Experimental verification towards feed-forward ground motion mitigation at ATF2

K. Artoos, C. Charrondiere, St. Jannsens, M. Patecki,
Jürgen Pfingstner, Y. Renier, D. Schulte,
R. Tomas – CERN, Switzerland

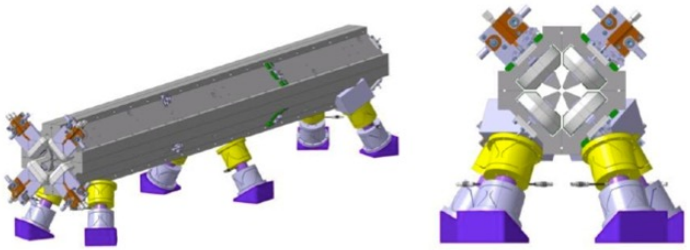
A. Jeremie – LAPP, France

K. Kubo, S. Kuroda, T. Naito, T. Okugi, T. Tauchi,
N. Terunuma – KEK, Japan

28th of January 2015

Ground motion effects and mitigation schemes

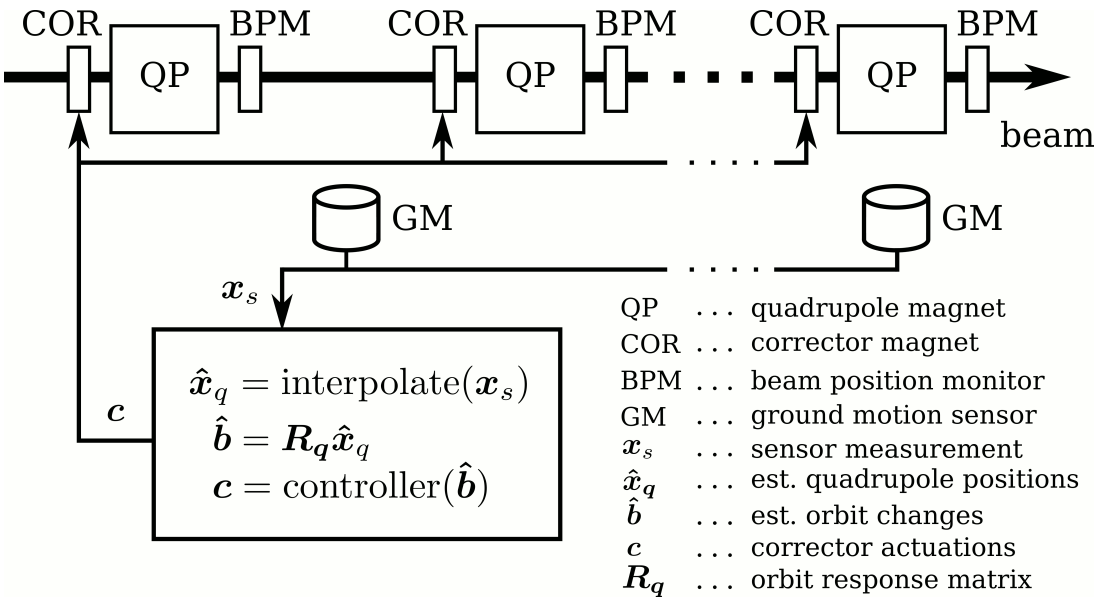
- Ground motion effects:
  - Problem for performance of future linear colliders.
  - Misaligned quadrupoles create beam oscillations.
  - Mitigation methods are necessary.
- Orbit feedback systems and transverse damping systems:
  - Very efficient for frequencies significantly below the beam (train) repetition rate f_R.
  - Higher frequencies cannot be suppressed.
  - f_R is small at linear colliders: 5 Hz (ILC), 50 Hz (CLIC).
- Intra-train feedback systems:
  - Very efficient for ILC.
  - Not sufficient for CLIC, due to the very short bunch spacing.
  - Also no spatially distributed corrections possible.
- Active and passive stabilisation systems:
  - Baseline for CLIC.
  - Relative costly.
  - Complex integration.



