FCC-Innovation Study (FCC-IS)

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Riunione della DA con Resp. di servizio, Capi Progetto e Direttore
30 settembre 2021

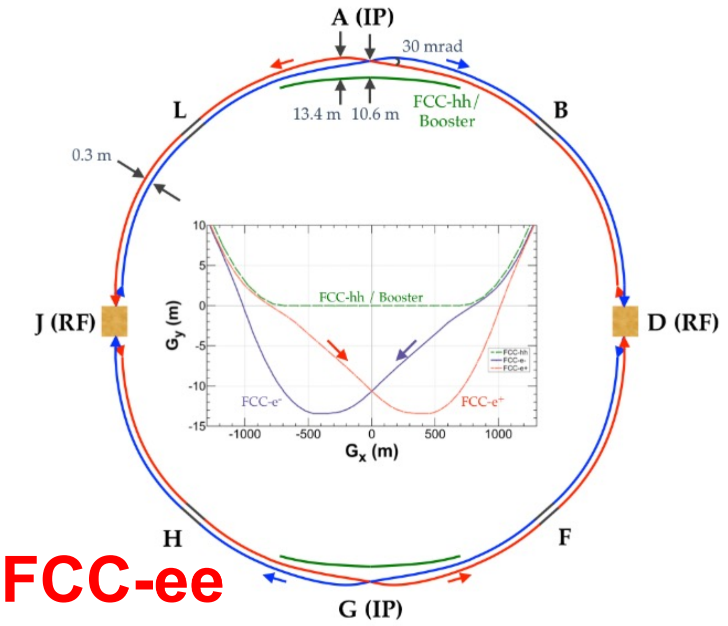
INFN
LNF
Istituto Nazionale di Fisica Nucleare

The FCC integrated program inspired by successful LEP – LHC programs at CERN

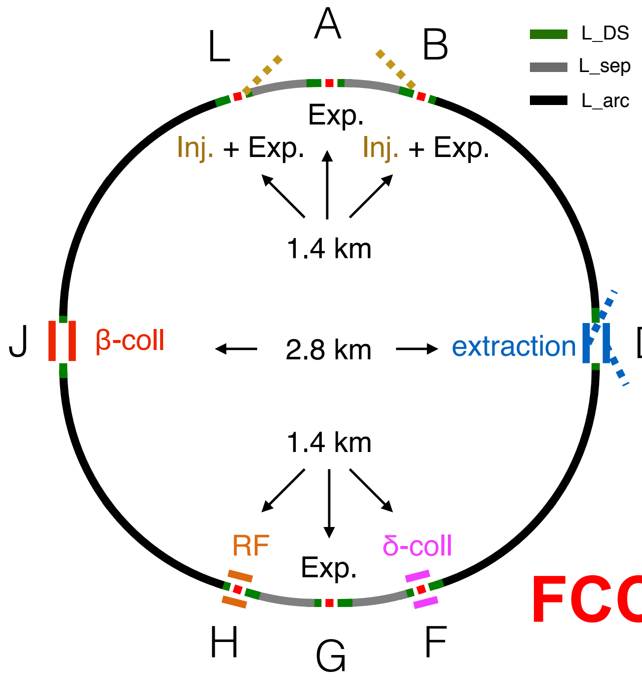
FUTURE CIRCULAR COLLIDER

Comprehensive long-term program, maximizing physics opportunities

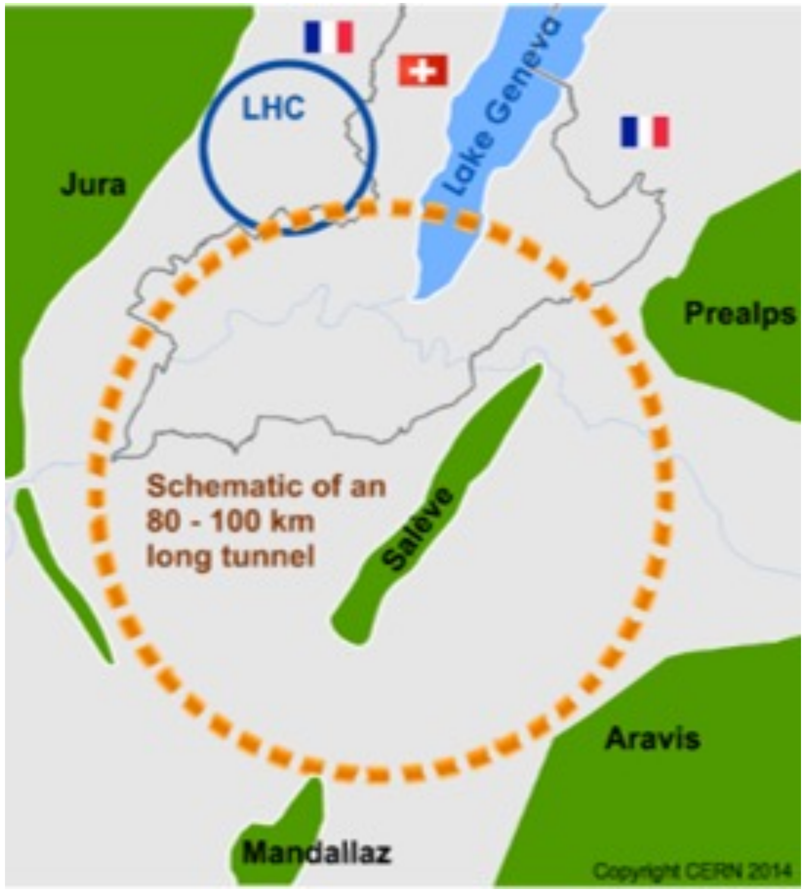
- **Stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & and top factory at highest luminosities**
- **Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options**
- Complementary physics
- Common civil engineering and technical infrastructures
- Building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of HEP after HL-LHC



