OMC improvements and prospects for 2015.

Andy Langner, on behalf of the OMC-Team

European Organization for Nuclear Research (CERN) & Universität Hamburg

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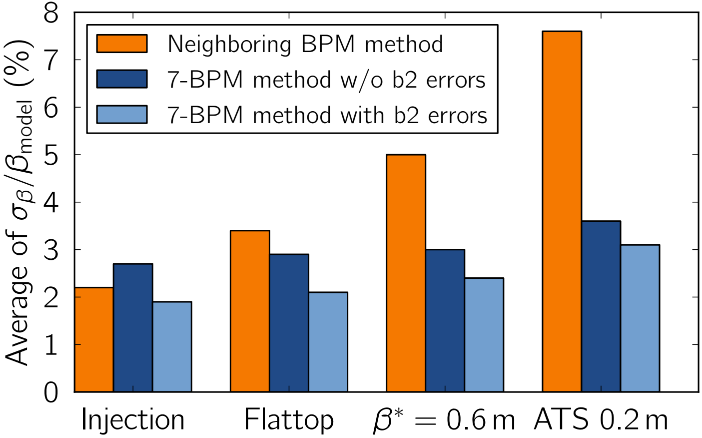
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Outline.

1. Improved optics measurement resolution
   1.1 Propagation to elements
   1.2 β-beating estimates for 2015
2. Towards a coupling feedback
3. Automatic local corrections
4. Setting of MSS, MCS, MCO, MCD
5. Software improvements

Improved optics measurement resolution.

- BPM selection algorithm (7-BPM method) **Better resolution**
- Dipole b_2 in model for analysis **More precise**

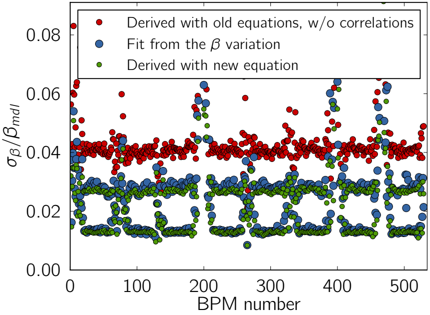


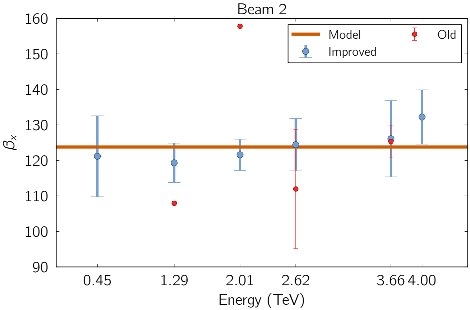
Propagation of optical functions & Corrections.

	How it is done before	now
Value of β, α from forth and back propagation	simple average $\frac{\beta_1+\beta_2}{2}$	weighted average $\frac{\frac{1}{\sigma_1}\beta_1+\frac{1}{\sigma_2}\beta_2}{\frac{1}{\sigma_1}+\frac{1}{\sigma_2}}$
Error propagation (β, α, Dispersion, Coupling)	2 MAD-X simulations	Analytic equations
Error bar of propagated phase (used in corrections)	not computed	Analytic equation

More precise optical functions & error bars

Study on the error bar.





- Correlations occur when using the same BPM more often
- If not taken into account $\rightarrow$ general overestimation of the error bar

- Estimating the error bar from initial uncertainty using MAD-X simulations has sometimes given too small error bars

at least 5 measurements recommened

A. Langner, R. Tomás 'Improvements in the Optics Measurement Resolution for the LHC', IPAC'14

Hardware improvements.

Motivation:

- More accurate phase measurements
- Time efficiency

Request:

- Longer AC dipole excitation
- Longer BPM acquisition

Measure for at least 6,000 turns

- Improved non-linear calibrations for BPMs are expected

  A. Nosych, 'Geometrical non-linearity correction procedure of LHC beam position monitors'

β-beat estimates for 2015 at $\beta^* = 40$cm.

	peak $\Delta\beta/\beta$
Extrapolation from 2012	100% (B1)
	130% (B2)
Missing MQT	2-5%
magnets	(locally)
Dipole b_2 errors	5-7%
Triplet fringe fields	1%
Hysteresis	0.5%
Saturation	1%

