ee-Detector Maintenance & Accessibility Challenges.

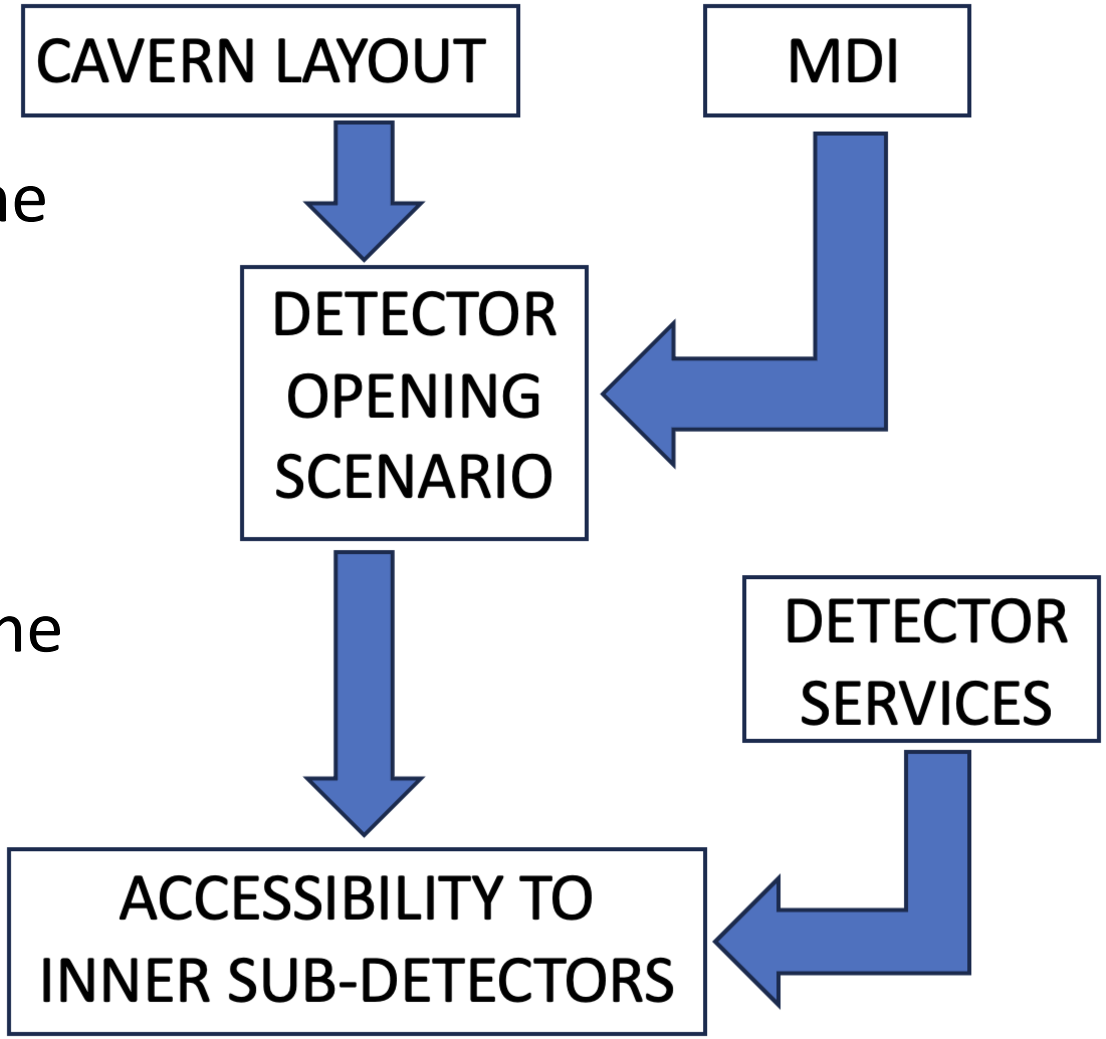
FCC-ee Vertex Detector Workshop – July 2nd, 2024

Summary

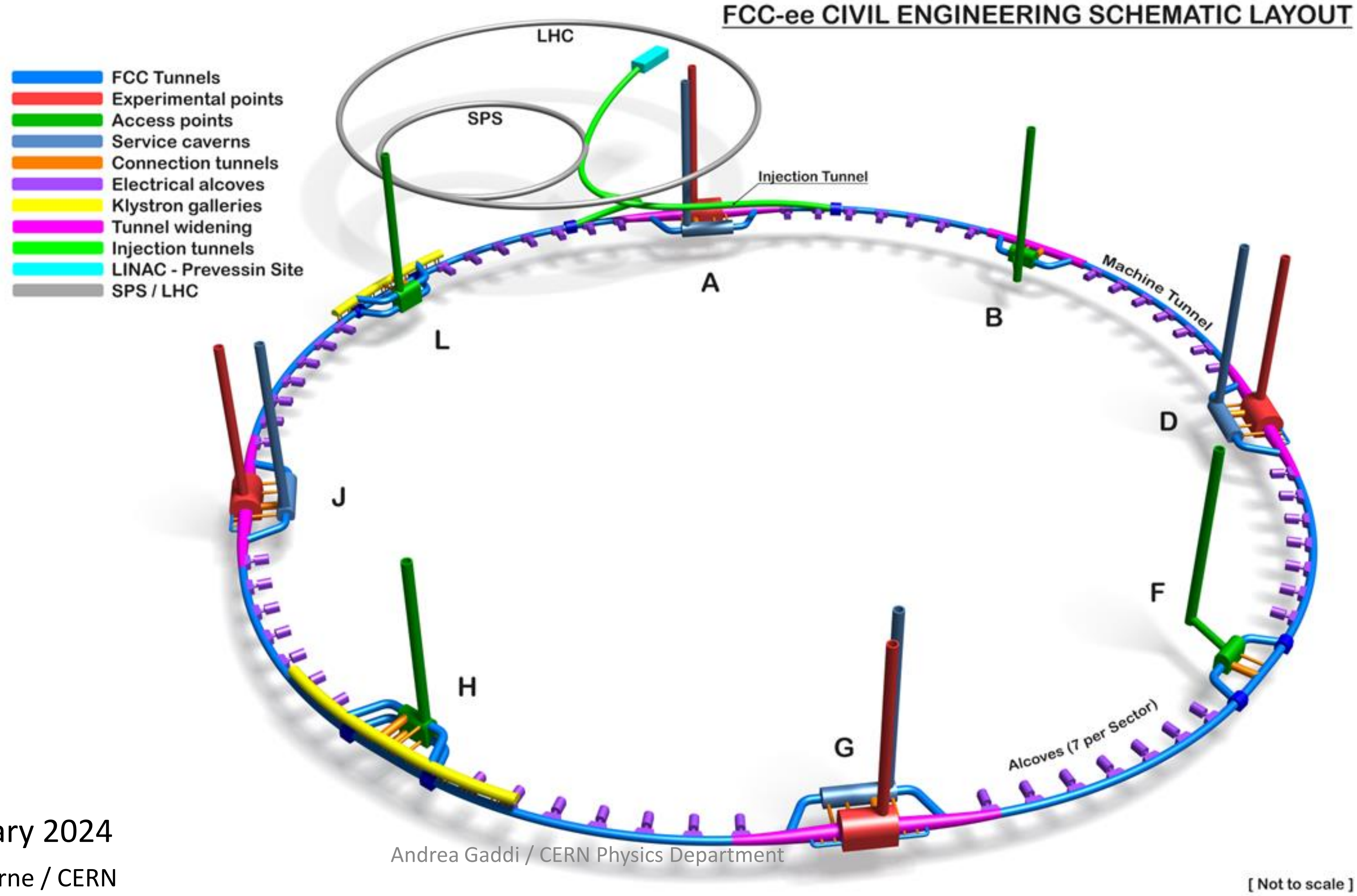
- Introduction
- FCC Overview of Underground Structures
- Vertex & Machine-Detector Interface Region Integration
- Detector accessibility for assembling & maintenance
- Detector opening scenarii
- Conclusions

Introduction

- The design of any HEP detector, including the inner tracker/vertex, shall include considerations on its accessibility for maintenance or repair tasks.
- This talk focuses on the constrains imposed by the external environment, in particular the layout of the experiment cavern and the interface with the beam-line elements.
- Other contraints, e.g. detector services routing, are not considered here.



