# Lecture 24

# Future Circular Collider (FCC-ee)
# JAI Student Design Project 2021-2022

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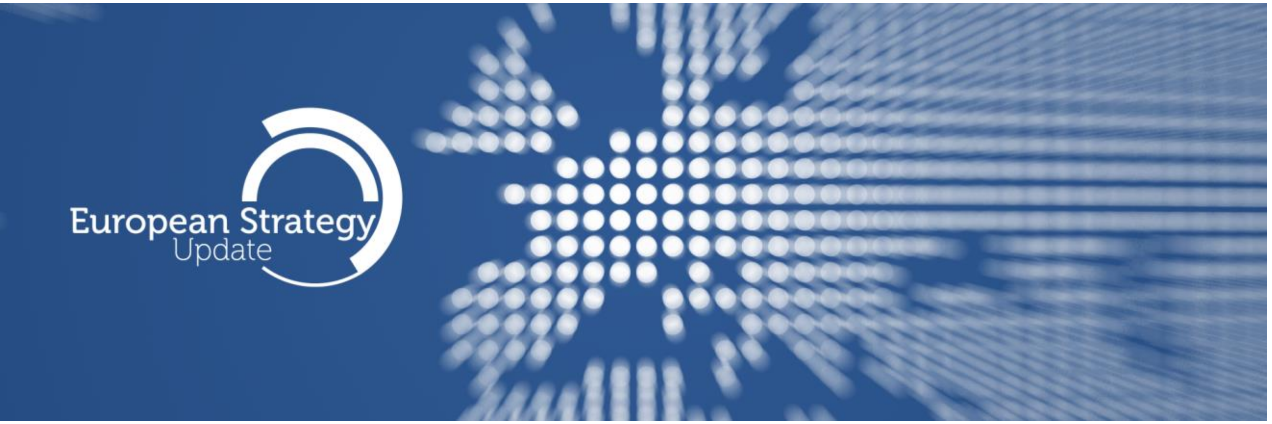
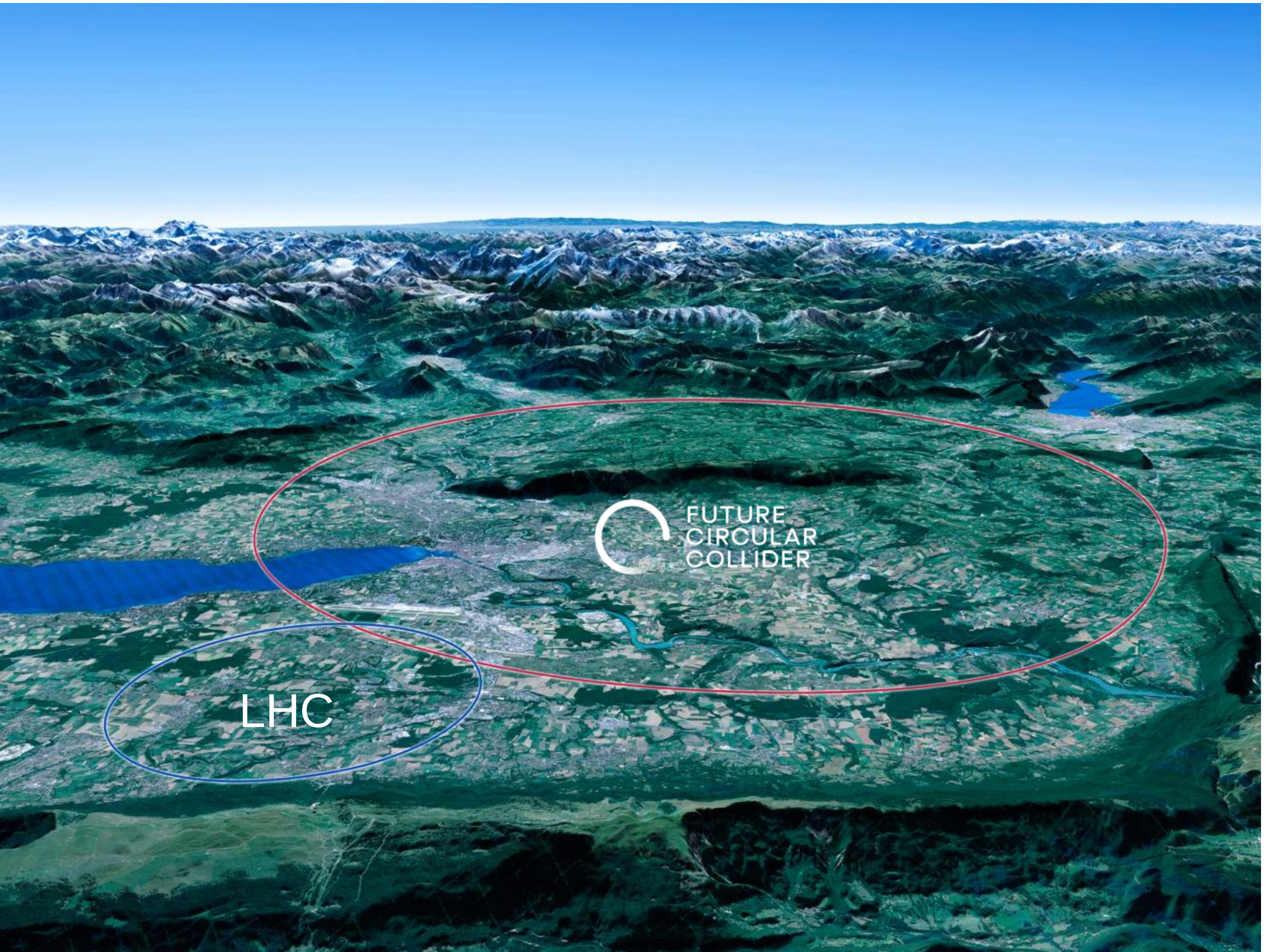
**Accelerator Physics Graduate Course**
**John Adams Institute for Accelerator Science**
**25 November 2021**





# CERN Scientific Priorities for the Future

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

- Fully exploit the 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.

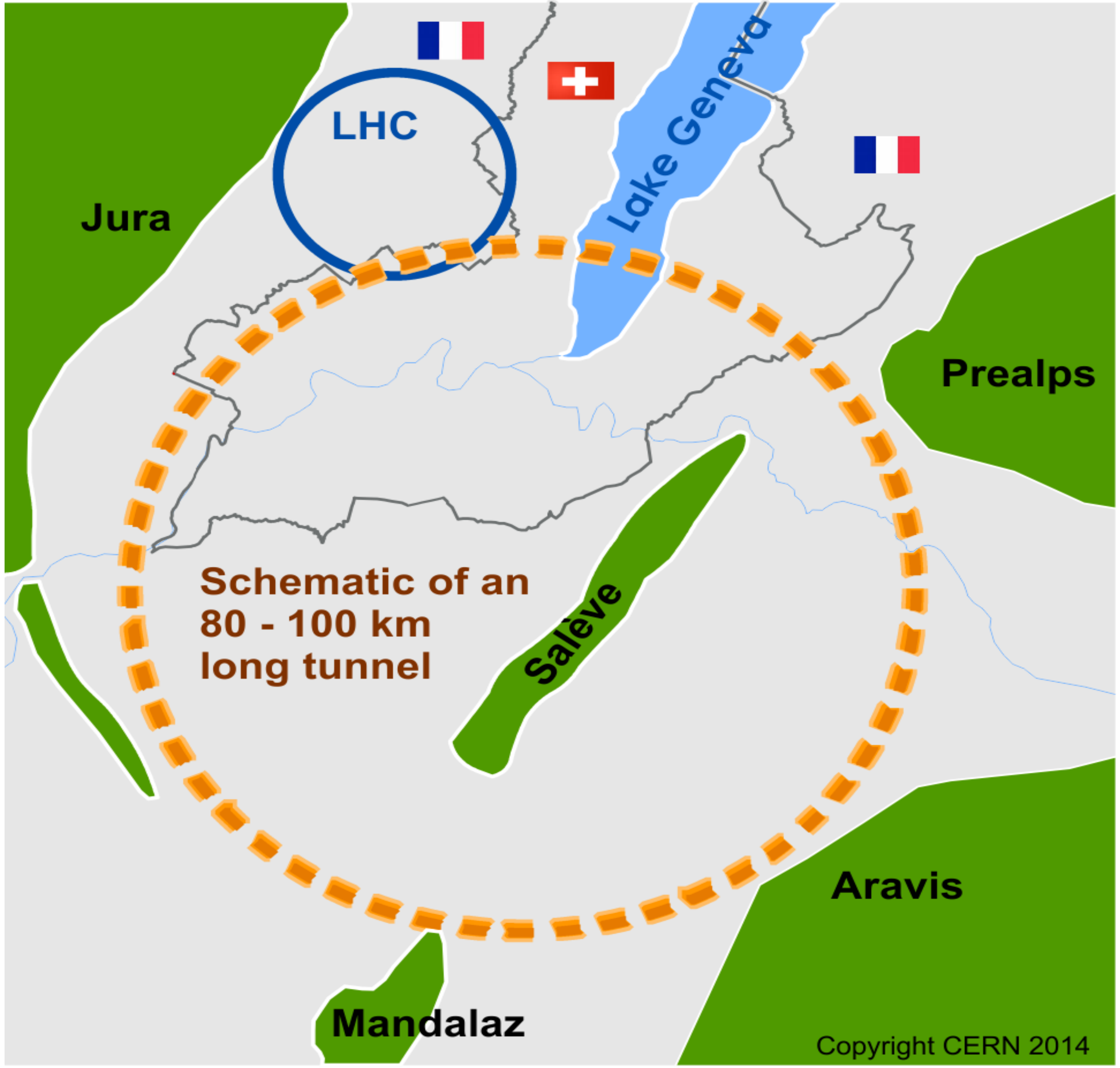
# Future Circular Collider Study Launched in 2014

**International FCC collaboration (CERN as host lab) to study:**

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements
  - **80-100 km infrastructure** in Geneva area

~16 T ⇒ 100 TeV *pp* in 100 km

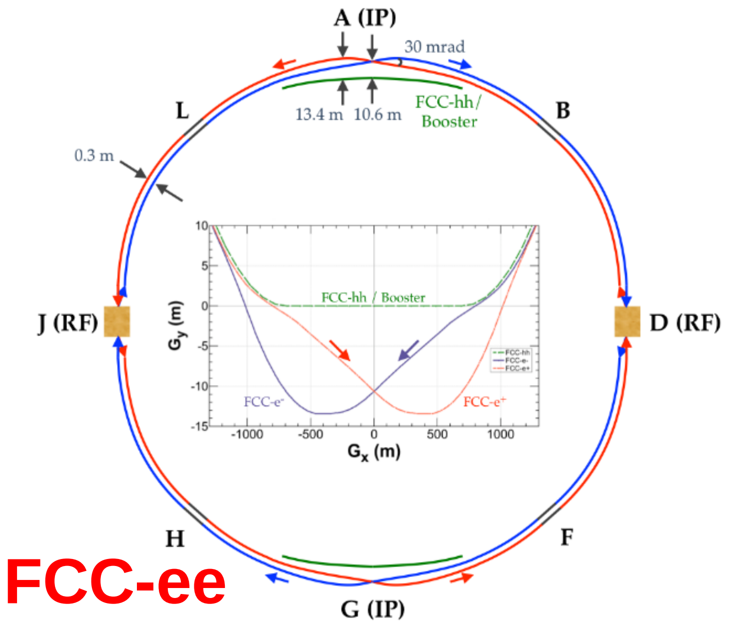
- ***e*$^+$*e*$^-$ collider (*FCC-ee*)** as a first step
- ***p-e* (*FCC-he*)** option, **HE-LHC …**



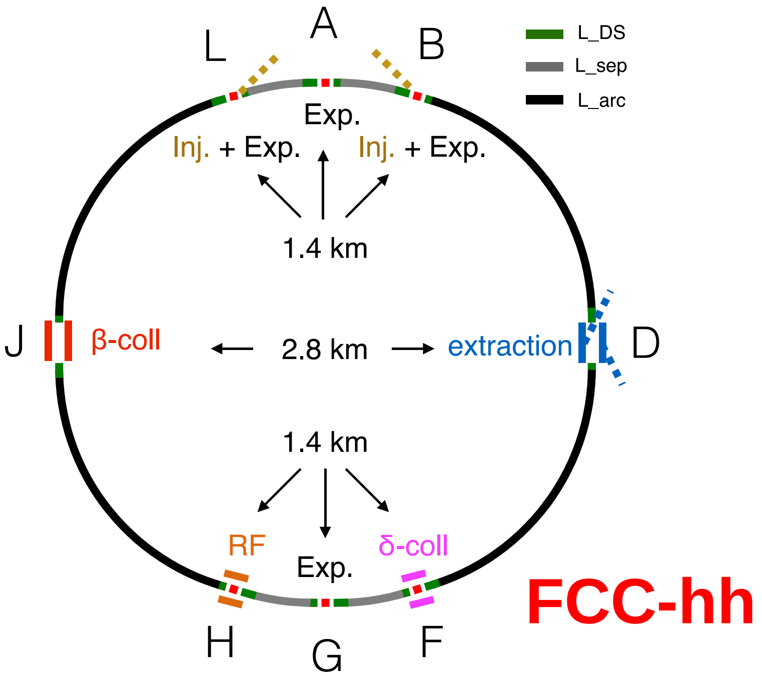
# The FCC Integrated Programme Inspired by Successful LEP – LHC programmes at CERN

## Comprehensive cost-effective program maximizing physics opportunities

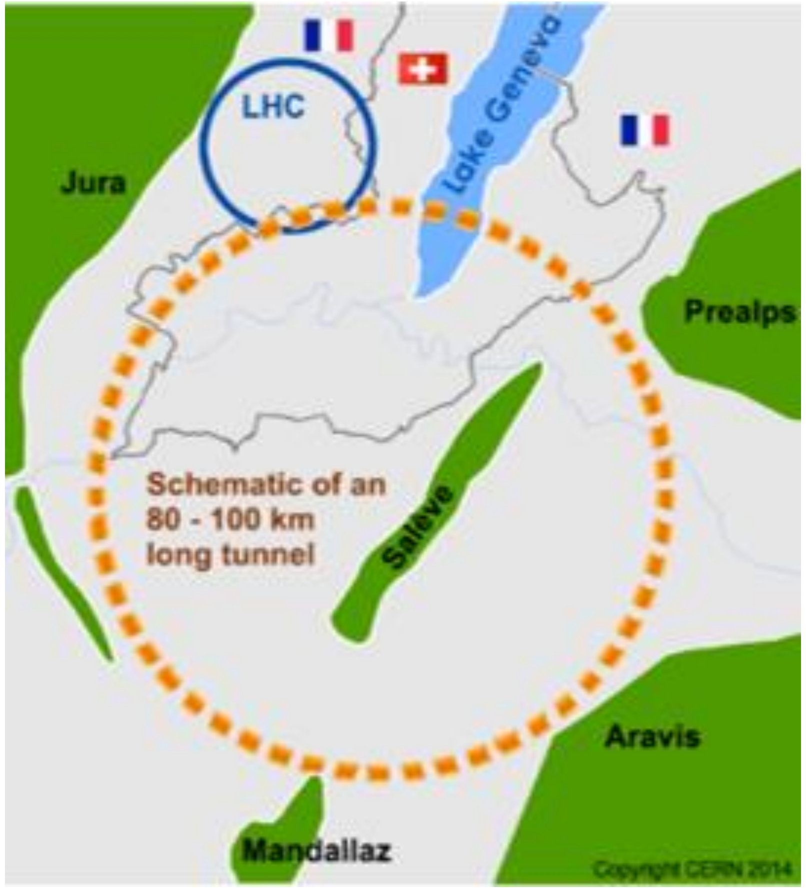
- **Stage 1: FCC-ee (Z, W, H, tt̄) as Higgs factory, electroweak & and top factory at highest luminosities**
- **Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options**
- Complementary physics
- Common civil engineering and technical infrastructures
- Building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of HEP after HL-LHC



