ATF2 Feed-Forward

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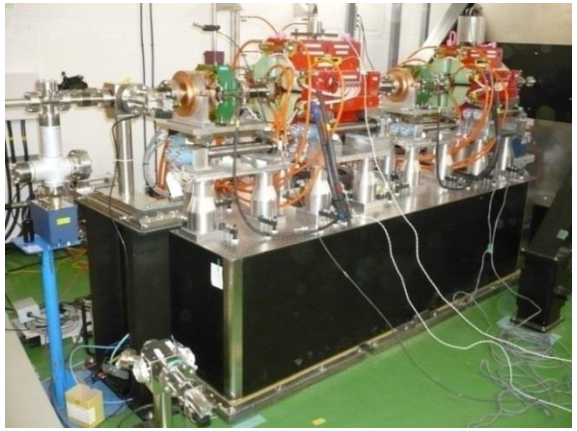
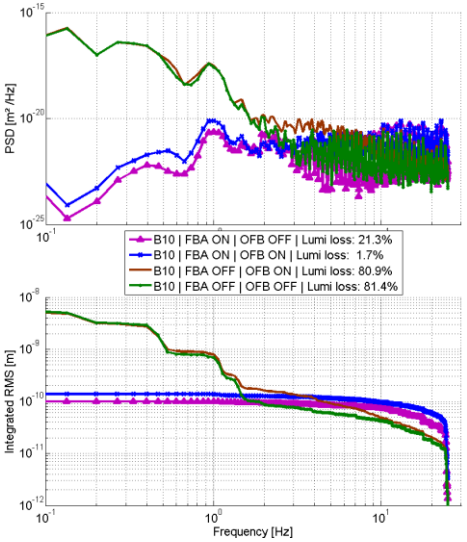
https://indico.cern.ch/event/753671/timetable/#all.detailed

Feedforward strategy

- ***LAPP motivations***



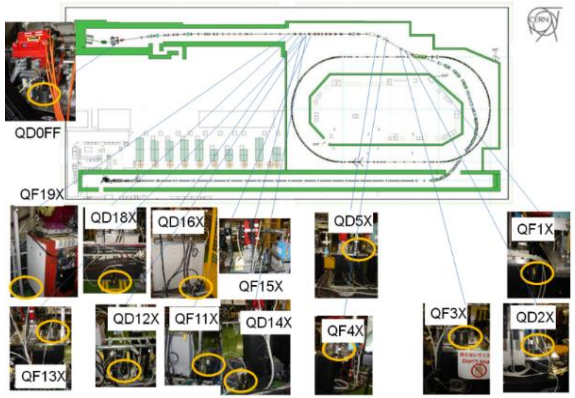
***ATF2 final focus**: coherence optimization*



0,25 nm RMS @ 4Hz

***CLIC final focus** : subnanometer demonstration*
Post BPM beam trajectory control < 4 Hz – "Mechanics" active control > 4Hz

- ***ATF2 Feedforward : opportunity to compare two different approaches***

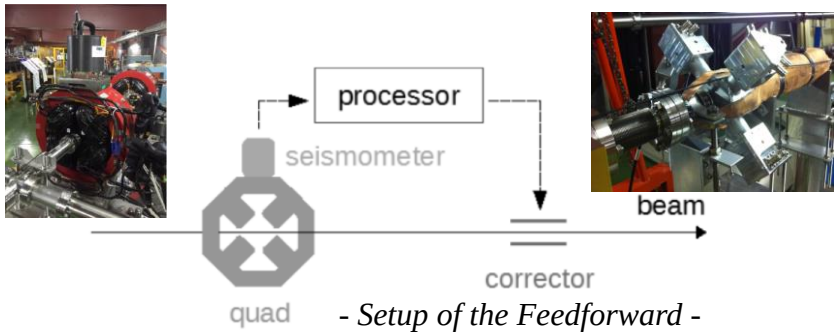


- During last years LAPP group has been responsible of the final focus mechanical stabilization and it has carried on GM measurements and identification of the vibration sources
- **Through 2017 CERN, KEK and LAPP successfully proved the principle of GM FF in operation**
- End 2017: LAPP began to study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

