GOALS OF THE WORKSHOP, OPEN QUESTIONS UPDATES FROM FCC-EIC WORKSHOP

Manuela Boscolo

FCC-ee MDI workshop
CERN, 24 October 2022

FCC-EIC Joint 17-21 October

Monday 17/10 Introduction to FCC/EIC workshop with overviews, outstanding questions and experience from existing high current rings.

- Welcome
- FCC & EIC Overview
- FCC & EIC IR optics
- FCC & EIC MDI
- Discussion: Example of challenges around the IR for high current rings, e.g. DAFNE, PEP-II, KEKB, SuperKEKB

Tuesday 18/10 IR magnet design – different concepts for IR magnets and possible limitations, diagnostics.

- Summary from FCC IR review and lessons from SuperKEKB
- FCC & EIC IR magnet design
- FCC & EIC IR beam instrumentation

Wednesday 18/10 Global collimation, beam collimation simulation tools and collimator design including SKEKB experience.

- EIC & FCC beam loss and SR backgrounds and tools
- EIC & SuperKEKB collimator design and experience
- Discussion of IR collimation versus global collimation

Thursday 20/10 Beam-beam, lifetime modeling tools, Dynamic aperture, impedance

- FCC & EIC beam-beam and lifetime limitations and modeling, simulation tools
- FCC & EIC Dynamic Aperture Beam
- FCC & EIC Impedance model
- HL-LHC Crab Cavity Noise and Impedance studies
- Discuss common EIC/FCC Beam-beam, DA studies and development, consider impedance models and IR heating

Friday 21/10 Tuning requirements and modeling needs. Close workshop with summary of common needs and studies.

- FCC & EIC Optics Tuning
- Discussion on future work topics and summary of common needs and studies.

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FCC-ee MDI 24-28 October

Monday 24/10 Open questions, IR Collimation, Detector backgrounds

- Open questions, with updates from EIC-FCC workshop
- IR collimation, SR masking and shielding, Detector backgrounds impact
- Beam background sources , experience from LHC modeling tool, what is needed for FCC
- IR Heat Load

Tuesday 25/10 IR Tolerances, Alignment, Stabilization

- Vibrational orbit effects
- Alignment and Stabilization of the IR
- Discussion: specify tolerances and tuning timescales; verify diagnostics and tuning elements
- Summary of FCC IR magnets review and IR cryostat design considerations

Wednesday 26/10 IR Mechanical model

- 3D CAD Model
- Vertex detector integration, Luminosity Monitor
- Thermal and Structural simulations for the vacuum chamber
- IR Bellows design and heat load evaluation
- Remote Vacuum Connection
- IR mock-up

Thursday 27/10 Detector integration

- Layout open questions, considerations from review of Experimental Surface Sites
- FCC Civil Engineering
- Fast luminosity monitor
- Beamstrahlung dump challenges, radiation, integration

Friday 28/10 Close-out

- Lessons from low-emittance light sources
- Summary discussion, next steps and preparing a set of requirements

Goals of the workshop

First week - FCC-EIC Joint Workshop:

- Discuss the common challenges between the FCC-ee and the EIC
- Identify opportunities for collaboration and set up contact

Second week - FCC-ee MDI Workshop:

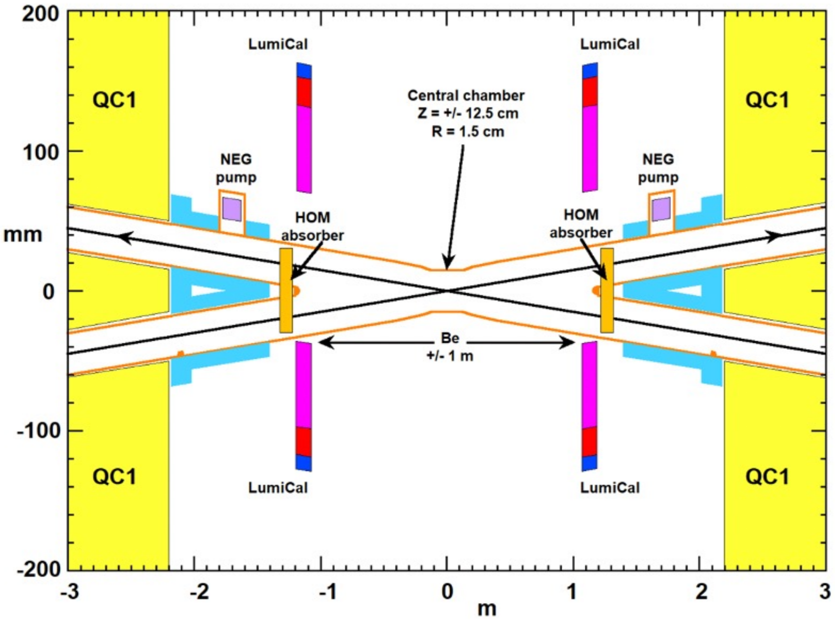
- **Cover the latest development in the FCC-ee IR and MDI**
  - **IR beam losses and SR, IR collimation, detector backgrounds, beam induced heat load**
  - **Tuning, stabilization, and alignment, specify tolerances and tuning timescales; verify diagnostics and tuning elements**
- **Progress on the mechanical design and integration of the interaction region layout**
- **IR mock-up**
- **Preparing a list of requirements**

