Laboratoire d'Annecy de Physique des Particules

Strategy for Vibration suppression

B. Aimard, G. Balik, L. Brunetti, J.P. Baud, A. Dominjon, S. Grabon, G. Lamanna, E. Montbarbon, F. Poirier

FCC IS WP2, 03th of December 2021

https://indico.cern.ch/event/1085318/timetable/

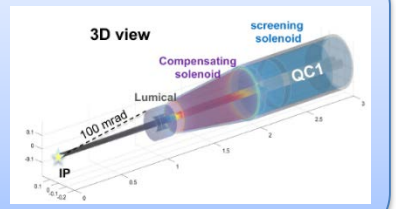
Team and objectives

- **Work Packages:**

MDI vibration aspects

- Mechanics & control
- Optics simulation

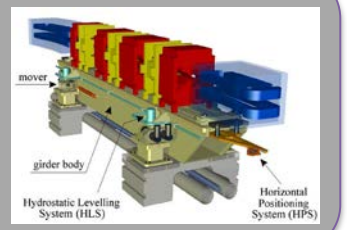
FCC IS WP2.3



Positioning technics

- At the interface with the alignment

FCC IS WP2.2



- **LAPP team: mechatronics & accelerator physics**

permanents
- G. Lamanna: FCC Project leader
- L. Brunetti: Leader of FCC R&D accelerator, control & instrumentation
- A. Dominjon: Instrumentation
- B. Aimard, J.P. Baud: Mechanics
- G. Balik: Control & instrumentation
- Electronic and informatic support

partnership
- F. Poirier: accelerator physics

2-year contracts
- E. Montbarbon: accelerator physics
- S. Grabon: mechanics

FCC-ee vibrations mitigation

$\Delta d=0$ → Criticality of the vibration issues → $d=0$

LHC

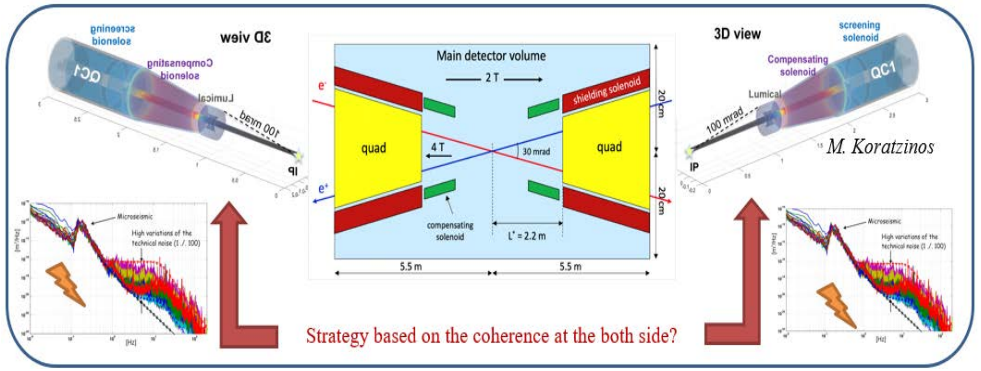
FCC-ee

CLIC

➢ **Tolerances related to the beam size and to the shape of the collider**

\+

- High repetition rate of the beams
- “Symmetry” of magnetic effects on both beams
- Coherence around the IPs
- Beam control (orbit correction, Post-IP BPM control)



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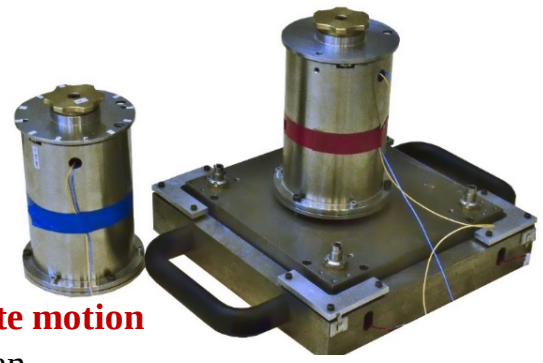
- Mechanical effects, resonance modes (**Cryostats in cantilever mode**), supports and magnets
- Stiffness of the positioning system
- **Nanobeam** in the vertical axis
- Weak coherence along the ring, relative to distance and frequency
- BPM resolution (and whole instrumentation)
- Two beam pipes…

FCC ee mitigation

- **Vibrations mitigation strategy – illustrations with LAPP developments**



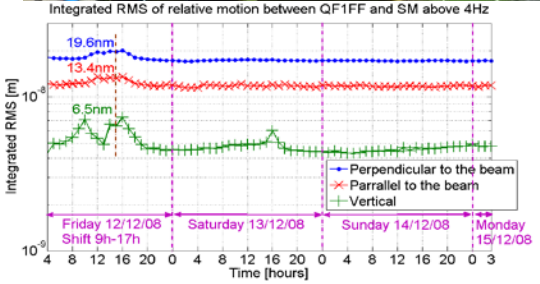
- ***LAPP** active foot + **LAPP** sensors (one on ground used to monitor ground motion and 1 on top used in feedback)* -

Option “low cost”

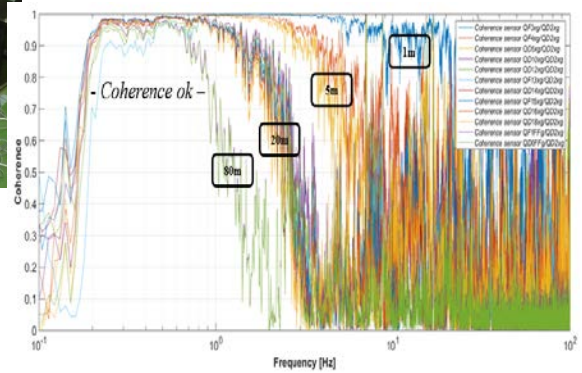
- **Based on the coherence motion, reducing the relative motions between the elements : strategy of the main experiments**

Example of ATF2 (jp) : relative motion between shintake monitor and final doublets of [4 – 6] nm RMS @ 0,1 Hz (vertical axis):

Very stiff in z direction (first eigenfrequency at 70Hz induced by the final doblets supports) - beeswax



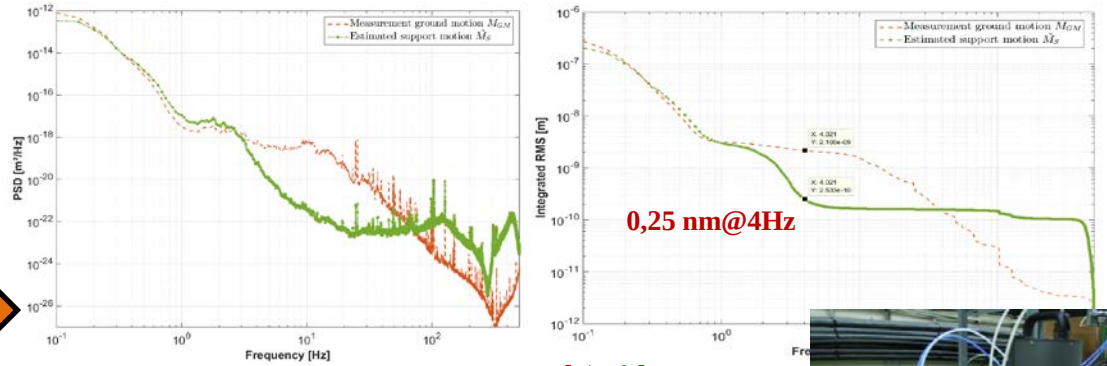
Coherence



Option “high cost”

- **Active control: reducing the absolute motion**

Example of CLIC : feasibility demonstration of an absolute displacement of 0,25nm RMS@4Hz with specific actuators and developed sensors



- *Displacement **without control** / **with control** **at LAPP*** -

CLIC Main Linac stabilization
CERN

Active control

Strategy for FCC-ee?

