

LHC re-commissioning

Dry runs and cold checkout

IRWG 26/03/2015

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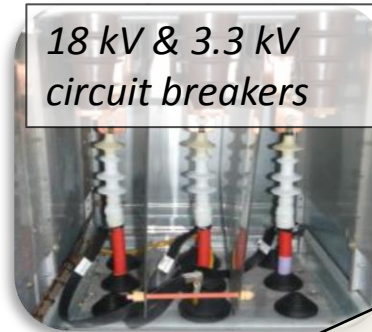
The main 2013-14 LHC consolidations

- 1 1495 Openings and final enclosure of the interconnections
- 2 Complete reconstruction of 1300 of these apertures
- 3 Consolidation of the 10170 1.8k apertures, installing 27 000 shunts
- 4 Installation of 5000 consolidated electrical insulation systems
- 5 300 000 electrical resistance measurements
- 6 10170 initial wetting of stainless steel leads
- 7 18 000 electrical Quality Assurance tests
- 8 10170 leak tightness tests to be replaced
- 9 4 quadrupole magnets to be replaced
- 10 15 dipole magnets to be replaced
- 11 Installation of 612 precision orbit devices to bring the total to 1544
- 12 Consolidation of the 11 kA circuits in the 16 main electrical feed-lines

LSI modifications



UPS



18 kV & 3.3 kV circuit breakers



Vacuum

+ personnel changes, including OP/LHC!

Word cloud containing terms: LBDS Kickers, Vacuum, P7-enclosure, Thermoswitch, Control, QPS, Tests, RF, Maintenance, Cryogenic AUG, Shielding, Helium, Upgrade, Consolidation, Instrumentation, Dump, Cooling-stations, Water-Cooled Cables, Cooling-towers, Collimators, Optical-fibbers, Survey, Cavities, Cables, Mappings, and Connections.

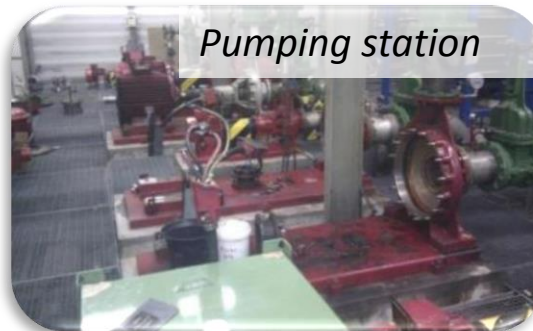


P7 enclosure



Cryogenics

3/26/2015



Pumping station



ACS transport

General Strategy

- **Intensive individual system tests** by the experts are essential
- As soon as systems are ready, even partially: **test campaigns of operational uses-cases** by OP team from the control room (dry runs)
- **A dedicated machine checkout period** (full integration tests) between the end of LS1 and the start of beam commissioning for a smooth transition
- **Commissioning of superconducting magnet circuits** :
 - 5 months to tests 1600 circuits (quench protection system, interlock system, training quenches of the dipoles etc) : started in September 2014
 - OP and experts on shifts
 - Coordinated by Matteo and Mirko
 - Not cover in this presentation

System tests scope

- System tests **from the control room by the operation team** with the help of the equipment experts
- Not individual equipment tests, but tests of **several systems working together**
- Run of operational scenario
 - as far as possible without beam
 - with the systems available
 - Including the experiments
 - i.e. operational sequence, interlocks, beam mode, post mortem, logging, timing

