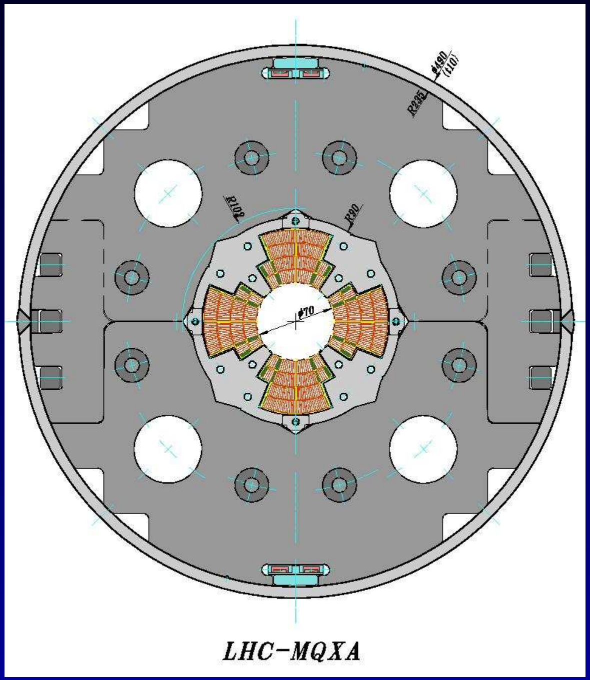

β-Beating correction in the LHC

R. Tomás & R. Calaga,
O. Bruning, S. Fartoukh, M. Giovannozzi &
Y. Papaphilippou

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Sources of β-beating

Sources considered in [Project Report-501]:

- The random b_2 of the LHC main dipoles
- The field error of all the quadrupoles in the machine
- Feed down from sextupoles due to alignment errors and closed orbit distortion ($\sigma \approx 200\mu m$)
- The errors due to the tune shift generated by the trim quadrupoles (Not considered here, β-beat correction uses all quad circuits)

Quadrupole corrector circuits

Basically all 210 k_1 defined in MADX: kq9.r2b2, kqd.a81, kq5.l4b2, ktqx2.r5, kq6.l5b2, kqtl11.l7b2, kq4.r2b2, kqt13.l1b2, ktqx2.r8, ktqx1.l1, kqt12.r8b2, ktqx1.l2, kqtd.a67b2, kqtf.a78b2, kq6.r4b2, kq9.l8b2, kqtl7.r3b2, kqtl11.r6b2, kq7.r5b2, ktqx1.l5, kq4.l8b2, kq8.r6b2, kq10.r8b2, ktqx1.l8, kqt12.l5b2, kq4.lr3, kq6.l1b2, kqt13.l6b2, kq5.r8b2, kqtl11.l3b2, kq7.l2b2, kq4.lr7, kqt12.r4b2, kq10.l5b2, kqf.a23, kqtd.a78b2, kqt13.r5b2, kq9.l4b2, kqtl11.r2b2, kq7.r1b2, kq10.r4b2, ktqx1.r1, kq8.r2b2, ktqx1.r2, kq5.l5b2, kqtl10.l7b2, kqf.a45, ktqx1.r5, kqt12.l1b2, kqtl11.l8b2, kqt13.l2b2, ktqx1.r8, kq5.r4b2, kq8.l8b2, kqtl9.l7b2, kq6.r5b2, kq5.lr3, kqtl11.r7b2, kq10.l1b2, kqt13.r1b2, kq5.lr7, kqf.a67, kqf.a81, kqd.a12, kq9.r8b2, kq5.l1b2, kqt12.l6b2, kq4.r8b2, kqtl10.l3b2, kqt13.l7b2, kq6.l2b2, kqtl11.l4b2, kqt12.r5b2, kqd.a34, kq8.l4b2, kq10.l6b2, kq6.r1b2, kqtl9.l3b2, kqt13.r6b2, kq9.l5b2, kqtl11.r3b2, kqtf.a81b2, kq7.r2b2, kq10.r5b2, kqx.l1, kq4.l5b2, kqx.l2, kq5.l6b2, kq9.r4b2, kqt12.l2b2, kqd.a56, kqx.l5,

β-beating observable

- The measurement of β-functions needs of good BPM calibration or good knowledge of focusing properties $\rightarrow$ Not suitable for commissioning
- Phase advance between nearby BPMs is a robust observable independent of BPM calibration, offset and tilt and focusing errors, thus phase-beating:

$$\Delta\phi_{n+1} = \phi_{n+1}^{meas} - \phi_n^{meas} - (\phi_{n+1}^{mod} - \phi_n^{mod})$$

