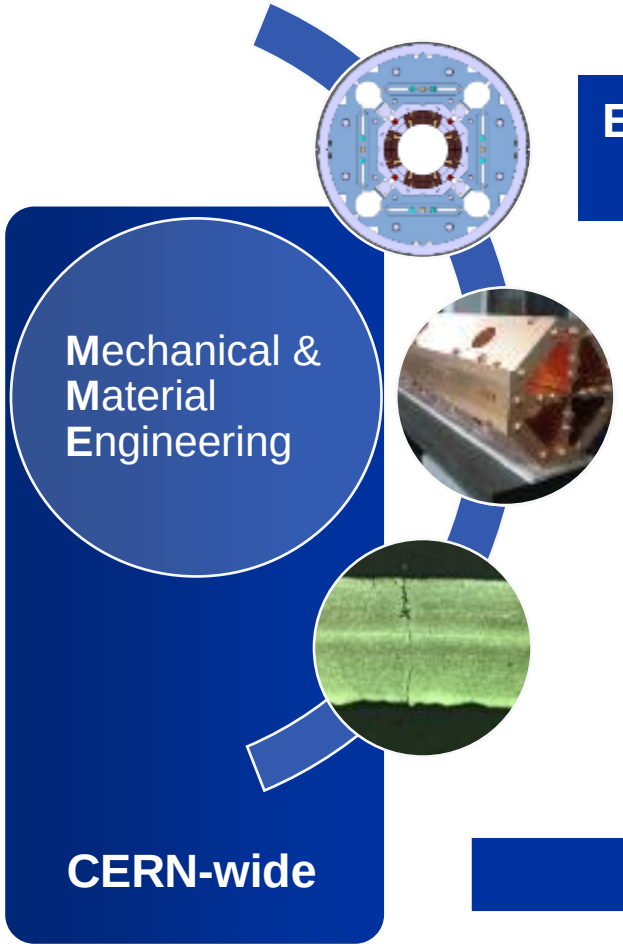
CERN Seismic Network & LHC Operation experience

Michael Guinchard - CERN

EN-MME Mechanical Measurement Lab

Mechanical Measurement Laboratory



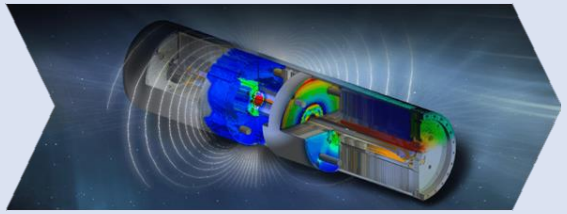
Engineering & Design

- **Design**
- **Simulations & Analyses**
- **Mechanical Measurements**

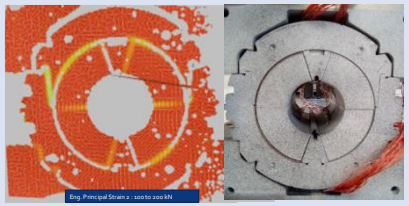
Inputs for FEM :

Mechanical properties

Thermo-physical properties



FEM Validation



Mechanical Measurement Laboratory

INPUTS FOR FEM

Mechanical properties characterization

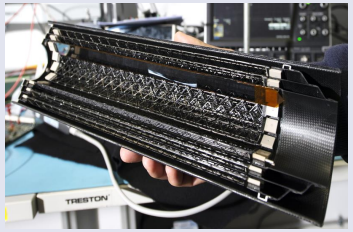
- Tensile, compression, bending tests
- From 77 K up to 1200°C
- Impulse Excitation Techniques

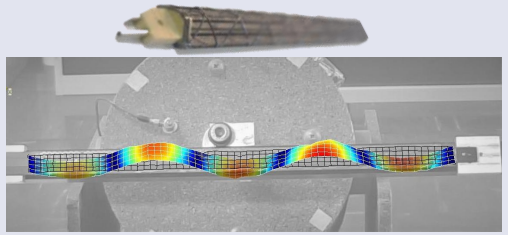
Thermo-physical properties

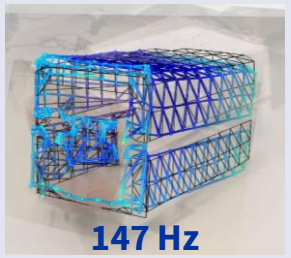
- CTE, Thermal Diffusivity, Specific Heat measurements
- From 1.8 K up to 2000°C

360° virtual tour

Lab Virtual Visit | Mechanical Measurement Laboratory of EN-MME







Experimental Stress Analysis

- Resistive measurements, Optical fiber based on Rayleigh backscattering and Fiber-Bragg grating (FBG)
- From 1.9 K up to 600°C

Vibration Analysis

- Seismic measurements, transfer function evaluation
- Experimental modal analysis

FEM VALIDATION

CERN Seismic Network

Our motivations in 2016 :

- **Continuous LHC monitoring;**
- **HL-LHC Civil engineering activities:**

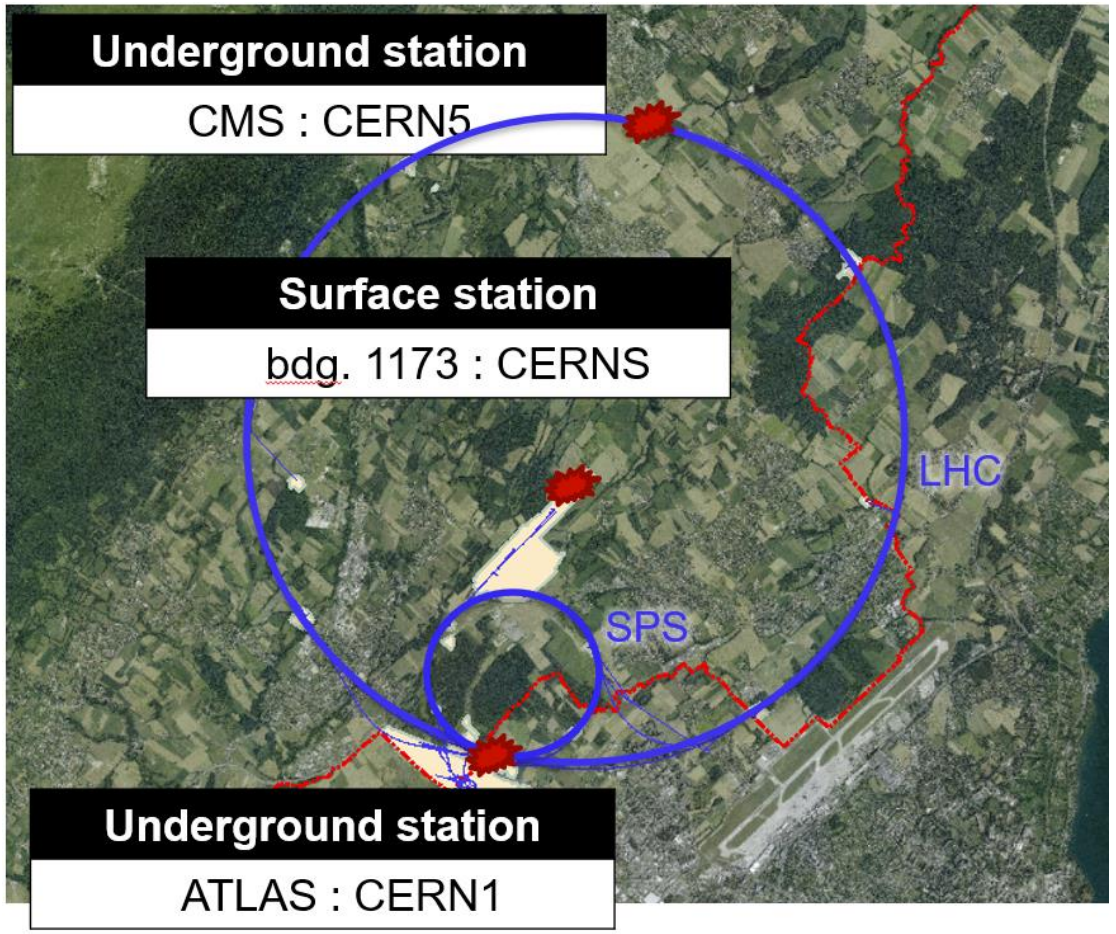
  Monitor our installation to anticipate some risks on the beam instability generated by civil engineering activities.
- **Geneva Program “Géothermie 2020/2030”:**

  Evaluate effects of the micro-seismicity induced by the geo-thermal exploitation on CERN accelerators;

  Collaboration with the Swiss authorities to densify the Geneva basin seismic network.

