Hump: how did it impact the luminosity performance and status

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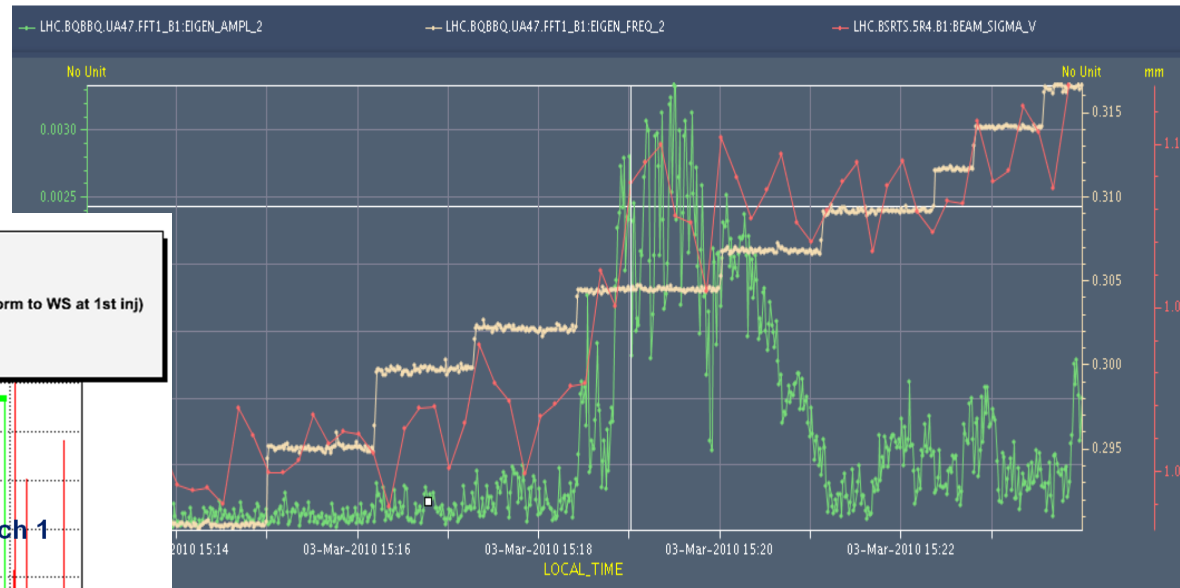
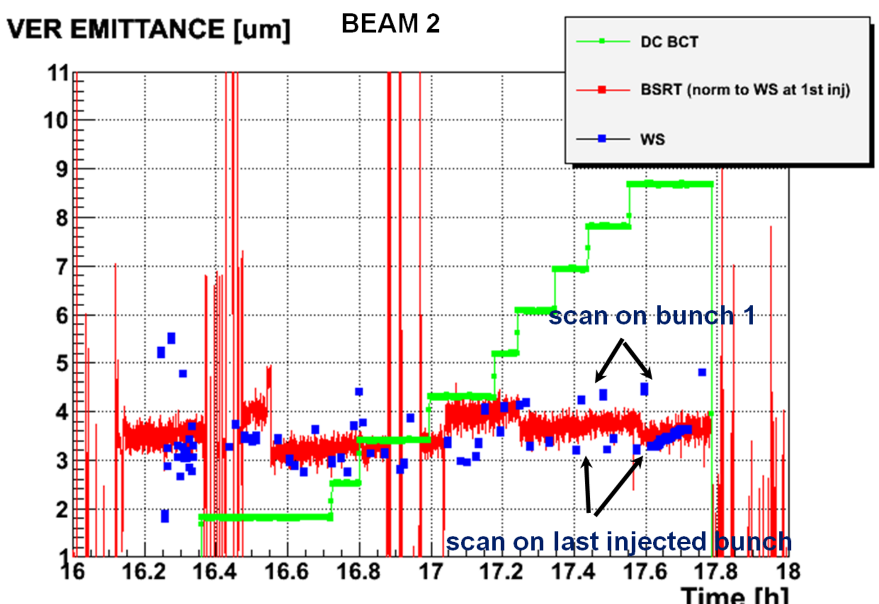
Outline

- Effect on luminosity:
  - Injection
  - Collision
- Mitigation measures
- Results
- Next steps
- Recent progress
- Summary

Effect on luminosity (injection)

- When the frequency of excitation overlaps with the n+Q or n-Q lines then blow-up and tail generation ➔ larger emittances when going in collision ➔ lower luminosity
- Here we moved the tune on top of the excitation frequency (“hump”)





