Can operation put the MPS in a unsafe state?

Laurette Ponce (BE/OP)

With input of all the OP team

Preambule

- 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

Some examples

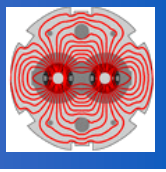
- Case 1 : Loss of the beam due to procedural errors caught by MPS → beam DUMP:
  - Sending incorrect trim values (5 units on tune instead of chroma)
  - Sending wrong commands/settings (OFB on during collisions, mega chirp)
  - ...
- Case 2 : putting the machine in an unsafe situation so that if something 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

MPS components integrity 1/2

- 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
  - ...

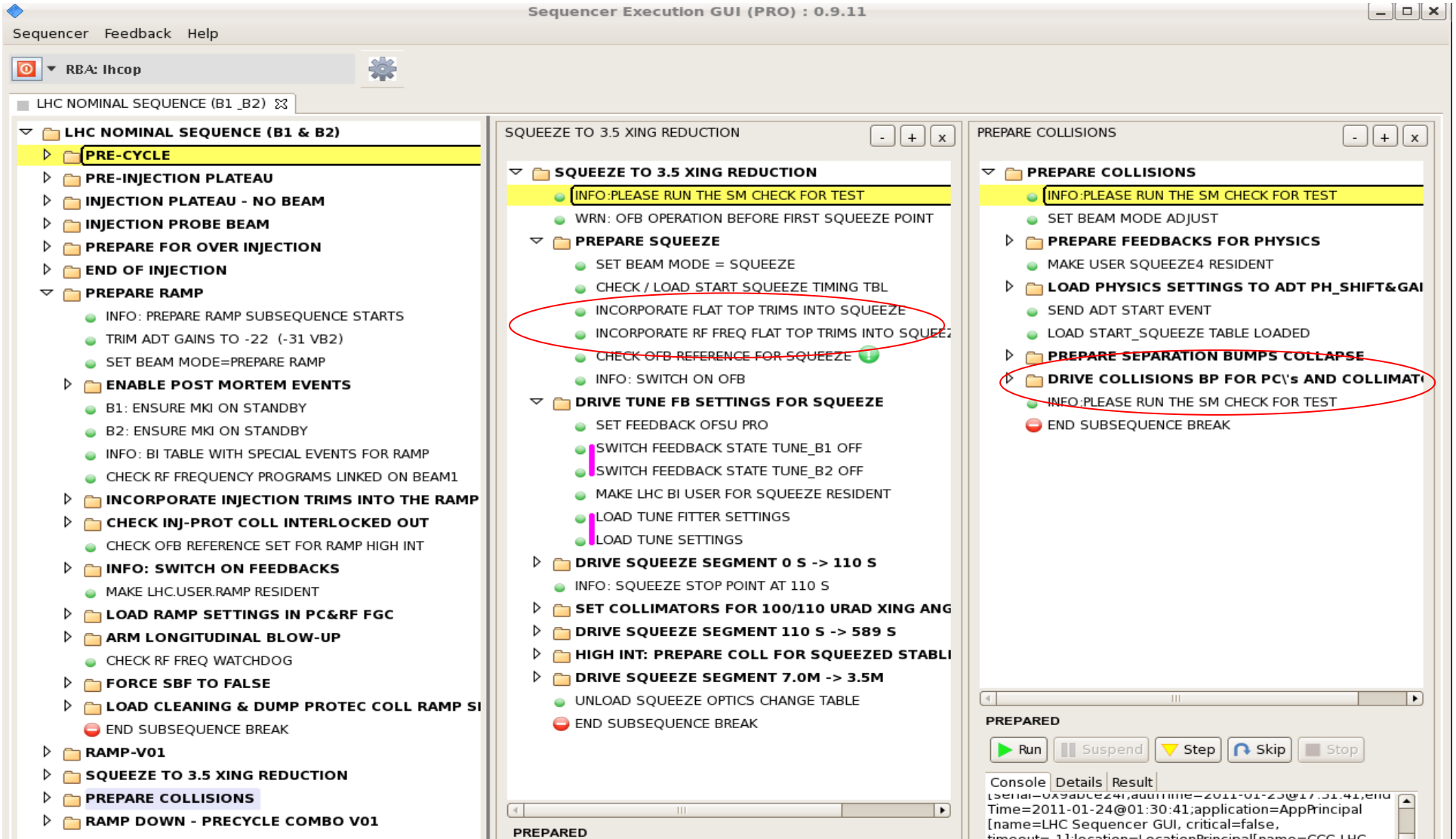
Un mal pour un bien?



