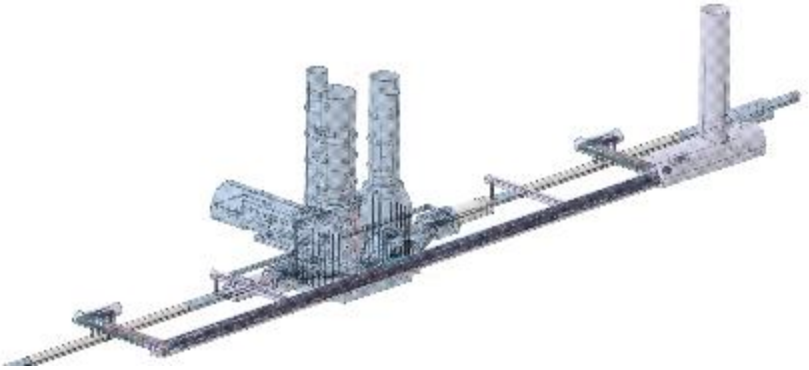


HL-LHC integration

Focussing on underground infrastructure

Baseline frozen on the 18th/09/2015

INTEGRATION: C. Magnier, S. Maridor, B. Vazquez de Prada
R. Calaga, F. Killing, E. Montesinos and the whole **WP4**
A. Masi, A. Rossi, S. Redaelli and the whole **WP5**
A. Ballarino, A. Jacquemod and the whole **WP6a**
J.P. Burnet, C. Coupat and the whole **WP6b**
F. Rodriguez Mateos, D. Wollmann **WP7**
S. Claudet **WP9**
G. Arduini, M. Fitterer: **WP2**
EN-MME: M. Guinchard Lukasz Jerzy Lacny

WP17: Isabel Bejar Alonso
R. Calaga, F. Killing, E. Montesinos and the whole WP4
J.P. Burnet, C. Coupat and the whole WP6b
S. Claudet WP9
EN-EL: Gerard Cumer, Nuno Dos Santos, Jean-Claude Guillaume
EN-CV: M. Battistin, F. Boralho, P. Pepinster
EN-HE: C. Bertone, B. Feral, R. Rinaldesi, I. Ruehl
GS-ASE: T. Hakulinen, S. De Luca, P. Ninin
GS-SE: J. Osborne, P. Mattelaer
T. Otto
DGS-RP: C. Adorisio
DGS-SEE: J. Gascon
And many others

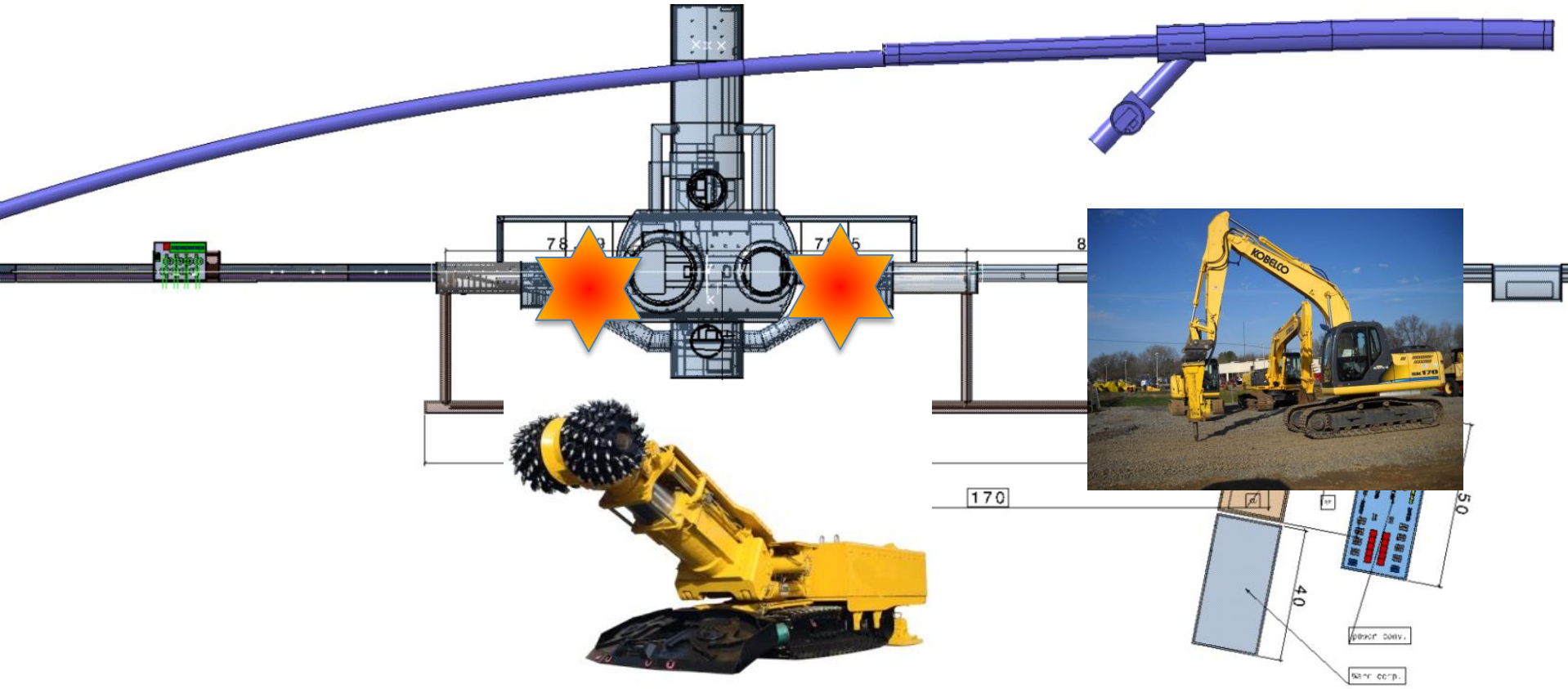
Prepared by P. Fessia

Summary

- The vibration issue
- The Double Decker approach in a nutshell
- What we need to fit in the Double Decker
- Optimising: reasons, consequences, timing and first actions in list *(my optimistic approach)*
- Conclusions

The vibration issue

Issue: vibrations induced by Civil Engineering excavation equipment possibly perturbing LHC exploitation



Effect of vibrations on the beam

Effect of construction works next to IR1/5:

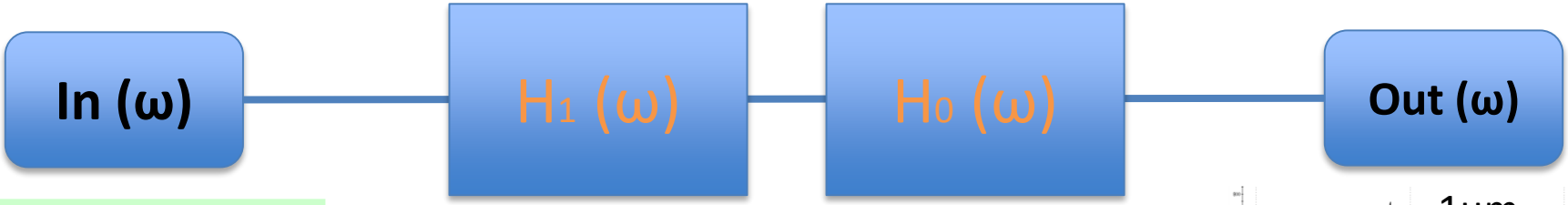
- main effect is a **closed orbit distortion** due to displacement of quadrupoles
- long term (weeks) drifts could be compensated with orbit correctors or more frequent alignment campaigns
- short term drifts (minutes/hours) could be compensated by current orbit feedback
- low frequency vibrations can not be compensated by current orbit feedback
  - largest contribution is expected from the **inner triplet** during collision due to high β-function and strength
  - main effects:
    - **luminosity loss** due to separation of the beams
    - **increased losses at collimators** (Run I: around 40 µm orbit deviation at TCPs caused high losses)
    - emittance growth/increased halo diffusion rate -> luminosity loss and higher losses at collimators
  - closed orbit distortion depends on **wavelength of the vibrations**, e.g. ±1 µm displacement of the IT can result in 0-14 µm separation of the beams at the IP and 3-170 µm residual orbit at collimators (1)
- Possible mitigation measures: warm magnets for low frequency (0-200 Hz) closed orbit feedback system in IR1/5

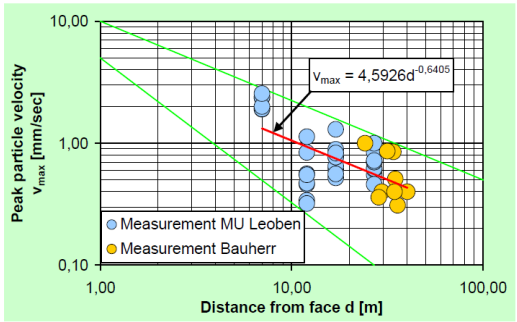
G. Arduini, M. Fitterer

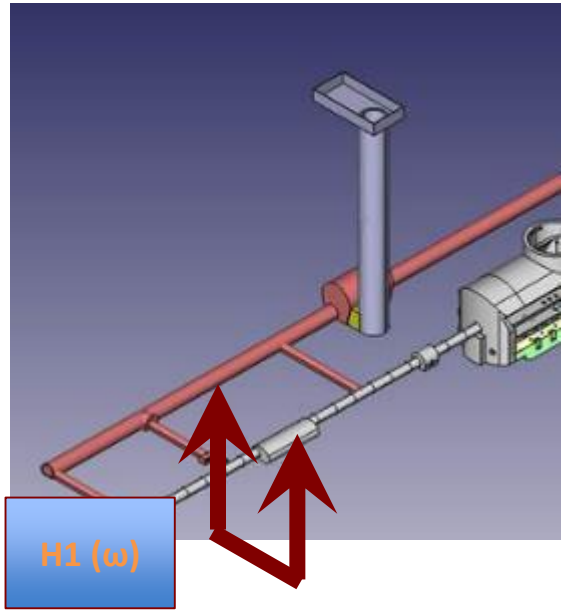
(1) Run III parameters: N_{bunch}=1.25x10^{11}, ε_N=2.0 µm, N_{tot}=2740, β*(IP1/5)=0.4 m (option med RunII), E=6.5 TeV, σ_{IP}=10.7 µm

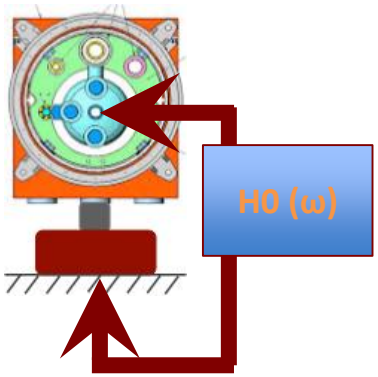
Which are the ingredients of the problem ?

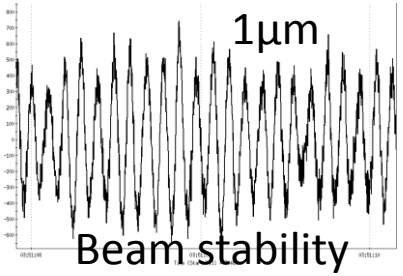
Build the transfer function from the point where the excavation takes place to the beam axis









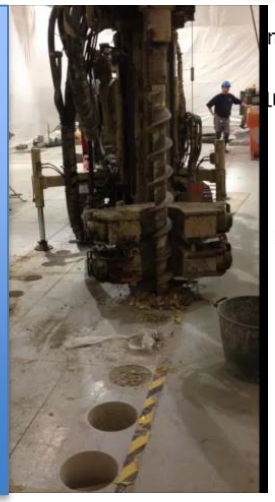


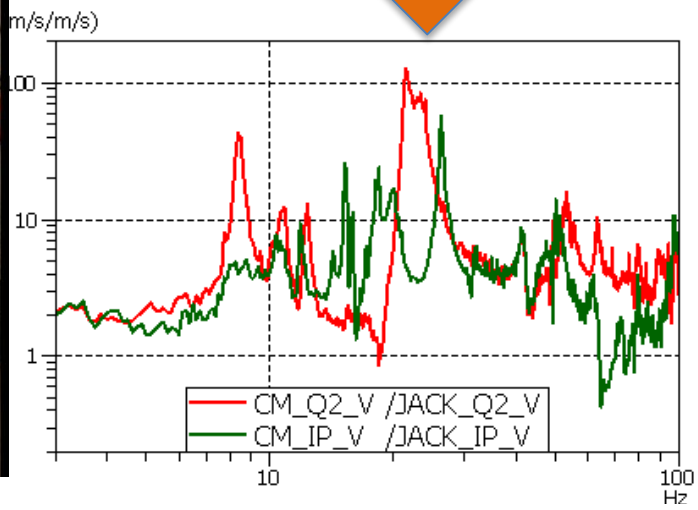
Results about H0 (ω)

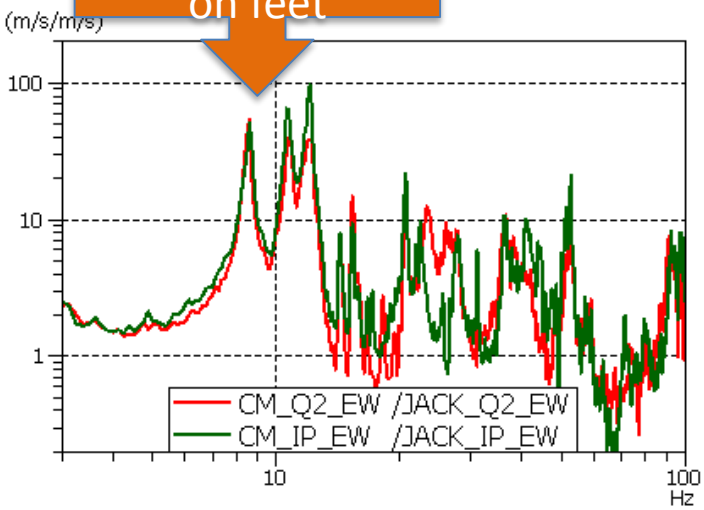
24 Hz
First bending mode

8Hz
Rigid movement on feet

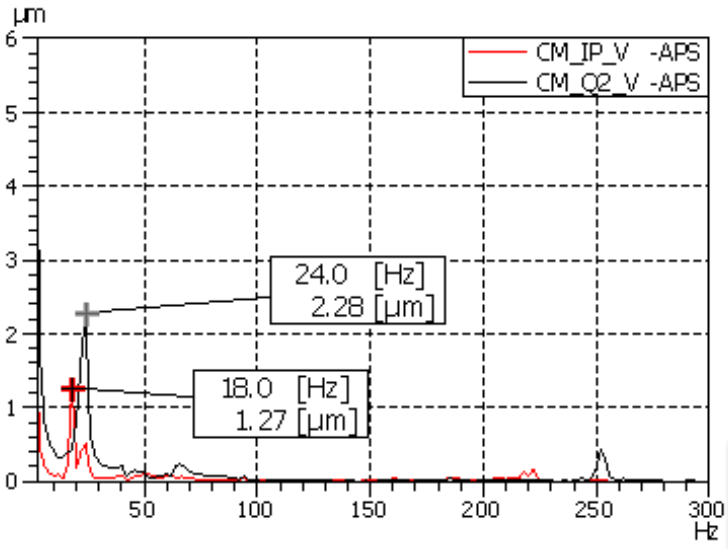
Ampl. factor with CE activity

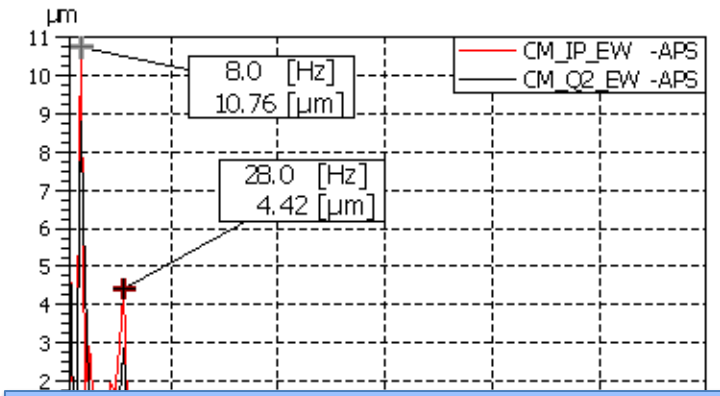






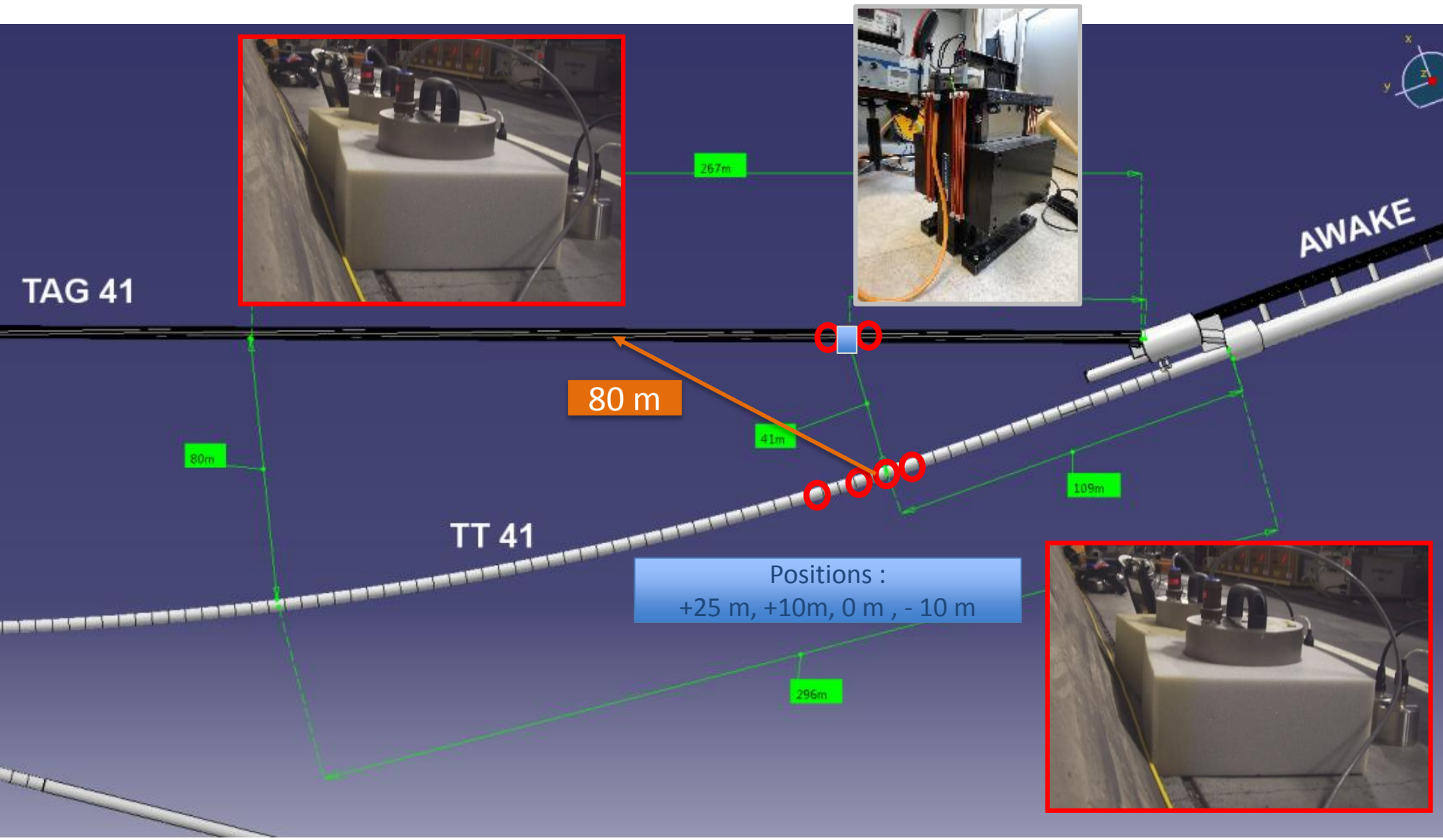
Displacement with hammer impact

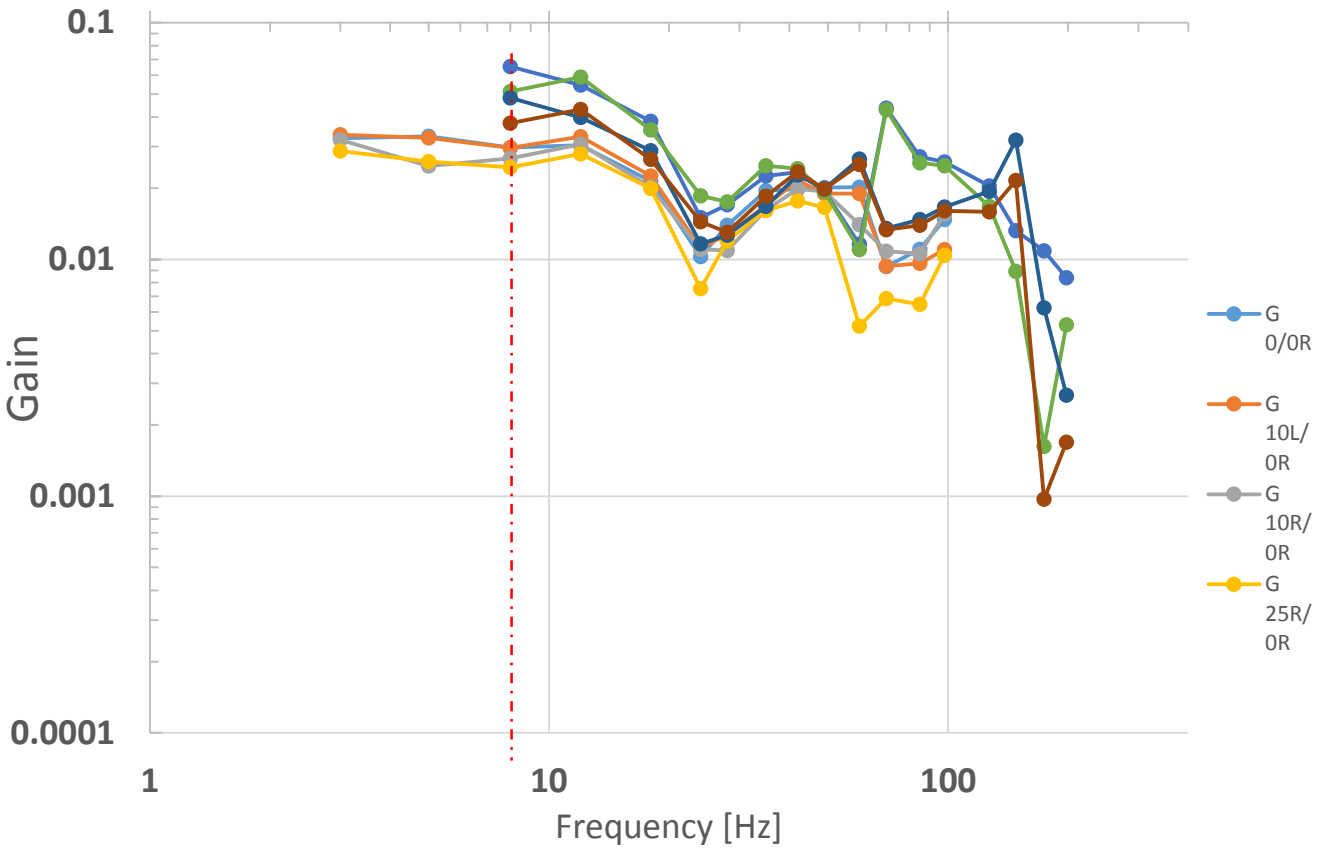


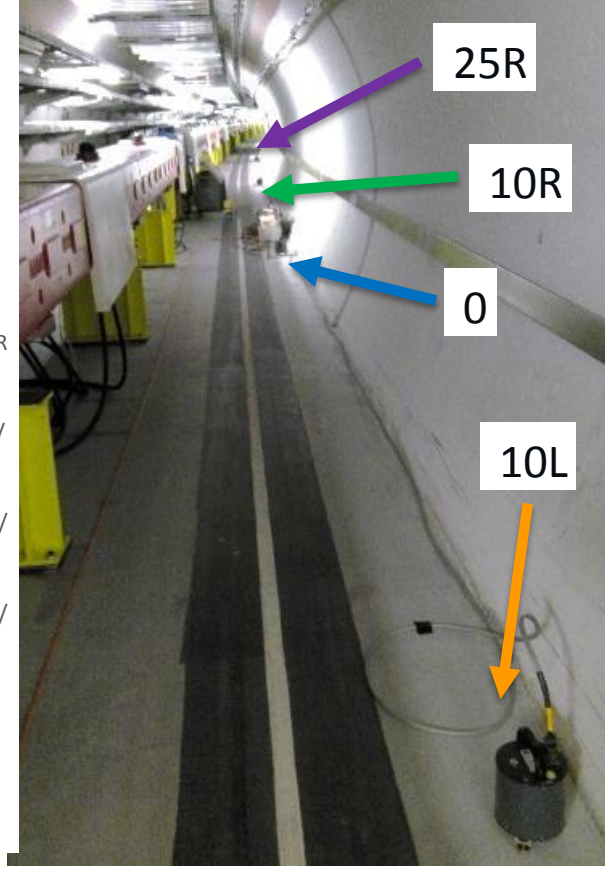


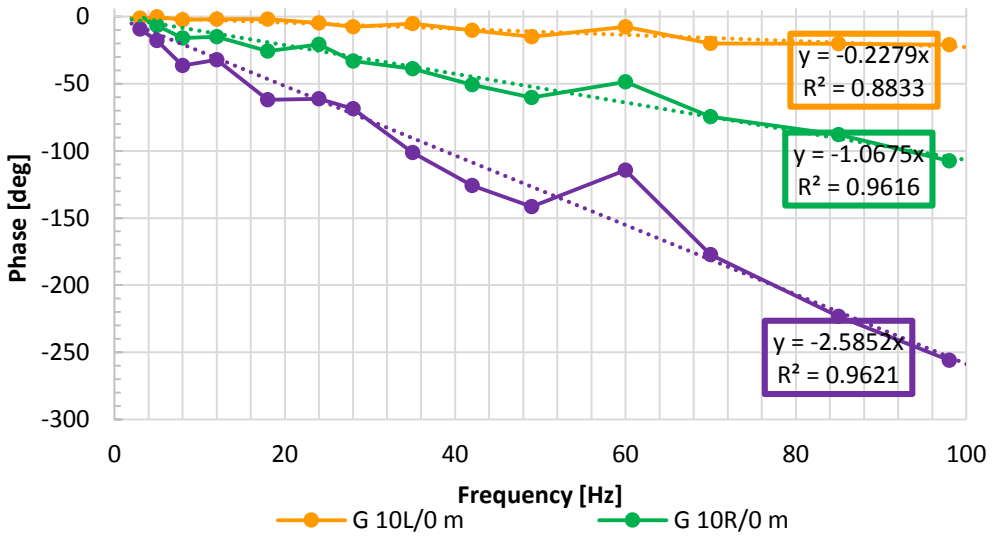
Courtesy M. Guinchard, Lukasz Jerzy Lacny

Tunnel transfer function $H_1(\omega)$ estimation



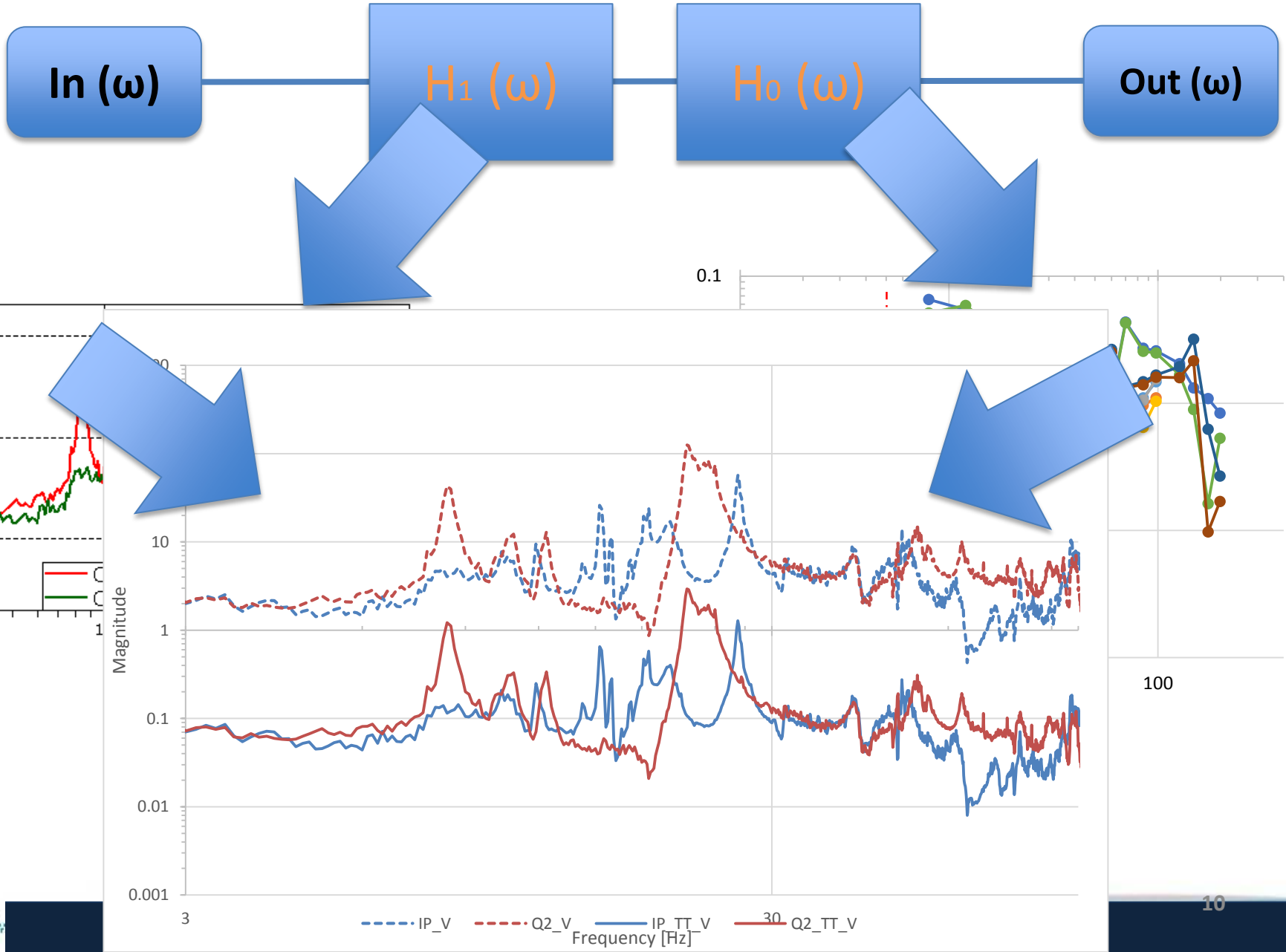






Courtesy M. Guinchard,
Lukasz Jerzy Lacny

Putting the pieces together

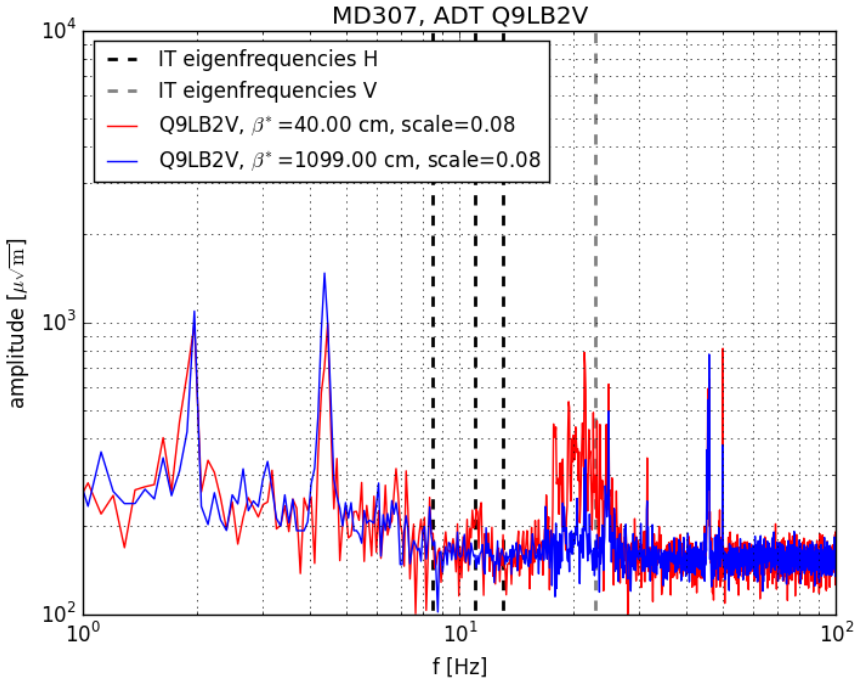


Measurements

Are the IT eigen-frequencies visible in the LHC beam spectrum?

