DETECTOR INTEGRATION AND DETECTOR BACKGROUNDS

Fabrizio Palla

INFN Pisa and CERN

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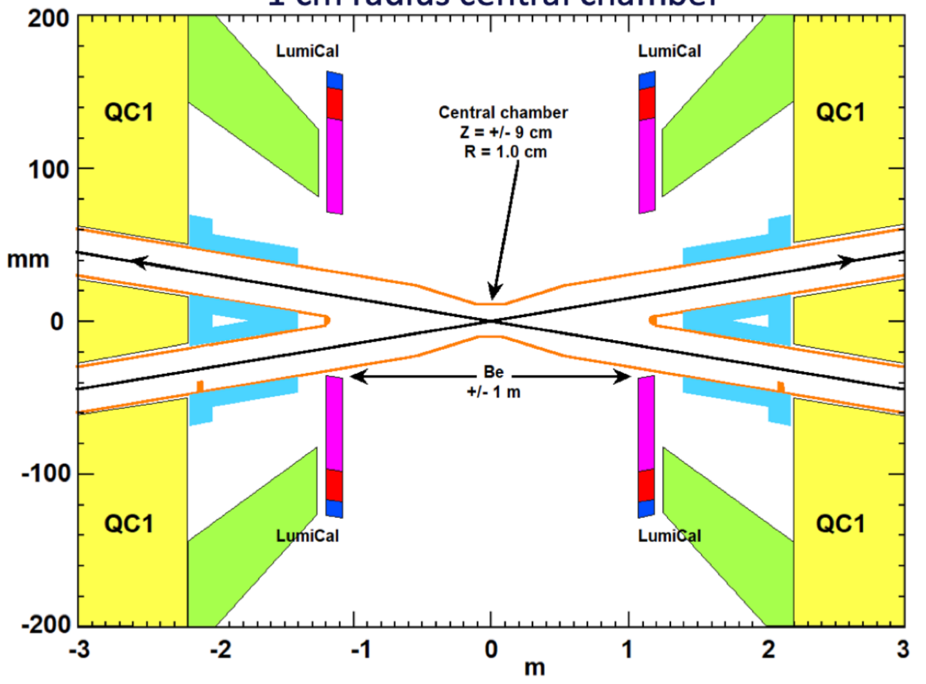
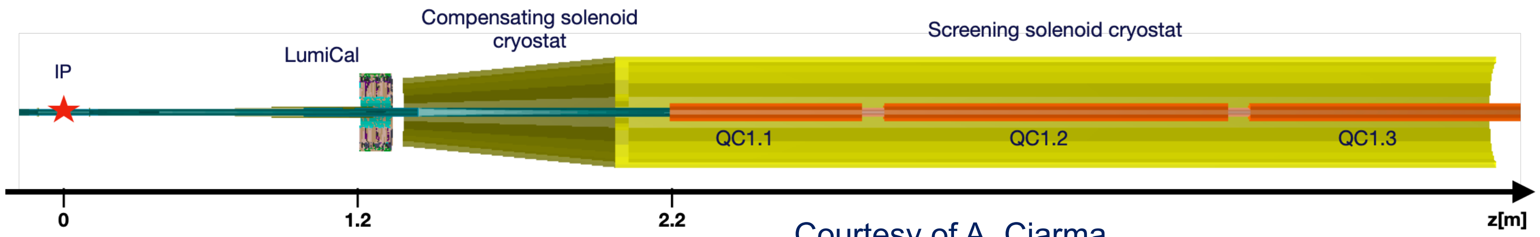
FCC-ee IR requirements

- **Crab-waist scheme** based on nano-beams and large (30 mrad) crossing angle to reach extremely high luminosity O(10^{36} $cm^{-2}s^{-1}$) at Z-pole.
- **Solenoid compensation** achieved via two anti-solenoids inside the detector.
- Shielding for beam induced **backgrounds**
- **Luminosity monitor**: absolute measurement to 10^{-4} with low angle Bhabhas
  - Strict alignment tolerances and **low material budget** in front
- **Vertex detector:** largest acceptance and low material budget (<0.2%X_0 per layer)
  - MAPS with **air-cooling**
- **Calorimeter**: highest possible hermeticity for total energy measurement
- **Beam pipe**: smallest material as possible

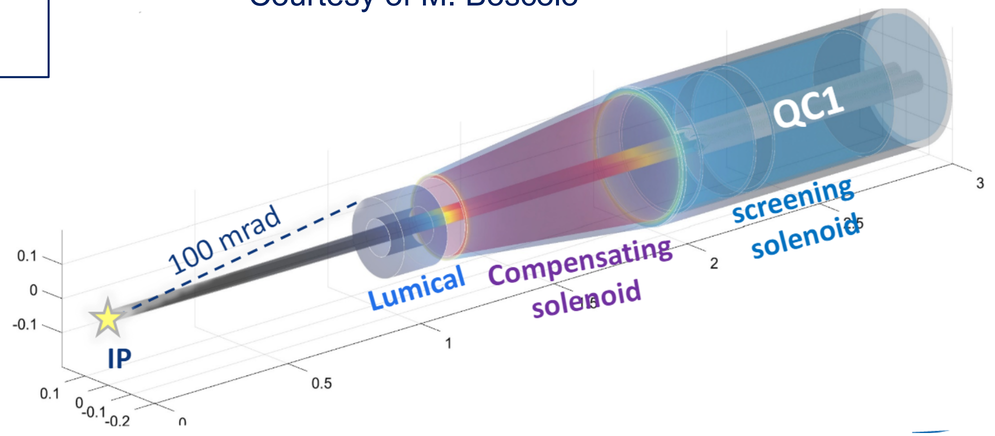
present low impedance beam pipe
1 cm radius central chamber



