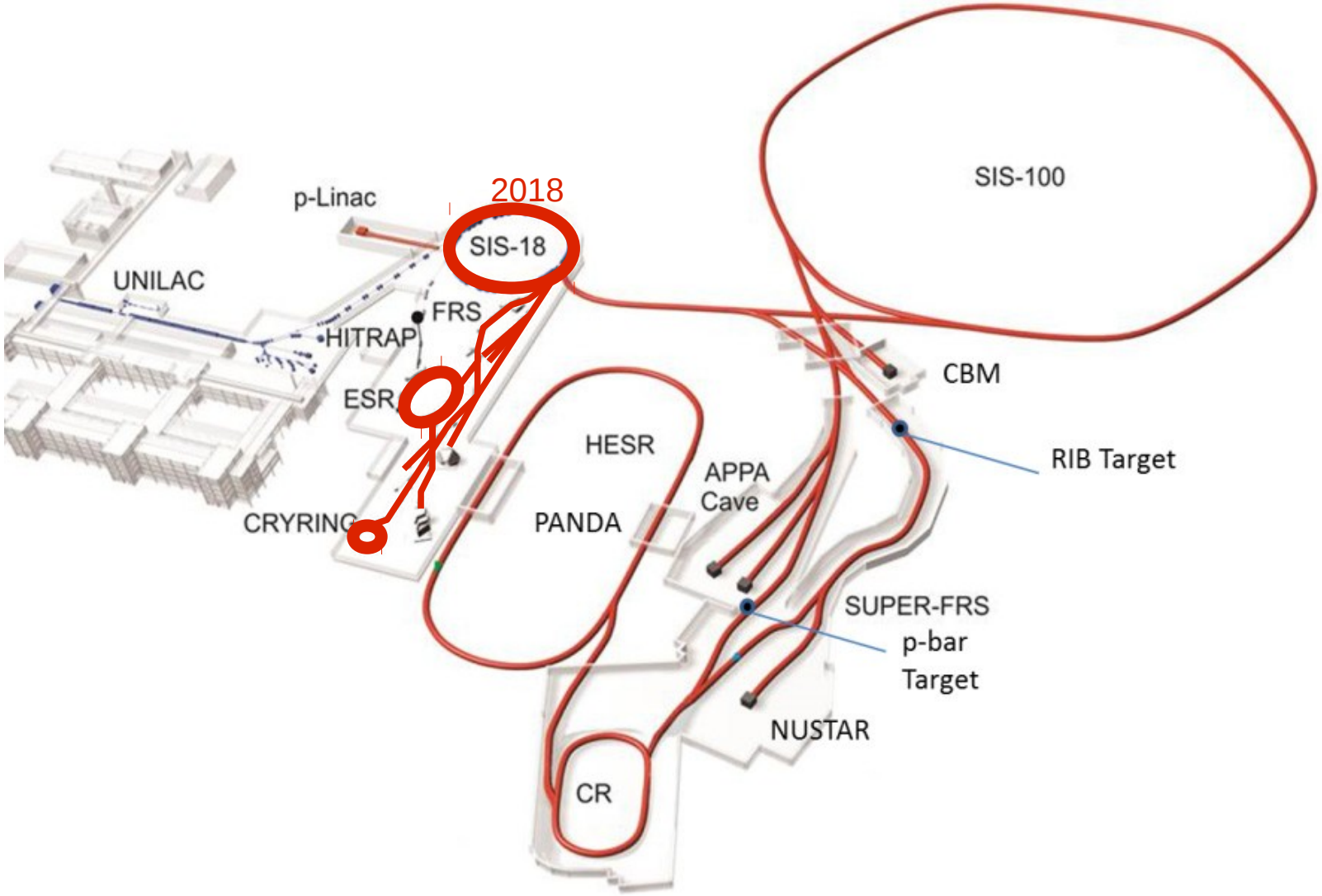
Cycle-to-Cycle Feedbacks for FAIR

– Prototype Tests at SIS18 –

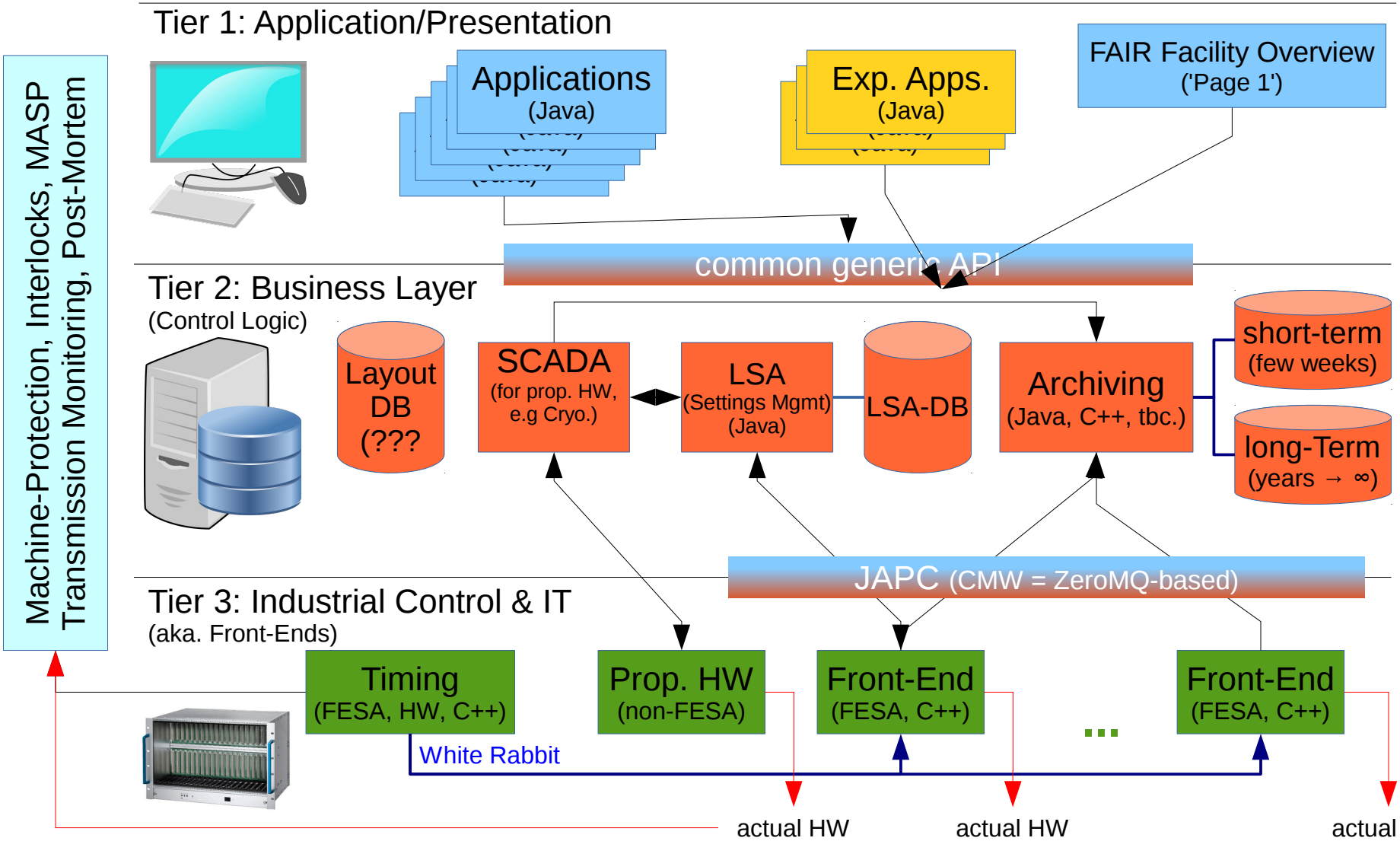
Ralph J. Steinhagen, Bernd Schlei

Acknowledgements: H. Liebermann (LSA)

Accelerator Controls Retrofitting
GSI → FAIR Transition in 2018



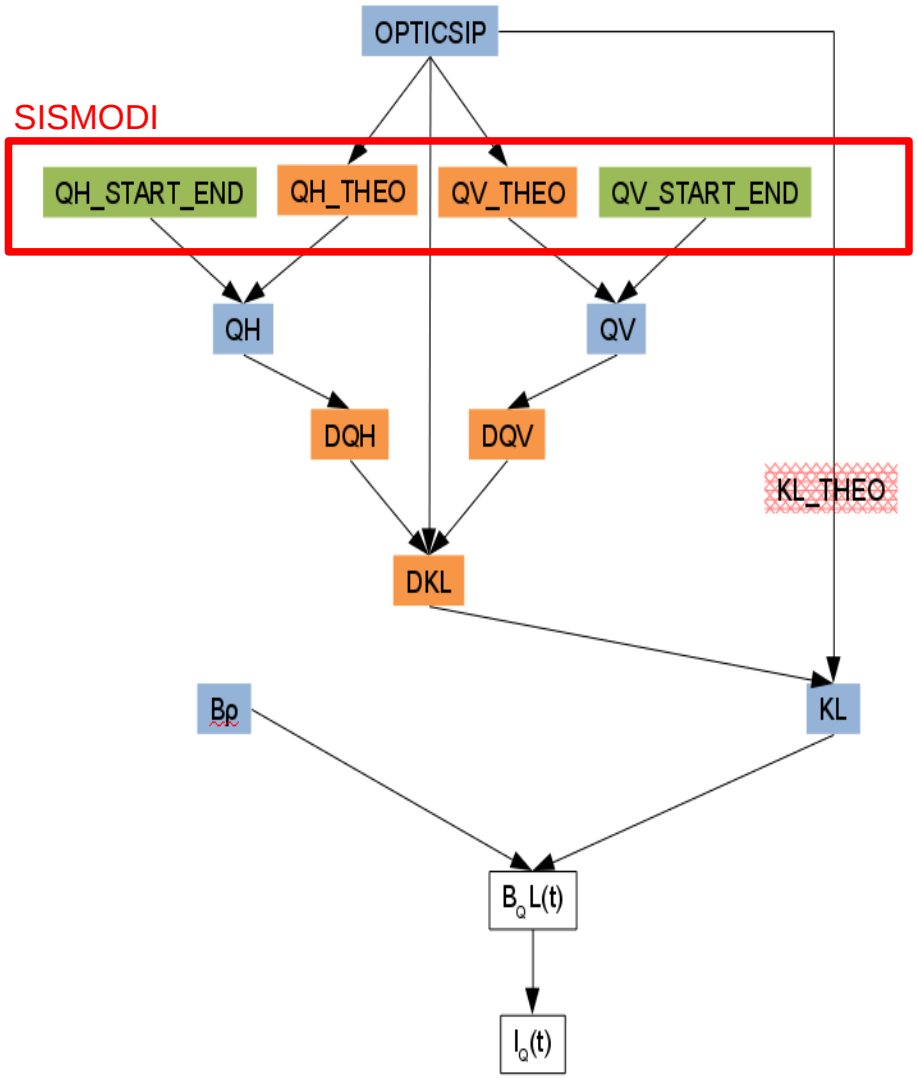
Anatomy of FAIR Acc. Control System
R. Baer (department head) et al.