Early start in May 2014

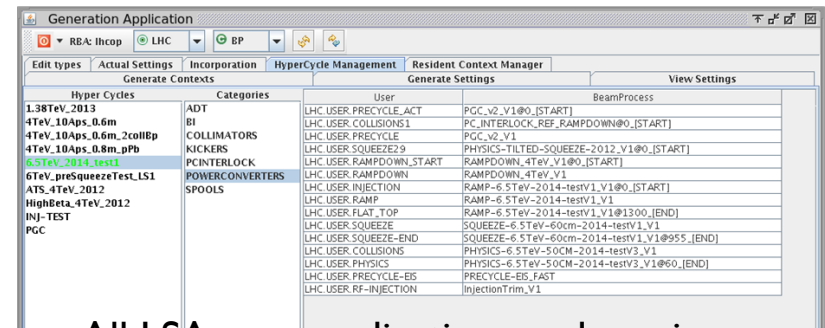
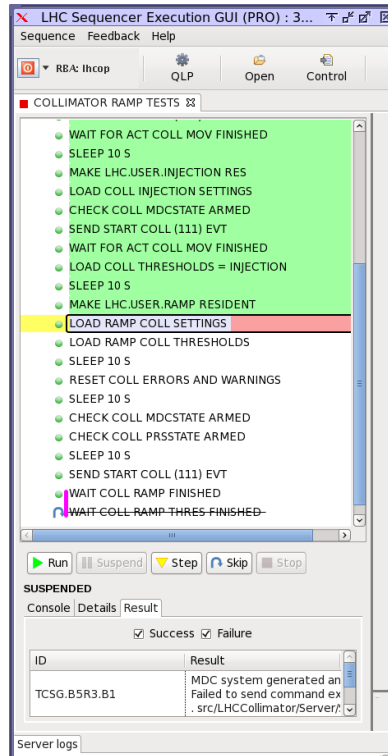
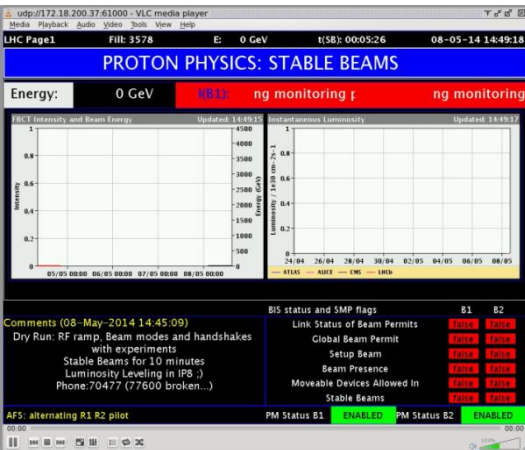
➤ Why so early?

- Detection of issues as soon as possible
- Provide still plenty of time for **corrective action**, even for complete review of a system, if needed.
- Ensure a tight collaboration with the expert and follow-up by OP of the new implementations and functionality
- Some stress tests or reliability tests have to be performed during several weeks. (collimators, LBDS, timing)

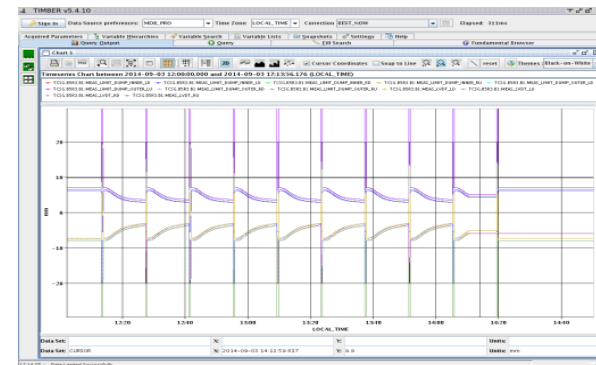
➤ Drawback

- Lots of systems are **not stable yet**, most of the time only partial tests are possible.
- Part of the tests will have to be repeated when the complete systems are ready.
- **Restart of the injectors is the priority** : experts not always available to help and solve issues immediately

Operational control environment need to be in place

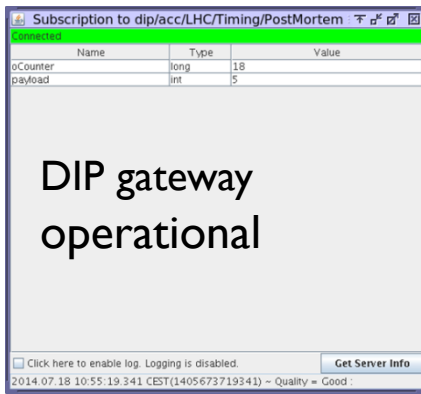


All LSA core applications and services operational. (→ new 6.5 TeV hypercycle generation)