- ϕ_n^{meas} is measured with standard FFT or SVD techniques of kicked data

β-beating correction

- We compute the non-square matrix **R** from ideal MADX model as

$$\vec{\Delta\phi} = \mathbf{R}\vec{\Delta k_1}$$

- we invert **R** using the SVD so the correction is

$$\vec{\Delta k_1} = -\mathbf{R}^{-1}\vec{\Delta\phi}$$

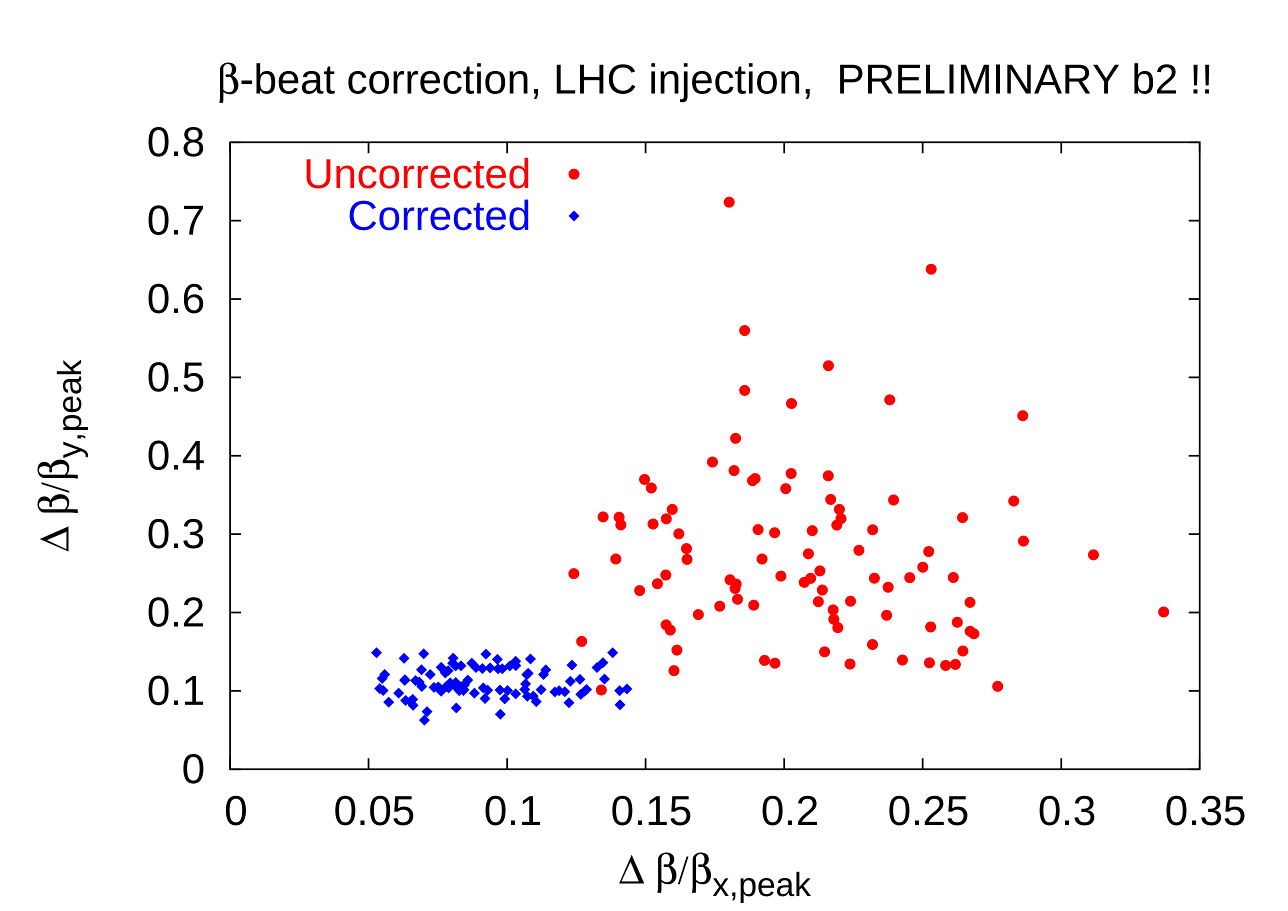
- However correction is not guaranteed, depending on the particular configuration of quadrupole circuits and the linearity of the system
- Simulations are needed to prove correction