K. Artoos et al.

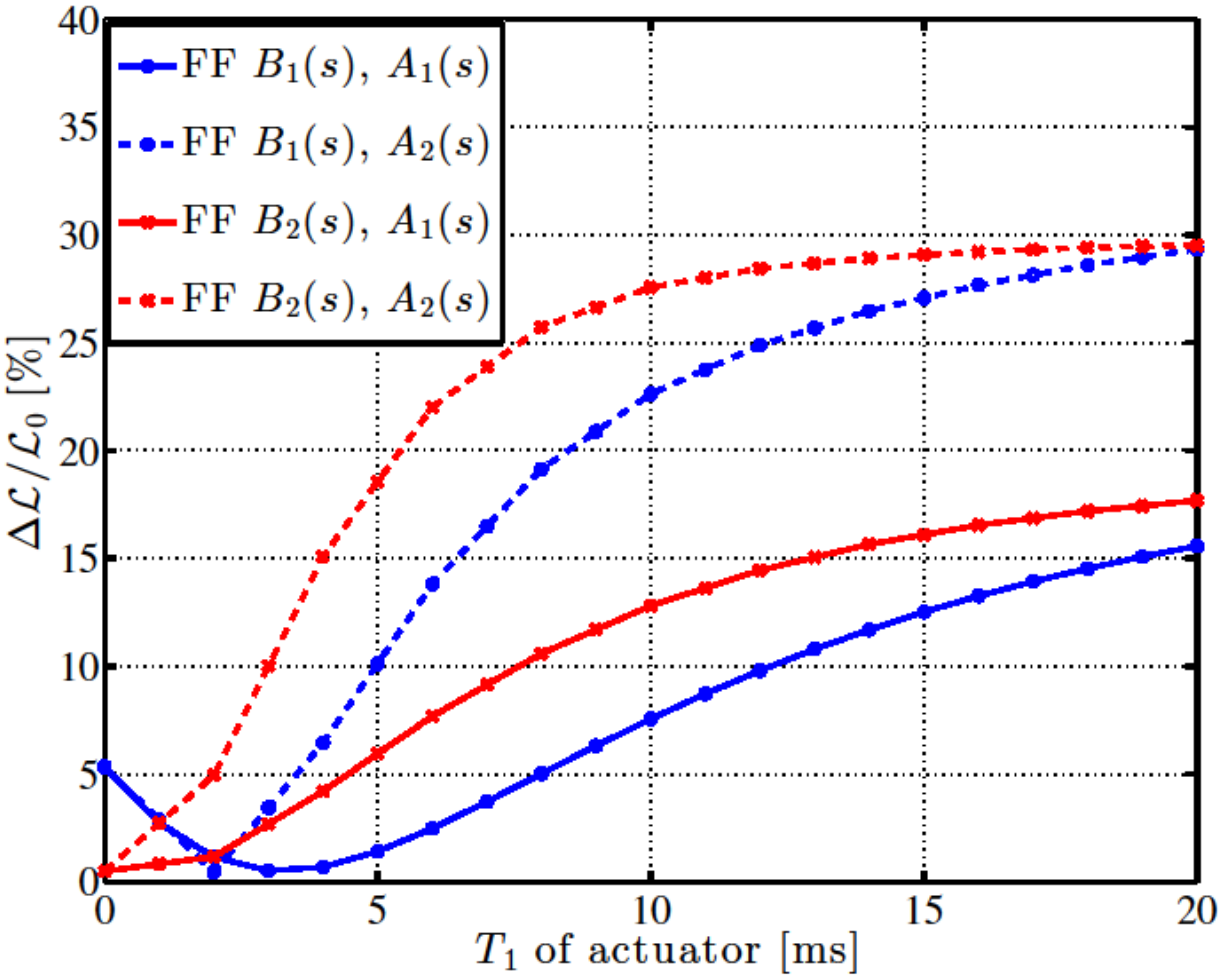
Ground motion mitigation via feed-forward control

- Concept is similar to an orbit feedback system.
- But ground motion measurements are used to predict the orbit changes.
- Orbit offsets are already corrected before the beam train arrives (feed-forward vs. feedback).