**FCC-ee**

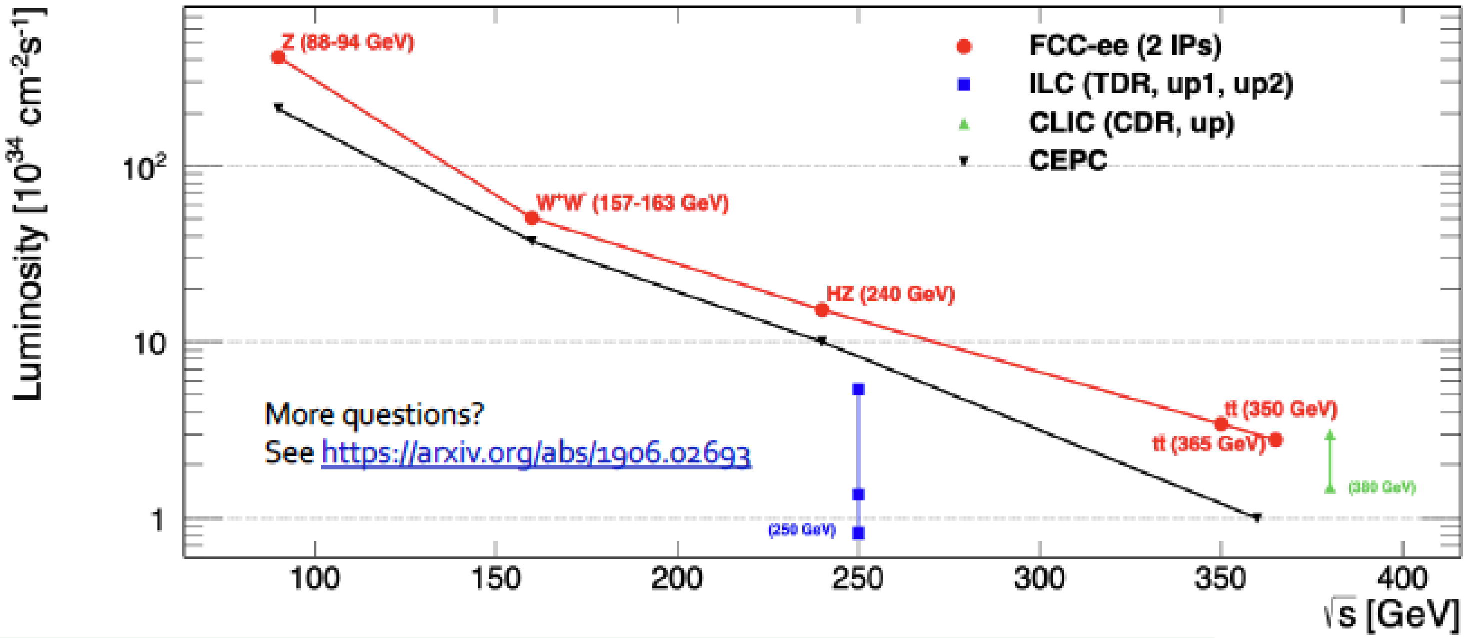


**FCC-hh**



# FCC-ee Higgs and Electroweak Factory

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



More questions?
See https://arxiv.org/abs/1906.02693

| | | | | | $E_{CM}$ errors: |
|---|---|---|---|---|---|
| Z peak | $E_{cm}$ ~ 91 GeV | $5 \times 10^{12}$ | 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 |
| $t\bar{t}$ threshold | $E_{cm}$ ~ 350 GeV | $10^6$ | e+e- → $t\bar{t}$ | Never done | 5 MeV |

P. Janot

# Physics Opportunities with FCC-hh

- With 30 $\text{ab}^{-1}$ @ 100 TeV in 25 years
  - $2\times10^{10}$ Higgs bosons (180 × HL-LHC)
    - $2\times10^{7}$ Higgs pairs, $10^{8}$ ttH events
  - $10^{12}$ top pairs (300 × HL-LHC)
  - $5\times10^{13}$ W, $10^{13}$ Z (70 × HL-LHC)
  - $10^{5}$ gluino pairs im $m_{\text{gluino}}$ ~ 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 $2.5\times10^{-4}$ (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

P. Janot

# FCC-ee Basic Design Choices

**Double ring** e+ e- collider

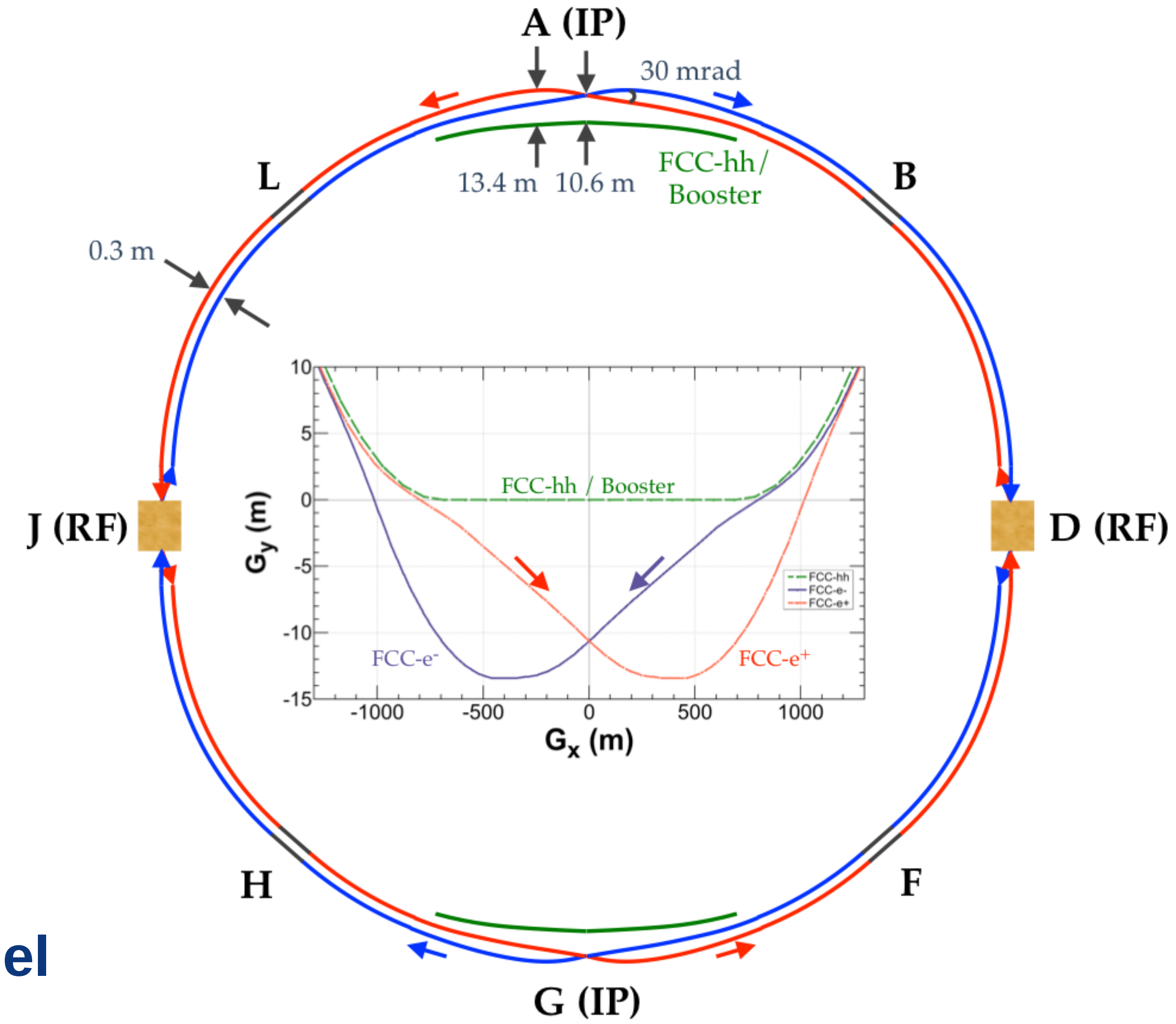
**Common footprint with FCC-hh**,
except around IPs

**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**

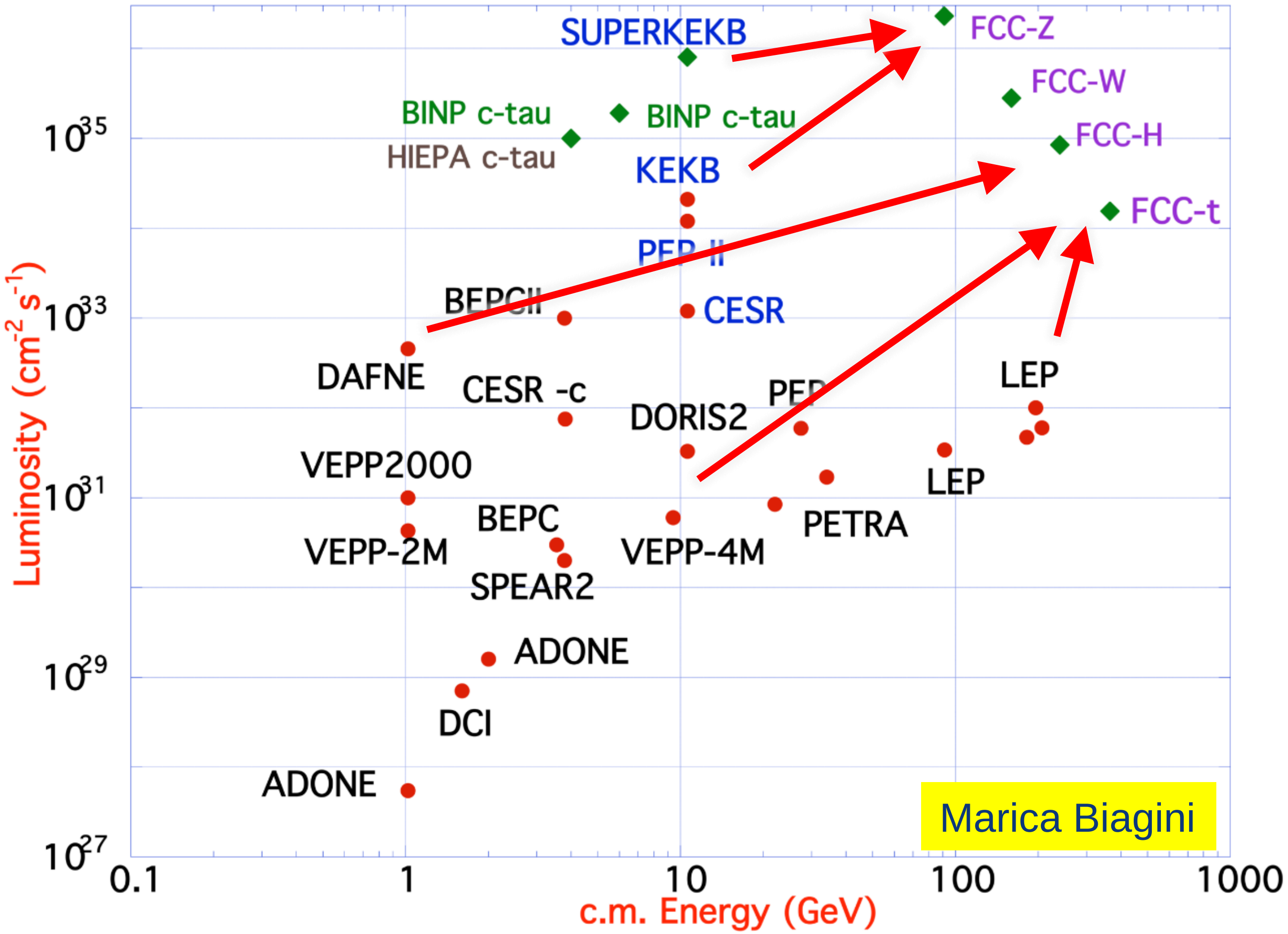


# FCC-ee Collider Parameters (Stage 1)

| parameter | Z | WW | H (ZH) | ttbar |
|---|---|---|---|---|
| beam energy [GeV] | 45 | 80 | 120 | 182.5 |
| beam current [mA] | 1390 | 147 | 29 | 5.4 |
| no. bunches/beam | 16640 | 2000 | 393 | 48 |
| bunch intensity [$10^{11}$] | 1.7 | 1.5 | 1.5 | 2.3 |
| SR energy loss / turn [GeV] | 0.036 | 0.34 | 1.72 | 9.21 |
| total RF voltage [GV] | 0.1 | 0.44 | 2.0 | 10.9 |
| long. damping time [turns] | 1281 | 235 | 70 | 20 |
| horizontal beta* [m] | 0.15 | 0.2 | 0.3 | 1 |
| vertical beta* [mm] | 0.8 | 1 | 1 | 1.6 |
| horiz. geometric emittance [nm] | 0.27 | 0.28 | 0.63 | 1.46 |
| vert. geom. emittance [pm] | 1.0 | 1.7 | 1.3 | 2.9 |
| bunch length with SR / BS [mm] | 3.5 / 12.1 | 3.0 / 6.0 | 3.3 / 5.3 | 2.0 / 2.5 |
| luminosity per IP [$10^{34}$ $cm^{-2}s^{-1}$] | 230 | 28 | 8.5 | 1.55 |
| beam lifetime rad Bhabha / BS [min] | 68 / >200 | 49 / >1000 | 38 / 18 | 40 / 18 |

# 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 $\beta_y^*$, 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

