Application-A-RD-23

Laboratoire d'Annecy de Physique des Particules

Correlation between vibrations, luminosity and IP beam position measurements at SuperKEKB

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TYL/FJPPN workshop, May 2025

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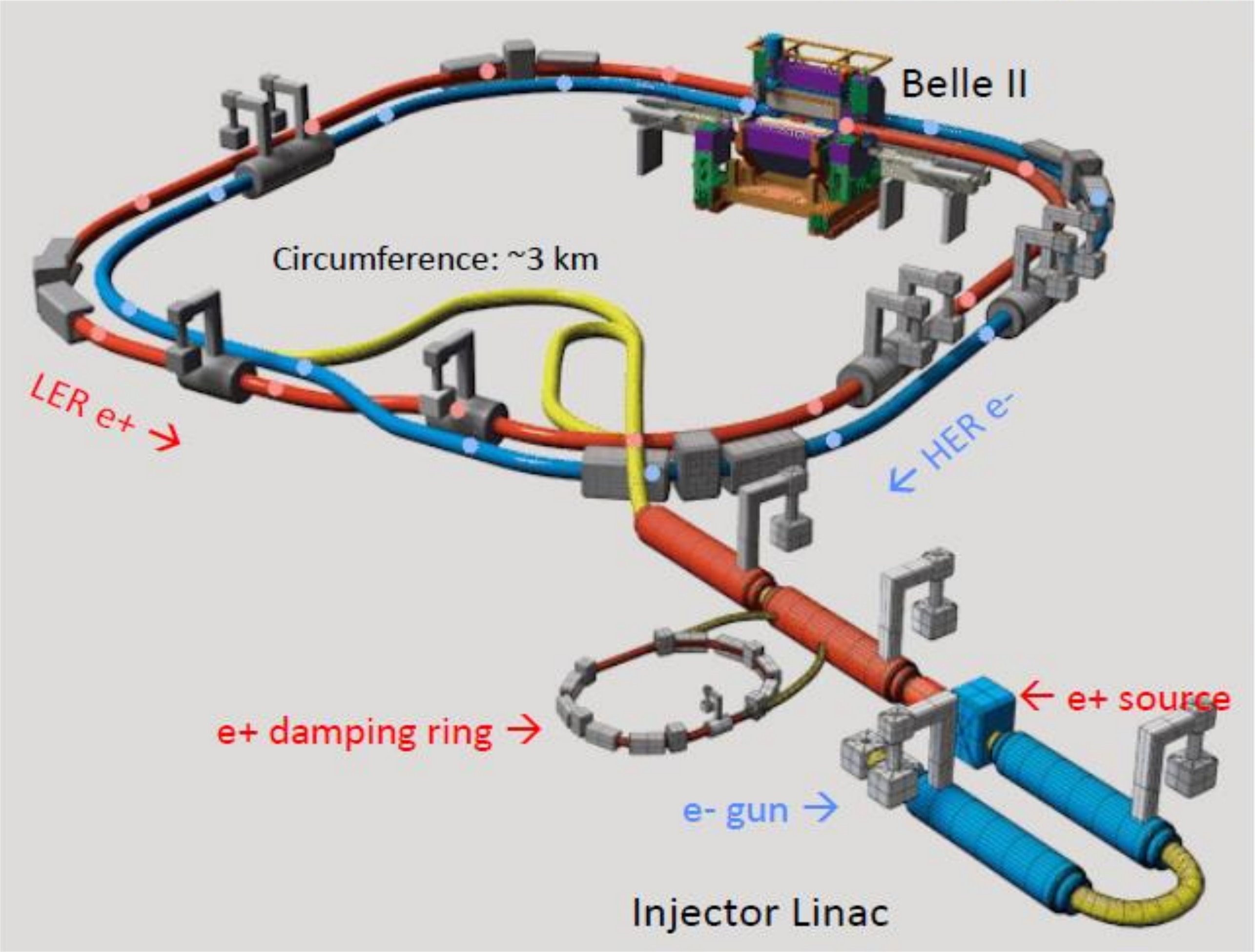
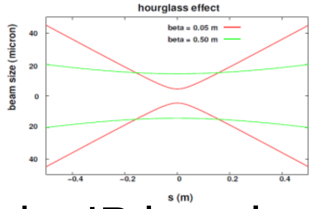
Electron-positron collider in Japan