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

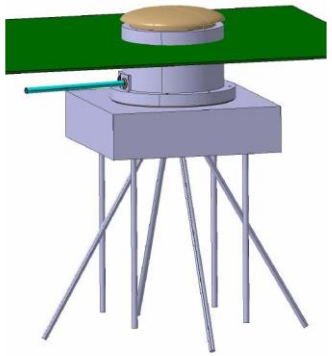
SIG



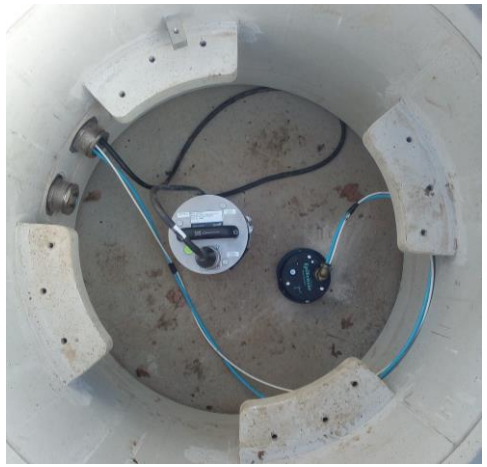
CERN Seismic Network : Hardware

Specific CERN development to fulfil the LHC underground constraints (radiations, R2E, space, transport , etc.)

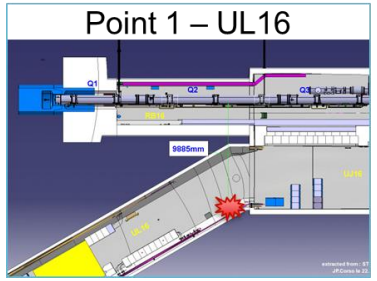
Surface Station

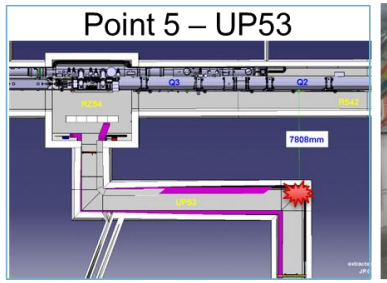


Sensors	Guralp 40T	Kinemetrics EpiSensor ES-T
Output	Velocity	Acceleration
Triaxial	Yes	Yes
Frequency range	**60s to 100Hz**	**DC to 200Hz**
Sensitivity	800 V/(m/s)	2,5 V/g
Noise	172 dB	155 dB
LHC Ground motion level	Yes	No
Threshold level for earthquake	< M3 @10km	≈ M 7,5 @10km



Underground stations





Sensors	Guralp 6T	Kinemetrics EpiSensor ES-T
Output	Velocity	Acceleration
Triaxial	Yes	Yes
Frequency range	**30s to 100Hz**	**DC to 200Hz**
Sensitivity	2400 V/(m/s)	2,5 V/g
Noise	172 dB	155 dB
LHC Ground motion level	Yes	No
Threshold level for earthquake	< M3 @10km	≈ M 7,5 @10km

CERN Seismic Network : Data management

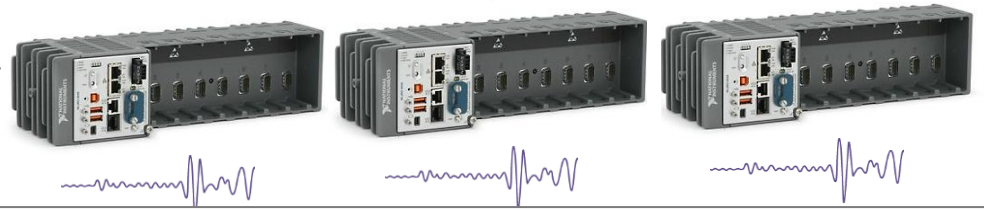
Remote connection

Virtual Machine

GPN

Settings

Data



Fs=250Hz

channels / station

16th Int. Conf. on Accelerator and Large Experimental Control Systems ICALEPCS2017, Barcelona, Spain JACoW Publishing

ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THPHA134

GROUND VIBRATION MONITORING AT CERN AS PART OF THE INTERNATIONAL SEISMIC NETWORK

C. Charrondière, K. Develle, M. Guinchard, M. Cabon, CERN, Geneva, Switzerland

Average PSD

CERN Users

timber The LHC Logging System

TIMBER browsing & data extraction

→ *For the LHC Operation*

Throughput data

CERN Experts

ObsPy A Python Framework for Seismology

Mechanical Measurement Laboratory

→ *For troubleshooting*

MiniSEED Files

SED and worldwide seismic databases

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

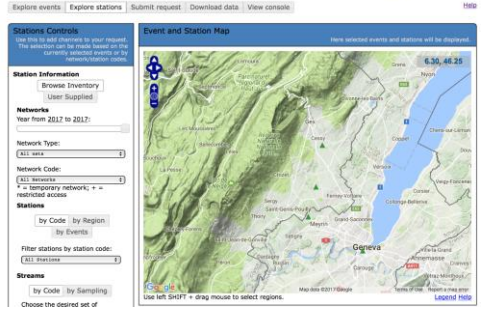
Done according IT safety rules

→ *For collaboration*

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

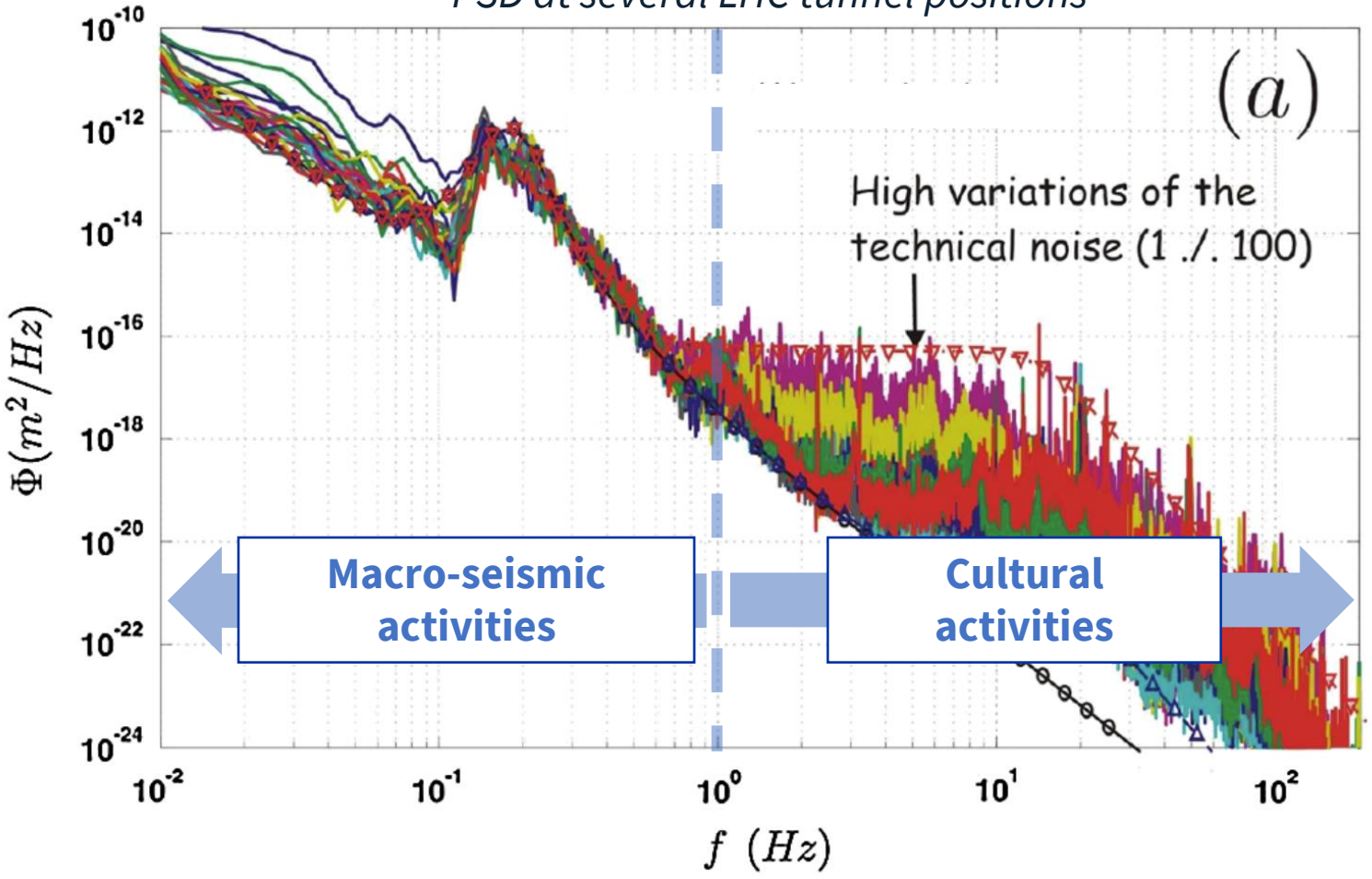
APPROVED

WebDC3 Web Interface to SED Waveform and Event Archives



CERN Seismic Network - Results

PSD at several LHC tunnel positions



PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **13**, 072801 (2010)

