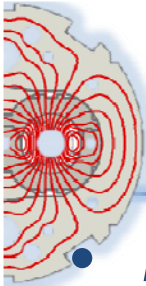




Session 8: What we will do for beam preparation in 2009

G. Arduini, R. Giachino



What we will do for beam preparation in 2009

- Magnet circuits (A. Vergara)
- Powering interlocks (M. Zerlauth)
- Beam interlocks (J. Wenninger)
- Injection and Beam Dump (J. Uythoven)
- RF (E. Ciapala)
- SC magnet (re)training (E. Todesco)

**Many thanks to
all the speakers!!**

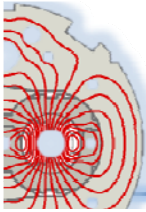


What we will do for beam preparation in 2009

- **Main questions for the speakers:**

- What could not be completed in 2008 and needs to be done in 2009?
- Planned modifications and impact on the re-commissioning of the systems.
- New procedures for the commissioning as a function of Sector 34 incident.
- Tools to speed-up the re-commissioning.
- Impact of new access rules on “sectorized” cold check-out in parallel to HW Commissioning.
- Needs and possible strategy for training of the SC circuits for 5 TeV operation or higher.

Magnet circuits



Where were we on September 19 - Documentation

2/5/2009 Antonio Vergara - Magnet Circuits

- Status of the commissioning of the circuits and existing non-conformities known and (being) summarized in EDMS documents
- The **main lines** of the strategy for the re-commissioning are sketched:
 - 3 different scenarios have been identified
 - Possible subsets of tests have been identified

• Commissioning up to ≤ 5 TeV does not save powering time but will reduce risks (for main circuits)

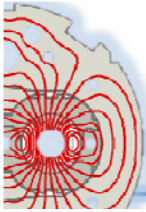
2009 S.C. Commissioning

- Scenarios:

- Circuits warmed-up and modified (e.g. circuits opened in S34)
 - EIQA: Full
 - Interlock Tests: Full
 - Powering: Full
- Circuits warmed-up but not modified (e.g. DS quadrupoles in S56)
 - EIQA: TP4 & DOC
 - Interlock Tests: Reduced
 - Powering: Reduced
- Circuits kept cold (e.g. circuits in sectors 7-8 and 8-1)
 - EIQA: TP4 (?) & DOC (?)
 - Interlock Tests: Reduced
 - Powering: Reduced

- Need a review of the parameters required for operation (e.g. current ramp rate and acceleration) before starting the tests
- Need re-definition of the **detailed** procedures for each of the commissioning scenarios above identified → started

