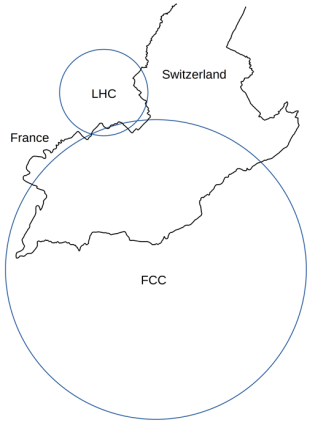
INFN LNF
Istituto Nazionale di Fisica Nucleare



FCC-RELATED NEWS

Manuela Boscolo

2nd FCC@LNF meeting
Frascati, Divisione Acceleratori
23 maggio 2023

FUTURE CIRCULAR COLLIDER
Innovation Study

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

Outline

- News
- Stato del progetto FCC
- Progresso studi LNF
- Upcoming events & deadlines

2nd meeting FCC@LNF

Tuesday 23 May 2023, 10:00 → 12:00 Europe/Rome

Div. Acc. (LNF)

Manuela Boscolo (Istituto Nazionale di Fisica Nucleare)

Description https://cern.zoom.us/j/67614409565?pwd=amhXaEFHcmdTdTNZMldQd0JDYmJ

10:00 → 10:25 **News FCC**
Speaker: Manuela Boscolo (Istituto Nazionale di Fisica Nucleare)

10:25 → 10:45 **Cooling System of the IR Beam pipe & Update of IR mechanical model**
Speaker: Francesco Fransesini (Istituto Nazionale di Fisica Nucleare)

10:45 → 11:05 **New IR optics design & detector Backgrounds**
Speaker: Andrea Ciarma (Istituto Nazionale di Fisica Nucleare)

11:05 → 11:20 **IR Beam losses and MDI collimation(* remote)**
Speaker: Giacomo Broggi

11:20 → 11:40 **Impedance budget study for FCC-ee(* remote)**
Speaker: Mauro Migliorati (Istituto Nazionale di Fisica Nucleare)

11:40 → 12:00 **Discussione - Richieste Preventivi RD_FCC**

Main events since 9 February (1st FCC@LNF meeting)

- **Seconda giornata Acceleratori** – 3 marzo, Catania https://agenda.infn.it/event/32573/

  FCC update, M. Boscolo
- **IFAE** , 12-14 aprile 2023, Catania https://agenda.infn.it/event/34702/ F. Fransesini
- **FCC-ee Pre-Injector: CHART Collab. Meeting**, 20-21 April 23
- **First Annual US FCC Workshop**, 24-26 April 23, BNL https://indico.cern.ch/event/1244371/

  LNF: M. Boscolo, A. Ciarma
- **IPAC23**, 7-12 May 23, Venezia
- **Riunione della CSN1, discussione futuri acceleratori (**su invito), 16-19 maggio, Isola d'Elba, https://agenda.infn.it/event/34835/

First US FCC Workshop

3 days workshop: 24-26 April 2023
Indico page: https://indico.cern.ch/event/1244371/
183 registrants

Motivation:

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.**

Program committee:

Anadi Canepa (FNAL)
Sergei Chekanov (ANL)
Regina Demina (University of Rochester)
Sarah Eno (University of Maryland)
Michelangelo Mangano (CERN)
Christoph Paus (MIT)
Marc-André Pleier (BNL, chair)
Tor Raubenheimer (SLAC)
Sally Seidel (University of New Mexico)
Vladimir Shiltsev (FNAL)
Chris Tully (Princeton University)

Agenda

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

24 April	25 April			26 April
Status of FCC with focus on challenges & opportunities to contribute	Accelerator **MDI and IR Magnets**	Detectors	Physics	BNL facility tours
Summary of US contributions	Accelerator Collimation, Energy Calibration, and Polarization	FCC Detector and Physics software tutorial		**Closing Plenary**
Detector R&D synergies across Higgs Factories	Accelerator and Detectors	Physics and software tutorials		
Snowmass Perspective	Round Table discussions			
BNL facility tours				

Comments

- Very pleasant workshop, warm and friendly atmosphere, many questions and interest with lively discussions both during sessions and coffee & lunch breaks.
- My impression is that US participants were very interested to FCC with strong interest to join the project in various areas of accelerator, detector, and physics.
- European participants felt a welcoming atmosphere.