Logging service and timber application

Page I up and running to communicate with experiments



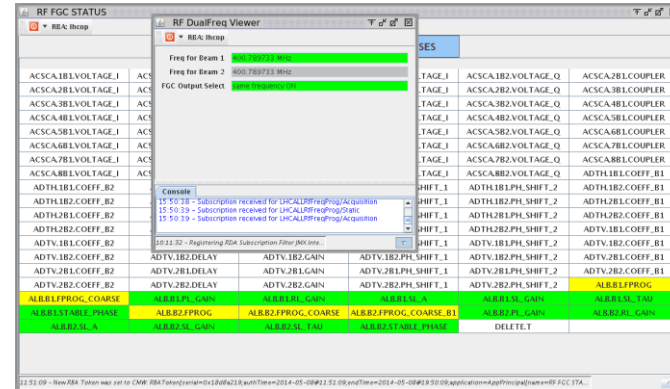
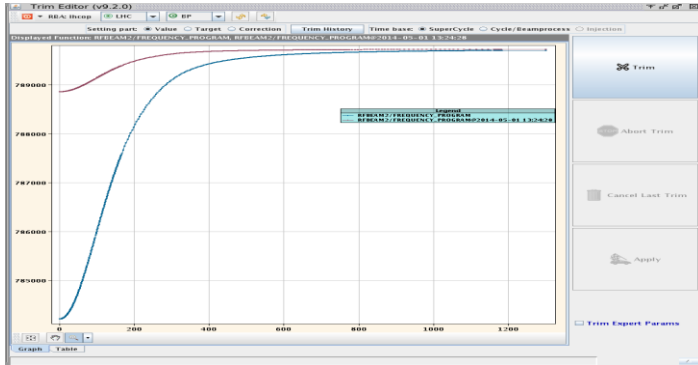
DIP gateway operational

Sequencer and sequences editor operational

Examples of tests achieved early before beam

RF synchro and Frequency ramp

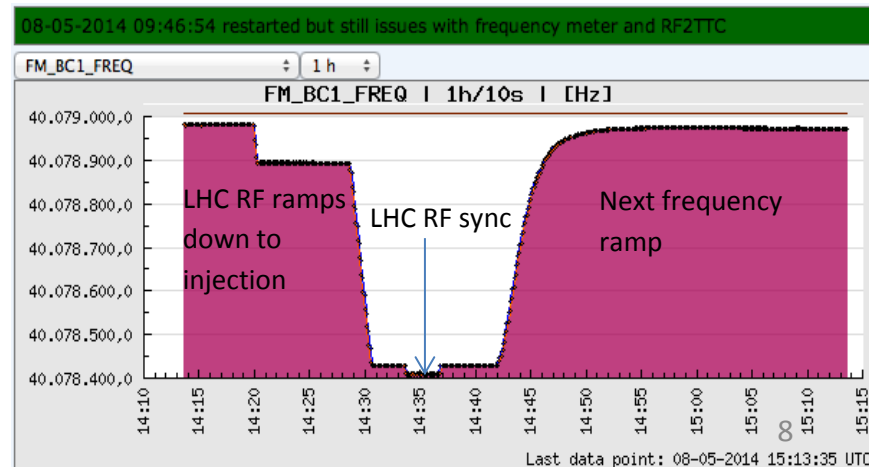
- Launch the frequency ramps with a RF beam control resynchronisation between each ramp.



Frequency monitoring RF FGCs in running state

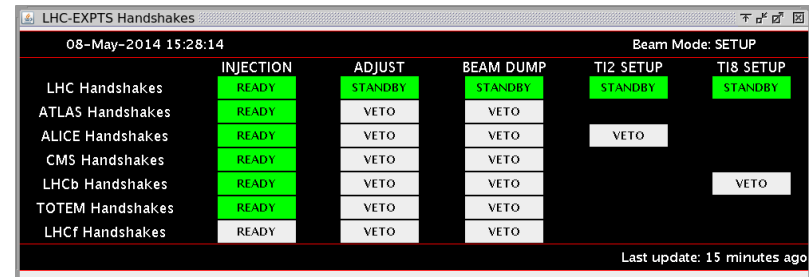
Proton and ions frequency settings for 6.5 TeV ramp

- Frequency is properly received by the experiments
- Resynchronisation of beam control successful.

