Physics Beyond Colliders

Civil Engineering Challenges

SCE Technical Seminar, 28th February 2022

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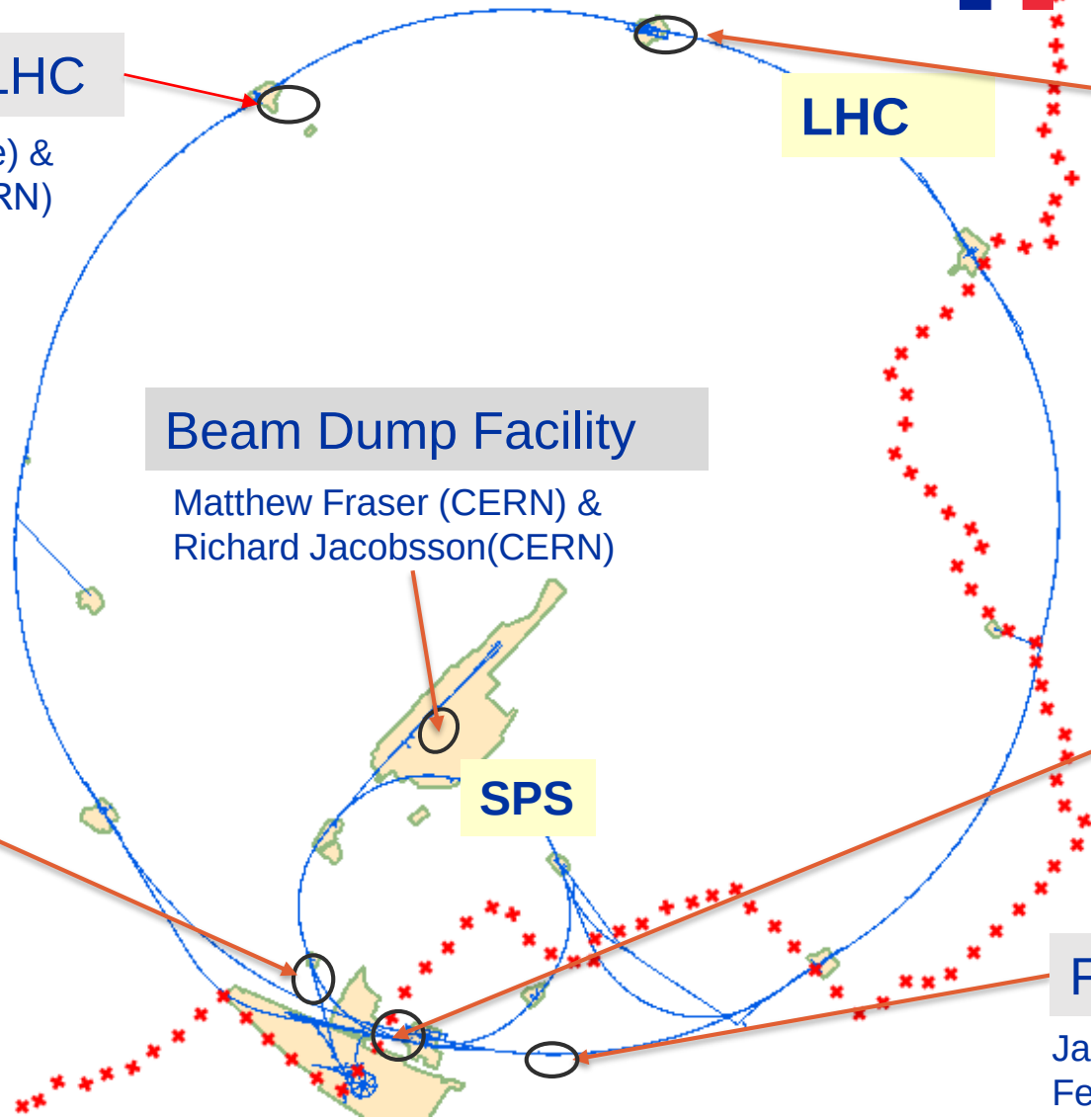
PBC Studies & Locations



AION-100 @IP4 LHC

Oliver Buchmuller (Imperial College) & Jonathan Ellis (King's College/ CERN)

MATHUSLA

Charlie Young (SLAC) & Henry J. Lubatti (University of Washington)

Beam Dump Facility

Matthew Fraser (CERN) & Richard Jacobsson(CERN)

Forward Physics Facility

Jaime Boyd (CERN) & Jonathan Feng(UC Irvine)

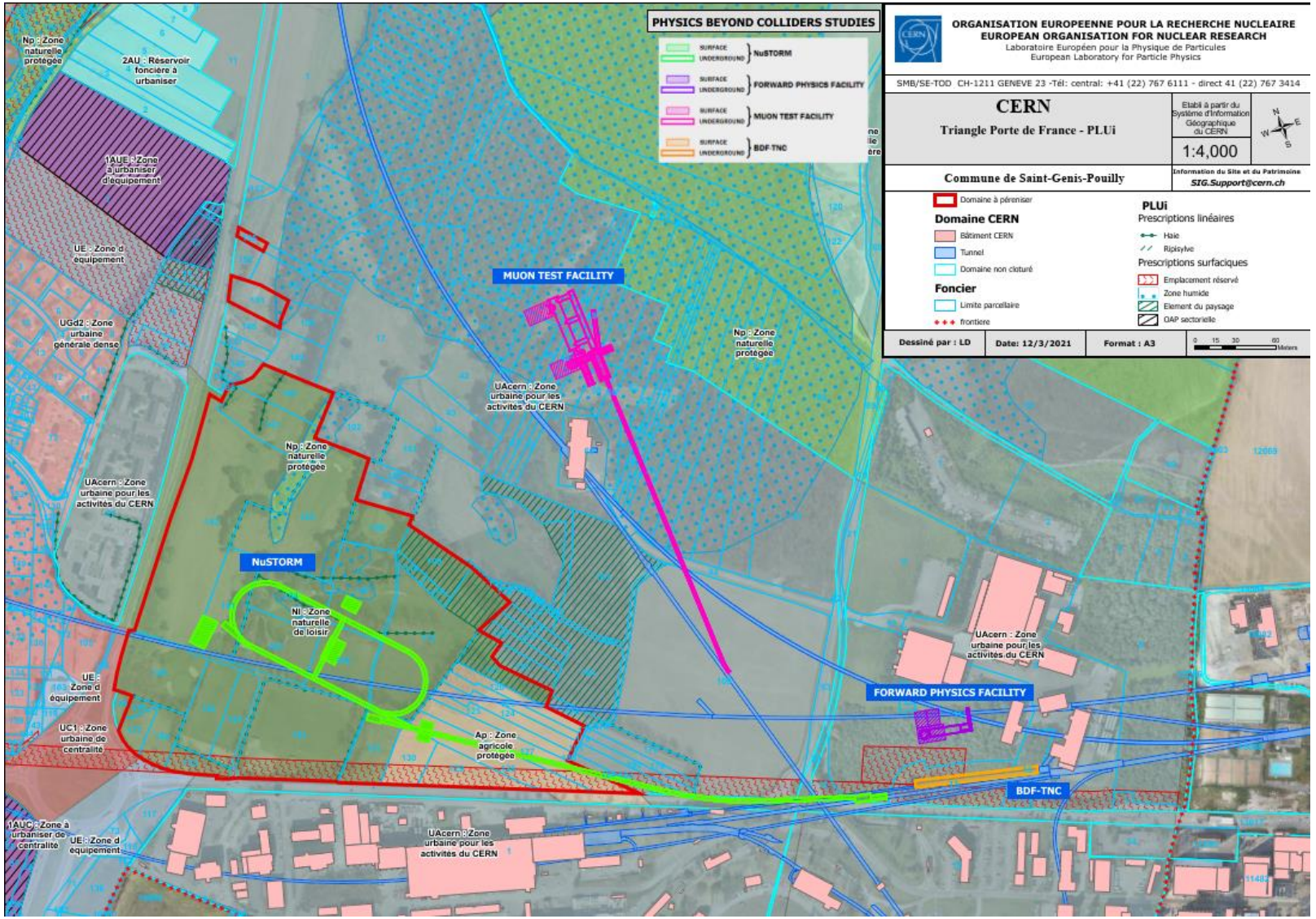
nuStorm

Kenneth Long (Imperial College)

FASER

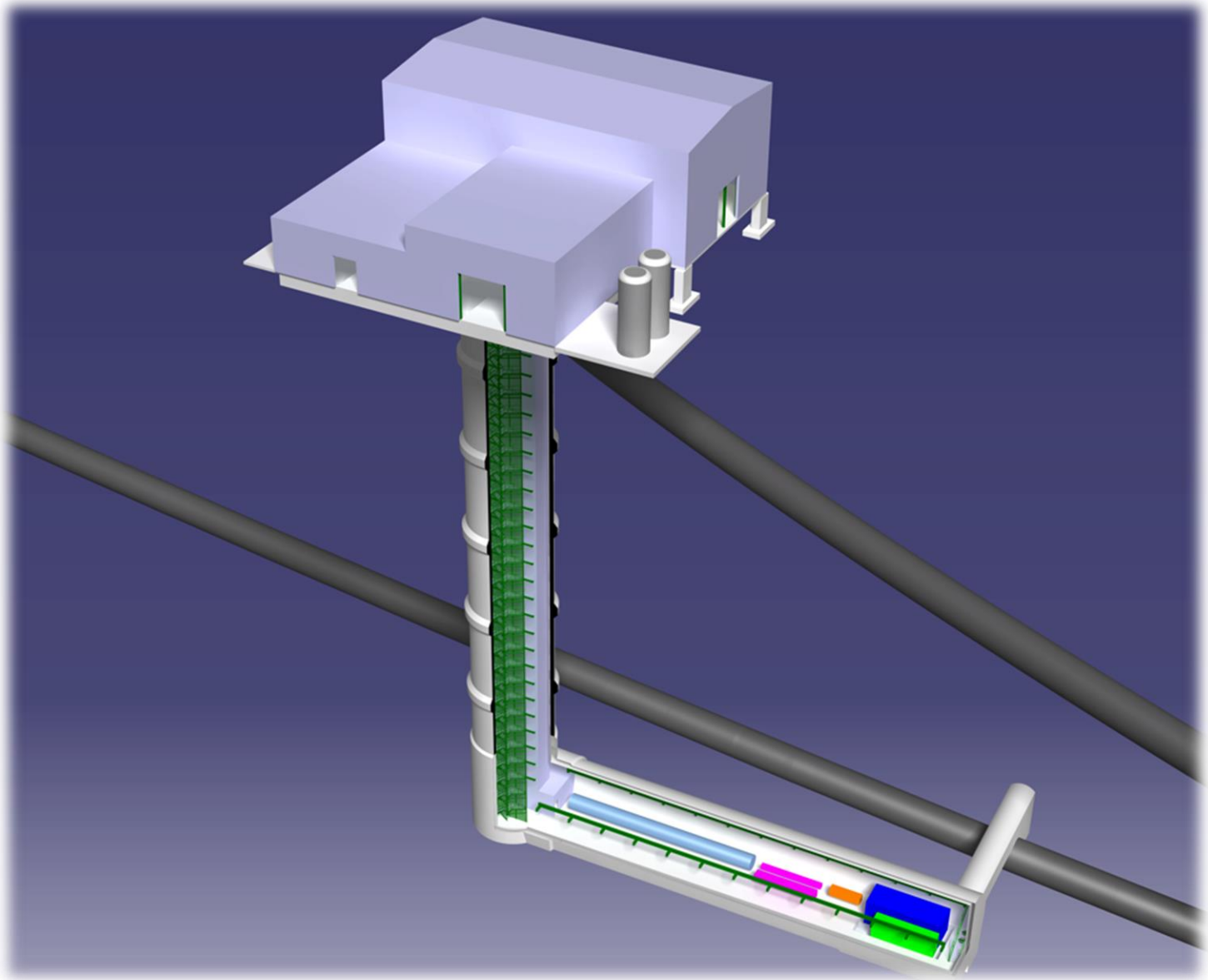
Jaime Boyd (CERN) & Jonathan Feng(UC Irvine)

PBC Studies & Locations



A. Navascues Cornago- SCE-SAM

Forward Physics Facility (FPF)



Forward Physics Facility (FPF)

Experimental Requirements and CE considerations

Requirements:

- Experimental area approx. 500-600 m away from LHC P1 or P5 on the Line of sight (LoS)
- Space for experiments (Integration study)
- Access needed for construction, installation and maintenance and required services
- Gathering requirements is always a challenge!

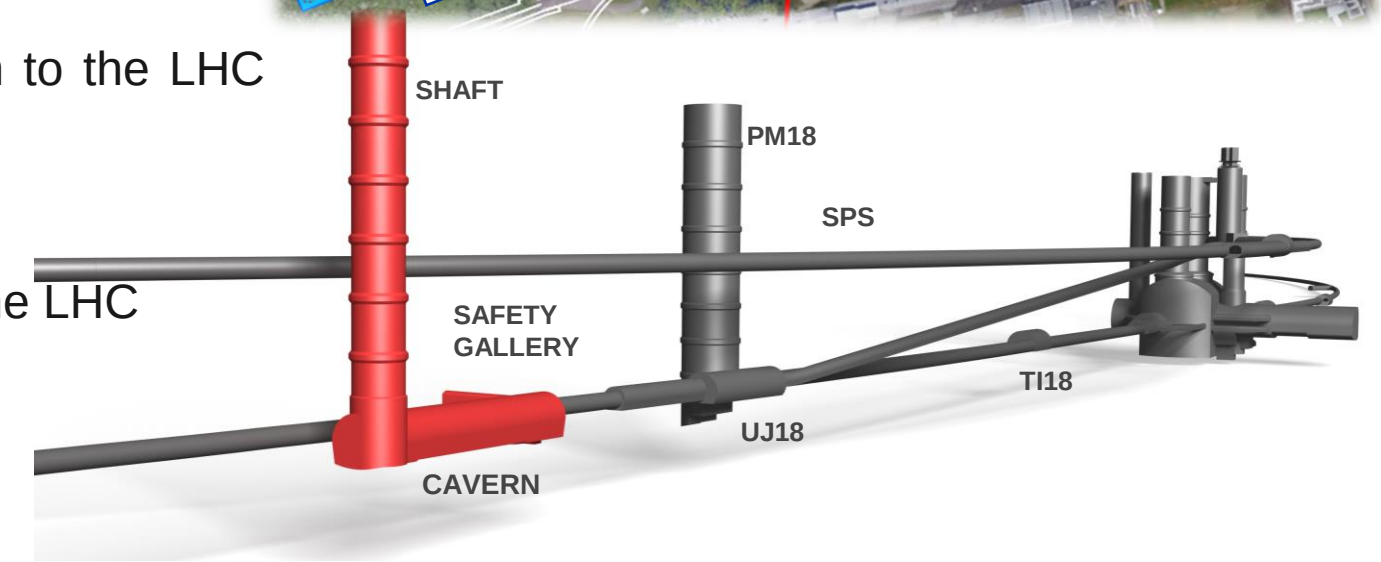
CE considerations (applies to all studies):

- Existing infrastructure (Tunnel assets management)
- Access for construction, operation and maintenance
- Environmental and safety aspects
- Disruption to LHC machine
- Geology
- Cost / Schedule

Forward Physics Facility (FPF)

Purpose-built facility

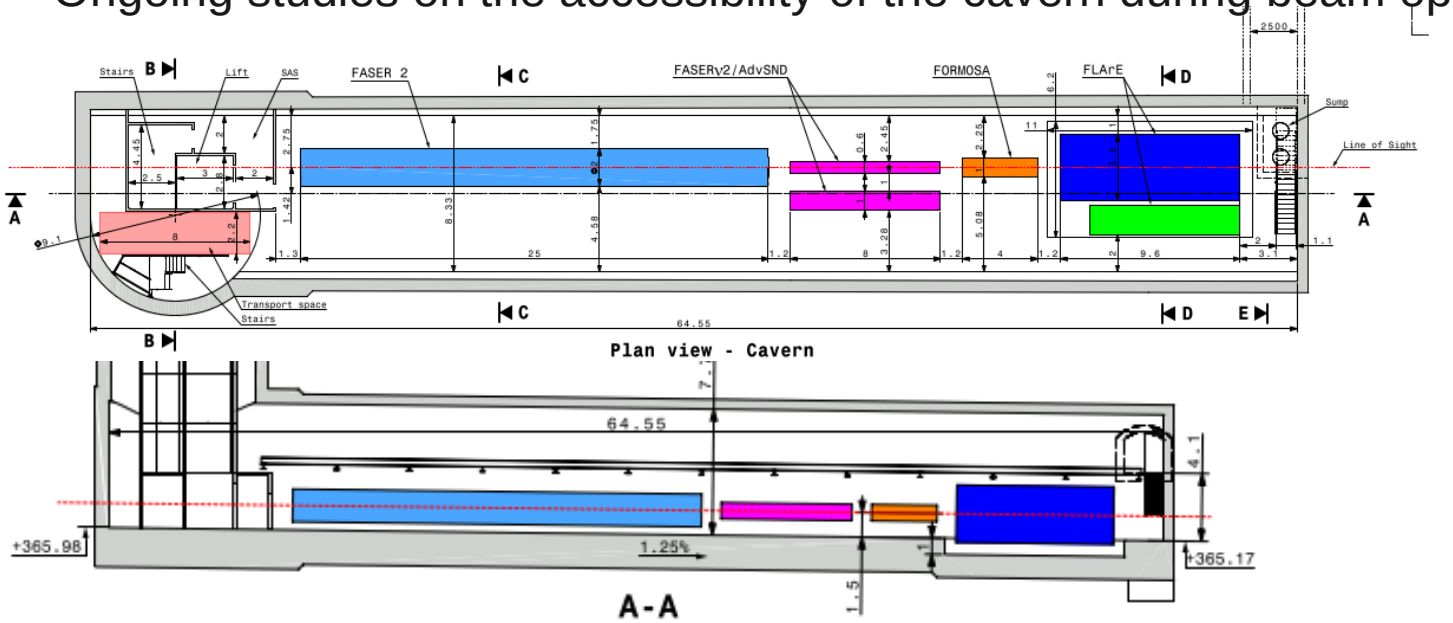
- Location approx. 617m from IP1 on the French side of CERN land, 10 m away from the LHC tunnel
- Baseline option
- Design includes
  - A 65m long experimental cavern
  - An 88m deep access shaft
  - A safety gallery connecting the FPF cavern to the LHC tunnel
  - Support buildings and infrastructure
- The impact of the excavation during works on the LHC needs to be evaluated