- 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

Inquiry about our meetings, mailing list, organization

Contributions from MDI group

- Challenges of the FCC-ee MDI – **M.B.**
- FCC-ee IR magnet challenges – B. Parker (BNL)
- FCC-ee Collimation studies – A. Abramov (remote)
- Diagnostics and components in the FCC-ee IR (Jacqueline & MB)
- Background calculations in the FCC-ee – **A. Ciarma**
- Mechanical integration of the IDEA detector in the FCC-ee IR – **F. Palla (INFN-Pisa)**

highlights of US participation in place since many years (SLAC)

interest in the VXD design, we encourage to join our MDI WG

For the accelerator discussions:

- Monday plenary: M. Benedikt, Tor
- EPOL session: J. Keintzel

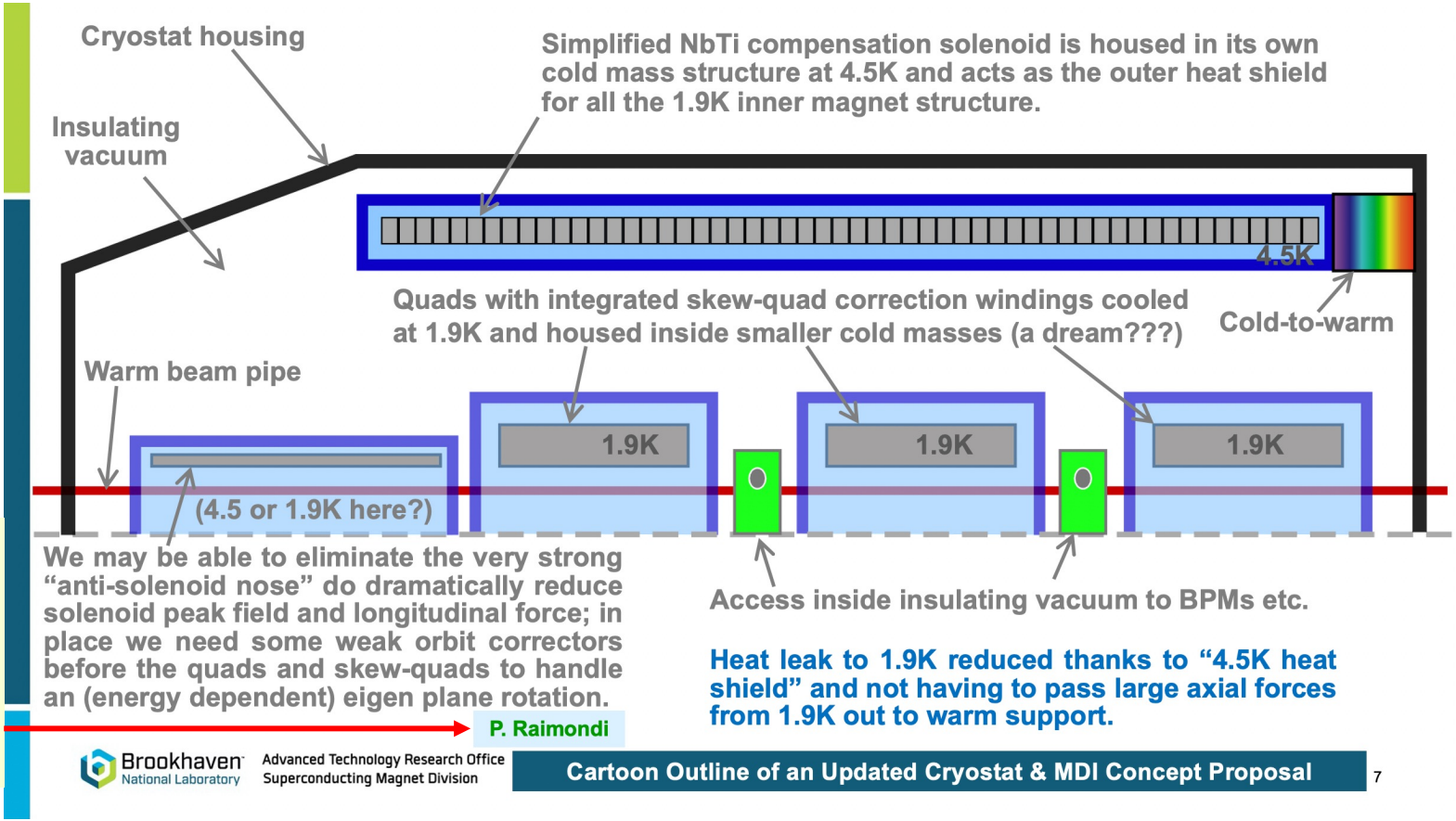
Goal of the workshop was also to prepare for the P5 meeting at SLAC the following week, to define areas of possible contributions to FCC accelerator and technology.

V. Shiltsev - Summary on Accelerator

IR magnets: proposed collaboration with BNL

see talk by B. Parker

slides implemented prior discussions with M.B. and A. Foussat



Relevant new IR proposal with great potential of improvement: by P.Raimondi & LNF (A. Ciarma, M. B.)

