DISCUSSION SUMMARY OF SESSION 2: AVAILABILITY

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INTRODUCTION

AVAILABILITY - A. APOLLONIO

The scope of the presentation is the Proton Run 2016. Data has been prepared by the AWG and fault review experts using the AFT. This presentation is a summary of three individual reports that were written for three periods: Restart - TS1, TS1 - TS2 and TS2 - TS3 When combining all of these, 782 faults were recorded and analysed, 65 parent / child relationships were identified and two new categories were added: access management and ventilation doors. 213 days were considered, 153 days of which were dedicated to physics and special physics. The time distribution for the considered period is the following:

- Restart - TS1; 45% downtime, 30% stable beams, 22% operations, 2% pre-cycle
- TS1 - TS2: 20% downtime, 58% stable beams, 21% operations, 1% pre-cycle
- TS2 - TS3: 16% downtime, 54% stable beams, 29% operations, 1% pre-cycle.
- Overall: 26% downtime, 49% stable beams, 23% operations, 2% pre-cycle

Availability ranged from a minimum of 30% to high of around 90%, which was stable over several weeks. The best weeks achieve around 3 fb^{-1}.

Over the 175 + 4 = 179 fills reaching stable beams, 47% reached end of fill, 48% were aborted, 5% were aborted due to suspected radiation effects. The main categories of premature aborts are UFO and FMCM. Short duration stable beams are due to intensity ramp up. Before MD1 and BCMS the machine was left to run for very long fill as luminosity lifetime was very good. The average fill duration for the three periods is the following:

Periods	Enf Of Fill	Aborted
Restart - TS1	6.9 h	8.0 h
TS1 - TS2	16.2 h	7.7 h
TS2 - TS3	11.5 h	7.8 h

In the period of physics production there were 779 faults, representing 1620 hours (integrated fault time duration) with 77 pre-cycles due to faults. The distribution by systems is presented ordered by "Integrated Fault Duration", "Machine downtime" (corrected for parallelism of faults) and by "Root Cause" (re-assigned for root cause dependencies). The Top 5 are:

System	Occurence
Injector Complex	25.4%
Technical Services	22.6%
Cryogenics	7.3%
Power Converters	6.1%
Magnet Circuits	5.6%

The period was dominated by high-impact faults. The big improvers versus 2015 are QPS which was almost invisible to OP, Radiation effects to electronics which presented significantly fewer events than predicted and Cryogenic system as impact of ecloud stayed under control, and recurring sources of faults were solved. In conclusions, 2016 was an excellent year. Several weeks with 90%, 3 fb^{-1} luminosity produced, and very re-produceable operating conditions. The un-Availability is due to typically long isolated issues and 2017 should be the same, unless we move from the zone in which we are now.

Discussion

J. Wenninger asked what is in the operation section of the pie-chart and if it can be separated. **A. Apollonio**answered that we can quantify it, but not automatically and **L. Ponce** added that the column for operation mode can be extracted, but we need an automated means to correlate this.

M. Lamont noted that the operational conditions of the machine being stable appears to influence the stability of the LHC availability and asked if keeping the operational conditions stable mean that systems will keep (or have kept) the same availability.**A. Apollonio** answered that we will see next year. The comparison of 2015 to 2016 is difficult, as the things like BCMS and bunch spacing has changed the operational conditions of the machine. **L. Ponce** commented that 2015 was dominated by cryogenic recovery and stability, 2016 has not had the same issues. The sources of aborted fills, which are immediately repaired, are a factor which needs to be considered, for example, a fault which leads to a beam abort, which requires no repair, but the machine to be re-filled.

S. Redaelli reminded that this year was one of the years where we lost the most number of operational days due to long faults and asked once this is corrected out, what the characteristic of the fault data is. **A. Apollonio** added that 2016 began with poor availability, with isolated faults, having a long duration, since then it appears that ”random faults” have been the driving factor.

S. Redaelli asked if it is understood why we observed so few failures related to R2E. **S. Danzeca** mentioned that the TCL settings are one of the main contributors of R2E failures.

G. Rakness asked how come that at the end of the year there is high availability and yet not much physics produced. **L. Ponce** reminded that at the end of the year there were several areas of machine exploitation that meant the machine was not producing physics, for example there were several MDs. It was noted that on 24th October in three consecutive days, there was the highest luminosity delivery of the year.

TECHNICAL SERVICES - J. NIELSEN

The five systems which are monitored by TIOC are : Cooling and Ventilation, Electricity, Safety Systems, Access System and IT network. These categories are distributed across several elements of the AFT tree. The events which occur are classified by groups, in the future this could be done by mapping systems and equipment instead of by group, matching the approach from the AFT. This will help classify events more clearly. For example, some systems are groups of systems, the classification could be improved and AFT could show groups of systems. To achieve this the definition of a ”system” should be improved.

