R&D Accelerators at LAPP

Vibration studies for FCCee: Status

Work from: G.Balik, L.Brunetti, I.De Bonis, E.Montbarbon, A.Dominjon, M.Marchand, G. Lamanna, F.Poirier (LAPP)

Discussion and exchange with G.Roy and J. Wenninger (CERN) + F.Carra, A.Piccini (CERN)

11/09/2024 - LAPP

Derniere conference: F.Poirier et al, "Update on the vibration work for the FCC-ee", FCC week, San Francisco, June 2024

See also:
L.Brunetti, “LAPP activities: ground motion, vibration models, simulations, SuperKEKB”, FCCIS Nov. 2023
E.Montbarbon, “An FCC-ee vibrations study for its MDI”, FCC Physics workshop, Fev. 2024

FCCIS:'This project has received funding from the European Union's Horizon 2020 research and innovation programme under the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754.'

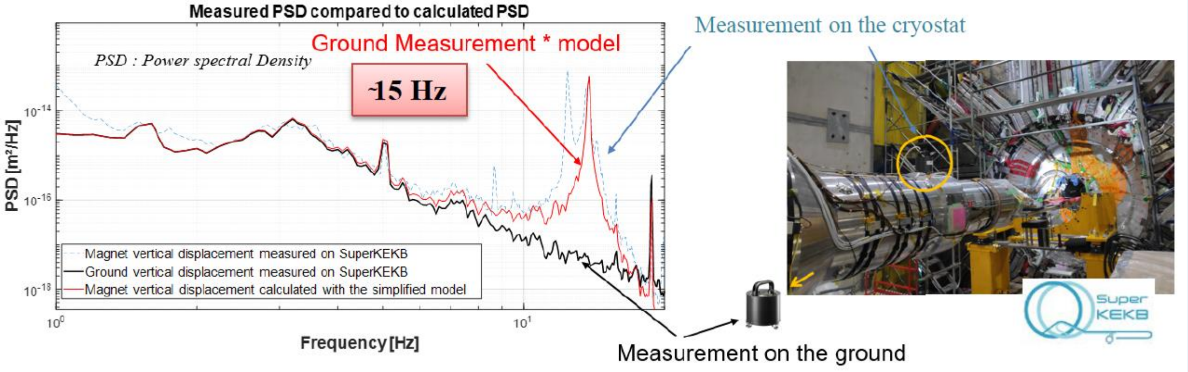
Vibration Measurements at SuperKeKB

L.Brunetti, G.Balik et al.

- LAPP performs, in collaboration with M.Matsusawa et al (KEK)
- Measurements of Power Spectral Density

- Measurements in the MDI region.
- PSD of ground and cryostat
- Modelling of the local magnet (transfert function)

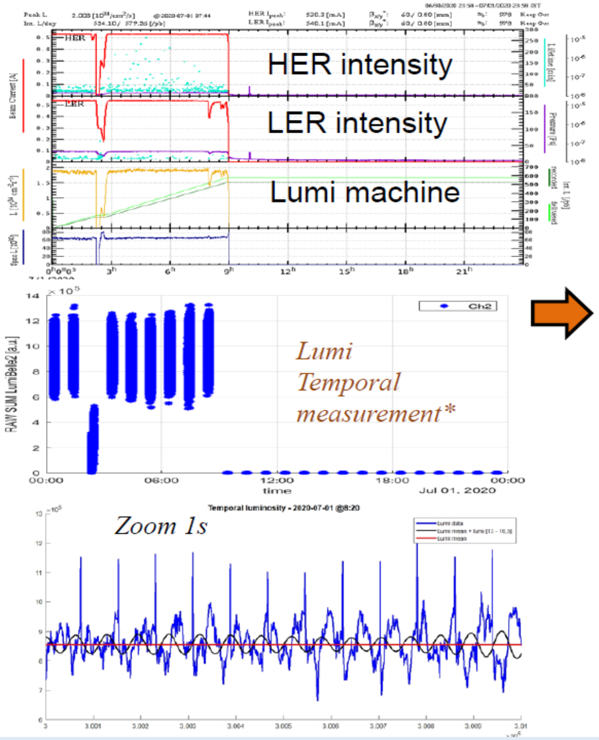
- Campaign of measurements with cryostat out



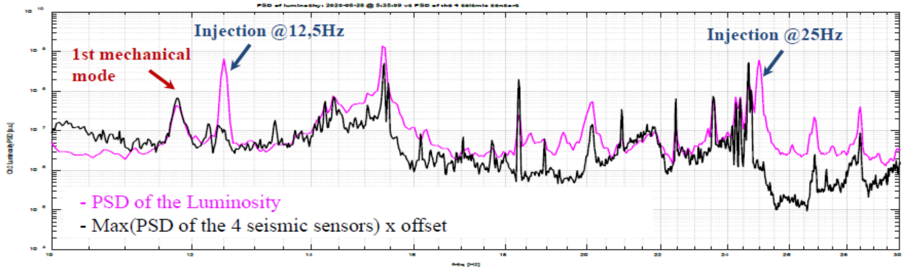
- Permanent vibration measurements (10min every hour)

Track change of vibration & put it in parallel to luminosity meas.

- **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.*



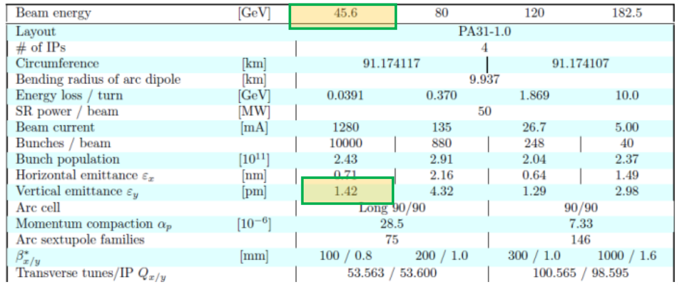
- Except the peaks at 12,5 Hz & 25 Hz dues to the injection, all the luminosity peaks are mainly dues to vibrations amplified by asymmetrical mechanical structures
- **Publication:** ***M. Serluca, G. Balik, L. Brunetti, B. Aimard, A. Dominjon, P. Bambade, S. Wallon, S. Di Carlo, M. Masukawa, S. Uehara,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

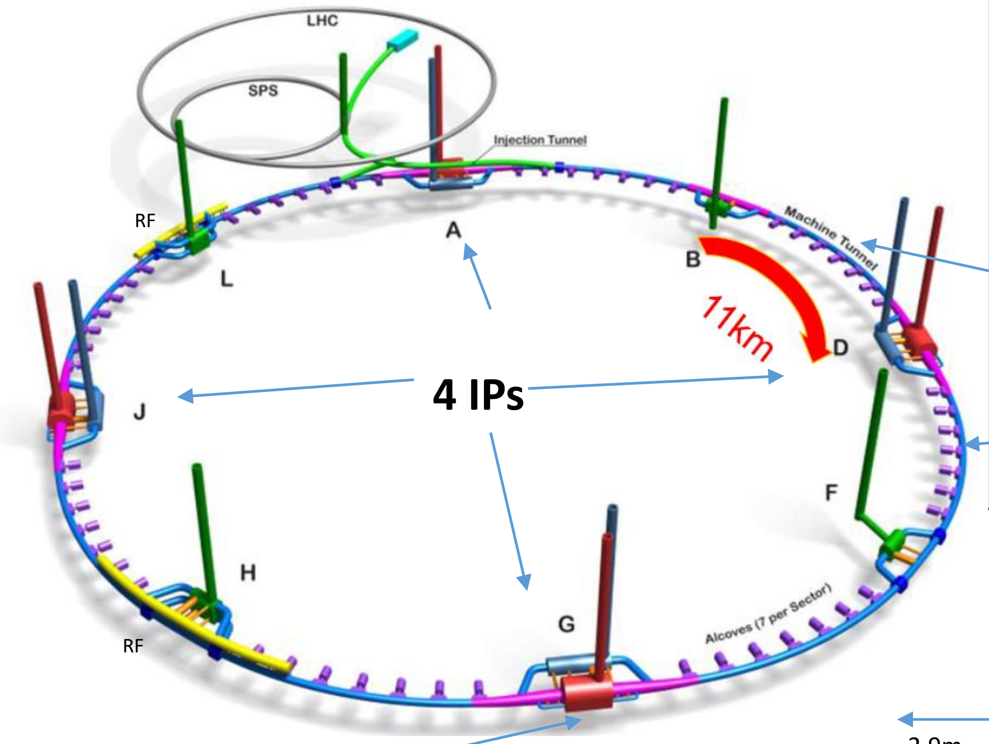
Impact of vibration on luminosity

FCC layout

- 90 km
- Four experiments at interaction points



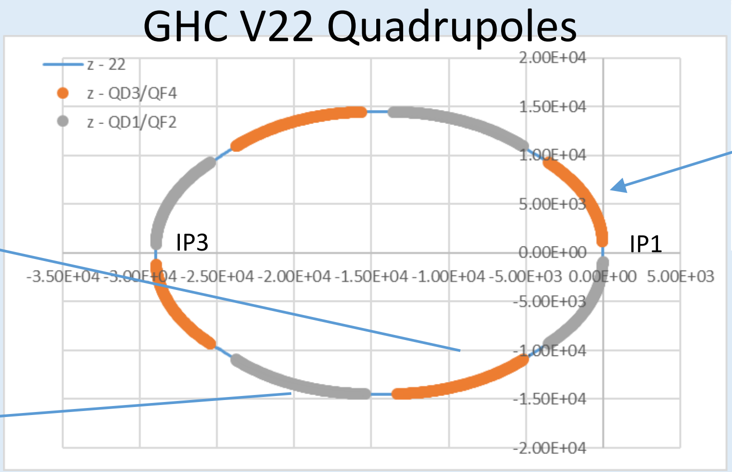
Beam energy	[GeV]	45.6	80	120	182.5
Layout		PA31-1.0			
# of IPs		4			
Circumference	[km]	91.174117		91.174107	
Bending radius of arc dipole	[km]	9.937			
Energy loss / turn	[GeV]	0.0391	0.370	1.869	10.0
SR power / beam	[MW]	50			
Beam current	[mA]	1280	135	26.7	5.00
Bunches / beam		10000	880	248	40
Bunch population	[10^{11}]	2.43	2.91	2.04	2.37
Horizontal emittance ε_x	[nm]	0.71	2.16	0.64	1.49
Vertical emittance ε_y	[pm]	1.42	4.32	1.29	2.98
Arc cell		Long 90/90		90/90	
Momentum compaction α_p	[10^{-6}]	28.5		7.33	
Arc sextupole families		75		146	
$\beta^*_{x/y}$	[mm]	100 / 0.8	200 / 1.0	300 / 1.0	1000 / 1.6
Transverse tunes/IP $Q_{x/y}$		53.563 / 53.600		100.565 / 98.595	