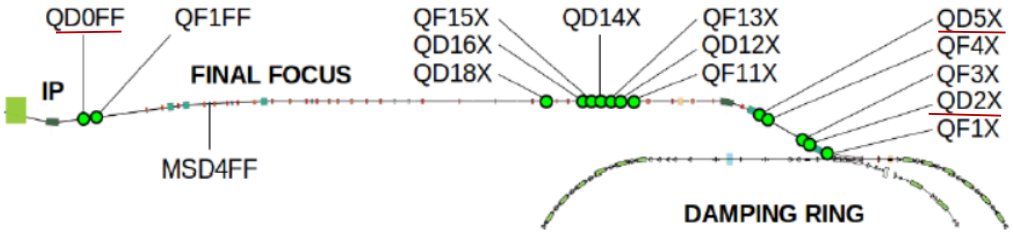
FF control

- ***Feedforward principle***

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

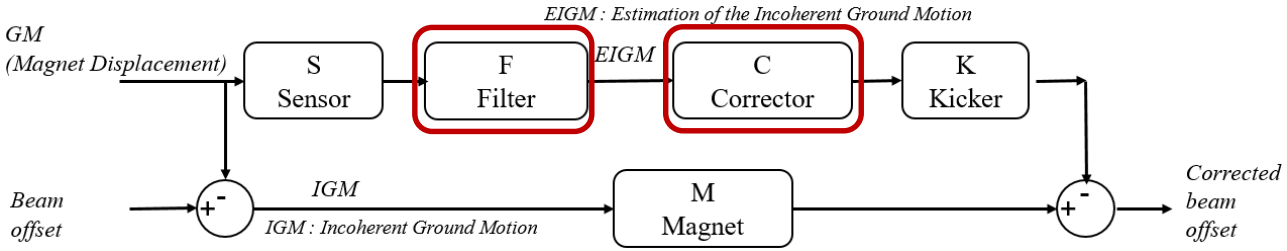


- Setup of the Feedforward -



- Layout of the GM sensors along the collider-

- ***Feedforward concept***



Control law – conceptual scheme

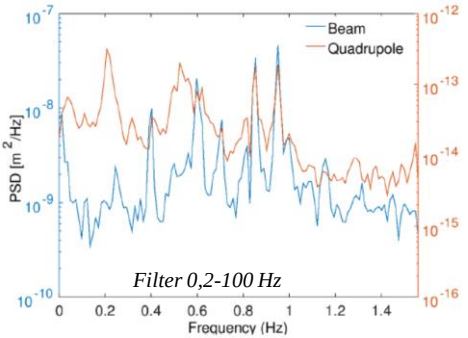
$M = S.F.C.K$ As consequence, the corrector has to satisfy the following condition: $C = \frac{M}{S.F.K}$

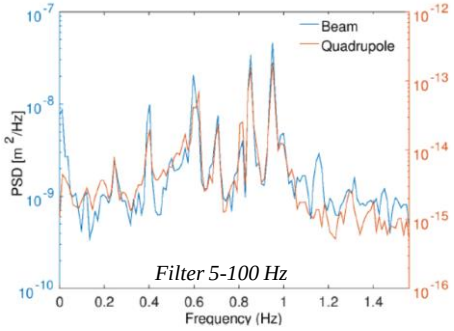
➢ Then *C is the constant gain* in the bandwidth of interest.

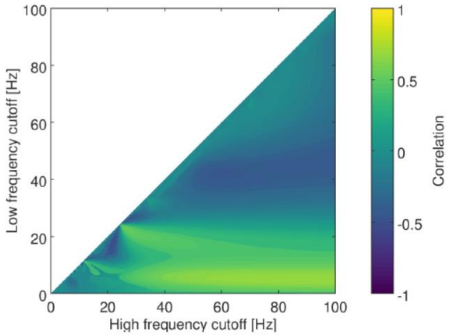
- ***Feedforward - issues***
  - To extract very accurately the disturbances (coherent vs incoherent motion)
  - **To know very well the system** (the effects of the vibrations and of the magnets on the beam)

