Status of the Investigations related to

The Broad-Band Perturbation Source(s) in the Vicinity of the Nominal Tune Working Points

Or

'The Hump'

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Special thanks to: M. Gasior, G. Arduini and the OP crew

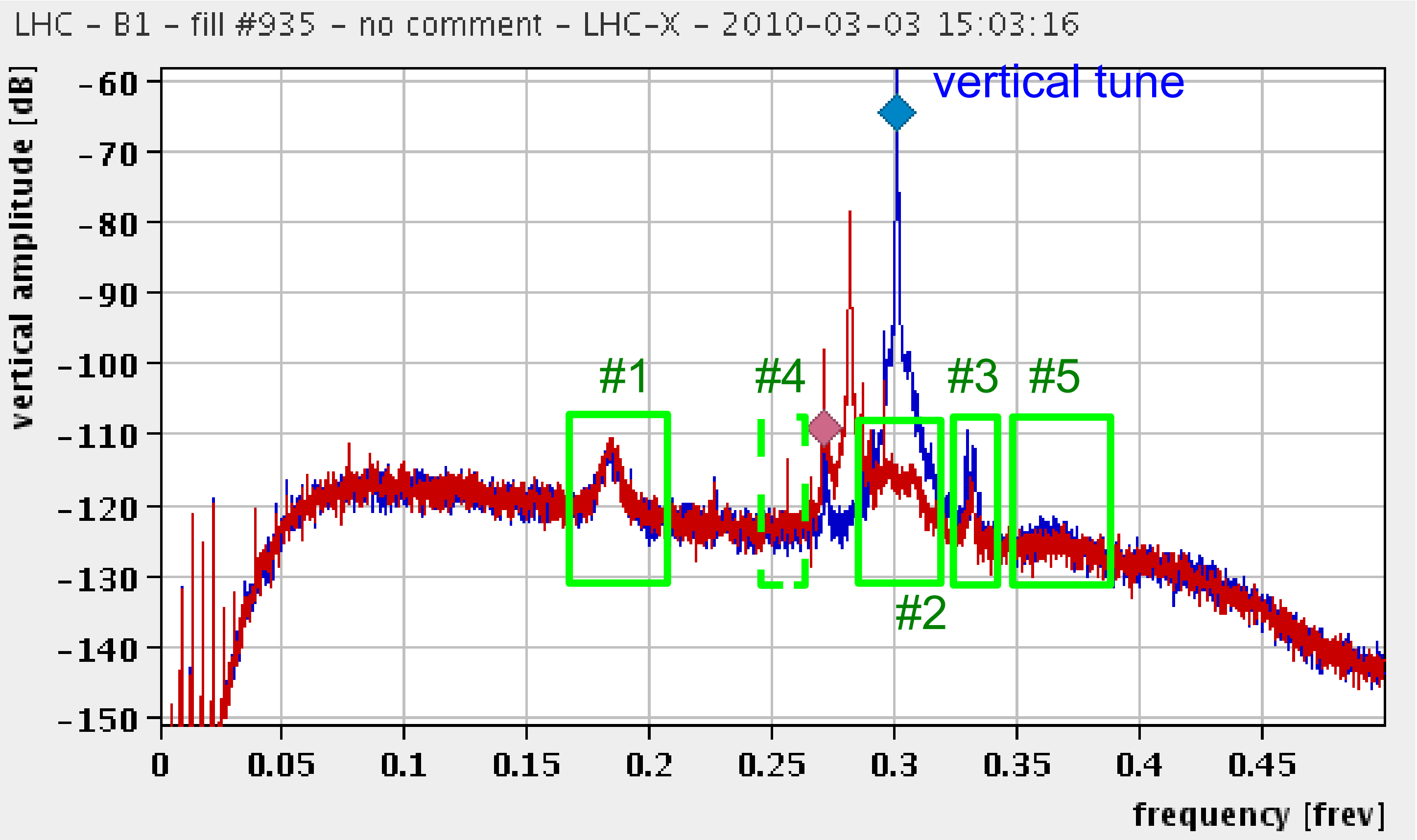
Overview and Summary

- Beam spectrum issues affecting beam diagnostics and operation
  - UPS' 8 kHz line et Co. → W. Höfle et al.
  - Residual tune stability (Q' and other higher-order diagnostics)
    - contribution of RQT[D/F] circuits only 10%
    - further investigation pending...
  - Broad frequency “hump” driven beam excitation
    - Better/more systematic understanding of symptoms
    - Could eliminate some circuits as pot. source by switching them 'off'.
    - No single source responsible for this effect has been identified
    - Collimator at nominal settings will make the effect more apparent

Effects seen so far I

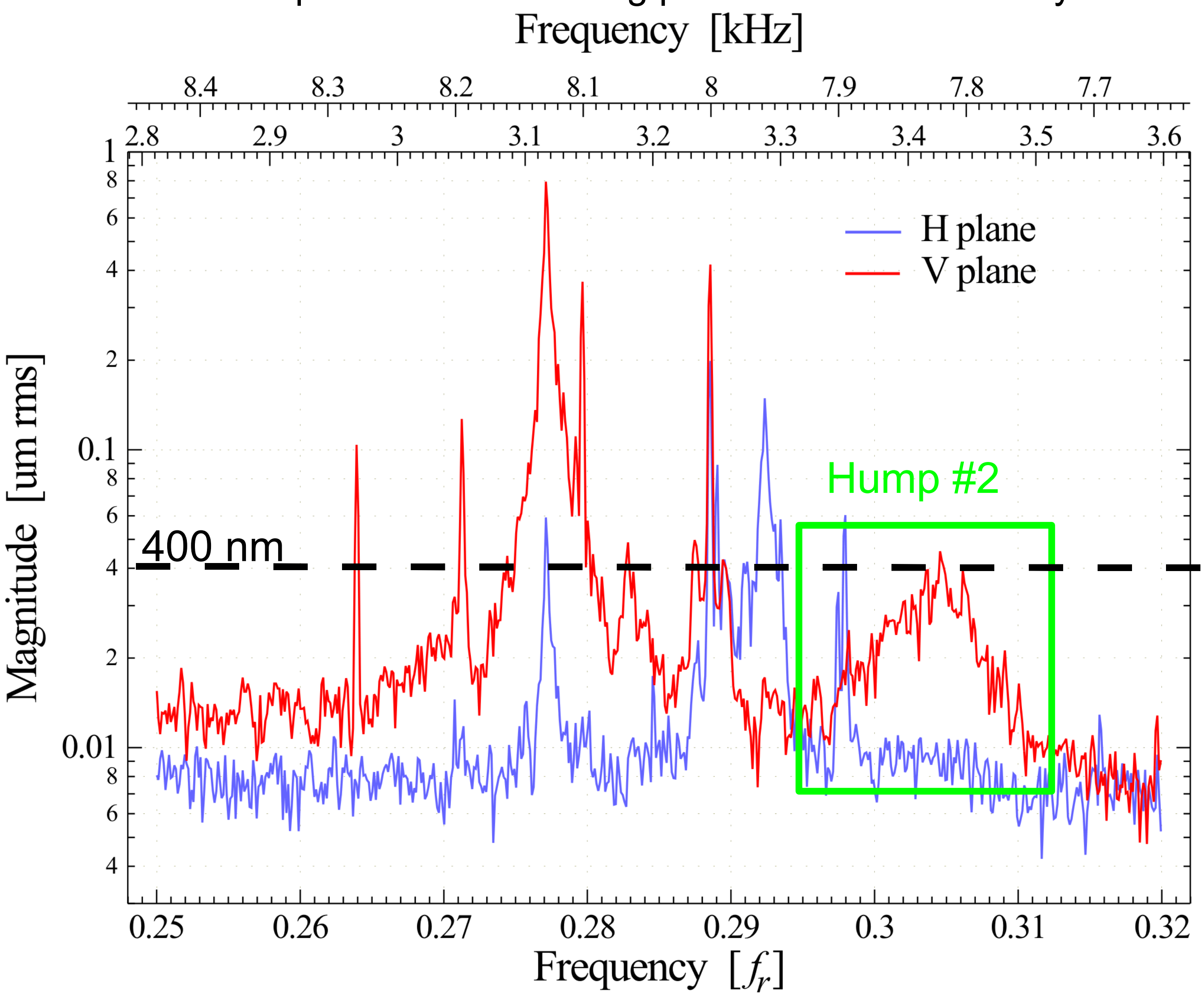
- There are at least three++ 'humps', with approx. base-band frequencies:
  - #1 @ ~ 0.185 f_{rev} , #2 @ ~ 0.302 f_{rev} (vertical tune), #3 @ > 0.333 f_{rev}, and
  - #4 & 5 @ ~0.25 & ~ 0.37 f_{rev} (much smaller and possible harmonic of #)

