FCC-ee DETECTOR INTEGRATION & MAINTENANCE SCENARII

Preliminary Study

Summary

Status of Experiment Facilities design

Considerations on Experiment Cavern design

Detector Integration & Maintenance scenarii

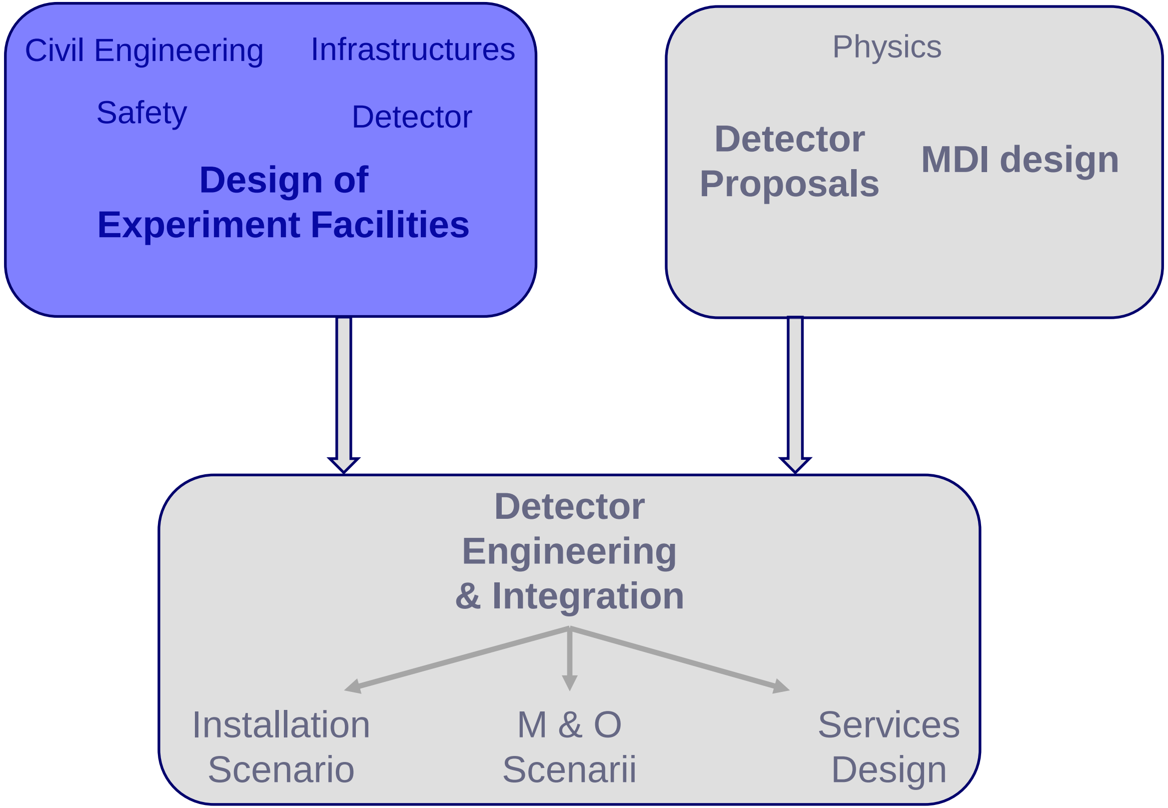
- Detector assembling scenarii
- Detector accessibility for assembling & maintenance
- Detector opening scenarii

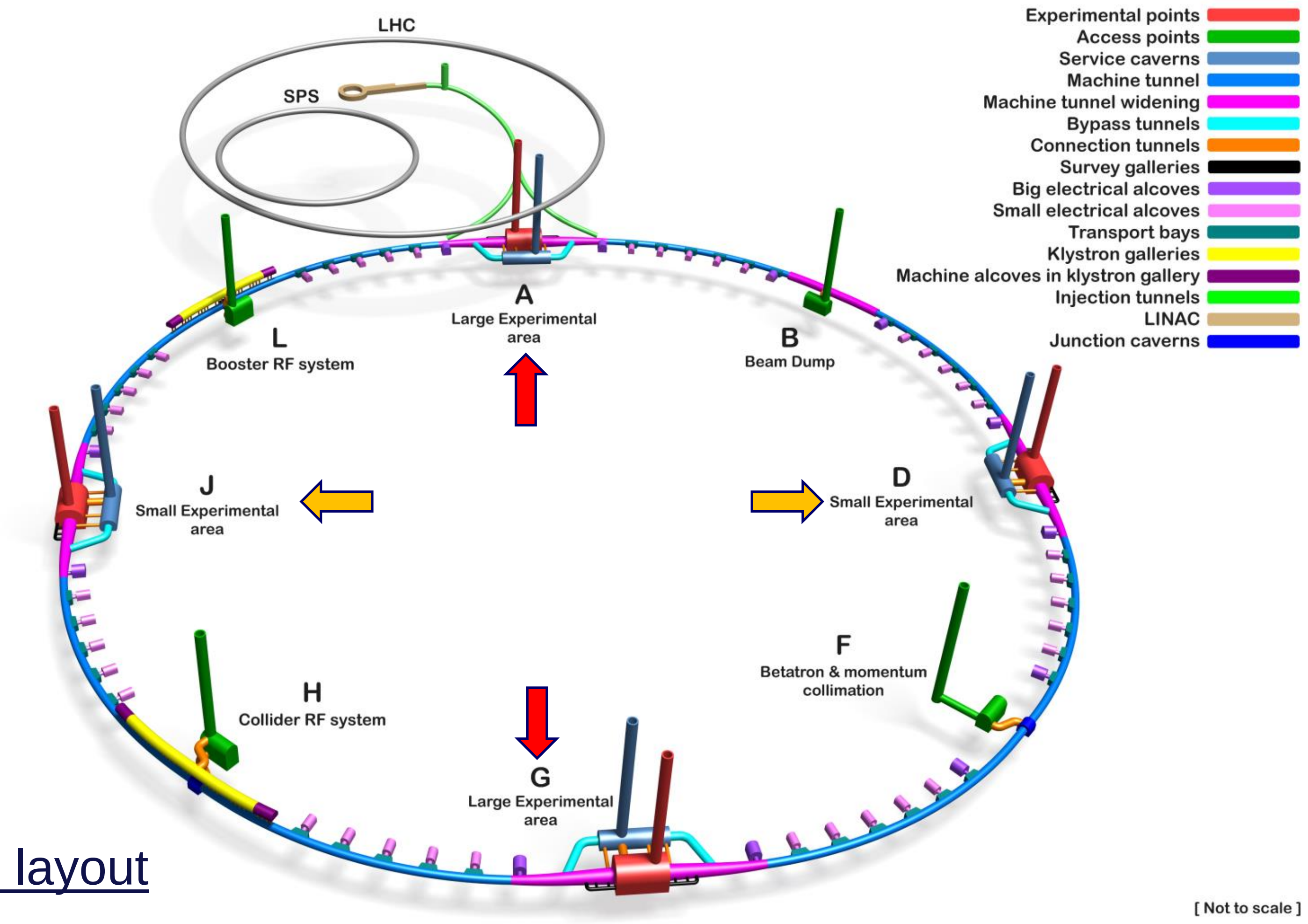
Outlook

Status of Experiment Facilities design

The underground facilities project is in the consolidation phase, gathering input from several groups (civil engineering, infrastructure, security, detector).

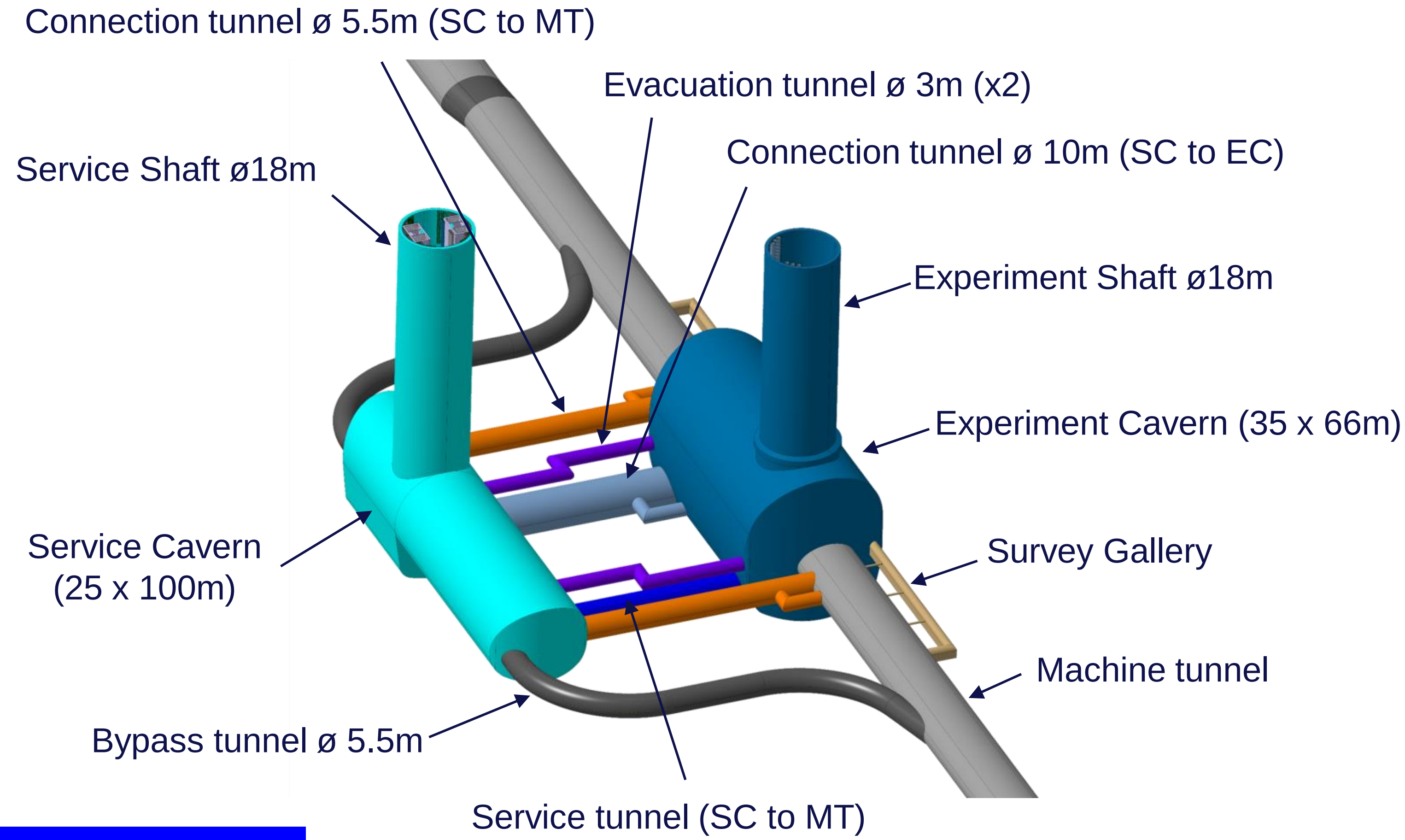
Many improvements have been done since the CDR and decisions made at this stage may have a major impact on the performance, maintenance and operation scenario of the detector.