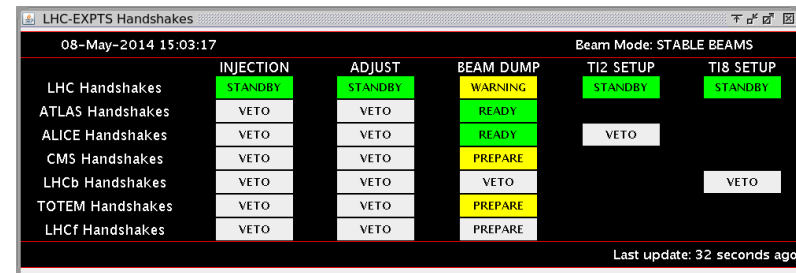


Handshakes and beam modes

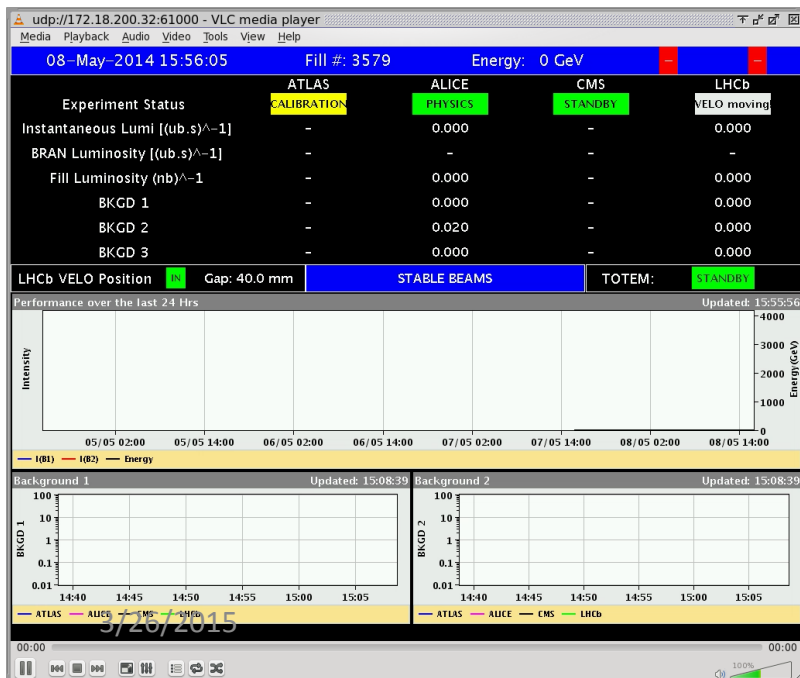
- Sequence prepared to mimic the consecutive handshakes and beam mode changes of the nominal sequence.