FCC Overview of Underground Structures



Layout January 2024

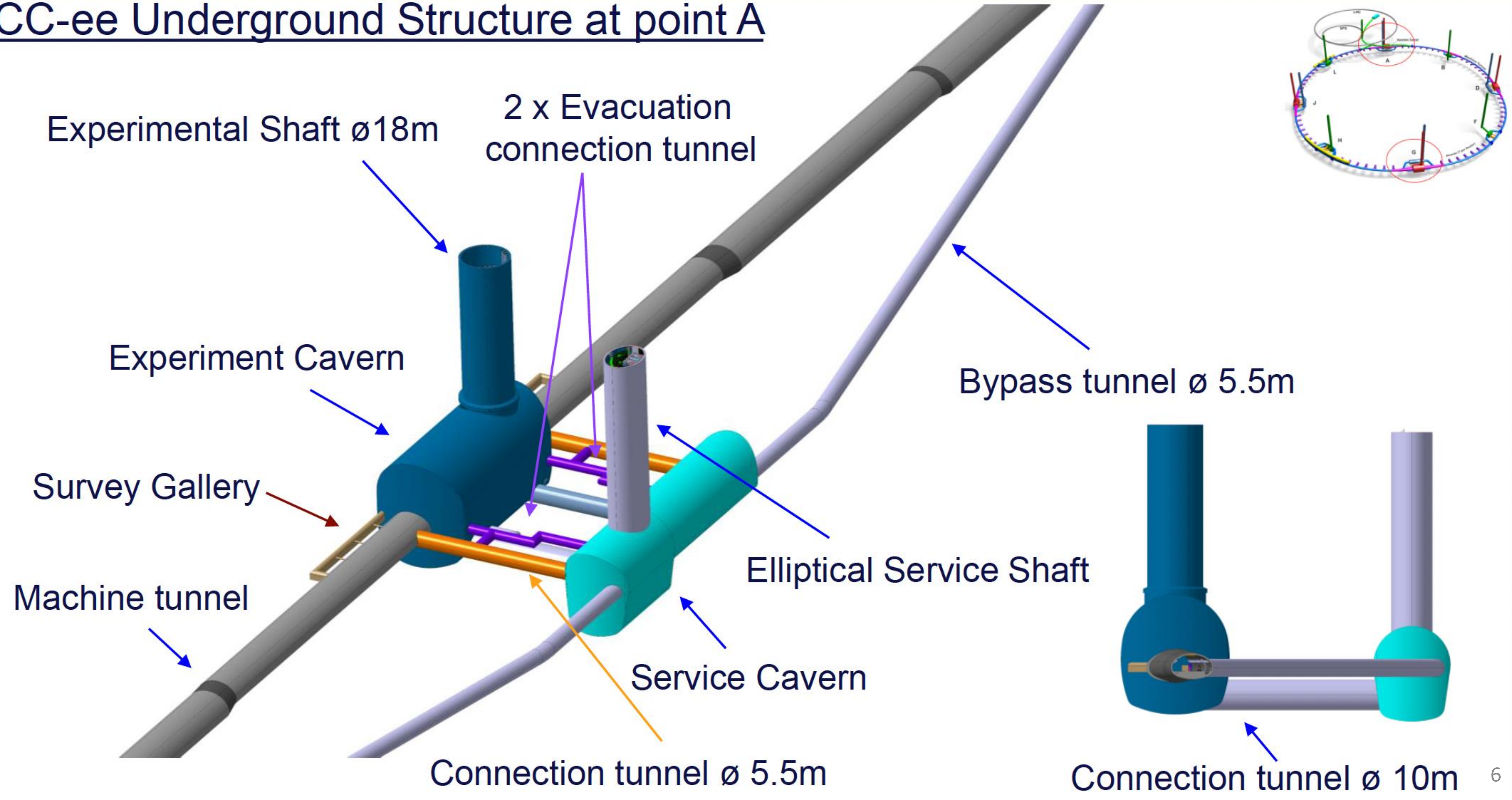
courtesy J. Osborne / CERN

Underground Works - Main Developments Since CDR

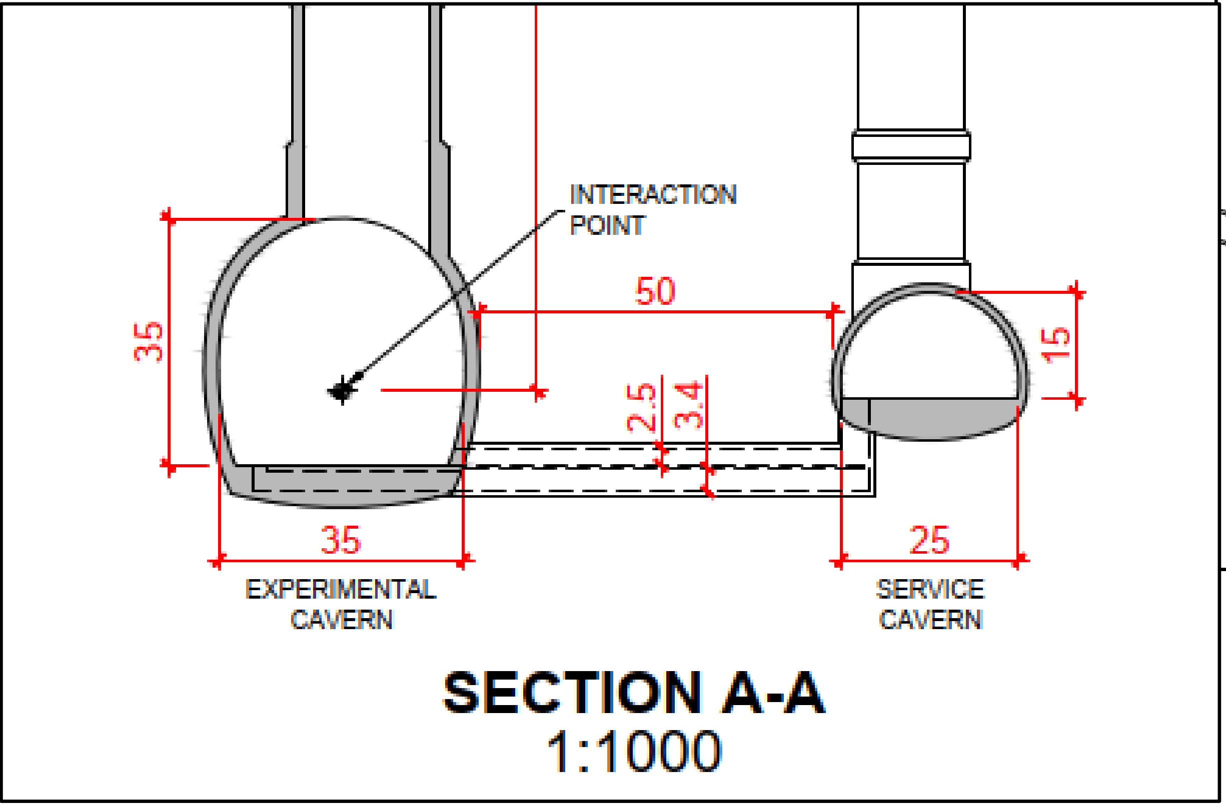
- Rationalization and simplification of the overall layout → cost reduction driven!
- Better understanding of needs of RF, ee injection and ee beam dump now incorporated into the civil engineering
- Circumference of the ring reduced from 97.8 km to 90.6 km
- Number of shafts reduced from 18 to 12 (+1).
- Beam Dump for ee integrated into beam tunnel (with widening required)
- Single tunnel for clockwise and anti-clockwise ee injection
- Increase in the civil engineering necessary to house the RF systems
- Development of a staged strategy for some structures (mainly on surface)
- Inclusion of a new LINAC chain at Prevessin as alternative to using SPS for ee injection

