Stability of Linear Coupling in Run 2

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Introduction

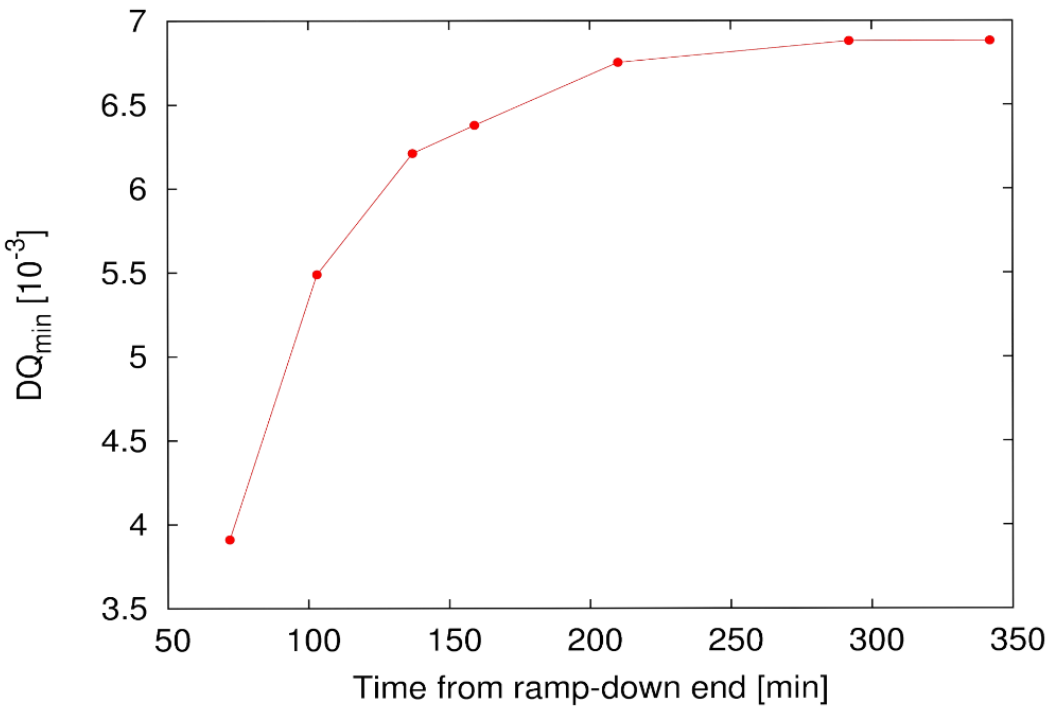
- Investigate the coupling stability at:
  - Injection
  - Flattop
  - Squeezed optics
- Timescales:
  - Short – Minutes to Hours
  - Long – Days to Months

Methodology and nomenclature

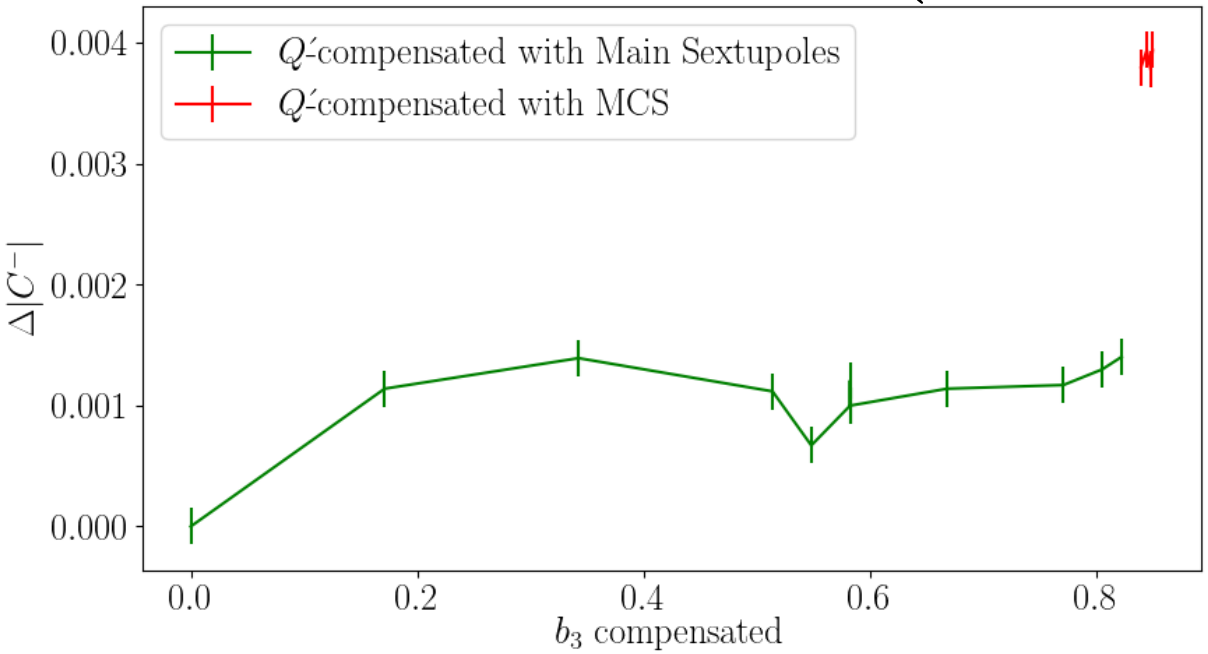
- |C-| is measured through a fit of the two corrections knobs that best fit the measurement
  - i.e. $$|C^-| = \sqrt{\mathrm{CORR}^2_{\Re e} + \mathrm{CORR}^2_{\Im m}}$$
- The measurement is either carried out with the AC-dipole or the ADT-AC dipole
  - AC-dipole measurements gives better accuracy but can only be used with pilots
    - Lower kicks with the ADT
    - Uncertainty of the tunes → Removed with the new tune measurement
  - An error estimate from a single measurement is planned for Run 3
    - Error bars presented in this presentation are statistical error bars based on several measurements

Injection (short term)

- The decay has been linked to powering of the MCS (b3-spool pieces) attached to every dipole.
  - Change in |C-| = 3-4*10^{-3} in ~2h



Measurement with and without MCS (Beam 2)



Total time of the decay was about 2 h and corresponds to a change in Q' of around 40 units

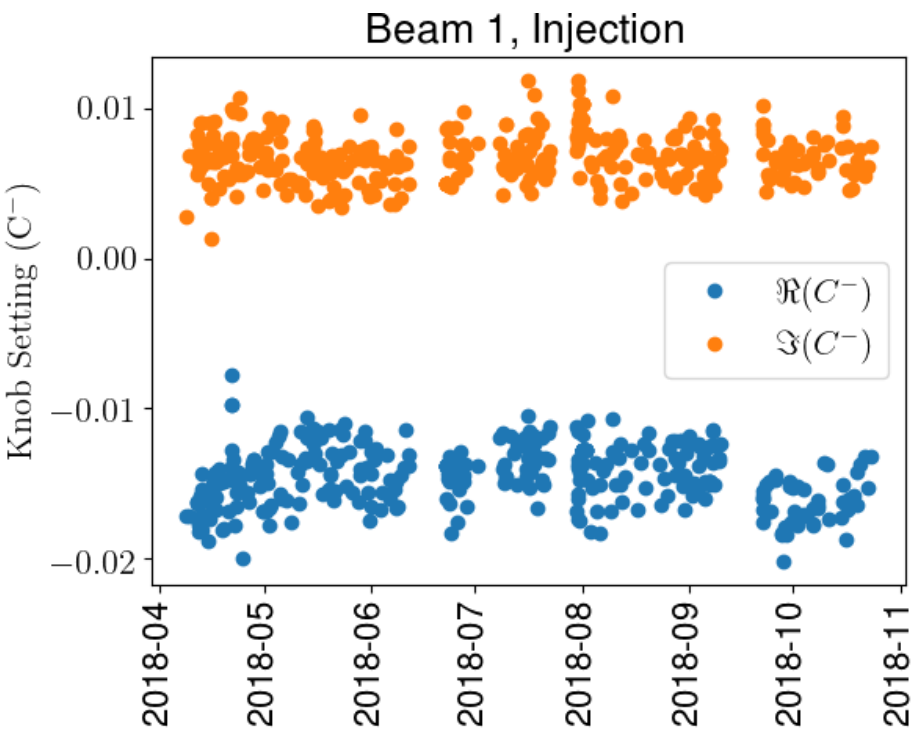
- Changing the b_3-error in the dipoles and the Main Sextupoles (green)
  - → Small impact on the $|C^-|$
- In the end of the test the Q' compensation was switched to the MCS (red).
  - → 4 times larger change in $|C^-|$
  - →The MCS have a larger impact on the coupling