Injection handshake



Beam dump handshake

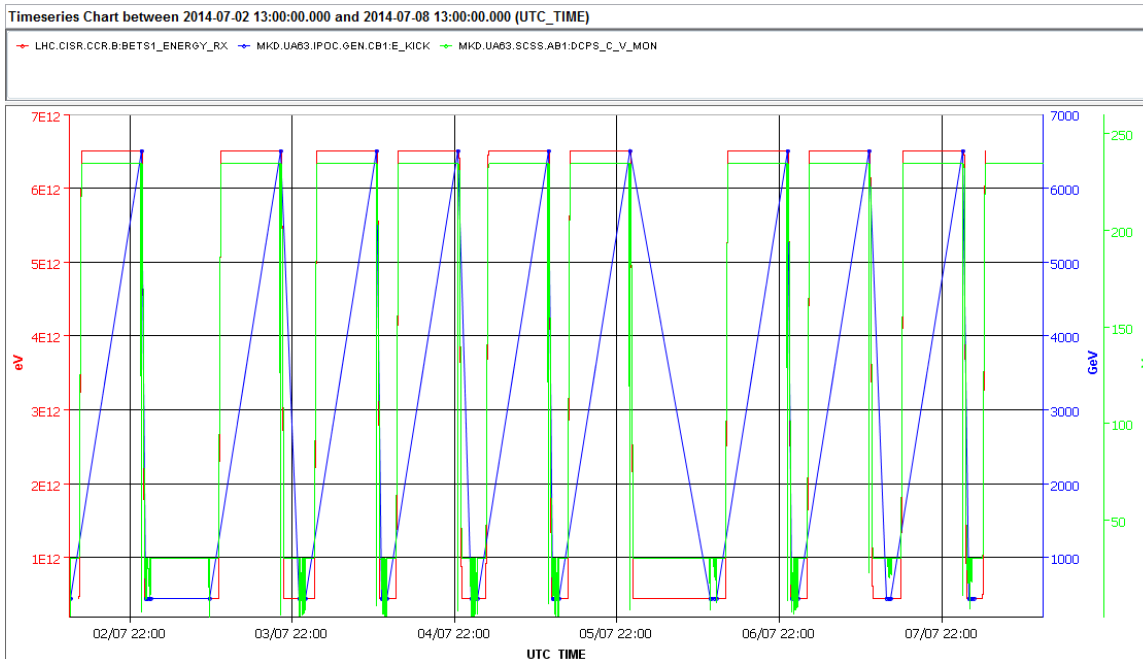


STABLE BEAM mode
LHCb velo moving

Beam dump reliability run

➤ Reliability run:

- Sequence to arm/ ramp/ dump is played in loop for several weeks.



The screenshot shows the 'LHC Sequence Execution GUI' with a sequence named 'B1B2LBDSRELIABILITYRUN'. The sequence is expanded to show the following steps:

- PREPARE BETSIM FOR THE RAMP
 - Reset betsim (should go to 450 GeV)
 - ARM BIC L6 FOR B1
 - ARM BIC R6 FOR B1
 - ARM BIC L6 FOR B2
 - ARM BIC R6 FOR B2
- B1: ARM LBDS SYSTEM
- B2: ARM LBDS SYSTEM
- START BETSIM RAMP
 - Start betsim
 - Sleep for TO BE DEFINED sec
 - Sleep for 30 sec
 - STOP CIBG
 - Sleep for 30 sec
 - Restart sequence

The screenshot shows the 'LHC LBDS Monitoring v0.0.43 2014' interface. It displays the status of the LBDS system, including the status of the kickers, the beam dump system, and the beam dump kicker. The interface is divided into several sections:

- Kicker Status & Control:** Shows the status of the kickers (Beam 1, Beam 2) and the beam dump kicker (Beam 1, Beam 2).
- Beam Dump Kicker - Status Control:** Shows the status of the beam dump kicker (Beam 1, Beam 2) and the beam dump kicker (Beam 1, Beam 2).
- Acquisition Control:** Shows the status of the acquisition control (Beam 1, Beam 2).
- BETS:** Shows the status of the beam dump system (Beam 1, Beam 2).
- Energy (B/E) ENGI:** Shows the energy of the beam (6129 GeV).

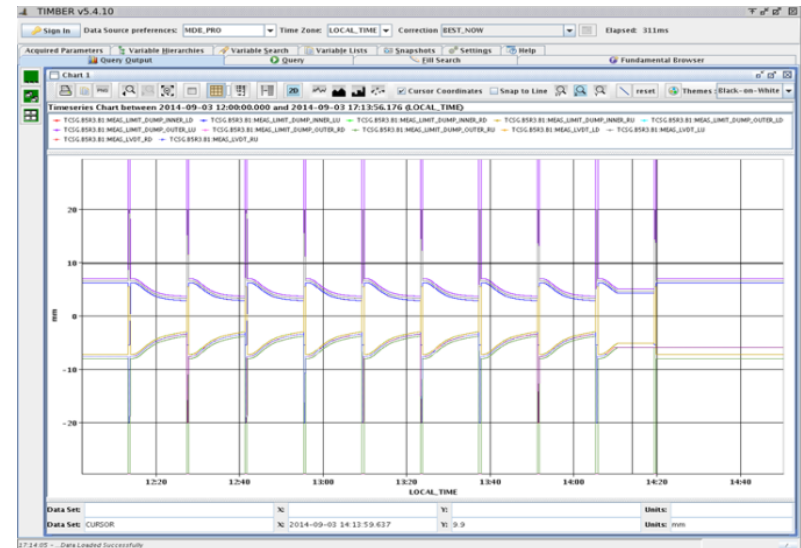
The console at the bottom shows the following messages:

```
09:15:59 - Taken is still valid (lifetime > 1 hour)
09:40:59 - Taking is ending (beam)
09:40:59 - Taken is still valid (lifetime > 1 hour)
09:45:59 - Taking is ending (beam)
09:45:59 - Taken is still valid (lifetime > 1 hour)
09:50:59 - Taking is ending (beam)
09:50:59 - Taken is still valid (lifetime > 1 hour)
09:55:59 - Taken is still valid (lifetime > 1 hour)
```

