
CERN

CERN High Luminosity (HL) LHC Civil Engineering and Vibration Issues during Shaft Excavation

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Site Management & Buildings Department, CERN

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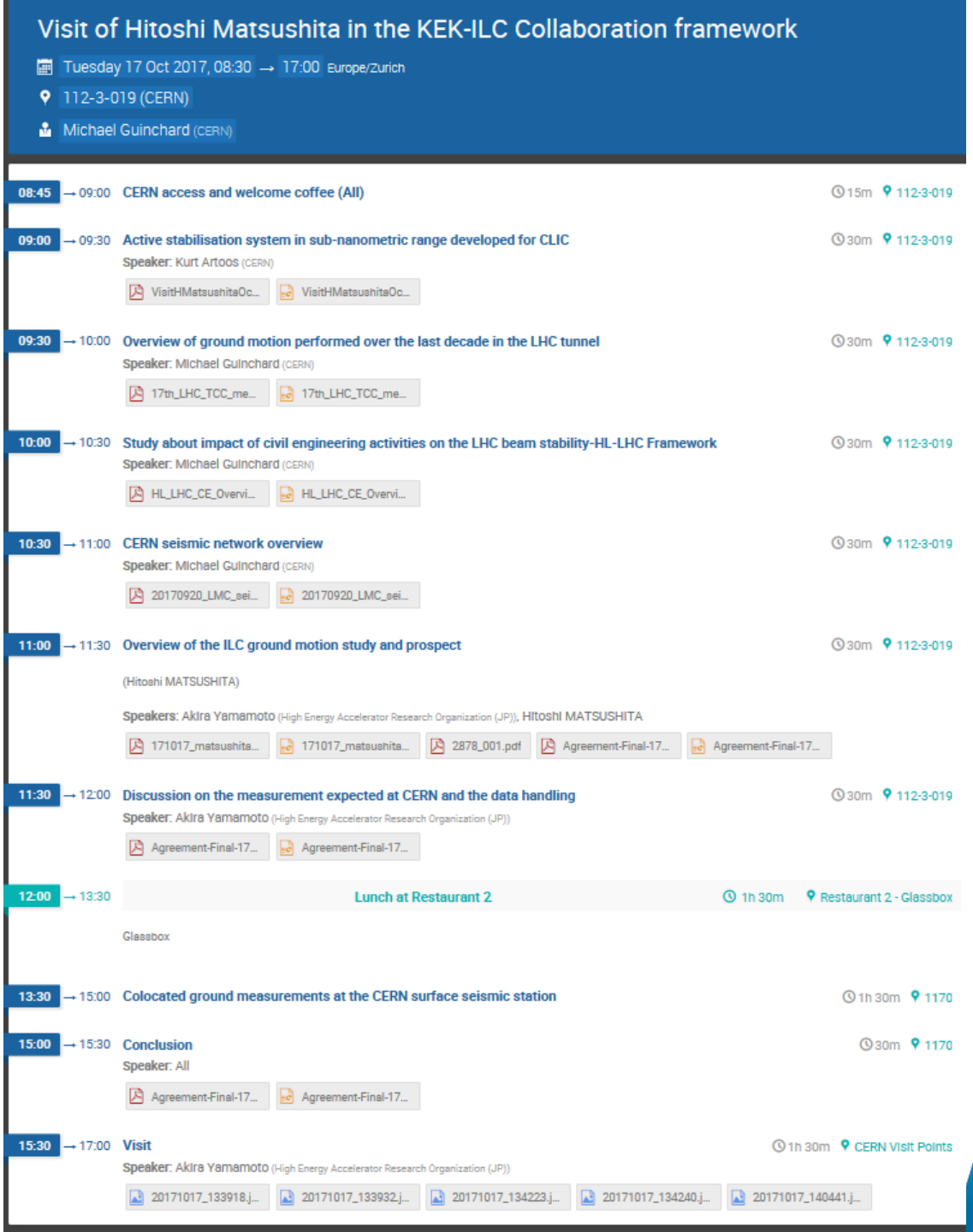
Special thanks to M.Guinchard, P.Fessia and P.Mattelaer from CERN

Agenda

- A mini Workshop on vibration matters was held CERN-KEK-ILC at CERN 17 October 2017
- Intro to High Luminosity LHC (HL-LHC);
- HL-LHC Civil Works;
  - Point 1 – ATLAS;
  - Point 5 – CMS;
- Civil engineering shaft design;
- Civil engineering outline schedule;
- Shaft excavation equipment;

A mini vibration working was held CERN-KEK-ILC at CERN 17 October 2017 with Hitoshi MATSUSHITA from Takenaka Corp. to share experience :

https://indico.cern.ch/event/672364/



Visit of Hitoshi Matsushita in the KEK-ILC Collaboration framework

Tuesday 17 Oct 2017, 08:30 → 17:00 Europe/Zurich

112-3-019 (CERN)

Michael Guinchard (CERN)

08:45 → 09:00 CERN access and welcome coffee (All) — 15m — 112-3-019

09:00 → 09:30 Active stabilisation system in sub-nanometric range developed for CLIC — 30m — 112-3-019
Speaker: Kurt Artoos (CERN)
VisitHMatsushitaOc... VisitHMatsushitaOc...

09:30 → 10:00 Overview of ground motion performed over the last decade in the LHC tunnel — 30m — 112-3-019
Speaker: Michael Guinchard (CERN)
17th_LHC_TCC_me... 17th_LHC_TCC_me...

10:00 → 10:30 Study about impact of civil engineering activities on the LHC beam stability-HL-LHC Framework — 30m — 112-3-019
Speaker: Michael Guinchard (CERN)
HL_LHC_CE_Overvi... HL_LHC_CE_Overvi...

10:30 → 11:00 CERN seismic network overview — 30m — 112-3-019
Speaker: Michael Guinchard (CERN)
20170920_LMC_sei... 20170920_LMC_sei...

11:00 → 11:30 Overview of the ILC ground motion study and prospect — 30m — 112-3-019
(Hitoshi MATSUSHITA)
Speakers: Akira Yamamoto (High Energy Accelerator Research Organization (JP)), Hitoshi MATSUSHITA
171017_matsushita... 171017_matsushita... 2878_001.pdf Agreement-Final-17... Agreement-Final-17...

11:30 → 12:00 Discussion on the measurement expected at CERN and the data handling — 30m — 112-3-019
Speaker: Akira Yamamoto (High Energy Accelerator Research Organization (JP))
Agreement-Final-17... Agreement-Final-17...

12:00 → 13:30 Lunch at Restaurant 2 — 1h 30m — Restaurant 2 - Glassbox
Glassbox

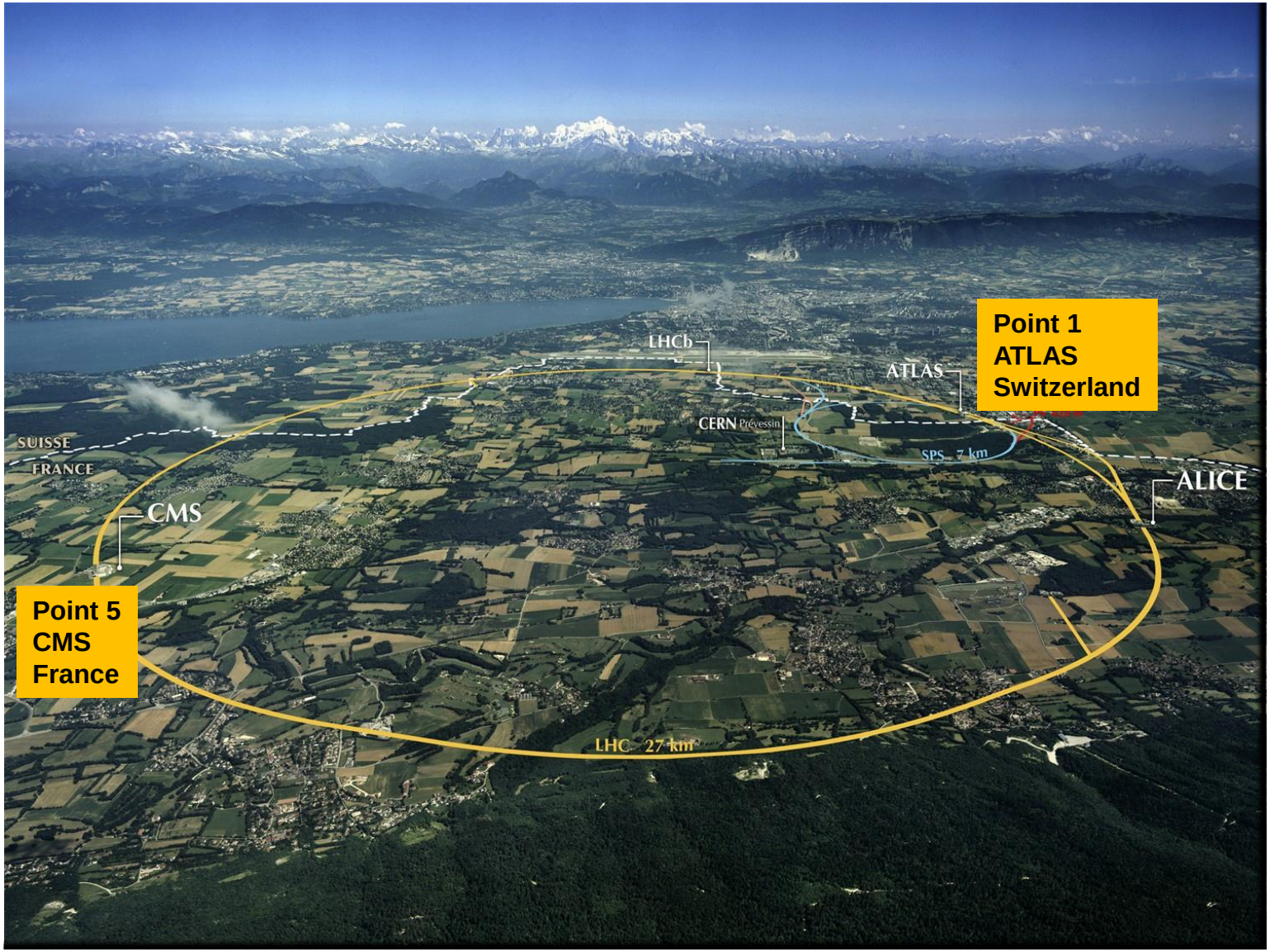
13:30 → 15:00 Colocated ground measurements at the CERN surface seismic station — 1h 30m — 1170

15:00 → 15:30 Conclusion — 30m — 1170
Speaker: All
Agreement-Final-17... Agreement-Final-17...