- Example: Q_v set below 'hump' (red) and after Q_v trim on top of 'hump' #2 (blue):
  - Driving of the tune resonance clearly visible → beam size growth → losses



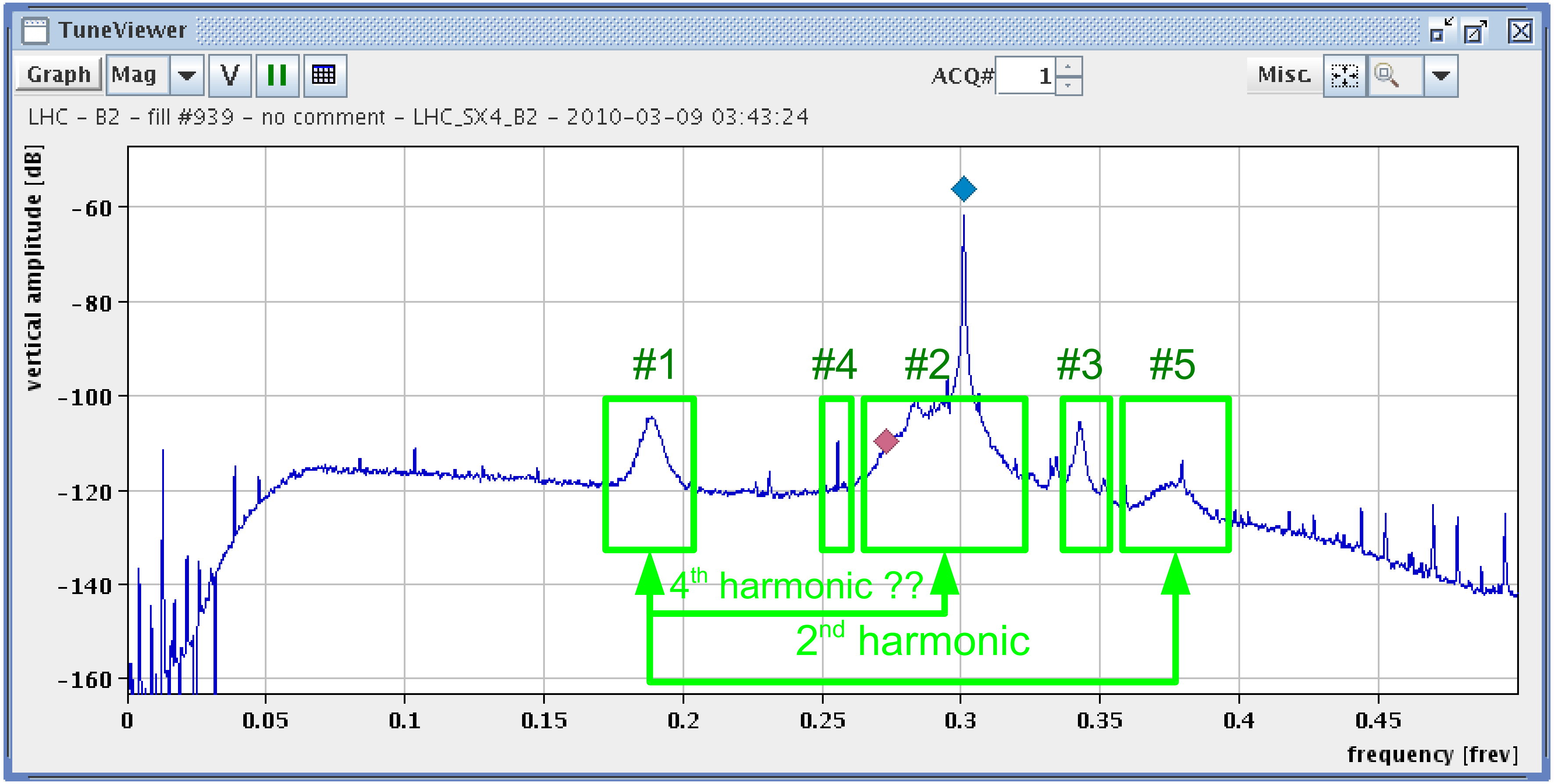
Effects seen so far II - Absolute Amplitude

- Assuming single dipolar pertubation → kick ~ 1 nRad kick only
  - a non-issue if the present tune working point wouldn't be exactly on it

