FCC-EE
MACHINE DETECTOR INTERFACE

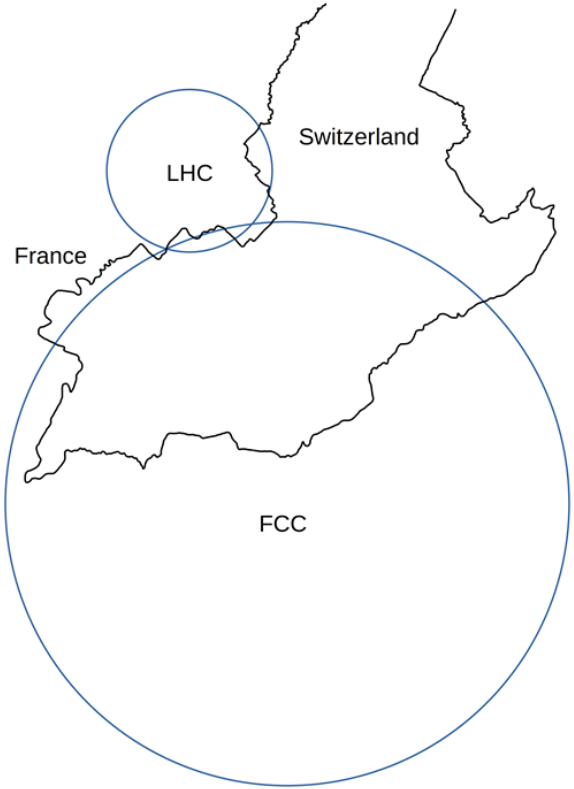
Manuela Boscolo (INFN-LNF)
for the MDI team

Thanks to: A. Abramov, A. Ciarma, F. Fransesini, H. Hofer, M. Koratzinos, , S. Lauciani, A. Novokhatski, K. Oide, T. Raubenheimer, M. Sullivan, F. Zimmermann, …

65th ICFA Advanced Beam Dynamics Workshop in High Luminosity Circular e+e- Colliders (eeFACT22)
Frascati, 13 September 2022

Outline

- FCC-ee collider
- Interaction Region design FCC-ee
  - Optics Layout
  - Mechanical layout and R&D
  - Beam Backgrounds
  - Beamstrahlung photon dump
- Conclusion

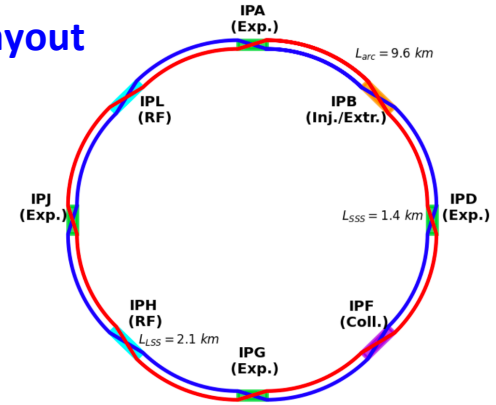


http://cern.ch/fcc

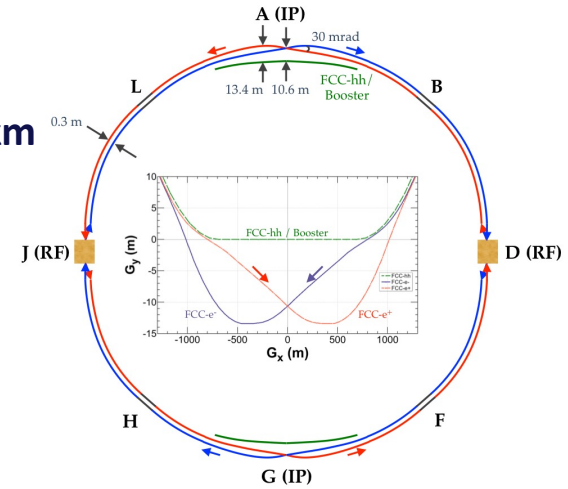
FCC-ee collider

- **Double ring** e+ e- collider
- Common footprint with FCC-hh, except around IPs
- Asymmetric IR layout and optics to limit synchrotron radiation towards the detector
- large horizontal crossing angle 30 mrad
- **crab-waist** collision optics
- Synchrotron radiation power **50 MW/beam** at all beam energies
- **Top-up** injection scheme for high luminosity requires booster synchrotron in collider tunnel
- "**Taperin**g" of magnets along the ring to compensate the sawtooth effect

evolution of layout
8 surface sites
4 IPs
C=91 km



CDR
C=97 km



High-level Requirements for the IR and MDI region

- **One common IR for all energies, flexible design** from 45 to 182.5 GeV with a constant detector field of **2 T**

  At Z pole: Luminosity ~ 10^{36} $cm^{-2}s^{-1}$ requires crab-waist scheme, nano-beams & large crossing angle.

  Top-up injection required with few percent of current drop.

  Bunch length is increased by 2.5 times by beamstrahlung

  At **ttbar threshold**: synchrotron radiation, and beamstrahlung dominated the lifetime

- **Solenoid compensation** scheme

  Two anti-solenoids inside the detector are needed to compensate the detector field

- **Synchrotron radiation** control in the IR

High-level Detector requirements for the MDI design

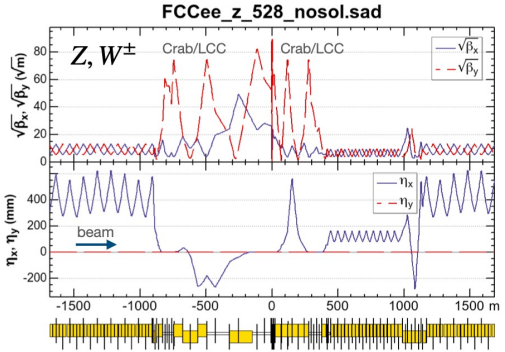
- 100 mrad of physics cone
  - trade-off between accelerator/detector needs expected
- Luminosity monitor @Z: absolute measurement to 10^{-4} with low angle Bhabhas
  - window acceptance of the lumical, alignment and stabilization constraints
- Low X/X0 vacuum chamber with cooling system, keep low material budget
- SR critical energy below 100 keV from last bendings upstream the IR at tt_{bar}
  - constraint to the FF optics, asymmetrical bendings
- Background suppression and radiation shielding
  - Detector occupancy below 0.1%-1%
  - Robustness against machine bkgs, radiation hardness
  - Impact to the collimation scheme and shielding around the beam pipe
- Accessibility of inner detectors (Lumical and vertex) for maintenance and repair

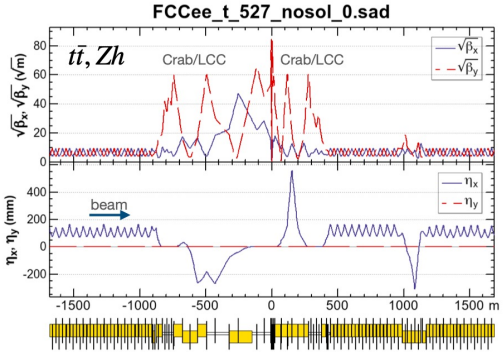
FCC-ee IR optics design

Driven by synchrotron radiation:

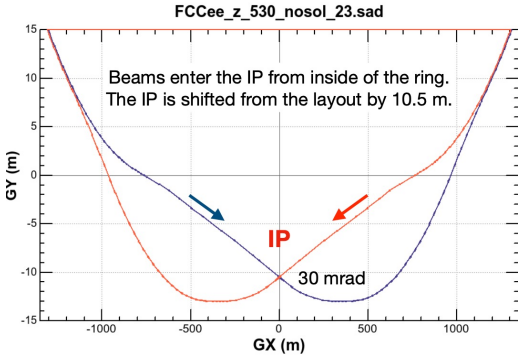
$E_{critical}$ <100 keV from 450 m from the IP at ttbar (detector requirement from LEP experience)

