Summary of Review on Civil Engineering and Techinal Infrastructure Requirements for FCC Experimental Sites October 3-4

Detector Concept Meeting

7 November, 2022

Mogens Dam, Niels Bohr Institute

The Review 3-4 October

Presentations

09:00 **Introduction**
Speakers: Andy Parker (University of Cambridge (GB)), Michael Benedikt (CERN)
MBenedikt_FCC FS ... MBenedikt_FCC FS ...

09:10 **FCC-hh detector concepts and requirements**
Speaker: Werner Riegler (CERN)
fcc_hh_CE_TI_requir... fcc_hh_CE_TI_requir...

09:40 **FCC-ee detector concepts and requirements**
Speaker: Mogens Dam (University of Copenhagen (DK))
20221003_CE_TI_re... 20221003_CE_TI_re...

10:10 **CE and TI requirements from the FCC-hh and FCC-ee detectors**
Speaker: Werner Riegler (CERN)
fcc_ee_hh_ce_ti_req... fcc_ee_hh_ce_ti_req...

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).

Preliminary conclusions (i)

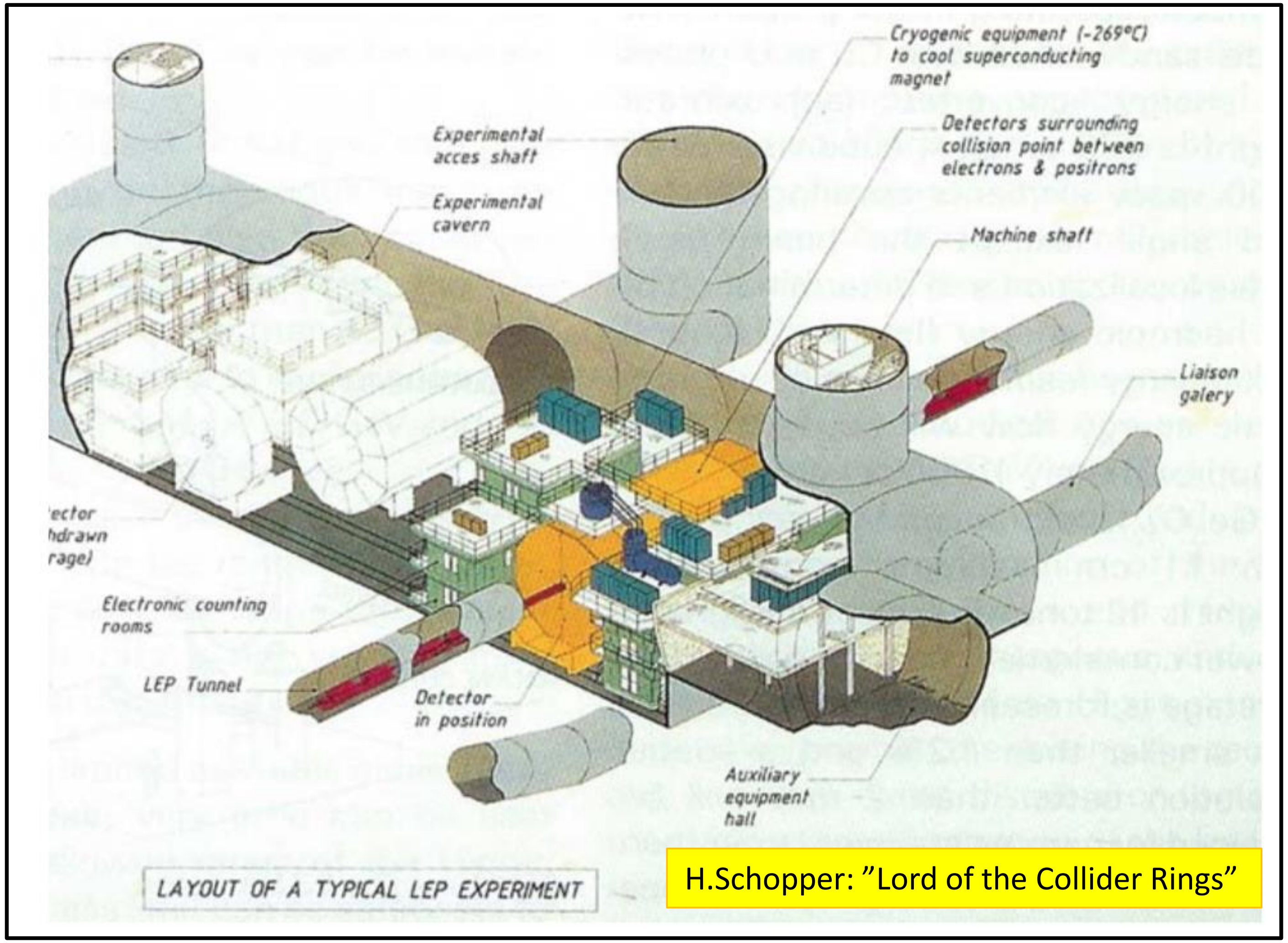
Michael Benedikt, October 7th

- **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.

