Update on Orbit & Tune Feedbacks

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Main changes from 2011-2012

- Event-driven dynamic orbit & Q/Q' references (tested/in place)
- Internal-FB to suppress Orbit-FB induced energy shifts (to be commissioned)
- Q/Q' response matrix flip and trim persistency: changed ZOH from 'd[Q,Q',C-]' to quadrupole strengths (needed for ATS)
- Flipped BBQ FFT1 ↔ FFT2 tune system usage: BBQ FFT2 connected to BPLX pick-up feeds now the Q/Q' Feedbacks, rationale:

  a) FFT1 uses separate BPLV/BPLH pickups perturbing the |C-| estimate
  b) BBQ bunch selector prototype is/will be deployed on the BPLX monitors

- Multiple/parallel Q-Tracker & 1024turn@12.5 Hz FFT acquisition
  - new/better background & tune width estimate, tune stability being logged
  - facilitates optimised independent fitter settings for the different use cases:
    - TUNE-FB → 1 Hz-level, optimised for robustness
    - FAST-TRACKING → 12.5 Hz optimised for Q' computation
    - MEDIUM-TRACKING → 0.1 Hz average, better |C-| estimate
    - SLOW-TRACKING → 60 s average (e.g. beam-beam studies)
    - DEVELOPMENT → test of to be deployed operations settings
    - LOGGING

