CERN

CERN Visit
16-18 October 2019

Canadian Light Source
Centre canadien de rayonnement synchrotron

Large Colliders:Civil engineering and Siting

- **Introduction**
- **CERN Intro and Geology (LEP and LHC)**
- **Future Circular Collider Study (FCC)**
- **Linear Colliders (ILC and CLIC)**
- **High Luminosity LHC Project (HL-LHC)**
- **Other Technical Infrastructure and Physics Beyond Colliders**

John Osborne CERN

SMB-SE-FAS Section Organisation September 2019

Future Accelerator Studies Section (FAS)

SL: John OSBORNE

International Linear Collider
Muon Collider

Engineers


Alexandra **Tudora**
Maximilian **Haas**
Future Circular Collider (FCC)

Compact Linear Collider (CLIC)

Jonathan **Gall**

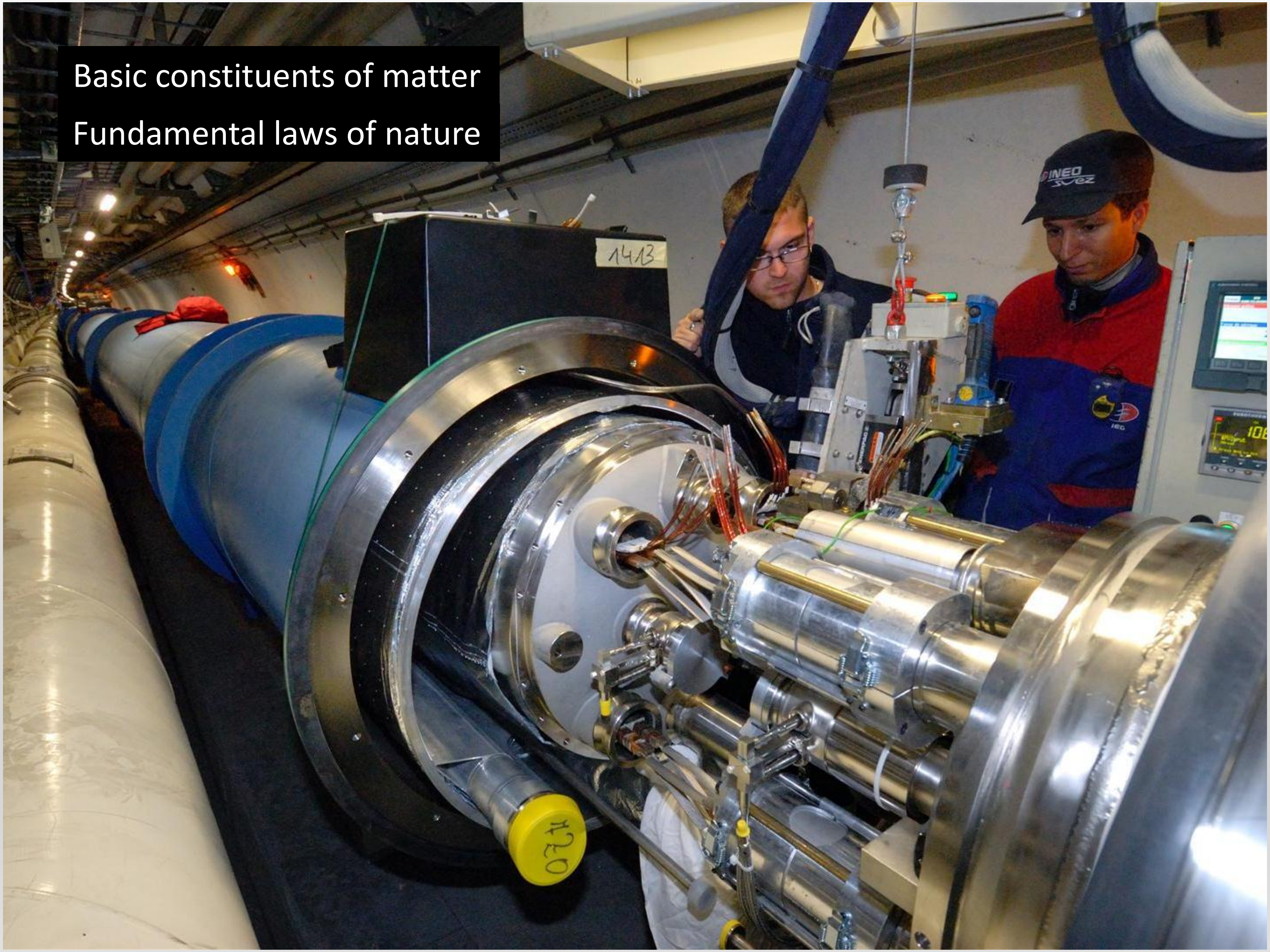
Physics Beyond Colliders

Eliseo Perez-Duenas

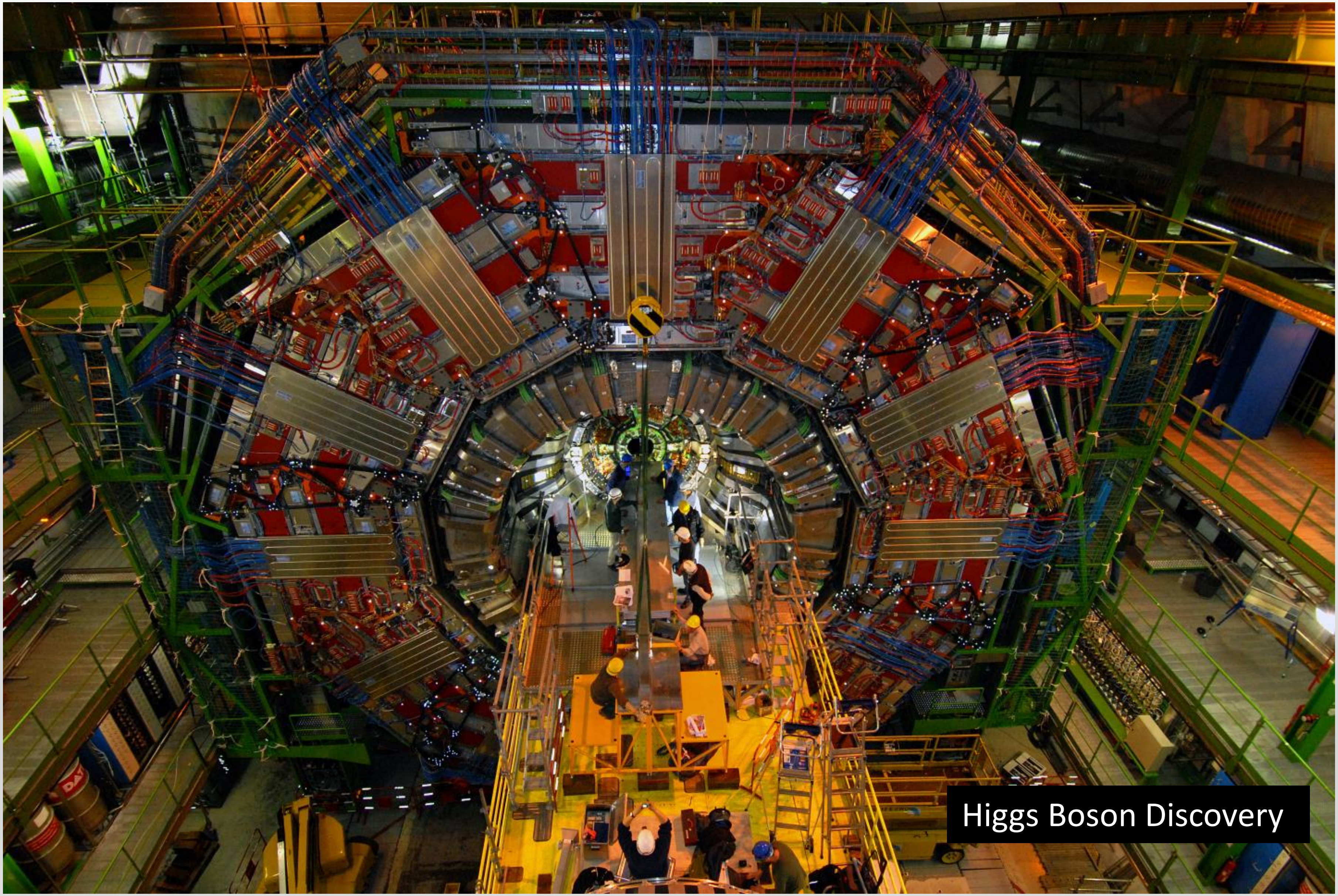

Ben **Swatton**
Zhipeng Xiao

Tunnel Asset Management

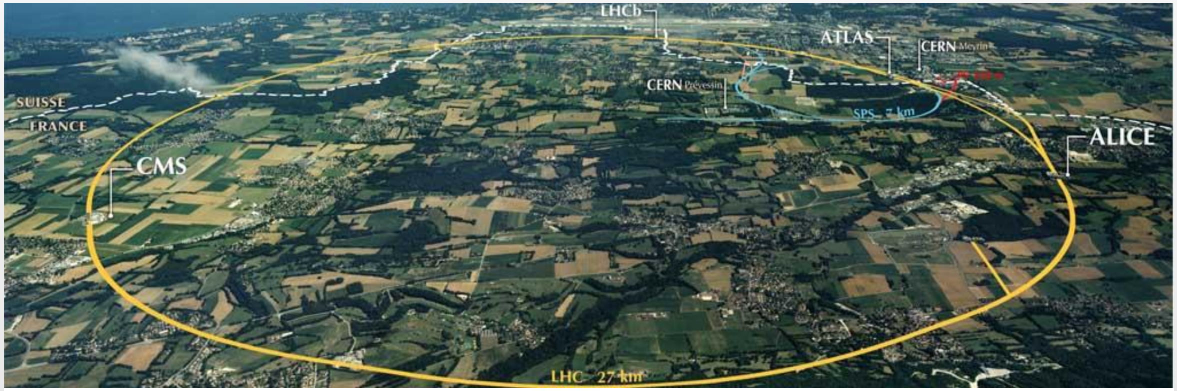

ALICE
ATLAS
CMS
LHCb

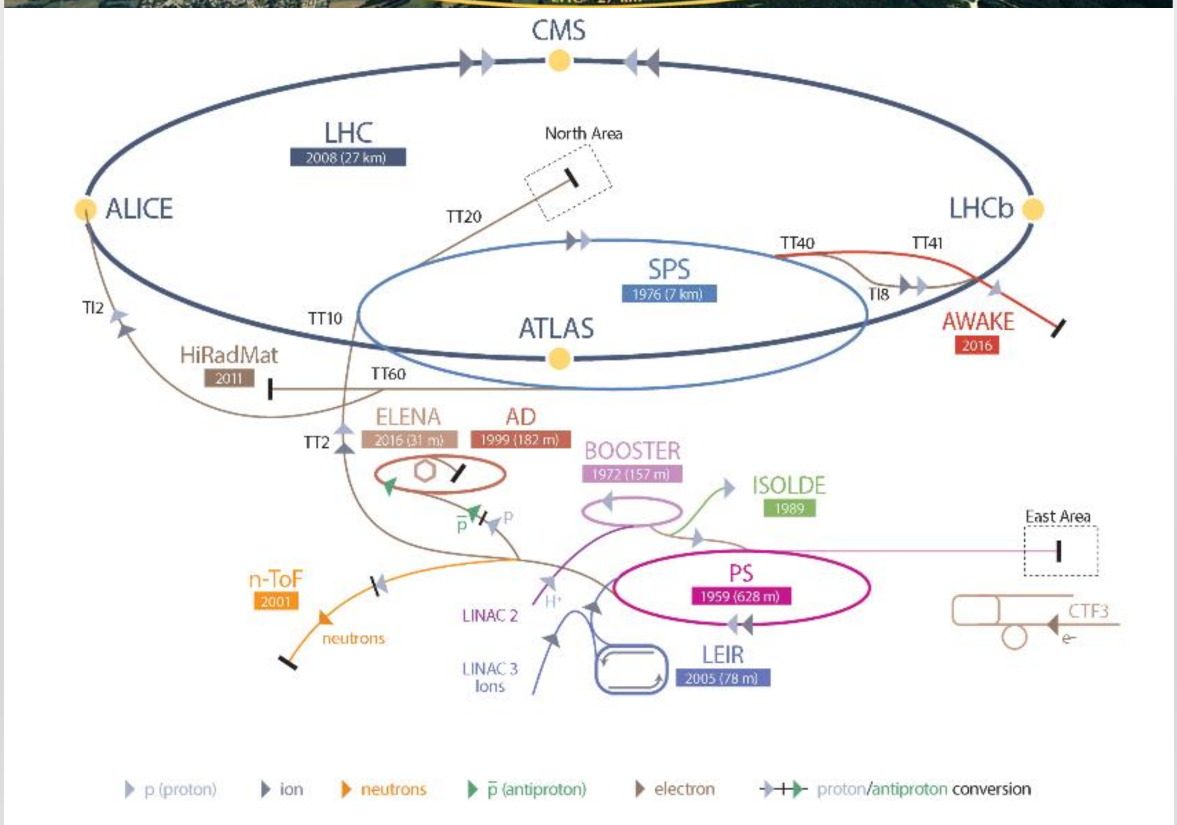

Basic constituents of matter
Fundamental laws of nature

CERN – European Centre for Nuclear Research



CERN tunnels and geology





- Large Hadron Collider :

  - 27km long
  - 50-175m depth
  - 4.5m ø TBM tunnels
  - Molasse and limestone

Total underground tunnels >70km
More than 80 Caverns

'CERN' Geology

Rock properties

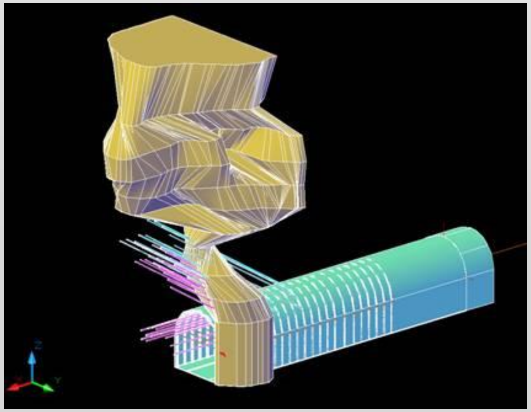
Moraines
- Glacial deposits comprising gravel, sands silt and clay
- Water bearing unit
- Low strength

Molasse
- Mixture of sandstones, marls and formations of intermediate composition
- Considered good excavation rock
- Relatively dry and stable
- Relatively soft rock
- However, some risk involved
- Weak marl horizons between stronger layers are zones of weakness
- Faulting due to the redistribution of ground stresses
- Structural instability (swelling, creep, squeezing)

Limestone
- Hard rock
- Normally considered as sound tunneling rock
- In this region fractures and karsts encountered
- Risk of tunnel collapse
- High inflow rates measured during LEP construction (600L/sec)
- Clay-silt sediments in water
- Rockmass instabilities

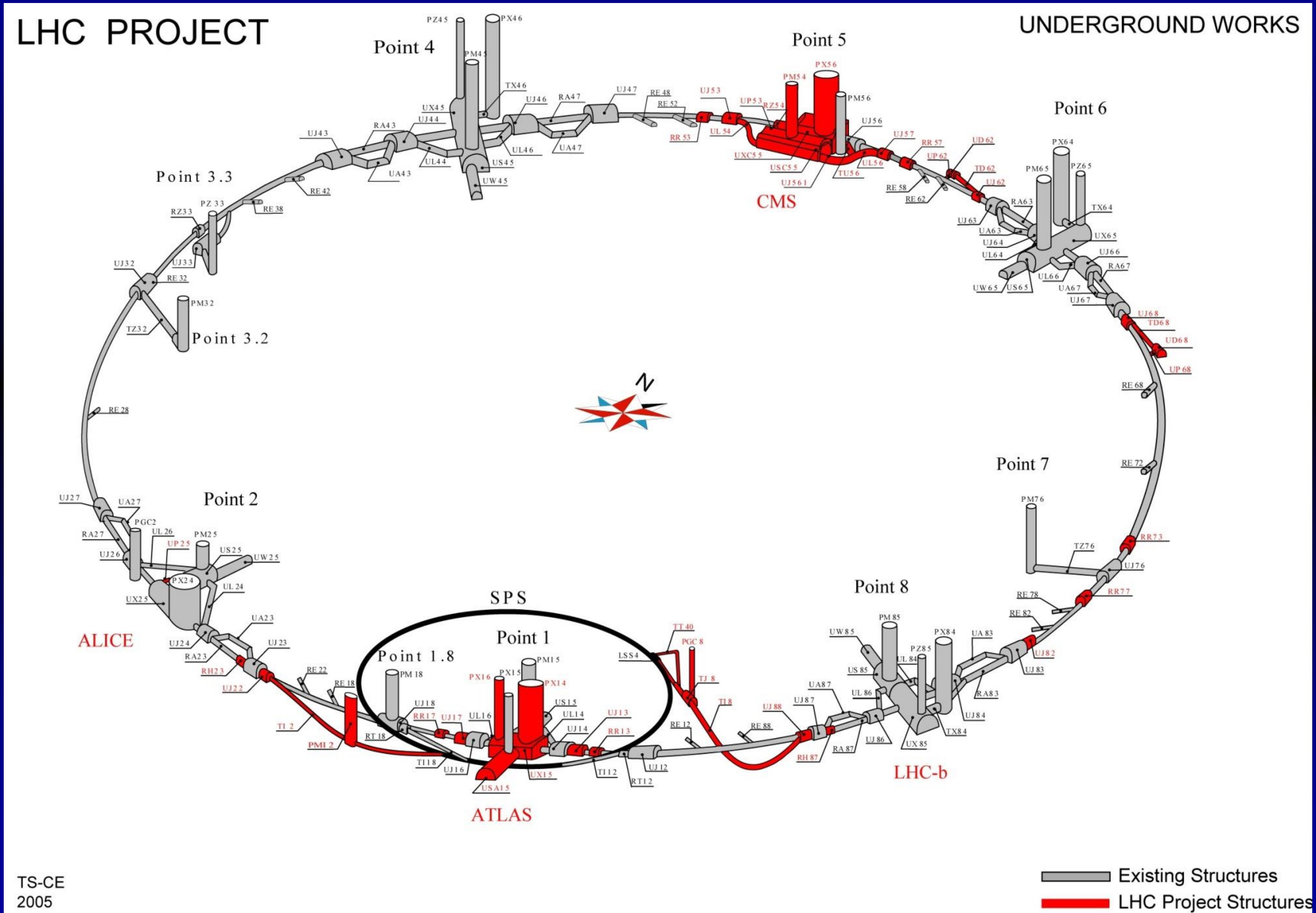
Rock type		Average σc (Mpa)
Sandstone	*weak*	10.6
	strong	22.8
	Very strong	48.4
Sandy marl		13.4
Marl		5.7

Molasse Compression strengths

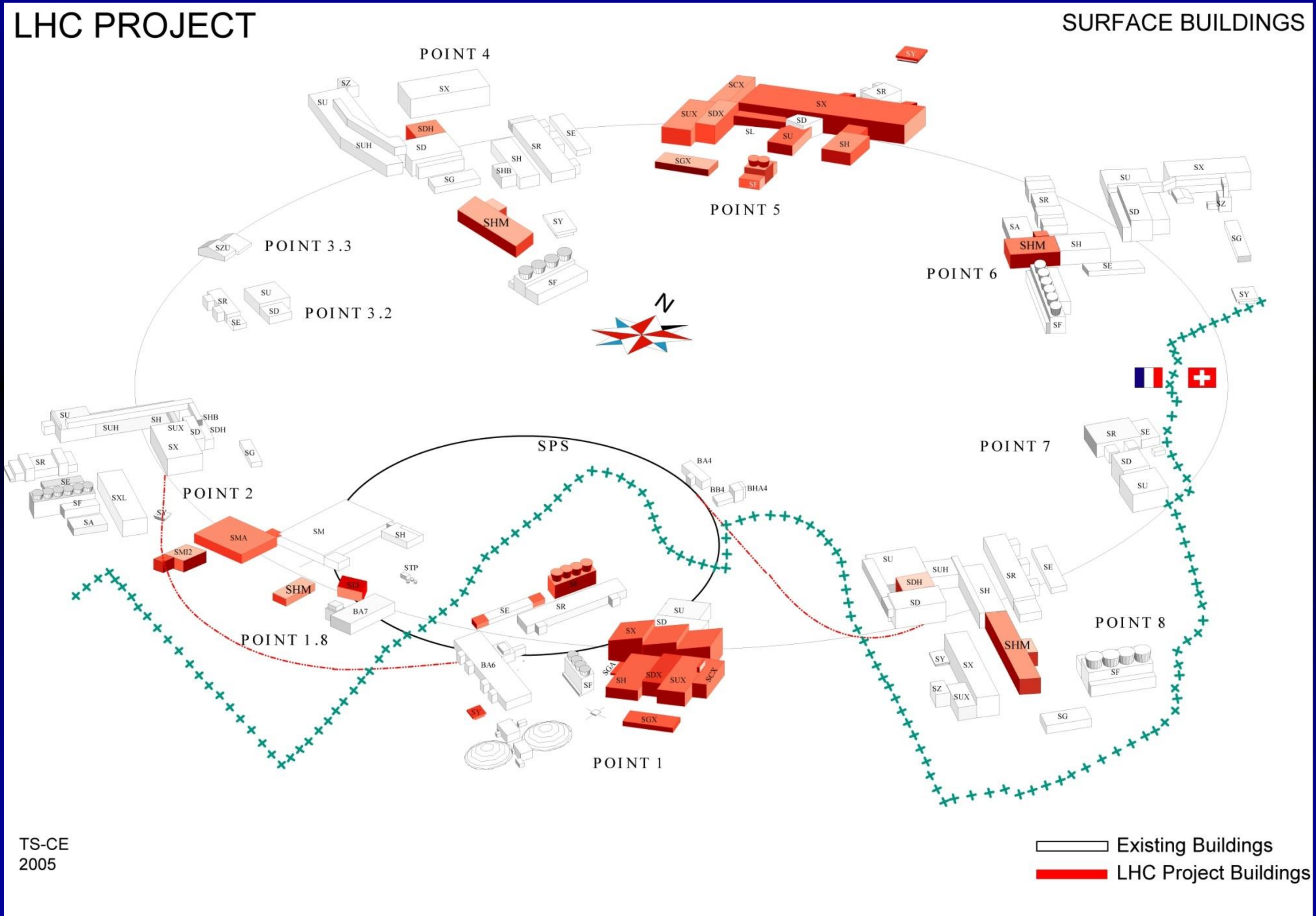


Model of tunnel collapse caused by Karsts

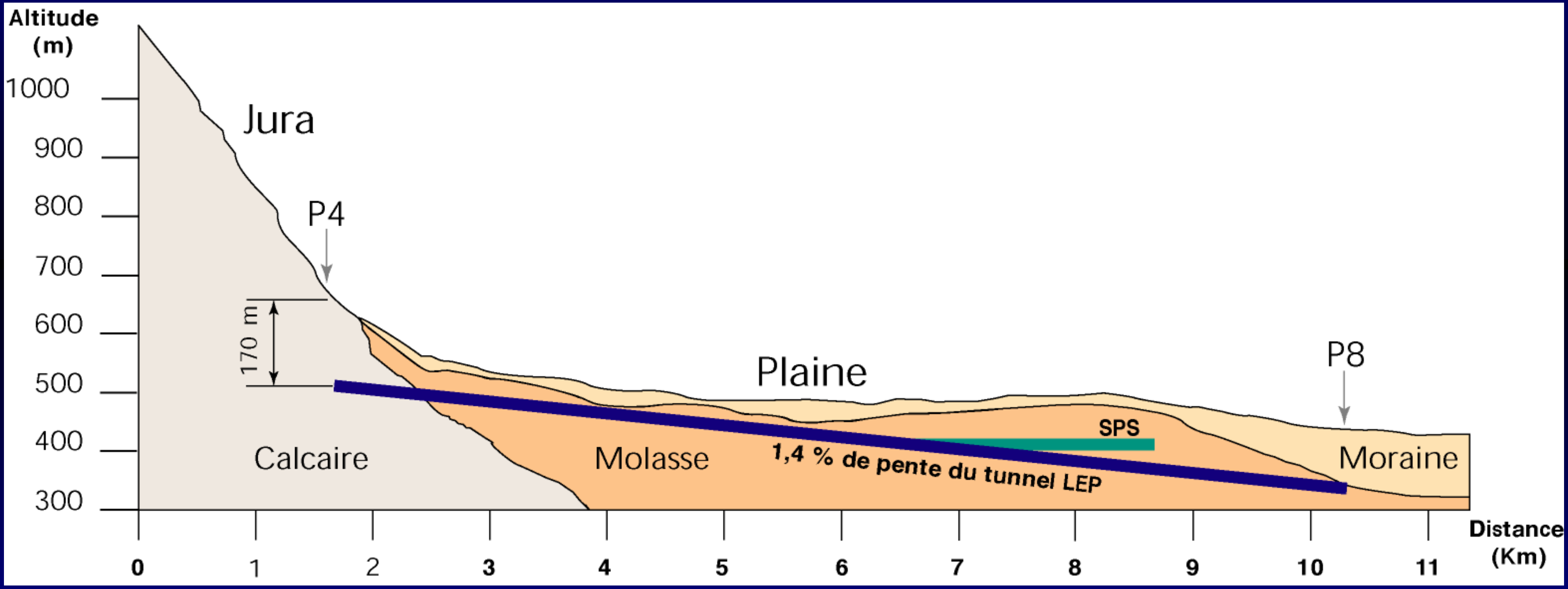
LHC Civil Engineering 1998-2005



LHC Civil Engineering 1998-2005



LHC tunnel aligment



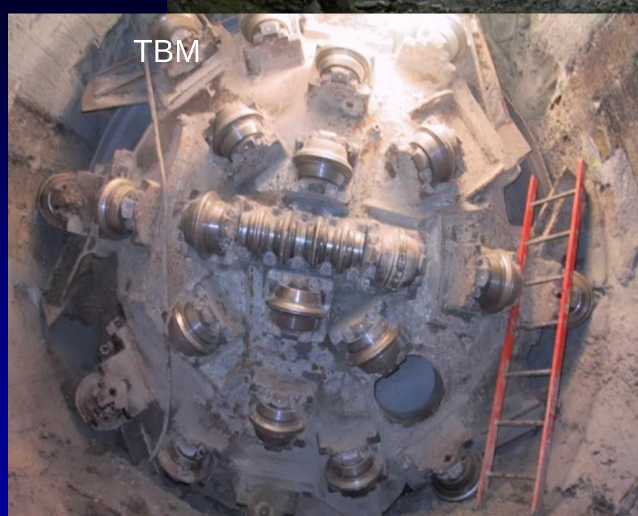
LHC Civil Engineering 1998-2005

	LEP	LHC
Number of Shafts	19	6
Number of underground caverns	37	32
Tunnel lengths (all diameters)	32’600m	6’500m
Number of buildings	70	30
Surface Area of buildings	59’000m2	28’000m2
Excavated Volumes	1’100’000m3	420’000m3
Volume of Concrete underground	230’000m3	125’000m3
Volume of Concrete on Surface	85’000m3	42’000m3

LHC Civil Engineering companies

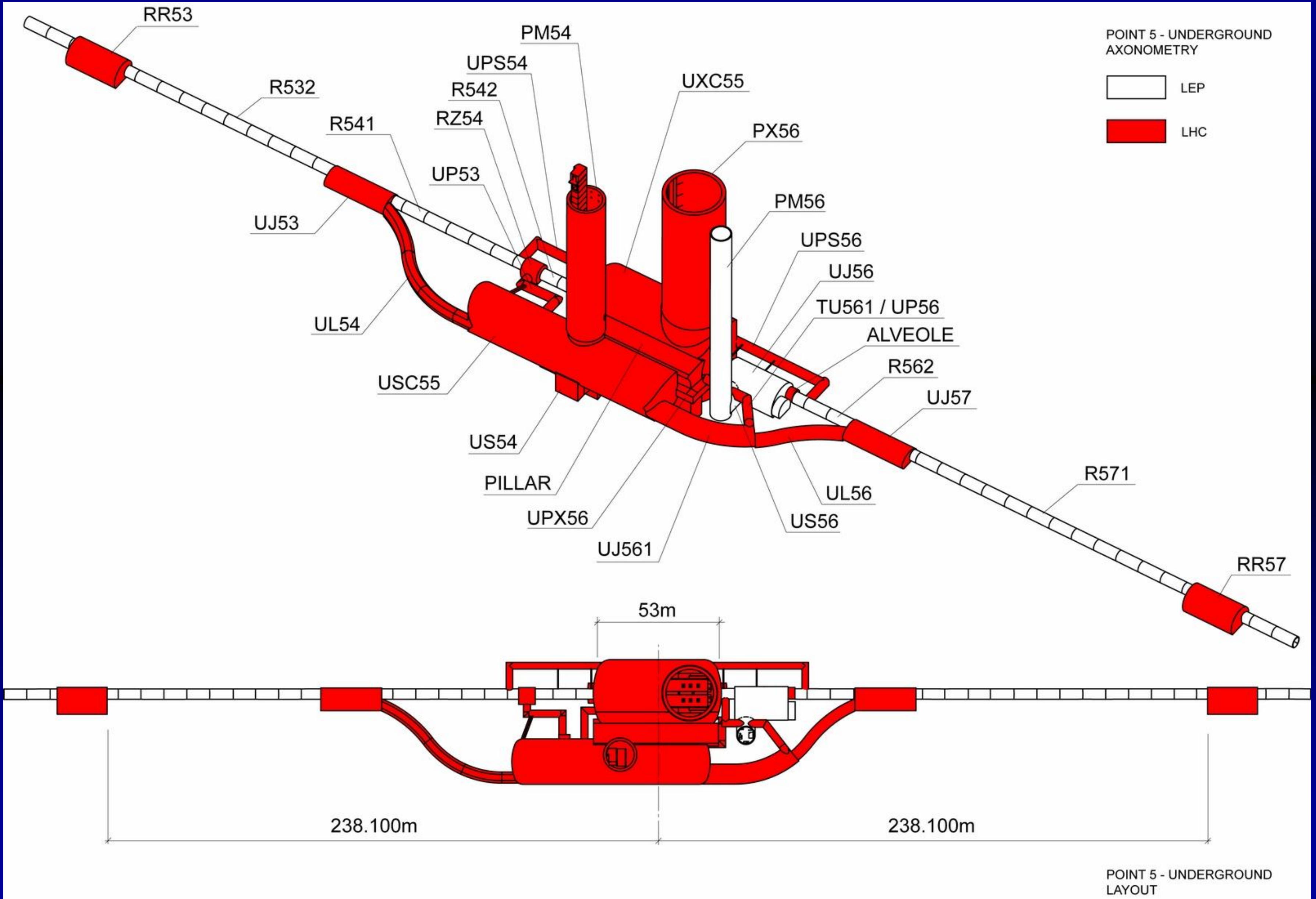
Package	Place		Consultants	Contractors
1	POINT 1	ATLAS	- EDF (F) - KNIGHT & PIESOLD (GB)	- TEERAG-ASDAG (A) - BARESEL (D) - LOCHER (CH)
2	POINT 5	CMS	- GIBB (GB) - GEOCONSULT (A) - SGI (CH)	- DRAGADOS (E) - SELI (I)
3A	Other Points	All other points except TI8 (including ALICE and LHC-b)	- BROWN & ROOT (GB) - INTECSA (E) - HYDROTECHNICA (P)	- TAYLOR-WOODROW (GB) - AMEC (GB) - SPIE-BATIGNOLLES (F)
3B	TI 8	TI 8 tunnel	DITO	- LOSINGER (CH)