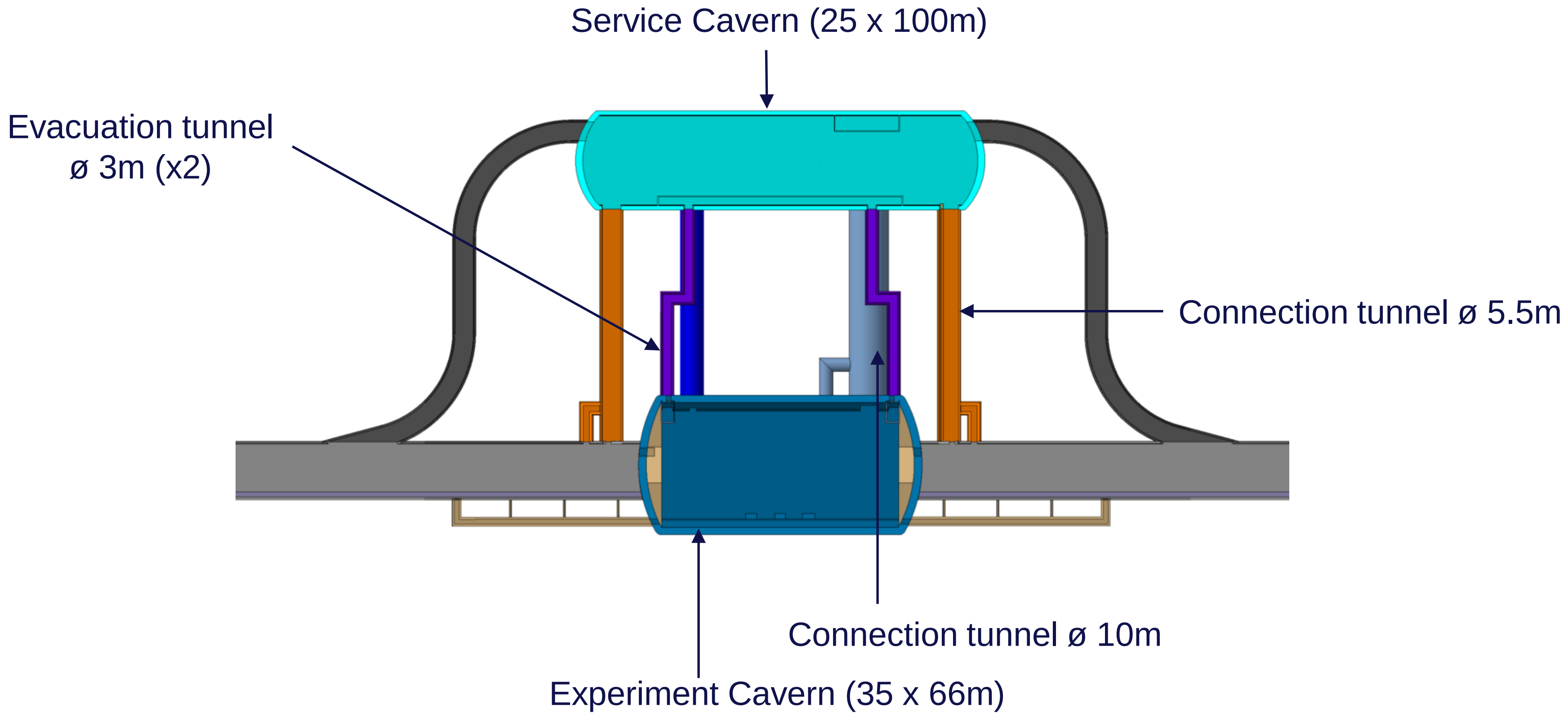


FCC-ee layout

FCC-ee Underground Structure at point A

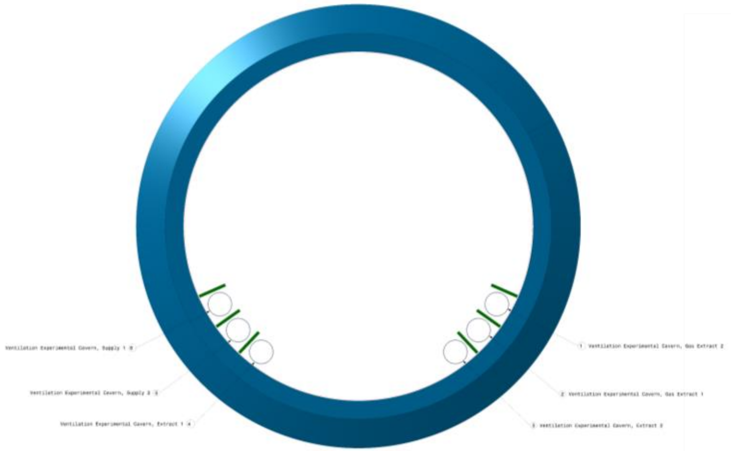


FCC-ee Underground Structure at point A



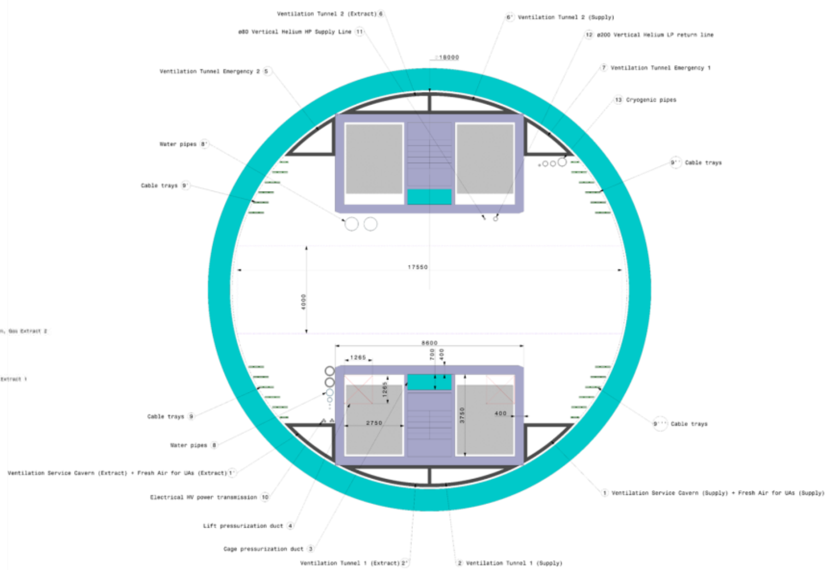
FCC-ee Underground Structure at point A

Experiment Shaft ø18m



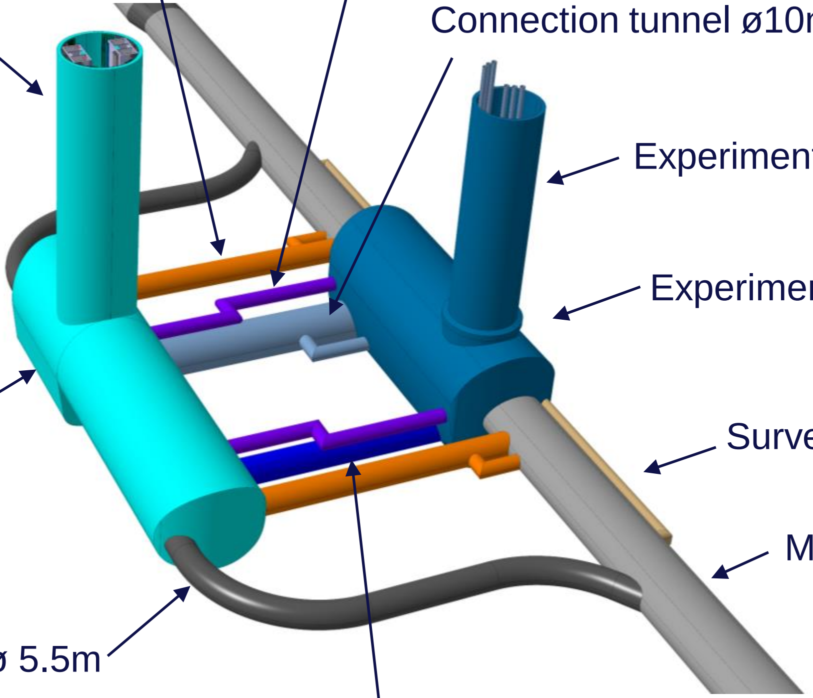
1	Ventilation experimental cavern, Gas extraction 2
2	Ventilation experimental cavern, Gas extraction 1
3	Ventilation experimental cavern, Extraction 2
3	Ventilation experimental cavern, Extraction 1
4	Ventilation experimental cavern, Supply 2
5	Ventilation experimental cavern, Supply 1

Service Shaft ø18m



1	Ventilation service cavern (Supply)+Fresh air for UAs (Supply)
2	Ventilation tunnel 1 (Supply)
2’	Ventilation tunnel 1 (Extraction)
3	Cage pressurization duct
4	Lift pressurization duct
5	Ventilation tunnel emergency
6	Ventilation tunnel 2 (Extraction)
6’	Ventilation tunnel 2 (Supply)
7	Ventilation tunnel Emergency 1
8	Water pipes
9	Cable trays
9’	Cable trays
10	Electrical HV power transmission
11	ø80 Vertical helium HP supply line
12	ø200 Vertical helium LP return line

FCC Underground Structure at point D



F. Valchkova-Georgieva EN-ACE

Documentation in EDMS

FCC Integration Approvals

- FCC-INF-SPC-0005 (v.0.2) FCC Integration - Requirements for Point A
- FCC-INF-SPC-0006 (v.0.2) FCC Integration - Requirements for Point B
- FCC-INF-SPC-0007 (v.0.2) FCC Integration - Requirements for Points D ans J
- FCC-INF-SPC-0008 (v.0.2) FCC Integration - Requirements for Point F
- FCC-INF-SPC-0011 (v.0.2) FCC Integration - Requirements for Point G
- FCC-INF-SPC-0009 (v.0.1) FCC Integration - Requirements for Point H
- FCC-INF-SPC-0010 (v.0.1) FCC Integration - Requirements for Point L
- FCC-INF-SPC-0012 (v.0.2) FCC Integration - Requirements for the Arcs
- FCC-INF-SPC-0013 (v.0.2) FCC Integration - Requirements for the Alcoves

FUTURE CIRCULAR COLLIDER — REQUIREMENTS FOR INTEGRATION OF — FCC-INF-SPC-0005 | EDMS 3126003 v.0.2 — Date: 2024-12-06 — DRAFT

Future Circular Collider

INTEGRATION

REQUIREMENTS FOR INTEGRATION OF FCC-EE AND FCC-HH AT POINT A

Document identifier:	FCC-INF-SPC-0005 | EDMS 3126003 v.0.2
Date:	2024-12-06
Work package/unit:	Technical Infrastructures / Integration

Abstract:

This document describes the configurations and 3D integrations for the FCC-ee and FCC-hh underground infrastructures at point A with concerning civil engineering constraints. It outlines the requirements of the FCC technical infrastructure work packages, such as survey, electricity, cooling & ventilation, cryogenic systems, safety, transport, and requirements from some beam line equipment groups, such as magnets, beam instrumentations, vacuum.

1 / 15

more info on <u>3D integration models for experimental areas</u> in the talk from F. Valchkova at 17:10 in room 4/3-006

Considerations on Experiment Caverns Design

- The caverns to be constructed are similar in span to the CMS and Atlas caverns constructed for the LHC, but with substantial reductions in number and diameters of shafts.
- Unlike CMS and ATLAS, there is no specific requirement for the Experiment and Service caverns to be very close together and a distance of 50m is currently considered as the optimum spacing between the caverns – it would also reduce the magnetic stray field of the h-h detector magnet(s)
- Although this increases the lengths of the connecting tunnels (and services inside!) 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 risky.