FCC-ee



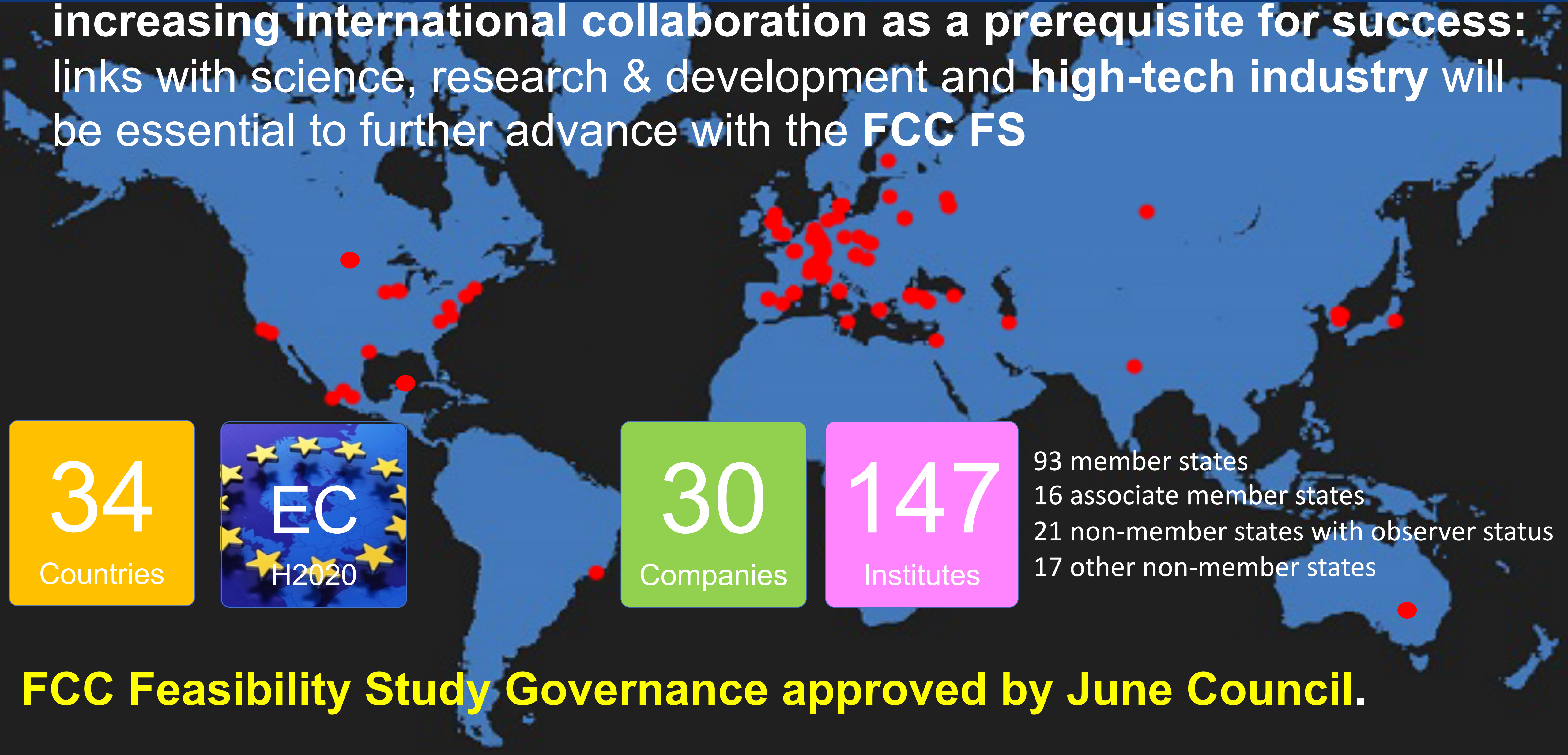
FCC-hh



Status of Global FCC Collaboration

FUTURE CIRCULAR COLLIDER

increasing international collaboration as a prerequisite for success: links with science, research & development and **high-tech industry** will be essential to further advance with the **FCC FS**



