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MD4944: Local linear coupling measurement at the IPs

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Summary

It was observed that a large local linear coupling around IP2 reduced the luminosity during the 2018 ion run. In this MD, we measure the local linear coupling around IP2 with lead ions using a rigidity waist shift knob that changes the strength of the triplet while scanning the colinearity knob and measuring the f_{1001} with the AC dipole. Beam 1 was unfortunately dumped during the ramp but the results from Beam 2 indicate that the method was overall successful, but might need to be refined in order to meet the strict tolerance on local linear coupling. Furthermore, K-modulation was performed with different settings of the the skew quadrupolar correctors close to the IP. The results show that the K-modulation is relatively insensitive to the change in the local linear coupling.

Contents

1 Introduction **2**

2 Measurement and Results **4**
2.1 K-modulation 4
2.2 Rigidity waist shift 4

3 Conclusion and Outlook **6**

Date	2018-12-02
Fill	7493
Beam Process	PHYSICS-6.37TeV-50cm-240s-Ion-2018_NegPolarity-V1@240_[END]
Intensity	10^{10}
Number of bunches	1
Tunes	(0.31, 0.32)
β^* (IP2)	50 cm
Species	Pb
Beams	Only Beam 2

Table 1: Summary of beam parameters and machine settings.

1 Introduction

In the ion run in 2018 new local linear coupling corrections were calculated using an automatic matching tool [1]. However, when the corrections were trimmed in, the settings of the right and left MQSX got swapped due to a human mistake. The phase advances and β-functions are such that the effect outside the triplet is almost identical when swapping the strength of the right and the left skew quadrupolar corrector. Inside the triplet there are only a few BPMs and the phase advances between them makes it hard to obtain a good measurement of the local linear coupling. The swap created around 50% reduction of the instantaneous luminosity for the ALICE experiment (IP2). This was mainly due to an increase of both horizontal and vertical beam sizes at the IP [2]. This was recovered by trimming the colinearity knob [3], originally designed for flat optics, while observing its impact on luminosity. This knob re-balances the strength of the left and right MQSX magnets as shown in Tab. 2. In order to avoid a similar situation in the future, several actions were taken. First, an automatic way to send the calculated corrections has been created, preventing human errors. However, even if the corrections would have been sent correctly, there would have been a difference to what was found optimal with luminosity. This error would have caused approximately 5% luminosity loss. In order to constrain the local linear coupling corrections further, in Run 3, this MD was proposed.

The idea was to introduce a rigidity waist shift which moves all the 4 waists simultaneously and breaks the symmetry between the right and left MQSX magnets while observing the global coupling, which is significantly easier to measure. In an ideal simulation without any other error sources the optimal of the colinearity knob will be found when $|C^-|$ is 0 as shown in Fig. 1. The plot shows how introducing an error by the colinearity knob has no impact on the $|C^-|$ for an ideal model. However, after introducing the rigidity waist shift knob a strong dependency on any error of the colinearity knob on the $|C^-|$ is observed.

The second part of the MD was aimed to measure the impact of the colinearity knob and hence the local linear coupling on the results from K-modulation.

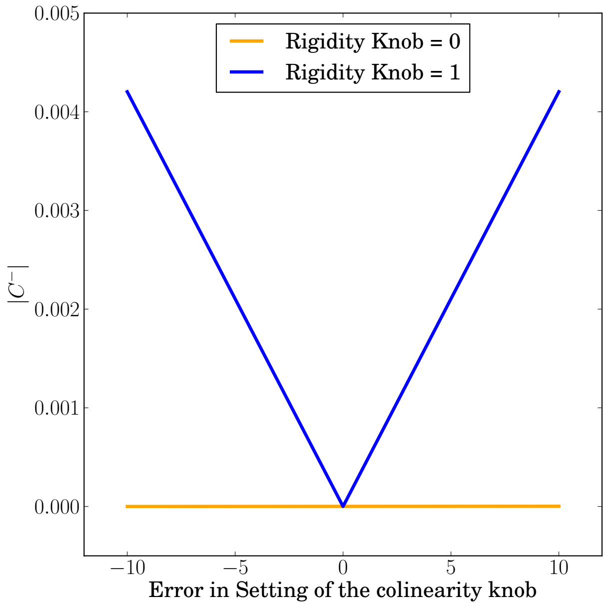

Figure 1: Simulation of the influence of the colinearity knob on the $|C^{-}|$ for an ideal machine. In this simulation a local coupling error was introduced using the colinearity knob, see Tab. 2. The strength of the rigidity knob is defined in Tab. 4.