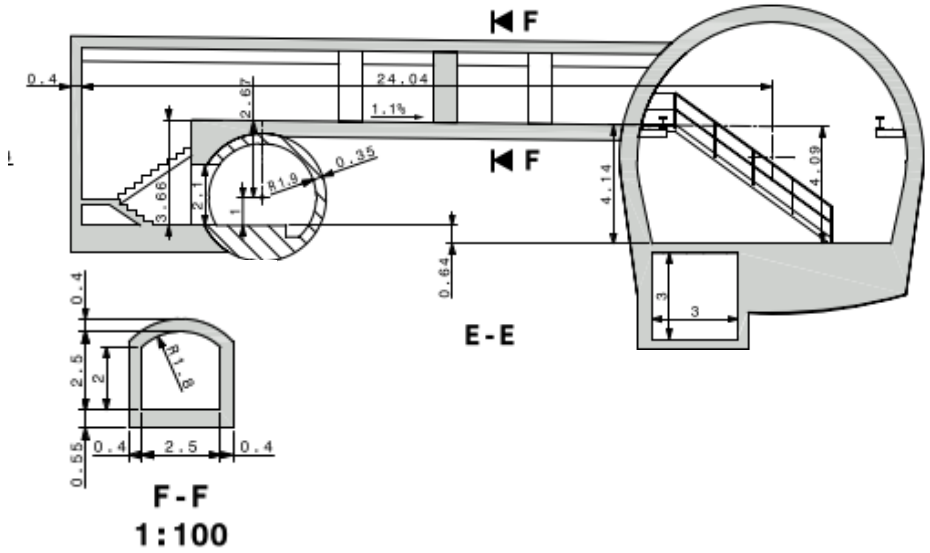


Forward Physics Facility (FPF)

Purpose-built facility

- Experiments centralised on the line of sight, 1.5m above the floor
- Floor parallel to the LoS, 1.25%fall
- Trench under the LAr detector to catch any escaped cold gas
- Safety gallery only used as an emergency escape route from the FPF cavern
- Ongoing studies on the accessibility of the cavern during beam operations

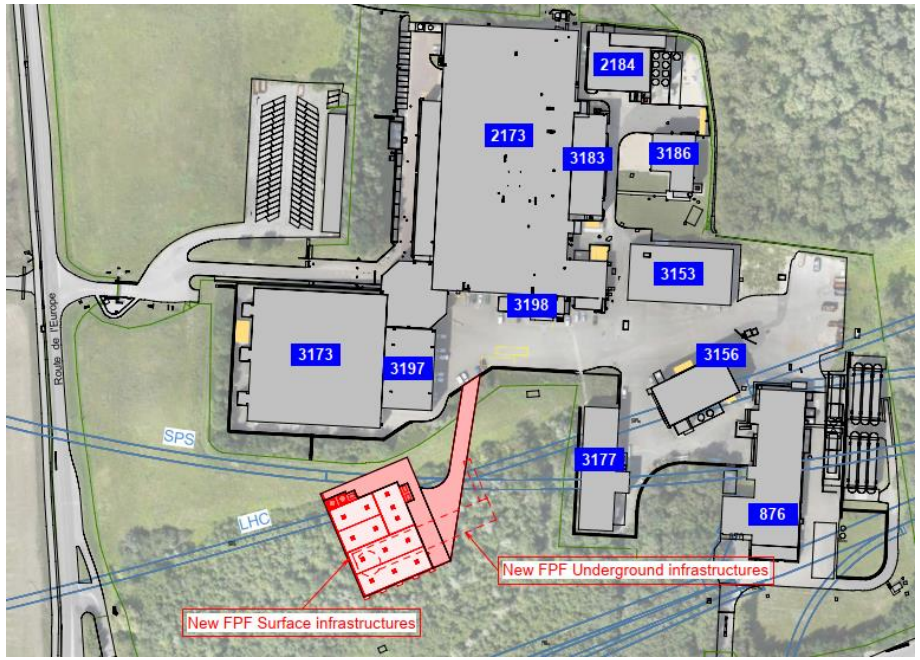




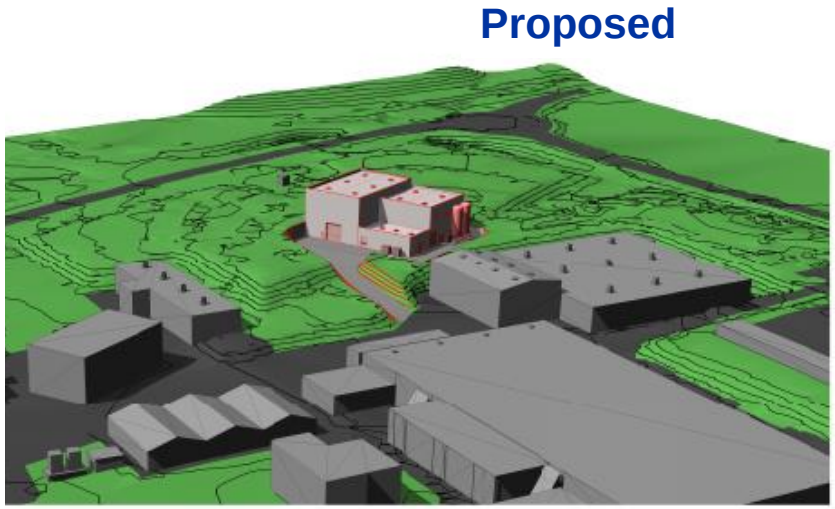
Forward Physics Facility (FPF)

Purpose-built facility

- Proposed surface buildings
  - Access building
  - Electrical building
  - Cooling & Ventilation building

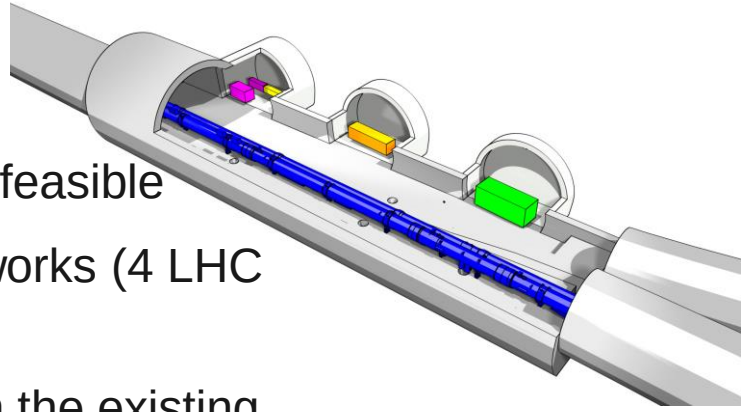


- Site used as a spoil disposal area for previous CERN projects
- Ground levels between 453-455m, approx. 7 m above the surrounding area
- Significant volume of excavation due to the existing conditions
- Possible disruption to existing services to be checked

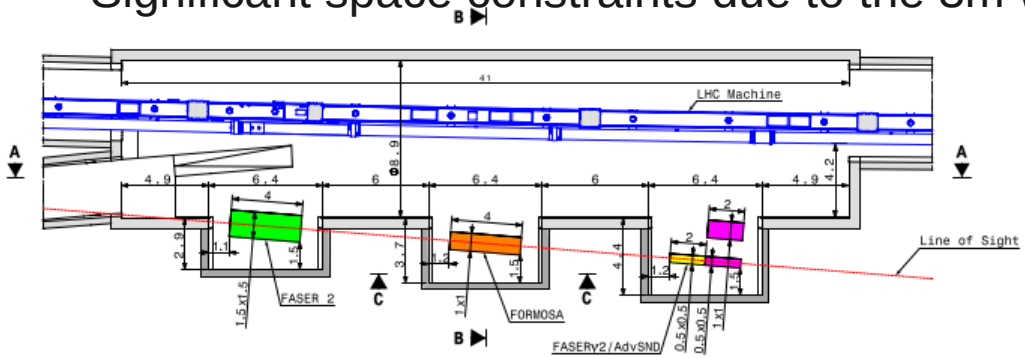


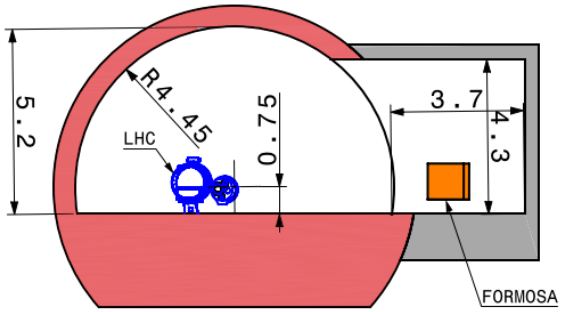
Forward Physics Facility (FPF)

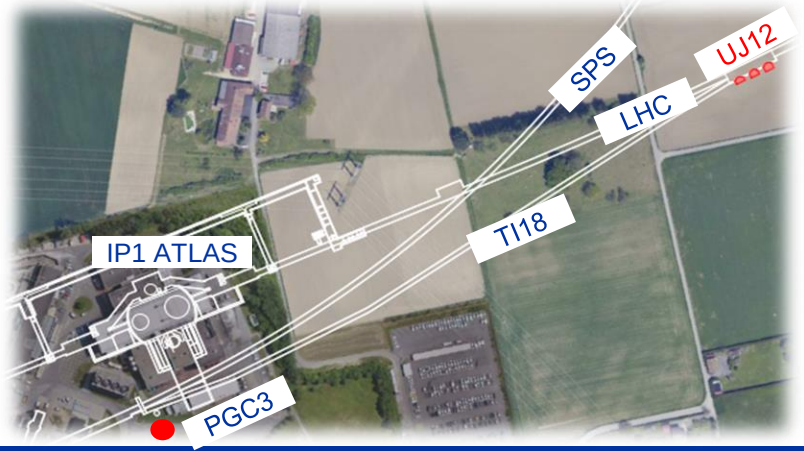
UJ12 Alcoves Option



- Option considered but not taken forward mainly due to the impact on LHC
- Expanding one side of the UJ12 with separate alcoves, only 2-3 alcoves are feasible
- Existing services and equipment need to be removed from the cavern prior works (4 LHC dipole magnets, a 60m long section of the QRL cryogenic line)
- Main challenge is to carry out the works in a way that minimize the impact on the existing structure
- Difficult access of the worksite, via PGC3 shaft and passing through the 536m long TI12 tunnel (housing the FASER experiment)
- Significant space constraints due to the 3m wide shaft



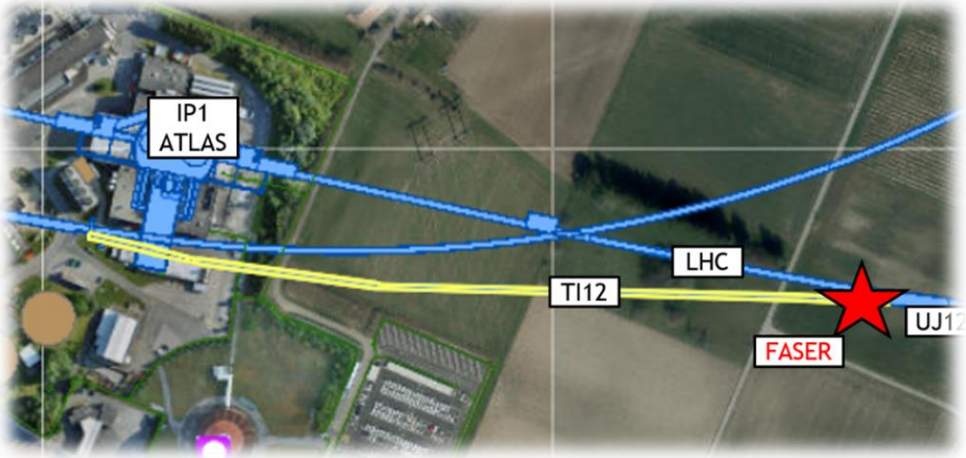


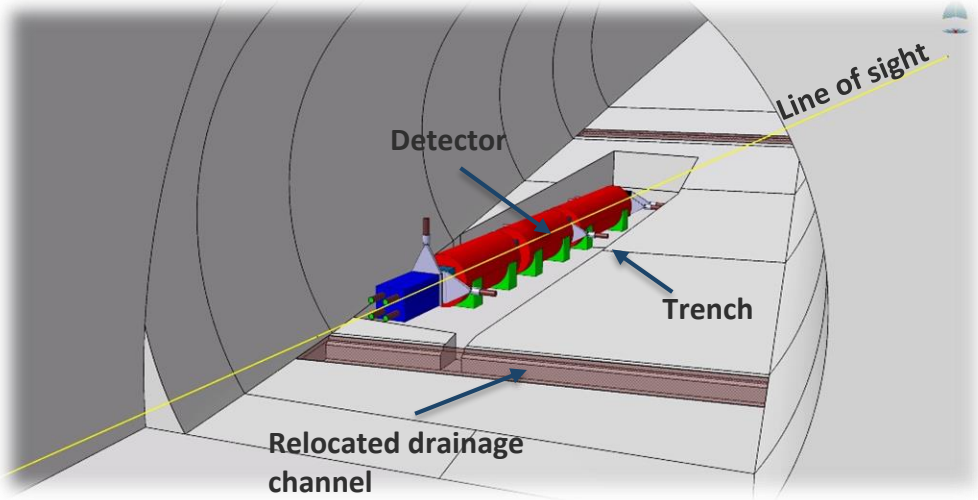


FASER

ForwArd Search ExpeRiment at the LHC

- Already approved and installed experiment
- Location in the bottom of the abandoned TI12, 480m from ATLAS IP1
- Required civil engineering:
  - ➢ Detector along line of sight (LoS) from IP1
  - ➢ Excavation of a trench measuring 8.1m in length by 1.5m wide with depth varying between 140mm and 600mm
  - ➢ Diversion of the longitudinal drain
- CE cost accounted to 350,000 CHF
- This area of tunnel was used as a demonstrator for proof of concept for a digital twin





FASER
Challenges

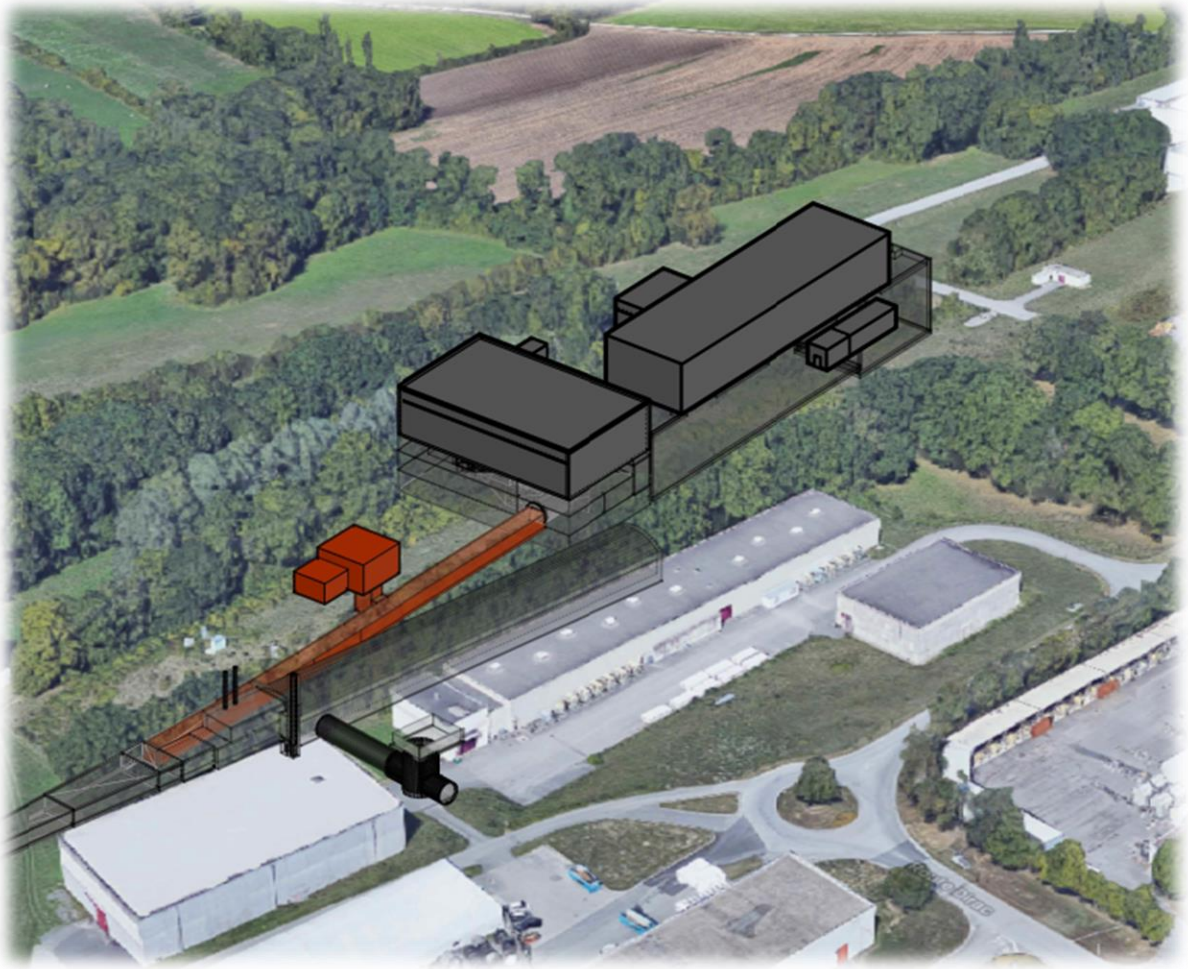
- To ensure structural stability is maintained (excavation in phases + tunnel monitoring)
- Dust suppression critical for such work in the LHC tunnel
- Difficult access to the site

