstration of the geological, technical, environmental and administrative feasibility of the tunnel and surface areas;
- pursuit, together with the Host States, of the preparatory administrative processes required for a potential project approval, with a focus on identifying and surmounting possible showstoppers;
- optimisation of the design of the colliders and their injector chains, supported by targeted R&D to develop the needed key technologies;
- development and documentation of the main components of the technical infrastructure;
- elaboration of a sustainable operational model for the colliders and experiments in terms of human and financial resource needs, environmental aspects and energy efficiency;
- identification of substantial resources from outside CERN’s budget for the implementation of the first stage of a possible future project;
- consolidation of the physics case and detector concepts for both colliders.



FUTURE CIRCULAR COLLIDER

Timeline of the FCC Integrated Programme

Technical schedule

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | ………………… | 19 | 20 | FCC-ee ~ 15 years operation | 10 years | FCC-hh ~ 25 years operation | 70

Feasibility Study

ESPP

Geological investigations, infrastructure detailed design and tendering preparation

Tunnel, site and technical infrastructure construction

FCC-ee dismantling, CE & infrastructure adaptations FCC-hh

FCC-ee accelerator and detector R&D and technical design

FCC-ee accelerator and detector construction, installation, commissioning

Superconducting magnets R&D

Long model magnets, prototypes, pre-series

High-field magnet industrialization and series production

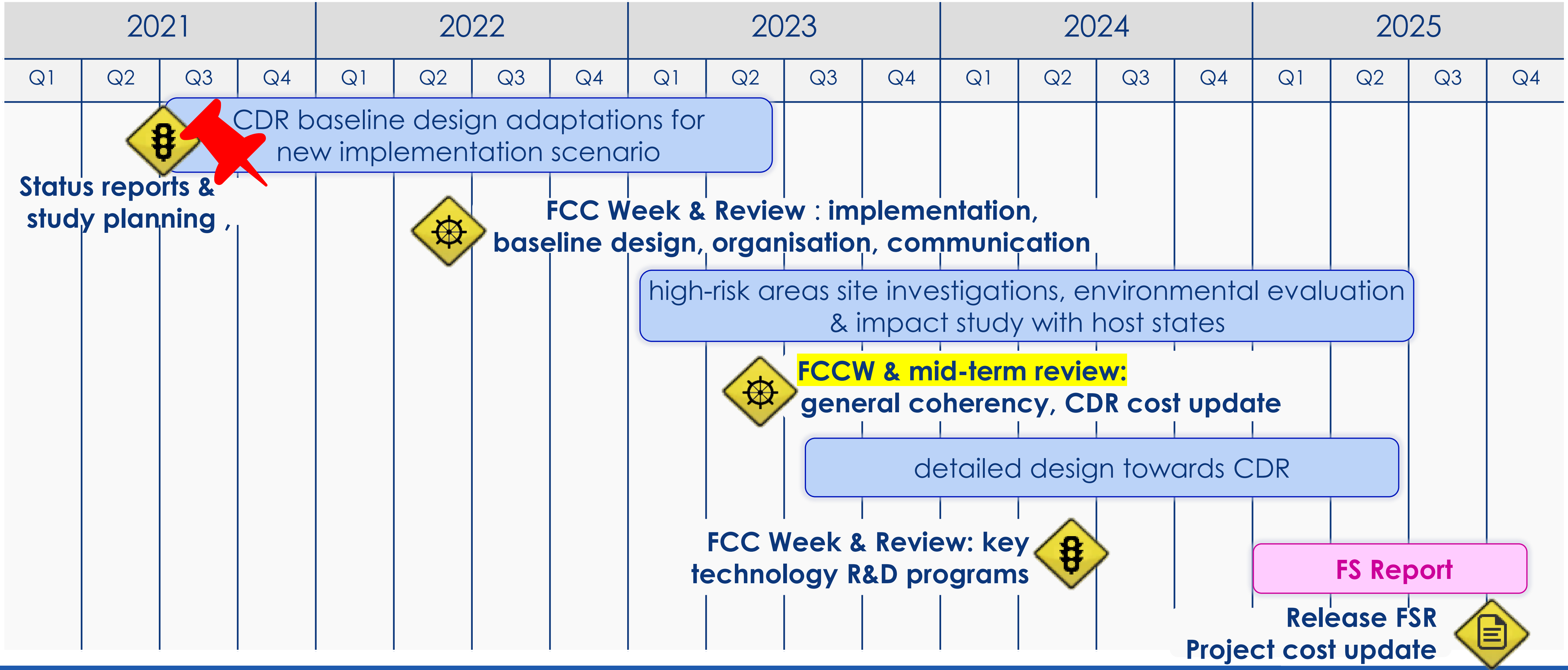
FCC-hh accelerator and detector R&D and technical design

FCC-hh accelerator and detector construction, installation, commissioning

	√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 $\times 10^{34}$ 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 $\times 10^{34}$ 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

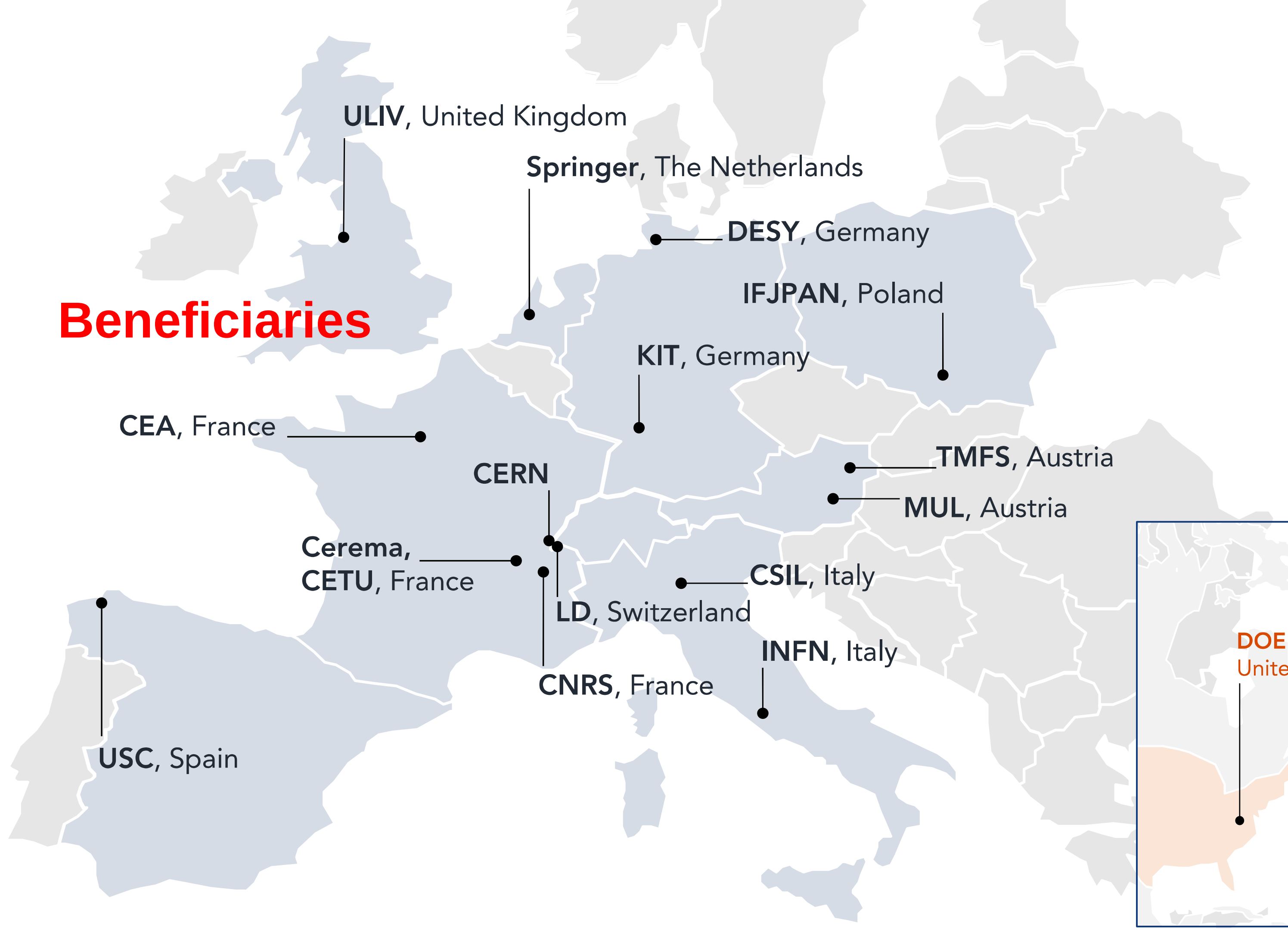
- Feasibility Study: 2021-2025
- If project approved before end of decade → construction can start beginning 2030s
- FCC-ee operation ~2045-2060
- FCC-hh operation 2070-2090++

