Considerations on impedance and beam stability

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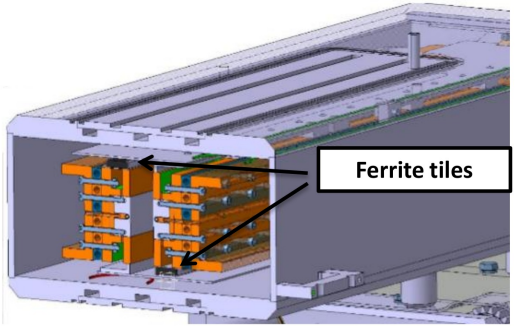
Second Workshop on Wire Experiment for Long-Range Beam-Beam Compensation – 20.03.2017

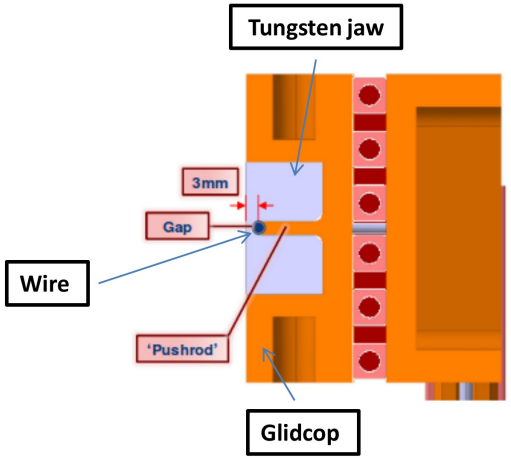
Content

- Impedance of the TCTWH
  - Coherent tune shift
- Stability margins, landau damping and beam transfer functions
- Experience with low collimator gaps and tune shift measurements

TCTWH

- **TCTP with embedded wire** for beam-beam compensation [1,2].
- Validated with **impedance bench measurements** on 13-12-2016
- **Main outcome: same as a TCTP** on 31-07-2014, i.e. **presence of 87 and 169 MHz transverse HOM** -> Detailed analysis confirmed **not an issue for beam stability** (see also PhysRevAccelBeams.20.011003)

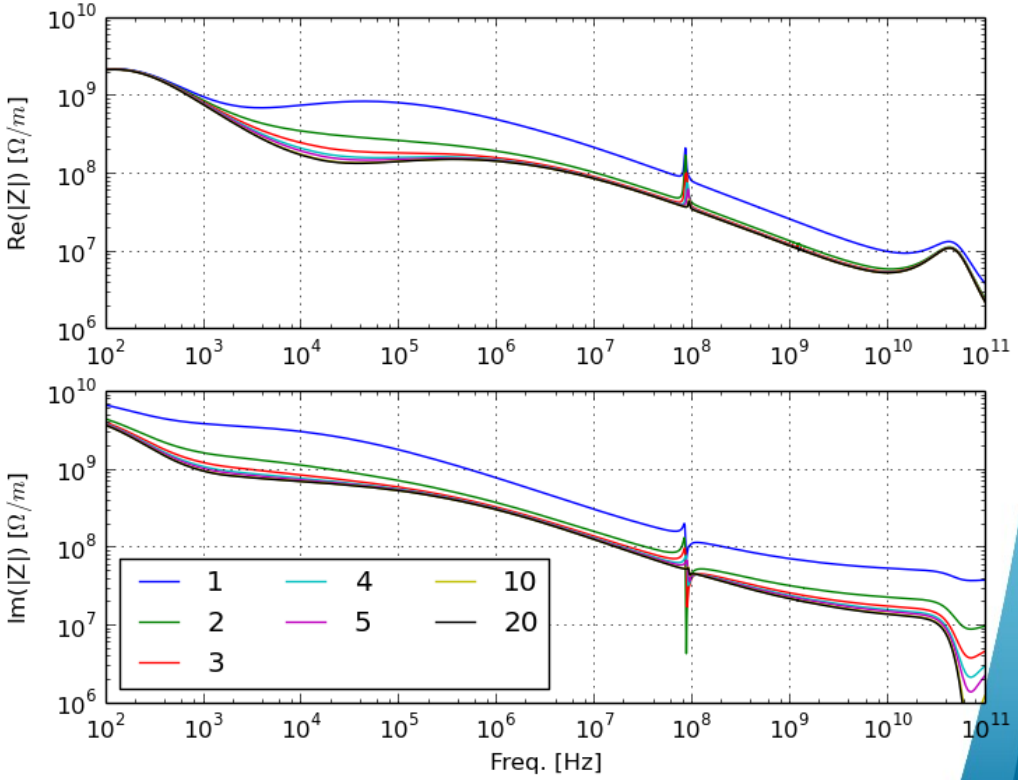




[1] D.Pierini, "Advanced collimation design studies (TCT with wire, hollow e lens)" 4th Joint HiLumi LHC-LARP Annual Meeting
[2] O.Aberle , "TCTW production, assembly procedure and validation" LHC Collimation Working Group #202

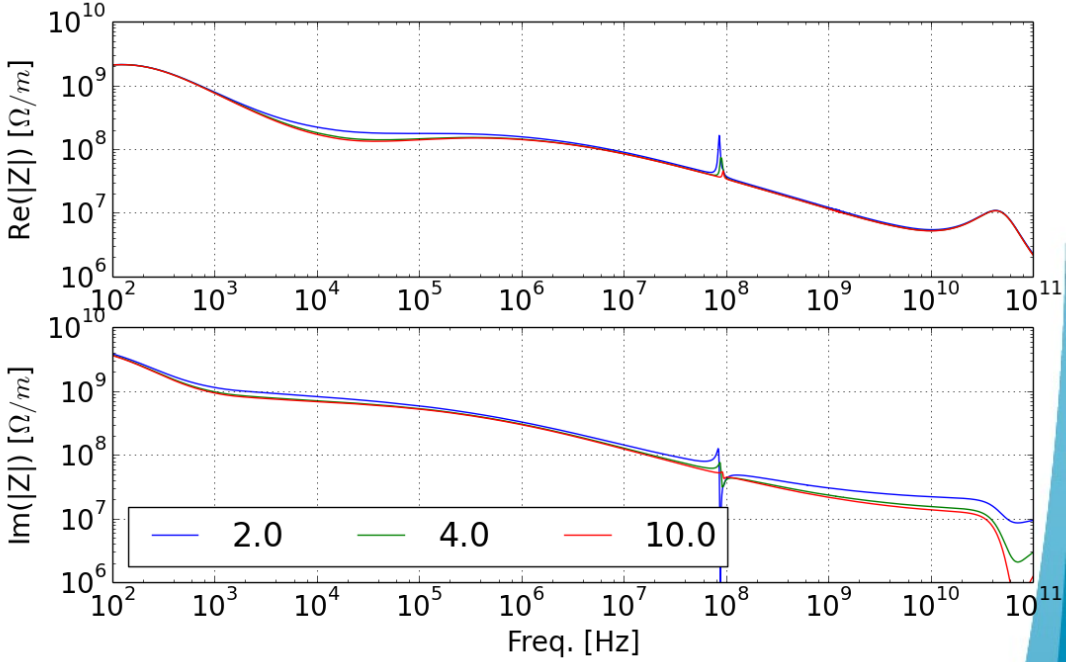
Total impedance when closing the TCTW

- The total impedance is significantly affected by the TCTWs with symmetric gaps in the order of 1 nominal σ



