

# **SPS Transverse Feedback System**

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**OP Shutdown Lectures** 

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## **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



Injection

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

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

- Damping time  $\tau$  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 nonlinearities 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<sup>12</sup> 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 intrabunch motion / single-bunch instabilities (bandwidth not sufficient ) "wideband feedback")

#### Injection error leading to emittance blow-up





### **SPS TFB** Hardware

### Per plane

### 4 signal processing systems

- **pLHC:** LHC beams (25 ns)
- **pFT:** SFTPRO
- lons
- Scrub: doublet beam

### **Pickups**

- **pFT:** 2 electro-static, processing in tunnel
- pLHC, lons, 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 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

**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

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



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LSA model: overview

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



LSA model: overview



LSA model: discrete damper parameters

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### **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

LSA model: discrete damper parameters

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### 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)

LSA model: discrete damper parameters

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### 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 (!)

LSA model: discrete damper parameters

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### 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

LSA model: discrete damper parameters

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### 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

LSA model: discrete damper parameters

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### 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/IntensityPerBun chE10 (parameter group: INSTRUMENTATION)

LSA model: discrete damper parameters

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### 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

LSA model: overview



LSA model: discrete acquisition parameters

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### 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<sup>(\*)</sup>

### 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

LSA model: overview



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 multibunch, 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*

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### **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*)

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### **Tools & procedures** *Python GUI*

	Super Proton Dam	per	<ul> <li>-</li> </ul>		
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	Pickup acquisition	Pickup acquisition	Pickup acquisition		
	PU1 Calibration Sum 0.	150000 C OL PU1 Calibration Sum	0.150000 🗘 🛇		
	PU1 Calibration Delta 0.	000700 🗘 🥥 PU1 Calibration Delta	0.000700 🗘 🕗		
	PU2 Calibration Sum 0.	150000 🗘 🤄 PU2 Calibration Sum	0.150000 🗘 🥝		
	PU2 Calibration Delta 0.0	000700 🗘 🛇 PU2 Calibration Delta	0.000700 🗘 Ø.		
	± >	±	>		
	GET SET (edited)	GET SE	ET (edited)		
	Module status	Module status			
	Module 1	Module 1			
	Loop closed	O Loop closed	0		
	External excitation	External excitation	0		
	Start trigger	-1000 ms 🕖 Start trigger	-1000 ms 🦲		
	Stop trigger	-1000 ms 🥥 Stop trigger	-1000 ms 🦲		
	Module 2	Module 2			
	Loop closed	O Loop closed	0		
Hiradmat Alpi EP11100 CTEO	External excitation	External excitation	6		
SPS.USER.HIRADMT2	Start trigger	-1000 ms 🔵 Start trigger	-1000 ms 🦲		
	Ston triager	1000 ms () Ston trigger	-1000 ms		

Obtained invalid data from ('ObsBoxB.SPS.ADT.V.PU1.Inj0sc/Acquisition#data', 'ObsBoxB.SPS.ADT.V.Sigma.Inj0

#### 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*



### **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)

Old version

### **Objective:** validate injection damping

## **Tools & procedures** *ObsBox buffer*



### 3. OBS \*damper module\*



- 1. Set "Buffer Size" to 500k or less if it freezes, adapt trigger time
- 2. Use "Position" preset
- 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 1<sup>st</sup> inj., 1012 ms is a good setting if buffer has length 500k
- 3. Press "Configure" button

## **Tools & procedures** *IQ display*



#### 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
- Signal from first bunch should be aligned with sample 0
- 3. If not, adjust LSA clock parameters (LL)

### **Objective:** clock sync / adjustment

## **Tools & procedures** *IQ display*

- 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 MHz = 8.333 ns

è.		LSA Applications	Suite (v 16.0.11)			• - • >
Eile Applications Search						Help
🔶 🖲 SPS 🔻 🕝 C	🔹 🛷 🅸 🐻 🔯 c	; spsop ▼				
Settings Management ×						
Source						
Cycle	Particle Transfer	Parameter Group	Prope	rty 🔻	Device	/Property 👻
LHCPILOT LHC PILOT Q20	SPSRING A	IN CRAIT CONTROL	ALLSpsDamperLoop/Be	amPos1PpmControl	DamperLoop H Io	ns/CLOCKPpmControl
LHC PILOT Q20 2022 V1	EastExtraction	RF Function General	ALLSpsDamperLoop/Be	amPos2PpmControl	DamperLoop_H_S	crub/CLOCKPpmControl
	LHCRITransfer	REOLD	ALLSpsDamperLoop/CL	OCKPpmControl -	DamperLoop_H_p	FT/CLOCKPpmControl
	Beam Dresses	RF SYNCHRO	ALLSpsDamperLoop/DS	PU1PpmControl	DamperLoop_H_p	LHC/CLOCKPpmControl
	Beam Process	RF TIMINGS	ALLSpsDamperLoop/DS	PU2PpmControl	DamperLoop_V_lo	ns/CLOCKPpmControl
	STCY 13.5 25.92 020 202	RF TRANSVERSE DAM	ALLSpsDamperLoop/FE	PpmControl	DamperLoop_V_S	Crub/CLOCKPpmControl
4	1INJ25.92 L300 Q20 2021	SERVO SPILL	ALL SpsDamperLoop/FG	ontEndExtControl	DamperLoop_V_p	HC/CLOCKPpincontrol
LHC_PILOT (1/2)	ACC SLOW 25 92 451 15	Select All	Sele	ct All	Select All	Hierarchy
000 OPERATIONAL	Function Discrete	P.Filter (1/36)	Filter	(1/27)	O Filter	(1/8)
Show Sub Contexts		Search Parameter(s)		Parameter	filters: none	
Setting P	art: 🖲 Value 🔾 Target 🤇	Correction Time Ba	se: 🖲 Cycle 🔾 Beamp	rocess O Injection		Trim History
🔲 Transpose table				Add delta		Table/Function
PAR	AMETER		LHC_PILC	T_Q20_2022_V1 \$SPSRING	G_BP	
DamperLoop_H_pLHC/CLOCKP	omControl#ClkDelayModulus	833		83	3	
DamperLoop_H_pLHC/CLOCKP	omControl#ClkTagBeamFreeldx	0		0		
DamperLoop_H_pLHC/CLOCKP	omControl#ClkTagDeltalIdx	1842		18	1842	
DamperLoop_H_pLHC/CLOCKPp	omControl#ClkTagDelta2ldx	1770		17	1769	
DamperLoop_H_pLHC/CLOCKP	omControl#ClkTagGP1Idx	0		0		
DamperLoop_H_pLHC/CLOCKP	omControl#ClkTagGP2ldx	0		0	04	
DamperLoop_H_pLHC/CLOCKP	pmControl#ClkTagOut1ldx	2184	2184			
DamperLoop H pLHC/CLOCKP	omControl#ClkTagSum1ldv	1842		21	82	
DamperLoop H pLHC/CLOCKP	omControl#ClkTagSum2ldx	1770		17	69	
DamperLoop_H_pLHC/CLOCKP	omControl#ClkTagSyncidx	910		91	0	
🖉 Zero Settings 🔻			of Trim	Cancel	l last trim 🔻	🗸 Apply Trim





