Work supported by the European Commission under the HORIZON 2020 project FCCIS, grant agreement 951754

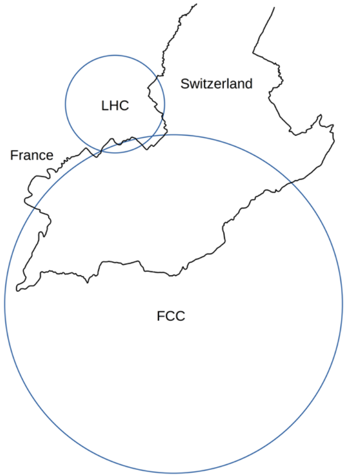
INFN LNF Istituto Nazionale di Fisica Nucleare

FUTURE CIRCULAR COLLIDER Innovation Study

# FCC FEASIBILITY STUDY STATUS & INFN ACTIVITY IN FCC-FS

**Manuela Boscolo (INFN-LNF)**
**per il gruppo RD_FCC - WP Acceleratore**

*Thanks to:* Roberto Tenchini and Franco Bedeschi

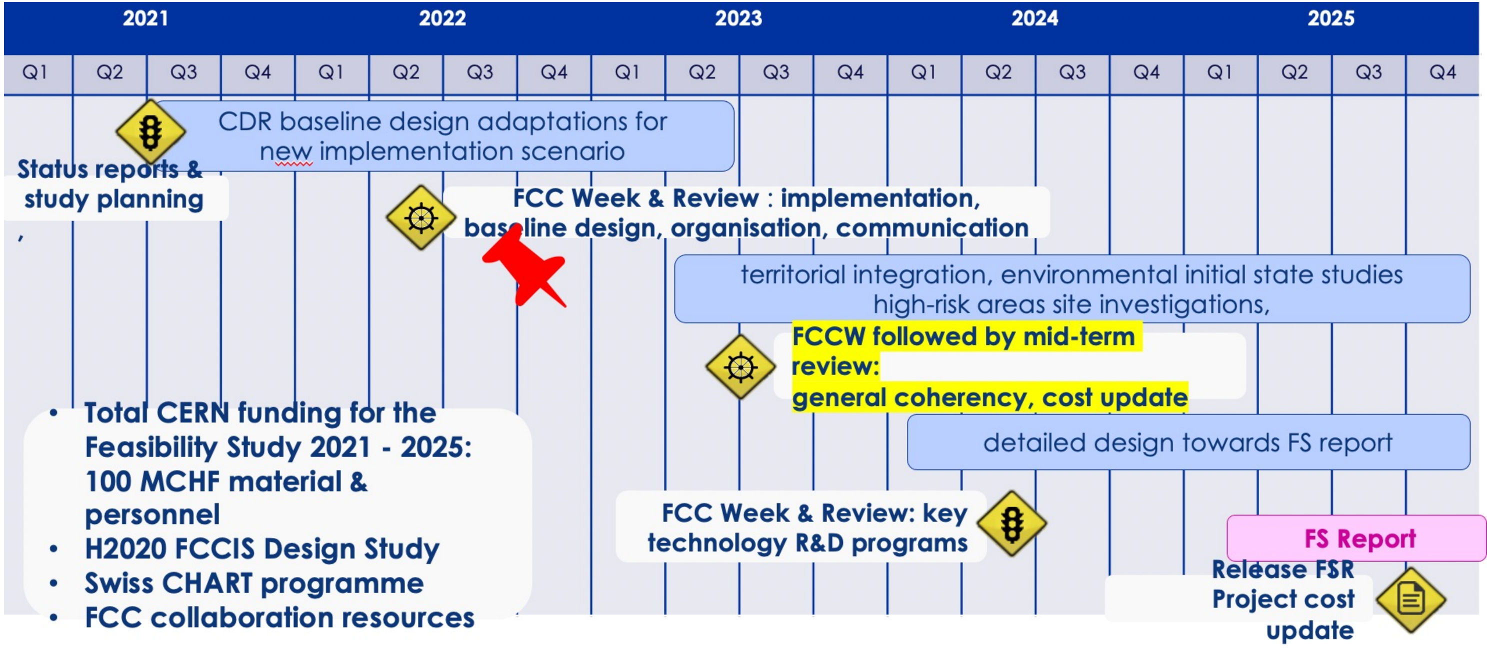



Seconda Giornata Acceleratori
Catania, LNS, 3 marzo 2023

# Outline

- Progresso sullo studio di fattibilità di FCC
- Attività di macchina per FCC-FS nell'INFN

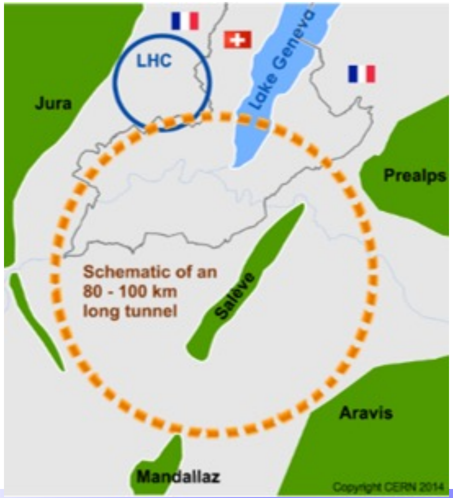
**FCC Feasibility Study timeline**

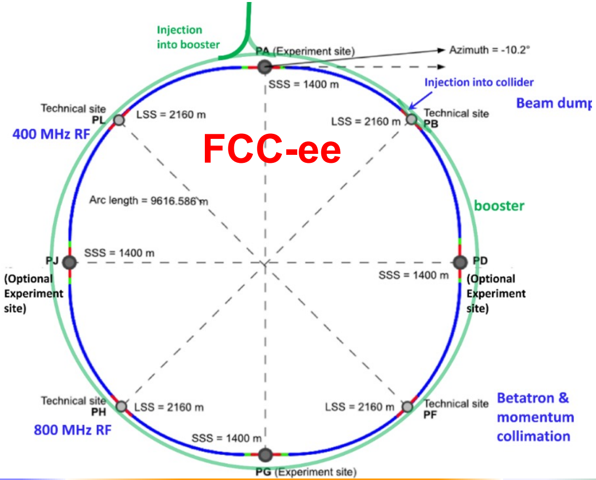


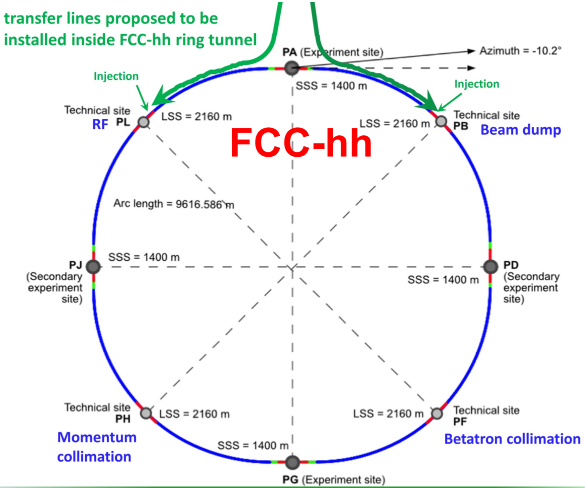
# The FCC integrated program inspired by successful LEP – LHC programs at CERN

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




2020 - 2040 | 2045 - 2060 | 2065 - 2090

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

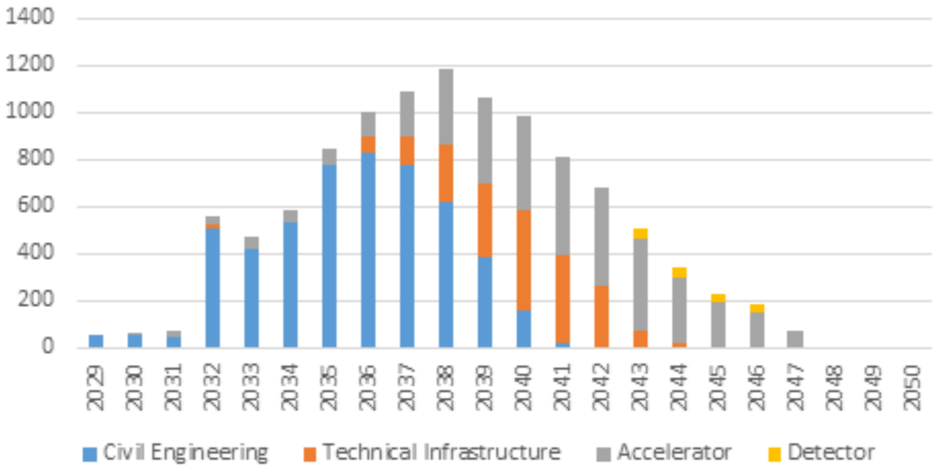
## Construction cost estimate for FCC-ee

- Machine configurations for Z, W, H working points included
- Baseline configuration with 2 detectors
- CERN contribution to 2 experiments incl.

| cost category | [MCHF] | % |
|---|---|---|
| civil engineering | 5.400 | 50 |
| technical infrastructure | 2.000 | 18 |
| accelerator | 3.300 | 30 |
| detector | 200 | 2 |
| | | |
| total cost (2018 prices) | 10.900 | 100 |

## Spending profile for FCC-ee

- CE construction 2032 - 2040
- Technical infrastructure 2037 - 2043
- Accelerator and experiment 2032 – 2045
- Commissioning and operation start 2045 -2048.



FUTURE CIRCULAR COLLIDER

# optimized placement and layout

M. Benedikt, FCC FS Status,
FCC physics workshop, Krakow
23-27/Jan/23

## 8-site baseline "PA31-3.0"

| | |
|---|---|
| **Number of surface sites** | 8 |
| **LSS@IP** (PA, PD, PG, PJ) | 1400 m |
| **LSS@TECH** (PB, PF, PH, PL) | 2032 m |
| **Arc length** | 9.6 km |
| **Sum of arc lengths** | 76.9 m |
| **Total length** | **90.6 km** |

8 sites – less use of land, <40 ha instead 62 ha

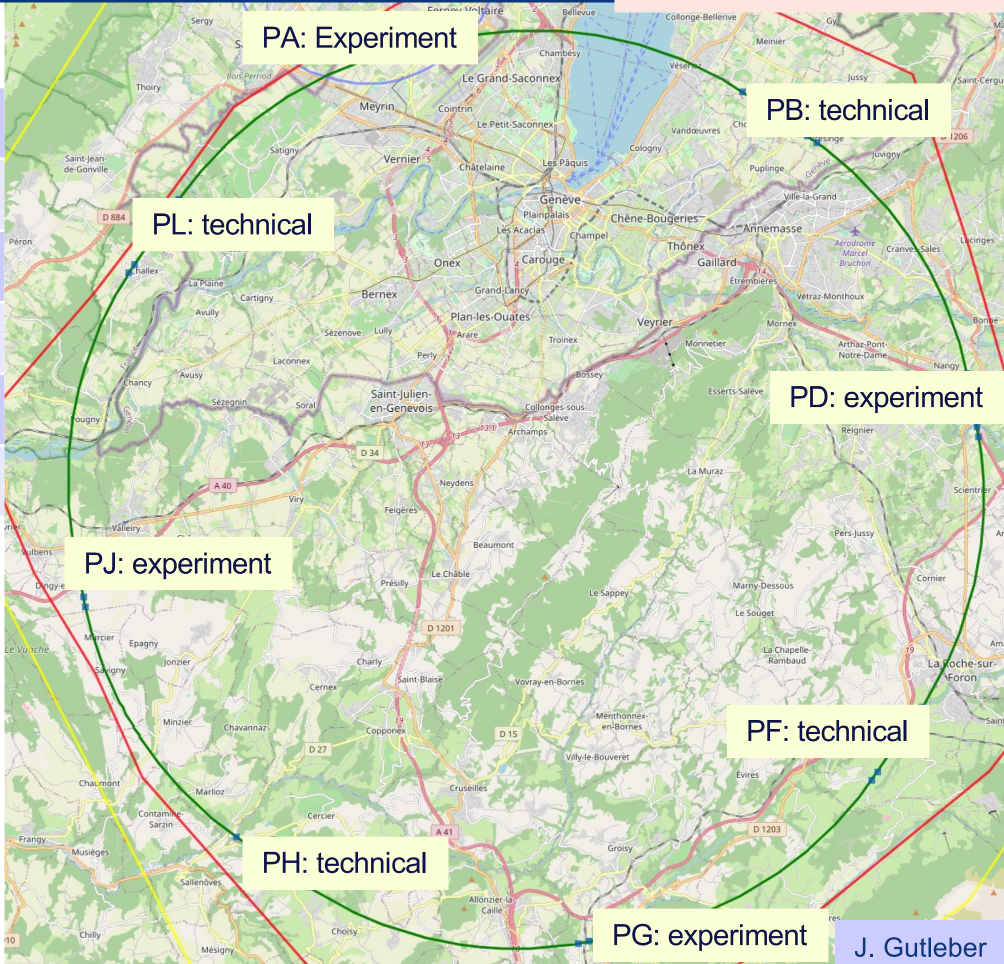
Possibility for 4 experiment sites in FCC-ee

All sites close to road infrastructures (< 5 km of new road constructions for all sites)