Tunnel excavation options



No explosives were used for LHC excavation

LHC Civil Engineering - CMS



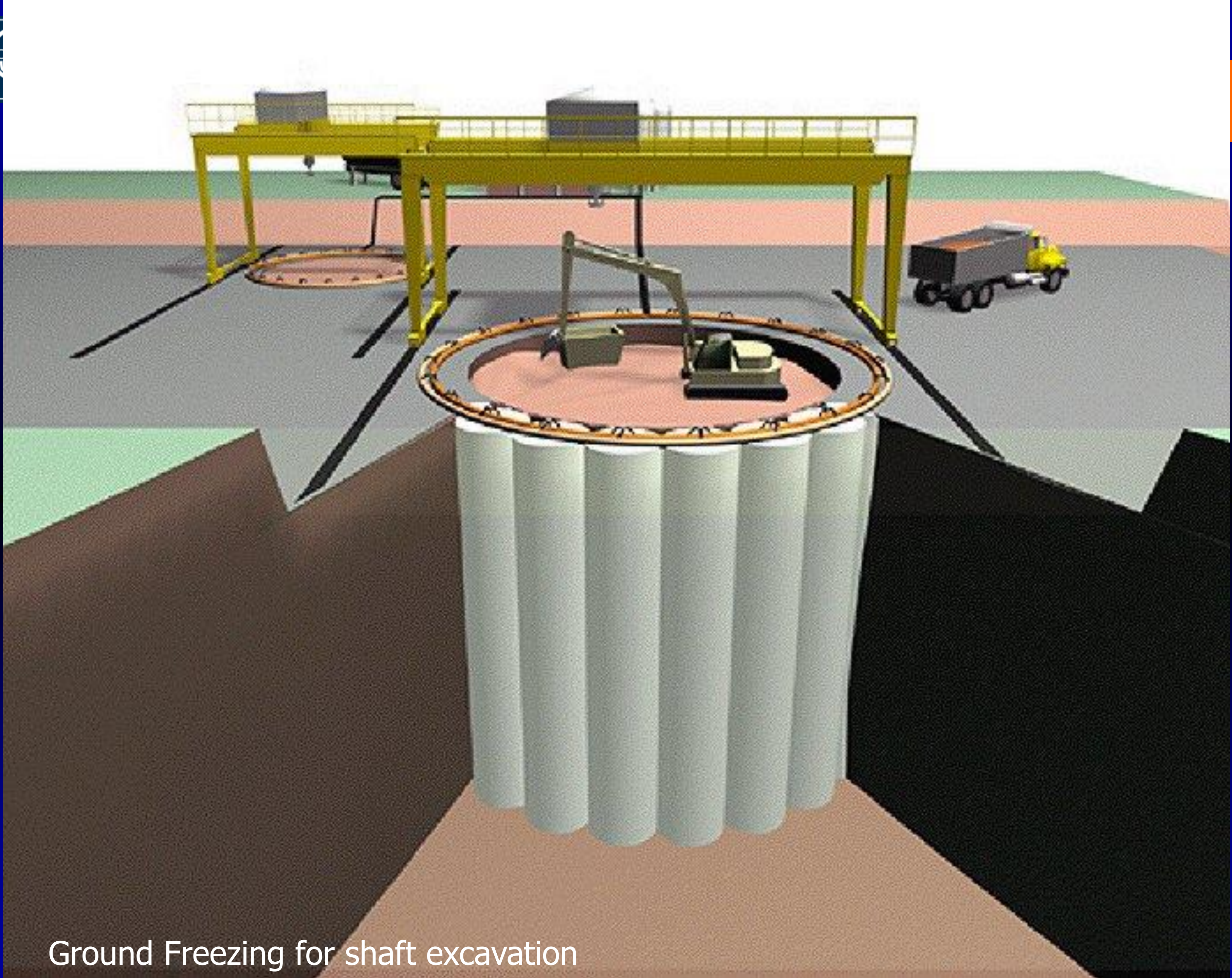
LHC Civil Engineering -CMS

LHC Civil Engineering - CMS

Roman Villa

LHC Civil Engineering - CMS

2001



Ground Freezing for shaft excavation

LHC Civil Engineering CMS ground freezing

1999

LHC Civil Engineering CMS ground freezing

Point 5 -Excavation commencement of PM54 shaft - July 09, 1999 - CERN ST-CE

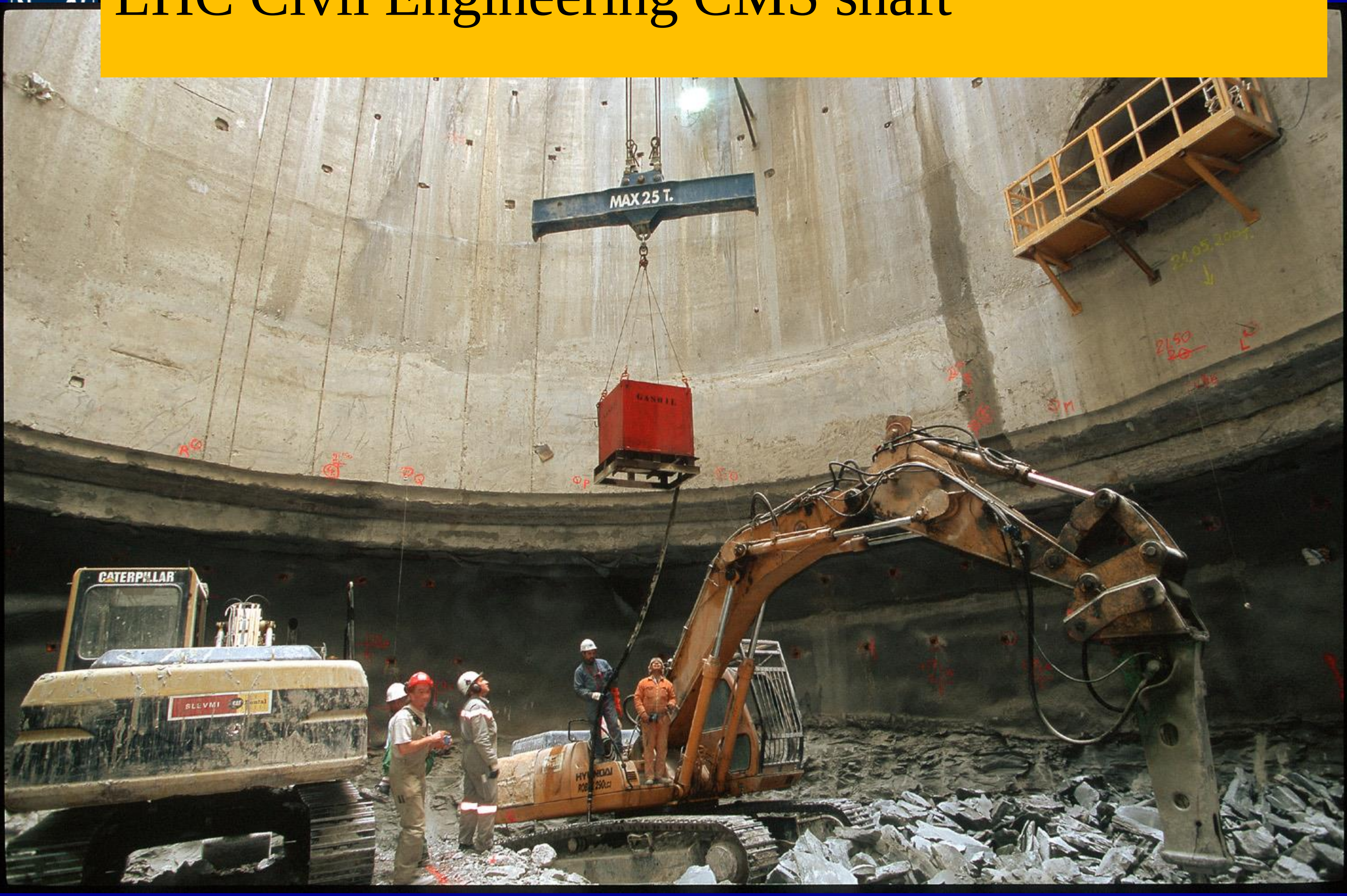

Dragados

Point 5 - PM54 additional drilling for grouting - October 01, 1999 - CERN ST-CE

2000

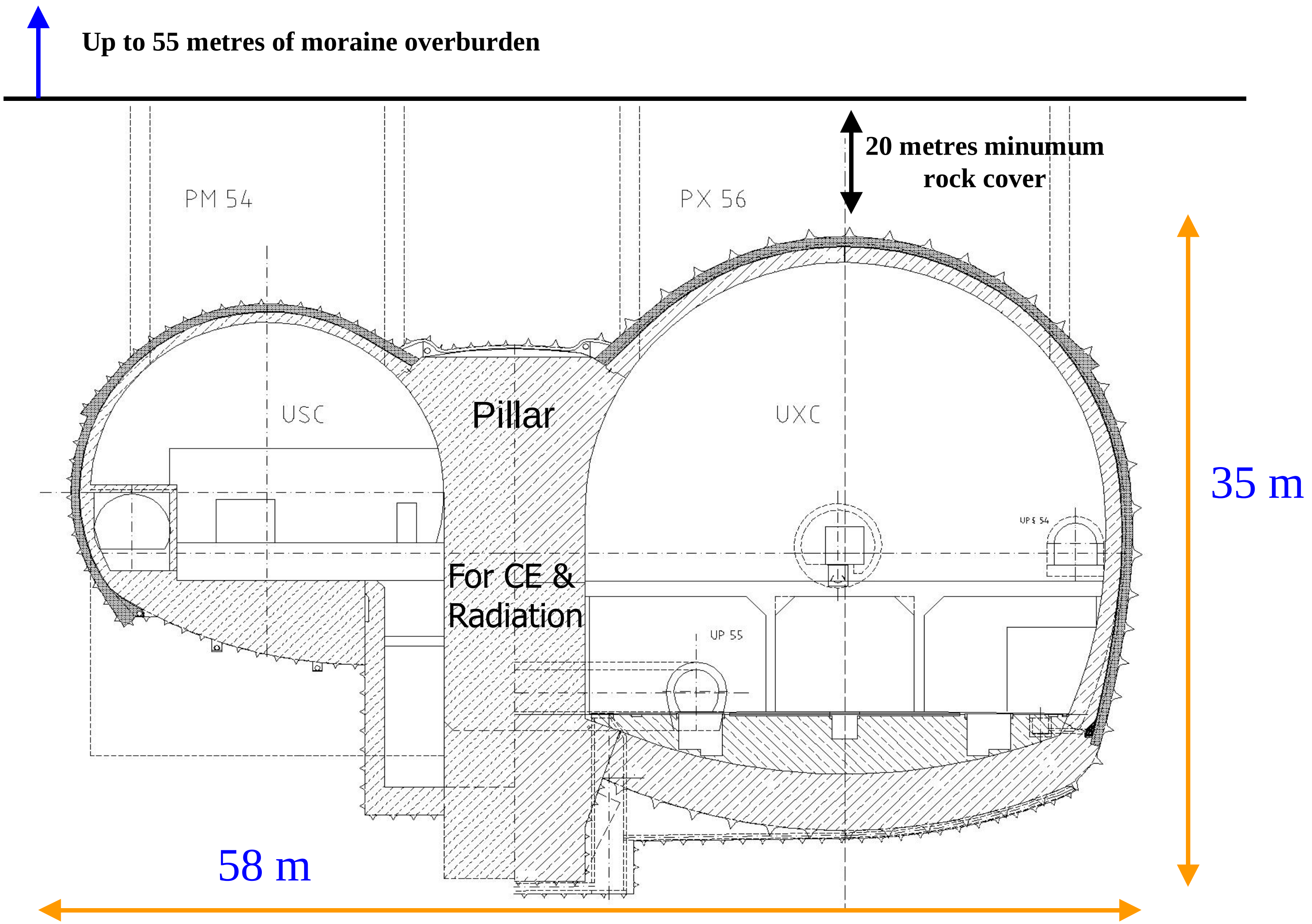
Shafts 12.1m and 20.5m diameters, both approx. 100m deep

LHC Civil Engineering CMS shaft

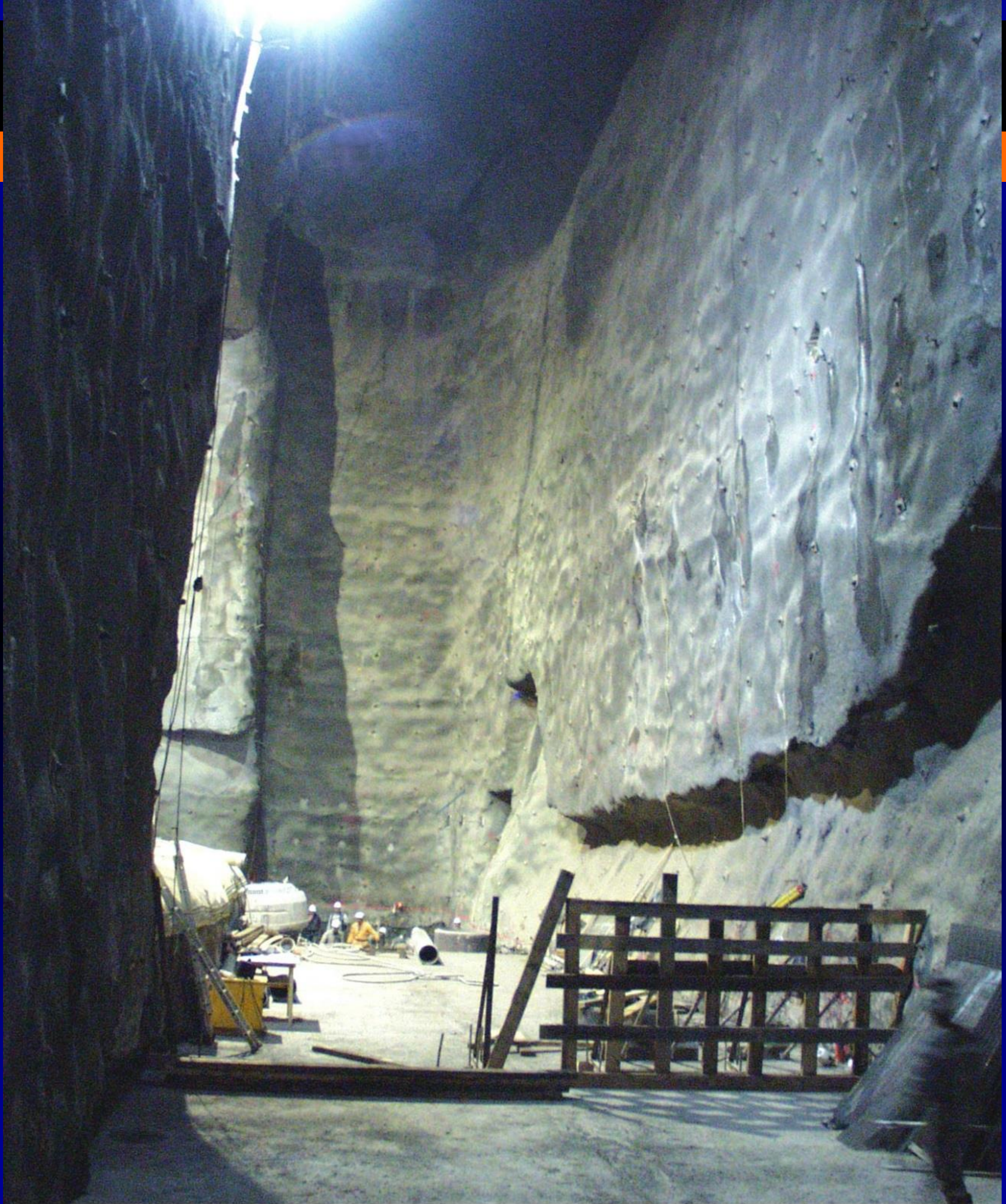


2000

Section through cavern complex at point 5



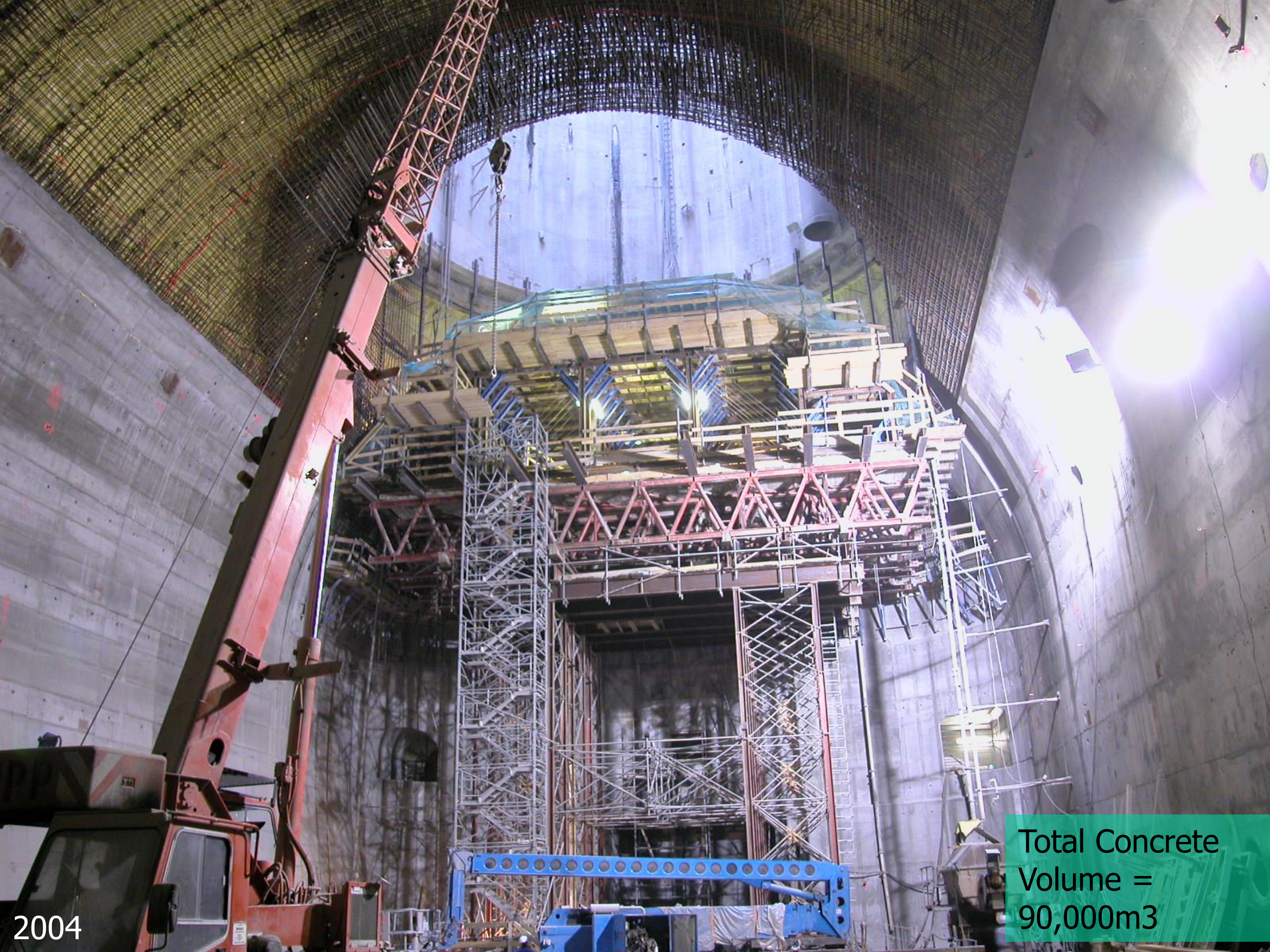
John Osborne

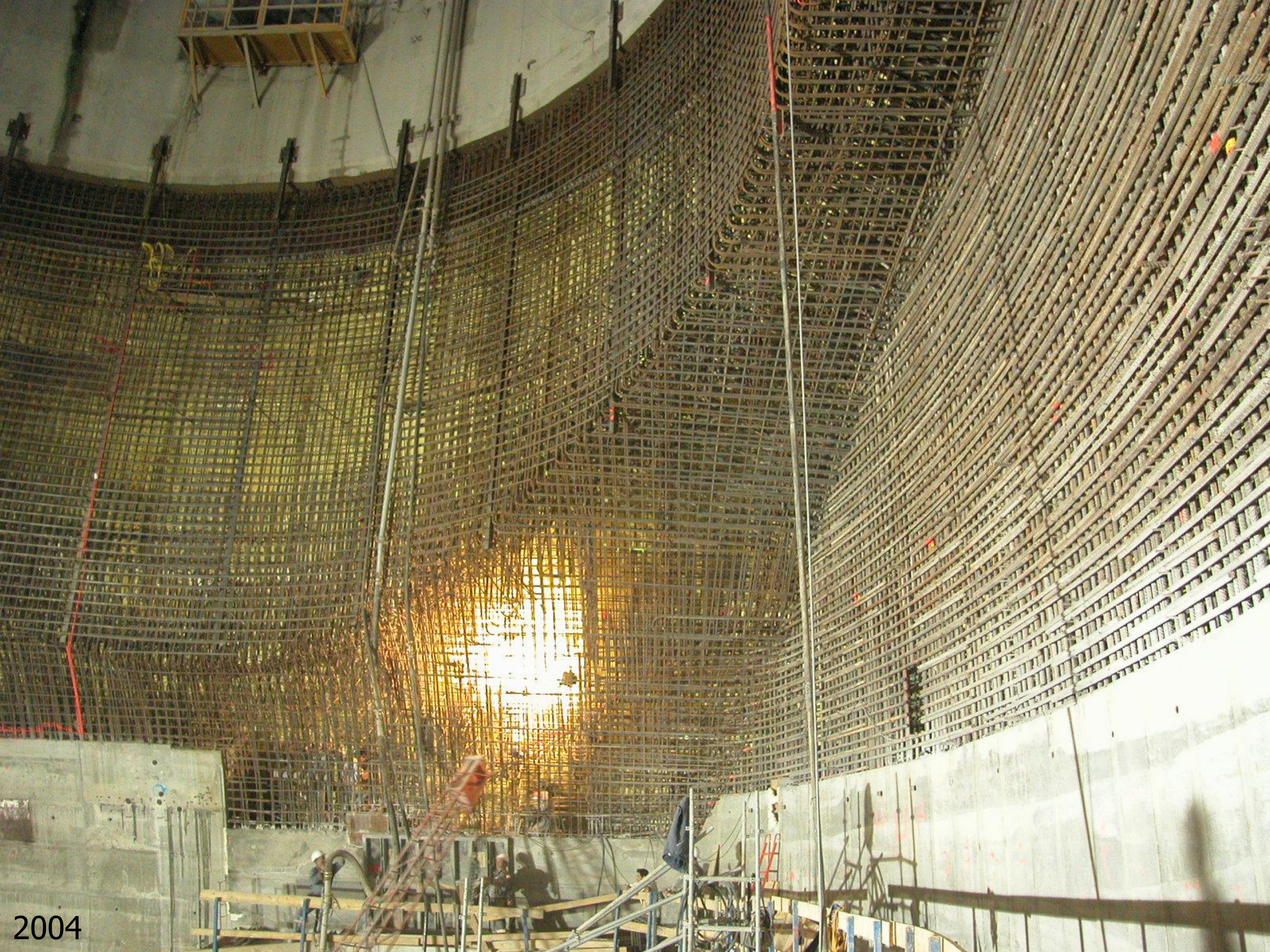


Point 5 - Shuttering for the first layer of pillar concrete - April 20, 2001 - CERN ST-CE

Point 5 - UXC55 cavern excavation - LEP demolition - January 23, 2002 - CERN ST-CE


Total Volume excavated =
216,000m3
2003


2004
Total Concrete Volume = 90,000m3



2004

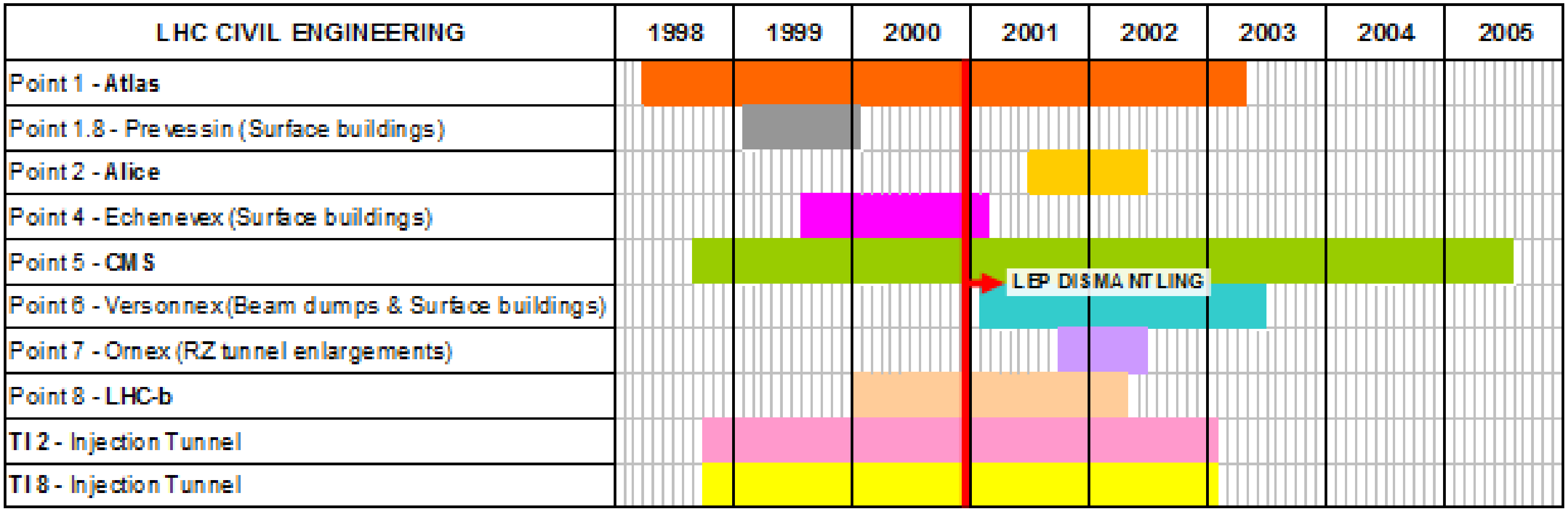

CMS cavern 53m long, 27m wide by 25m high
2005

- Why FIDIC form of Contract ?

- **FIDIC** – the International Federation of Consulting Engineers.
- CERN used a modified version of FIDIC “Conditions of Contract for Works of Civil Engineering Construction” 4th Edition, or “**The Red Book**”. Re-measurement type of contract.
- This type of contract was well suited to the LHC type of construction for the following reasons :
    - Well recognised contract documents for International Projects
    - Suitable for projects where main responsibility for the design lies with the Client (or his Engineer).
    - Work done is measured, payment via Bill of Quantities
    - Scope to modify the works via Variation Orders
    - Adjudication Process for Claims & Disputes

- **Adjudication** procedure was deemed a great success.
- A panel of 5 “experts” agreed with the Contractors.
- 3 disputes were referred to the panel (2 with the Contractors and 1 with the Consultants).
- Several disputes settled without need for Adjudication because one party “feared losing control”.
- Decisions made very quickly (within 2 months) in accordance with Contract.
- Each adjudication cost less than 1.5% of the adjudicated amount.
- **All disputes** during LHC construction have been resolved.
- No Arbitrations.

