



# CERN Civil Engineering Future Studies Section and Opportunities

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SCE-DOD-FS

13/02/2023

# SCE-DOD-FS Section



Future Accelerator Studies  
[FS]

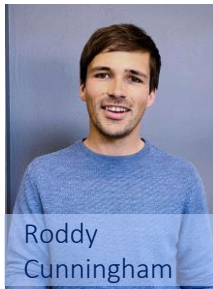
SL: John Osborne  
DL: Mar Capeans



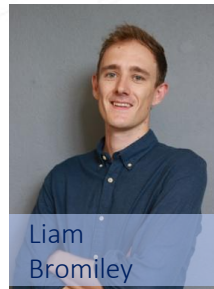
International Linear Collider ,CLIC, Muon Collider, LHeC  
External Reviews e.g. ESS, XFEL, DUNE etc.



Future Circular Collider (FCC) Underground  
Studies and Site Investigations



Roddy  
Cunningham



Liam  
Bromiley

Physics Beyond Colliders (PBC)



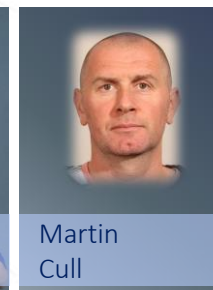
Kincső  
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Tunnel Asset Management (TAM)

Tunnel R&D  
Photogrammetry/Fibre  
Optic Studies



Vanessa  
Di Murro



Martin  
Cull



Aohui  
Ouyang

# SCE-DOD-FS Mandate

- Co-ordination of the civil engineering and infrastructure studies for large-scale physics projects. These include the Future Circular Collider (FCC), Linear Colliders (LC), Muon Colliders, Physics Beyond Colliders and ISOLDE studies.
- Lead of the studies in conjunction with other SCE groups from conception, feasibility and technical design towards construction preparation.
- Inspections and monitoring of all existing underground assets within the 'Tunnel Asset Management' unit, including some research and development for monitoring technologies like photogrammetry and fibre optic monitoring

# The Future Circular Collider Study (FCC)

**Collision energy:**

100TeV

**Circumference:**

80km-100km

**Physics considerations:**

Enable connection to the LHC (or SPS)

**Construction:**

c.2029-35

**Cost:**

Civil Engineering 6BCHF

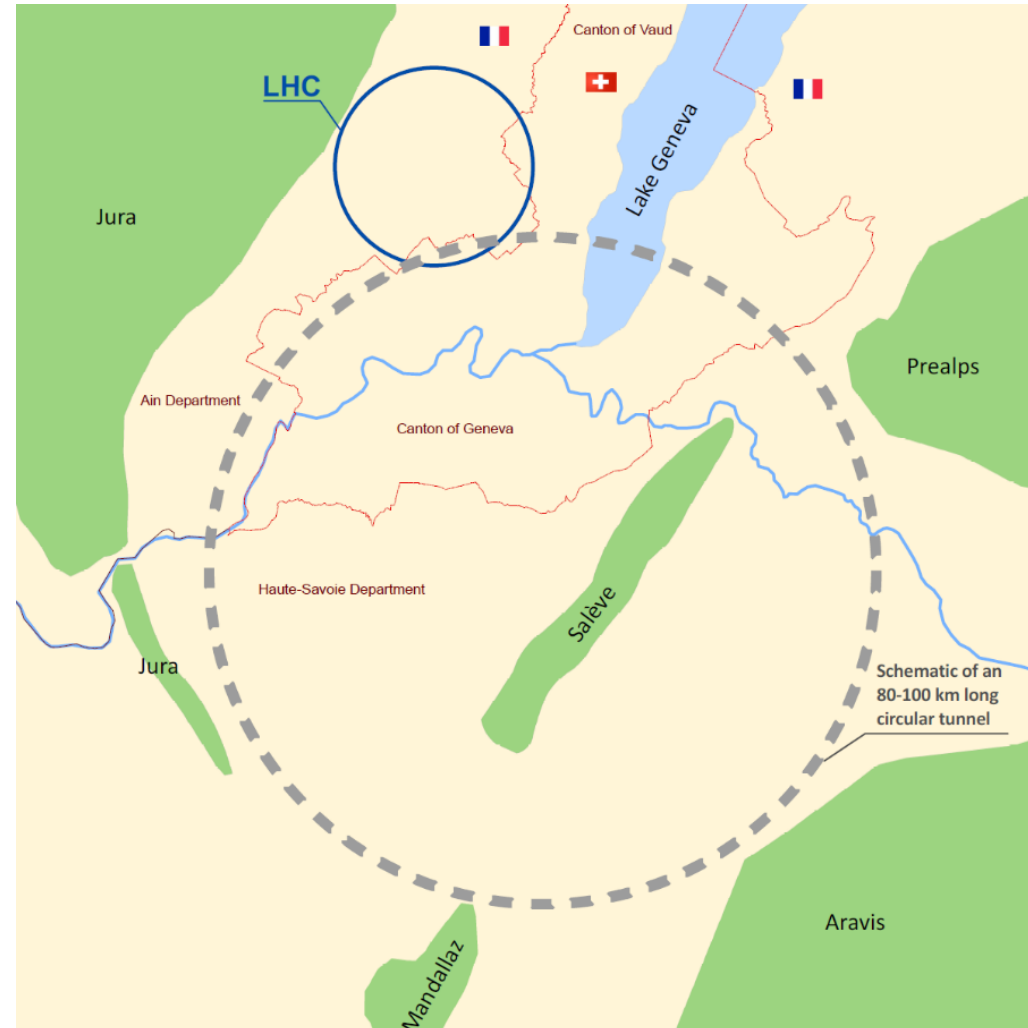
**Aims of the civil engineering feasibility study:**

Is 80km-100km feasible in the Geneva basin?

Can we go bigger?

What is the 'optimal' size?

What is the optimal position?

