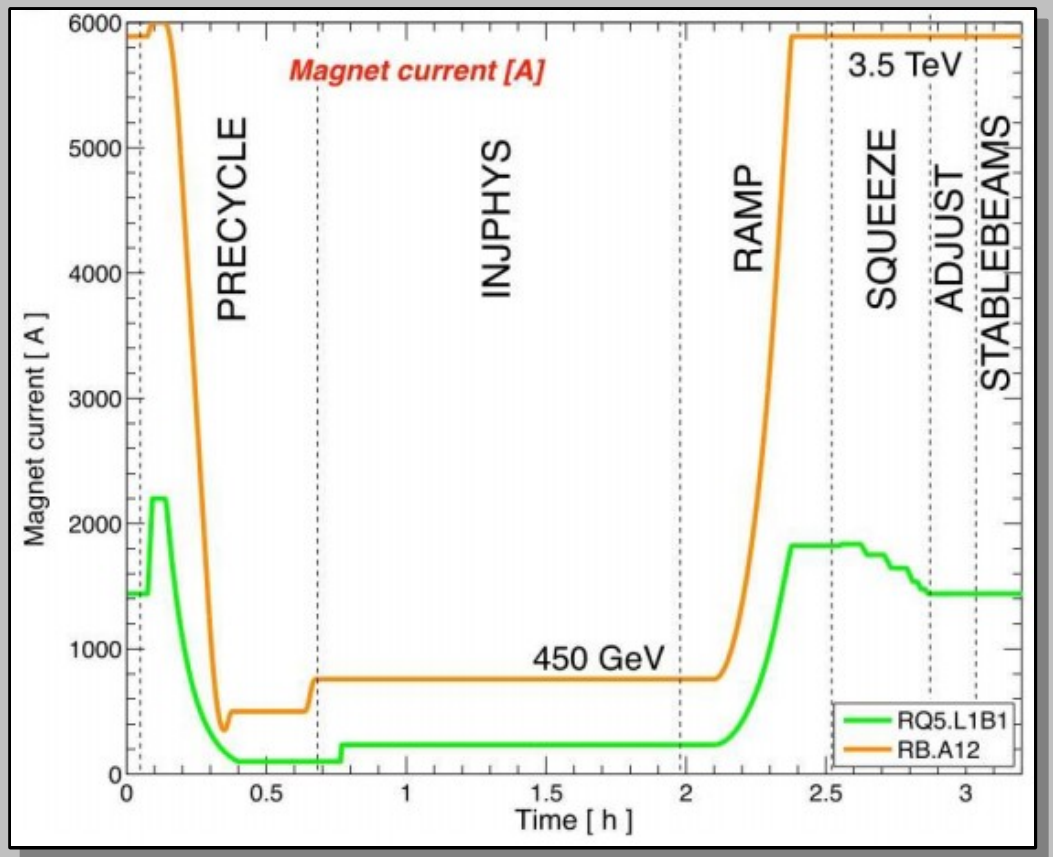
Feed-forward in the LHC

X. Buffat, K. Fuchsberger, M. Lamont, **G.J. Müller**,
M. Pereira, S. Redaelli, R.J. Steinhagen, J. Wenninger
CERN, Geneva, Switzerland