Thinking Ahead

Our Message to P5 (on the US FCCee):

Higgs Factory is slated to be the next high priority Energy Frontier project following the completion of HL-LHC.

FCCee is one of the most feasible HF options

We are considering a plan for R&D that could lead to fabrication of several critical components for the FCCee….. for example:

Magnets/MDI - R&D, Design and Fabrication

1. IR magnets, cryostats, masks (fabr. for 4 IPs)
2. FCCee collider ring magnets (low field, DC)
3. Booster ring magnets (low field, ~1s ramp)
4. Polarization wigglers (0.1-0.7 T, EM)
5. FCChh collider ring magnets (~14-20T, DC)
   - Already part of the GARD magnets (MDP)

“Dynamics” - R&D, Design and Fabrication

1. Interaction region design, and integrated machine design
   - Modeling/simulations: crab waist and beam-beam/beamstrahlung, DA, chromatic compensation and optics correction schemes
2. Losses, collimation and background
   - Modeling/simul: codes on halo formation, background in detectors, efficient collimation system(elens/NLO/CS), detector background masking, TMCI, build collimation system for 4 IRs and rings
3. Polarization (esp. at 45 GeV and 80 GeV beam energies):
   - Modeling/simulations: 45-80 GeV energy calibration, error analysis, design and build wigglers, polarimeters, polarized sources
4. Instrumentation:
   - Design and prototyping, then build, IR BPMs and lumi monitors, TMCI feedback systems, emittance and halo monitors, Low Level RF

IPAC23

- **The status of the Interaction region design and machine detector interface of the FCC-ee**, M. Boscolo et al. https://www.ipac23.org/preproc/pdf/MOPA091.pdf
- **Estimated heat load and proposed cooling system in the FCC-ee Interaction region beam pipe**, A. Novokhatski (SLAC) et al., accepted with light peer review https://www.ipac23.org/preproc/pdf/MOPA092.pdf
- **Beam Dynamics Studies for the FCC-ee Collimation System Design,** G. Broggi(CERN&LNF&Sapienza)
- **FCC_ee injector complex: damping ring and transfer lines**, C. Milardi et al.
- **New consideration for the damping ring design of the FCC e+e- injector complex**, O. Etisken et al.
- **Studies of FCC-ee single bunch instabilities with an updated impedance model,** M. Migliorati et al., accepted with light peer review
- **Study of beam-beam interaction in FCC-ee including updated transverse and longitudinal impedances,** Y. Zhang et al., accepted with light peer review

IPAC23

The Status of the Interaction Region Design and Machine Detector Interface of the FCC-ee

FUTURE CIRCULAR COLLIDER

INFN LNF

M. Boscolo†, A. Ciarma, F. Fransesini, S. Lauciani, INFN-LNF, Frascati Italy; F. Bosi, F. Palla, INFN-Pisa, Italy;
A. Novokhatski, T. Raubenheimer, M.K.Sullivan, SLAC, Stanford, USA;
A. Abramov, K. D. J. André, J. Bauche, M. Benedikt, G. Broggi[1,2], H. Burkhardt, J.C. Eriksson, A.P. Foussat, R. Kersevan, M. Koratzinos,
B. A. Lechner, K. Oide, J. Salvesen[3], L. Watrelot, M. Wendt, F. Zimmermann, CERN, Geneva, Switzerland;
M. Dam, NBI, Copenhagen; B. Parker, BNL, USA; P. N. Burrows, Oxford U., U.K.; L. Brunetti, S. Grabon, E. Montbarbon, F. Poirier, LAPP, Annecy, France
[1]also at INFN-LNF, Frascati and Sapienza U., Rome, Italy; [3]also at Oxford U., U.K.

†manuela.boscolo@lnf.infn.it

Abstract

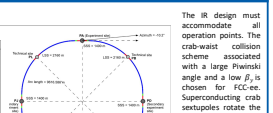
We present the latest development for the FCC-ee interaction region. It represents a major challenge for the FCC-ee collider, which has to achieve extremely high luminosity over a wide range of centre-of-mass energies. The FCC-ee will host two or four high-precision experiments. The machine parameters have to be well controlled and the design of the machine-detector-interface has to be carefully optimized. In particular, the complex final focus hosted in the detector region has to be carefully designed, and the impact of beam losses and of any type of radiation generated in the interaction region, including beamstrahlung, have to be simulated in detail. We discuss mitigation measures and the expected impact of beam losses and radiation on the detector background. We also report on the progress of the mechanical model of the interaction region layout, including the engineering design of the central beam pipe, and other MDI components.