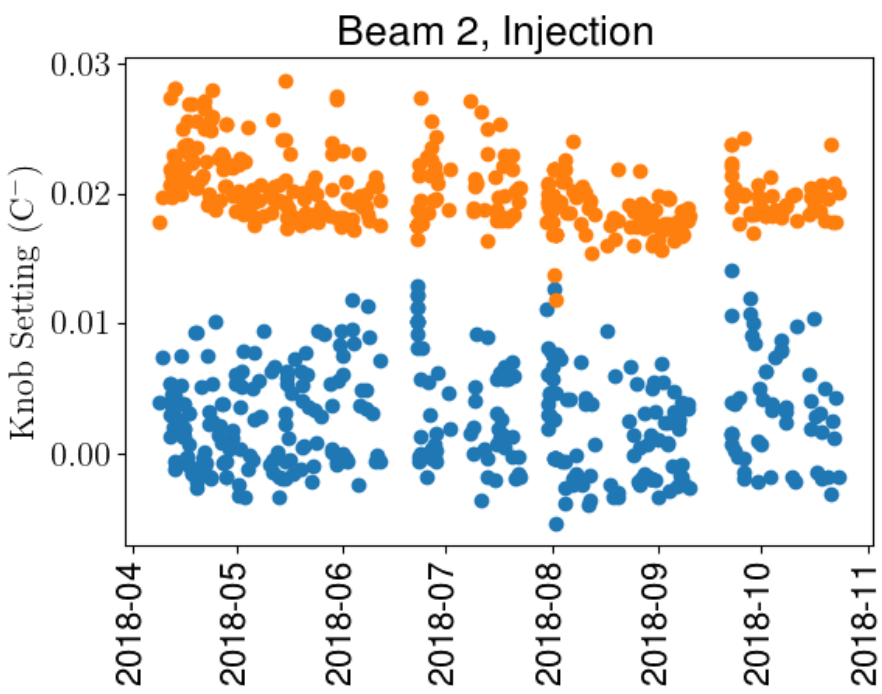
(2017-05-15)

Injection

- We have developed a mitigation strategy based on changing the powering of the MCS differently between the different arcs
  - Compensates the Q' drift (b_3-compensation)
  - Compensated the global coupling drift in MD
  - Ready to be used in the next run

What about long term stability?

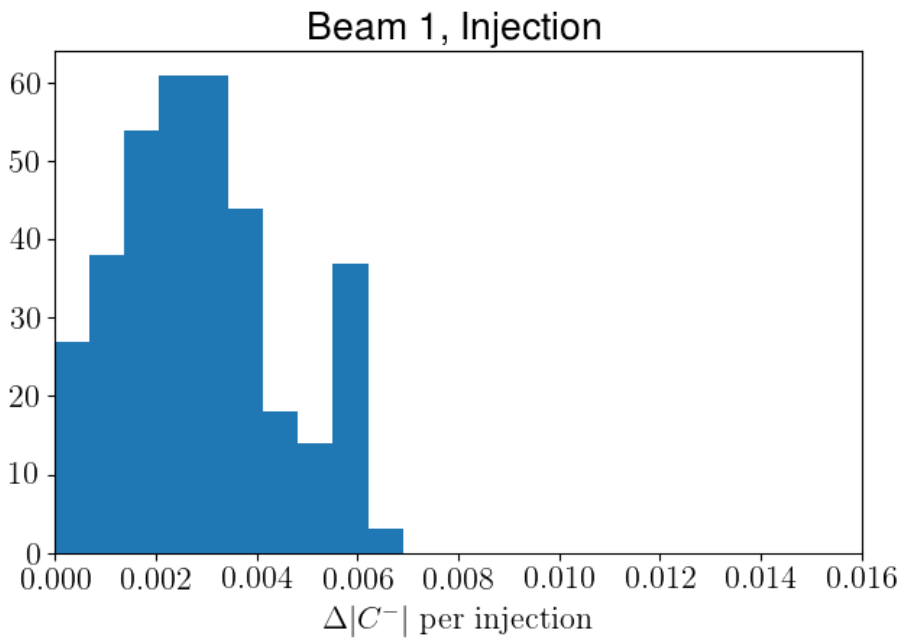


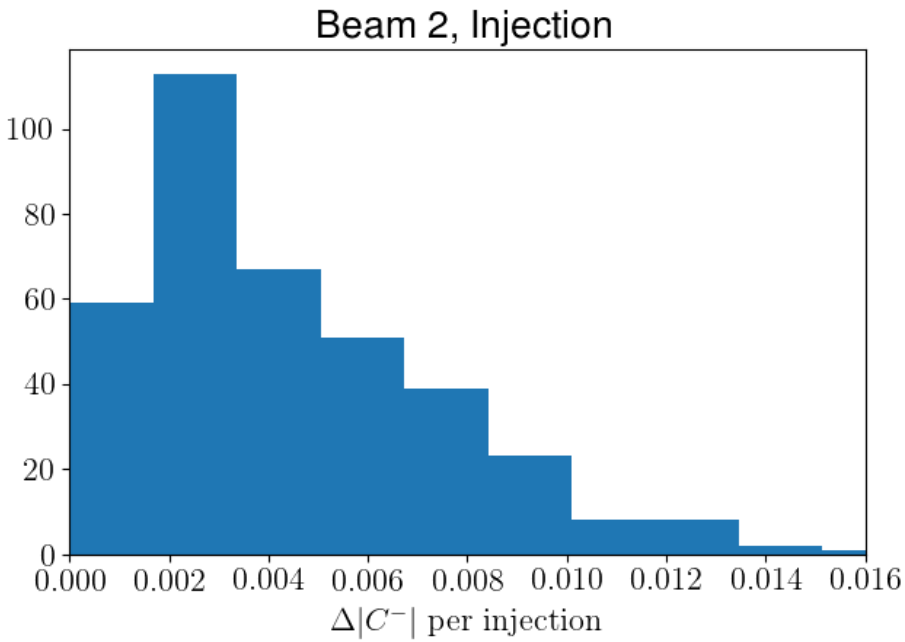


→ Fill-to-Fill variations but no drift of the setting of the coupling knobs throughout 2018

In general larger corrections after a technical stop

What about fill to fill?



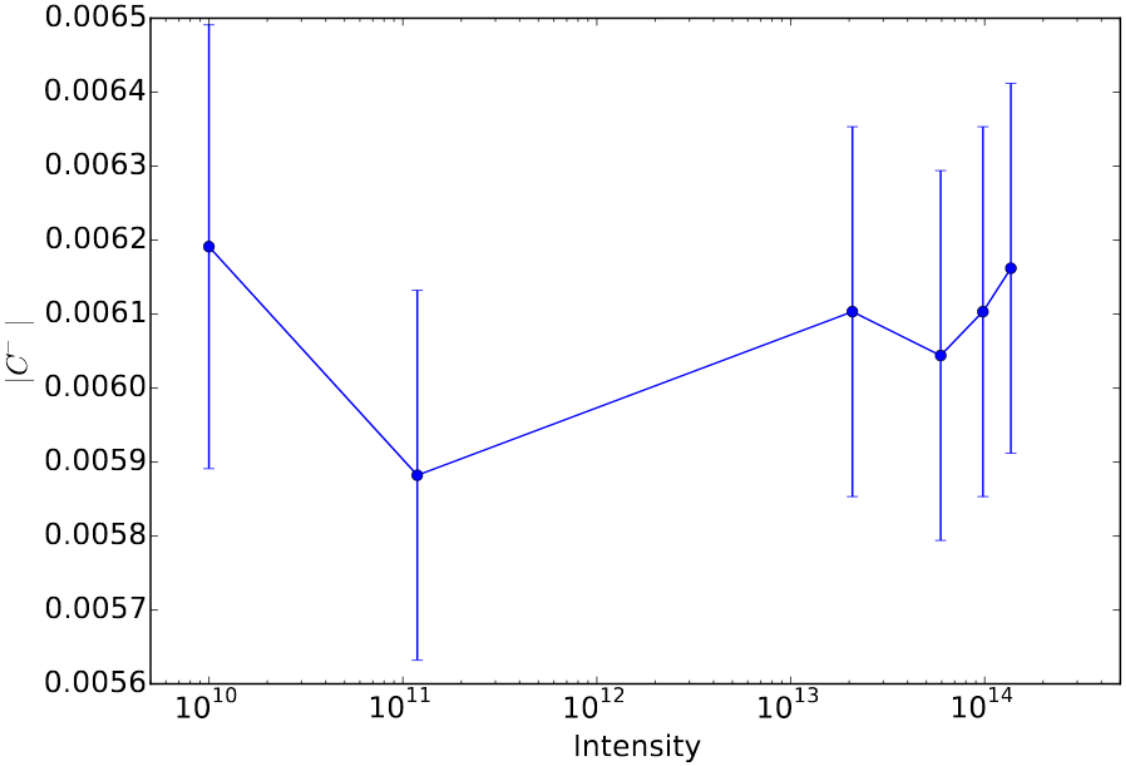


The fill-to-fill variation is larger than what can be explained by just the coupling decay.