Considerations on Experiment Caverns Design

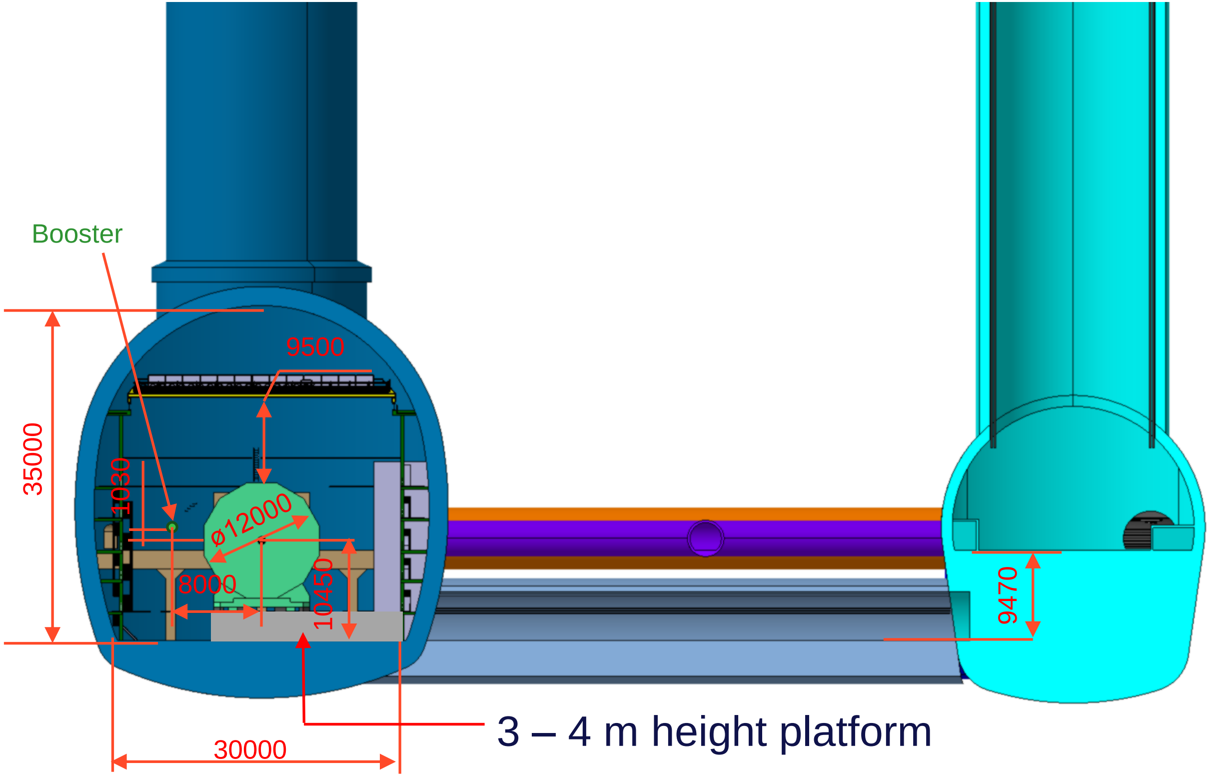
- The rationale in designing the experiment caverns at FCC has been:

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

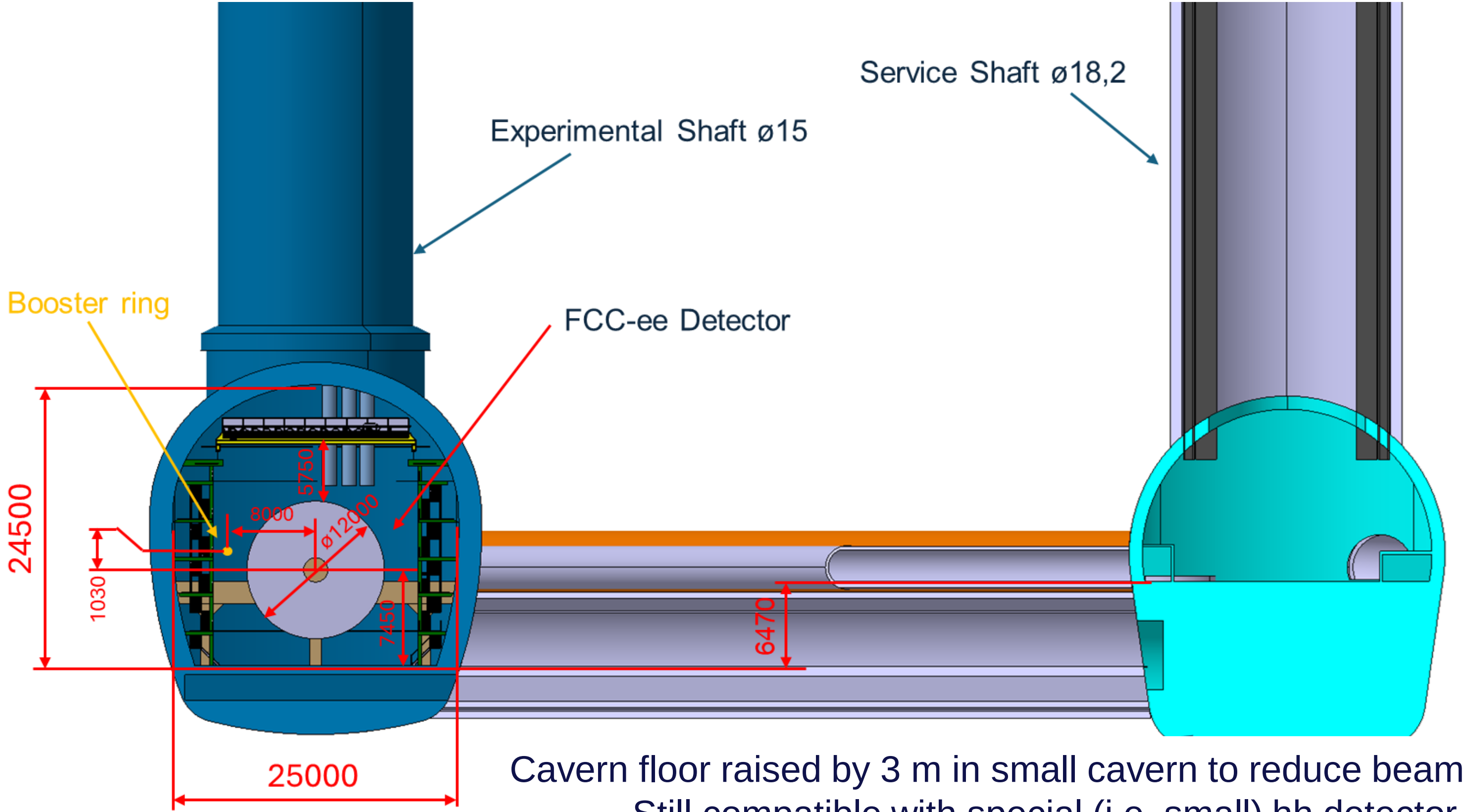
  True, but:

  - Beam height for hh is much higher than for ee → cavern shall have raised floor
  - MDI for hh much simpler than for ee → the optimum cavern layout for an ee-detector is transversal to the beam, as it was built for LEP (and also designed for CLIC detectors). The choice of a longitudinal cavern significantly complicates the design of both the detector and the MDI region, in particular in the small experimental points.

