2015 International Workshop on Future Linear Colliders

Ultra low β* optics at ATF2

Marcin Patecki[1,2],

A. Aloev[1], D. Bett[1], E. Marin[3], M. Modena[1], R. Tomás[1], G. White[3]

Ground motion feed-forward at ATF2

Douglas Bett[1],

C. Charrondiere[1], A. Jeremie[6], M. Patecki[1,2], J. Pfingstner[1,7], Y. Renier[1], D. Schulte[1], R. Tomás[1]

K. Kubo[4,5], S. Kuroda[4,5], T. Okugi[4,5], T. Naito[4,5], T. Tauchi[4,5], N. Terunuma[4,5]

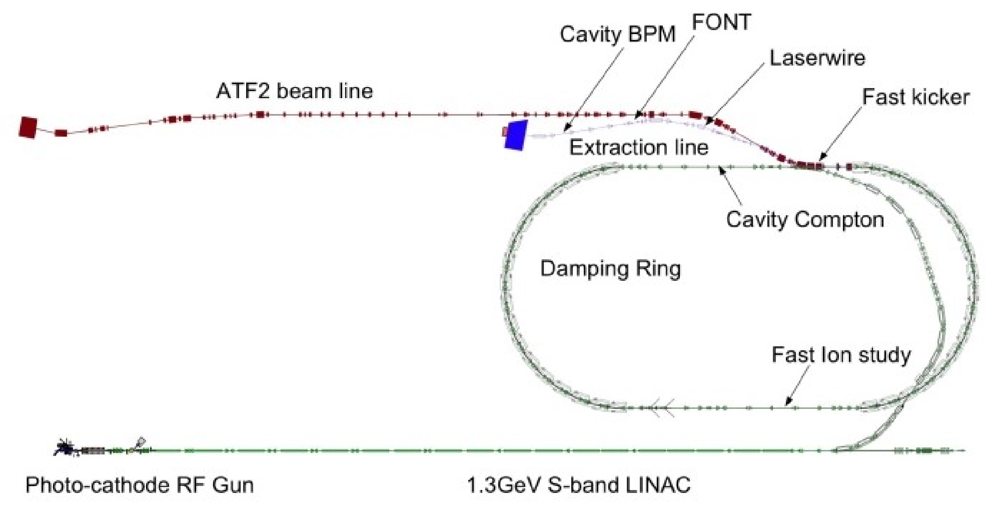
[1] CERN, European Organization for Nuclear Research , Geneva, Switzerland.
[2] Warsaw University of Technology, Faculty of Physics, Poland.
[3] SLAC, National Accelerator Laboratory, California, USA.
[4] KEK, High Energy Accelerator Research Organization, Tsukuba, Japan.
[5] SOKENDAI, School of High Energy Accelerator Science, Hayama, Japan.
[6] LAPP, Annecy Laboratory of Particle Physics, France.
[7] Universiy of Oslo, Norway.

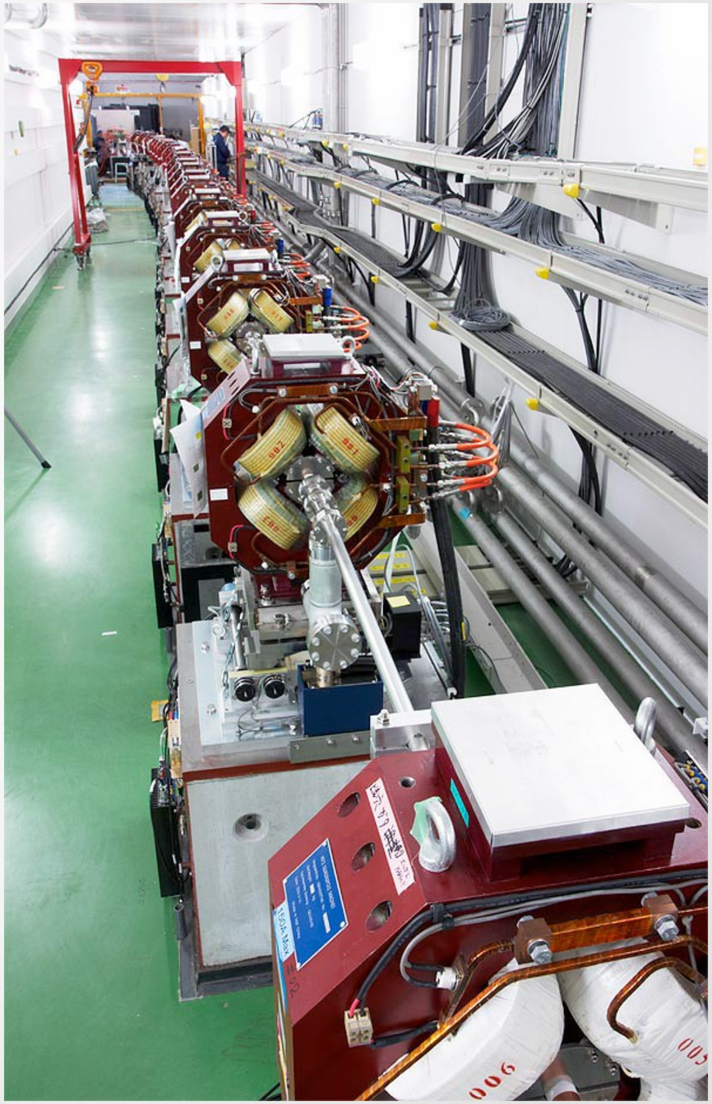
Outline

- **Ultra low β* optics**
  - Motivation for ultra low β* optics study
  - Planned installation of octupoles
  - Results of half β* tuning
- **Ground motion feed-forward**
  - Current set-up and results from ATF2
  - Expected feed-forward performance

Accelerator Test Facility ATF2

- Test facility for future linear colliders located in KEK in Japan [1]
- **World record of smallest vertical beam size: < 45 nm (design is 37 nm)** [2,3]
- First Final Focus beam line using a local chromaticity correction scheme [4]





Motivation for ultra low β* in ATF2

- ATF2 ultra low β* project [5] aims to test a Final Focus System (FFS) with a chromaticity similar to CLIC
  - Level of chromaticity ξ_y in ATF2 is comparable to ILC
  - Larger chromaticity ξ makes it more difficult to operate
- IP vertical beam size will be reduced to ~20 nm, allowing experience to be gained working in conditions similar to those of a linear collider
- Octupole magnets for stronger beam focusing are required

	β_y^* [μm]	$\sigma^*_{y,\,design}$[nm]	L* [m]	$\xi_y \sim (L^*/\beta_y^*)$
ILC	480	5.9	3.5/4.5	7300/9400
CLIC	70	1	3.5	50000
ATF2 nominal	100	37 (44[a])	1	10000
ATF2 half β_y^*	50	25[b]	1	20000
ATF2 ultra-low β_y^*	25	20[b]	1	40000