FCC-ee MDI design
few highlights from the overview

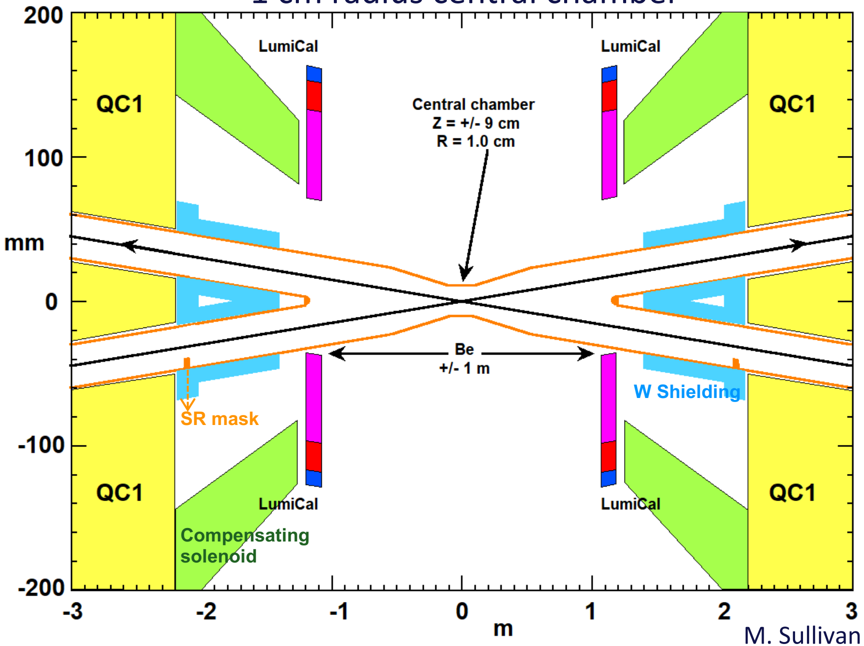
Interaction Region layout

2D-top view with expanded x-coordinate

CDR
1.5 cm radius central chamber



present low impedance beam pipe
1 cm radius central chamber

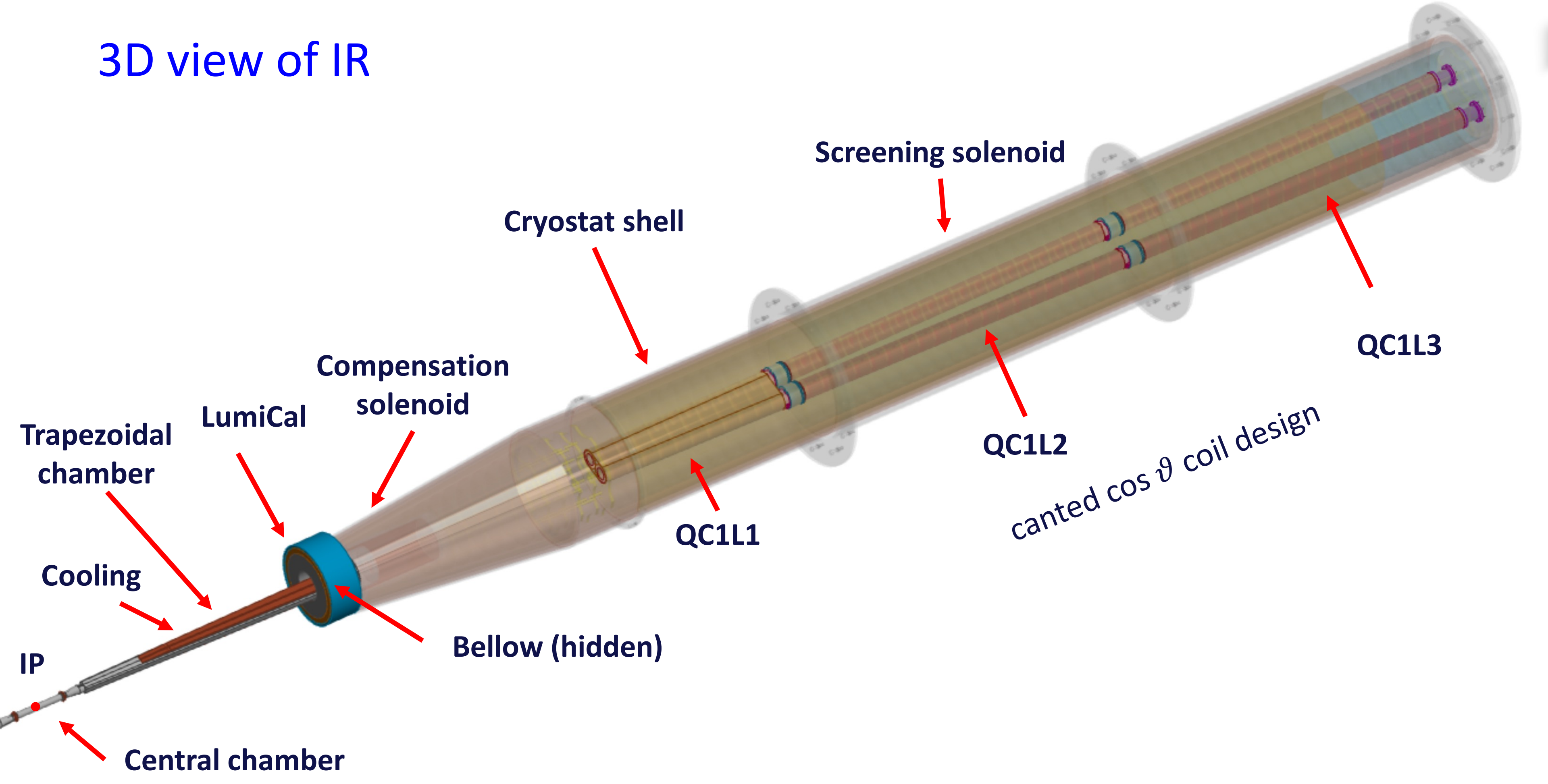


M. Sullivan

a smaller central vacuum chamber allows for a smaller radius of the innermost vertex detector layer