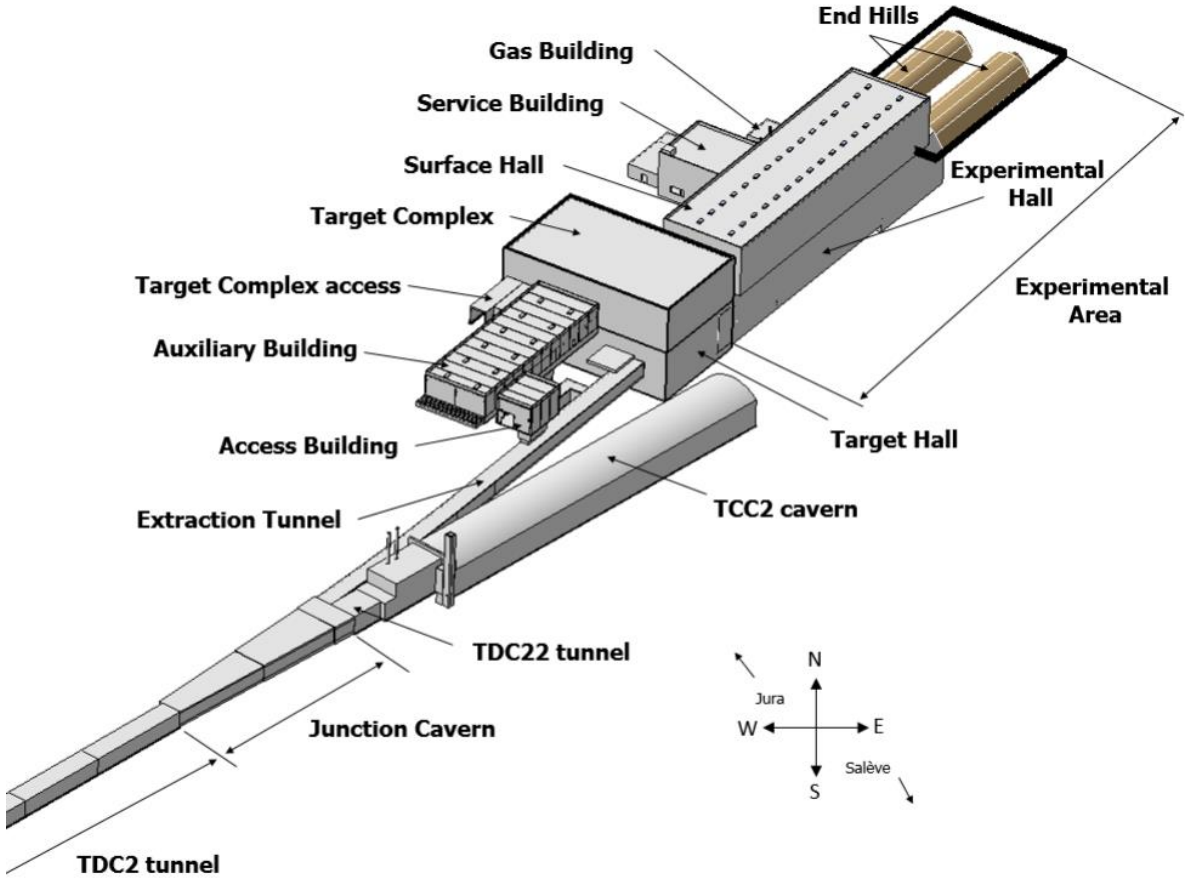
Internal SAS installed

Tunnel monitoring

Diamond coring of the main drain

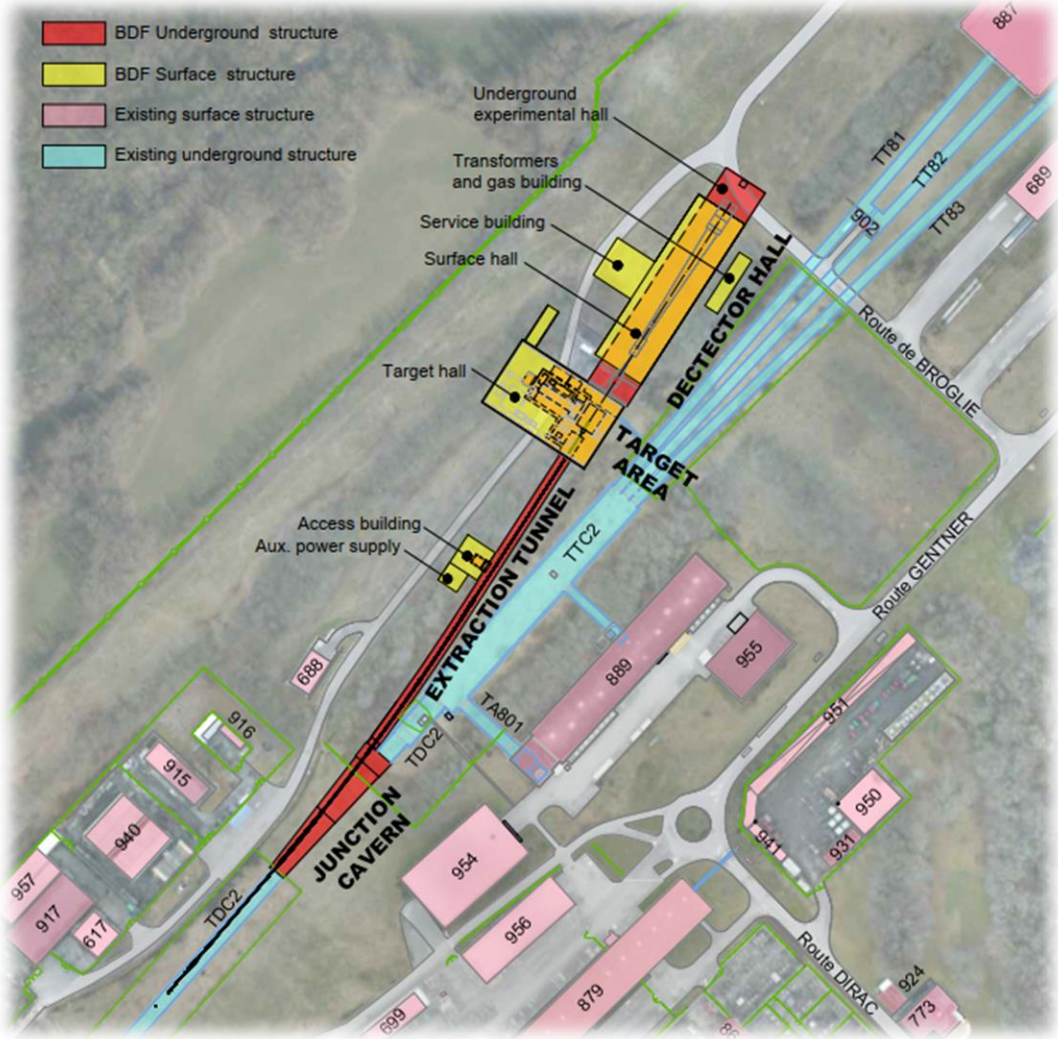
Beam Dump Facility (BDF)





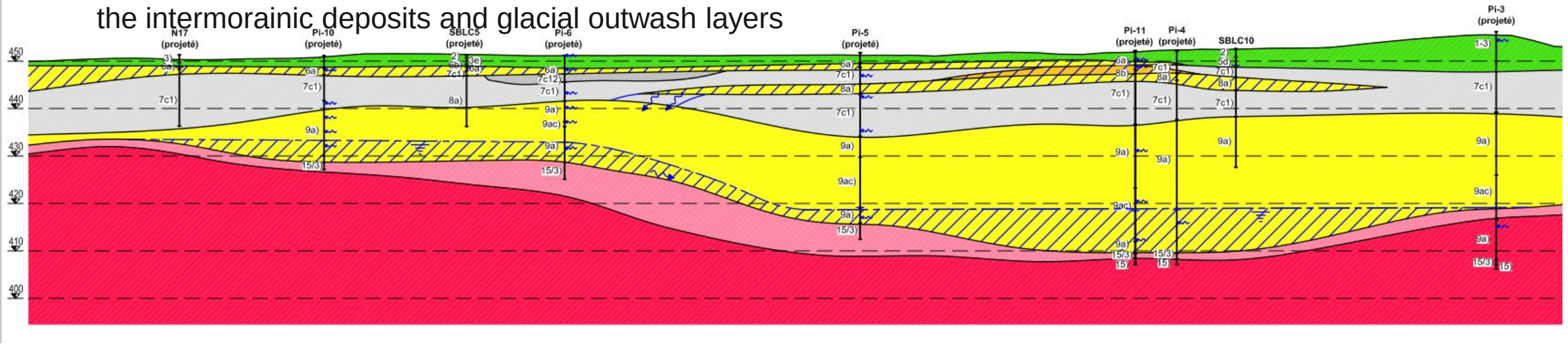
Beam Dump Facility (BDF)
Layout and location

- Location at French CERN site in Prevessin
- Proposed BDF Facilities:
  - 75m long junction cavern
  - 165m long extraction tunnel
  - Access building including a heavy equipment access shaft
  - Auxiliary building servicing the extraction tunnel and target complex
  - 36m long by 58m wide target complex
  - 120m long by 20m wide experimental hall
  - 100m long by 27.5m wide surface building above the experimental hall
  - Service building and workshop
  - Gas building



Beam Dump Facility (BDF)
Ground conditions

- Ground conditions well known and understood (North Area ground investigation in 2020/2021)
- Underground works in the moraine deposits layer at depths up to 20m
- Site characterised by several groundwater tables, independent one of another mostly established in the intermorainic deposits and glacial outwash layers



2) Moraine backfill
3) Colluvium
6a) Glacial outwash (gravely phase)
7a) Consolidated silty moraine deposits

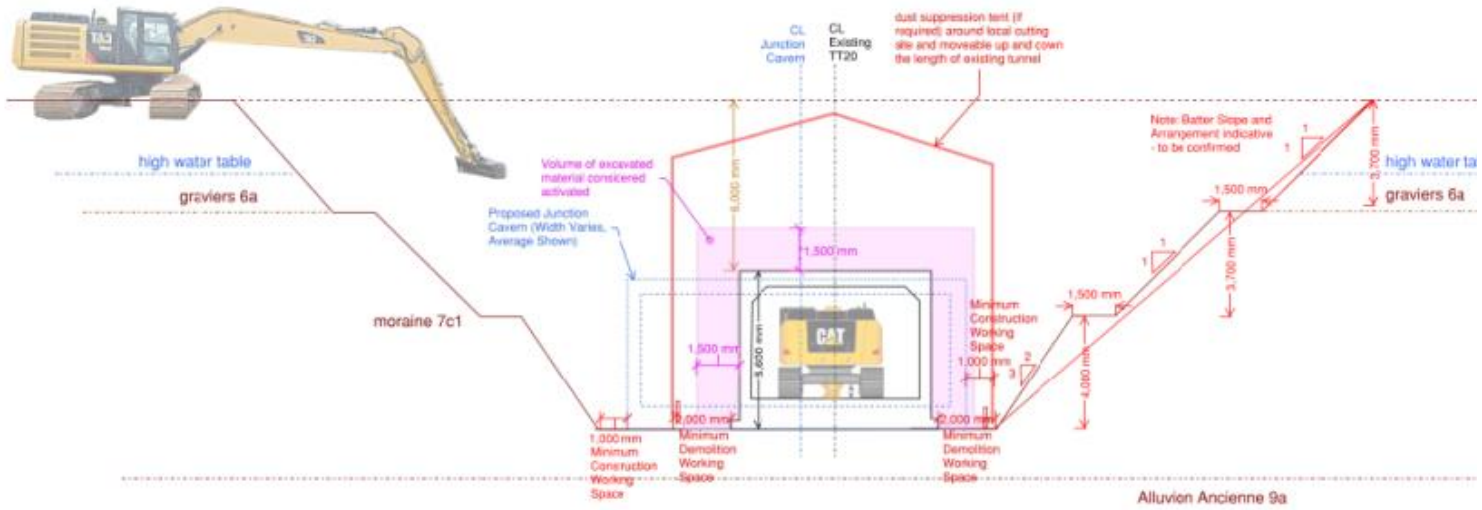
8) Intermorainic deposits (gravel and sand)
9) Deep morainic gravel
15) Molasse mudstone

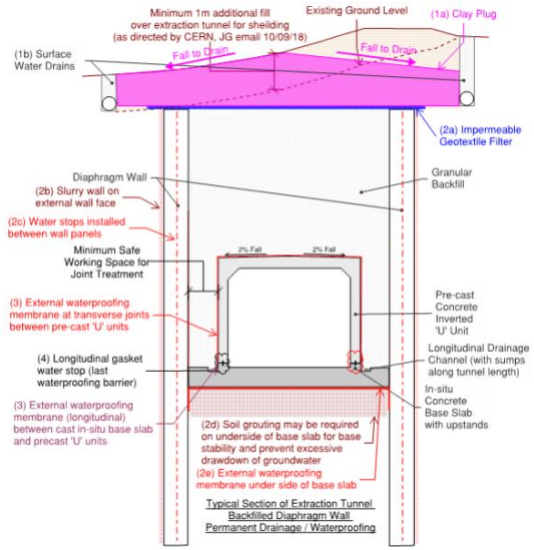
Beam Dump Facility (BDF)
Challenges

- Close vicinity of existing infrastructures (TCC2 cavern and TT81,82,83 transfer tunnels), sensitivity to vibration and excavation carried out during works
- Demolition of the existing TDC2 required for the construction of the junction cavern
- Prior to demolition, approximately 100 m length of machine and services will have to be removed from TDC2
- Radioprotection constraints (concrete in the TDC2 classified as radioactive, all soil within 1.5 m of the tunnel walls was assumed to be activated as well)
- Planning of works: works cannot be carried out within 8 m of the existing beam line during operations
- Existing groundwater → radiation contamination risk needs to be assessed

Beam Dump Facility (BDF)
CE Solutions

- Demolition of TDC2 via traditional methods using crushing and hammering in opencut excavation
- Precast elements to reduce the duration of works next to the activated soil and the overall construction time