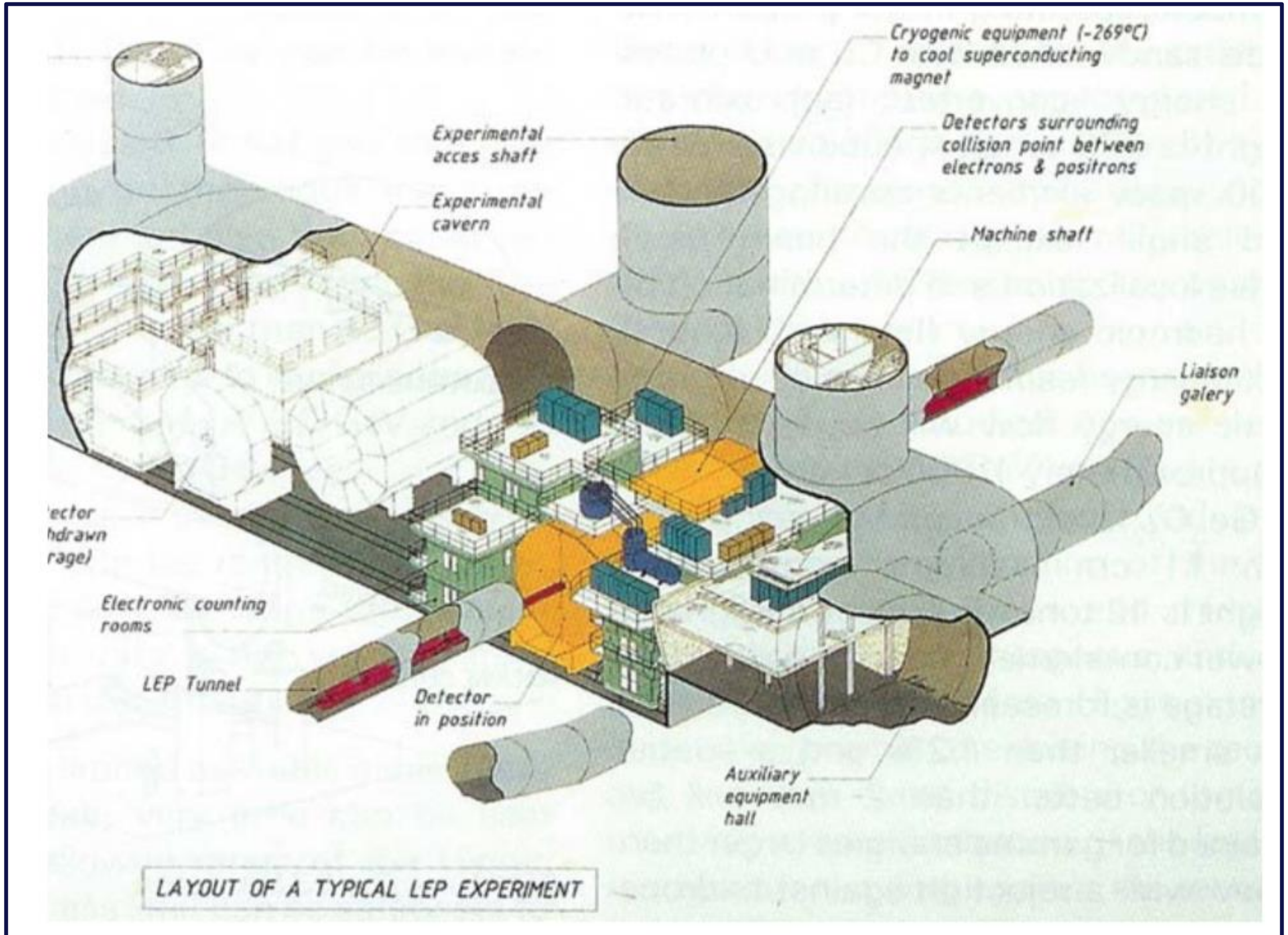
FCC-ee Underground Structure at point A



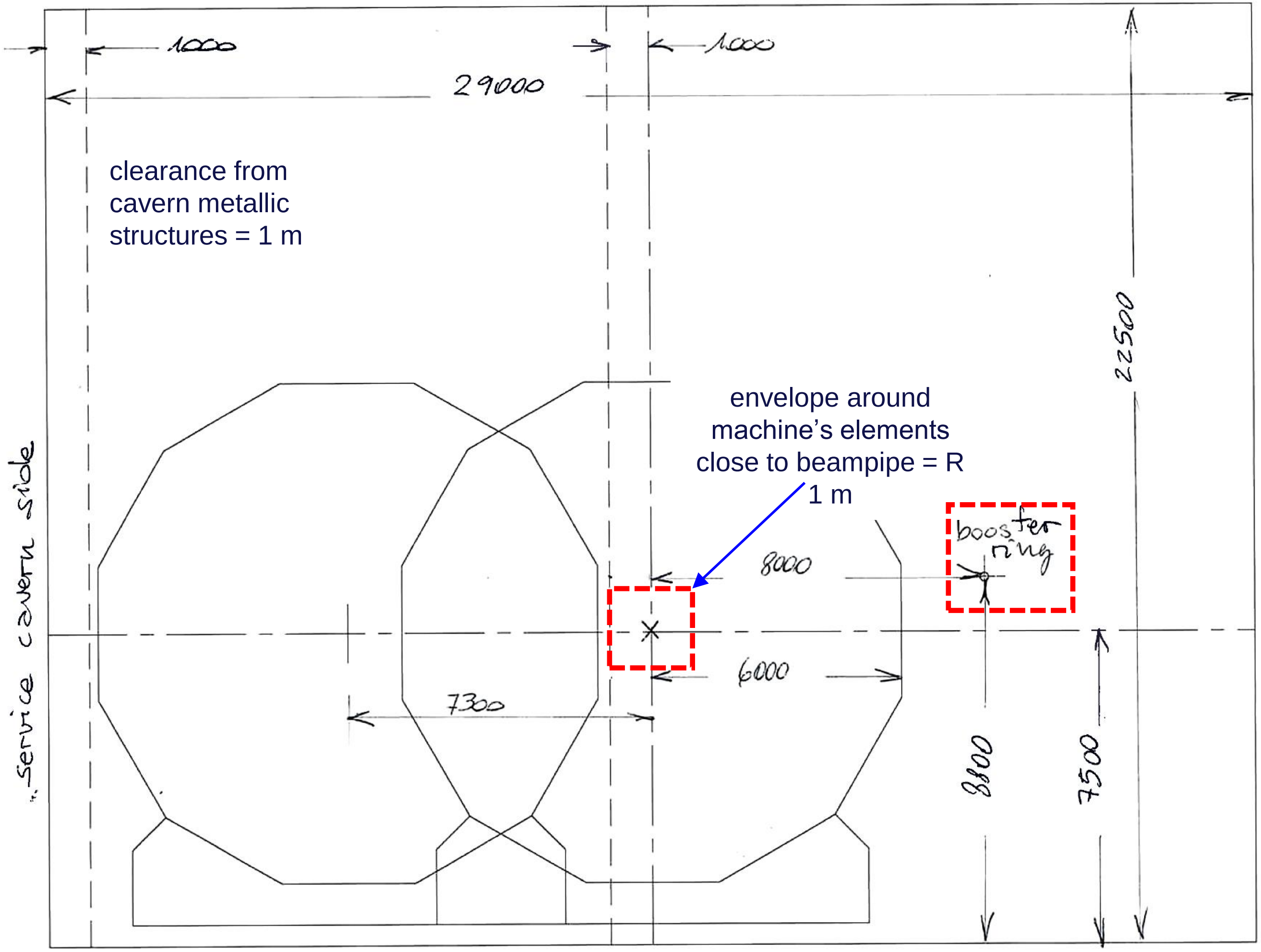
FCC-ee Underground Structure at point D



Cavern floor raised by 3 m in small cavern to reduce beam-height.
Still compatible with special (i.e. small) hh detector.

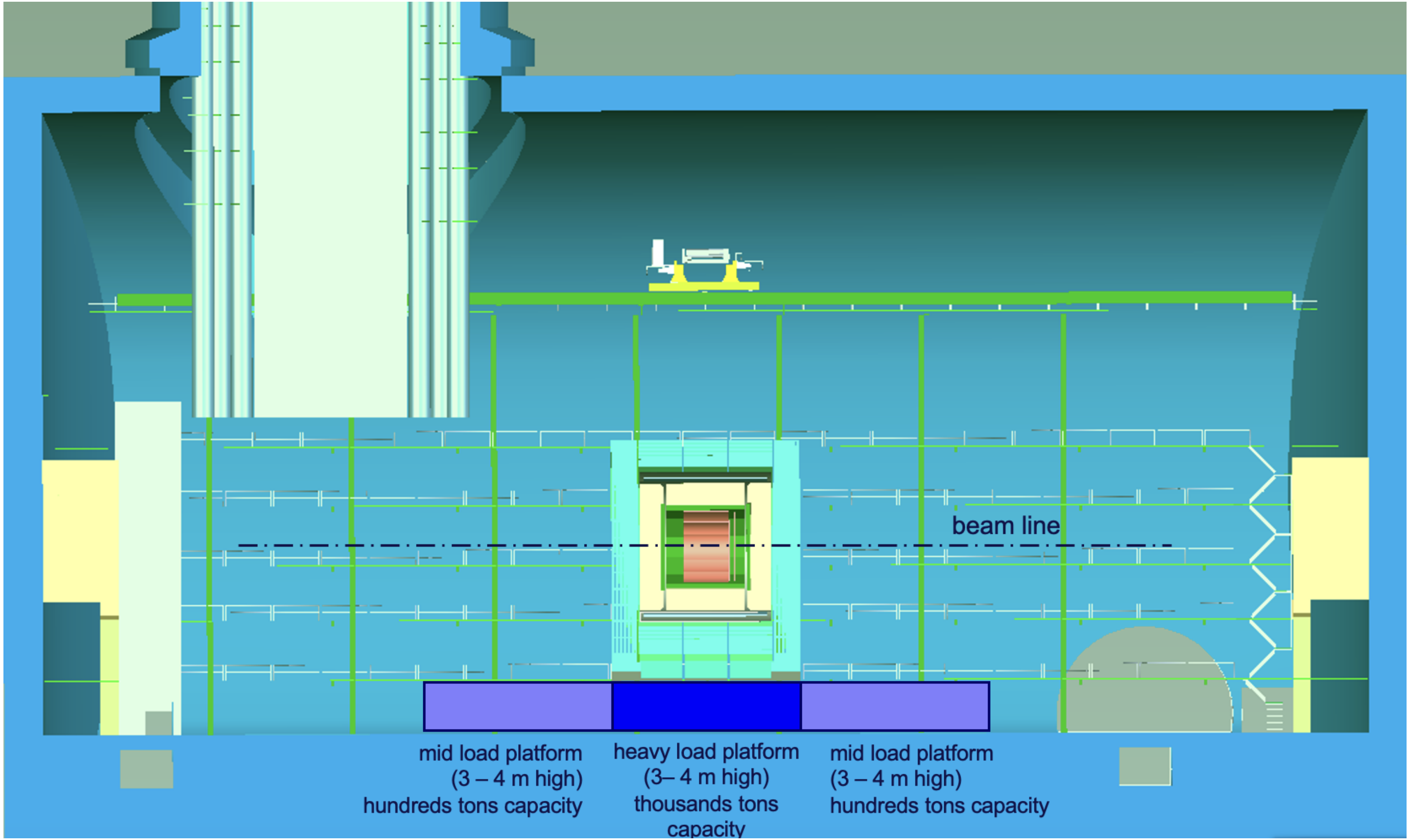


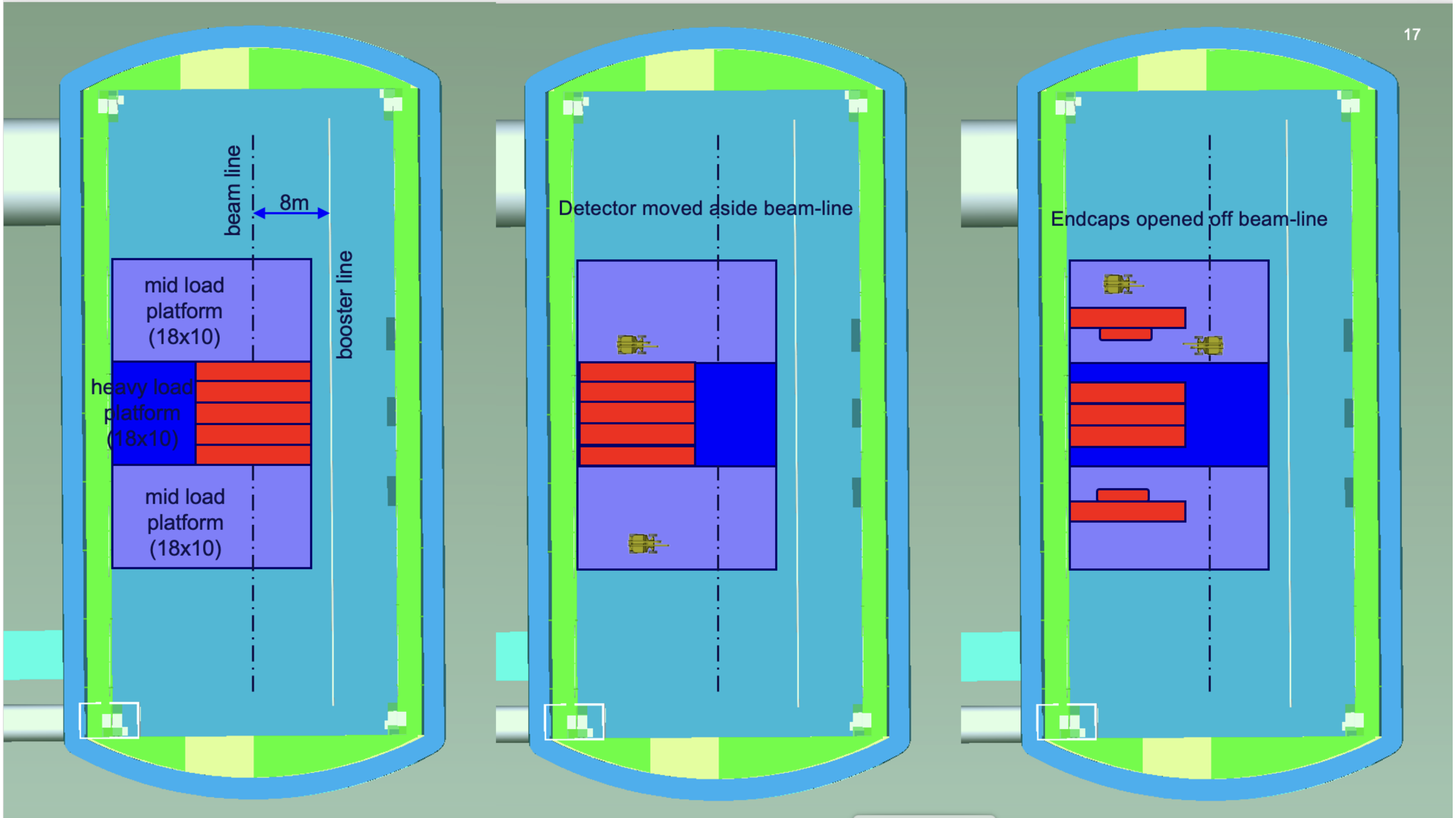
LEP time:
experiment cavern trasversal to beam axis. Three shafts (!)
Note the detector in parking position for maintenance.



