LHC Consolidation after Beam Operation – Radiation Protection Constraints

D. Forkel-Wirth and S. Roesler
on behalf of DG-SC-SL

Chamonix, 3rd February 2009
Table of Content

- 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
Activation of Material

Beam losses result in the activation of material (beam line components, tunnel structure, etc.)

Risk of external (all work) and internal exposure (destructive work)
Ambient Dose Equivalent Rate as Function of LHC Operation

Contribution of short-lived radioactive nuclides

Contribution of long-lived radioactive nuclides

M. Huhtinen, RPC/2003/XXXVIII/138
Activation of air, gas, water, cooling liquids, risk of external and internal exposure

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Halflife</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be-7</td>
<td>53 D</td>
</tr>
<tr>
<td>Na-22</td>
<td>3 Y</td>
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<tr>
<td>Sc-46</td>
<td>84 D</td>
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<td>Cr-51</td>
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<td>Fe-59</td>
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<td>Co-60</td>
<td>5 Y</td>
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<td>Zn-65</td>
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<td>SB-124</td>
<td>60 D</td>
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ventilation filter (SPS)

demineralised water (SPS)

γ-emitter only
LHC since 19th September 2008

Ambient dose equivalent rate is background with exception of
- TDI (Pt. 2 + 8)
- Collimators and absorbers (Pt. 3 + 7)

Supervised Radiation Area

Survey collimateurs Point 3 LHC le 21/11/08

<table>
<thead>
<tr>
<th>N° CERCA</th>
<th>Mesures en µSv/h</th>
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<tr>
<td>TCP 6R3 B2</td>
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</tbody>
</table>

Cooling liquids and gases not radioactive
LHC since 19\textsuperscript{th} September

LHC is Supervised Radiation Area:
- Only radiation workers are allowed to access this area (DIS dosimeter required)

- Any destructive work (machining, grinding, etc.) on beam line components has to be announced to SC-RP, work procedures to be discussed with and approved by SC-RP prior to the start of the work

- Risk of contamination for any non-destructive work can be excluded

- All material that had been in the LHC tunnel during beam operation and that will leave the LHC needs to be controlled by SC-RP
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
Resuming LHC Operation

Scenario until 20th December 2009 (M. Lamont):

1) 30 days commissioning
   pilot beam up to few $10^{10}$ protons / bunch, 450 GeV - 5TeV

2) 65 days pilot physics
   up to $156 \times 156$ bunches with $9 \times 10^{10}$ protons / bunch
   ($=1.4 \times 10^{13}$ protons/beam, i.e., factor ~20 below nominal )
   luminosity: $5 \times 10^{31} \text{/cm}^2\text{/s}$

RP studies:

1) Arc magnets
   single bunch losses:
   $2.82 \times 10^9$ protons / bunch, 450 GeV and 7 TeV
   beam gas interactions:
   $2.4 \times 10^4$ protons/m/s (both beams, nominal machine), 7TeV, 180 days op.

2) Inner triplets
   particle cascade from pp-collisions: 1 month operation at $10^{32} \text{/cm}^2\text{/s}$
Arc: Loss of Single Bunch (2.82 x 10^9 protons)

Ambient dose equivalent rate

450 GeV

<150 nSv/h (contact)

7 TeV

~1 μSv/h (contact)

Residual dose rates scale with beam energy approximately like $E^{0.8}$

$(7000 \text{ GeV} / 450 \text{ GeV})^{0.8} = 9.0$

$(5000 \text{ GeV} / 450 \text{ GeV})^{0.8} = 6.8$
Arc: Loss of Single Bunch (2.82 x 10⁹ Protons)

2.82 E9, 450 GeV, t_{cool} = 1 hour

2.82 E9, 450 GeV, t_{cool} = 1 day

2.82 E9, 7 TeV, t_{cool} = 1 hour

2.82 E9, 7 TeV, t_{cool} = 1 day
Arc: Specific Activity after Single Bunch Loss

450 GeV

1 month cooling

7 TeV

2.82E9 protons, 450 GeV, $t_{cool} = 1$ month

2.82E9 protons, 7 TeV, $t_{cool} = 1$ month

Point loss: 2.82E9 protons, 450 GeV

Point loss: 2.82E9 protons, 7 TeV

Ratio Activity / LE(Material)

Ratio Activity / LE(Material)

x in cm

z in cm

x in cm

z in cm

factor 9

radioactive
Arc: Beam Gas Interactions (2008)

Ambient dose equivalent rate

< $10^{-5}$ uSv/h (contact)

Radioactivity

< $10^{-5}$ below limit
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 ~20 uSv/h, Aisle: ~200 nSv/h
- **1 week**: Ambient dose equivalent rate in uSv/h ~10 uSv/h, Aisle: ~100 nSv/h
- **1 month**: Ambient dose equivalent rate in uSv/h
- **4 months**: Ambient dose equivalent rate in uSv/h
Arc: Beam Gas Interaction (nominal)

1 week

4 months

Level of radioactivity 2:1 for 1 week to 4 month cooling

even for 1/100 of nominal beam intensity beam gas interactions cause at least the inner parts of the magnet to be radioactive
Inner Triplet and pp-Collisions

Assumption: 1 month operation at $10^{32}$ /cm$^2$/s

Dose rates in uSv/h on the cryostat surface
- ~10 uSv/h after 1 week
- few uSv/h after 1 month
- ~1 uSv/h after 6 months

Courtesy of F.Cerutti, EN-STI
Inner Triplet and pp-Collisions

Specific activity:
in the magnet yokes values up to 100 above limits - even after 6 months of cooling
material is radioactive

Courtesy of F.Cerutti, EN-STI
Roadmap for Repair and Maintenance

Inner Triplet
Collimator regions
TAS, TAN regions

Recommendation: maintenance and new installation before start-up

Arcs: maintenance after restart

Arc magnets slightly radioactive

Ambient dose equivalent rates in the order of few uSv/h inside and some few 100 nSv/h outside the cryostat

-> Radiological risk involved in repair and maintenance is tolerable – but procedures and tooling (e.g. no grinder!) need to be qualified for work on radioactive items. Radioactive workshop is required.
Conclusion

• Repair and maintenance work before start-up has advantages:
  ▫ RP can declare most of the equipment as non-radioactive
  ▫ Non-radioactive items can be repaired in ordinary workshops and sent to any company
  ▫ Waste zonage is waved

• RP constraints for repair, maintenance and installation will become severe after restart of the machine
  ▫ Special procedures including use of special tooling to be respected
  ▫ Radioactive workshops required
  ▫ Radioactive equipment can be only sent to few, specialised companies
  ▫ Waste zonage applicable
Conclusion

The development of one specific read-out tool for various radiation monitoring systems (Beam Loss Monitors, RADMON and RAMSES) would increase the efficiency of operational radiation protection:

The information obtained by radiation monitoring on beam losses, in combination with Monte Carlo calculations and screening measurements would allow a simplified RP approach to the radiological classification of material.
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