

BLM near miss event in the SPS – post mortem and proposed improvements

E. Carlier, K. Cornelis, E. Effinger, F. Follin, S. Jackson,
L. Jensen, F. Velotti, C. Zamantzas

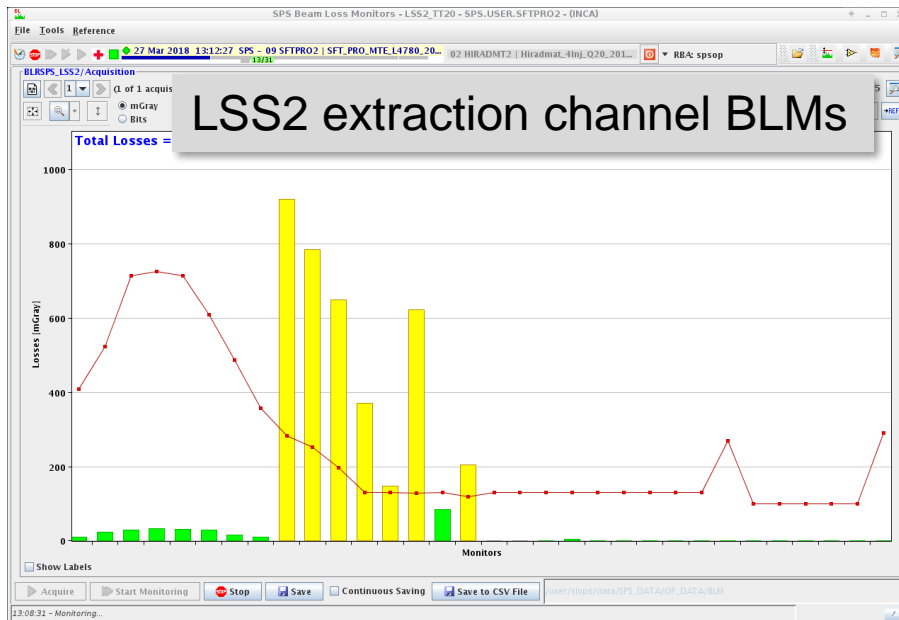
Introduction

- ❑ Several “different” BLM systems in the SPS
 - **Ring BLMs:** integrating through cycle and comparison to threshold done in software. Acquisition every 20 ms and interlock reaction time also max. 20 ms
 - Same spec for the BLMs in transfer line to North Area
 - **LSS BLMs:** integrating through cycle, comparison to threshold done in hardware. Interlock reaction time ~ 500 us
 - **BLMs in the LHC transfer lines:** measure extraction/transfer losses. Only have effect on following extraction. Interlocking done in SW

- ❑ Thresholds and gain settings are user dependent.

SPS BLMs – issues during start-up with beam

- ❑ FESA2 to FESA3 and OS upgrades during YETS
- ❑ Check list tests during check-out focus on controls behavior, basic interlocking verification
- ❑ With beam noticed: Gain settings not correctly taken into account
 - Losses measured too high