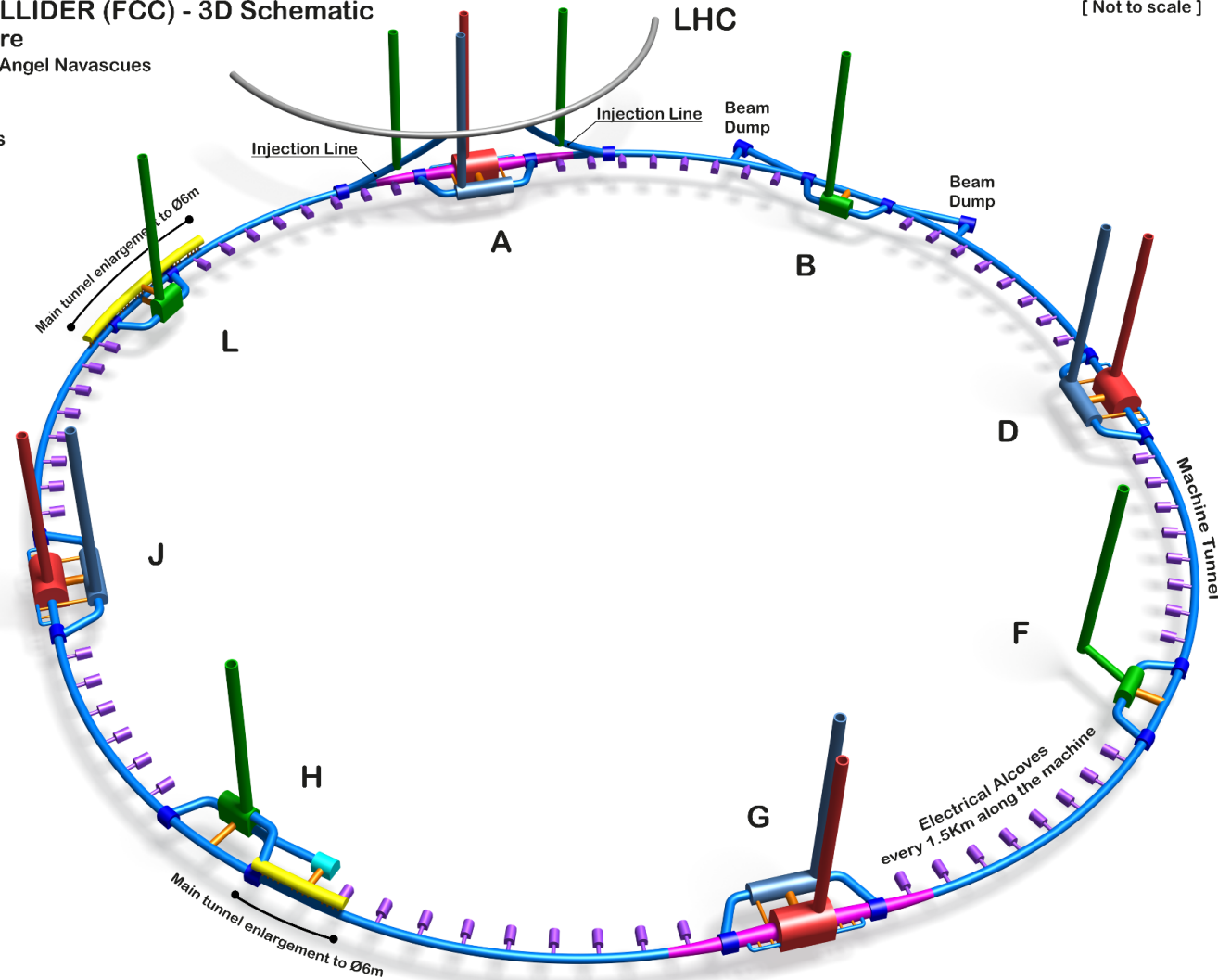


# FCC Baseline Schematic: Single Tunnel

FUTURE CIRCULAR COLLIDER (FCC) - 3D Schematic  
Underground Infrastructure  
John Osborne - William Bromiley - Angel Navascues

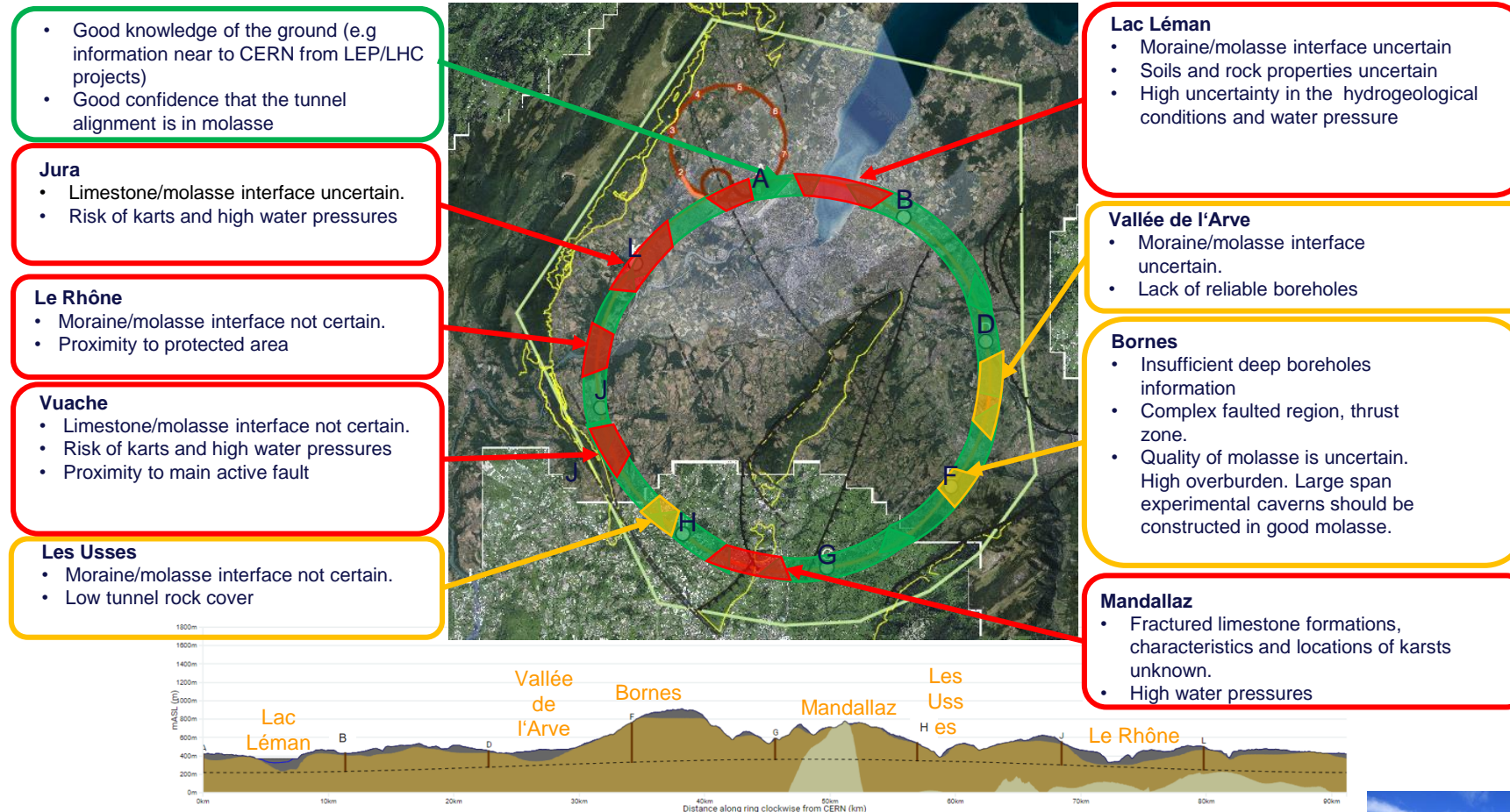
[ Not to scale ]

