Ground Motion and Feed-Forward

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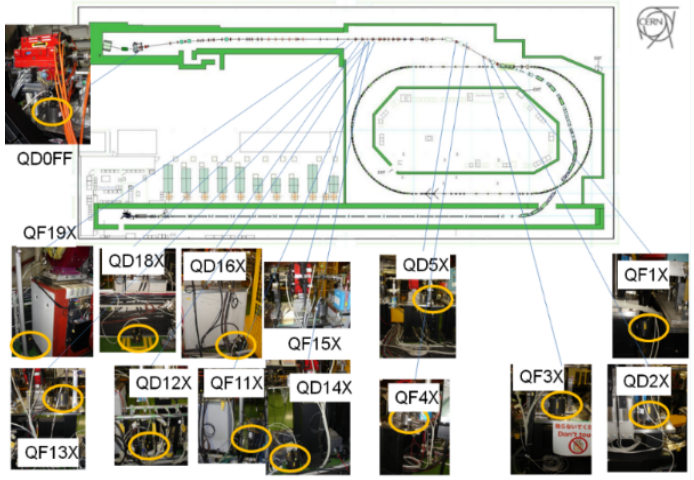
GM ACTIVITIES

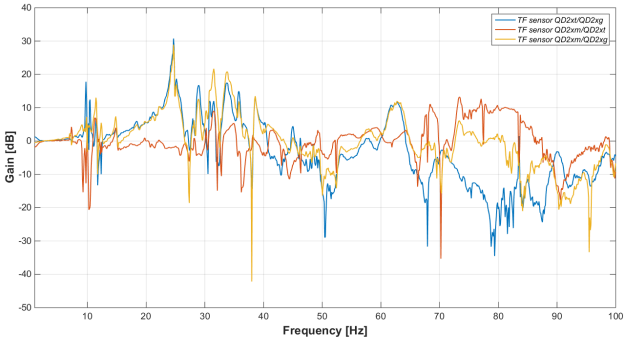
- ***Collaboration on Ground Motion and Feed-Forward***



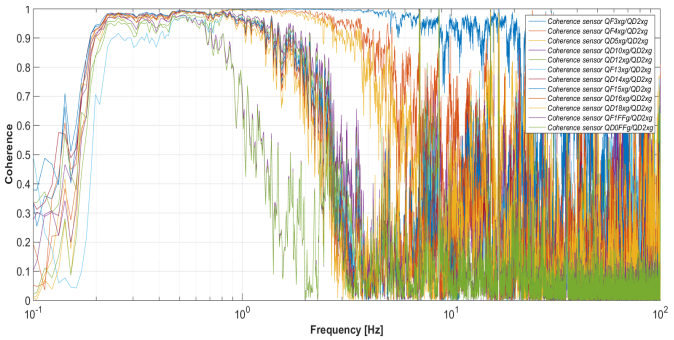
14 Geophones (Guralp 6T) - Collaboration CERN, LAL & KEK

- During last years LAPP group has been responsible of the final focus mechanical stabilization and it has carried on GM measurements and identification of the vibration sources
- **Through 2017 CERN, KEK and LAPP successfully proved the principle of GM FF in operation**
- End 2017: LAPP began to study the control aspects of the FF

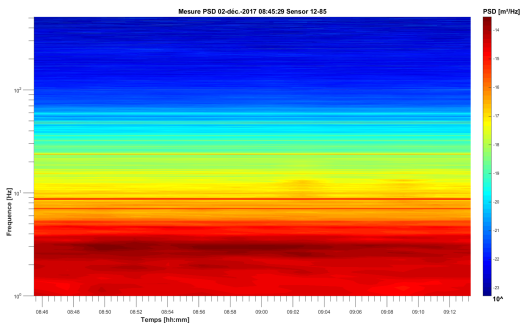
- ***Preliminary studies (November 2017)***



