SPS Transverse Feedback System

M. Schenk, G. Kotzian

Acknowledgments: S. Cettour, K. Li, H. Pahl

Overview

- Working principle & hardware location
- High-level parameter model
- Tools & procedures
- Future plans & final remarks

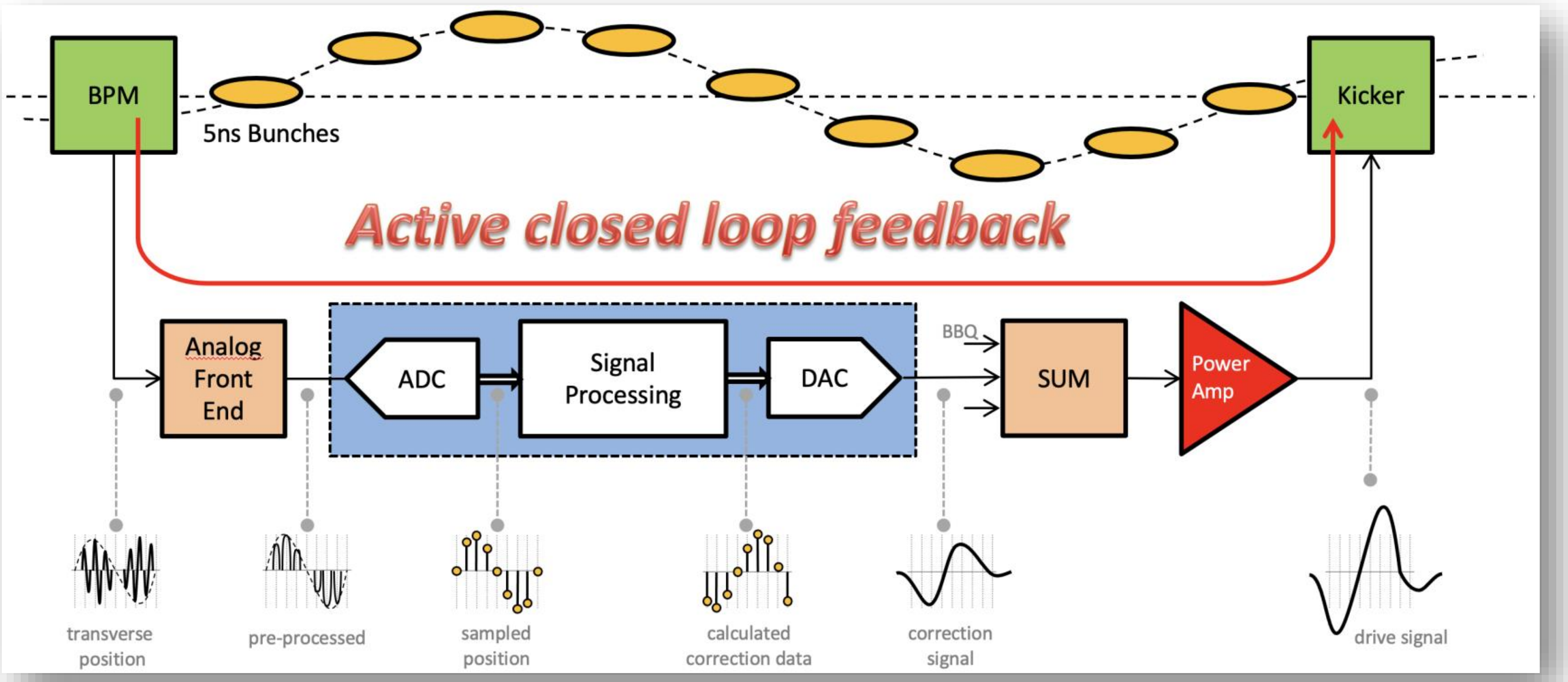
Working principle & hardware location

Working principle

Overview

The transverse damper is a feedback system to reduce horizontal and vertical bunch oscillations

1. At every turn, measure **bunch-by-bunch transverse oscillations** with a pick-up / BPM
2. Based on position data, **calculate correction signal**, accounting a. o. for phase advance BPM <-> kicker
3. **Kickers apply amplified correction signal to individual bunches** to reduce their oscillation amplitudes



Working principle

Damping process

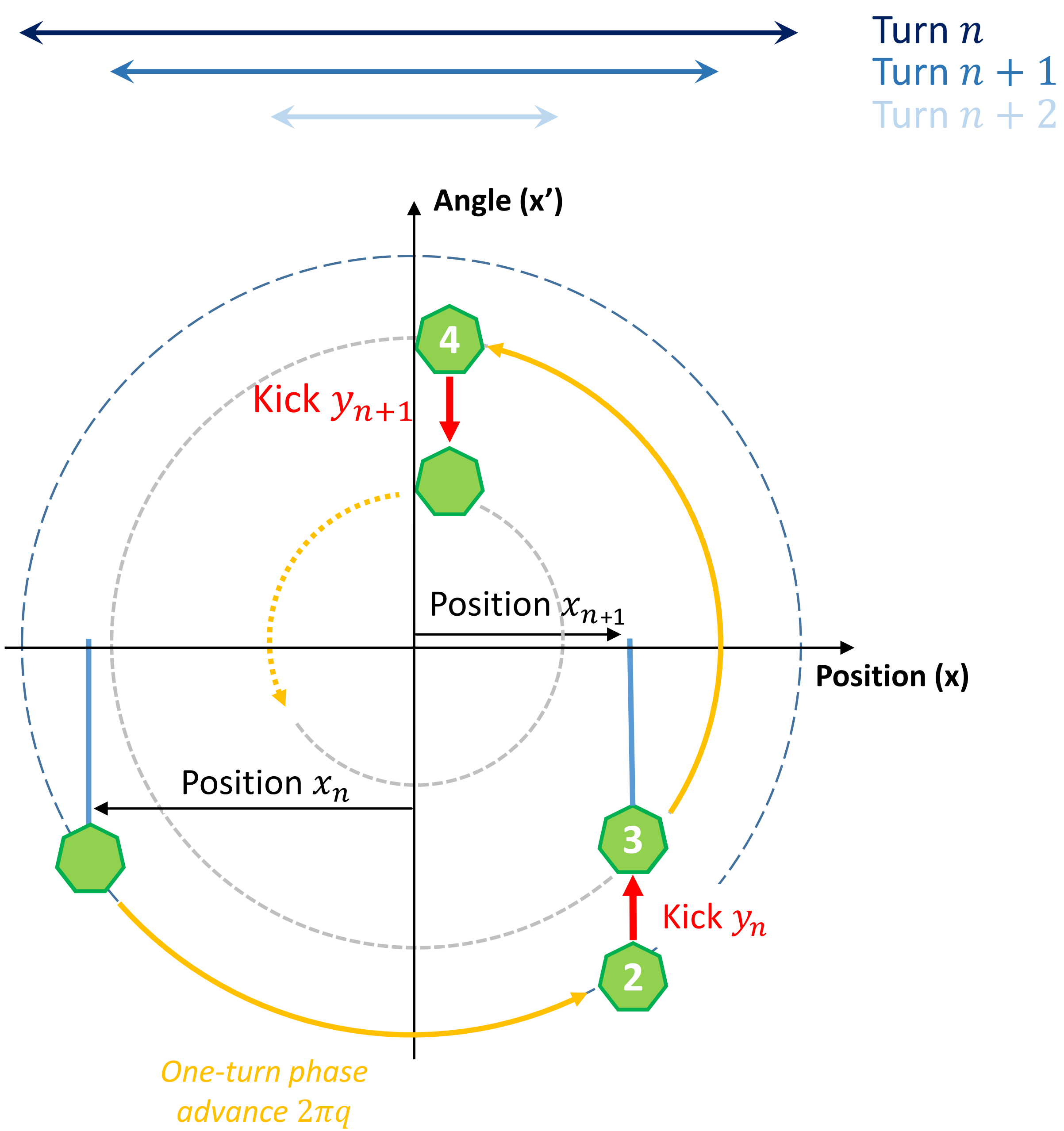
Feedback action

1. Measure bunch position x_n
2. Calculate and apply kick y_n to reduce oscillation amplitude
   taking into account phase advance

Repeat at every turn

Bunch oscillation amplitudes are reduced over time ***(exponential decay)***

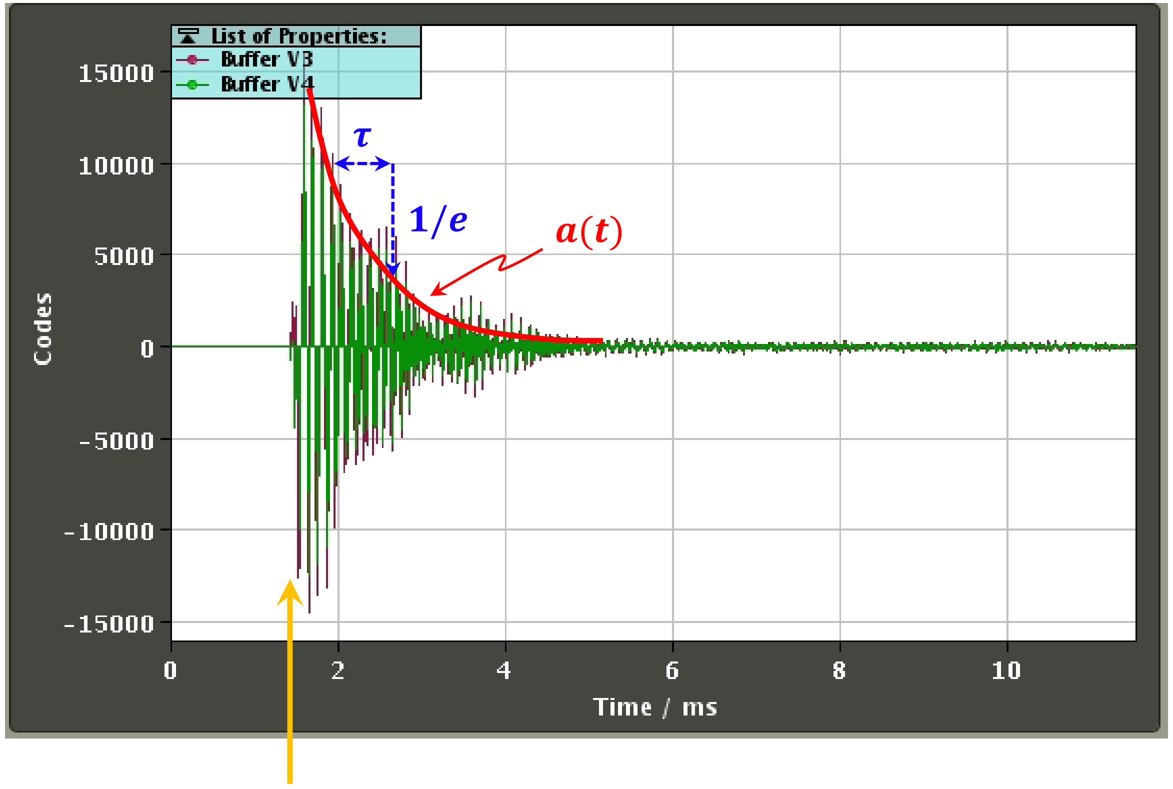
Assumptions: *one-turn delay, pickup & kicker at same location in the ring, linear machine. Typically not the case.*



Working principle

Damping process

SPS injection oscillation damping



- Bunch **oscillation amplitude** under influence of TFB is described by **exponential decay**

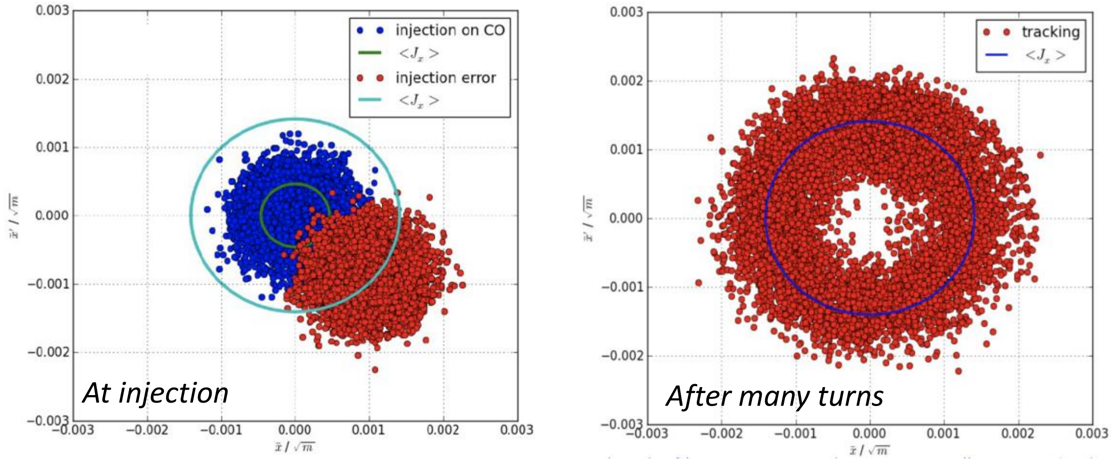
$$a(t) = a_0\, e^{-t/\tau}$$

- **Damping time τ** is
  - time it takes for amplitude to drop by $1/e$
  - inversely proportional to loop gain
- **SPS TFB** can achieve damping times of **about 20 turns** (~0.5 ms)
- *N.B.: amplitude decay is also partially due to decoherence*

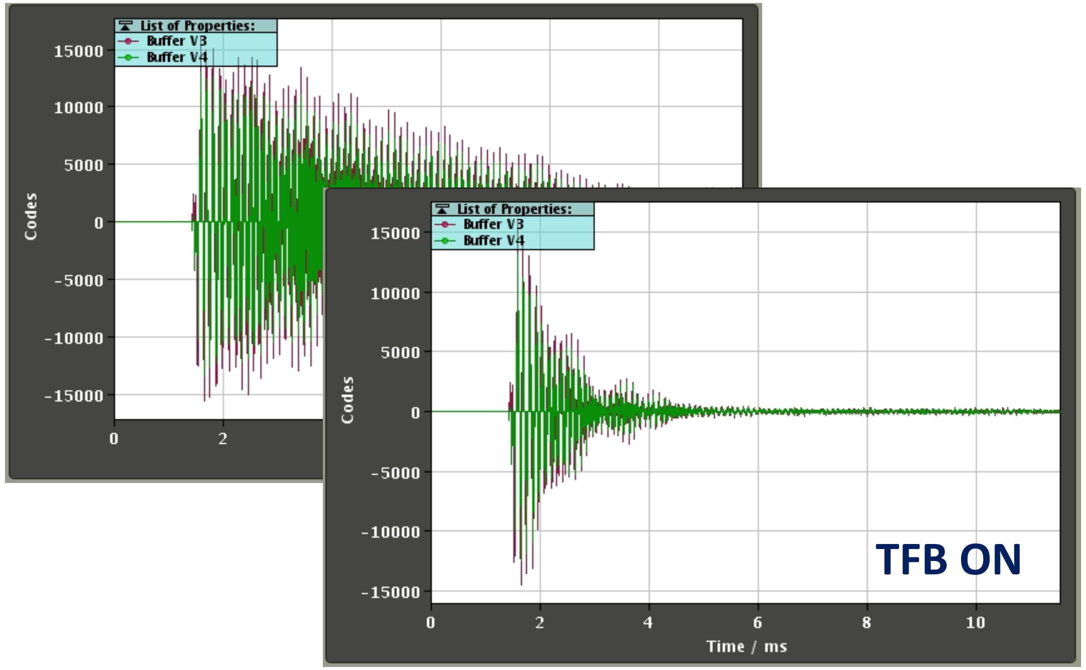
Working principle
SPS TFB use case

- **Take care of injection errors and its consequences**
  - **Injection damping** *(up to several mm)*
  - **Reduce emittance blow-up** induced by non-linearities thanks to **fast enough** damping times. *Note that the TFB does not create blow-up*
- **Cure coupled-bunch instabilities** (CBI)
  - In particular **resistive-wall-induced CBI**
    Threshold 5 x 10^{12} p beam intensity
  - **Suppress all CBI** at 25 ns bunch spacing, i.e. up to 20 MHz (highest-order coupled-bunch mode)
- **SPS operational TFB *not designed to suppress intra-bunch motion* / single-bunch instabilities**
  (bandwidth not sufficient ➡ "wideband feedback")