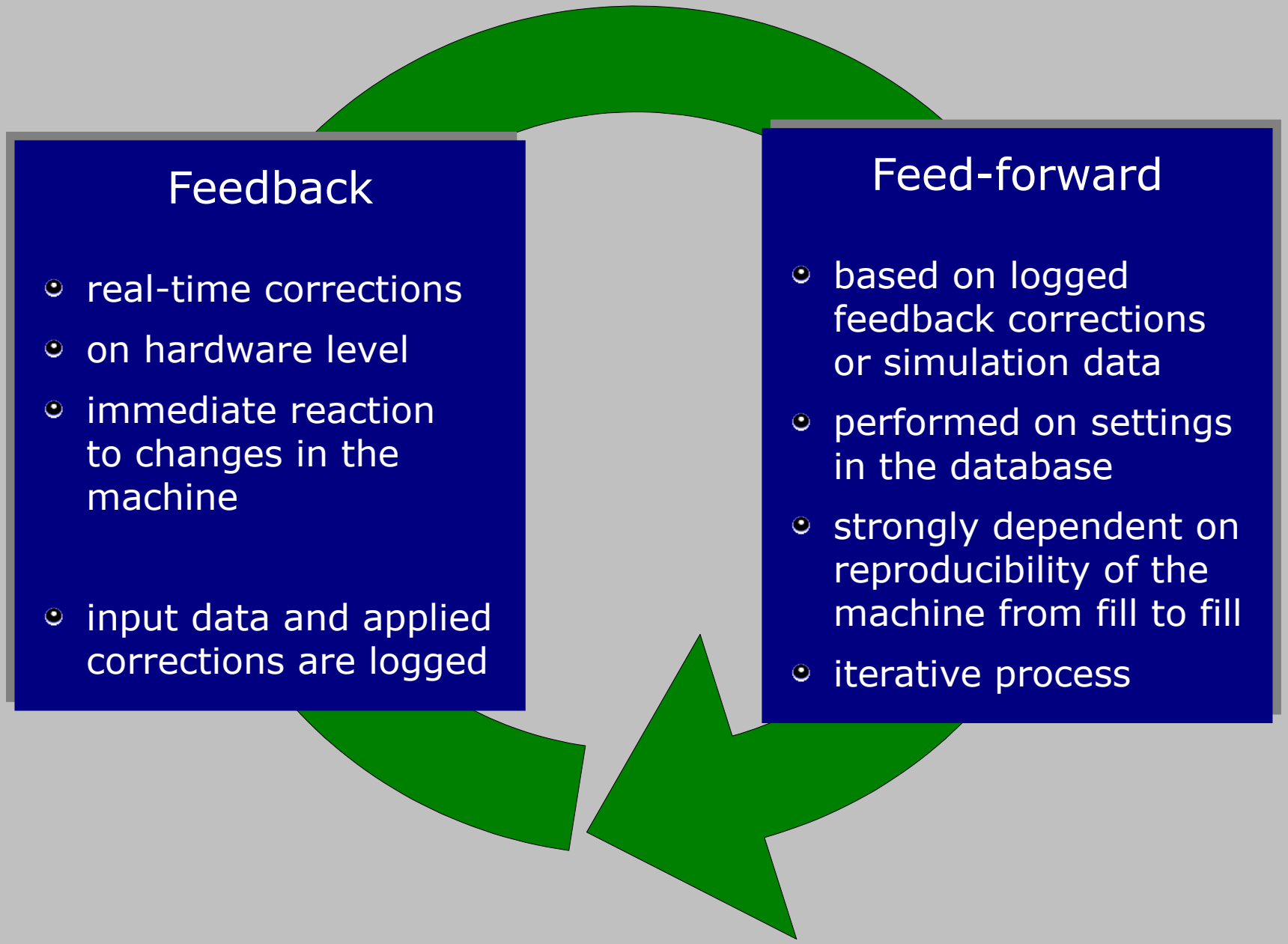
Motivation

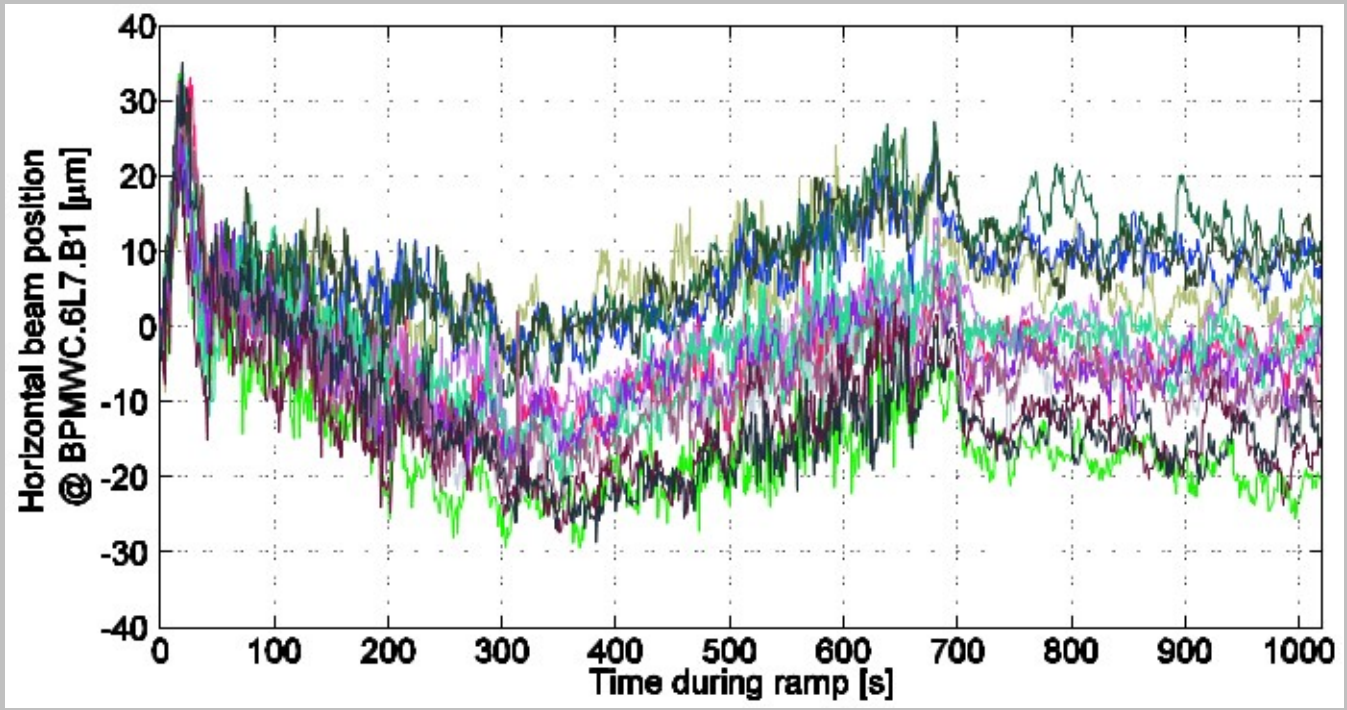
- performance and safe operation of the LHC heavily relies on the tight control of the key beam parameter (KBP)
  - tune
  - chromaticity
  - orbit
- feedback systems are in operation to monitor the machine and apply required corrections in real-time
- incorporation of all available knowledge into the settings used for machine operation
- reduction of the stress on the feedback systems by minimizing required corrections
- operation of the LHC should not completely rely on the feedbacks, e.g. keep the possibility to continue in case of feedback failure



