LHC Performance Workshop 2016
Session 3 + 4
LHC Hardware Performance

D.Nisbet, M.Pojer, Matteo Solfaroli, Markus Zerlauth

Outline session #3

6 talks:

- Accelerator Fault Tracker & Availability Working Group
  Where do we go from here?  B.Todd
- LHC Availability – Status and Prospects  A.Apollonio
- Cryogenics  G.Ferlin
- Quench Detection System  R.Denz
- Electrical Performance of Magnet Circuits  F.Rodriguez Mateos
- Power Converters  V.Montabonnet
Integrated Luminosity Production

Hardware Performance (Cryogenics, QPS, Power Converters, ...)

R2E effects, heat loads

Beam Parameters (Intensity, Energy, $\beta^*$, ...)

Operational Efficiency (Turnaround, ...)

Limit Dumps due to Beam Losses

UFOs, instabilities

Longer turnaround

Premature dumps, longer turnaround

Longer turnaround

Session 1+2

Session 5, 6, 7

Session 3+4
Maximizing physics output of the LHC

- Dependability of LHC systems is one of key drivers of physics output (integrated L)
- While machine safety cannot be compromised, one of priorities for future years (and conception of HL-LHC, FCC) will be to maximize system availability to meet physics goals
- Availability is the only means to increase integrated luminosity once a machine is levelled
- Past experience is key to understanding of equipment failures (root cause) and assessing impact and cost of mitigations
Availability Working Group

- LHC Availability Working Group (AWG) launched in 2012
- 2010-2012: objective view of availability not possible = weaknesses in data captured -> coherent & objective information capture is primary concern – biggest challenge of AWG
- 2012-2013: AWG proposed the Accelerator Fault Tracker to solve data issues
- 2014: Accelerator Fault Tracker (AFT) launched by BE/CO, BE/OP and TE/MPE
- 2015: AFT was extensively used for availability data analysis → See later

aft.cern.ch
Coherent & objective = viewpoint from both operations & equipment

“Cardiogram”

Operations Viewpoint

- Impact on Physics
- Duration of No Beam
- Fault Duration
- Fault Root Cause
- System
- Sub-System
- Equipment Code
- Failure Mode

Equipment Viewpoint

“Availability Matrix”

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Power Converters Downtime [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/week</td>
<td>&lt; 1h 1-4 4-8 8-12 &gt; 12</td>
</tr>
<tr>
<td>1/month</td>
<td>RPCL (60 A) RPHE (900 A)</td>
</tr>
<tr>
<td>1/year</td>
<td>RPPL RPPT RPTM</td>
</tr>
<tr>
<td>&lt; 1/year</td>
<td>RPTN RPTU RPS2</td>
</tr>
</tbody>
</table>

V. Montabonnet

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Next steps for AWG

**AFT 1.0 → AFT 2.0:** Add equipment group information  TE/MPE and TE/EPC already started work

New Analysis Requests
- E.g. “what is the influence of energy / intensity on availability?”
- E.g. “why was the ion run having such high availability?”

**AFT & AWG in the Injectors:** It is possible to propagate the AFT tool, primary focus of AWG is the LHC

**Day to Day**
- Data validation and continuous improvement of the AFT remains a core aspect of the AWG effort to maintain fault data increased x3 – used to be a part-time job...
  - Dedicated (long-term) resources required!

**Strategic View**
- Information created for the LHC can be exploited for HL-LHC, FCC, ...
- New and existing machines are being designed facing availability as a primary deliverable.
- AFT information should be able to be used to create generic models
  - Centralised modelling & strategy into a different dedicated (sub-) working group
2015 Availability – TS2 to TS3

System Downtime [h]

Stable Beams, 29 %
LHC Operation, 40 %
LHC Downtime, 31 %

Beam Injection
Orbit
Beam-induced Quench
SIS
IT Services
Ventilation Door
Transverse Damper
Other
Beam Losses
Operation
Injection Systems
Vacuum
Access Request
Experiments
Magnet circuits
6 hours
Accelerator Controls
Machine Interlock Systems
Collimation
Radio Frequency
Technical Services
LBDS
Power Converters
Beam Instrumentation
QPS
36 hours
Injector Complex
Cryogenics
227 hours

Beam Commissioning
Ph. S S Scr. 50 M D Scr. 25 M D T S

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Cryogenics in 2015

Downtime in line with Run1, despite higher beam induced heat loads

Most frequent CM losses:
- **DFBMI**: 39 losses; addressed during YETS
- **DFBAF**: 29 losses; Trigger origin tbd with stakeholders (thresholds, timer...)