FF results and issues

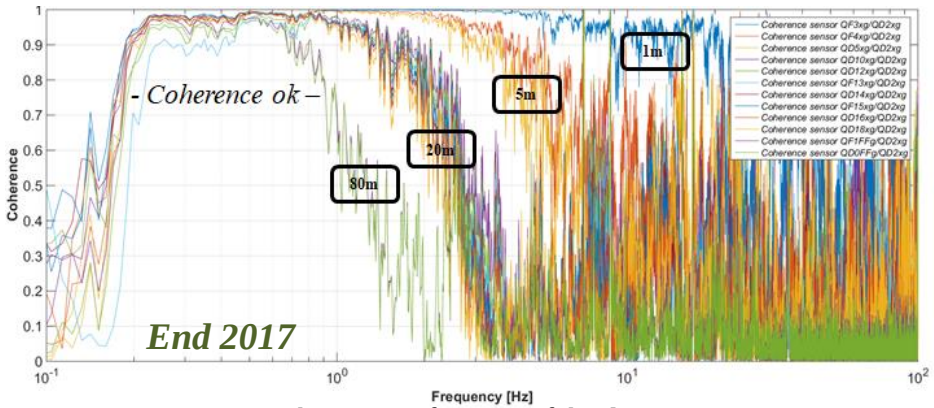
- ***Previous results - demonstration***
  - *Only the incoherent disturbances / motions along the collider have an influence on the beam*
  - *Low frequencies are quite coherent*
    - ***Gain:*** *scanning method*
    - ***Filter:*** *determination of the bandwidth to reject the coherent part*





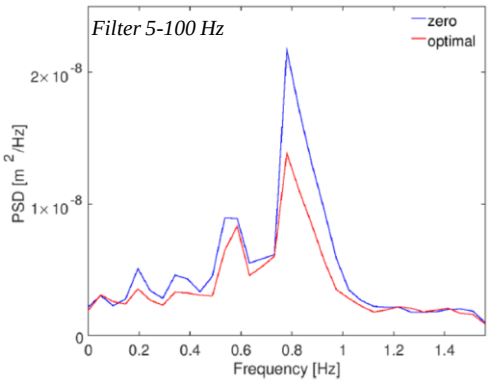


Correlation between beam position and QD2 displacement in function of the selected bandwidth



Coherence in function of the distance

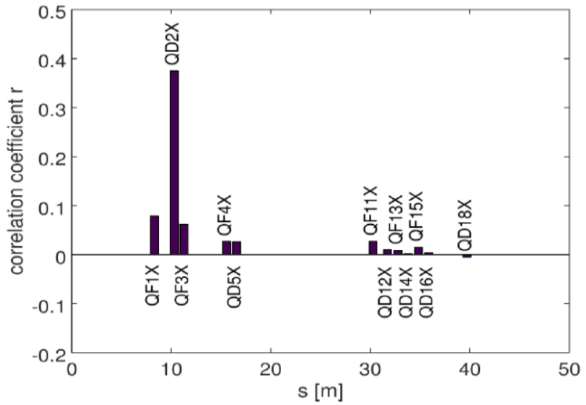
➢ *Control these perturbations with the optimized* ***gain***



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

Feedforward ojectives

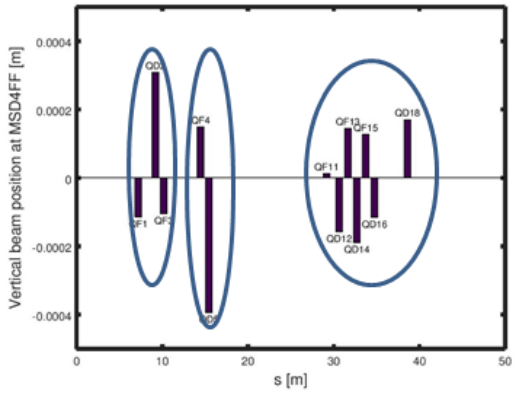
- ***Choice of the sensor for Feedforward operation***
  - *QD2 has been selected as function of the **measured correlation** between magnet motion vs beam position*



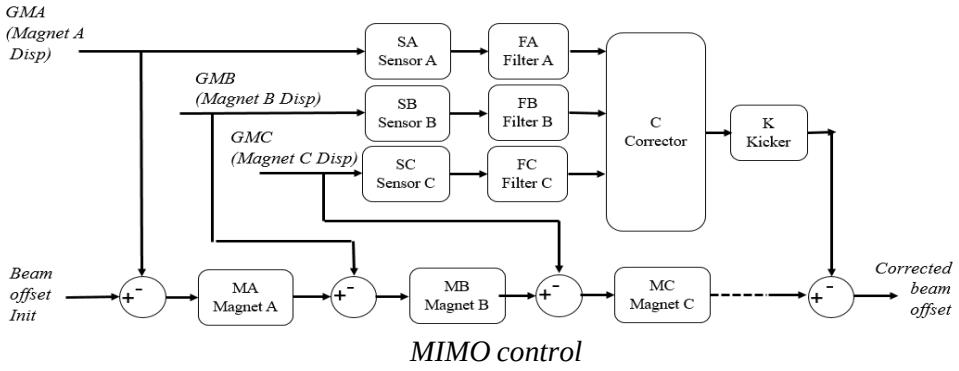
Correlation between the position of the beam at MSD4FF and the positions of various seismometers measured by CERN team