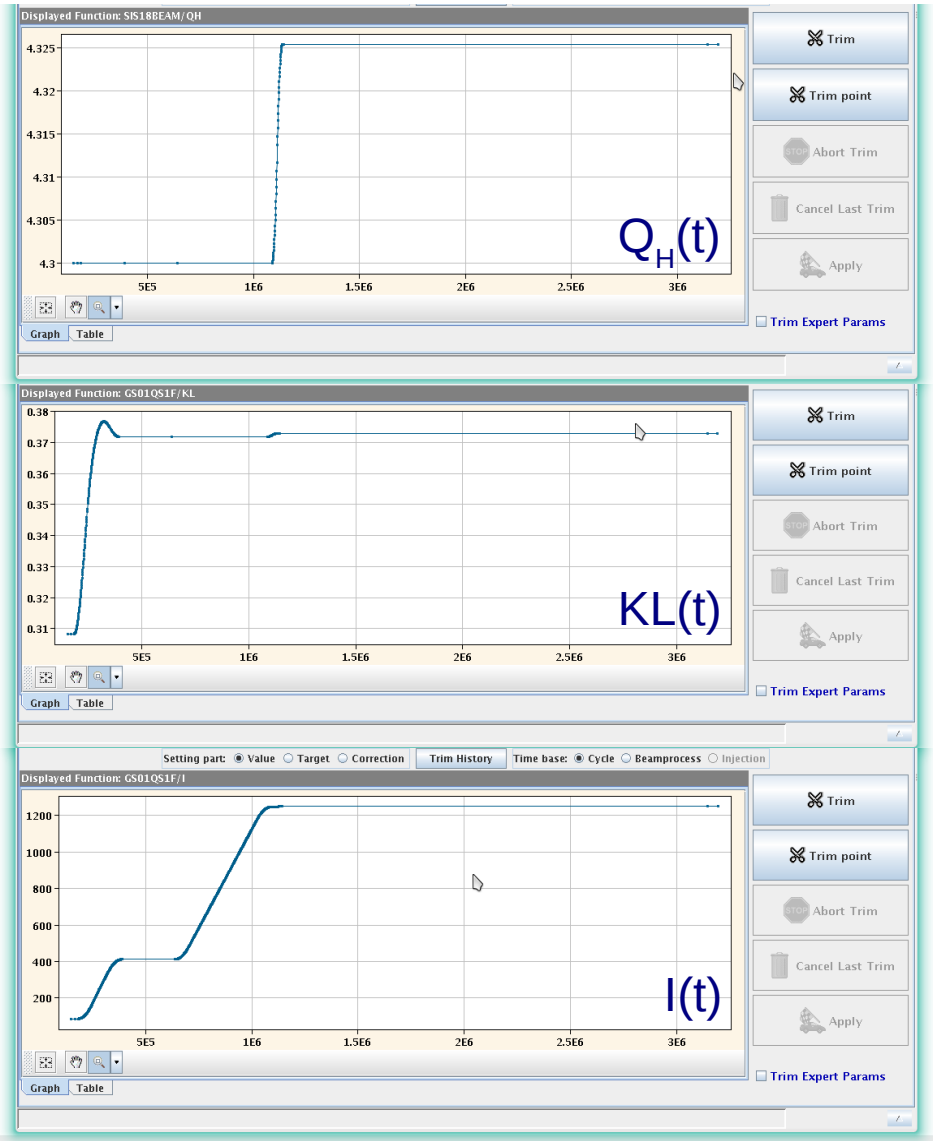


Some FAIR Acc. CO Highlights

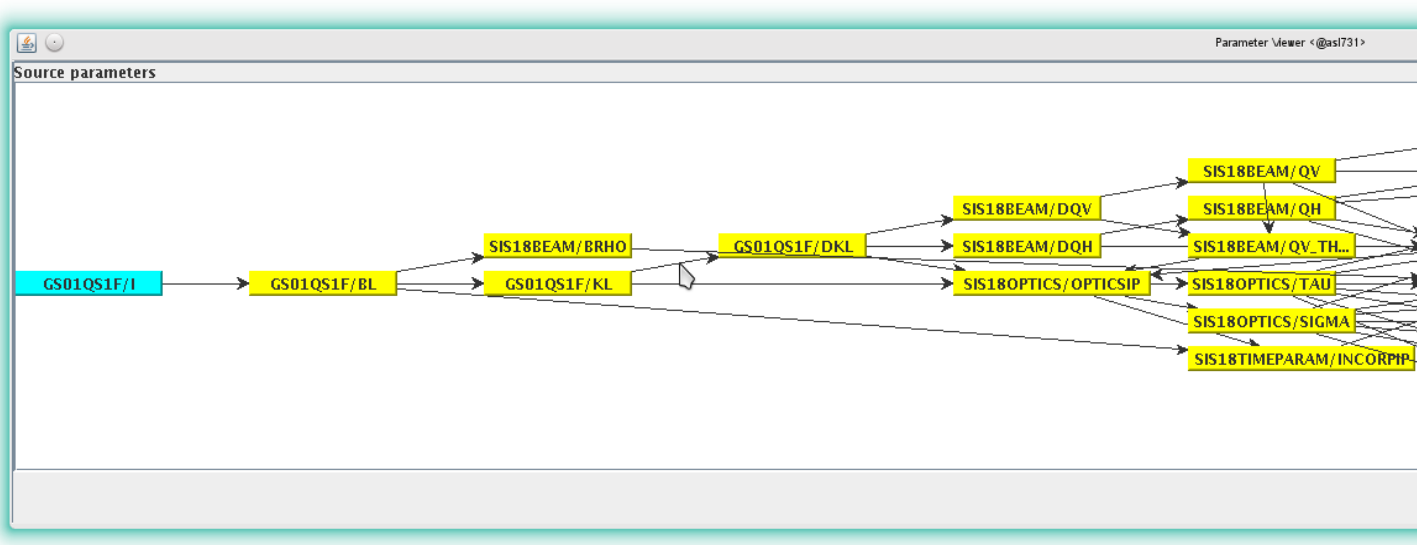
- Non-monolithic, distributed accelerator control system
  - Standardised open interfaces across accelerator chain
- Full control on accelerator modelling & interdependencies
  - Consistency across devices and settings
  - Parameter hierarchy (trans. abstraction/separation of: accelerator physics ↔ controls)
- Tracking of accelerator performance & corresponding settings
- Distributed development & expertise (e.g. code shared with CERN)
  - Better more efficient code review & medium-/long-term maintenance
  - Continuous improvement & evolution to actual accelerators' & experiments' needs
- Better more flexible integration of beam-based diagnostics systems
  - possibility of arbitrary (user-driven) functions (+actual vs. reference comparisons)
    → opens the possibility of powerful semi-/fully automated cycle-to-cycle feedbacks
    - trajectory/target steering, orbit control, …
    - Easy macro-spill-control,
    - ...