Injection error leading to emittance blow-up



H. Schmickler, Feedback systems, CAS, 2017



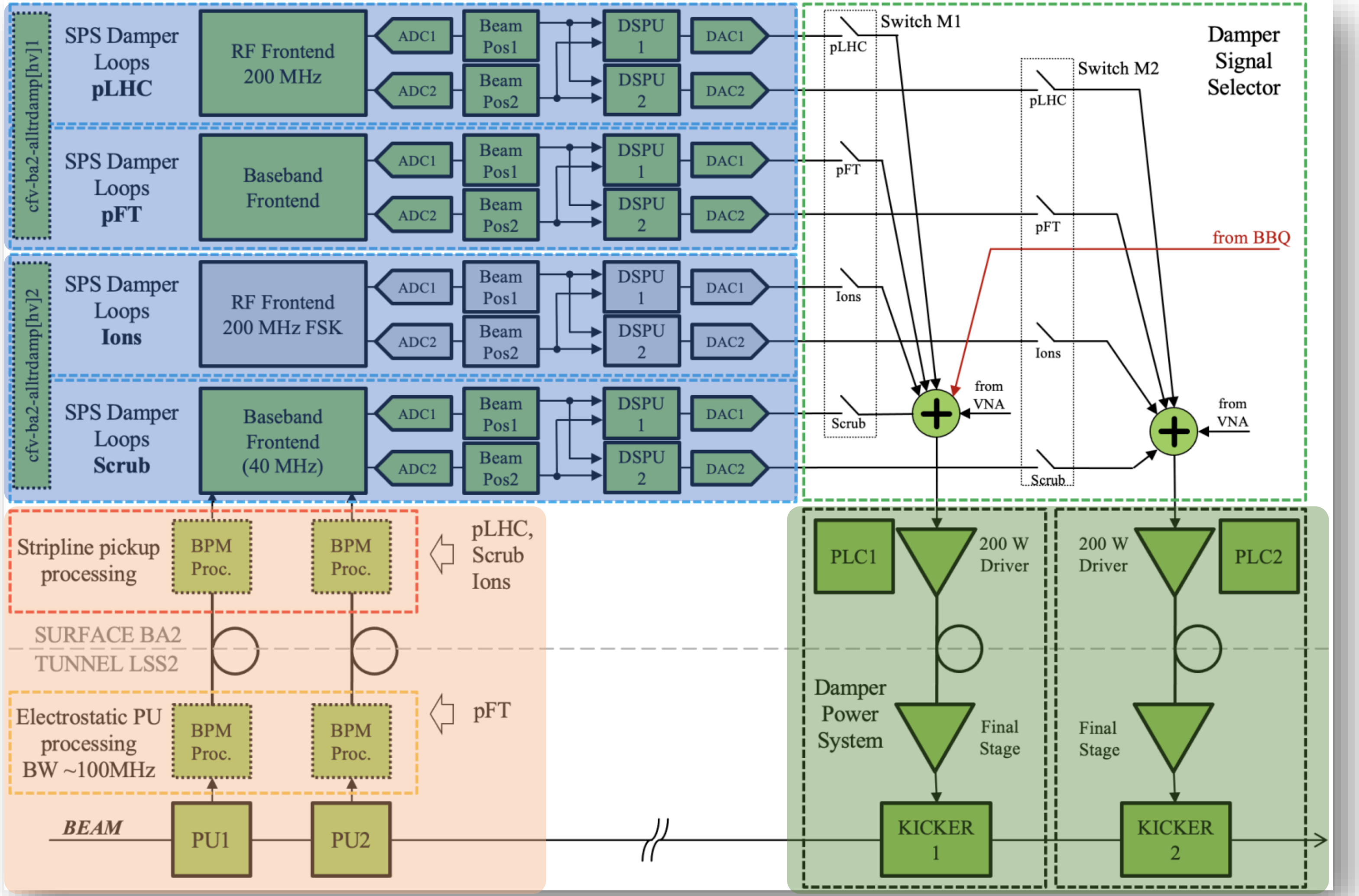
SPS TFB
Hardware

Per plane

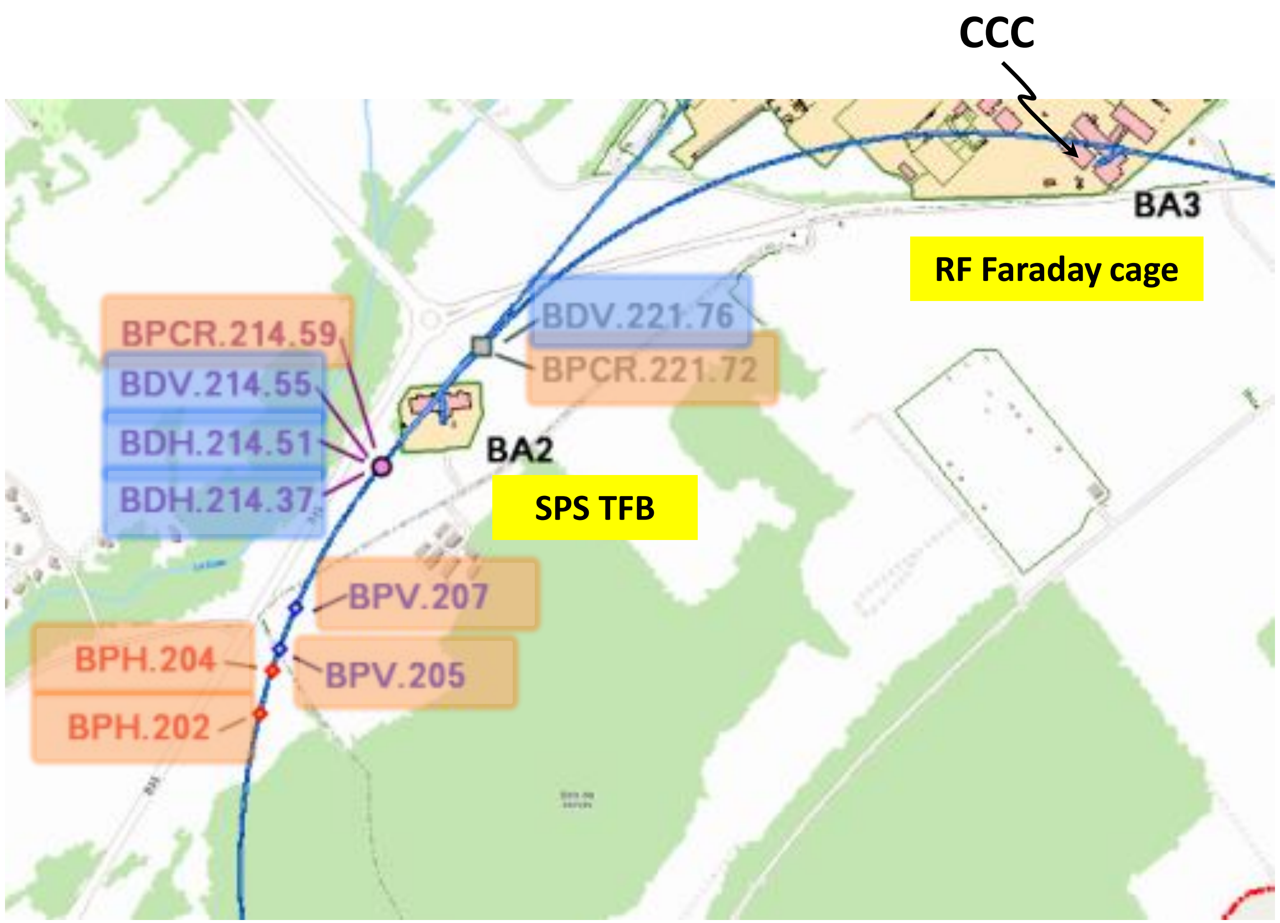
4 signal processing systems
- **pLHC:** LHC beams (25 ns)
- **pFT:** SFTPRO
- **Ions**
- ~~**Scrub:** doublet beam~~

Pickups
- **pFT:** 2 electro-static, processing in tunnel
- **pLHC, Ions, Scrub:** 2 striplines, processing on surface

Power system with 2 kicker modules



SPS TFB
Pickup and kicker locations



Pickups

- **pFT**
  BPH.202, BPH.204
  BPV.205, BPV.207
- **LHC-type beams** *(p, ions, scrub)*
  BPCR.214.59 (H/V)
  BPCR.221.72 (H/V)

Kickers

- ***Horizontal***
  BDH.214.37: module H1
  BDH.214.51: module H2
- ***Vertical***
  BDV.214.55: module V1
  BDV.221.76: module V2

SPS TFB

Take away

- SPS TFB **reduces oscillation amplitudes** on **bunch-by-bunch level**
- Amplitude damping follows **exponential decay** with time constant typically **~20 turns** (0.5 ms)
- **Main purpose:** take care of **injection errors** to limit emittance blow-up, and mitigate **coupled-bunch instabilities**
- **Hardware**
  - Located in / near BA2
  - 4 processing systems optimized for different beams (e.g. SFTPRO vs LHC-type beams)
  - Different pairs of pick-ups for SFTPRO and LHC-type beams
  - 2 kicker modules per plane

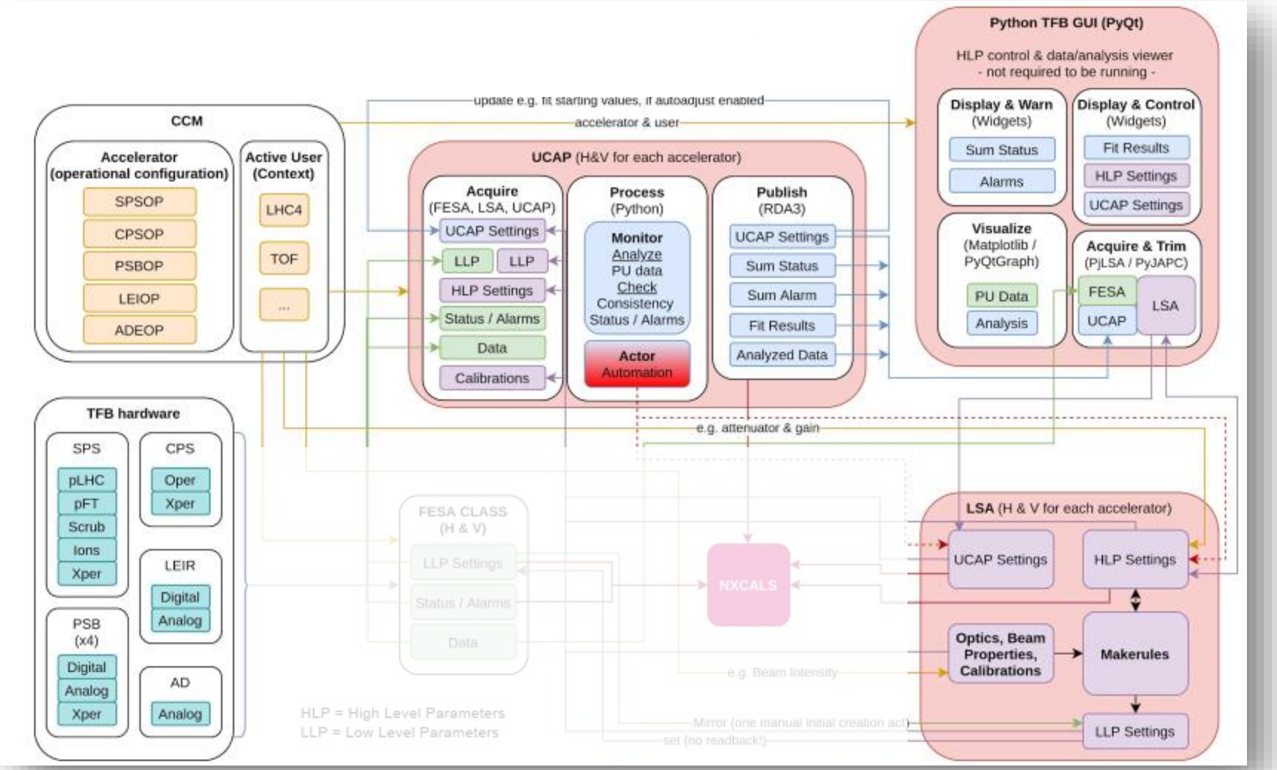
High-level parameter model

High-level parameter model
Motivation

Goal: simplify TFB commissioning and operation, expose relevant features

1. **Cycle generation:** automatically provide correct / reasonable settings
2. **Provide clear interface to change settings**
   - **Feedback modes:** *Hilbert, VectorSum, Komppula,* **bandwidth, active time** in cycle, etc.
   - **Phase calculation:** based on *phase advances* between pickups and kickers from *optics along cycle*, *programmed tune functions*, and *HLP phase* for fine tuning or MDs
   - **Front-end gain calculation:** injected intensity, bunch length, oscillation amplitude, calibration
   - **Adjust loop gain** throughout cycle
3. **Monitoring / control:** Python GUI for main settings, status overview, and diagnostics

High-level parameter model
Status



F. Armborst et al.

- **LSA:** value generators & makerules
- **Python GUI**
- **UCAP**

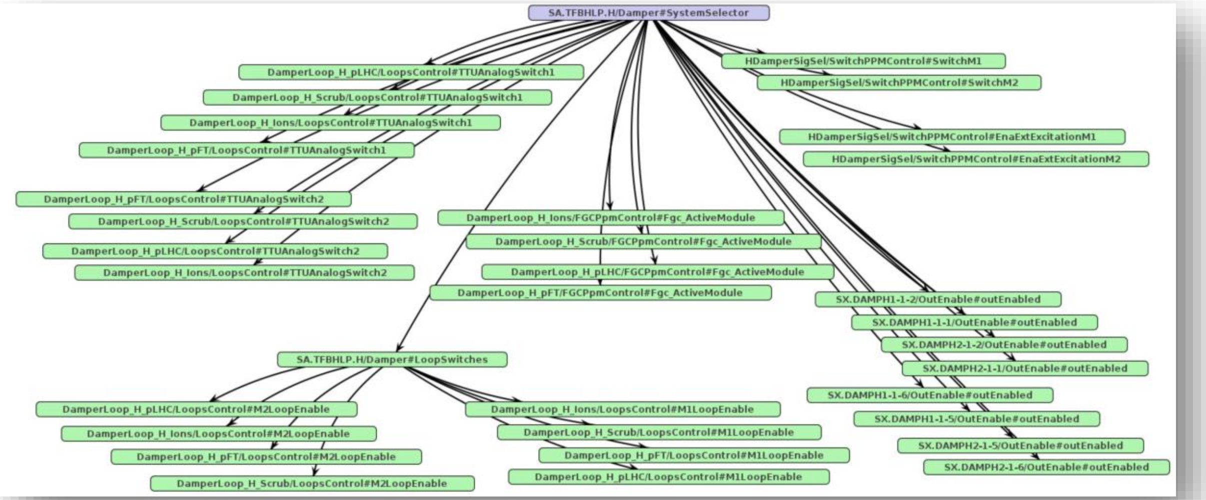
First implemented and used in 2021 – still partially under development, but LSA model & GUI mostly "stable"

H. Pahl (BE-OP-PS) working on this

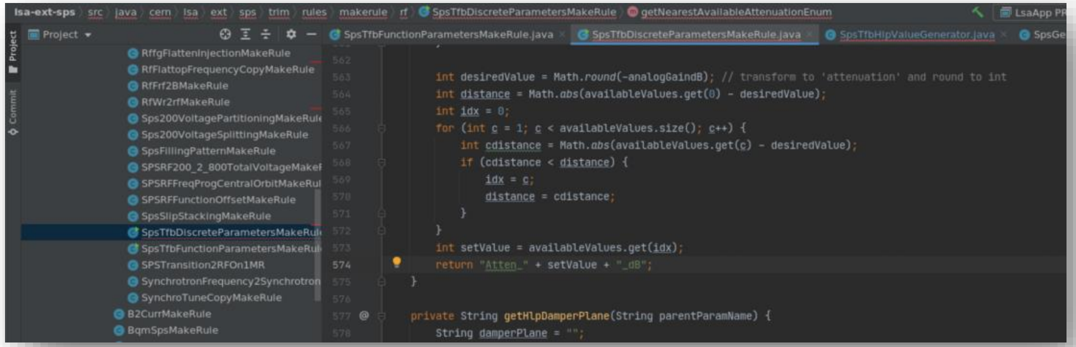
High-level parameter model

LSA model: overview

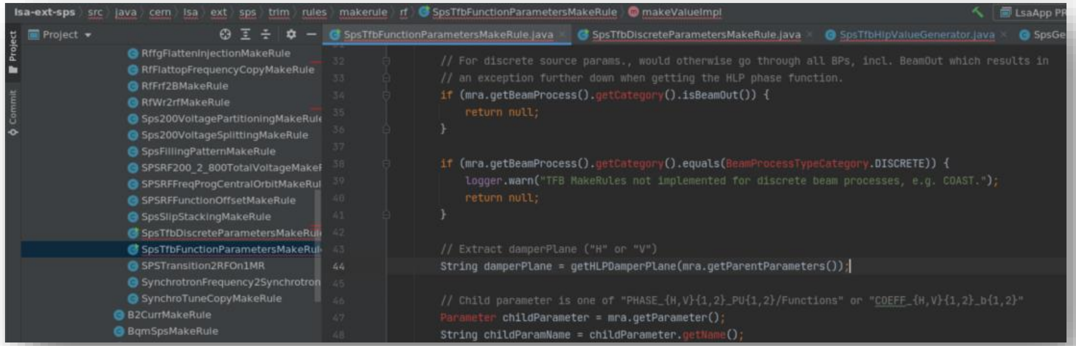
- **Logics:** 2 Makerules for discrete and function parameters, respectively
- **Value generators:** CONST_VG & SPS_TFBHLP_VG
  Default values for all HLP settings
- Rather **wide tree of parameter relations**:
  4 different systems, 2 planes, many LL switches, …
- **Goal is not to have to deal with LL settings during OP**