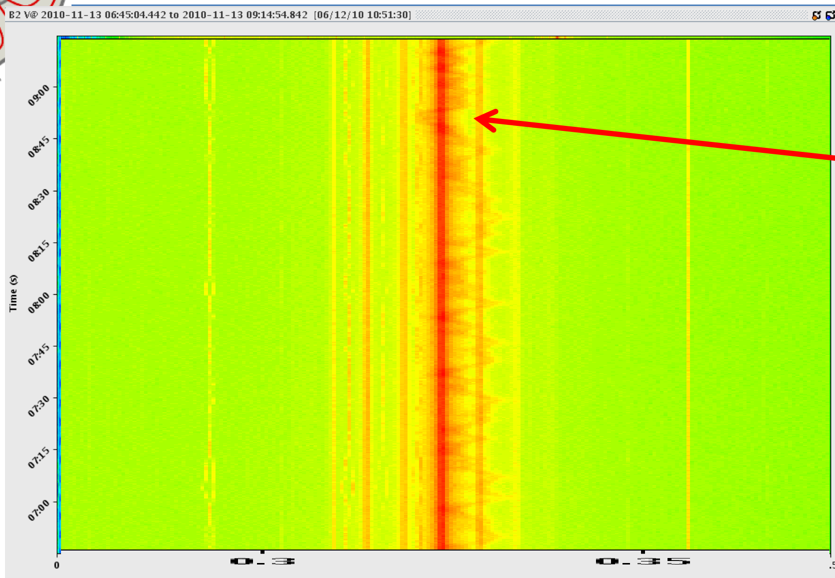
R. Steinhagen

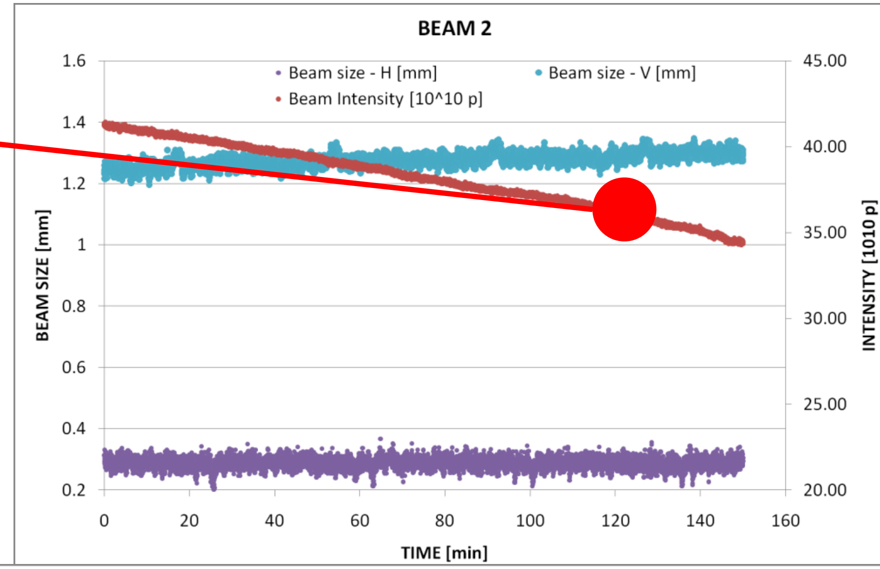
M. Meddahi, F. Roncarolo

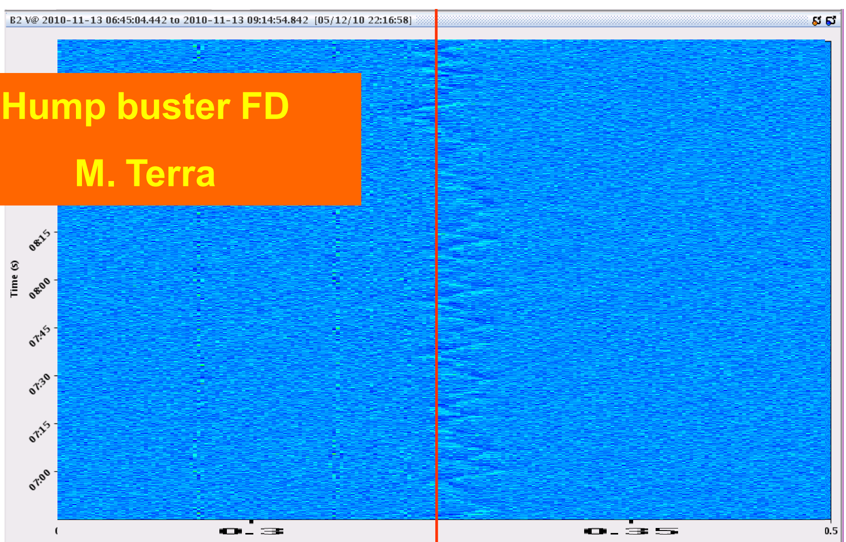
Effect on luminosity (collision)

- When in collision beam-beam acts as a strong non-linear lens ➔ faster decoherence ➔ generation of tails ➔ losses
- Excitation can also drive beam-beam coherent modes leading to losses
- Faster decrease in intensity lower lifetime: observed with ions and protons when no transverse feedback was ON in collision

Effect on luminosity (collision)

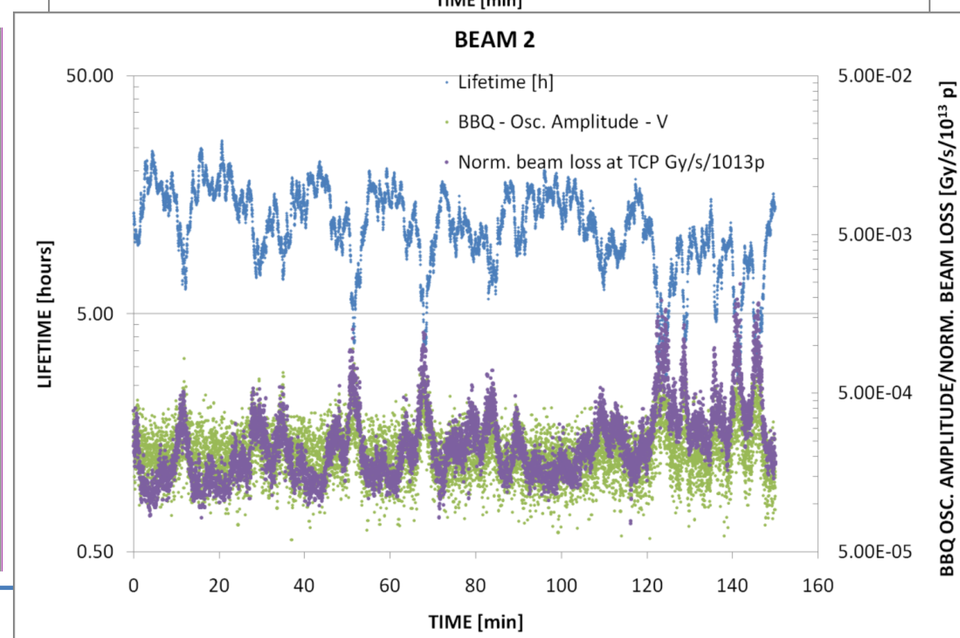






Hump buster FD

M. Terra



Mitigation measures

- While searching for origin we have worked on mitigation:
  - Damp the excitation by means of the transverse feedback:
    - At low energy first of all as the relative emittance blow-up of the excitation decreases linearly with energy
    - In collision to avoid excitation of beam-beam modes

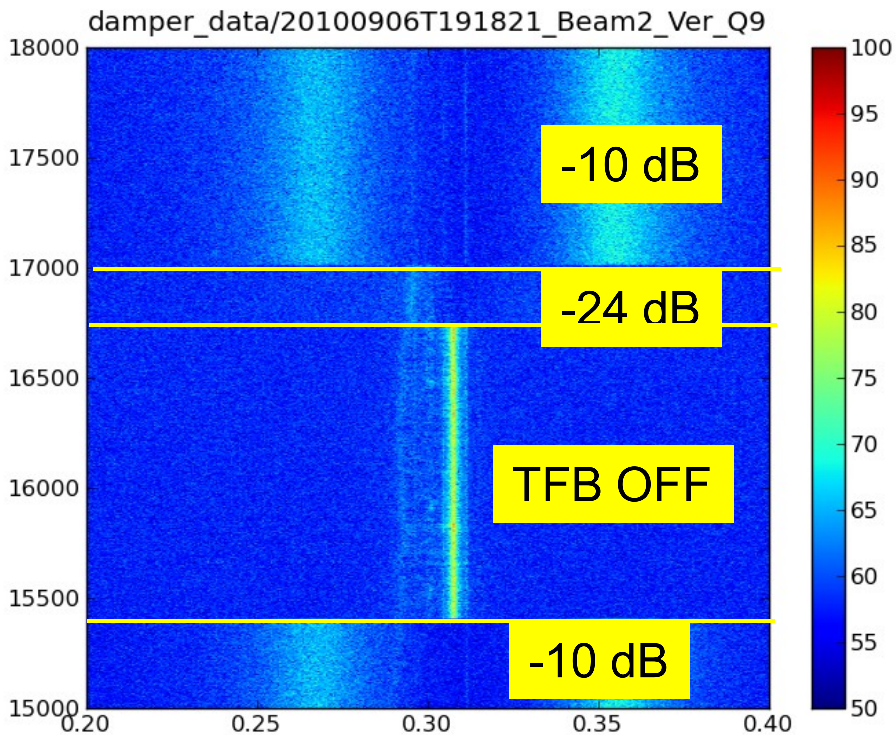
$$\left(\frac{d\varepsilon}{dt}\right)_{with\ \ fdbk} \propto \frac{\Delta Q_{rms}^{2}}{g^{2}}\left[\left(\frac{d\varepsilon}{dt}\right)_{w/o\ fdbk} + \frac{f_{rev}\, g^{2}}{2\beta_{BPMfdbk}} X_{noise\ \ rms}^{2}\right] \quad for \quad \Delta Q_{rms} < g < 1$$