- 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

Sequence and sequencer

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

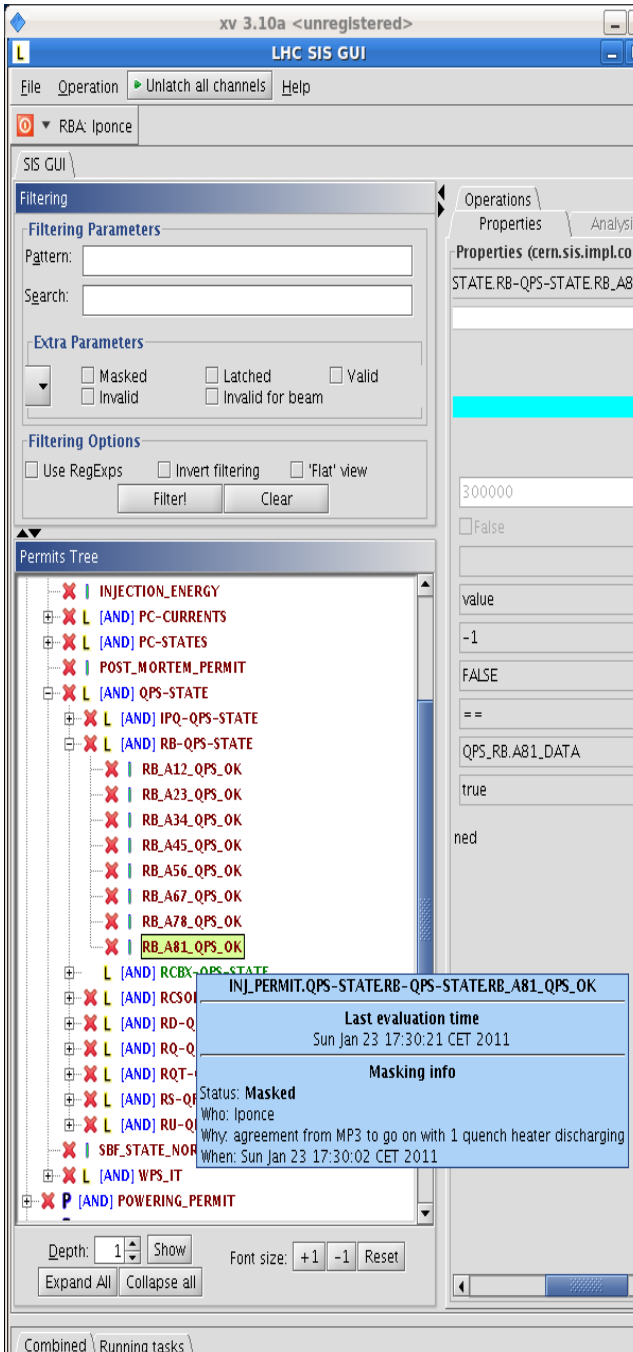


What can OP still do?