Collimators

- Tests of operational functionalities with available collimators
 - Settings generation for 6.5TeV, including new collimators
 - Loading functions for positions and thresholds, reset faults, disarm, start ramp with timing event
 - Logging functionality
 - New BPM collimators
 - Sequences and tasks

LHC Collimators Beam: B2 Set: HW Group:LHC COLLIMATORS										
LHC Collimators Beam: B2 Set: HW Group:LHC COLLIMATORS										
17-09-2014 20:33:28										
L(mm) MDC	IP1	PRS R(mm)								
2.31	TCTPV.4R1.B2	-4.8	monitorin	TCL5L5.B2	monitorin	7.46	TCSG.A5R7.B2	-7.44		
			monitorin	TCL.4L5.B2	monitorin	7.28	TCSG.B5R7.B2	-7.3		
9.09	TCTPH.4R1.B2	-10.5	itoring	TCTPV.4R5.B2	itoring	6.07	TCSG.A6R7.B2	-6.08		
2.35	TCL.6L1.B2	-4.79	itoring	TCTPH.4R5.B2	itoring	5.06	TCP.B6R7.B2	-5.06		
2.3	TCL.5L1.B2	-4.85					5.98	TCP.C6R7.B2	-5.98	
2.3	TCL.4L1.B2	-4.83	itoring	IP6		4.32	TCP.D6R7.B2	-4.3		
			o: Critic	TCD0A.A4L6.B2						
30.67	TCTPV.4R2.B2	-30.74								
30.24	TCTPH.4R2.B2	-30.45								
			6.94	TCL.A.7L7.B2	-6.93	28.12	TCLIB.6L8.B2	-27.94		
			30.28	TCL.A.D6L7.B2	-29.81	21.57	TCLIA.4L8	-25.59		
6.94	TCL.A.7L3.B2	-6.94	10.58	TCL.A.C6L7.B2	-10.53	2.3	TCTPV.4R8.B2	-30.81		
9.73	TCL.A.6L3.B2	-9.72	10.8	TCL.A.B6L7.B2	-10.8	14.22	TCTPH.4R8.B2	4.48		
10.54	TCL.A.B5L3.B2	-10.52	5.98	TCL.A.A6L7.B2	-5.95					
11.36	TCL.A.A5L3.B2	-11.32	10.5	TCSG.6L7.B2	-10.5	25.44	TCDIH.87441	-25.41		
5.89	TCSG.B5L3.B2	-5.88	30.48	TCSG.E5L7.B2	-65.21	2.31	TCDIV.87645	-4.8		
5.25	TCSG.A5L3.B2	-5.26	7.68	TCSG.D5L7.B2	-7.69	2.3	TCDIV.87804	-4.8		
4.06	TCSG.4L3.B2	-4.08	7.66	TCSG.B5L7.B2	-7.69	2.31	TCDIH.87904	-4.78		
5.87	TCSG.5R3.B2	-5.9	6.64	TCSG.A4L7.B2	-6.63	2.32	TCDIH.88121	-4.81		
7.84	TCP.6R3.B2	-7.84	6.66	TCSG.A4R7.B2	-6.65	2.3	TCDIV.88123	-4.78		
			7.04	TCSG.B4R7.B2	-7.05					
BETAD01.DIAG 3/26/2015 BETATRON_VER OFFMOMENTUM_POS_DP OFFMOMENTUM_NEG_DP										



TCSG.B5R3.B1 jaw positions and threshold of as logged in timber during reliability test.