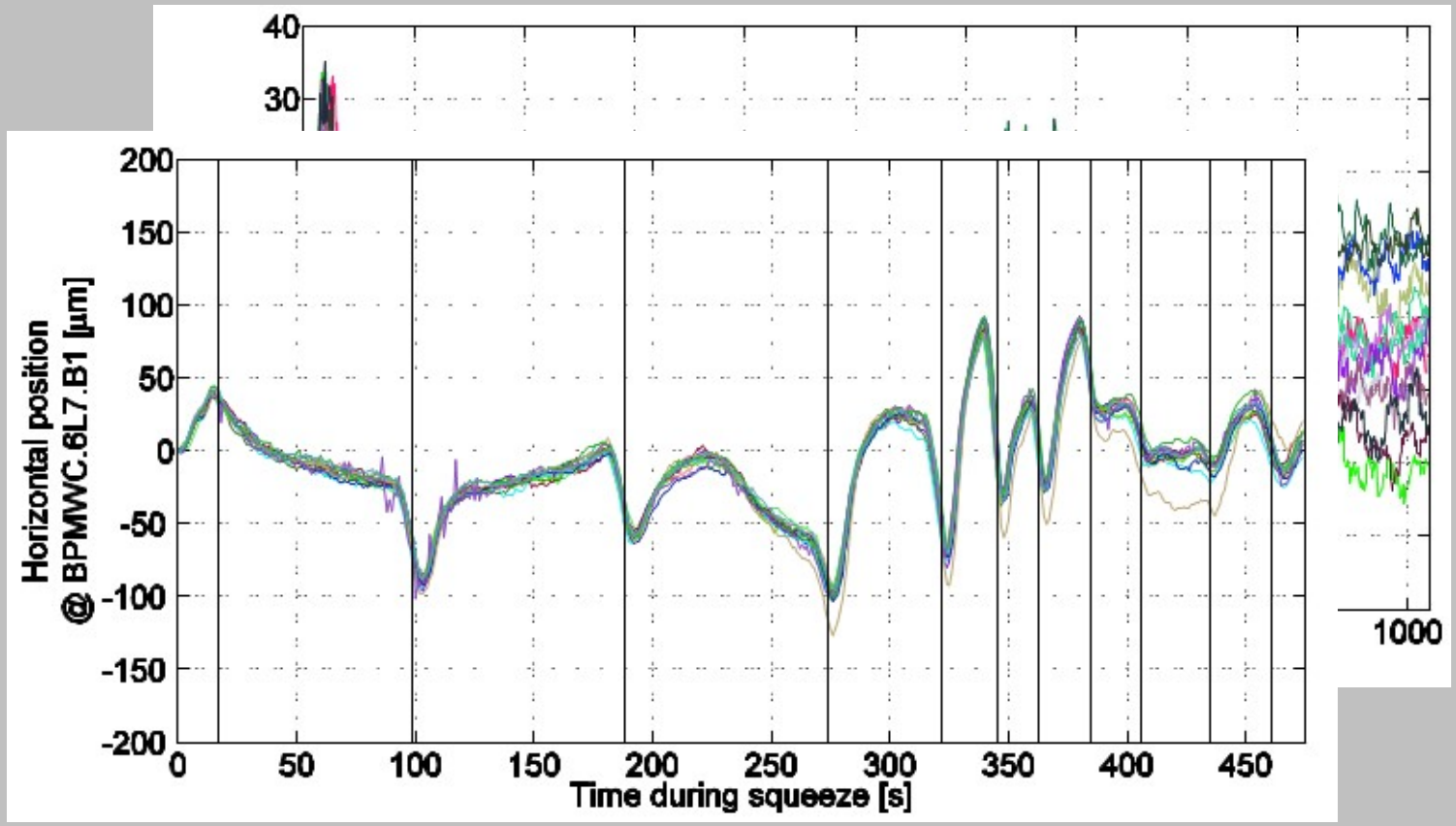
Operational Cycle of the LHC (by S. Redaelli)

Feedback and feed-forward

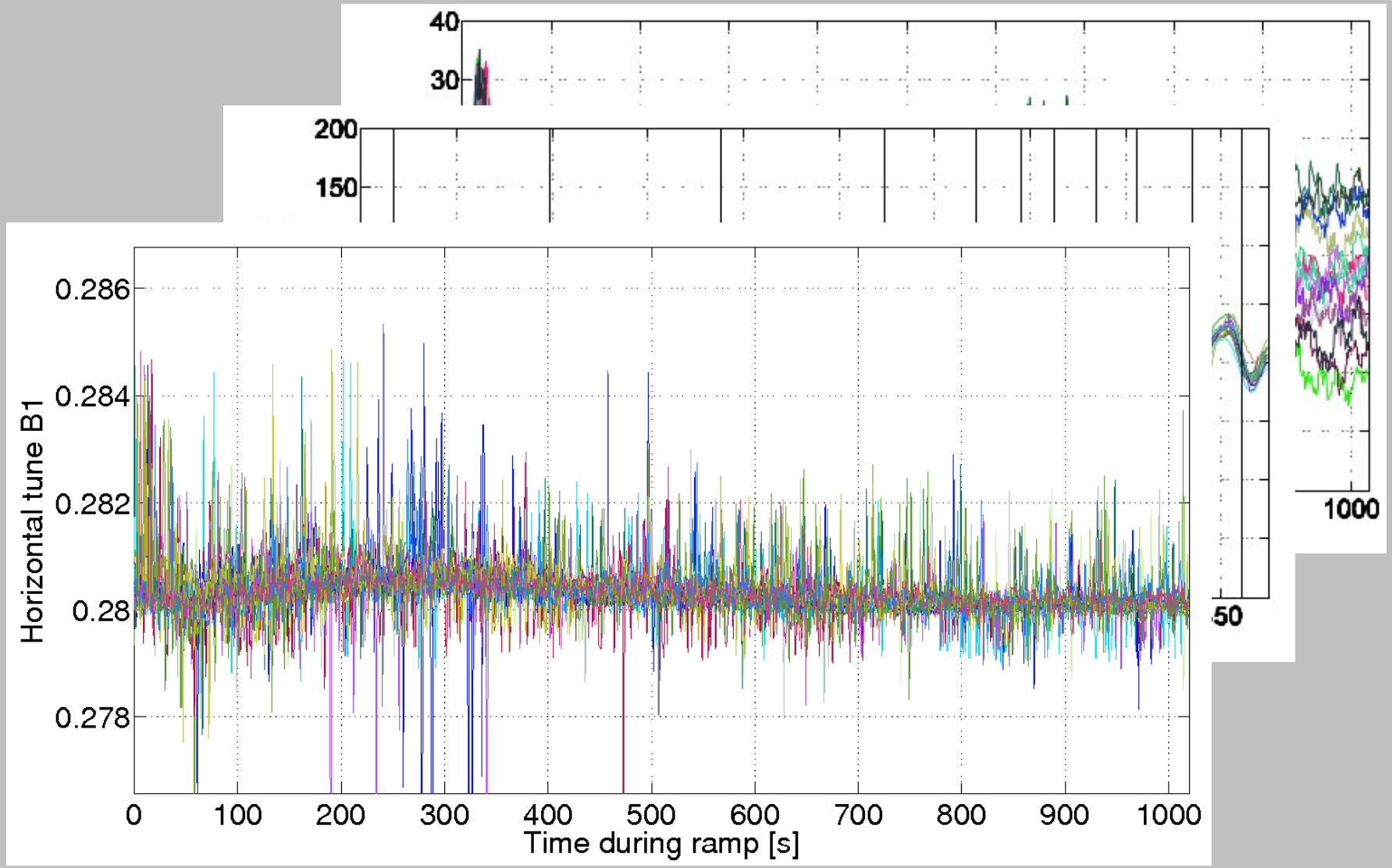




Horizontal beam-position over 15 fills in the ramp (by X. Buffat)

