Expected Performance of LHC HL Transverse Feedback

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Acknowledgement
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Outline

- Run 2 and ongoing improvements of ADT
- Key performances
  - Kick strength
  - Signal-to-Noise ratio
  - Bandwidth and damping time
- Conclusions

ADT – Run 2

see G. Kotzian @ Evian 2015

- Power System (bandwidth and kick strength)
  - Maintenance of power amplifiers, no changes in LS1
- Pick-up System
  - Additional pick-ups cabled and available (2x)
- Electronics (LLRF)
  - New processing VME electronics
    - Capable of combining four pick-ups per plane and beam
    - Disentangled gain functions for feedback (main/witness bunches), cleaning and blow-up (four functions) available
  - New A/D converters and processing of analogue PU signals
    - In preparation → potential to improve S/N
    - Tested on one of the additional pick-ups (D.V.)

ADT – Run 2

see G. Kotzian
@ Evian 2015

- Algorithms (also define gain versus frequency)
  - Potential improvements for feedback (vector sum)
  - Diagnostics (head tail movement mode 1)
  - Automated set-up and check of damping time
- Obs Box for data recording and LIST instability network
  - Extendable, under exploitation

Additional Pick-ups

- Will become gradually available
- Improved performance of electronics (S/N)
- More degrees of freedom for algorithms (robustness to tune changes)

B1 horizontal	Q10L	Q9L	Q8L	Q7L	Q7R	Q8R	Q9R	Q10R
		β = 111 m		β = 106 m		β = 133 m		β = 153 m
		existing		existing		new		new

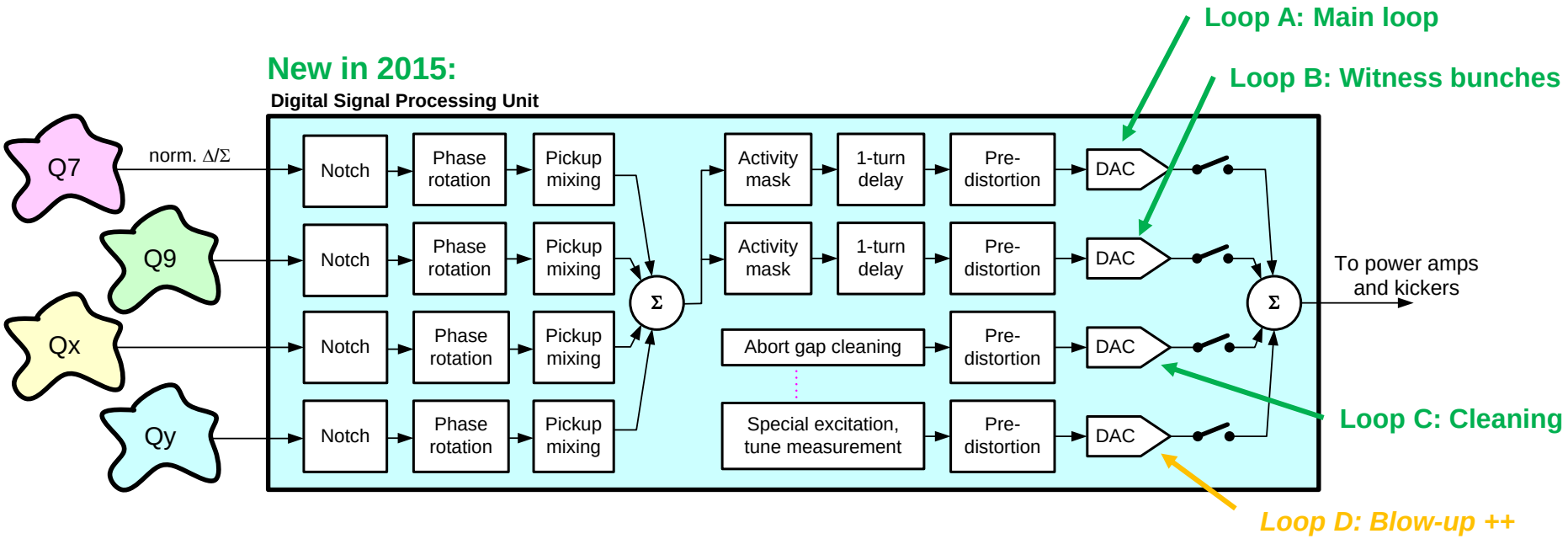
B1 vertical	Q10L	Q9L	Q8L		Q7R	Q8R	Q9R	Q10R
	β = 175 m		β = 155 m		β = 161 m		β = 142 m	
	new		new		existing		existing	

