# some slides on:
# SPS prototype tests for the baseline LHC Q' measurement

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# LHC Tune and Chromaticity Requirements

- The measurement and control of

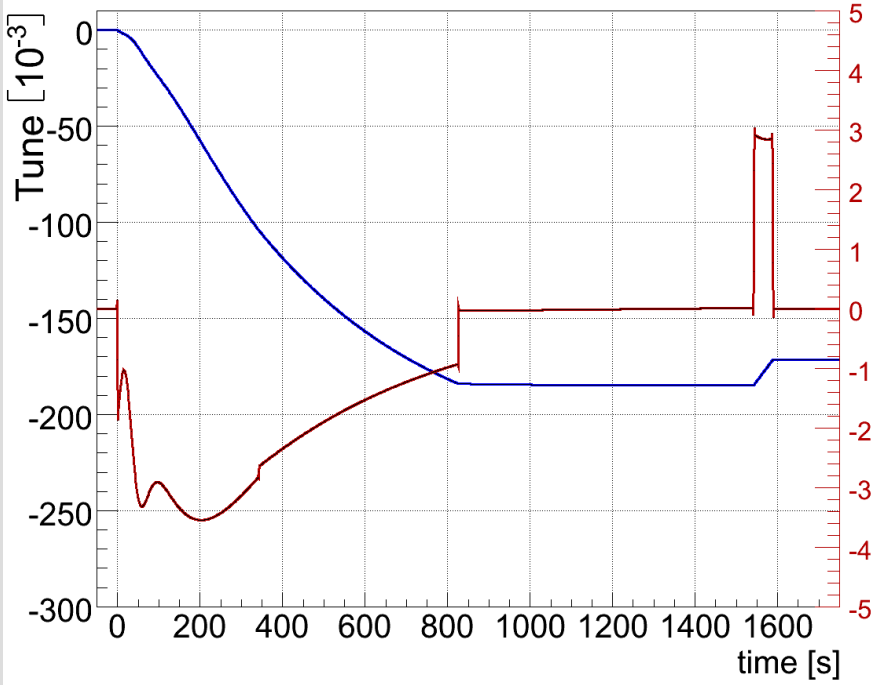
  -- orbit, tune, chromaticity, energy and coupling --

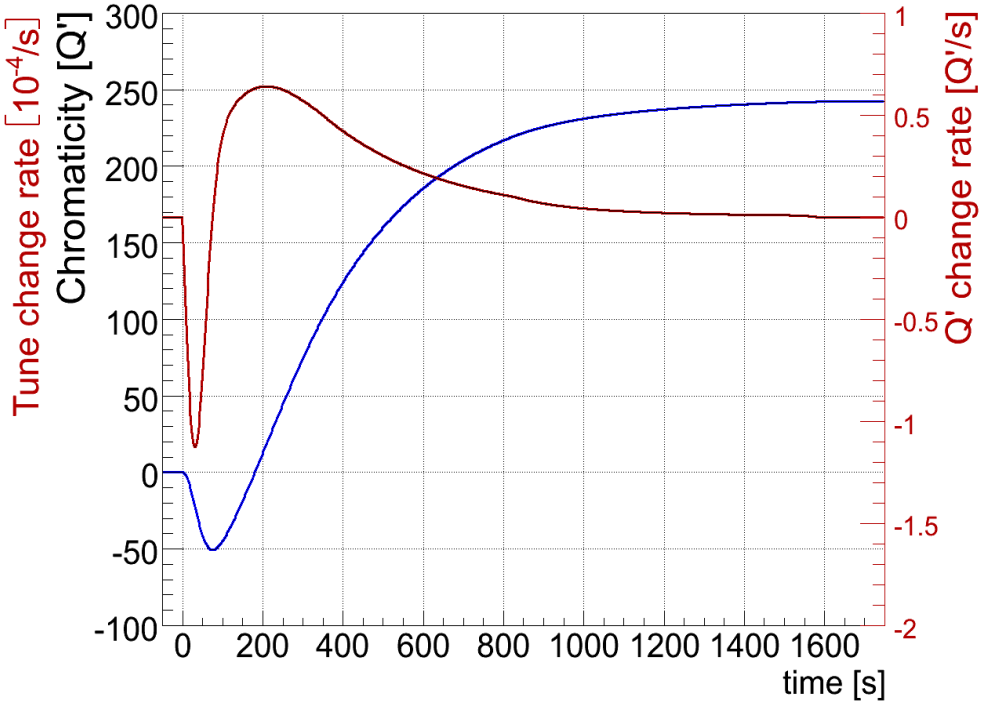
  will be an integral part of the LHC operation