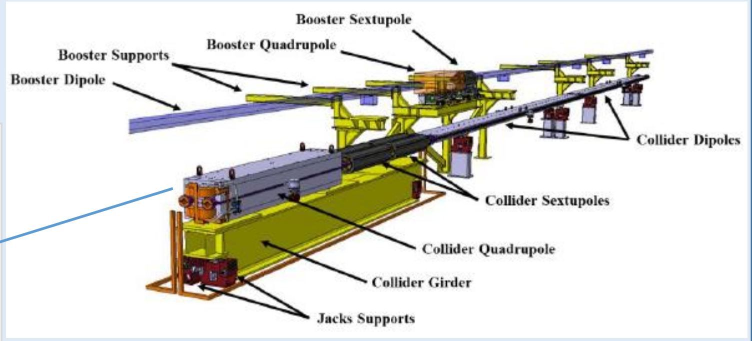


Arc-cell: Lots of repetition

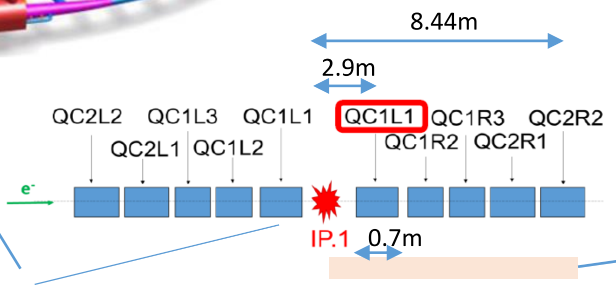
- Quadrupoles in arc-cell
- Several optics are being designed by FCC-ee physics group

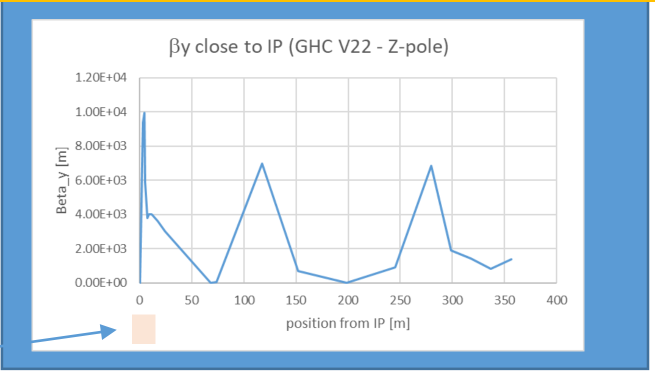
- **Arc half-cell =** the most repeated region of mechanical hardware in the tunnel: *~77 km over 90 km are arc cells, i.e. between 1400 to 2400 repetitions (depending on Optics)*





MDI: Very sensitive area x 4: → beam size modified by factor of 10000





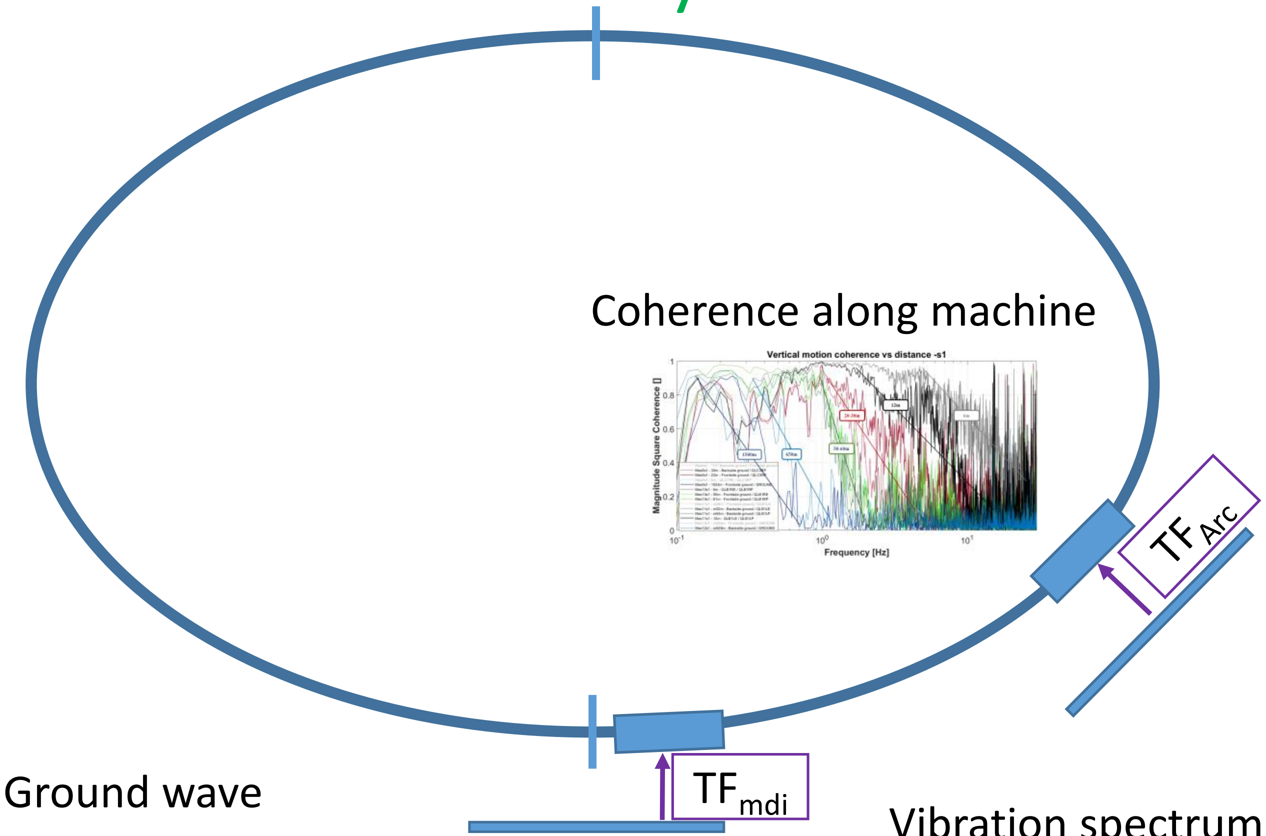
σ^*_y=0.03μm

How do the choices impact the beam and the luminosity from a vibration Point Of View?

Luminosity impacted by

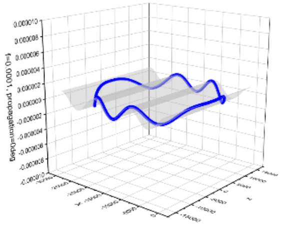
- Local effect close to IP*:
  - beam position, beam size, emittance
  - Relative beam position as 2 beams
  - Luminosity effect from interaction (hour glass effect, beam-beam, beamstrahlung,…)
  - Optics: Magnet amplitude function (β)
  - Beam position readjustment with local feedback
- Displacements during operation:
  - Local effect from magnets (MDI):
    - Quad vibration according to spectrum (cultural activities, environment (ground motion, earthquake), operation impact (eg: valve), local impact (eg: detector movement)
    - Technics to encapsulate the magnets (SC casing, cantilever, support,…)
  - Global effect on the beam in the ring:
    - Similar displacement during operation to local one
    - Impact from MDI Magnets to beam at other IPs
    - Feedback along the ring
    - Misalignments and technic to steer the beam (BBA)
- Dependance from the lattices (=list of magnets at the various energies)

Simplified view on vibrations: key words



Coherence along machine

Ground wave

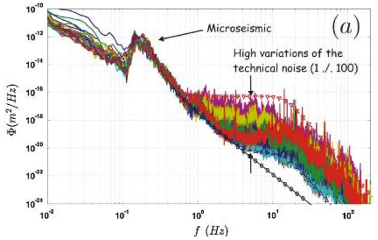


Ground moves: Plane wave + cultural noise + …

Coherent vs non coherent

global vs local

Vibration spectrum



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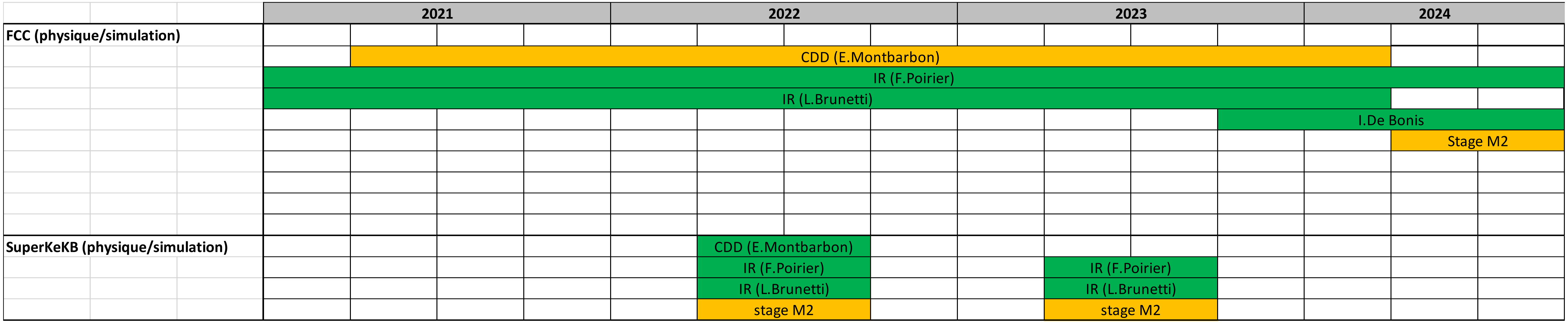
* Not exhaustive as crab crossing and top-up injection specific to FCCee