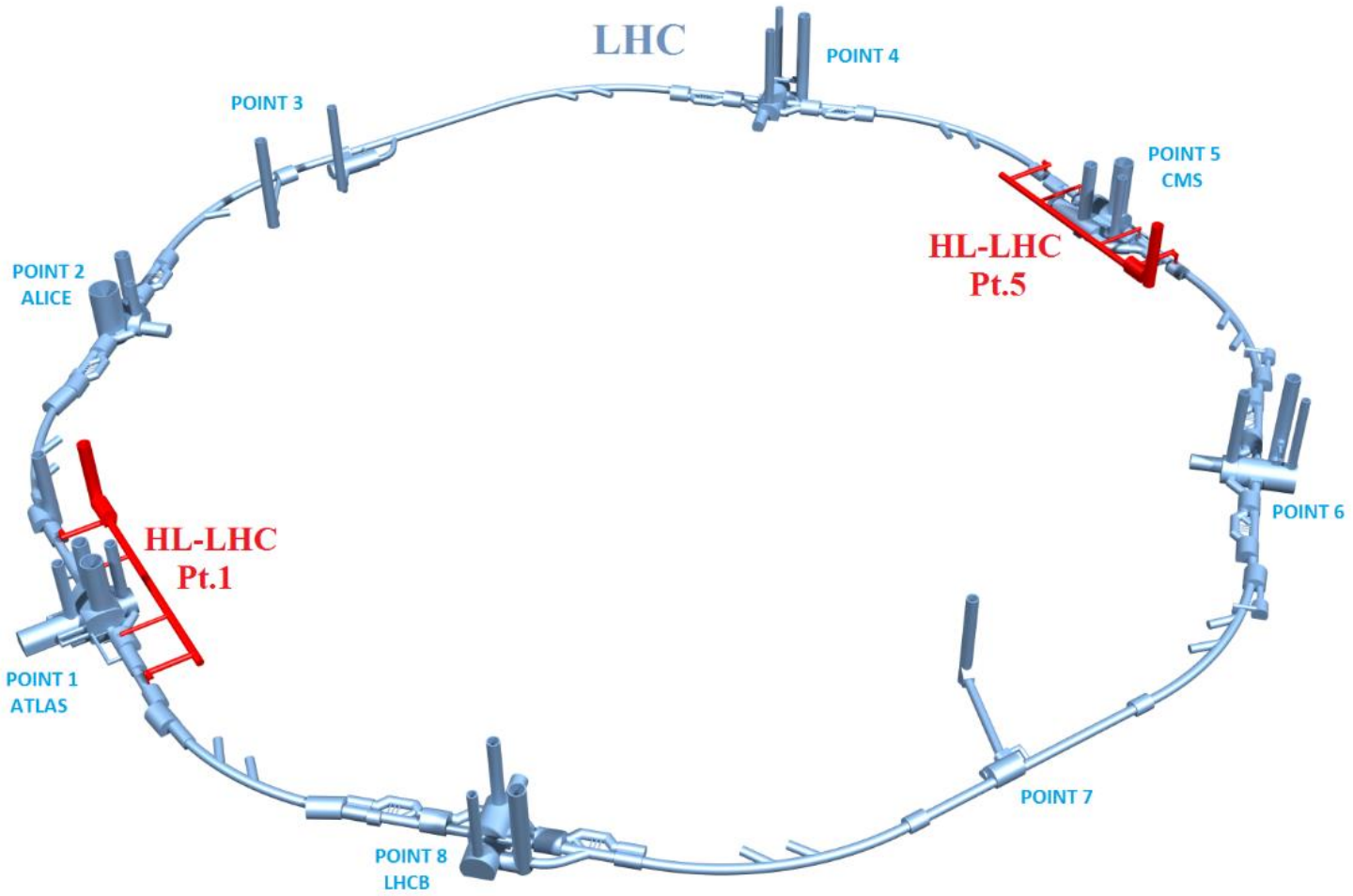
15:30 → 17:00 Visit — 1h 30m — CERN Visit Points
Speaker: Akira Yamamoto (High Energy Accelerator Research Organization (JP))
20171017_133918.j... 20171017_133932.j... 20171017_134223.j... 20171017_134240.j... 20171017_140441.j...