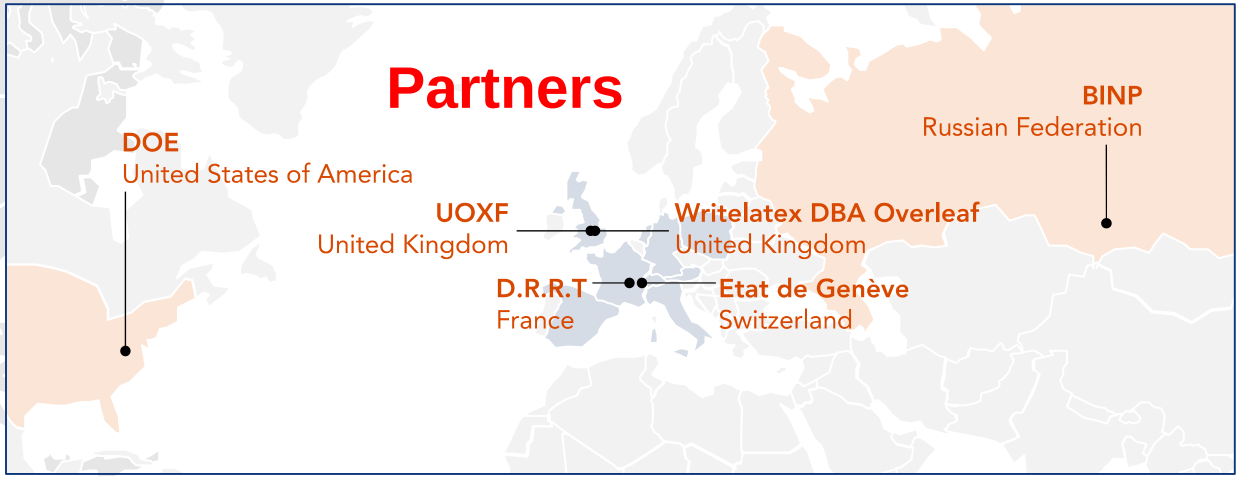
Feasibility Study Timeline



H2020 DS FCC Innovation Study 2020-24

Topic	INFRADEV-01-2019-2020
Grant Agreement	FCCIS 951754
Duration	48 months
From-to	2 Nov 2020 – 1 Nov 2024
Project cost	7 435 865 €
EU contribution	2 999 850 €
Beneficiaries	16
Partners	6





Objectives of FCCIS (Description of Action)

- O1: **Design a circular luminosity frontier particle collider** with a research programme to remain at the forefront of research
- O2: **Demonstrate the technical and organizational feasibility** of a 100 km long, circular particle collider
- O3: **Develop an innovation plan for a long-term sustainable research infrastructure** that is seamlessly integrated in the European research landscape
- O4: **Engage stakeholders** from different sectors of the society
- O5: **Demonstrate the role and impact of the research infrastructure in the innovation chain**, focusing on responsible resource use and managing environmental impacts

Luminosity-frontier Collider Design

FCCIS Result: 4

High Technology Readiness

9
8
7
6
5
4
3
2
1

Low Technology Readiness

Beam **optics validated** at BINP, DESY, INFN, KIT. Components specified. **Performance calculated & simulated.**

Research Infrastructure Placement

FCCIS Result: 5

High Technology Readiness

9
8
7
6
5
4
3
2
1

Low Technology Readiness

Ecodesigned **layout** and **responsible resource use validated** for the relevant environment.

FCCIS Work Packages

WP1: study management

WP2: collider design

Deliver a performance optimised machine design, integrated with the territorial requirements and constraints, considering cost, long-term sustainability, operational efficiency and design-for- socio-economic impact generation.

WP3: integrate Europe

Develop a feasible project scenario compatible with local – territorial constraints while guaranteeing the required physics performance.