→ Very Asymmetric IR optics



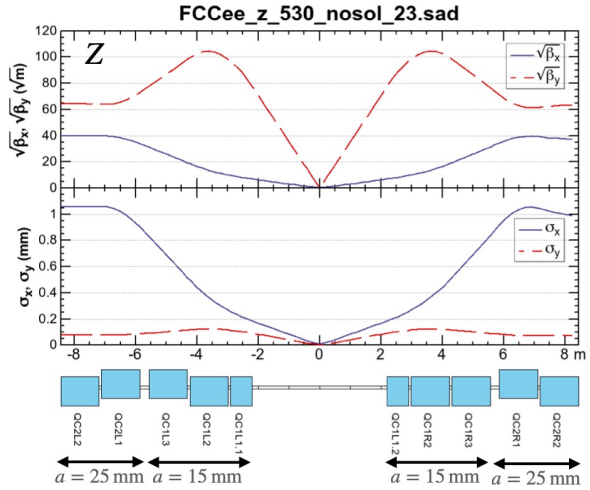


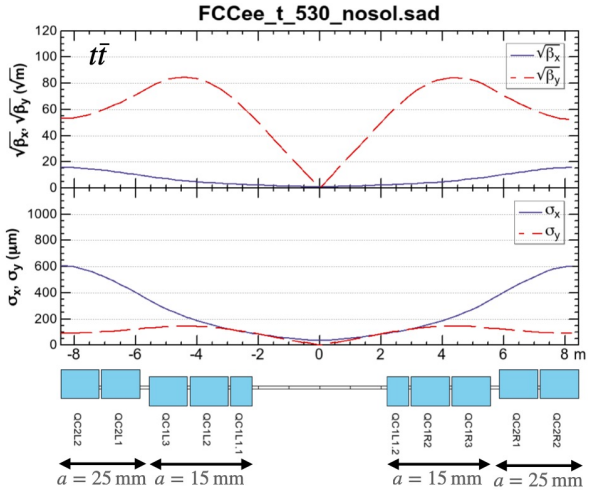
Beams enter the IP from inside of the ring (left).
Bypass of the booster near the detector still an open question.



FCC-ee IR optics design

Flexible design with final focus doublet
in slices to adapt for the different beam energies





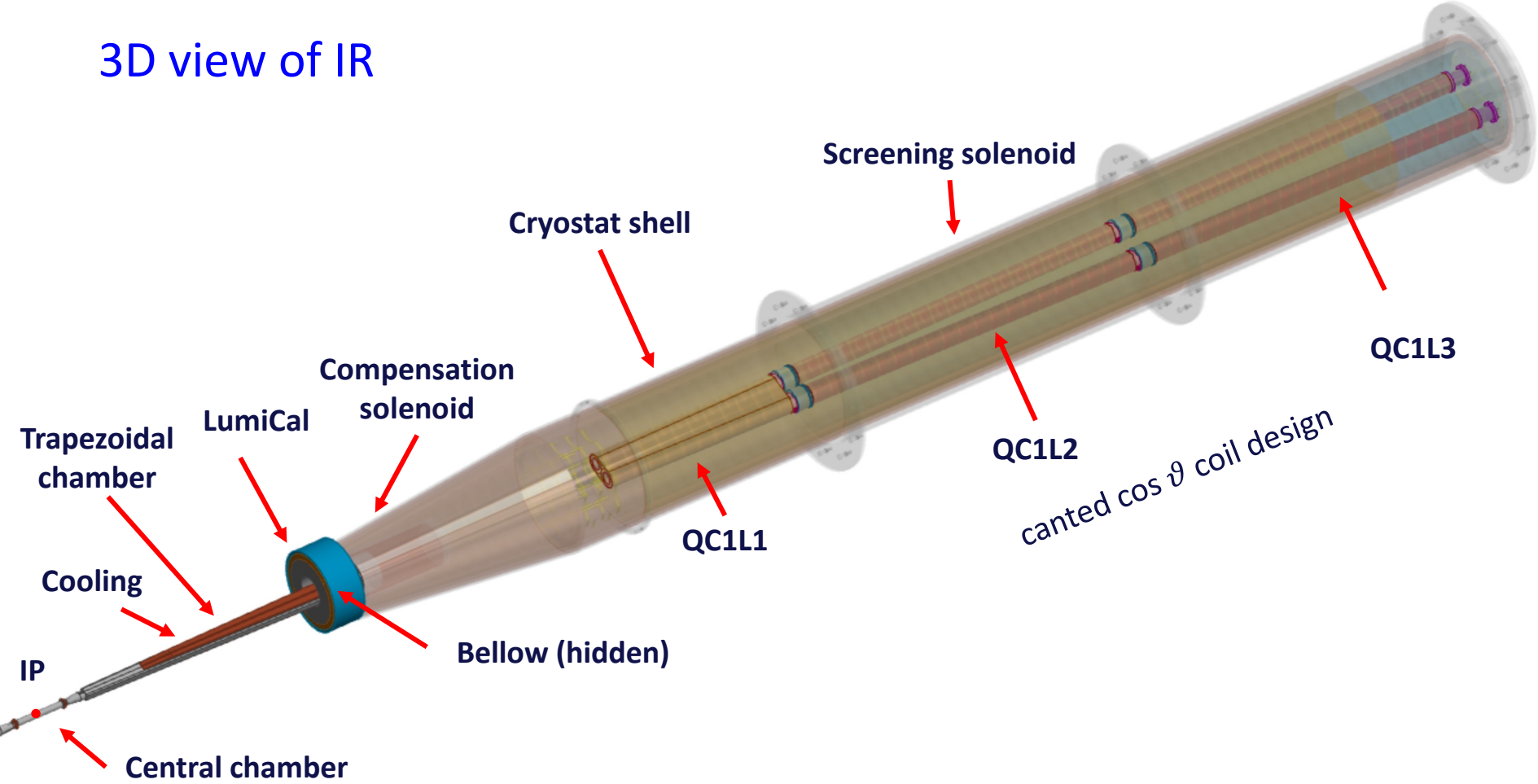
K. Oide

Horizontal aperture
15 mm ≅ 18.7 σ_x at QC1
25 mm ≅ 23.6 σ_x at QC2
(potential issue at Z but larger than dynamic aperture)