- 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)

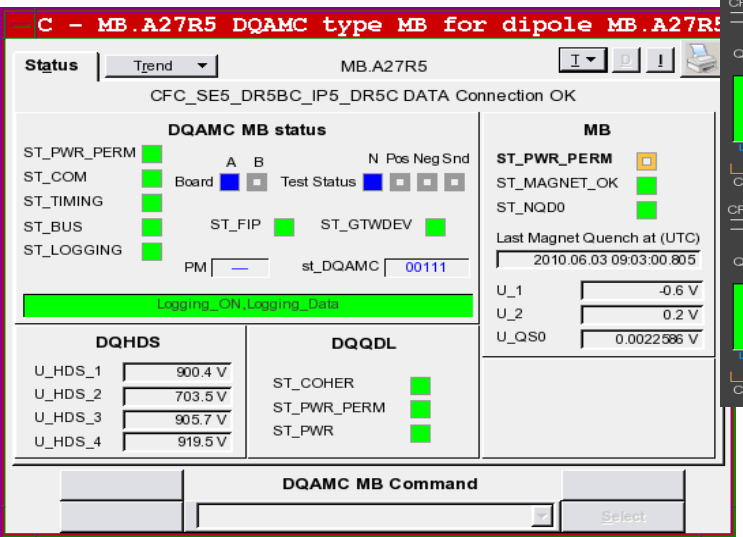
Masking policy in 2010

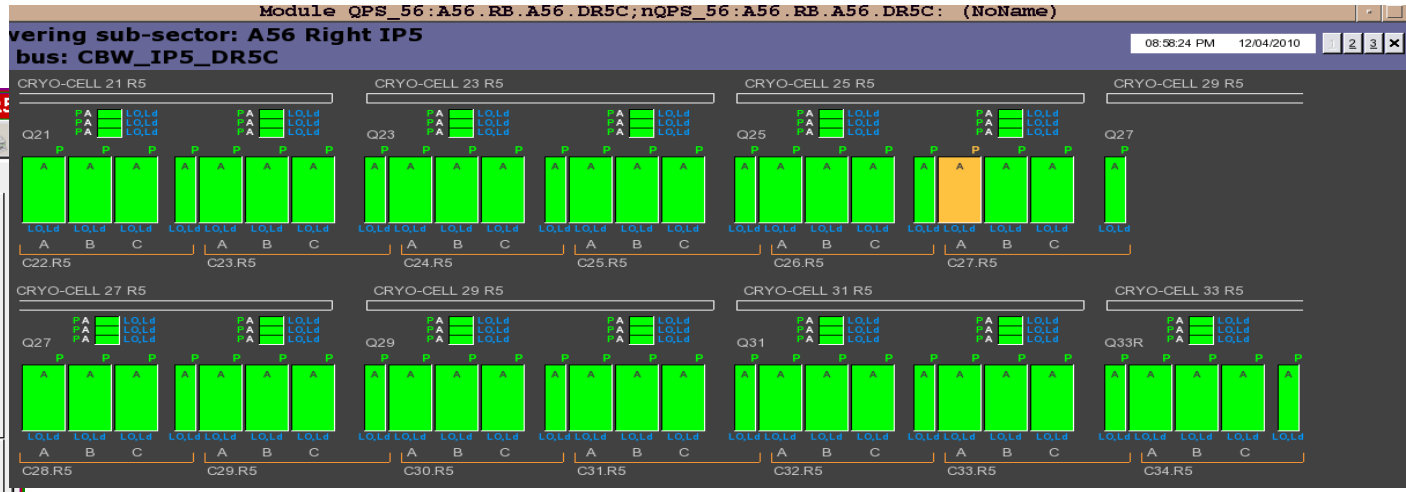
- Conditions for masking:
  - BIC masks are conditioned by set-up beam flag
    - Mask ignored above
  - Cryo mask : manual procedure to force value and lock circuits
  - SIS masks : only access rights protected
  - QPS-OK : SIS interlock for injection only + consigne to not ramp
- Some examples:
  -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



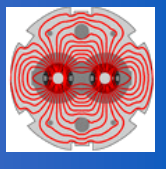
Mask :Improvement for 2011

- 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 sytem: if more than 2 heaters discharging for MB → dump
  - No more visual checks





Risk at injection : key role of TDI



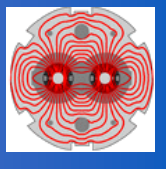
- Injection system is designed to handle injection failures:
  - TDI has saved us in all cases of injection failure
  - Importance of the TDI positions
- Injection procedure implies movement of the TDI in/out:
  - Sequences to handle the movements
  - End of filling sequences to be played in right order
- 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