- FCC Tunnels
- Experimental points
- Access points
- Service caverns
- Connection tunnels
- Electrical alcoves
- Klystron galleries
- Tunnel widening
- Cryo cavern
- LHC





# FCC: Areas with highest geological uncertainty

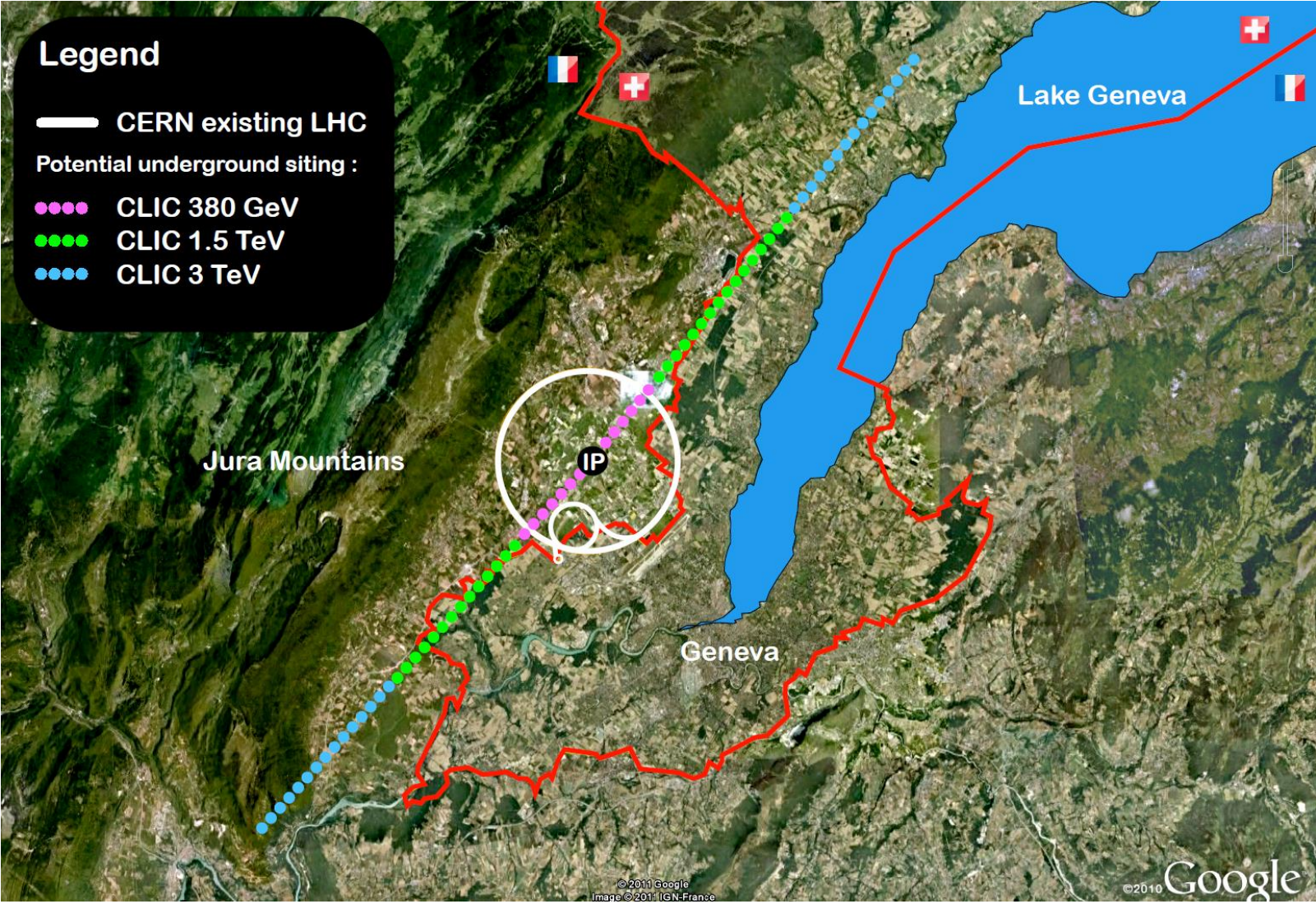


On-site investigation works 2024-25





# Compact Linear Collider (CLIC) Studies at CERN



# Physics Beyond Colliders (PBC)



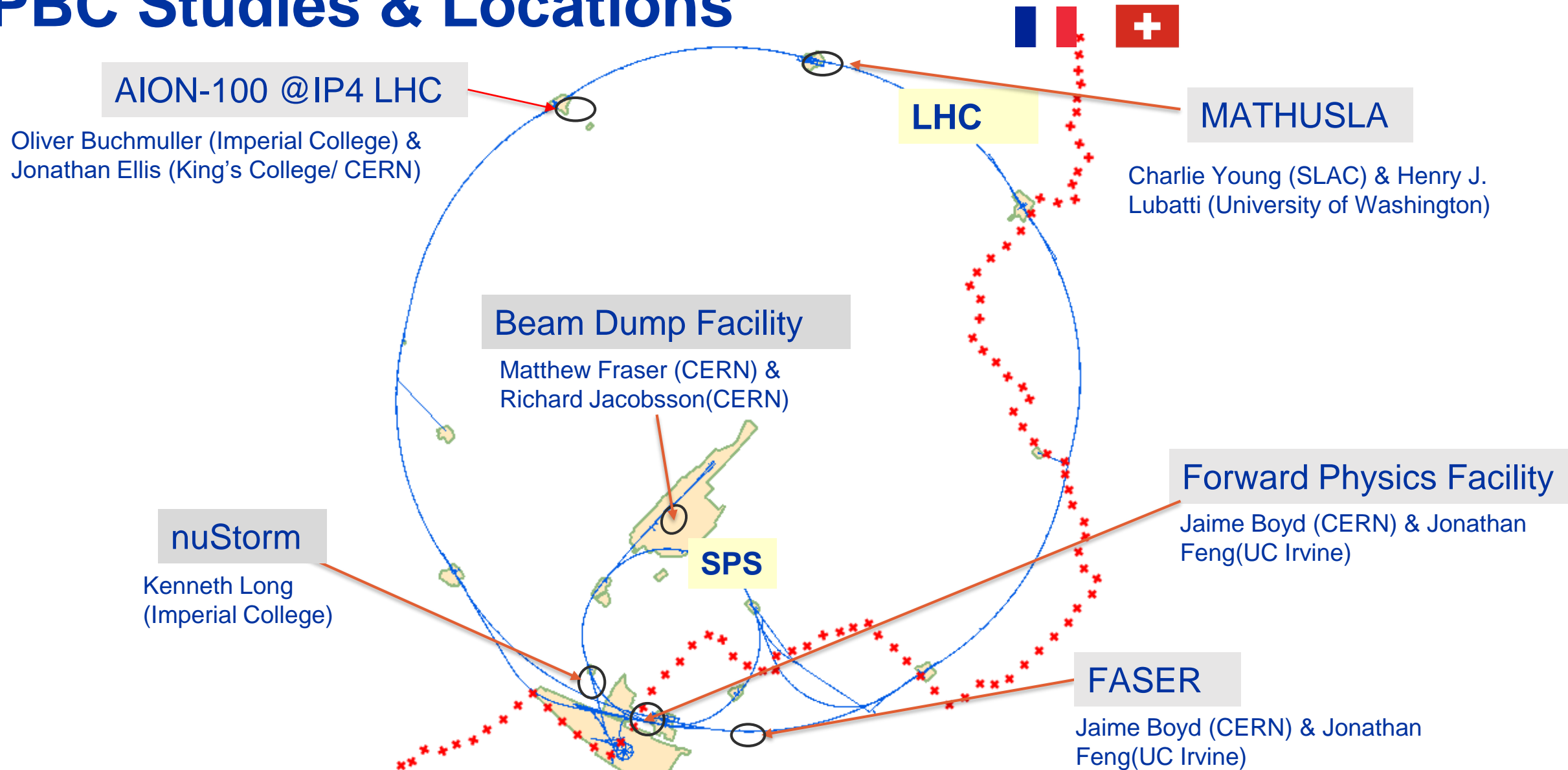
PBC is a programme aimed at exploiting the full scientific potential of CERN's accelerator complex and its scientific infrastructure through projects complementary to the LHC, HL-LHC and other possible future colliders.

## Main studies:

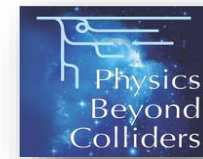
- Beam Dump Facility (BDF)
- Forward Physics Facility (FPF)
- electrons in the SPS (eSPS)
- ForwArd Search ExpeRiment (FASER)