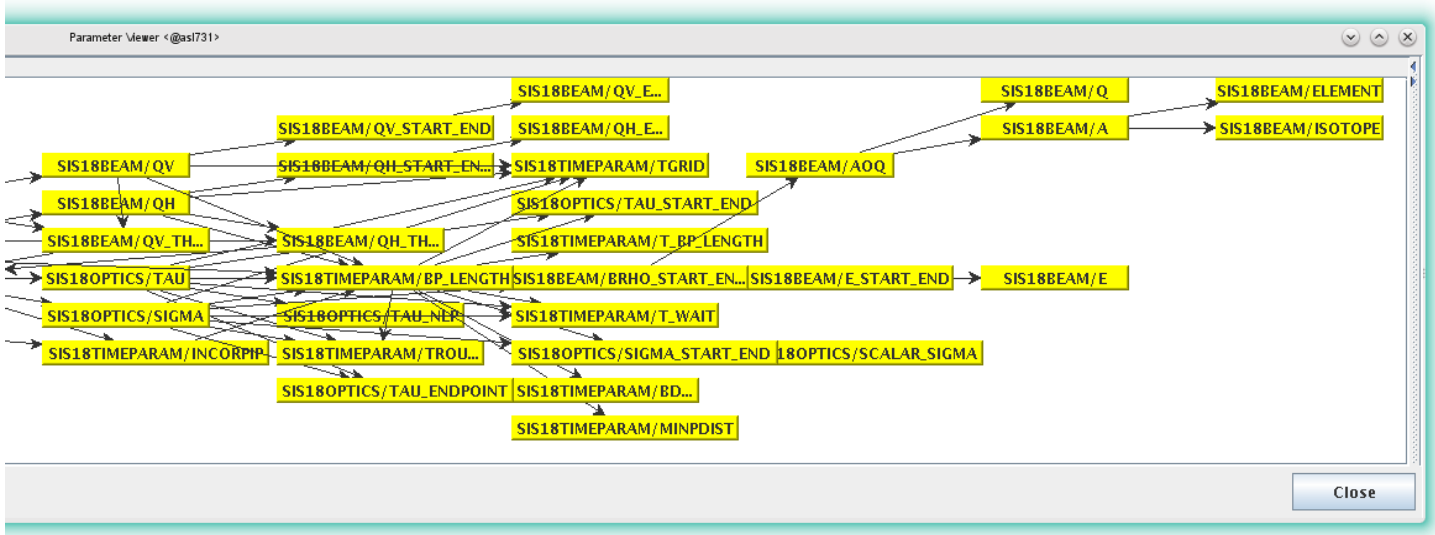
LSA Parameter Hierarchy



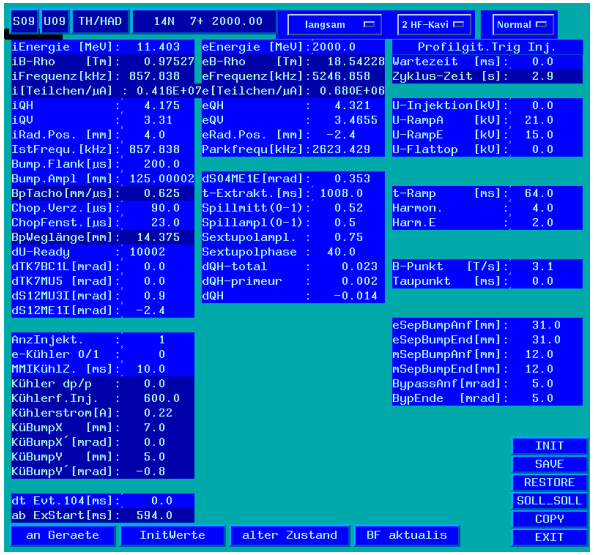


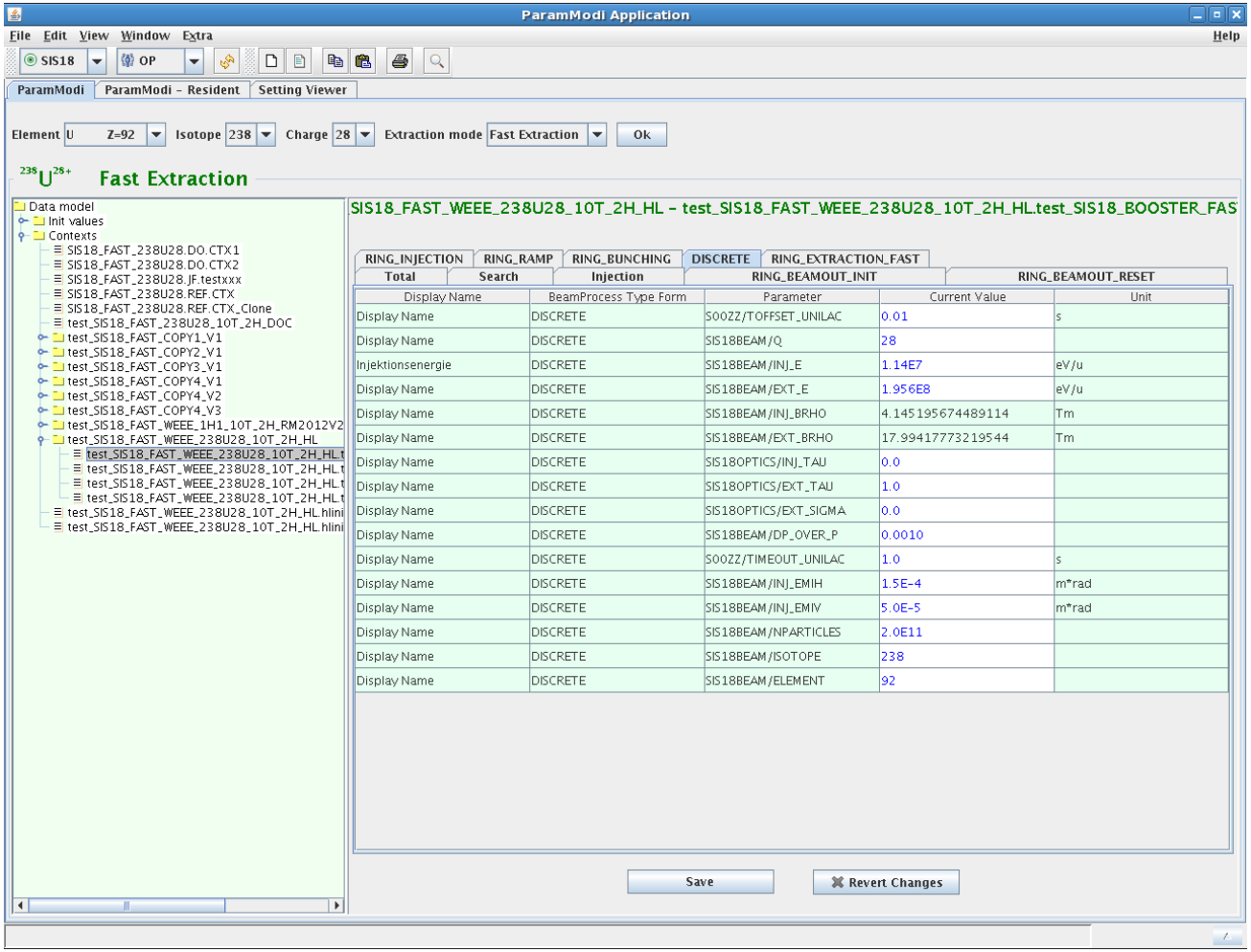
Disclaimer for restart in 2018:





Disclaimer: KISS Restart in 2018
SISMODI → ParamModi (function-equivalent)





FAIR Control System Documentation

Good entry point:

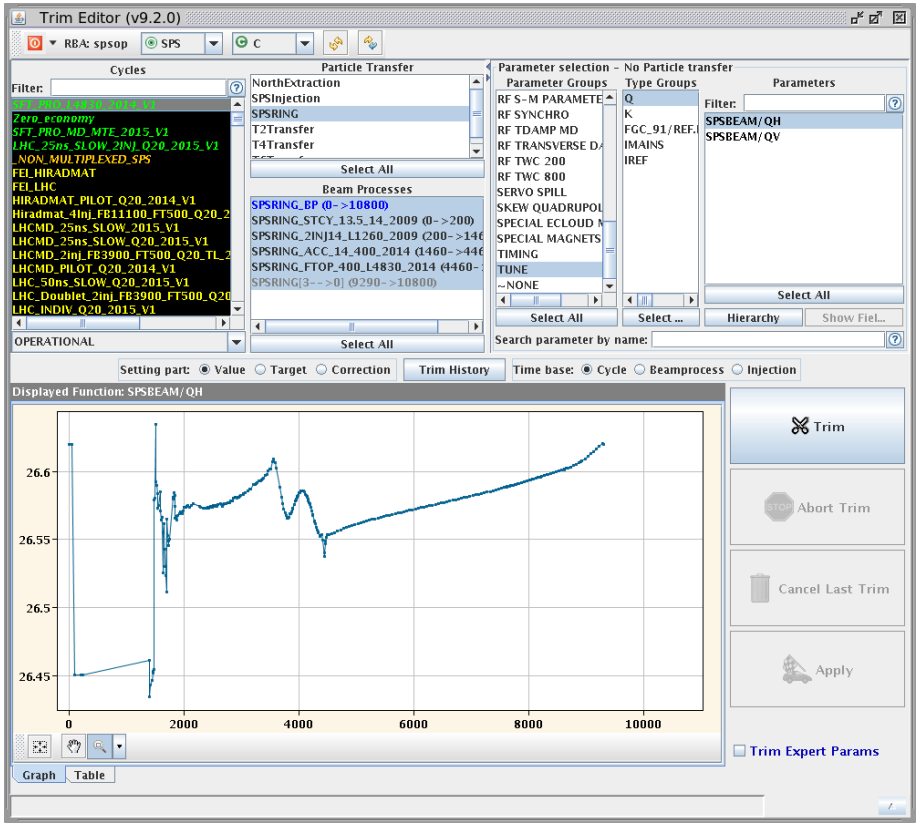
https://www-acc.gsi.de/wiki/

Specifically, some more meat in:

- Glossary: https://www-acc.gsi.de/wiki/FAIR/FAIRGlossar
- Timing: https://www-acc.gsi.de/wiki/Timing/
- FESA: https://www-acc.gsi.de/wiki/FESA
  - https://www-acc.gsi.de/wiki/FESA/WhatIsFESA
- LSA: https://www-acc.gsi.de/wiki/Applications/LsaMainPage
  - https://www-acc.gsi.de/wiki/Applications/LsaPresentationsAndPublications
  - https://www-acc.gsi.de/wiki/Applications/LsaFrequentlyAskedQuestions
  - https://edms.cern.ch/ui/#!master/navigator/document?D:1935804008:1935804008:subDocs
- Applications: https://www-acc.gsi.de/wiki/Applications/

