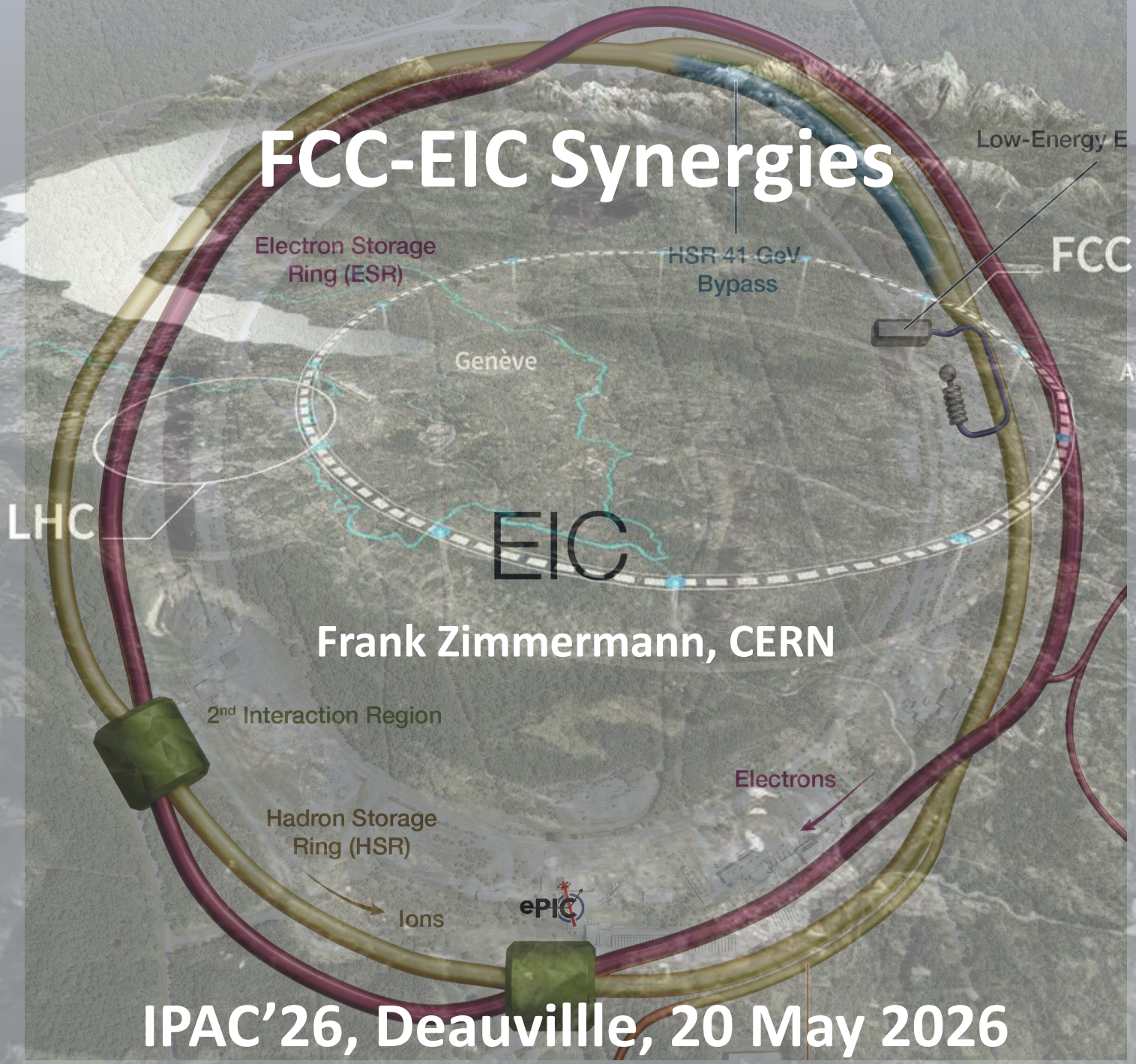
FCC-EIC Synergies

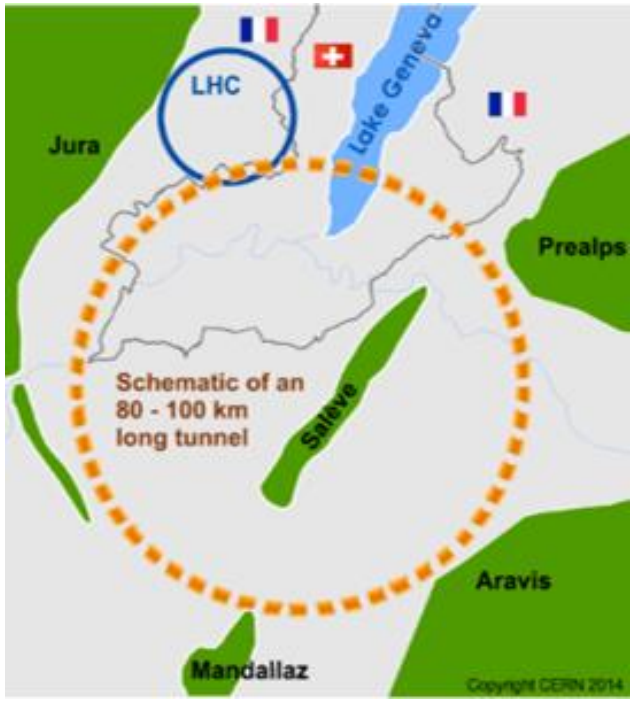


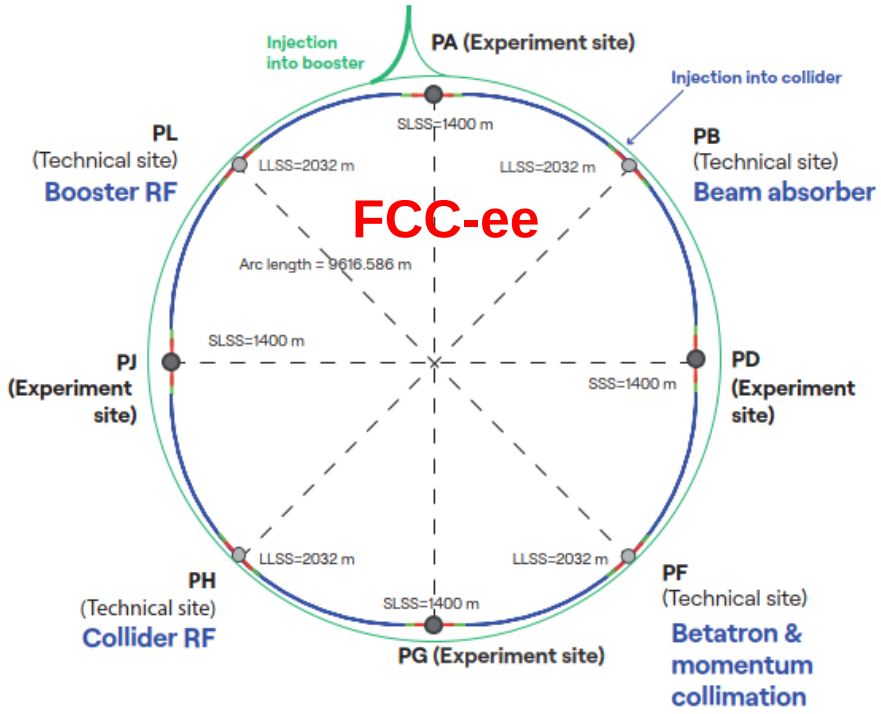
Frank Zimmermann, CERN

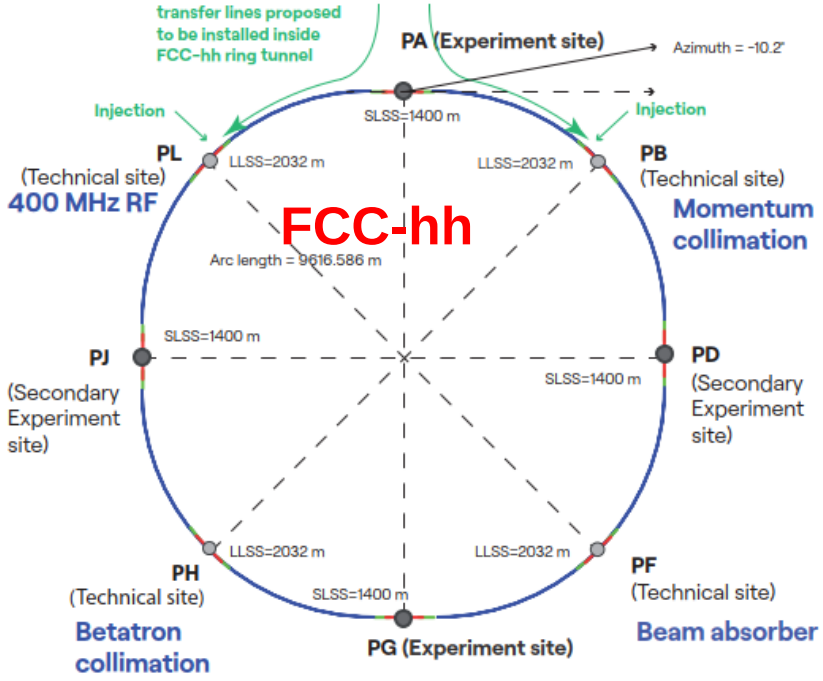
IPAC'26, Deauvillle, 20 May 2026

Future Circular Collider integrated program – scope

- **stage 1: FCC-ee (Z, W, H, tt̄) 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 maximising the physics opportunities
- 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 - 2045 | 2048 - 2062 | ~2075 - ~2100

FUTURE CIRCULAR COLLIDER

FCC-ee basic design choices and performance

- **Double ring** e^+e^- collider, allowing many bunches, high current, like LHC and B factories, different from LEP