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

Feasible with tight constraints in the large caverns (sites A & G), impossible in small cavern sites (D & J)

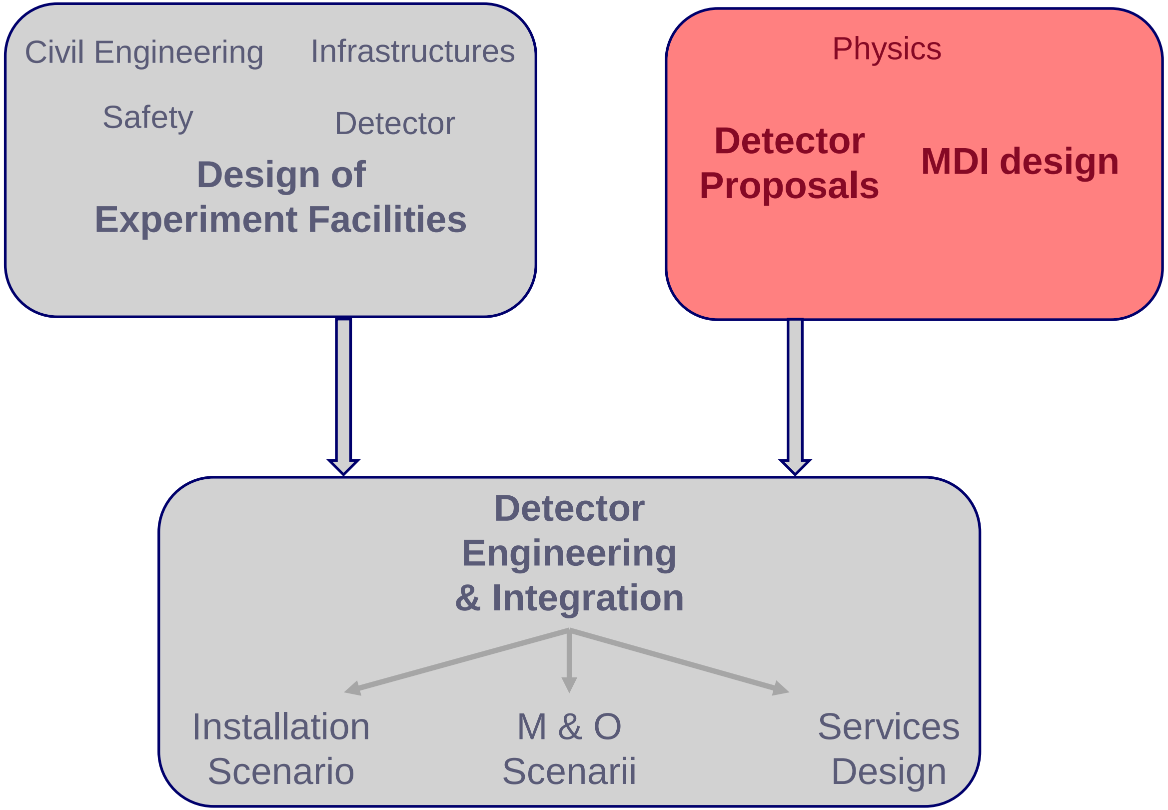

beam line
mid load platform
(3 – 4 m high)
hundreds tons capacity
heavy load platform
(3– 4 m high)
thousands tons
capacity
mid load platform
(3 – 4 m high)
hundreds tons capacity


17
beam line
8m
booster line
mid load platform (18x10)
heavy load platform (18x10)
mid load platform (18x10)
Detector moved aside beam-line
Endcaps opened off beam-line

MDI & Detector Proposals

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

} Cryostat (superconducting)

- Beam Positioning Monitor
- Beam-pipe + vacuum flanges/valves + bellows

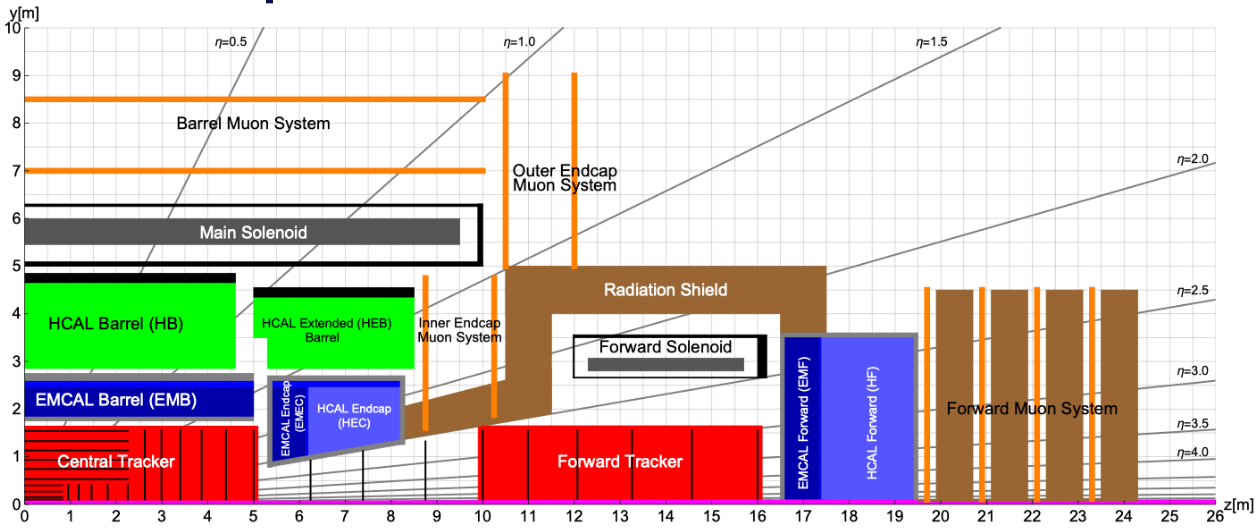
from the Detector side

- Luminometer
- Vertex detector / Inner Tracker + their services
- Mask for background suppression

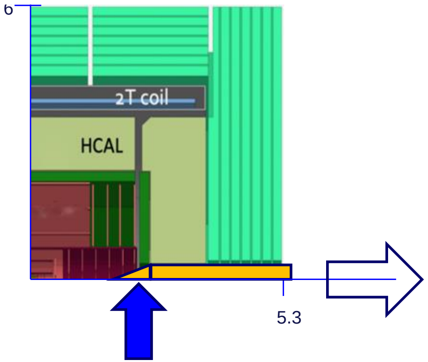
common to both:

- Supporting structures
- Alignment system
- Vibration stability features

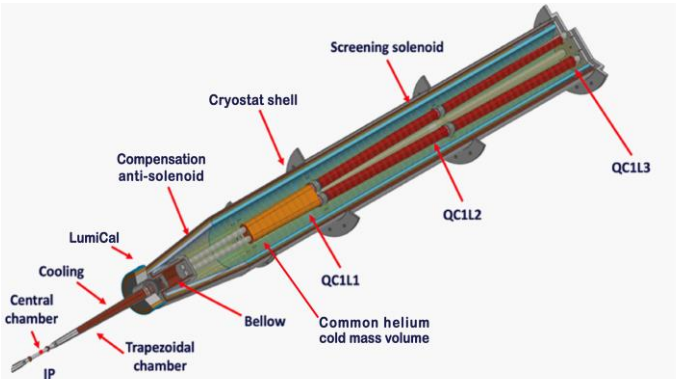
Comparison between h-h and e-e MDI regions



Last machine element here



Last machine element here

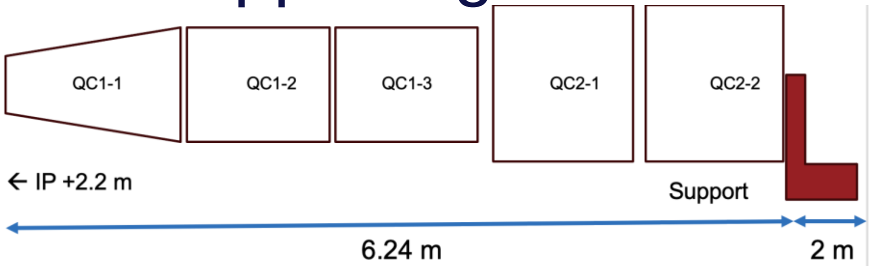


Machine-Detector Integration in FCC-ee is a major challenge. To access the inner detector parts, an adequate detector's segmentation and opening sequence has to be carefully studied.

Possible QCs layouts and their supporting structures

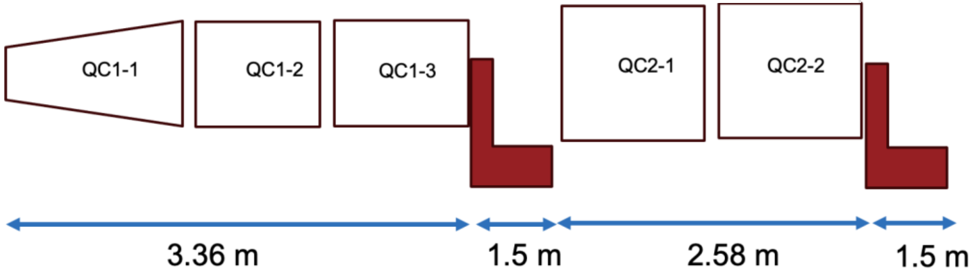
Option 1:
IR QC1 and QC2 in one cryostat and girder.

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



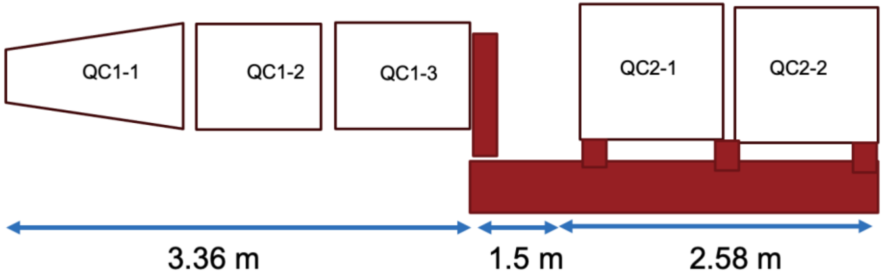
Option 2a:
IR QC1 and QC2 in two different cryostats and girders.

- 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

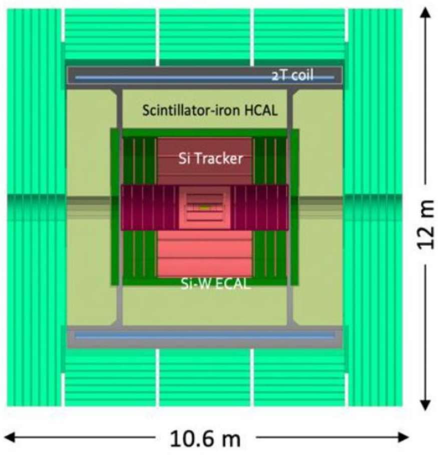


courtesy J. Seeman / SLAC

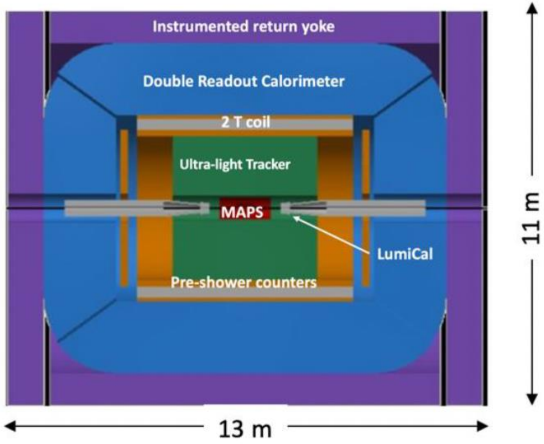
Detectors typical dimensions

The three detector proposals show comparable dimensions, this facilitate the integration study.
The largest monolithic object is the superconducting coil within its cryostat, or the IDEA’s barrel Calorimeter.