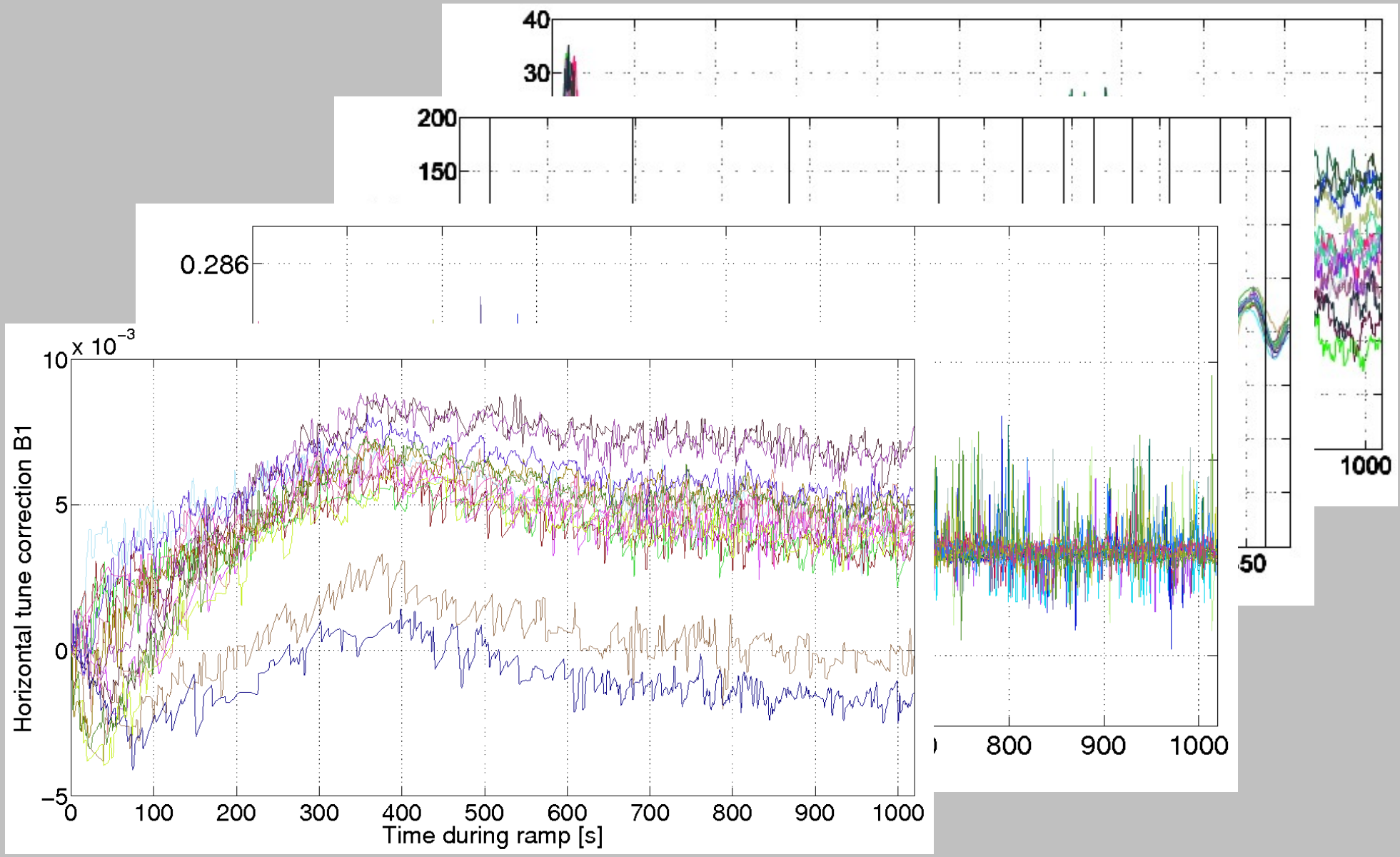


Horizontal beam-position over 15 fills in the squeeze (by X. Buffat)