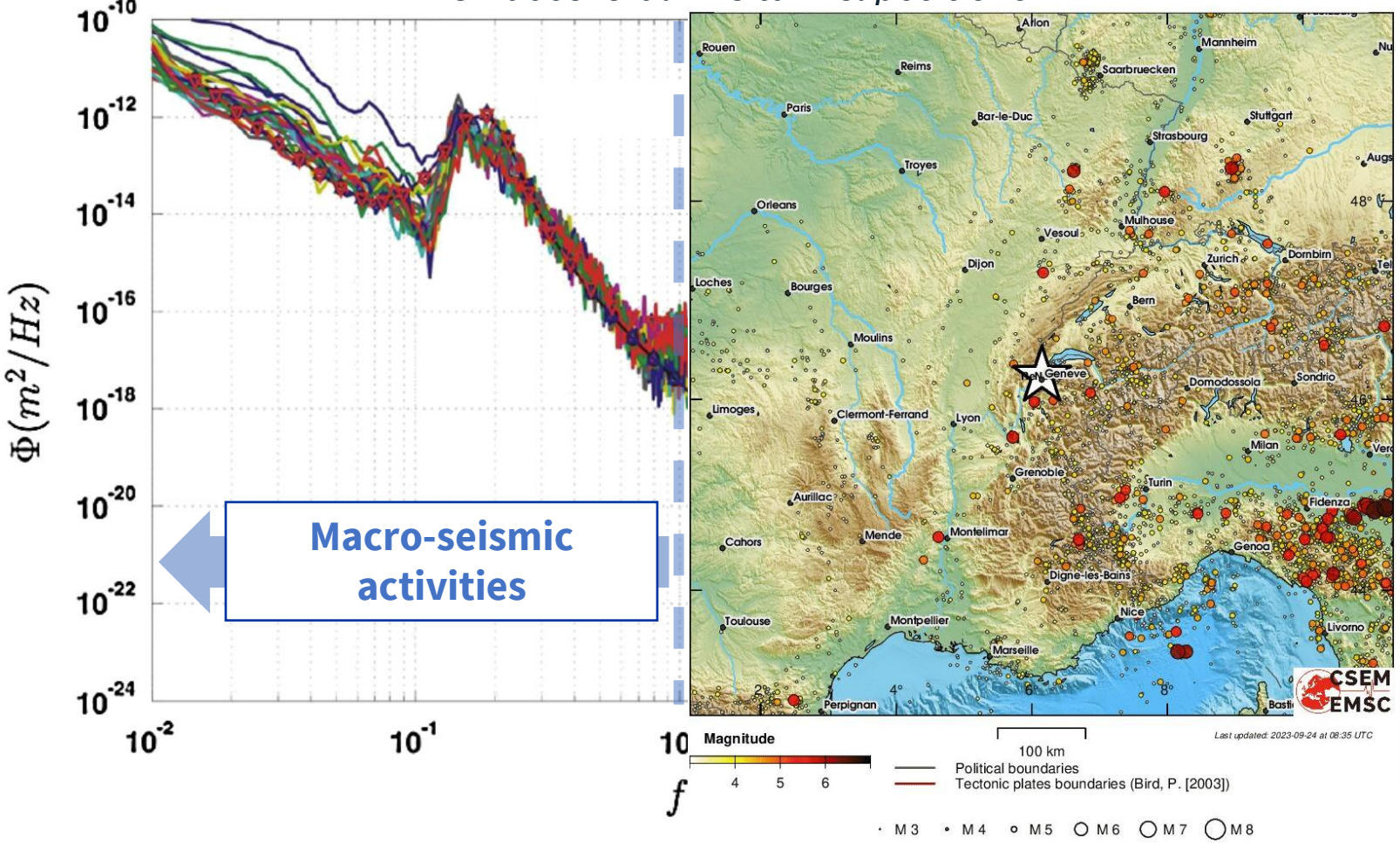
Seismic response of linear accelerators

C. Collette, K. Artoos, M. Guinchard, and C. Hauviller
CERN, CH-1211 Geneva 23, Switzerland
(Received 20 November 2009; published 26 July 2010)

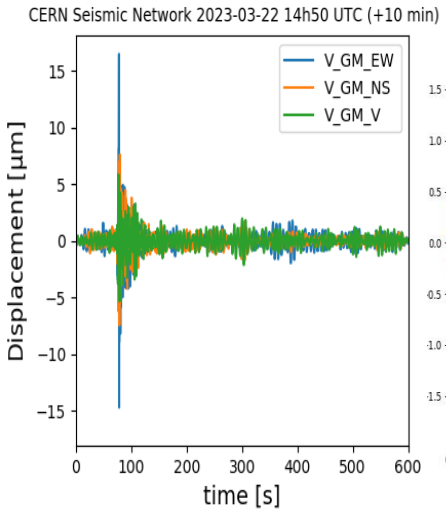
This paper is divided into two parts. The first part presents recent measurements of ground motion in the LHC tunnel at CERN. From these measurements, an update of the ground motion model currently used in accelerator simulations is presented. It contains new features like a model of the lateral motion and the technical noise. In the second part, it is shown how this model can be used to evaluate the seismic response of a linear accelerator in the frequency domain. Then, the approach is validated numerically on a regular lattice, taking the dynamic behavior of the machine alignment stage and the mechanical stabilization of the quadrupoles into account.