Continuous Interlock systems tests

- **All BIS input will have to be tested one by one**
 - Almost 200 BIS inputs : PIC, FMCM, vacuum, collimators, experimental magnets, BPMs, SIS...
 - Tests organised following the readiness of the systems
 - Vacuum interlock preliminary tests foreseen end of September
 - Huge and systematic work, that is essential to ensure the machine protection before beam can be injected.
- **Software Interlock system :**
less critical but nevertheless essential, every inputs logic need to be checked as well.

Intermediate Milestones

➤ Transfer line tests November 2014

- LHC mastership and beam request mechanism
- RF synchro and rephasing
- Transfer line trajectory, kick response, stability
- Transfer line collimator alignment test
- Inject and dump mechanism, LHC injection kickers

➤ Sector test 7/8 March

- A lot of systems could be tested : instrumentation, timing, beam dump, injection settings etc...
- Some issues discovered : wrong magnet polarity, MKI injection permit, vacuum valves not in the interlock chain, some software interlock not operational etc...
- Very useful exercise: the issues can be solved while the hardware commissioning is ongoing ➡ gain of time for beam commissioning

Final machine checkout

➤ Pre -conditions

- Machine closed, access system ready for beam.
- All systems are operational, mainly
 - All magnet circuits
 - PIC and QPS
 - Beam vacuum system
 - BIS



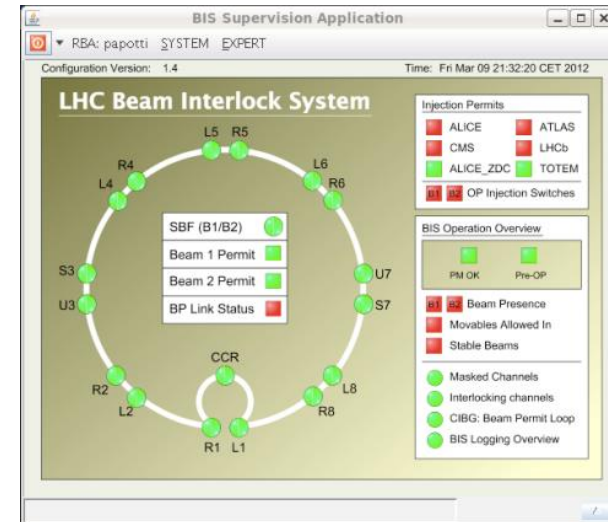
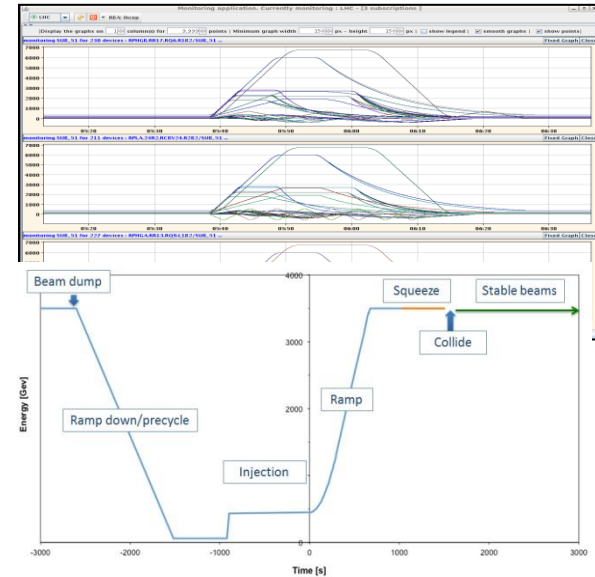
This we will have only a few days before first beam!

➤ Organization

- Coordinated by Rossano Giachino and Markus Albert
- Daily meeting in CCC to organize access needs and adjust the test plan for the day
- Operation's team on shift day/night/week-ends

Final machine checkout

- Full integration tests : first opportunity to run the entire LHC systems together and run the tests that require the machine to be fully closed. i.e :
 - Heat run of warm magnets (already tested and polarity checked)
 - Test of **complete LHC cycle** (pre-cycle, injection, ramp up/down) with all the operational magnets
 - Complete the machine protection tests (**all BIS inputs**)
 - **Close beam permit loop** with all BIS inputs connected
 - **Final LBDS checks** : energy tracking tests under real configuration
 - **Final MKI tests** with full operational conditions