Personnel involvement on simulation studies



	2021				2022				2023				2024		
FCC (physique/simulation)															
		CDD (E.Montbarbon)	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨			
	IR (F.Poirier)	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	IR (L.Brunetti)	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
												I.De Bonis	🟩	🟩	🟩
														Stage M2	🟨
SuperKeKB (physique/simulation)						CDD (E.Montbarbon)	🟩								
						IR (F.Poirier)	🟩			IR (F.Poirier)	🟩				
						IR (L.Brunetti)	🟩			IR (L.Brunetti)	🟩				
						stage M2	🟨			stage M2	🟨				

Main Involvements on simulations of beam dynamics with magnets movements:

- Specific MDI modelisation :
  - E.Montbarbon, F.Poirier, L.Brunetti, S.Grabon
- Global:
  - MADX: First plane ground wave Simulation:
    - E.Montbarbon, F.Poirier, L.Brunetti
  - Plane ground wave parametric study
    - E.Montbarbon, I. De Bonis, Stagiaire M2, F.Poirier
  - Study on Lattice comparison (MADX)
    - E.Montbarbon, I. De Bonis, Stagiaire M2, F.Poirier
  - Etude comparative MADX/Analytics:
    - E.Montbarbon, I. De Bonis, F.Poirier
- Global and specific:
  - Non correlated model and analytic study F.Poirier
  - Arc-cell: G.Balik, F.Poirier

And F. Chollet Le Flour (MUST)

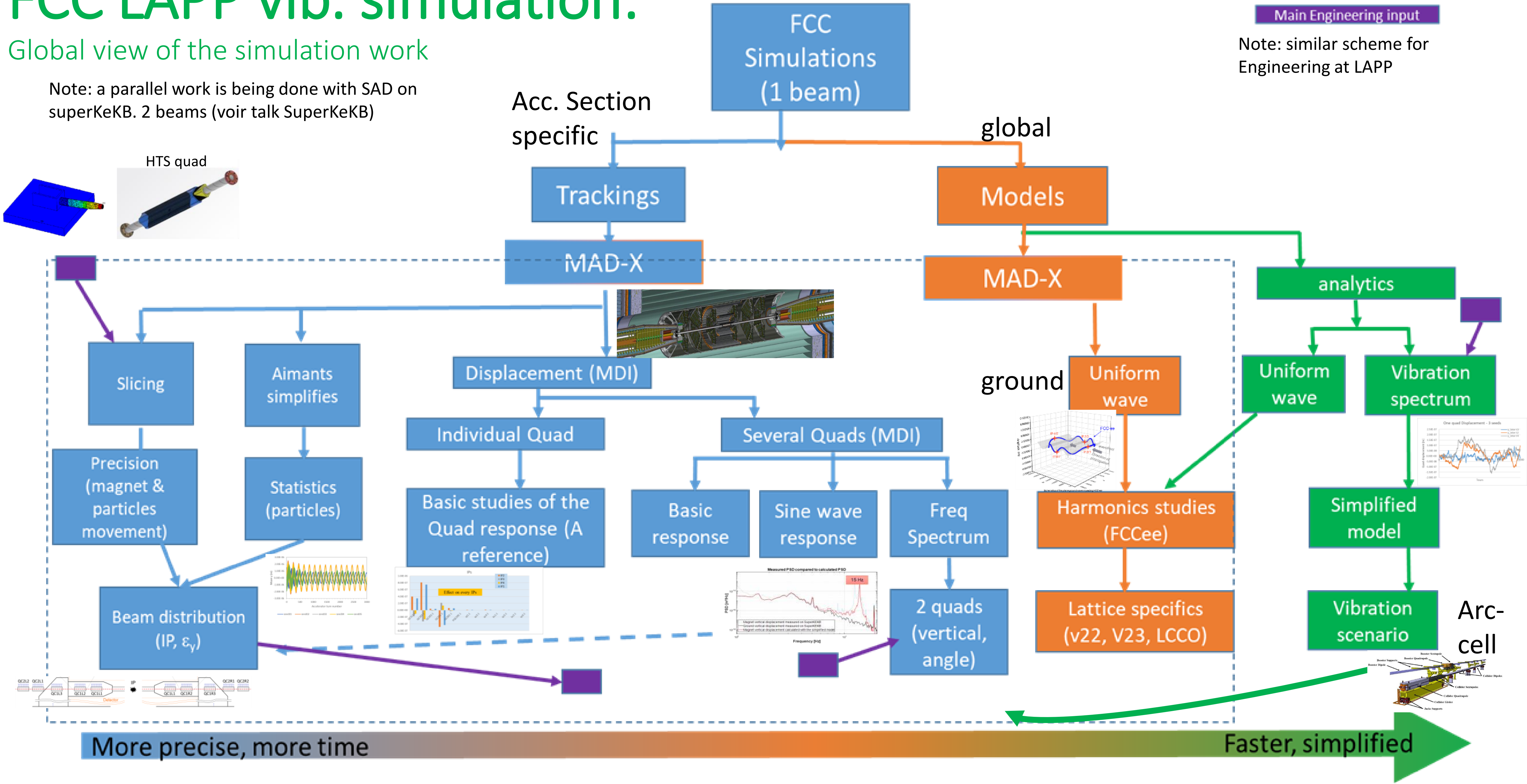
FCC LAPP vib. simulation:

Global view of the simulation work

Note: a parallel work is being done with SAD on superKeKB. 2 beams (voir talk SuperKeKB)

Main Engineering input

Note: similar scheme for Engineering at LAPP



FCC Simulations (1 beam)

Acc. Section specific

global

Trackings

Models

MAD-X

MAD-X

analytics

Slicing

Aimants simplifies

Displacement (MDI)

ground

Uniform wave

Uniform wave

Vibration spectrum

Individual Quad

Several Quads (MDI)

Precision (magnet & particles movement)

Statistics (particles)

Basic studies of the Quad response (A reference)

Basic response

Sine wave response

Freq Spectrum

Harmonics studies (FCCee)

Simplified model

Beam distribution (IP, ε_y)

2 quads (vertical, angle)

Lattice specifics (v22, V23, LCCO)

Vibration scenario

Arc-cell

More precise, more time

Faster, simplified

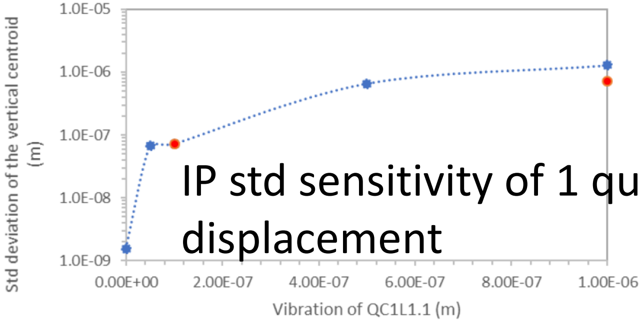
F.Poirier et al, "Update on the vibration work for the FCC-ee", FCC week, San Francisco, June 2024

MDI specific study

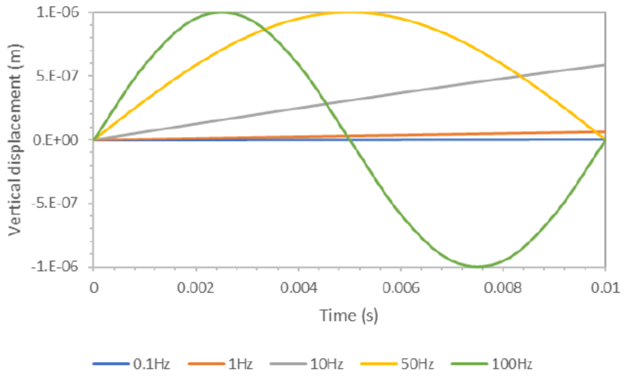
- Initially in 2022, we concentrated the work on MDI and the building up the needs for the temporal dynamics of the modelisation:
- Response function of the quadrupoles in MDI
  - Beam:
    - Working with single particle (tracking)
    - Working with a beam distribution and emittance (multi-particle tracking)
  - Movements over time:
    - Step function
    - Sinus/step
  - Magnets: Impact of detailing (slicing) the magnets
- Very slow simulation with the present modelisation settings:
  - We Developped further automatisation (python or perle based software)
- The study indicated that local and global impact have to be taken into account:
  - If we want to get a global ideal: Need to concentrate on more simplistic models
- MDI region description not mature to take into account engineering (transfer function)

① Case 1: static vertical displacement

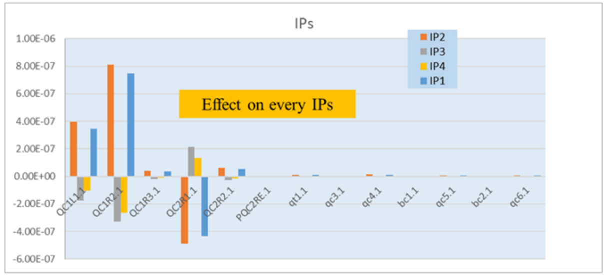
② Case 2: « bump » like displacement



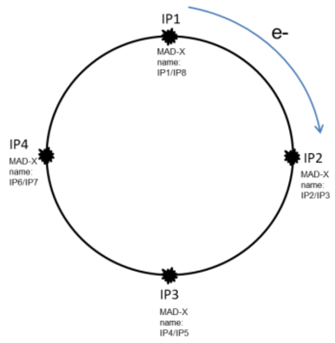
IP std sensitivity of 1 qua displacement

