



# FCC-ee

M. Boscolo (INFN-LNF)

# Sommario

- Organizzazione gruppo macchina nell'INFN e ai LNF su FCC
- Attività FCC ai LNF in corso e per il 2024
- News dalla FCC WEEK 23

# Introduzione -

## Attività FCC Acceleratore in CSN1 nella sigla RD\_FCC

resp naz F. Bedeschi

**WP1 Physics & software**

P. Azzi PD, N. De Filippis BA

**WP2 Acceleratore**

**M. Boscolo LNF**

**WP3 Silicon/Vertex detectors**

M. Caccia MI, A. Andreazza MI

**WP4 Drift chamber**

F. Grancagnolo LE

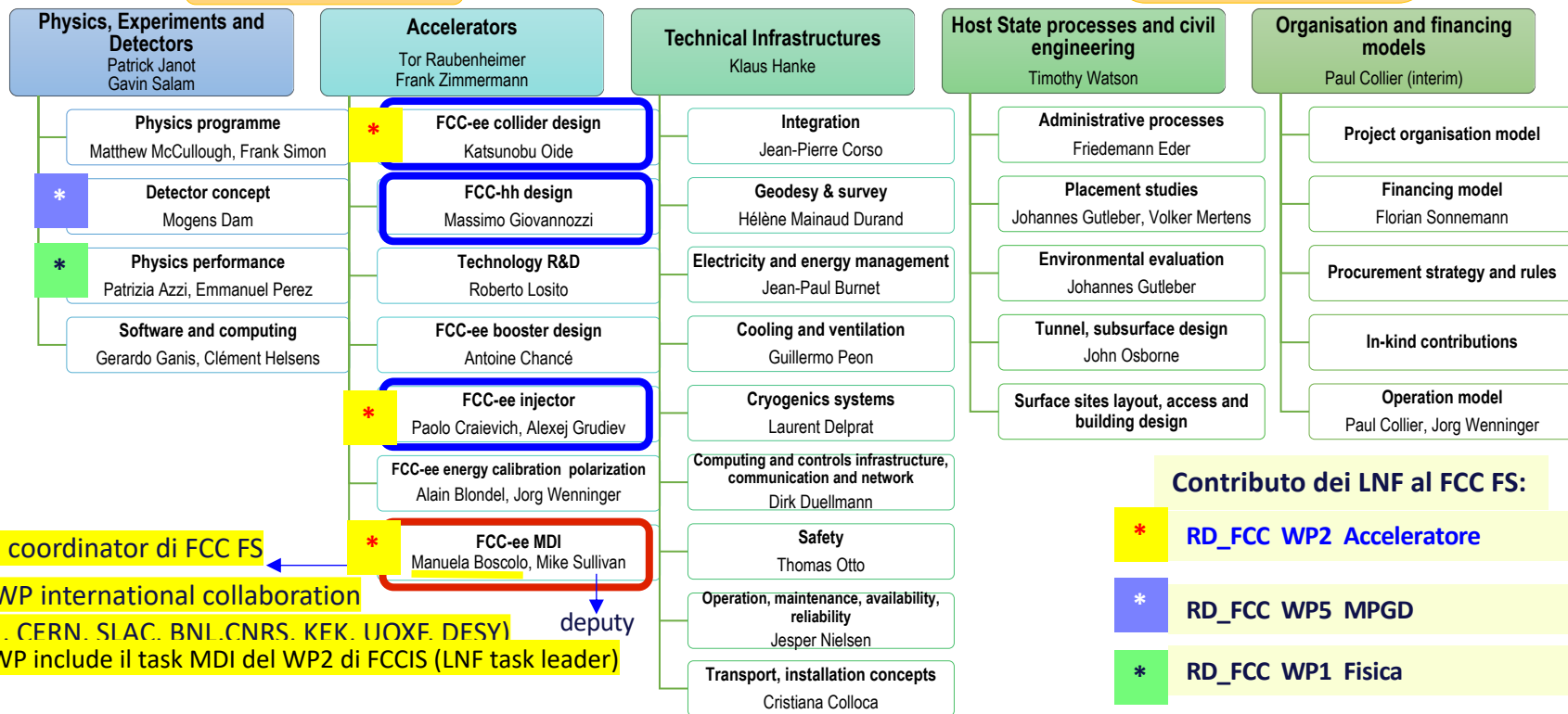
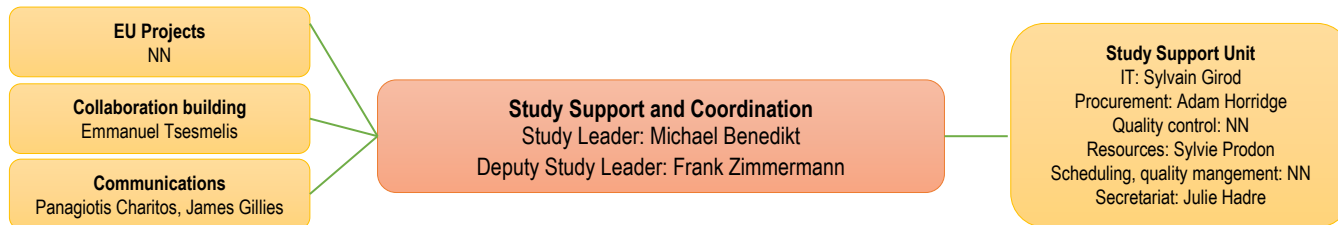
**WP5 MPGD for muon/preshower**

P. Giacomelli BO

**WP6 Dual readout calorimetry**

R. Ferrari PV

# FCC Feasibility Study – coordination team and contact persons



WP coordinator di FCC FS

MDI WP international collaboration

(INFN, CERN, SIAC, BNL, CNRS, KEK, UOJF, DESY)