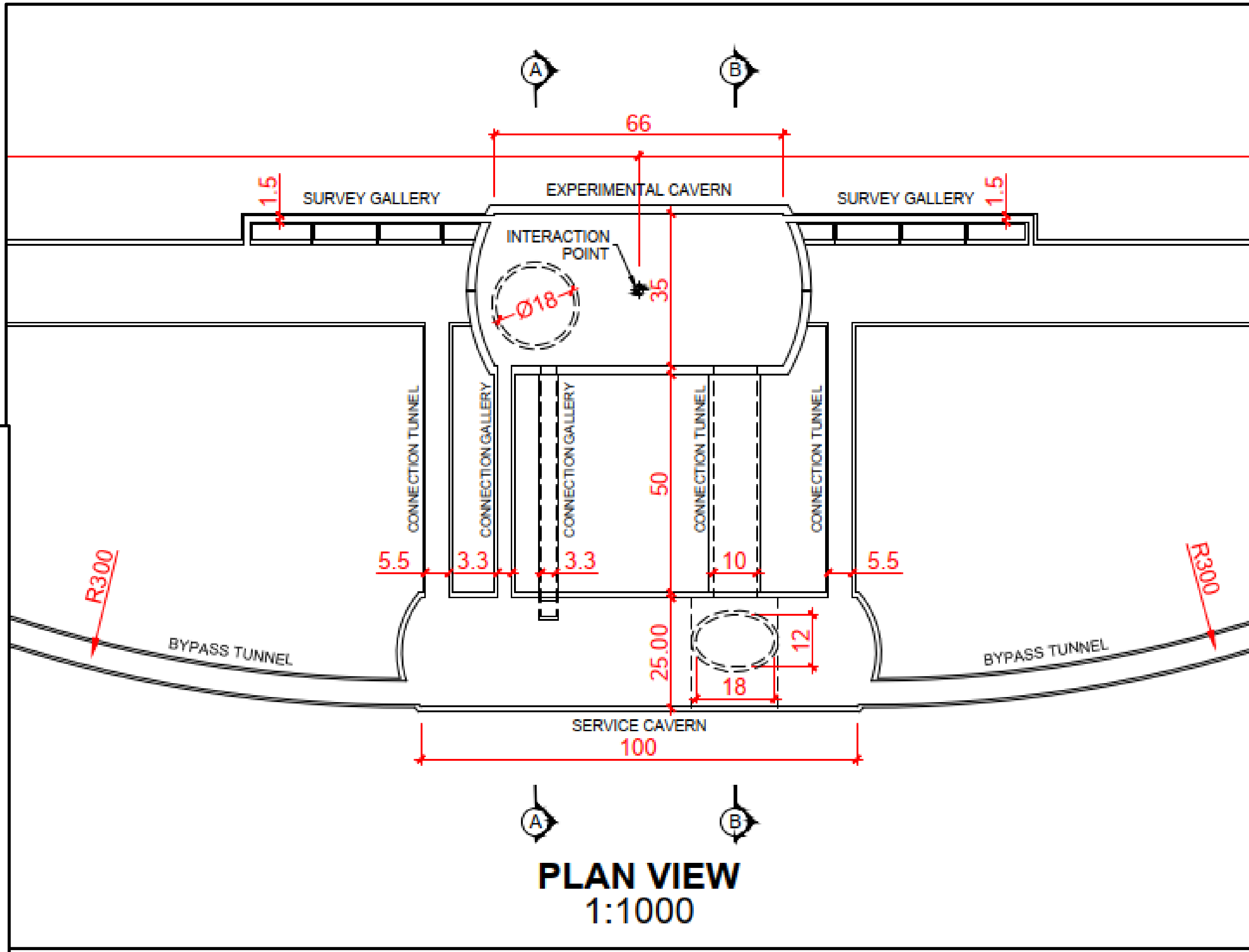
Typical Experiment Underground Layout

FCC-ee Underground Structure at point A

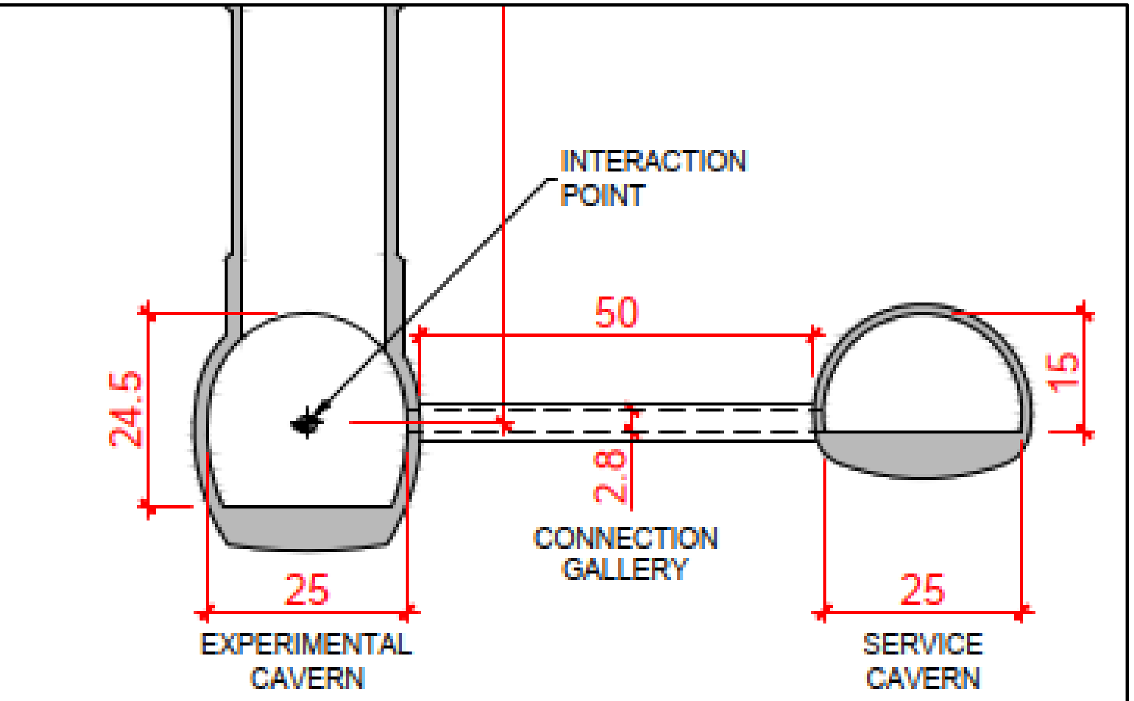


Large Cavern Complex

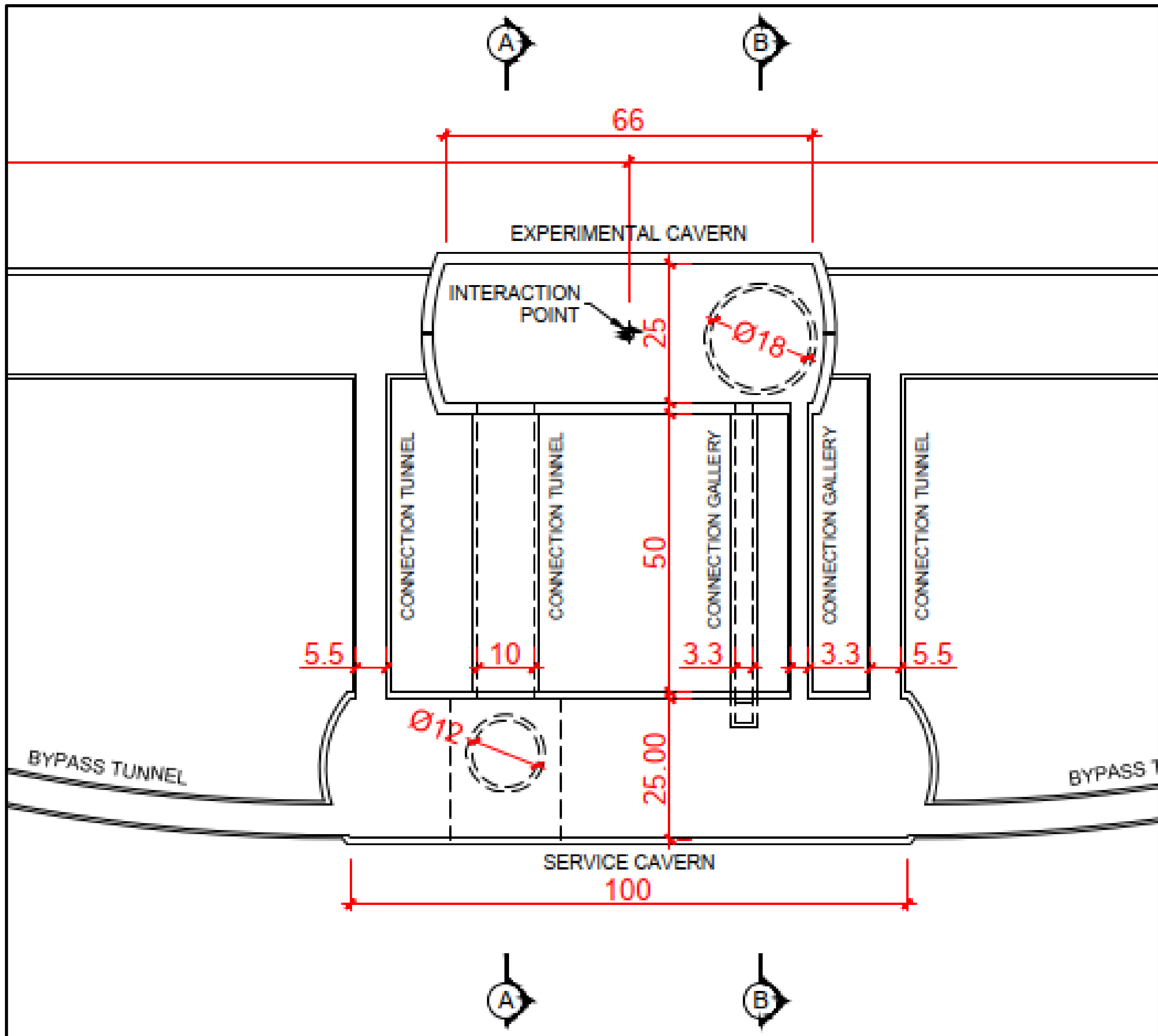




Small Cavern Complex



SECTION B-B
1:1000



PLAN VIEW
1:1000

Experiment Caverns

- The caverns to be constructed are similar in span to the CMS and Atlas caverns constructed for the LHC
- This gives us some confidence that these caverns can be constructed within the molasse rock
- Unlike CMS and ATLAS, there is no specific requirement for the Experimental cavern and Service caverns to be very close together and a distance of 50m is currently considered as the optimum spacing between the caverns.
- Although this increases the lengths of the connecting tunnels between the two caverns, it results in less interference in the rock stress distribution around the excavations which should make their design simpler and construction less risk.

Experiment Caverns

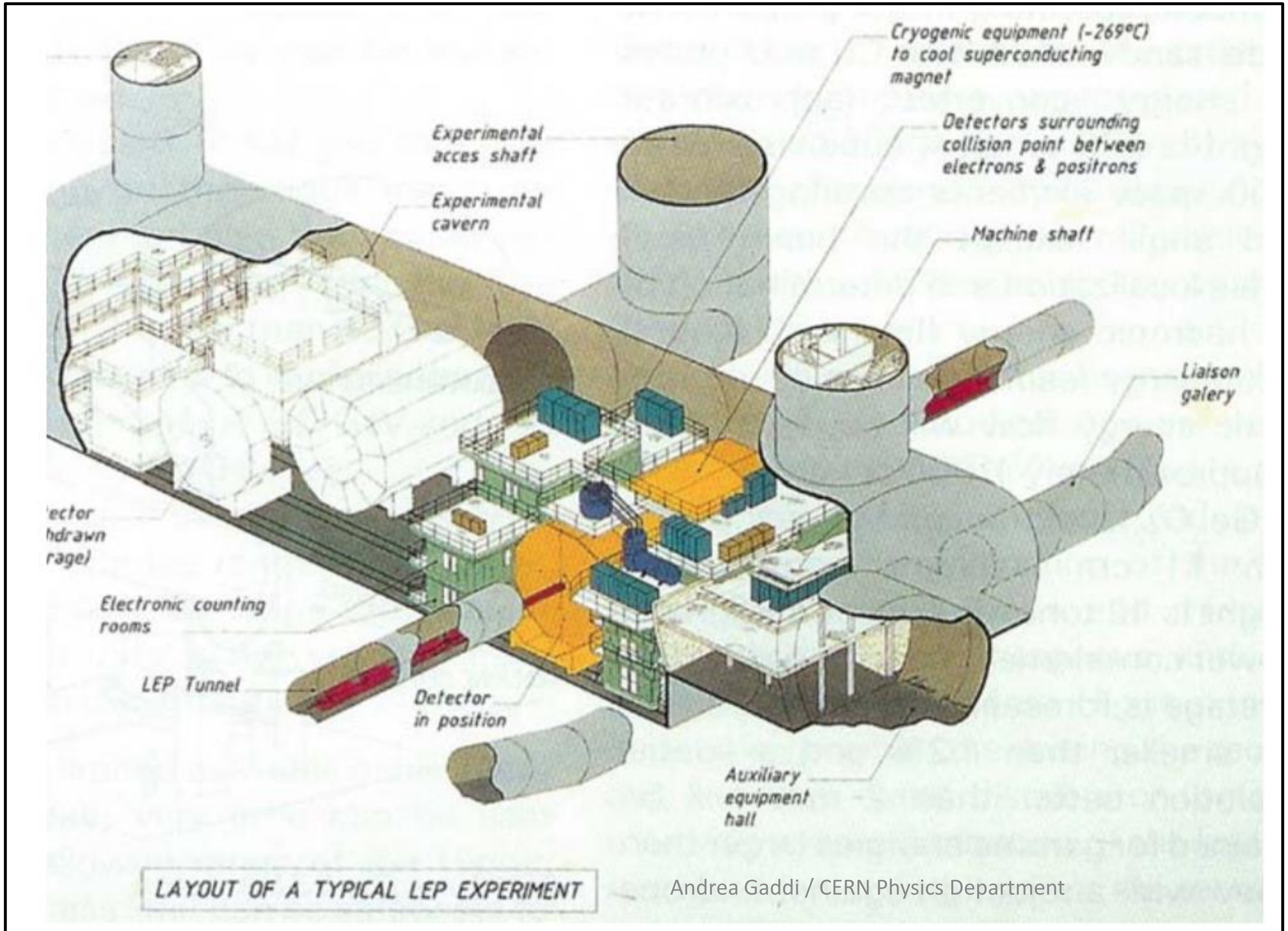
- The rationale in designing the experiment caverns at FCC has been:

  <u>Optimize for large hh-detectors, assuming that compact ee-detectors will easily fit-in.</u>

  True, but:

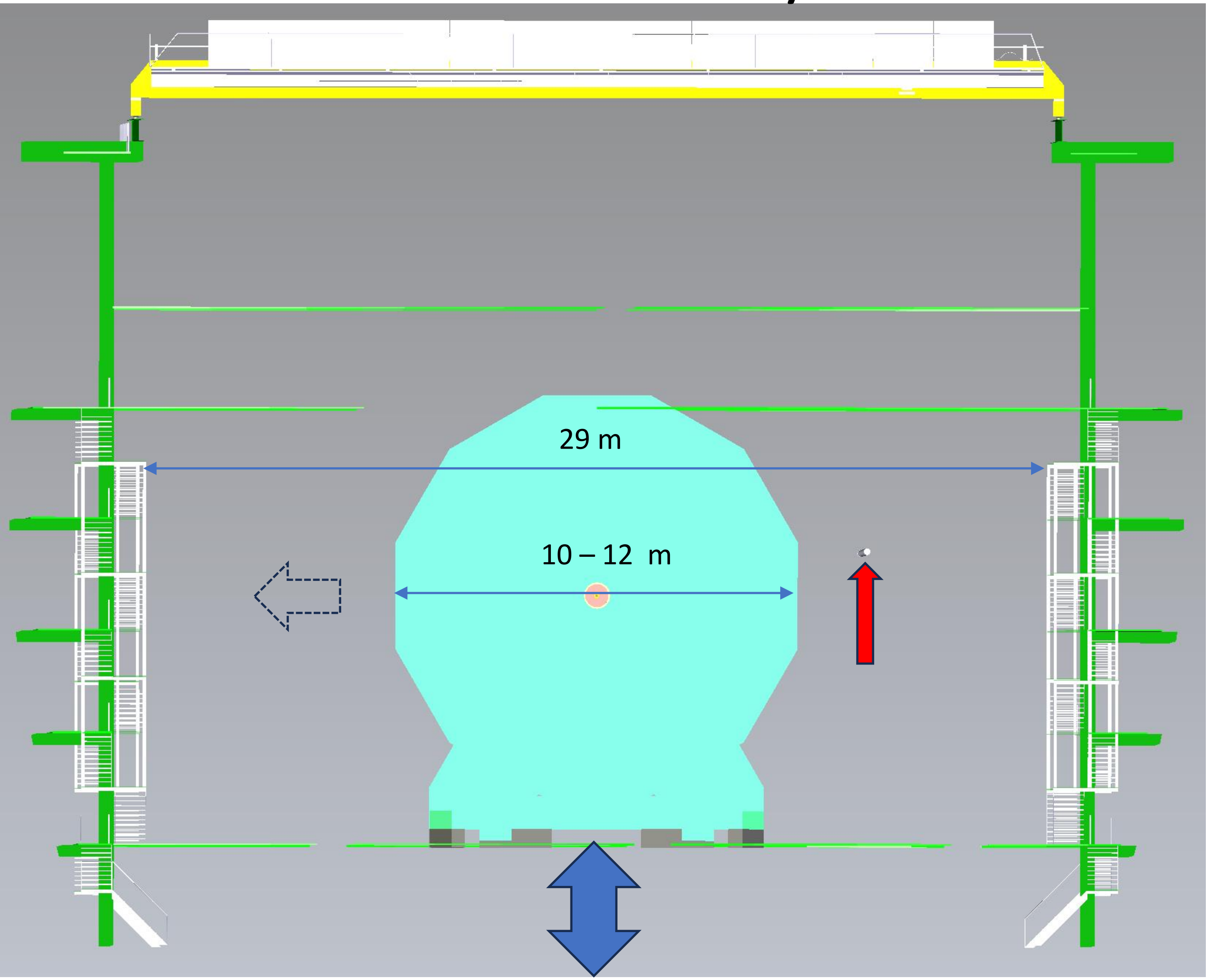
  - Beam height for hh is much higher than for ee → cavern shall have two floor levels
  - MDI for hh much simpler than for ee → the optimum cavern layout for an ee-detector is transversal to beam, as it was built for LEP (and also designed for CLIC detectors).

LEP Cavern Layout for Detector



Cavern trasversal to beam axis.
Three shafts (!)
Note the detector parking position for maintenance.