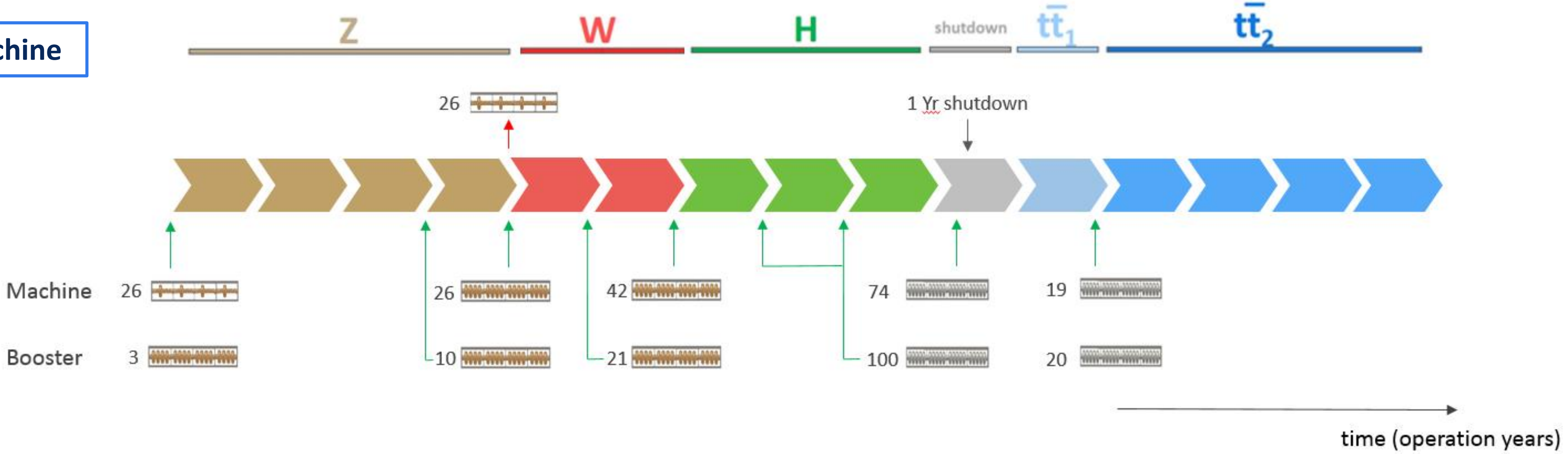
“Ampere-class” machine

| 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

## Luminosity vs. capital cost

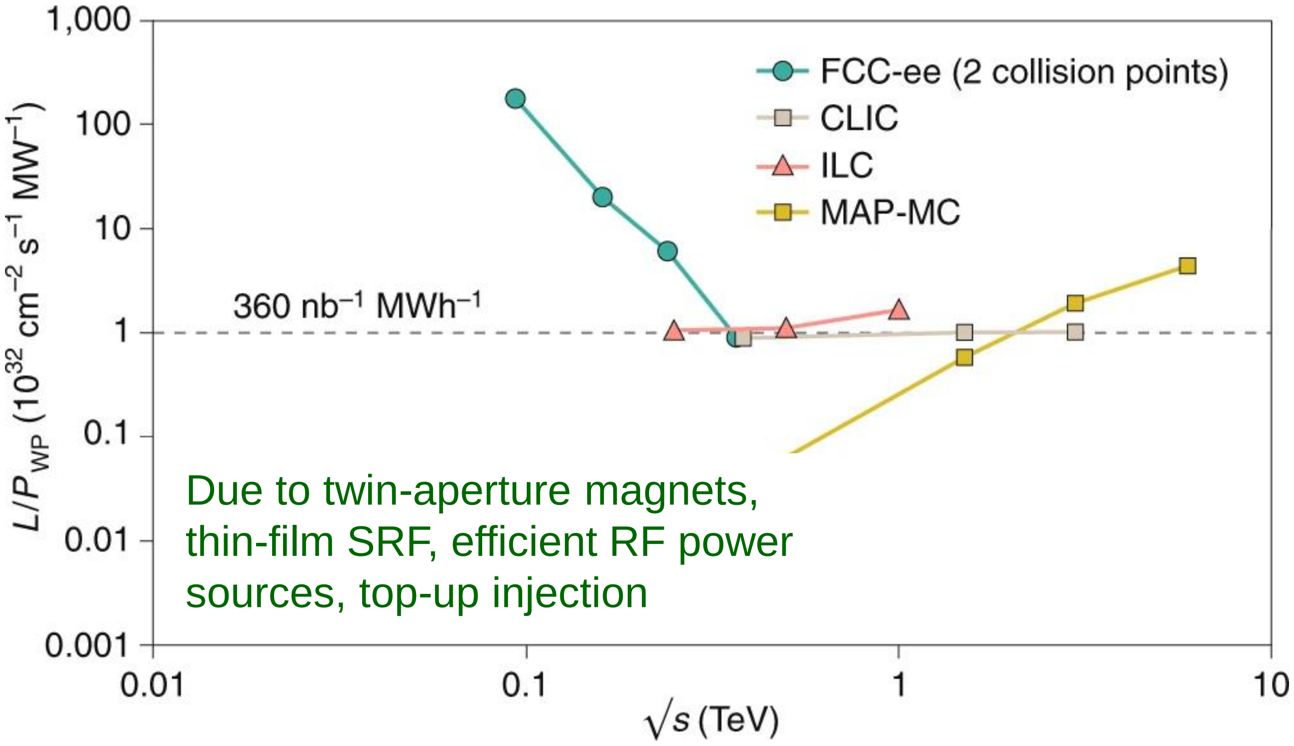
- for the H running, **with 5 ab$^{-1}$ accumulated over 3 years and 10$^6$ H produced**, the total investment cost (~10 BCHF) corresponds to
  → **10 kCHF per produced Higgs boson**

- 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

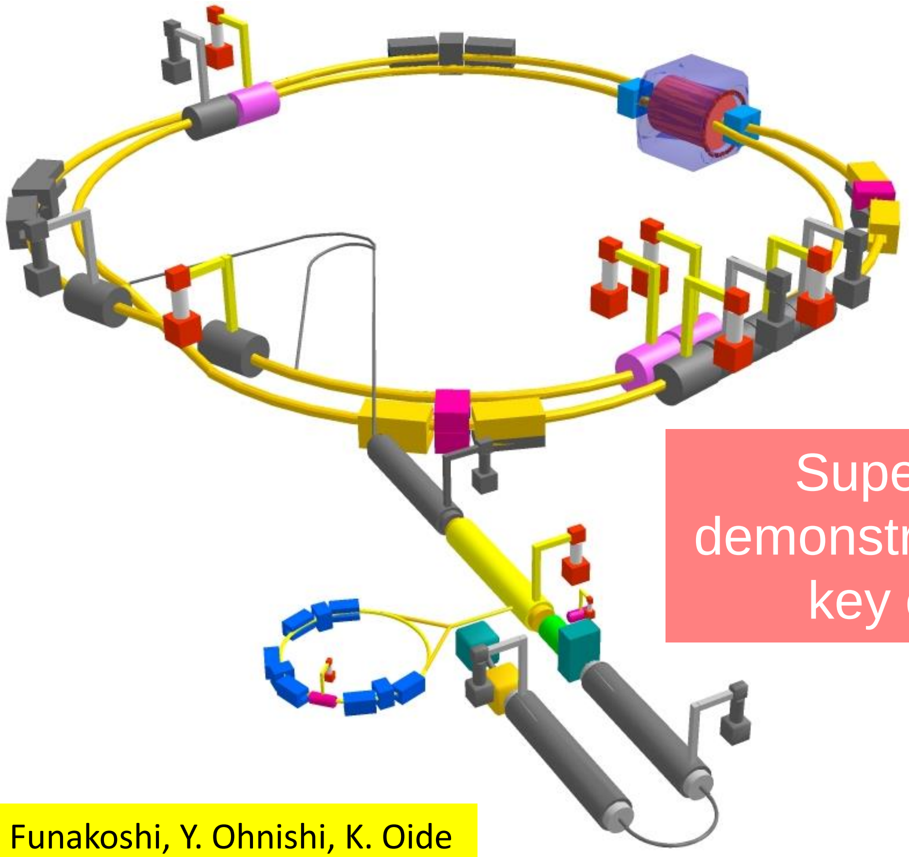


Due to twin-aperture magnets, thin-film SRF, efficient RF power sources, top-up injection

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

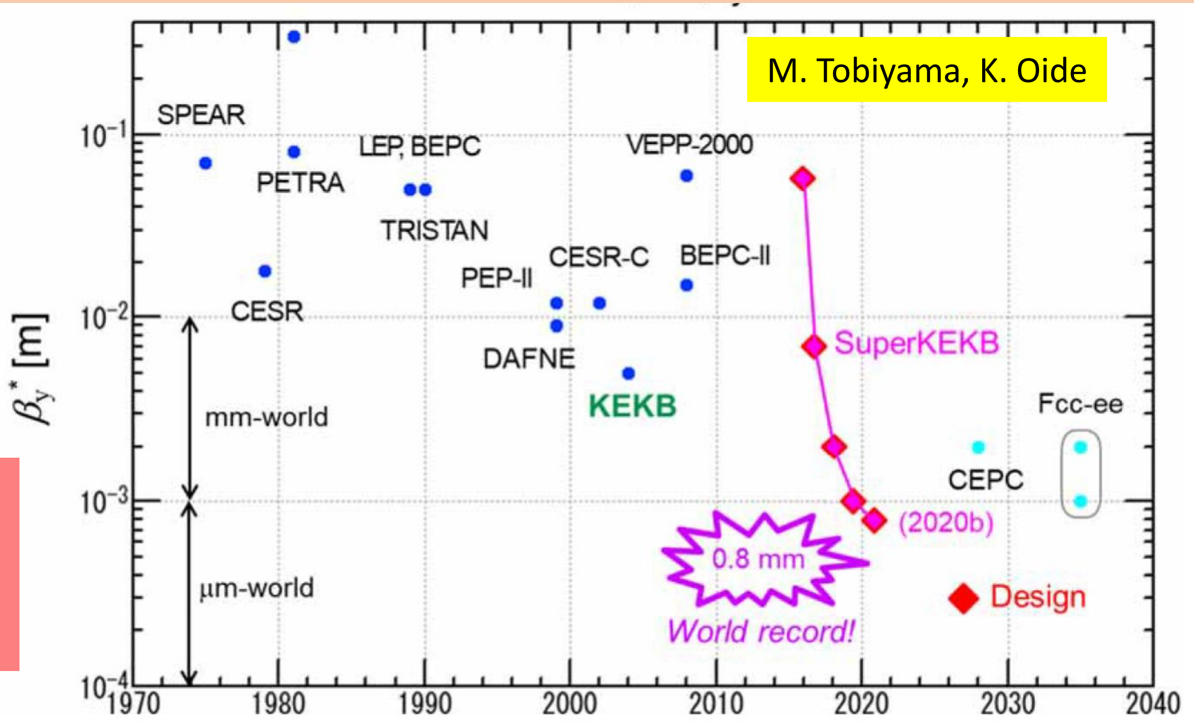
# SuperKEKB – Pushing Luminosity and β*

**Design: double ring $e^+e^-$ collider as *B*-factory** at 7($e^-$) & 4($e^+$) GeV; **design luminosity ~8 x $10^{35}$ cm$^{-2}$s$^{-1}$**; **$\beta_y^*$ ~ 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** ; **under commissioning**



Y. Funakoshi, Y. Ohnishi, K. Oide

SuperKEKB is demonstrating FCC-ee key concepts



M. Tobiyama, K. Oide

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

# Potential EIC – FCC collaboration

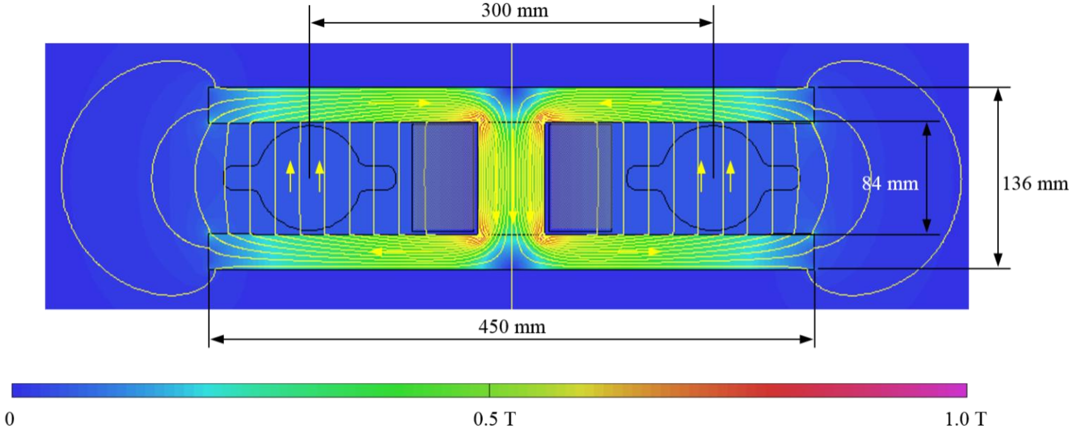
## NSLS-II, EIC & FCC-ee beam parameters

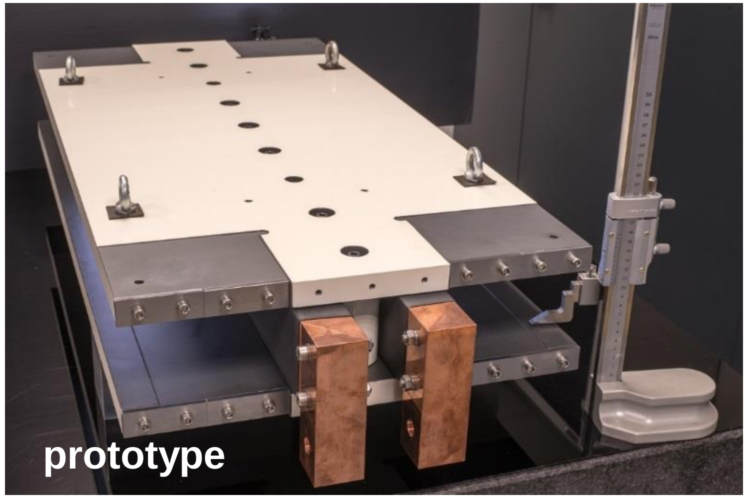
| | NSLS-II | EIC | FCC-ee-Z |
|---|---|---|---|
| **Beam energy [GeV]** | **3** | **10 (20)** | **45.6** |
| **Bunch population [$10^{11}$]** | **0.08** | **1.7** | **1.7** |
| **Bunch spacing [ns]** | **2** | **10** | **15, 17.5 or 20** |
| **Rms bunch length [mm]** | 4.5 - 9 | **2** | **3.5 (SR)**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

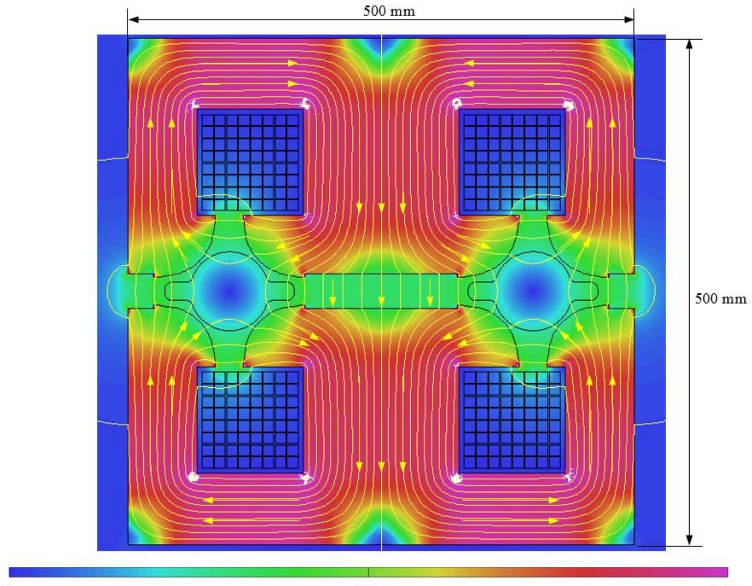
**Similarity of several parameters strongly suggests collaboration to exploit synergies in areas such as beam instrumentation, SRF, vacuum system with SR handling, etc.**