MDI WP include il task MDI del WP2 di FCCIS (LNF task leader)

deputy

## Team italiano FCC Acceleratore: WP2 RD\_FCC

nuove attività e gruppo in espansione, nuovi finanziamenti

- Regione di Interazione e Machine-Detector Interface **LNF, Pisa, Perugia** (FCCIS, AidaInnova)
- Collimation studies **CERN doctoral student & Sapienza /LNF**
- Cavita' SRF **LNL** (iFAST)
- Effetti collettivi **INFN-Roma1, LNF** (FCCIS)
- Sorgente ibrida di positroni a cristalli **INFN-Ferrara** (PRIN)
- Ottimizzazione beamline linea di cattura e+ **INFN-Milano**
- Diagnostica per il controllo della corrente bunch-by-bunch via Compton scattering **INFN-Milano**
- Damping Ring e+ e linee trasferimento vicine al DR **LNF** (CHART)
- Interesse sui magneti SC di FCC-ee **INFN-Genova**
- Magneti ad alto campo FCC-hh [progetto separato dal feasibility study FCC] **INFN-Genova, INFN-Mi**

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# Anagrafica LNF 2024

## WP Acceleratore

### Disegno della regione di interazione

- Progettazione meccanica IR
- New!

 R&D sperimentale con progetto mockup IR (finanziam. GE&CERN)
- Studio dei fondi macchina nel rivelatore e disegno shieldings
- New!

 Studio beam losses & collimation, specialmente nella MDI area
- Final Focus optics & monochromatization optics
- Beamstrahlung radiation and handling

### Studio effetti collettivi

- Impedenza & beam-beam
- Simulazione impedenza collimatore

### Positron Damping Ring [tbc]

## WP MPGD

- R&D 2024: costruzione di N. 2 rivelatori 50x50 cm2 con lettura 2D X-Y. La scelta del layout 2D per il 2024 si baserà sui risultati ottenuti nel TB-23 e i test con x-ray gun e cosmici

New!

WP Fisica

- Fisica del B

| ANAGRAFICA           | WP     | FTE  | sinergica       | FTE totale | RD_FCC LNF TOTALE |
|----------------------|--------|------|-----------------|------------|-------------------|
| Boscolo Manuela      | Accel  | 0.6  | 0.4 FCCIS       | 1          | FTE 6.9           |
| Broggi Giacomo       | Accel  | 1    |                 | 1          |                   |
| Ciarma Andrea        | Accel  |      | 1 FCCIS         | 1          |                   |
| De Pasquale Enrico   | Accel  | 0.3  | 0.1 FCCIS       | 0.4        |                   |
| Fransesini Francesco | Accel  |      | 1 FCCIS         | 1          |                   |
| Lauciani Stefano     | Accel  | 0.3  |                 | 0.3        |                   |
| Bethouei Mostafa     | Accel  |      | 1 FCCIS         | 1          |                   |
| Mikhail Zobov        | Accel  | 0.2  |                 | 0.2        |                   |
| Gianni Bencivenni    | MPGD   | 0.2  |                 | 0.2        | MPGD FTE 0.9      |
| Marco Poli Lener     | MPGD   | 0.25 |                 | 0.25       |                   |
| Gianfranco Morello   | MPGD   | 0.15 |                 | 0.15       |                   |
| Danilo Domenici      | MPGD   | 0.1  | 0.1 Aidainnova  | 0.2        |                   |
| Erika De Lucia       | MPGD   | 0.1  |                 | 0.1        |                   |
| Monica Bertani       | MPGD   | 0.05 | 0.05 Aidainnova | 0.1        | Fisica FTE 0.1    |
| Marcello Rotondo     | Fisica | 0.1  |                 | 0.1        |                   |
| De Santis Antonio    | Accel  |      | [tbc]           |            |                   |
| Etisken Ozgur        | Accel  |      | [tbc]           |            |                   |
| Simone Spampinati    | Accel  |      | [tbc]           |            |                   |
| Catia Milardi        | Accel  |      | [tbc]           |            |                   |

## Progetti su FCC finanziati dalla giunta INFN per la prossima European Strategy for Particle Physics Update (ESPPU)

- **IR and MDI full-scale mockup (LNF)**
- SRF cavities (LNL)

Progetti revisionati ed approvati dal MAC, finanziati separatamente dalla Giunta ma senza FTE dedicati, gli FTE sono conteggiati in RD\_FCC e quindi l'attività è anche parte di RD\_FCC WP-Acceleratore.



# Disegno Regione di Interazione e MDI

Attività MDI in corso per il 2023-24 nell'INFN e ai LNF

**LNF:** M. Boscolo, G. Broggi, A. Ciarma, E. Di Pasquale, F. Franesini, S. Lauciani;

**Pisa:** F. Bosi, F. Palla;

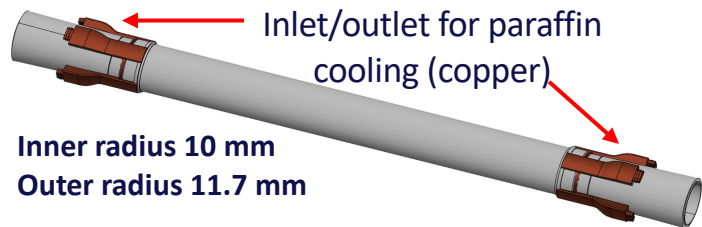
**Perugia:** G. Baldinelli, L. Fanò, C. Turrioni

