First Study on ee-Detector Integration on the Beamline.

7th FCC Physics Workshop – January 30th, 2024

Summary

- Introduction
- Main MDI components – Comparison between h-h and e-e MDI
- Detector accessibility for assembling & maintenance
- Detector opening scenarii
- FCC Overview of Underground Structures
- Conclusions

Introduction

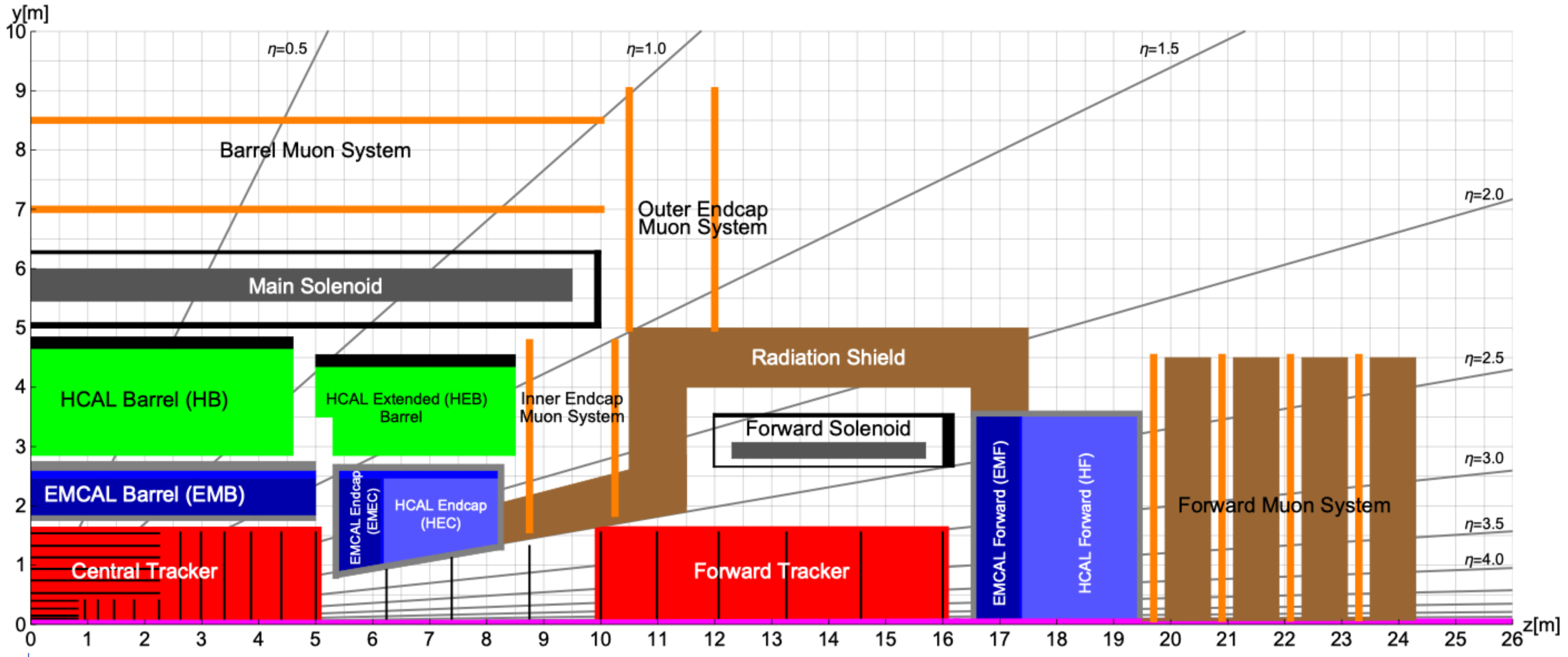
- The Machine – Detector Interface is the region that encompasses the last accelerator components before the Interaction Point and those detector elements closest to the beam-pipe.
- The design of the MDI region shall take into account the (conflicting) requirements from the machine (luminosity, reliability, serviceability, mechanical stability) and those from the detector (lowest background, largest acceptance, easy accessibility to detector parts for maintenance).

Main MDI components

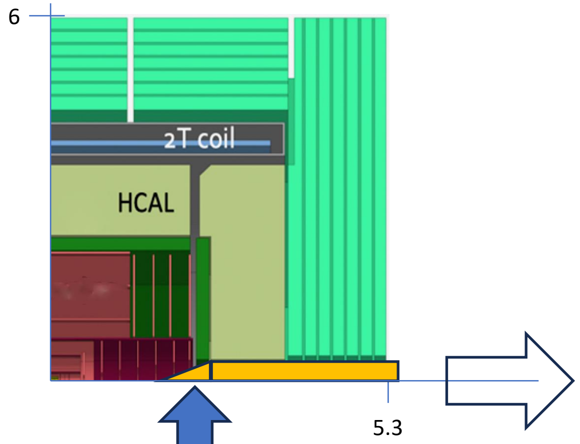
- from the Machine side:
  - Final focus quads
  - Anti-solenoid / Compensator
  - Beam Positioning Monitor
  - Beam-pipe + vacuum flanges/valves + bellows

  } Cryostat (superconducting) — Final focus quads, Anti-solenoid / Compensator
- from the Detector side
  - Luminometer
  - Vertex detector / Inner Tracker + their services
  - Mask for background suppression
- common to both:
  - Supporting structures
  - Alignment system
  - Vibration stability features

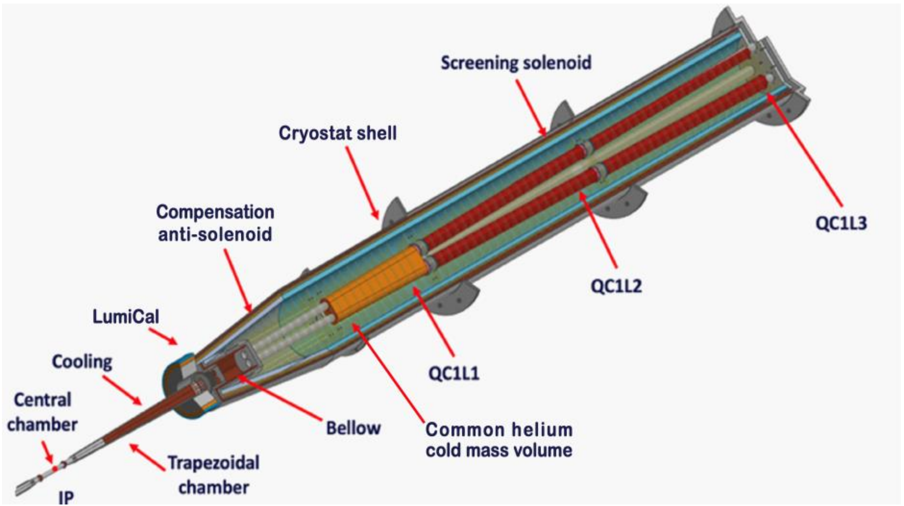
Comparison between hh and ee MDI regions



Last machine element here



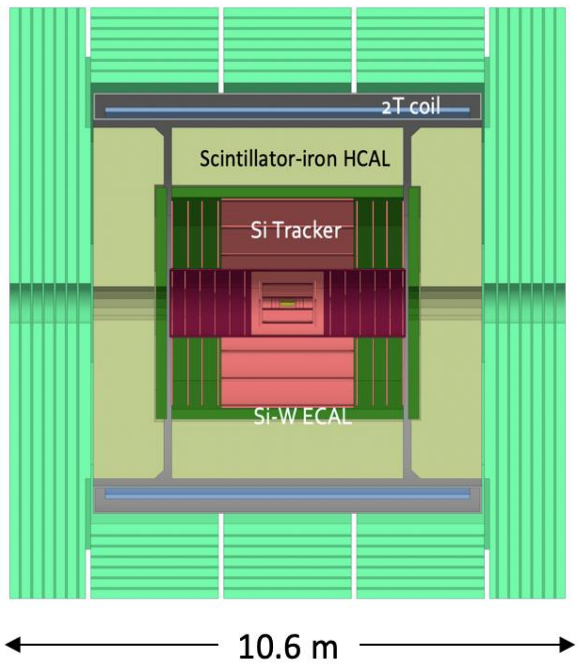
Last machine element here



Machine-Detector Integration in FCC-ee is a major challenge. To access the inner detector parts, an adequate detector's segmentation and opening sequence has to be carefully studied.

