LHC Q Stability Revisited

M. Gasior & Ralph J. Steinhagen, BE-BI

for the BI-QP team: A. Boccardi, M. Gasior,

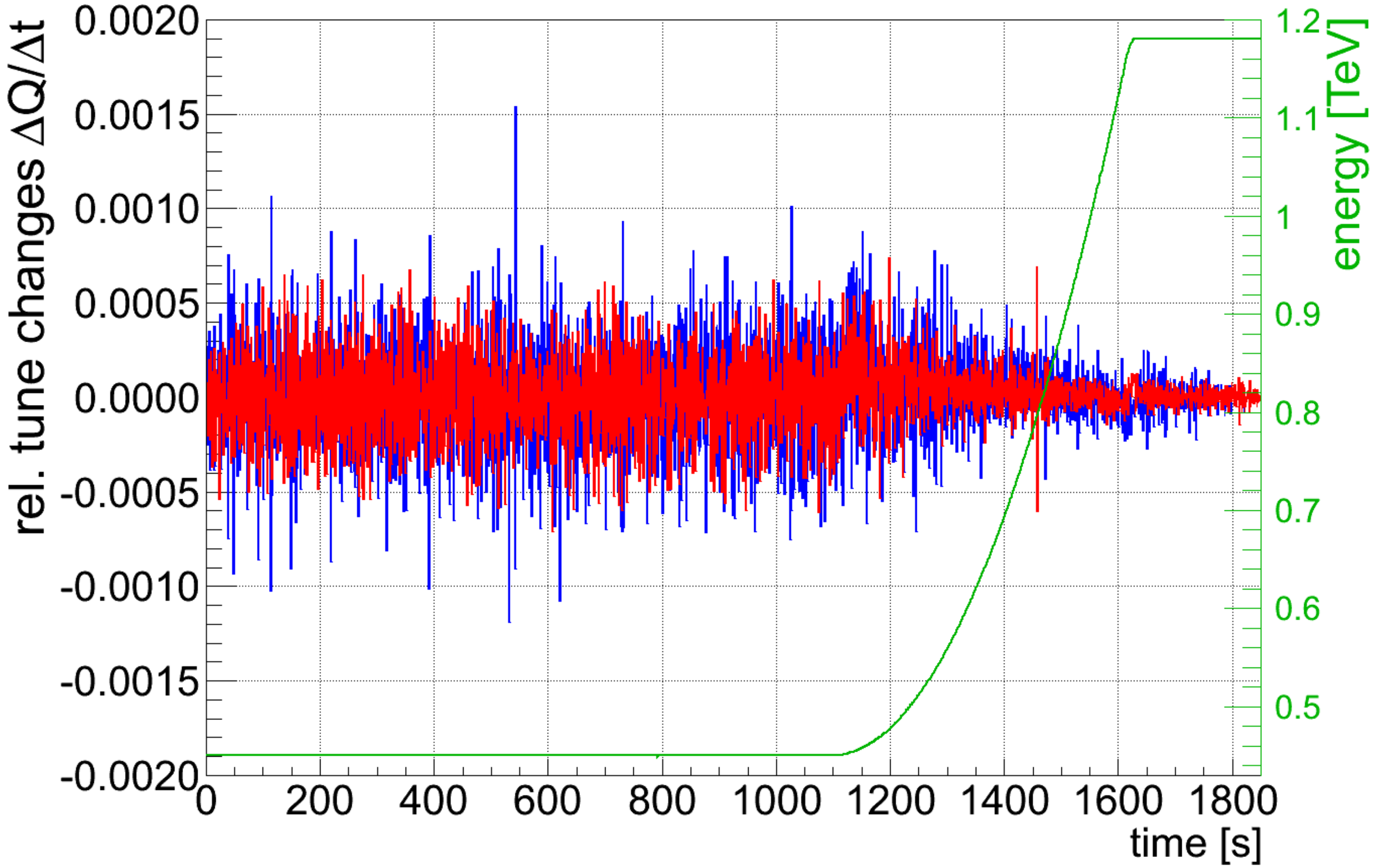
S. Jackson, R. Jones, R. Steinhagen

Outline

- Effects/features discovered so far:
  - Residual tune stability
    - RQT[D/F] circuit current ripple
    - Other sources??
  - Broad frequency “hump” driven beam excitation → emittance blow-up
    - Amplitude calibration
    - B1-B2 correlation
  - Beam-Beam coupling effect @1.17 TeV
- N.B. will skip particularities of transverse damper & res. 8 kHz line issues → found to be related to UPS (courtesy BE-RF)

Residual LHC Tune Stability

- Example: 3. ramp (2009-11-30 @00:15, HP-filtered, Q-FB 'off'):



  – Residual tune stability $\Delta Q \approx 5 \cdot 10^{-4}$
    - no particular frequency dependence → 'white noise'
    - Since it scales with energy → checked relevant quadrupole circuits...