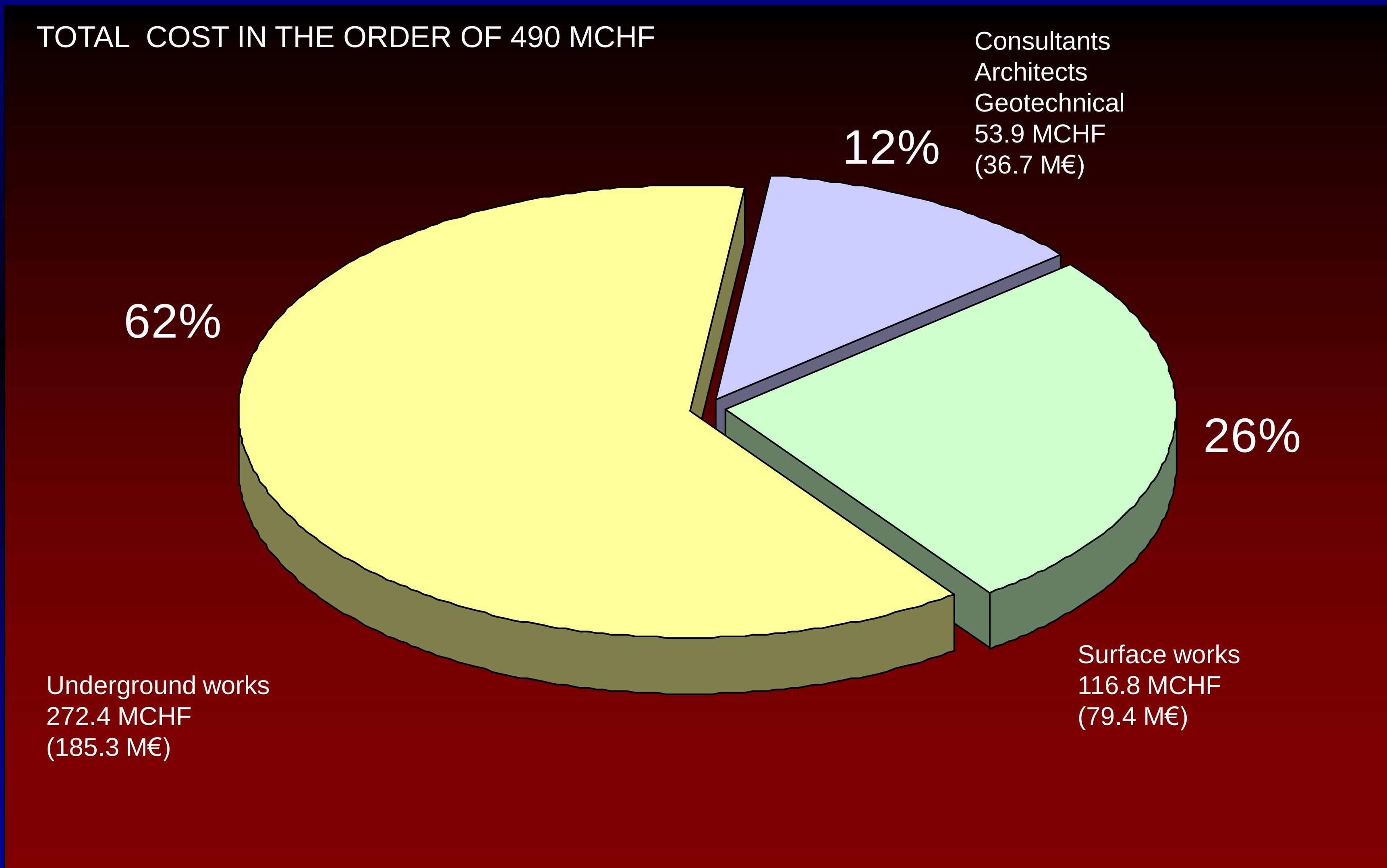
LHC Civil Engineering simplified schedule



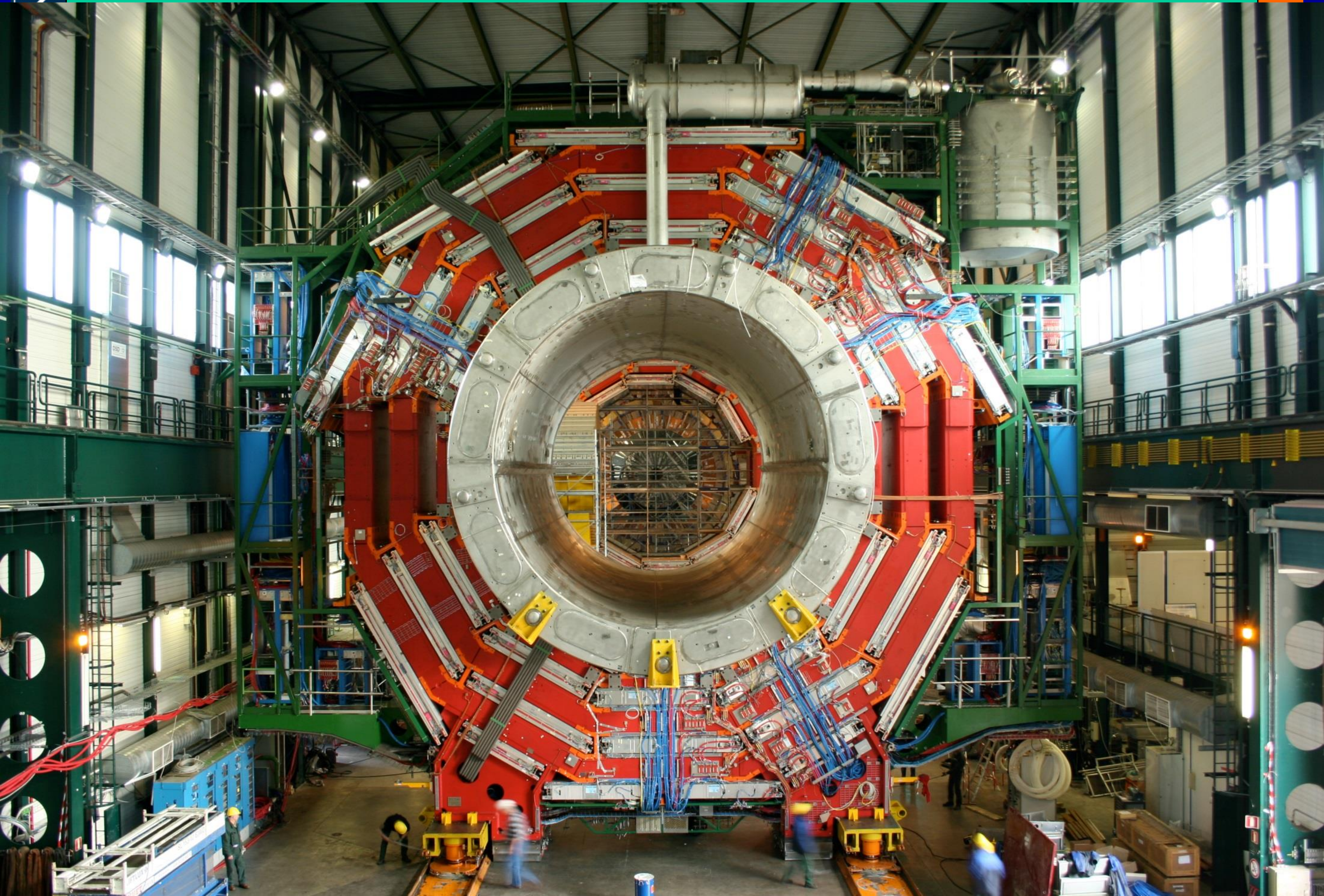
Civil Engineering as-built schedule

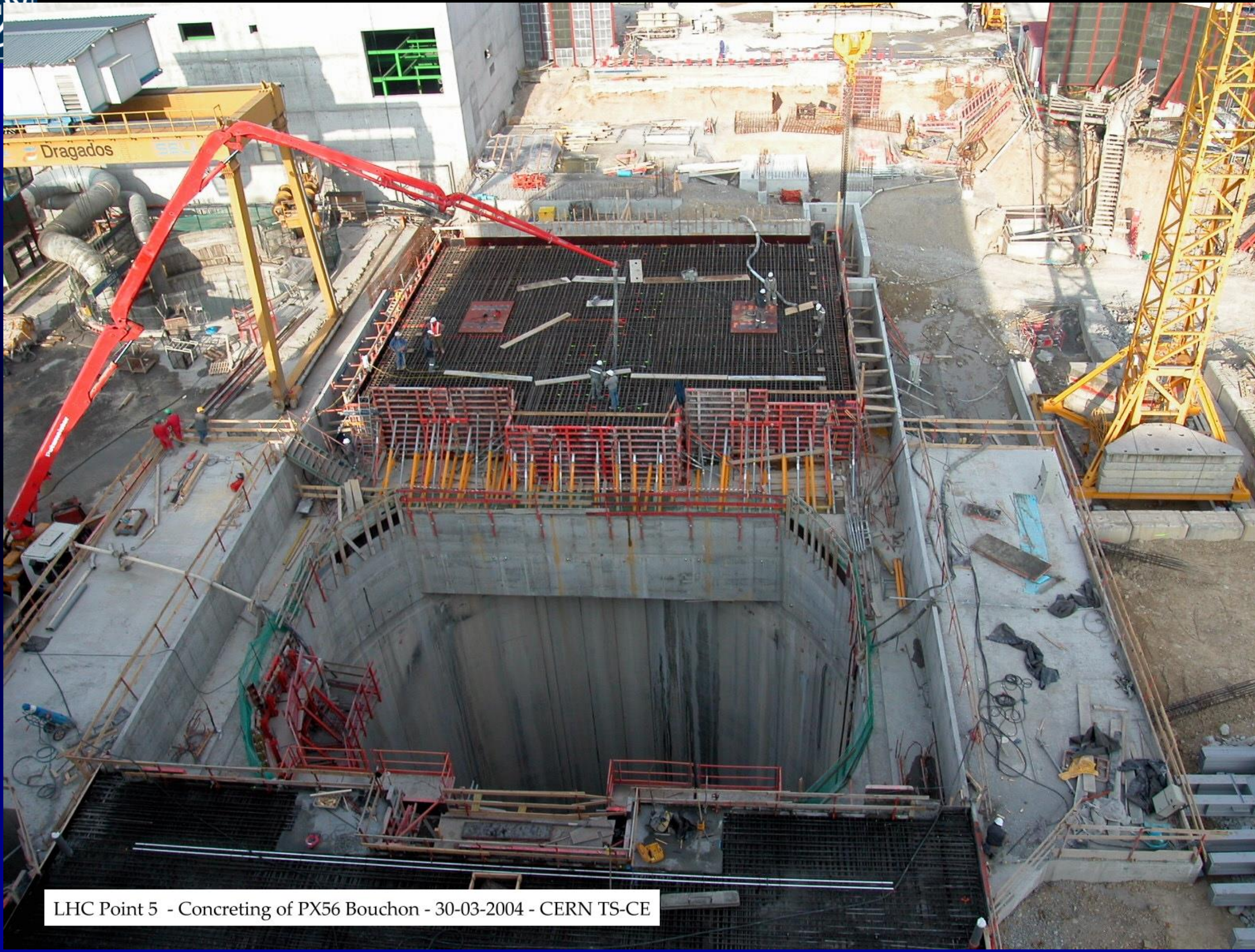
- LHC : 3 years pre-construction preparation (Site investigation, Environmental Impact Study, Tendering etc.)
- LEP civil engineering approximately 6 years (27km tunnels)

LHC Civil Engineering costs



CMS Detector Assembly and Lowering



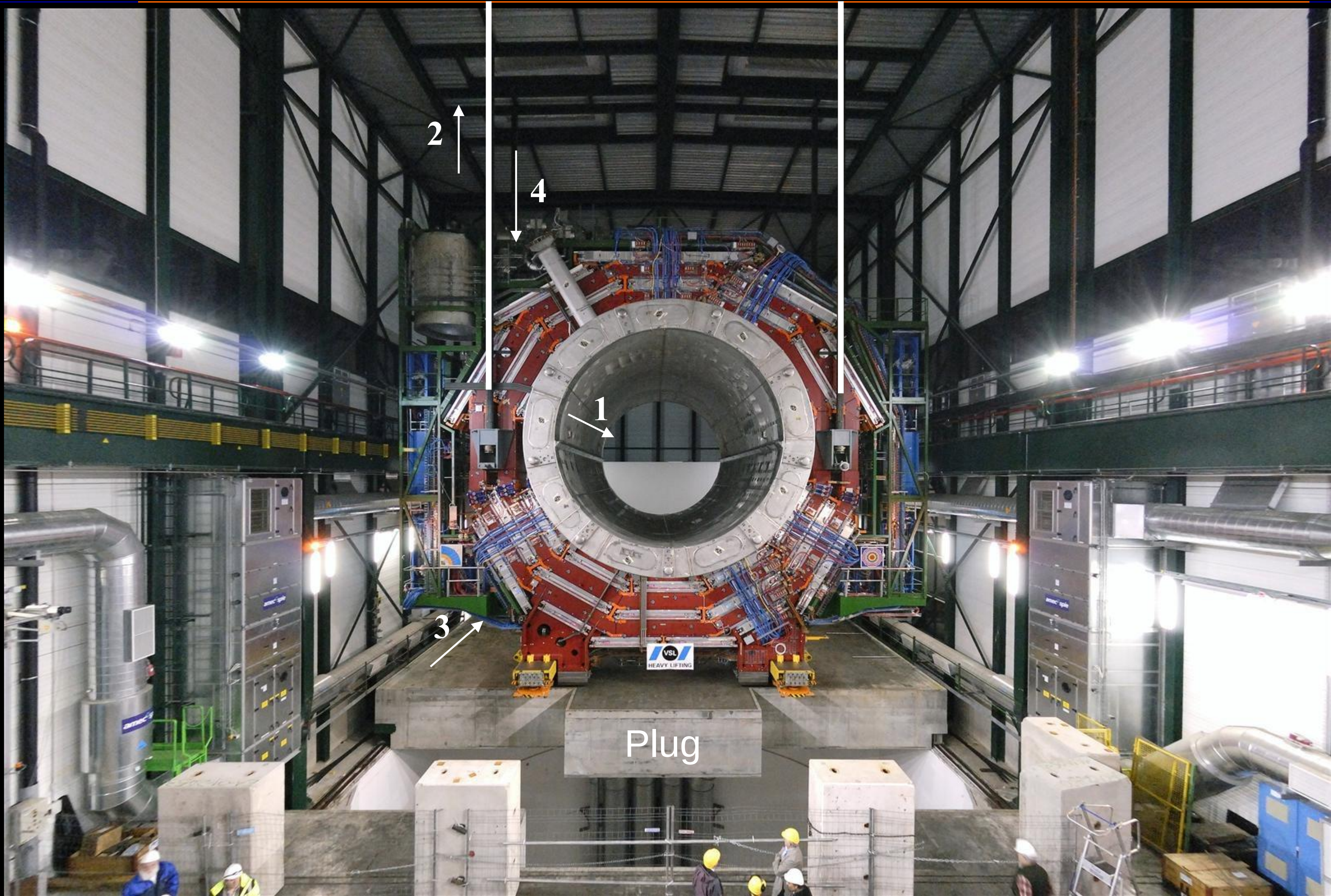


LHC Point 5 - Concreting of PX56 Bouchon - 30-03-2004 - CERN TS-CE

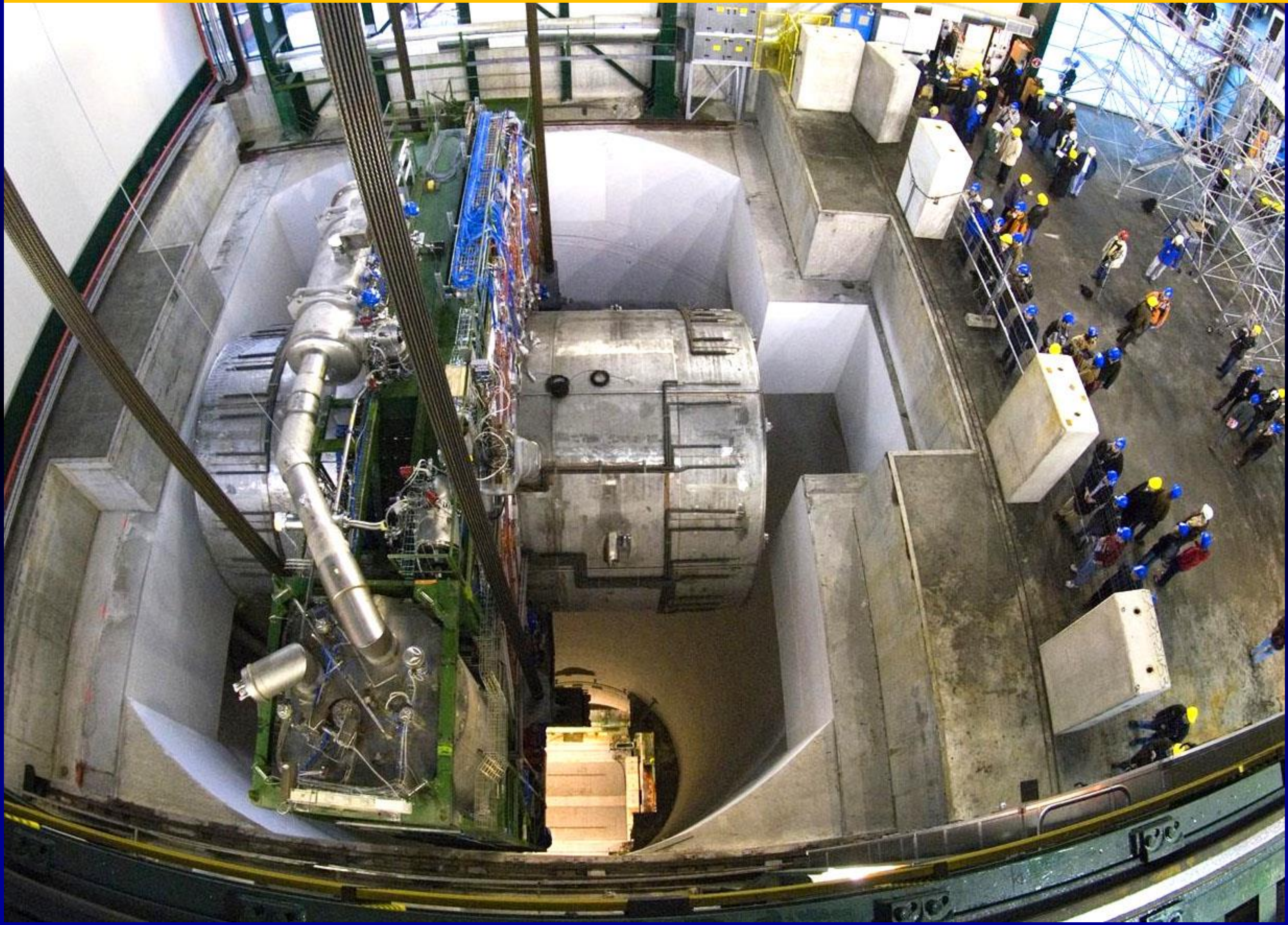

Dragados
LHC Point 5 - SX5 Extension - Bouchon Complete - 20 April 2004 - CERN TS-CE

Gantry Installation

Opening the plug under the 2000-ton load

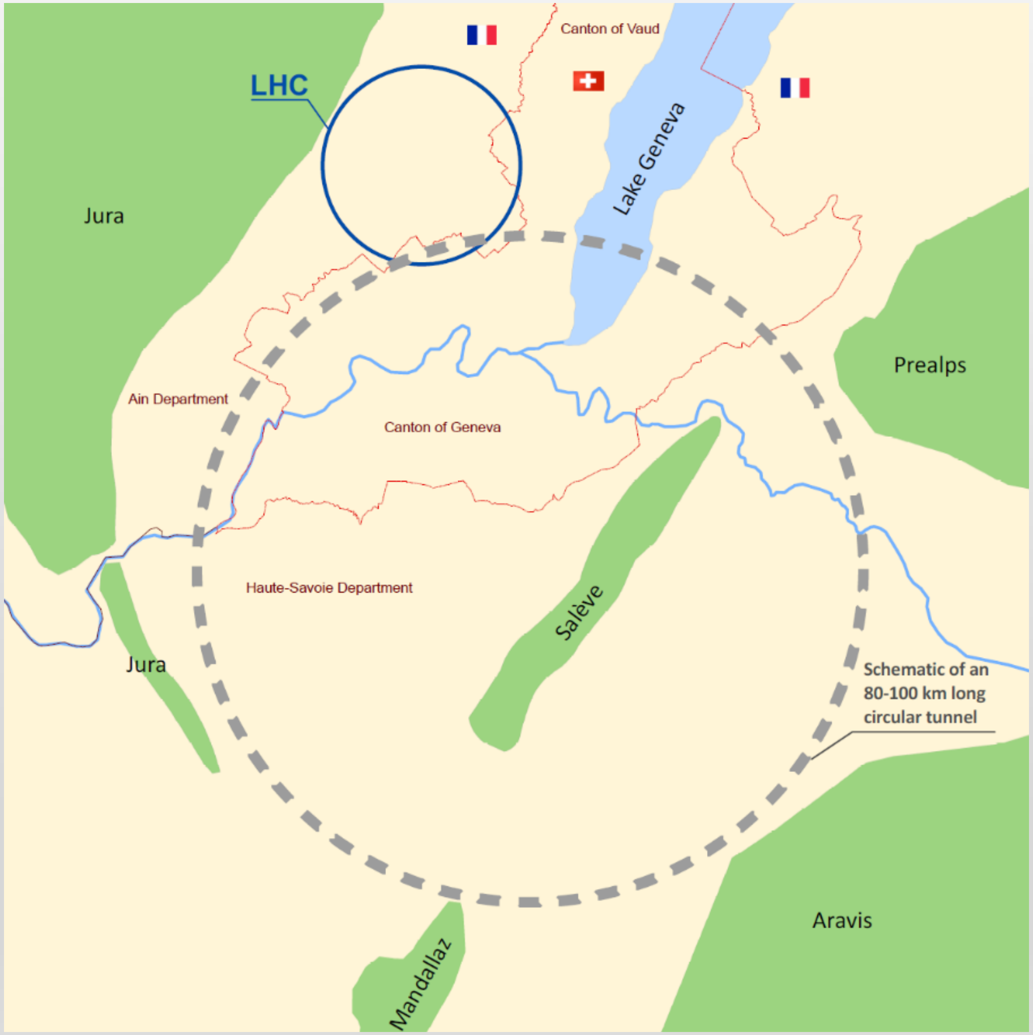


LHC Civil Engineering CMS lowering



The Future Circular Collider Study (FCC)

Collision energy:
100TeV
Circumference:
80km-100km
Physics considerations:
Enable connection to the LHC (or SPS)
Construction:
c.2025-35
Cost:
TBC
Aims of the civil engineering feasibility study:
Is 80km-100km feasible in the Geneva basin?
Can we go bigger?
What is the 'optimal' size?
What is the optimal position?



Potential locations : European Strategy : Krakow 2012

Pre-feasibility study focused on:

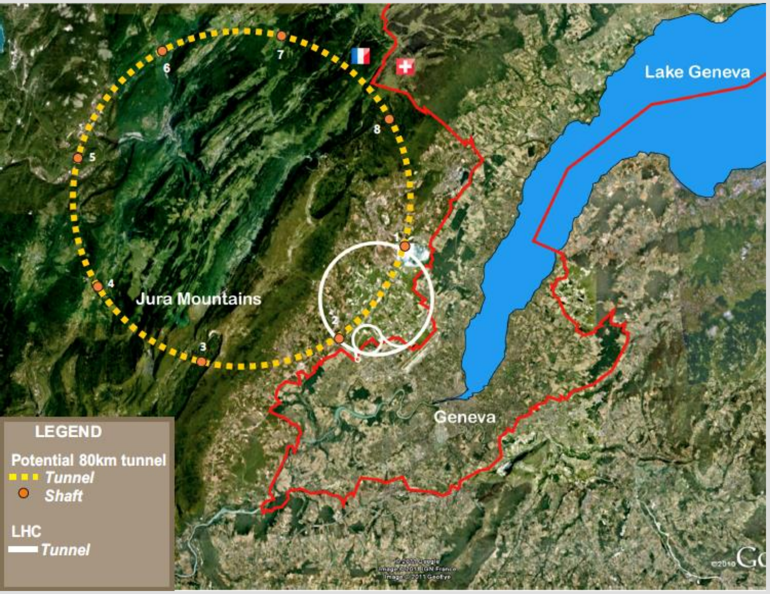
- geology & hydrogeology,
- tunneling & construction,
- environmental impacts

Result: for the 80km long tunnel location 2 ‘80km Lakeside’ is most feasible.

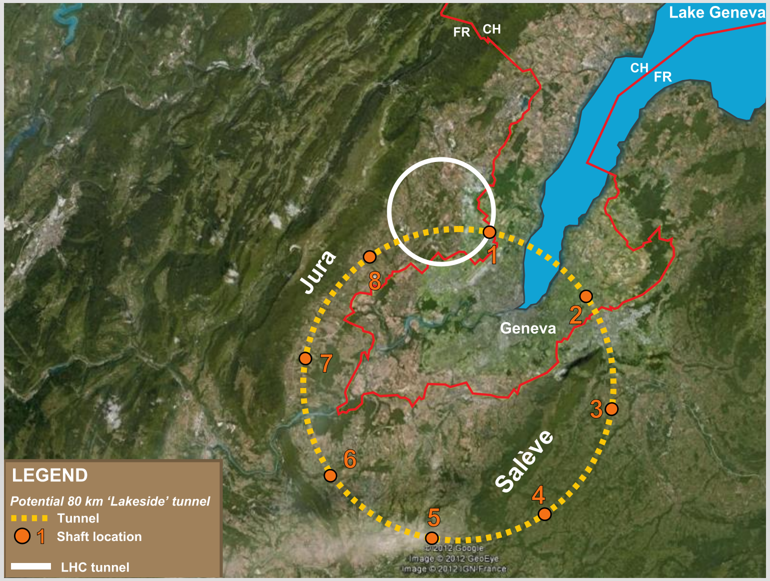
Risk

	water ingress	heaving ground	weak marls	hydro carbons	support & lining	ground response & convergence	hydrostatic pressure & drainage	Pollution of aquifers	effect of shafts on nature	effects of shafts on urban areas	**Total**
Jura 80	5	3	0	0	5	4	5	5	4	2	**33**
Lake 80	2	0	3	3	3	3	2	2	3	2	**23**
Lake 47	1	0	2	2	2	2	1	1	2	5	**18**

Feasibility
Low
High



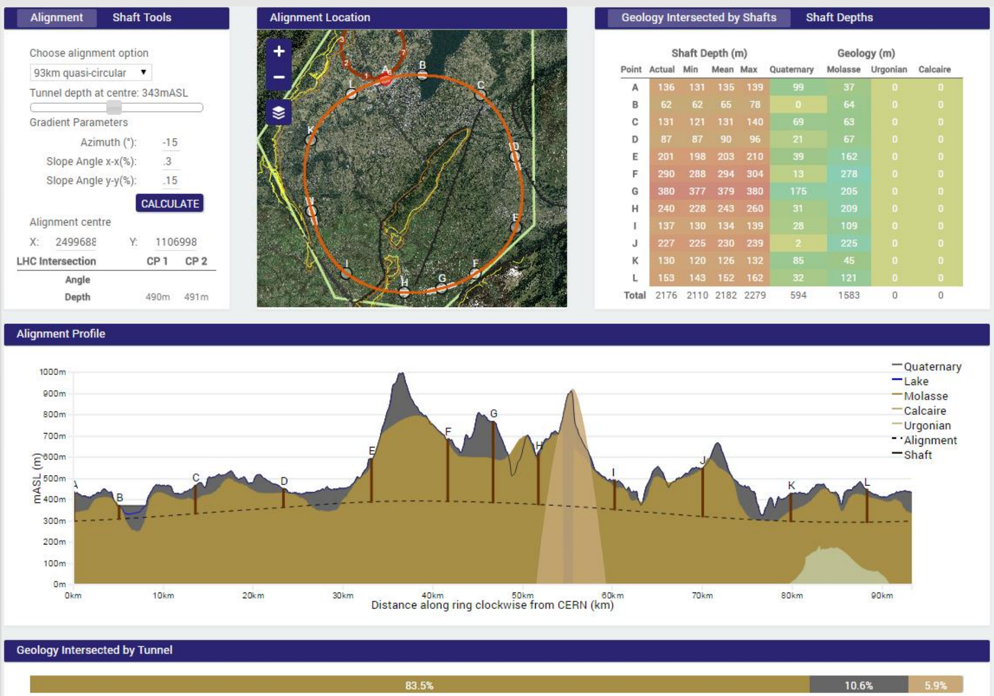
Option 1: 80km Jura



Option 2: 80km Lakeside

The Digital Approach – ARUP & the Tunnel Optimisation Tool (TOT)

- Optimisation studies for the project configuration have been the focus of work since the Kick-Off meeting
- ARUP(UK) mandated to produce a 3D geological model to allow various layouts for the machines to be analysed. This model will allow different tunnel shapes, circumferences, inclinations etc. to be entered into the model and determine the rock types housing the machine



User Inputs

- Initially 6 Alignments Options
- Interactive alignment location on map
- Alter Shaft locations - slidebar
- Select Tunnel Depth - slidebar
- Select Tunnel Gradient - slidebar

Outputs

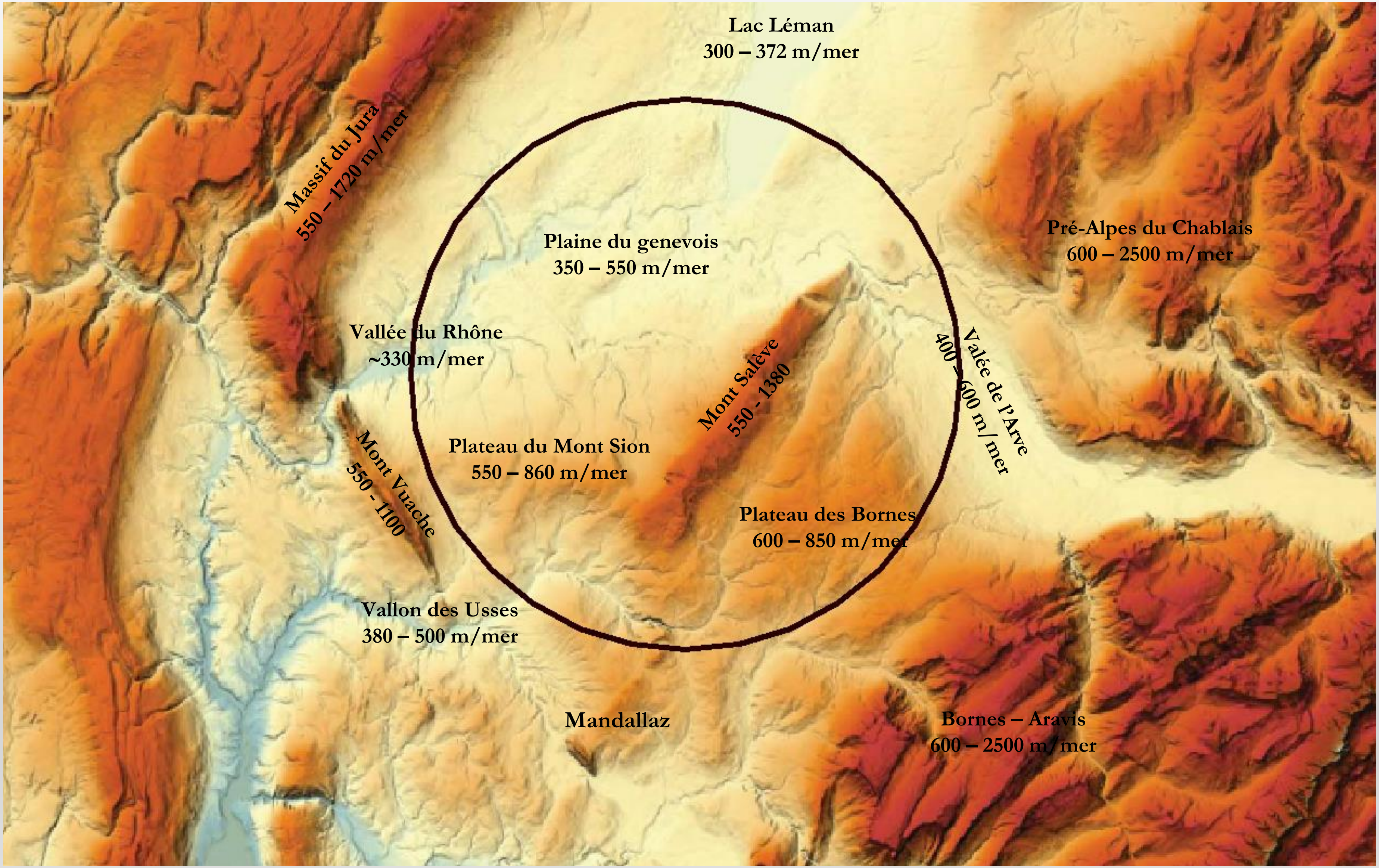
Dynamic Chart:

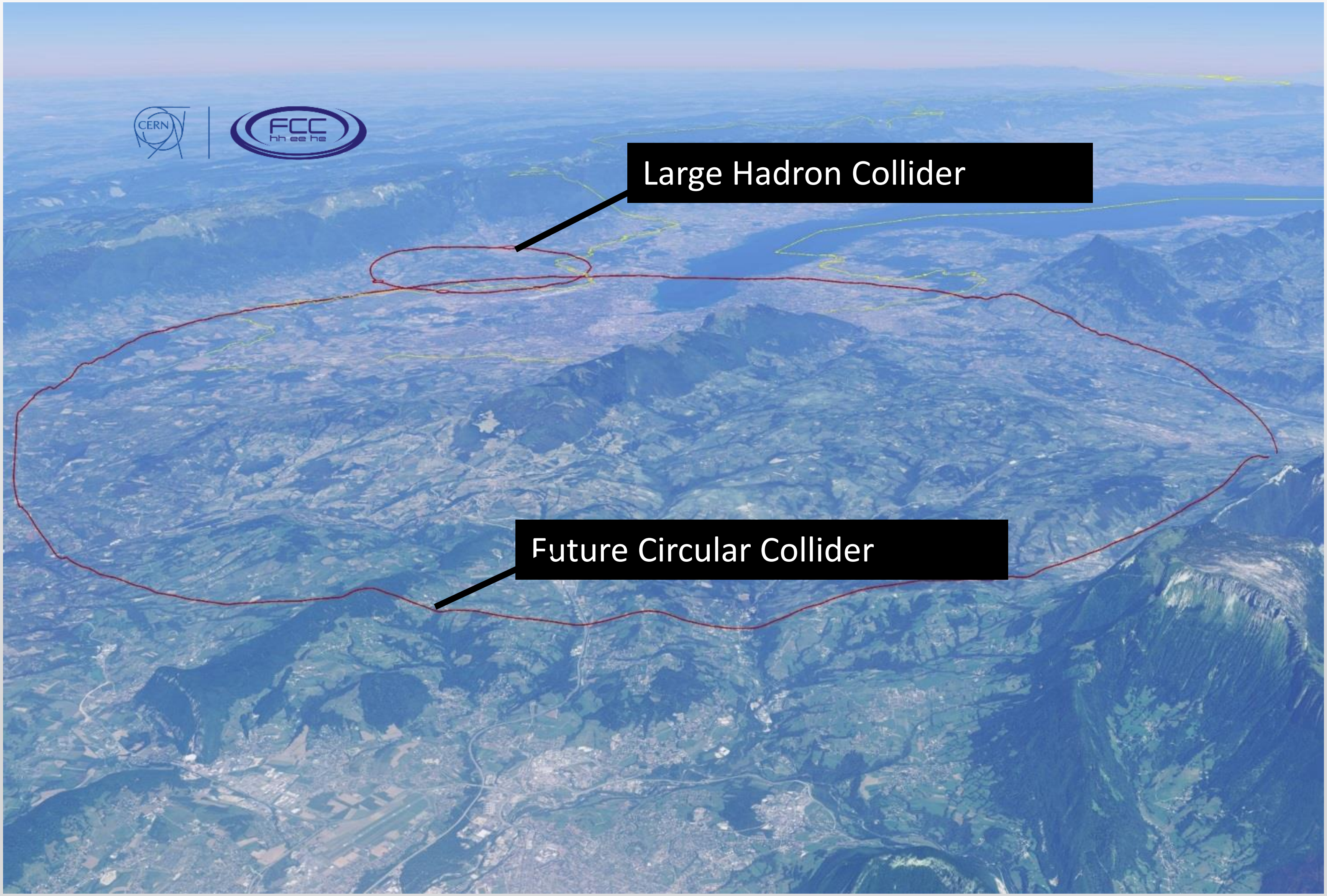
- Profile surface elevation and geology
- Profile of tunnel
- Shaft Locations
- Warnings when tunnel above ground level