Most time-consuming CM losses:
- **1.8 K units**: 8 losses, Average equivalent to Run1; should decrease if new configuration P18/P2 works well.
- **PLCs**: 4 losses, should be solved with new firmware during YETS
- **OP/Human factor**: 9 losses; should be partially solved by process optimization under high BS load
- **Elec/Instrumentation/Tunnel**: 22 losses; Average equivalent to Run1
Cryogenic outlook for 2016 operation

- Further testing during cool-down
  - to minimize number of rotating machinery to improve the global availability
- Boost cooling capacity of cryo-plant in P2 and BS cooling power for S23 (non symmetric configuration)
- Continuous improvement of software to fulfil cryogenic power increase (anticipation of thermal load on BS,...)
- Data mining to detect drifts and anticipate issues
- Expecting 93-95% of availability during 2016
QDS system dependability in 2015

Challenging year after major system upgrades during LS1
- Overhaul of MB protection system (yellow racks)
- Revision of safety critical firmware
- Automatic system configuration and verification
- Relocation of equipment (Inner Triplet protection)
- Deployment of radiation tolerant electronics (IPQ, IPD)

Enhancement of supervision & diagnostic capabilities
- Enhanced quench heater circuit supervision
- Earth voltage feelers
- QPS fieldbus upgrade
- CSCM for all sectors (objective added in 2014)

Very (=100%) reliable operation and effective protection of superconducting circuits

Detection of 40 main dipole quenches during proton run 2015

Note: \( A_{QPS} = \frac{T_{OPERATION} - T_{FAULT(AFT)}}{T_{OPERATION}} \)
QDS Outlook for 2016 operation

- Firmware upgrade for nQPS DAQ systems
  - Sampling rate for earth voltage feelers increased to 10 Hz
  - Better detection and recovery of local communication faults; transparent error handling

- Deployment of radiation tolerant QDS for 600 A circuits
  - Mandatory for radiation exposed areas in point 1, 5 and 7

- Considering a successfully implementation of the ongoing upgrades:
  - The same level of availability as in 2015 after TS#2 (~98%) should be feasible despite the increasing radiation load
  - The system maintainability is expected to improve, mainly to the better handling of certain error types

- The complexity of the system remains a challenge
Magnet Circuits chronology (highlights)

- HV test at cold: modified procedure (2-step*) on RB
- B24L5 heater failure -> reconfiguration and retest
- RQ4.R2 heater failure -> reconfiguration and retest
- Earth fault in sector 5-6
- Earth fault in sector 3-4
- ELQA after the QPS firmware upgrade in sector 2-3
- RCS.A78B2 earth fault
- ELQA after the exchange of DQQBS boards
- A26R8 heater failure -> reconfiguration and retest

* 2.1kV and 1.5kV
Outlook & Actions Magnet Circuits 1/2

- Completing feasibility studies for new methods on earth faults localization with use of additional signals:
  - $U_{\text{diode}}$ to be triggered by earth faults
  - Current measurement transformers at the level of the current leads
  - Current measurement in grounding loops
- New hardware for “curing” known fault cases:
  - “weak-spot blower” – new, more controllable version required, possibility to cover larger $V$-range as shorts may occur above the HDS level (900 V)
- Studying the margin with respect to lifetime for some large scale systems (e.g. capacitors in HDS)
  - Special aging tests should allow to get an estimation of the remaining (statistical) lifetime
Outlook & Actions Magnet Circuits 2/2

• Monitoring of the long term evolution of high-current joints’ resistance in main circuits + possible design of appropriate tooling for applying torques in a controlled manner

• Spares for 600A switches should be envisaged

• Galvanic separation in an automated manner of warm and cold parts of the main circuits by means of a ‘disconnector’ would help reducing intervention times, minimizing manipulation risks and improving safety. Technical and financial feasibility of this in the LHC main circuits should be analyzed

• Some of above tasks are not yet programmed, manpower efforts should be properly estimated
## Power converter 2015 performance