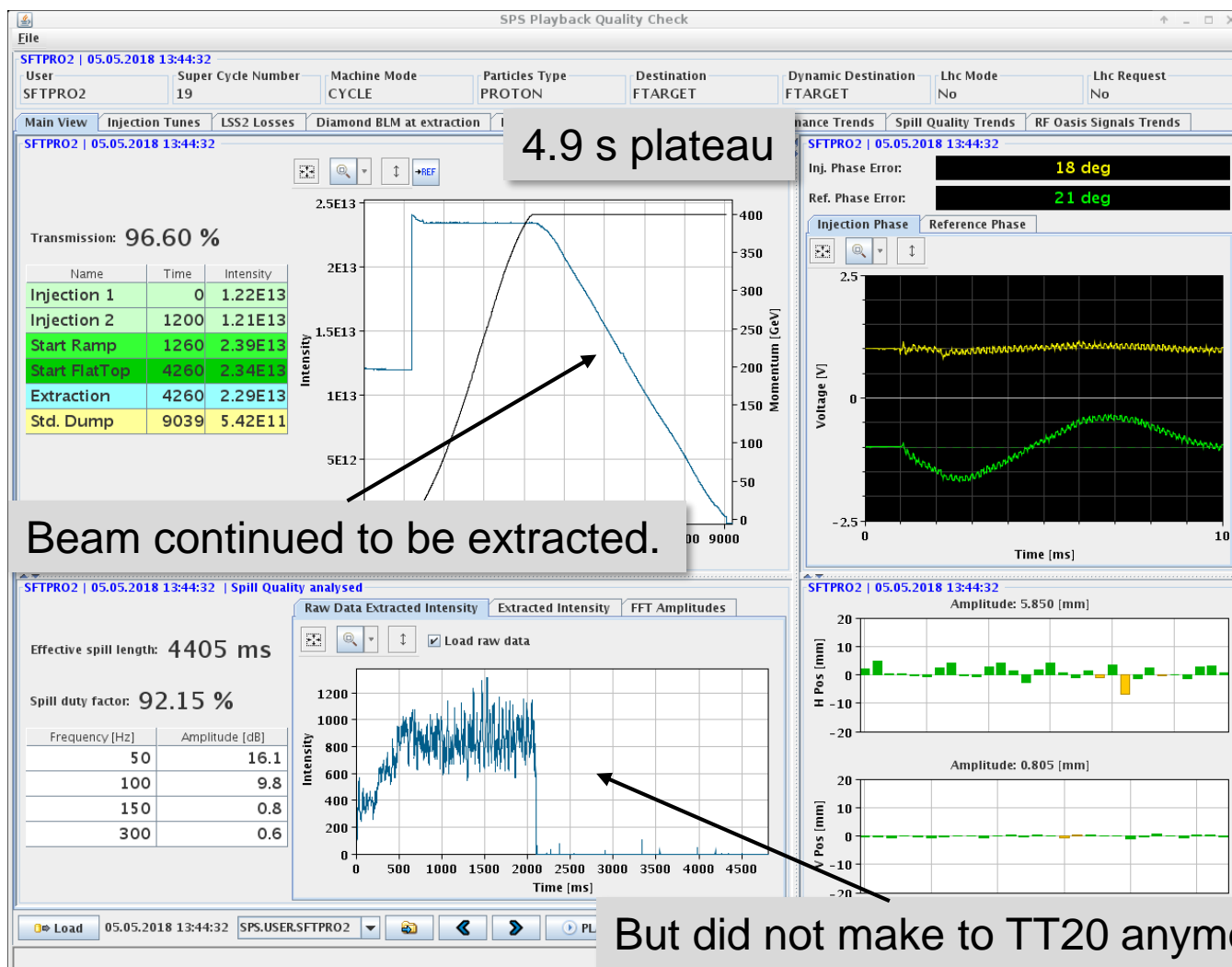


- ❑ Could not run like this.
- ❑ BI experts rolled back to previous OS
- ❑ Only the reading of the BLMs was verified

Extraction elements: 5 x ZS, TCE, TPST, 3 x MST, 5 x MSE, TT20

Near miss event on 5th of May

- Electro magnetic interference on temperature probe on MST → MST switched off during slow extraction.



Near miss event on 5th of May


- Where did the beam go?

Email by Etienne

Etienne Carlier

To: Francesco Maria Velotti Cc: Jan Borburgh, Brennan Goddard, [and 2 more...](#)
Trip of MS circuit in LSS2

5 May 2018 at 17:07

Inbox - Cern 

EC 

Francesco,

We have had this afternoon a trip of the MS circuit in LSS2. As identified by Cedric, a bad acquisition on a PT100 on a MST2 has been the source of the fault after switching off the MST power converter at ~13:44:37. What is worrying me is that at ~13:44:39 we have had a vacuum interlock on the MSE circuit (upstream) and then a significant increase of the water temperature on the MSE1. It seems that beam has been extracted with the MST OFF and has touched the MSE... but looking to the BIC BA2 history buffer I don't see any trigger coming from the LSS2 BLM. So not clear for me if the beam has been dumped under this fault condition or fully extracted.

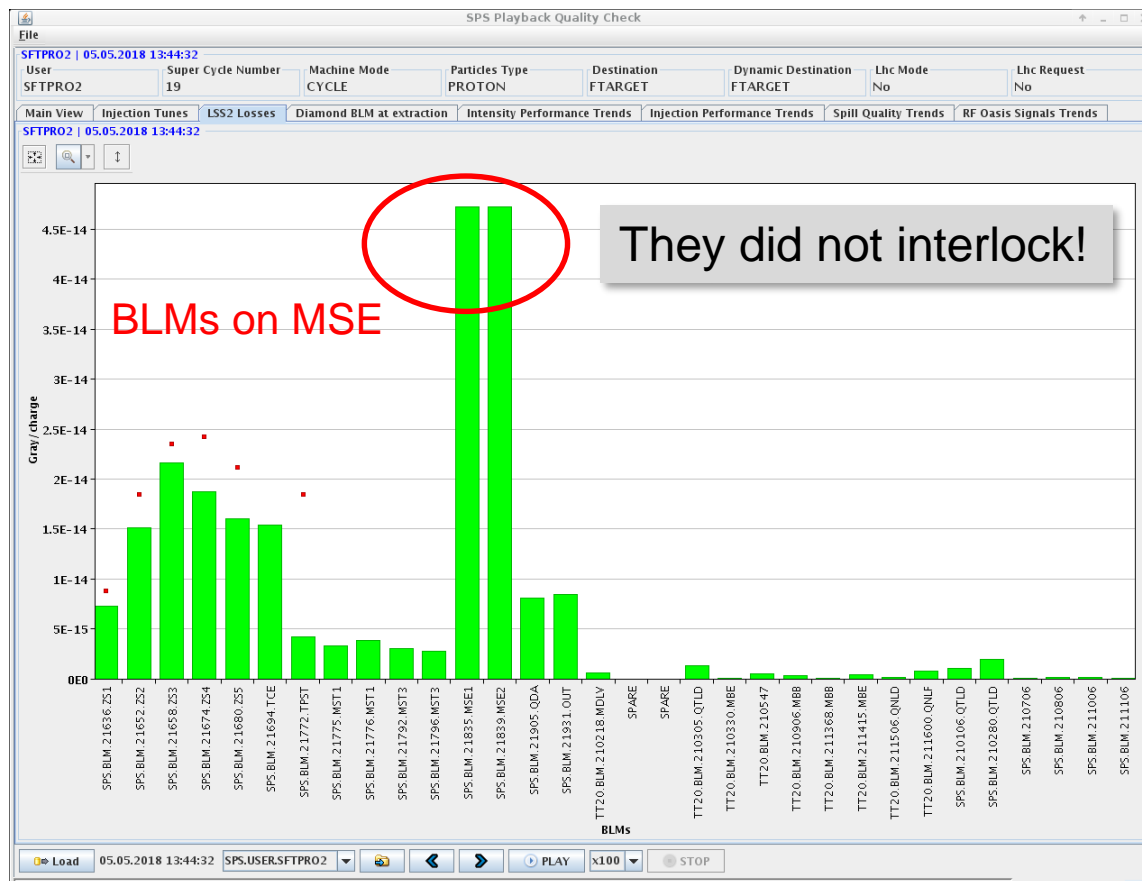
Can you have a look? I think it is worth to understand it properly.

Cheers, Etienne

PS. Some screen shots are available in ABT eLogbook <http://elogbook.cern.ch/eLogbook/eLogbook.jsp?lgbk=331&date=20180505&shift=1>

Near miss event on 5th of May

- Losses in LSS2 from SPS QC



- Tests in the control room then later on confirmed: LSS BLMs were not interlocking if loss above threshold.