- 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 inejction
  - 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

Transfer Lines trajectory

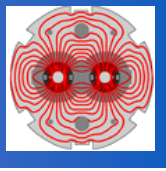


- Trajectory correction during injection process
  - Effect of correction only validated by next injection
  - Rely only on procedure, no constraints on beam current
- SPS extraction interlock on the converter current
  - Limit set to 1.5 sigma (about 10 urad)
  - Limits editable by OP, except very critical 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

Orbit control

- 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 inejction 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 betwen 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

Risks in circulating beam



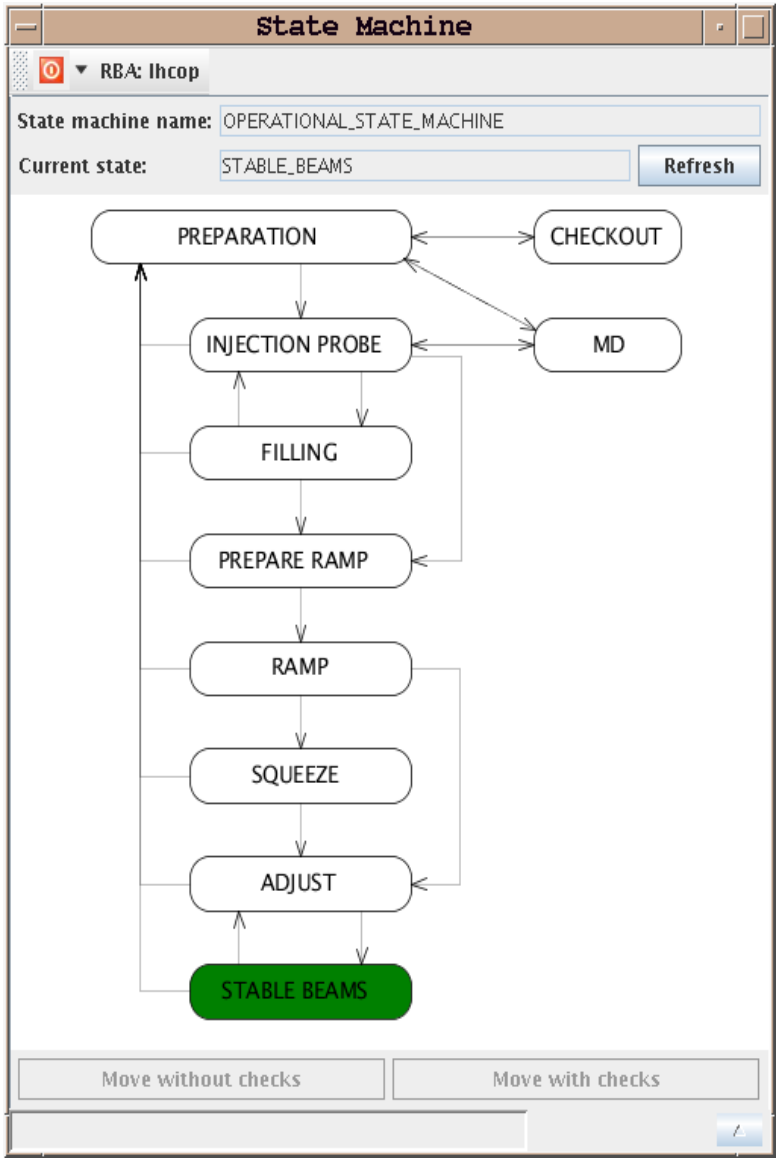
- Collimators aligned around a reference orbit
  - Problem when the orbt is not the reference one
  - But also if the settings are not the correct ones
- Management of the collimators by sequences = human:
  - Forgotten sequence : Stable beam without TCT in place
  - Wrong settings or wrong beam process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

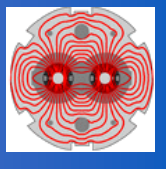
State machine

- 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...)



Where is the danger?



- 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...

Recovery nominal operation

- 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

Summary

- 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!