➢ ***Step 1: to perform the previous results with QD2***

  - *QD2 is not the only one interesting magnet*



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



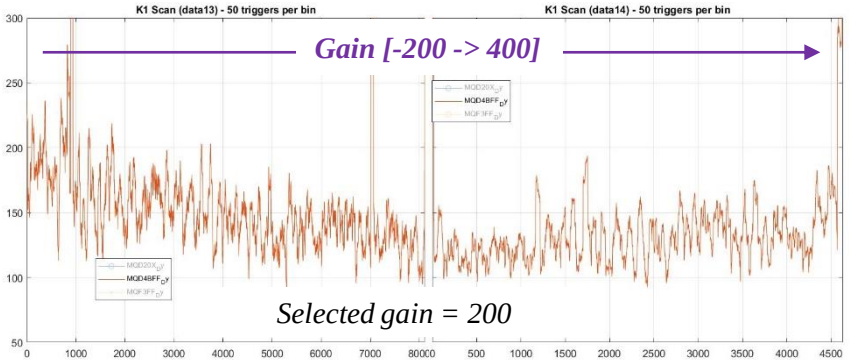
MIMO control

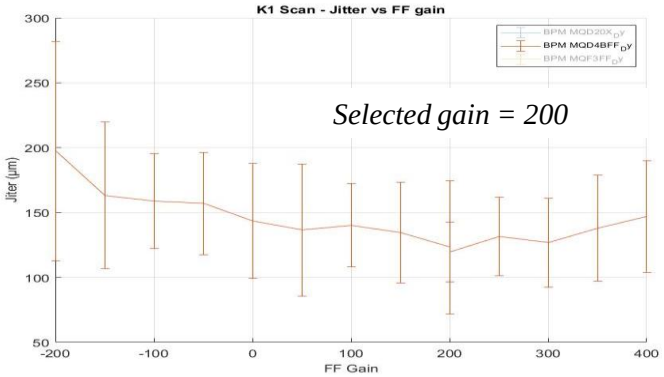
➢ ***Step 2: MIMO control with 3 groups of magnets which move relatively together (except the transfer function of the support)***

Extraction line (low beta optics)

➢ ***No similar results in 2018 (June: incoherent results and November: no relevant results)***

- ***Scan of parameters (gain Kicker 1)***

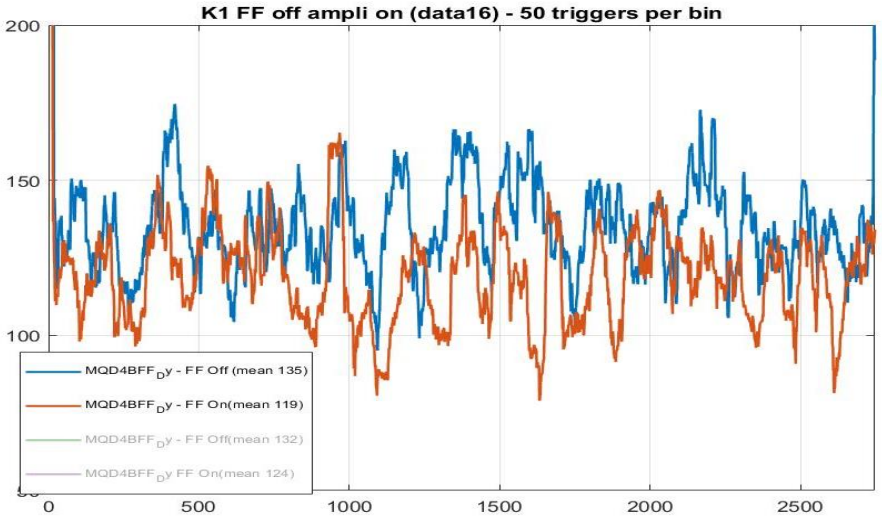




Nov 2018

Jitter variation during a scan of FF gain (MQD4BFF)