- **Synchrotron radiation power 50 MW/beam** at all beam energies. Energy loss ΔE per turn:

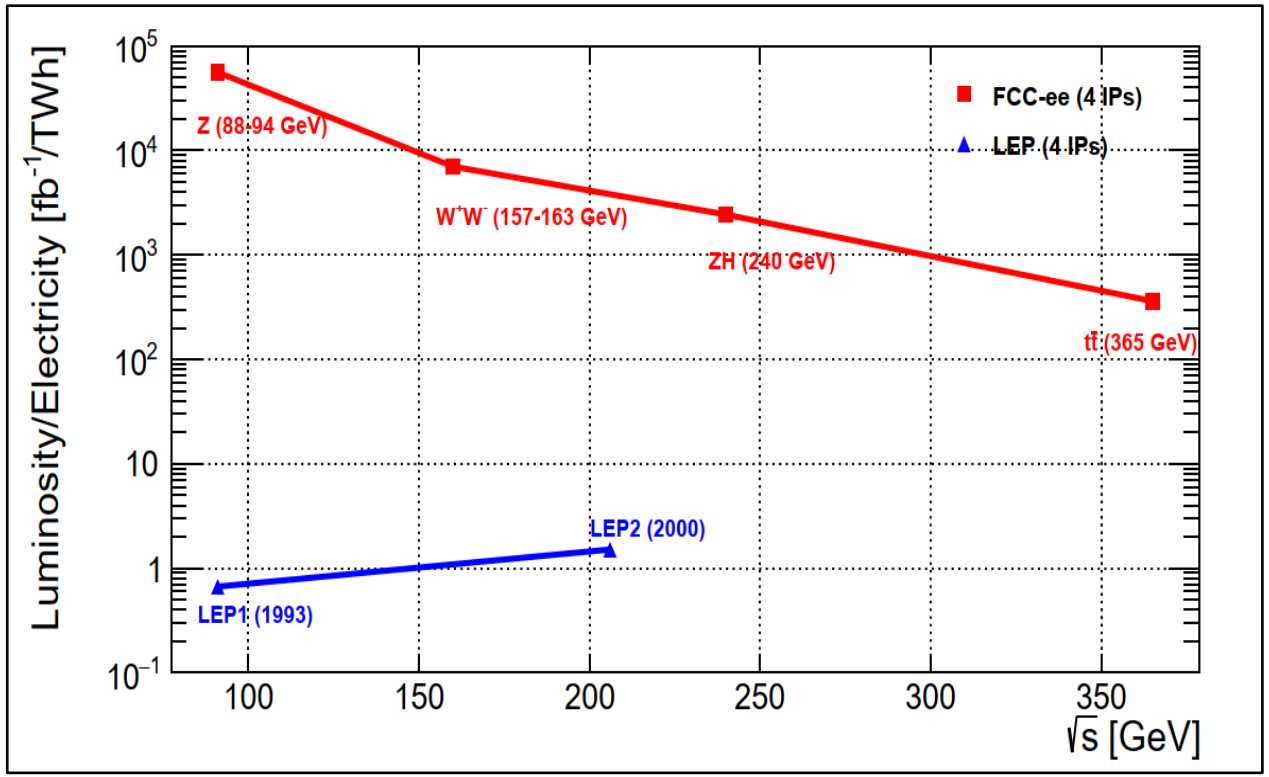
$$\Delta E \sim \gamma^4/\rho = (E/m_0)^4/\rho$$

- **Asymmetric IR layout** and optics to **limit synchrotron radiation towards the detector** and to provide **large** horizontal crossing angle **30 mrad for crab-waist collision optics,** demonstrated at DAFNE (Italy) and SuperKEKB (Japan)
- **Top-up injection** scheme as at modern light sources (APS, SLS,…) and as at recent e^+e^- colliders, PEP-II (USA), KEKB & SuperKEKB (Japan), BEPCII (China), requires **booster synchrotron in collider tunnel**

Combining concepts from past and present lepton colliders and using high-efficiency SRF system results in a giant step in efficiency:

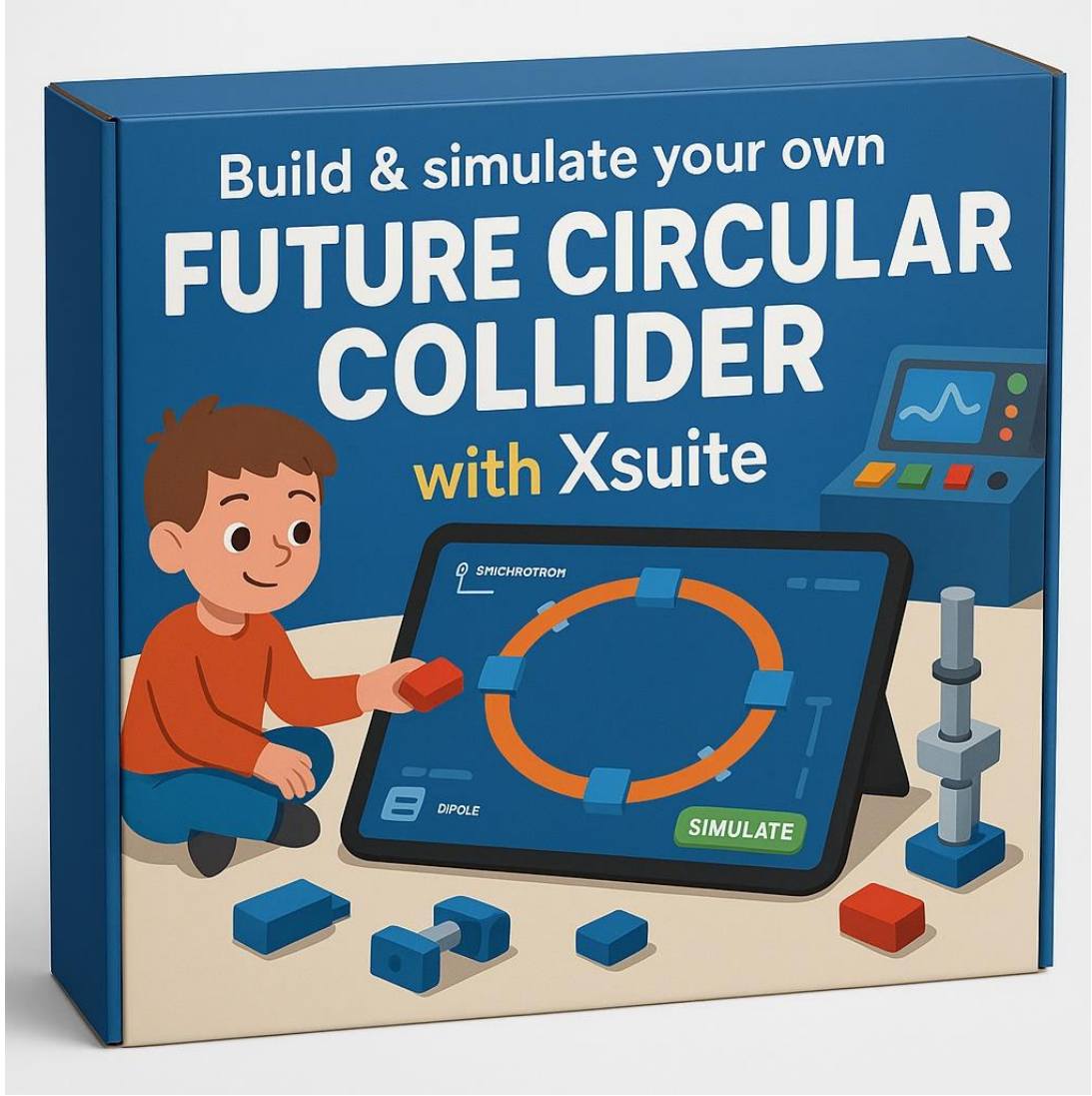
→10^4–10^5x luminosity/el.energy of LEP

→ sustainable physics



FCC design with Xsuite

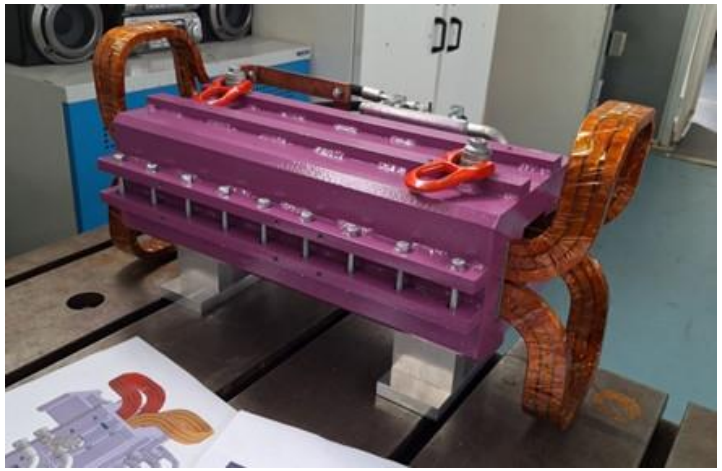
Powerful modular modern successor of MAD-8 (LEP design) and MAD-X (LHC design) etc.



tutorials in form of Jupyter notebooks

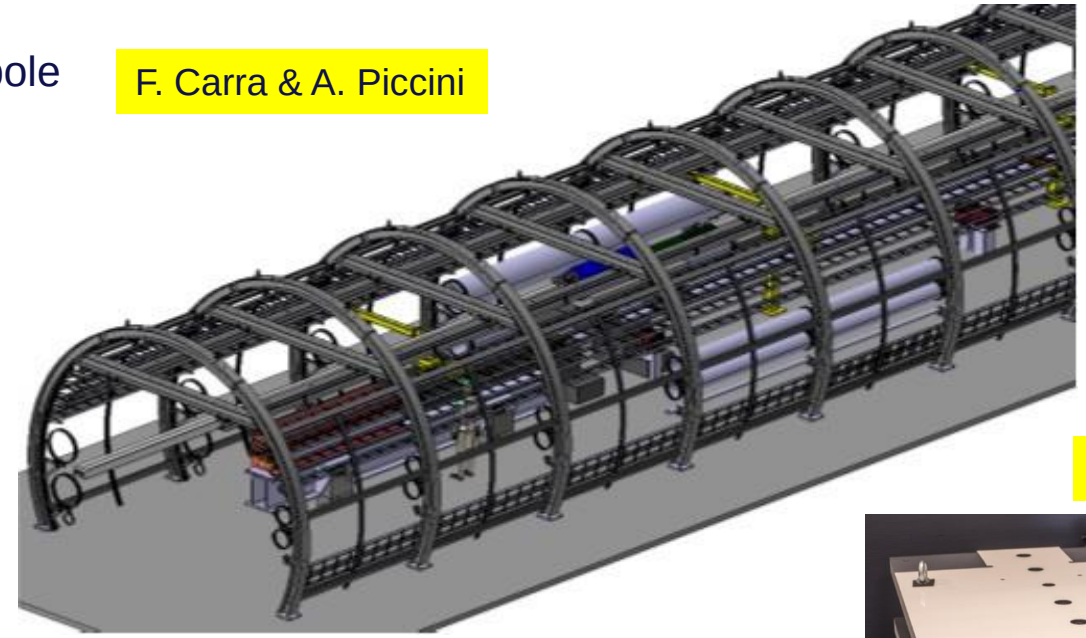
G.