Effect of a single jaw

- The impedance is greatly reduced by moving a single jaw



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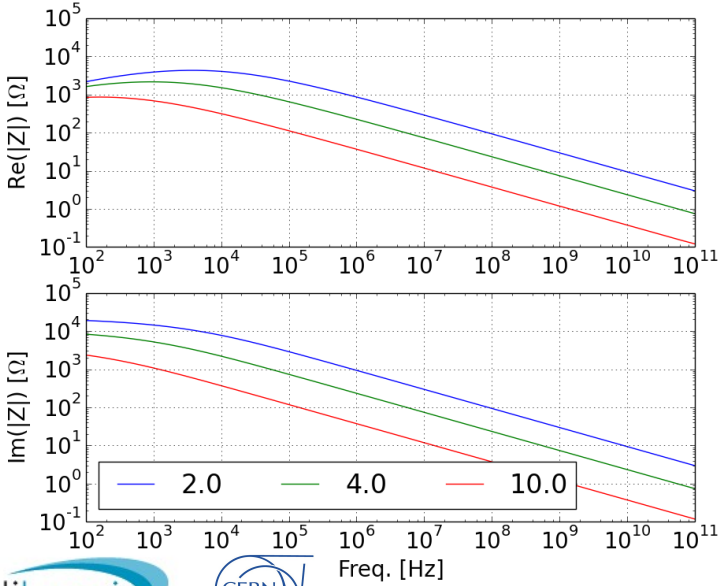
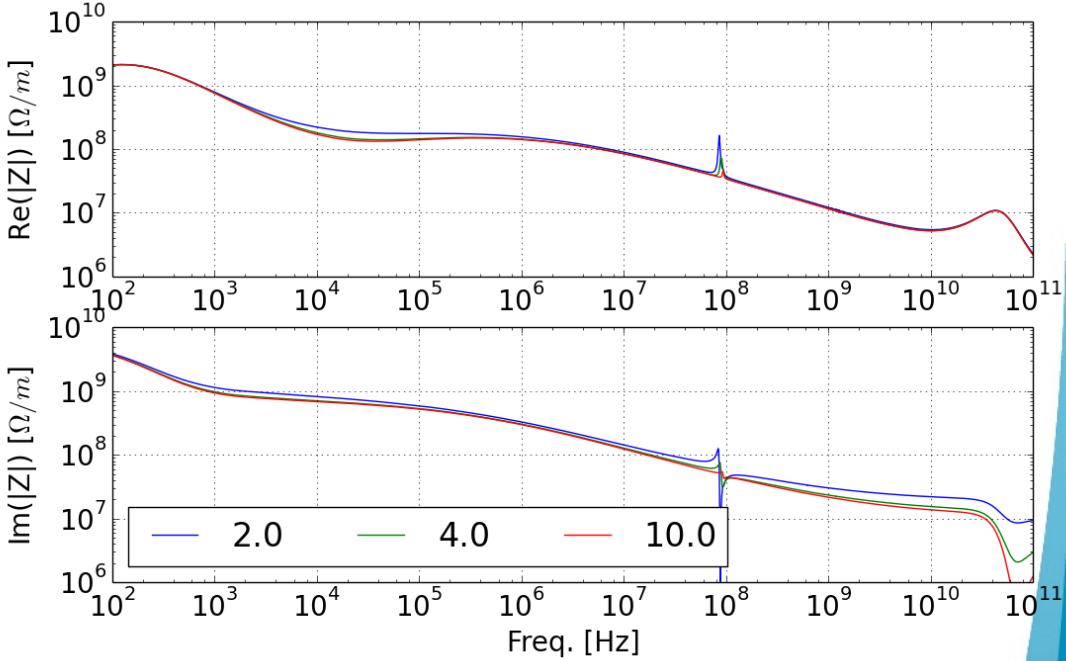
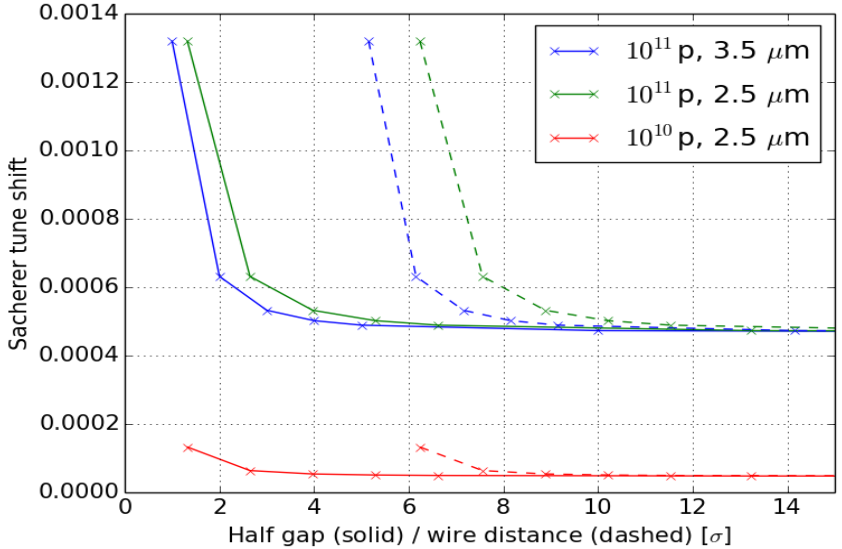




- The asymmetry creates a constant impedance resulting in an orbit effect, but negligible

Expected tune shift due to the TCTW impedance

- With 10^{11} protons per bunch, the variation of the tune shift due to the collimator movement is in the order of ~10^{-4} for wire separations below 10 σ