A. Vergara

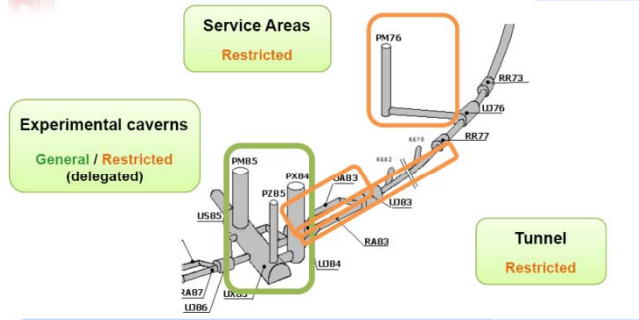


Magnet circuits

Safety: access during powering

- All circuits in the access sector < 1 kA

Before 19/09

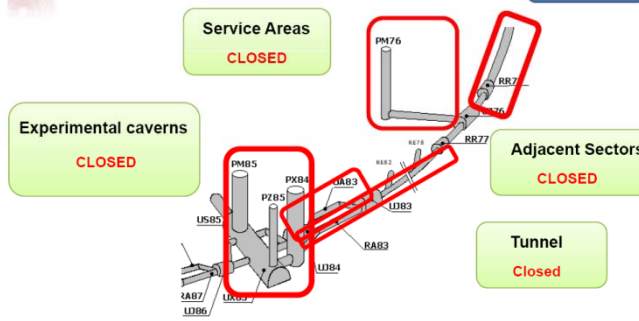


2/5/2009

Safety: access during powering

- One or more circuits powered

After 19/09

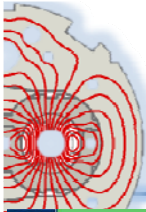


2/5/2009

A. Vergara

- Parallelism is possible but will be strongly conditioned by access procedures during powering.
- Most of the powering tests at low current
- 2 access modes/powering phases:
 - Sector in Low Current Mode \rightarrow Restricted access with current limitation (HW)
 - Sector in High Current Mode \rightarrow Machine closed and no current limitation
- Need to define the access conditions during powering \rightarrow ongoing
- Tools for showing on-line powering conditions and compatibility with access are needed
- Possibility of running nights/WE: feasible? Enough expert coverage? Many people involved in HW Commissioning have left!

Powering interlocks

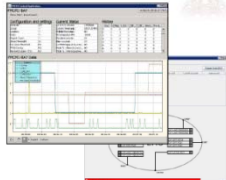
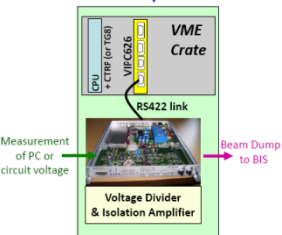


Fast Magnet Current Change Monitors (FMCM) in 2008

- For startup 2008 11 oo 12 FMCM units installed
- Fully commissioned in TL (for previous CNGS runs and injection tests), partially commissioned in LHC (no priority during startup 08 as maskable inputs to BIC)
- With operational systems (once commissioned) very satisfactory functional performance

‘Modifications’ during shut-down:

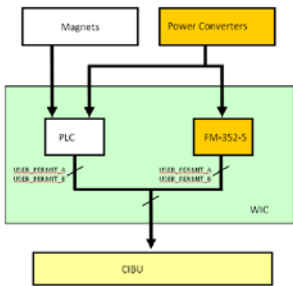
- Completion of installations (missing device on ALICE compensator)
- Resolved and improved multiple pending issues on LHC devices (cross-talk on MSD, optimized settings for injection and nominal energy)
- Completion of controls and PM interface (mainly transfer line issue with target dependent timing signals)

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WIC modifications during shut-down

- No modifications to WIC hardware nor connections, with exception of temporary removal of WIC in TZ76
- Inclusion and test of FM352 (redundant path to PLC for beam dump requests from power converters)
- To assure fast transmission of beam dump request following internal PC faults (due to inherently longer cycle time of safety PLCs)
- Modules were already installed in 2008
- Will be connected into logic through new electronic card and tested during re-commissioning phase
- SCADA representation & diagnostic for module will be added

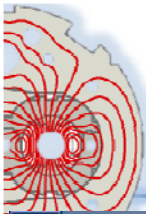


M. Zerlauth

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- Modifications ongoing in the protection of the warm magnet circuits:
 - FMCM (12 circuits):
 - To complete the installation (1 -unused- circuit missing on 10/9)
 - To improve settings for full operational range (injection to nominal) and complete controls interface
 - Warm Magnet Interlock Controller (45 circuits):
 - To add redundancy and even faster reaction time (required for operation with “unsafe beams”)
- **Need full re-commissioning**
- Given the limited number of circuits and the limited time required for the commissioning of a circuit no automatic procedure will be available for 2009 (but later)

Powering interlocks



PIC modifications during the shut-down

- Revision of functionality of Global Powering Subsector OFF for corrector circuits
 - Functionality anticipates a shut-down of circuits in the same powering subsector / cryogenic volume in case of main magnet quenches and consequent risk of quench propagation
 - Currently performing a Fast Power Abort, resulting in a quench-back of numerous 600A corrector magnets (and activation of EE systems)
 - New proposal for SPA summarised in ECR and tested in laboratory, impact on all 36 installations
- Installation of QPS upgrade
 - No impact on HW installations (new interlocks included in existing channels on QPS side), but on PVSS SCADA system (additional agents to be included)
- Relocation of equipment UJ76/TZ76
 - Interlock racks already previously located in TZ76, but temporary removal due to civil works (PIC for arc 67 and 78)
- Connection Access – Powering Interlocks (under discussion)
- Temperature interlocks on top part of HTS current lead (under discussion)

