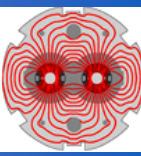


Can operation put the MPS in a unsafe state?

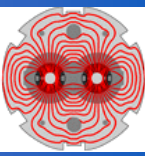
Laurette Ponce (BE/OP)

With input of all the OP team

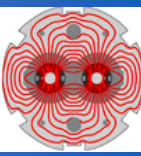


- 2 questions in one:
 - Can operation put the machine in an unsafe state ?
 - Can operation put the Machine Protection System in an unsafe state?

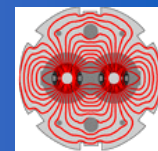
- YES , we did both:
 - The OP team has been very efficient in stressing the Machine Protection System over the 2010 run
 - (long?) list of errors presented in OP review and Evian
 - But we have learnt from our mistakes



- Case 1 : Loss of the beam due to procedural errors caught by MPS → beam DUMP:
 - Sending incorrect trim values (5 units on tune instead of chroma)
 - Sending wrong commands/settings (OFB on during collisions, mega chirp)
 - ...
- Case 2 : putting the machine in an unsafe situation so that if something else goes wrong, it is not properly protected:
 - Forgotten masked software interlocks (SIS, cryo,...)
 - Tasks forgotten or played in the wrong order
 - Wrong orbit
 - **Major risk**

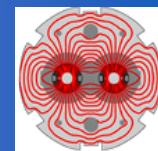


- Case 1 errors caught by MPS suppose that MPS is properly working
- MPS components are designed to be fail-safe:
 - Redundancy, sanity checks, pre-ops checks
- Before beam injection, series of sanity checks to guarantee MPS integrity:
 - BLM sanity checks
 - BI checks
 - LBDS IPOC, XPOC
 - Collimators energy thresholds
 - MCS checks for LBDS and injection
 - BIC pre-ops checks
 - ...



- Based on 2010 run experience, a lot of improvements were added over summer time (thanks again to OP for the appreciated contribution):
 - Several new SIS interlocks (injection settings, RF frequency range, CODs settings,...)
 - New tasks in the nominal sequence, to check settings during all the phases, for the incorporation (injection checks, run through the squeeze, collisions preparation...)
 - New beam process for preparing collisions including most of the critical settings management (collimators, copying lumi scan values ...)

- Reduced a lot the mis-manipulation and as a consequence the stress of the MPS



- Rationalization of the nominal sequence and procedure
- Automatization as much as possible, especially the tricky tasks: really few left

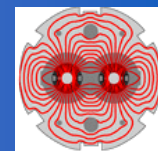
The screenshot displays the Sequencer Execution GUI (PRO) : 0.9.11. The interface is divided into three main panels:

- Left Panel:** A tree view showing the overall sequence structure. The 'PREPARE RAMP' section is expanded, showing tasks like 'INFO: PREPARE RAMP SUBSEQUENCE STARTS', 'TRIM ADT GAINS TO -22 (-31 VB2)', 'SET BEAM MODE=PREPARE RAMP', 'ENABLE POST MORTEM EVENTS', 'INCORPORATE INJECTION TRIMS INTO THE RAMP', 'CHECK INJ-PROT COLL INTERLOCKED OUT', 'INFO: SWITCH ON FEEDBACKS', 'LOAD RAMP SETTINGS IN PC&RF FGC', 'ARM LONGITUDINAL BLOW-UP', 'FORCE SBF TO FALSE', 'LOAD CLEANING & DUMP PROTEC COLL RAMP SI', 'RAMP-V01', 'SQUEEZE TO 3.5 XING REDUCTION', 'PREPARE COLLISIONS', and 'RAMP DOWN - PRECYCLE COMBO V01'.
- Center Panel:** A detailed view of the 'SQUEEZE TO 3.5 XING REDUCTION' subsequence. Tasks include: 'INFO: PLEASE RUN THE SM CHECK FOR TEST', 'WRN: OFB OPERATION BEFORE FIRST SQUEEZE POINT', 'PREPARE SQUEEZE' (with sub-tasks: 'SET BEAM MODE = SQUEEZE', 'CHECK / LOAD START SQUEEZE TIMING TBL', 'INCORPORATE FLAT TOP TRIMS INTO SQUEEZE', 'INCORPORATE RF FREQ FLAT TOP TRIMS INTO SQUEEZE', 'CHECK OFB REFERENCE FOR SQUEEZE', 'INFO: SWITCH ON OFB'), 'DRIVE TUNE FB SETTINGS FOR SQUEEZE' (with sub-tasks: 'SET FEEDBACK OFSU PRO', 'SWITCH FEEDBACK STATE TUNE_B1 OFF', 'SWITCH FEEDBACK STATE TUNE_B2 OFF', 'MAKE LHC BI USER FOR SQUEEZE RESIDENT', 'LOAD TUNE FITTER SETTINGS', 'LOAD TUNE SETTINGS'), 'DRIVE SQUEEZE SEGMENT 0 S -> 110 S', 'SET COLLIMATORS FOR 100/110 URAD XING ANG', 'DRIVE SQUEEZE SEGMENT 110 S -> 589 S', 'HIGH INT: PREPARE COLL FOR SQUEEZED STABLI', 'DRIVE SQUEEZE SEGMENT 7.0M -> 3.5M', and 'UNLOAD SQUEEZE OPTICS CHANGE TABLE'. A red circle highlights the 'INCORPORATE FLAT TOP TRIMS INTO SQUEEZE' and 'INCORPORATE RF FREQ FLAT TOP TRIMS INTO SQUEEZE' tasks.
- Right Panel:** A detailed view of the 'PREPARE COLLISIONS' subsequence. Tasks include: 'INFO: PLEASE RUN THE SM CHECK FOR TEST', 'SET BEAM MODE ADJUST', 'PREPARE FEEDBACKS FOR PHYSICS', 'MAKE USER SQUEEZE4 RESIDENT', 'LOAD PHYSICS SETTINGS TO ADT PH_SHIFT&GAI', 'SEND ADT START EVENT', 'LOAD START_SQUEEZE TABLE LOADED', 'PREPARE SEPARATION BUMPS COLLAPSE', 'DRIVE COLLISIONS BP FOR PC's AND COLLIMATI', 'INFO: PLEASE RUN THE SM CHECK FOR TEST', and 'END SUBSEQUENCE BREAK'. A red circle highlights the 'DRIVE COLLISIONS BP FOR PC's AND COLLIMATI' task.

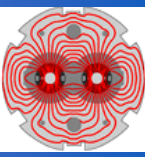
At the bottom of the GUI, there is a 'PREPARED' status bar with buttons for 'Run', 'Suspend', 'Step', 'Skip', and 'Stop'. A console window at the very bottom shows system logs.



What can OP still do?



- Direct errors are caught by the MPS, so the major risk is combination of MPS put in an unsafe state and another error:
 - Case 2 errors
- masking/forcing interlocks is the first obvious way of putting MPS unsafe:
 - Masks in BIC, SIS
 - Force value for cryo
 - Some interlocks used only for injection (QPS-OK)
- Some examples of dangerous situation:
 - TCDQ retraction interlock left masked after collimator set-up
 - Wrong references used for orbit or tune feedback
 - Movement of collimators at constant gap (interlocks only on the gap)