Assuming β = 900m
at the wires' locations

Expected tune shift due to the TCTW impedance

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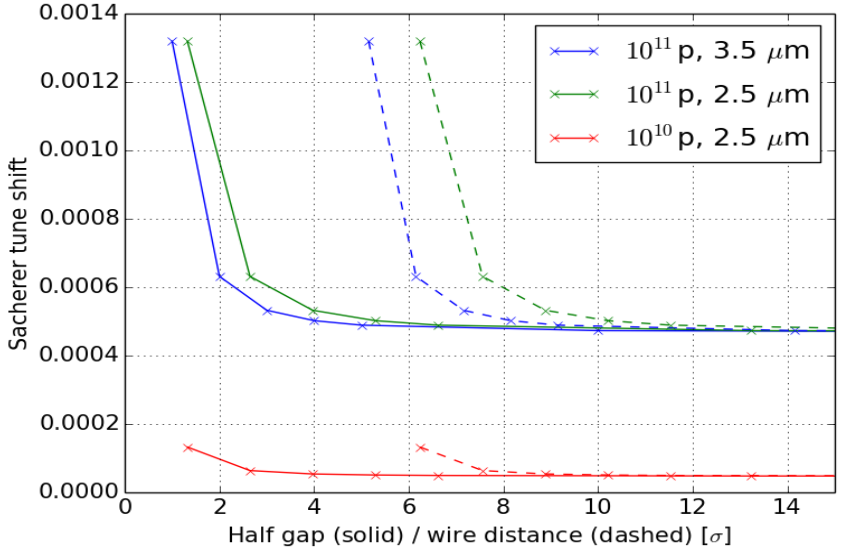
- A factor ~2 reduction can be expected with a single jaw

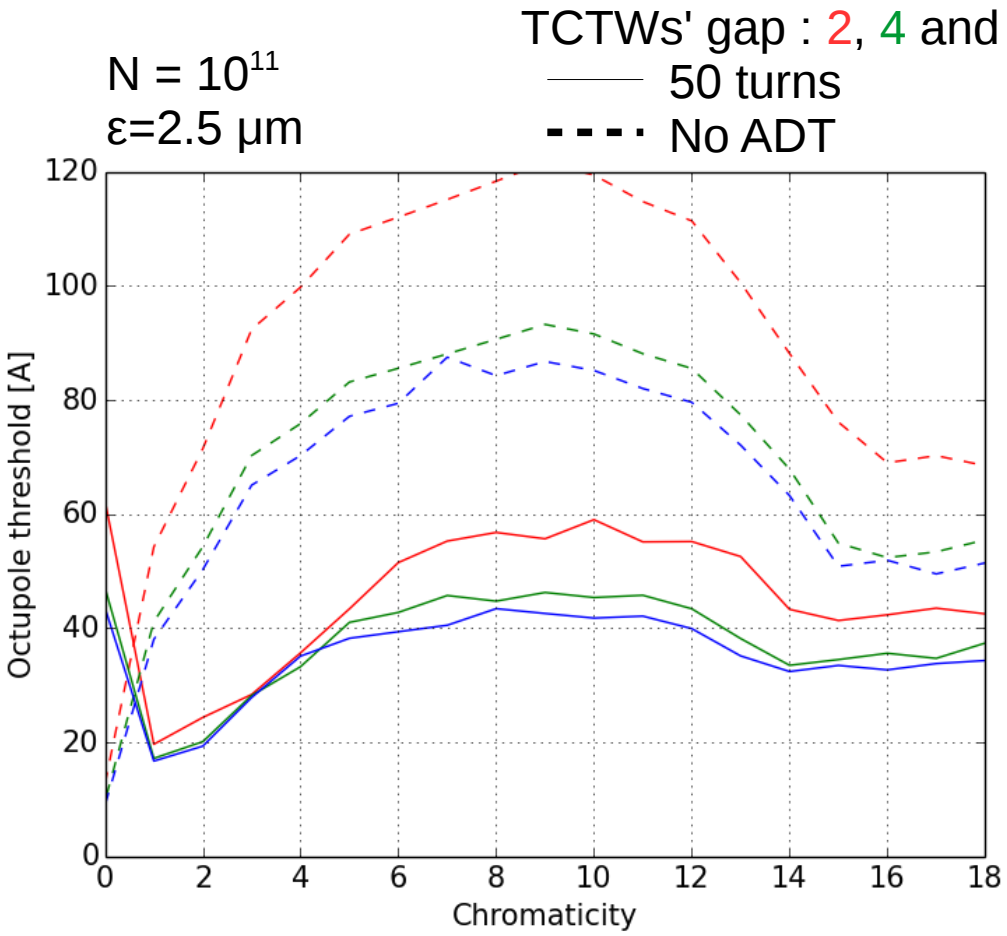


Assuming β = 900m
at the wires' locations

Beam stability

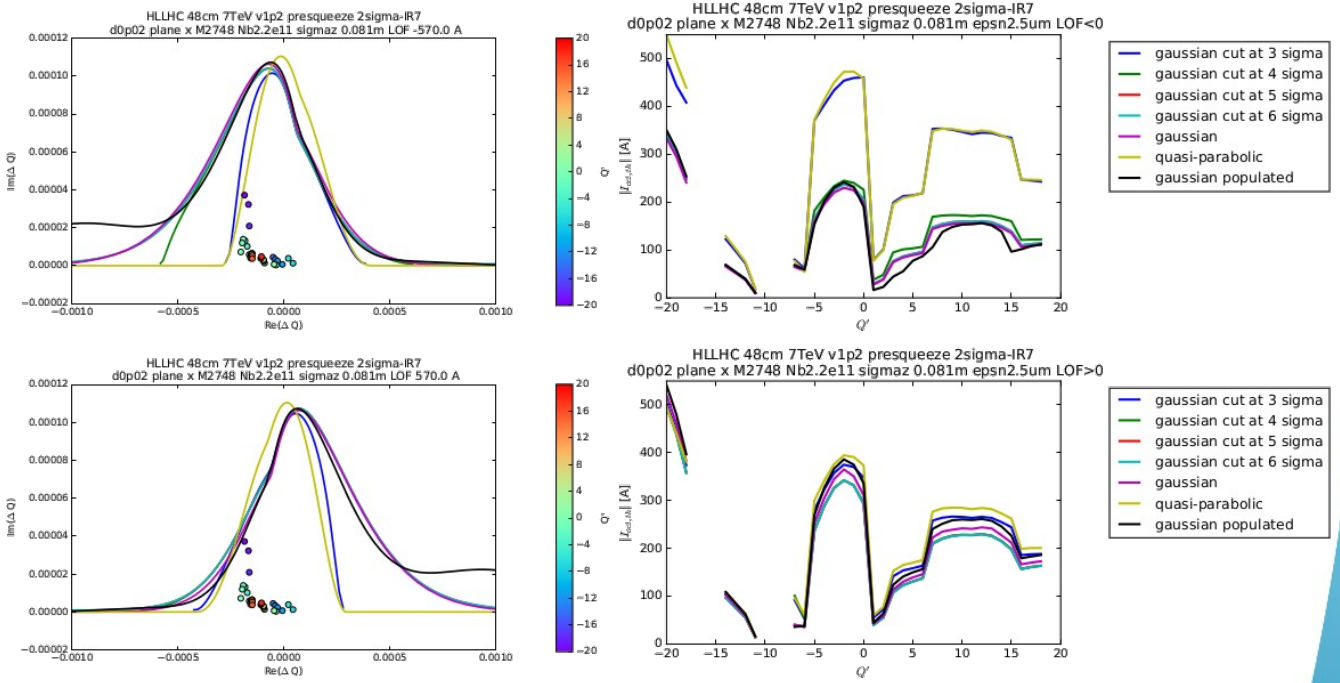
- The requirements in octupole current due to the increased impedance are almost unaffected with TCTW gaps as low as 2 σ