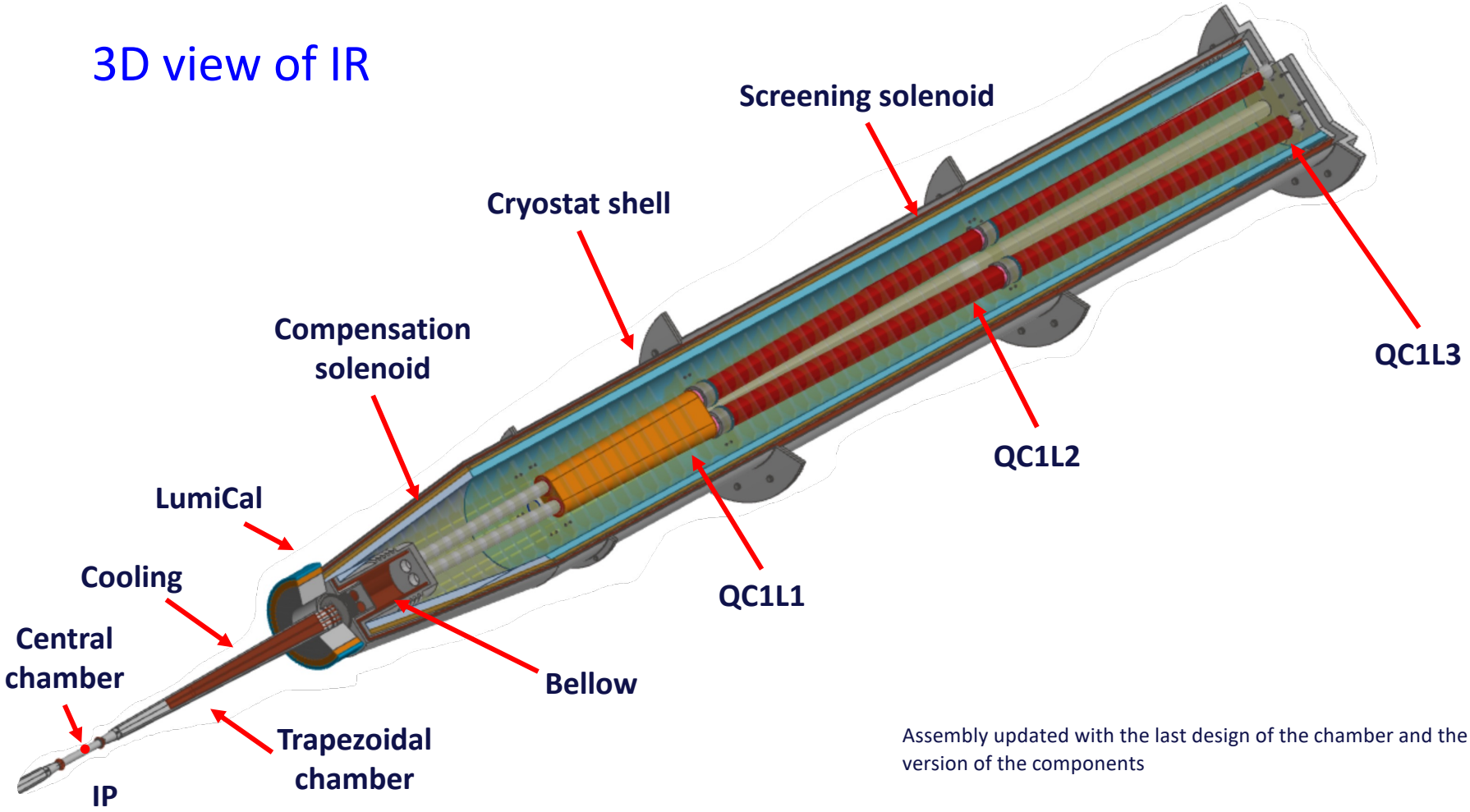
FCC-ee Parameters

Parameter [4 IPs, 91.1 km, T_{rev}=0.3 ms]	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45	80	120	182.5
beam current [mA]	1280	135	26.7	5.0
number bunches/beam	10000	880	248	40
bunch intensity [10^{11}]	2.43	2.91	2.04	2.37
SR energy loss / turn [GeV]	0.0391	0.37	1.869	10.0
total RF voltage 400 / 800 MHz [GV]	0.120 / 0	1.0 / 0	2.08 / 0	2.5 / 8.8
long. damping time [turns]	1170	216	64.5	18.5
horizontal beta* [m]	0.1	0.2	0.3	1
vertical beta* [mm]	0.8	1	1	1.6
horizontal geometric emittance [nm]	0.71	2.17	0.64	1.49
vertical geom. emittance [pm]	1.42	4.34	1.29	2.98
horizontal rms IP spot size [μm]	8	21	14	39
vertical rms IP spot size [nm]	34	66	36	69
beam-beam parameter ξ_x / ξ_y	0.004 / 0.159	0.011 / 0.111	0.0187 / 0.129	0.093 / 0.140
rms bunch length with SR / BS [mm]	4.38 / 14.5	3.55 / 8.01	3.34 / 6.0	1.95 / 2.75
luminosity per IP [10^{34} cm^{-2}s^{-1}]	182	19.4	7.26	1.25
total integrated luminosity / year [ab^{-1}/yr]	87	9.3	3.5	0.65
beam lifetime rad Bhabha + BS [min]	19	18	6	9

3D view of IR


Screening solenoid
Cryostat shell
QC1L3
Compensation solenoid
LumiCal
Trapezoidal chamber
QC1L2
canted cos ϑ coil design
QC1L1
Cooling
IP
Bellow (hidden)
Central chamber

3D view of IR



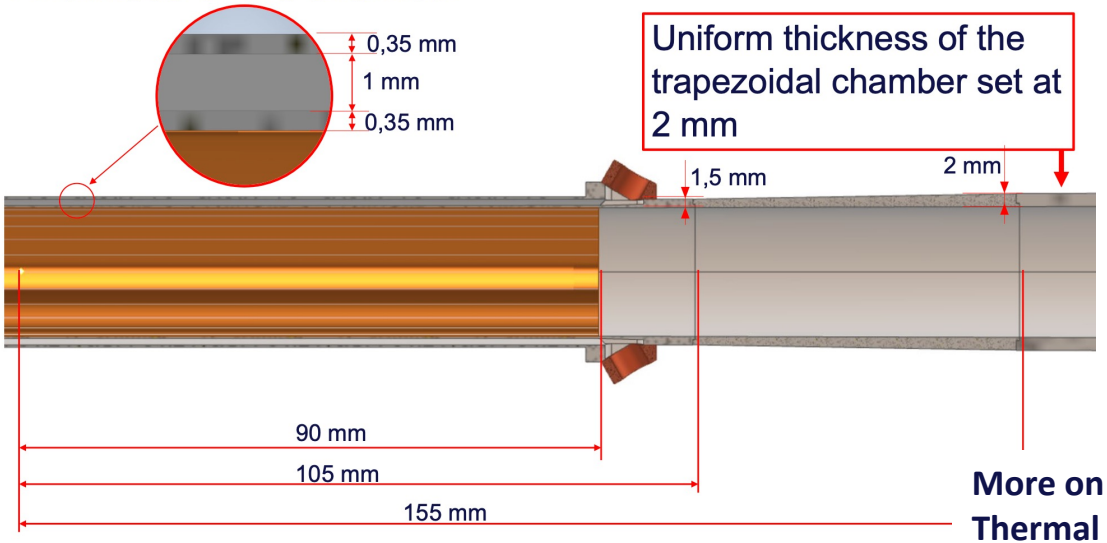
Assembly updated with the last design of the chamber and the last version of the components

Low impedance central chamber

warm and cooled central beam pipe

Inner radius 10 mm

Thickness of the chamber



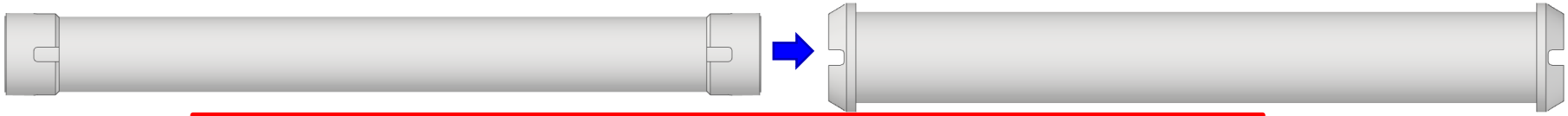
Material	thickness
AlBeMet162 (62% Be and 38% Al alloy)	0.35 mm
Paraffin (PF200)	1 mm
AlBeMet162	0.35 mm
Au	5 μm
TOTAL	**1.7 mm**
X/X_0	**0.59 %**

More on CST calculations for this vacuum chamber, Thermal analysis and heat load calculations later by A. Novokhatski