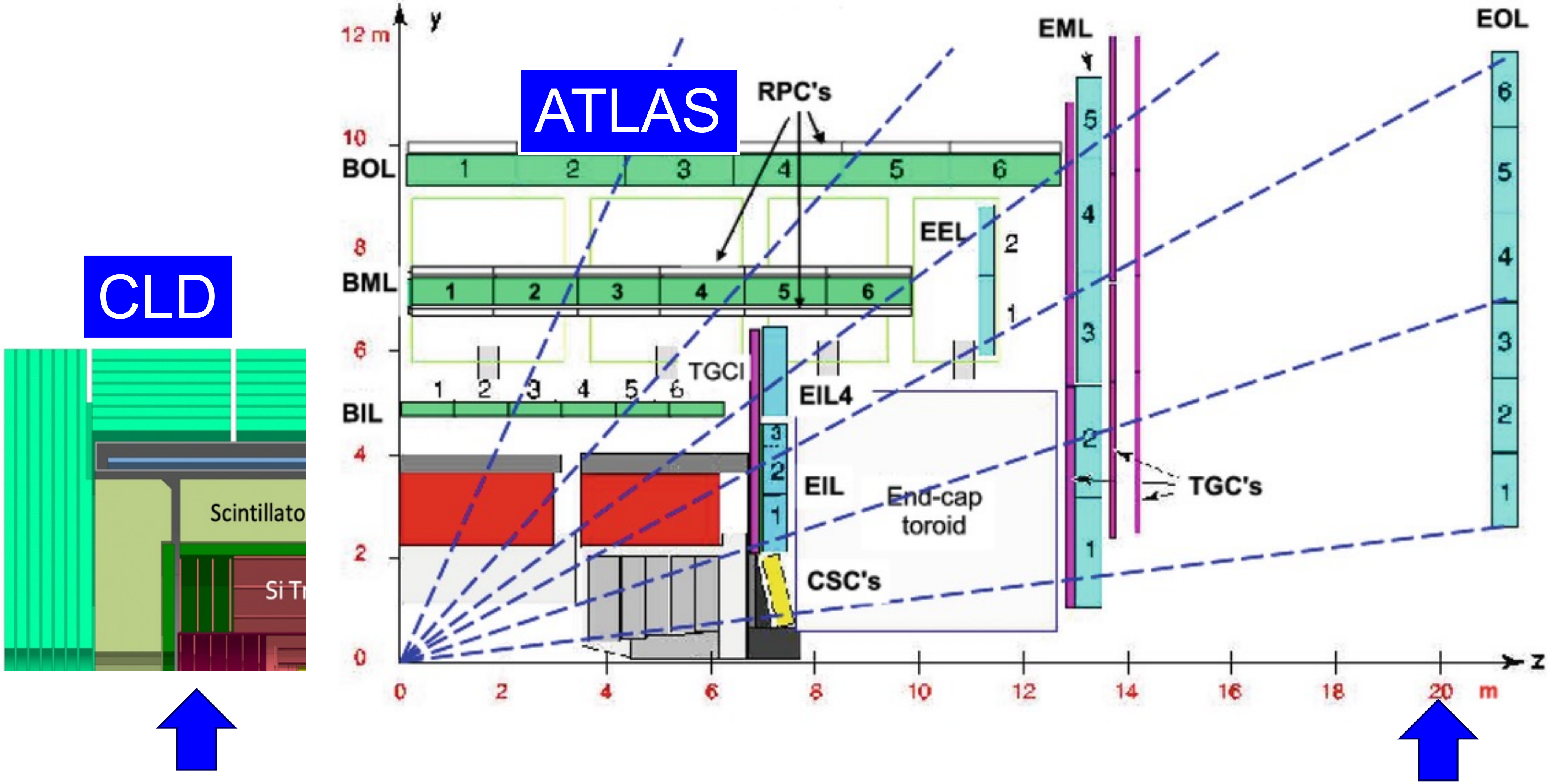
Courtesy of M. Boscolo



Courtesy of A. Ciarma



Comparison between LHC and FCC-ee MDI

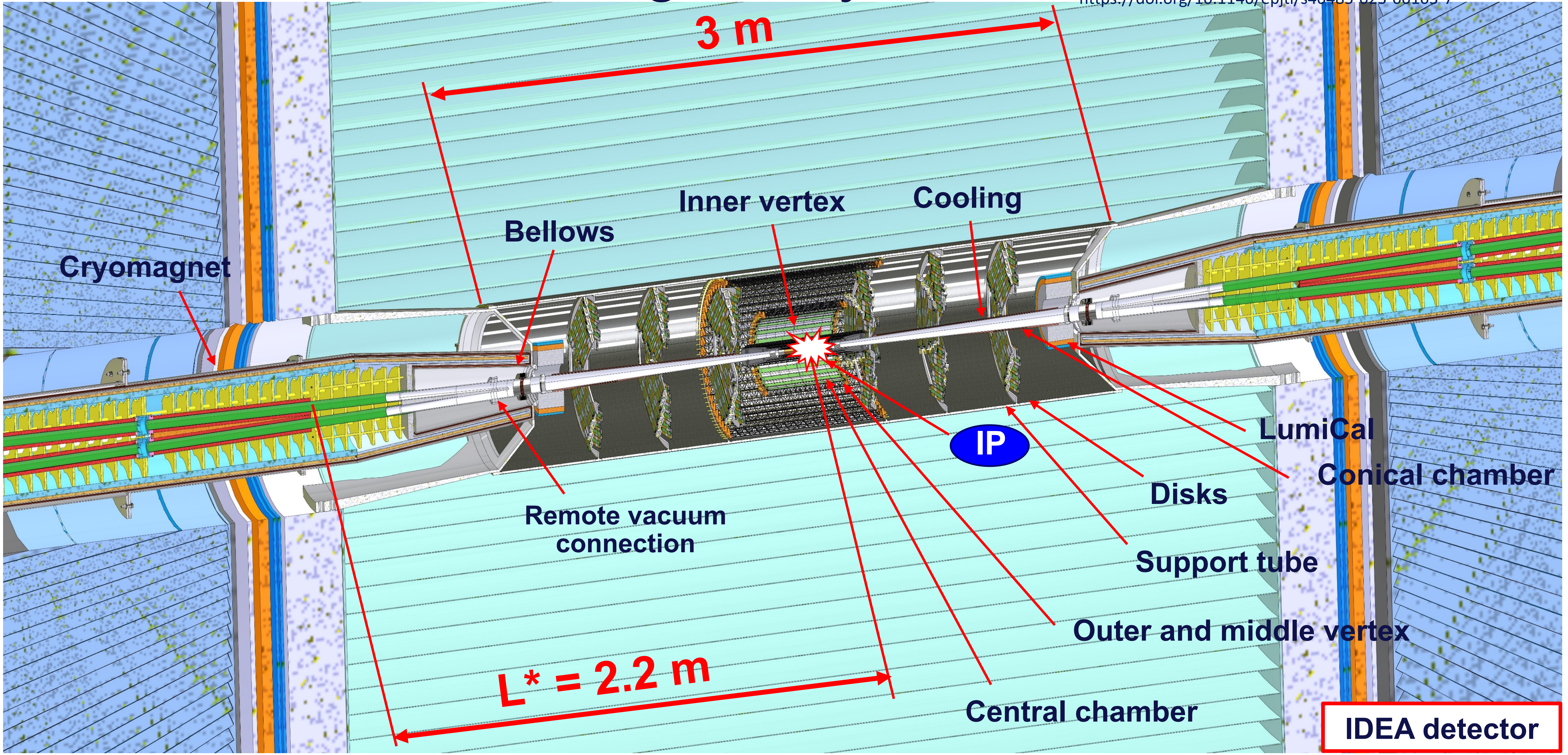


Last accel. element 2.2 m

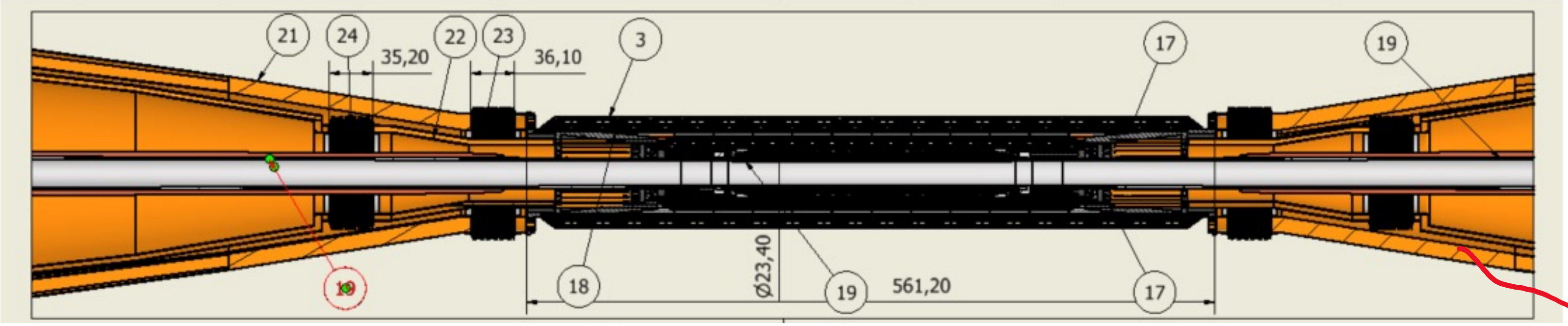
Last accel. element 20 m

FCC-ee interaction region layout

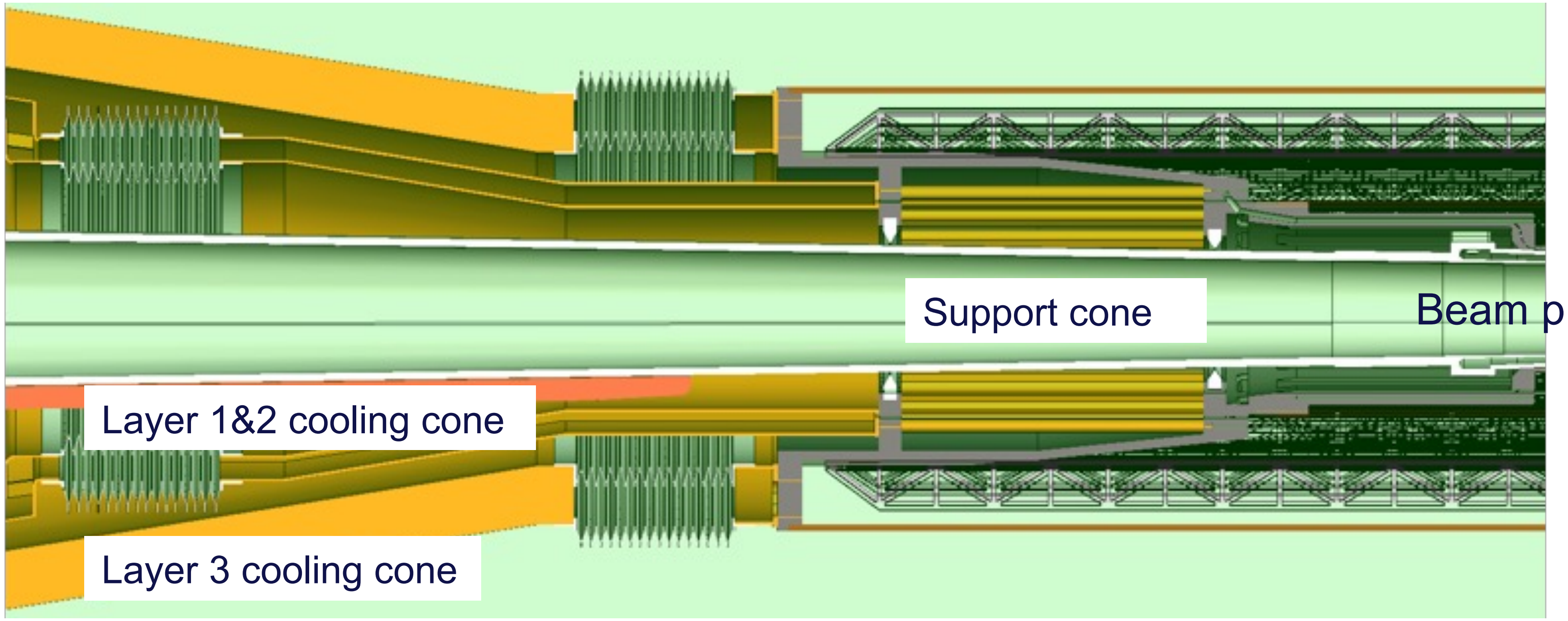
M. Boscolo, F. Palla, F. Fransesini, F. Bosi and S. Lauciani, Mechanical model for the FCC-ee MDI, EPJ Techn Instrum **10**, 16 (2023). https://doi.org/10.1140/epjti/s40485-023-00103-7



