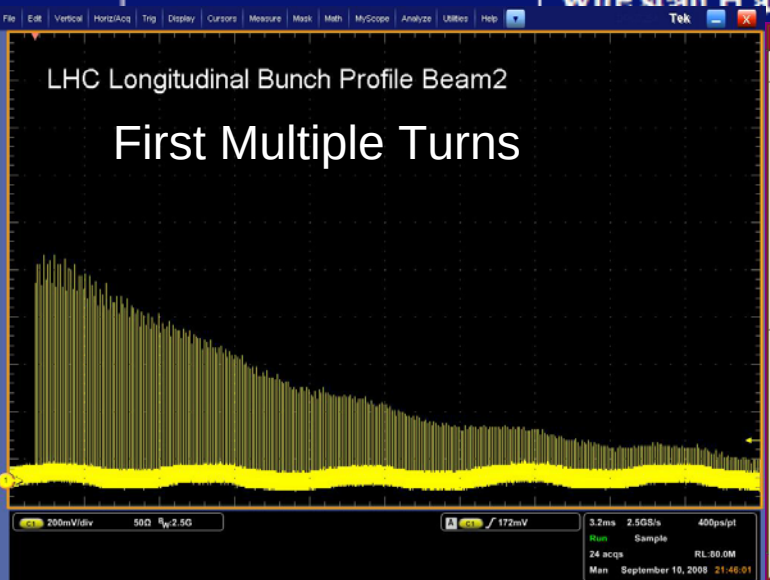
Status of the LHC and First Run Plan

US CMS JTERM IV
Aug 3-5, 2009
Fermilab

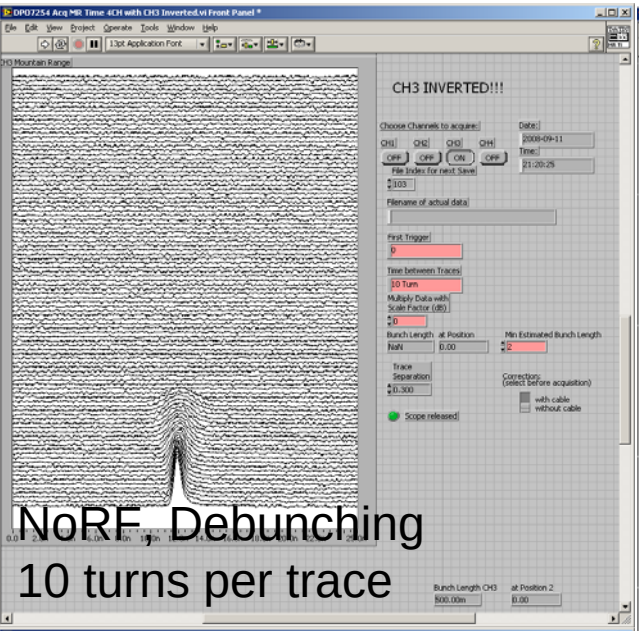
Thanks to: Ch. Darve, J. Strait, J. Spalding
Slides from M. Lemont, R. Bailey, T. Camporesi, L. Evans, S. Myers, R. Schmidt

Great Start on Sep 10, 2008

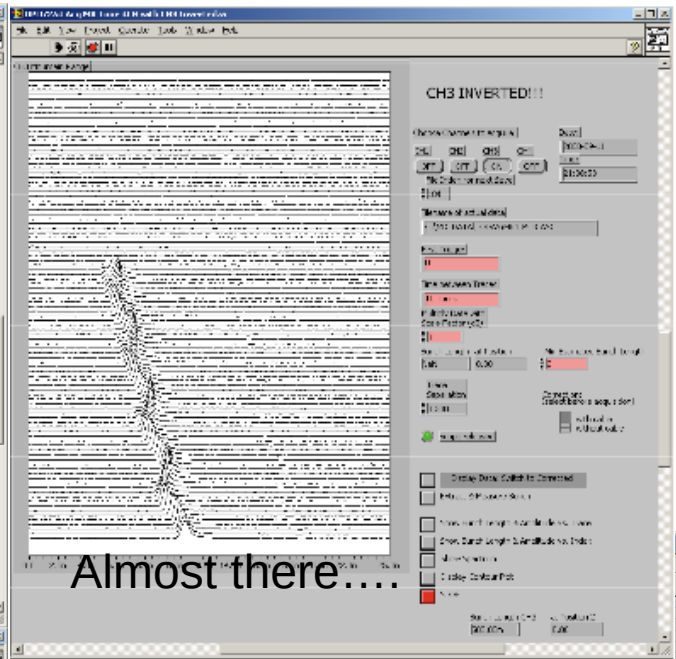
Wed 10	First turn 09.30 to 10.30 Makes 2 to 3 turns	First turn 13.30 to 15.00 Few hundred turns BPM on multiple turns Measure Q working Fast BC working Systematic polarity checks	screen shows beam on turns 1& 2 few 100 turns tune measurements fast BCT	Turbine stop in 78 at 04h Search dropped in point 2 All OK by 08h !!
Thu 11		Inject and dump Circulate and dump 50ms Circulate - dump request RF capture working Integer tunes OK Mountain range working Systematic polarity checks	dump dilution sweep integer tunes mountain range	RB34 trip in early hours Other problems follow in 56, R8, R2 QPS experts need to go in Access until 18h
Fri 12		Circulating beam Beta-beat measurement Wire scan H and V works	H beta-beat H wire scan	No beam from SPS 16h to 20h Transformer fault point 8 at 23.30 - serious



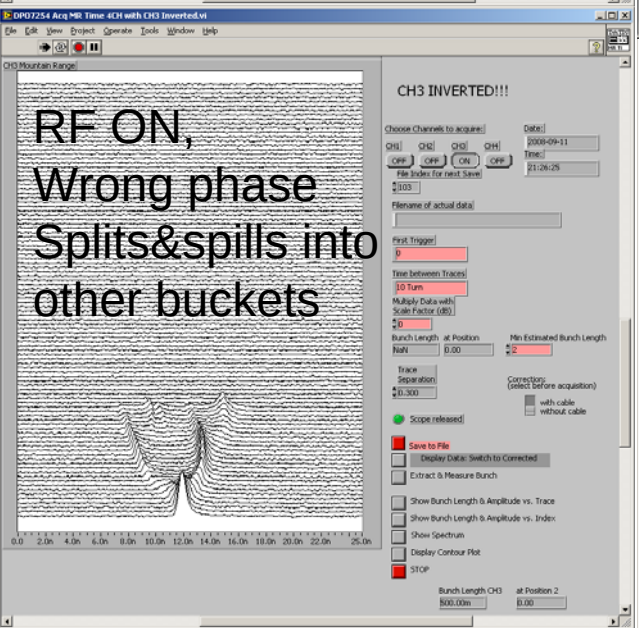
LHC Beam Commissioning in Sep 2008
Mountain range plots