Vicinity of several sites to 400 kV grid lines

Good road connection of PD, PF, PG, PH suggest operation pole around Annecy/LAPP

**Exchanges with ~40 local communes in preparation**



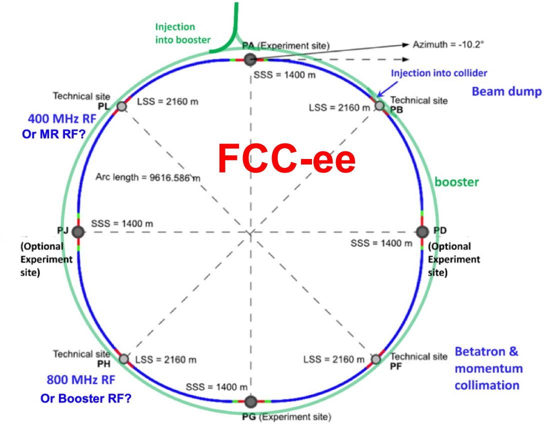

J. Gutleber

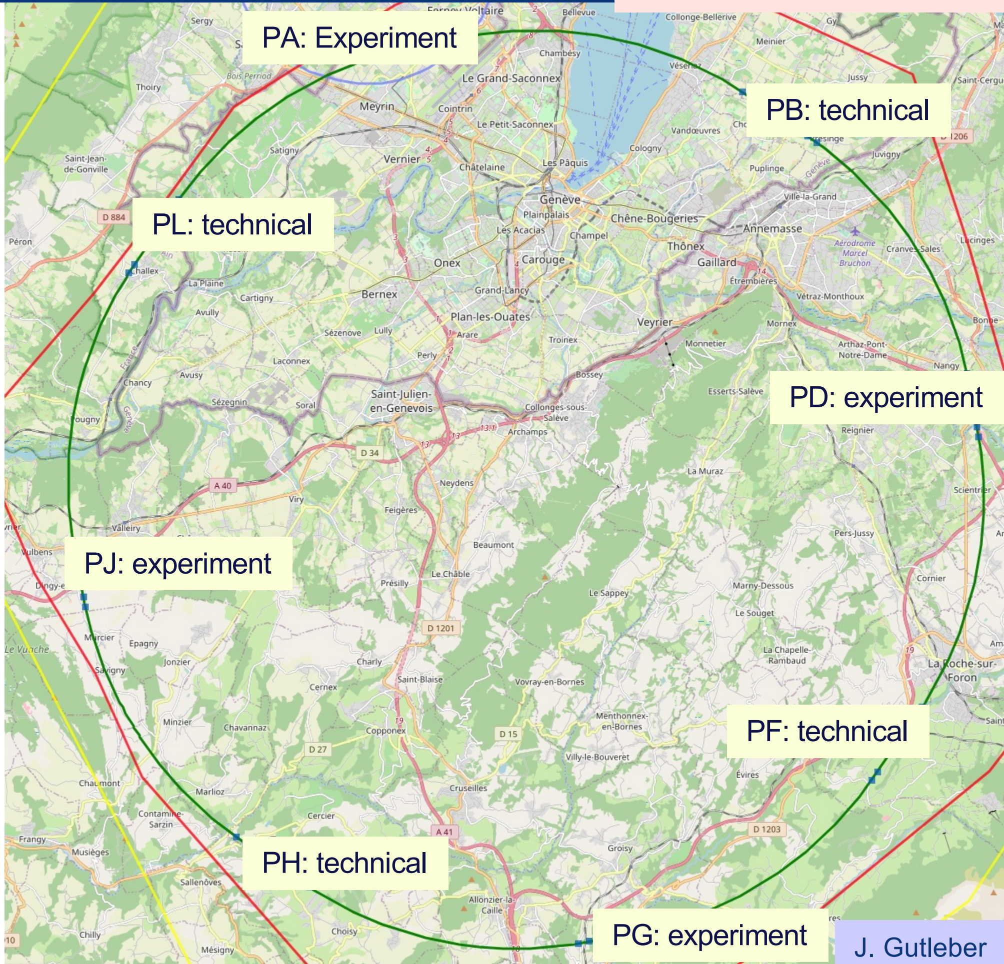
# optimized placement and layout

M. Benedikt, FCC FS Status,
FCC physics workshop, Krakow
23-27/Jan/23

## 8-site baseline “PA31-3.0”

- New ~90 km circumference placement with 8 access points
- Layout with 4IPs that is consistent with upgrade to FCC-hh
- Optimizing allocation of straight sections
- New FCC-ee optics to optimize beam-beam
- 400 MHz and 800 MHz RF systems
- Tunnel integration studies for RF and Arc sections
- Full energy booster that will fit in FCC tunnel for top-up injection
- e+/e- injector to fill booster



# Mid-Term Review & Cost Review, autumn '23

M. Benedikt, FCC FS Status,
FCC physics workshop, Krakow 23-27/Jan/23

**Mid-term review report, supported by additional documentation on each deliverable, will be submitted to review committees and to Council and its subordinate bodies, as input for the review.**

**Results of both general mid-term review and the cost review should indicate the main directions and areas of attention for the second part of the Feasibility Study**

**Infrastructure & placement**

- Preferred placement and progress with host states (territorial matters, initial states, dialogue, etc.)
- Updated civil engineering design (layout, cost, excavation)
- Preparations for site investigations

**Technical Infrastructure**

- Requirements on large technical infrastructure systems
- System designs, layouts, resource needs, cost estimates

**Accelerator design FCC-ee and FCC-hh**

- FCC-ee overall layout with injector
- Impact of operation sequence: Z, W, ZH, $t\bar{t}$ vs start at ZH
- Comparison of the SPS as pre-booster with a 10-20 GeV linac
- Key technologies and status of technology R&D program
- FCC-hh overall layout & injection lines from LHC and SC-SPS

**Physics, experiments, detectors:**

- Documentation of FCC-ee and FCC-hh physics cases
- Plans for improved theoretical calculations to reduce theoretical uncertainties towards matching FCC-ee statistical precision for the most important measurements.
- First documentation of main detector requirements to fully exploit the FCC-ee physics opportunities

**Organisation and financing:**

- Overall cost estimate & spending profile for stage 1 project

**Environmental impact, socio-economic impact:**

- Initial state analysis, carbon footprint, management of excavated materials, etc.
- Socio-economic impact and sustainability studies

FUTURE CIRCULAR COLLIDER

# FCC Feasibility Study

**2013 ESPPU requested FCC Conceptual Design** four-volume report → 4 volumes delivered in 2018/19, describing the physics cases, the design of the lepton and hadron colliders, and the underpinning technologies and infrastructures.

**2020 ESPPU→ 2021 Launch of FCC Feasibility Study** (FCC FS) by CERN Council

- Feasibility Study Report (FSR) expected by the end of 2025 , not only the technical design, but also numerous other key feasibility aspects, including tunnel construction, financing, and environment
- FSR will be an important input to the next ESPPU expected in 2026/27.

**FCC FS is organized as an international collaboration**

The FCC FS and a possible future project will profit from CERN's decade-long experience with successful large international accelerator projects, e.g., the LHC and HL-LHC, and the associated global experiments, such as ATLAS and CMS.

**Organisational Structure of the FCC Feasibility Study**
http://cds.cern.ch/record/2774006/files/English.pdf

**Main Deliverables and Timeline of the FCC Feasibility Study**
http://cds.cern.ch/record/2774007/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.

CERN/SPC/1161
CERN/3588
Original: English
21 June 2021

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

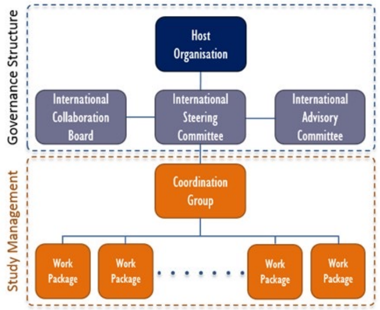
| Action to be taken | | Voting Procedure |
|---|---|---|
| For information | RESTRICTED COUNCIL 203rd Session 17 June 2021 | - |

FUTURE CIRCULAR COLLIDER FEASIBILITY STUDY:
MAIN DELIVERABLES AND MILESTONES

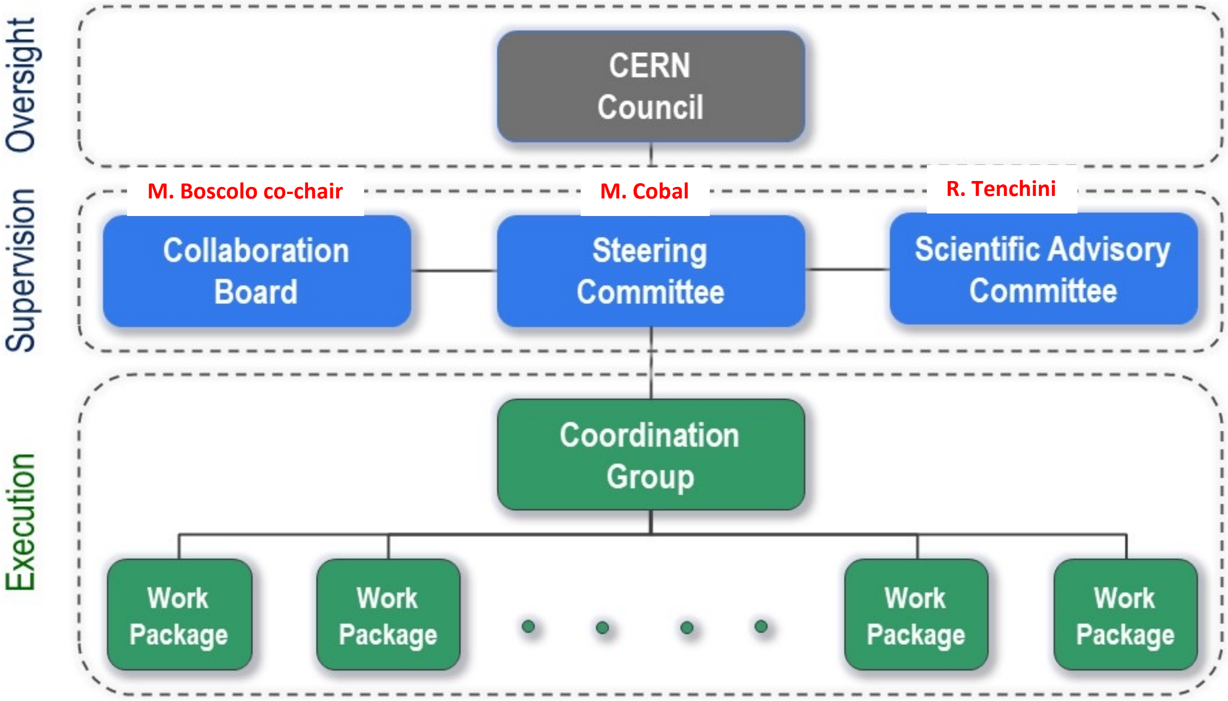
This document describes the main deliverables and milestones of the study being carried out to assess the technical and financial feasibility of a Future Circular Collider at CERN. The results of this study will be summarised in a Feasibility Study Report to be completed by the end of 2025.

# FCC Feasibility Study - organizational structure

- New structure very similar to the first phase of the FCC Study (2014-2020), leading to the Conceptual Design Report as input to the ESPPU.




- Classical structure common to CERN projects.



# FCC Feasibility Study – coordination team and contact persons

**EU Projects**
NN

**Collaboration building**
Emmanuel Tsesmelis

**Communications**
Panagiotis Charitos, James Gillies

**Study Support and Coordination**
Study Leader: Michael Benedikt
Deputy Study Leader: Frank Zimmermann

**Study Support Unit**
IT: Sylvain Girod
Procurement: Adam Horridge
Quality control: NN
Resources: Sylvie Prodon
Scheduling, quality mangement: NN
Secretariat: Julie Hadre

## Physics, Experiments and Detectors
Patrick Janot
Gavin Salam

- **Physics programme** – Matthew McCullough, Frank Simon
- **Detector concept** – Mogens Dam
- **Physics performance** – Patrizia Azzi, Emmanuel Perez
- **Software and computing** – Gerardo Ganis, Clément Helsens

## Accelerators
Tor Raubenheimer
Frank Zimmermann

- **FCC-ee collider design** – Katsunobu Oide
- **FCC-hh design** – Massimo Giovannozzi
- **Technology R&D** – Roberto Losito
- **FCC-ee booster design** – Antoine Chancé
- **FCC-ee injector** – Paolo Craievich, Alexej Grudiev
- **FCC-ee energy calibration polarization** – Alain Blondel, Jorg Wenninger
- **FCC-ee MDI** – Manuela Boscolo, Mike Sullivan

## Technical Infrastructures
Klaus Hanke

- **Integration** – Jean-Pierre Corso
- **Geodesy & survey** – Hélène Mainaud Durand
- **Electricity and energy management** – Jean-Paul Burnet
- **Cooling and ventilation** – Guillermo Peon
- **Cryogenics systems** – Laurent Delprat
- **Computing and controls infrastructure, communication and network** – Dirk Duellmann
- **Safety** – Thomas Otto
- **Operation, maintenance, availability, reliability** – Jesper Nielsen
- **Transport, installation concepts** – Cristiana Colloca

## Host State processes and civil engineering
Timothy Watson

- **Administrative processes** – Friedemann Eder
- **Placement studies** – Johannes Gutleber, Volker Mertens
- **Environmental evaluation** – Johannes Gutleber
- **Tunnel, subsurface design** – John Osborne
- **Surface sites layout, access and building design**

## Organisation and financing models
Paul Collier (interim)

- **Project organisation model**
- **Financing model** – Florian Sonnemann
- **Procurement strategy and rules**
- **In-kind contributions**
- **Operation model** – Paul Collier, Jorg Wenninger

# Attività FCC è in Gruppo1

Attivita' strutturata in work packages, ognuno con coordinatore

| | |
|---|---|
| WP1 Physics & software | (P. Azzi/PD, N. De Filippis/BA) |
| WP2 Accelerator | (M. Boscolo/LNF) |
| WP3 Silicon/Vertex detectors | (M. Caccia/MI, A. Andreazza/MI) |
| WP4 Drift chamber | (F. Grancagnolo/LE) |
| WP5 MPGD for muon/preshower | (P. Giacomelli/BO) |
| WP6 Dual readout calorimetry | (R. Ferrari/PV) |

**RD_FA** (2017-2020)
resp naz F. Bedeschi

**WP2: FA MDI**
convener M. Boscolo

**RD_FCC** (2021- )
resp naz F. Bedeschi

**WP2: FCC MDI**
convener M. Boscolo

**WP2: FCC Acceleratore**
convener M. Boscolo

2017 2018 2019 2020 2021 2022

https://agenda.infn.it/event/29752/

FCC Accelerator activities: Italian involvement (M.Boscolo)

# First FCC-Italy workshop 21-22 March22

Strong interest by the President and the INFN Board to consolidate the Italian collaboration in FCC


04 APRILE 2022

IL PRIMO WORKSHOP ITALIANO SUL GRANDE ACCELERATORE DEL FUTURO

Si è recentemente tenuto a Roma il First FCC-Italy Workshop, il primo workshop italiano dedicato al progetto per il successore del Large Hadron Collider al CERN, il Future Circular Collider. All'evento, organizzato dall'INFN, hanno partecipato 120 ricercatori e ricercatrici, e sono state presentate 15 relazioni.

