Machine Protection and Operation

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And special thanks to all the OP team

Introduction

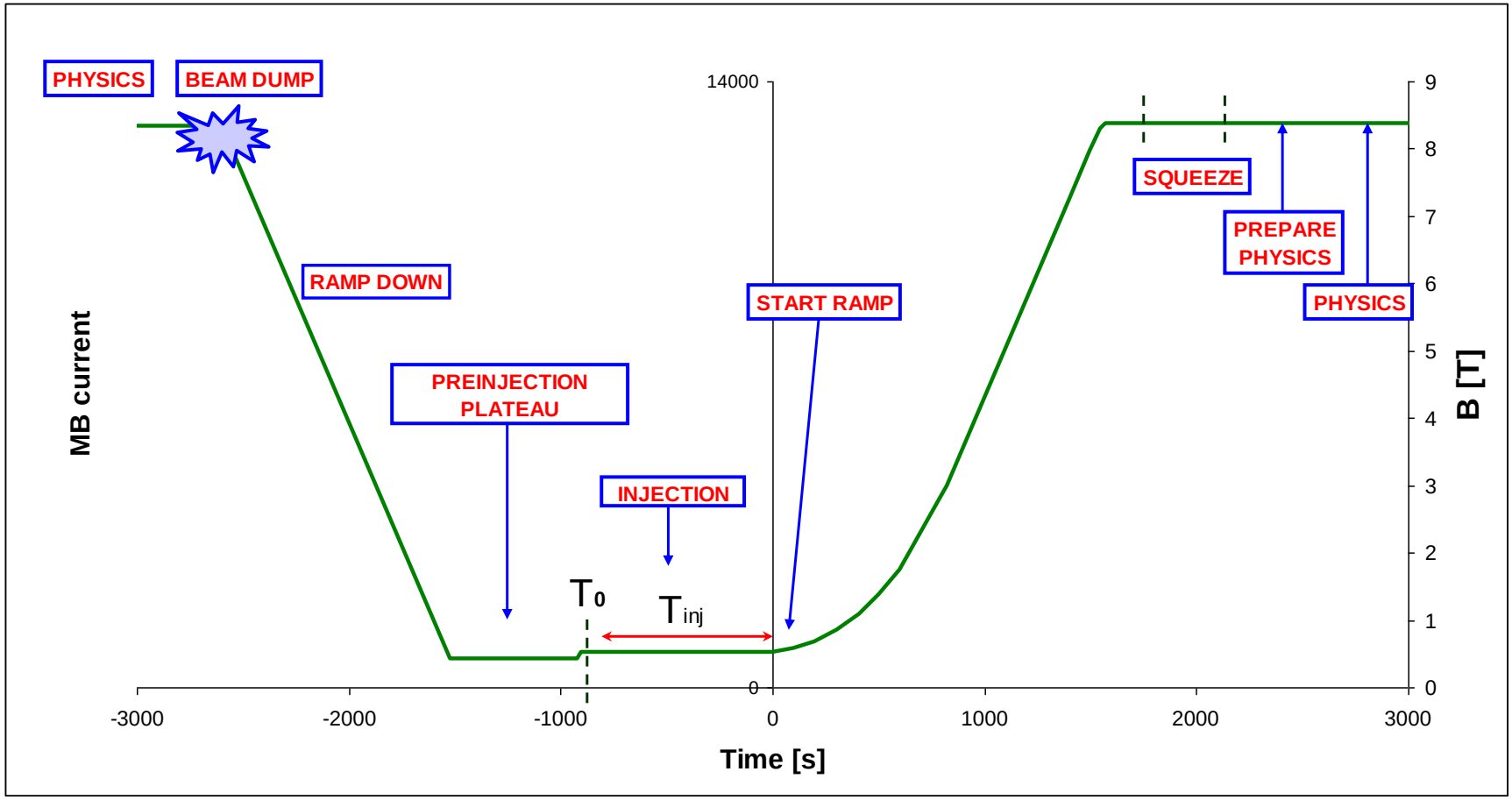
- Introducing the human factor in the well organized Machine Protection System
- To recover, prepare or setting-up the machine, still several by-hand actions to perform
- Operators play also an important role in machine protection
- Operation of the machine relies on :
  - BIC
  - Sequencer
  - SIS
  - Procedure
  - tools to measure and trim the machine parameters

Outlines

- Operational procedure
- Introduction to the sequencer
- Overview of the Software Interlock System
- Outcomes from the review on operation
- Outstanding issues

LHC hypercycle

- Nominal hypercycle, divided in phases (= beam processes)



Operational procedure 1/3

- Operational procedure is a kind of checklist with all the tasks to run the machine through the different phases of the hypercycle:
  - Ramp-down
  - pre-injection
  - Injection
  - Over-injection
  - prepare ramp
  - Ramp
  - Squeeze
  - Collisions
- very efficient old fashioned paper checklist at the beginning, imported now to WIKI, updated on-line by shift crew with change tracking
- contains also all the agreed operational parameters for each phase
- "translated" in a sequence to be run in a more automated way

Operational procedure 2/3

- Before injection, series of sanity checks to guarantee the integrity of MPS components:
  - BLM sanity checks,
  - BI checks,
  - LBDS,
  - BIC sanity checks,
  - Collimators energy thresholds
  - MCS checks for beam dump system components
  - …
- Tests to be run regularly, frequency defined by equipment reliability studies (every 12 hours, once per day…)