- Stability requirements summary (Chamonix'06):

| | Orbit [σ] | Tune [0.5·$f_{rev}$] | Chroma. [units] | Energy [Δp/p] | Coupling [$c_-$] |
|---|---|---|---|---|---|
| Exp. Perturbations: | ~ 1-2 (30 mm) | 0.025 (0.06) | ~ 70 (140) | ± 1.5e-4 | ~0.01 (0.1) |
| Pilot bunch | - | ± 0.1 | + 10 ?? | - | - |
| Stage I Requirements | ± ~ 1 | ±0.015→0.003 | > 0 ± 10 | ± 1e-4 | « 0.03 |
| Nominal | ± 0.3 / 0.5 | ±0.003 / ±0.001 | 1-2 ± 1 | ± 1e-4 | « 0.01 |

# Expected Tune and Chromaticity Drifts during LHC ramp



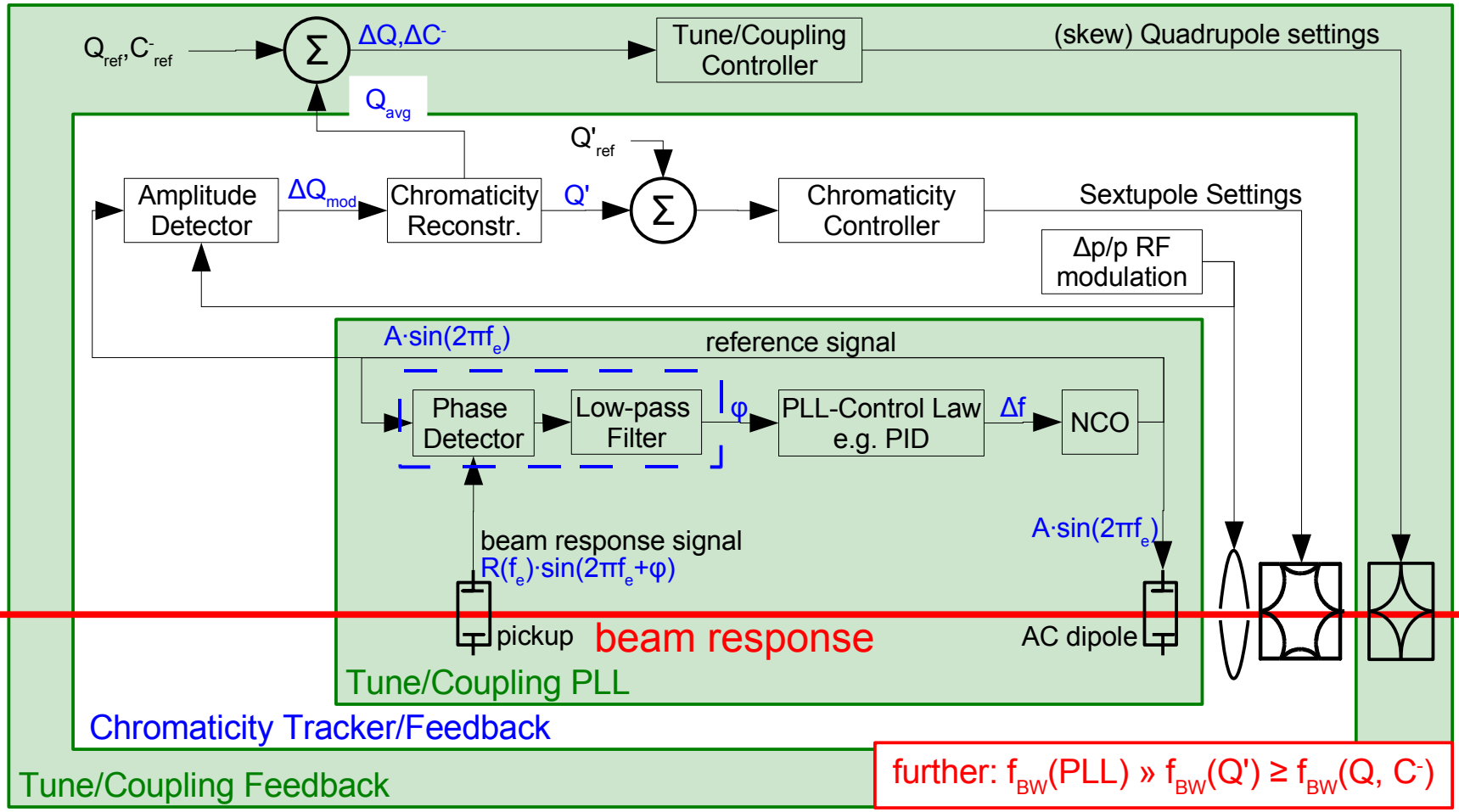

- Exp. perturbations are about 200 times than required stability!
- however: maximum drift rates are expected to be slow in the LHC
  - Tune: $\Delta Q/\Delta t|_{max} < 10^{-3}\ s^{-1}$
  - Chromaticity: $\Delta Q'/\Delta t|_{max} < 2\ s^{-1}$ ← the critical/difficult parameter
- Requires active control relying on beam-based measurements
- Feedbacks are only as good as the measurements they are based upon!