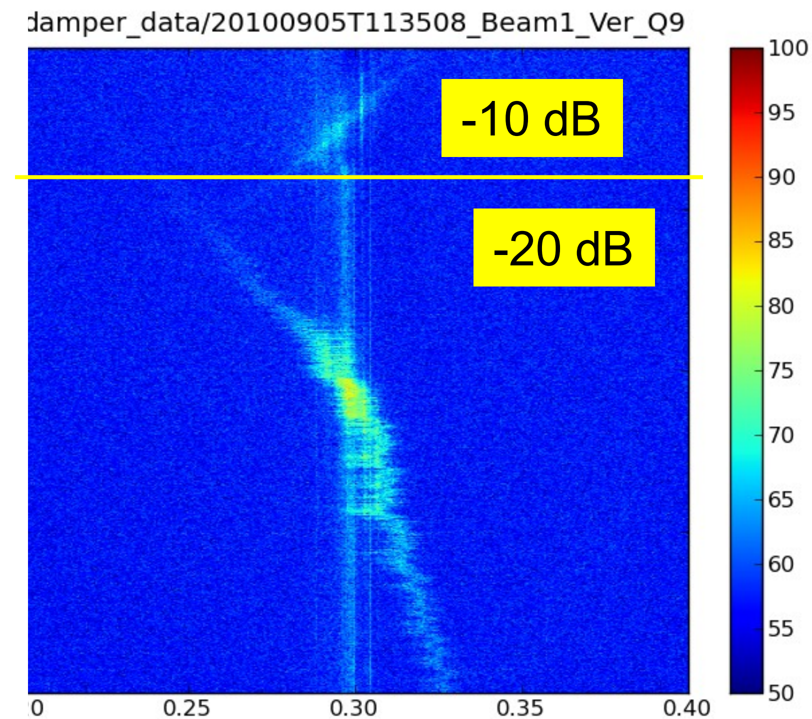
V. Lebedev, V. Parkhomchuk, V. Shiltsev, G. Stupakov, SSCL Pre-print (1993)

- Requirements:
  - need to work at high gain (power)
  - need to reduce the r.m.s. noise on the detection part of the feedback ==> W. Höfle and team during summer. Achieved 1-2 μm resolution by the beginning of September. Before the hump was hardly visible to the damper pick-ups

Mitigation measures

- We can see the hump and the damper can act on its amplitude.

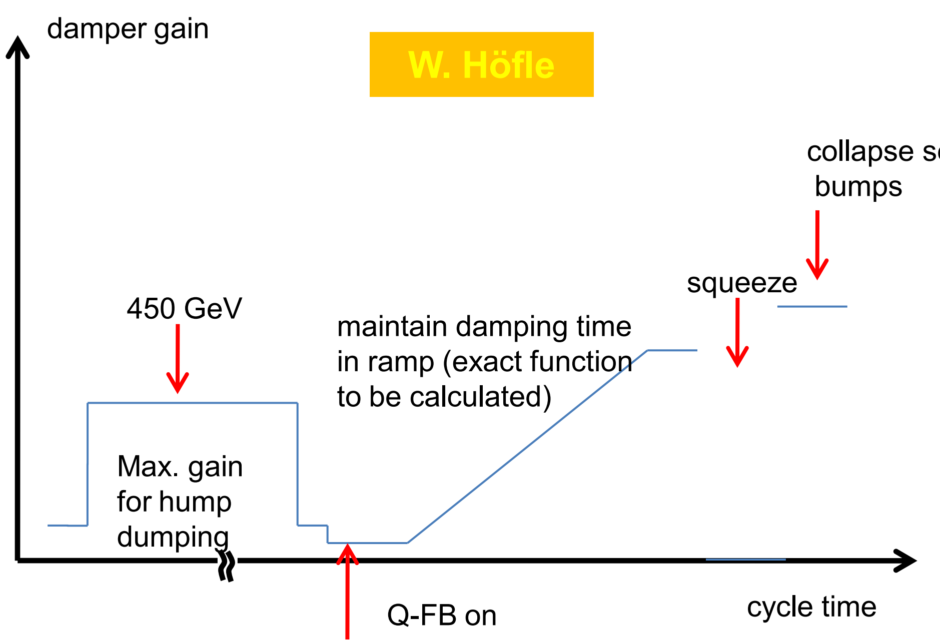




W. Höfle, R. De Maria

Mitigation measures

- Mitigation of the hump effect with the transverse feedback ➔ operation at maximum gain. Compatibility with with tune feedback has been addressed and compromise found