IR design

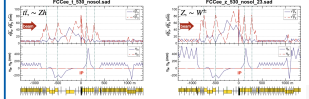
Preliminary parameter table for scenarios with 4 IPs

Running mode	Z	W	ZH	tt
Circumference [km]	90.659			
Beam energy [GeV]	45.6	80	120	182.5
Bunches/beam	15880	880	248	40
Beam current [mA]	1270	135	26.7	5.0
Lum. / IP [10^{34}cm^{-2}s^{-1}]	140	19.4	7.26	1.25
SR power / ring [MW]	50			
σ_E (SR) [mm]	5.60	3.55	3.34	1.94
σ_z (BS) [mm]	12.7	8.01	6.00	2.74
En. Spread σ_E (SR) [%]	0.039	0.069	0.103	0.157
En. Spread σ_E (BS) [%]	0.089	0.154	0.185	0.221
Rms hor. emit. ε_x [nm]	0.71	2.16	0.64	1.469
Rms vert. emit. ε_y [pm]	1.40	4.32	1.29	2.98
Hor. IP beta β_x^* [mm]	110	200	300	1000
Vert. IP beta β_y^* [mm]	0.7	1.0	1.0	1.6
Lifetime* [min.]	22	17.8	10	12.3

(*) Lifetime is by radiative Bhabhas and beamstrahlung.



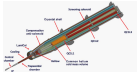
FCC-ee layout with 4 IPs



IR optics

The IR design must accommodate all operation points. The crab-waist collision scheme associated with a large Piwinski angle and a low β_y is chosen for FCC-ee. Superconducting crab sextupoles rotate the β_y function at the IR so that its waist is on the central trajectory of the opposite colliding beam and suppress betatron and synchrobetatron resonances.

The IR magnet system also comprises a compensating solenoid which locally corrects the betatron coupling and avoids any net spin rotation, and a screening solenoid surrounding the FFQ.



An asymmetric optics minimises the emission of SR fans onto the IR by a weaker bending of the incoming beam trajectory.
The detector magnetic field is set to 2 T to keep the blow-up due to the residual dispersion and SR in the solenoid fringe fields at a fraction of the nominal ε_y ~1 pm.

Mechanical Model of the IR & Detector Integration

Central beam pipe

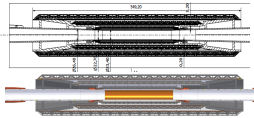
Material	Thickness
AlBeMet162(*)	0.35 mm
Paraffin (coolant)	1 mm
AlBeMet162	0.35 mm
Au	5 mm

(*) 62% Be & 38% Al alloy

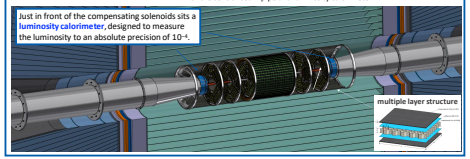
The radius of the central inner pipe now is 10 mm instead of 15 mm, allowing for better resolution and decreasing the geometrical impedance. For the central chamber the cooling will be based on paraffin flowing inside a double layer structure, while for the trapezoidal chamber water cooling is provided by asymmetric thick copper channels.

The scheme requires a large crossing angle at the IP, set to 30 mrad. Beam pipes separate at about ±1.2 m from the IP.

We have engineered the very central region of the IR. An evolution of the detector IDEA concept has been studied to integrate the silicon tracker in the IR. **Vertex detector** and outer tracker use respectively MAPS and DMAPS technology.
A similar study is also planned for the CLD vertex detector.

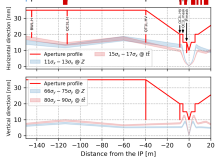


A **carbon-fiber lightweight support cylindrical structure** eases the integration of the accelerator and detector components, providing a cantilevered support for the central beam pipe and luminosity calorimeter.



Detector Backgrounds

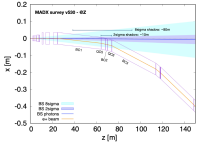
- The main sources of background from SR come from the last dipole magnet before the IP, the solenoid fringe field, and the FFQ. The SR from the FFQ and solenoid fringe field lead to an increasing power deposition near the IP as the transverse beam tails widen.
- The beam halo collimation system has been designed and installed in PF (collimation section in the layout) and has been studied using Xtrack-BDSIM coupling framework. Good protection has been demonstrated against beam losses due to a beam lifetime drop to 5 min at the most critical Z mode.
- The MDI description in Key4HEP was implemented with the 10mm radius central beam pipe and with the solenoidal field map to evaluate the occupancy in the CLD from SR, beam losses and IP backgrounds. Results are encouraging, the maximum occupancy per bunch crossing is below the safe 1% level.