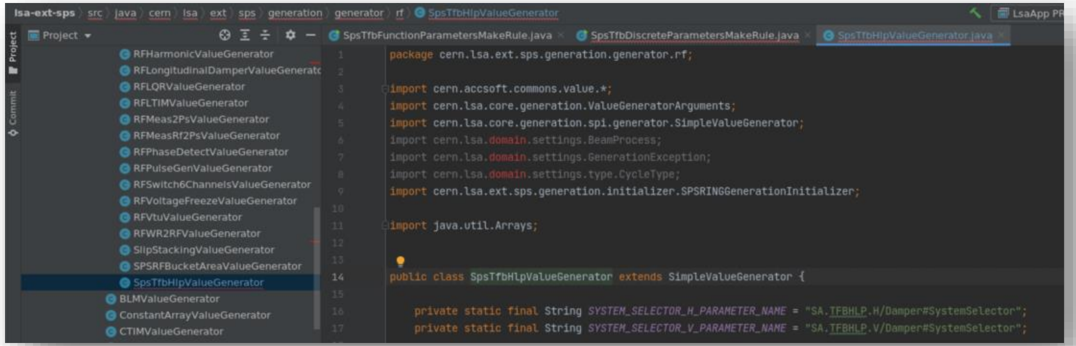
SPSTFBDISCRETEMR



SPSTFBFUNCTIONSMR



SPS_TFBHLP_VG



High-level parameter model
LSA model: overview

All these parameters are accessible and editable from the Python GUI (see later on)

LSA TFB HLP

Discrete

Damper settings

- SystemSelector
- StartTime
- StopTime
- LoopSwitches
- Bandwidth
- FeedbackMode
- InjectionBunchLengthNs
- InjectionIntensity1E10
- PeakOscillationAmplitudeMm

Acquisition settings

- PU1CalibSum
- PU2CalibSum
- PU1CalibDelta
- PU2CalibDelta

Functions

Damper settings

- CentralTune
- LoopGain
- FeedbackPhase

per plane

High-level parameter model

LSA model: overview

LSA TFB HLP

Discrete

Functions

Damper settings

- `SystemSelector`
- `StartTime`
- `StopTime`
- `LoopSwitches`
- `Bandwidth`
- `FeedbackMode`
- `InjectionBunchLengthNs`
- `InjectionIntensity1E10`
- `PeakOscillationAmplitudeMm`

Acquisition settings

- `PU1CalibSum`
- `PU2CalibSum`
- `PU1CalibDelta`
- `PU2CalibDelta`

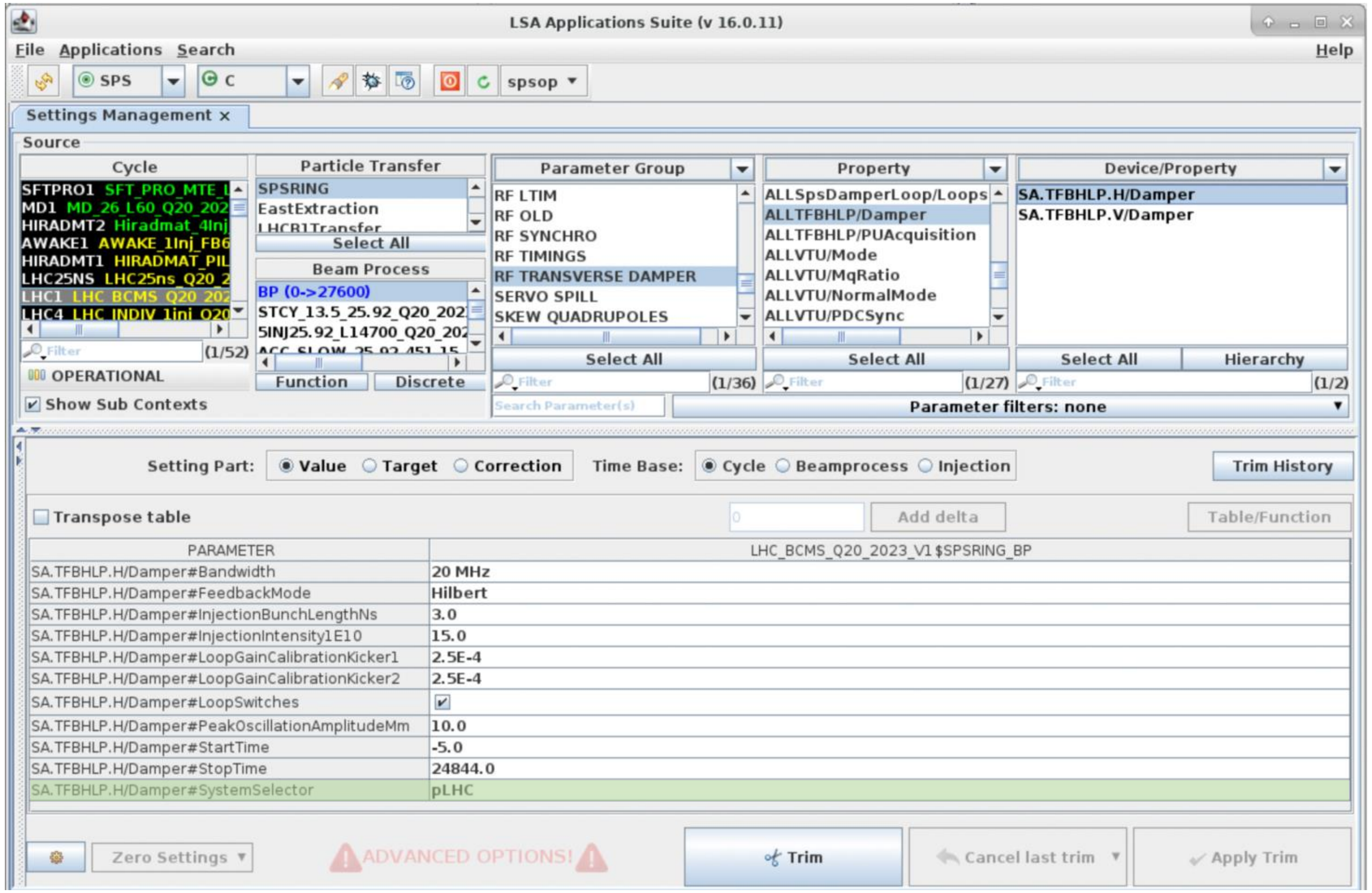
Damper settings

- `CentralTune`
- `LoopGain`
- `FeedbackPhase`

per plane

High-level parameter model

LSA model: discrete damper parameters



SystemSelector: *OFF, pLHC, pFT, IONS, SCRUB*

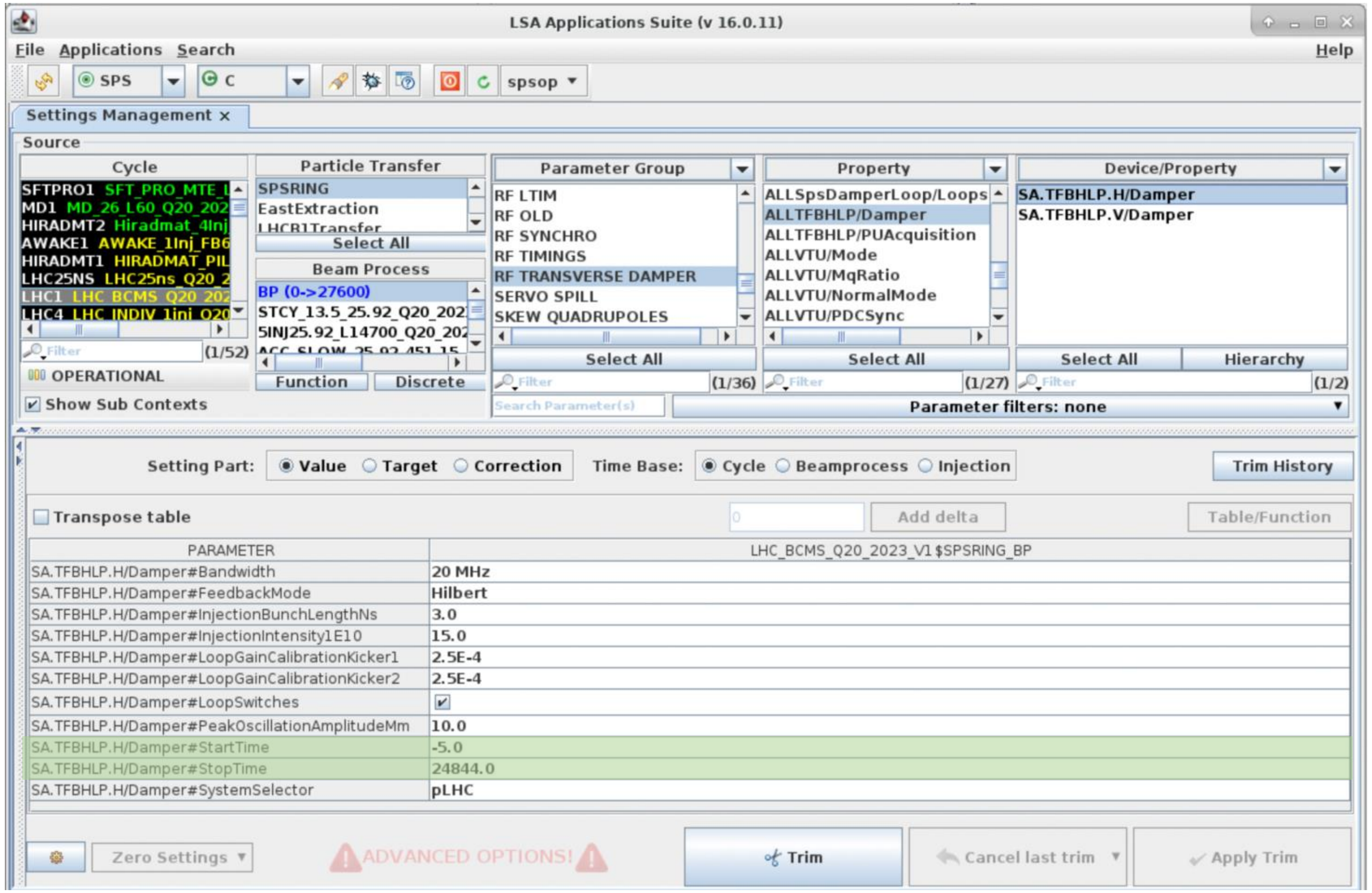
- Depending on beam type, pick suitable system
- Nearly all LL parameters depend on it …

SPS_TFBHLP_VG

- LHC-type beams: pLHC
- SFTPRO: pFT
- Ions: IONS

High-level parameter model

LSA model: discrete damper parameters



`StartTime`, `StopTime`: active time in cycle

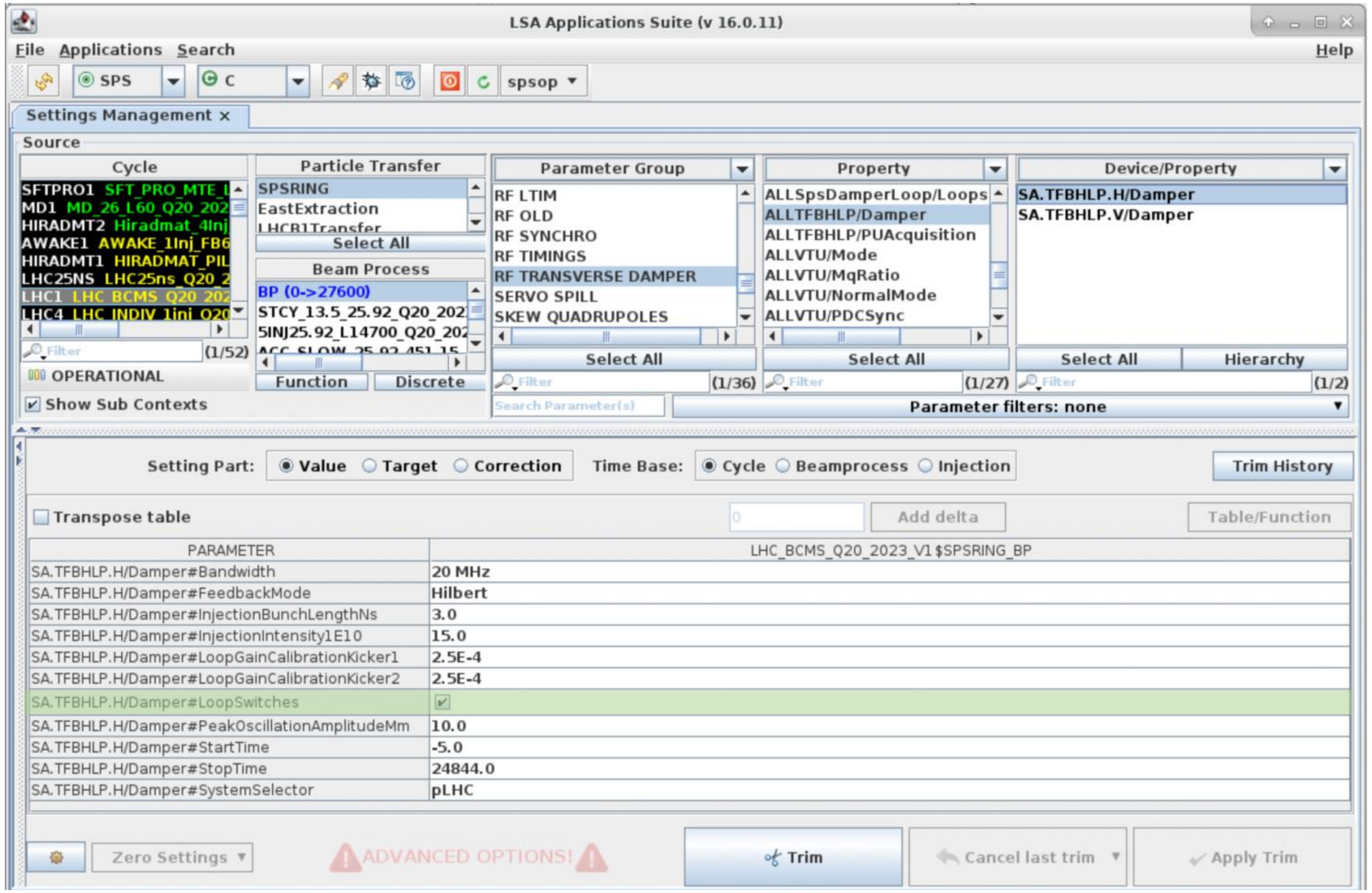
- Sets delays in RF TIMINGS LTIM/Delay and corresponding event flags / triggers
- Measured with *injection time reference*

VGs

- `StartTime`: -5 ms (CONST_VG)
- `StopTime`: 5 ms after beamOut (SPS_TFBHLP_VG)

High-level parameter model

LSA model: discrete damper parameters



LoopSwitches

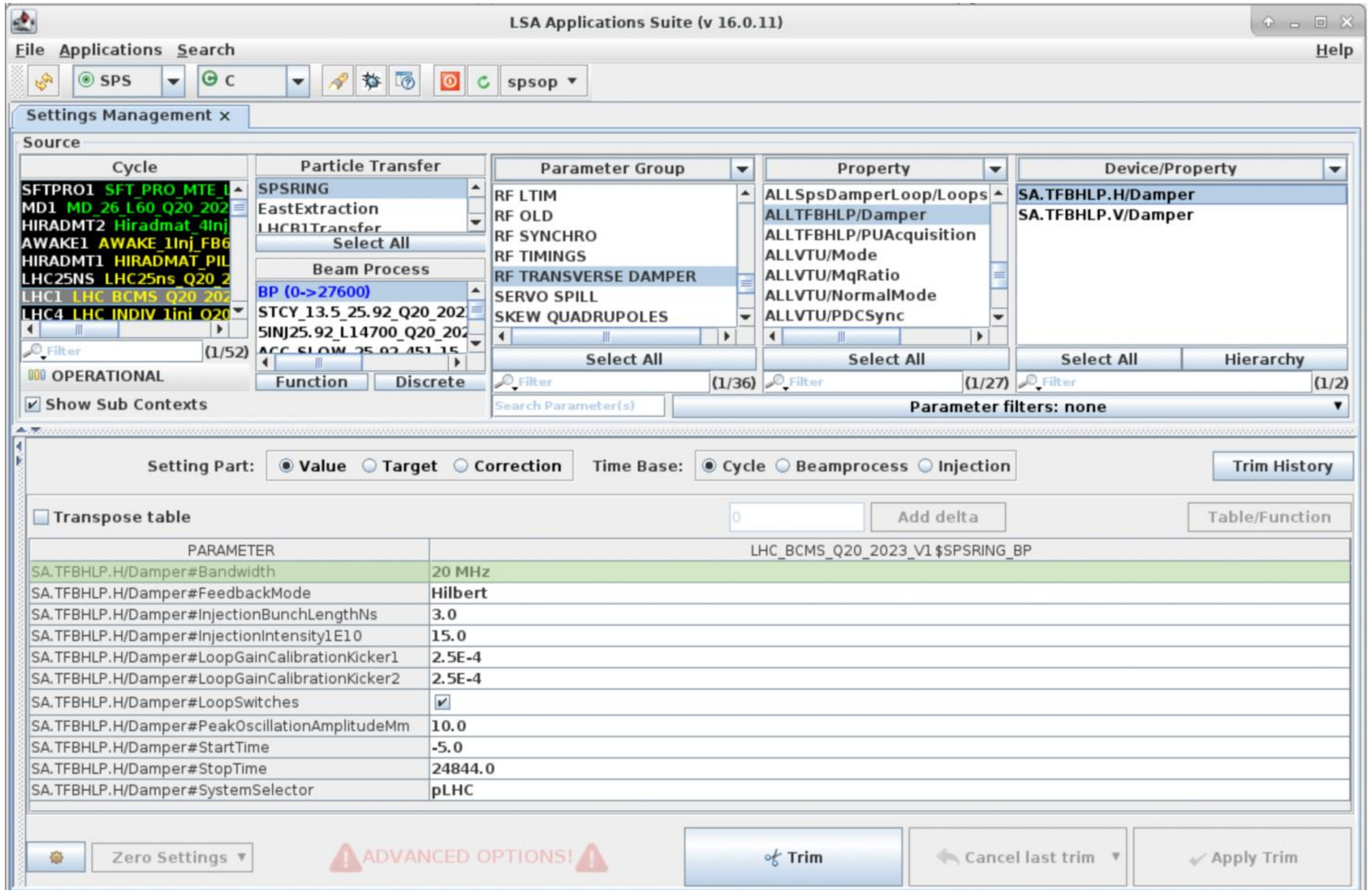
- Sets `M{1,2}LoopEnable` switches in `LoopsControl` based on `SystemSelector`
- *N.B.: cannot disable individual module with HLP. To be done on LL (see later)*

