Proposal to modify the RT input of the LHC RF FGCs to include an anti-aliasing (/low-pass) Filter

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➔RT-trim modulation of the RF frequency are regularly used by OP for centering orbits (aka. radial-loop) and online Q' measurements during ramp and squeeze

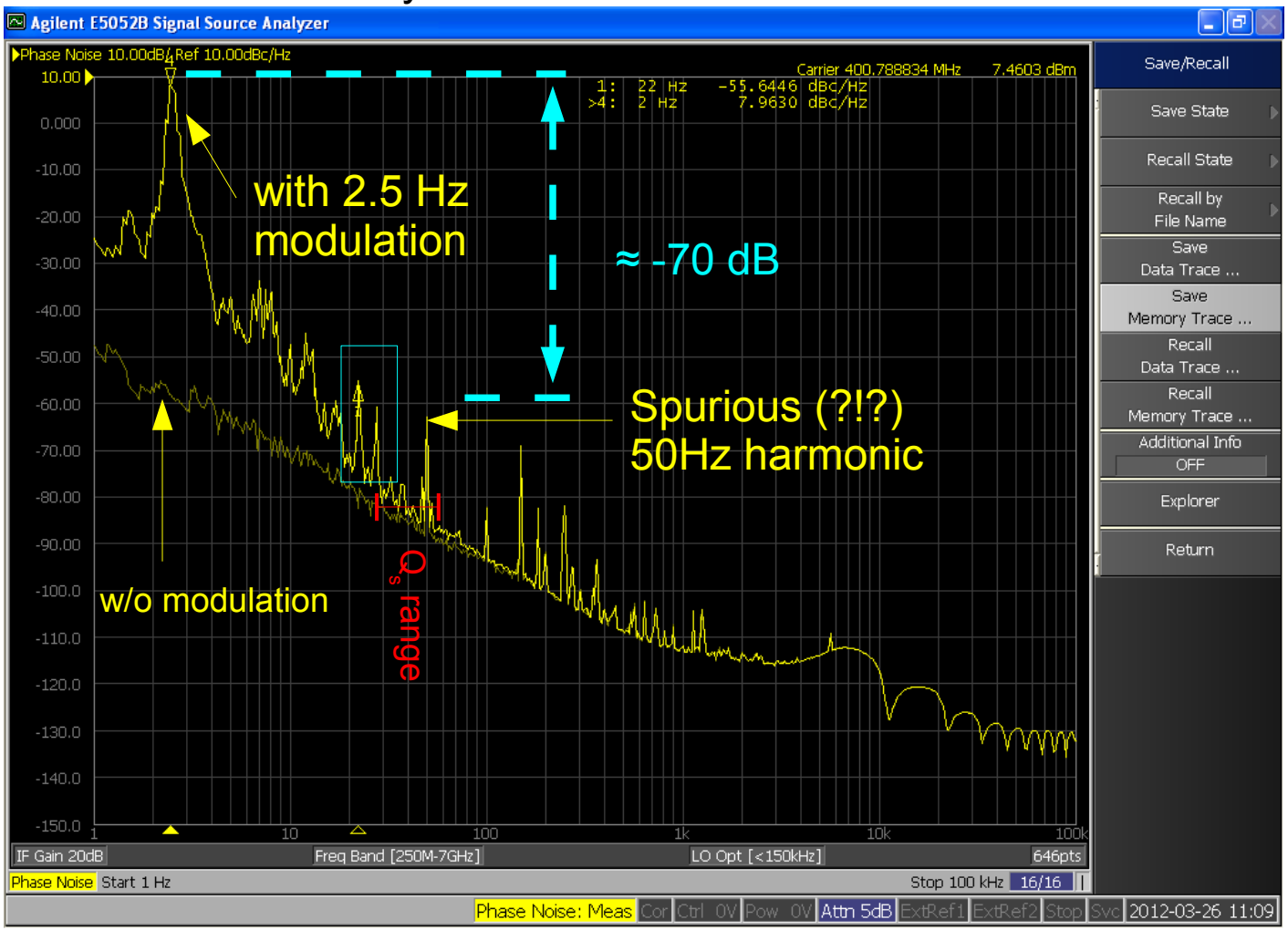
– typ. parameter: $\Delta p/p = 5 \cdot 10^{-5}$@2.5 Hz ↔ $dE/dt|_{max} \approx 3.141$ GeV/s*

➔The latter is believed to cause undesired long. emittance blow-up, particularly since some of the generated modulation harmonics appear to be dangerously close to/cross the Q_s at flat-top → not a nice effect but could be mitigated