Operational procedure 3/3

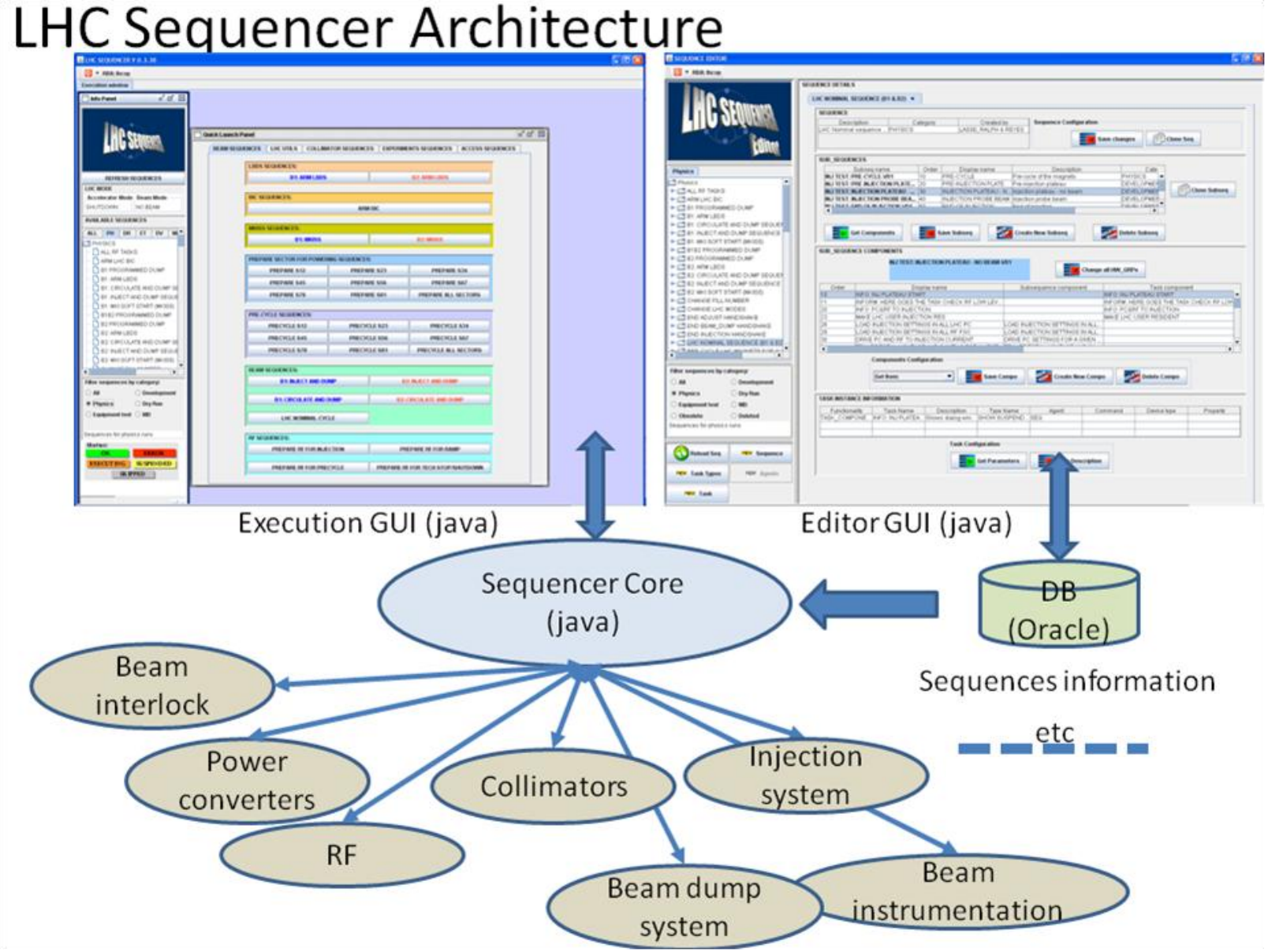
- Some of the tests are linked to beam permit (BLM) to enforce the regular execution: beam permit not given if successful test not run within the last 24 hours
- Some are linked to the software interlock system (BIC pre-operational checks) for injection permit
- But most of them rely on the shift crew executing the corresponding sequencer tasks

- 2 software very important in the daily operation, not yet presented:
  - Sequencer
  - SIS