WP4: impact & sustainability

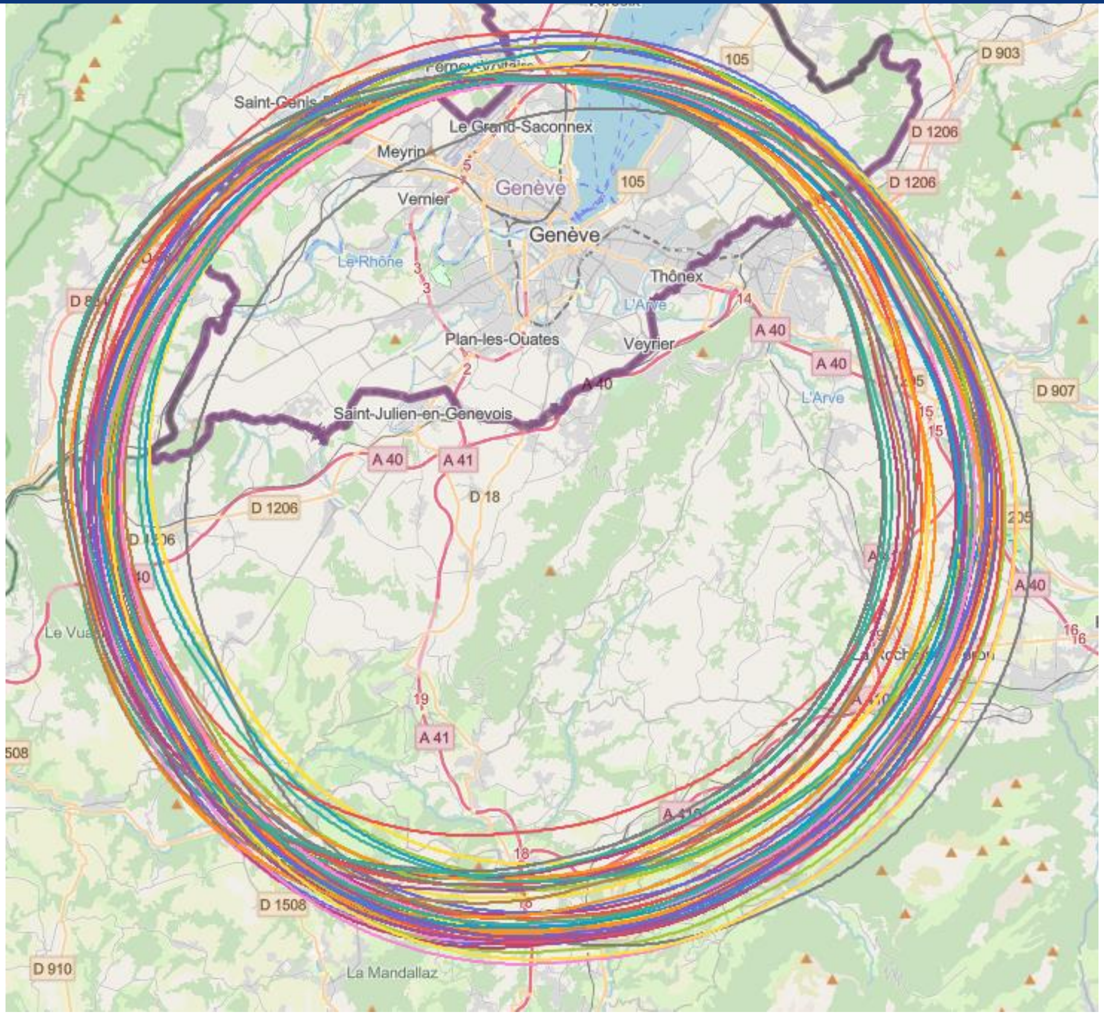
Develop the financial roadmap of the infrastructure project, including the analysis of socio-economic impacts.

WP5: leverage & engage

Engage stakeholders in the preparation of a new research infrastructure. Communicate the project rationale, objectives and progress. Create lasting impact by building theoretical and experimental physics communities, creating awareness of the technical feasibility and financial sustainability, forging a project preparation plan with the host states (France, Switzerland).

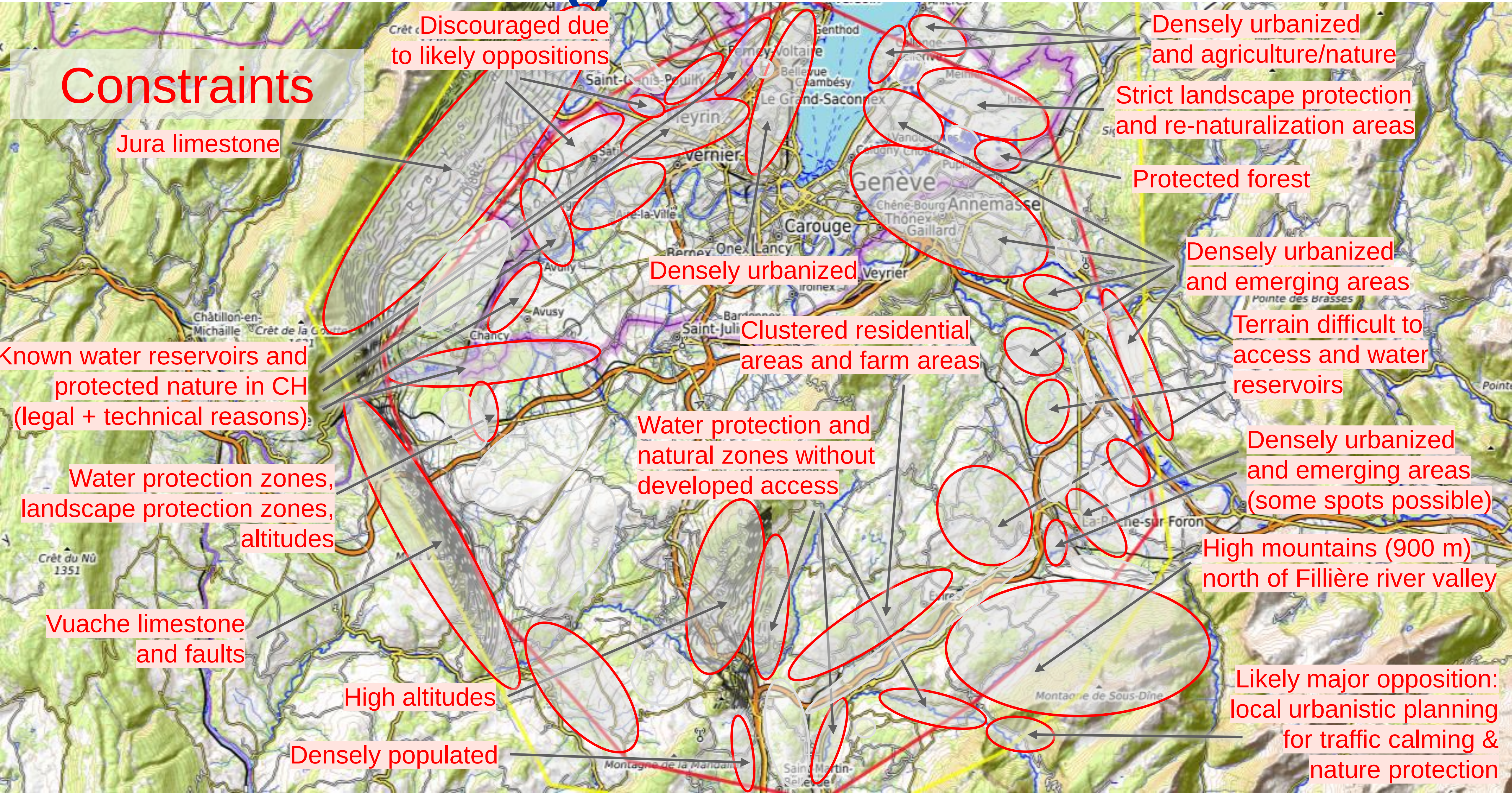
Collider Placement Optimisation

- An overall layout and placement optimisation process across both host states that follows the "avoid-reduce-compensate" directive according to European and French regulatory frameworks.
- Process integrates a diverse set of requirements and constraints, such as
  - performance for the scientific research to be competitive at international scale
  - civil engineering technical feasibility and subsurface constraints
  - territorial constraints at surface and subsurface
  - nature, accessibility, technical infrastructure and resource needs and constraints
  - economic factors including the development of benefits for and synergies with the regional developments
- Work takes place as a collaborative effort by technical experts at CERN, consultancy companies and government notified bodies