FCC Cavern Layout for ee-Detector

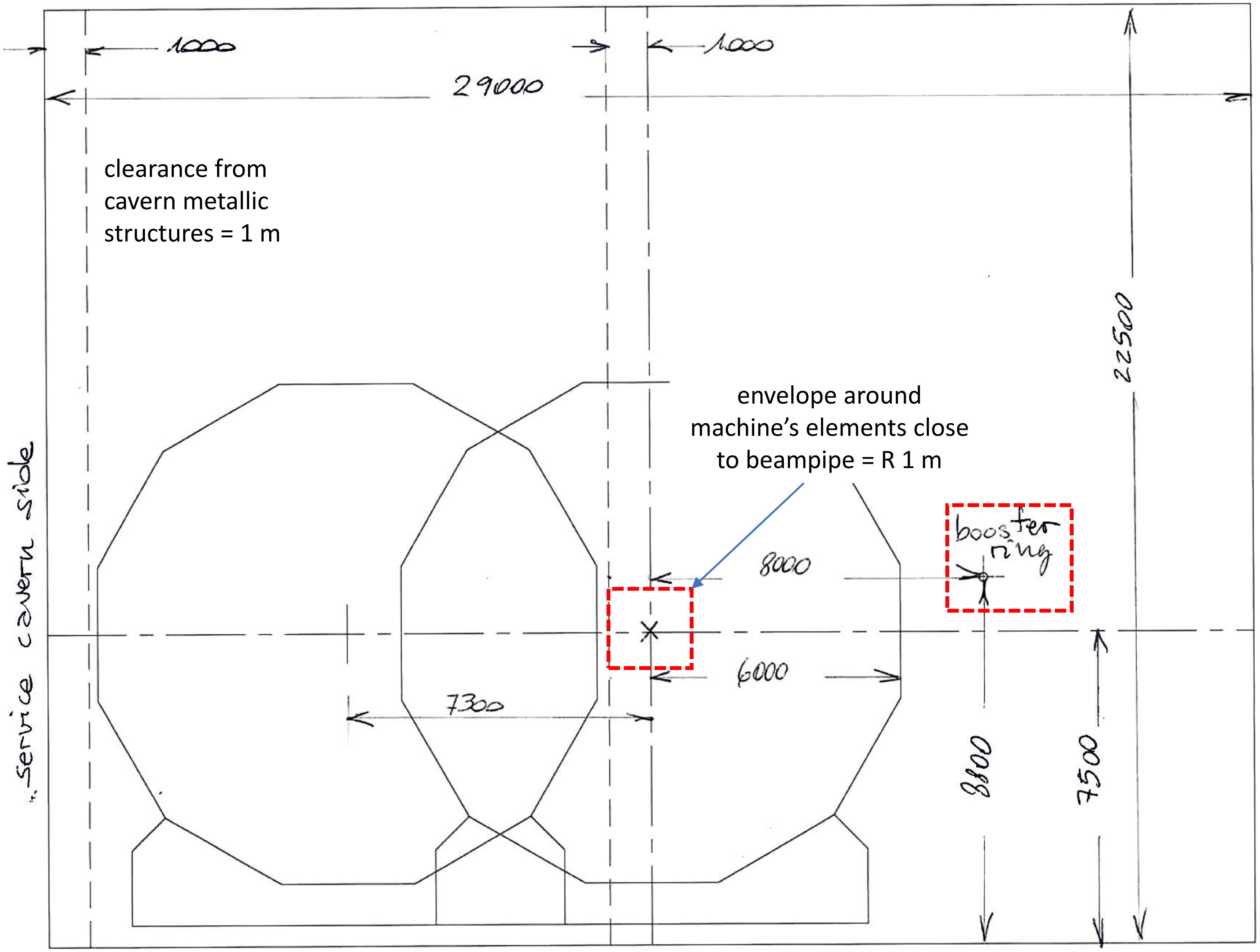


A typical FCC-ee detector sits comfortably inside the experiment cavern (but note the presence of the booster ring on its right), floating at 3 to 4 m hight from the cavern floor. This would make challenging to achieve a good mechanical stability of the FFQ.

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 ***(vertex)*** *would be simplified?*

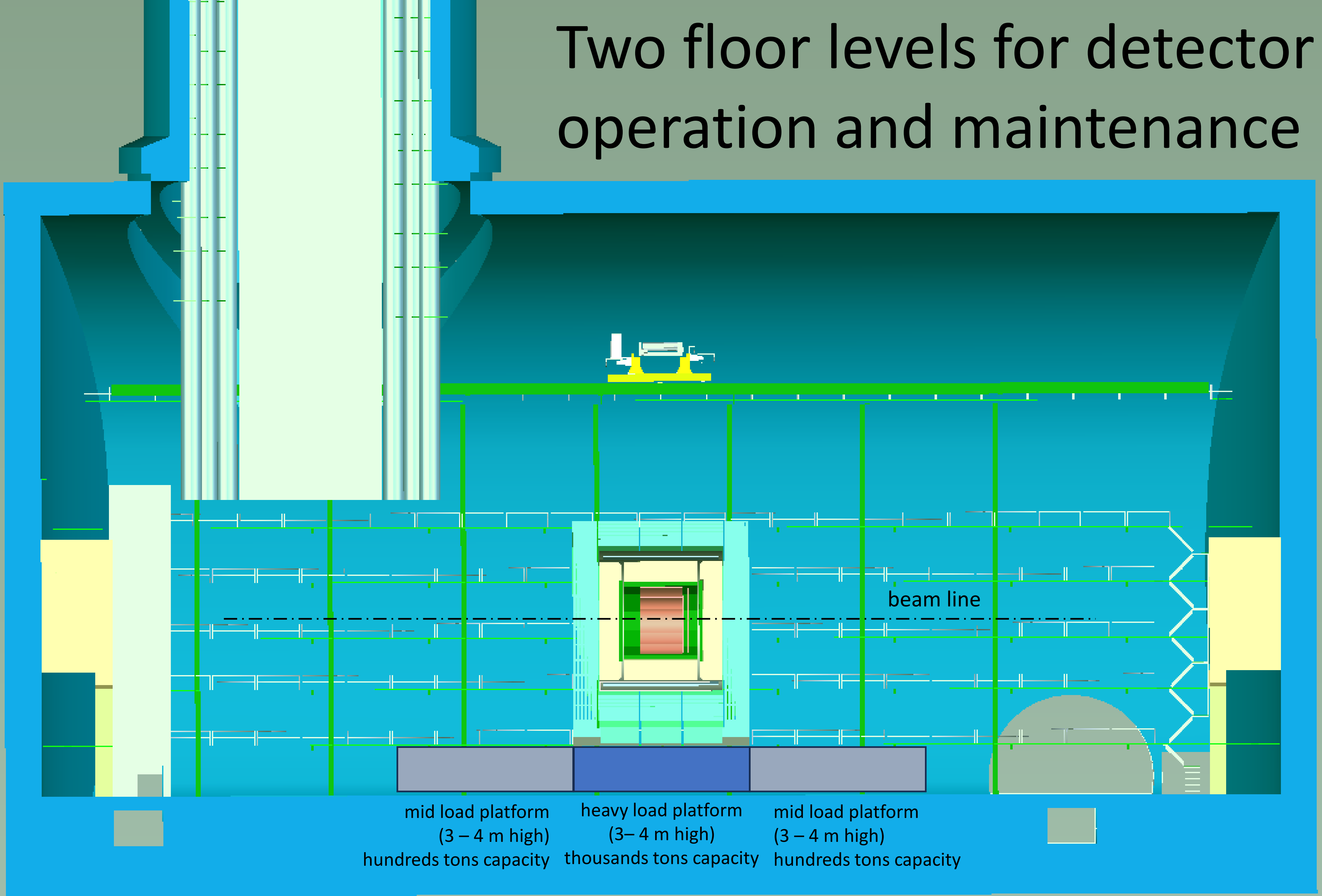
courtesy F. Valchkova / CERN

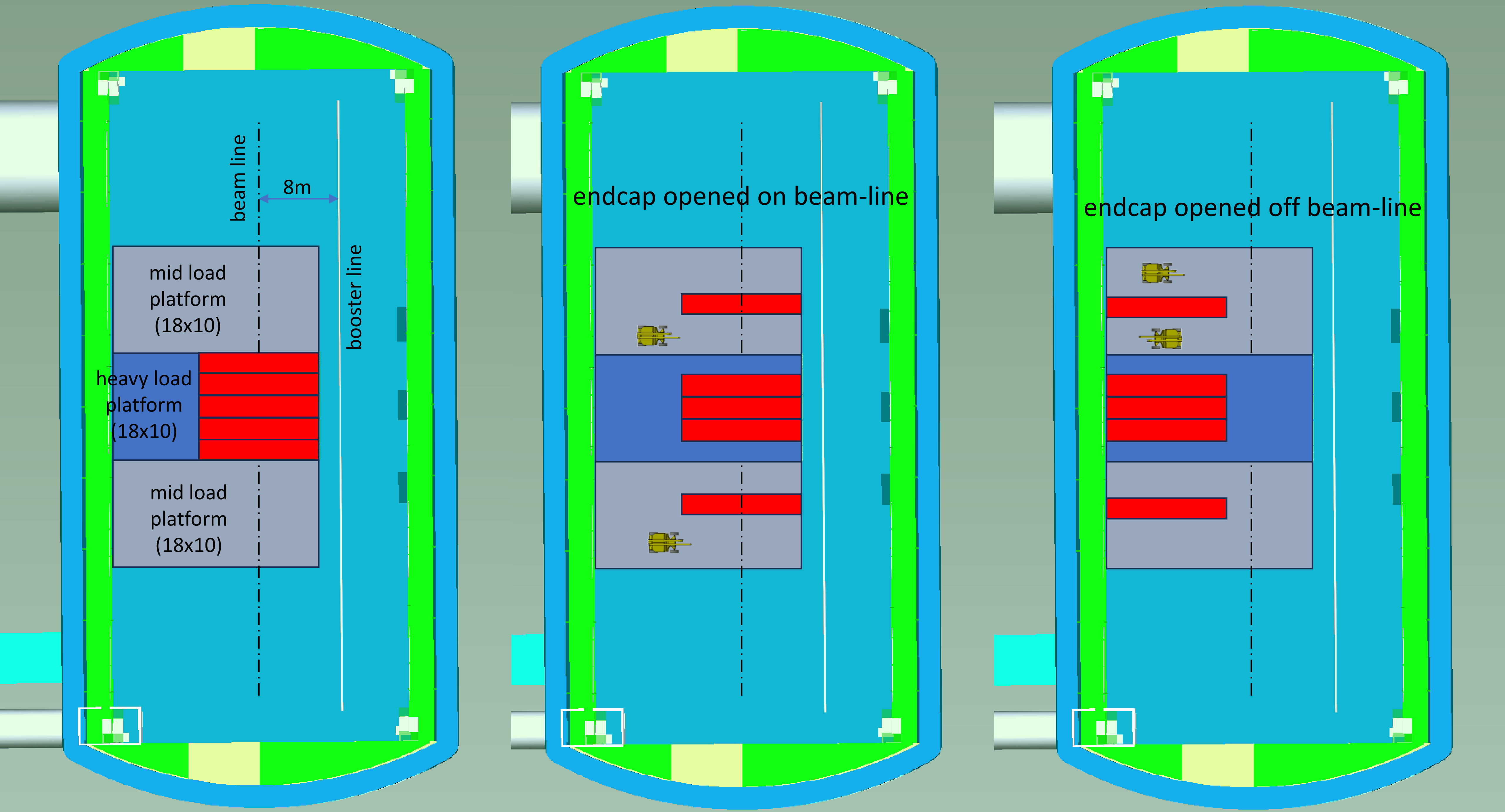
Minimum vital space around the detector



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

Two floor levels for detector operation and maintenance





beam line
8m
booster line
mid load platform (18x10)
heavy load platform (18x10)
mid load platform (18x10)
endcap opened on beam-line
endcap opened off beam-line