LSA-based Cycle-to-Cycle Feedbacks

Generic LSA trim interface:



… open to all accelerator parameter that fulfil basic control theory criteria:

- Stability: *"parameter should be ~ reproducible from fill-to-fill … "*
  - *good OP experience provided hysteresis is respected*
- Controllability: "need affine (but not necessarily linear dependence between observable effect and control actuator, ..."
- Observability: "... need to be able to measure it reliability (noise, …), ..."
  → N.B. interface to experiment's detectors

Appetizer: – LSA enabling Beam-based cycle-to-cycle feedbacks

Generic Beam Control (focus on use-case)

1. Transmission Monitoring System (R. Steinhagen, FC²WG Meeting #6)
2. Orbit Control (work in progress)
3. Trajectory Control (threading, inj./extr., targets)
4. Q/Q'(') Diagnostics & Control
5. TL&Ring Optics Measurement + Control (LOCO, AC-dipole techniques etc.,)
6. RF Capture and (later) RF gymnastics
7. Longitudinal Emittance Measurement
8. Transverse emittance measurement
9. Transverse and longitudinal feedbacks

Bread-and-Butter systems for OP ~ ideally for SIS18 restart

Machine-specific Beam-Based Systems:

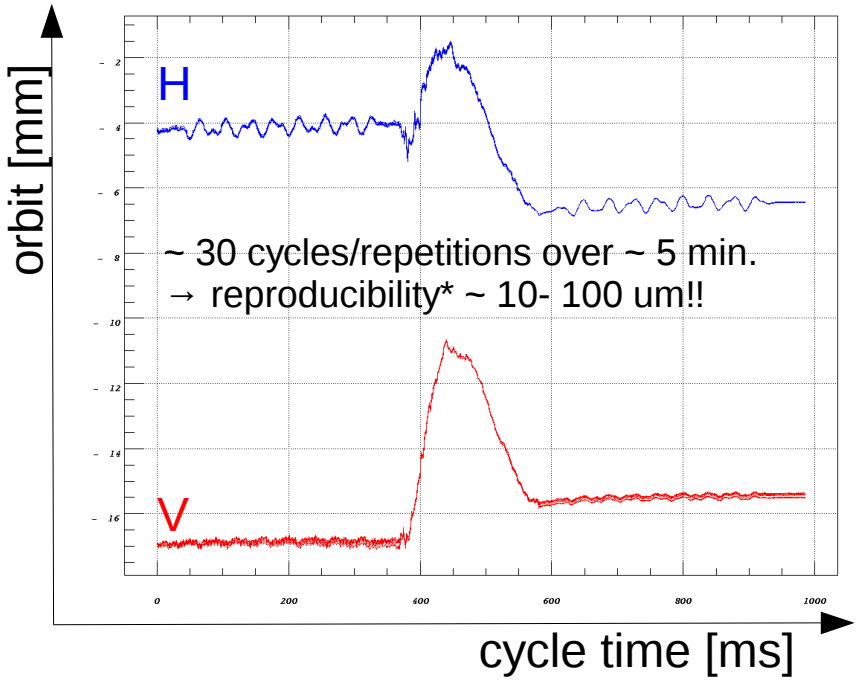
- SIS18: multi-turn-Injection (N.B. highly non-trivial, complex subject), Slow-Extraction (K.O. exciter, spill-structure, …)
- SIS100: Slow-Extraction (K.O. exciter, spill-structure, …), RF Bunch Merging and Compression
- ESR, HESR & CR: Stochastic cooling, Schottky diagnostics, …, tbd.

Generic:

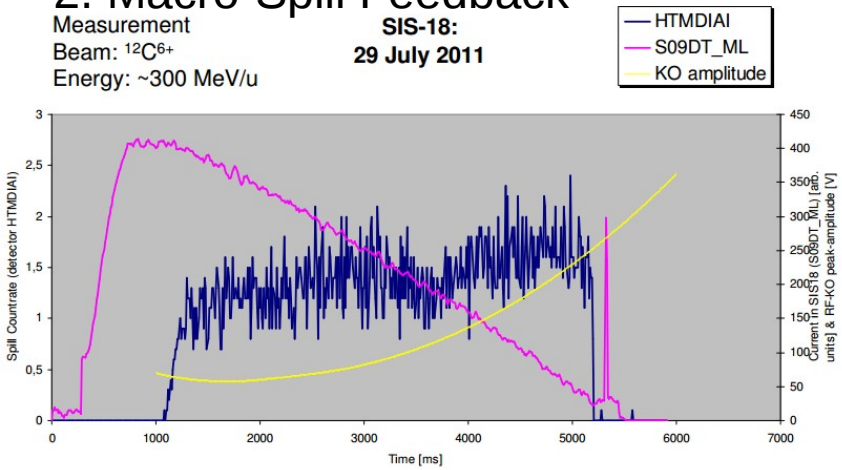
- Remote DAQ of Analog Signals (strong impact on HKR migration/operation!)
- Facility-wide fixed-displays, facility & Machine Status (“Page One”)
- context-based monitoring of controls and accelerator Infrastructure,
- … *“the sky is the limit”*

