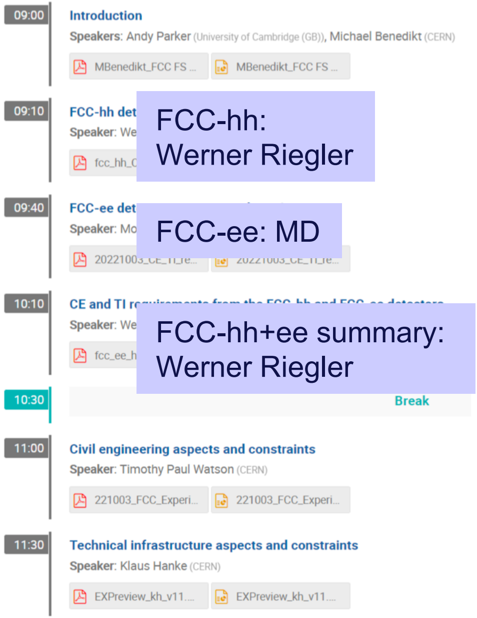
SUMMARY OF REVIEW ON REVIEW OF CIVIL ENGINEERING AND TECHNICAL INFRASTRUCTURE REQUIREMENTS FOR FCC EXPERIMENTAL SITES

The October 3-4 Review

Review goals and charge

…review the surface and underground CE and TI requirements, implied by the principal detector concepts (in particular detector magnets and main support structures) of both FCC-ee and FCC-hh, for construction, installation, operation and maintenance phases.

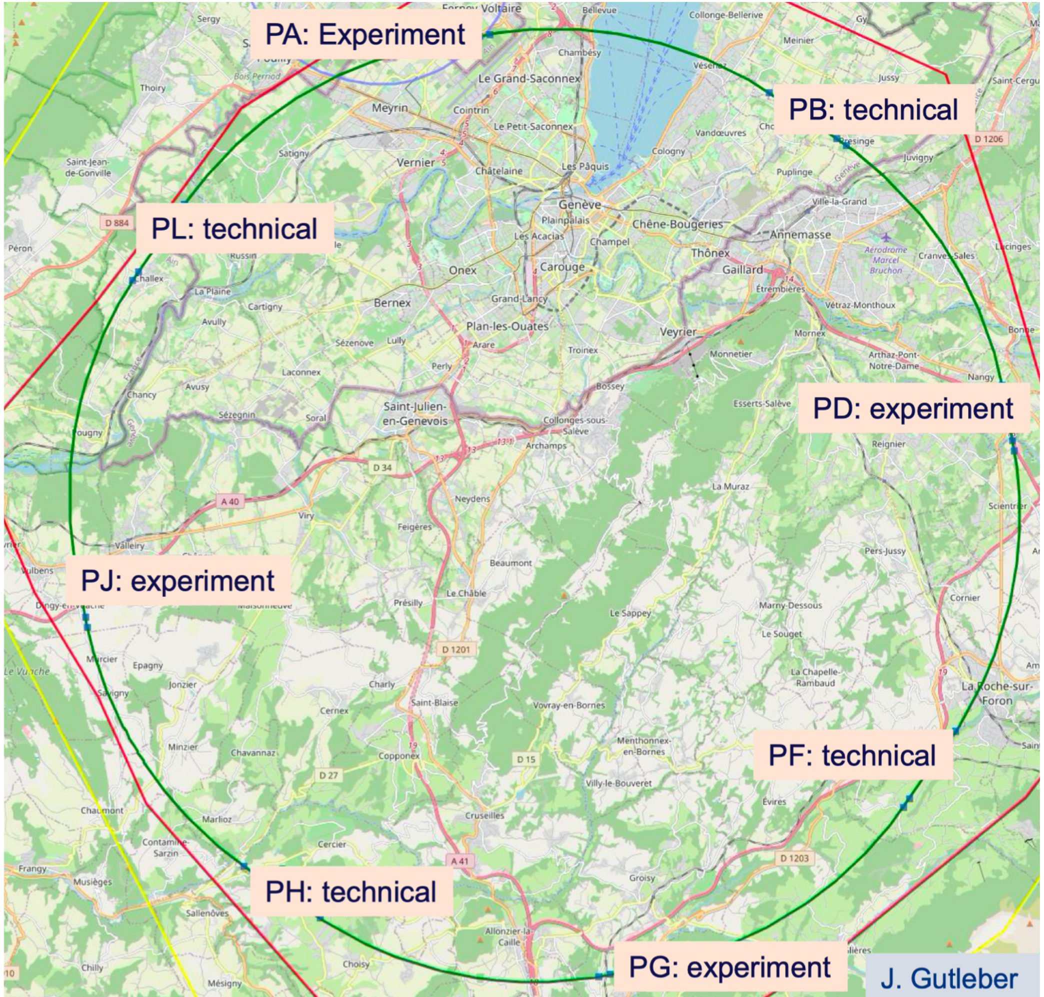
Presentations


09:00 Introduction
Speakers: Andy Parker (University of Cambridge (GB)), Michael Benedikt (CERN)
MBenedikt_FCC FS ... MBenedikt_FCC FS ...
09:10 FCC-hh det
Speaker: We
fcc_hh_C
FCC-hh: Werner Riegler
09:40 FCC-ee det
Speaker: Mo
20221003_CE_TI_re... 20221003_CE_TI_re...
FCC-ee: MD
10:10 CE and TI requirements from the FCC-hh and FCC-ee detectors
Speaker: We
fcc_ee_h
FCC-hh+ee summary: Werner Riegler
10:30 Break
11:00 Civil engineering aspects and constraints
Speaker: Timothy Paul Watson (CERN)
221003_FCC_Experi... 221003_FCC_Experi...
11:30 Technical infrastructure aspects and constraints
Speaker: Klaus Hanke (CERN)
EXPreview_kh_v11.... EXPreview_kh_v11....

Review committee

- **Composition**
  - Austin Ball (STFC),
  - Alain Chabert (SFTRF),
  - Peter Krizan (Jozef Stefan Institute),
  - Rolf Lindner (CERN),
  - Andrew Parker (University of Cambridge – Chairperson),
  - Roberto Tenchini (INFN Sezione di Pisa),
  - Frank Zimmermann (CERN – Secretary).

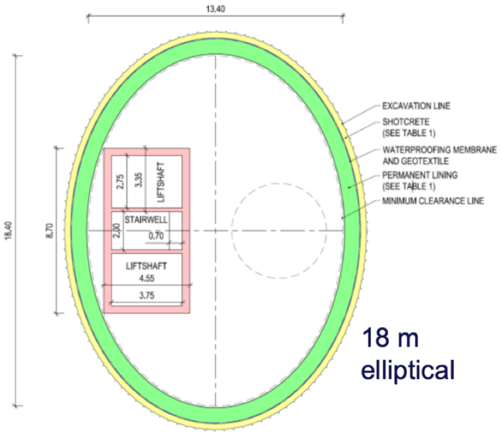
A reminder


PA: Experiment
PB: technical
PL: technical
PD: experiment
PJ: experiment
PF: technical
PH: technical
PG: experiment
J. Gutleber

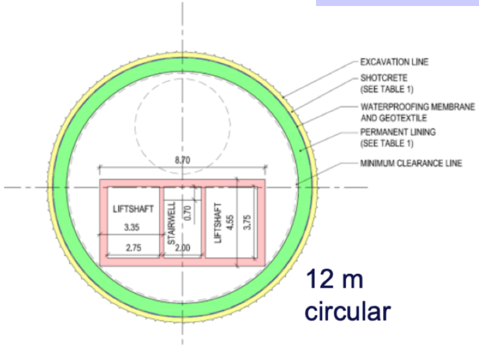
Liam Bromiley SCE-DOD-FS

Shafts

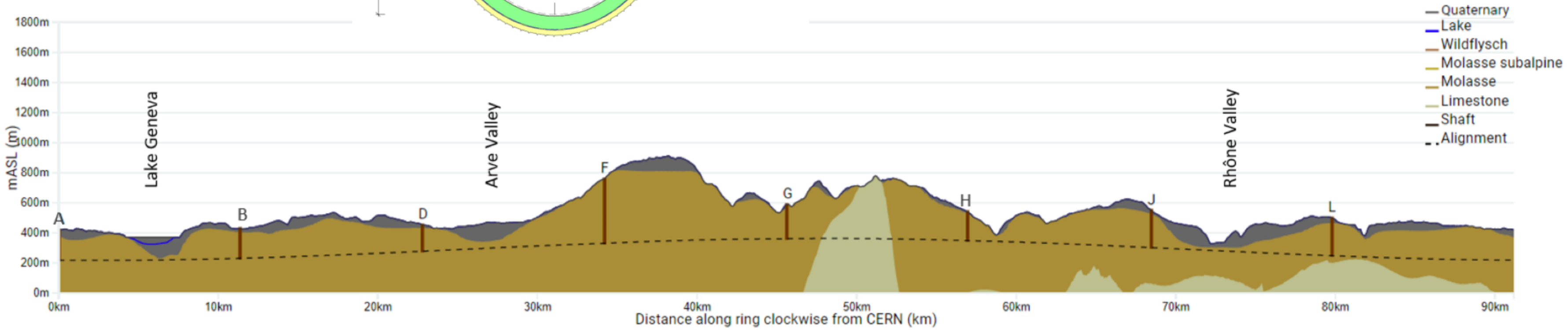
are deep …



18 m
elliptical



12 m
circular



Shaft depths:

A: 202 m   B: 200 m   D: 177 m   F: 399 m   G: 228 m   H: 139 m   J: 251 m   L: 253 m

Experimental shafts

…and surface area is scarce

Example: PA site close to LHC P8

Review starting point

Detectors are assumed to be assembled under ground as at LEP and LHC

- Saving on shaft volume and surface building needs

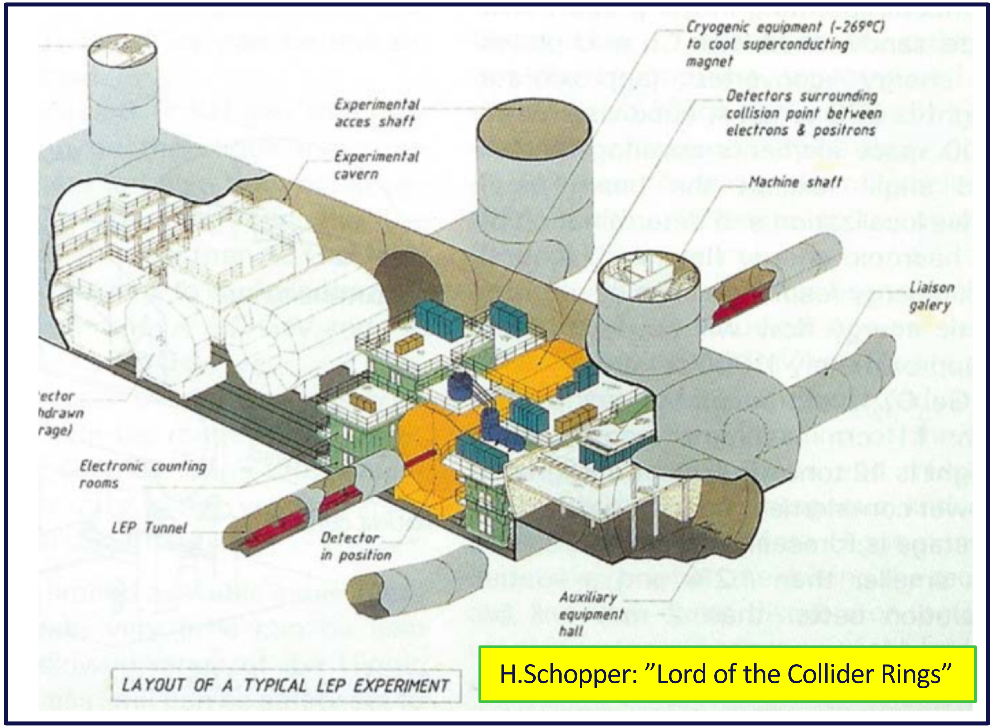
Did not consider a CMS type scenario with assembly of Coil and Yoke on the surface which would require a large diameter shaft, in the 20m range.