- Neutrinos from STORed Muons (nuSTORM)
- Plasma Electron Proton/Ion Collider (PEPIC)
- Advanced Proton driven Plasma Wakefield Experiment (AWAKE)++
- Electric Dipole Moments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



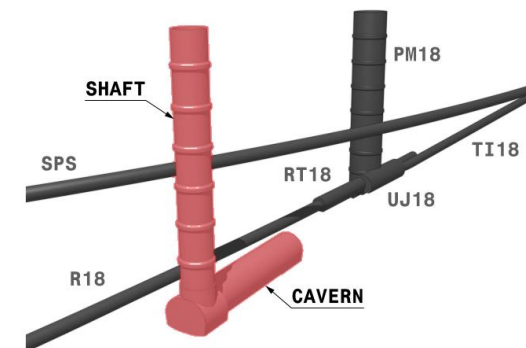
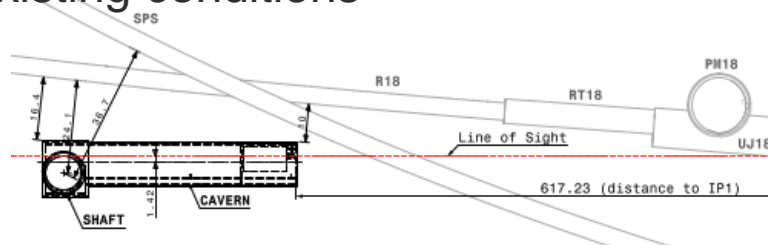
# PBC Studies & Locations



# Forward Physics Facility



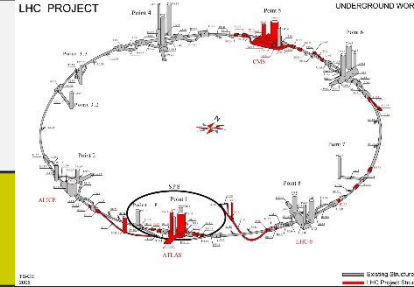
- Location approx. 617m from IP1 on the French side of CERN land, 10 m away from the LHC tunnel
- Design includes
  - A 65m long experimental cavern, experiments centralised on the line of sight (LoS)
  - An 88m deep access shaft
  - Support buildings and infrastructure
- Site previously used as spoil disposal area for LEP, ground levels approx. 7m above the surrounding area
- Significant volume of excavation due to the existing conditions