2016 SIS18 MD's Proof-of-Concepts

1. Orbit/Trajectory (e.g.Target-) Steering



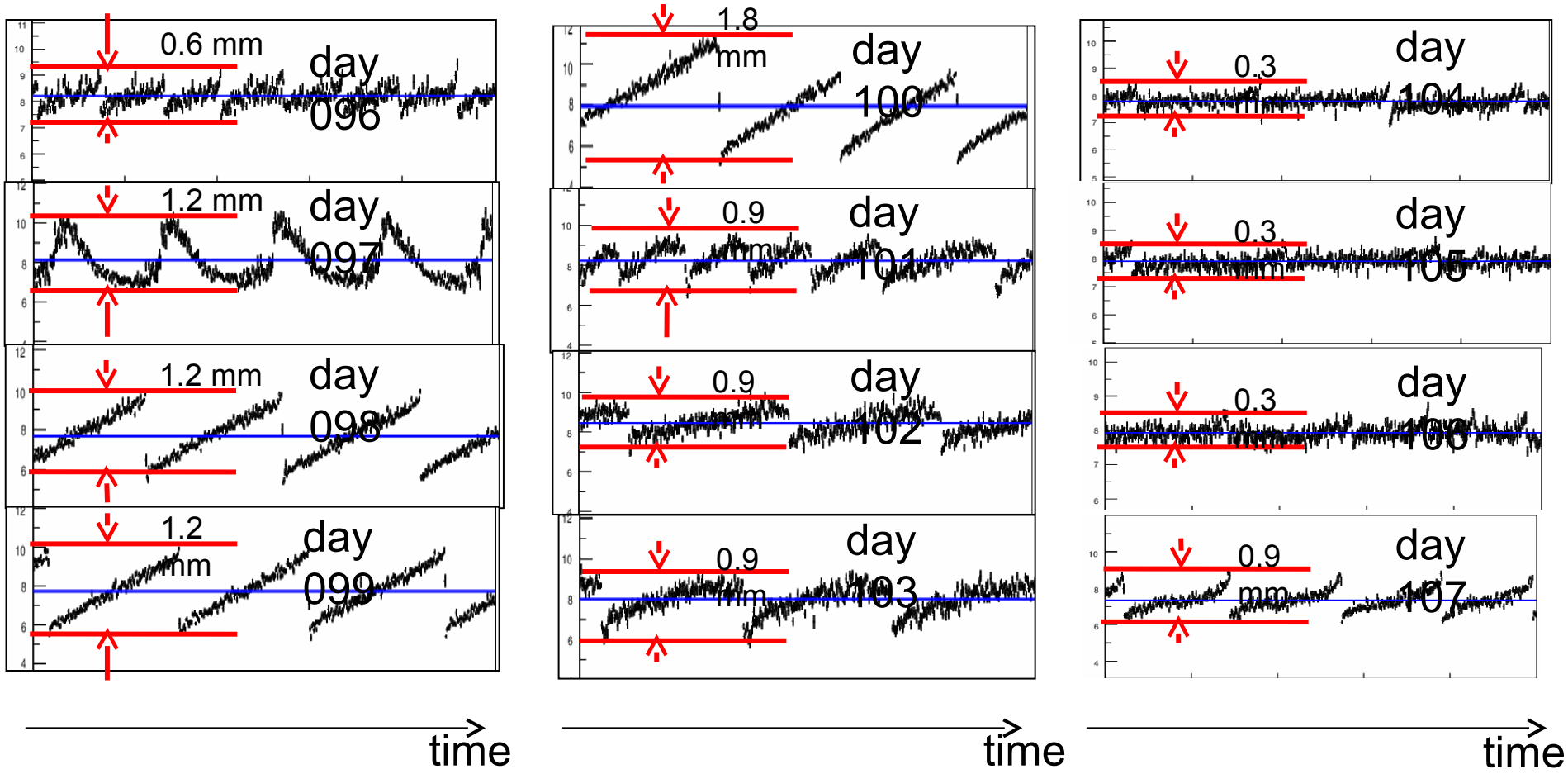
2. Macro-Spill Feedback



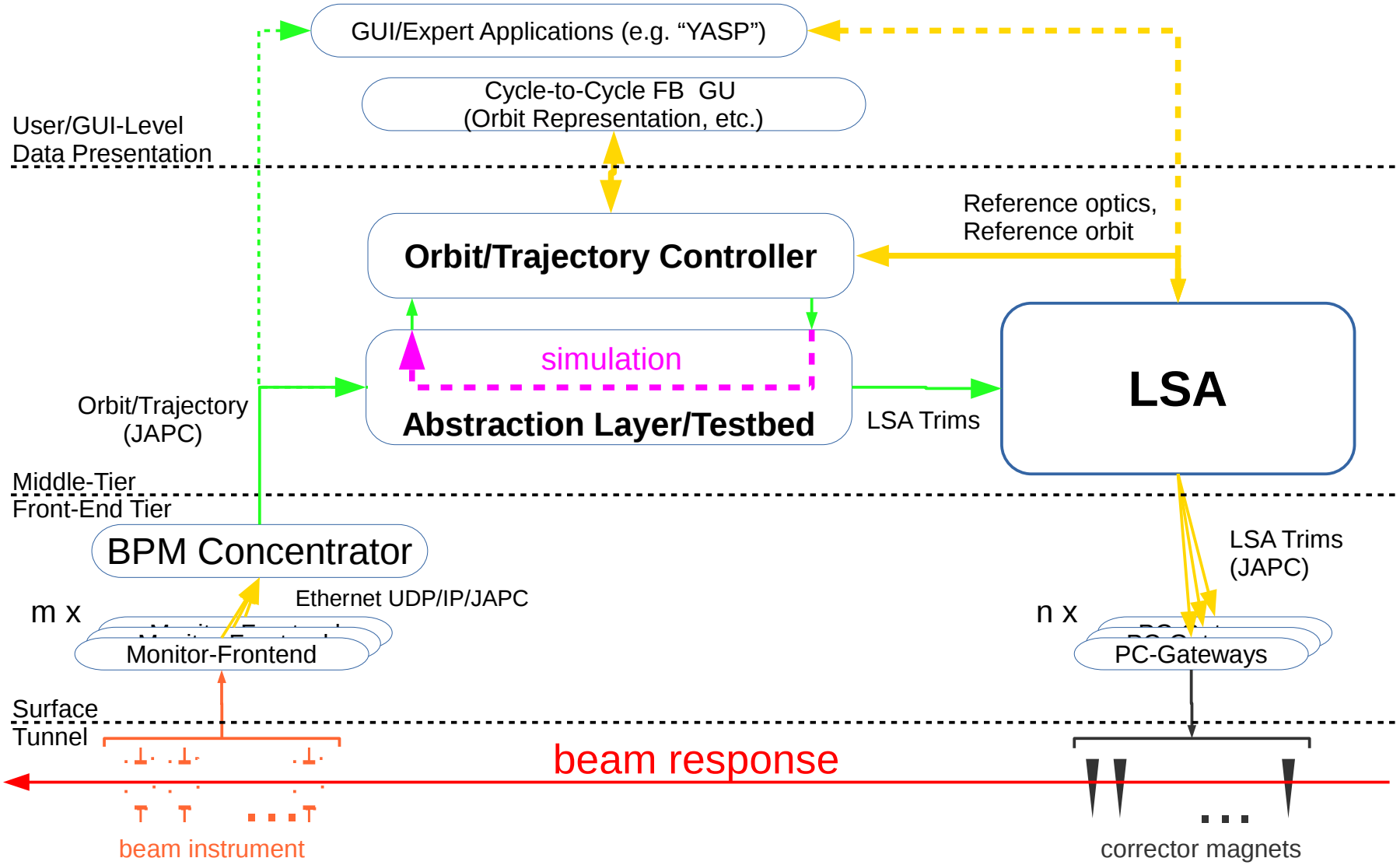
courtesy C. Bert, A. Constantinescu, D. Ondreka, M. Kirk et. al.

*modulo BPM stability/bias

Beam position stability – day-wise



Beam-Based FB Prototype Tests example: Orbit-FB



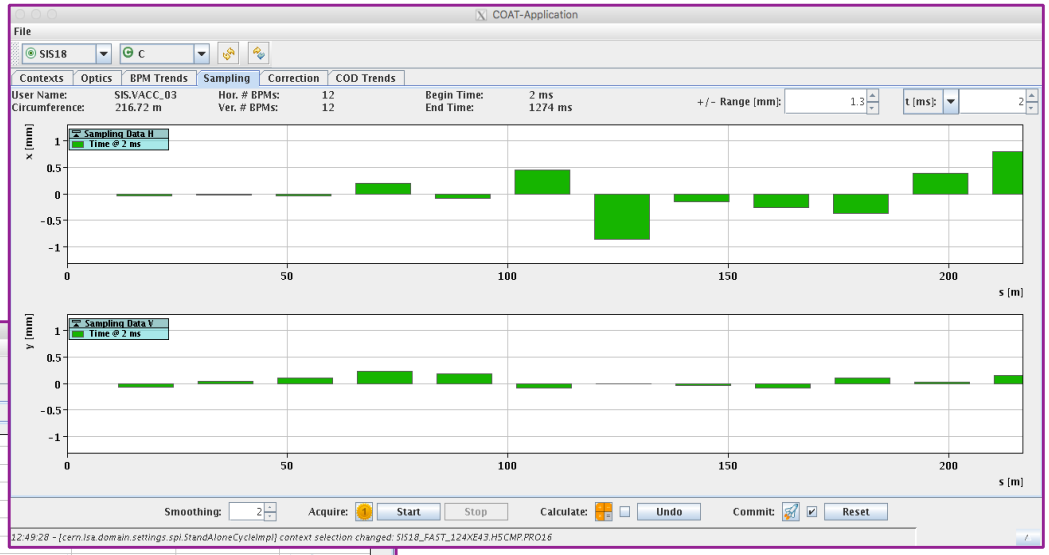
Orbit-FB Prototype Tests I/II
B. Schlei et al.

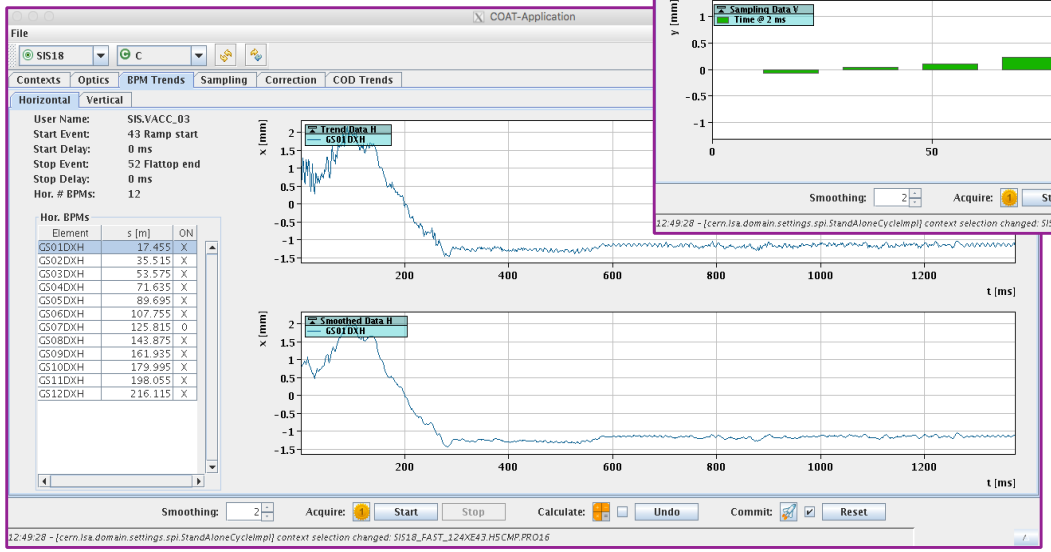
COAT - controlling orbits and trajectories:

app-opticsviewer

coat-client ↔ coat-domain ↔ coat-service ↔ coat-acquisition

First working prototype





Individual measurement

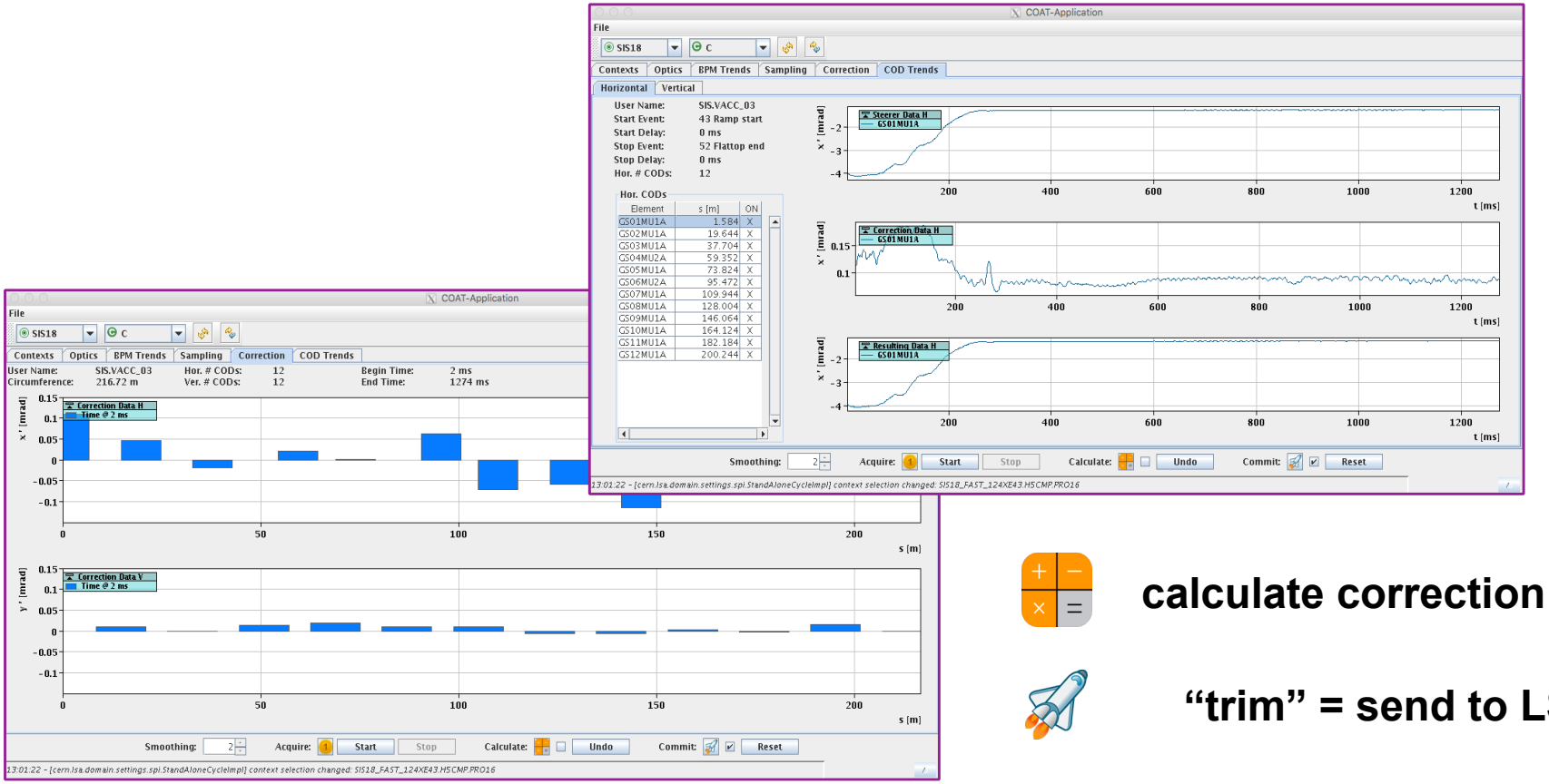
continuous

Orbit-FB Prototype Tests II/II
B. Schlei et al.

COAT - controlling orbits and trajectories:

app-opticsviewer

coat-client ↔ coat-domain ↔ coat-service ↔ coat-acquisition



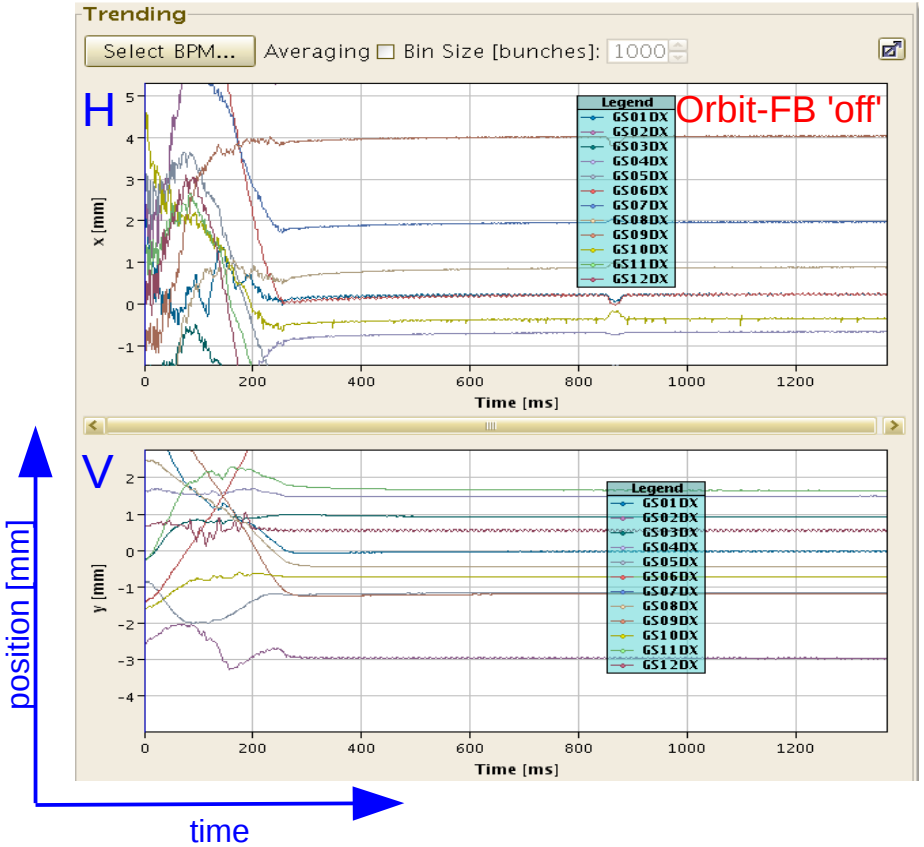
calculate correction

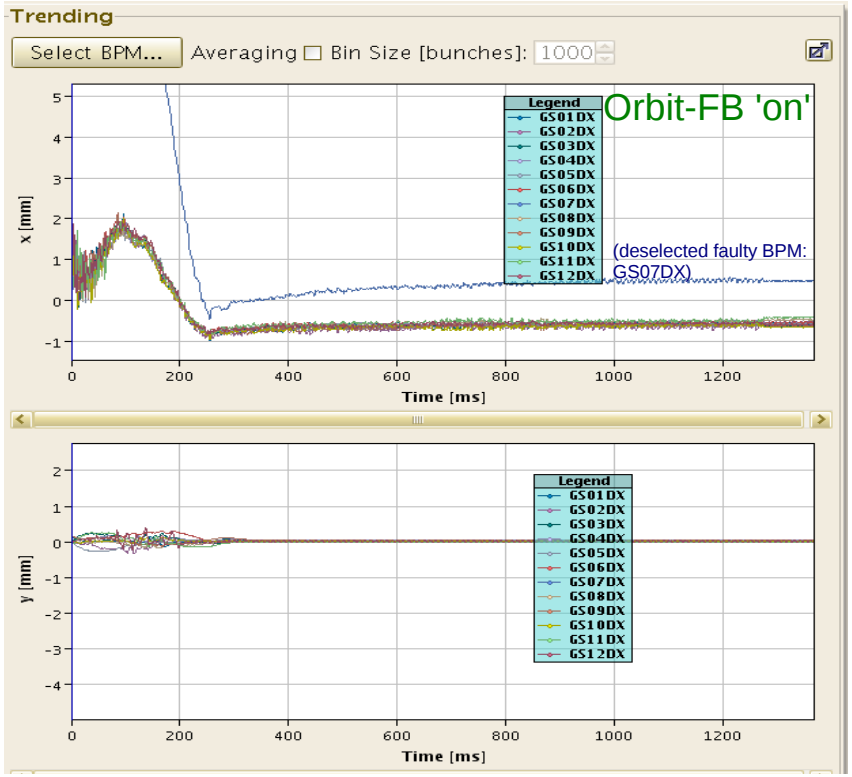
“trim” = send to LSA

2016-06-12: First Orbit-FB Prototype Test
B. Schlei et al. @ **23:46:13**

2016-06-12: Orbit-FB Proof-of-Concept MD

B. Schlei, H. Liebermann, R. Steinhagen





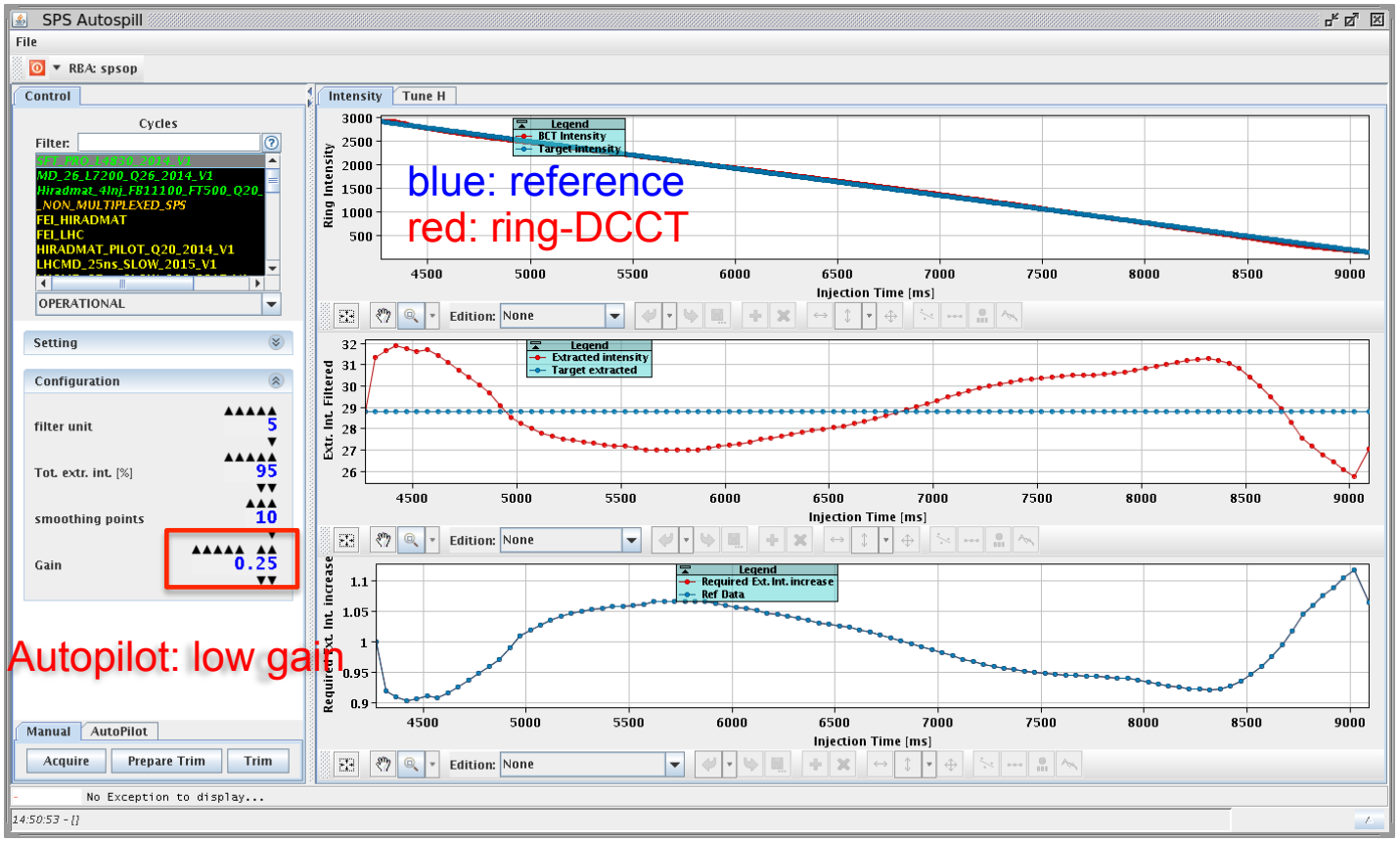
- some workarounds needed, but overall success and results look promising
  - need to follow-up: reliability, performance issues related to CO & BI + detailed integration before being put into regular operation (→ routine operation for 2018 looks feasible)
  - N.B. remaining horizontal oscillation due to uncorreted Δp/p mismatch → radial-loop/Energy-FB