- **Progettazione meccanica IR e MDI parte del WP MDI FS**
  - attività partita all'inizio del feasibility study e prevista fino a fine 2025
  - Deliverable INFN FCCIS (1 luglio 2023) - IR and MDI design
- **R&D sperimentale sul disegno della regione di interazione con un mockup della IR** (finanziamento ad hoc GE & CERN)
- **Disegno ed integrazione vertex detector (Pisa, in collaborazione con LNF)**
  - IDEA: cabling & services, Simulazioni termo-meccaniche cooling vertex detector
  - adattamento del VXD CLD per la IR di FCC-ee
- **Studio dei fondi macchina nel rivelatore e disegno shieldings**
  - 1 art.36 tecn. x 2 anni LNF, dal 1/2/23 (grant FCCIS)
- **Studio beam losses & collimation design**
  - 1 CERN doctoral student dal 1/3/23, associato ai LNF & Sapienza
- **Final Focus optics – non-local solenoid compensation scheme with P. Raimondi**
  - In progress ai LNF, non è la baseline per il mid-term review
- **Beamstrahlung radiation and handling**
  - Studio fatto con GuineaPig (LNF), update simulazioni con update parametri e ottica, recentemente iniziate simulazioni anche con Fluka.

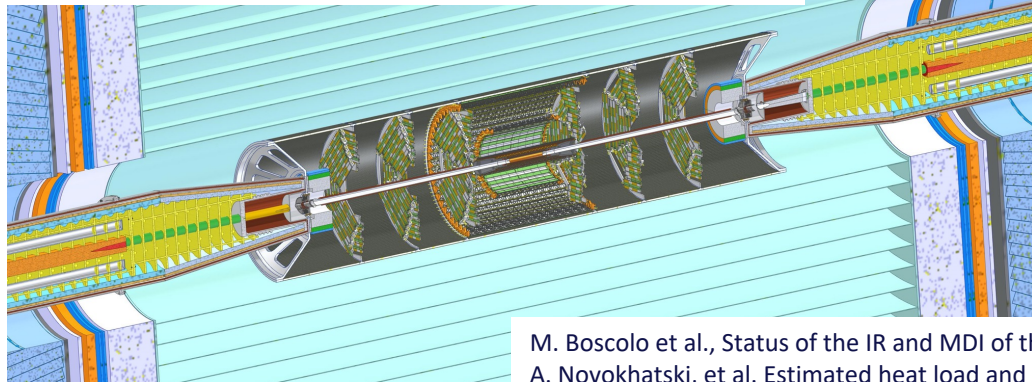
# Mechanical model for the FCC-ee MDI

M. Boscolo, F. Palla, F. Franesini, F. Bosi and S. Lauciani, *Mechanical model for the FCC-ee MDI*, EPJ Techn Instrum 10, 16 (2023)  
<https://doi.org/10.1140/epjti/s40485-023-00103-7>

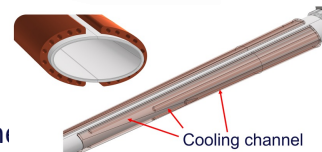
## Low impedance vacuum chamber, warm and cooled (prototyping and mockup planned)



## Central Support tube with endcaps



To reduce the cooling material, this provides **five channels** for each side; in this way is possible to use the needed quantity of coolant and reduce the material, creating a light structure.



M. Boscolo et al., Status of the IR and MDI of the FCC-ee, IPAC23, 7-12 maggio 2023;

A. Novokhatski, et al. Estimated heat load and proposed cooling system in the FCC-ee IR beam pipe, IPAC23, 7-12/5/2023

# FCC-ee Interaction Region rationale

**Crab-waist** scheme, based on two ingredients:

- concept of **nano-beam scheme**: vertical squeeze of the beam at IP and large horizontal crossing angle, large ratio  $\sigma_z/\sigma_x$  reducing the instantaneous overlap area, allowing for a lower  $\beta_y^*$
- **crab-waist sextupoles**

- This scheme, with the goal luminosity of  $10^{36} \text{cm}^{-2} \text{s}^{-1}$  at 45.6 GeV sets constraints to the IR design, among which:

- $L^*$  (free distance between IP and first quad)
- the **strength of the final focus doublet**
- the solenoid **detector field**

$L^* = 2.2 \text{ m}$   
 $G \sim 100 \text{ T/m}$   
 $B(\text{detector}) = 2 \text{ T}$

- Compact IR with the first final focus quadrupole (FFQ) QC1 and two anti-solenoids inside the detector.
- No common magnet between the two beams.
- The two beam pipes split at  $\sim 1 \text{ m}$ .

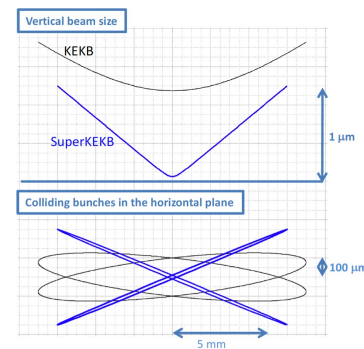


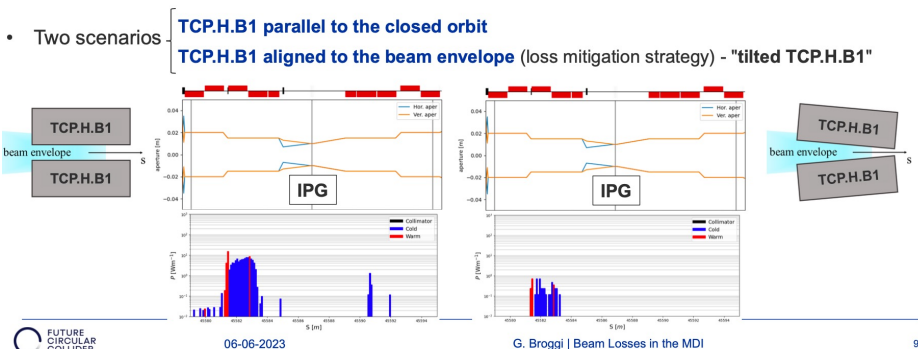
Figure 2: Schematic view of the nanobeam collision scheme.