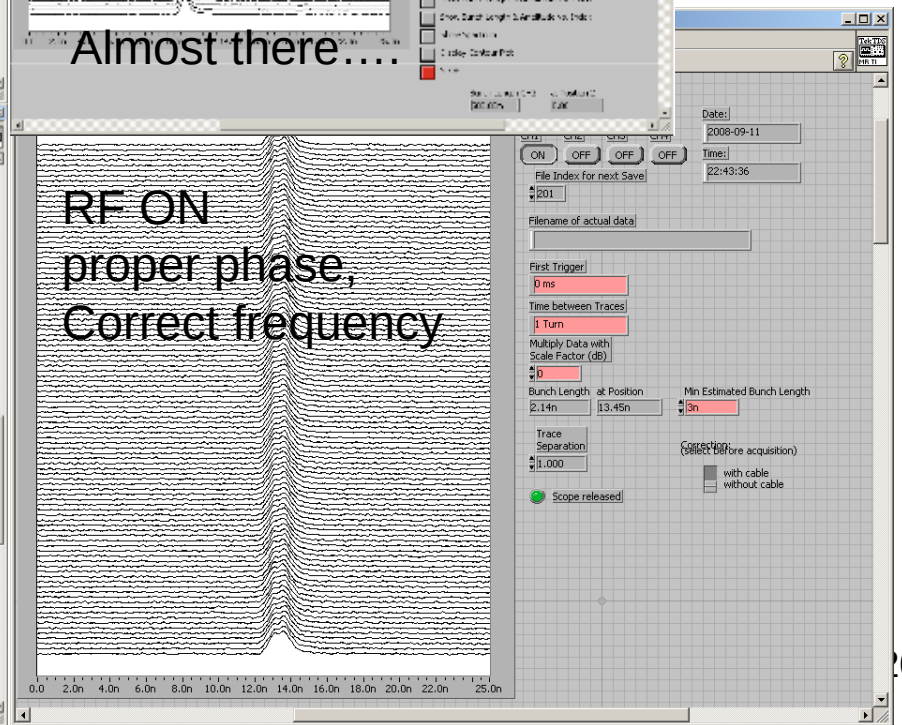
NoRF, Debunching
10 turns per trace



Almost there….



RF ON,
Wrong phase
Splits&spills into
other buckets



RF ON
proper phase,
Correct frequency

LHC Beam Commissioning in Sep 2008

- Amazing performance and rapid (10-12 Sep) progress in commissioning!
- Meticulous preparations paid off:
  - Critical instrumentation in place and working quickly
  - Logging multitude of parameters
  - Dry runs and injection sequence tests
    - Controls, LHCBeamDumpSystem, Injection, RF, Collimators
- Basic functionality achieved quickly and early look in many machine parameters with beams made possible!
  - Systematic check of orbit system
  - Machine checkout – by sector when available and all together
  - Optics and aperture measured
  - Magnetic model of the machine validated
  - Machine protection system tests including enhanced QPS
  - Many subsystems commissioned simultaneously
  - Experts gained some experience
- Huge success and congratulations well deserved! (also in the media!)

Chamonix Workshop – Feb 2009

- Addressed the problem in Sector 34 following "incident" of 19 Sep 2008 release of He in the tunnel
- Defined "Chamonix baseline" plan 2009/2010:
  - 1 month commissioning
  - 10 months proton physics run
  - 1 month Lead ions
  - Short stop for Dec 2009 Holiday break,
  - Shut down at the end Sep 2010
  - Focus on high energy collisions 4-5TeV
- Physics message from the experiments:
  - Energy 10-8 TeV preferred
  - Luminosity 300-50pb-1 – competitive reach for the Higgs
  - Highest possible luminosity even with multiple interactions/xing
- Message from the DG: "…goal for the LHC's first running period is an integrated luminosity of more than 200pb-1 operating at 5TeV per beam…"

BC - time

Phase	Days	
Circulating beams	4	capture, energy, RF
450 GeV initial commissioning	4	tune, Q', C-, orbit, collimators, LBDS, instrumentation
450 essential optics checks	2	polarities, response, beating
450 two beams	1	bumps, instrumentation
450 GeV collisions	2	experiments on at 450 GeV
Snap back and ramp to 1 TeV	4	orbit, PLL
Ramp to 4 TeV	2	machine protection
Experiments' magnets etc	2	solenoids, dipoles, machine pro.
Total	**21**	

Optimistic machine availability - 1 month elapsed

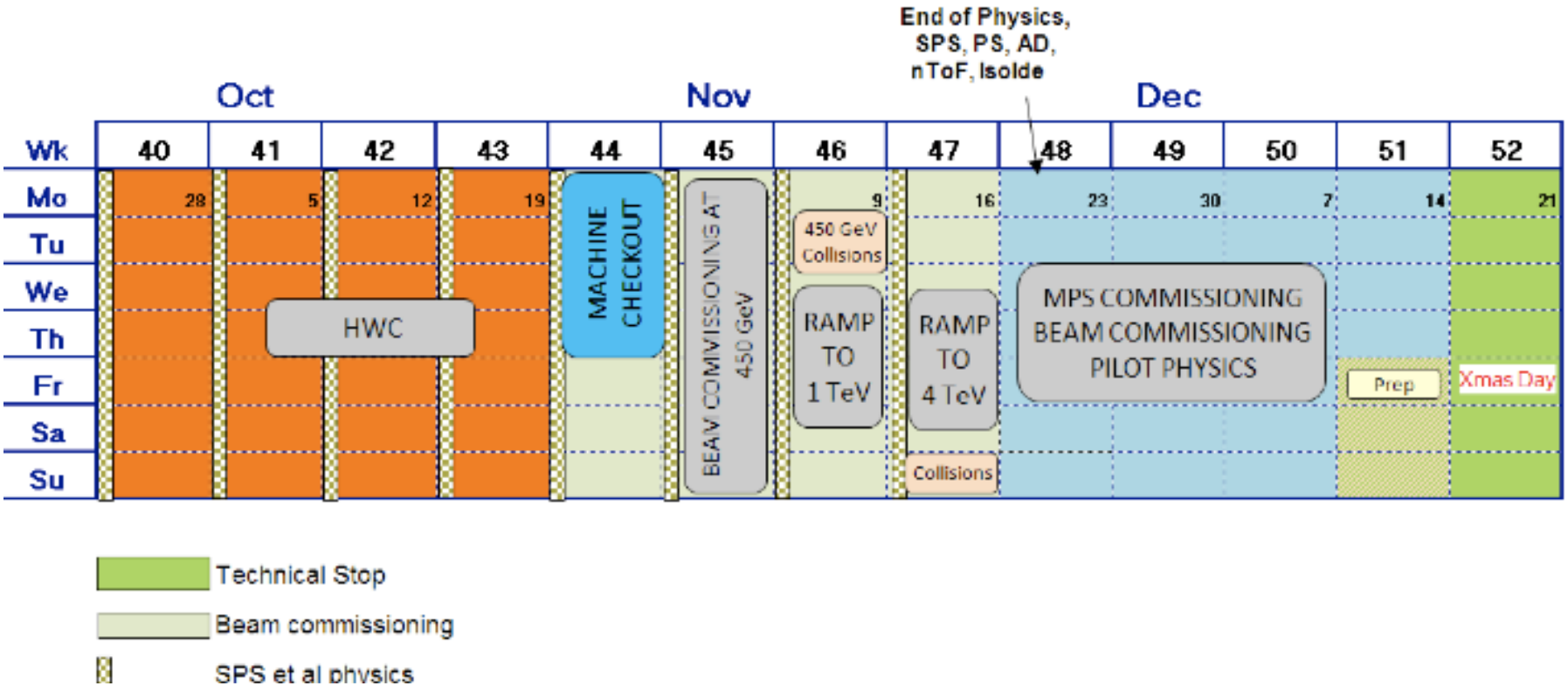
LHC Commissioning with Beams 2009

- Establish circulating beams at given energy(450GeV or more)
- Key instrumentation and measurements
  - Tune, chromaticity, coupling, optics, orbit acquisition and correction
- Essential machine protection for given energy
  - LBDS, BLMs, BInterlockSystem, collimators
- RF capture and adjustment
- Test of snap back and ramp
- Collisions at selected energy
  - Solenoids/dipoles off and on
- Ramp to next energy step
  - Test collision procedure and commission squeeze at 1 TeV or higher
  - Commission machine protection at each step
- Time estimate – 1 month
- Pilot Physics