Example: LSA-based Macro-Spill & Harmonics Control I/II

from SISMODI:

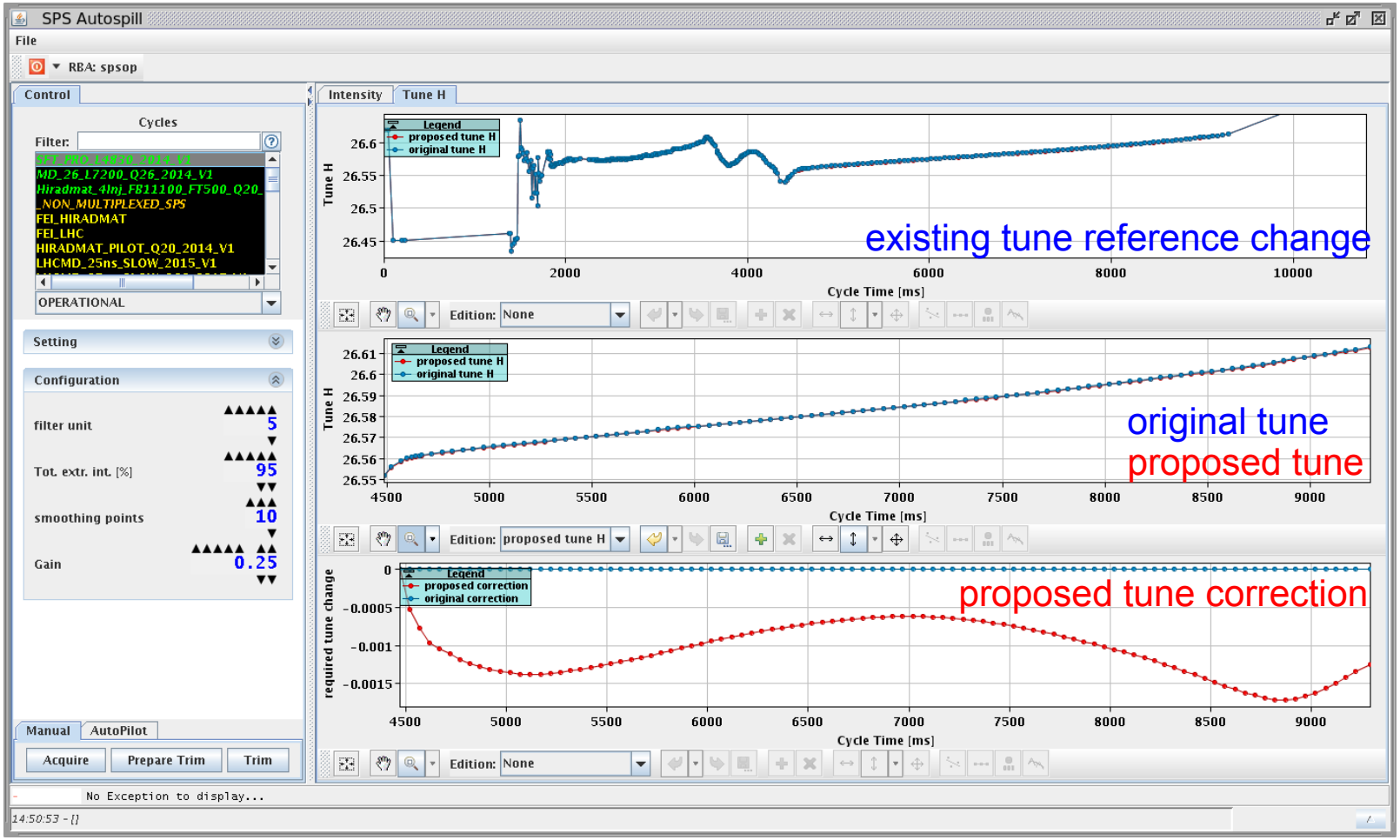
```
eEnergie [MeV]:  150.0
eB-Rho     [Tm]:    5.97614
eFrequenz[kHz]:2811.561
eTeilchen [µA]:  0.122E+06
eQH            :    4.29998
eQV            :    3.26
eRad.Pos. [mm]:   -2.0
Parkfrequ[kHz]:1062.66

dS04ME1E[mrad]:    1.337
t-Extrakt.[ms]:  1000.0
Spillmitt(0-1):    0.32
Spillampl(0-1):    0.6
Sextupolampl.  :    0.15
Sextupolphase  :  105.0
dQH-total      :     0.035
dQH-primeur    :     0.022
dQH            :    -0.01
```

to LSA-based cycle-to-cycle feedback:



courtesy V. Kain, J. Wenninger, CERN

Example: LSA-based Macro-Spill & Harmonics Control II/II

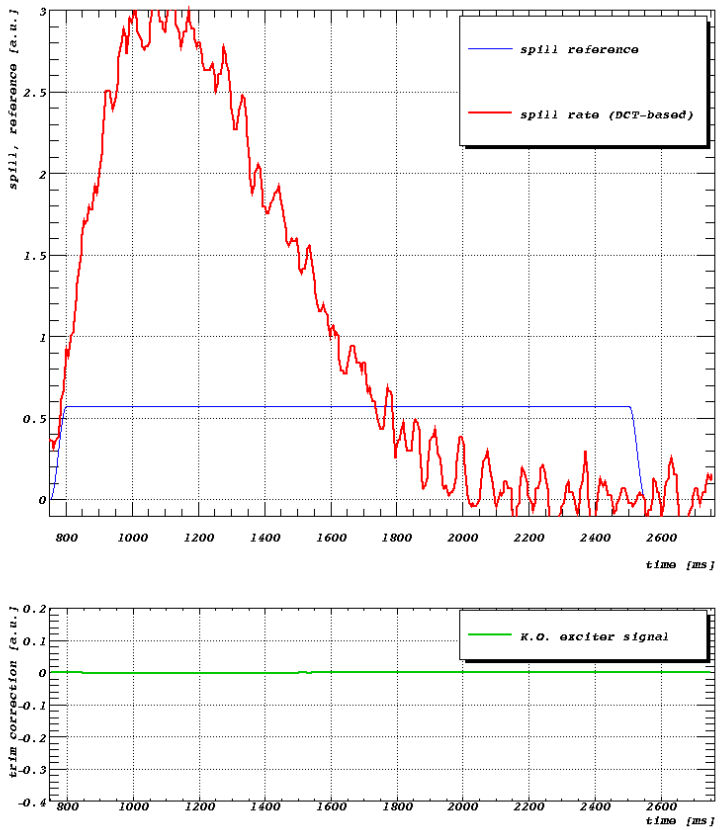


The Autospill interfaces via the standard LSA trim client (API) → trim history, propagation to other parameter…