Civil Engineering
The HL-LHC Works

HL Civil Engineering : Site Locations

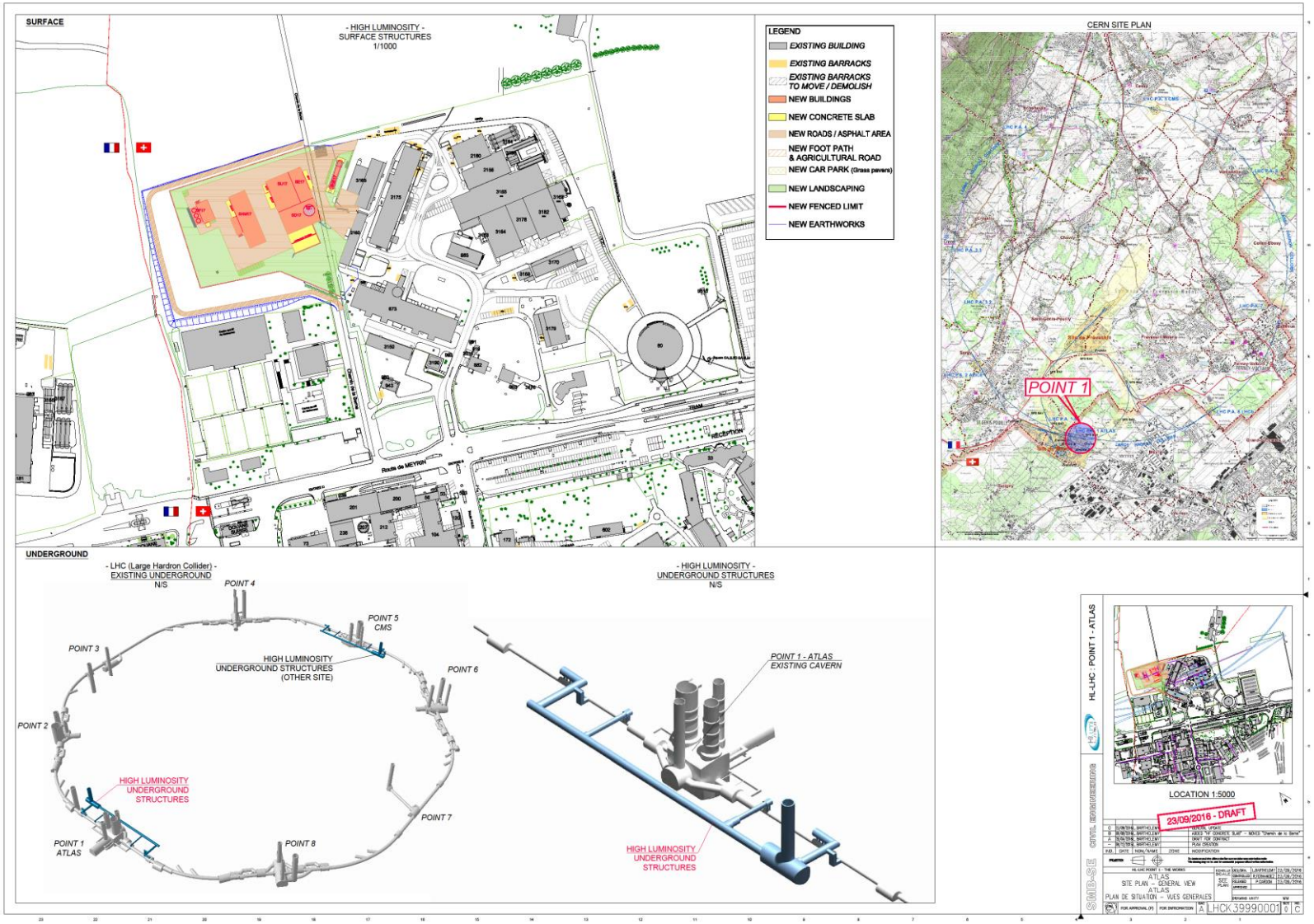


HL-LHC underground works at Points 1 & 5



Civil Engineering
Point 1 - ATLAS
Switzerland

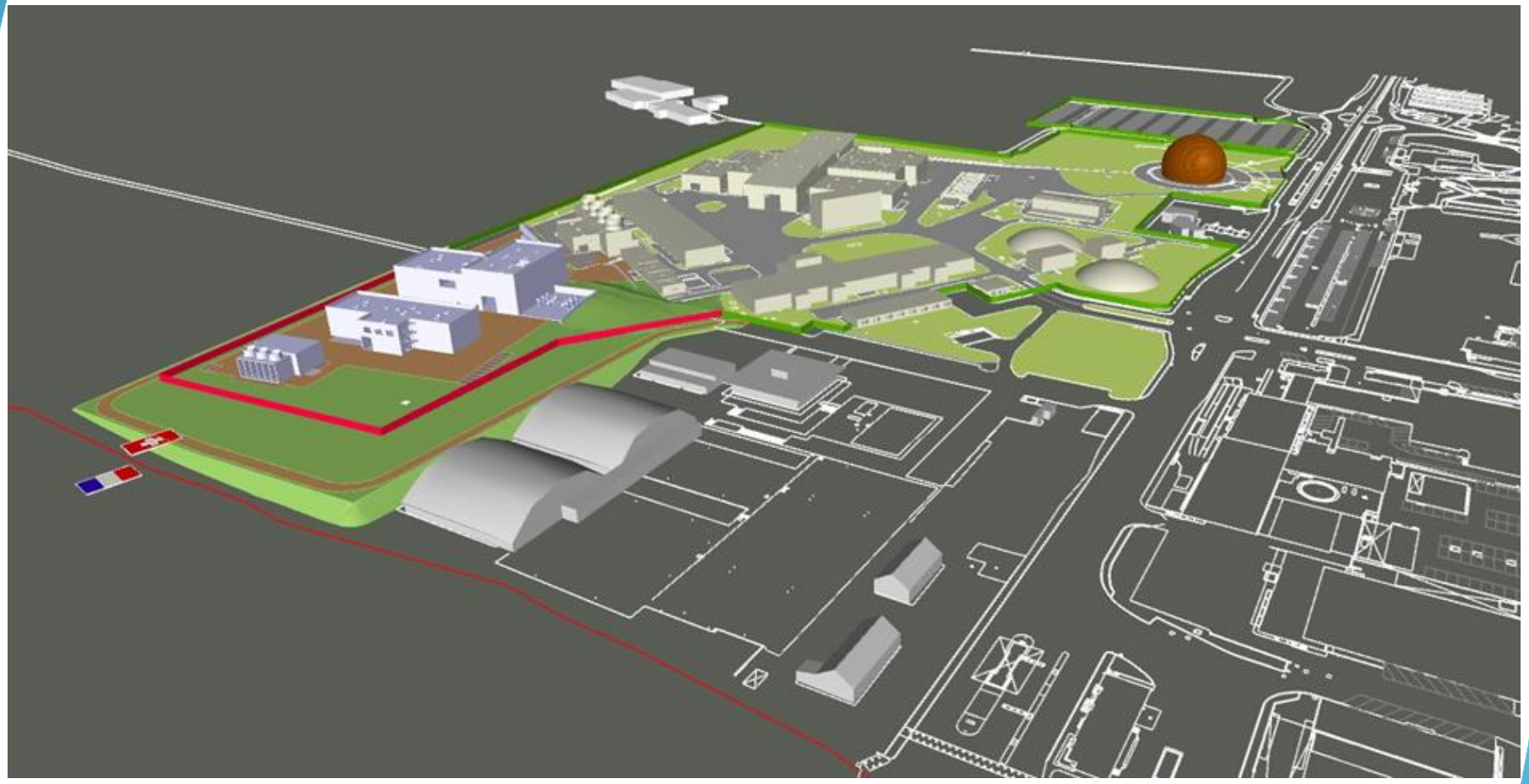
HL-LHC Works at Point 1 (ATLAS)