- Upgraded from KEKB B-factory (KEKB)
- Stored-beam energies
  - **H**igh **E**nergy **R**ing (**HER**) : 7.0 GeV (e$^-$)
  - **L**ow **E**nergy **R**ing (**LER**) : 4.0 GeV (e$^+$)
- $E_{\rm cms} \approx M_{\Upsilon(4S)}$
- Stored-beam currents (design)
  - HER : 2.6 A
  - LER : 3.6 A
- Toward 6.0×10^{35} cm^{-2}s^{-1}
  - Higher beam currents than those at KEKB
  - Squeezing β_y^* with the nano-beam collision scheme

$$\mathcal{L} = \frac{N_{e+}N_{e-}f_{rev}N_b}{4\pi\sigma_x^*\sigma_y^*}R_{hg}$$

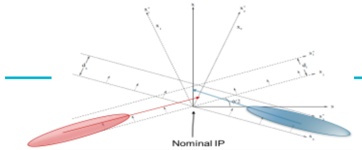


Though the instantaneous luminosity is dependent not only on the beams size at the IP but also on the respective beams position

$$\mathcal{L} = \frac{N_1N_2f_{rev}N_b}{4\pi\sigma_x^*\sigma_y^*}.W.e^{\frac{B^2}{A}}.S$$

W: respective Beams displacement

$$W = e^{-\frac{1}{4\sigma_x^2}(d_2-d_1)^2}$$

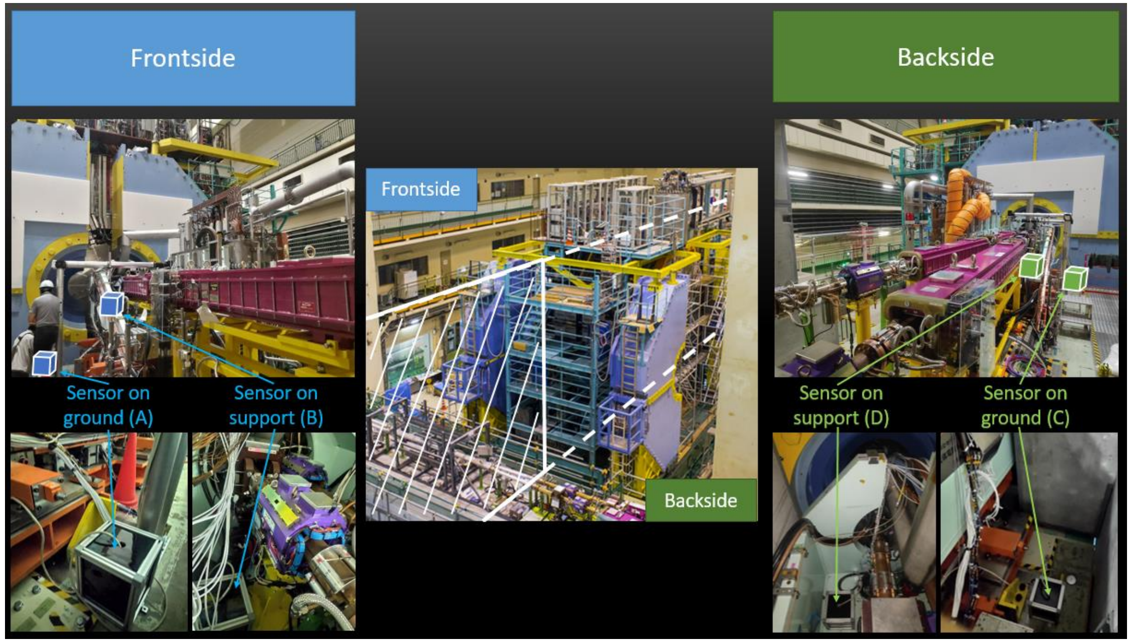


SuperKEKB – overview of the RD14 (last few years)