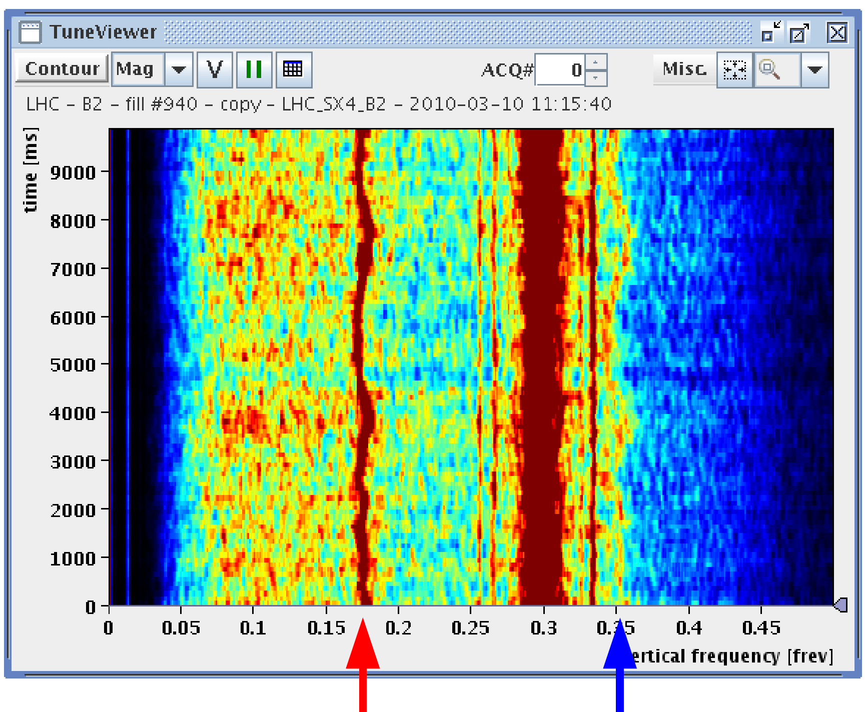


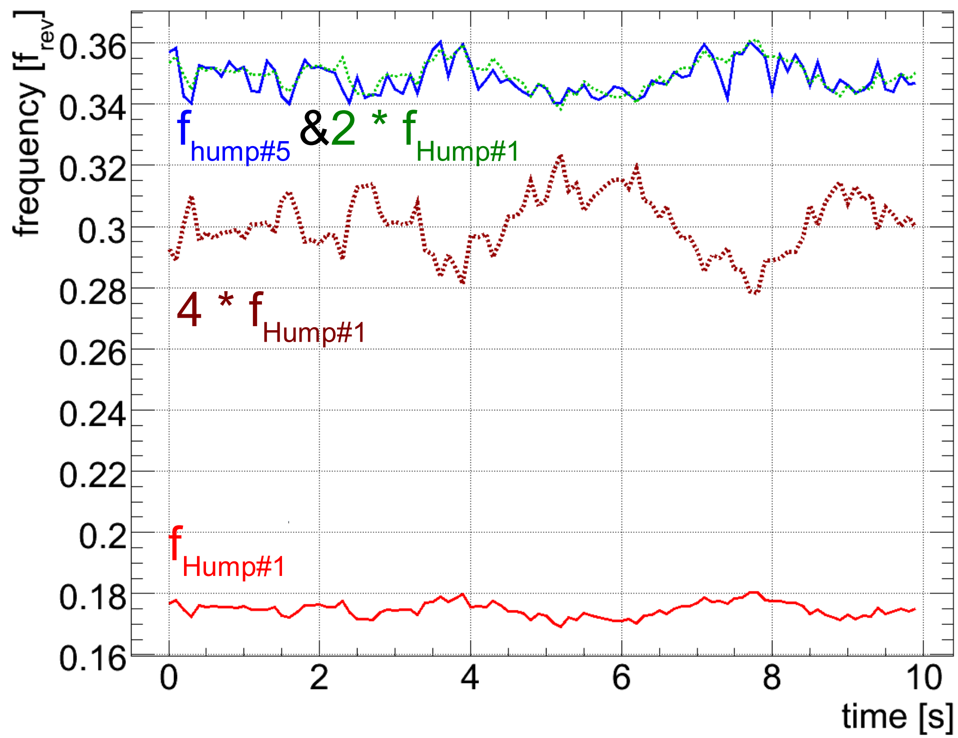
Effects seen so far III – Correlation between Humps I/II

- If structure '#5' is a true second harmonic of '#1' → width difference would give an indication on the base-band origin of the effect
  - Central frequency #1: 0.185 f_{rev} or ~2 kHz
  - Shifting the tune out this region would help for the diagnostics



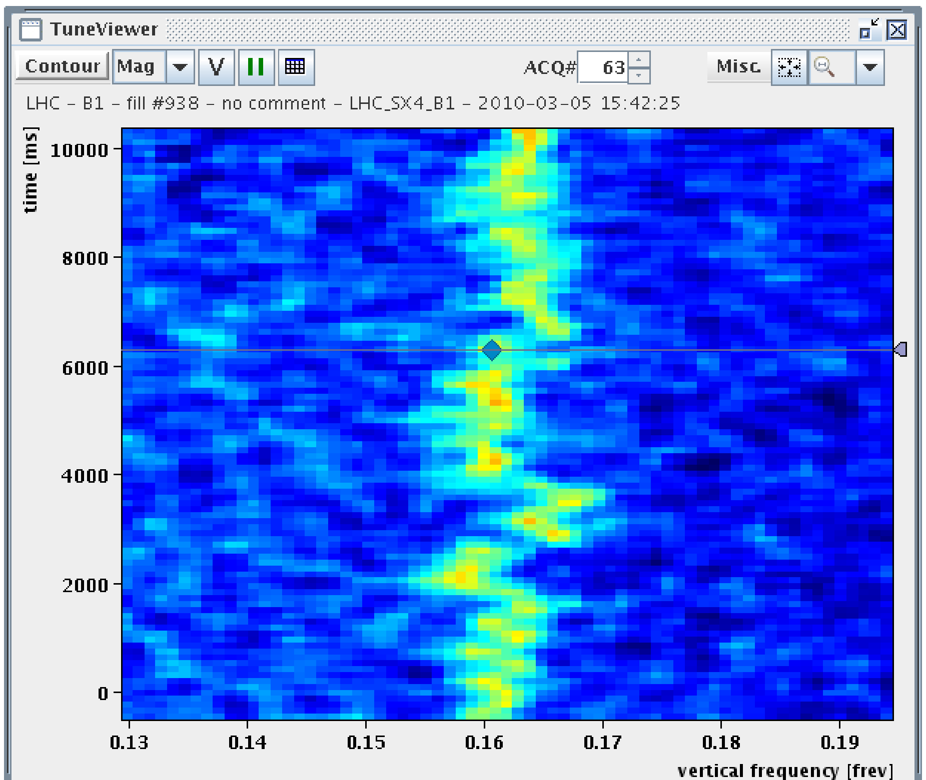
- Detailed correlation between Hump #1 & #5:
  - likely second harmonic
  - Perturbation #2 (~0.3, vertical tune) could be the fourth harmonic?
    - Would also explain why it is much broader than the others
    - need to move tune off the present tune working point for further studies