Residual LHC Tune Stability – Source #1: RQT[D/F] Circuit Noise

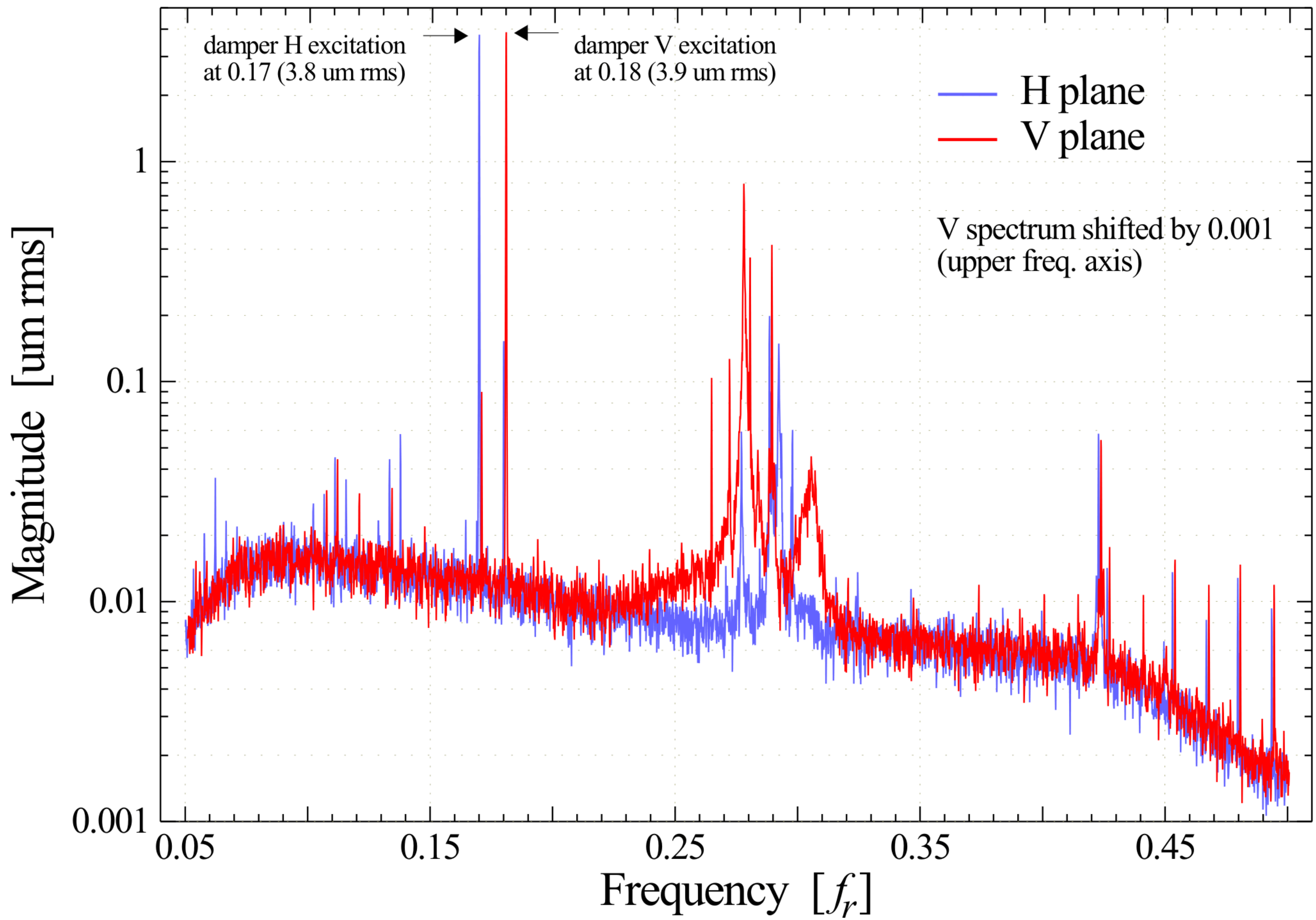
- Tune trim ↔ circuit correlation as used by LSA & Q-FB:

$$\begin{pmatrix} \Delta I_{RQTD}[A] \\ \Delta I_{RQTF}[A] \end{pmatrix} \approx \frac{p[GeV]}{450\,GeV} \cdot \begin{pmatrix} +4.3 & +22.2 \\ +22.7 & +3.9 \end{pmatrix} \cdot \begin{pmatrix} \Delta Q_H \\ \Delta Q_V \end{pmatrix}$$