- ***Comparison Feedforward ON / OFF***

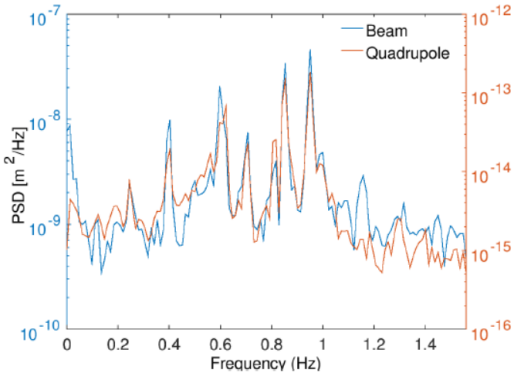


Jitter comparison feedforward ON/OFF

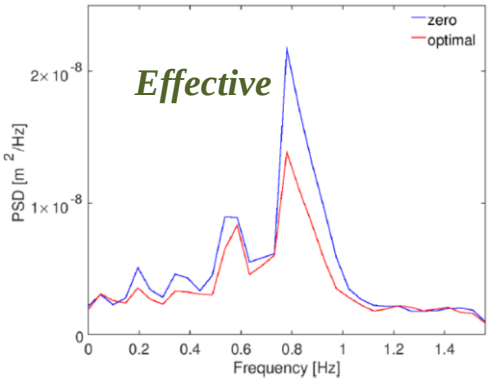
- *The reduction of the jitter is very modest : about **10%***
- *The gain could be optimized a little bit*

Extraction line issues

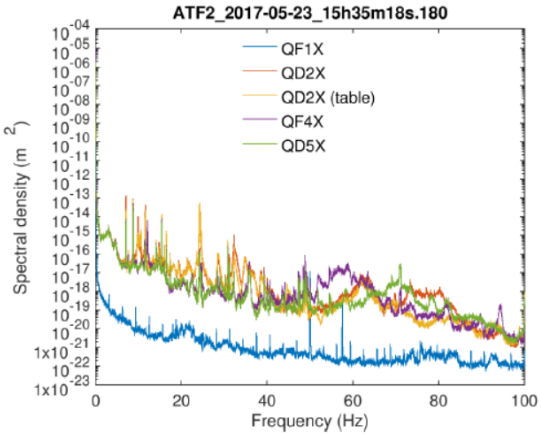
- ***Performances analysis***
  - *Feedforward efficiency is mainly function of the correlation between Magnet displacements and BPM measurements*



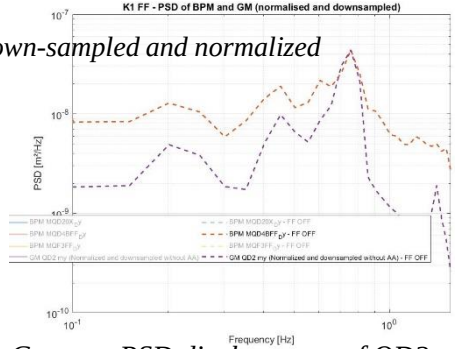
Past: PSD displacement of QD2 and measured by a BPM (FF off)



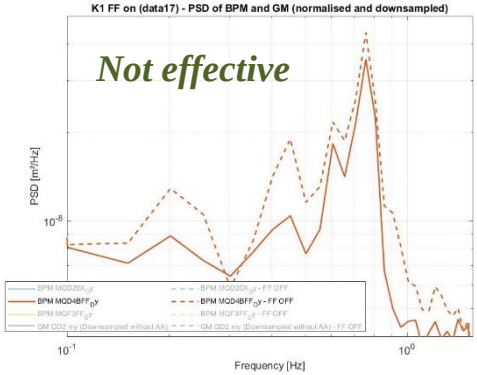
The obtained experimental results by CERN team with 1 geophone and 1 kicker



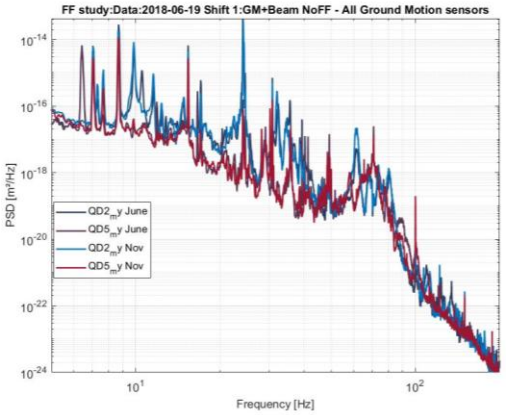
Down-sampled and normalized



Current: PSD displacement of QD2 and beam position measured by MQD4BFF (FF off)