Developing landscape of FCC-ee detector concepts

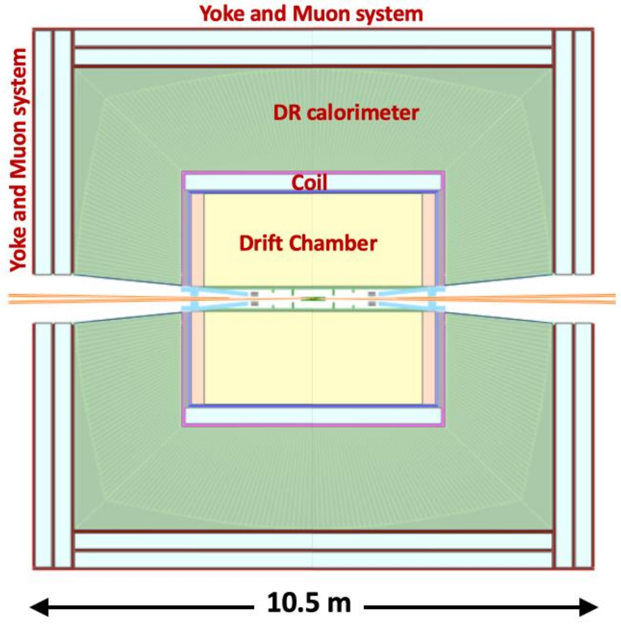
CLD



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

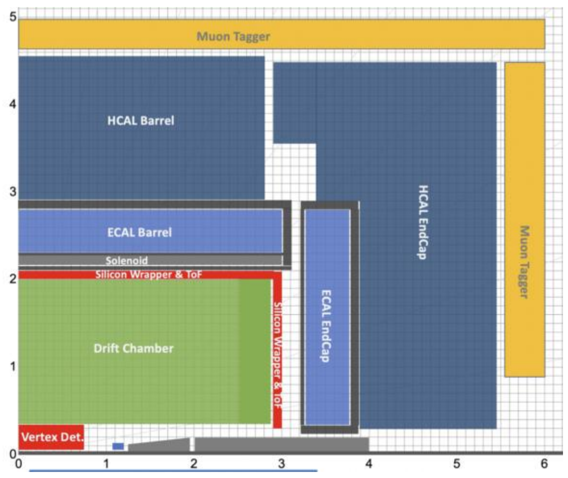
CDR

IDEA



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

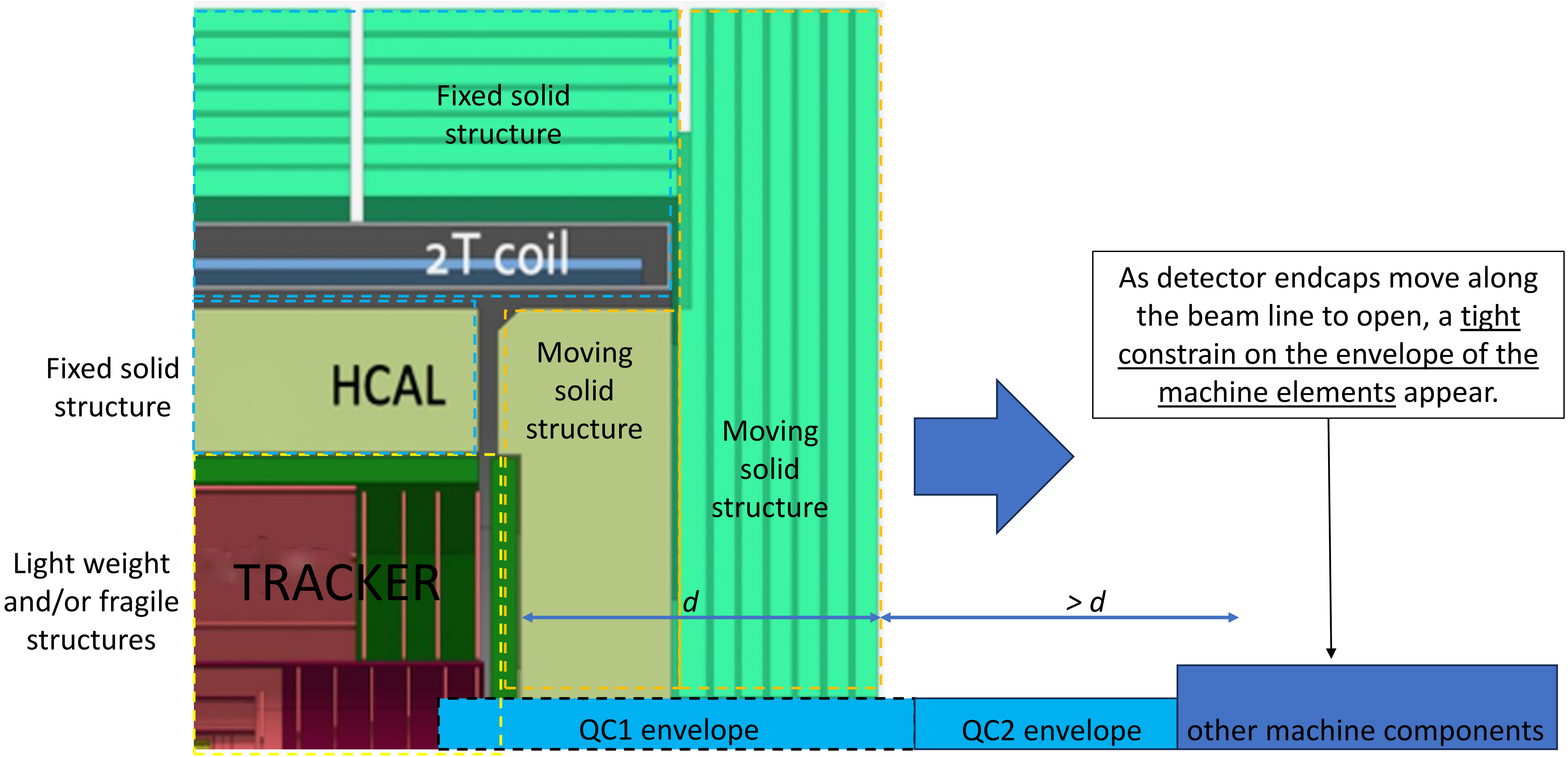
Noble Gas Liquid ECAL based



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

courtesy M. Dam, Niels Bohr Institute

Typical detector structure.



General issues for e-e final focus components

- **Mechanical stability.**
- The needed mechanical stability of the final focus is an important machine parameter that influences the MDI design. It is usually measured as rms(*) relative displacement of the two opposite sides, integrated over the period between two bunches (high frequency stability).
- The low frequency stability refers any possible drift from the nominal position of the FF and interleaves with the alignment system of the FF.

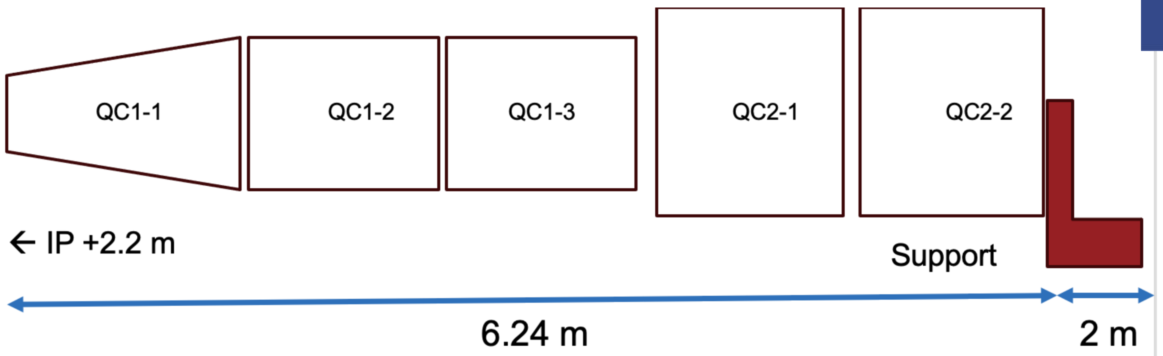
- **Support of forward instrumentation / shielding**
- As the mechanical stability of the FF elements is a requirement that directly impacts on the machine luminosity, the supporting structure of the FF shall be optimized to achieve the highest vibration frequency (stiffness) and shall rest on a stable and massive support.
- The background masks or any other IR heavy weight hardware (LumiCal, …) should not be supported from the same support of the final focus magnets, as it would significantly lower the vibration frequency of the latter.