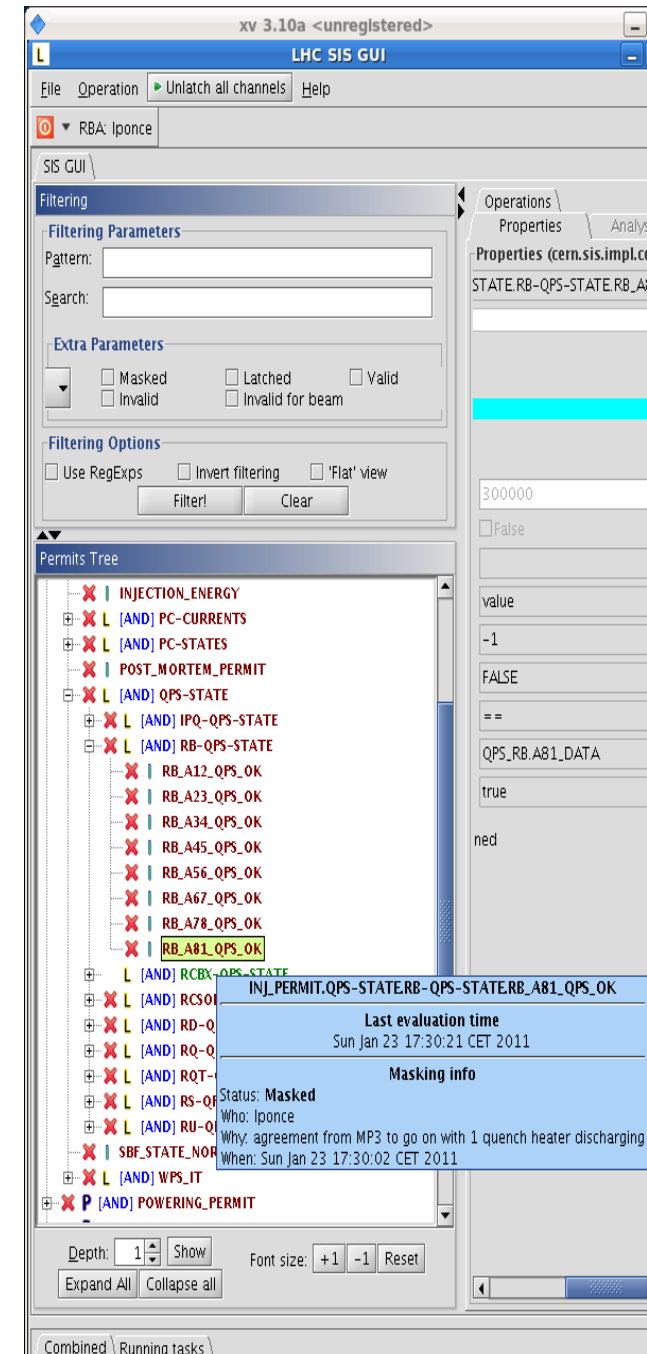


- Conditions for masking:

- BIC masks are conditioned by set-up beam flag
 - Mask ignored above
- Cryo mask : manual procedure to force value and lock circuits
- SIS masks : only access rights protected
- QPS-OK : SIS interlock for injection only + consigne to not ramp

- Some examples:

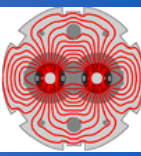
- Cryo signal forced at the wrong level
- BIC interlock forgotten → beam dump during the high intensity filling or ramp
- SIS interlock latched → beam dump
- QPS-OK masked for ages



The screenshot shows the LHC SIS GUI interface. The main window displays a 'Permits Tree' with various interlock conditions. A dialog box titled 'Masking info' is open, showing the following details:

- Last evaluation time:** Sun Jan 23 17:30:21 CET 2011
- Masking info:**
 - Status: Masked
 - Who: Iponce
 - Why: agreement from MP3 to go on with 1 quench heater discharging
 - When: Sun Jan 23 17:30:02 CET 2011

The 'Permits Tree' shows a list of conditions, with 'RB_A81_QPS_OK' highlighted in yellow. Other conditions include 'INJECTION_ENERGY', 'PC-CURRENTS', 'PC-STATES', 'POST_MORTEM_PERMIT', 'QPS-STATE', 'IPQ-QPS-STATE', 'RB-QPS-STATE', 'RB_A12_QPS_OK', 'RB_A23_QPS_OK', 'RB_A34_QPS_OK', 'RB_A45_QPS_OK', 'RB_A56_QPS_OK', 'RB_A67_QPS_OK', 'RB_A78_QPS_OK', 'RCBX-QPS-STATE', 'RCSO', 'RD-Q', 'RQ-Q', 'RQT-Q', 'RS-Q', 'RU-Q', 'SBF-STATE_NOR', 'WPS_IT', and 'POWERING_PERMIT'.



- In SIS:

- Possibility to TAG a set of interlocks to unmask/mask per group
- Sequencer task will be added in the nominal sequence to unmask before injection/ramp...

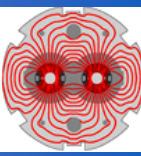
- QPS-OK: (See Walter's talk)

- New interlock for quench heaters within the QPS system: if more than 2 heaters discharging for MB → dump
- No more visual checks

