Optics-based-BPM calibration

Ana García-Tabarés Valdivieso
Supervisor: Rogelio Tomás

BE-ABP-HSS

16.January.2018

Table of Contents

β function from Turn by Turn data.

- BPM records the position every time the particle pass through it. The pick up is recording a sinusoidal signal as a function of the turn number.
- The BPM readout is affected by the calibration factor (C_i).
- The oscillations recorded by the BPMs are a superposition of beam betatron oscillations and induced betatron excitations.

$$x_{i,N} = C_i\sqrt{2J\beta_d}\sin(Q_d \cdot N + \Phi_i) \Rightarrow \beta_{x,y} = \frac{A_i^2}{2J_{x,y}C_i^2} \quad (1)$$

From Fourier Transformation to β from amplitude (II): Action calculation

- Action can be computed either using the amplitude of the main line of the spectrum recorded by all the BPMs or by a subset of BPMs (assuming that for a set of BPMs $\sum_i^{\mathrm{N_{set}}} \approx \mathrm{N_{set}} C_i^2$)

$$2J_{x,y} = \frac{1}{N}\sum_i^N \frac{(\mathrm{C}_i \mathrm{A}_i)^2}{\beta_{model}} \xrightarrow[\text{set of BPMs}]{\text{reducing}} 2J_{x,y} = \frac{1}{N_{set}}\sum_{i=1}^{N_{set}} \frac{\mathrm{A}_i^2}{\beta_{model}} \quad (2)$$

- β can be therefore reconstructed

$$\beta_{\mathrm{amp,i}} = \frac{\mathrm{A}_i^2}{\mathrm{C}_i^2 2J_{x,y}} \quad (3)$$

Limitations of the existing methods (I): β from phase

β from phase reconstruction diverges for given values of phase advance between two given BPMs

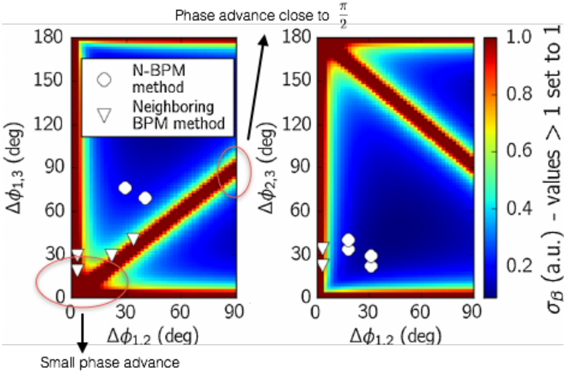
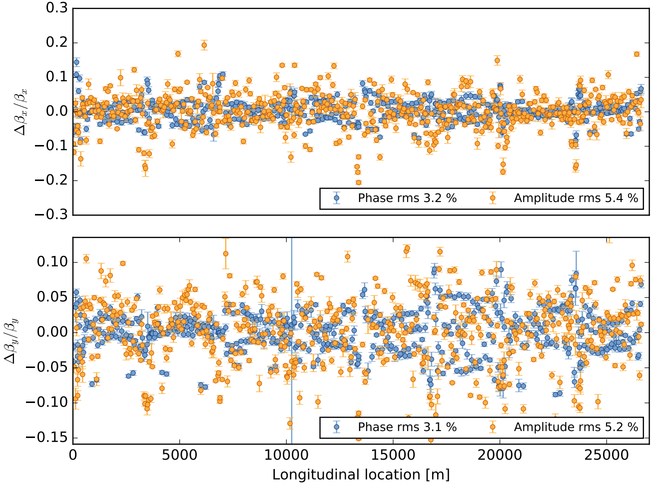
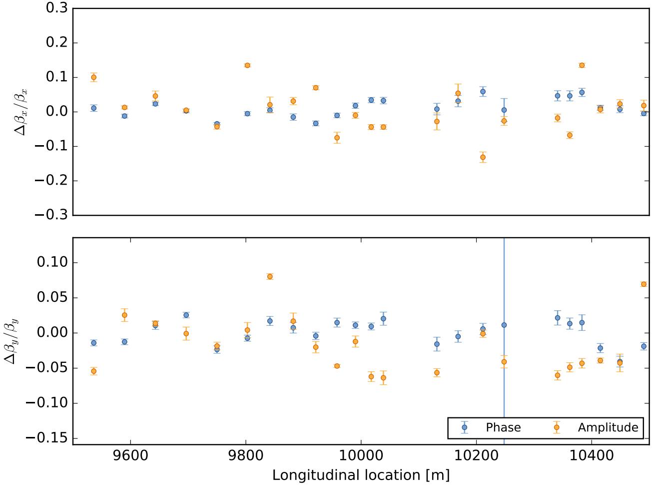


Figure: Langner, A. & Tomas, R.. (2015). "Optics measurement algorithms and error analysis for the proton energy frontier." Physical Review Special Topics - Accelerators and Beams. 18. 031002. 10.1103/PhysRevSTAB.18.031002.