Simulation ingredients

- All b_2 errors from measurements (ongoing, Massimo, Yannis, etc.)
- Extra Gaussian noise of 5 units added to quad b2 to account for uncertainty
- rms misalignments of all sextupoles, $\sigma_{x,y} = 2$mm
- Gaussian noise, σ_ϕ, added to the MADX phase to account for error measurements. σ_ϕ depends on BPM noise ($\sigma_{noise} \approx 200\mu$m), decoherence time (N=400 turns?) and kick amplitude (a=4 mm?). Tracking simulations on the way, analytical:

$$\sigma_\phi \approx \sqrt{\frac{2}{N}} \frac{\sigma_{noise}}{a} = 0.2^\circ$$

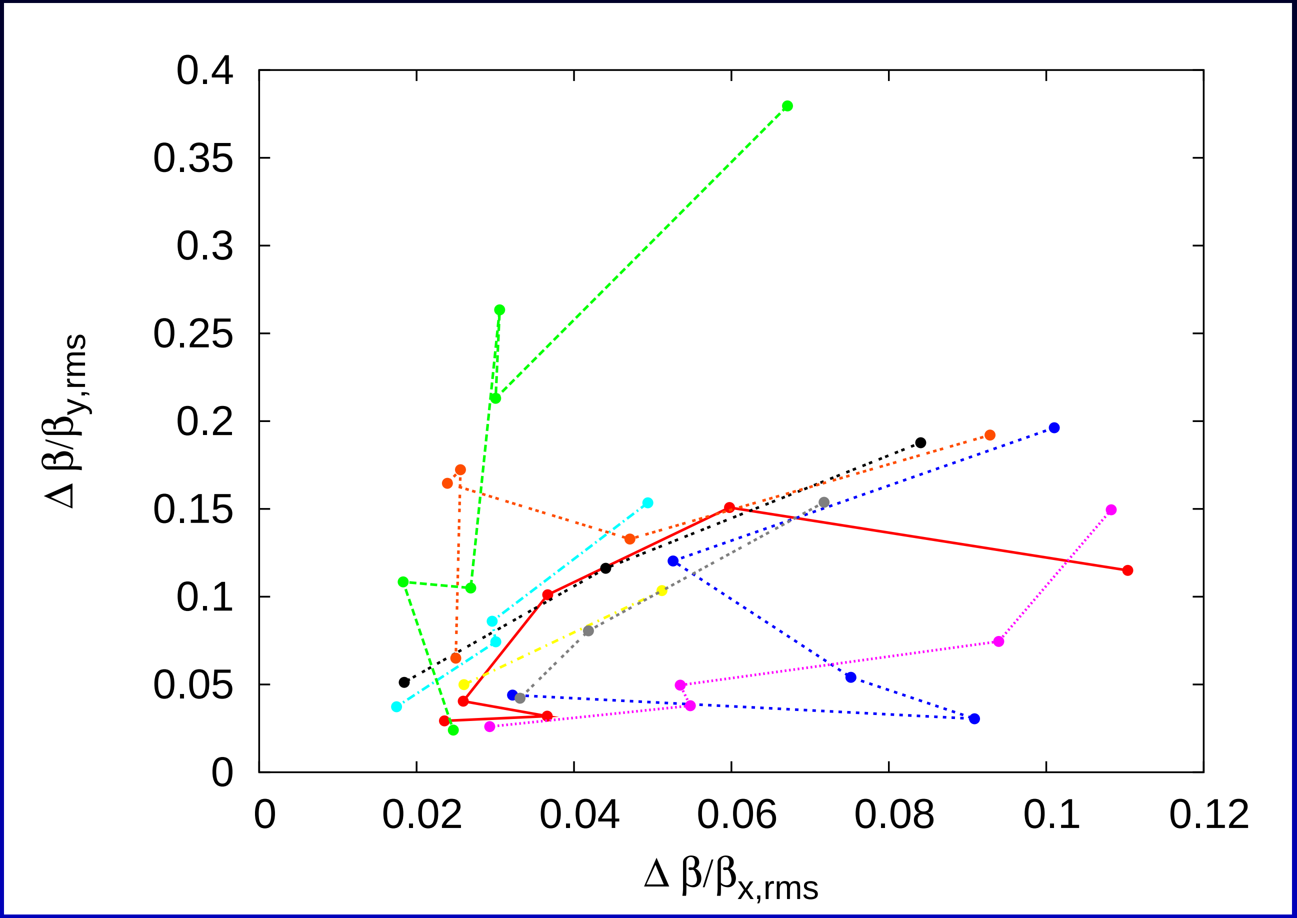
Preliminary results



→ Correction seems to work!