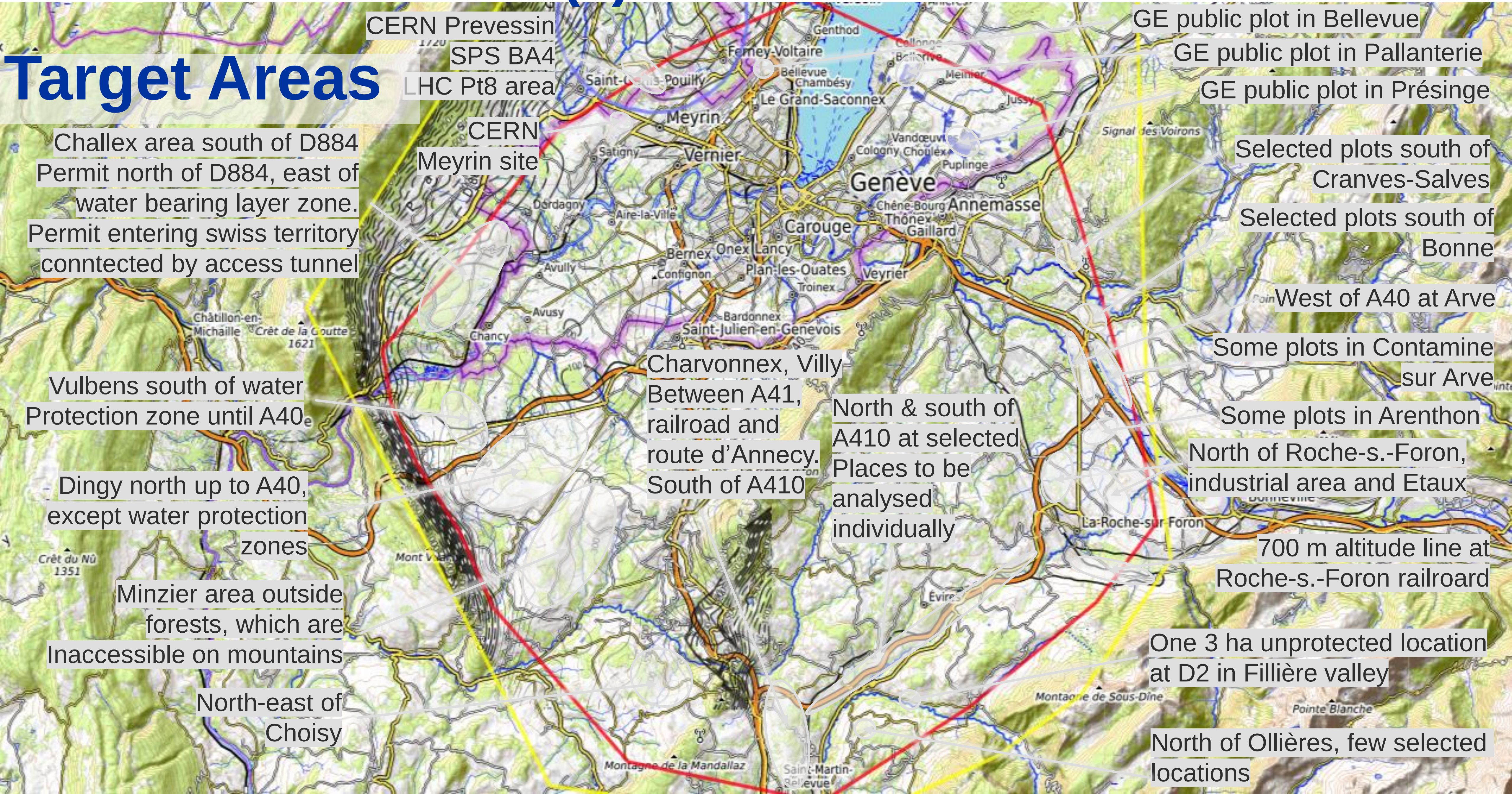
Placement Studies (I)

J. Gutleber, V. Mertens

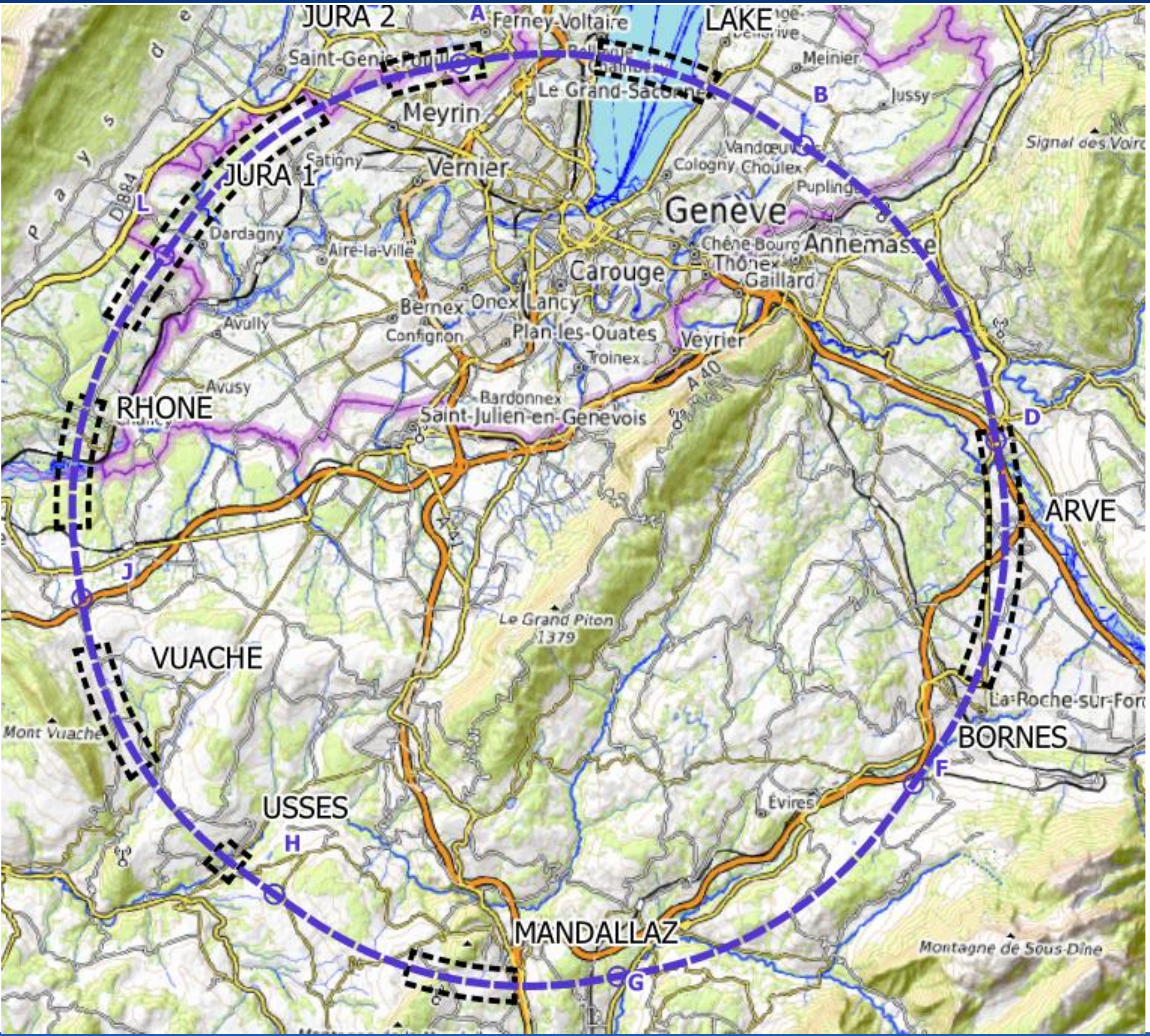


Placement Studies (II)