Transfer functions



Coherence study



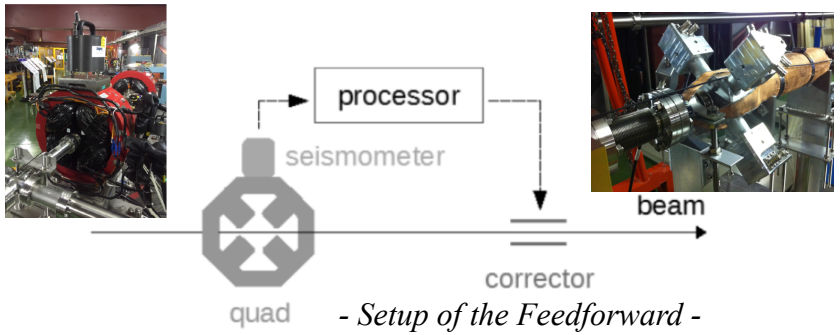
Stability study in time

➢ **Data useful for simulations setup and FF control**

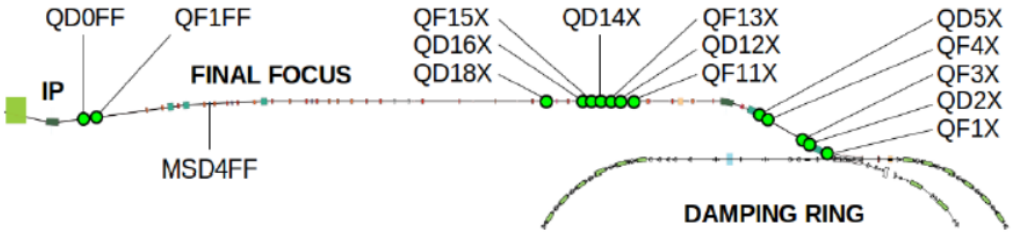
FEED-FORWARD

Feedforward principle and status

FF status is made in reference to different documents / works (Doug, Jonas, Jurgen, Rogelio and all…). The main references (plots...) comes from the useful article ***"D. Bett et al, Compensation of orbit distortion due to quadrupole motion using feed-forward control at KEK ATF"***



- Setup of the Feedforward -

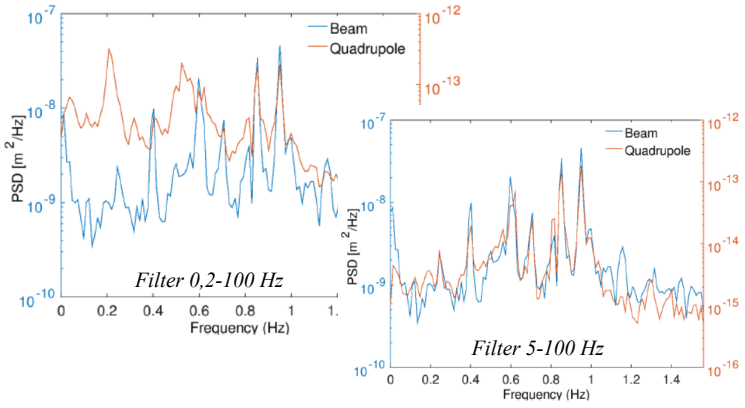


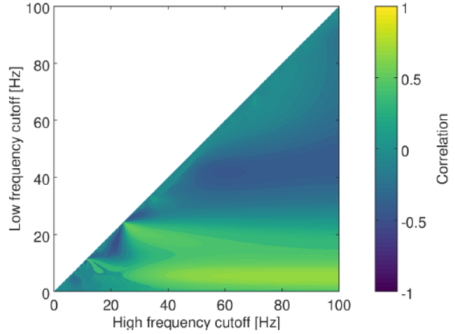
- Layout of the GM sensors along the collider-