Mitigation – will be implemented soon (1)

- Software changes
 - Interlock functionality relevant settings grouped into non-PPM property (FESA): will be MCS
 - Fields: Hardware/software interlock enabled, how many channels to be above threshold, which BLMs enabled for interlock
 - Interlock thresholds stay PPM
 - Gain can be read back from hardware → SIS interlock + alert in application
 - Normalised loss threshold concept to be extended to all BLMs in LSS2

- Additional interlocking
 - MST and MSE sum signal interlock

Mitigation – will be implemented soon (2)

- Timing monitoring
 - BLM system acquisition and interlocking functionality dependent on timing
 - Timing watchdog/ “I am alive” watchdog – BI/CO
 - Every 100s currently
 - 20 ms LTIM settings monitoring not clear yet (only publish on change, SIS not a solution)

- Testing
 - With and without beam

Software changes

- ❑ Towards protected interlock settings

The screenshot shows the LSA Applications Suite (v 10.18.0) interface. The main window is titled "Settings Management x" and displays a hierarchical view of settings. The "Source" pane on the left shows a tree structure with "Cycle" selected, containing items like "SFTPRO2", "MD1", "LHC2", "AWAKE1", "HIRADMT1", "HIRADMT2", and "LHC2SNS". The "Particle Transfer" pane shows "SPSRING" and "NorthExtraction". The "Parameter Group" pane shows "COLLIMATORS", "CORRECTORS H", "CORRECTORS V", "EXTR OCTUPOLES", "FEI", and "INSTRUMENTATION". The "Property" pane shows "BLRSPS/InterlockSetting", "BLRSPS/Setting", "BPMOPOS/Setting", and "SPS.BWS.APP/References". The "Parameter" pane shows "BLRSPS_LSS1/InterlockSetting", "BLRSPS_LSS2/InterlockSetting", "BLRSPS_LSS4/InterlockSetting", "BLRSPS_LSS5/InterlockSetting", and "BLRSPS_LSS6/InterlockSetting".

Below the panes, there are controls for "Setting Part" (Value, Target, Correction), "Time Base" (Cycle, Beamprocess, Injection), and a "Trim History" button. A "Transpose table" section is visible, showing a table with parameters and their values.

PARAMETER	Value	SFT_PRO_MTE_L4780_2018_V1\$SPSRING.
BLRSPS_LSS2/InterlockSetting#bldInhibit	0	
BLRSPS_LSS2/InterlockSetting#bldMask	65535	
BLRSPS_LSS2/InterlockSetting#blrDumpCnt	0	
BLRSPS_LSS2/InterlockSetting#calThresholds	0.2, 0.38, 0.5969969, 0.5469969, 0.43, 0.4122601, 0.15, 0.15, 0.19552562, 0.13, 0.13, 0.05, 0.05, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1	

Settings already in LSA. Not MCS yet.
But not final version of property

At the bottom, there are buttons for "Zero Settings", "Trim", "Cancel last trim", and "Apply Trim". A status bar at the bottom left indicates "12:19:38 - Trim operation successfully completed."

Additional hardware interlocking



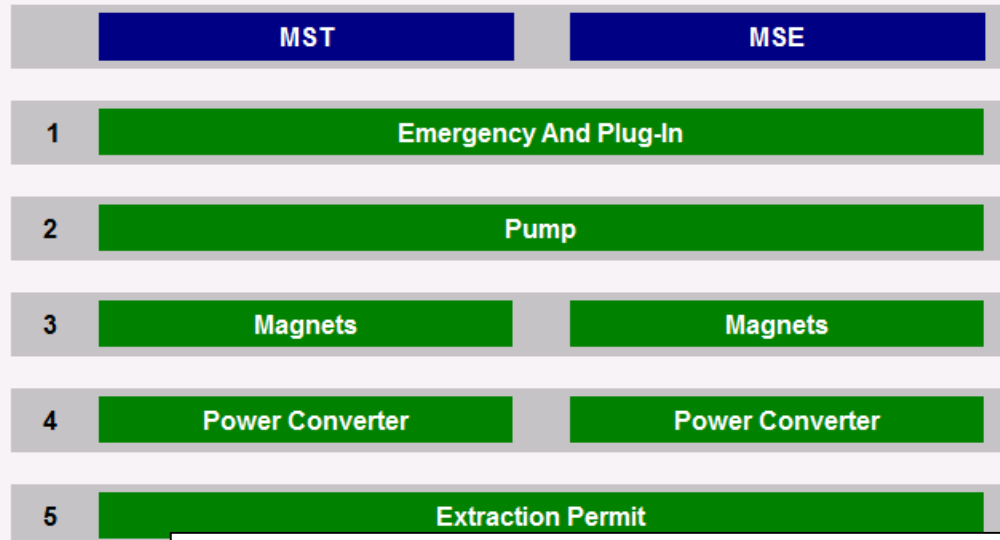
TE/ABT Equipment Control Pre-Injector & SPS

SPS - MS2 - North Extraction Electromagnetic Septa

OPERATION

ON

Process Control



Proposal:

- Connect existing STAGE 5 “Extraction PERMIT” output of MST/MSE state machine to SPS RING BIS
- Implement PPM interlock management on SFT cycles
- Use maskable BIS channel (...at least for commissioning)

ABT Systems	SPS	Interlock MST	System	Girder MST		Trends
		Interlock MSE	Magnets	Girder MSE		Alarm