Inner vertex – beam pipe integration



Air-cooling cones

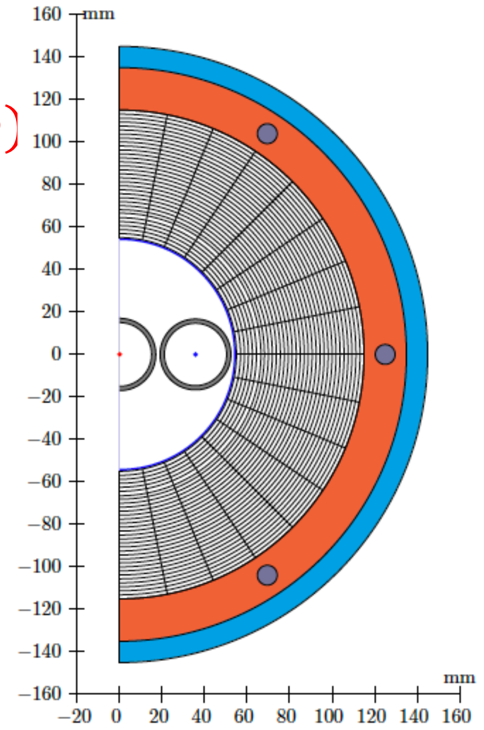


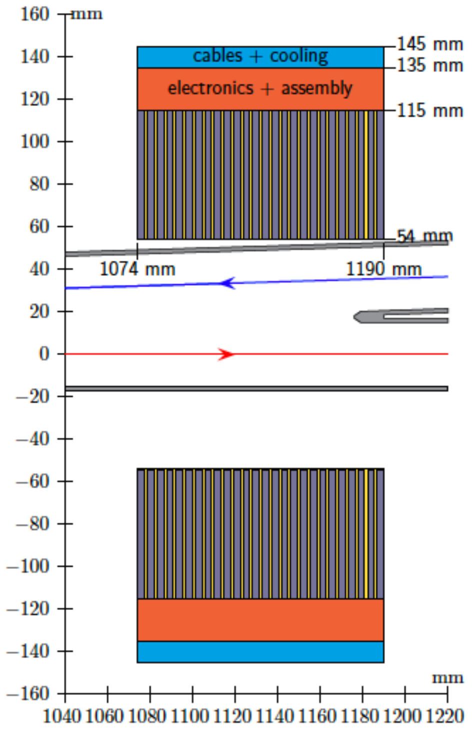
Beam pipe cooling manifold

Courtesy F. Bosi

Luminosity monitor integration

- Luminosity measurement with low angle Bhabha scattering
  $64 < \theta[mrad] < 88\,;\sigma = 14\,nb$ (TBC with $\sigma_{had} = 30\,nb$)
- Silicon (active) + Tungsten (passive) sampling calorimeter with pointing resolution
- Aiming 10^{-4} precision
  - Tight construction and alignment tolerances
    - $\delta R_{min} = \pm 1.5\ \mu m$
    - $\delta R_{max} = \pm 3.5\ \mu m$
    - $\delta z = \pm 110\ \mu m$
  - Dictates the smallest angular acceptance of the vertex detector
  - Careful understanding of materials in front
  - Sensitive to thermal stability

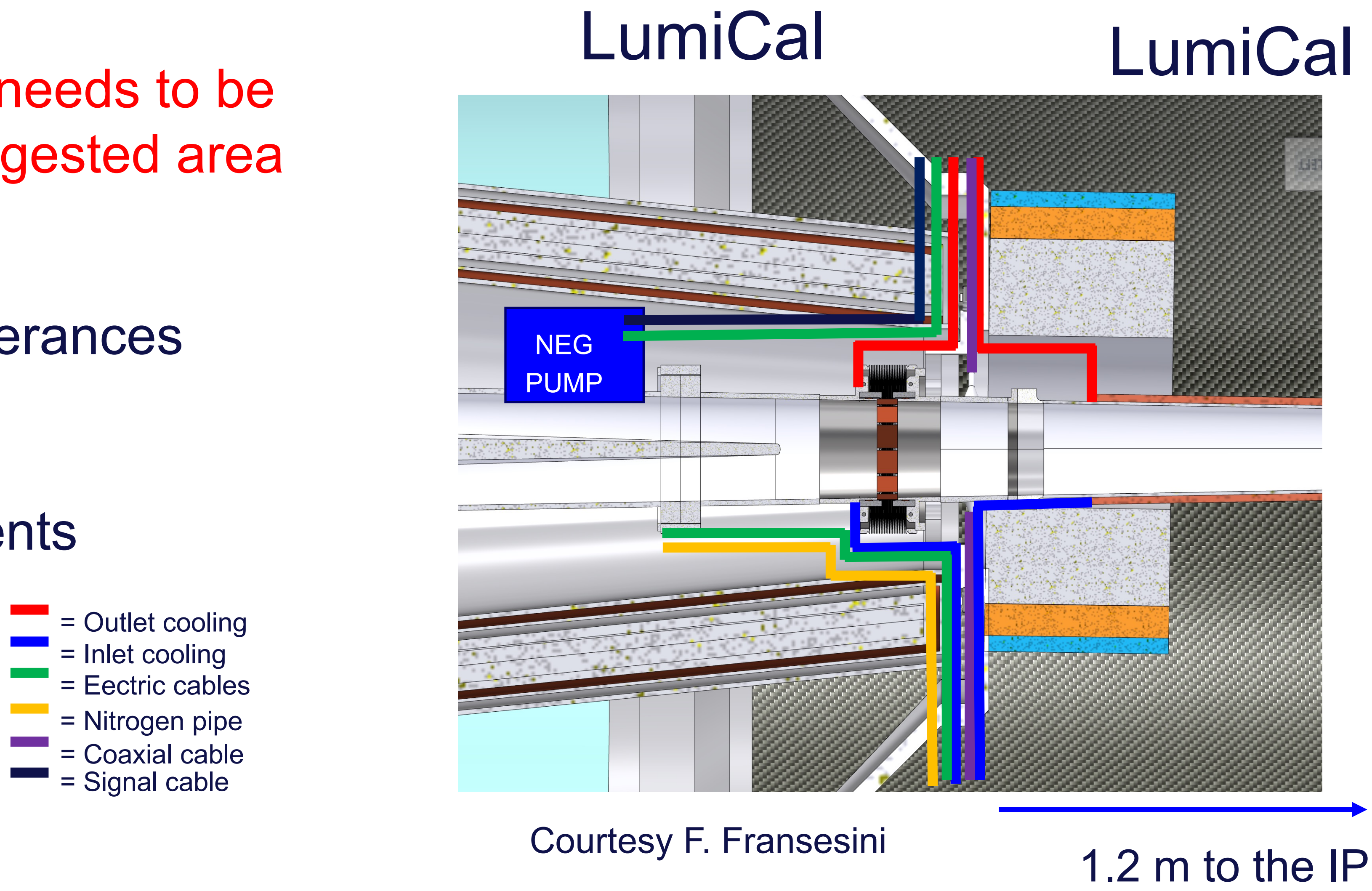




Courtesy M. Dam

Integration with cryo-magnet system

- Luminosity calorimeter needs to be integrated in a very congested area
  - Service routings
  - Tight construction tolerances
  - Alignment system
  - Accelerator components