Principle: β-function during squeeze changes mainly in the IT in IR1/5 -> IT eigen-frequencies are visible in the beam spectrum if an increase of the amplitude for the IT eigen-frequencies is observed during the squeeze

Result: 20 Hz first vertical eigen-frequency visible, 10 Hz peak visible, but no increase of amplitude during squeeze



MD to study effect of a low frequency noise on emittance evolution and tail population

- beam and machine setup:
  - weak-strong scenario (single bunch) at injection (colliding)
  - mimic long-range encounters with octupoles
  - apply sinusoidal (10 Hz horizontal, 20 Hz vertical) excitation on both beams
- record time evolution of emittance + tail population with wire scanners and BSRT and diffusion rates with collimator scans

G. Arduini, M. Fitterer

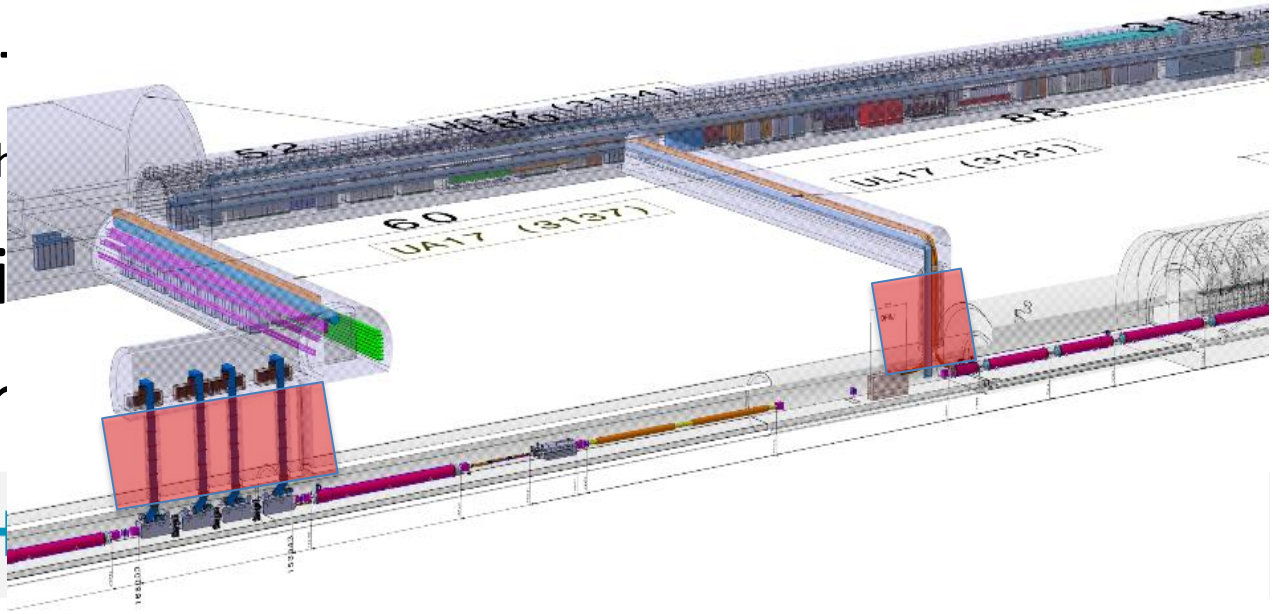
Conclusions and consequences

- No margin to perform CE engineering work during LHC beam opera

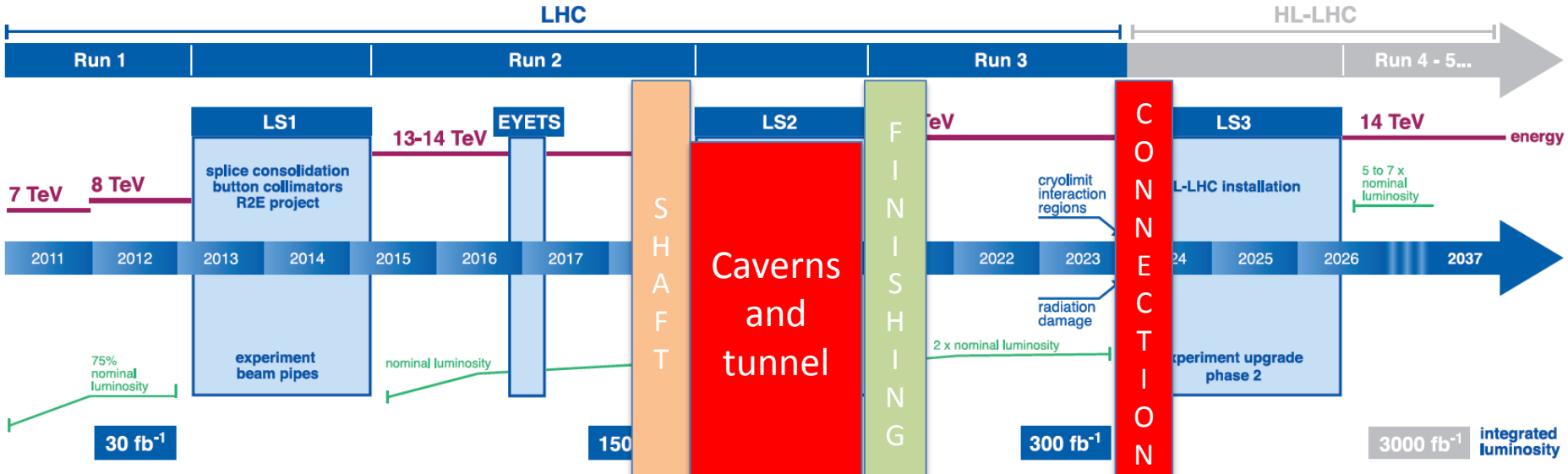
  already signature today of th

- Today the only vi

  beam time that r



LHC / HL-LH



The Double Decker in a nutshell

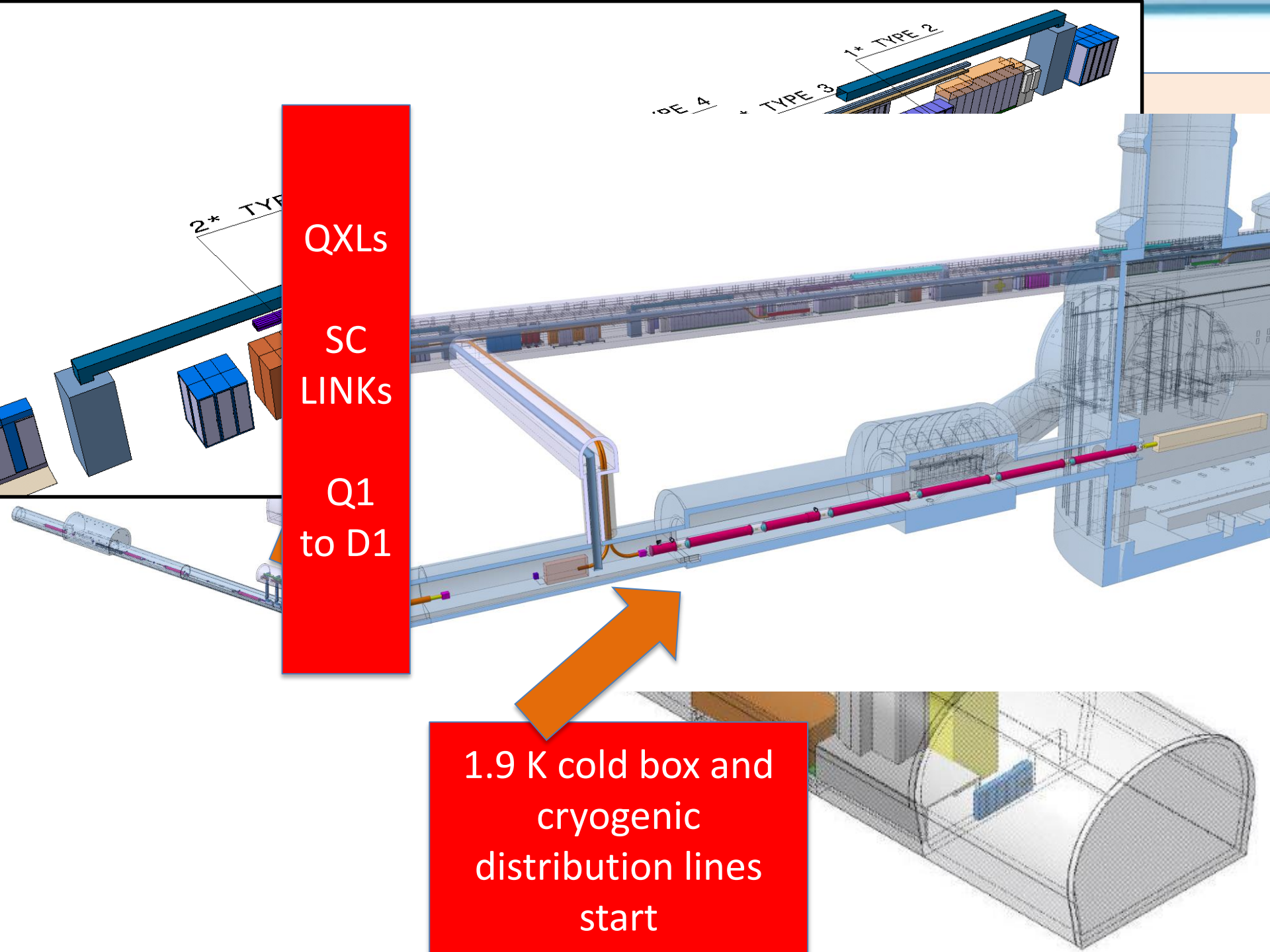
Double decker key facts

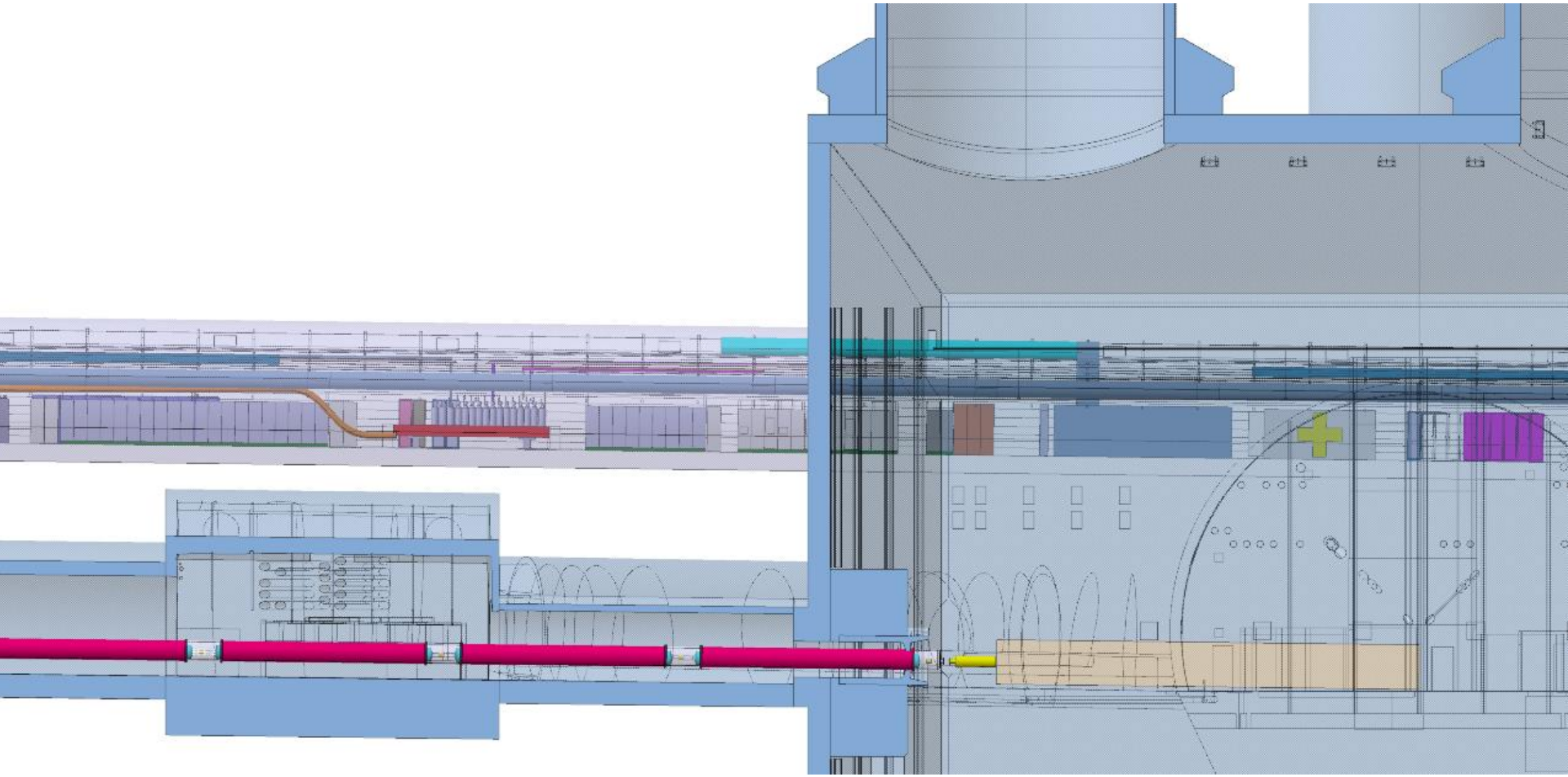
- Allows having the underground infrastructure on the same side of the LHC tunnel both for Point 1 and Point 5 (avoiding interference with the transport area)
-
-
-
-
- increasing further vibration reduction during excavation (Shaft moved far from the IT area)
- Provide the solution for the connection to the BBLRs , if they will be integrated in the baseline (space already accounted for)
- It is considered that the following equipment can be installed in the LHC tunnel
  - Q.H. power units: possible location present installation area for the IT power converters
  - Extra collimation racks near the present collimation racks

Key requirement:
access to all the active equipment installed in the underground structure in all the machine conditions included in beam

Double Decker safety

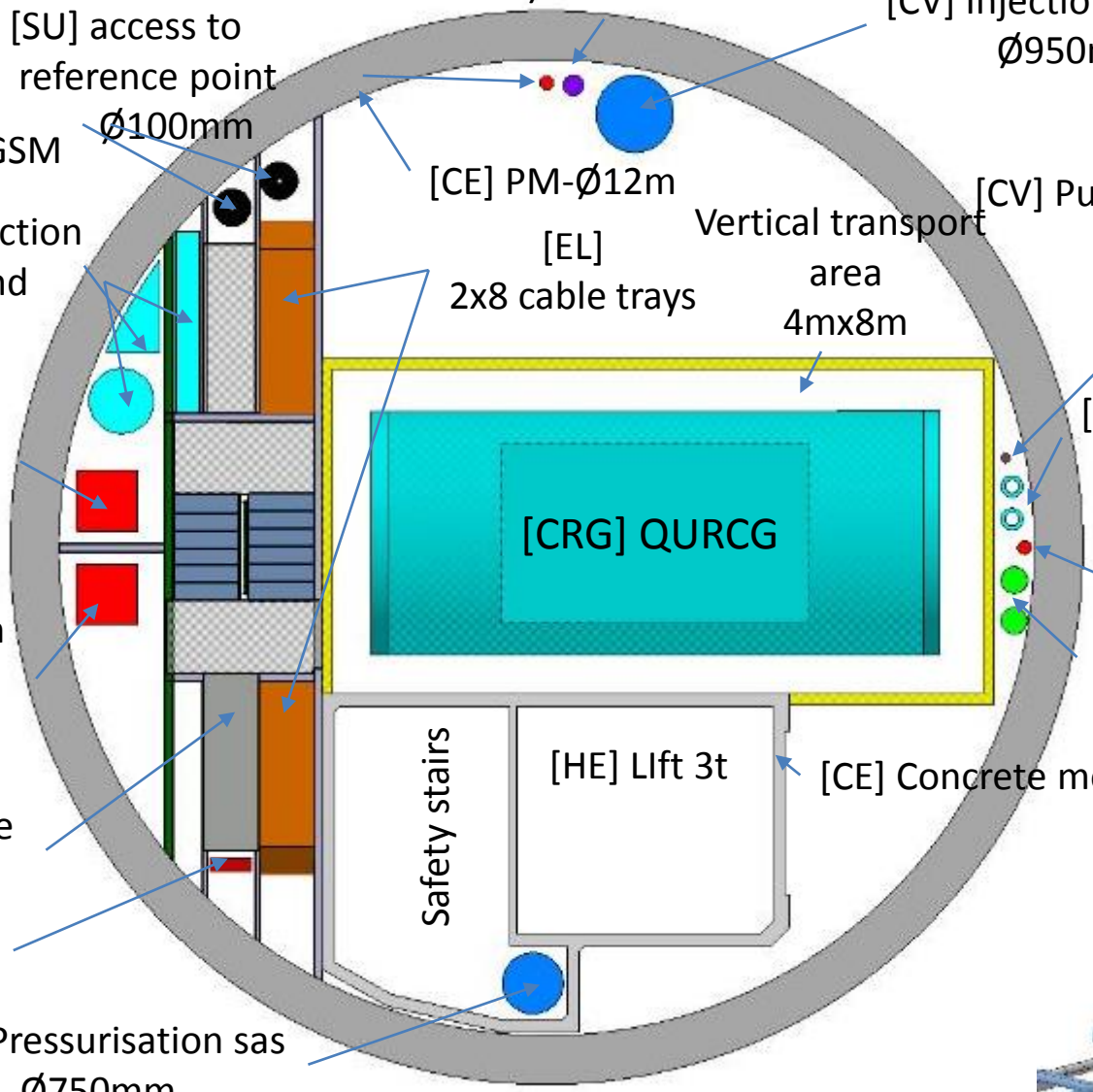
- All required ventilation and safety ducts have been added as such for this integration. The real related loads should be re-analysed in the next optimisation phase
- Emergency rooms have been installed along the tunnel length
- A safety exit from the UA opposite to the main access shaft to the LHC tunnel is under study (not pictured here). The implementation requires in depth analysis of the impact of linking the LHC tunnel and the Double Decker structure (importing risks, operational impact,…). Its addition it is transparent from the integration point of view with the exception of ventilation and accesses.

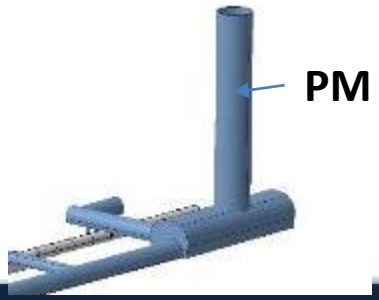

1* TYPE 2
TYPE 3
2* TYP
QXLs
SC LINKs
Q1 to D1
1.9 K cold box and cryogenic distribution lines start



What we need to fit in the Double Decker?

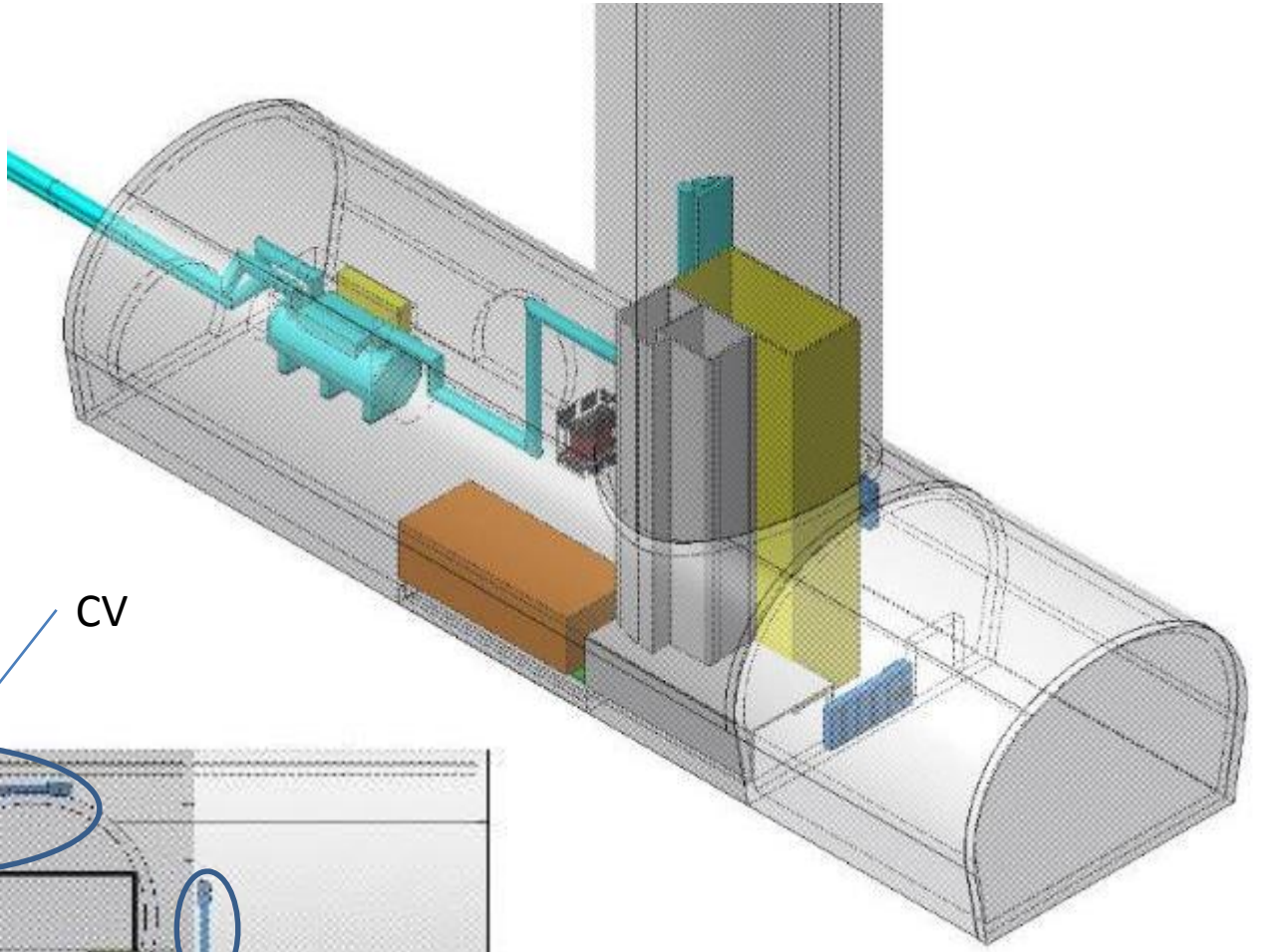
The Shaft (PM): how to fill 12 meter of diameter

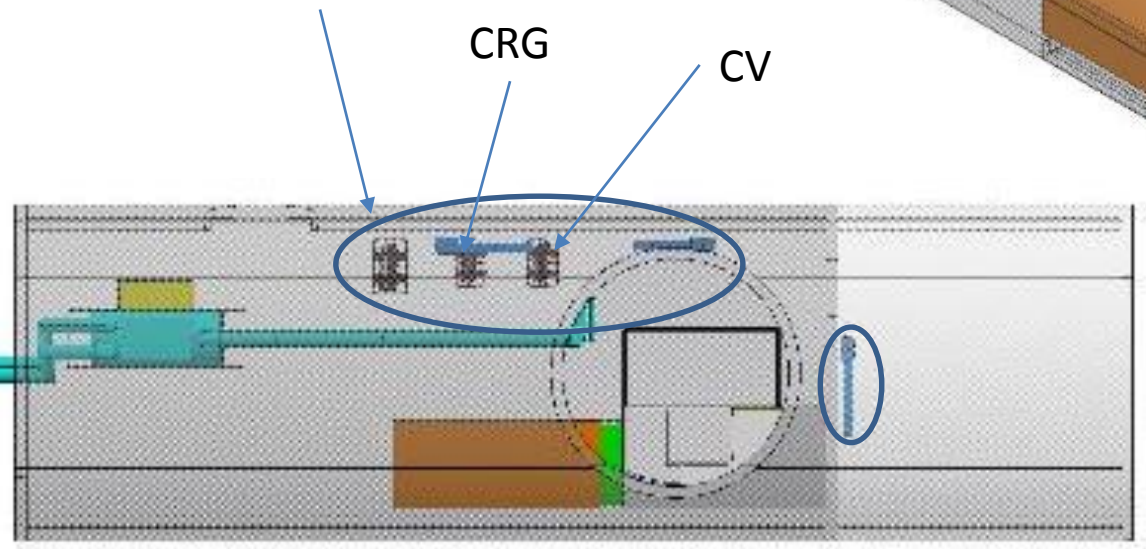




US part I:

PM lowering volume, concrete pressurized volume and lift, safe room, 1.9 K Cold Box with cryogenic distribution lines, transformers and low voltage departures





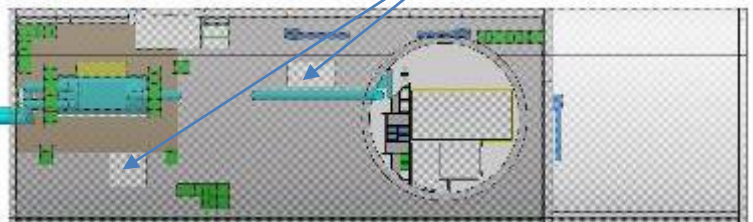
US Part II:
Metallic support structures for equipment, personnel and services

PM metallic support structure for services and stairs

Floor in the CRG area : + 3.8m
False floor for cabling everywhere else (except UW) : +4.3m

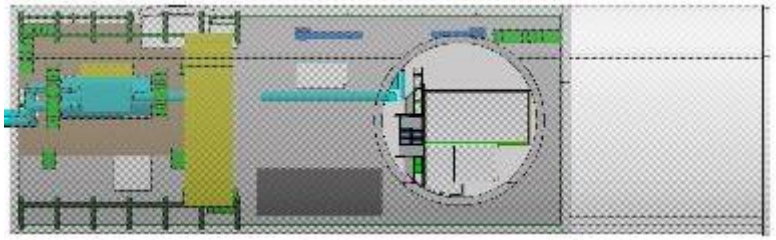
Metallic structure to support floor 1

Loading access to 1st floor



US part III:
Faraday Cage for the RF and for the BBLR

RF (and BBLR) Faraday cage
Right side

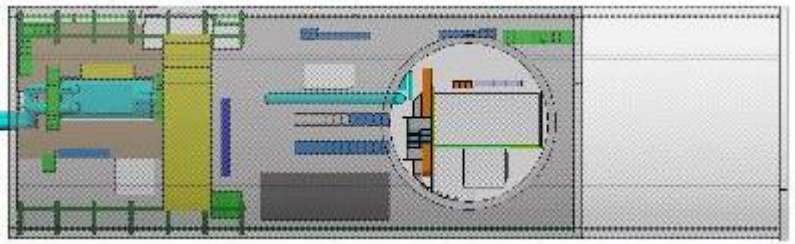


US Part IV:
Racks, control and cable trays ….