PIC re-commissioning in 2009 – Hardware Commissioning

- From interlock point of view, no need to systematically re-test internal functionality (except for S34 and not yet commissioned circuits from HWC08)
- For all other sectors, need to test that no (unwanted) modifications of cabling have taken place, ie between PIC and QPS/PC
 - Systematically re-test all links with Cryogenics
 - Systematically re-test all links with UPS and AUG system
 - Repeat Power Permit test (link with PC) and Circuit Quench (link with QPS), tbc with other system experts, MPP/HWC

CIRCUIT NAME	LAST PASSED TEST	TESTS EXEC	LAST EXEC	SUC	UNDER EXEC	HWC steps for Powering Interlocks					
						PIC - CRYO OK	PIC - PC PERMIT	PIC - CIRCUIT QUENCH VIA QPS	PIC - TEST W/ LINKS		
RCD-A78B1	2009-02	11/14 (100%)	2009-02	Y	-	PCL	2009-02	PIC - CRYO OK	PIC - PC PERMIT	PIC - CIRCUIT QUENCH VIA QPS	PIC - TEST W/ LINKS
RCD-A78B2	2009-02	11/14 (100%)	2009-02	Y	-	PCL	2009-02	PIC - CRYO OK	PIC - PC PERMIT	PIC - CIRCUIT QUENCH VIA QPS	PIC - TEST W/ LINKS

- Working on full automation of test sequences and analysis of HWC tests with EN-ICE for start-up 2009 and future shut-downs (except main circuits)

M. Zerlauth

- **Powering Interlock Controller** (820 circuits + 752 - 60 A orbit correctors). No modification of the HW but:
 - Different logic for the “Global Powering Sub-Sector”
 - Relocation of equipment due to civil engineering in TZ76
 - **A New QPS System connected to PIC.....**
- Except for Sector 34 (to be considered a new sector) HWC steps for powering interlocks need to be repeated → automatic procedure being put in place (except for main circuits)
- **Automatic** tests procedures for the PIC to BIC connection verification are available as well (1 hour/sector)
- Potential issue: **Robustness of CPLD XC95144 used in PIC against Single Event Upsets** after recent radiation tests (not conclusive yet).

Beam Interlocks

BIS client connections

A **COINCIDENCE** of 5 'events' have led to a complete Blind Failure of a BIS input in 2008

Event	Change 2009
1. Two different Equipment systems sharing to the same channel	No longer tolerated.
2. PLC Voltage against rules	No additional protection possible with existing design... Test, test, test.
3. Transient Voltage Suppressor blocked Short-Circuit	Slight change of the interface (on User system side) for each connection.
4. Inputs were not redundant	Redundant signals should be supplied. It will become mandatory in 2009.
5. Not re-commissioned after change	Tests, tests and tests... Regular tests before every fill will be the best option : => implementation of Automatic tests

B. Puccio, MPP 5th Dec. 2008

05.02.2009 Preparation for Beam Interlocks Chamonix 09 10

CERN CH-1211 Geneva 23 Switzerland
The Large Hadron Collider project
Date: 2007-02-19

MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

MPS ASPECTS OF THE INJECTION PROTECTION SYSTEM COMMISSIONING

Abstract
This document describes the set of tests which will be carried out to validate for operation the machine protection aspects of the LHC injection protection system. The area concerned by these tests extends over the LHC injection regions (including SPS extraction to some extent) for each of the two LHC beams. These tests include the hardware commissioning, the machine check-out and the tests with beams.

Commissioning procedures

- Most procedures have been reviewed based on 2008 experience.
- Procedures should be released by April 2009 !

