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HL Studies : Vibration effects during civil engineering activities
Vibration measurements

Mechanical Measurements Laboratory
M. Guinchard – L. Lackny

Courtesy : John, Jean Pierre, Marzia, Kurt, etc…

Outline

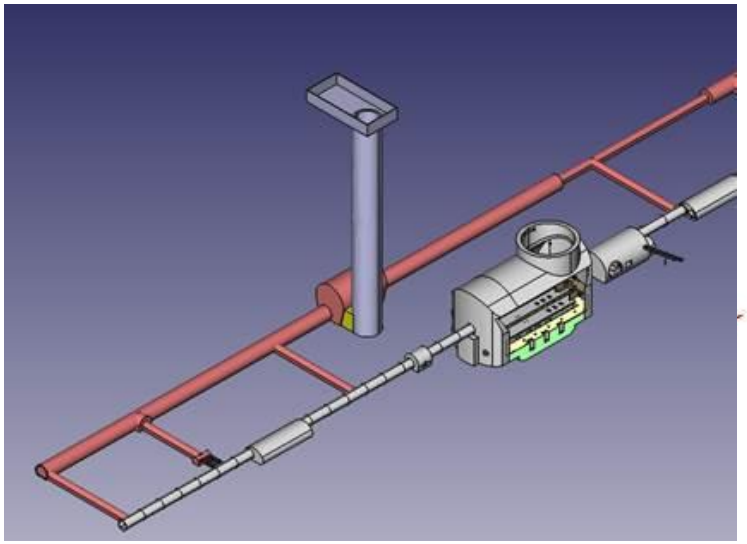
- Motivations
- Magnet transfer function
- Results of SM18 Measurements
- Tunnel transfer function
- Measurement proposal
- Schedule

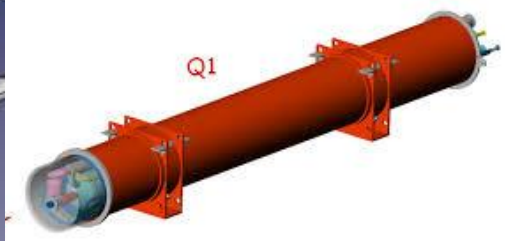
Motivations

- This study is requested for two projects :

  - HL-LHC : How much underground civil engineering can we do around CMS and ATLAS during LHC operations?

  - Geneva Program “Géothermie 2020”, to be able to evaluate the sensitivity of CERN’s installation from potential drilling or jetting?





Motivations

- Simulations vs Measurements…
- Feedbacks from consultants :

→ No realistic alternative to improve current prediction/approximation without conducting some site trials and measuring with specialist instruments that give the full range of vibration that is of interest

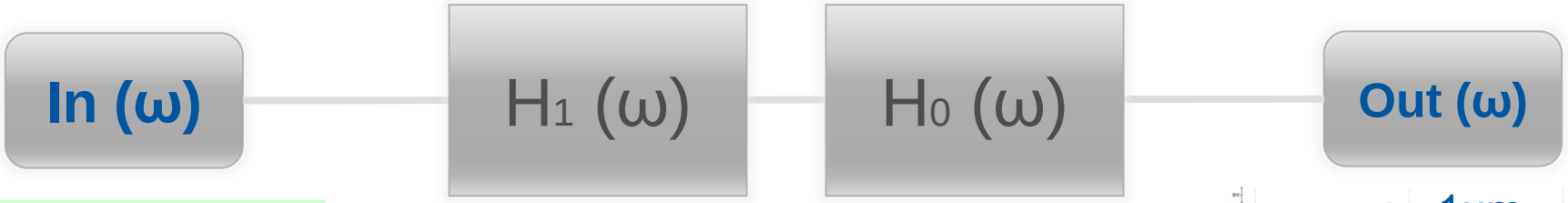
→ Test measurements necessary and mandatory to understand and investigation of the profile of vibrations across the affected length of the LHC

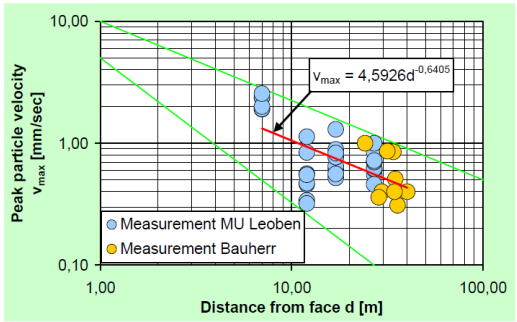
ARUP

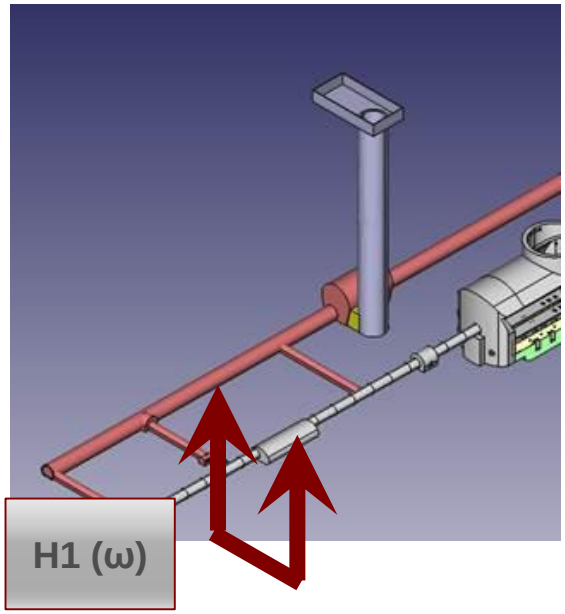
Résonance
Génie dynamique, parasismique et acoustique
Ingénieurs-Conseils SA

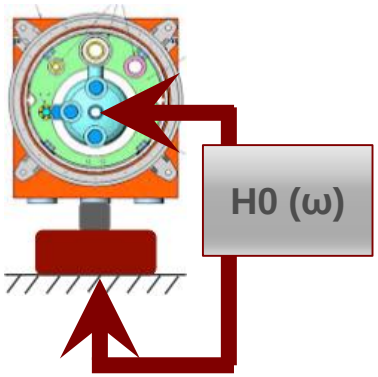
How measurements can help ?

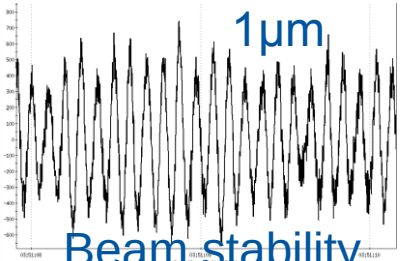
- Measurements of the complex transfer functions between equipments (sensibility evaluation)





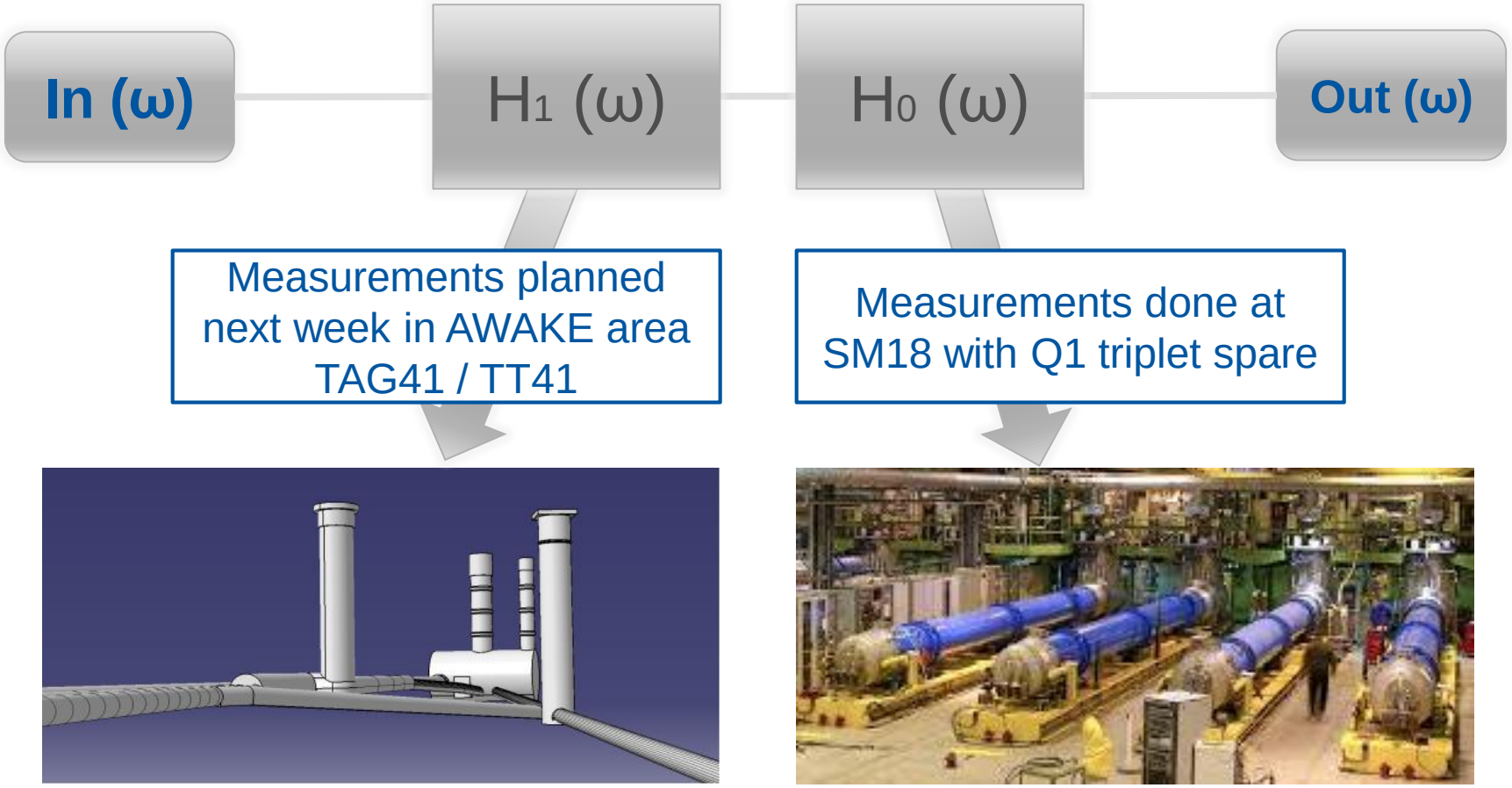






How measurements can help ?