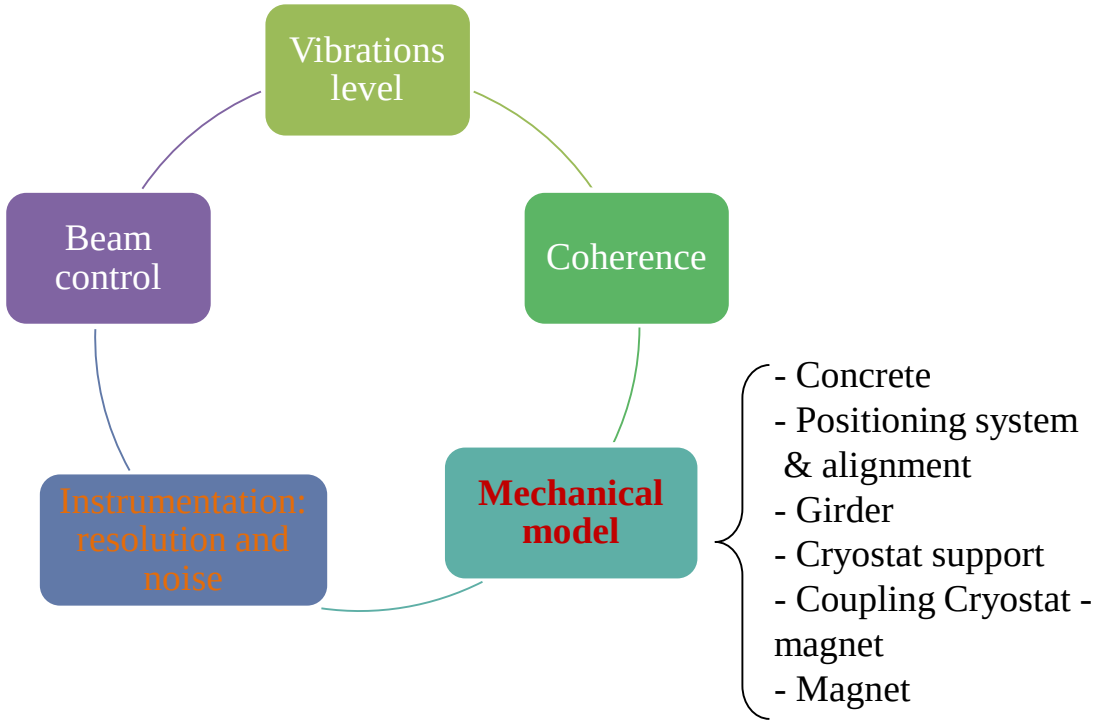
Δd=0 — Criticality of the vibration issues — *d=0*

Not very critical | **Has to be defined** | **Extremely critical**

- **MDI vibrations tolerances**

➢ *1st evaluation of K. Oide*

1st step: integration of the dynamics of the mechanics (especially the MDI) in the optics simulation



- ❑ **This optics simulation is needed to validate the MDI assembling**
- ❑ **The MDI assembling transfer functions have to be integrated in the whole simulation**

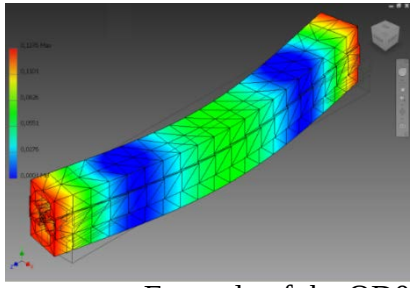
➢ Complementary study to the current ones (T. Charles, K. Oide et al)

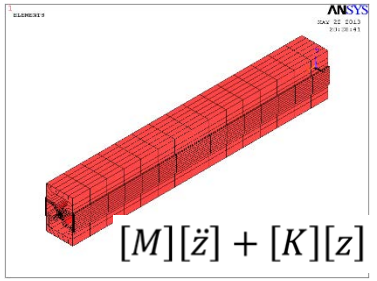
➢ **See presentation of E. Montbarbon "**MAD-X Simulations of vibrations in the MDI region"

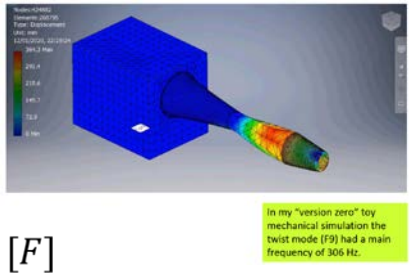
MDI : mitigation method (1)

- **Has to be implemented**

- FEM : Modal analysis using finite elements - Determination of the most significant modes of the whole assembling (frequency response characteristics)
- Expression in the form of a state space model (and eventually study of the control strategy)

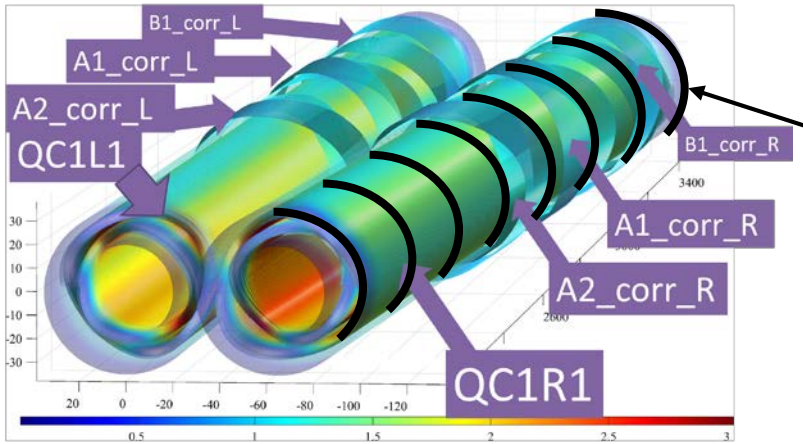






Example of the QD0 CLIC FF Magnet

- Evaluation of a temporal sequence excitation at each node of the strategic elements



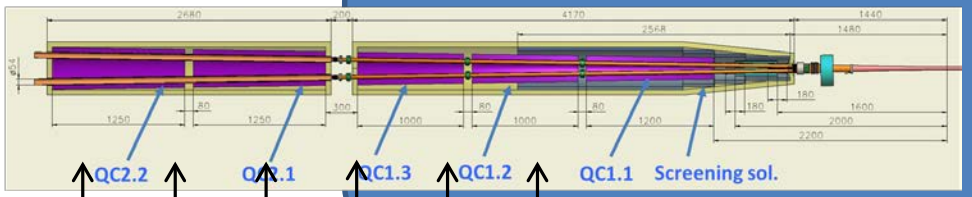
Slices corresponding to the optics simulation