Nell'ultimo documento sulla strategia europea per la fisica delle particel approvato dal Council del CERN nel giugno 2020, FCC è indicato come il progetto futuro di massima priorità: da qui è iniziato un vasto programm di studi di fattibilità, che costituirà un input importante per la prossima edizione dell'Update della Euroepan Strategy for Particle Physics.

Il progetto FCC prevede una nuova macchina acceleratrice molto più potente dell'attuale LHC, con una circonferenza di circa 91 km in un tunnel sotto il territorio francese e svizzero, in prossimità del CERN per sfruttarne le infrastrutture già esistenti. In una prima fase (FCC-ee) il tunnel dovrebbe ospitare un collisore di elettroni e positroni di energia variabile da 90 a 365 GeV. Successivamente, questo verrebbe sostituito da un collisore di protoni (FCC-hh) con un'energia nel centro di massa di 100 TeV, quasi un ordine di grandezza superiore a quel di LHC. L'idea è di partire con FCC-ee e in parallelo proseguire il lavoro di R&D necessario per realizzare i dipoli di 16 T necessari a mantenere la traiettoria dei protoni di 50 TeV di energia all'interno dell'anello.

"Con FCC si lavora a una grande infrastruttura che garantirebbe all'Europa di mantenere la sua leadership nella ricerca in fisica delle alte energie: il progetto è dunque di importanza strategica nel panorama internazionale negli anni a venire", ha sottolineato Antonio Zoccoli, presidente dell'INFN, nel suo discorso di apertura in occasione del workshop. "L'INFN ha grandi potenzialità e può dare un contributo notevole alla sua realizzazione: in questa prospettiva è quindi importante identificare con chiarezza le principali attività dove investire, coalizzare le necessarie risorse umane e individuare possibili partner industriali".

link INFN news

FIRST FCC-ITALY WORKSHOP

## Future Circular Collider workshop debuts in Italy

The first Italian workshop on the Future Circular Collider (FCC) took place in Rome from 21 to 22 March and was attended by around 120 researchers.

The FCC study is exploring the technical and financial feasibility of a 91 km-circumference collider situated under French and Swiss territory near CERN, thus exploiting existing infrastructures. In a first phase (FCC-ee) the tunnel would host an electron-positron collider at energies from 90 to 365 GeV, which would be replaced by a proton-proton collider (FCC-hh) with a centre-of-mass energy of at least 100 TeV, almost an order of magnitude higher than that of the LHC. The proposed roadmap foresees the R&D for the 16 T superconducting dipole magnets needed to keep the FCC-hh proton beams on track to take place in parallel with FCC-ee construction and operation

"The FCC is a large infrastructure that would allow Europe to maintain its worldwide leadership in high-energy physics research. This project is therefore of strategic importance in the international science scenario of the coming years," remarked INFN president Antonio Zoccoli in his introduction. "INFN has great potential and could make a significant contribution to its implementation. In this perspective, it is important to clearly identify the main activities in which to invest, assemble the necessary human resources and identify possible industrial partners."

The workshop was opened by FCC study leader Michael Benedikt, who gave an overview of the FCC feasibility study, while deputy study leader Frank Zimmermann covered the technological challenges, design features and machine studies for FCC-ee. Opportunities for technological development related to the FCC-ee were then presented, along with machine studies, in which INFN are already involved. Scientific and technological R&D areas where collaborations could be strengthened or initiated were also identified, prompting an interesting discussion with CERN colleagues.

INFN is already well integrated both in the FCC coordination structure and several ongoing studies, having participated in the project since its beginning, and provides important contributions on all aspects of the FCC study. These range from accelerator and detector R&D, such as the development of superconducting magnets, to experimental and theoretical physics studies. This is made evident by the strong Italian involvement in FCC-related European programmes, such as EuroCirCol for FCC-hh and FCC-IS for FCC-ee, and AIDAinnova on innovative detector technologies for future accelerators. INFN is committed to the development of superconducting magnets for FCC-hh, for which substantial additional funding could come from a project in the context of the next-generation funding programme Horizon Europe.

The second day of the workshop focused on the work that experimental and theoretical physicists have been carrying out to deeply understand the scientific potential of the visionary FCC project, the specific requests for the detectors and the associated R&D activities.

This workshop was the first in a series organised by INFN to promote and support the FCC project and pursue the key technological R&D needed to demonstrate its feasibility by the next update of the European strategy for particle physics.

**Visionary** *Participants at the FCC's Rome workshop discussed the proposed project's scientific potential.*

Franco Bedeschi *INFN Pisa*, Manuela Boscolo *INFN Frascati and* Marina Cobal *University of Udine.*

18 CERN COURIER JULY/AUGUST 2022

Second African Conference on Fundamental and Applied Physics

## Accelerating knowledge transfer with physics

Sesame Cultural Heritage Day

## SESAME revives the ancient Near East

CERNCOURIER VOLUME 62 NUMBER 4 JULY/AUGUST 2022

link CERN courier Jul/Aug ed.

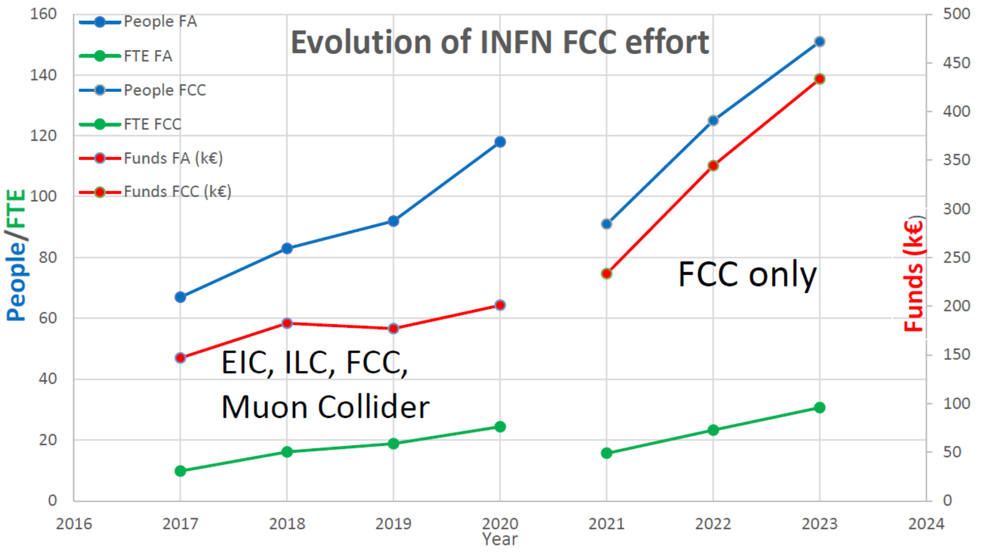
# RD_FCC

## INFN FCC Work Packages

- **WP1: Physics and software**
  - All 19 INFN sections
- **WP2: Accelerator**
  - GE, LNF, LNL, MI, RM1
- **WP3: Silicon Detectors**
  - GE, MI, PI, TO
- **WP4: Drift Chamber**
  - BA, LE
- **WP5: MPGD muon**
  - BO, FE, LNF
- **WP6: DR calorimetry**
  - BO, MI, MIB, NA, PI, PV, RM1, RM3

**Current situation**

| Sezione | Total FTE | Scientists |
|---|---|---|
| BA | 2.40 | 11 |
| BO | 3.40 | 16 |
| CT | 1.80 | 4 |
| FE | 1.50 | 7 |
| FI | 0.15 | 2 |
| GE | 0.75 | 8 |
| LE | 1.10 | 6 |
| LNF | 4.85 | 15 |
| LNL | 0.10 | 1 |
| MI | 3.45 | 7 |
| MIB | 0.10 | 1 |
| NA | 1.00 | 9 |
| PD | 1.25 | 9 |
| PI | 2.10 | 21 |
| PV | 4.10 | 12 |
| RM1 | 0.30 | 2 |
| RM3 | 0.90 | 5 |
| TO | 0.90 | 10 |
| UD | 0.55 | 5 |
| **Totali** | **30.70** | **151** |




Encouraging Evolution of the person power and of the support

# RD_FCC   WP Acceleratore

**Nel 2022 ci sono state molte novità**
**Acceleratori crescono come richiesto dal top management**

Alcune attività già ben inserite in FCC FS e  in corso da tempo, quindi con accordi CERN-INFN MoU/addenda e fondi esterni,  altre sono nuove

Oltre CSN1, finanziamenti da fondi esterni, sinergie, CSN5

| | | |
|---|---|---|
| • **Disegno IR & MDI** | **LNF, Pisa** | FCCIS-INFRADEV + MoU (CERN-LNF), AidaInnova |
| • **Effetti collettivi** | **RM1, LNF** | FCCIS+MoU(CERN-Sapienza), sinergia Arya(CSN5) |
| • **Cavita' SRF** | **LNL** | sinergia SAMARA(CSN5) +  iFAST |
| • **Damping Ring** | **LNF** | CHART(Swiss program) + Addendum (LNF) |
| • **Sorgente di positroni** | **INFN-Mi** | |
| • **Diagnostics for bunch intensity control** | **INFN-Mi** | |
| • **Detector Solenoid e magneti della IR** | **INFN-Ge** | sinergia con PNRR-IRIS |

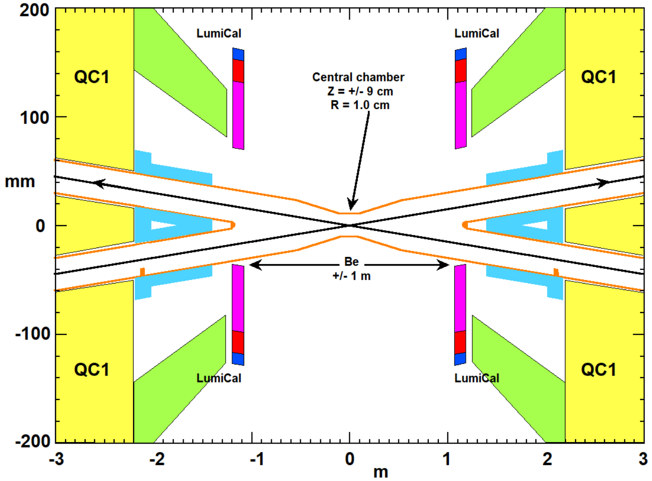
# Progetti su FCC presentati alla giunta INFN per la European Strategy for Particle Physics Update (ESPPU)

- **IR and MDI full-scale Experimental Validation**
  - Interaction Region design including mock-up (first attempt toward executive design)
  - Beam backgrounds, beam and synchrotron radiation collimators
  - Background shielding and dump
- **Injector**
  - damping ring and transfer lines design
- **SRF**

**Review del MAC appena conclusa per fondi addizionali rispetto a CSN1**
**Sulla base di questi risultati verrà preparata una proposta da sottoporre a breve alla GE**

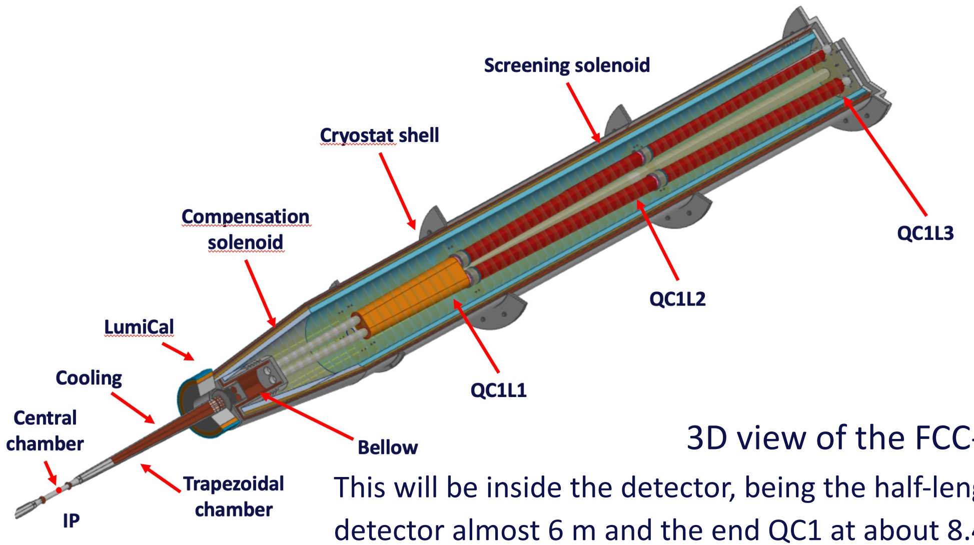
**MDI group is a large and international group**
**INFN-LNF (leader MB), CERN, CNRS, DESY, SLAC, BNL, NBI, UOXF**

# FCC-ee Interaction Region




L*, is 2.2 m. The 10 mm central radius is for ± 9 cm from the IP, the two symmetric beam pipes with radius of 15 mm are merged at 1.2 m from the IP.

**Crab-waist scheme: nano-beams & CW sextupoles**




3D view of the FCC-ee IR

This will be inside the detector, being the half-length of the detector almost 6 m and the end QC1 at about 8.4 m.