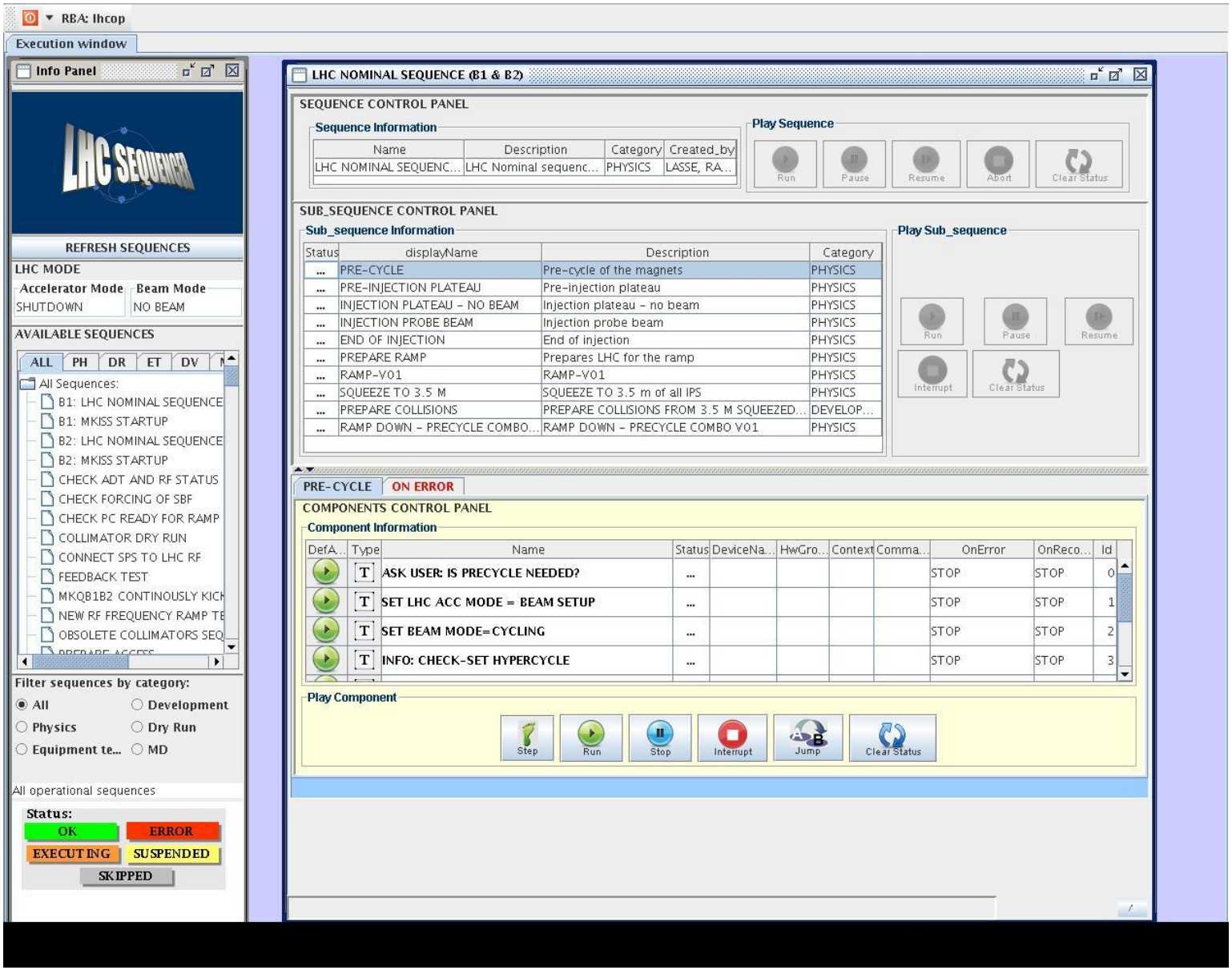
The LHC Sequencer

- Sequencer allows the machine to be driven through all parts of its operational cycle.
- run a large number of tasks that need to be executed in a given and strict order and have to be performed successfully to allow the LHC machine to go from one phase to another.
- It interfaces almost all the machine equipment and experiments.
- provides a first version of a checklist that allows shift crews to see progress through the sequences

The LHC Sequencer



The LHC nominal sequence



The LHC nominal sequence (1/2)

- all phases correspond to a subsequence, grouped in the nominal sequence
- you can run a whole sub-sequence or step in
- possibility to skip some tasks, replay
  - a lot of flexibility in the execution, mandatory in the start-up phase (Debugging phase)
  - but alternative pathways might be dangerous
- each task has predefined parameters (hardware group, commands, values) not editable in the GUI, need to use the sequencer EDITOR to update

The LHC nominal sequence (2/2)

- Definition of the nominal sequence components is critical to avoid pathways
- Role of the Operational procedure : Up-to date definition of what tasks are done in what order in the nominal sequence
- Balance between safety and efficiency: mainly in the preparation phases (no beam)
  - a lot of tasks not related to magnet powering
  - long tasks can be executed in parallel: sanity checks, kickers conditionning, RF LBDS frequency checks…
- But actual GUI does not allow real parallelism within a sequence: as a consequence, several identical sequences are run in parallel!
  - Sequencer checklist panel allows to follow-up what is done

Software Interlock System

- SIS core functionality is to provide a framework to program high level interlocks based on accelerator device parameters published over the BE Common Middleware (CMW) protocol.
- The interlock results (permits) are exported to the Beam Interlock Controller devices to trigger beam dumps or inhibit extraction from SPS.
- The framework is flexible enough to be able to export a result over CMW to any standard accelerator controls (used also to interlock power converters with access conditions)
- Interlock types:
  - *Initially*: used simple test logic comparison of acquired value to reference value (number or boolean) – hardcoded into configuration.
  - *Now*: more and more complicated interlocks (JAVA) that pull together multiple signals and DB references. Very flexible, but complex interlocks are tricky to test !

SIS Structure

- To perform its job for LHC, SIS has subscriptions to 2409 control system devices / parameters
- Within a tree interlock tests are grouped in a hierarchical manner. The resulting permit is exported to different system through a CMW connection.
  - BICs (8 signals) — update period 2 s — BIC timeout 20 s
  - MTG (2 signals) — update period of 4 s
  - PICs (36 signals) — update period of 2 s
- All interlock trees are evaluated every **2 seconds**. The evaluation is triggered from the 1 second clock signal provided by the LHC timing system.

SIS Availability

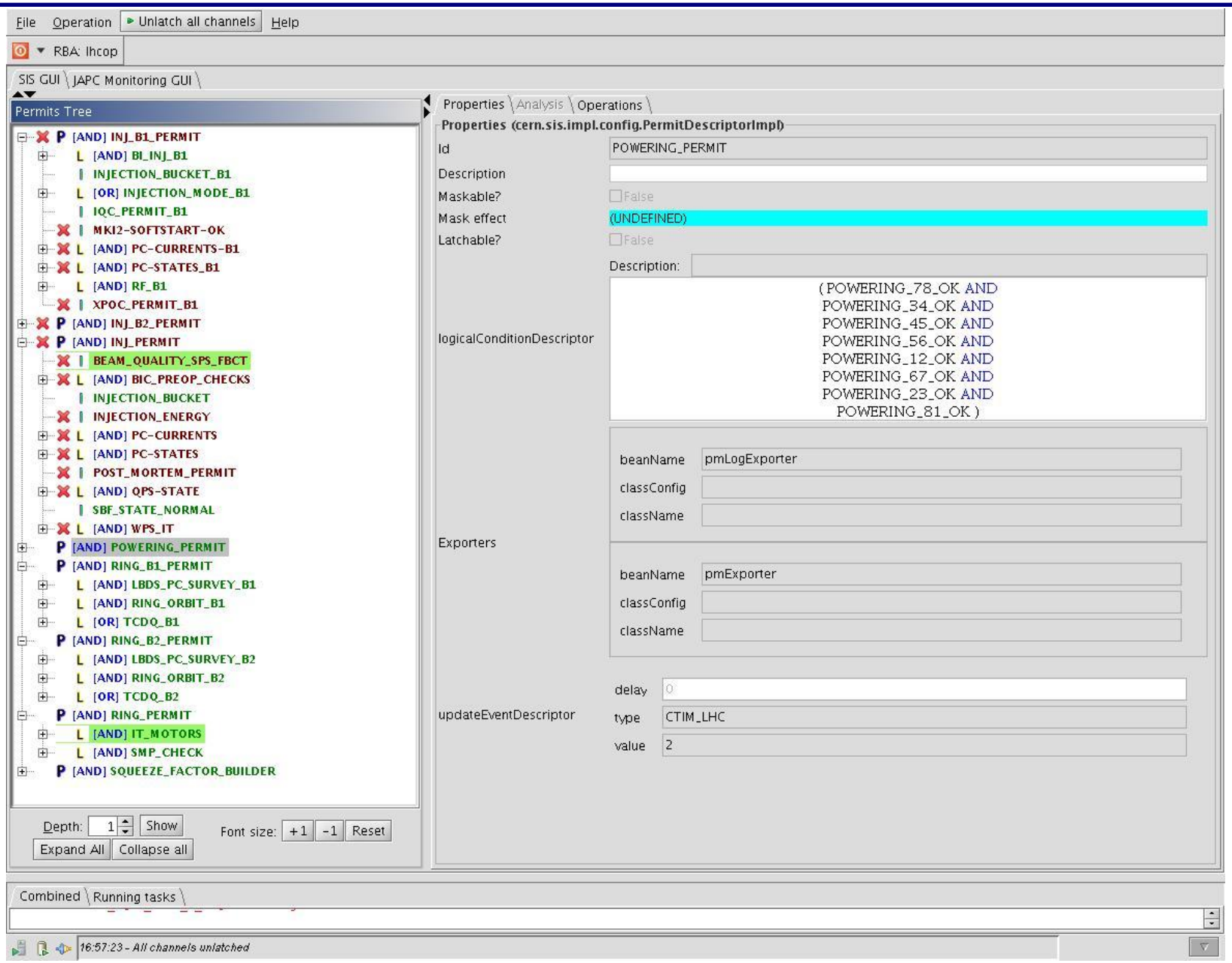
- LHC SIS runs on dedicated HP server in the CCR.
  - The server is equipped with a timing card (CTRI).