(*) *The rms of a function is the square root of the integral of the squares of the instantaneous values during a cycle*

Possible QCs layouts and their supporting structures

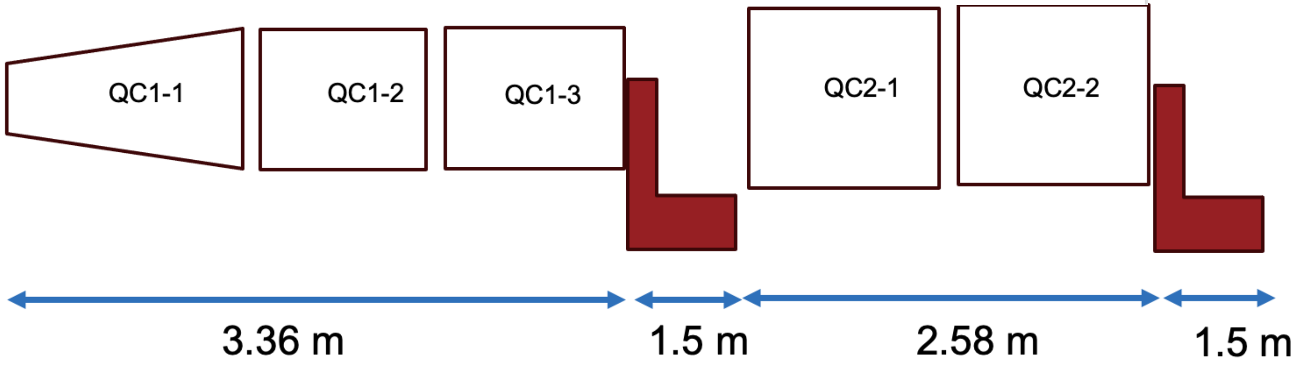
Option 1:
IR QC1 and QC2 in one cryostat and girder.

- minimal cryogenics & powering interconnections
- long & heavy cantilever assembly → stability issues
- complex handling



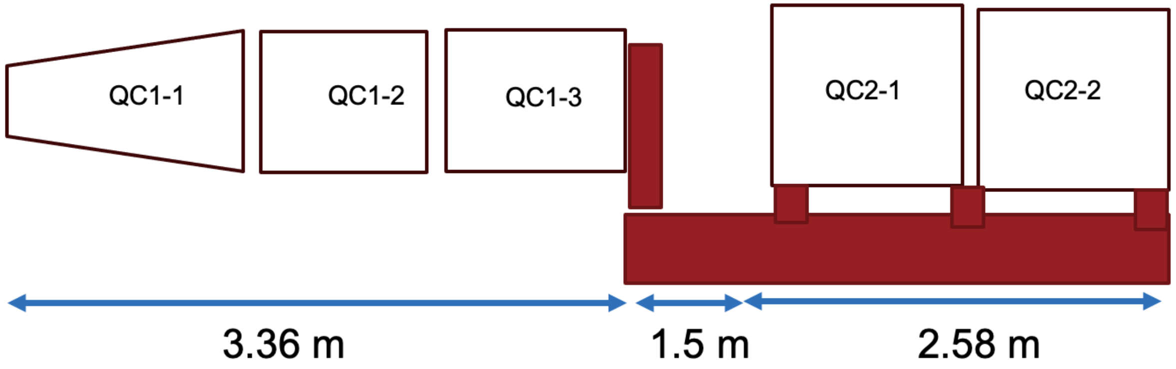
Option 2a:
IR QC1 and QC2 in two different cryostats and girders.

- shorter cantilever → less vibration
- tricky alignment between QC1 & QC2



Option 2b:
IR QC1 and QC2 in different cryostats, but one integrated girder.

- same as above, quicker assembly installation & removal
- most interesting to get quick access to detector inner parts

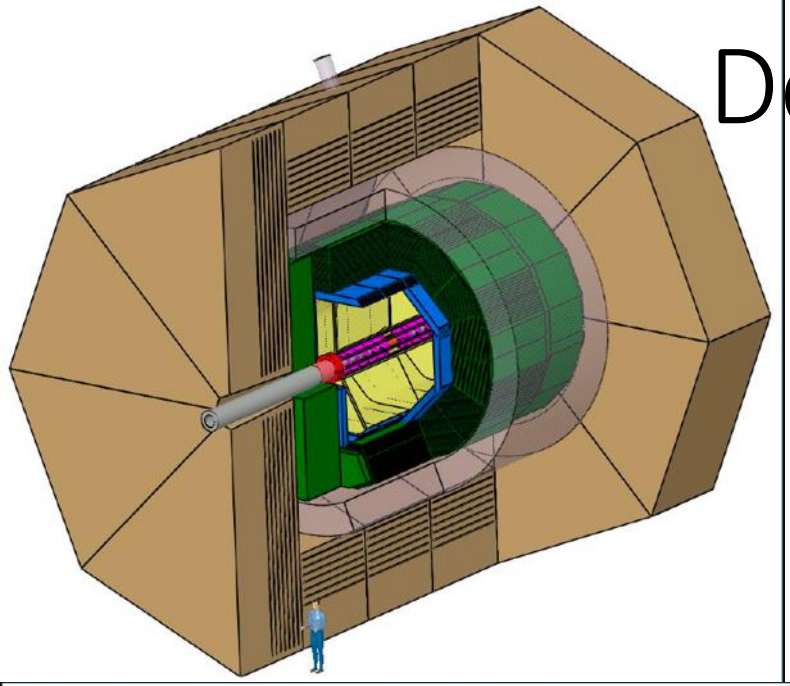


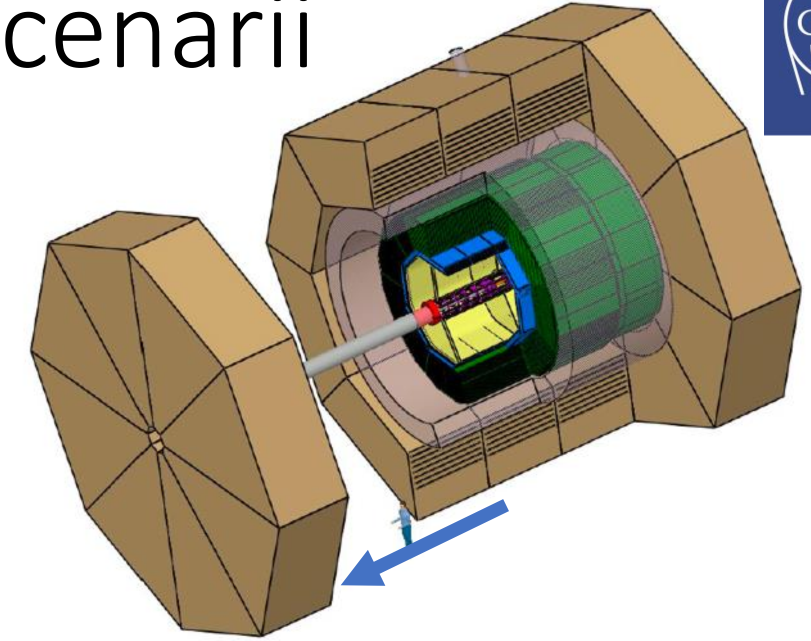
courtesy J. Seeman / SLAC

Detector access for assembling & manteinance

- **Segmentation of detector.**
  - Segmentation of detector shall be compatible with the assembly & maintenance scenario. In particular, the question whether the detector endcaps are split vertically or not, has great importance for the design of the MDI region. For this latter point, the choices are the following:
- **Opening of detector on the beamline.**
  - MDI design should allow for (partial) detector opening or closing to be performed on the beam-line, ideally without breaking the beam-pipe vacuum. This can be achieved as follows:
  - Endcaps split vertically – *make the integration of the QCs simpler, but require supporting QCs elsewhere; large magnetic forces complicate the design of the endcaps in addition to detector hermeticity issues in the vertical forward plane.*
  - Endcaps not split – *detector integrity respected, require longer longitudinal opening stroke, tight requirements on the external size of the QCs to keep good acceptance for detector, installation and access to beam-pipe and machine elements more complex.*
- **Opening of detector off the beamline.**
  - In this case, the detector is translated off the beam line to a “garage” position where the QCs machine elements can be easily removed and the detector opened. It is the case for ILC & CLIC proposals and was also an option at LEP.