TE/ABT Equipment Control Pre-Injector & SPS

SPS - MS2 - North Extraction Electromagnetic Septa

OPERATION

ON

MST / MSE Process Control - Step5 Details

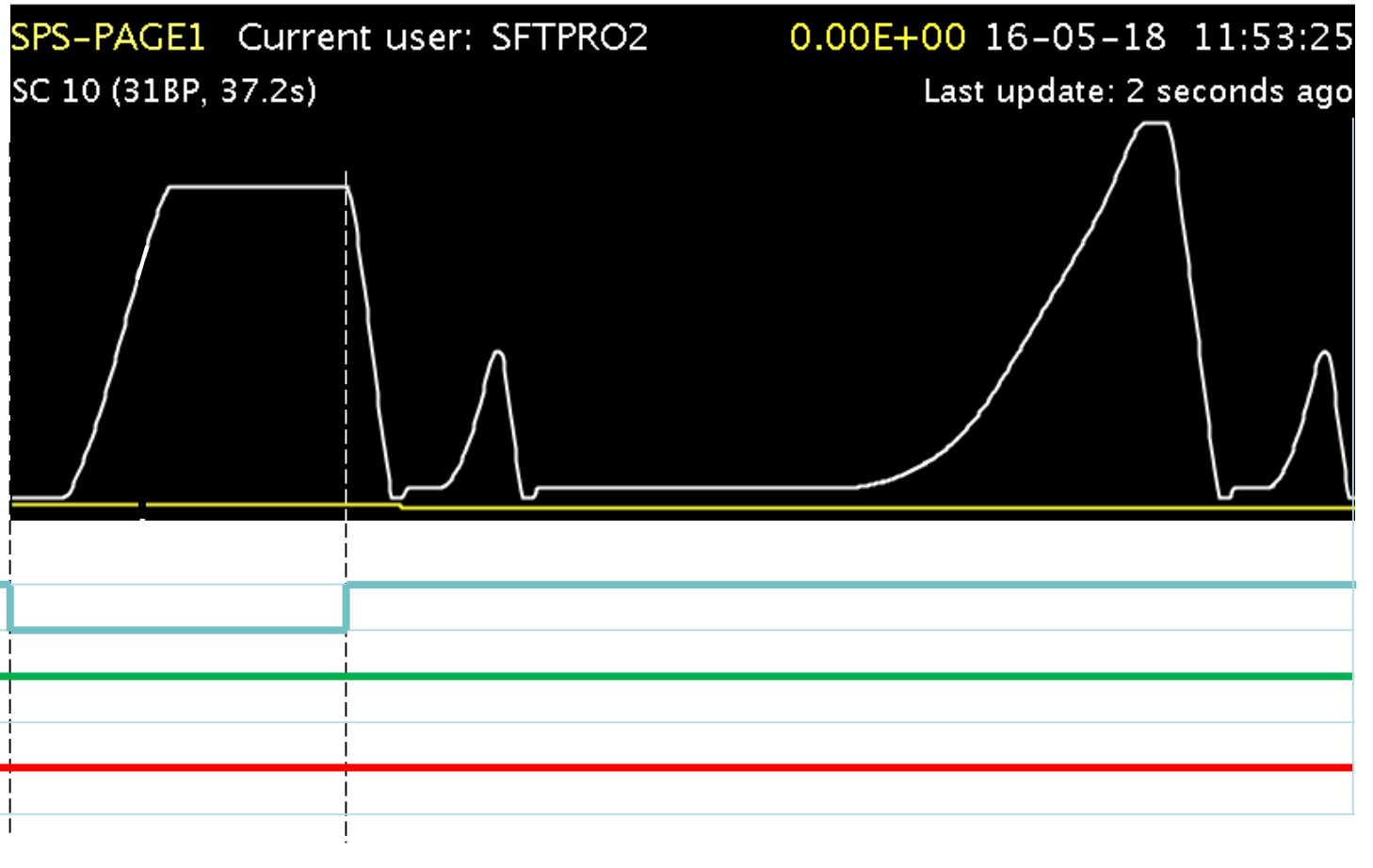
Interlocks		Status
S501	MST Upstream Girder Position	
S502	MST Downstream Girder Position	
S503	MSE Upstream Girder Position	
S504	MSE Downstream Girder Position	
S505	MST Upstream Girder Moving	
S506	MST Downstream Girder Moving	
S507	MSE Upstream Girder Moving	
S508	MSE Downstream Girder Moving	
S509	MST Ready	
S510	MSE Ready	

STAGE 5 "TRUE" conditions:

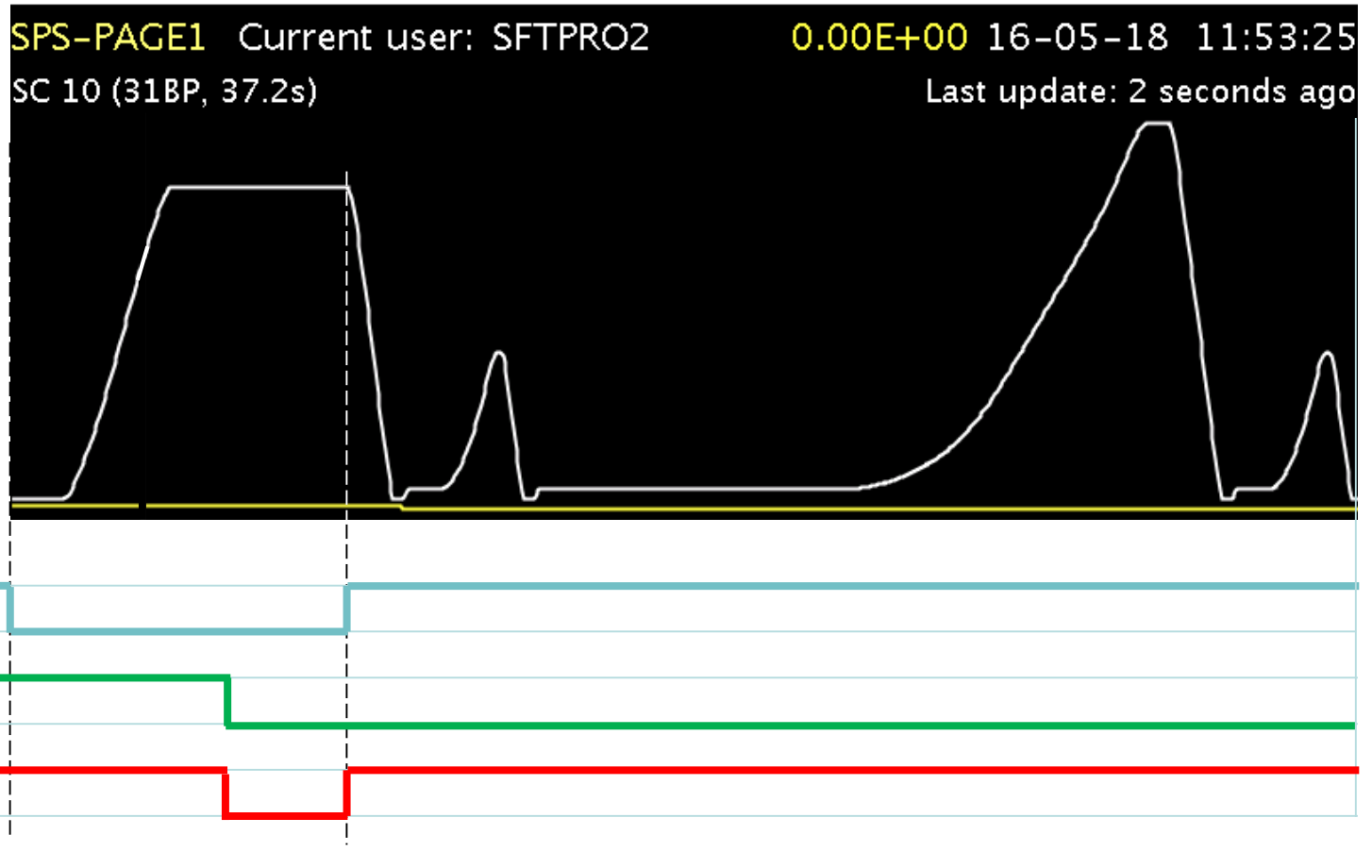
- MST and MSE girders IN_BEAM
- MST and MSE girders NOT_MOVING
- MST and MSE power converters in PULSING mode (requested function not checked)