CONST_VG

- Initialized to *False (!)*

High-level parameter model

LSA model: discrete damper parameters



Bandwidth: *ZERO, FLAT, 3 MHz, …, 24 MHz*

- 32 FIR Gain eq. coeffs. in DSPU{1,2}
- 32 FIR Phase eq. coeffs. In DSPU{1,2} *(fixed to 6.5 MHz for now)*

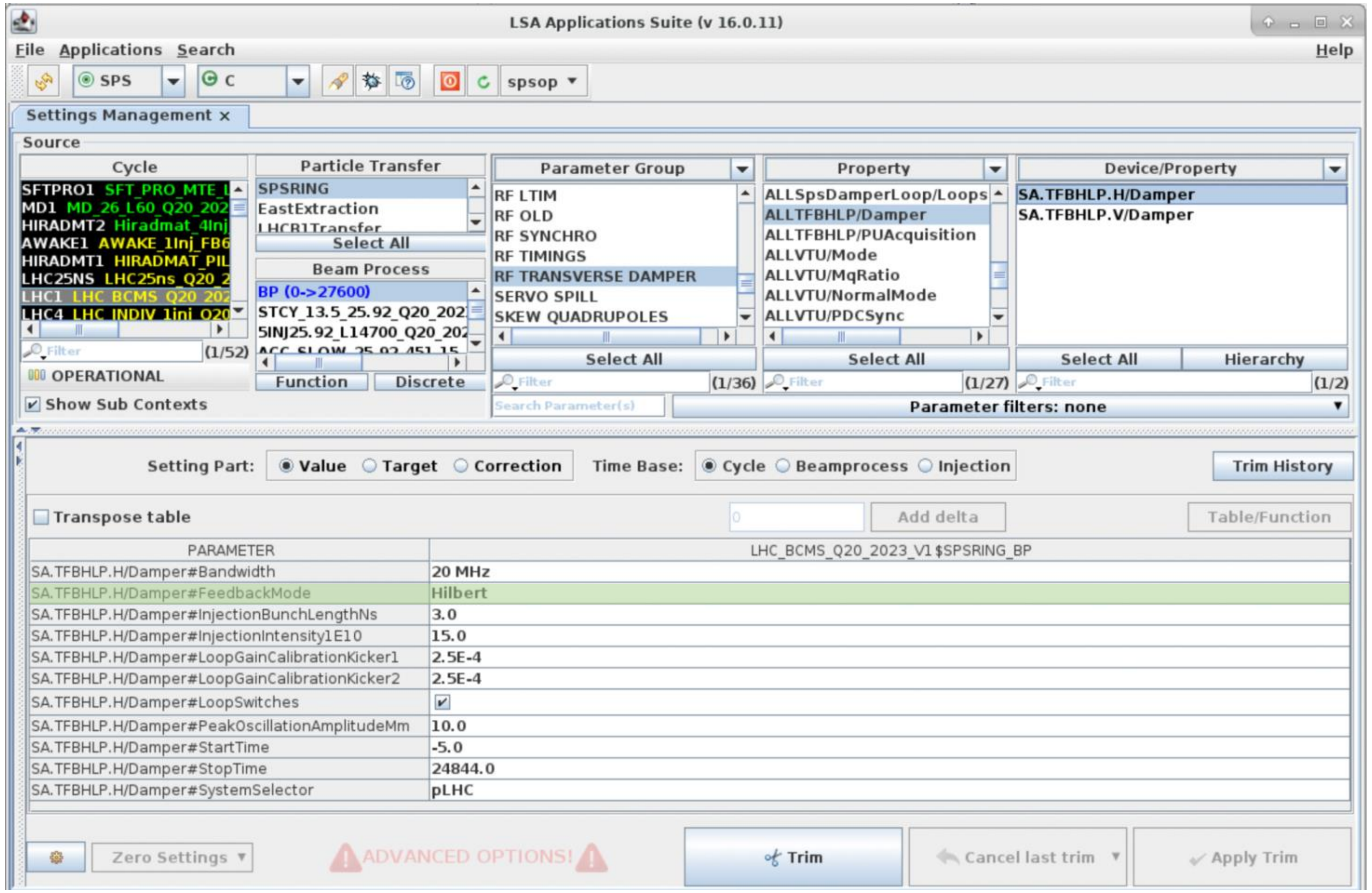
SPS_TFBHLP_VG

- LHC-type single bunch: 3 MHz
- LHC 25 ns multi-bunch: 20 MHz
- SFTPRO: 14 MHz

N.B.: lower bandwidth means larger kick strength, but TFB can potentially no longer act bunch-by-bunch

High-level parameter model

LSA model: discrete damper parameters



`FeedbackMode:` *Hilbert, VectorSum, Komppula*

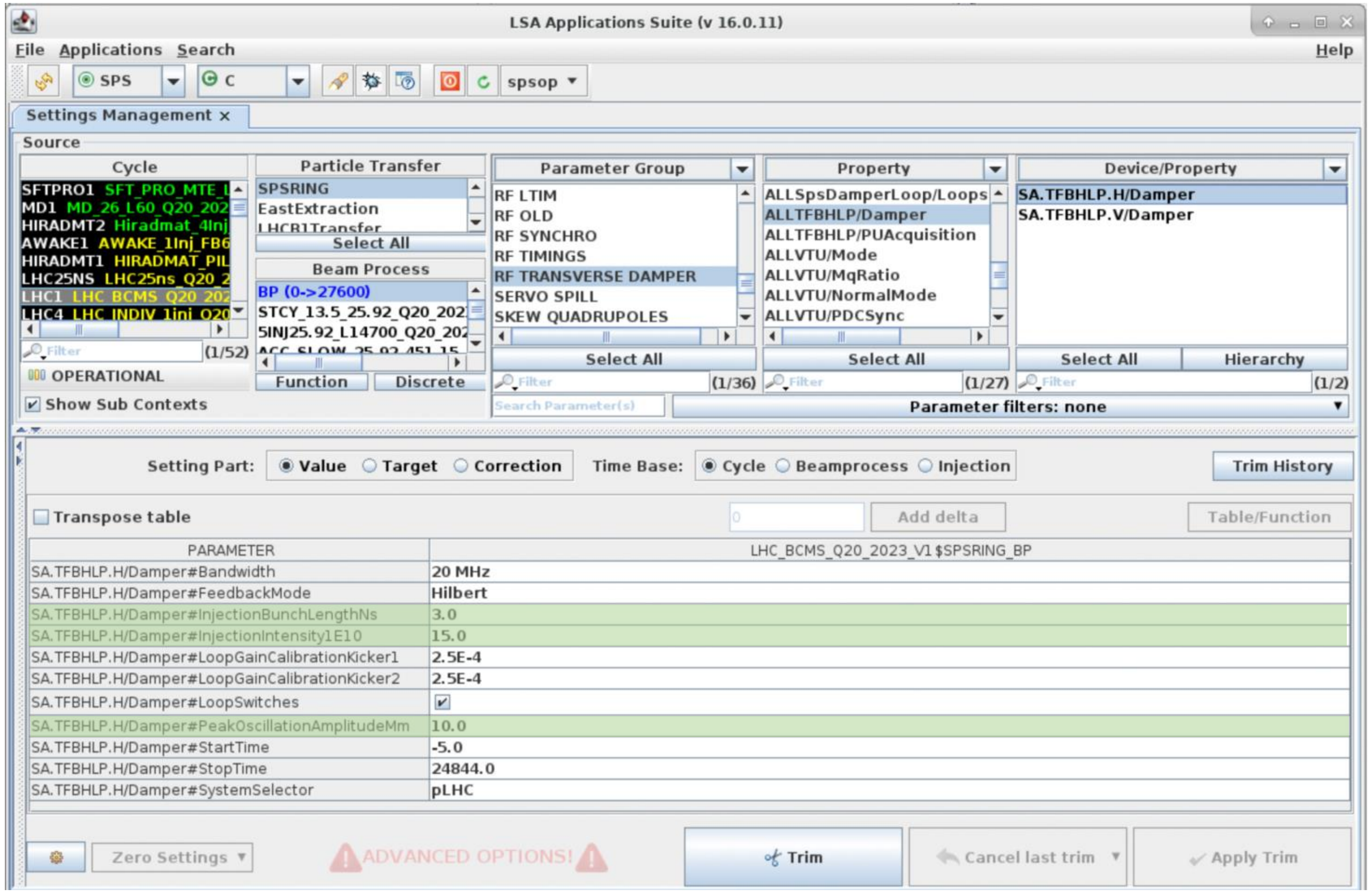
- Sets switches in DSPU{1,2}, FGC, and LoopsControl depending on mode
- Triggers calculation of LL PHASE functions based on `CentralTune`, `SystemSelector`, `FeedbackPhase`, and optics throughout cycle

`SPS_TFBHLP_VG`

- LHC-type beam, ions: Hilbert
- SFTPRO: VectorSum

High-level parameter model

LSA model: discrete damper parameters



`InjectionBunchLengthNs`, `InjectionIntensity1E10`, `PeakOscillationAmplitudeMm`

- Calculate and set front-end (FE) gains for sum & delta signals to best use dynamic range
- Depends on `SystemSelector` (RF or BB FE) and calibration factors for PU

VGs

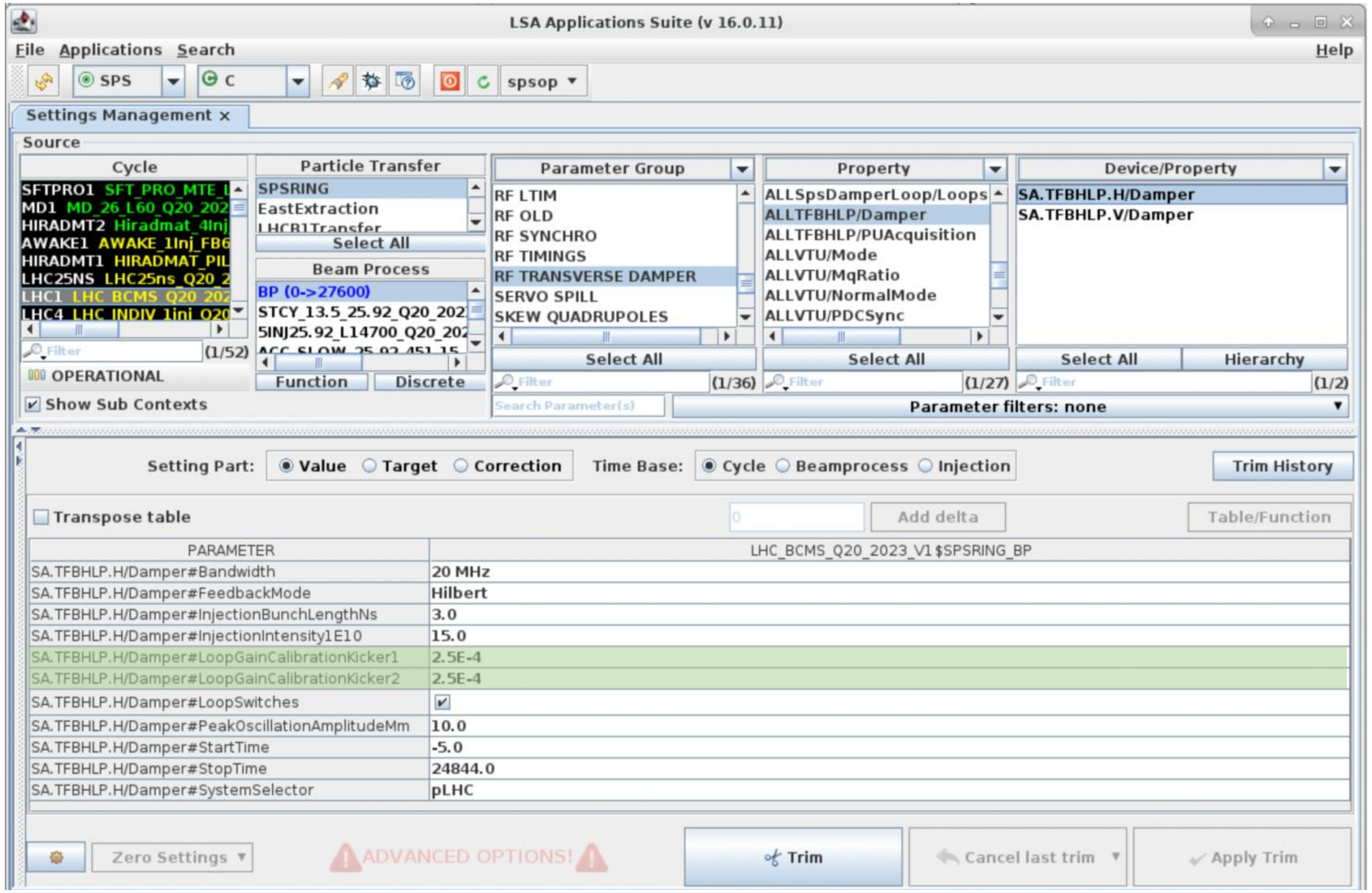
- `InjectionBunchLengthNs`: 3 ns (CONST_VG)
- `PeakOscillationAmplitudeMm`: 10 mm (CONST_VG)

N.B.: `InjectionIntensity1E10`

- Controlled by SPSGAINMR (*Y. Le Borgne*)
- **Hence, please change on even higher level:** `SpsGainCalculation/IntensityPerBunchE10` (parameter group: INSTRUMENTATION)

High-level parameter model

LSA model: discrete damper parameters



LoopGainCalibrationKicker{1,2}

- Multiplication factor to LoopGain function for the two kicker modules *(see next)*
- Could be calibrated for LoopGain to correspond to specific damping time *(this has not been done)*

CONST_VG

- Initialized to 2.5E-4

High-level parameter model

LSA model: overview

LSA TFB HLP

Discrete

Functions

Damper settings

- SystemSelector
- StartTime
- StopTime
- LoopSwitches
- Bandwidth
- FeedbackMode
- InjectionBunchLengthNs
- InjectionIntensity1E10
- PeakOscillationAmplitudeMm

Acquisition settings

- PU1CalibSum
- PU2CalibSum
- PU1CalibDelta
- PU2CalibDelta

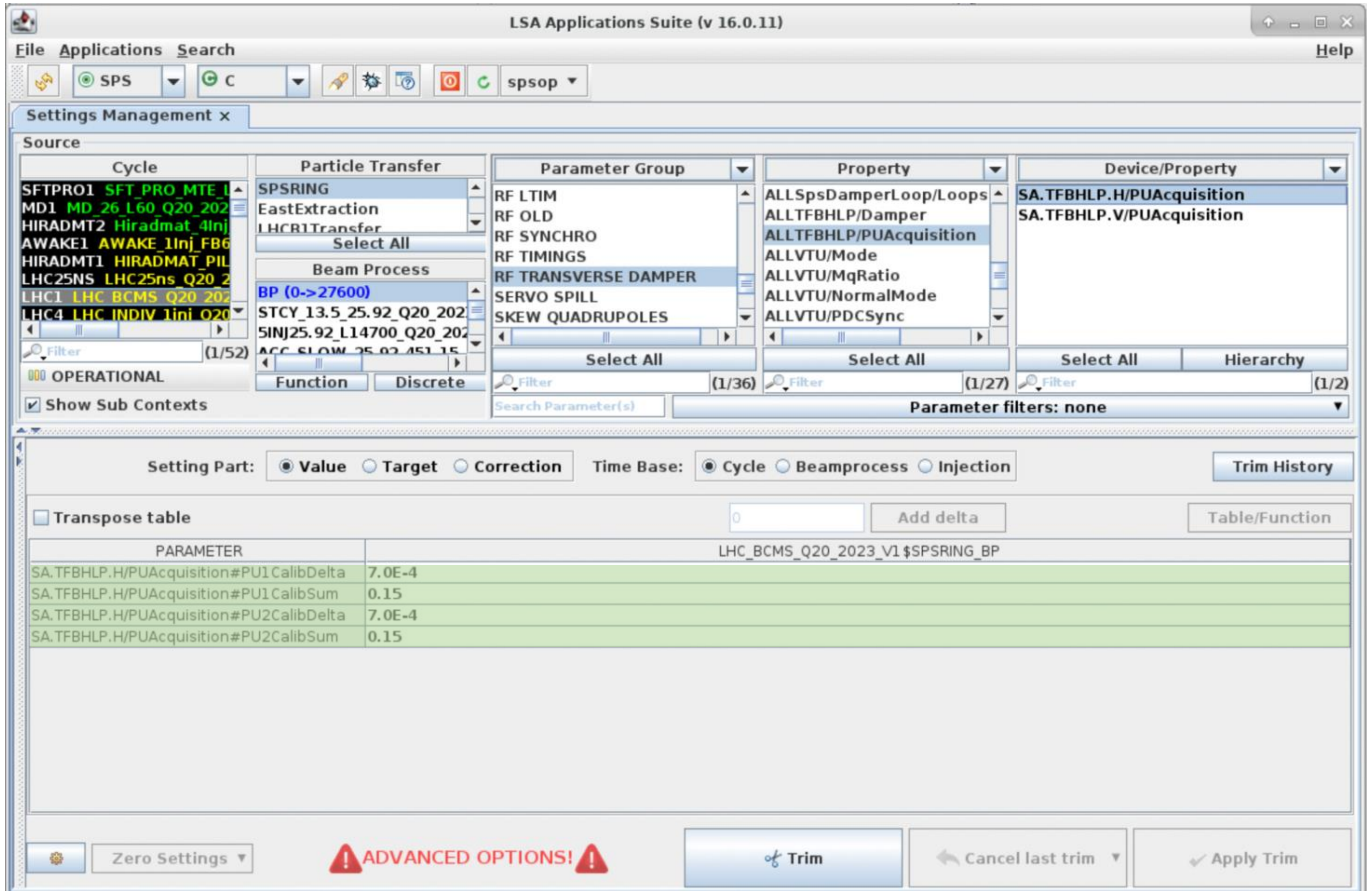
Damper settings

- CentralTune
- LoopGain
- FeedbackPhase

per plane

High-level parameter model

LSA model: discrete acquisition parameters



`Acquisition#PU{1,2}Calib{Delta,Sum}`

- PU calibration factors
- PU-, and hence beam-type dependent
- Enter FE gain calculations
- Defined in 2021 when setting up with beam(*)