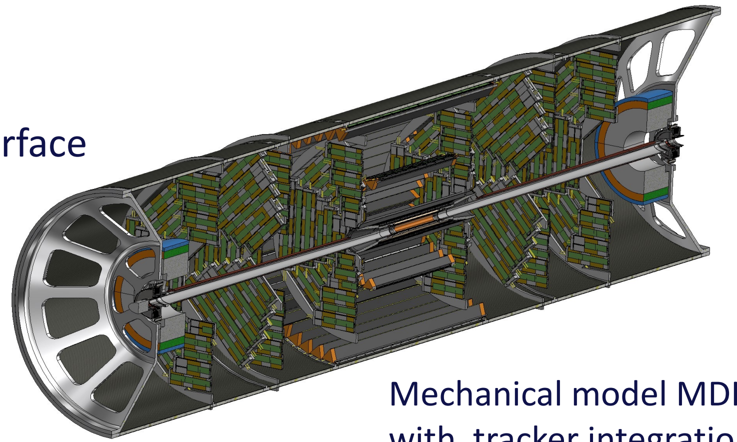

*Some Refs.:* in preparation for EPJ+ Tech. and Instr., *Mechanical model for the FCC-ee MDI*
MB et al., *IR design of the FCC-ee*, for IPAC23
A. Novokhatski, F. Fransesini, S.Lauciani, L. Pellegrino, MB, "Estimated heat load and proposed cooling system in the FCC-ee IR beam pipe", IPAC23
MB , H. Burkhardt, K. Oide, and M. Sullivan, *IR Challenges and the MDI at FCC-ee*, EPJ+ 2021;
MB et al. Proc. of IPAC 2021

# Attività INFN disegno IR & MDI

- Disegno della regione di interazione e machine-detector-interface with mockup (first attempt toward executive design)

Ingegnerizzazione IR & MDI

- Definizione camera da vuoto centrale e fino ai final focus quads
- Disegno soffietto, studio impedenza, carico termico
- Supporti meccanici, tubo di supporto in fibra di Carbonio, ancoraggio al rivelatore
- Integrazione vertex detector, tracker e luminometro



Mechanical model MDI with tracker integration

MB, F. Fransesini, S. Lauciani (LNF), F. Palla, F. Bosi (Pisa) *et al.*

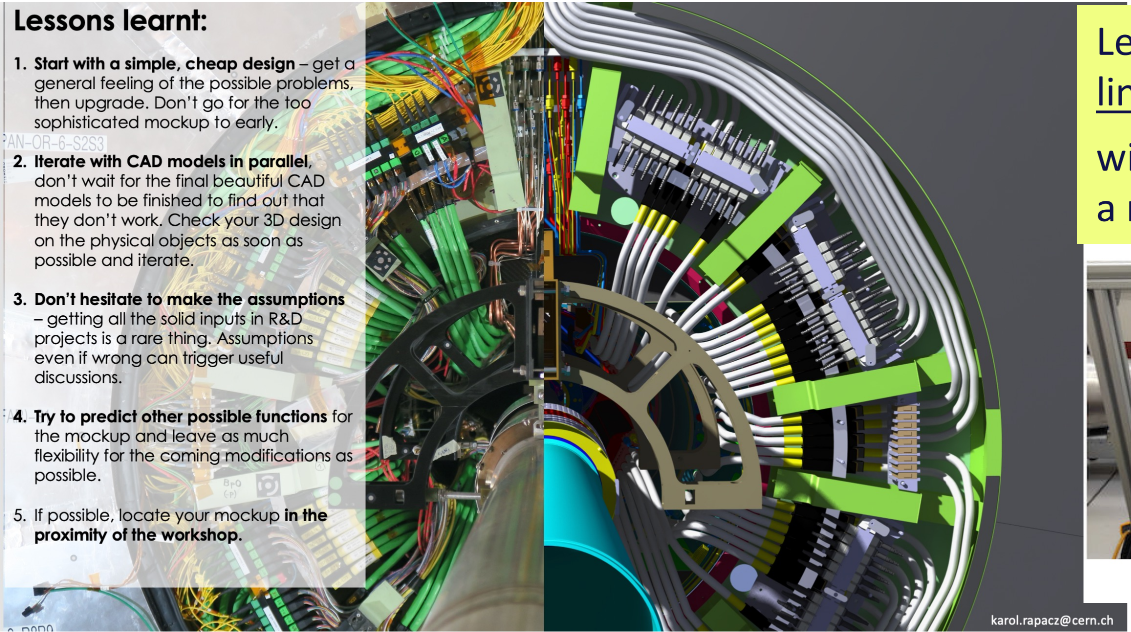
- Studio dell'impatto dei fondi macchina e radiazione di sincrotrone sui rivelatori, studio delle schermature
- Valutazione e *mitigation* della radiazione di sincrotrone e di Beamstrahlung prodotta nella IR

Also the following topics relevant/critical for the design of the IR

- Remote flange design based on shape-memory-alloy (SMA)
- IR magnets design, key component for the MDI
- Supports & vibration control, Alignment system

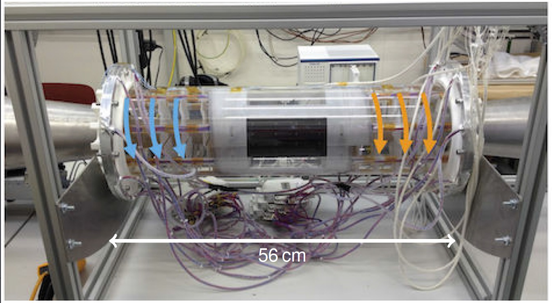
# FCC-ee IR mock-up at Frascati

- Progetto complementare al disegno della IR & MDI
- Progetto presentato alla giunta, previo accordo e con pieno supporto del direttore LNF
- Processo in corso

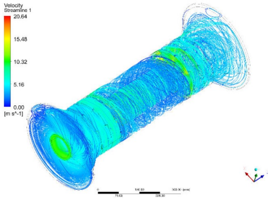



Lessons Learnt from CMS Mock-ups
link talk Andrea Gaddi(CERN)

with considerations on
a mock-up for FCC-ee IR




(a)

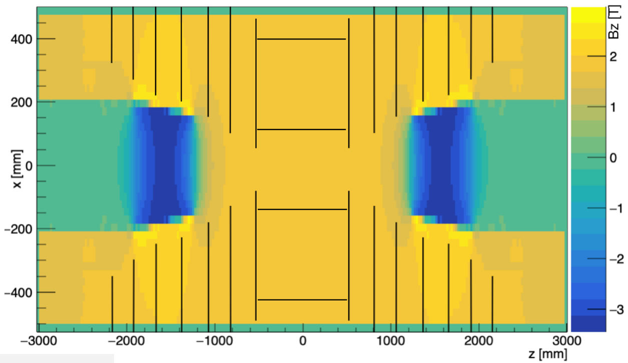


(b)

*courtesy F. Duarte Ramos*

# Detector Backgrounds

Backgrounds tracking studies in **CLD detector** in Key4HEP, including screening and compensating solenoids **magnetic field map.**



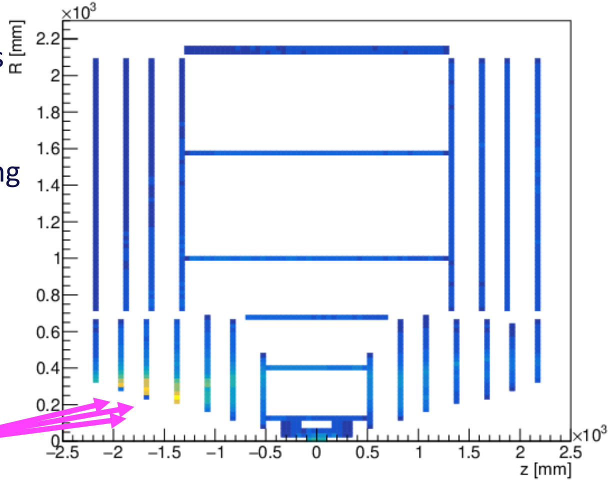

- Occupancy from incoherent pair production (**IPC**) below safety values at all working points.

## Beam Backgrounds & Collimation

G Broggi (CERN Doctoral & Sapienza & LNF)

- Failure scenarios: beam losses in the MDI region
  - horizontal **primary** collimators: not concerning at Z, high occupancy at ttbar
  - **off-momentum** collimators: only Z data available, occupancy above 1% for negative mom. offset
  - energy density deposited in FFQs **below quenching limit**, but total power may be an issue O(1-10 W)
- **SR induced background** studies has started:
  - study the efficiency of the CDR tungsten shielding (180kg)

Beam losses induced Background in CLD tracking system



# Beamstrahlung Photon Dump

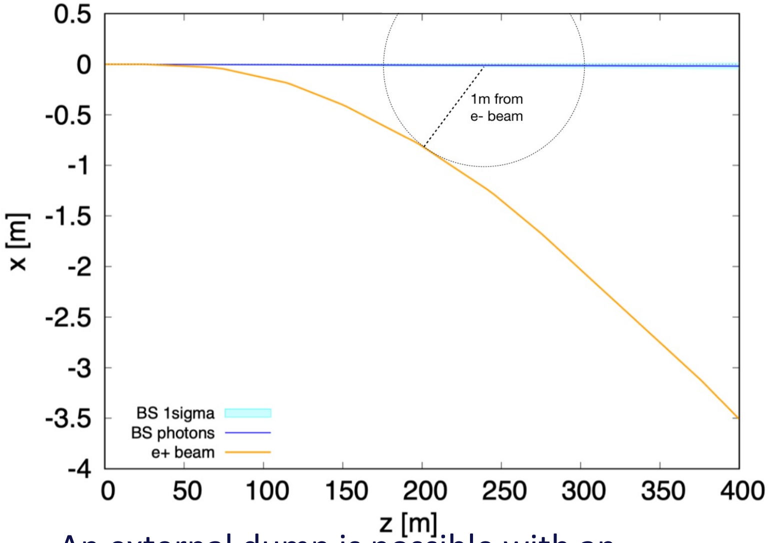
GuineaPig++

| | Total Power [kW] | Mean Energy [MeV] |
|---|---|---|
| Z | 370 | 1.7 |
| WW | 236 | 7.2 |
| ZH | 147 | 22.9 |
| Top | 77 | 62.3 |

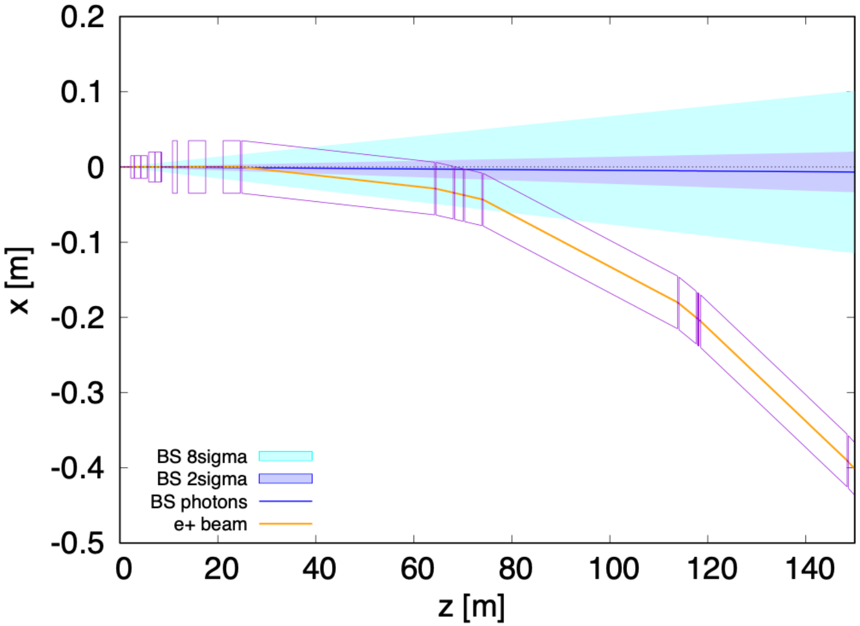
**Radiation from the colliding beams is very intense 370 kW at Z**

**Synchrotron Radiation from the fringe solenoid and anti-solenoid is ~ 77 kW**

An **external dump** **is preferrable**




An external dump is possible with an **extraction line up to at least 400 m downstream of the IP.**




The **size of the shadow** on the pipe wall depends on the amount of radiation which is necessary to collect with the extraction line, and it is **10 meters at just 2 sigmas**.

M. Migliorati (Sapienza & INFN-Roma1) leads the activity for FCC-ee
M. Zobov (LNF), M. Bethouei (LNF)

# Collective effects

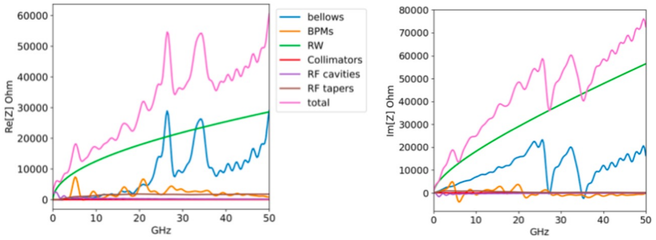
- Impedance budget evaluation in longitudinal and transverse planes for the 4IP layout and for the booster (booster in collab. with DESY)

  Refined collimators design (SuperKEKB geometry)
- Single beam collective effects in longitudinal plane: microwave instability

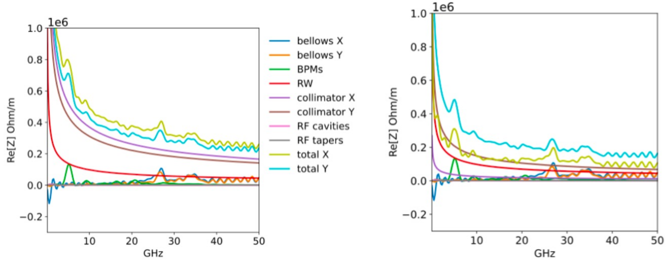
  can be cured with beam-beam
- Single beam collective effects in transverse plane: transverse mode coupling instability (TMCI)

  typically not cured in beam-beam collisions. Simulations give us an indication if we can expect problems with the transverse impedance.
- Beam-beam interaction including the longitudinal impedance

Total impedance: longitudinal




Total impedance: transverse dipolar




initial table updated table

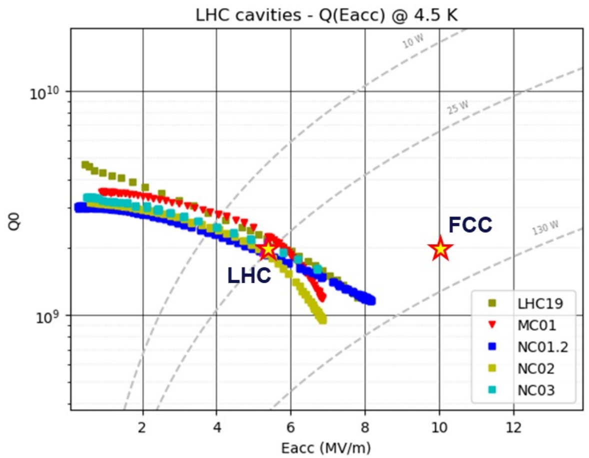

Refs.
M. Migliorati et al, Study of Beam-Beam Interaction in FCC-ee Including Updated Transverse and Longitudinal Impedances», for IPAC23
M. Migliorati et al, *Studies of FCC-ee Single Bunch Instabilities with an Updated Impedance Model*», for IPAC23
IPAC22
M.Migliorati, M.Zobov, et al. EPJ+ (2021) link