Larger corrections for Beam 2 than Beam 1. Interesting to understand but no impact for the performance since it is corrected at each fill

Any changes due to intensity?

- Measured the coupling as a function of intensity at injection
  - No sign of a “skew” Lasslet



MD report

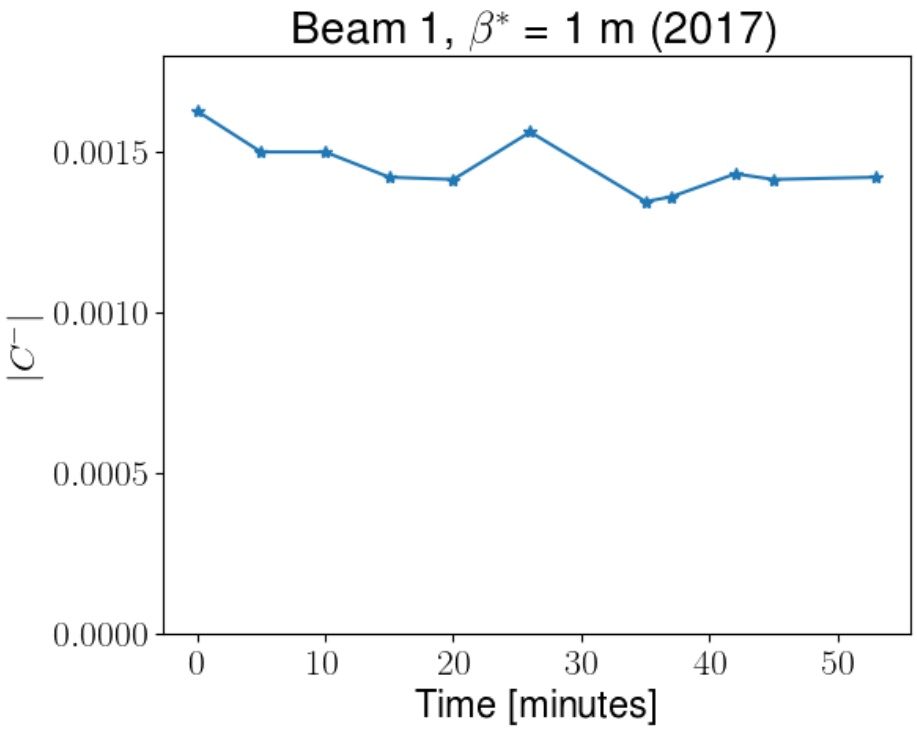
Summary injection and outlook

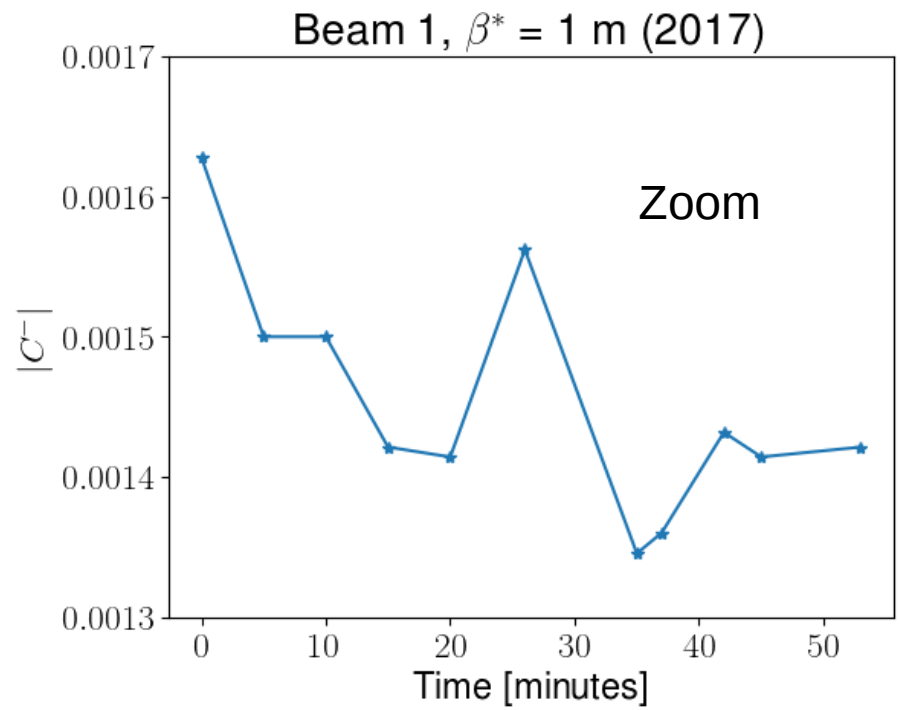
- Changes of the |C-| up of ~10^{-2} between injections
  - Larger than just coupling decay from b_3

    → Interesting to understand the fill-to-fill variation
- The corrections strategy used in operation is to use a pilot and correct the coupling and tune → Fill-to-fill variation is corrected
  - Still a drift of the |C-| to be up to (3-4)*10^{-3} in the end of the injection due to the b_3-correction
  - With the proposed uneven dynamic b_3-compensation : |C-| drift $< 10^{-3}$