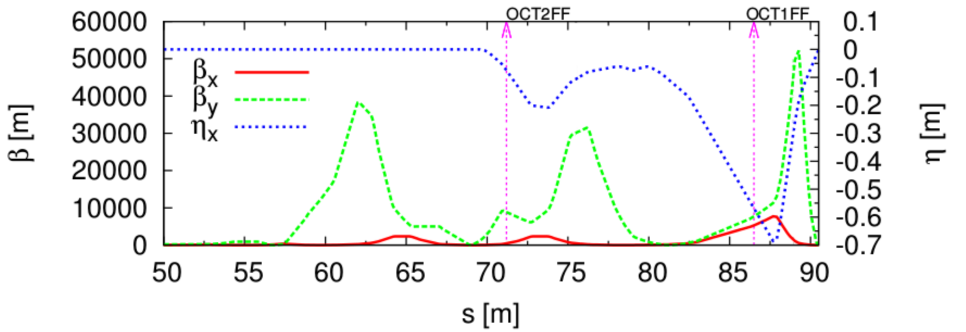
[a] measured, June 2014

[b] using octupoles

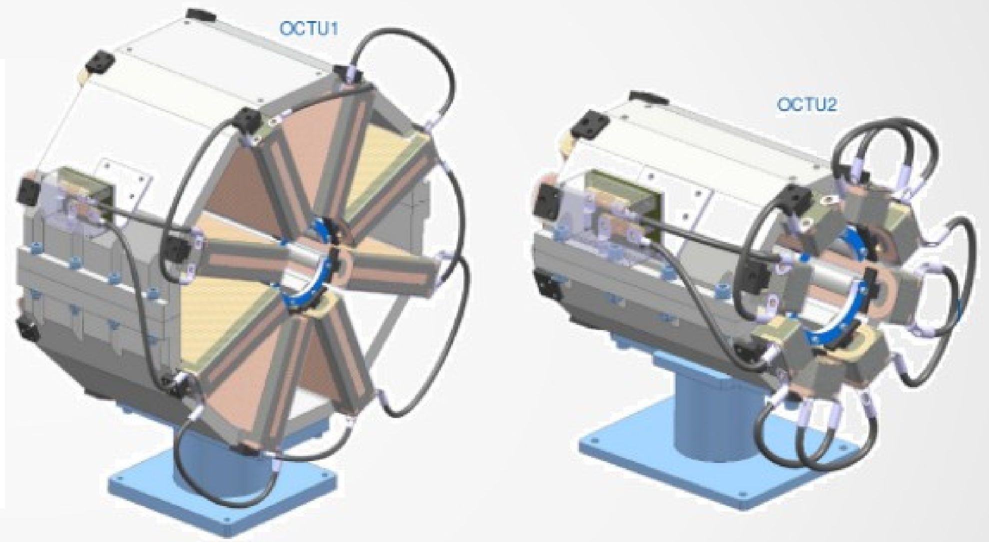
Octupole magnets for ATF2

Octupoles will be installed in dispersive and non-dispersive regions with 180° difference of phase advance [8]:

- OCT1 at 86.41 m between QD2AFF and SK1FF (3.8 m)
- OCT2 at 71.85 m between QD6FF and SK3FF (1.0 m)



Magnet design and assembly performed at CERN (M. Modena et al.) [9]:

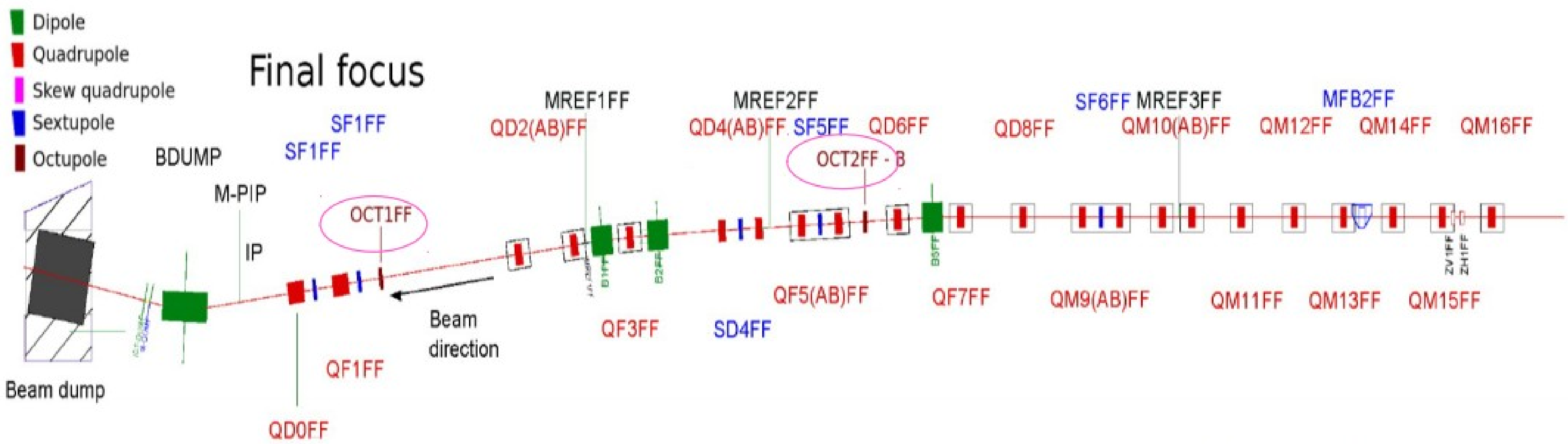


Plan to install OCT1 on a mover with initial tilt of 0.5°

Octupoles air cooled and yokes composed of two halves for mounting simplicity

	G [T/m^3]	tunability	magnetic length [mm]	aperture radius [mm]	ampere-turns per coil [A]	# of turns per coil	I [A]	power max. [W]
OCT1	6820	-90%/+20%	300	52	1800	60	30	152
OCT2	708	-90%/+20%	300	52	180	6	30	15.2