# Thin film SRF cavities R&D @LNL

Cristian Pira (LNL)

## CERN-INFN Collaboration proposal
## (INFN European Strategy for Particle Physics)

CERN contacts: G. Rosaz e W. Venturini



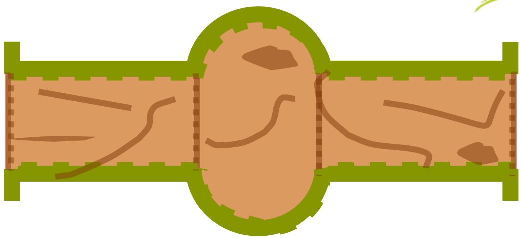

FCC-ee requires higher cavities performances rather than LHC

Mandatory improve all production steps

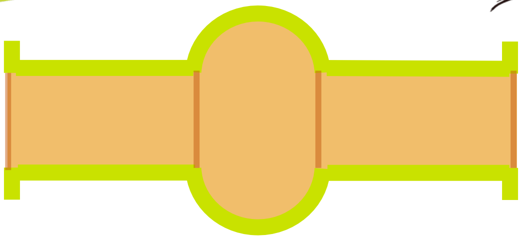
IPAC2023 e SRF2023:
Pira C. et al, *"Nb3Sn on Cu Coating By Magnetron Sputtering From Target Synthesized via Liquid Tin Diffusion"*,
Chyhyrynets at al, *"Progress of application and surface enhancement by Plasma Electrolytic Polishing as a new treatment for SRF substrates and accelerator components preparation"*,

# Proposed 3 Different R&D on:

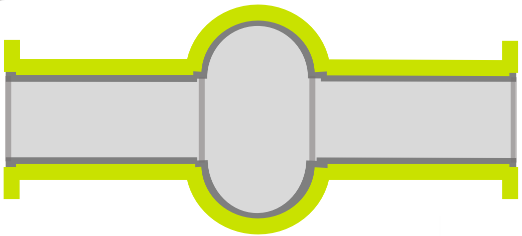
## Cavity Forming

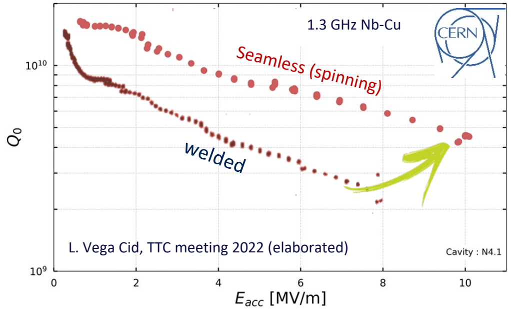


## Surface Polishing

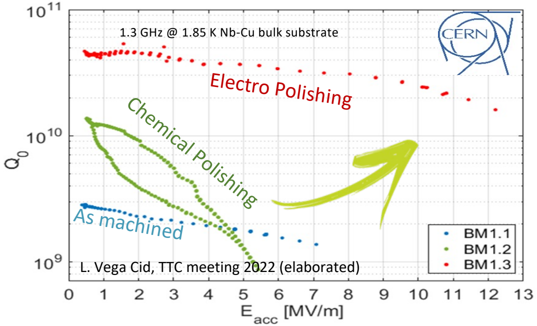


## SC Coating

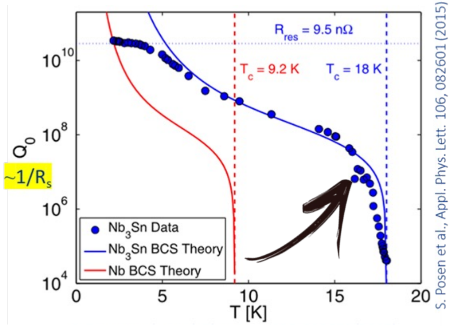





Seamless Spinning




Plasma Electrolytic Polishing (PEP)

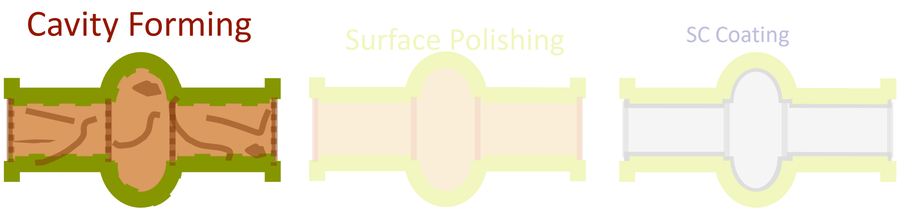



$Nb_3Sn$

Higher Tc than Nb → Lower $R_{BCS}$ @4.2 K

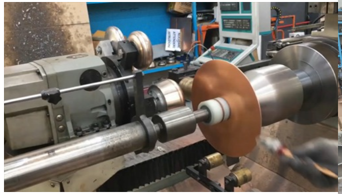
# Seamless Cavity Fabrication @LNL by spinning

Cristian Pira (LNL)




**PROPOSAL:**

CNC Machine process evaluation
on 1.3 GHz cavities
to increase process reproducibility and geometrical accuracy
of seamless spinning



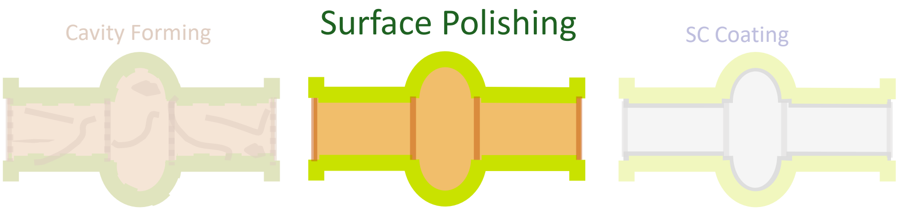
1.3 GHz seamless copper production by spinning


400 MHz seamless copper Prototype

Azzolini et al, SRF2019 proceedings

Cristian Pira (LNL)

# Plasma Electrolytic Polishing @LNL




**INFN PATENT**

PEP Compared to standard electropolishing:
10 times faster and 3 times more efficient
Safer and more eco-friendly than EP
Polishing of large areas challenging

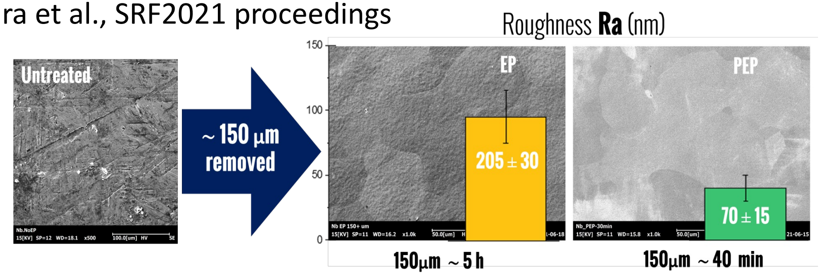
## PROPOSAL:

Polishing technique comparison
on small samples to define
the best polishing technique for FCC cavities

Developing @LNL a 1.3 GHZ PEP system

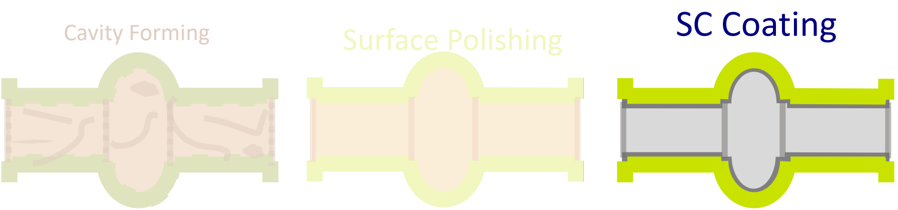
Polishing a 1.3 GHz CERN cavity @LNL
and coating @ CERN

Pira et al., SRF2021 proceedings

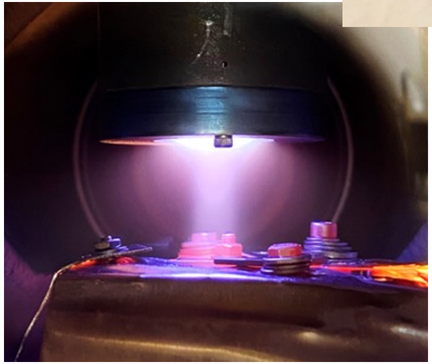


Cristian Pira (LNL)

# $Nb_3Sn$ on Cu @LNL




$Nb_3Sn$ target by dipping



Sputtering $Nb_3Sn$

## PROPOSAL:

Information exchange on coating R&D (CERN is studying HIPIMS and LNL DC Magnetron Sputtering)

1.3 GHz target production by dipping @INFN for CERN coatings

# FCC-ee Injector

Funded by CHART –Swiss program: Collaboration between PSI and CERN with external partners

WP0. Coordination (PSI/CERN)
Task 0.1 Coordination
Task 0.2 Overall parameter optimization

WP1. e+/e- 6 GeV Injector Linacs CERN

WP2. Electron and positron Linac extension study (PSI)

WP3. Positron source: target and capture system (IJCLab)

WP4. Damping ring and transfer lines (INFN/LNF)

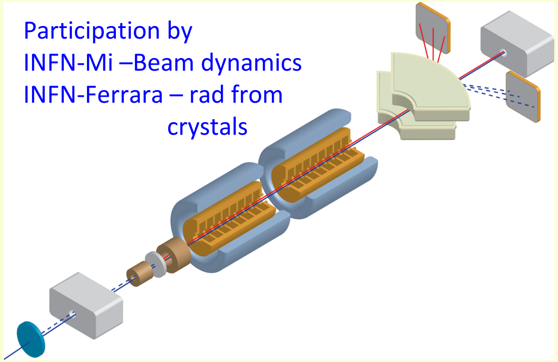
WP5 CDR+, all partners

CDR+ and cost estimate

P³ project

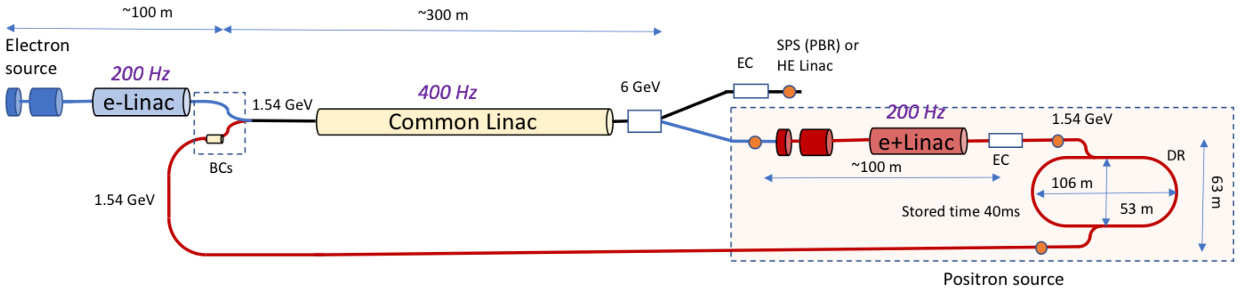
WP6. Proof of Principle positron source and capture in SwissFEL (PSI)

Participation by
INFN-Mi –Beam dynamics
INFN-Ferrara – rad from crystals



PSI Positron Production (P³) project

Several injector layout have considered with different TL arrangements, latest FCC-ee injector layout 6 GeV option (since April 2022)

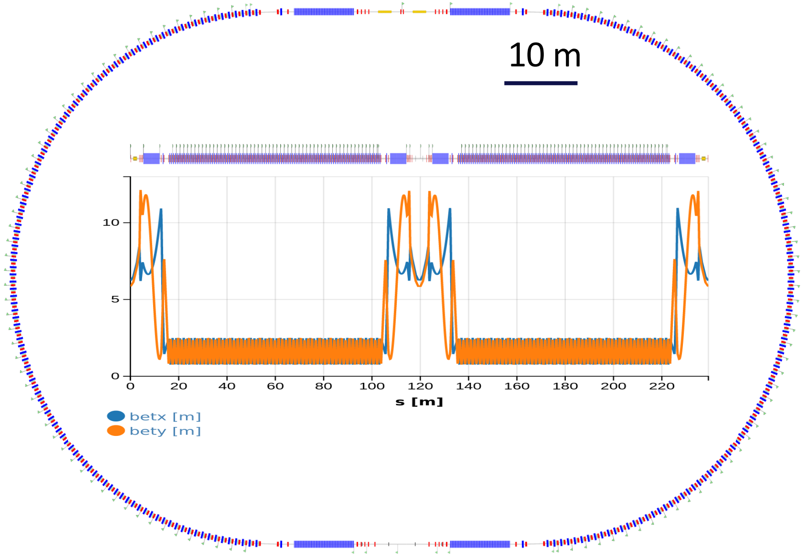



C. Milardi, Damping Ring and Transfer Lines Overview, FCC-ee Injector Studies Mini-Workshop, Nov. 24-25, 2022, IJCLab, France

*WP4 Injector :*
***Milardi C.***, *De Santis A., Spampinati S. (LNF-INFN, Italy);*
*Etisken O., (LNF-INFN, Italy and Kirikalle University, Turkey);*
*Ramjiawan R. L., Dutheil Y., (CERN, Geneva, Switzerland).*

# FCC_ee Injector complex: transfer line and damping ring

Damping Ring optics has been optimized starting from the layout initially proposed by K. **Oide** and S. **Ogur** in 2020, with special attention to: dynamic aperture evaluation, beam acceptance and injection section design.