  → The beam stability can be ensured by the octupoles, even with 10^{11} p and without ADT



Beam stability

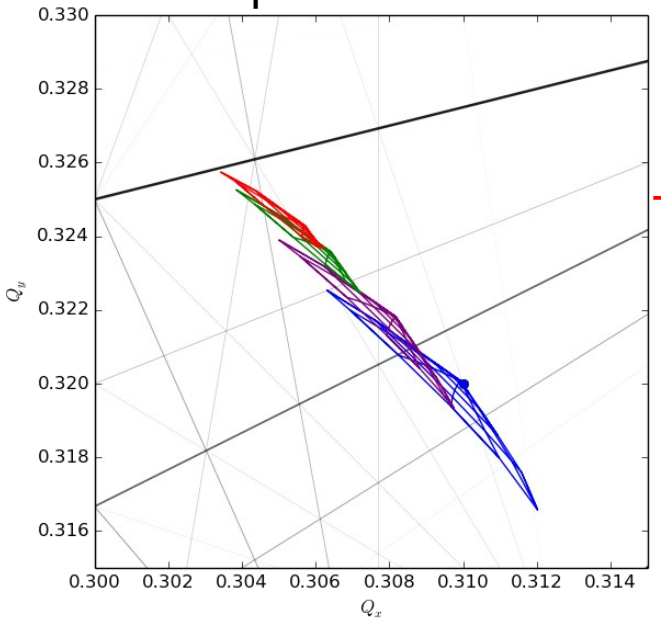
Example : HL-LHC pre-squeezed w/o low Z collimators nor CC :
(N. Biancacci @ WP2 meeting, 03.10.2016)



- Cut tails results in an increase of the required octupole by a factor 1.5 to 2 with the negative octupole polarity
- Almost no effect with the positive polarity

Landau damping with octupoles, long-ranges and wires

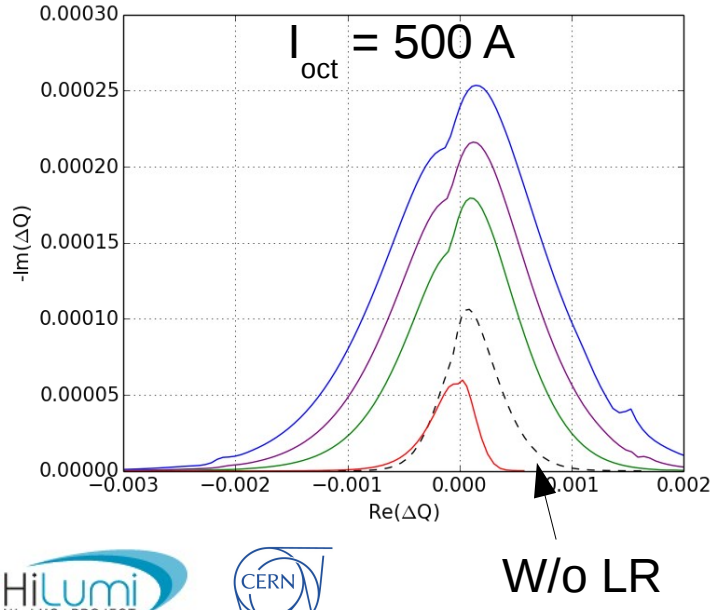
Compensation of LRs in IR5 :



None
Half
Full
+20%

Landau damping with octupoles, long-ranges and wires

- With the positive polarity of the octupoles, the long-range effects improve Landau damping



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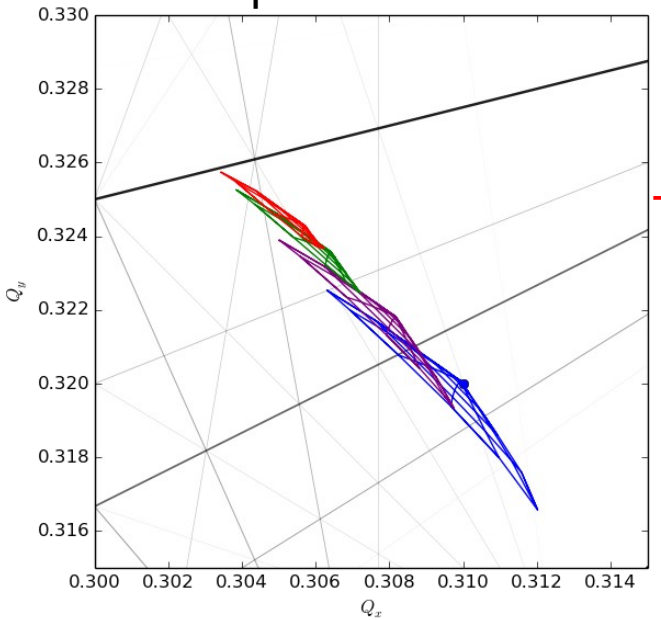

- Only an over compensation of the spread leads to a deterioration of the stability diagram, which should be compensated by increasing the octupole current