Estimate for 2015

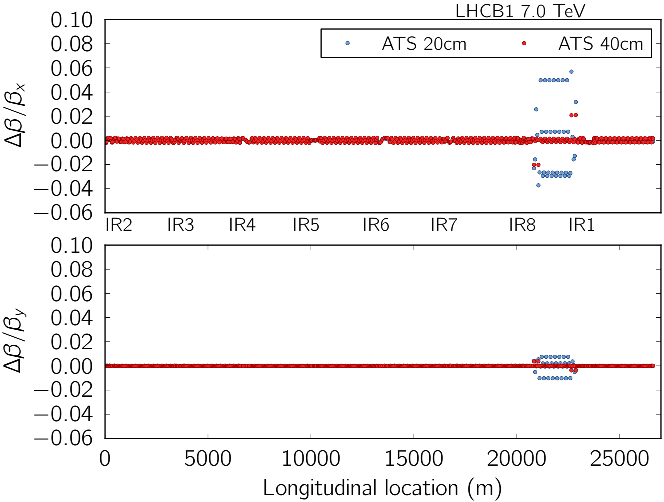
peak $\Delta\beta/\beta$

100% (B1)
140% (B2)

(before corrections)

Missing MQT magnets.

- Tune shift of 0.08 applied
- 4 MQTs in arc81 switched off
- Compensated by other MQTs from the same arc
- Global beta-beat is negligible
- 2-5% in arc81



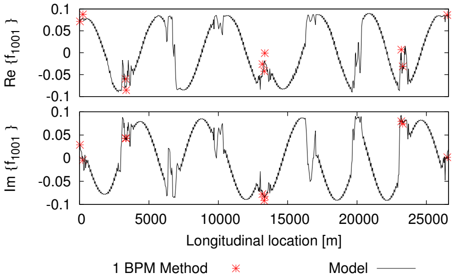
Towards a Coupling Feedback.

Motivation:

- BBQ coupling measurement not suited for a coupling feedback

Coupling feedback using Diode ORbit and OScillation (DOROS)

- $\approx$ 10 BPMs close to the IPs
- Excitation in the 10 µm range for a high quality measurement
- Looks promising in simulations [1]

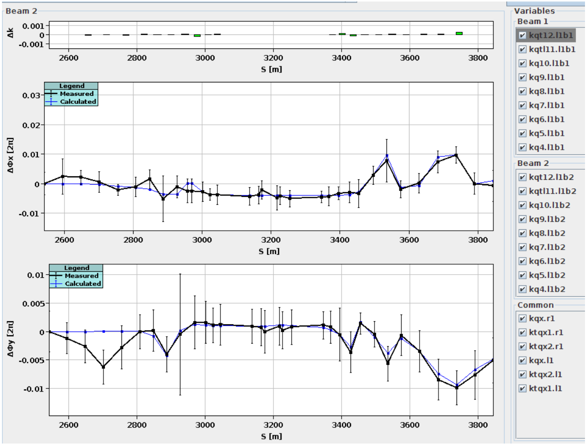


[1] T. Persson and R. Tomás, 'Improved Control of the Betatron Coupling in the Large Hadron Collider', Phys. Rev. ST Accel. Beams **17**, 051004

Automatic local corrections.

Measurement of phases → Find quadrupole setting which reproduces the error pattern → Apply setting with negative sign

- Step 2 can be **time consuming** during MD **when done manually**
- Automatic tool to find quadrupole settings
  - Match both beams with MAD-X
  - **takes around 90 sec**
  - Implemented in the GUI



Arc Skew Sextupoles (MSS).

Correction of

- Chromatic coupling $\frac{|\Delta f_{1001}|}{\Delta\delta}$
- Main source: a_3 in arc dipoles

Setup

- Four MSS per arc
- $\approx$ 180-90-180 deg phase advance

Method

- Arc-by-arc
- Response matrix
  - considers cancellation between arcs
  - lower strengths

- Commissioned with beam in a MD 2012, **but not used**
- **Should be implemented in Run II**

	$\frac{|\Delta f_{1001}|}{\Delta\delta}$ Before corrections	After corrections
Beam 1	32 ± 5	13 ± 5
Beam 2	50 ± 9	31 ± 9

Sextupole Corrector (MCS).