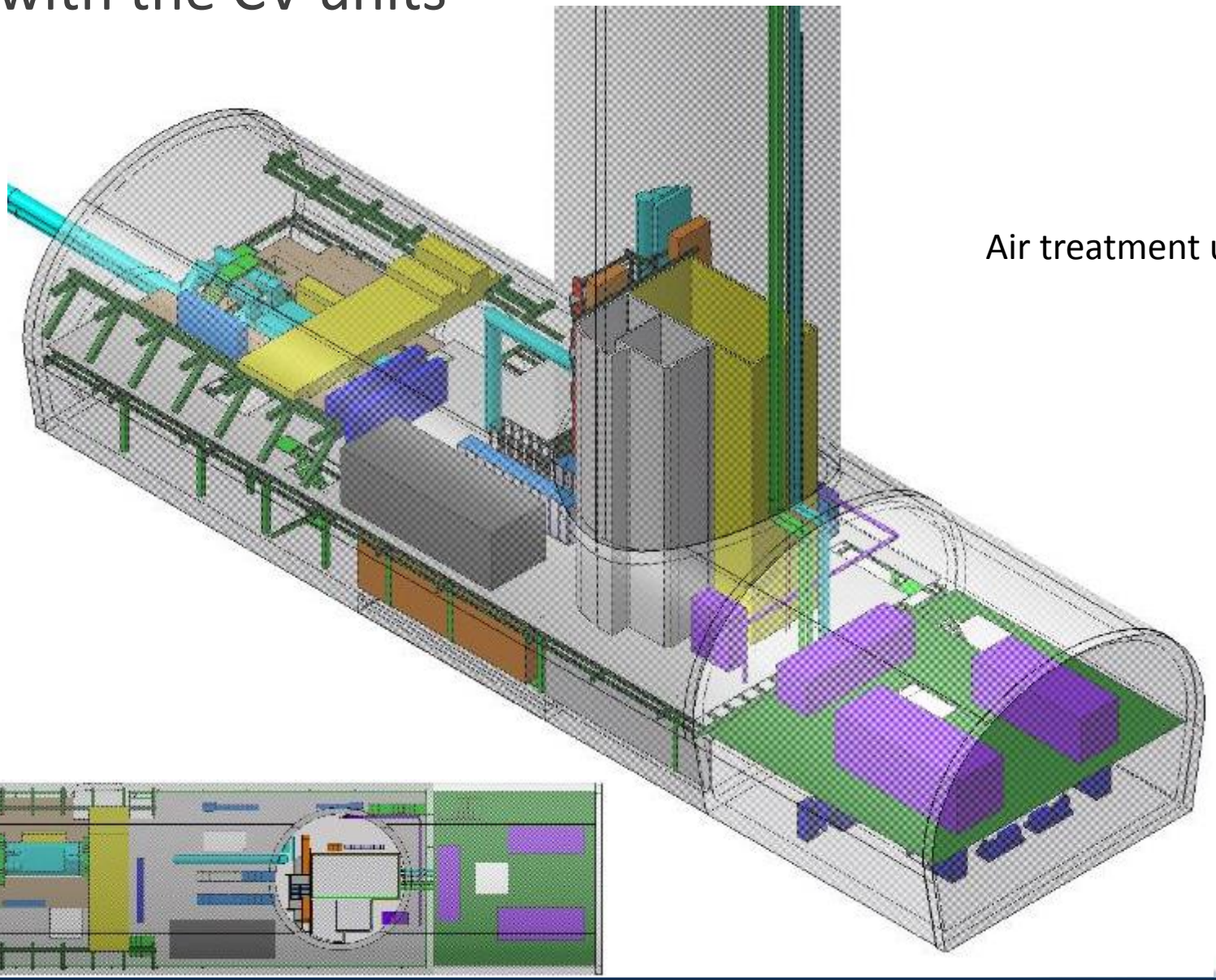
Cable trays

Other Racks :
Access system : x5 (it could go to surface)
Survey : x 1
RF
SSA : x 6
PLC : x 4
Not assigned spare racks : x 7

Cryogenic electrical supply and controls
2 x (6000 mm x 600 mm x 2200 mm)
1 x (4000 mm x 600 mm x 2200 mm)
1 standard rack

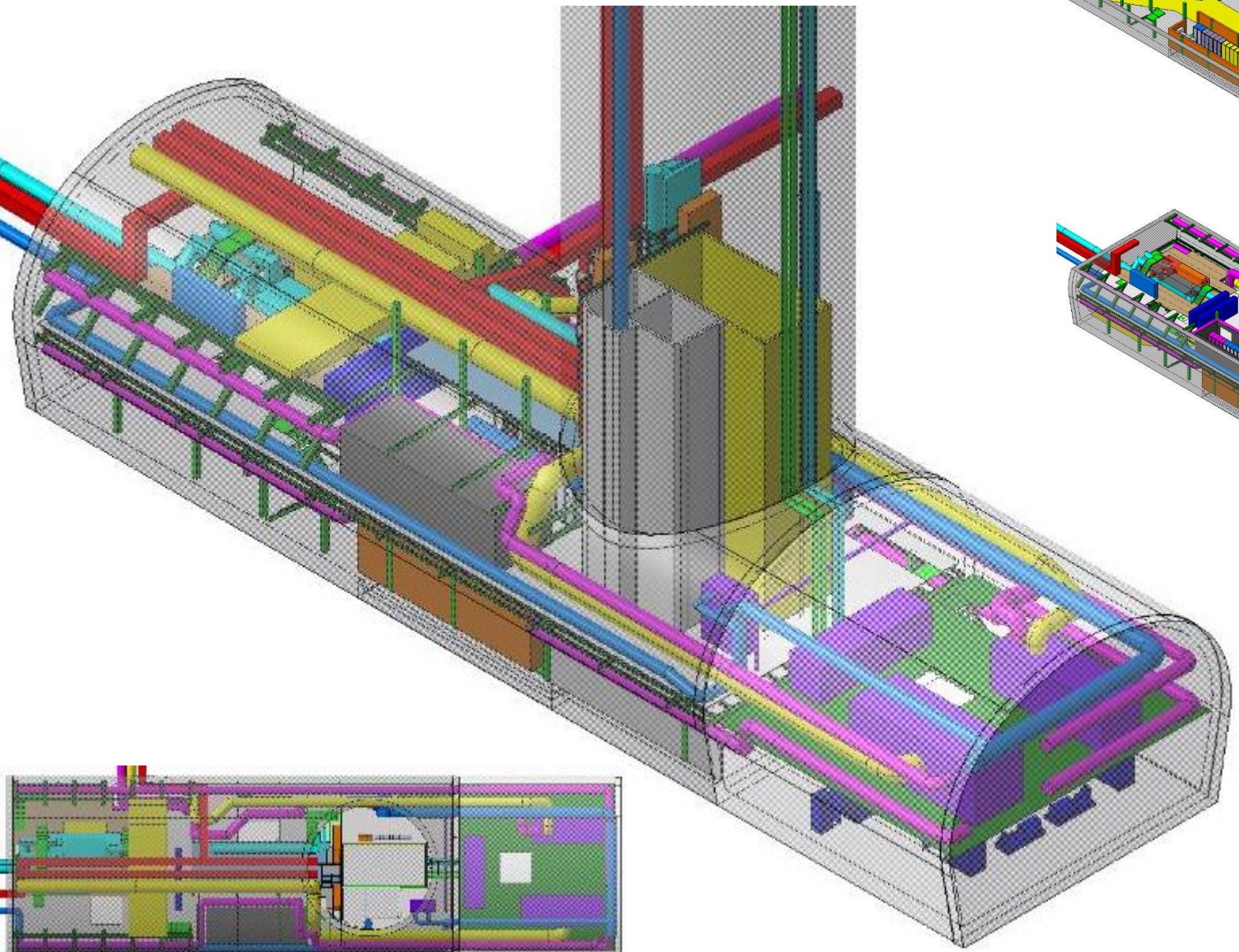


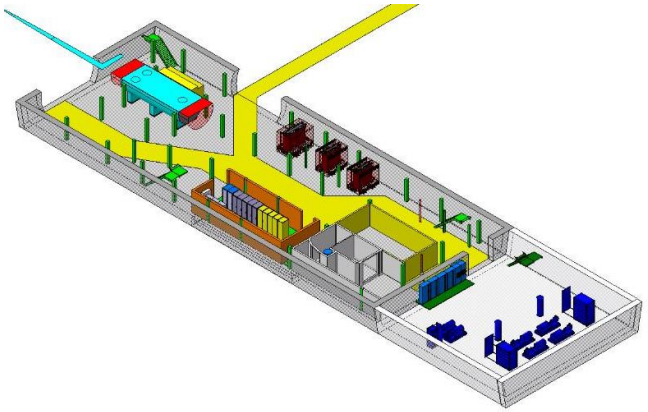
US Part V:
UW with the CV units

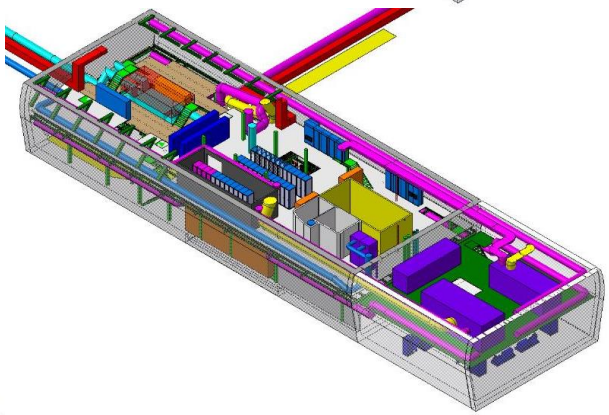


Air treatment units

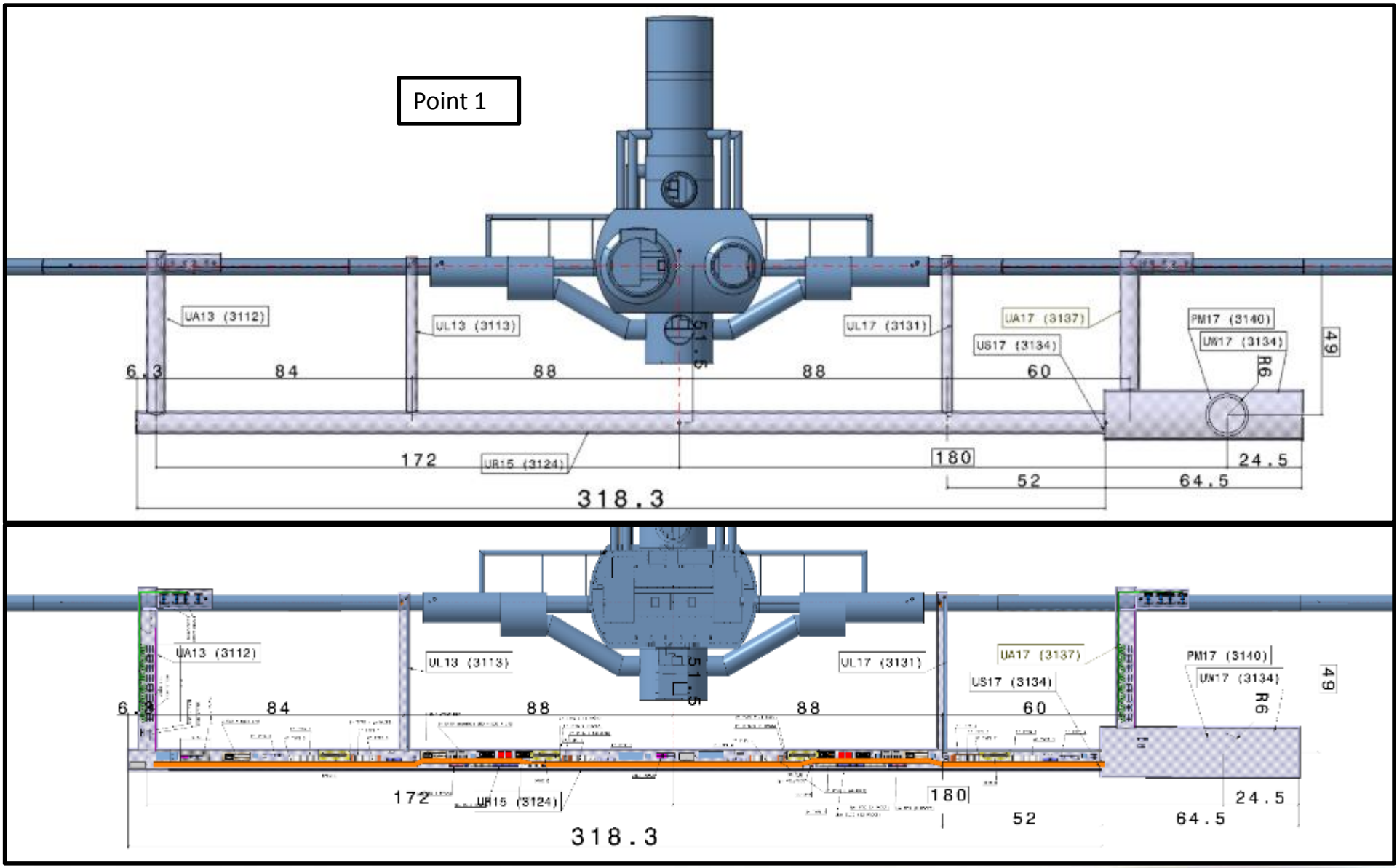
General view with all the cooling and ventilation distribution



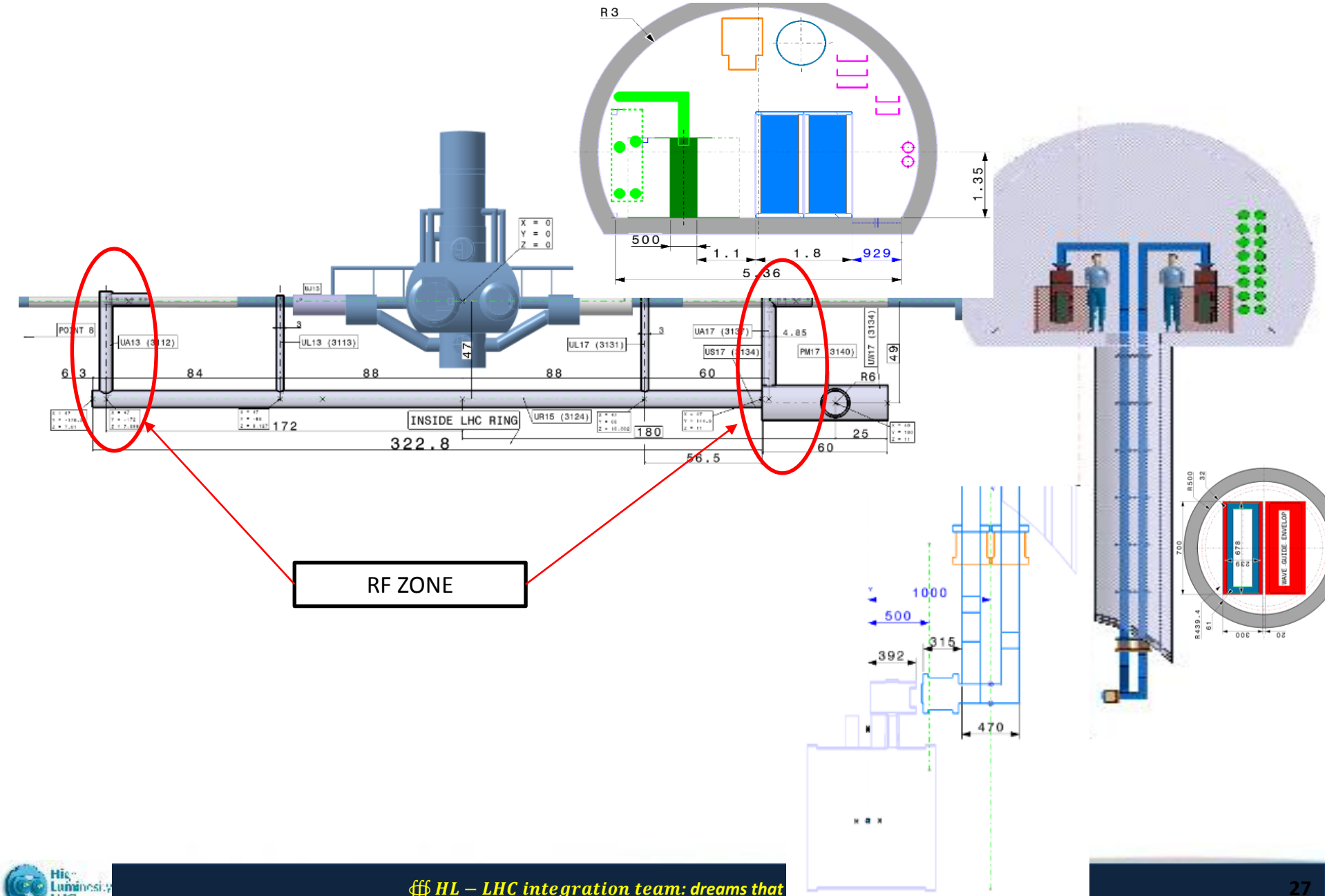




Overall view: US, UW, URs, UAs and ULs

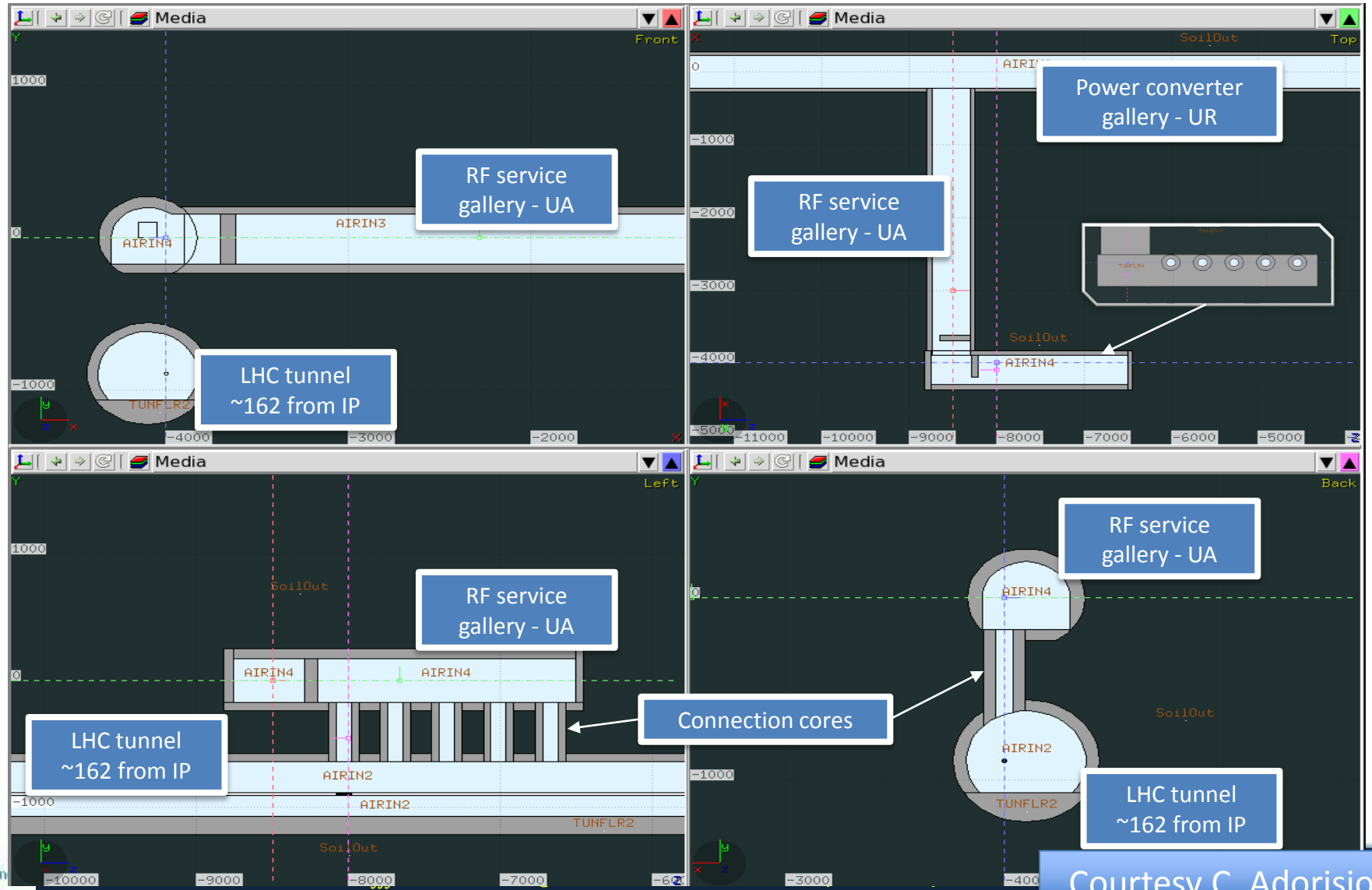


The UA dedicated to RF installation



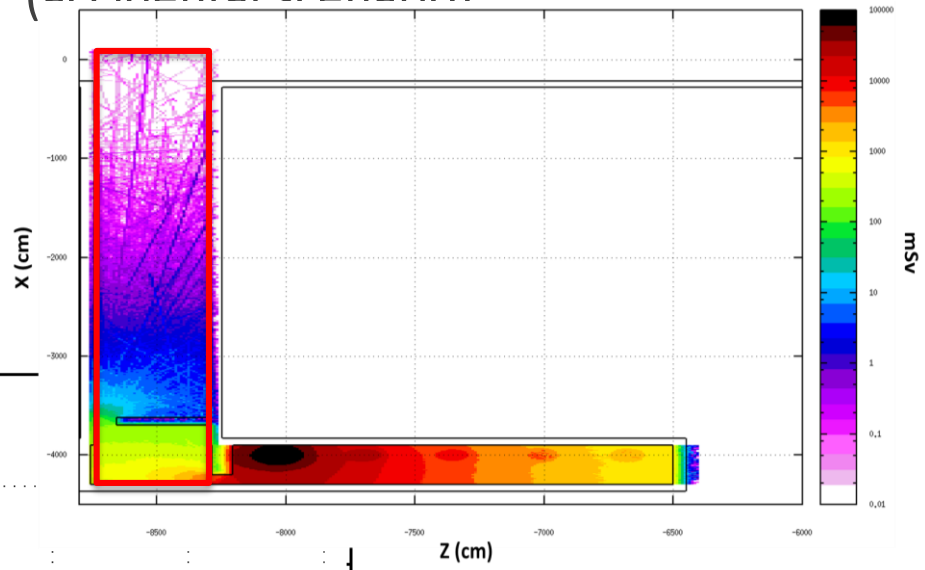
UA: the Radio Protection studies: implemented geometry

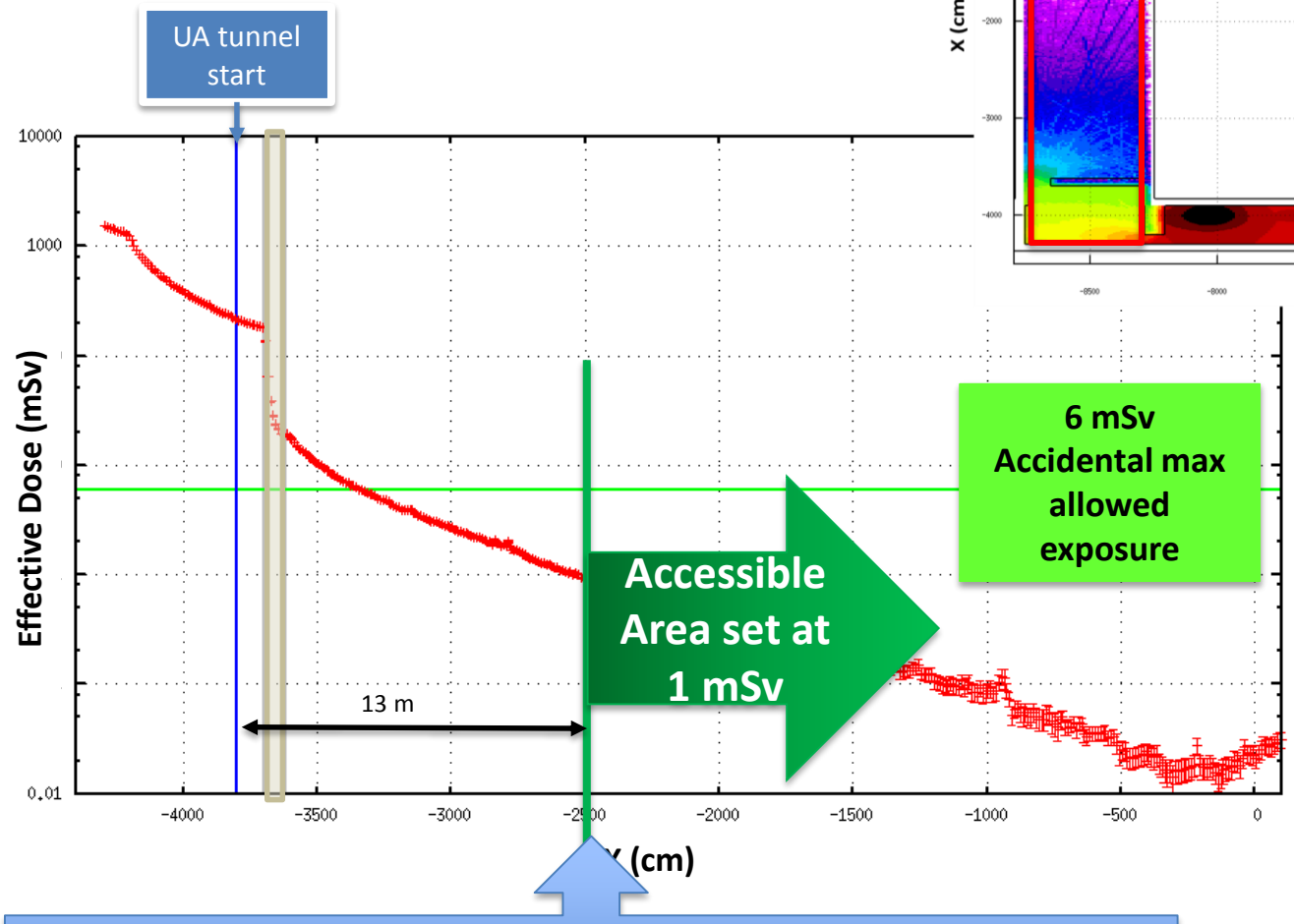
Geometry 4.4



Courtesy C. Adorisio

Effective Dose Profile (accidental scenario)





This position matches the 0.2 µSv/h in operation.
Limit for Non-Designated area < 0.5 µSv/h

he reality

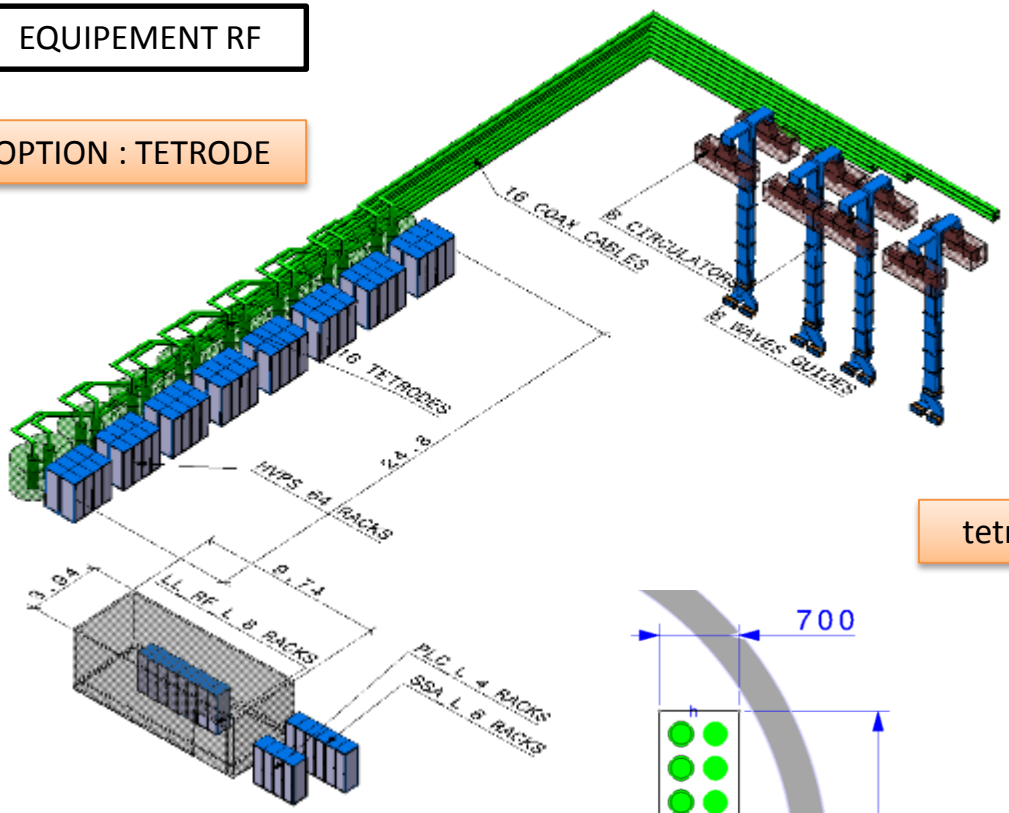
Courtesy C. Adorisio

Integration with Tetrode Option.