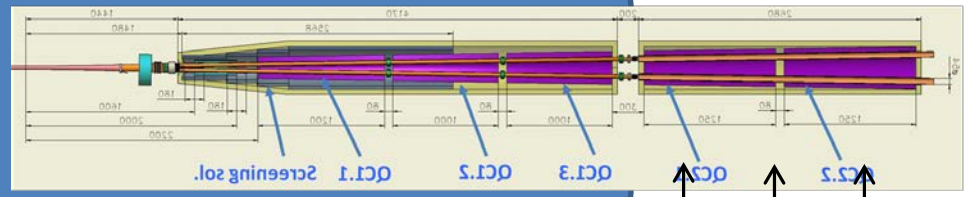
- *If active control:*

- Integration in a control loop with the full simulation (sensor, actuators, ADC, DAC, Data processing….
- Control in simulation (location and number of active feet, type of active feet, degrees of freedom, type of control (SISO, MIMO))

MDI : mitigation method (2)

➢ *New comer: S. Grabon (FCC IS)*





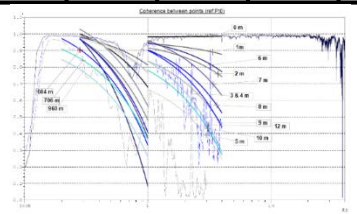
n temporal sequences which could be integrated in the whole optics simulation

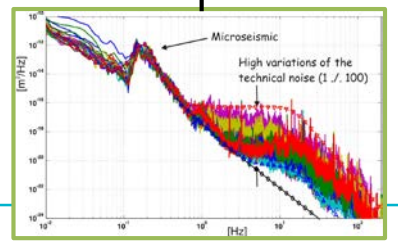
n Transfer functions:
GND -> each relevant nodes (ex: magnet slices of the optics simulation)

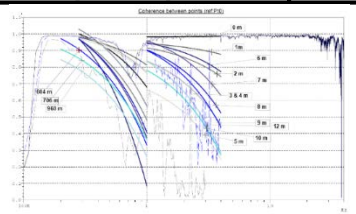
$$K\frac{(s-z_1)(s-z_2)\dots(s-z_n)}{(s-p_1)(s-p_2)\dots(s-p_m)}$$

MAD-X
emittance (α luminosity)

CAD
In collaboration with INFN



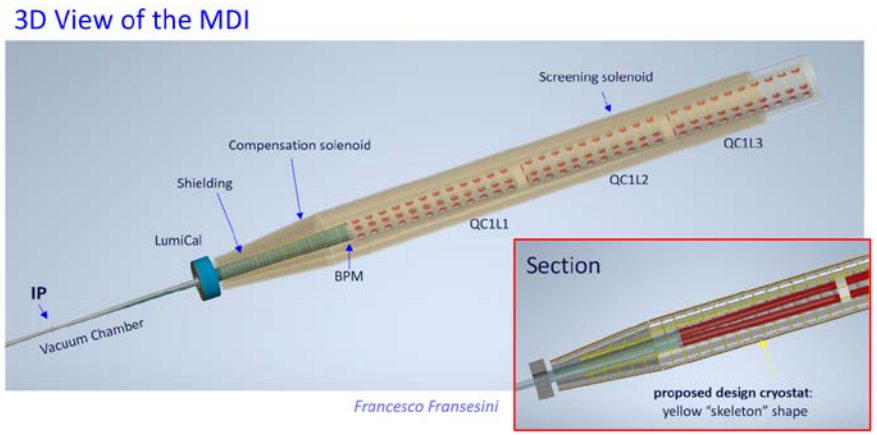


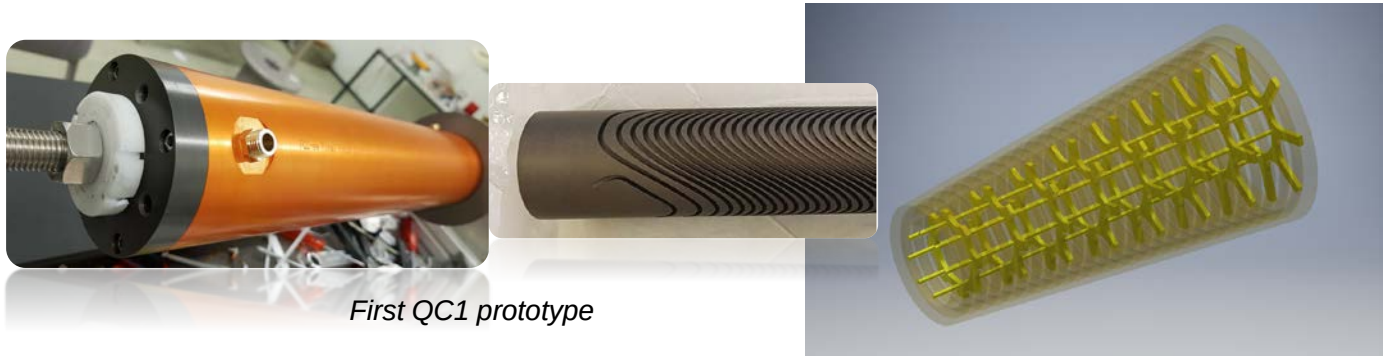


Measurements or model of ground motion in taken into account the coherence & local disturbances