J. Gutleber, V. Mertens



Plans for High-risk Site Investigations



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

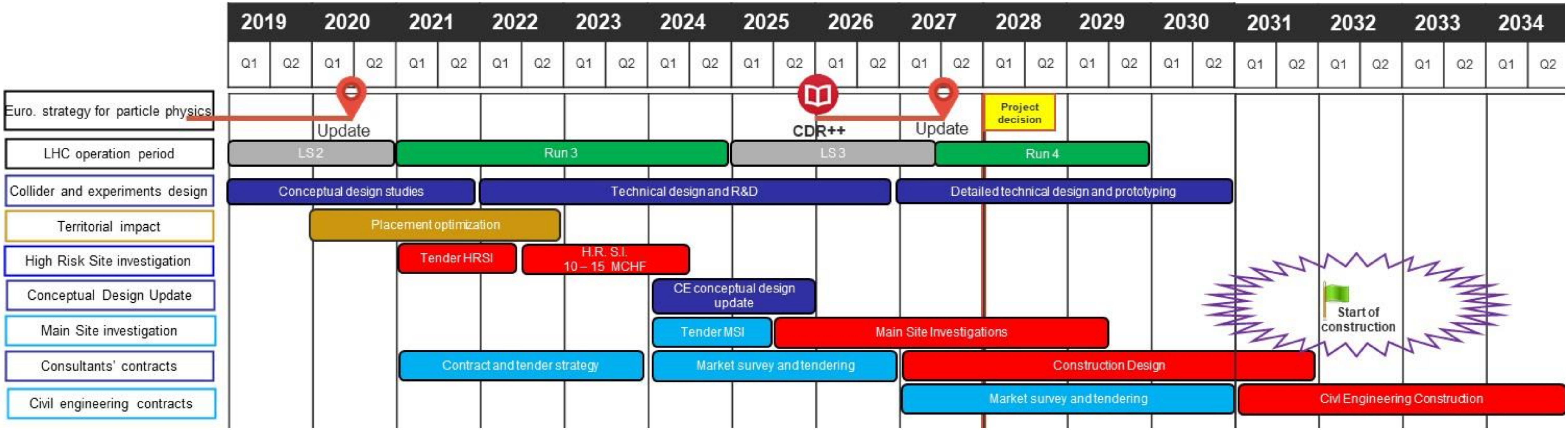
LAKE, RHÔNE, ARVE AND USSES VALLEY (4 AREAS)
Top of the molasse
Quaternary soft grounds, water bearing layers

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

BORNES (1 AREA)
High overburden molasse properties
Thrust zones

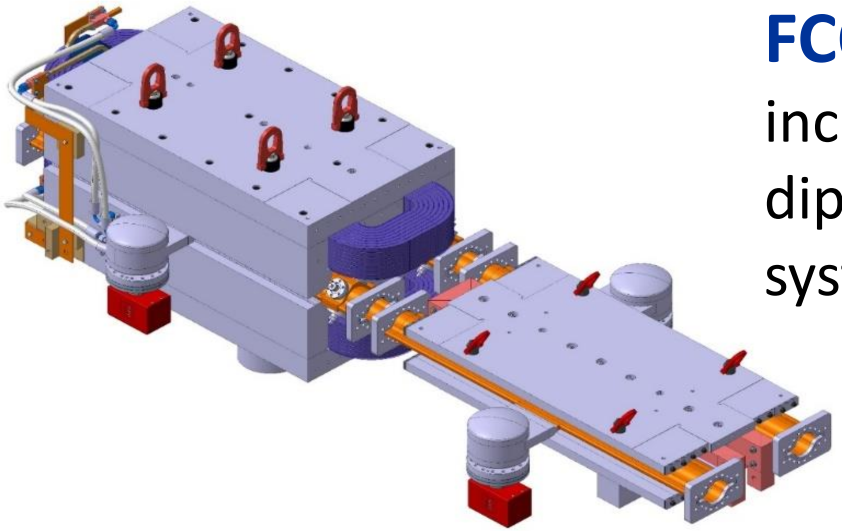
Site investigations planned for mid 2023 – mid 2025: ~40-50 drillings, 100 km of seismic lines

CE Preparatory Activities 2020 - 2030



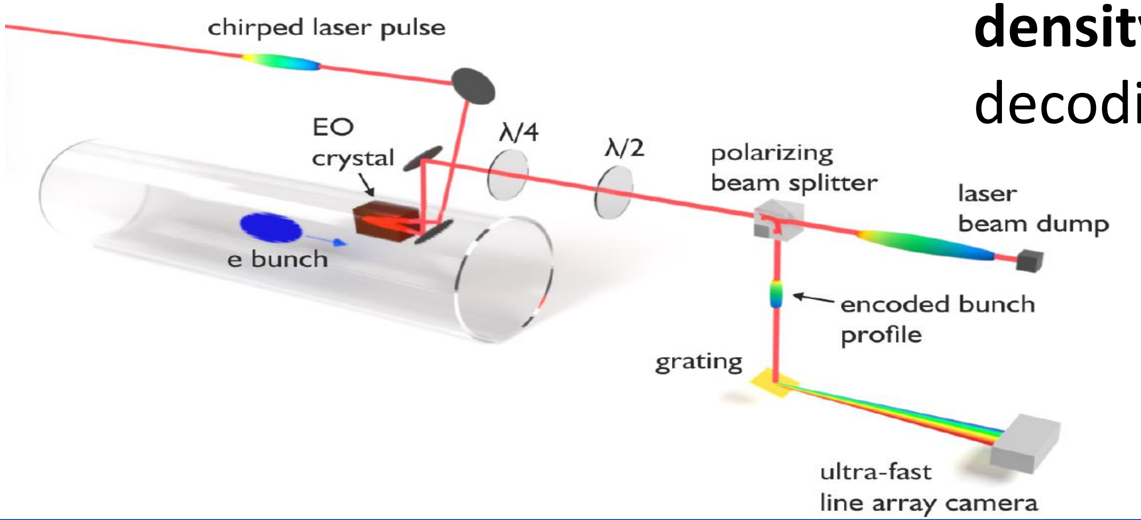
- **Technical schedule of main processes leading to start of construction begin 2030s**
- **For proof of principle feasibility: High risk area site investigations, 2022 – 2024**
- **Followed by update of civil engineering conceptual design and CE cost estimate 2025**

FCC Key Deliverables: Prototypes by 2025



FCC-ee complete arc half-cell mock-up

including girder, vacuum system with antechamber + pumps, dipole, quadrupole + sext. magnets, BPMs, cooling + alignment systems, technical infrastructure interfaces.