SuperKEKB <https://arxiv.org/pdf/1809.01958.pdf>

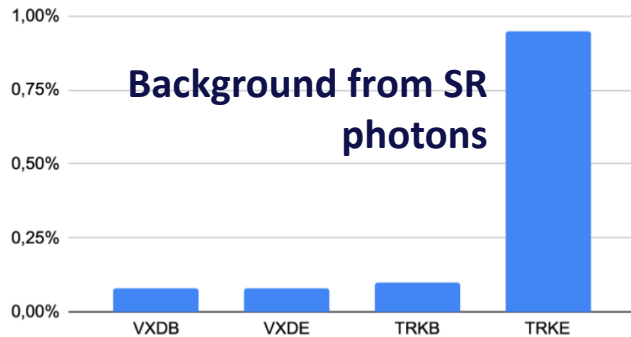
DAFNE, [PRL 104, 174801 \(2010\)](#)

# MDI – Studio dei fondi nel rivelatore e particelle perse con ottimizzazione collimatori

- Studio dell'impatto dei fondi macchina e radiazione di sincrotrone, studio di shielding a protezione del rivelatore e componenti della macchina
- Lavoro di modellizzazione della IR nel software di fisica per tracciare primari e secondari
- Ottimizzazione delle maschere per la radiazione di sincrotrone, e collimatori per fermare particelle che si perderebbero nella IR



Maximum Occupancy in subdetector/BX



( $t\bar{t}$  threshold - CDR beam parameters  
CLD detector - NO shieldings)

Giacomo Broggi

Andrea Ciarna

## FCC-ee IR and MDI full-scale mockup

- The design of the Interaction Region and of the Machine Detector Interface is critical for the entire collider performance. Therefore, this is a **key activity for the FCC Feasibility Study (FS)** to be presented at the **next EU Strategy**.
  - The MDI activity is a WP of the FCC FS, it is set as an international collaboration, and I have the WP coordinating role since 2015, confirmed in 2020 for this FS phase.
- The MDI activity at INFN is well established in terms of MoU & Addenda INFN-LNF/CERN since 2015. It is centered in Frascati.
- R&D project proposed at the FCCIS annual workshop in November 2021
- **Formally approved by the GE after the revision by the MAC in March 2023**
- Signatory phase between INFN-CERN hopefully to be concluded this summer.

**Project in the order of 500 Keuro including personnel**

## Accordo INFN-FCC CERN (aka Addendum)

In via di approvazione da parte degli uffici legali dell'INFN (ok) e del CERN

|                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| <b>Equipment, material</b> | <p>Vertex <u>CF+Al</u> mockup, Al mockup Outer tracker and disks, support cradle, generic tooling: <b>80 <u>kEuro</u></b></p> <p>Central chamber, bellows, trapezoidal chamber with cooling system: <b>100 <u>kEuro</u></b></p> <p>Support tube: <b>100 <u>kEuro</u></b></p> <p><u>Lumical</u> mock-up based on Pb &amp; Al: <b>10 <u>kEuro</u></b></p> <p>Other in-kind equipment (~10kEuro)</p> <ul style="list-style-type: none"><li>- Coordinate Measuring Machine (CMM)</li><li>- Milling machine</li><li>- Chiller</li><li>- Metrology</li><li>- Other infrastructures</li></ul> <p><b>Total cost: 300 <u>kEuro</u></b></p> | <p>} INFN</p> <p>} CERN</p> <p>} To be defined</p> |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|

## Personale

- 1.4 FTE x 2 anni 2 Tecnologi meccanici (LNF) → art.36 assegnato dalla GE ad hoc
- 0.3 FTE x 2 anni 1 Progettista meccanico (LNF)
- 0.2 FTE x 2 anni 1 Primo tecnologo (LNF)
- 0.1 FTE x 2 anni 1 Dirigente ricerca (Pisa)
- 0.1 FTE x 2 anni 1 Tecnologo meccanico (Pisa)
- + 1 associato senior tecnologo (Pisa) best effort
- + personale tecnico sia ai LNF che a Pisa

### Team Preliminare:

LNF: M. Boscolo (PI), F. Franesini, E. Di Pasquale, S. Lauciani

Pisa: F. Palla, F. Bosi, + ing. mecc. [tbd]

CERN: A. Gaddi, R. Kersevan

## Spazi di assemblaggio e test ai LNF



- Identificato un laboratorio con un tavolo di granito sufficiente.
- Alcuni lavori di ammodernamento strutturale e di equipaggiamento in fase di discussione.