MDI: current issues

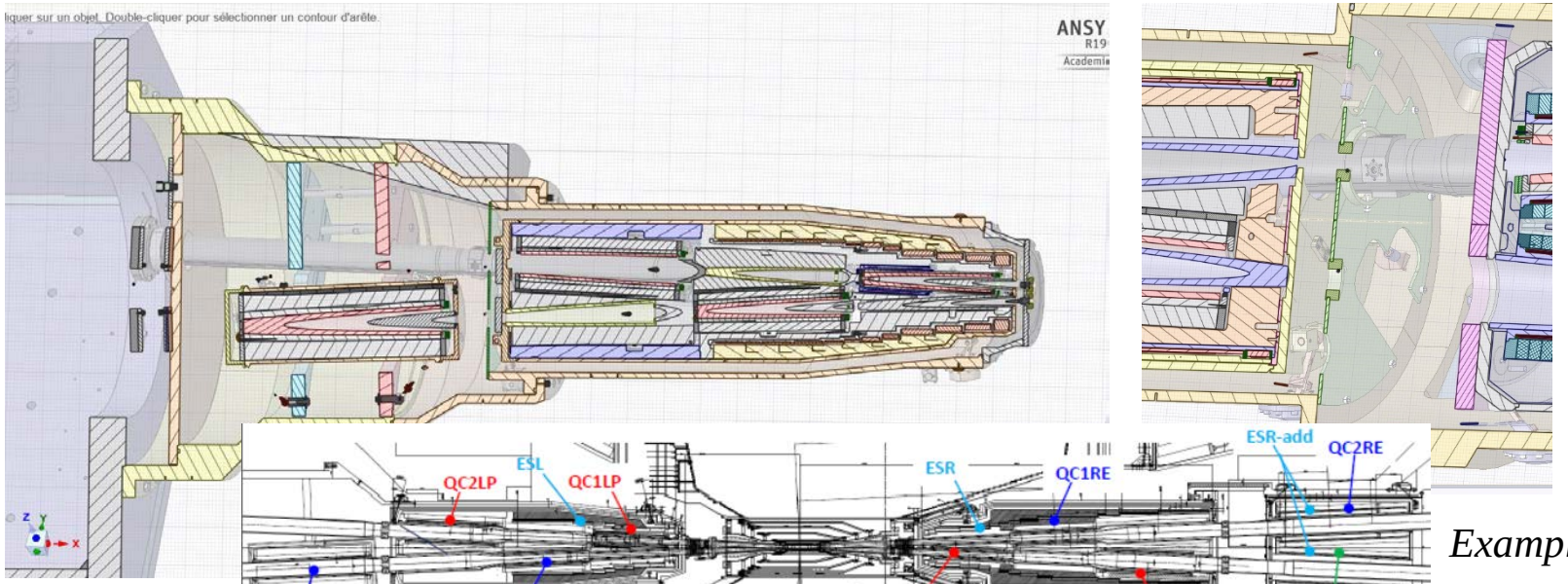
- **Only a few elements are designed**

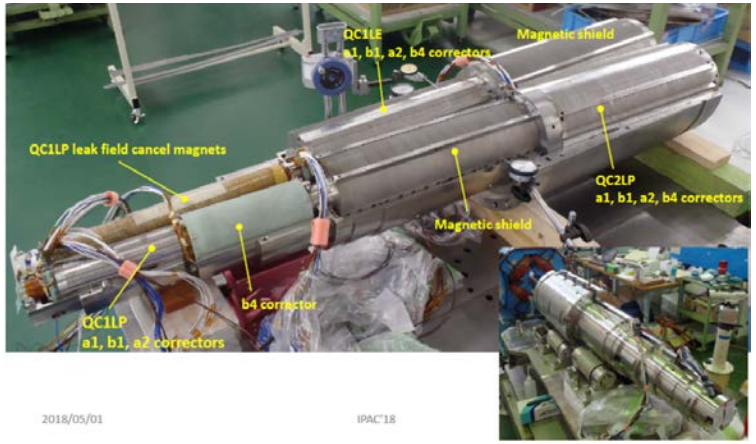




First QC1 prototype

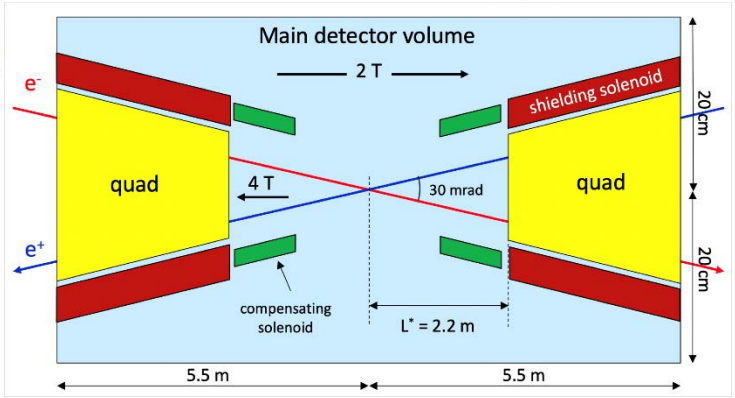
➢ ***See presentation of Manuela (ABP Day)***



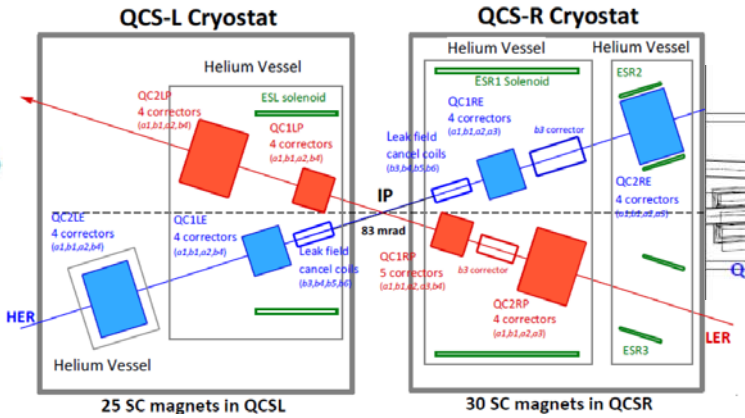


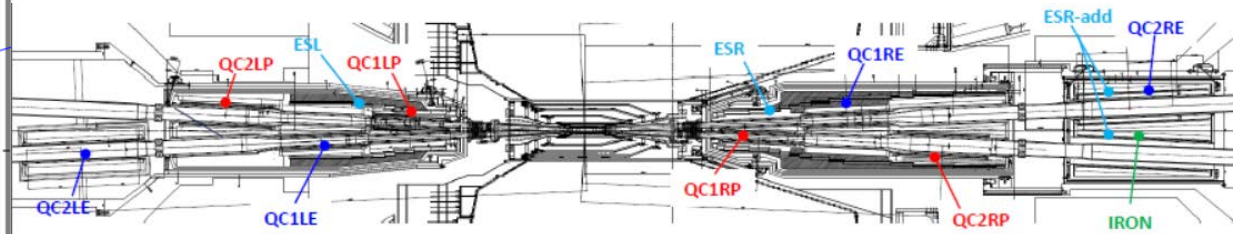
Example of the SuperKEKB cryostat

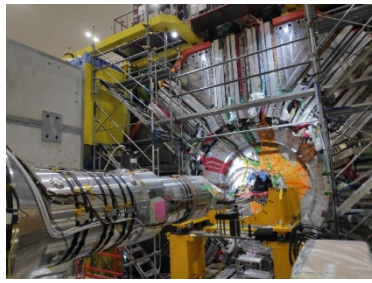
Vibration mitigation : SuperKEKB vs FCC-ee



	SuperKEKB	FCC-ee
Energy(GeV)	7 (e^-) | 4(e^+)	45.6,80,120,175
σx(IP) (μm)	11 | 10	6.4,13,13,36
σy(IP) (nm)	56 | 48	28,41,36,66
Cryostat in cantilever	yes	yes





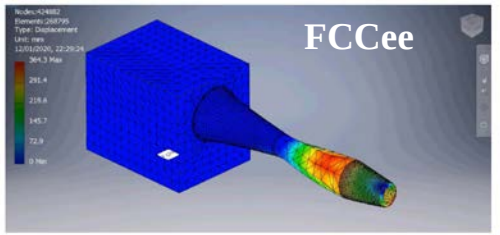


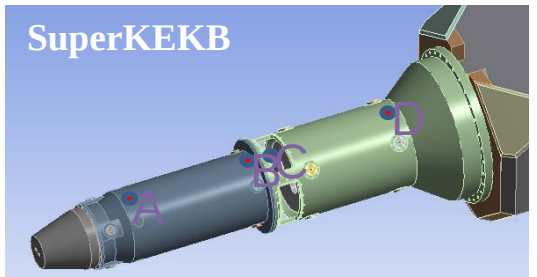
- **Similarities, advantages and opportunities:**