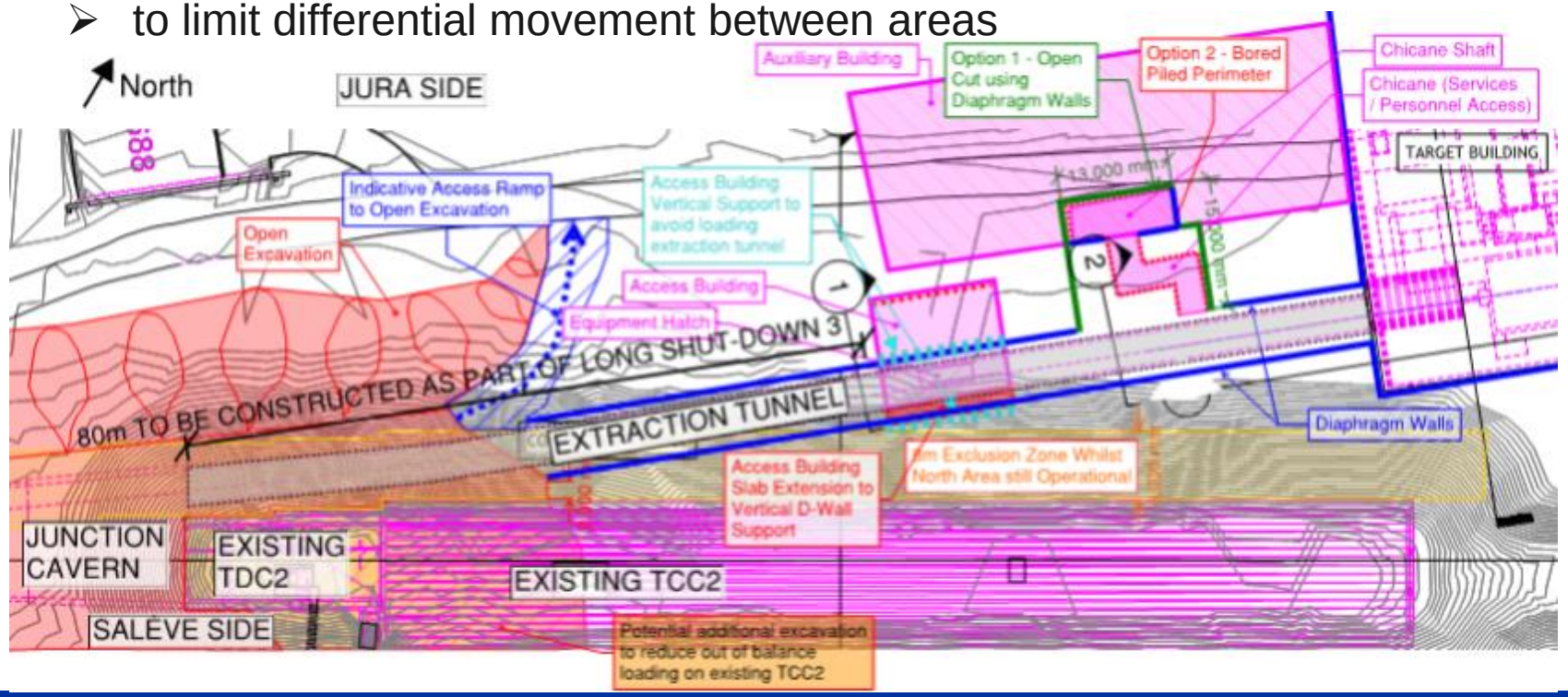




- Demolished concrete and activated earth reused as backfill above the new junction cavern and extraction tunnel to avoid disposal off-site and producing additional activated soil

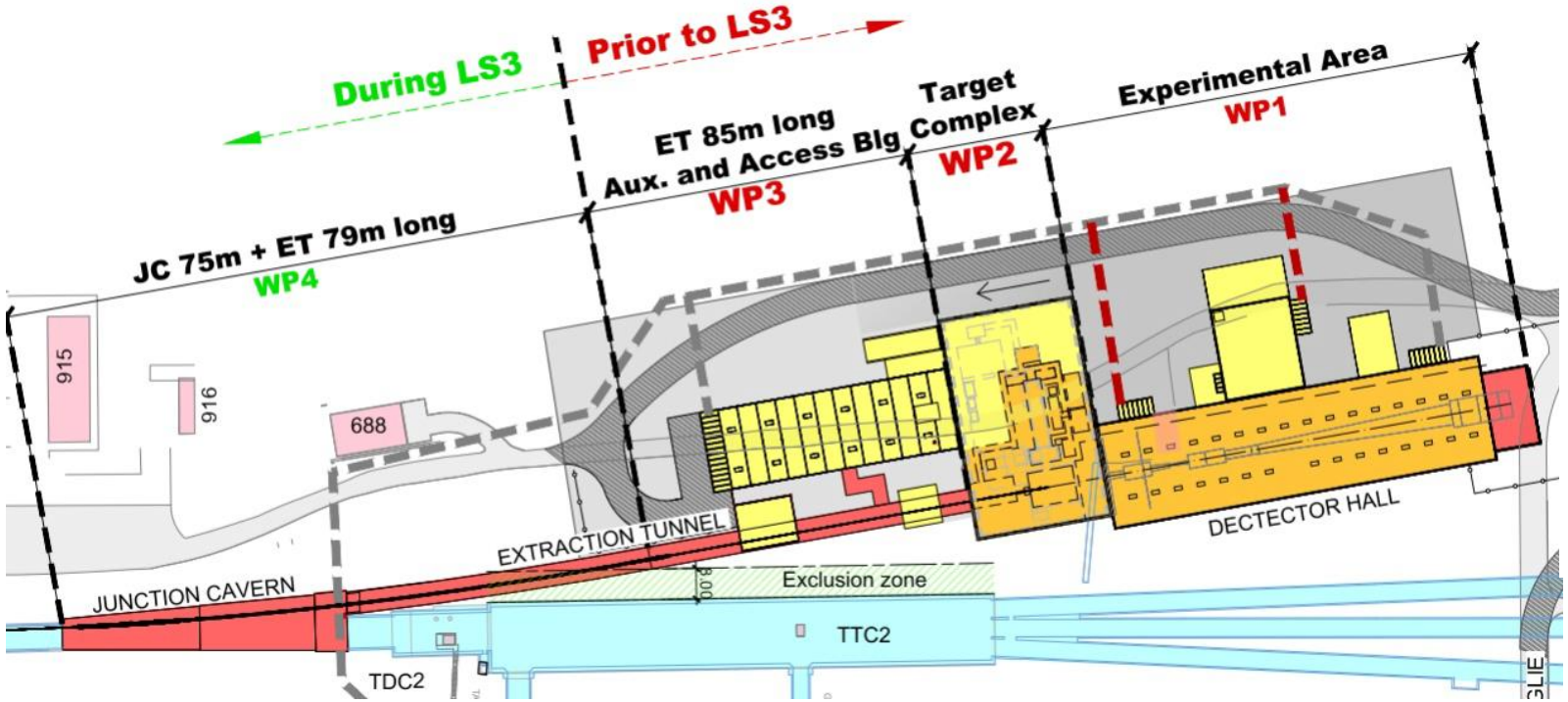
Beam Dump Facility (BDF)
CE Solutions

- Diaphragm wall required :
  - ➢ to allow the construction close to the TCC2 cavern
  - ➢ to act as a primary barrier to groundwater infiltration
  - ➢ to limit differential movement between areas



Beam Dump Facility (BDF)
Cost estimate and schedule of works

- Estimated construction time is 2.75 years for the underground works and 1.75 years for surface works
- The civil engineering cost is estimated to be 68.3m CHF

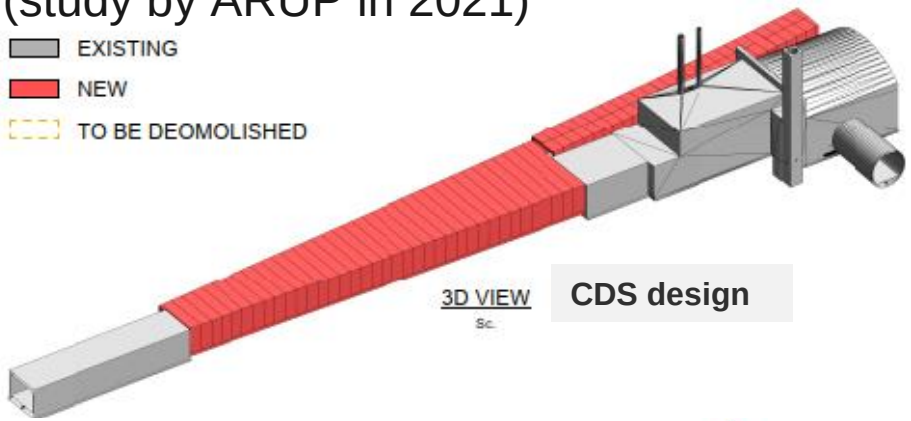


Work package	Cost [MCHF]
Work Package 1	31.7
Work Package 2	16.5
Work Package 3	10.9
Work Package 4	7.3
Work Package 5	1.3
Site investigation	0.6
Facility total	68.3

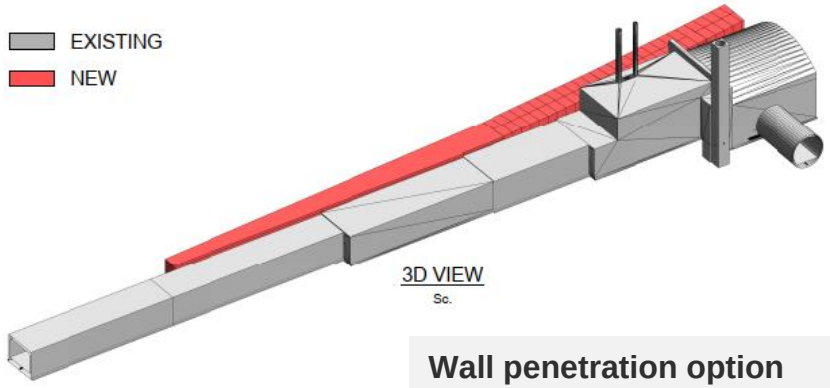
*The accuracy of the estimate is considered Class 4 - Study or Feasibility which could be 15-30 % lower or 20-50 % higher (in line with AACE international's best practice recommendations [3] as has been used for previous CERN projects). Until the project requirements are further developed, it is suggested that a suitable band to adopt would e −20 % to +40 % for CE costs (Future Accelerator Studies Section Civil Engineering Cost Estimation Strategy and Methodology **EDMS 2405682**)*

Beam Dump Facility (BDF)
Possible optimization

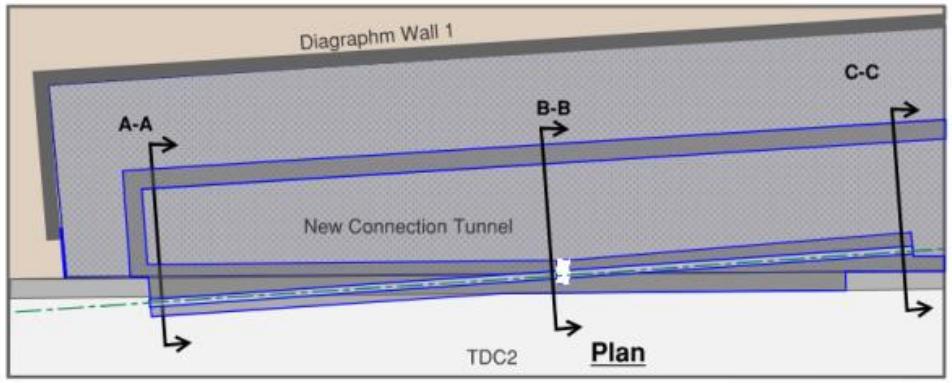
- To create a small channel by penetration into the wall of the TDC2 allowing the beam line passing through to the newly constructed tunnel to reduce the impact on the existing structure and the related risk (study by ARUP in 2021)

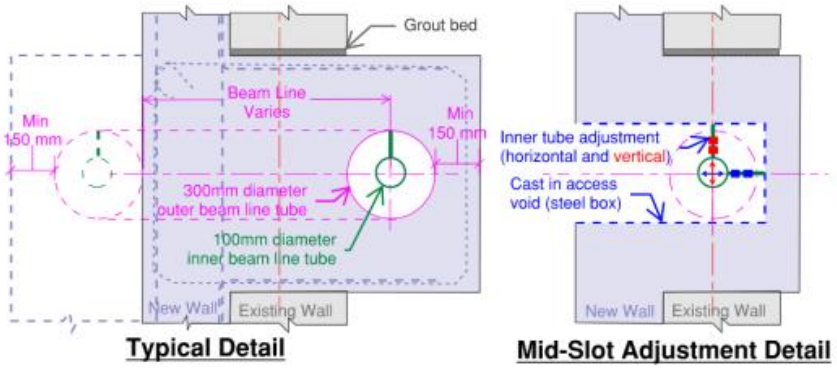


CDS design



Wall penetration option





Concrete follows beam line to improve reinforcement detailing

Beam Dump Facility

Alternative Locations

TT90-TCC9-ECN4
(CDS study)

ECN3

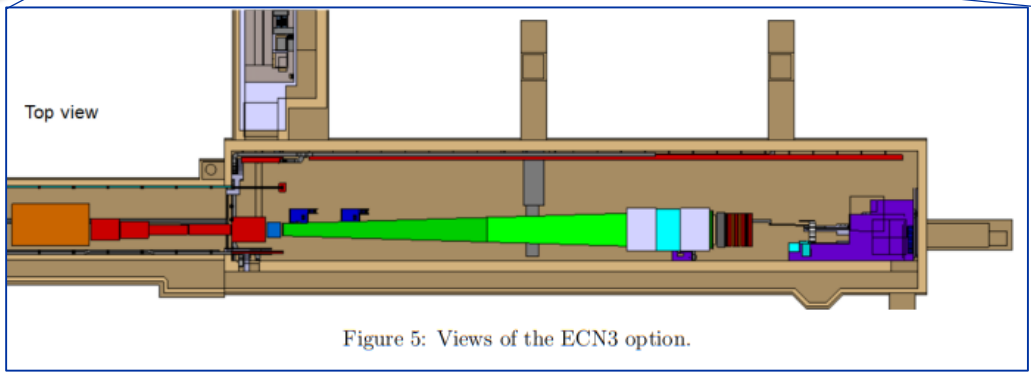
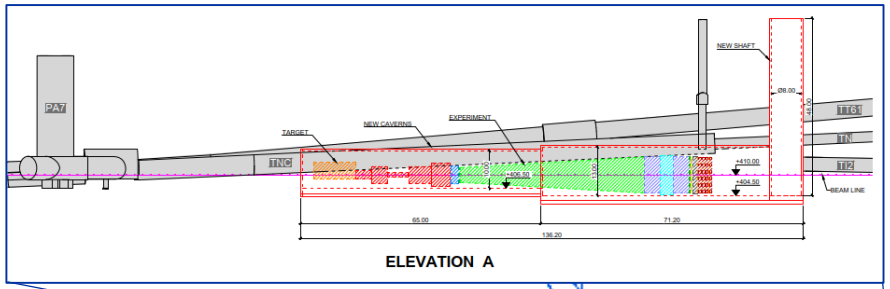


Figure 5: Views of the ECN3 option.



SPS

TNC

TCC4

LHC

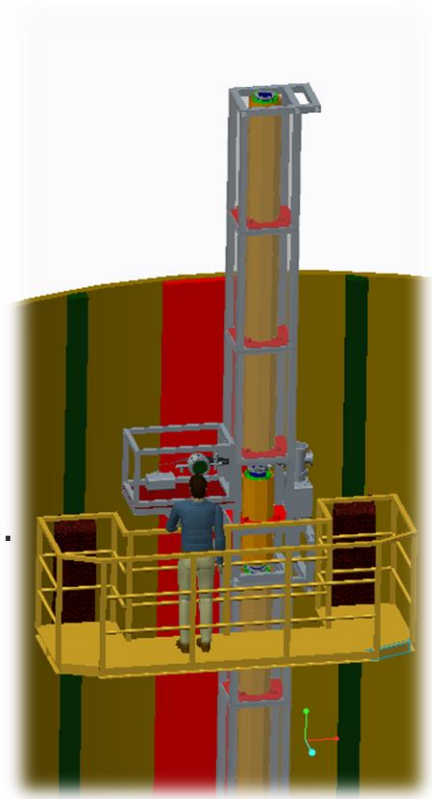
AION-100@CERN

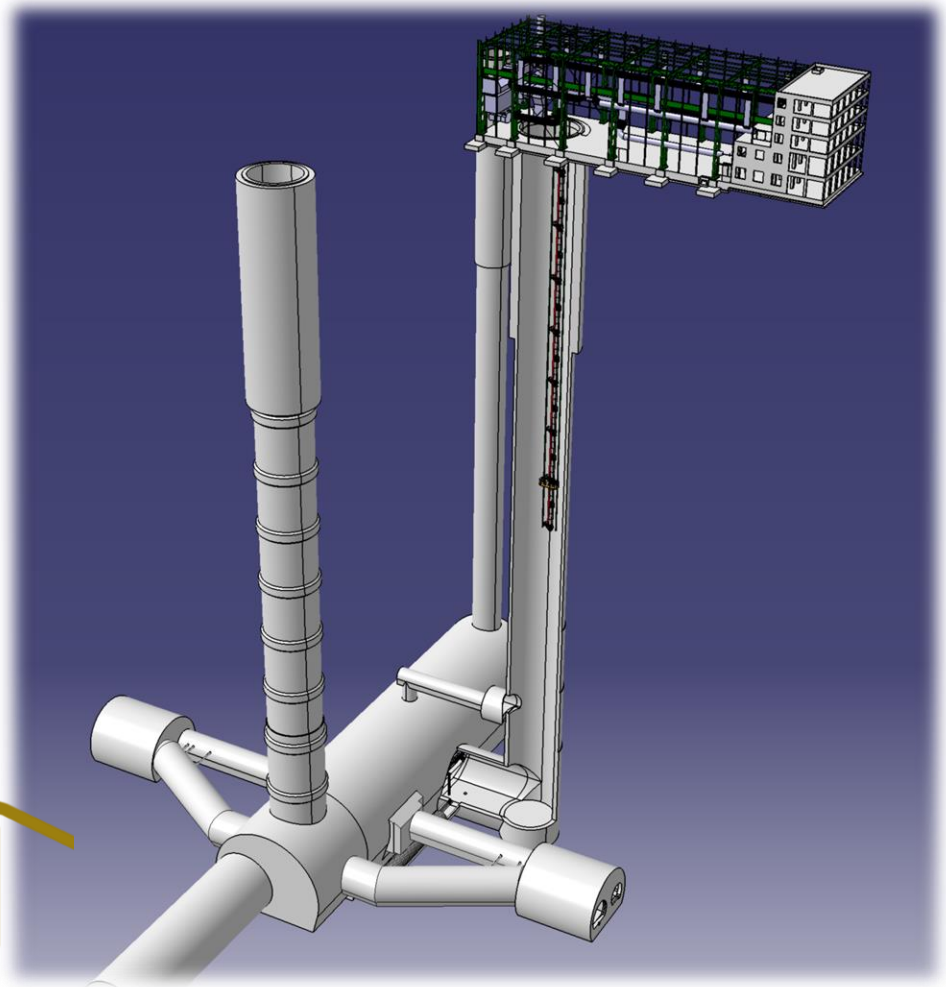
The experiment

- 100 m long Interferometer (possibly built with 5m long modules)
- Moving platform around the detector to carry the atom sources, ion pumps up and down etc.