Dynamic Tables:

- Depth to tunnel (mASL)
- Shaft Length intersecting geology layer
- % age of tunnel intersecting geology

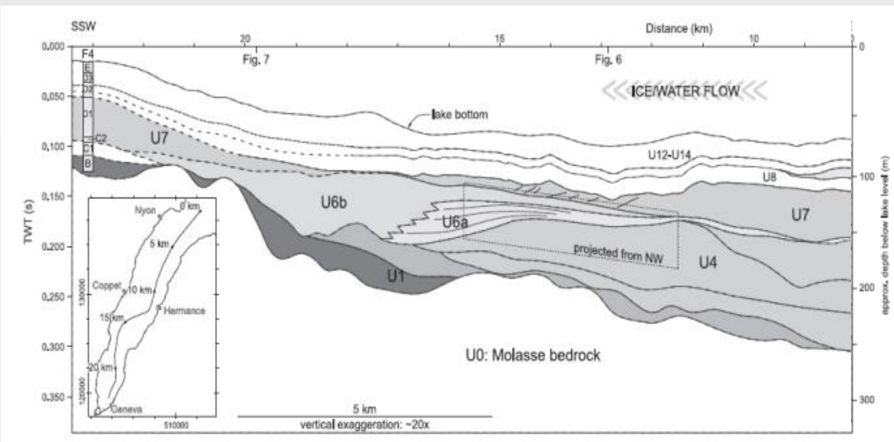
CE considerations for input into the tool : *topography*




Large Hadron Collider
Future Circular Collider

CE considerations for input into the tool : *some critical areas*

Rhone leaving the Geneva Basin



Depth under lake Geneva
(in molasse or moraines)

Avoid Vuache faulting

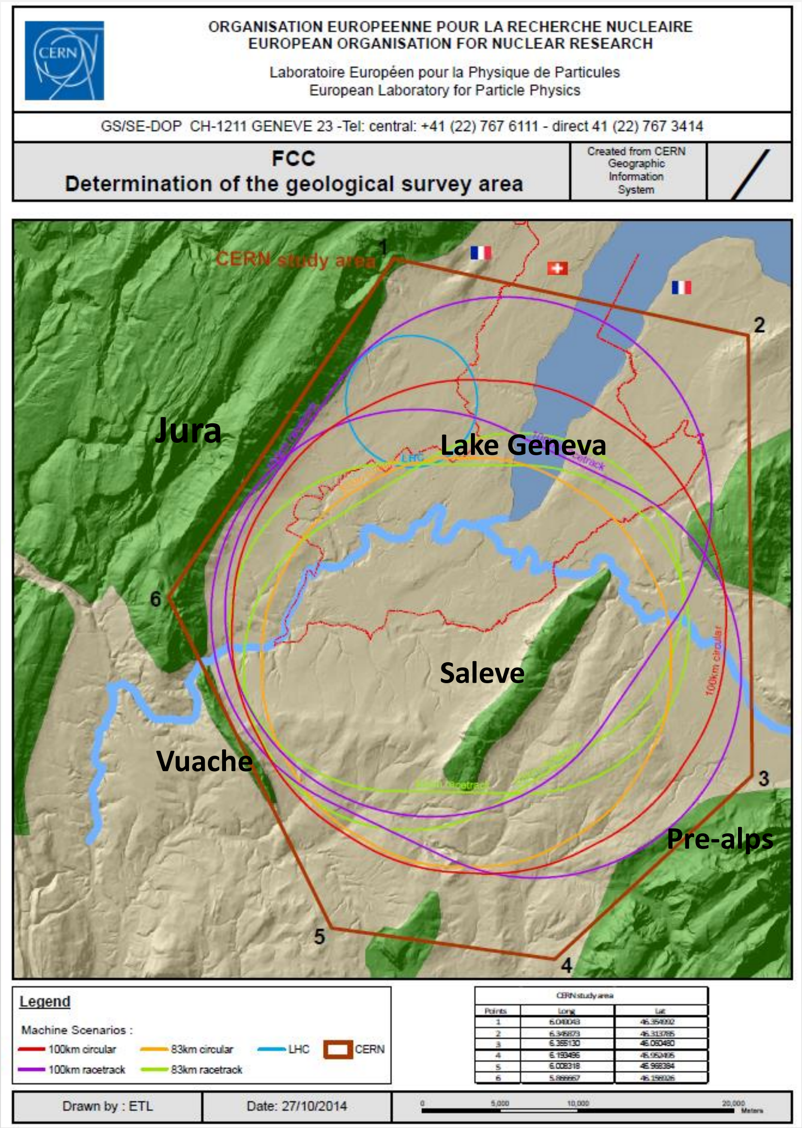
Feasibility Study – Study Boundaries

Jura
High overburden
Karstic limestone

Vuache
Highly fractured limestone with karst

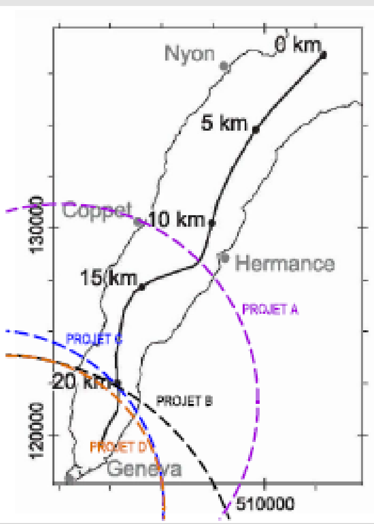
Pre-alps
Rapidly increasing tunnel depth
Less well-known limestone

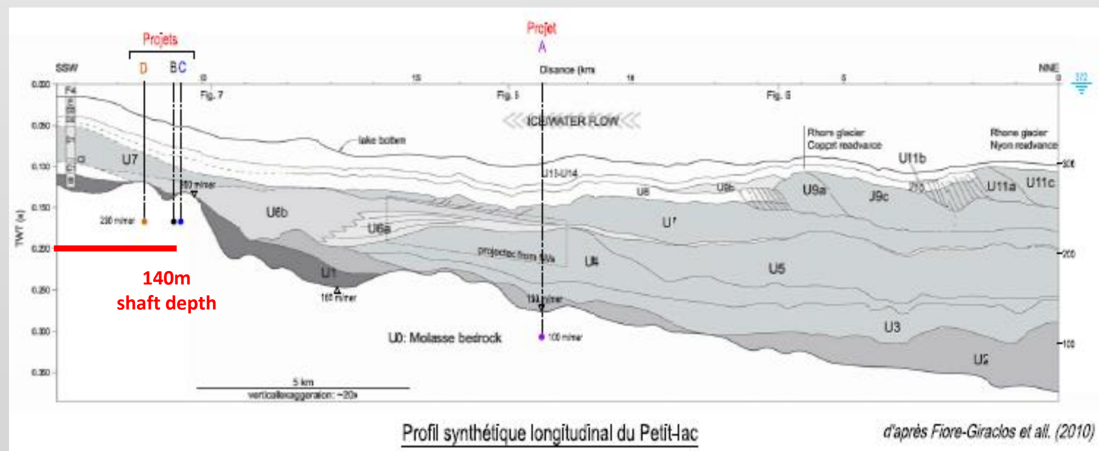
Lake Geneva
Lake depth increases quickly in NE direction



Feasibility study – Lake Geneva

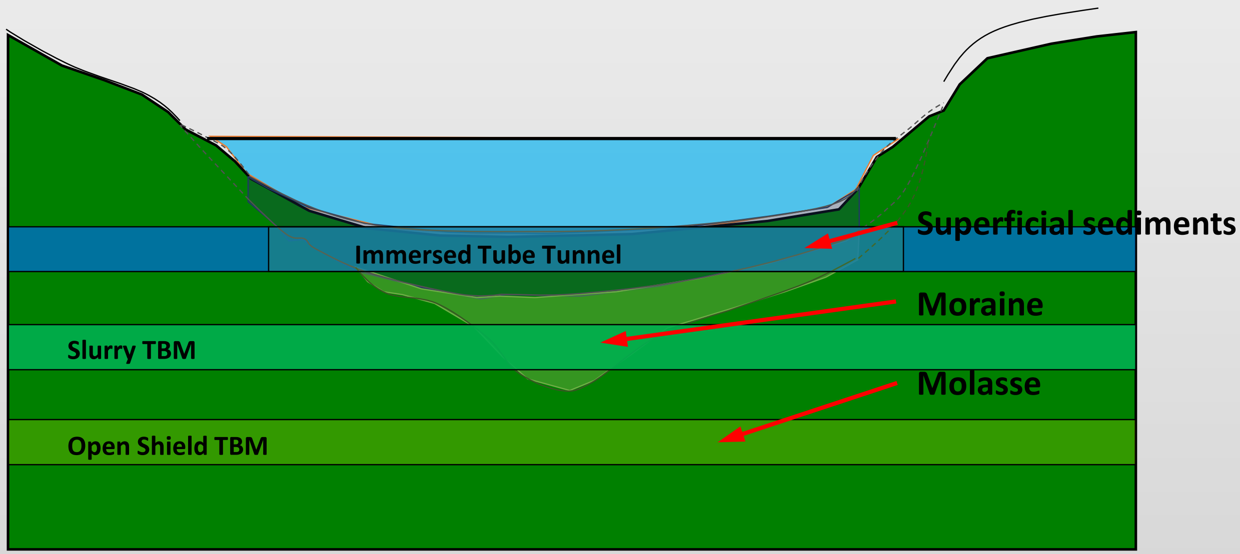
- Geology is not yet well understood
- Some seismic soundings performed for the possible construction of a road tunnel
- Molasse bedrock covered by a deep layer of moraines





Feasibility Study – Geology

Lake Crossing: Tunnelling Considerations

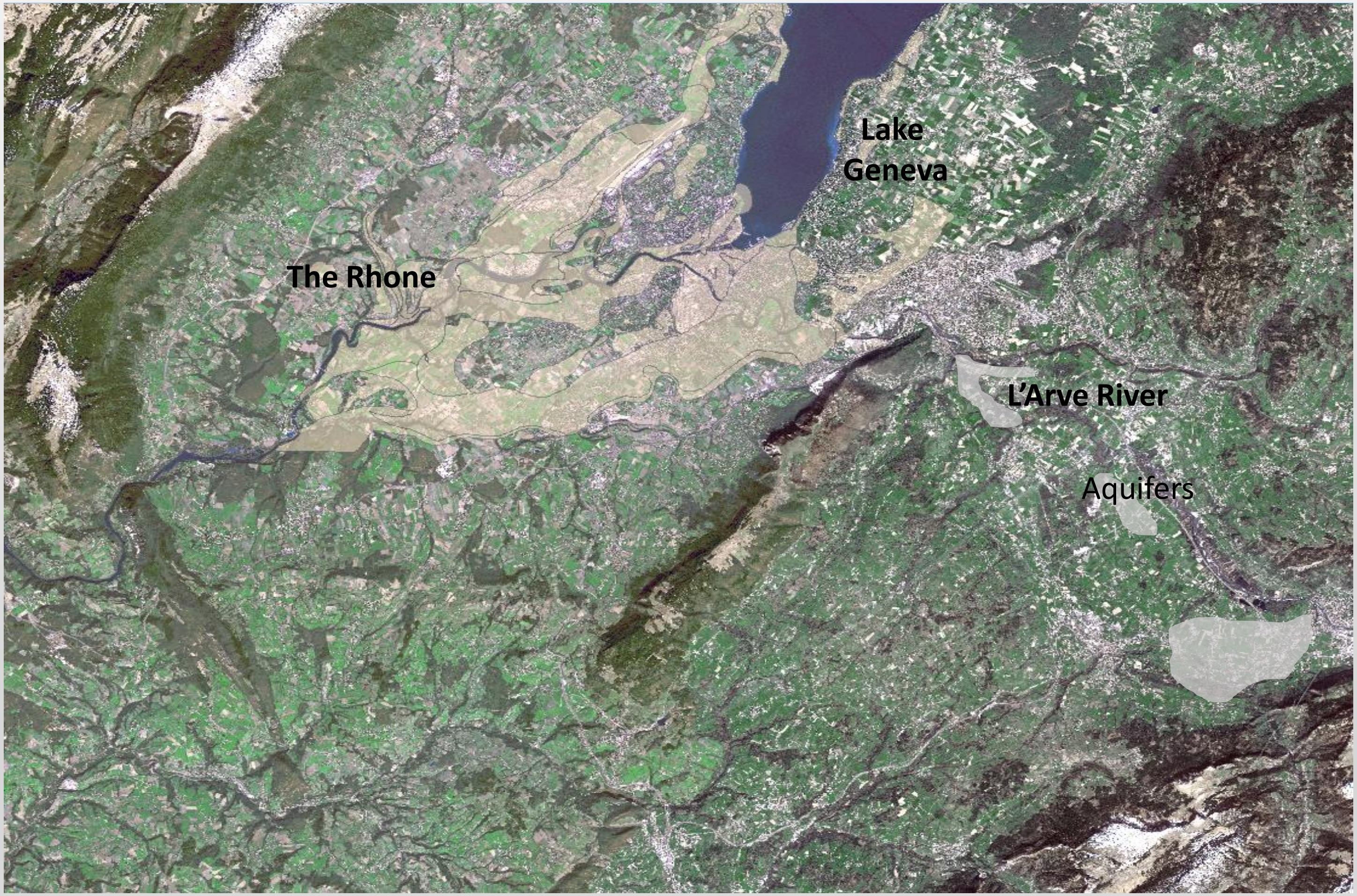


Medway
Tunnel
Immersed
Tube Tunnel

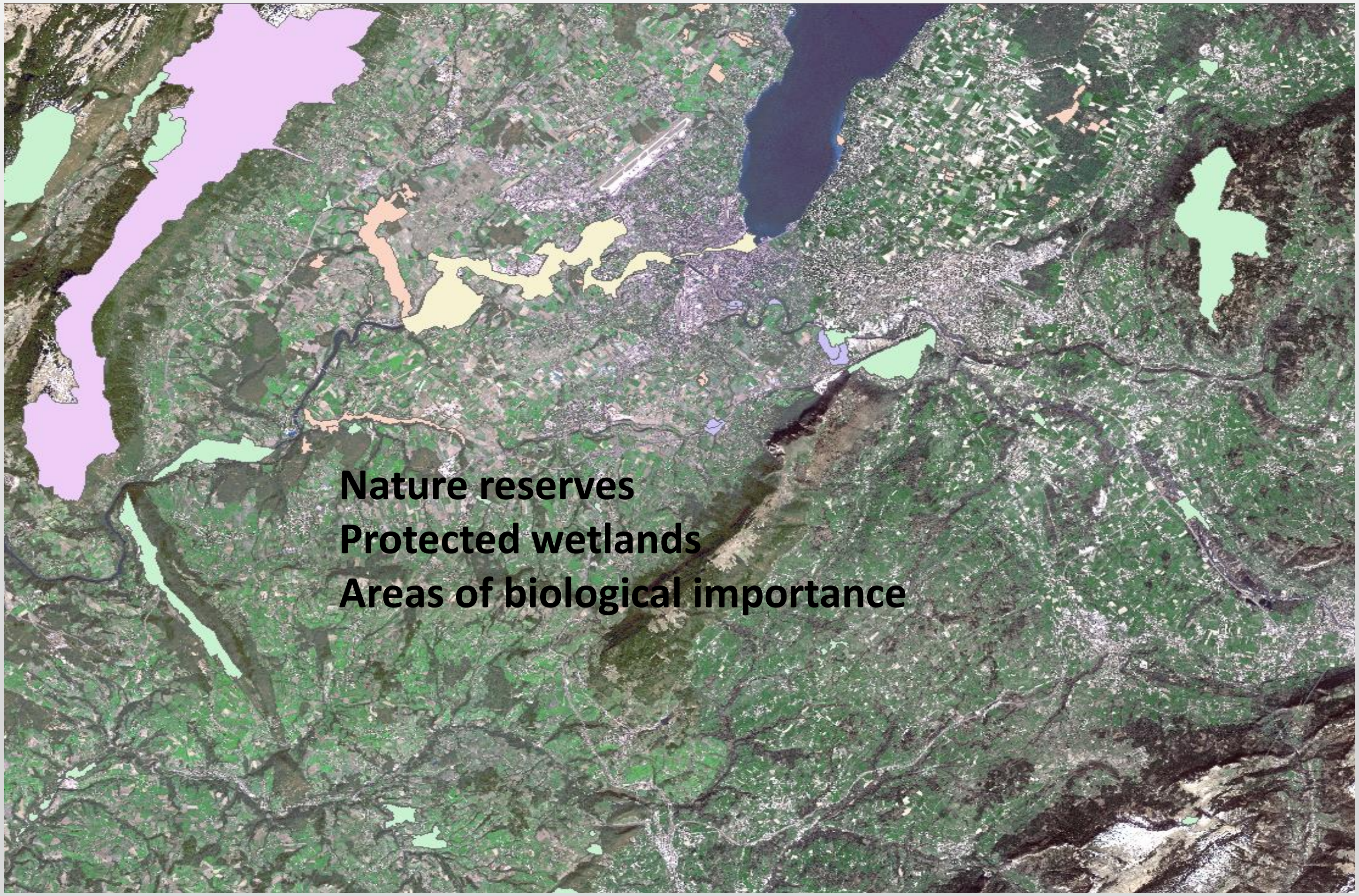
BIM – Tunnel Optimisation Tool

- Streamlines the conventional approach which is broadly linear and manual
- Max value extracted from early project data
- Single Source of Data
- Visual decision aid
- Clash detection – Regional Scale
- Iterative process and comparison of options

Feasibility Study – Hydrology

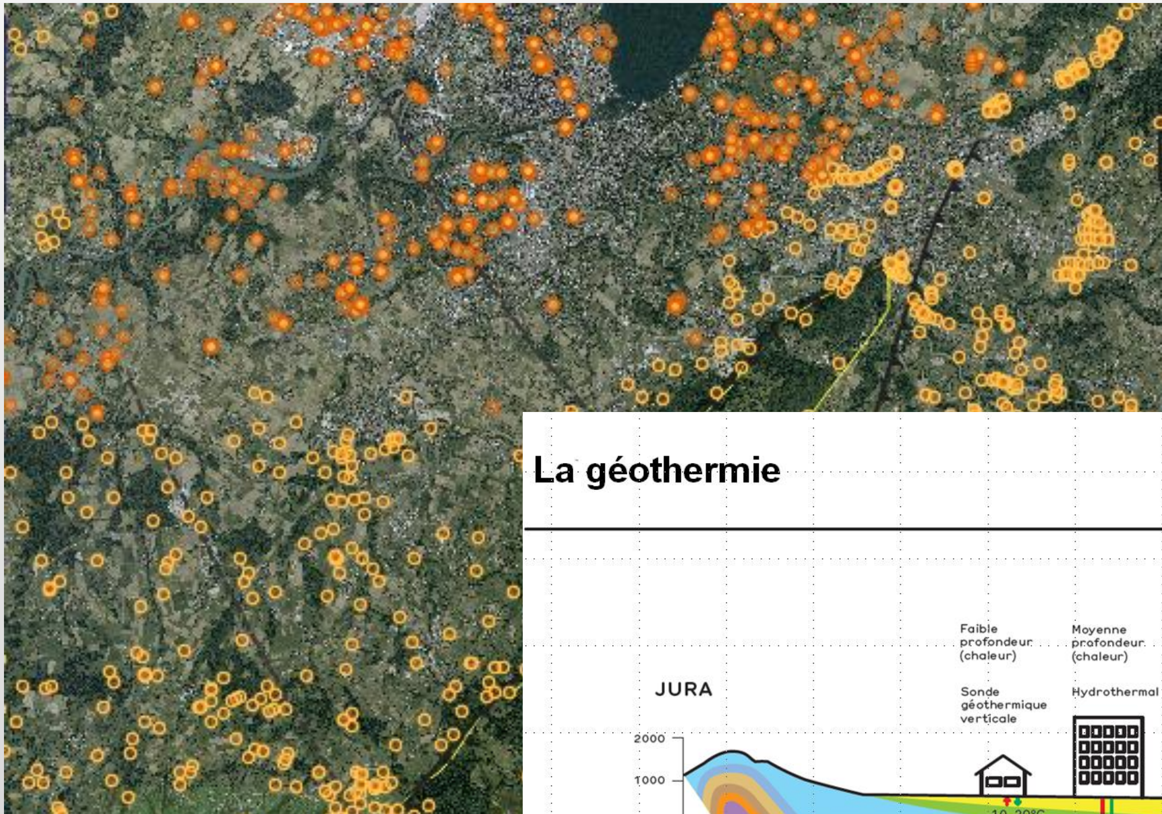


Feasibility Study – Environmental Considerations

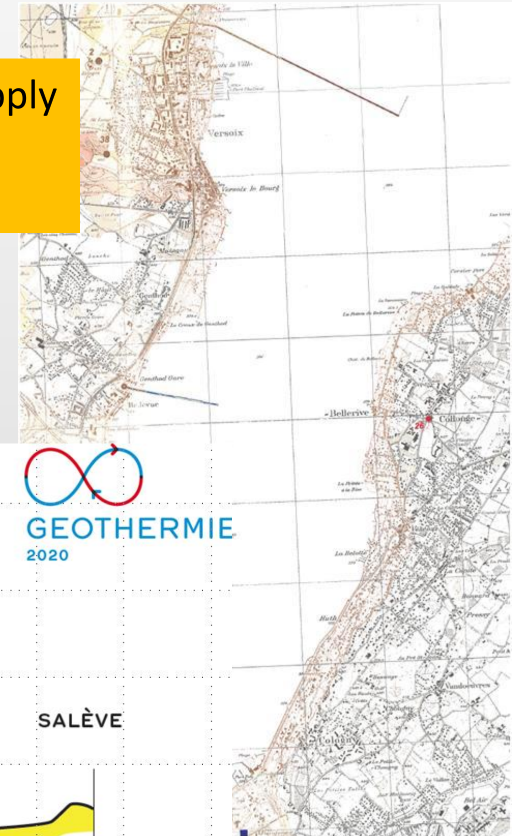


Feasibility Study – Buildings

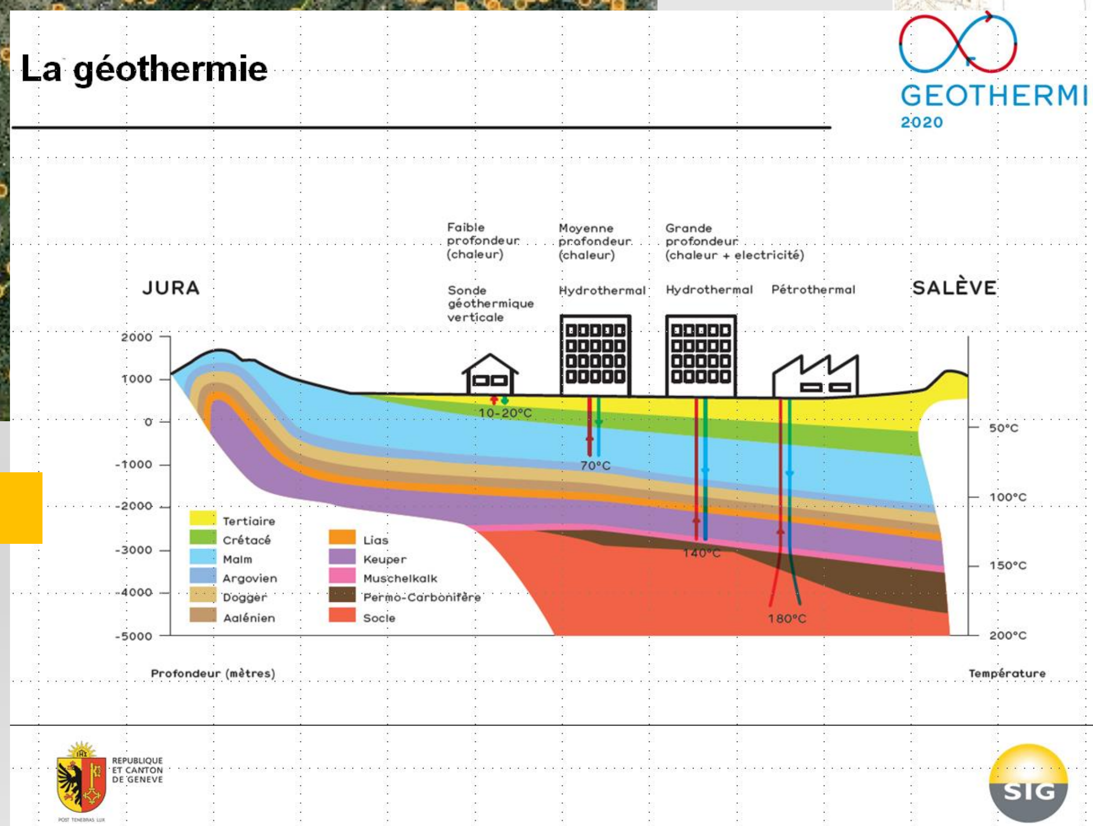
Feasibility Study – Geothermal Boreholes