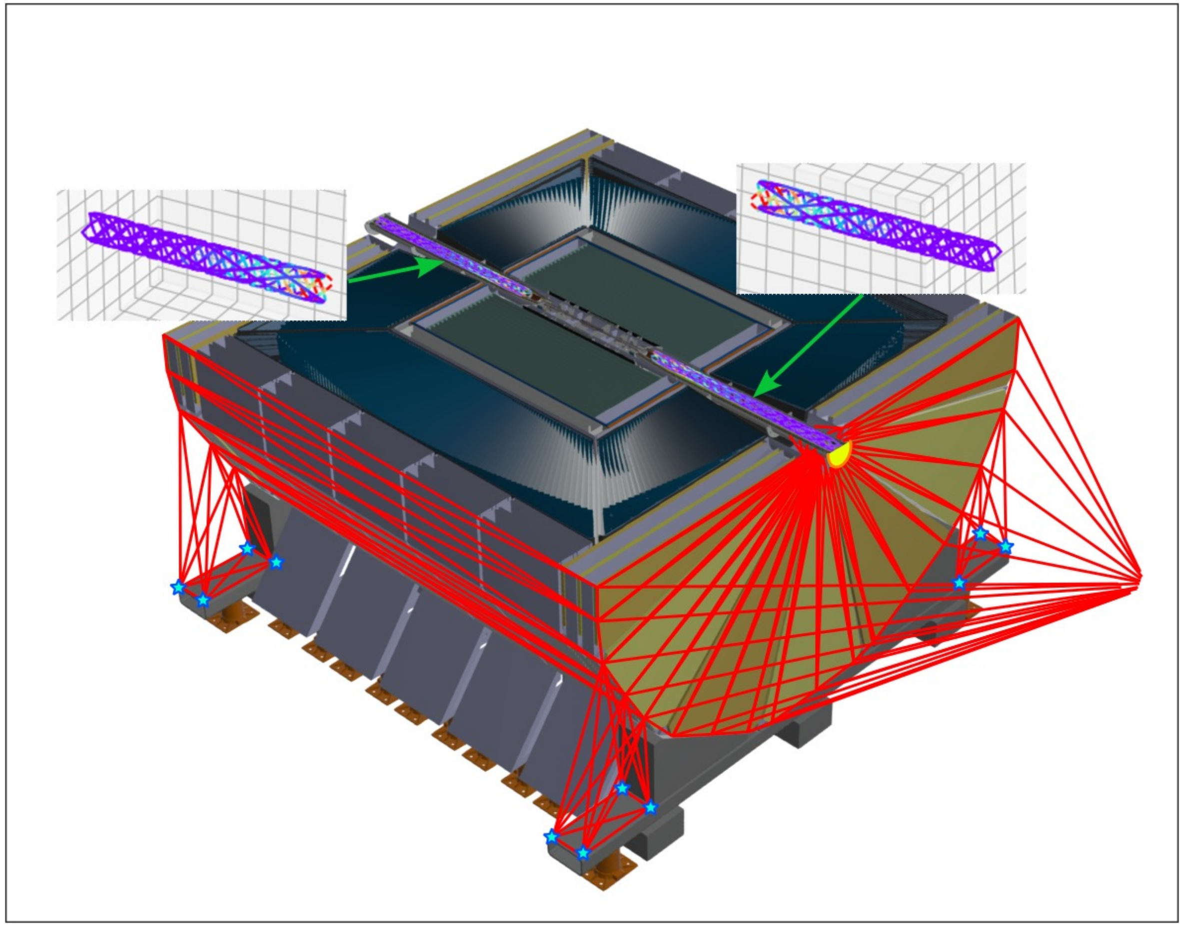
Courtesy F. Fransesini

Alignment system

Using 3 subsystems with Frequency Scanning Interferometry:

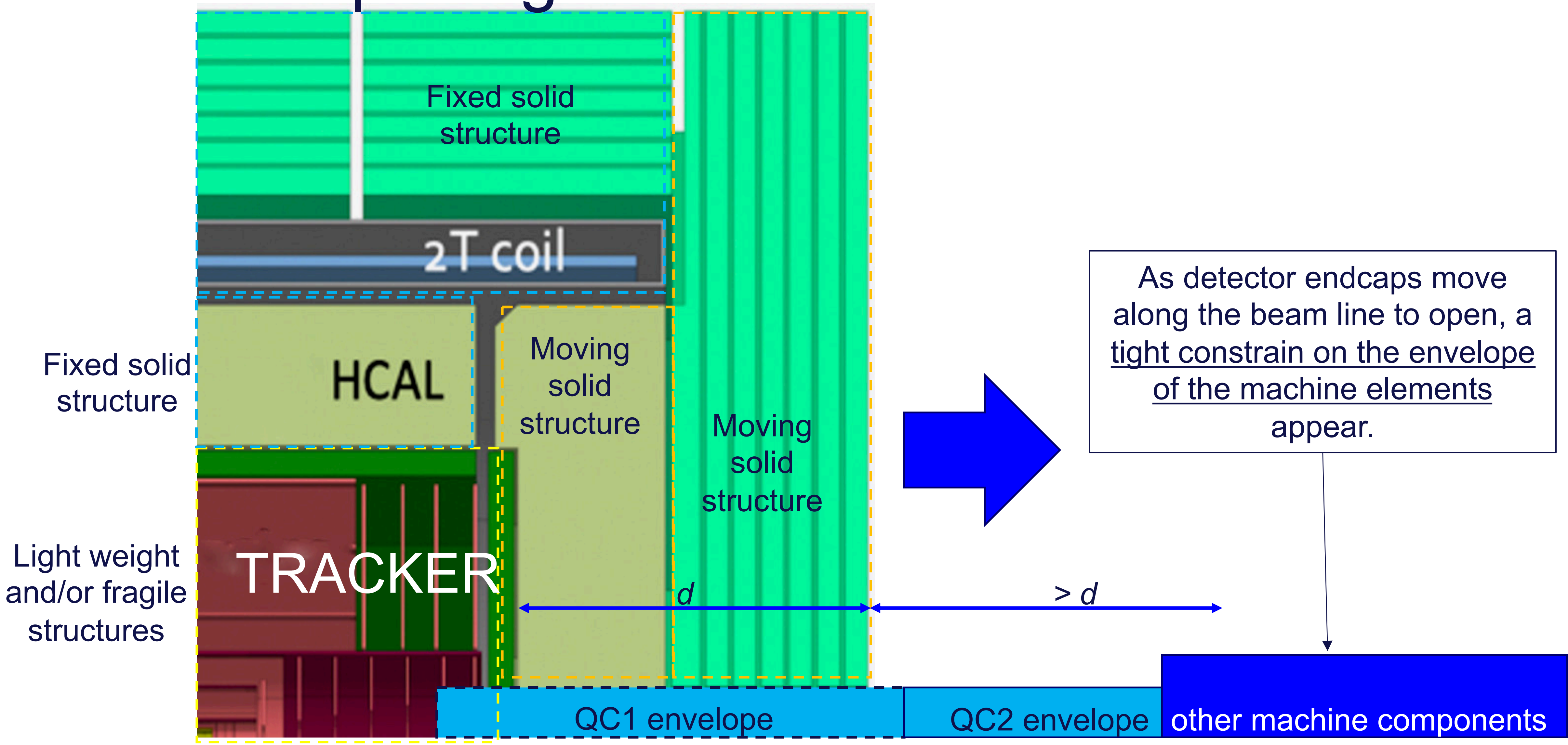
- Deformation monitoring of the QC1 as reference system
- Short distance between the QC1 end and the LumiCal, BPM, + other elements
- A Long distance monitoring

- Work ongoing on the technical side
  - Need detectors to give feedback



Courtesy L. Watrelot

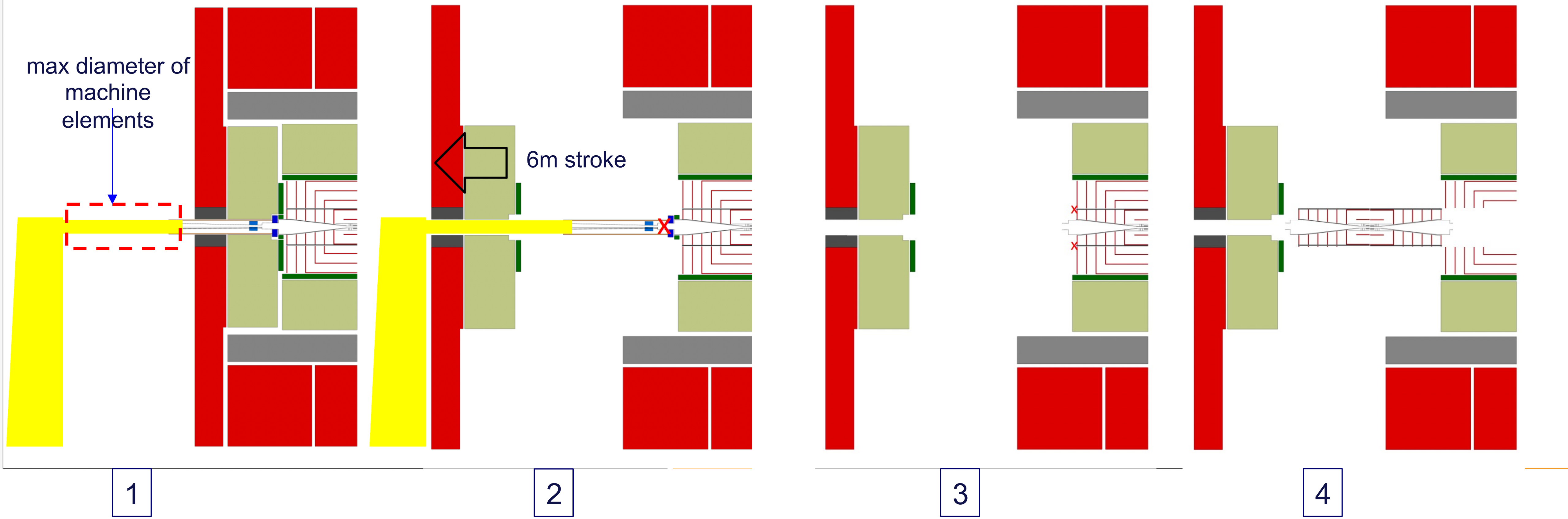
Detector opening and maintenance



As detector endcaps move along the beam line to open, a <u>tight constrain on the envelope of the machine elements</u> appear.