CERN Seismic Network - Results

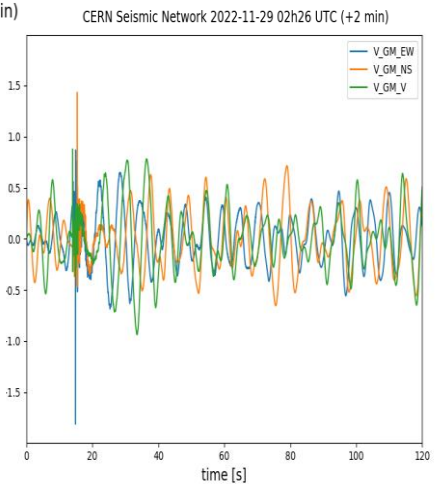
PSD at several LHC tunnel positions

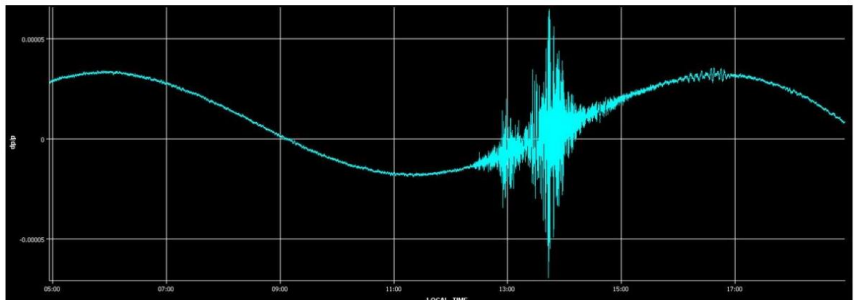


Porrentruy (CH) – M4.3 – 22 March 2023 – 6 km depth



Cessy (FR) – M1.6 – 29 November 2022 – 3.4 km depth

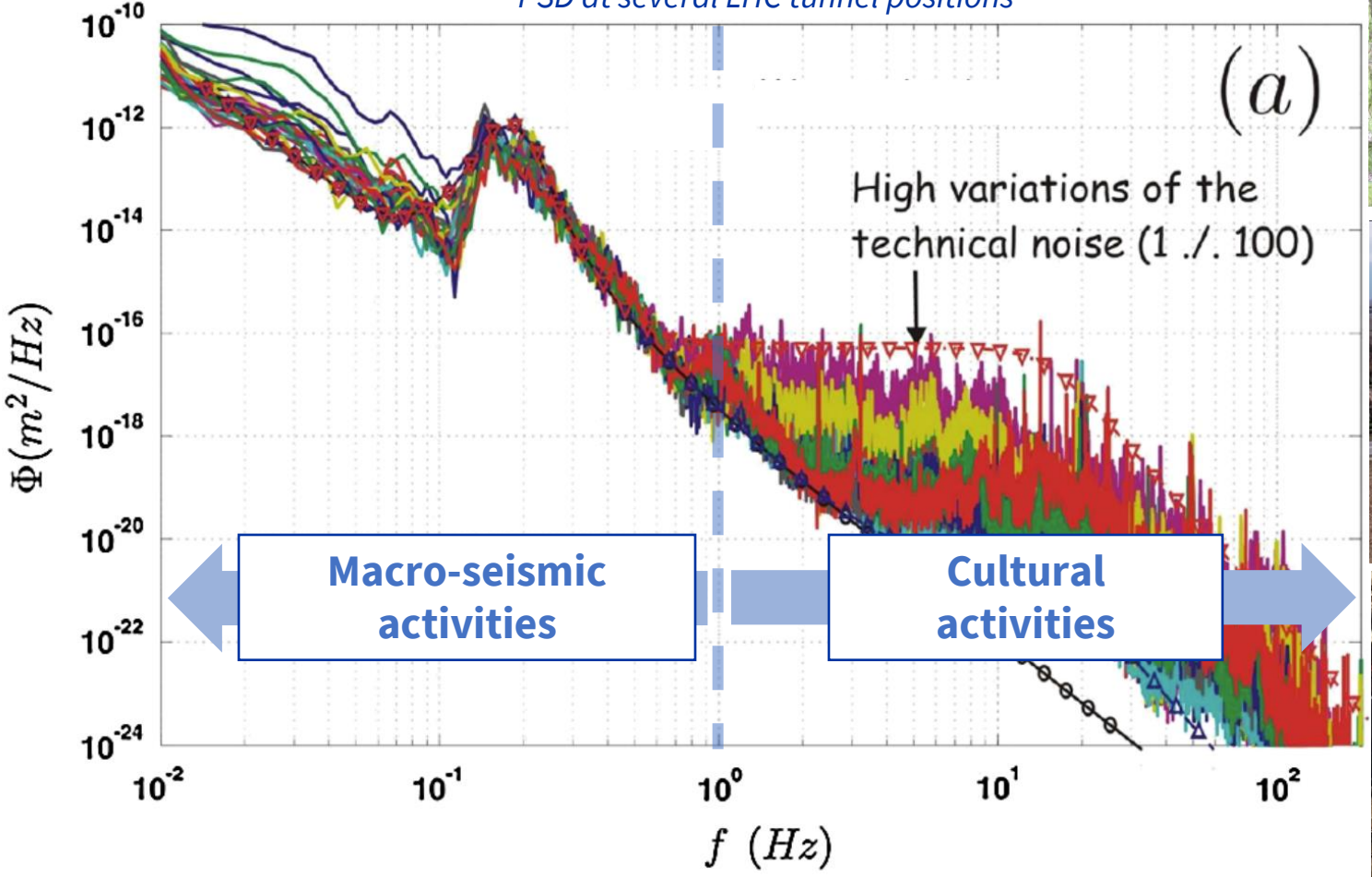


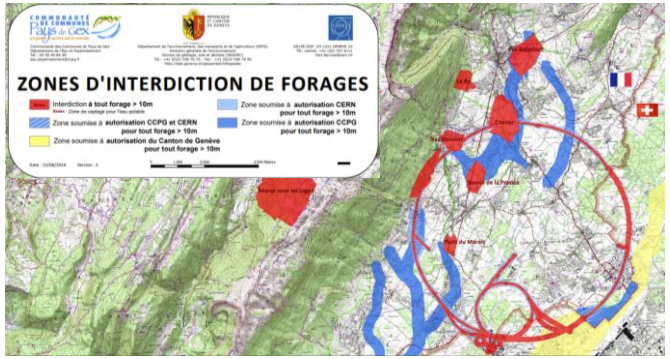


Mag. 7.9 – New Zealand– 13/11/2016
LHC perturbation over a day

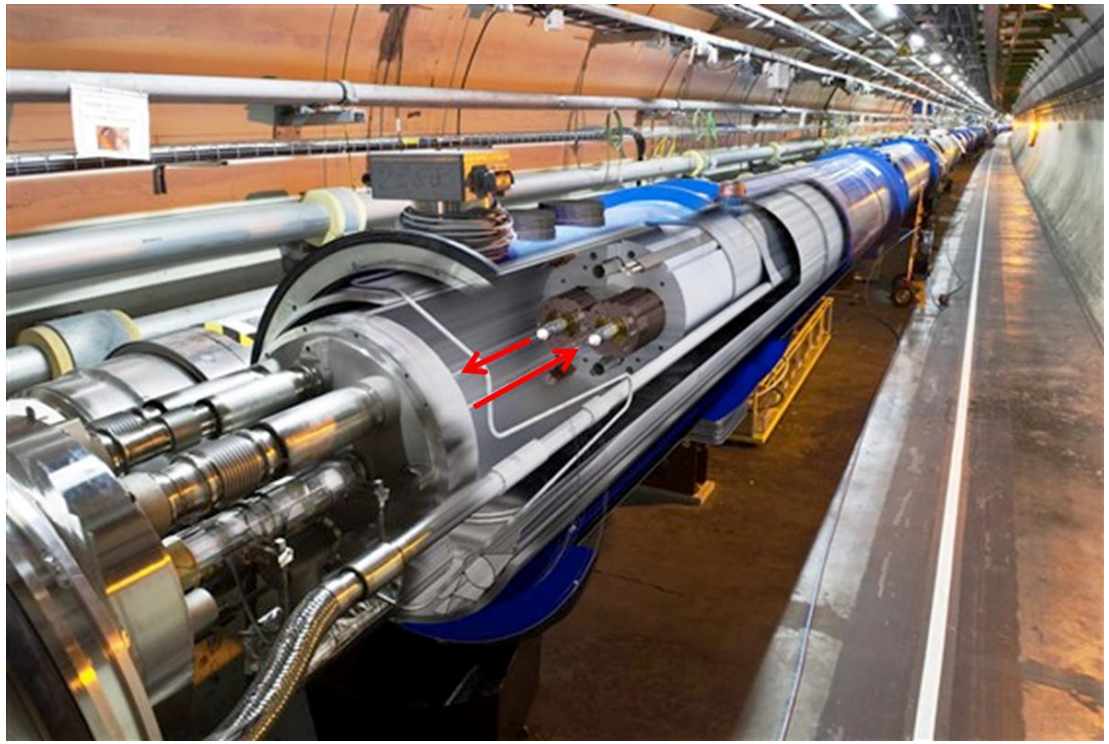
CERN Seismic Network - Results

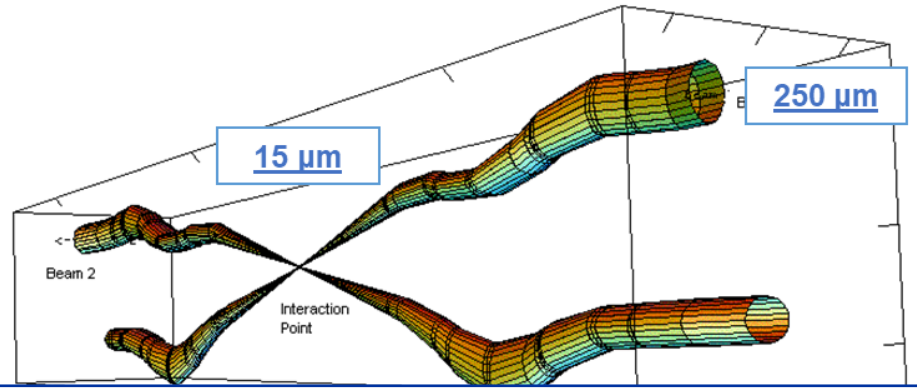
PSD at several LHC tunnel positions





The Large Hadron Collider (LHC)