34 Countries

EC H2020

30 Companies

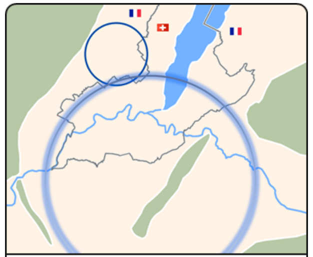
147 Institutes

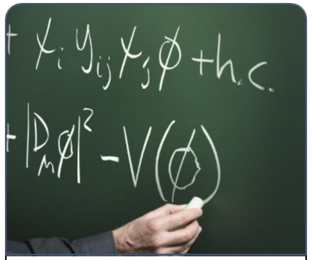
93 member states
16 associate member states
21 non-member states with observer status
17 other non-member states

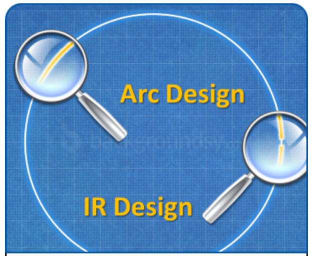
FCC Feasibility Study Governance approved by June Council.

High-level goals of Feasibility Study 2021-2025

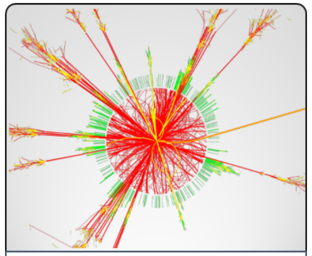
- optimisation of placement and layout of the ring and related infrastructure, and demonstration of the geological, technical, environmental and administrative feasibility of the tunnel and surface areas;
- pursuit, together with the Host States, of the preparatory administrative processes required for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