- The SIS processes of SPS and LHC have never failed during operation in the last 2 years.
  - Server crashes were however observed in the 2009-10 shutdown. This was traced to a timing library (concurrency) and fixed.
  - In case of failure the timeouts on the SIS inputs to the BICs lead to beam dump/injection or extraction inhibit.

SIS Structure : permit trees

- **INJ_B1_PERMIT (INJ_B2_PERMIT) :** injection interlocks that apply to beam1/ring1 (beam2/ring2) only. The PERMIT state (TRUE/FALSE) is exported to injection BIC for TI2 (TI8).
- **INJ_PERMIT:** injection interlocks that apply to both beams. The PERMIT state (TRUE/FALSE) is exported to injection BICs TI2 and TI8.
- **RING_B1_PERMIT (RING_B2_PERMIT) :** ring interlocks that apply to beam1/ring1 (beam2/ring2) only. The PERMIT state (TRUE/FALSE) is exported to ring1 (ring2) BIC (CCR BIC).
- **RING_PERMIT:** ring interlocks that apply to both rings. The PERMIT state (TRUE/FALSE) is exported to ring BICs (SR3 B1 and B2)
- **POWERING_PERMIT:** interlocks that apply to powering and access conditions. The signals are exported by sector to the PIC PVSS system to lock PCs when access and powering conditions do not match.

SIS


File
Operation
Unlatch all channels
Help
RBA: lhcop
SIS GUI
JAPC Monitoring GUI
Permits Tree
[AND] INJ_B1_PERMIT
[AND] BI_INJ_B1
INJECTION_BUCKET_B1
[OR] INJECTION_MODE_B1
IQC_PERMIT_B1
MKI2-SOFTSTART-OK
[AND] PC-CURRENTS-B1
[AND] PC-STATES_B1
[AND] RF_B1
XPOC_PERMIT_B1
[AND] INJ_B2_PERMIT
[AND] INJ_PERMIT
BEAM_QUALITY_SPS_FBCT
[AND] BIC_PREOP_CHECKS
INJECTION_BUCKET
INJECTION_ENERGY
[AND] PC-CURRENTS
[AND] PC-STATES
POST_MORTEM_PERMIT
[AND] QPS-STATE
SBF_STATE_NORMAL
[AND] WPS_IT
[AND] POWERING_PERMIT
[AND] RING_B1_PERMIT
[AND] LBDS_PC_SURVEY_B1
[AND] RING_ORBIT_B1
[OR] TCDQ_B1
[AND] RING_B2_PERMIT
[AND] LBDS_PC_SURVEY_B2
[AND] RING_ORBIT_B2
[OR] TCDQ_B2
[AND] RING_PERMIT
[AND] IT_MOTORS
[AND] SMP_CHECK
[AND] SQUEEZE_FACTOR_BUILDER
Depth: 1
Show
Expand All
Collapse all
Font size: +1 -1 Reset
Properties
Analysis
Operations
Properties (cern.sis.impl.config.PermitDescriptorImpl)
Id
POWERING_PERMIT
Description
Maskable?
False
Mask effect
(UNDEFINED)
Latchable?
False
logicalConditionDescriptor
Description:
(POWERING_78_OK AND
POWERING_34_OK AND
POWERING_45_OK AND
POWERING_56_OK AND
POWERING_12_OK AND
POWERING_67_OK AND
POWERING_23_OK AND
POWERING_81_OK)
Exporters
beanName
pmLogExporter
className
beanName
pmExporter
className
updateEventDescriptor
delay
0
type
CTIM_LHC
value
2
Combined
Running tasks
16:57:23 - All channels unlatched

SIS Injection Interlocks

Test	Coverage	Status	Comments
PC states	All PCs	Operational	
PC currents	RB, RQ, RD, MCBX	Operational	Extend to IPQ?
QPS_OK	All circuits with QPS	Operational	
RF	Synchronization Cryo maintain	Operational	Include ADT state monitoring?
BTV position	Ring and dump line BTVs	Operational	Dump BTV not tested with intensity (more int. needed)
Injection bucket	Abort gap and over-injection protection	Operational	
Injection mode		Operational	Avoid injecting with wrong mode
Energy		Operational	
(Pre)-op checks	XPOC, PM, IQC, BIC	Operational	
Triplet alignment	WPS in all IRs	Operational	