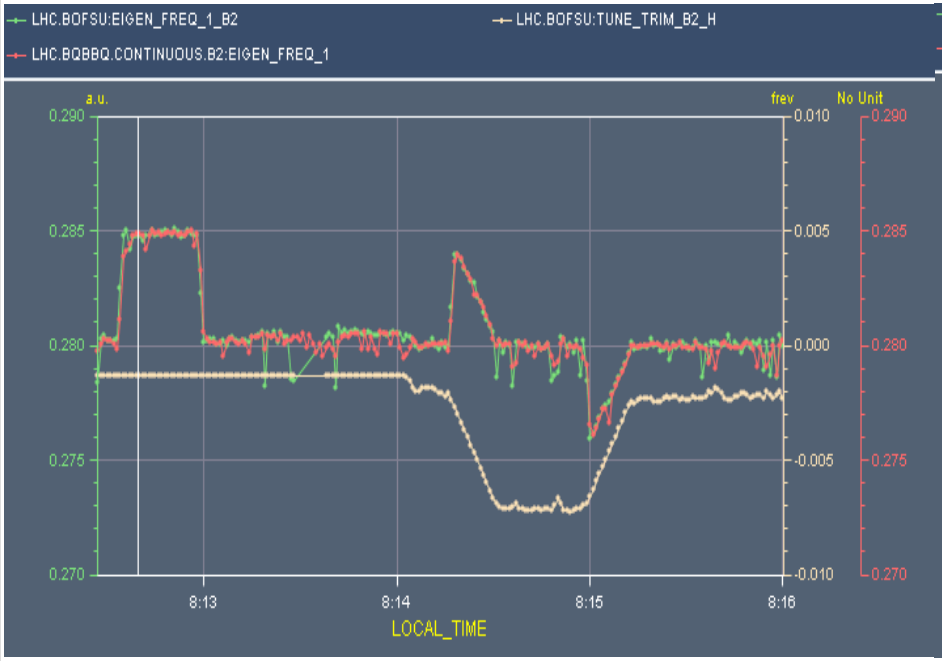
Smaller Item changes from 2011-2012

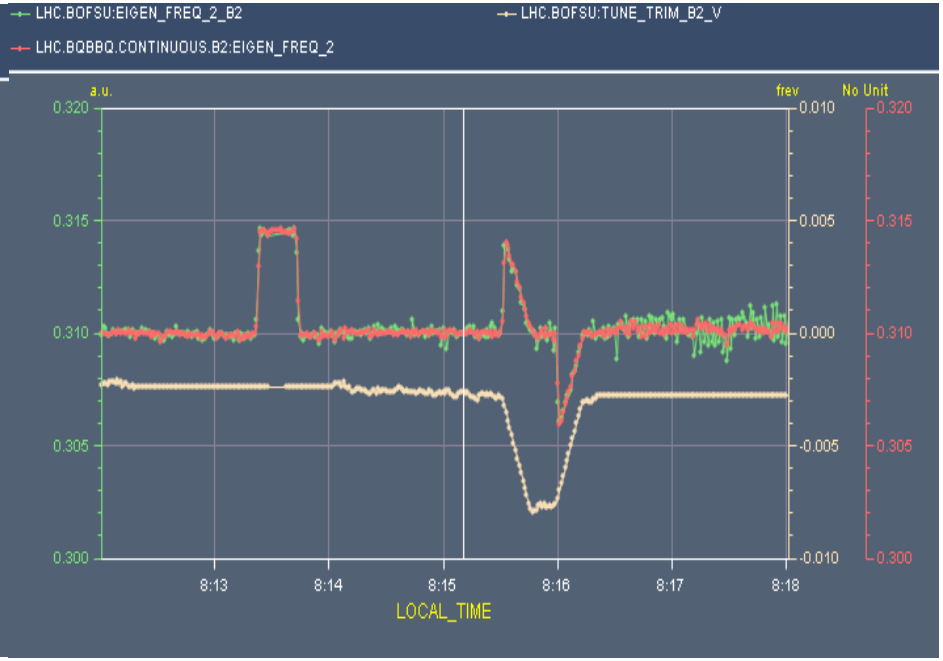
- RF commutation switches to study long-term stability of IR BPMs
  - Now fully integrated in OFC, studies planned during stable beam periods and complemented with BPM response and k-modulation measurments
- Additional diagnostic for IIR vs. Synchronous orbit mode
- Direct 25 Hz direct BST-driven synchronisation to improve robustness of data concentration (presently slightly sensitive to single front-end misbehaviours)
- Minor items: clean-up and OP integration, export of additional parameters, DAB temperature warning, OP mask and status bits, updating limits, etc.

- Most of the issues related to the new functionalities were fixed in time and/or related to beam specific effects that could be tested only now:
  - Dead FGC RT input
  - duplicate/incomplete packets being sent to OFC
  - Q'-sign required configurable phase adjustments between Q & dp/p-trims
  - 'Higher order correction' to equalise FESA FE/GUI based Q/Q' estimates
- Criticality and availability of these system is obvious as they are needed early on during the commissioning