  - Similar scenarios pursued at ILC & CLIC

FCC-ee – Lessons from LEP

With similar sizes, FCC-ee detectors would fit into a typical LEP underground area

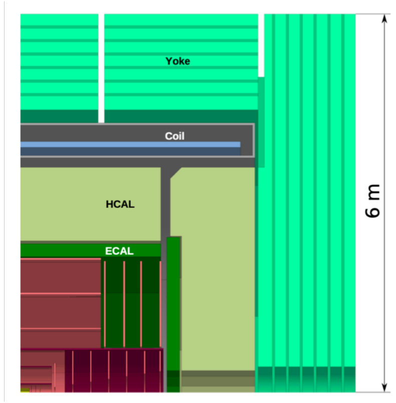
- Cavern: 70m long, 17m wide, 18.5 m high
- A single shaft of 10.1 m diameter
- Main cavern with enough space for detector, including barracks for electronics, cryogenics, services, and even empty space to move the detector into garage position (never used)
- No service cavern used by experiments



H.Schopper: "Lord of the Collider Rings"

Developing landscape of FCC-ee Detector Concepts

CLD



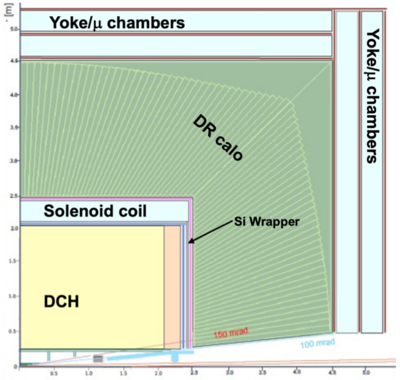
CDR

Conceptually extended from CLIC detector design
- Full silicon tracker
- High granularity silicon-tungsten ECAL
- High granularity scintilator-steel HCAL
- Instrumented return-yoke for muon detection
- Large 2 T coil surrounding calorimeter system

Engineering needed for adaptation to continous beam operation (no power pulsing)
- Cooling of Si-sensors & calorimeters

Possible detector optimisations
- Improved ECAL and momentum resolutions
- Particle identification (TOF and/or RICH)

IDEA

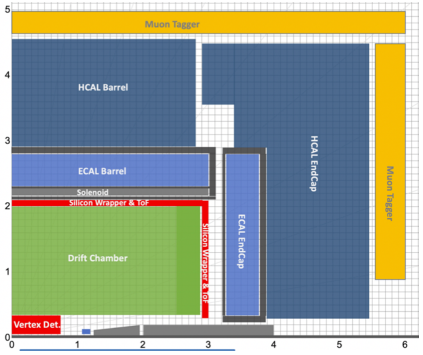


Specifically designed for FCC-ee (and CEPC)
- Silicon vertex detector
- Low X_0 drift chamber with high-resolution particle ID via ionisation measurement
- Silicon wrapper around drift chamber
- Light, thin 2T coil inside calorimeter system
- Pre-shower detector based on MPGC
- Dual-readout calorimeter; copper-scintilating/Cherenkov fibres
- Instrumented yoke with MPGC muon system

Possible detector optimisation
- Much improved EM energy resolution via crystal ECAL in front of coil

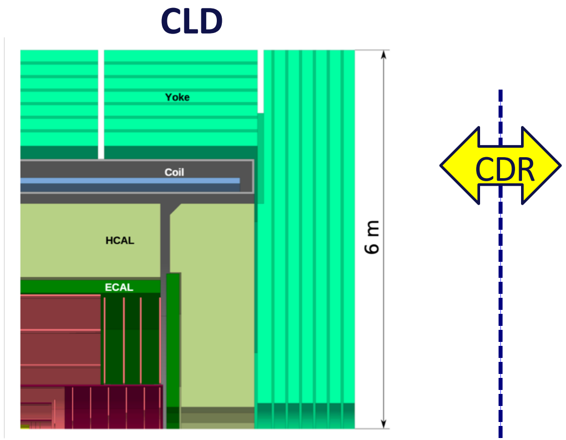
Noble-Liquid ECAL based

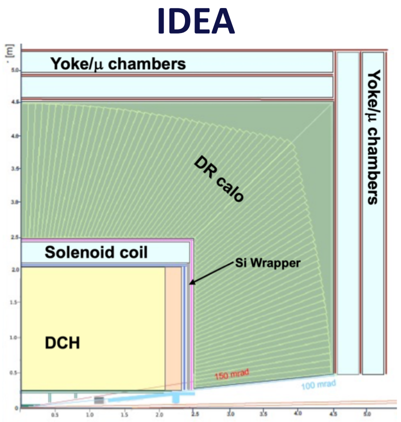
new

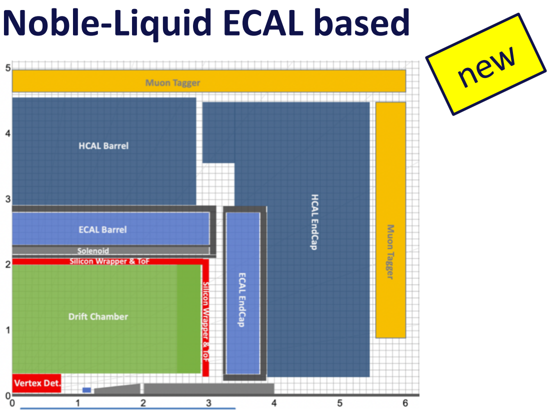


Specifically designed for FCC-ee, recent concept, under development
- Silicon vertex detector
- Low X_0 drift chamber with high-resolution particle ID via ionisation measurement
- Light, thin 2T coil inside same cryostat as ECAL
- High granularity Lead/Noble Liquid (LAr, possibly LKr) ECAL
- HCAL and muon systems to be specified

FCC-ee Detector Concepts







- All concepts fit inside 12x12 m envelope
- Tentatively, assume that largest single piece (undismountable) is coil/cryostat
- Assume that coil/cryostat dimensions allow remote production with transportation to site
  - CLD has the largest coil/cryostat with dimensions similar to that of CMS:
    - length x outer diameter = 7.4m x 8.55m [CMS: 12.5m x 7.2m]

FCC-ee needs

Consumables

Electricity: Consider a total need of **3 MW** for detector solenoid, accelerator quadrupoles, sub-detectors, and utilities

- Smaller than the 5 MW for LHC detectors
- Larger than the estimated 1 MW needed for ILC detectors

Gas & Cryogenics: Somewhere between LEP and LHC

- Detectors are generally smaller than at LHC
- The CLD detector concept has a considerably larger coil that LEP detectors

Dimensions and capacity of electricity, gas, and cryogenic systems of CMS will more than suffice.

Surface buildings

Detector pre-assembly and storage

- **As at LEP, need ~1000 m^2**

Computing system:

- Experience from ALICE with a comparable event rate as FCC-ee Tera-Z, but much higher particle multiplicity, is that space needs for computing are small
- No specific consequences on CE and TI

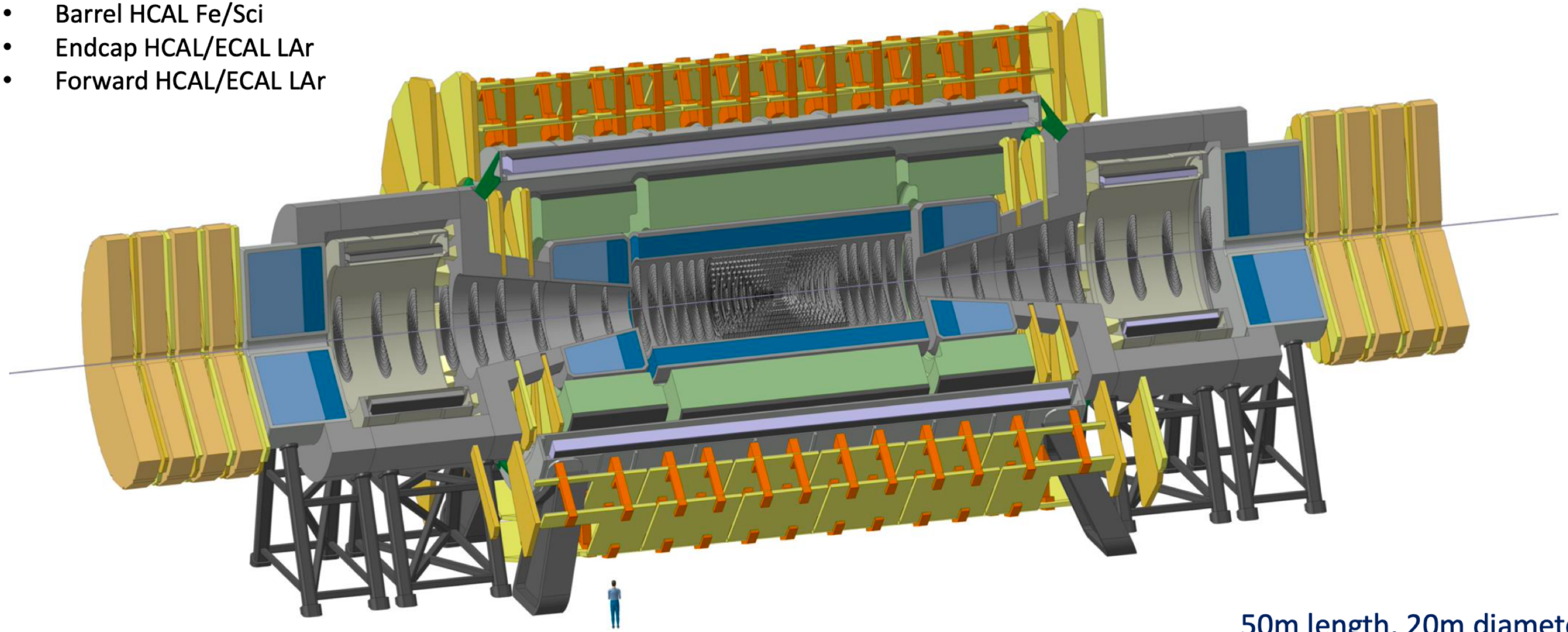
Offices:

- Experimental sites are away from CERN; people need places to work

FCC-hh Reference Detector

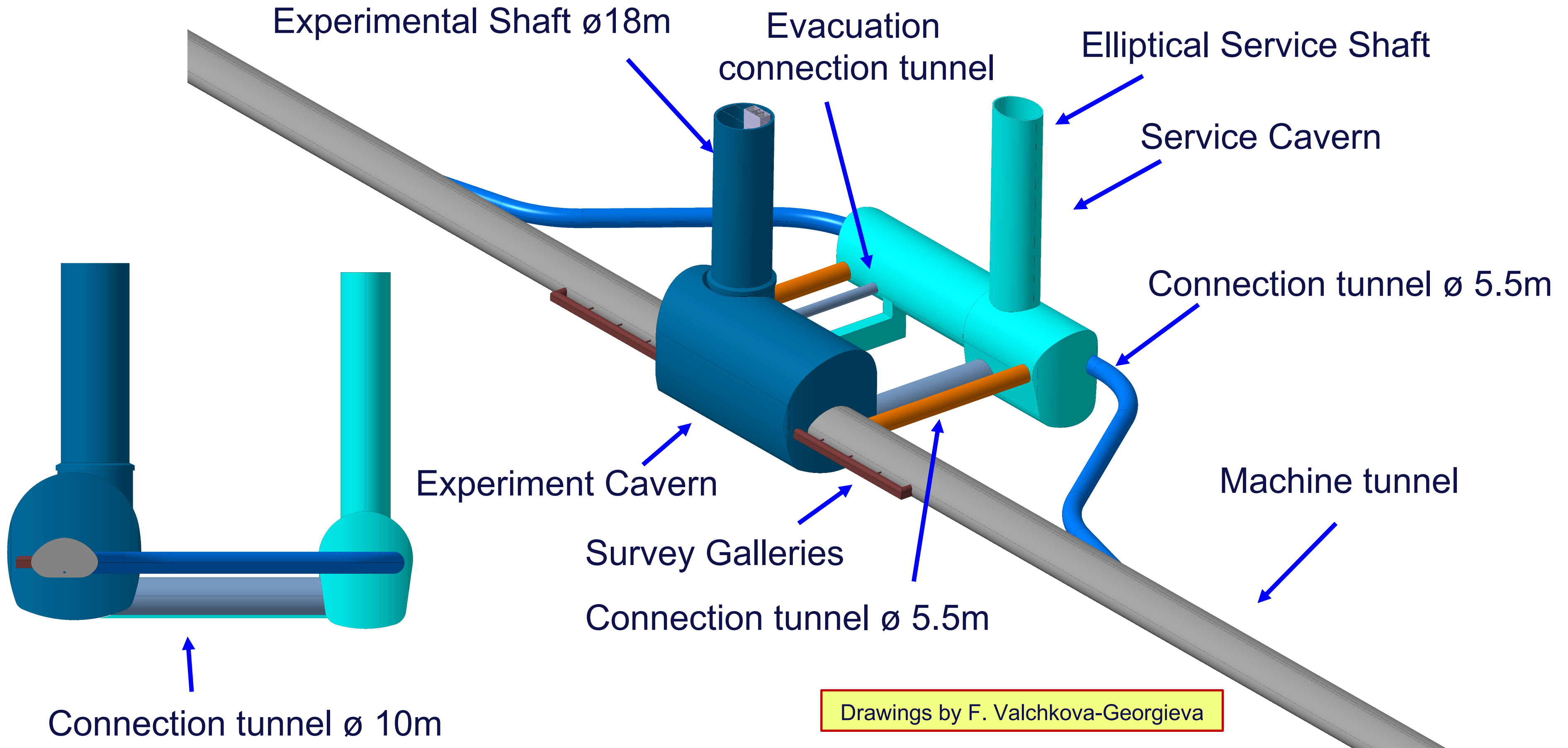
- 4T, 10m solenoid, unshielded
- Forward solenoids, unshielded
- Silicon tracker
- Barrel ECAL LAr
- Barrel HCAL Fe/Sci
- Endcap HCAL/ECAL LAr
- Forward HCAL/ECAL LAr

The cost and weight of a yoke that returns the magnetic flux is considered excessive.



50m length, 20m diameter similar to size of ATLAS

Proposed Layout for FCC-hh Experimental Cavern

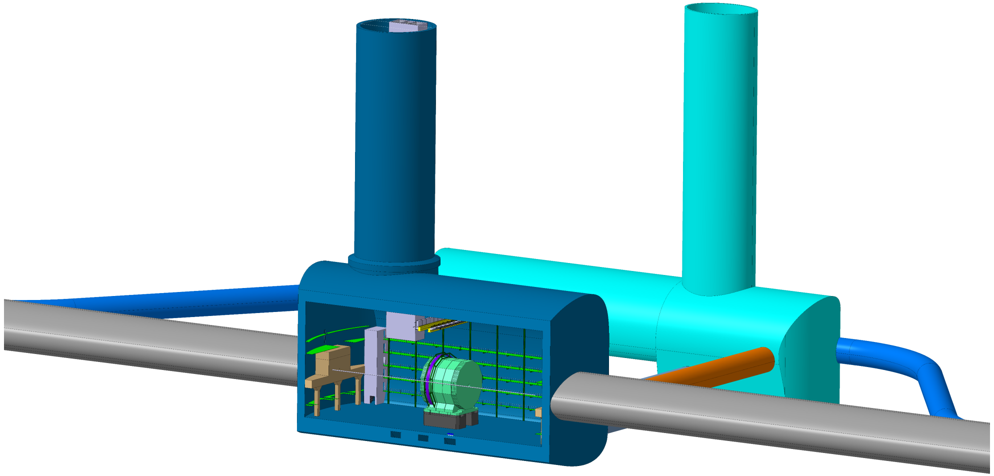


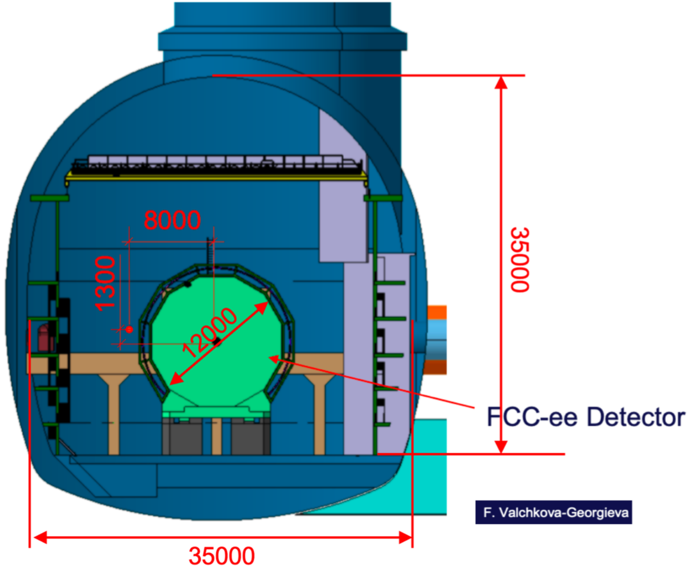
Drawings by F. Valchkova-Georgieva

FCC-hh Experiment Underground Structure

With FCC-ee detectors being considerably smaller than FCC-hh detectors, a baseline FCC-hh cavern works perfectly for the housing of a FCC-ee detector including all services

- cooling plants, cryo cold box, gas systems, electronics barracks

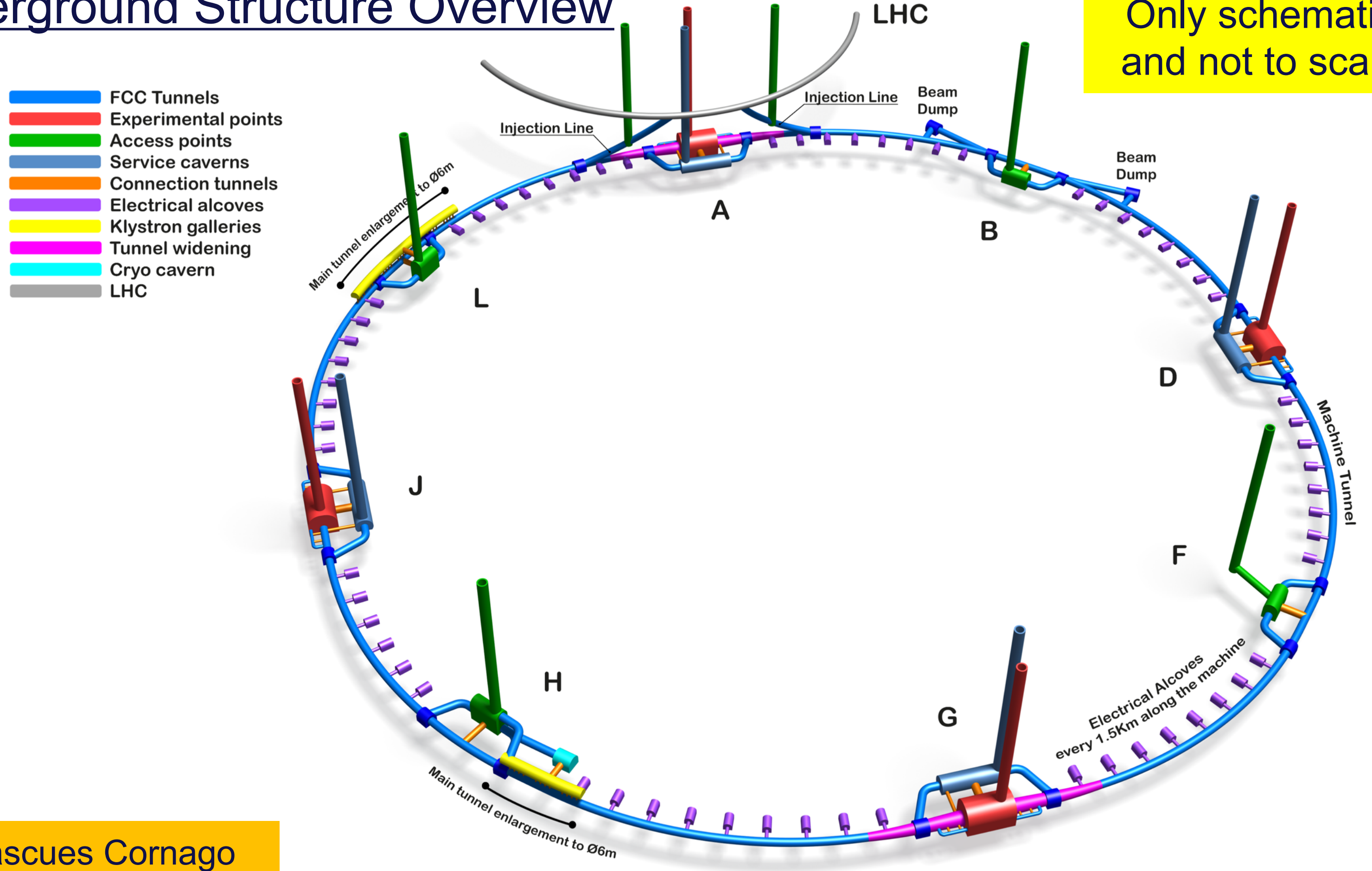




A FCC-ee detector would also fit well inside a somewhat smaller CMS-like cavern of size 53x25x25 m^3.
A shaft of 10m diameter is sufficient

FCC-ee Underground Structure Overview

Only schematic, and not to scale.