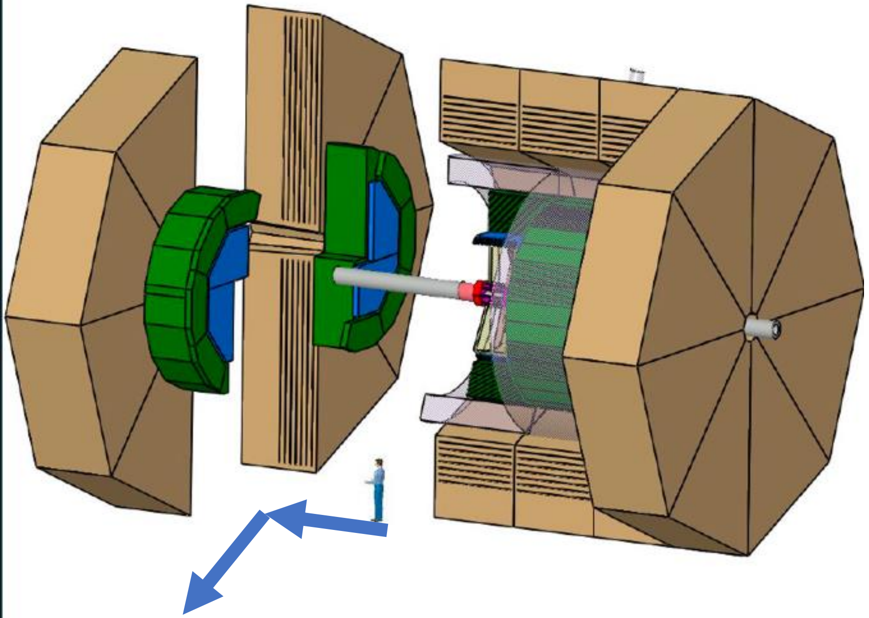
Detector opening scenarii

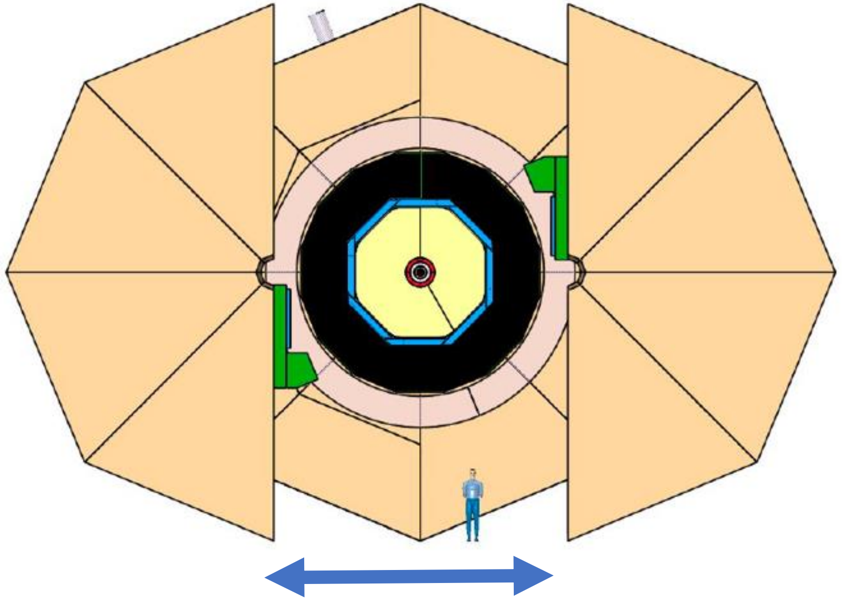




Solid Endcaps

Long longitudinal stroke to access inner detector elements. Last machine elements envelope restrained.





Split Endcaps

Combined short longitudinal stroke + transversal opening to mitigate impact on last machine elements envelope.

Issues with detector endcaps opening scenarii

- Solid endcaps & long longitudinal opening on the beamline
  - high constraints on machine outer radius and cantilevered supports over several meters
  - no accelerator changes → operate the next day (*)

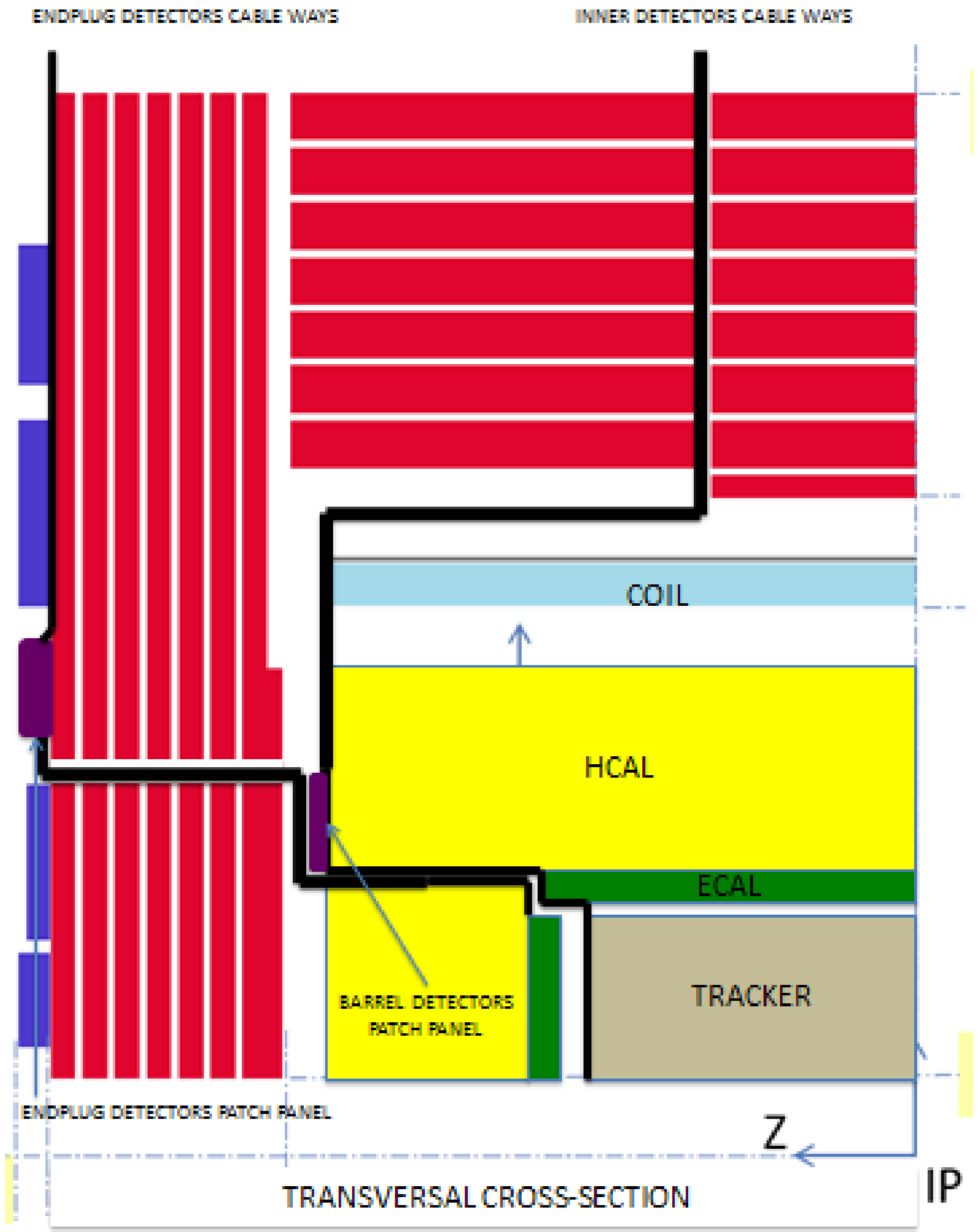
(*) to be considered the risk of having personnel working in proximity of the beampipe under vacuum.

- Split endcaps & short longitudinal opening + transversal opening on the beamline
  - less constraints on machine elements design
  - no accelerator changes → operate the next day (*)
  - complex endcap mechanics & detector hermeticity issues

(*) to be considered the risk of having personnel working in proximity of the beampipe under vacuum.

- Solid endcaps & long longitudinal opening off the beamline
  - no constraints on machine elements design
  - little risk for beampipe integrity
  - beam vacuum broken, longer shut-down