Key beam diagnostics elements

bunch-by-bunch turn-by-turn **longitudinal charge density profiles** based on electro-optical spectral decoding (beam tests at KIT/KARA) ;

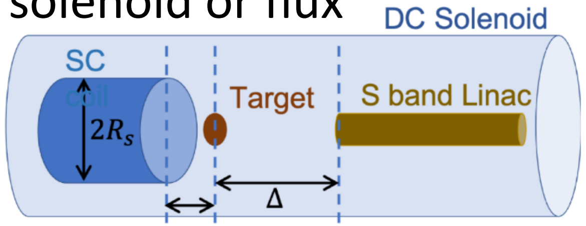
ultra-low emittance measurement (X-ray interferometer tests at SuperKEKB, ALBA) ;
beam-loss monitors (IJCLab/KEK?) ;
beamstrahlung monitor (KEK);
polarimeter ; **luminometer**

FCC Key Deliverables: Prototypes by 2025

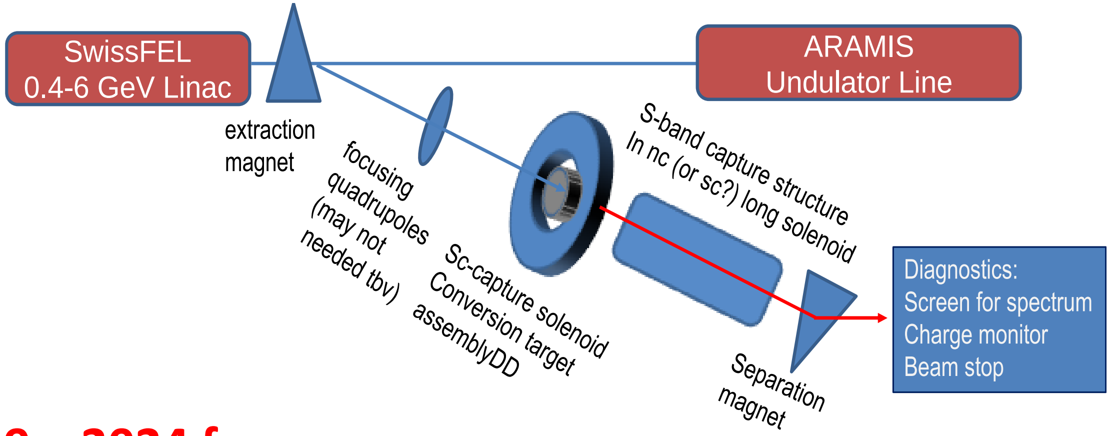
400 MHz SRF cryomodule,
+ prototype multi-cell cavities for FCC ZH operation
High-efficiency RF power sources

High-yield positron source

target with DC SC solenoid or flux concentrator



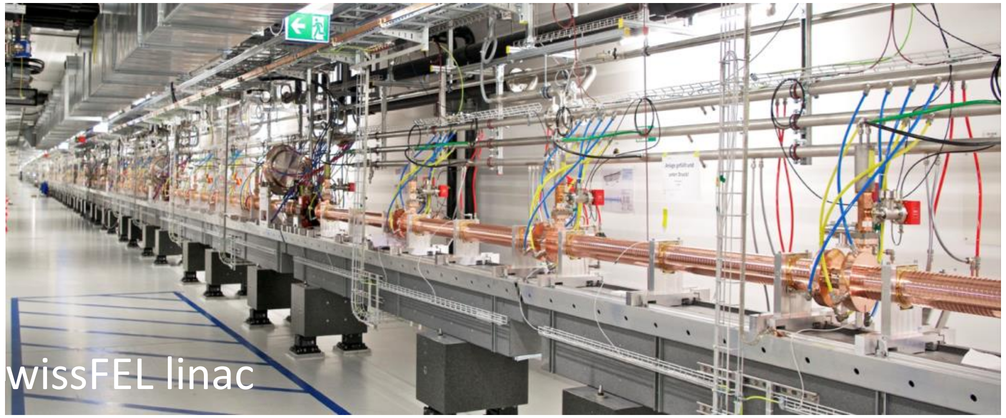
Beam test of e⁺ source & capture linac at SwissFEL – yield measurement



Positron capture linac

large aperture S-band linac

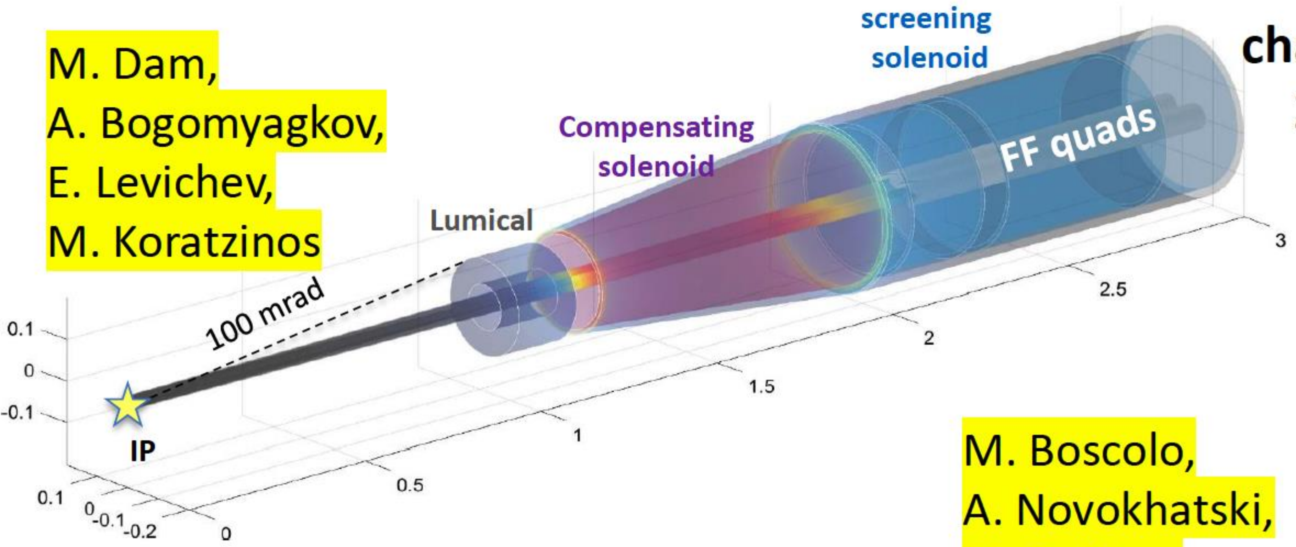
- Freq : 2.856 GHz
- 90 cells per structure
- Length: 3.254 m
- Distance between two TWs: 45 cm
- Gradient: 20 MV/m
- Aperture: 30 mm



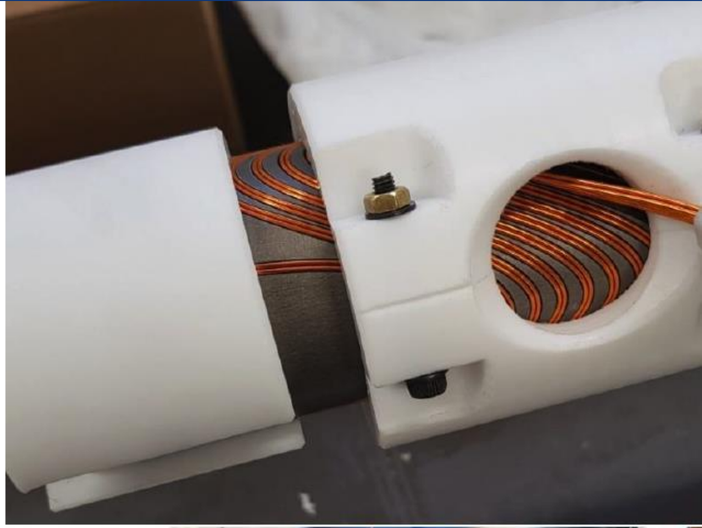
Strong support from Switzerland via CHART II programme 2019 – 2024 for FCC-ee injector, HFM, beam optics developments, geology and geodesy activities.