B2 horizontal	Q10L	Q9L	Q8L		Q7R	Q8R	Q9R	Q10R
	β = 158 m		β = 96 m		β = 150 m		β = 101 m	
	new		new		existing		existing	

B2 vertical	Q10L	Q9L	Q8L	Q7L	Q7R	Q8R	Q9R	Q10R
		β = 160 m		β = 167 m		β = 151 m		β = 180 m
		existing		existing		new		new

Processing Electronics

- VME based, FESA 3
- HL-LHC: Jointly drive with CO / BI migration to new plat-form, post VME
  - Considered a “consolidation”
  - Increased controllability and accessibility to data expected

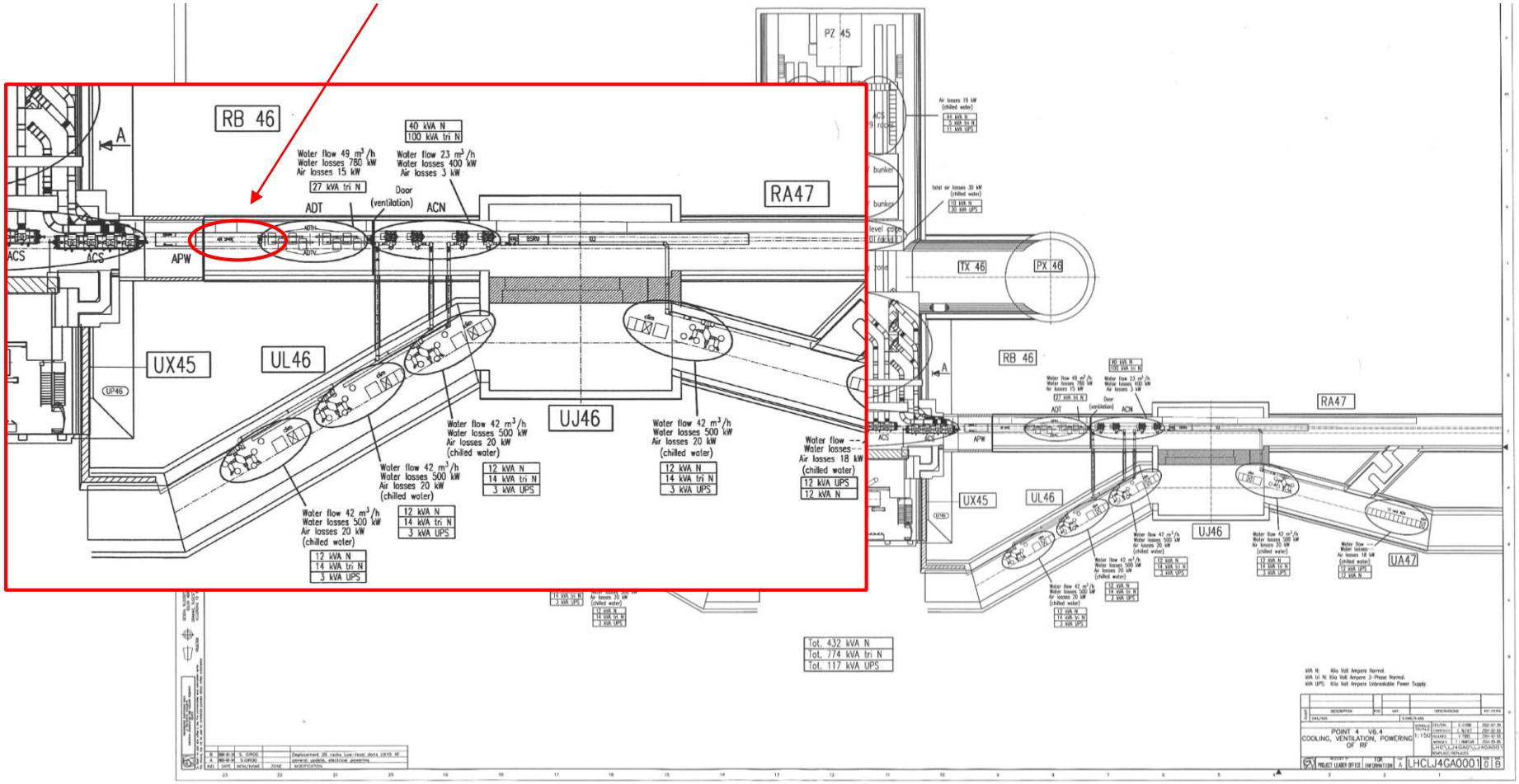


ADT Key Performance

- Maximum kick strength → 2 μrad @450 GeV
  - Given by max operating voltage (12 kV) and current of the tetrode amplifier system and the need to change voltage for injection damping in the kicker gap
  - Needed for injection damping & cleaning
  - Regular change of tetrodes needed to maintain peak kick strength (32 tetrodes in operation)
    - Lifetime of tetrode (2-3 years under current operating conditions)
    - Consider R&D for replacement before 2035 if indications that tetrode system becomes obsolete → needs study
  - Impact on beam can be improved by higher beta function at kickers (ATS optics ?) if needed
  - As kick strength sufficient additional kickers of the same kind not needed

Original Layout

Reserve space for ADT upgrade (left and right of IP 4)



