System’s Performances in BI

Volker Schramm on behalf of the BI group

Special thanks to:
David Belohrad, Enrico Bravin, Ewald Effinger, Rhodri Jones, Tom Levens, Patrick Odier, Georges Trad, William Viganò, Manfred Wendt, Christos Zamantzas
Agenda

- AFT statistics 2017 & previous years
- Upgrades 2017 - BCT, BPM, WS
- Faults analysis
- BI past and future efforts
- Conclusion
AFT statistics - 2017

Registered 22 BI faults in 2017 which account to 32h LHC downtime

BI systems contributing to unavailability:
- BLM 93% (18 faults)
- BPM 3% (1 fault)
- BCT 1% (1 fault)
- Other 3% (2 faults)

Total 32.6 hours

Courtesy B. Todd
AFT statistics – previous years

- BI availability increased for the 2\textsuperscript{nd} year in a row (all systems!)
- 2017: Highest availability ever achieved for BPMs and BCTs
  - Strong positive trend since 2015 (consistent AFT recording since 2015)
- The BLM normalized downtime is almost constant during 2016 and 2017

Focus on the performance of the BLM

*2017: 28/04 – 10/11
Upgrades 2017 – BCT, BPM, WS

- **DCCT:**
  - Software optimisation to eliminate issues with calibration & flickering of safe beam flag
  - System B front end electronic modification to reduce noise level by a factor of 3 (system A to be done YETS 17-18)

- **FBCT:**
  - New digital acquisition system with enhanced measurement precision which improves the instrument availability

- **BPM:**
  - Continuous analysis of “dancing BPMs” with interventions during TS to change front-end cards
  - New rack monitoring system put in place

- **Wire Scanner:**
  - Split of B1 & B2 electronics
  - Architecture change from LynxOS to Linux
## Faults Analysis - BLM

Detailed BLM faults in 2017:

<table>
<thead>
<tr>
<th>Issue</th>
<th>2017</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#</td>
<td>%</td>
<td>downtime</td>
</tr>
<tr>
<td>SEU (surface)</td>
<td>4</td>
<td>22%</td>
<td>04h 40m</td>
</tr>
<tr>
<td>VME Power Supply Fail</td>
<td>1</td>
<td>6%</td>
<td>07h 47m</td>
</tr>
<tr>
<td>Connection Lost: FESA/VME/CPU</td>
<td>1</td>
<td>6%</td>
<td>00h 04m</td>
</tr>
<tr>
<td>HV Power Supply Drop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HV Power Supply Noise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanity Error: Communication/VME</td>
<td>4</td>
<td>22%</td>
<td>01h 23m</td>
</tr>
<tr>
<td>Sanity Error: IC</td>
<td>1</td>
<td>6%</td>
<td>00h 29m</td>
</tr>
<tr>
<td>Sanity Error: LIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanity Error: SEM</td>
<td>3</td>
<td>17%</td>
<td>13h 54m</td>
</tr>
<tr>
<td>BLECF optical link issues</td>
<td>4</td>
<td>22%</td>
<td>02h 13m</td>
</tr>
<tr>
<td>BLETC optical link issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other optical link issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>18</td>
<td></td>
<td>1d 06h 32m</td>
</tr>
</tbody>
</table>

- **Failed transformer**
- **~50% Sanity Check related faults**
- **All 3 faults at the dump**
- **Failed Connectivity Test**

12/12/2017
Faults Analysis - BLM

Detailed BLM faults of previous years: separate AFT & BI-BL accounting

- Throughout all years high number of Optical Link and Sanity Check related faults
- Own accounting helps to identify weak parts and to react earlier (e.g. Optical Link)

<table>
<thead>
<tr>
<th>Issue</th>
<th>2012</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AFT</td>
<td>Jira</td>
<td>AFT</td>
<td>Jira</td>
</tr>
<tr>
<td>SEU (surface)</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>VME Power Supply Fail</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connection Lost: FESA/VME/CPU</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>HV Power Supply Drop</td>
<td></td>
<td></td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>HV Power Supply Noise</td>
<td></td>
<td></td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Sanity Error: Communication/VME</td>
<td>3</td>
<td>9</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Sanity Error: IC</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sanity Error: LIC</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanity Error: SEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLECF optical link issues</td>
<td>1</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLETC optical link issues</td>
<td>3</td>
<td>11</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other optical link issues</td>
<td>2</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 main fault cases:

- **Power supplies:**
  - Constant low failure rate
- **SEMs (at the dump):**
  - Constant high failure rate
- **Optical links:**
  - Decreased, then in Run2 constant low failure rate

*No consistent AFT recording (Run1)
Faults Analysis – 1 example

2 BLM failures within 30 hours this August:

- Failed Sanity Check
  Accounted downtime: **5 h**

- SIS interlock on HV status triggered
  Accounted downtime: **4 min**

- System fault detected before it can lead to a dump (function fulfilled)
- $\mathcal{L}_{\text{loss}} \rightarrow \text{‘Equivalent to 5 hours of scheduled operation’}$
- Fault lead to unscheduled beam dump (false dump)
- $\mathcal{L}_{\text{loss}} \rightarrow \text{‘Equivalent to >>4 min of scheduled operation’}$?

- How to quantify the luminosity loss?
- How to scale availability and luminosity?
Faults Analysis – 1 example

Example of two 12-hour fills as intended and the same scenario with a fault in the first fill:

1. Two 12-hour fills as intended:
   - \( t_{\text{t.a.}/2} \) to \( t_{\text{fill1}} \)
   - \( t_{\text{fill1}} \) to \( t_{\text{turnaround}} \)
   - \( t_{\text{turnaround}} \) to \( t_{\text{fill2}} \)
   - \( t_{\text{fill2}} \) to \( t_{\text{t.a.}/2} \)

2. Same scenario with a fault in the first fill:
   - \( t_{\text{t.a.}/2} \) to \( t_{\text{fill1}} \)
   - \( t_{\text{fill1}} \) to \( t_{\text{turnaround}} \)
   - \( t_{\text{turnaround}} \) to \( t_{\text{fill2}} \)
   - \( t_{\text{fill2}} \) to \( t_{\text{t.a.}/2} \)

Fault

By using intensities of a typical 12h13min fill at 6.5 TeV [03/09/2017, 4:17am] as well as \( t_{\text{turnaround}} = 6.2h \) the integrated area below the fills is \( \geq 14\% \) bigger for the 1\textsuperscript{st} scenario.
Past Efforts – LHC BLM

2005 ➢ Dependability analysis:
  o Prediction
  o FMECA
  o FTA
  o Sensitivity Analysis

2008 ➢ Redesign of the backend mezzanine

2012 ➢ Preventive system fault analysis
  o Daily automatic mails
  ➢ Jira failure logging

2013 ➢ 1st big maintenance intervention:
  (LS1)
  o Preventive exchanges: Cables, detectors, cards, fans
  o Acquisition electronics modification & recalibration
  o Clean-up: Optical adaptors, connectors
  o Shuffle of optical links & firmware modification

2017 ➢ Dependability analysis update (PhD)
Future Efforts – LHC BLM

Ongoing PhD to study and improve the LHC BLM system. Results will also be projected to enhance the injector’s upgrade and the new VFC processing card.

Methodology for dependable PCB design, production, installation & operation

- Reliability Prediction ✓
- FMECA + FTA (ongoing)
  - Assign system checks
- Failure analysis ✓

Dependability analysis update of the LHC BLM

- Reliability Prediction
- FMECA + FTA (ongoing)
  - Assign system checks
- Failure analysis

Failure analysis of the optical link ➔ Analysis of the new VFC card (ongoing)

- Optical link weaknesses identified ✓
- Improvements for the VFC suggested ✓
- Reliability prediction of the VFC ✓
- Definition of a testing strategy for the VFC (ongoing)

Presented at ARW, Versailles, Oct ’17
Future Efforts – DAB64x upgrade

Post LS2 upgrade of the surface processing electronics. The DAB64x and mezzanine will be replaced by the new VFC:

- Additional functionalities with an increased FPGA size
  - Possible to facilitate different processing
  - Improvement of the most critical part of the code using redundancies
- Mezzanine replacement by an SFP standard connector

Predicting the VFC performance:
- Higher number of components
- More functionalities
- Production quality

Demonstrate sufficient low failure rate!
Future Efforts – Testing

① Component tests

Reliability tester of VFC power supplies

② Functional tests

Functional tester VFC card

③ Burn-In/Reliability tests

Climatic chamber

Model: BINDER MKF 240
Rapid temperature changes with humidity control
Temperature range: -40 °C to 180 °C
Humidity range: 10 % to 98 % RH
Future Efforts – Sanity Check

Optimising the Sanity Check sequence:

- Merge 5 sequence steps into 4 \(\rightarrow 20\%\) time saving
- Enable to perform checks of only 1 group \(\rightarrow\) Up to 75\% time saving
- Upgrades of the code in the long term

Checks sequence:

1. Each point center crate
2. Each point left crate
3. Each point right crate
4. Injection crate
5. Extra crate in point 7

\(\rightarrow\) Merge steps 4 and 5
Future Efforts – Dump Upgrade

6 new detectors to be installed outside of the dump for both dump regions:

• Exact positions have been defined with ABT
• Radiation tolerant cabling to be added locally

2 BLM on each side (right/left) 2 additional BLM behind dump

Courtesy C. Wiesner, W. Bartmann
Conclusion

- In 2017 a **better availability** was achieved than in previous years
  - Very strong performance of BCTs and BPMs
  - Future efforts need to focus on the BLM which contributed >90% of BI downtime

- Various measures are put in place:
  - Constant maintenance and exchange of less reliable systems
  - Preventive system fault analysis & failure logging
  - System upgrades which include:
    - Functional tests before installation
    - Component reliability testing
    - System burn-in/reliability testing

- To measure system performance both the availability and the luminosity impact of a fault needs to be considered
Thank you for your attention
Backup

Calculation of the ~ 14% reduced luminosity:

- \( \mathcal{L}_{\text{loss}} = 2A - (A + B + C) = A - B - C \)
- \( t_{\text{total}} = 2 \cdot 12h + 2 \cdot 6.2h = 36.4h \)
- \( t_C = 36.6h - 12h - 2.5 \cdot 6.2h - t_B \quad \Rightarrow t_B + t_C = 9.1h \quad \Rightarrow \text{Highest } \mathcal{L} \text{ for } t_B = t_C = 4.55h \)
- \( A = \frac{0.46h \cdot 1.68e14p}{2} + 11.75h \cdot 1.24e14p + \frac{11.75h \cdot 0.44e14p}{2} = 17.55e14h \cdot p \)
- \( B = C = \frac{0.46h \cdot 1.68e14p}{2} + 4.08h \cdot 1.24e14p + \frac{4.08h \cdot 0.44e14p}{2} = 6.35e14h \cdot p \)
- ① \( 2A = 35.1e14 \quad \text{② } A + B + C = 30.24e14 \)

\( \Rightarrow "\mathcal{L}_{\text{loss}}" = 4.85e14 \approx 14\% \)
Backup

Example of a 12-hour fill at 6.5 eV:
Backup

Methodology PCB design:

<table>
<thead>
<tr>
<th>#</th>
<th>Actions</th>
<th>$Q_{\text{ind}}$</th>
<th>$Q_{\text{tot}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FMECA performed/foreseen</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Additional FTA</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Maintenance strategy defined</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>Well-known manufacturer (CERN experience)</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>Inspection</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Camera (3D)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Microscope / X-Ray (BGA)</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Burn-In at operating temperature</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>At $\geq 40^\circ$C</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Functional PCB Tests</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>Failure analysis of field returns by manufacturers</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>8</td>
<td>Failure/Repair logbook; Jira-Tracking</td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>

$Q_{\text{SUM}} (\leq 3) = 3$

AdjustmentFactor $A_0 (0.25 \leq A_0 \leq 1) = 0.250$
Backup

Dump Region with BLM:

Courtesy C. Wiesner, W. Bartmann