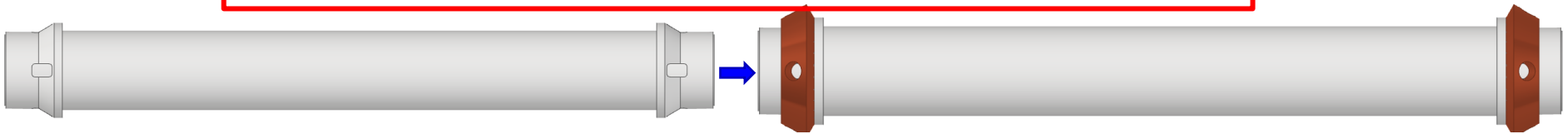
Courtesy F. Fransesini

Central chamber

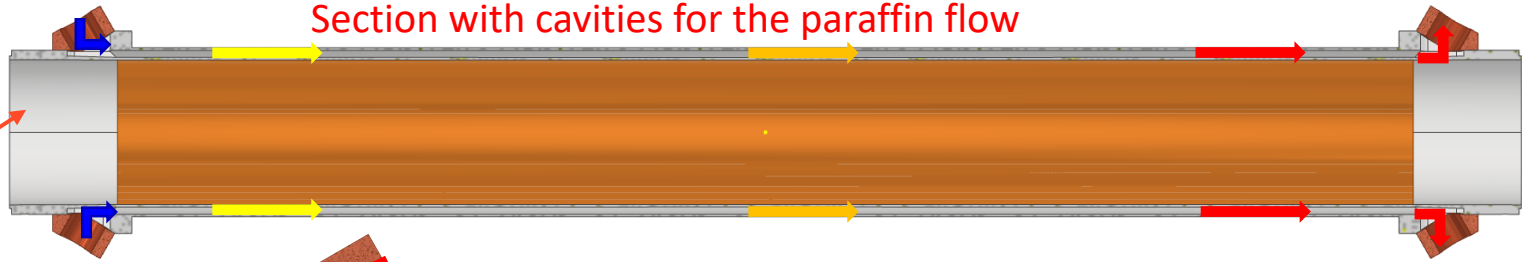
Insertion of the internal part

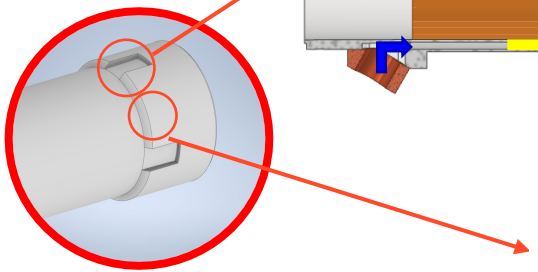


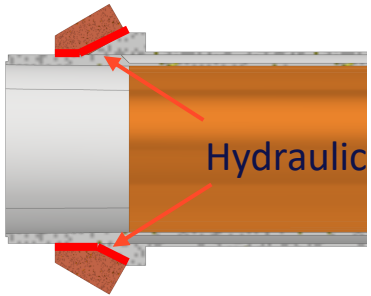
Thick copper deposition to create the cooling inlet and outlet



Section with cavities for the paraffin flow







Hydraulic tightness

The channel for paraffin is opened only in the part where the internal central chamber has cavities. Using the "*thick copper deposition*" the hydraulic tightness is assured in the parts in contact with AlBeMet

IR mock-up

Central chamber Prototype

- Central IP vacuum chamber
  - test the cooling system and the vacuum system
- AlBeMet162 – steel transition
  - study the shape of the transition, ElectroBeam Welding process
- Bellow
  - vacuum and thermal tests
- Welding
  - EBW for elliptical geometry
- Trapezoidal vacuum chamber
  - test remote vacuum connection
- Central chamber support tube

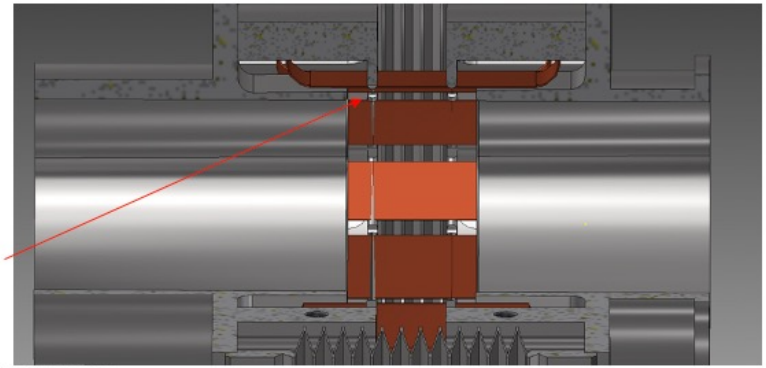
- Vibration sensors
- Alignment sensors

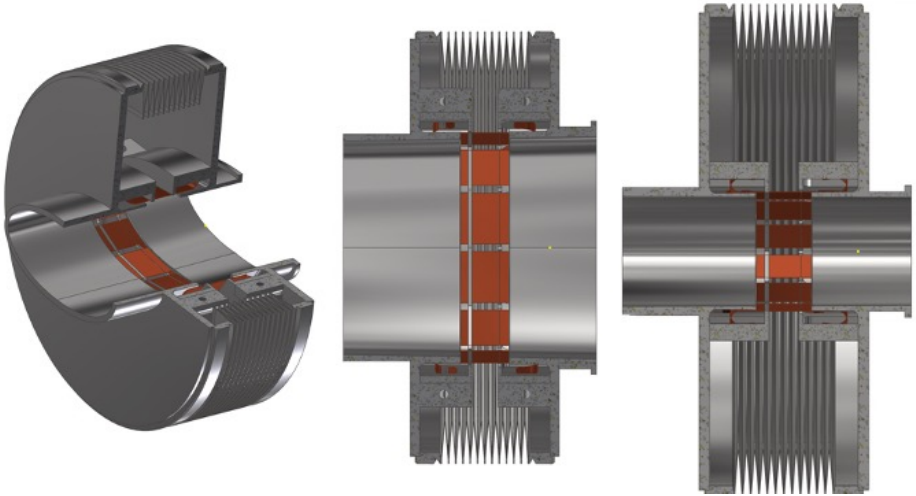
require also

- QC1 design & prototype
- cryostat model & prototype & support

Bellow

- 12 RF copper spring (can be increased to 16)
- Compact size in length
- 8mm stroke (-5mm +3mm)
- Finger to ensure contact between RF-spring to bellow (like ESRF bellow)



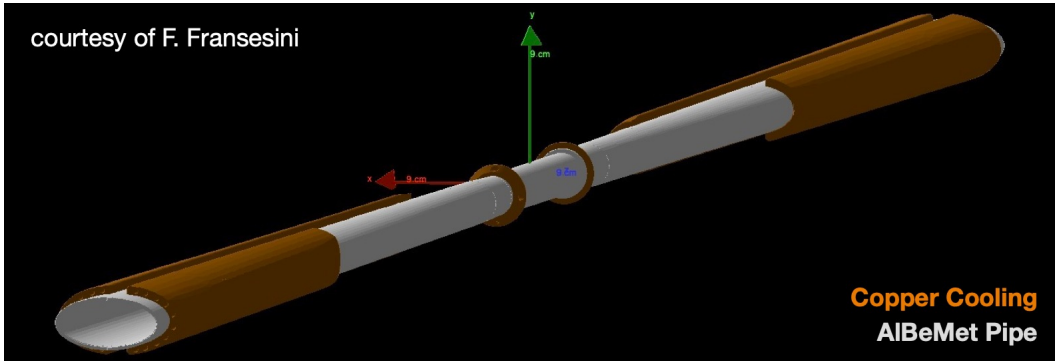


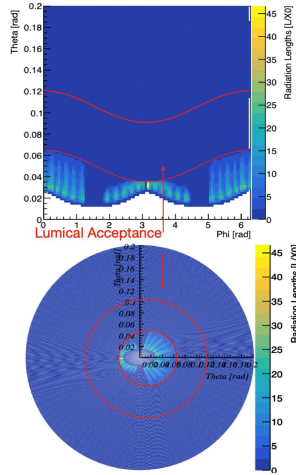
Future steps for the bellow:

- Simulation to validate the design
- Optimization of the size and the convolutions number
- Inclusion of cooling
- Evaluation of different designs

Luminosity Monitor acceptance and the vacuum chamber

- The central chamber has double layer with Paraffin cooling
- The vacuum chamber (2 mm AlBeMet162) before the luminosity monitor (LM) has cooling channels, copper thermal exchangers with water channels.
- The requirement coming from the LM is an acceptance of a 50 mrad cone with a low material budget.





The design has a radiation length between 0.2-0.5 X_0 in front of the LM, due to AlBeMet162