Courtesy A. Gaddi

Scenario for inner detector assembly or servicing



Detector closed.

Detector Endcap opened to access the double vacuum valve on the beam-pipe after the QC magnets.

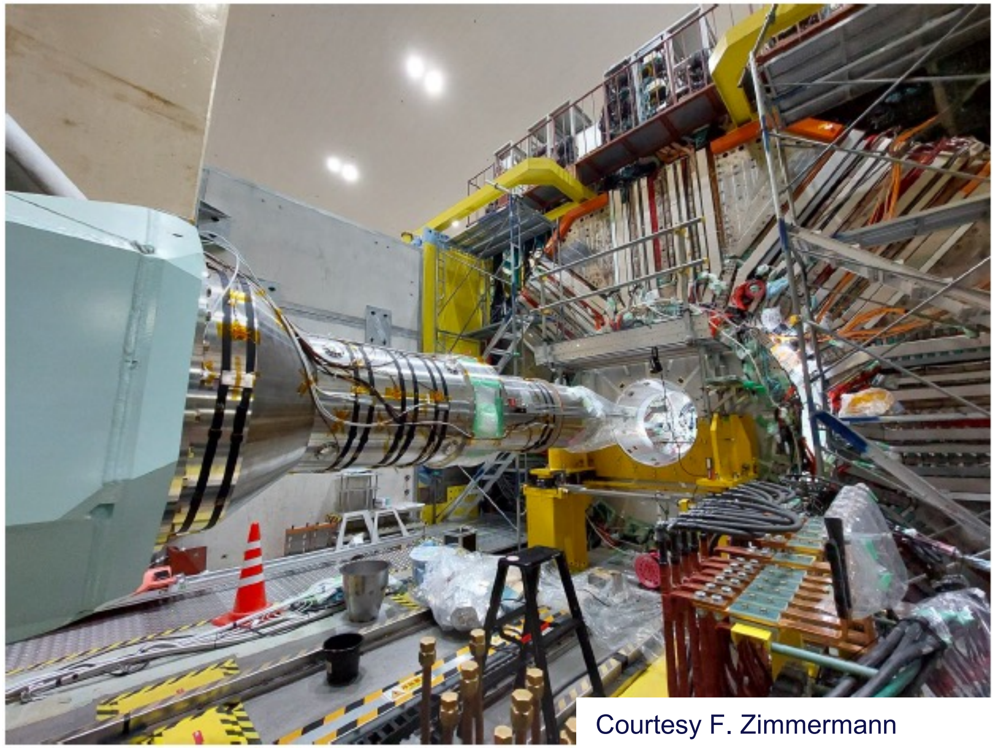
QC removed, access to the Inner Tracker.

Inner Tracker, Vertex & Beam-pipe removed. Same process for Outer Tracker removal.

Courtesy A. Gaddi

Opening issues

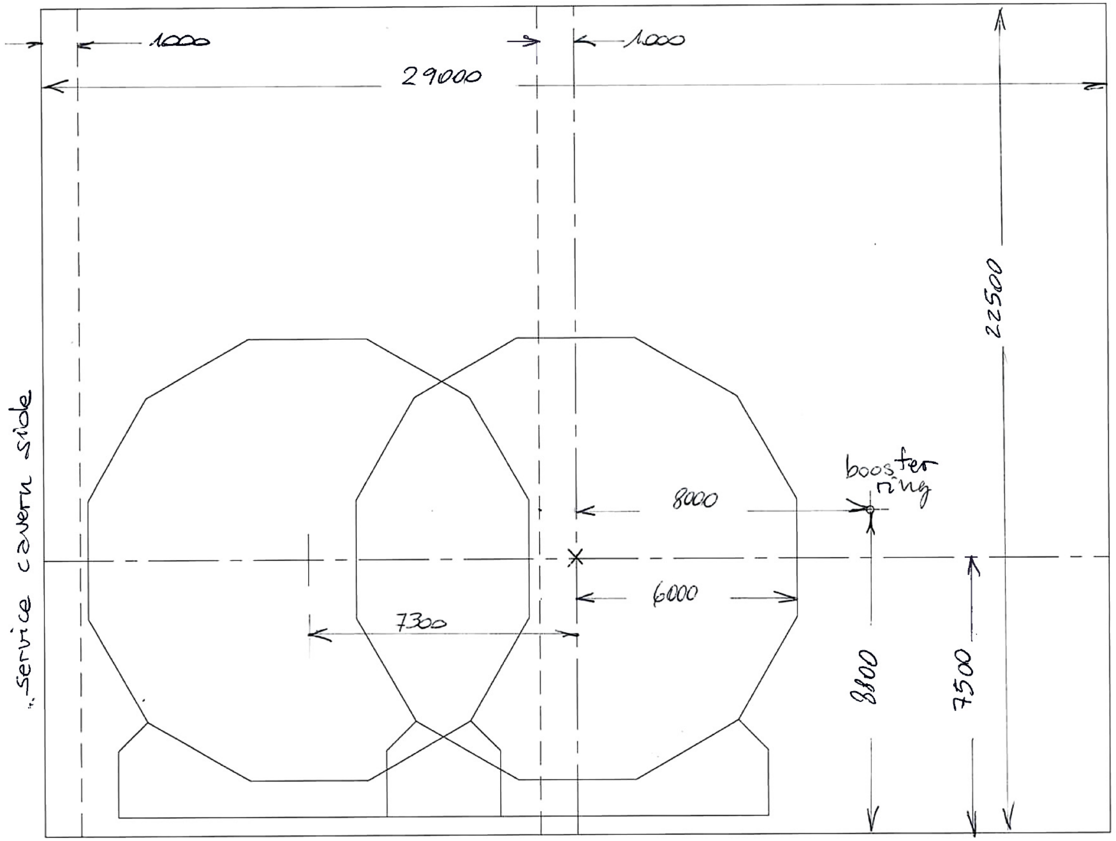
Belle-II detector opening at SuperKEKB



Courtesy F. Zimmermann

FCC-ee FFQ are ~3 times longer wrt SuperKEKB (9 meters instead of 3m)

FCC-ee detectors need to deal with booster ring and other machine elements around



Courtesy A. Gaddi

Beam induced backgrounds (& simulation)

- **Luminosity backgrounds (synchronous with collision – proportional to Luminosity)**
  - **Radiative Bhabha $e^+e^- \rightarrow e^+e^-\gamma$**
    - Main effects on quadrupoles from off-momentum electrons - need to estimate effects on detectors (esp. calorimeters) – work ongoing
  - **Beam-strahlung: photons and 'spent beam'**
    - *Incoherent pair creation* (real or virtual photon scattering e^+e^-) – **dominant** - work started
    - Coherent pair creation (photon interaction off the collective field of the opposite bunch) – negligible
    - $\gamma\gamma \rightarrow$ hadrons – negligible

- **Single beam effects (Mitigated with collimators, masks and shielding)**
  - Synchrotron radiation – work in progress
  - Beam-gas – work in progress
  - Injection backgrounds – work just started
  - Touschek – negligible
  - Thermal photons (dominant at LEP) – to be started

Luminosity backgrounds

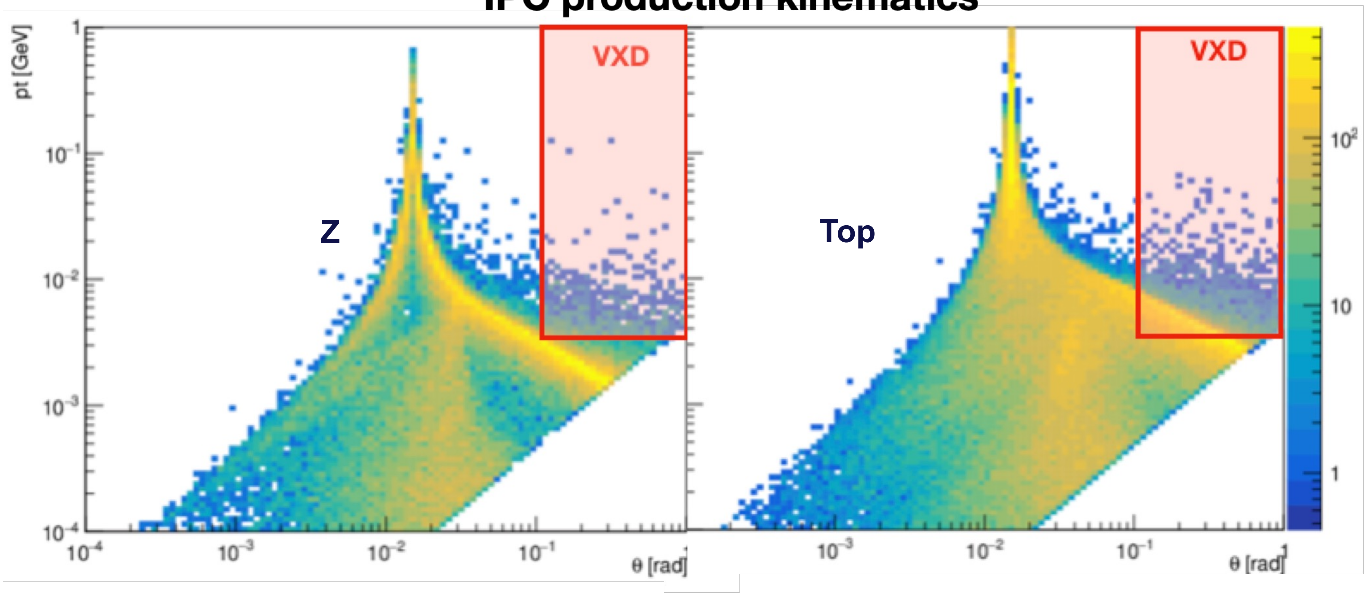
Incoherent Pairs Creation (GuineaPig ++)