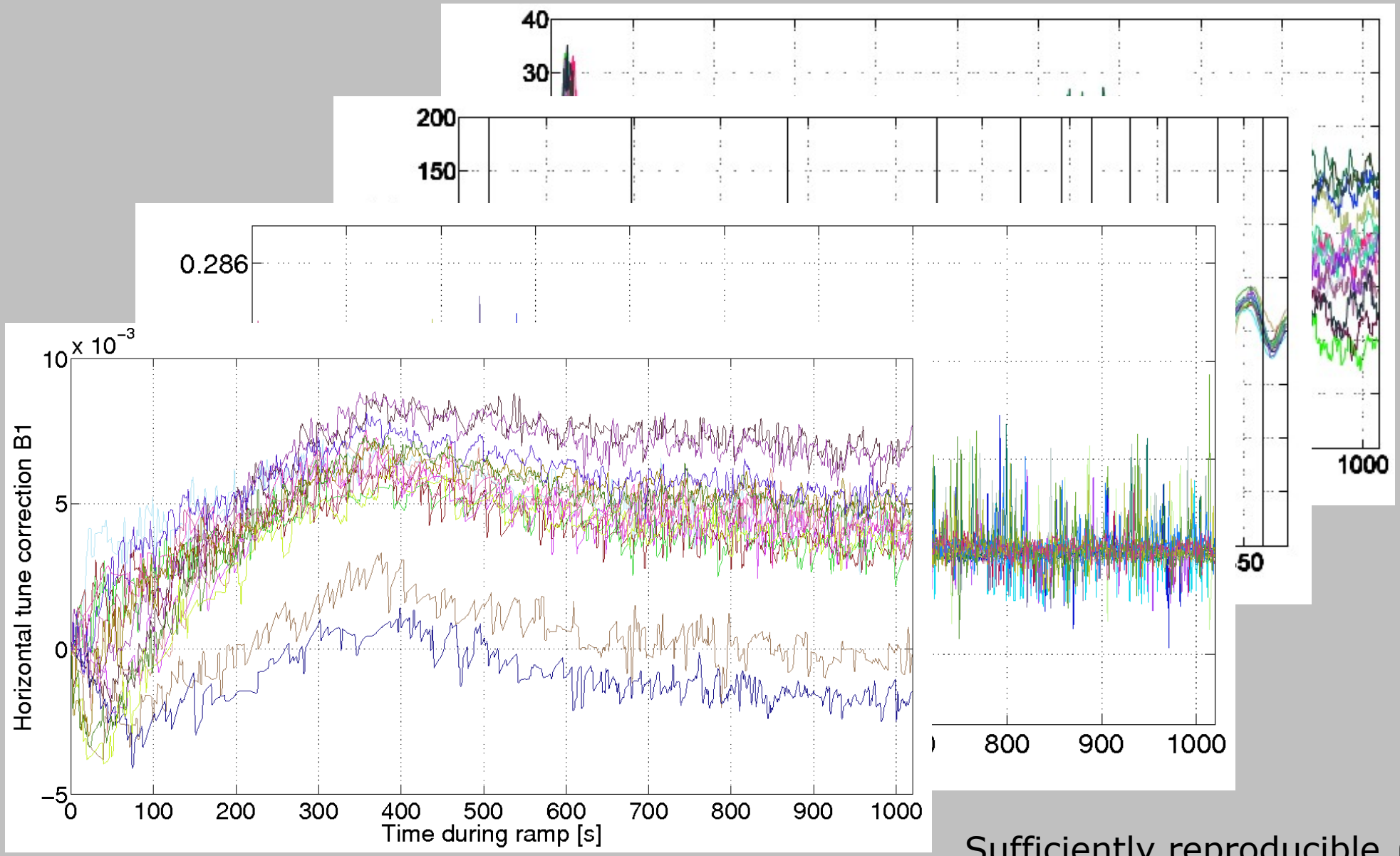
Horizontal tune over 15 fills in the ramp (by X. Buffat)

Feed-forward in the LHC
Reproducibility



Horizontal tune-correction over 15 fills in the ramp (by X. Buffat)

Feed-forward in the LHC
Reproducibility



Horizontal tune-correction over 15 fills in the ramp (by X. Buffat)

Sufficiently reproducible to perform feed-forward!

Environment

- **L**HC **S**oftware **A**rchitecture (LSA)
  - implemented using Java and Spring
  - client API for all setting, optics, ... related functionality
  - covers most relevant aspects of controls:
    i) setting generation/modification and management
    ii) hardware exploitation
    iii) measurement data access

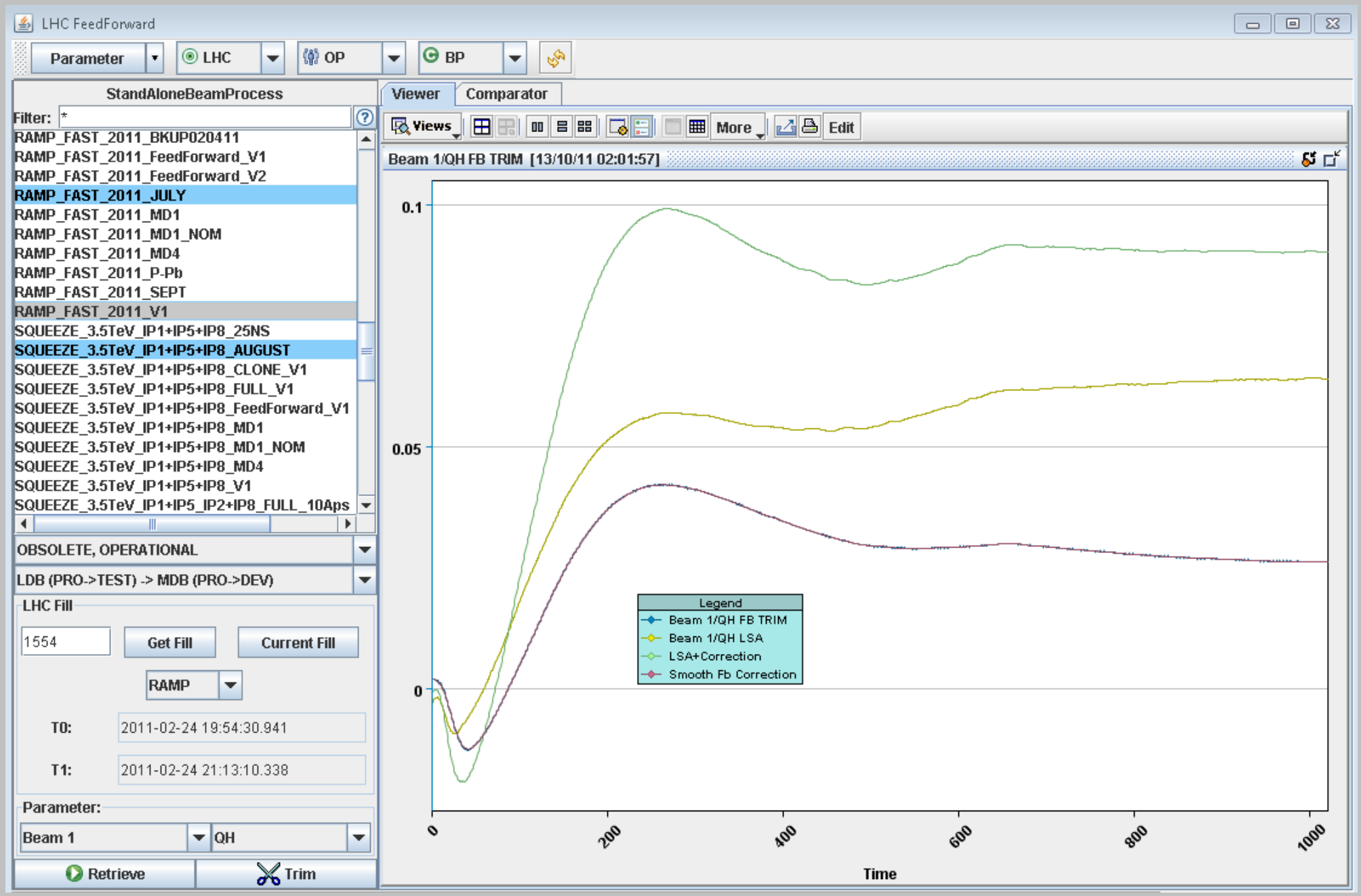
- **C**ERN **A**ccelerator **L**ogging **S**ervice (CALS – THCHAUST06)
  - flexible measurement/controls data logging service
  - ORACLE logging database
  - accessible via client API or the standalone application TIMBER