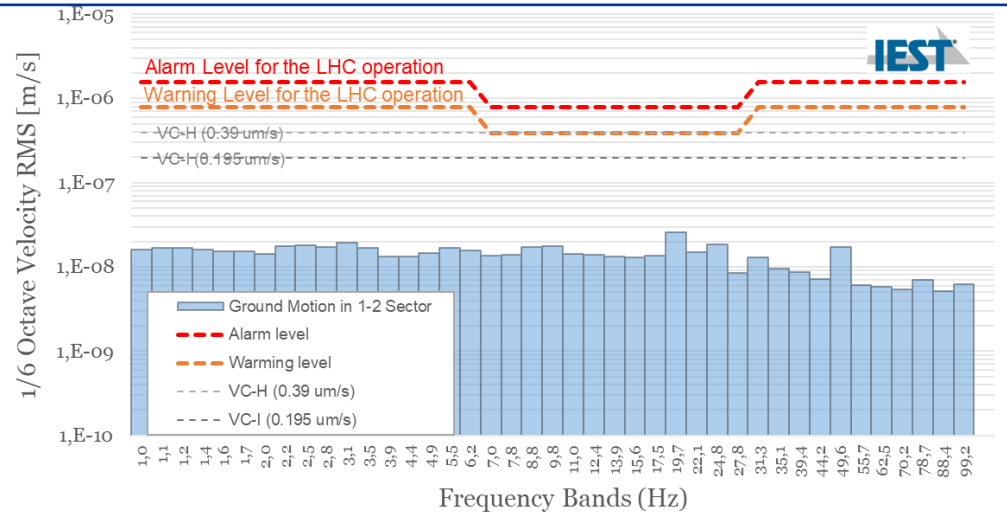


LHC beam stability requirements:

Normal operation : < **5 µm** beam oscillations

Instable operation : **5 µm to 20 µm** beam oscillations

Beam dump : **> 20 µm** beam oscillations

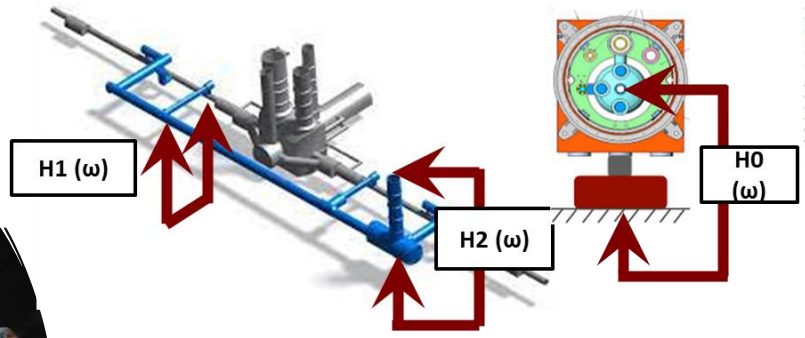


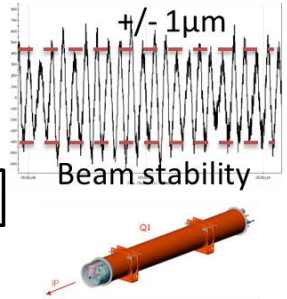
Key Numbers :

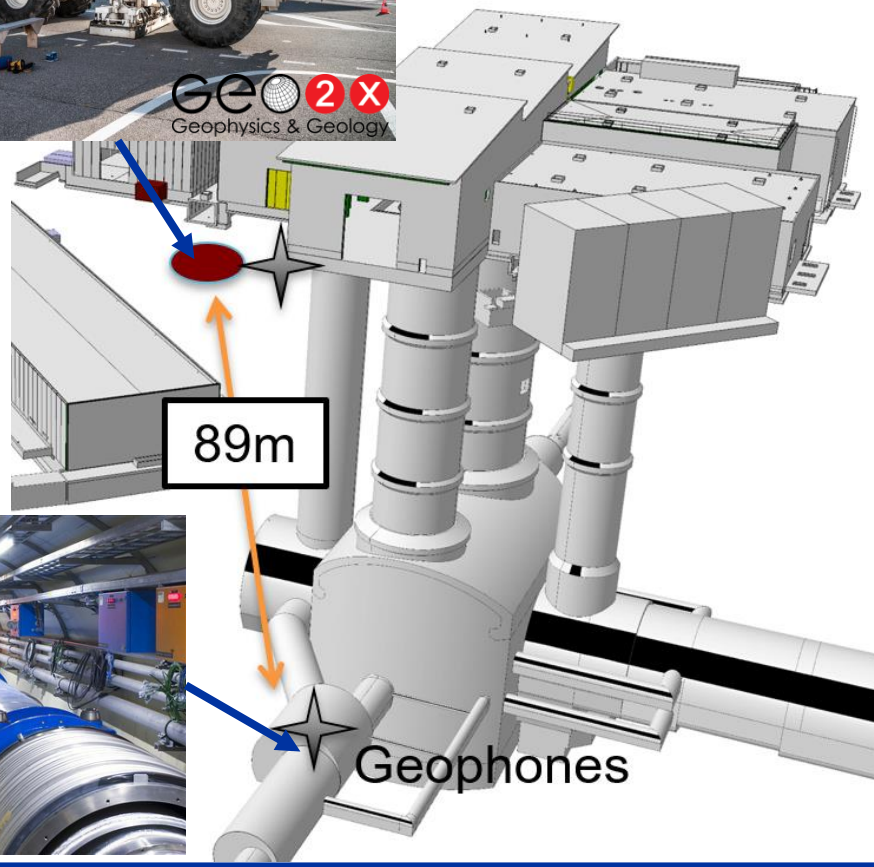
1752 Superconducting Magnets
6,8 TeV Stored Energy per Beam
420 MJ Stored Energy
2800 bunches of 1.6x1011 protons
Hundred Millions of collisions per second

HL-LHC Civil Engineering activities

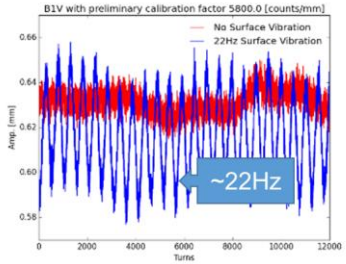
An experimental study based on transfer functions approach was launched to estimate the vibration effects during civil engineering activities. The outcomes of the study drives the CE planning (shaft excavation during LS2, underground excavation during LS2)