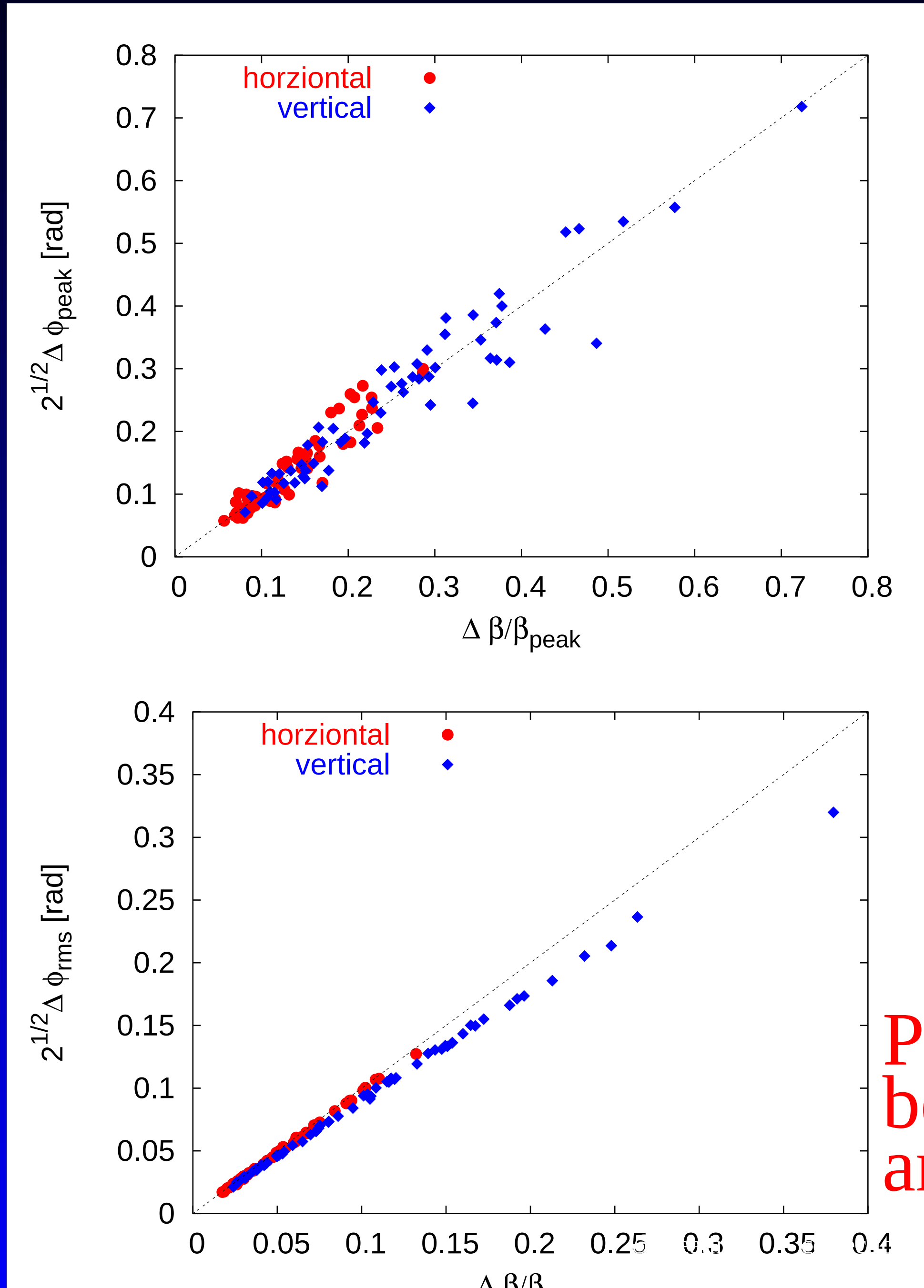
→ Best peak corrections in the 5% level

Iterations: extreme cases



→ Maximum of 5 iterations required

β-beat Vs phase-beat



Precise relation between $\Delta\phi_{rms}$ and $\Delta\beta/\beta_{rms}$

Conclussions and outlook

- A β-beat correction based on the phase measurement works so far
- The most realistic b2 needs to be included in the model
- Tracking for the determination of the measurement error
- Other sources could be included (feed down from b3, quad tilts)
- Limitations on correction circuits?
- Your suggestions...