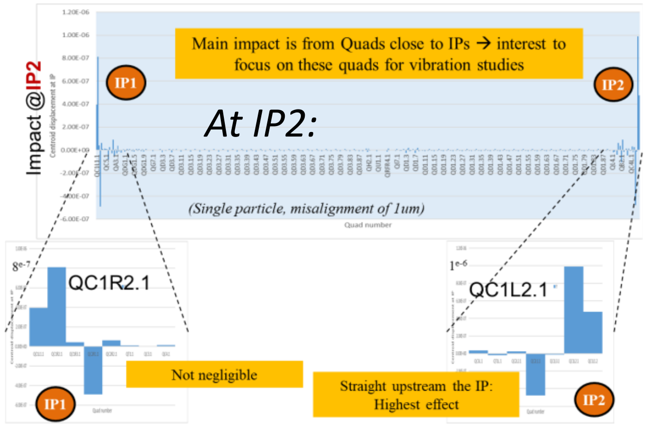


At the other IPs:



Lattice: GHC v22





Quads have a local impact and a distant impact

- E.Montbarbon et al, "First studies of final focus quadrupoles vibrations of the z lattice of FCC-ee", IPAC23, MOPL077, Venice, May 2023

Technics also used for SuperKeKB

Plane Ground wave Studies: a corrugated model (E.Montbarbon et al)

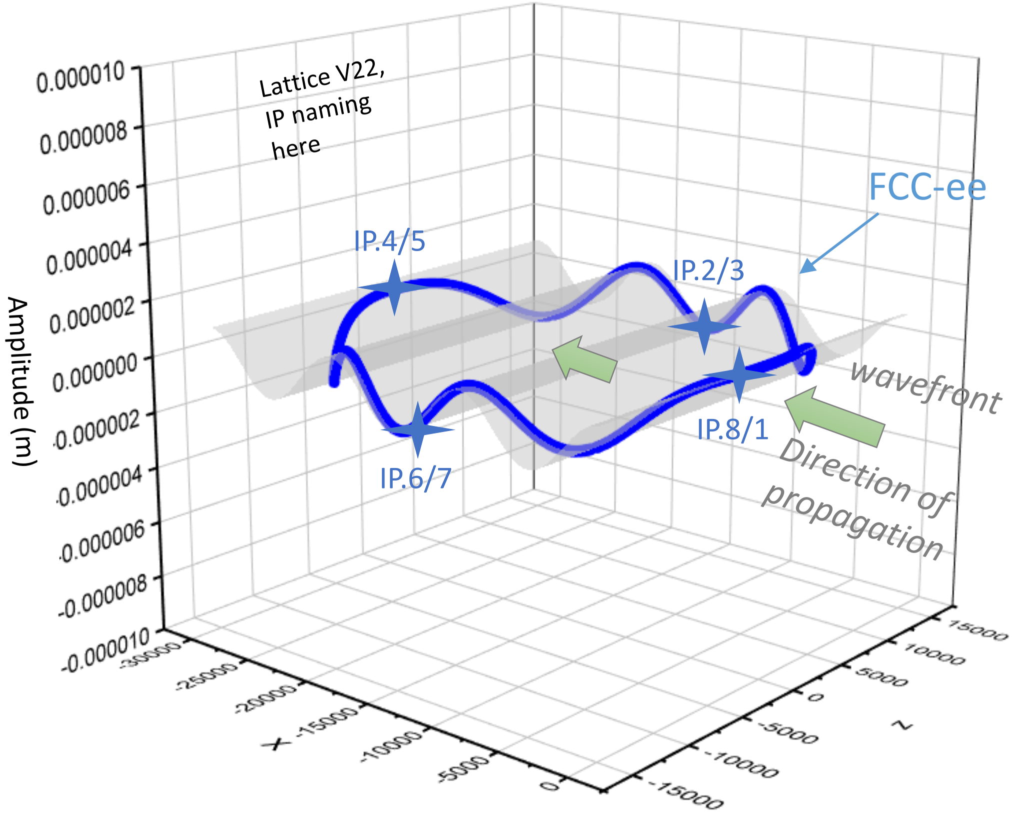
- Discussion and request from F. Zimmerman lead to this work
- Aims of the study:
  - Compute the response of a potential spatial coherence on the performances of FCC-ee
  - Compare simulation results obtained to the ones of other machines (e.g. LEP, LHC)
- Definition:
  - The coherence length is the maximum distance of two points oscillating on a same ground wave.
- In our study:
  - Vertical misalignement of beam elements according a plane sinusoidal wave
  - Photography of the wave impact on the accelerator

Computer tools:

- Optics simulations carried out with MAD-X (5.09.00)
- Post-treatment held with Python, thanks to cpymad module (3.6.9)

Optics-related matters:

- Z lattice (GHC V22), with 4 IPs
- Start of the sequence at IP.1



Schematics of the plane ground wave impacting FCC-ee

Study performed with MAD-X, with the TWISS module & analytical model

- Vertical misalignment attributed to each quadrupole *j* along the accelerator ring, in terms of **harmonic number**, to be fully independent from the wave velocity:

$$\varepsilon(j) = A\sin\left(\frac{2\pi h}{C}(X(j)\times\cos(\alpha) - Z(j)\times\sin(\alpha)) + \varphi\right)$$

A: amplitude of oscillation

h: harmonic number $h = \frac{Cf}{v_{wave}}$

C: circumference of FCC-ee

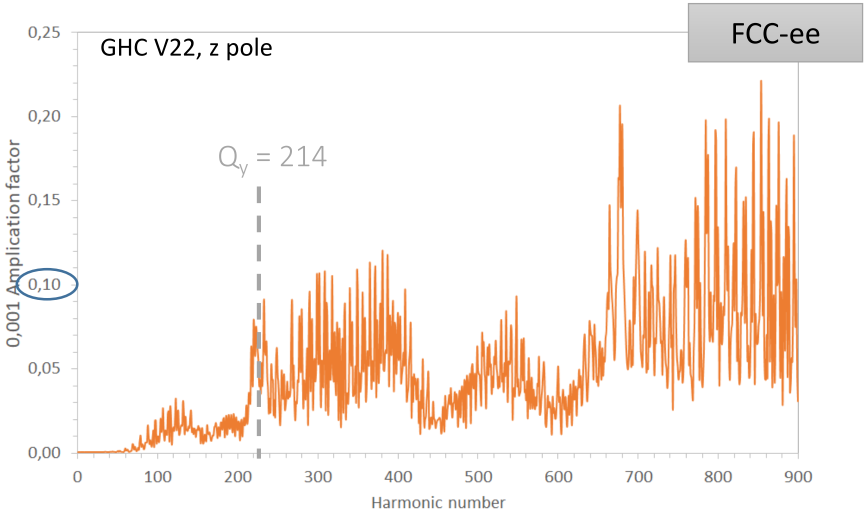
α: wavefront tilt angle

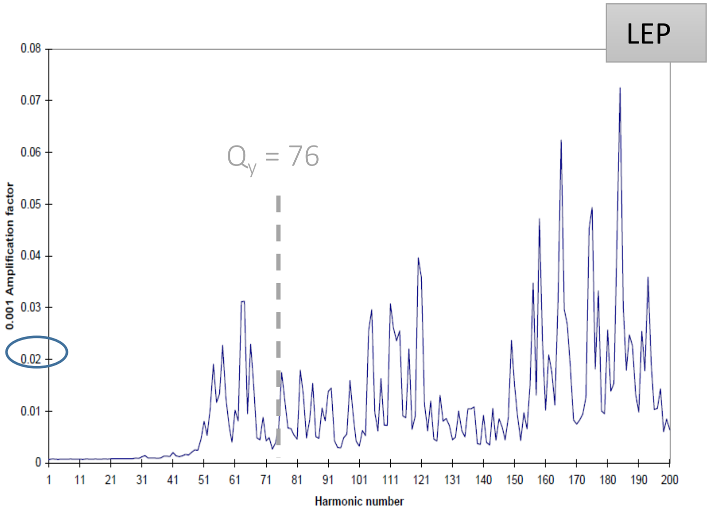
φ: phasing advance

Parameters of the model

FCC-ee ycorms results: comparison with LEP

- Variables evaluated by MAD-X:
    - yco: vertical position y of the orbit, referred to the ideal orbit, given by the TWISS table (m)
    - ycorms : vertical RMS value of the vertical closed orbit offset over the whole ring, written in the SUMM table (m)
- Calculation of the amplification factor to normalize from the maximum amplitude:
- To refer to literature, this factor is: $\frac{closed\ orbit\ offset}{maximum\ amplitude\ of\ the\ wave} \times C$ C can be 1 or another value (for comparison with previous work)





$$h = \frac{Cf}{v_{wave}}$$

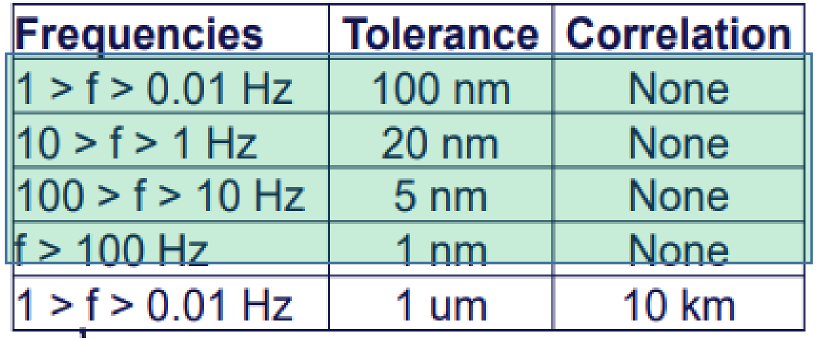
- Similar shape of the vertical RMS value spectra for FCC-ee and LEP
- However, more sensitivity in the case of FCC-ee: at h = Q_y: 4 times bigger amplitude for FCC-ee
- It has to be investigated the induced effects on the machine with further analysis:
    - Part of the work was continued in 2024 by Master student for parametrical studies and included use of data center (MUST)