Geothermal drillings

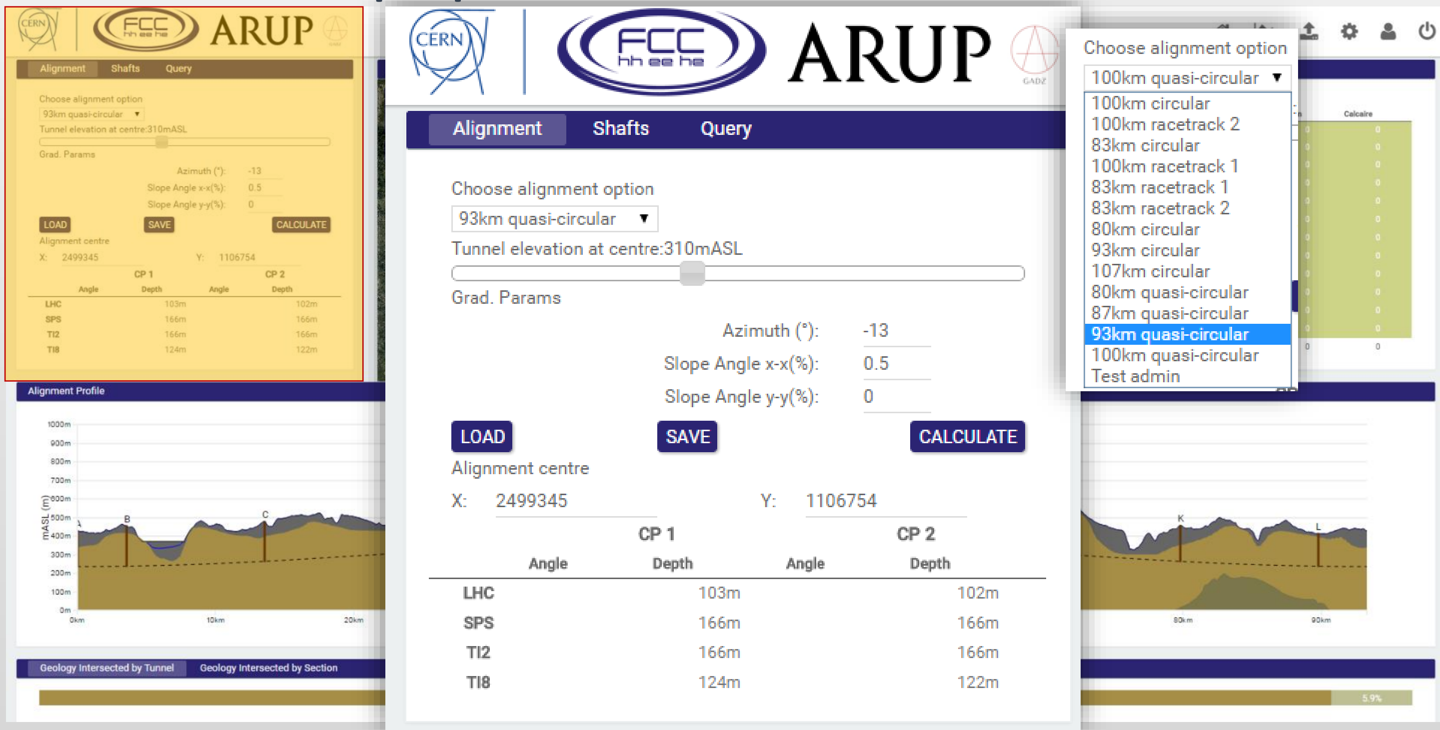


Water supply pipelines



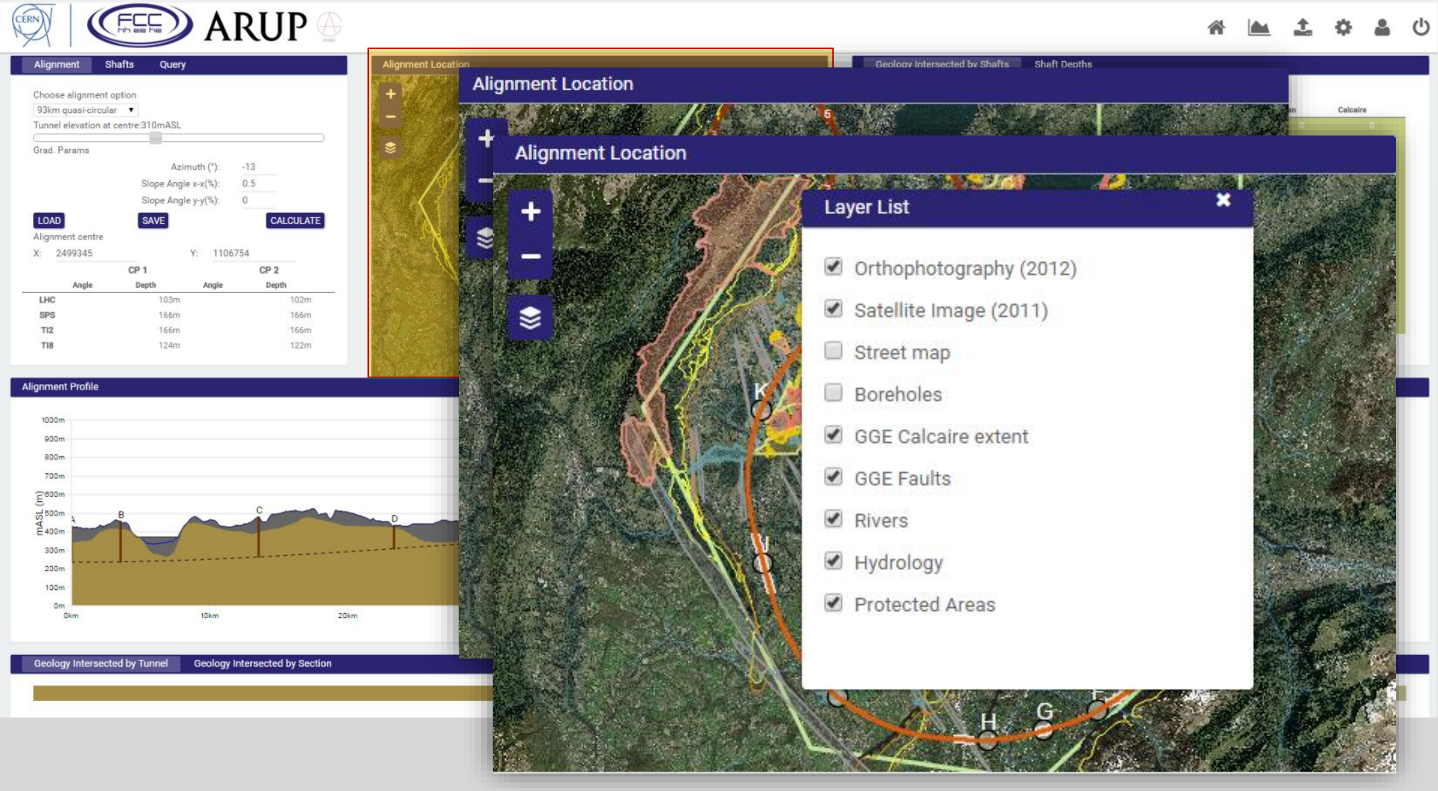
BIM – Tunnel Optimisation Tool

User interface - Input parameters



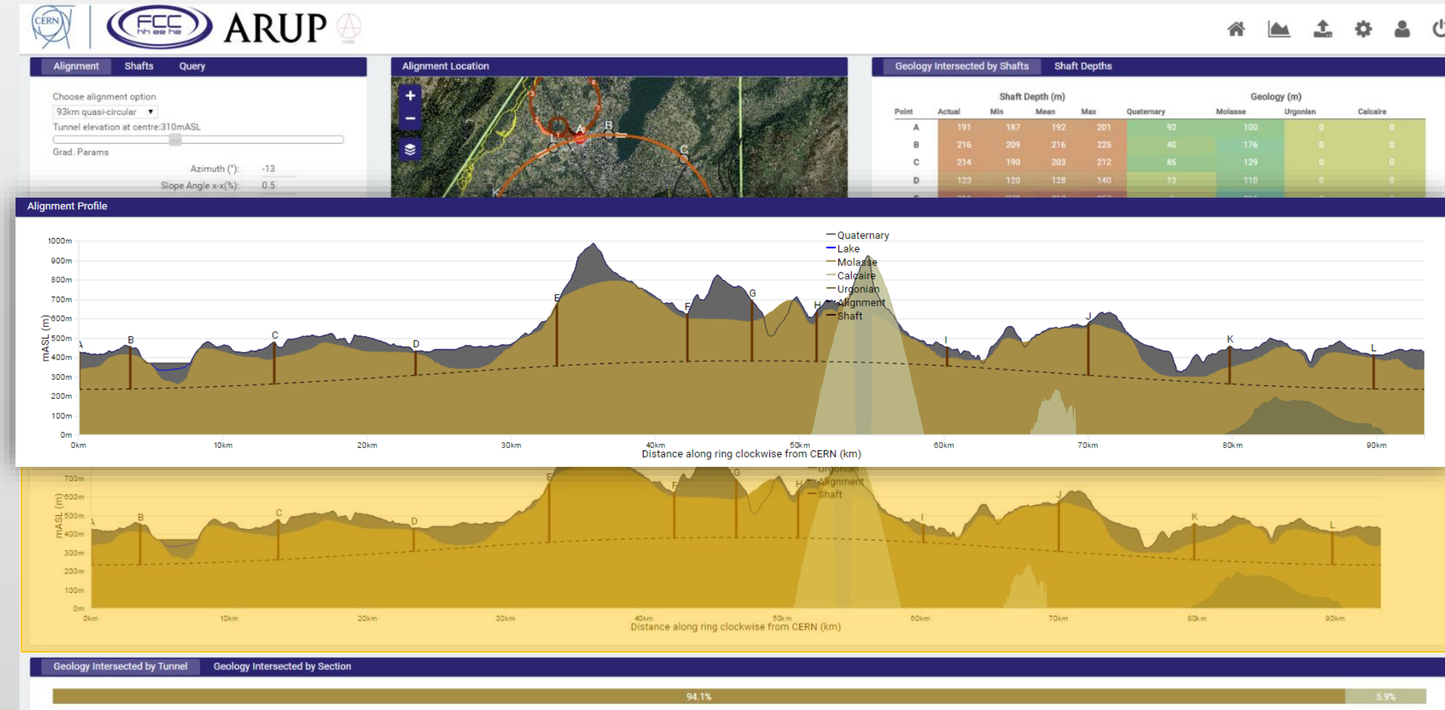
BIM – Tunnel Optimisation Tool

User interface - Input parameters



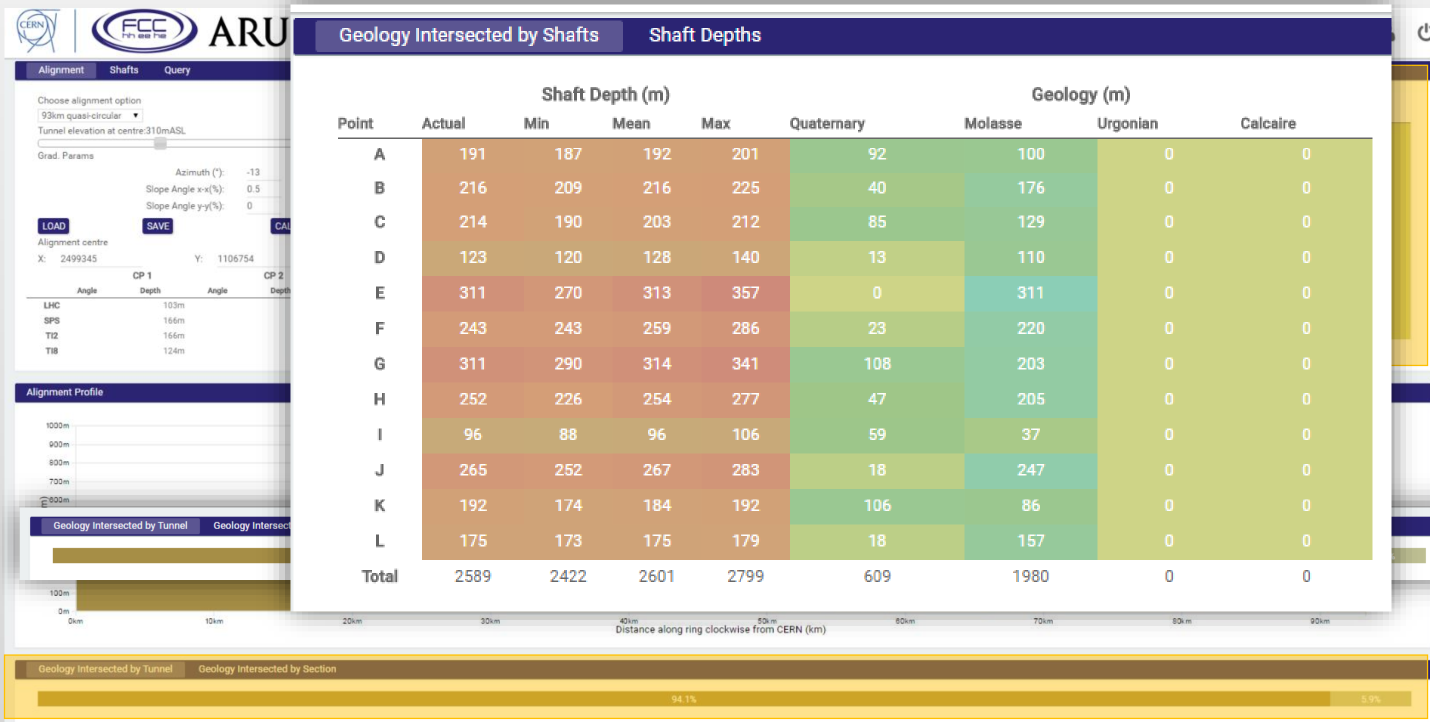
BIM – Tunnel Optimisation Tool

User interface – Alignment profile



BIM – Tunnel Optimisation Tool

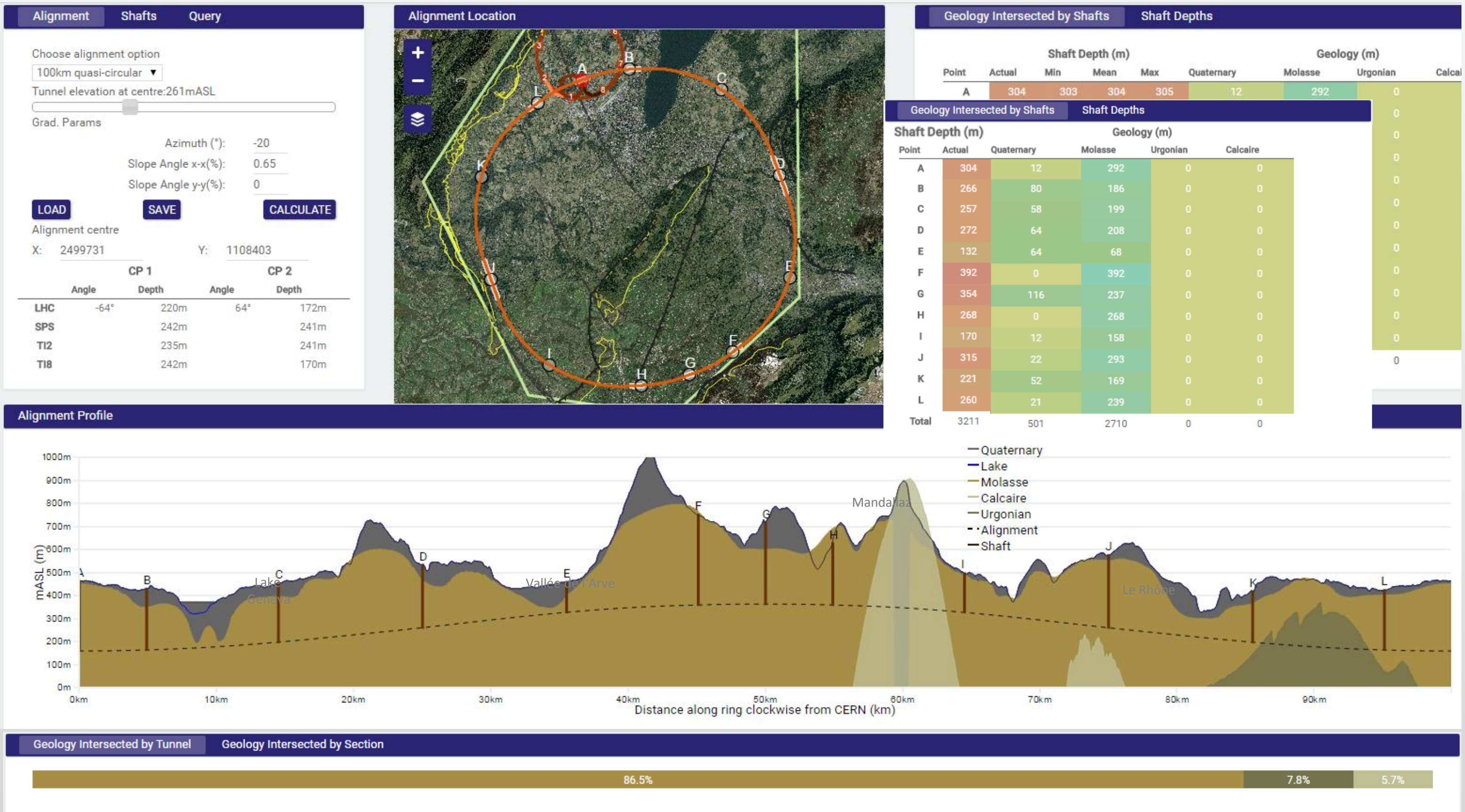
User interface – Outputs



Geology Intersected by Shafts | Shaft Depths

Point	Shaft Depth (m) Actual	Min	Mean	Max	Geology (m) Quaternary	Molasse	Urgonian	Calcaire
A	191	187	192	201	92	100	0	0
B	216	209	216	225	40	176	0	0
C	214	190	203	212	85	129	0	0
D	123	120	128	140	13	110	0	0
E	311	270	313	357	0	311	0	0
F	243	243	259	286	23	220	0	0
G	311	290	314	341	108	203	0	0
H	252	226	254	277	47	205	0	0
I	96	88	96	106	59	37	0	0
J	265	252	267	283	18	247	0	0
K	192	174	184	192	106	86	0	0
L	175	173	175	179	18	157	0	0
Total	2589	2422	2601	2799	609	1980	0	0

Feasibility Study – Early results
100km circumference : "LHC Intersecting option"



- Avoids Jura limestone: **No**
- Max overburden: **650m**
- Deepest shaft: **392m**
- % of tunnel in limestone: **13.5%**
- Total shaft depths: 3211m

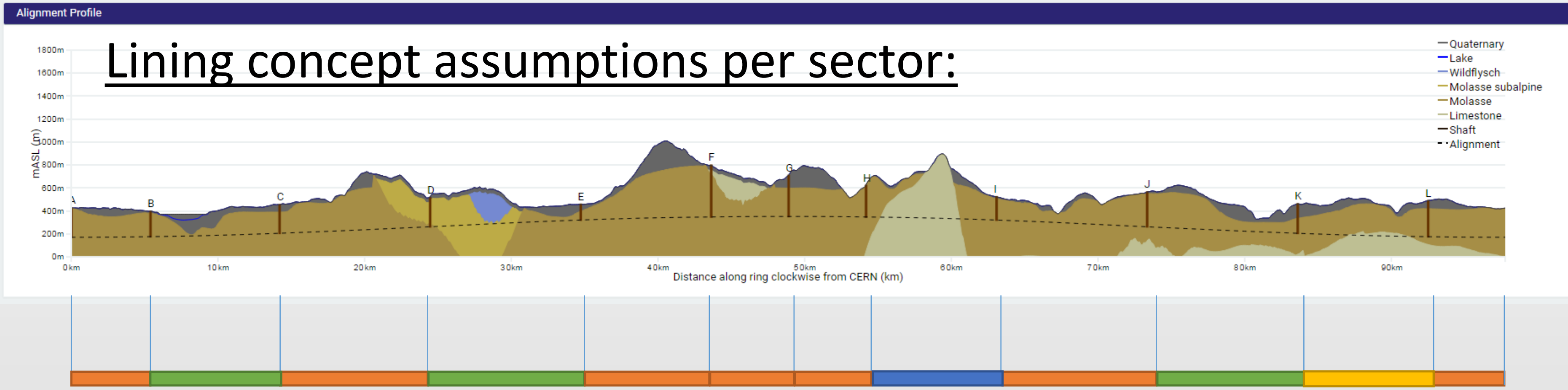
Point A Campus: Prevessin (large potential area)

Challenges:

- 7.8km tunnelling through Jura limestone
- 300m-400m deep shafts and caverns in molasse

FCC Tunnel Lining Concepts

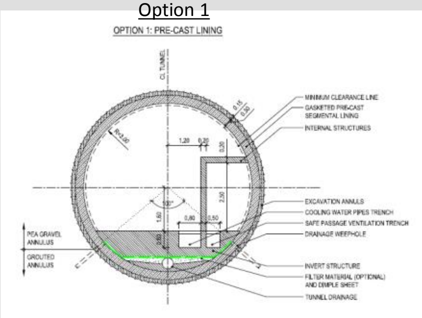
Lining concept assumptions per sector:



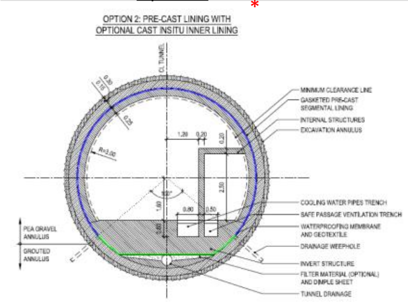
Lining option: 1 2 1 2 1 1 1 3 1 2 4 1

TBM Tunnel options

Option 1



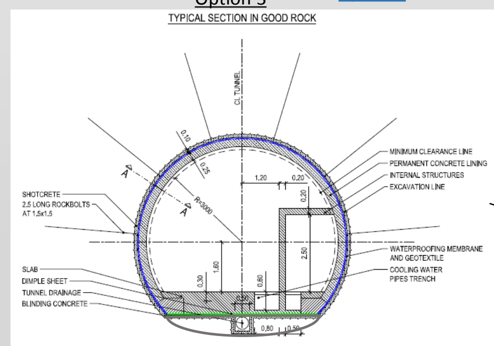
Option 2 *



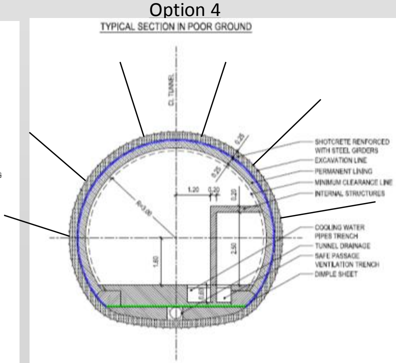
*It is assumed 50% will have optional inner lining

Mined Tunnel options

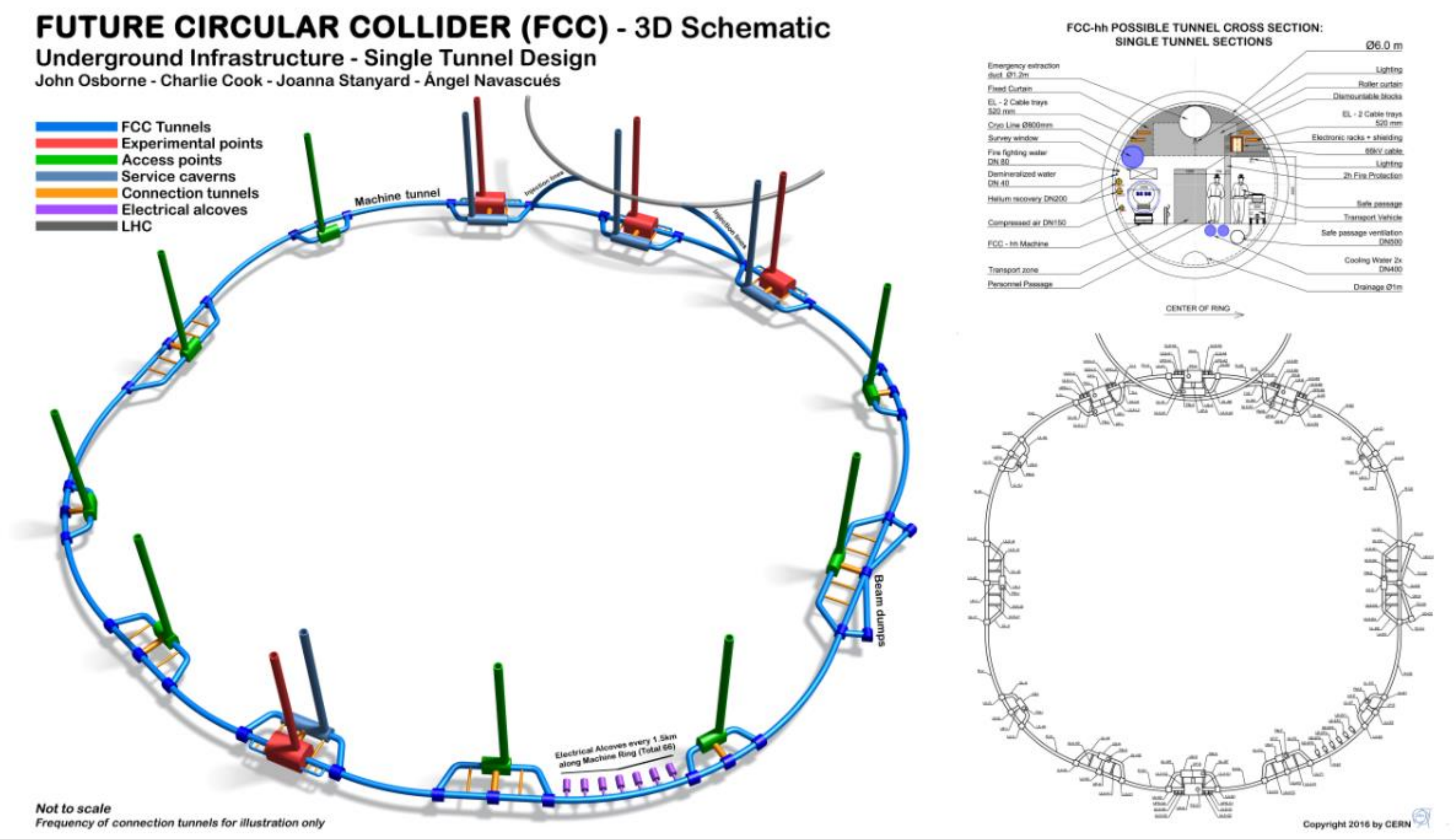
Option 3



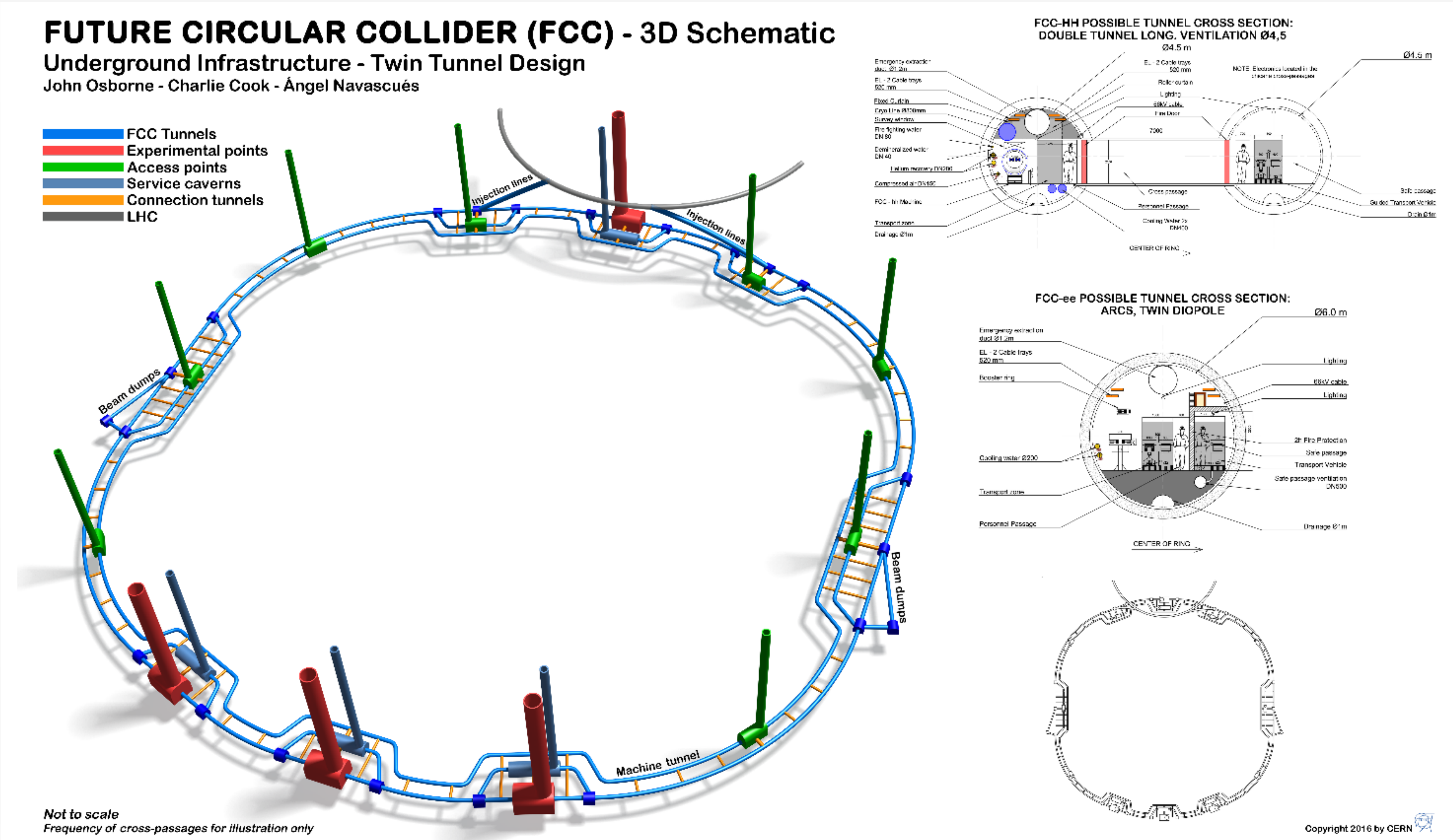
Option 4



FCC Baseline Schematic : Single Tunnel

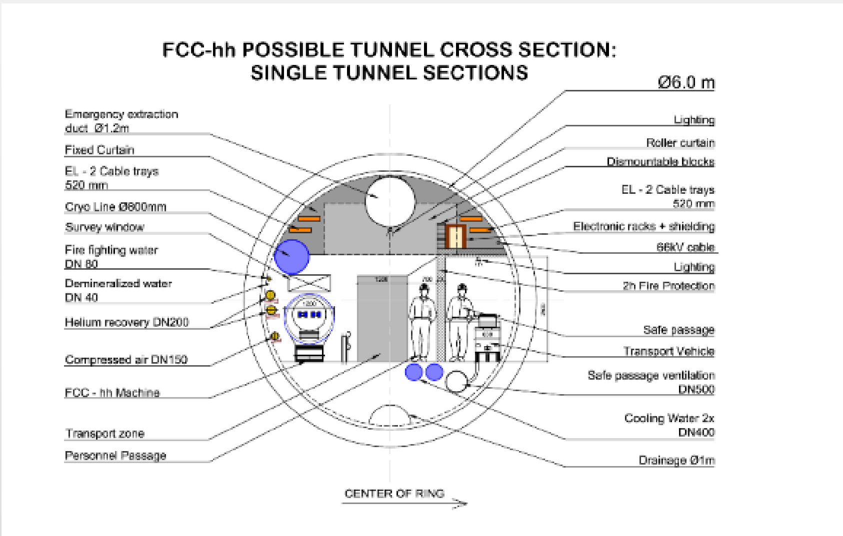


FCC Baseline Schematic : Double Tunnel

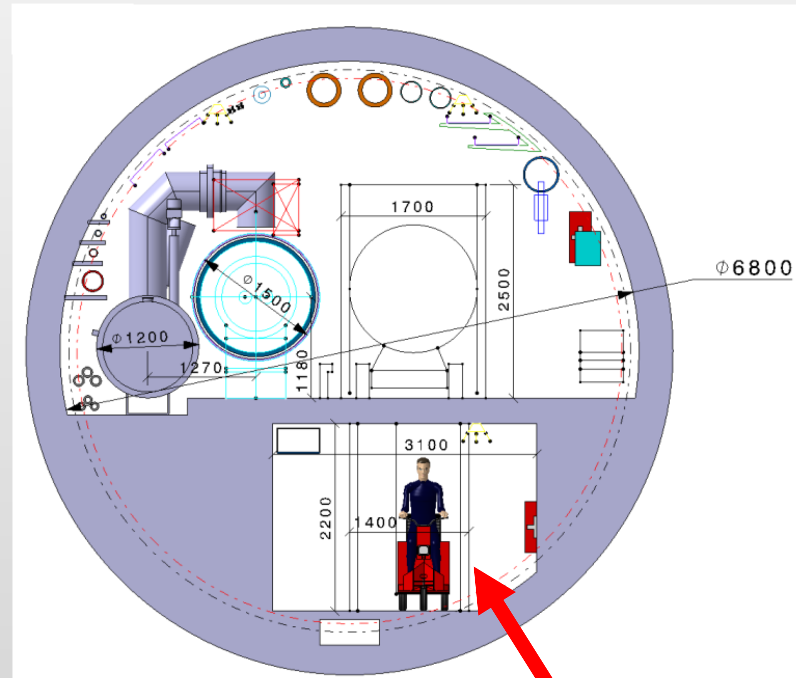


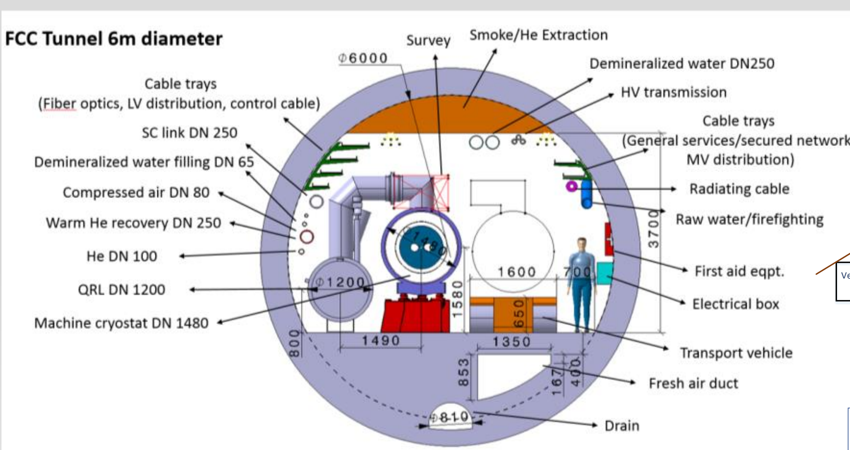
FCC Single tunnel – possible cross-sections

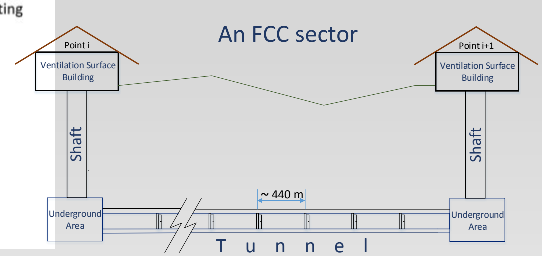
6.0m tunnel



6.8m tunnel





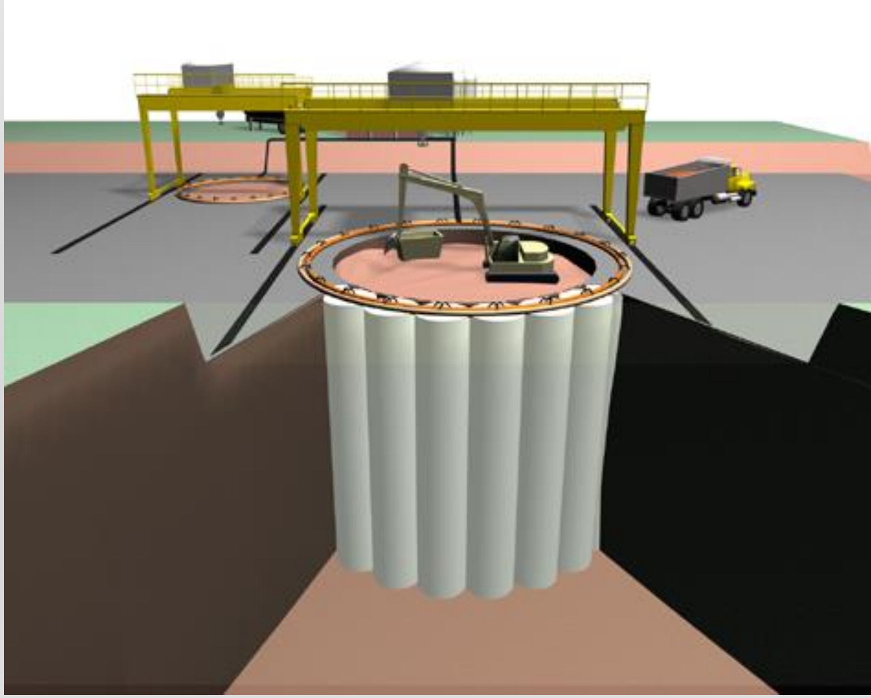


Emergency escape under floor ?

