

CERN Civil Engineering Future Studies Section and Opportunities

John Osborne, Vanessa Di Murro, Martin Cull, Aohui Ouyang

SCE-DOD-FS

13/02/2023

SCE-DOD-FS Section

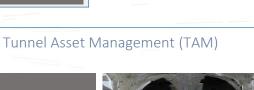


Future Accelerator Studies [FS] SL: John Osborne DL: Mar Capeans

Physics Beyond Colliders (PBC)

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





Future Circular Collider (FCC) Underground Studies and Site Investigations



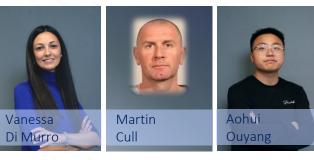






Tunnel R&D Photogrammetry/Fibr e Optic Studies







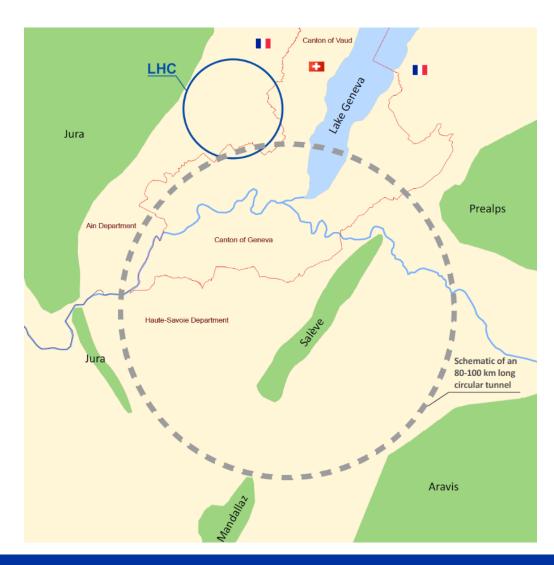
SCE-DOD-FS Mandate

- 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



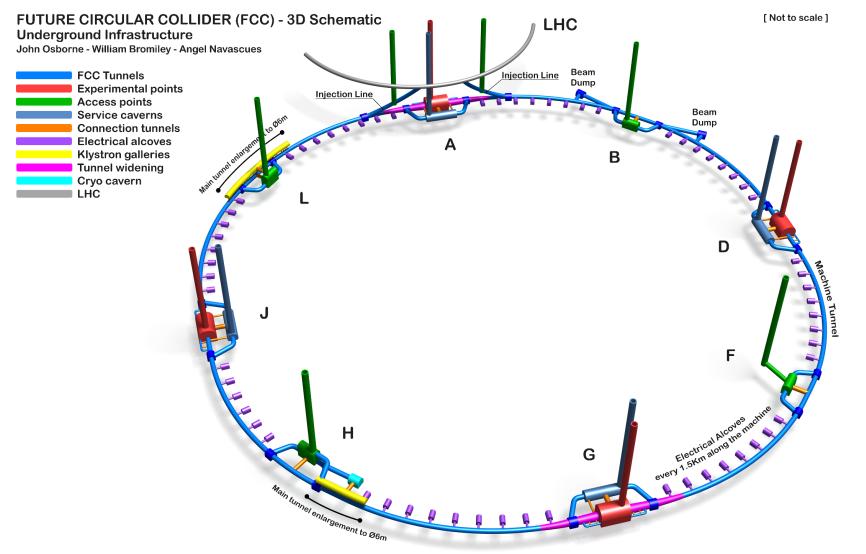
The Future Circular Collider Study (FCC)

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





FCC: Areas with highest geological uncertainty

- Good knowledge of the ground (e.g information near to CERN from LEP/LHC projects)
- Good confidence that the tunnel alignment is in molasse

Jura

- Limestone/molasse interface uncertain.
- Risk of karts and high water pressures

Le Rhône

- Moraine/molasse interface not certain.
- · Proximity to protected area

Vuache

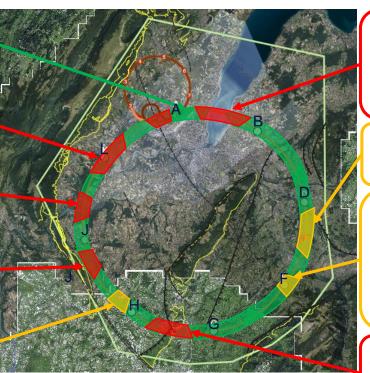
- · Limestone/molasse interface not certain.
- Risk of karts and high water pressures
- Proximity to main active fault

Les Usses

· Moraine/molasse interface not certain.