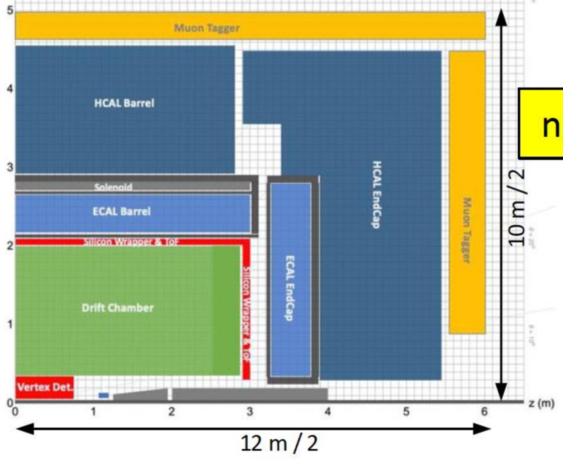
CLD



IDEA



ALLEGRO (Noble Liquid ECAL based)



new

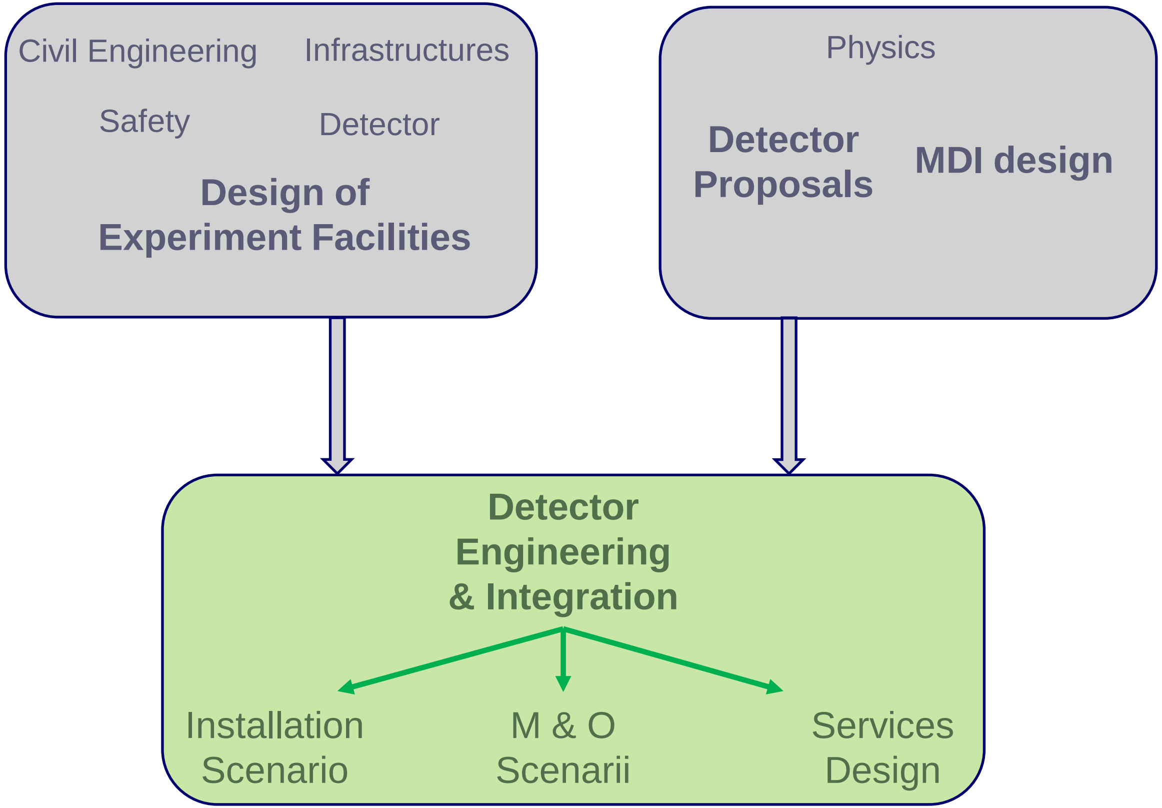
- Silicon Vertex detector + Tracker
- High granularity calorimetry
- Muon system
- Large coil outside calorimeter

- 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

Detector Integration

After having considered the constrains imposed by the external environment, in particular the layout of the experiment cavern and the interface with the beam-line elements (MDI), the following part will focus on the possible installation and mantenance & operation scenarii.



Detector assembling strategy

The way the detector is assembled on the beamline depends on many factors:

- The detector segmentation (moving endcaps, fixed barrel)
- The geometry of the cavern and the shaft(s)
- The handling tools available on surface and underground (cranes)
- The MDI layout, that essentially determines the sequence how pieces must be installed.

Detector assembling strategy

Assembling the detector on surface has several advantages:

- Space constrains less critical than underground → large assembly halls
- Accessibility from all sides
- Large detector parts tested on surface before lowering
- Repairs or last-minute changes easier to be implemented
- Crane underground is mid-size capacity (e.g. 20 tons).

Cons:

- It requires a large shaft to lower down pre-assembled detector parts (e.g. full endcap disk).
- Detector check-out needed after lowering.

Detector assembling strategy

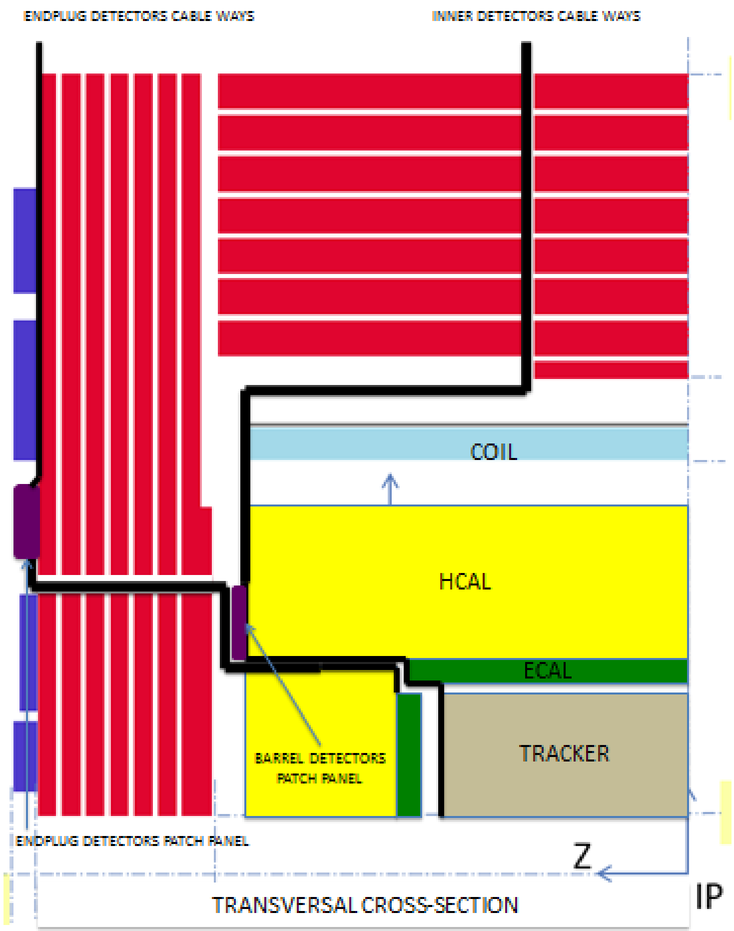
Assembling the detector underground has the following advantages:

- The shaft size is fit to the largest detector component (typically the magnet cryostat) and the hall on surface is smaller.
- Detector check-out and commissioning at the same time.

Cons:

- Timely delivery of detector elements for assembling
- Requires large capacity crane underground (e.g. 80 – 100 tons).
- Repair and modification tasks require more time.

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

Detector opening scenarii

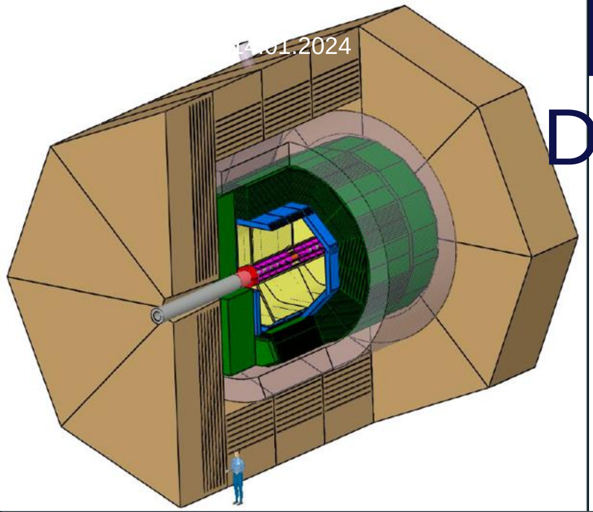
Detector vs machine requirements:

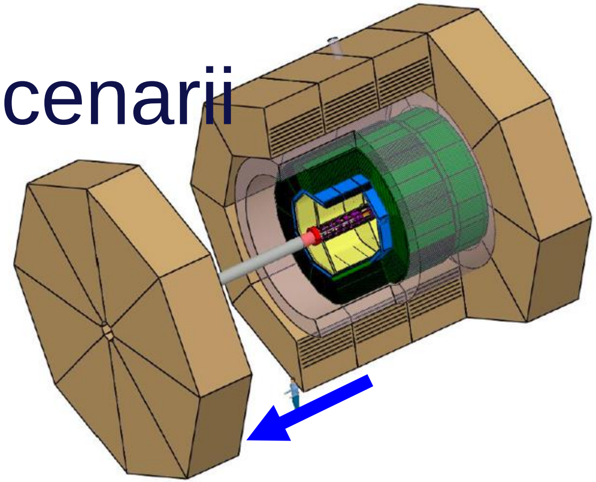
Detector side:
- Detector acceptance and hermeticity
- Simple opening sequence – minimal services disconnection & handling
- Accessibility to detector inner parts in reasonable time during shut-downs

Machine side:
- Stability of the FFQ supports
- Quick and reliable alignment procedure
- Beampipe vacuum preserved during short-accesses

A. Gaddi, F. Valchkova, G. Roy, K. Oide

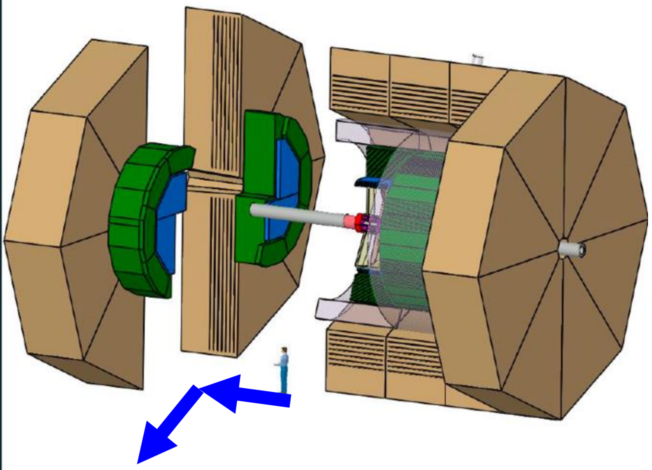
Detector opening scenarii

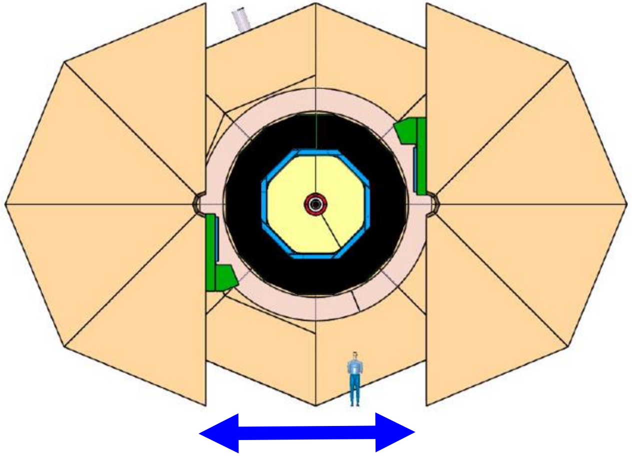




Solid Endcaps

Long longitudinal stroke to access inner detector elements. Last machine elements cantilevered & removed for opening.





Split Endcaps

Combined short longitudinal stroke + transversal opening to mitigate impact on last machine elements envelope. Detector acceptance seriously compromised in the forward region.

Detector opening scenarii

The detector’s endcaps could be opened following three different options:

#1. Full longitudinal opening of the two endcaps.

Detector acceptance in the forward region depends on machine layout

FFQ and other machine elements beyond detector endcaps shall be removed (with their supports). BP vacuum broken also in cold pipes. Realignment of the machine needed.

#2. Limited longitudinal opening to disengage the detector endcaps plus transversal opening (split endcaps) or diagonal opening of the split endcaps.

Split endcaps significantly deteriorate detector precision measurements

The cross section of the FFQ cryostat determines the envelope into which the machine elements just behind the detector endcap shall ideally stay. This constraint refers specifically to the cryo-services of the FFQ assembly.