Courtesy F. Fransesini

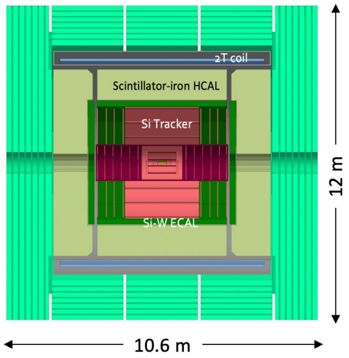
3D view of IR



Thursday 27 October

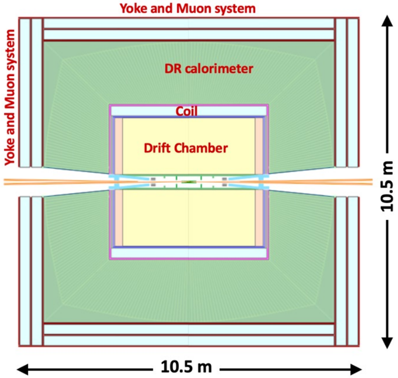
FCC-ee Detector Concepts

CLD

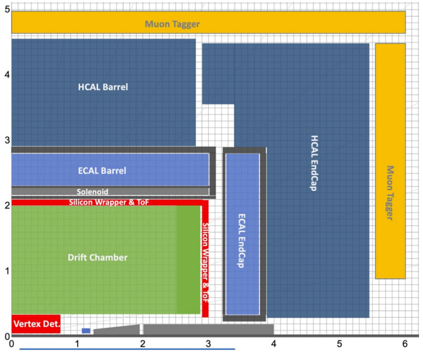


CDR

IDEA



Noble Liquid ECAL based



new

CLD

- Full Silicon vertex detector + tracker;
- Very high granularity, CALICE-like calorimetry;
- Muon system
- Large coil outside calorimeter system;
- Possible optimization for
  - Improved momentum and energy resolutions
  - PID capabilities

IDEA

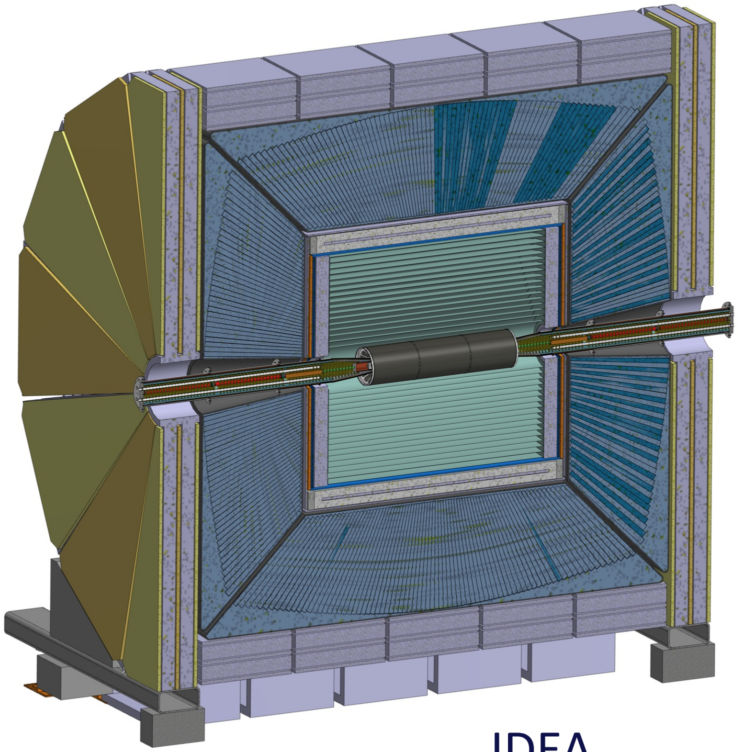
- Si vertex detector;
- Ultra light drift chamber w. powerfull PID;
- Monolitic dual readout calorimeter;
- Muon system;
- Compact, light coil inside calorimeter;
- Possibly augmented by crystal ECAL in front of coil;