- **Important consolidation activities during LS1** (R2E relocation, diode replacement in IPD/IPQ/RQF/RQD output, auxiliary power supplies...)
- **Top 3 of the main downtime contributors (80% of the intervention duration):**
  - LHC600A-10V converters
  - LHC4-6-8kA / IPD, IPQ, Inner Triplets converters
  - LHC120A-10V converters

### Cumulative Intervention Duration [Hour:Minutes]

<table>
<thead>
<tr>
<th>CONVERTER TYPE</th>
<th>CUMULATIVE INTERVENTION DURATION</th>
<th>NUMBER OF INTERVENTIONS</th>
<th>CONVERTER QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPMBA/B - LHC600A</td>
<td>47:00</td>
<td>38</td>
<td>394</td>
</tr>
<tr>
<td>RPHF/G/H - IPD, IPQ, IT</td>
<td>15:15</td>
<td>12</td>
<td>188</td>
</tr>
<tr>
<td>RPLB - LHC120A</td>
<td>13:45</td>
<td>15</td>
<td>291</td>
</tr>
<tr>
<td>RPHE - Main Quadrupoles</td>
<td>8:15</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>RPTN - LHCb Compensator</td>
<td>6:45</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>RPTI - ALICE LHCb Dipole</td>
<td>6:30</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>RPTM - Beam Dump Septum</td>
<td>3:45</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>RPLA - LHC60A</td>
<td>2:30</td>
<td>5</td>
<td>750</td>
</tr>
<tr>
<td>RPMC - LHC60A-40V</td>
<td>2:30</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>RPTG - Warm Dipole</td>
<td>2:15</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>RPTF - Warm Quadrupole</td>
<td>2:00</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>RPTE - Main Dipole</td>
<td>0:45</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

**Important for orbit stability/FB!**

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Power converter outlook for 2016 operation

- Several mitigations (software, interlock masks and procedure improvements) put in place during YETS to further increase availability
- R2E remains concern, FGClite will progressively replace the FGC2 until 2017

<table>
<thead>
<tr>
<th>Year</th>
<th>Control Part</th>
<th>Power Part</th>
<th>Beam Dump</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>5</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2016</td>
<td>31</td>
<td>4*</td>
<td>21</td>
</tr>
<tr>
<td>2017</td>
<td>1</td>
<td>6*</td>
<td>4</td>
</tr>
</tbody>
</table>

* Pessimistic Case: 0 fault in 2015

Ratio linked to Operational redundancy

FGClite Installation
Outline session #4

6 talks:

- LBDS and injection protection
- RF/ADT
- Beam Instrumentation
- Technical infrastructure
- Radiation to electronics – R2E
- Availability in view of increasing beam energy to 7 TeV

C. Bracco
A. Butterworth
W. Vigano
R. Ledru
S. Danzeca
R. Schmidt
**Injection - MKI**

**Main goals of LS1 activities:**
- Improve high voltage performance
- Reduce:
  - Ferrite MKI yoke heating
  - Pressure rise and e-cloud
  - Number of UFOs

**UFOs @MKI have disappeared**

**Q5 interconnect occasionally limited operation. Improvements under study**

**No stop/delay in 2015 operation**

25 ns downtime = 25 hours (for all beam transfer systems)
Injection - TDI

- **Limitation** in number of bunches per inj. due to hBN non-conformities
- **Significant pressure rise** during injection and spurious spikes during fill with jaws retracted
- Much worse behavior for TDI in IP8
Injection - TDI

- **Limitation** in number of bunches per ini. due to hBN non-conformities
- Significant pressure rise during injection and spurious spikes during fill with jaws retracted
- Much worse behavior for TDI in IP8

![Diagram of injection system with labels](image)

- Replacement of the hBN blocks with Graphite R4550 blocks to improve the robustness to beam impact
- 2 μm Copper coating on R4550 blocks to reduce the resistive heat load (2015: 5 μm Ti on hBN)
- Modified clamping of cooling pipes to improve their contact with the frame
- Refurbishment of the jaw displacement mechanism
- Interferometric system to allow for a direct gap measurement
- Replacement of the CuBe blocks with CuCrZr blocks (CuBe blocks were found deformed after bake-out)

![Blisters in Cu coating](image)
Main aim:
Reduce spontaneous triggers (reliability) and radiation resistance