# Collective effects activity ongoing 2023 and for 2024

- **Essential to assess beam current limits and instability thresholds → luminosity**
- 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

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



# FCCWeek2023 Best Poster Awards

Prize Committee: Freya Blekman / DESY, Angeles Faus-Golfe / CNRS, Michiko Minty / BNL, Frank Zimmermann / CERN  
Online survey, trophy & certificate: David Goldsworthy, Jeanette Kotzian, Panos Charitos



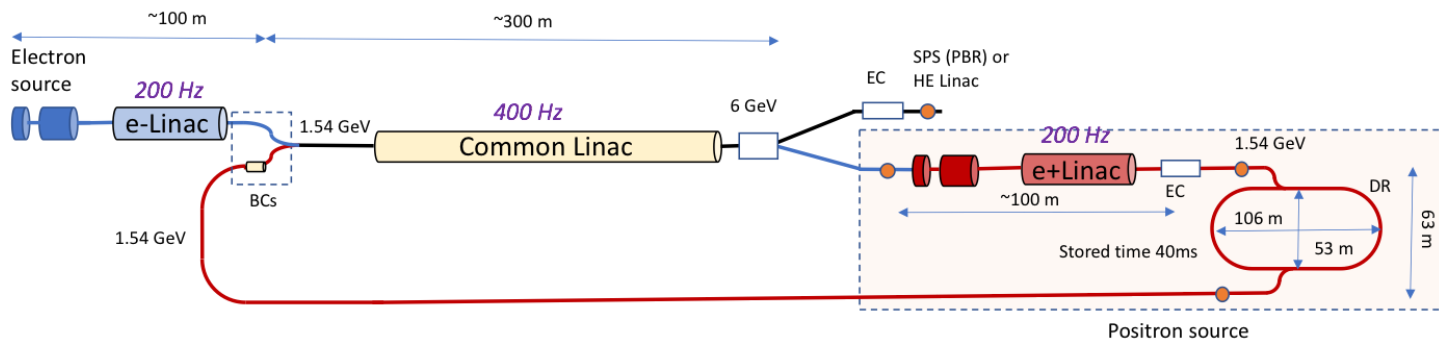
Vasiliki Batsari , the FCC-ee HTS4 Project

Mostafa Behtouei, Wakefields of the FCC-ee Collimation System

## FCC-ee e+ Damping Ring

C. Milardi, A. De Santis, S. Spampinati, O. Etisken (LNF);  
R.L. Ramijawan, Y. Dutheil (CERN)

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



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

L'attività è prevista fino al mid-term review (2023), possibile coda di qualche mese per il 2024.

## News su FCC

## News sulla macchina:

### **First US FCC Workshop, 24-26 April 2023** <https://indico.cern.ch/event/1244371/>

- Very pleasant workshop, warm and friendly atmosphere, lively discussions, strong interest to join the project.
- Goal of the workshop was also to prepare for the P5 meeting at SLAC the following week, to define areas of possible contributions to FCC accelerator and technology.
- Lots of interest on MDI-related topics
  - IR magnets
  - Collimation modelling
  - Detector Backgrounds
  - MDI layout, luminosity measurement, diagnostics, optics,
  - Synergy with EIC, lessons from SuperKEKB
- Lots of interest on detector concepts design, questions on vertex detector design and integration in the MDI