*(for comparison, ramp itself accelerates with about 7 GeV/s)

Cavity return signal with nominal RF modulation

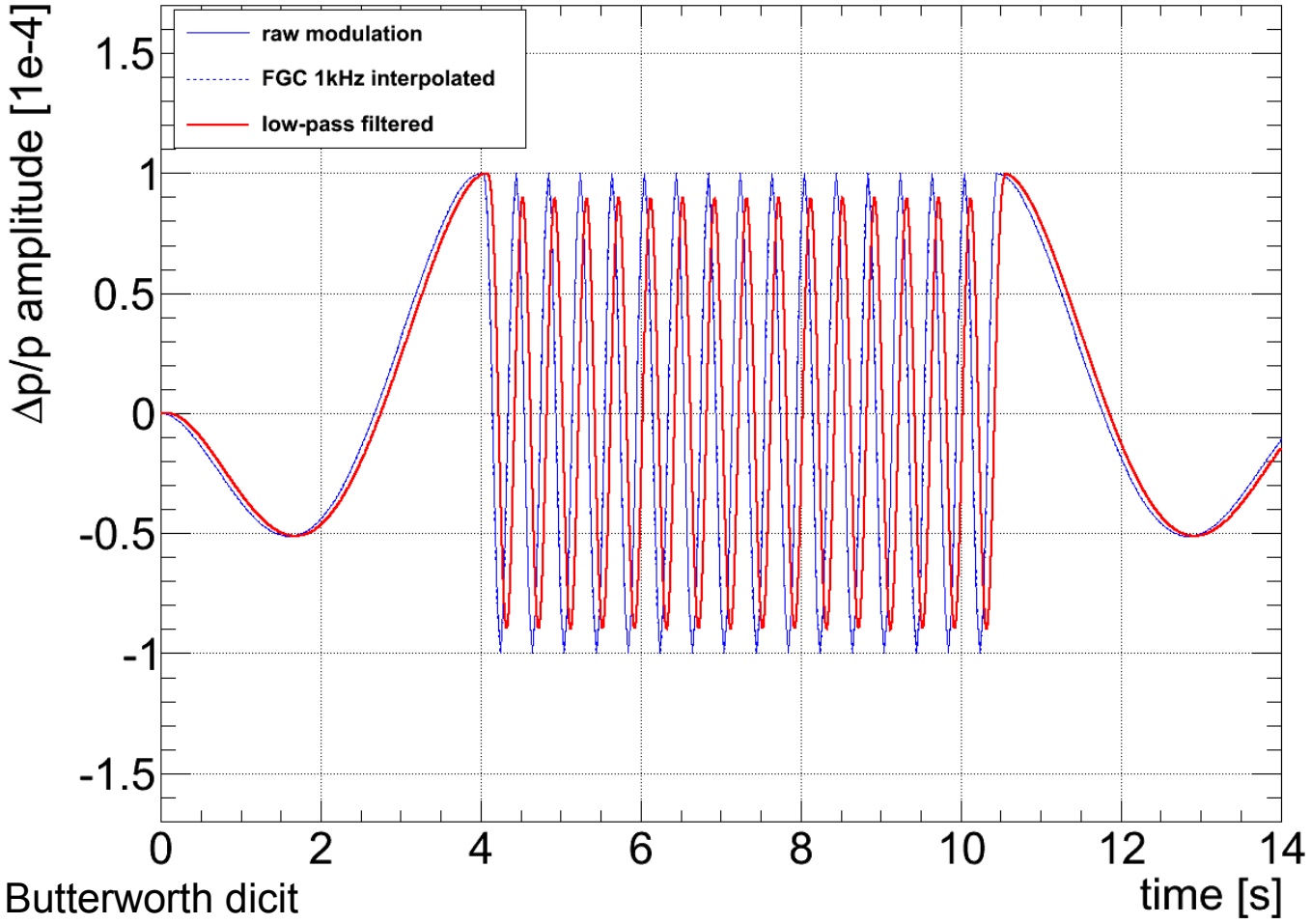
- Measurements courtesy Themistoklis Mastoridis BE-RF:



- Additional harmonics at 22.5 and 27.5 Hz dangerously close to Q_s@4TeV
  - expected imperfection of generated 2.5Hz sine wave with a f_s=25 Hz!