FCC-ee Machine Detector Interface

M. Dam,
A. Bogomyagkov,
E. Levichev,
M. Koratzinos

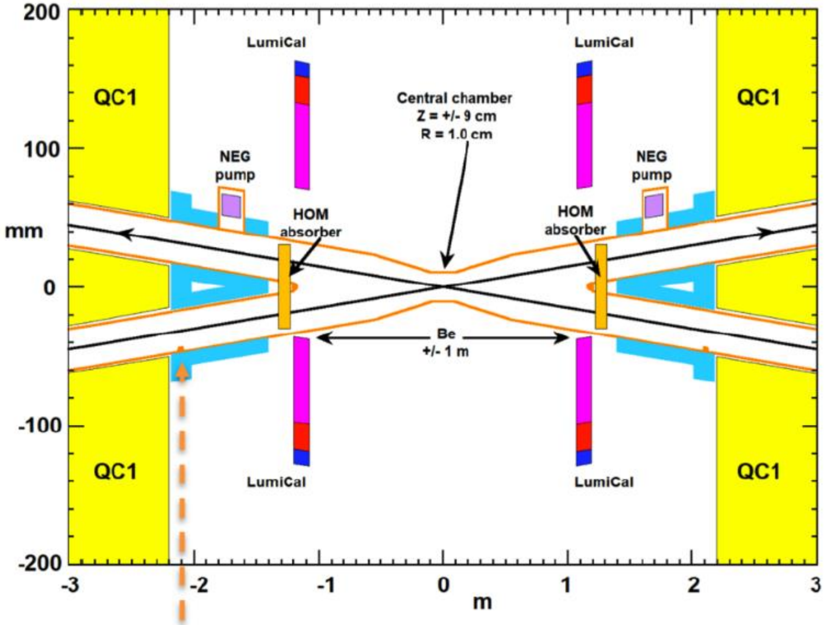


challenging integration:
2 T detector solenoid,
luminosity monitor
(Bhabha scattering),
compensation &
shielding solenoids



M. Boscolo,
A. Novokhatski,
M. Sullivan

1 cm radius central chamber

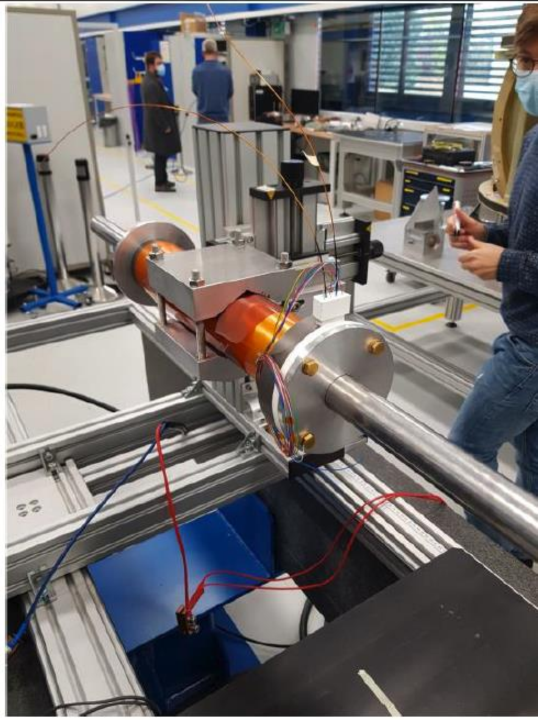


narrow central chamber
with 1 cm radius,
also avoids trapped modes

prototype Q1
canted cosine theta with fringe field correction,
using LHC SC cable

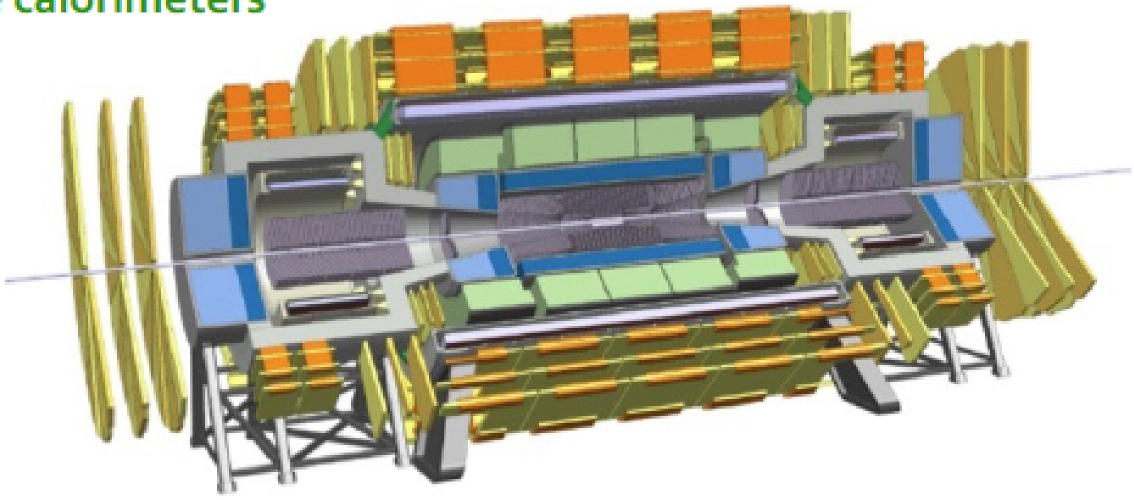
field measurement at warm

M. Koratzinos



FCC-hh Detector – A Formidable Challenge

- Well beyond HL-LHC – to be revisited during FCC-FS with HL-LHC experience
  - Much larger longitudinal event boost
    - Enhanced coverage at large rapidity (with tracking and calorimetry)
    - Forward solenoids or dipoles
    - Length ~ 46 m
  - Zs, Ws, Higgses, tops will be highly boosted (esp. in high p_T final states)
    - High granularity tracking and calorimetry
    - 4T, 10 m bore main solenoid surrounding the calorimeters
  - Up to 1000 PU events over a bunch length of 5 cm
    - High resolution vertexing
    - Ultra fast detector / electronics
  - Energetic jets
    - 2m - thick HCAL
  - High p_T muons
    - 20% resolution @ 10 TeV
  - Radiation hardness



P. Janot

FCC FS Council Documents, June 2021

FUTURE CIRCULAR COLLIDER

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
21 June 2021

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

Action to be taken		*Voting Procedure*
For information	**RESTRICTED COUNCIL** 203rd Session **17 June 2021**	-