Procedures:	Status
• Powering interlock system	approval closed
• Fast magnet current change monitors	approval closed
• Warm magnet interlock system	under approval
• Beam interlock system	released
• Collimators	work in progress
• Beam loss monitors	under approval
• Injection	approval closed
• Beam dumping system	work in progress
• Vacuum system	work in progress

J. Wenninger

- Very large Beam Interlock System (BIS):
 - ~10000 devices/interlocks connected to Beam Interlock Controllers (BIC)
 - ~3800 Software Interlocks
- 2008 experience & status:
 - Blind failure detected during LHC cold check-out → solution in place for 10/9
 - Definitive changes and measures being implemented during the SD → 2 new channels (+ additional one)
 - Safe beam flag not commissioned (we ran only with probe beam)
- Full test needed of all the system
- Automation is a must → started in 2008 (e.g. PIC-BIC connection) → being extended
- Documentation/issue tracking effort ongoing (procedures, MTF)

Beam Interlocks

MPS Commissioning Phases

Phase	Energy	Int.	Comments
MPS-1: Probing 450 GeV	0.45	$\leq 10^{10}$	<ul style="list-style-type: none"> • Early commissioning phase. • Can run with 'minimal' interlocks – '2008-style' • 'Light' powering interlocking (maskable). • Experiments protection must be ready!
MPS-2: Ramp	0.45 – 7	$\leq 10^{10}$	<ul style="list-style-type: none"> • All interlocks commissioned. • Post-mortem recording operational. • Beam related MPS tests passed at 450 GeV. • Commission in steps of 0.5-1 TeV.
MPS-3: Increased intensity at 450 GeV (injection $\leq 10^{11}$)	0.45 – 7	$\geq 10^{11}$	<ul style="list-style-type: none"> • All interlocks commissioned. • Post-mortem recording operational. • Beam related MPS tests passed at 450 GeV.
MPS-4: Squeeze			<ul style="list-style-type: none"> • All interlocks commissioned. • Subset of beam tests must be repeated for every significant squeeze step.
MPS-5: Unsafe injection	0.45	$\geq 10^{11}$	<ul style="list-style-type: none"> • All beam related injection MPS tests passed.

05.02.2009

Preparation for Beam Interlocks
Chamonix 09

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MPS test with 'entire' LHC

- Some MPS components can only be tested when the **Beam Energy Tracking System (BETS)** of the **LBDS** is working.
- Requires dedicated periods where *eventually* at least ½ of the LHC must be available (also ramps!) – sectors 45,56,67 and 78.
- Systems:
 - BETS – internal interlock tests.
 - LBDS dry dumps.
 - SMP : Safe Energy.
 - BLM thresholds with energy.
 - Full chain interlock tests (source → dump) on a selection of inputs.

>> we must avoid to push that to the 'last minute' – 2008 effect!

05.02

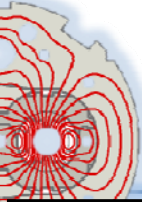
J. Wenninger

ks

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- Reliability run is needed for the BLM system (~4000 channels) on top of radioactive source verification.
- Post-mortem (including BIS, powering and BI) is needed.
- Phases for the commissioning identified to provide some flexibility for **safe** beam and MPS parallel commissioning:
 - few days with machine **closed and operational** are needed to commission the Beam Dump System + BIS for low intensity and energy operation
 - **Rule of the Probe:** go back to probe beam any time new territory is explored (energy, optics, ...)
- Need MPS Experts to trigger and follow-up MPS staged/safe commissioning and to support Machine Coordinators/EiCs in the definition of the possible envelope of operation in case of abnormal operation of any BIS element.

Injection and Beam Dump

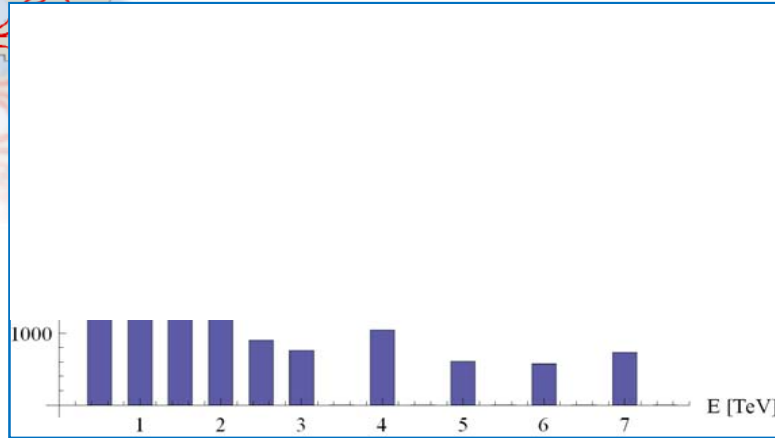


J. Uythoven

2008 experience thanks to dry runs:

- MKI magnet D in LSS2L showed a breakdown (over-voltage during lab conditioning?) → replaced by spare
- MKI flashovers due to beam loss (aperture studies)? → BLM installation (interlocks?) and improved conditioning sequence (SoftStart)
- Injection absorbers (TDI) and TI8 transfer line collimators (TCDI) being “consolidated” → need re-commissioning
- Effect of the injection magnetic septum (MSI) stray field on the circulating beam orbit → need to test possibility to run magnetic septum in DC
- Dependence of the strength of beam dump extraction kickers MKD on tunnel temperature ($\sim -0.2\%/^{\circ}\text{C}$) → Regulation of the MKD generator temperature & interlock on it at $\pm 1^{\circ}\text{C}$ → **need operational experience**
→ **availability !!**

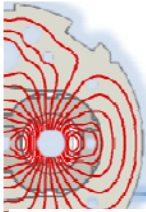
Injection and Beam Dump



- Beam dump dilution kicker (MKB) flashovers:
 - Weak elements identified and replaced
 - “Common mode” failure due to vacuum deterioration → reduction of conductance and additional pumping speed
 - MKBH installation will become nominal
 - MKBV: 4 out of 6 magnets

→ **Beam Dump Reliability run is needed: > 4 weeks effective running for failure statistics**

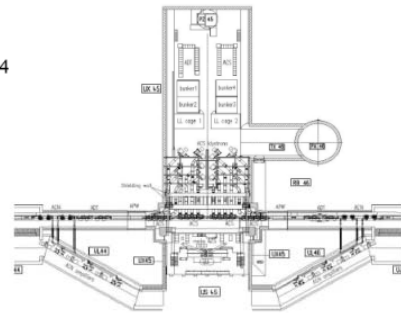
- Energy tracking to be tested before beam (main bends in 45/56/67/78) → coordination required
- Additional redundancy will be added for the verification of the position of TCDQ collimator (protecting Q4 and the arc in case of asynchronous dump): ‘independent’ check vs. beam energy (now only triggered via timing)



RF System – Status up to Sept 19th

- Klystrons, controls & LLRF electronics in UX45 cavern
All fully commissioned
- 16 ADT Transverse Damper kickers- 4 modules left / 4 right of IP4
Kickers & amplifiers fully power tested
- 16 SC cavities, in 4 Cryomodules (each 4 single cell cavities).
All 16 conditioned to nominal gradient in 2008
(Checked with beam)
BUT Problem with tuning mechanism found..
- APW Wideband Monitors 3 left / 3 right of IP4
Set up and used for beam measurements

- Beam controls for RF synchro, capture, and transverse damping tested with beam
Beam 2 successfully captured
- Collision, acceleration, radial loop
Nearly tested (Was planned Sept 19/20th)
2008

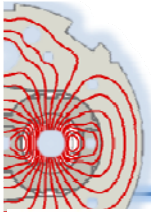


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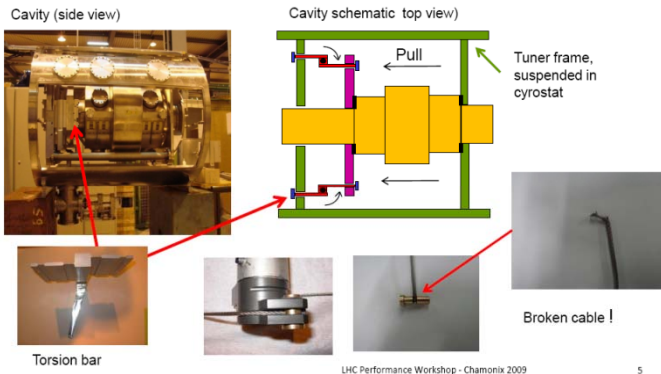
E. Ciapala

- Some of the Beam Controls systems could not be tested with beam due to the abrupt stop on 19/9 → **still a lot of work to be done!**
- No damage to the RF systems on 19/9
- Similar event close to IP4, with sector valves open would result in dust contamination or even mechanical damage → **Need to keep valves closed during powering tests without beam**
- Use of **fast sector valves** evoked but perhaps only limited protection for cavities from vacuum incidents occurring in the LSS and additional risk that the beam might not be dumped before the valves close with more severe risk of damage for the cavities.