- Measurements of the complex transfer functions between equipments (sensibility evaluation)



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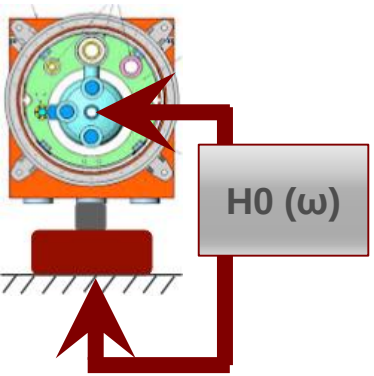
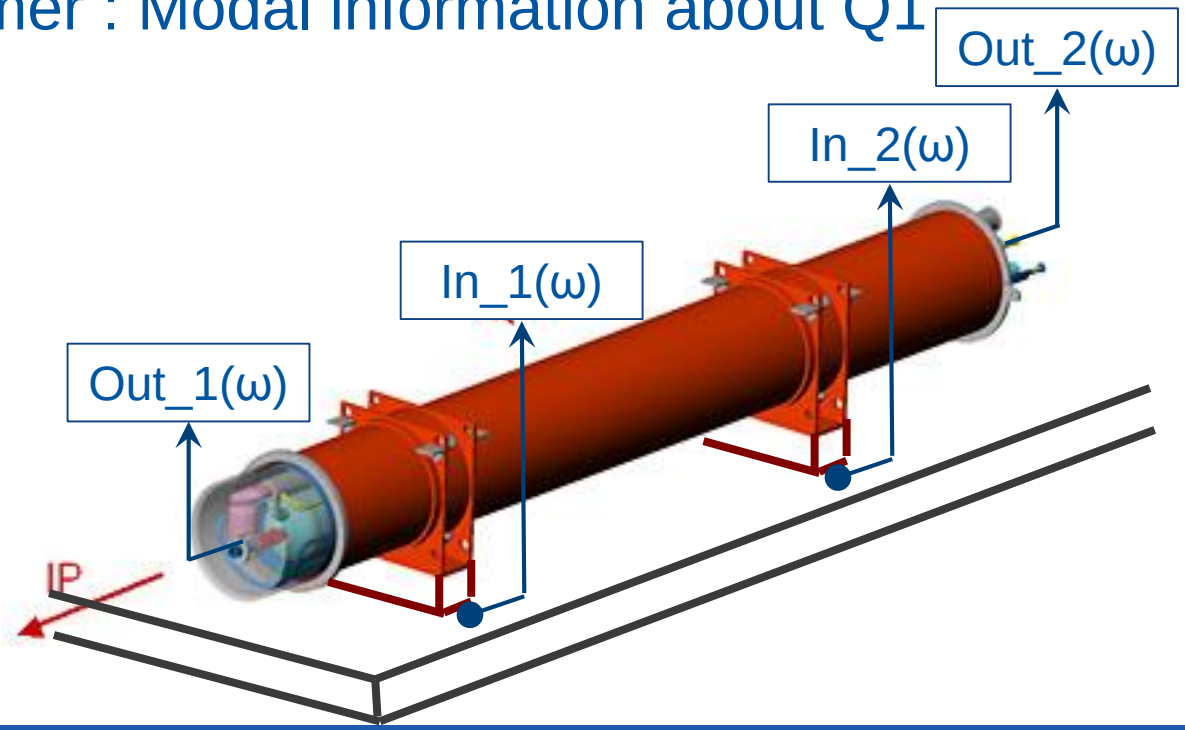
SM18 measurements : Goal

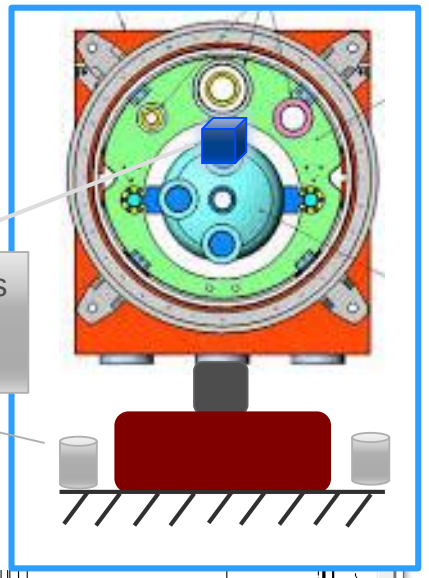
- Evaluation the magnet transfer function Ho(ω) (ground-cold mass) with civil engineering source of vibrations at proximity (Cluster D) and with an impact hammer :
  - Civil engineering source : Vibration transmissibility
  - Impact hammer : Modal information about Q1

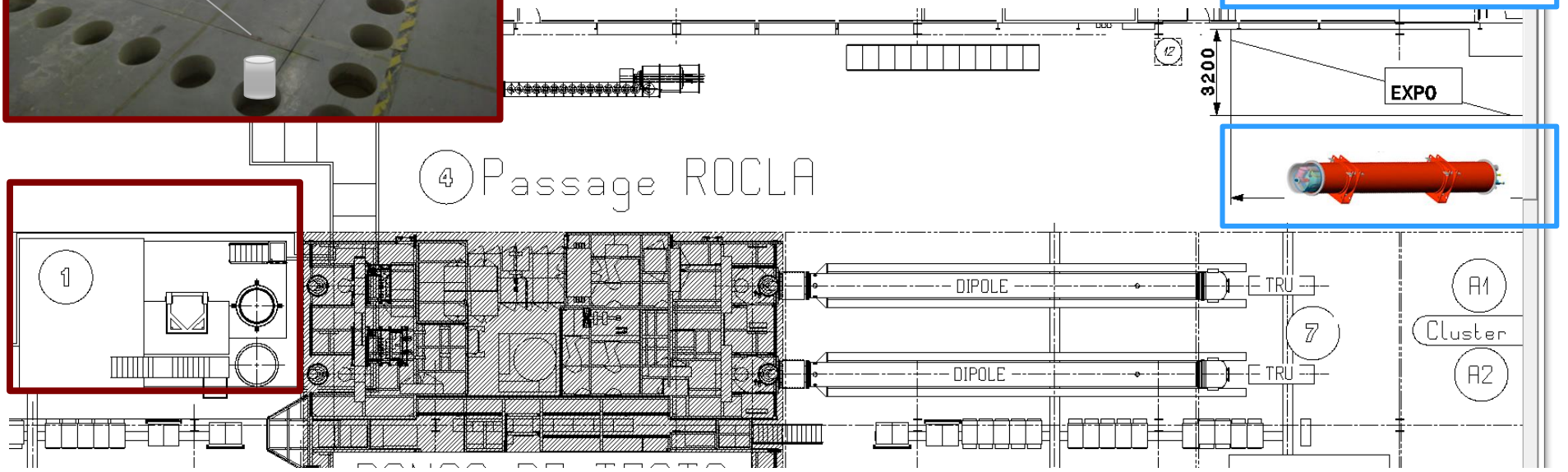




SM18 measurements : Goal

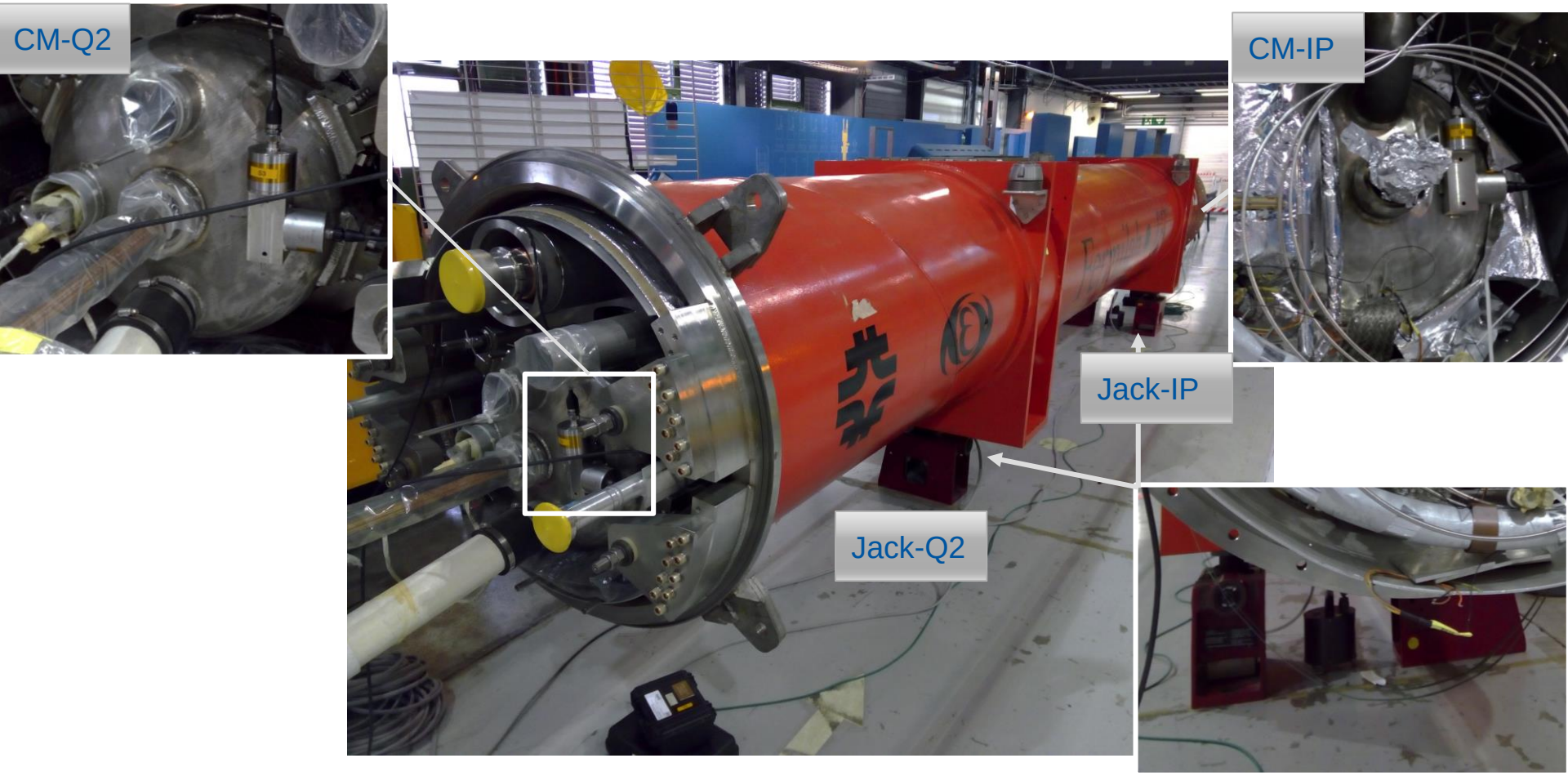
- Determine the magnet transfer function
- Evaluate the source of vibrations