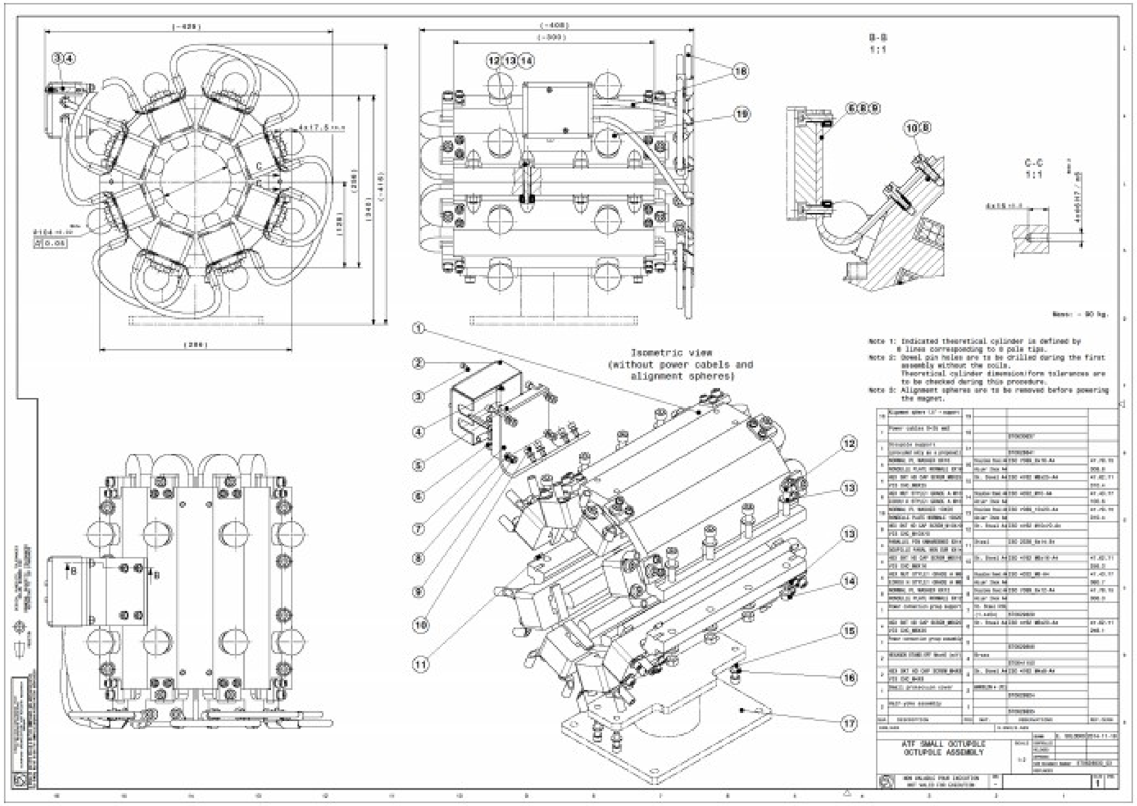
ATF2 two octupoles procurement

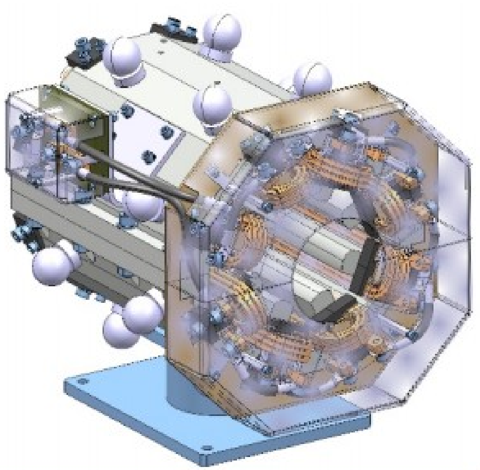


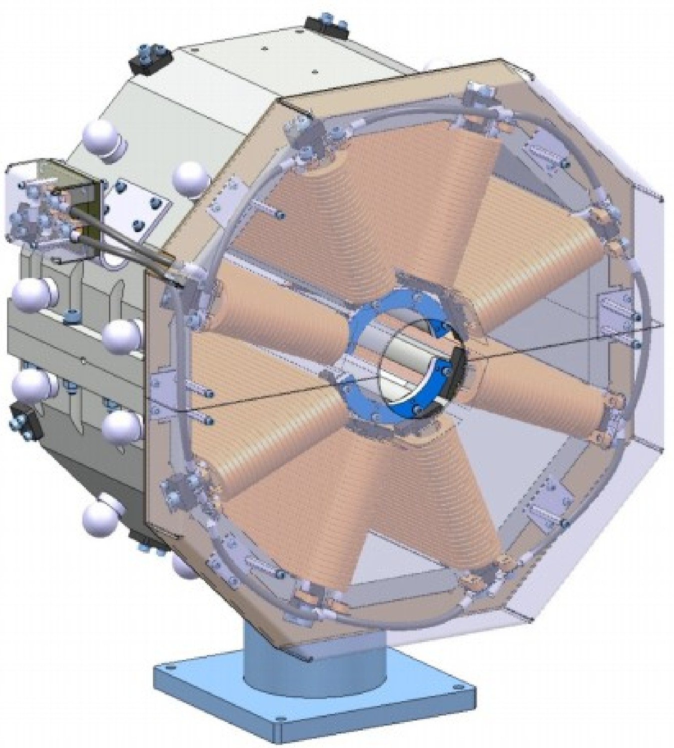
Octupoles built by ~March 2016

STATUS:

- ***10 + 10 coils** were received and tested at CERN **in August***
- ***Iron yokes** under machining by EDM (electro-erosion) at CERN Main Workshop. They will be available in **November**.*
- *Still under discussion **alignment procedure details** (CERN Survey is waiting info from KEK colleagues) but the fiducials layout was anyway decided and fixed*



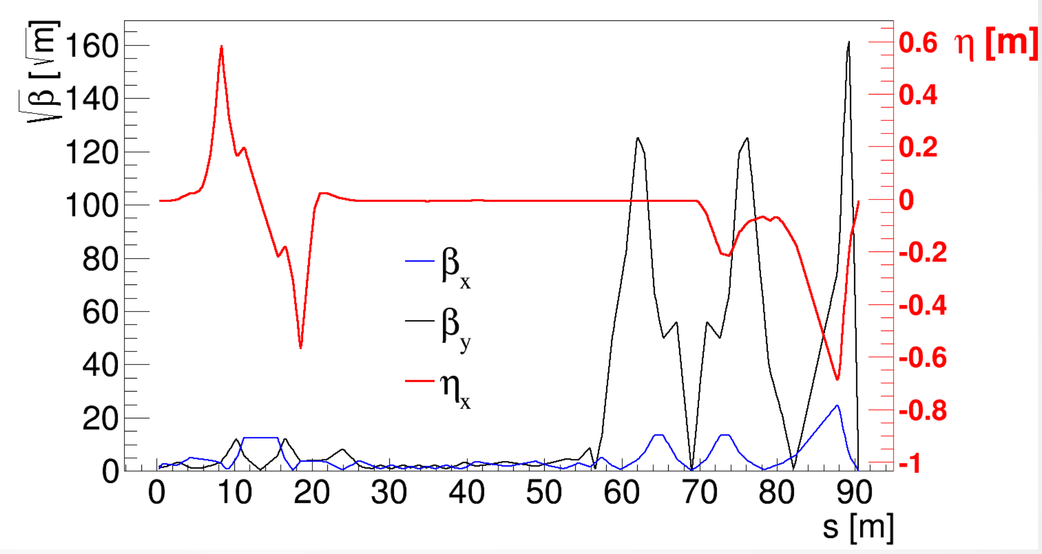


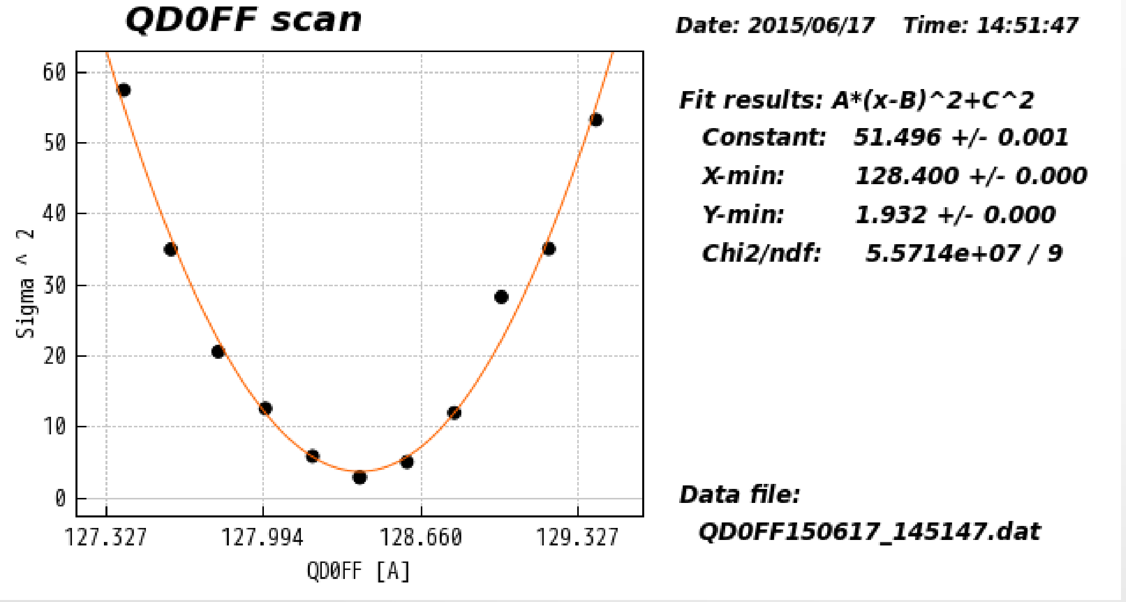


ATF octupoles status (M. Modena)

Half β* study at ATF2, June 2015

- Used $10\beta_x 0.5\beta_y$ optics (40mm, 50μm)
- **Expected IP vertical beam size: 26 nm**
  - after very fine sextupole tuning
  - assuming $\varepsilon_y = 12$ pm





β_y* can be estimated from QD0FF current scan

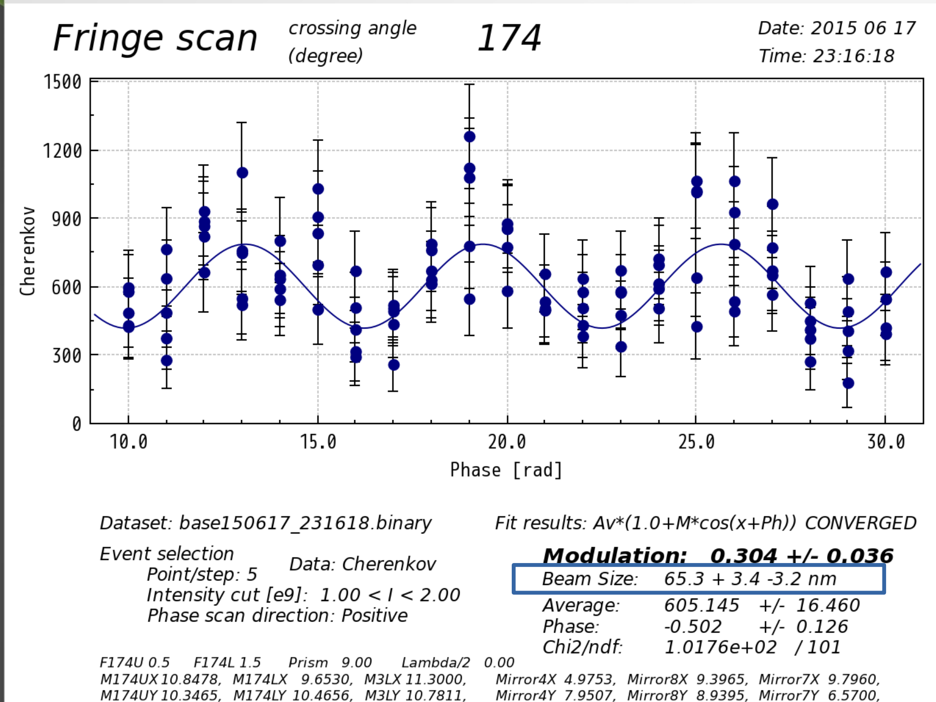
$$\boxed{\beta^* \approx \frac{\varepsilon}{\sigma^2}(\Delta f)^2}$$

