LHC BLM SYSTEM:
RE-COMMISSIONING AFTER LS2 AND SUMMARY OF SW & FW CHANGES

Machine Protection Panel 30/04/2021

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Overview

- Checks to be performed during:
  - Hardware Commissioning
  - Machine Checkout
  - Beam Tests
- Overview of changes in SW & HW
- Outstanding Issues
- Summary

CHECKS TO BE PERFORMED

Hardware and Machine Checkout

- All Hardware Commissioning and Machine Checkout checks need to be completed successfully.
- Those include:
  - 8 Hardware checks
  - 3 Machine Checkout checks

➢ See also the MPS document LHC-OP-MPS-0009 v.3.4 for explanations on reasons and conditions
  - New version in preparation with minor changes

HW Checks Progress (1/2)

Status	Rep.	Action	Comments
1	S FW-CS	**High voltage modulation test (BLM test 710), checks the connectivity up to the surface card before every fill.** 1) Test the functionality of the T1 and T2 counting (warning issued and USER_PERMIT set to FALSE). 2) Test that the limits for "test OK" are correct, can be done for all channels at the same time: • Reduce and increase accepted min/max gain value locally (verify that USER_PERMIT to FALSE when test fails). • Check that each monitor goes to "failed" (check of firmware: is the comparison of the measured gain to the accepted gain correct). *All tests to be applied on all crates.*	Functionality and application operational; Some channels fail due to links or installation changes
2	FW-CF	**10pA signal monitoring (BLM test 712), acquisition chain test via 10pA test signal (one count within 100 s).** 1) Test that the limits for "test OK" are correct: reduce and increase bias voltage below and above threshold (verify that the test fails and that the USER_PERMIT is to FALSE). *Laboratory test on one card for each firmware.*	Not needed; It is done to any card removed from the installation.
3	FW-TC	**Double optical line comparison: continuous check of the connectivity up to the surface card.** 1) Force input through all the parameter space of the decision matrix and verify that the correct answer is given. *Laboratory test on one card for each firmware.*	Completed
4	S FW-CF	**100pA signal test (BLM test 711). The bias current is increased by 100 pA and the 1.3 second running sum is measured and checked.** 1) Test the functionality of the T1 and T2 counting (verify that warning issued and USER_PERMIT set to FALSE). *To be applied to all crates.* 2) Verify that the test can be failed (by artificially increasing the bias current). *Laboratory test on one card for each firmware.*	Completed
5	S	**Radioactive Source Test [6]; functional test of full acquisition chain (BLM test 720, Acquisition chain test by a radioactive source):** • Create a signal on the detector with a radioactive source. • Check the presence of signal in the corresponding BLETC card and Logging DB. *To be done for every detector.*	In preparation
6	S	**EMC test (BLM test 730) based on the 40μs and 1.3s running sums.** • Observe noise level. • ~~Switch on/off possible interference sources (motors, kickers, PCs …)~~. *To be verified for every detector.*	Not started: To be done when the installation & DBs are complete.
7	S FW-CS	**Beam Energy Reception test (BLM test 350)** • Disconnect CISV input cable (observe error in toggle bit) and verify that energy is set to FFFF (max. energy). • Disconnect CISV output cable (observe lost packets) and verify that energy is set to FFFF (max. energy). *To be done for every BLECS.*	Executed, but will repeat after SMP FW update

- Check functionality has been updated to follow BE-CSS changes
- TIM Irradiation campaign will need to interleave FW & SW changes and tests
- Noise analysis code ready, but need to wait HW & DB changes

HW Checks Progress (2/2)