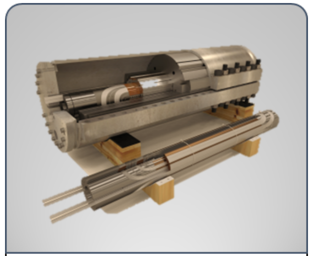

Infrastructures


Physics Cases



Collider Designs


Experiments

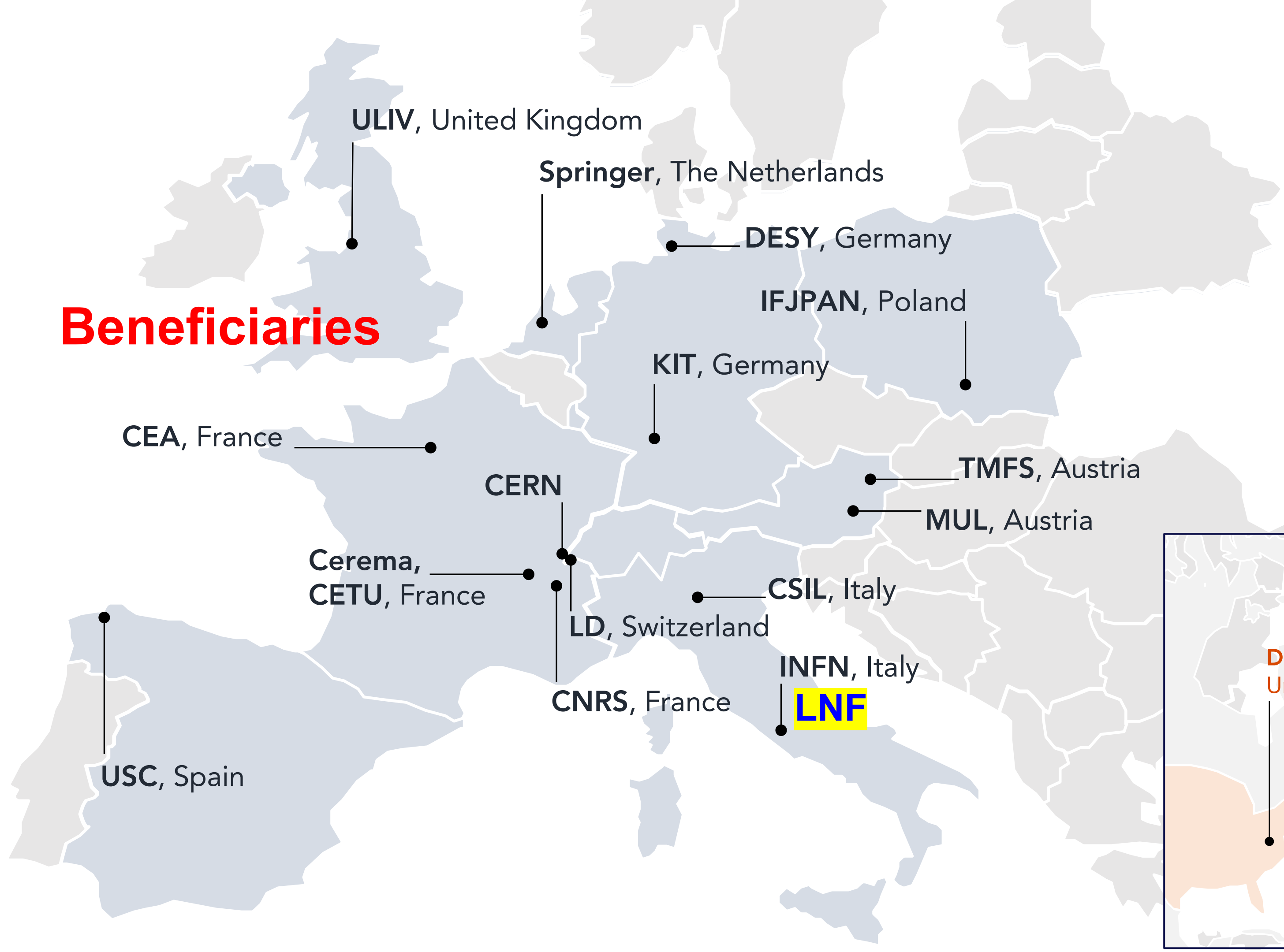

R&D Programs

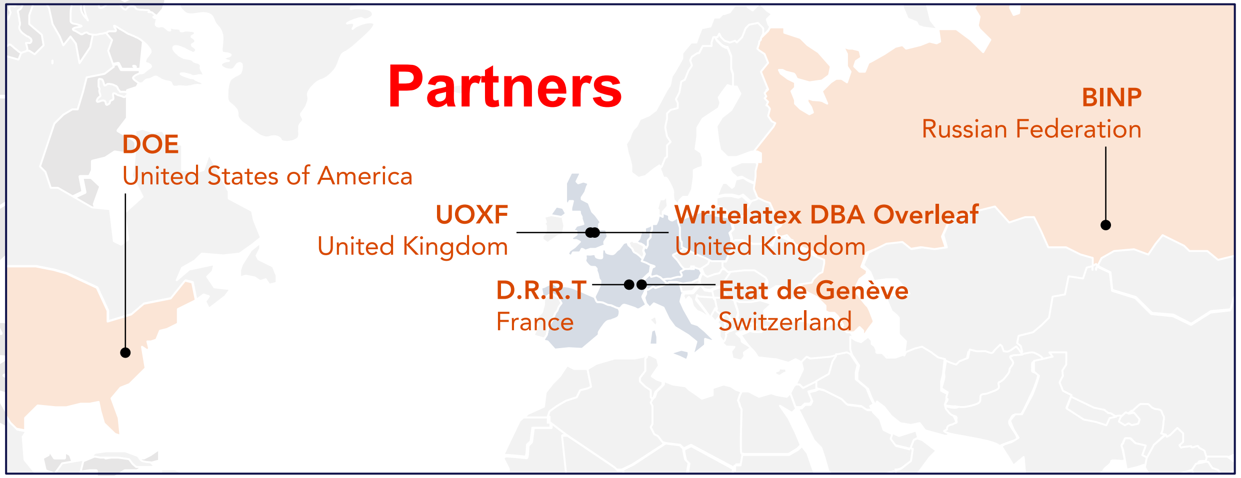
Cost Estimates

H2020 DS FCC Innovation Study 2020-24

FUTURE CIRCULAR COLLIDER

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





EC Evaluation Results: Total score: 15/15. Excellence: 5/5; Impact: 5/5; Quality and efficiency of the implementation:5/5. Scope of the proposal: yes; Operational Capacity: yes.

FCC Innovation Study (FCCIS)

organized in 5 WPs:

WP1: study management
WP2: collider design →
WP3: integrate Europe
WP4: impact & sustainability
WP5: leverage & engage

Task 2.2: Collider design (lead: DESY, CEA, CERN, KIT, IFJPAN, INFN, BINP)

- Analyse and mitigate impedance and single-beam collective effects in the collider rings (INFN)

Task 2.3: Interaction region and machine detector interface design (lead: INFN, participants: CERN, CNRS, DESY, partners BINP and UOXF)

Staff scientifico coinvolto in FCCIS

- **Manuela Boscolo** (resp. scientifico per l'INFN)
- **M. Migliorati**, Sapienza & INFN-Roma1
- **Luigi Pellegrino**
- **Mikhail Zobov**

+ TD col grant :

- **Francesco Fransesini** Ing. mecc., nel serv. Ing. meccanica (AdR dal 4/5/2021)
- 1AdR selezione in corso per studio degli effetti collettivi ed impedenze

Impegno Divisione Acceleratori LNF

staff scientifico	FTE Timesheets	commento
Manuela Boscolo	6 PM/year	
Luigi Pellegrino	1.2 PM/year	
Mikhail Zobov	1.2 PM/year	
Francesco Fransesini	12 PM/year	Progettazione meccanica della regione di interazione del Future Circular Collider e+e-
AdR-selezione in corso	12 PM/year	Modello di impedenza ed effetti collettivi per il Future Circular Collider e+e-

richieste servizi
1 progettista 0.5 FTE/year (6PM/year)