Detector Services routing

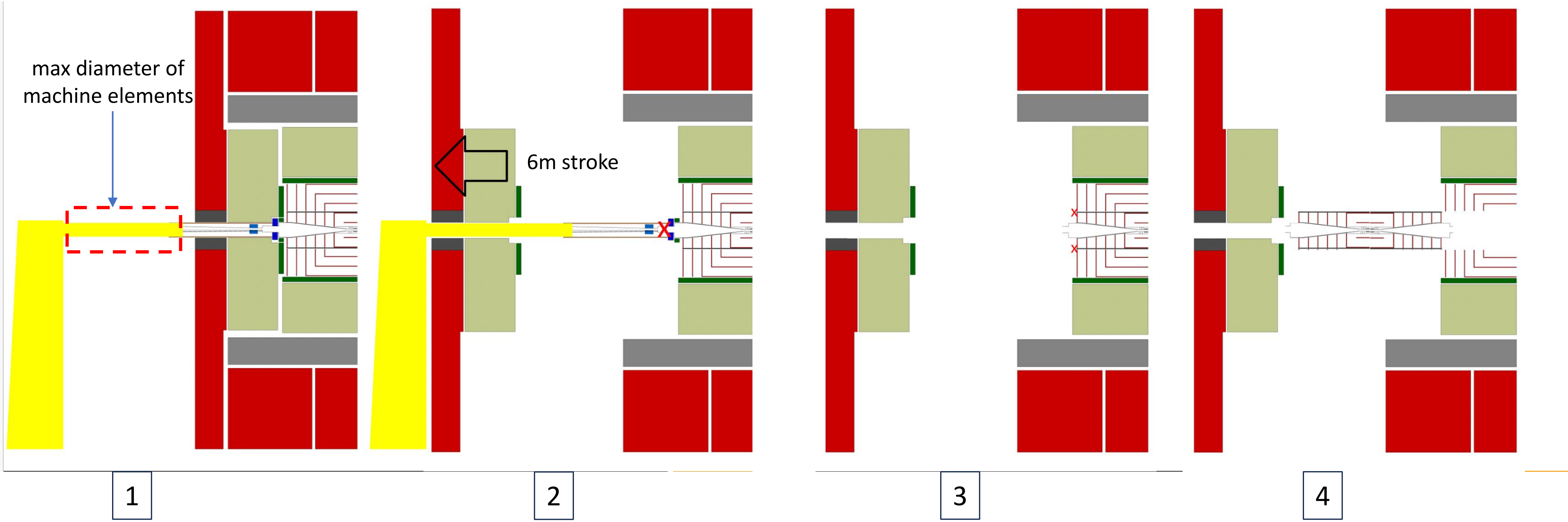


General considerations on detector services:

Barrel and Endcap sub-detectors services shall follow indipendent paths to allow quick opening of the detector.

Patch-panels at the periphery of the detector allow for an easier services installation, check-out and troubleshooting.

Scenario for inner detector assembly or servicing



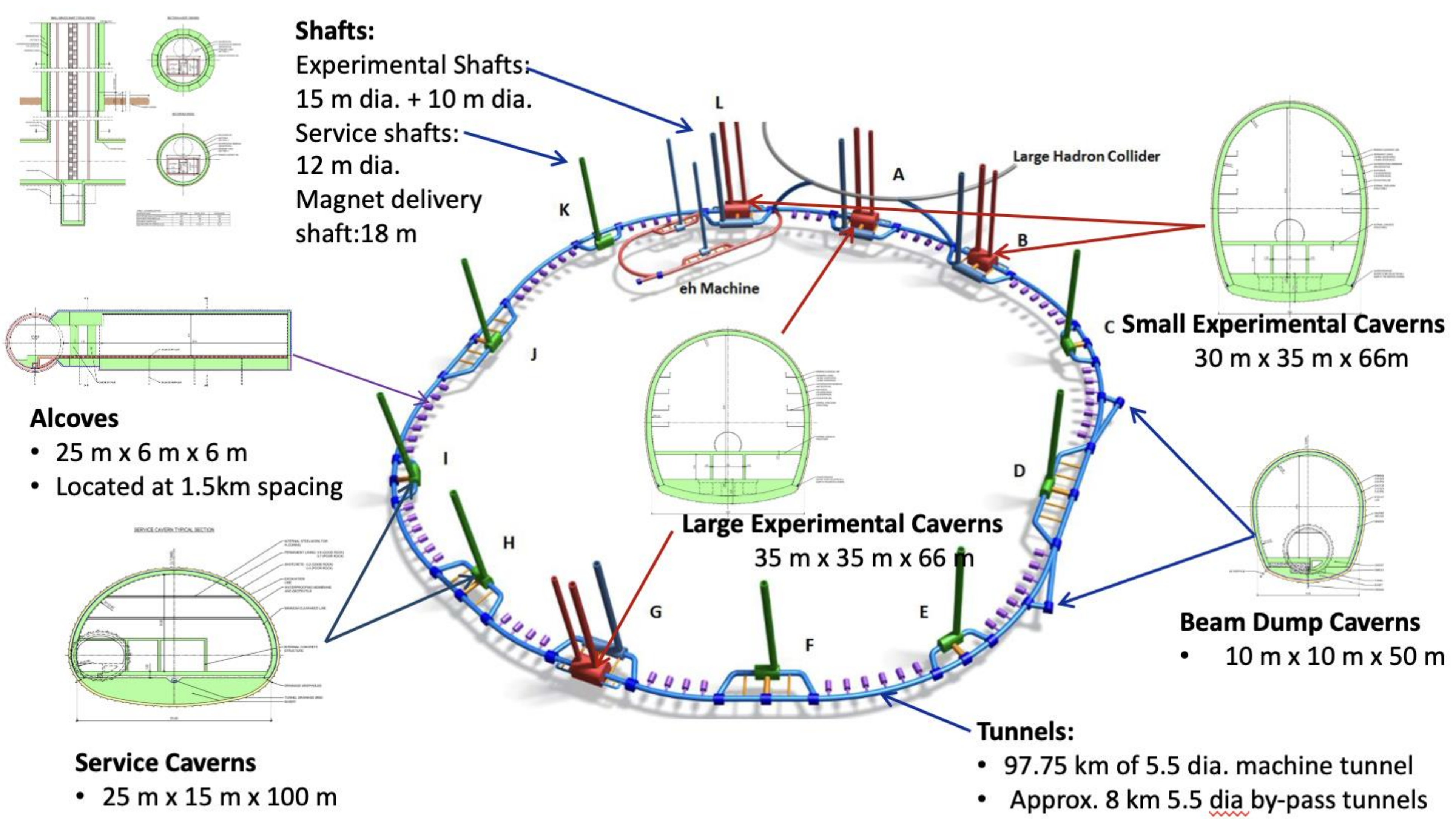
Detector closed.

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

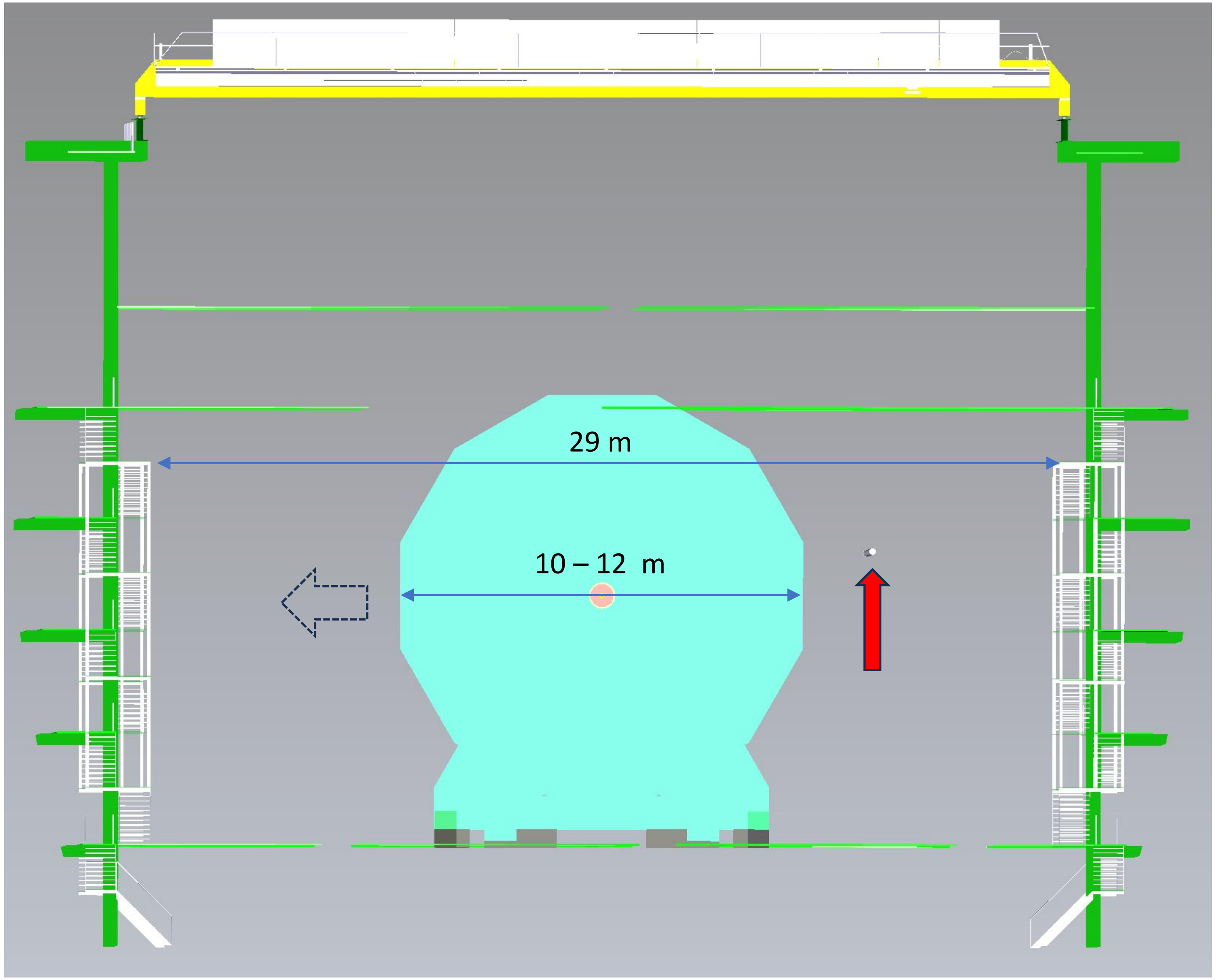
QC removed, access to the Inner Tracker.