`SPS_TFBHLP_VG`

- LHC-type
  - `PU{1,2}CalibSum`: 0.15
  - `PU{1,2}CalibDelta`: 7E-4
- SFTPRO
  - `PU{1,2}CalibSum`: 0.25
  - `PU{1,2}CalibDelta`: 2E-3

(*) https://logbook.cern.ch/elogbook-server/GET/showEventInLogbook/3284228

High-level parameter model

LSA model: overview

LSA TFB HLP

Discrete

Damper settings

- SystemSelector
- StartTime
- StopTime
- LoopSwitches
- Bandwidth
- FeedbackMode
- InjectionBunchLengthNs
- InjectionIntensity1E10
- PeakOscillationAmplitudeMm

Acquisition settings

- PU1CalibSum
- PU2CalibSum
- PU1CalibDelta
- PU2CalibDelta

Functions

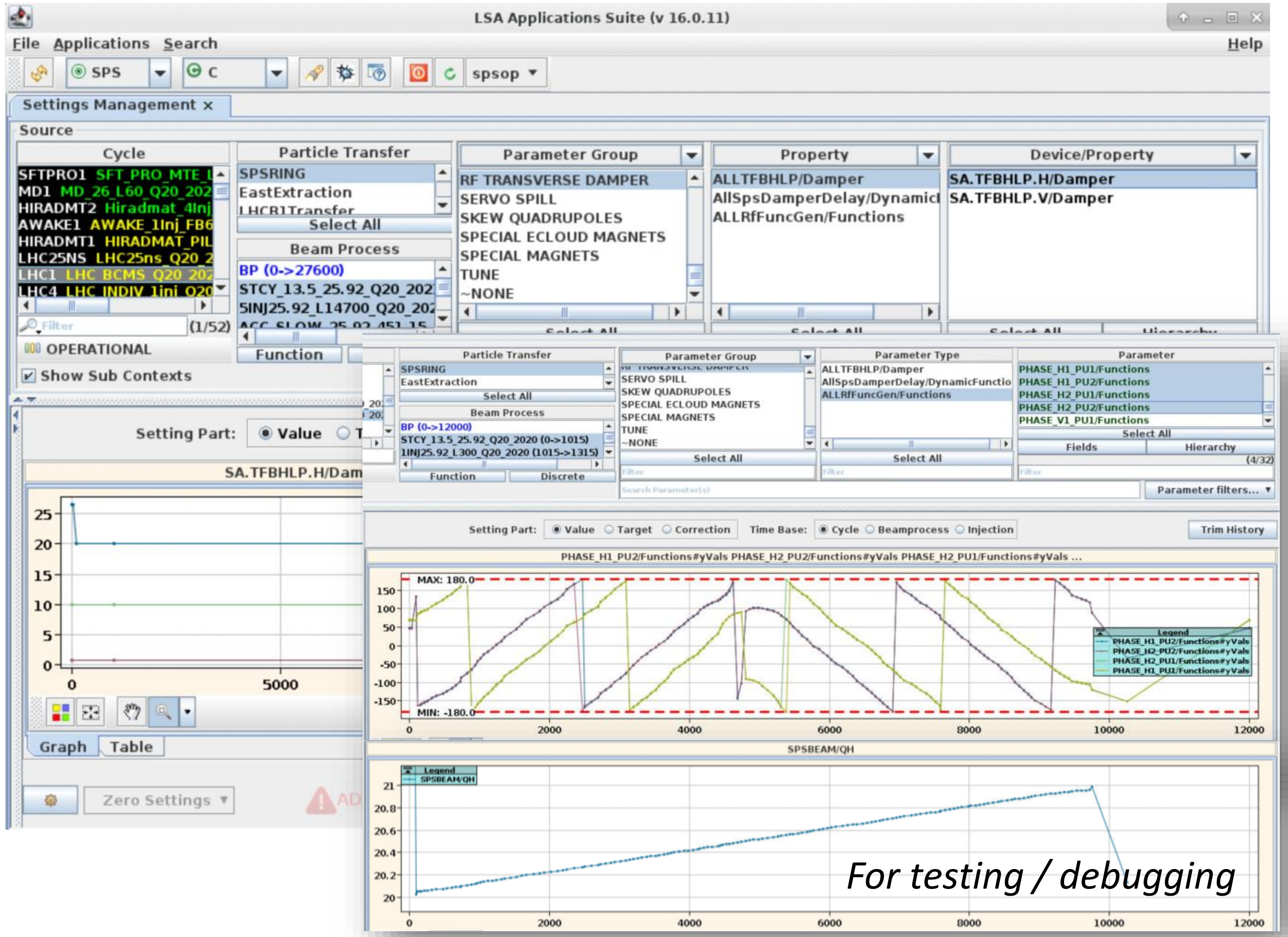
Damper settings

- CentralTune
- LoopGain
- FeedbackPhase

per plane

High-level parameter model

LSA model: functions



- **`CentralTune:`** should correspond to machine tune to ensure proper calculation of feedback phase
- **`FeedbackPhase:`** additional phase offset that is added on top of the one calculated from optics model. Used for fine-tuning / MDs.
- **`LoopGain:`** damper gain setting in arbitrary units. Check LL parameter to verify if in saturation

VGs

- **`CentralTune:`** `SPSBEAM/Q{H,V}` (target)
- **`FeedbackPhase:`** 0 deg (*)
- **`LoopGain:`** 0 (!)

(*) *If optics model is accurate and tunes are properly set, FeedbackPhase zero is ideal setting. Runs in ‘21 & ‘22 have shown this is mostly the case except for multi-bunch, high-intensity beams where we expect an offset.*

High-level parameter model

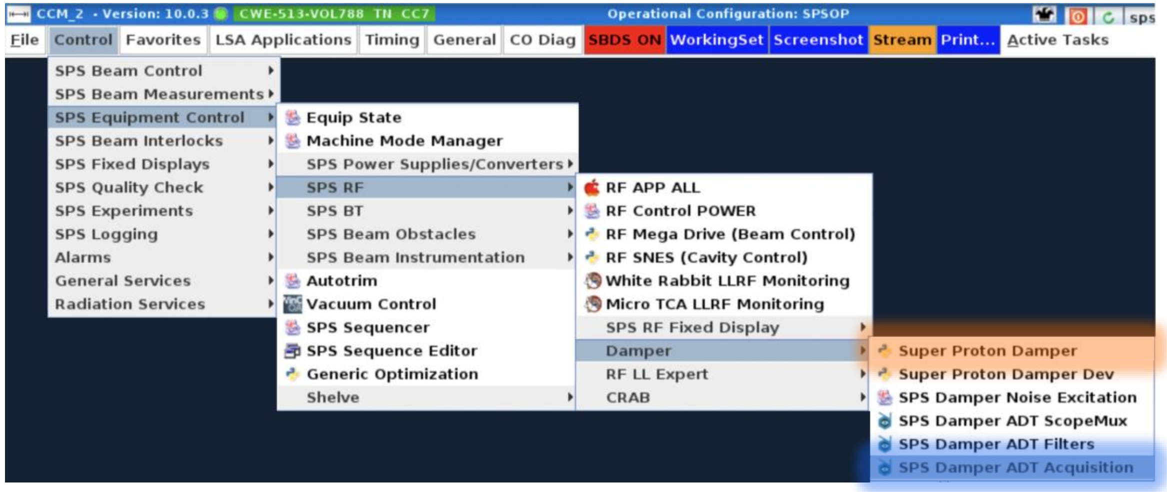
Take away

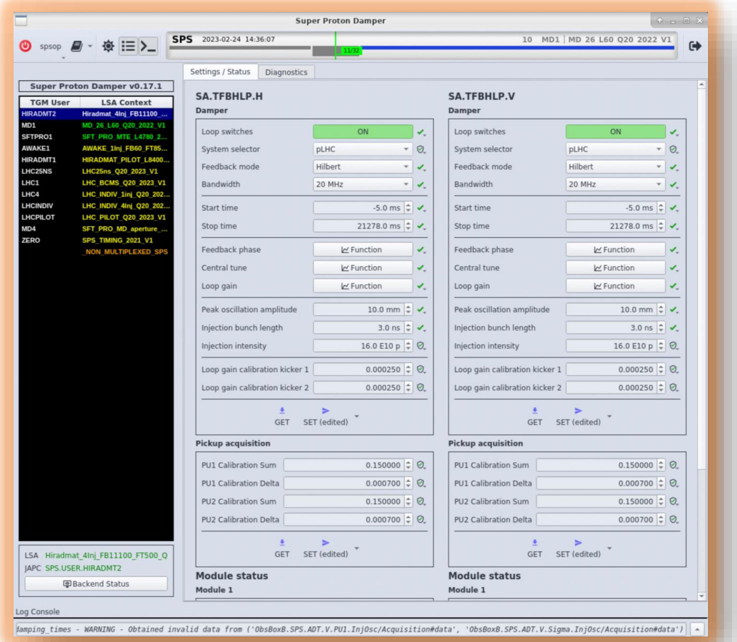
- **Typically, HLP settings do not need to be changed during operation**
- **Notable exceptions**
  - **Intensity steps**
    `InjectionIntensity1E10` **via `SpsGainCalculation/IntensityPerBunchE10`**
    in parameter group INSTRUMENTATION.
  - **In case of instabilities**, e.g. after intensity steps, you can try to adjust
    `SA.TFBHLP.{H,V}/Damper#LoopGain`
    N.B.: check also LL if not in saturation already: `GAIN_{H,V}{1,2}_OUTA/Functions#yVals`.
  - **Once injection trajectory corrected: reduce `PeakOscillationAmplitudeMm`** to improve resolution
  - **MDs**
- When generating HLP settings: **`LoopSwitches`** and **`LoopGain` function** are **initialized to False** and **zero,** resp., i.e. **damper OFF**

Tools & procedures

Tools & procedures

Overview





Python GUI "Super Proton Damper"

Day-to-day operation

Inspector panel "Damper Launcher"

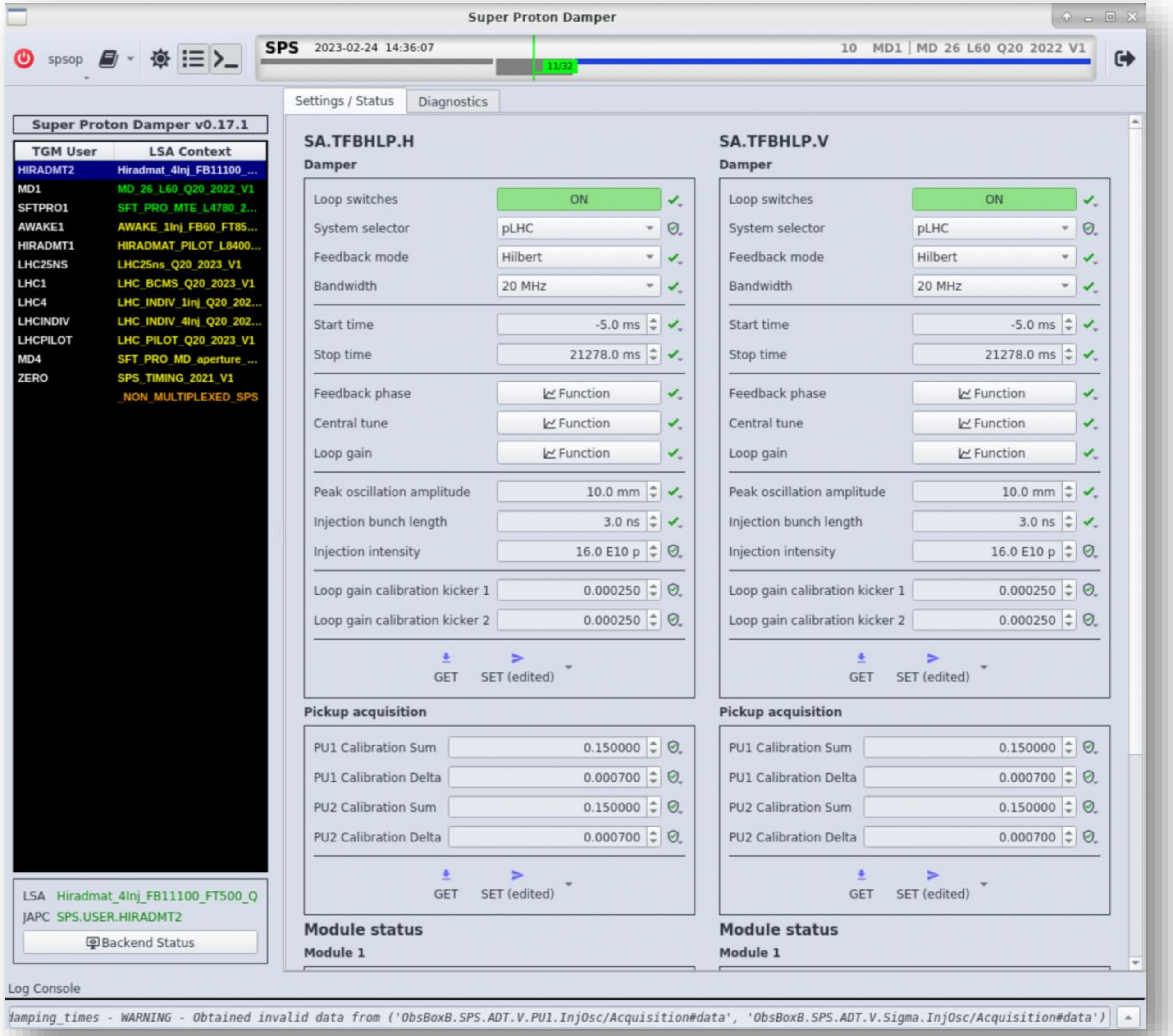
Commissioning, TFB diagnostics, e.g. to validate phase & delay settings