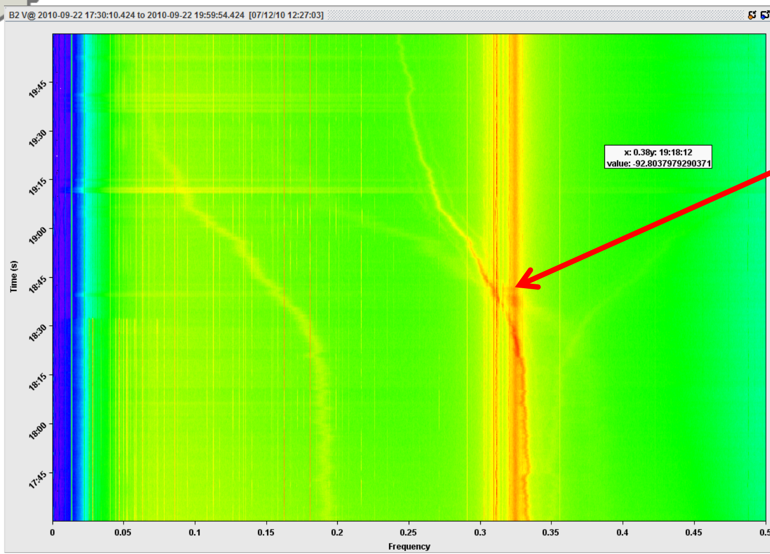


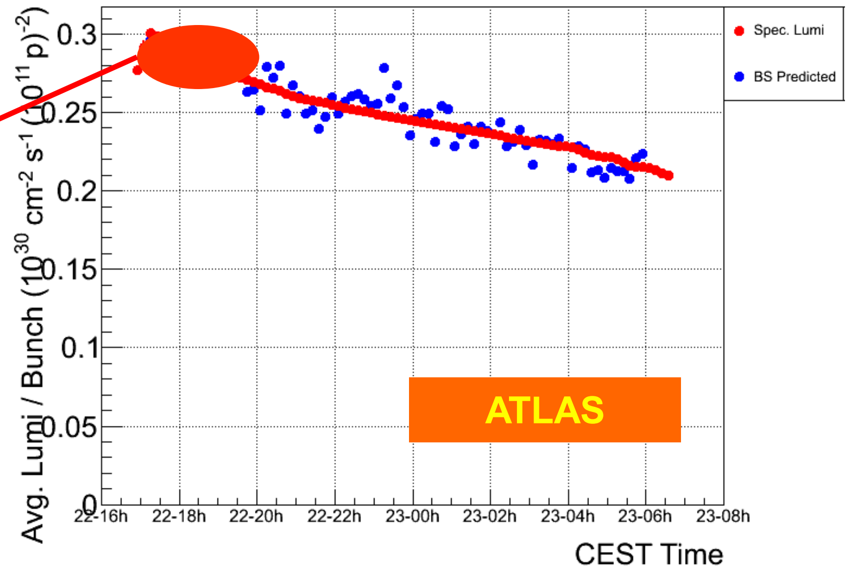
Results

Fill	# bunches	$\varepsilon_{H\ B1}$ @inj	$\varepsilon_{V\ B1}$ @inj	$\varepsilon_{H\ B2}$ @inj	$\varepsilon_{V\ B2}$ @inj	ε_{HV} @coll (from init. Lumi)	ε_{H} @end of coast (from Lumi scan or WS)	ε_{V} @end of coast (from Lumi scan or WS)
1364	25	2.5	1.9	3.2	2.7	3.2	4.0/4.5	3.8/4.9
1366	56	1.7	1.7	2.0	2.3	2.2	3.5	3.5
1369	56	2.2	2.1	2.6	2.9	2.9	-	-
1372	104	2.1	2.2	2.3	2.8	2.8	3.7	4.5

- New functions for the damper allow to mitigate blow-up due to hump in the vertical plane. Gain functions during the ramp remain to be optimized (ongoing). ~10-20% blow-up during injection plateau and ramp.
- Systematic difference B1/B2 already at injection remains to be understood (not himp related)
- Blow-up in collision (~40-50 %) to be further studied

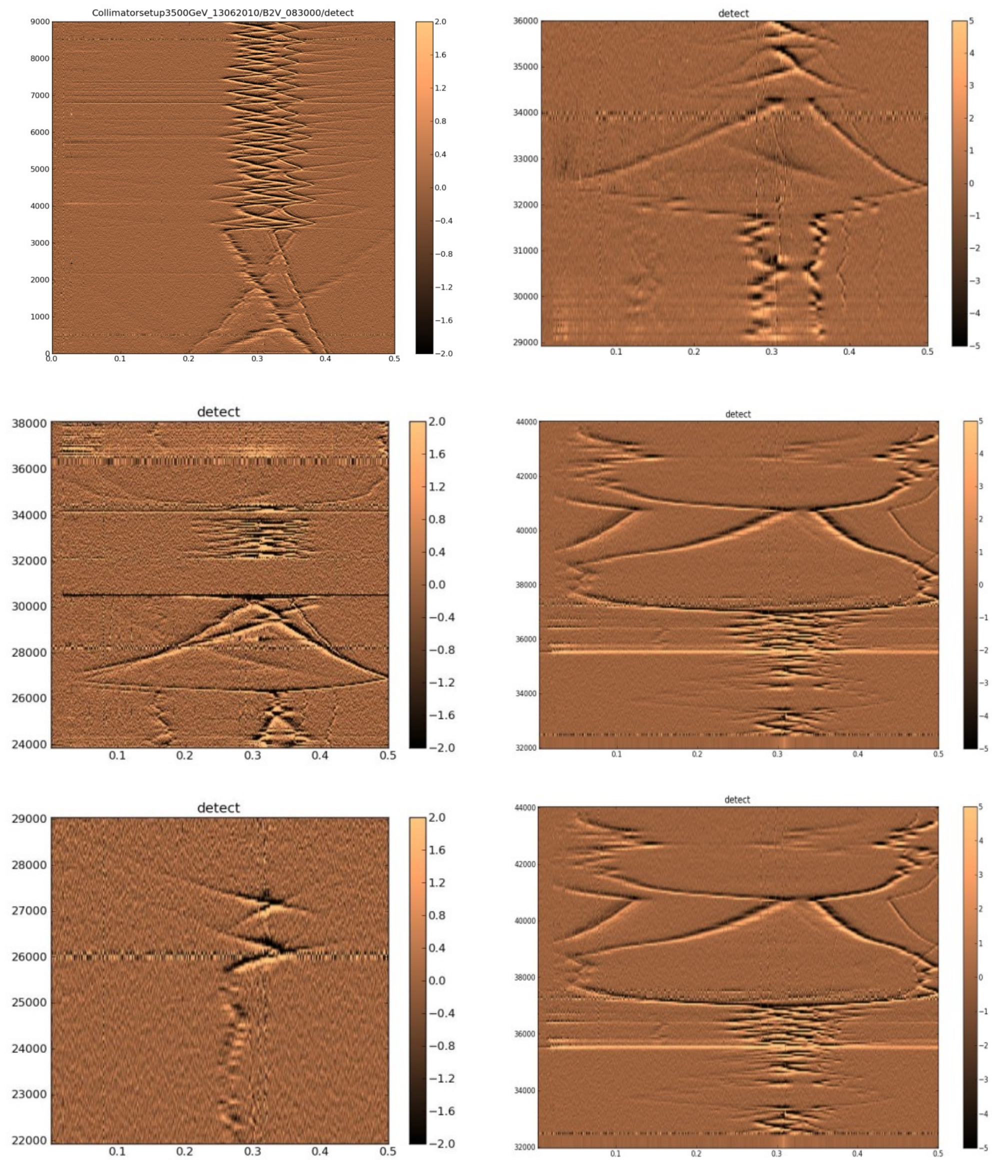
Mitigations: next steps





- Some effects are still visible in collision, some of them related to the hump:
  - Optimization of the damper gain in collision not done yet. Observed tail generation and tiny losses when the hump crosses the tune.
- Remaining effects:
  - Beam-beam and working point
  - Noise level in the damper position monitors ➔ more critical at higher energy due to the emittance reduction ➔ preparation work for understanding possible means for noise reduction ongoing