SR horiz./vert. collimators, and masks

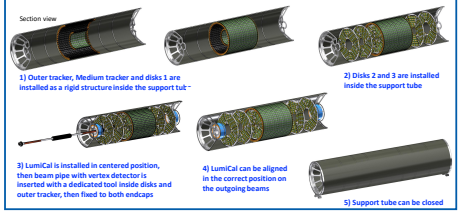
Radiation from the IR

The radiation produced at the IP is mostly collinear with the exiting beam and hits the vacuum chamber at the first dipole magnet at about 65 m from the IP.
Beamstrahlung radiation from the colliding beams is intense on the order of 400 kW at the Z-pole.
Other sources are radiative Bhabhas and SR.
A high-power photon dump is necessary to dispose of this radiation. Studies performed with GuineaPig++ show that the photon line is separated by the electron beam line by 1 m at about 250 m.
A dump with a separate alcove and safety shield can be located at about 500 m.



Beamstrahlung photon and electron beam lines.

Assembly Procedure



Conclusion

We have described recent progress of the FCC-ee MDI study, including on the mechanical model of the central inter- action region, the mitigation of SR backgrounds, and early studies of local beam losses with a preliminary set of collimators. The first look at the expected detector backgrounds is encouraging. We have also reviewed other MDI-related studies such as the handling of beamstrahlung and the early conceptual design of a photon dump.

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[2] A. Abada et al. [FCC], "FCC-hh: The Hadron Collider: Future Circular Collider Conceptual Design Report Volume 3," Eur. Phys. J. ST 228 (2019) no.4, 755-1107.
[3] K. Oide, FCCIS workshop, CERN, 6 Dec.22
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[9] B. Parker, "Correctors and Anti-solenoids Design for FCC-ee, MDI Workshop," CERN, 18 Oct. 2022 https://indico.cern.ch/event/1186798/
[10] A. Novokhatski, M. Boscolo, F. Fransesini, S. Lauciani, "Estimated heat load and proposed cooling system in the FCC-ee IR beam pipe," These Proc.
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[14] J. Allison, et al. "Recent developments in Geant4," Nucl. Instrum. Meth. A 835 (2016), 186-225 doi:10.1016/j.nima.2016.06.125
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[16] A. Abramovet al., "Development of Collimation Simulations for the FCC-ee," in Proc. IPAC'22, Bangkok, Thailand, 7 2022, pp. 1718–1721.
[17] A. Abramovet al., "Status of Layout and Cleaning Performance for the FCC-ee Collimation System," These Proc.
[18] A. Ciarma, M. Boscolo, G. Ganis and E. Perez, "Machine Induced Backgrounds in the FCC-ee MDI Region and Beam strahlung Radiation," JACoW eeFACT2022 (2023), 85-90
[19] G. Voutsinas, K. Elsener, P. Janot, D. El Khechen, A. Kolano, E. Leogrande, E. F. Perez, N. A. Tehrani, O. Viazlo and M. Boscolo, et al. "FCC-ee interaction region backgrounds," Int. J. Mod. Phys. A 35 (2020) no.15n16, 2041009
[20] M. Boscolo, et al. "Machine detector interface for the e+e− future circular collider," doi:10.18429/JACoW-eeFACT2018-WEXBA02
[21] M. Boscolo, et al. "Challenges for the Interaction Region Design of the Future Circular Collider FCC-ee", in Proc. IPAC'21 doi:10.18429/JACoW-IPAC2021-WEPAB029
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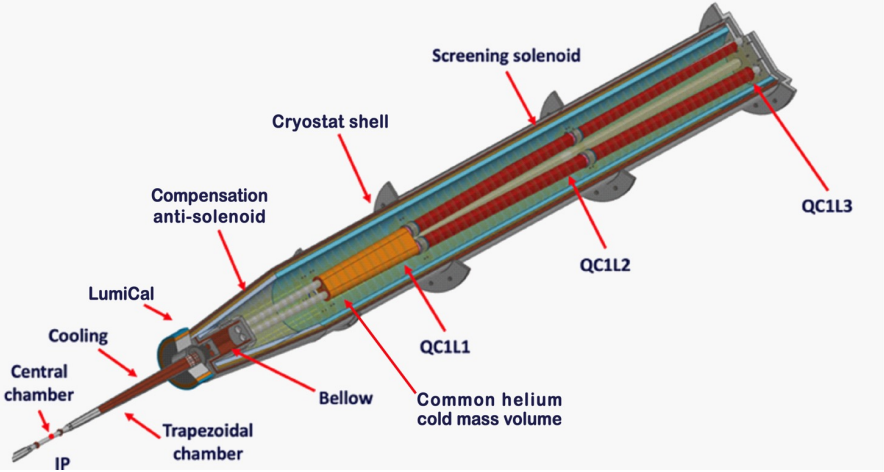
[23] C. J. Eriksson and J. Bauche, "Magnet Design for Beamstrahlung Photons Extraction Line," FCC-ee MDI meeting n.43, 6 Feb. 2023.