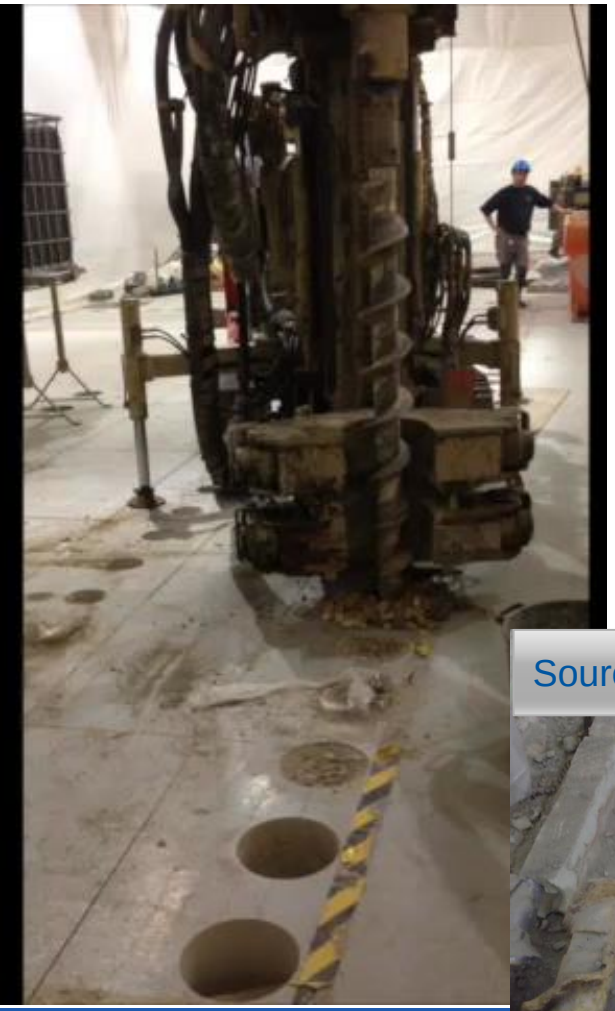
SM18 measurements : In practice

- Response measurements



SM18 measurements : In practice

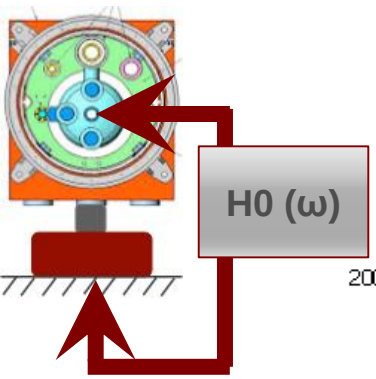
- Two type of excitation sources

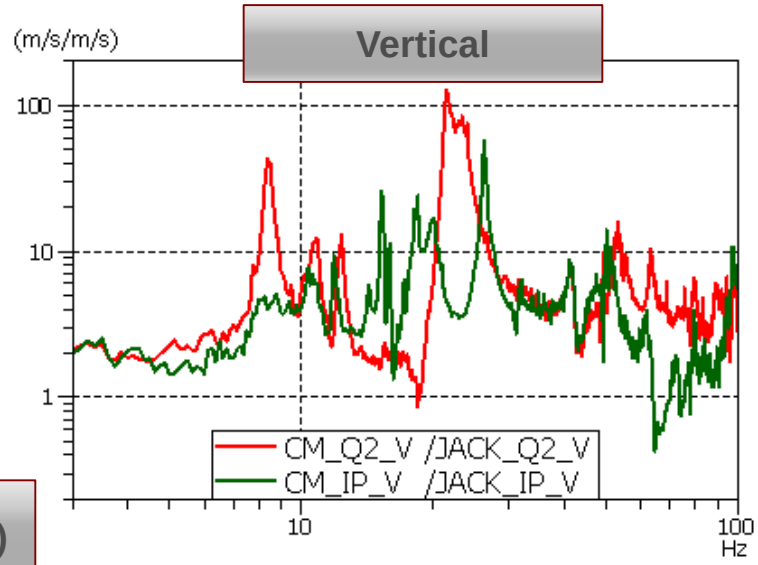


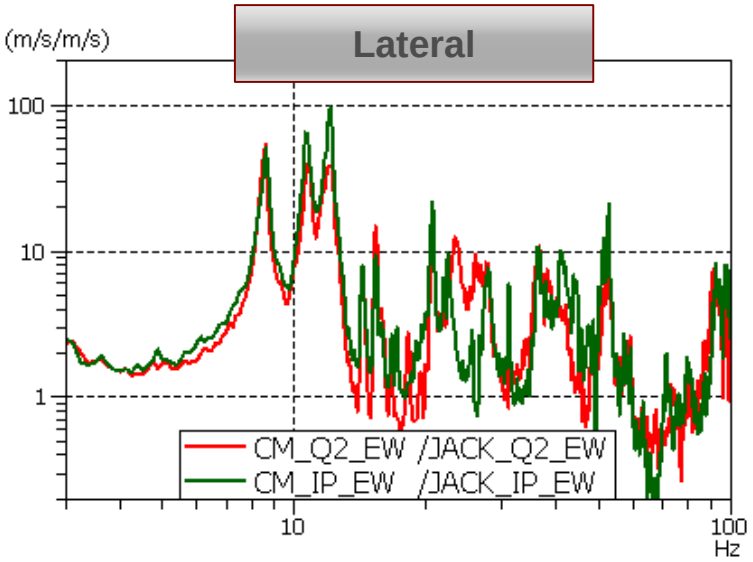
Performance

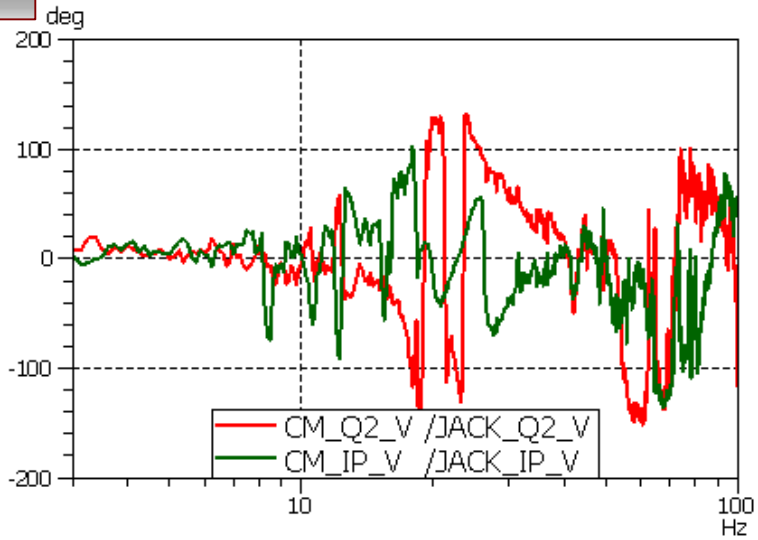
Sensitivity (±15 %)	0.23 mV/N
Measurement Range	±22240 N pk
Resonant Frequency	≥12 kHz

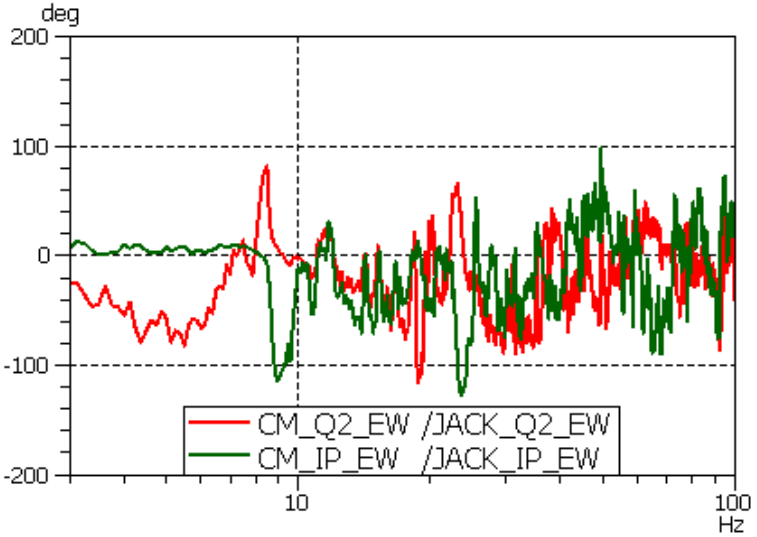
Results about H_0 (ω) with drilling machine source





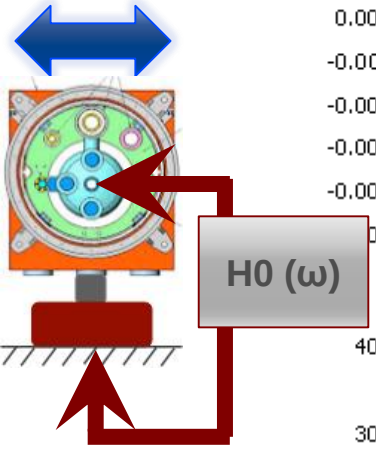


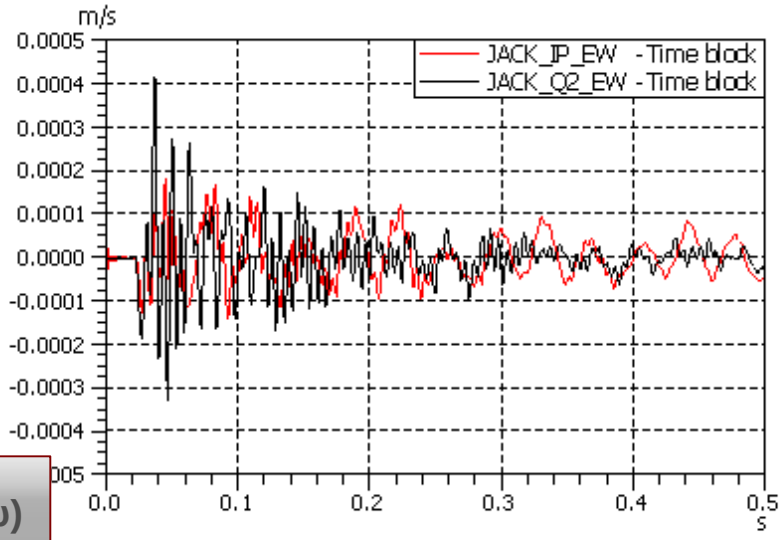


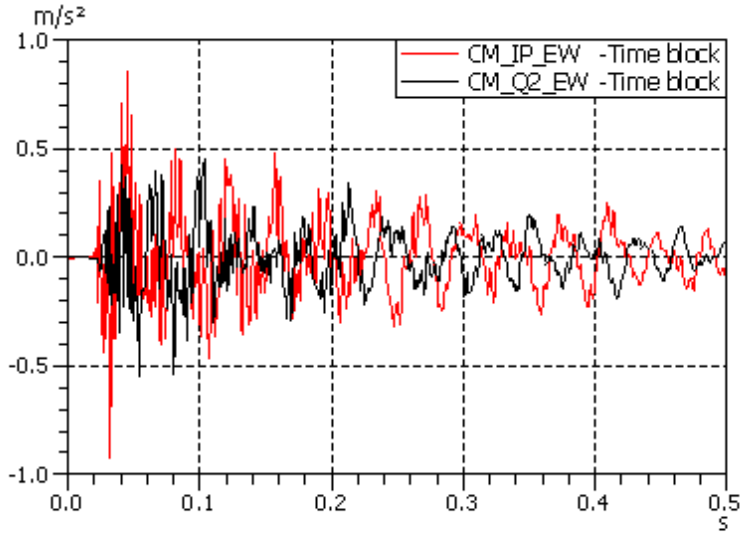


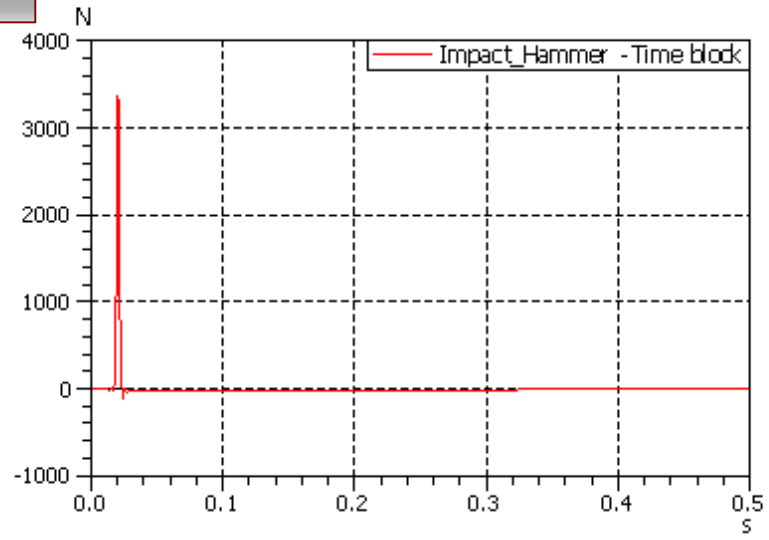
Results about $H_0(\omega)$ with the impact hammer