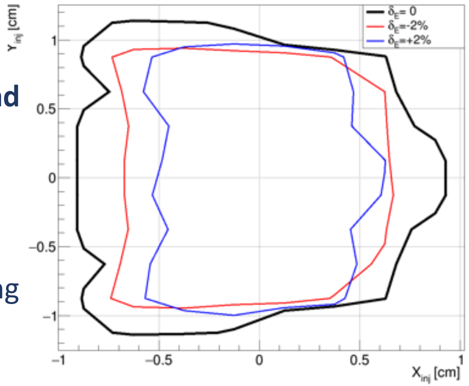

| Parameter | FCC_ee DR (CDR) |
|---|---|
| Circumference | 241.8 m |
| Equilibrium emittance (x/y/z) | 0.96 nm/ - /1.46 μm |
| Dipole length, Field | 0.21 m / 0.66 T |
| Wiggler #, Length, Field | 4, 6.64 m, 1.8 T |
| Cavity #, Length, Voltage | 2, 1.5 m , 4 MV |
| Bunch # Stored, Charge | 16, 3.5 nC |
| Damping Time $\tau_x/\tau_y/\tau_z$ | 10.5 / 10.9 / 5.5 ms |
| Store Time | 40 ms |
| Kicker Rise Time @1.54 GeV | 50 ns |
| Energy Loss per Turn | 0.225 MV |
| SR Power Loss Wiggler | 15.7 kW |

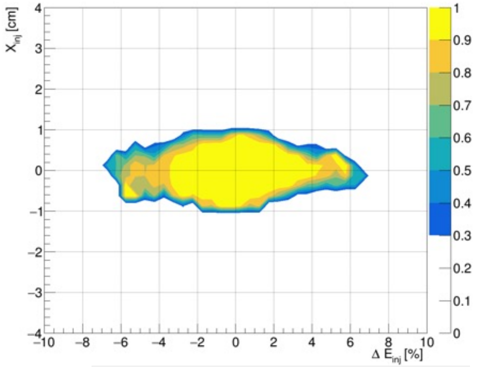
Project Timeline

- TDR frozen by summer 2023 for the FCC-ee mid-term review
- Cost evaluation by the end 2023
- It might very well be that the FCC-ee Injector study will be prolonged beyond the end of 2023.
- FCC-ee feasibility report document by end 2025

# Damping Ring dynamic aperture

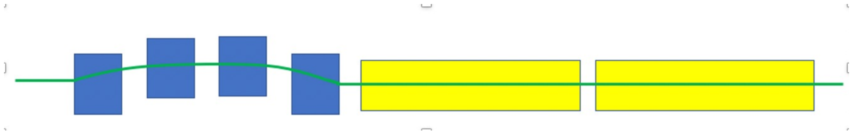
- The stable region is kept quite constant within **2% energy spread** and it drops significantly for higher deviations.
- Full simulation to esteem the dynamic aperture of the damping ring have been performed
- The **color map represents the fraction of survived particles at the end of the tracking as a function of the initial horizontal position and energy deviation.**
- A gaussian beam with the value of horizontal and vertical emittances (1.29 and 1.22 mm mrad) indicated in the CDR is used




*Courtesy* of A. De Santis (LNF)

# Energy Compression System design

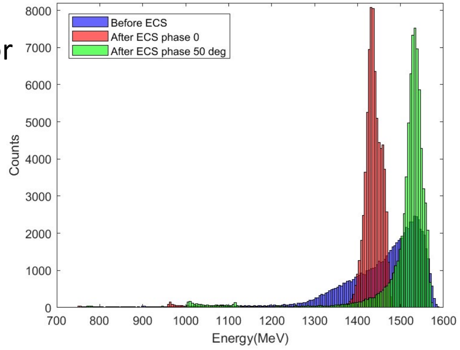


ECS **Dispersive path R56**

**RF cavity at zero crossing to compensate the linear chirp**

- A four bending C-shape chicane is a simple choice for the dispersive region
- Two cavities of the type used for the positron linac

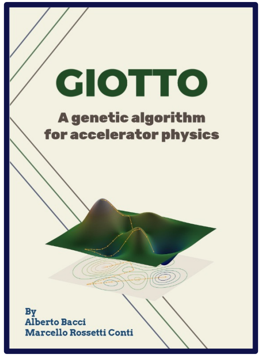
**R56=-0.25m**
Total RF voltage **120M**
RF frequency **2GHZ**




- System simulated with ELEGANT including CSR (1-D model)
- **ECS compresses the beam energy distribution**
- **The fraction of the beam accepted by the damping ring (+/-2%) is increased by more than a factor 2 from 0.36 to 0.86**

*Courtesy* of S. Spampinati (LNF)

# Genetic Interface for OpTimizing Tracking with Optics

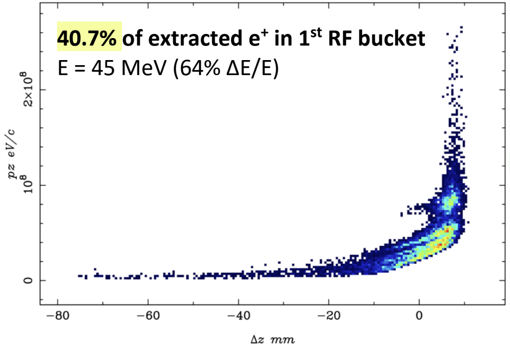



**One of first AI codes for beam line design & optimization born @ INFN-Milano.**
**Solves complex multi-objective problems** (space-charge BD) & statistical analysis (BD jitters studies).

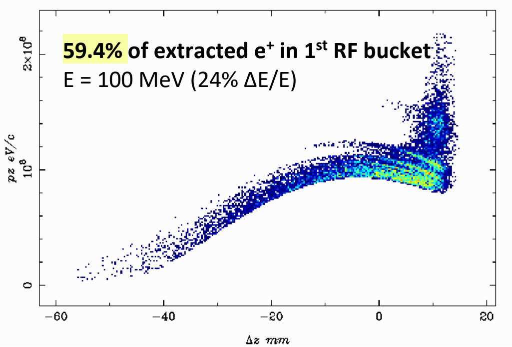
Successfully used for
EUPRAXIA, MARIX, SPARC_LAB, ELI-NP

- Electron acceleration to drive the positron source by using code like Astra and Elegant
- Simulation of the electron+target interaction (i.e. positron generation) by using codes like Geant4 and/or Fluka
- Entrapment chain study and optimization **by using the GIOTTO code**. **Main goals: to maximize positrons flux and beam quality**.
- Last activities under development: Coding of GIOTTO postpro for a new fitness function based on Damping ring dynamic aperture

### Starting Point




### GIOTTO Optimized Point




## @ FCC-ee: first application in $e^+$ capture line

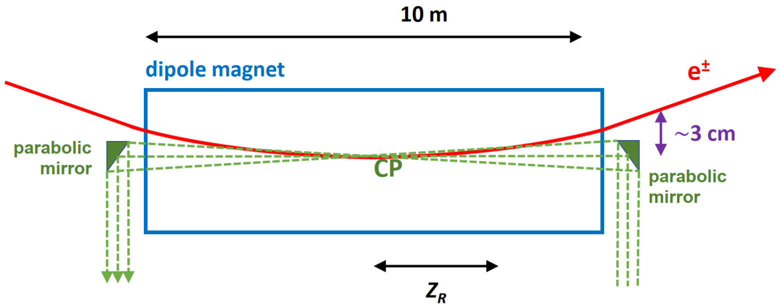
*presented by M. Rossetti Conti in Lyon FCC-workshop 21-nov-22*

Refs.: PRAB **22** (2019) - NIM A **909** (2019) - JAP **133** (2013)
New study Submitted @ PRAB in January (2023)

# Intensity control and diagnostic by Compton scattering

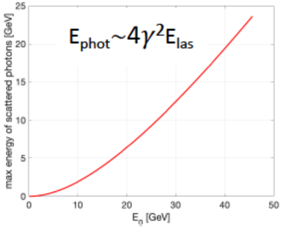
**Motivation:**

- In FCC-ee the intensity of colliding bunches must be tightly controlled, with a maximum charge imbalance between collision partner bunches of less than 3–5%.
- **Laser Compton backscattering could be used to adjust and fine-tune the bunch intensity.**

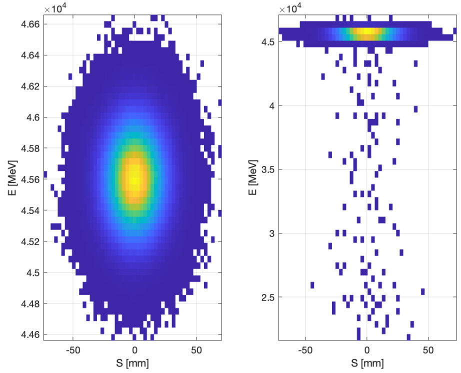



Sketch of the Compton collision inside a single 10 m long dipole.

| Laser | |
|---|---|
| $\alpha_0$ | 0. [deg] |
| Pulse Energy | 1 [J] |
| $\sigma_{x,y}$ | 400 [µm] |
| $\lambda$ | 800 [nm] |
| $\sigma_t$ | 300 [ps] |




Before collision After collision




$Ne_{tot}$=2.68e+11; $Ne_{scat}$=3.45e+07;

- **To-Do**: Find optimal position for Compton IP and optimise focusing parameters to increase efficiency of collision
- **Next:** Make full tracking simulation using beam after collision
  Find application and users for 25 and 150 GeV photon beam

**IPAC23**

*"Optimization of the FCC-ee positron capture line"*, A. Bacci, F. Broggi, M. Rossetti Conti, (INFN-Mi), F. Alharthi, I. Chaikovska, V. Mytrochenko (IJCLab)
*"Optimizing the beam intensity control by Compton back-scattering in FCC-ee"*, Illya Drebot (INFN-Mi), Michael Hofer, Frank Zimmermann
*"Positron beam dynamics at the beginning of a large aperture FCC-ee capture linac"*, V. Mytrochenko (Nat. Sc. C.), A. Bacci, M. Rossetti Conti (INFN-Mi), F. Alharthi, E. Bulyak, I. Chaikovska, R. Chehab (IJCLab)

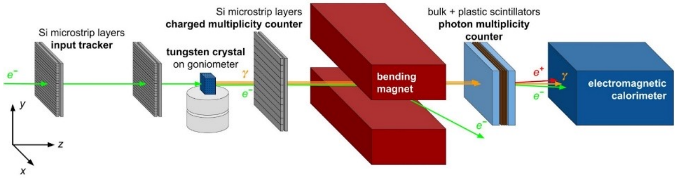
# Hybrid crystal based e+ source for FCC-ee

- Involved Italian teams: INFN Ferrara, LNL,MiB, Sapienza
  Other: IJCLab Orsay and INP Minsk
- MoU on crystal based positron source between INFN-Ferrara & CNRS IJCLab signed in September 2022

Main advantages of the hybrid source:

- Enhancement of photon generation in crystals in channeling conditions -> enhancement of pair production in the converter target
- High rate of soft photons -> creation of soft e+ easily captured in matching systems
- Decrease of the deposited energy and Peak Energy Deposition Density (PEDD) in the converter target

## 2022 Experimental activities: irradiation and testbeam




Test beam with a 2mm W crystal and 6 GeV electrons at CERN PS T9 beamline to validate the MC

## Current and future plans

- ❑ Continuation of the irradiation test also with different materials for amorphous target (purchased by IJCLab). Test of radiation enhanchement @CERN PS/SPS in different crystals*.
- ❑ The simulation environment has now been fully developed and can be used for more sophisticated studies (capture system etc…) and to be included in the full injection chain for direct comparison with the conventional scheme.

*Irradiation tests and crystal targets financed within CSN1 RD-MUCOL for 2023

Some Refs.:
L. Bandiera et al., EPJC 82, 699 (2022) Crystal-based pair production for a lepton collider positron source
M. Soldani, A. Sytov (INFN-Fe) Hybrid source optimization for FCC, https://indico.ijclab.in2p3.fr/event/8920/contributions/28017/

R. Musenich, S. Farinon (INFN-Ge)

# Detector solenoid & IR magnets

- **Contributo allo sviluppo del solenoide per il rivelatore IDEA con R&D sul conduttore.**

  Attualmente i magneti per rivelatori sono avvolti con conduttori basati sulla lega NbTi ($T_c$=9 K). La stabilità rispetto a eventi che possono provocare il quench è garantita da un rivestimento di allumino puro realizzato per co-estrusione. Al momento non esistono più aziende che forniscono questi conduttori.
  Tra le possibili alternative, l'uso di conduttori a base di $MgB_2$ ($T_c$=39 K) è particolarmente interessante e promettente.
  La fase iniziale (2023) riguarda uno studio di principio di magneti avvolti con $MgB_2$.
  La seconda fase richiederà un R&D specifico sui conduttori .

- **Contributo alla modellizzazione final focus quads QD0, molto simile a quello di SuperB, e test.**

  La Sezione di Genova ha il software e le competenze per la modellizzazione nonché le attrezzature per i test funzionali (a 4.2 K) su modelli e prototipi.

