Summary: Repair of 34

Magnets repair for 3-4 sector
Lucio Rossi

Reinstallation and interconnections
Francesco Bertinelli

Vacuum system – How to get ready for beam?
Vincent Baglin

Other systems – What needs to be done? Repair and reinstallation of other systems (QPS, PC, BLM, Cryo, Survey, …)
Matteo Solfaroli

Consolidation after beam operation – constraints from radioprotection considerations
Doris Forkel-Wirth
• Magnets along a zone of about 700 m to be removed from the tunnel and repaired / exchanged (a few % of entire LHC)

• Some pollution (soot) extending beyond this zone in the beam lines

• Pieces of superinsulation along the entire arc in the beam lines

• Very limited damage to other equipment in the sector

• What happens for consolidation and interventions after operation with beams?

(* Note, some PIMs and some random minor GBT pollution also, OUTSIDE zone Q19-Q33 (up to Q7 R3 and Q7 L4))
Magnet repair for 3-4 sector, L.Rossi

- Enough spares are available to cover the sector 3-4 reinstallation (+ two dipole magnets for sectors 1-2 & 6-7)
- Magnets reused or remaining in the tunnel are inspected (visual, electrical, cold test for the removed ones,…) but defects could be missed so cautious repowering procedures required
- Quick restart of the facilities, requiring an impressive logistics effort was achieved
- Many Short Straight Sections (quadrupole + corrector magnets) variants exist - for 3-4 reinstallation some correctors will be lost due to reshuffling (no major impact on beam operation)
- Last magnet should be lowered calendar week 15
- Operations to rebuild stock of spare magnets will start as soon as possible with the recovery/repair of the damaged magnets
Assessing magnet damage

- Cold mass removed and substituted when:
  - Electrically damaged
  - Mechanically damaged,
  - Bus–bar system damaged due to displacements
  - Dirtiness

- Cold mass removed and re–used:
  - No electric damage or soot in the cold mass;
  - No movements at rest: we estimate from models that at max the displacement for such CM was < 50 mm well within the max elongation of the lyra (180 mm). For Q22 the displacement at rest is about 20 mm. We believe that it is safe.
  - No visual damage from endoscopy (except minor scratch on bus bar that are similar to other seen in installed magnet).
  - Qualification after cold test
Impossibility to have an exact substitution for the SSS. We will lose correctors, because:

- We don’t have in stock all type and needed number of SSS spares as necessary
- BE-ABP priorities are:
  1. Sorting of MQ to minimize the effect on the beta-beating
  2. Preserve the orbit corrector layout
  3. Leave as last the preservation of the MQT/MQS/MO layout

1. It is foreseen to loose 2 MQS/beam (out of 4 in sector 3–4) and 2 MO out of 13 in sector 3–4.
Magnets repair for 3-4 sector

Lucio Rossi
Reinstallation and interconnections, F.Bertinelli

Shutdown/Repair/Consolidation activities are taking place in the 8 LHC sectors (not only in sector 34)

Main activities
- Repair in sector 34
- Sector 12 and 67 exchange of dipole magnet requires warming up the sector
  - needs RF ball test to locate PIMs to be replaced and finally validate free beam tube aperture
- Sector 56 repair of connection cryostat
  - needs RF ball test to locate PIMs to be replaced and finally validate free beam tube aperture
- Several other interventions in stand alone cryostats
Repair in sector 34

- QRL service modules, especially the interface for connection to cryomagnets (jumpers) to be repaired in four locations
- Magnet re-installation and making interconnects
  - Making interconnects is a complex chain of operations; the last magnets will be available week 15 and the last interconnect will be closed in week 23
- High level of Quality Control is required
  - It will be enhanced for the main busbars splices
- Clamping: Some suggestions for system have been made
- The replacement of the undulator in L4: not for now
## Repair in sector 34