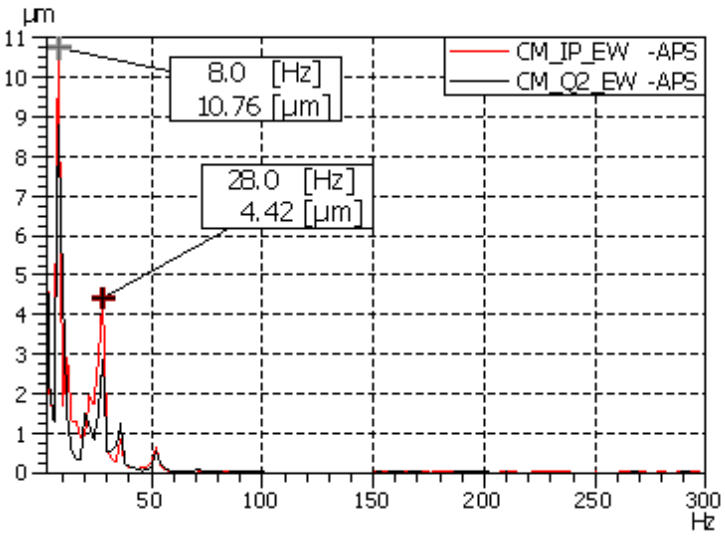
Lateral excitation





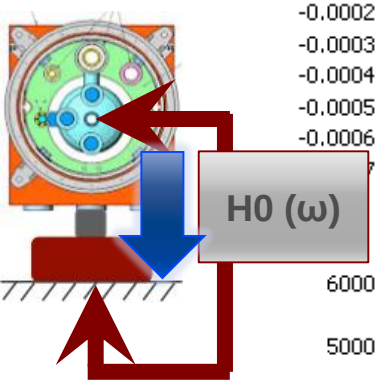


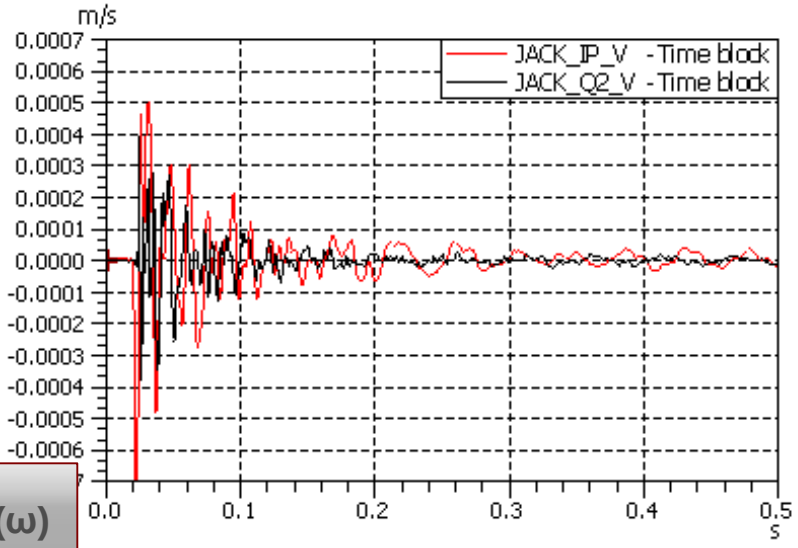


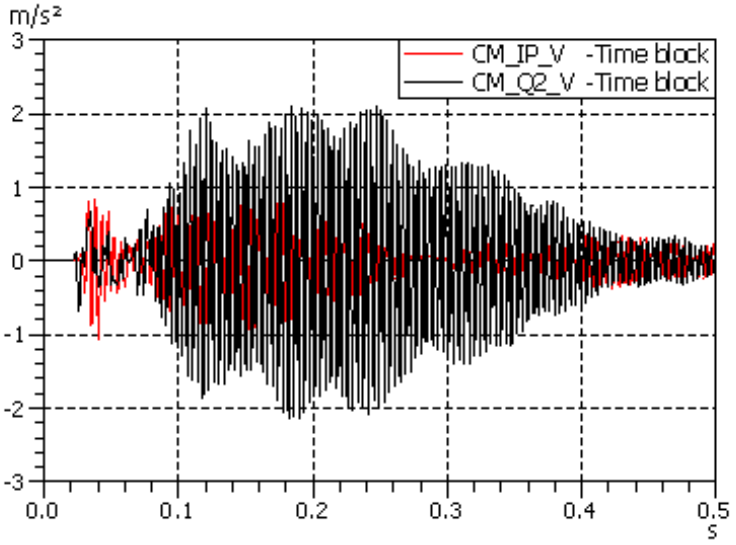


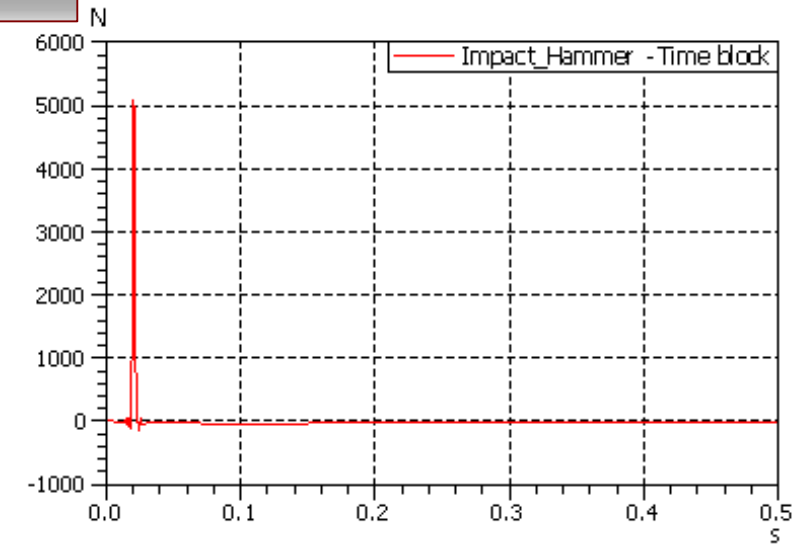
Results about H₀ (ω) with the impact hammer

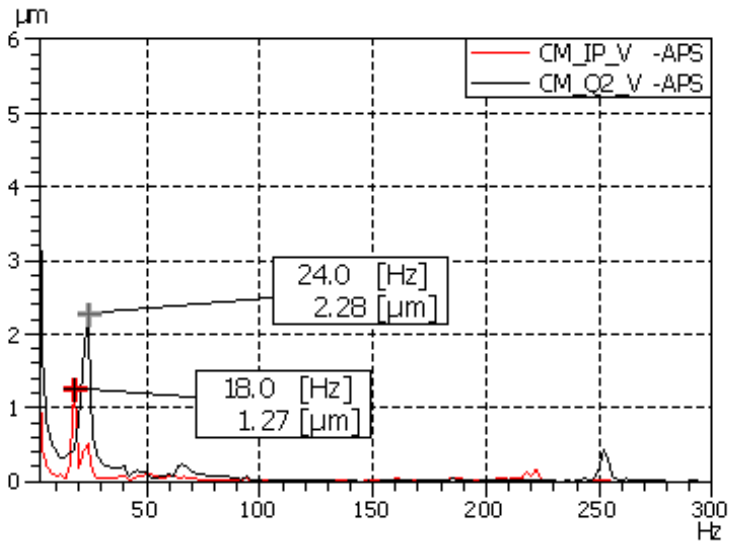
Vertical excitation











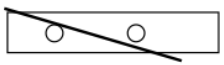
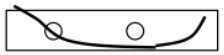
Results about H_0 (ω) : SSS Comparison

LHC-CRI Technical Note 2002-06
EDMS No: 347269
2002-07-30
Kurt.Artoos@cern.ch

Experimental modal analysis and acceleration measurements during transport of a LHC Short Straight Section

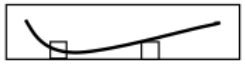
K. Artoos (EST/ME), O. Capatina (LHC/CRI)

Table 1 – Lateral modes of SSS5, with and without transport restraints

Mode	Modal shape	Frequency (Hz)	
		Without restraints	**With** restraints
Lateral 1		**7**	
Lateral 2		**12**	**14**
Lateral 3		**14**	**15**
Lateral 4		**29**	**29**
Lateral 5		**40**	**40**
Lateral 6		**46**	/
Lateral 7		**54**	**55**