## Baseline: RF/energy induced tune change $Q' = \Delta Q_{mod}/(\Delta p/p)$

- SPS standard operation: $\Delta p/p > 10^{-3}$ & $\Delta Q_{res} \approx 10^{-3} \rightarrow \Delta Q'_{res} \sim 1$
- LHC operation (requirement): $\Delta p/p < 10^{-4}$ & $\Delta Q'_{res} \sim 1 \rightarrow \Delta Q_{res} < 10^{-4}$
  - limited by LHC Collimation orbit 'budget': $\Delta x < 35$ µm (nominal)
  - Important milestone:
    - feasibility established during 2007 SPS MD tests (see examples):
      - modulation frequency: 0.5 Hz
      - $\Delta p/p < 2 \cdot 10^{-5}$ & $\Delta Q_{res} \sim 10^{-6}$ !! (limited by RF ADC quantisation)
  - Foreseen LHC parameter: $\Delta p/p \sim 10^{-5}$ @ $f_{mod} = 1\text{-}2$ Hz
    - essentially limited by whether: $\frac{Q' \cdot \Delta p/p}{\Delta t} > \left|\frac{\Delta Q}{\Delta t}\right|_{max}$
      - possible remedies:
        - » either: increasing $Q'_{ref}$ to e.g. 10 units
        - » or: increasing $\Delta p/p$ amplitude (if low-intensity beam)
        - » or: increasing $f_{mod}$ (PLL limit: << 60 Hz)