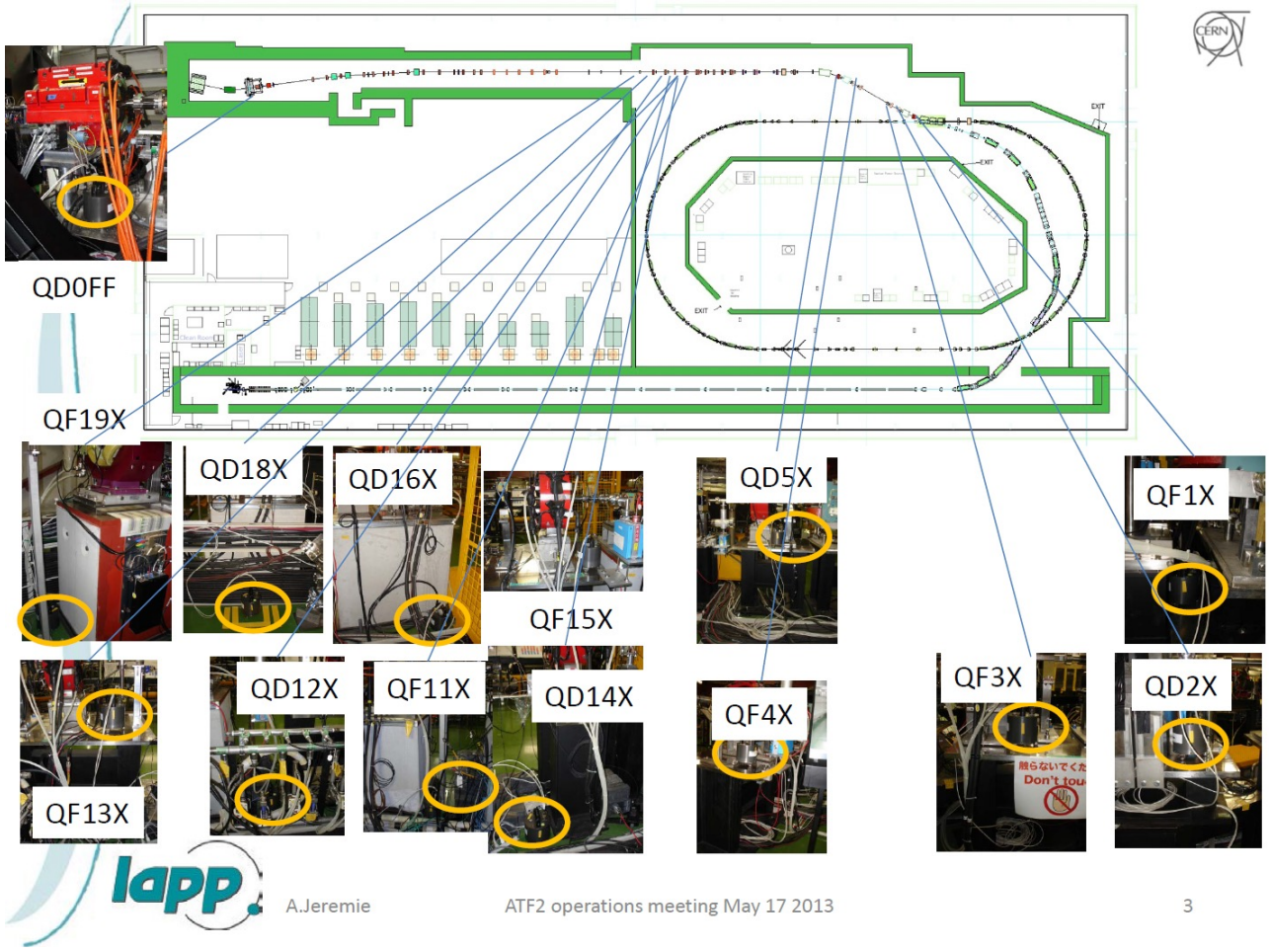
- Advantages:
  1. System is faster than orbit feedback systems.
  2. It is cheaper and easier to implement than stabilisation systems.
  3. It is also efficient, when the bunch spacing is very short and when the beam oscillations have to cured distributed along the machine (CLIC).

Analytic estimate of performance in CLIC main linac



- Luminosity loss due to ground motion (B10).
- First and second order actuator A_1 and A_2.
- T_1 is the actuator time constant (rise time).
- Two different sensors B_1 (Guralp seismometer) and B_2 (Geophone) are tested.