Interaction region and machine detector interface design

- **Ensure that the interaction region design meets the collider performance goals and develop an accelerator-detector interface coherently with the collider design**.
- Develop a **3D model** of the interaction region, including final quadrupole and solenoid magnets, support structures, cooling schemes, and vacuum system.
- Develop **heat-load budget** and determine cooling requirements.
- Analyse **vibration and stability**.
- Develop and refine concepts for the **luminosity measurement**.
- Analyse and propose effective design measures to control the **background** and to protect the machine. Design the **collimation system**, develop a collider aperture model and develop an accelerator- detector protection concept.
- Review the SuperKEK **IP feedback** architecture, performance, merits and limitations.
- Experimental **beam studies** exploring the sensitivity of the beam- beam performance to IP optics aberrations are planned at DAΦNE and SuperKEKB with the crab-waist collision scheme.
- Document the interaction region design and integrate the findings in the main deliverable.

MDI/IR engineering design and mechanical layout with integration

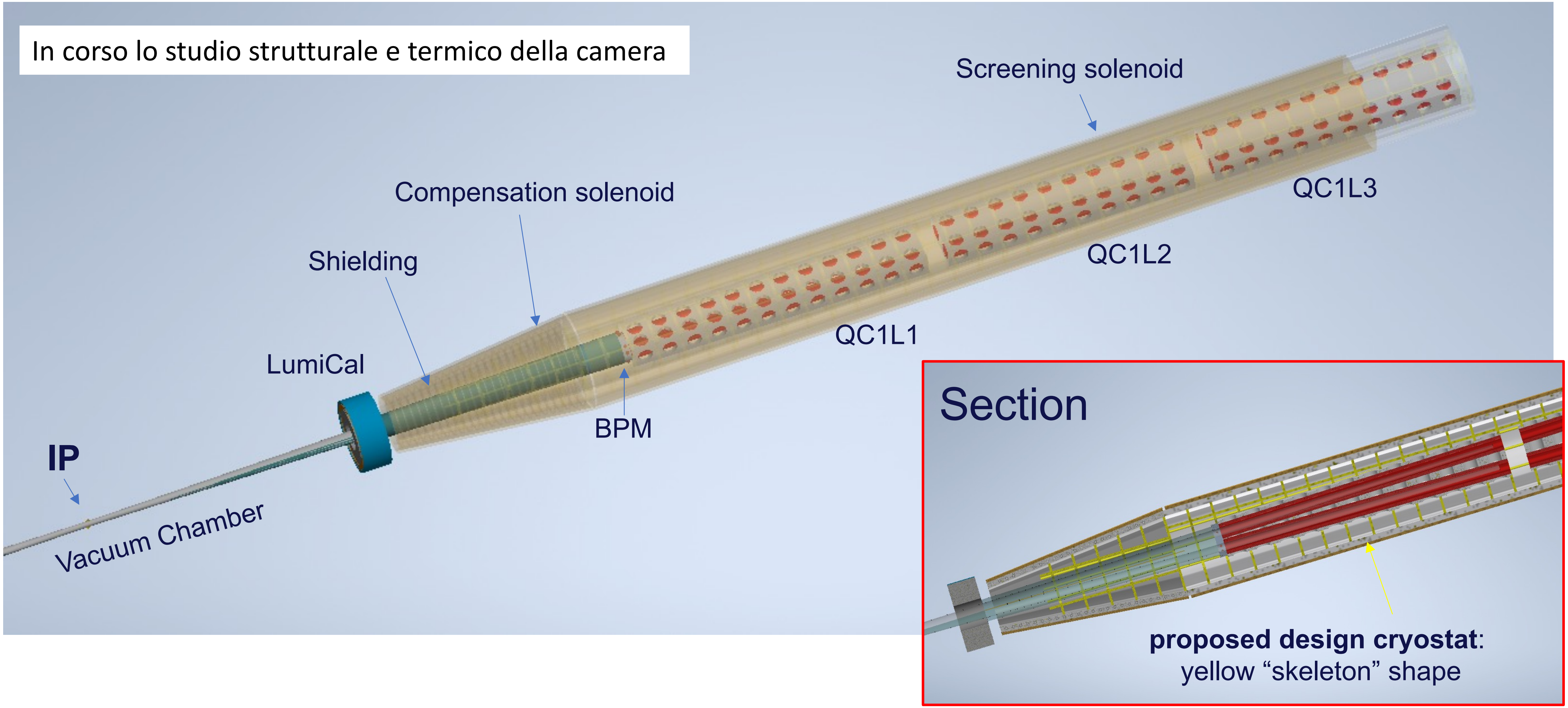
Luigi Pellegrino, Francesco Fransesini

- Beam pipe design
- Magnet integration including el.-magn/ forces
- Cryostat integration
- Shielding against hard synchrotron radiation & collision debris
- IP detectors integration (luminosity calorimeter, vertex detector) support & alignment
- Vacuum system integration
- Supporting structures
- Thermal simulations
- Management of electrical and hydraulic connection/routing
- Mechanical IR assembly, disassembling & repair procedures