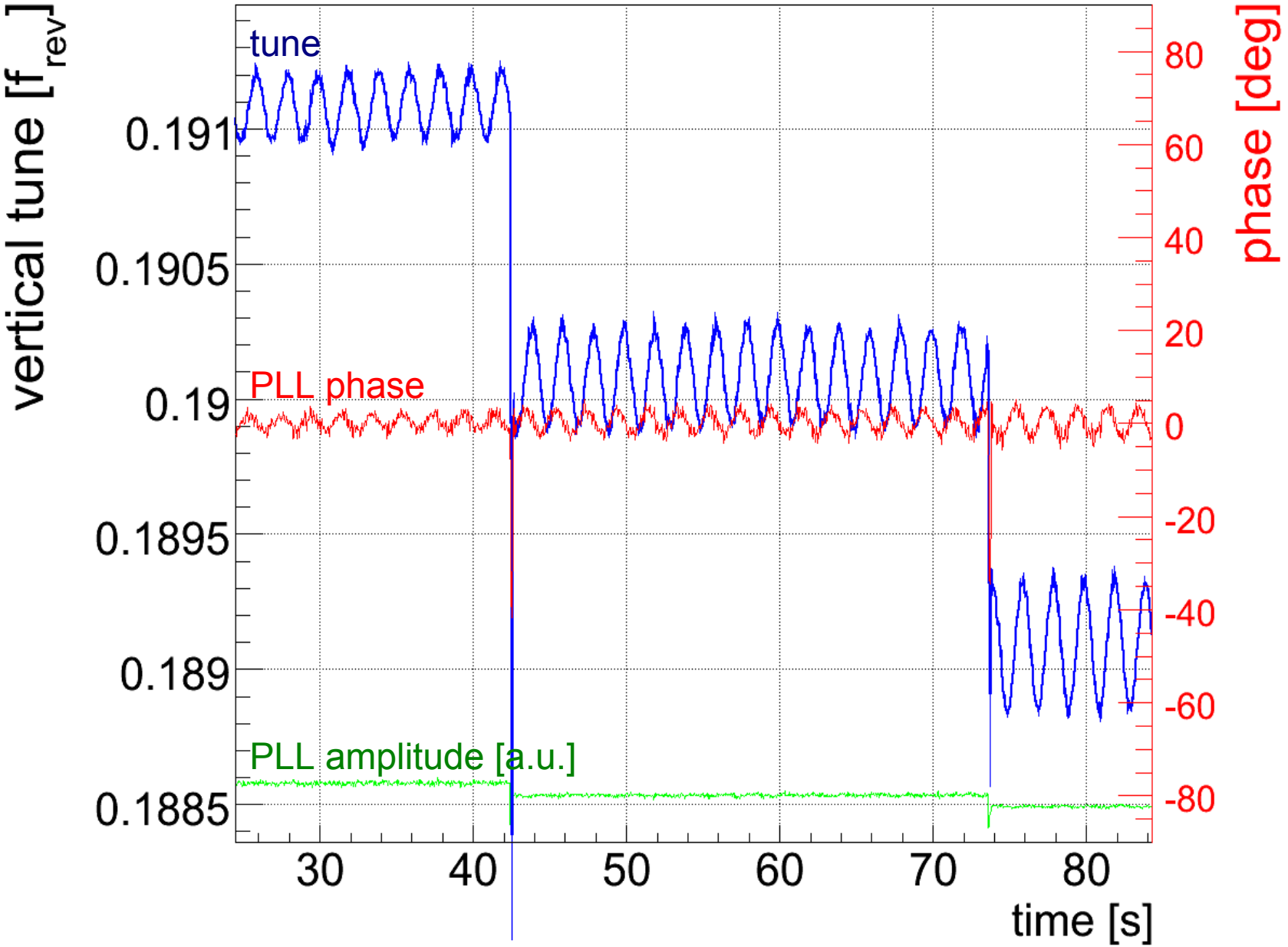
# Cross-Dependability and Constrains of FB Loops - Nested Feedback Loops