Approach

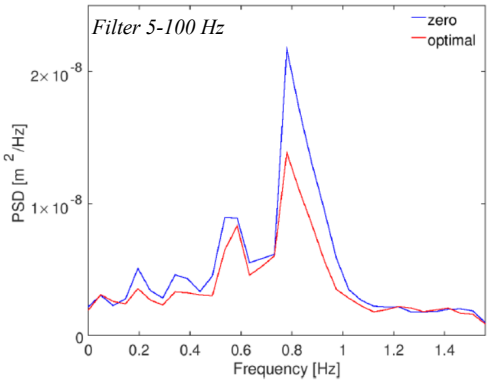
- *Only the incoherent disturbances / motions along the collider have an influence on the beam*
- *Low frequencies are quite coherent*

➢ ***Filter the sensor signals to select the part to use***





➢ ***Control these perturbations with the optimized gain***



- The obtained experimental results by CERN team with 1 geophone and 1 kicker -

FF LAST MISSION (2 shifts in February 2018)

Brief report from J. Breunlin and V. Cilento

1st GM-FF shift (''Ground motion activities'' at ATF2 operation meeting Feb 9th 2018):

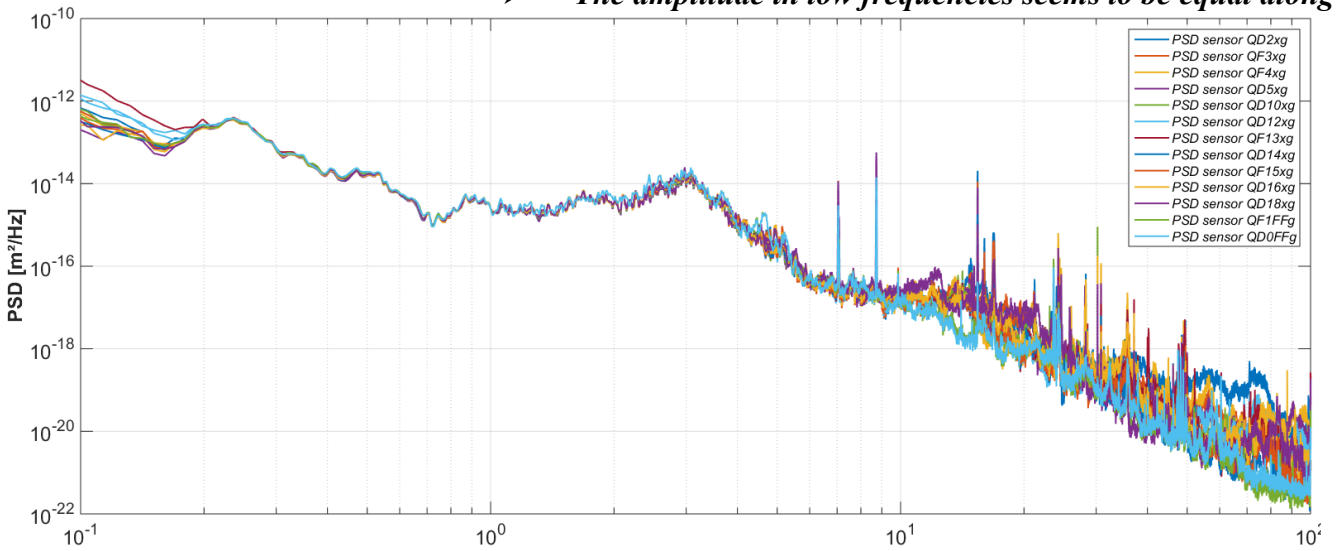
- The FF system worked again, during Nov-Dec shifts it was not possible to operate it.
- FF effect on the beam vertical orbit at BPMs (MQD20X and MQD4FF) was weak independently of the gain.

2nd GM-FF shift (very preliminary results):

- Optics file produced after tuning shift by Fabien and Edu was loaded in the FF system.
- Orbit response from kickers was different from 1st GM shift.
- Kicker calibration showed strong nonlinearities with respect to 1st GM shift.
- Discrepancy could be due to mistakes in loading files, tuning the beam and applying kicks.
- Analysis of the data is in progress.