Aim & Objectives

- Explore the possibility of housing the experiment in one of the existing LHC shafts
- Coordination of infrastructure

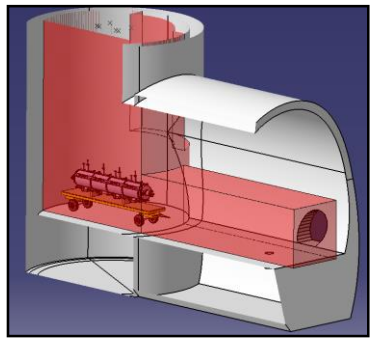


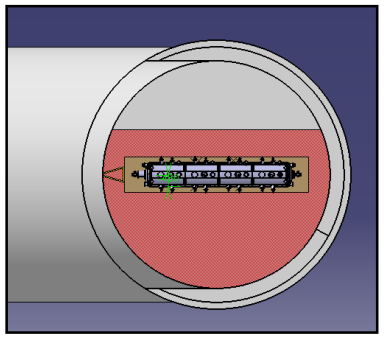


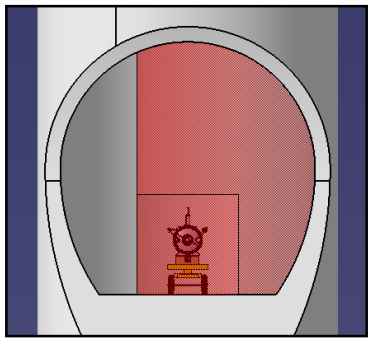
AION-100@CERN
Proposed location

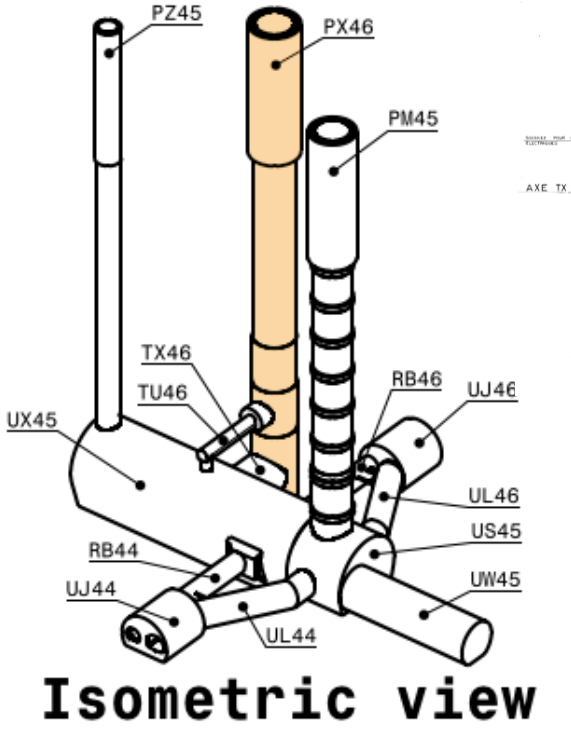
Location: PX46 shaft at the IP4 LHC

- Internal diameter :10m
- Internal height: 143 m
- Shaft used to raise/lower LHC and HL elements, PX46, TX46 need to stay open at any time
- Air extraction for the UX45 at the top of the shaft by a unit located in TU46 (no ducts in PX46)

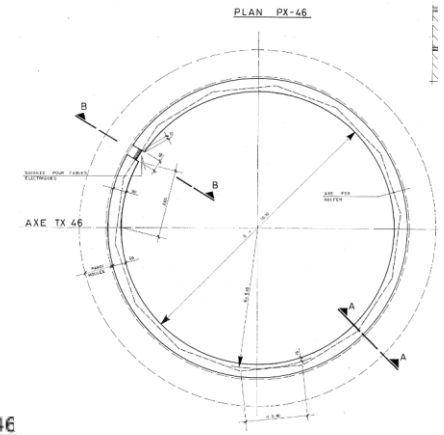




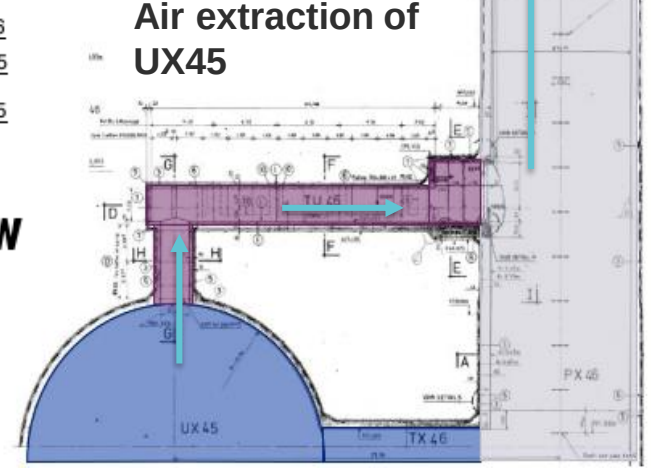




Isometric view



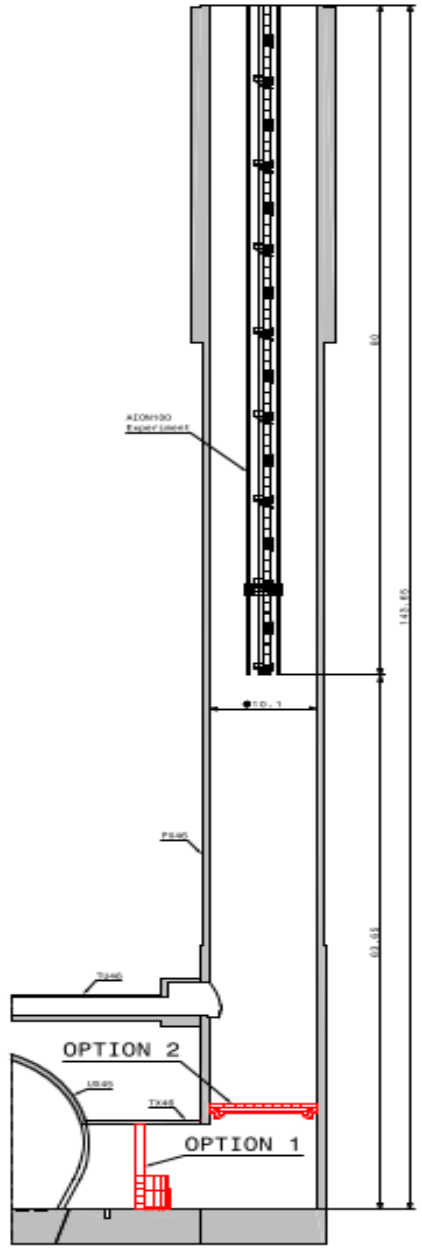
Air extraction of UX45



Transport zone required to be kept in the TX46, PX46

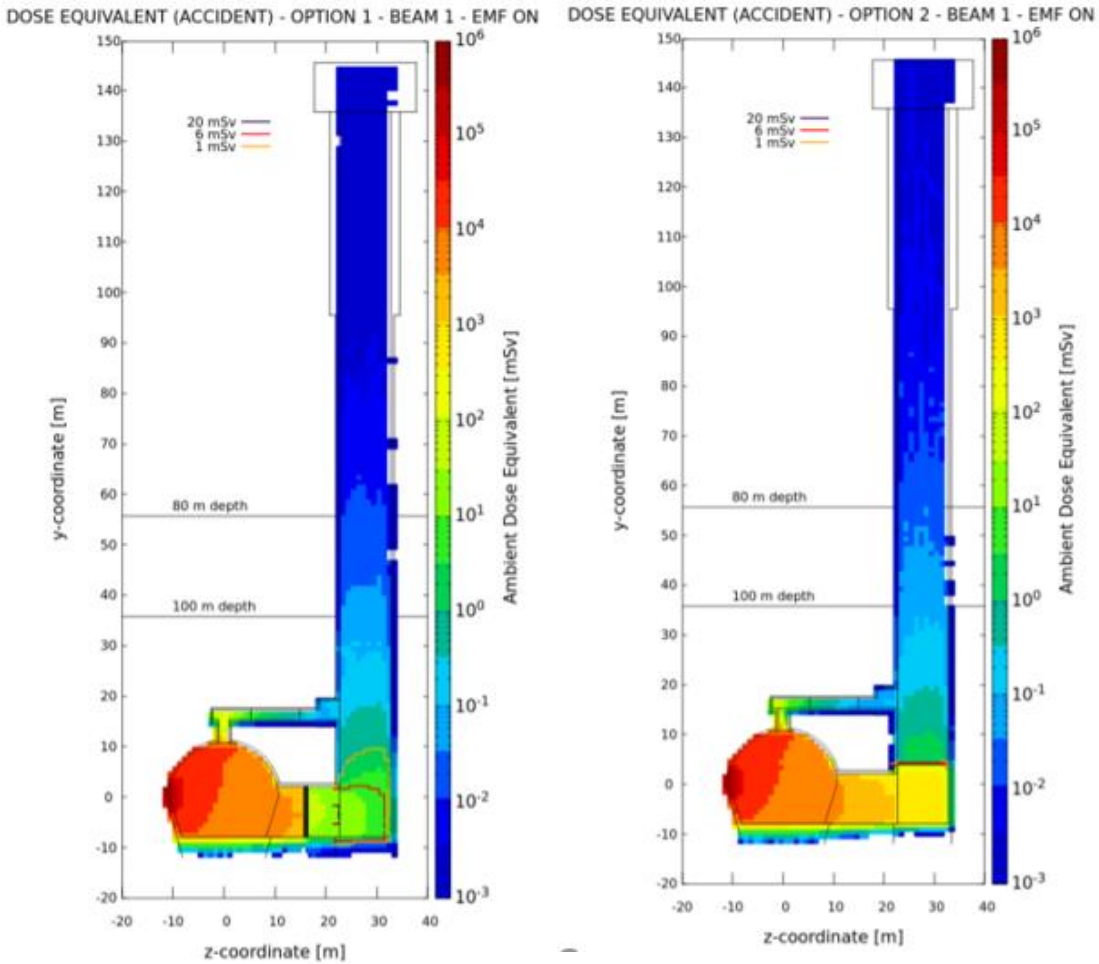
AION-100@CERN
Challenges

- Experimental requirement to access the shaft on a regular basis
- Study needed to determine the length of experiment that could be installed in the shaft
- Conclusion of a first preliminary RP study
  - ➢ Experiment with a maximum depth of 80m from the surface
  - ➢ Access platform should not go beyond the maximum depth of 90 m, should not reach the bottom of the shaft
- Shielding option proposed to increase the possible length of the experiment
  - ➢ Solutions with removable shielding blocks to avoid blocking the area reserved for transport/handling



AION-100@CERN
Challenges

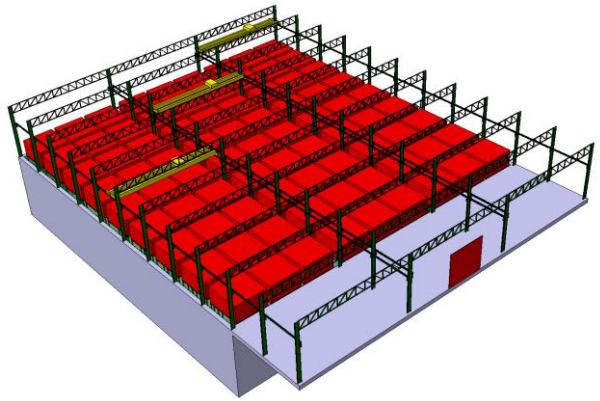
- Second RP study considering the shielding proposed
  - ➢ Option 1 : possibility to use (almost) the full depth of the shaft
  - ➢ Option 2 : possibility to use up to 120 m (overruled due to handling constraints)
- With the proposed shielding only one exit way is possible
  - ➢ Chicane instead the shielding ➡ RP study
- Fire safety issues

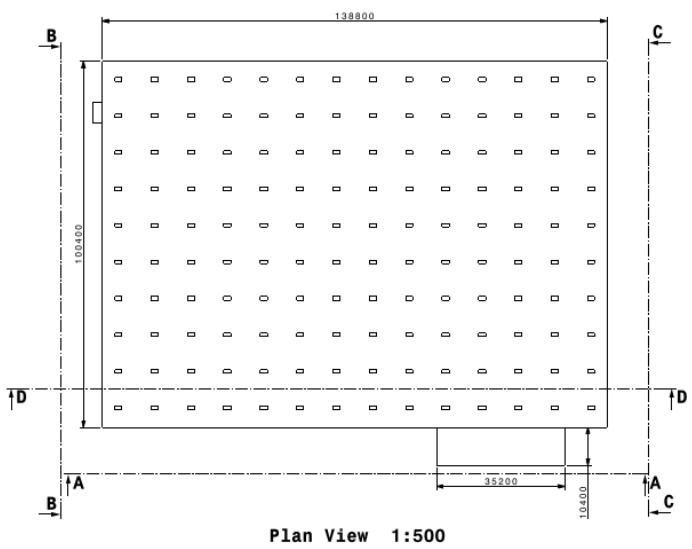


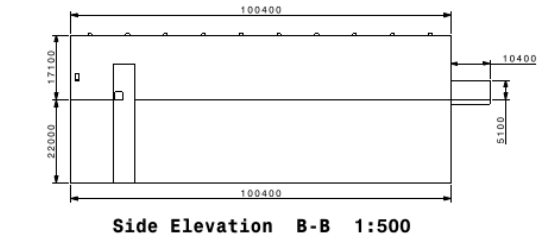
MATHUSLA

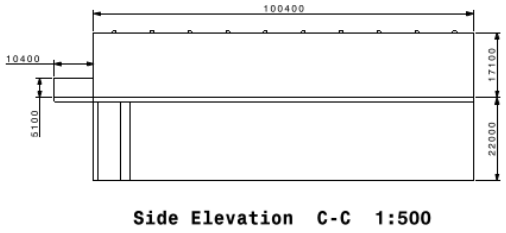
Massive Timing Hodoscope for Ultra-Stable neutraL pArticles

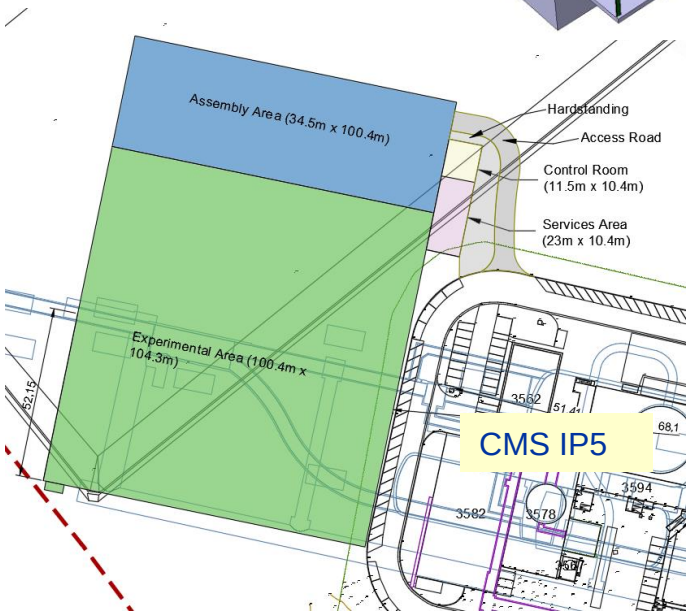
- Study involving a very large detector building next to the surface buildings of CMS (IP5 LHC)
- Dimension in plan 100m x 138m, height is 17m above ground and 22m under ground
- Diaphragm walls estimated at twice the depth of retained structure
- Preliminary cost estimate prepared in 2019, 51.4m CHF