# Prototypes of FCC-ee Low-power Magnets

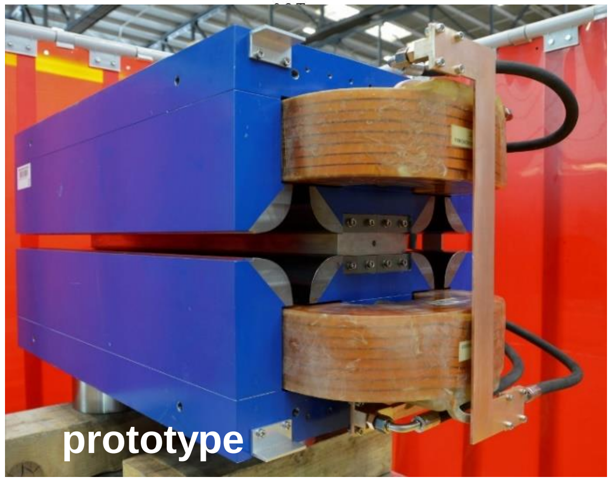
## Twin-dipole design with 2× power saving 16 MW (at 175 GeV), with Al busbars



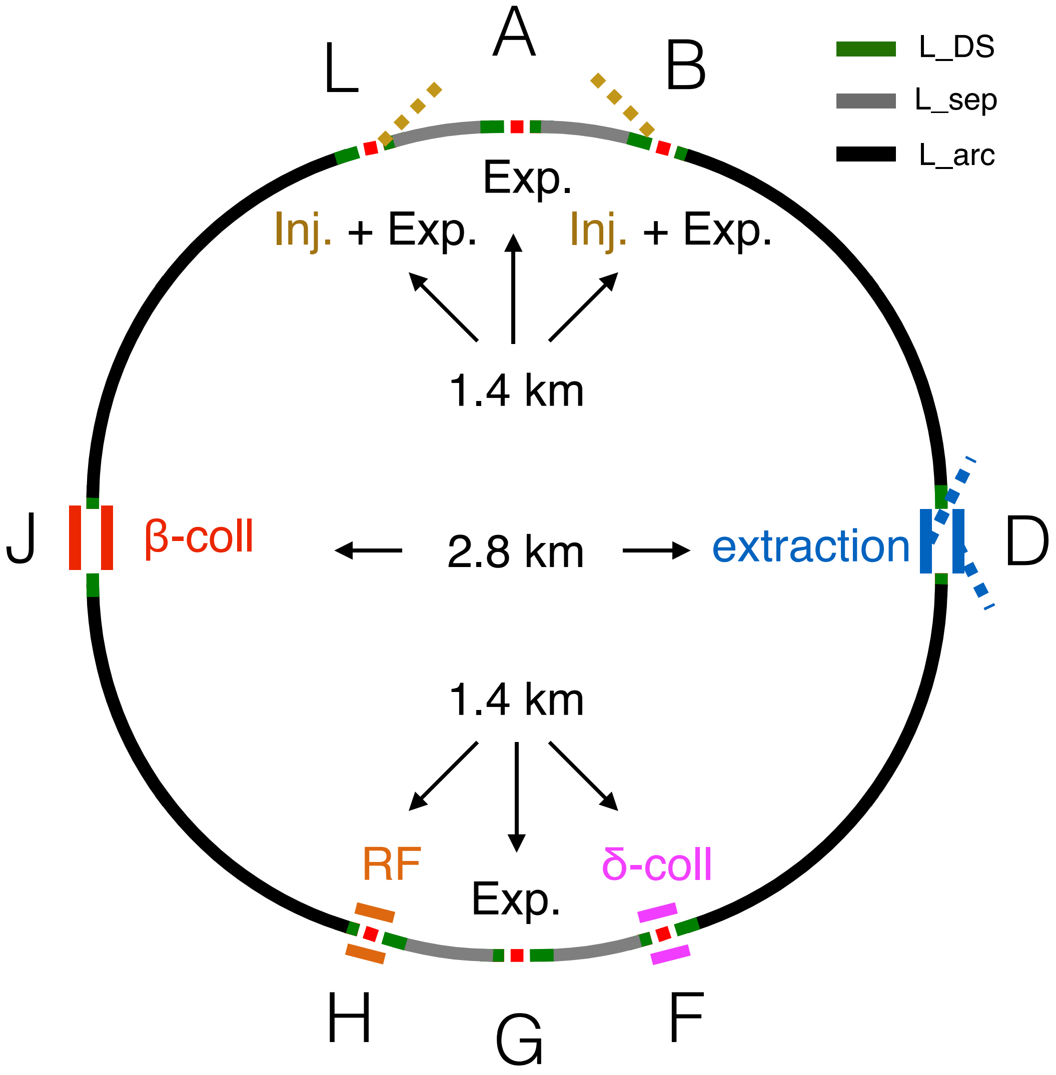




## Twin F/D arc quad design with 2× power saving 25 MW (at 175 GeV), with Cu conductor



# FCC-hh Basic Design Choices

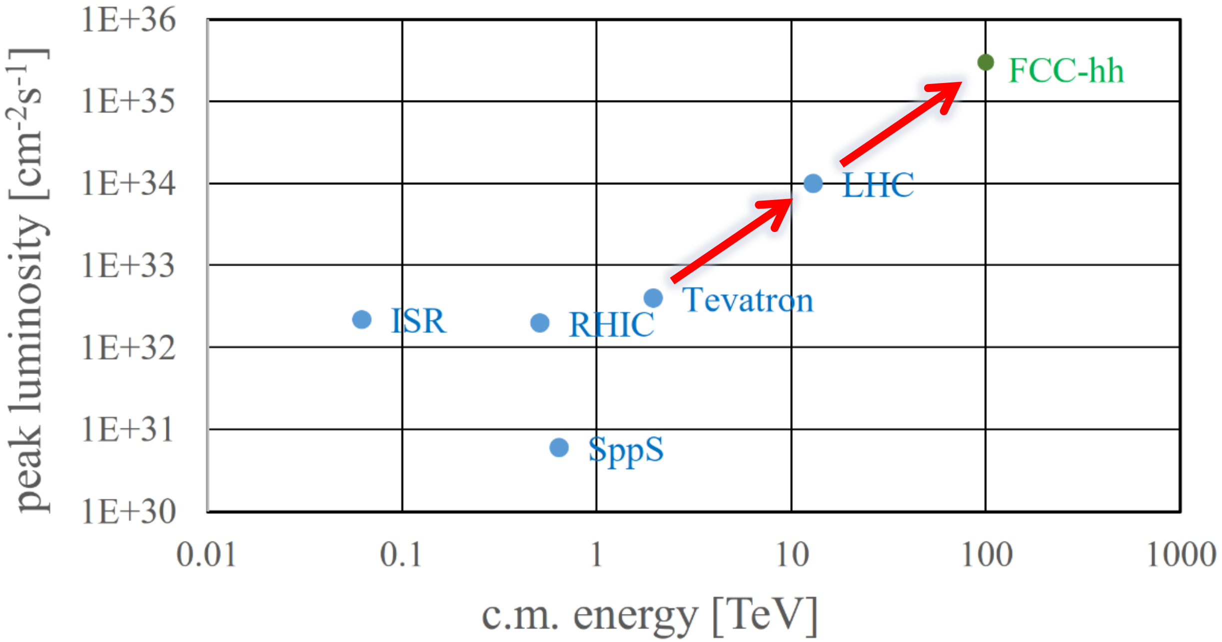


- **dual aperture superconducting magnets**
- **two high-luminosity experiments (A & G)**
- **two other experiments (L & B)** combined with **injection upstream** of experiments
- **two collimation insertions**
  - betatron cleaning (J)
  - momentum cleaning (F)
- **extraction/dump insertion (D)**
-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

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

| parameter | FCC-hh | | HL-LHC | LHC |
|---|---|---|---|---|
| collision energy cms [TeV] | 100 | | 14 | 14 |
| dipole field [T] | 16 | | 8.33 | 8.33 |
| circumference [km] | 97.75 | | 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] | 2400 | | 7.3 | 3.6 |
| SR power / length [W/m/ap.] | 28.4 | | 0.33 | 0.17 |
| long. emit. damping time [h] | 0.54 | | 12.9 | 12.9 |
| beta* [m] | 1.1 | 0.3 | 0.15 (min.) | 0.55 |
| normalized emittance [$\mu$m] | 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] | 8.4 | | 0.7 | 0.36 |

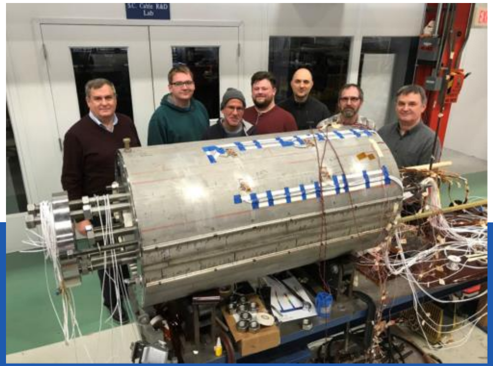
# FCC-hh: Highest Collision Energies



- **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**



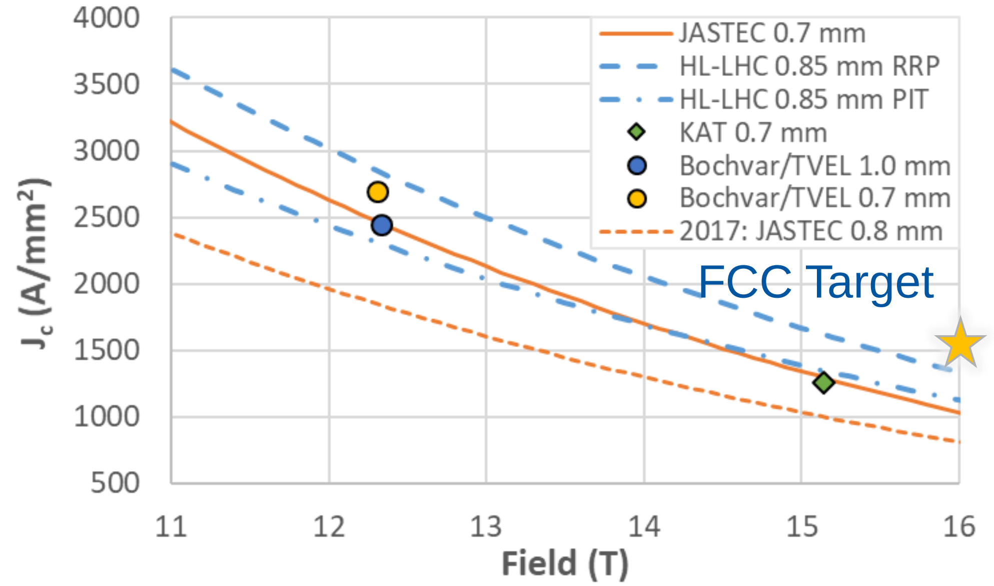
**FNAL dipole**
**demonstrator**
**14.5 T $Nb_3Sn$**

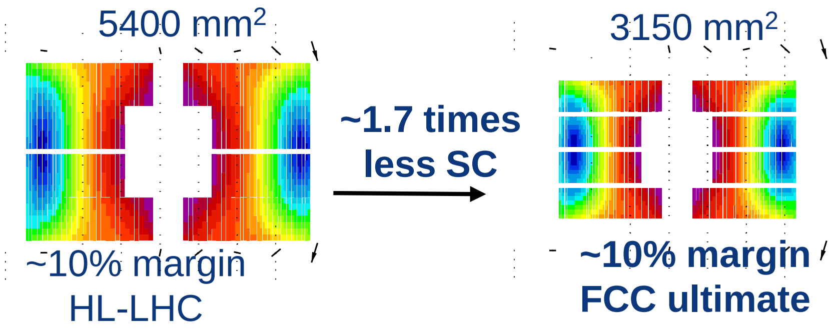
# World-wide FCC $Nb_3Sn$ Programme

**Main development goal is wire performance increase:**

- **$J_c$ (16T, 4.2K) > 1500 A/mm$^2$ →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.

FUTURE
CIRCULAR
COLLIDER

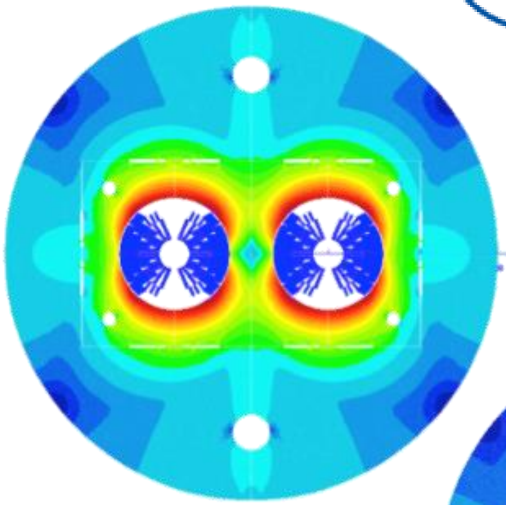
# 16 T Dipole Design Activities and Options

H2020

EuroCirCol

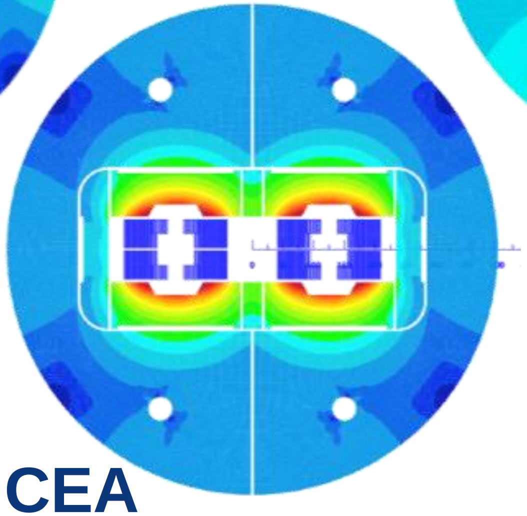
A key to New Physics

Cos-theta



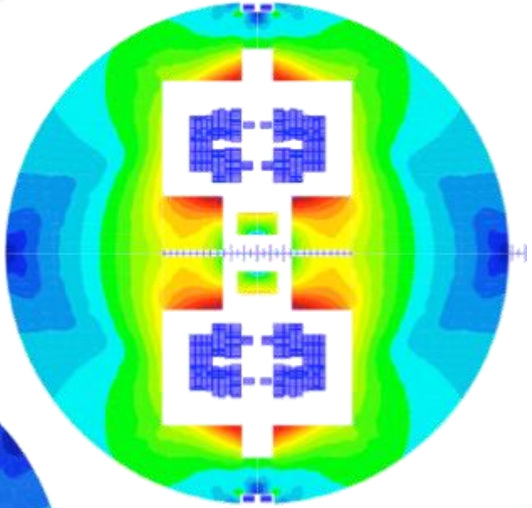
**INFN**

Blocks



**CEA**

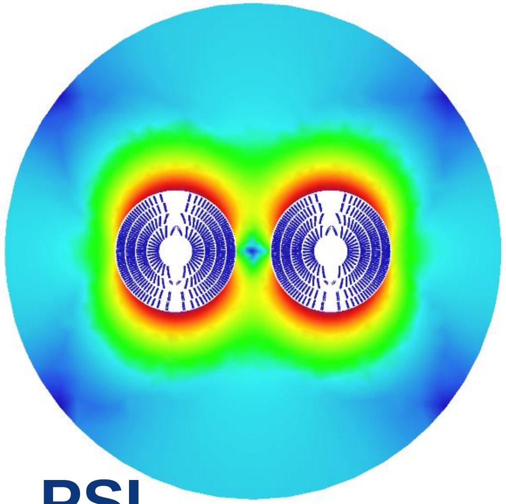
Common coils



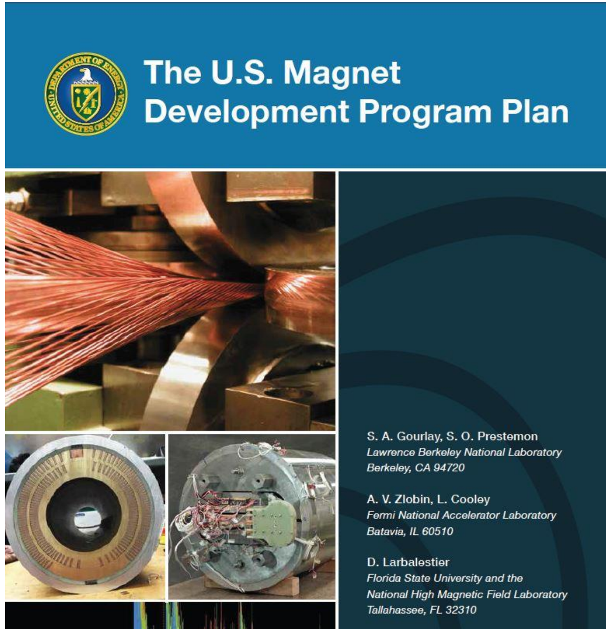
**CIEMAT**

**Swiss contribution**

Canted
Cos-theta



**PSI**



The U.S. Magnet Development Program Plan

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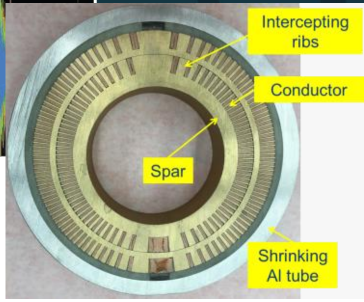
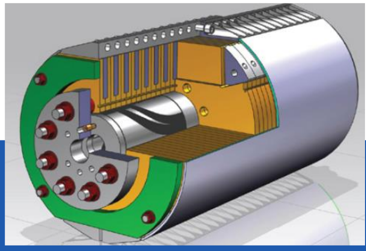