ADT Key Performance

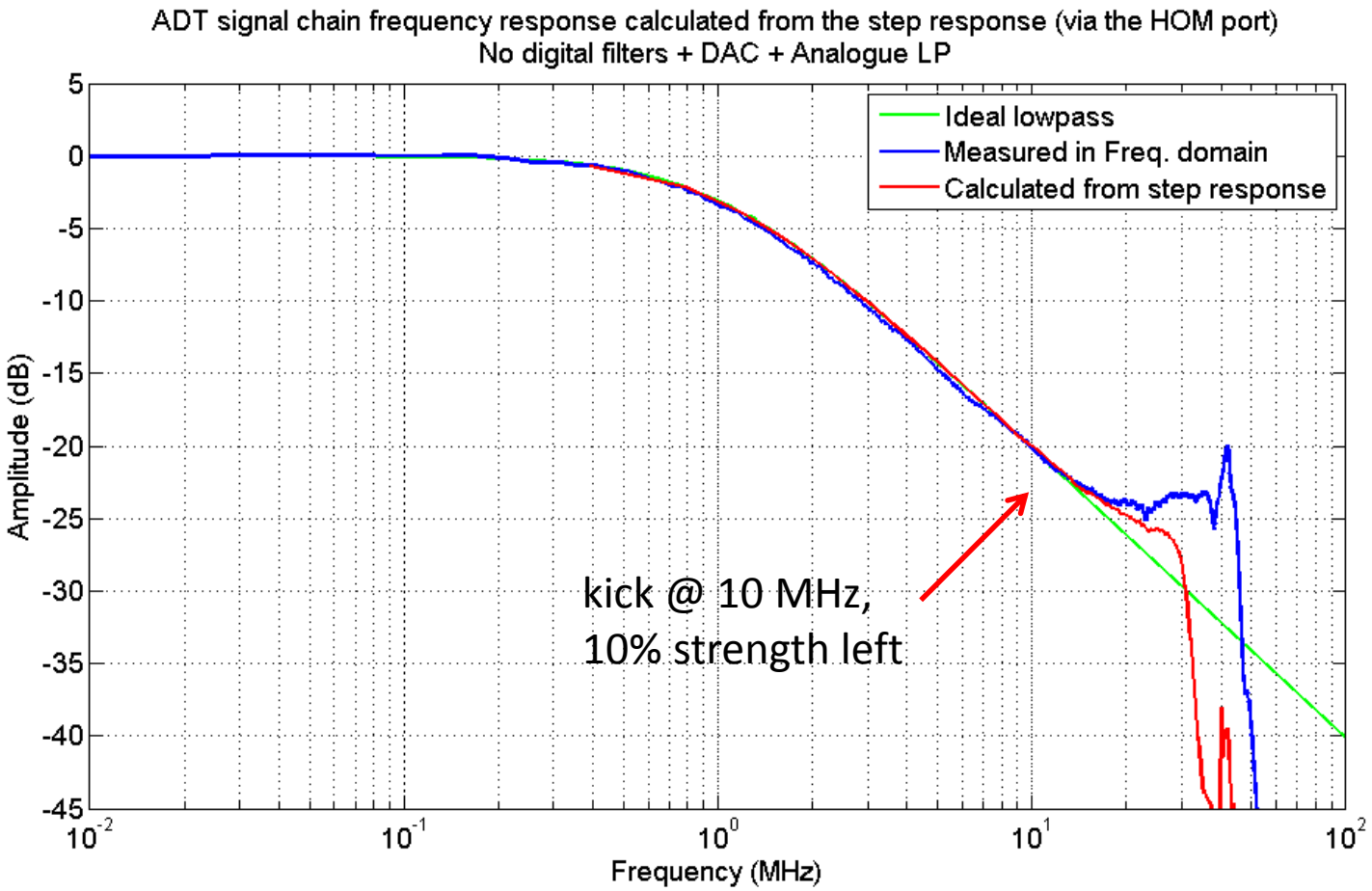
- Signal to noise ratio
  - defines smallest amplitude oscillation that can be detected
  - can lead to blow-up
    - potentially more critical for HL LHC with increased tune spread and operation with crab cavities
  - Experience to be gained in SPS for concurrent Operation of transverse feedback and crab cavities
  - Presently beam rms 2 μm observed with ADT at β ~150 m

    → target: improvement for high lumi era by a factor two to four (benchmark method to be defined)

