LHC and Injectors failure statistics for Run 2

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Introduction

• Data sources
• Introduction to LHC Operations
  • Fault statistics in BModes
• Injection Investigation
  • Physics and Probe
• AvailSim inputs
LHC Cardiogram
Availsim

- Monte-Carlo simulation tool
  - Simulate the operation of accelerators eg. LHC
- Inputs based on observed performance
  - Works using different reliability measures (Mean Time To Repair, Mean Time To Fail) from faults
  - These change depending on the beam mode they occur in.
- Also requires Beam Mode durations as an input
LHC Operation Breakdown

OPERATIONAL MODES
- No Beam
- Pre-Cycle
- Setup
- Beam In
- Stable Beams

BEAM MODES
- No Beam Cycle
- Setup
- Injection Probe
- Injection Physics
- Ramp
- Pre-Ramp
- Squeeze
- Adjust
- Stable Beams

Aim is to calculate Beam Mode durations and calculate failure rates and repair times based on beam mode.

E-Logbook
Data Sources

- Timber
  - Fill number timings
  - Beam modes
- AFT
  - Fault data
- Post Mortem
  - Injection scheme
Time to Fail for Mode Injection Physics

System names

MTTF (hrs)

1 Fault
2 Faults
3 Faults
Time To Repair for Beam Mode Injection Physics

MTTR (hrs)

System names:
- BeamInjection
- BeamInstrumentation
- BeamLosses
- Beam-inducedQuench
- Cryogenics
- ElectricalNetwork
- Experiments
- InjectorComplex
- LDDS
- Operation
- Orbit
- PowerConverters
- RadioFrequency
- TransverseDamper
Time to Fail for Mode Stable Beams

MTTF (hrs)

System Names

Accelerator Controls
Access Management
Access System
Beam Instrumentation
Beam Losses
Beam-induced Quench
Collimation
Cryogenics
Electrical Network
Experiments
Machine Interlock Systems
Magnet Circuits
Operation
Other
Power Converters
QPS
Radio Frequency
Transverse Damper
Time To Repair for Beam Mode Stable Beams

MTTR (hrs)

System Names

Accelerator/Controls
Access Management
Beam Instrumentation
Beam Losses
Beam-induced Quench
Collimation
Cryogenics
Electrical Network
Experiments
LBDS
Machine Interlock Systems
Magnets/Circuits
Operation
Power Converters
OPS
Radio Frequency
Transverse Damper
System Performance over Modes

Failure Rate of PowerConverters with respect to different beam modes

MTTR of PowerConverters with respect to different beam modes

CERN

8/29/2019
Skipped beam mode “incorrect data” UFO

16L2
Looking a bit deeper...

<table>
<thead>
<tr>
<th>BeamLossesOther</th>
<th>10/08/2017 21:48:44</th>
<th>10/08/2017...</th>
<th>7</th>
<th>[402x1 dou...</th>
<th>6063</th>
<th>Blocking O...</th>
<th>16L2 (B1: 2556b)</th>
<th>dt</th>
</tr>
</thead>
<tbody>
<tr>
<td>BeamLossesOther</td>
<td>11/08/2017 00:59:25</td>
<td>11/08/2017...</td>
<td>7</td>
<td>[402x1 dou...</td>
<td>6064</td>
<td>Blocking O...</td>
<td>16L2 (B1: 2556b)</td>
<td>dt</td>
</tr>
<tr>
<td>BeamLossesOther</td>
<td>15/05/2018 06:43:57</td>
<td>15/05/2018...</td>
<td>7</td>
<td>[402x1 dou...</td>
<td>6604</td>
<td>Blocking O...</td>
<td>B2, 16L2 (2556bunches)</td>
<td>dt</td>
</tr>
<tr>
<td>BeamLossesOther</td>
<td>15/05/2018 10:46:37</td>
<td>15/05/2018...</td>
<td>7</td>
<td>[402x1 dou...</td>
<td>6585</td>
<td>Blocking O...</td>
<td><strong>B2</strong>, 16L2 (2556bunches)</td>
<td>dt</td>
</tr>
<tr>
<td>ElectricalNetworkDistribution</td>
<td>20/05/2018 04:14:42</td>
<td>20/05/2018...</td>
<td>7</td>
<td>[402x1 dou...</td>
<td>6703</td>
<td>Blocking O...</td>
<td>ElectricalNetwork</td>
<td>E</td>
</tr>
<tr>
<td>BeamLossesOther</td>
<td>20/05/2018 07:31:53</td>
<td>20/06/2018...</td>
<td>7</td>
<td>[402x1 dou...</td>
<td>6705</td>
<td>Blocking O...</td>
<td>16L2 (2556bunches)</td>
<td>dt</td>
</tr>
</tbody>
</table>

Shortest 9 durations in Ramp:

- 14-Jul-2017 14:41:58  6.3513
- 15-May-2018 08:42:00  4.6035
- 20-May-2018 02:04:54  9.7912
- 20-May-2018 05:29:26  2.4589
- 13-Jul-2018 00:21:34  1.2604
Plotting Observed Beam Mode durations against Fault Adjusted duration for ModeSqueeze over 209 points. Adjusted for 8 Faults.
Looking a bit deeper...