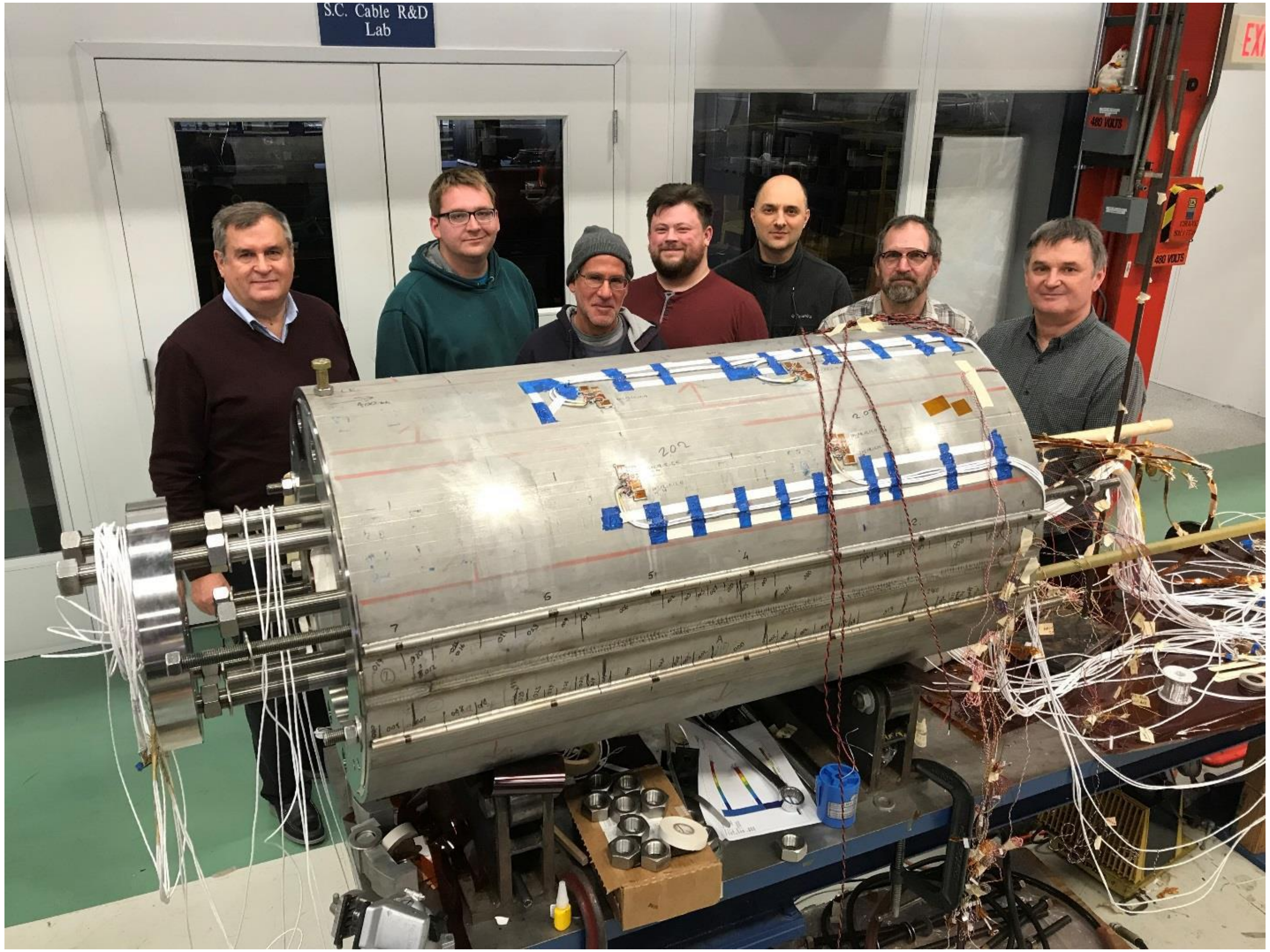
**LBNL**

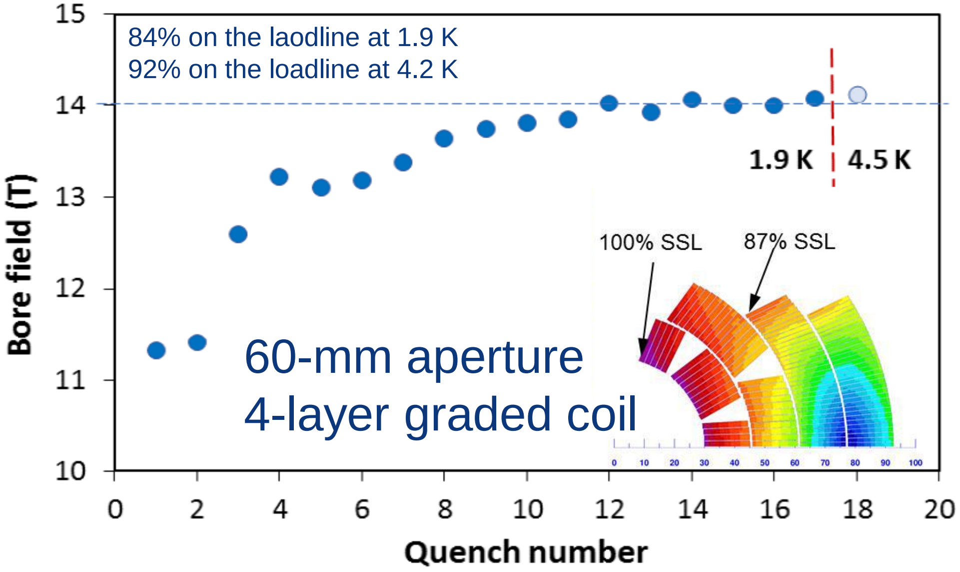
**FNAL**



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

# US – MDP: 14.5 T Magnet Tested at FNAL

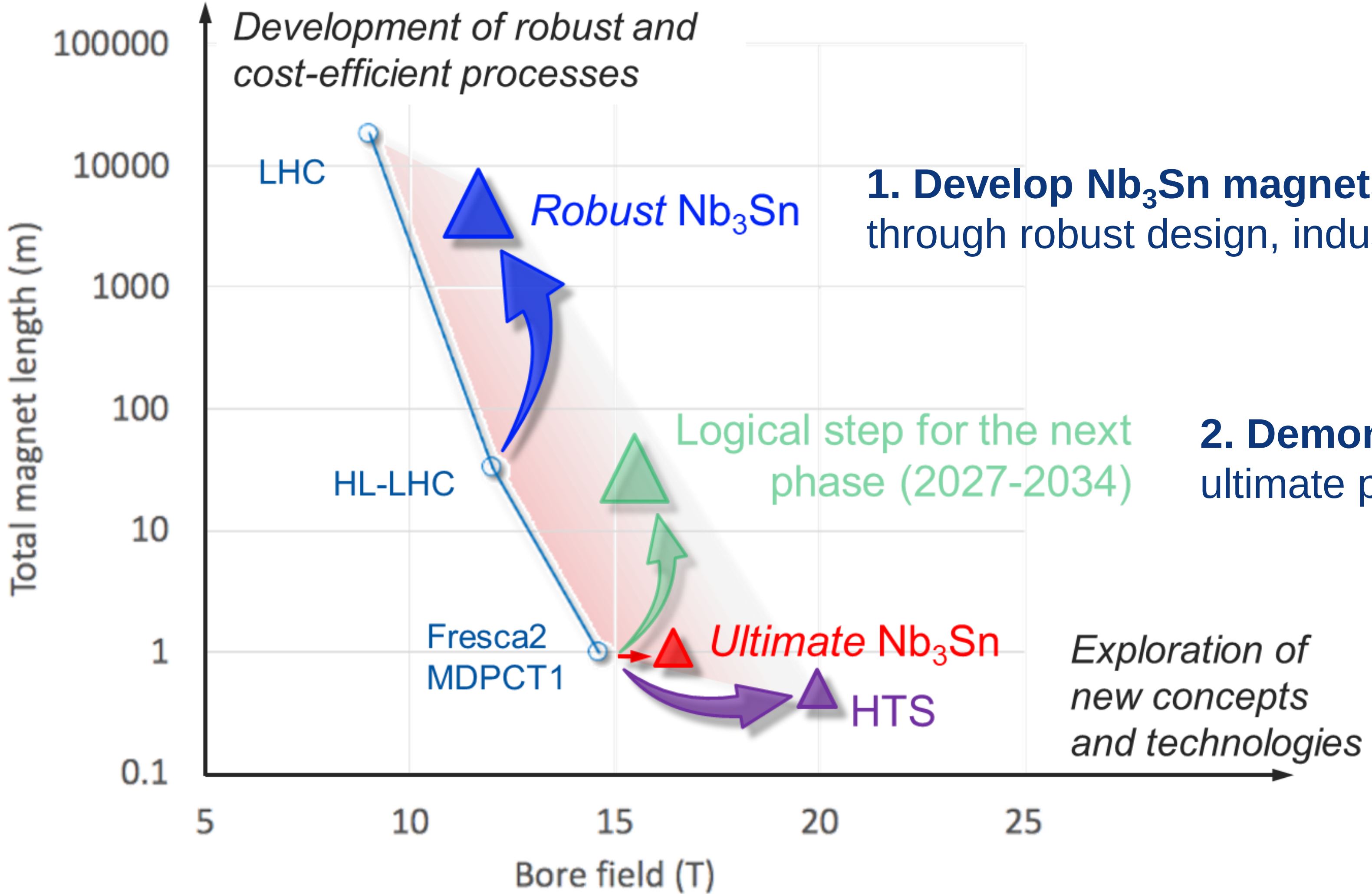




- 15 T dipole demonstrator
- Staged approach: In first step pre-stressed for 14 T
- Second test in June 2020 with additional pre-stress reached 14.5 T

# High Field Magnet Programme Goals until 2027

L. Bottura

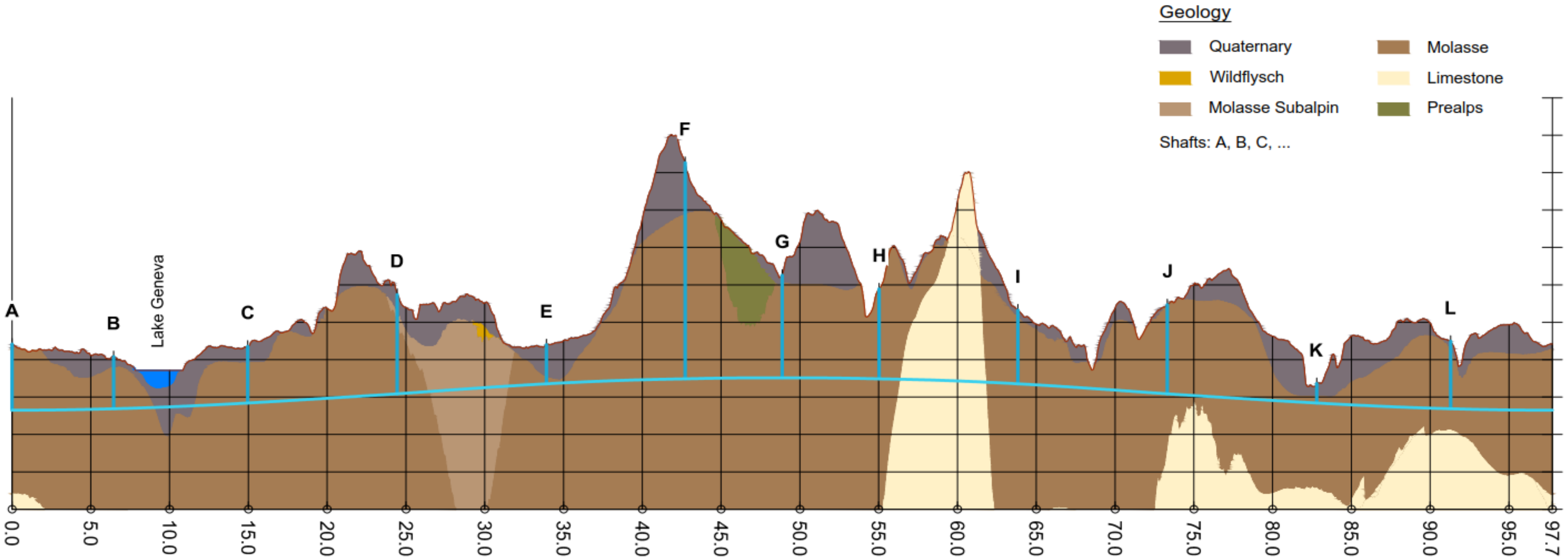


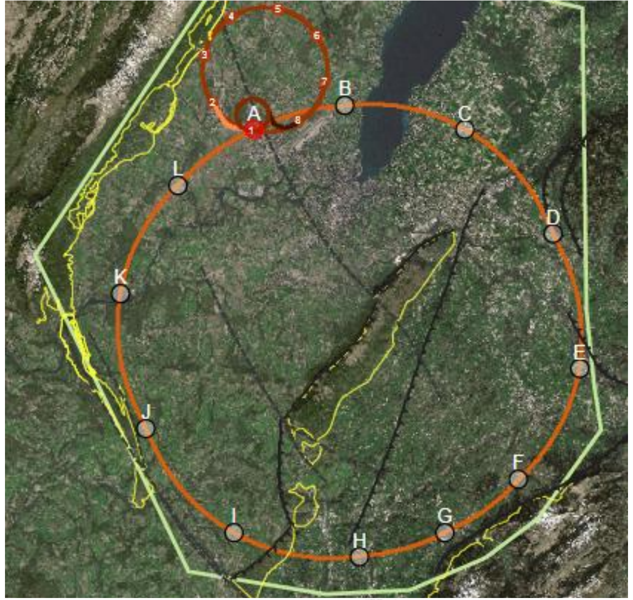
1. **Develop $Nb_3Sn$ magnets for collider-scale production**, through robust design, industrial processes and cost reduction