Lac

Low tunnel rock cover



Lac Léman

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

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

Le Rhône

Les

Uss

н <mark>es</mark>

Mandallaz

40km Distance along ring clockwise from CERN (km)

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



Vallée

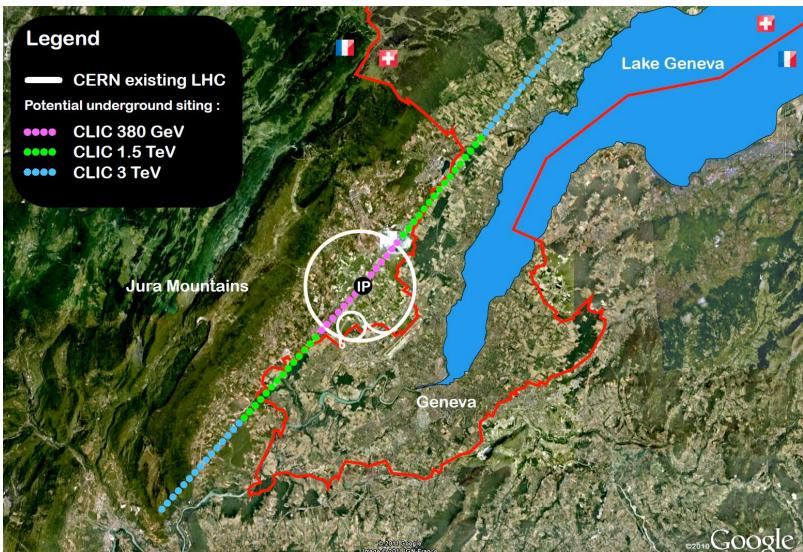
de

l'Arve

Bornes



Compact Linear Collider (CLIC) Studies at CERN





Physics Beyond Colliders (PBC)

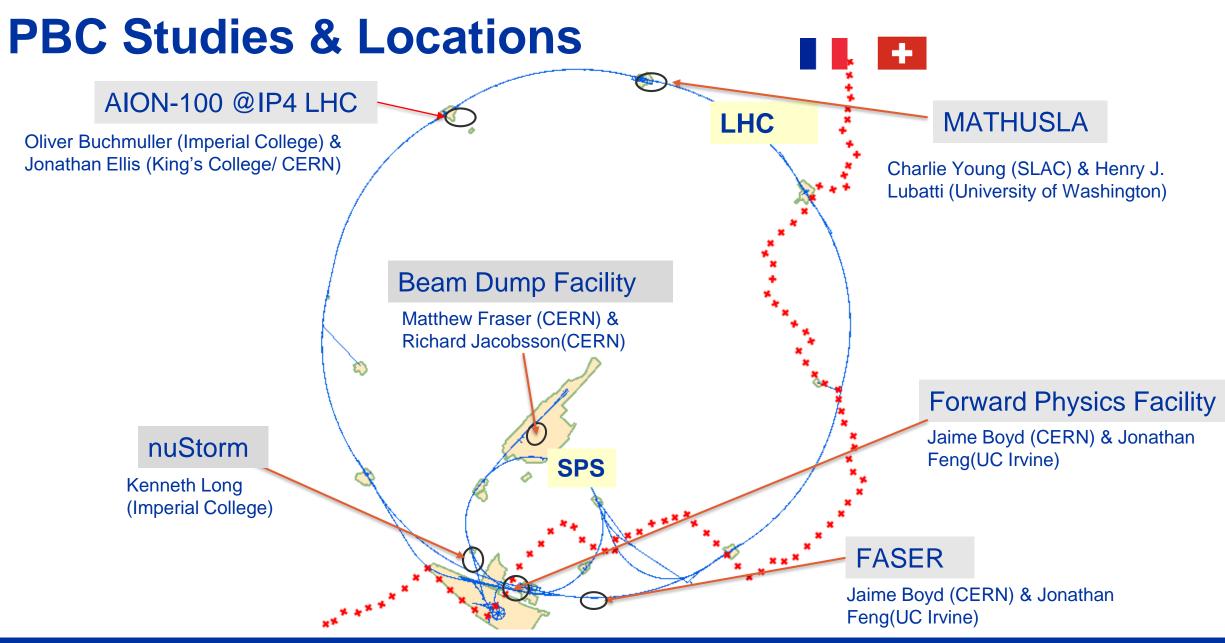


PBC is a programme aimed at exploiting the full scientific potential of CERN's accelerator complex and its scientific infrastructure through projects complementary to the LHC, HL-LHC and other possible future colliders.