This work needs to be finalised for publication:

- Systematics on parameters (angle/phase)
- Multiple optics (GHC/LLCO, multiple energy)

Introduction of an analytical approach

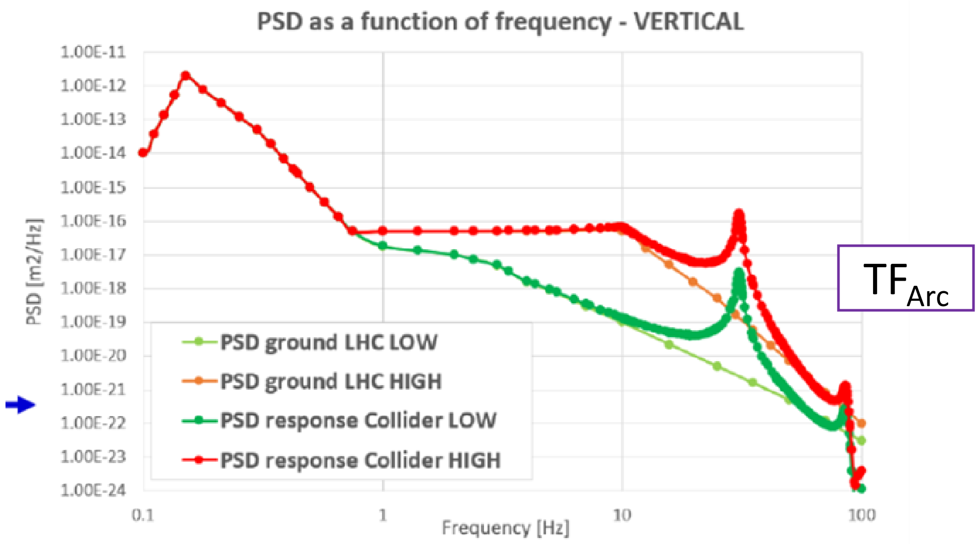
- To be able to manage the global simulation quickly:
  - Use of an analytic model, where each magnets is moved and applicable to the large repetition of the Arc-cell sections
  - Use a more realistic (than plane wave) excitation model: cultural noise
    - based first on the suggestion from T.Raubenheimer (Deputy machine director), of which tolerances are loosely based on the LHC vibration level



Frequencies	Tolerance	Correlation
1 > f > 0.01 Hz	100 nm	None
10 > f > 1 Hz	20 nm	None
100 > f > 10 Hz	5 nm	None
f > 100 Hz	1 nm	None
1 > f > 0.01 Hz	1 um	10 km

Suggestion from T.Raubenheimer [1]

Note= same as plane ground wave h=9

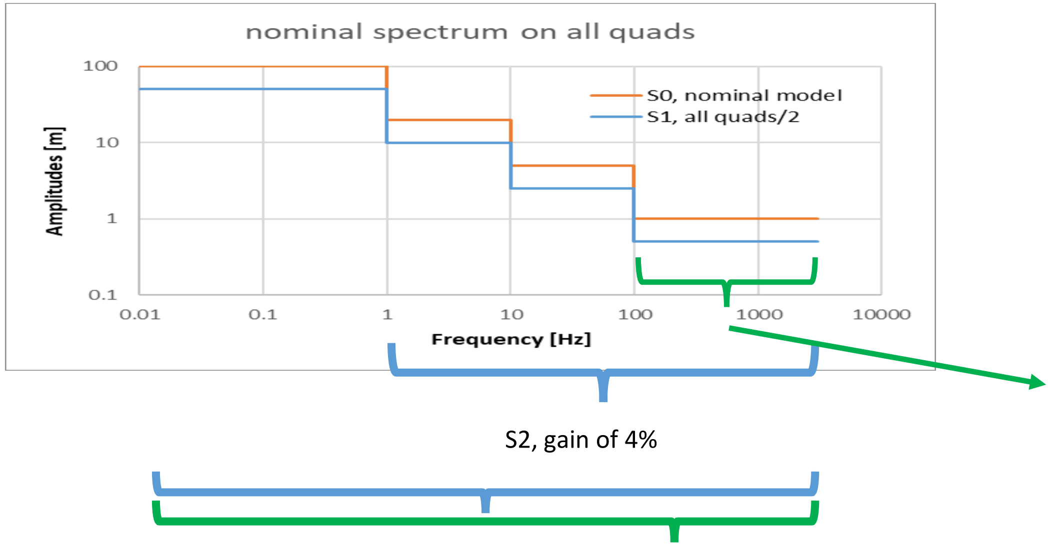


Introduction of scenarios

- At IP, what is the beam displacement (at the 3000th turn)?
- Study with the modification of amplitudes within the model:

Still a worst case but scenarios (not real) are included: testing out a simplified computing chain and showing how much data we might need

Scenario name	Type	Std (centroid) [m]	Gain wrt S0
S0 —	Nominal	7.34 10-8	
S1 —	All quads move by a factor 2 less	3.67 10-8	50%
S2 —	All quads move by a factor 2 less in the range 1Hz to 3000Hz	7.04 10-8	4%
S3 —	MDI quads move by a factor 2 less in the range 100 Hz to 3000Hz	7.33 10-8	0.06%
S4 —	MDI quads move by a factor 2 less – all range of frequency	3.86 10-8	47%



S3, MDI, gain of 0.06%

S2, gain of 4%

S1, gain of 50%

S4 (MDI), gain of 47%

For ref, beam size at 45.6 GeV with ε_y=1.42pm = 33nm (with βy=7.99e-4m from GHC v22)

A few words on vibration simulation

- A simplified approach for the simulation of the vibration:
  - Analytical accelerator model:
    - Fast (1.18 billions data for the spectrum: runs for 4h)
    - Ok for first scenario studies and some comparison studies
    - The model has its limit and limited parameters check (Here centroid, can be extended though)
  - A first vibration model spectrum that needs to be “played with” to check various vibration scenario (spectrum and amplitude)
    - It is versatile and can relatively quickly produce some results
      - point out to the needs and what to do (in terms of simulation)
      - But very naïve approach here (better approach would start-up from a modeled/real PSD and translate that in a temporal displacement)
  - Focus on
    - MDI: tightening there, will help to be less sensitive to vibrations
    - ARCs: some differences between the lattices → Much more detailed work required*. (work with F.Carra group)
- Though this will need:
  - A more refined/thorough and in-depth scrutiny for the accelerator and vibration model:
    - MAD-X (and other codes. We might explore Xsuite if adapted?)
      - Tracking (not yet)? Quadrupole Slicing (not yet) useful when mechanics come into play?
    - Modeled and more real spectrum will be included
      - A suggestion with the ARC-Cell group is to take in PSD for LHC (low and high amplitude model)
      - Use of more real model and/or measurements
        - LAPP is discussing with experts from local branch of earth science Institute
        - Discussed also with the SLAC/Lucretia team on their Algorithm (G.White thanks to T.Raubenheimer)
      - Integration of the spectrum in a MAD-X study?
  - Simulation with MAD-X does take a lot of time so we need to point to what could be done (here is the need for the analytics)
  - The use of a data center: MUST**, at University of Haute Savoie, is being assessed for MAD-X simulation.: last week work has started and been used for further studies of plane ground wave with various lattices

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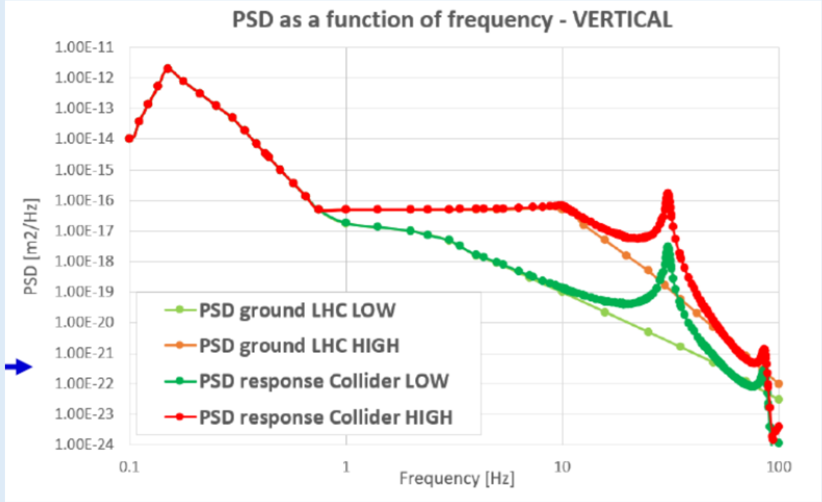
*Will the amplitude & dispersion of an uncorrelated High Freq over large amount of quadripoles plays a substantial role at IP: to be checked in simulation!

**MUST: Mésocentre de calcul et de stockage de l'Université Savoie Mont Blanc

Where are we?

- Towards more realistic scenario (infancy):
  - Integration of the model of the frequency spectrum from LHC

Application to the Arc-Cell



Present work -→ time series are being tested with this spectrum

Where do we want to go?

- Evaluation of the luminosity impact from vibration:
  - More realistic ground displacement
  - Response from magnets (quadrupoles)
  - More realistic beam (beam size, emittance evolution)
  - More realistic accelerator operation mode: From ideal to a disaligned machine with BBA technics already in place
  - Take into account:
    - feedback systems (real but also participate in their crude definition): collaboration with the teams
    - 2 beams:
      - Displacement of beams (beams size,…)
      - Interactions at the IP
- Interaction with the FCC community:
  - Optics:
    - What are the various accelerator sections bringing?
      - MDI, Arc-cell
    - Are there some optics more sensitive to vibration?
    - How sensitive are we to events? (earthquake)
  - Engineering on accelerator sections:
    - MDI, Arc-Cell
    - Design and response function of each section

Road towards determination of luminosity impact from beam vib.