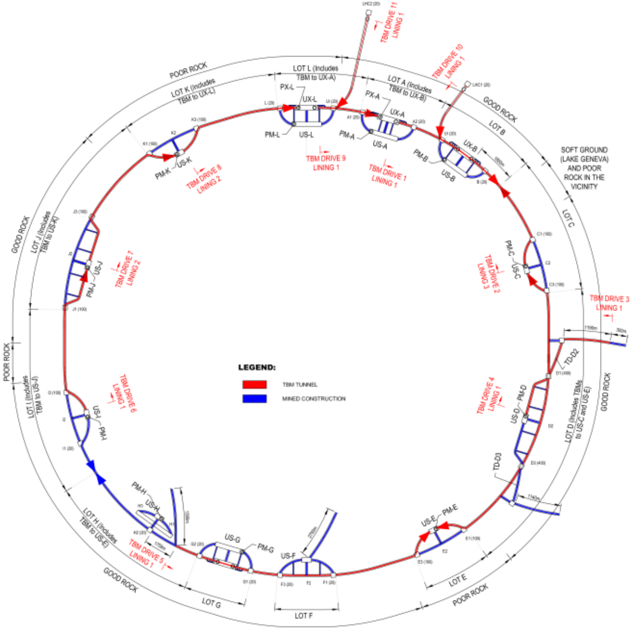
2. **Demonstrate $Nb_3Sn$ full potential** in terms of ultimate performance

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

# FCC Implementation - Footprint Baseline



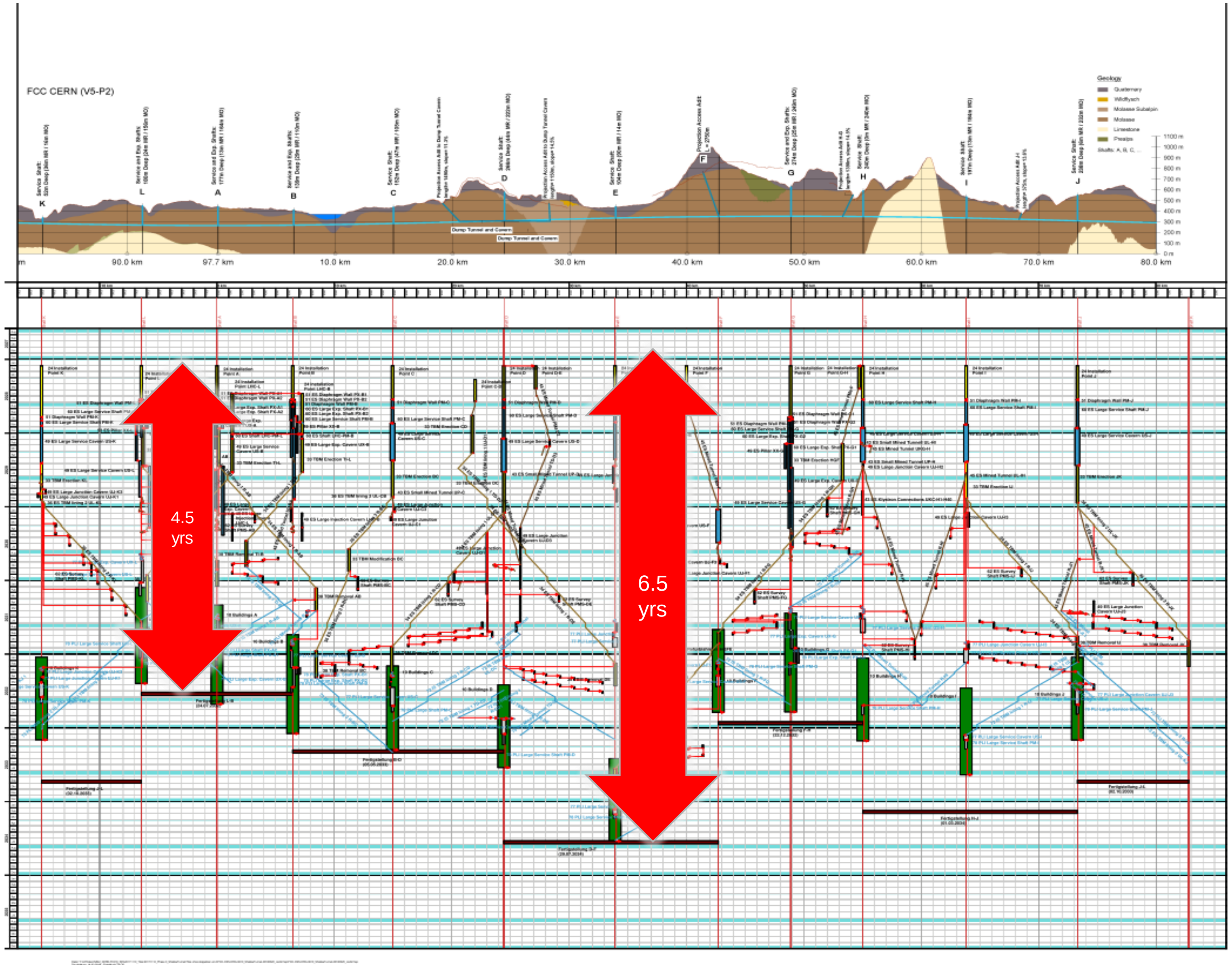


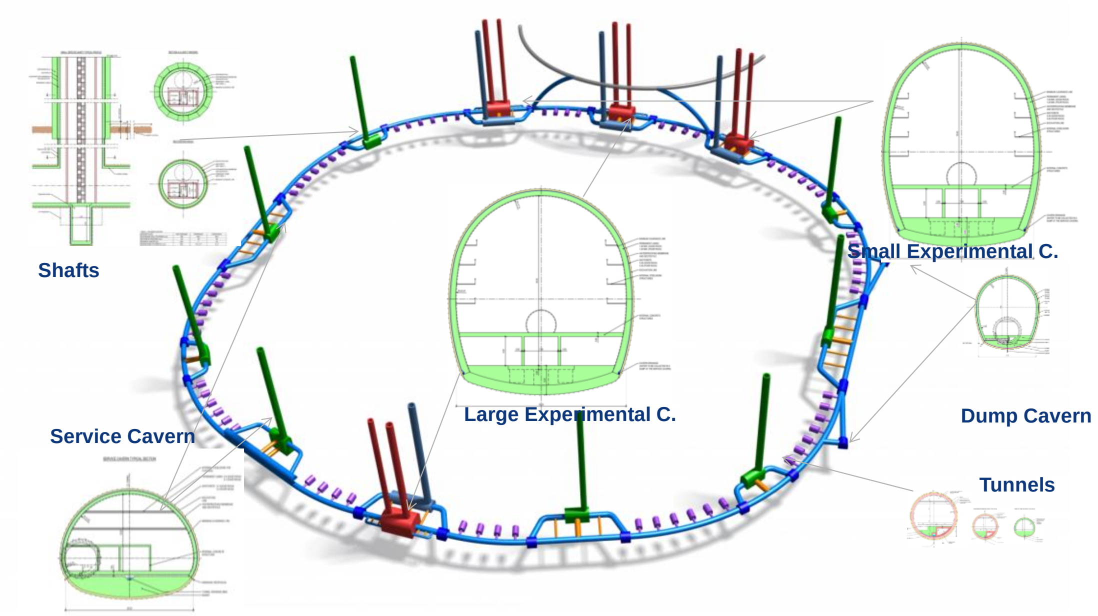


- **Present baseline position was established considering:**
- lowest risk for construction, fastest and cheapest construction
- Molasse rock preferred for tunnelling, avoid limestone with karstic structures

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

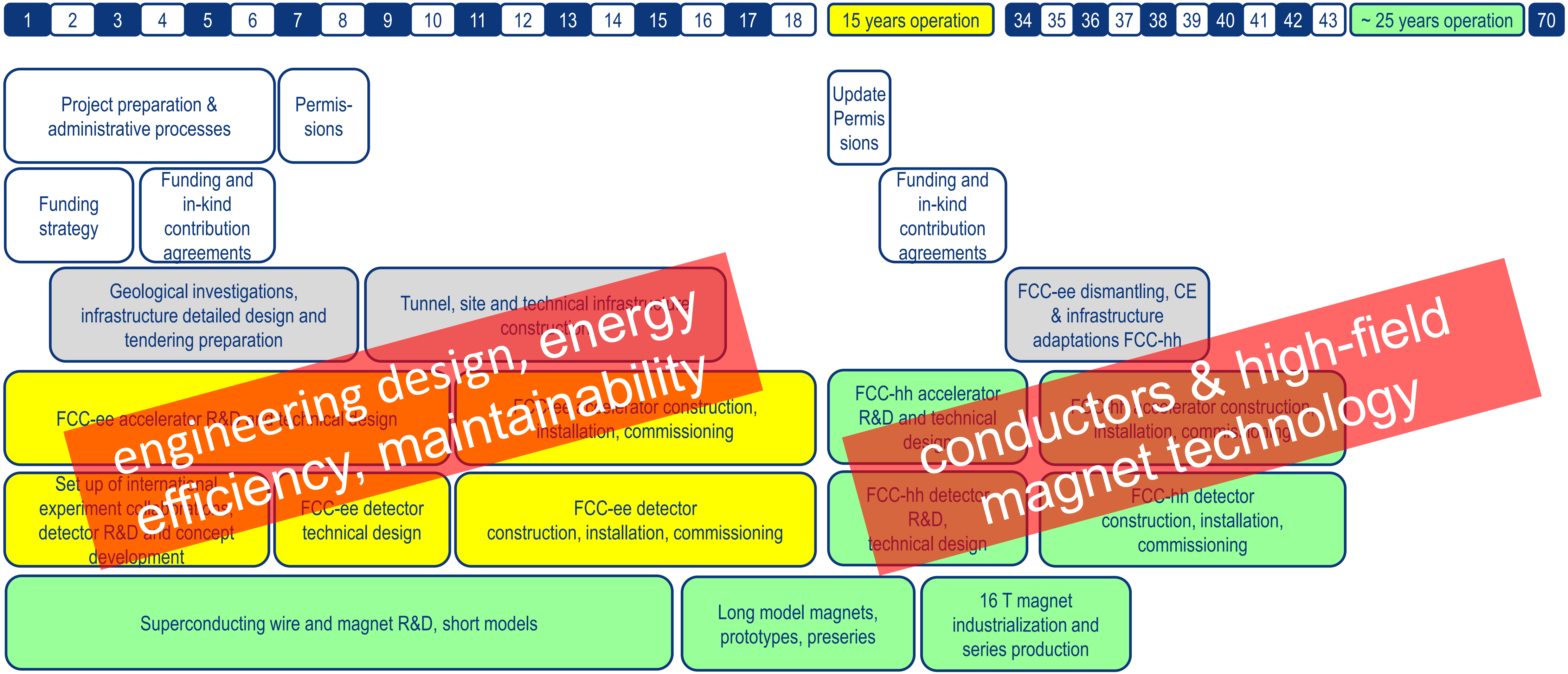
# Civil Engineering Construction Schedule





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

# FCC Integrated Project Technical Schedule



1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 years operation | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | ~ 25 years operation | 70

Project preparation & administrative processes

Permis-sions

Update Permis sions

Funding strategy

Funding and in-kind contribution agreements

Funding and in-kind contribution agreements

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 R&D and technical design

FCC-ee accelerator construction, installation, commissioning

FCC-hh accelerator R&D and technical design

FCC-hh accelerator construction, installation, commissioning

Set up of international experiment collaborations, detector R&D and concept development

FCC-ee detector technical design

FCC-ee detector construction, installation, commissioning

FCC-hh detector R&D, technical design

FCC-hh detector construction, installation, commissioning

Superconducting wire and magnet R&D, short models

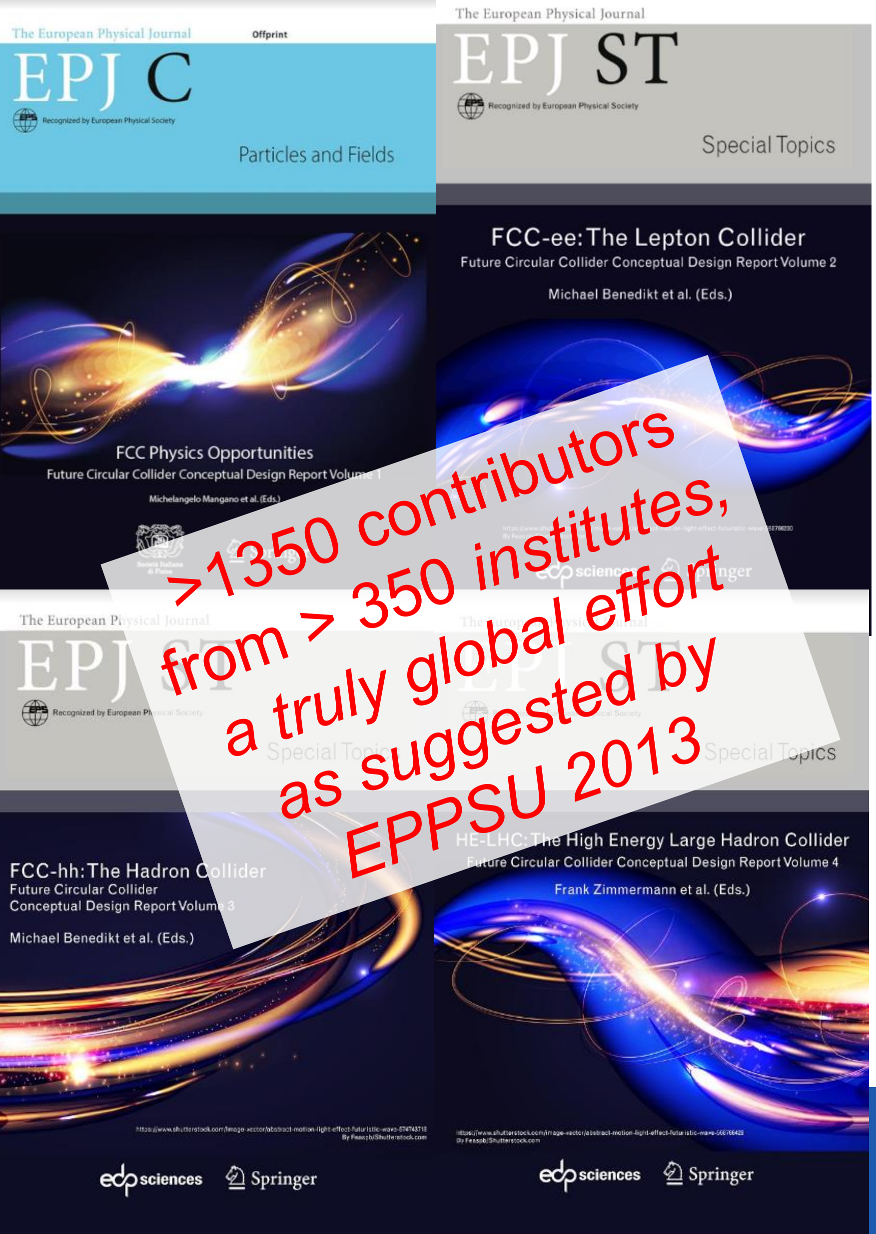
Long model magnets, prototypes, preseries

16 T magnet industrialization and series production

engineering design, energy efficiency, maintainability

conductors & high-field magnet technology

# FCC CDR and Study Documentation



>1350 contributors
from > 350 institutes,
a truly global effort
as suggested by
EPPSU 2013

- **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.”