RD23 is a development proposition following the RD14 conclusions (Vibrations influence on the SuperKEKB beam)

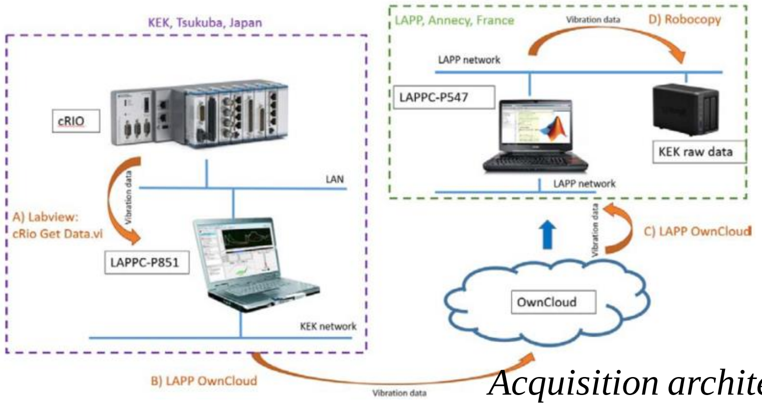
- **Long-term monitoring with continuous available data for the collaboration:**

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



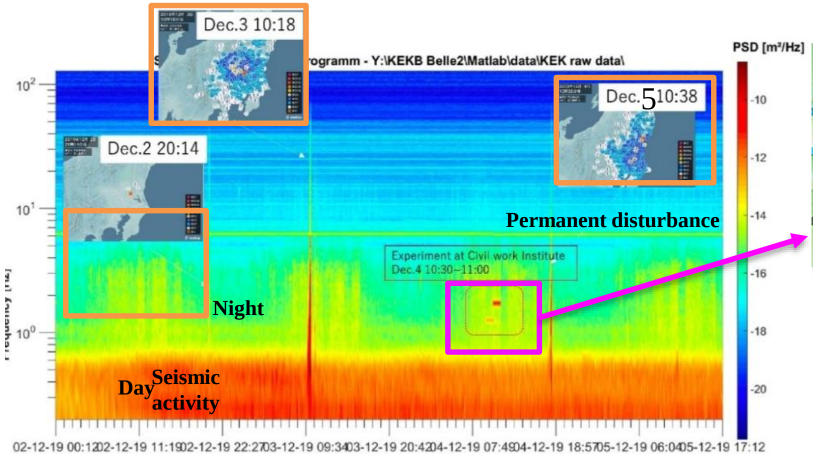
Monitoring 10'/hour to limit the data

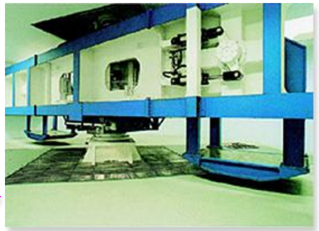
Guralp 6T



Acquisition architecture

- Weekly reports are available at : https://lappweb.in2p3.fr/SuperKEKB/





Experiment of accelerate centrifugal force close to KEK

Vibration analysis: earthquake and external perturbations

- **Objective 1 (initial): Identification of disturbances or specific events:**
  - Comparison day – night
  - Seismic events
  - External disturbances
  - Drift in time…

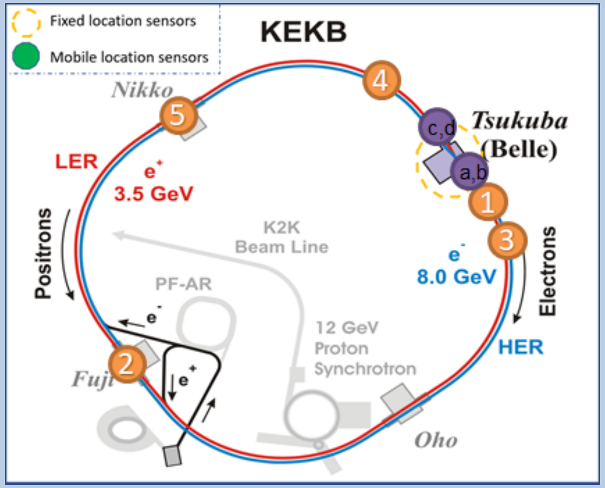
SuperKEKB: last compaign, 2023 Nov.