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)

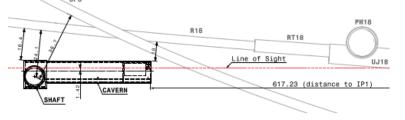


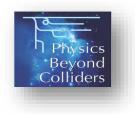




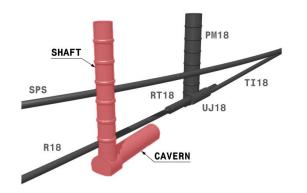
Forward Physics Facility

- 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 Ha	LHC PROJECT MARK DEPENDENCE DEPENDENCE DEPENDENCE DEPENDENCE DEPENDENCE DE PENDENCE DE PEN		
Package	Consultants	Contractors	
POINT1 ATLAS	 EDF (F) KNIGHT & PIESOLD (GB) 	 TEERAG-ASDAG (A) BARESEL (D) LOCHER (CH) 	
POINT 5 CMS	Joint Venture: • GIBB (NOW JACOBS) (GB) • GEOCONSULT (AT) • SGI (CHH)	 DRAGADOS (E) SELI (I) 	
Other points	 BROWN & ROOT (GB) INTECSA (E) HYDROTECHNICA (P) 	 TAYLOR-WOODROW (GB) AMEC (GB) SPIE-BATIGNOLLES (F) 	
TI 8	 DITO 	 LOSINGER (CH) 	



Civil Engineering companies

High Lu CE Contrac	ct (HL-LHC)	
Package	Consultants	Contractors
POINT1	Consortium ORIGIN: SETEC (F) CSD ENGINEERS (CH) ROCKSOIL (I)	Joint Venture Marti Meyrin: MARTI TUNNELBAU (CH) MARTI DEUTSCHLAND (DE) MARTI ÖSTRERREICH (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 	



Civil Engineering companies

Future Circ	United Call Cold Cold Cold Cold Cold Cold Cold Co		
Package	Consultants	Contractors	
PRE-DESIGN	 ILF (A) GADZ (CH) ARUP (UK) AMBERG (CH) 		
Permitting GiS suppport	 SETEC (FR) SETEC (FR) & ARUP (UK) 		
PRELIM SITE INVESTIGATION	 EGIS (F) BG (CH) 		



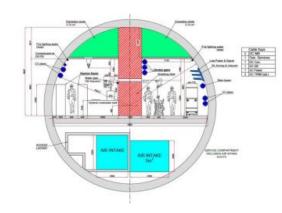
Life Cycle Assessment – Future Tunnels

Goal and Scope

- Goal: Reduce embodied and construction environmental impacts
- LCA for 3 tunnel options (tunnels, caverns & access shafts)
- System boundaries: Embodied and construction. *Excluding operation, use and end of life.*
- CLIC Drive Beam tunnel, 5.6m internal diameter

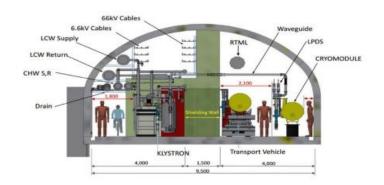
2. CLIC Klystron tunnel, 10m internal diameter

And the state of t





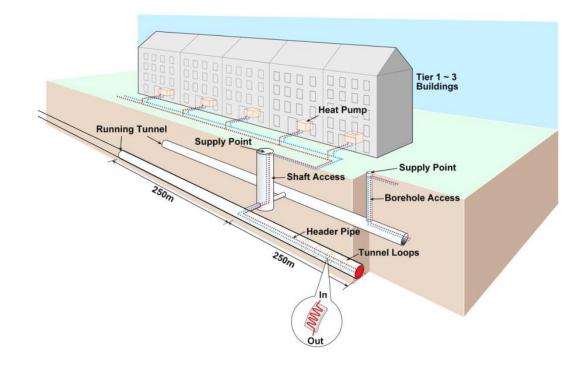
ARUP

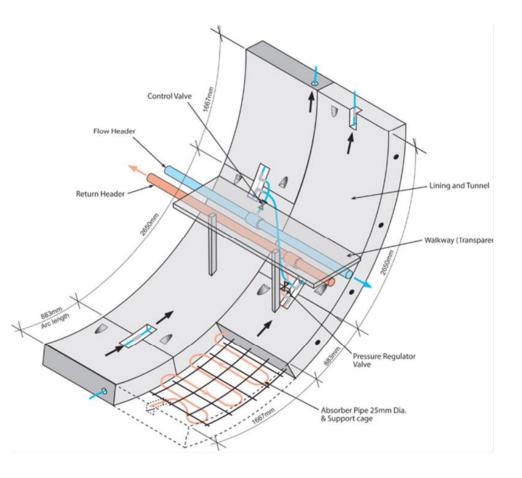




Heat Recovery Study - 2022









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)





KE4442/SMB + ADDENDUM № 1 In FRAMEWORK COLLABORATION AGREEMENT KN4433/SMB EVENT THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN) and UNIVERSITY COLLEGE CORK, NATIONAL UNIVERSITY OF IRELAND (*UCC

concerning Field Monitoring and Numerical Modelling of existing CERN Tunnel Infrastructure