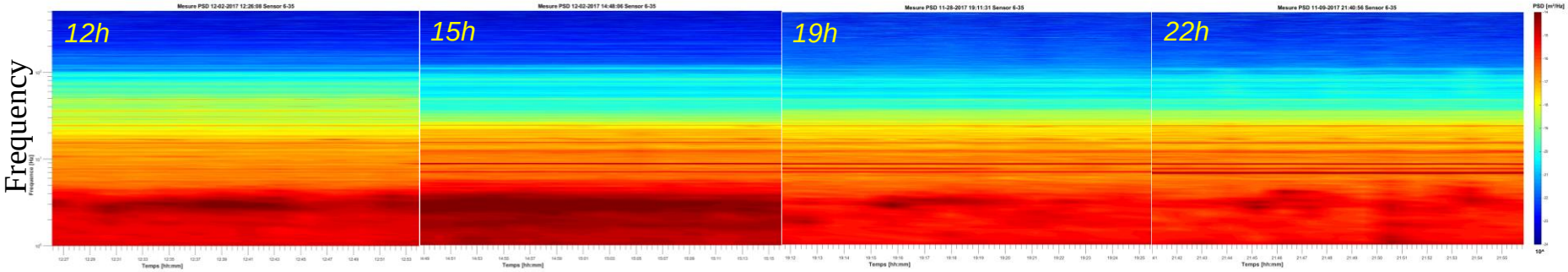
Current: PSD of the beam position measured by MQD4BFF with FF OFF / ON



PSD displacement of QD2 and QD5 in June 2018 and in Nov 2018

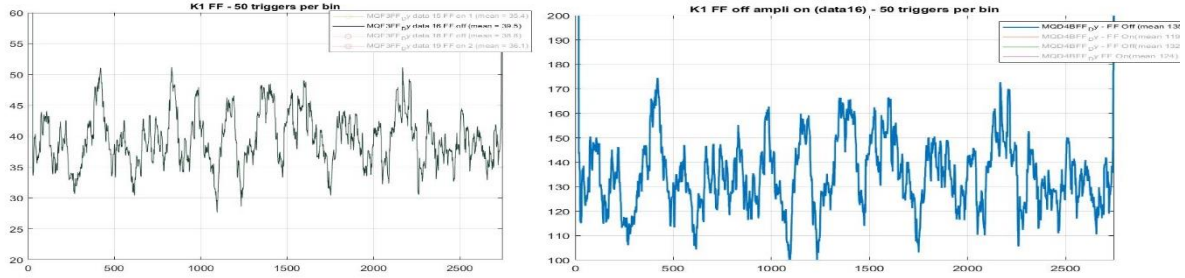
Extraction line issues

- ***Amplitudes variation of QD2 displacement in time is not important***



PSD displacement of QD2 Magnet in time

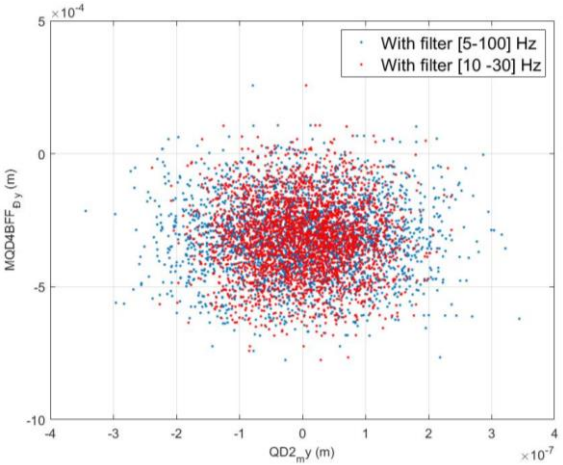
- ***Amplitudes variation of beam position in time is quite important***



Jitter measured by two BPM (MQF3FF and MQD4BFF)

- ***Similar signals in time but with important dispersion***
- ***Additional problems of synchronization: 5 – 10% of the data are lost***