  Collider in operation, similar beam, cryostat in cantilever
  Various common issues : BPM resolution, IP feedback…

- **Difference:**

  The HER and LER final focus magnets are not symmetrical inside the cryostat

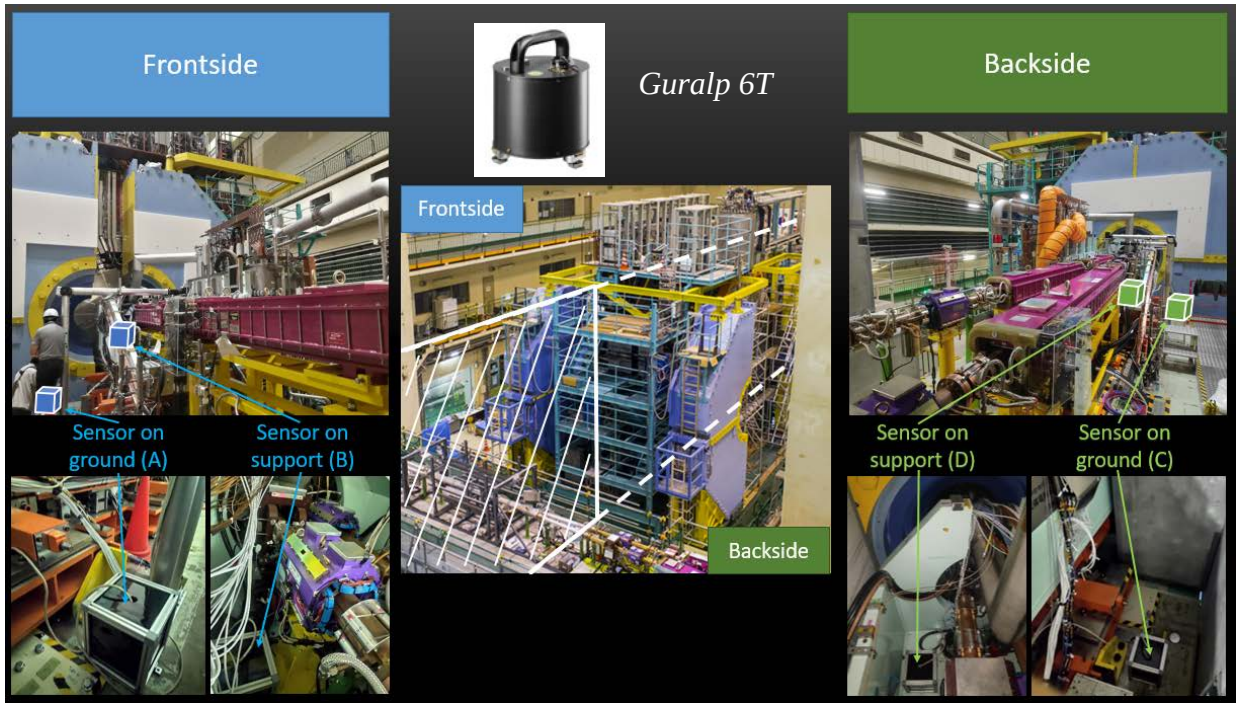




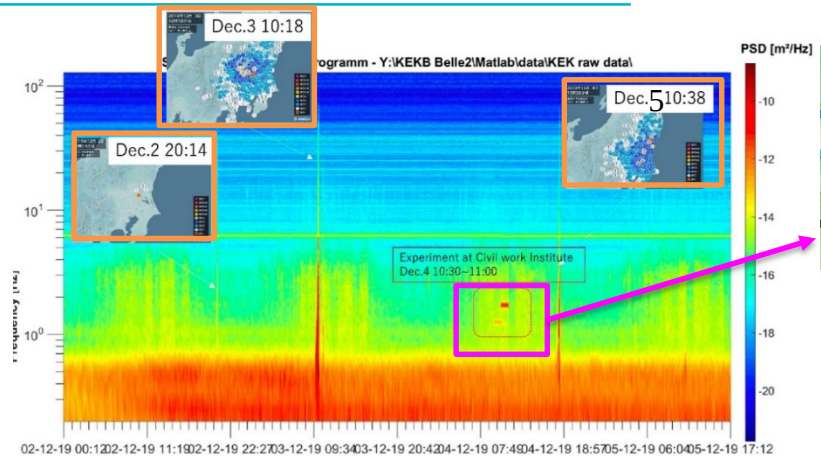
Design of the cryostat (KEK)