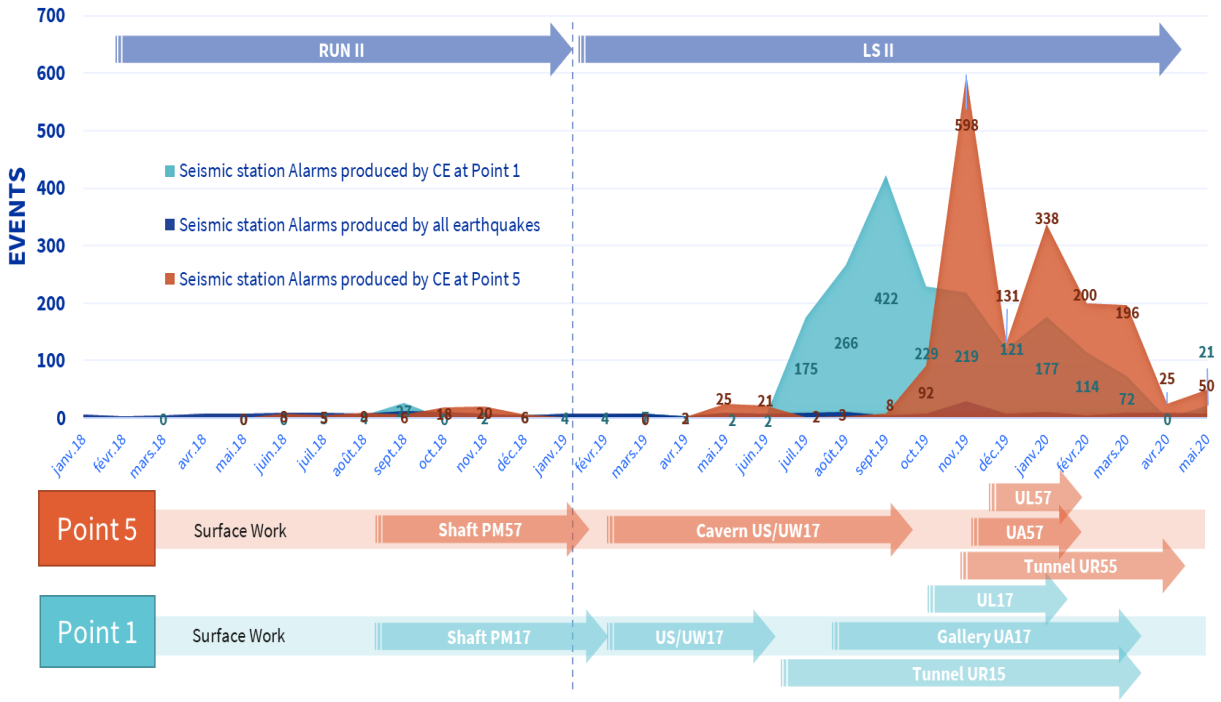


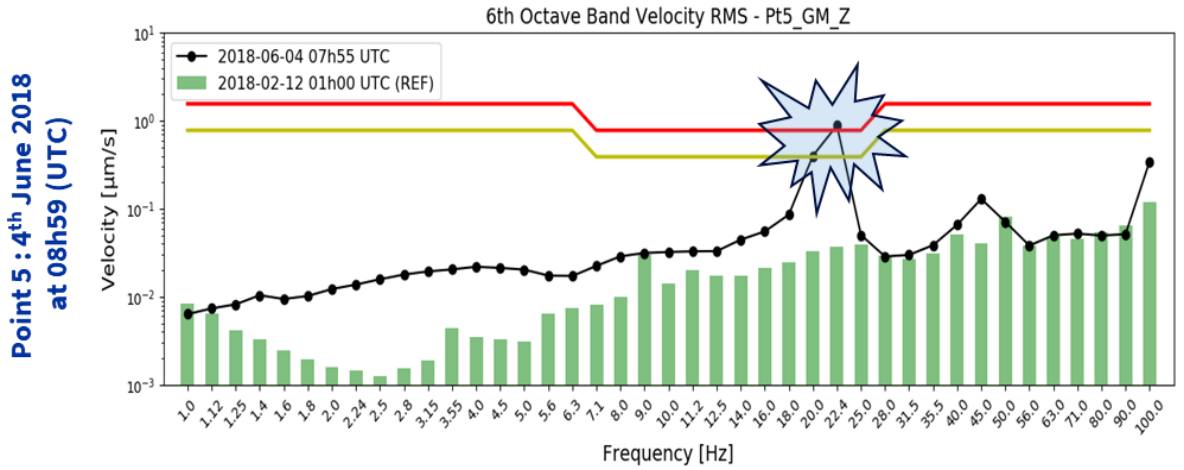


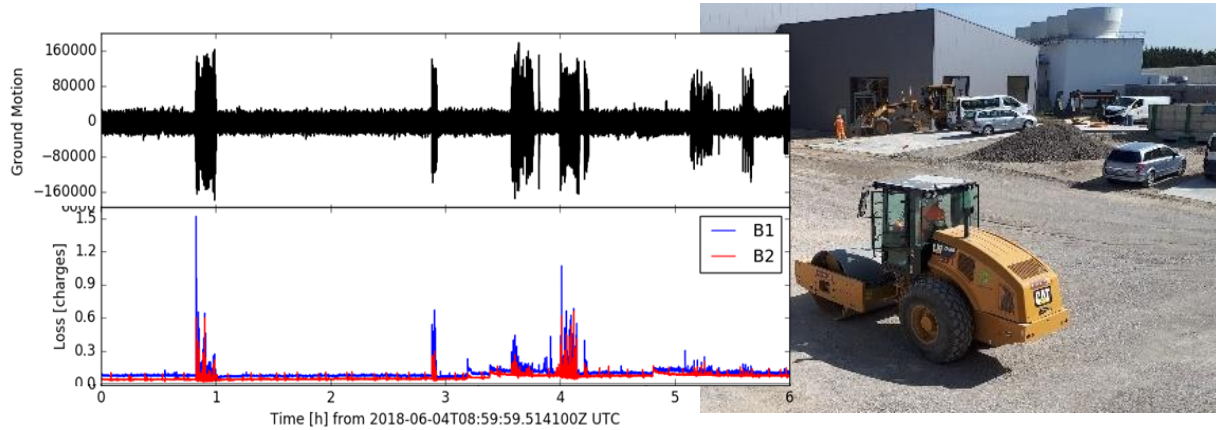

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 1055, October 2023, 168495
Full Length Article
The effect of ground motion on the LHC and HL-LHC beam orbit
M. Schaumann, D. Gamba, H. Garcia Morales, R. Corsini, M. Guinchard, L. Scislo, J. Wenninger