Flattop

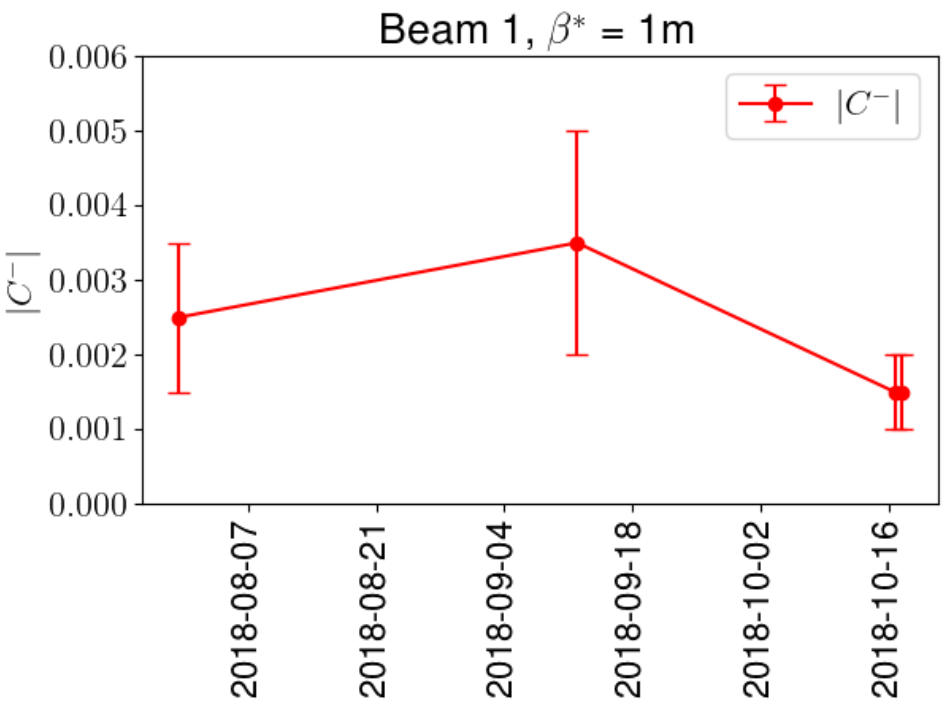
Short term Flattop

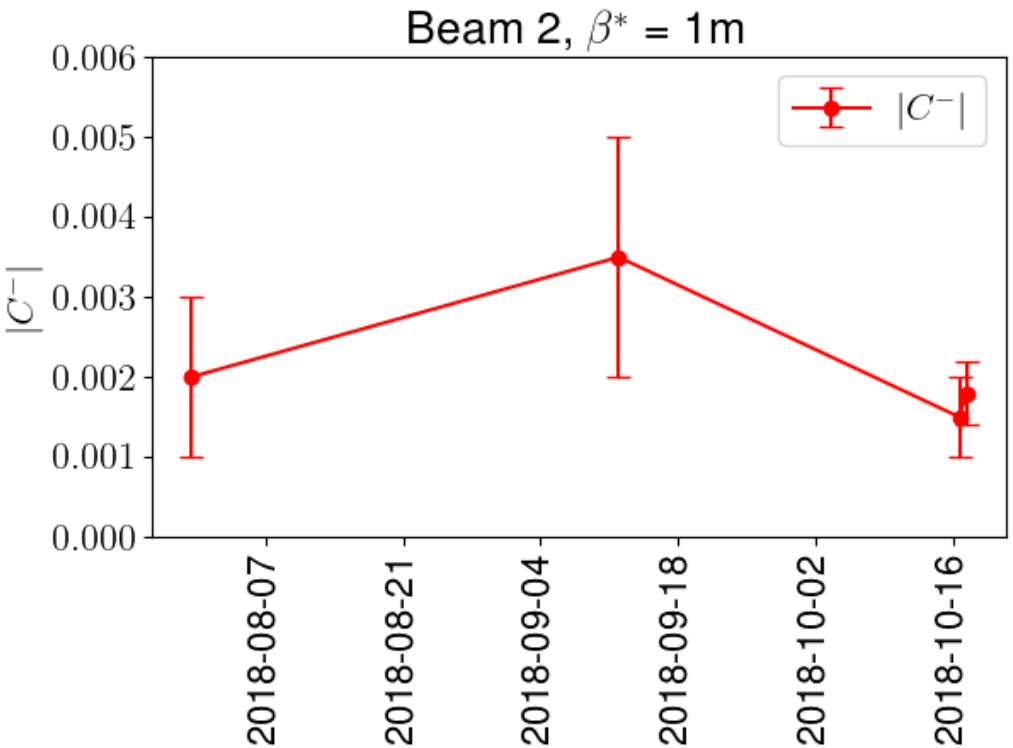




No indication of drifts of the coupling in time scales of hours at flattop (same for beam 2)

Long term Flattop

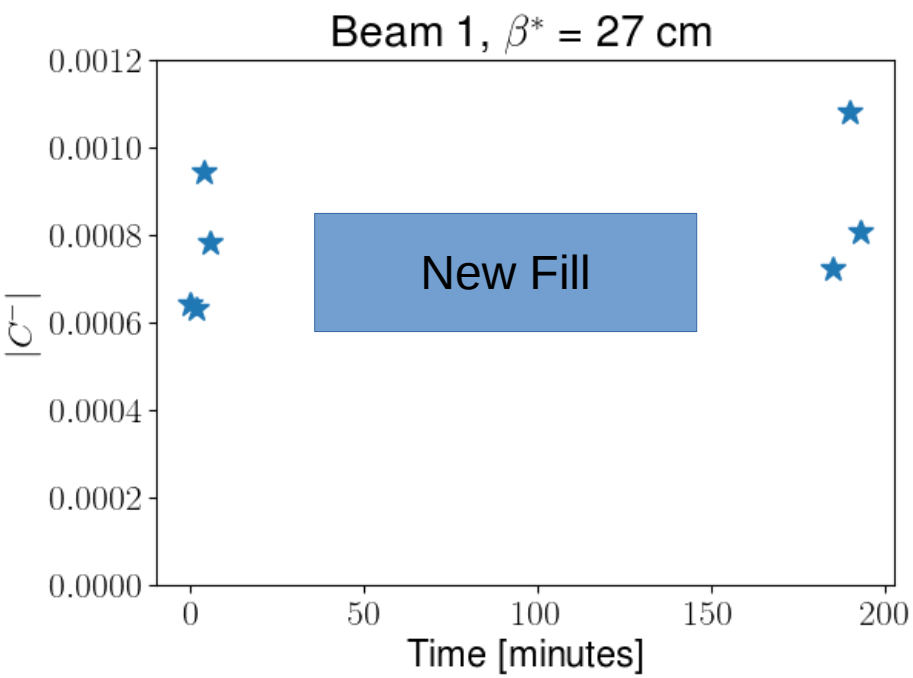


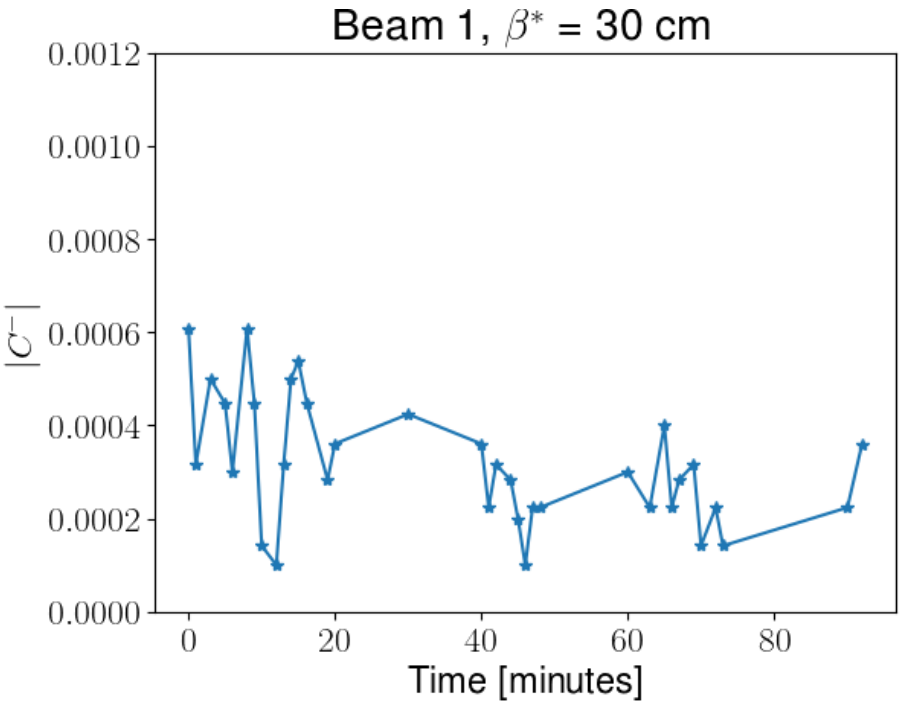


No indications that the |C-| has drifted within the precision of the measurement in 2018