Feed-forward application

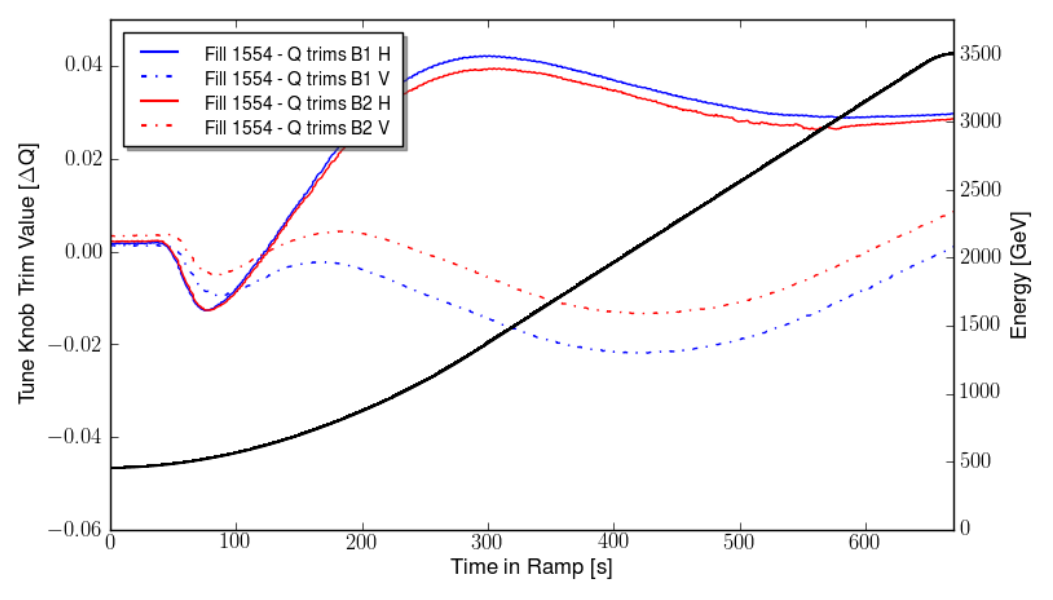
- desktop application, available in the CERN Control Center (CCC) for feed-forward of tune, chromaticity and orbit corrections
- well integrated into environment by using
  - Java, Spring and Swing
  - LSA client API
  - Logging Service client API
- feed-forward performed by
  - i) feedback correction data retrieval from the logging database
  - ii) data processing
    - a) smooting for noise reduction
      - moving average with 5 data point window
    - b) reduction of data density by sampling at 0.1 Hz
  - iii) merge of current LSA settings and found correction
  - iv) update of settings in the LSA settings database

Data processing approach quite simple,
but sufficient for effective feed-forward corrections!