- In order to address cross-dependence and constraints → nested FB loops

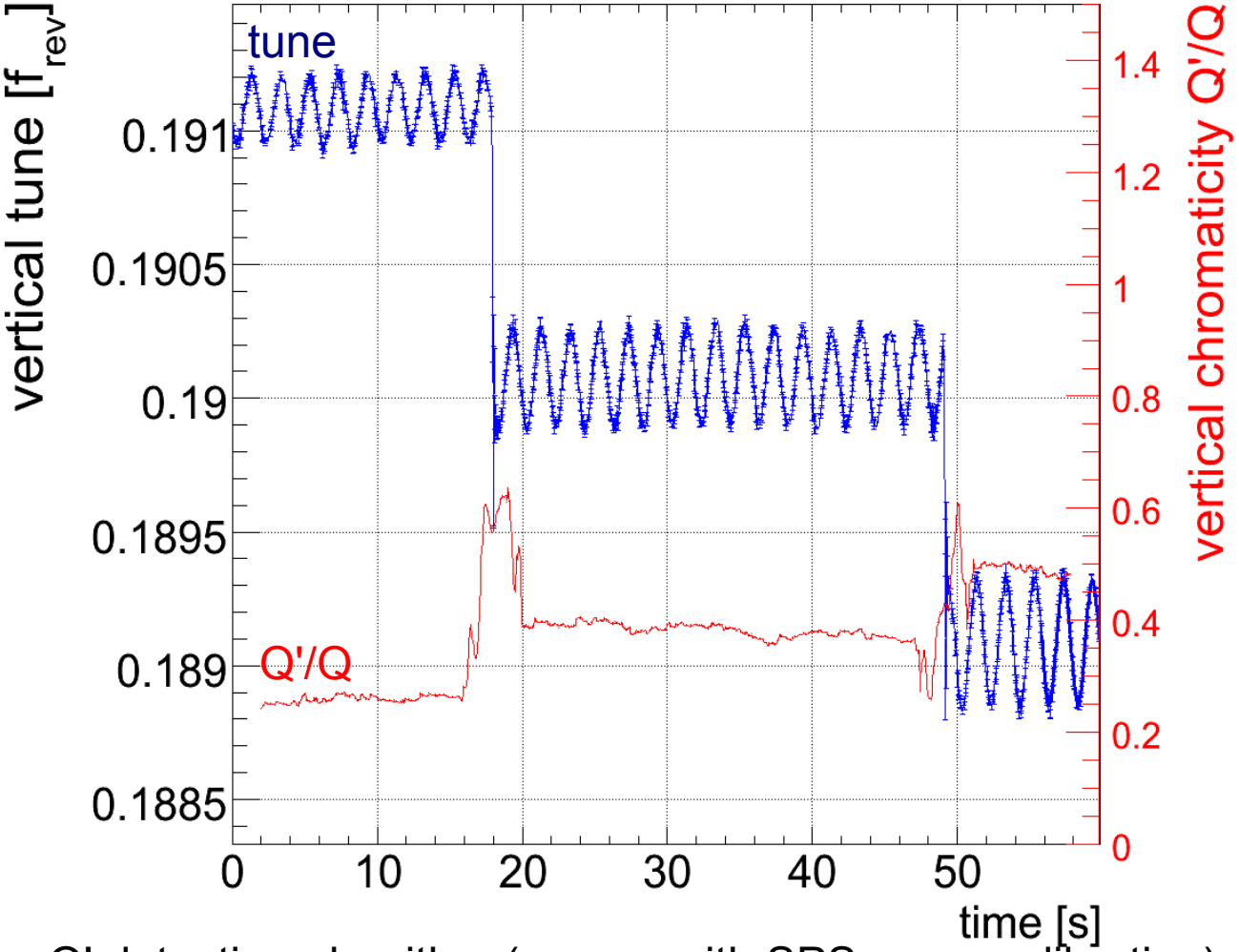



- cascading & separation of operational range (e.g. bandwidth or amplitude)
- orbit and energy feedback subtract ( = no correction of) dispersion orbit

# Example: Prototype in the SPS (measurement) modulation amplitude: $\Delta p/p \approx 1.85 \cdot 10^{-5}$



# Chromaticity Reconstruction (measurement)
# modulation amplitude: $\Delta p/p \approx 1.85 \cdot 10^{-5}$




- real-time Q' detection algorithm (agrees with SPS cross-calibration):
  - Q' resolution better than 1 unit (nominal performance)
  - N.B. tracking transients: ΔQ' feed-down on ΔQ (non-centred orbit)
    - $\Delta Q/\Delta t \gg \Delta Q'/\Delta t \rightarrow$ SPS specific, LHC: $\Delta Q/\Delta t|_{max} < 10^{-4}/s$