This work was partially supported by the EC Horizon2020 project FCC-IS, grant agreement no. 951754.

FCC-ee Interaction Region

Crab-waist collision scheme: nano-beams & Crab-Waist sextupoles (inventato e dimostrato a Frascati, link: PRL 104, 174801 (2010)

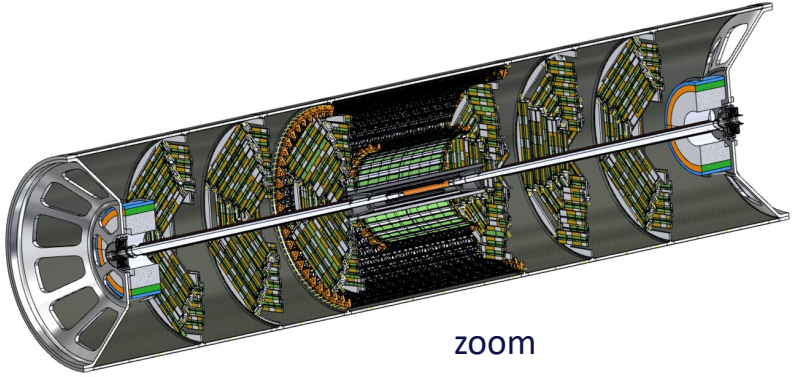


Half-length of the detector ~5.2 m; end face QC1 ~8.4 m.

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.

Central Support tube with endcaps carbon-fibre lightweight rigid structure, to be anchored to the detector

All elements in the interaction region (vertex, Tracker and LumiCal) are mounted rigidly on a support cylinder that guarantees mechanical stability and alignment. Once the structure is assembled it is slided inside the rest of the detector



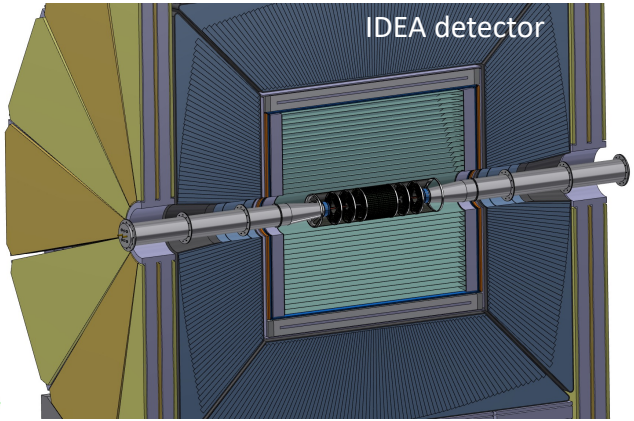
zoom

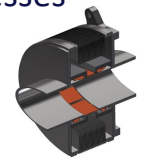
MDI central region ±1.5 m from the IP

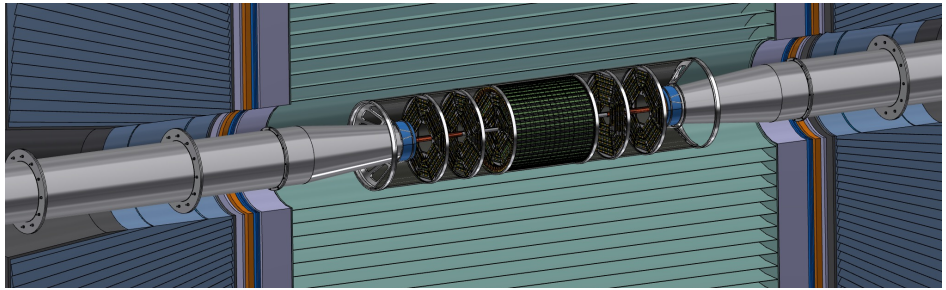
- M. Boscolo, F. Palla, F. Fransesini, F. Bosi and S. Lauciani, *Mechanical model for the FCC-ee MDI,* EPJ+ Techniques and Instrumentation, accepted for publication
- M. Boscolo et al., Status of the *IR and MDI of the FCC-ee*, IPAC23, 7-12 maggio 2023;
- A. Novokhatski, et al. *Estimated heat load and proposed cooling system in the FCC-ee IR beam pipe*, IPAC23, 7-12/5/2023