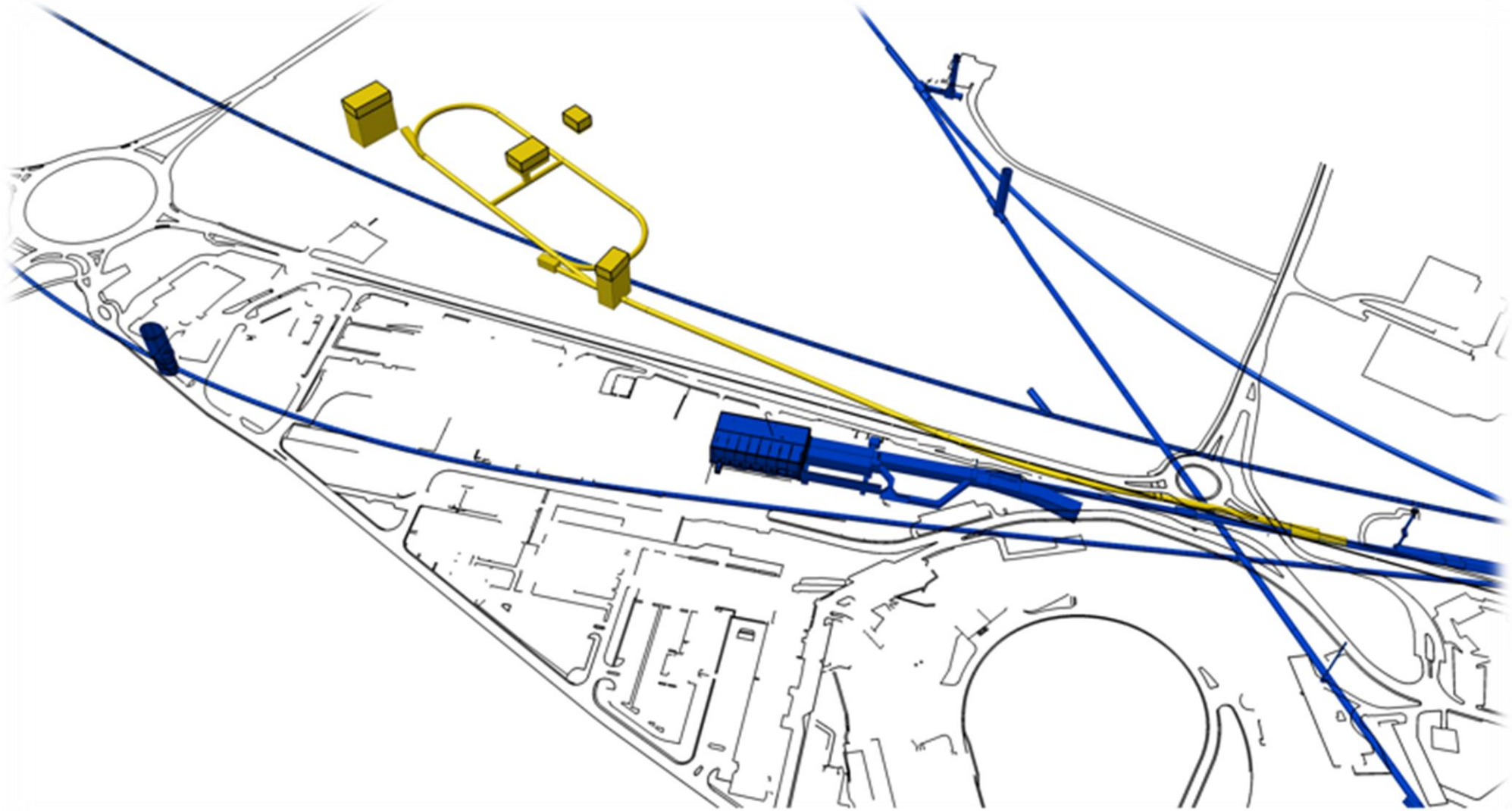






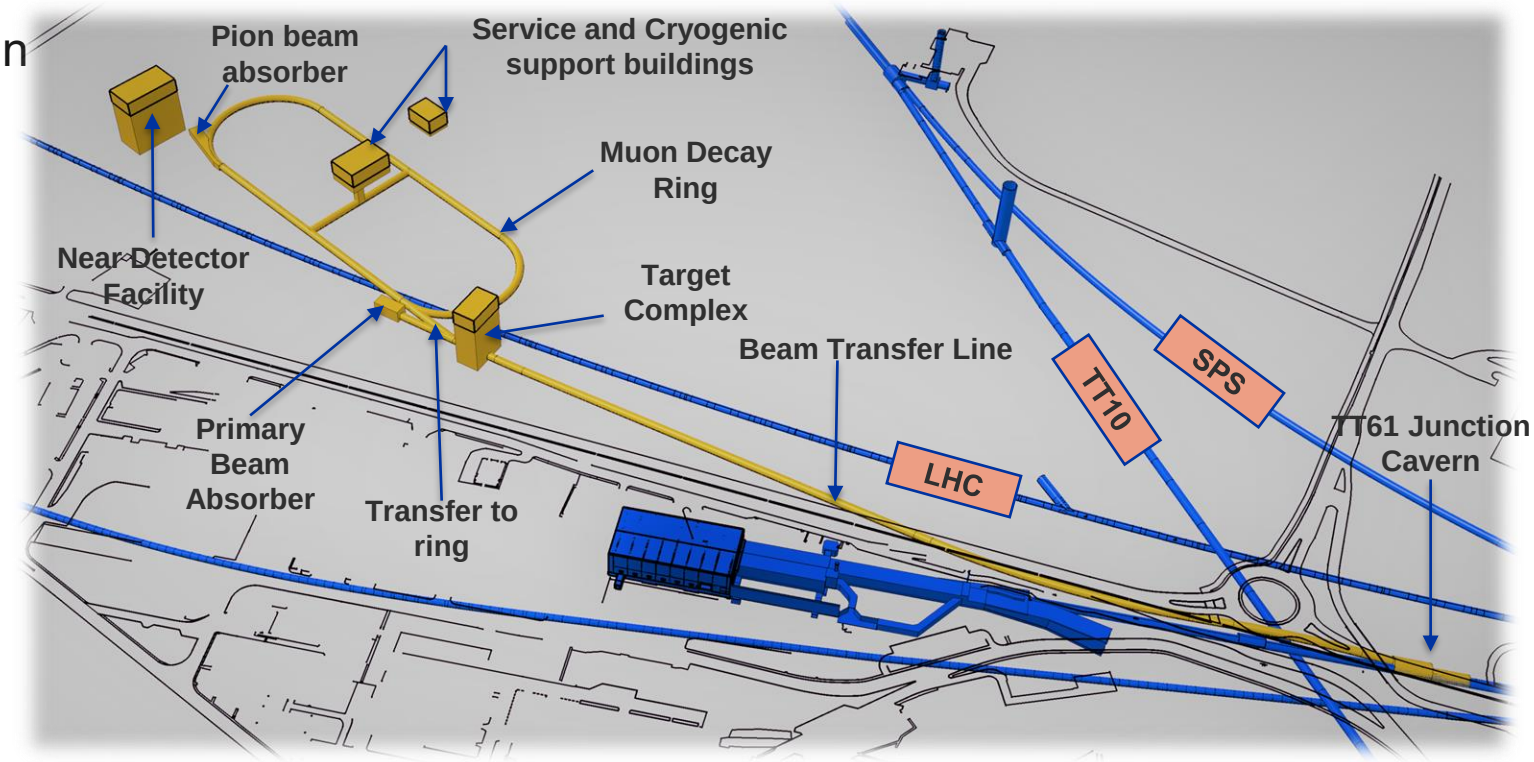


nuStorm



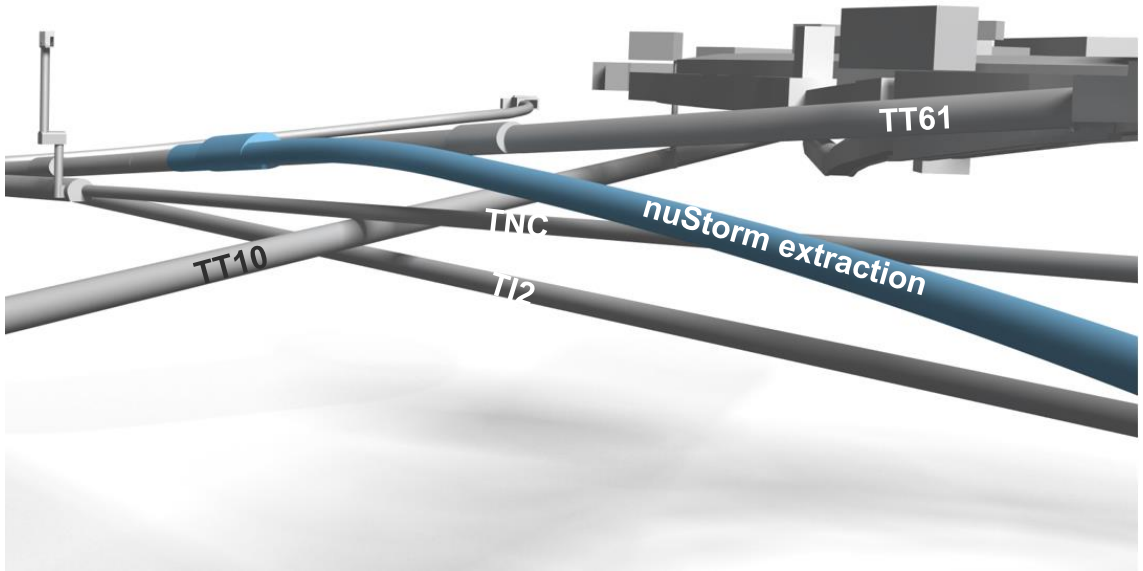
nuStorm
Layout and location

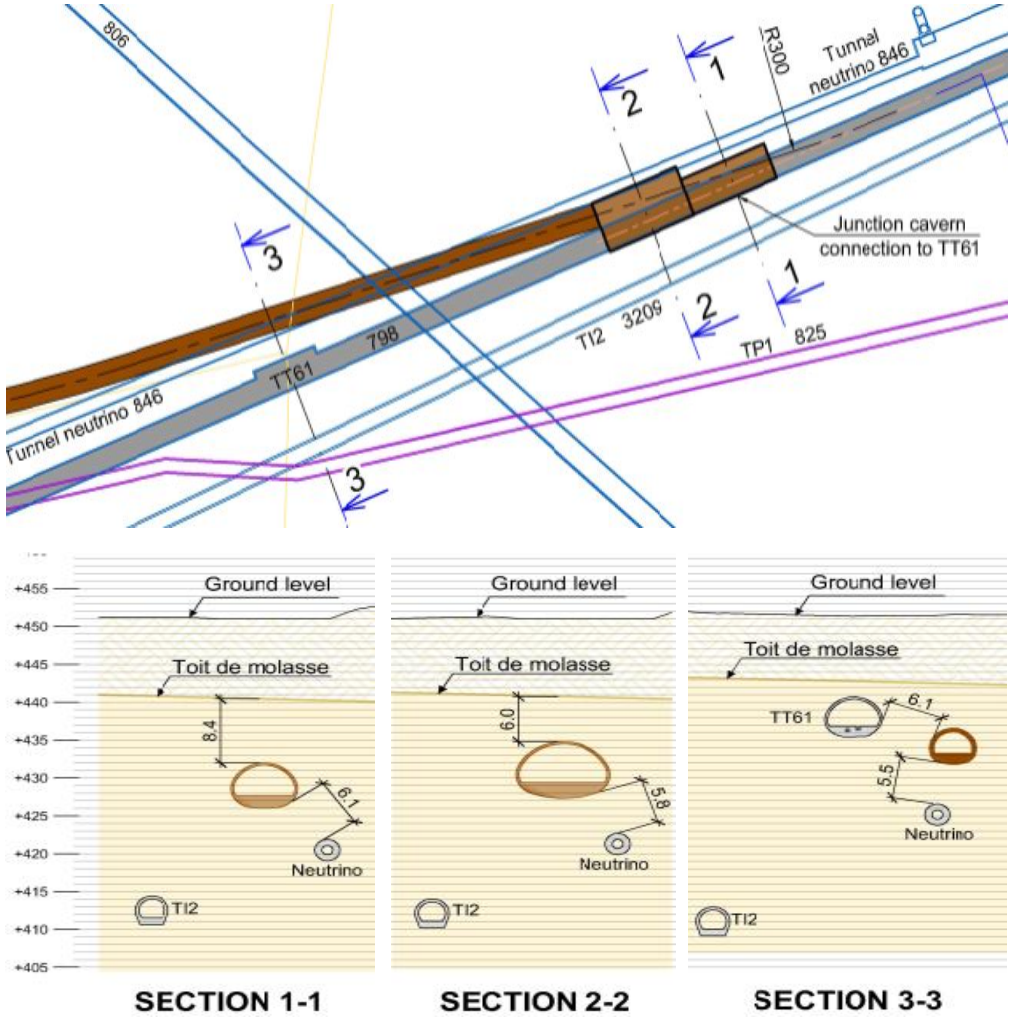
- Location at north of CERN's Meyrin site in France
- Proposed facilities:
  - 40m long junction cavern
  - 545m long extraction tunnel
  - Target complex
  - 625m circumference decay ring
  - Near detector facility
  - Support buildings and infrastructure
- Extraction from TT61



nuStorm
Challenges

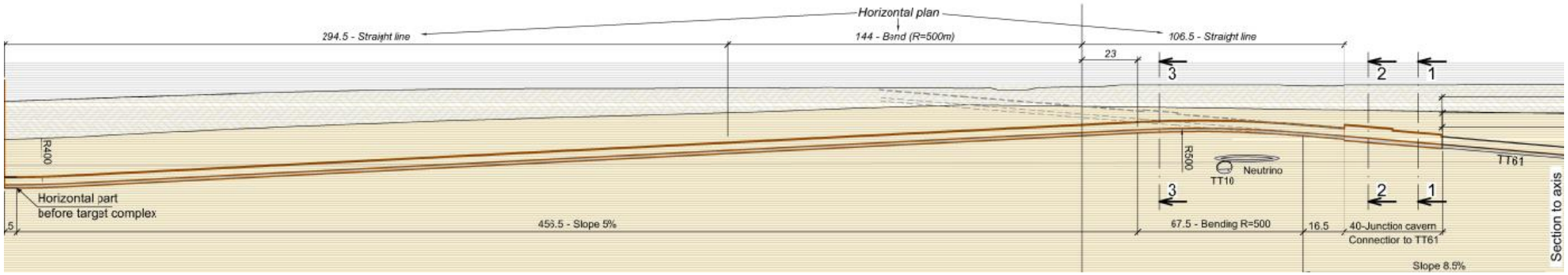
- Congested existing infrastructure in the area
- Design constrained by existing ground conditions
- Close to Molasse-Moraines interface





nuStorm
CE Solutions

- Junction cavern and extraction tunnel designed to avoid going within 5m of the rockhead, reducing the risk of encountering very poor rock quality
- Junction cavern split into two separate section to optimise the size and the cost
- Tunnel alignment optimise based on bending radii from beam transfer team and maximum transportation gradient



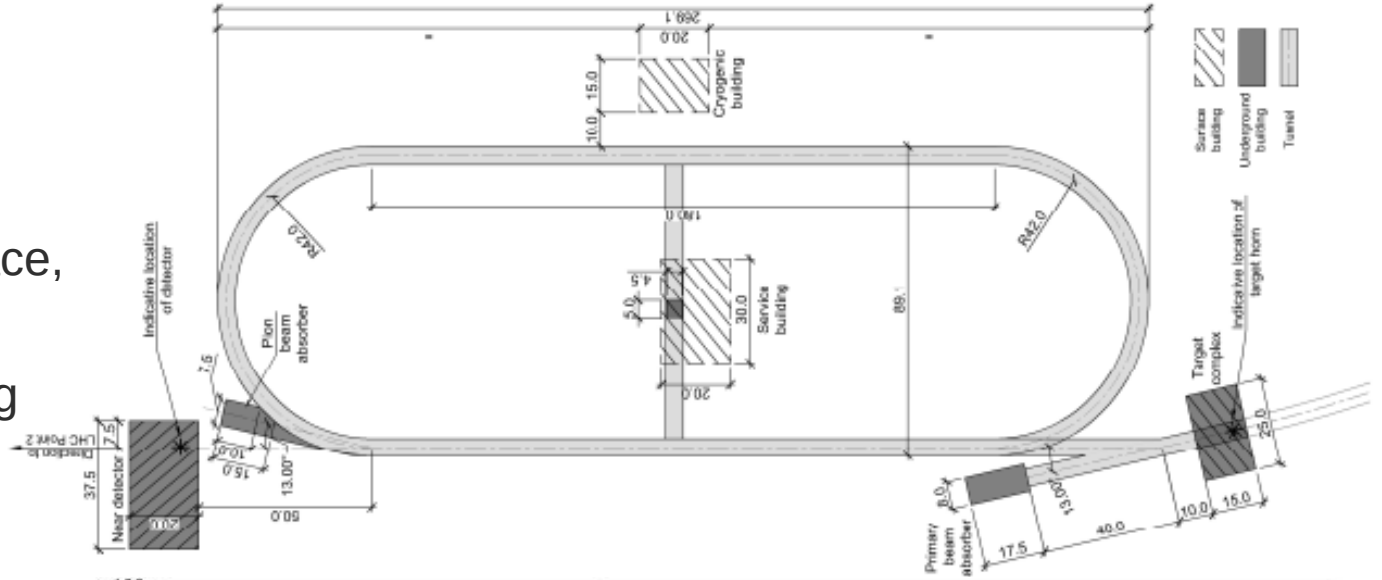
nuStorm
CE Solutions

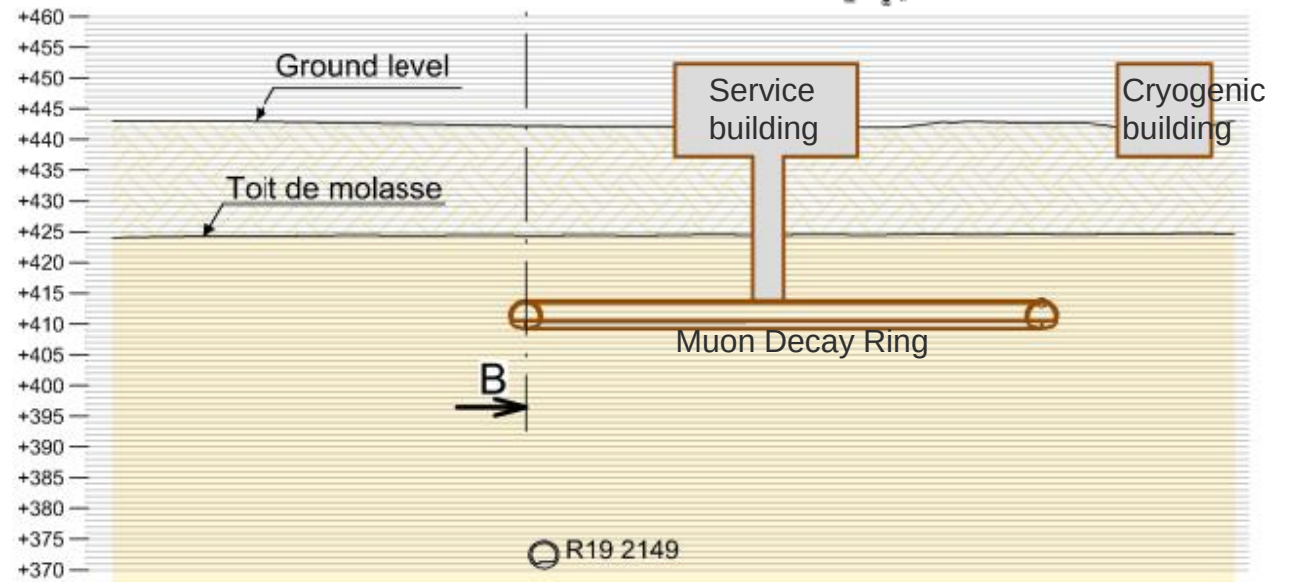
Target Complex

- Conventional steel portal frame building at surface, 9m above ground level
- Shaft extending to beam level, constructed using diaphragm walls

