CERN Existing and Future Tunnels

18 January 2024
Norwegian Tunnelling Society - ATLAS

Thursday 18 Jan 2024, 08:00 → 12:05 Europe/Zurich

3162/1-K01 (CERN)

08:15 → 08:30 Meet CERN Tram Stop
https://maps.app.goo.gl/pA2153zt9NLcJ8Dq8

08:35 → 09:00 Room 3162/1-K01

09:00 → 10:00 Group 1 ATLAS Cavern Visit
Speakers: Christoph Rembser (CERN), John Andrew Osborne (CERN)

09:00 → 10:00 Group 2 Visit Science Gateway
Speakers: Frederic Magnin (CERN), Liam Bromiley (CERN)

10:00 → 11:00 Room 3162/1-K01
CERN Civil Engineering Talk
Speakers: Mr. Jens Vigen (CERN), John Andrew Osborne (CERN)

11:00 → 12:00 Group 1 Science Gateway Visit
Speakers: Frederic Magnin (CERN), John Andrew Osborne (CERN)

11:00 → 12:00 Group 2 ATLAS Cavern Visit
Speakers: Johannes Junggeburt (University of Massachusetts (US)), Liam Bromiley (CERN)

12:00 → 12:05 End of visit
• Graduated from Liverpool University 1988 with Civil Engineering Degree  
  • 1987 Summer placement on Gateshead Western By-pass

• Worked for 10 years for UK Contractor, Carillion (formally Tarmac) on:
  • Conwy tunnel : Tarmac/Costain JV
  • Design Secondment in Glasgow with Sir Alexander Gibb & Partners (now Jacobs)
  • Medway tunnel
  • Jubilee Line Extension, Canary Wharf Station
  • A13 extension, Dagenham, Precast Segmental Bridge over Ford’s factory

• Joined CERN in 1998 for Large Hadron Collider Works (CMS)

• Fellow of Institution of Civil Engineers (UK) in 2017. Swiss country Rep for ICE.

• “Member” of the ITA Maintenance & Repair WG and “Clients Forum”

• Now working on CERN’s Future Accelerator Projects
Contents

• Introduction
• CERN Existing Tunnels
• Tunnel Asset Management of CERN Tunnels
• CERN Future Projects
CERN – European Centre for Nuclear Research

- CERN is the world's biggest laboratory for particle physics
- Our goal is to understand the most fundamental particles and laws of the universe.
Four pillars underpin CERN’s mission

- RESEARCH
- EDUCATION & TRAINING
- TECHNOLOGY & INNOVATION
- COLLABORATION
Science for peace

CERN was founded in 1954 with 12 European Member States

23 Member States
Austria – Belgium – Bulgaria – Czech Republic
Denmark – Finland – France – Germany – Greece
Hungary – Israel – Italy – Netherlands – Norway
Poland – Portugal – Romania – Serbia – Slovakia
Spain – Sweden – Switzerland – United Kingdom

3 Associate Member States in the pre-stage to membership
Cyprus – Estonia – Slovenia

7 Associate Member States
Croatia – India – Latvia – Lithuania – Pakistan
Türkiye – Ukraine

6 Observers
Japan – Russia (suspended) – USA
European Union – JINR (suspended) – UNESCO

Geographical & cultural diversity
110 nationalities, from 77 countries

~ 2676 Staff members
~ 2000 contractors’ employees
~ 13000 physicists /users

Around 50 Cooperation Agreements with non-Member States and Territories
Albania – Algeria – Argentina – Armenia – Australia – Azerbaijan – Bangladesh – Belarus – Bolivia
Bosnia and Herzegovina – Brazil – Canada – Chile – Colombia – Costa Rica – Ecuador – Egypt – Georgia – Honduras

Yearly budget ~ 1347 MCHF
Large Hadron Collider (LHC)

- 27 km in circumference
- About 100 m underground
- Superconducting magnets steer the particles around the ring
- Particles are accelerated to close to the speed of light
CERN Experiments
CERN Detectors

ATLAS Detector
(ITA Executive Council Visit December 2022)

Higgs Boson Discovery

CMS Detector in France
CERN Tunnels and Geology

- **Large Hadron Collider:**
  - 27km long
  - 50-175m depth
  - 4.5m Ø TBM tunnels
  - Built in the Molasse and limestone

Total underground tunnels >70km
More than 80 Caverns
Geology

**Molasse**
- Mixture of sandstones, marls and formations of intermediate composition
- Relatively weak rock (Avg. 5.5 - 48 Mpa)
- Good excavation rock
- Relatively dry and stable
- Faulting due to the redistribution of ground stresses
- Structural instability (swelling, creep, squeezing)

**Moraines (Quaternary Deposits)**
- Glacial deposits comprising gravel, sands silt and clay
- Water bearing unit
- Unfavourable tunneling

**Limestone**
- Hard rock
- Good tunneling rock
- Fractures and karsts likely present
- High inflow rates during LEP construction (600L/sec)
- Rock mass instabilities
LHC Civil Engineering 1998-2005
Tunnel excavation options

No explosives were used for LHC excavation
CERN Civil Engineering Works: Past and Future Projects

John Osborne

ATLAS
LHC Civil Engineering ATLAS

24 Mai 2002
LHC Civil Engineering - CMS

All spoil generated was used for landscaping

Access road for CE works

1999
Ground Freezing for shaft excavation
LHC Civil Engineering CMS ground freezing
LHC Civil Engineering CMS ground freezing

Point 5 - Excavation commencement of PM54 shaft - July 09, 1999 - CERN ST-CE
Total Volume excavated = 216,000m³
Total Concrete Volume = 90,000m³
CERN Civil Engineering Works: Past and Future Projects