Simulation of displacements and impact on beams

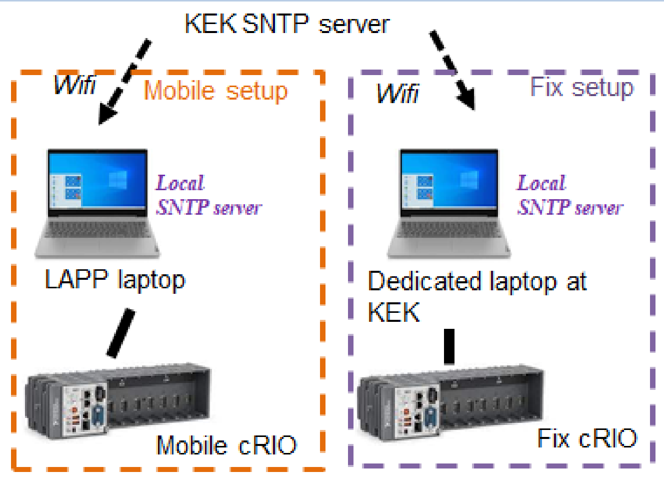
Measurement	Magnet HER	Distance (HER) in m	Magnet LER	Distance (HER) in m
8	QLC7RE	26,4	QLC3RP	26,6
9	QX3RE	1524,3	-	-
10	QLB1RE	55,4	QLB1RP	61,2
11	QLB1LE	2960,4 (55,6)	QLB1LP	2948 (67,2)
12	-	-	QW7NRP	652

Objectives (campaign):

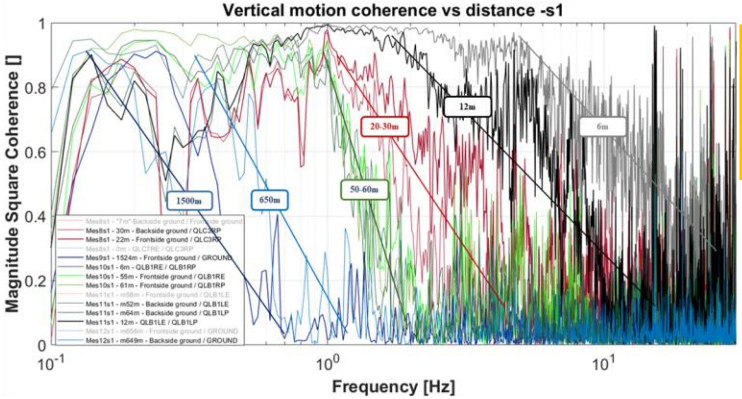
- Coherences measurements: vibrations effects analysis (SuperKEKB) and behavior of the tunnel (**FCC-ee** uniform waves studies and GND generator) with two synchronized ADC setups
- Evaluation of the behavior of the main impacting magnets (QLC7RE, QLC3RP, QX3RE, QLB1RE, QLB1RP, QLB1LE, QLB1LP, QW7NRP)



Various sensors locations in the tunnel



Setup of the synchronization

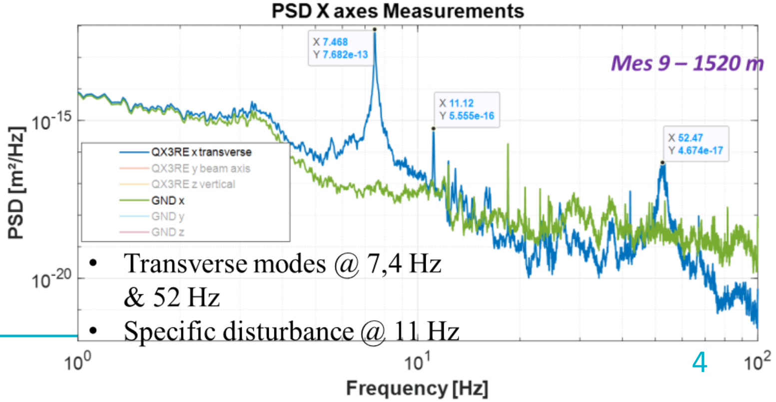


Vertical Coherence measurements in the SuperKeKB tunnel

Coherence over frequency for several distances

1) “Permanent” setup (a, b, c & d): measuring vibration (vertical and transversal axes) closed to Belle II detector