Key deliverables: 3D CAD proof-of-principle engineered mechanical design of the interface between the accelerator and the detector components in the interaction region. (1/7/2023)

Preliminary assembly of the MDI

Presentation at the FCC WEEK 2021, MDI session by Francesco Fransesini (LNF): link



Open questions for mechanical model

attività in progress ai LNF

- **Introduce the weight of the components to design the supports and start with the structural studies.** This will allow the optimization of the different options of different configurations of supports for **vibration** mitigation, in collaboration with LAPP.
- Space for the **alignment system** to fulfill the stringent requirements.
- **Thermal and mechanical simulations** Just started, with preliminary studies (cooling of central pipe, strength of simplified X pipe to vacuum load at several thicknesses)
- We will define the **strategy for the integration.**
- **Progress with the mechanical assembly** adding all the main components as they will be provided by the experts of the different systems. →

Cryostat design
IR beam diagnostic devices
IR corrector magnets
Shielding
Vacuum system
Remote vacuum connection

Vertex detector & other IP detectors

Interaction Region Layout

L*=2.2 m B=2 T

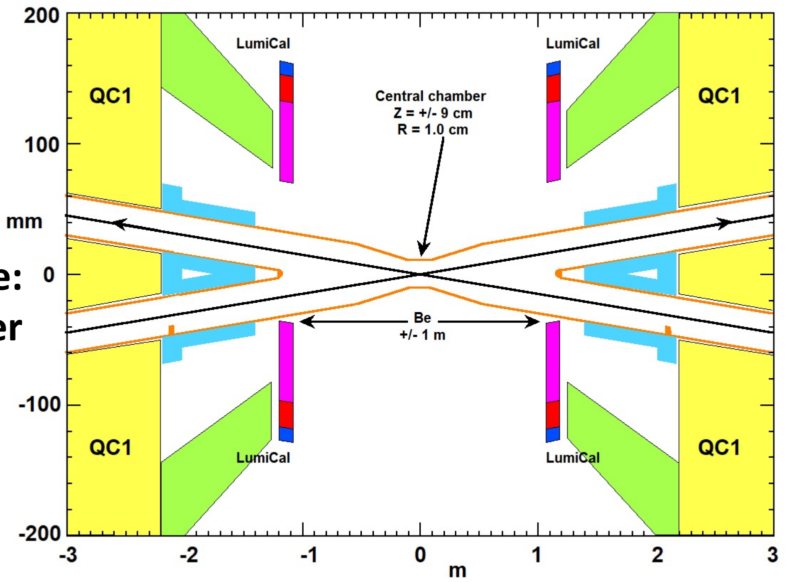
beam pipe disegnata a Frascati

- Il nuovo disegno della beampipe ha un'impedenza piu' piccola, che quindi genera minor *heating power*, che evita la necessità degli *HOM (Higher Order Modes) absorbers*
- La beampipe centrale ha raggio = 1 cm, spessore X/X0(tot)=0.59%

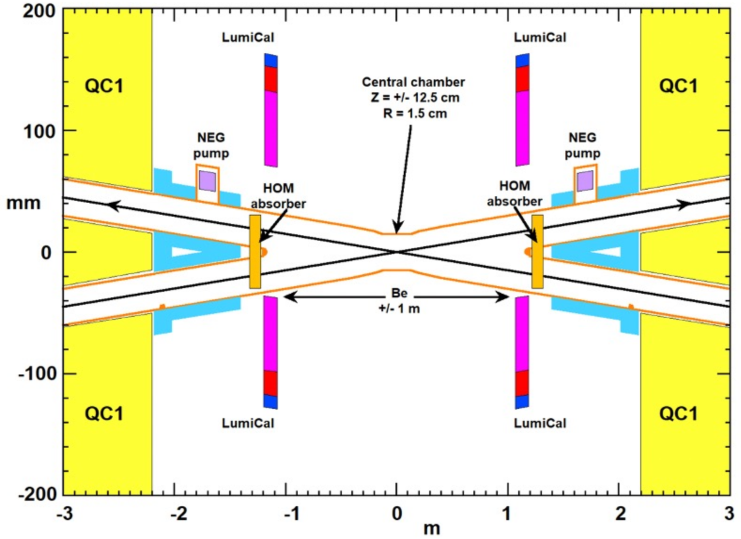
5 mu m Au (X/X0 = 0.15%)
0.35 mm AlBeMet (X/X0 = 0.14%)
1 mm paraffin X/X0 = 0.18% for PF200
0.3 mm AlBeMet ((X/X0 = 0.12%)