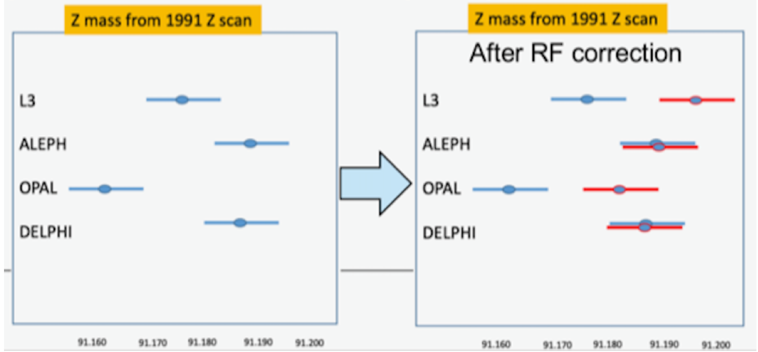
Courtesy A. Navascues Cornago

The case for four FCC-ee Interaction Points

One of the many advantgages of circular colliders: Can serve several IPs

2208.10466

- Overall gain in luminosity, in luminosity/MW, and in luminosity/kg CO_2 equivalent
  - Many measurements are statistics limited – some are tantalizingly close with only 2 IPs
    - E.g., Higgs self-coupling, search for Heavy Neutral Leptons, Flavour anomalies, Electron Yukawa coupling, etc.
- Variety of detector requirements may not be satisfied by one or even two detectors
  - E.g., high precision, high granularity, high stability, geometric accuracy, PID
  - Having four IPs allows for a range of detector solutions to cover all FCC-ee opportunities
- Four IPs provide an attractive challenge for all skills in the field of particle physics
- Redundancy is invaluable in uncovering hidden systematic biases or conspiracy of errors
  - E.g., m_z discrepancy at LEP in 1991
    - Found to be an effect of RF phases and voltages
    - Correction of ~+19 MeV for L3 and OPAL
    - Could have remained unnoticed for ever with
      - only ALEPH and DELPHI, or
      - only L3 and OPAL



Preliminary conclusions (i)

Michael Benedikt, October 7th

FCC-2110051230-APA

- **GENERAL**
  - The committee endorses the baseline concept for the FCC experiment site underground structures of an experimental cavern with a single experimental shaft for the main detector installation, linked via a transfer tunnel to the service cavern, with a second shaft, and connected via bypass tunnels to the machine tunnel on either side of the experimental area. This is an effective and efficient solution, taking into account also experience from LEP and LHC.

Shaft diameter: 17m

- **CAVERN SIZE**
  - The committee recommends that the cost change which would be produced by a change in the main cavern size be evaluated, in the event that it is possible to consider a smaller width than the default 35 m, perhaps as low as 30 m. Length: 66m
  - The decision to operate the cavern with a single shaft has implications for the logistics of the detector installation and operation which need to be studied.
  - Secondary experimental caverns could be of CMS size and costed for this. Height/Width: 25m; Length: 55m
  - We recommend that the construction of the service caverns, even though not strictly required for FCC-ee, be not staged, subject to proper cost estimates being checked for initial and staged construction. Also essential for FCC-ee, to keep machine cryogenic equipment vibrations far from the beam.

Preliminary conclusions (ii)

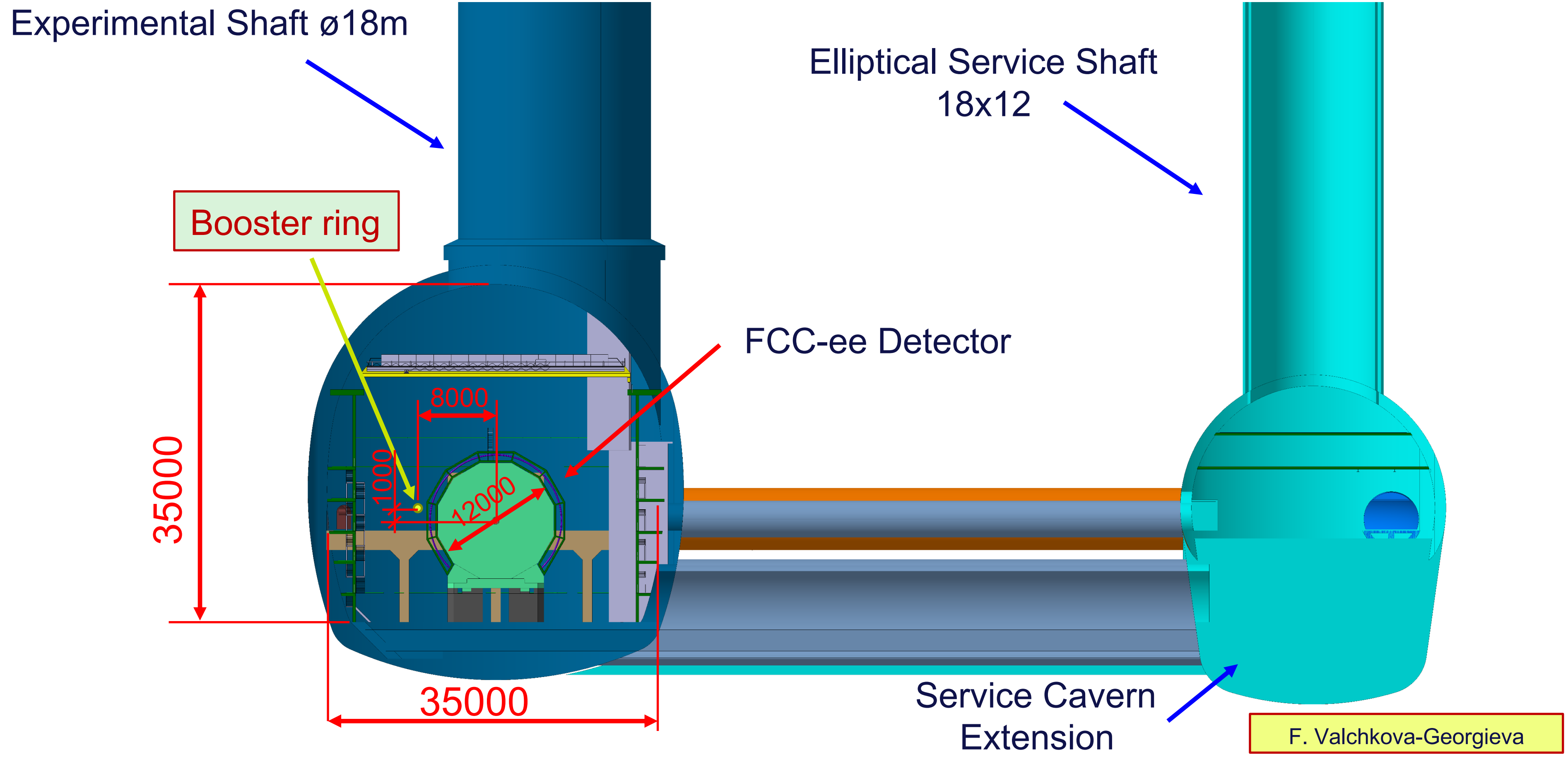
Study of FCC-ee detector stray field on the booster to be continued

- **STRAY FIELDS OF FCC-hh DETECTORS**
  - The committee is not yet convinced that all the implications of the large stray field from a detector magnet without a return yoke, as proposed for the two FCC-hh general-purpose experiments, are fully understood.
  - Therefore, we recommend that the option to build a return yoke is retained, and this option should be costed.
  - This recommendation may have implications for the default cavern size.
  - Working solutions for the effects of the stray field on all active components and passive structures nearby, including cranes, lifts, access and safety systems, as well as experiment-related infrastructures such as coolant pumps need to be considered, together with the cost of novel solutions, and the implications for operations.
  - The option to build a return yoke should only be discarded when convincing solutions to the above issues are in place.
- **NUMBER OF DETECTORS**
  - Plan for 4 FCC-hh experiments, two large general-purpose detectors and two specialized ones.
  - The plan for four ee detectors needs to be clearly justified on the basis of better science value for the investment in the infrastructure, for example the total delivered luminosity per run and the possibility of housing detectors optimised for different types of physics searches, in addition to physics arguments relating to systematics.

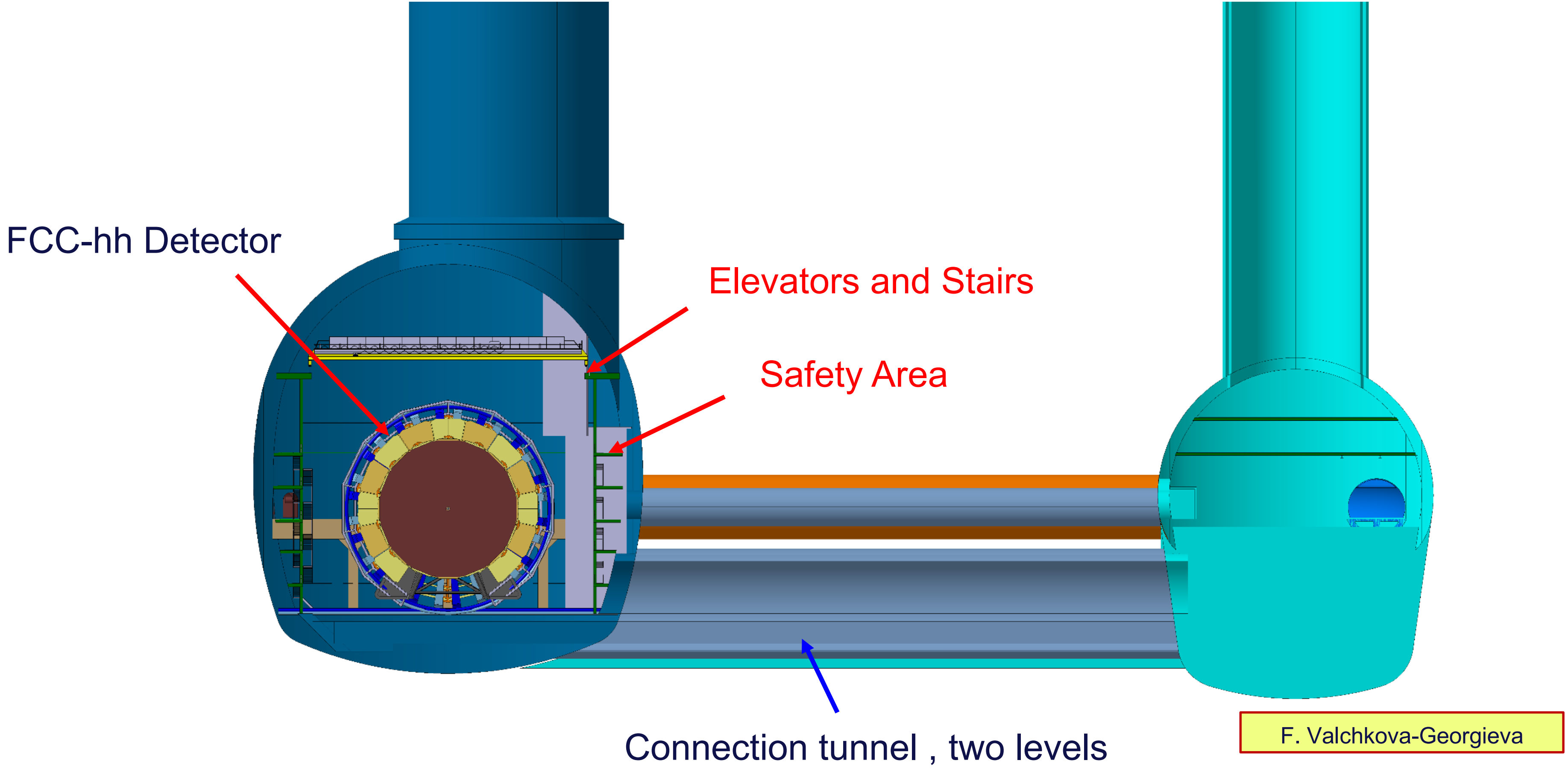
Preliminary conclusions (iii)