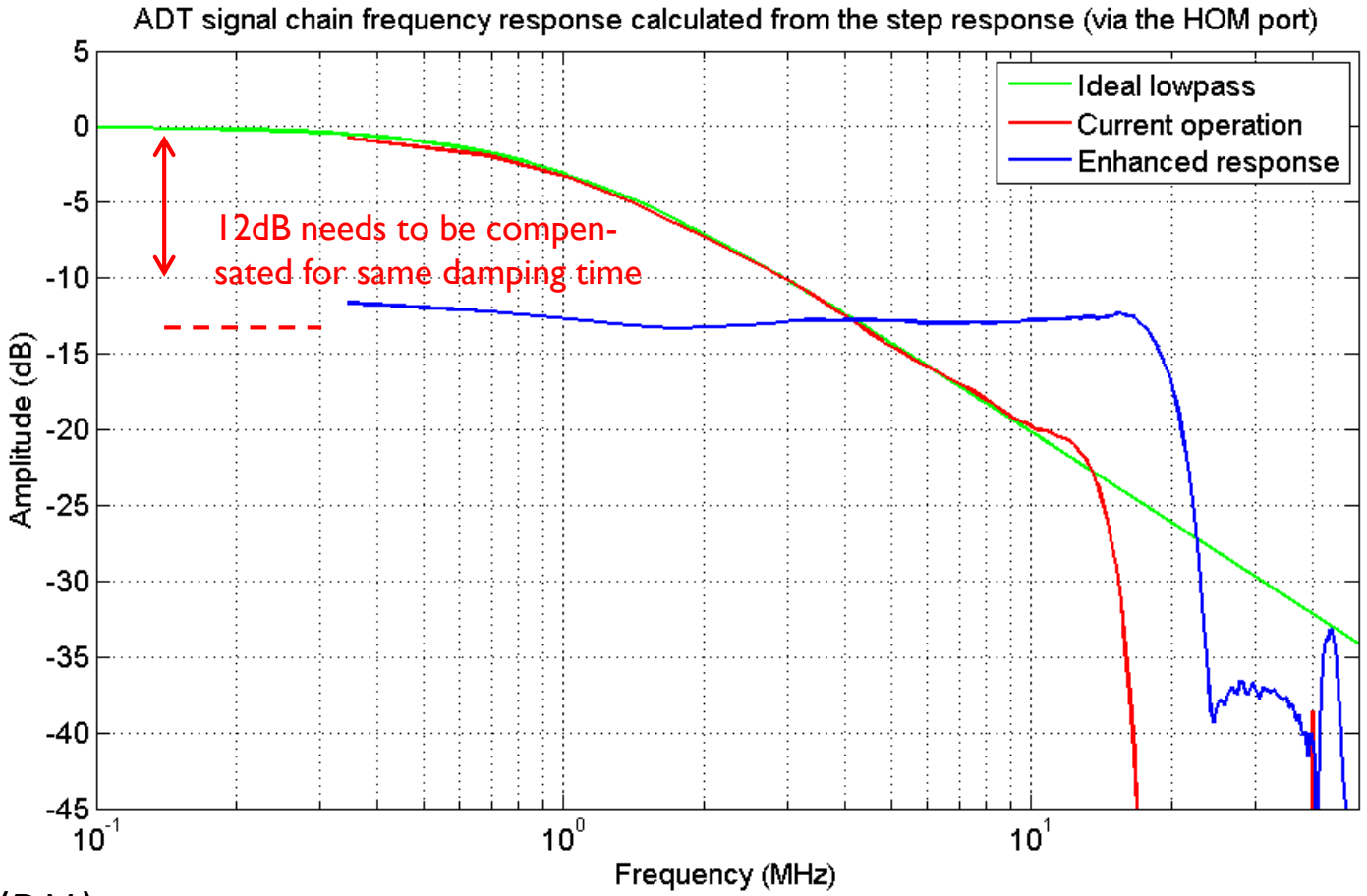
ADT key Performance

- Bandwidth (linked to damping time vs. frequency)
  - Power system adapted to a resistive wall impedance that rolls-off with frequency
  - Flat frequency response and faster rise-time possible by pre-distortion of drive signal
    - implemented in digital processing
    - used operationally in Run 1 and Run 2
    - at expense of max kick strength
    - impact on blow-up in stable beams seen in run 1
  - Present system not optimally adapted to “popcorn” instability (one bunch going unstable)
  - Damping effect to internal modes with dipolar moment shown in simulation