Muon Decay ring and associated infrastructures

- Cross section same as the extraction tunnel
- Ring crosses the line of the LHC, but there is nearly 35 m vertical clearance





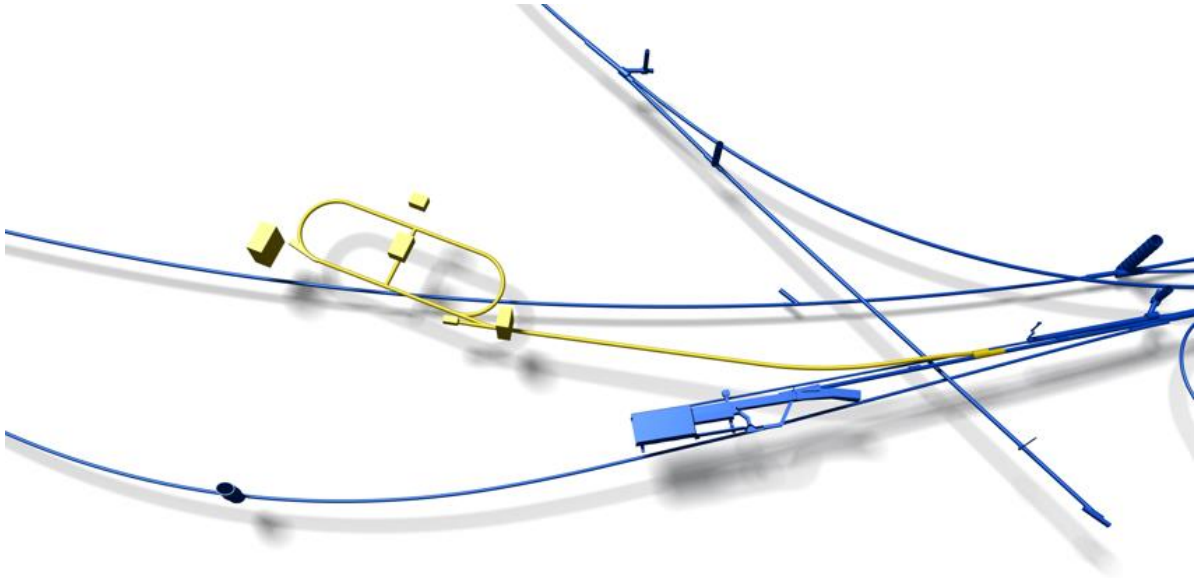
nuStorm
CE Solutions

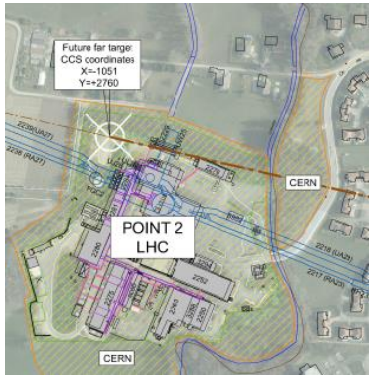
Near detector facility

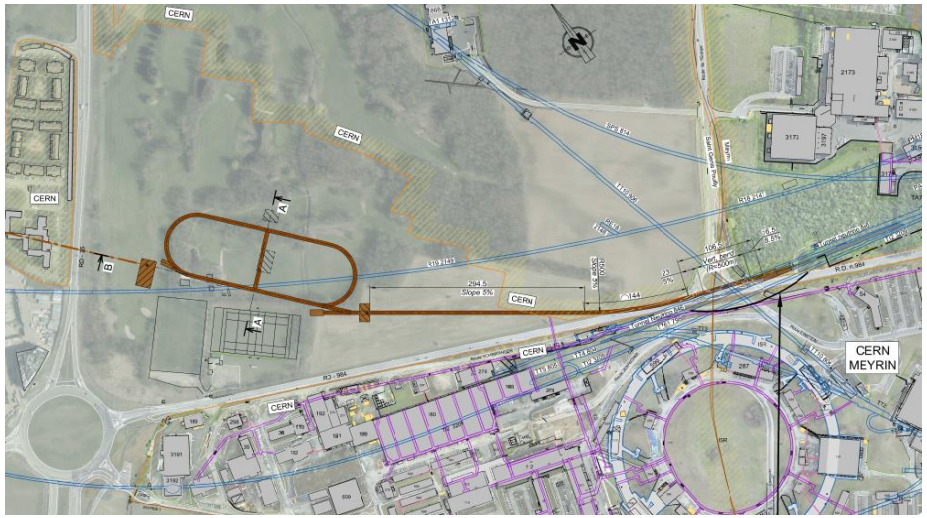
- Similar to the target complex
- Detector hall (below ground) and detector assembly/ support building (at the surface)

Future far detector facility

- Siting and civil engineering alignment designed to accommodate potential future far detector
- Suitable site at Point 2 of the LHC
- Approximately 1.75km beyond near detector



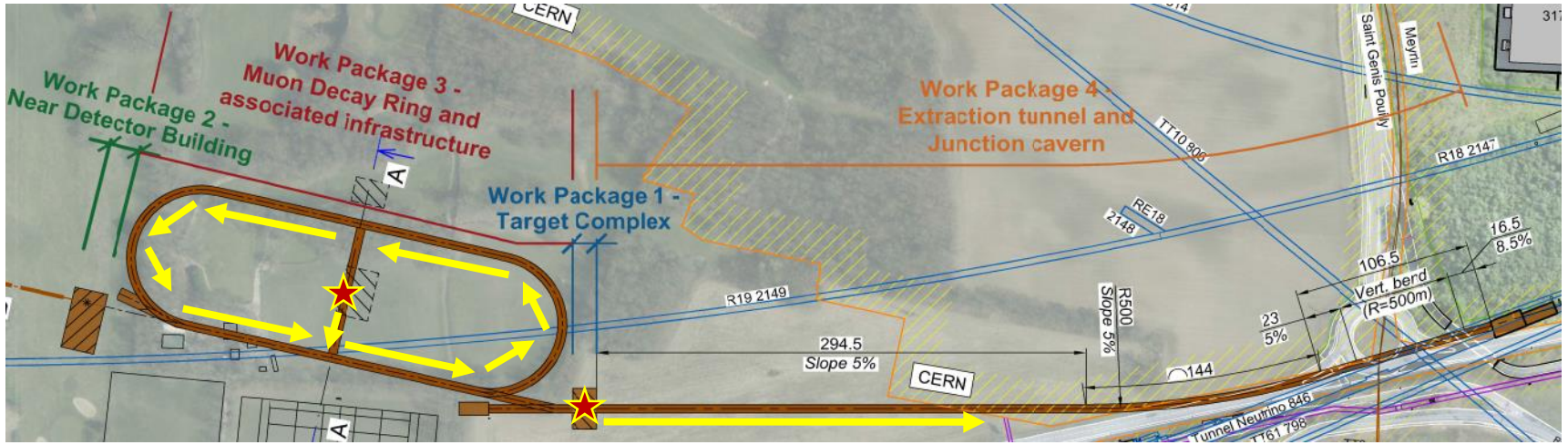




nuStorm

Cost estimate and schedule of works

- The civil engineering cost is estimated to be 47.7m CHF
- Estimated construction period is 4 years
- Multiple tunnelling launch points from required shafts to optimise schedule



Work package	Cost [kCHF]
Work Package 1	6.2
Work Package 2	11.1
Work Package 3	17.8
Work Package 4	11.2
Miscellaneous CE	0.9
Site investigation	0.5
nuSTORM total	47.7

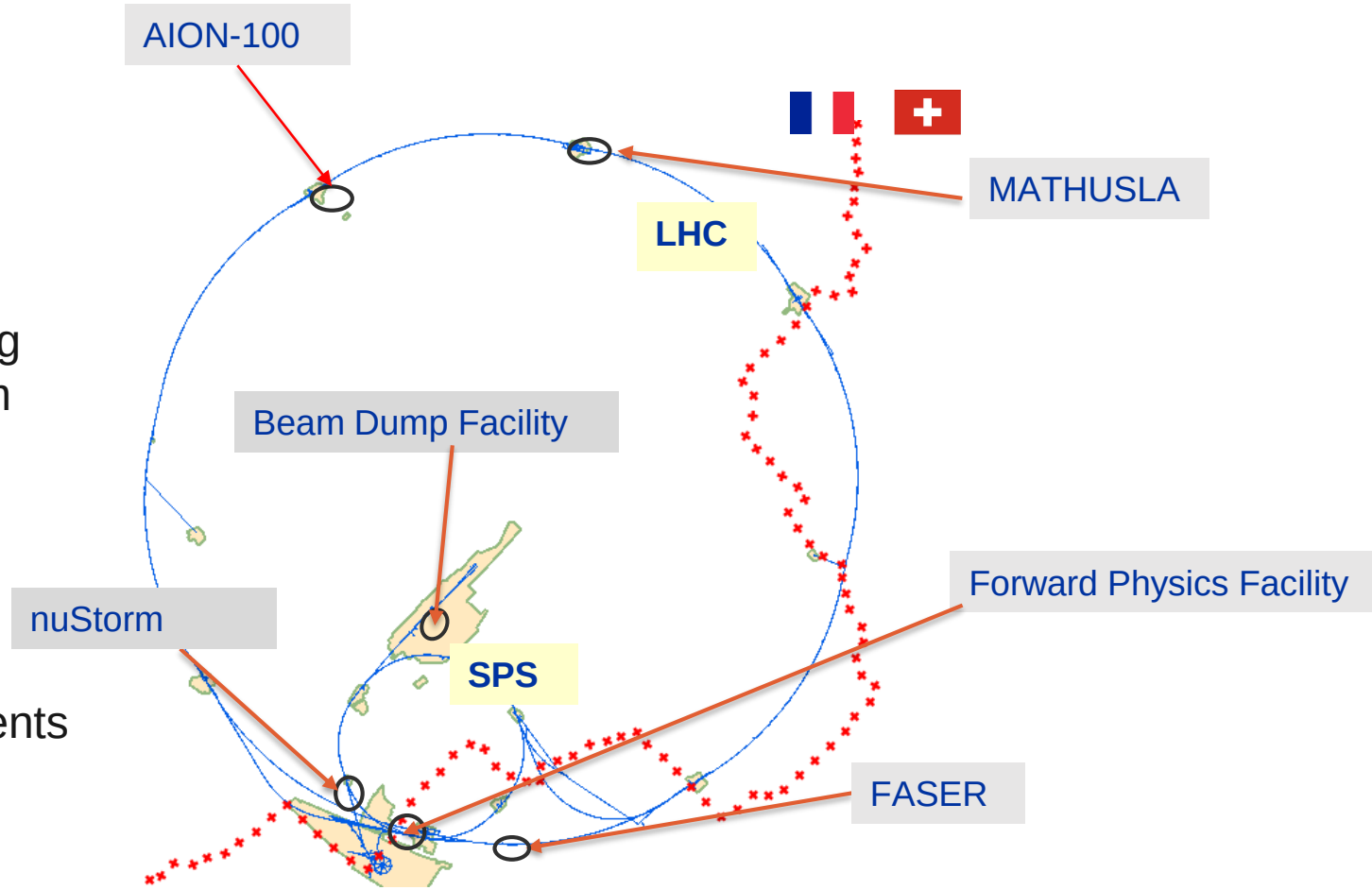
The accuracy of the estimate is considered Class 4 - Study or Feasibility which could be 15-30 % lower or 20-50 % higher (in line with AACE international's best practice recommendations [3] as has been used for previous CERN projects). Until the project requirements are further developed, it is suggested that a suitable band to adopt would be −20 % to +40 % for CE costs

★ Tunnelling 'Launch' points

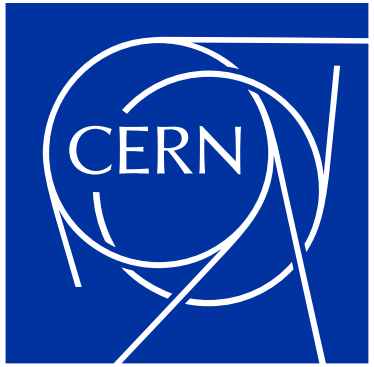
→ Direction of tunnelling

Physics Beyond Colliders Studies
Conclusion

- Studies under the PBC programme have a significant support from CERN management
- Studies often with international collaborators
- <u>Main studies and key objectives in 2022</u>**:**
  - ➢ FPF: Completion of the RP study regarding the accessibility of the cavern during beam operation / possibility of avoiding the connecting gallery
  - ➢ BDF: Alternative location study / preferred option
  - ➢ AION-100: Conclude the EMF measurements and safety requirements



Thank you!



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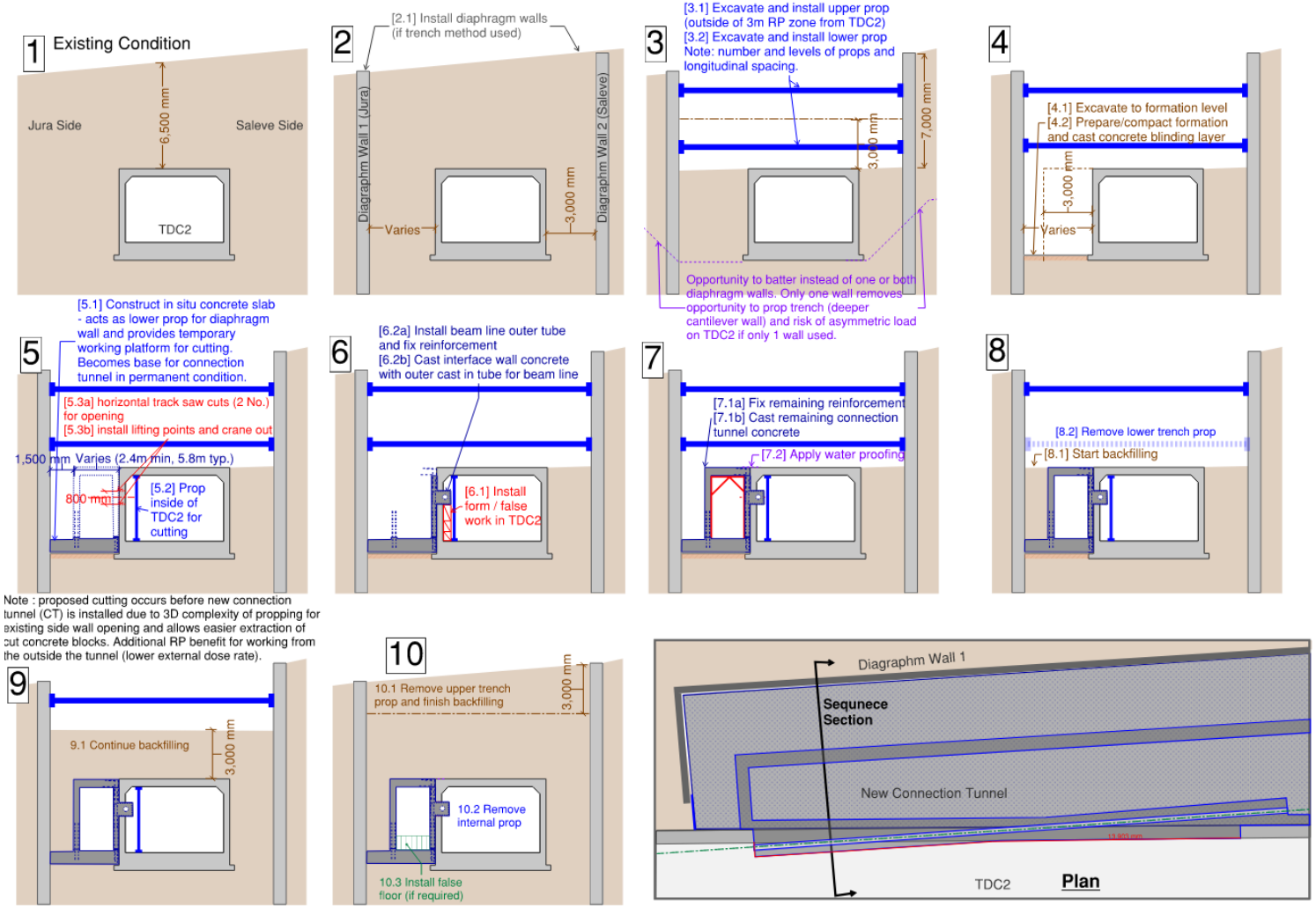
Back-up Slides