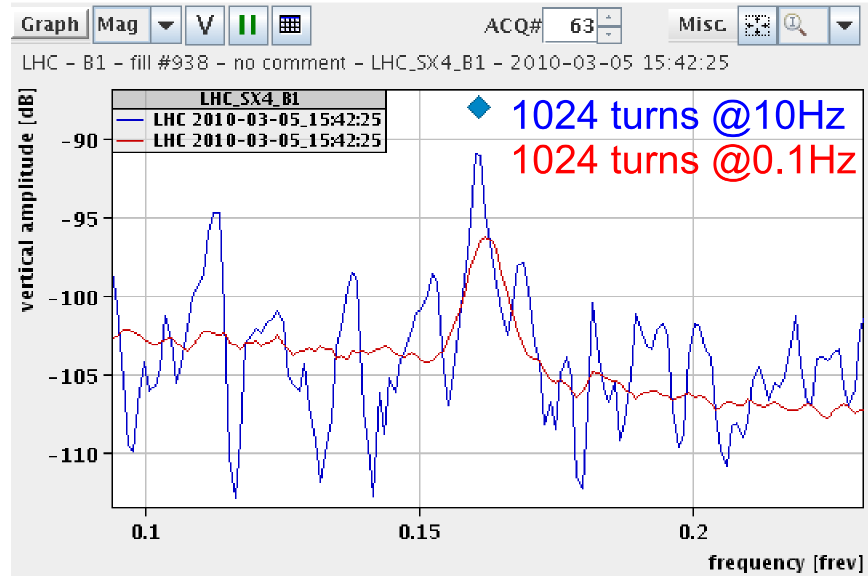


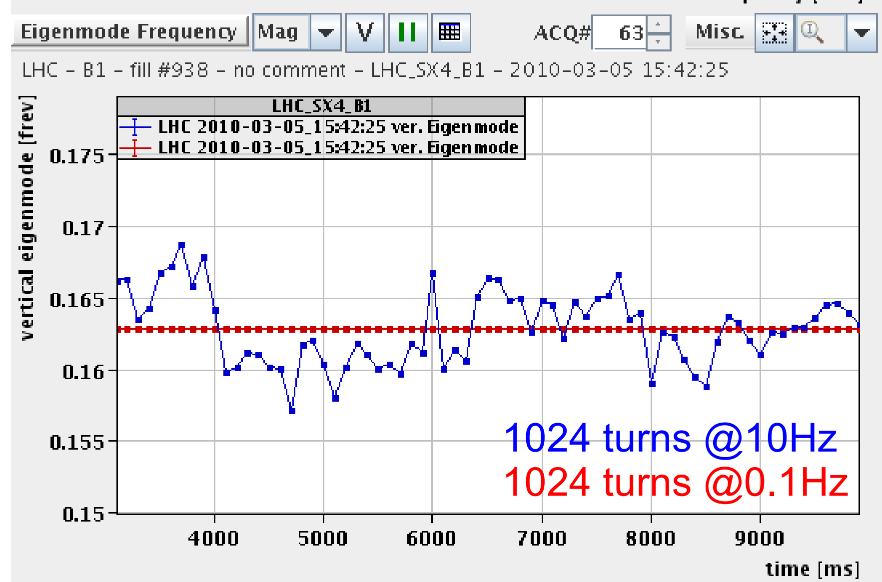


Effects seen so far IV

- Structure of the perturbation depends on the observation time-scale, e.g.
  - 0.1 Hz b→ broad 'hump', or
  - 10 Hz acquisition BW → narrow-bandwidth line with shifting mean frequency
- Here, 'Hump' at 0.16 f_{rev}:

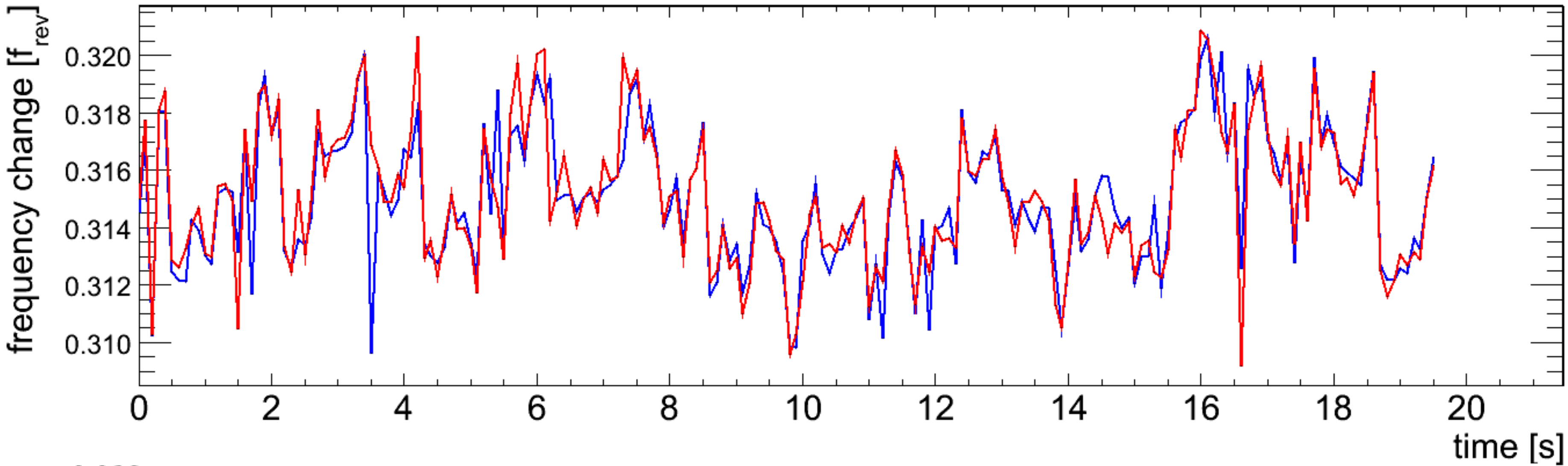


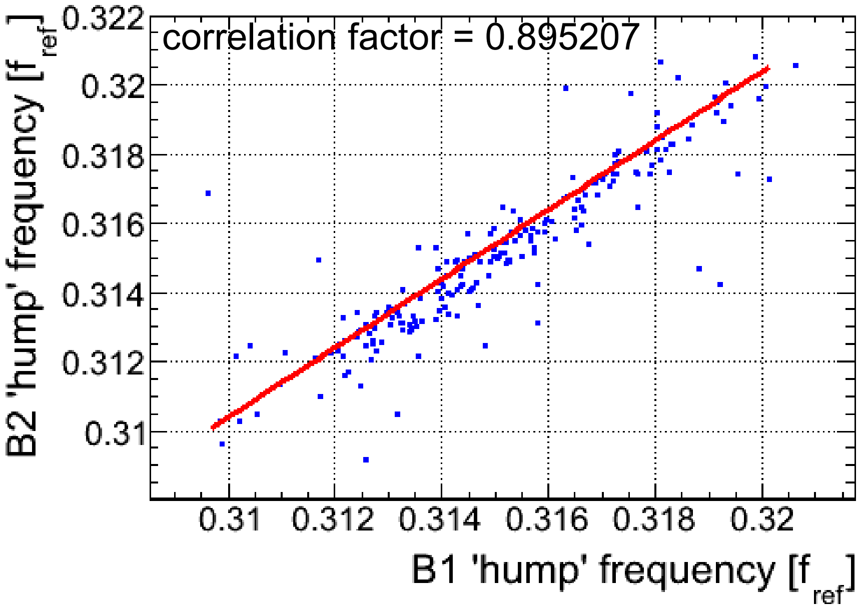


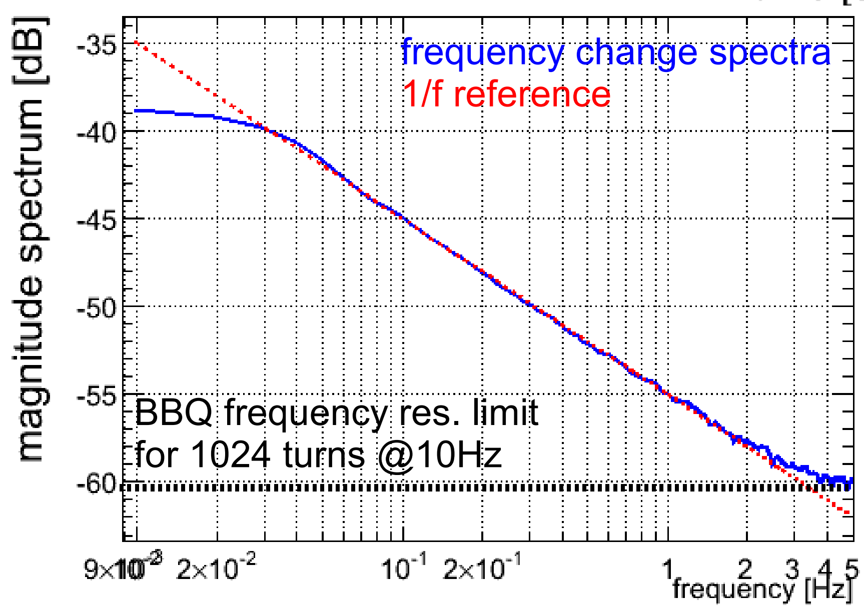


Effects seen so far V – B1/B2 Correlation

- Hump on Beam 1 is correlated with the one in Beam 2:

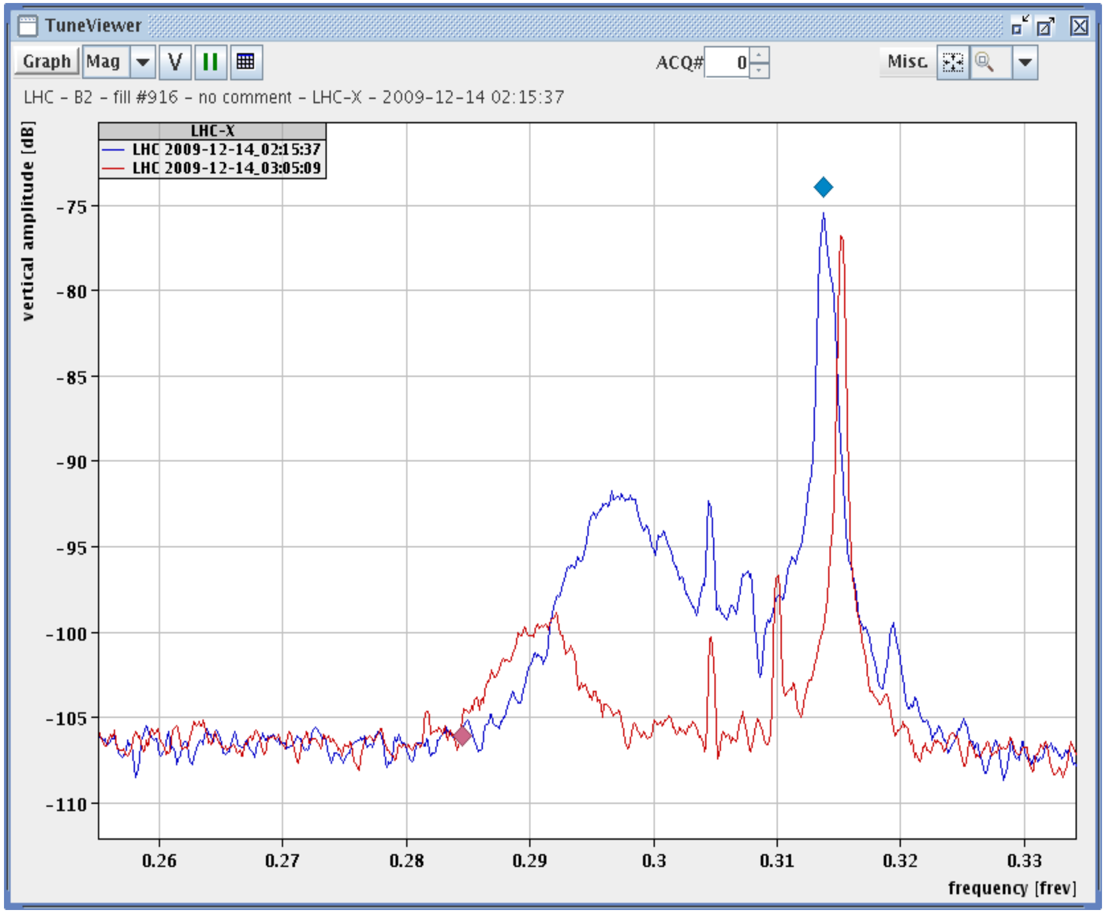






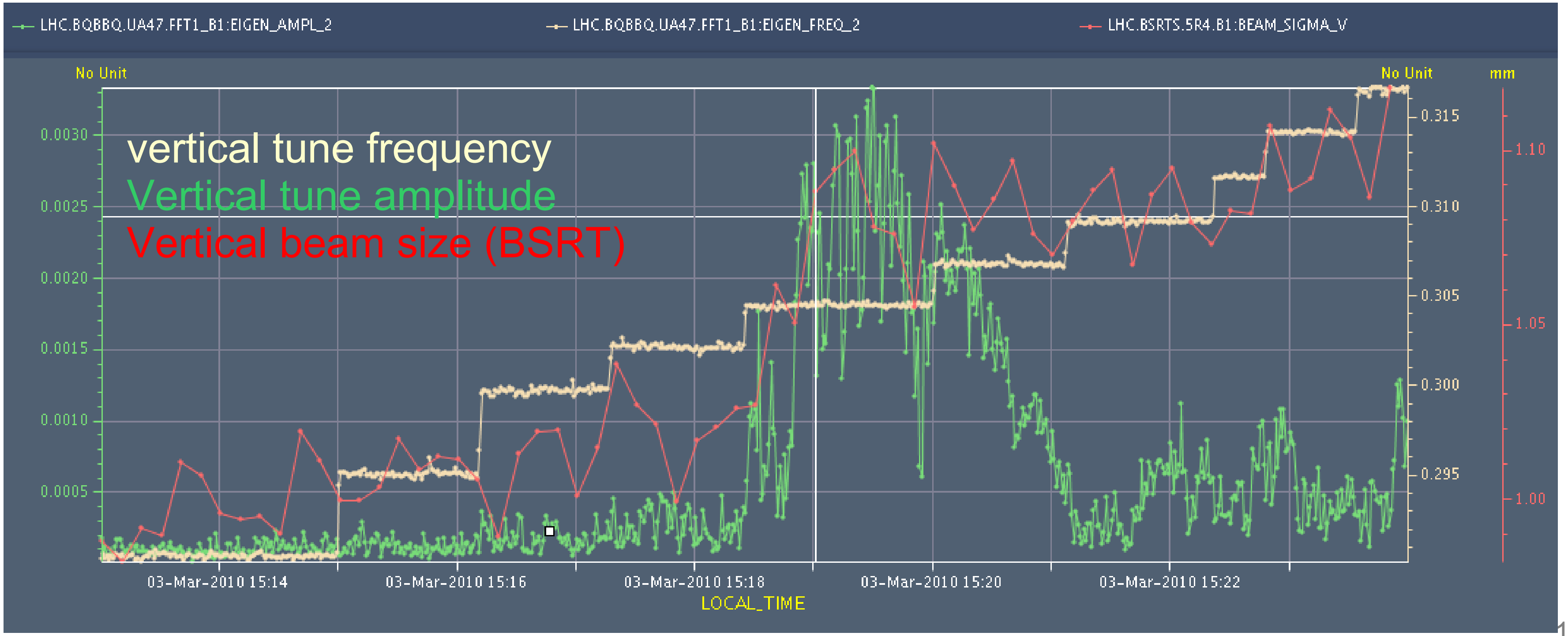
Effects seen so far IV – Energy Scaling

- Amplitude seems to approximately scale with energy (-8dB reduction)
  - excludes some effects (e.g quad. vibration)...
    … but not all (e.g. quad. current noise)
  - tune spectra before (450 GeV) and after (1.18 TeV) the ramp #6:



Vertical Tune Scan across 'Hump Domain'

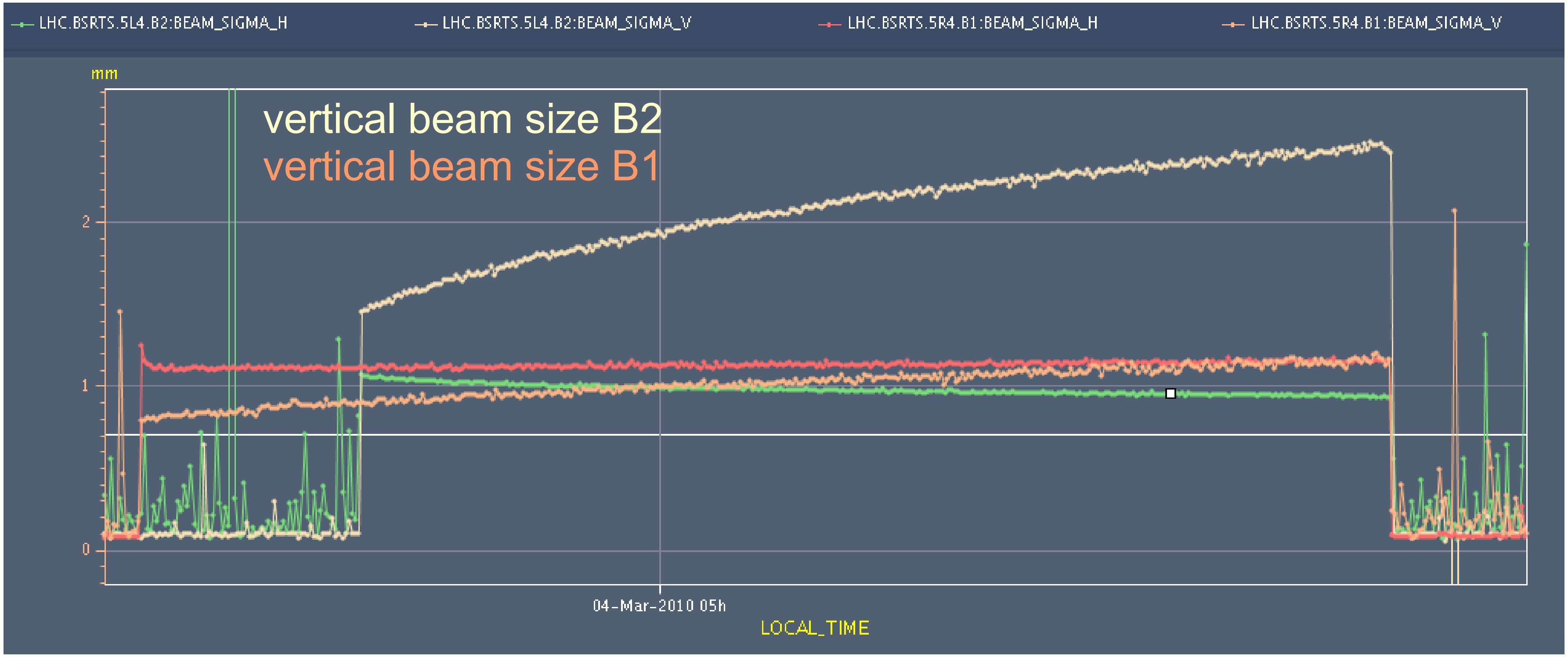
- The observed excitation frequency are real and cause a blow-up of the vertical emittance
  - 10 % beam size blow-up within about 5 minutes
  - beam is eventually intercepted at an aperture bottlenecks (e.g. TDI or TCDQ)
    - → later collimator would intercept this at an earlier stage



Beam Size Growth and Effect of Power Converter

- Verified effect on the hump for following circuits:
  - Both MSI's, transfer lines, RSS, RCO, RCD and vertical 60A orbit correctors → **No effect!**