SIS Circulating Beam Interlocks

Test	Coverage	Status	Comments
SMP energy	All RBs, SMP energy	Operational	0.2% to 2% (ramp or not)
SMP energy distribution	All BLM crates	Operational	Verify energy across all BLM crates
BETS	Q4 and MSD in IR6	Operational	
TCDQ – beam	Beam center in TCSG TCSG gap TCDQ-TCSG retraction	Operational	Achievable tolerances depend on orbit stability
COD integral	All arc Hor. CODs	Operational	dp/p < 0.2%
Orbit	All ring BPMs	Operational	Achievable tolerances depend on orbit stability
COD settings	All CODs	Operational in stable beams	Achievable tolerances depend on reproducibility and variation in ramp & squeeze
COD trips	60 A CODs (not in PIC)	Operational	Dump if COD(s) trips and missing kick > threshold.

SIS Masking

- For the moment all interlocks are maskable except:
  - XPOC
  - BIC pre-operational checks
  - SMP energy checks (BLMs and main bends)
  - Orbit and COD settings in stable beams
  - COD trips and field integral

- Masking:
  - Independent of Set-up Beam Flag.
  - Allowed for all holders of RBAC roles : LHC-EIC, MCS-SIS

- Some interlocks are “masked” with safe beam condition with a logic OR in the tree.

SIS and MPS

- SIS is a reliable solution for quite a class of interlocks:
  - Injection interlocks (reliability less critical).
  - (Complex) interlocks involving multiple systems.
  - Interlocks for distributed systems like orbit.
  - Quick solutions for un-expected situations.
- It is all software:
  - Reaction time limited to around 1 second.
  - Safety will never be SIL3… even if it is better than expected some years ago.

OP review in June

- Identified the weak points during all the different states of the machine in procedure and tools before increasing intensity
- OP is the most efficient MPS tester
- First months of operation stressed the system and found several holes
- During first phases of the commissioning, a lot of by-hand actions
  - Triggered actions to correct them

- A lot of tasks have been added to the nominal sequence and new beam process commissioned

Operational dangers

- Coming back to M. Lamont's cases, (long?) list of examples presented in the OP review

- Different impact for Machine Protection System:
  - Case 1: Loss of beam due to procedural error or sub-system failure
    - caught by BIS
  - Case 2: Putting the machine in a dangerous state so that if something does go wrong it is not properly protected
    - Major risk

Examples 1/2

- C1: ramp-down with beam still in machine (sequencer run through)
- C2: RQD not at injection level (sequence not completed)
- C1: coupling trim wrong order of magnitude
- C1: repeat trim of collimators by mistake
- C2: out of date sequence for collimators
- C1: Q’ measurement by mistake during squeeze
- C1: Mega-chirp at 3.5 TeV
- C1: use of 1/3 order to scrape beams with high intensity
- C1: rogue RT packets

Examples 2/2

- C2: Collimator actual trim – end of ramp
- C2: New orbit in ramp with 1e11 with FB off
- C1: Energy jumps in OFB system
- C1: injection Kicker didn’t fire – into fault
- C1: Vacuum attempting to mask interlock with unsafe beam
- C2: Transverse feedback by-passing hierarchy in V-plane
- C1: Zeroing separation bump actual settings in stable beams
- C2: Squeeze to 2 m with tertiary not in position
- C1: bare orbit by mistake

From recent week-end (1 MJ+)

- Spurious RF RT trims
- OFB and QFB off in ramp at 2.5 TeV
  - carry on without
  - lose beams attempt FB reset at 3.5 TeV
- Loss of beam at start ramp, QFB on wrong peak (hump?)
- Faulty converter not removed from SOCs
- drive horizontal correctors through squeeze by hand
- functions to 2m.
- Wrong collision beam process in place

OP procedure 1

Black – Sequencer
Red – by hand

long, complicated and error prone

Injection

- Collimators are set to injection positions, ready for injecting beam after running through the sequence
- Arm LBDS (which includes Arm BIC, to be done after the collimators)
- If we are going for a physics fill change accelerator mode to PROTON PHYSICS. If short machine study, use BEAM SETUP. If extended machine studies, use MACHINE DEVELOPMENT. Close the Injection handshake, chamge the accelerator made and reopen a new injection handshake (detectors statuses prepared in accordance to the accelerator mode)
- Change beam mode to INJECTION PROBE
- Increment fill number
- Inject 1 bunch for beam 1 and beam 2
- Measure and correct RF injection phase** Use TRIM and select the NON_MULTIPLEXED_LHC BP and correct RF INJ PASE B1 and RF INJ PHASE B2. Sign convention: if the fixed display shows an offset of -X then you apply a trim of -X
- Correct orbit with respect to reference** "450 GeV collimator setup, separation is ON, low int." (for 2-3x10^{10})
  - "450 GeV collimator setup, separation is ON, high int." (for 8-10x10^{10}) ~~(used for all intensities now)~~
- Re-inject 1 bunch for beam 1 and beam 2
- **Verify Injection oscillations (use the CAPTURE mode): this is giving the difference between first turn and closed orbit.**
  - Contexts for YASP (cycles):
  - LHCFAST_L7200_2900_v2 = pilot (until 1.2e10) = LHCFAST1
  - LHCFAST_L7200_2900_v1 = indiv (anything above pilot) = LHCFAST2
- Verify Injection synchro error : max peak to peak amplitude should be less than 30 degree. In case it is not, can correct with a trim of few Hz on FREQUNCY_PROGRAM beam 1 (+14 Hz correspond to 1e-4 in deltaP/P)
- Measure and set fractional tunes to 0.28 (H) and 0.31 (V)
- Measure and set chromaticities to **2, 2**

OP procedure 2

Over-injection

- **ADT phase shift to injection** (if not already done before)