ABT Systems	SPS	Interlock MST	System	Girder MST	Trends
		Interlock MSE	Magnets	Girder MSE	Alarm

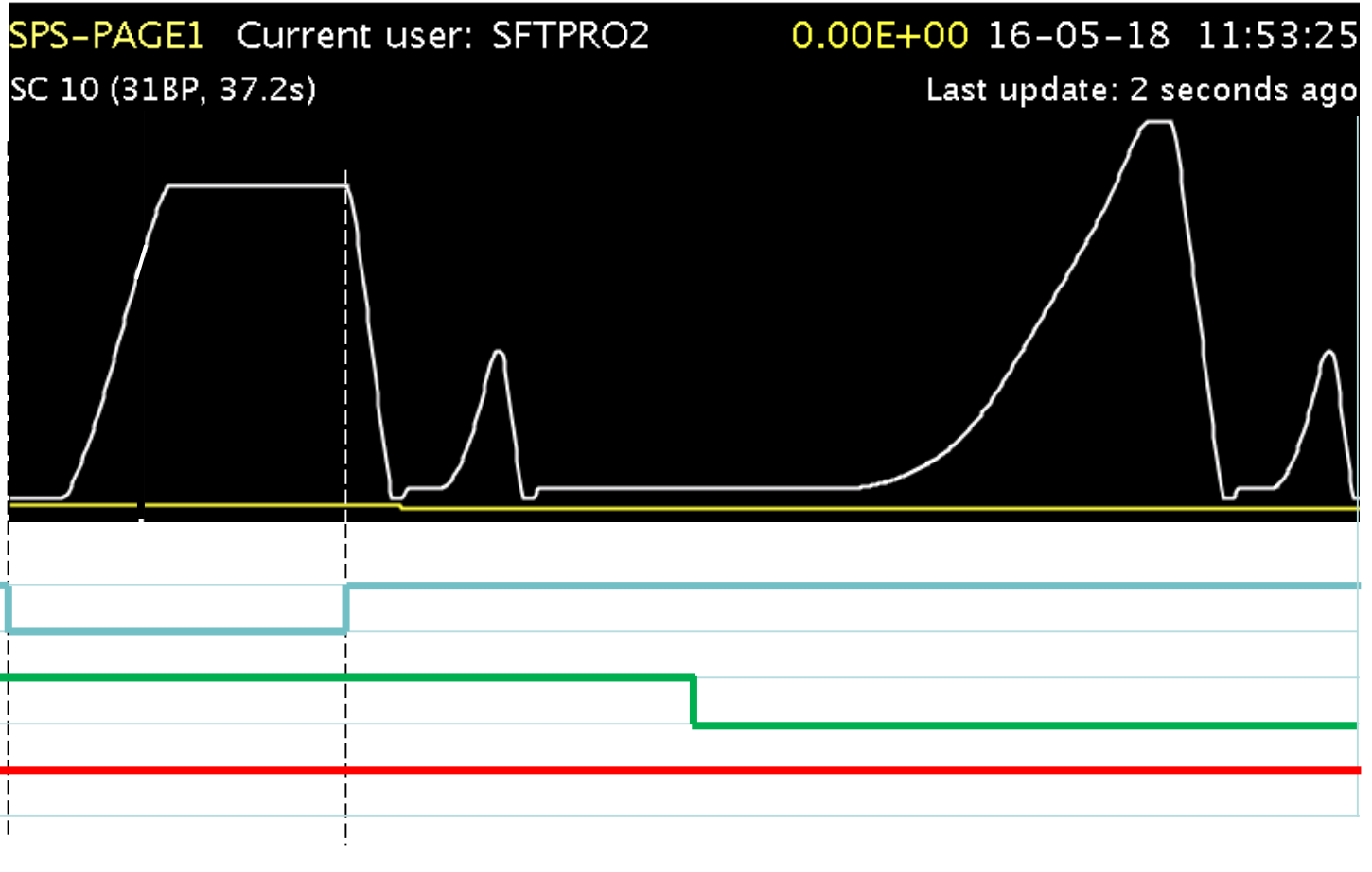
Case Study : MST/MSE OK