Limitations of the existing methods (II): β from amplitude (LHC)

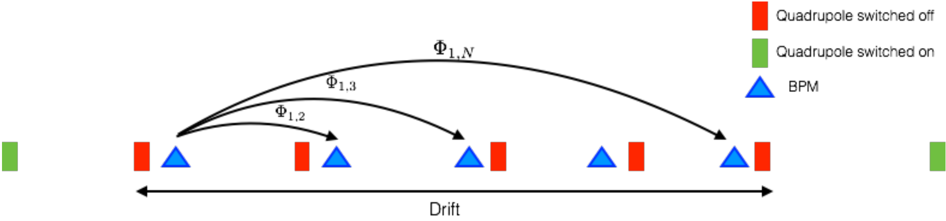


Limitations of the existing methods (II)): β from amplitude (IP 5)



Disconnecting key quadrupoles from the lattice

- Creating a drift in the area of interest by switching off the quadrupoles surrounding the BPM that wants to be calibrated.



Disconnecting key quadrupoles from the lattice (II)

- Propagation of the β function in a drift space (no quadrupoles)

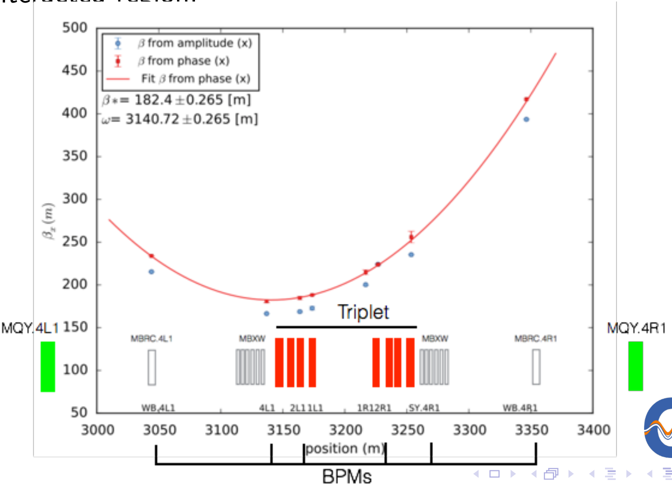
$$\beta(s) = \frac{(s-\omega)^2}{\beta^*} + \beta^* \tag{4}$$

- The β_{phase} is not affected by strongly localized errors and it can be used as a reference value.
- Calibration factor is the calculated using the equation:

$$C_i^2 = \frac{\beta_{amplitude}}{\beta_{phase}} \xrightarrow[\text{to other optics}]{\text{applying}} x_{\text{corrected}} = C_i \cdot x_{\text{measured}} \tag{5}$$

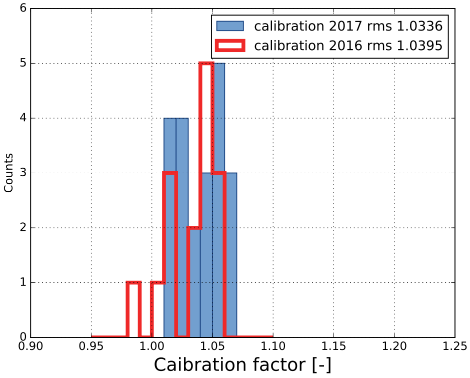
Disconnecting quadrupoles from the lattice (II): LHC experience

- The experiment in LHC studies are focused on the BPMs placed in the interacted region.

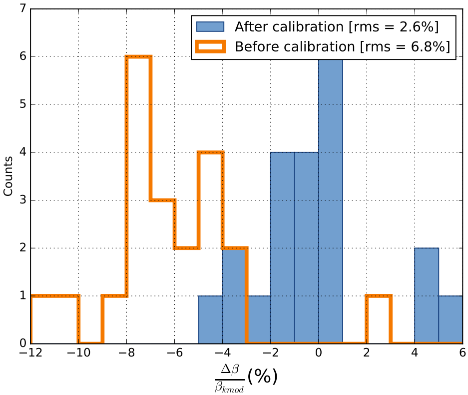


Disconnecting quadrupoles from the lattice (III)