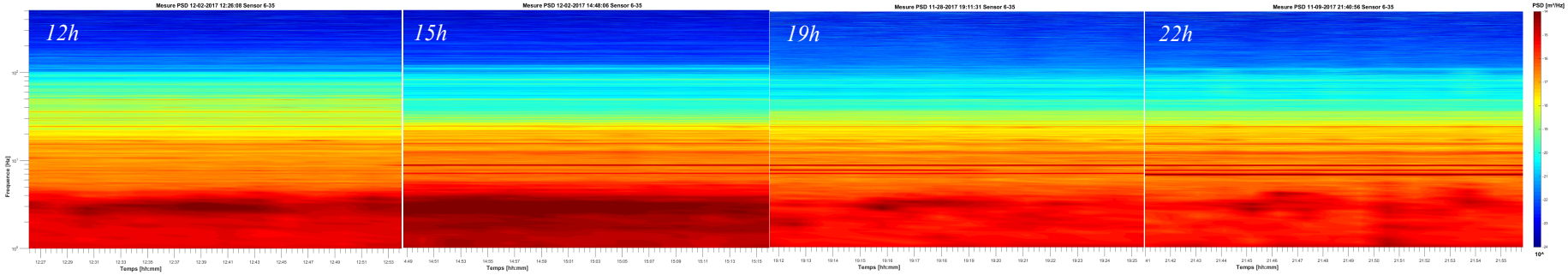
PSD AND COHERENCE MEASUREMENTS - 2017

- ***Evaluation of the cut-off frequencies vs coherence measurement along the collider***
  - *Preliminary evaluation with PSD as function of QD2*
    - ***The amplitude in low frequencies seems to be equal along the collider***



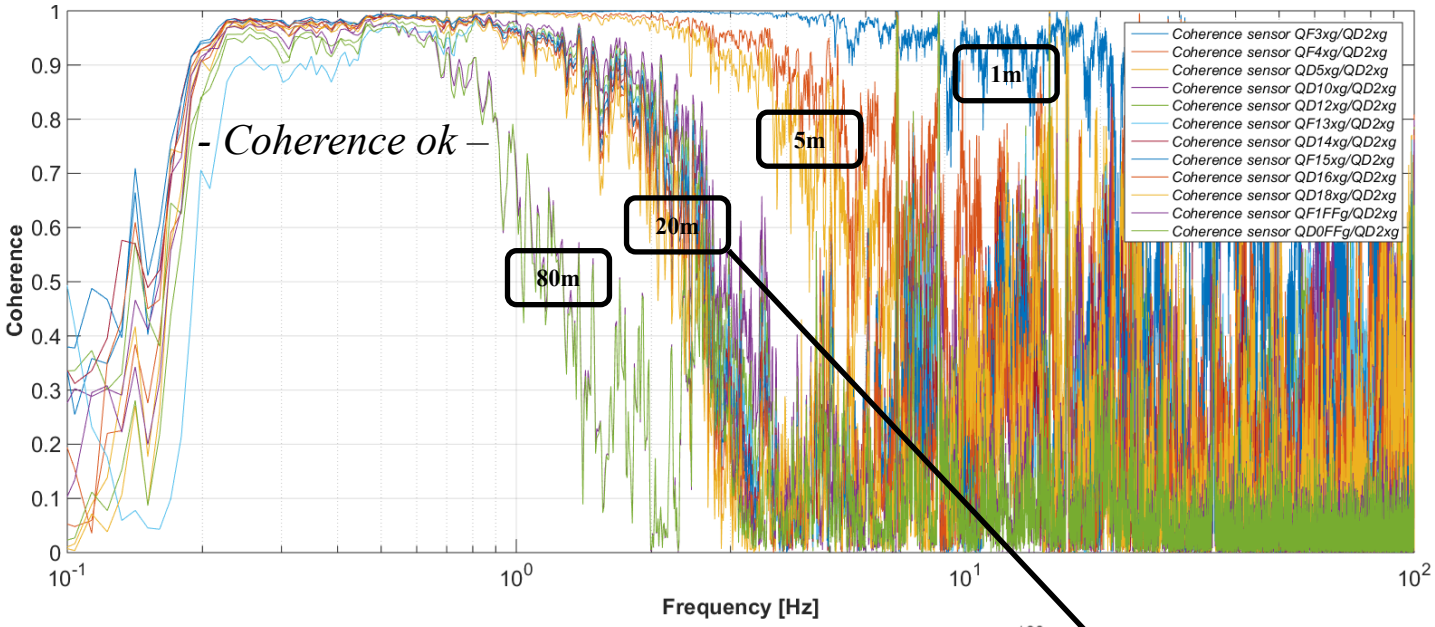
- Seems coherent – Mainly seismic activities