Ongoing work on mechanical model of the FCC-ee MDI

- **Integration of the support tube with the detector**
  Anchoring points with the detector
  Required space for services
- **Support and alignment of the LumiCal**
- **Cryostat-Support tube interface**
- Refine **FEA calculation with weights and thermal loads**
- Refine the **assembly procedure** while the MDI design progresses
- **Design of the Bellows** in progress, started from ESRF ones
  Wakefields calculations in progress
  Engineered design of endcap-bellows &
  flange-bellows interface



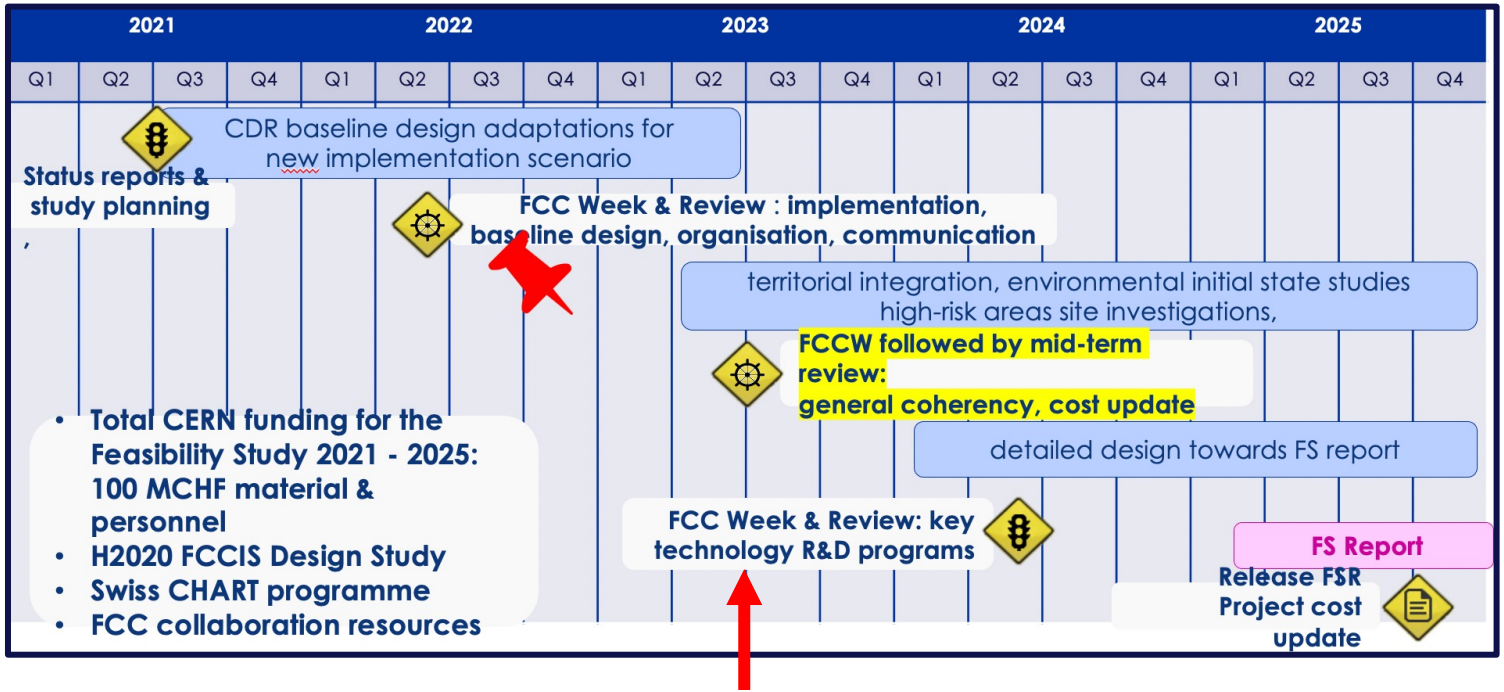




- shape-memory-alloy (SMA) remote flange design
- IP diagnostics, especially BPMs
- Supports & vibration control
- Alignment system

- IR magnets design, key component for the MDI

FCC feasibility study - status



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

MDI Mid-term Review Report

MDI paragraph in the Accelerator document

I wrote a first draft ready for internal review by the end of last week (19 May), it is a living document

- Draft of most documents to be available at FCC WEEK or before
- Will use FCC Week to start reviews of near-final drafts with plans to internally review sections in the weeks preceding FCC Week.
- Many subsections will be based on existing documentation and complementary FCC note(s) that will come on due time.
  - IPAC23 papers
  - MDI FCC Note in preparation: M. Boscolo and F. Palla editors on tracking detectors description, integration in the MDI software description, detector performance, material budget, ..
  - Paper on the Mechanical Model of the FCC-ee MDI, accepted on EPJ+