Commissioning Examples I/II

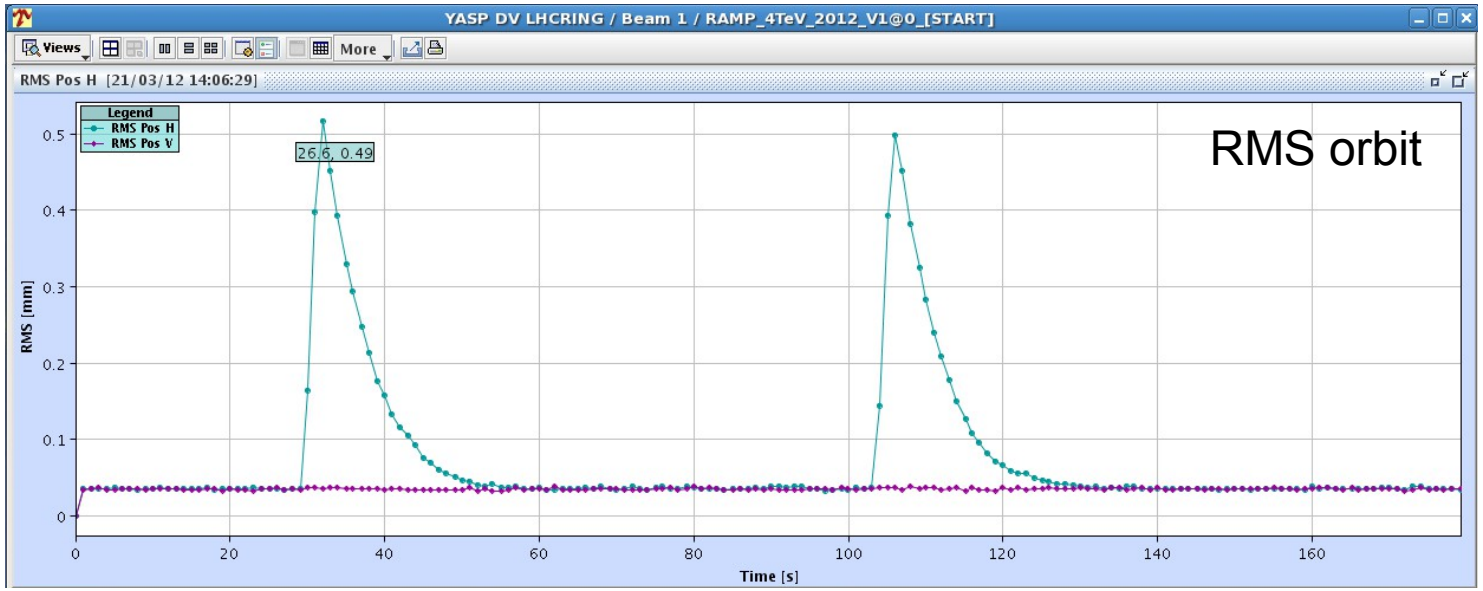
- re-commissioned Orbit-FB systems – no issues, works as in 2011
- re-commissioning of Q/Q' diagnostics and FB systems
  – minor issues but now as in 2011
- Had to remind ourself's that we have...
  a) … significantly lower programmed bandwidth compared to proton run
     → should expect larger transients during snap-back and squeeze
  b) … very harsh rate-limit of dQ/dt|max = 0.003 in place
  c) … operation with pilot beam (+ octupole settings) yield very low (<6 dB!!) S/N levels → advise to use chirp excitation