Magnet	K_1 $[\mathrm{m}^{-2}]$
MQXS.3L2/K1S	+10e-4
MQXS.3R2/K1S	-10e-4

Table 2: Table showing one unit of the colinearity knob.

	IP 2 (Beam 2)			
	β^* [cm]		Waist shift [cm]	
Colinearity Setting	H	V	H	V
-12	51.4 ± 0.2	50.3 ± 0.1	-8.0 ± 1.1	2.0 ± 0.5
-5	50.8 ± 0.2	50.6 ± 0.1	-5.0 ± 0.7	3.0 ± 0.5

Table 3: The measured β^* for different settings of the colinearity knob. Positive values are in the direction of the focusing magnet for the specific beam and plane.

2 Measurement and Results

The optics measurements were taken with ions. The measurement quality was as good as for the protons, however, the emittance was larger, which was acceptable for this MD and linear optics measurements in general, but might hinder the use of ions for studies where higher amplitude kicks are needed, *e.g.* amplitude detuning.

Beam 1 was dumped during the energy ramp due to interlock on the intensity. The intensity was just below 10^{10} but some noise on the intensity measurement increased it above the threshold and the beam was dumped. The measurements were taken with negative polarity of the ALICE spectrometer. The optimal setting for the colinearity knob had been found to be -12 with luminosity.

2.1 K-modulation

A K-modulation measurement was performed for two different settings of the colinearity knob, shown in Tab. 3. The difference between the measured β^* for the two settings is relatively small. This shows that the K-modulation is resistant to local linear coupling errors. This also indicates that it is hard to use K-modulation in its present form to constraint the local linear coupling corrections.

2.2 Rigidity waist shift

In the second part of the MD, two settings of the rigidity waist shift knob (+1 and -1) was applied and the colinearity knob were scanned. The measurement of the coupling before the measurement was subtracted and the result can be seen in Fig. 2. The optimal setting of the colinearity knob is found at -15.5, which is to be compared with -12 (found with luminosity). It is possible that the optimum is slightly different for the two beams and that -12 was a compromise between the two beams.

There are also other possible reasons why the colinearity knob did not give the same result as what was obtained from luminosity. One reason is the change in the β-functions coming in other locations of the machine. This means that the coupling errors add up in a different way, which also contribute to the change in C^-. A comparison of the β-beat with and without the rigidity waist shift is shown in Fig. 3. A β-beat of 15% is observed when the rigitdity waist shift knob is applied and this is consistent with what is expected from simulations of an ideal model with only the knob applied, shown in Fig. 4.

Magnet	K_1 [m^{-2}]
MQXA1.L2/K1	-4.46e-5
MQXB2.L2/K1	4.46e-5
MQXA3.L2/K1	-4.46e-5
MQXA1.R2/K1	-4.46e-5
MQXB2.R2/K1	4.46e-5
MQXA3.R2/K1	-4.46e-5

Table 4: The rigidity waist shift knob used during the MD (2018_waist_rigidity_shift_v2). Trimming it to 1 corresponds to shifting the waist by about 60 cm (Beam 2 horizontal: 64 cm and Beam 2, vertical: 59 cm).