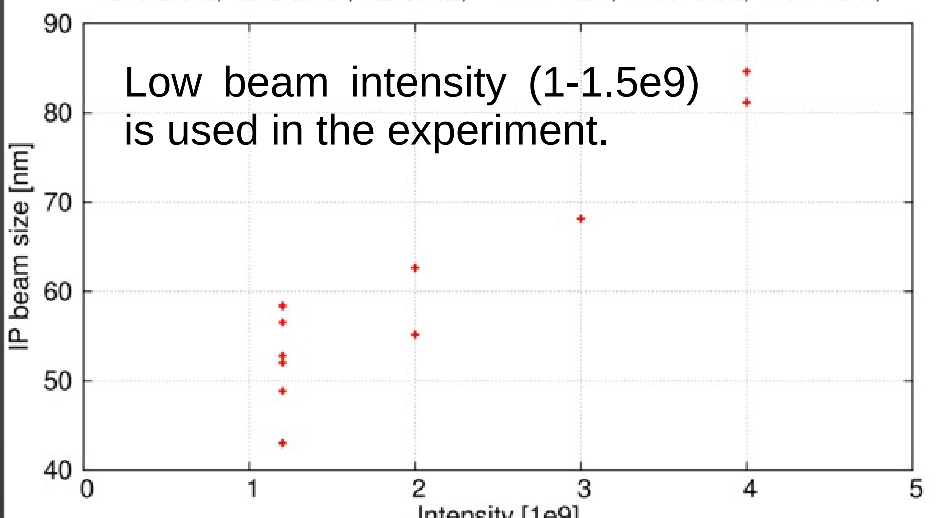
Δf = distance from nominal IP

Vertical emittance of 14.4 ± 1.1 pm was measured using the OTRs for an estimate of:

β_y = 47.3 ± 4.3 μm (design: 50 μm)

Beam size tuning in half β* optics

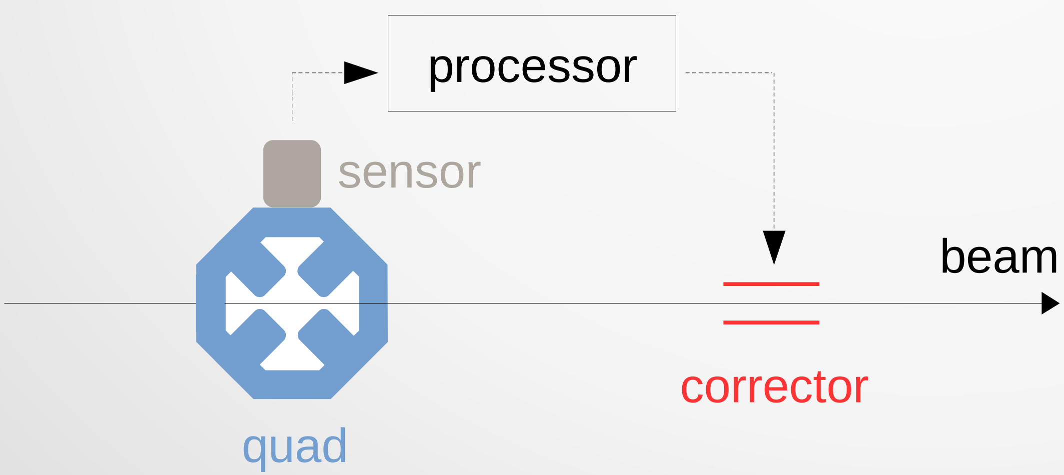




- The first experience with half β_y* optics was collected during the December 2014 and April-May-June 2015 runs in ATF2
- Beam size tuning (June 2015) with the linear knobs:
  - IP vertical beam size about 65 nm
  - Far from expected 28.5 nm (assuming measured emittance)
  - Same beam size was measured one day before in $10\beta_x 1\beta_y$ optics (should be easier to operate)
- The source of beam size growth (e.g. wakefields, beam position jitter, IP-BSM performance, non-optimal sextupole correction) has to be identified and mitigated
- Next experiment scheduled for December 2015. Plans: achieve good control over β* values, IP beam size tuning

Ground motion feed-forward

- Ground motion misaligns quadrupole magnets
  - Unwanted dipole kicks cause increase in emittance
- Ground motion feed-forward is a novel scheme using ground motion sensors to drive correctors



ADVANTAGES

Cheaper than active stabilization systems.

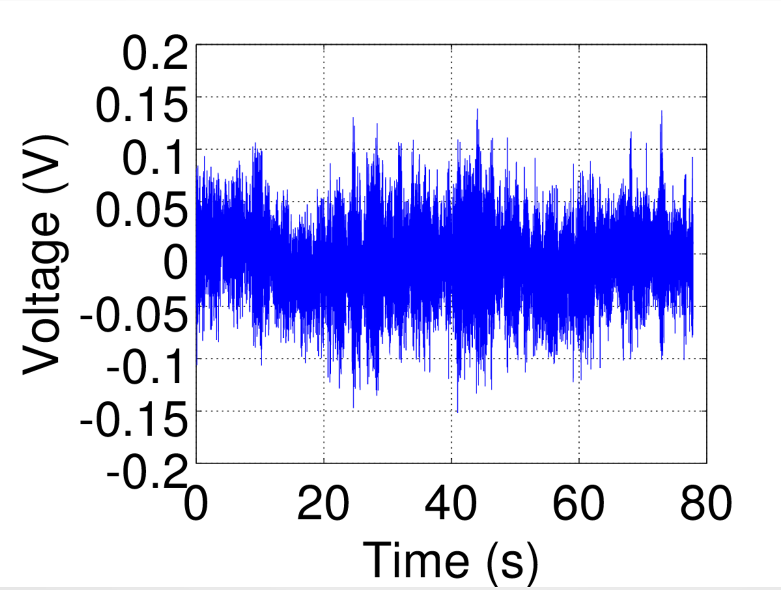
Correct frequencies out of limits for orbit feedback systems.

Ground motion sensors

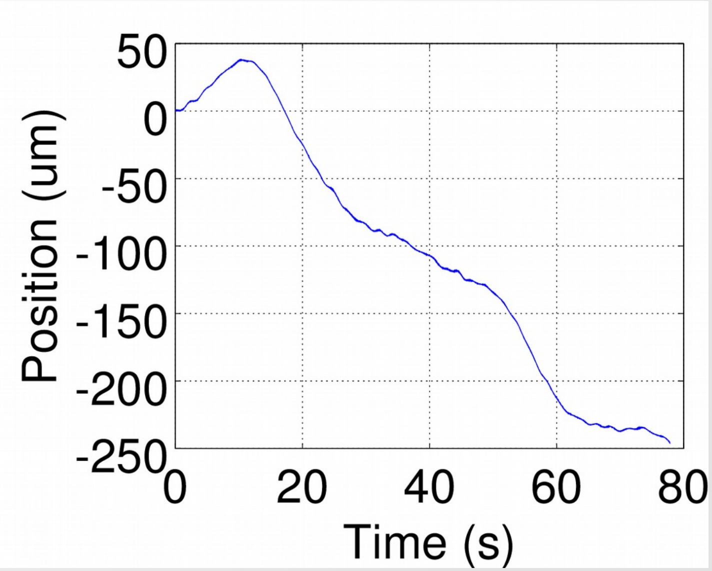
- 14 Güralp Systems CMG-6T seismometers
- Frequency response: 0.2 – 100 Hz
- Measure velocity in horizontal and vertical axes