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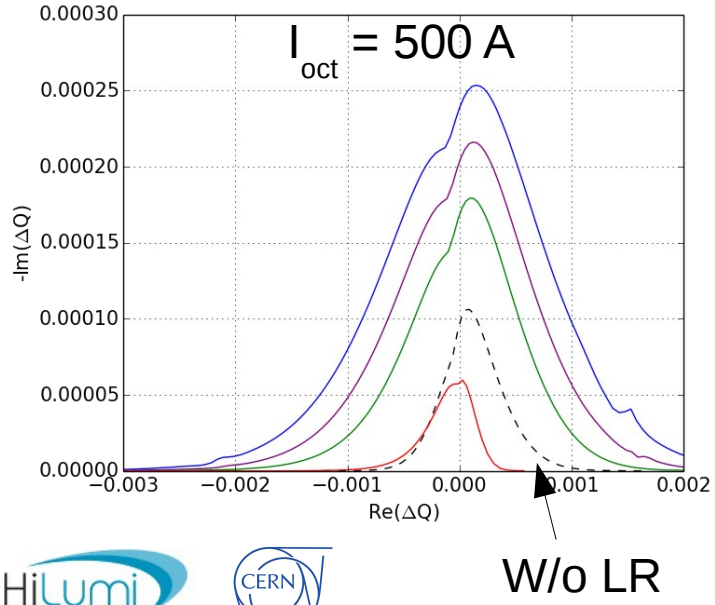

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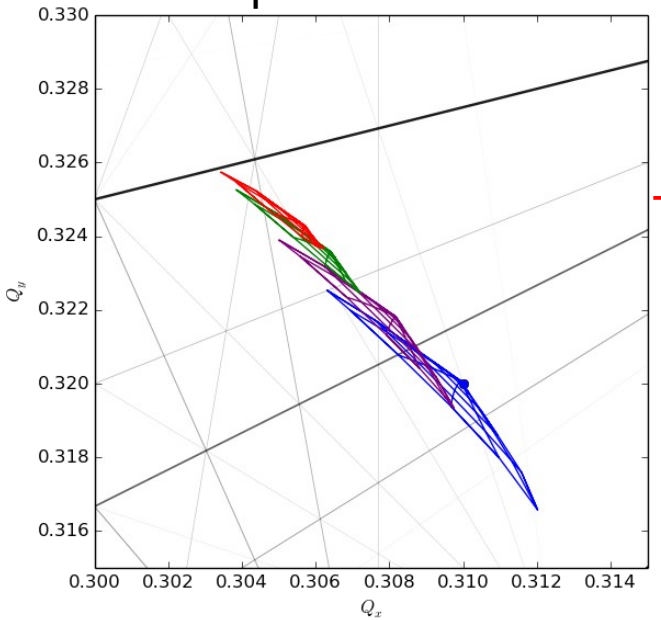

- Only an over compensation of the spread leads to a deterioration of the stability diagram, which should be compensated by increasing the octupole current
- Tune spread from head-on collisions ensures Landau damping of all impedance driven instabilities for any wire current / position

Measuring Landau damping

- The beam transfer function is proportional to the inverse of the stability diagram
- Relative variations of the tune spread due to the wire can be measured
- The information of the detuning with amplitude is combined with the particles distribution

Compensation of LRs in IR5 :

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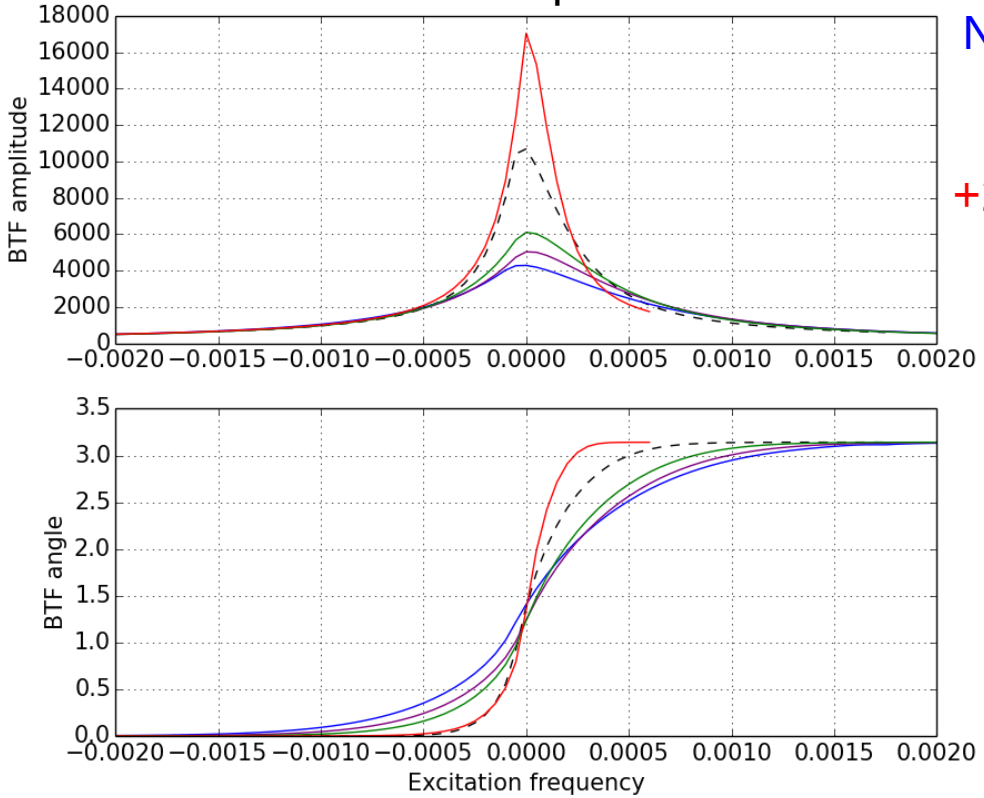