John Osborne

2004
CMS cavern 53m long, 27m wide by 25m high
Point 5 - PM54 additional drilling for grouting - October 01, 1999 - CERN ST-CE
Shafts 12.1m and 20.5m diameters, both approx. 100m deep
LHC Civil Engineering CMS shaft
LHC Civil Engineering simplified schedule

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

Automated Image data acquisition
- Robotics solutions (CERNbot & TIM) for remote monitoring of CERN underground
- R&D for photogrammetry for crack detection and quantification (machine learning and structure from motion)
- R&D for Distributed Fibre Optic Sensors (DFOS) monitoring

Tunnel Inspections
- LHC, PS, SPS, Transfer Tunnels Inspections during YETS
- Collaboration with BE-GM Survey team to measure beam movement & floor movement

Other Monitoring technologies
- Drone ie. Flyability Elios 3
- Laser scanning (Point Cloud system)

Tunnel Asset Management Workshop at CERN
- TAM Innovation Workshop on the 26-27th October 2023

Collaboration with University College Cork (UCC)
- 4th International Symposium of Machine learning and Big Data in Geoscience ISMLG2023
  29th August - 1st September 2023
The Future Circular Collider Study (FCC)

- **Collision energy:**
  100 TeV

- **Circumference:**
  91 km

- **Physics considerations:**
  Enable connection to the LHC (or SPS)

- **Construction:**
  c.2033-2043

- **Aims of the civil engineering feasibility study:**
  What is the cost?
  What is the optimal position?
  Site Investigations to confirm assumptions.
Civil Engineering Sub Surface

- 8 surface sites
- 13 shafts
- 4 experiment caverns
- 8 service caverns
- Beam dump
- RF klystron galleries
- SPS injection lines
Main Beam Tunnel

- Smoke extraction duct
- Precast concrete tunnel segments
- Tunnel monitoring/maintenance robot
- In-situ concrete floor
- Tunnel invert drainage
- Ventilation duct

Credit: Fani Valchova-Georgieva
Areas with the highest geological uncertainty

- **Lac Léman**
  - Moraine/molasse interface uncertain.
  - Soils and rock properties uncertain.
  - High uncertainty in the hydrogeological conditions and water pressure.

- **Mandallaz**
  - Fractured limestone formations, characteristics and locations of karsts unknown.
  - High water pressures.

- **Jura**
  - Limestone/molasse interface uncertain.
  - Risk of karsts and high water pressures.
  - Good knowledge of the ground (e.g., information near to CERN from LEP/LHC projects).
  - Good confidence that the tunnel alignment is in molasse.

- **Le Rhône**
  - Moraine/molasse interface not certain.
  - Proximity to protected area.

- **Vuache**
  - Limestone/molasse interface not certain.
  - Risk of karsts and high water pressures.
  - Proximity to main active fault.

- **Les Usses**
  - Moraine/molasse interface not certain.
  - Low tunnel rock cover.

- **Vallée de l’Arve**
  - Moraine/molasse interface uncertain.
  - Lack of reliable boreholes.

- **Bornes**
  - Insufficient deep boreholes information.
  - Complex faulted region, thrust zone.
  - Quality of molasse is uncertain. High overburden. Large span experimental caverns should be constructed in good molasse.

- **Mandallaz**
  - Fractured limestone formations, characteristics and locations of karsts unknown.
  - High water pressures.

On-site investigation works 2024-25
Planned start of civil works mid 2030’s
MATEX Study

- Study to estimate quantity and disposal of excavated material
- Baseline TBM layout and direction of drives
- Balance of material between France and Switzerland
- 96% molasse
- 3% limestone
- 1% moraine
- Total, 8,100,000 m³
Compact Linear Collider (CLIC)
Arup undertaking lifecycle assessment (LCA) of future CERN tunnels.

Study of the total embodied carbon across a project’s lifetime

Project carbon cost is now a major factor in the decision making process.

Assessment of embodied carbon can identify significant areas to reduce CO2.
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)
  - Forward Physics Facility (FPF)
  - 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)
Forward Physics Facility

• Location approx. 617m from IP1 on the French side of CERN land, 10m away from the LHC tunnel

• Design includes:
  ➢ A 65m long experimental cavern, experiments centralised on the line of sight (LoS)
  ➢ An 88m deep access shaft
  ➢ Support buildings and infrastructure

• Site Investigation drilling completes in March 2023
**Civil Engineering companies**

**Large Hadron Collider (LHC)**

*CE Contracts approx. EUR 600m*

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<th>Package</th>
<th>Consultants</th>
<th>Contractors</th>
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<td>POINT1 ATLAS</td>
<td>▪ EDF (F)</td>
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<td>▪ KNIGHT &amp; PIESOLD (GB)</td>
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## High Luminosity LHC Project (HL-LHC)

*CE Contracts approx. EUR 200m*

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<th>Package</th>
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| POINT1           | Consortium ORIGIN:  
  ▪ SETEC (F)  
  ▪ CSD ENGINEERS (CH)  
  ▪ ROCKSOIL (I) | Joint Venture Marti Meyrin:  
  ▪ MARTI TUNNELBAU (CH)  
  ▪ MARTI DEUTSCHLAND (DE)  
  ▪ MARTI ÖSTERREICH (A) |
| POINT 5          | Consortium LAP  
  ▪ LOMBARDI (CH)  
  ▪ ARTELIA (F)  
  ▪ PINI SWISS ENGINEERS (CH) | Consortium CIB:  
  ▪ IMPLENIA (CH/ F)  
  ▪ BARESEL (DE) |
| Building Permit  | ▪ DELTA ARCHITECTS  
  ▪ ASS ARCHITECTS |                                                 |
# Future Circular Collider (FCC)

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<td>PRELIM SITE INVESTIGATION</td>
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THANK YOU FOR YOUR ATTENTION