Correlation between dust presence inside generators and sparking activity was found…as result of the cleaning only one asynchronous dump with beam in 2015

Estimated async. dumps @ 6.5 TeV:
3 per beam per year

Modifications planned in LS2 to allow operation at 7 TeV

R2E: No SEB in 2015 (no limitation for 7 TeV)
Future activities for LBDS and injection

Run 2

- **TCDI**: < 144 BCMS bunches before LS2 (transmission problems)
- **TDE**: HW interlock on N$_2$ pressure to be added as soon as possible

Run 3

- **TDI**: new hardware will be installed during LS2
- **TCDI**: new HW with 2.1 m jaws in LS2
- **MKB/MKD**: switch modification needed to go to 7 TeV

HL-LHC

- **MKI**: Several interventions are foreseen for LS2 and LS3
- **TCDD**: additional mask at D1 is needed
- **TCDQ/TCSP/TCDS/TDE**: ongoing studies to define optics constraints and if any HW issues are present
- **TDE**: solution to avoid overheating is being studied
RF

RF - LS1 ACTIVITIES

- All HV connectors repaired ➔ no more klystron filament glitches
- 8/16 klystrons replaced to avoiding aging
- Crowbars: Thyratrons replaced by Solid State devices (better performance & reliability) ➔ no more spurious crowbar trip
- Replacement of faulty cavity
  - Cavity 3 B2 was quenching at 2 MV (clamped at 1.2 MV during Run1)
  - Decided to replace America cryomodule by the spare module Europa
  - Conditioning in pulsed mode to burn emitters was successful ➔ Nominal performance re-gained…America is now a valid spare!

Potential limitation in spare production in case America is used
RF FAULTS IN 2015

- 57 RF and HV trips recorded, 76 hours downtime
- 13 beam dumps (all during 25 ns run)

23% LLRF and control
Several components replaced

15% beam related faults
Conditioning to 300 MW in 2016

17% HV faults
Real crowbar issue, soon after restarting RF

26% Mitigated faults
Interlock levels, T glitches,…

26% Child faults
Cryo loss, electrical glitches,…

25 ns downtime = 13 hours
ADT - LS1 ACTIVITIES

- More performant signal processing HW
- Proper integration of all new functionality added during Run 1:
  - Fully independent feedbacks for main loop and witness bunches
  - Abort gap and injection gap cleaning
  - Blow-up
  - Excitation functionality through the whole cycle

18 ADT faults in 2015

- UW45 cooling recovery ADT
- ADT Power
- ADT controls / interlocks
- ADTLL/configuration

Good hardware availability
- Few minor isolated issues

Few operational issues identified
- Monitoring of performance
- Settings management

25 ns downtime = 23 hours
Beam Instrumentation

**ACTIVITIES TO INCREASE AVAILABILITY**

- **Online monitoring**
  - Improving analysis tools to quickly understand system status

- **Offline monitoring**
  - Daily checks to control parameter degradation

- **New event warning**
  - Automatic alert to experts in case of parameter change

- **Test benches**
  - e.g. Orbit feedback software test bench

- **Intervention time reduction**
  - Creation of dedicated piquet service with piquet manual

Among others, BE-BI Group would profit from a longer term Reliability Analysis team
Beam Instrumentation

All 75 faults analyzed and divided in 4 categories:
- External faults
- System faults
- Design and installation
- Human factor

No R2E failures thanks to heavy testing at design stage

<table>
<thead>
<tr>
<th>Failure Type</th>
<th>Number of failures [#]</th>
<th>Total stop time [h]</th>
<th>Contribution Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Fault</td>
<td>4</td>
<td>28.8</td>
<td>26%</td>
</tr>
<tr>
<td>System Fault</td>
<td>35</td>
<td>37.5</td>
<td>34%</td>
</tr>
<tr>
<td>Design Issue</td>
<td>21</td>
<td>27.4</td>
<td>25%</td>
</tr>
<tr>
<td>Human factor</td>
<td>16</td>
<td>15.7</td>
<td>14%</td>
</tr>
</tbody>
</table>
A Major Event is created when a technical problem stops an accelerator