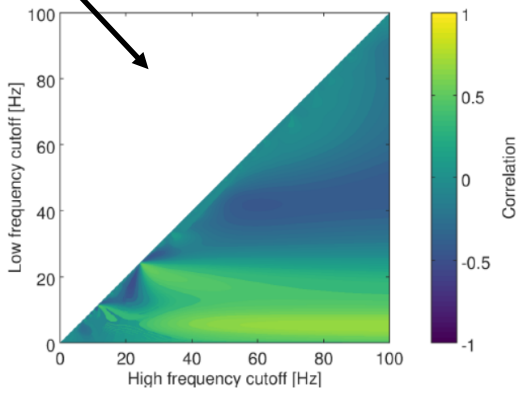
- Seems not coherent – Mainly cultural noise



- ***But the amplitudes reveal variation in time***

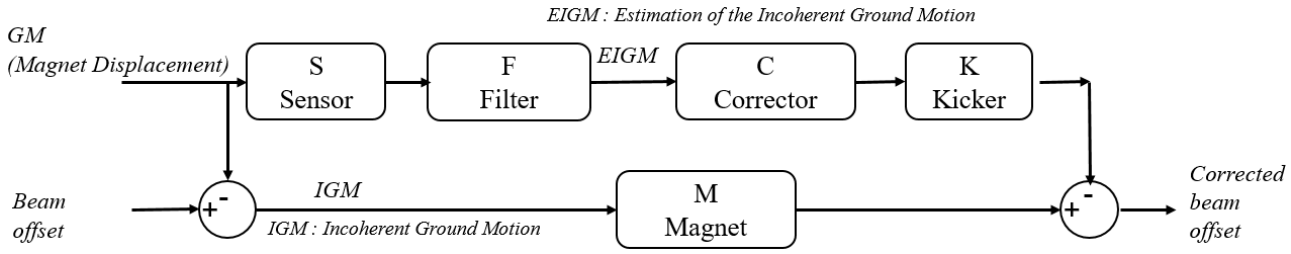
- ***Evaluation of the cut-off frequencies vs coherence measurement along the collider***
  - *More accurate evaluation with coherence (in this case as function of QD2)*





➢ ***The coherence plot could define the pattern of the filters which have to be used as function of the magnet positions (all the data with a coherence of 1 have to be filtered out)***

- ***Feedforward control***



$M = S.F.C.K$ As consequence, the corrector has to satisfy the following condition: $C = \frac{M}{S.F.K}$

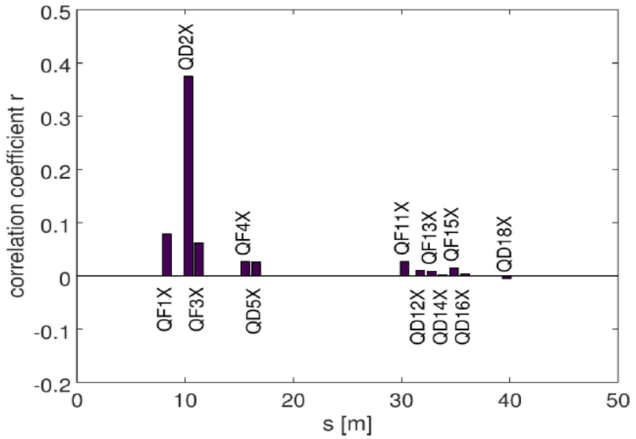
Then *C is the constant gain* in the bandwidth of interest.