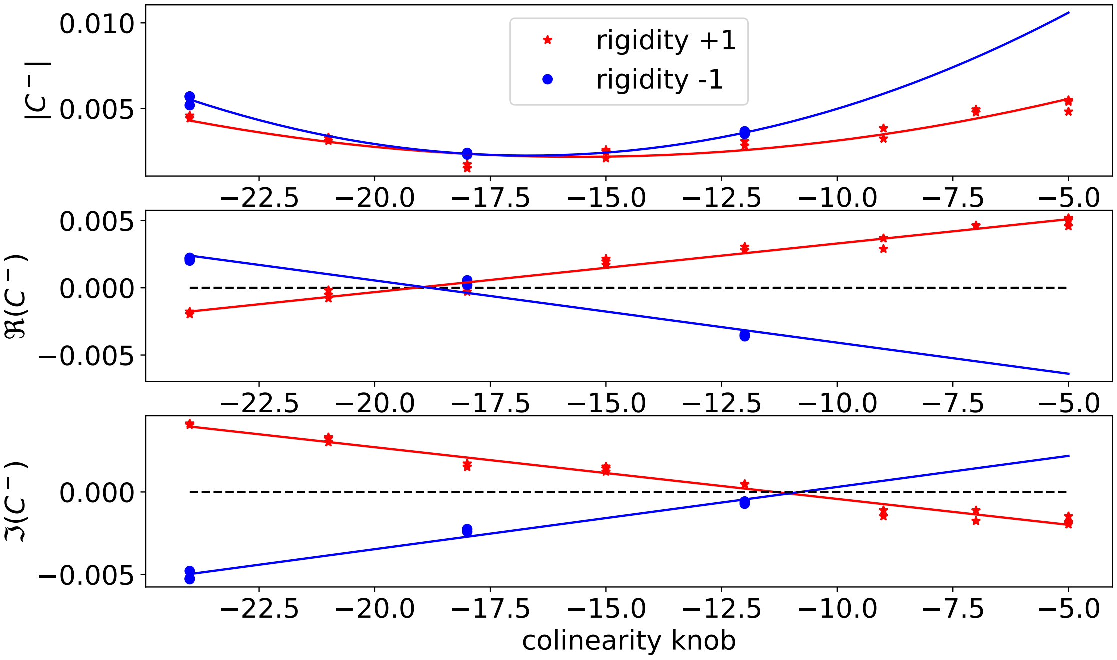

Figure 2: The change of C^- as a function of the setting of the colinearity knob for the two tested values of the rigitidty waist shift knob.

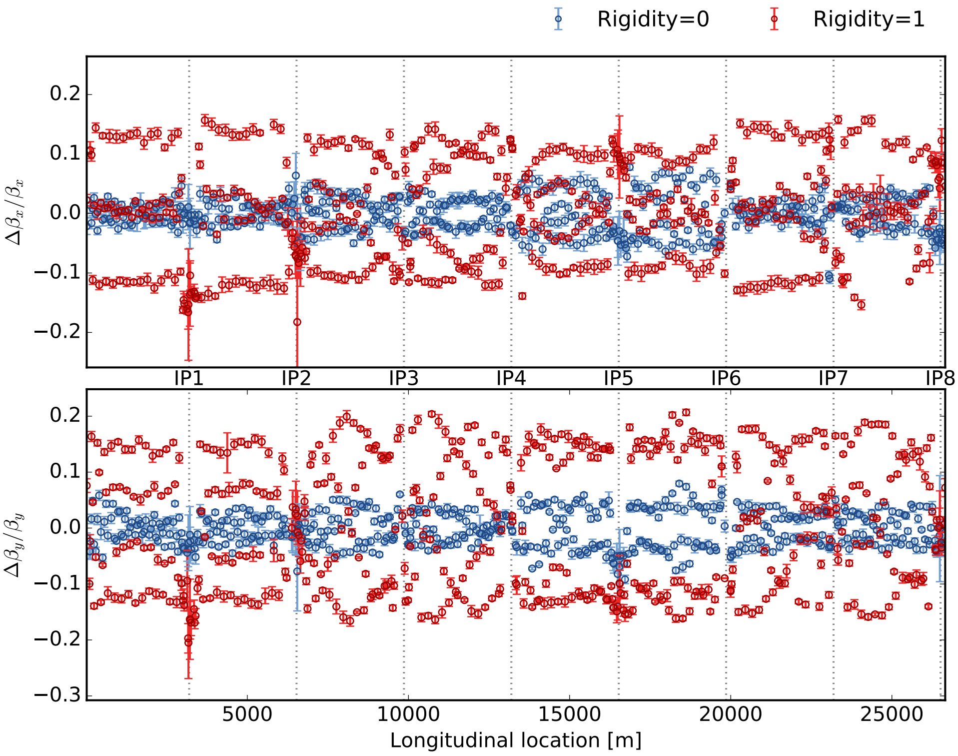

Figure 3: The β-beat with and without the rigidity waist shift knob.

In Fig. 5 the change of the real part of the transverse linear coupling, when going from -5 to -12 in the colinearity knob, is shown. We observe that the rather big change in the phase of the coupling is most likely due to magnetic imperfections leading to an asymmetry in the optics functions between the two skew quadrupoles. There could also be differences in the strength of the MQSX magnets leading to this. This observation could potentially be used together with other measurements to confine the optics corrections further.

3 Conclusion and Outlook

The measurement of the β^* using K-modulation showed to be relatively insensitive to changes in the local linear coupling. This makes it possible to disentangle the normal quadrupolar corrections from the skew quadrupolar corrections.

The rigidity waist shift approach showed promising results but needs to be explored further in simulations before Run 3. The final validation of the local linear coupling corrections is recommended to be done with luminosity.

References

[1] J. Coello *et al.*, “New local optics measurements and correction techniques for the LHC and its luminosity upgrade”, to be published.