2020 UPDATE OF THE EUROPEAN STRATEGY FOR PARTICLE PHYSICS

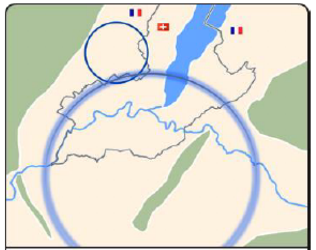
by the European Strategy Group

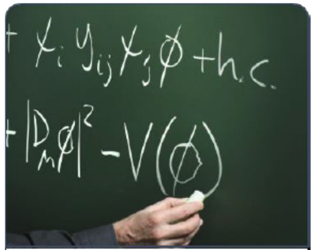
European Strategy Update

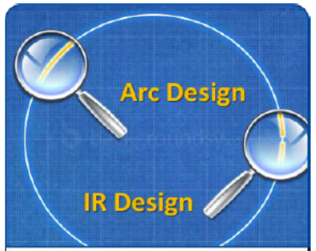
# High-level Goals of Feasibility Study

## High-level goals of Feasibility Study

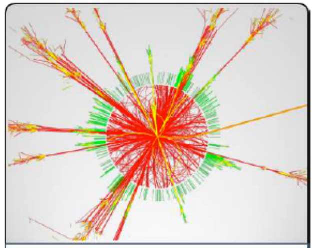
- optimisation of placement and layout of the ring and related infrastructure, and demonstration of the geological, technical, environmental and administrative feasibility of the tunnel and surface areas;
- pursuit, together with the Host States, of the preparatory administrative processes required for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

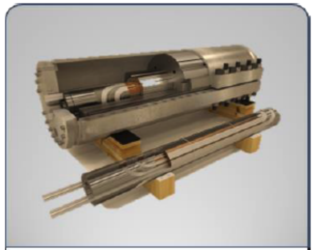

Infrastructures


Physics Cases



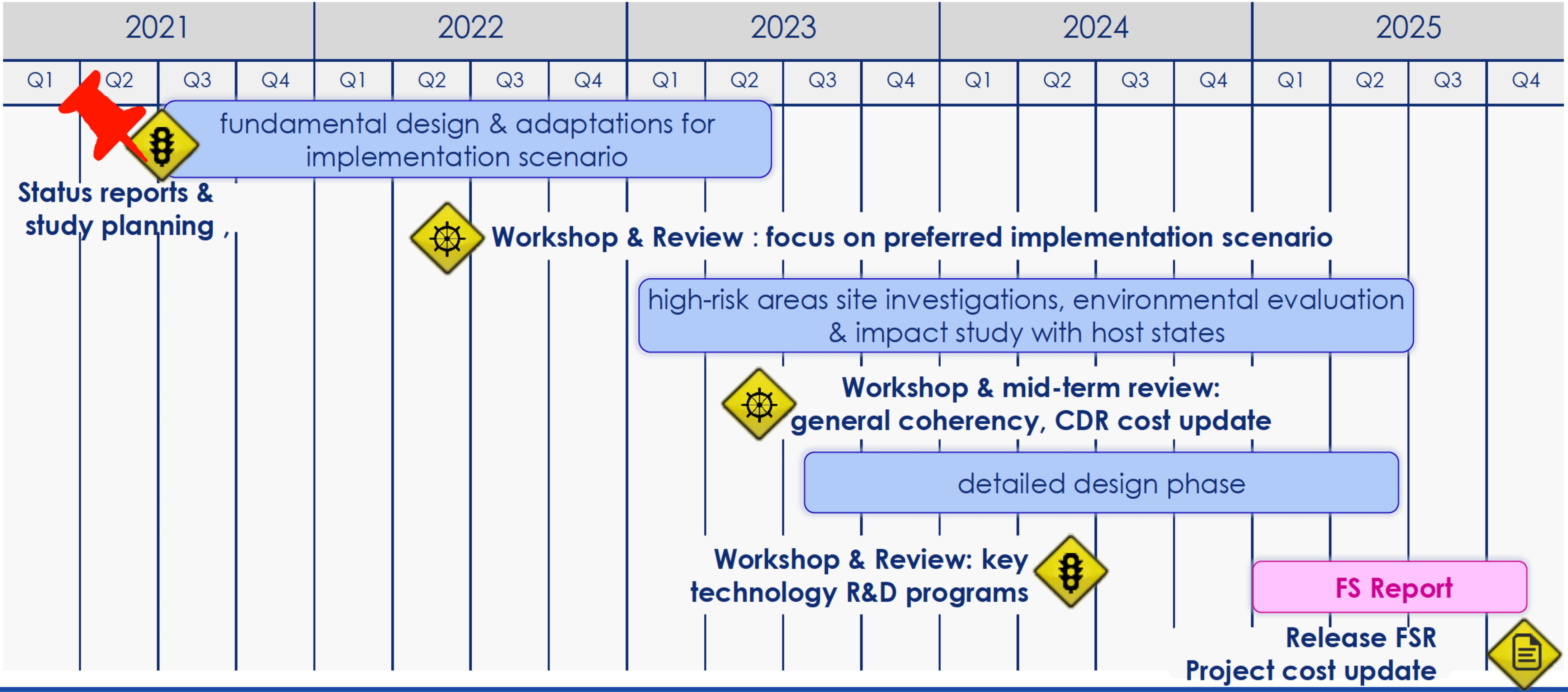
Collider Designs


Experiments


R&D Programs

Cost Estimates

# Feasibility Study Timeline



fundamental design & adaptations for implementation scenario

**Status reports & study planning ,**

**Workshop & Review : focus on preferred implementation scenario**

high-risk areas site investigations, environmental evaluation & impact study with host states