R&D on arc magnets, girders, cavities, prototypes, mock-ups



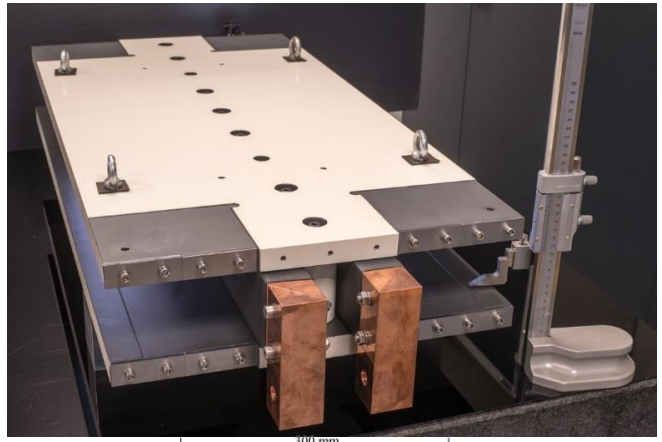
Booster dipole low-field cycling magnet

F. Carra & A. Piccini

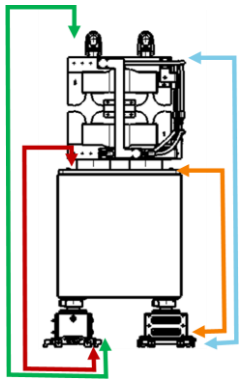


Arc half-cell = the most repeated region of mechanical hardware in the tunnel: → ***77 km over 90 km are arc cells***

A. Milanese

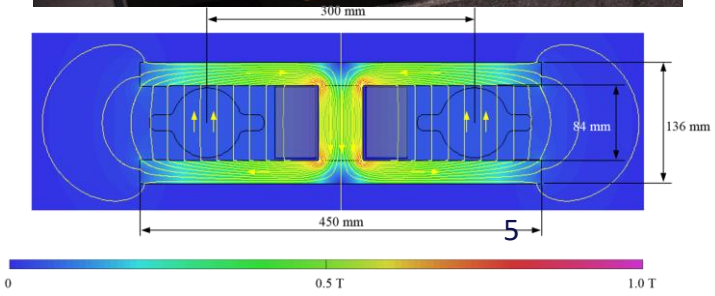


800 MHz bulk Nb 5-cell cavity
Prototype fulfilling FCC specs
JLAB, F. Marhauser



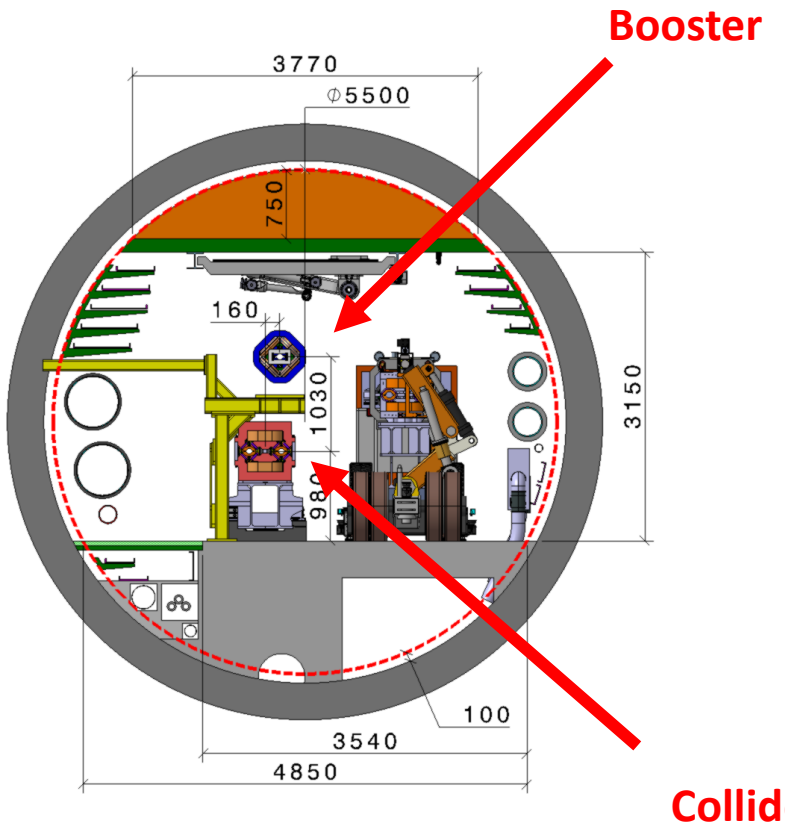
Vibration studies with girder on PSI jacks

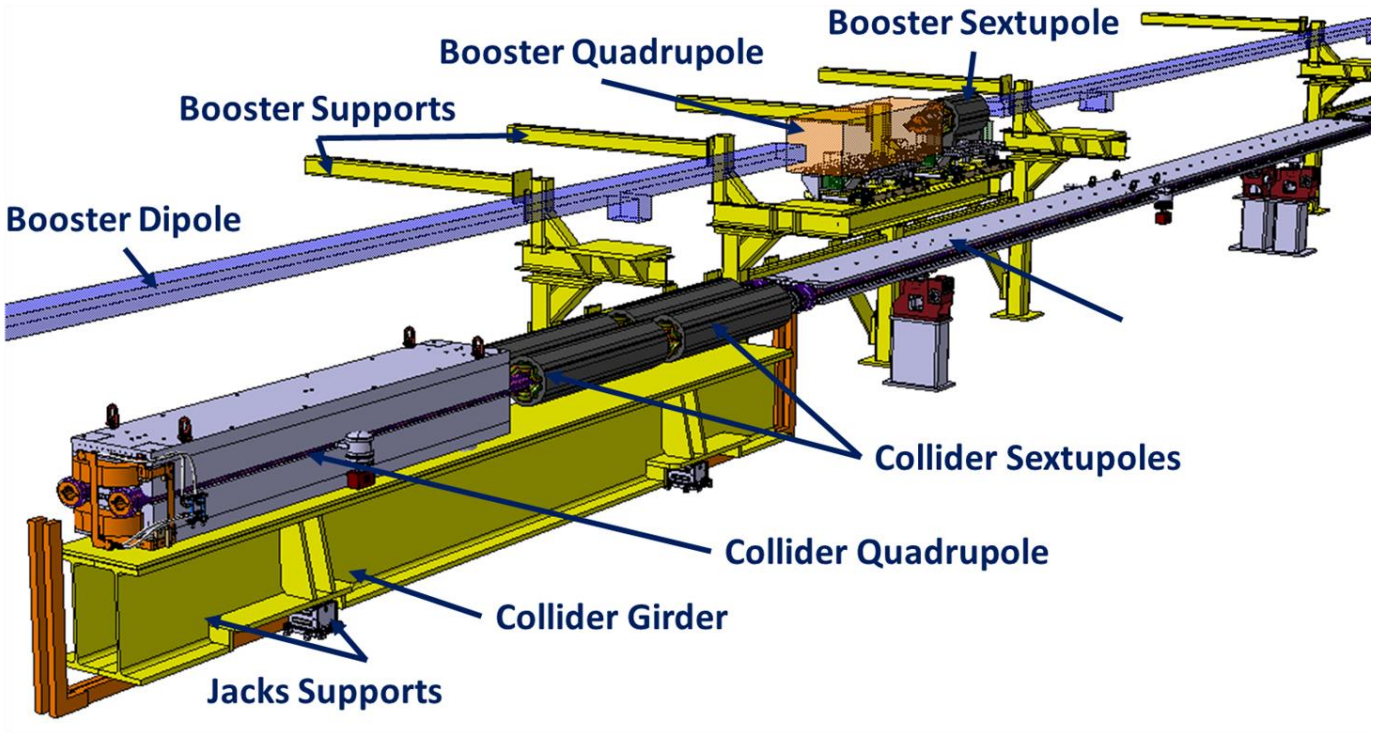
Twin-dipole design with 2× power saving
16 MW
(at 175 GeV)



FCC-ee booster

full energy booster, ramping from 20 GeV to 46 GeV – 182.5 GeV; injection ~several times per minute to keep collider beam currents constant; booster intensity ~1% of collider; full RF voltage as in collider





Territorial dialogue and public participation

First cycle of public information meetings completed (April 2024 – March 2025)

11 sessions reached over 1,500 people in France & Switzerland

During 2025:

Second cycle of **public information meetings**.