DATA QUALITY IS CRUCIAL

TI has well established process to analyze and handle Major Events

- Link to data from the machine logbooks
- Associate the fault to a precise device (Computerized Maintenance Management System)
- Determine fault category
- Major events review by Technical Infrastructure Operations Committee (TIOC) weekly
Technical infrastructure

101 major events on LHC in 2015
(57 needing access)

Big efforts in LS1 to make equipment less sensitive to perturbations

25 ns downtime = 12 hours
R2E

- Failure rates proportional to radiation level
- Several equipment installed in the tunnel: QPS, EPC, Cryo,…

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Dumps 2012</th>
<th>Dumps 2015 (After TG)</th>
<th>Dumps 2016 35fb-1</th>
<th>Dumps 2017 45fb-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPS</td>
<td>32</td>
<td>2+1</td>
<td>0-5</td>
<td>0-5</td>
</tr>
<tr>
<td>Power Converter</td>
<td>15</td>
<td>5+2</td>
<td>~25</td>
<td>0-10</td>
</tr>
<tr>
<td>Cryo</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>EN/EL</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vacuum</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Collimation</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RF</td>
<td>1</td>
<td>4*</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Others (hidden)</td>
<td></td>
<td></td>
<td>~1-1.5 /fb⁻¹</td>
<td>~0.5 /fb⁻¹</td>
</tr>
<tr>
<td>Total</td>
<td>3 /fb⁻¹</td>
<td>~3.4 /fb⁻¹*</td>
<td>~1.5 /fb⁻¹</td>
<td>~0.5 /fb⁻¹</td>
</tr>
</tbody>
</table>

* To be confirmed

R2E limitation strategy

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td>3.5/4.0</td>
<td>~30</td>
<td>&lt;&lt;1</td>
<td>~10</td>
</tr>
<tr>
<td>Run 2</td>
<td>6.5/7.0</td>
<td>~100</td>
<td>~1</td>
<td>~20</td>
</tr>
<tr>
<td>Run 3</td>
<td>7</td>
<td>~300</td>
<td>~2-4</td>
<td>~40</td>
</tr>
<tr>
<td>HL-LHC</td>
<td>7</td>
<td>~3000</td>
<td>~4-8</td>
<td>~80-160</td>
</tr>
</tbody>
</table>

from R2E Availability workshop 2014

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R2E – recipe for the future

- **Equipment inventory**
  - Knowledge of installation in critical areas and failure tracking
  - Radiation testing coordination

- **Radiation Monitoring**
  - Global and local level (failure points, DS and ARC) in order to foresee an equipment rotation

- **Follow new component developments**
  - Radiation Hardness Assurance (RHA) dedicated guidelines should be used for development of new HW

**Strong collaboration is mandatory!!!**
- Equipment groups
- Radiation Working Group (RADWG)
- Monitoring & Calculation Working Group (MCWG)

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Availability for 7 TeV

- It is premature to run today the LHC at 7 TeV
- The long time needed for training (400 to 700 quenches expected) will eventually affect integrated luminosity
- Several aspects to be studied and better knowledge to be acquired on:
  - Magnet system
  - UFOs
  - MKD
  - Cryogenic system
- Increasing availability is possible by small steps, but they contribute to higher availability when integrated over many years
## Availability for 7 TeV

<table>
<thead>
<tr>
<th>Systems</th>
<th>Impact of 7 TeV operation on availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Injector complex</td>
<td>No change</td>
</tr>
<tr>
<td>2 Injection systems</td>
<td></td>
</tr>
<tr>
<td>3 Beam injection</td>
<td></td>
</tr>
<tr>
<td>4 Access system</td>
<td></td>
</tr>
<tr>
<td>5 Machine Interlock Systems</td>
<td></td>
</tr>
<tr>
<td>6 Accelerator Controls</td>
<td></td>
</tr>
<tr>
<td>7 Technical services (electricity supplies, ..)</td>
<td></td>
</tr>
<tr>
<td>8 Beam Instrumentation</td>
<td></td>
</tr>
<tr>
<td>9 Transverse damper</td>
<td></td>
</tr>
<tr>
<td>10 Magnet protection system (QPS)</td>
<td></td>
</tr>
<tr>
<td>11 Experiments</td>
<td></td>
</tr>
<tr>
<td>12 Vacuum</td>
<td></td>
</tr>
<tr>
<td>13 RF</td>
<td></td>
</tr>
<tr>
<td>14 Cooling and ventilation</td>
<td></td>
</tr>
<tr>
<td>15 Collimation</td>
<td></td>
</tr>
<tr>
<td>16 Beam Dumping System</td>
<td>Potentially worse</td>
</tr>
<tr>
<td>17 Power converters</td>
<td>Expected to become worse</td>
</tr>
<tr>
<td>18 Cryogenics</td>
<td></td>
</tr>
<tr>
<td>19 Beam Losses (incl. UFOs)</td>
<td></td>
</tr>
<tr>
<td>20 Beam induced quenches (UFOs)</td>
<td></td>
</tr>
<tr>
<td>21 Magnet circuits</td>
<td></td>
</tr>
</tbody>
</table>