- L'impatto della radiazione di sincrotone sulla zona centrale della pipe (e quindi sul vertex detector) è stato studiato, trovando che è necessario aumentare la *mask tip* all'uscita di QC1 per bloccare parte dei fotoni che altrimenti illuminerebbero la pipe centrale.
- È stato fatto uno studio di performance del vertex detector per diverse dimensioni della pipe.

low impedance beam pipe:
1 cm radius central chamber

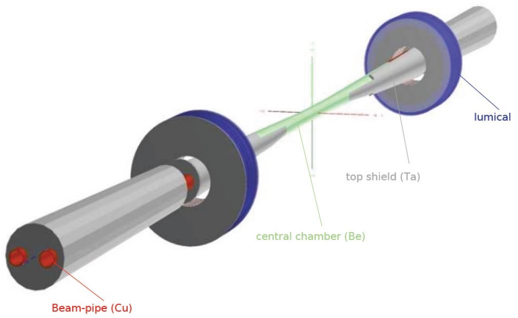


CDR 1.5 cm radius central chamber



M. Boscolo et al., "Challenges for the interaction region design of the Future Circular Collider FCC-ee", IPAC21 ArXiv:2105.09698

Beam Background studies



Geant4 model for detector background studies

Synchrotron radiation background

complementary codes (MDISim*, Synch_bkg, SYNRAD+)

conceptual design of shielding, SR absorbers, vacuum chamber done, we need to do to the next step of detailed study

* Per lo sviluppo di MDISim c'e' stato un contributo fondamentale dei LNF per gli studi di SR backgrounds in FCC-hh IR (funded by EuroCirCol)

Generation and tracking of beam scattered particles

- IP backgrounds
- Single beam backgrounds

  (thermal photons, beam-gas studied for the CDR)

First case-study GuineaPig++ performed integrated in FCCSW key4hep, *goal*: events reconstruction for detector backgrounds sim. study Beamstrahlung photons

Radiative Bhabha BBBrem

tracking spent beam

radiation from radiative Bhabha

FCC WEEK 2021 A. Ciarma

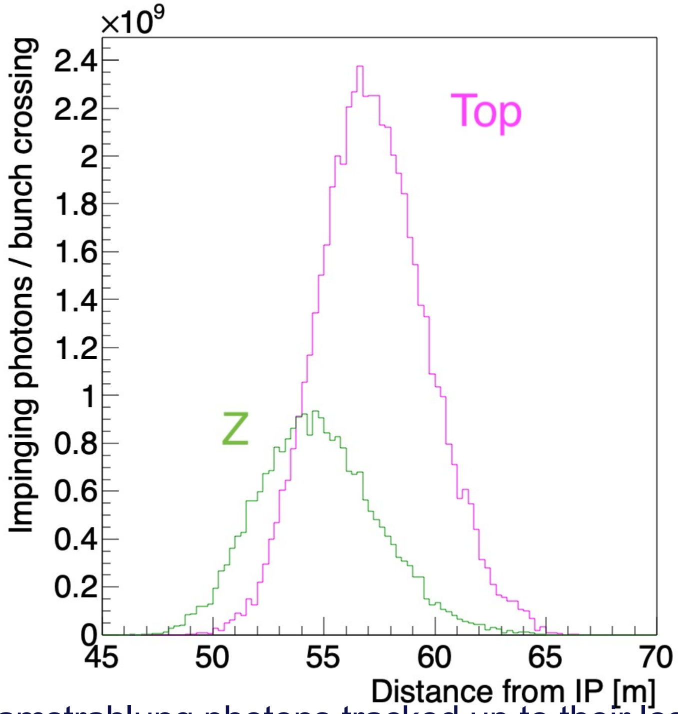
Relevant for MDI are especially IR loss maps,

Collimation study has started in collaboration with the BE-APB group at CERN

Beamstrahlung Radiation generated at the IP

[GuineaPig++]

- A significant flux of photons is generated at the IP in the very forward direction by Beamstrahlung, radiative Bhabha, and solenoidal and quadrupolar magnetic fields.
- **Beamstrahlung** interactions produce an **intense source of locally lost beam power**
- The impinging angle of the **Beamstrahlung** photons with the pipe is about 1 mrad for both beam energies.



Beamstrahlung photons tracked up to their loss points, at about 50-60 m after the IP

	Beam energy	Beamstrahlung Radiation power
<Eγ> = 2 MeV	45.6 GeV	387 kW
<Eγ>=67 MeV	182.5 GeV	89 kW