# Timeline LEP3-TLEP-FCC

| | | | |
|---|---|---|---|
| Higgs Boson Discovery | 2012 | 20/Jan/12 A. Blondel and F. Zimmermann, TLEP, ArXiv:1112.2518v1 | |
| Snowmass | 2013 | 14/Feb/13 LNF mini-Workshop: Higgs Factories LEP3 and TLEP, Physics opportunities (chair, MB) | |
| | 2014 | MoU INFN-FCC (CDR preparation phase) | |
| 1st FCCWEEK15 Washington DC | 2015 | | |
| | 2016 | 2nd FCCWEEK16 Rome (LOC chair, MB) | **RD_FA** [CSN1] resp. naz. F. Bedeschi<br>**WP2: MDI** (convener MB) |
| | 2017 | | |
| CDR phase | 2018 | EUROCIRCOL (INFN resp. MB) FCC-hh | |
| **CDR Release** | 2019 | | |
| EPPSU | 2020 | | |
| | 2021 | MoU INFN-FCC (FS report) | **RD_FCC** (RD_FA tolto WP Muon C) |
| | 2022 | 21/March/22 Rome, First FCC Italy workshop<br>21/Nov/22 Lyon, FCC Italy-France workshop | **WP2: Acceleratore** (convener MB) |
| Snowmass | 2023 | | |
| Feasibility Study Phase | 2024 | FCCIS (INFN resp. MB) FCC-ee | |
| **FS Report Release** | 2025 | | |
| EPPSU | 2026 | | |

# First US FCC Workshop

**This workshop aims to better organize the FCC-ee community within the US and identify the most important and feasible areas of research to enable optimal FCC-ee accelerator, detectors and physics output by leveraging our domestic expertise.**
We will discuss the most needed elements and venues of FCC research in the US that can benefit the anticipated "**integrated future colliders R&D program**" for the next decade.
**Outcomes of this workshop will provide input to the P5 discussions.**

*Covered Topics:*
Physics, Detector, MDI, IR design, Backgrounds, IR magnets

# Joint FCC-France & Italy Workshop in Lyon

Nov. 21-23, 2022
https://indico.in2p3.fr/event/27968/

Important opportunity to develop R&D collaborations on theory, software, accelerator, experiments/detectors

Proposta di rendere questi workshop periodici

FUTURE CIRCULAR COLLIDER
Expanding our Horizons

cnrs IN2P3

cea

INFN
Istituto Nazionale di Fisica Nucleare

FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754.

iP2i LES 2 INFINIS LYON

UNIVERSITÉ DE LYON

Joint FCC-France & Italy Workshop in Lyon

Nov 21 – 23, 2022
IP2I Lyon
Europe/Paris timezone

Enter your search term

- Accueil
- Timetable
- Inscription
- Participant List
- Practical information
- FCC organization in France and in Italy
- Committees

contact
gregorio@in2p3.fr
smgascon@in2...

Dear Colleagues,

The first joint FCC-France&Italy workshop on Higgs, Top, EW, HF and SM physics will take place at the Institut de physique des 2 infinis de Lyon (IP2I Lyon) from Nov 21st to 23rd, 2022, on the Université Claude Bernard Lyon 1 Campus, Domaine Scientifique de la Doua, Villeurbanne (next to Lyon). This meeting corresponds also to the 4th FCC-France / Higgs, Top & ElectroWeak Factory workshop.

Since this is an in-person workshop to strengthen the community, all the speakers are expected to be on-site for their presentations, while remote access will be available to the registered colleagues who just want to follow the plenary sessions of Monday and Wednesday (no zoom for the parallel sessions on Tuesday).

The Workshop will take place from Monday November 21st noon, to Wednesday 23rd 2022 early afternoon.

Registration for on-site participation will close on November 11th. Practical information can be found in the registration section and in the practical information section.

The workshop aims at intensifying French and Italian collaboration and participation to the FCC feasibility study through accelerator and detector concepts studies, concrete studies on physics and the constraints that this physics entails on detectors, in particular the physics of FCC-ee, but also FCC-hh. Detector R&D. Progress on Theory and on Accelerators for FCC will be presented in details. Synergies with developments for the ILC will also be discussed.

A quasi complete version of the agenda is on-line.

**Starts** Nov 21, 2022, 8:30 AM
**Ends** Nov 23, 2022, 4:00 PM
Europe/Paris

IP2I Lyon
zoom: https://cern.zoom.us/j/68076047
pwd=NWNsVy9HcOhEaWVwWVpqVlErN
Lyon, campus de la Doua, University Clau
Bernard
4 Rue Enrico Fermi, 69100 Villeurbanne
Go to map

Franco Bedeschi
Gregorio Bernardi
Manuela Boscolo
Suzanne Gascon-Shotkin

GeraldPlan_local.pdf

# FCC-EIC Collaboration

## FCC-EIC Joint & MDI Workshop

*Chair* M. Boscolo, 2 weeks, 91 participants, Indico page: link

- Common challenges and collaborative opportunities
- MDI and IR topics

- Initiative to strengthen collaboration
- Collaboration is endorsed by management on both sides (link)
- Currently identifying common areas of interest and contact persons

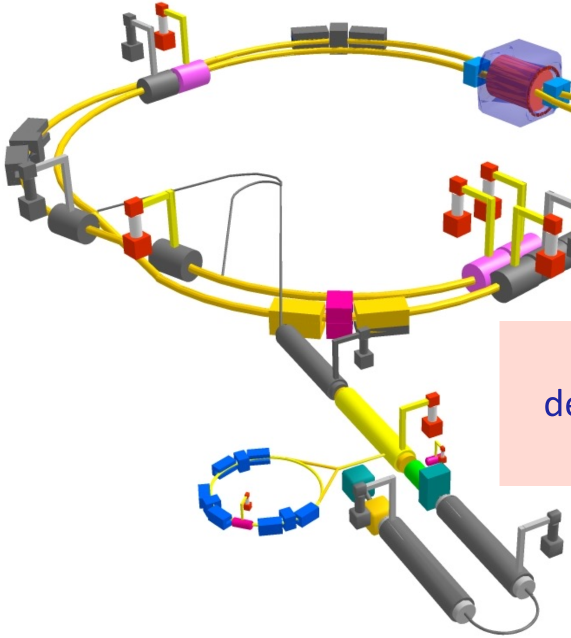
Frank Zimmermann's closing remarks: link

**CERN FCC – EIC collaboration, contact persons - *preliminary***

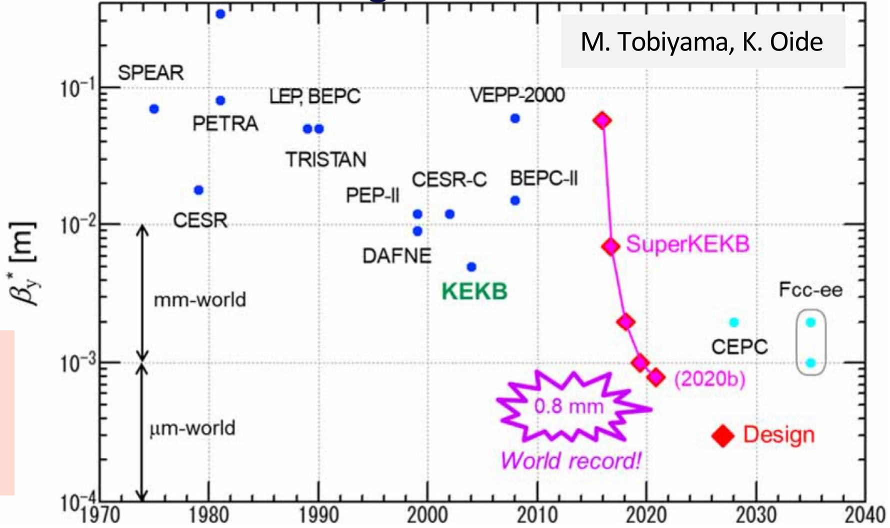
| Domain | CERN/FCC contacts | BNL/EIC contacts | JLAB/EIC contacts | Other contacts FCC | Other contacts EIC |
|---|---|---|---|---|---|
| **impedance model, instabilities, HOM, ion instability** | Mauro Migliorati (INFN), Ivan Karpov (CERN) | Mike Blaskiewicz, Alexei Blednykh, Silvia Verdu (?) | Todd 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) | |
| **SRF** | Erk Jensen, Frank Gerigk, (CERN) | Kevin Smith | Robert Rimmer | | |
| **MDI, IR shielding, handling equipment associated with the IR** | Manuela Boscolo (INFN), Helmut Burkhardt (CERN) | Holger Witte | Walter Wittmer | Mike Sullivan (SLAC) | |
| **Collimation – beam tails** | Andrey Abramov (CERN) | | | Dmitry Shatilov (BINP) | |
| **Beam-beam interactions (limits with multiple IPs)** | Xavier Buffat (CERN) | | | Dmitry Shatilov (BINP) | |

# SuperKEKB – "FCC-ee demonstrator"

**Double ring $e^+e^-$ collider *B*-factory** at 7($e^-$) & 4($e^+$) GeV; **design luminosity ~8 x $10^{35}$ $cm^{-2}s^{-1}$; design $\beta_y^*$ ~ 0.3 mm; beam lifetime ~5 min; top-up** inj.; ~ **2.5 $10^{12}$ $e^+$/s ; under commissioning**




SuperKEKB is demonstrating FCC-ee key concepts




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

Invitata nel SuperKEKB IR Upgrade group recentemente creato, siamo in contatto costante in questi anni sin dall'inizio. CERN fellows andati a fare esperienza di commissioning, discussione su soluzioni tecnologiche e disegno per FCC-ee.

# Summary

- Fase preparatoria dello studio di fattibilità di FCC per la prossima Strategy

- INFN ben rappresentata nella governance FCC
- Anche l'INFN prepara i suoi contributi per la Strategy su FCC

- Attivita' di macchina su FCC è finanziata da CSN1 in RD_FCC
- WP-Acceleratore fondato l'anno scorso espandendo il gruppo MDI, nuove attività avviate
- Partecipazione al progetto FCCIS, CHART Swiss program, collaborazioni internazionali

# Outlook

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 in all domains.**

Unique (might be the only one) opportunity for the community involved on high luminosity and high energy colliders!

**Italian contribution well in place at the coordination and individual activity level.**

**Need to follow the acceleration of the project to secure full support, strongly needed for its success.**

# Infos about FCCIS & EUROCIRCOL INFRADEV EU-H2020
# e sinergie con altri fondi esterni

# FCCIS H2020-INFRADEV Design Study

INFN Scientific coordinator M.Boscolo

**WP2: collider design** (DESY) 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.

**Task Interaction region and machine detector interface** design [Deliverable: 1/7/2023 IR & MDI Design]

(lead: M. Boscolo, participants: CERN, CNRS, DESY partners BINP and UOXF)

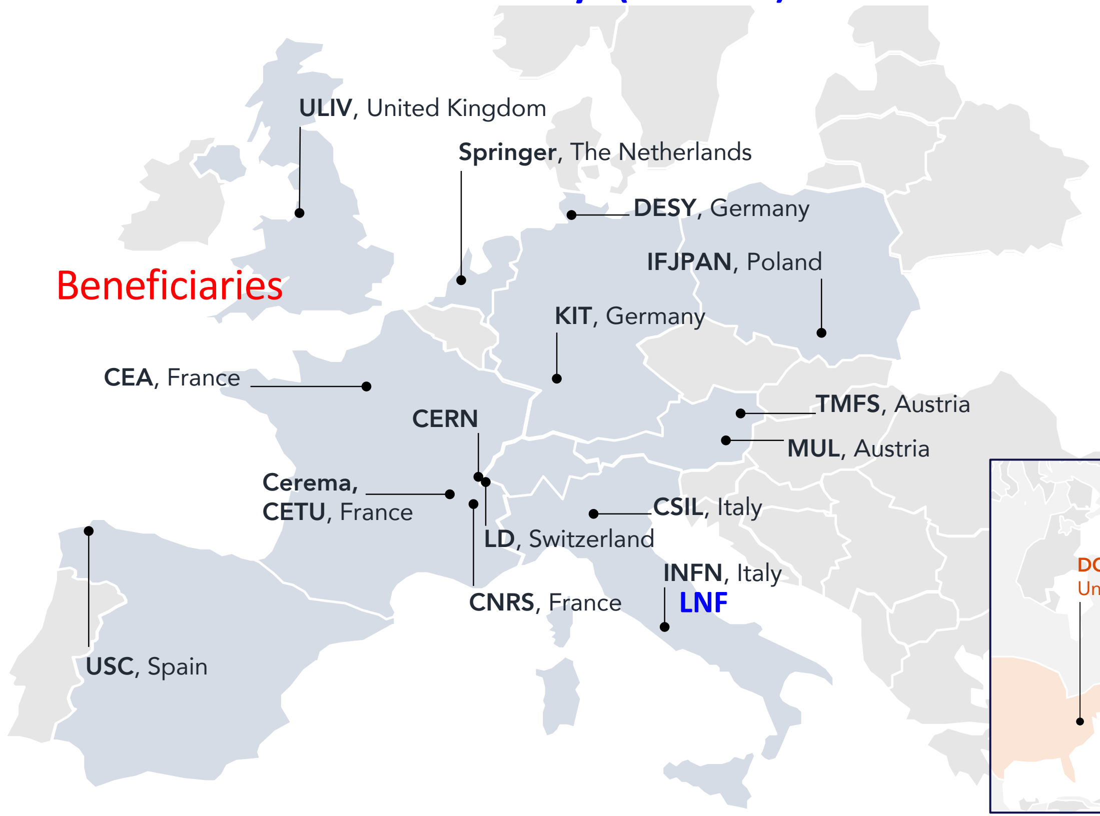
**Subtask:** Analyse and mitigate **impedance and single-beam collective effects** in the collider rings (M. Migliorati)

WP3: integrate Europe (CERN) Develop a feasible project scenario compatible with local – territorial constraints while guaranteeing the required physic performance.

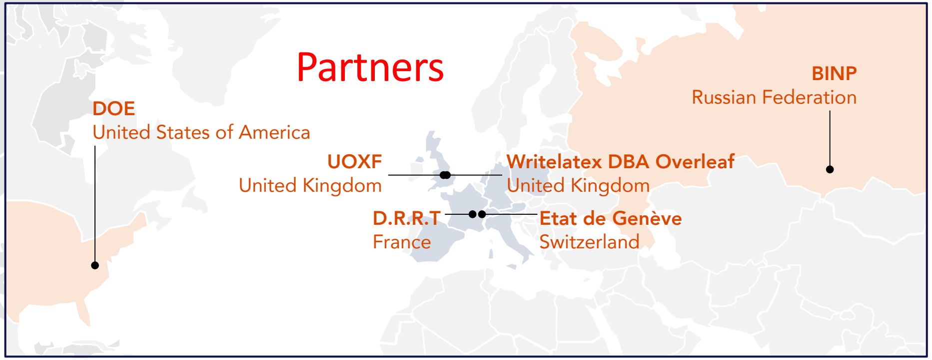
WP4: impact & sustainability (CSIL, *Centro Studi Industria Leggera, Italy*) Develop the financial roadmap of the infrastructure project, including the analysis of socio-economic impacts.

WP5: leverage & engage(IFJ PAN) 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).