LEP Cavern Layout of the three typical Detectors



H.Schopper: "Lord of the Collider Rings"

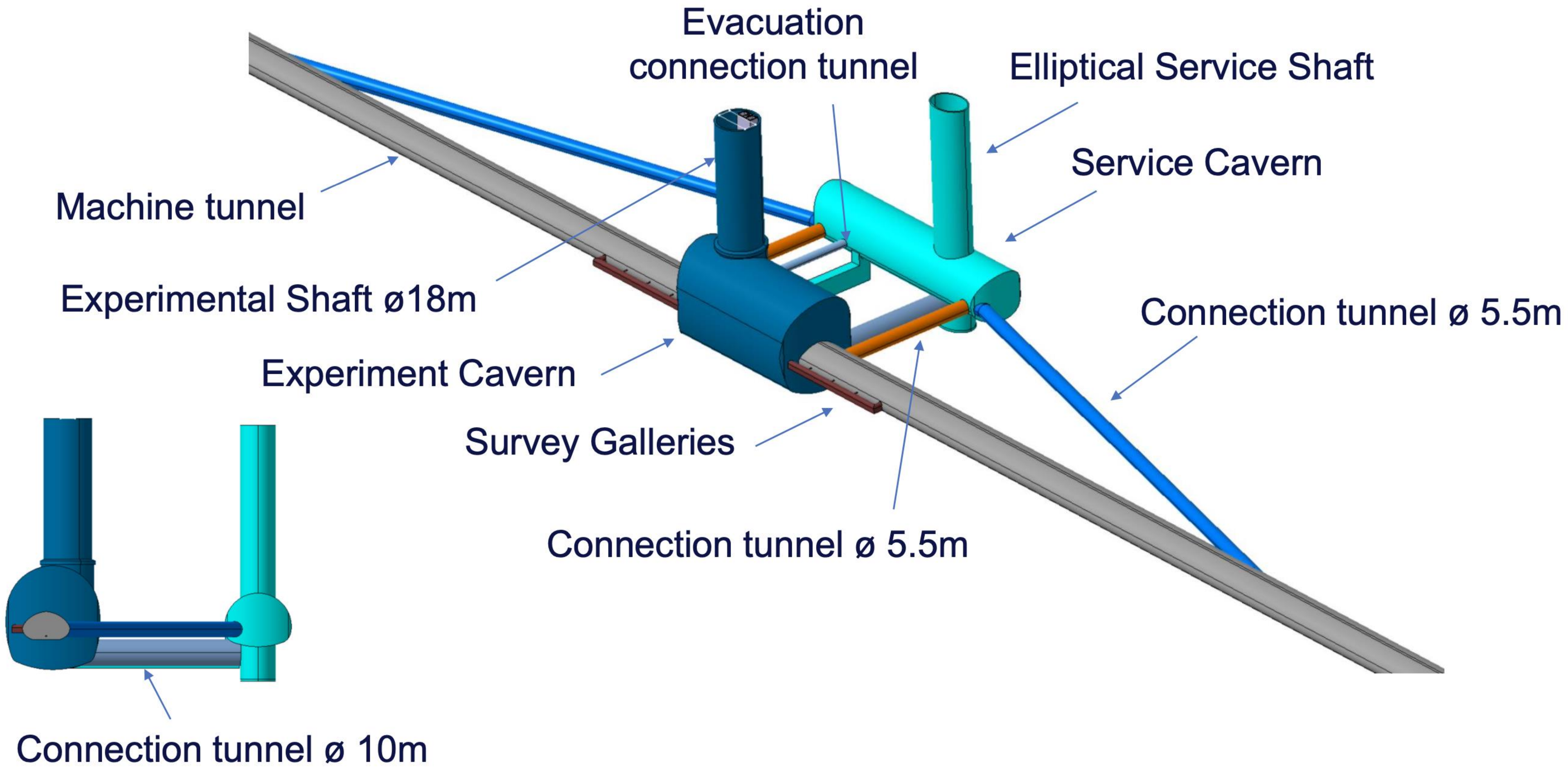
Baseline is that FCC-ee detetors will be assembled under ground as at LEP.