HiLumi HL-LHC PROJECT

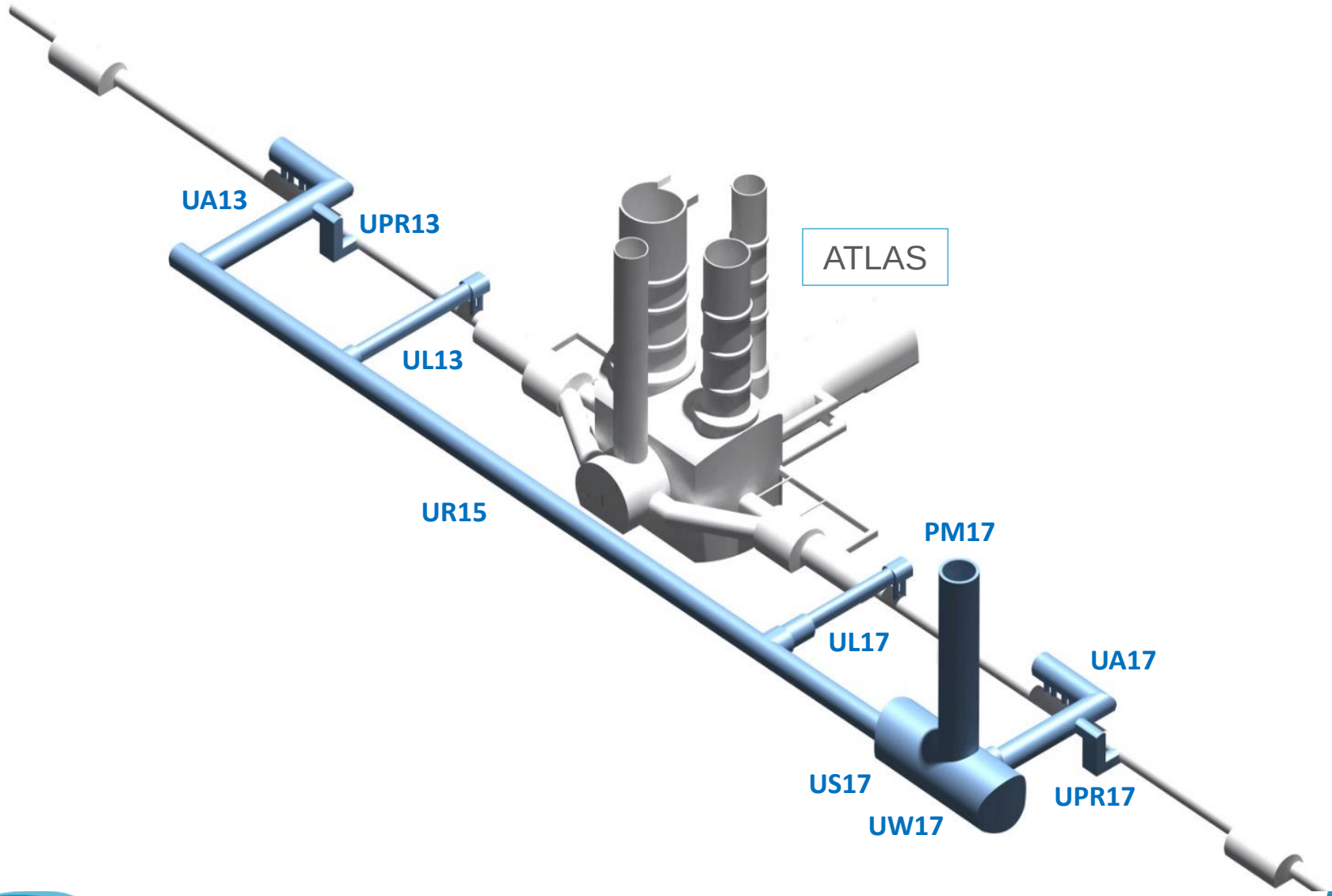
Worksite Area at Point 1

HL-LHC Works at Point 1



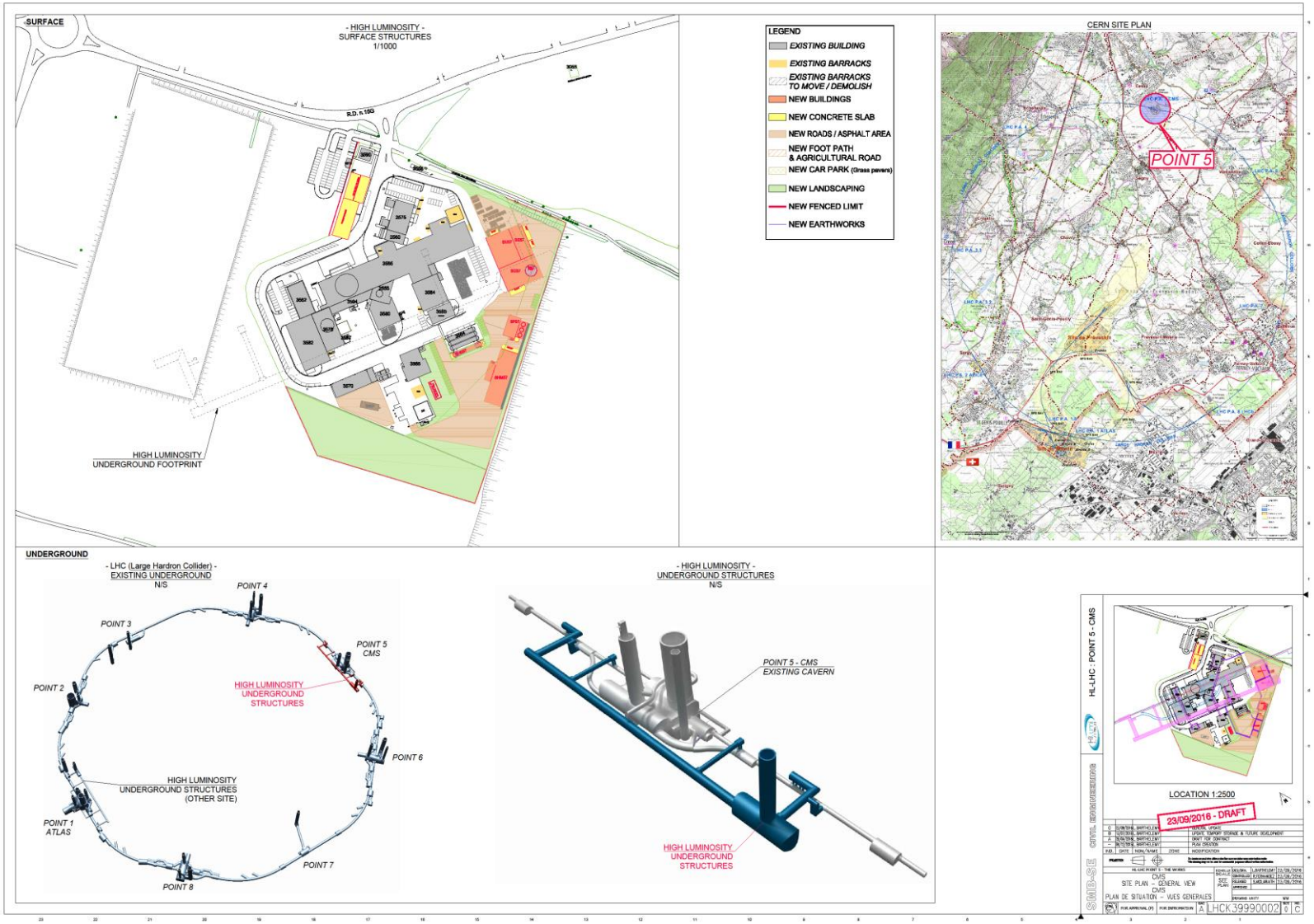
HL-LHC Surface Works at Point 1

Underground Structures at Point 1



Civil Engineering
Point 5 - CMS
France

HL-LHC Works at Point 5 (CMS)