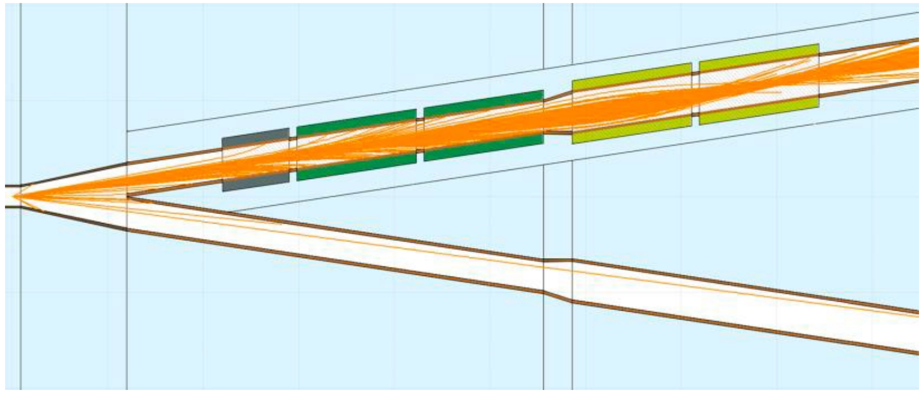
Detector acceptance more populated at high energies due to production kinematics

Impact more at low radii, but may scatter around.

Courtesy of A. Ciarma

IPC production kinematics





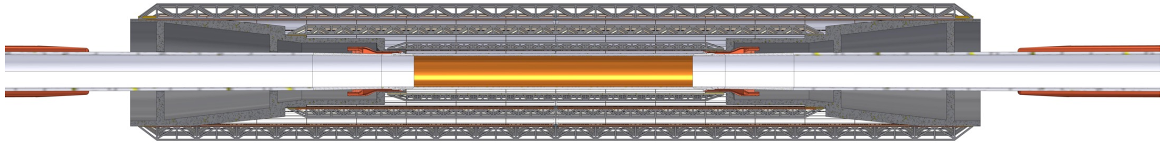
Courtesy of A. Frasca

Radiative Bhabha (GuineaPig++, BBBREM)

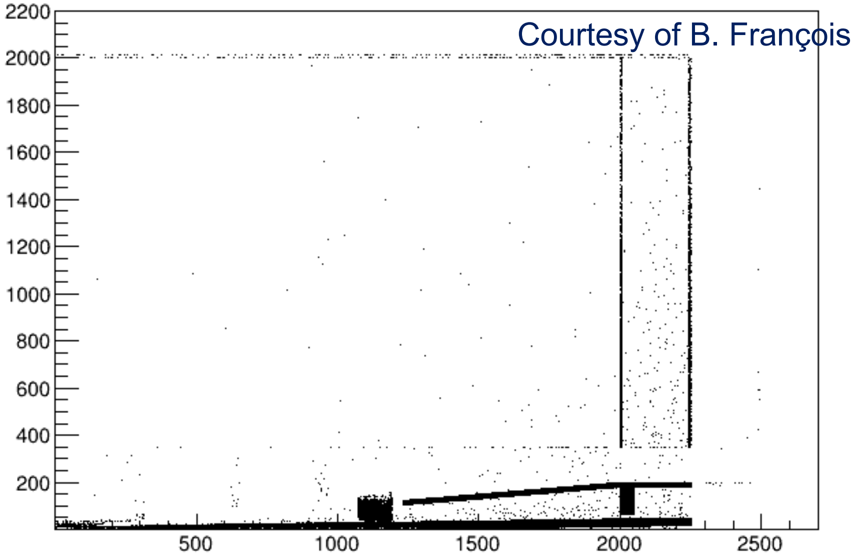
Beam particles **radiating energy** during bunch crossing can **exit the dynamic aperture**

Particles lost at downstream Final Focus Quadrupoles **may quench the SC elements (and produce showers in the calorimeters – *still to be investigated*)**

Effects on Detectors (incoherent pairs only)



- **Vertex detector**
  - 1st layer occupancy ~200 MHz/cm^2 (ALICE3 100 MHz /cm^2)
    - Implications on the electronics of the MAPS and high-speed links (~1 Tb/s for the entire layer 1)

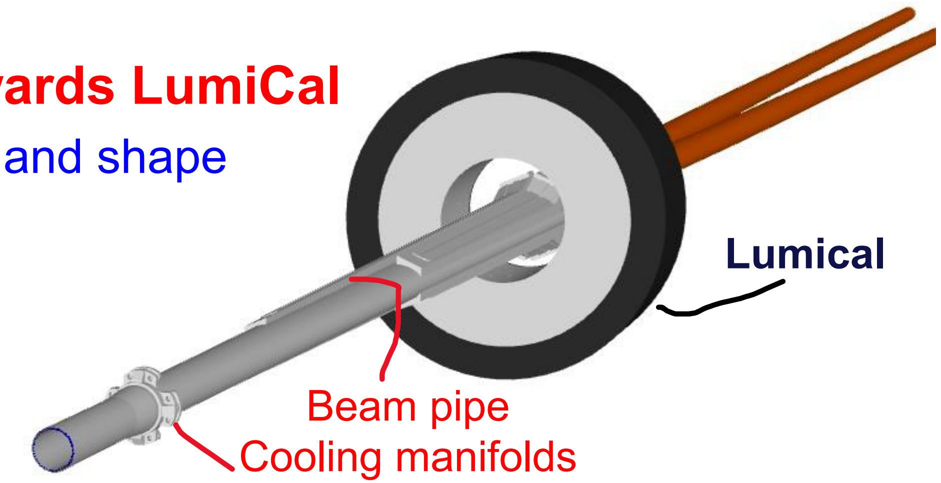


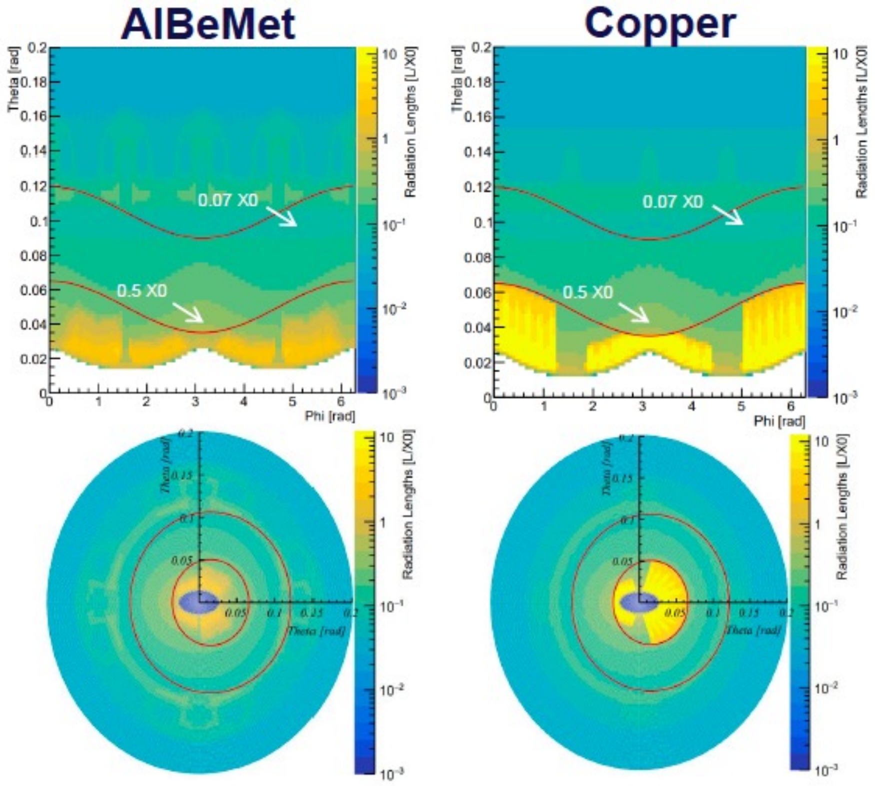
- **Drift chamber**
  - Mostly from secondaries scattered off accelerator parts
  - 6-7% occupancy
- **Liquid Argon Calorimeter**
  - *O*(1 MeV) energy deposited in all layers
    - *Between 0.05 % (Barrel) to 0.2 %(Endcaps) occupancy*
  - *Same pattern of secondaries coming from accelerator backscattering as in drift chamber*