FCC Shafts

- Several possible shaft excavation methods :
    - Traditional in-situ lining during excavation
    - Diaphragm walling or ground freezing
    - Slipform technique for lining shaft

TI2 Area - Start of excavation of PMI 2 shaft - February 17, 1999 - CERN ST-CE



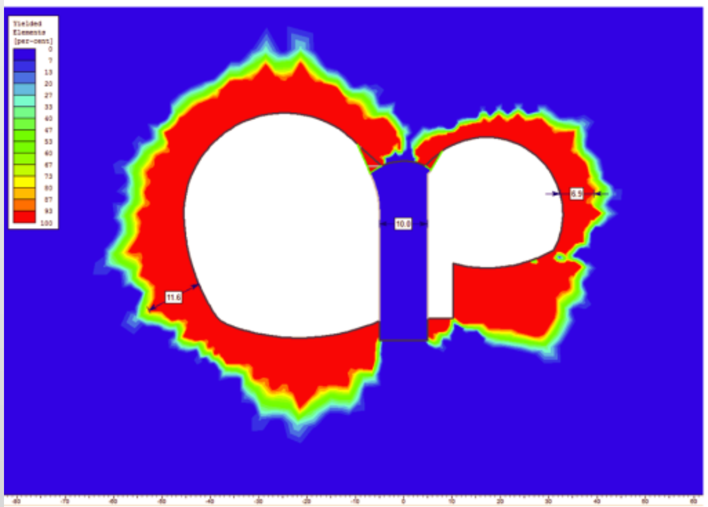
Ground freezing technique used at P5

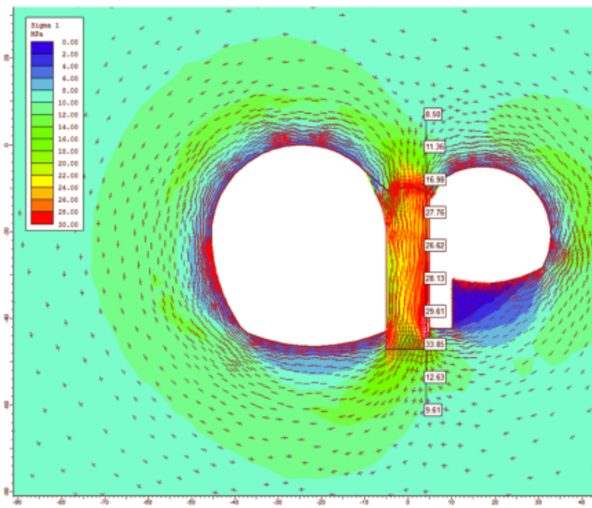
FCC Cavern spacing : Concrete Pillar required

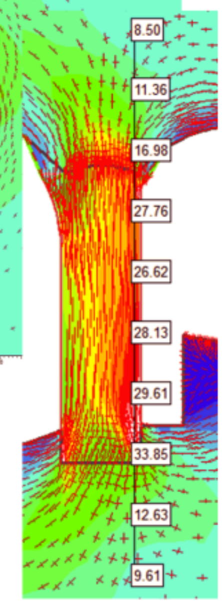
FCC Cavern Study - CERN

Basic Stress Analysis

Cavern situated in Good Molasse, Spacing 10m



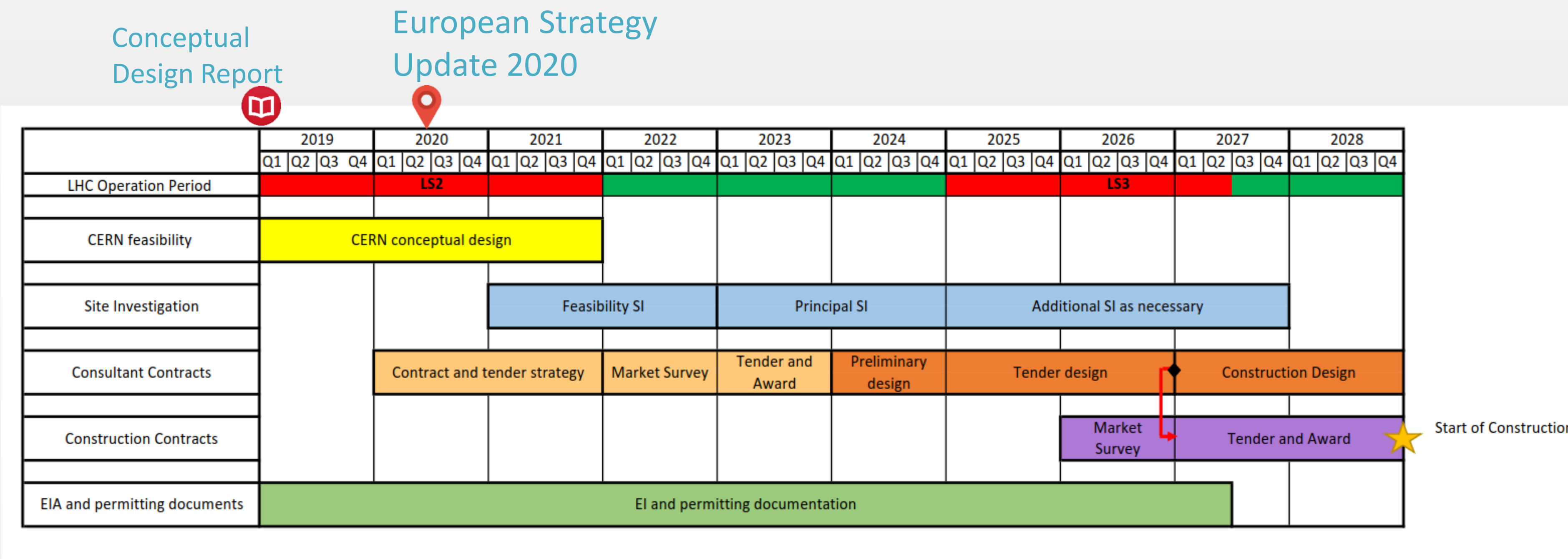




- Depth of failure zone = 12 m
- Expected stresses in concrete Pillar = 35 MPa

AMBERG ENGINEERING

FCC Site investigation planning and pre-construction planning



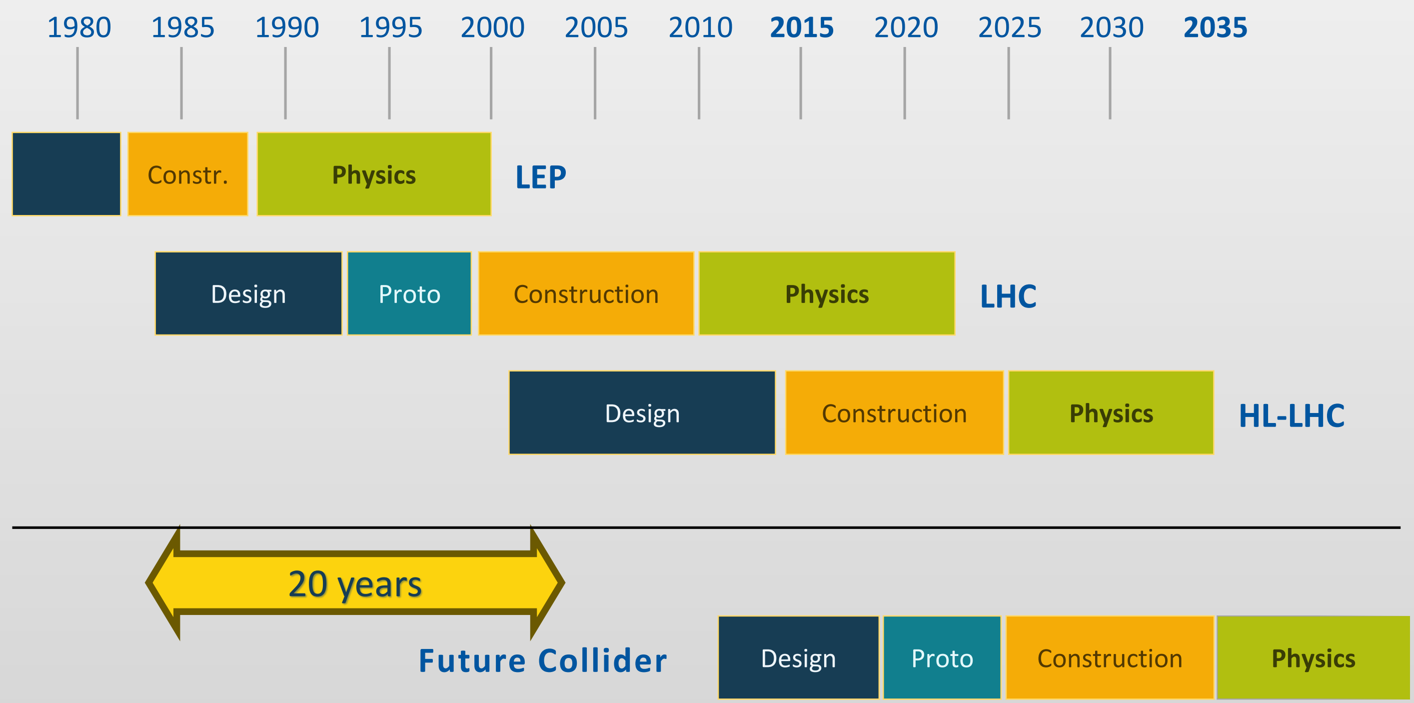
Types of site investigation:

- Collection of existing information
- Walkover survey
- Geophysical investigations (to define interfaces)
- Boreholes
  - Site testing (eg Insitu stress test, point load testing, SPT)
  - Rock laboratory testing.

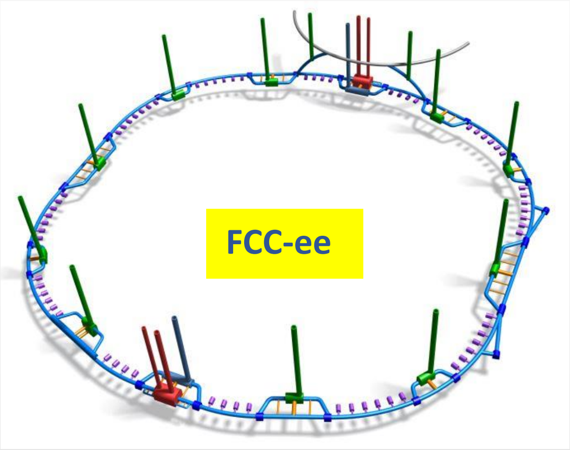
Phases:

Feasibility: Non-intrusive investigations to allow consolidation of alignment. Focus on access points, Lake crossing and the Rhone and Arve crossings.
Principal: Substantial portion of the geotechnical investigations. As a result of this, the alignment might need to be changed.
Additional: Any investigations required for the final design, emphasis on obtaining date required for the contractors.
Administration

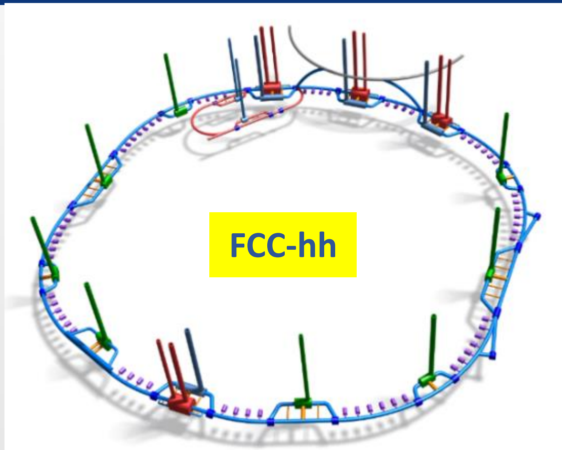
CERN Circular Colliders + FCC



Cost estimates for civil engineering

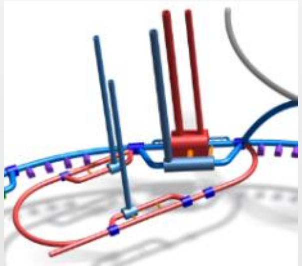


Stage 1: CE Cost estimate: 5400 MCHF



Stage 2 CE Cost estimate: 600 MCHF
Two experimental points added including: 4 shafts, 2 caverns, beam dump tunnels beam transfer tunnel and injection caverns, survey galleries, linkage tunnels, surface structures

Optional eh machine

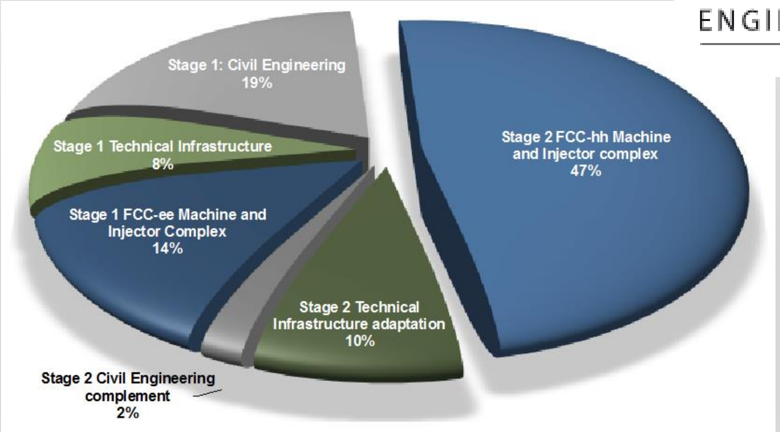


CE cost estimate: 430MCHF

CONSULTING ENGINEERS

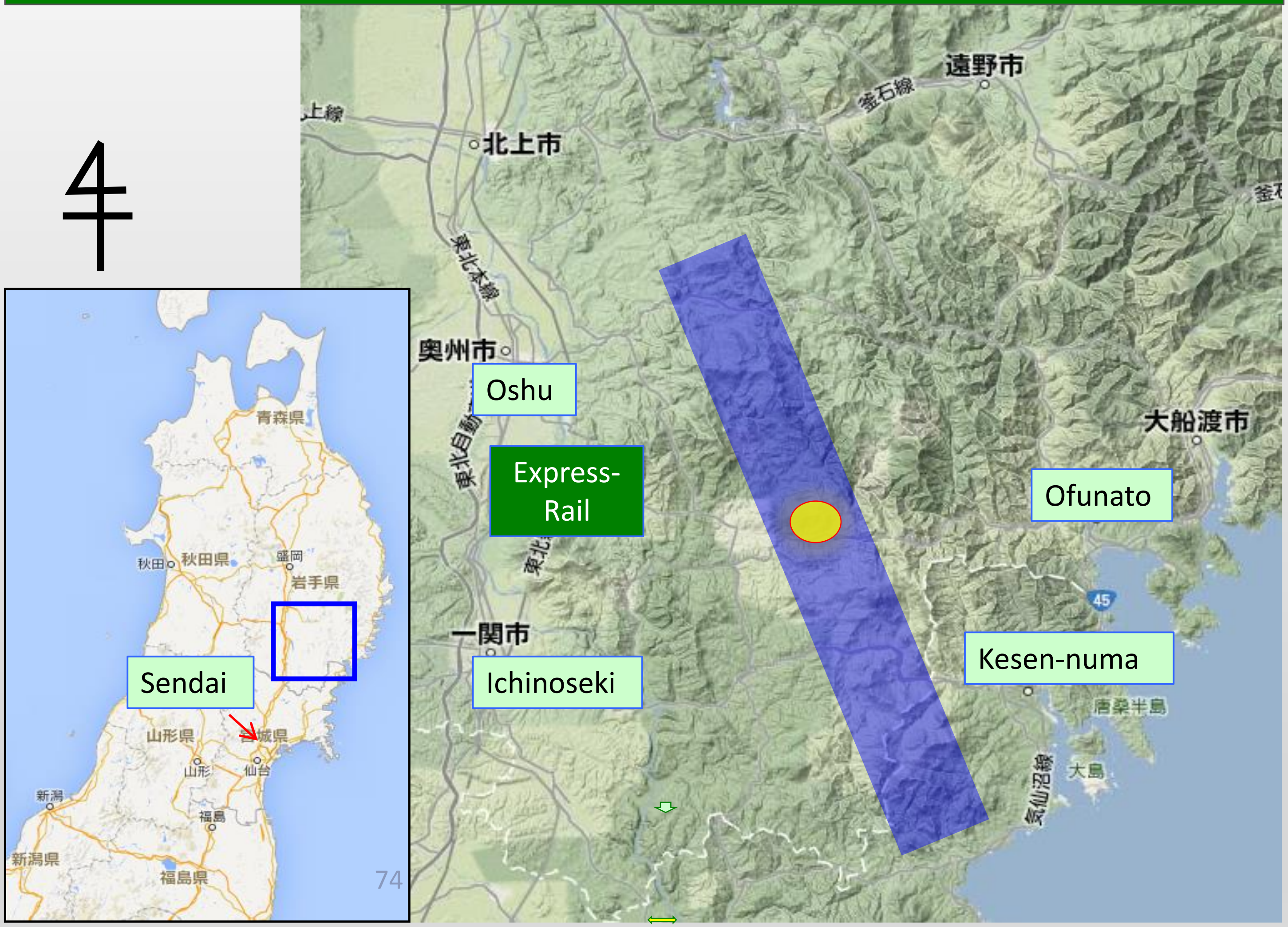
FCC integrated project cost estimate

Domain	Cost in MCHF
Stage 1 - Civil Engineering	5,400
Stage 1 - Technical Infrastructure	2,200
Stage 1 - FCC-ee Machine and Injector Complex	4,000
Stage 2 - Civil Engineering complement	600
Stage 2 - Technical Infrastructure adaptation	2,800
Stage 2 - FCC-hh Machine and Injector complex	13,600
TOTAL construction cost for integral FCC project	**28,600**



**The expected accuracy range is between -30% and +50% for feasibility stage*

ILC Site Candidate Location in Japan: Kitakami



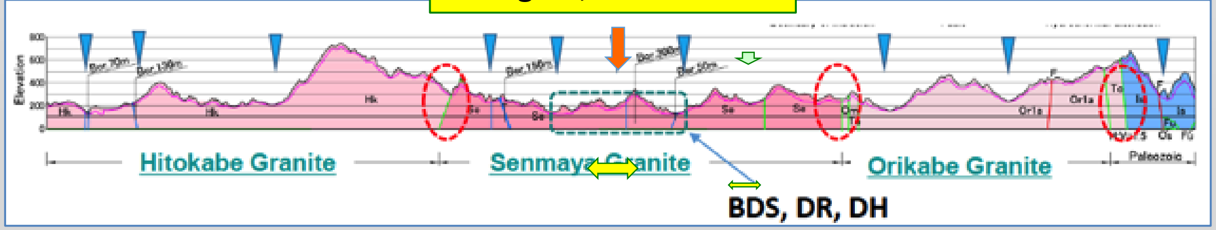
A. Yamamoto,
15/11/02

A New Borehole at a Candidate Interaction Point

Courtesy: T. Sanuki

A new boring test progressed to demonstrate the “vertical access feasibility” for detector hall at IP

IP Region, candidate

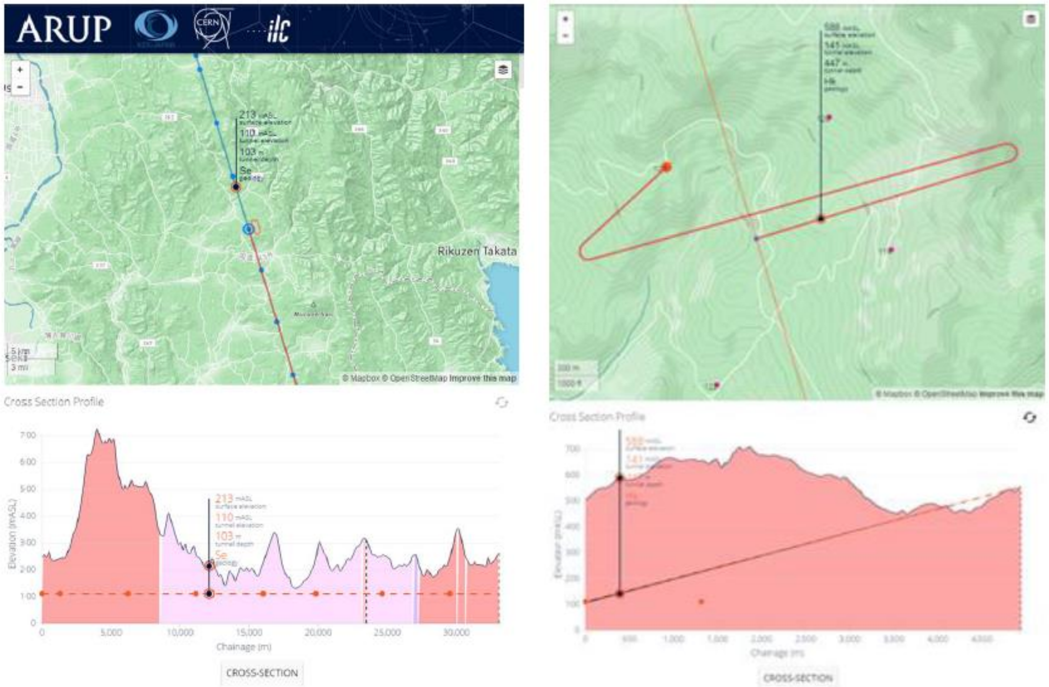


CERN/KEK Collaboration to develop TOT for ILC Optimisation

Many new features added to the tool, such as :

- IP position can be changed
- LINAC Rotation/Flip
- Access tunnels

New 250GeV Layouts/costing in 2017

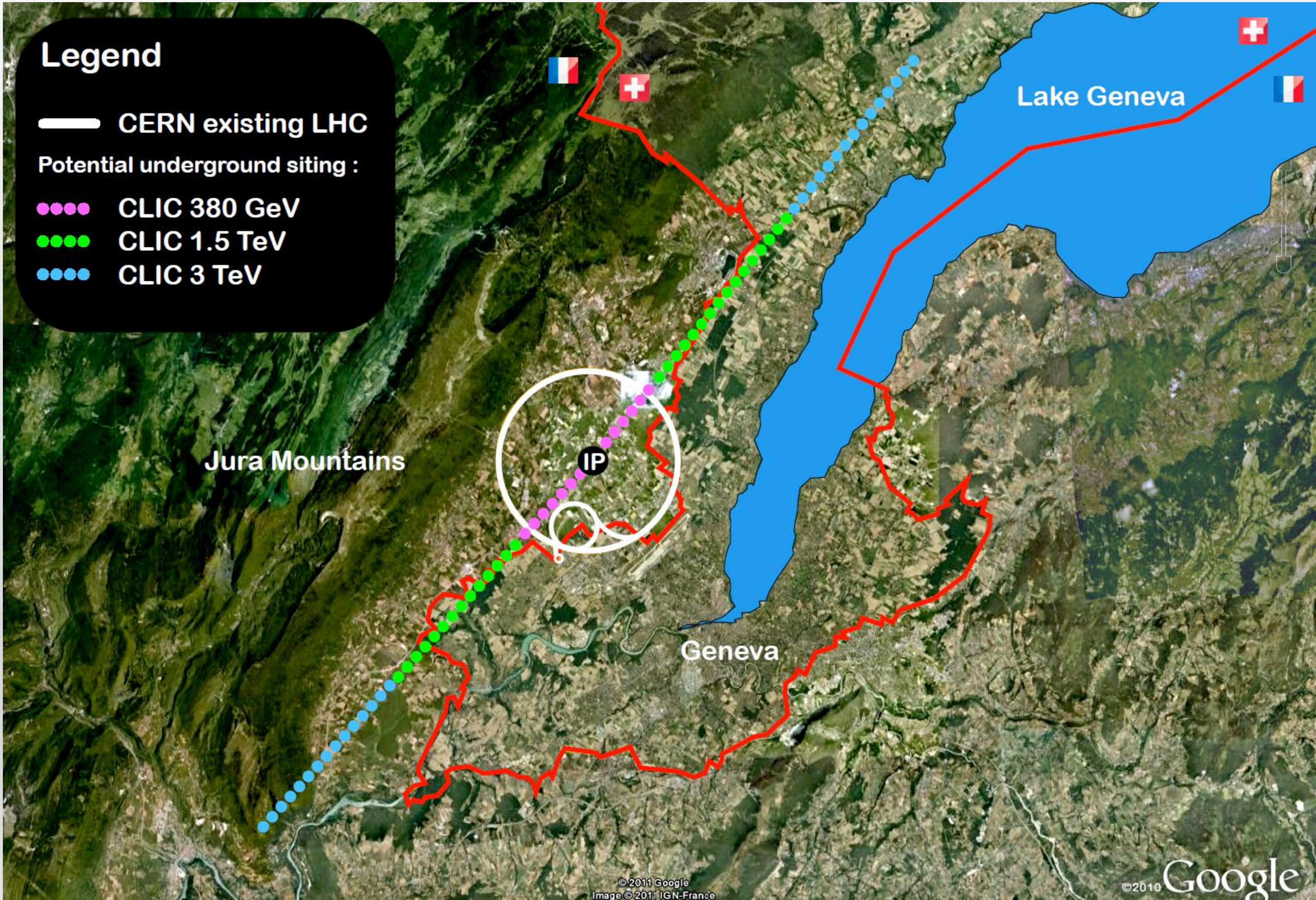


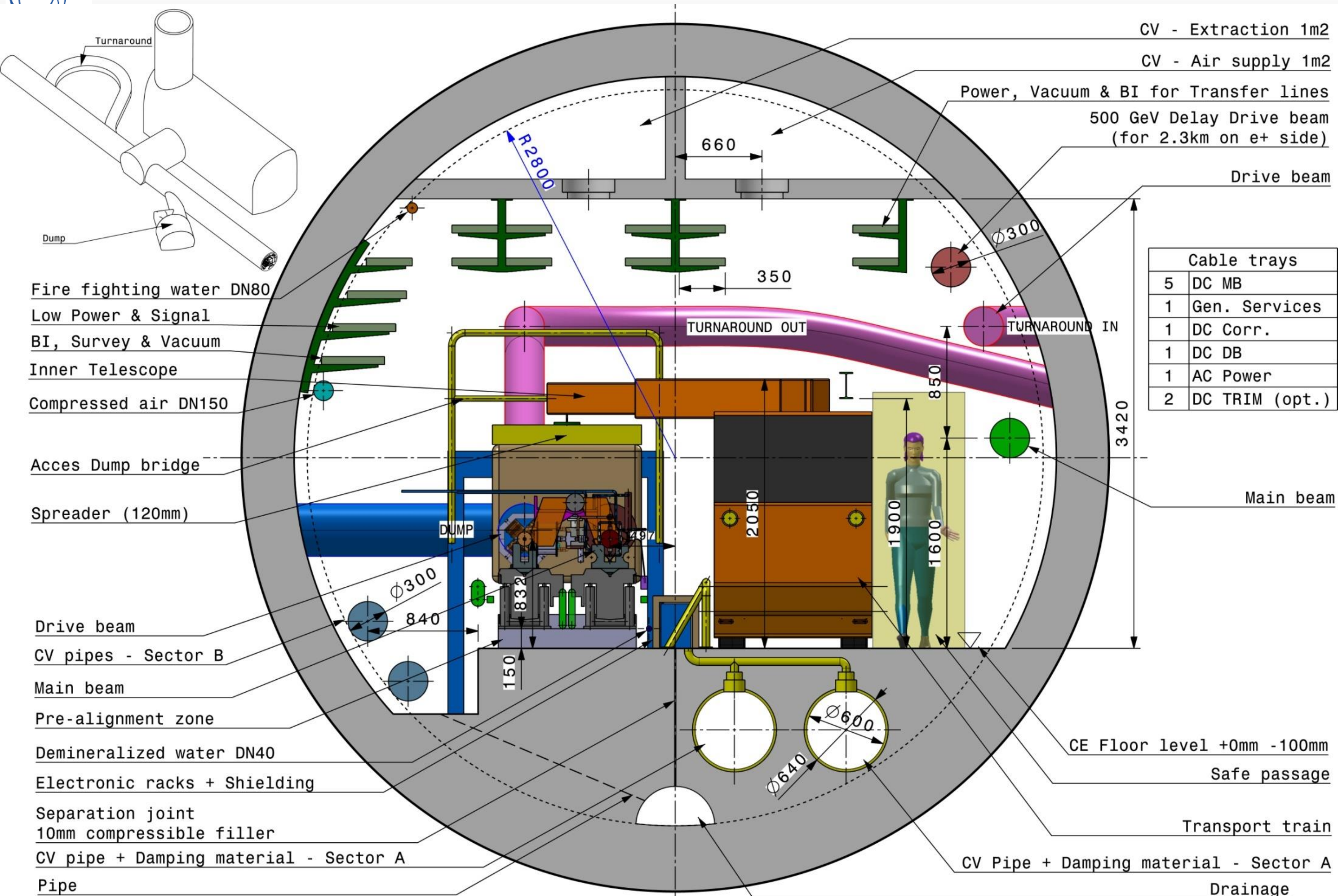
- Surface elevation: 305mASL
- Tunnel elevation: 110mASL
- Tunnel depth: 195mASL
- Geology: Se

- Surface elevation: 588mASL
- Tunnel elevation: 141mASL
- Tunnel depth: 430mASL
- Geology: Hk

TOT now being developed for ILC Japan Site and road tunnel under Stonehenge

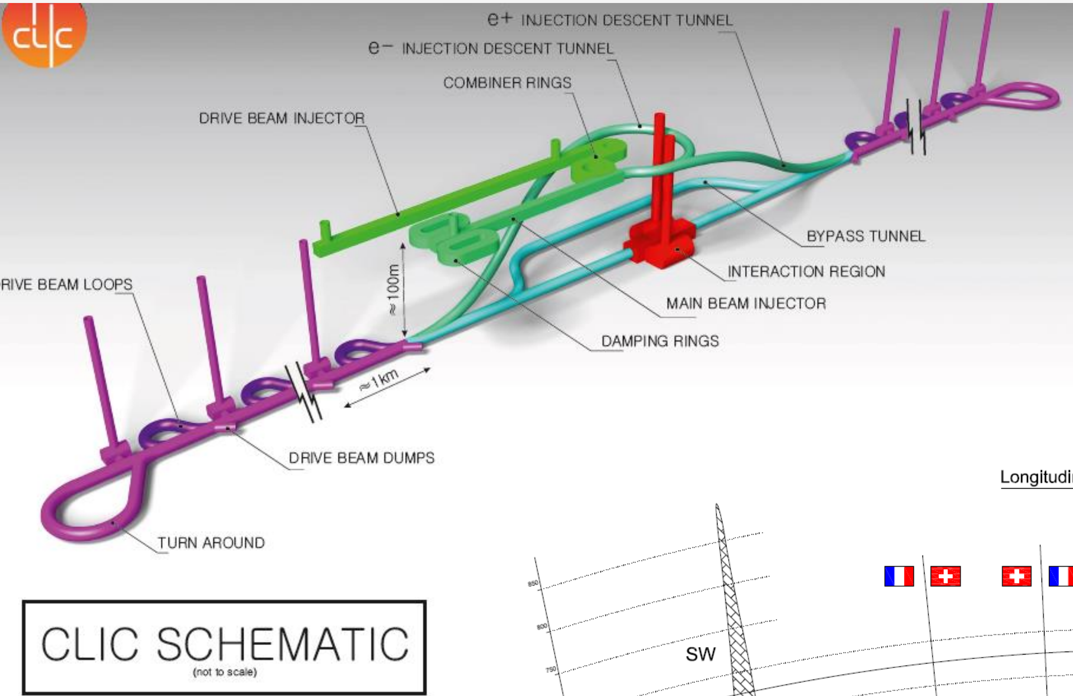
Compact Linear Collider (CLIC) Studies at CERN





CLIC - Typical Cross Section - Diameter 5600mm - Junction with Turnaround - 1:25
Draft - J.Osborne / A.Kosmicki - August 9th 2010

CLIC Studies at CERN

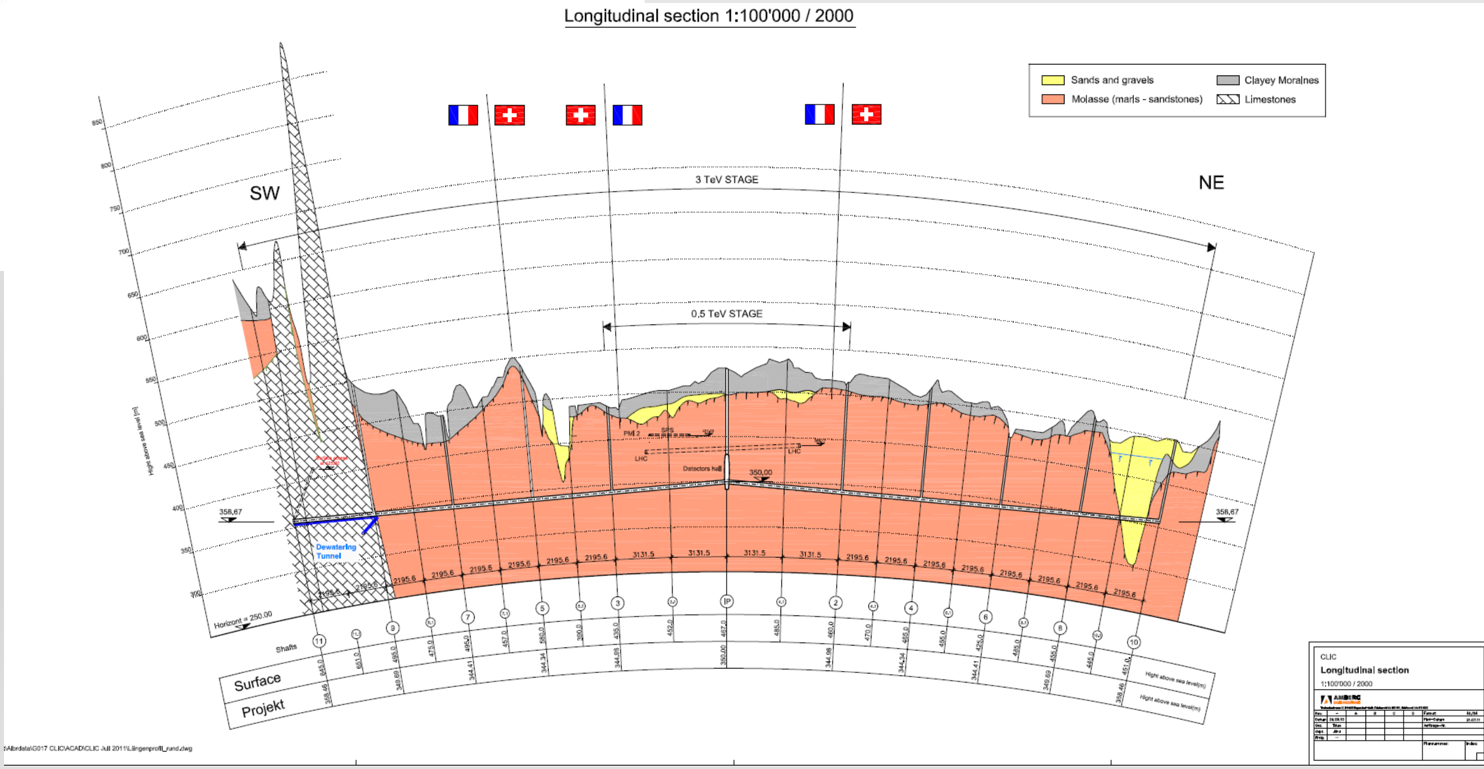


New 380GeV, 1.5TeV and 3.0TeV accelerator layouts to be developed in 2017 ready for next European Strategy update.