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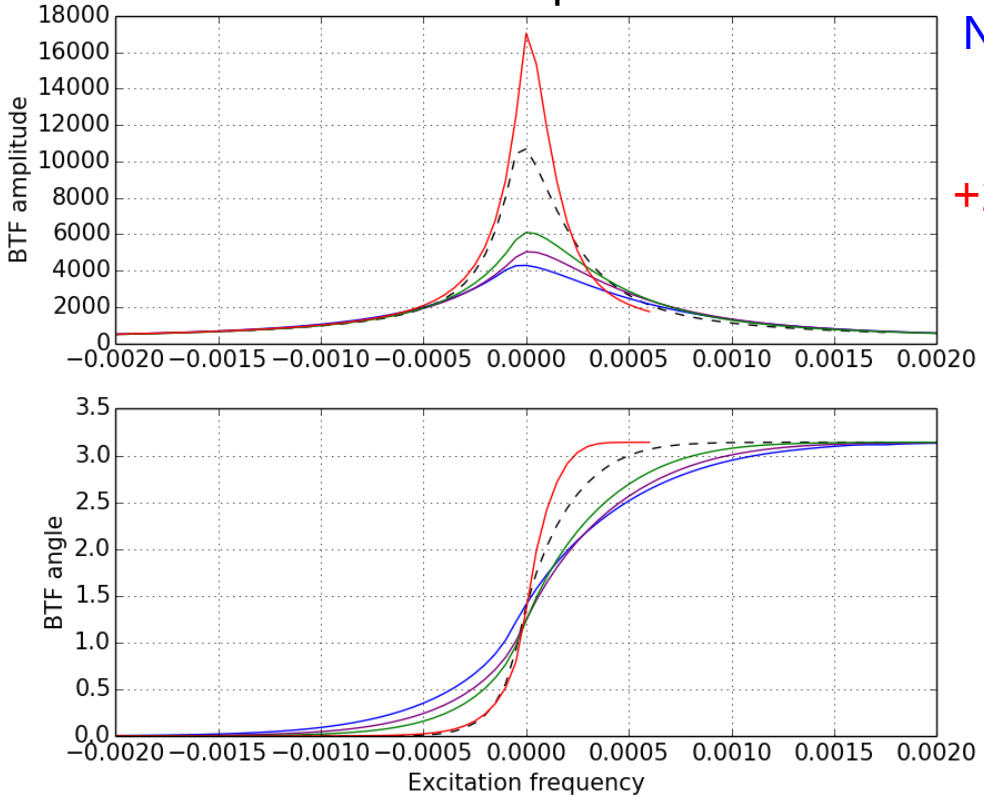
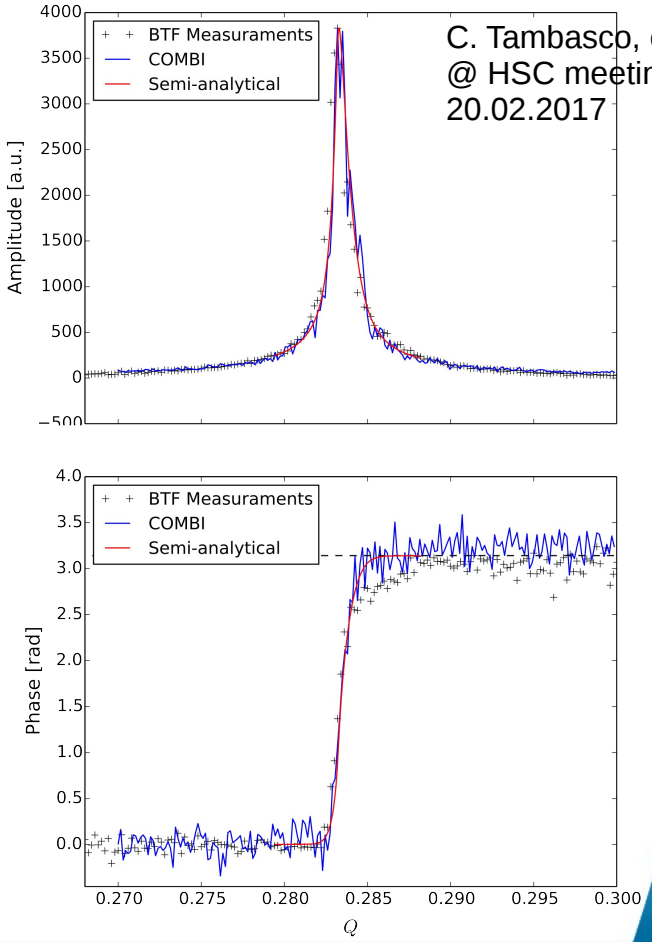


- Used at RHIC to demonstrate the effect of the e-lens
  (X. Gu, et al.,Phys. Rev. Accel. Beams 20, 023501)

Experience with beam transfer function measurements

- BTF cannot be measured with the ADT on (since it dominates the beam response)
- Coherent beam-beam modes perturb significantly the measurement → Only weak-strong configurations possible (tested with bunches of 10^{11} against 10^{10})
- Good agreement between expectations and experimental data at injection with 6.5 A in the octupoles and a chromaticity of ~0 unit

  → Good setup to test the tune spread induced by the wire at injection



C. Tambasco, et al, @ HSC meeting, 20.02.2017

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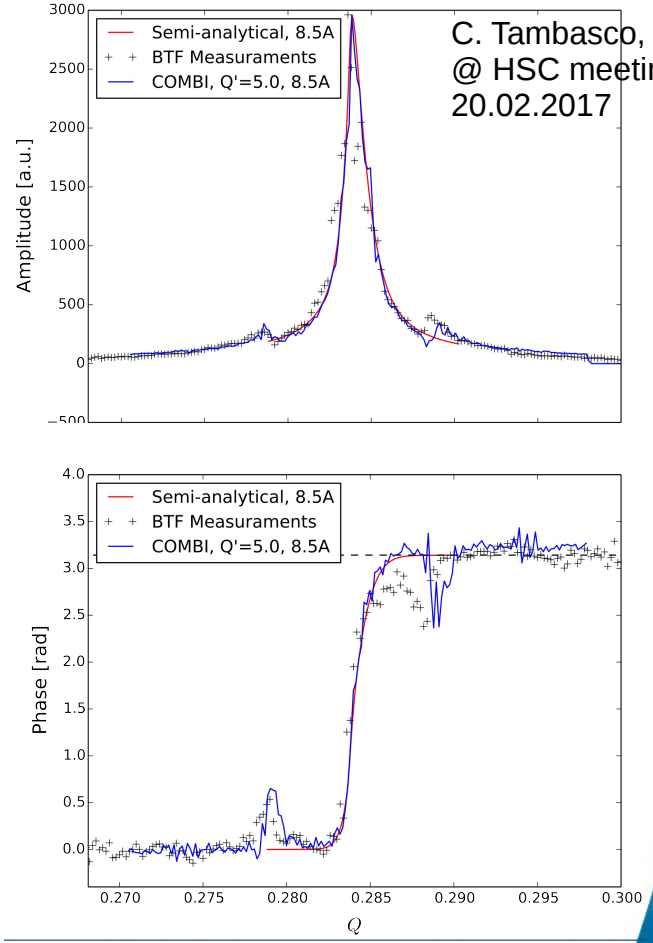
- A non-zero chromaticity has a significant impact on the measured BTF