BP vacuum stay (or Ne flushing), no realignment needed.

A. Gaddi, F. Valchkova, G. Roy, K. Oide

Detector opening scenarii

#3a. Transversal shift of the full detector plus the FFQ assembly (parking position), then extraction of the FFQ and full longitudinal opening of the detector endcaps

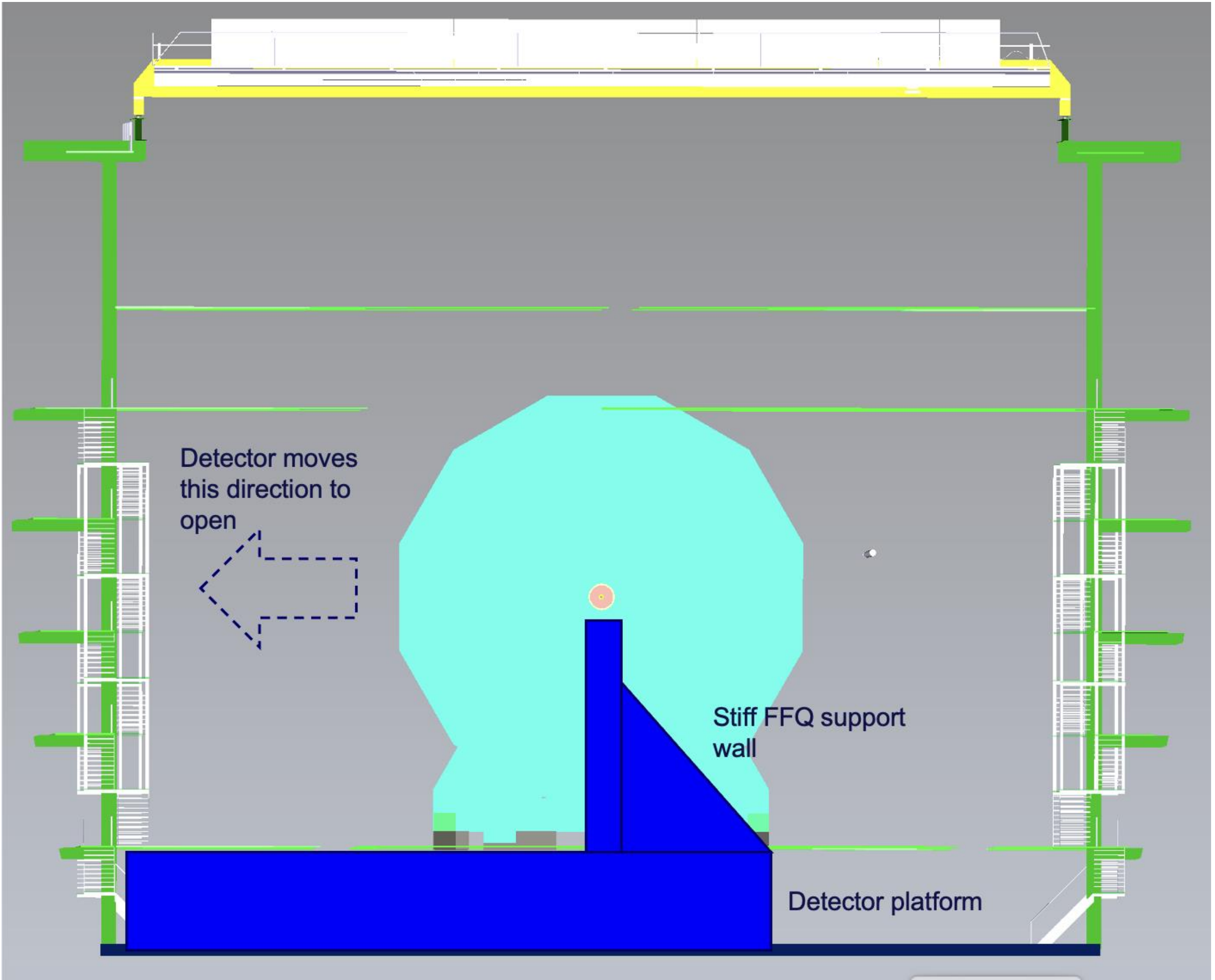
Detector acceptance preserved.

FFQ assembly stays inside the detector, temporarily supported by the detector's endcaps. Machine elements beyond detector endcaps also stay in place. Vacuum is broken for detector beampipe. Realignment needed.

#3b.Longitudinal pull-back of the FFQ assembly, followed by a transversal shift of the full detector (parking position), then full longitudinal opening of the detector endcaps

Detector acceptance preserved.
FFQ assembly is mechanically isolated from detector supporting and positioning and extracted before transversal movement. Vacuum is broken for detector beampipe. Realignment needed.

A. Gaddi, F. Valchkova, G. Roy, K. Oide



Scenario #3

In large experiment sites A & G there is enough clearance to envisage to move the detector aside the beamline and get full access to the detector's inner parts.

The FFQ can either be removed before the translation or move with the detector and then be removed from the garage position.

In small experiment sites D & J this scenario is only possible by adding an alcove (approx.10x25m) on the near side of the ring.

Accessibility to detector internals during long shut-downs vs year-end technical stops.

Whilst during a long shut-down it is reasonable to remove the machine elements (and their services) closest to the detector, the short length of a year-end technical stop of few weeks/months would suggest to try to preserve the alignment of the FFQ and the BP vacuum.

This is possible only in the scenario #2, thus it is of paramount importance that, for scenarios #1 & #3, the FFQ have a quick and reliable alignment system. If the re-alignment is done at the same time of the BP vacuum pumping, the full operation shall be completed within a week.

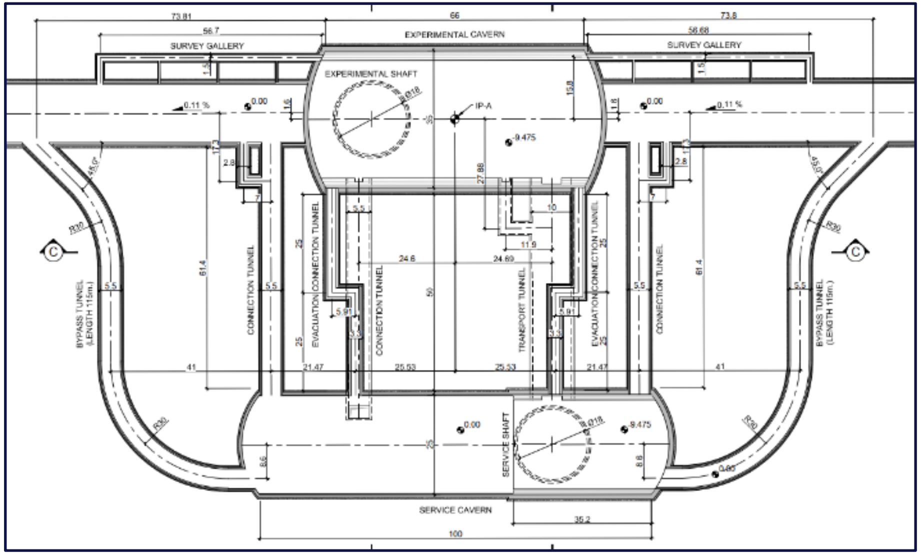
Outlook

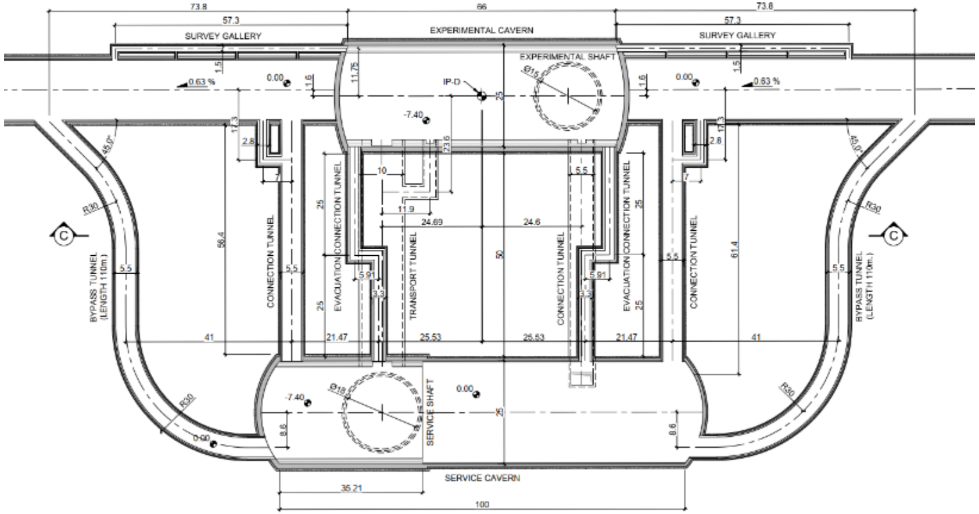
Progresses have been made to solve some inconsistency between the civil engineering design and the detector proposals (beam height). Discussions to be continued on the layout of the service cavern, the connecting tunnels and possibility of transversal shifting of the detector in the small cavern complex (alcove) – opening scenario #3.

Fruitful discussions going on with K. Oide and G. Roy on the MDI layout between +5 and +15m from IP.

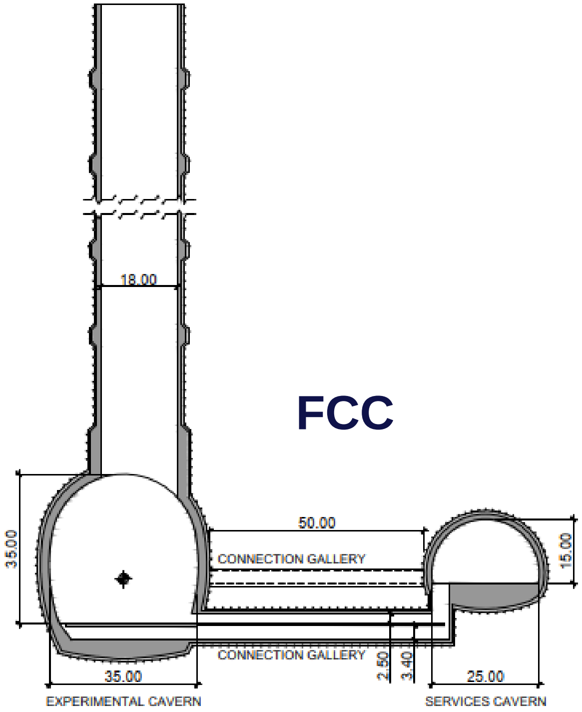
Start looking at the details of the different detector proposals for their engineering and integration, including the opening sequence, following the scenarii depicted here before, for both short and long machine shutdowns.

