

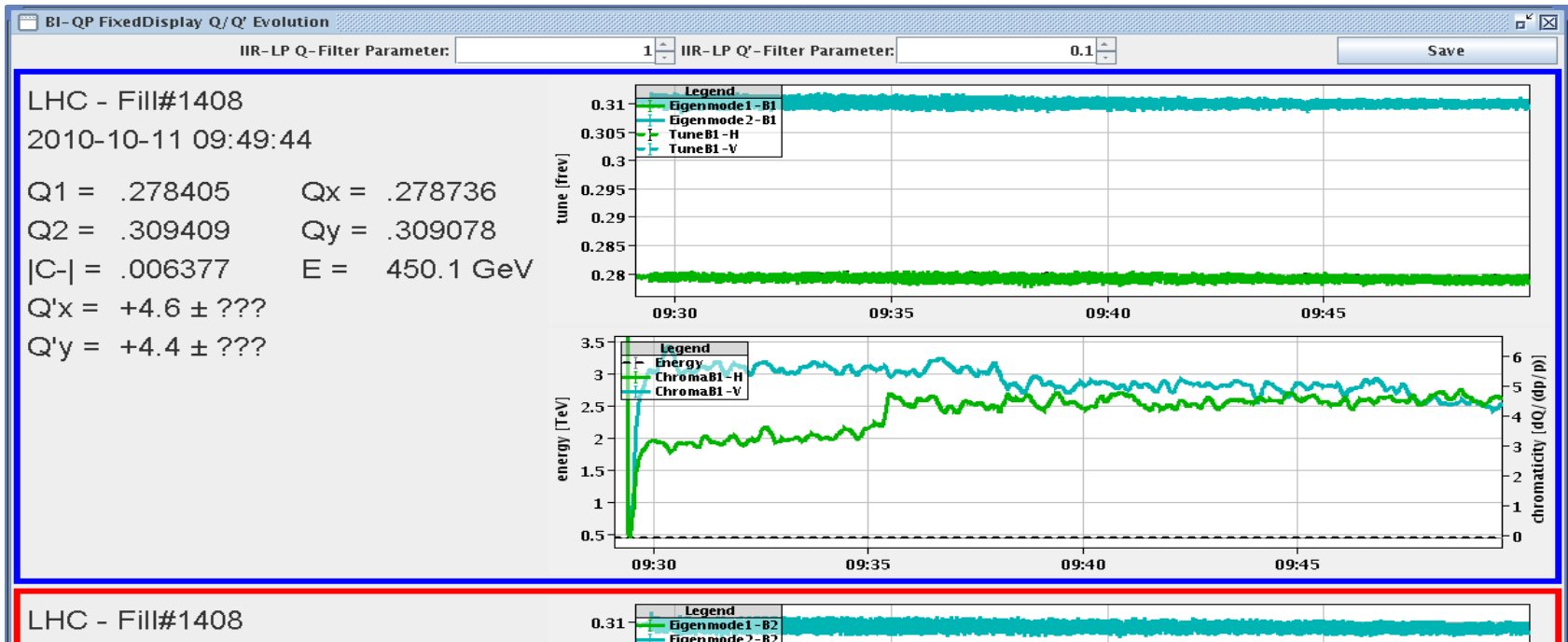
Update on:
Tune and Chromaticity Measurements
during the 10 A/s Ramp(s)

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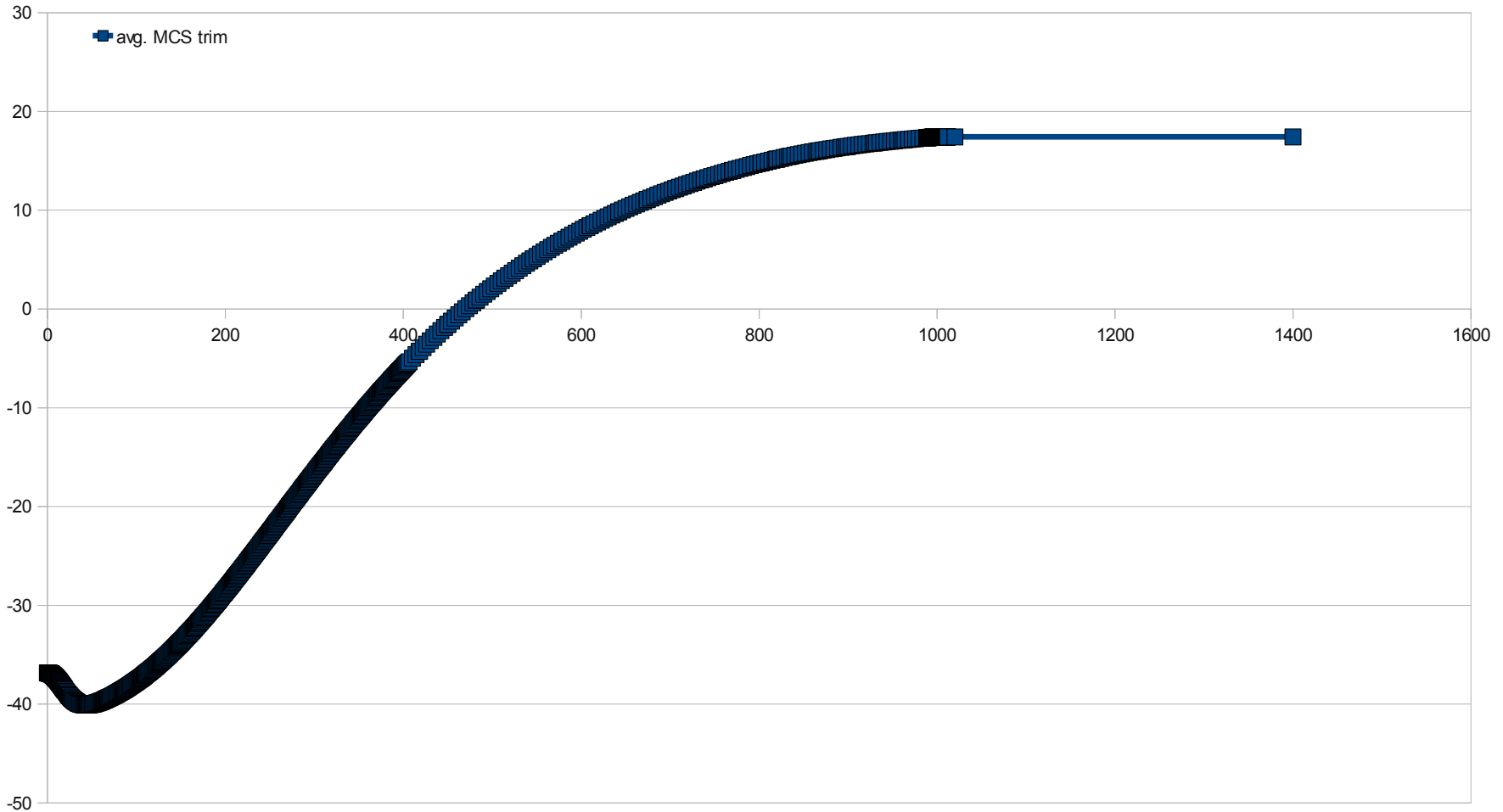
Acknowledgments: OP crew, M. Lamont