Correction of	Setup	How to check
• b_3 in arc dipoles	• Mounted at the end of arc dipoles	• π orbit bumps [1] → b_3 feed down to b_2 → correct shift in tune difference

- MCS have been used, but **no beam based checks**
- **Beam based checks recommended in commissioning of Run II**

[1] M. Hayes, 'Tolerances of the spool piece correction system for the LHC', LHC Project Report 590

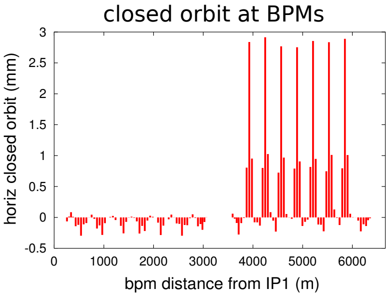
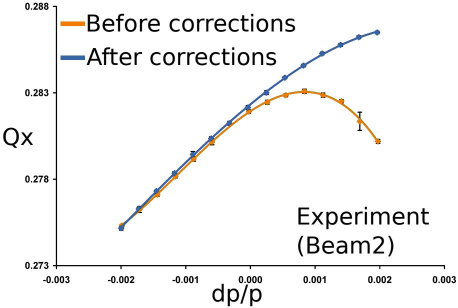
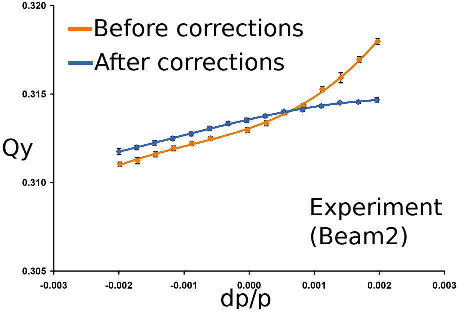


Figure from [1]

Octupole (MCO) and Decapole (MCD) Correctors.

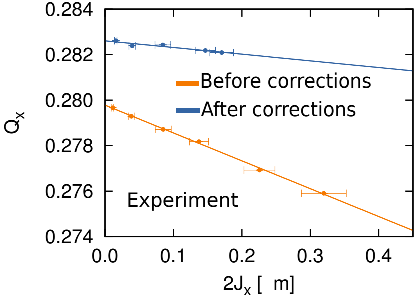
Correction of	Setup	Effect on
• b_4 in arc dipoles (MCO) • b_5 in arc dipoles (MCD)	• MCO nested in MCD $\rightarrow$ MCDO • Mounted at end of every second arc dipole	• Amplitude detuning • non-linear chromaticity

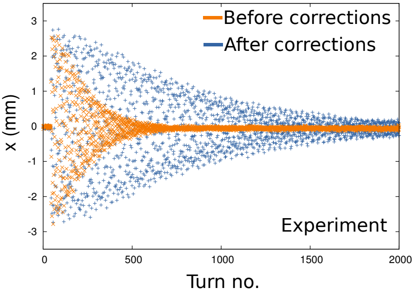




Octupole (MCO) and Decapole (MCD) Correctors.

- Substantial amount of **Q” and Q”’ missing from model**
- Allowed horizontal misalignment of MCDs (<0.12 mm) has only small effect
- MCO has **large hysteresis error** $\rightarrow$ explains 30% to 55% of missing Q”
- Q” and Q”’ corrections reduced also amplitude detuning and improved decoherence





E. Maclean, ’Non-linear modeling and machine set-up’, OMC review 2013

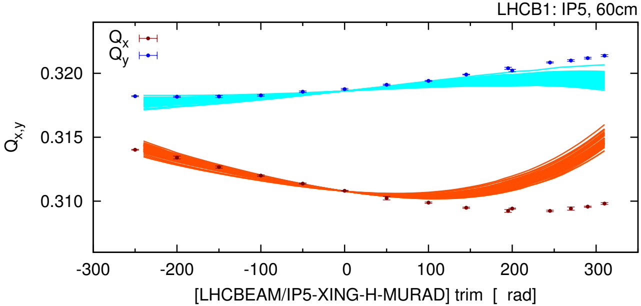
Octupole (MCO) and Decapole (MCD) Correctors.

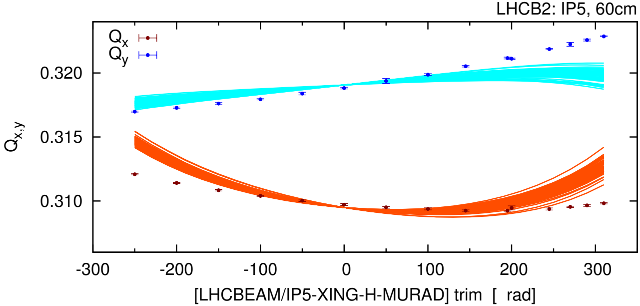
Injection	**Correction proposed**
Flattop	Amplitude detuning was negligible in 2012
Squeeze	Main source are triplet errors $\rightarrow$ **Job of the triplet correctors**

Triplet correctors.