integrate

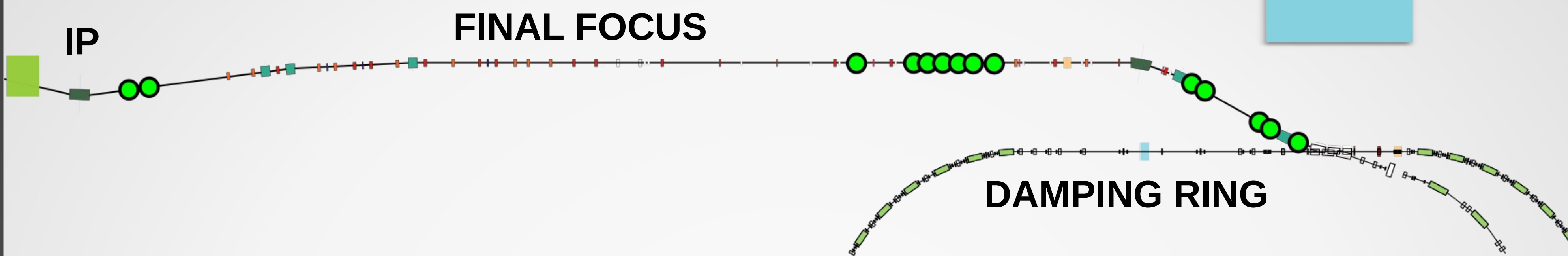
raw sensor output



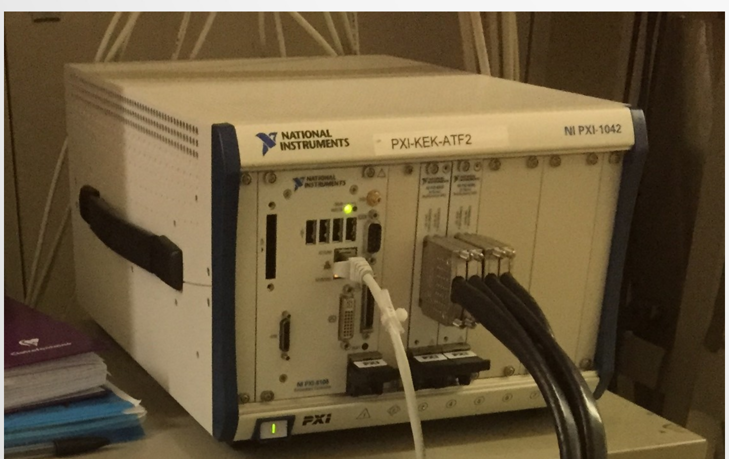
calibrated sensor position



Current setup at ATF2

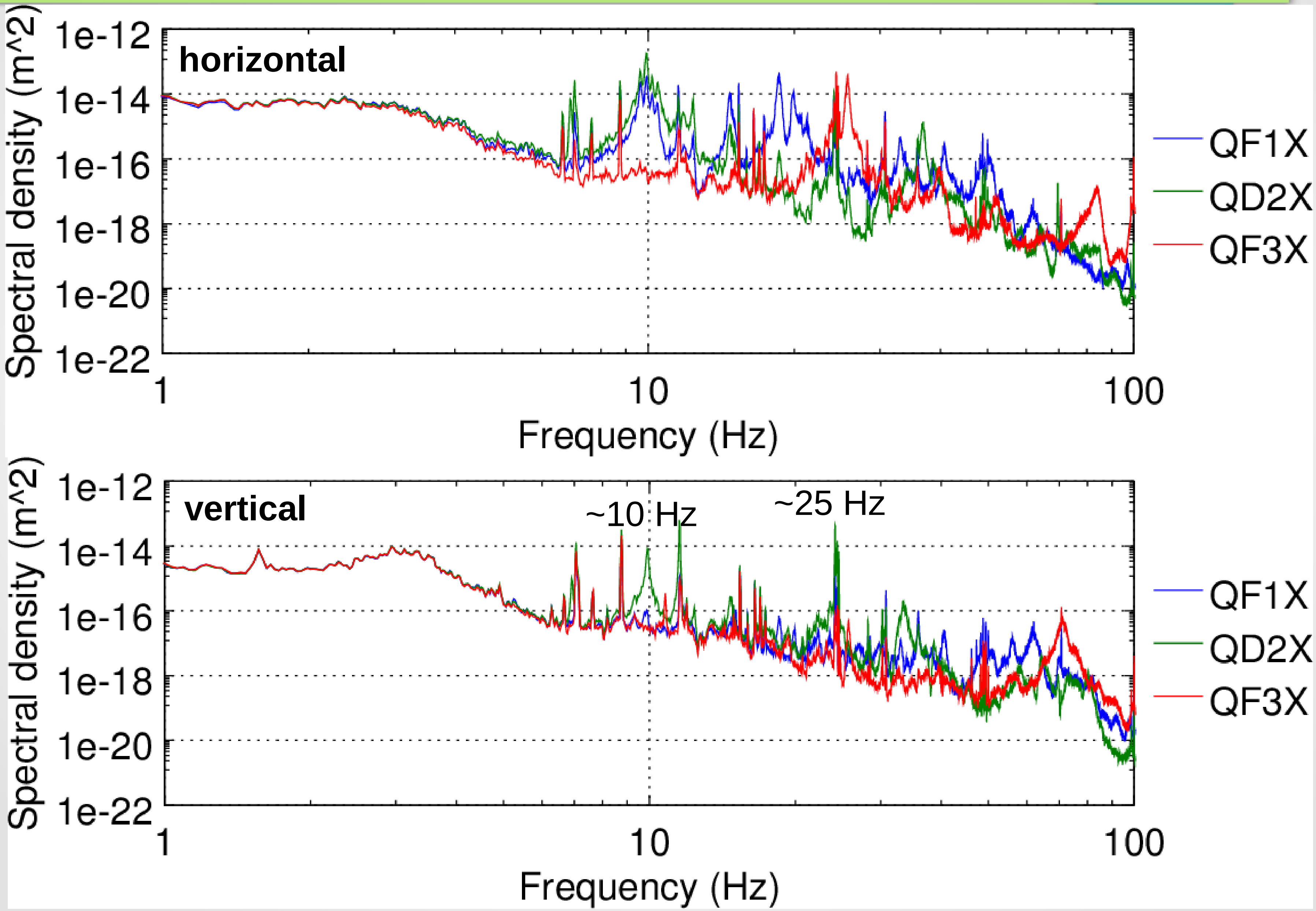


- Sensor distribution guided by simulation [10]
- Sensor readouts plus synchronization signal recorded with National Instruments PXI system