Presence days in municipalities affected by surface sites to enable discussion with habitants.

Meetings with stakeholders of the territory.

- *First dialogue and exchange meeting with local environmental associations, 5 may, 2025*

Dialogue Website

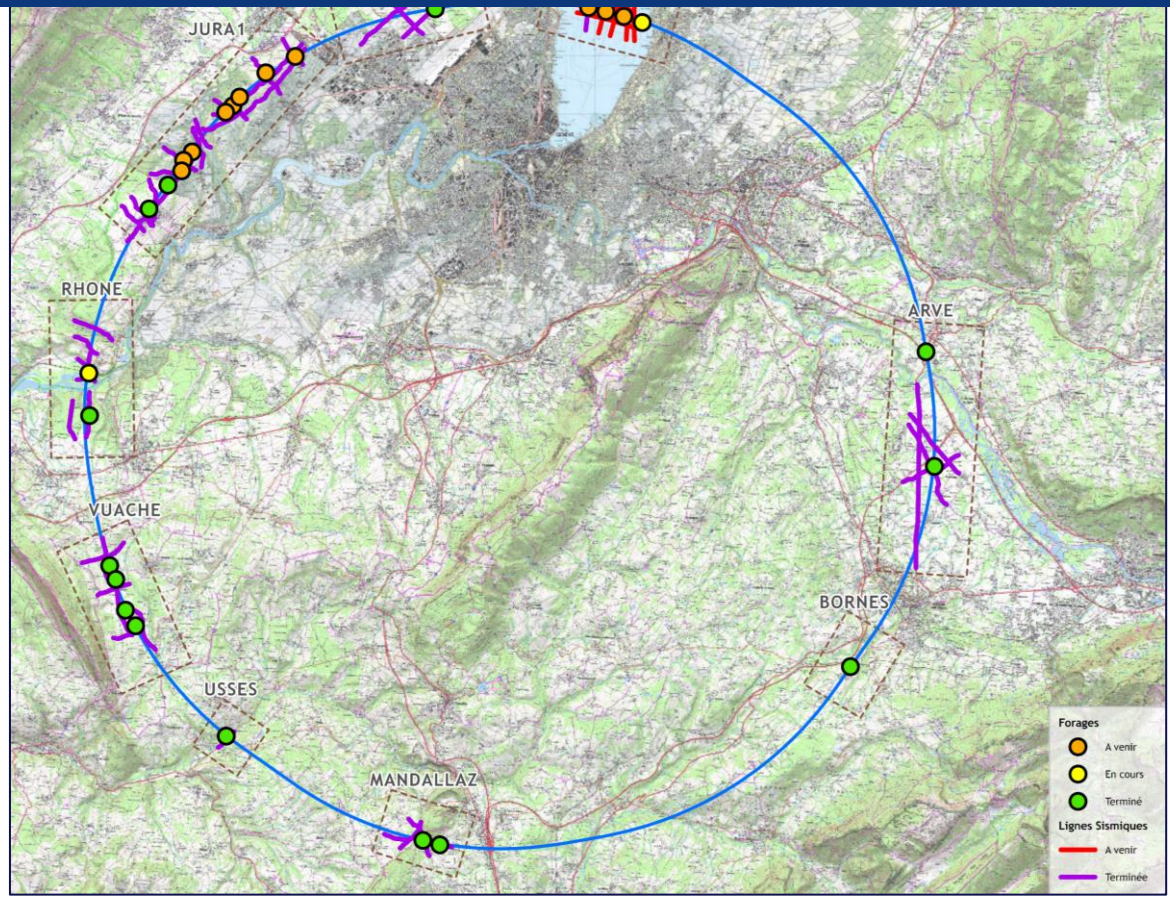
During 2026:

Formal public participation process planned in France (Débat Public) and Switzerland (public concertation).

FUTURE CIRCULAR COLLIDER

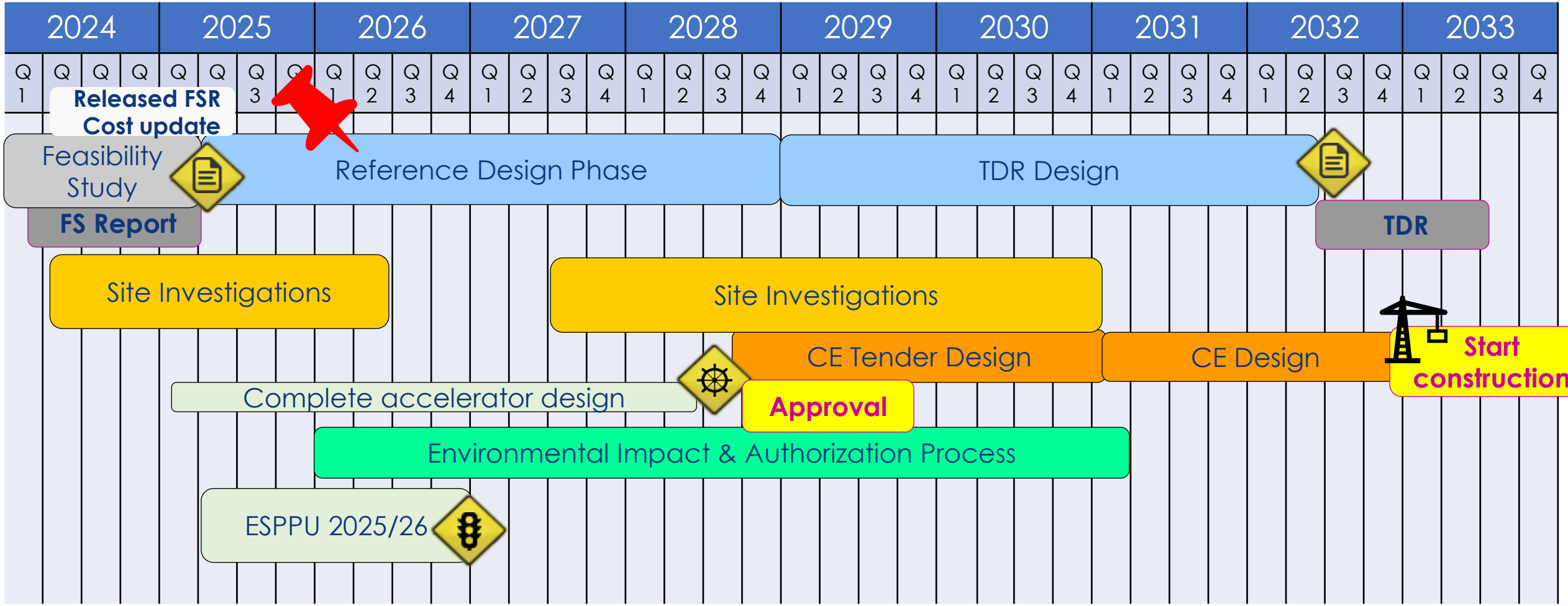
Geological investigations

- Focused on 8 zones to improve precision of geological model and identify the interfaces moraine – molasse and molasse – limestone
- **86 km of seismic investigations completed**
- **15 of 27 bore holes completed**
- **1st lake bore hole completed**
- **Completion of all bore holes ~June 2026**
- Results so far confirm geological model