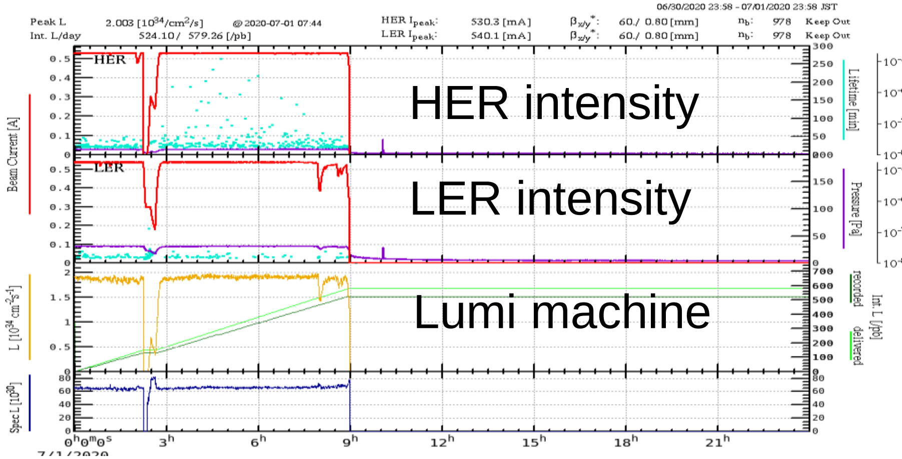
2) “moving and temporary” setup: measuring vibration inside the tunnel of quadrupole and/or ground at 5 specific locations inside the tunnel

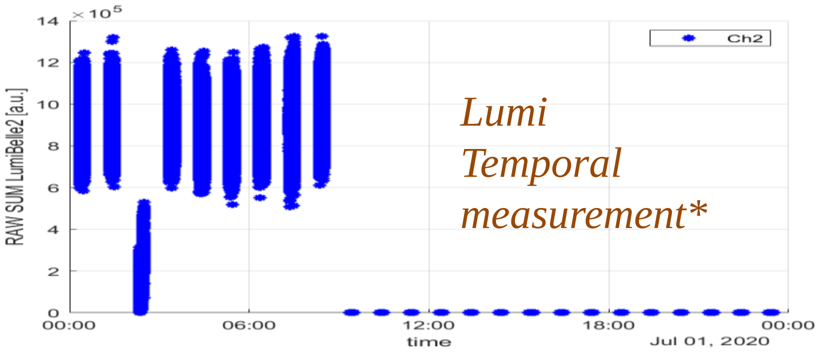


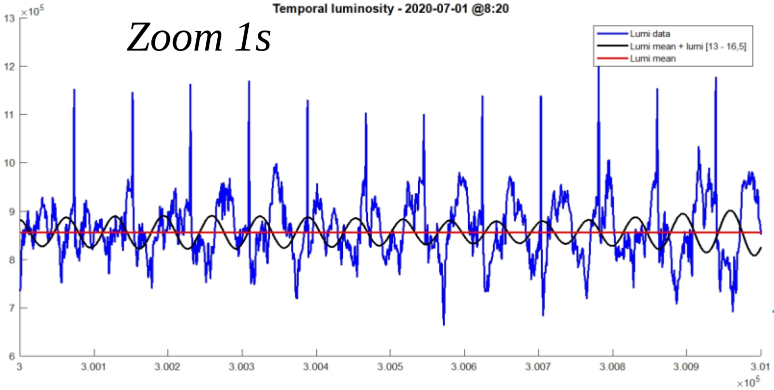
PSD at several locations:
- Local specificities & transfert functions
- Coherence of vibration