- **SURFACE SITES AND INFRASTRUCTURE**
  - Power needs (e.g. for experimental IT farms) are uncertain, and so a modular expandable approach to powering is recommended.
  - The available surface site size is quite limited due to surrounding land use and public infrastructure.
  - The final configuration of the surface site will require additional features, but at the moment the general-purpose detector site layout is dominated by the magnet production hall for FCC-hh general-purpose detectors, which is temporary; the magnet has to be built well before the detector assemblies and data centres; the big hall site can be repurposed. Check that the big CLD magnet can be transported to CERN from outside (or that its size can be reduced).
  - Parking and office spaces are needed, also food, recreation areas, rapid fire brigade and emergency responses. The most remote site must be an efficient, safe and attractive work place.
- **ACCESS AND OPERATIONS**
  - A lift in the experimental cavern shaft is foreseen as single direct access to the experimental cavern. The lift system will have to integrate with a pit-head radiation cover at the surface that must be closed during operation.
  - The integrated shaft, service cavern and bypass designs (i.e. staging areas, route to transfer tunnel, machine and experiment technical areas etc.) should allow factorised and, as much as possible simultaneous, activity by machine and experiment teams.
  - The large-diameter transfer tunnel linking experimental and service caverns will need appropriate separation for radiation aspects that will need to respond to various access procedures and safety conditions.

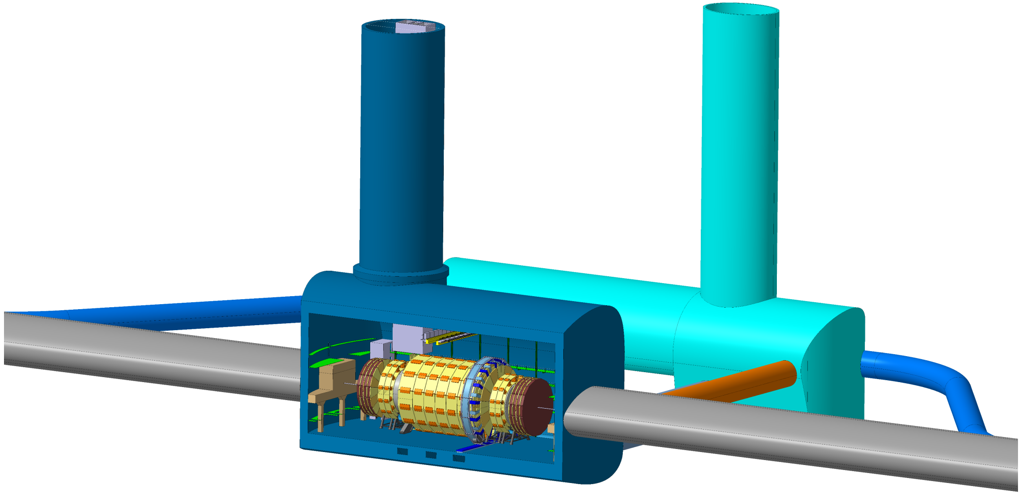
FCC Experiment Underground Structure version 2022