<table>
<thead>
<tr>
<th>IC half-cell</th>
<th>SSS C30</th>
<th>MB A31</th>
<th>MB B31</th>
<th>MB C31</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IC name</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Magnet ready for installation</td>
<td>W15</td>
<td>W15</td>
<td>W15</td>
<td>W15</td>
</tr>
<tr>
<td>2 Magnet transported</td>
<td>W15</td>
<td>W15</td>
<td>W15</td>
<td>W15</td>
</tr>
<tr>
<td>3 Survey positioning / check</td>
<td>W10</td>
<td>W10</td>
<td>W10</td>
<td>W10</td>
</tr>
<tr>
<td>4 O/C: start IC</td>
<td>W16</td>
<td>W16</td>
<td>W16</td>
<td>W16</td>
</tr>
<tr>
<td>5 EB: Bushing Brazing</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
</tr>
<tr>
<td>6 O/C: BB</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
</tr>
<tr>
<td>7 insulate BB</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
</tr>
<tr>
<td>8 US: ultrasonic welding spots</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
</tr>
<tr>
<td>9 insulate spots</td>
<td>W19</td>
<td>W19</td>
<td>W19</td>
<td>W19</td>
</tr>
<tr>
<td>10 ELOA: PAO</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
<td>W17</td>
</tr>
<tr>
<td>11 Insert N-Line</td>
<td>W18</td>
<td>W18</td>
<td>W18</td>
<td>W18</td>
</tr>
<tr>
<td>12 Cable N-Line</td>
<td>W18</td>
<td>W18</td>
<td>W18</td>
<td>W18</td>
</tr>
<tr>
<td>13 ELOA: HVON</td>
<td>W18</td>
<td>W18</td>
<td>W18</td>
<td>W18</td>
</tr>
<tr>
<td>14 ELOA: AV1</td>
<td>W19</td>
<td>W19</td>
<td>W19</td>
<td>W19</td>
</tr>
<tr>
<td>15 US weld N-line</td>
<td>W19</td>
<td>W19</td>
<td>W19</td>
<td>W19</td>
</tr>
<tr>
<td>16 ELOA: MPAO</td>
<td>all D-area</td>
<td>all D-area</td>
<td>all D-area</td>
<td>all D-area</td>
</tr>
<tr>
<td>17 ELOA: AV2</td>
<td>W20</td>
<td>W20</td>
<td>W20</td>
<td>W20</td>
</tr>
<tr>
<td>18 insulate N-line board</td>
<td>W20</td>
<td>W20</td>
<td>W20</td>
<td>W20</td>
</tr>
<tr>
<td>19 ELOA: MHVON</td>
<td>all D-area</td>
<td>all D-area</td>
<td>all D-area</td>
<td>all D-area</td>
</tr>
<tr>
<td>20 THG weld 139 N-line flange</td>
<td>W21</td>
<td>W21</td>
<td>W21</td>
<td>W21</td>
</tr>
<tr>
<td>21 THG weld Mt-N</td>
<td>W21</td>
<td>W21</td>
<td>W21</td>
<td>W21</td>
</tr>
<tr>
<td>22 Cryo Thermometers</td>
<td>W21</td>
<td>W21</td>
<td>W21</td>
<td>W21</td>
</tr>
<tr>
<td>23 Final QC, certification</td>
<td>W22</td>
<td>W22</td>
<td>W22</td>
<td>W22</td>
</tr>
<tr>
<td>24 Close W bellows</td>
<td>W23</td>
<td>W23</td>
<td>W23</td>
<td>W23</td>
</tr>
</tbody>
</table>
Conclusions on 3-4 i/ii

✓ Where do you stand today?
  • IC work starting W07 (next week)
  • main current effort: to finish qualifying machines and people, organising coordination while satisfying shutdown requests in other sectors

✓ Is quality under control?
  • Yes, technique is sound (no showstoppers), but ...
  • still risky/weak (organisation and routine not smooth, e.g W04 and W05 for surface activities)
  • ... but why did 19 September incident happen?
  • so no paranoia, but keep this in mind
Conclusions on 3-4 ii/ii

When do you finish?

- Plan for W23 (close W bellows), but ...
- are we confortable? No, see quality, no slack, holidays
- 4 extra weeks more confortable (more will further complicate with Summer months ...)

(How) can you go faster?

- No, see quality above, don’t take chances
- can extra resources help? Difficult, little time for integration: possibly yes in few special cases (ad-hoc needs e.g. QC and specific individual profiles)
- flexibility measures will help (coactivity, holidays, longer hours ...)
Remarks

- The last magnets will be available week 15 and the last interconnect will be closed in week 23
- The planning is very optimistic, and the schedule is tight, for both, preparing the magnets and for reinstallation
- Several teams with many people involved
- During such a complex operation problems come up and need to be solved
- Quality must not be compromised
- The undulator replacement is for later
- Clamping main busbar interconnects
  - The new interconnect will present less risk as the quality control is enhanced. Adding a non fully validated clamping system could create other problems. However, clamping should still be considered as an option.
Vacuum system – how to get ready for beam?
V. Baglin