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

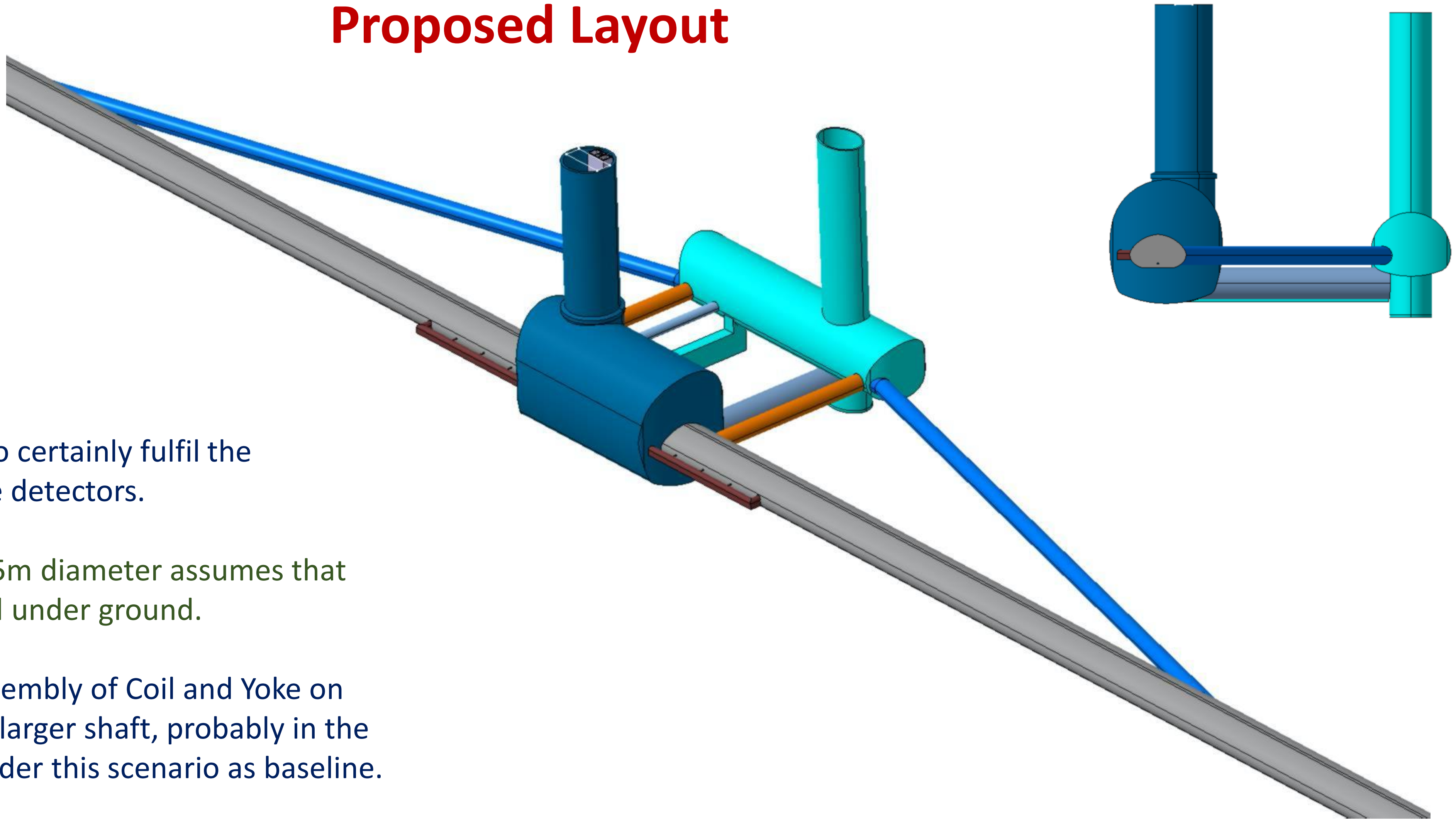
- Cavern: 70m long, 17m wide, 18.5 m high
- A single shaft of 10.1 m diameter
- Main cavern with enough space for detector, including barracks for electronics, cryogenics, services, and even empty space to move the detector into garage position (never used)
- No service cavern used by experiments
- Length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

Proposed Layout

Werner Riegler



Proposed Layout



This FCC-hh requirements do certainly fulfil the requirements for the FCC-ee detectors.

The specified shaft size of 15m diameter assumes that the detectors are assembled under ground.

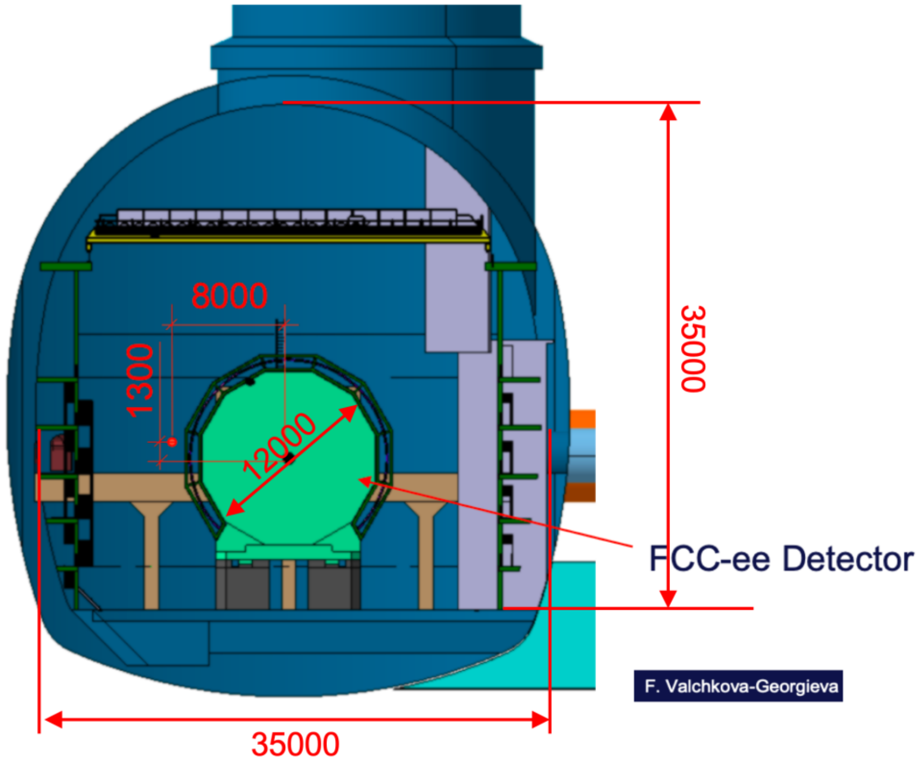
CMS type scenarios with assembly of Coil and Yoke on the surface would require a larger shaft, probably in the 20m range. We do not consider this scenario as baseline.