Forward Physics Facility
Preliminary Cost Estimate

- Very preliminary cost estimate prepared for both options
- Cost estimate Class 4 – total could be 50% higher and 30% lower than the given estimate
- Comparative Costing
- HL-LHC Point 1 as reference point
- Conclusion: purpose-built facility including the needed services would cost about 40M CHF, whereas the UJ12 option would cost about 15MCHF

Beam Dump Facility (BDF)

Sequence of works- In situ concrete with diaphragm walls



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Study Progress - Radioprotection

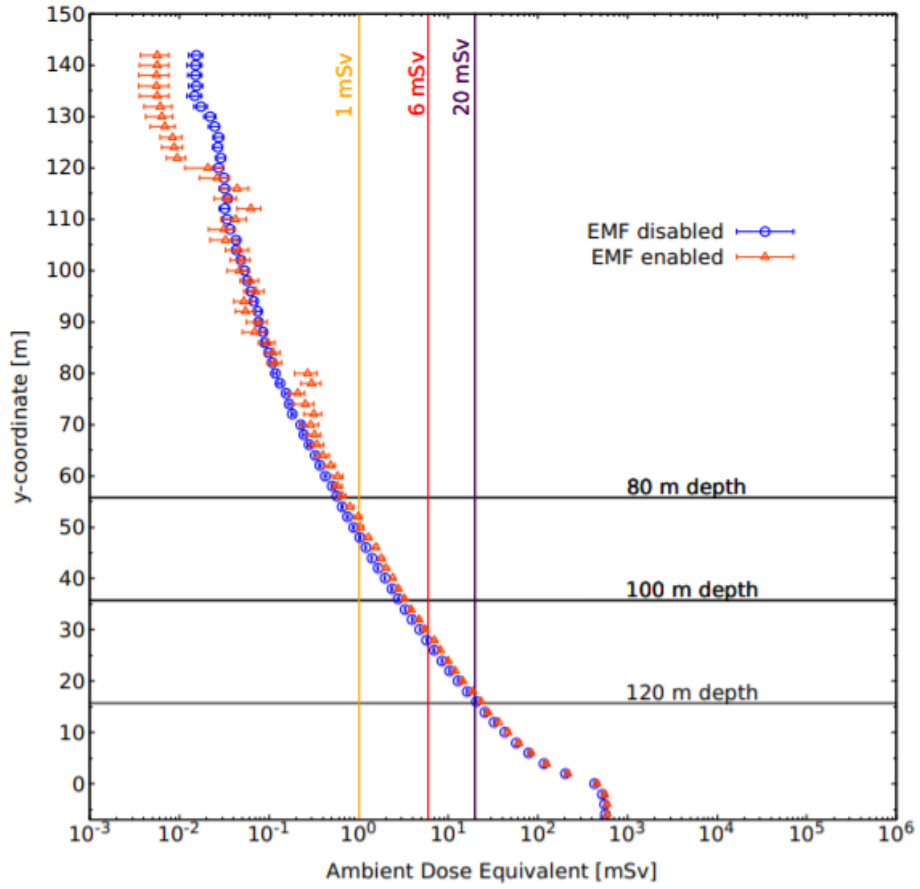
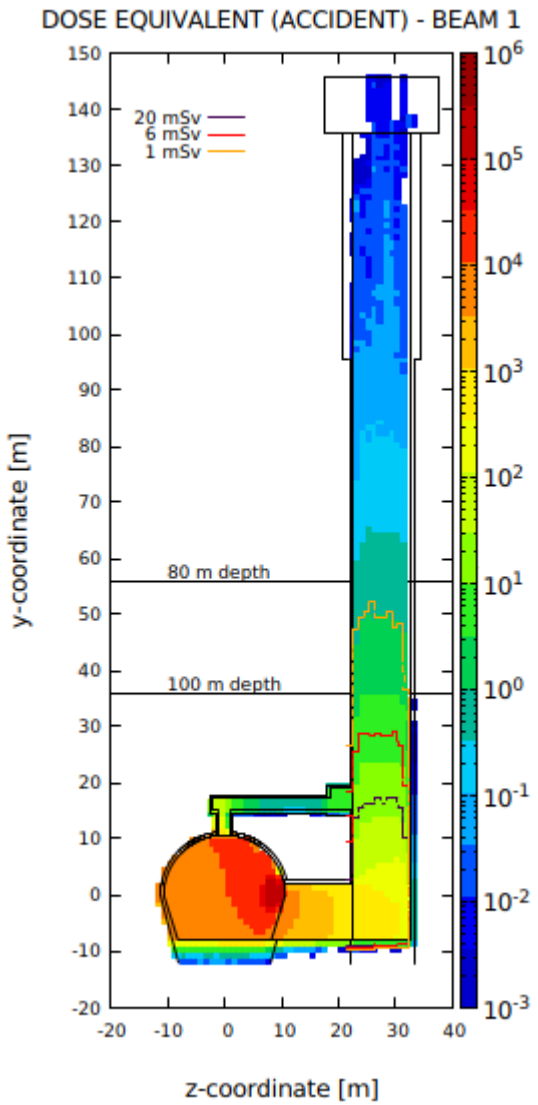
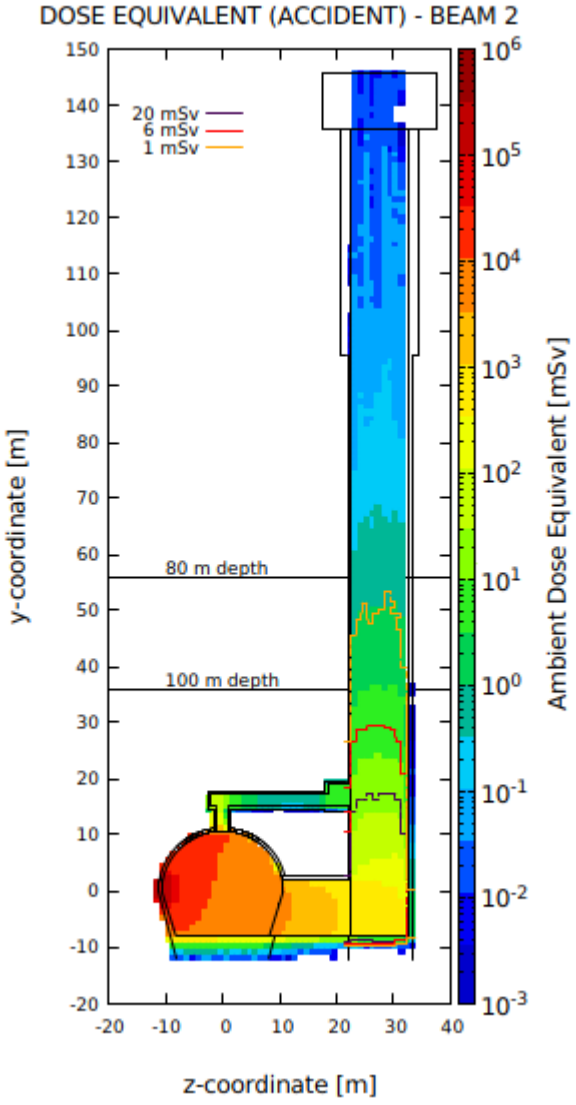


Figure 8: Ambient dose equivalent 1D profile along the PX46 shaft.





Courtesy of L. Elie and A. Infantino (HSE-RP-AS)

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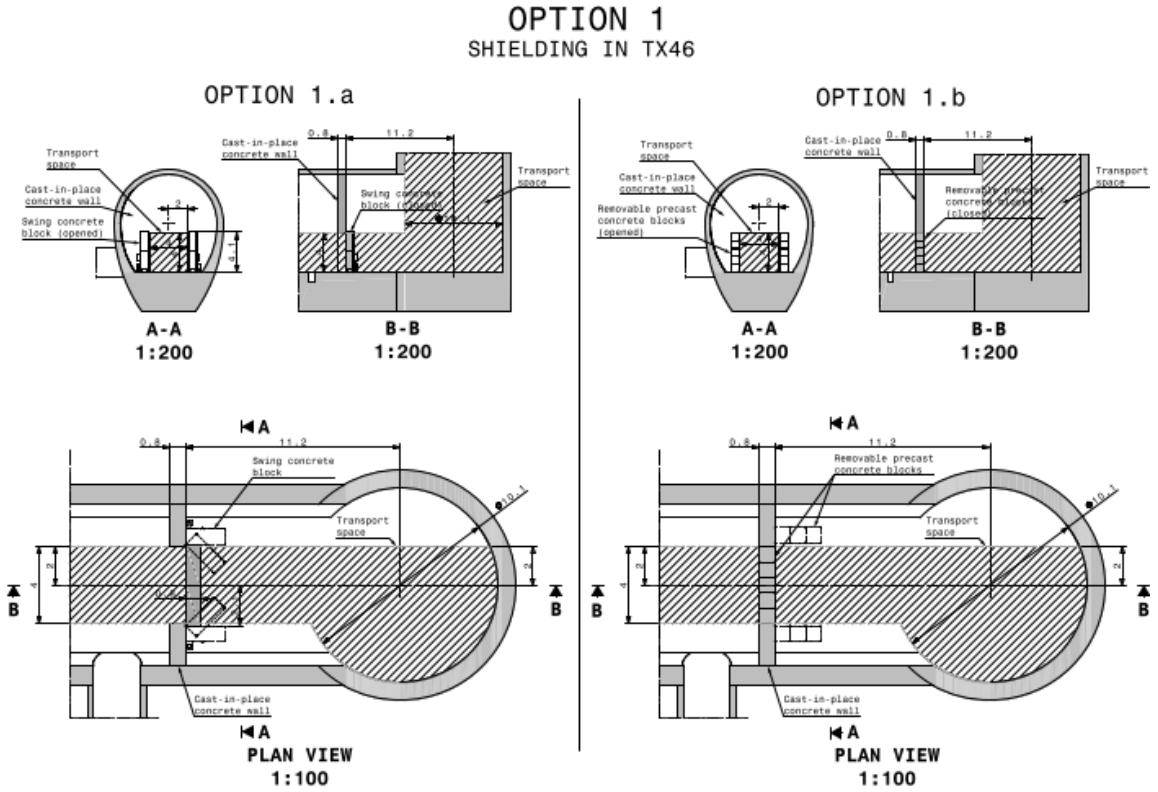
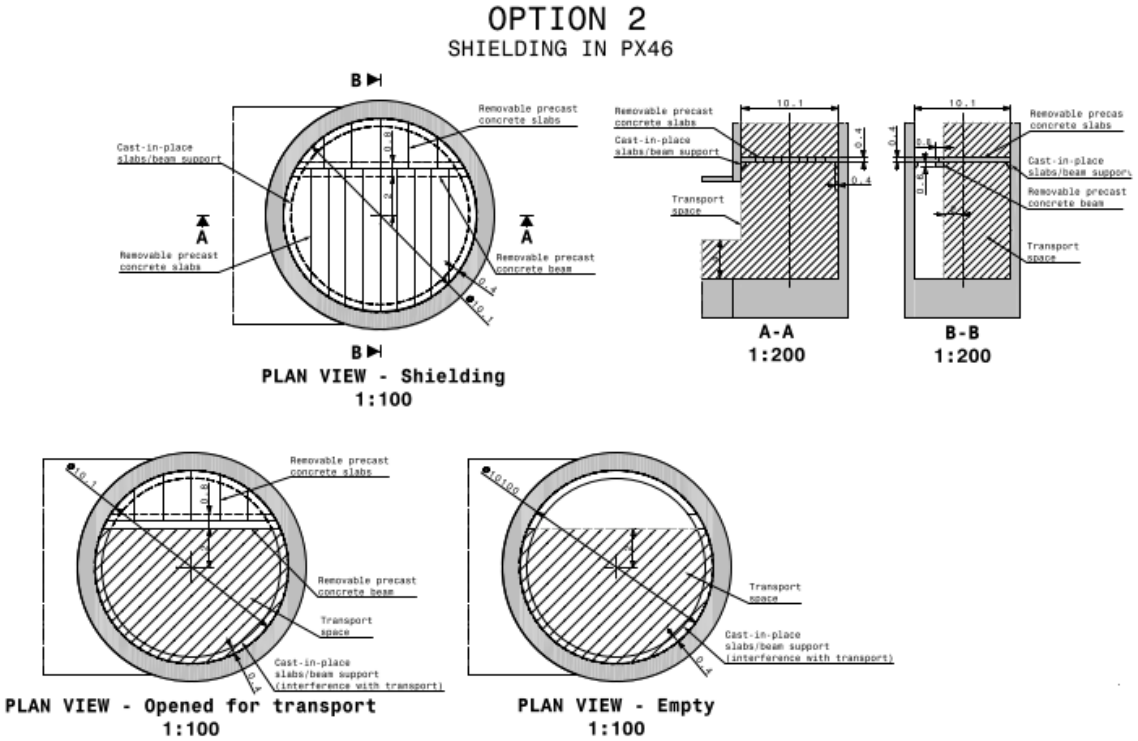
Shielding options





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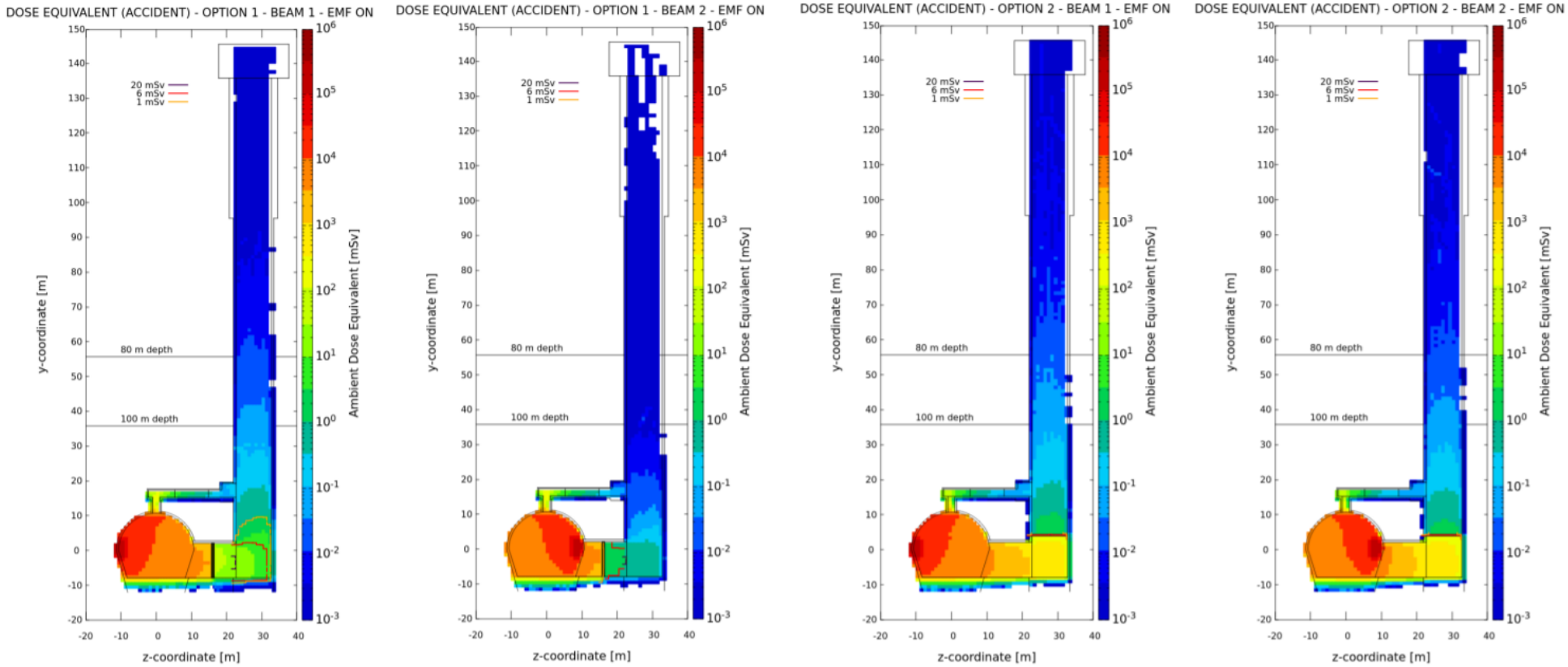
Study Progress – Radioprotection with shielding

Prompt ambient dose

HL-LHC: 2748 bunches and 2.3E11 ppb



Courtesy of L. Elie and A. Infantino (HSE-RP-AS)