HL-LHC Civil Engineering activities

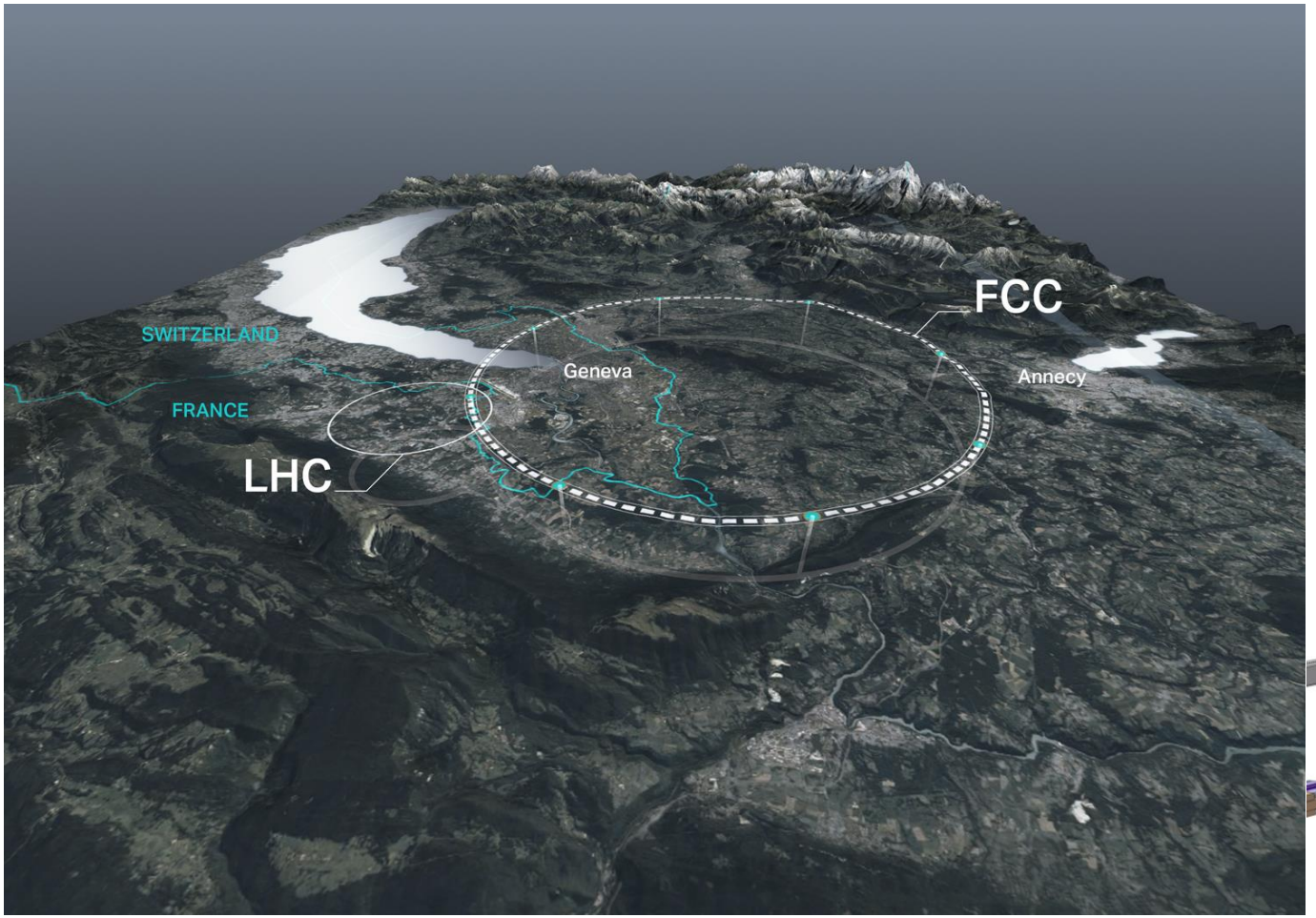




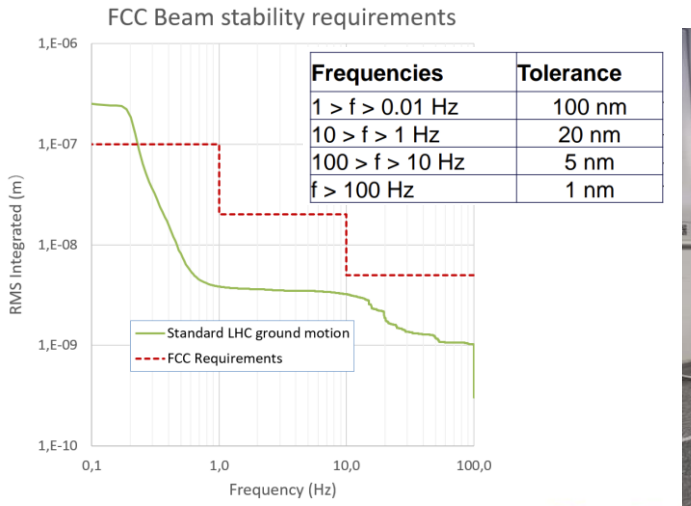


https://edms.cern.ch/ui/file/1976860/1/wepmf080.pdf

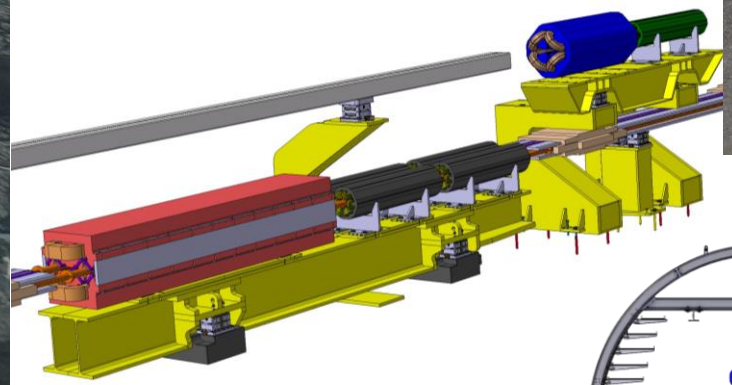
Future

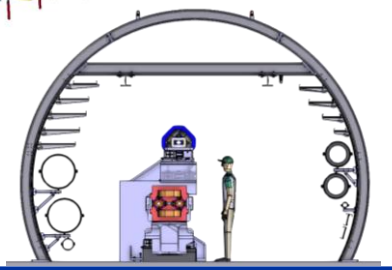


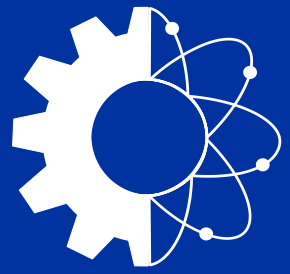
Specifications provided at FCCIS workshop:



Frequencies	Tolerance
1 > f > 0.01 Hz	100 nm
10 > f > 1 Hz	20 nm
100 > f > 10 Hz	5 nm
f > 100 Hz	1 nm

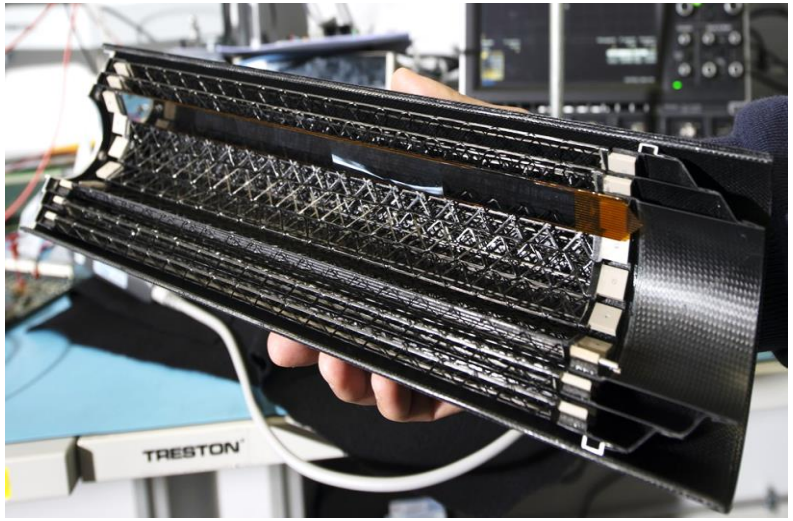




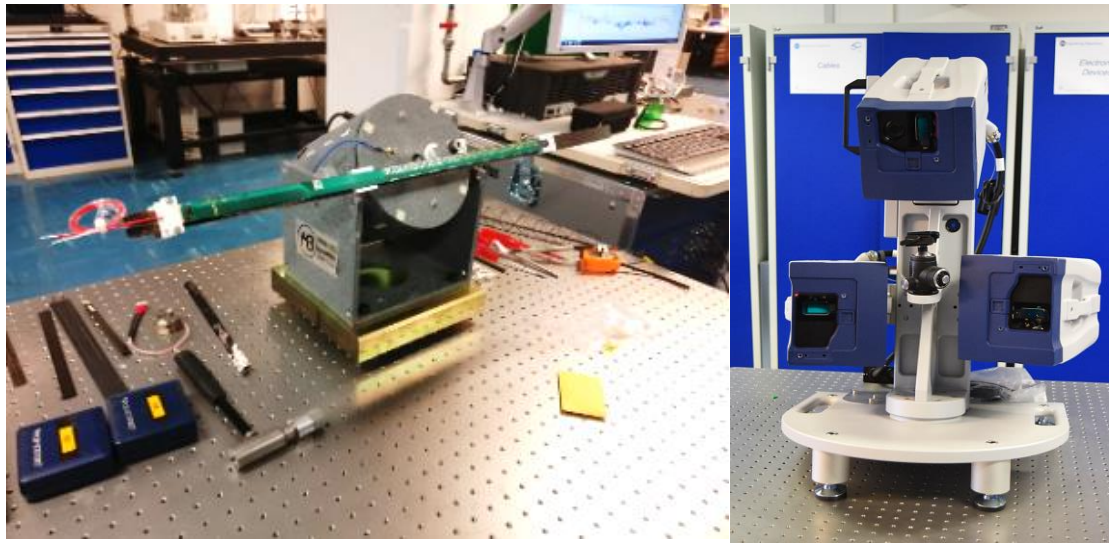


Engineering Department

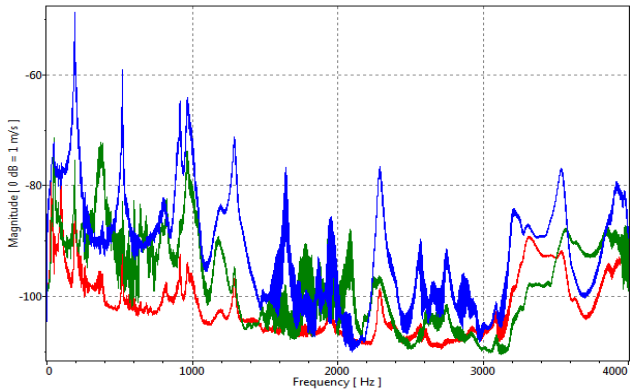
Experimental modal analysis of light weight structure

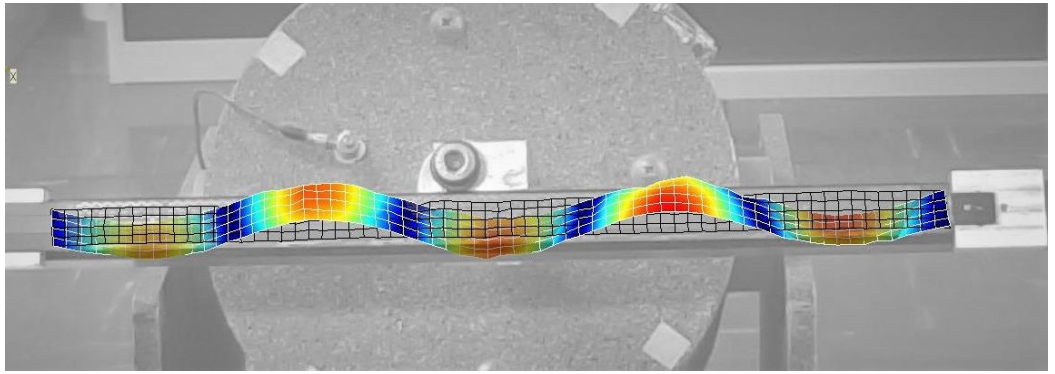


ALICE Inner Tracking System Stave layout.