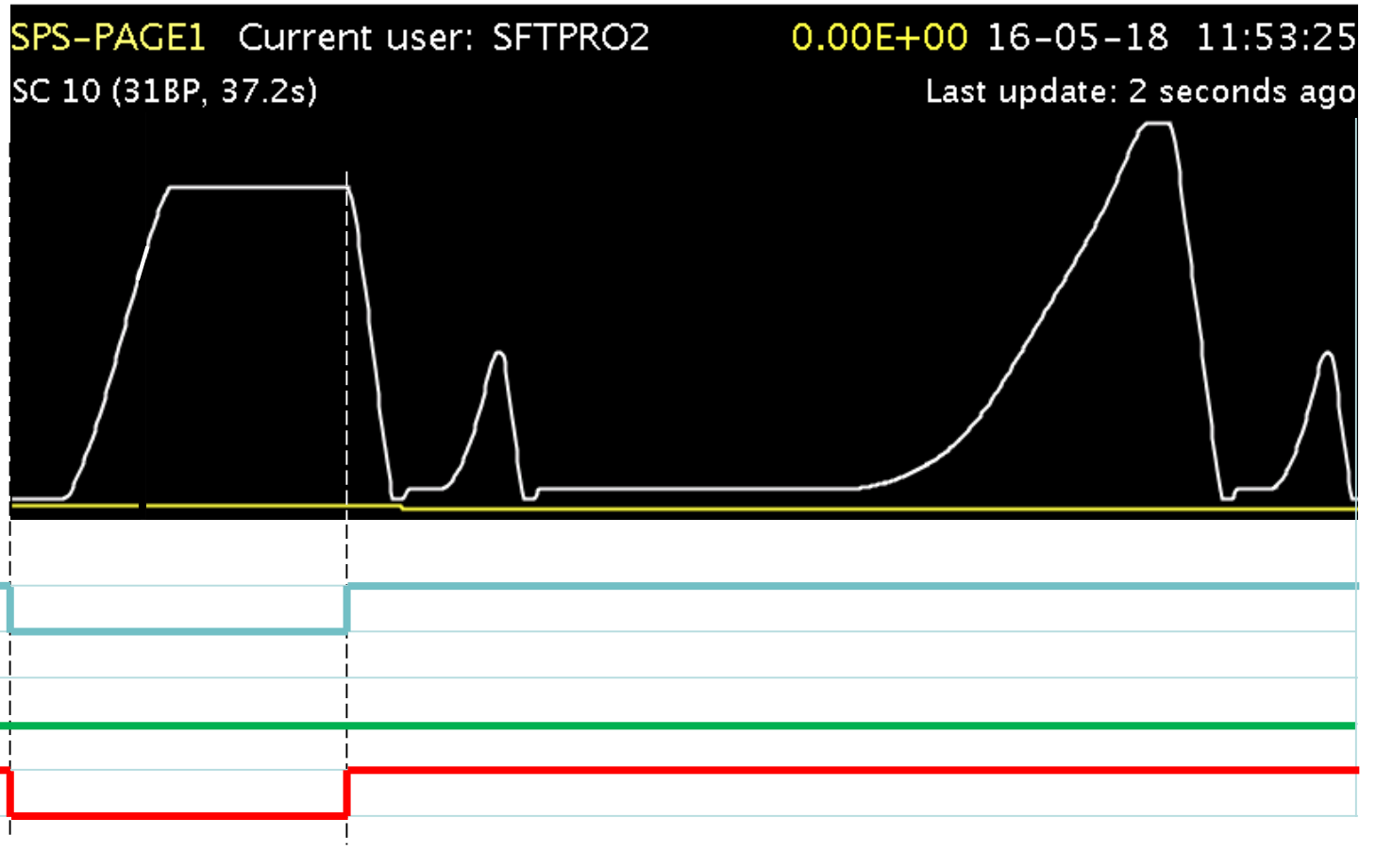
Case Study : MST/MSE transition to FAULT inside SFT cycle



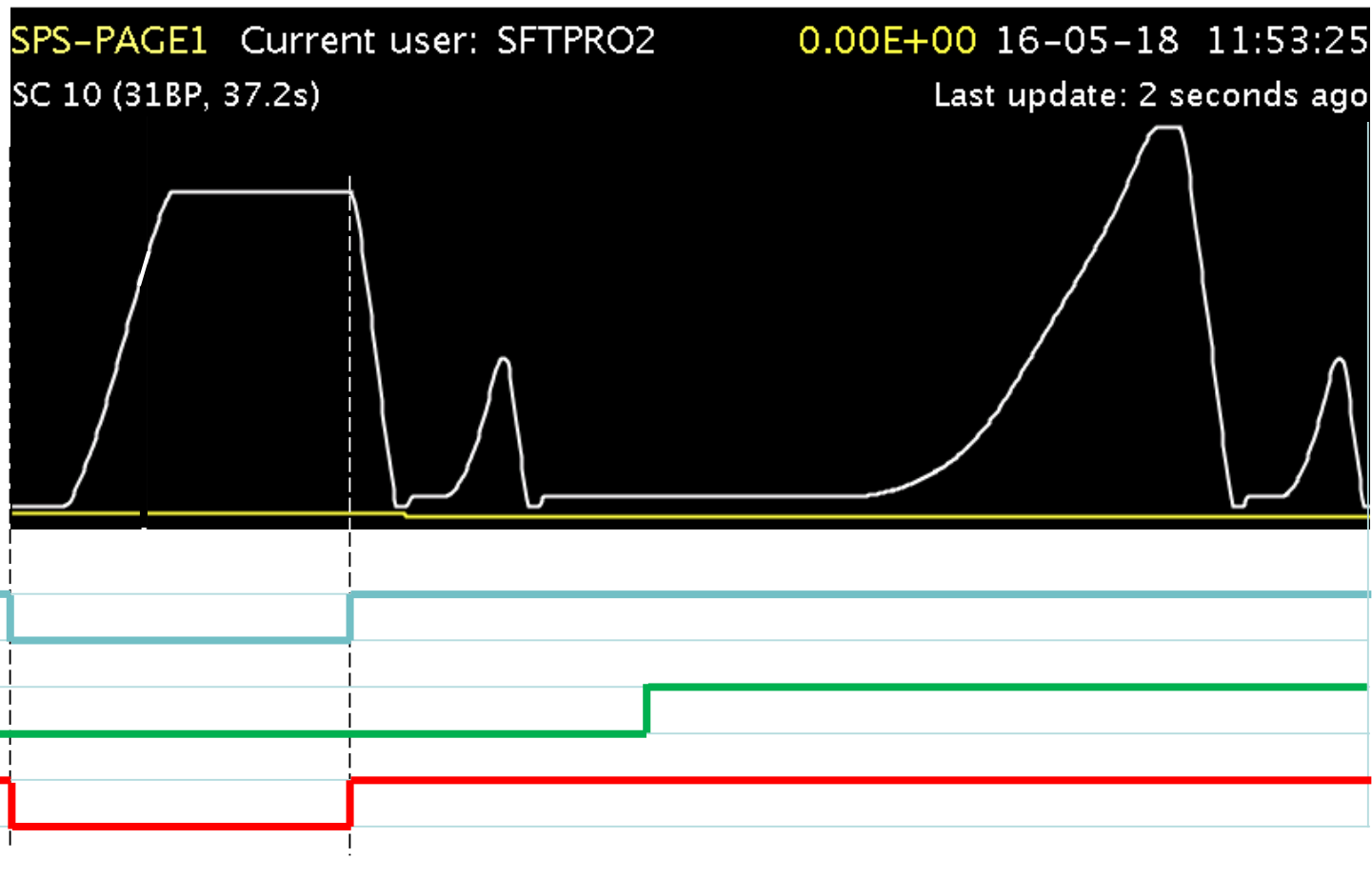
Case Study : MST/MSE transition to FAULT outside SFT cycle