Status	Rep.	Action	Comments
8	S FW-TC FW-CS S FW-TC	**TC & CS versus DB comparison (BLM test 330, which is a comparison performed through the MCS online check).** 1) For each crate, test the functionality of the T1 and T2 counting (verify that warning issued and USER_PERMIT set to FALSE if the MCS check has not run within the T1 and T2 time periods, respectively). *To be applied to all crates.* 2) Selective test procedure of the parameter space: Thresholds (16 channels, 12 integration time intervals, 32 energies), names, DCUM, mask tables, connection tables, etc).Change parameter value in BLETC (do not update data base) and observe the detection of the disagreement between BLETC value and MCS data base (verify that USER_PERMIT to FALSE when test fails). *~ 10 checks per crate.*	Functional at SW & HW: To be repeated with the final FW releases of TC & CS modules
9	S FW-TC	**Test of "remove beam permit"; Tested all 16 channels, all 12 running sums and all 32 energy steps of one BLETC.** • In the TC, for each channel, each running sum (at each energy step) is brought above the abort threshold (increasing the signal and/or lowering the threshold value). Check if firmware correctly identifies the channel above threshold. *Laboratory test on one card for each firmware.*	Not started: To be done with the final FW releases of TC & CS modules
10	S FW-CS S FW-TC FW-CS	**USER_PERMIT transmission from all BLETCs to the BLECS (BLM test 331).** 1) For each crate, test the functionality of the T1 and T2 counting (verify that warning issued and USER_PERMIT set to FALSE) 2) Verify with the data stored in the logging database the sequence (frequency ~ 1 Hz) of the test on one octant. *To be done for every BLECS.*	Functional at SW & HW: To be repeated with the final FW releases of TC & CS modules
11	S FW-CS	**USER_PERMIT transmission from last BLECS card of each rack to CIBU (BLM test 332).** • Functionality tested with BIS, EDMS 889281. *To be done for every USER_PERMIT/CIBU.*	Not started: To be done with the final FW releases of TC & CS modules

- Check functionality has been updated to follow BE-CSS changes
- Independent of the current state, these checks will need to be repeated with the final FW releases of TC & CS modules

Pending tasks

Most time consuming tasks pending:

- Exchange acquisition & processing modules
  - Several already repaired or exchanged
  - Approx. 50 more modules to be corrected
  - ➢ Most common issue: optical reception part
  - ➢ Few more to appear after the noise analysis step.

- LSA Settings database
  - Renaming, addition or removal of monitors following LS2 changes
  - Changes need to propagate through MTF, Layout, LSA to electronics
  - ➢ Already with Configuration team since 01/2021
  - ➢ Necessary for the TIM irradiation tests
  - ➢ ECR to be circulated before June. Draft: EDMS: 2510506 v0.2

- Calculate new Connectivity Check limits
  - Need approx. 20h of modulation results
  - 2-3 nights data taking early September

System Checks

Status	Rep.	Action	Comments
1	S FW-CS FW-TC	**Test of the successful transition of USER_PERMIT.** • The BLM system sets its USER_PERMIT to FALSE (using the toggle functionality of BLM system for each output, i.e. A and B, of the MASKABLE and UNMASKABLE channels). • The transition of each separate connection of BLM USER_PERMIT to FALSE and the signal arrival at the BIC and if possible also at the dump system is acknowledged through the BIC supervision application. The test must be performed on at the centre crate of each sector (i.e. device cfv-s**-blmc). Results are to be documented in MTF. Time estimate: 5' x 8 (sectors) *To be done for every USER_PERMIT/CIBU.*	This has been automatised and should be included in the Sequencer
2	S FW-CS FW-TC	**Test the change of the threshold values according to the beam energy signal received.** The main dipoles circuits in sectors 45, 56, 67 and 78 are ramped from injection to physics energy (7 TeV or less) or a simulation energy ramp is transmitted by the timing system. The logging of beam energy and threshold values is checked in the data logging. Time estimate: 1h *To be done for every detector.*	To test all THRESH vs DB with a internally simulated ramp (0-31)
3	S FW-CF FW-TC FW-CS	**Check of the correct detection (by the electronics) and propagation (by the front-ends) to the SIS for requesting a beam dump due to missing HV power supply on the system's detectors.** Using the expert tools reduce the value of all HV power supplies to values lower or equal to 900 V. Acknowledge the reception of the interlock request in the SIS application for each crate according the time delay setting applied for each of them. Time estimate: 1h *To be done for every processing crate.*	The expected FESA class functionality to be tested first in the lab with the dedicated testbench

- System checks to be executed (one last time) before giving the beam permit to OP.