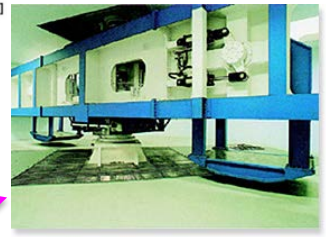
SuperKEKB - setup

- **SuperKEKB – vibration measurements**



4 seismic sensors - 2 at each side of the BELLE II detector



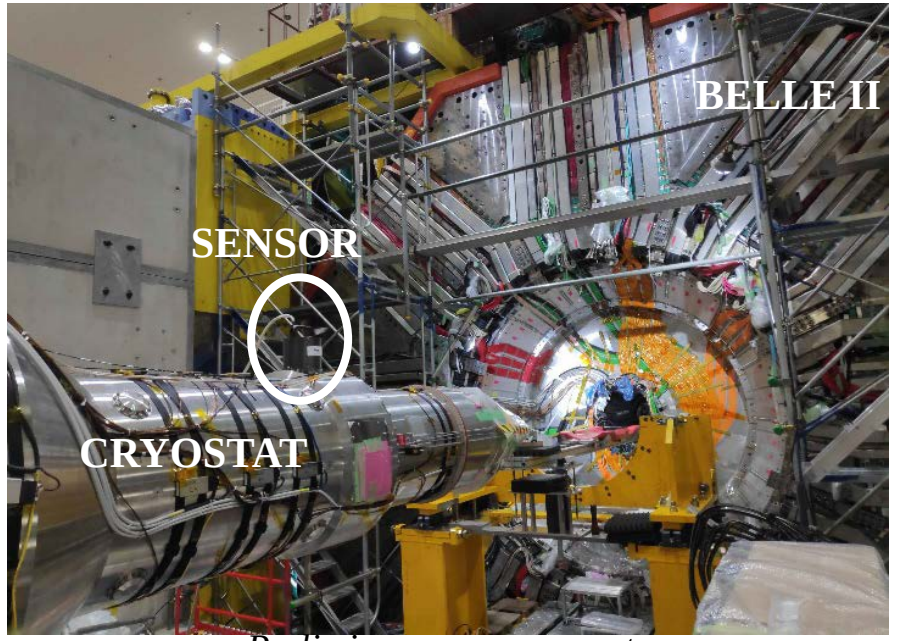


Experiment of accelerate centrifugal force close to KEK

Vibration analysis: earthquake and external perturbations

- **Long-term monitoring with continuous available data for the collaboration**

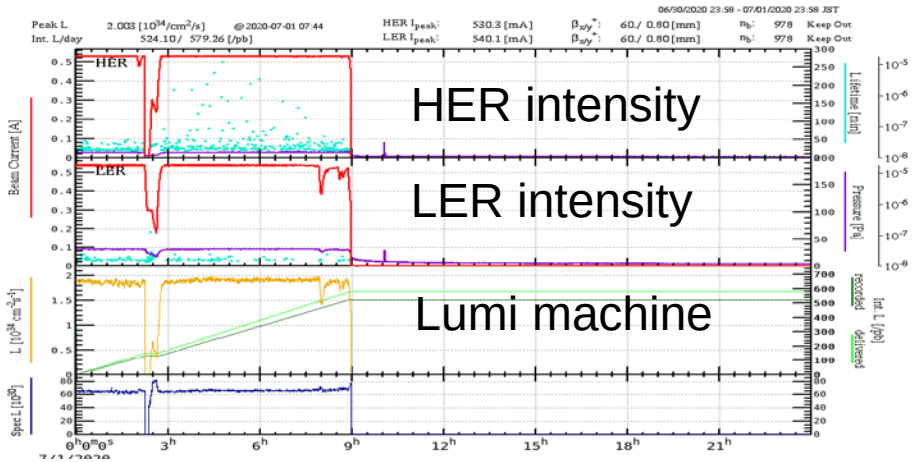
  - Monitoring of the seismic motion and the collider cultural noise
  - Identification of disturbances or specific event (not the topic)
  - Weekly reports are available at : https://lappweb.in2p3.fr/SuperKEKB/

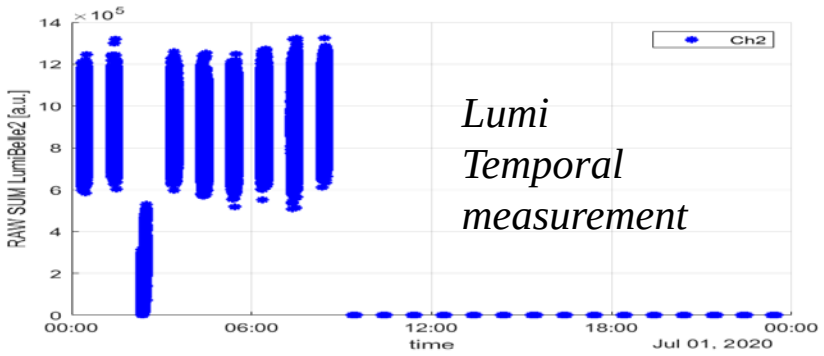


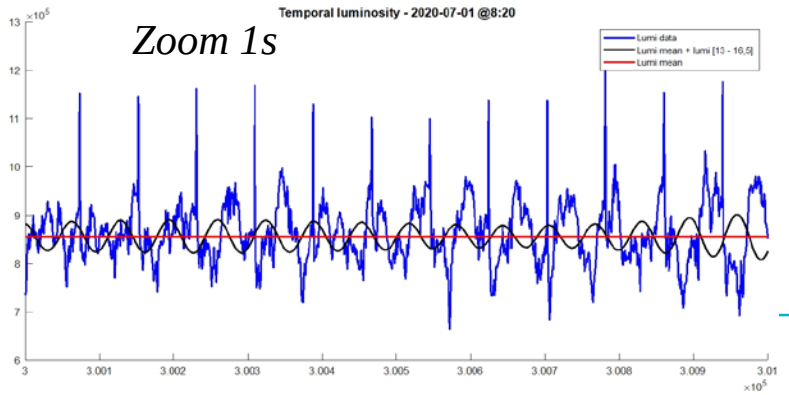
Preliminary measurements
Modelling and measurements done by KEK are also available

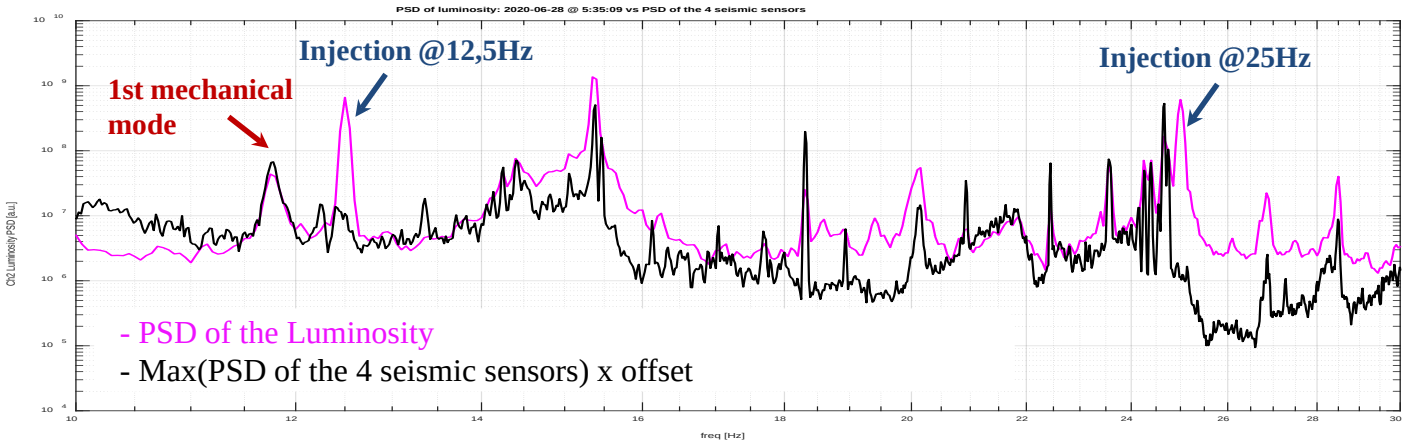
SuperKEKB: comparison vibrations – luminosity (1)

- **Comparison vibrations vs Luminosity monitoring via Bhabha scattering (IJCLab & KEK)**





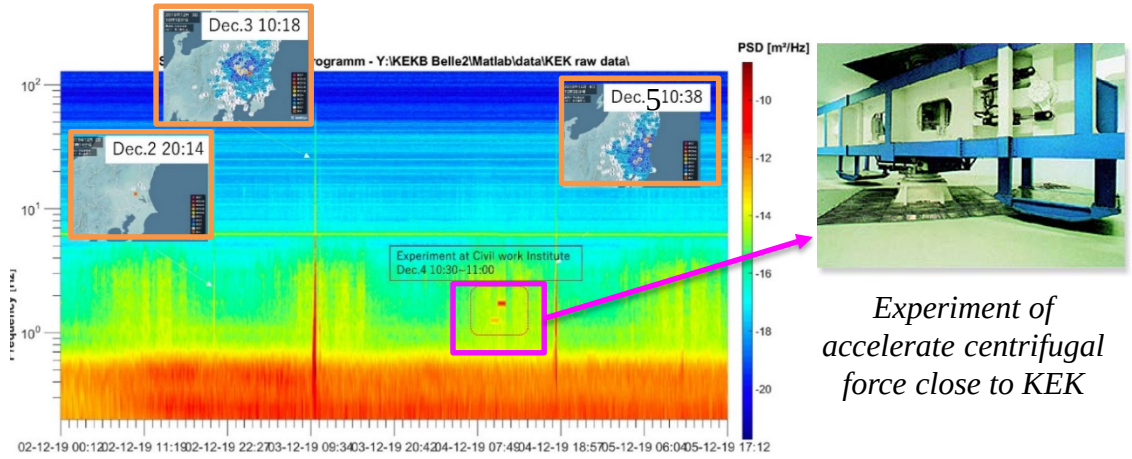




- Except the peaks at 12,5 Hz & 25 Hz dues to the injection, all the luminosity peaks are mainly dues to vibrations amplified by asymmetrical mechanical structures
- Publication: *M. Serluca, G. Balik, L. Brunetti, B. Aimard, A. Dominjon, P. Bambade, S. Wallon, S. Di Carlo, M. Masukawa, S. Uehara, Vibration and luminosity frequency analysis of the SuperKEKB collider, NIMA (2021).*