Illustration of β-beat at the BPMs

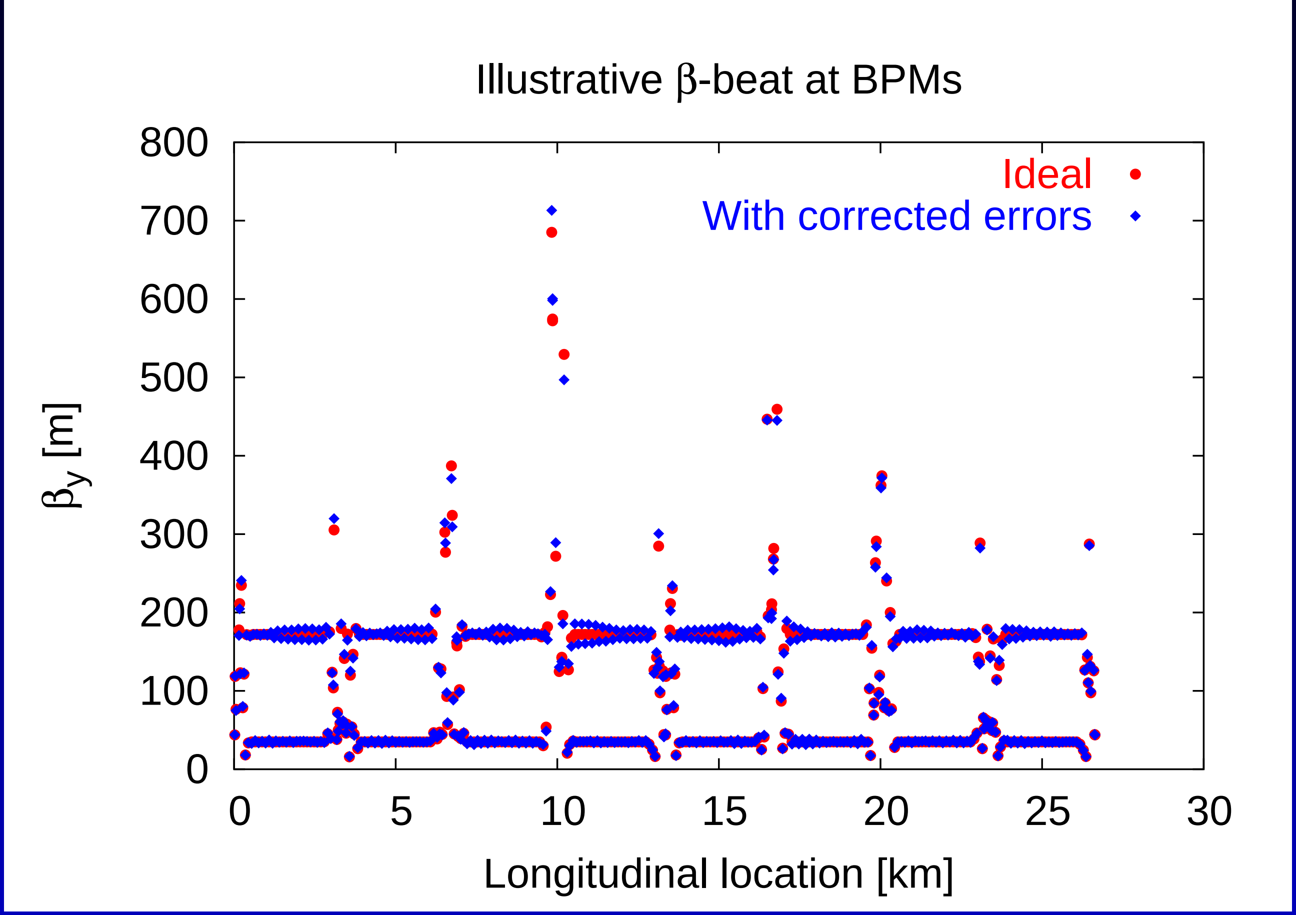


Illustration of phase-beat at the BPMs