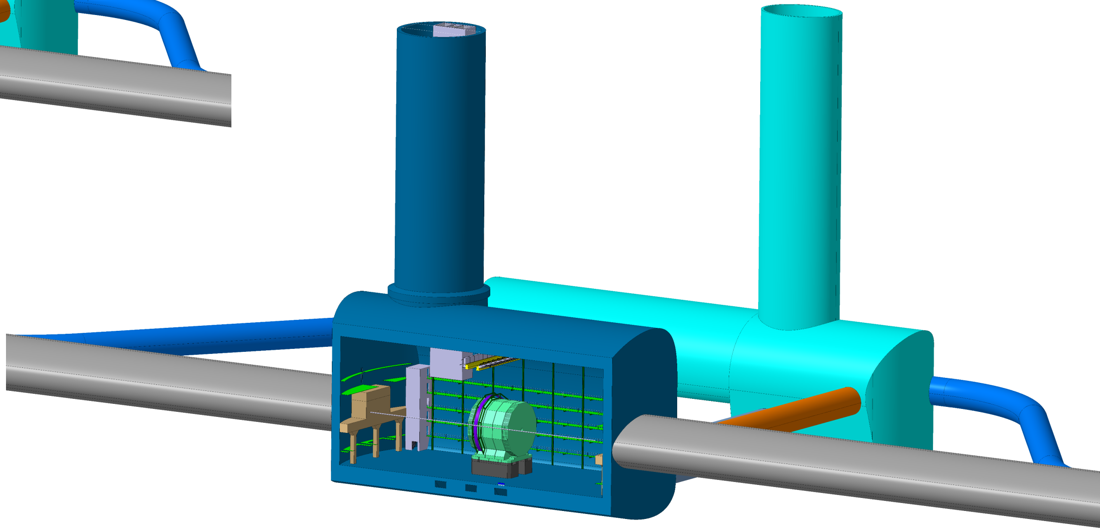


FCC Experiment Underground Structure version 2022

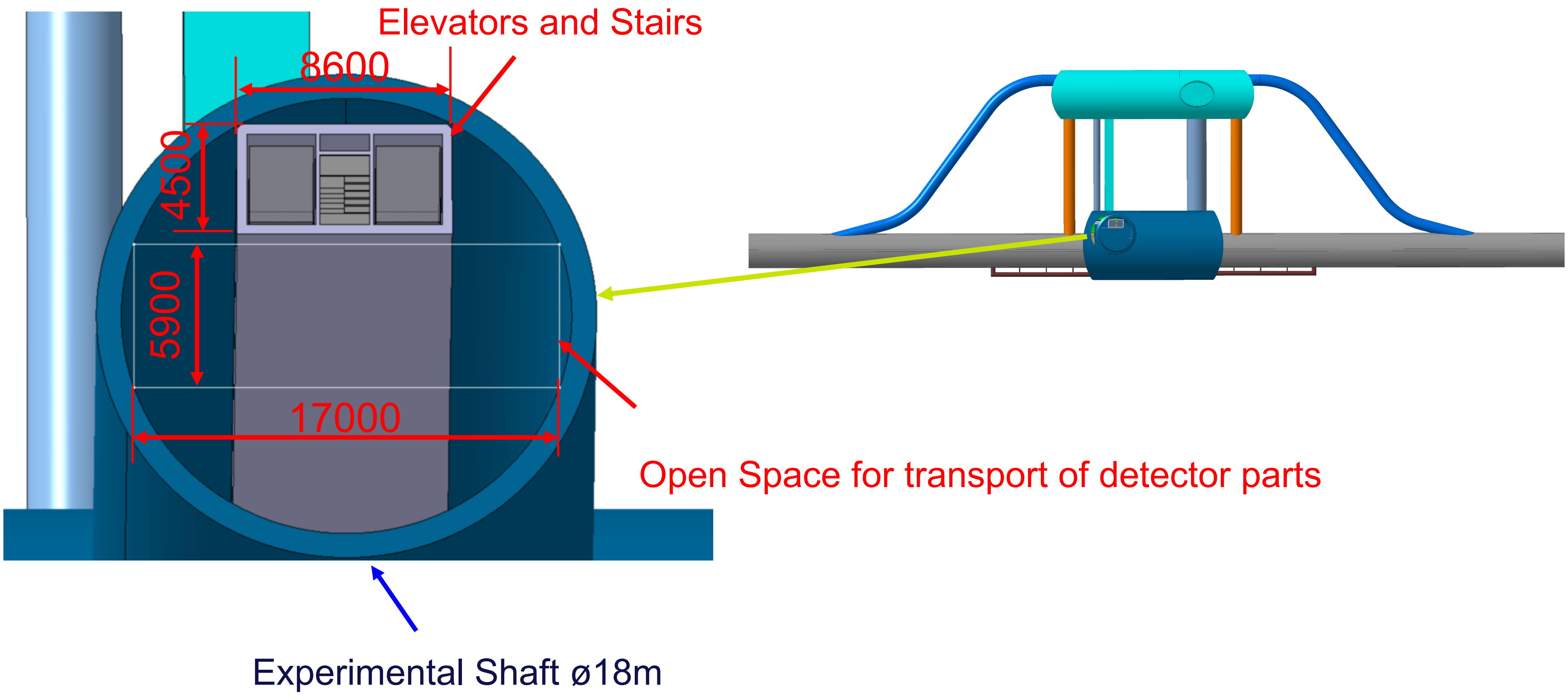


FCC Experiment Underground Structure version 2022





FCC Experiment Underground Structure version 2022

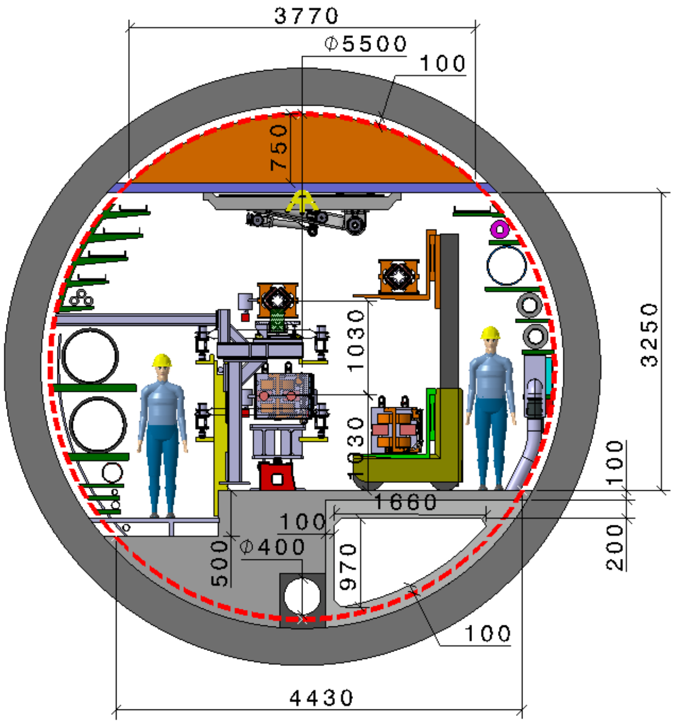


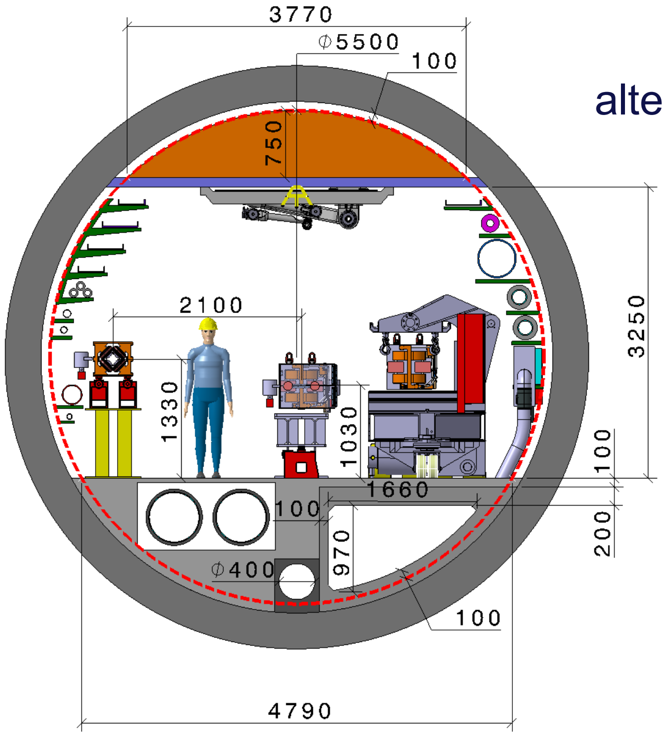
F. Valchkova-Georgieva

Booster ring

F. Valchkova-Georgieva, December DC meeting

Booster ring may be at either 103cm or 30cm above collider rings depending on tunnel layout

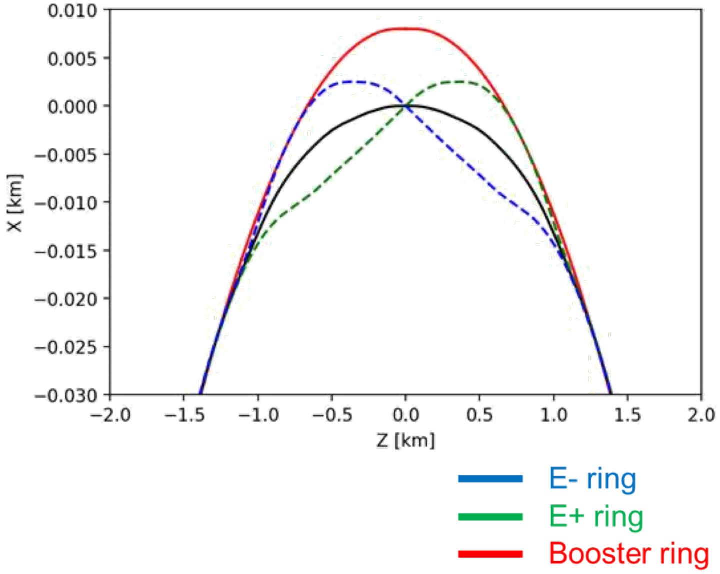


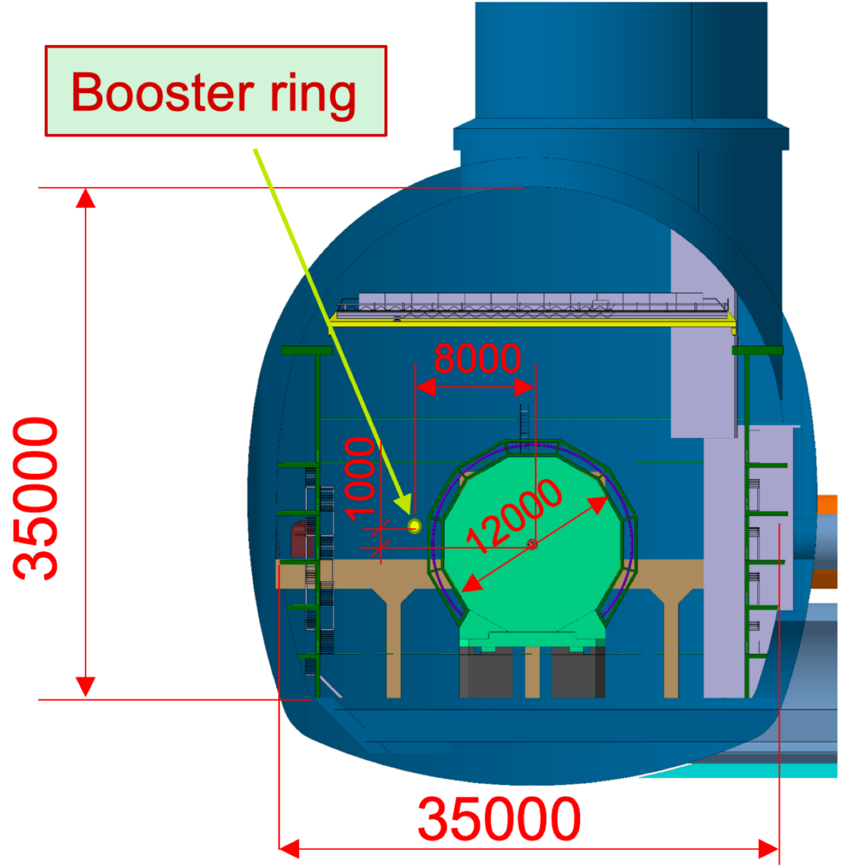


alternative

Booster ring

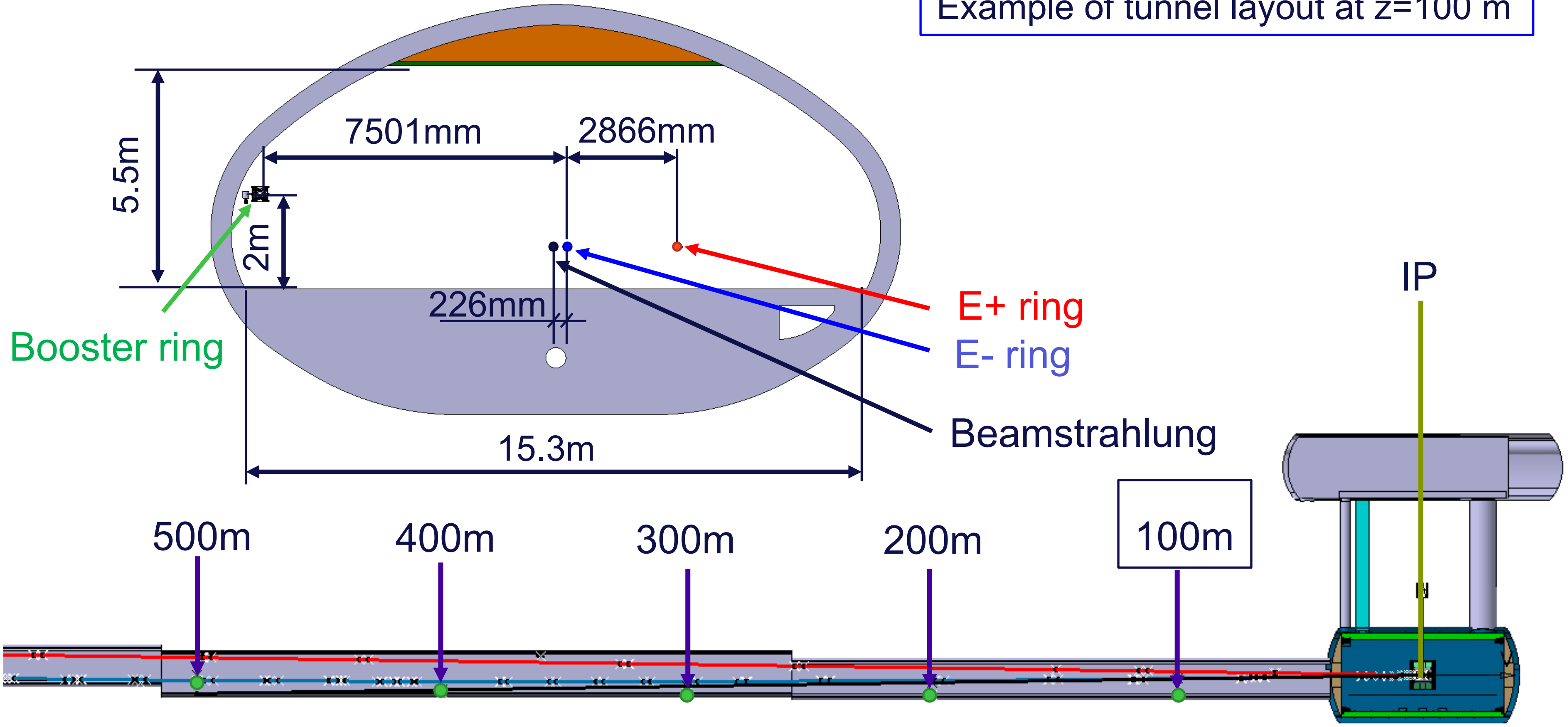
Trajectory for booster ring





Talk later in this session by Nikkie Deelen:
Detector Stray Magnetic Fields in booster region,