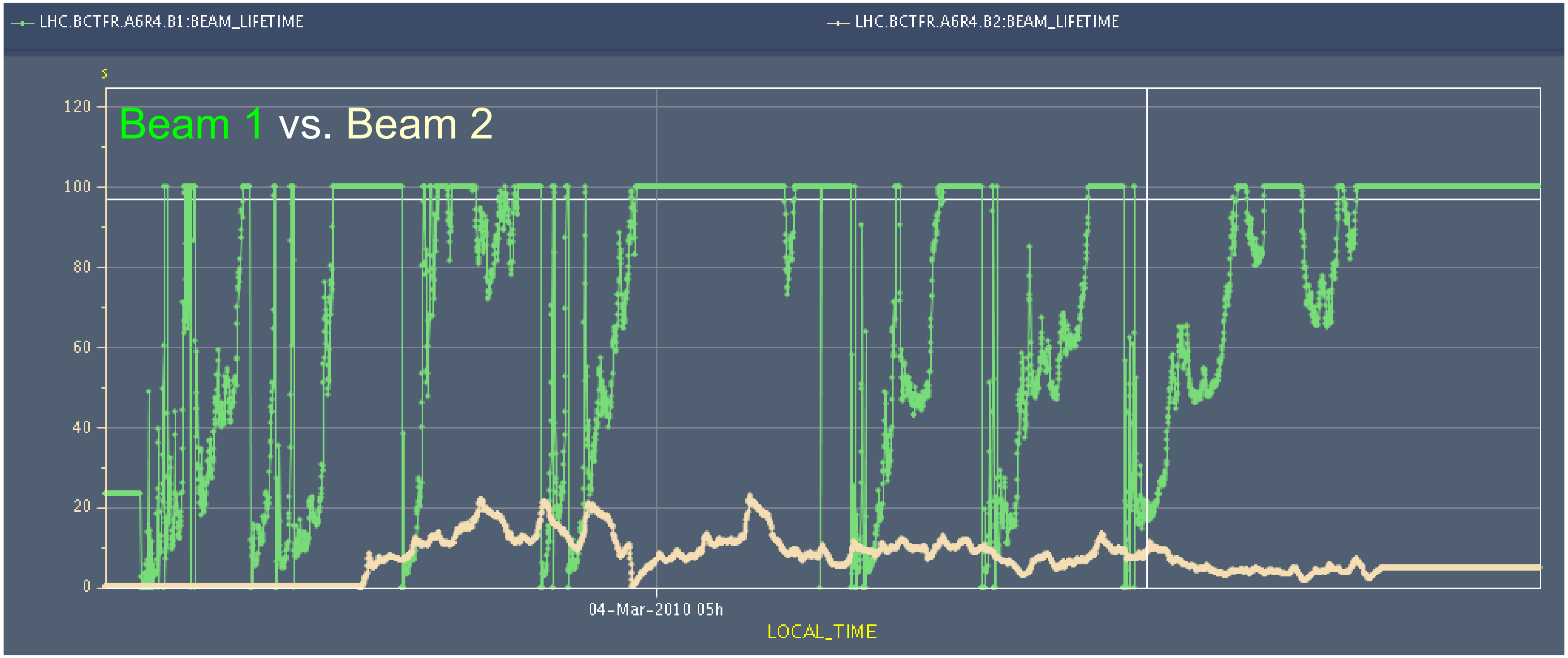
- However, whilst effect is visible on both beams, the vertical plane of B2 seems to be more affected:



Effect on Beam Life-Time

- Each transient causes some short term beam-life loss but eventually recovers
  – Again: B2 beam-life time much poorer than for B1

- FastBCT based beam life-times with minimal collimation:



  – Be aware: these life-times tell you how much intensity is kept in the LHC but not in which shape (e.g. transverse/long. bunch sizes)!!

Facts and Figures of 'Hump' Investigations

- Not one but at family (at least 3) of different perturbations

- Seen already in 2009 (and 2010)
  - Amplitudes are in the few hundred nanometre range
  - Effect scales down with energy (2009 ramps)
  - Either 'hump' or 'fast shifting line' depending on observation time-scale
  - Correlated between Beam 1 & 2, – however – while seen on both beams, hump effect on beam-life time is more apparent for B2

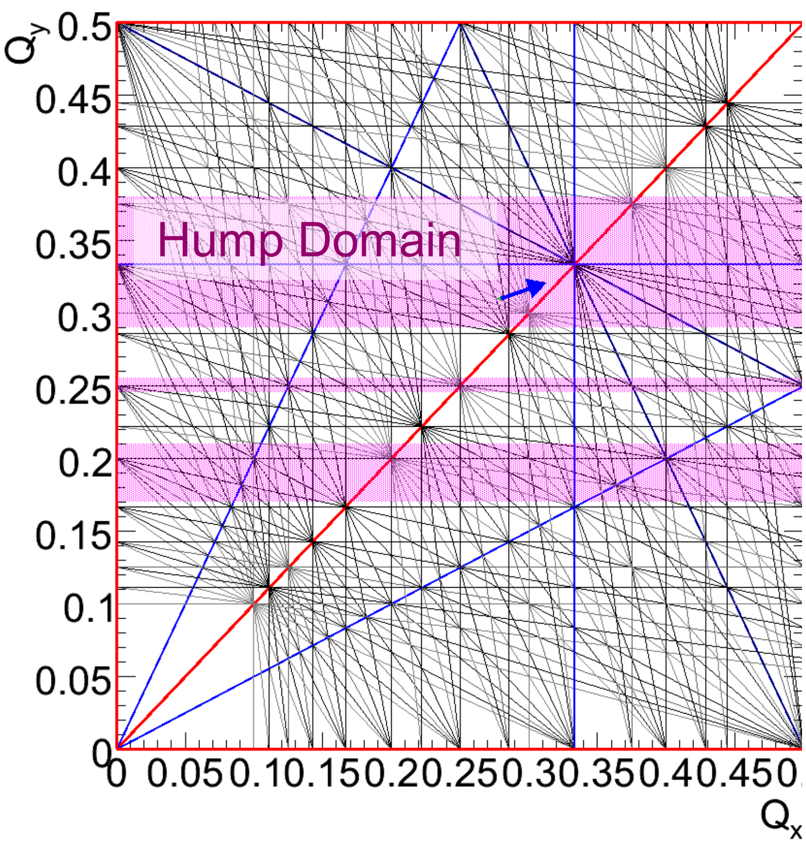
- Additional studies in 2010 revealed no effect on 'hump' regardless of:
  - Tune or chromaticity changes
  - Single or two beam operation
  - Switching 'off'/'on' circuits: MSI's, transfer lines, RSS, RCO, RCD and vertical 60A orbit correctors
  - If B1/B2 RF frequencies are unlocked
  - If B1/B2 RF frequencies are set apart
  - If damper (ADT) power driver being switched 'off'