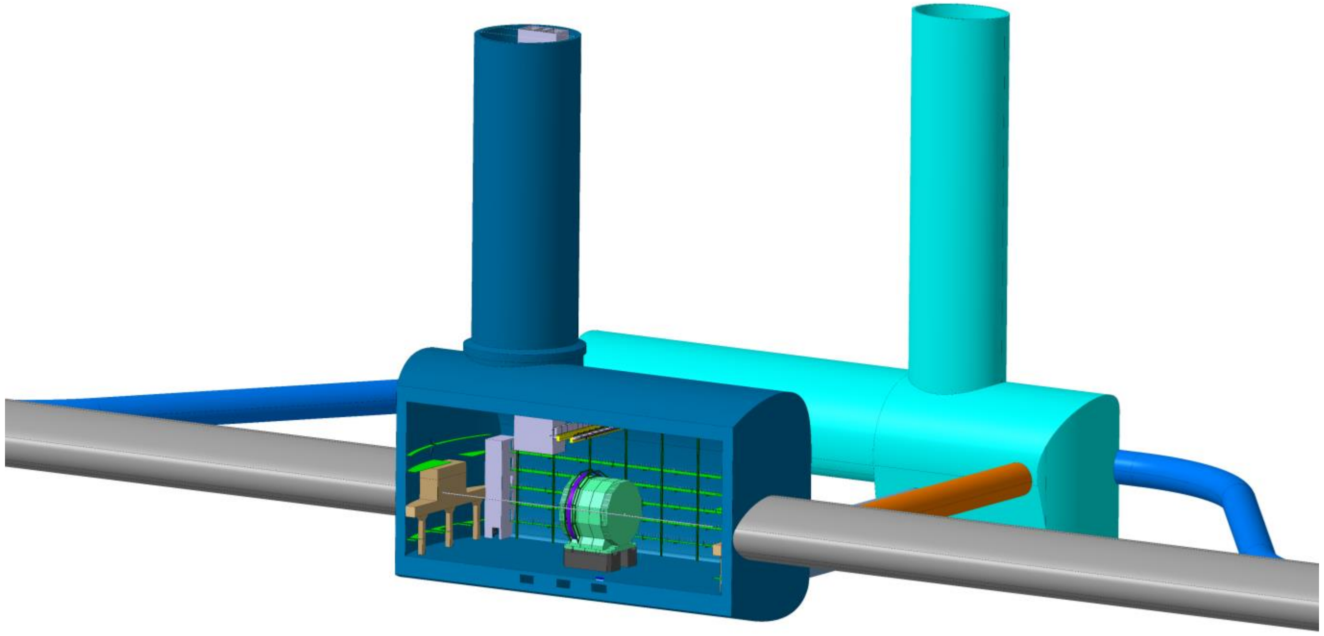
Werner Riegler

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 diamater is sufficient

Preliminary conclusions (ii)

Michael Benedikt, October 7th

- **STRAY FIELDS OF FCC-hh DETECTORS**

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

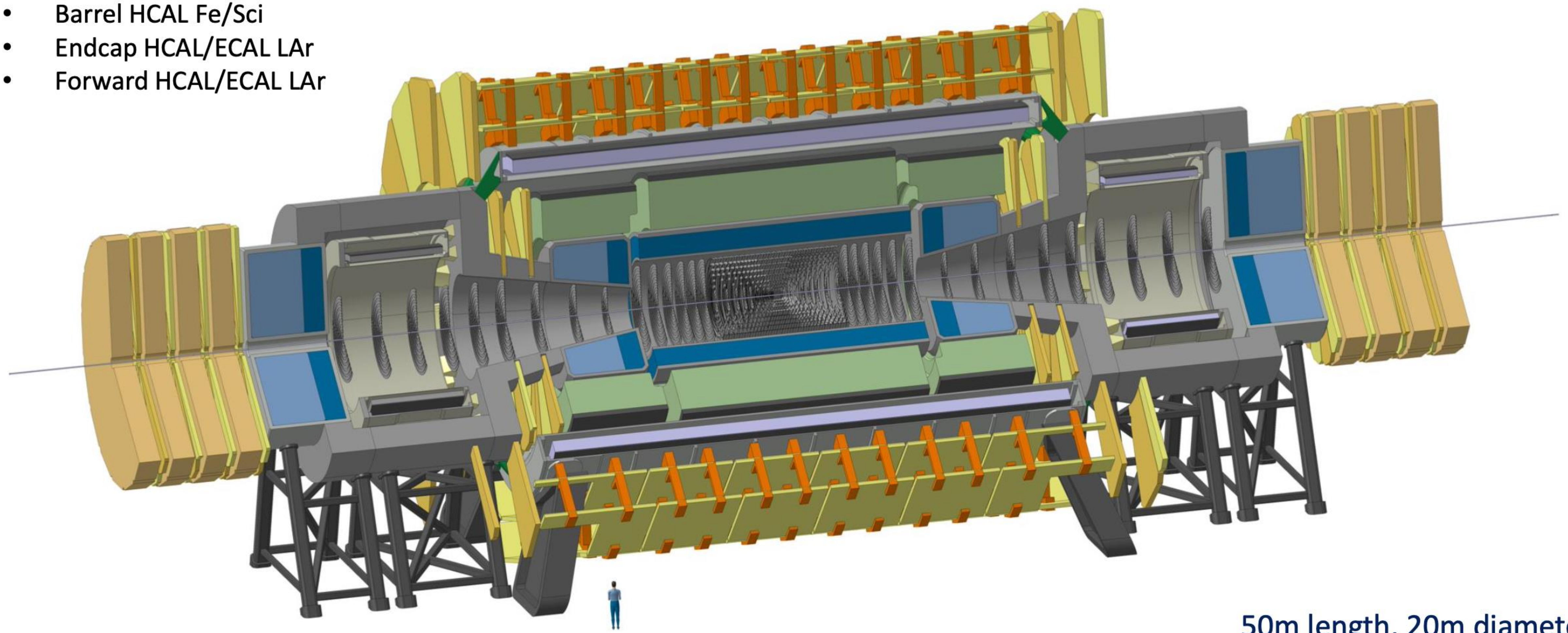
  - The committee is not yet convinced that all the implications of the large stray field from a detector magnet without a return yoke, as proposed for the two FCC-hh general-purpose experiments, are fully understood.
  - Therefore, we recommend that the option to build a return yoke is retained, and this 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.