Tools & procedures

Python GUI

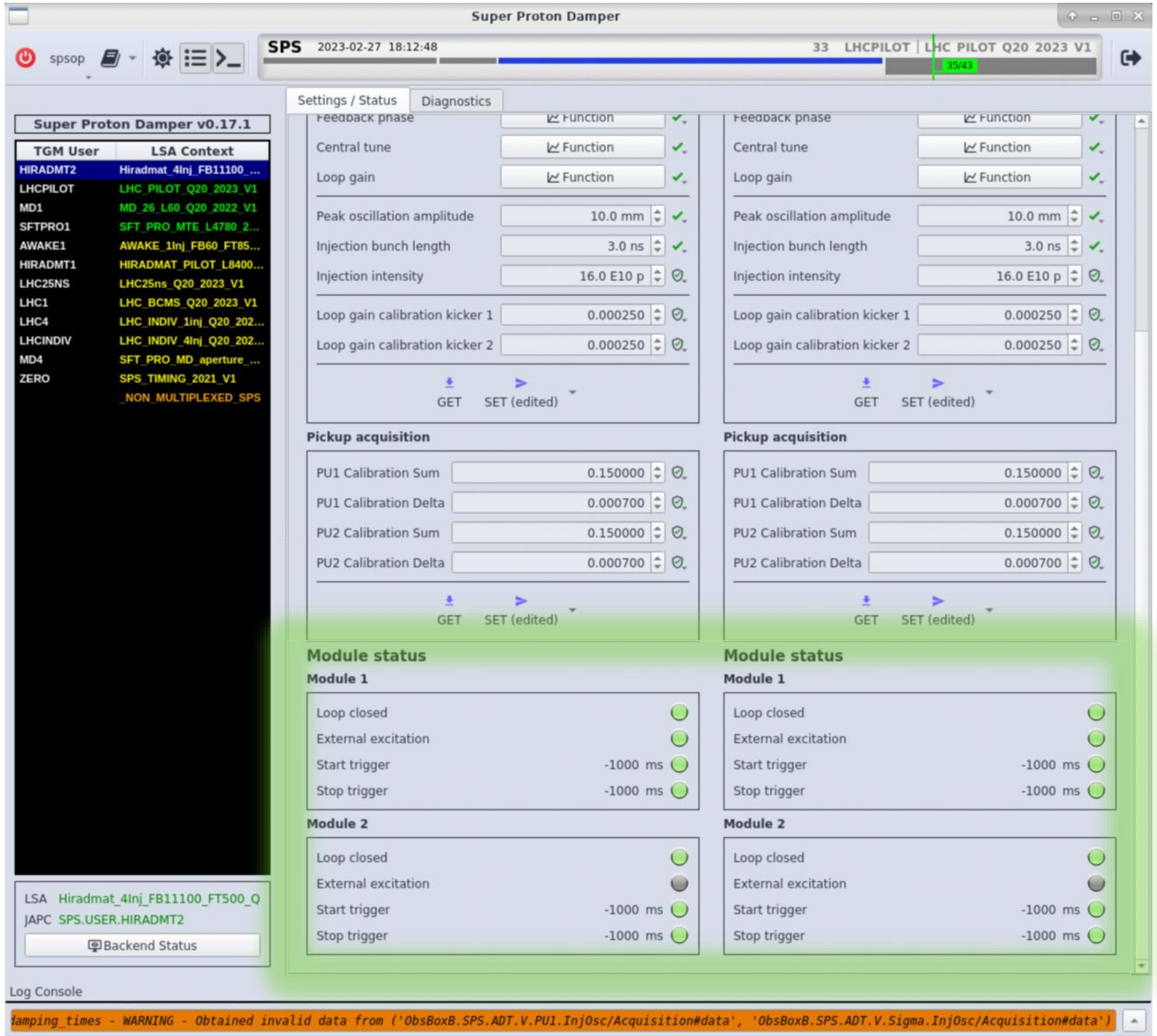
Settings

- **All HLP settings** visible & trimmable
- They are **subscriptions** and hence update automatically when changed elsewhere
- Parameters can be set **individually or as a group**
- Some **parameters are protected** to prevent accidental changes *(e.g. calibration factors)*



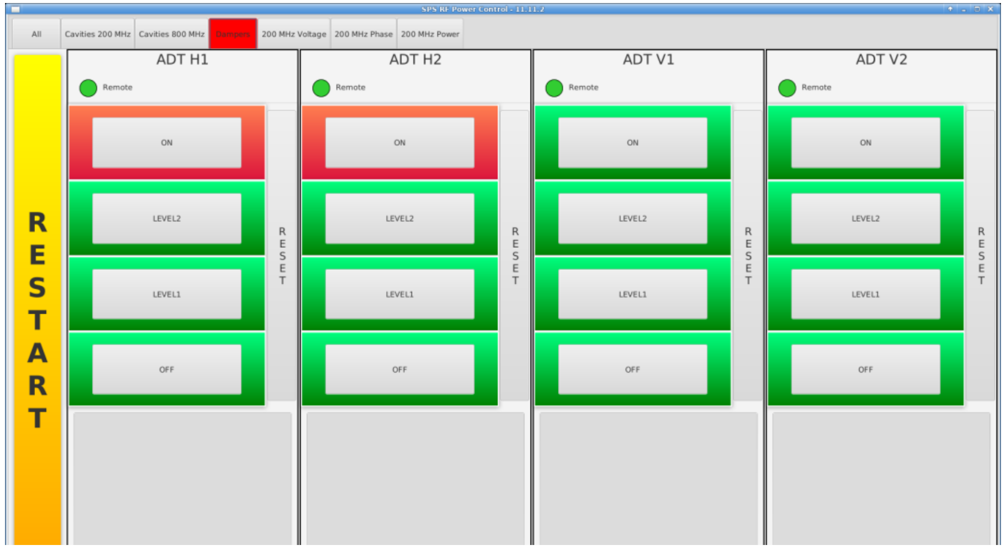
Tools & procedures

Python GUI



Status

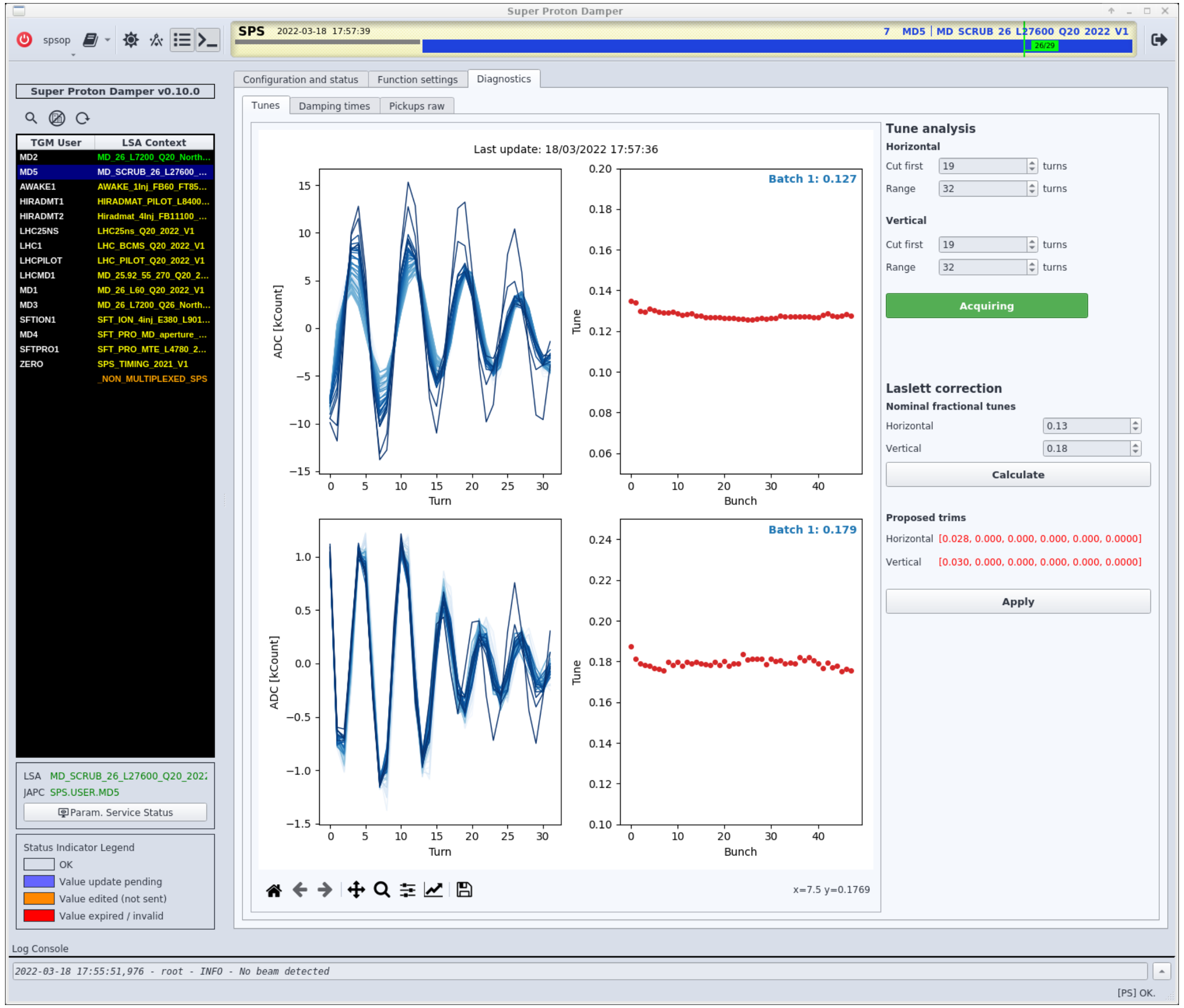
- Loops and trigger status per module & plane
  Updates at end of cycle
- Power system not integrated as there is a separate app and display



Power systems display

Tools & procedures

Python GUI



Old version

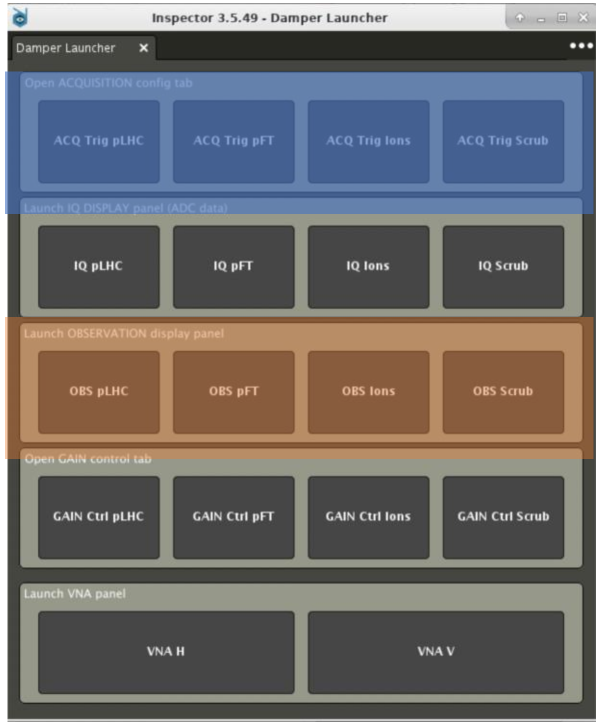
Diagnostics tab

- Bunch-by-bunch **tunes and damping times** as measured using old TFB ObsBox **injection oscillation buffer**
- Results **not always reliable** (H/V coupling, S/N)
- To measure bunch-by-bunch tunes accurately, **can also use Laslett application** (LHC BPMs & MKQ)

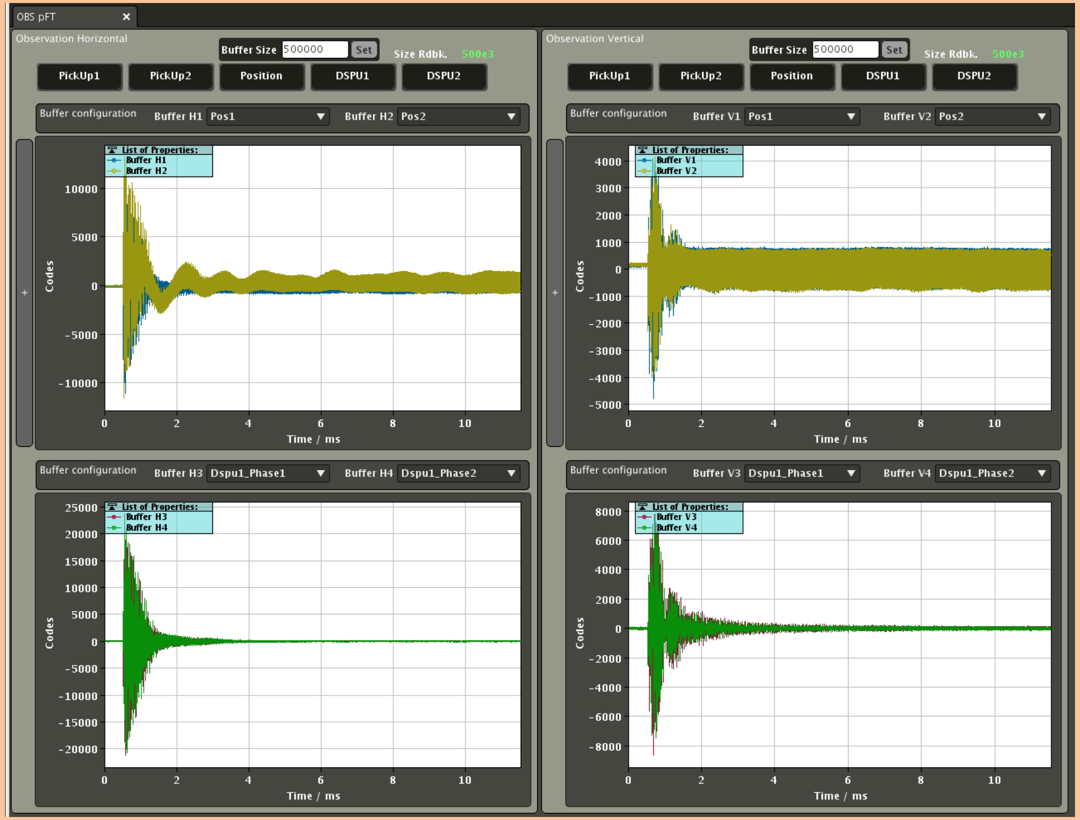
Tools & procedures
ObsBox buffer

Objective: validate injection damping

1. SPS Damper ADT Acquisition



3. OBS *damper module*



1. Set "Buffer Size" to 500k *or less if it freezes, adapt trigger time*
2. Use "Position" preset
3. Signals should be within [-32k, 32k] and show damping times ~1 ms
4. **If no signal or if saturated:** likely wrong front-end gain setting. Check HLP bunch intensity, bunch length, max. oscillation amplitude.

2. ACQ TRIG *damper module*

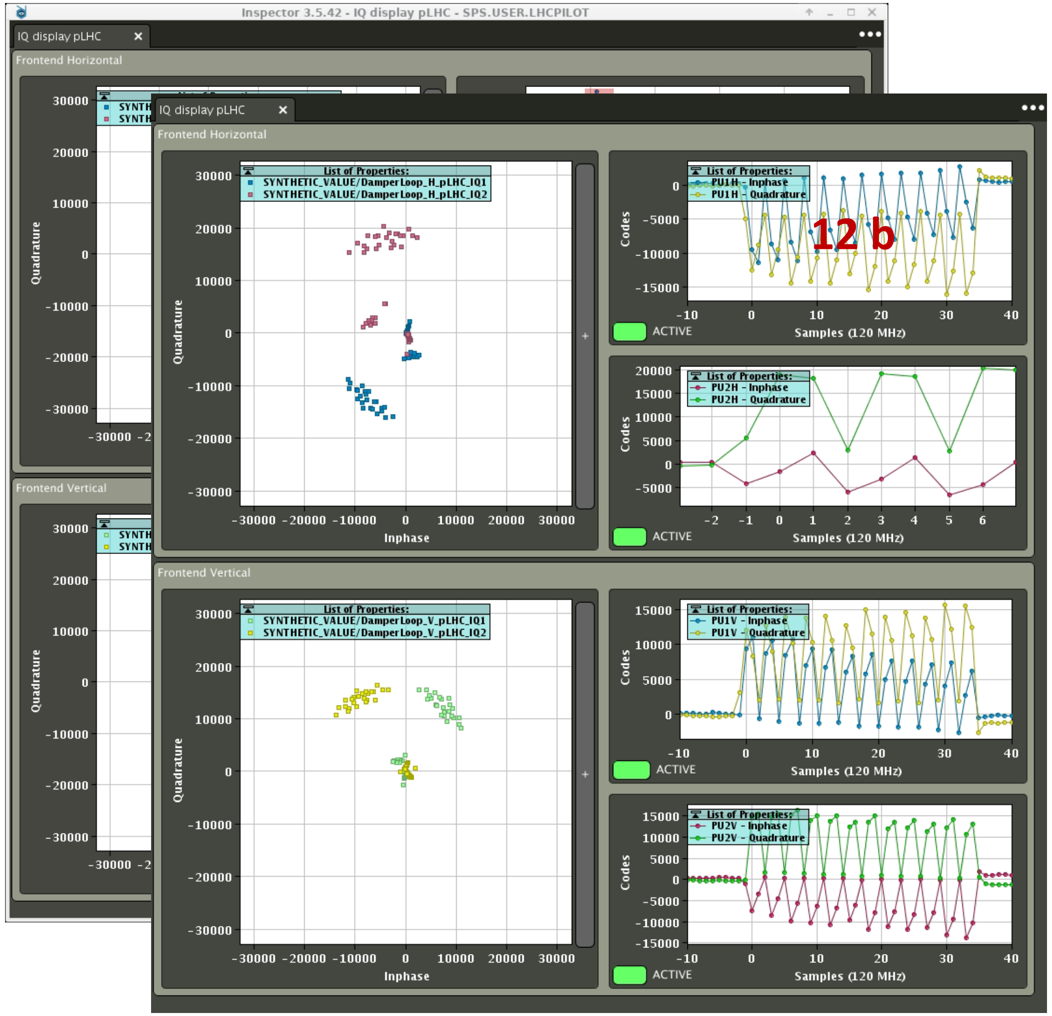
1. Delay is with F1KFO: *forewarning 1000 ms, first occurrence*
   Marks when buffer is frozen
2. To see 1st inj., 1012 ms is a good setting if buffer has length 500k
3. Press "Configure" button

Tools & procedures
IQ display

Objective: clock sync / adjustment

1. SPS Damper ADT Acquisition

2. IQ *damper module*



1. Shows PUs 1 & 2, H & V
   Here: single bunch, resp. 12 b.
   Sampling at 120 MHz, i.e. 3 samples per 25 ns slot
2. Signal from first bunch should be aligned with sample 0
3. *If not, adjust LSA clock parameters (LL)*