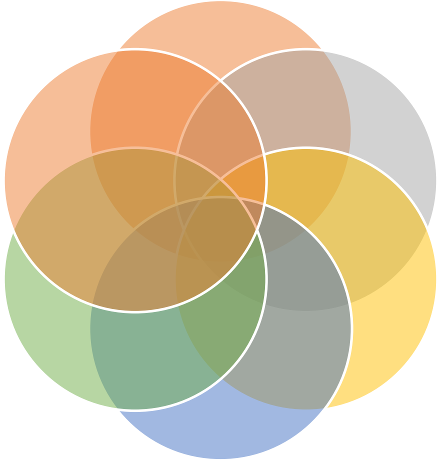
- Deliverable (FCC):
  - Papers (IPAC May 2025) on uniform wave (MAD-X + Analytics) – depending on PostDoc
  - Papers within 1.5 year which include a first approximate full chain with “incoherent” + Arc cell
    - Based on the first findings here + extension with one specific codes (MADX?)
  - Co author in the Feasability report (section not defined today)
- Personnel needs:
  - Present Involvement :
    - IR (F.Poirier) + occasional (LB + GB)
  - 1 post-doc (2025-2026):
    - working on MADX/Xsuite, inclusion of the spectrum, application to section (finalization plane ground wave + Arc-Cell in priority)
    - Participation in SuperKeKB simulation
  - 1 PhD:
    - Support FCC beam dynamics closer to IP and MDI. Take into account feedback system, work at SuperKeKB (IPBPM + feedback + vibration) → Include Machine Learning work for data analysis
  - Need to stabilised the team if we want to make a substantial input
  - 1 senior physicist:
    - Management of the team, increase/sustain national and international collaboration
    - Increase the dynamics on the realistic vibration simulation (long term work)
- Besoin de consolidation :
  - Implication sur la physique des vibrations sur applications
  - Implication sur le global, Arc-cell et le MDI (solidification workpackage)

- FIN!

- Additional slide:
  - Extensive study on MADX: why do we concentrate on Quadrupoles?
  - Analytical model
  - Comparison analytical/MADx on plane ground wave
  - Gain of stability if quadrupoles in MDI moves less
    → A first reason to focus on MDI
  - Description of the Arc-cell for our simulation

More exhaustive studies (would need much more slides!)

E.Montbarbon + I.Debonis + F.Poirier + J.Tamarzit (MSc Student) et al.



1: All beam elements or only quadrupoles

2: Only quadrupoles when sextupoles are on or off

3: Both quadrupoles and sextupoles or quadrupoles only

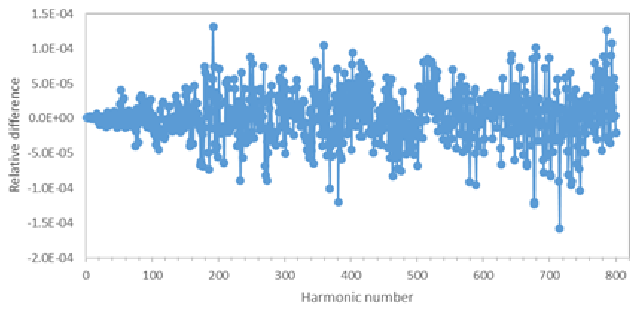
4: Only dipoles

5: Only IR quadrupoles

6: All quadrupoles except IR quadrupoles

1: Misalignment of all beam elements or only quadrupoles relative to the wave:

Relative difference @ IP.8 = $\frac{yco_Q - yco_{SQ}}{yco_Q}$



- *1: Misalignment of all beam elements or only quadrupoles relative to the wave:*
  - Maximum relative difference: 0.016%
  - The impact on the closed orbit is dominated by quadrupoles misalignments: no peculiar characteristic added by other beam elements
  - Consistent with results obtained for the comparison between the analytical model and MAD-X simulations
- *2: Misalignment of only quadrupoles when sextupoles are on/off*
  - Maximum relative difference: 0,3%
  - Peak at h = 677 observed
  - No considerable impact on yco given by the sextupoles
- *3: Misalignment of both quadrupoles and sextupoles*
  - Maximum relative difference: 0,015%
- *4: Only dipoles affected by the plane wave:*
  - Maximum yco = 3 nm
  - No relevant impact on dipoles misalignment because of the plane ground wave
- *5: Only IR quadrupoles affected by the plane ground wave:*
  - Periodic structure of yco at IP.8 relative to h

More ongoing: scan of plane wave parameters + lattices

Definitions of the analytical model

- We put up an analytical model (with rather standard definition) to explore rapidly various parameters (from plane wave to vibration)
- The sequence used to solve analytically the Plane Ground Waves study **only** considers **quadrupoles**.
- Each misalignment of quadrupole ε generates a dipole kick δ:
  - $\delta = kl\varepsilon$

k_1: normal quadrupole coefficient (m^{-2})
l: effective length of the quadrupole (m)

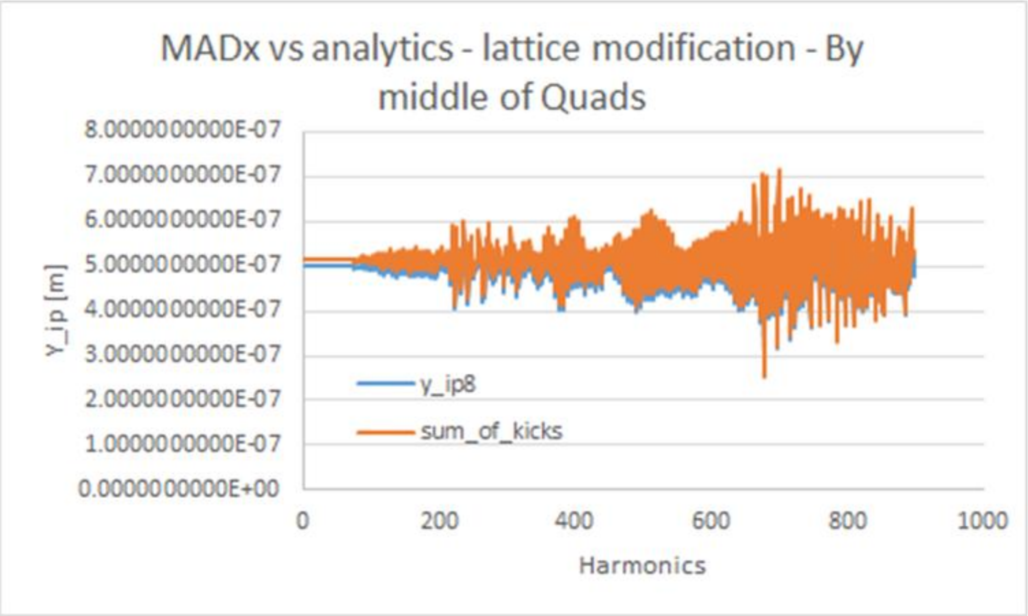
- The ith dipole kick creates a perturbation y_i of the closed orbit:

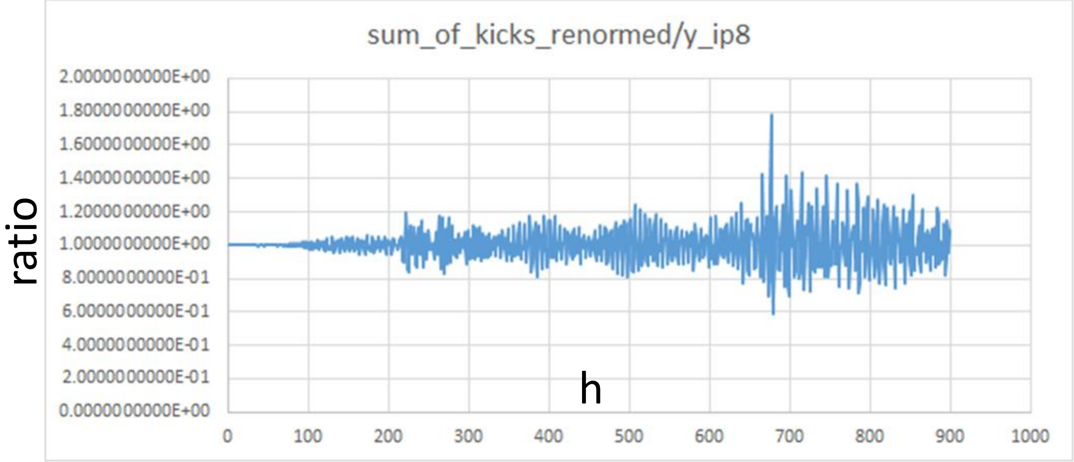
$$y_i = -\sum_{j=0}^{n} \frac{\sqrt{\beta_i \beta_j}}{2sin(\pi Q)} cos(\pi Q - 2\pi\Delta\mu_{ij}) \times \delta_j$$

Comparison between MAD-X and the analytical model

- ***We have access to yco at the IP relative to h***

- The two methods are **very consistent**.
- The first oscillation at h=214 corresponds to the FCC-ee vertical tune (GHC v22).
- The amplitude at IP is significant regarding the amplitude of the wave (0,5 um).
- There is a small offset:
  - At h = 1: 2,8 % of difference
  - Offset not constant relative to h
  - Due to the fact that the β functions defined at the centre of each quadrupole are higher than defined at the exit