Squeezed

Short term Squeezed

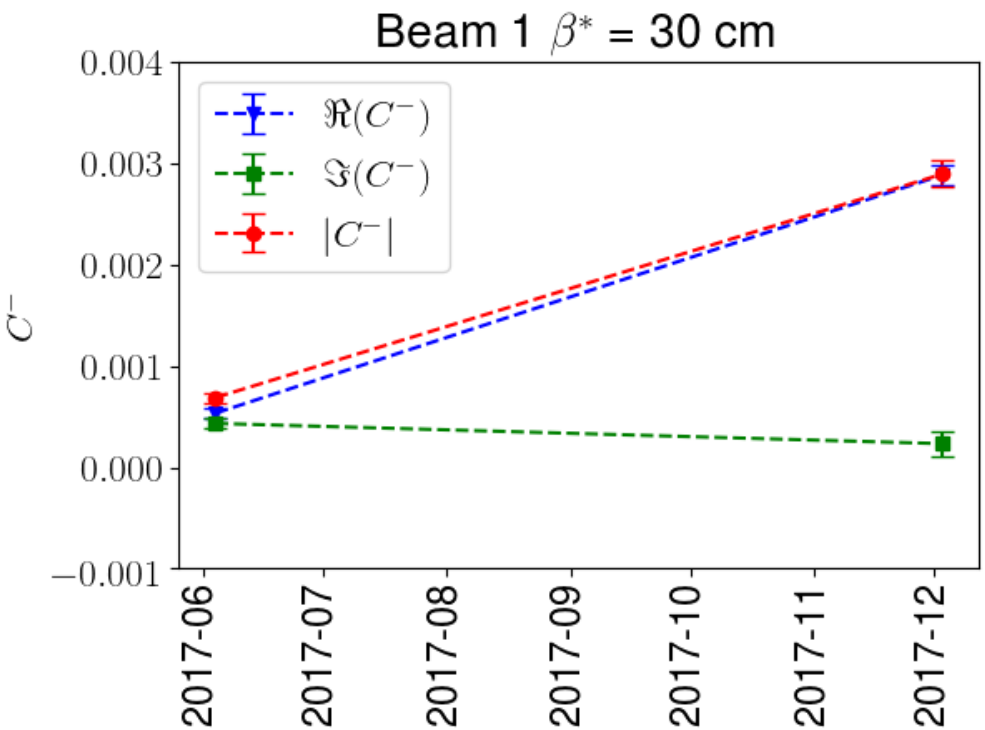


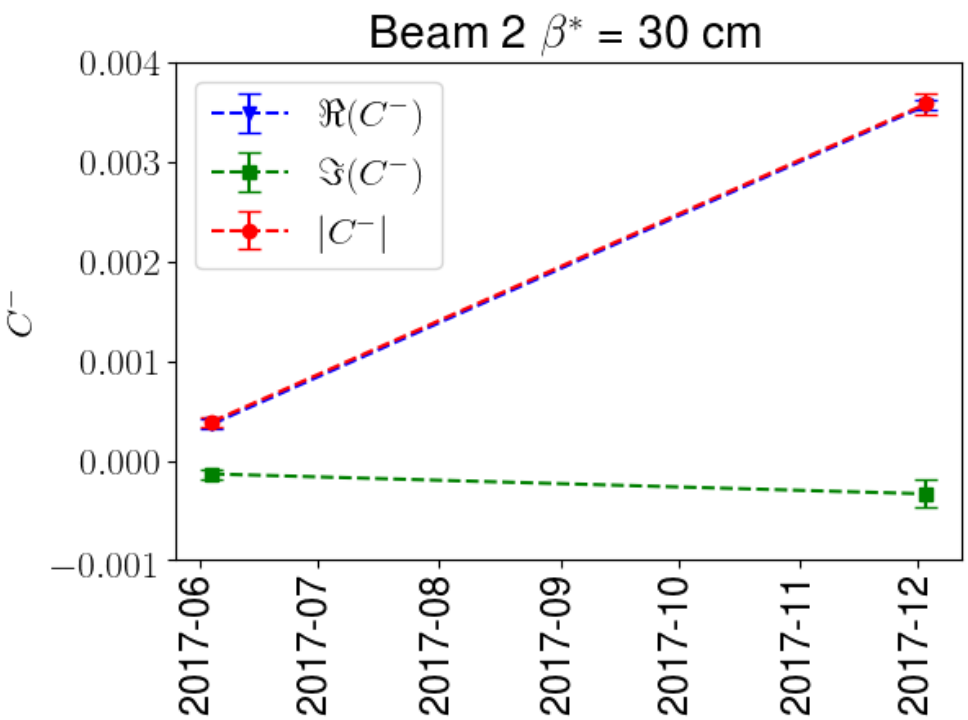


The drift on the coupling is within the measurement precision

→ Drift |C-| < 10^{-3} (Similar results for beam 2)

2017 squeezed

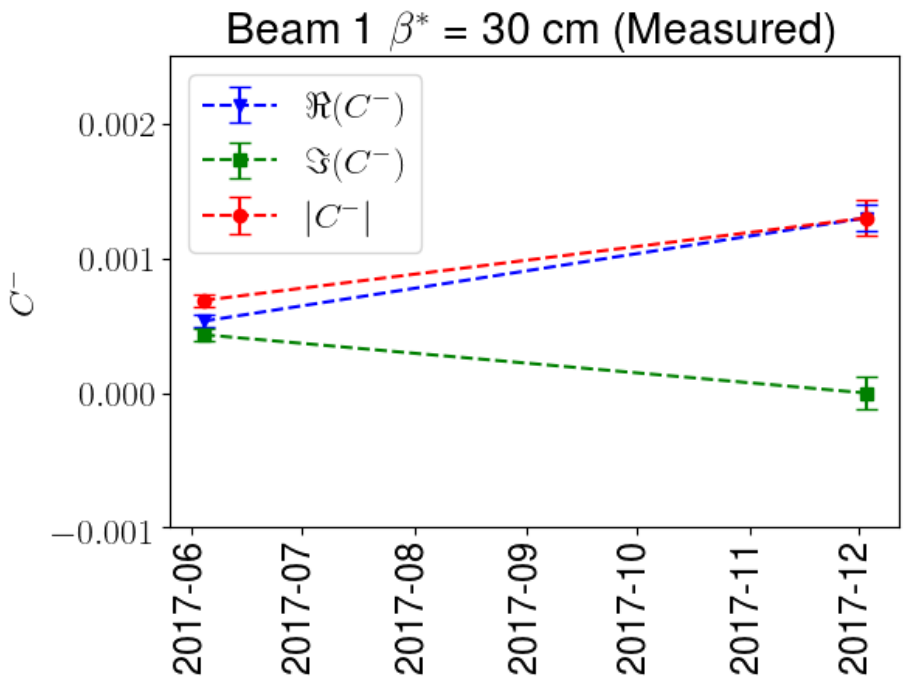


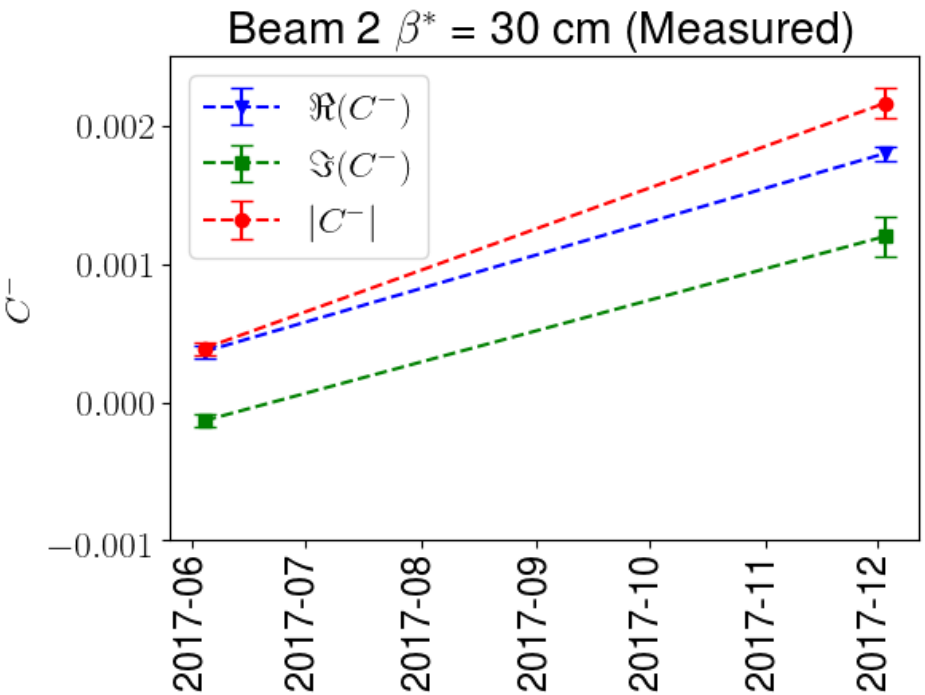


Prediction if **no correction** would have been applied

→ Beam 1: 2.5***10**$^{-3}$ and Beam 2: **3*10**$^{-3}$ in 6 months

2017 (squeezed)