- PXI system: control chassis containing I/O modules
- Runs real-time LabVIEW

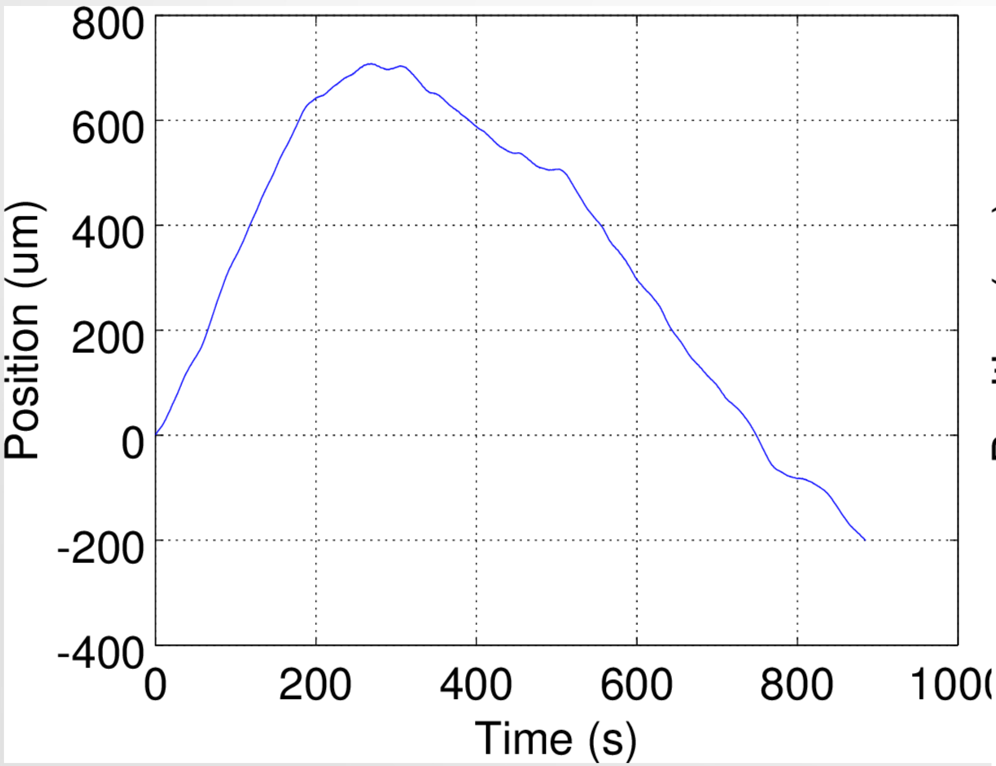
Ground motion at ATF2



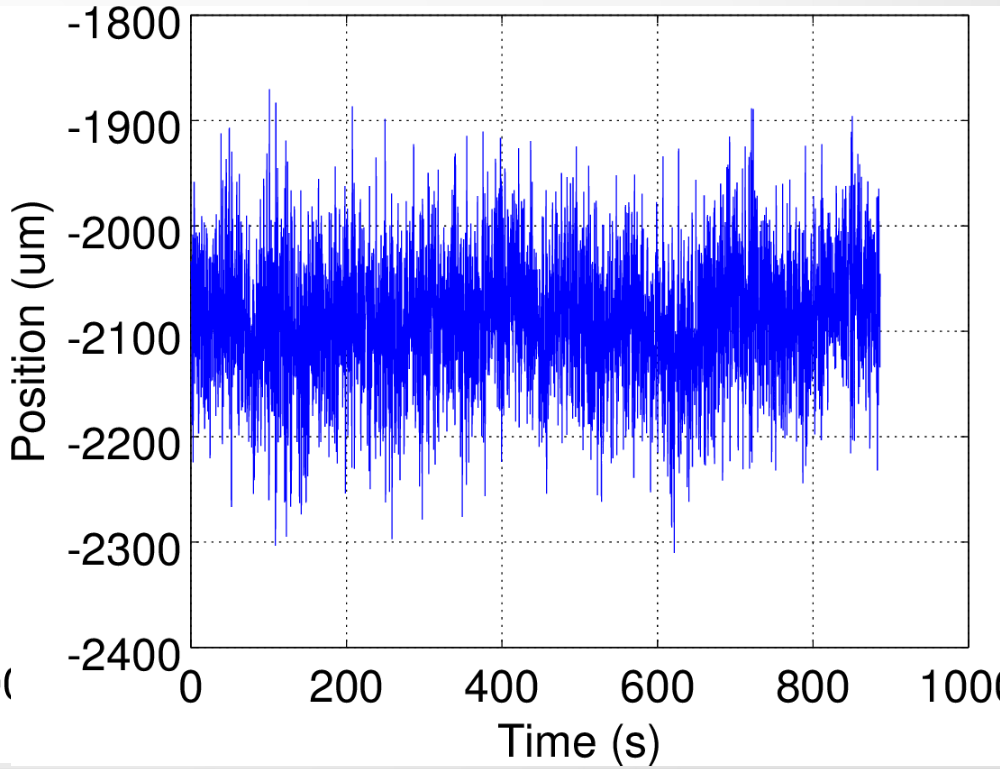
Effect of ground motion on orbit

- Simultaneously gather data from ground motion sensors and ATF2 BPMs
- Calculate correlation of each sensor/BPM pair

Position of sensor on **QD2X**



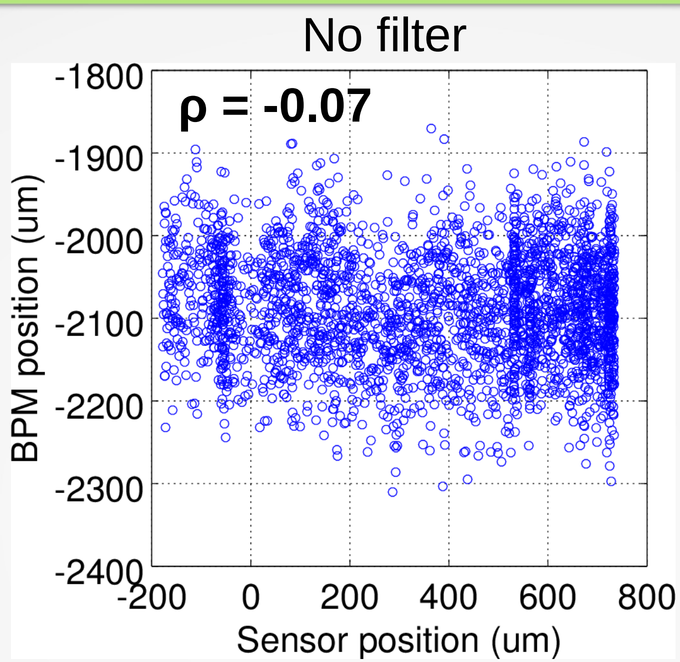
Position from BPM **MSD4FF**

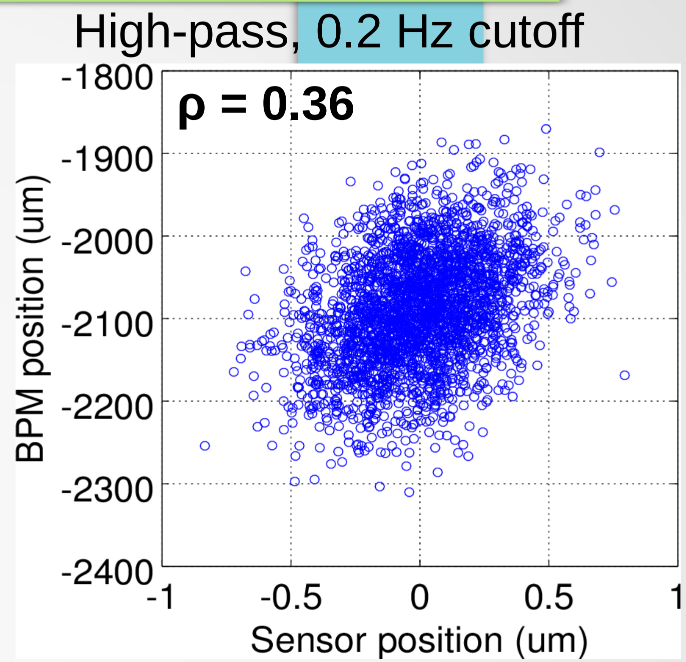


Factors affecting correlation

High noise below 0.2 Hz [11]