LHC From Hardware to Beam Commissioning 2009

- Rapid progress expected based on past good experience.
- Safety of personnel and the machine of high importance!
- Machine HW checkout – by sector when available and all together
- Machine Protection Commissioning requires adjusted and understood machine
- Phased qualification of the protection systems: emphasis on using very safe beams in initial stages
- Commissioning of essential systems and extensive measurements at injection energy 450GeV
- Full machine protection qualification after establishing first low-intensity collisions
- Collisions at 4-5 TeV as soon as reasonable

LHC 2009



LHC 2010 – very draft

- All dates necessarily approximate
- Caveat: good machine availability assumed

Physics run modes

* expt magnet ON means at full nominal field (as for 14 TeV)

900 GeV

toroids & solenoids ON*, spectr. dipoles OFF

2x2
5e10
10-11m

toroids, solenoids & spectr. dipoles ON*

10 TeV

2x2
5e10
10-11m

2x2
5e10
2m

43x43
5e10
2m

156x156
5e10
2m

Dominated by beam commissioning

Lumi goes over 1e32

Dominated by physics

156x156
9e10
1m

50ns/432
9e10
3m

develop 50 ns, truncated

introduces crossing angle

short physics runs at 50 ns and go back to best luminosity (156x156) for mass lumi production

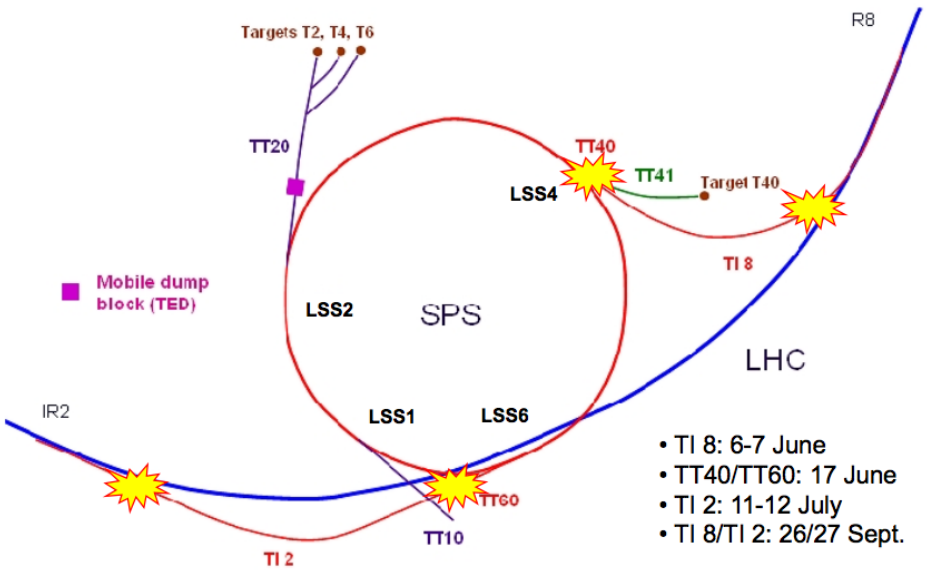
until 50ns breaks even (then stay at 50 ns)

try also 25 ns at the end

Planning of LHC Commissioning

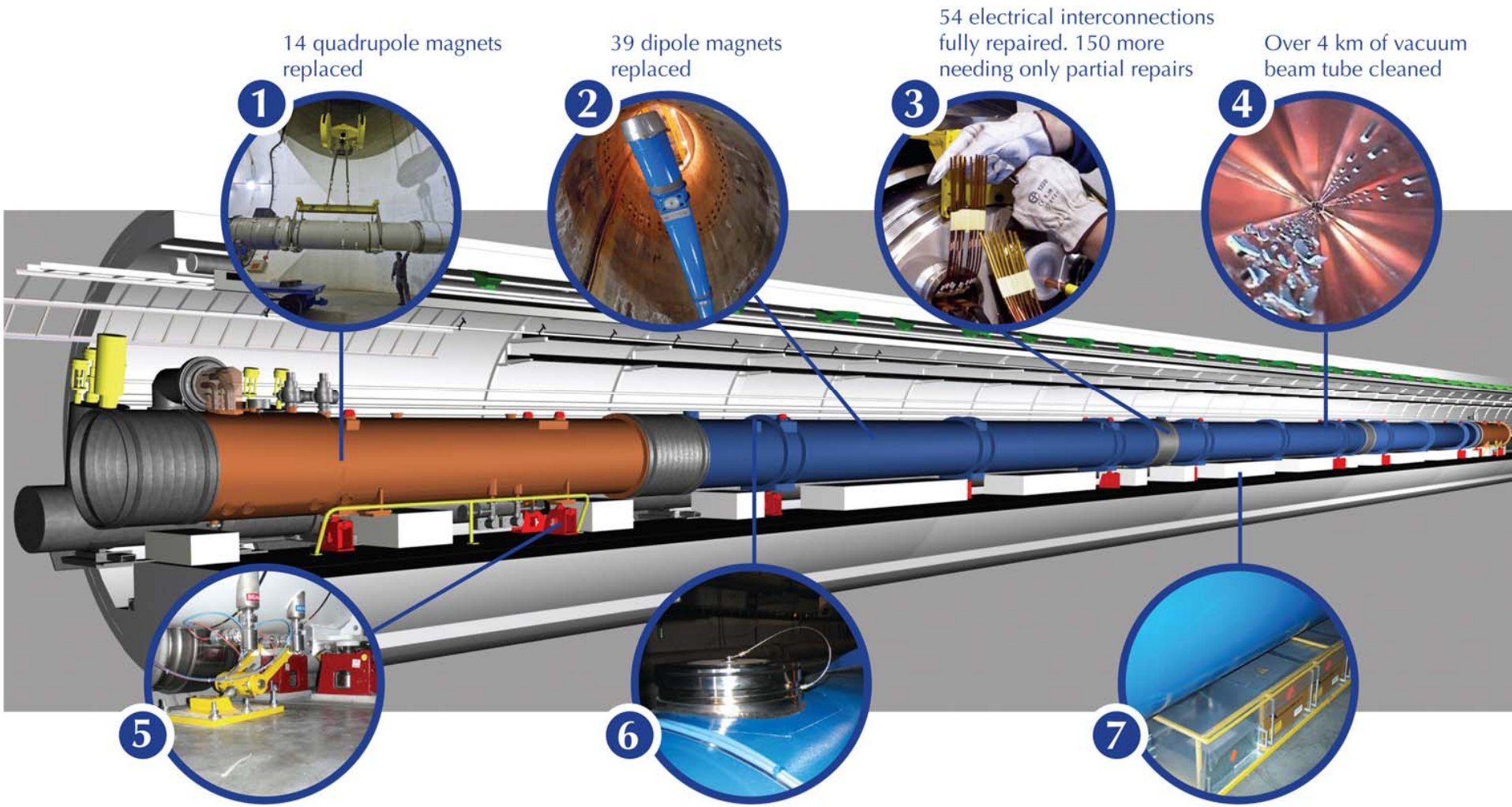
- Tests injection lines with beams:
  - TI8 – 6/7 June injections shown OK
  - TI2 – 11/12 July injections OK
  - TI2/TI8 – 29/30 August
  - Beam 1 injection – W39 (tbc)– 26/27 Sept
  - Beam 2 injection – W41 (tbc)