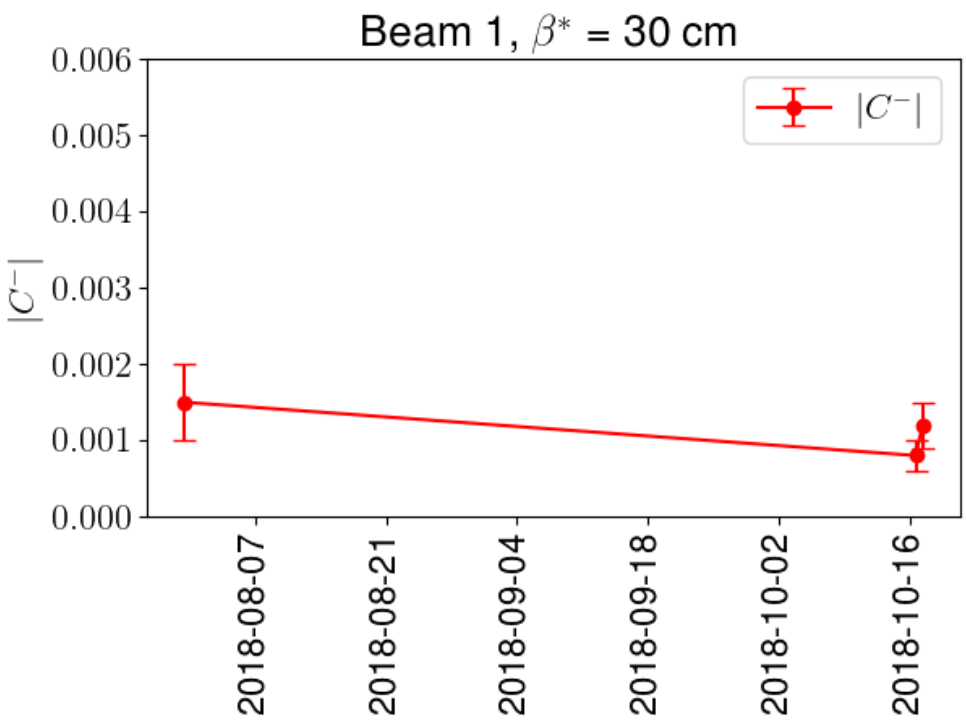


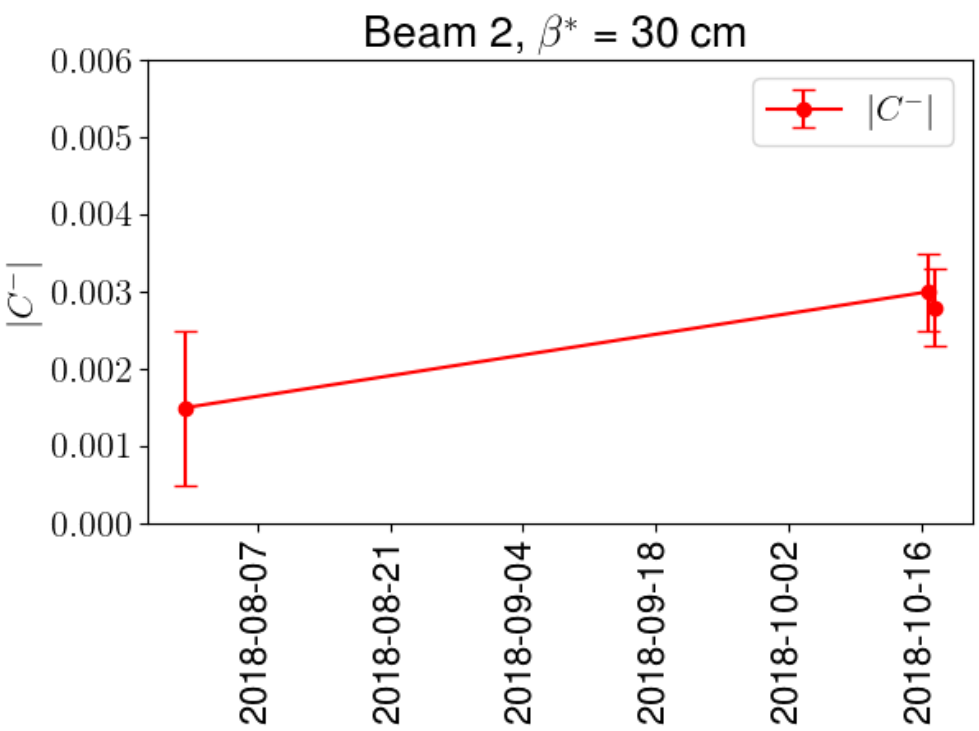
Measurements done with AC-dipole and pilots

Well corrected coupling at the end of the run.

Several corrections applied during the year!

Long term 2018 (squeezed)

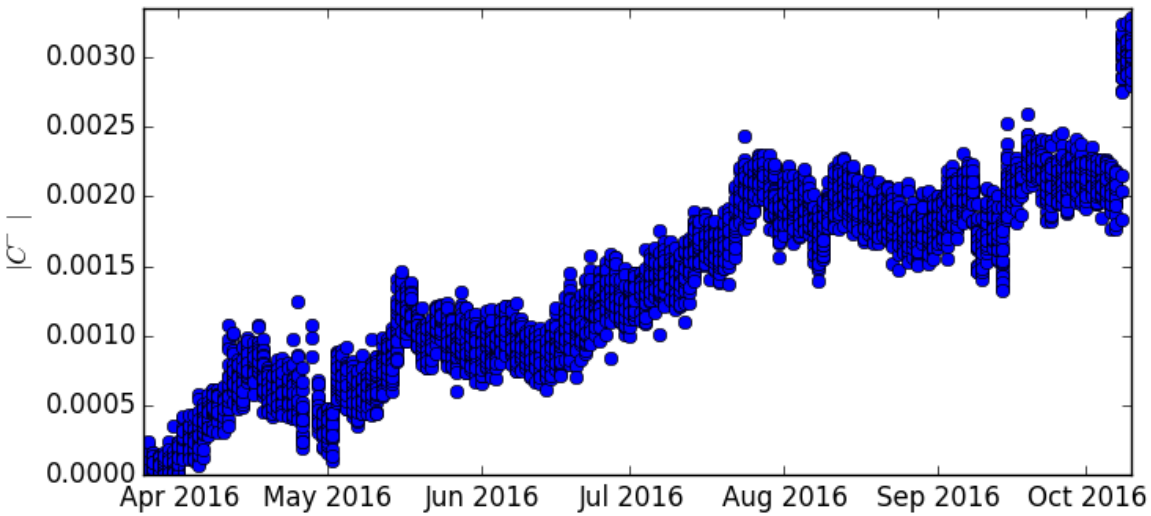




The measurements supports that the change of the |C-| was ~**1-2*10^{-3}** in **4 month**

Potential explanations

- The tilt of the triplets are measured and recorded
  - Use these measurements as misalignment in MAD-X gives the following results (2016):



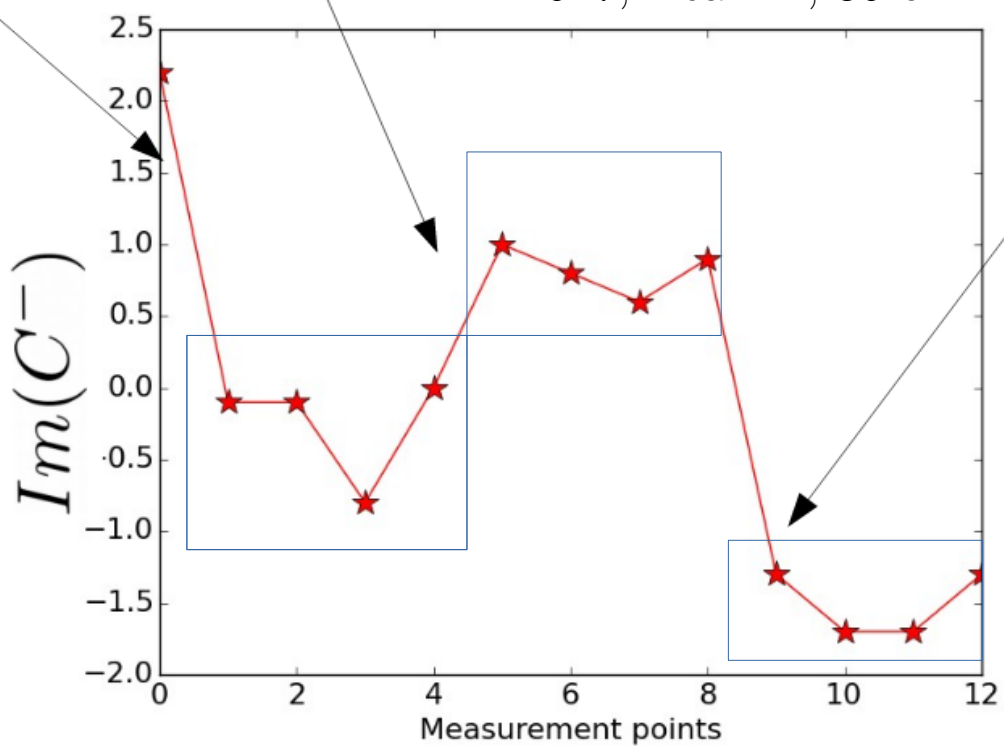
Waiting for 2018 data

Long range (squeezed)

Changed filling scheme

Trim of coupling knob (2*10-3)

2017, Beam 2, 30 cm



Single bunches (around 10 per beam)