- Ask injectors to switch to LHC INDIV and to **copy over transfer line settings**
- Check that the SPS has longitudinal emittance blow up on and at the nominal settings: (0.6eV.s which corresponds to a bunch length of ~1.6ns)
- Mask BLMs in 2 and 8 (masking is still required)
- Change **BPM sensitivity** through YASP (LOW for nominal bunches, HIGH for probe and bunch intensities below 3-4 x 10^{10})
- Change **BQM attenuation**: three buttons available: pilot, intermediate (indiv up to some 10^10), nominal (10^11)
- Change beam mode to INJECTION PHYSICS BEAM
- **ADT**:
  - **CHECK with the ADT application in the CCM that the ADT system is switched on, i.e. "RF ON". If it is off, in level 1 or level 2, switch it to "RF ON".**
    - *The gain of the feedback is controlled by 8 FGC functions. These have to be correctly started at the ramp and set back to the injection value. Pending further studies the injection values are -20 dB except for the vertical beam 2 plane where -24 dB is programmed. During the ramp the gain is linearly increased to -3 dB except vertical beam 2 which ramps to -7 dB. Beta functions at vertical beam 2 are higher so a lower gain is used.*
  - **VERIFY in the working sets (RF-LHC:ADT) that the damper off and on are enabled for the four timing cards in question, i.e. eight knobs to verify, Damper H/V B1/B2 On/Off, all enabled**; if they are disabled then this has the effect that the action of the corresponding HX.ADTSTART-CT and HX.ADTSTOP-CT on the damper on/off switch located inside the damper lowlevel system is masked.
    - *The timing delay is not really important, this is an expert setting to be used if RF teams make local observations synchronised with the On or OFF command.*
    - *The damper system is currently configured to close the loop automatically on turn 3 after injection. In fact the beam in signal opens the feedback loop, then an internal turns counter starts and will close the feedback loop at turn 3. This delay allows for filter transients that will not be put onto the beam.*
    - *The damper feedback loop can be opened ("switched off") by sending a timing event, HX.ADTSTOP-CT; it can be switched on again if wanted, using the HX.ADTSTART-CT event. The Beam_in signal will briefly open the loop (if it was closed) and activate the turns counter to issue the ON on turn 3 (see point 4 above).*
  - **OBSERVE with the fixed display "Injection oscillations what happens**. Currently the damper is configured to not act on the pilot, you should see flat lines. For the nominal bunch a damped oscillation should be seen.
- Clear "circ bunch config" in Injection sequencer, and then request injection
- For these injections, make sure that "Circ bunch confing autoClear" in unticked in the Injection Sequencer, or else the circulating bunch configuration will only contain the latest injection per beam.
- Bunch positions can be verified through LHC BQM display (LHC Control -> Beam Measurements -> Beam Quality Monitor)
- Measure emittance H&V of both beams with the wire scanner
  - Parameters to be used for the wire scan, both beams both plane: Gain:1300V, filter T_1_PER_CENT for B1 H/V and B2 H, filter T_10_PER_CENT for B2 V

OP procedure 3

Flat-top / Prepare for squeeze

- Go to FLAT TOP mode
- ~~Turn on the **octupoles** for landau damping~~
  - ~~To do this, go to the Actual Trim and select LANDAU DAMPING. Trim at the K level and set the **absolute value** for all octopole **to -6.0**~~
- **Turn off the Transverse Damper** (also called transverse feedback) by sending a timing event to the ADT
  - the timing event to send is "HX.ADTSTOP-CT(0)-Stop dampers" event. No payload is needed.
- At the end of the ramp after few minutes (to let the decay to complete) switch **Tune FB OFF** after having verified that the correction applied is constant** Note that in case of tune drift, need to correct = 5mrect back to injection tunes (0.28, 0.31)
- **Stop the orbit feedback**
- Turn off continuous chromaticity measurement (if switched on for the ramp)
- **Measure** and correct **chromaticity** (dp/p **0.2 per mille**), **coupling**, **orbit** (reference injection orbit), **tune**.
  - Re-measure and correct orbit wrt "**Reference for collimation at 3.5 TeV separated**", defined on June,12. in the MD catalog
    - If the radial position is not correct compared to the reference, trim the frequency to center it -> by steps of 5Hz max (i.e. deltaP = 0.05, correction of 6Hz needed).
  - If you are not losing too much, wait 15 minutes at flat-top, then re-measure and correct chromaticity (set it to 3 to 5 units)
  - Check that the coupling is <0.005 otherwise correct it with COUPLING KNOB -> LHCBEAMn/CMINUS_IM.IP1 and LHCBEAMn/CMINUS_RE.IP1
    - Reason: If coupling is larger then the tune feedback will automatically switch off (the QFB switches off when the coupling is greater than 70% of the tune split between Q_H and Q_V)
- Start orbit acquisition/saving with a YASP
- Start the beta * monitoring tool in CCM (LHC Beam Measurement-> Beta Star)
- Optional: It could be helpful to bring up some EquipMonitoring for the matching quadrupoles of the IPs to be squeezed
- **Open windows of tune viewers** (H: 0.295 - 0.315 ; V: 0.315 - 0.325)
- **trim the TUNE-FB reference for tune feedback to collision tunes** with the continuous tune viewer application
  - go in FB/Trim tab, enter the right values (64.31 and 59.32) and press H&V button

OP procedure 4

Pre-ramp

- Go to PREPARE RAMP MODE
- Preparation for the ramp:
- **Incorporation: Sequencer task, alternatively, do the following**
  - Generation application, incorporation tab
    - select from beam process - [RAMP_3.5TeV_2Aps_short_High_Int@0[START]
    - select to beam process - RAMP_3.5TeV_2Aps_short_High_Int
    - click button - Show Not Incorp. Parameters (DB Proc.)
      - this will show a list of systems where the program has found discontinuities
      - Parameters to be incorporated (select and hit "Incorporate Parameters"):
        - ORBIT-H, at K level
        - ORBIT-V, at K level
        - Tune_trim at knob level
        - Chromaticity at knob level.
        - Coupling at knob level
- if RF Frequency has been trimmed, incorporate into ramp with the Generation application
- Unlatch the BPM beam excursions in pt 6 if false (use BIS monitor menu, Inits & Resets)
- **Check Hidden interlocks and remove all masks** for interlocks
- Launch prepare ramp
- Trim in RF COUPLING to 60000 (nominal sequence task)
- **Measure** the beam emittance with the wire scanner and save them in the logbook (both beams and planes)
- **Tune feedback** Q-FB on (see BI procedure)
- **Orbit feedback** on; check that RT trims are reasonable (vertical line means NaN !)
- **Longitudinal blowup**: sequencer task now. It can also be armed with FESA :
  - FESA navigator->read-only privileges-> class AllBlowup->devices (version 210): LHCALLBlowupB2, LHCALLBlowupB1
  - property: Settings: partial set armingTiming TRUE (or GET; armingTiming=TRUE; SET)
- Check that RF (+ADT gain) and collimators are armed before starting the ramp