Where to find $Q'(t)/Q(t)$

- Logging database (LHC→Beam Instrumentation→Tune and Chroma/Beam Feedbacks→ ...):
 - Tune eigen-modes: [LHC.BQBBQ.UA\[47/43\].FFT1_B\[1/2\]:EIGEN_FREQ_\[1/2\]](#)
 - excludes effect of |C-|, better meas. precision → source for Tune-FB
 - 'Unperturbed' Tunes: [LHC.BQBBQ.UA\[47/43\].FFT1_B\[1/2\]:TUNE_\[H/V\]](#)
 - Tunes in the absences of |C-|,
 - Tune-FB corrections: [LHC.BOFSU:TUNE_TRIM_B\[1/2\]_\[H/V\]](#)
 - Chromaticity measurement: [LHC.BOFSU:CHROMA_B\[1/2\]_\[H/V\]](#)
 - Chromaticity-FB corrections: [LHC.BOFSU:CHROMA_TRIM_B\[1/2\]_\[H/V\]](#)
- Online via BI-QP Fixed-Display → Q' Display (now more routinely used):

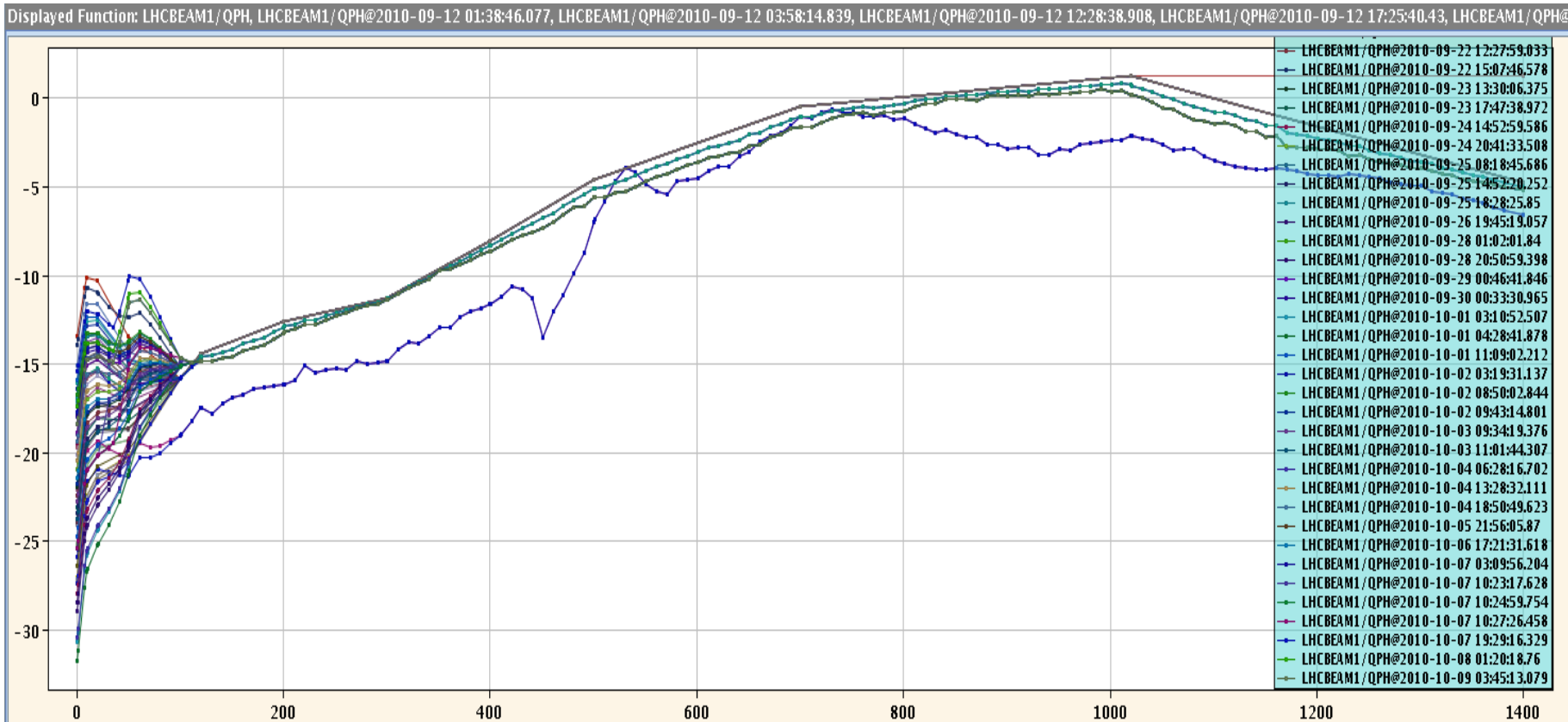


- Status quo, kept the same snap-back compensation as for 2 A/s ramp:



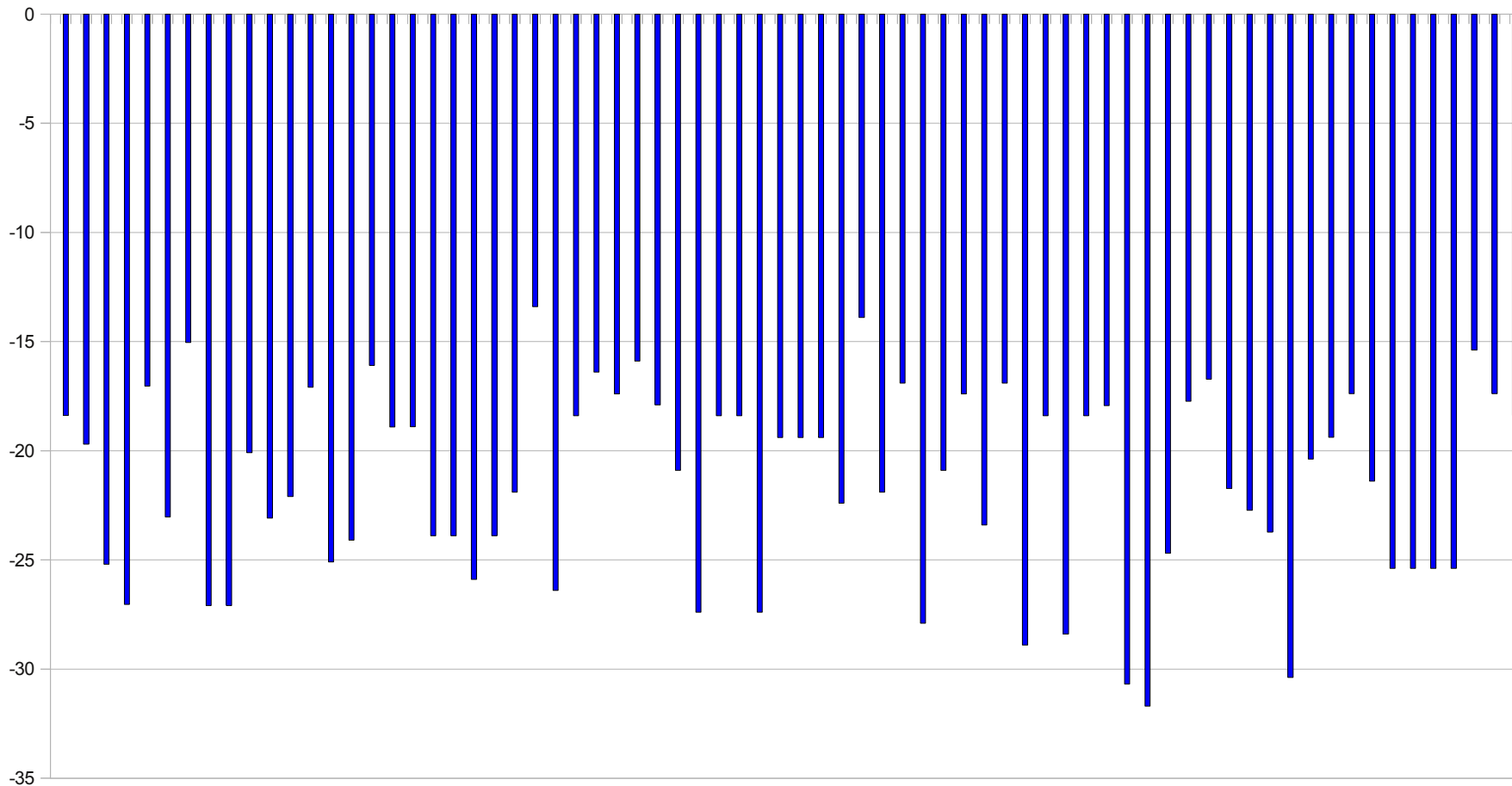
- Measured differences are incorporated into main sextupoles to keep modeled compensation (spool pieces) clean from fill-to-fill variations.

- Q'(t) routinely measured and corrected at injection (target: $Q'_{H/V} := 4$)
- Incorporated into ramp assuming pure b3 decay variations
 - gradual-out within first 120 s (ramp-based measurements)
- Example latest 1400 s $Q'_{B1H}(t)$ operation:

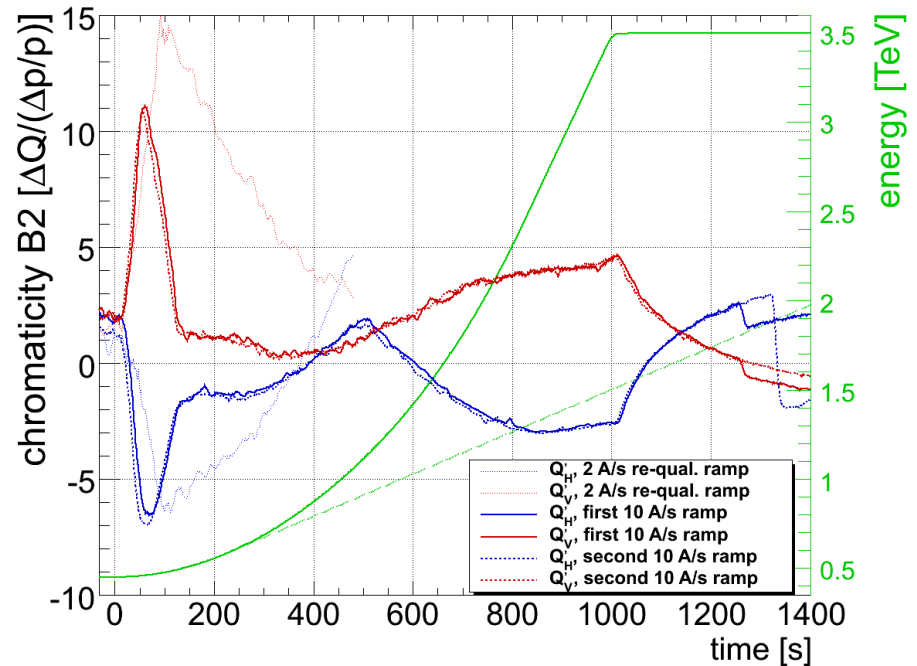
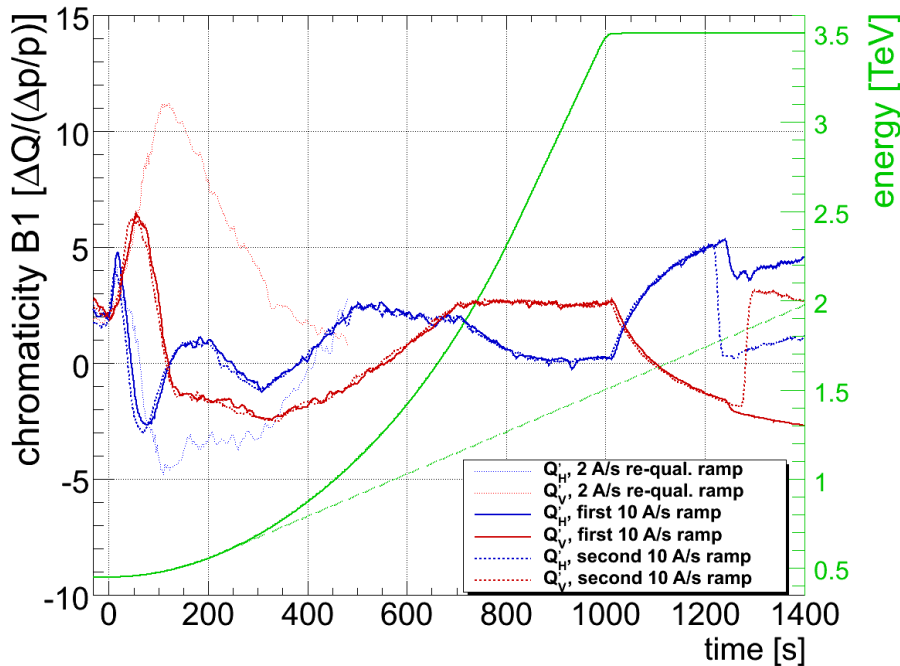


- Fairly large variation of up to 20 units of Q' → but it's justified

- Chroma variations at injection:
 - No clear fill-to-fill trend on injection tune variations visible...
 - Exception: partially or non-standard (\neq physics fill) pre-cycled machine
 - Effect of single re-pre-cycled sector: $Q' \sim \pm 3-4$ units

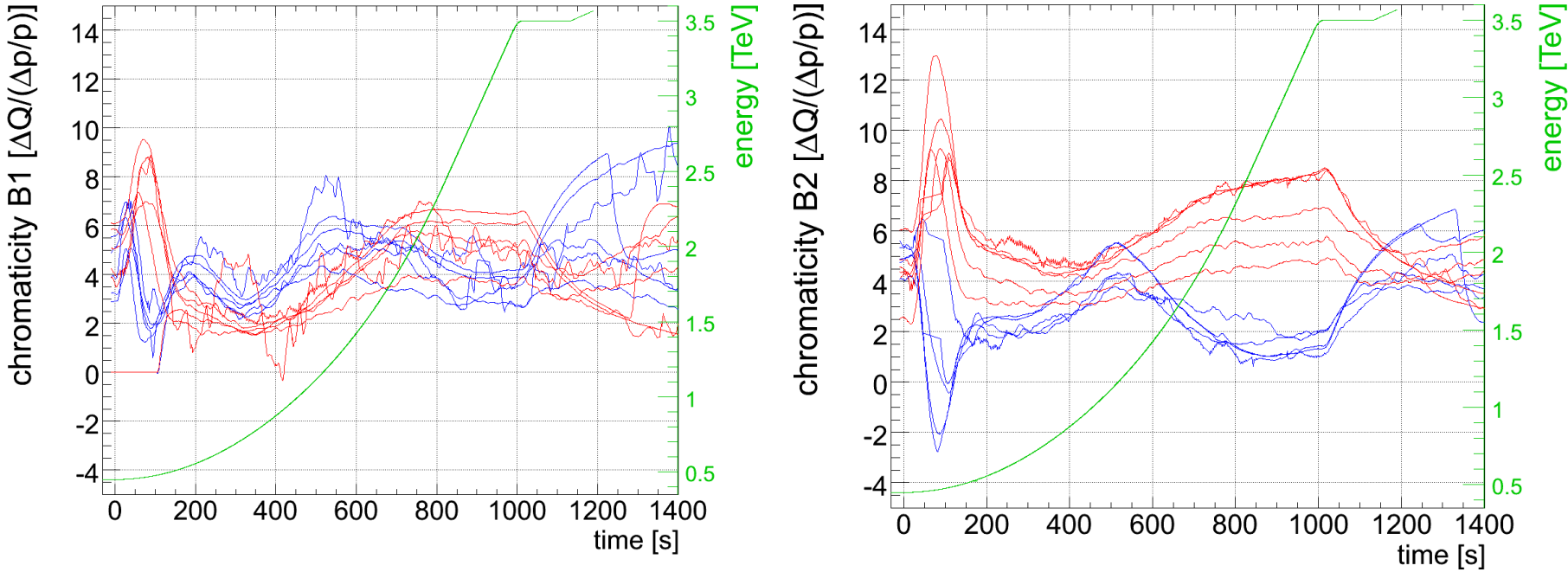


- Most measurement attempts shoot down by EICs/Coordinators
→ no long-term monitoring available
- Only a few dedicated systematic Q' measurements during the ramp
 - March this year, most of them semi-manual
 - Ramp (rate) re-commissioning 2 A/s → 10 A/s (Mike sponsoring):