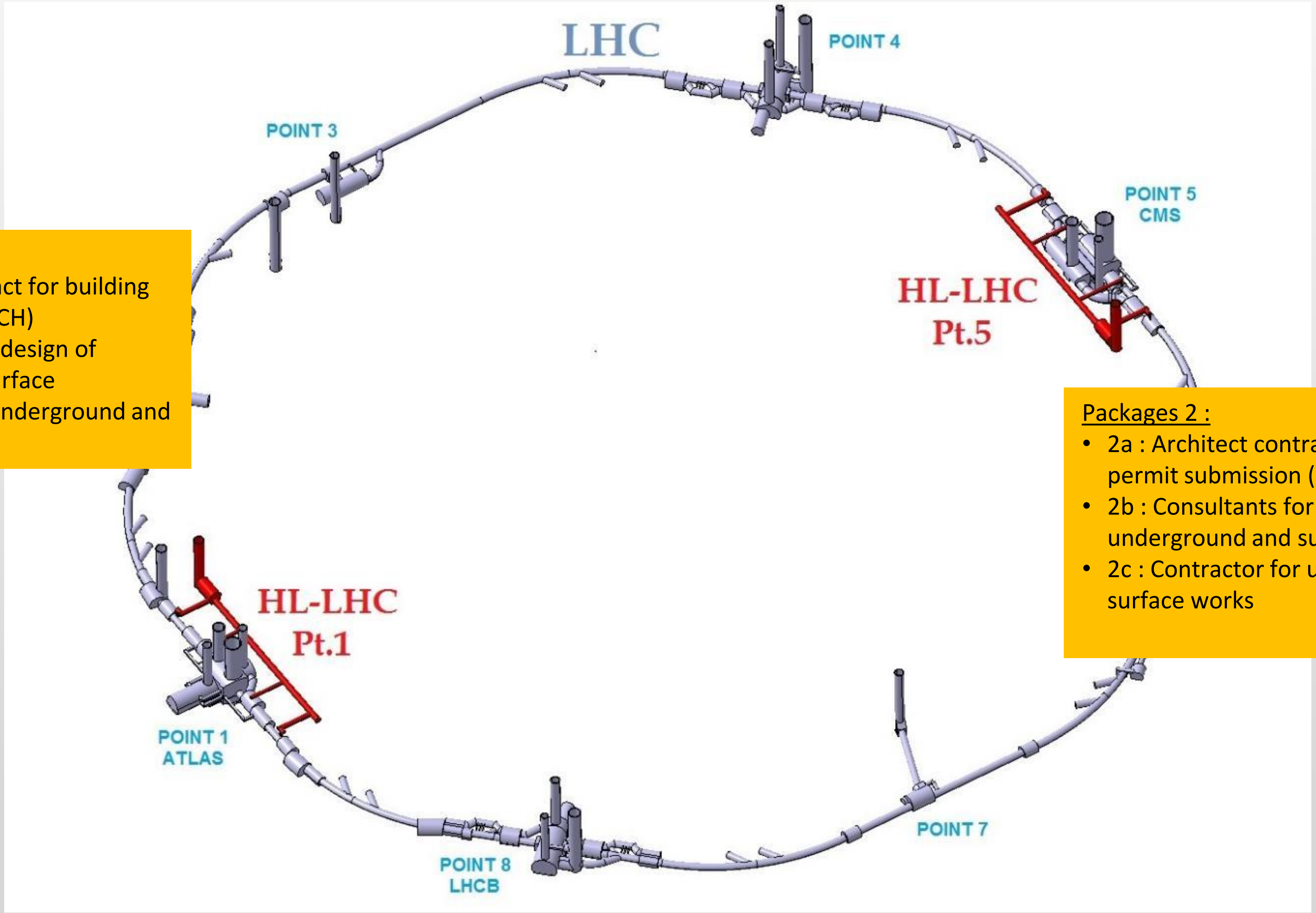
Klystron option also being studied.

CLIC TOT

New Infrastructure WG being set-up (CE, EL, CV etc).



• High Luminosity LHC Project (HL-LHC)



Packages 1 :

- 1a : Architect contract for building permit submission (CH)
- 1b : Consultants for design of underground and surface
- 1c : Contractor for underground and surface works

Packages 2 :

- 2a : Architect contract for building permit submission (F)
- 2b : Consultants for design of underground and surface
- 2c : Contractor for underground and surface works

Civil Engineering Design

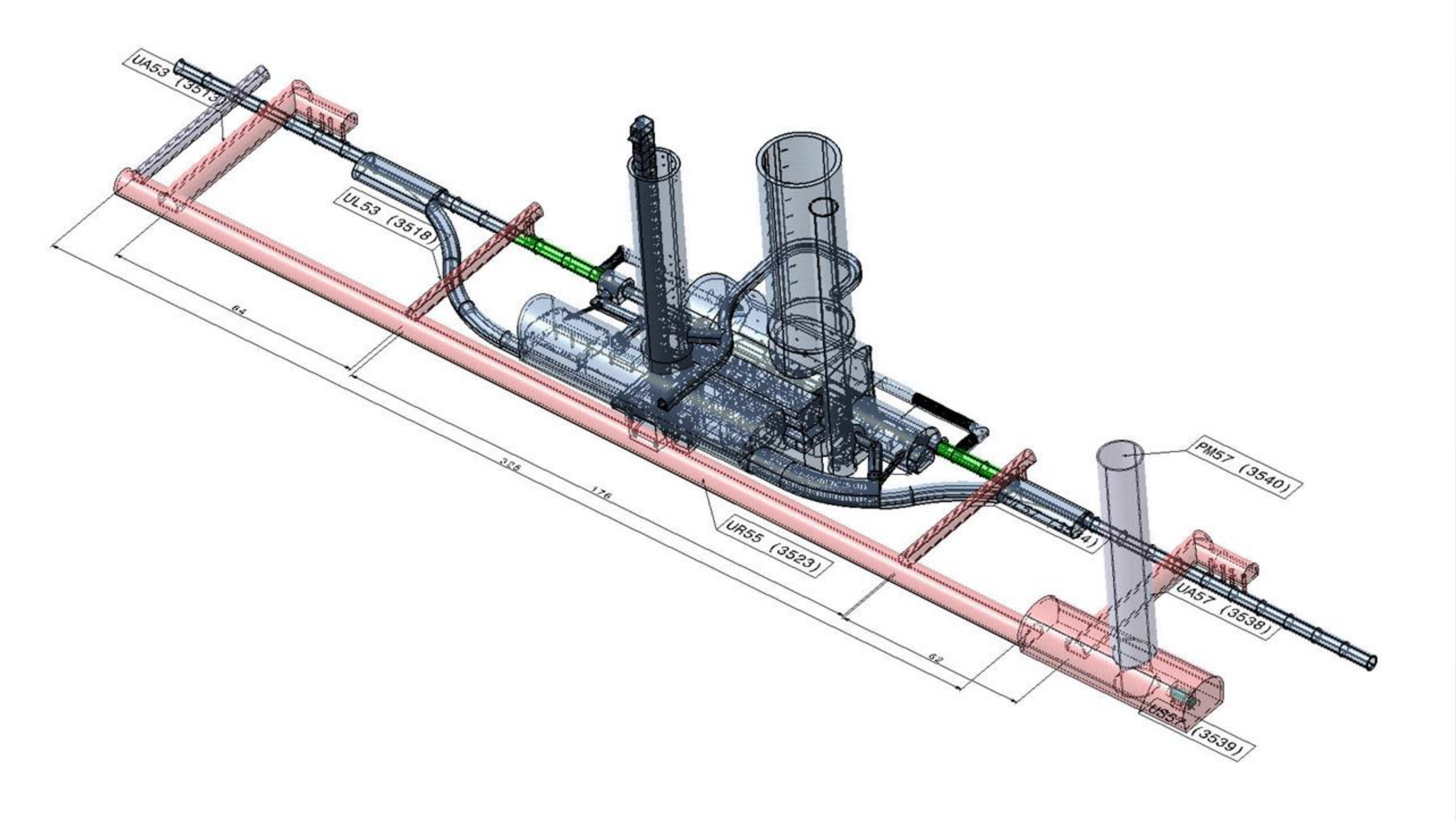
- Building Permit (CH/FR) architects:
- Civil engineering Consultants started Preliminary design in June 2016:
  - Consortium ORIGIN at P1:
  - Consortium LAP at P5:

• High Luminosity LHC Project (HL-LHC)

Construction Contracts

- <u>Point 1 Contractor</u>:
  - Joint Venture Marti Meyrin (JVMM);
  - Accepted Contract Amount ≈ 67 million CHF; contract duration of 53 months (until 31.08.2022)
  - Country of origin: Switzerland, Austria, Germany;
- <u>Point 5 Contractor</u>:
  - Consortium Implenia Baresel (CIB);
  - Accepted Contract Amount ≈ 58 million EUR; contract duration of 54 months (until 30.09.2022)
  - Country of origin: Switzerland, Germany, France;

• High Luminosity LHC Project (HL-LHC)



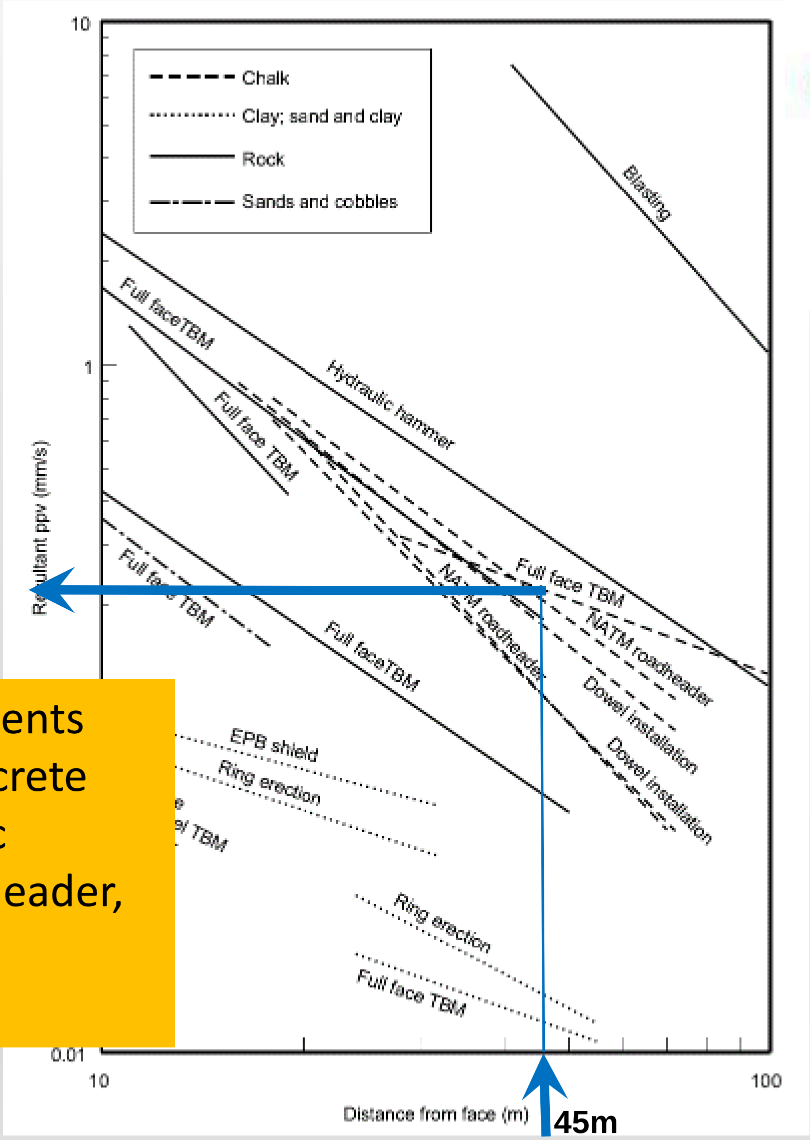
• High Luminosity LHC Project (HL-LHC)

Surface Works at Point 5 CMS

The main 'vibration' activities are driving the civil engineering planning

Results from Dr Hiller's (Arup) studies - Vibration from tunnelling

0.2 mm/s
2x10^{-4} m/s
200µm/s



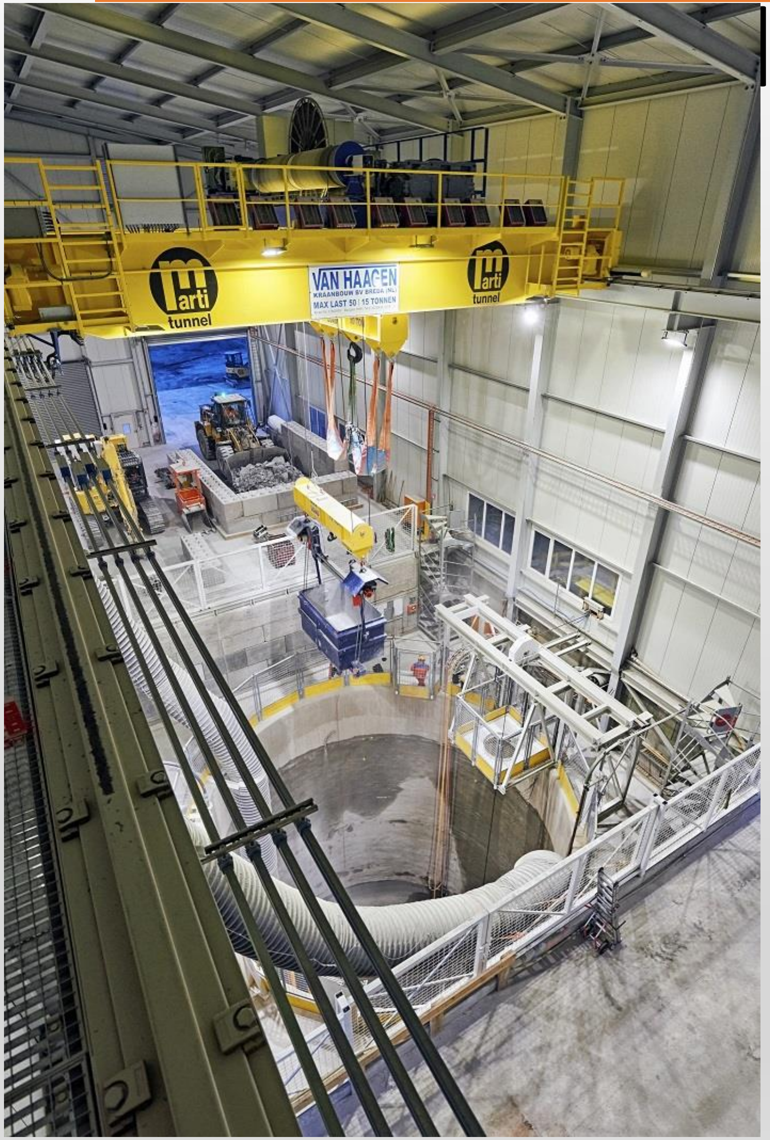
New measurements needed for concrete pump, hydraulic hammer, roadheader, Jumbo

Roadheaders will be used for excavation

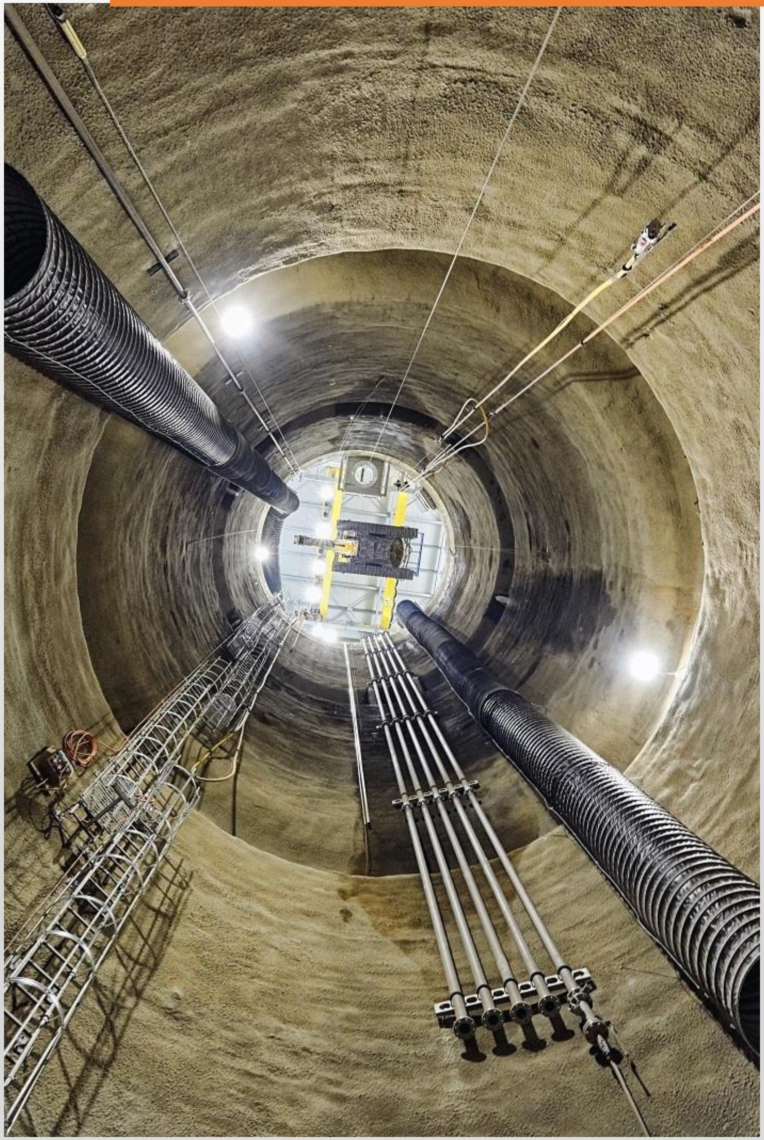
At 45m, tunnelling vibration would give ~200µm/s peak

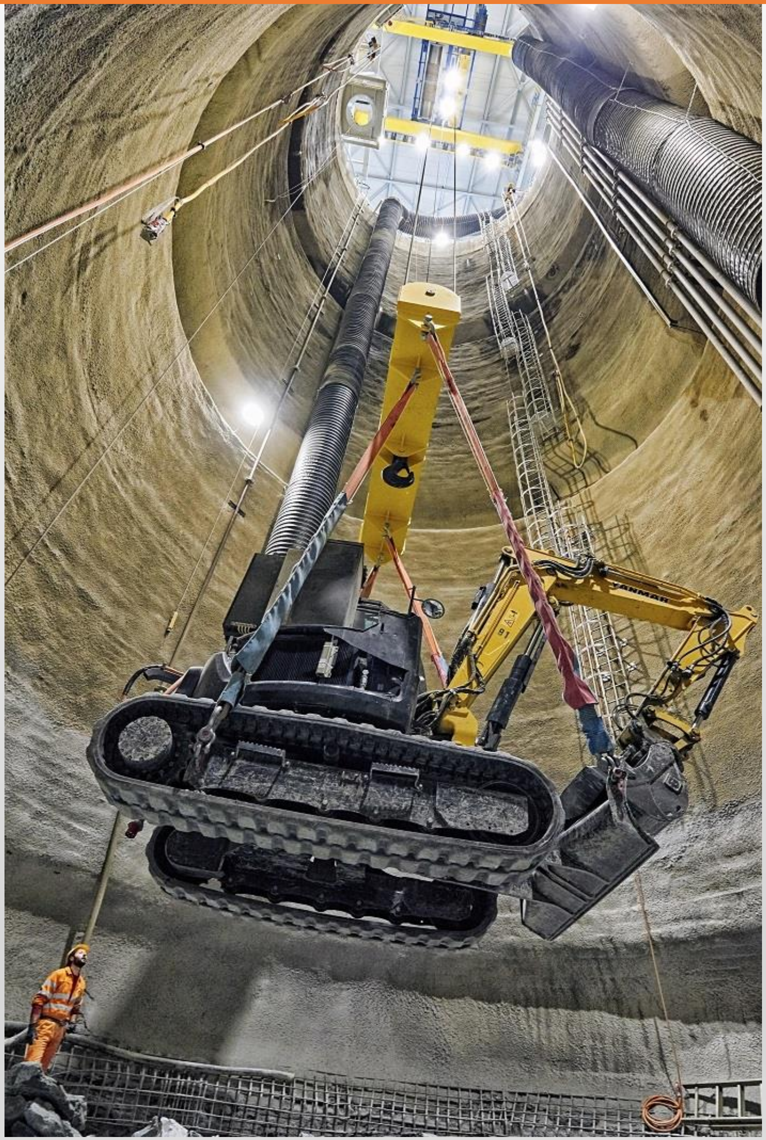
- High Luminosity LHC Project (HL-LHC)

• High Luminosity LHC Project (HL-LHC)



• High Luminosity LHC Project (HL-LHC)

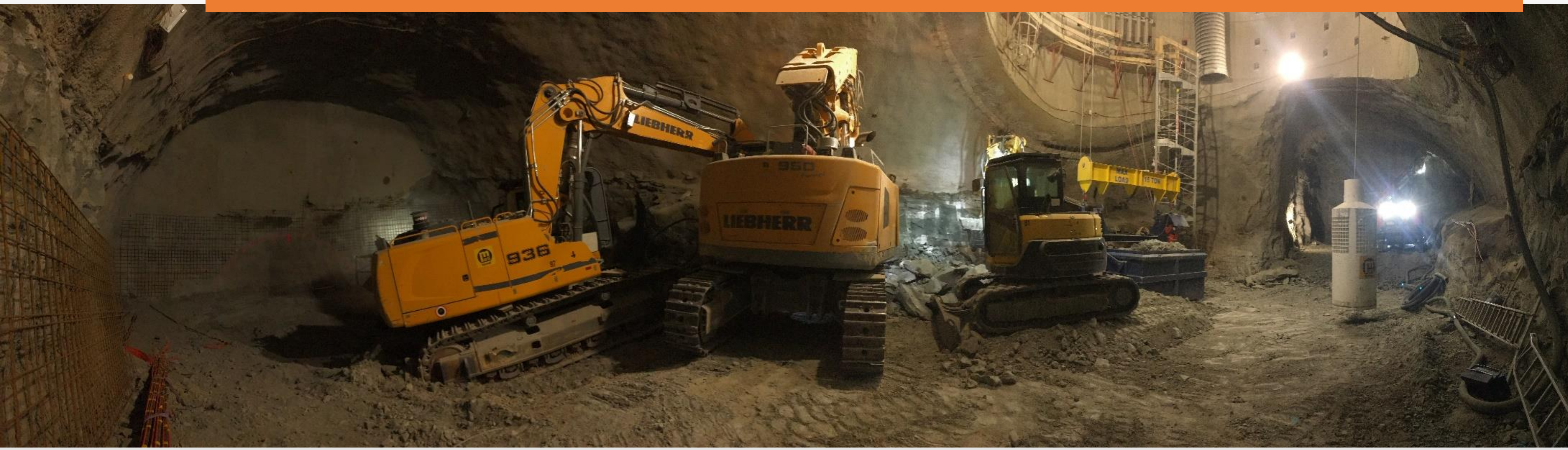




• High Luminosity LHC Project (HL-LHC)

CERN

• High Luminosity LHC Project (HL-LHC)



CERN

• High Luminosity LHC Project (HL-LHC)

Gathering Infrastructure Requirements
For example for CLIC : Civil Engineering, Infrastructure & Siting (CEIS) Working Group Disciplines:

Discipline	Representative
Chair & Civil Engineering	J.Osborne & **Matthew Stuart**
CLIC Link Persons	S.Stapnes/D.Schulte/C.Rossi/R.Corsini/W.Wuensch/A.Latina/D.Aguglia
Cooling and Ventilation (CV)	M.Nonis/P.Cabral
Electricity (EL)	**Davide Bozzini**
Survey (SU)	H.Mainaud Durand
Transport & Handling (HE)	I.Ruehl/**Michal Czech**
Interaction Region	K.Elsener
Logistics/Lab readiness	M.Tiirakari
CE Layouts & Cross-sections	SMB/CE Design Office
Health Safety & Environment (HSE)	S.Baird/S.Marsh
Schedule	K.Foraz/**Marzia Bernardini**
ILC Link Persons	J.Osborne/A.Yamamoto

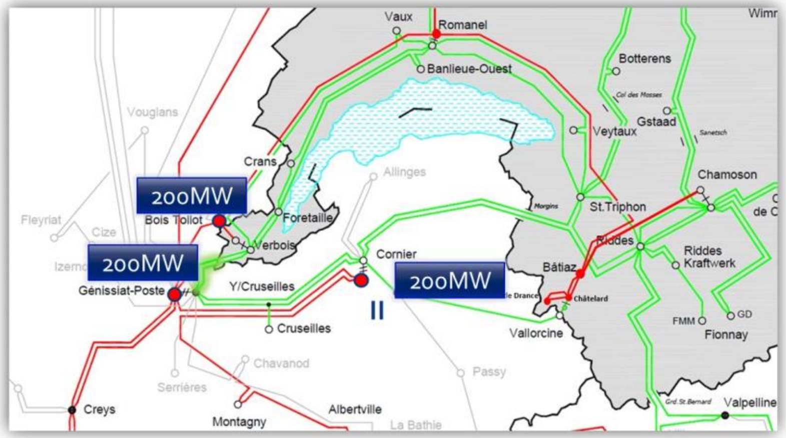
General Objective: *Develop the existing layouts for the project from a civil engineering and technical infrastructure point of view, and work with the various actors towards a realistic design and project planning as needed for the 'CLIC Implementation Plan', due late 2018.*

Meetings for the CEIS Working Group are taking place every 5 weeks to ensure full integration of the work done by each discipline.

Full Activity tracker updated at each meeting outlining the tasks for each discipline.

Other Infrastructure : FCC Supply and distribution of electrical energy

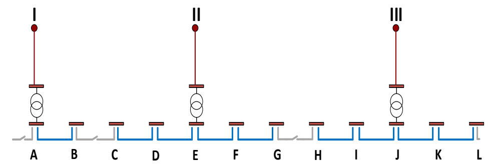
Power available at grid level at horizon 2030



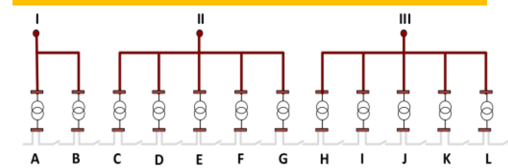
---- 400 *Réseau autour du Lac Léman, base case 2022* ---- 230

- Power estimates are being updated and appear not to exceed the available power.
- „FCC service level“ to be defined (full availability, degraded modes, redundancy).
- Local energy buffers could cover short (100 ms) network interruptions and increase availability.