# Civil Engineering companies

## Large Hadron Collider (LHC)

CE Contracts approx. EUR 600m

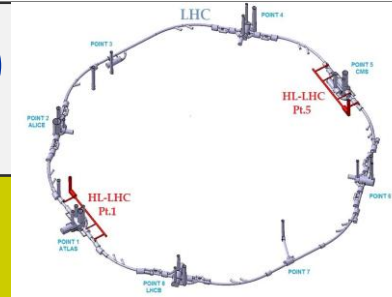


| Package      | Consultants   | Contractors  |
|--------------|---|--|
| POINT1 ATLAS | <ul style="list-style-type: none"> <li>EDF (F)</li> <li>KNIGHT &amp; PIESOLD (GB)</li> </ul>  | <ul style="list-style-type: none"> <li>TEERAG-ASDAG (A)</li> <li>BARESEL (D)</li> <li>LOCHER (CH)</li> </ul>           |
| POINT 5 CMS  | Joint Venture: <ul style="list-style-type: none"> <li>GIBB (NOW JACOBS) (GB)</li> <li>GEOCONSULT (AT)</li> <li>SGI (CHH)</li> </ul> | <ul style="list-style-type: none"> <li>DRAGADOS (E)</li> <li>SELI (I)</li> </ul>                                       |
| Other points | <ul style="list-style-type: none"> <li>BROWN &amp; ROOT (GB)</li> <li>INTECSA (E)</li> <li>HYDROTECHNICA (P)</li> </ul>             | <ul style="list-style-type: none"> <li>TAYLOR-WOODROW (GB)</li> <li>AMEC (GB)</li> <li>SPIE-BATIGNOLLES (F)</li> </ul> |
| TI 8         | <ul style="list-style-type: none"> <li>DITO</li> </ul>  | <ul style="list-style-type: none"> <li>LOSINGER (CH)</li> </ul>  |

# Civil Engineering companies

## High Luminosity LHC Project (HL-LHC)

CE Contracts approx. EUR 200m



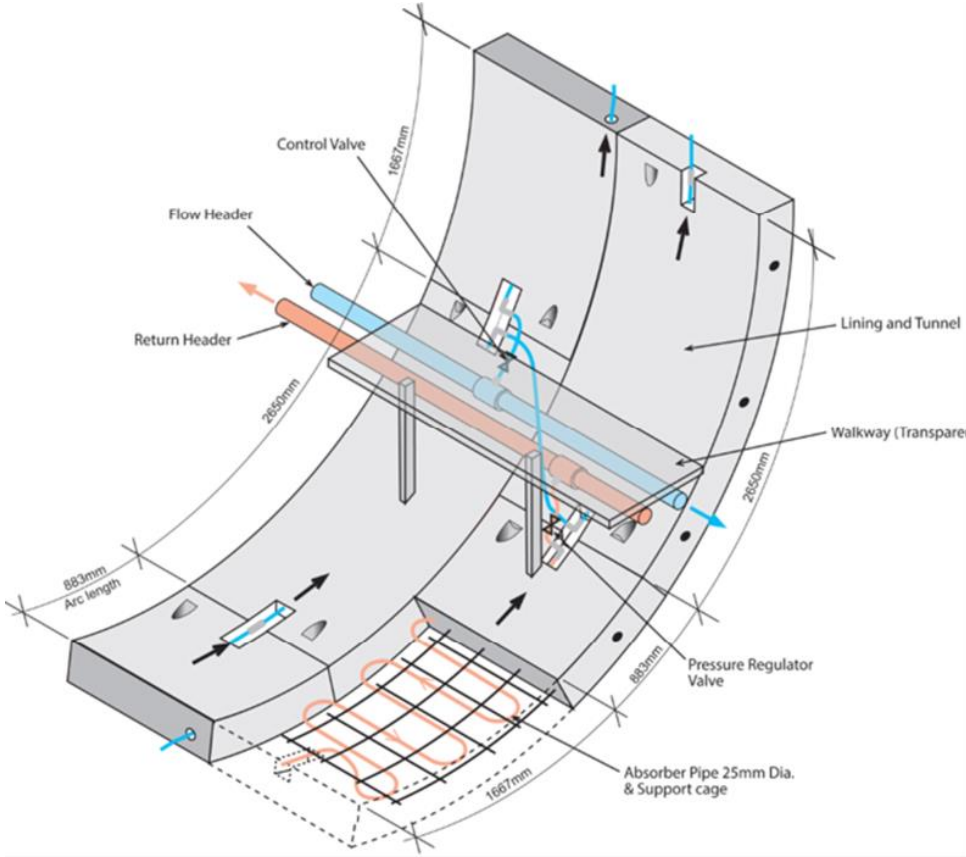
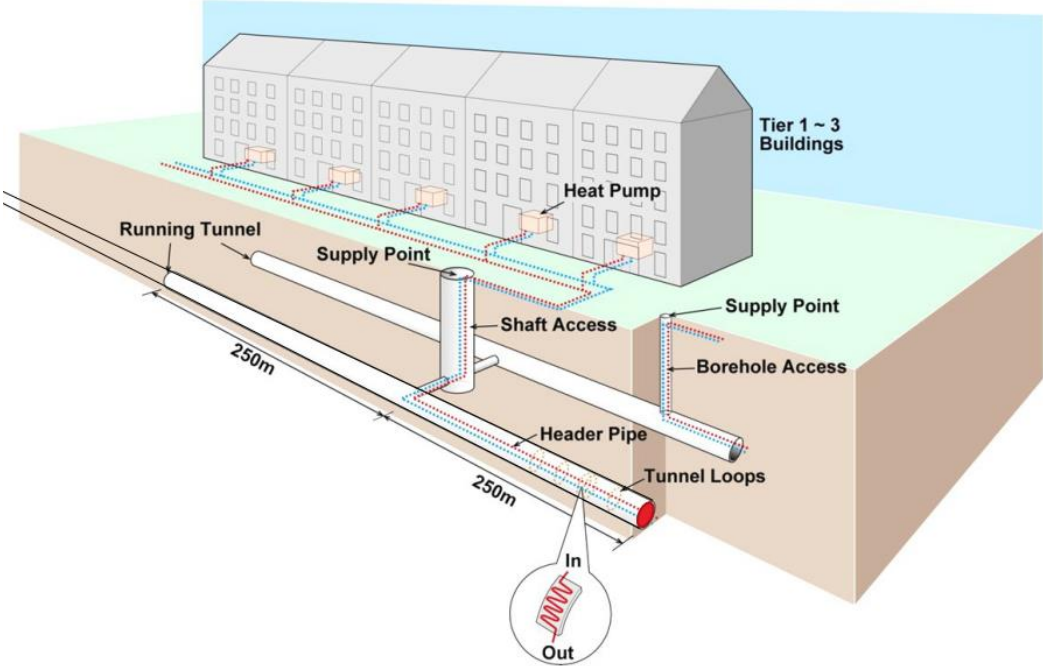
| Package         | Consultants  | Contractors   |
|-----------------|--|---|
| POINT1          | Consortium ORIGIN: <ul style="list-style-type: none"> <li>▪ SETEC (F)</li> <li>▪ CSD ENGINEERS (CH)</li> <li>▪ ROCKSOIL (I)</li> </ul>       | Joint Venture Marti Meyrin: <ul style="list-style-type: none"> <li>▪ MARTI TUNNELBAU (CH)</li> <li>▪ MARTI DEUTSCHLAND (DE)</li> <li>▪ MARTI ÖSTERRERICH (A)</li> </ul> |
| POINT 5         | Consortium LAP <ul style="list-style-type: none"> <li>▪ LOMBARDI (CH)</li> <li>▪ ARTELIA (F)</li> <li>▪ PINI SWISS ENGINEERS (CH)</li> </ul> | Consortium CIB: <ul style="list-style-type: none"> <li>▪ IMPLENIA (CH/ F)</li> <li>▪ BARESEL (DE)</li> </ul>  |
| Building Permit | <ul style="list-style-type: none"> <li>▪ DELTA ARCHITECTS</li> <li>▪ ASS ARCHITECTS</li> </ul>   |   |