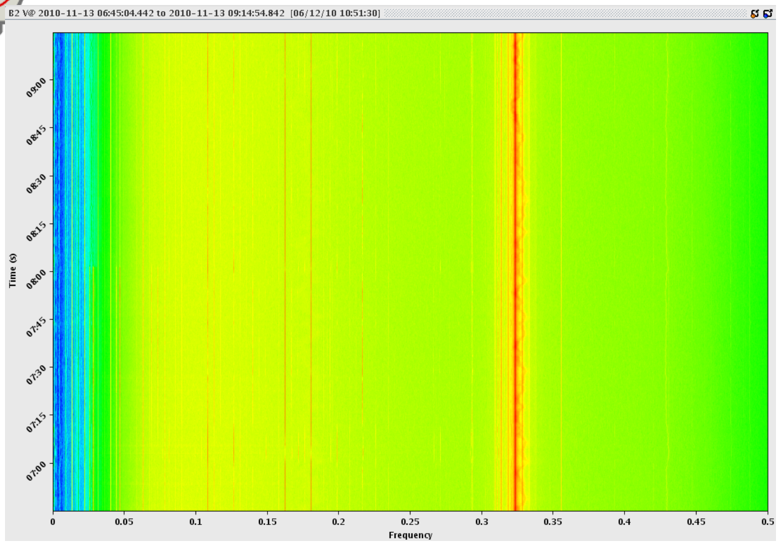
The hump is there all the time...



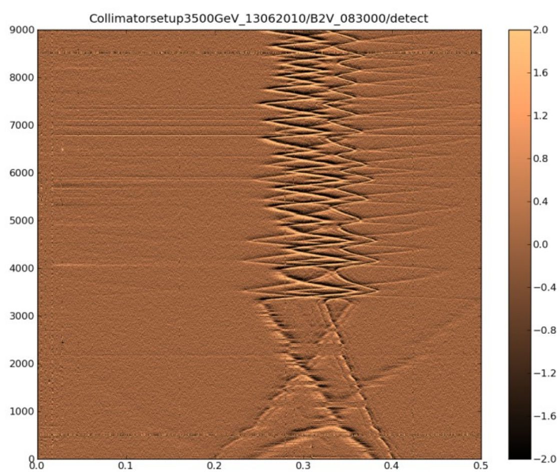
- But with different patterns more or less disturbing for the beam according to the amount of overlap with the tune...
- Sudden changes of the time pattern observed in some occasions.
- Analysis of the period March-August being completed ➔ try to find find periodicity and correlations

R. De Maria, M-C Alabau-Pons

Mitigations



- In this case small shift of the working point can help ➔ Fixed display for real time "hump" monitoring is available ➔ Use it!

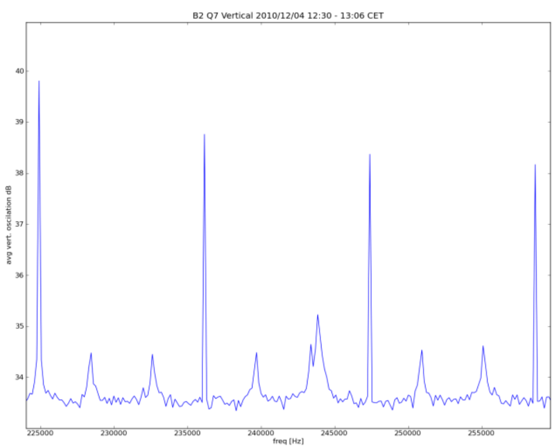


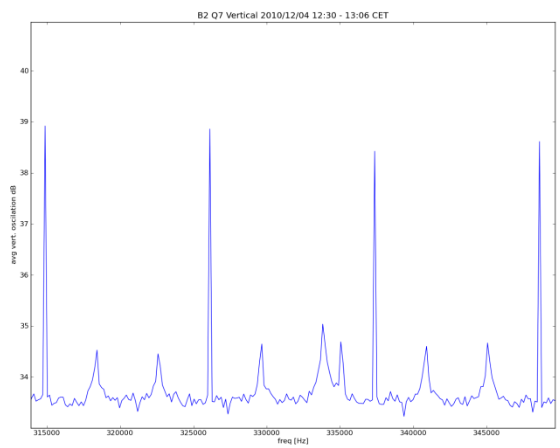
- There is not much to do in this case except damping the oscillation

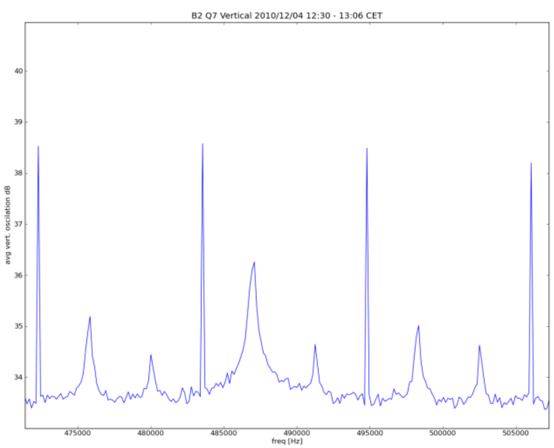
Recent progress (frequency meas.)