Bandwidth – Power System



Bandwidth - Enhanced

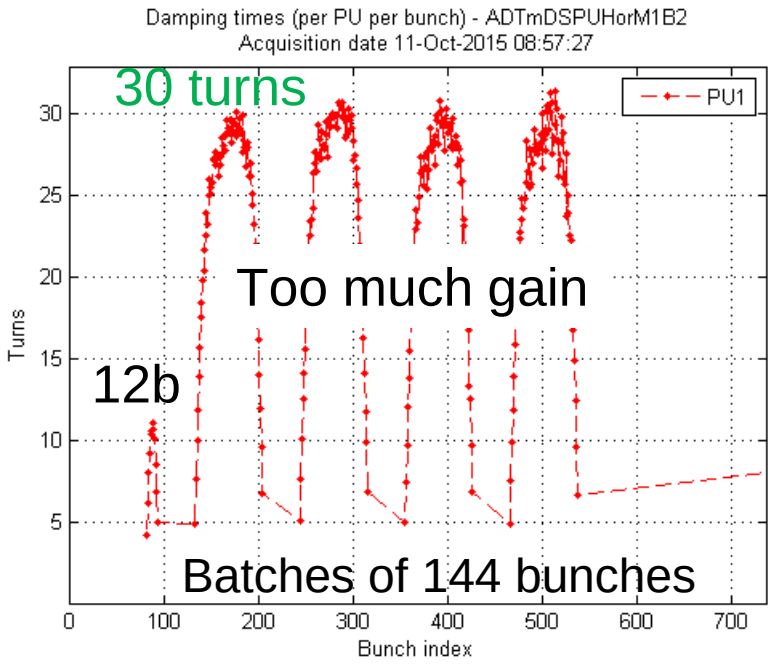


LBOC 2012 (D.V.)

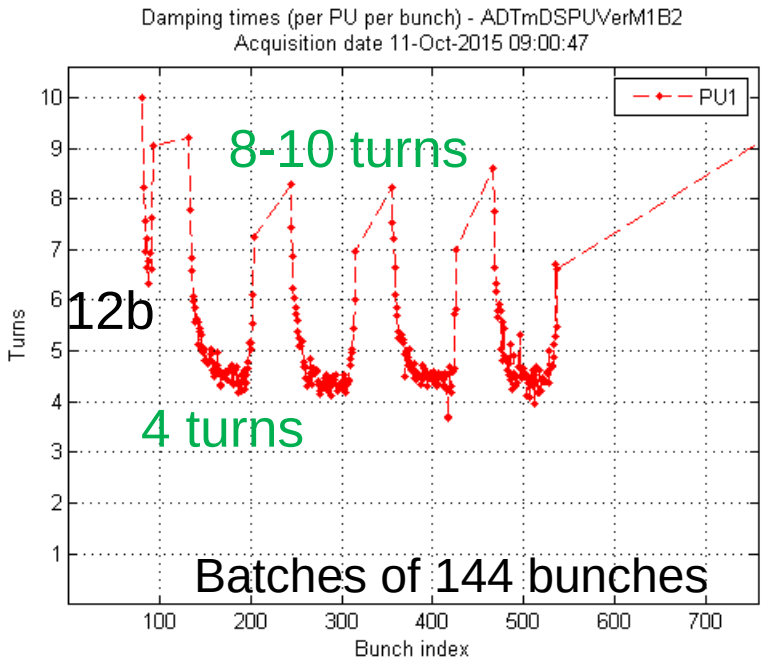
Bandwidth – Injection Damping

- Performance (examples) w/o bandwidth enhancement
  - Risk of control instability if damping times pushed below 10 turns

H-plane (beam 2)