SuperKEKB: comparison vibrations – luminosity

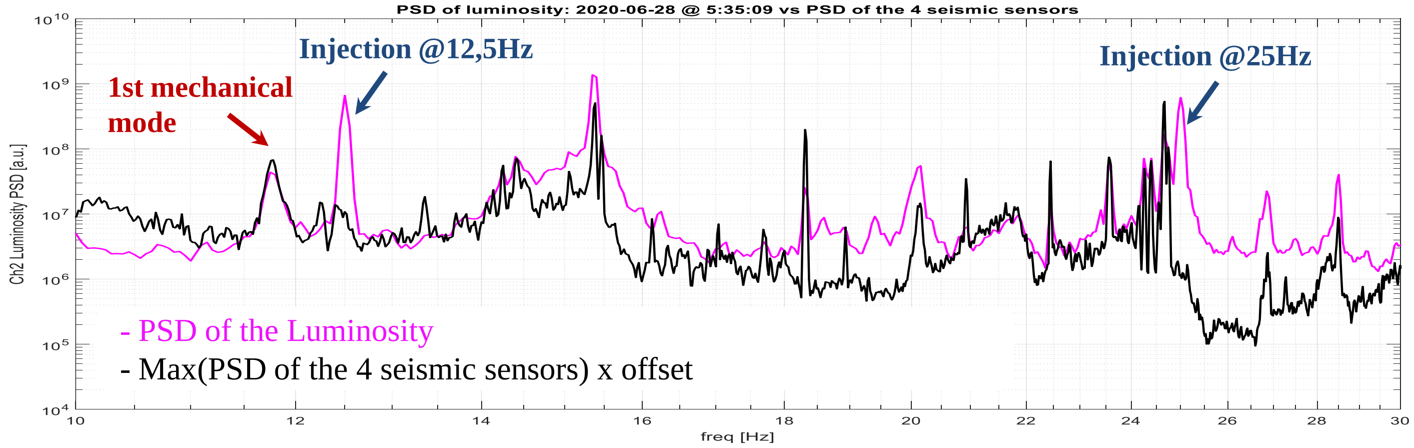
- **Comparison vibrations vs Luminosity monitoring via Bhabha scattering (IJCLab & KEK)**







*: The 4 permanent luminosity measurements are managed by the IJClab team: *C. G. Pang et al., "A fast luminosity monitor based on diamond detectors for the SuperKEKB collider", Nucl. Instrum. Methods Phys. Res., Sect. A, vol. 931, pp. 225–235, Jul. 2019.*



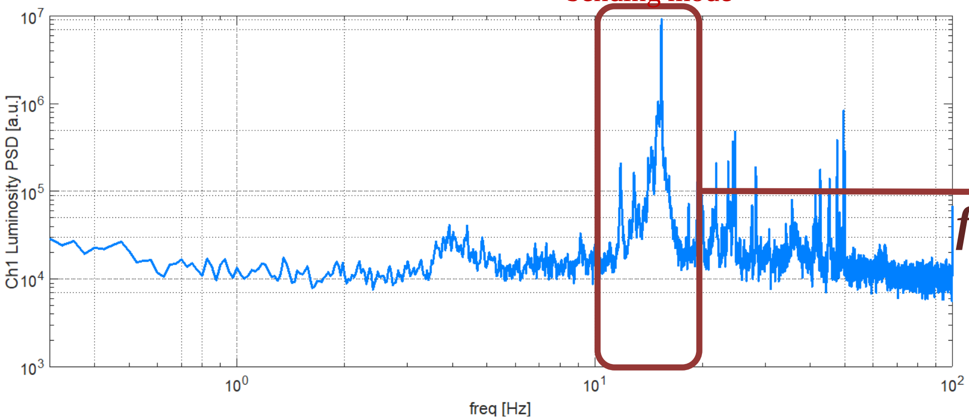
- Except the peaks at 12,5 Hz & 25 Hz dues to the injection, all the luminosity peaks are mainly dues to vibrations amplified by asymmetrical mechanical structures
- **Publication:** ***M. Serluca, G. Balik, L. Brunetti, B. Aimard, A. Dominjon, P. Bambade, S. Wallon, S. Di Carlo, M. Masukawa, S. Uehara,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