**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)





## **Tools & procedures** *Vector Network Analyzer (VNA)*

#### 1. SPS Damper ADT Acquisition



#### 2. VNA H / V



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

### **Objective:** delay and phase validation

- 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

## **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#fi
   neDelayOUT{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



- 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.

Settings Management x				
Source				
Cycle Particle Transfer	Parameter Group 🔻	Property 💌	Device/Pro	operty 💌
SFTPRO1 SFT PRO MTE L478C MD1 MD_26_L60_Q20_2022_V1 HIRADMT2 Hiradmat_4linjFB60_FT HIRADMT1 HIRADMAT PILOT L LHC25NS LHC25ns_Q20_2023 HC1 HIRADMS 020_2023 V1 C C C C C C C C C C C C C C C C C C C	RF CAVITY CONTROL 800 EXPERT     RF Function Generators     RF LTIM     RF OLD     RF SYNCHRO     RF TIMINGS     RF TRANSVERSE DAMPER	ALLSpsDamperLoop/DSPU2PpmControl ALLSpsDamperLoop/FEPpmControl ALLSpsDamperLoop/FGCPpmControl ALLSpsDamperLoop/FontEndExtCont ALLSpsDamperLoop/LoopsControl ALLTFBHLP/Damper	DamperLoop_H_lons/LoopsCo DamperLoop_H_Scrub/LoopsCo DamperLoop_H_pFT/LoopsCo DamperLoop_H_pLHC/LoopsCo DamperLoop_V_lons/LoopsCo DamperLoop_V_Scrub/LoopsCo DamperLoop_V_pFT/LoopsCo	ontrol  Control Control Control Control Control Control
Filter (1/52)	Select All	Select All	Select All	Hierarchy
Func Discr		©_Filter (1/27)	Filter	(1/8)
Show Sub Contexts	Search Parameter(s)		Parameter filters: none	•
Setting Part:   Value	○ Target ○ Correction Time Base: ● C	cle 🔾 Beamprocess 🔾 Injection		Trim History
Transpose table		0 Add de	ta	Table/Function
PARAMETER		LHC_BCMS_Q20_2023_V1 \$SPSRING_B	2	
DamperLoop_H_pLHC/LoopsControl#DSPU2SwitchCh2				<u> </u>
DamperLoop_H_pLHC/LoopsControl#DSPU2SwitchLoopA				
DamperLoop_H_pLHC/LoopsControl#DSPU2SwitchLoopB				
DamperLoop_H_pLHC/LoopsControl#M1LoopEnable				
DamperLoop_H_pLHC/LoopsControl#M2LoopEnable				
DamperLoop_H_pLHC/LoopsControl#TTUAnalogSwitch1				
DamperLoop_H_pLHC/LoopsControl#TTUAnalogSwitch2				
DamperLoop_H_pLHC/LoopsControl#TTUDisNormalization				

# **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

#### Horizontal

SA.TFBHLP.H/Damper#Bandwidth		20 MHz
SA.TFBHLP.H/Damper#FeedbackMode	Hilbert	
SA.TFBHLP.H/Damper#InjectionBunchLength	Ns	3.0
SA.TFBHLP.H/Damper#InjectionIntensity1E1	D	15.0
SA.TFBHLP.H/Damper#LoopGainCalibrationK	ickerl	2.5E-4
SA.TFBHLP.H/Damper#LoopGainCalibrationK	2.5E-4	
SA.TFBHLP.H/Damper#LoopSwitches	~	
SA.TFBHLP.H/Damper#PeakOscillationAmplit	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



For single bunches, use 3 MHz

### 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#InjectionBunchLengthM	٧s	3.5
SA.TFBHLP.V/Damper#InjectionIntensity1E10	5.0	
SA.TFBHLP.V/Damper#LoopGainCalibrationKid	kerl	2.4998188E-4
SA.TFBHLP.V/Damper#LoopGainCalibrationKic	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 0.00199		99743
SA.TFBHLP.V/PUAcquisition#PU1CalibSum 0.25		
SA.TFBHLP.V/PUAcquisition#PU2CalibDelta	0.00199	99743

0.25

SA.TFBHLP.V/PUAcquisition#PU2CalibSum