# FCC Innovation Study (FCCIS) EU- H2020



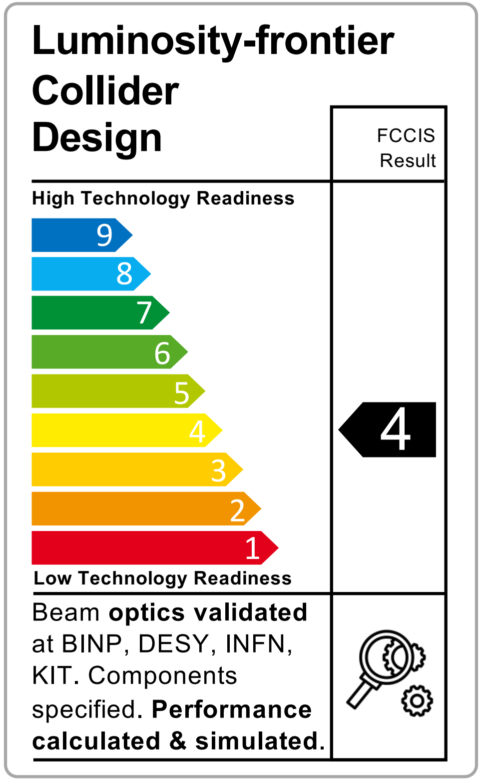

| Topic | INFRADEV-01-2019-2020 |
|---|---|
| Grant Agreement | FCCIS 951754 |
| Duration | 48 months |
| From-to | 2 Nov 2020 – 1 Nov 2024 |
| Project cost | 7 435 865 € |
| EU contribution | 2 999 850 € |
| Beneficiaries | 16 |
| Partners | 6 |

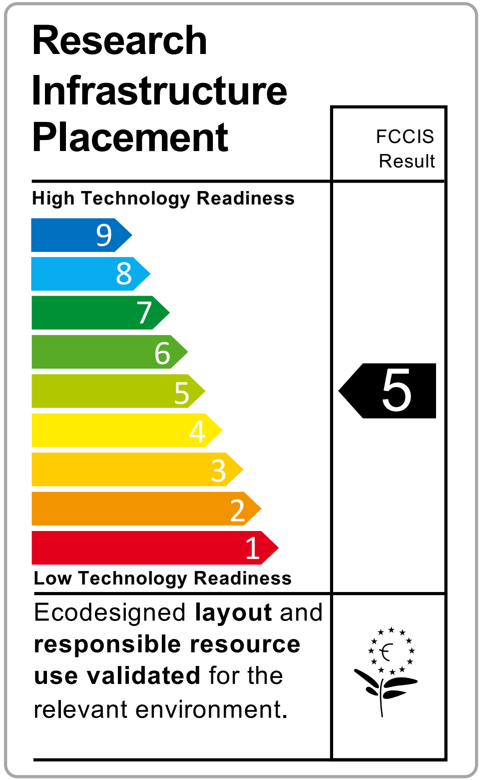



2 AdR, 1 art.36

# 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



# Sustainability aspects and studies

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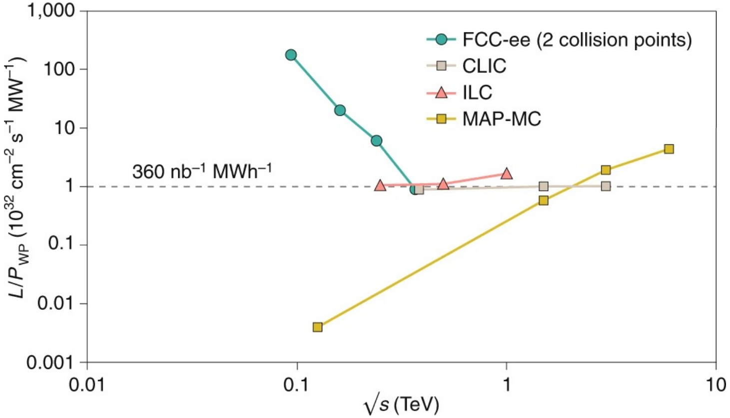
## highly sustainable Higgs factory

### luminosity vs. electricity consumption




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

## optimum usage of excavation material

### int'l competition "mining the future®"

https://indico.cern.ch/event/1001465/

## FCC-ee annual energy consumption ~ LHC/HL-LHC

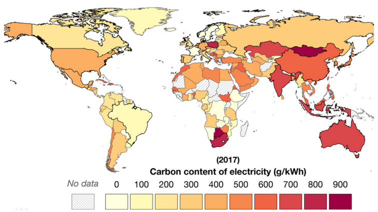
| 120 GeV | Days | Hours | Power OP | Power Com | Power MD | Power TS | Power Shutdown | | |
|---|---|---|---|---|---|---|---|---|---|
| Beam operation | 143 | 3432 | 293 | | | | | 1005644 | MWh |
| Downtime operation | 42 | 1008 | 109 | | | | | 110266 | MWh |
| Hardware, Beam commissioning | 30 | 720 | | 139 | | | | 100079 | MWh |
| MD | 20 | 480 | | | 177 | | | 85196 | MWh |
| technical stop | 10 | 240 | | | | 87 | | 20985 | MWh |
| Shutdown | 120 | 2880 | | | | | 69 | 199872 | MWh |
| Energy consumption / year | 365 | 8760 | | | | | | 1.52 | TWh |
| Average power | | | | | | | | 174 | MW |

J.-P. Burnet, FCC Week 2022

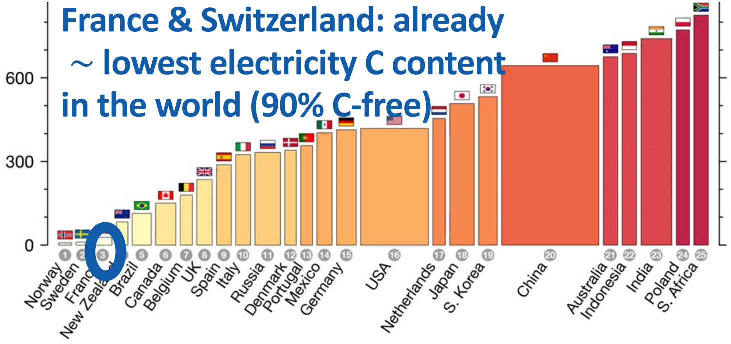
incl. CERN site & SPS

| CERN Meyrin, SPS, FCC | Z | W | H | TT |
|---|---|---|---|---|
| Beam energy (GeV) | 45.6 | 80 | 120 | 182.5 |
| Energy consumption (TWh/y) | 1.82 | 1.92 | 2.09 | 2.54 |

## powered by mix of renewable & other C-free sources



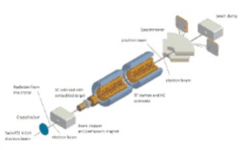

https://www.carbonbrief.org/




France & Switzerland: already ~ lowest electricity C content in the world (90% C-free)

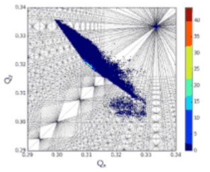
FUTURE CIRCULAR COLLIDER

# CHART - Switzerland



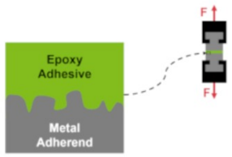
### FCCee Injector

Design and positron production test program for FCC-ee Injector



### FCChh Stability

Long term coherent stability and diffusion studies for the Future Circular Hadron Colliders




### MagAM

Additive Manufacturing for Structural Components in Superconducting Coils

### MagDev1

Superconducting Accelerator Magnet R&D


### MagNum

Sustainable and Consistent Integrated Modelling of Superconducting Magnets

### MagRes

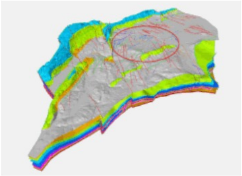
Development of optimized resin systems for SC magnet coil production

### FCCee-Beam Dynamics Simulations

Accelerator design and simulation framework for FCC-ee: optics and collective effects

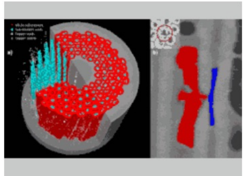
### FCC Geodesy

Determination of a high-precision gravity field model for the FCC region and improvement of the Geodetic Reference Frames and the Geodetic Infrastructure



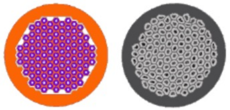
### FCC Geology 3D Model

Development of a high-resolution 3D geological model and associated GIS-based subsurface data set for the FCC tunnelling work



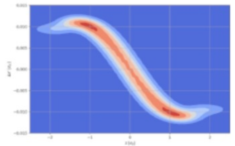
### WireChar

Multiphysical characterization of Nb3Sn wires and of REBCO coated conductors



### WireDev

Development of recipes and methods for the fabrication of Nb3Sn multifilamentary wires with enhanced current carrying capabilities



### FCC / LHC-Lumi

Luminosity Precision Measurements for Hadron Colliders

Founded in 2016 as umbrella organization for accelerator research and technology in Switzerland to support FCC via projects with CERN, PSI, ETHZ, EPFL and U Geneva and further partners.

# **FCC-hh** Key aspects funded by H2020-INFRADEV Design Study **EUROCIRCOL**

resp. M. Boscolo

**Strategic activity for the FCC CDR and cost review for the EPPSU in 2019**

(2015-2019) 3 MEuro, INFN grant: **422 k€**

AdR + Art.36
3 TI ai LNF
+ … INFN

- WP3: **Experimental insertion region design** (M. Boscolo, LNF)
  Impact of synchrotron radiation emitted by protons on detector and machine components and develop mitigation techniques (outcome study: only tens of W reach the central Be chamber, not an issue)

- WP4: **Cryogenic beam vacuum system** (R. Cimino, LNF)
  SR power ~30W/m/beam in arcs, total 5 MW (LHC 7kW), 100 MW of cooling power
  → R&D planned at DAFNE (MoU)

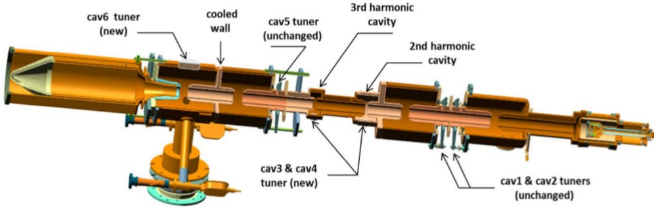
- WP5: **High field magnet design** (S. Farinon, Ge)
  The target field strengths to the order of 16 T require novel concepts and R&D studies
  → High field magnet program

# Additional Material

# Accelerator R&D examples

## efficient RF power sources (400 & 800 MHz)

I. Syratchev



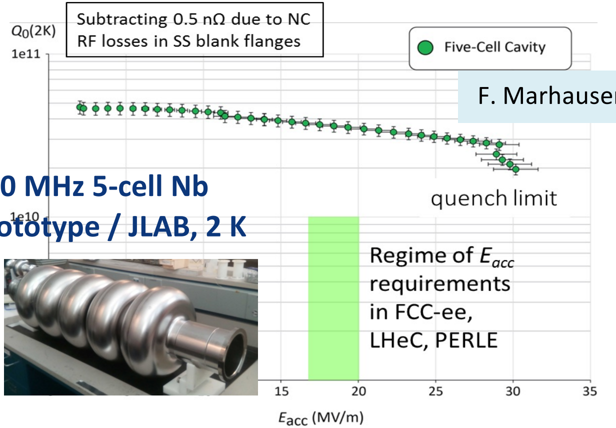

FPC & HOM coupler, cryomodule, thin-film coatings…

## efficient SC cavities

Jefferson Lab

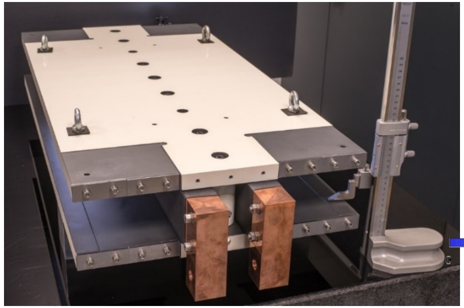
**400 MHz 1-,2- & 4-cell Nb/Cu , 4.5 K**

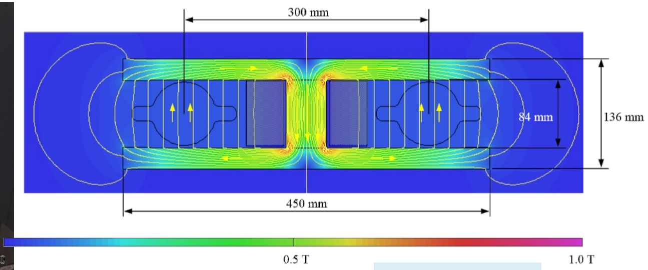
**800 MHz 5-cell Nb prototype / JLAB, 2 K**




F. Marhauser

## energy **efficient** twin aperture **arc dipoles**

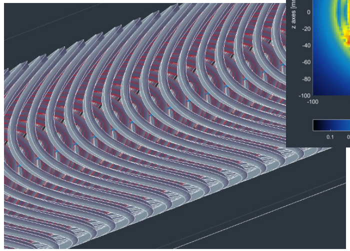


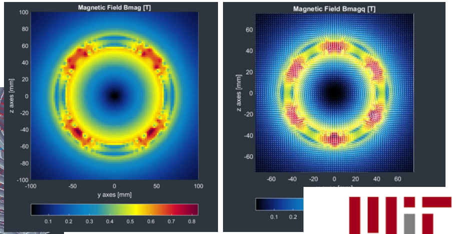



A. Milanese

## under study: **CCT HTS quad's & sext's for arcs**

PAUL SCHERRER INSTITUT PSI






Massachusetts Institute of Technology

M. Koratzinos

Giacomo Broggi (CERN doctoral student & Sapienza & LNF)
within CERN collimation & MDI team

# Collimation studies & IR loss maps

- Using newly-developed simulation tools to study collimation for the FCC-ee

pyAT, Xtrack — Particle tracking
BDSIM (Geant4) — Collimator interactions
Particle transfer at every collimator pass

- First collimation scheme
- Currently focussing on beam halo losses with a workflow similar to LHC studies

- Various beam loss scenarios are being considered
- → The beam loss maps are used to evaluate the impact to the detector using the detector software (Key4HEP)