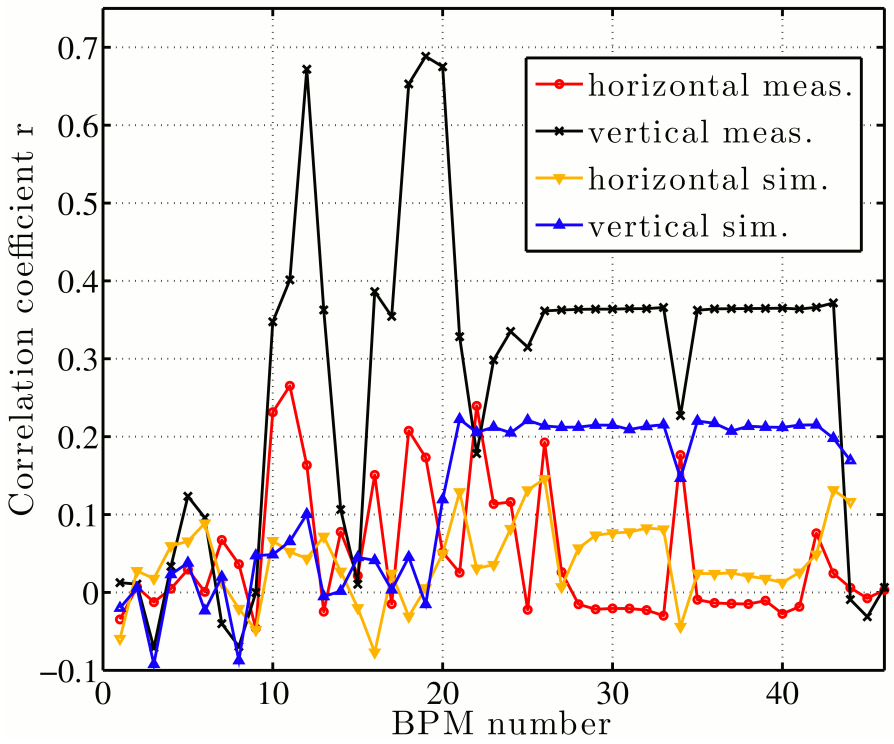
Experimental setup at ATF2



- 14 vibration sensors have been installed.
- National Instruments data acquisition hardware.
- Synchronisation signals for BPM and ground motion data are formed.

Experimental results at ATF2

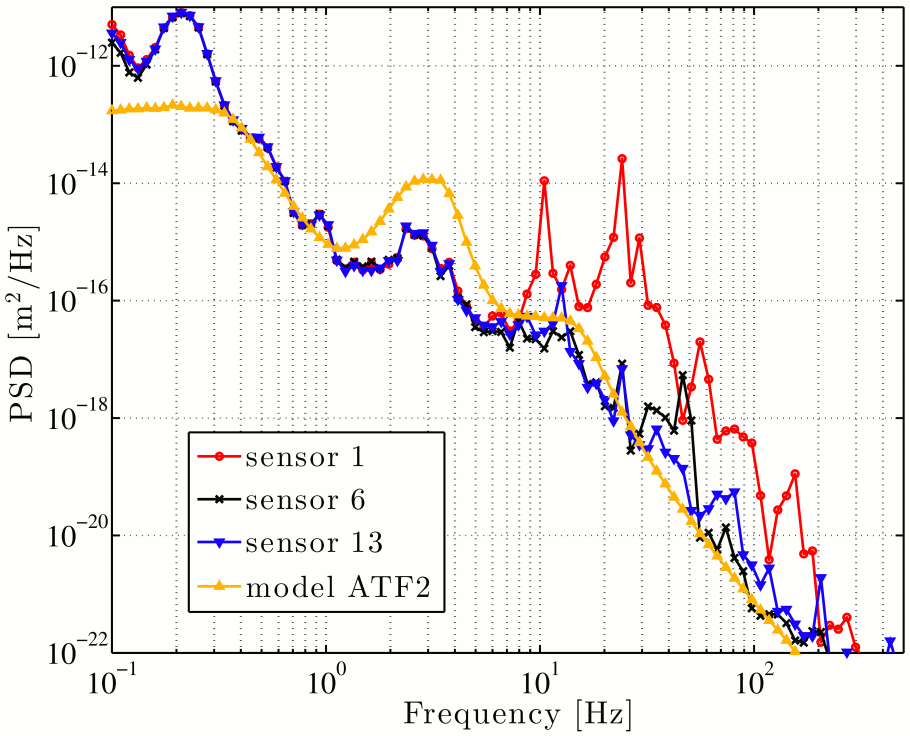
- Full demonstration split into two parts:
  1. Prediction of orbit change due to ground motion measurements.
  2. Correction of the predicted changes (future work).
- Measure: correlation coefficient *r* computed from the measured orbit changes (BPMs) and the predictions.