Feed-forward in the LHC
Feed-forward application – GUI

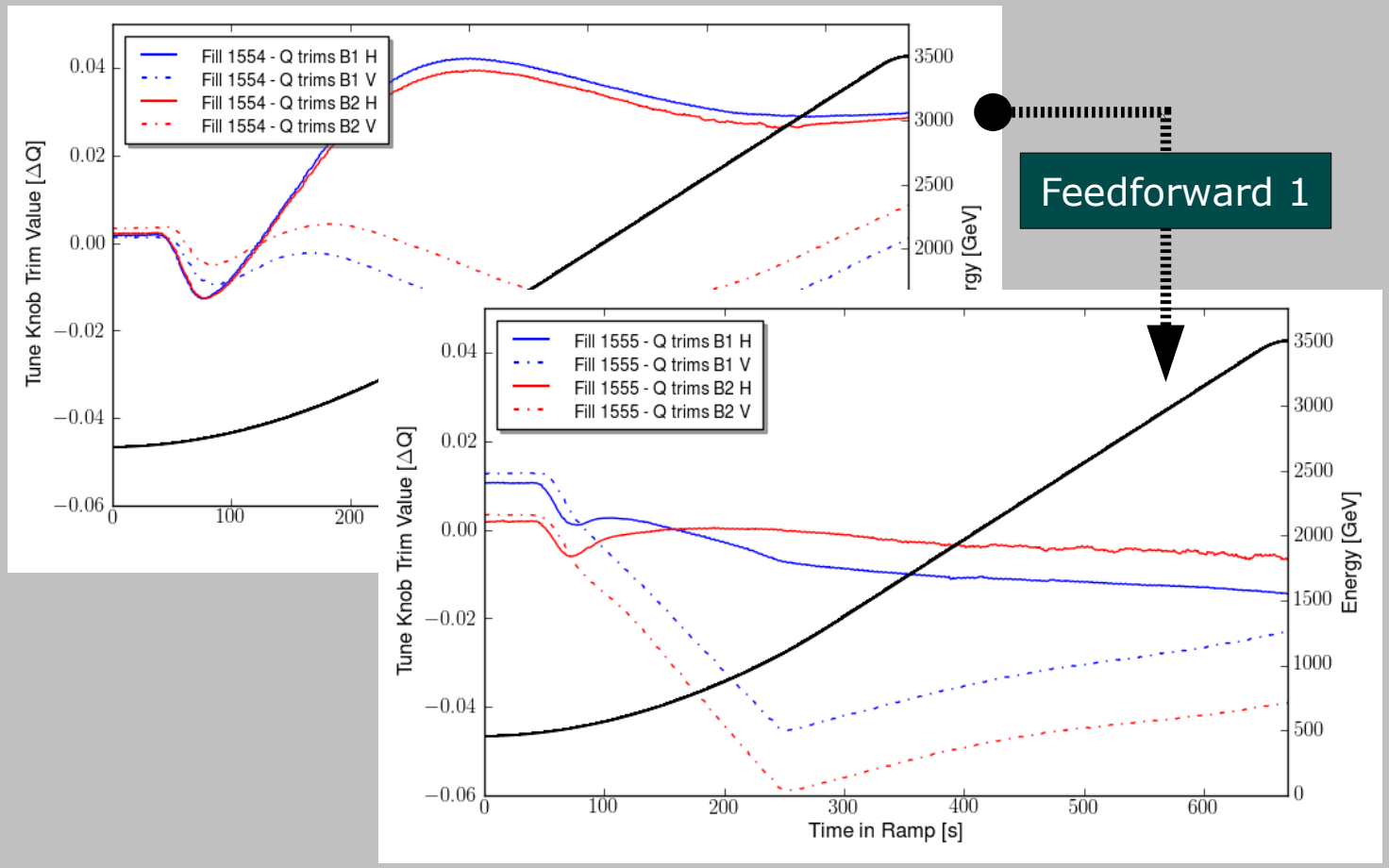


Feed-forward for the Ramp



- iterative process
- can produce new effects
- very good results achievable

Feed-forward for the Ramp



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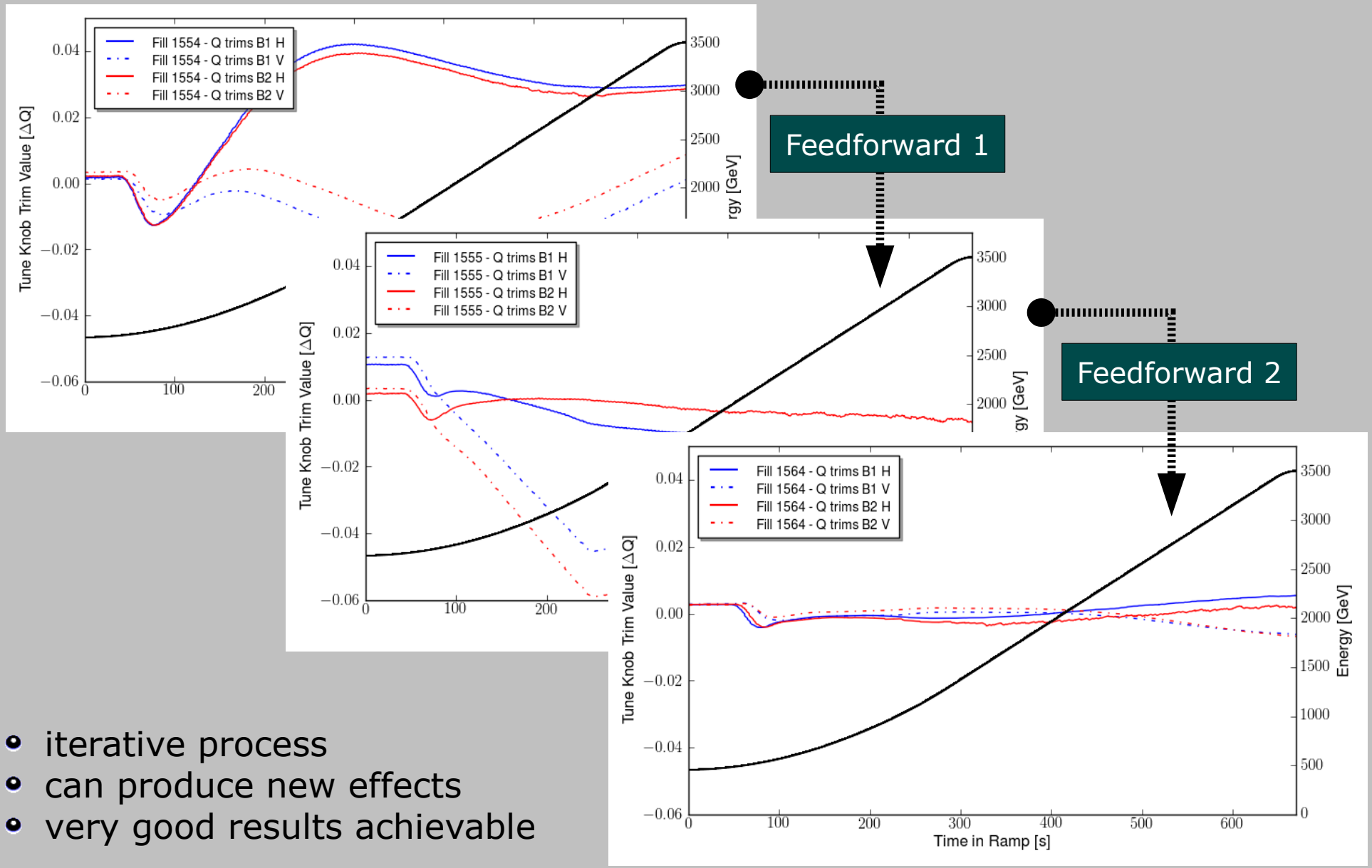