Time: ~1 week

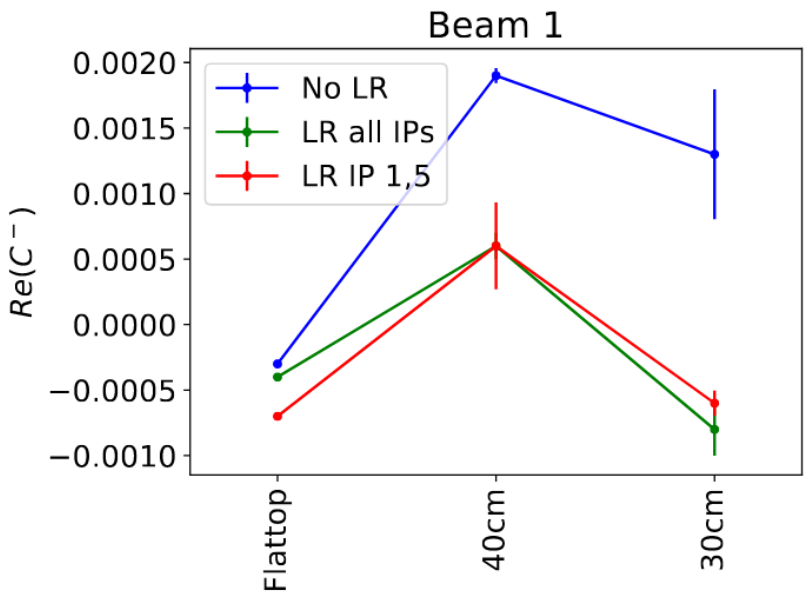
Each point is from a different fill (except the last 4)

Measurements rather stable between fills but changes when the filling scheme changes.

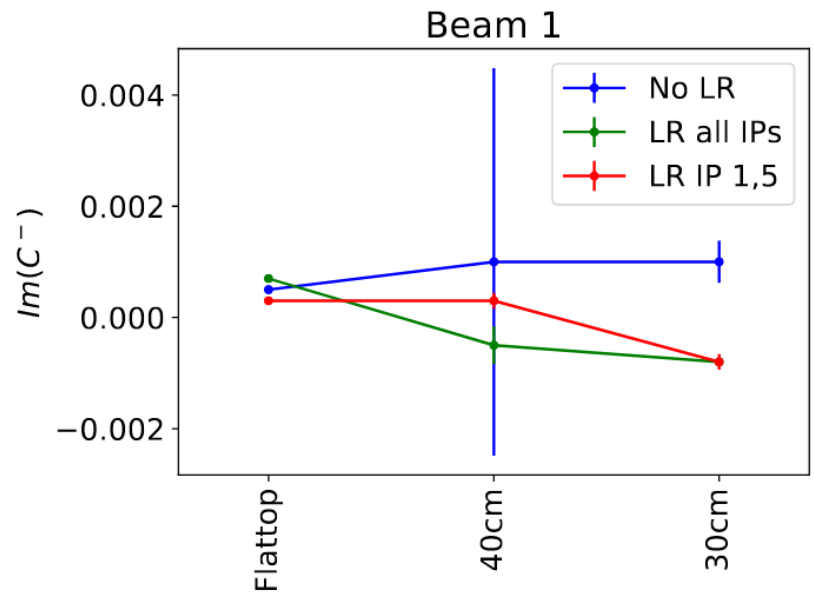
Data taken during operation and put togheter by J.Wenninger

Impact on long range on coupling (PACMAN coupling)

- Investigated during MD



(a) Real C^-, B1



(b) Imaginary C^-, B1

A measurable effect in the order of ~$2*10^{-3}$ for the 30 cm and 40 cm
In commissioning we are correcting the "single bunch coupling" →
More studies and simulations should be performed to see if this is this best correction target

Conclusion

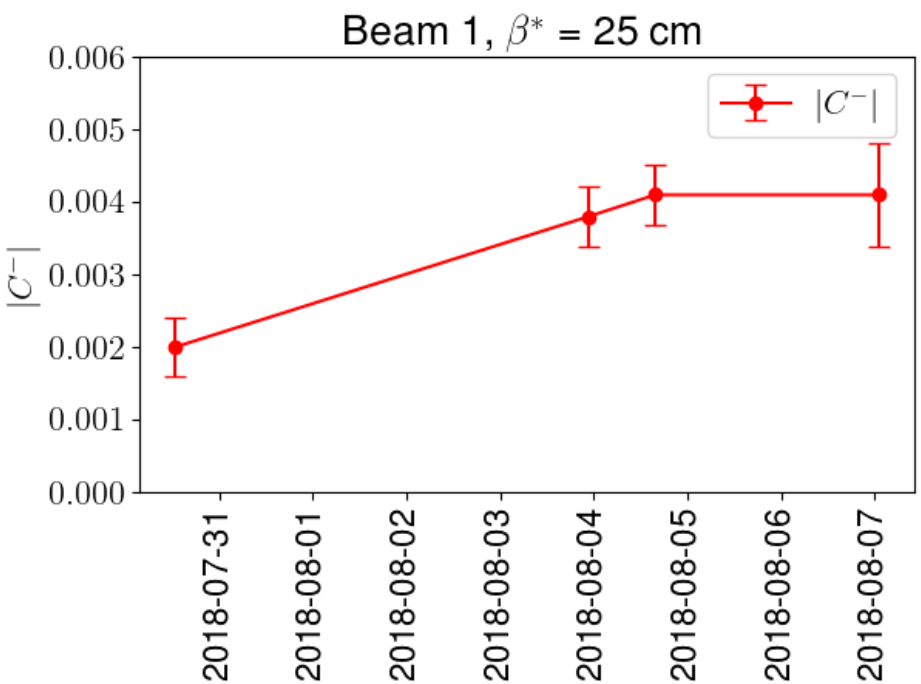
- The coupling was drifting at injection in run 2
  - The fill-to-fill is corrected by OP with the use of the ADT coupling tool
  - A strategy to compensate the decay in place for Run 3
  - No measured effect of the intensity on the transverse coupling
- Flattop variation less than 10^{-3}
- Squeezed:
  - Would have drifted ~$3*10^{-3}$ in 2017 (6 month) but was corrected throughout the year with the ADT
  - Less precise measurement with the ADT in 2018 but indicates changes around ~$1\text{-}2*10^{-3}$ in a 4 month period

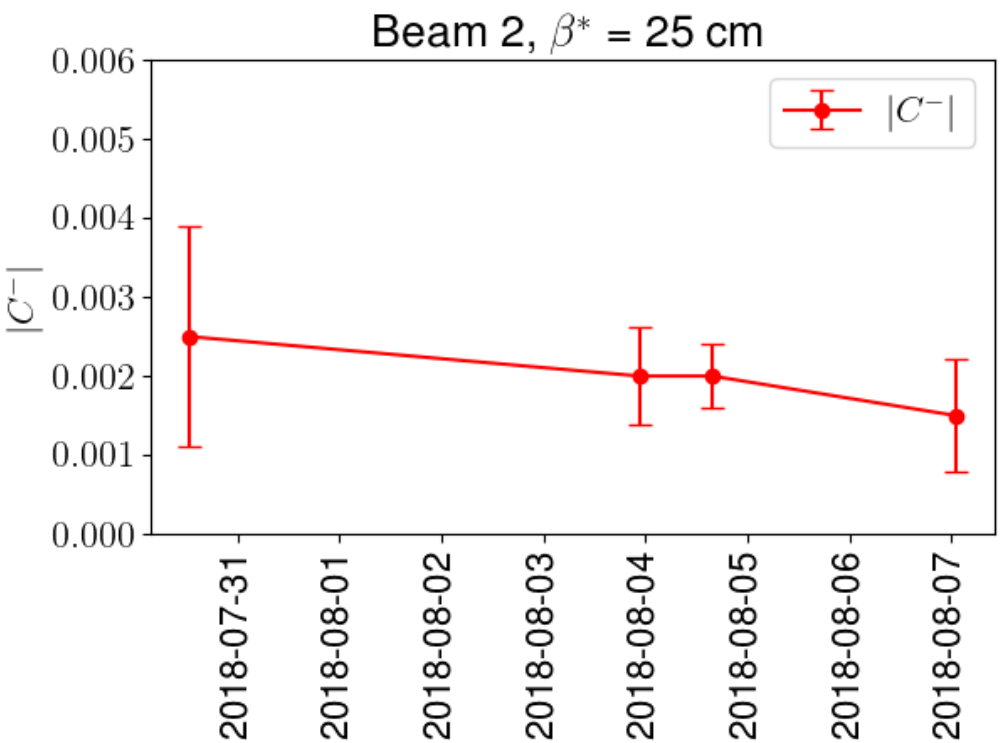
Outlook

- Injection:
  - The new b_3 compensation together with the present correction procedure using the ADT AC-dipole will control the coupling to ~10^{-3}
  - Fill-to-fill variations is interesting to understand from an academic point but has no impact on performance
- Squeezed
  - Regular measurements with the same configuration to determine and correct the changes in the coupling
    - Complement the measurements with the AC -dipole when possible (MDs)
  - The effect of LR on transverse coupling opens the question if the best thing is to compensate for the "single bunch" coupling