➢ **This study highlights the effects of the dynamic of the cryostat on the beam**

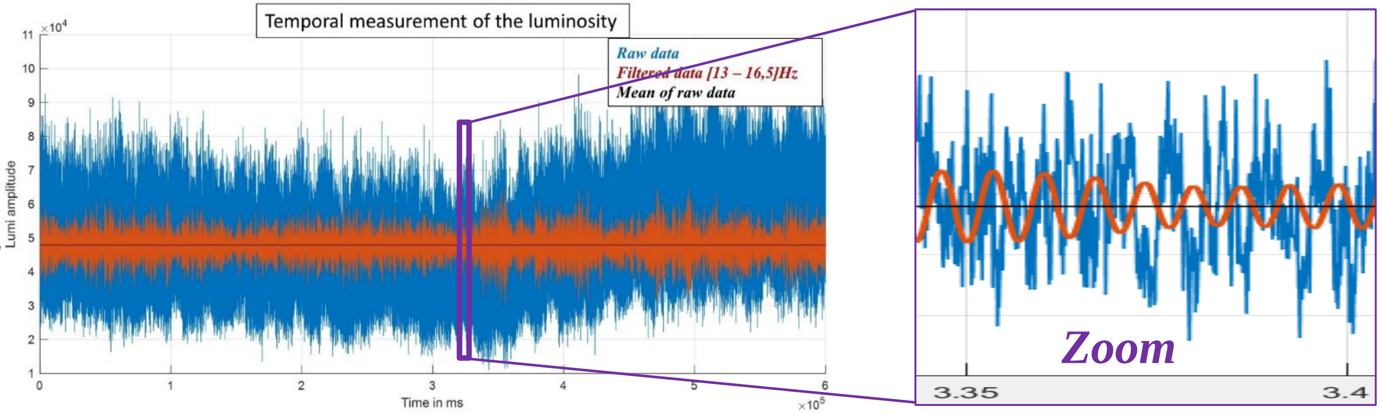
- **Comparison of the measured and theoretical ratio of luminosity disturbance due to the cryostat vibrations**

(vs beam energies, HER or LER, beam size…)

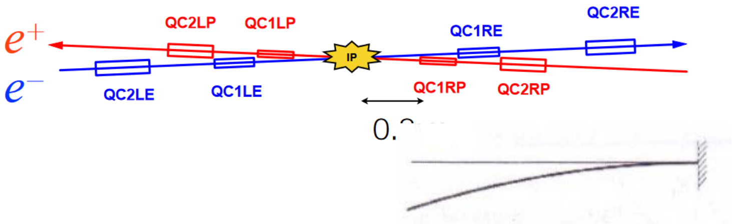
Bandwidth of the cryostat bending mode



filtering



➤ **Measured ratio of luminosity disturbance** due to the cryostat bending mode, [2 : 20]% of amplitude compared to the luminosity average