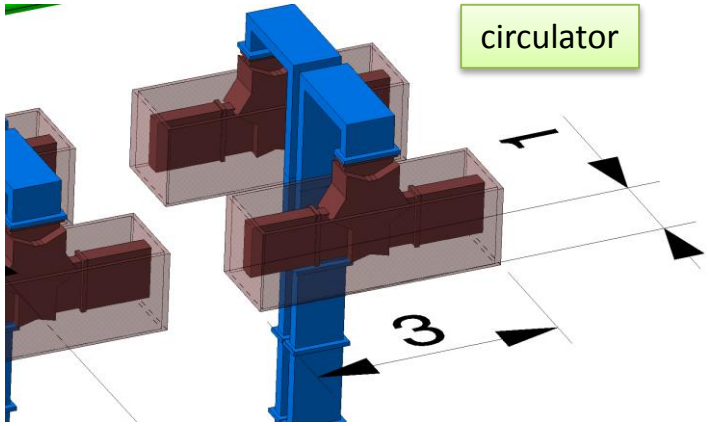
Remark: IOT option requires less volume underground, but a building on surface. The Integration account for the envelope of the two

EQUIPEMENT RF

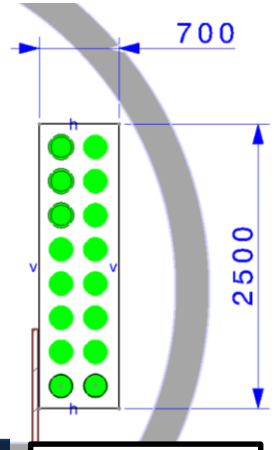
OPTION : TETRODE

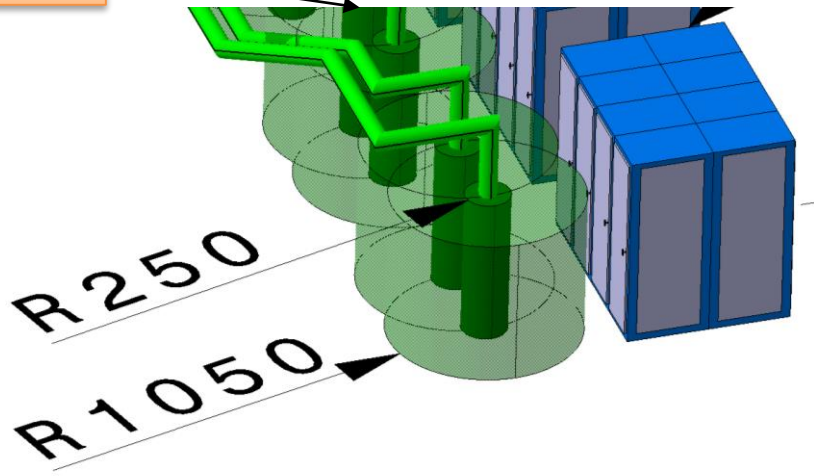


circulator



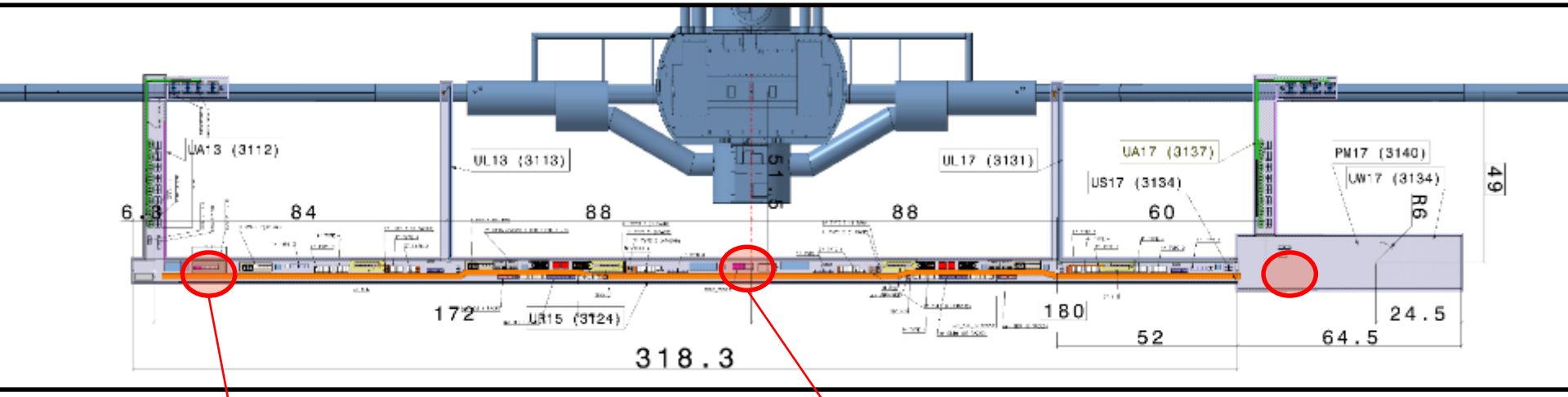
tetrodes

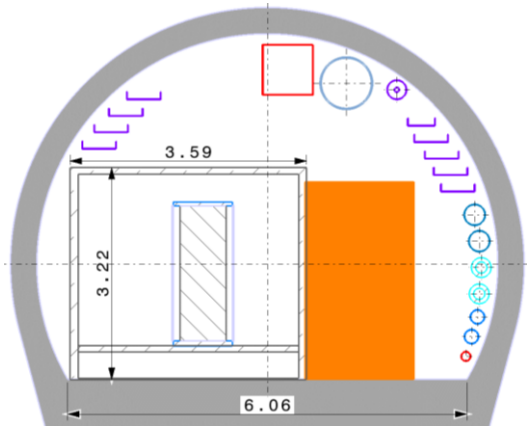




Coax cables

RF and BBLR





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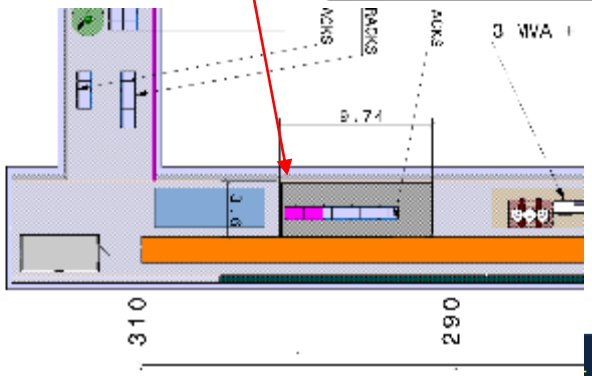
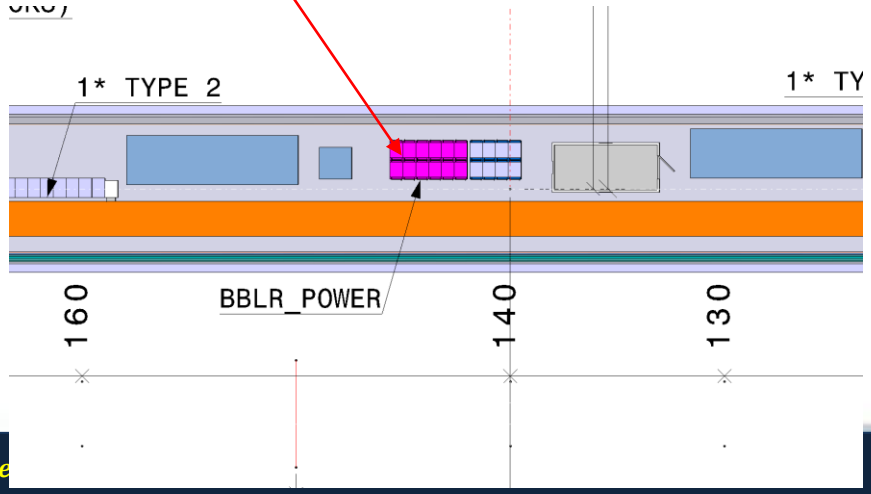
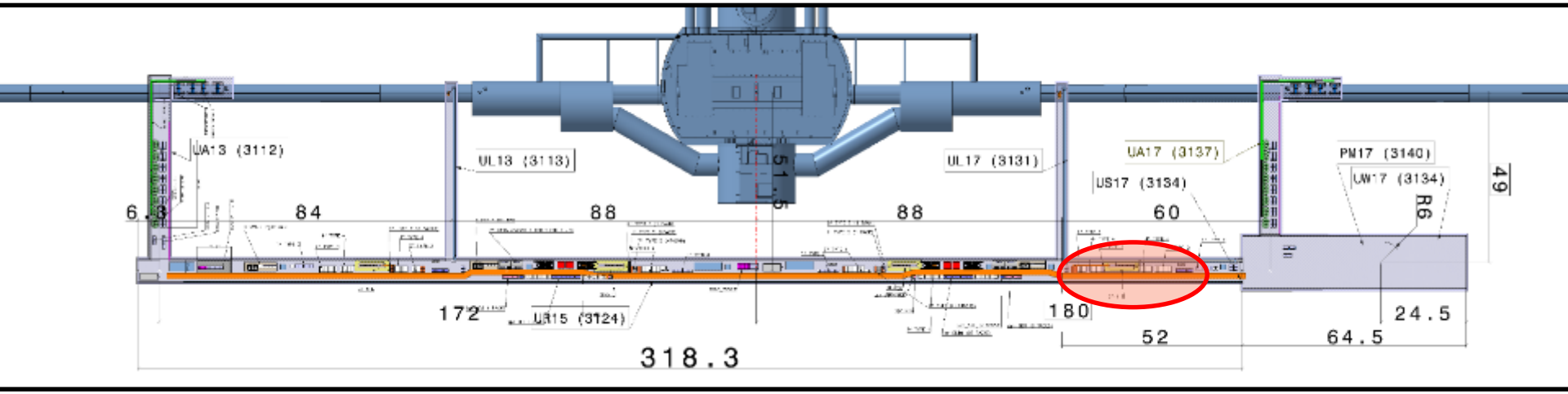


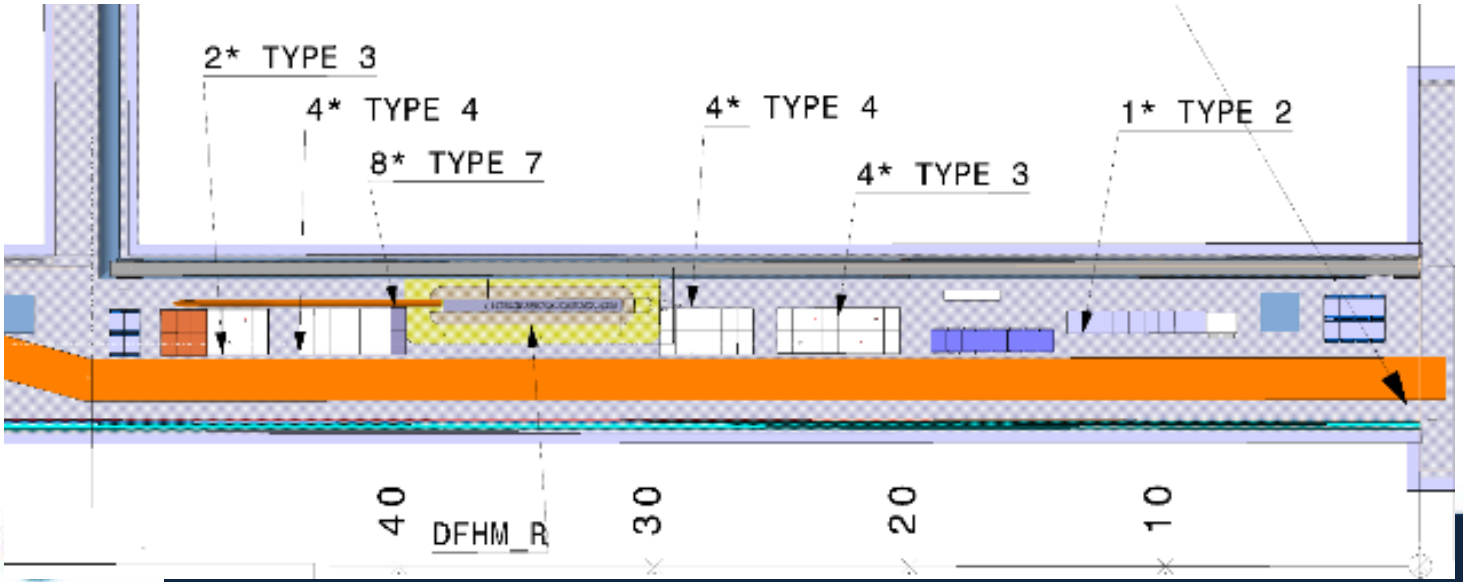
BBLR :

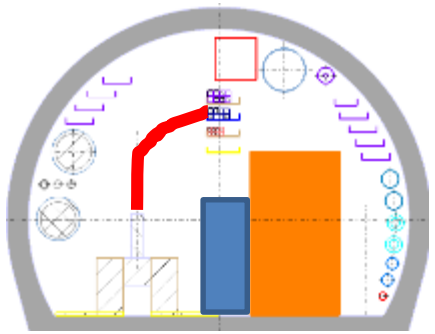
Powering 2* 8 RACKS (UR)
Control 2*4 RACKS (UR/US) Faraday cage

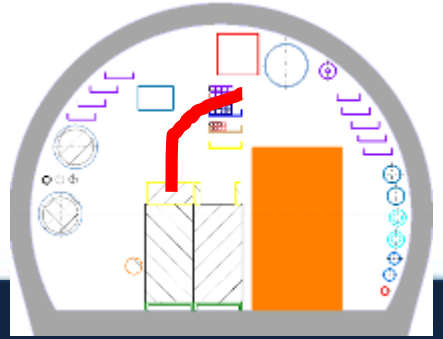


SC Magnet Powering I: D2 to Q6

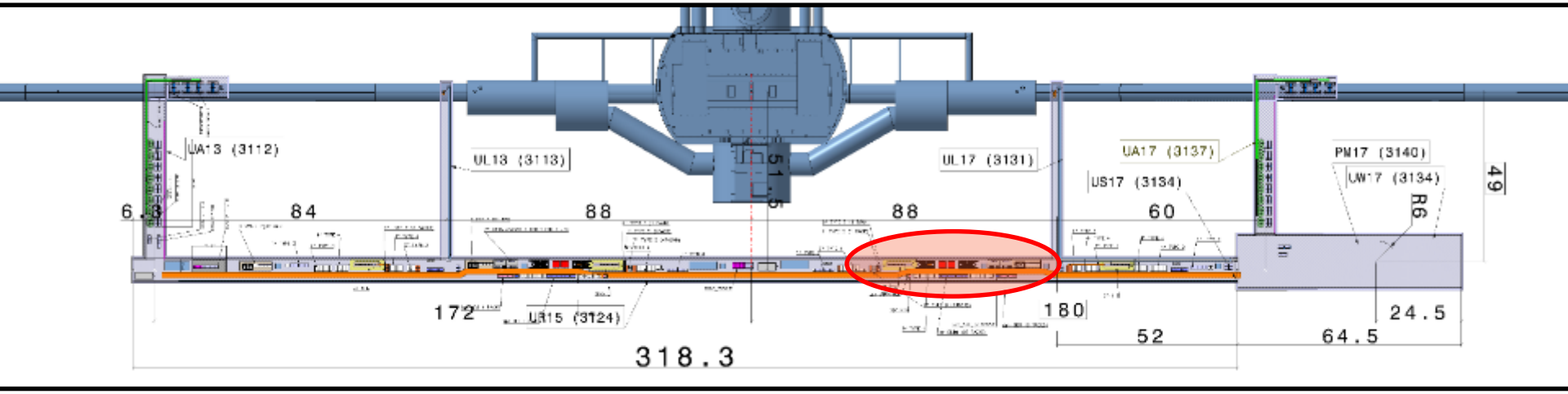


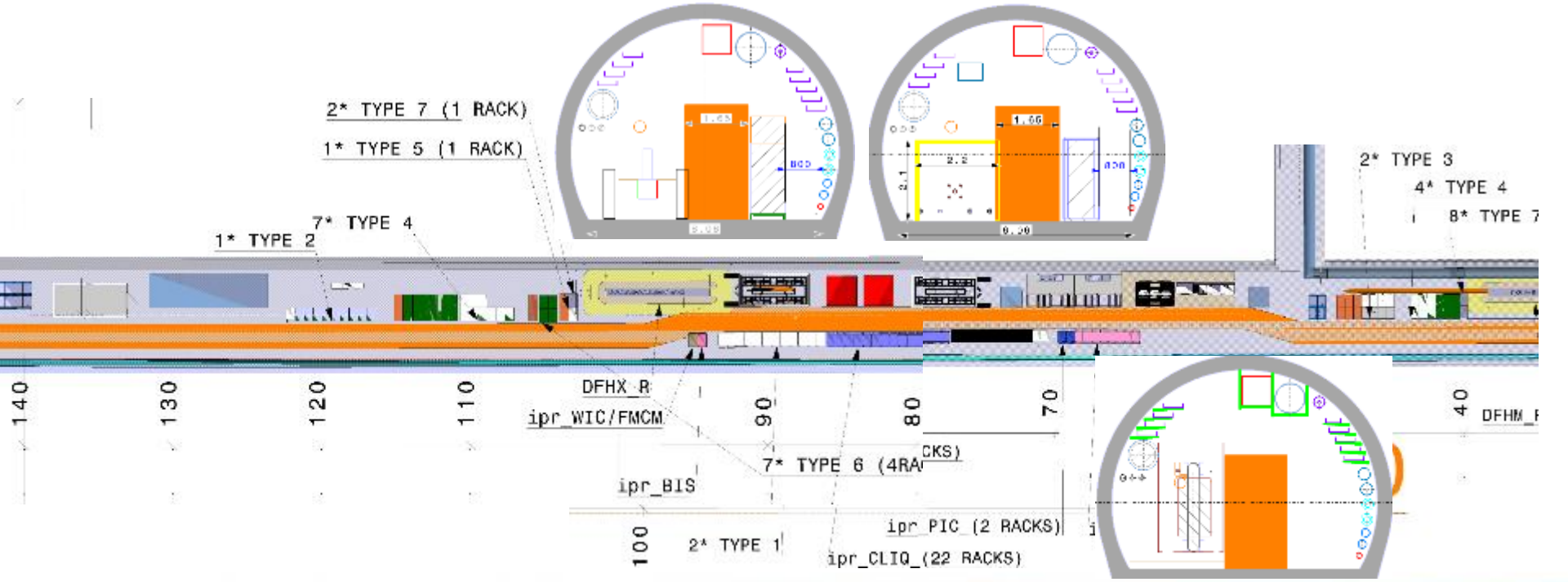




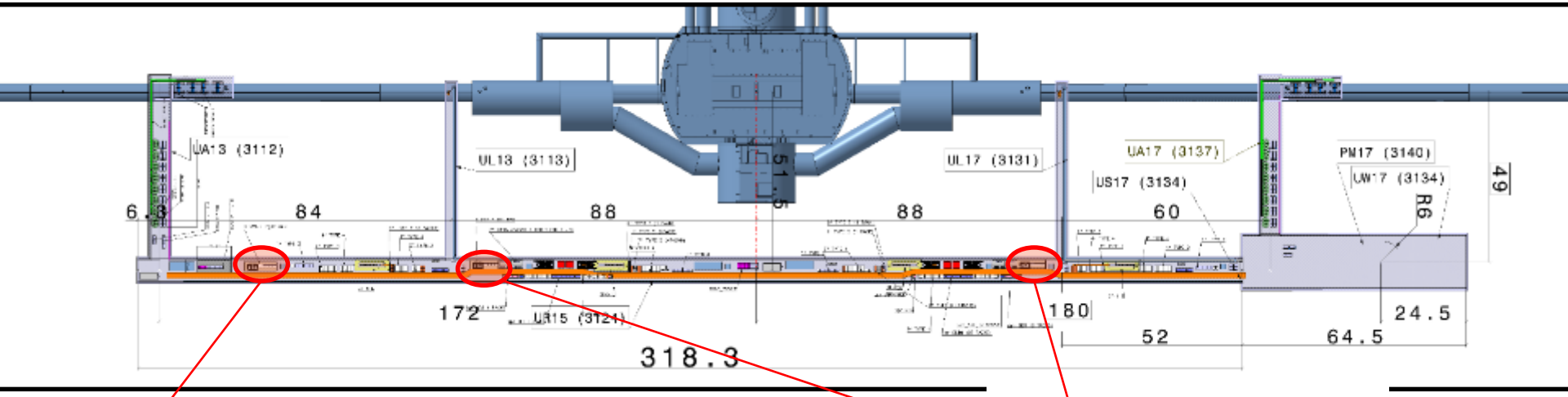


SC Magnet Powering II: Q1 to D1

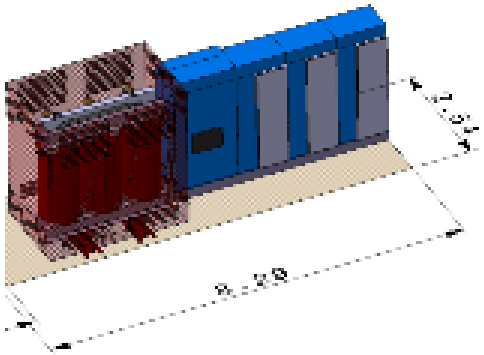


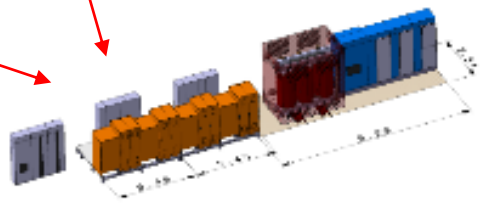


Electrical supplies

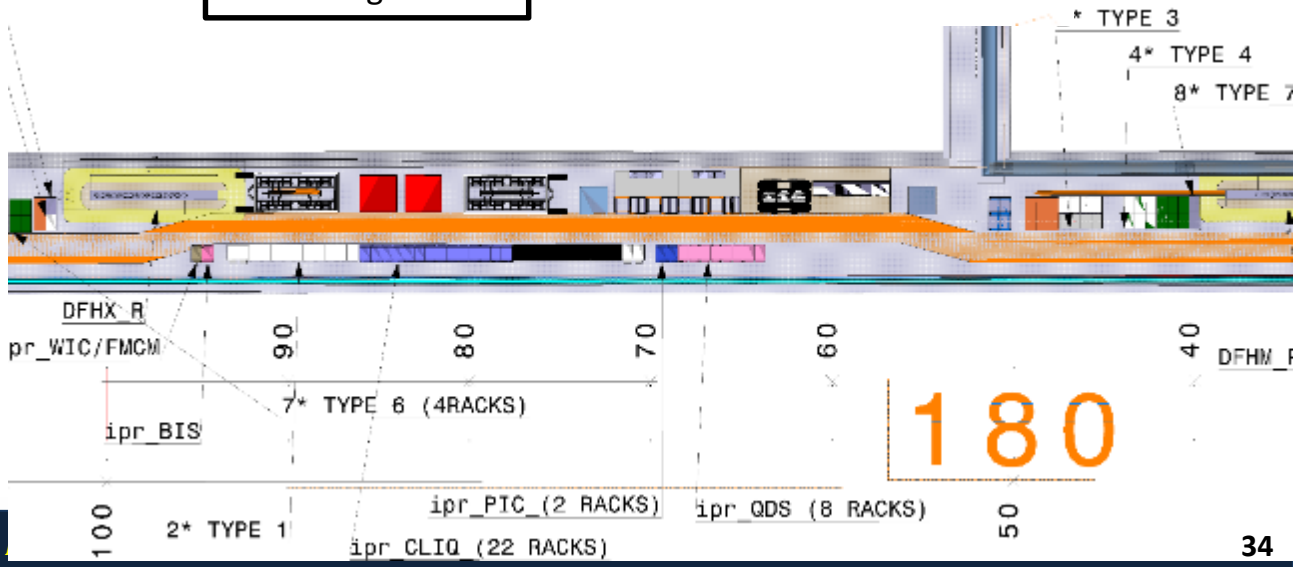


Transformer and distribution RF LEFT SIDE

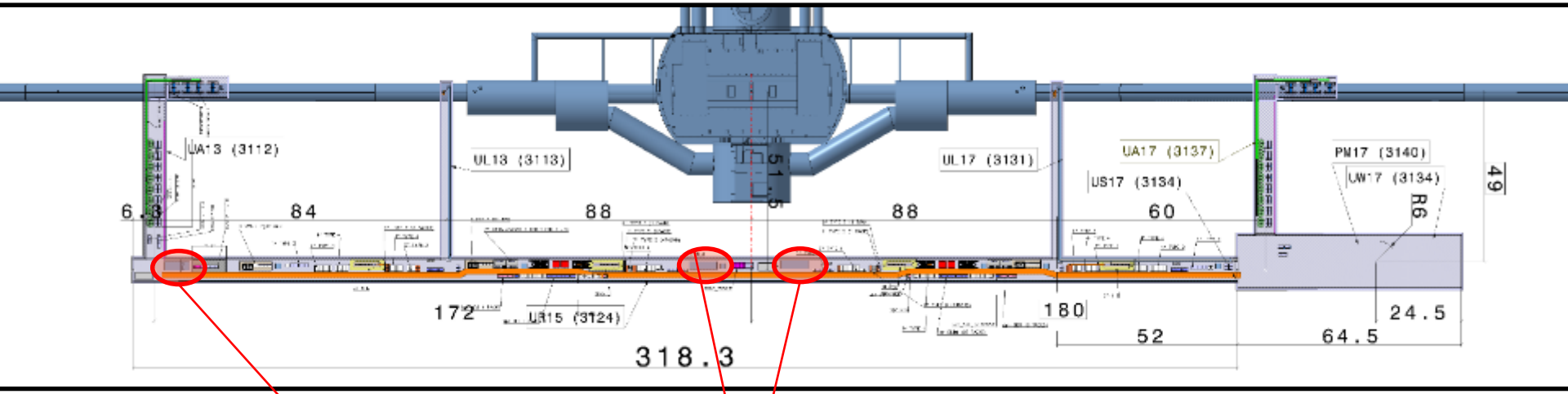




Transformers for PC for magnets



Ventilation



Unit for UA

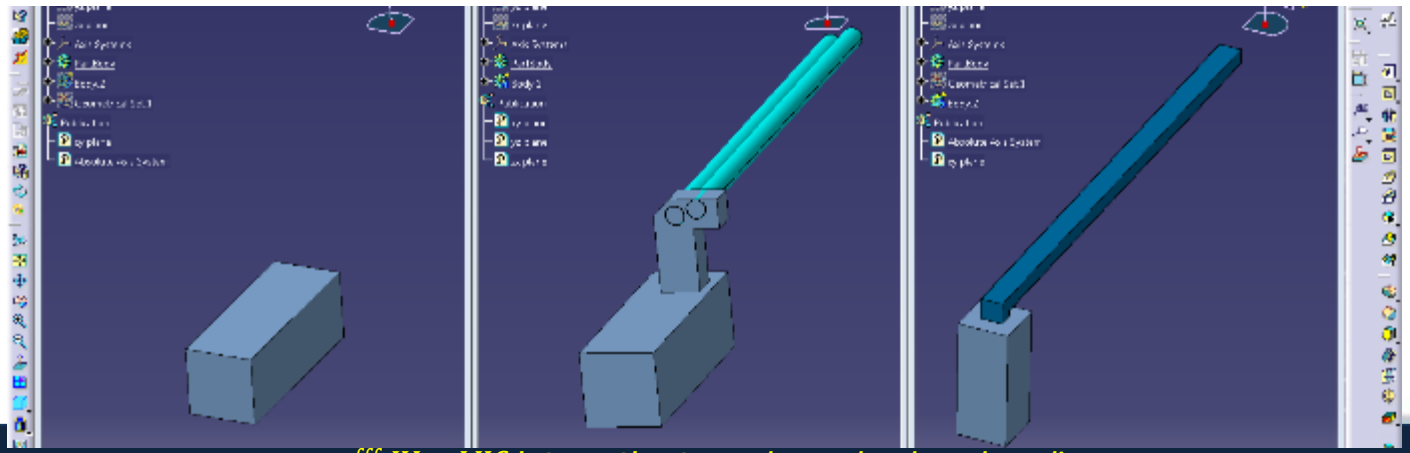
2.5 m x *2.5 m x 7 m

Unit for the powering warm cables

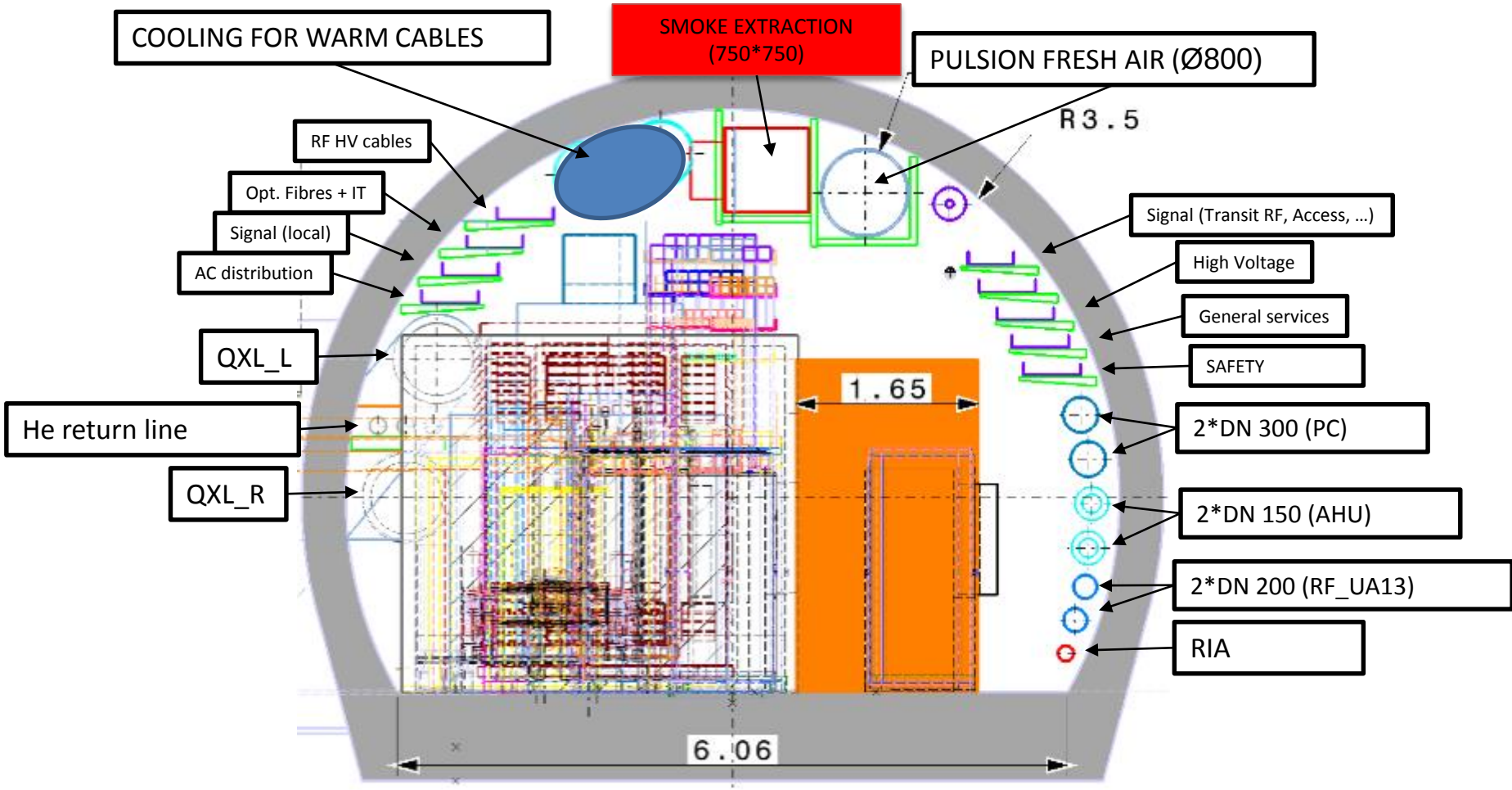
2 x (2.3 m x 2.3 m X 8 m)

Units for local air treatment

6 x (1.5 m x 1.5 m x 3.5 m)