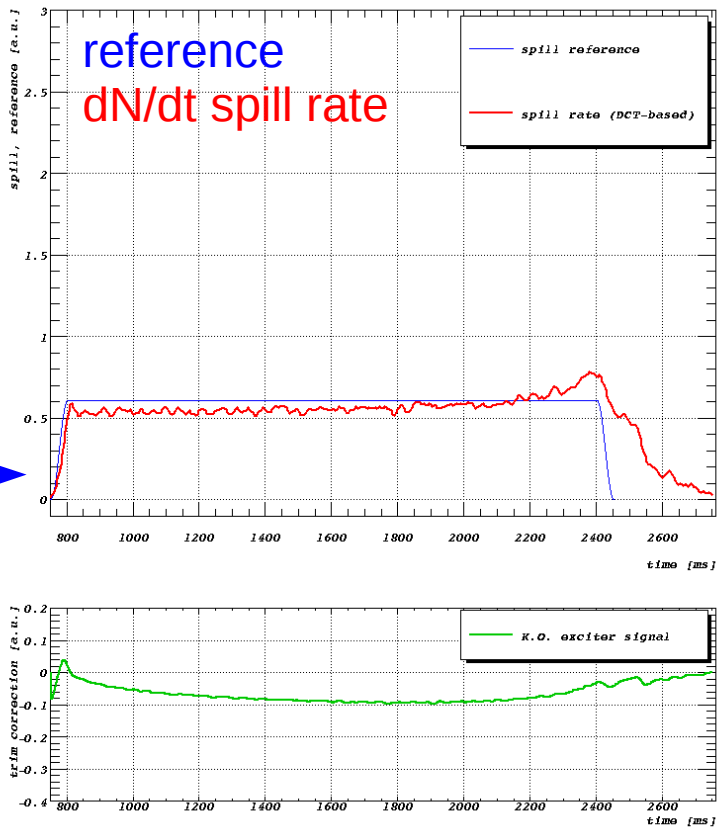
courtesy V. Kain, J. Wenninger, CERN

2016-07-03: Macro-Spill-FB Proof-of-Concept MD

R. Steinhagen, H. Liebermann

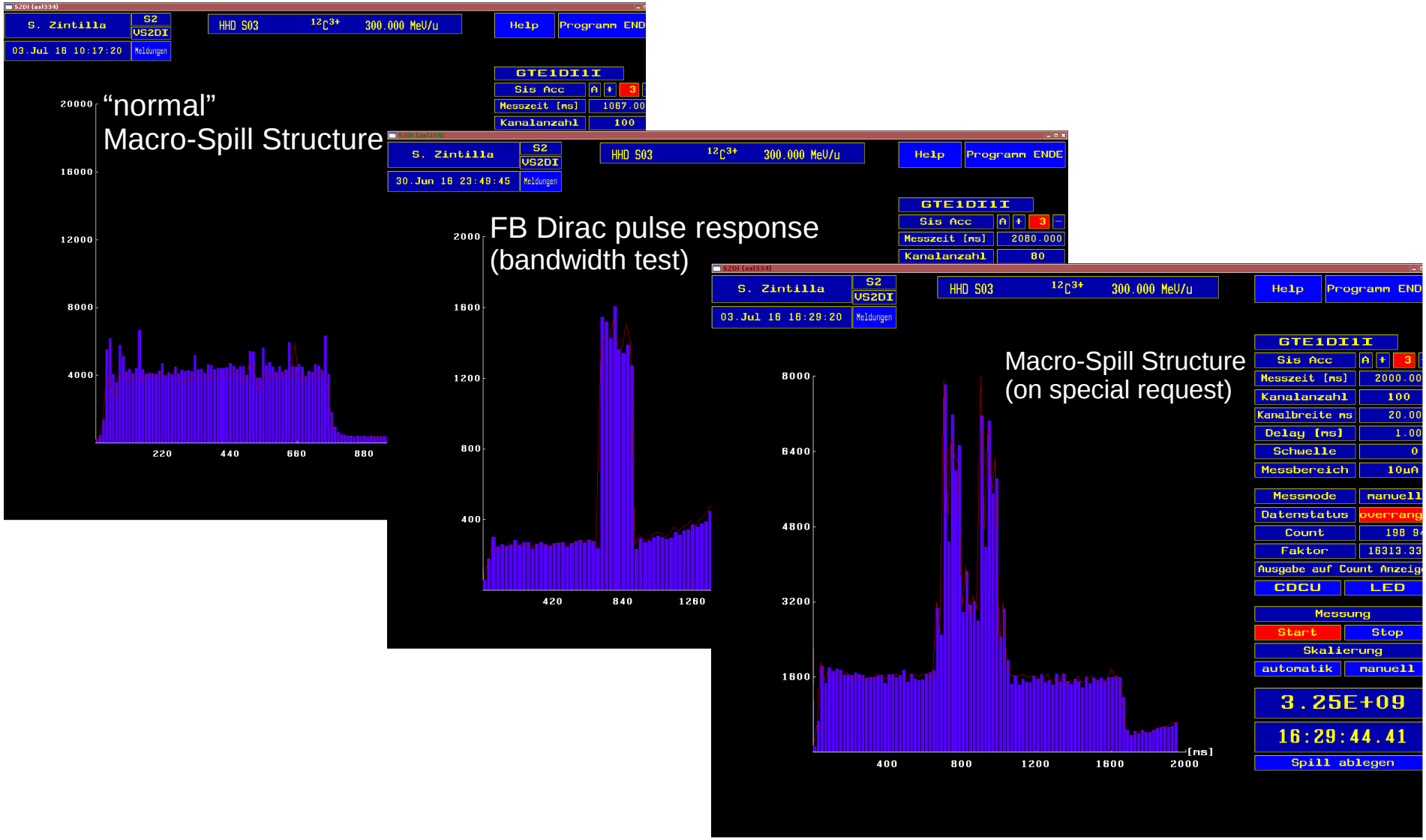


Fill-to-Fill
FB on dN/dt
(DCCT-based)



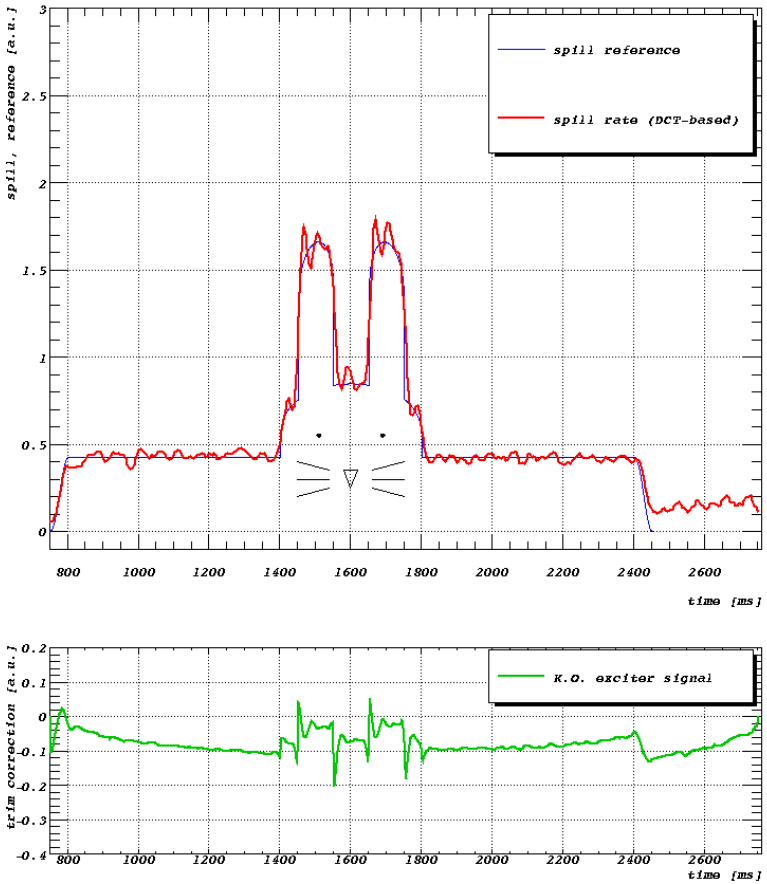
- some workarounds needed, but overall success and results look promising
  - need to follow-up: K.O. exciter power-limitation handling (easily for >10 Tm operation)
    - Alternative: FB using fast extraction quadrupole or main-quads
  - Desirable: direct FB signal from experimental detectors
  - routine operation for 2018 feasible (provided priority/manpower will be allocated for OP/CO integration)

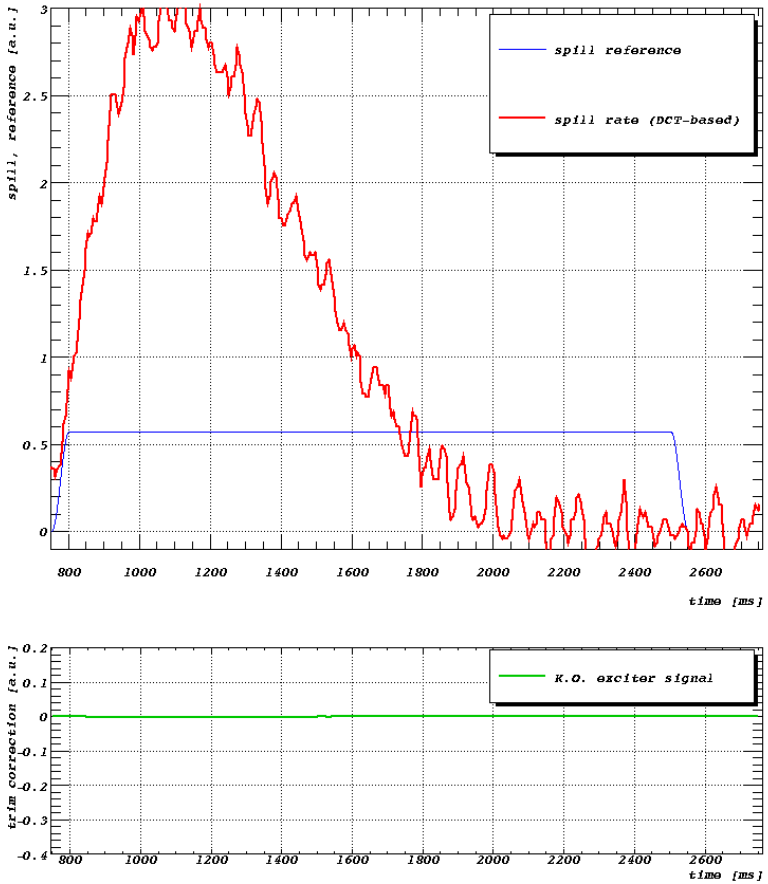
… as seen in extraction channel (counters)



… what's also possible with the Spill-FB

N.B. animated GIF





FIN

Cycle-to-Cycle Feedback

example: Q'-correction @ LHC