Noble Liquid ECAL based

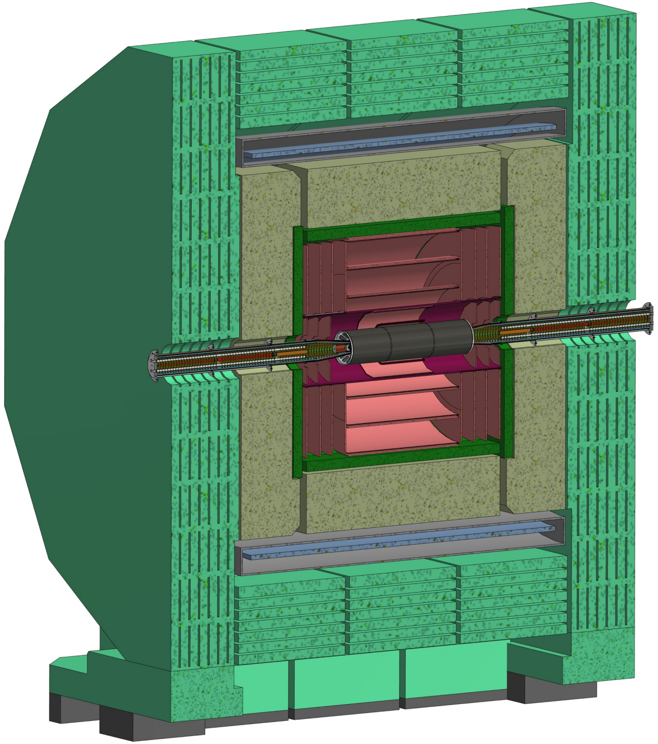
- High granularity Noble Liquid ECAL as core;
  - PB+LAr (or denser W+LCr)
- Drift chamber (or Si) tracking;
- CALICE-like HCAL;
- Muon system;
- Coil inside same cryostat as LAr, possibly outside ECAL.

Thursday 27 October

Interaction Region in two detectors



IDEA



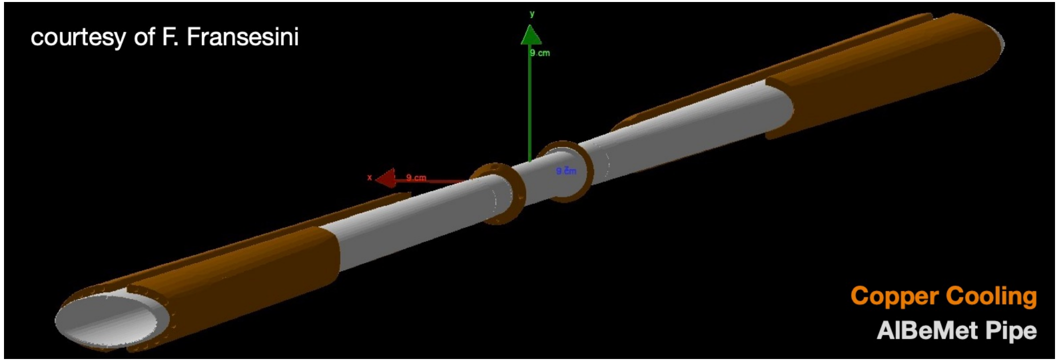
CLD

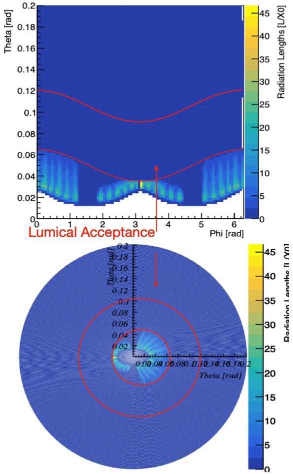
High-level Detector requirements for the MDI design

- **The cone angle of 100 mrad cone between accelerator and detector** seems tight,
  - it should be optimized considering constraints on both sides.
- **Luminosity monitor** @Z: absolute measurement to 10^{-4} with low angle Bhabhas
  - **Acceptance of the lumical**, low material budget for the central vacuum chamber
  - alignment and stabilization constraints
- **Critical energy below 100 keV** of the Synchrotron Radiation produced by the last bending magnets 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

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.