2009 LHC transfer line beam tests



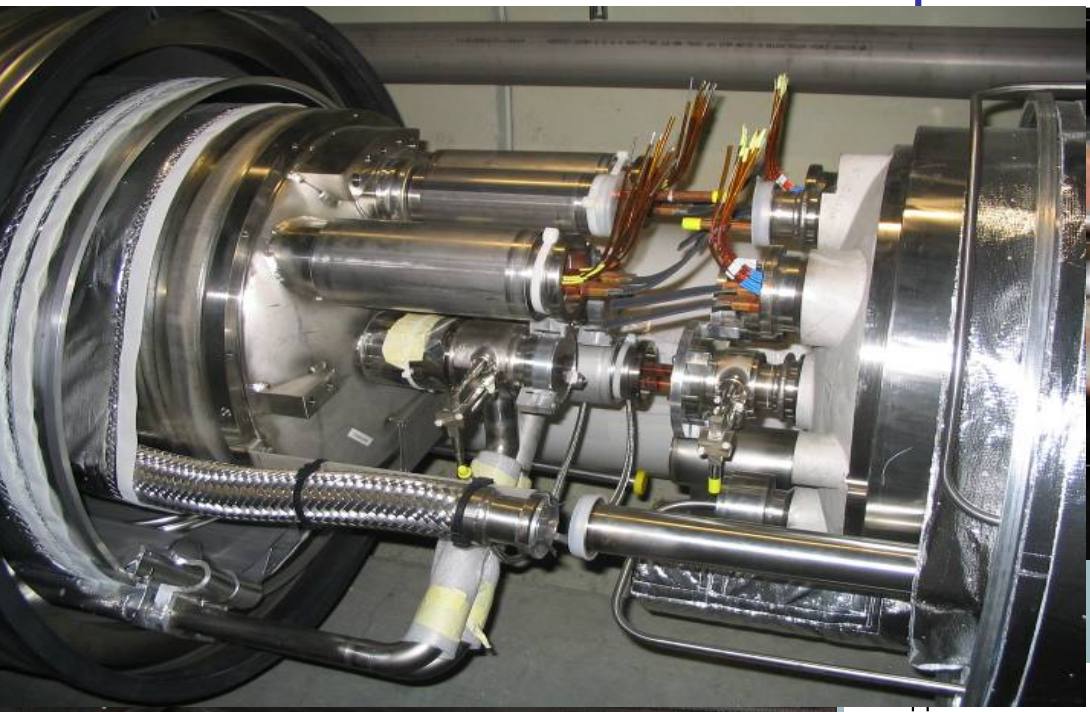
LHC Status
July 2009

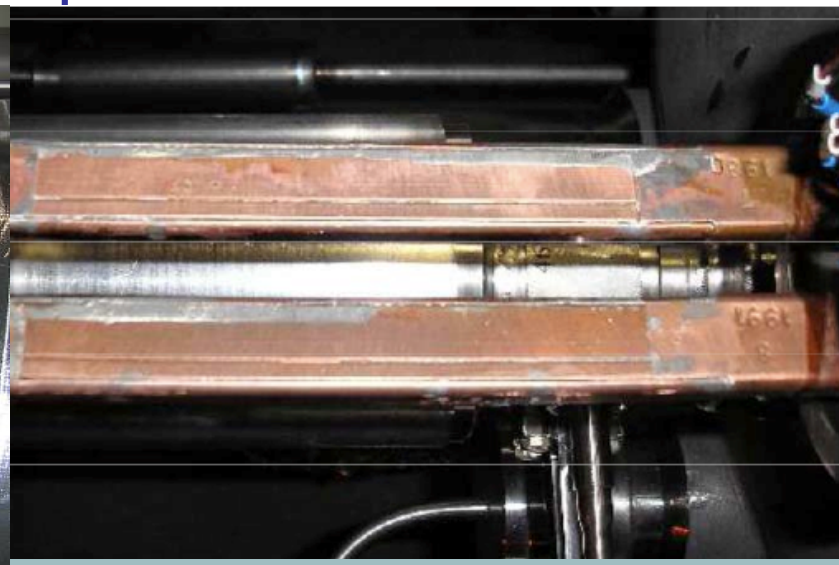
The LHC repairs in detail

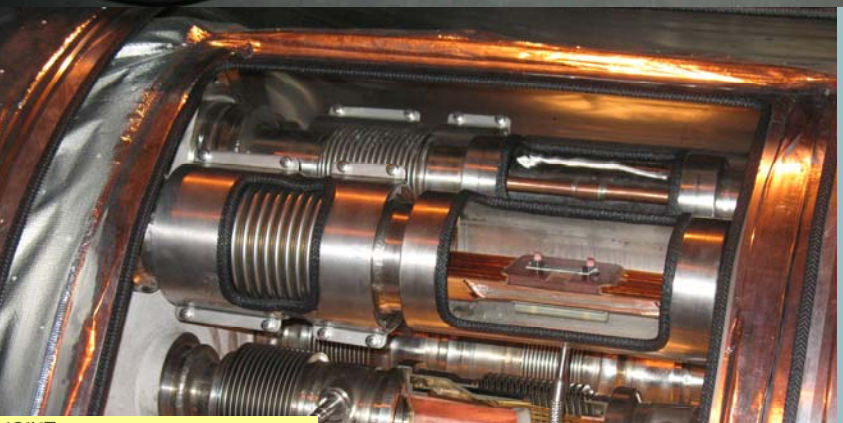


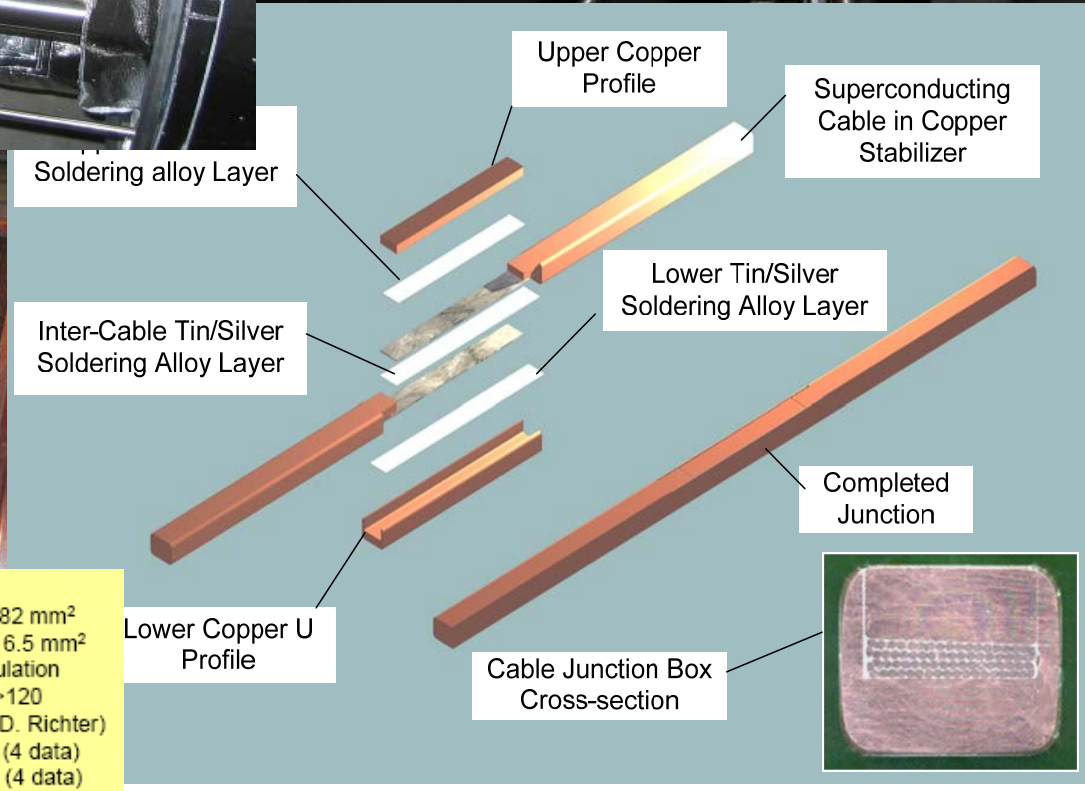
CERN

Bus bar splice repairs







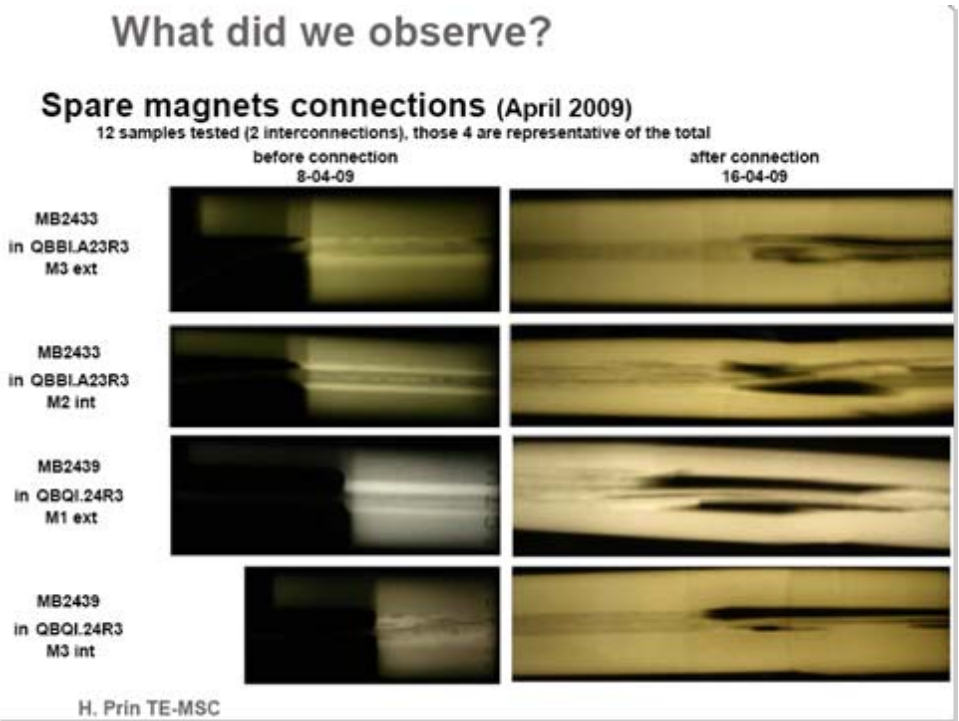


JOINT
Joint length: 120 mm
Cu U-profile: 155 mm x 20 mm x 16 mm
Cu wedge: 120 mm x 15 mm x 6 mm
Insulation:
- 2 U-shaped layers of kapton (240 mm x 0.125 mm thick)
- 2 U-shaped layers of G10 (190 mm x 1 mm)

BUS
Cross-section Cu: 282 mm^2
Cross section NbTi: 6.5 mm^2
Kapton+isopreg insulation
RRR specification: >120
RRR experimental (D. Richter)
- RB bus: 223-276 (4 data)