SuperKEKB: correlation vibrations – luminosity (2)

- **Works in progress:**



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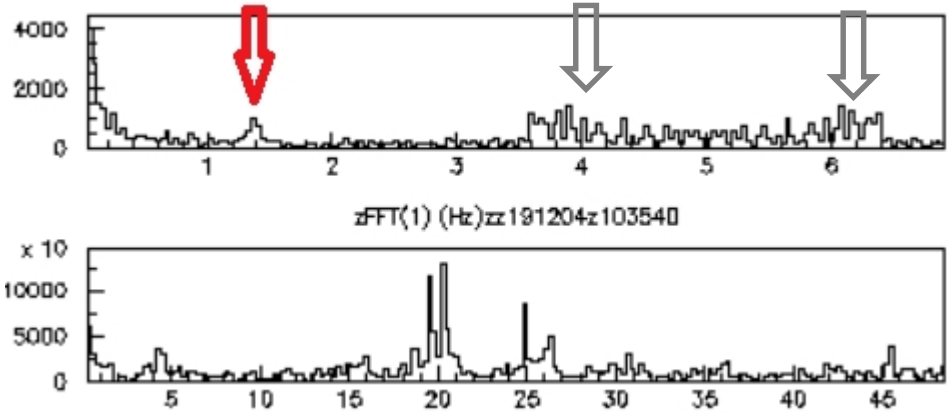
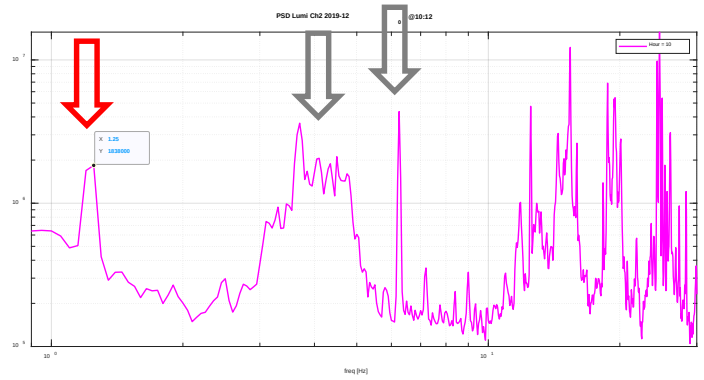
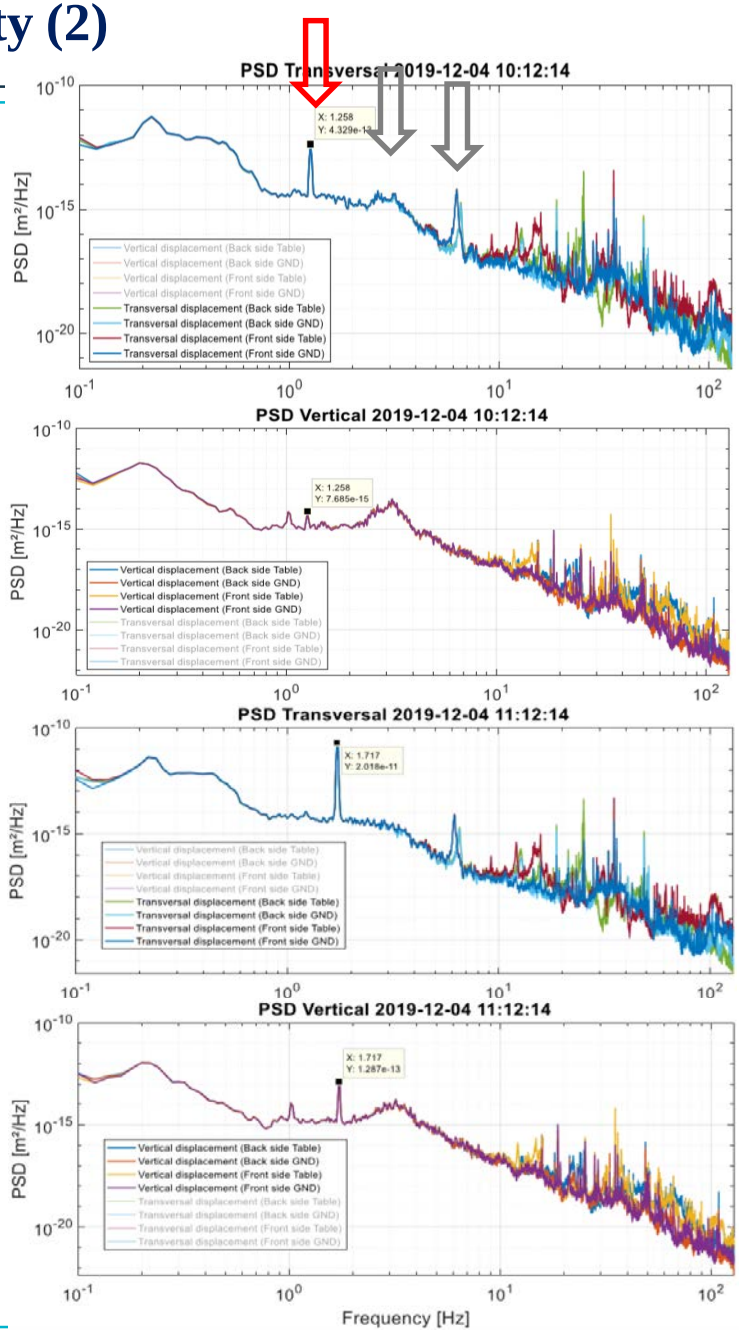


FFT of the ZDLM luminosity (KEK)

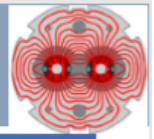


PSD of the luminosity (IJClab) at the beginning of the acceleration phase



- The peak [1,2 – 1,7] Hz is measured (during the acceleration phase) by the luminometers and by the seismic sensors even if the disturbance effects are coherent for the four sensors…