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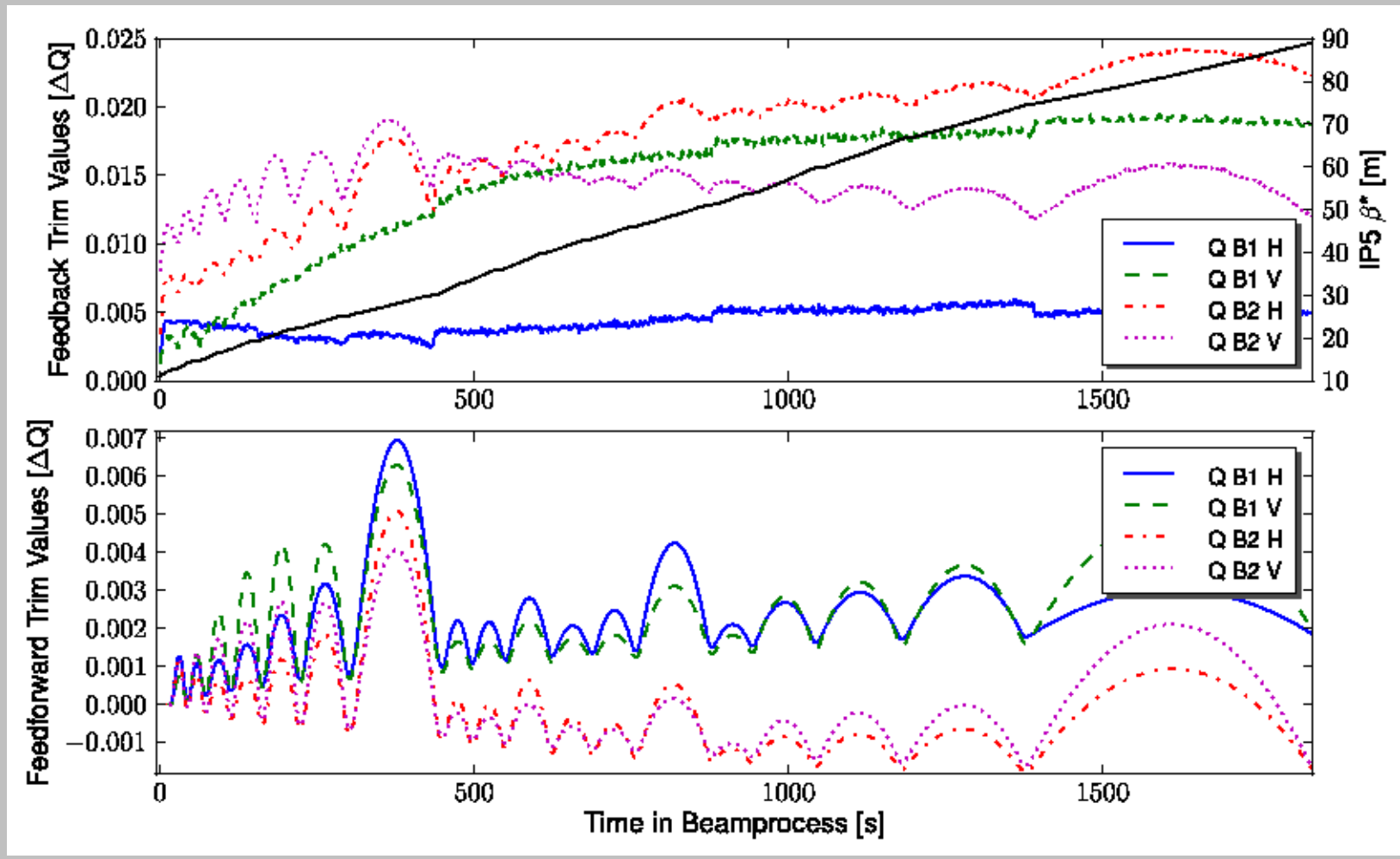
Feed-forward from simulation

- LSA setting generation creates continuous setting functions for all power converters for a given sequence of nominal optics that should be reached
- *Beamprocess Scanner* application developed in the online modeling toolchain – MOPMN018 – for optimization of the squeeze duration (Diploma Thesis X. Buffat) allows to
  - scan over the generated settings of a beam process, extract power converter settings at discrete times and calculate the optics functions
  - plot and store the evolution of the optics key paramter
- observed distortions introduced from the generation routine are inverted and applied as corrections to the settings
- performed during setting preparation to eliminate all known errors

successfully applied for tune of beam 1 during the commissioning of the 90m Un-squeeze

Feed-forward from simulation



Comparison of proposed feed-forward trims from simulation with feedback trims performed during commissioning of the 90m Un-squeeze
(beam 1 corrections where applied, beam 2 uncorrected)

Match between feedback and feed-forward pattern for beam 2 and nearly no correction required for beam 1.

Conclusion

- feed-forward application fully operational for ramp and squeeze to generate and apply feed-forward corrections for
  - tune
  - chromaticity
  - orbit
- effective reduction of stress on the feedback systems
- simulation based feed-forward options successfully applied
- feed-forward based on simulation performed before setting commissioning and afterwards from feedback corrections only frequently due to high reproducability of the LHC and small required correction
- no feed-forward policy defined – more experience required
- application undergoes further developement to merge the different feed-forward options and improve the user interface

Acknowledgments

As the presented work was carried out to large extend by other people then the presenter, the following people have to mentioned explicitely:

M. Lamont, S. Redaelli and J. Wenninger
concept of feed-forward and application to the machine settings

M. Pereira
concept & implementation of the feed-forward application

X. Buffat
concept & implementation of the beamprocess scanner

Thank You!