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

FCC Overview of Underground Structures



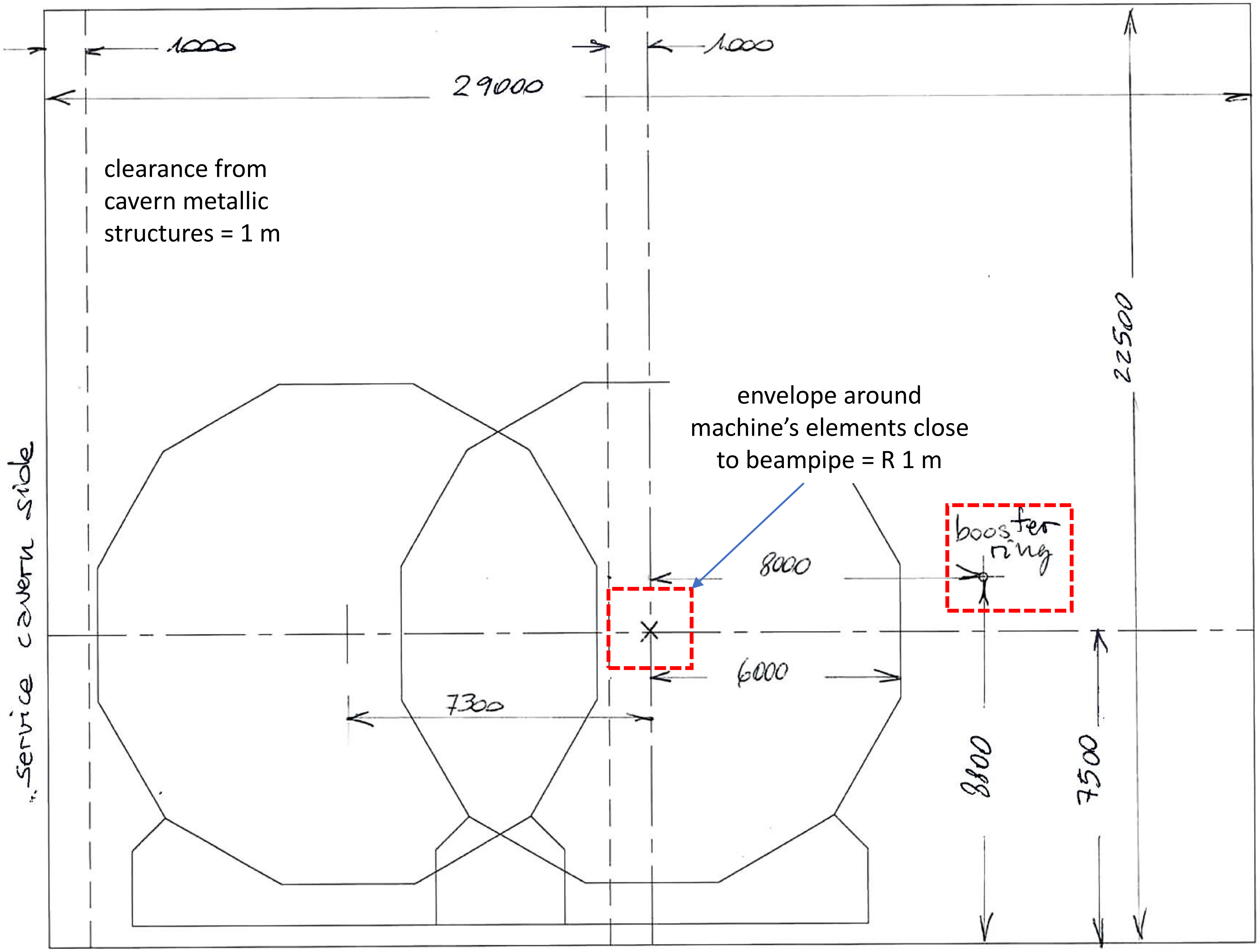
by J. Osborne / CERN



A typical FCC-ee detector sits comfortably inside the experiment cavern (but note the presence of the booster ring floating in the air without shielding or compensator…).

Is the cavern large enough to eventually allow for moving the detector aside the beamline, in a parking position where the access to the inner components would be simplified?

by F. Valchkova / CERN



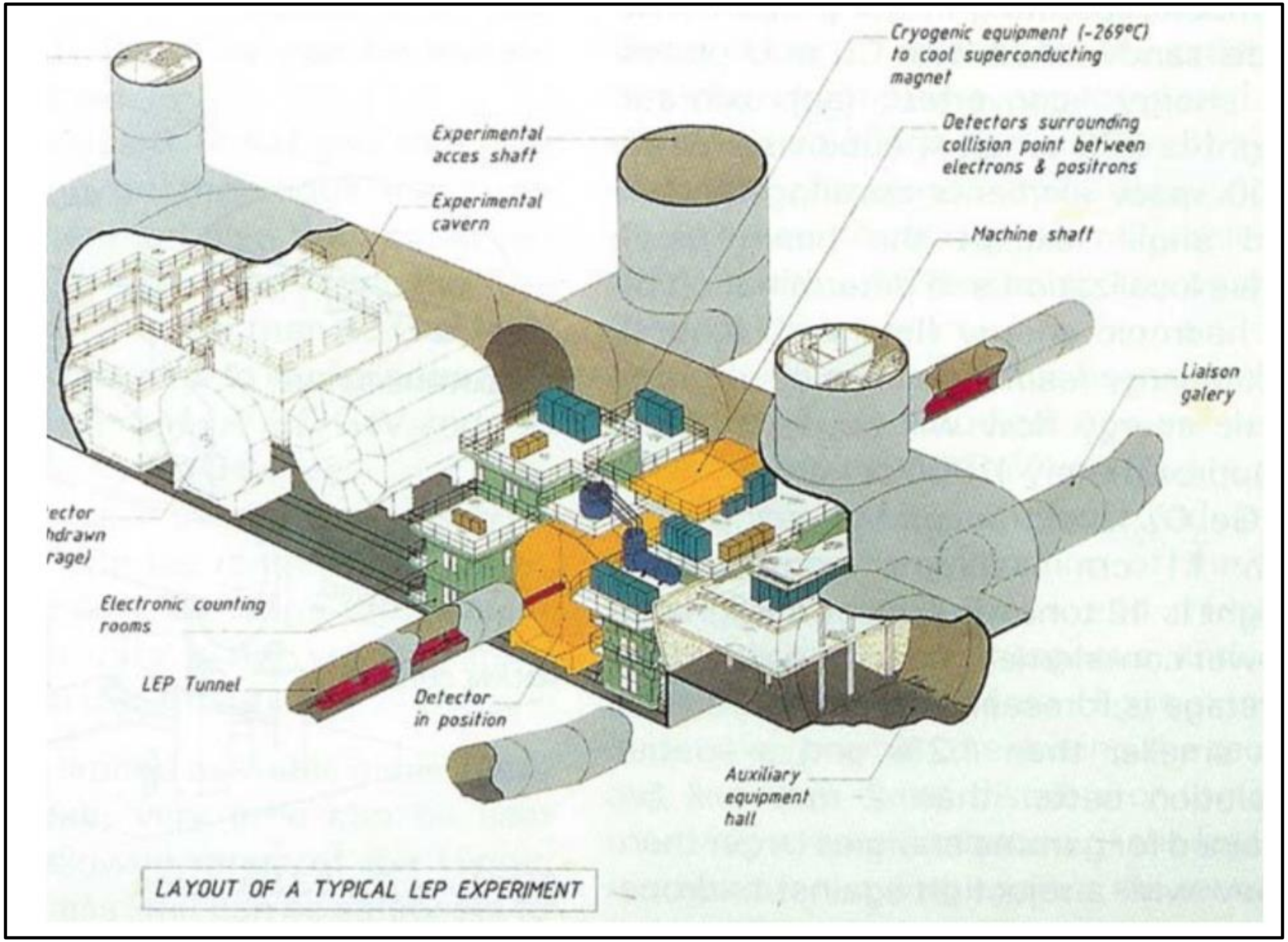
There is enough clearance to envisage the scenario to move the detector aside the beamline and get full access to the detector's inner parts