- RQ bus: 237-299 (4 data)

Recent Bus Bar Non-Conformity

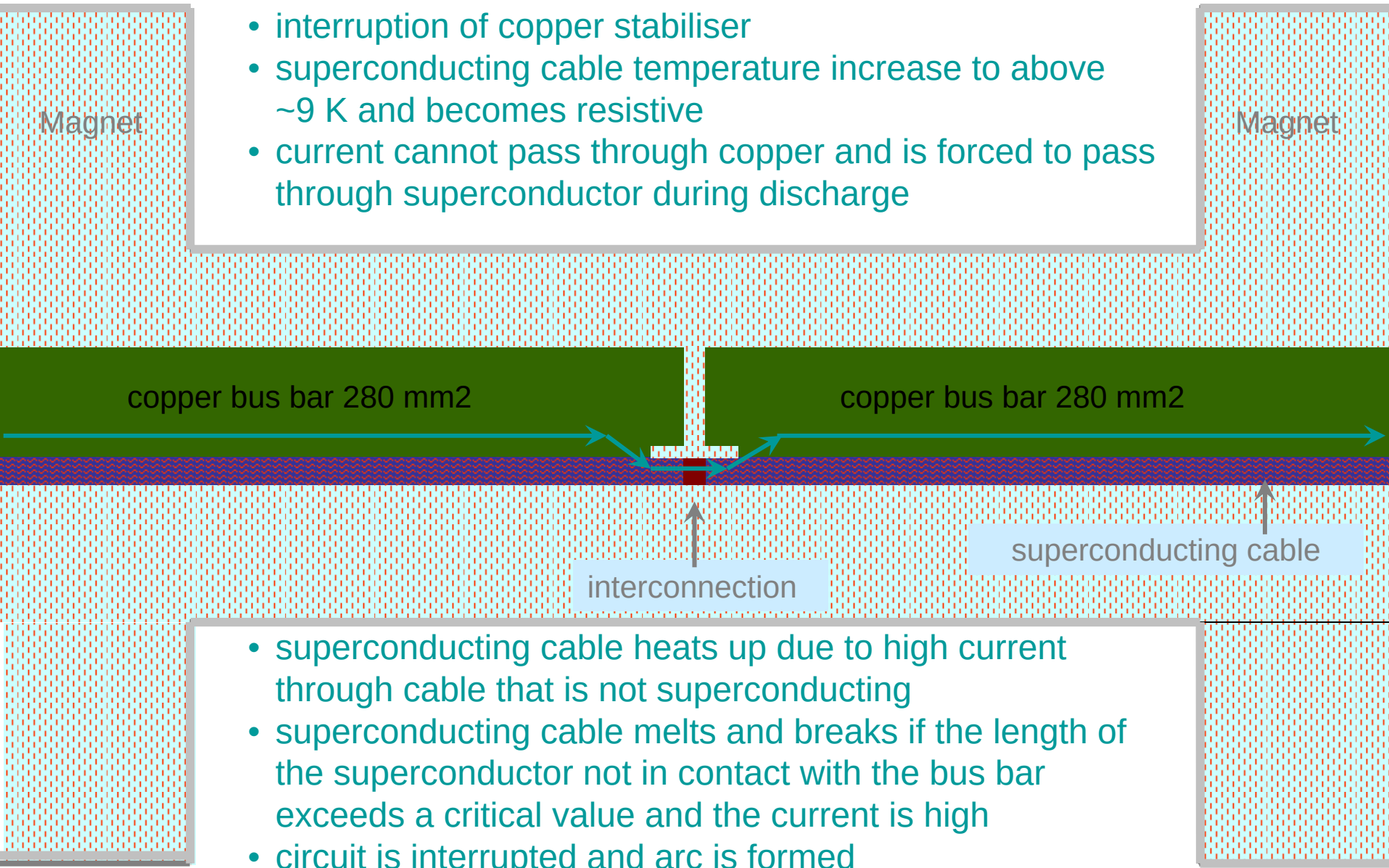
- During consolidation work in sector 34 a lot has been learnt about magnet interconnects!
- Enhanced quality assurance program introduced early!
- A couple of issues identified during consolidation activities
- A handful of high resistance splices found in the area of Cu Stabilizer Connection - "non-conforming" CSC
  - Careful micro-ohm precision measurement revealed that soldering the splice can melt and move the solder inside the interconnection creating voids. (Announced on 4 May)



How many cases in the machine?
Distribution between WARM and COLD Sectors?
How to calculate the risk to determine the safe current?