FUTURE CIRCULAR COLLIDER

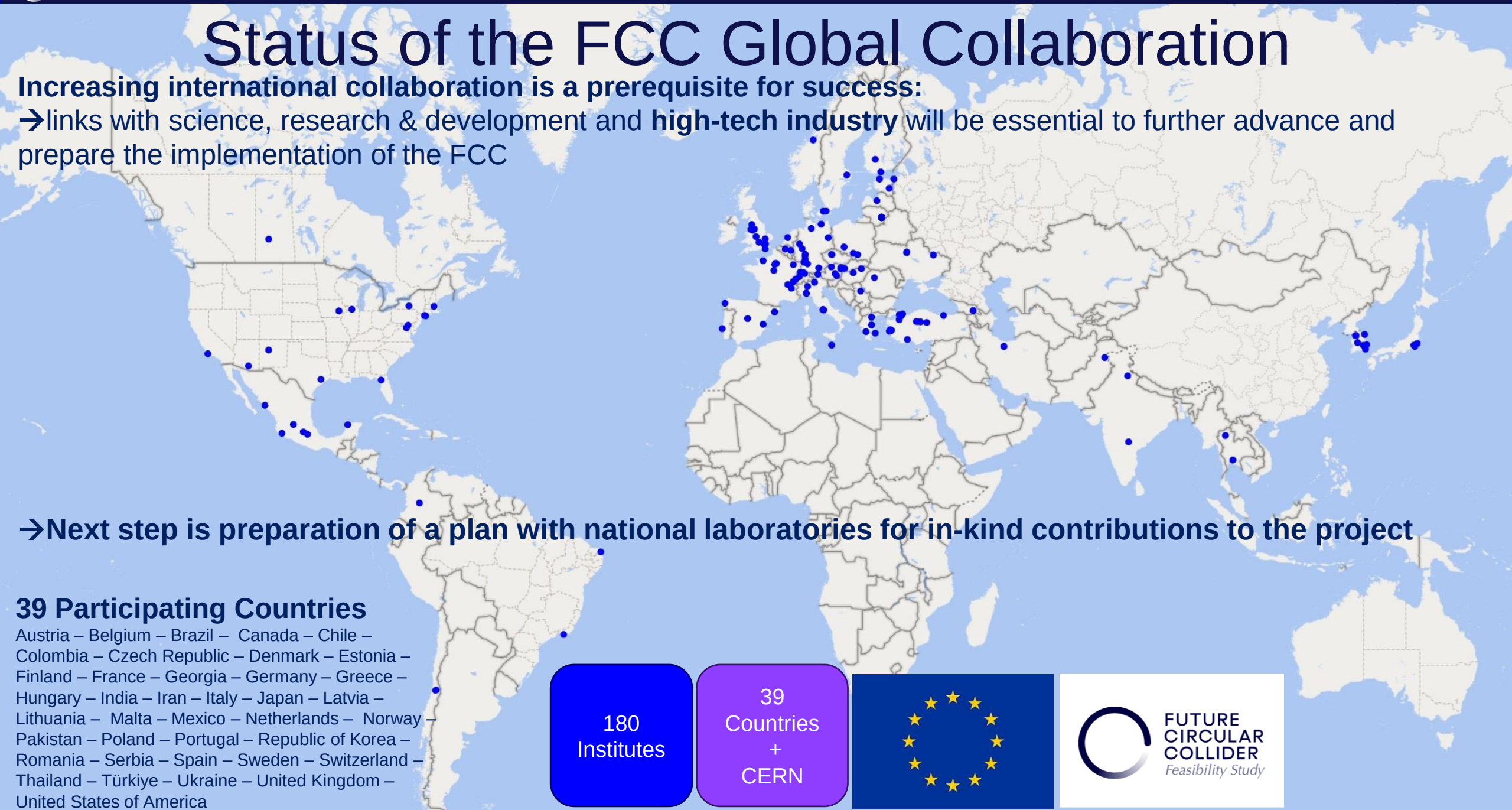
timeline till start of construction



Status of the FCC Global Collaboration

Increasing international collaboration is a prerequisite for success:

→links with science, research & development and **high-tech industry** will be essential to further advance and prepare the implementation of the FCC



→Next step is preparation of a plan with national laboratories for in-kind contributions to the project

39 Participating Countries

Austria – Belgium – Brazil – Canada – Chile – Colombia – Czech Republic – Denmark – Estonia – Finland – France – Georgia – Germany – Greece – Hungary – India – Iran – Italy – Japan – Latvia – Lithuania – Malta – Mexico – Netherlands – Norway – Pakistan – Poland – Portugal – Republic of Korea – Romania – Serbia – Spain – Sweden – Switzerland – Thailand – Türkiye – Ukraine – United Kingdom – United States of America