Conclusions

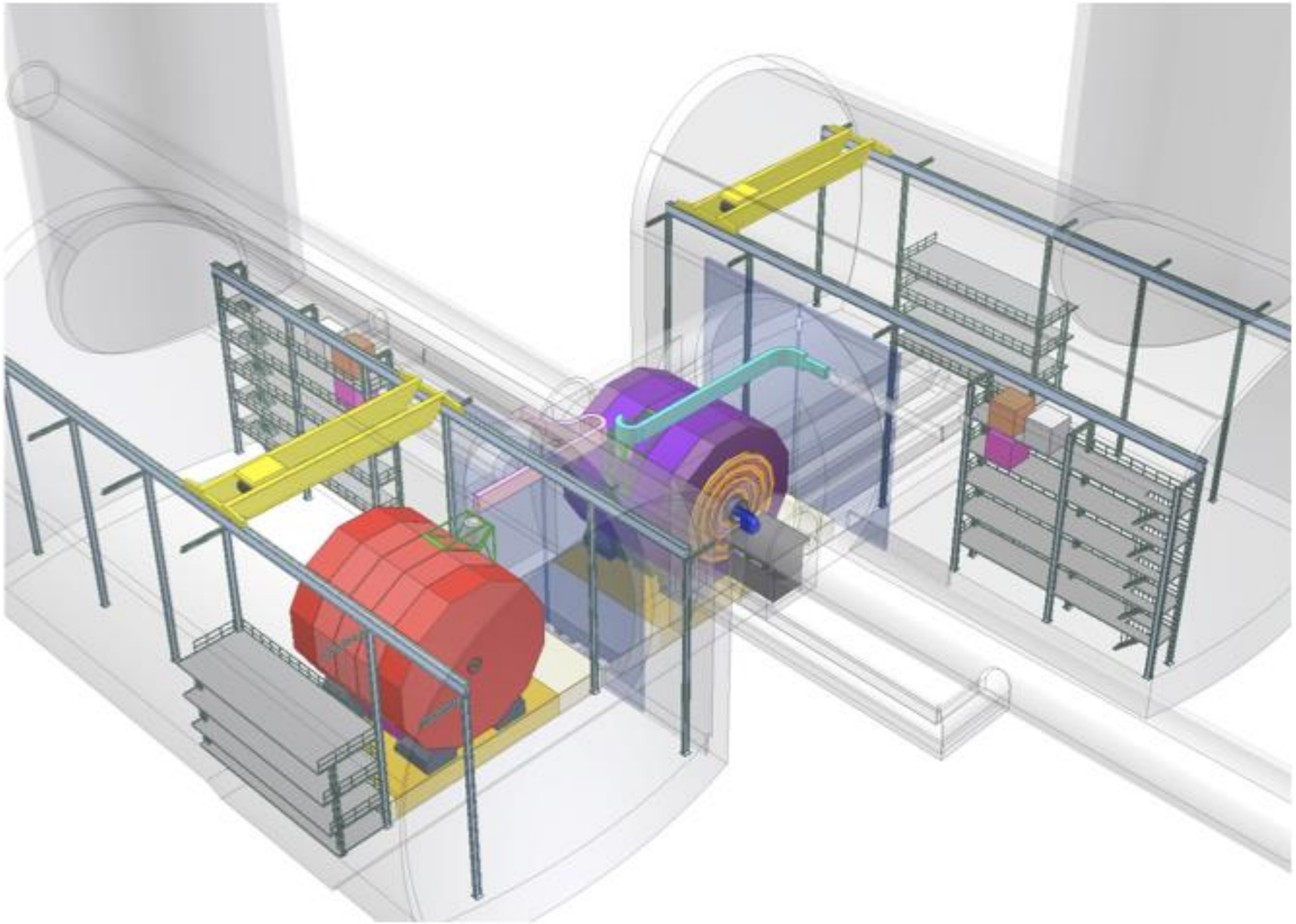
- MDI design in ee machines has to take into account multiple conflicting requirements.
- Detector wise, the choice of segmentation and opening scheme plays a fundamental role.
- Many options exist to access the detector, either on or off the beamline and all of them seem to be compatible with the detector proposals and the present design of the underground cavern.