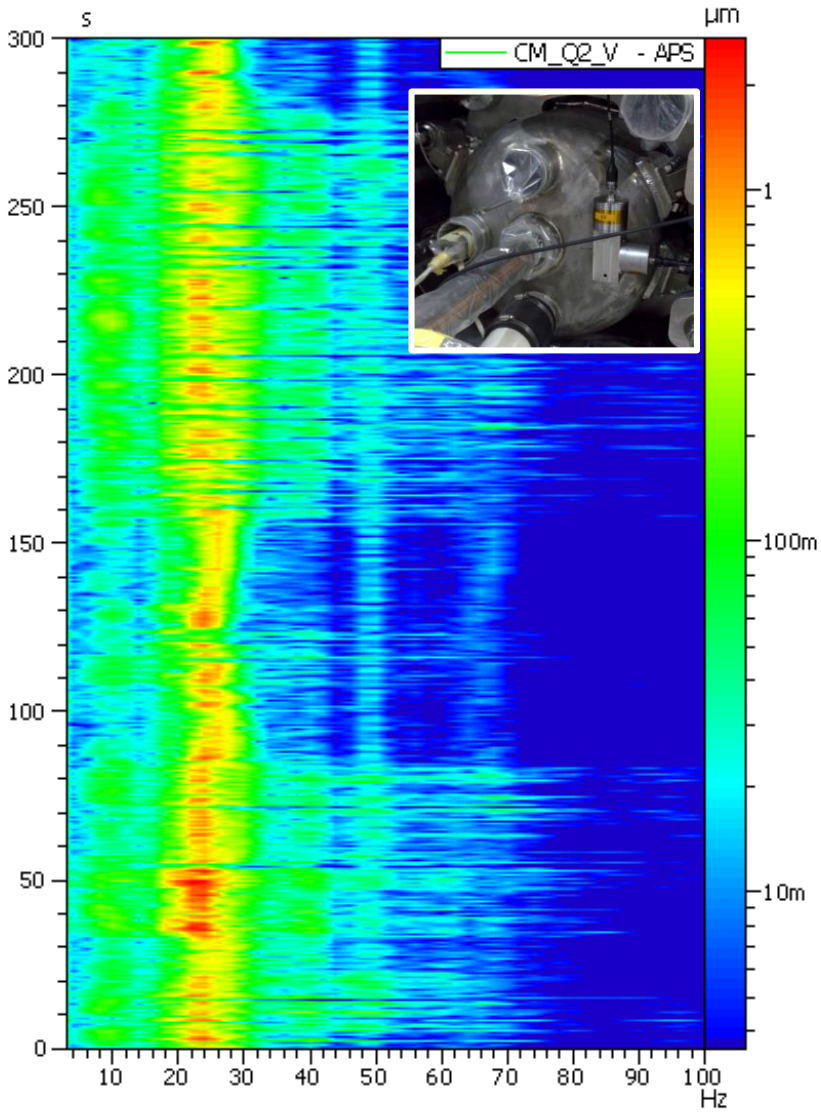
8 Hz for Q1

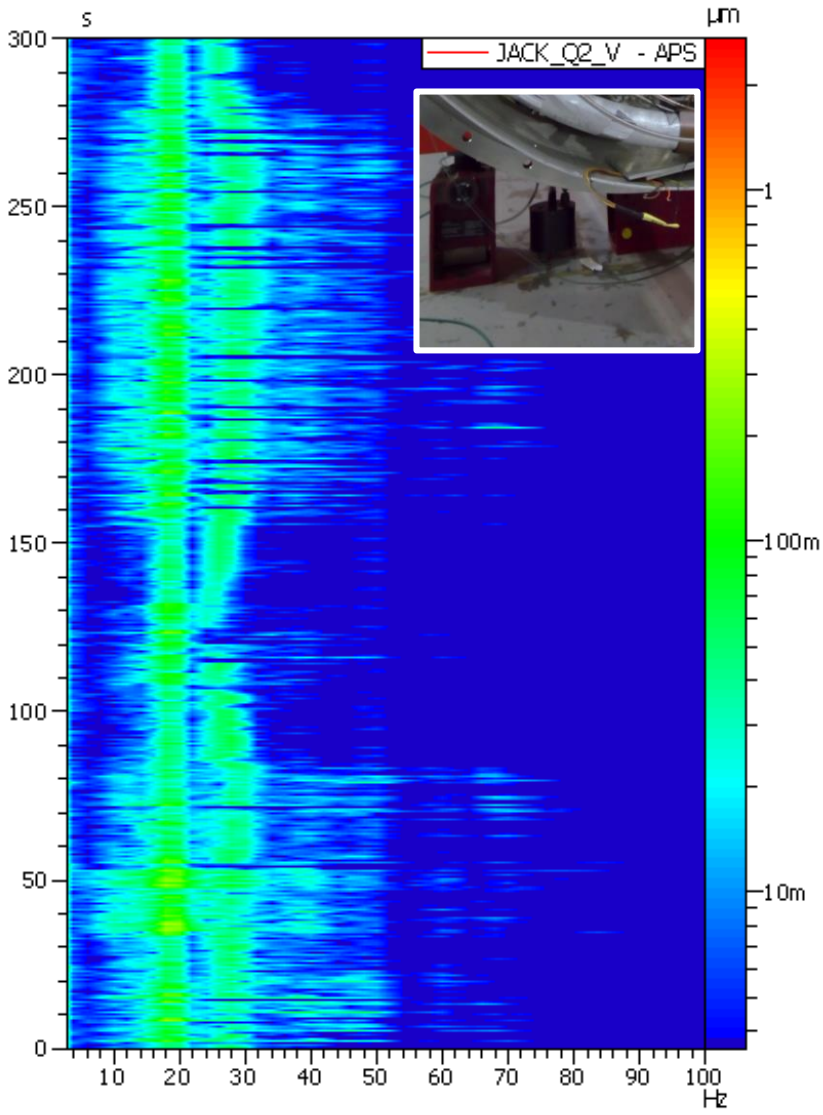
Table 2 - Vertical modes of SSS5, with and without transport restraints

Mode	Modal shape	Frequency (Hz)	
		Without restraints	**With** rest
Vertical 1		**22**	
Vertical 2		**27**	**28**
Vertical 3		**42**	**42**
Vertical 4		/	**44**
Vertical 5		**53**	**53**
Vertical 6		/	**57**

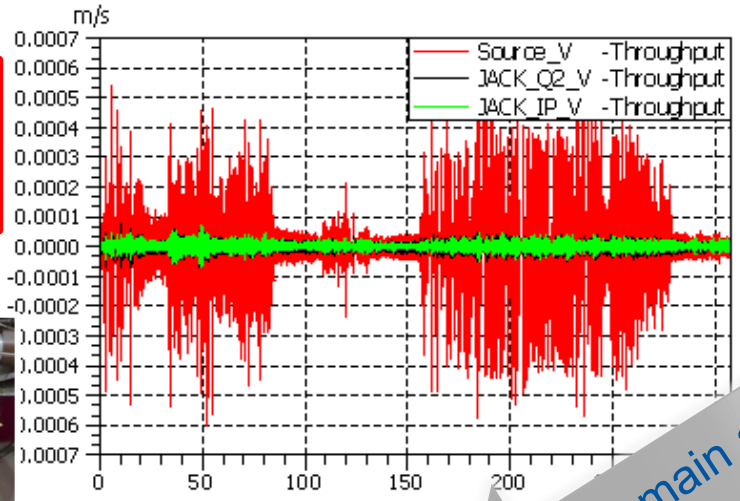
18 Hz for Q1

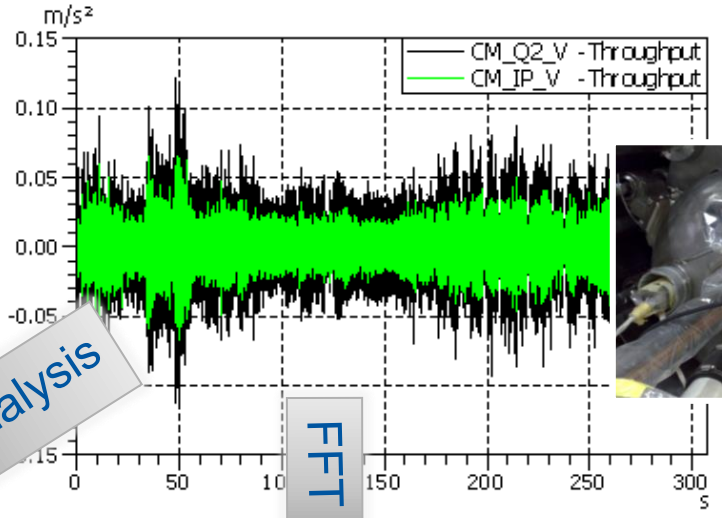
Results about vibration level during drilling operation





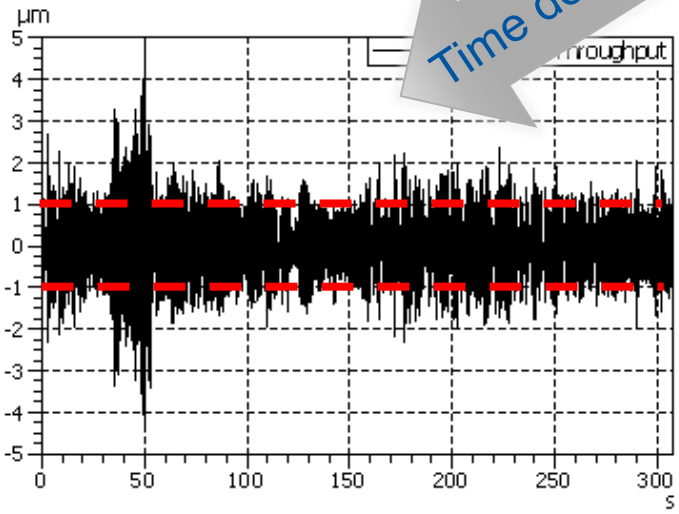
Results about vibration level during operation