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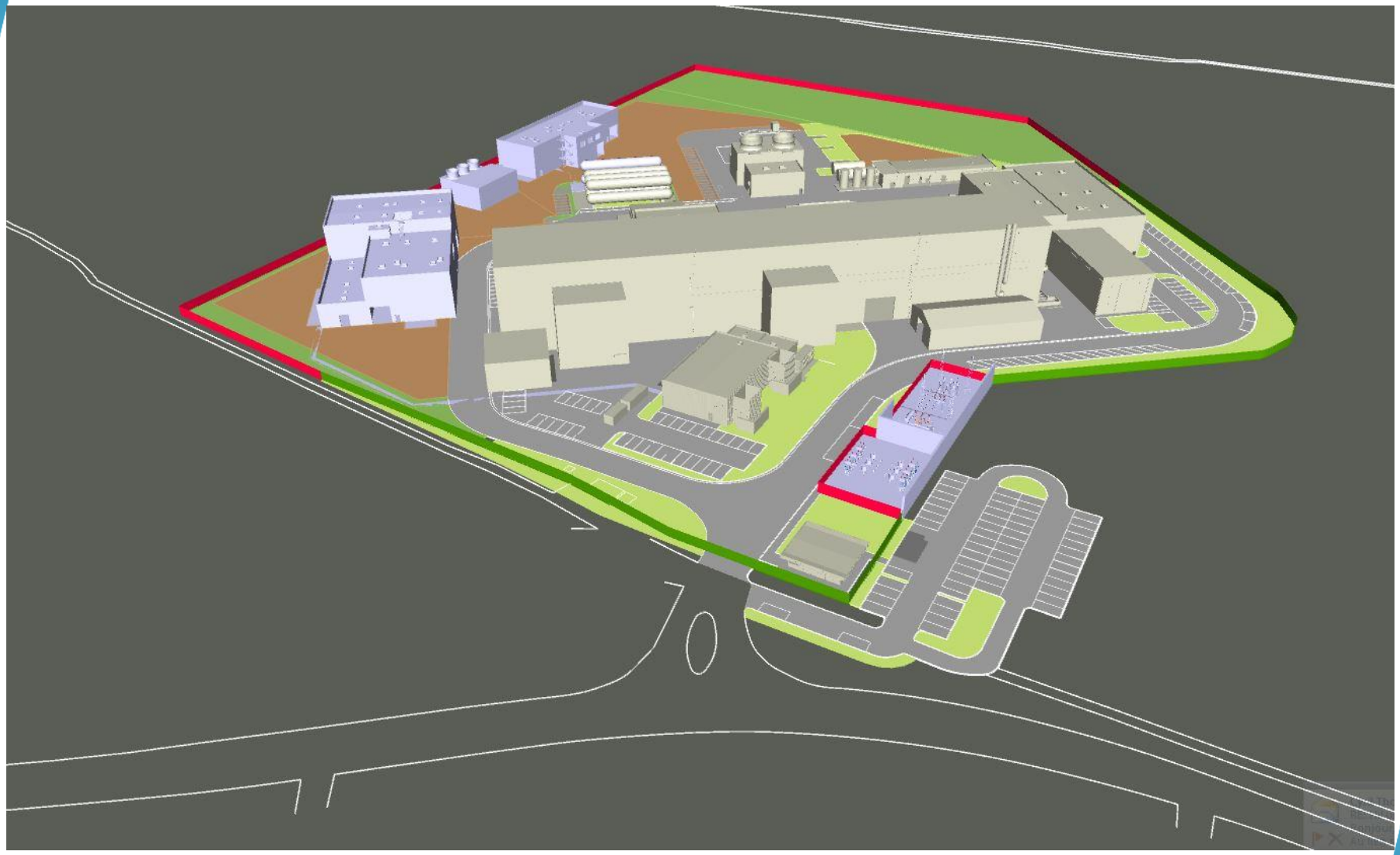
Worksite Area at Point 5

HL-LHC Works at Point 5



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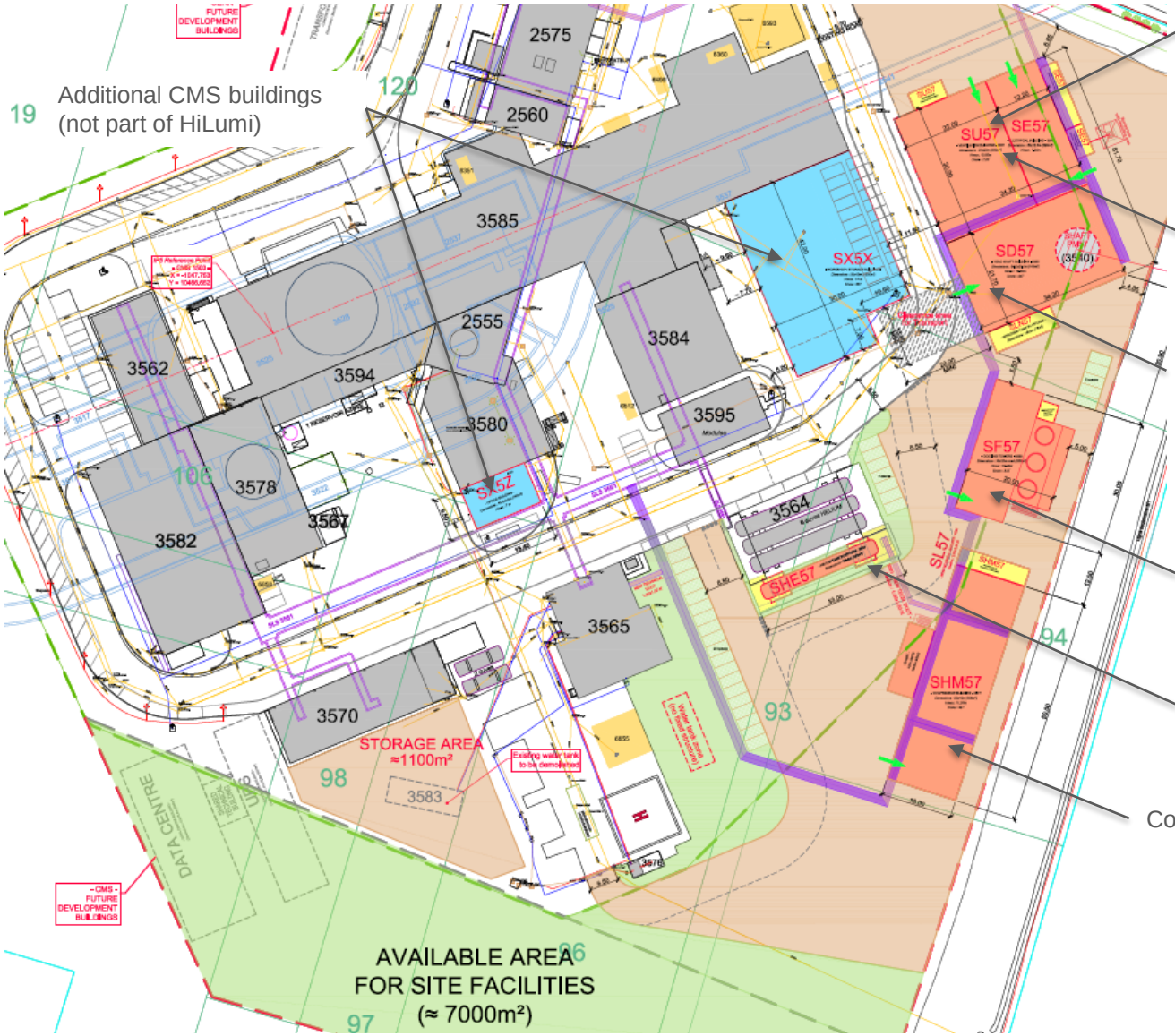
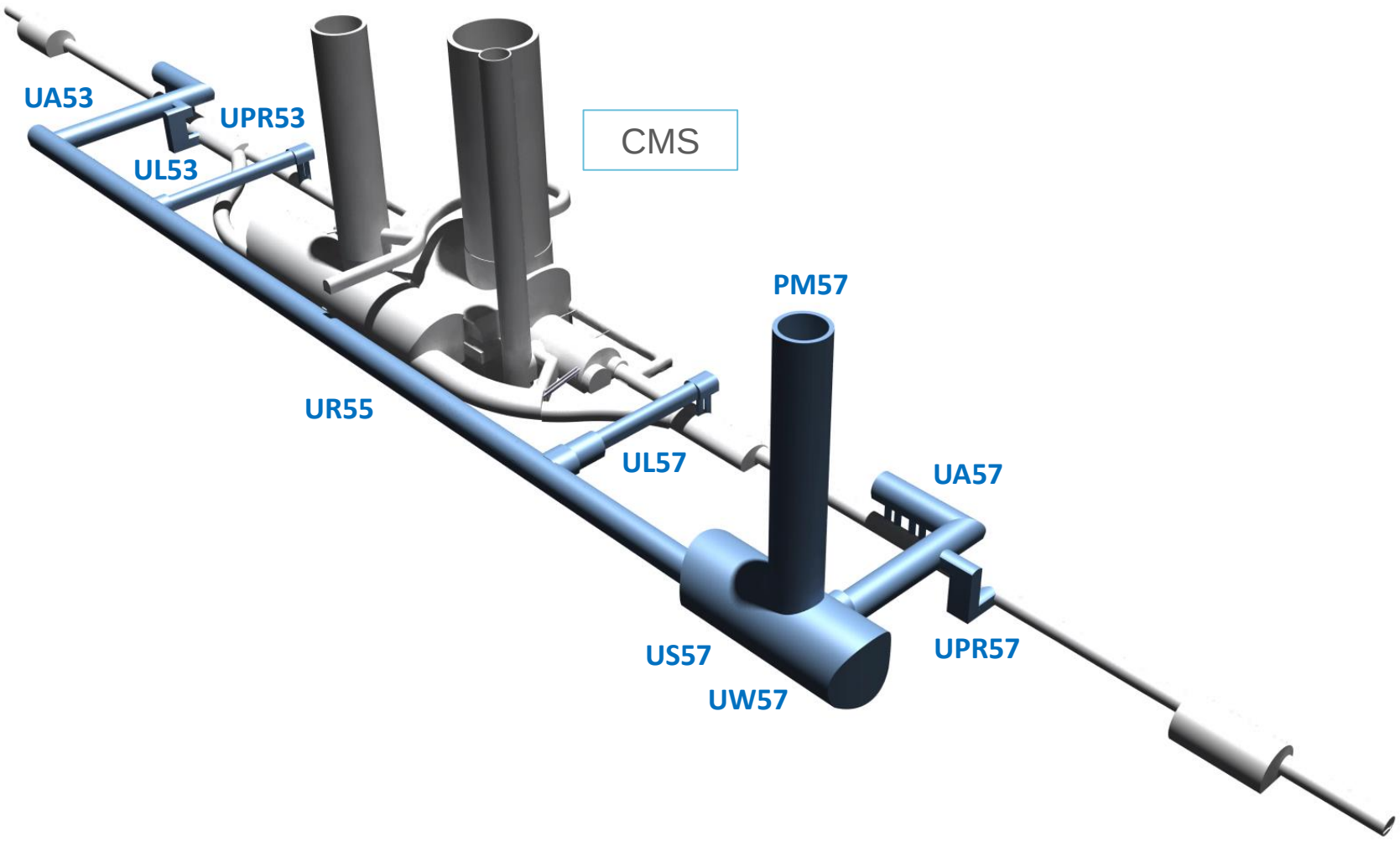
HL-LHC Surface Works at Point 5