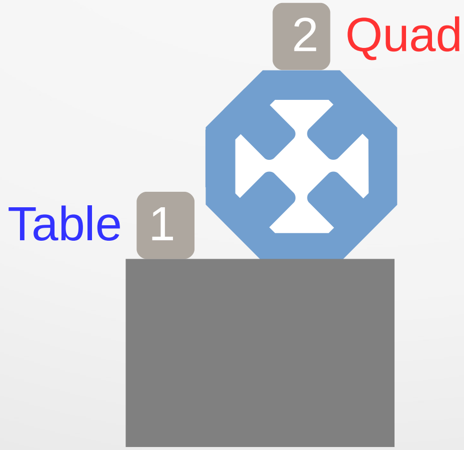
→ apply filter to sensor data

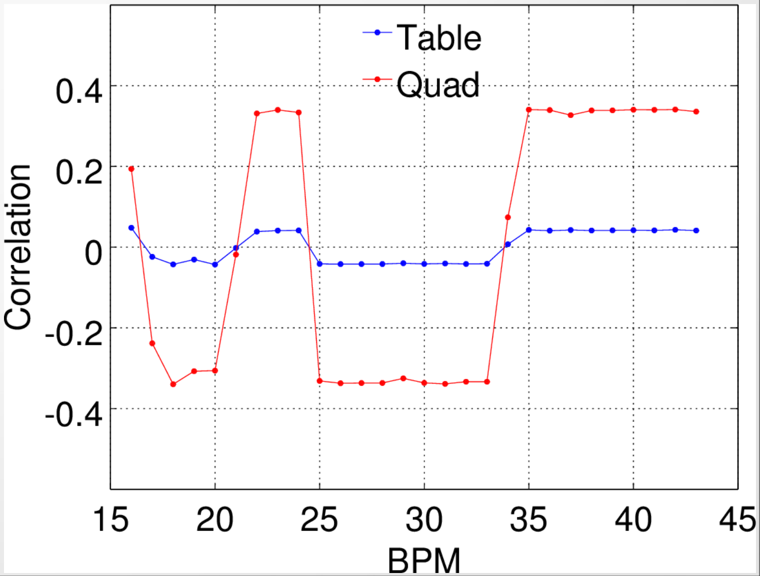




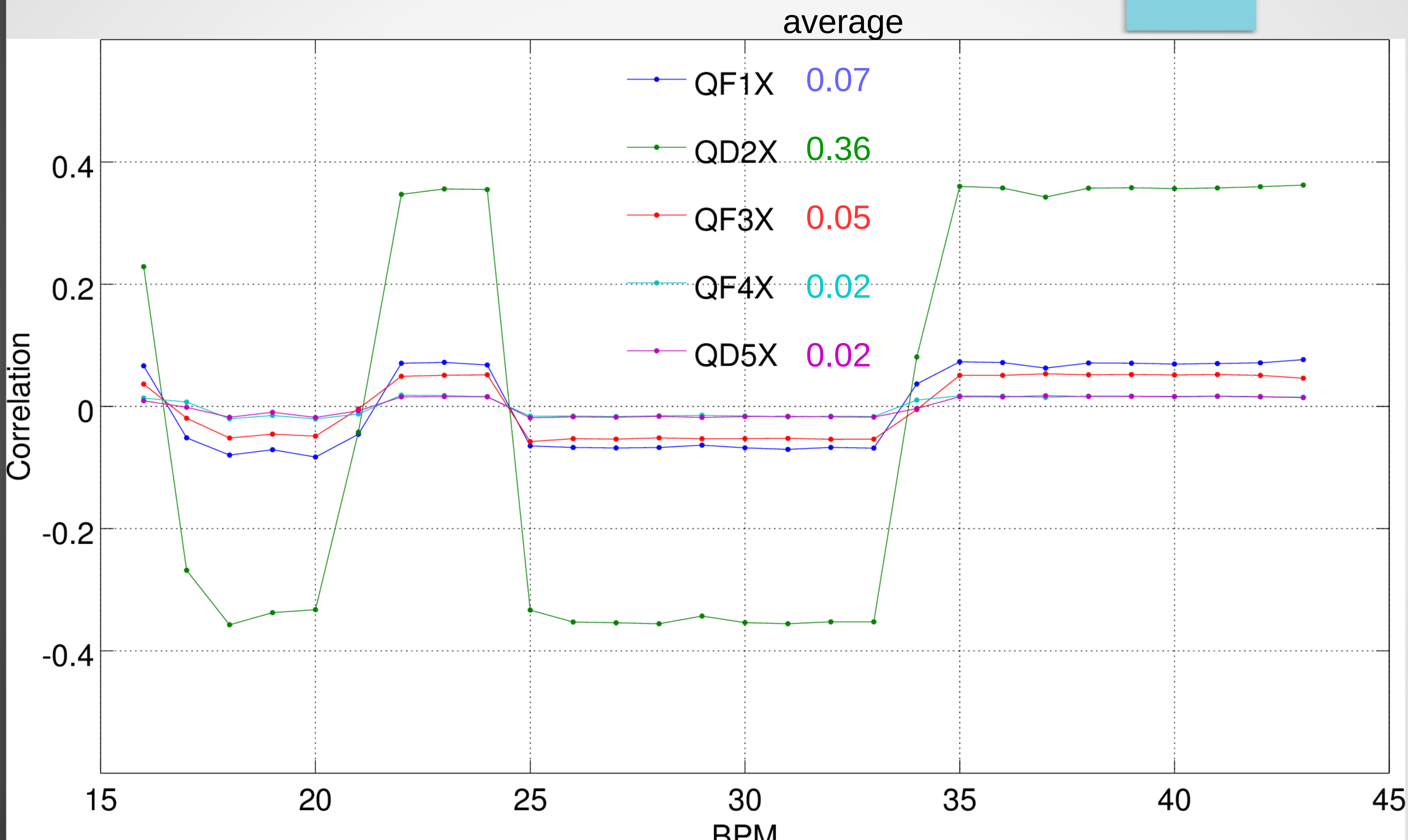
Ground motion measured depends on sensor placement

→ mount sensors on quads





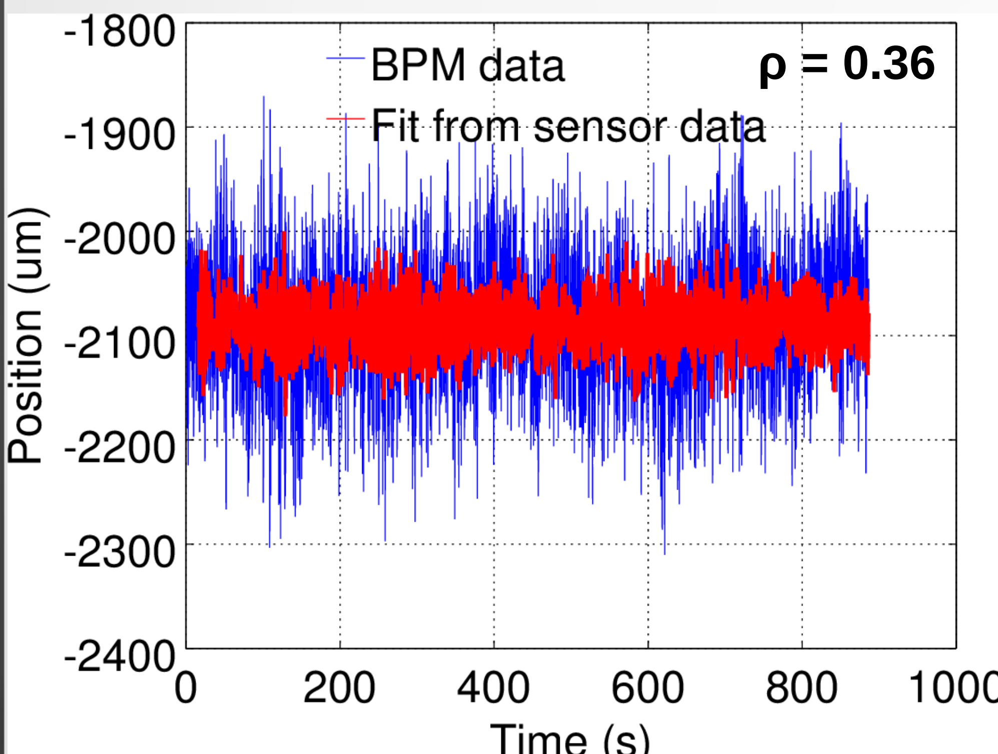
Sensor-BPM correlations



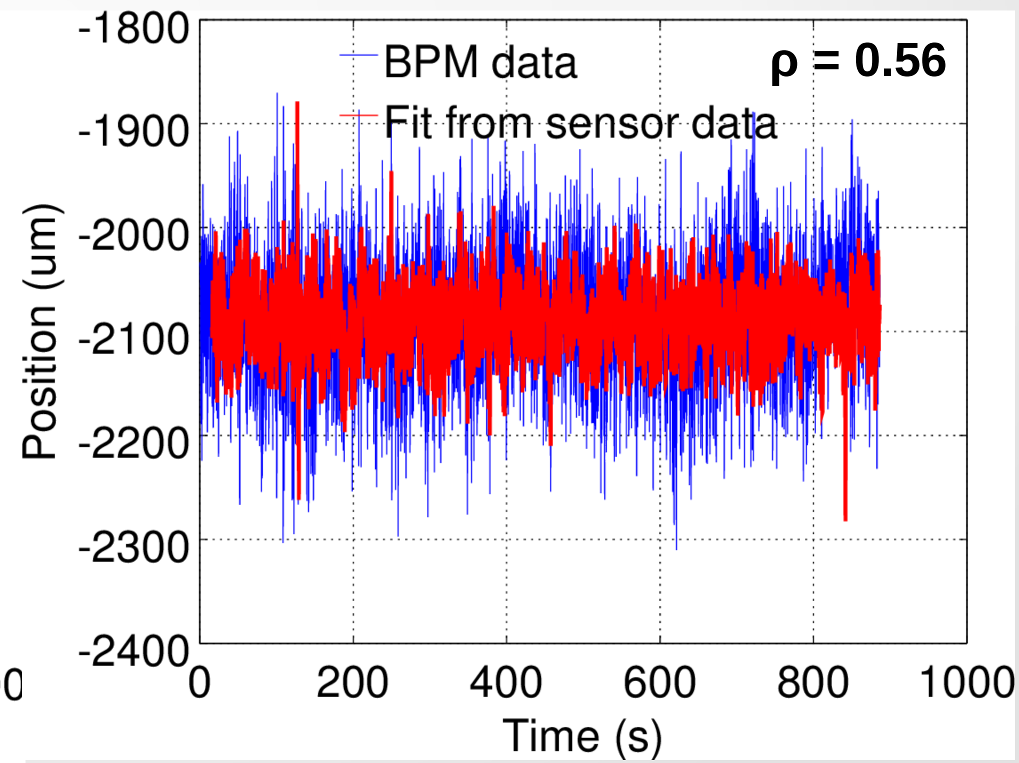
Simulating feed-forward

- Fit position at selected BPM as a function of (filtered) sensor position(s)
  - Consider single sensor / five sensor cases