Yco: vertical position y of the orbit

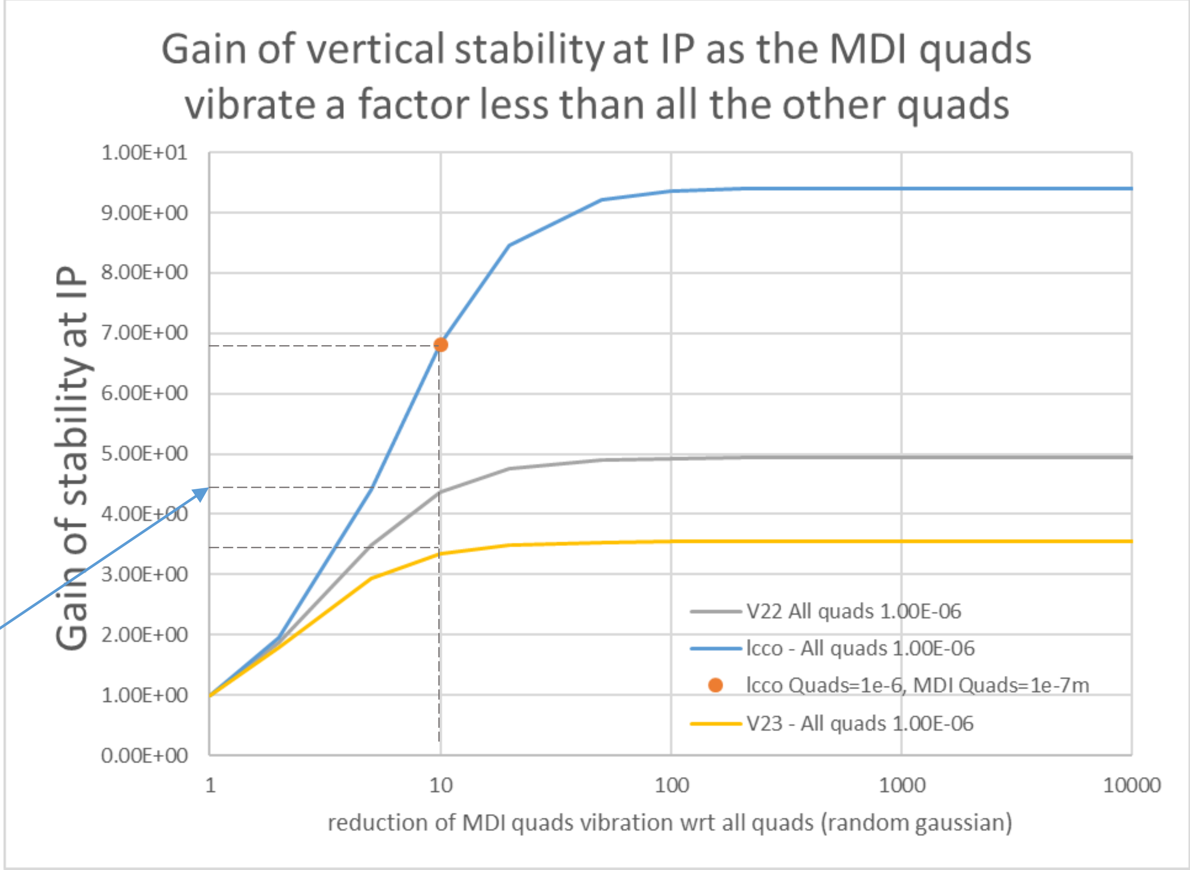
To go beyond the Plane Ground Wave model: random vibration

Worst ideal case scenario

- No plane wave in this case!
- Analytical method:
- “Vibrations” model:
  - Random vertical displacements of the quadrupoles, following a gaussian distribution
  - 1000 seeds
- **Focus on the MDI region:**
  - 5 quadrupoles for GHC V22/V23
  - 4 quadrupoles for lCCO

$$Gain = \frac{\sigma_{y_{0\_mdi}}}{\sigma_{y_{0\_all}}}$$

$\sigma_{y_{0\_mdi}}$	Corresponds to the std of the vertical position of the beam at IP8 when the IR quads vibrate less (by a reduction factor)
$\sigma_{y_{0\_all}}$	Corresponds to the std of the vertical position of the beam at IP8 when the vibration is the same for all quads (here taken as the reference)



If the “vibrations” in the IR region are reduced by a factor 10 compared to the rest of FCC-ee, the vertical closed orbit is ≈ **5 times less mouving (& closer** to the nominal orbit).

In the case of QC1 vibrations (3 quadrupoles), the maximum gain is equal to 2.

lattice	Gain if factor=10
V22	4.37
V23	3.35
lcco	6.81

Points at an effort of lowering vibration closest to IP = gain

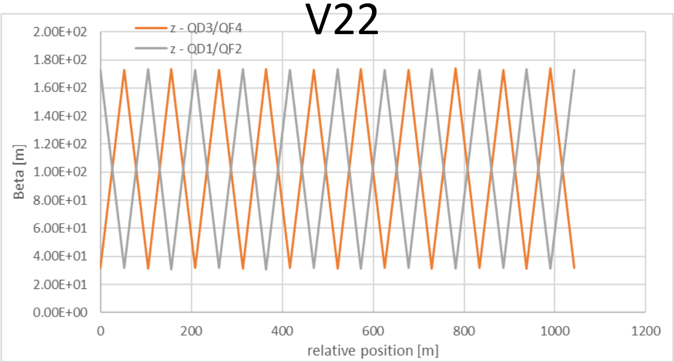
Study could be extended further away from IP

Arc-cell (AC) Quadrupoles random distribution impact at IP

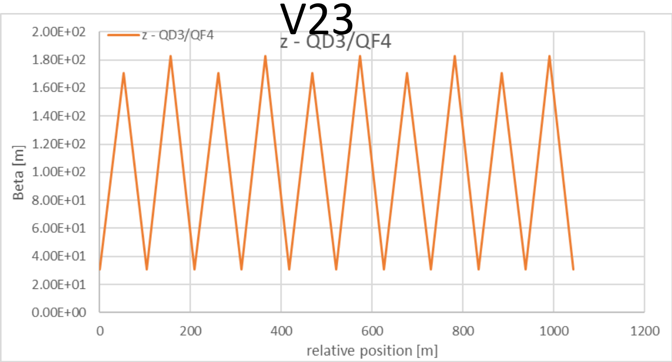
- Beta function in the arcs as seen by the analytical code for each lattice:

Worst ideal case scenario

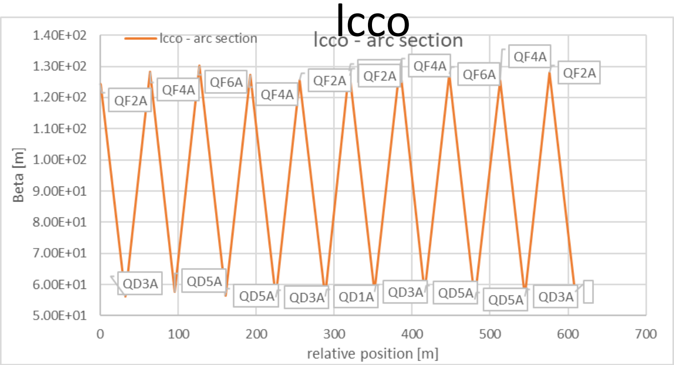
V22



V23



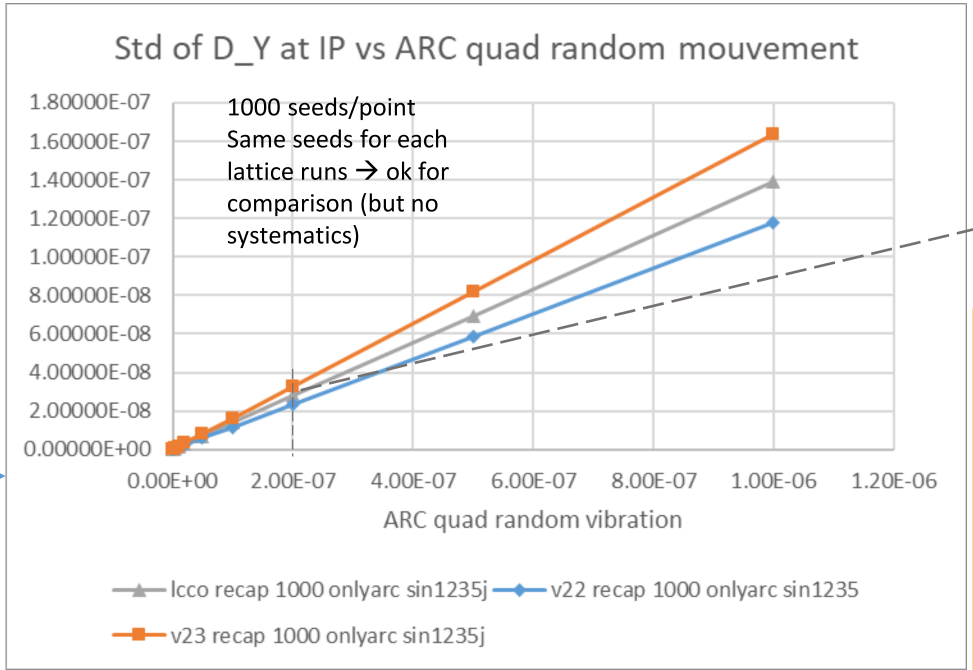
Icco



lattice	v22	v23	Icco
FCC circ [m]	91174.1174	90658.7453	90658.6089
Q_y tune [m]	2.14E+02	2.22E+02	1.74E+02
nb of quads	1856	1876	2960
QD1*	360	360	448
QF2*	360	360	432
QD3*	348	348	432
QF4*	352	352	432
QD5A	0	0	432
QF6A	0	0	216
% arc beta coverage (analyt	18.1613795	15.4965878	32.1978599
beta max (arc QD3/QF4)	174.50465	191.067471	130.280799
beta min (arc QD3/QF4)	31.1029765	29.0008244	55.6523112

Some relevant characteristics

Response at IP to random gaussian (RG) displacement of quads in arcs



1000 seeds/point
Same seeds for each lattice runs → ok for comparison (but no systematics)

i.e. if the arc quads only are moved by a RG of 200nm, the sigma of the centroid is:

ARC quads by RG=200 nm		
lattice	IP centroid sigma [m]	sigma wrt V22
v22	2.35586E-08	1
v23	3.2756E-08	1.39
Icco	2.77775E-08	1.18

- Not a big difference between the lattices
- Least sensitive → V22
- Sensitivity is global
- Where does come from the difference?