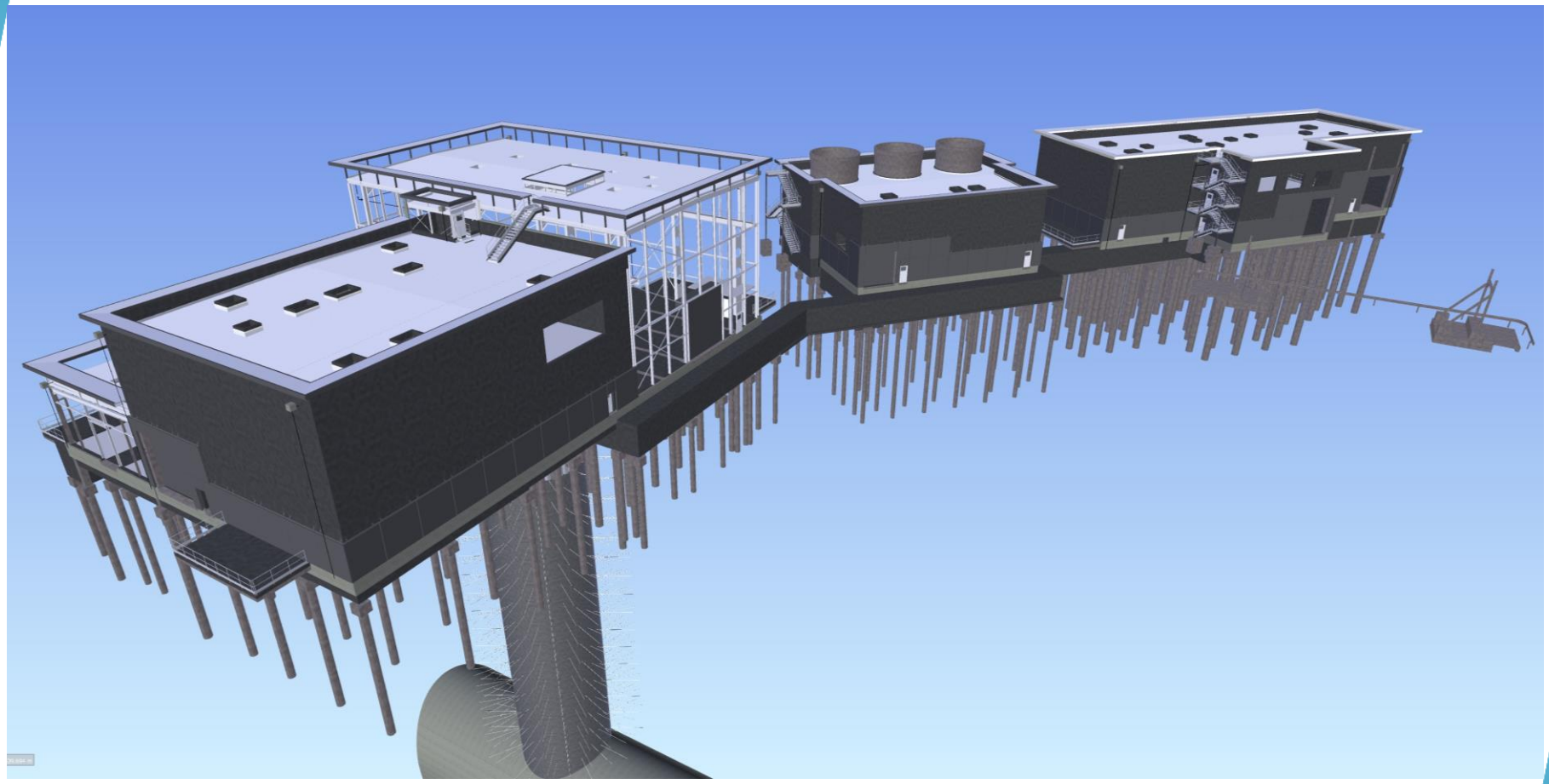


Underground Structures at Point 5



Civil Engineering
Shaft Design

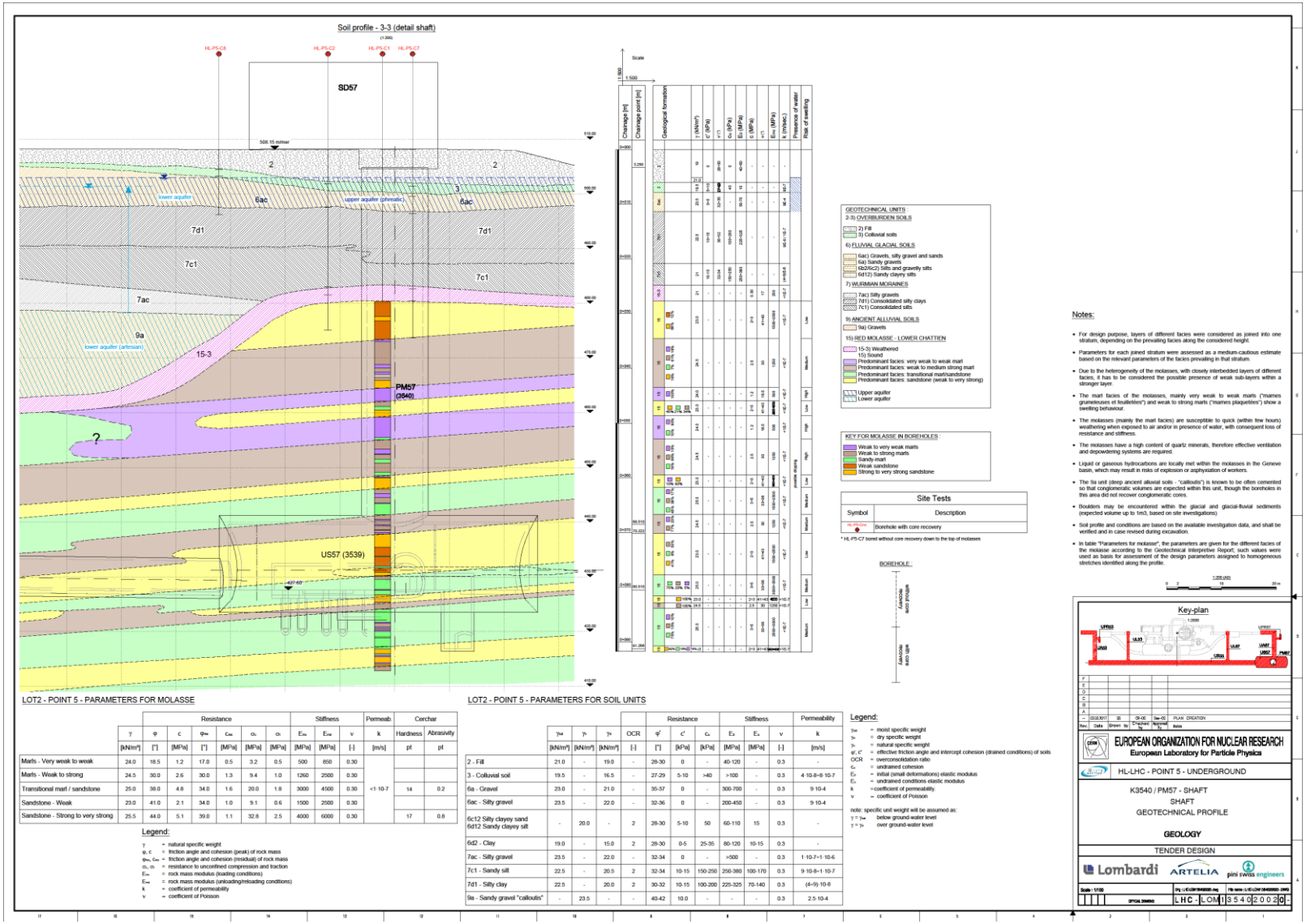
Civil Engineering Design



Point 5 image by LAP

HiLumi HL-LHC PROJECT

Point 5 Shaft Design



LOT2 - POINT 5 - PARAMETERS FOR MOLASSE

	γ	φ	c	φ_{res}	c_{res}	σ_c	σ_t	E_m	E_{ur}	ν	Permeab. k	Cerchar Hardness	Cerchar Abrasivity
	[kN/m³]	[°]	[MPa]	[°]	[MPa]	[MPa]	[MPa]	[MPa]	[MPa]	[-]	[m/s]	pt	pt
Marls - Very weak to weak	24.0	18.5	1.2	17.0	0.5	3.2	0.5	500	850	0.30			
Marls - Weak to strong	24.5	30.0	2.6	30.0	1.3	9.4	1.0	1260	2500	0.30			
Transitional marl / sandstone	25.0	38.0	4.8	34.0	1.6	20.0	1.8	3000	4500	0.30	<1·10-7	14	0.2
Sandstone - Weak	23.0	41.0	2.1	34.0	1.0	9.1	0.6	1500	2500	0.30			
Sandstone - Strong to very strong	25.5	44.0	5.1	39.0	1.1	32.8	2.5	4000	6000	0.30		17	0.8

Legend:

γ = natural specific weight
φ, c = friction angle and cohesion (peak) of rock mass
φ_{res}, c_{res} = friction angle and cohesion (residual) of rock mass
σ_c, σ_t = resistance to unconfined compression and traction
E_m = rock mass modulus (loading conditions)
E_{ur} = rock mass modulus (unloading/reloading conditions)
k = coefficient of permeability
ν = coefficient of Poisson

LOT2 - POINT 5 - PARAMETERS FOR SOIL UNITS

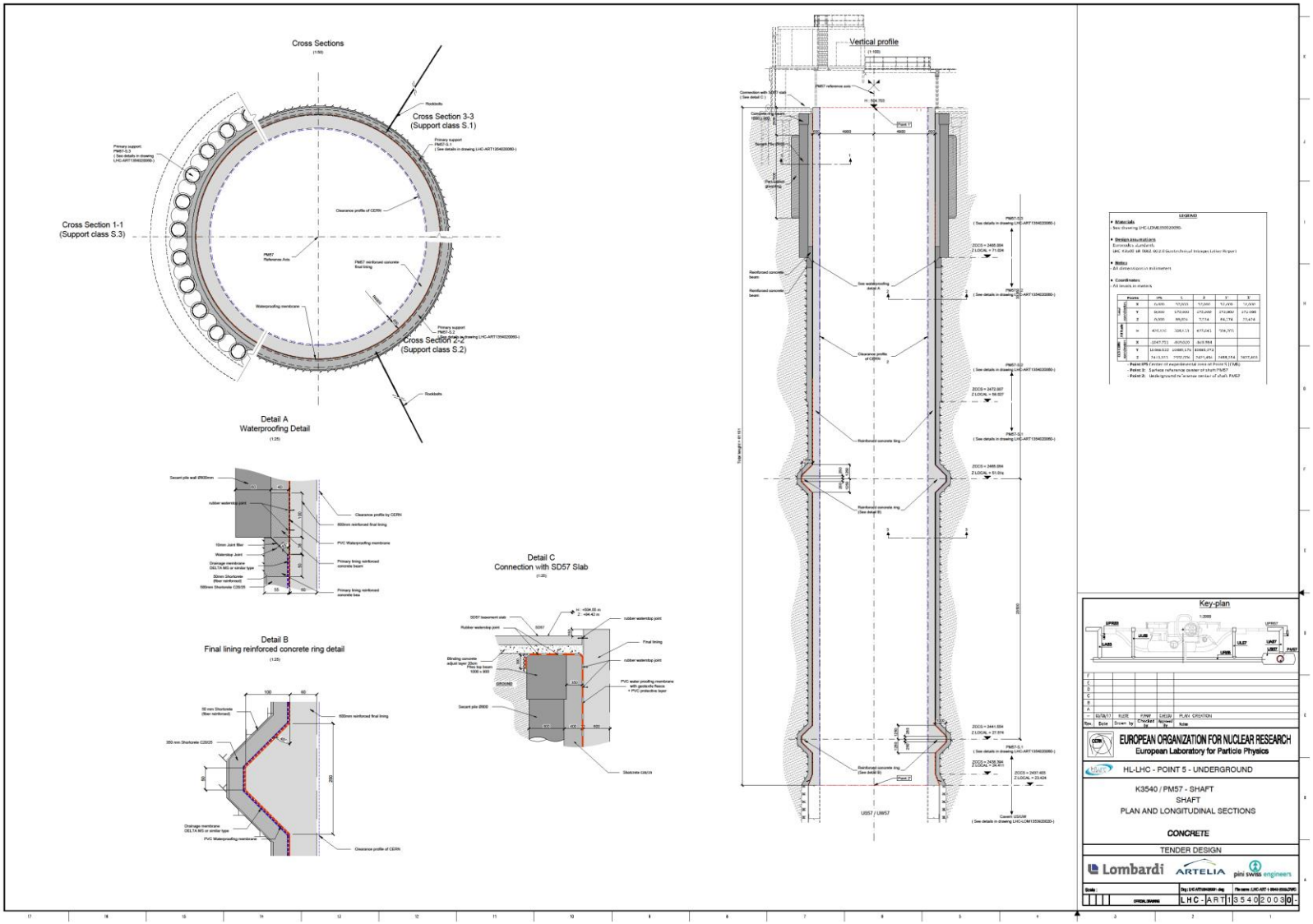
	γ_{wet}	γ_d	γ_{sr}	OCR	φ'	c'	c_u	E_s	E_{ur}	ν	k
	[kN/m³]	[kN/m³]	[kN/m³]	[-]	[°]	[kPa]	[kPa]	[MPa]	[MPa]	[-]	[m/s]
2 - Fill	21.0	-	19.0	-	28-30	0	-	40-120	-	0.3	-
3 - Colluvial soil	19.5	-	16.5	-	27-29	5-10	>40	>100	-	0.3	4·10-8–8·10-7
6a - Gravel	23.0	-	21.0	-	35-37	0	-	300-700	-	0.3	9·10-4
6ac - Silty gravel	23.5	-	22.0	-	32-36	0	-	200-450	-	0.3	9·10-4
6c12 Silty clayey sand 6d12 Sandy clayey silt	-	20.0	-	2	28-30	5-10	50	60-110	15	0.3	-
6d2 - Clay	19.0	-	15.0	2	28-30	0-5	25-35	80-120	10-15	0.3	-
7ac - Silty gravel	23.5	-	22.0	-	32-34	0	-	>500	-	0.3	1·10-7–1·10-6
7c1 - Sandy silt	22.5	-	20.5	2	32-34	10-15	150-250	250-380	100-170	0.3	9·10-8–1·10-7
7d1 - Silty clay	22.5	-	20.0	2	30-32	10-15	100-200	225-325	70-140	0.3	(4–9)·10-8
9a - Sandy gravel "cailloutis"	-	23.5	-	-	40-42	10.0	-	-	-	0.3	2.5·10-4

Legend:

γ_{wet} = moist specific weight
γ_d = dry specific weight
γ_{sr} = natural specific weight
φ', c' = effective friction angle and intercept cohesion (drained conditions) of soils
OCR = overconsolidation ratio
c_u = undrained cohesion
E_s = initial (small deformations) elastic modulus
E_{ur} = undrained conditions elastic modulus
k = coefficient of permeability
ν = coefficient of Poisson

note: specific unit weight will be assumed as:
γ = γ_{wet} below ground-water level
γ = γ_{sr} over ground-water level