Vertex & MDI Region Integration

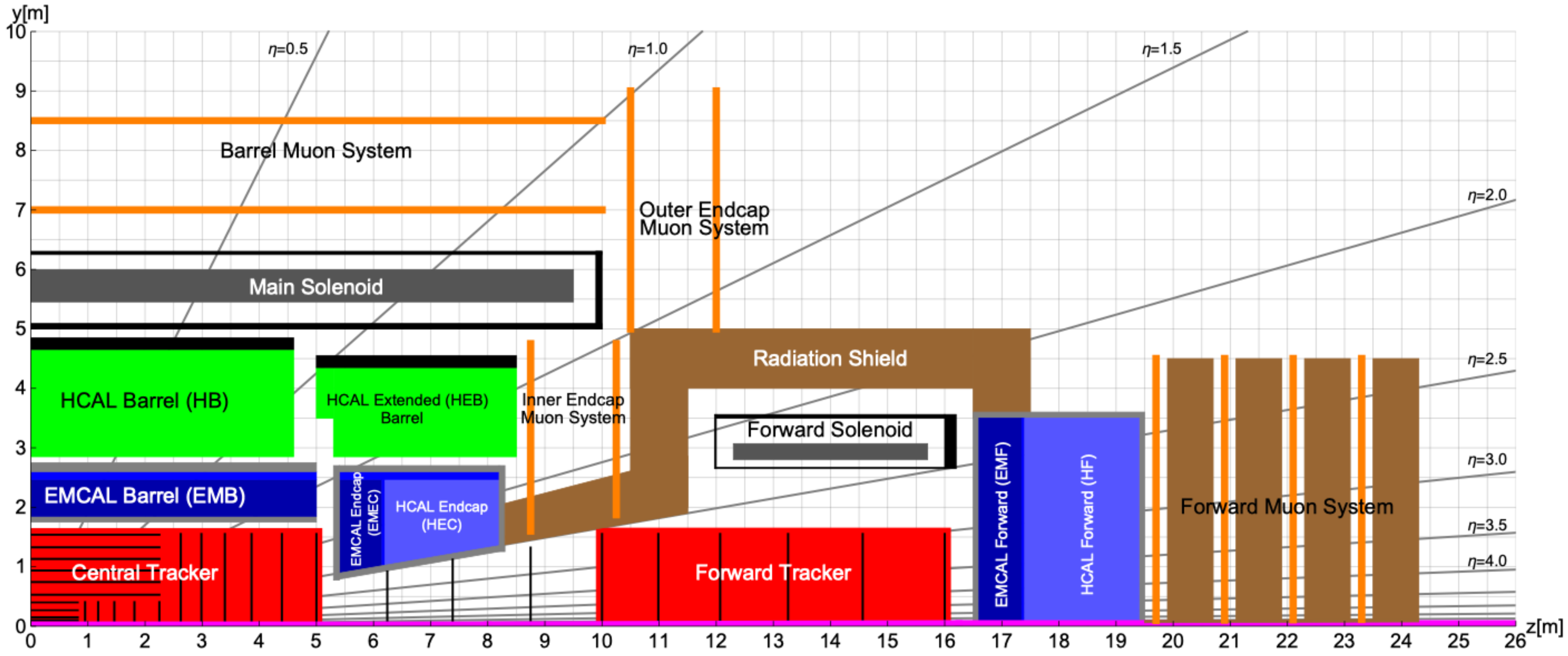
- The Machine – Detector Interface is the region that encompasses the last accelerator components before the Interaction Point and those detector elements closest to the beam-pipe.
- The design of the MDI region shall take into account the (conflicting) requirements from the machine (luminosity, reliability,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

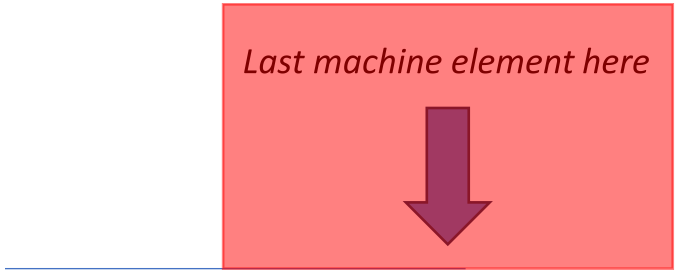
Main MDI components

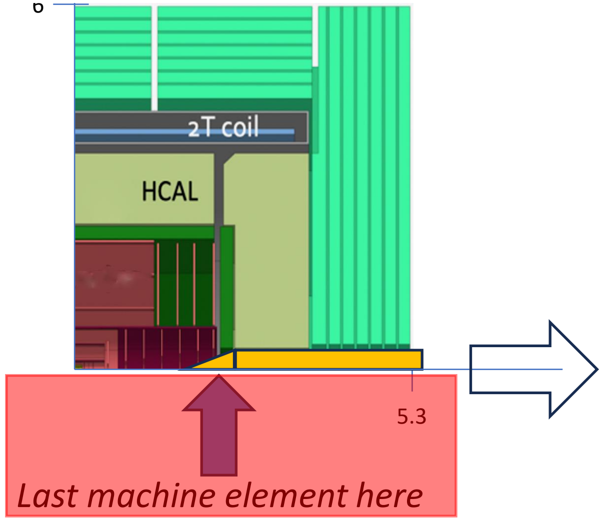
- from the Machine side:
  - Final Focus Quads
  - Anti-solenoid / Compensator
  - Beam Positioning Monitor
  - Beam-pipe + vacuum flanges/valves + bellows

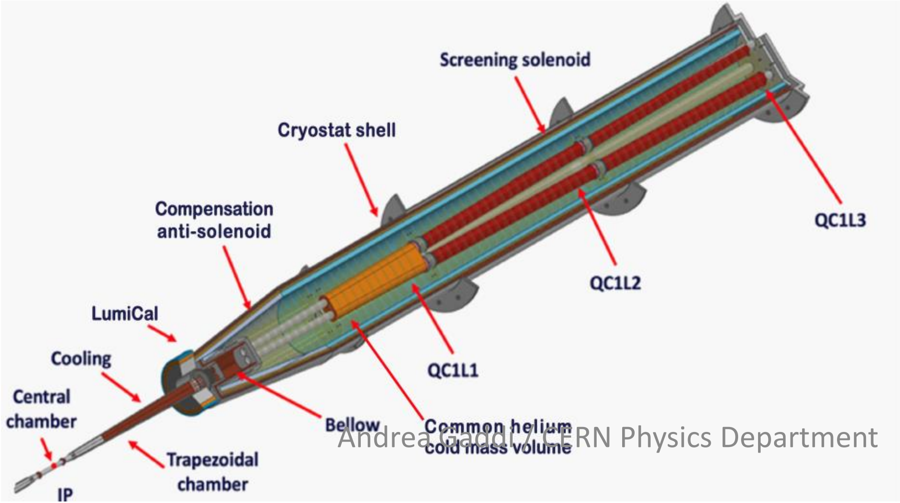
  (Final Focus Quads and Anti-solenoid / Compensator: Cryostat (superconducting))
- from the Detector side
  - Luminometer
  - Vertex detector / Inner Tracker + their services
  - Mask for background suppression
- common to both:
  - Supporting structures
  - Alignment system
  - Vibration stability features

Comparison between hh and ee MDI regions





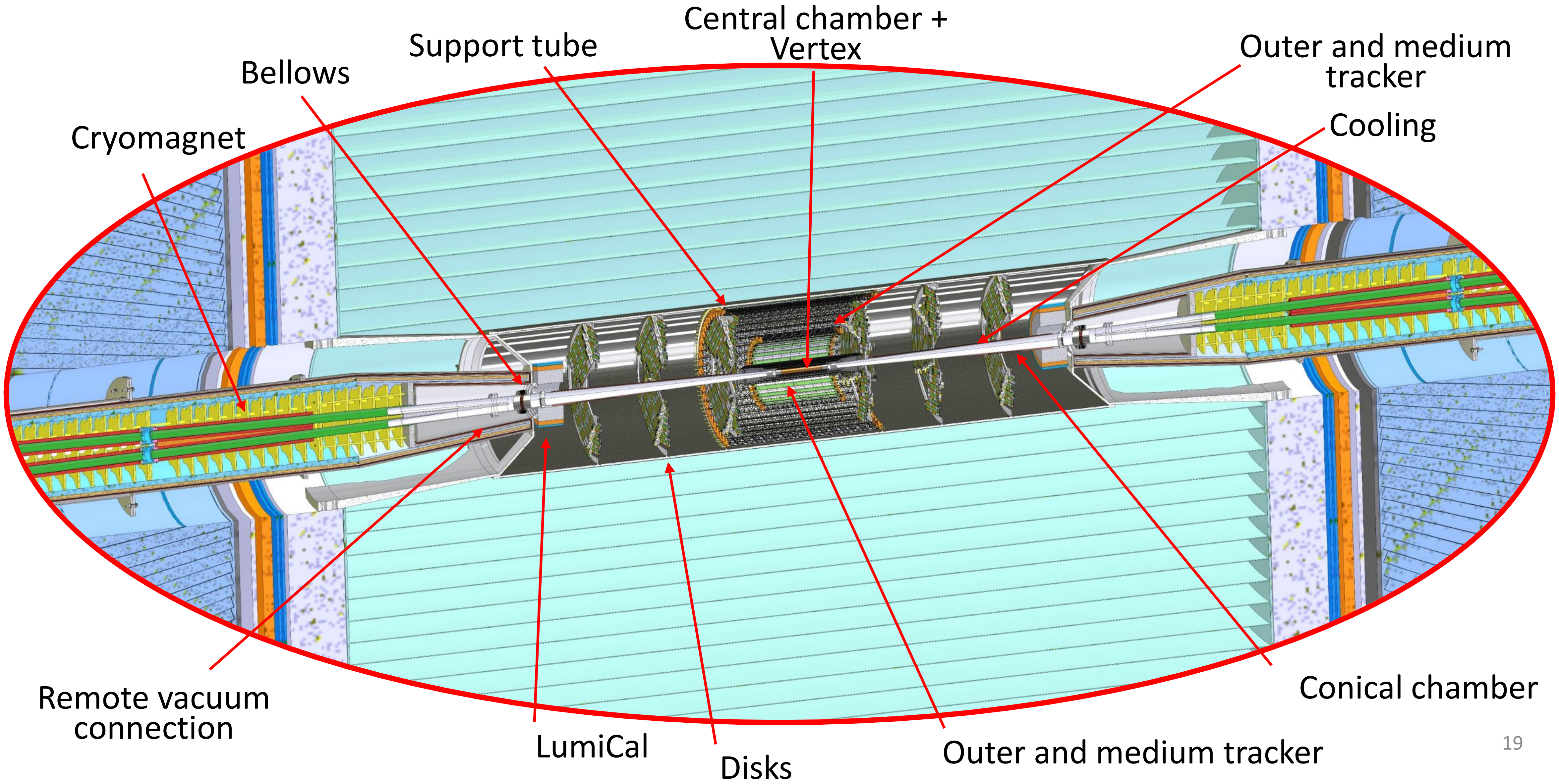




Machine-Detector Integration in FCC-ee is a major challenge. To access the inner detector parts, an adequate detector's segmentation and opening sequence has to be carefully studied.