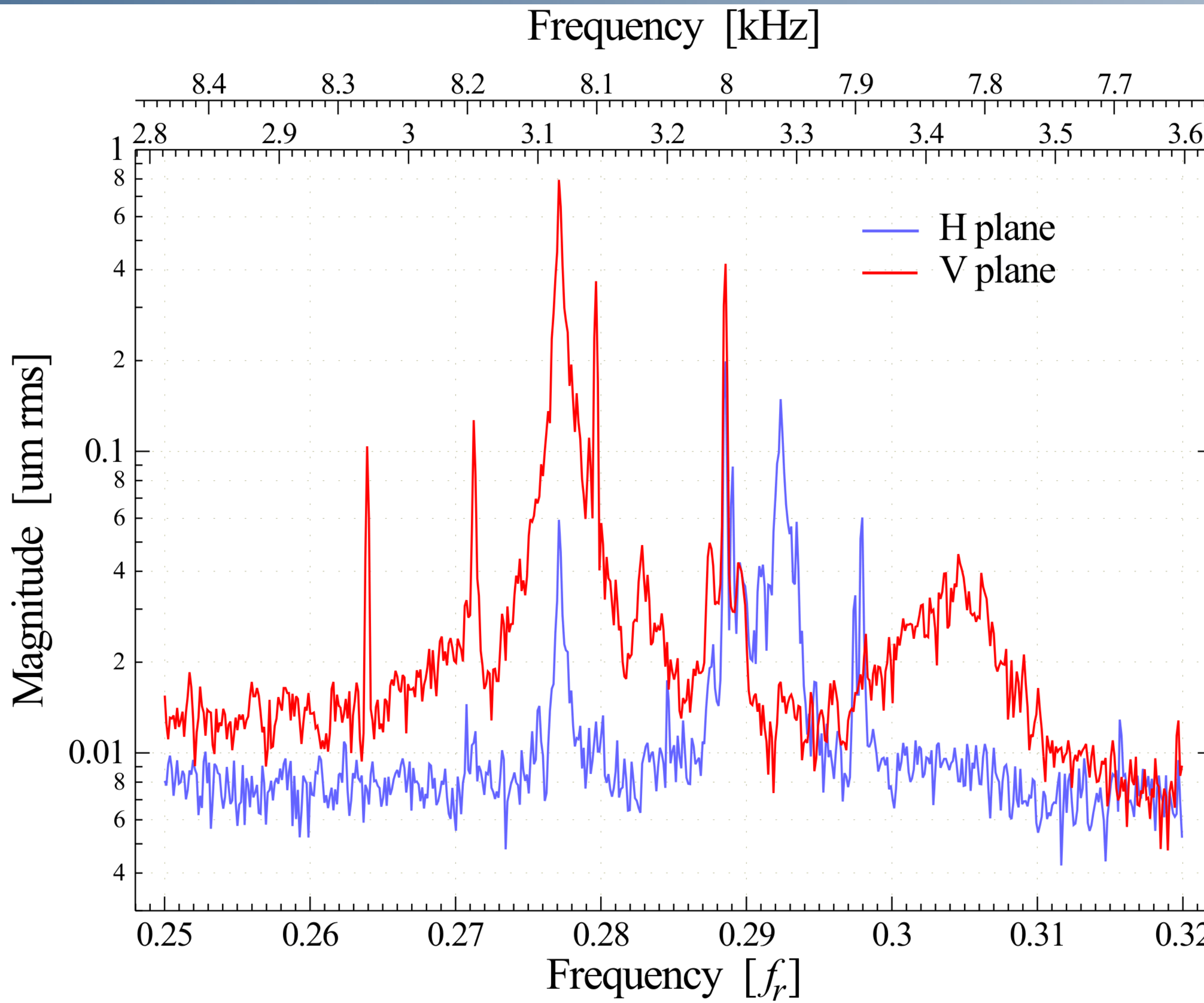
- For comparison:
  - e.g. $\Delta Q_H = 10^{-4}$ @450 GeV → ΔI_{RQTF} = 2.2 mA & ΔI_{RQTD} = 0.4 mA
  - Specified nominal current stability (over 0.5 h): $\Delta I = 10^{-5} \cdot 600$ A = 6 mA
  - Some RQT circuits have short-term stabilities of ~ 1-2 mA
    - Why do some other jitter by up to 10 mA?
    - Is this an effect of the parallel (protection) resistor?
    - Would '$\sigma(I_{RQT[D/F]}) < 2$ mA' feasible or is it too ambitious?
      → being investigated/addressed by our PC experts

- Hampers Q'-tracker operation with targeted mod. amplitudes of ~10^{-5}
  - increase dp/p modulation to 10^{-4} in order to compensate for this effect?
    → many not-so-nice side-effects and implications for every-day operation!!