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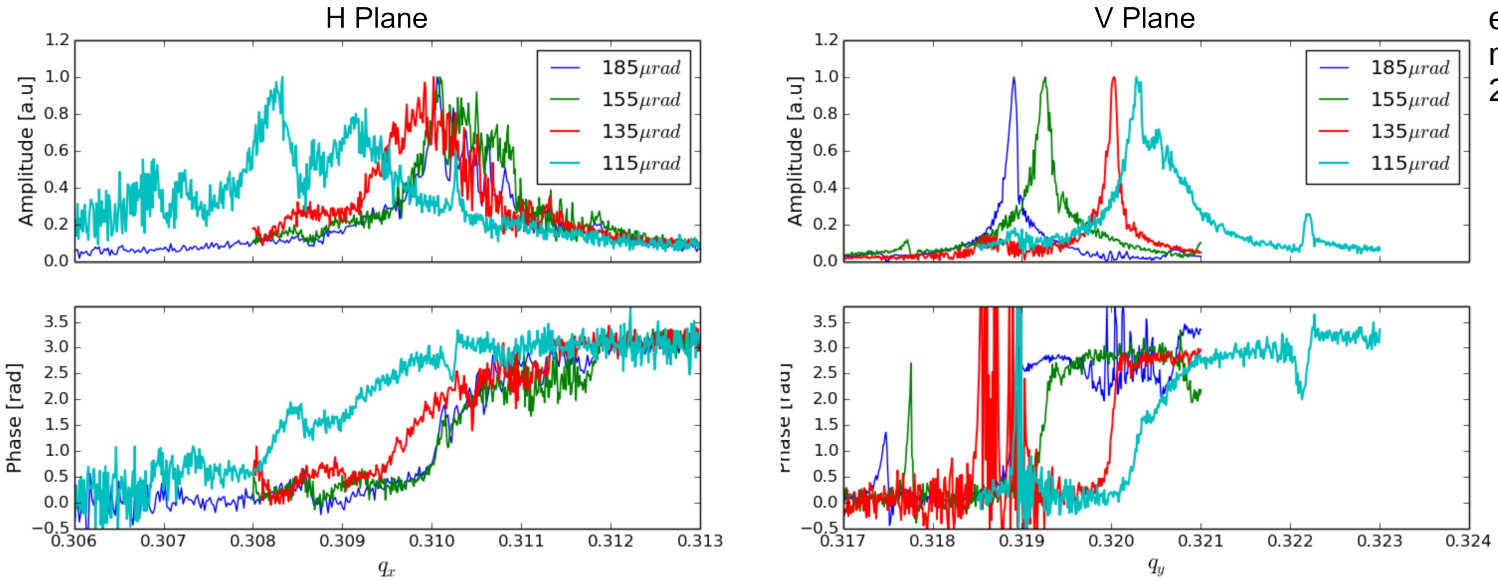

- Asymmetric behaviour between the two planes when reducing the crossing angle shows that the tune spread due to long-range beam-beam is not well understood

  → Breaking of the passive compensation ? Local coupling in the IRs 1 and/or 5 ?

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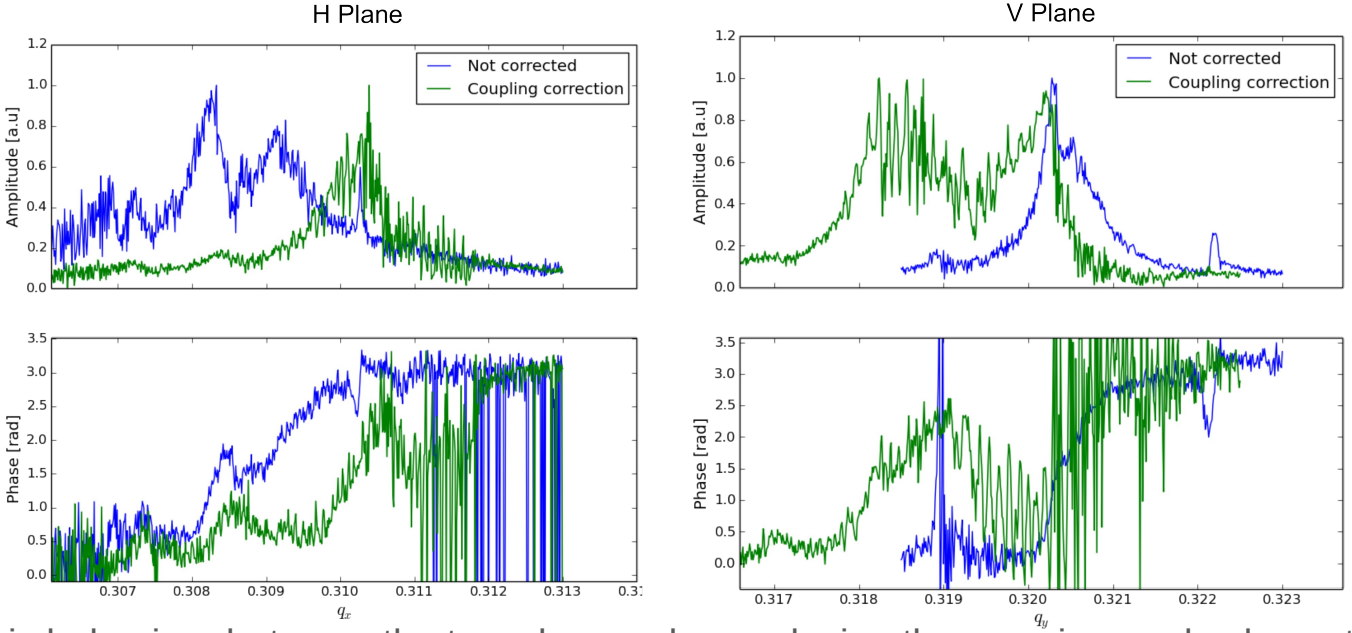