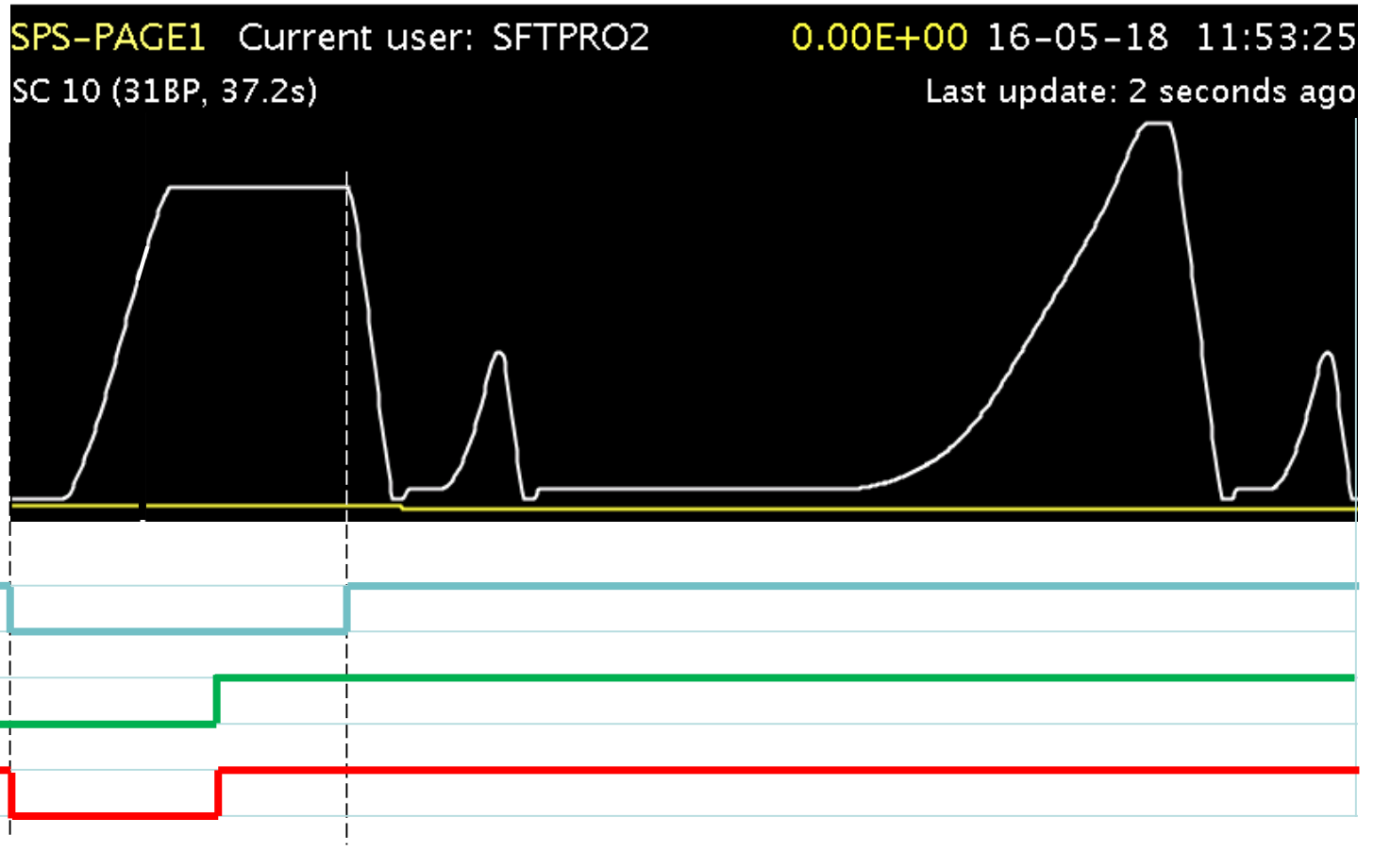
Case Study : MST/MSE in FAULT



Case Study : MST/MSE transition to OK outside SFT cycle



Case Study : MST/MSE transition to OK inside SFT cycle



Testing (1)