 **LHC ready for beam!**

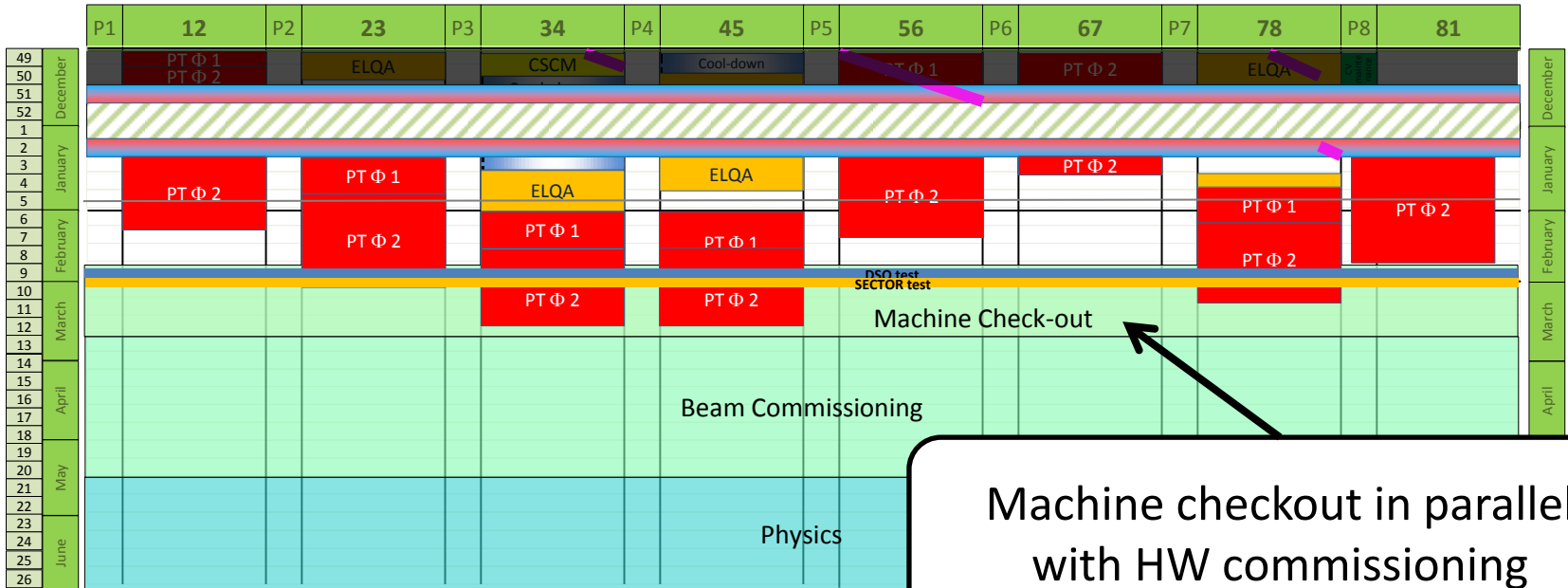
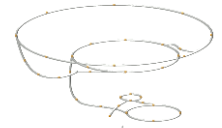
What could be improved

- We have one team for dry runs (mainly Reyes) and another one for machine check out (Rossano and Markus), with overlapping responsibilities : confusing for the equipment groups, not the most efficient
 - We should have only one team for system tests, in which the responsibility are well defined.
- Good follow up by OP of the new implementation of the systems
 - We should reorganize to involve more OP members
- We have to be careful not to overdo it : respect the equipment team priorities.
- A lot of access are needed until last moment: difficult to reduce them or concentrate them to improve the commissioning efficiency.

Conclusion

- Aside individual system tests, the LHC operations team organises various tests from the CCC with the equipment experts and experiments.
- Aim is to tests systems **as early as possible** to anticipate on software bugs, hardware issues etc...
- **Transfer line tests and sectors tests** have been very useful to anticipate on issues that would have been discovered only during beam commissioning
- **Tight collaboration** between OP and the equipment specialists for the organisation and follow-up of tests is essential.
- The last checkout test period is done with full operational condition and machine closed : this dedicated period shrinks as circuit commissioning is late.

V4.1H – Jan. 2015



Machine checkout in parallel with HW commissioning