# Heat Recovery Study - 2022



# CERN & University College Cork Collaboration

➤ In 2014, CERN established a collaboration with CSIC University of Cambridge (UK) in 2014



➤ Since 2019, a Collaboration between CERN & University College Cork (UCC) was established by Dr Zili Li on Tunnel Asset Management on three research projects:



- 2019-2020: Post-doc **Zhipeng Xiao**

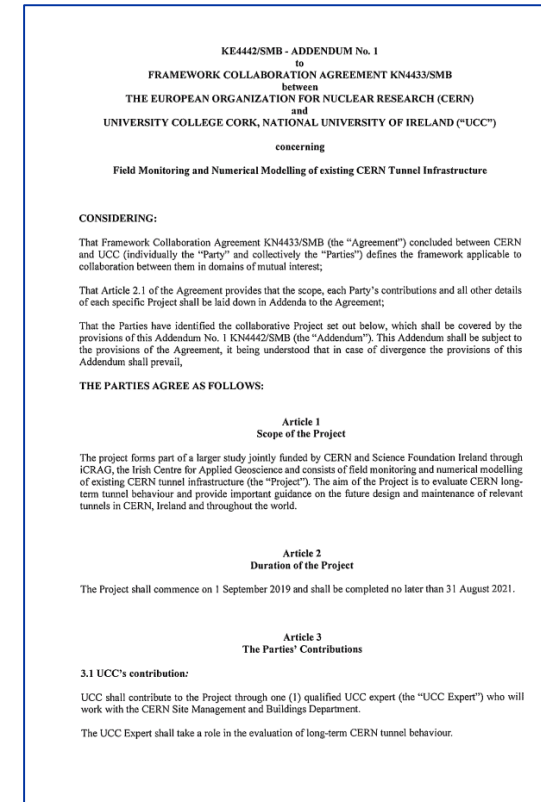
*Long-term ageing tunnel structural behaviour at CERN and probabilistic risk assessment*

- 2020-2021: Master Student **Darragh O'Brian**

*Automated crack classification for underground tunnel infrastructure using deep learning*

- 2022-2024: PhD student **Aohui Ouyang**

*Deep learning-based photogrammetric analysis of ageing underground infrastructure (in progress)*



Collaboration Agreement



# Tunnel Asset Management

The TAM team within the SCE-DOD-FAS section is responsible for the coordination and research & development of tools that enables to assess the status of our underground infrastructure in order to operate it safely and efficiently. The use of **Smart** monitoring technologies will help to predict where maintenance is required and, hence, optimize future tunnel constructions.

## Main Objectives

- Reduce inspection time
- Increase objectivity of inspection
- Increase quantitative data
- Reduce personnel presence in tunnels by using remote monitoring technologies
- Develop a technology for future inspection to be implemented in new underground infrastructures (eg. FCC, Linear Colliders)

# Tunnel Monitoring

- Collaboration with BE-CEM Robotics team by using advanced 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 for tunnel lining deformation detection
- Other Monitoring technologies
  - Drone ie. Flyability Elios 3
  - Laser scanning (Point cloud system)



FLYABILITY

# Train Inspection Monorail – TIM

- Currently two TIM units are running in the LHC
- Used for real-time monitoring of the LHC machine: the tunnel structure, the oxygen percentage, communication bandwidth and the temperature
- Provides visual and infrared imaging of LHC tunnel
- Can move up to 6km/h and can also pull small wagons for specific tasks

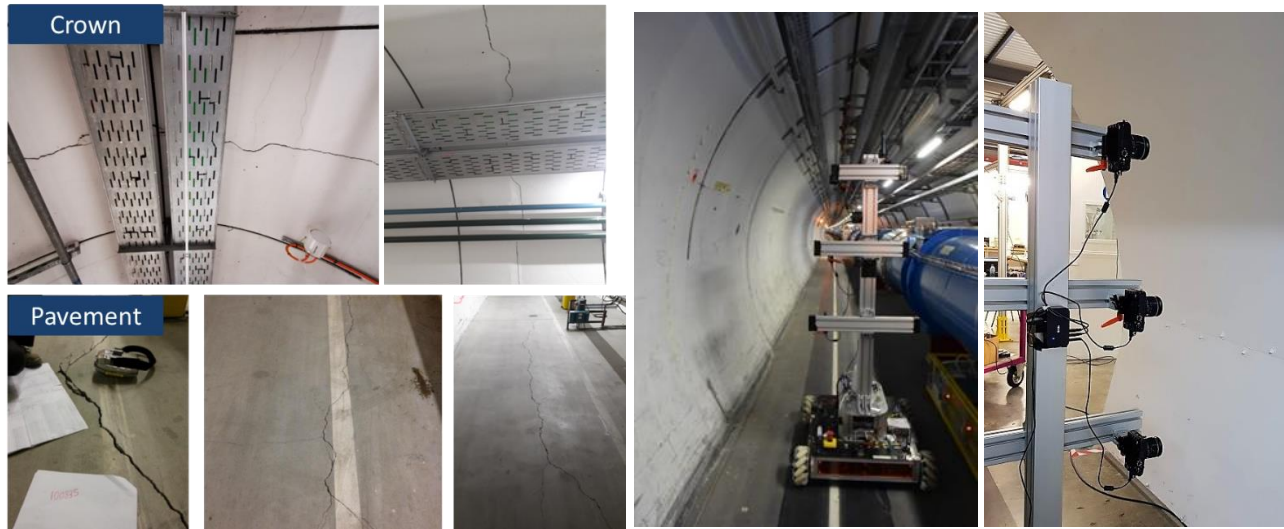


# Deep learning-based photogrammetric analysis of ageing underground infrastructure

infrastructure



CERN owns 83 km-long underground infrastructure and cracks appear as the dominant ageing defect