<table>
<thead>
<tr>
<th>Fill</th>
<th>Event</th>
<th>Description</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>10:59</td>
<td>LHC RUN CTRL: BEAM MODE changed to SQUEEZE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>10:57</td>
<td>AVT module V1B1 ok again</td>
<td></td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>11:01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Global Post Mortem Event

- Event Timestamp: 28/09/18 11:03:45.690
- Fill Number: 7232
- Accelerator beam mode: PROTON PHYSICS /
- Energy: 649200 [MeV]
- Intensity L1/L0 27702 / 27725 (e+10 charge)
- Event Category Classication: PROTECTION
- First BIC input Triggered: First USR_PERMI

- strong and fast UFO at 17R7 quenched dipol
- secondary quenches:
  - MB.A18R7
  - MB.C18R7
  - MB.A19R7
  - MB.C17R7
  - NO.17R7
Plotting Observed Beam Mode durations against Fault Adjusted duration for ModeAdjust over 1015 points. Adjusted for 73 Faults.

Special physics

No Filter
Looking a bit deeper...

I think this tells us something already..

Spent the **whole** time scraping
Also some tests for ALFA and TOTEM
Injectors Statistics

Mean Time To Fail for LINAC2 destination PSB

MTTF (hrs)

System name

2401.5 4002.5 2001.3 12007.52139 12007.52139 12007.52139 6003.8 522.07 255.48 750.47
Injectors Statistics

Mean Time To Repair for LINAC2 destination PS

MTTR (hrs)

System name

- Accelerator Controls
- Access Management
- Beam Instrumentation
- Beam Stoppers
- Cooling and Ventilation
- Electrical Network
- Operation
- Other
- Power Converters
- Radio Frequency
- Source
- Vacuum
Injectors Statistics

Mean Time To Fail for PSB destination PS

MTTF (hrs)

System name

Injectors Statistics

Mean Time To Repair for PSB destination PS
Injectors Statistics

Mean Time To Fail for PS destination SPS

MTTF (hrs)
Injectors Statistics

Mean Time To Repair for PS destination SPS
Injectors Statistics

Mean Time To Fail for SPS destination LHC
Injectors Statistics

Mean Time To Repair for SPS destination LHC

MTTR (hrs)

System names

Injectors

29/08/2019
AvailSim and AWG Report

Simulation 2017-18 2556b

- Stable
- Fault
- Operations

Observed 2018

- Fault / Downtime 24%
- Pre-Cycle 2%
- Stable Beams 49%
- Operations 25%
Conclusions

• Analysed failure data for LHC and injector complex from 2017 to 2018
• Failure rates and repair times available for further analysis
  • Performance predictions in AvailSim
  • Risk matrices
  • Data for consolidation requests
• Ideally this data could be provided from the AFT service in the future
• Data will be stored in EDMS Dependability folder.
• Scripts available for use in SWAN
Extra Slides
Plotted Observed Beam Mode durations against Fault Adjusted duration for ModeRamp over 223 points. Adjusted for 11 Faults.

Skipped beam mode “incorrect data”

16L2
Looking a bit deeper...

### LHC Event Log

<table>
<thead>
<tr>
<th>Event ID</th>
<th>LHC</th>
<th>Event Type</th>
<th>Timestamp 1</th>
<th>Timestamp 2</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>186976</td>
<td>LHC</td>
<td>BeamLossesOther</td>
<td>20/05/2018 07:31:53</td>
<td>20/05/2018...</td>
<td>7</td>
</tr>
<tr>
<td>191594</td>
<td>LHC</td>
<td>BeamLossesFastLosses (UFO)</td>
<td>07/06/2018 14:35:51</td>
<td>07/06/2018...</td>
<td>7</td>
</tr>
<tr>
<td>191548</td>
<td>LHC</td>
<td>Beam-inducedQuench</td>
<td>07/06/2018 14:35:51</td>
<td>07/06/2018...</td>
<td>7</td>
</tr>
<tr>
<td>191598</td>
<td>LHC</td>
<td>CryogenicsUsersQuench</td>
<td>07/06/2018 14:35:51</td>
<td>08/06/2018...</td>
<td>7</td>
</tr>
<tr>
<td>257501</td>
<td>LHC</td>
<td>RadioFrequencyHardware</td>
<td>13/07/2018 02:22:50</td>
<td>13/07/2018...</td>
<td>7</td>
</tr>
</tbody>
</table>

**Beam Mode Changes**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/14:16</td>
<td>BEAM MODE &gt; RAMP</td>
</tr>
<tr>
<td>06/14:16</td>
<td>LHC SEQ: ramp started</td>
</tr>
<tr>
<td>09/14:16</td>
<td>Another trip of a sector... this time: Sector 34</td>
</tr>
</tbody>
</table>

**Global Post Mortem Event**

- Event Timestamp: 07/06/18 14:35:51
- Fill Number: 6765
- Accelerator / beam mode: PROTON PHYSICS / RAMP
- Energy: 6356580 [MeV]
- Intensity [1/1]: 27295 / 26939 [x10 charges]
- Event Category / Classification: PROTECTION_DUMP / First BIC input Triggered: First USR_PERMIT change

**Global Post Mortem Event Confirmation**

- Dump Classification: UFO (Fast Beam Losses)
- Operator / Comment: molfaro / Large UFO in 22R3,
Looking a bit deeper…

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>257501</td>
<td>LHC</td>
<td>RadioFrequencyHardware</td>
<td>13/07/2018 02:22:50</td>
</tr>
<tr>
<td>292256</td>
<td>LHC</td>
<td>BeamLossesOther</td>
<td>19/10/2018 14:35:47</td>
</tr>
</tbody>
</table>
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Looking a bit deeper...