IN2P3 FCC-NPC: in a nutshell

FCC - Next Particle Collider

Institut national de
physique nucléaire et
de physique des particules

Coordinator:
A. FAUS-GOLFE
16.15 FTE/y

2024

WP1 Parameters
0.1 FTE/y

A. FAUS-GOLFE 0.1
L. BRUNETTI
P. BAMBADE
I.CHAIKOVSKA
A.MARTENS
B.MERCIER
Y. GOMEZ-MARTINEZ

ILC-ATF3
CLIC
SuperKEKB
FCCee
HL-LHC

MP-IN2P3

WP2 Nanobeams
3.2 FTE/y

A. FAUS-GOLFE 0.2
G. SIMON (PhD) 1
Z. ZHANG (PhD) 1
R. SOOS (PhD) 1

ILC-ATF3
CLIC
FCCee

MP-IN2P3
FJPPL
FCPPL
EAJADE
MoU FCC

WP3 Stabilisation
3. 6 FTE/y

L. BRUNETTI 0.8
G. BALIK 0.3
NEW ENGINEER 1
A. DOMINJON 0.1
E. MONTBARBON 1
I. de BONIS 0.1
F. POIRIER 0.3

ILC-ATF3
SuperKEKb
FCCee

MP-IN2P3
FJPPL
FCC-IS
EAJADE
MoU FCC

WP4 Luminosity
1.5 FTE/y

P. BAMBADE 0.2
S. WALLON 0.3
M. LI (PhD) 1

SuperKEKB

MP-IN2P3
EAJADE

WP5 Positrons
3.5 FTE/y

I. CHAIKOVSKA 0.6
S. WALLON 0.2
V. KUBYTSKY 0.1
H. GULER 0.1
V. MYTROCHENKO 0.5
F. ALHARTHI (PhD) 1
Y. WANG 1

FCCee
SuoerKEKB
ILC
Muon colliders

MP-IN2P3
IFAST
ANR INSPIRER
EAJADE
MoU FCC

WP6 Polarimetry
0.9 FTE/y

A. MARTENS 0.2
F. ZOMER 0.1
D. NUTARELLI 0.2
Y. PEINAUD 0.1
F. MAWAS (PhD) 0.3

ILC
FCCee
SuperKEkB

MP-IN2P3
FJPPL
EAJADE
MoU FCC *

WP7 Vacuum
1.9 FTE/y

B. MERCIER 0.4
G. SATTONNAY 0.3
E. MISTRETTA 0.1
S. BILGEN 0.6
J. YEMANE 0.2
T. GERARDIN 0.1
NEW POSTDOC 0.2

FCCee
HL-LHC

MP-IN2P3
MoU FCC
MoU HL-LHC*

WP8 SRF
1.45 FTE/y

Y. GOMEZ-MARTINEZ 0.2
F. BOULY 0.1
A. PLACAIS 0.25
M. MEYER (InT) 0.5
D. LONGUEVERGNE 0.1
G. SATTONAY 0.1
A. MIYAKAZI 0.2

FCCee

MP-IN2P3
MoU FCC

* MoU HL-LHC in progress

WP3 Nanobeam stabilization & Positioning

Scientific Issues

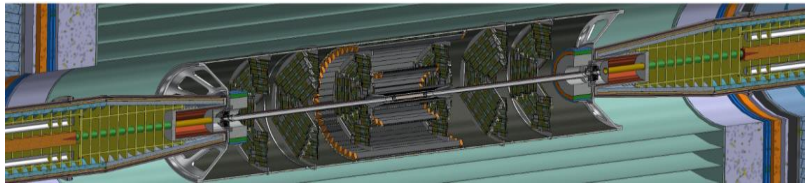
Vibration mitigation and **misalignments control** are crucial to obtain **high luminosity** (CLIC FFS magnet specification displacements 0.2 nm at 4Hz).
With thousand of magnets**, dynamic positioning approach** by girder is the most effective approach.

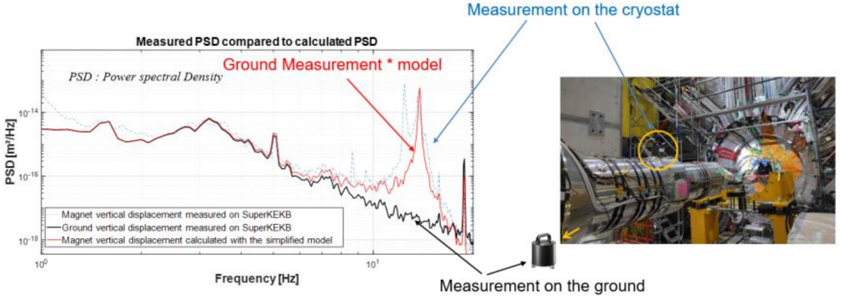
Design:

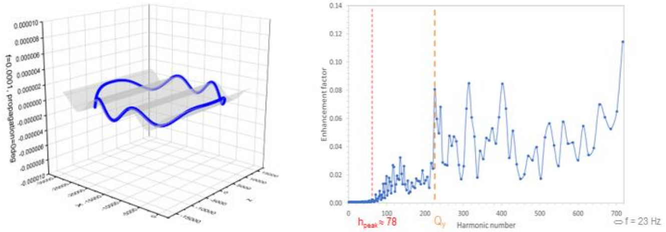
➢ FCC-ee beam stabilization

- **FCC-ee MDI:** guarantee the mechanical behavior of the MDI assemblies in integrating the estimated motion of the last focusing magnets into the global optics simulation (MADx)
- **FCC-ee arc-cell prototype:** static and dynamics studies with a special interest on the positioning system
- **FCC-ee uniform waves:** Simulation in function of frequency, phase and direction. Further beam dynamics studies with GND generator.

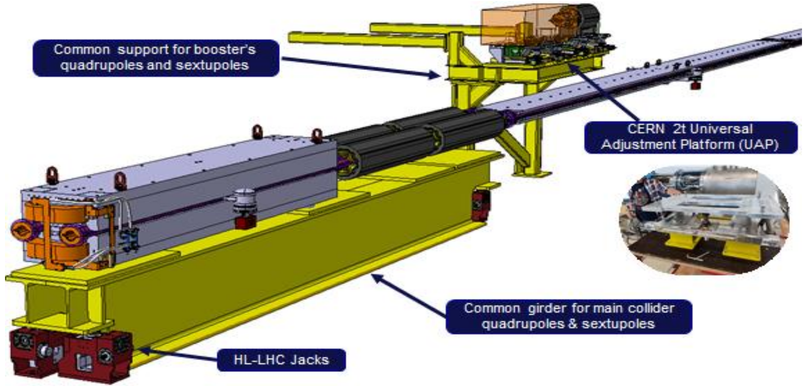
Setup of the MDI







Vertical displacement along the collider (frequency at 1Hz)



Setup of the arc-cell prototype

WP3 Nanobeam stabilization & Positioning

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(CLIC FFS magnet specification displacements 0.2 nm at 4Hz).
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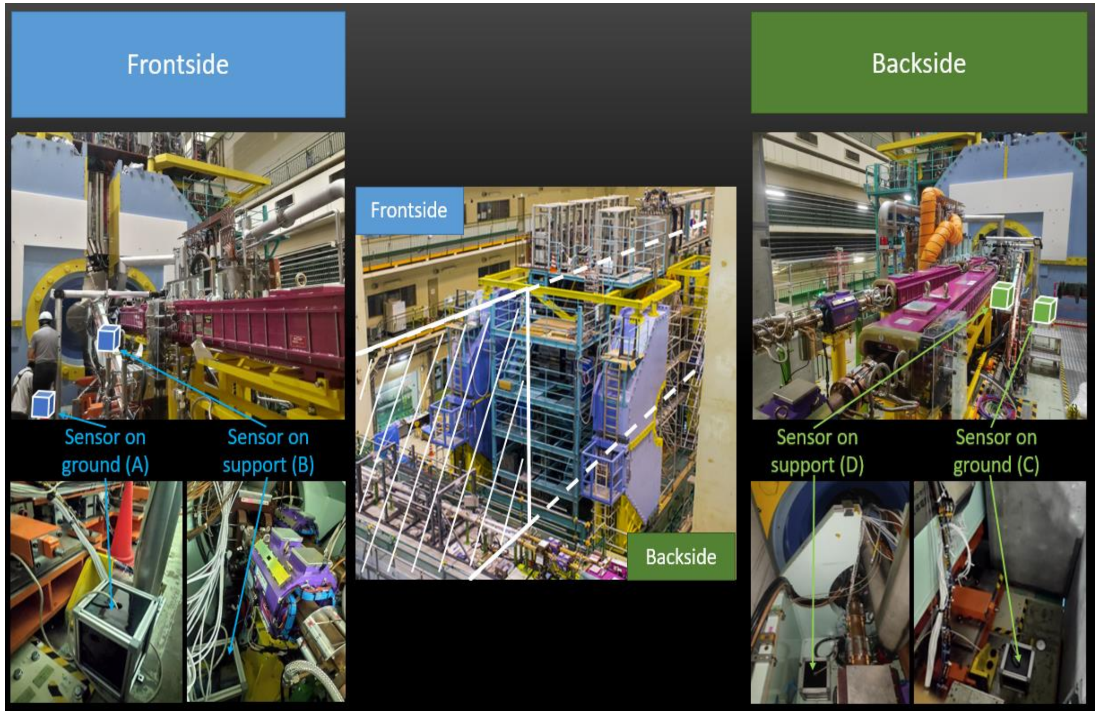
Experimental PoC:

➢ SuperKEKB stabilization

- Analysis of the **vibrations effects** on **beam parameters** and relevance of the associated optics simulation



4 seismic sensors (2 each side) BELLE II

➢ Positioning

- Development of a **low cost system** dedicated to a **singular magnet** on **two transverse axes**
- Application to **FCCee arc cell** prototype and **ATF3 final focus** magnets