CONSIDERING:

That Framework Collaboration Agreement KN4433/SMB (the "Agreement") concluded between CERN and UCC (individually the "Party" and collectively the "Parties") defines the framework applicable to collaboration between them in domains of mutual interest;

That Article 2.1 of the Agreement provides that the scope, each Party's contributions and all other detail of each specific Project shall be laid down in Addenda to the Agreement;

That the Parties have identified the collaborative Project set out below, which shall be covered by the provisions of this Addendum No. 1 KN4442/SMB (the "Addendum"). This Addendum shall be subject to the provisions of the Agreement, it being understood that in case of divergence the provisions of this Addendum shall prevail,

THE PARTIES AGREE AS FOLLOWS

Article 1 Scope of the Project

The project forms part of a larger study jointly funded by CERN and Science Foundation Ireland through ICRAO, the Irish Centre for Applied Geoscience and consists of field monitoring and numerical modelling of existing CERN tunnel infrastructure (the "Project"). The aim of the Project is to evaluate CERN longterm turnel behaviour and provide important guidance on the future design and maintenance of relevant tunnels in CERN; Ireland and throughout the world.

> Article 2 Duration of the Project

The Project shall commence on 1 September 2019 and shall be completed no later than 31 August 2021.

Article 3 The Parties' Contribution

3.1 UCC's contribution:

UCC shall contribute to the Project through one (1) qualified UCC expert (the "UCC Expert") who will work with the CERN Site Management and Buildings Department.

The UCC Expert shall take a role in the evaluation of long-term CERN tunnel behaviour.

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)





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







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



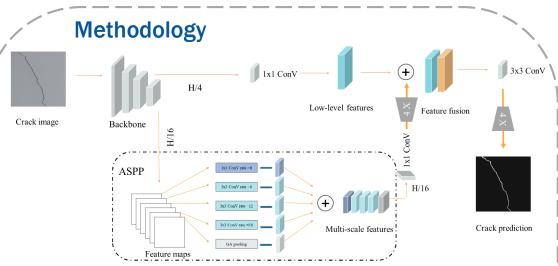


Observed cracks

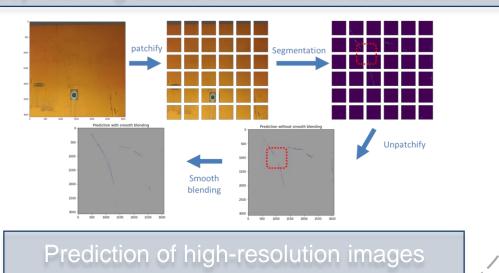
CERNBot for data collection

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

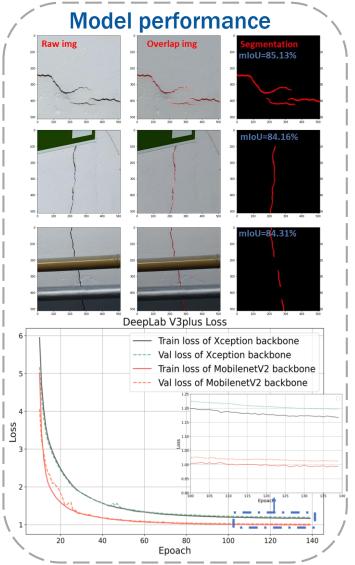


Deep learning-based automated crack detection





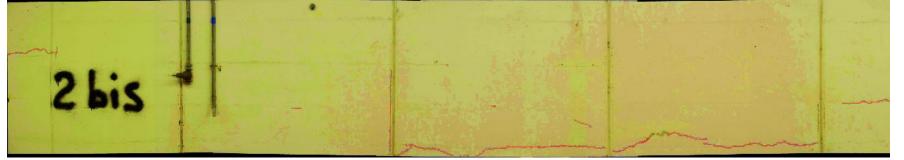
Deep learning-based photogrammetric analysis of ageing underground *infrastructure*



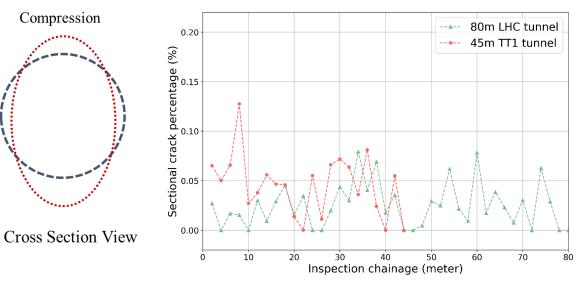








Identified crack spatial patterns



Deformation mechanisms of LHC and TT1 Tunnel

Plan View

.....

Deformed shape

Designed shape

Tunnel axis

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