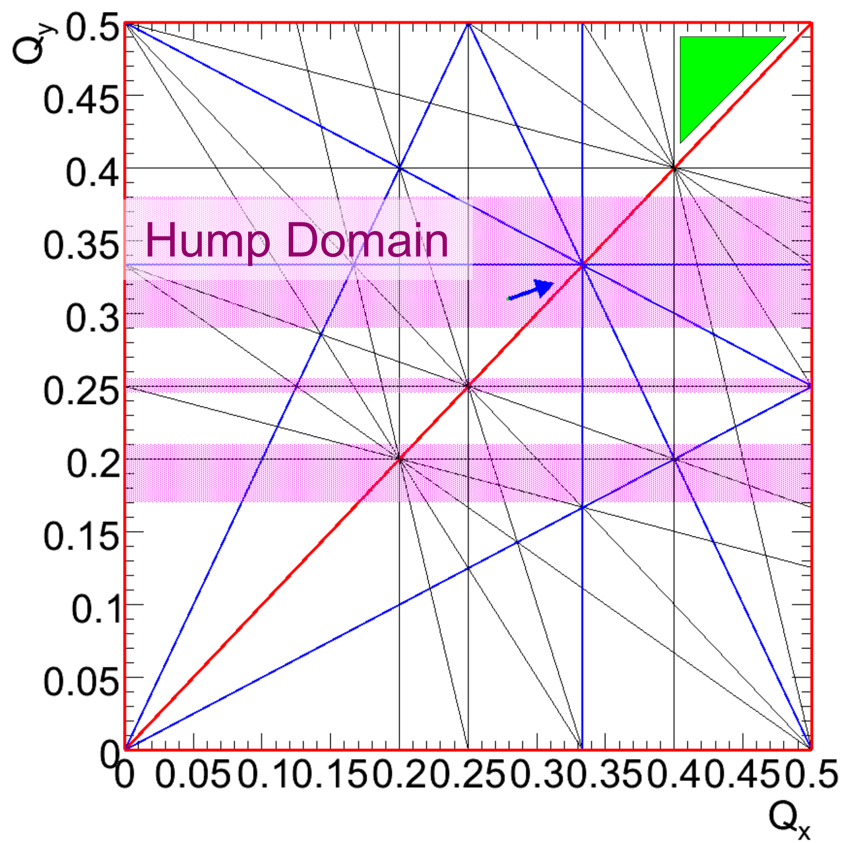
How to proceed?
Two options the LMC should decide whether:

A) Find and mitigate the perturbation source – the “clean solution”

- Other circuits/systems: RCS, MS, RF, effects of He flow-rates/orbit
- More exotic sources: triplet vibrations, beam screen, vacuum pumps
  → mechanical vibrations in the > 3 kHz range?!?
- However, we may need soon to move to effective operation with higher intensities

B) Shift the tunes to another working point (e.g. .45/.46) – the “practical approach”





Reserve Slides

Impact

The “clean solution”

(if hump not identified soon)

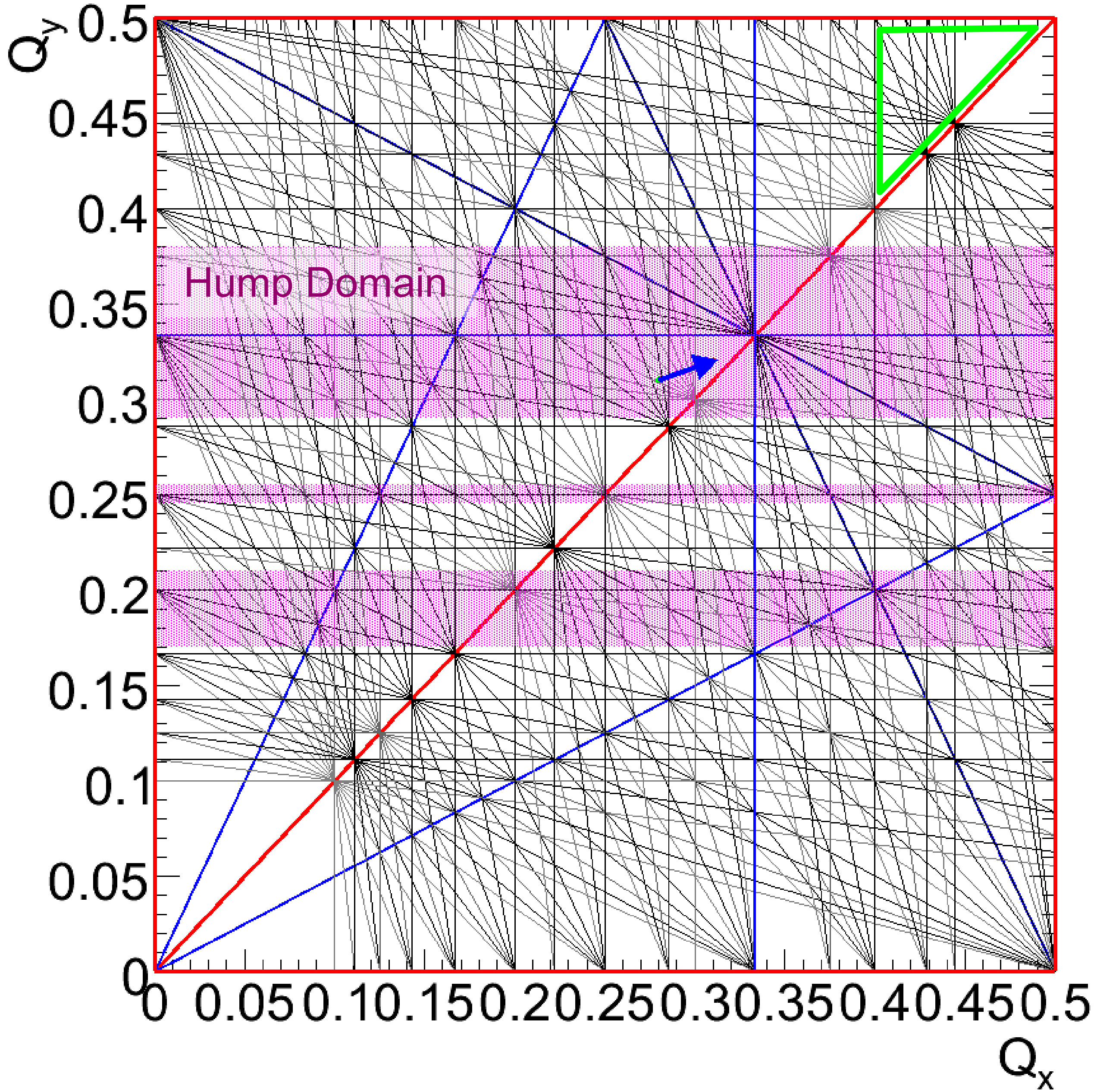
- This does probably not impact 3.5 TeV ramps/operation with a few bunches, However:
- Poor life-time with closed collimators
- Limits the intensity we can store and accelerate nominal beam safely

The “practical solution”

(provided beam is stable at 0.45/0.46)

- Buys us some time until we found the 'true' hump source
- Tune/Orbit not an issue with the given diagnostics and controls
- Non-local beta-beating correction may need to be redone

Enlarged Tune Diagram up to 10^{th} order



- Effect of trimming RF voltage from 8MV → 4MV → 8MV
  - Only preliminary observations → need to redo these more systematically