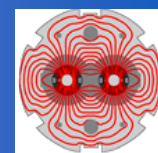
The screenshot displays the control interface for the QPS system. The main window title is "Module QPS_56:A56.RB.A56.DR5C;nQPS_56:A56.RB.A56.DR5C: (NoName)". The sub-window title is "Monitoring sub-sector: A56 Right IP5 bus: CBW_IP5_DR5C". The interface shows a grid of cryo-cells (CRYO-CELL 21 R5 to 33 R5) with their respective quench heaters (Q21 to Q33R) and status indicators (LOLd, A, B, C). A red banner at the top left reads "C - MB.A27R5 DQAMC type MB for dipole MB.A27R5". The left panel shows the "DQAMC MB status" for "MB.A27R5" with various status indicators (ST_PWR_PERM, ST_COM, ST_TIMING, ST_BUS, ST_LOGGING) and a "DQAMC MB Command" field. The right panel shows the "MB" status with "ST_MAGNET_OK" and "ST_NQD0" indicators, and a "Last Magnet Quench at (UTC)" timestamp of "2010.06.03 09:03:00.805". The bottom right corner shows the time "08:58:24 PM 12/04/2010" and page numbers "2 3 x".



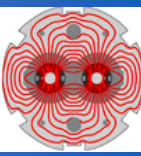
Risk at injection : key role of TDI



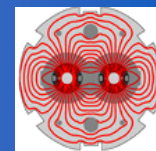
- Injection system is designed to handle injection failures:
 - TDI has saved us in all cases of injection failure
 - Importance of the TDI positions
- Injection procedure implies movement of the TDI in/out:
 - Sequences to handle the movements
 - End of filling sequences to be played in right order
- SIS interlock on the TDI gap added during the run to prevent injection in case of wrong settings:
 - Avoid pulsing the kicker with TDI out
 - But nothing prevents movements at constant gap.
- Improvement for 2011:
 - TDI energy gap interlock for the SPS extraction



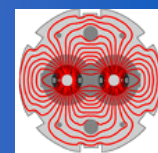
- Over-injection is not a major risk in itself, except if combine with a wrong TDI settings
- Based on the Injection Quality Check results, injection sequencer should prevent over-injection
- But during 2010 run, reliability problem of the transfer line BCT
 - Beam injected but not seen and IQC ask for repeat injection
 - Risk of over-injection on high intensity train
- When beam presence flag is OK, no extra check on injected intensity
 - Rely only on communication with injectors OP to get intermediate intensity
- New for 2011: Cross-check of injection between BQM and configuration database
 - But still manual validation from operation



- Trajectory correction during injection process
 - Effect of correction only validated by next injection
 - Rely only on procedure, no constraints on beam current
- SPS extraction interlock on the converter current
 - Limit set to 1.5 sigma (about 10 urad)
 - Limits editable by OP, except very critical one at the end of the line
- New for 2011:
 - IQC latch on injection oscillation
 - Injection oscillation interlock to force going down to intermediate intensity after correction

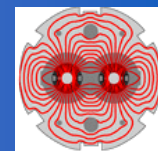


- Not discussing HW or software (feedback) failure, but only human factor
- Major risk in circulating beam:
 - run with an orbit displaced w.r.t the reference orbit for collimators settings
- Possible human origins:
 - Wrong reference used to correct: keep injection orbit for collisions
 - Create a local bump
 - Lumi-scans: free parameters in the application in
- Mitigation in place in 2010:
 - Sequencer tasks to checks references
 - Quite tight orbit tolerance interlock in SIS at injection and STABLE BEAM, less protective in between because of the separation and Xing reduction
- For 2011:
 - Dynamic change of the references for feedback,
 - providing feedback controller reports state, to be translated in sequencer task
 - Aperture-meter to monitor orbit @ TCT with lumi-scan