BBQ spectra with absolute amplitude scaling



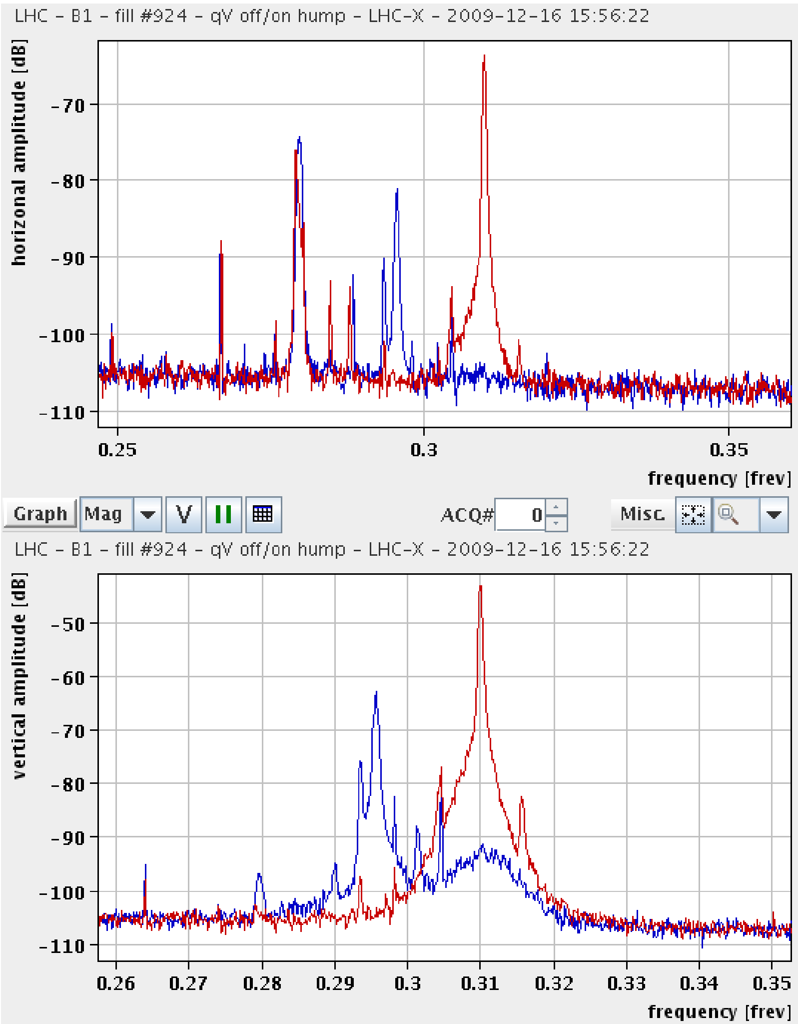
BBQ spectra with absolute amplitude scaling



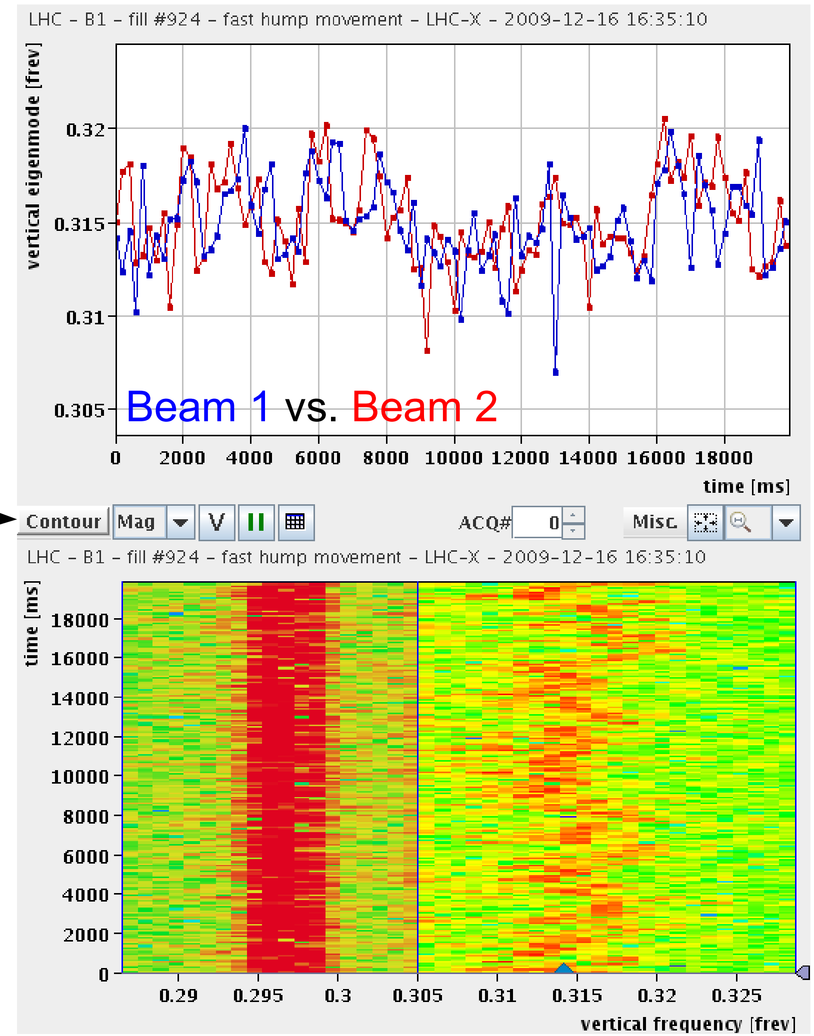
Shifting Frequency Dune → LHC's 'Hunchback'