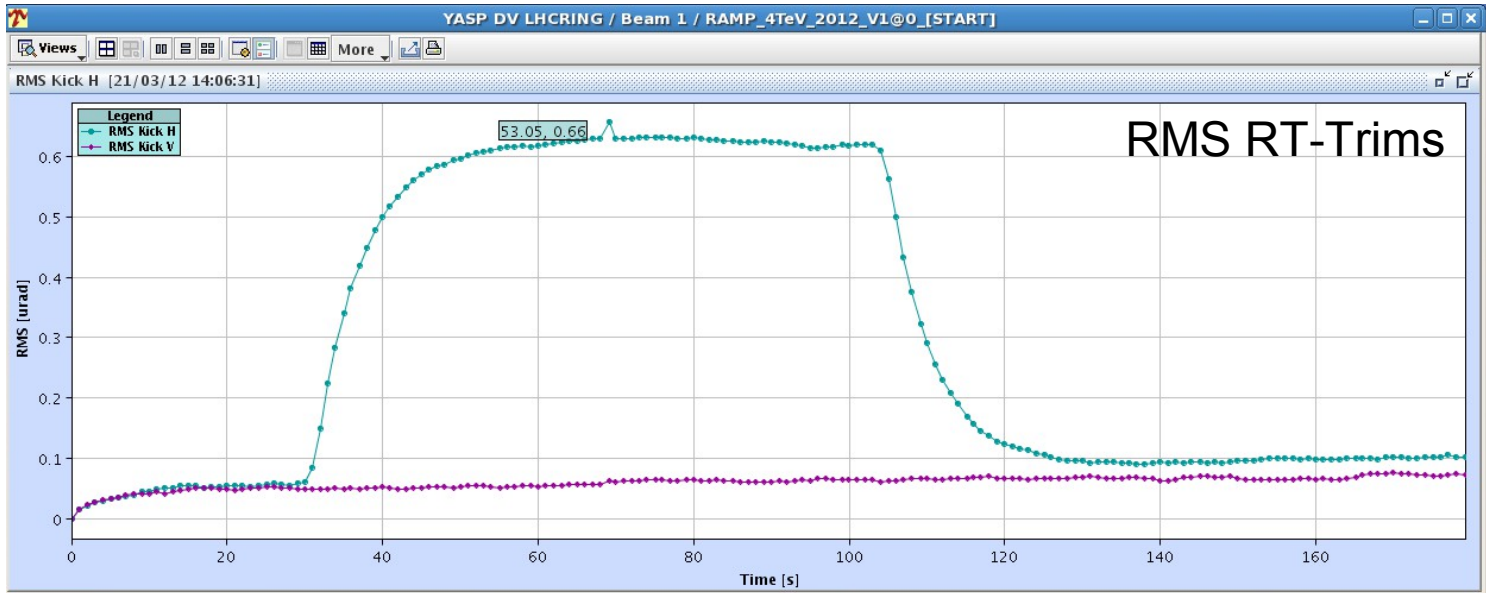




Commissioning Examples II/II

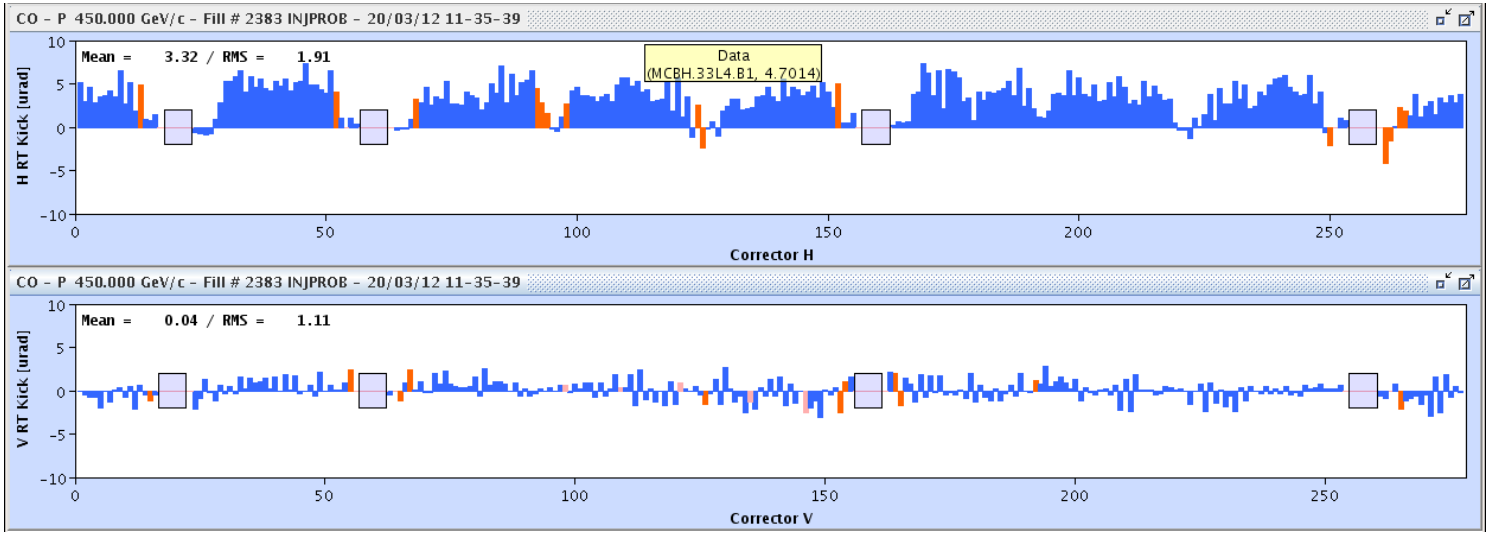
- Design Orbit-FB response to a single kick:





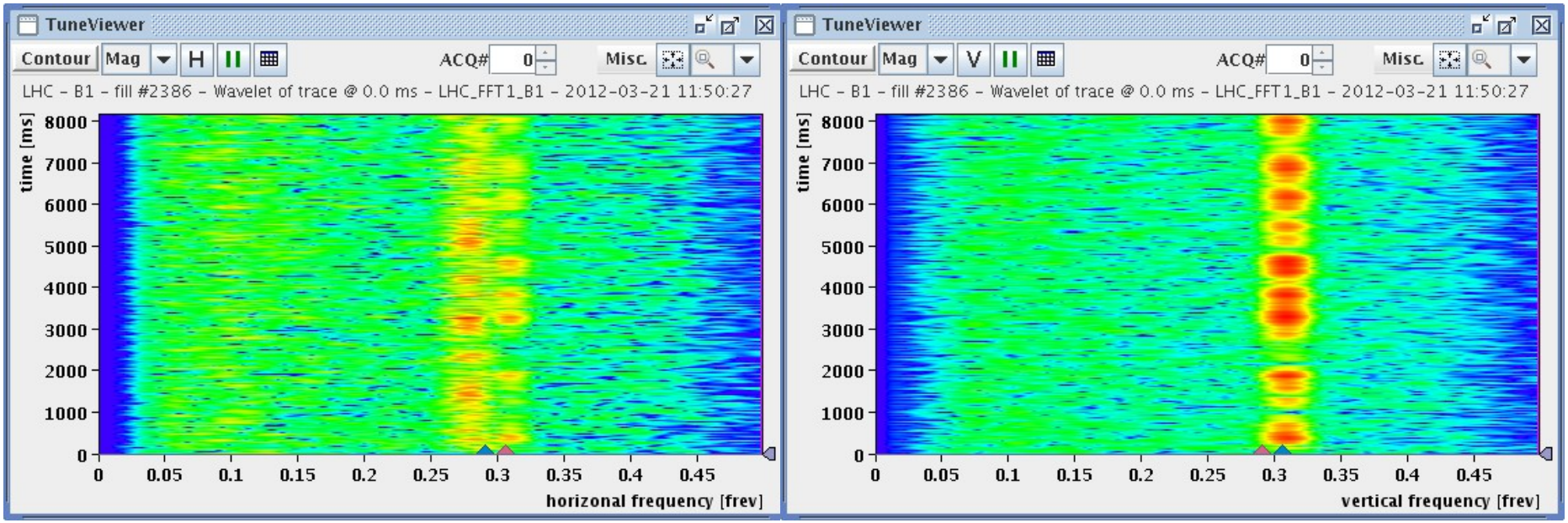
Energy-FB

- Orbit-FB induces minute systematic energy shifts via horizontal CODs that via the natural chromaticity create large tune shifts. Not a big impact on the orbit per-se but unnecessarily increases dependence in Tune-FB.
- Present understanding: dp/p dispersion orbit is subtracted prior to correction but a very small residual <10^{-5}-level error remains that is not visible/ correctable by the OFB. This error integrates over every OFB period (~ 100k periods per fill) reaching important levels.
- 2011: introduced calibration factor to correct for the estimation error, however not constant w.r.t. optics changes (notably going from proton-> ion operation)
- 2012: re-commission/re-purpose existing energy feedback to re-center the measured integrated OFC trims (or possibly total corrector strengths)



