RF MD: Cavity Voltage Phase Modulation

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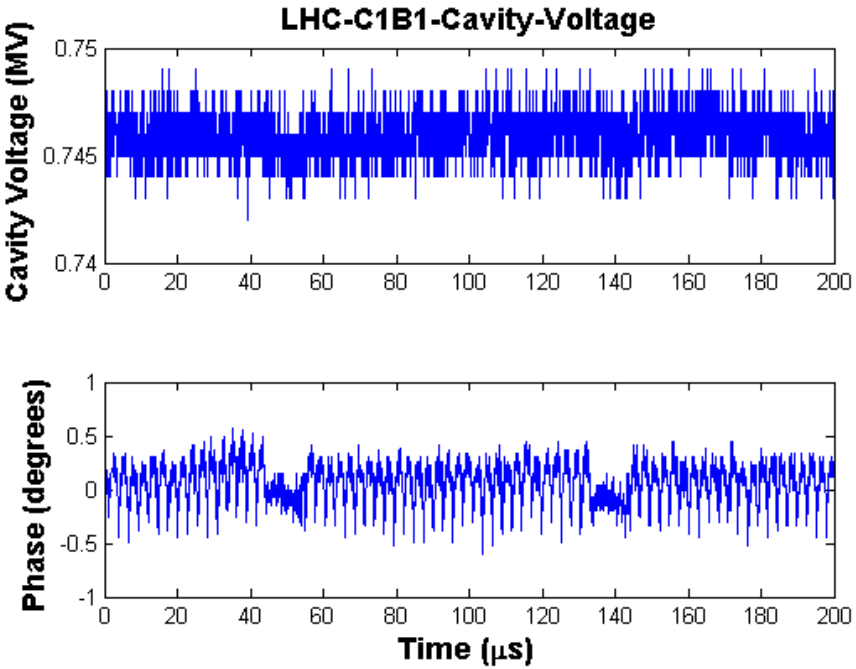
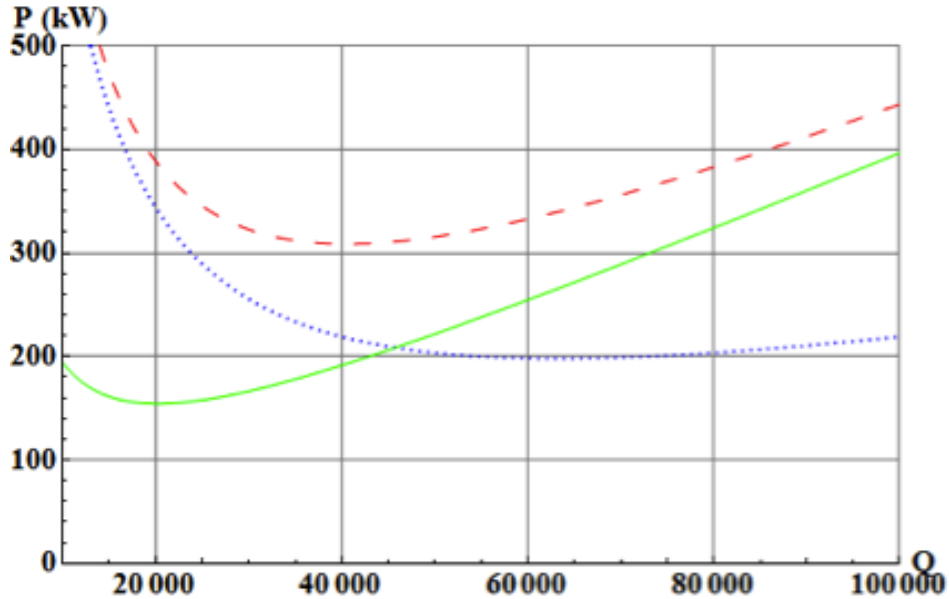
Background

- RF/LLRF currently setup for extremely stable RF voltage (minimize transient beam loading effects). Less than 1° RF phase modulation (7 ps)
- To continue this way, we would need at least 200 kW of klystron forward power at nominal intensity
  - Klystrons saturate at 200 kW with present DC parameters (ultimately 300 kW). Sufficient margin necessary for reliable operation, additional RF manipulations etc.
  - The present scheme cannot be extended beyond nominal