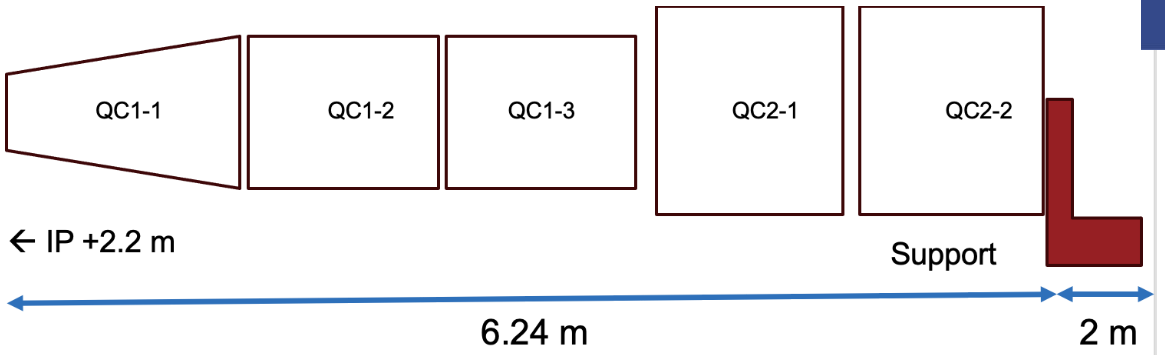
MDI Integration Study

courtesy F. Fransesini / LNF-INFN

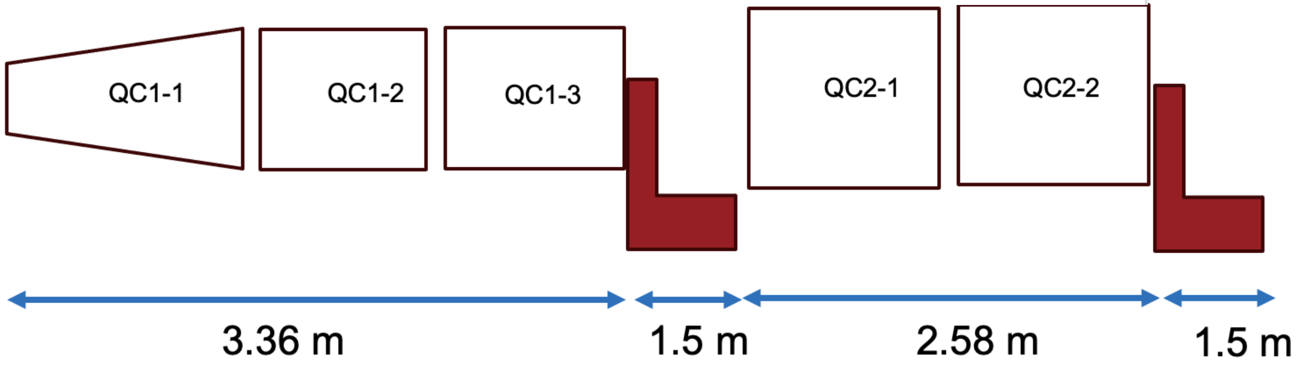


Possible QCs layouts and their supporting structures

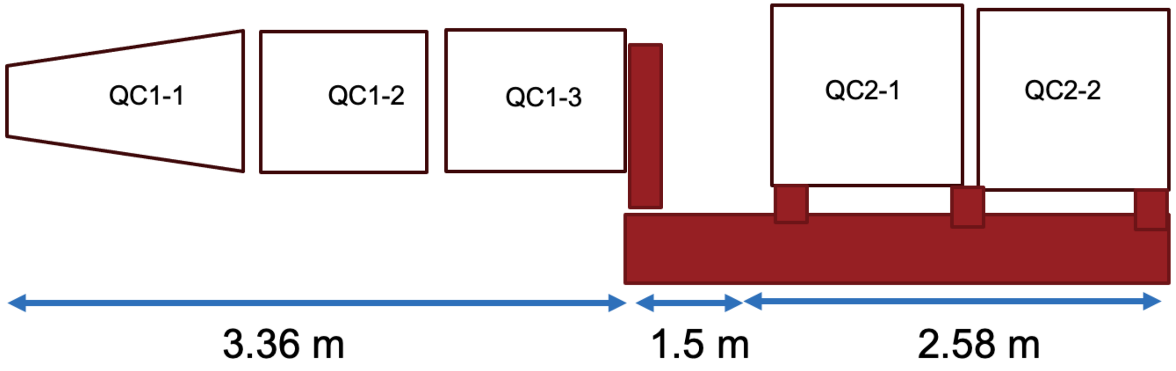
Option 1:
IR QC1 and QC2 in one cryostat and girder.
- minimal cryogenics & powering interconnections
- long & heavy cantilever assembly → stability issues
- complex handling



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

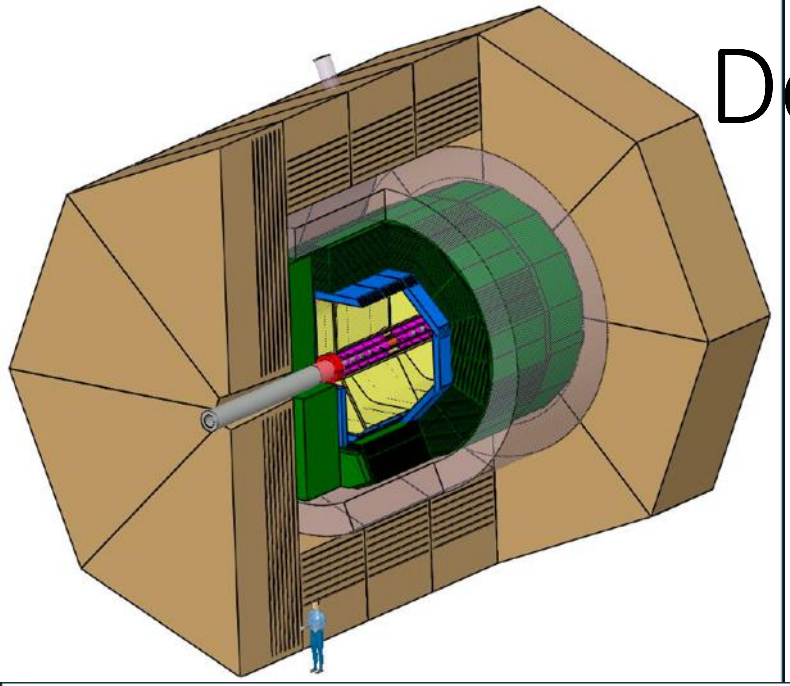


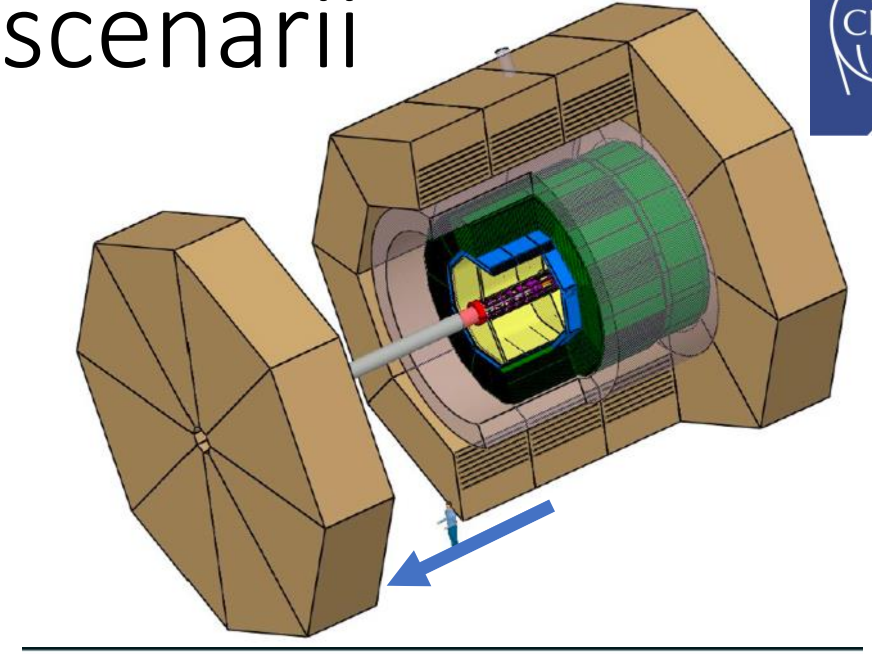
courtesy J. Seeman / SLAC

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.

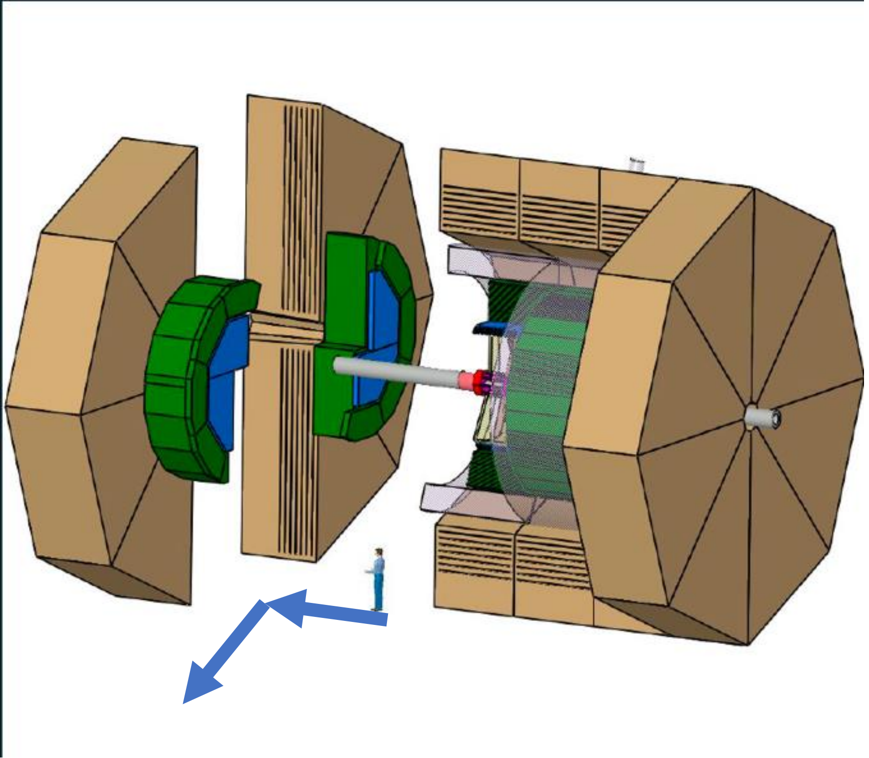
Detector opening scenarii

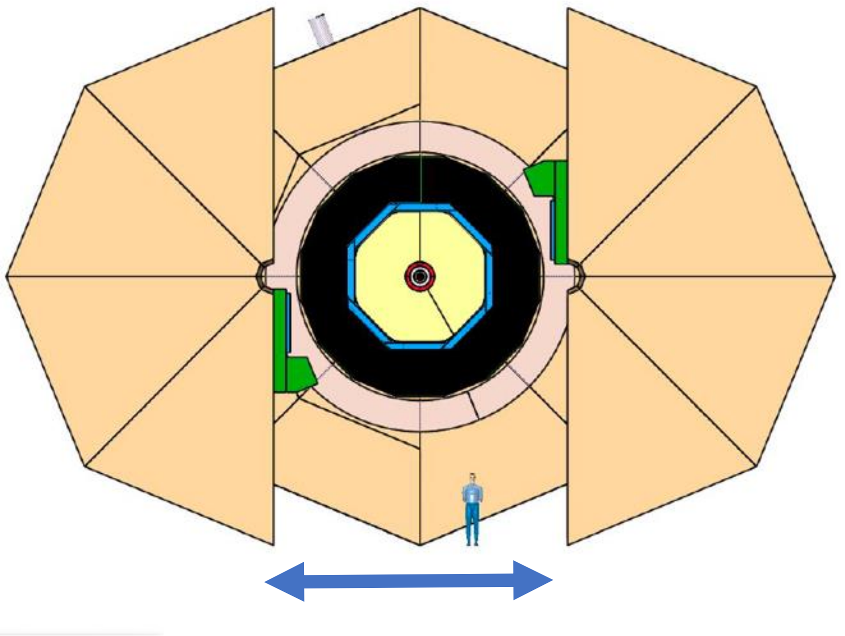




Solid Endcaps

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.

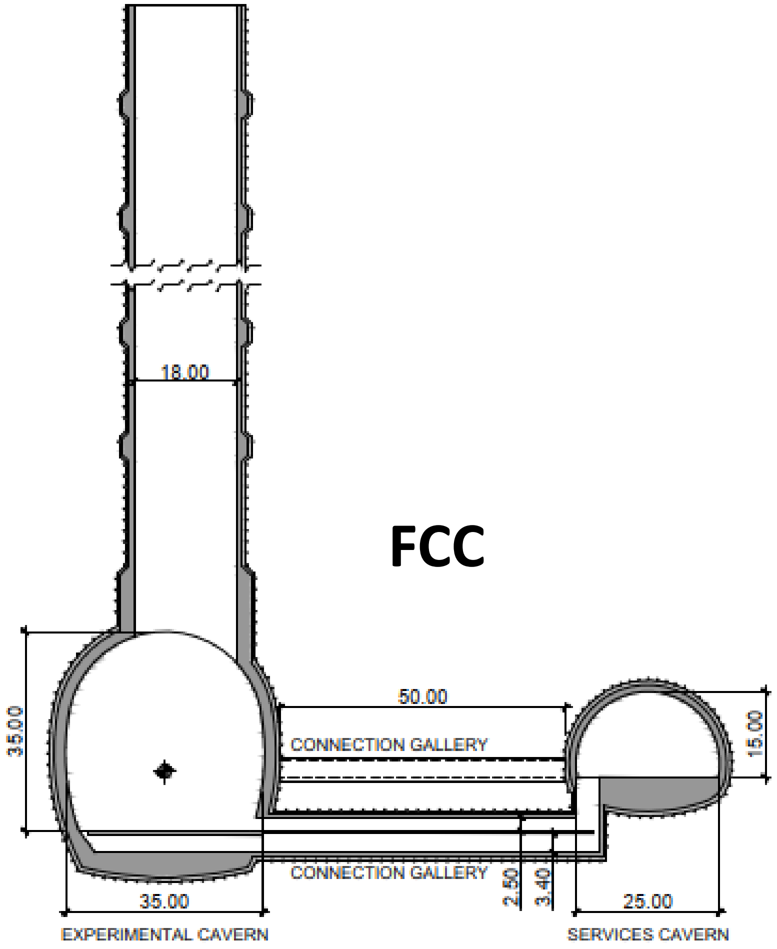
- Solid endcaps & long longitudinal opening off the beamline
  - no constraints on machine elements design
  - little risk for beampipe integrity
  - beam vacuum broken, longer pumping down time