Beam Tests

	Rep.	Action
1	S	**Validate Interlock Request functionality of the BLM crates.**
	FW-CS	Decrease thresholds to very low value (trim application).
	FW-TC	Inject low intensity pilots in regular intervals in Beam 1 and/or Beam 2.
		At each interval close sequentially collimator jaws around the ring in order to force different BLM crates to trigger interlock requests.
		Aim to have the majority of crates at least once.
		Time estimate: 2h
2	S	**Validate Interlock Request functionality of the BLETC modules.**
	FW-TC	Decrease thresholds to very low value (trim application).
	FW-CS	Inject a low intensity pilot in Beam 1 and/or Beam 2.
	FW-CF	Create a local bump until an interlock request is sent by the system.
		Aim to have up to the 1.3 s Running Sum measurement over its Threshold value.
		Time estimate: 1h
3	S	**Measure the interlock request system latency.**
	FW-TC	Decrease thresholds to very low value (trim application).
	FW-CS	Close one TCP collimator jaw in Point 3 and a second in Point 7 in order to block completely the passage of beam.
	FW-CF	Inject a low intensity pilot in Beam 1 and Beam 2.
		Calculate the system latency to initiate an interlock request by making the difference between the timestamps recorded by the BIS and the Injection Kicker. (for added accuracy the propagation delays can be removed for the beam to reach from the injection region to the detector the requested the interlock)
		Time estimate: 2h
4	S	**Test interface of direct BLMs with the beam dumping system (same test as 7.3.4 of [1]).**
		Reduce the voltage setting of the abort threshold.
		Dump the injected beam on the collimator TCDQ and TCSG (with local bump). The threshold must have been lowered sufficiently, to provoke a beam dump request.
		Record the beam dump.
		This test must be repeated for each beam and for both TCDQ and TCSG.
		From the amount of lost beam and the BLM reading, deduce the nominal threshold setting.
		Are there variations with respect to the impact conditions?
		Measure delay between the time where the loss signal exceeds the threshold and the time of the beam dump (time stamps in logging DB).
		Time estimate: 2h (without the two accesses: could be scheduled during injection tests)
5	S, O	**Verify Injection Interlock Inhibit functionality**
		Tests with pilot beam during commissioning of injection protection system. Create losses above dump threshold and modify blindout time Record interlock input from blindable/non-blindable crates If losses above dump threshold cannot be reached, lower the monitor factor of blindable crates BLMs
		Tests with trains (288 b or what is being used for scrubbing) Tighten TCDIs from 5 sig to 4.5 sig (likely settings for Hilumi) Tighten monitor factor
		Time estimate: 1h (first time might be more)

Injection Interlock Inhibit

- Tests with pilot beam
  - During commissioning of injection protection system
  - Create losses above dump threshold
  - Modify blindout time
  - Record interlock input from blindable/non-blindable crates
  - If losses above dump threshold cannot be reached, lower the monitor factor of blindable crates BLMs
- Tests with trains
  - 288 b or what is being used for scrubbing
  - Tighten TCDIs from 5 sig to 4.5 sig (likely settings for Hilumi)
  - Tighten monitor factor

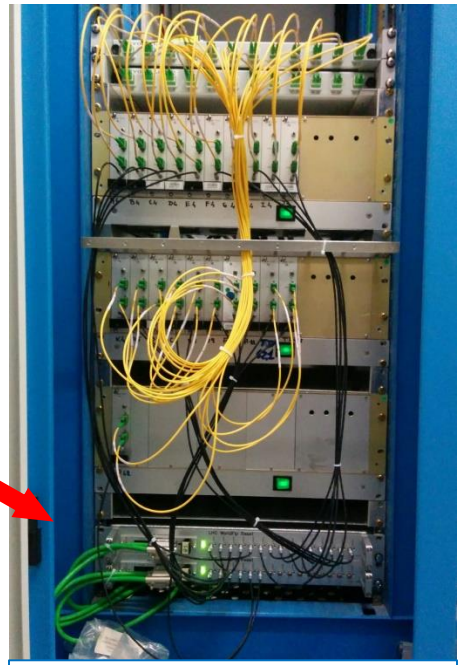
Criteria for successful test:

- Functionality: 'blindable' detectors DO NOT interlock within given blindout time and losses above threshold
- Redundancy: 'non-blindable' detectors DO interlock in case losses go above threshold on those, while blindable ones do not interlock
- Inhibit time: setup the necessary blindout time – not critical, can be adjusted later

OVERVIEW OF SW & FW CHANGES

Corrective Actions during LS2

- Multiple cards have been exchanged
  - From next run changes will be tracked with InfoEAM
- Acquisition card reset through WorldFIP to become operational for the complete installation
  - Connection in the ARCs was done in YETS2018
  - Aim to reduce the number of interventions
  - ExpertGUI under development by BI-SW
- BST got an update and fixes regarding timestamps
  - XPOC & PM could be analysed better
  - Note: LTIMs were upgraded to FESA3 in 2018
- Many applications re-delivered to get latest libraries
  - Resolution for some was simple
  - Many needed major changes/effort



New custom FIP fanout module for the DS/LSS BLMs

Concentrators & NXCALS

- All concentrators re-build to follow BE-CSS changes
  - New version in parallel with UCAP method for the main one.
  - Aim to eradicate the custom one with a standardised solution.
  - ➢ IQC and UFO Buster have not been tested yet.