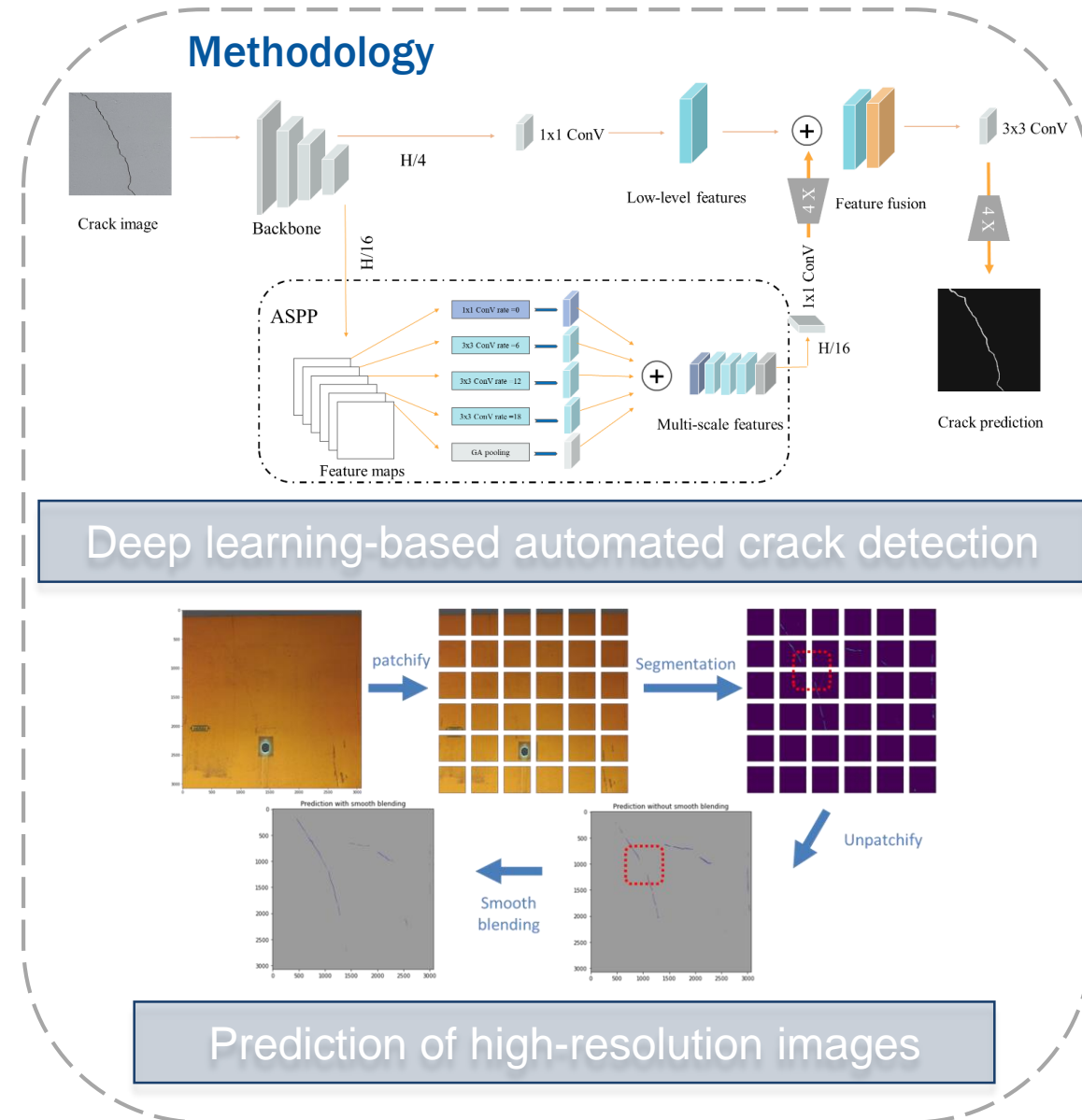


Observed cracks

CERNBot for data collection

## Objectives:

- Achieve remote tunnel visual inspection in a radioactive environment
- Achieve automated crack detection and quantification
- Analyzing crack patterns for understanding long-term structural behavior