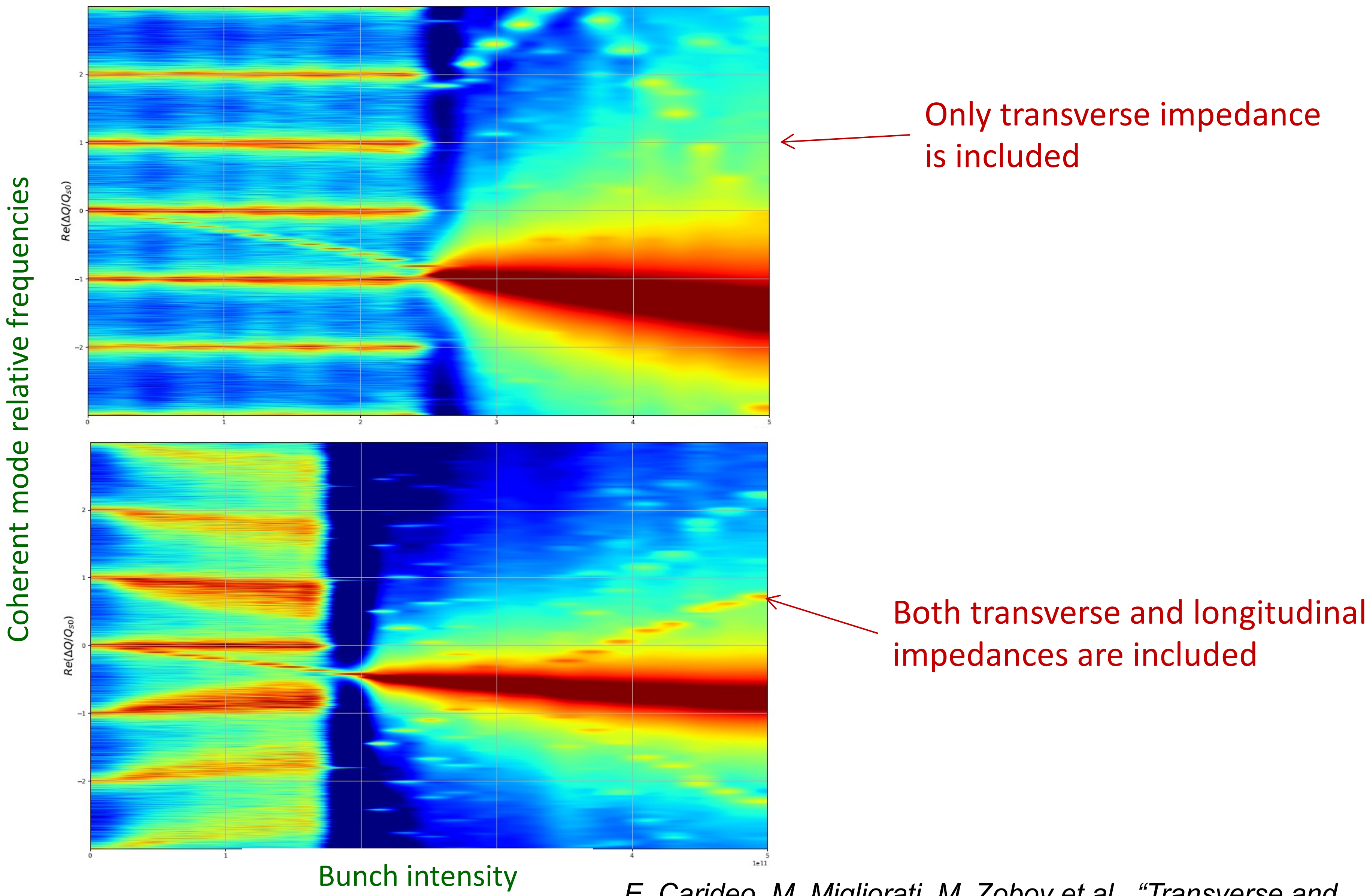
Fluka or Geant4 simulation to design the proper shielding for this radiation is necessary.

Activity on collective effects: summary

M. Migliorati, M. Zobov

- Determination of machine impedance and coupling impedance in longitudinal and transverse planes
- Single beam collective effects in longitudinal plane: microwave instability
- Single beam collective effects in transverse plane: transverse mode coupling instability (TMCI)
- Combined influence of beamstrahlung and coupling impedance: collaboration with Y. Zhang from IHEP who has developed a beam-beam code with the inclusion of longitudinal impedance effects
- Create a repository for impedance/wakefields and input files for beam dynamics simulations
- Impedance and collective effects for the FCC-ee Booster (collaboration with DESY)

TMCI instability including the longitudinal impedance



E. Carideo, M. Migliorati, M. Zobov et al., “Transverse and Longitudinal Single Bunch Instabilities in FCC-ee”, IPAC2021

Conclusion

At this stage the focus of the whole project FCC is on the accelerators design as well as on the steps necessary to be ready to start construction if approval arrives at the next strategy in 2025.

Wonderful opportunity for the community involved on high luminosity and high energy colliders!

More details on ongoing studies in:

- M. Boscolo et al., "Challenges for the interaction region design of the Future Circular Collider FCC-ee", IPAC21 https://arxiv.org/abs/2105.09698
- E. Carideo, M. Migliorati, M. Zobov et al., "Transverse and Longitudinal Single Bunch Instabilities in FCC-ee", IPAC2021