- The extraction of the coherent motion is the critical part of the control

Proposal 1a: test different forms of filters, especially the influence of the order (current filter order is 2 while the displacement decreases as $1/f^4$). The coherent GM will be better filtered but the phase will be altered, then the performances have to be compared.

Proposal 1b: test the possibility to do FF control using the difference of two absolute motions (for example between QD2X and a second sensor on the ground at the beginning of the extraction line).

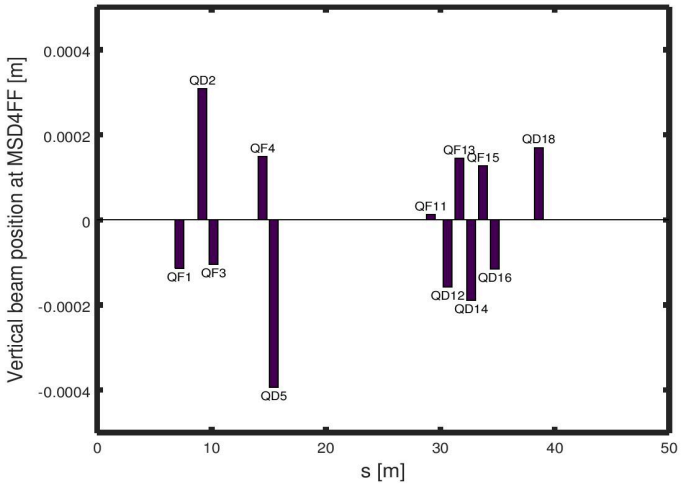
- ***Choice of the sensor for Feedforward operation***
  - *QD2 has been selected as function of the **measured correlation** between magnet motion vs beam position*



- *Correlation between the position of the beam at MSD4FF and the positions of various seismometers measured by CERN team*
- *Pearson correlation coefficient r gives an indication of FF performance and it is calculated between the reconstruction of the beam position and the actual measurement:*

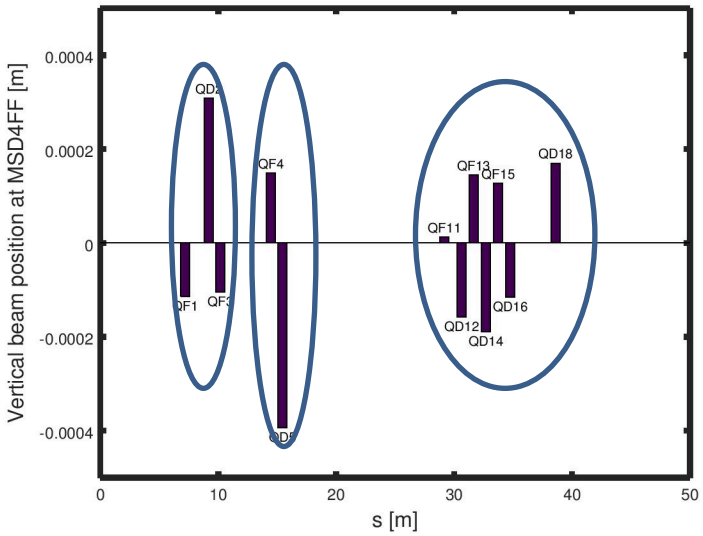
$$r = \frac{cov(y_m, y_r)}{\sigma_{ym}\sigma_{yr}}$$

  - *But the importance of QD2X vs other magnets seems not so important in **simulation***



- *Optics calculation with MADX (10BX1BY optics) displacing vertically by 1μm one quadrupole at a time and extracting the vertical beam position at MSD4FF*