Need to establish effects on other subdetectors and for other type of backgrounds
Mitigation methods to be designed in case the effects will be too large

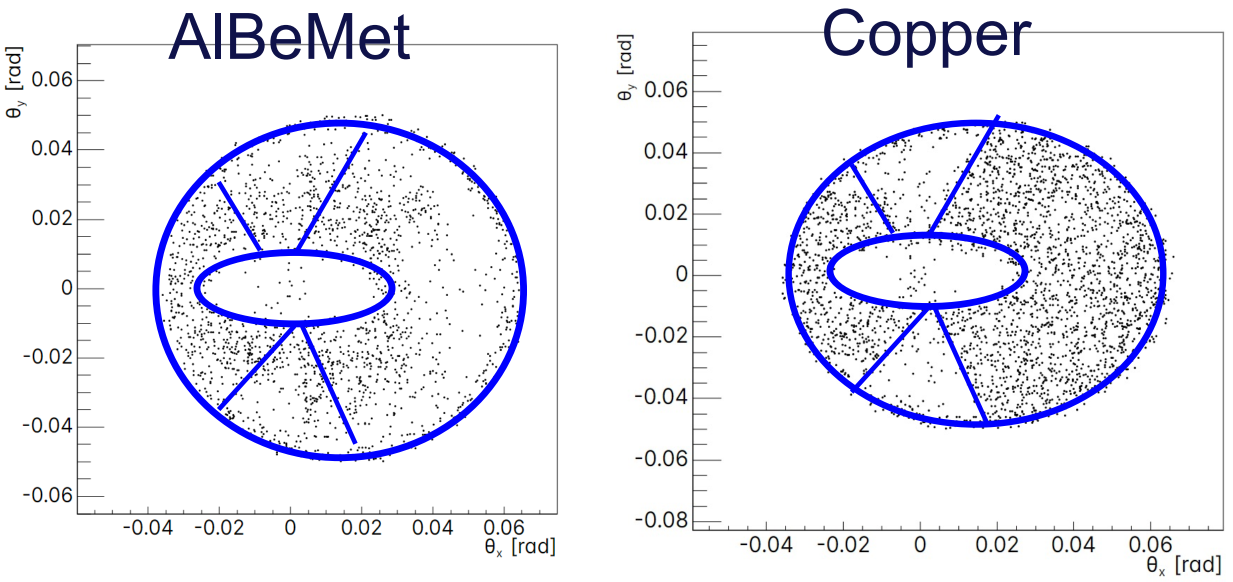
Other types of ‘backgrounds’ (use case study)

- **Showers from Bhabhas scattered off the beam pipe towards LumiCal**
  - Modification to the central beam pipe cooling manifold material and shape





Material Budget



Courtesy of A. Ciarma and G. Nigrelli

Plans for the MDI for the pre-TDR

- **IR mechanical model, including vertex and calorimeters integration, and assembly concept**
  - Integration of the Final Focus Quadrupoles and Solenoid compensation
  - Integration of Vertex, Luminosity Calorimeter and Calorimeters
    - Services (e.g. air&water cooling for VTX and vacuum chambers)
    - Sub-detector clearance and interference with accelerator elements
  - (sub)Detector assembly and maintenance
  - Integration of the alignment system

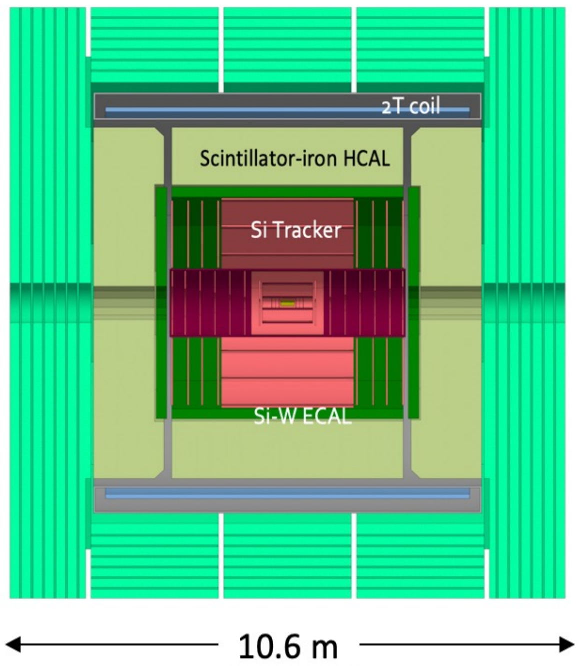
- **Beam induced backgrounds study**
  - Work together with the accelerator experts has started to simulate backgrounds
  - Need to evaluate effects on the sub-detectors systems
    - Feedbacks for mitigations with shielding and collimators (whenever possible)
    - Evaluate requirements on detector R&D (occupancies, radiation levels …)

Indico agenda: https://indico.cern.ch/category/5665/
E-groups fcc-ee-MDI
Contact: Fabrizio.Palla@cern.ch, Manuela.Boscolo@lnf.infn.it

Thank you
for your attention.

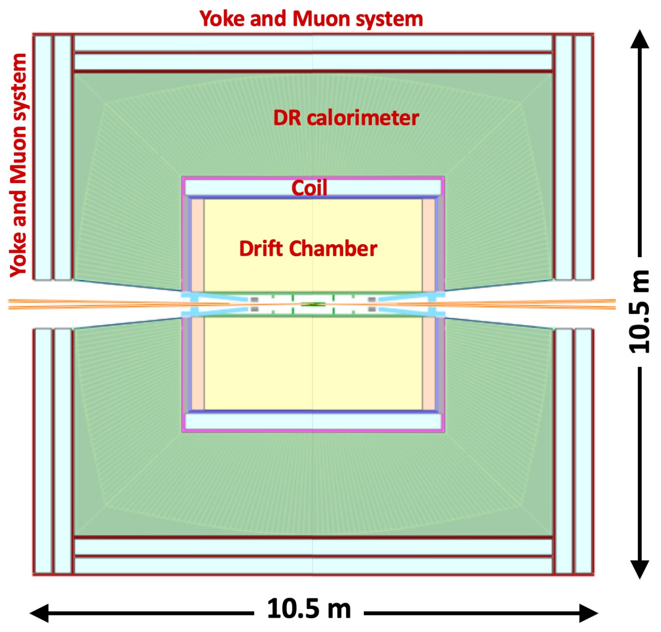
Developing landscape of FCC-ee detector concepts

CLD

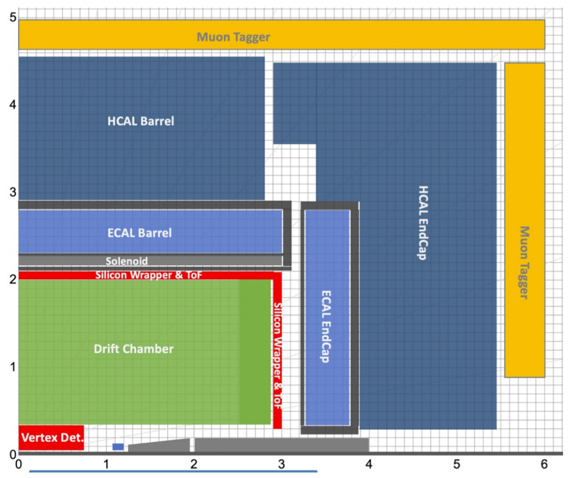


CDR

IDEA



Noble Gas Liquid ECAL based



- Silicon Vertex detector + Tracker
- High granularity calorimetry
- Muon system
- Large coil outside calorimeter

- Silicon Vertex detector
- Ultra-light Drift Chamber
- Monolitic dual-readout calorimeter
- Muon system
- Compact, light coil inside calorimeter