## Meetings with municipalities concerned in France (31) and Switzerland (10)

## PA – Ferney Voltaire (FR) – site experimental

## PB – Présinge/Choulex (CH) – site technique

## PD – Nangy (FR) – site technique et experimental

## PF – Roche sur Foron/Etaux (FR) – site technique

### PG – Charvonnex/Groisy (FR) – site experimental

## PH – Cercier (FR) – site technique

**PJ – Vulbens/Dingy en Vuache (FR)** site technique et experimental

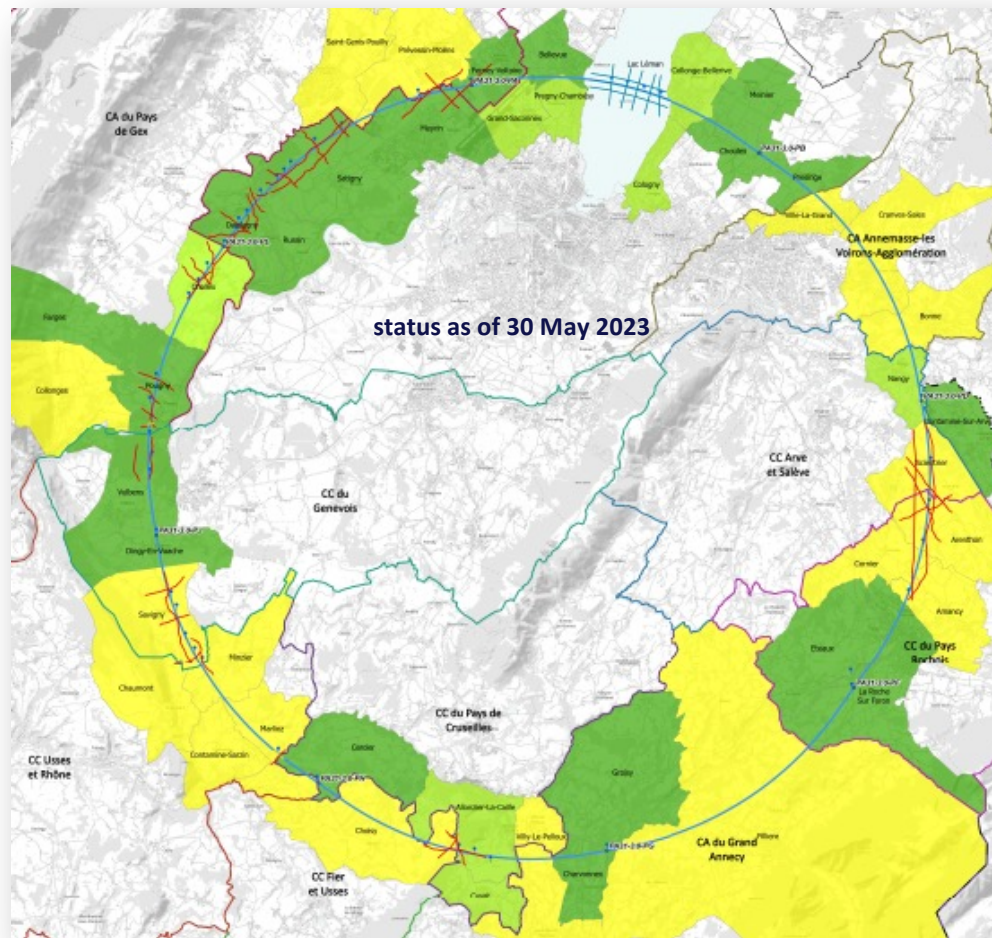
## PL – Challex (FR) – site technique

## Rencontrée individuellement

Rendez-vous proposé / programmé

## Rencontre collective

## Environmental studies and preparation of geological investigations (drillings and seismics) ongoing since February 2023



- 1) **Physics:** energy and intensity frontier facility addressing some of the most crucial outstanding questions
  - ❑ FCC-ee : best of all proposed Higgs and electroweak factories, indirect exploration of next energy frontier ( $\sim x10$  LHC)
  - ❑ FCC-hh : direct exploration of next energy frontier ( $\sim x10$  LHC)
  - ❑ Also provides heavy-ion collisions and, possibly, ep/e-ion collisions
  - ❑ 4 collision points  $\rightarrow$  robustness; specialized experiments for maximum physics output
- 2) **Timeline**
  - ❑ FCC-ee technology is mature  $\rightarrow$  construction can proceed in parallel to HL-LHC operation and physics start a few years after the end of HL-LHC operation (2045-2048 according to current schedule)  $\rightarrow$  This would keep the community, in particular the young people, engaged and motivated.
  - ❑ FCC-ee before FCC-hh would also allow:
    - cost of the (more expensive) FCC-hh machine to be spread over more years
    - 20 years of R&D work towards affordable magnets providing the highest achievable field (high-T superconductors)
    - optimization of overall investment : FCC-hh will reuse same civil engineering and large part of FCC-ee technical infrastructure
- 3) It's the only facility commensurate to the size of the CERN community (at least 4 experiments)



The 2020 update of the European Strategy identified a Higgs factory as the highest-priority next collider and FCC as the preferred option for a future collider at CERN.

The FCC integrated programme has an immense physics potential, offering exciting physics opportunities until the end of the century, with 4 collisions points per machine.

Construction of FCC-ee could start in the early 2030s and proceed in parallel to HL-LHC operation  
→ opportunities for the community to work on HL-LHC data analysis and construction of new facility.  
Physics exploitation could start within a few years of the end of HL-LHC (2045-2048).

FCC is a very challenging and ambitious project, requiring new technologies, some of which may have a disruptive impact on society (e.g., HTS magnets).

Feasibility Study progressing well, will be completed at the end of 2025, with a mid-term review in 2023.  
Substantial resources allocated. Plenty of opportunities for very interesting work.  
Environment and sustainability are a major focus.



## COMMON: MAINTAIN A LEADERSHIP VIA A VISION

CERN TO PROVIDE THE BEST SCIENCE AND TECHNOLOGY ARENA.

- **WHAT VISION? CONSIDERATIONS AND CONCERNS**

- Scientific (Higgs and?)
- Technological (HL and High Field Magnets)
- New Detectors
- Construction: Geology , Environment
- Financial
- ECRs?
- Politics and overlap issue.

THE FUTURE REQUIRES SCIENTIFIC AND TECHNOLOGICAL VISION.

EXCELLENCE IS EXTREMELY HARD TO ACHIEVE AND SO EASY TO LOOSE.







**Implementation scenario well defined** and all design parameters adapted to new layout

Significant **progress with host states at departmental/cantonal and local level**. **Direct exchange with communes concerned** by surface sites as basis for detailed optimization. Environmental studies ongoing.

**3D underground civil engineering model** established for scheduling and costing.

**FCC-ee 4 IP variant being documented for mid-term review.**

Significant effort in **FCC-ee lattice design with two complete optics solutions**. **Major progress towards full performance simulations** including beam-beam and full optics with alignment errors.

**Siting study for implementation of FCC-ee pre-injector on CERN Preveessin site**. Flexible transfer line solutions for FCC-ee and hh for potential use of SPS tunnel/scSPS.

**FCC-ee SRF** configuration and layout further optimized and international R&D collaborations being prepared

**FCC powering concept defined in cooperation with French network operator RTE.**

Most technical deliverables for mid-term review covered, **focus now on documentation and cost update.**