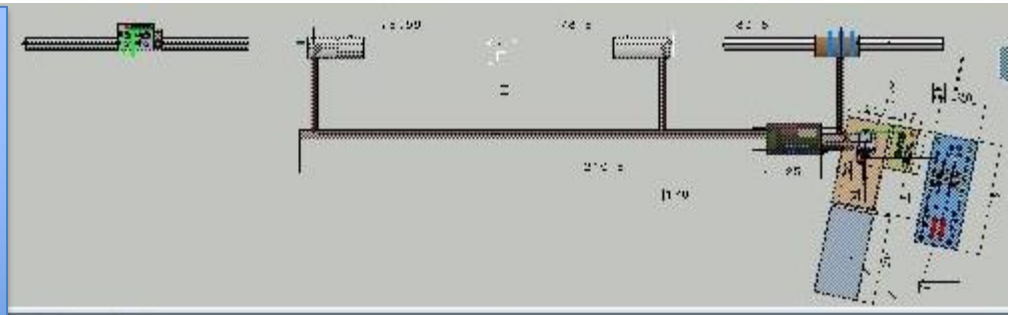
The most busy section with all longitudinal services



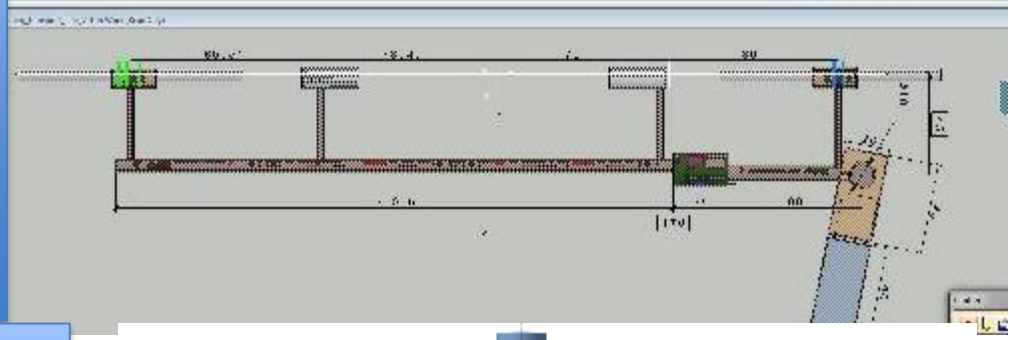
Optimising reasons, consequences, timing and first actions in list (my optimistic approach)

One of the reasons to optimise: volume to excavate

CS review

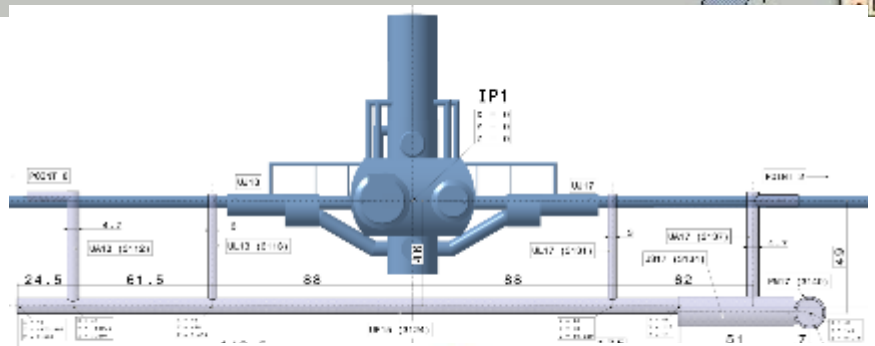


1 – OLD BASELINE : ≈ 20 000 m³



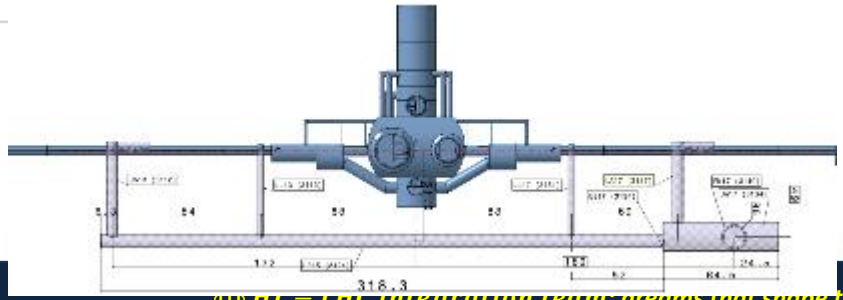
2 - OPTION : ≈ 28 000 m³

CE optimisation and D. Decker approval



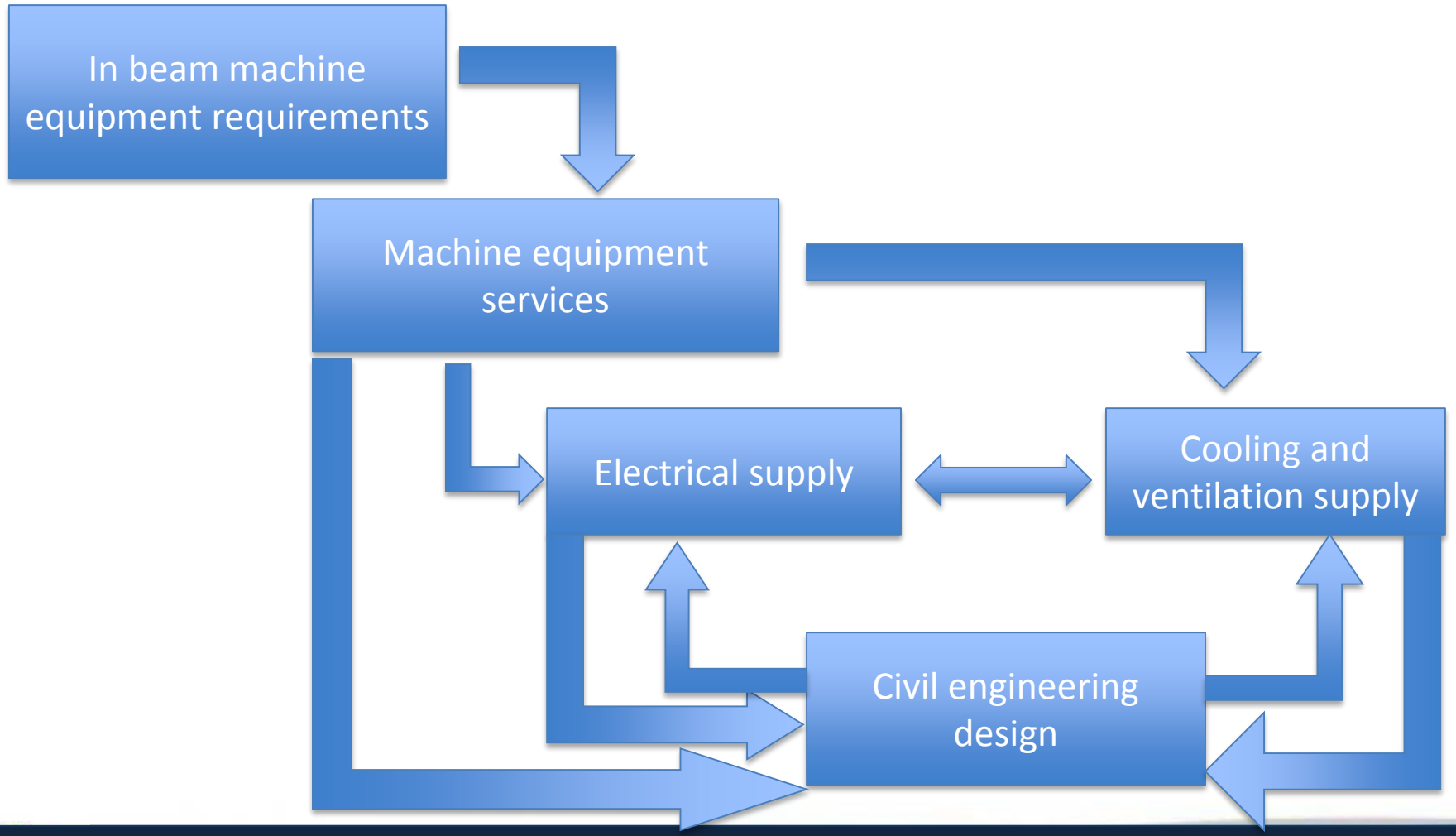
≈ 33 000 m³

Volume integration completed



≈ 41 000 m³

Optimisation for cost efficiency targeting possible reduction of infrastructure needs



Shaft

TARGET:

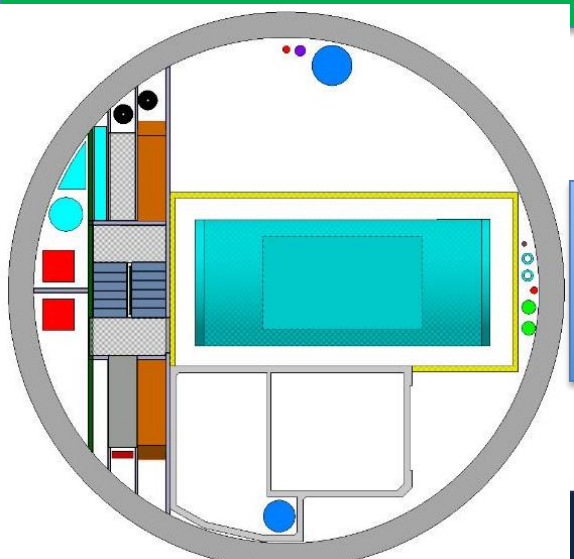
Reduction of diameter of the shaft from 12 m

MEANS/ISSUES TO DEAL WITH

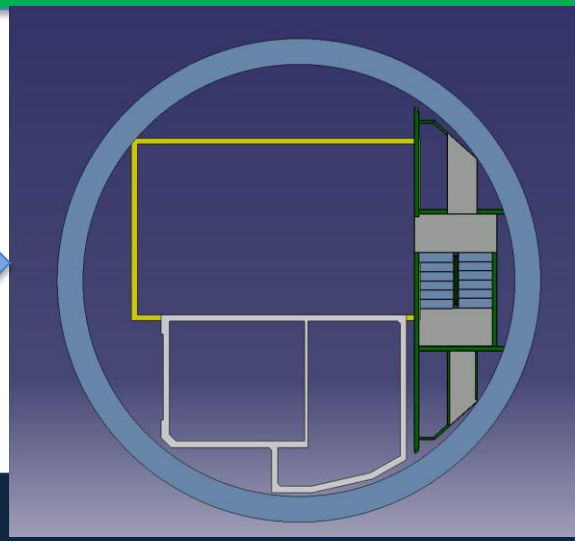
- Need to transport the QURC in inclined or vertical position
- Provide sufficiently and correctly positioned routing for ventilation and cable trays

BENEFITS:

- Reduction of CE cost
- Reduction of excavation time->planning risk mitigation
- Reduction of the water infiltration risks and volumes at Point 5



From 12 to 10 m:
Model under screening and study



UR

TARGET:

Reduce the ohmic heating of the SC magnet powering installation without increasing the cold part length

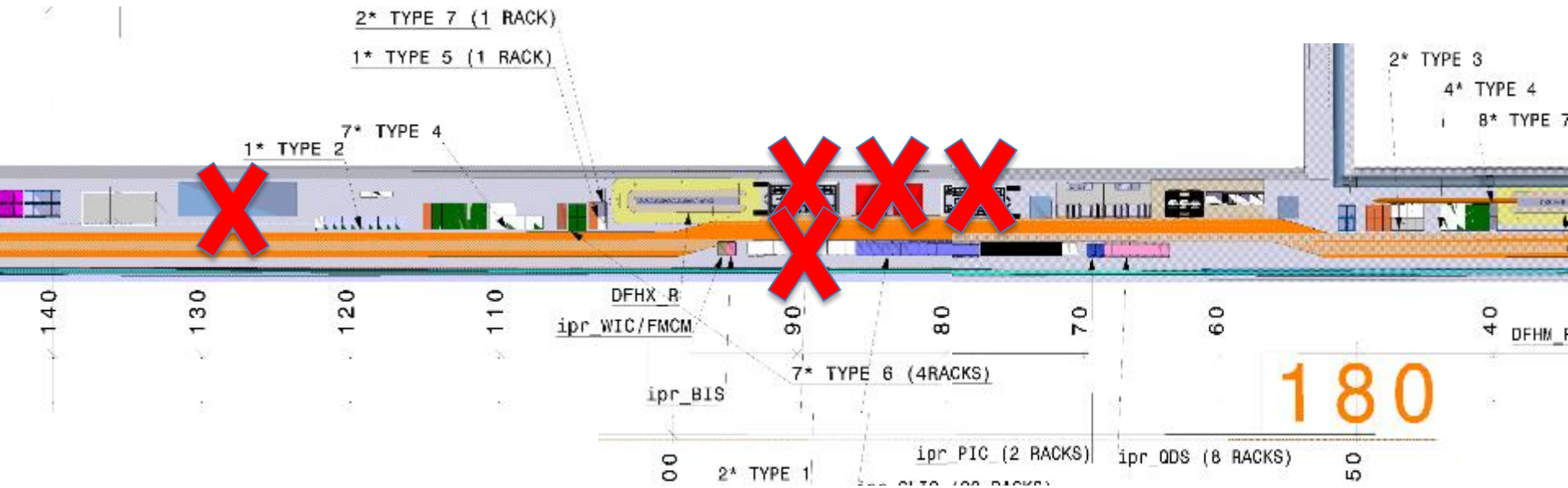
MEANS/ISSUES/OPTIONS/OPPORTUNITIES TO DEAL WITH

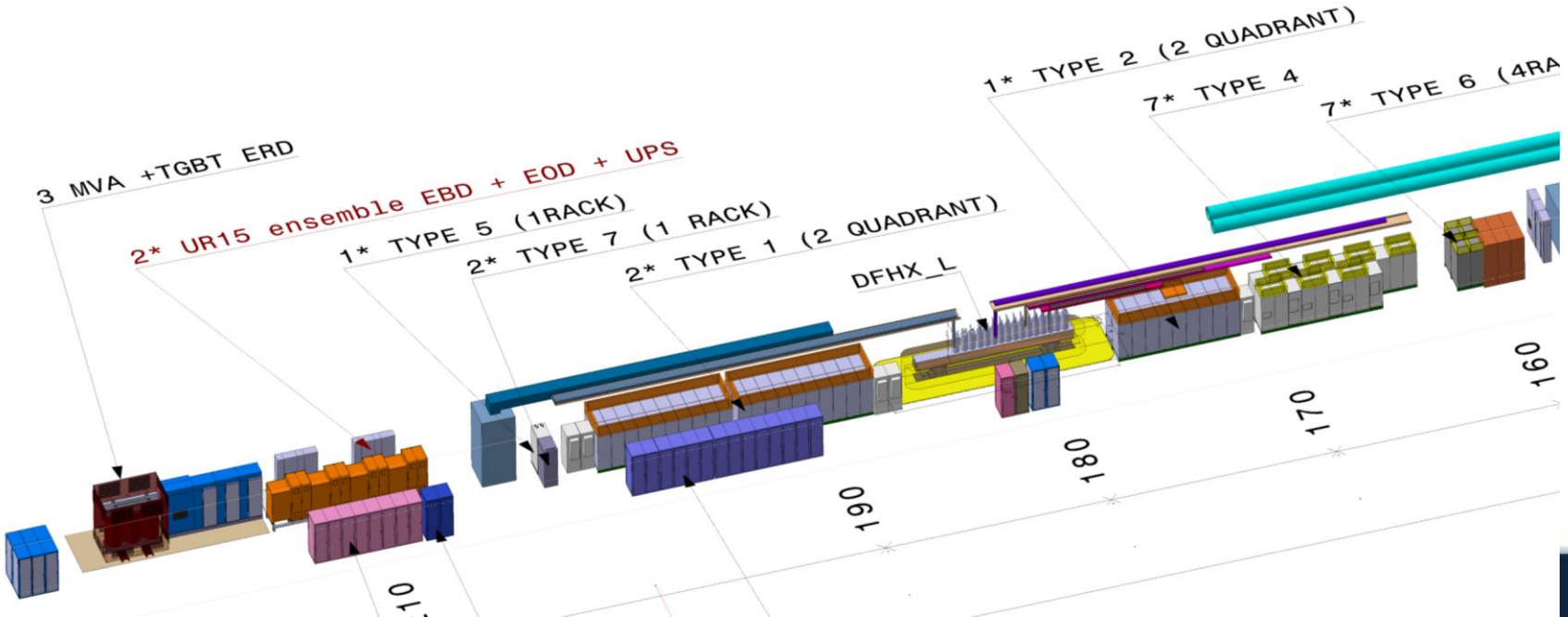
- Adoption of 2 quadrant PCs for the Q1->Q3 circuit
- Adoption of 2 quadrant PCs for the D1 and D2
- Allowing to place PCs as near as possible to the DFHs in electrical dissipation reduction approach
- Dropping of the Dump and Switches for Q1->Q3 circuit
- Lumping of Q1->Q3 in one circuit

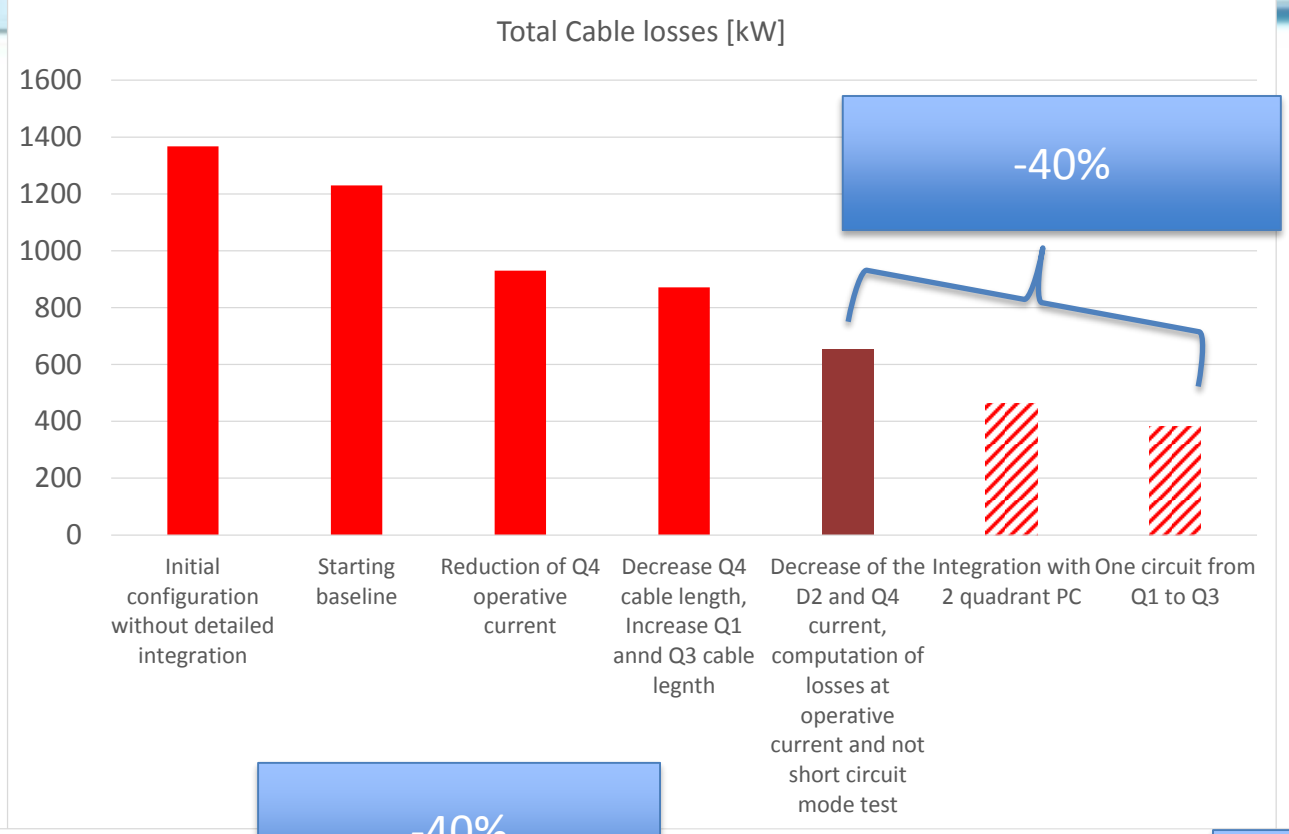
BENEFITS:

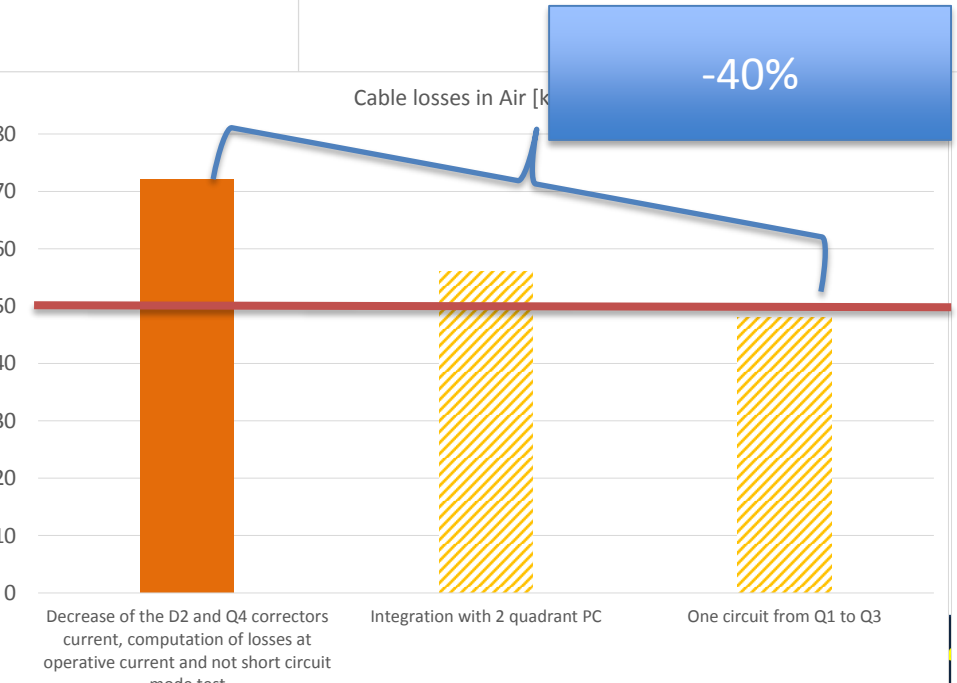
- Reduction of the warm and water cool cable footprint
- Reduction of the ohmic dissipation
- Reduction of the electrical installation footprint
- Reduction of the cooling ventilation system
- Reduction of the UR diameter (to be seen)
- Reduction of capital and operative cost

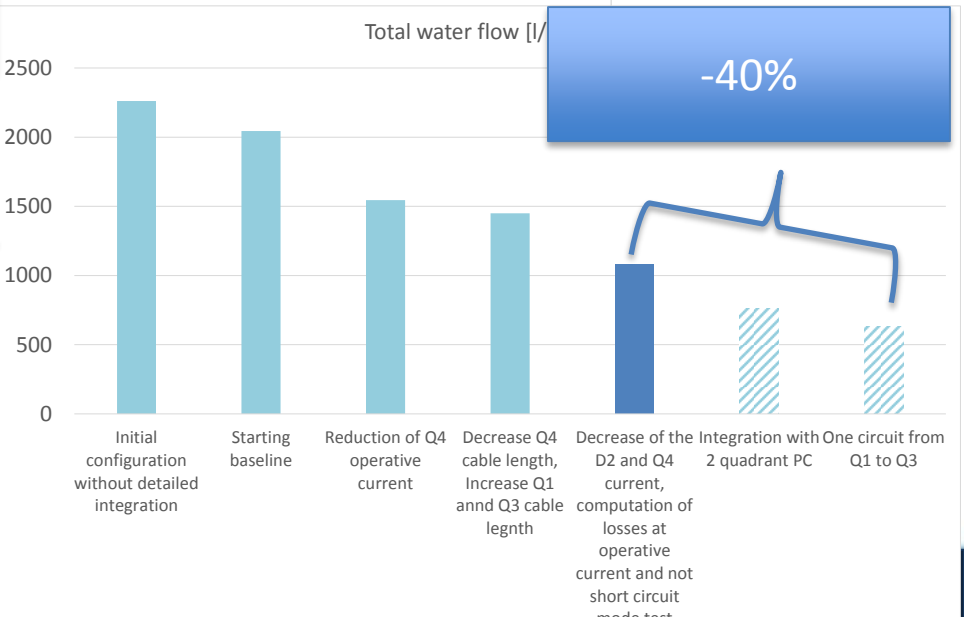
Optimisation working hypothesis






Total Cable losses [kW]
1600
1400
1200
1000
800
600
400
200
0
-40%
Initial configuration without detailed integration
Starting baseline
Reduction of Q4 operative current
Decrease Q4 cable length, Increase Q1 annd Q3 cable legnth
Decrease of the D2 and Q4 current, computation of losses at operative current and not short circuit mode test
Integration with 2 quadrant PC
One circuit from Q1 to Q3


Cable losses in Air [k
-40%
Decrease of the D2 and Q4 correctors current, computation of losses at operative current and not short circuit
Integration with 2 quadrant PC
One circuit from Q1 to Q3


Total water flow [l/
-40%
2500
2000
1500
1000
500
0
Initial configuration without detailed integration
Starting baseline
Reduction of Q4 operative current
Decrease Q4 cable length, Increase Q1 annd Q3 cable legnth
Decrease of the D2 and Q4 current, computation of losses at operative current and not short circuit
Integration with 2 quadrant PC
One circuit from Q1 to Q3

UA

TARGET:

Reduce the ventilation installation and if possible reduce the UA diameter

MEANS/ISSUES/OPTIONS TO DEAL WITH

- Installation of the HVPS for the tetrodes on the surface

BENEFITS:

- Adopt similar strategies for the RF crab powering baseline (tetrodes) and IOT powering with the HVPS in surface on both cases
- Reduce the powering delivered to the air in the UA

Timeline

Phase I: COMPLETED

- Definition of the full needs and full integration in tunnel and first analysiss on surface: USED FOR THE INVITATION TO TENDER FOR THE CIVIL ENGINEERING DESIGN

Phase II: ONGOING

- Optimisations of volumes and of the technical Infrastructure Specification (WP17). It will provide refine drawings for the SIGNATURE OF THE CIVIL ENGINEERING DESIGN. ***February 2016***

Phase III: continuous improvement and refinement keeping in line the milestones for civil engineering activities

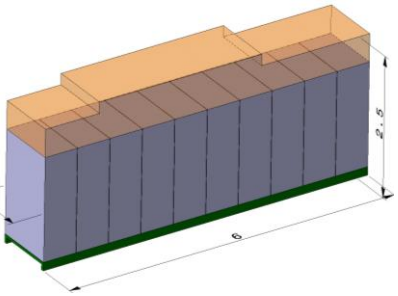
Double decker it is taking up speed, we can steer, but better do not break or it will be painful for passengers

Conclusions

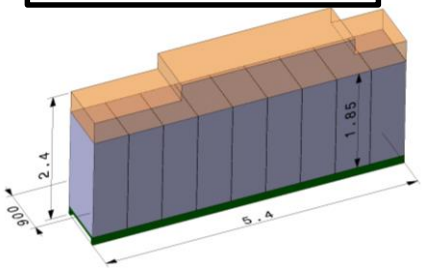
- The approach for the installation of the supplies and services for the HL-LHC has been reviewed following the vibration studies
- The Double Decker approach has been developed and, on the base of this approach, all the services identified by WP17 integrated
- The volumes for the surface (not shown here) and underground infrastructures have been frozen as first complete Baseline on the 18th/09/2015

Extra slides

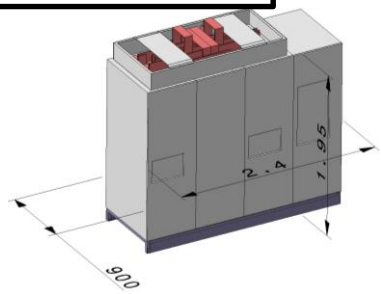
Type 1: 16.5kA



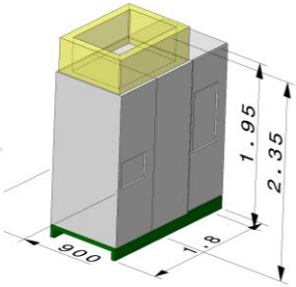
Type 2: 13 kA



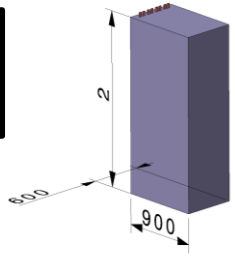
Type 3: 6 kA



Type 4: 2kA

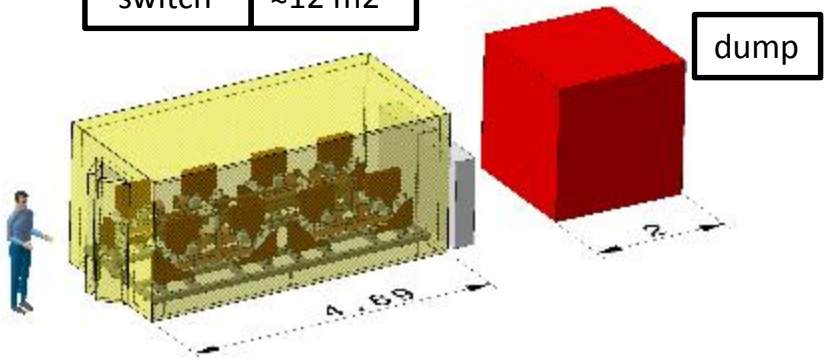


2 * Type 5(0.3kA) = 1 racks
2 * Type 6(0.2kA) = 1 racks
4 * Type 7(0.12kA)= 1 racks