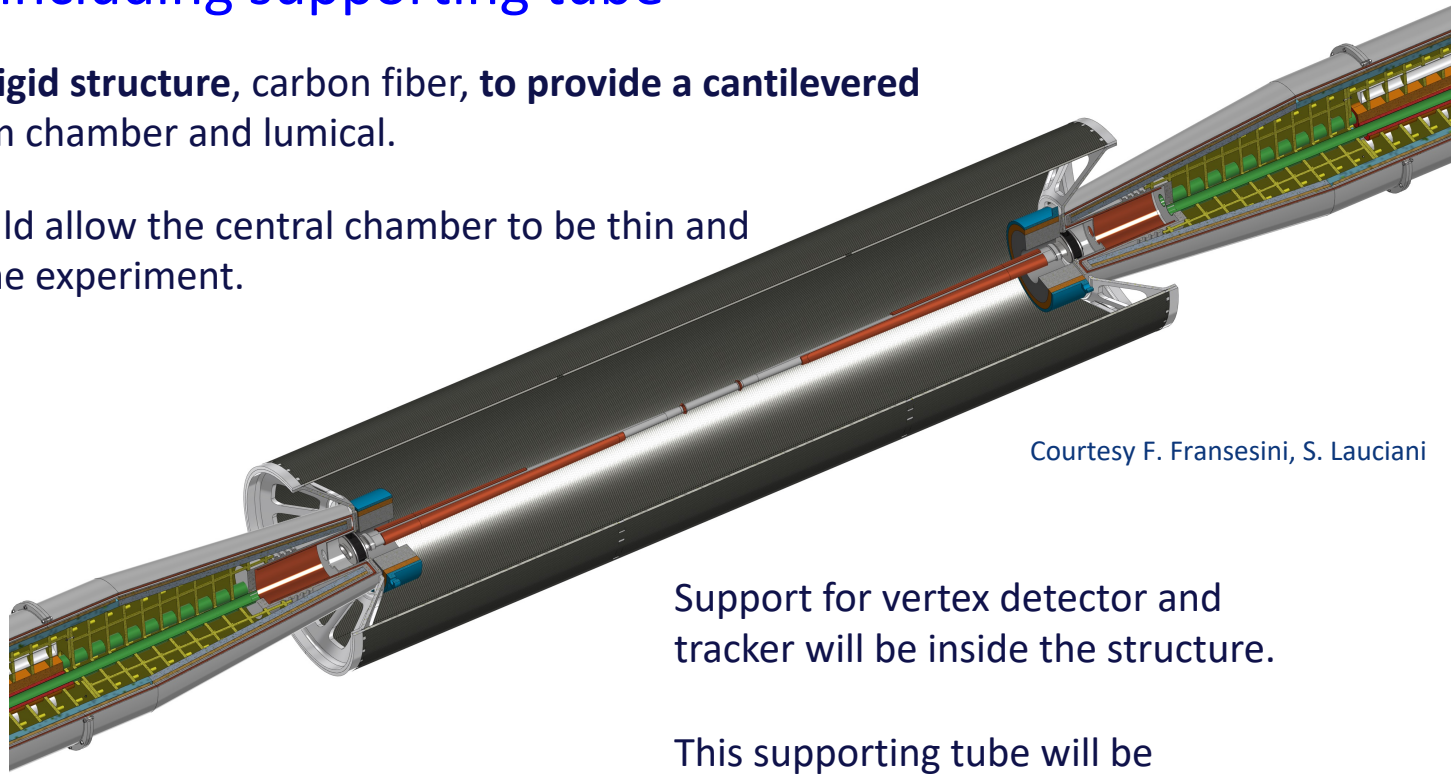
GEANT4, A. Ciarma

The chamber thickness and shape and dimension of the cooling channel fits the requirements, and it is technologically feasible.

3D view of IR including supporting tube

Proposed lightweight **rigid structure**, carbon fiber, **to provide a cantilevered support** for the vacuum chamber and lumical.

The rigid structure would allow the central chamber to be thin and light as requested by the experiment.



Courtesy F. Fransesini, S. Lauciani

Support for vertex detector and tracker will be inside the structure.

This supporting tube will be anchored to the detector.

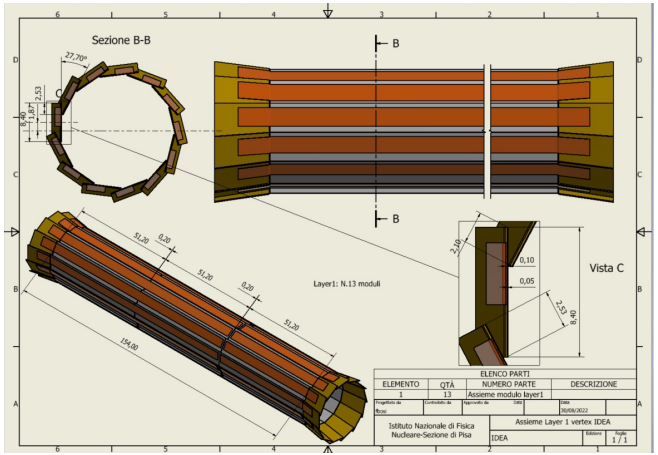
F Palla, F Bosi, INFN-Pi

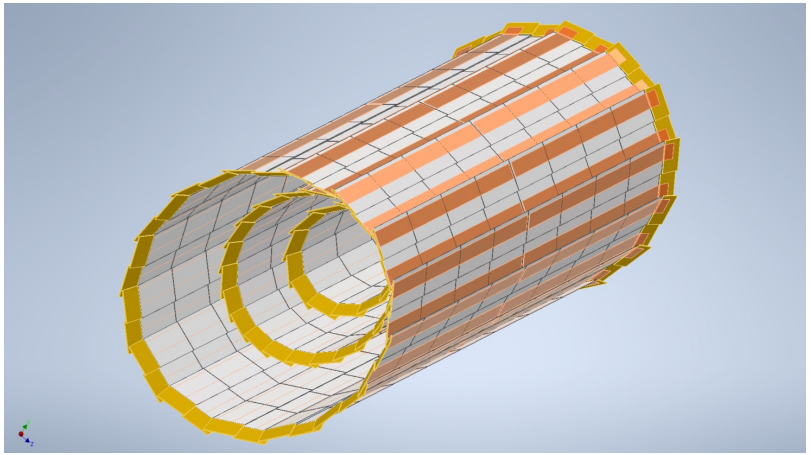
Study the integration of the vertex detectors

The design of the vertex detector region has started
Presently we are studying the insertion of vertex detectors inside the cylindrical rigid structure supporting the LumiCal and the beam pipe

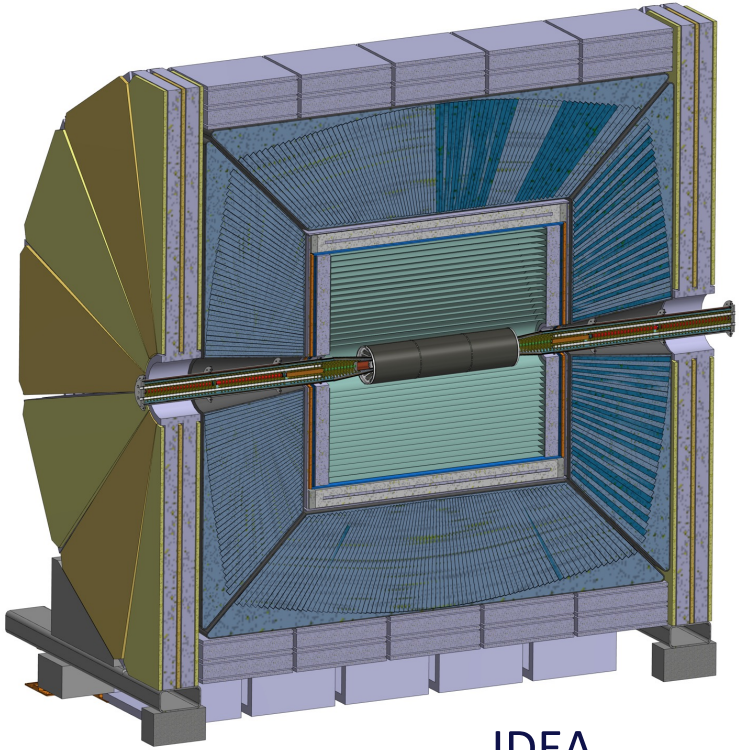
- Innermost structures supported by the beampipe
- Outermost layers (and endcaps) supported by the rigid structure - Mechanical structure still under study

- IDEA barrel vertex detector almost defined, wrapper and endcap will soon be finished
- The integration of the CLD vertex detector will follow