**Mid-term review deliverables** (approved by the Council):  
CERN/SPC/1183/Rev.2

**Documentation will be submitted to review committees by end September**

**Review by Scientific Advisory Committee (SAC) and Cost Review Panel (CRP):  
16-17 October 2023**

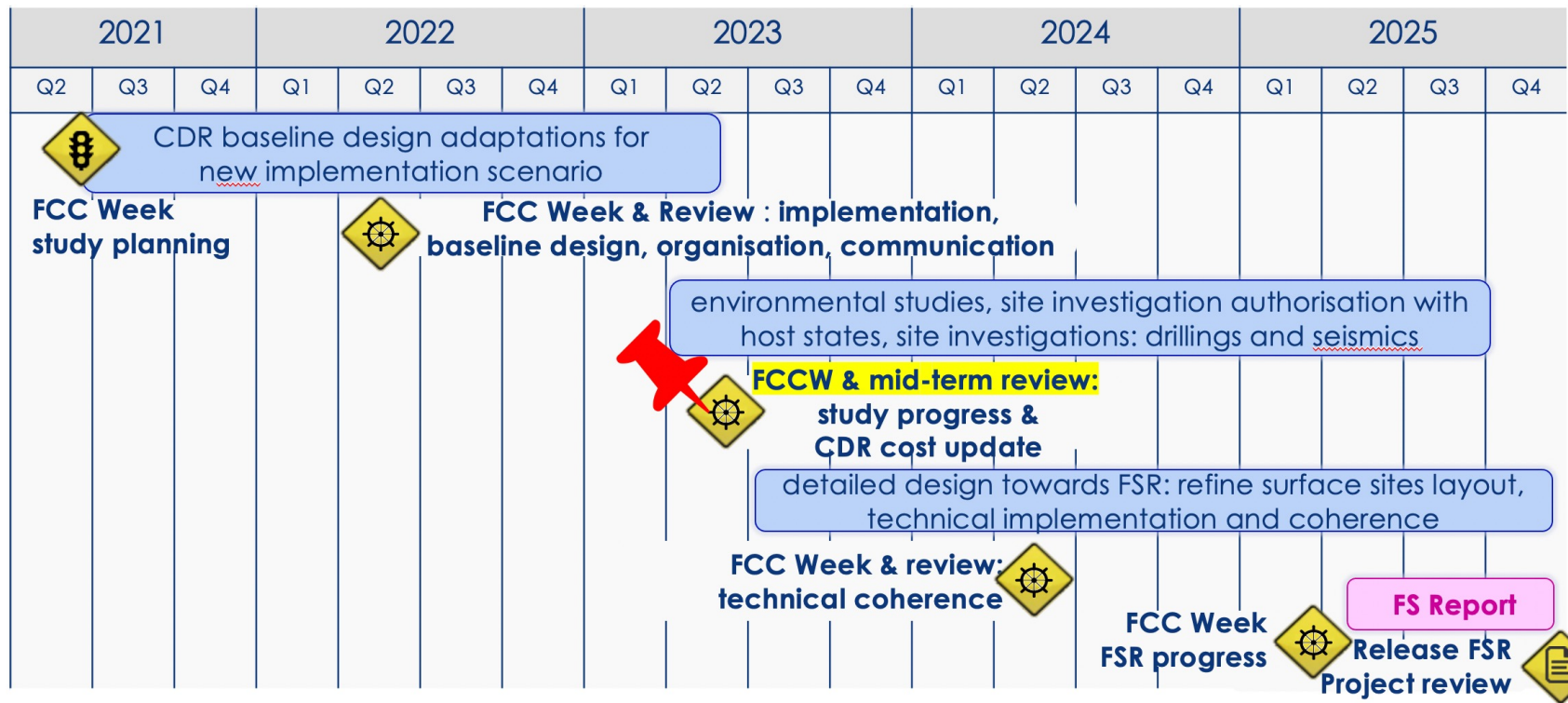
→ Reports available to SPC and FC end October

Special meetings of the SPC and FC: 20-22 November

→ Reports to Council by 31 December

Special Council meeting: 2 February 2024

# Feasibility Study Timeline and main activities/milestones



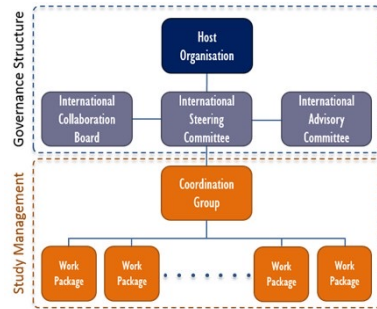
# Conclusioni

- Forte spinta di FCC dal CERN e dalla comunità internazionale
- Le attività di macchina su FCC sono in crescita, con un aumento degli FTE in RD\_FCC WP-Accel
- Siamo un gruppo impegnato su diversi item rilevanti.
- A Frascati c'è un team impegnato su item dei collider circolari grazie all'expertise maturato su DAFNE
  - Meeting di gruppo FCC@LNF: <https://agenda.infn.it/category/1855/>
- Quest'anno sono partite anche attività di R&D di validazione sperimentale in vari ambiti
  - R&D: Mockup IR a LNF, finanziato dalla GE&CERN