Conclusions

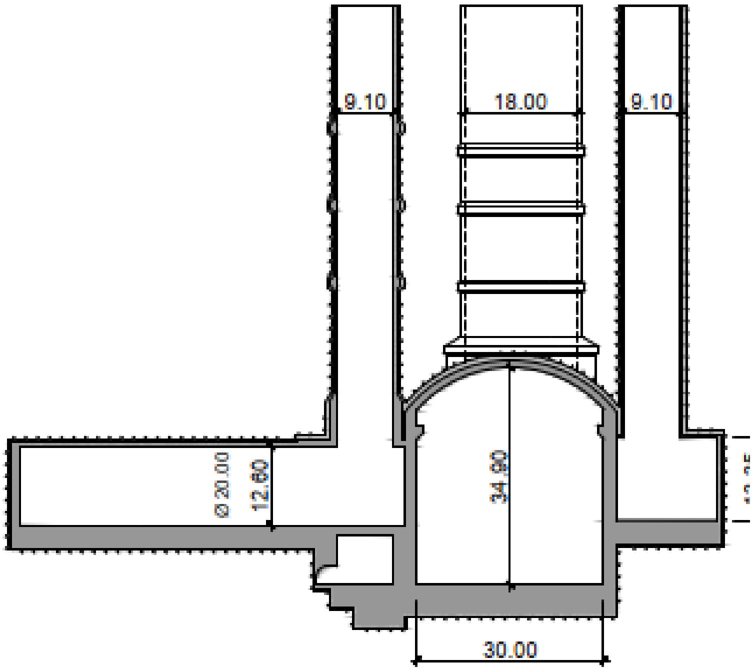
- Inner tracker/vertex design in ee machines has to take into account multiple conflicting requirements and contrains, including those coming from the cavern layout and the MDI integration.
- Detector wise, the choice of segmentation and opening scheme plays a fundamental role. For accessibility purposes, carefully consider the routing of inner detector services.
- Many options exist to access the inner sub-detectors, either *on* or *off* the beamline. The final choice has to come from an accurate optimization and prioritizing those criteria that prime the most.

Back-up slides

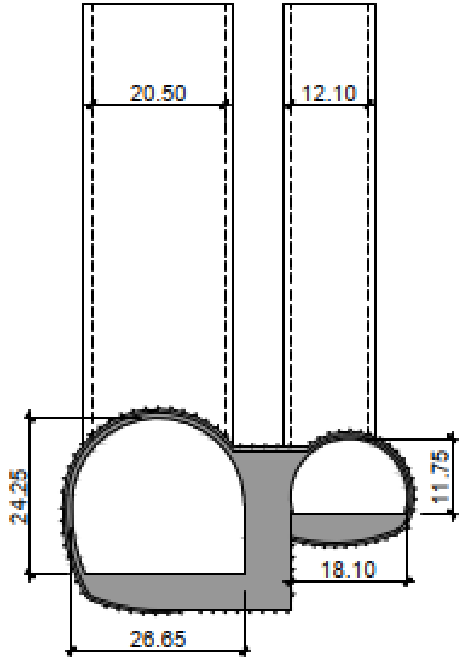
Comparison FCC to ATLAS and CMS Cavern Complexes