Interconnect with nonconformity, quench in adjacent magnet

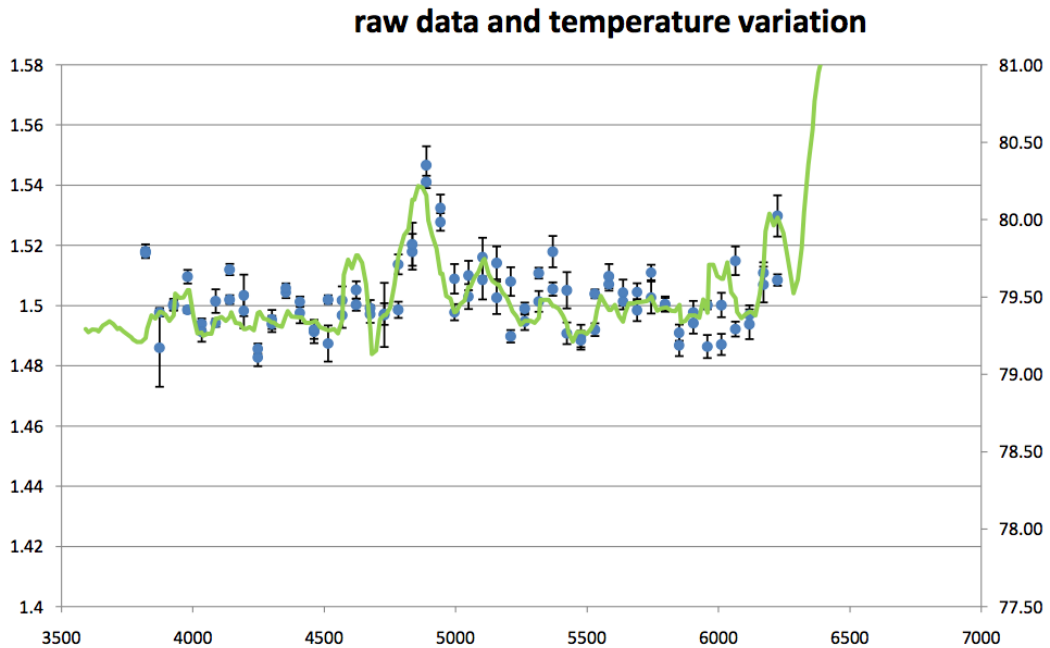
- interruption of copper stabiliser
- superconducting cable temperature increase to above ~9 K and becomes resistive
- current cannot pass through copper and is forced to pass through superconductor during discharge



- superconducting cable heats up due to high current through cable that is not superconducting
- superconducting cable melts and breaks if the length of the superconductor not in contact with the bus bar exceeds a critical value and the current is high
- circuit is interrupted and arc is formed

Bus Bar Splice Repair Status

- Good understanding of the origins and rapid progress in fixing
- Measurements performed at 300K and 80K (S45, S23, S81, S78)
- Extrapolation from 80K -> 300K are not easy!
- Measurements with large systematic – non-uniform T distribution



- 3 high resistance splices found @80K in S45, which after extrapolating to room temp end up in the tail of previous measurements;
- Highest outlier predicted ~100uΩ
- Decided to warm S45 to 300K to confirm results
- Actual measurements at 300K: 70, 60, 52 μOhm,
- Comparisons of extra-polated and actual measurements validated measurements at 80K!

1K temperature rise changes resistance by 40uOhms

7/22/2009 Mike Koratzinos

Splice Resistance Measurements

Summary of the measurements for RB & RQ circuits performed at 300K and 80K

Sector 12	Sector 23	Sector 34	Sector 45	Sector 56	Sector 67	Sector 78	Sector 81
300		300, 300	300	300	300, 300		
	80		80			80	80, 80

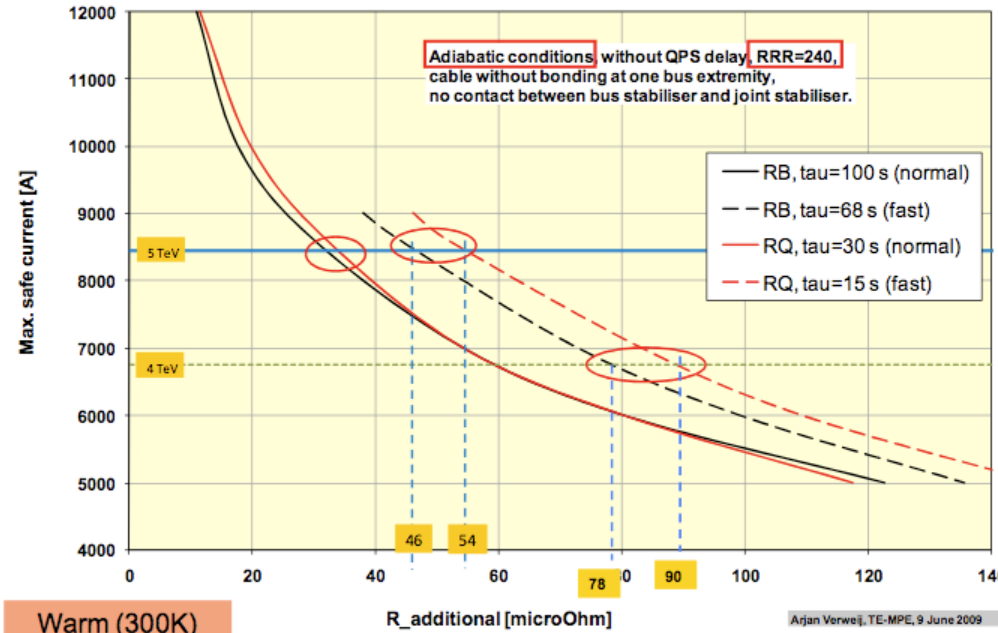
- Very intensive programme of 80K measurements last week:
- Wed: RB in A78 DONE;
- Thu:RQ in A78 DONE;
- Fri: RQ in A81 DONE;
- Mon: RB in A81 DONE;
- Tue: supplementary measurements in RB A81 DONE.

LHC Interconnect Splice Repairs

- Interconnect resistance determines the safe energy during the first run
- Simulations of Safe Current vs resistance of splices developed
- For specific current (beam energy!) identify splices for repairs and time needed to warm up (300K)
- Increase in energy possible:
  - Repairs of outliers in slice resistance
  - Speed up dumping the current
- New dump resistors installed for faster current removal
- Prepare scenarios of safe energy vs date of first beams!
- Highest energy on shortest timescal
- Highest energy with no repairs

• Key meetings on Wed 5 Aug:
• LMC: summary of understanding of LHC issues and possibly recommendation on the max “safe” current in SC
• Meeting between Director, Machine and Experiment reps to agree on running strategy for the start up in Nov and energy

Simulations: Maximum safe currents vs copper joint resistance



Additional Consolidation Tasks

- Enhanced Quench Protection (detection) System installation on schedule!
- LHC should not be operated unless the FULL Quench Protection System is tested and operational !