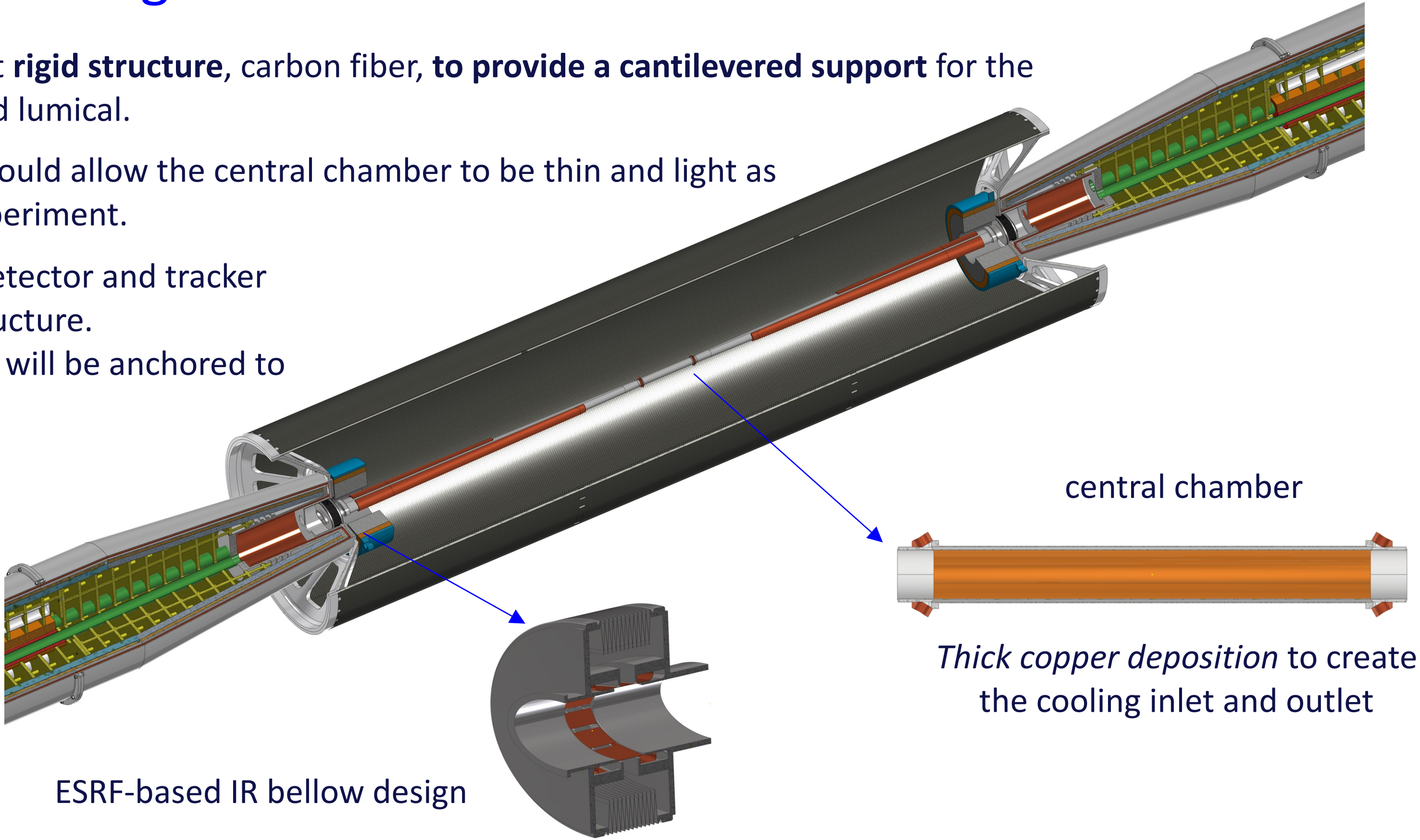
Wednesday 26 October

Mechanical Design

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.