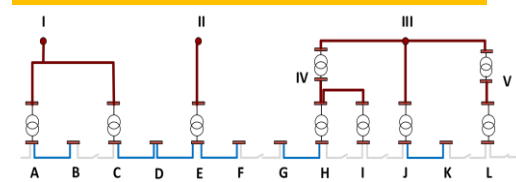
Transmission alternatives



400 kV to nearest FCC point and underground transmission ring

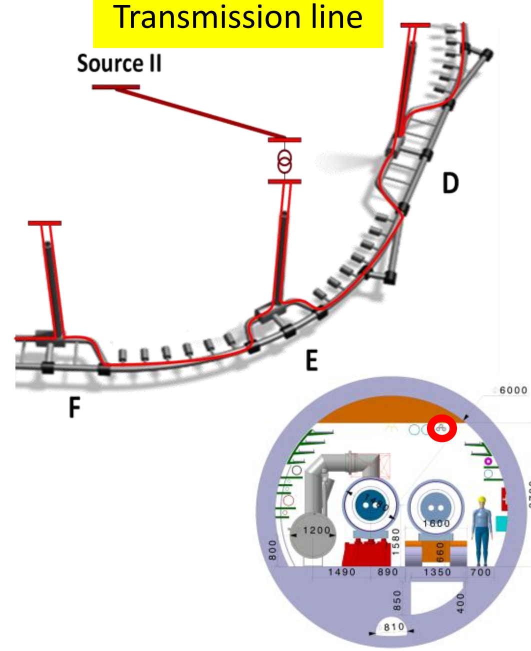


Radial feeding from existing sources



Powering by zones

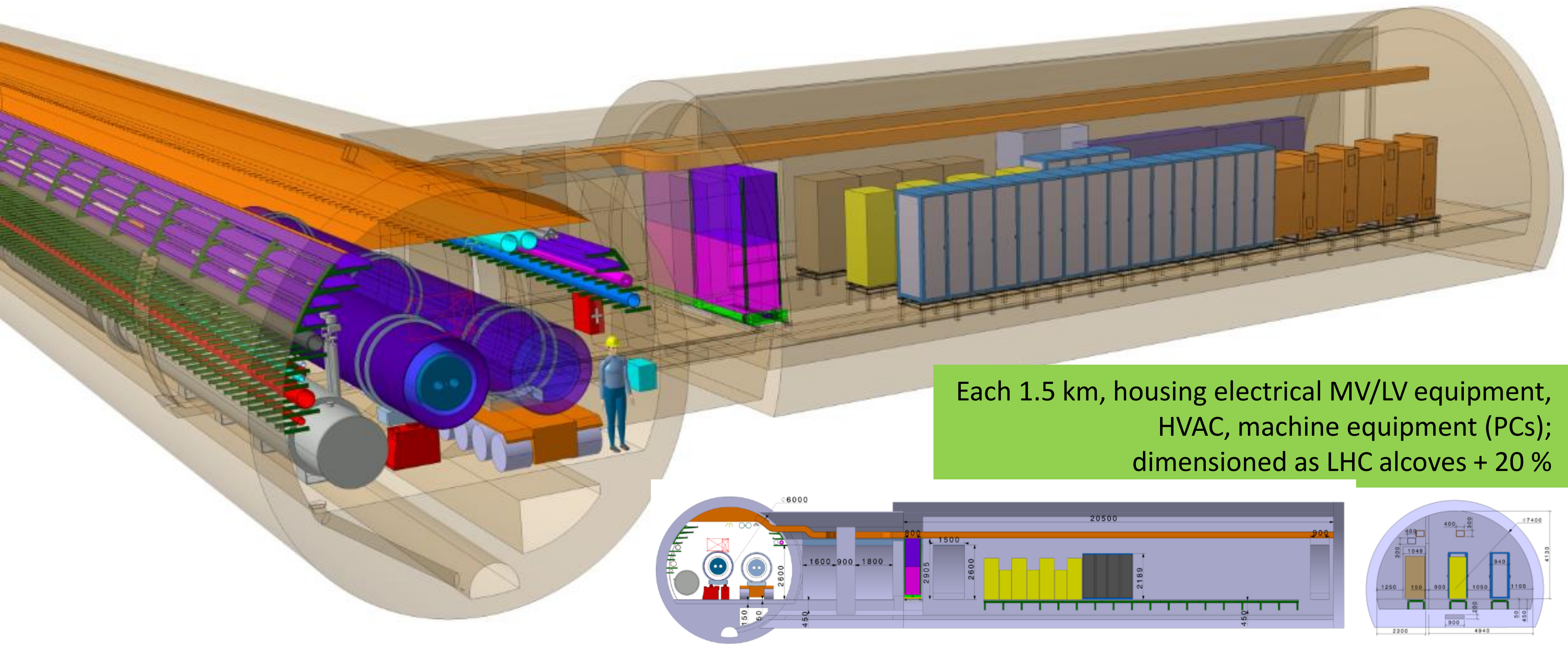
Transmission line



Study ongoing with cable company
Comparative study NC/SC foreseen.

D. Bozzini EN-EL

FCC Alcoves



Each 1.5 km, housing electrical MV/LV equipment, HVAC, machine equipment (PCs); dimensioned as LHC alcoves + 20 %

F. Valchkova-Georgieva

Logistics and transport

Fraunhofer IML

FCC collaboration with Fraunhofer Institute for material flow and logistics (FIML, Dortmund)

on several work packages:

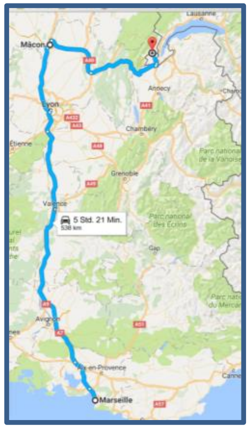
1) Design and evaluation of global supply chains for large and heavy components.
2) Logistics concept for storage, assembly, testing and handling of cryomagnets.
3) Vehicle concept for underground transportation and handling of cryomagnets.

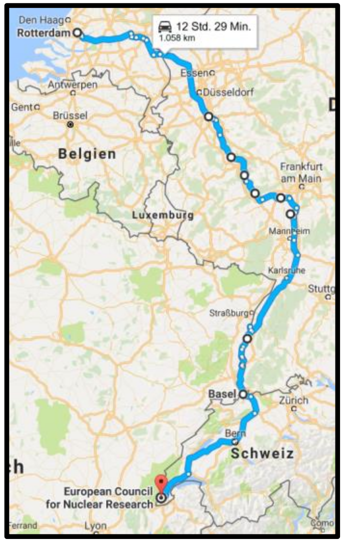
1) Supply chain – investigating and assessing ...

- Transport options (seaship, barge/truck, ...)
- Constraints (road size, maximum weight, road blockage)
- Transport enclosures (non-standard containers, special handling equipment)
- Maximum tolerable g-forces during transport and loading, maximum tilt angles

3) Vehicle

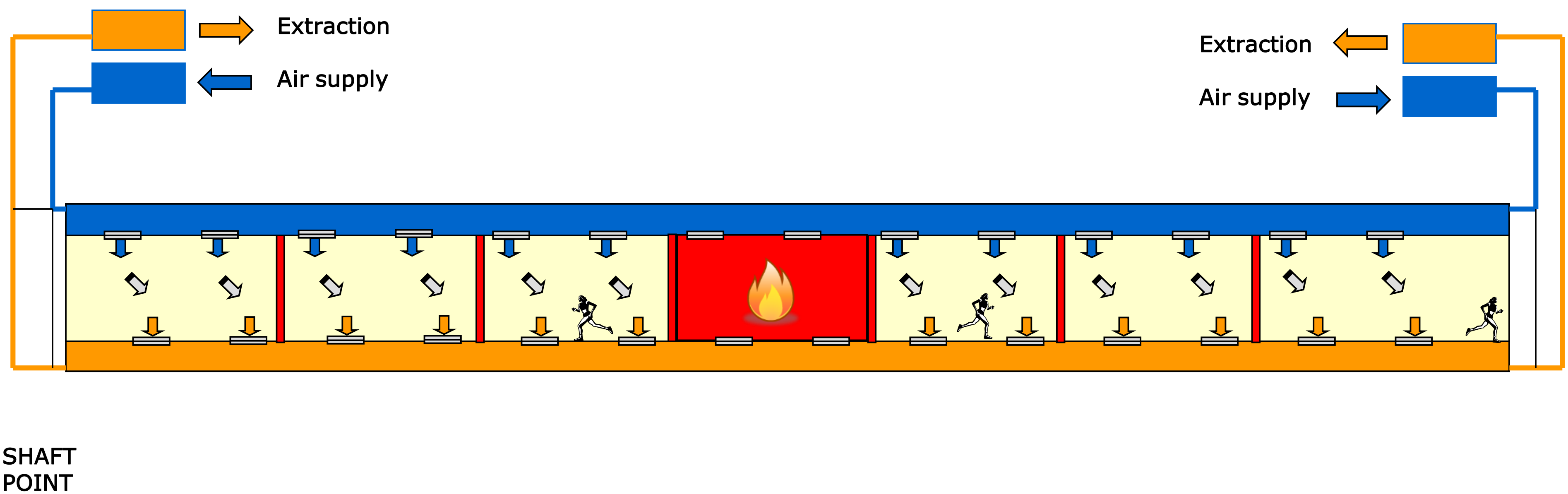
- Rail vs wheel-based
- Track guidance (optical/wire/marker) vs sensor based free navigation
- Ideally covering/compatible with other transport needs
  (other equipment, personnel, remote reconnaissance/interventions)





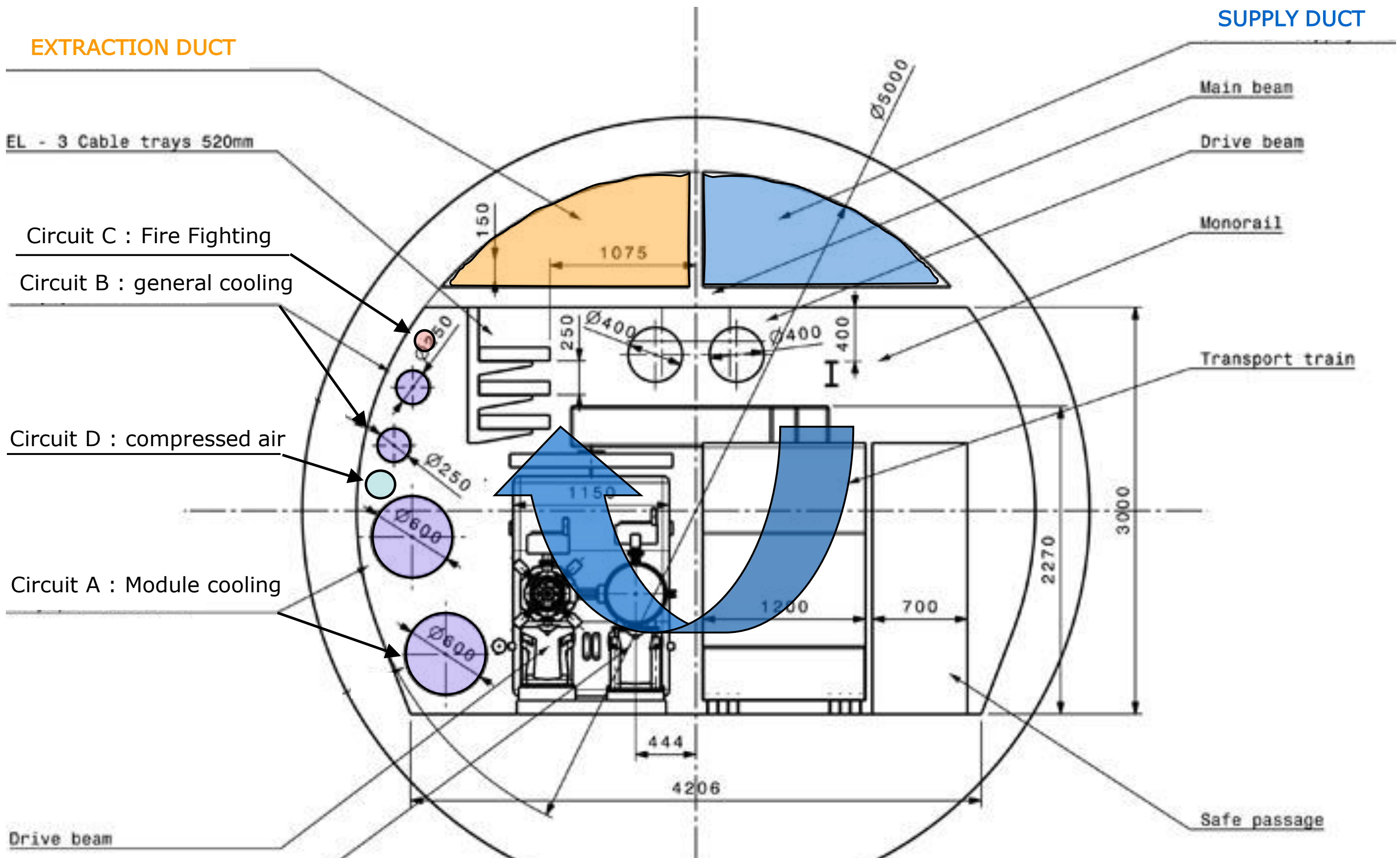
FIML, M. Tiirakari, I. Rühl

Safety considerations



- Control of the pressure from both ends of a sector.
- Control of the pressure (overpressure or underpressure in each area).
- Fire detection per sector compatible to fire fighting via water mist.

Tunnel section



This cross section is for study purposes only

Approved CLIC tunnel Diameter is currently 5.6m

CLIC - Typical Cross Section - Diameter 5000mm
Draft - J.Osborne / A.Kosmicki - October 14th 2008

Physics Beyond Colliders (PBC)

PBC is a programme aimed at exploiting the full scientific potential of CERN's accelerator complex and its scientific infrastructure through projects complementary to the LHC, HL-LHC and other possible future colliders.

- Main studies:
  - Beam Dump Facility (BDF)
  - electrons in the SPS (eSPS)
  - ForwArd Search ExpeRiment (FASER)
  - Neutrinos from STORed Muons (nuSTORM)
  - Plasma Electron Proton/Ion Collider (PEPIC)
  - Advanced Proton driven Plasma Wakefield Experiment (AWAKE)++
  - Electric Dipole Moments (EDM) Storage Ring
  - MAssive Timing Hodoscope for Ultra Stable neutraL pArticles (MATHUSLA)

Physics Beyond Colliders

PBC Map - Meyrin

Name (green)	FAS study
Name (blue)	Existing experiment
Name (red)	Other non-FAS study

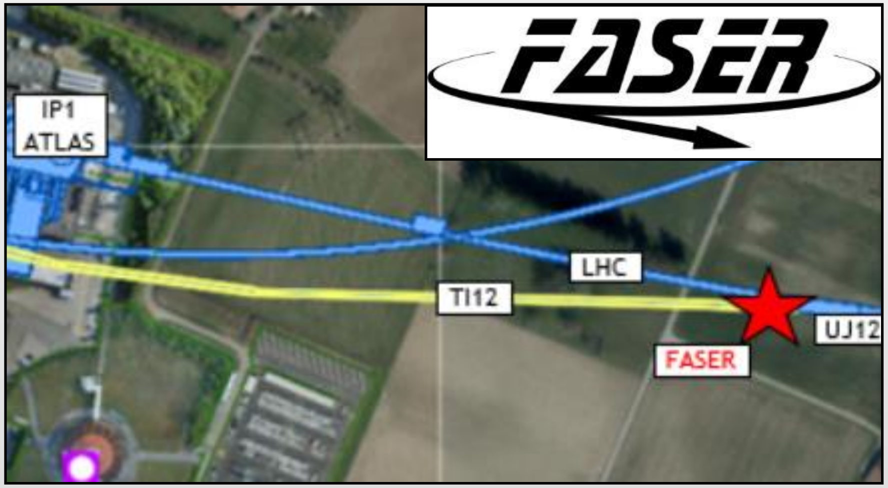
Physics Beyond Colliders

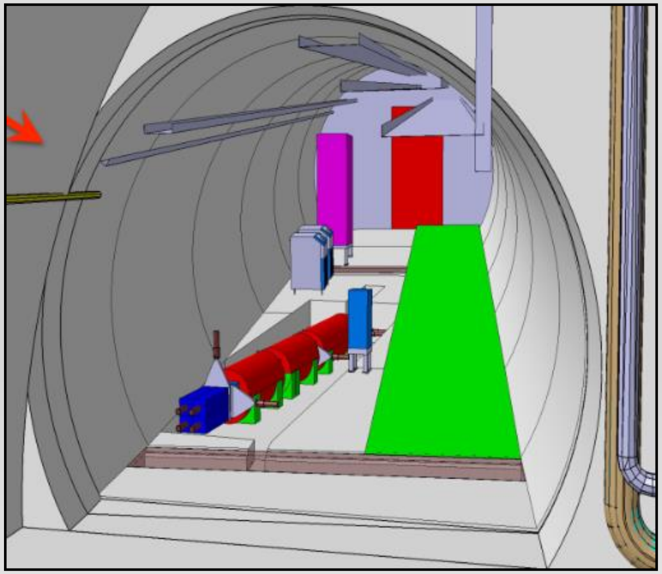
PBC Map – Across CERN

Name	FAS study
Name	Existing experiment
Name	Other non-FAS study

FASER Study Overview

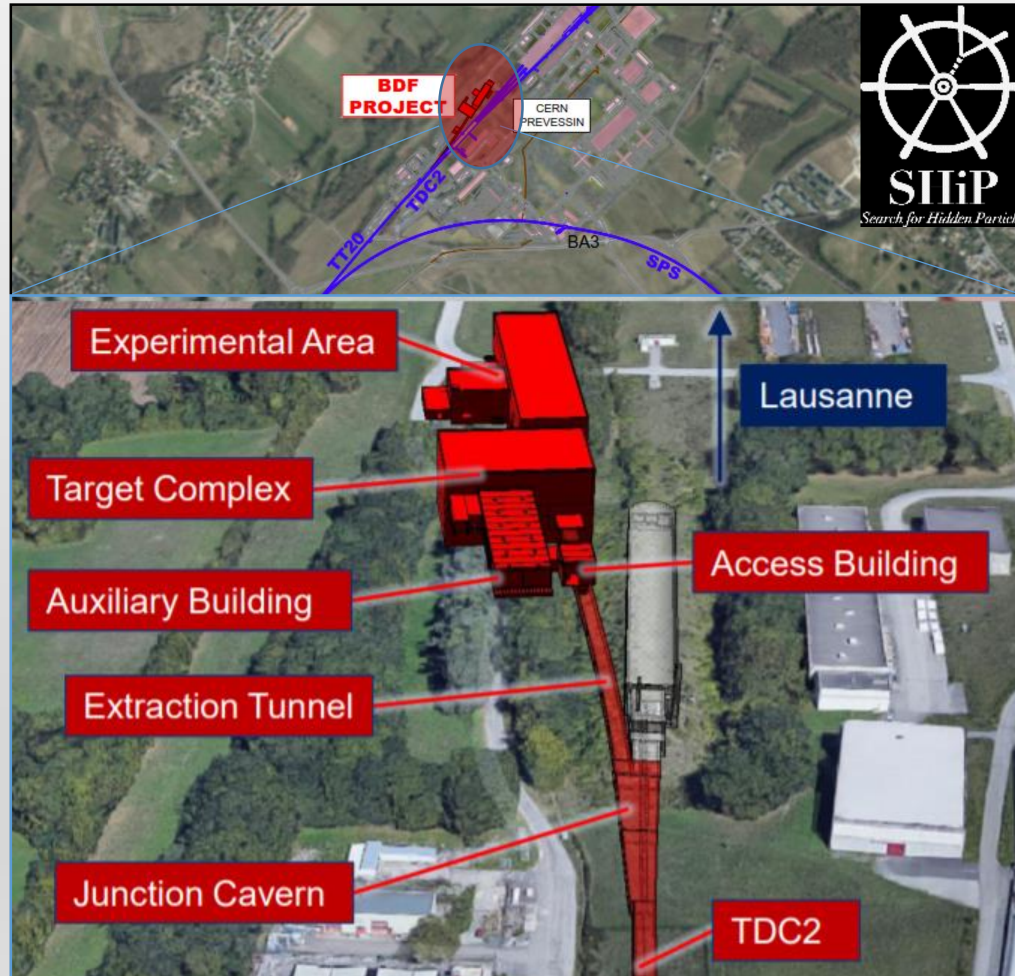
- Location
  - Meyrin - 480m from ATLAS
- Description
  - Magnet and detector to search for dark photons, dark Higgs bosons, heavy neutral leptons
- Status
  - Currently under construction during LS2
- Challenges
  - Dust
  - Vibration
  - Tunnel stability
  - Work around existing LHC





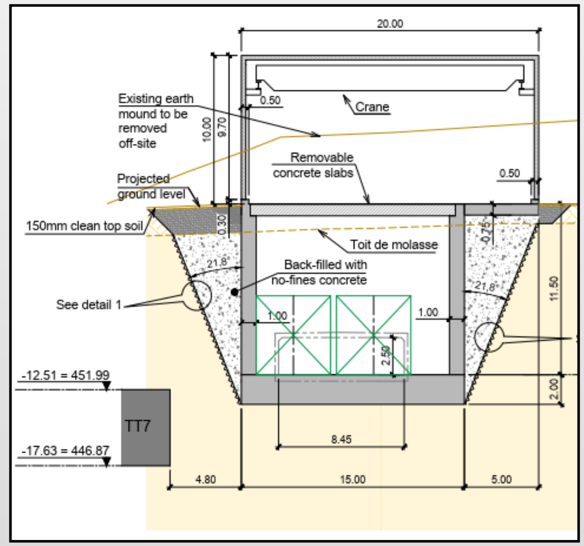
BDF Study - Overview

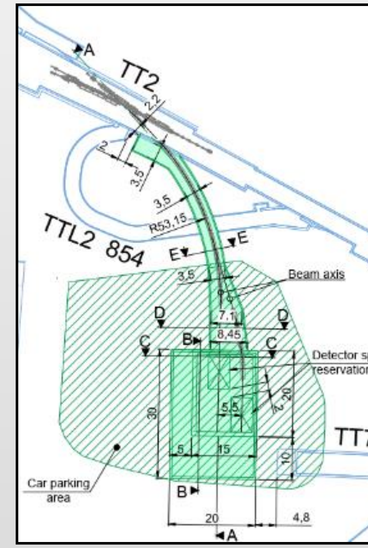
- Location
  - Prévessin Site
  - Just off SPS
- Description
  - Fixed target experiment looking for dark matter particles
- Status
  - Comprehensive design study complete
- Challenges
  - Very high radiation levels
  - Existing infrastructure
  - Considerations for target

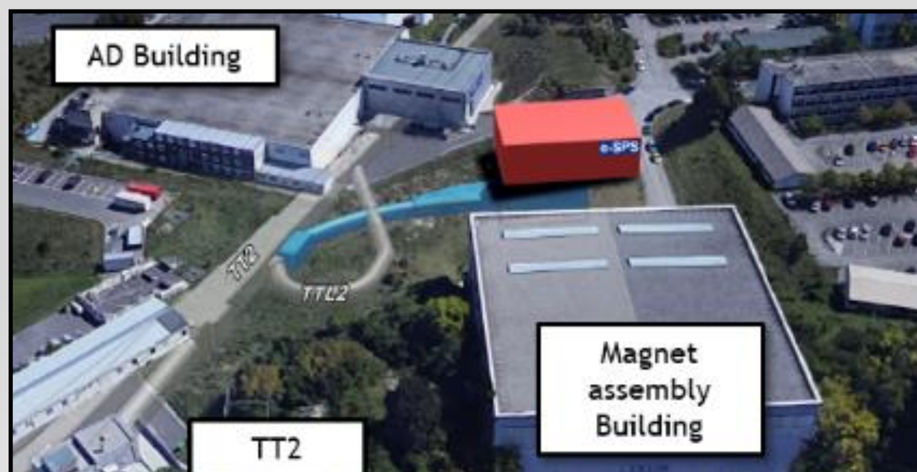


e-SPS Study Overview

- Location
  - Meyrin Site near ‘The Ear’
- Description
  - Reintroduce electrons in SPS and search for light dark matter and carry out accelerator R&D
- Status
  - Concept Design
- Challenges
  - Work close to existing experiments
  - Removal of old magnets

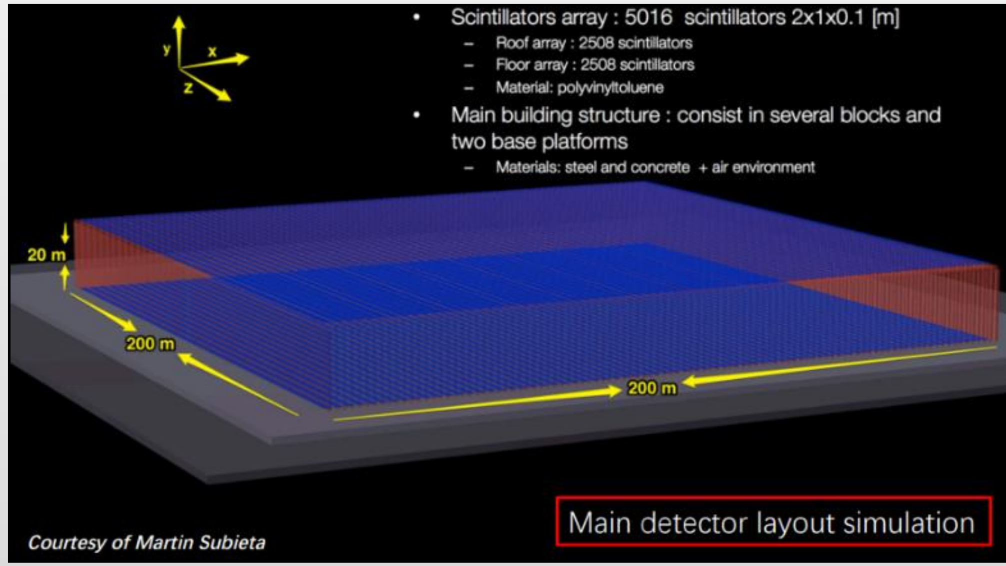




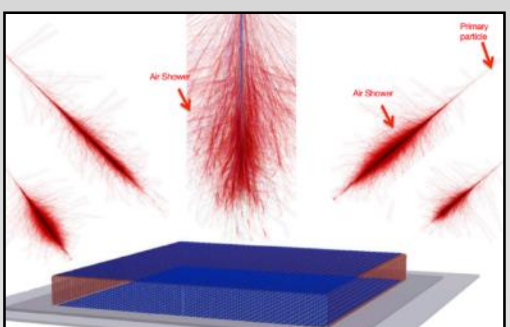


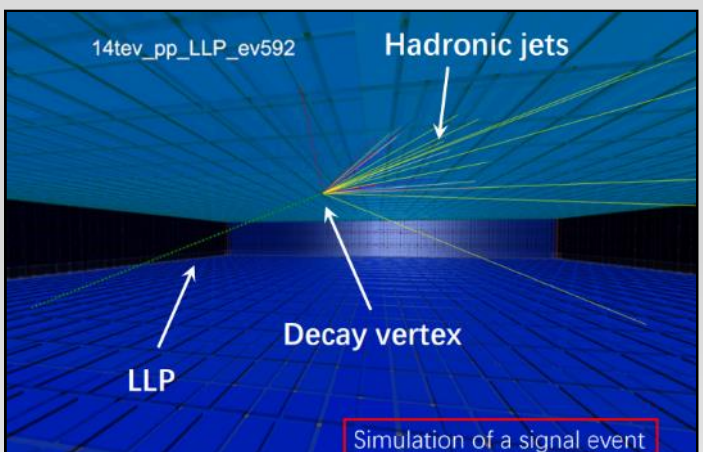
MATHUSLA Study Overview

- Location
  - Close to CMS, Cessy, France
- Description
  - Detector for decay particles from LHC interactions
- Status
  - Concept to develop in 2019
- Challenges
  - Political issues and relations with Cessy

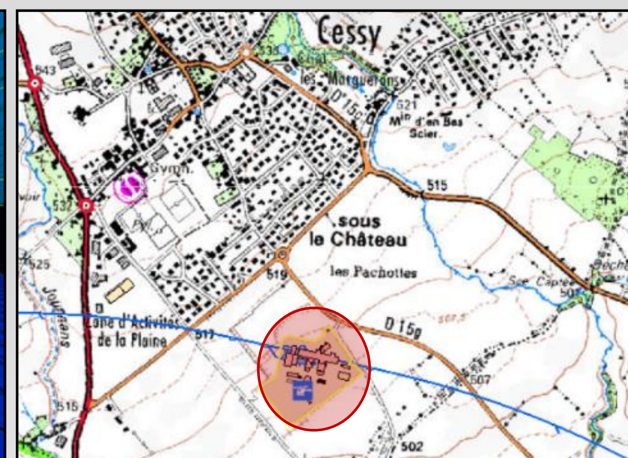


Main detector layout simulation



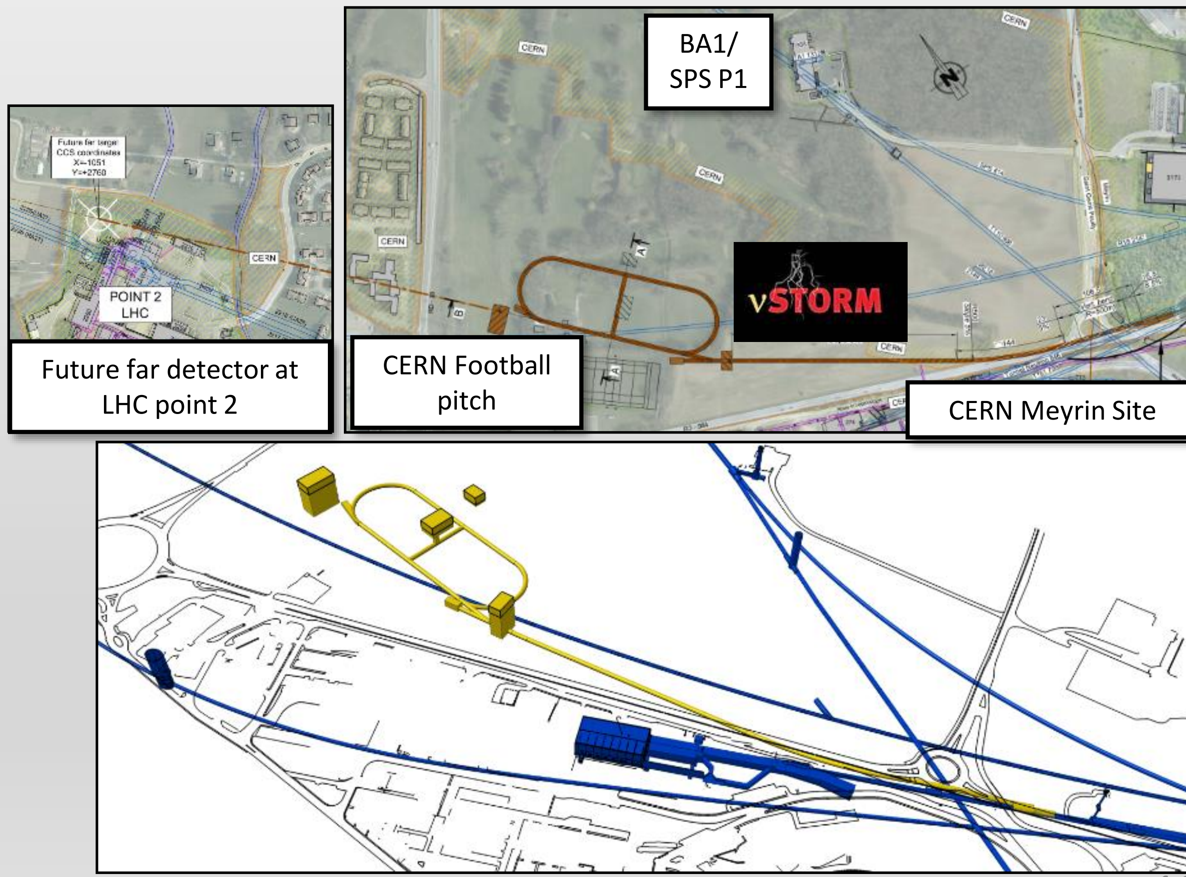


Simulation of a signal event



nuSTORM Study Overview

- Location
  - North of Meyrin Site
- Description
  - Project searching for new physics working with Ken Long from Imperial
- Status
  - Concept Design
- Challenges
  - Construction close to existing tunnels and connecting to existing tunnels



Summary

- CERN have several studies underway
- All the mentioned infrastructure studies will be reported at the next European Strategy meeting 2019/2020.
- Civil engineering and Infrastructure requirements should be considered from very early stages of feasibility studies
- Design of machines/detectors should be adapted to suit local geology/environment
- CE and Infrastructure Costs/Schedule critical part of projects

CERN

THANK YOU FOR YOUR ATTENTION

And Questions

John Osborne (CERN SMB Department)