- Reconfiguration of Dump resistors in progress
  - Current can be brought down faster in case of magnet quench
  - For dipoles, 104 sec → 68 or 53 sec.
  - For the quadrupole, 25 sec → 15 or 12 sec.

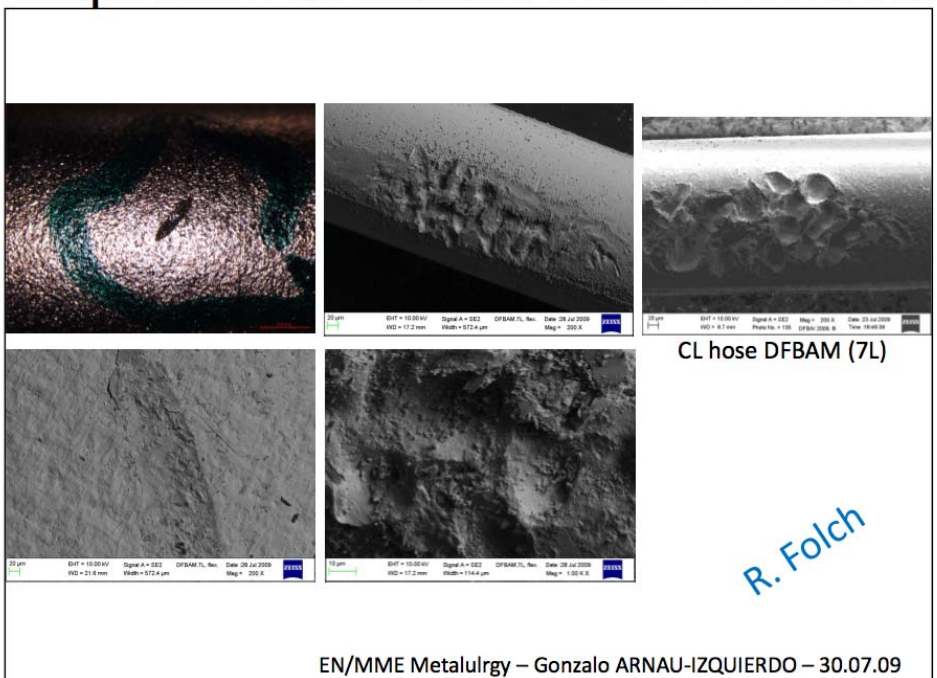
- "Annoying" two He leaks in flexible hoses inside DFBa found during partial warm-up of 2 sectors – understood and fix in place

- Repair campaign had an impact on the Chamonix baseline schedule!
- Machine startup expected mid-November!

Small He Leaks in DFBA

- Recently developed in sector S23 and S81 during warm-up to 80K
- The symptoms similar to last year's finding in S45
- Need to warm up one cryo cell: s81 accessed on 27 July
- Cause of problem is operation outside specs in terms of flow rate
- No additional degradation when flow rate reduced
- In 'principle' can operate without flow in the hose: it is used to speed up cooling of DFBs

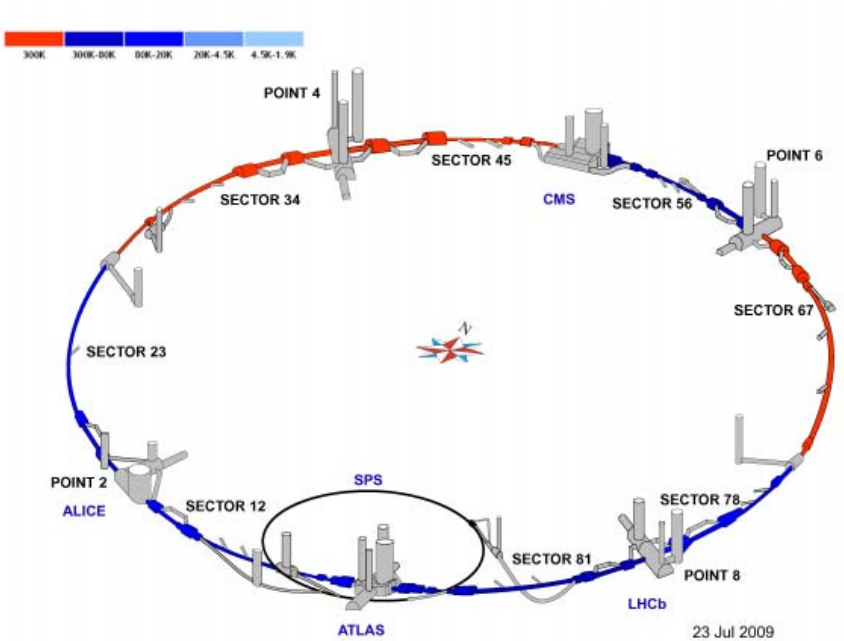
Inspection of flexible hose of DFBA L7



- Not critical for the machine schedule
- TWO DFBa in sectors already warm opened for inspection
- Two leaky hoses inspected
- Correlation with He velocity
- Recommendation to reduce the He velocity slowing down cool down
- Repair only the leaky hoses at this time

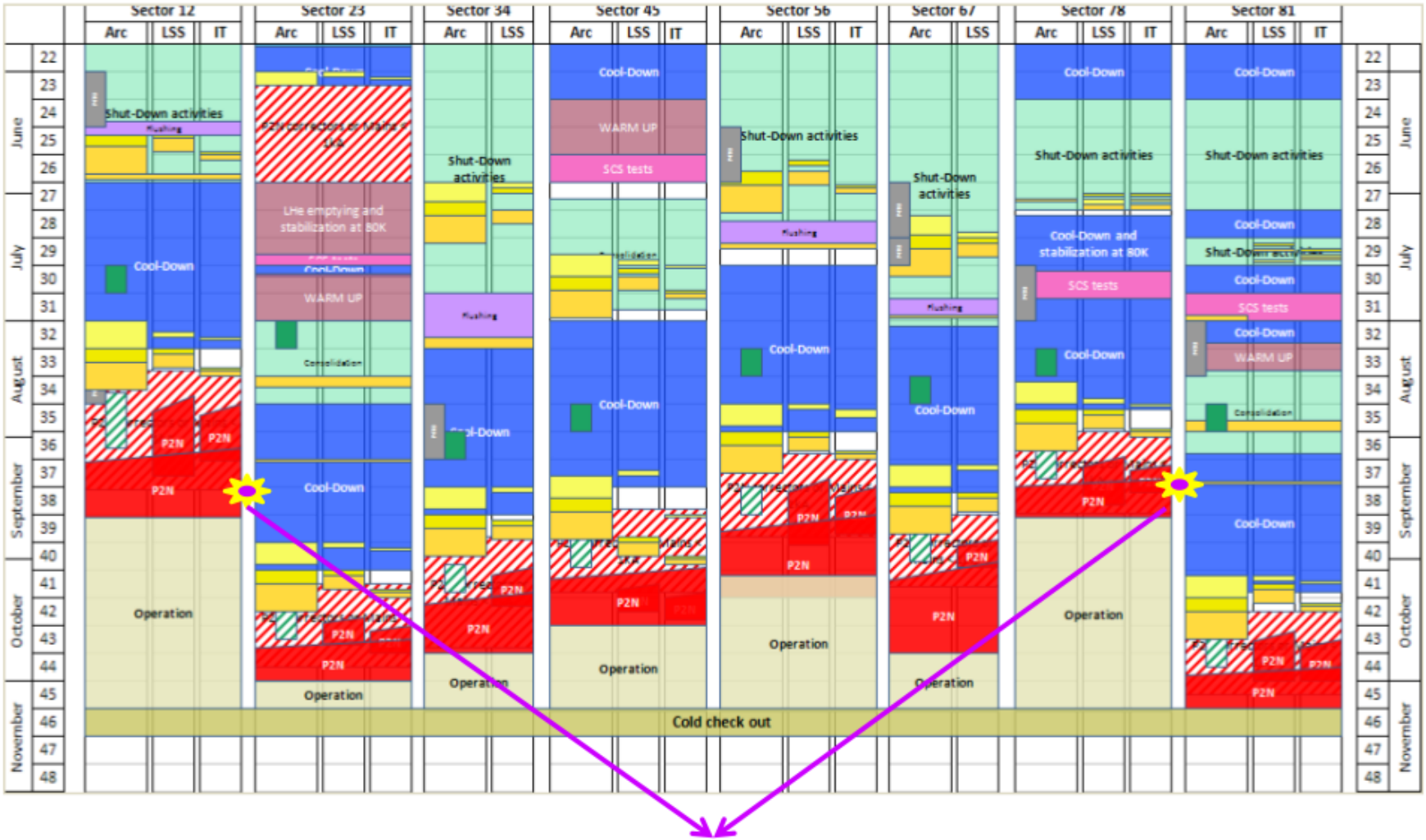
- Prepare for consolidation next time around