**Priority for studies on availability increase!!**
Availability in general

- An **availability working group** has been set up to pursue the studies on availability improvement.
- The **Accelerator Fault Tracking (AFT)** is a fundamental tool to study availability and will soon be extended to other accelerators.
- Information exchange between the different groups is a crucial ingredient (e.g. Single Event Upsets).
- Collaboration with many institutes has been started and proved to be very fruitful.
Conclusions

- Many efforts have been done to establish an “Availability culture” at CERN, but further long-term efforts + resources are mandatory to meet ambitious goals.

- Availability plays a crucial role in complex accelerators, defining performance and ultimately the integrated luminosity.

- Some points requiring thorough follow-up have been identified:
  - Potential limitations for 7 TeV (MKD, UFOs) – 2016 statistics
  - RF facility for spare generation
  - ‘creative’ ideas for availability increase

- LS1 activities have largely demonstrated beneficial for system availability.

- AFT has proven to be the essential tool for availability studies and will be a powerful tool to identify priorities for future efforts.
Backup Slides
Availability for Physics – 25 ns Run

- 22 End-Of-Fill, 48 dumped due to faults
- Fraction of premature dumps: $48/70 = 68.6\%$
- Average operational turnaround (per SB) = $511/70 = 7.3$ h
- Average Fault time (per SB) = $426/70 = 6$ h
Impact on LHC Operation (25 ns Run)

‘Lost Physics’ Time: 3 h additional time assigned to each fault dumping while in stable beams (= average duration of SB to EOF – average duration of SB, slide 11)

66 % of the total time lost for luminosity production
2015 Fault + Downtime Overview

- Earth fault RCS.A78B2 + QPS mBS SEUs
- Earth fault + cryo valve replacement + LBDS self trigger + ADT

- Linac2 HV Cable
- Cryo CV + SPS magnet replacement

- Beam Commissioning

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Standardized Availability Summary

“Cardiogram” of LHC operation
Child faults still assigned to parents (e.g. cryogenics → quench recovery)
Child faults still assigned to parents (e.g. cryogenics → quench recovery)
Statistics for Heater Discharges on LHC main dipoles, 2014-2015

- Data provided by Zinur Charifoulline:
  
  Since October 2014 (QPS-IST included):
  - 2533 full charge firings in total
  - About 1660 firings at zero current

  Since April 2015 (1st beam in the machine):
  - 247 full charge firings in total
  - About 175 firings at zero current

- Expected to be less in 2016

No firing campaign scheduled for 2016
Power converters – Main LS1 activities

• Relocation of power converters [in UL14/16, UL557, TZ76]
  • Mitigation measure for Single Event Effect induced by radiation [R2E project]
• LHC600A-10V Converters
  • Consolidation of the Auxiliary Power Supply as mitigation measure for Single Event Effect [R2E project]
• IPD/IPQ and RQD/RQF converters
  • Output module consolidation due to diode case reliability issue and improvement of the thermal environment for a better reliability at 7TeV (full current)
• LHC60A converters
  • Consolidation of the Auxiliary Power Supply due to capacitor ageing
Availability increase, some ‘creative’ ideas

- Shorter shut-downs or less shut-downs?
- Very short technical stop over Christmas? Compatible with injectors?
- Reduced time for “Hardware and Beam Commissioning”?
- Reduced time for “Intensity ramp-up”?
- Do we need to switch off a sector when a fast power abort is generated?
- Can we delay the abort of a circuit in case of training quenches to generate multiple quenches (idea from 2007)?