FCC-hh Reference Detector

Werner Riegler

- 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

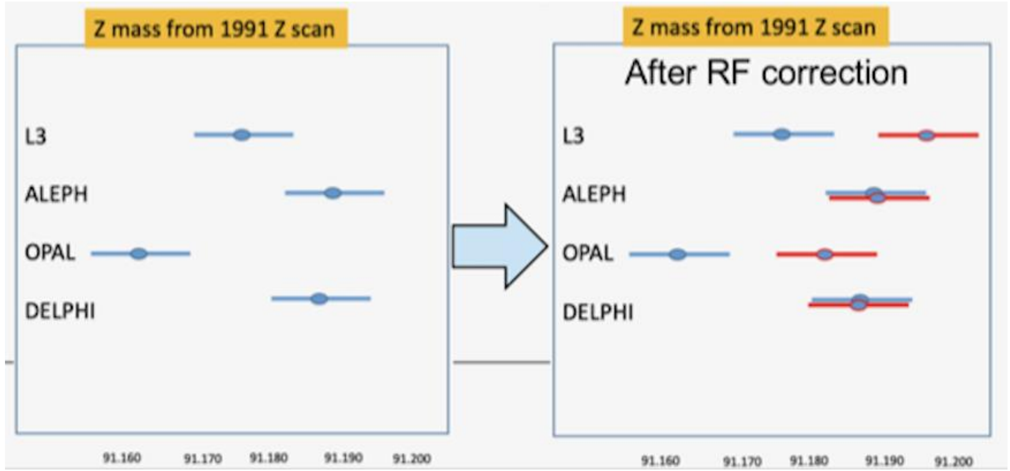
The case for four Interaction Points

MD

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

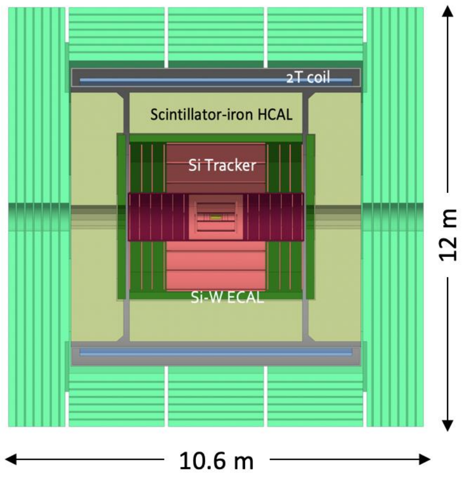
2208.10466

- Overall gain in luminosity, in luminosity/MW, and importantly in luminosity/kg CO_2 equiv
  - 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



Developing Landscape of FCC-ee Detector Concepts

CLD

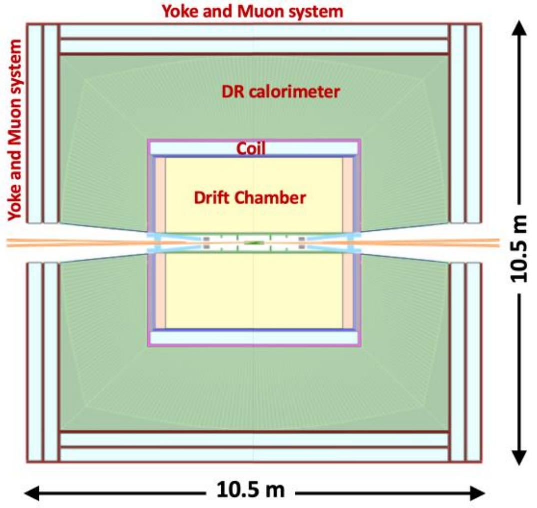


- Full Silicon vertex detector + tracker;
- Very high granularity, CALICE-like calorimetry;
- Muon system
- Large coil outside calorimeter system;