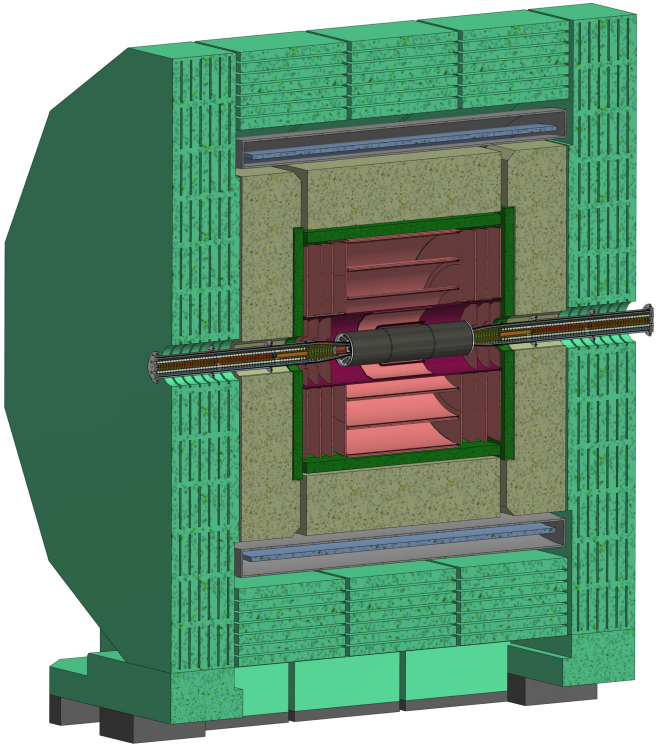




Overall view: IR with two detectors



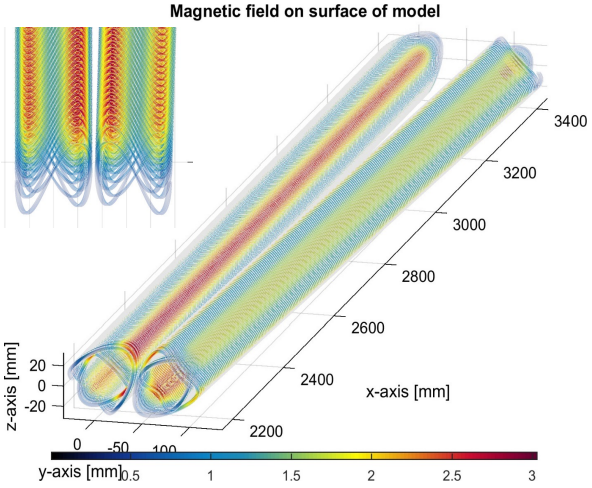
IDEA



CLD

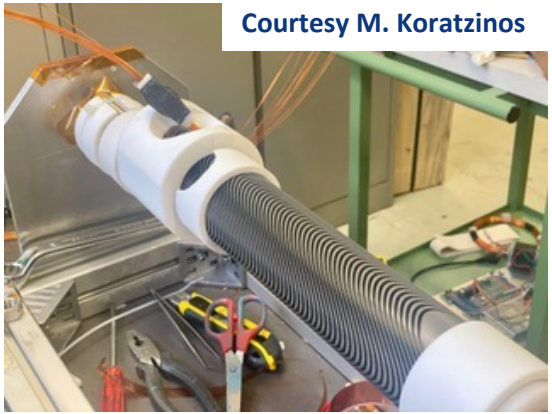
Magnets of the Interaction Region

- **Two superconducting compensating solenoids inside** the detector
- **Final Focus superconducting Canted Cos theta (CCT) quadrupole QC1** at 2.2 m from the IP, inside detector and embedded in one of the two compensating solenoids.
- Max gradient 100 T/m, NbTi, 4.2 K.
- It provides an an excellent field quality and allows for embedded correctors.



minimum distance between the magnetic centers of e+/e- for QC1L1 is only 66 mm

Courtesy M. Koratzinos



QC1 prototype during construction, tested at warm at CERN

Proposal by INFN-Genova to perform cold tests on this prototype.

The experiment will consist in a functional test for quench analysis.

Major Highlights from IR magnet review

4-5 April 2022 (chair J. Seeman)

- **The cone angle of 100 mrad cone between accelerator and detector** seems tight, it should be optimized considering constraints on both sides.

- Various **magnetic fields** and correctors in the cryostat **to be studied all together** (and produce a **3D field map** for DA and optics studies) to assess field quality, compatibility and constructability

- **Mechanical, electrical and field tolerances** to be studied as an **integrated group and loosened as much as possible.**

- Determine a clear picture of **heat loads** on the magnets and components.
  worst-case scenario for the cryogenic system from individual sources of heat loads

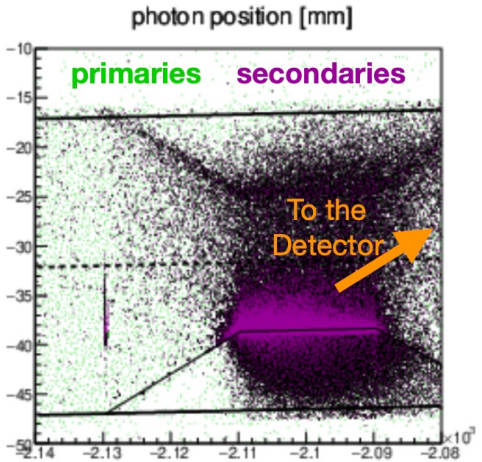
Synchrotron Radiation background

- New independent simulations performed with **BDSIM** from about 1.2 km from the IP, very good agreement with previous studies with MDISim
- **Only the last dipole upstream the IP, and the quadrupoles QC3L, QT1L, QC1L produce SR that propagates until or traverses the IP.**

- **SR from last bend intercepted by the mask has been tracked through the present beam pipe to the detector with Geant4**

- **The SR mask shows its effectiveness as expected from previous study (M. Sullivan)**

more by Andrea Ciarma

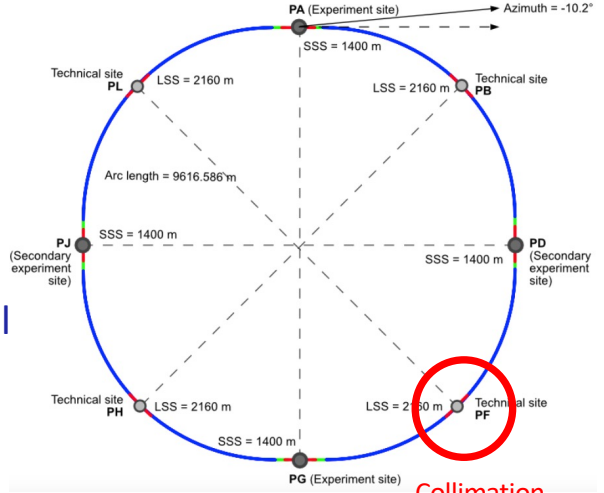


FCC-ee collimation studies

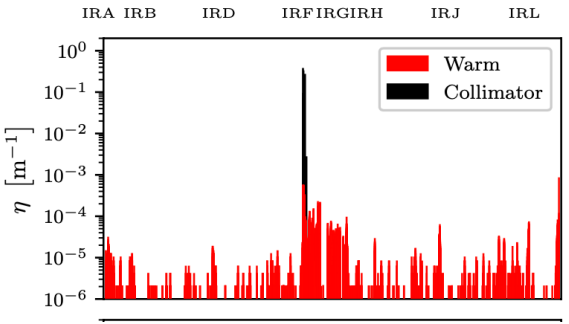
The first design of a halo collimation system is ongoing

Studies involved:

- Aperture studies, including tolerances, definition of aperture model
- Design of layout and optics in collimation insertion
- Definition of collimator settings, materials, needed active lengths
- Studies of protection during regular and irregular beam loss scenarios
- Performance evaluation, including particles out-scattered from
- collimators and residual loss patters around the ring
- Development of simulation tools for collimation simulations



Collimation insertion



Loss map for collimation losses in the full FCC-ee (benchmark with SIXTRACK-FLUKA, Xtrack-BDSIM, pyAT-BDSIM)

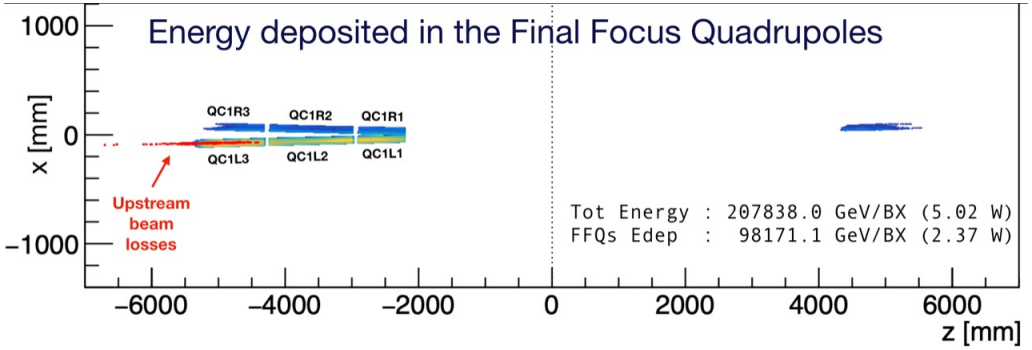
Ref. M. Hofer et al, IPAC22 doi:10.18429/JACoW-IPAC2022-WEPOST017
A. Abramov et al, IPAC22 doi:10.18429/JACoW-IPAC2022-WEPOST016