Example of tunnel layout at z=100 m

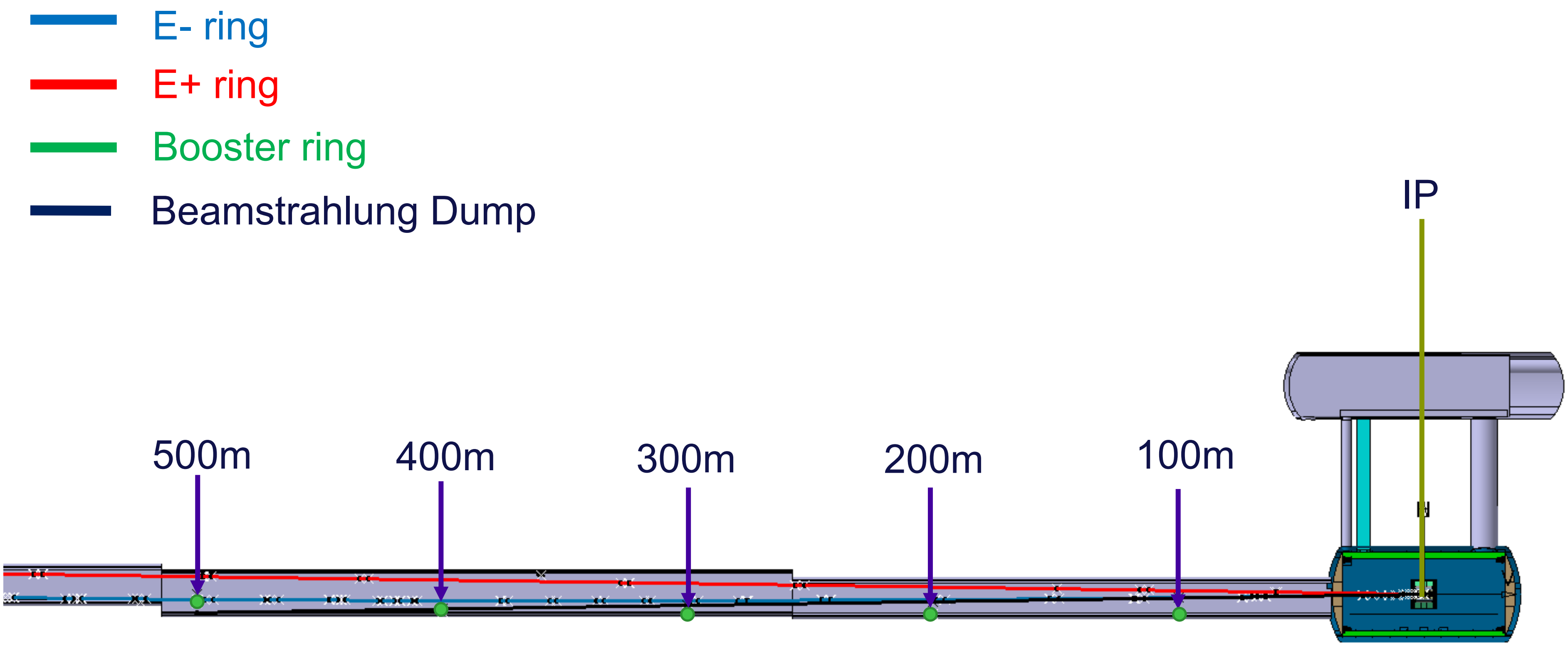


Main take home messages

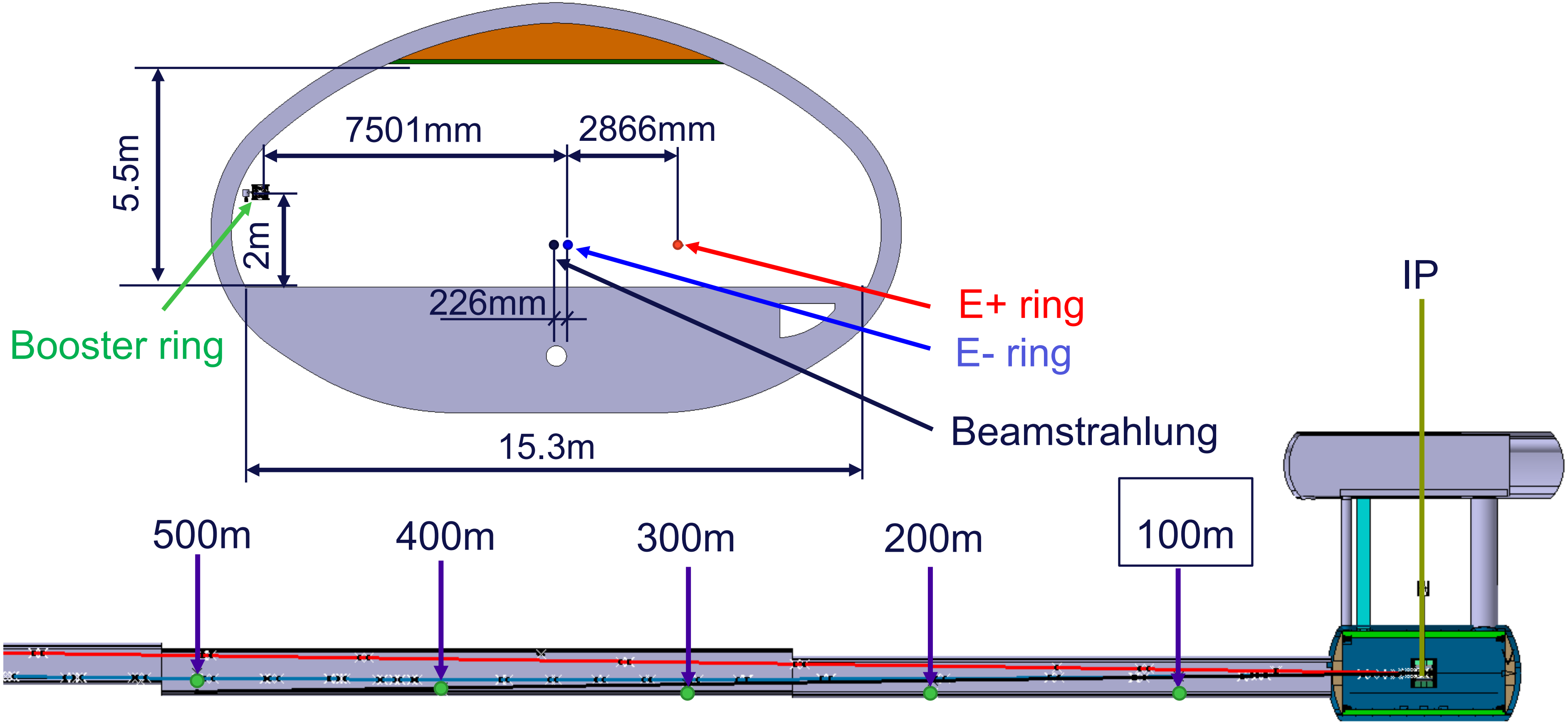
- Baseline is that detectors will be assembled under ground
- Four experimental sites:
  - Two main (FCC-hh) experimental caverns: 66 x 35 x 35 m^3
  - Two secondary (FCC-hh) experimental cavers: (CMS size) 55 x 25 x 25 m^3
  - Encouraged to clearly justify the need for four experiments also at FCC-ee
- FCC-ee detectors will likely not make use of service caverns
  - Will be used by machine infrstructure to keep vibrations away from beam
- FCC-ee booster line will pass close to detectors
  - Important to understand necessary shielding of detector stray fields

Thank you for your attention.

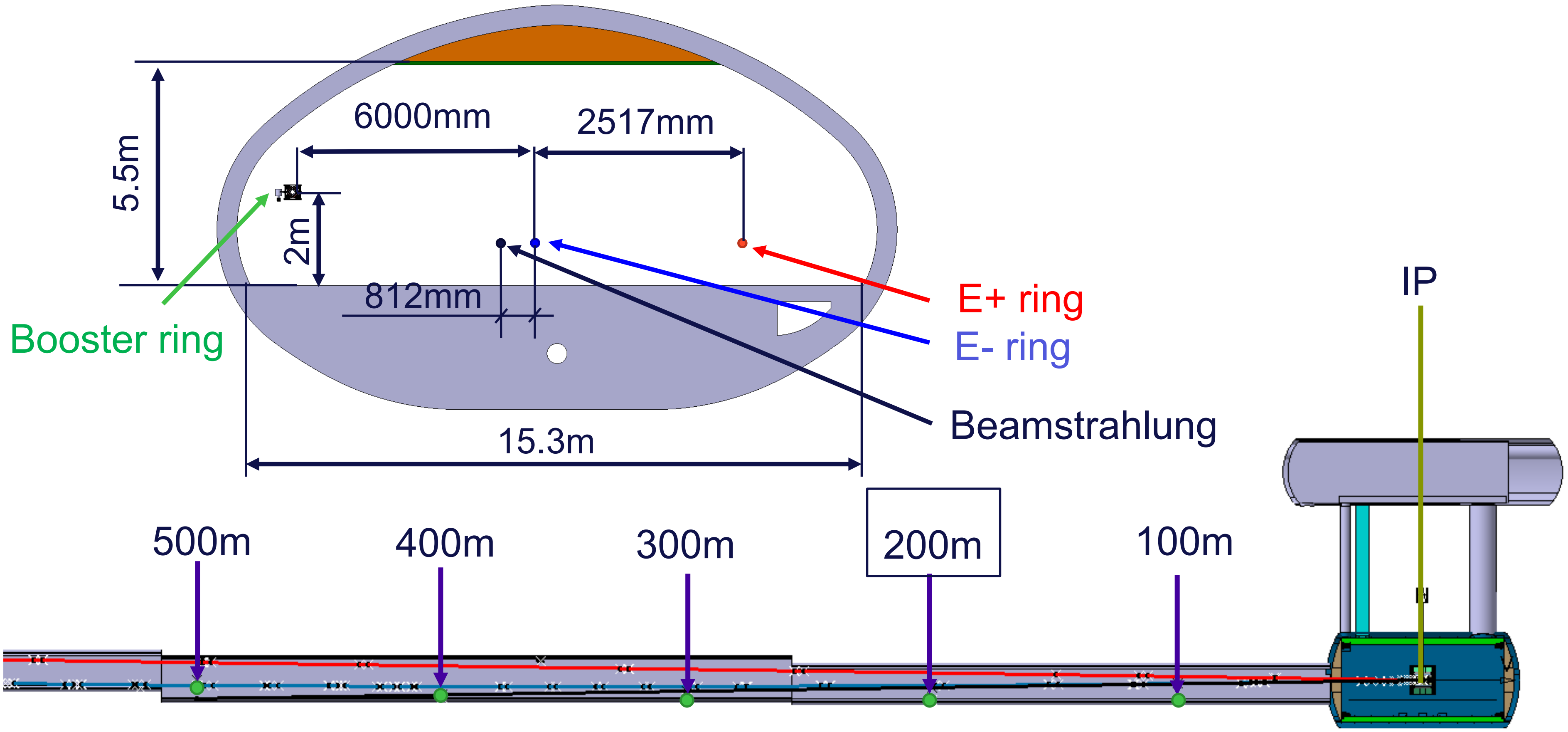
FCC-ee beamstrahlung dump integration at point A