Back-up slides

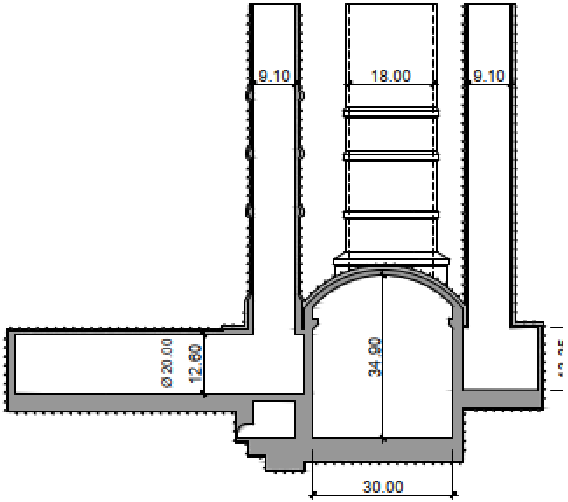

73.81
66
73.8
56.7
SURVEY GALLERY
EXPERIMENTAL CAVERN
56.68
SURVEY GALLERY
EXPERIMENTAL SHAFT
Ø18
IP-A
0.11 %
0.00
-9.475
CONNECTION TUNNEL
EVACUATION CONNECTION TUNNEL
TRANSPORT TUNNEL
BYPASS TUNNEL (LENGTH 115m.)
R30
61.4
24.6
24.69
11.9
5.91
21.47
25.53
41
SERVICE SHAFT
SERVICE CAVERN
35.2
100


73.8
66
73.8
57.3
SURVEY GALLERY
EXPERIMENTAL CAVERN
57.3
SURVEY GALLERY
EXPERIMENTAL SHAFT
Ø15
IP-D
0.63 %
0.00
-7.40
CONNECTION TUNNEL
EVACUATION CONNECTION TUNNEL
TRANSPORT TUNNEL
BYPASS TUNNEL (LENGTH 110m.)
R30
56.4
61.4
24.69
24.6
11.9
5.91
21.47
25.53
41
Ø18
SERVICE SHAFT
SERVICE CAVERN
35.21
100

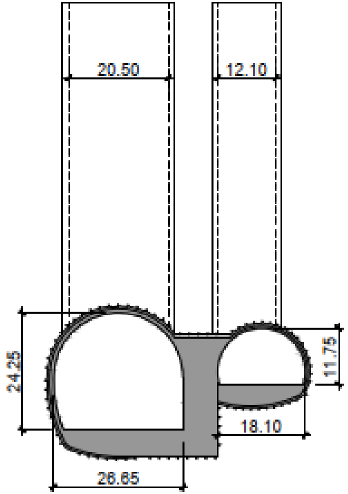
Comparison FCC wrt ATLAS and CMS Cavern Complex



FCC

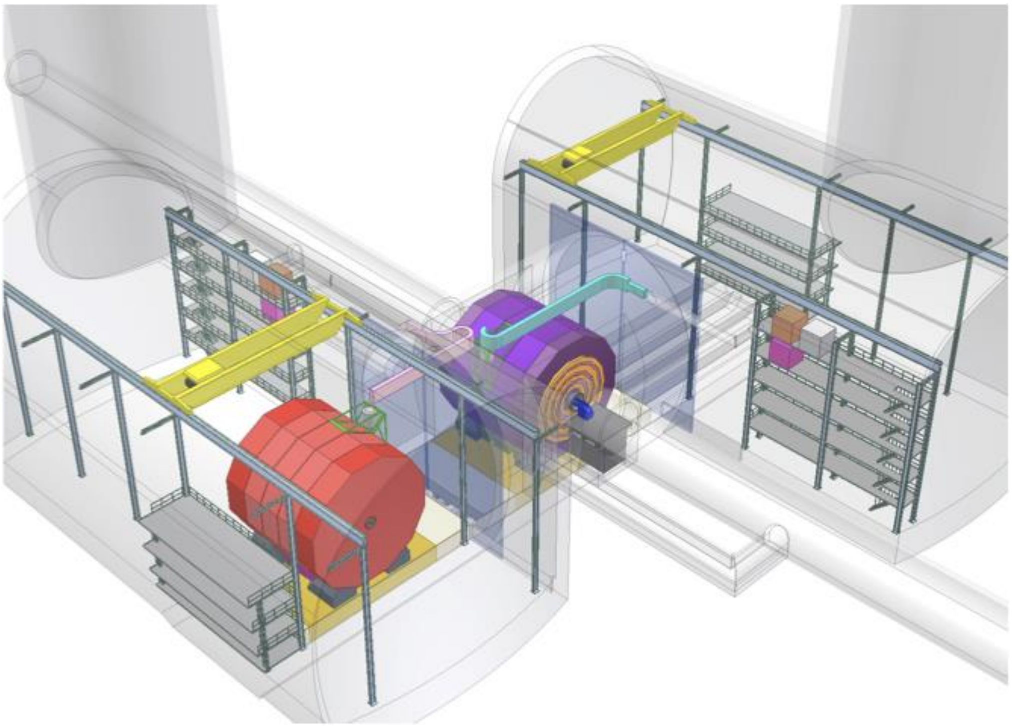


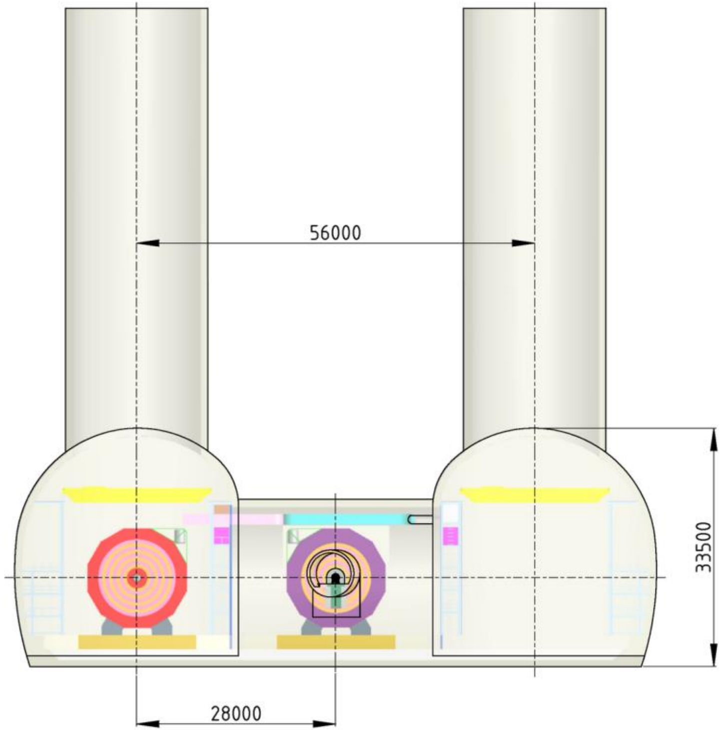
ATLAS



CMS

ILC / CLIC Push-Pull Cavern Layout





by A. Gaddi, H. Gerwig / CERN

Detector opening scenarii

General consideration common to all the detector opening scenarii:

- The design of the FFQ assembly, including their cryo-services, must include the possibility of being disconnected from the conical BP chambers, that are mechanical integrated with the vertex detector, at z = 1190 mm, via a bellow and a remote actuated flange plus one or two vacuum valves to isolate the vacuum pipe of the quadrupoles (cold vacuum pipe).
- The FFQ assembly is supported cantilevered by a removable pillar at the edge of the endcaps from the ground to be mechanically decoupled from the detector (opening option 1). If the pillar supporting the FF assembly cannot guarantee enough stiffness, then the cavern floor on the vertical projection of the beamline, shall be raised to a convenient height to increase the pillar stiffness (this rules out the opening option 1 hereabove). The maximum width of such structure shall be limited to 2m to allow the detector to be opened from the parking position (option 3) in the large cavern site.

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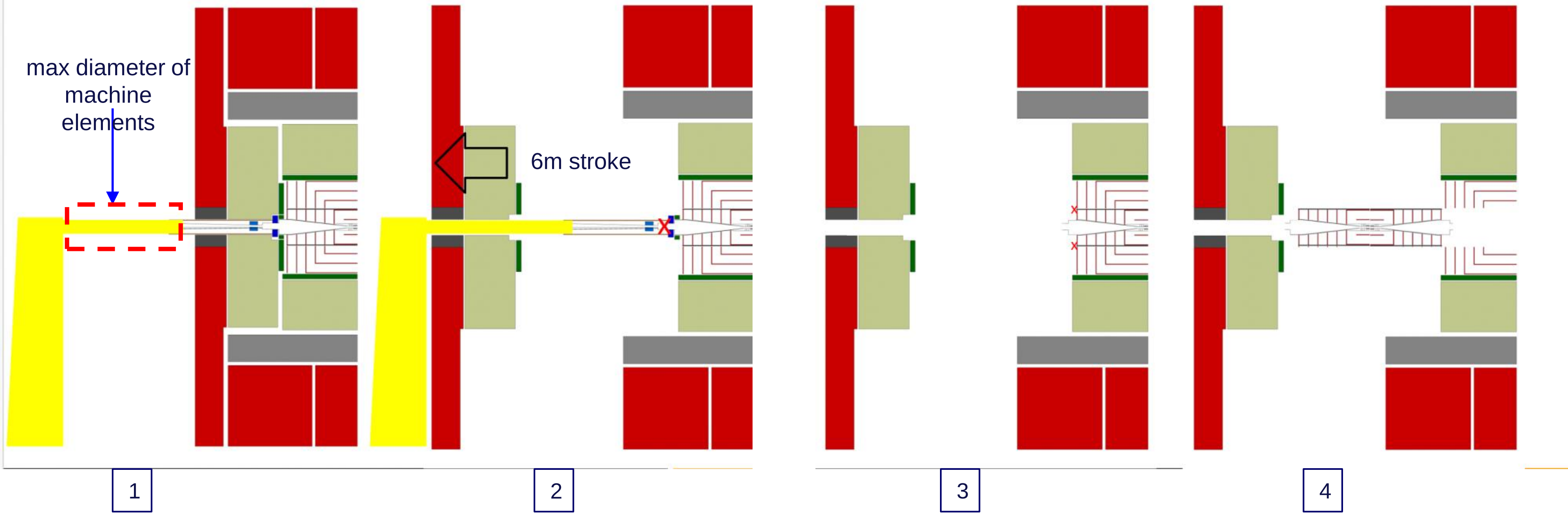
Scenario for inner detector assembly or servicing



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 MDI layout at point A/G

NAME	KEYWORD	S	L	ANGLE	X	Y	Z	T
%s	%s	%le	%le	%le	%le	%le	%le	%
FCCEE_P_RING	MARKER	0	0	0	0	0	0	
IP.1	MARKER	0	0	0	0	0	0	
IPA	MARKER	0	0	0	0	0	0	
DRIFT_0	DRIFT	2.20022502	2.20022502	0	0.03300214	0	2.1999775	
QC1R1.1	QUADRUPOLE	2.90022502	0.7	0	0.04350174	0	2.89989875	
DRIFT_1	DRIFT	2.98022502	0.08	0	0.0447017	0	2.97988975	
QC1R2.1	QUADRUPOLE	4.23022502	1.25	0	0.063451	0	4.22974913	
DRIFT_2	DRIFT	4.31022502	0.08	0	0.06465095	0	4.30974013	
QC1R3.1	QUADRUPOLE	5.56022502	1.25	0	0.08340025	0	5.55959951	
DRIFT_3	DRIFT	5.86022502	0.3	0	0.08790008	0	5.85956576	
QC2R1.1	QUADRUPOLE	7.11022502	1.25	0	0.10664938	0	7.10942514	
DRIFT_4	DRIFT	7.19022502	0.08	0	0.10784933	0	7.18941614	
QC2R2.1	QUADRUPOLE	8.44022502	1.25	0	0.12659863	0	8.43927551	
PQC2RE.1	MARKER	8.44022502	0	0	0.12659863	0	8.43927551	
DRIFT_5	DRIFT	8.56024471	0.12001969	0	0.12839886	0	8.5592817	
QC0.1	QUADRUPOLE	11.4602447	2.9	0	0.17189722	0	11.4589555	
DRIFT_6	DRIFT	19.0216369	7.56139222	0	0.28531385	0	19.019497	
QC3.1	QUADRUPOLE	21.9216369	2.9	0	0.32881222	0	21.9191708	
DRIFT_7	DRIFT	24.095566	2.17392908	0	0.36141994	0	24.0928553	
QC4.1	QUADRUPOLE	26.995566	2.9	0	0.40491831	0	26.9925291	
DRIFT_8	DRIFT	27.295566	0.3	0	0.40941814	0	27.2924953	
BC1.1	RBEND	83.6467184	56.3511524	0.00482702	1.11866191	0	83.6391295