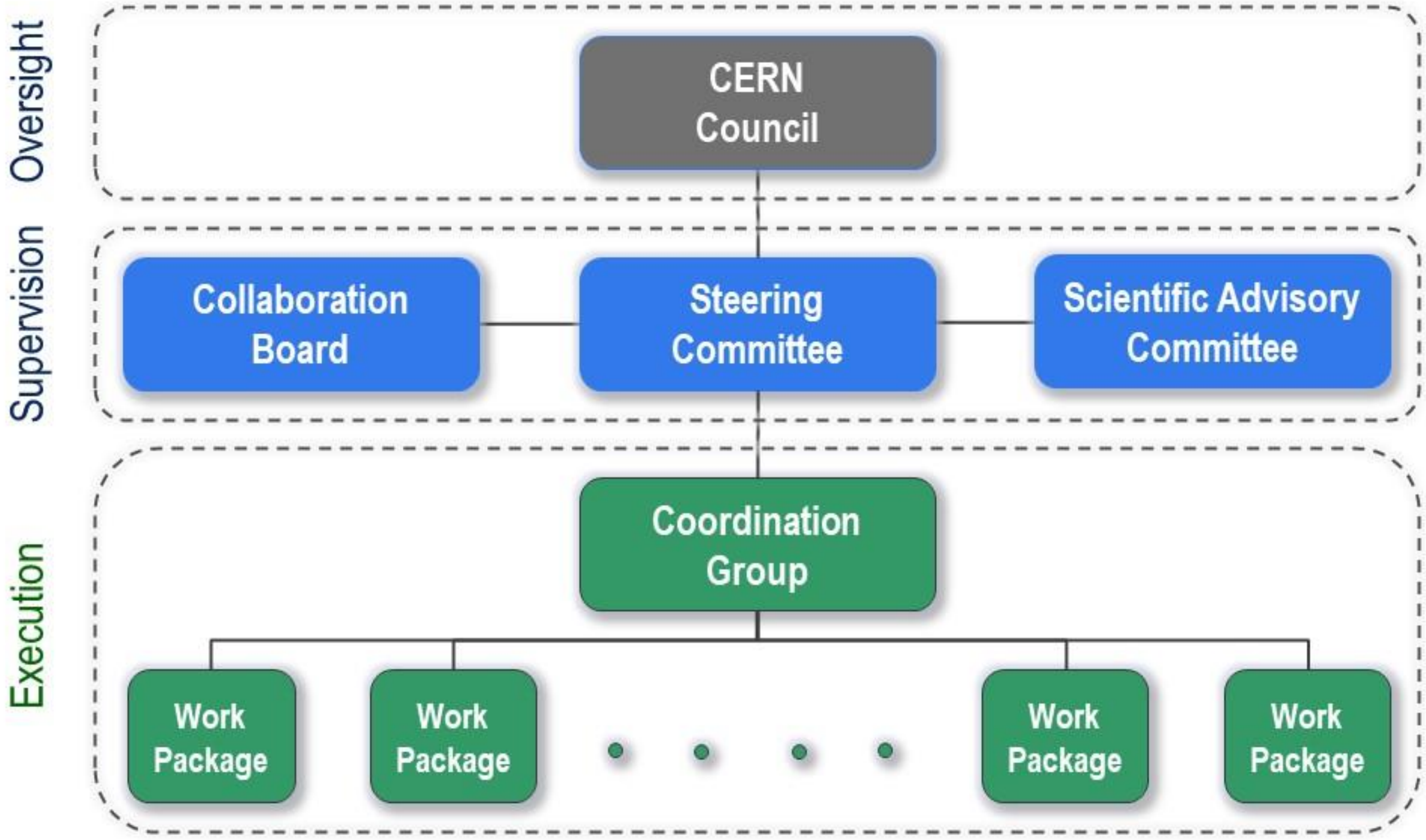
FUTURE CIRCULAR COLLIDER FEASIBILITY STUDY:

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.

FCC Feasibility Study Organisational Structure

- **Ownership** of the Feasibility Study by the Council.
- Effective and timely **supervision**.
- Integration of scientific and technical **advice**.
- **Participation of stakeholders** that can potentially make significant financial and technical contributions to a possible future project.
- **Execution** of Feasibility Study.



FUTURE CIRCULAR COLLIDER

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 and Greece

FCC MoUs signed with

- Hellenic Open University (Patras), 3 September 2014
- University of Patras, 17 November 2016
- Aristotle University of Thessaloniki, 20 December 2016
- National and Kapodistrian University of Athens, 23 January 2017

FCC Physics Workshop 7-11 February 2022

FUTURE CIRCULAR COLLIDER
Innovation Study

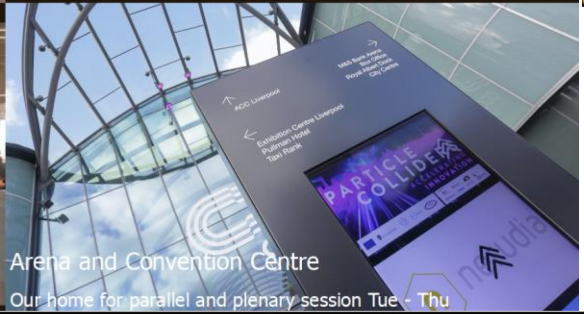
Liverpool, UK


Yoko One Lennon Centre
University of Liverpool


Tung Auditorium
Plenary sessions on Monday and Friday


Royal Liver building
Dinner venue


Central Teaching Laboratory
Poster session on Monday evening w/ reception


Arena and Convention Centre
Our home for parallel and plenary session Tue - Thu

number of in-person participants limited to ~160 (first come -- first served)
- registration fee: 300£
- broadcast on zoom

Date	Monday 7.2.22		Tuesday 8.2.22		Wednesday 9.2.22		Thursday 10.2.22		Friday 11.2.22	
Location	*UoL Campus*		*ACC*		*ACC*		*ACC*		*UoL Campus*	
	Coffee/Tea		*Coffee/Tea*		*Coffee/Tea*		*Coffee/Tea*		*Coffee/Tea*	
Morning	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12	Parallel	Rm 4A, 4B, 14, 12	Plenary	Rm 11	Plenary	Yoko Ono LT
	Coffee Break		Coffee Break	Rm 12	Coffee Break	Rm 12	Coffee Break	Rm 11	Coffee Break	
	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12	Parallel	Rm 4A, 4B, 14, 12	Plenary	Rm 11	Plenary	Yoko Ono LT
	Lunch		**Lunch**	Rm 12	**Lunch**	Rm 12	**Lunch**	Rm 11		
Afternoon	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12	Excursion	Around Liverpool City Centre	Plenary	Rm 11		
	Coffee Break		Coffee Break	Rm 12			Coffee Break	Rm 11		
	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12			Plenary	Rm 11		
Evening	Drinks and Posters	Atrium CTL	Outreach Event	Anglican Cathedral	Dinner	Liver Building				

FCC Week 2022

In Paris 30 May to 3 June 2022

We are looking forward to seeing you there !

FUTURE CIRCULAR COLLIDER

Summary

- The European Strategy Update in 2020 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:**
  - **Local/regional implementation scenario** in collaboration **with Host State authorities.**
  - Accompanied by **machine optimisation, physics studies and technology R&D.**
  - Performed **via global collaboration** and supported by **EC H2020 Design Study FCCIS.**
  - In parallel **High-Field Magnet R&D programme** as separate line, to prepare for FCC-hh.
- Long term goal: **world-leading HEP infrastructure for 21st century** to push the particle-physics **precision and energy frontiers** far beyond present limits.
- **Success of FCC relies on strong global participation. Everybody interested is warmly welcome to join the effort!**

FUTURE CIRCULAR COLLIDER

Thank you