- Initially identified has 'hump' but actually a fast frequency shifting oscillation with the mean drifting slowly between 0.25...0.32 f_{rev}

Example: Q_v being shifted onto the 'hump'

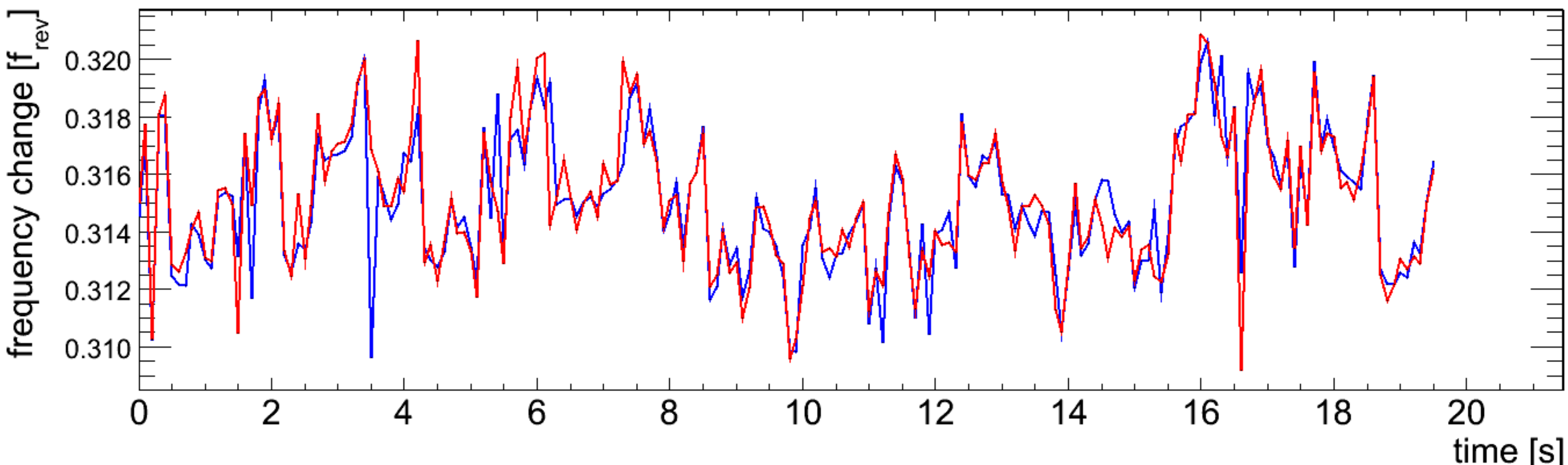


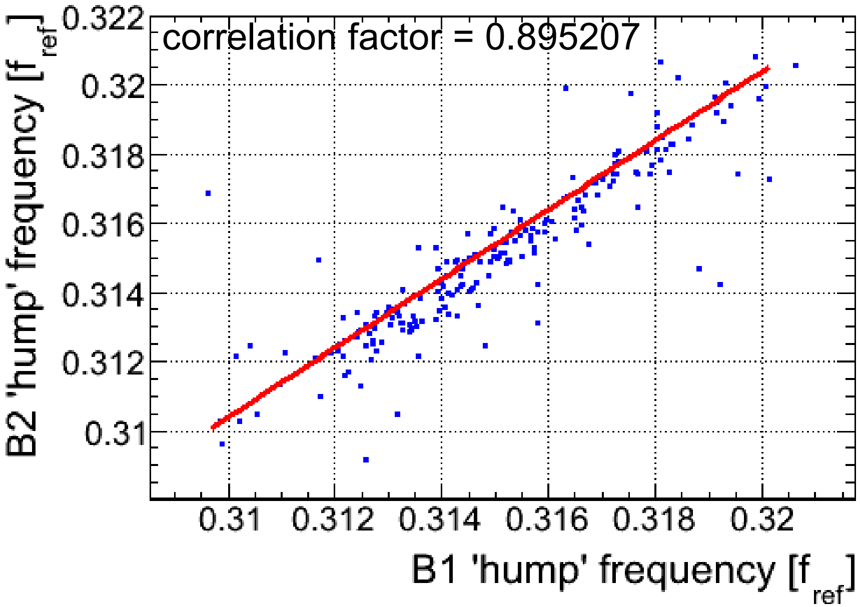
Time-resolved 'hump' structure:

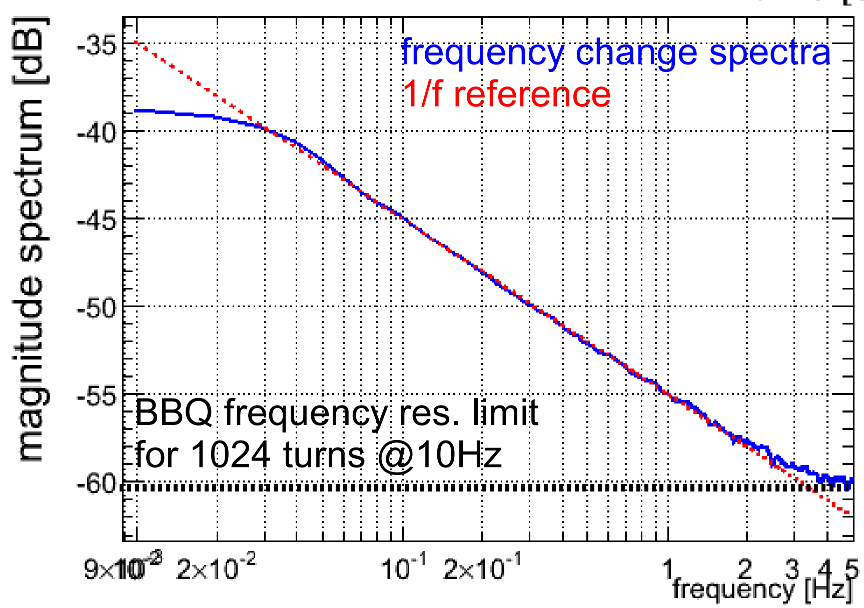


Shifting Frequency Dune → LHC's 'Hunchback' Correlation and Frequency Characteristics