- IR1 IR2 roughly well understood
- **IR5 not understood**

→ MD activities?





Software improvements.

- Since 2012 computer scientists are optimizing the OMC software
- Software development best practices
  - Version control (Git)
  - Unit tests
  - Static analysis

	2013	2014
Lines of code	331 k	141 k
Static analysis issues	479 k	165 k
GUI Critical bugs	7	0
GUI Time startup to corrections	25 min	2 min
GUI Memory usage per shot	100 MB	12 MB
GUI Unit test coverage	0%	43%

Faster and more robust execution

Thank you for your attention.

OMC-Team: Thomas Bach, Andy Langner, Yngve Levinsen, Ewen Maclean, Viktor Maier, Jaime Martinez Vazquez, Meghan Mcateer, Tobias Persson, Piotr Skowronski, Rogelio Tomás, Robert Westenberger, Simon White

Backup Slides.

β^* measurement 2012.

- Measurement from 30.03.2012
- Optics configuration: 0.6m / 3m / 0.6m / 3m

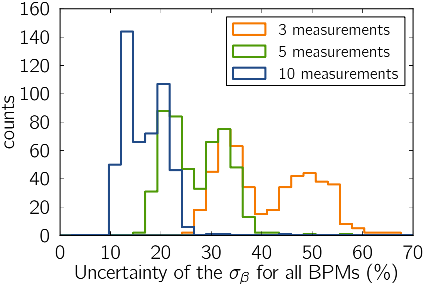
Beam 1	$\beta^*{}_x$ (m)	$\beta^*{}_y$ (m)
IP1	0.61 ± 0.07	0.613 ± 0.013
IP2	3.02 ± 0.18	2.94 ± 0.05
IP5	0.597 ± 0.015	0.594 ± 0.010
IP8	3.1 ± 1.3	3.04 ± 0.16

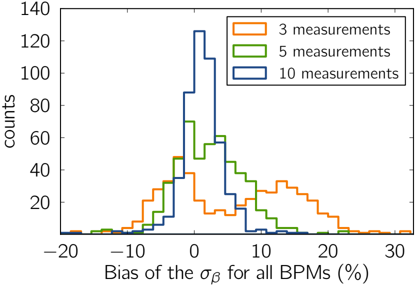
Beam 2	$\beta^*{}_x$ (m)	$\beta^*{}_y$ (m)
IP1	0.59 ± 0.02	0.612 ± 0.012
IP2	2.8 ± 0.4	3.01 ± 0.13
IP5	0.59 ± 0.02	0.62 ± 0.07
IP8	2.99 ± 0.14	2.98 ± 0.08

Uncertainty of the error bar for β from simulations.

- Simulated turn-by-turn data (Gaussian noise of 300 μm) (500 data sets)
- Run analysis with different amount of measurement data (100 times for statistics)

→ Observe the deviation of the derived error bar to the known one at each BPM (for β-function)





A. Langner, R. Tomás 'Improvements in the Optics Measurement Resolution for the LHC', IPAC'14

MCDO.

Quoted from: E. Maclean, 'Non-linear modeling and machine set-up', OMC review 2013

"From difference between modelled and measured $\Delta Q''$ on correction with MCDO, the allowed systematic misalignment is:
-0.12 mm $\leq \delta_x \leq +0.05$ mm (based on $\pm 2\sigma_{fit}$)
Best fit: $\delta_x = -0.055$ mm $\rightarrow Q''_x = -200$ units, $Q''_y = 150$ units"

	Q''_x (10^3)	Q''_y (10^3)	Q'''_x (10^6)	Q'''_y (10^6)
meas	-2.1 (0.02)	0.74 (0.03)	-1.9 (0.06)	0.8 (0.09)
meas-mod	-1.8 (0.1)	0.6 (0.1)	-1.0 (0.1)	0.7 (0.1)
(mod_hyst)-mod	-0.5	0.34	0.006	-0.003

Missing Q'' in model: ≈ -1100 units in x, ≈ 100 units in y