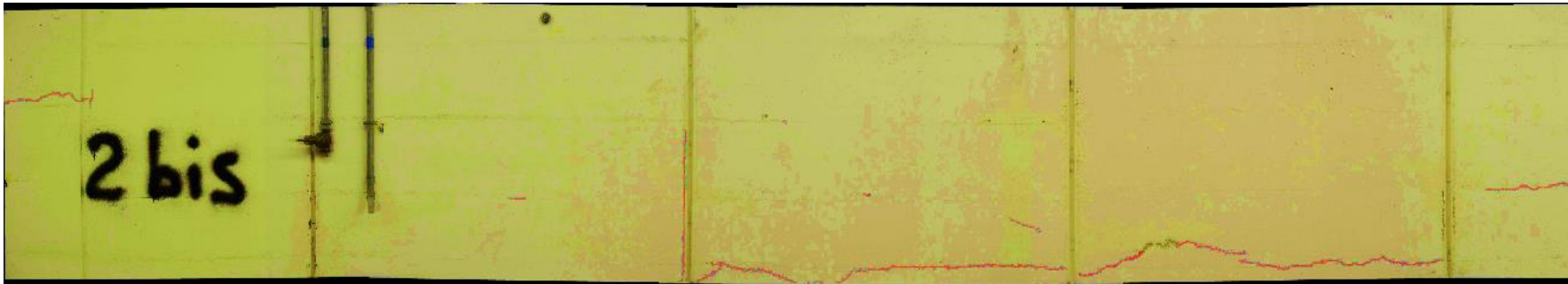
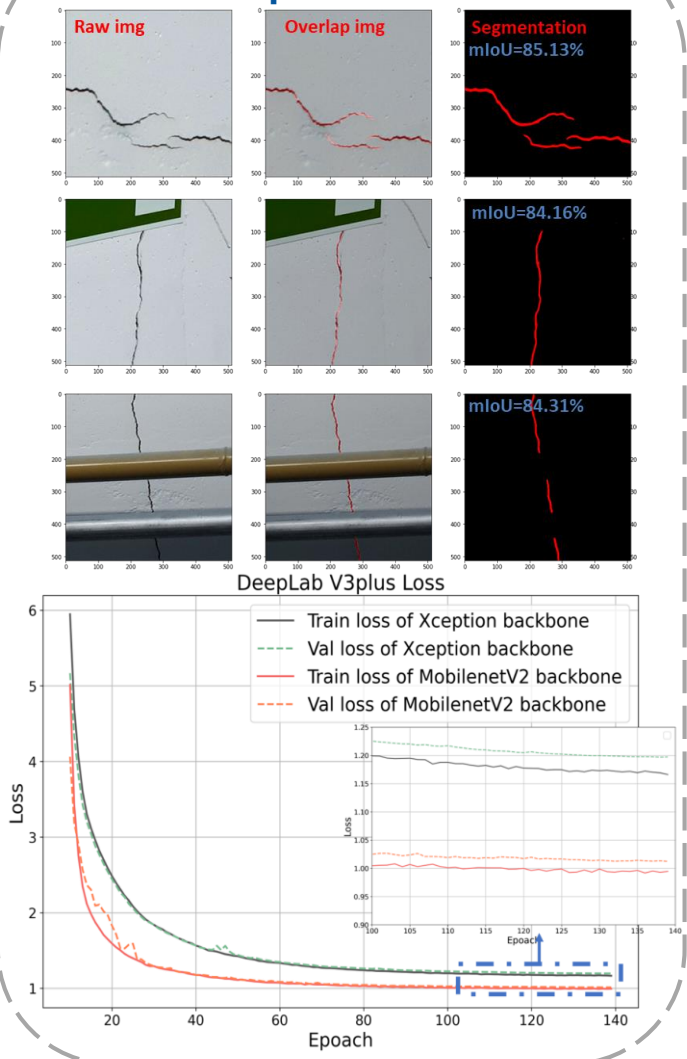




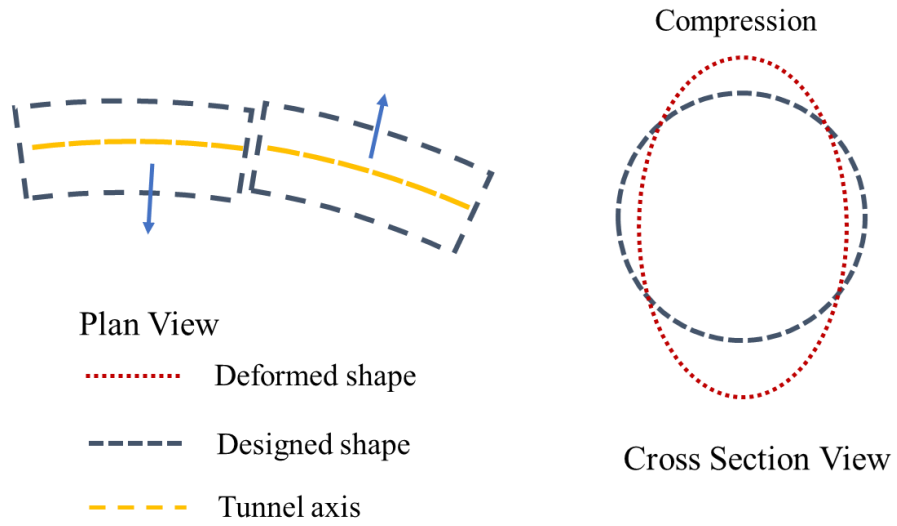
# Deep learning-based photogrammetric analysis of ageing underground infrastructure



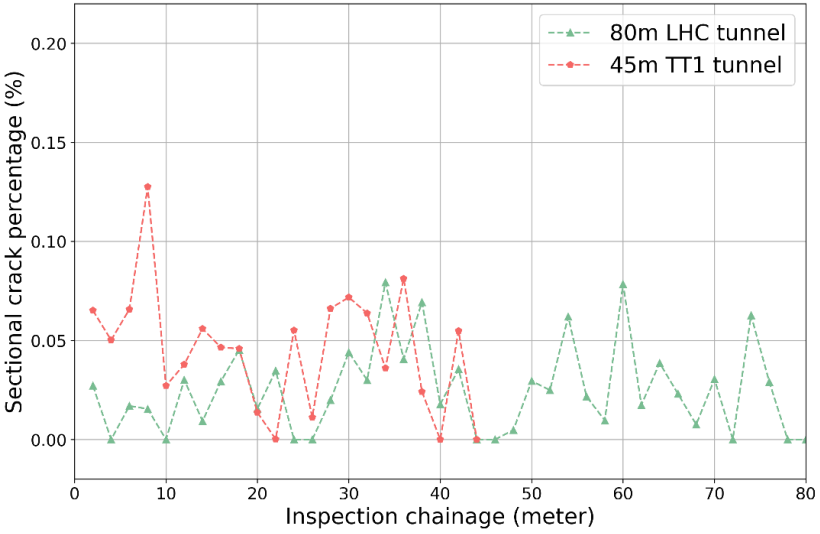
## Model performance



## Identified crack spatial patterns



Deformation mechanisms of LHC and TT1 Tunnel



Crack distribution

# Future TAM Events

- 4th International Symposium of Machine learning and Big Data in Geoscience **ISMLG2023**  
29th August - 1st September 2023 at University College Cork



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

## TAM Innovation Workshop Tunnel Asset Management

### Knowledge & Smart Technologies

- Tunnel inspections
- Monitoring
- Repairs
- Recent developments



Organized by the CERN Civil Engineering TAM team  
John Osborne, Vanessa Di Murro, Martin Cull, Aohui Ouyang

For Registration Email: [Tam.workshop@cern.ch](mailto:Tam.workshop@cern.ch)



# Thank you!