- Possible optimization for
  - Improved momentum and energy resolutions
  - PID capabilities

CDR

IDEA

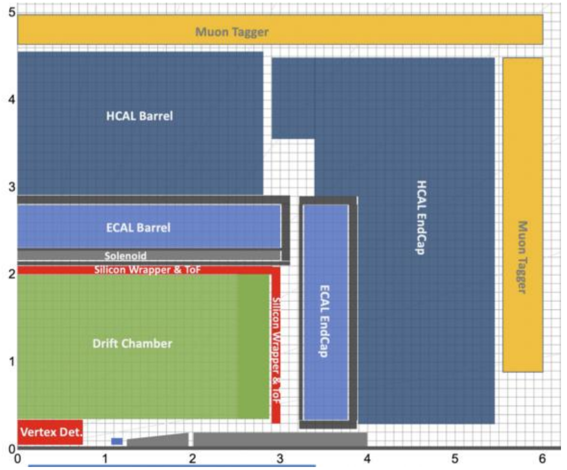


- Si vertex detector;
- Ultra light drift chamber w. powerfull PID;
- Monolitic dual readout calorimeter;
- Muon system;
- Compact, light coil inside calorimeter;

- Possibly augmented by crystal ECAL in front of coil;

Noble Liquid ECAL based

new



- High granularity Noble Liquid ECAL as core;
  - PB+LAr (or denser W+LCr)
- Drift chamber (or Si) tracking;
- CALICE-like HCAL;
- Muon system;
- Coil inside same cryostat as LAr, possibly outside ECAL.

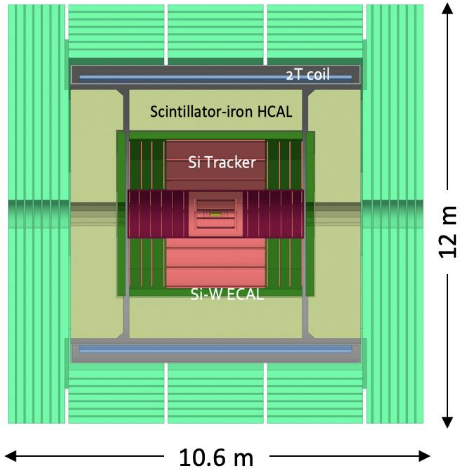
Michael Benedikt, October 7th

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.

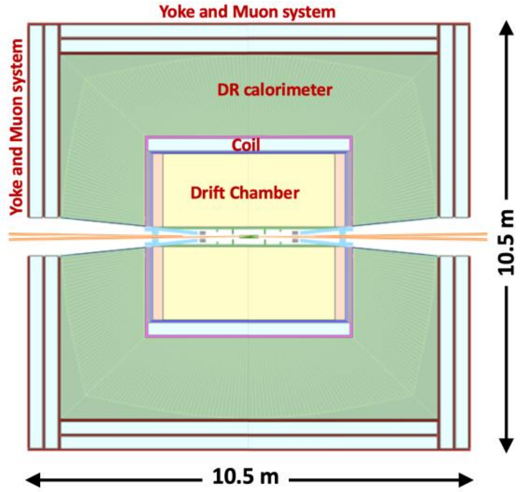
CLD



Cryostat:

- Outer diameter: 8.55 m
- Length : 7.4 m

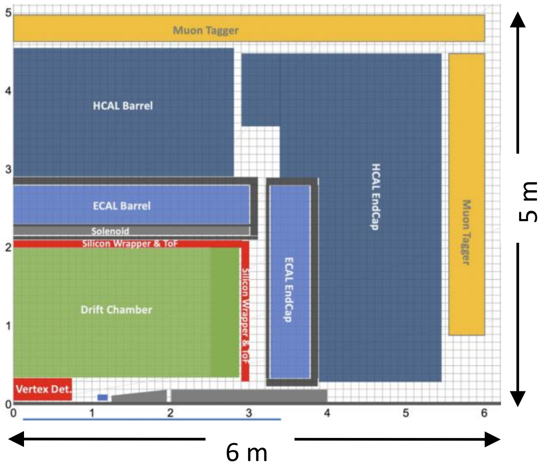
IDEA



Cryostat:

- Outer diameter: 4.8 m
- Length : 6.0 m

Noble Liquid ECAL based



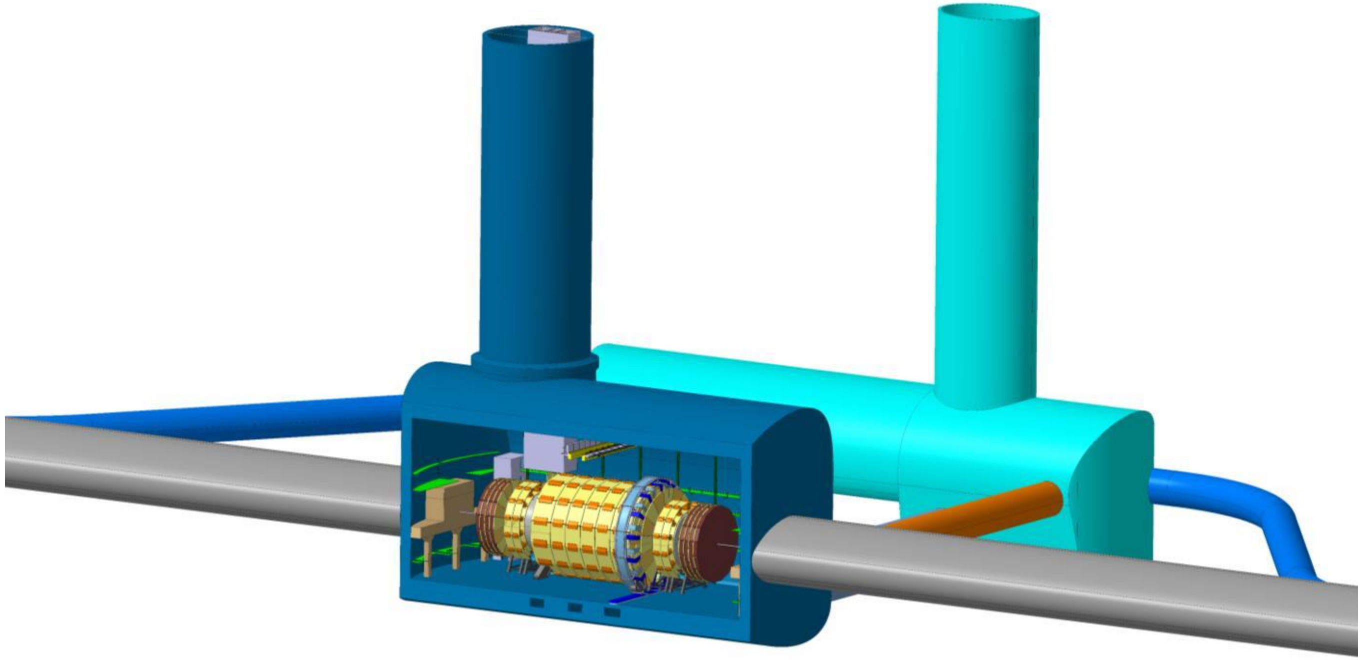
Cryostat:

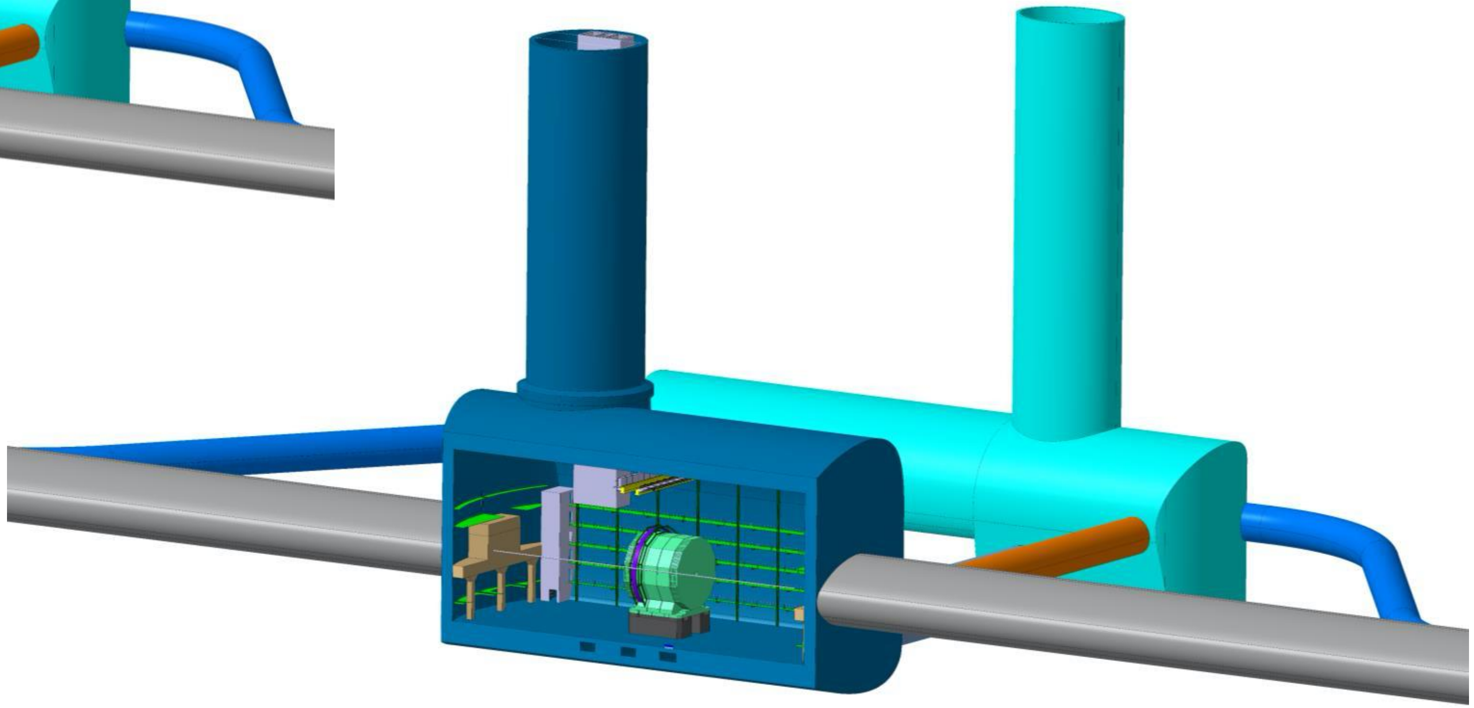
- Outer diameter: ~6 m
- Length : ~6 m

- 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 Experiment Underground Structure version 2022