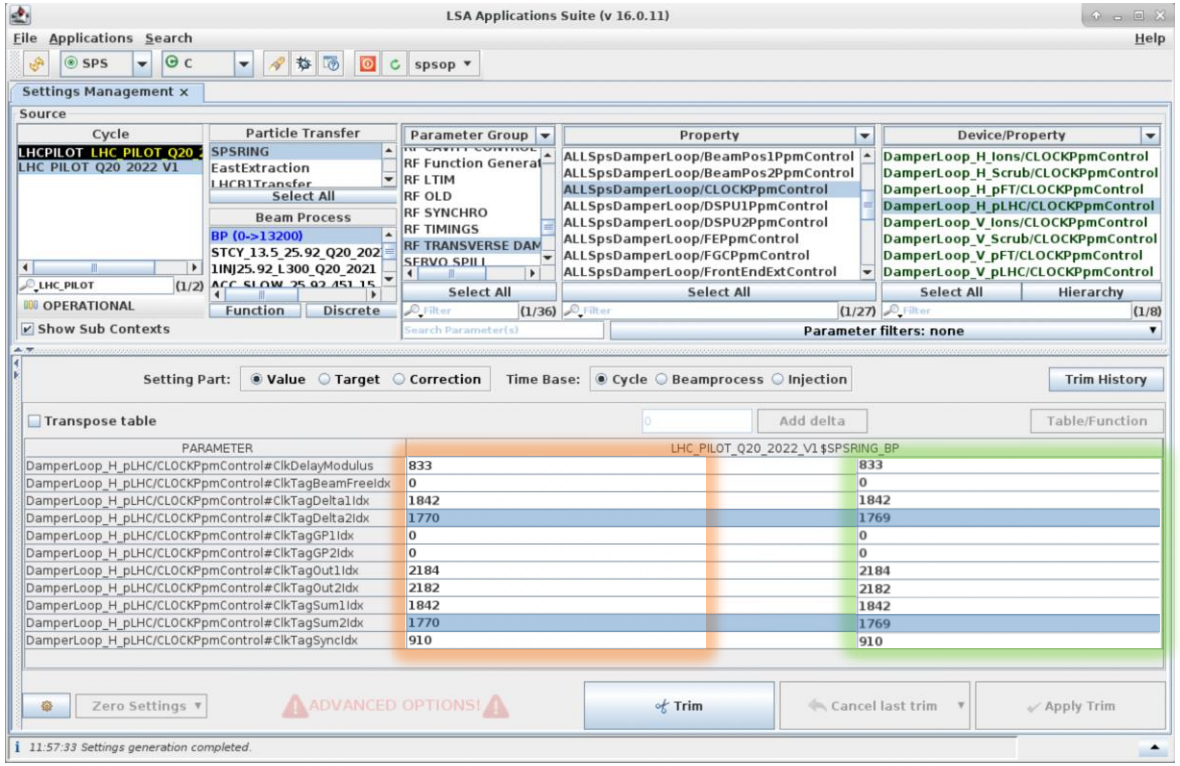
Tools & procedures

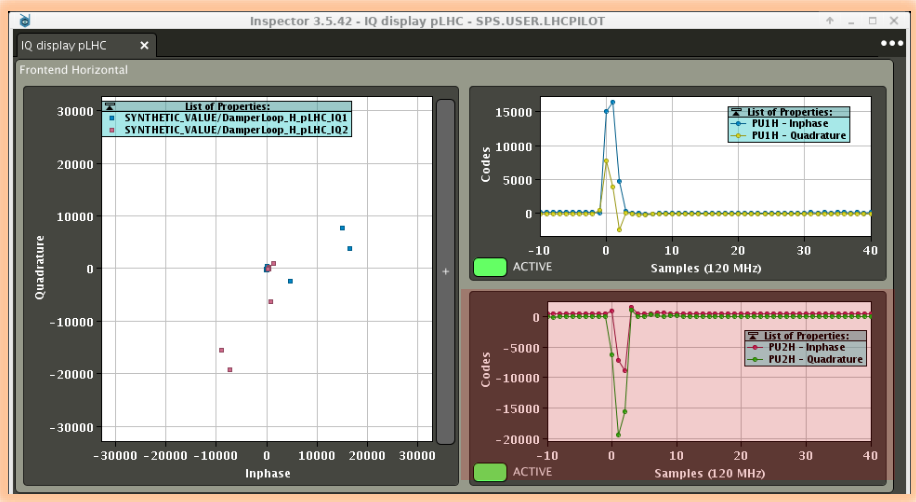
IQ display

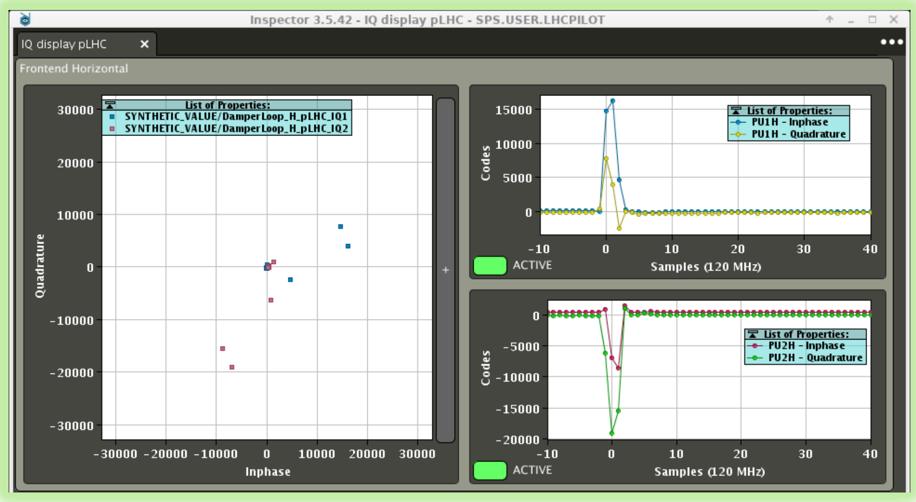
Objective: clock sync / adjustment

1. Identify PU signal that is "misaligned" *(here PU2H)*
2. Find clock parameter for PU, plane, and module in Trim Editor
3. Change `ClkTagDelta` & `ClkTagSum` consistently

1 tick corresponds to $1/120\ \text{MHz} = 8.333\ \text{ns}$



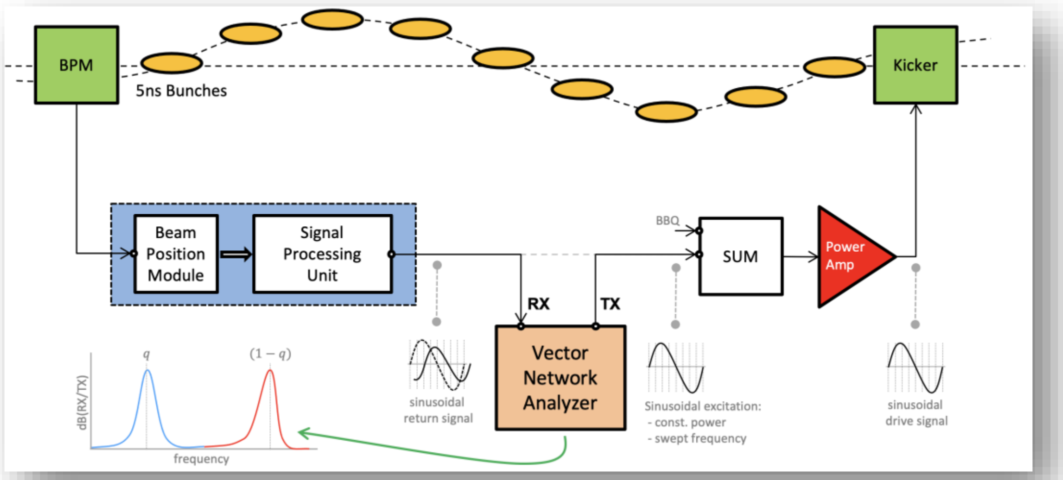




***N.B.** these parameters should be identical for all LHC-type beams (pFT beams resp.), and typically not change during a run*

Tools & procedures

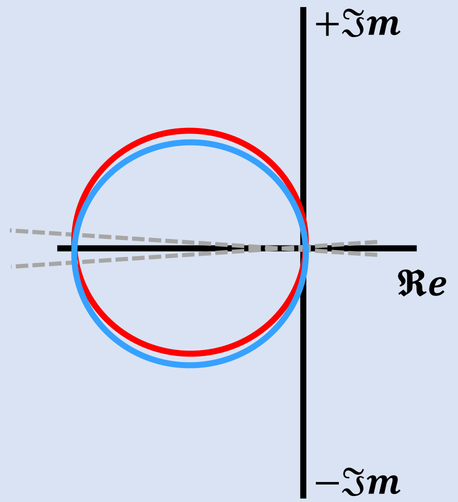
Beam transfer function (BTF)



- **BTF with Vector Network Analyzer (VNA)**
  - Excite transverse resonances with sinusoidal signal (TX)
  - Measure narrowband beam response and display as polar plots (RX)
- **Two settings issues** can be identified with BTF
  - **Feedback phase:** should be OK thanks to HLP Makerule (for single bunch)
  - **Fine delay:** may need to be adjusted during commissioning (during run for thermal effects)

Target: aligned

NB: $\arg(G) + \omega T + \phi_{PK} = -180°$



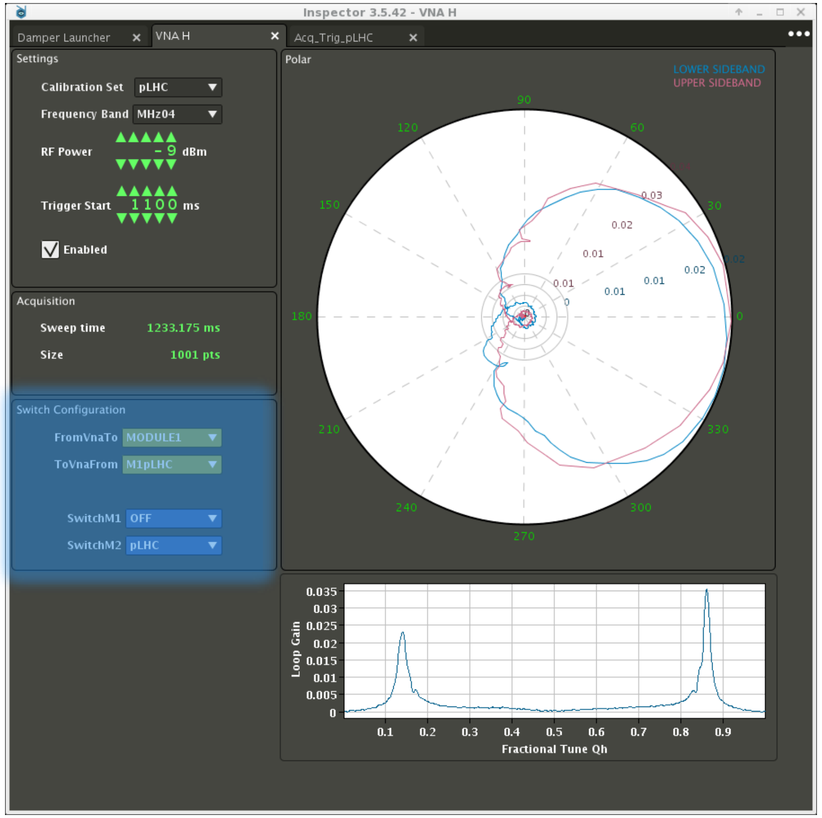
Tools & procedures

Vector Network Analyzer (VNA)

Objective: delay and phase validation

1. SPS Damper ADT Acquisition

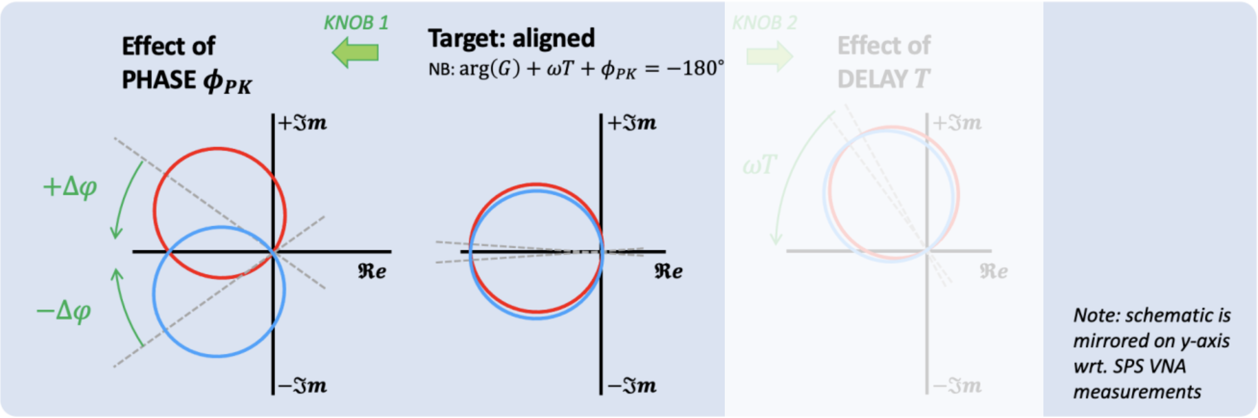
2. VNA H / V



1. Frequency Band: start low, e.g. at 1 MHz and move up in steps, but stay within HLP Bandwidth
   Low freq.: phase adjustments
   High freq.: fine delay adjustments
2. RF Power between -30 dBm to -10 dBm. If too high can trip power system.
3. Trigger Start: 1100 ms
4. Enabled: True
5. Switch configuration: here e.g. open-loop measurement for module 1, with module 2 actively damping
6. HLP LoopSwitches must be set to True
7. Revert settings when done
   VNA chirp visible in MultiQ

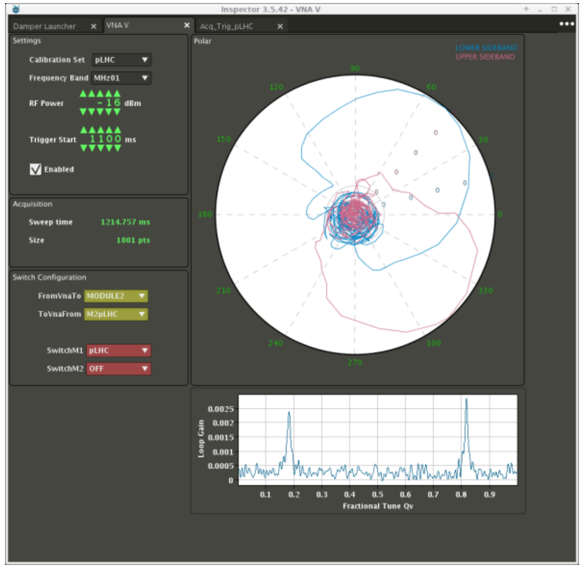
N.B.: the VNAs crash / freeze occasionally. G. Kotzian and M. Schenk have accounts to reset and restart them.