- “Fairly” reproducible (very low statistics of ~ 7 ramps), assuming
 - Mostly (only) done with “perfect” pre-cycled machine
 - Need to have some more checks with
 - Fill-to-fill re-measuring of Q' and incorporation into ramp

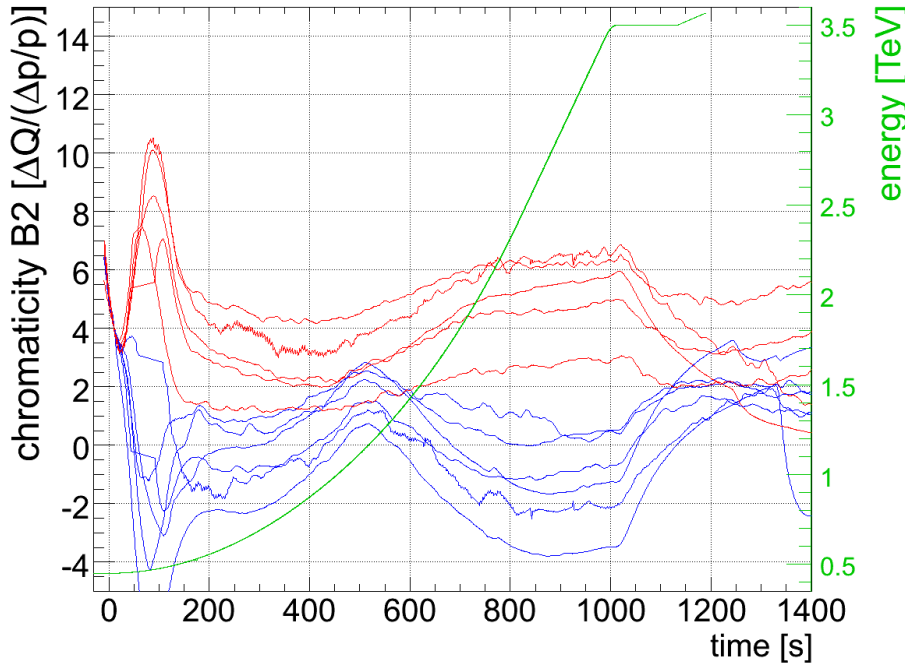
- Unfortunately, statistics did not increase by much: 6 (useful $Q'(t)$ during ramp)
 - B2 measurements a bit cleaner



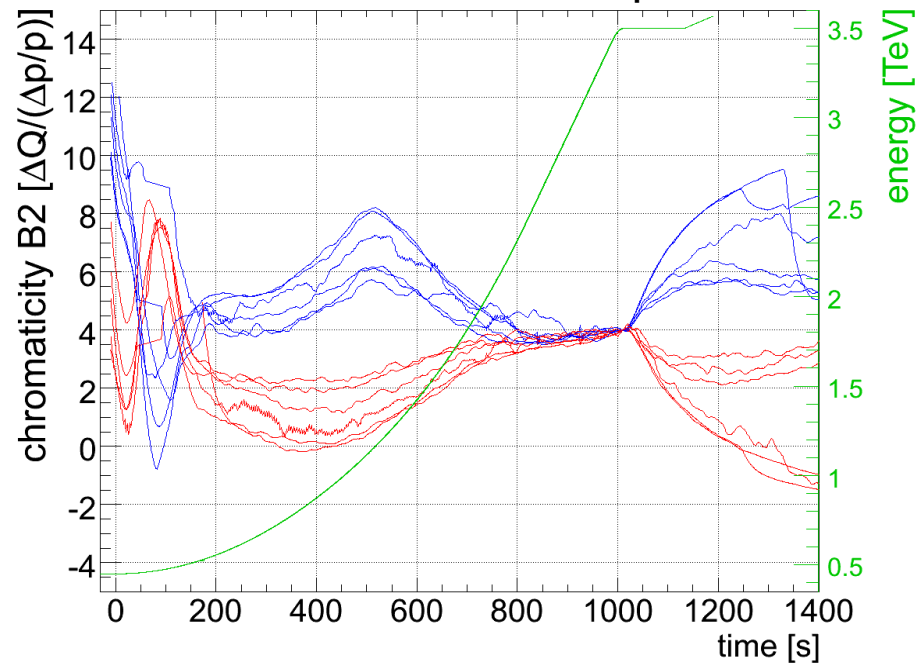
- Besides snap-back, de-facto the same $Q'(t)$ during three consecutive cycles!
 - The machine can be quite reproducible...
- Decay at 3.5 TeV with 10 A/s ramp visible (less/no decay with 2 A/s):
 - ~6 units max, initially ~1 unit/minute decay
 - compensated by qualitative linear trim
 - 450 GeV-like decay

- Started of ramps with slightly different initial Q' values
 - Normalised (=shifted) for comparisons between ramps

normalised to start of ramp:

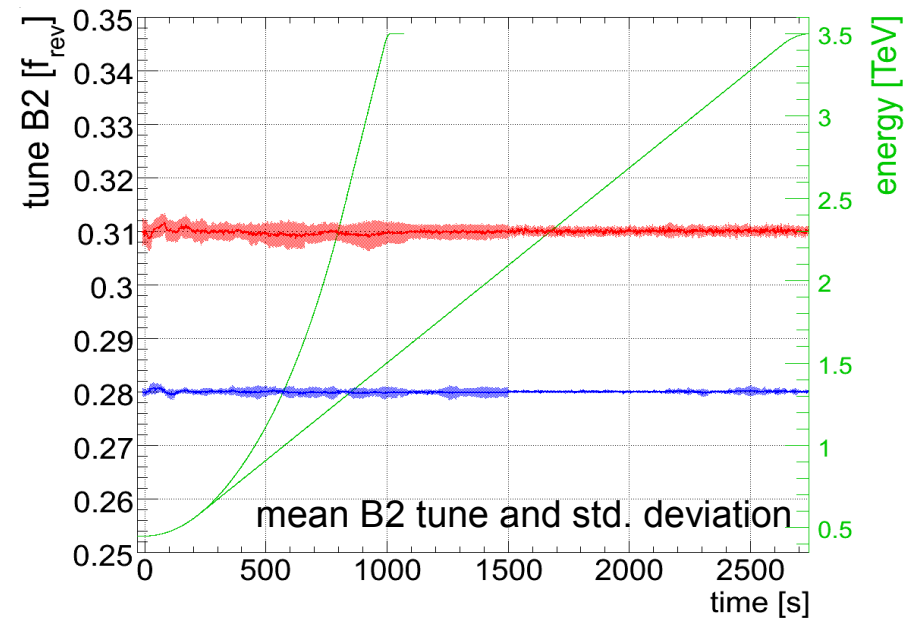
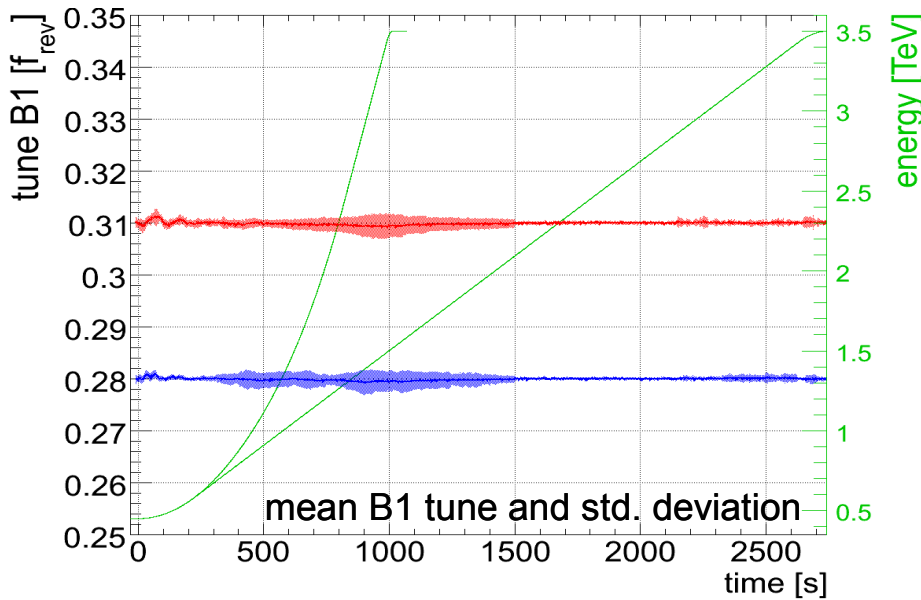
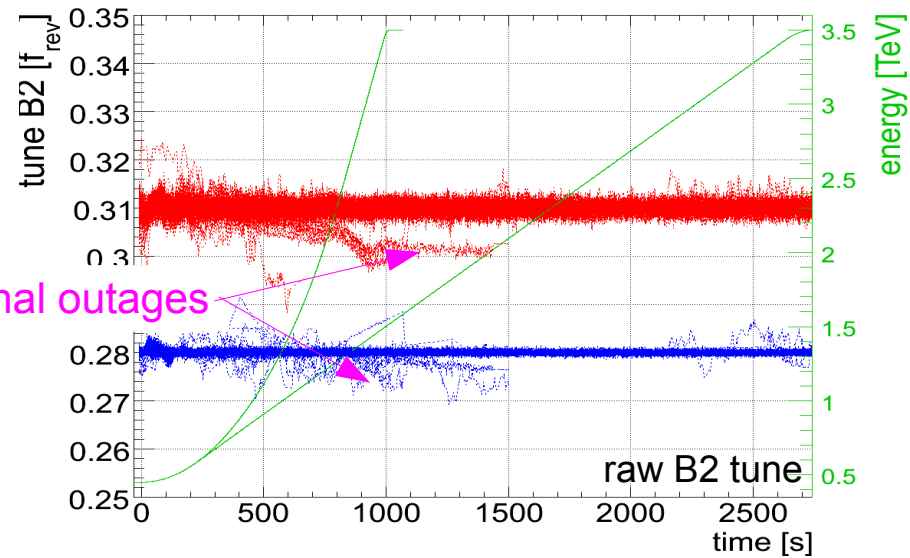
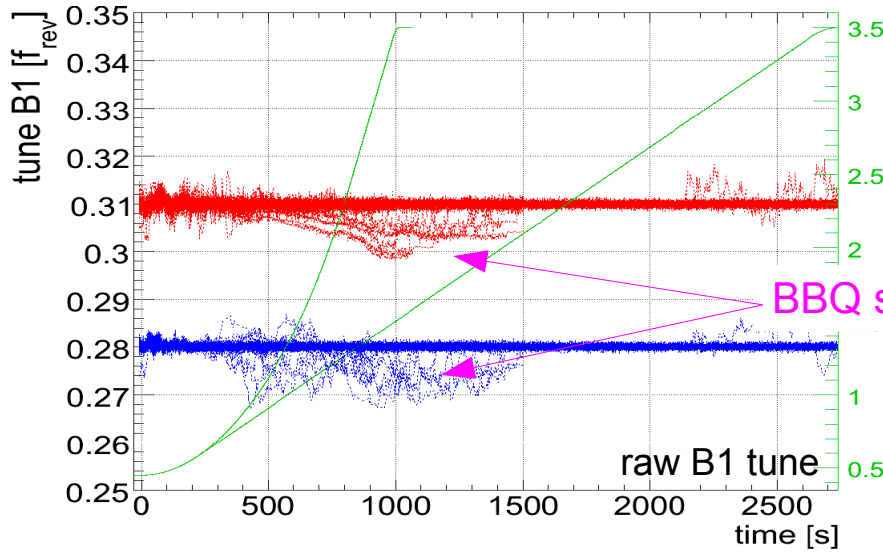


normalised to end of ramp:



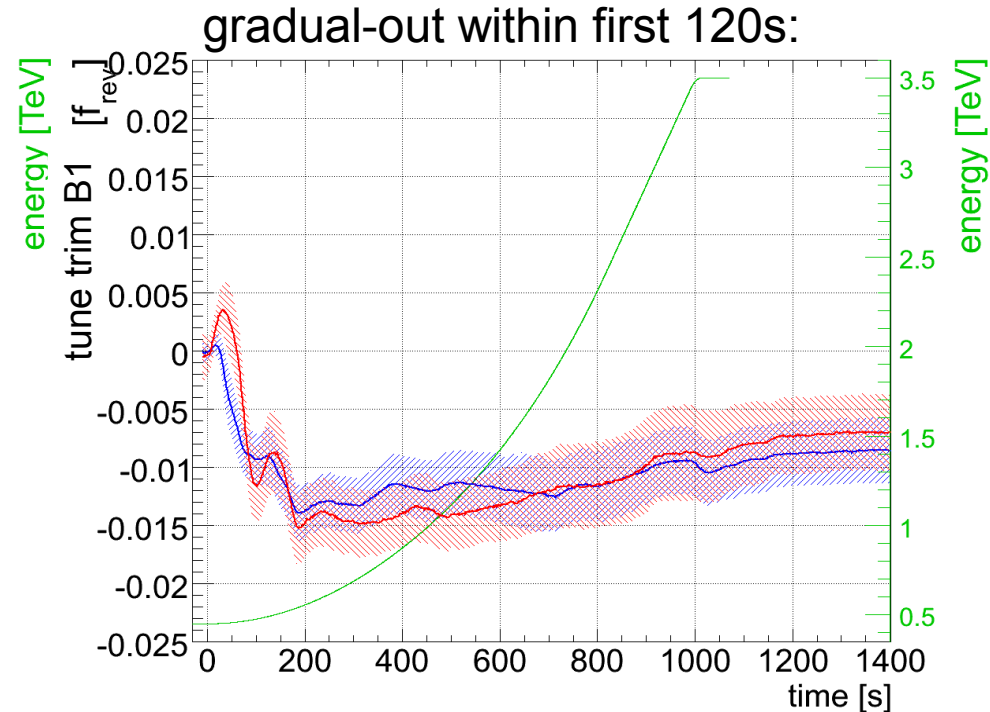
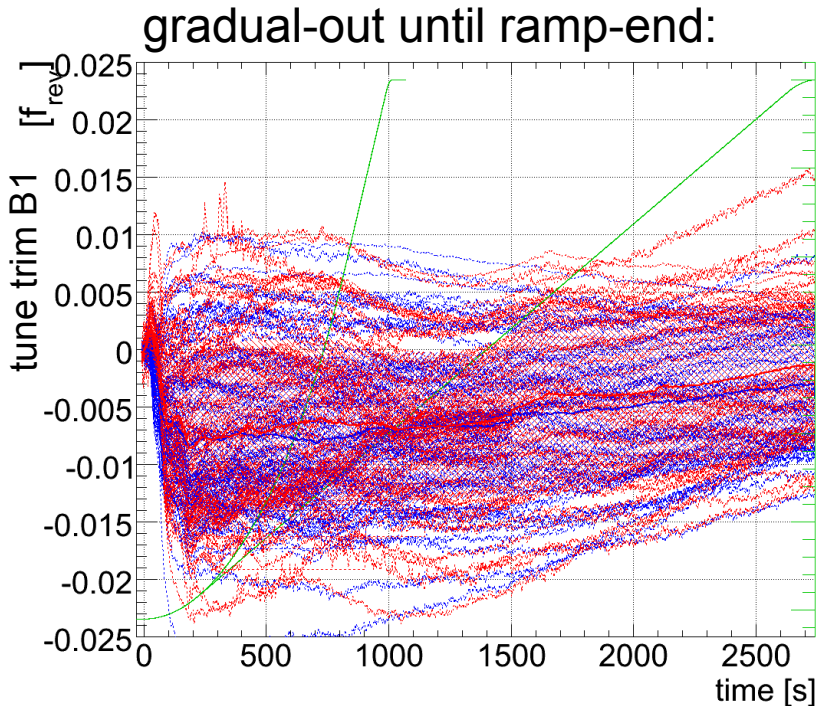
- Initial better fit if matched at injection → latter: common Q' value at flat-top
 - seems to confirm hypothesis of decay-currents dying-out with energy
- Ramp sometimes run with slightly negative chromaticities