FCC

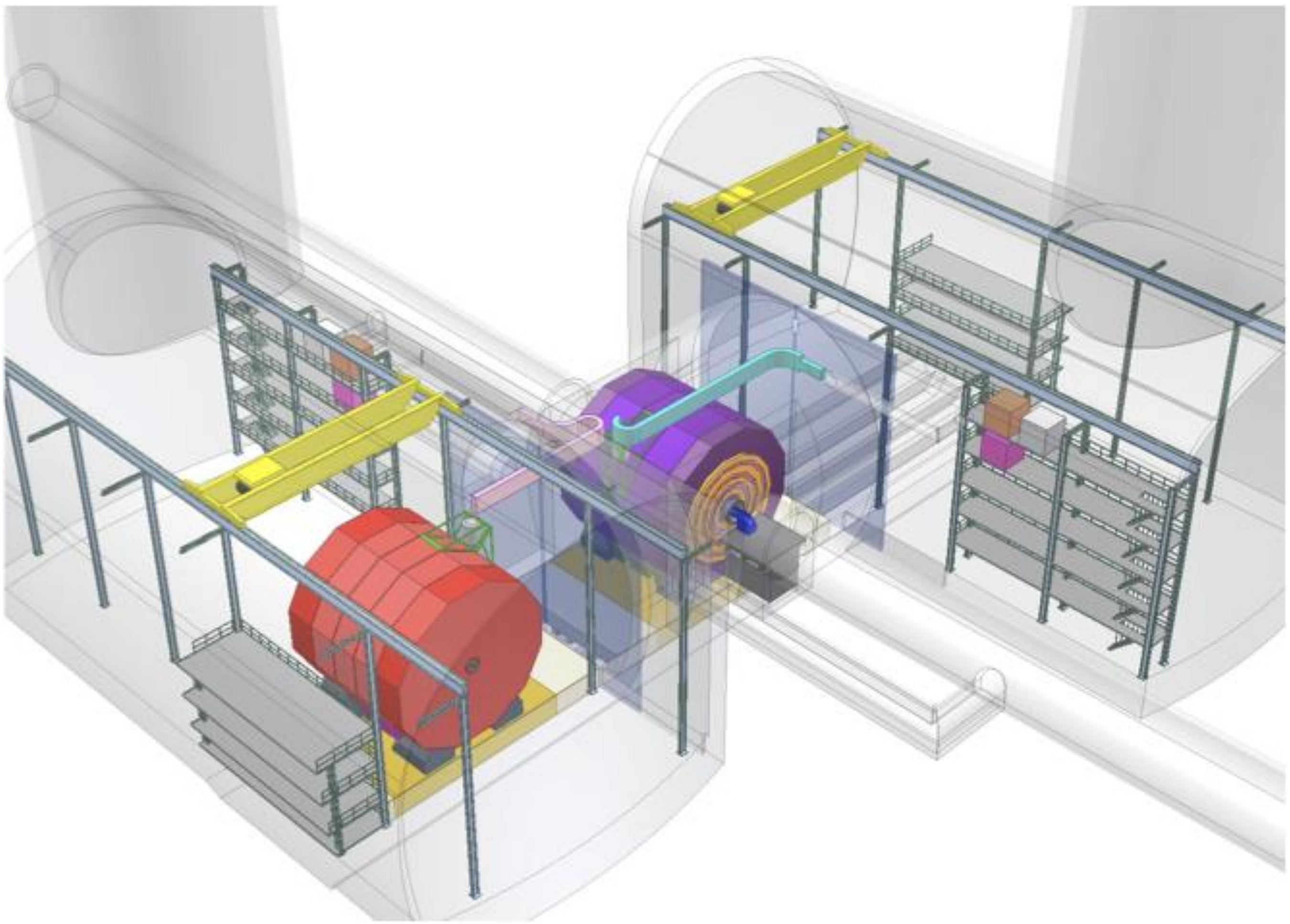


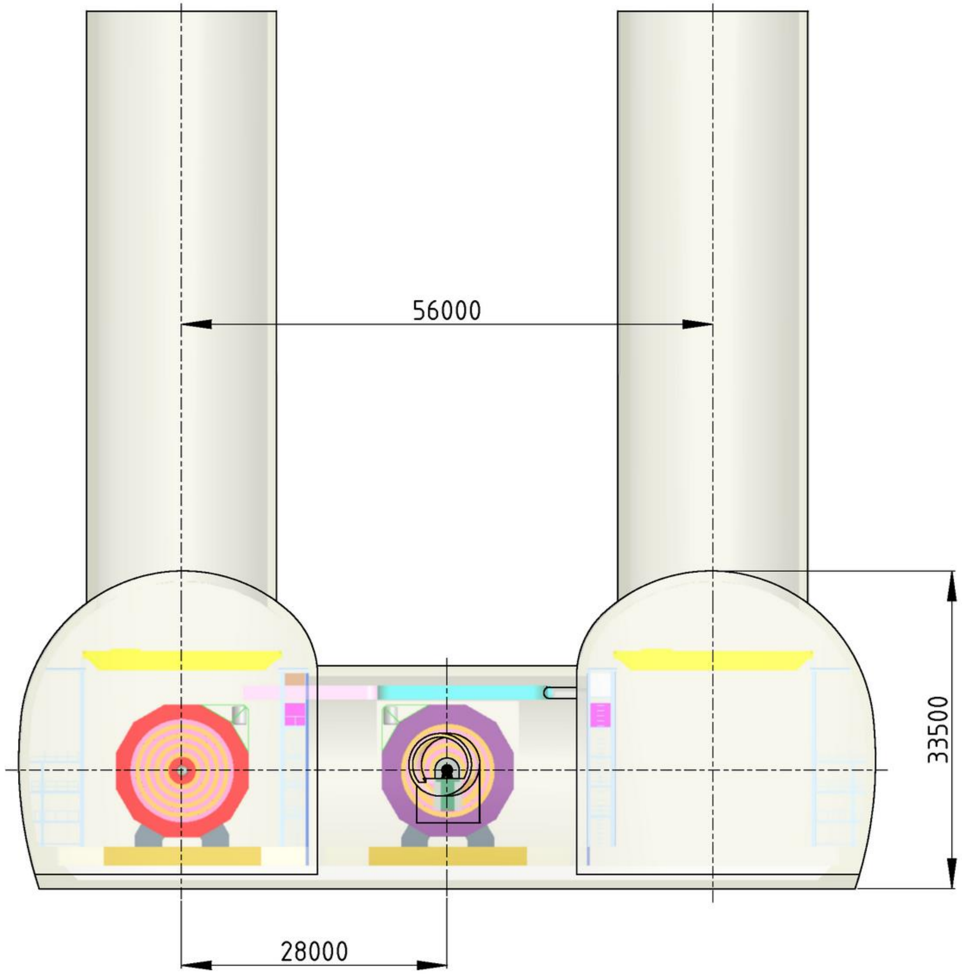
ATLAS



CMS

ILC / CLIC Push-Pull Cavern Layout

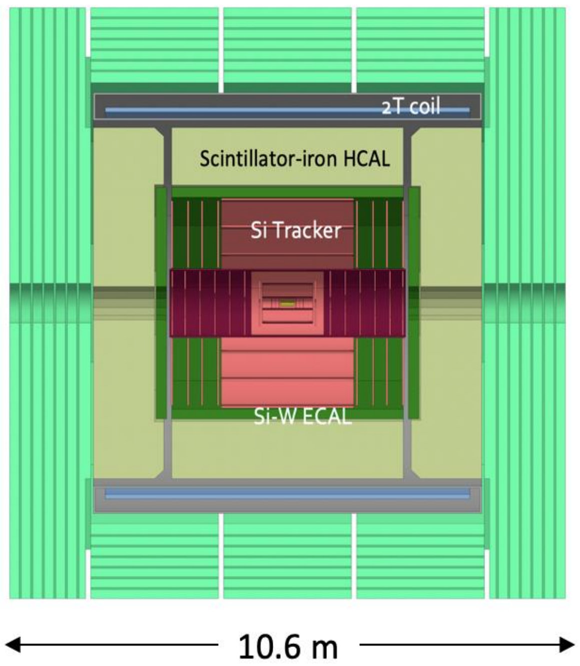




by A. Gaddi, H. Gerwig / CERN

Developing landscape of FCC-ee detector concepts

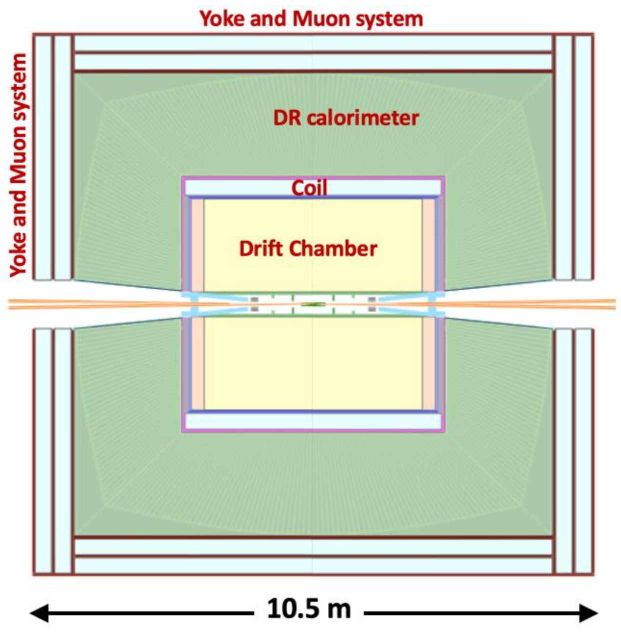
CLD



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

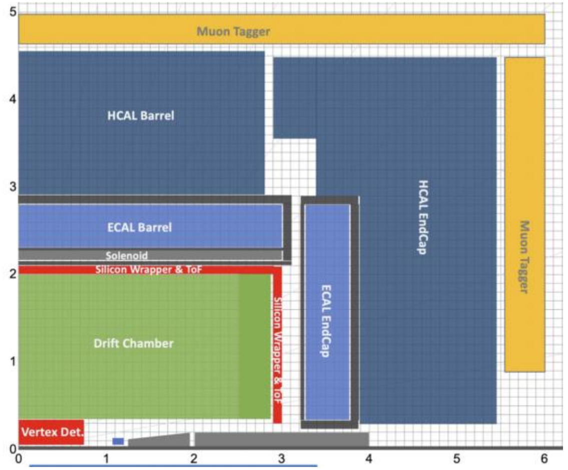
CDR

IDEA



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

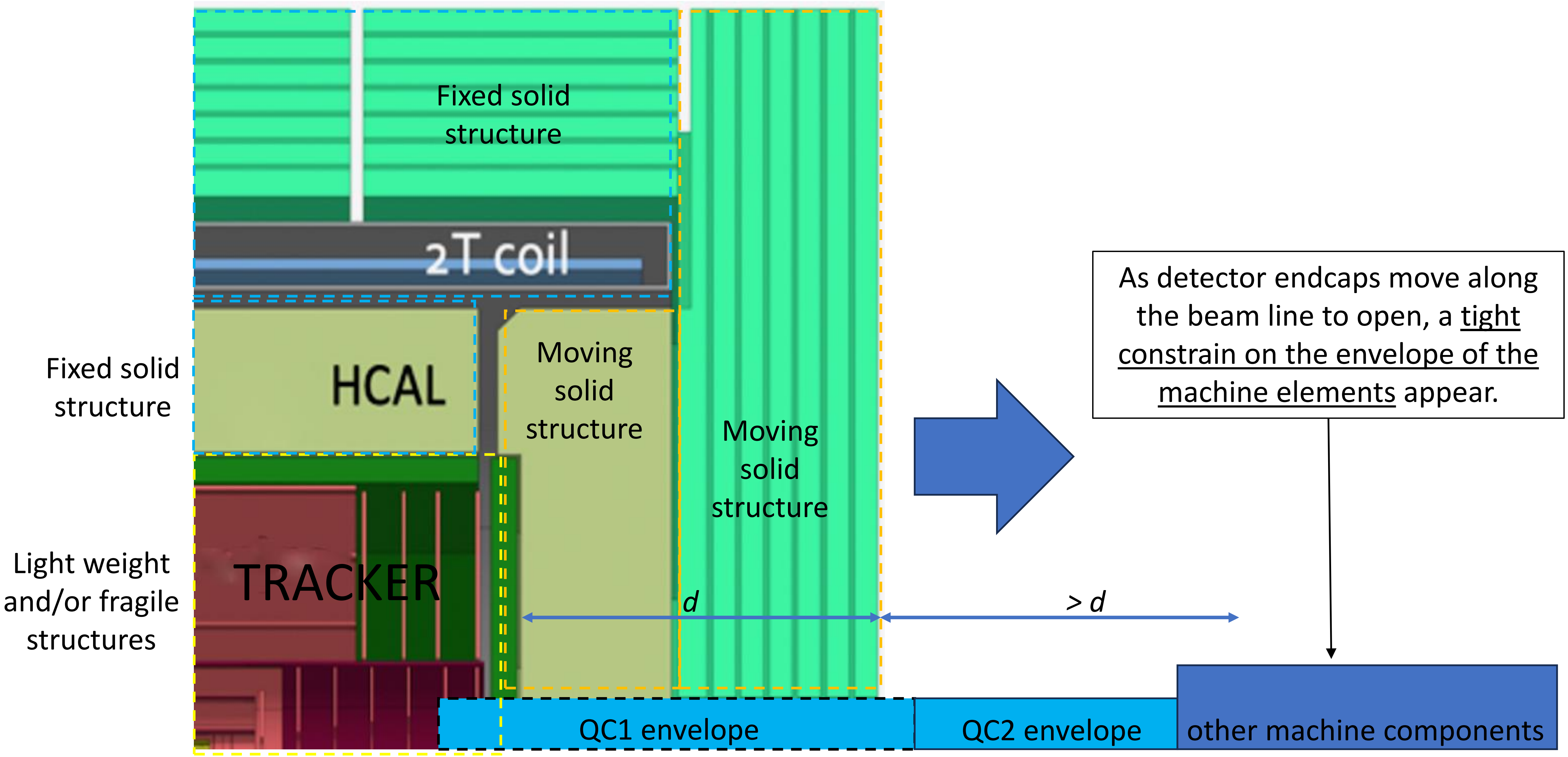
Noble Gas Liquid ECAL based



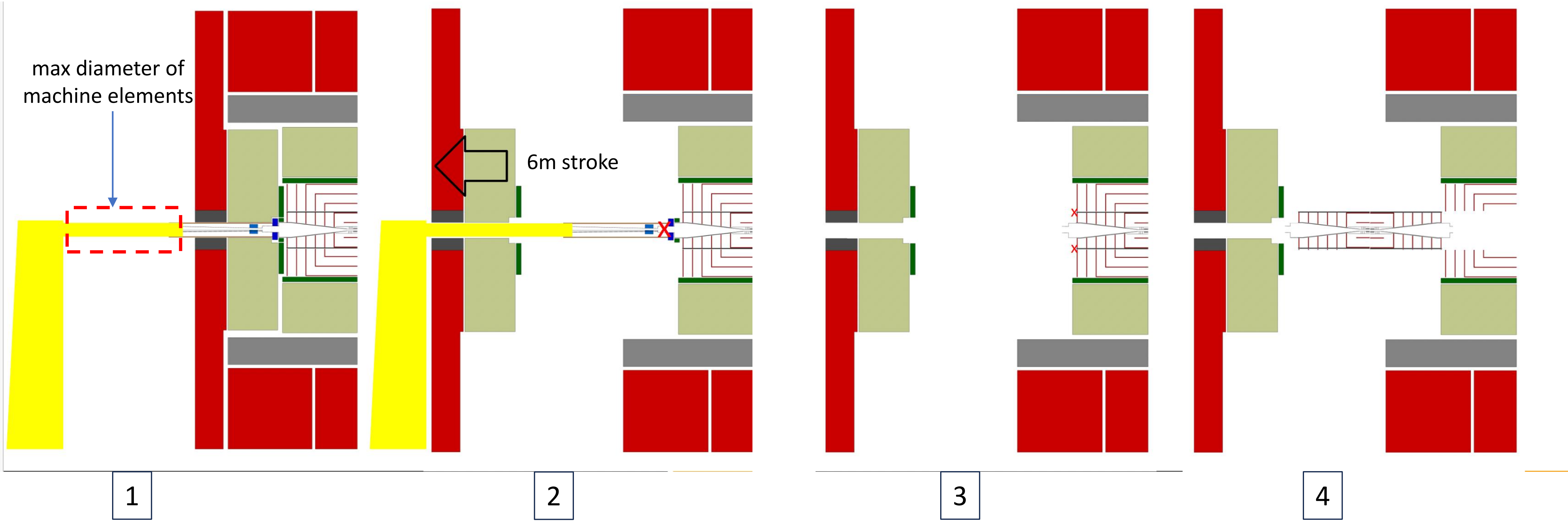
- High granularity noble gas liquid ECAL
  - Pb + L-Ar (or W + L-Cr)
- Drift chamber (or Silicon) tracking
- HCAL
- Muon system

courtesy M. Dam, Niels Bohr Institute

Typical detector structure.



Scenario for inner detector assembly or servicing



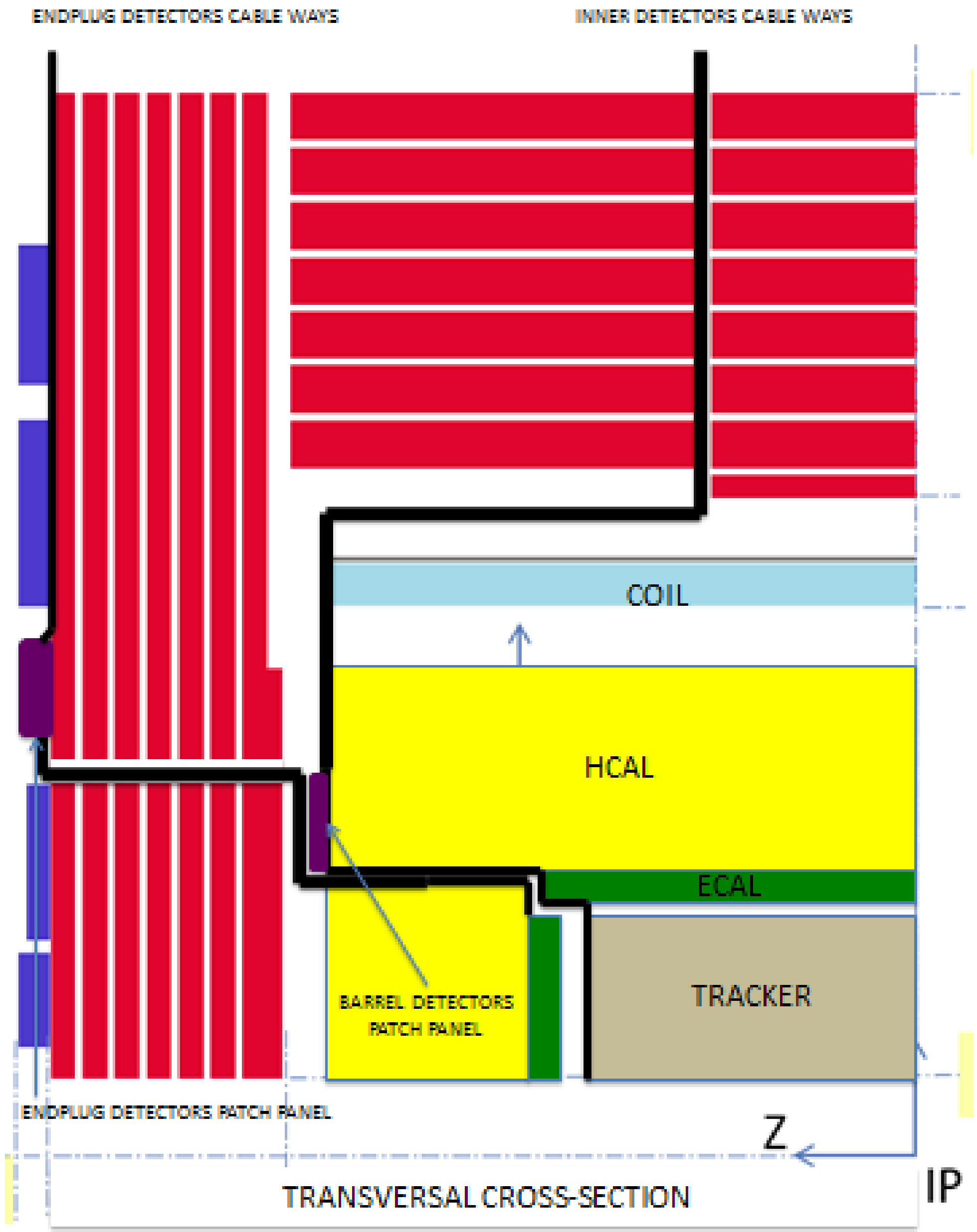
Detector closed.

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.

Detector Services routing



Another important criterium for assessing the accessibility to the inner detector parts is the routing of services.

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.

Cable-chains will allow for quick detector opening