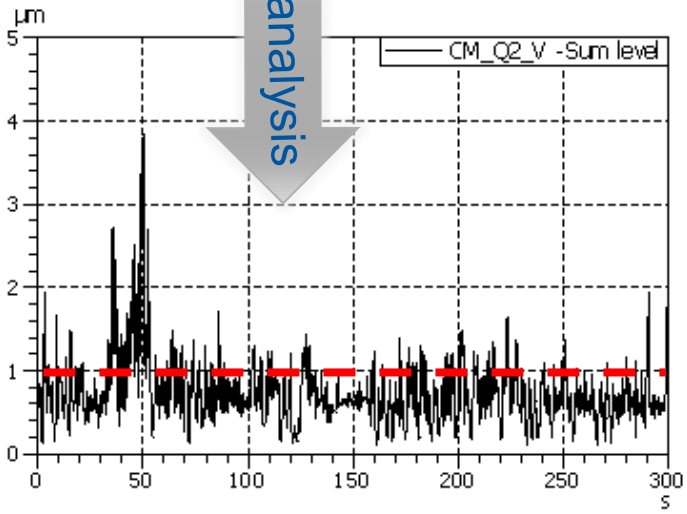




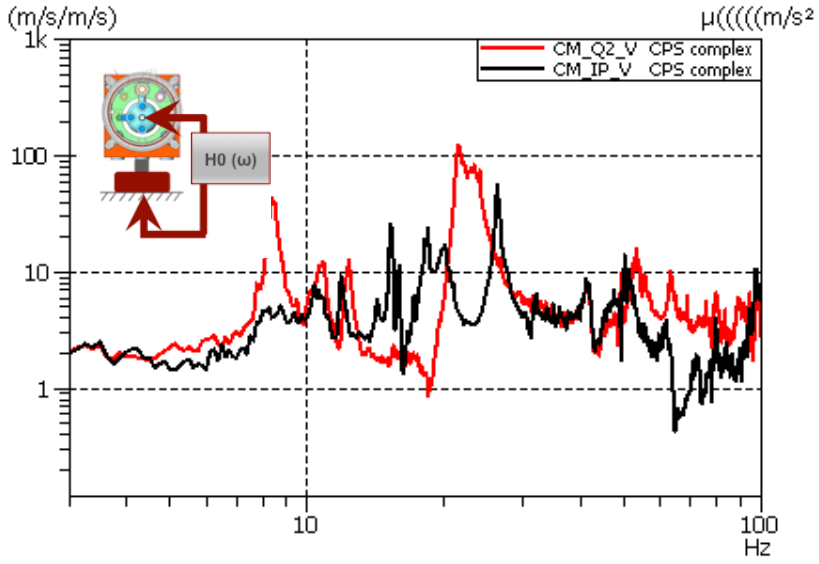
Time domain analysis

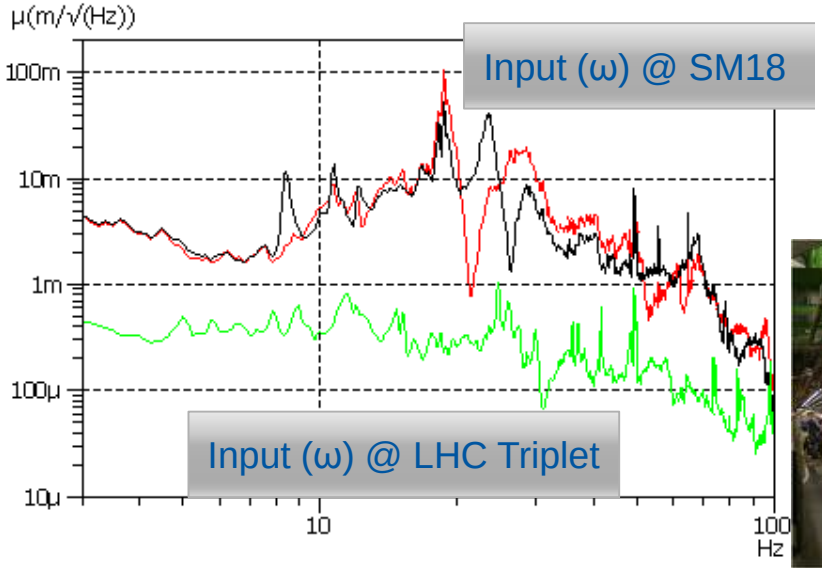
FFT analysis

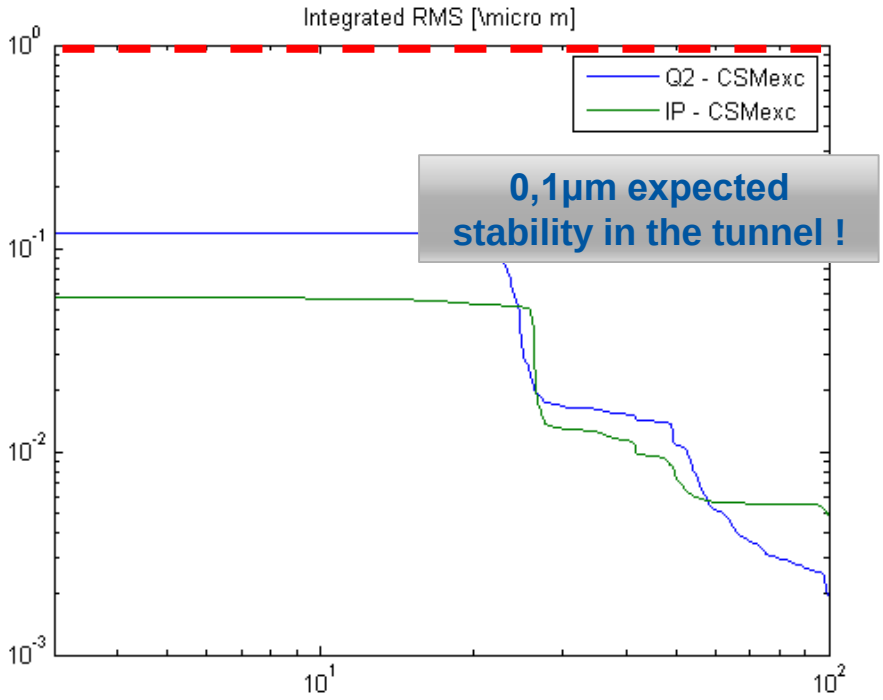




Expected results for LHC configuration







SM18 Measurements : Conclusion

- High vibration amplification between the floor and cold mass was measured, due to the dynamic behavior of the Q1 structure (max gain of 100 on the 0-100 Hz bandwidth) ;
- Several natural frequencies were identified below 50 Hz, and comparable to LHC quadrupoles ;
- At SM18 **without** civil engineering activities, the cold mass motion is **close to the limit of 1 µm** (0-peak). With activities, a level of several microns is achieved ;
- According to the transfert function measured at SM18 on Q1, the expected motion of the coldmass during **LHC operation** is around **0,1 µm** integrated from 100 Hz

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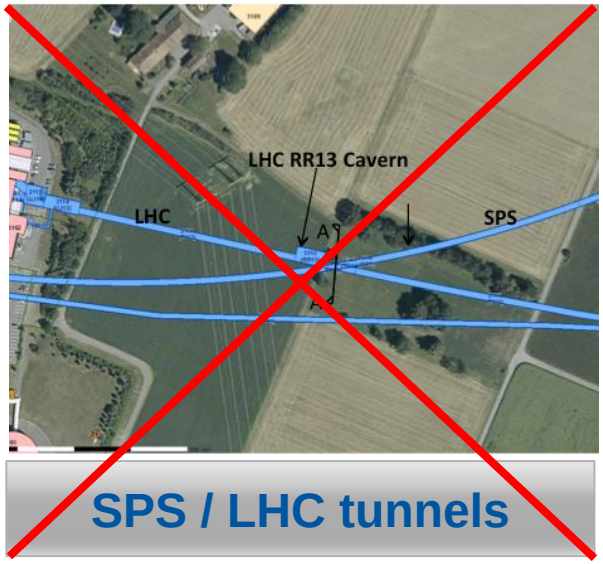
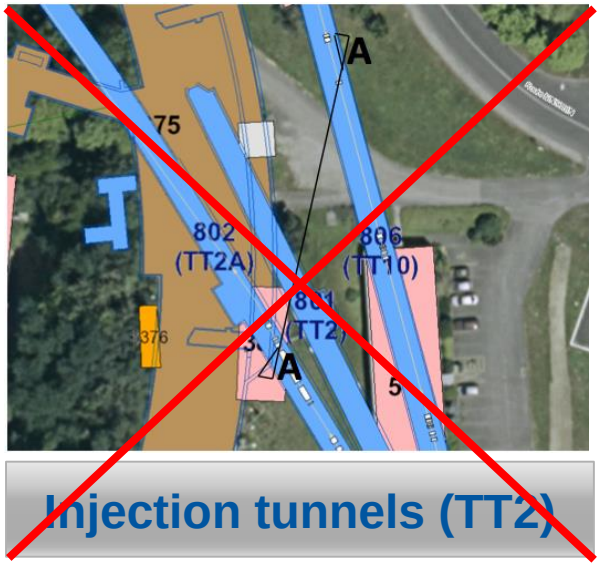
Tunnel transfer function H_1 (ω)

- No chance to reach the same conditions today than HiLumi Project !
- Use actual tunnels to do some preliminary tests
- Shaker will be used like known excitation source

Several options identified :



SPS / LHC tunnels



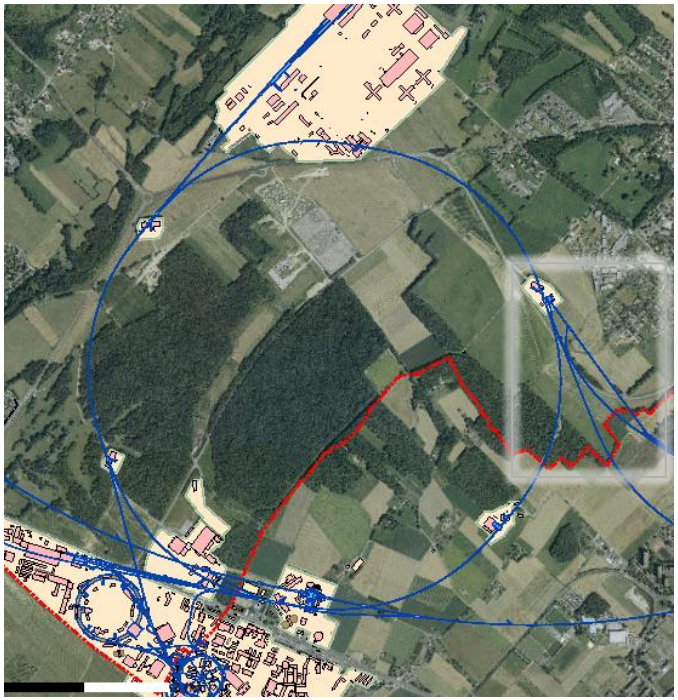
Injection tunnels (TT2)

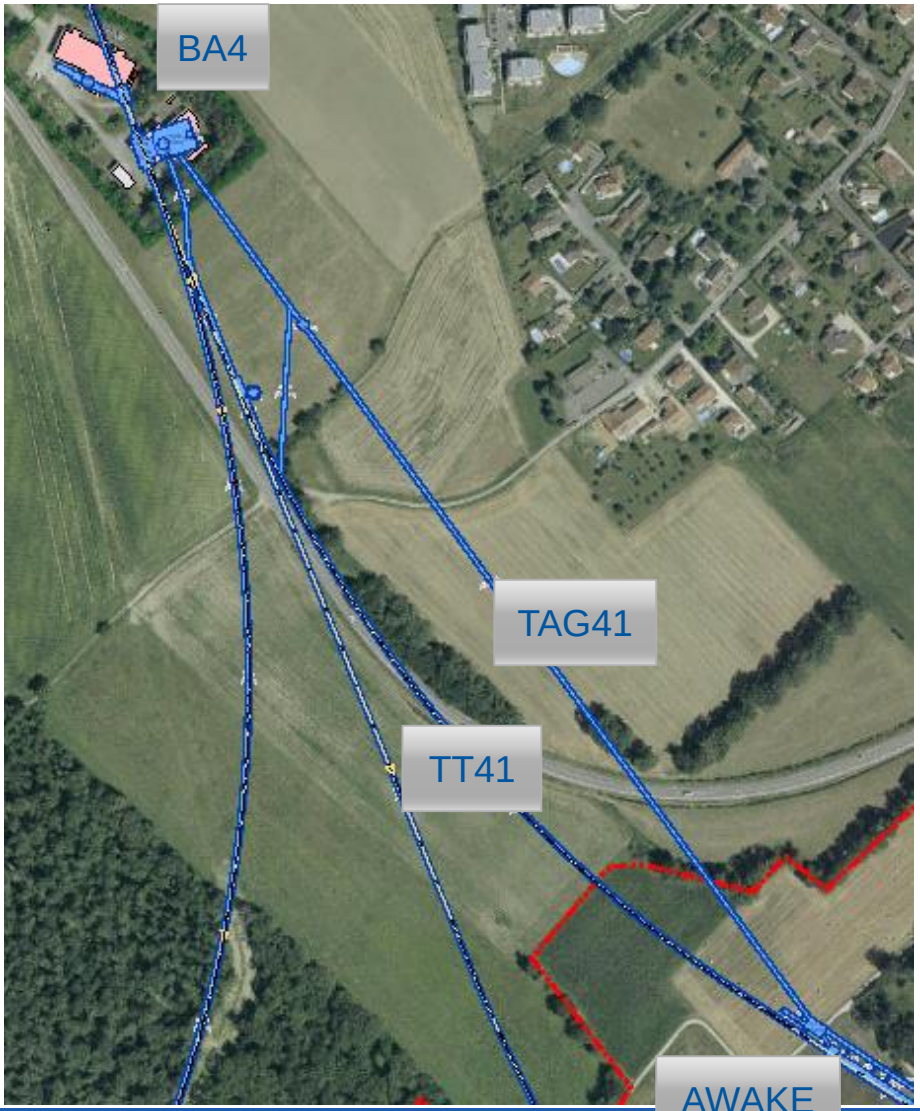
TAG41 / TT41

Tunnel transfer function $H_1(\omega)$

Why TAG41/TT41:

- Molasse rock as Pt1 and Pt5
- Tunnel distance between 0 and 85 m
- TAG41 : Access tunnel
- TT41 : under assembly for AWAKE