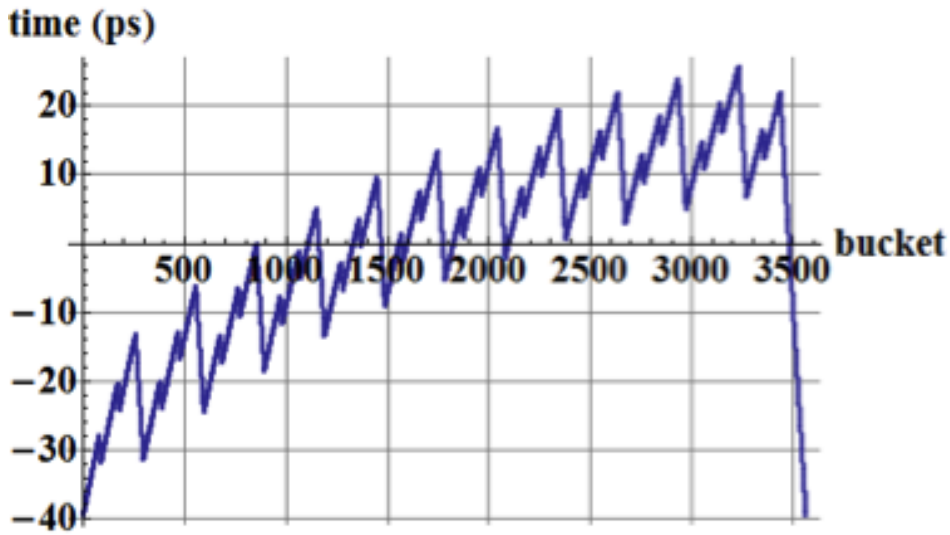




Solution

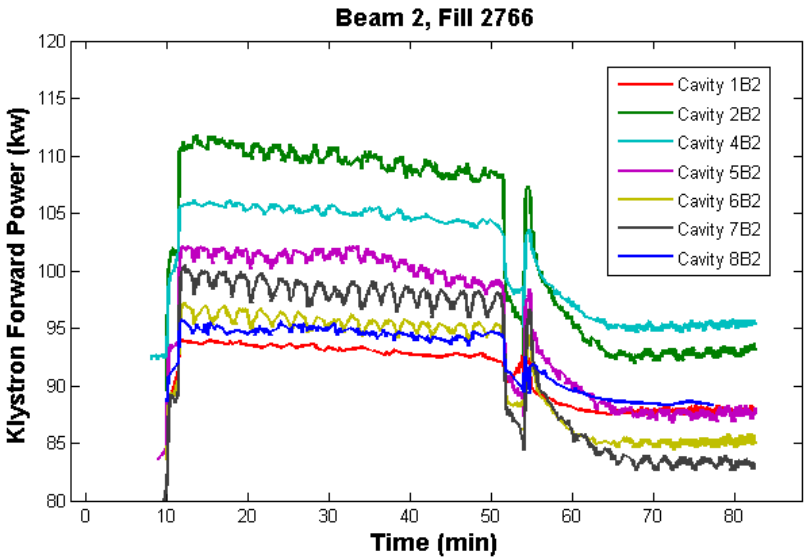
- For beam currents above nominal (and possibly earlier), we will accept the cavity phase modulation by the beam (transient beam loading), but keep the strong RF/OTFB for loop and beam stability
- To achieve this, we have to adapt the voltage set point for each bunch
  - Method proposed by D. Boussard for the LHC in 1991! [1]
  - More details in IPAC '12 paper [2]

- 65 ps peak to peak displacement over a turn in physics (compared to 1.25 ns bunch length)
  - Even smaller shift of collision point in IP1, IP5 due to symmetry
- More significant phase modulation at 450 GeV $\rightarrow$ fill with current scheme, switch over during Pre-Ramp.

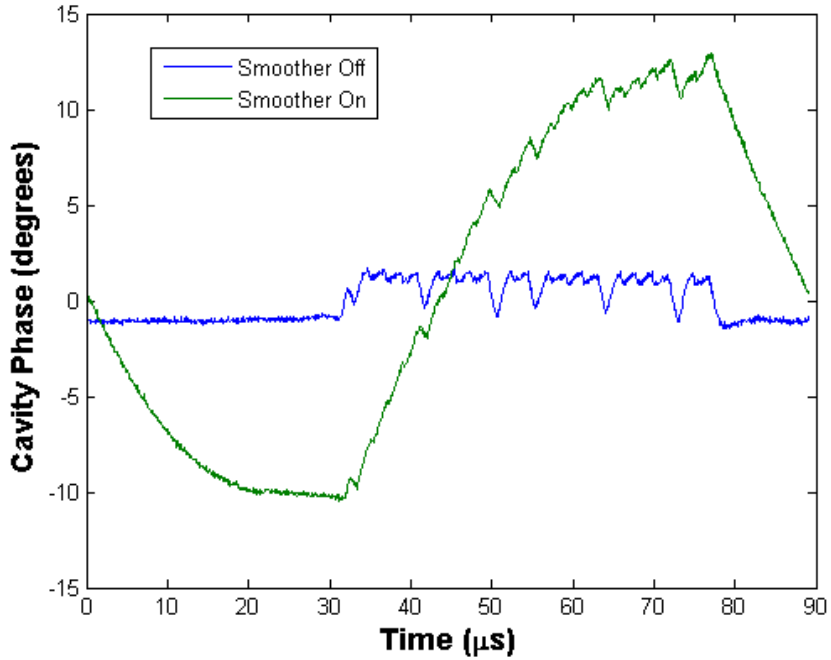


MD Details

- During MD block #2, we tested the algorithm to adjust the voltage set point adaptation over a turn (“feedforward" algorithm)
- The initial implementation provided useful and promising results
  - A significant reduction in klystron forward power was achieved



Average Klystron forward power. 12+144 bunches



Cavity phase modulation with 732 bunches

MD Details

- With the knowledge from the previous MD, firmware has been developed and extensively tested in simulations
- The firmware will allow us to apply the correction every 1-2 turns (vs. 20 seconds with Matlab!)
- It will also allow us to use a much smaller gain $\rightarrow$ adiabatic process for the beam, smoother-quicker-better convergence.
- We will need one or a few nominal batches (144b) at 450 GeV
- MP Classification B?
- If the debugging time is limited, we would be interested in a ramp.

References

[1] D. Boussard, “RF Power Requirements for a High Intensity Proton Collider", CERN-SL-91-16-RFS, 1991

[2] P. Baudrenghien, T. Mastoridis, “Proposal for an RF Roadmap Towards Ultimate Intensity in the LHC", Proceedings of Third International Particle Accelerator Conference 2012, New Orleans, Louisiana, USA, 20 - 25 May 2012.