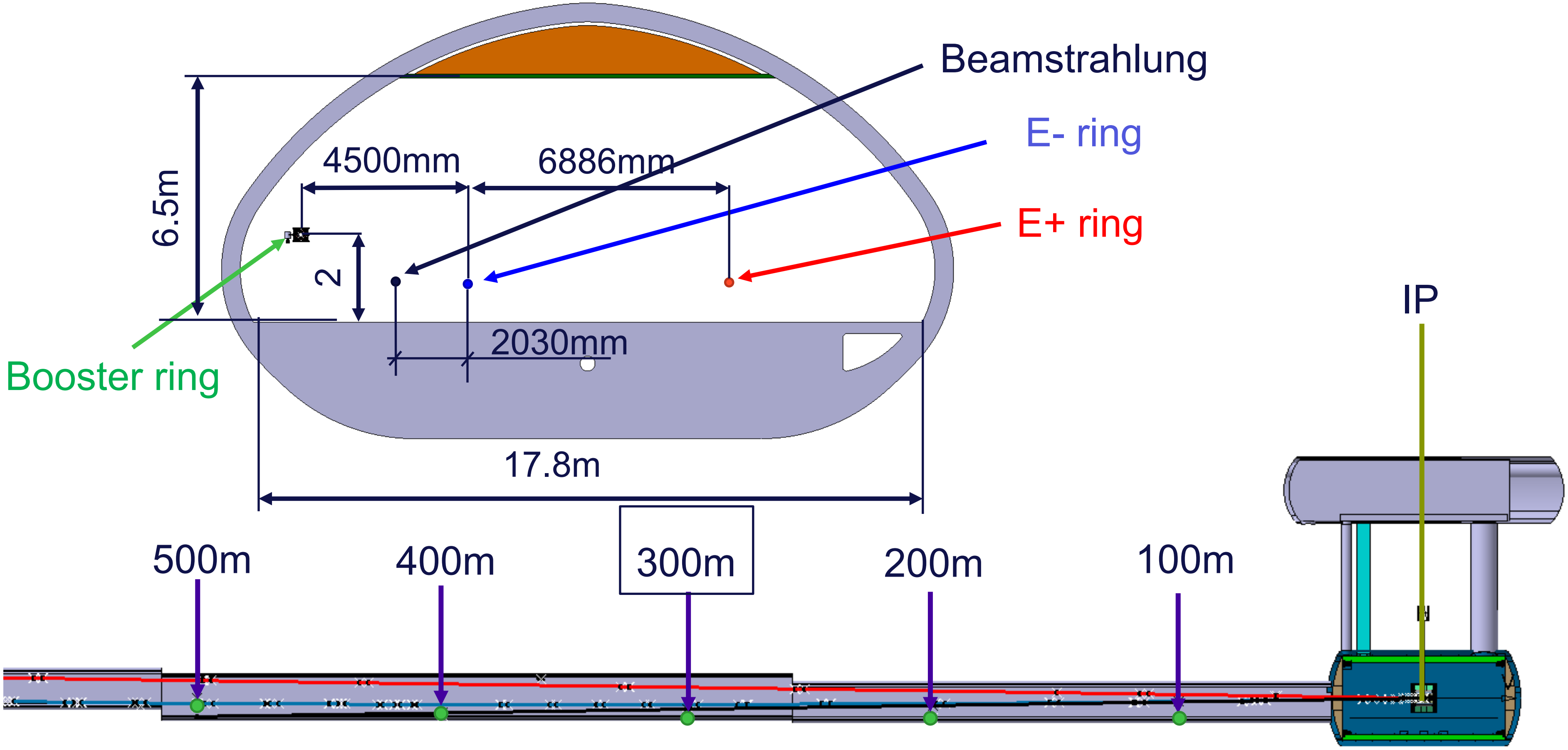
FCC-ee beamstrahlung dump integration at point A



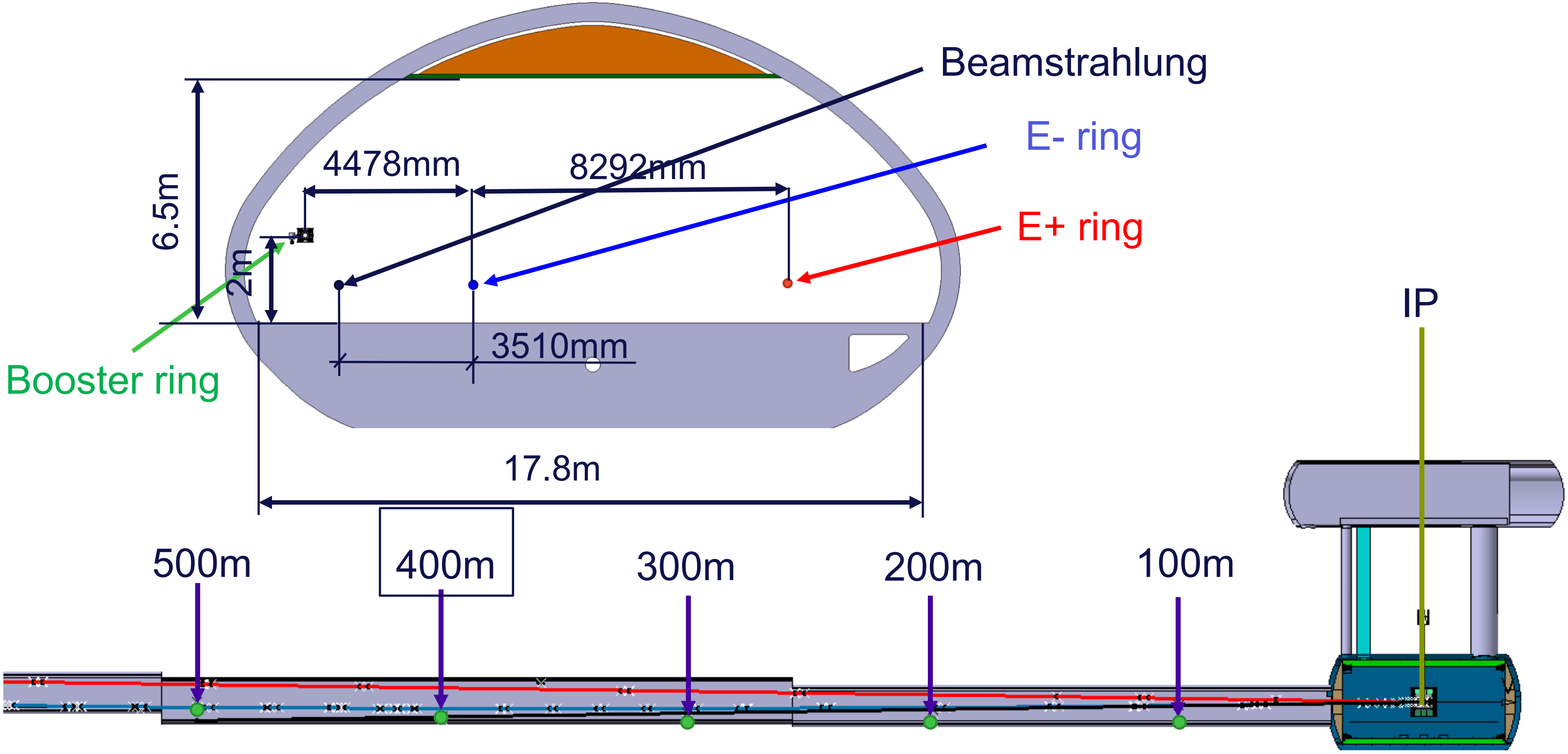
FCC-ee beamstrahlung dump integration at point A



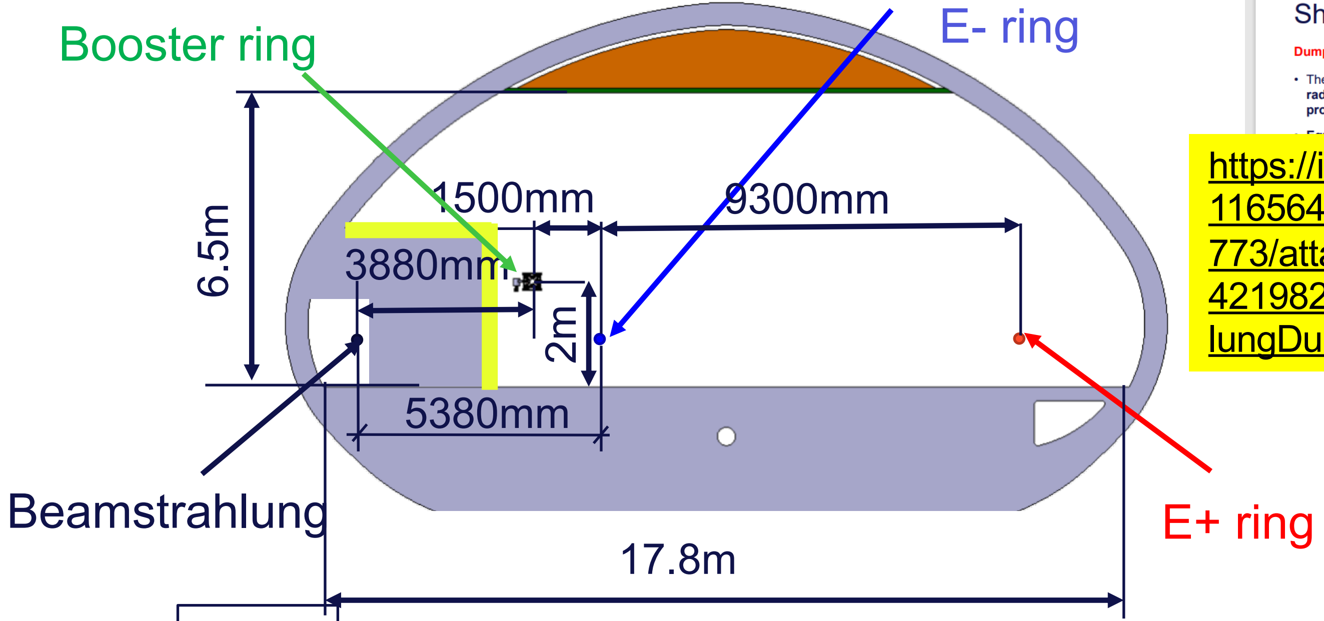
FCC-ee beamstrahlung dump integration at point A

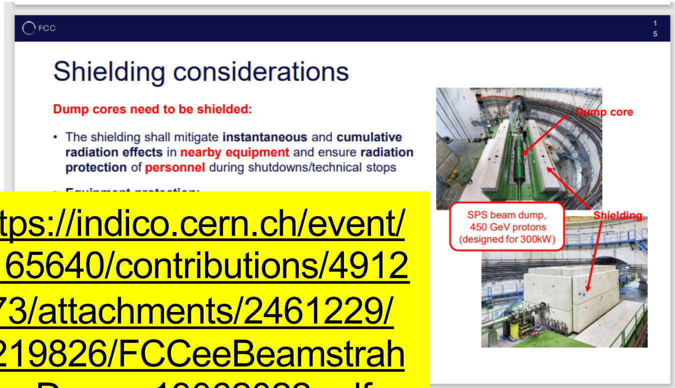


FCC-ee beamstrahlung dump integration at point A



FCC-ee beamstrahlung dump integration at point A





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