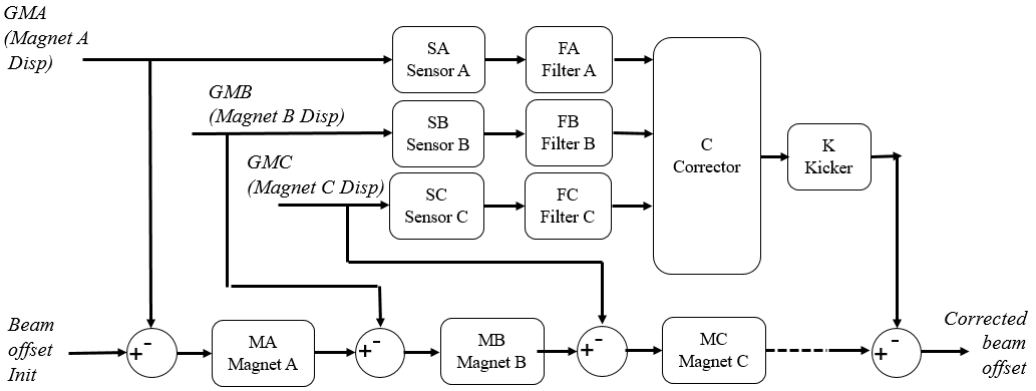
- ***Feedforward with several sensors***



- *Optics calculation with MADX displacing vertically by 1μm one quadrupole at a time and extracting the vertical beam position at MSD4FF*

- *3 groups of magnets which move probably relatively together (except the transfer function of the support)*

➢ *3 main actions on the beam have to be corrected*

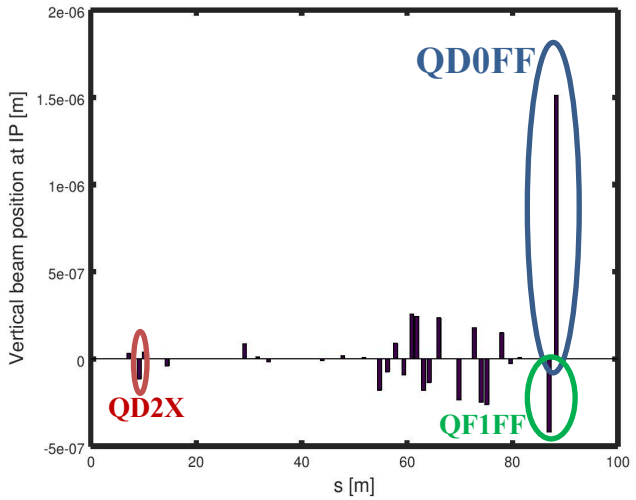


- Foreseen multi-sensors control with 3 geophones and 1 kicker -

<u>Proposal 2:</u> Take into account more than one magnet (the most critical ones) and evaluate the performance with respect to the actual system

FEED-FORWARD – FINAL FOCUS AREA

- ***Feedforward on the final focus***



- *Optics calculation with MADX displacing vertically by 1μm one quadrupole at a time (ext and ff quads) and extracting the vertical beam position at IP*
- *QD0FF is the most important magnet for the beam trajectory*
- *FF control with one geophone and one kicker*
- *Necessity to have access to the IP kicker in real time and to the data IP BPM for the efficiency evaluation -> FONT connection?*

- *Optics calculation and correction with IP kicker in MADX*
- *QF1FF and QD0FF moved together vertically in step of 100 nm plus final focus line and extraction line quadrupoles with random uniform vertical displacement in* [-1,1] *μm range, each point is an average over 20 rnd seeds*
- *Max offset at IP: +/- 1100 nm*
- *With one kicker only offset can be corrected*

<u>Proposal 3:</u> Carry on Feed-Forward experiments using IPBPMs.

CONCLUSION

- ***Different proposals-priorities have to be defined***
  - *Pattern of the filter*
  - *Use relative motion: difference between two absolute motion measurements*
  - *Multisensors*
  - *FF in the final focus area*

➢ These approaches will be studied in more detail in simulation to define priorities.

➢ PLACET tracking simulations are needed to implement realistic quadrupoles displacements due to Ground Motion and evaluate effect on beam emittance (work in progress!)

➢ **To test these options, at least two 8h shifts dedicated to control will be needed during this spring.**

THANKS FOR YOUR ATTENTION!