Residual overall Tune Stability over last 198 Ramps



- Main limitations: residual noise on tune (ADT), limited Tune-FB bandwidth

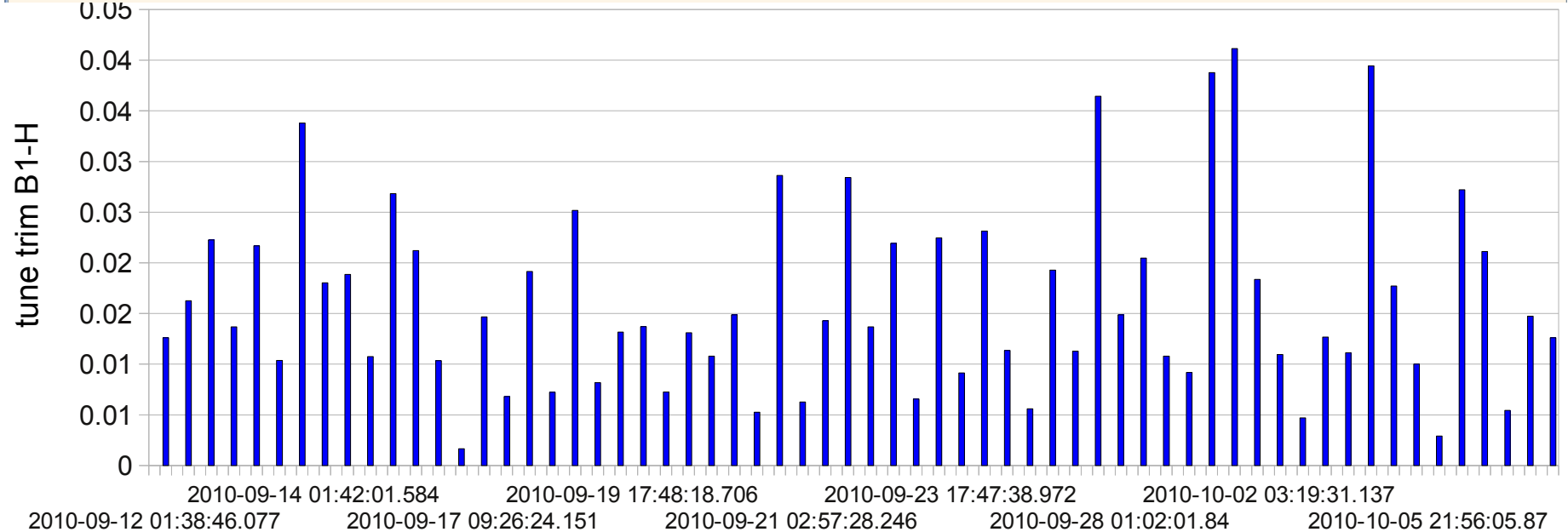
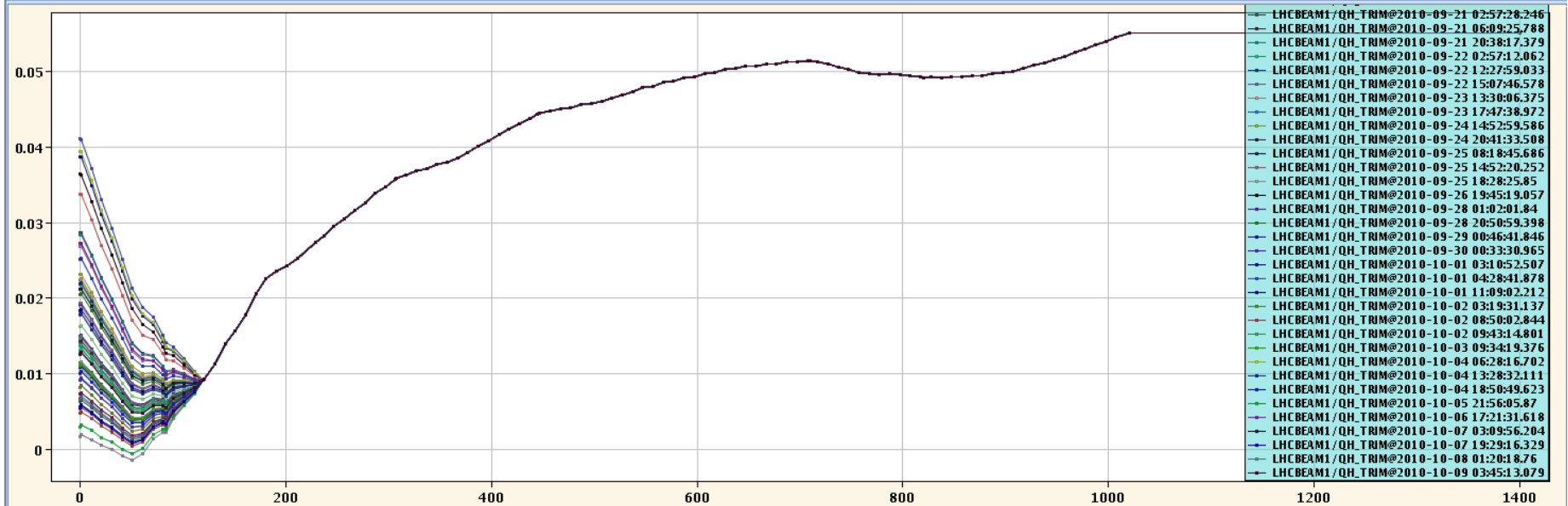
- Ramp dynamics and variations are compensated by Tune-FB
- As for $Q'(t)$, no clear fill-to-fill trend on injection tune variations...
 - tune measured & compensated before ramping
 - Initially: gradual out until end-of-ramp
 - Saw snap-back type structure: gradual-out within first 120 s for 10 A/s
 → improved Tune-FB trim reproducibility (now $< 2\cdot 3\cdot 10^{-3}$, 2010-09-05)
 - Smaller (< 0.003) but measurable decay at flat-top also visible





Day-to-Day Q(t) compensation LSA trims & Feed-Forward Compensation

Displayed Function: LHCBEAM1/QH_TRIM, LHCBEAM1/QH_TRIM@2010-09-12 01:38:46.077, LHCBEAM1/QH_TRIM@2010-09-12 03:58:14.839, LHCBEAM1/QH_TRIM@2010-09-12 12:28:38.908, LHCBEAM1/QH_TRIM@2010-09-12 17:25:...



- Tune:
 - 0.06 units of systematic corrections
 - About 0.06 units pp of variation at the start of ramp between fills
 - Gradual-out within first 120 seconds improved significantly reproducibility down to a few 10^{-3}
- Chromaticity:
 - Some remaining measurement-vs-model errors
 - persistent currents of about 15 units missing
 - Snap-back still large, up to 20 units variations from fill to fill
 - 'Decay' at 3.5 TeV: ~ 6 units, ~ 1 unit/minute
 - Decay of main field component?
 - Eddy-currents due to ramp rate (since smaller/non-existent for 2 A/s)?