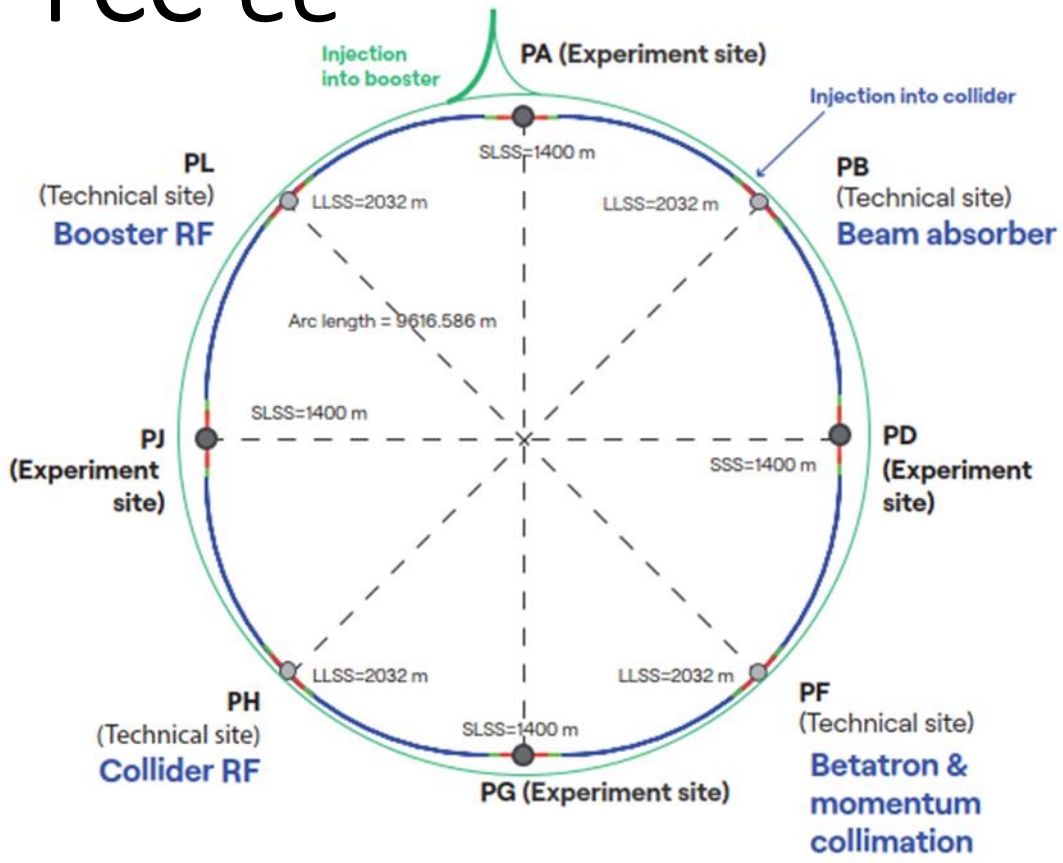
180 Institutes

39 Countries + CERN

FUTURE CIRCULAR COLLIDER *Feasibility Study*

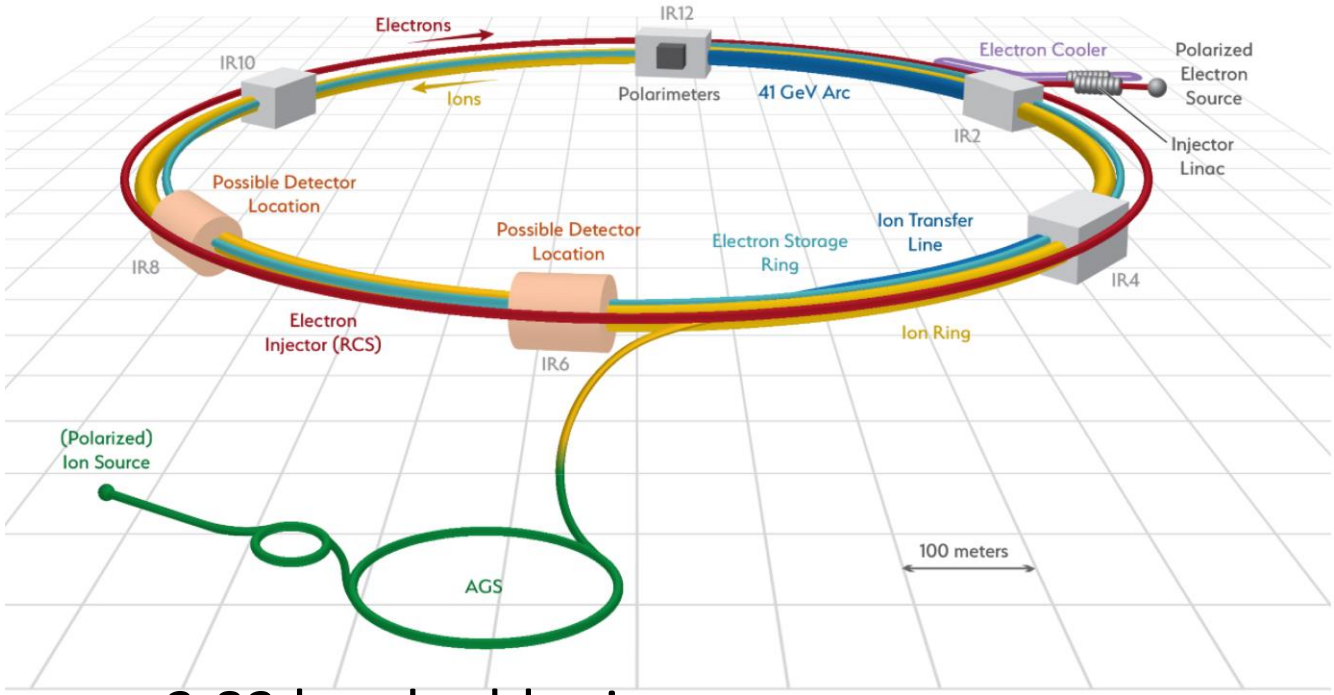
FCC & EIC similarities

FCC-ee



90.7 km double ring, full-energy $e^{\pm}$ injection,
> 1 A beam current (at the Z),
injection rate Hz, every min. into same bucket,
polarised $e^{\pm}$ pilot bunches

EIC



3.83 km double ring,
full-energy e^{-} injection,
> 2 A beam current (at 10 GeV)),
injection rate 1 Hz,
every 1 or 3 min into same bucket,
polarised e^{-} pilot bunches

FUTURE CIRCULAR COLLIDER

Electron Ion Collider (EIC)

Brookhaven National Laboratory

Jefferson Lab

US EIC Electron Storage Ring similar to, but more challenging than, FCC-ee

beam parameters almost identical, but twice the maximum electron beam current, or half the bunch spacing, and lower beam energy

	EIC	FCC-ee-Z
Beam energy [GeV]	**10 (18)**	**45.6 (80)**
Bunch population [10^{11}]	**1.7**	**2.2**
Bunch spacing [ns]	**10**	**25**
Rms bunch length [mm]	**20**	**15.2 (w BS)**
Beam current [A]	**2.5 (0.23)**	**1.29**
Beam-beam tune shift $\xi_{x,y}$	**0.073/0.1**	**0.002/0.1**
RF frequency [MHz]	**591**	400→**600 ?**
SR power/beam/meter [W/m]	**3000**	**650**
Critical photon energy [keV]	**6.2 (36)**	**20 (106)**

>10 areas of common interest identified by the FCC and EIC design teams, which had been meant to be addressed through **joint EIC-FCC working groups** – mostly not really active

EIC will start beam operation about a decade prior to FCC-ee

The EIC will provide another invaluable opportunity to train next generation of accelerator physicists on an operating collider, to test hardware prototypes, beam control schemes, etc.

CERN FCC – EIC collaboration, contact persons - *to be updated*

Domain	CERN/FCC contacts	BNL/EIC contacts	JLAB/EIC contacts	Other contacts FCC	Other contacts EIC
impedance model, instabilities, HOM, ion instability	Mauro Migliorati (INFN), Ivan Karpov (CERN)	Mike Blaskiewicz, Alexei Blednykh, Silvia Verdu (?)	Todd Satogata	Alexander Novokhatski (SLAC)	
polarization	Jorg Wenninger (CERN), Jacqueline Keintzel (CERN)	Vadim Ptitsyn	Todd Satogata	Eliana Gianfelice (FNAL), Guy Wilkinson (Oxford)	
beam instrumentation, SR monitors (BPMs)	Thibaut Levefre (CERN), ~~Manfred Wendt (CERN)~~	David Gassner, Dany Padrazo	Todd Satogata	Anke Susanne Mueller (KIT)	
beam feedback systems	Wolfgang Hofle (CERN)	Mike Blaskiewicz (BNL) Another ?	Todd Satogata	John Fox (SU)	
vacuum system	~~Roberto Kersevan~~, Cedric Garion (CERN)	Charles Hetzel	Mark Wiseman		
final focus quadrupoles		Brett Parker, Holger Witte	~~Walter Wittmer~~	Mike Koratzinos (~~MIT,~~ PSI)	
SRF	~~Erk Jensen~~, Frank Gerigk, (CERN)	Kevin Smith	Robert Rimmer		
MDI, IR shielding, handling equipment associat'd w IR	Manuela Boscolo (INFN), Helmut Burkhardt (CERN)	Holger Witte	~~Walter Wittmer~~	Mike Sullivan (SLAC), John Seeman (SLAC)	
Collimation – beam tails	~~Andrey Abramov (CERN),~~ Roderik Bruce (CERN)			Dmitry Shatilov (~~BINP,~~ NIU~~)~~	
Beam-beam interactions (limits with multiple IPs)	Xavier Buffat (CERN)			Dmitry Shatilov (~~BINP~~, NIU)	

FUTURE CIRCULAR COLLIDER

FCC-EIC Joint Working Meetings

1st working meeting EIC-FCC on polarized beam operation

- CERN, 19-23 September 2022, in conjunction with the 2nd FCC EPOL workshop https://indico.cern.ch/event/1181966/

2nd FCC-EIC joint working meeting on beam dynamics, stability, impedances, feedback, vacuum and MDI