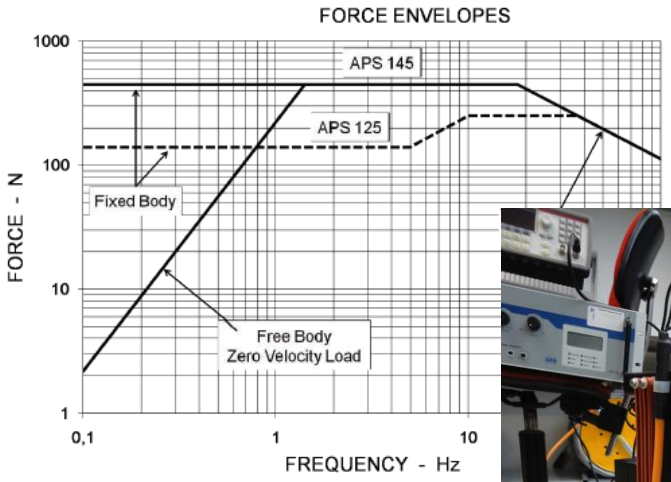


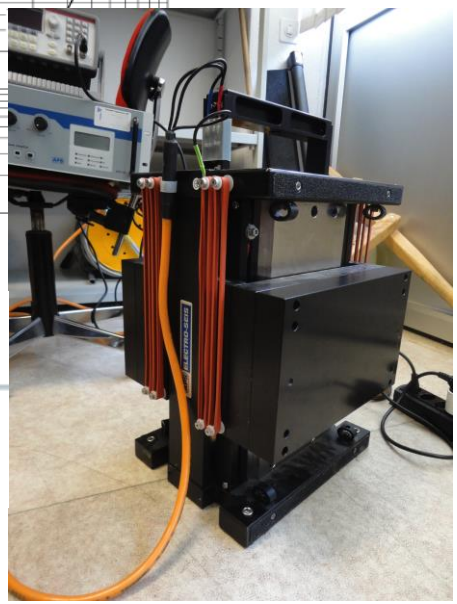


Tunnel transfer function $H_1(\omega)$, in practice

EXCITATION

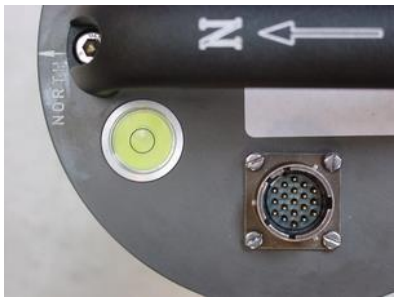
- Electro Shaker :
  - APS 420 ELECTRO-SEIS®





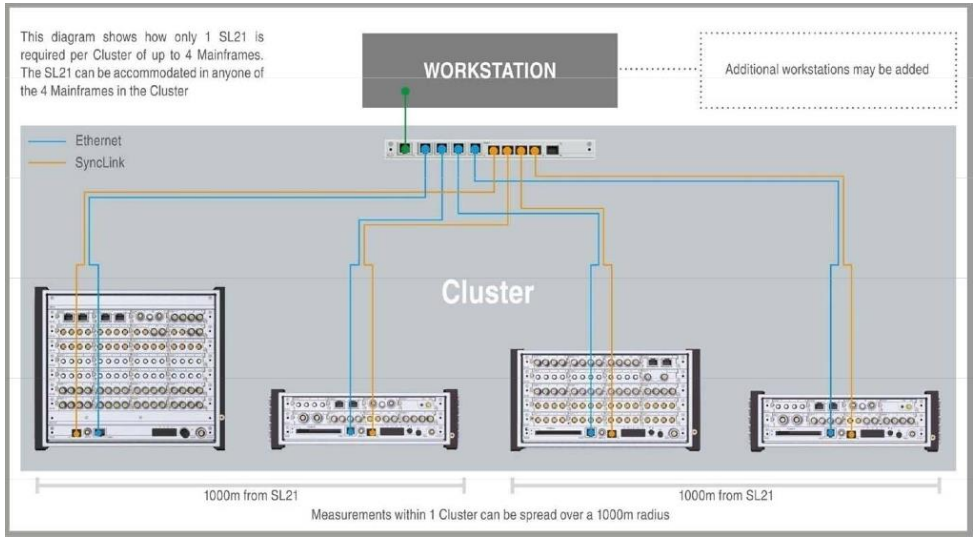
RESPONSE

- Geophones :
  - CMG-T60-0004 from Guralp Systems
  - Three directions measurements
  - Sensitivity of about 2000 [V/(m/s)]
  - Frequency range between 30 [s] and 100 [Hz].
- Seismic accelerometers :
  - ENDEVCO T86
  - Sensitivity of about 1 [V/(g)]
  - Frequency range between 0,1 and 200 [Hz].



Tunnel transfer function $H_1(\omega)$, in practice

- Synchronous vibration measurements up to several kms done by optical fibre connection
- Phase shift below 0.1° on the bandwidth between two spectrum analyser

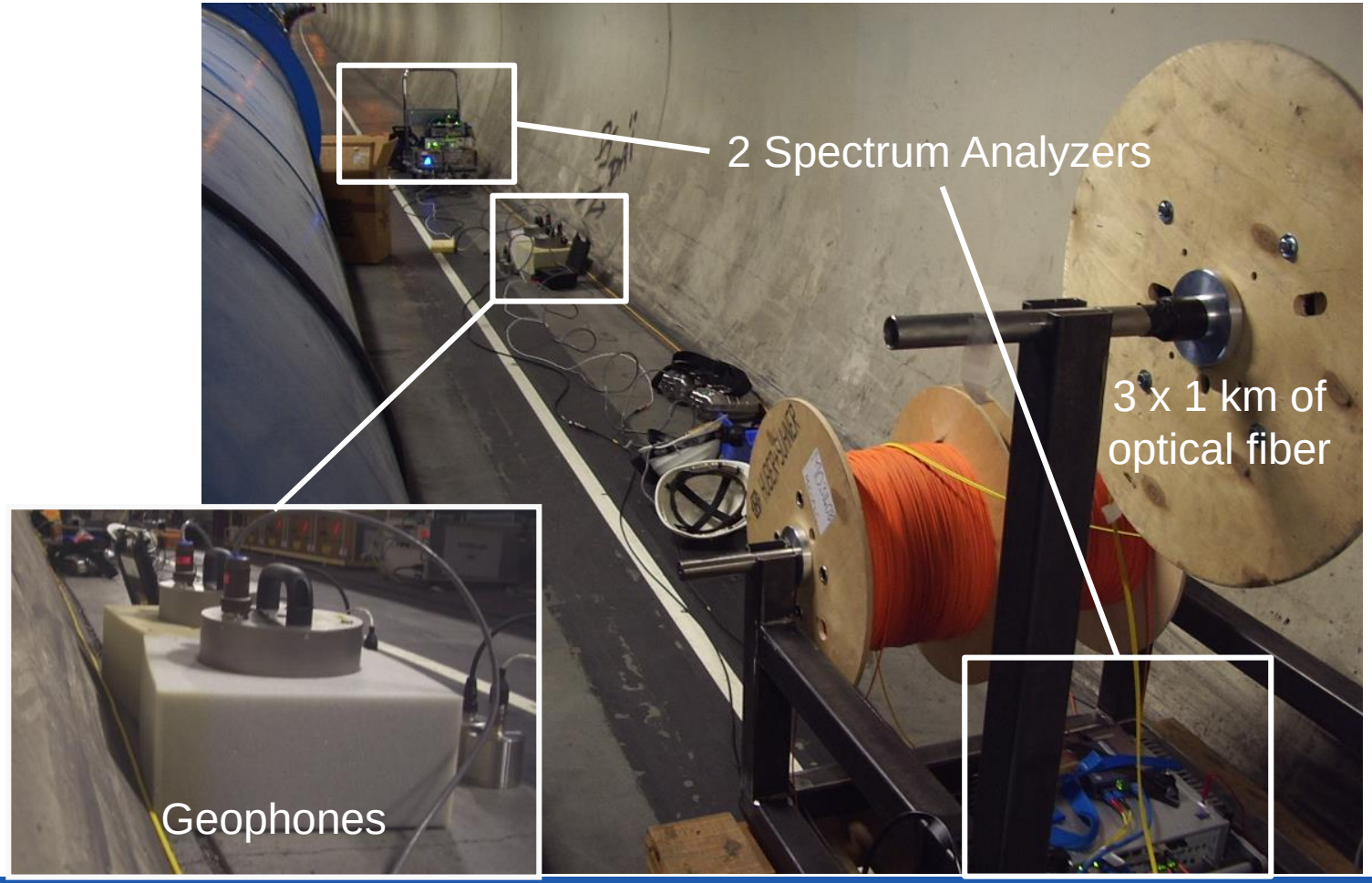


ICP42S G2 features:

• 24-bit resolution, 204.8 kSa/s sampling rate per channel, 90 kHz bandwidth
• <0.1° @ 10 kHz phase accuracy between channels of the same or any other Modules

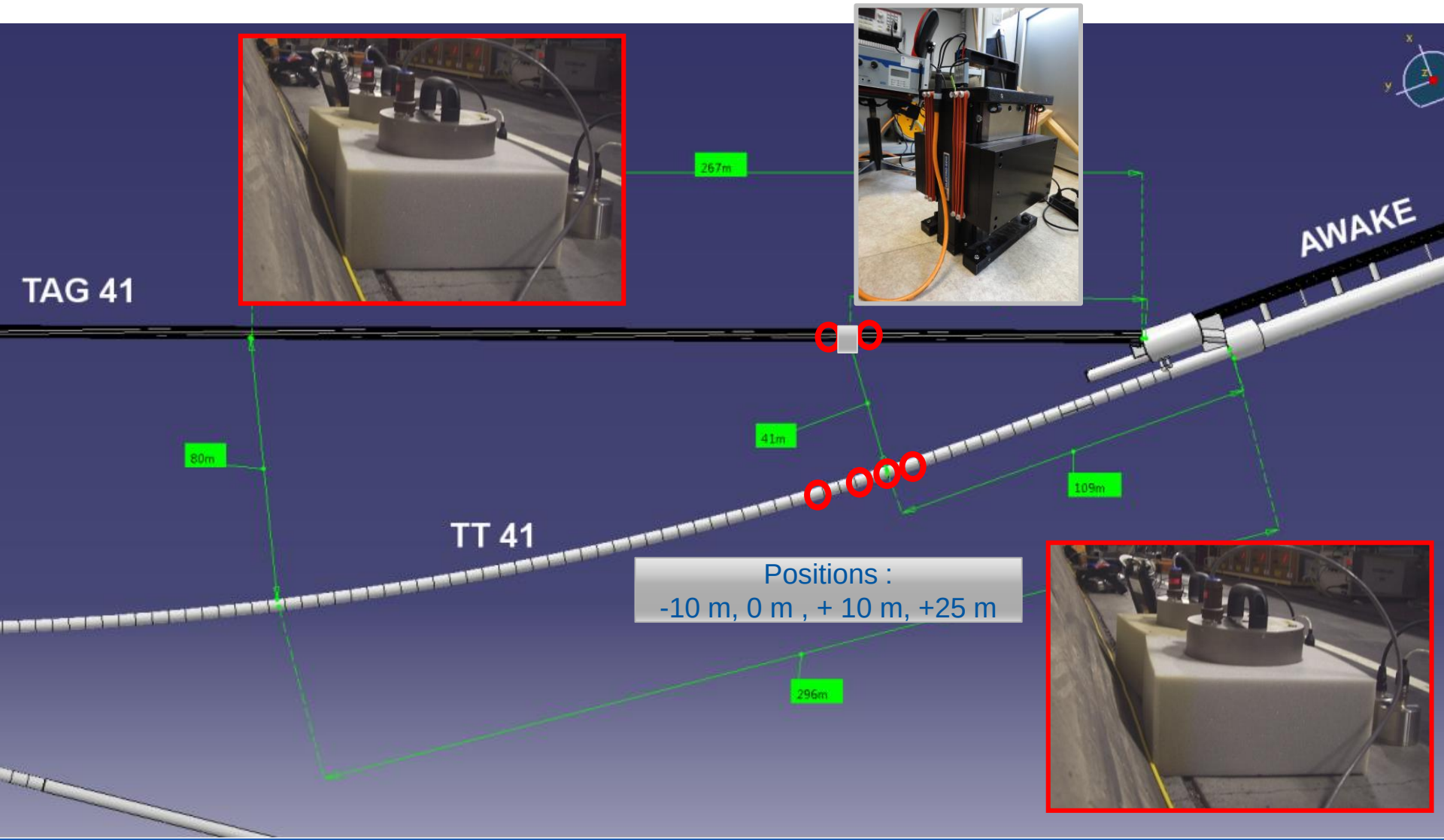
Tunnel transfer function $H_1(\omega)$, in practice