LHC Current Status – August 3
Finishing up the repair tasks!



- S34 – last W bellow closed Jun23; pressure tests Jul 4; couple small leaks
- S56 – last W bellow closed Jun 26; vacuum leaks repaired, cool down
- S12 – cool down started; @80K in W29
- S67 – last W bellow closed Jul13
- S45 – last W bellow closed on Jul15; 60 pressure release nozzle installed (1/3 all)
- S23 – floating at 80K, phase I power tests in progress
- S78 – cool down
- S81 – at 80K busbar tests, floating, DFBa repairs

New Schedule



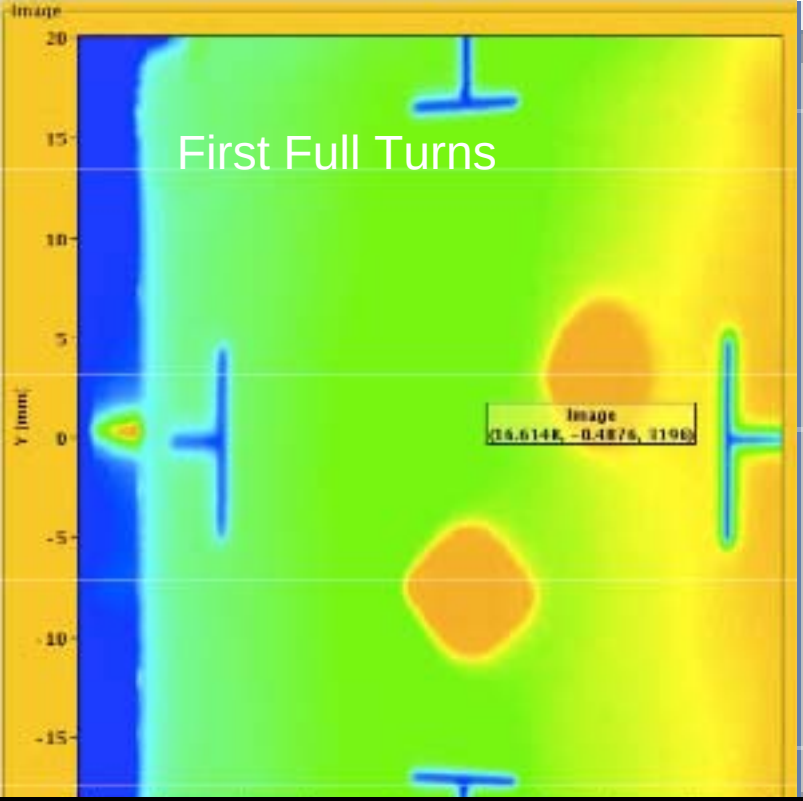
TI2 and TI8 tests: 12 – 13 September

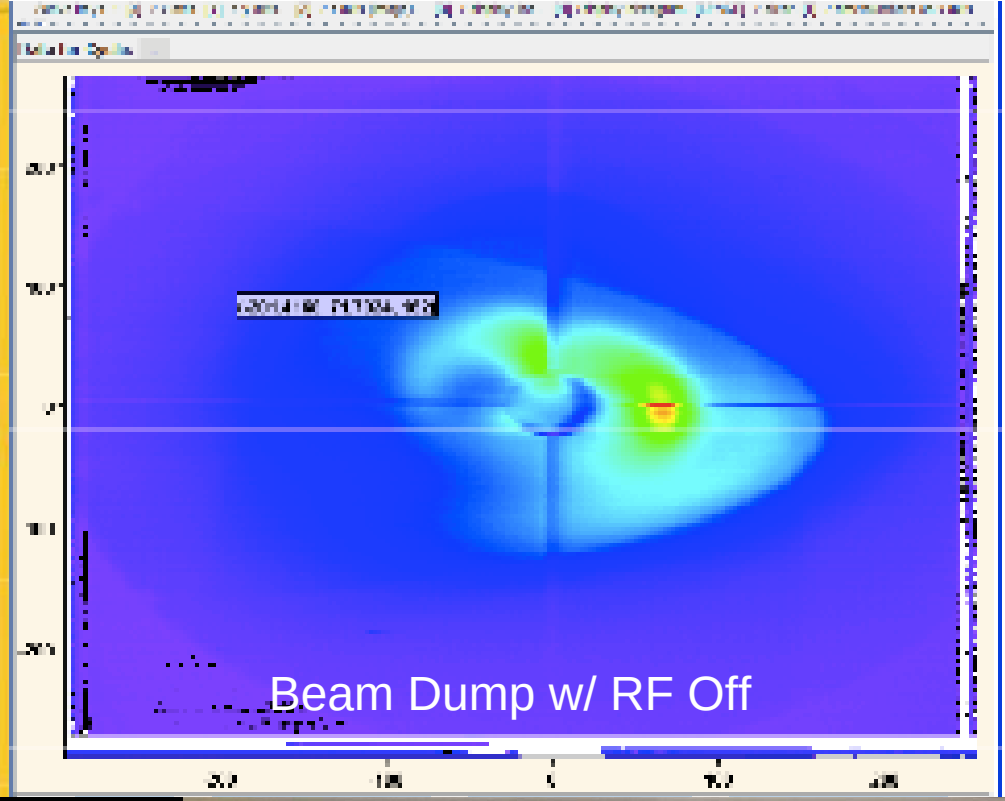
Summary

- Preliminary run plan for 2009/2010
- LHC Hardware and Beam Commissioning plans ready
- Extensive Tests with and without beams
  - Last year's experience helpful
- Staged MPS commissioning
- Quickly establish low intensity collisions (1 month)
- Full MPS qualification followed by intensity increase
- Interleave physics running and continued commissioning
- Monthly maintenance periods to address problems

Summary

- CERN DG circulated a memo informing that the LHC will be closed up and ready for beam injection by mid-November.
- Excellent communication from the Directorate, regular updates on detailed progress and LHC schedule.
- Run plan decision on Aug 5
- Collisions at injection energy could be established very quickly!
- Amazing progress shown last September!


First Full Turns


Beam Dump w/ RF Off


Halo Muons in CSCs and HB
Run 62384, Event 113639


CMS Centre Meyrin Sep 2008