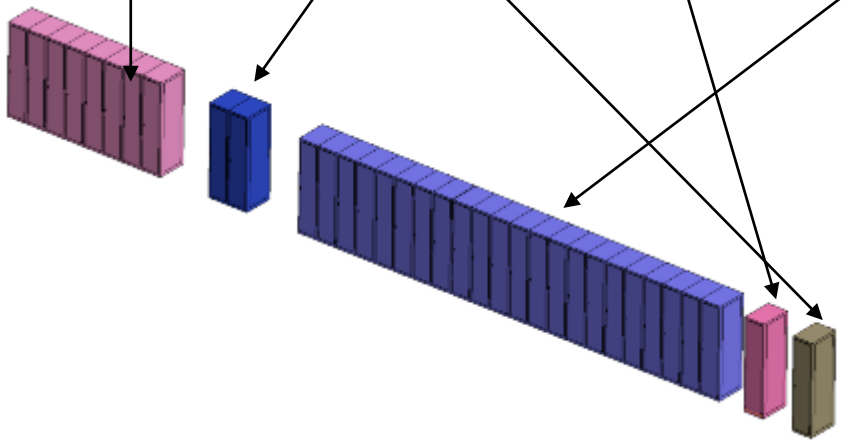


“switch”	≈12 m2

dump

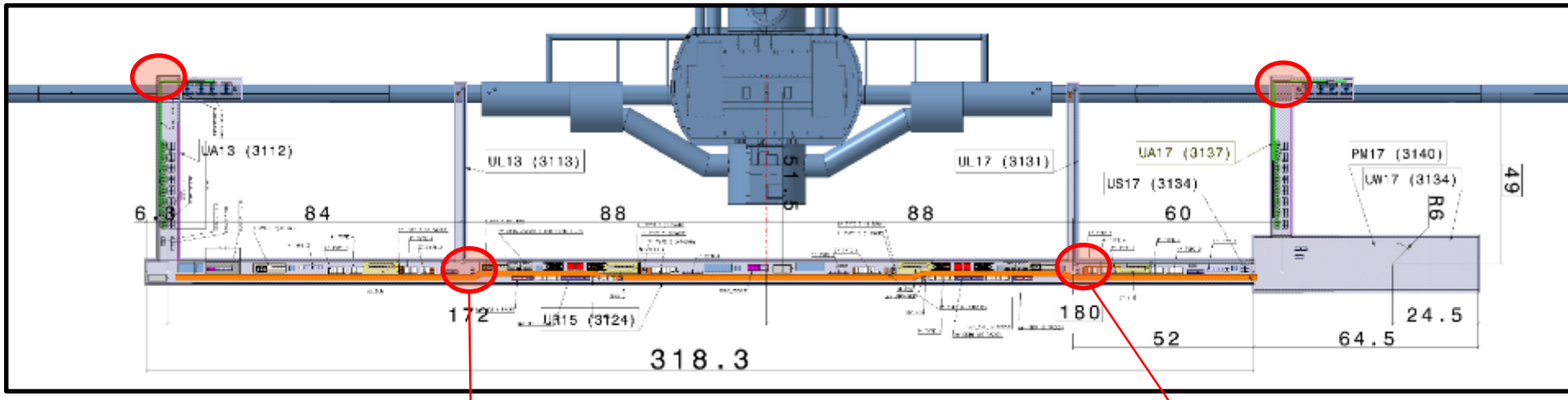


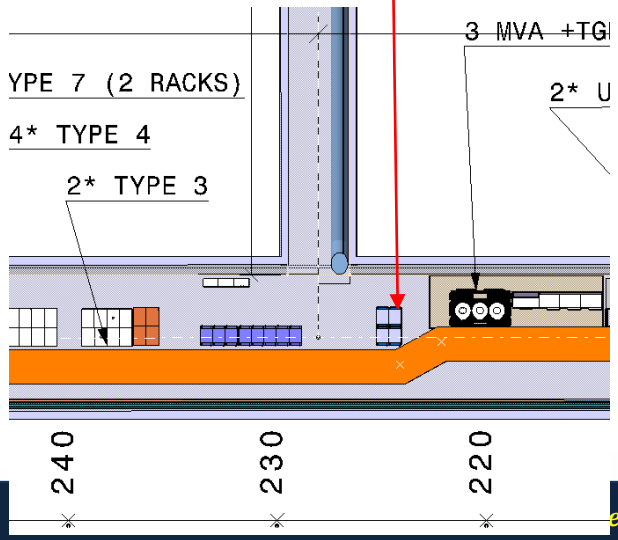
Location	Quench Detection Systems (QDS)	PIC	WIC/ FMCM	BIS	CLIQ
	# of Racks	# of Racks	# of Racks	# of Racks	# of Racks
L1	8	2	1	1	22

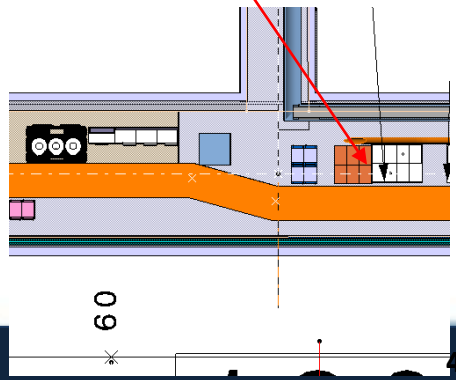


Survey

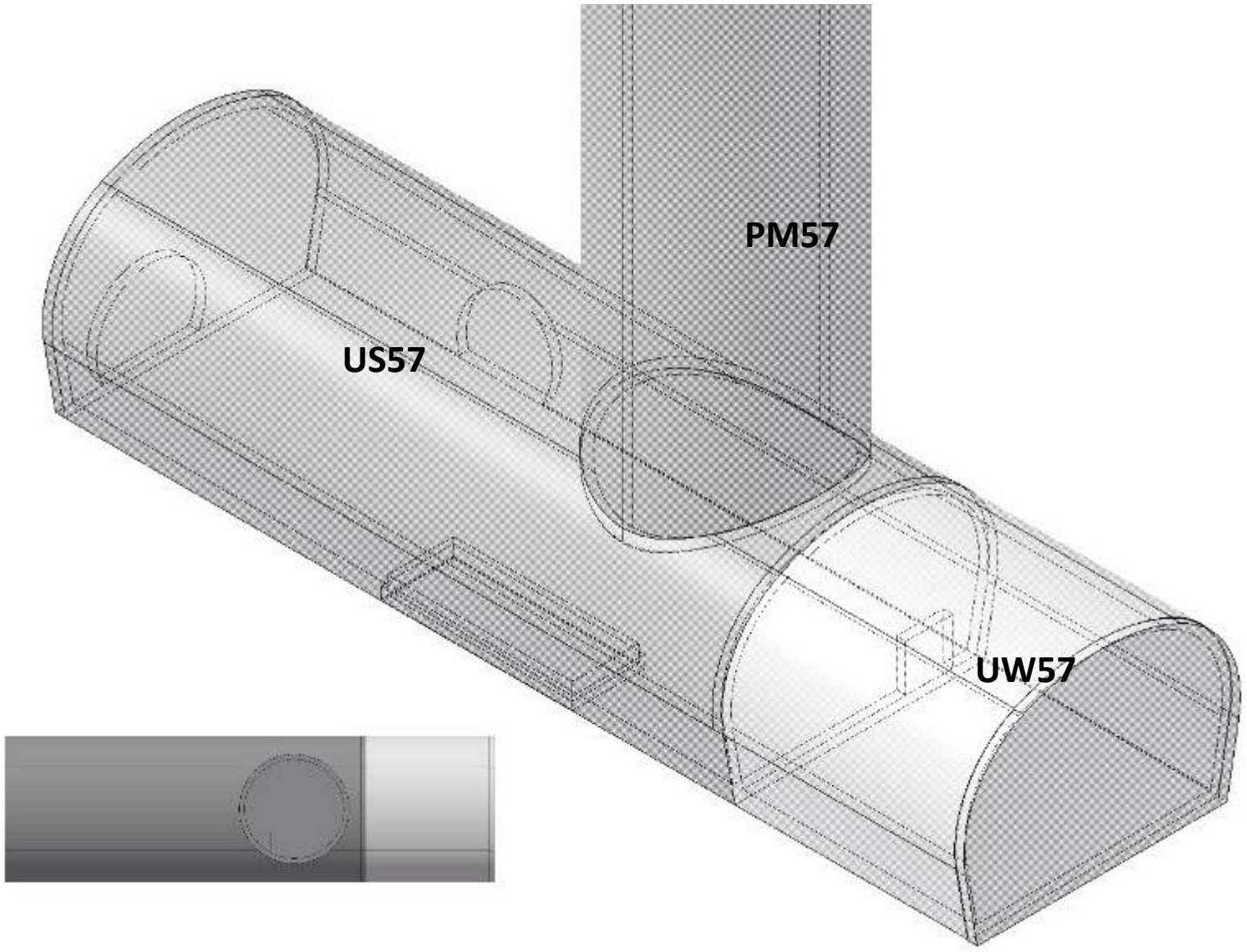
2* 4 RACKS (UR)
2*1 RACKS (UA13/17)



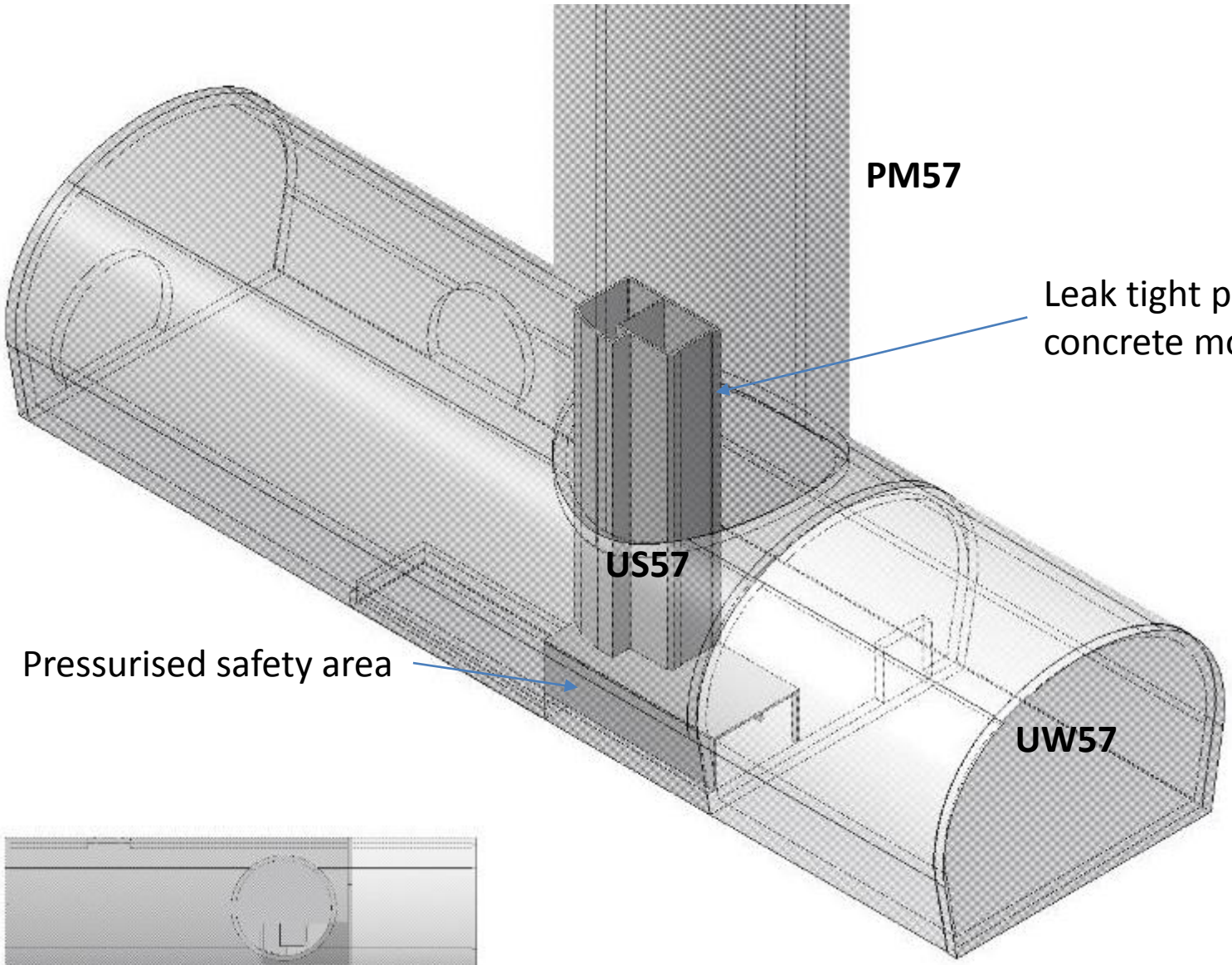




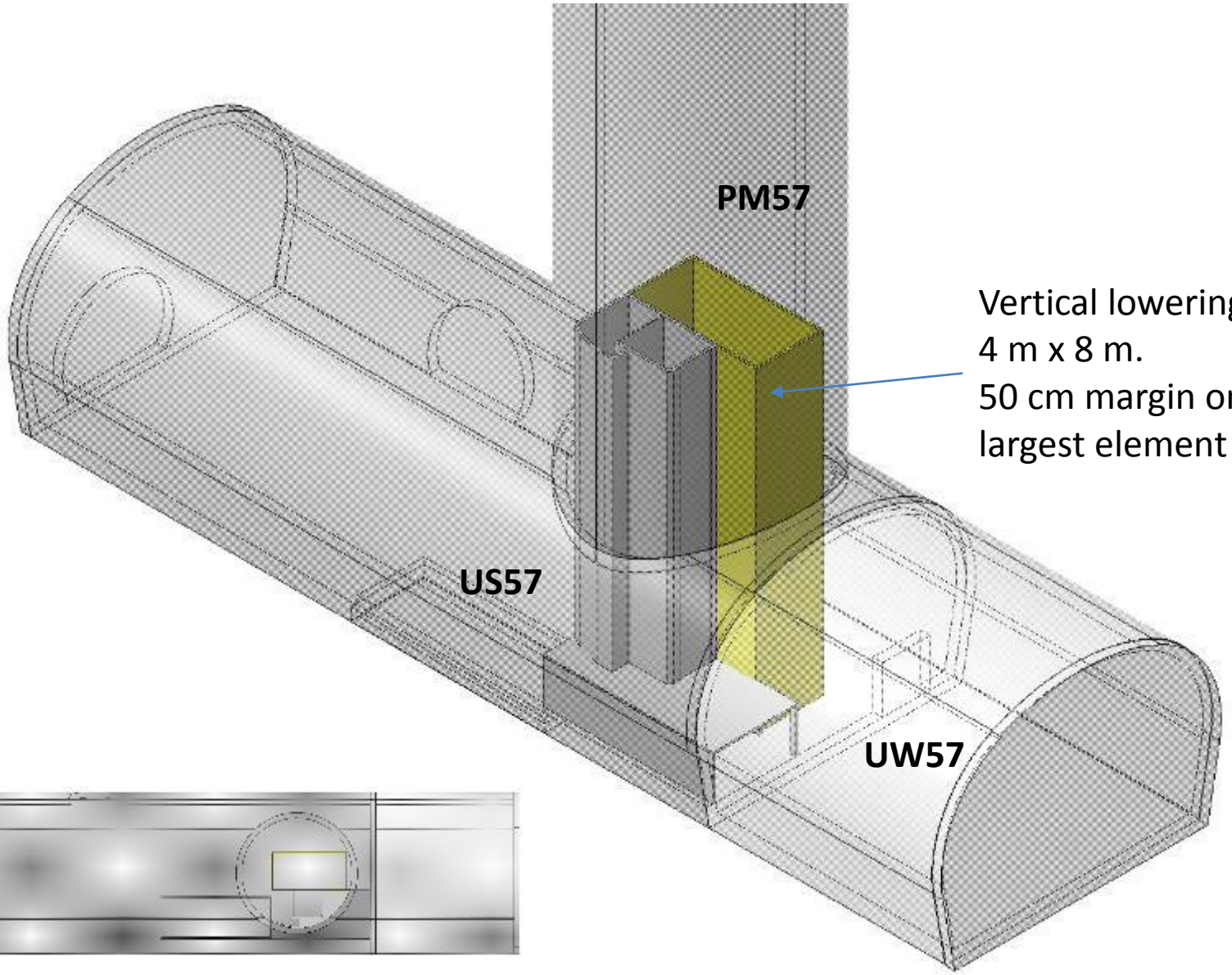
General View



Civil engineering structure related to personnel safety



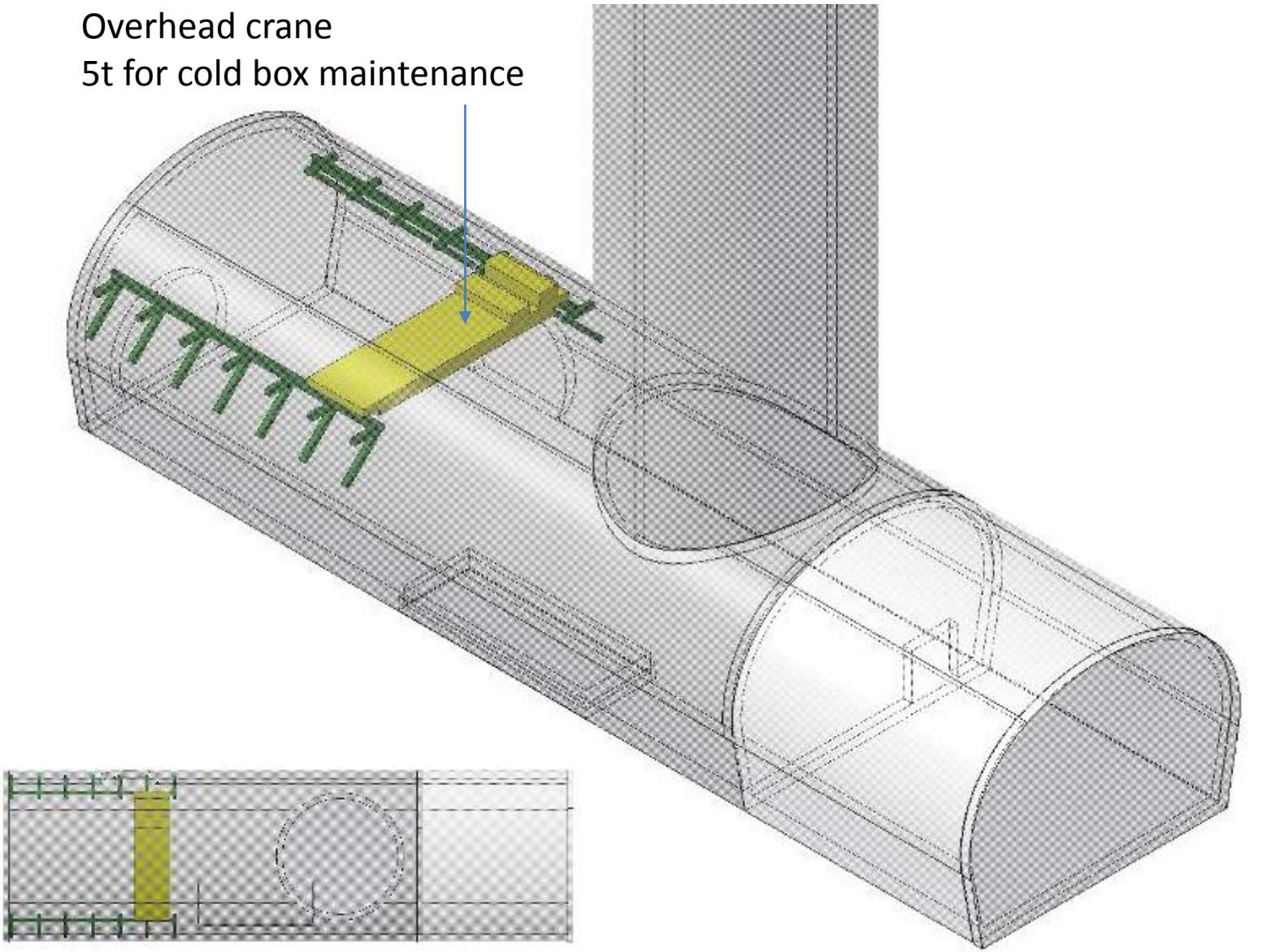
Transport volume in the shaft



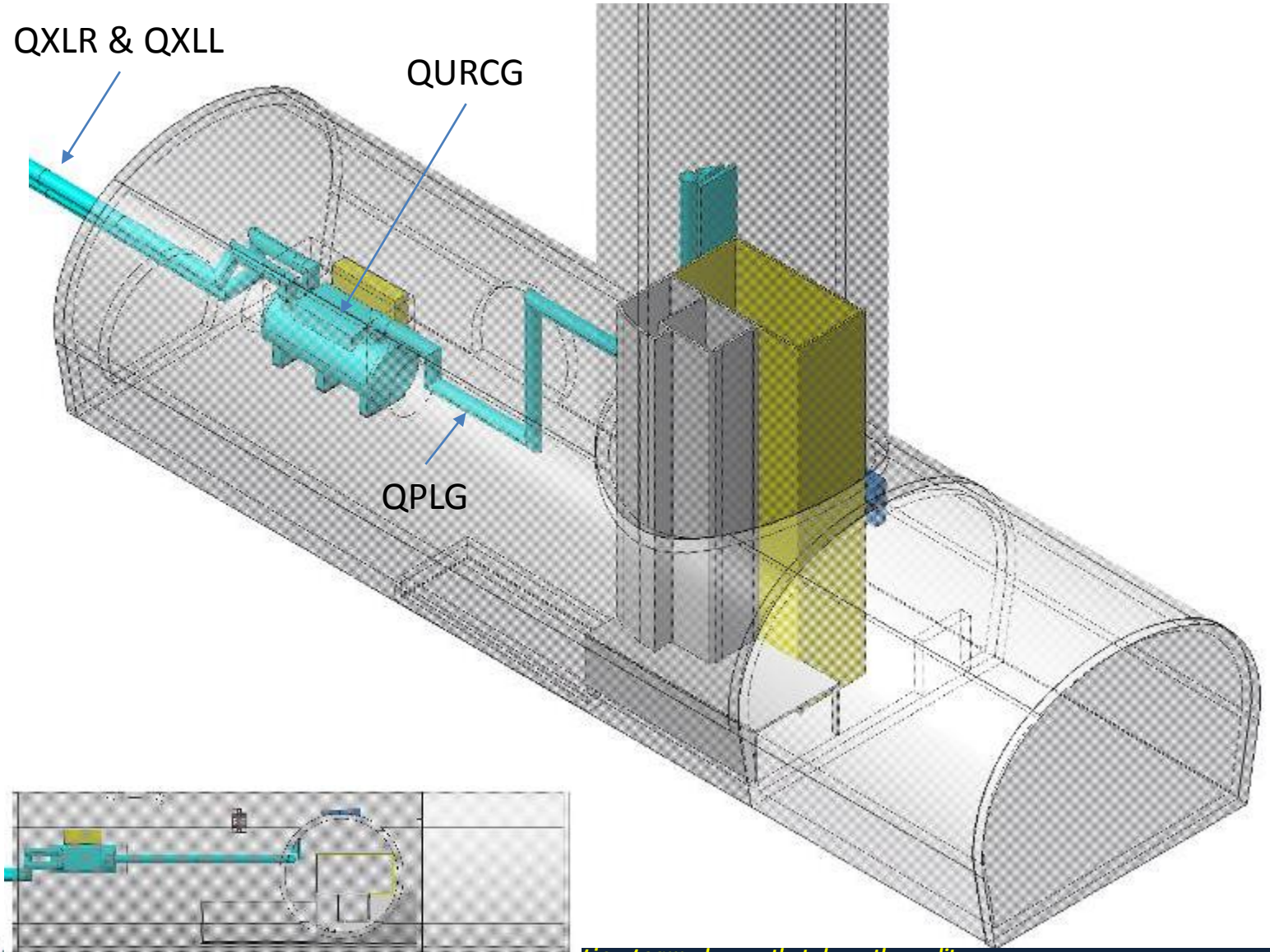
Vertical lowering volume
4 m x 8 m.
50 cm margin on sides for largest element

US handling equipment (more foreseen in the UW)

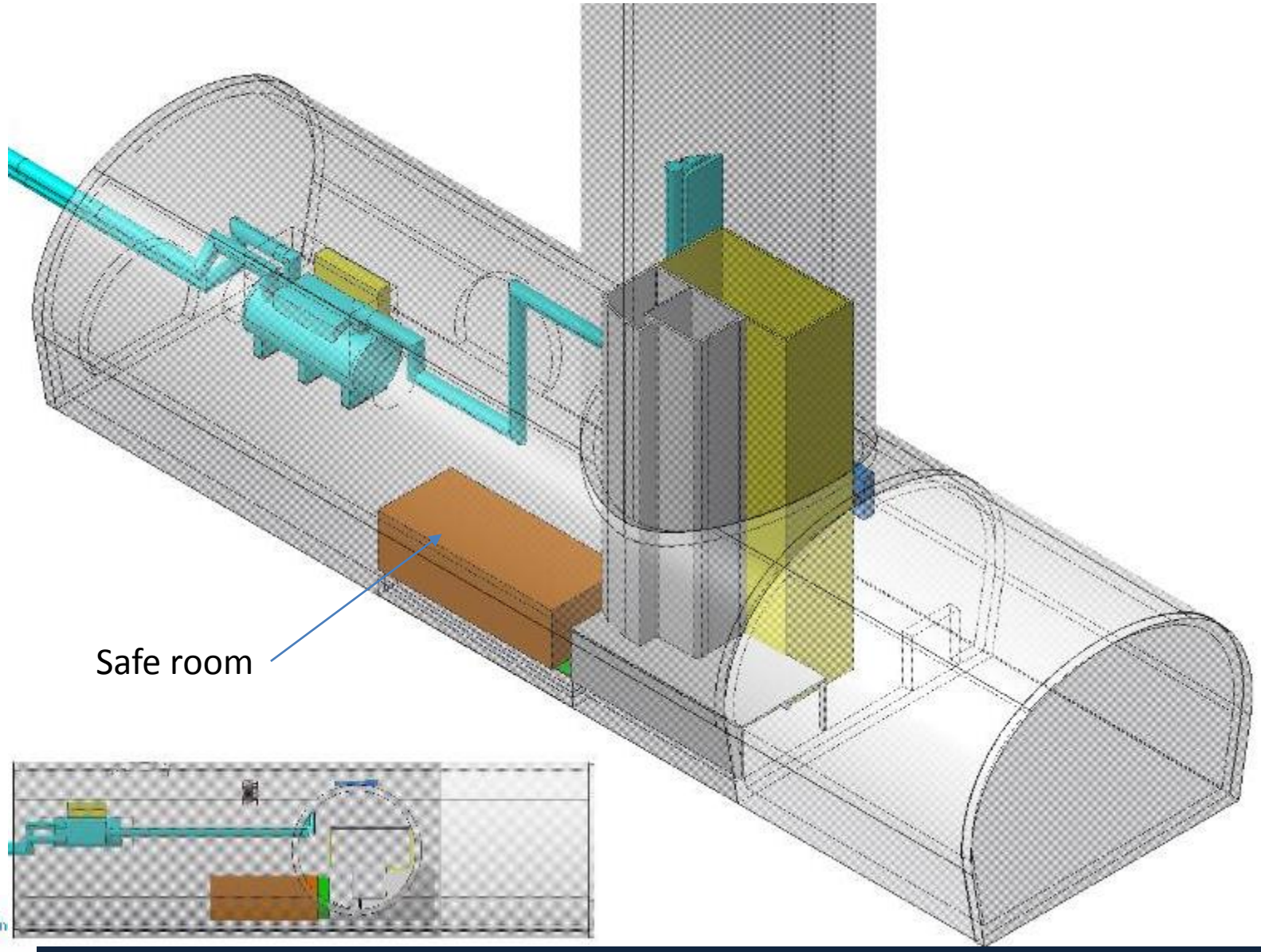
Overhead crane
5t for cold box maintenance



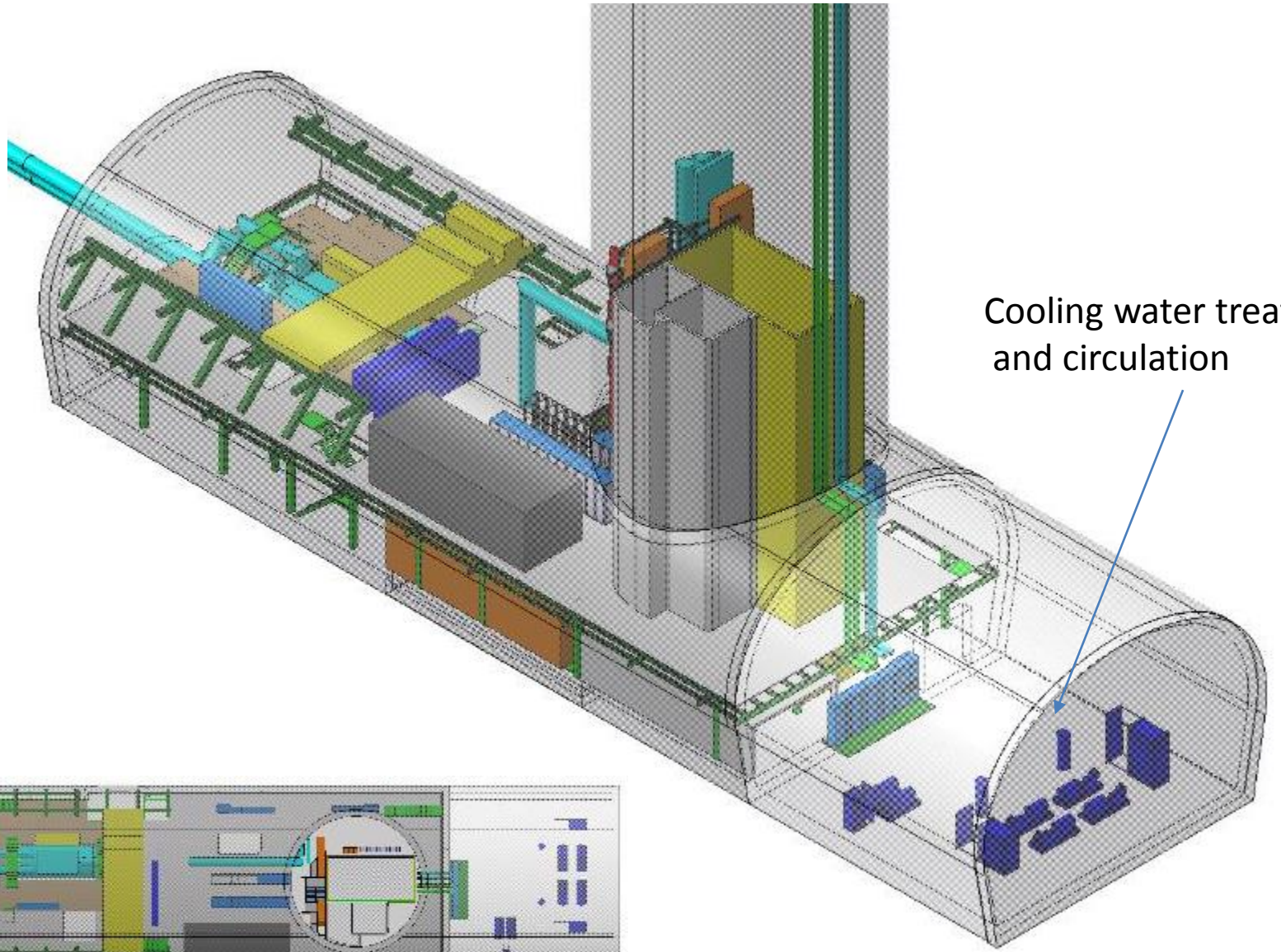
Cryogenic installation without control and electrical supply part