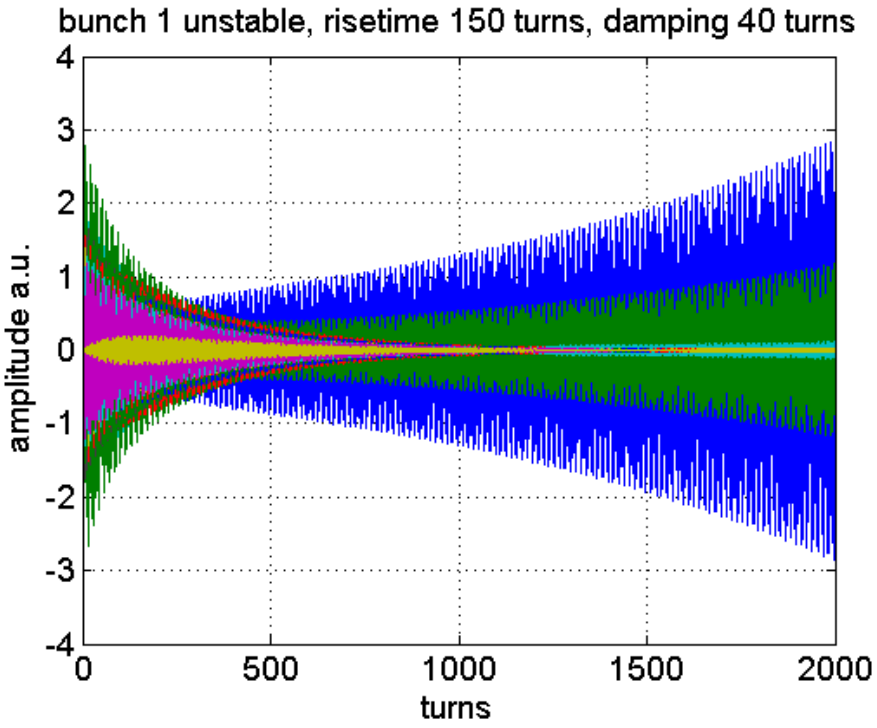


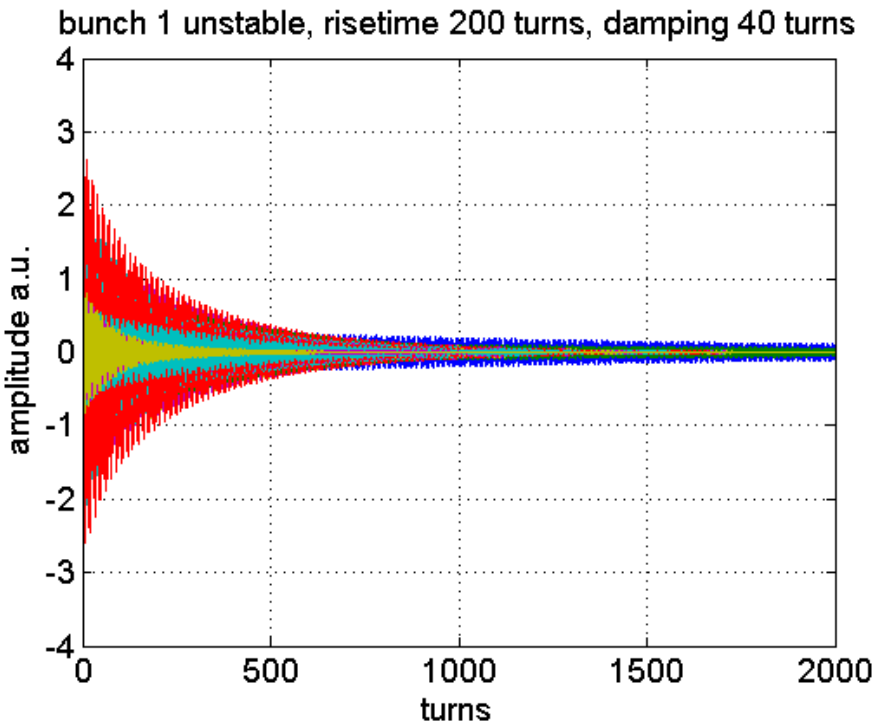
V-plane (beam 2)



Bandwidth - Instability

LMC, 30.05.2012





5x Gain needed to cure single bunch instability at edge of batch

7 to 8x Gain needed for case of bunch well inside batch

HL-LHC Bandwidth - Summary

- Injection damping with 10 turns possible
- Expect slower damping for kicker ripple and on edges
  - can make damping equal for all bunches, but at expense of damping time, 40 turns more realistic in this case
- Popcorn instability and intra bunch motion (when dipolar movement present) can be damped by present feedback but higher bandwidth desirable as effective gain is low

Conclusions

- Three possible directions of performance improvement
  - Bandwidth is critical and HL may profit a lot from a new kicker system
  - Signal-to-Noise is critical with operation with crab cavities, potential for improvement exists
  - Kick Strength is considered sufficient
- Consolidation and Obsolescence (→ 2035)
  - Power system (tetrodes ?)
  - Electronics (plat-form beyond VME)