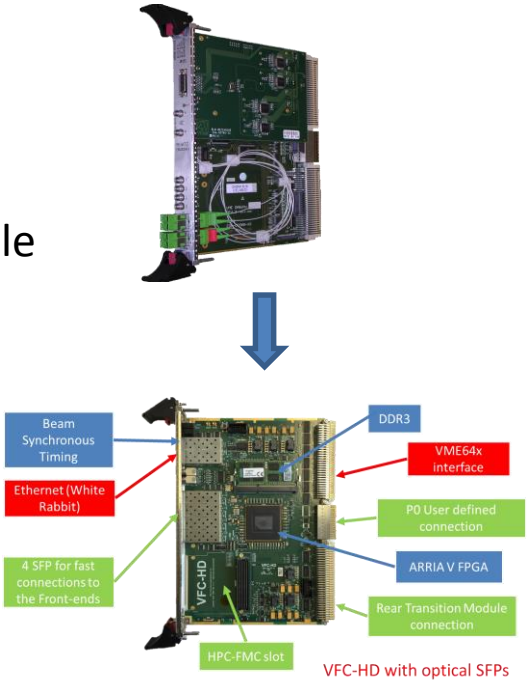
- All LHC BLM historical data transferred successfully to NXCALS
  - New schema has been agreed to optimise performance
  - All metadata have been created
  - ➢ Concentrator was modified to push data to both DBs since 2018

Sequencer & Daily Checks

- Sanity checks code have been taken over by BI-SW
  - Modifications are done to improve speed of execution and connections to LSA DB
  - Some changes due to FESA3 & new APIs pending
- Automatic daily checks update
  - Checks updated to use NXCALS as source
  - Some issues in the code under investigation
  - Working on optimising data extraction for easier analysis
  - Probably need to set filtering criteria on diagnostic data

FW & SW Changes

- Both Processing & Combiner and Survey modules firmware modifications:
  - Added better compatibility with new CPUs
    - New VMEbus core with MBLT mode
    - Memory map optimized for block transfers
  - Restructure & rewrite parts of the code
    - Allow the use of common libraries with the other developments
  - Preparation for the transition to the new processing module
- Critical functionalities completed and tested
  - New FPGA Verification testbenches
- Many changes to the FESA server
  - FESA2 to FESA3 architecture – New API required in places
  - VME data transfer rates allows FESA design optimisation



VFC-HD with optical SFPs

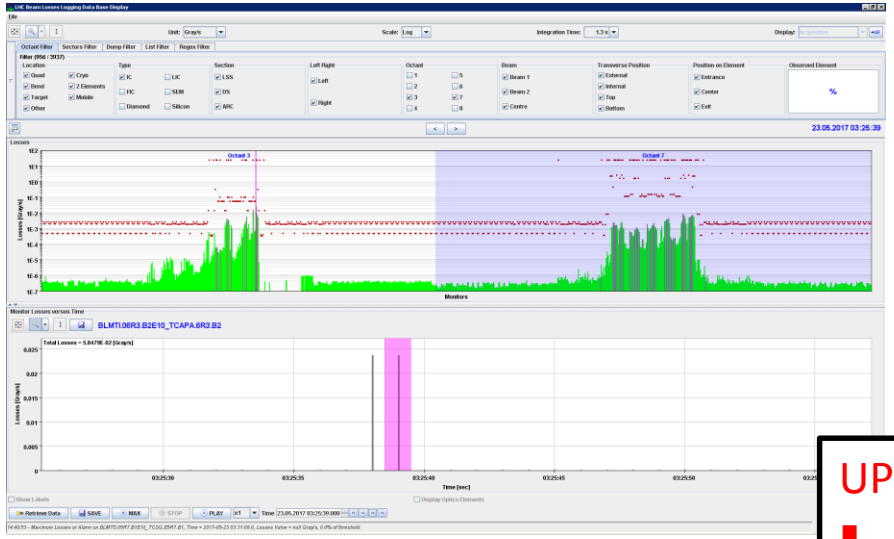
Pending:

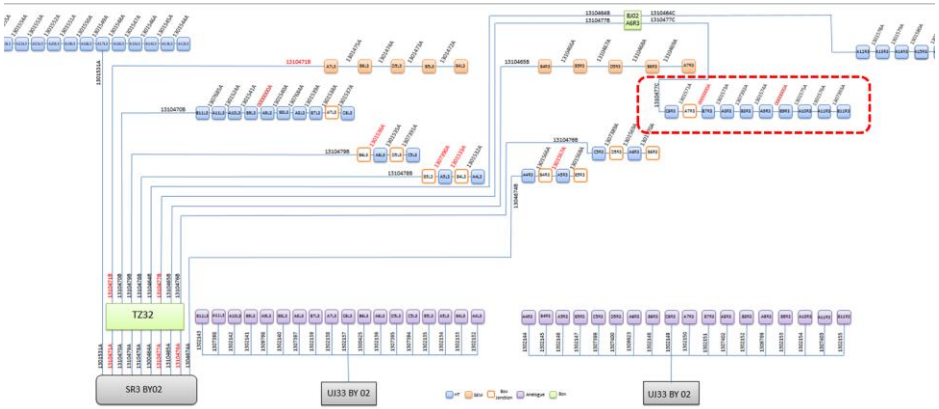
- Verify IQC, XPOC, Post-Mortem, Capture & Collimation data
- Full deployment of the “Injection Inhibit” feature

OUTSTANDING ISSUES

Signal Drop at IP3

- During the Loss Maps Validation several BLM signals drop to zero at DS of R3
- The issue has been reported twice in Run 2:
  - BIBML-990 on 2015/05/05 & BIBML-1344 on 2017/05/23
- Specificities of the location
  - HV cable is ~ 3km (all other locations < 200m)
  - Very long signal cables (~ 800m)

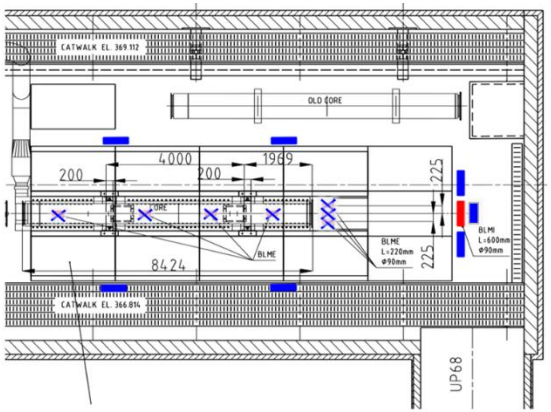


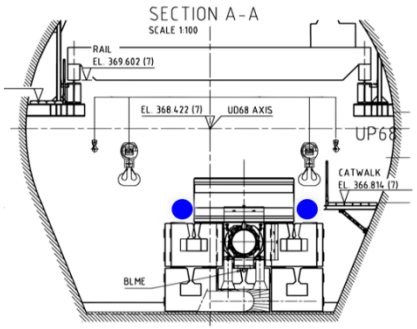


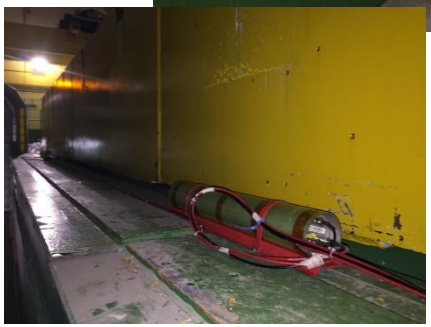
UPDATE:
- Solution with isolation using diodes identified
- Aim is still to apply it this year

BLMs at the DUMPs

- Solution consisted of
  - Adding six ICs and one LIC per DUMP
  - using rad-tol cables (kapton insulation)
  - Portable supports







- Open question if we need to add a filter to the IC behind the dump
- In high intensity will most probably saturate
- If necessary, better to do it now
  - Before completing verification of the installation
  - Set up the appropriate threshold

Summary

Commissioning:

- Hardware and Machine checkout checks ongoing
  - DBs and HW modifications to complete to assume results final
- Tests with beam to be planned
  - For most of them good experience to achieve them
  - Test for the ‘blindable’ channels was not successful in the past

System Issues:

- No known machine protection critical issues
- Significant work still needed to bring the system into proper ‘operational mode’, but no major obstacles
- Some interleaving needed to deliver updates while performing the TIM irradiation tests

Thank you