- CERN, 17-21 October 2022, in conjunction with the FCC-ee MDI working meeting https://indico.cern.ch/event/1186798/

2nd FCC Polarisation workshop

- CERN, 19-30 Sept. 2022, https://indico.cern.ch/event/1181966

V. Ranjbar: EIC e-Injector Polarization; E. Gianfelice: EIC esr Polarization; M. Signorelli: EIC ESR Tracking Studies; V. Ptitsin: Physics with polarized beams at the EIC; F. Zimmermann, V. Ptitsin: Synergies EIC-FCC

3rd FCC-FNAL-US joint working meeting on SRF

- FNAL, 29-30 March 2023 800 MHz RF cavities, SRF Cryomodules, SSA, HOMs

FUTURE CIRCULAR COLLIDER

topics of common interest

simulation code development

- collaboration on Xsuite
- code benchmarking

polarisation

- simulation & code development
- suppressing spin resonance
  - lattice design
  - knobs: harmonic spin matching
- polarisation transport thru booster
- resonant depolarisation & spin flip
- coherent spin precession as tool
- beam-beam effect on polarisation
- polarimetry
  - integration, detector, bkgd, laser

MDI concepts & simulations

- IR optics, IR magnet design
- mechanical integration
- beam losses and SR in the MDI
- collimation, detector backgrounds
- tuning, mechanical stabilization
- impedance, heat load evaluation
- det. solenoid compensation scheme

accelerator design & beam dynamics

- DA, tolerances, machine learning
- mechanical alignment & BBA
- impedance, collective effects, e-cloud
- sudden beam loss events as in SKEKB
- machine protection

FUTURE CIRCULAR COLLIDER

more topics of common interest

injector

- S-band linac & S-band rf structures (FCC/PSI, EIC)
- polarised e- source

SRF

- RF cavities (2-cell?)
- RF power source
  - tristron R&D

beam diagnostics

- BPMs
- BLM system
- emittance measurements, halo
- bunch length measurement
- polarimeters & lasers

MDI hardware

- final quadrupole technology & production, cryostat design
- choice of IR cryogenic temperature

vacuum systems

- automated production & NEG coating

beam-intercepting devices

- primary, secondary & tertiary collimators – design & materials
- collision debris collimators
- protection devices, beam dumps

training

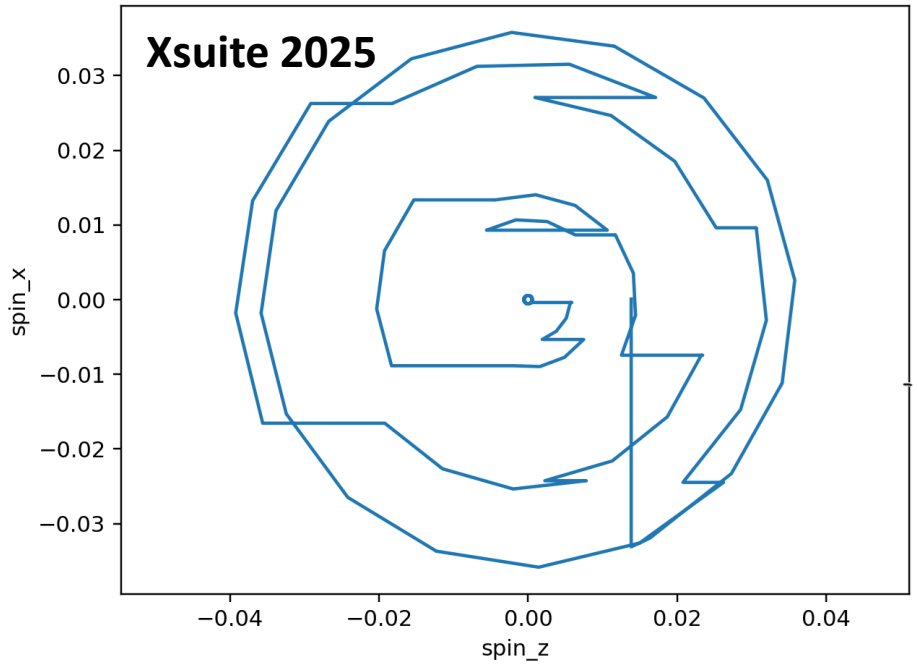
- working visits of young scientists

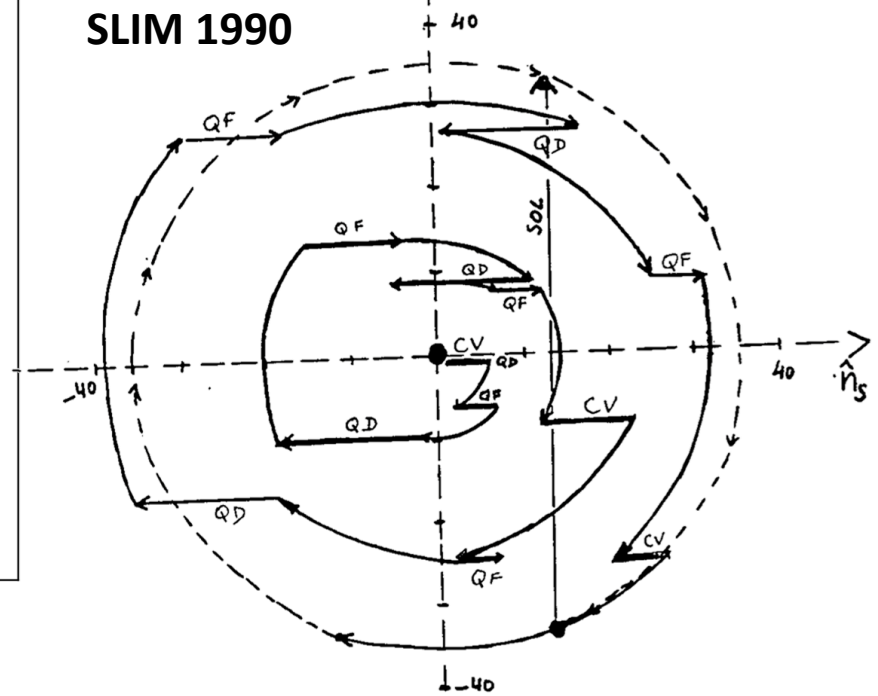
spin tracking: a success story

spin tracking implemented in Xsuite !

tests,
benchmarking,
and first simulation studies ongoing

Benchmarking case of **LEP1** with orbit bumps to compensate precession in the experimental solenoids → **good agreement** found against SLIM simulations





Compensation of Integer Spin Resonances Created by Experimental Solenoids

Alain Blondel

L. P. N. H. E., Ecole Polytechnique, 91128 Palaiseau Cedex, France

22 April 1990

G. Iadarola,
K. Hock,
Y. Wu,
J. Keintzel,
T. Pieloni,
J. Wenninger

17

conclusions & outlook

- a lot of FCC-EIC synergies in many areas & mutual interest to collaborate
- formal agreement between CERN and DOE/NP on EIC upcoming ?
- CERN/FCC has agreement for HEP and with DOE Office of Science
- may common successful work on Xsuite usher in a new era ?
- suggest continuing joint effort on polarisation and adding themes:
  - S-band linac
  - collimator design
  - beam-beam studies
  - electron-cloud studies
  - MDI ?, beam diagnostics ?
  - mechanical alignment ? e^- polarimetry ?

Next satellite event in Detroit!?