- So far only turn by turn position meas. (peak among several bunches) ➔ possibility to define the frequency as $\pm f_0 + n \times f_{rev}$ with $0 < f_0 < f_{rev}/2$

- Since middle of November turn-by-turn/bunch-by-bunch position with damper pick-up. Ion filling scheme with basic spacing of 500 ns ➔ possibility of determining the frequency of the hump $\pm f_0 + n \times 2$ MHz with $0 < f_0 < 1$ MHz





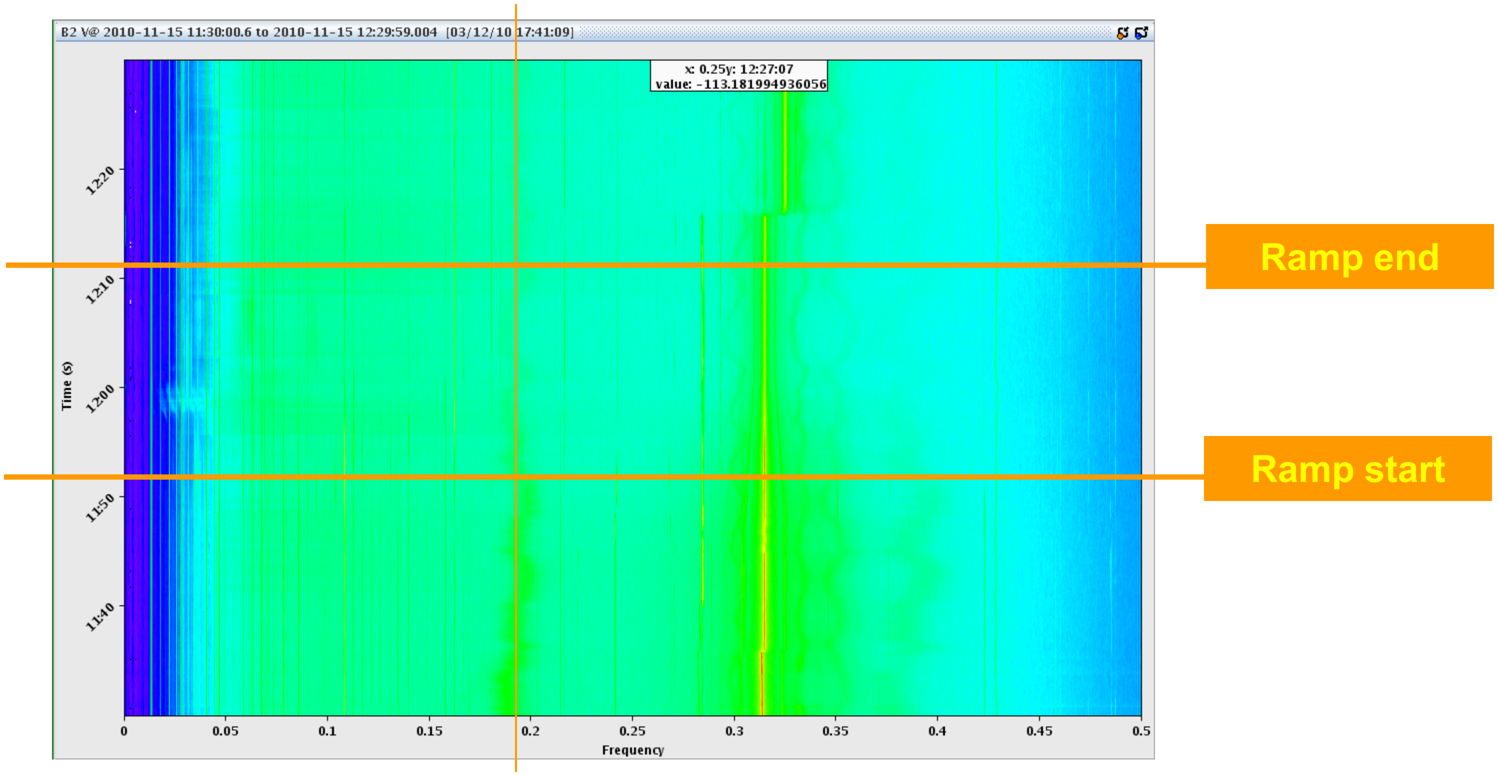


- If confirmed this would rule out UPS as origin

R. De Maria - PRELIMINARY

Recent progress (frequency meas.)

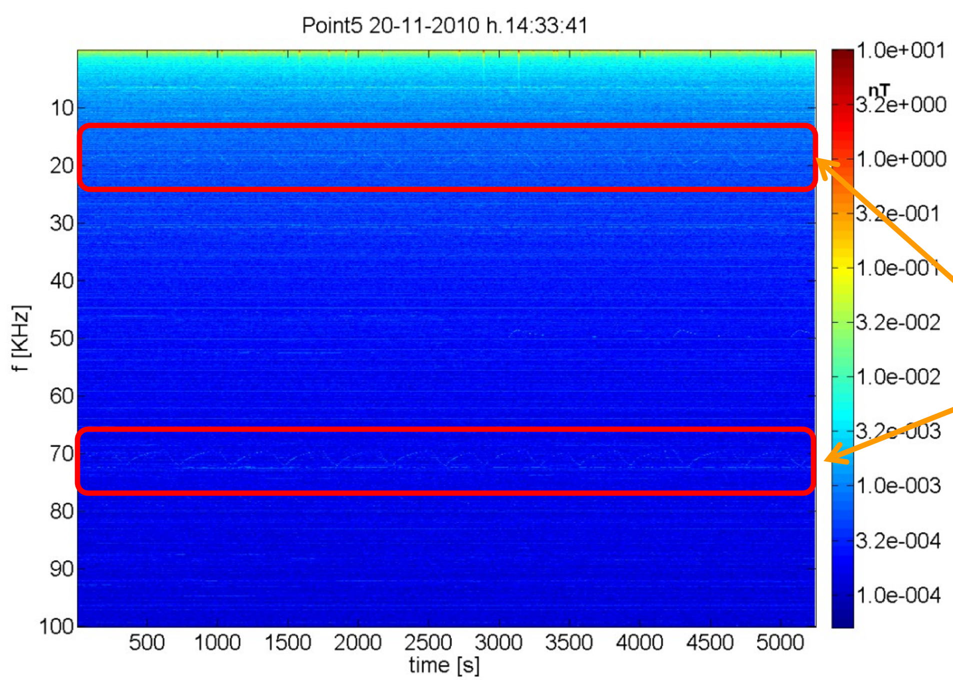
- Ions operation has allowed reducing the upper limit on the maximum frequency of the hump. Ions are less relativistic then protons ➔ f_{RF} changes by ~5KHz. No shift larger than 0.01 observed ➔ f_{hump} < 10 MHz.



- Analysis of the signal in time domain and correlation beam 1/beam 2 ongoing

Ongoing activities

- Remote magnetic measurements (J-B Jeanneret, L. Walckiers and team) and comparison with beam data to attempt localization of the source at least identification of the point/sector (1 coils/point installed and 6 out of 8 equipped with electronics and remote access) ➔ Important for hump investigations and in general understanding of the possible sources of noise affecting the beam.