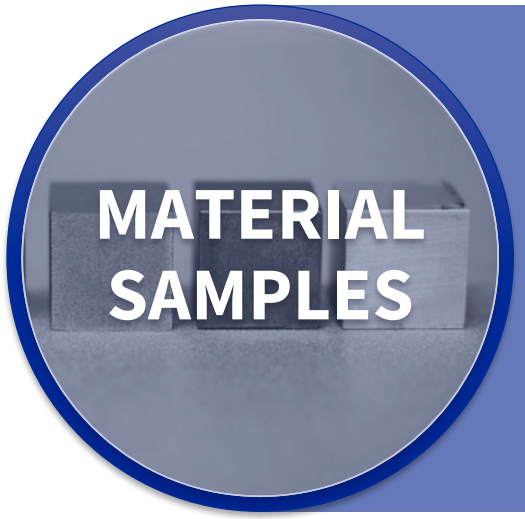
ALICE Inner Tracker beam mounted on an electromagnetic shaker and Polytec PSV-500-3D Scanning Vibrometry System





Freq. [Hz]	Modal Shape
29	Rigid Mode
98	Rigid Mode
192	1st Bending Mode
359	1st Lateral Mode
520	2nd Bending Mode
915	3rd Bending Mode
968	1st Torsional Mode

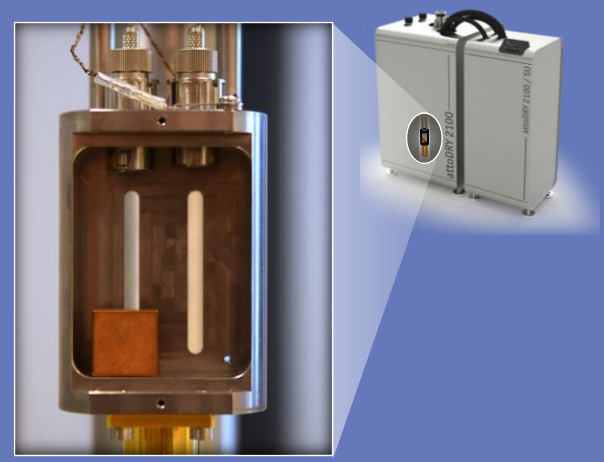
CTE measurements from 1.8 K up to 2000°C

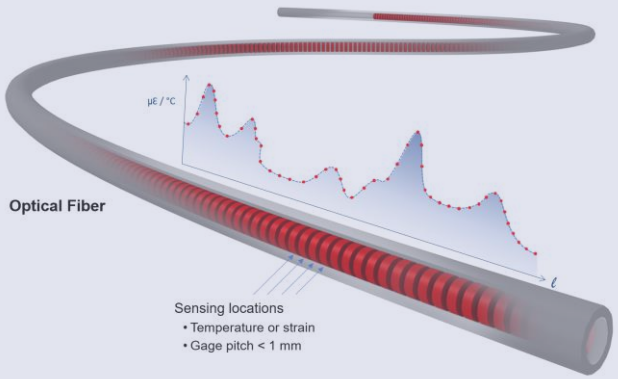


Optical dilatometer from RT down to 1.8 K

- Interferometric setup combined with a closed-cycle cryostat
  - Validated with certified reference sample to an accuracy of **better than 1%** relative to copper at 4 K
  - Integrated superconducting magnet allows to study magnetostriction

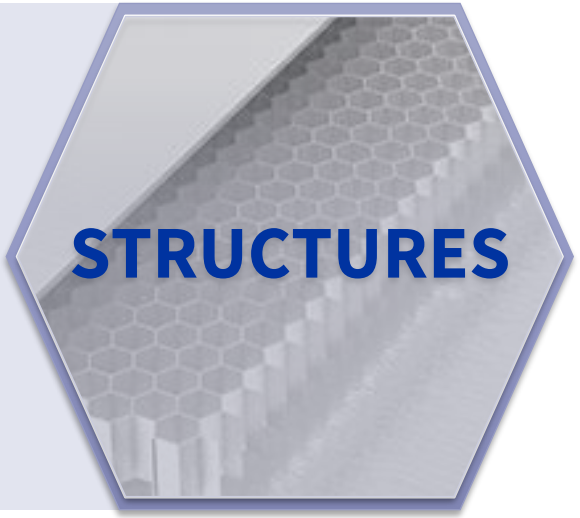
Push-rod dilatometer from 2000°C down to 100 K





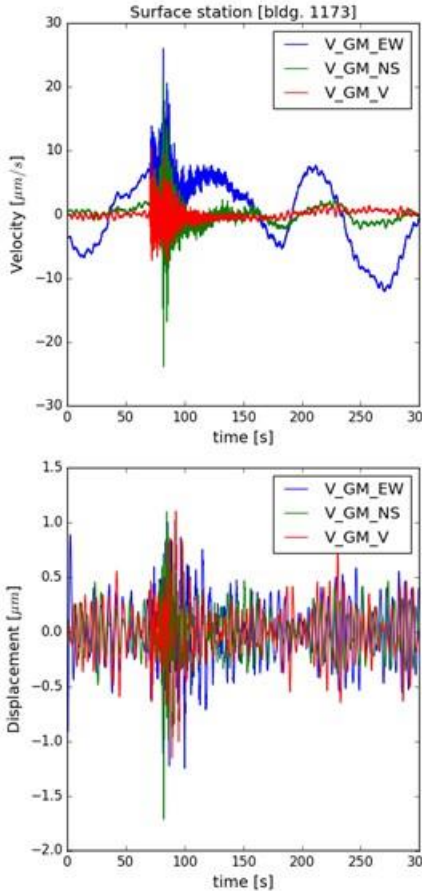
CTE measurements on large scale structure

- Rayleigh backscattering (RBS) and Fiber-Bragg grating (FBG) as established techniques to measure strain at cryogenic temperatures
  - Resilience also to magnetic fields and radiation
- High-level versatility
  - Portable instrumentation
  - Installation of the optical fibers directly on the structures

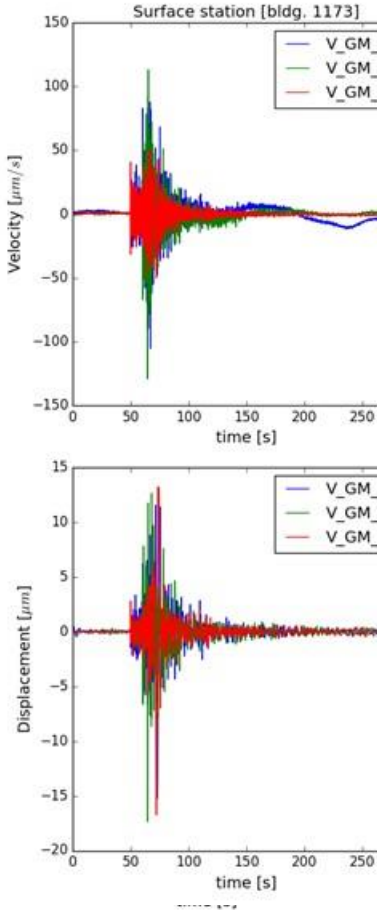


CERN Seismic Stations Performance

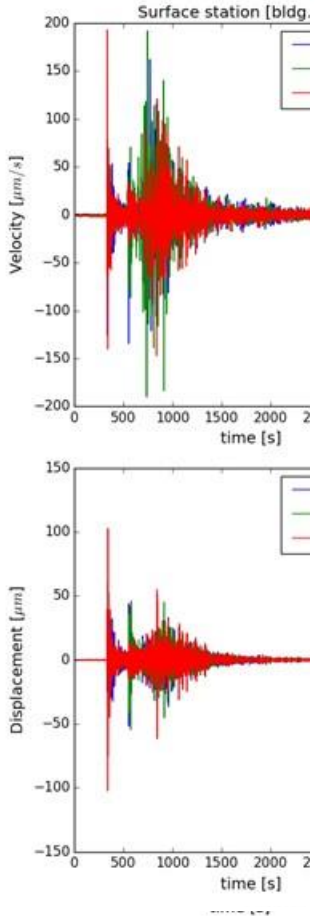
- Magnitude **ML 3.1**
- Region **FRANCE**
- Date time **2017-03-20 21:09:10.3**
- Location **46.04 N ; 6.90 E**
- Depth **3 km**



- Magnitude **ML 4.3**
- Region **SWITZERLAND**
- Date time **2017-07-01 08:10:34.**
- Location **46.47 N ; 7.10 E**
- Depth **5 km**



- Magnitude **Mw 6.6**
- Region **DODECANESE IS.-**
- Date time **2017-07-20 22:31**
- Location **36.96 N ; 27.45 E**
- Depth **2 km**



- Magnitude **Mw 6.5**
- Region **GANSU, CHINA**
- Date time **2017-08-08 13:19:50.2 UTC**
- Location **33.21 N ; 104.03 E**
- Depth **10 km**

China Region