- ❑ Provide sequence to run MCS check
 - Will verify all interlock configuration through FESA

- ❑ Tests before beam during hardware commissioning:
 - Connectivity test with high voltage: every BLM needs to trigger BIS
 - Change gains and read them back from hardware
 - Test all BLM SIS interlocks

Testing (2)

- Test with beam: for LSS2, 4 and 6 and few chosen locations
 - LSS2, 4 and 6 (hardware interlock):
 - Put bump at location of BLM of interest
 - trim threshold to 0.1 mGy
 - Use LHC BPMs, turn-by-turn FBCT or mountain range to measure time until beam is dumped from moment of injection
 - Ring BLMs (software interlock): need 2 BLMs to trigger
 - Adjust incorporation rules to have slow rising bump
 - Reduce BLM thresholds at two adjacent QF magnets (H) or QD magnets (V) and put bump in Q20 [4C bump, zero angle] at 26 GeV in the middle of flat bottom
 - Record time evolution of losses and DC BCT. Calculate reaction time. Should be max 20 ms

A propos: Testing

- ❑ Added tests to SPS check lists

The screenshot shows the 'Machine Checkout' interface. At the top, there are navigation tabs: 'SPS', 'MACHINE PROTECTION', 'BLM QUALIFICATION', and 'WITHOUT BEAM'. Below these, the 'SPS' section is expanded, showing a list of test categories with counts in orange circles:

- 0 ▶ PREREQUISITES
- 1 ▶ HARDWARE TESTS
- 2 ▶ SPECIAL APPLICATIONS
- 3 ▼ MACHINE PROTECTION
 - 0 ▶ SPS RING
 - 1 ▶ WEST EXTRACTION LHC B1
 - 2 ▶ EAST EXTRACTION LHC B2
 - 3 ▼ BLM QUALIFICATION
 - 0 **WITHOUT BEAM**
 - 1 WITH BEAM
- 4 ▶ SPECIAL OPERATION
- 5 ▶ BEAM COMMISSIONING
- 8 ▶ SOFTWARE INTERLOCKS

On the right side, there are two buttons: '+ Add Test' and '+ Add Target'. Below these, a list of tests is displayed, each with a count in an orange circle:

- 0 run MCS check sequence
- 0 connectivity test
- 0 check gain setting

At the bottom right, there is a target entry: 1 SPS BLM.

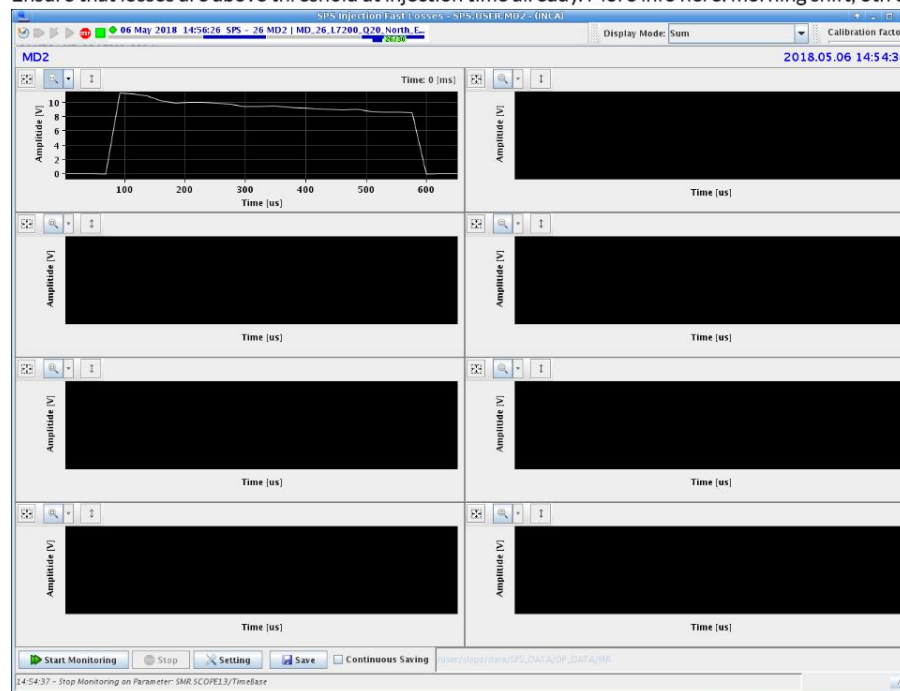
A propos: Testing

Added tests to SPS check lists

In order to validate the BLM interlock capability, an MD cycle is needed. The step to follow are listed here:

1. Put an INDIV on an MD cycle
2. Change threshold to 0.1 mGy
3. Calculate a closed orbit bump with YASP in vertical at the location of interest (e.g. 217)
4. Go to a bump amplitude where significant losses are produced
5. Set the threshold of the chosen BLM below the loss level
6. Set up a turn-by-turn instrument (mountain range, fast BCT in turn-by-turn mode, LHC BPMs...)
7. Provoke a dump and check the time between injection and dump. Expect ~ 500 us

Ensure that losses are above threshold at injection time already. More info here: morning shift, 6th of May 2018



+ Add Target

- 3 LSS2 TT20 BLM
- 4 BLM LSS6
- 5 BLM LSS1
- 5 BLM LSS4
- 6 BLM RING

Summary

- ❑ The SPS BLM system underwent several software upgrades during the YETS
 - Some of the modifications could only be tested with beam (correct BLM readings,...)
- ❑ Needed bug fixes during the run
- ❑ Interlocking functionality was not tested afterwards
- ❑ MST tripped during slow extraction on 5th of May 2018 and BLMs did not stop beam
 - Similar issue had occurred already 15th of April
- ❑ Only protection systems so far: BLMs

- ❑ Will improve software and monitoring, including timing
- ❑ Will include hardware interlock on MST/MSE sum fault
- ❑ Will test
 - More at start-up
 - And after every modification

EXTRA SLIDES