**Workshop & mid-term review: general coherency, CDR cost update**

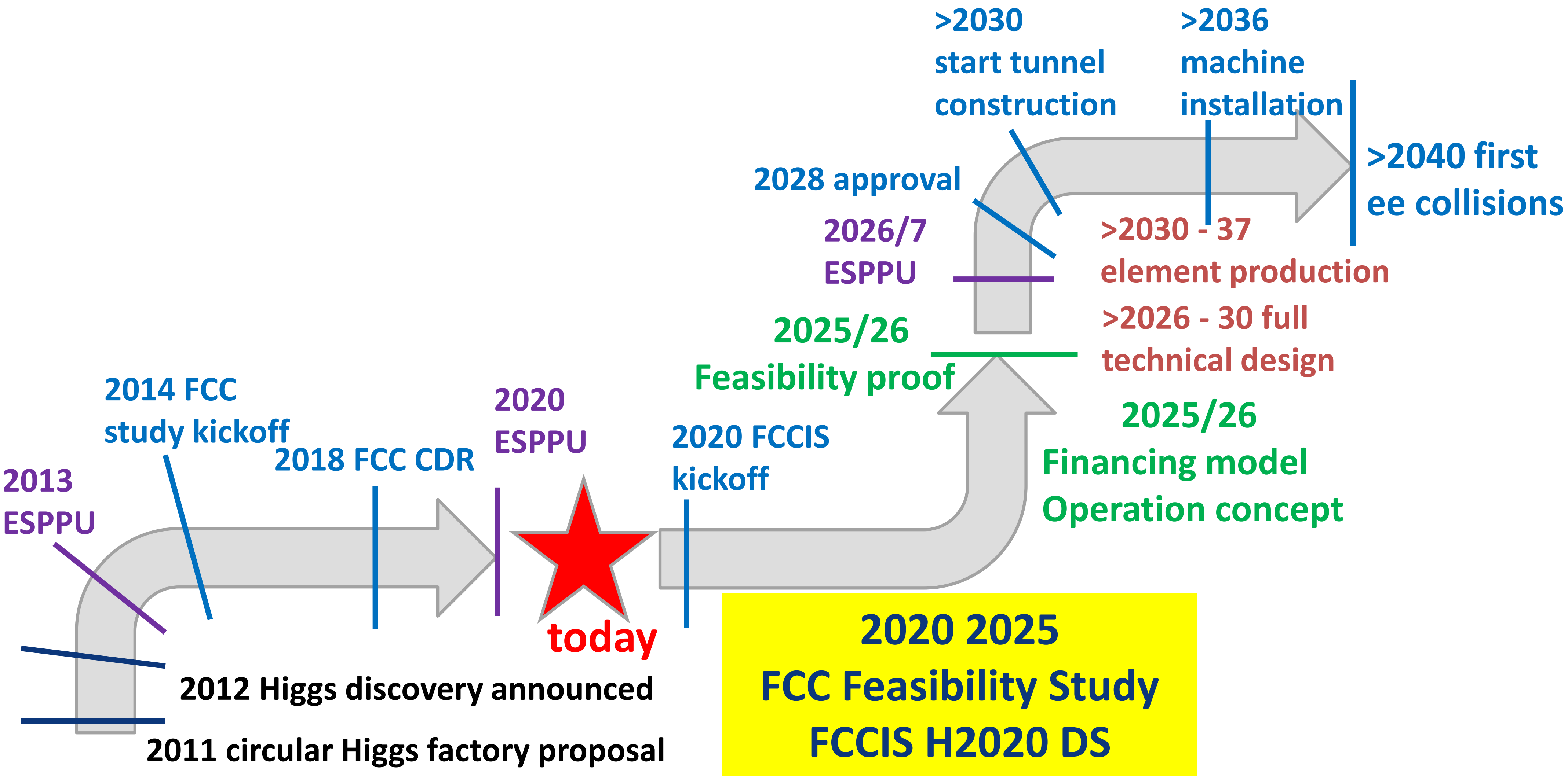
detailed design phase

**Workshop & Review: key technology R&D programs**

**FS Report**

**Release FSR**
**Project cost update**

# FCC Roadmap Towards Stage 1



2011 circular Higgs factory proposal

2012 Higgs discovery announced

2013
ESPPU

2014 FCC
study kickoff

2018 FCC CDR

2020
ESPPU

today

2020 FCCIS
kickoff

**2020 2025**
**FCC Feasibility Study**
**FCCIS H2020 DS**

2025/26
Feasibility proof

2025/26
Financing model
Operation concept

>2026 - 30 full
technical design

2026/7
ESPPU

2028 approval

>2030 - 37
element production

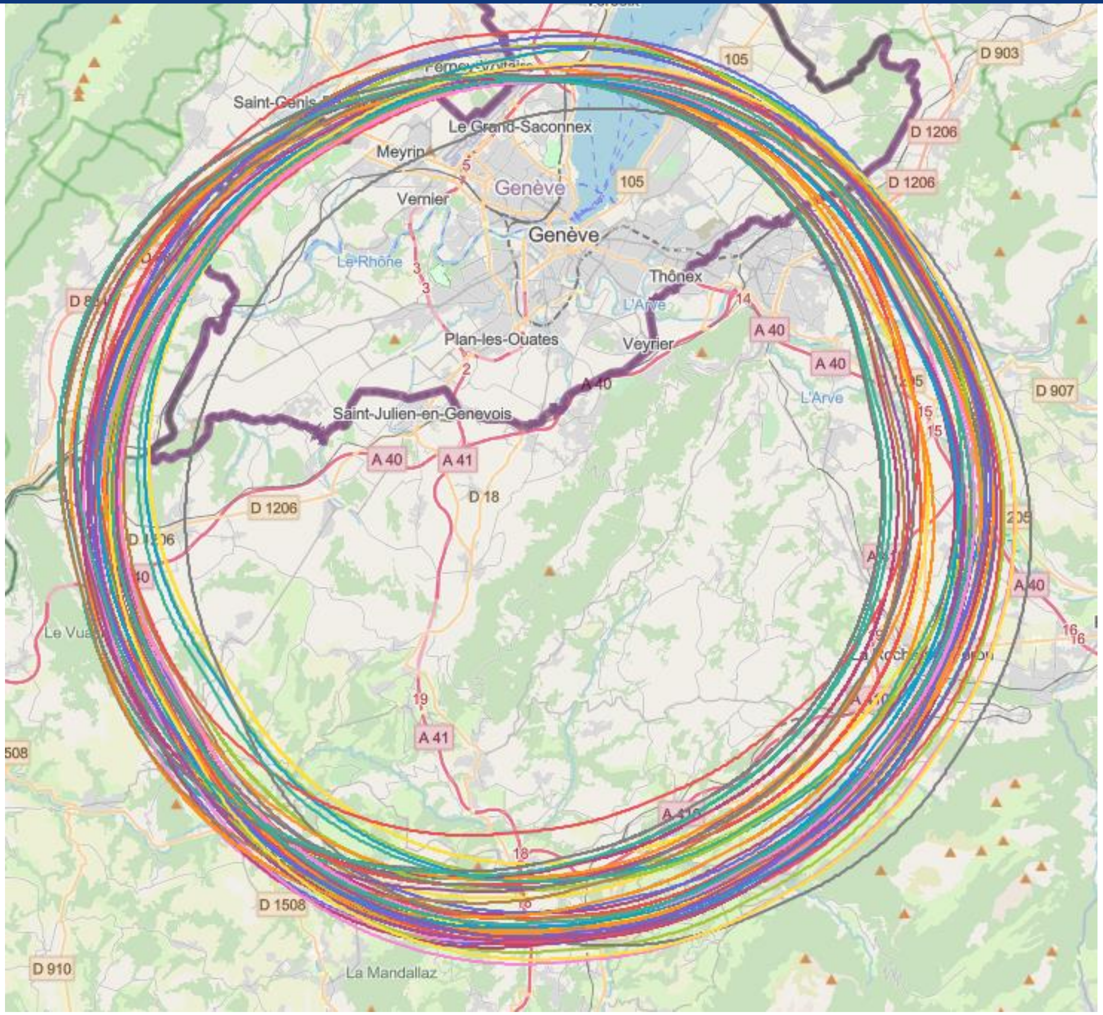
>2030
start tunnel
construction

>2036
machine
installation

>2040 first
ee collisions

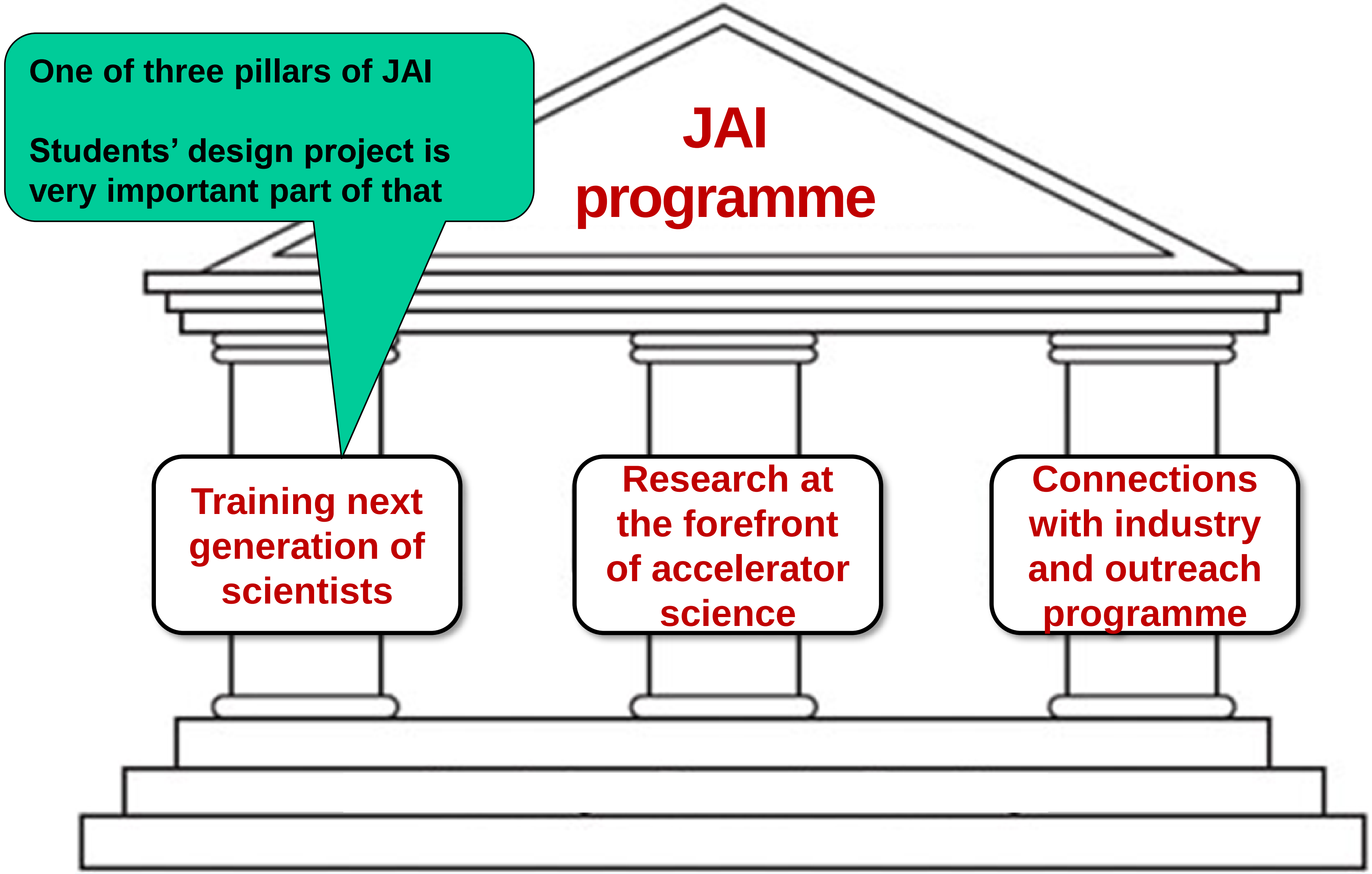
# Collider Placement Optimisation

- 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



# JAI Training

# Foundation of the JAI Programme



One of three pillars of JAI

Students’ design project is very important part of that

**JAI programme**

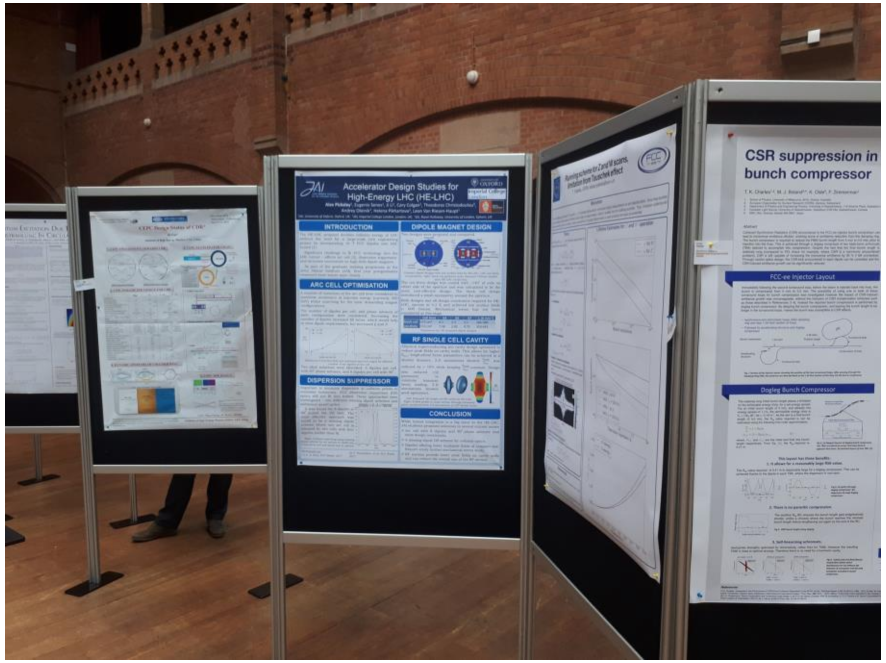
Training next generation of accelerator scientists

Research at the forefront of accelerator science

Connections with industry and outreach programme

# Accelerator Design Project 2017-2018

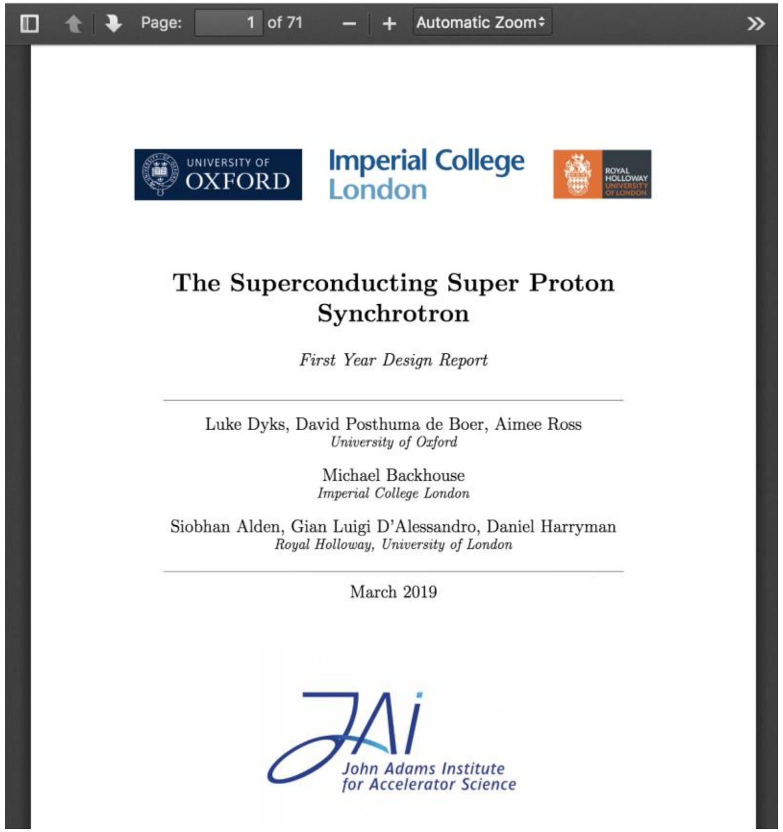
- **Accelerator Design Studies for the High-Energy LHC (HE-LHC) for 2017-2018**
  - **The aim of the 2017-2018 JAI student project work was to prepare a design for HE-LHC.**
  - **Design work consisted of study of the lattice, magnet systems and RF cavities.**
  - **Student presentations made at CERN in June 2018 (together with visits to accelerator facilities).**



HE-LHC Student Poster at FCC Week Amsterdam, April 2018

# Accelerator Design Project 2018-2019

- **Accelerator Design Studies for the Superconducting SPS (scSPS) for 2018-2019**
  - **The aim of the 2018-2019 JAI student project work was to prepare a design for the scSPS.**
  - **Design work consisted of study of the lattice, magnet systems and RF cavities.**
  - **Student presentations made at JAI Advisory Board in April 2019 and at CERN in June 2019 (together with visits to accelerator facilities).**



UNIVERSITY OF OXFORD Imperial College London ROYAL HOLLOWAY UNIVERSITY OF LONDON

The Superconducting Super Proton Synchrotron

*First Year Design Report*

Luke Dyks, David Posthuma de Boer, Aimee Ross
*University of Oxford*

Michael Backhouse
*Imperial College London*

Siobhan Alden, Gian Luigi D'Alessandro, Daniel Harryman
*Royal Holloway, University of London*

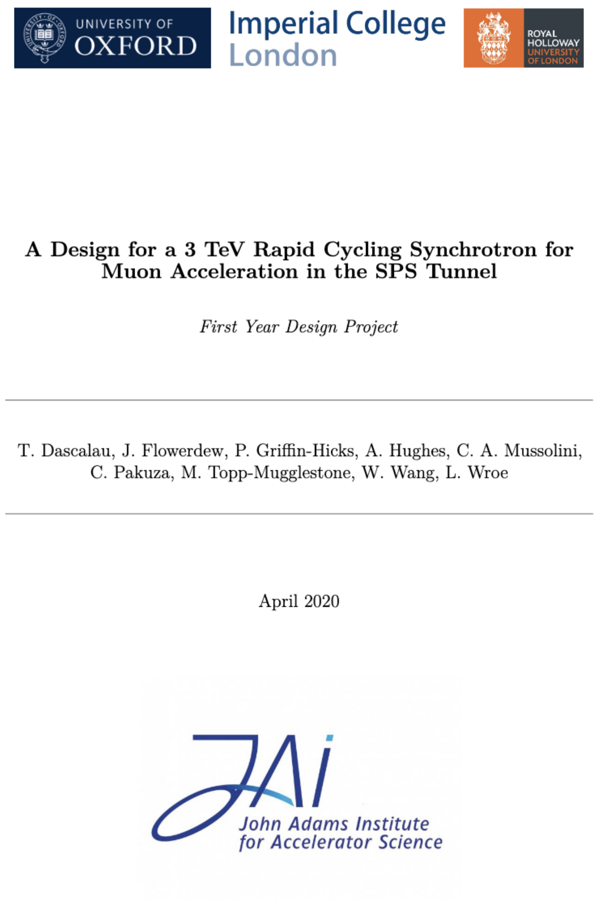
March 2019

John Adams Institute for Accelerator Science

scSPS Student Publication
*cds.cern.ch*

# Accelerator Design Project 2019-2020

- **Accelerator Design Studies for the Muon Collider for 2019-2020**
  - **The aim of last year’s JAI student project work was to prepare a design for the 3 TeV RCS for Muon Acceleration in the SPS tunnel.**
  - **Design work consisted of study of the lattice, magnet systems and RF cavities.**
  - **Student presentation as a JAI Seminar. (Due to COVID-19 pandemic, presentations to JAI Advisory Board and at CERN were not possible).**



UNIVERSITY OF OXFORD Imperial College London ROYAL HOLLOWAY UNIVERSITY OF LONDON

A Design for a 3 TeV Rapid Cycling Synchrotron for Muon Acceleration in the SPS Tunnel

*First Year Design Project*

T. Dascalau, J. Flowerdew, P. Griffin-Hicks, A. Hughes, C. A. Mussolini, C. Pakuza, M. Topp-Mugglestone, W. Wang, L. Wroe

April 2020

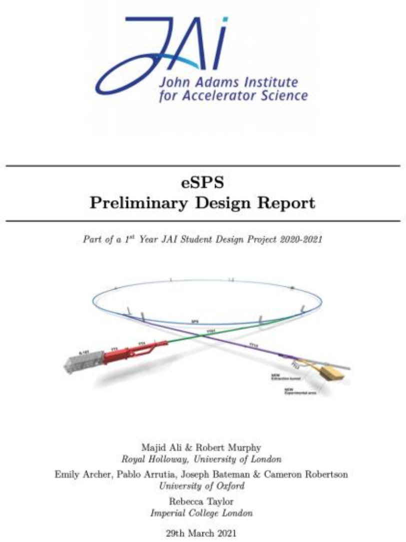
John Adams Institute for Accelerator Science

JAI Student Design Project Publication

*cds.cern.ch*

# Accelerator Design Project

- Accelerator Design Study for
  - Electron SPS: 2020-2021
  - Design work consisted of study of the lattice, magnet systems and RF cavities.
- Student visits and presentations at CERN delayed due to Covid-19.



John Adams Institute
for Accelerator Science

eSPS
Preliminary Design Report

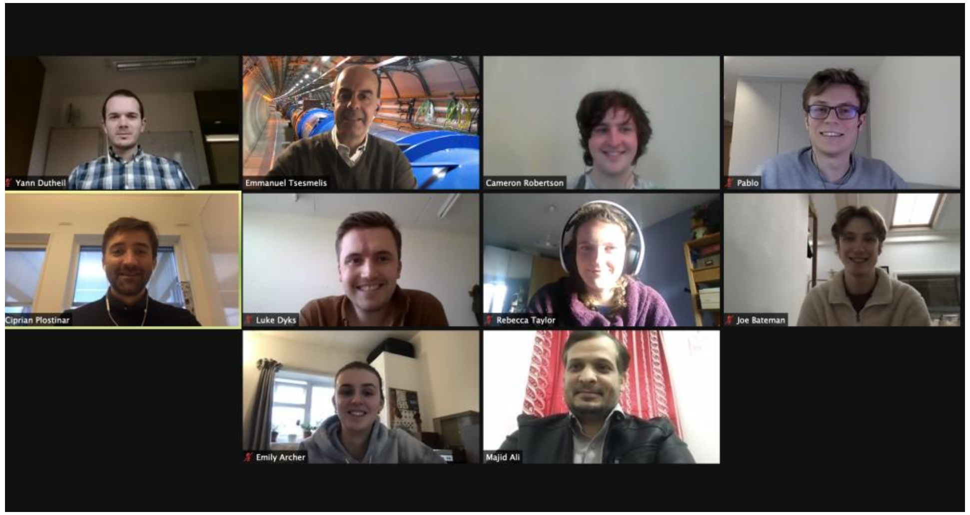
*Part of a $1^{st}$ Year JAI Student Design Project 2020-2021*

Majid Ali & Robert Murphy
*Royal Holloway, University of London*
Emily Archer, Pablo Arrutia, Joseph Bateman & Cameron Robertson
*University of Oxford*
Rebecca Taylor
*Imperial College London*
29th March 2021

eSPS Design Report published
on CDS **(DOI 10.17181/CERN.Q29A.V5M6)**
& delivered JAI Seminar (Zoom)

*“The design project significantly contributes to the value of a PhD at the JAI, and is a very effective learning tool ... it played an essential role in helping me to find a postdoc.”*

*“To me, the design project was by far the best part of the course. It puts the material taught into context and bridges the gap between lectures ... and a DPhil project ... .”*



# FCC-ee Student Design Project Plan

- **Optics Studies**
  - **Study various lattice options.**

- **Magnet Design**
  - **Optimise dipole and quadrupole magnets.**

- **RF System**
  - **Design RF system.**

- **Overall parameter tables and sub-system inventory**

FUTURE
CIRCULAR
COLLIDER

**Thank you**