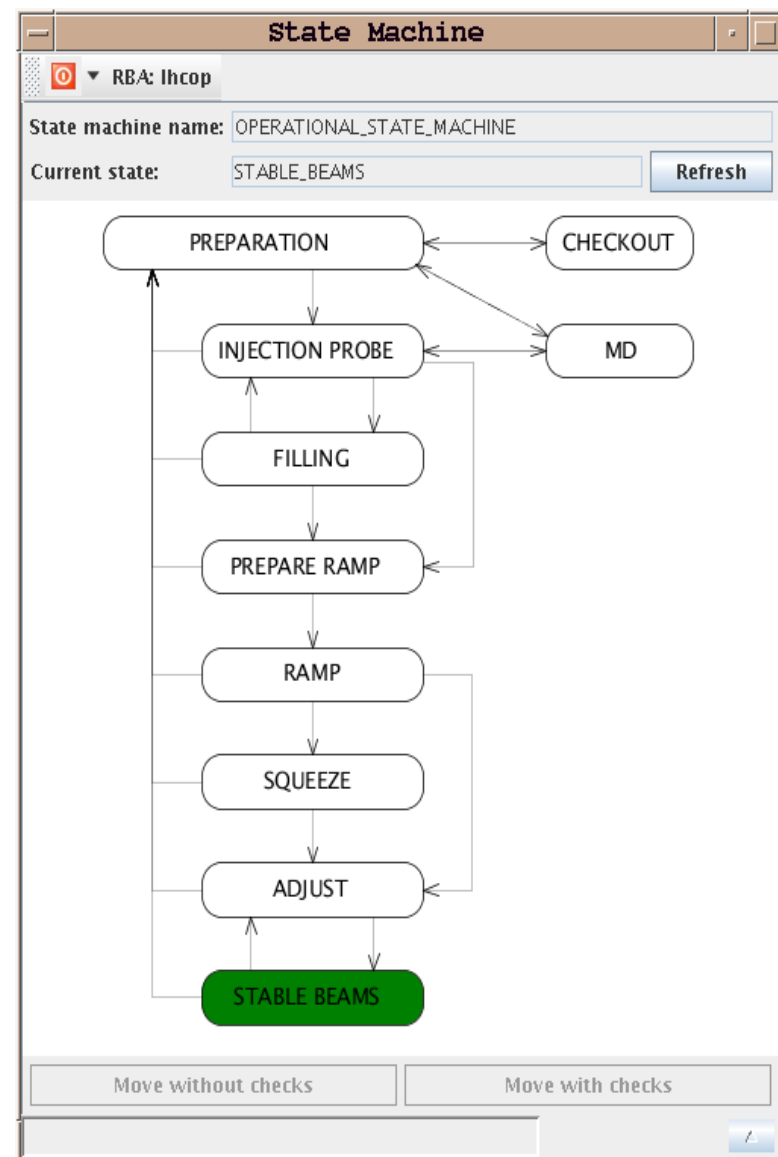


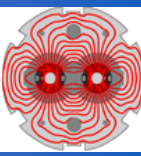
- Collimators aligned around a reference orbit
 - Problem when the orbit is not the reference one
 - But also if the settings are not the correct ones
- Management of the collimators by sequences = human:
 - Forgotten sequence : Stable beam without TCT in place
 - Wrong settings or wrong beam process used with loading also the wrong limits

- For 2011:
 - Function instead of stopping point in the squeeze
 - Check real position versus reference settings to be implemented



- To ensure the execution of tasks in the safe order
- Series of checks automatically executed when moving to a new state, only certain transition permitted
- To be added in 2011:
 - **ALLOWED TASKS:** to block execution of certain tasks in a given state (like moving out collimators...)

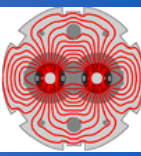




- Non-interlocked systems, still relying on procedure:
 - Abort gap cleaning : interlock logic to be defined
 - Gas injection for BGI
 - Injection cleaning with transverse dampers

- MDs : ab-normal operation, huge human factor
 - Protection of the physics settings to be put in place
 - Masking or skipped task for studies

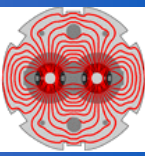
- In the flexibility:
 - Several hypercycles, Beam Processes, IP optics...



- How to ensure the nominal settings after MDs
 - Recovery sequence? How to protect physics settings?
 - Reset all masks, change of thresholds, special settings
 - Reset skipped tasks in the sequence
 - Low intensity cycle after each period?

- After HW intervention, technical stops:
 - Powering tests procedure defined by MP3
 - Interlocks tests
 - Check of the PIC configuration

=>To be as rigorous as during HWC



- During 2010 run, a lot of efforts to suppress the human factor:
 - suppressing manual tasks
 - Interlocks added in SIS
- Improvement for 2011:
 - Sequence to unmask + TAG in SIS
 - Interlock on injection oscillation
 - TDI energy gap for injection interlock
 - Dynamic reference for the feedbacks
 - Reduce the number of stopping points in the cycle: Functions for the squeeze
- Recovery procedure from MDs, TS or piquet intervention to be clearly discussed
- For certain errors (collimator movements at constant gap), human factor can do it but also catch it

Conclusion

Can operation put the MPS in unsafe state?

Certainly still YES, but it is harder and harder!