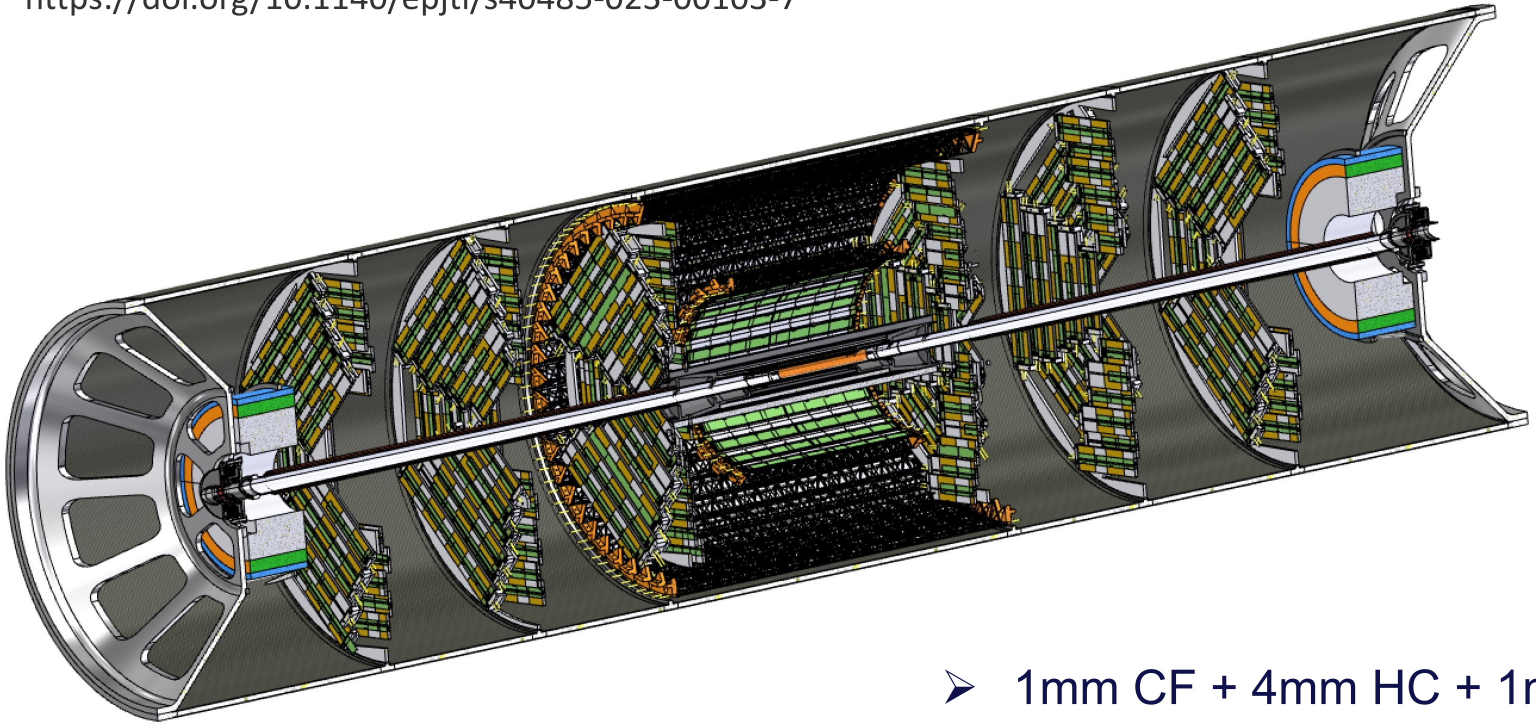
- High granularity noble gas liquid ECAL
  - Pb + L-Ar (or W + L-Cr)
- Drift chamber (or Silicon) tracking
- HCAL
- Muon system

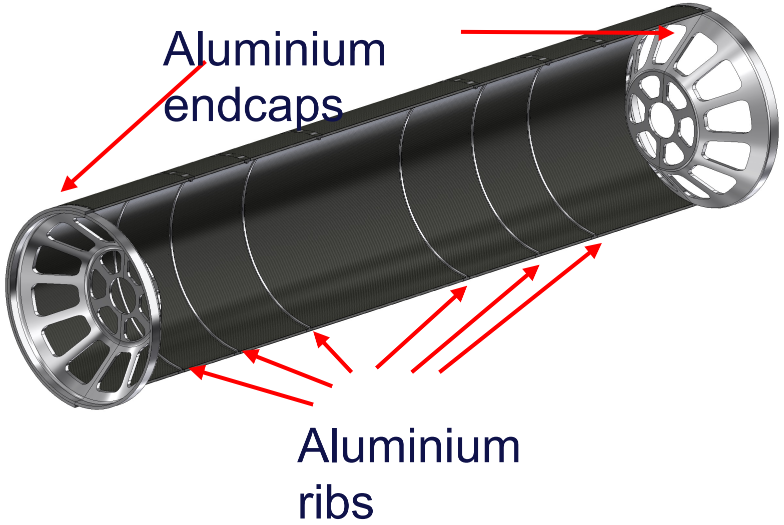
Beam-pipe, Vertex and LumiCal integration

All elements in the interaction region (Vertex and LumiCal) are mounted rigidly on a support cylinder that guarantees mechanical stability and alignment

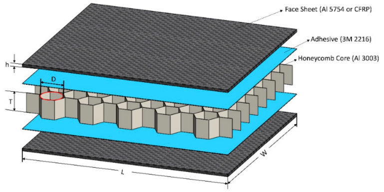
- Once the structure is assembled it is slided inside the rest of the detector

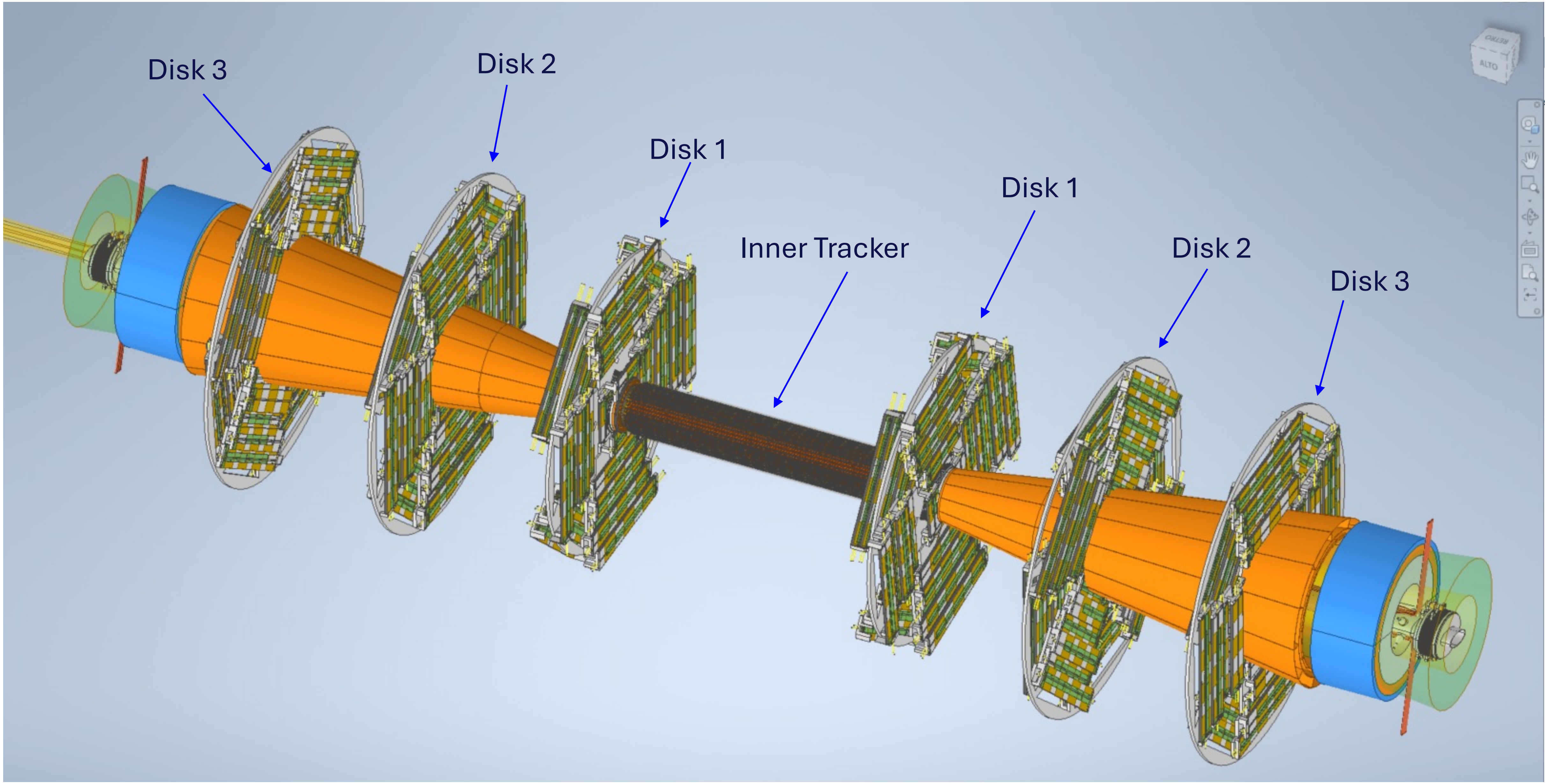
M. Boscolo, F. Palla, F. Fransesini, F. Bosi and S. Lauciani, Mechanical model for the FCC-ee MDI, *EPJ Techn Instrum* **10**, 16 (2023). https://doi.org/10.1140/epjti/s40485-023-00103-7





- 1mm CF + 4mm HC + 1mm CF




Disk 3
Disk 2
Disk 1
Inner Tracker
Disk 1
Disk 2
Disk 3

CDR LumiCal Design

Design considerations:

- Need to control geometry to a precision of $\mathcal{O}$(1 µm)
  - Keep geometry as simple as at all possible

Multilayer barrels where all layes have identical circular geometry

- 25 layer SiW sandwich
  - 3.5 mm W (1 X_0) + 1.0 mm gap for Si pads
- Physical dimensions
  - Sensitive region: r = 54-115 mm
  - Region for ”services”: 115-145 mm
  - Calorimeter face at x = 1074 mm
- Proposed segmentation
  - 32x32 pads/layer (1.9 x 10-22 mm² pads)
  - 25,600 channels per LumiCal
- Weight
  - About 65 kg per LumiCal