Summary of the calibration factors measured in 2016 and 2017 in horizontal plane. (C_i)



Example of application of the calibration factors in 40 cm optics in LHC. (2017)



Normalized dispersion (I): Introduction

Dispersion function also depends on the calibration factors of the BPMs. Looking for new observables for the dispersion correction,the quantity

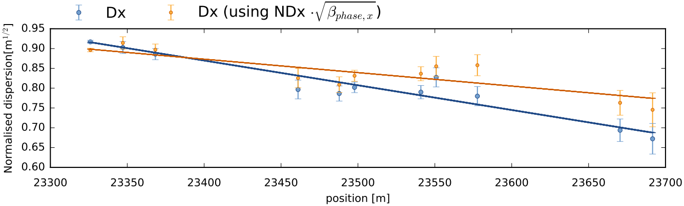
$$\frac{\mathrm{D}_x}{\sqrt{\beta_{x,\mathrm{amp}}}} \tag{6}$$

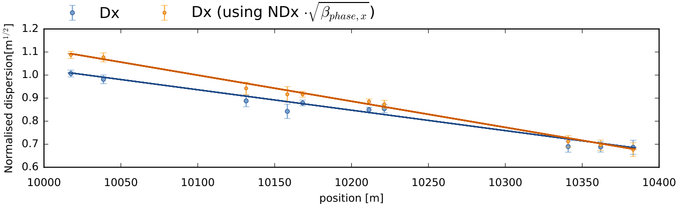
appears very interesting since it can be measured independently of the BPM calibration.

Comparison between D_x and $\mathrm{ND}_x \rightarrow \frac{\mathrm{D}_x}{\sqrt{\beta_{x,\mathrm{amp}}}}\sqrt{\beta_{x,\mathrm{phase}}}$.

$$C_{i,\mathrm{D}} = \frac{\mathrm{D}_x}{\mathrm{ND}_x \cdot \sqrt{\beta_{x,\mathrm{phase}}}} \tag{7}$$

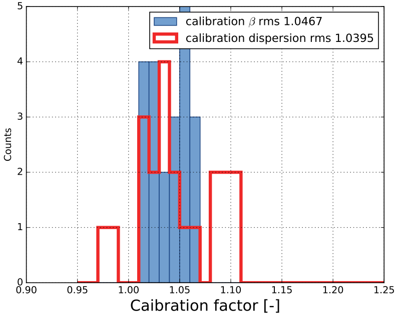
Normalized dispersion (II): LHC measurements





Normalized dispersion (III): Dispersion vs Ballistic

- Calibration factor using drift vs using dispersion.

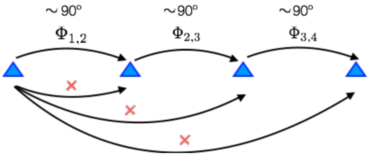


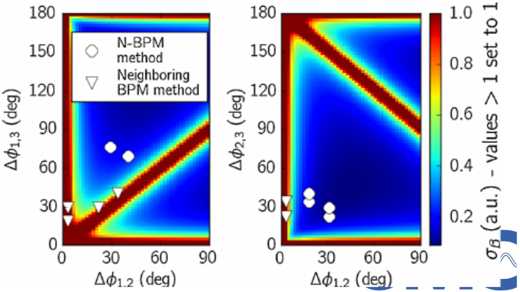
Moving the working point

- Alternative approach for the scenarios where the phase advance between the neighbor BPM is $\sim \frac{\pi}{2}$

Possible solution

- Change the working point in order to have a better resolution of β from phase.





Conclusions

- Drift method and normalized dispersion method allow to obtain calibration factors of a set of BPMs.
- Calibration factors can be applied into operational optics in order to decrease the β-beating (β from amplitude with respect β from phase.
- Globally, the β from phase resolution can be improved when phase advance is problematic. This can be done by changing the working point of the machine.

References

- R. Tomás et al. "BPM calibration independent LHC optics correction", Proceedings of PAC07, Albuquerque, New Mexico, USA
- A. Langner et al. Optics measurement algorithms and error analysis for the proton energy frontier. Physical Review Special Topics - Accelerators and Beams. 18. 031002. 10.1103/PhysRevSTAB.18.031002.
- M. McAteer "Linear optics measurements and preparations for nonlinear optics measurements in the PSB." https://ab-dep-abp.web.cern.ch/ab-dep-abp/HSS/HSS_meetings/2014/20140331/HSS%20meeting%20slides.pdf
- A. García-Tabarés "Optics-measurements-base BPM calibration", Proceedings of IPAC2016, Busan, Korea