Tools & procedures
VNA: phase adjustment

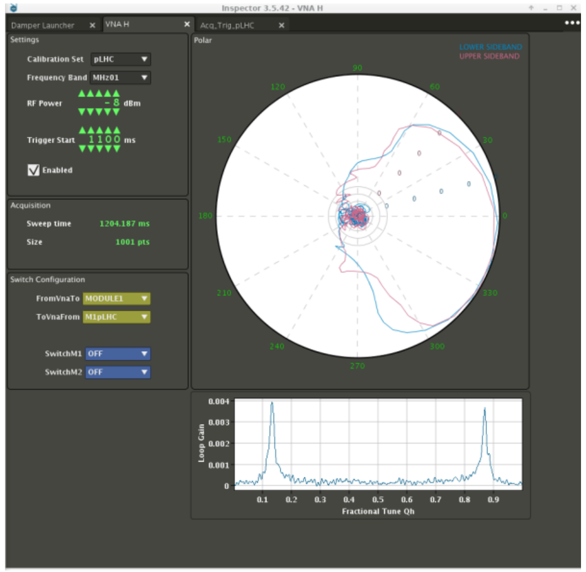


- In case you observe phase error, verify first that
  - HLP `CentralTune` corresponds to machine tune
  - HLP `FeedbackPhase` is set to zero
- If these settings are correct and phase error persists, use HLP `FeedbackPhase` parameter to adjust
- Move e.g. in steps of ±20 deg
- ***N.B.:*** *if phase is badly set, TFB can cause tune shift or worse, drive beam unstable (anti-damping)*

Phase is off

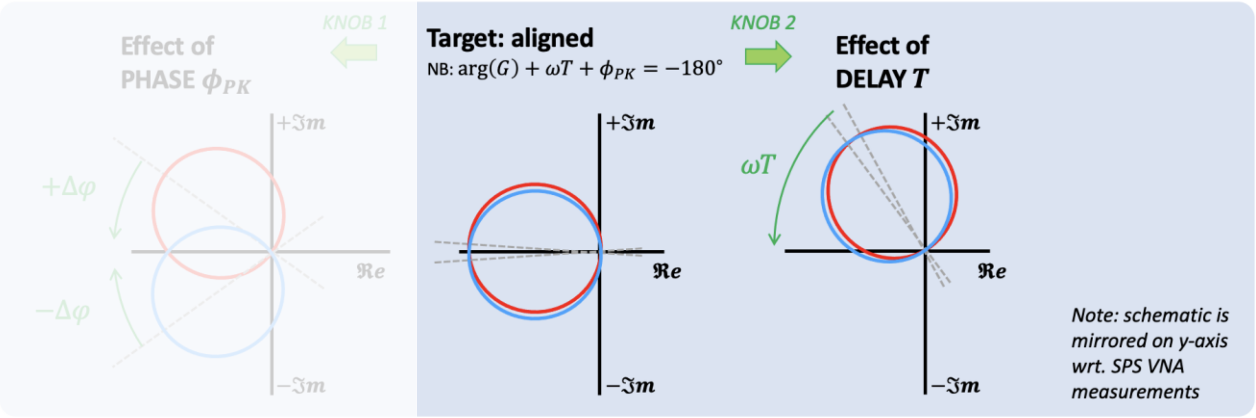


Phase well set



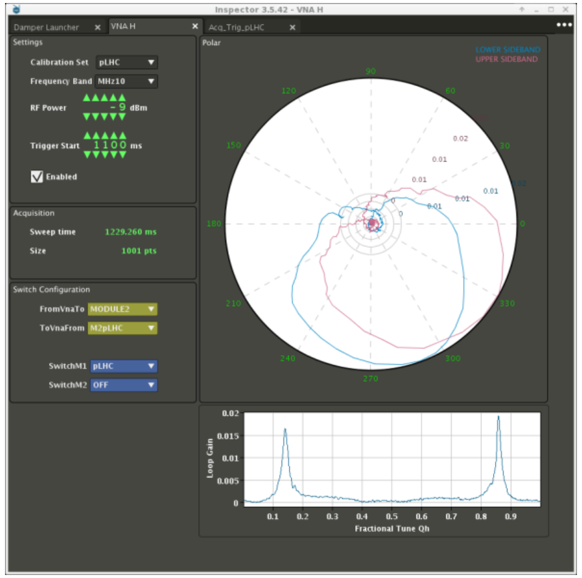
Tools & procedures

VNA: fine delay adjustment

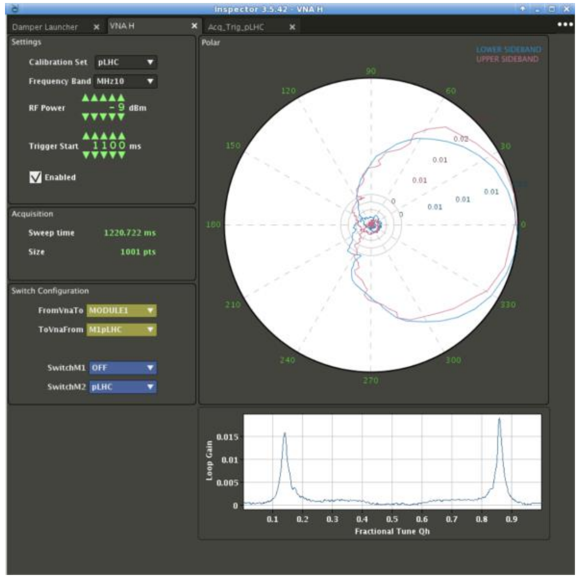


- Consider LSA parameter `DamperDelayFunc/FineDelayValues#fineDelayOUT{1,2}{H,V}` for the concerned plane and module
- Move in small steps. Can be tricky. "Sensitivity" to delay mismatch depends also on `Frequency` Band chosen for BTF
- **Delay should ideally not change during run. Inform damper expert if you suspect this kind of problem.**

Delay off



Phase & delay well set

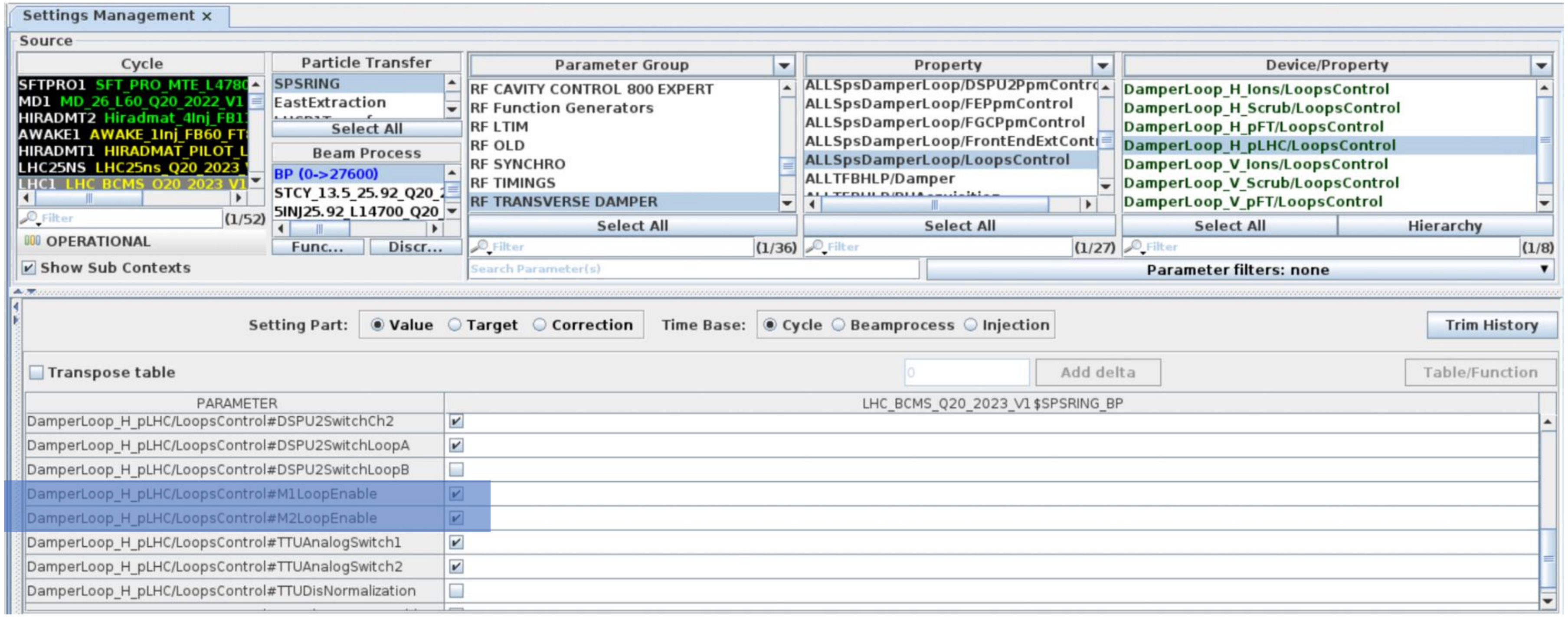


Tools & procedures

Disabling modules

Objective: disable individual kicker modules

- E.g. when suspicion that one module is not doing its job
- **This can neither be done from the GUI nor the HLP settings**
  The HLP loop switch will always enable / disable both kicker modules
- **To disable individual kicker module:** go to `DamperLoop_{H,V}_{pLHC,pFT,Ions}/LoopsControl` and untick either of the `M{1,2}LoopEnable` switches
- ***N.B.:** if you trim entire HLP Property (incl. HLP `LoopSwitches`), both M1 and M2 will be re-enabled.*



Future plans & final remarks

Future plans

- **Use “pLHC” module for all beam types:** reduce from 4 systems to 1
  - Requires White Rabbit to RF
  - Greatly simplify LSA HLP Makerules, parameter relations, and maintenance thereof
  - First parasitic tests done by G. Kotzian in 2022 (pLHC for SFT). To be continued this year (MD)
  - Challenge: with pLHC module, cannot ”see” SFTPRO beam < 2E13 p (amps needed for PUs?)
- **Fine delay adjustments**
  - Should eventually become obsolete thanks to White Rabbit (temperature drift compensating)
  - To be tested this year
- **New ObsBox installed:** running in parallel, to be tested
- **Data analysis on UCAP:** WIP
- **Bunch-by-bunch tune corrections** using TFB? -> MD

Final remarks

- **Thanks to HLP model & VGs**
  - Most of setting up is straightforward, incl. feedback phase & mode, FE gains, LL switches, etc.
  - Significantly fewer expert interventions needed, now handled by OP
- Main **knobs to tweak during OP**, e.g. after intensity changes: bunch parameters (intensity), and potentially loopGain
- **Main commissioning work:** phase and delay validations.
- **Let us know about issues / improvements that would be helpful for OP**

Questions?

Backup

Working settings 2022

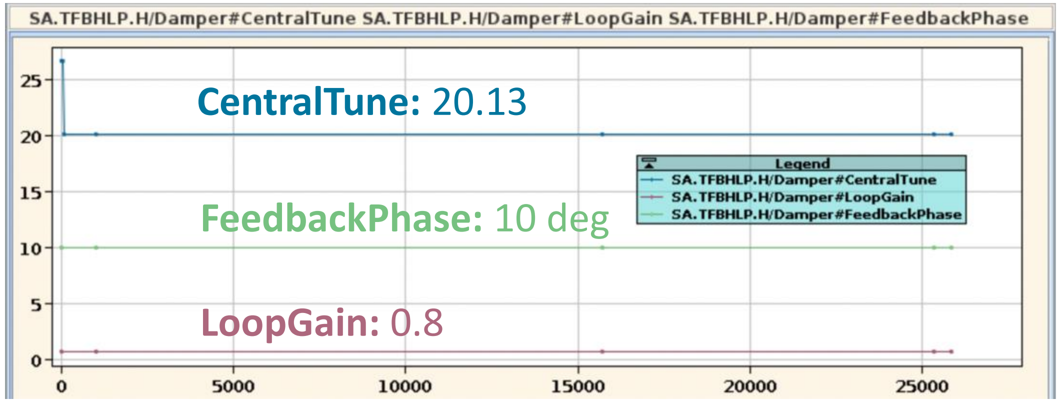
25 ns LHC-type multi-bunch beams

For single bunches, use 3 MHz

Horizontal

SA.TFBHLP.H/Damper#Bandwidth	20 MHz
SA.TFBHLP.H/Damper#FeedbackMode	Hilbert
SA.TFBHLP.H/Damper#InjectionBunchLengthNs	3.0
SA.TFBHLP.H/Damper#InjectionIntensity1E10	15.0
SA.TFBHLP.H/Damper#LoopGainCalibrationKicker1	2.5E-4
SA.TFBHLP.H/Damper#LoopGainCalibrationKicker2	2.5E-4
SA.TFBHLP.H/Damper#LoopSwitches	☑
SA.TFBHLP.H/Damper#PeakOscillationAmplitudeMm	10.0
SA.TFBHLP.H/Damper#StartTime	-5.0
SA.TFBHLP.H/Damper#StopTime	24844.0
SA.TFBHLP.H/Damper#SystemSelector	pLHC

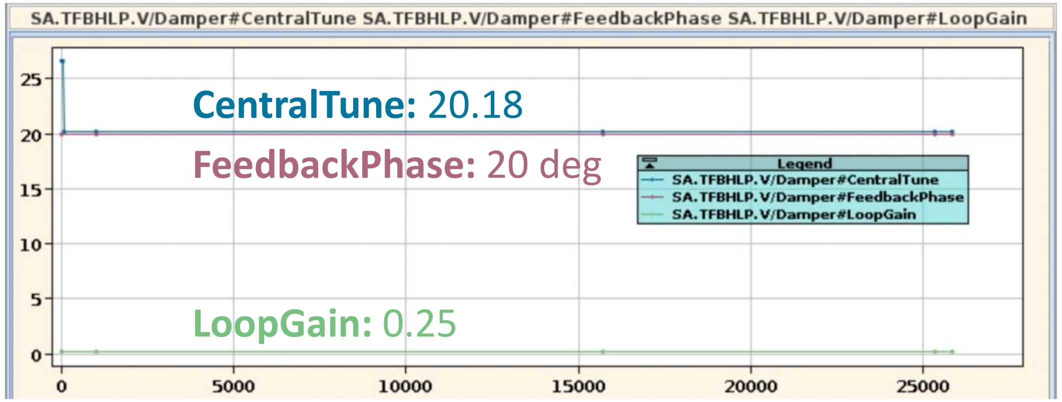
SA.TFBHLP.H/PUAcquisition#PU1CalibDelta	7.0E-4
SA.TFBHLP.H/PUAcquisition#PU1CalibSum	0.15
SA.TFBHLP.H/PUAcquisition#PU2CalibDelta	7.0E-4
SA.TFBHLP.H/PUAcquisition#PU2CalibSum	0.15



Vertical

SA.TFBHLP.V/Damper#Bandwidth	20 MHz
SA.TFBHLP.V/Damper#FeedbackMode	Hilbert
SA.TFBHLP.V/Damper#InjectionBunchLengthNs	3.0
SA.TFBHLP.V/Damper#InjectionIntensity1E10	15.0
SA.TFBHLP.V/Damper#LoopGainCalibrationKicker1	2.5E-4
SA.TFBHLP.V/Damper#LoopGainCalibrationKicker2	2.5E-4
SA.TFBHLP.V/Damper#LoopSwitches	☑
SA.TFBHLP.V/Damper#PeakOscillationAmplitudeMm	10.0
SA.TFBHLP.V/Damper#StartTime	-5.0
SA.TFBHLP.V/Damper#StopTime	24844.0
SA.TFBHLP.V/Damper#SystemSelector	pLHC

SA.TFBHLP.V/PUAcquisition#PU1CalibDelta	7.0E-4
SA.TFBHLP.V/PUAcquisition#PU1CalibSum	0.15
SA.TFBHLP.V/PUAcquisition#PU2CalibDelta	7.0E-4
SA.TFBHLP.V/PUAcquisition#PU2CalibSum	0.15

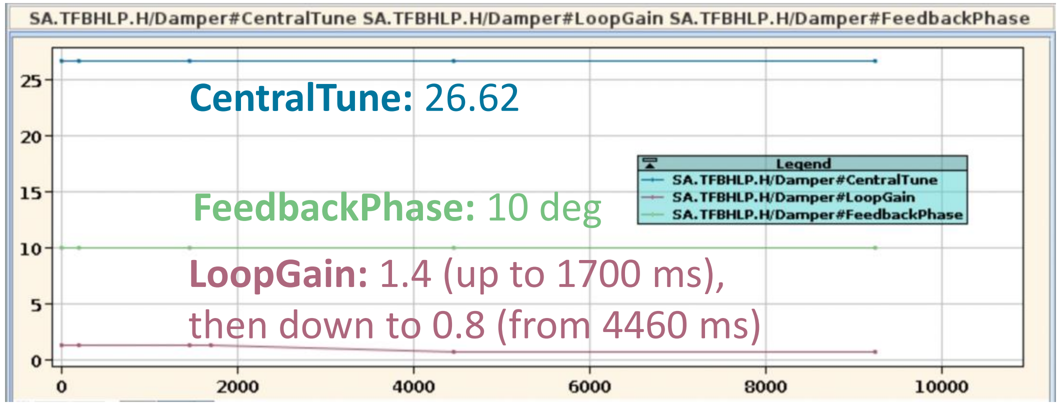


Working settings 2022
SFTPRO

Horizontal

SA.TFBHLP.H/Damper#Bandwidth	14 MHz
SA.TFBHLP.H/Damper#FeedbackMode	VectorSum
SA.TFBHLP.H/Damper#InjectionBunchLengthNs	3.5
SA.TFBHLP.H/Damper#InjectionIntensity1E10	5.0
SA.TFBHLP.H/Damper#LoopGainCalibrationKicker1	2.4998188E-4
SA.TFBHLP.H/Damper#LoopGainCalibrationKicker2	2.4998188E-4
SA.TFBHLP.H/Damper#LoopSwitches	☑
SA.TFBHLP.H/Damper#PeakOscillationAmplitudeMm	7.0
SA.TFBHLP.H/Damper#StartTime	-5.0
SA.TFBHLP.H/Damper#StopTime	9045.0
SA.TFBHLP.H/Damper#SystemSelector	pFT

SA.TFBHLP.H/PUAcquisition#PU1CalibDelta	0.0019999743
SA.TFBHLP.H/PUAcquisition#PU1CalibSum	0.25
SA.TFBHLP.H/PUAcquisition#PU2CalibDelta	0.0019999743
SA.TFBHLP.H/PUAcquisition#PU2CalibSum	0.25



Vertical

SA.TFBHLP.V/Damper#Bandwidth	14 MHz
SA.TFBHLP.V/Damper#FeedbackMode	VectorSum
SA.TFBHLP.V/Damper#InjectionBunchLengthNs	3.5
SA.TFBHLP.V/Damper#InjectionIntensity1E10	5.0
SA.TFBHLP.V/Damper#LoopGainCalibrationKicker1	2.4998188E-4
SA.TFBHLP.V/Damper#LoopGainCalibrationKicker2	2.4998188E-4
SA.TFBHLP.V/Damper#LoopSwitches	☑
SA.TFBHLP.V/Damper#PeakOscillationAmplitudeMm	7.0
SA.TFBHLP.V/Damper#StartTime	-5.0
SA.TFBHLP.V/Damper#StopTime	9045.0
SA.TFBHLP.V/Damper#SystemSelector	pFT

SA.TFBHLP.V/PUAcquisition#PU1CalibDelta	0.0019999743
SA.TFBHLP.V/PUAcquisition#PU1CalibSum	0.25
SA.TFBHLP.V/PUAcquisition#PU2CalibDelta	0.0019999743
SA.TFBHLP.V/PUAcquisition#PU2CalibSum	0.25