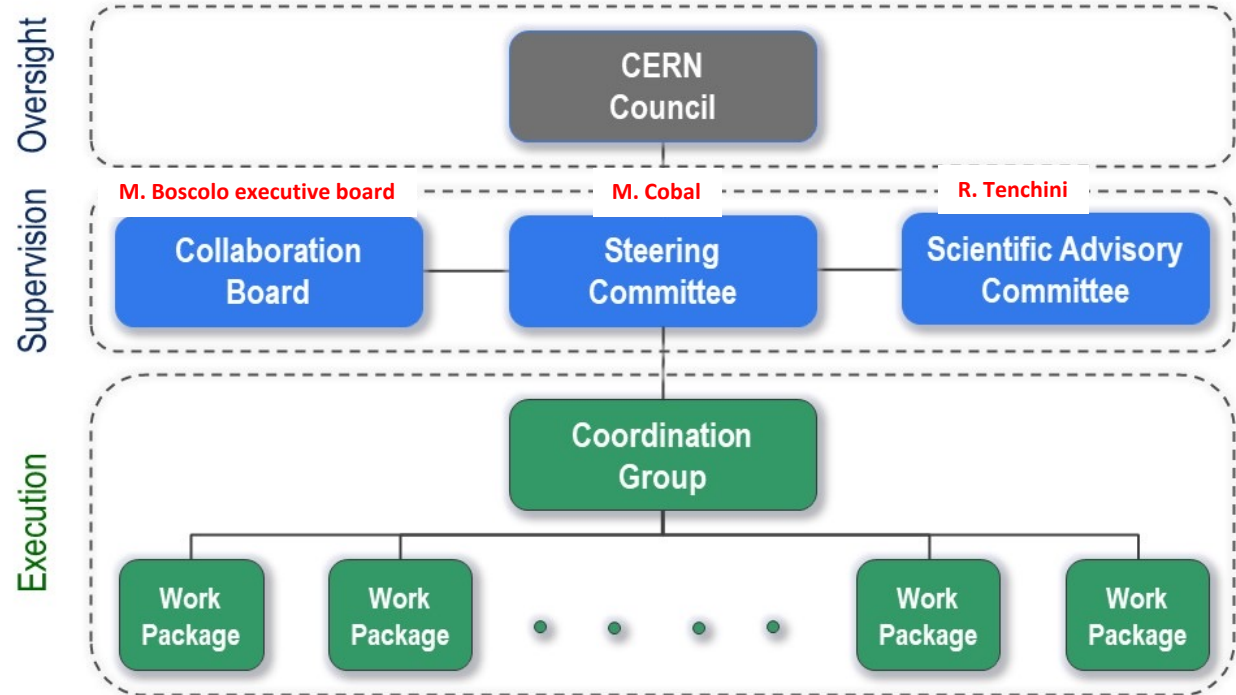


# FCC Feasibility Study - organizational structure

- 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.



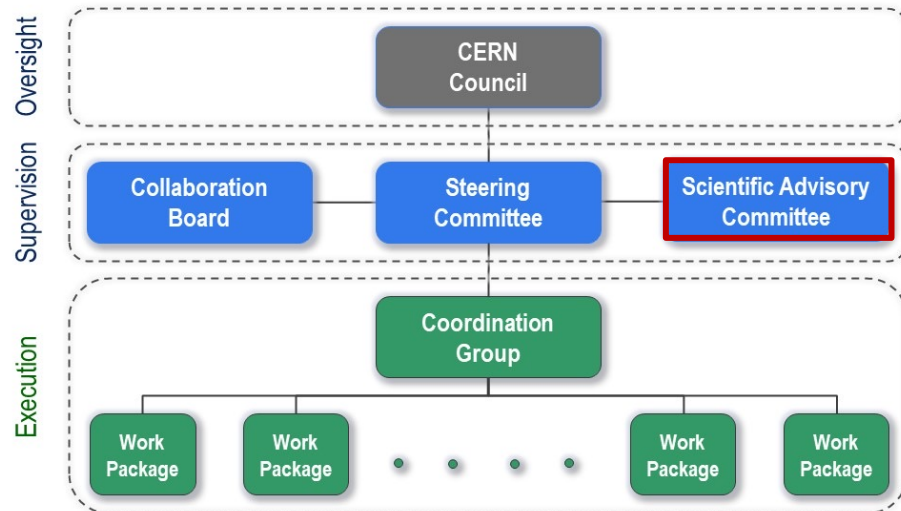
- Classical structure common to CERN projects.





# Scientific Advisory Committee (SAC)

SAC follows and reviews the implementation of the Feasibility Study, giving scientific and technical advice to FCC Steering Committee and Coordination Group, and providing them with guidance to facilitate major technical decisions.



**Composition:** up to 16 international experts not directly involved in the Feasibility Study with renowned expertise in one or more scientific and technical domains relevant to the Study (accelerators, technical infrastructure, key technologies, physics, detectors, etc.). Members and Chair are appointed by the Steering Committee.

Riccardo Bartolini (DESY), Alain Chabert (Société Française du Tunnel Routier du Fréjus), Brigitte Fargevieille (Électricité de France), Belen Gavela Legazpi (UAM), Katri Huitu (Helsinki), Srinivas Krishnagopal (BARC), Peter Krizan (Ljubljana), Philippe Lebrun (CERN, retired), Peter McIntosh (STFC), Michiko Minty (BNL), **Andrew Parker (Chair, Cambridge)**, Kyo Shibata (KEK), Roberto Tenchini (Pisa)



# Cost Review Panel (CRP)

Ad-hoc committee established to review the updated cost assessment of the FCC project, which is one of the mid-term review deliverables.

CRP's mandate:

- Review the methodology and assumptions used in producing the cost estimates
- Identify inaccurate or missing cost information
- Check the consistency of the cost estimates with respect to applicable reference work, e.g., recent large-scale infrastructure and accelerator projects
- Review the uncertainty estimates
- Identify potential areas of savings and cost mitigation for future work
- Advise the FCC Feasibility Study team on matters of cost estimation with a view to the preparation of the final Feasibility Study Report by end 2025.

**Composition:** around 10 international experts, not directly involved in the Feasibility Study, with renowned expertise in costing and project management aspects related to the scientific and technical domains relevant to the Study (accelerators, technical infrastructure, civil engineering, detectors, etc.). Members and Chair are appointed by the Steering Committee.

[Carlos Alejalde](#) (Fusion for Energy), [Austin Ball](#) (CERN, retired), [Umberto Dosselli](#) (INFN), [Vincent Gorgues](#) (CEA), **[Norbert Holtkamp](#)** (Chair, Stanford), [Christa Laurila](#) (National Audit Office, Finland), [Ursula Weyrich](#) (German Cancer Research Centre), [Jim Yeck](#) (BNL), [Thomas Zurbuchen](#) (ETH Zürich)



Site investigation of 9 “high-risk areas”, with uncertain geological conditions, will start in 2024 (~ 40 drillings and 100 km of seismic lines): crucial milestone to assess the geological feasibility

FCC WEEK 2023 London

## Areas of Geological Uncertainty