BPM: MSD4FF, Sensors: QD2X



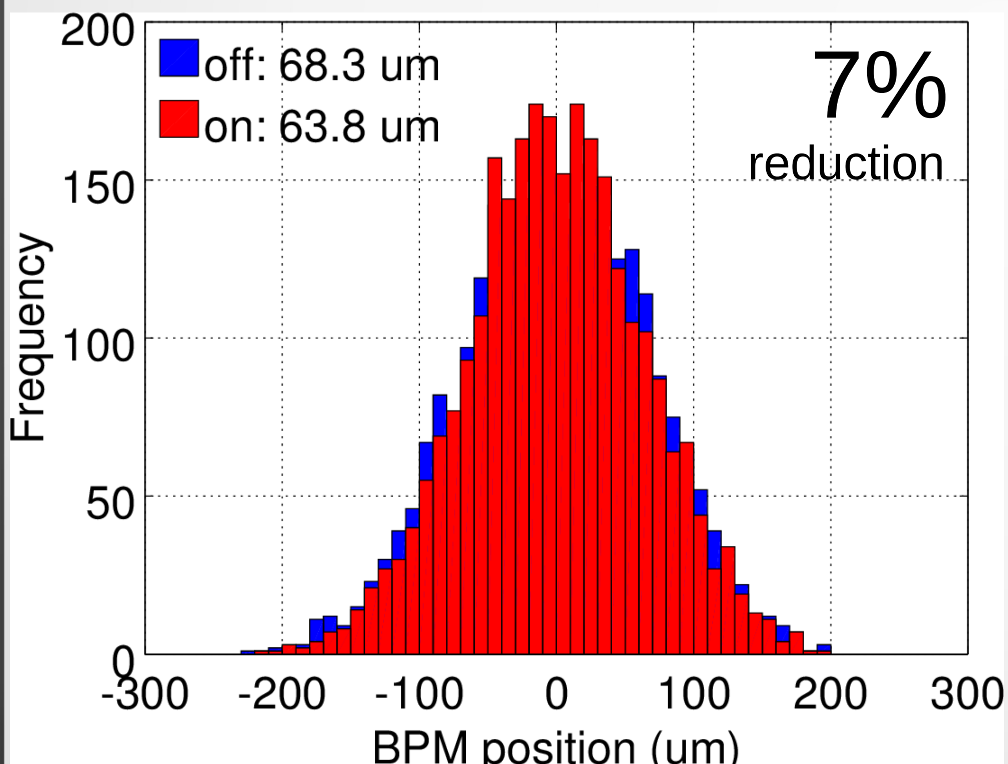
BPM: MSD4FF, Sensors: QF1X-QD5X



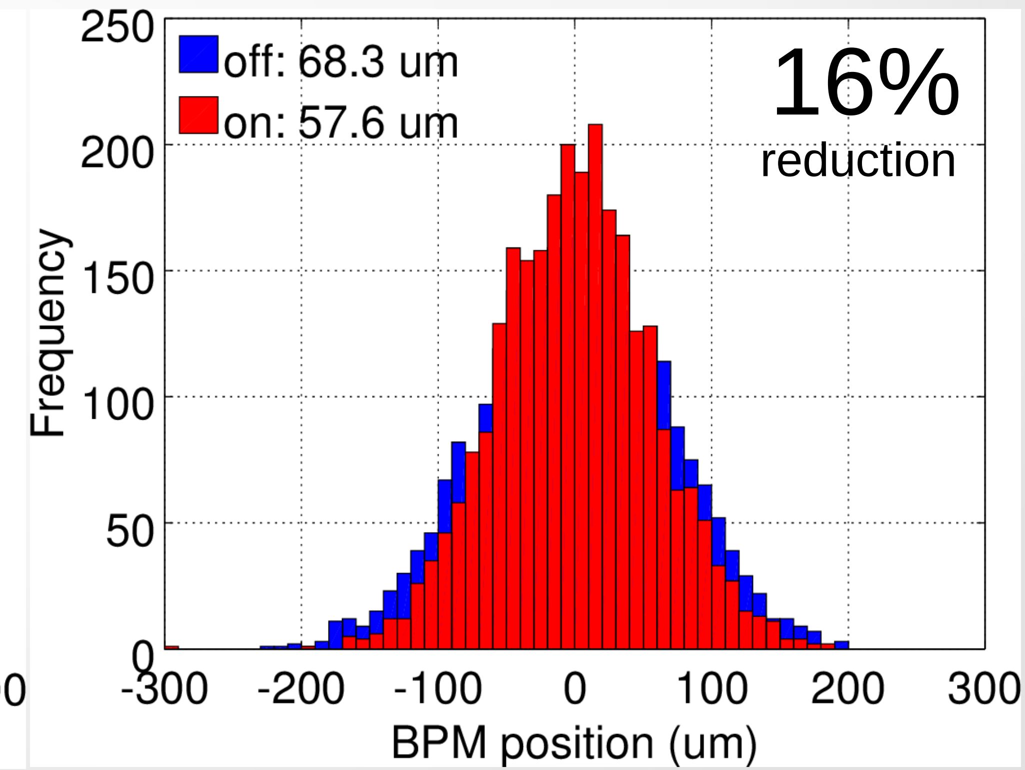
Expected jitter reduction

- Simulate correction by subtracting fit from actual BPM data to give a residual position
- Assumes perfect latency & correction resolution

BPM: MSD4FF, Sensors: QD2X

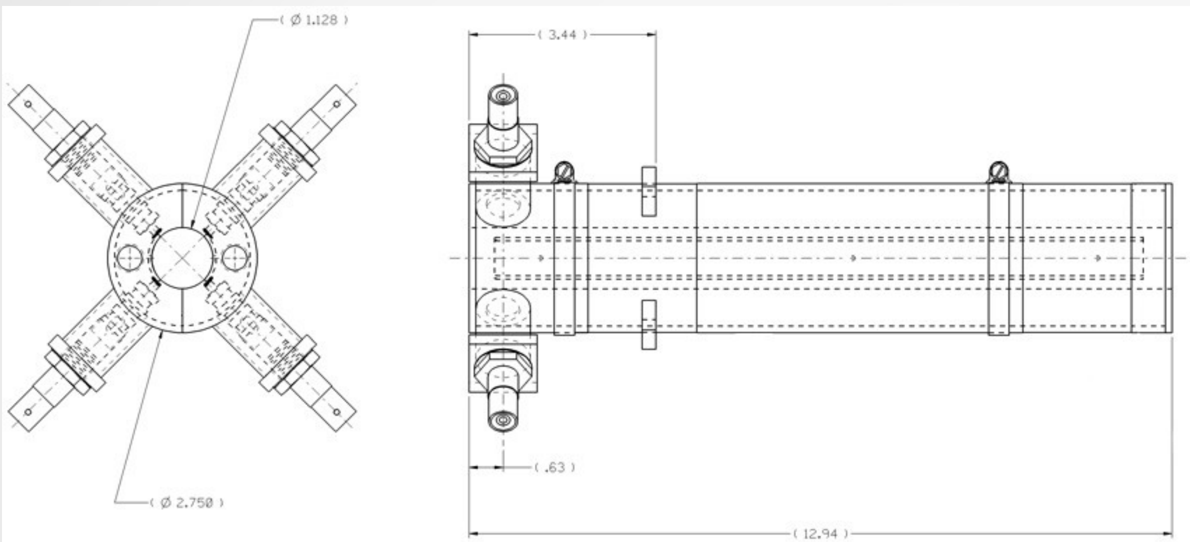


BPM: MSD4FF, Sensors: QF1X-QD5X



Feed-forward setup

- Corrector: use FONT stripline kicker(s)



Many thanks to the FONT team, University of Oxford, for the use of their hardware

- Processor: NI CompactRIO FPGA-based system
  - Low feed-forward latency compared to existing PXI hardware

Summary

- **Ultra low β* optics**
  - Useful for studying the behavior of a machine with chromaticity similar to CLIC
  - Makes beam more sensitive to imperfections but will install a pair of octupoles in March 2016 to mitigate this
- **Ground motion feed-forward**
  - Ground motion feed-forward aims to reduce beam jitter caused by dynamic displacement of quads
  - High correlation of sensor position and beam motion achieved by mounting sensors directly on quads and high-pass filtering
  - Expect ~5% reduction in beam jitter if correcting using just the QD2X sensor and a maximum expected reduction ~15%
- Both studies will continue in December 2015

References

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[11] C. Collette et al. "*Review: Inertial Sensors for Low-Frequency Seismic Vibration Measurement*", Bull. Seismol. Soc. Am. 102, 1289 (2012)