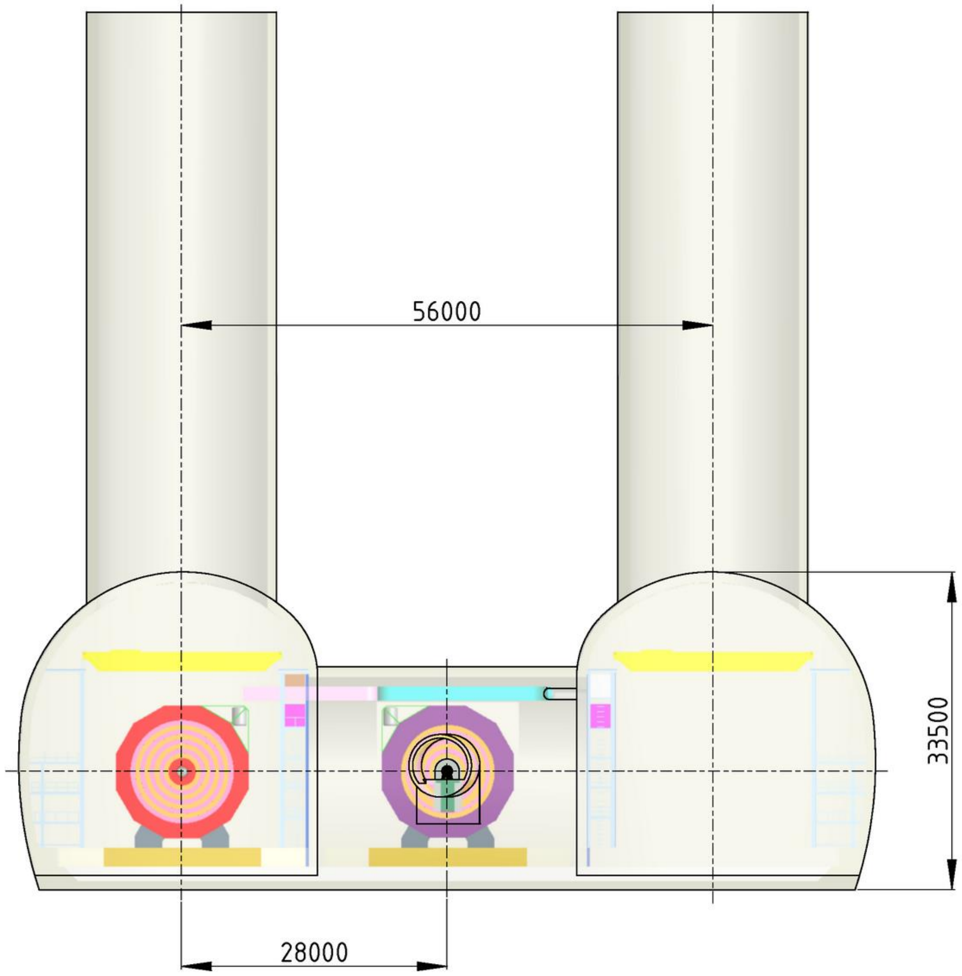
Back-up slides

LEP Cavern Layout for Detector



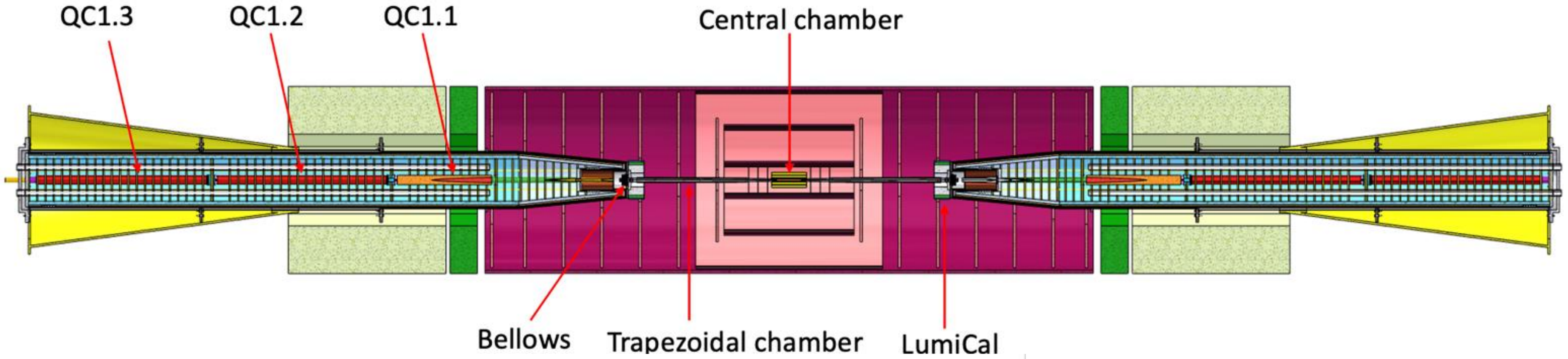
ILC / CLIC Push-Pull Cavern Layout

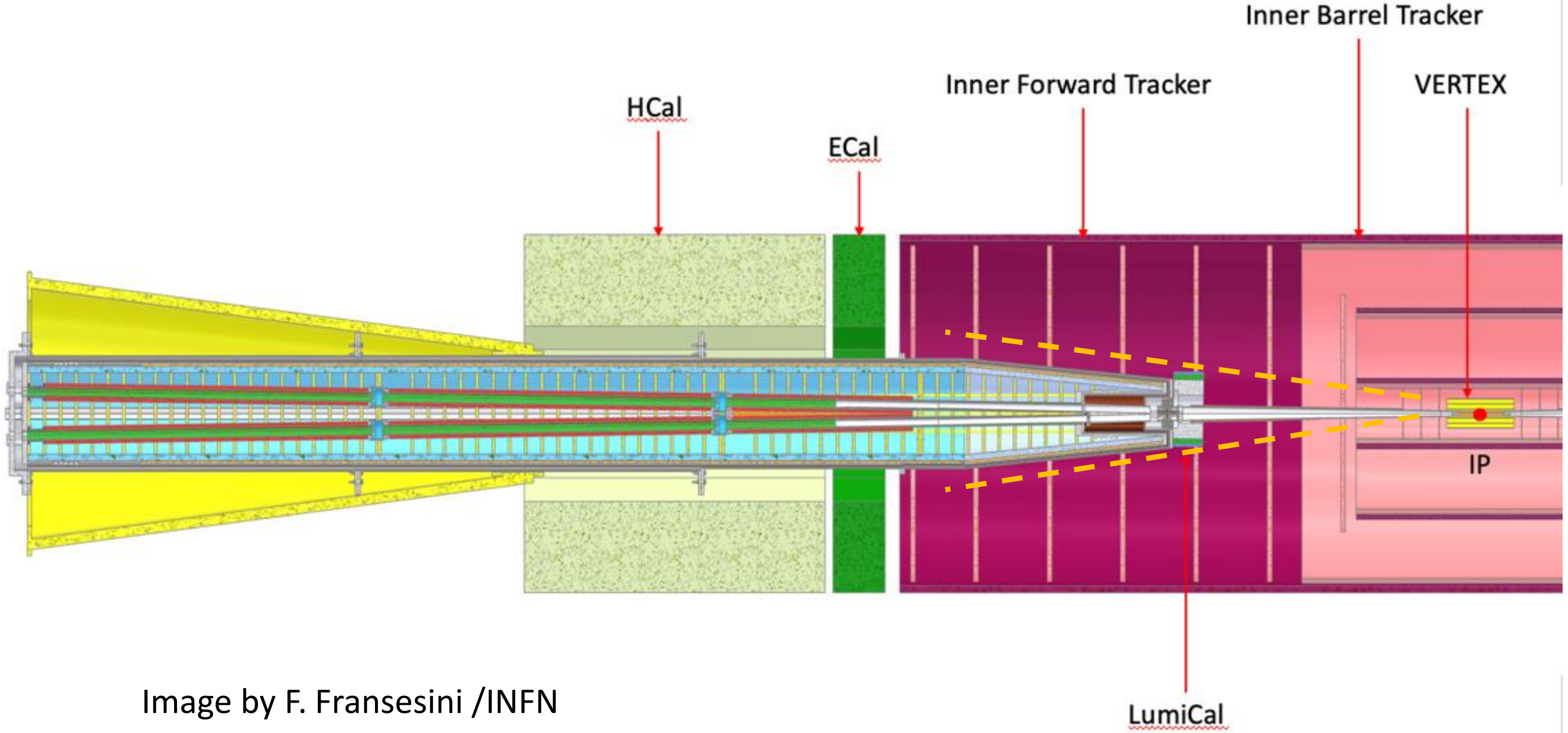




by A. Gaddi, H. Gerwig / CERN

MDI at FCC-ee & impact on detector design (I)





Due to the short L*, the LumiCal is very close to IP, thus it shall be supported by the Tracker CFRP tube (see next slide).

Image by F. Fransesini /INFN

MDI at FCC-ee & impact on detector design (II)

CLD Inner Tracker

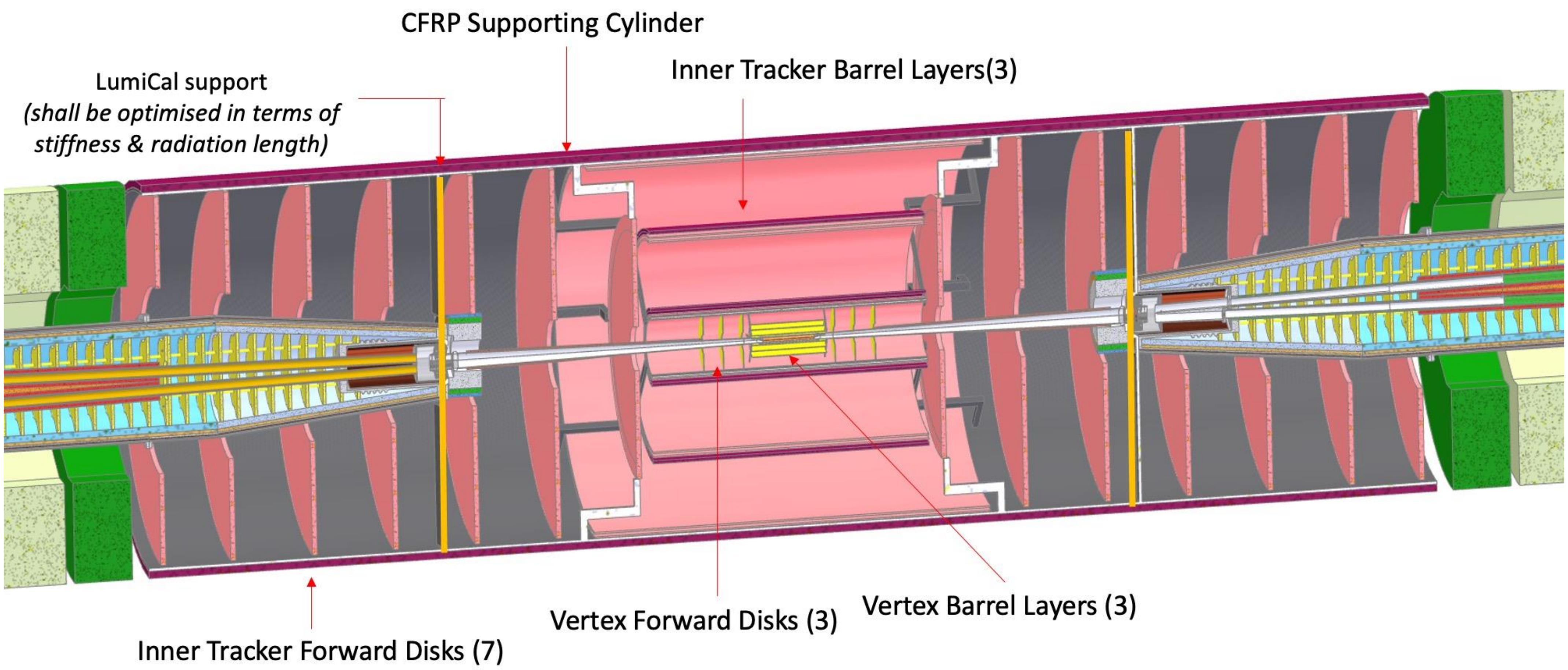


Image by F. Fransesini /INFN

Study for Inner Tracker supports for CLD

possible solution:

- Proceeding from inner to outer sub-detectors, the IT CFRP supporting cylinder, is supported by the nearest detector element, i.e. the Outer Tracker.
- The easiest way is to have a light material budget CFRP rails + pads system at the interface between the IT cylinder and the OT boundary, e.g. at 3 and 9 o’clock to let the IT slide inside the OT inner tube.
- The Outer Tracker is then supported by the barrel hadron calorimeter by three adjustable brackets / tie-rods per end.