Upcoming events

- **FCC WEEK23**, 5-9 June 23, London https://indico.cern.ch/event/1202105/
- CL Preventivi, 6 luglio 23, LNF (richieste RD_FCC)

FCC WEEK 2023 – MDI sessions

https://indico.cern.ch/event/1202105/

3 sessions

Tue. 6 + Wed. 7

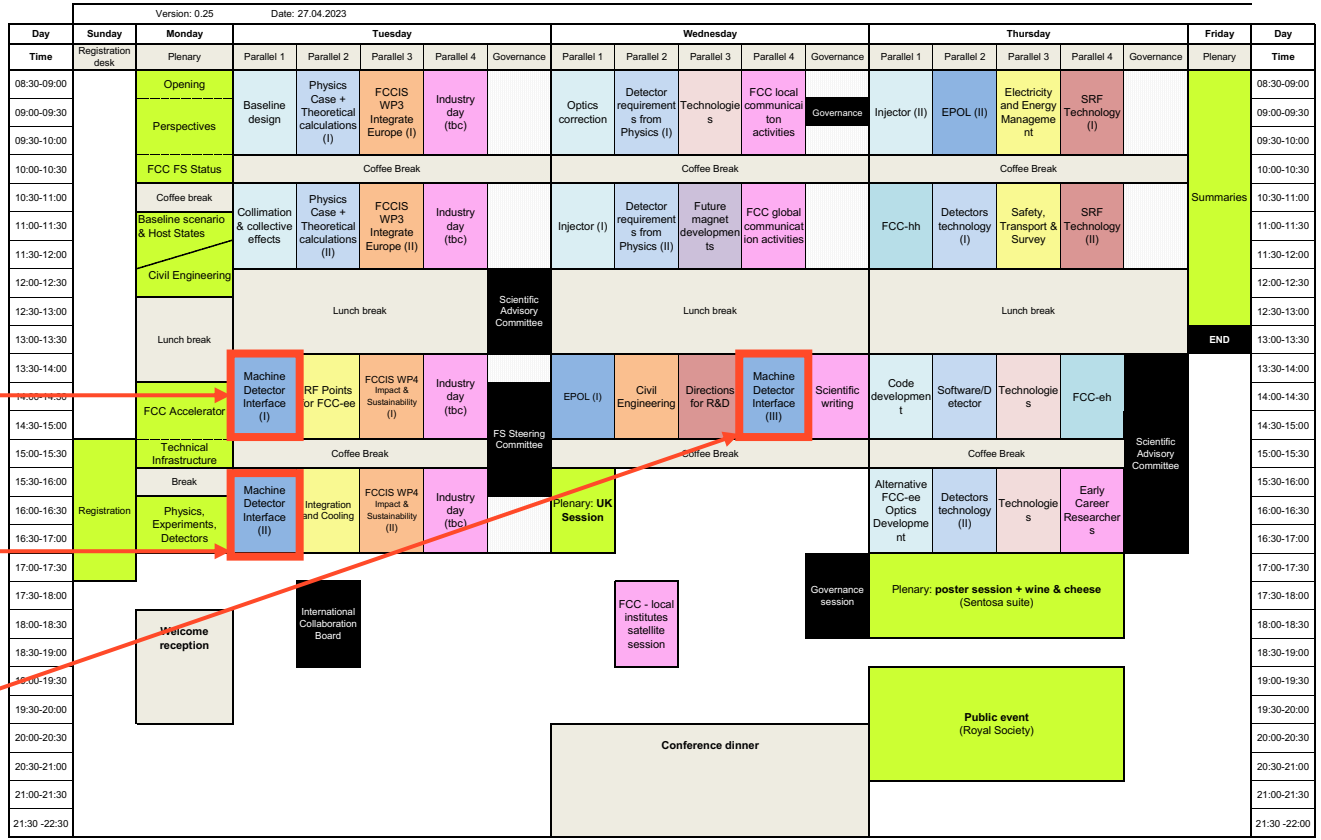
90 min. each

On Indico **almost** final agenda

Mechanical model & related topics

Backgrounds, losses, SR, beamstrahlung

IR magnets, IR BPMs & related topics



RD_FCC Attività 2024

- Anagrafica
- Attivita’ prevista
- Richieste

Summary

- Increasing interest in the High Energy Physics (HEP) community for FCC-ee (US, INFN,..)
- Busy with the midterm review preparation that will be given to the advisory committee in London
- Cost review preparation
- Lots of progress in the studies at LNF

RD_FCC Attività 2024

- Anagrafica
- Attivita' prevista
- Richieste