OPTIONAL:

- Only if needed during the ramp: instructions for **Continuous chromaticity measurement** (done with tune feedback on)** Verify that the Continuous tune viewer is running
  - On the On-demand viewer (needed for one beam only), in the Q' tab, set:
    - RF mod amplitude (dp/p) to 0.0002
    - RF mod frequency (Hz) to 0.2
    - RF modulation ON
- At the end of the ramp switch off the radial modulation from the same panel.

OP procedure 5

Ramp

- Go to RAMP MODE
- Link the beam permits (except if there are special studies)
- Send timing event

- Once the ramp has started...
  - regenerate end of ramp actual BP: alternatively go to generation application, actual settings tab, select to beam process - RAMP_3.5TeV_2Aps_short_High_Int on the LEFT, select RAMP_3.5TeV_2Aps_short_High_Int@2800[END] on the RIGHT and hit Regenerate
  - **Make ..... [END] resident**
  - Measure the beam emittance with the wire scanner and save them in the logbook (both beam and planes) approximately every 5 minutes in order to have the evolution of the emittance through the ramp. With higher intensity (few 10^{11} p/beam) watch the losses. Above 2.8 TeV losses are not negligible.
    - Parameters to be used for the wire scan, both beams both plane: Gain:1300V, filter T_1_PER_CENT for B1 H/V and B2 H, filter T_10_PER_CENT for B2 V

OP procedure 6

Prepare for Physics

- make resident the regenerated end of squeeze actual beam process
- **Orbit feedback OFF**
- **Tune feedback OFF**
- Set the OFC Status on the feedback: Click on "**Disable RT Trims**"
- **Tune split:** change Beam 1: Q_H **-0.0025,** Q_V : **-0.0025** and change beam2 Q_H **+0.0025,** Q_V **: +0.0025**

- set the last orbit acquisition as reference for non-closure correction and then set it as reference

- Prepare YASP in case you need to correct orbit non-closure** Set YASP->Status-Control->LHC Status Control->Disable IR BPMs** YASP->Status-Control->LHC Status Control->Enable Xing bump CODs ONLY
- From the Actual Trim, switch on **crossing angles** in point 1 (-100 urad) and point 5 (+100 urad)**
  - correct non-closure: corrections should not be larger than +/-10 urad. Typically you sould use either 2 or 4 correctors
  - After orbit correction, enable all CODs
- **ADT** (Transverse FB):
  - Drive system TRANSVERSE_DAMPERS (groups: **ADT_GAIN_Digital** & **PHASE_SHIFT**) for BP SQUEEZE_3.5TeV_IP1+...FULL_High_Int@1041 using the application ***Drive Hardware***
  - Send **ADTSTART** event with timing editor and prepare another timing editor with ADTSTOP event selected in case there are sudden losses

New Collision procedure (PREPARE FOR COLLISIONS sequence)

- Start BRAN display
- Start LumiScan Application
- run the sequence : alternatively ,* Incorporate into the TEST-COLLISIONS_V1 the present orbit corrections (for the correctors concerned by lumi scans+sep.
- This is done with the incorporation of the actual beam process SQUEEZE...@1041 into the START of TEST-COLLISIONS_V1 for the following systems:
- IP_SEPARATION at K level
  - **Do a re-show of non-incorporated parameters after incorporating this system**.
- LUMI_SCAN at K level
  - **Do a re-show of non-incorporated parameters after incorporating this system**.
- At the end, check that you get no more orbit correctors to incorporate.

- Re-create ACTUAL BP [TEST-COLLISIONS_V1@108[END]
- Make TEST-COLLISIONS_V1 resisident.
- Incorporate [TEST-COLLISIONS_V1@108[END] into actual BP SQUEEZE...@1041
  - IP_SEPARATION at KNOB Level
  - LUMI_SCAN at KNOB Level
- From equip state: update context, then for the Hardware group "COLLIDE" do the following
  - Command LOAD_FUNCTION
  - Set event group 123
- Make SQUEEZE..... @1041 resident
- Prepare YASP in case you need to correct orbit non-closure** Set YASP->Status-Control->LHC Status Control->Disable IR BPMs** YASP->Status-Control->LHC Status Control->Enable Sep bump CODs ONLY

- **Correct non-closure:** corrections should not be larger than +/-10 urad. Typically you should use either 2 or 4 correctors

long, complicated and error prone

“Un mal pour un bien”

- Several new SIS interlocks to capture the errors:
  - injection settings
  - RF frequency range
  - CODs settings
- New tasks in the nominal sequence, to check settings during all the phases, incorporation:
  - injection checks
  - ramp loading
  - run through the squeeze, collisions preparation...
- New beam process for preparing collisions including most of the critical settings management (collimators, copying ...)
  - Rationalization of the nominal sequence