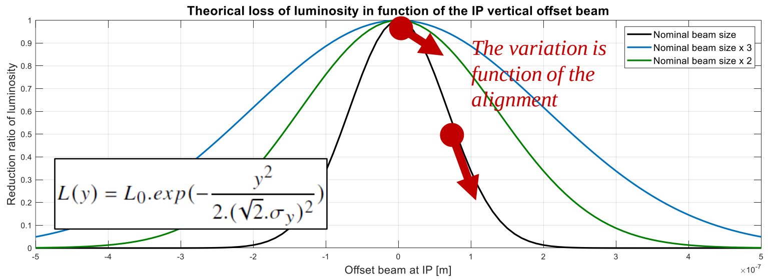


Differential motions between QC1RP, QC1RE, QC2RP QC2RE

Optics simulation (SAD) with magnet movement amplitudes as maximum misalignments

Induced residual offset between the two beams at IP

Simplified calculation

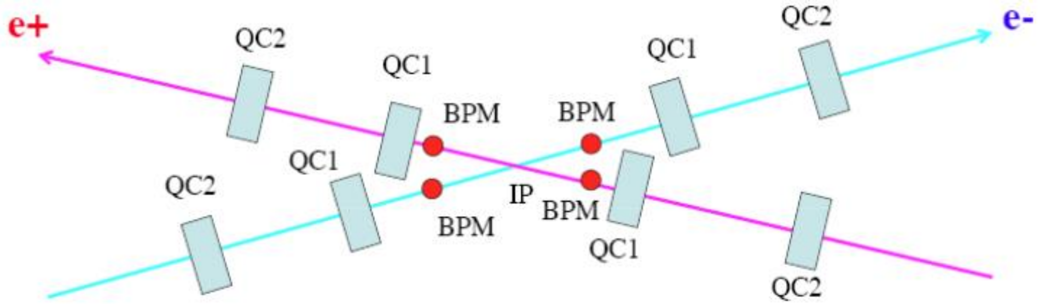


Theoretical ratio of luminosity disturbance

RD23 : Objectives

- RD14 has allowed to highlight the vibration effects on the beam parameters, especially in the luminosity measurements. To evaluate and to quantify more into details these effects, it is necessary to know the position of the beam at the IP with a similar frequency rate.

➤ **Correlation vibration, luminosity and beam position at the IP -> RD23**

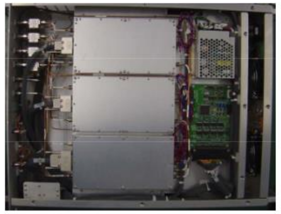


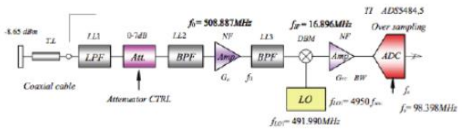
Makoto Tobiyama, *"IP feedback for SuperKEKB"*

- **Need: to have a data logger of the 4 IP BPM (2 axes) at a frequency rate similar to the vibration measurements (250 Hz) or to the luminosity measurements (evaluated at 1 KHz).**

IP BPM acquisition status:

- Down convert 508.8MHz component to IF of 16.9MHz with analog mixer (with level FB).
- Convert IF signal with 16 bit ADCs (99.4MHz=4950 frev).
- Digitally down convert to DC (I & Q ch) through CIC and FIR filters.





Makoto Tobiyama, *"IP feedback for SuperKEKB"*

- **Only very fast measurements**
- **Used for IP BPM**
- **Only evaluation of the differential beam positions is logged: slow control at 1 Hz (can't be used for this analysis)**

RD23 : Development

- **To study the feasibility of an interface between the µTCA (fast acquisition) to a slower acquisition similar to the vibration acquisition (CRio National Instruments at 1 KHz with analog ADC cards for example, DAQ has to be defined) with the SuperKEKB BPM experts**

µTCA performs calculation on each channel of each BPM

Setup of the vibration acquisition on site

- **Benefits to have the knowledge of the beam positions at the IP in real time:**
  - To quantify the vibration influence on the beam parameters which depend to the beam alignment
  - Singular coupling for a leptonic collider (vibration, luminosity and alignment)
  - Could be very valuable for the IP feedback studies
  - Very important for FCC-ee studies

SuperKEKB: Schedule & budget

- **Collaboration:**
  - IJClab, KEK and LAPP
- **Possible milestones**
  - Definition of the setup : Summer 2025
  - Development and first tests on site : end of 2025 (before run)
- **Key issue:**
  - Technical definition sufficient to be inserted into existing system → several key points
- **Next mission on site**
  - To carry out the required setup to have the analysis of the correlation between the beam position (KEK - BPMs), the vibrations level (LAPP - seismic sensors) and the luminosity (KEK&IJCLab - in the transverse and in the vertical directions)
- **Communication**
  - Beyond superKeKB (first interest): Of interest also to the FCC-ee collaboration (→ FCC week)

➢ **LAPP request:**

- ❑ Travels on site (2 persons) ➢ **Total 3 Keuros**

SuperKEKB :
Luminosity frontier e^+e^- collider