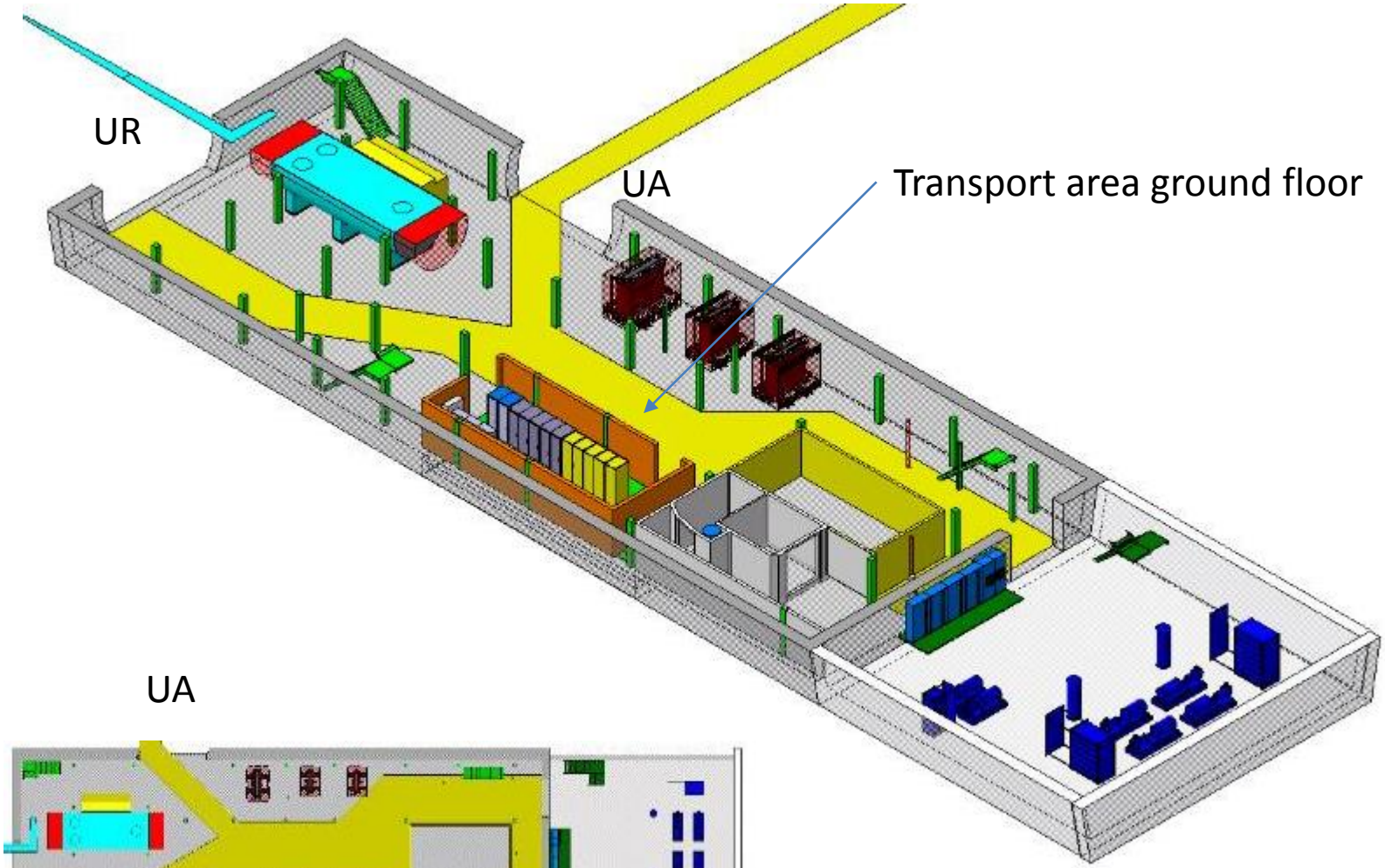
Safe room



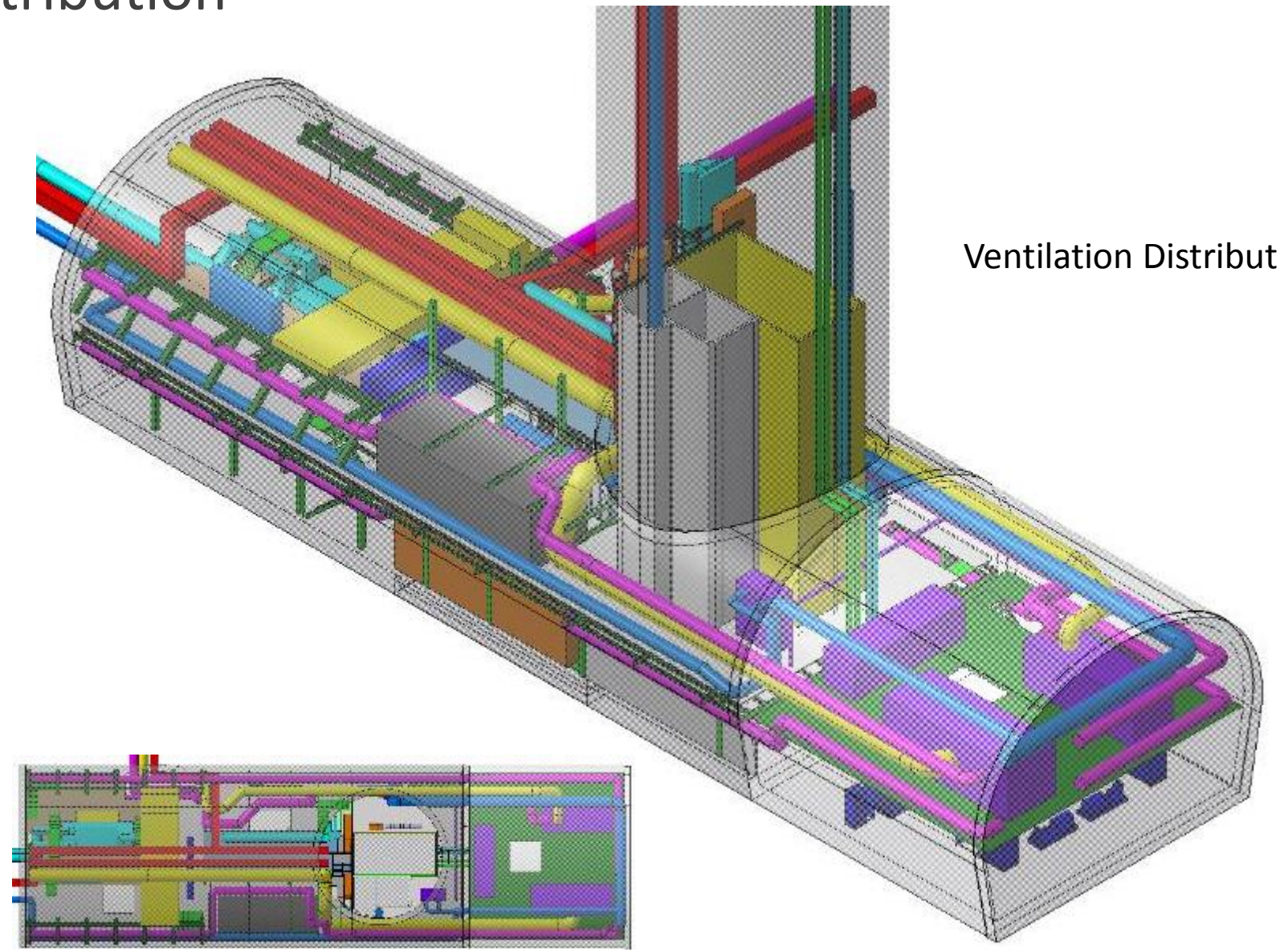
UW ground floor



Ground floor with transport areas

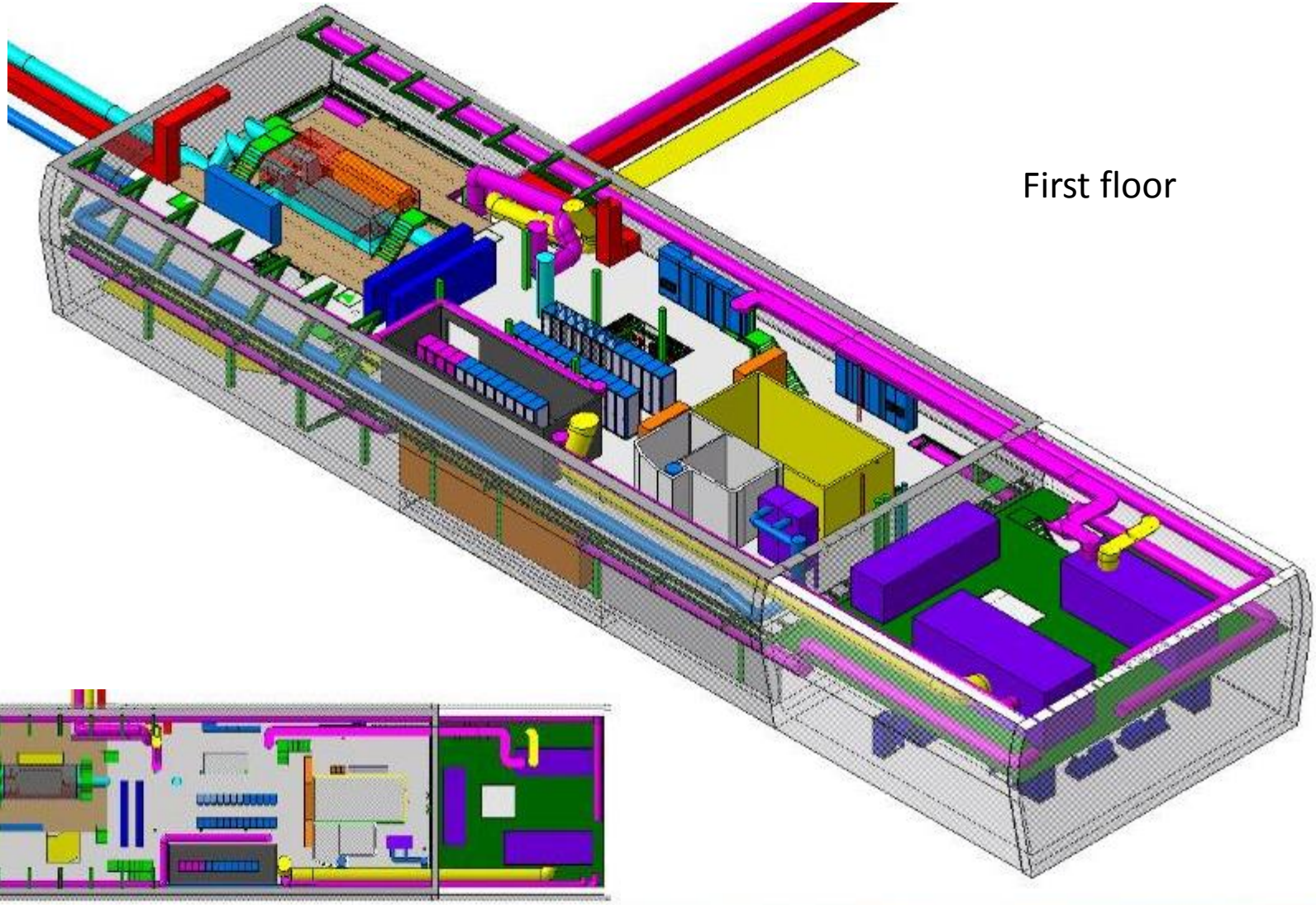


General view with all the cooling and ventilation distribution



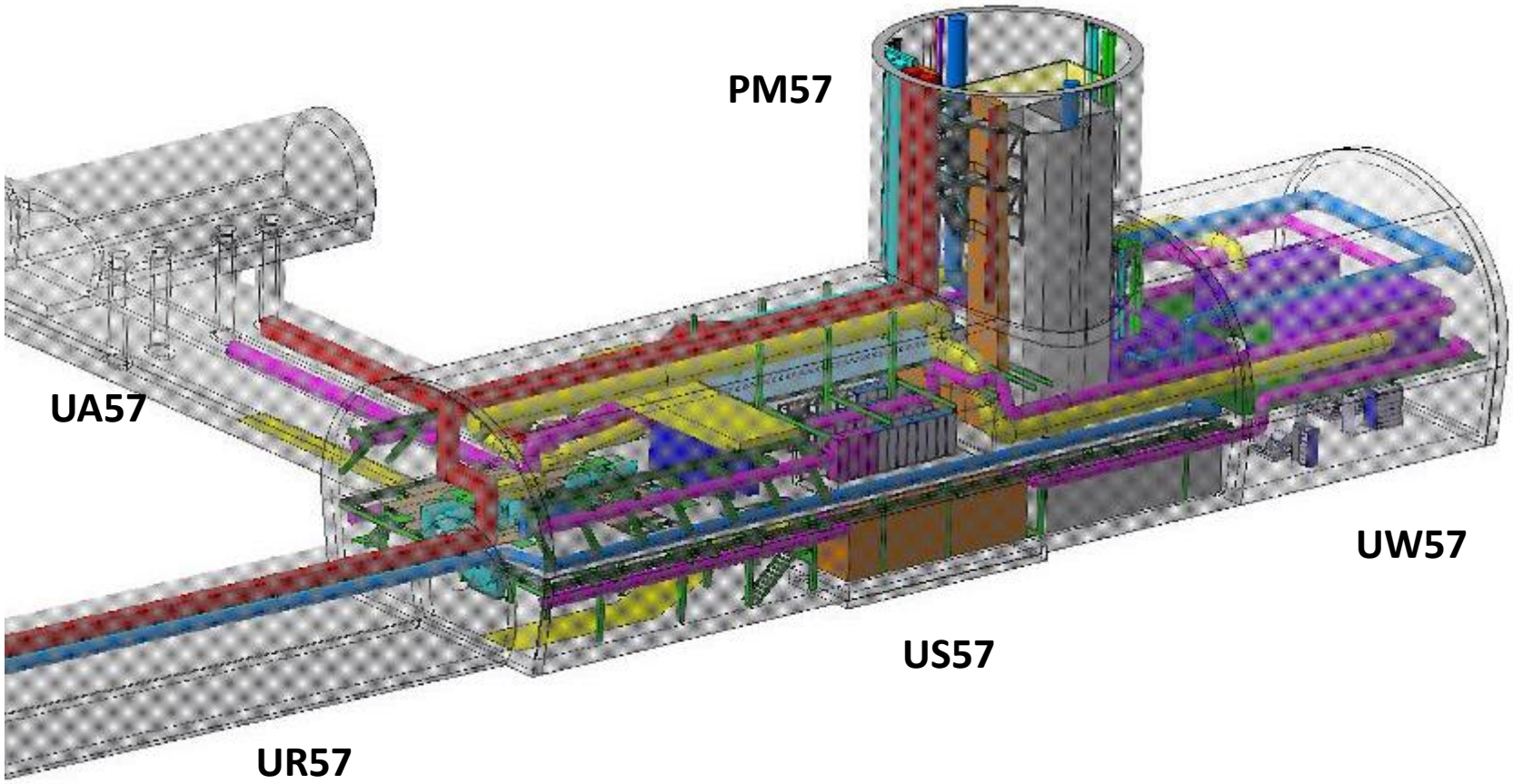
Ventilation Distribution

First floor with transport areas

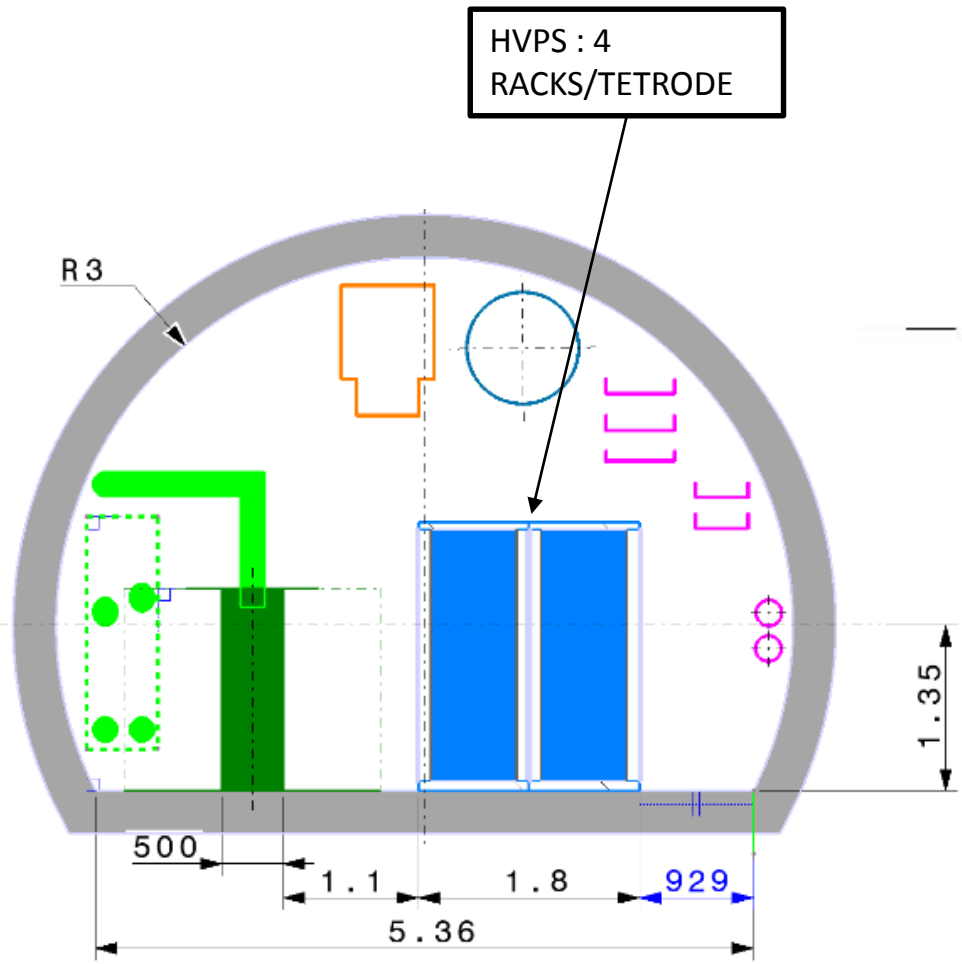


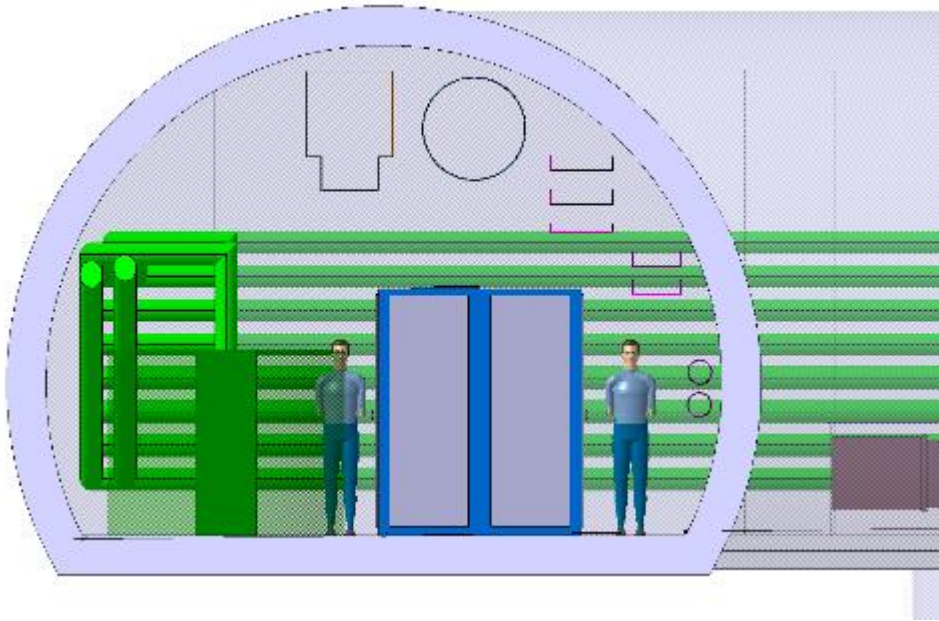
First floor

General view

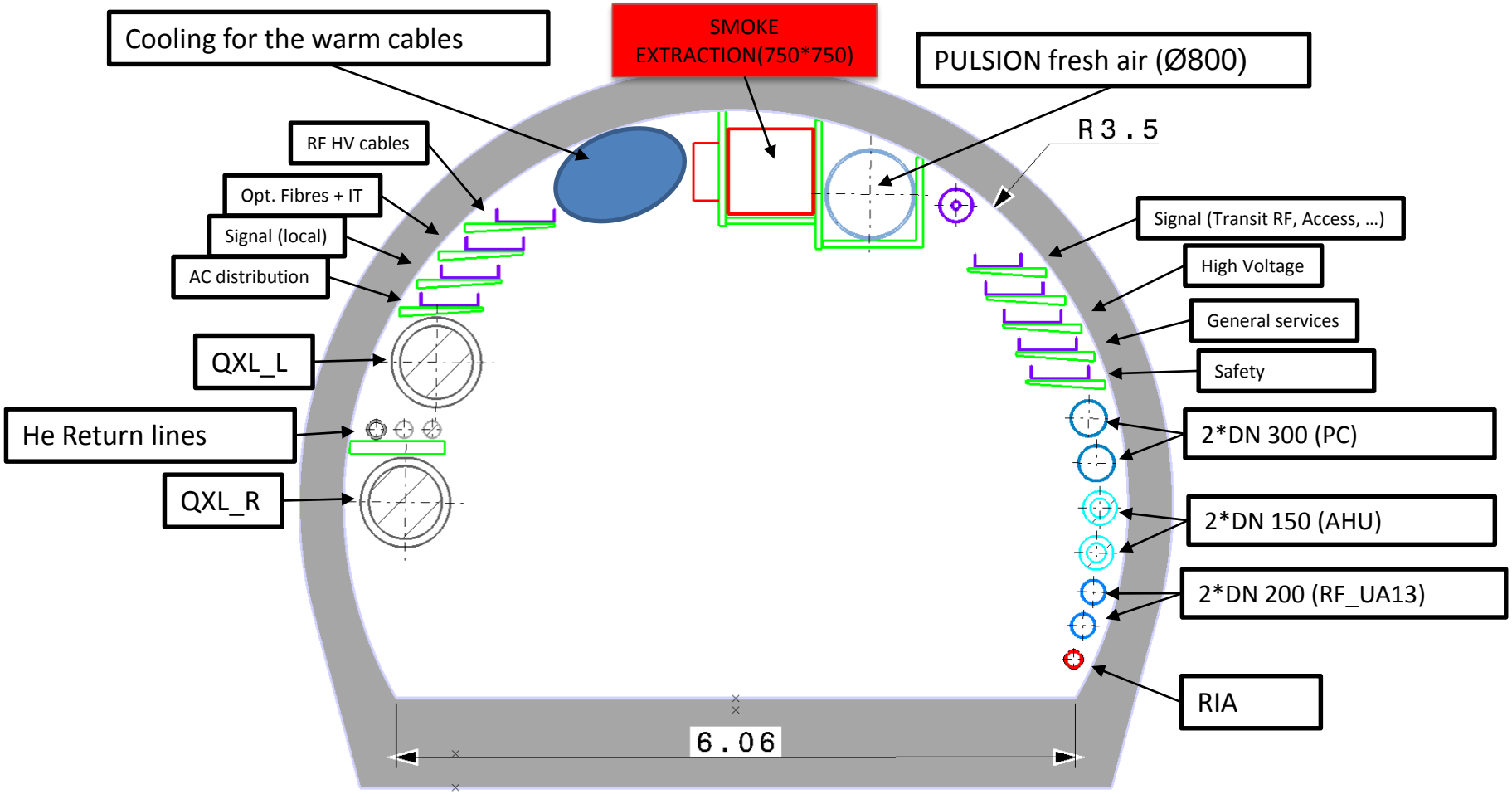


Integration with Tetrode Option.

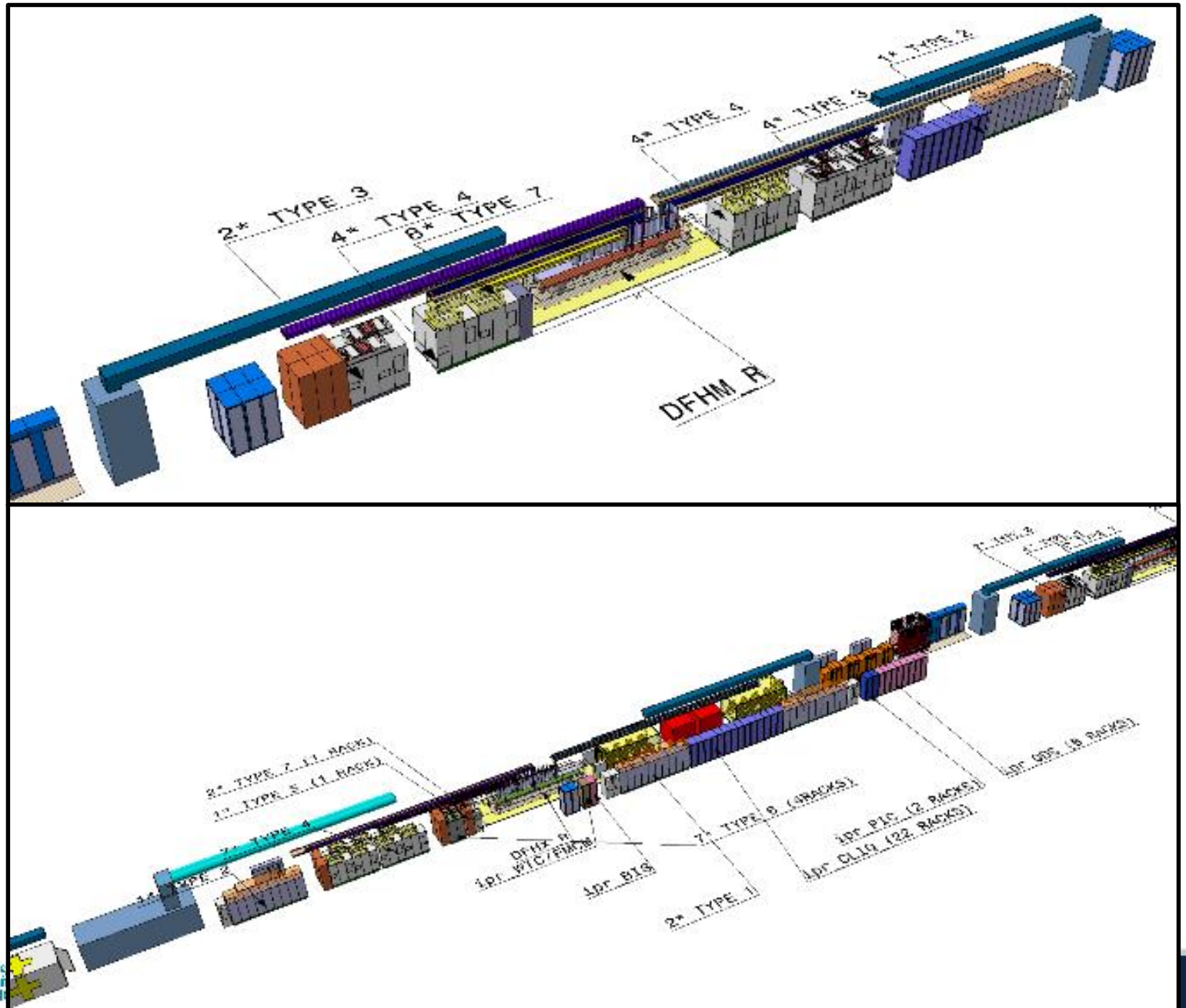


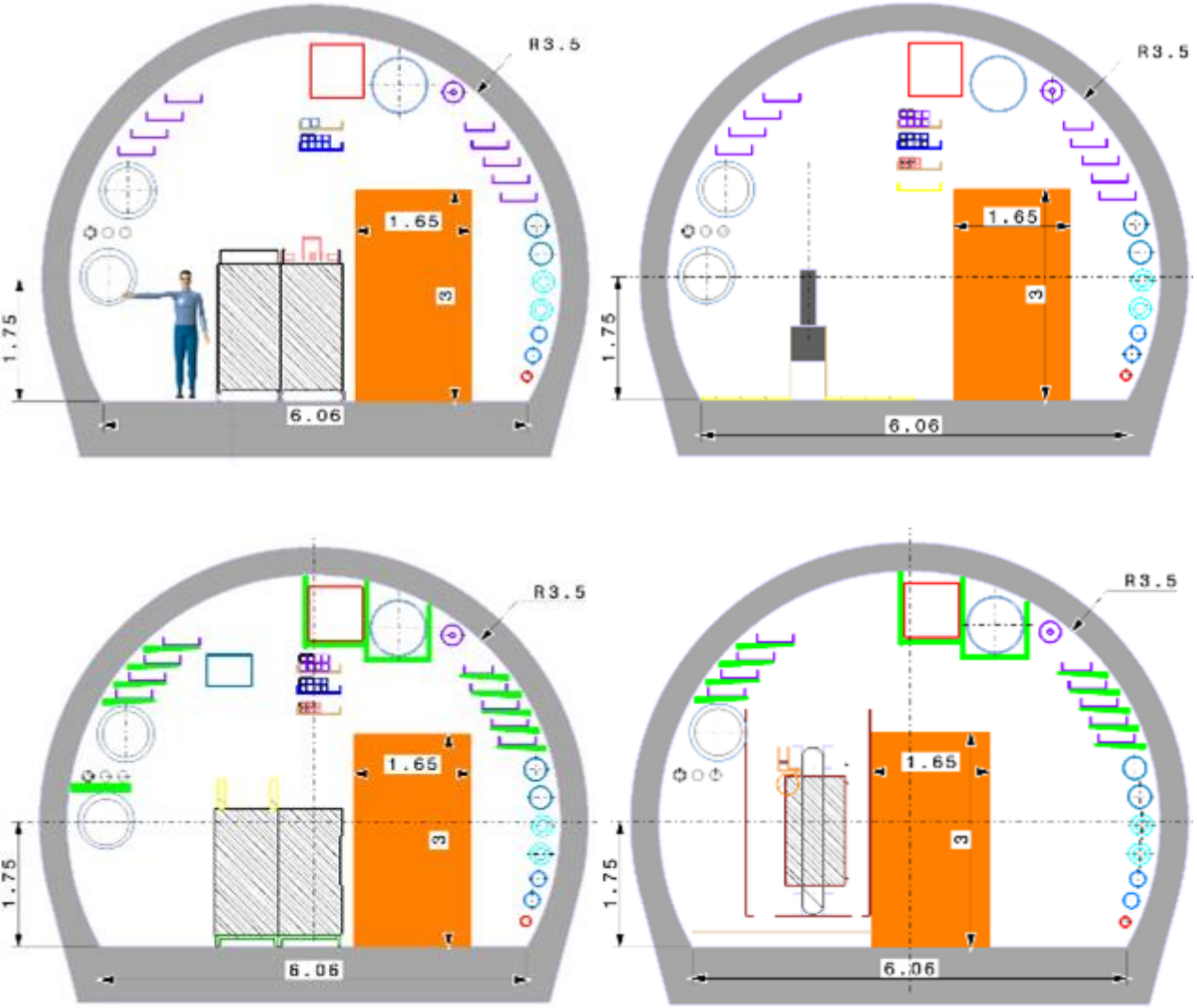


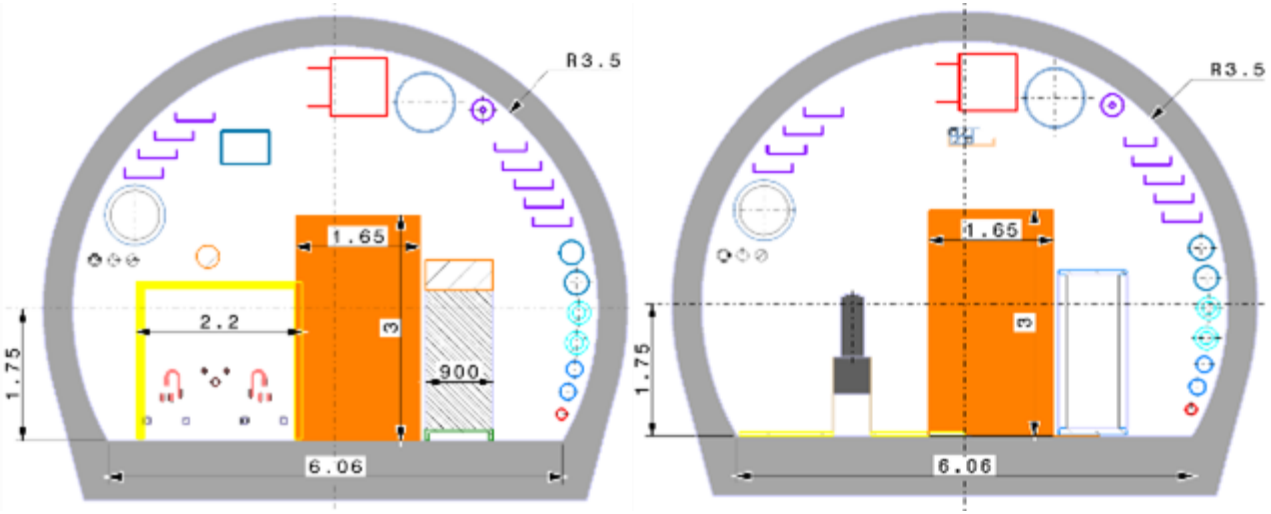
The longitudinal services in the section