Point 5 Shaft Design

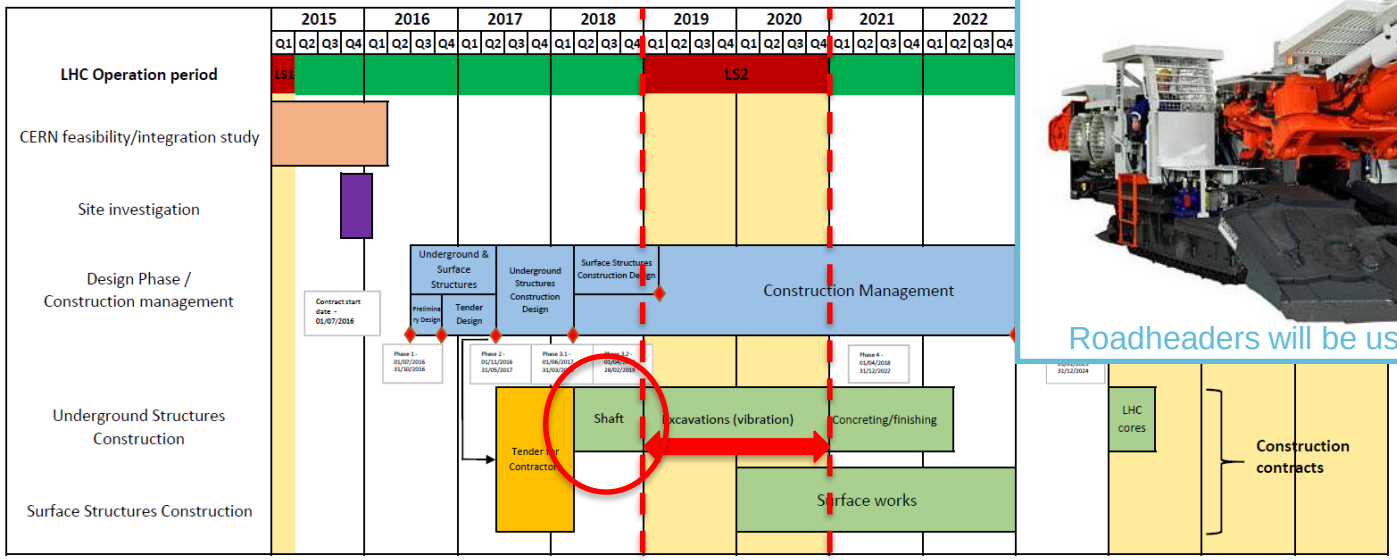


HiLumi HL-LHC PROJECT

Civil Engineering
Outline Planning

Vibration affecting LHC operation

- Vibration caused by shaft excavation may affect LHC operation (beam stability);



NOTE: Staged Handovers for the underground and surface structures is envisaged. The timing of these handovers will be agreed during Phases 1 & 2.

Roadheaders will be used for excavation

- Main excavation works planned during LS2; sensitivity to vibrations drives CE planning.

Shaft Excavation Equipment

Shaft Excavation Equipment

- Assumed conclusions from vibration studies:
  - Hydraulic hammer / rock breaker will generate unacceptable vibrations;
  - Excavators powered by diesel engines will generate unacceptable vibrations (resonance frequency);
  - Vibrations due to electrically powered excavation tools would likely be acceptable;

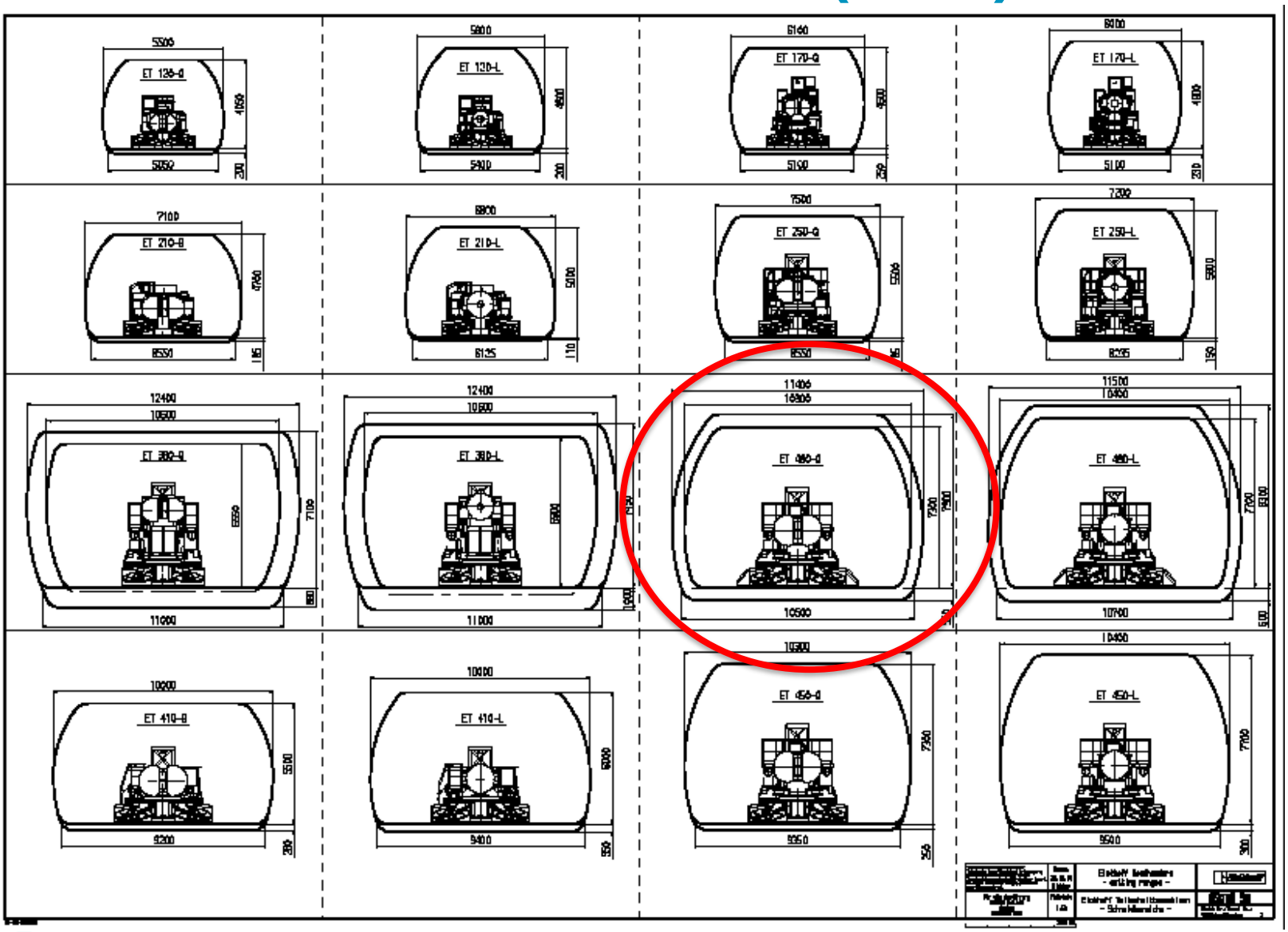
- Electrically powered excavation tools:
  - Electric roadheader;
  - Hydraulic cutter head mounted on electric excavator;

Electric roadheader

- Key points:
  - Vibrations caused by large model measured in Thun;
  - Cutter head is directly powered by electric engine (no hydraulic system in btwn engine & cutter head);
  - Smallest versions would likely not fit inside the ≈∅11.5m shaft to be excavated;
  - Customised machines (excl. spoil transport band and other features) may just fit;
  - Downside is limited under-cut below bottom of excavation;

Electric roadheader (Thun)

Electric roadheader (Thun)



HiLumi HL-LHC PROJECT

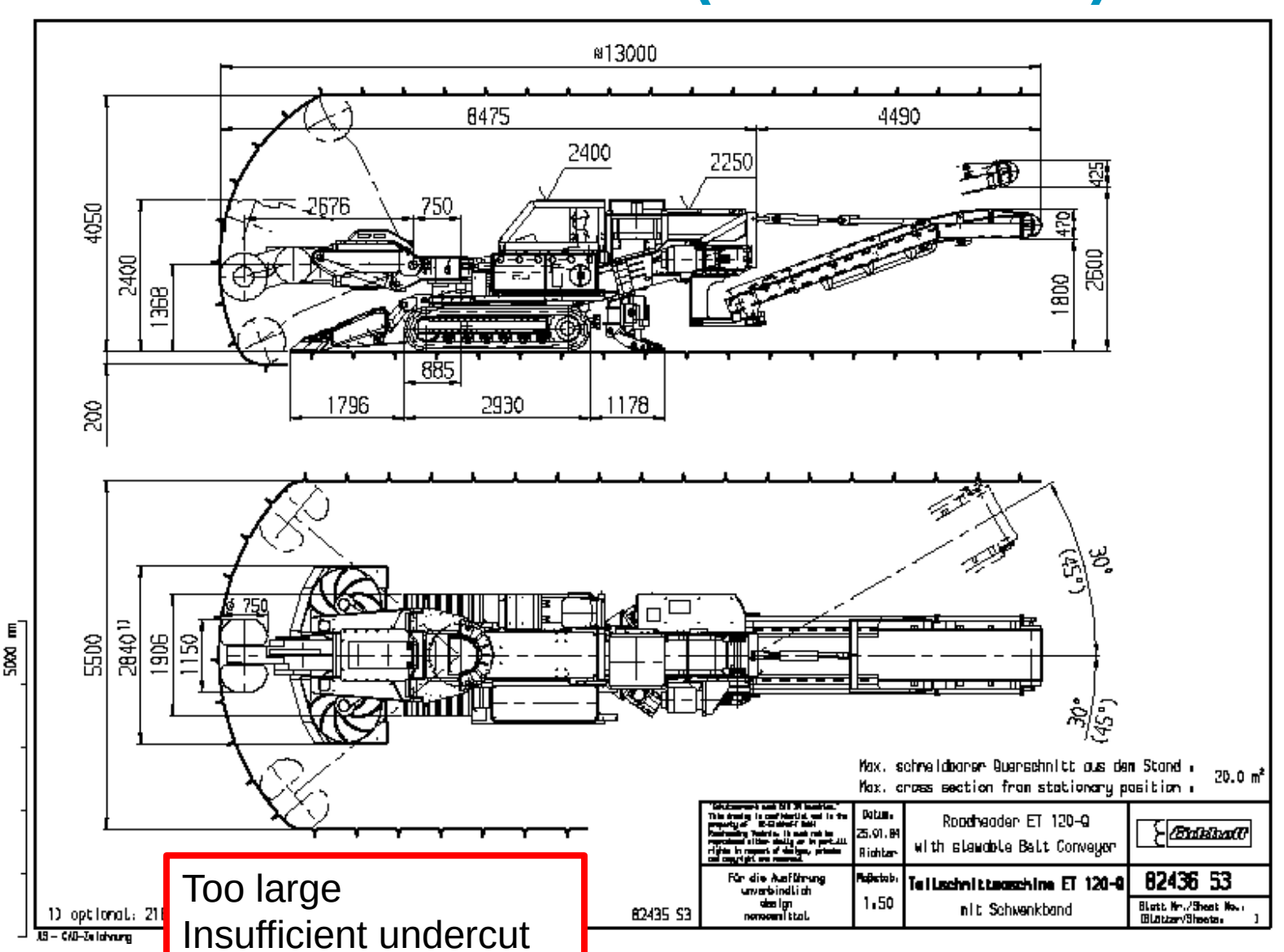
Electric roadheader (Thun)