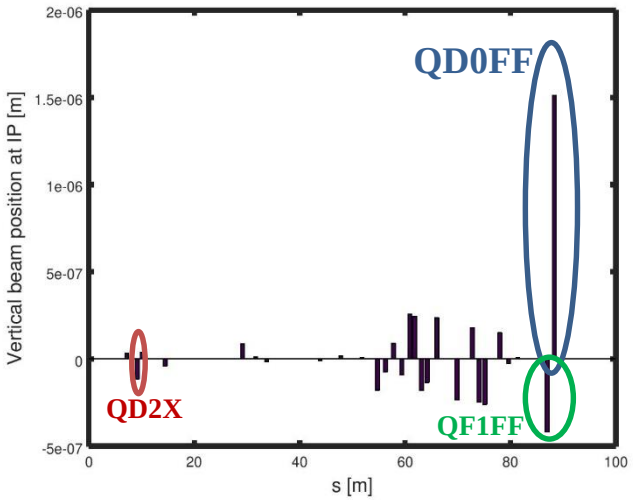
➢ ***Correlation between BPM measurement and Magnet displacement is pretty bad : has to be fixed***



Beam position (MQD4BFF) in function of the QD2 position

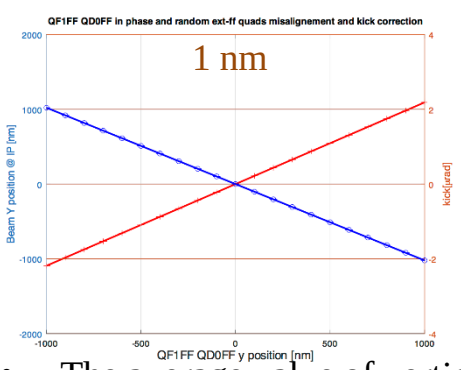
Final Focus

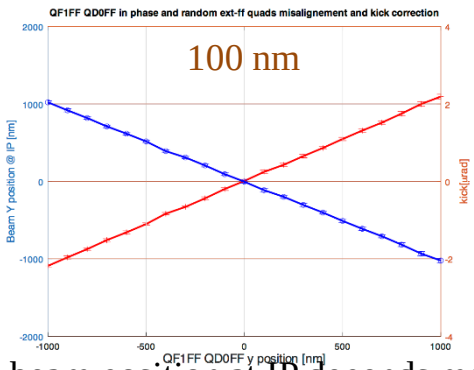
- ***Feedforward on the final focus***

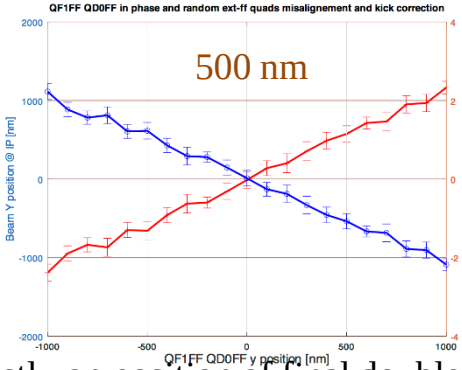


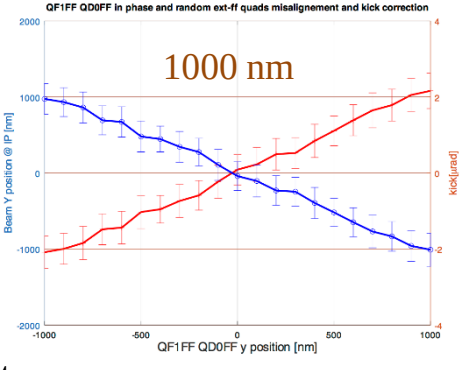
- *Optics calculation with MADX displacing vertically by 1µm one quadrupole at a time (ext and ff quads) and extracting the vertical beam position at IP*
- *QD0FF is the most important magnet for the beam trajectory*
- *FF control with one geophone and one kicker*
- *Necessity to have access to the IP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

- QD0FF and QF1FF moved in phase with 100 nm step, all quads in ext. and ff line with **x nm** uniform random, average over 20 seeds