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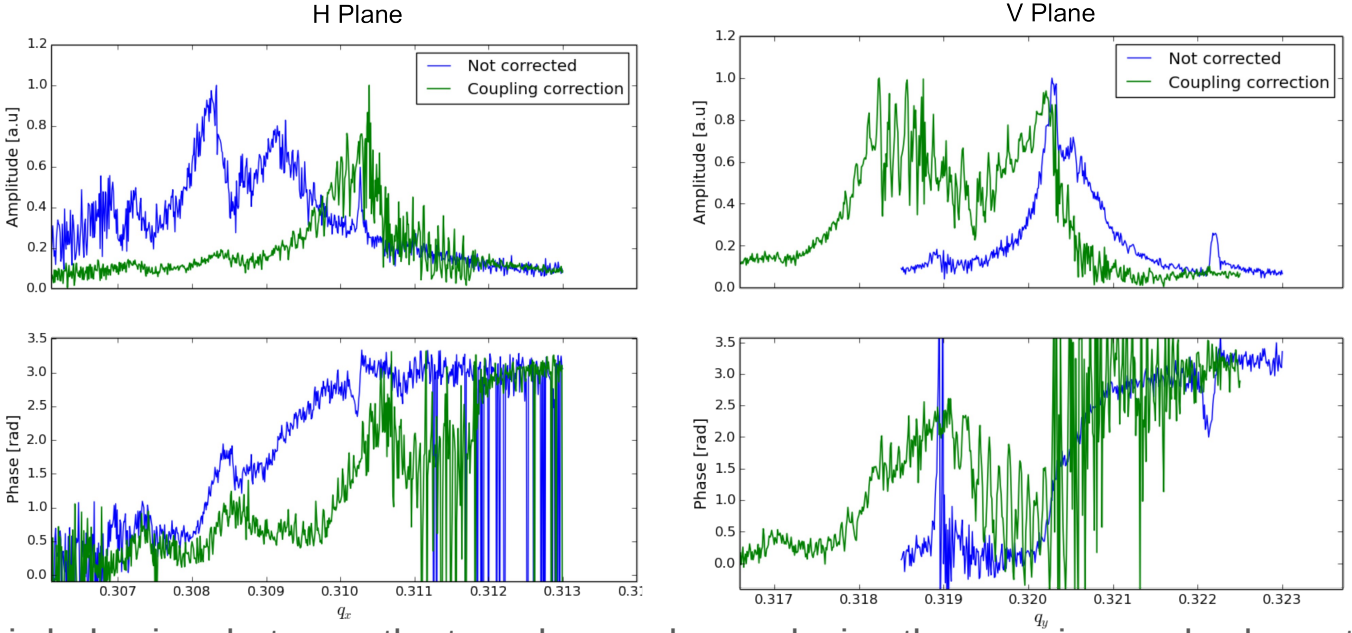

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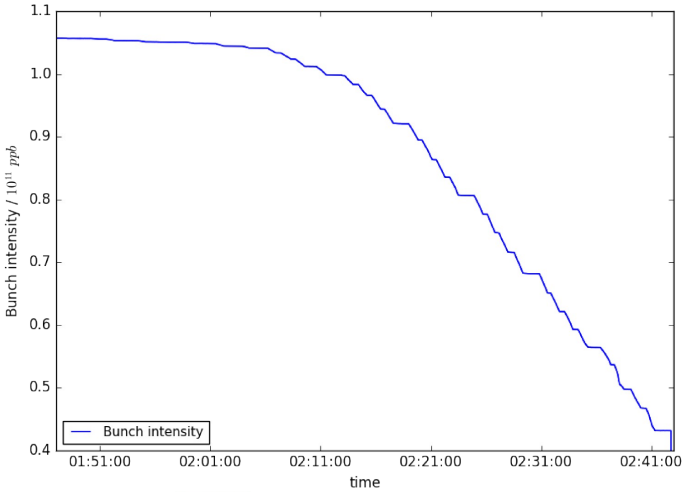
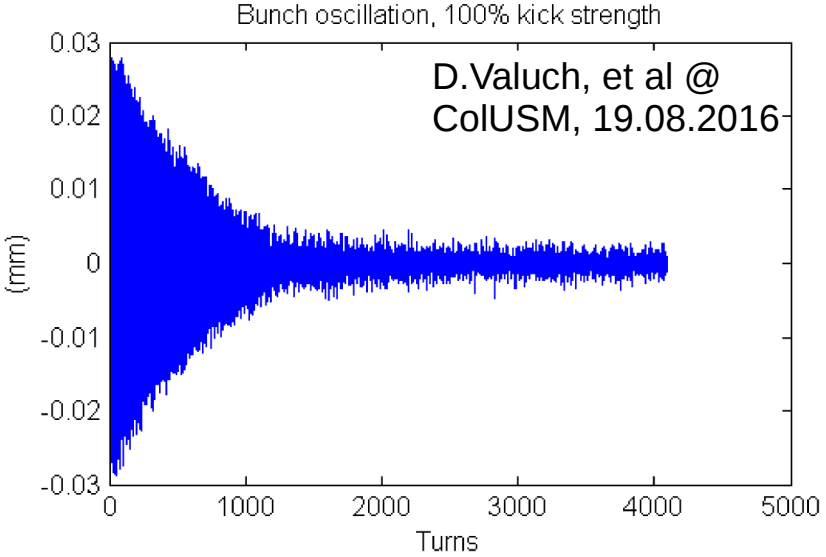
- A lot of progress have been made since last workshop, several further improvement ongoing in collaboration with BI

Experience with small tune shift measurements

- Tune resolution in the order of 10^{-5} possible with kicks resulting in 30 µm (~0.1σ at 6.5 TeV) oscillations with the ADT on with ~100 turns damping time



N. Biancacci, et al @ ColSUM, 24.02.2017



- Decoherence and beam losses with reduced collimator gaps

  → Lowest gain (limited by instabilities) needed to improve the tune measurement without leading to losses

Conclusion

- The TCTW impedance is similar to the TCTPH's
- The increase of the impedance due to the reduced gaps (>2 nominal σ → >~7 beam sigma for the wire) of the TCTW does not affect significantly the beam stability. The cut tails also has a marginal impact with the positive polarity of the octupole
- For a single bunch, operation without ADT should be possible
- The variation of the tune shift due to the impedance when moving the wire can be in the order of few 10^{-4} with 10^{11}p per bunch
- Beam transfer function measurements provide a measurement of the amplitude detuning, mixted with the particle distribution

  → Detailed studies usually needed to fully understand the measurements

  → Relative impact of the wire (tune shift and spread) should be visible
- Small tune shift measurements where achieved with reduced collimator gaps using the ADT as an exciter, significant losses were observed