Rationale of 8192turns@2.5Hz → 1024turns@12.5Hz I/II

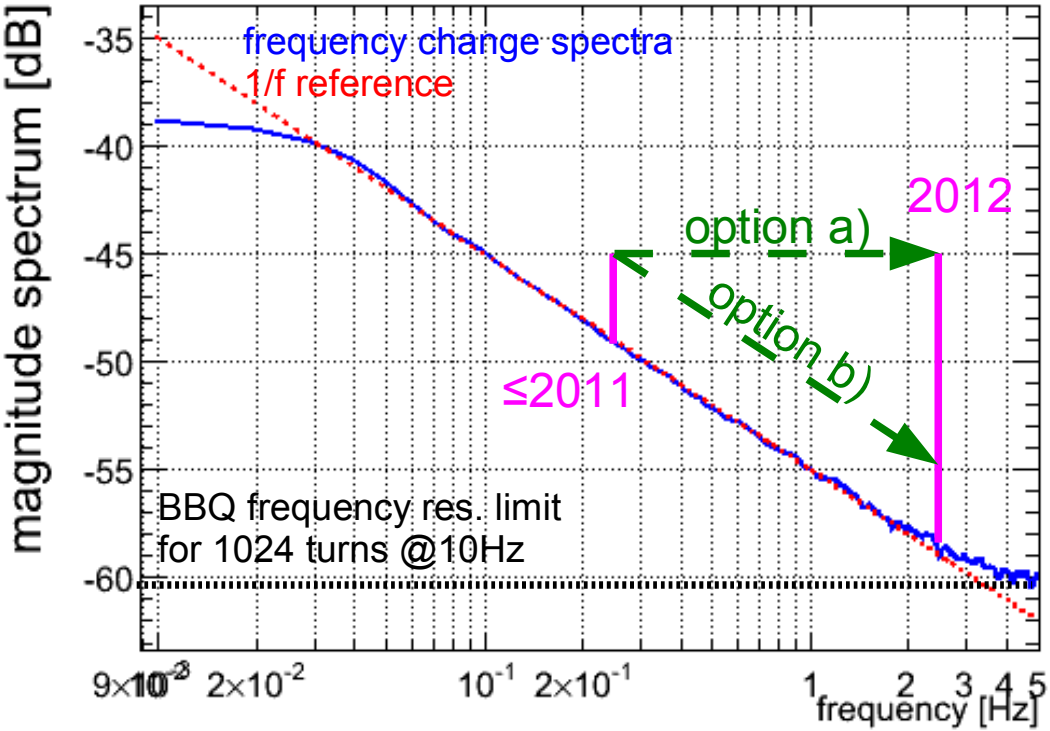
- Residual oscillations are only coherent on time-scales of a few hundred turns*
- Two main advantages:
  a) Phase jumps between 'blurbs' reduces the S/N if averaged/taking one full 8192-turn based FFT compared to incoherent sum of the power spectra.
  b) Faster modulation improves the achievable S/N of Q' measurements
  c) Reduced latency → improved Tune-FB closed-loop stability margin



*exception: Injection oscillation, AC-dipole, tune kicker and certain instabilities

Rationale of 8192turns@2.5Hz → 1024turns@12.5Hz II/II

- Tune stability determined by power converter ripple → 1/f noise
- Chromaticity estimate significantly improves for 0.25 → 2.5 Hz modulation
- Two exploitation options:
  a) Const. dp → improves Q' res./time response (e.g. snap-back diagnostics)
  b) Const S/N → reduces impact on tight collimator settings and potentially allows Q' monitoring with nominal beam (to be furthre studies)
- For illustration: Fourier components of residual tune ripple



Summary

- Main functional changes between 2011 → 2012:
  - Dynamic orbit & Q/Q' reference
  - Internal-FB to suppress Orbit-FB induced energy shifts
  - ATS-related Q/Q' Feedback adjustments
  - Flipped BBQ system to use BPLX pick-up for feeding the Feedbacks
  - Multiple/parallel Q-Tracker & 1024turn@12.5 Hz FFT acquisition

- With the exception of the Energy-FB, all systems have been re-commissioned and perform as or (hopefully) better than in 2011
  - First indication of improved Q' diagnostics

- However, to be kept in mind:
  - significantly lower programmed bandwidths compared to proton run
    → should expect larger transients during snap-back and squeeze
    - at least a factor 5 possibly even 10 margin
  - very harsh rate-limit of $dQ/dt|_{max} = 0.003$ in place
  - Operation with pilot beam (+ octupole settings) yield very low (<6 dB!!) S/N levels (see picture) → advise to use chirp excitation