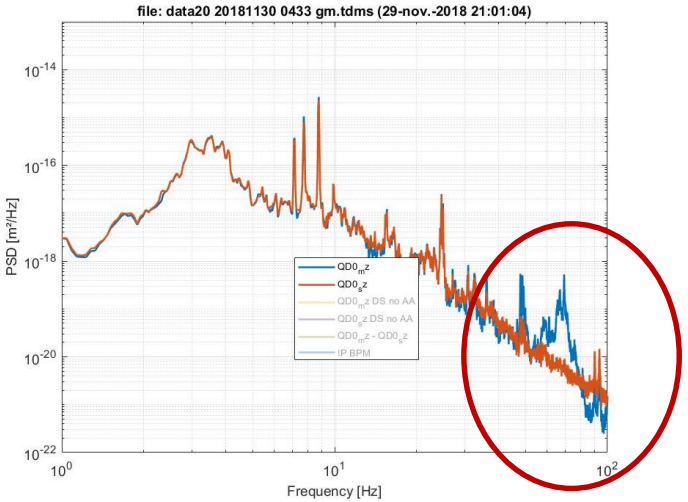


- The average value of vertical beam position at IP depends mostly on position of final doublet
- For movements of quads in ext and ff lines in the range of [-100, 100]nm position of the beam at IP is almost not affected
- For higher values of ext and ff quads movements error bars increase up to 200 nm

Final focus

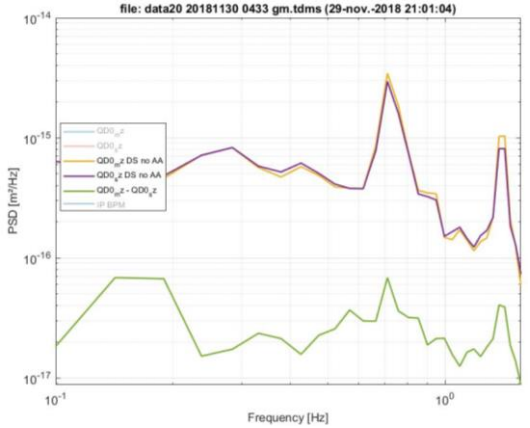
- ***Final focus strategy & issues***

  - *The shintake monitor and the final focus magnet are quite coherent. The main disturbance is due to the first mode of the magnet support.*
  - *The FF is applied with the difference between the Final Focus magnet and the magnet support*

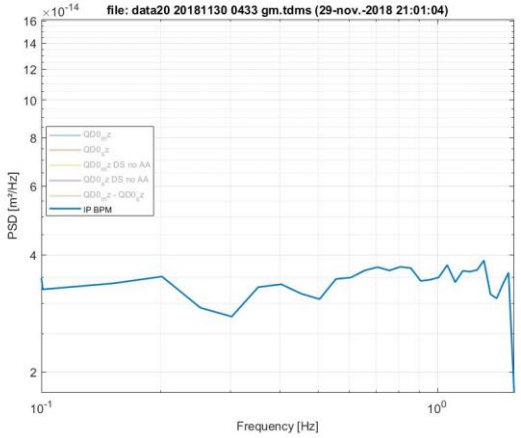


First mode of the magnet support

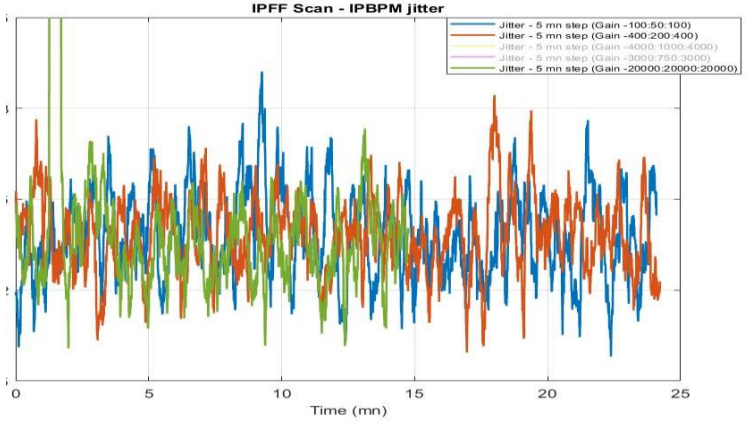
PSD of displacement (vertical direction) of QD0 magnet and its support



PSD of displacement (down-sampled at 3,12Hz) of QD0 magnet, its support and their difference



PSD of the beam position measurement at the shintake monitor position



Jitter of the beam position measurement at the shintake monitor position during a scan of the feedforward parameters (gain)

- ***The efficiency of IP BPM seems not enough sensitive to perform the feedforward at the IP with the final focus magnets.***

Conclusion

- ***Extraction line***
  - *The previous results were not reproduced during the last shifts*
  - *Problems of jitter variations and synchronization have to be fixed*
  - *The issues have to be investigated in details to understand what seems now not similar to the past*

- ***Final focus***
  - *At this moment the IP BPM are not enough sensitive to perform the feedforward with QD0 magnet displacement*