Backup

Long term 2018 (squeezed)



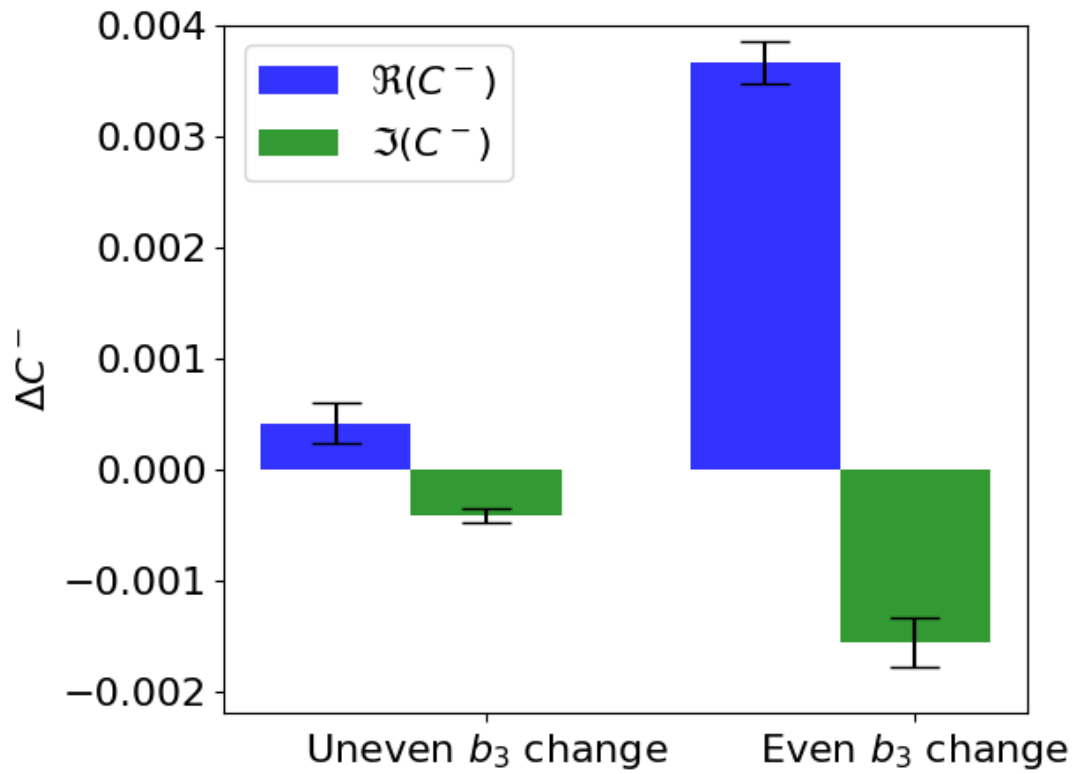


At 25 cm there seem to have been a drift of up to $2*10^{-3}$.

Note that the time do not align in time with the measurement of the 30 cm so not possible to compare

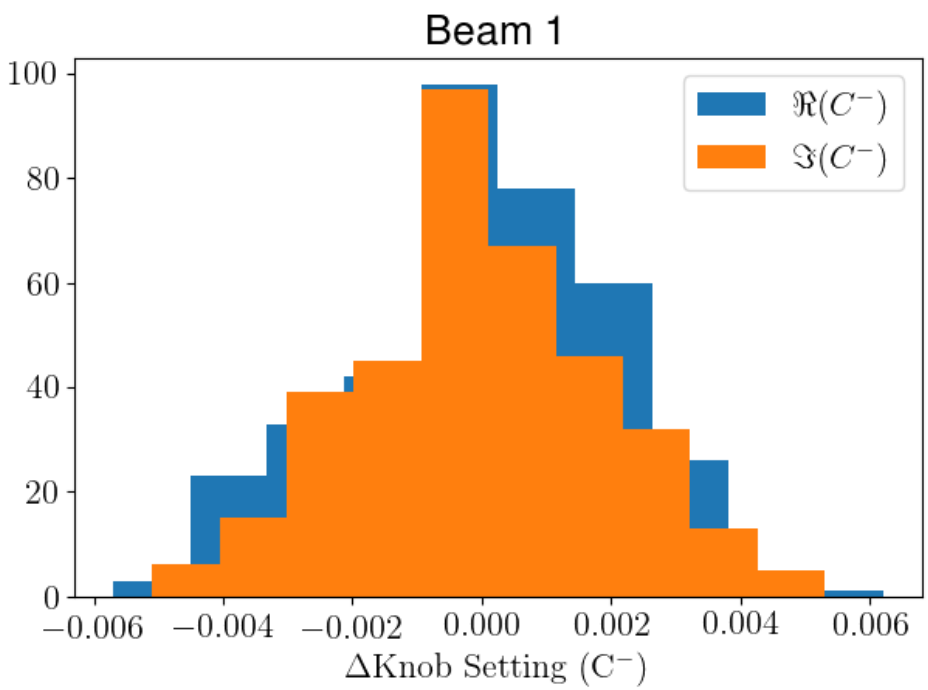
Change in C- due to the MCS powering

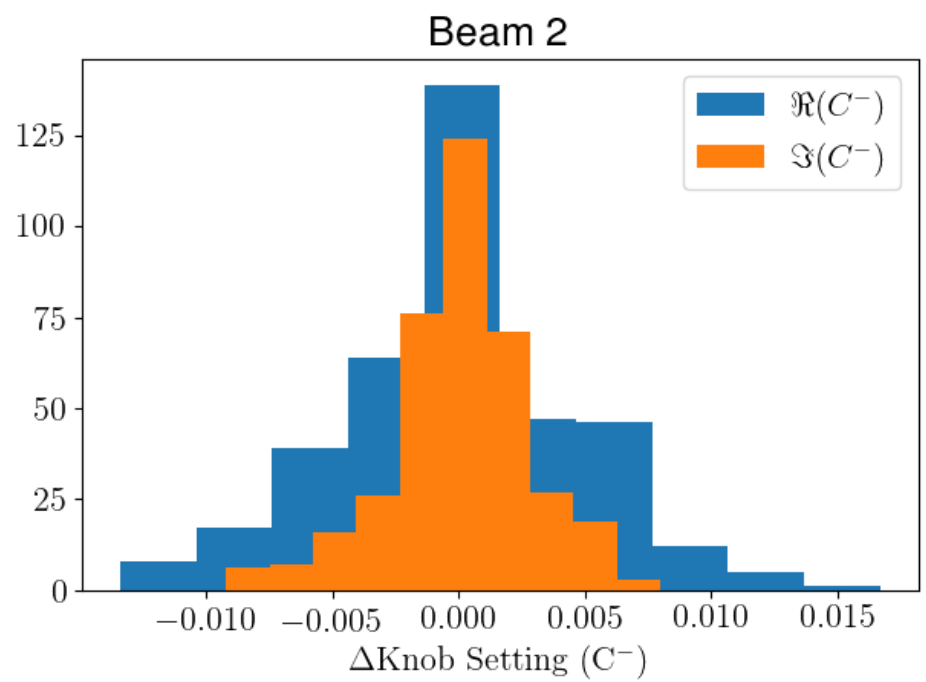
Arc	Even $[K_2]$	Uneven$[K_2]$
RCS.A12B2	0.004	0.0030535
RCS.A23B2	0.004	0.0034902
RCS.A34B2	0.004	0.0070352
RCS.A45B2	0.004	0.0027526
RCS.A56B2	0.004	0.0035134
RCS.A67B2	0.004	0.0055220
RCS.A81B2	0.004	0.0027993



The chromaticity between the two knobs were within 1 unit in the two planes

What about fill to fill?





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