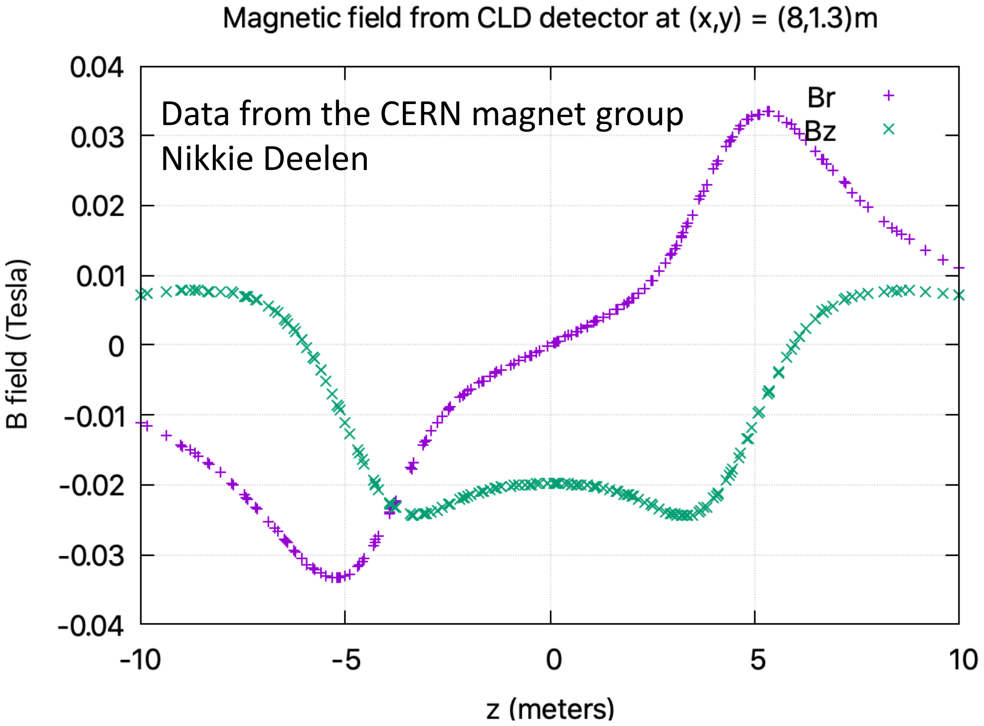
Werner Riegler

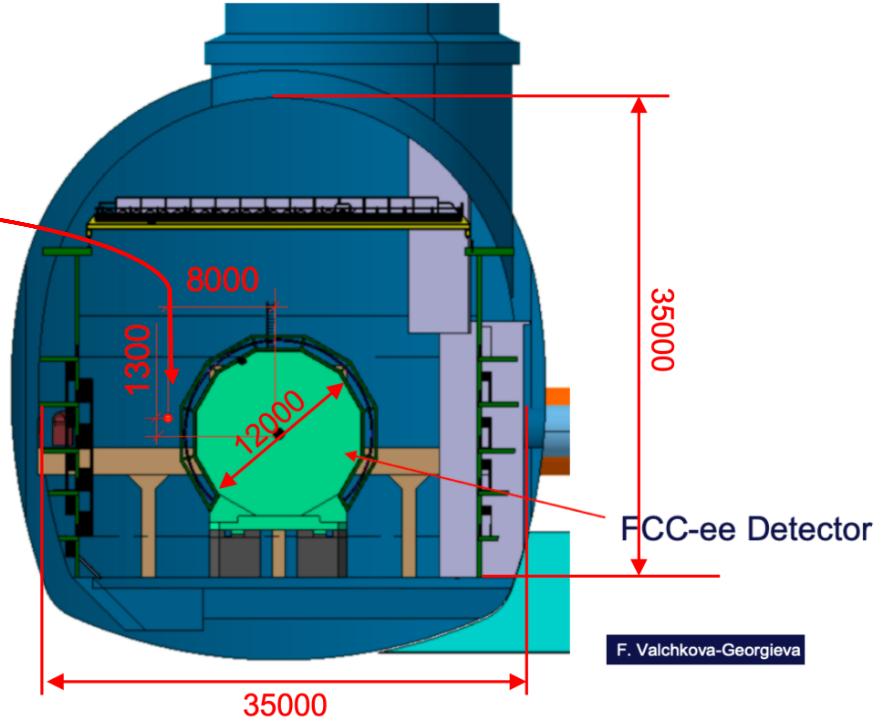




A side issue: Position of the booster ring

- Booster position may have consequences on the tunnel layout around the IP
- For this study, booster ring passes through cavern outside detector volume at [x, y]= [8.0, 1.3]m
- Detector stray field at the booster location is up to ten times stronger than the 3 mT dipole field strength at injection
  - Needs to be corrected for





A solution for shielding and/or correction has to be developed

- The booster location must be such that there is at least 1 m free space around the detector envelope with the shielding/compensation in place
- The shielding/compensation must not sizeably affect the magnetic field of the detector.

Extras