First *full-simulation* from primary losses to detector beam background

- Collimation simulation assuming a failure scenario evaluated beam losses close to the IR
- IR / MDI area modeled in GEANT4 including the present mechanical model

- GEANT4 tracking of primary losses has been performed into the IR with the goals of evaluating:
  - the occupancy in the VXD and TRK
  - energy deposition in the final focus quadrupole

First results are encouraging:
occupancy below 1%,
energy deposition few Watts



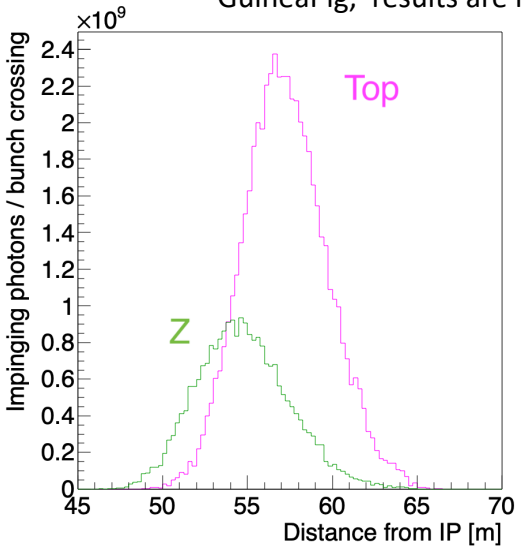
Beamstrahlung Radiation generated at the IP

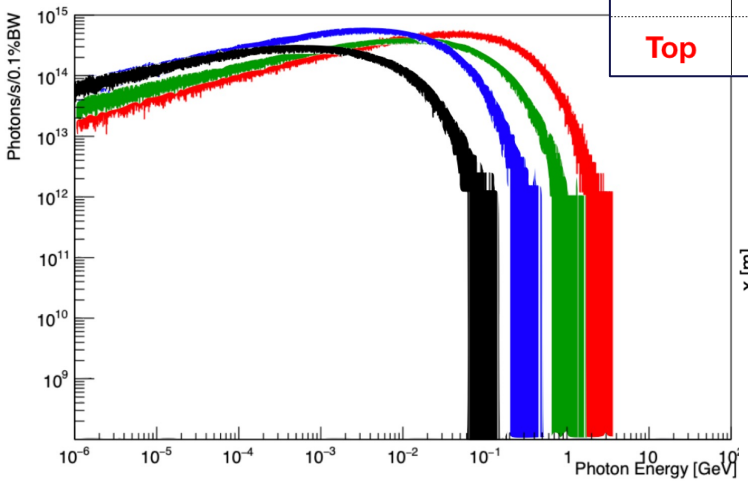
A. Ciarma

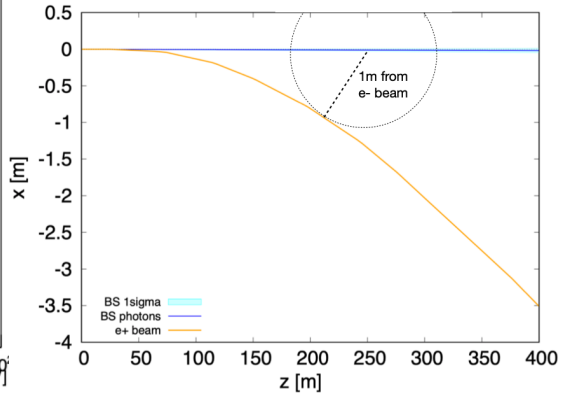
Radiation from the colliding beams is very intense (370 kW over cm^2 section!)

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

GuineaPig, results are in agreement with D. Shatilov's results







Beamstrahlung radiation hits the vacuum chamber at the first bend downstream the IP

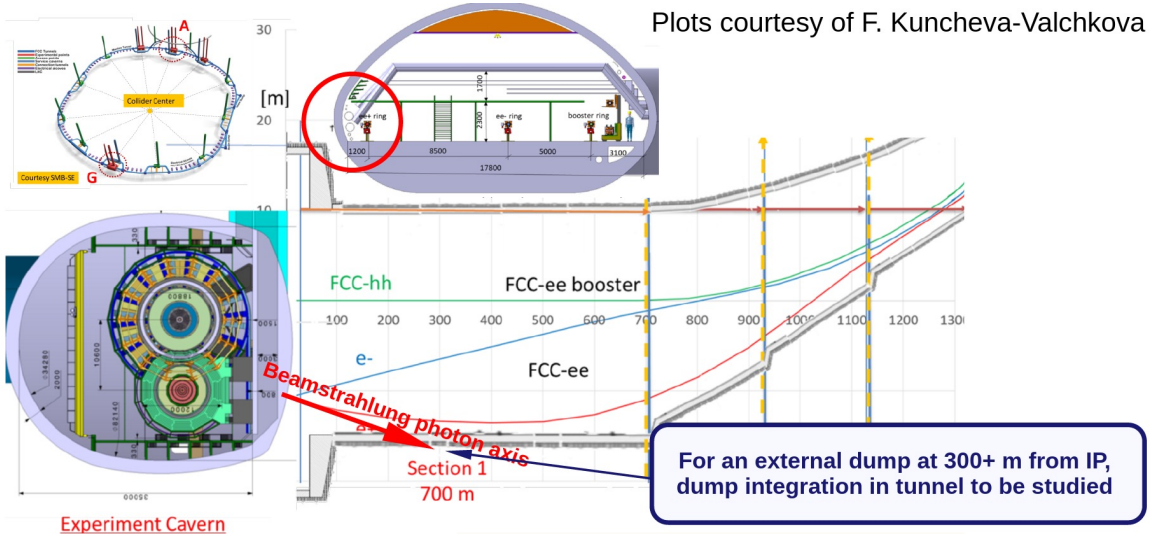
Requires special beam pipe extraction line and alcove -> Beamstrahlung instrumented photon dump

Challenge for a Beamstrahlung instrumented dump

M. Calviani

- High energy and power densities (several kW/cm^3)
- High average deposited power (hundreds of kW)
- Radiation damage and TID (hence shielding) in neighbouring areas
- Internal / external dumps
- Integration in the tunnel

Plots courtesy of F. Kuncheva-Valchkova



First FCC-Italy workshop 21-22 March 22

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

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

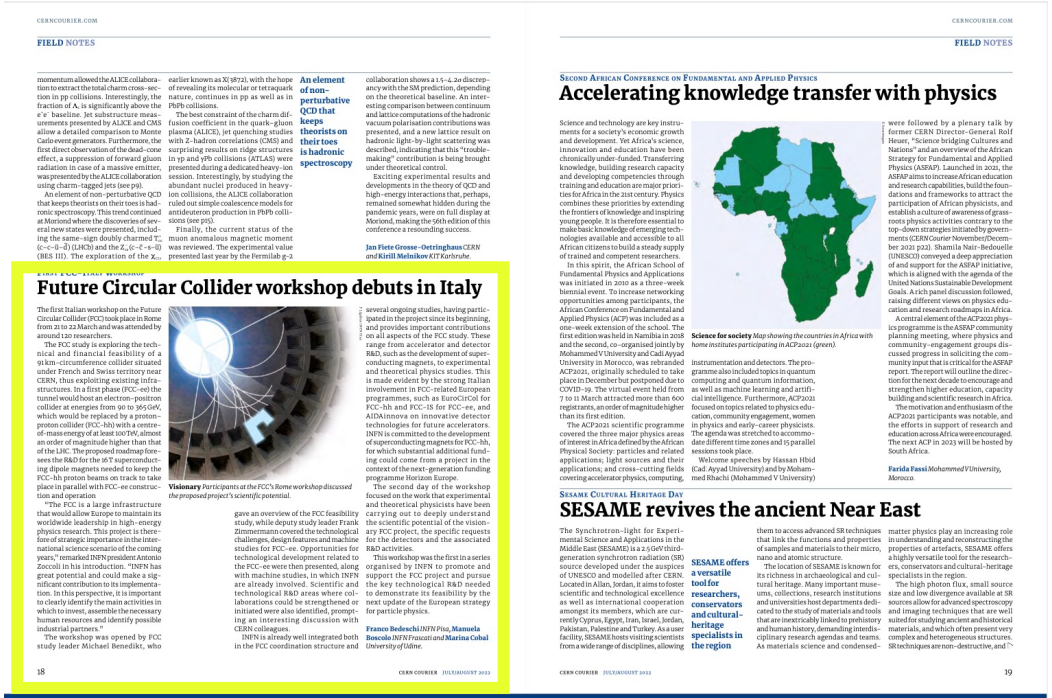
Si è recentemente tenuto a Roma il First FCC-Italy Workshop, il primo workshop italiano dedicato al progetto per il successore del Large Hadron Collider al CERN, il Future Circular Collider All'evento, organizzato dall'INFN, hanno partecipato 120 ricercatori e ricercatrici, e sono state presentate 15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