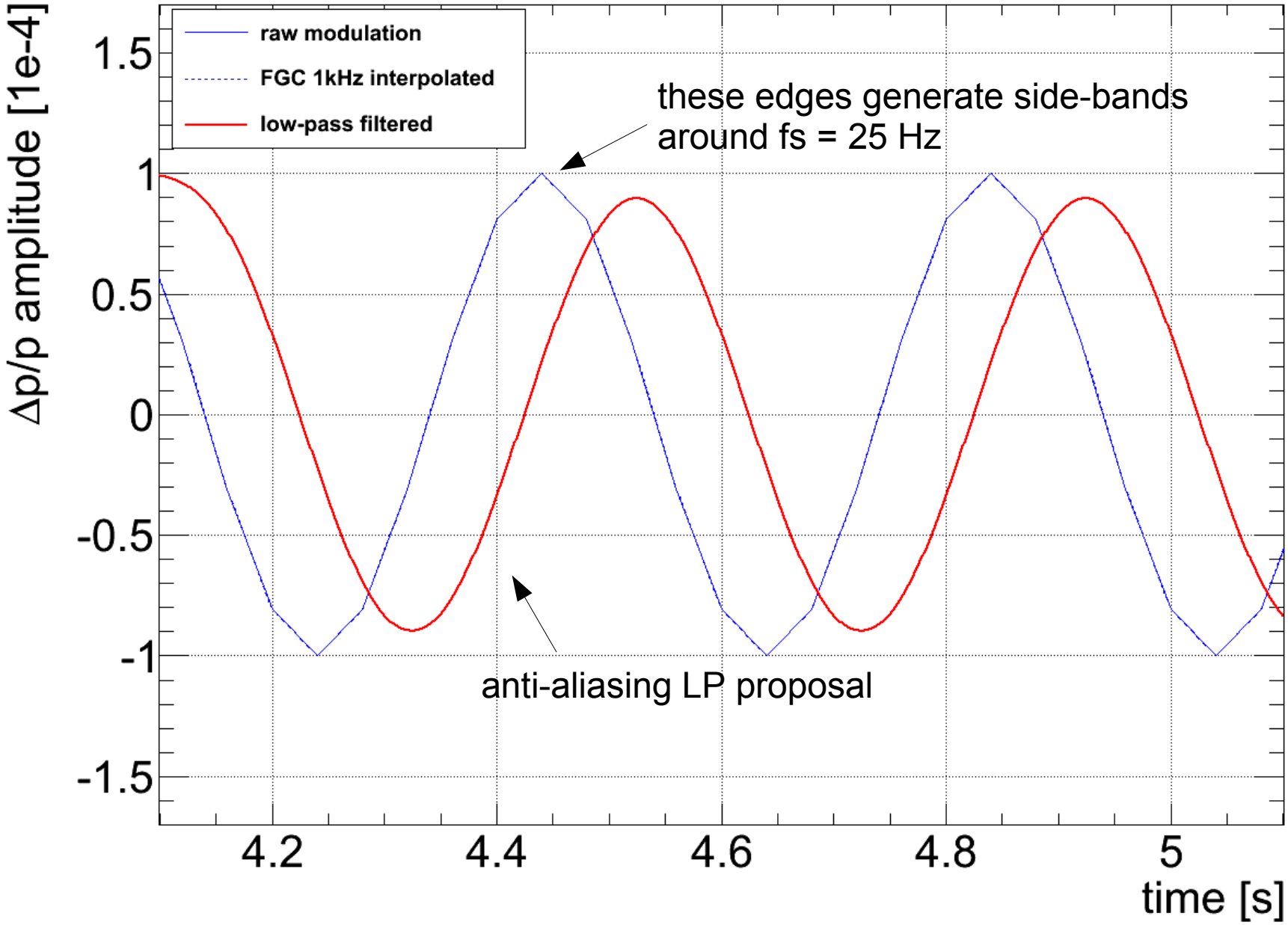
RF FGC Change Proposal

- These Harmonics are neither beneficial for the long. blow-up nor Q' measurement
- Imperfections are by design: sine interpolated through 40 ms long mini-ramps further interpolated to 1 kHz base-line sampling by the FGC
- Not possible to improve on OFC end due to 25 Hz limitation but could envisage* n x second-order low-pass filter after the mini-ramp interpolation with f_s=1kHz, e.g.:

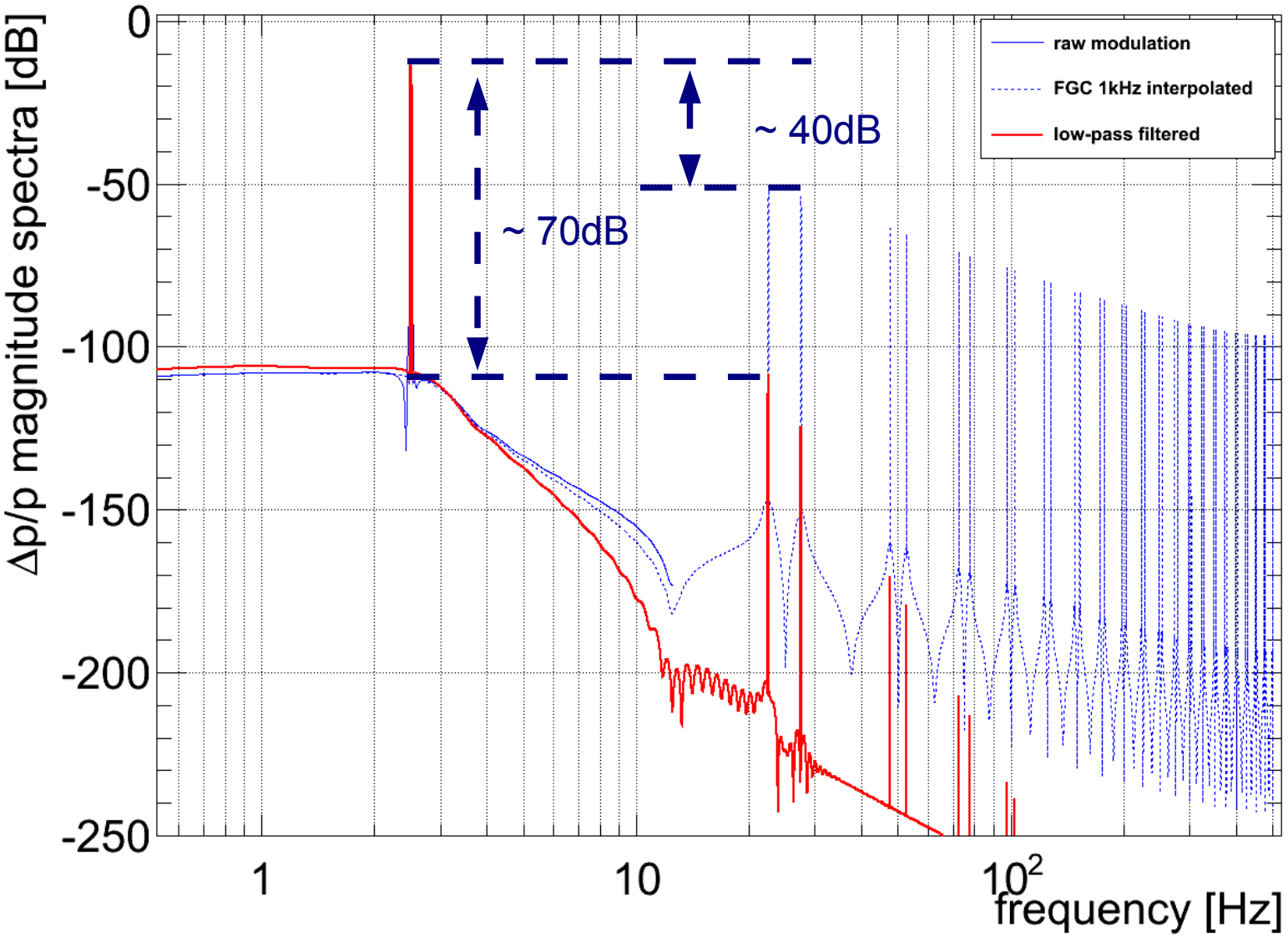


*Q. King, A. Butterworth dicit

RF FGC Proposal – ZOOM



Nominal Q' Radial Modulation with and without LP



Some aspects

Numerical complexity is limited:

- needed for only for two RT channels on the RF FGCs
- IIR-Bessel-type filter would require only a limited number of multiplications and very short history buffer
  (proposed filter, re-generation and example code already attached)

Cons:

- Needs to be coded, of course checked but can be tested without beam
- Draw-back of IIR filter generating systematic phase delay
- RF FGCs are fairly stable and need to balance the overhead w.r.t. usefulness and work-load overhead (→ Q. King's & RF group's call)

Pros:

- systematic dp/p RT trim to tune measurement delay has to be handled anyway within the OFC (static, settings dependent)
- The proposed solution would keep the RT-trim input LP independent from the other RF cavity trim functionalities
- Cleaner solution that would eliminate the doubt and reduce uncertainty on
  - Q' measurement impacting the longitudinal beam emittance,
  - in addition, reduce potential radial-loop noise,
  - safety net to suppress fast/abrupt trims via the RT channel