Cavity Tuning Problem

End August, Cavity 2 Beam 1 – suddenly could not be tuned (out of range)
 "Bricolage" done to increase pull the mechanism back on tune..



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Risks, Spares etc.

Other Risks to SC Cavities – in addition to vacuum pipe break.

- Cavity / Coupler incident with RF
 - In LHC, could lead to contamination of two modules
- Cryogenics malfunction :
 - Risk of severe mechanical damage to cavities & He tanks
 - Maximum precautions taken, adequate, & with redundancy.
 - But all systems need to be pre-checked before cool down, and monitored during running.

Down time

Removal of module, dismantling, cavity rinsing, re-assembly, re-conditioning, roughly ½ year to 1 year. The time is considerably increased if we have to procure new cavities.

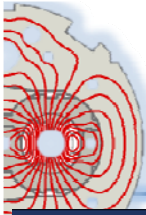
NOTE The cumulated final testing of all the four installed RF modules in SM18 took over three years

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E. Ciapala

- Weakness in the tuning system detected and being repaired
- Powering tests of the acceleration and transverse damping system are required. In particular Cavity Conditioning.
- Access restrictions in UX45 can slow down this process → **definition of access procedures**
- Situation of the spares is worrying
 - Proposal to purchase 3 more spare cavities + He tanks (~300 kCHF) whilst companies have still the know-how.
 - Possible to run cavities to ~half gradient should be possible (limited voltage at capture)

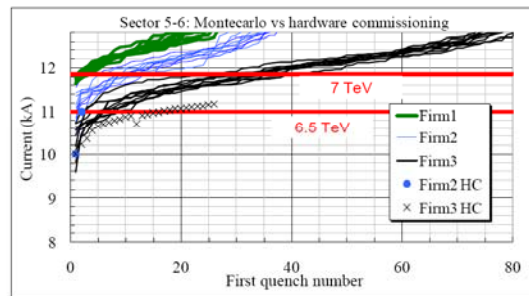


Magnet (re)training



COMPARISON TO HARDWARE COMMISSIONING DATA

- What we can explain of hardware commissioning data
 - **Qualitatively is fine:** a lot of Firm3, a few Firm2, no Firm1
 - Agreement up to ~6.3 TeV
 - Above 6.3 TeV, a unexpected longer training of Firm3 magnets



E. Todesco

5th February 2009 - Magnet training 2009 - 24

E. Todesco

- Analysis of the data collected in SM18 and during HW Commissioning for all the magnet types
- For the dipoles Monte-Carlo simulation of the training based on SM18 and HW Commissioning data
- Comparison of the model with the experience in Sector 56 is good up to 6.3 TeV equivalent current

- Retraining estimates (mainly dominated by dipoles):
 - 5.5 TeV: **a few** (<5) quenches over all the machine
 - 6.0 TeV: **~15** quenches from MB, 5 from MQM and 5 from MBR
 - 6.5 TeV: **~80** quenches from MB, 5 from MQ, 15 from MQM-Y, 10 from MBR
- Difficult to give an estimate of how to get to 7 TeV before having the experience of at least one octant

Conclusions

- **Quite some modifications** are taking place on top of those resulting from the Sector 34 incident or as a result of the experience collected during HWC/Dry Runs/Machine Check-Out/Beam Commissioning in 2008
- We know what needs to be re-commissioned
- For the superconducting circuits the following issues need to be addressed and are being addressed:
 - **New procedures for powering safely** taking into account the modifications of the magnet protection systems
 - **Definition of access conditions during powering**
- As a result of the 2008 experience the steps for a staged commissioning of the Machine Protection System have been sketched → This requires in particular a **period of a few days with machine closed and operational** before establishing circulating beam.
- In general we know how to do the Commissioning (2008 experience) but some of the people have left → **procedures, automation are essential**
- Number of spare RF cavities to be increased before the know-how in industry is lost