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

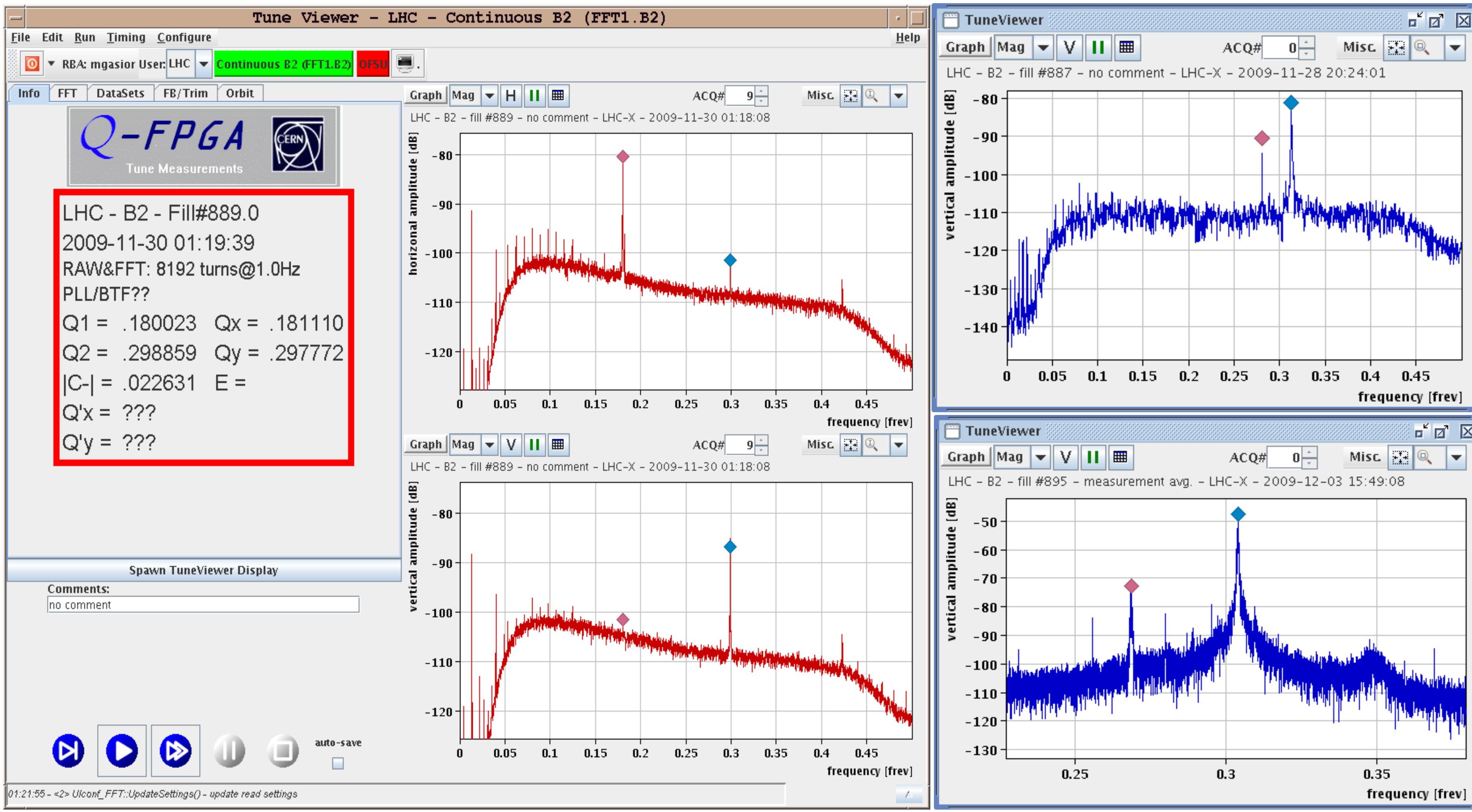






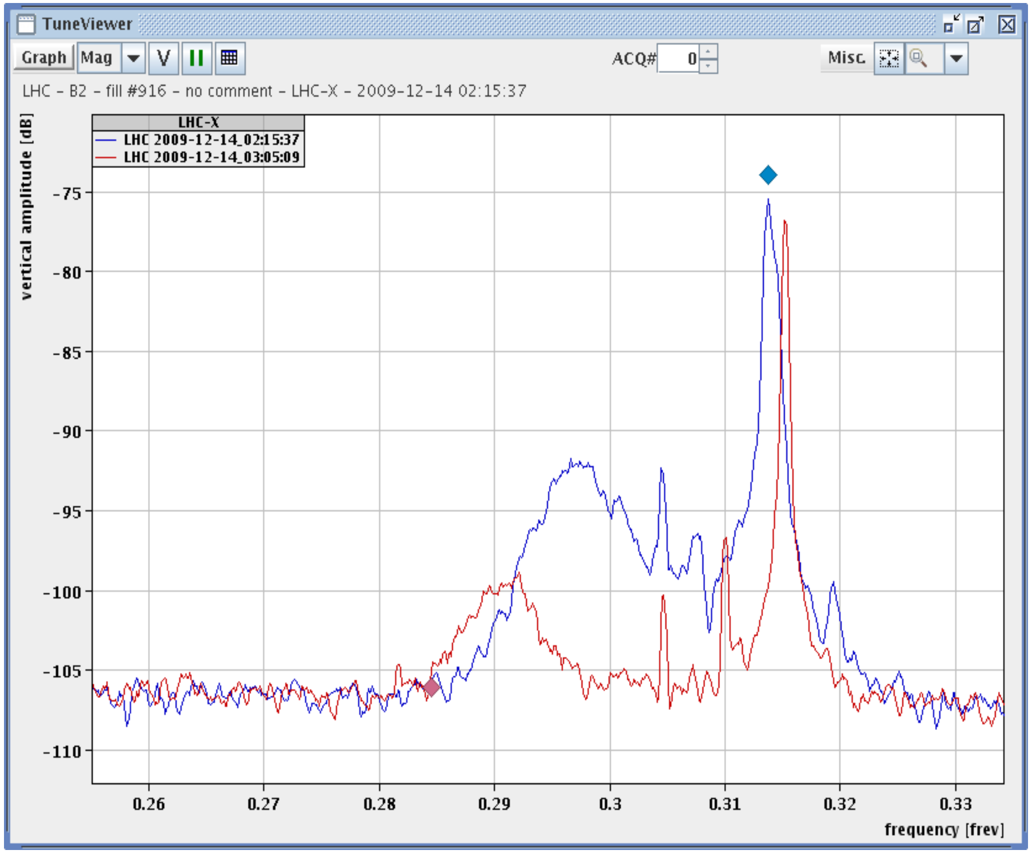
Shifting Frequency Dune → LHC's 'Hunchback'