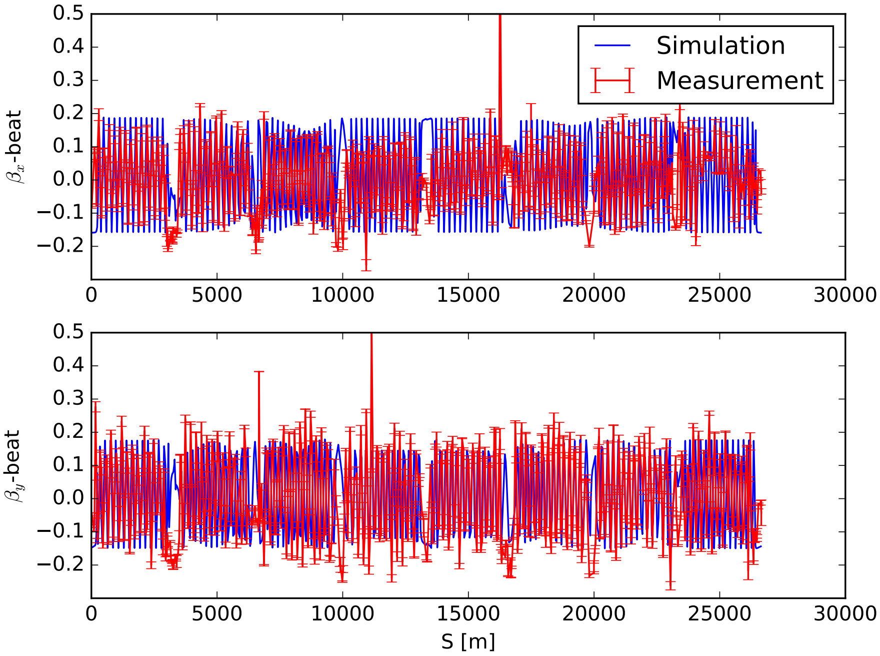

Figure 4: The expected β-beat from simulation together with the measured. Note that the β-beat of the nominal machine is not included in the simulation and that will contribute to an uncertainty of around 0.07.

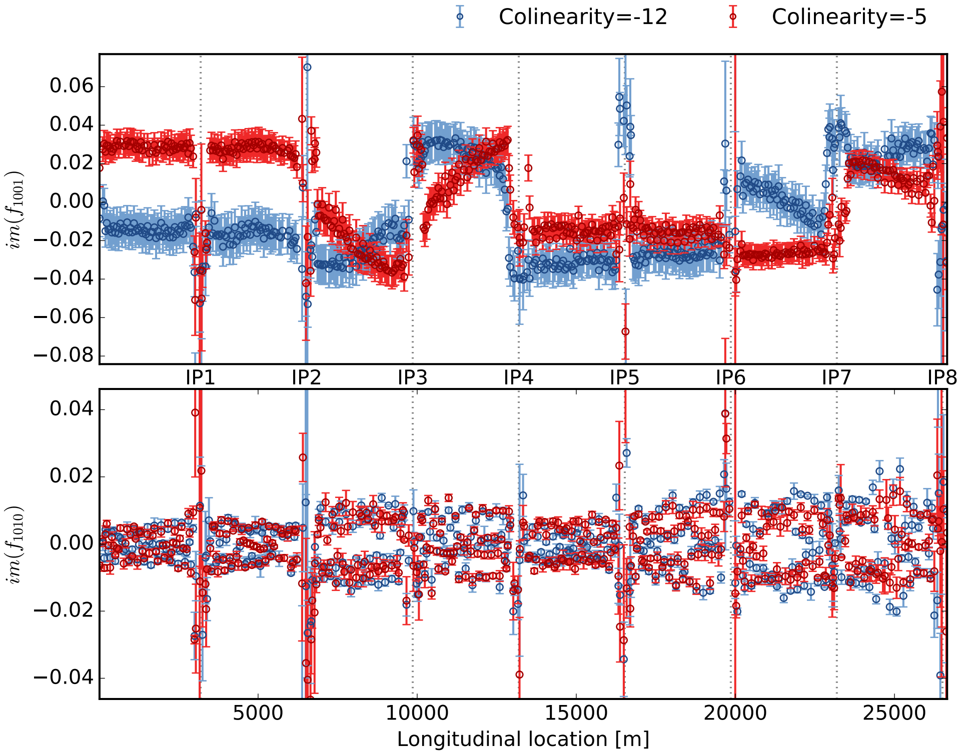

Figure 5: The change in the imaginary part of f_{1001} and f_{1010} when changing the colinearity knob from -12 to -7.

[2] T. Persson, *et al.*, “LHC Optics Corrections in Run 2”, Proceedings of the 9th Evian Workshop (2019).

[3] S. Fartoukh, *et al.*, “ First High-Intensity Beam Tests with Telescopic Flat Optics at the LHC”, CERN-ACC-2019-0052.