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momentum allowed the ALICE collaboration to extract the total charm cross-section in pp collisions. Interestingly, the fraction of Λ_c is significantly above the e^+e^- baseline. Jet substructure measurements presented by ALICE and CMS allow a detailed comparison to Monte Carlo event generators. Furthermore, the first direct observation of the dead-cone effect, a suppression of forward gluon radiation in case of a massive emitter, was presented by the ALICE collaboration using charm-tagged jets (see p9).

An element of non-perturbative QCD that keeps theorists on their toes is hadronic spectroscopy. This trend continued at Moriond where the discoveries of several new states were presented, including the same-sign doubly charmed T_{cc}^+ ($c-c-\bar{u}-\bar{d}$) (LHCb) and the $Z_c(c-\bar{c}+u-\bar{u})$ (BES III). The exploration of the χ_{c1} earlier known as $X(3872)$, with the hope of revealing its molecular or tetraquark nature, continues in pp as well as in PbPb collisions.

An element of non-perturbative QCD that keeps theorists on their toes is hadronic spectroscopy

The best constraint of the charm diffusion coefficient in the quark–gluon plasma (ALICE), jet quenching studies with Z–hadron correlations (CMS) and surprising results on ridge structures in γp and γPb collisions (ATLAS) were presented during a dedicated heavy-ion session. Interestingly, by studying the abundant nuclei produced in heavy-ion collisions, the ALICE collaboration ruled out simple coalescence models for antideuteron production in PbPb collisions (see p9).

Finally, the current status of the muon anomalous magnetic moment was reviewed. The experimental value presented last year by the Fermilab g-2 collaboration shows a 1.5–4.2σ discrepancy with the SM prediction, depending on the theoretical baseline. An interesting comparison between continuum and lattice computations of the hadronic vacuum polarisation contributions was presented, and a new lattice result on hadronic light-by-light scattering was described, indicating that this "trouble-making" contribution is being brought under theoretical control.

Exciting experimental results and developments in the theory of QCD and high-energy interactions that, perhaps, remained somewhat hidden during the pandemic years, were on full display at Moriond, making the 56th edition of this conference a resounding success.

Jan Fiete Grosse-Oetringhaus *CERN* and Kirill Melnikov *KIT Karlsruhe.*

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 technology 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 to 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.

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

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

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SECOND AFRICAN CONFERENCE ON FUNDAMENTAL AND APPLIED PHYSICS

Accelerating knowledge transfer with physics

Science and technology are key instruments for a society's economic growth and development. Yet Africa's science, innovation and education have been chronically under-funded. Transferring knowledge, building research capacity and developing competencies through training and education are major priorities for Africa in the 21st century. Physics combines these priorities by extending the frontiers of knowledge and inspiring young people. It is therefore essential to make basic knowledge of emerging technologies available and accessible to all African citizens to build a steady supply of trained and competent researchers.

In this spirit, the African School of Fundamental Physics and Applications was initiated in 2010 as a three-week biennial event. To increase networking opportunities among participants, the African Conference on Fundamental and Applied Physics (ACP) was included as a one-week extension of the school. The first edition was held in Namibia in 2018 and the second, co-organised jointly by Mohammed V University and Cadi Ayyad University in Morocco, was rebranded ACP2021, originally scheduled to take place in December but postponed due to COVID-19. The virtual event held from 7 to 11 March attracted more than 600 registrants, an order of magnitude higher than its first edition.

The ACP2021 scientific programme covered the three major physics areas of interest in Africa defined by the African Physical Society: particles and related applications; light sources and their applications; and cross-cutting fields covering accelerator physics, computing, instrumentation and detectors. The programme also included topics in quantum computing and quantum information, as well as machine learning and artificial intelligence. Furthermore, ACP2021 focused on topics related to physics education, community engagement, women in physics and early-career physicists. The agenda was stretched to accommodate different time zones and 15 parallel sessions took place.

Welcome speeches by Hassan Hbid (Cad Ayyad University) and by Mohammed Khachi (Mohammed V University) were followed by a plenary talk by former CERN Director-General Rolf Heuer, "Science bridging Cultures and Nations" and an overview of the African Strategy for Fundamental and Applied Physics (ASFAP). Launched in 2021, the ASFAP aims to increase African education and research capabilities, build the foundations and frameworks to attract the participation of African physicists, and establish a culture of awareness of grass-roots physics activities contrary to the top-down strategies initiated by governments (CERN Courier November/December 2021 p22). Shamila Nair-Bedouelle (UNESCO) conveyed a deep appreciation of and support for the ASFAP initiative, which is aligned with the agenda of the United Nations Sustainable Development Goals. A rich panel discussion followed, raising different views on physics education and research roadmaps in Africa.

A central element of the ACP2021 physics programme is the ASFAP community planning meeting, where physics and community-engagement groups discussed progress in soliciting the community input that is critical for the ASFAP report. The report will outline the direction for the next decade to encourage and strengthen higher education, capacity building and scientific research in Africa.

The motivation and enthusiasm of the ACP2021 participants was notable, and the efforts in support of research and education across Africa are encouraged. The next ACP in 2023 will be hosted by South Africa.

Science for society *Map showing the countries in Africa with home institutes participating in ACP2021 (green).*

Farida Fassi *Mohammed V University, Morocco.*

SESAME CULTURAL HERITAGE DAY

SESAME revives the ancient Near East

The Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) is a 2.5 GeV third-generation synchrotron radiation (SR) source developed under the auspices of UNESCO and modelled after CERN. Located in Allan, Jordan, it aims to foster scientific and technological excellence as well as international cooperation amongst its members, which are currently Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine and Turkey. As a user facility, SESAME hosts visiting scientists from a wide range of disciplines, allowing them to access advanced SR techniques that link the functions and properties of samples and materials to their micro, nano and atomic structure.

SESAME offers a versatile tool for researchers, conservators and cultural-heritage specialists in the region

The location of SESAME is known for its richness in archaeological and cultural heritage. Many important museums, collections, research institutions and universities host departments dedicated to the study of materials and tools that are inextricably linked to prehistory and human history, demanding interdisciplinary research agendas and teams. As materials science and condensed-matter physics play an increasing role in understanding and reconstructing the properties of artefacts, SESAME offers a highly versatile tool for the researchers, conservators and cultural-heritage specialists in the region.

The high photon flux, small source size and low divergence available at SR sources allow for advanced spectroscopy and imaging techniques that are well suited for studying ancient and historical materials, and which often present very complex and heterogeneous structures. SR techniques are non-destructive, and

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Summary

- Progress on various key aspects of the MDI design.
  - Vacuum chamber with thermal analysis and cooling system and bellow, compatible with the acceptance required by the luminosity monitor
  - Collimation scheme for the FCC-ee ring
  - Beam loss map from failure scenario tracked with GEANT4 through the IR to evaluate detector backgrounds
  - Synchrotron Radiation background *full-simulation*: primary photons from BDSIM tracked through the IR to evaluate the impact on detector, IR heat load, and optimize shieldings.
  - Beamstrahlung radiation, challenging photon bump

Next steps

- Progress on the **overall IR magnets design including solenoids and correctors** will help with the **cryostat design, supports**, and the overall general **assembly and integration**.
- **List of requirements** for IR magnets, detector, luminosity monitor, MDI key elements.