- In 3-4, 59% of the beam vacuum was contaminated with Multi Layer Insulation (MLI) and 19% with soot (the beam vacuum has a length of ~6 km)
- The soot pollution concerns six cryodipoles that have not been brought back to surface. Some soot will remain between beam screen and cold bore
  - could this create any problem for beam operation?
- In some location, an oxide layer coming probably from the melting of an ice block appeared during warm-up is present
  - The thickness should be in the nanometer range so acceptable for the impedance of the machine
- No problem was found in the warm sectors – RF system ok
- **Ultra High Vacuum system does not mean Ultra Clean system**
Beam screens with soot in tunnel: Cleaning Method

- Two plugs: one for horizontal and one for vertical parts of the beam screen
- Use of a foam-plug wet with alcohol
- Use of a dry foam-plug

- Up to 50 passages in each direction with wet foam-plug
- Up to 15 passages with dry plug
Beam screens with soot in tunnel: C20R3

C20R3.V2 before cleaning

After cleaning

V. Baglin - Chamonix 2009
Beam screens with soot in tunnel: Q19R3

Q19R3.V2 before cleaning

After cleaning

V. Baglin - Chamonix 2009
• 4-5 passages will allow to remove 95% of what can be removed by the tool

• 8-10 passages will allow to remove 99% of what can be removed by the tool
Remarks

- Impressive progress on cleaning the beam tubes in situ.
- Could an extra test on cold test bench be done to quantify the effect of soot in presence of magnetic field?
- Extra instrumentation is discussed to detect moving particles touching the beam (Beam Loss Monitors to be installed along the magnets in part of sector 34?).
- Theoretical simulations could be done to evaluate the effect on the beam of MLI, soot and oxide layer.
Other systems – What needs to be done?
M. Solfaroli

- In sector 3-4, a lot of other activities are taking place in parallel with the repair of the damaged area.
- Very limited damage to the infrastructure (tunnel concrete, cables, electronics,…)
- QPS heater power supply damages to be understood
  - many seem to have suffered from an electrical breakdown
- The few power converter failures should be investigated
- Power converter short-circuit tests need to be done to demonstrate that the converters are ok, time needs to be allocated
- The circuits powered by the cryogenic link in point 3 (DSLC) will have to be recommissioned after the DSLC repair (not related to incident)
Other systems – What needs to be done?
Consolidation after beam operation - Constraints from radioprotection considerations, D. Forkel-Wirth

Radiation risks at High Energy Accelerators – a short reminder

- LHC after the 19th of September 2008
- LHC after resuming operation
- RP’s point of view on repair and maintenance scenarios
LHC since 19th September

However:

- Negligible dose to personnel during maintenance
- Information on beam losses from beam operation (M. Lamont) in combination with RP Monte Carlo calculations eases the radiological classification of material by RP.
- A considerable amount of LHC accelerator equipment can be declared as non-radioactive (*after control by RP*). Consequently, simplified repair procedures and repair techniques inside the tunnel can be authorized by RP.
- Equipment (*declared as non-radioactive by RP*) can be repaired in ordinary work shops
- Equipment (*declared as non-radioactive by RP*) can be sent to any company for repair or modifications
Arc: Beam Gas Interaction (nominal)

Assumption: $2.4 \times 10^4$ protons/m/s (both beams), 7TeV, lost for 180 days continuously (corresponds to an H$_2$-equivalent beam gas density of $4.5 \times 10^{14}$/m$^3$)

1 day
- Ambient dose equivalent rate in uSv/h
- Aisle: ~200 nSv/h

1 week
- Ambient dose equivalent rate in uSv/h
- Aisle: ~100 nSv/h

1 month
- Ambient dose equivalent rate in uSv/h
- Aisle: ~20 uSv/h

4 months
- Ambient dose equivalent rate in uSv/h
- Aisle: ~10 uSv/h
Remarks

- Presently no problem from radioprotection, LHC tunnel is a supervised area; the main impact is on the waste management
- In the arcs, dose at the cryostat level after a “representative” physics run should be very low
- Special procedures including use of special tooling to be respected after restart of the machine
- Centralized workshop for work on activated material is favored wrt separate workshops for each equipment where mix between conventional and activated material could occur. This has to be assessed at the accelerator sector level
- One specific read-out tool for various radiation monitoring systems would be useful
Session summary

• The damage in sector 34 can be repaired within the planned schedule (few weeks uncertainty)
  • no showstoppers, although damage was severe
• There are many other activities in 34 !!! see next session
• Quality of reinstallation should not suffer
  • resist pressure to take shortcuts!
• State of the sector
  • magnets seem all ok but careful recommissioning required
  • vacuum system – everything fine for (high intensity?) beam
• Commissioning of magnets and (later) with beam - be careful
• Repair / consolidation before beam operation has some advantages - however, no showstopper for delayed consolidation of arc (e.g. relief valves)

Thanks to all speakers
end