- Results:
  1. High correlations observed: *r* up to 0.7 in the vertical direction.
  2. Prediction of orbit changes due to seismometer measurements was successful.

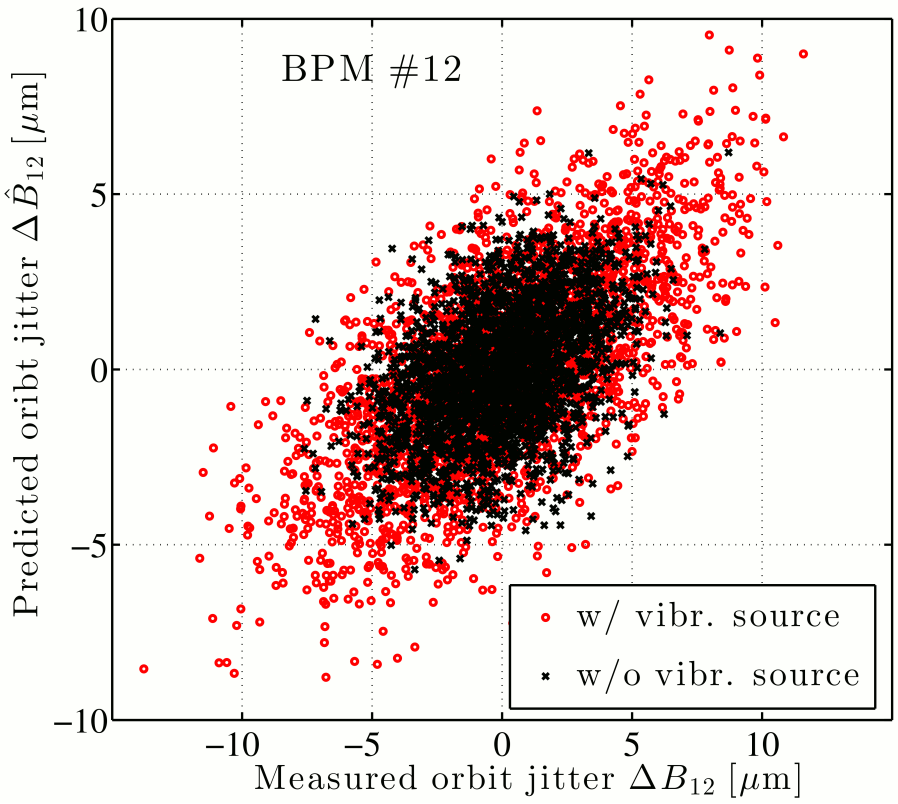
Ground motion analysis

- Simulation forecast: only a small fraction of the orbit jitter at ATF2 is due to ground motion.
- Small *r* was expected, which is in contradiction to measurement results.
- Explanation of discrepancy: strongly increased vibrations measured by sensor 1.
- Local vibrations source with frequencies from 10 Hz to 100 Hz.



Orbit jitter reduction

- Beamline around sensor 1 has been inspected.
- Two vibration sources (water cooling pipes) could be identified.
- After the removal of the two sources, the RMS orbit jitter was reduced by a factor 1.4.
- This corresponds to halving the excitation power.



Conclusions

- Ground motion mitigation via feed-forward control is designed to suppress ground vibrations of high frequencies.
- It has significant advantages compared to existing methods (cost, speed, distributed correction).
- For the experimental verification, a setup has been installed at ATF2 and the overall verification was split into two parts:
  - prediction of ground motion
  - correction of predicted motion
- The prediction of ground motion has been successfully performed at ATF2.
- The predicted beam oscillations were much higher than expected and originated from one local vibration source (water cooling pipe).
- After removing the source the beam jitter was reduced by a factor of 1.4.
- However, only correlation from one localised source was observed. Without the data of the corresponding sensors, the correlation is much lower than predicted by simulations. There are interesting results to this discrepancy in the next talk!

Thank you for your attention!