Indications that these are aliases of higher frequencies

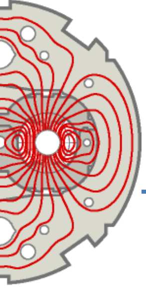
O.-O. Andreassen, G. Golluccio

Summary

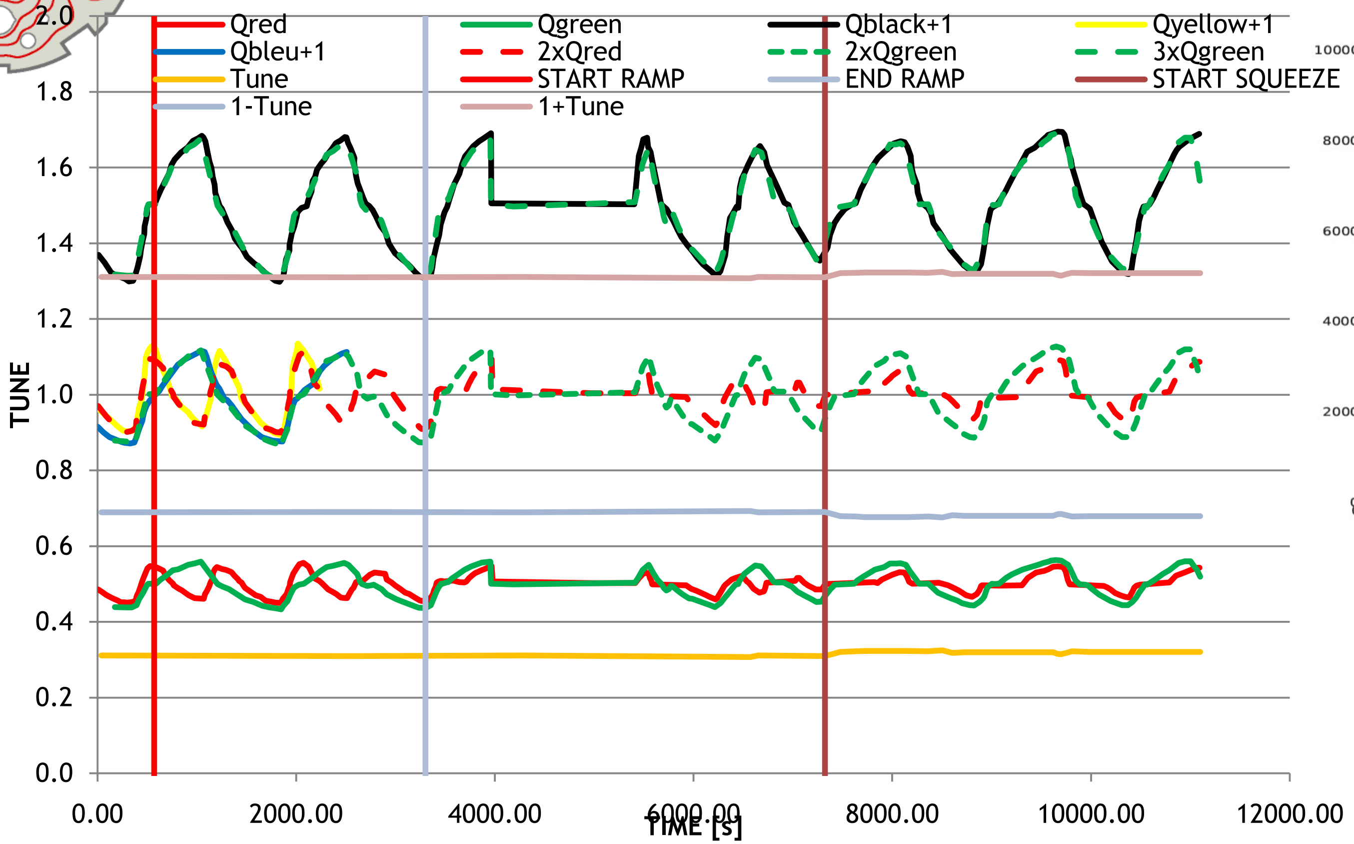
- The hump affects luminosity performance due to blow-up (particularly at 450 GeV). In collision it can excite beam-beam coherent modes or generate tails and therefore losses.

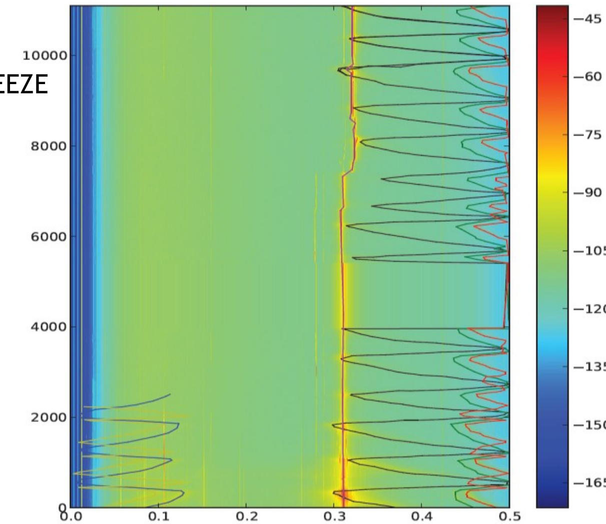
- Priority has been given to implement mitigation measures: the transverse feedback has proven to be effective to mitigate these effects and as a result of that beams with emittances in the range of 2.5 micrometers could be regularly brought in collisions.

- The identification (and possibly eradication) of the origin remain the (challenging) goal of the ongoing analysis and measurements.



Characterization





R. De Maria

- We do not know yet the real frequency of the hump ➔ hope to get it soon
- Behaviour during the ramp and dependence during non-linear chromaticity measurements indicate that it is not close to a very high harmonic of the revolution frequency