Support for vertex detector and tracker will be inside the structure.
This supporting tube will be anchored to the detector.



central chamber

Thick copper deposition to create the cooling inlet and outlet

ESRF-based IR bellow design

Monday 24 October

IR Collimation and Detector Backgrounds

Beam loss and SR backgrounds and tools presented last week 18/10
Today we discuss SR masking, IR losses, IR collimation and detector background impact.
Set of requirements for the MDI design

IR mock-up

Wednesday 26 October

IP chamber critical for collider performance
Discussion on the proposal and on the main goal and objectives of this R&D

Beamstrahlung Dump

Thursday 27 October

Highlight the challenge, the high energy and power densities in the game
Discussion on the reasonable main goals for the MT review and FS

Short summary of discussions

High Current Beams & Interaction Region Design

Comment to the Interaction Region Design:

- At EIC weekly meetings on the IR design accelerator-detector group
- Suggestion to have regular meetings with colleagues designing the detector

- **Experience and need of High Order Modes Absorbers in the IR**

Experience can be worse than simulation, heating of the IR beam pipe needs to be cooled down. At DAFNE the induced heating at the crotch was so high that the gradient of the permanent magnets was modified. Experience at PEP-II discussed as well.

- **Beam dump**

Relevant for FCC, very high energy stored beam, and whenever one beam dies the other must be immediately damped. IR steering failure to be considered. Possible need for additional dump. Machine protection: if a sudden event happens, we must protect the detector –in any case to be designed as robust as possible to high backgrounds and radiation.

- **Collimators**

Impedance, non-linear collimators, experience from SuperKEKB

- **Backgrounds modelling**

Key issue for the success of any collider, its modeling should be as detailed as possible. From experience both at DAFNE and at SuperKEKB the background modeling was greatly improved only during operation, as a result of the need from the experiment to mitigate the beam background rates, which resulted higher than expected.

IR magnets design

- **CCT design:** advantages, implications, tapering
- **Direct winding:** limits, advantages
- FCC Correctors winding coils
- **Iron structure:** advantages, implications, experience at SuperKEKB, e.g. it magnetizes, it creates showers, it protects the detector
- **Beam induced quenches,** experience at SuperKEKB, it happens at a deposited beam energy of ~10mJ
- **Magnet protection scheme**
- **Shields:** at EIC shields prevent stray field and higher harmonics from the hadron ring for the e- line, at SuperKEKB It was added to protect the detector.

CCT IR quadrupole design:

- FCC based
- EIC plans to considers it

Beam Instrumentation

EIC and FCC IR beam instrumentation very different
FCC: Beamstrahlung photons
EIC: Large Angle Beamstrahlung photons

FCC
- BPM resolution < 1μm (orbit mode), <10 μm (BxB / TxT mode)
- BPM alignment & accuracy 1-10 μm

Global Collimation, Collimation design

- FCC-EIC same collimation simulation tool Xsuite
- Suggestion and discussion on steady-state beam, diffusion process, check whole phase space covered by collimators
- Lesson from ESRF: pyAT was unable to simulate the halo formation, the Touschek simulation turned out not very realistic, due to the complexity of simulating this diffusive process, backtracking of lost particles performed. Reality is much more complicated than simulation.

- Experience from SuperKEKB: damage of collimators due to sudden beam loss, study to make them more robust.

- FCC SR produced by IR quads and solenoid, ~kW downstream the IP, will hit the beampipe at the same location of BS photons, this radiation will be tracked through the detector, but also masks, shields and cooling studied.

- Injection backgrounds, important to simulate.

Let’s have a pleasant and productive workshop!