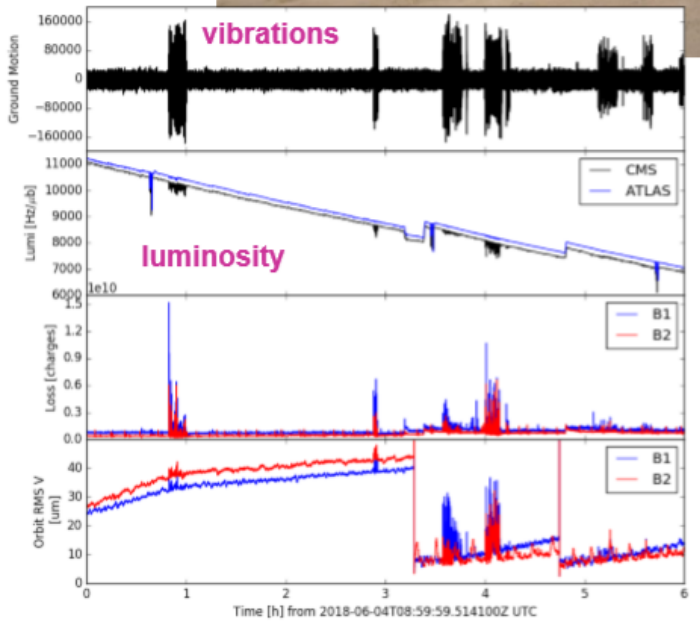
… and there's the man-made waves (2)



- In the early part of the CE work, an important volume of soil was moved around and compacted while LHC was operating.
- Ground compactors compact soil by… **vibrating**.
- …and they managed to **shake the beams colliding at the IP ~100 m underground**.

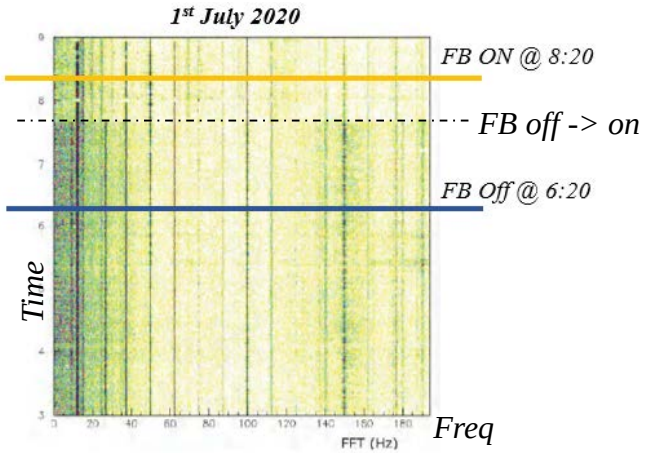
Mechanism:

- The vibrations with **frequencies ~20 Hz** were transmitted through 100 m of rock to the tunnel magnets and their supports that resonate in the frequency range 8-22 Hz.
- The resonant excitation generated ~ **micrometer amplitude beam movements** that were clearly visible on the CMS experiments luminosity (= rate of collisions).

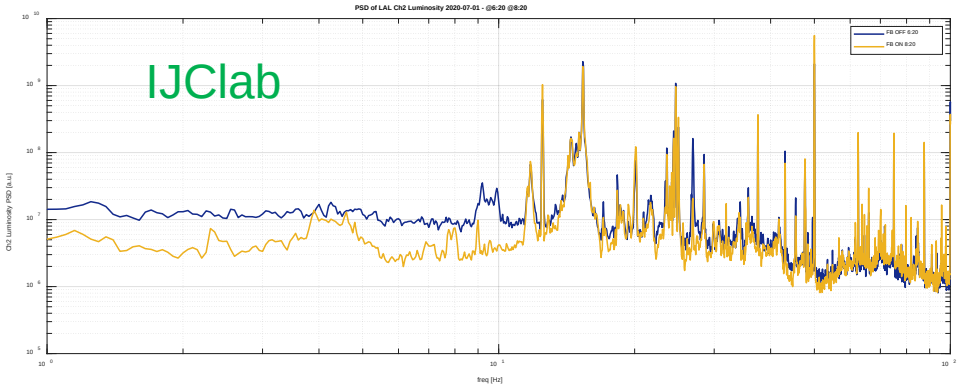


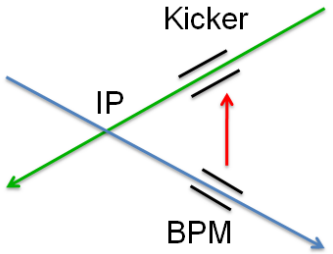
SuperKEKB: some examples of potential studies

- **Performances of the IP BPM control:**

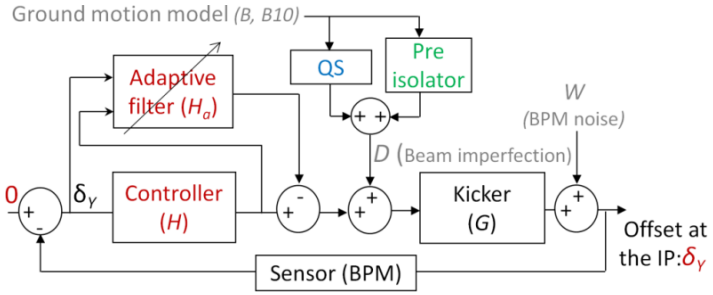


3D spectral measurement of ZDLM lumi (KEK)



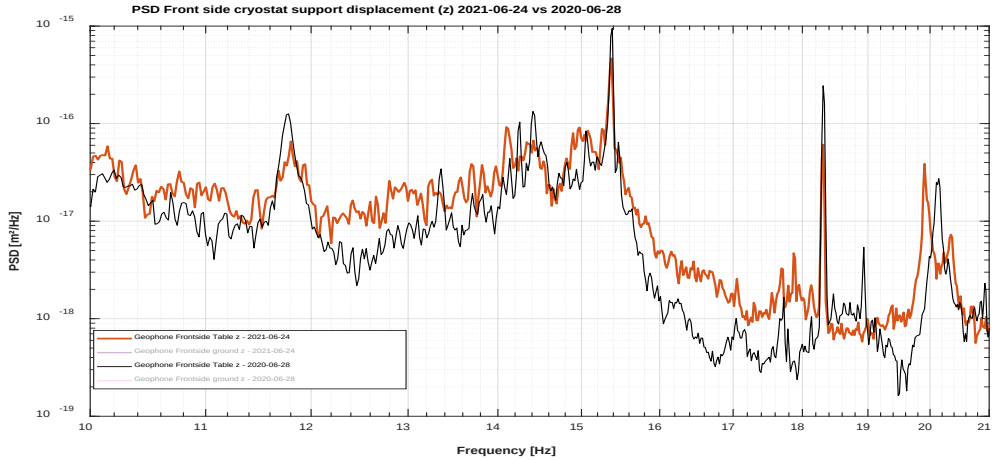


Principle



Similar feedback developed for CLIC
Feedback and adaptive control scheme

- **Drift of the cryostat behavior in time:**



Conclusion

- Dynamics effects require specific and further optics simulations to define the specifications of the mechanics
- The method to integrate the mechanical behaviour will be developed asap
- Additional inputs are needed
- Collaboration with INFN

- SuperKEKB is a great opportunity to test a lot of aspects

- The active positioning will be probably needed close to the IR -> has to be investigated in collaboration with CERN team