- Installation in the tunnel (from previous measurements)



PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 072801 (2010)
Seismic response of linear accelerators
C. Collette, K. Artoos, M. Guinchard, and C. Hauviller

Tunnel transfer function $H_1(\omega)$, in practice



Tunnel transfer function $H_1(\omega)$, in practice

TAG 41

TT 41

AWAKE

267m

89m

41m

109m

80m

Positions :
-10 m, 0 m , + 10 m, +25 m

Status and schedule

- Shaker will be operated by Resonance firm (subcontractor for the shaker). CERN registration of Resonance team is done, and safety training is in progress

- Shaker should be at CERN this week

- Schedule :

Week 18 Admistrative procedure for Resonance and preparation of the equipmens (MME lab)

5th May

Day : Installation of the equipments in TT41 and TAG41

Night : Measurements at 40 m, if possible at 80 m

6th May

Day : Equipment removal

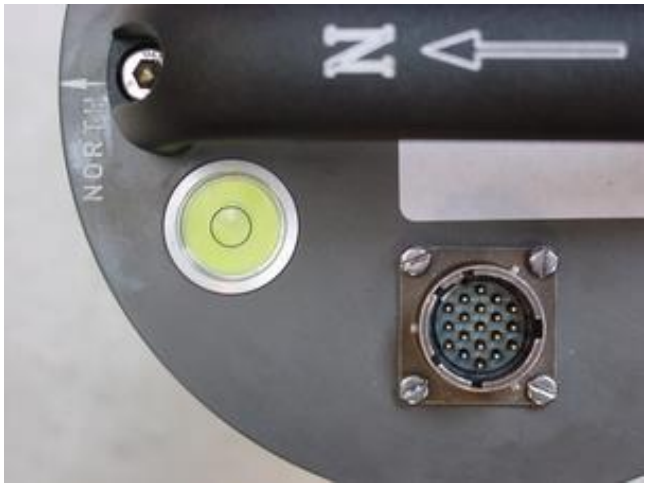
Week 20 First results

www.cern.ch

Additional slides…

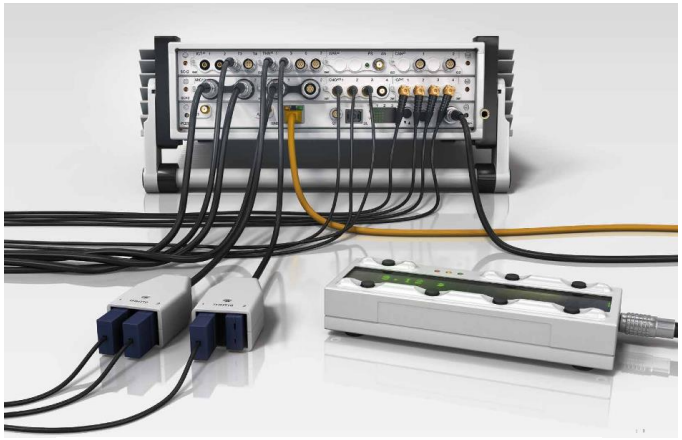
Technique of measurements

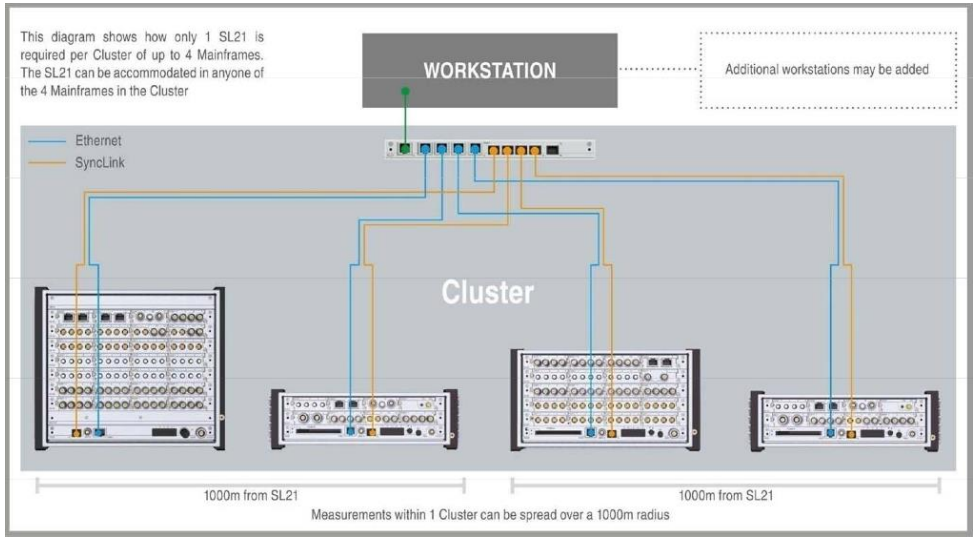
- Geophones :
  - CMG-T60-0004 from Guralp Systems
  - Three directions measurements V, NS and EW
  - Sensitivity of about 2000 [V/(m/s)]
  - Frequency range between 30 [s] and 100 [Hz].



Technique of measurements

- Synchronous vibration measurements up to several kms done by optical fibre connection
- Phase shift below 0.1° on the bandwidth between two spectrum analyser

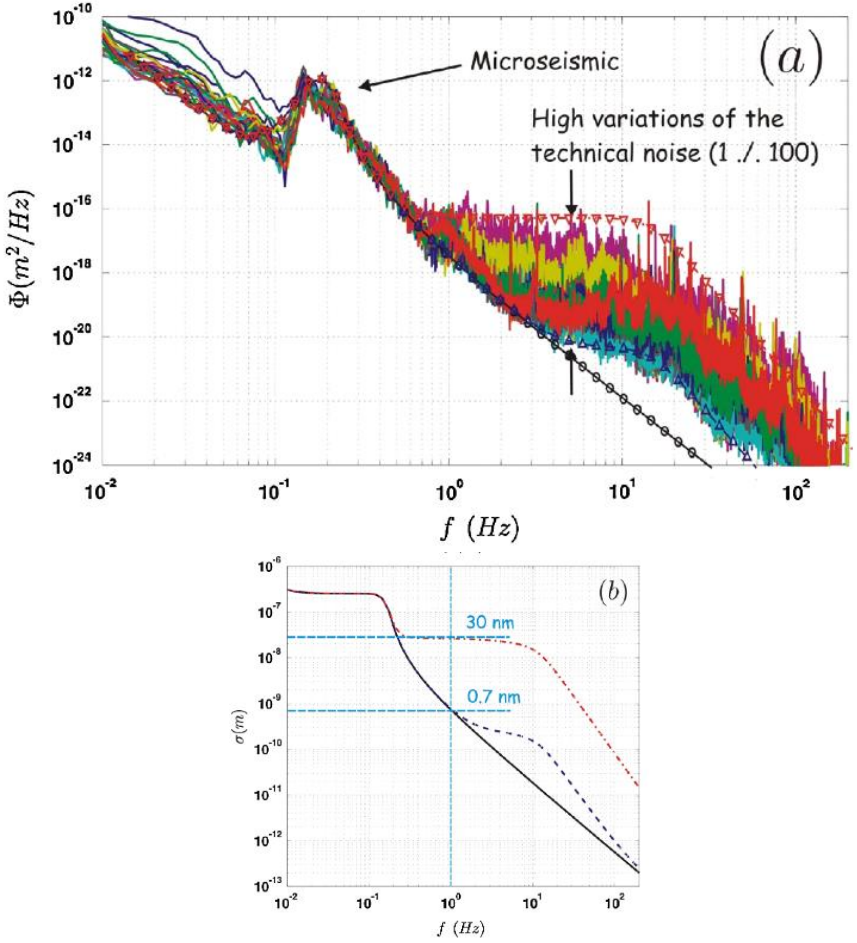


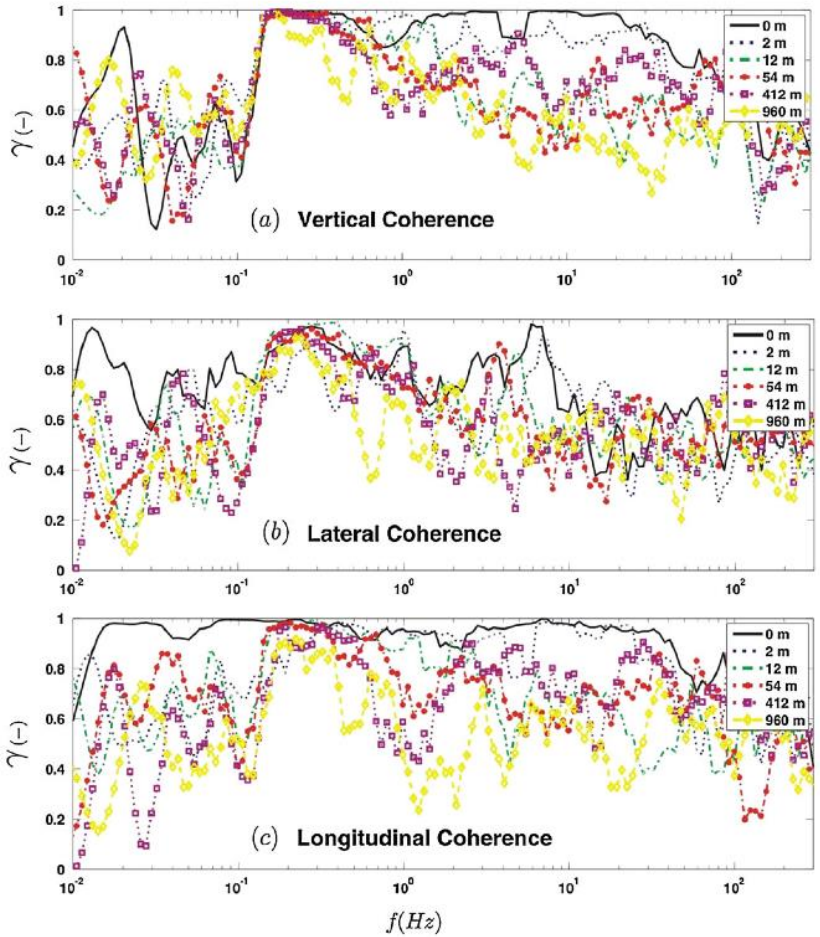


ICP42S G2 features:

- 24-bit resolution, 204.8 kSa/s sampling rate per channel, 90 kHz bandwidth
- <0.1° @ 10 kHz phase accuracy between channels of the same or any other Modules

Typical measurements in LHC





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

Seismic response of linear accelerators

C. Collette, K. Artoos, M. Guinchard, and C. Hauviller