Outcomes from OP review

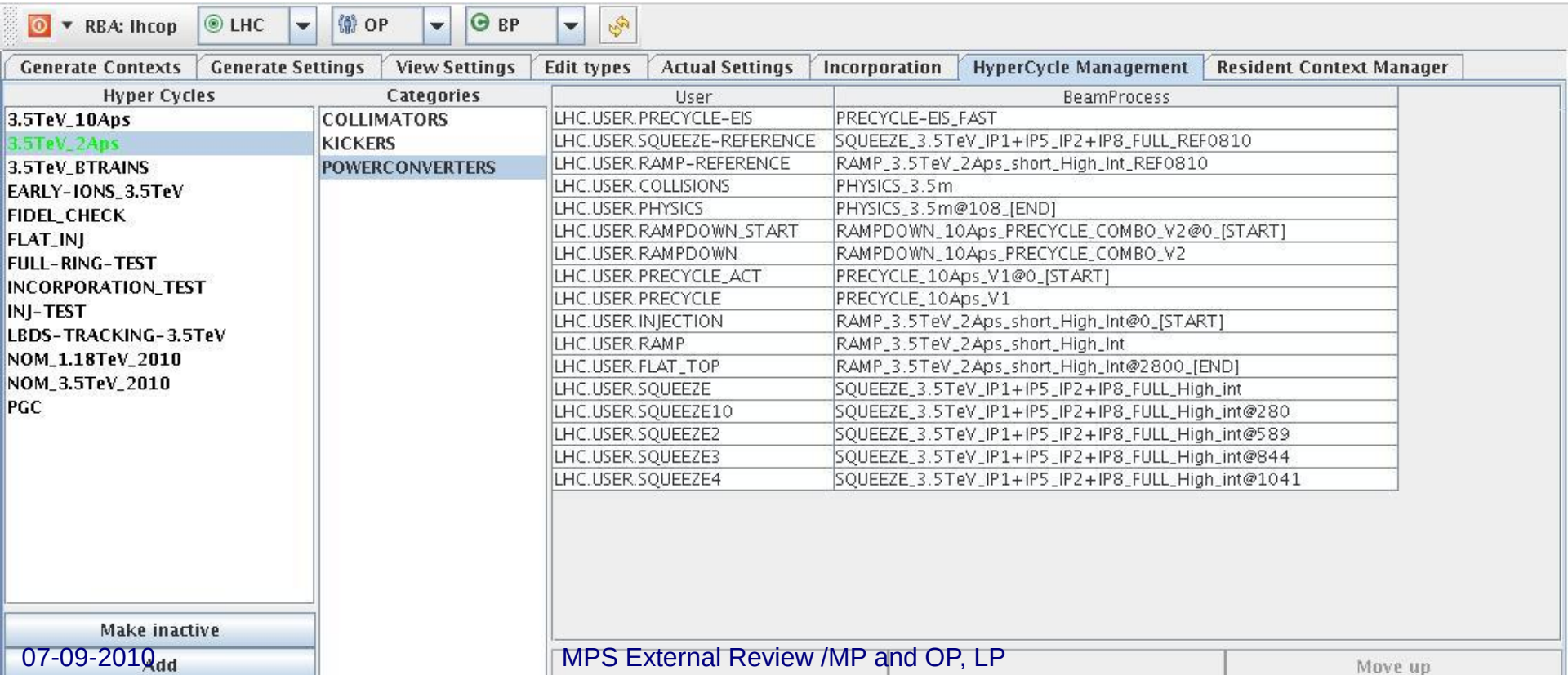
- Remaining issues with Controls:
  - Alarm system not really used as alarms but more as diagnostics tools: not properly configure for operation
  - RBAC : now in strict mode
  - still some back doors to front-ends: RT feedbacks?
  - crashed not always detected on time : DIAMON status to be optimized, description of FE, coherent status green/red
- LSA:
  - Actual trim : very useful but coherent limits should be defined to be even more protective.
  - Trim, Production database and incorporation wide open (not solvable by RBAC)
-

Outcomes from OP review: Sequencer

- As mentioned during the Internal MPS review, sequencer should not be relied on to ensure that things are done properly, possibility of alternative pathways
- If a task is skipped it something else should catch it, however…
- Some improvements could help:
  - bugs to be fixed : run through
  - clarity/vision : new GUI under development
  - check lists : deployed but need to be configured properly
  - State Machine to enforce a tasks execution: to control/channel all commands, under development

Settings management through sequencer

- Sequencer is addressing settings through a “key word”, namely the LHC user
- Each beam process is attached to a user, unique in a hyper-cycle, hard-coded in the tasks
- Same LHC users are used across different hyper-cycles:
  - Possibility to really mess-up settings



Outcomes from OP review: SIS

- Protection of the subscription UI.
  - Avoid accidental stopping of data subscription – mostly availability, but also safety when there are timeouts.
- Masking.
  - So far masking rights apply to all (maskable) signals. Could consider making masking role-dependent.
  - Automatic reset of masks – in work.

Remaining issues

- Settings:
  - machine state after MD – not checked systematically
  - Checks against last time or limits
  - routine feed-forward (via sequencer)
  - squeeze in one go – function for collimators
- Feedbacks :
  - Thorough testing needed (dedicated time needed)
  - More robust behavior in case of incorrect data input
  - Too much dependant on a single person
- Firmware updates:
  - Improve tracking or even enforce a kind of piquet-role?
- New software releases:
  - Proper testing procedure to be put in place for critical applications

Remaining issues

- Technical stops:
  - Recover is always tricky, proper machine check-out needed
  - Set Of Circuits management : improve the follow-up of disable/enable correctors when not available/repaired, masking in SIS, YASP...
- Ergonomics & fixed displays
  - Not always optimum…
  - Floating Keyboards
- Control of connections to front-ends to avoid loss of connection for CCC based applications used to run the machine
  - Enforce a proper proxy strategy
- Real enforcement of the operational envelope:
  - Allowed intensity
  - Allowed missing equipment or add new interlocks?
  - Involvement of OP crew in MPS test tracking

Conclusions

- Conclusion of OP review: not ready for 0.5-1 MJ… but we are there.
- During the first phase to get above 1 MJ,
  - Many issues addressed
  - Remarkably fast turnaround on problem resolution
  - A lot of automation and cross-checks put in place
- Still some improvements needed before pushing much further
  - Procedures, settings, sequencer, feedbacks…
  - Reduce to a minimum the by-hand tasks
  - Close some more doors
- Well MPS-aware operation crew is the first line of defense