Type	Power* total [kW]	Power cutting [kW]	Voltage [V]	Weight* [t]	Dimensions* length x width x height [m]	Cross Section (min) W x H [m]	Cross Section (max) W x H [m]
ET 100 Series							
ET 120-Q	210	132	400	32	8.5 x 2.1 x 2.4	2,9 x 2,6	5,5 x 4,05
ET 120-L	210	132	400	32	9.0 x 2.1 x 2.4	2,9 x 2,6	5,8 x 4,6
ET 170-Q	210	132	400	33	9.0 x 2.1 x 3.28	2,9 x 3,1	6,1 x4,6
ET 170-L	210	132	400	33	9.1 x 2.1 x 3.28	2,9 x 3,1	6,0 x 4,9
ET 200 Series							
ET 210-Q	360	200	1000	58	10.2 x 3.0 x 2.55	4,4 x 2,85	7,1 x 4,7
ET 210-L	360	200	1000	56	10.5 x 3.0 x 2.55	4,4 x 2,85	6,8 x 5,0
ET 250-Q	360	200	1000	58	10.5 x 3.0 x 3.81	4,4 x 3,53	7,5 x 5,5
ET 250-L	360	200	1000	56	10.74 x 3.0 x 3.81	4,4 x 3,53	7,2 x 5,8
ET 300 Series							
ET 380-Q	390	200	1000	109	16.8 x 3.7 x 4.8	4,9 x 5,0	12,4 x 7,1
ET 380-L	390	200	1000	107	17.3 x 3.7 x 4.8	4,9 x 5,0	12,4 x 7,45
ET 400 Series							
ET 410-Q	490	300	1000	104	16.4 x 3.9 x 3.55	5,7 x 3,7	10,0 x 5,5
ET 410-L	490	300	1000	104	16.9 x 3.9 x 3.55	5,7 x 3,7	10,0 x 6,0
ET 450-Q	490	300	1000	110	16.6 x 3.6 x 4.55	5,7 x 4,8	10,3 x 7,3
ET 450-L	490	300	1000	110	17.1 x 3.6 x 4.55	5,7 x 4,8	10,4 x 7,7
ET 480-Q	490	300	1000	114	16.6 x 3.6 x 4.55	5,7 x 4,8	11,4 x 7,9
ET 480-L	490	300	1000	114	17.1 x 3.6 x 4.55	5,7 x 4,8	11,5 x 8,3

* without slewing belt conveyor
-Q = machine type with transverse cutter gear box
-L = machine type with in-line cutter gear box

HiLumi HL-LHC PROJECT

Electric roadheader (smallest size)



Too large
Insufficient undercut

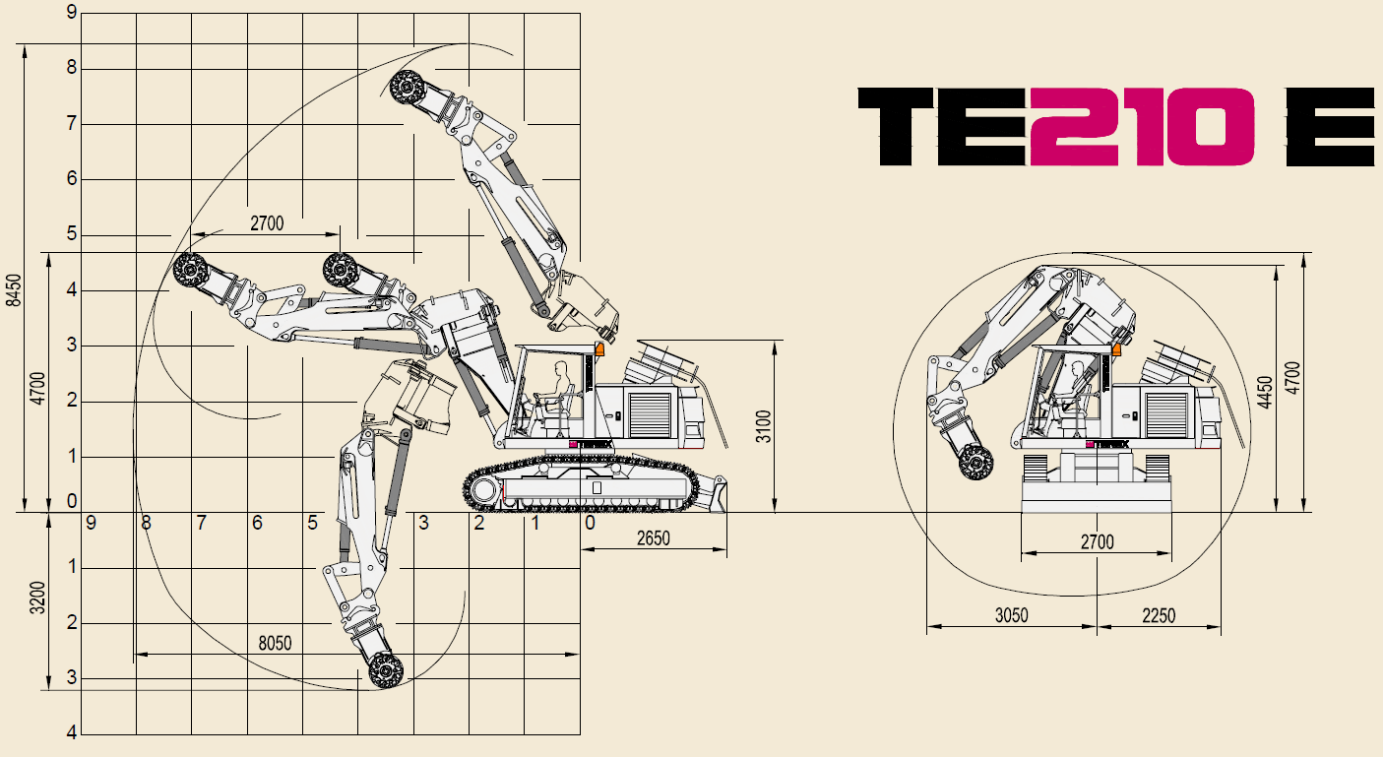
Hydraulic cutter head on electric excavator

- Key points:
  - Various sizes of electric excavators available;
  - Many models would fit inside shaft;
  - Not many models have enough kW / ton to be efficient (req'd excavation rate to meet schedule);
  - Cutter head is indirectly powered by electric engine via a hydraulic system;
  - Very good under-cut capabilities;
  - Cutter head can easily be exchanged for rock breaker/hammer or ripper/rock bucket;

Terex electric excavator

- Example of ‘suitable’ equipment:
  - Terex TE210 E;
  - 160kW electric; (400V / 50Hz)
  - Hydraulic system: Performance Regulated Rexroth; Axial piston double pump with load-sensing control and load limiting control;
  - Hydraulic Cutting unit Schaeff WS150N;
  - 28 ton;

Terex electric excavator



Technical Main Data

Maximal vertical reach	mm	8.500	Power electric drive	kW	135
Maximal digging depth	mm	3.900	Electric connection	A	250
Minimal operating height	mm	4.700	Travel speed	km/h	0-1.7 / 4,5
Machine width	mm	2.700	Crawler chain drawbar pull	kN	280
Machine height over cab	mm	3.100	Operating weight, acc. too equipment	t	28

HiLumi HL-LHC PROJECT

Terex electric excavator

Conclusions and Remarks

- A mini vibration working was held CERN-KEK-ILC at CERN 17 October 2017 with Hitoshi MATSUSHITA from Takenaka corp. to share experience :
  - https://indico.cern.ch/event/672364/
- IPAC18 Paper :
  - ***"INVESTIGATION AND PREDICTION OF THE LHC MAGNET VIBRATIONS DUE TO HL-LHC CIVIL ENGINEERING ACTIVITIES"***
- HL-LHC shaft excavation starting very soon, so we will learn more this year !
- This information will be made available for LC studies…..

Thank you for attention!
Any questions?

Special thanks to M.Guinchard, P.Fessia and P.Mattelaer from CERN