- The 'hump' became more apparent around 2009-11-28 – 2009-12-03



Shifting Frequency Dune → LHC's 'Hunchback'

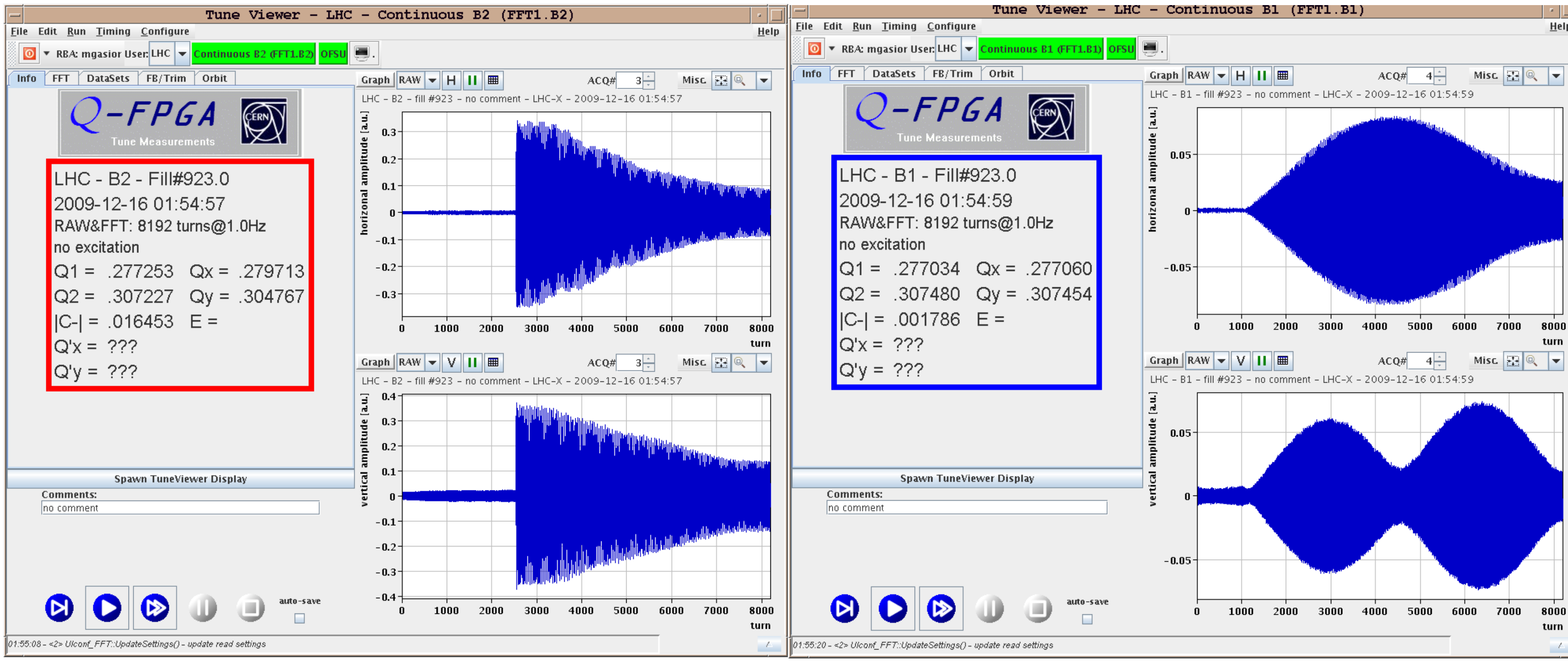
- On the question 'Whether we see the 'hump' at 1.17 TeV':
  - tune spectra before (450 GeV) and after (1.18 TeV) the ramp #6:



  - Central frequency shifted down
  - Amplitude seems to approximately scale with energy (-8dB reduction)

Beam-Beam Effect @1.18 TeV

- Tune kick in B2 was also seen in B1!
  - an indication that we were colliding two beams...



  - surprising/interesting: B1-B2 coupling is about 0.15
    - N.B. $n_b \approx 3\cdot10^{-9}$ p/bunch

Summary

- 'Hump' issue remains:
  - predominantly seen in the vertical plane,
  - beam gets resonantly excited if tune in the vicinity of this frequency → emittance blow-up as nicely documented by the BSRT
  - To 1st order unlikely effects causing the 'hump' (tested with beam):
    - ADT, MSI, CODs, ...?
- Some other remaining questions:
  - Can the MQT[D/F] corrector circuit stability be improved?
  - Why does the beam oscillate with um amplitudes at the tune frequency?
  - Origin of the non-8kHz lines?