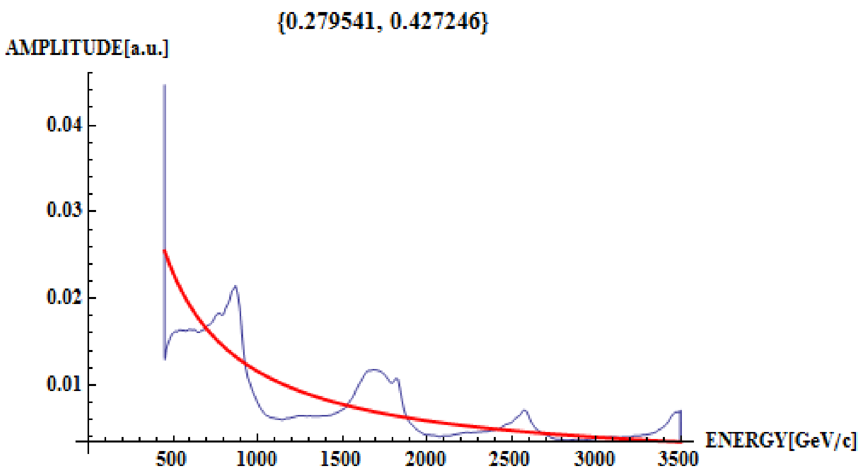
Characterization

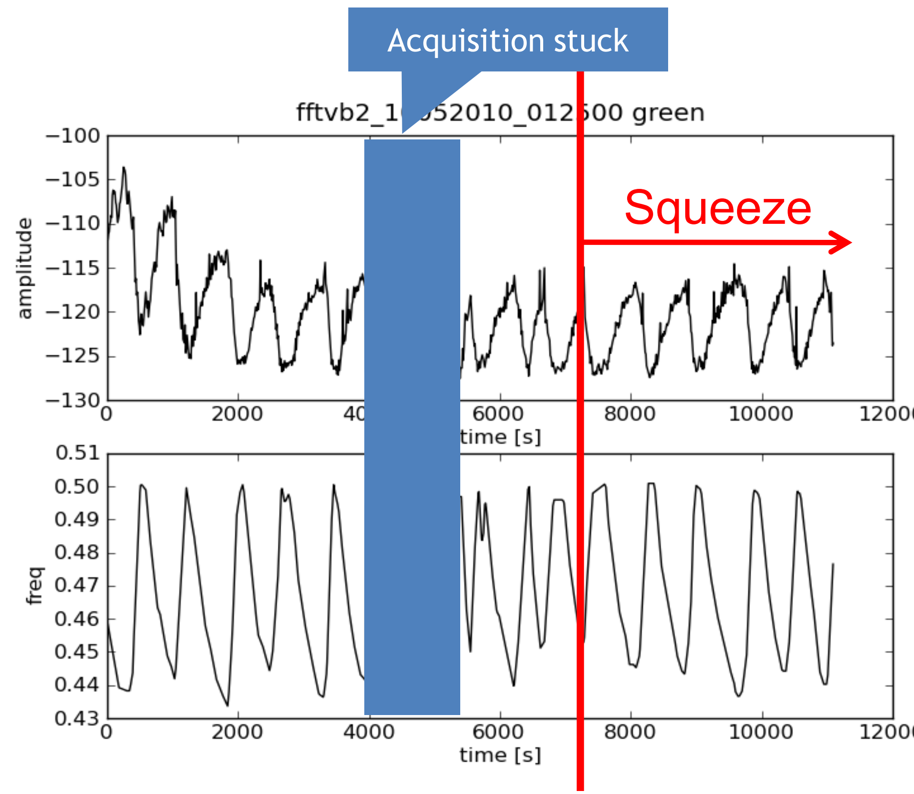
Momentum dependence during the ramp

A(p)=<A_{450GeV}>/ p

Relative emittance blow-up should decrease with momentum

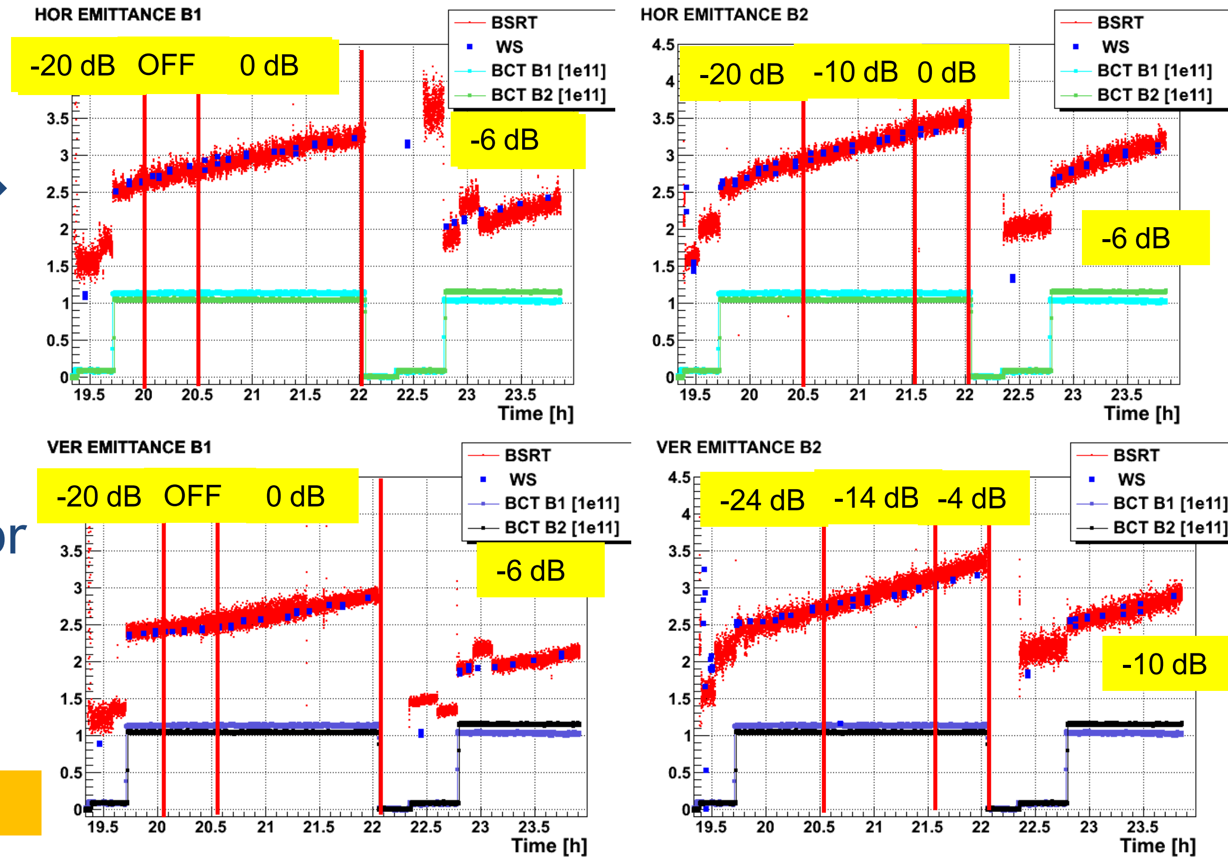
No evident amplitude dependence during the squeeze ➔ No **localized** source in the insertions in IR1/2/5/8





Countermeasures

- Noise in the TFB pick-up compatible with operation at high gain ➔ might see some small blow-up above -10 dB



- To be compared with ~1.5-2 μm/h observed for B2-V in the presence of hump

F. Roncarolo

- Proposal to run at 450 GeV at max gain (> -10 dB) to be reduced just before starting the ramp (to allow tune tracking) for the time being
- This will allow verifying the effectiveness in controlling the emittance blow-up on B2 V

Possible origins

- Possible explanation (J. B. Jeanneret):
- Spectrum compatible with :
  - Harm. 2, 4, 6 of 8 kHz (UPS)
  - Frequency sweep few %
- Failure mode of one of the APC UPS in the tunnel?
- Not excluded according to the experts
- Behaviour could depend on load, temperature, response to network fluctuations,…