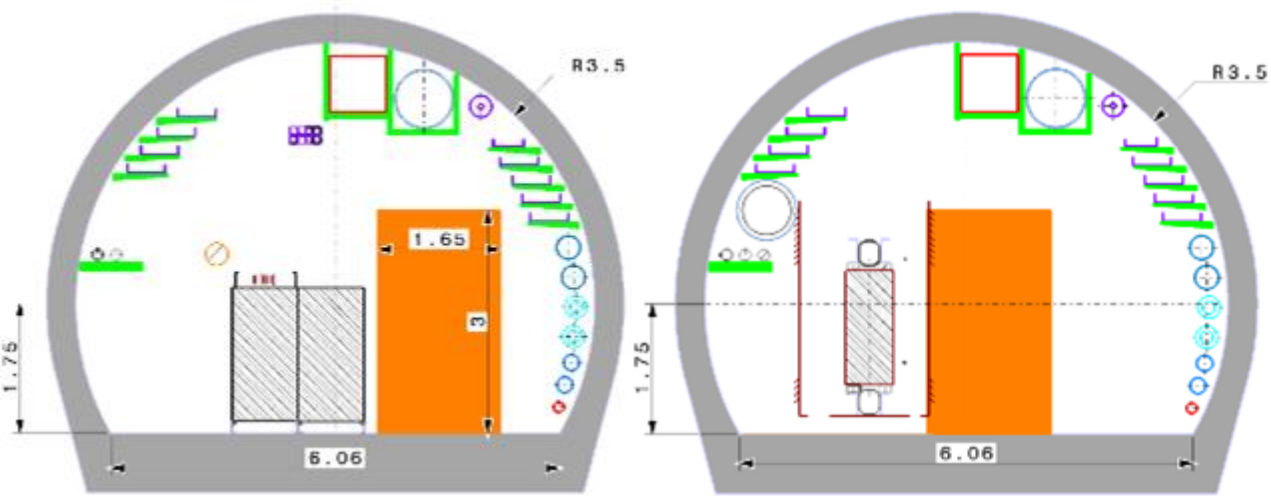
SC Magnet Powering 3D



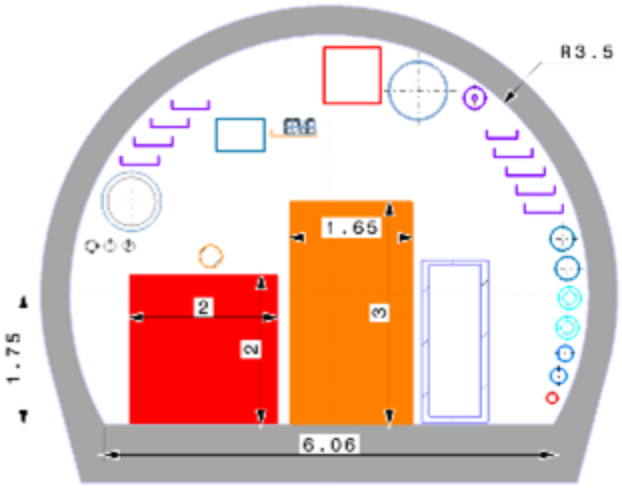

R3.5
1.65
3
1.75
6.06
R3.5
1.65
3
1.75
6.06
R3.5
1.65
3
1.75
6.06
R3.5
1.65
3
1.75
6.06

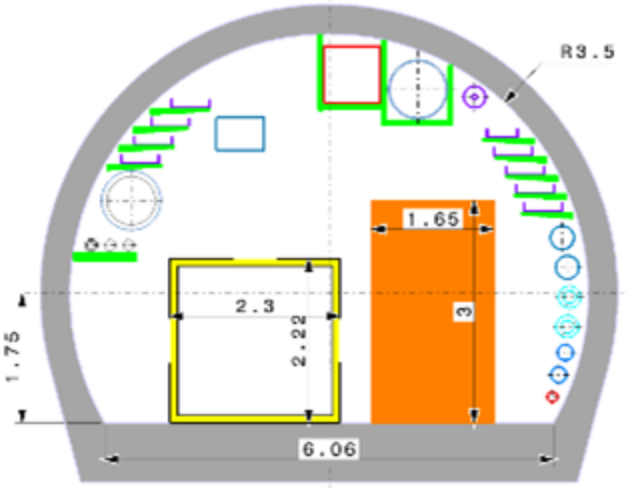

R3.5
1.65
2.2
3
900
1.75
6.06

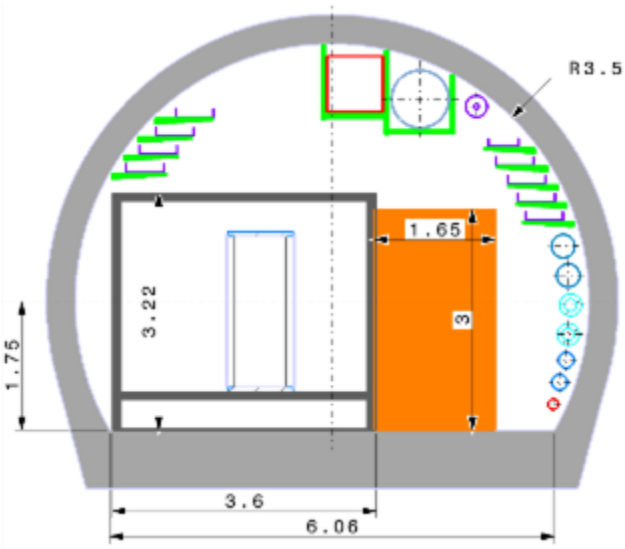
R3.5
1.65
3
1.75
6.06

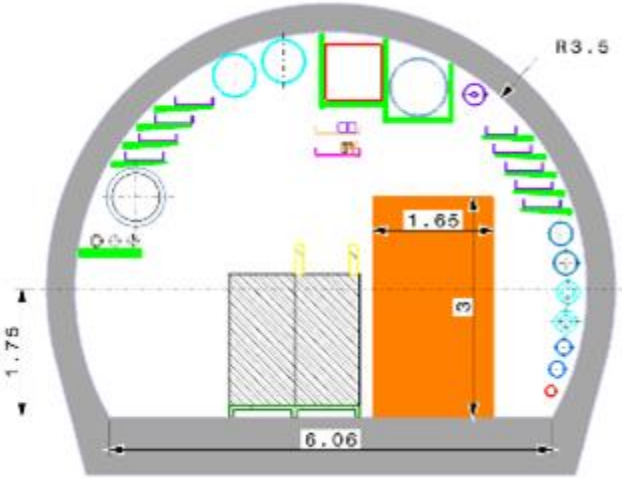

R3.5
1.65
3
1.75
6.06

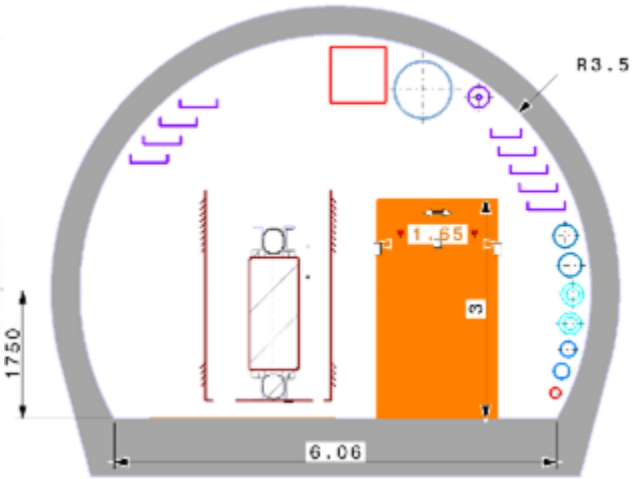
R3.5
1.75
6.06


R3.5
1.65
2
2
3
1.75
6.06

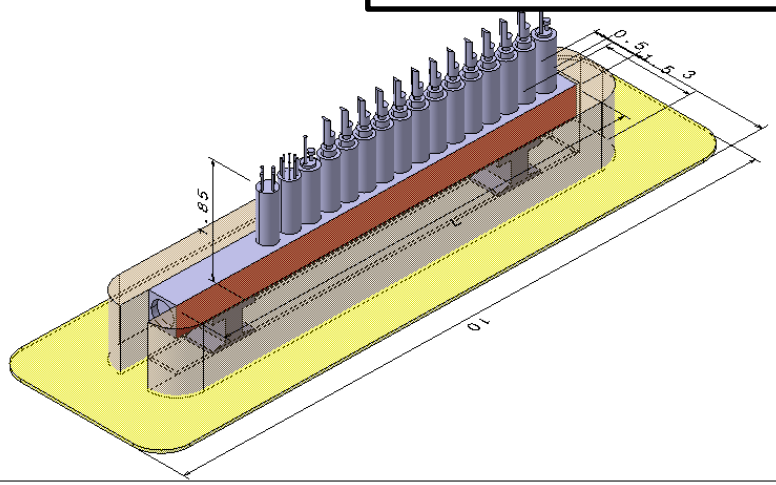

R3.5
1.65
2.3
2.22
3
1.75
6.06

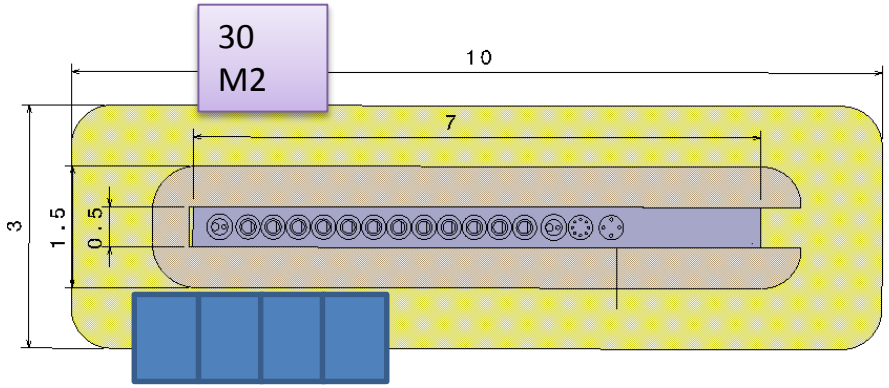

R3.5
1.65
3.22
3
1.75
3.6
6.06

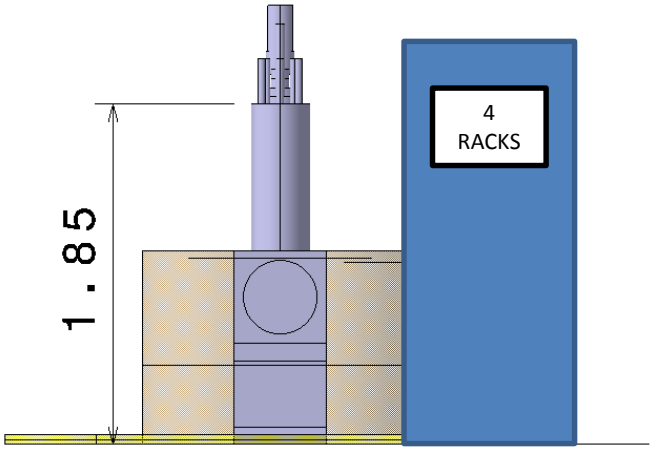

R3.5
1.65
3
1.75
6.06

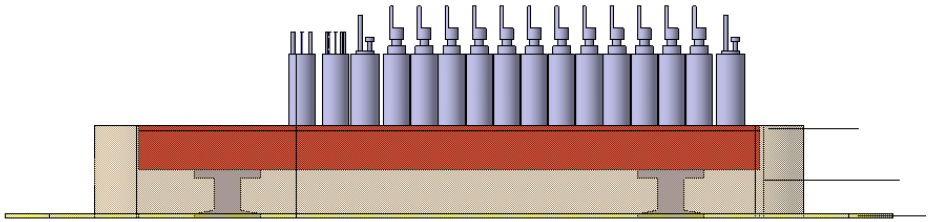

R3.5
1.65
3
1750
6.06

VOLUME DE RESERVATION POUR DFH (DFHM ET DFHX)









POWER CONVERTOR LIST (PC)

(EXTRACT FROM
Power_converter_list_V16.xlsx)

PC type		DFHM_L	DFHX_L	IP_L	IP	IP_R	DFHX_R	DFHM_R	Number of rack 19'' BY TYPE		RACK BY IP SIDE	TOTAL BY IP
New	Type 1	0	2	2	4	2	2	0	10		20	40
Existing	Type 2	1	1	2	4	2	1	1	9		18	36
Existing	Type 3	6	0	6	12	6	0	6	4		24	48
New	Type 4	8	7	15	30	15	7	8	3		45	90
Existing	Type 5	0	1	1	2	1	1	0	0.5		1	2
New	Type 6	0	7	7	14	7	7	0	0.5		4	8
Existing	Type 7	8	2	10	20	10	2	8	0.25		3	6
											115	230

3d

SMARTEAM	TYPE	QTY	COMMENTAIRE			total	
ST0686322_01	TYPE 1	4	ENSEMBLE equivalent de	10	RACKS	40	RACKS
ST0686345_01	TYPE 2	4	ENSEMBLE equivalent de	9	RACKS	36	RACKS
ST0049908_01	TYPE 3	8	ENSEMBLE equivalent de	6	RACKS	48	RACKS
ST0686309_01	TYPE 4	30	ENSEMBLE equivalent de	3	RACKS	90	RACKS
ST0186528_01	TYPE 5	2	RACKS			2	RACKS
ST0619391_01	TYPE 6	8	RACKS			8	RACKS
ST0186602_01	TYPE 7	6	RACKS			6	RACKS
					total	230	RACKS

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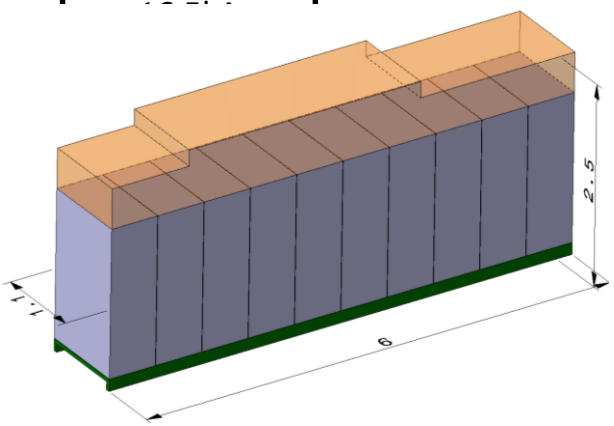
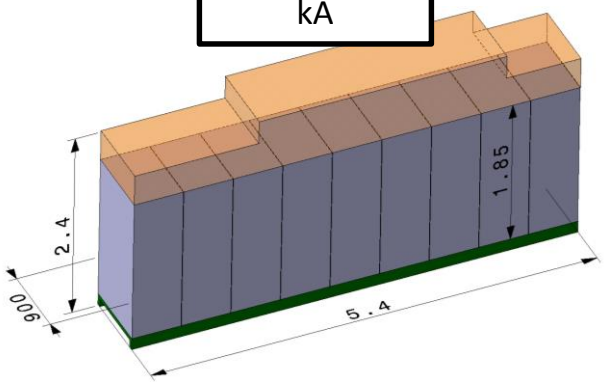
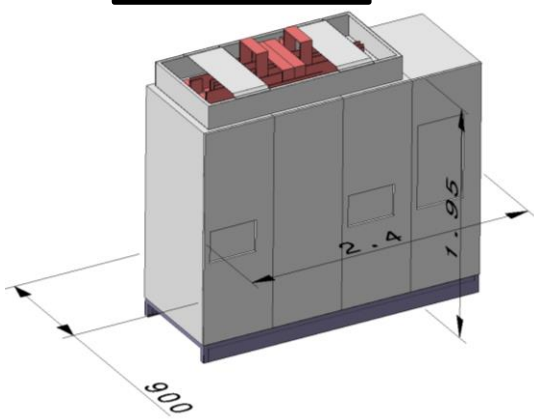
Type 1:



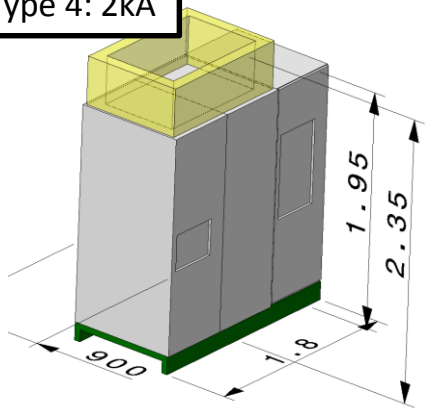
Type 2: 13 kA



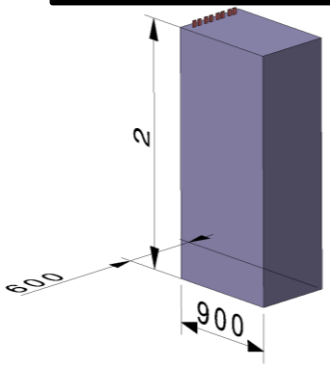
Type 3: 6 kA



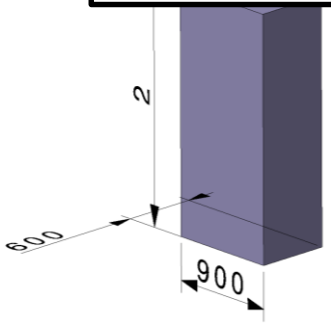
Type 4: 2kA



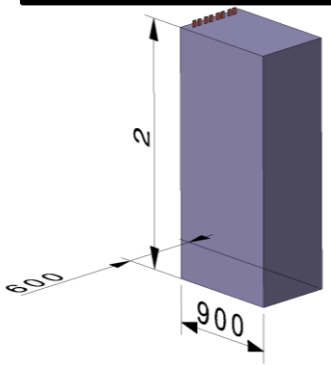
2 * Type 5(0.3kA) = 1 racks



2 * Type 6(0.2kA) = 1 racks



4 * Type 7(0.12kA)= 1 racks



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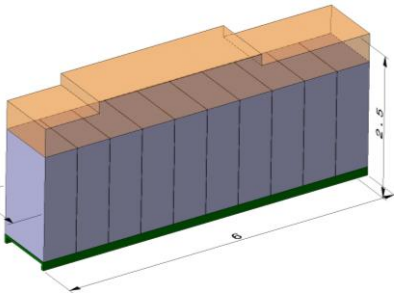
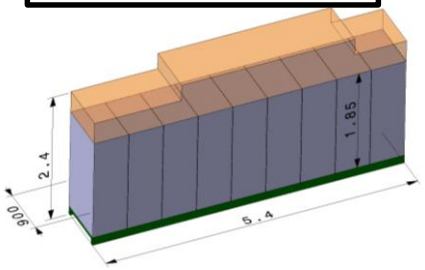
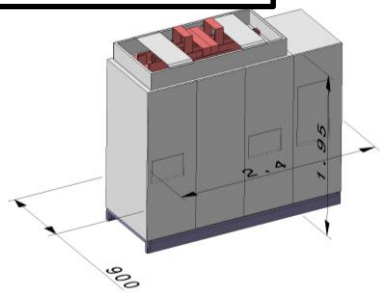
Type 1: 16.5kA



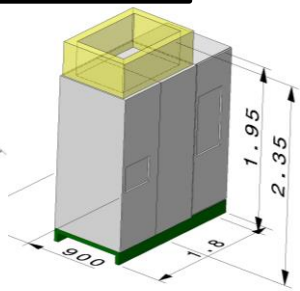
Type 2: 13 kA



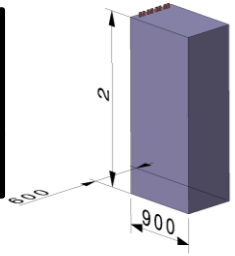
Type 3: 6 kA



Type 4: 2kA

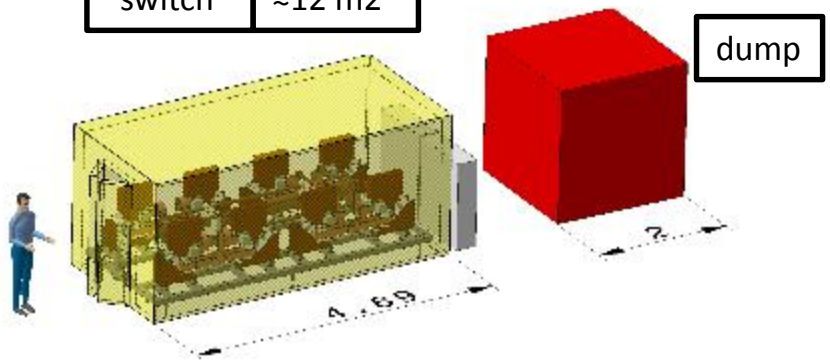


2 * Type 5(0.3kA) = 1 racks
2 * Type 6(0.2kA) = 1 racks
4 * Type 7(0.12kA)= 1 racks

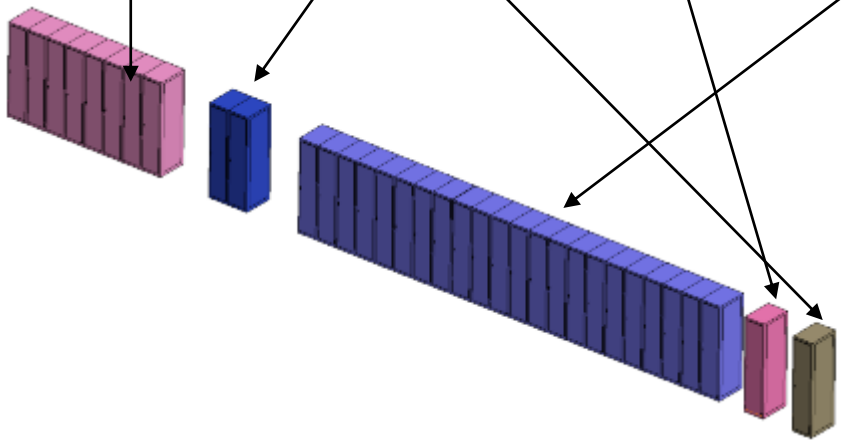


“switch”	≈12 m2

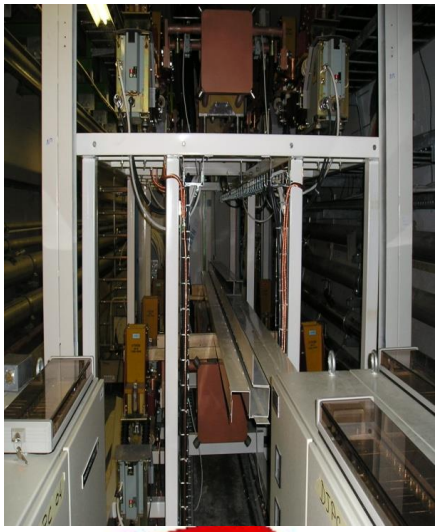
dump



Location	Quench Detection Systems (QDS)	PIC	WIC/ FMCM	BIS	CLIQ
	# of Racks	# of Racks	# of Racks	# of Racks	# of Racks
L1	8	2	1	1	22

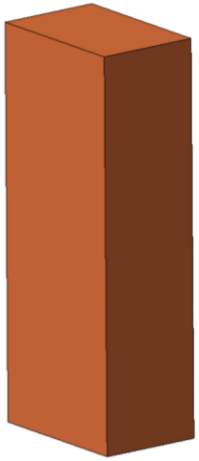


ENERGY EXTRACTION



Corrector circuit

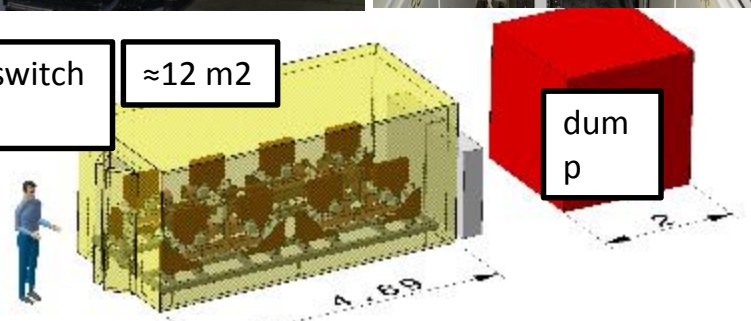
1 rack = 600 x 900



"switch"

≈12 m2

dump



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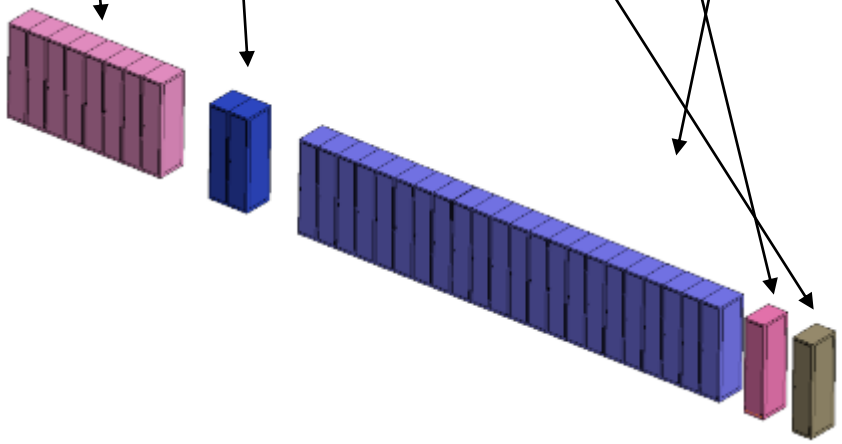
Interlock Systems

Location	Quench Detection Systems (QDS)	PIC	WIC/ FMCM	BIS	CLIQ
	# of Racks	# of Racks	# of Racks	# of Racks	# of Racks
L1	8	2	1	1	22
R1	8	2	1	1	22
L5	8	2	1	1	22
R5	8	2	1	1	22

1 rack = 600 x 900



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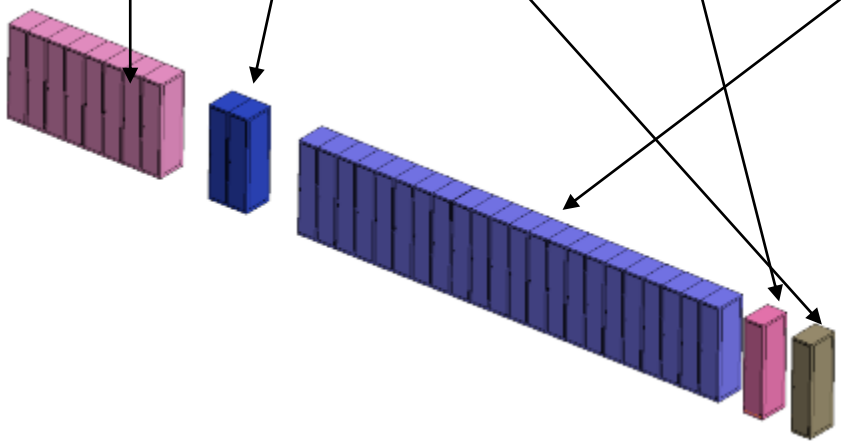
Interlock Systems

Location	Quench Detection Systems (QDS)	PIC	WIC/ FMCM	BIS	CLIQ
	# of Racks	# of Racks	# of Racks	# of Racks	# of Racks
L1	8	2	1	1	22



18/09/2015

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.