TIOC meets every Wednesday to analyse the events that have occurred during the week, then recommendations are made to mitigate root causes. TIOC coordinates the larger technical interventions. If an accelerator is stopped, then a major event is created. The data for such an event is taken once, and is not subsequently synchronised, this could be improved. The major events are presented in the weekly TIOC meeting. The machine or service operator fills in the first part of the information, then the user and/or group then fills in more information.

The fault information for 2016 shows 3 major groups: EN-EL for 40% (largely due to the weasel), EN-CV for 32% and BE-ICS for 17%. To be noted that this does not include the cryogenics. The Breakdown by fault count (with duration) is the following:

- Controls and instrumentation = 12% (15%)
- Equipment = 31% (36%)
- Electrical perturbations are 46% of the faults (45%)

For “Controls and Instrumentation” category, the faults are mostly PLC failures. For “Equipment Faults”, faults are usually due to common-mode power supply faults, for example a failure which trips the power supply to several element (selectivity tripping at a higher level). Certain events are due to equipment not suitable for use (old installations being re-tasked), general equipment failure, or calibration problems. Downtime attributed to this category is higher than 2015, but if you remove the weasel, it is lower (-30%). Concerning Electrical Perturbations, in 2015 we had 3 hours of downtime representing around 15 faults, whereas in 2016, we accumulated 23 hours of downtime for around 45 faults. A general report from the mains supply services shows that 2016 has had -19% thunderstorms than a typical year.

In conclusions, TIOC is effective, and the follow-up has been good. Several things are being worked on and followed up. The next goals are to try and exploit the AFT in a better way, to align and synchronise the information.

Discussion

M. Lamont asked if the weasel event showed that there were some spares issues. **J. Nielsen** answered that there were spares, but not in good condition.

D. Nisbet asked how we close the loop with equipment groups and how we can see improvements. **J. Nielsen** mentioned that next year we hope the duration of fault assigned to the technical services will be lower as this year suffered from long effect faults. For the follow up it is the equipment groups and users. An event is not closed in the TIOC unless it is not going to be mitigated, or that it has been mitigated. **L. Ponce** remarked that the TIOC is doing much more follow up on a regular basis than the machines do for the AFT.

INJECTOR COMPLEX - B. MIKULEC

Injectors were the number one cause of 2016 LHC downtime, although it should be taken into account that there are four injectors before LHC. If this was split, then the LHC ”injector” would be a shorter bar per machine. It is not easy to find which accelerator is the source of LHC downtime, AFT is being discussed to be added to assist in this work. 138 faults were attributed to the injectors, with 15 days downtime. This analysis was very time consuming, as the connection from LHC to the injectors logbooks is not automatic.

LINAC2 accumulated 6 h 20 m downtime as seen by LHC, mainly due to 3 faults, including the replacement of an ignitron. **Booster** accumulated 11 h 45 m as seen by LHC due to several faults, mainly electro-valves with the longest individual fault of 4 hours. **PS** accumulated 9 days 10 hours of downtime as seen by LHC, due to power converters, MPS and POPS, vacuum and radio frequency. Power converter is over 6 days of this, vacuum over 1 day, and RF over 15 hours. Finally **SPS** is 4 days 19 hours as seen by LHC due to power converters (no real systematic) over 1 day and 8 hours, targets and dumps (23 hours), and radio frequency (over 18 hours). A lot of systematic issues have been reported affecting beam quality, but which should be considered as degraded mode, not an actual fault.

If you contrast the overall performance of the injectors, as LHC only needs beam during filling, considering each machine as a continuous operation, availability numbers are the following.

LINAC2 has a bad year with 97.3% uptime, 166 h downtime. Source problems are 44.1% (a new source being tested in EYETS), RF system is 34.6% (analysis is ongoing) and External is 14.7% - power glitches and cooling water

Booster showed 93.9% uptime, 384 h downtime. LINAC2 is 33.6%, RF system is 17.5% (was in a degraded mode, but incorrectly actioned), Beam Transfer is 15.8% (septa and electro valves issues - will be replaced next year) and Power converters for 14.3% (random faults).

PS had 88% uptime, 727 h downtime. Power Converters is 38.3% (POPS capacitors will be replaced), Injectors is 26.6% (detailed in the previous category), RF is 10.7% and Beam Transfer is 6.9%. The availability per user varies from 79-94%.

SPS accumulated 74.8% uptime, 1366 h downtime. Faults are mainly due to injectors and targets problems, looks random failures.

Several issues are reported with fault tracking in the injectors: Not everything is captured in the injectors, perhaps automated tools can be added, the concept of a destination and user is tricky to add, SPS cannot distinguish between no request, or request but fault, faults attributed to a timing user currently, but rather has to be LSA context, Root fault cause is not correctly identified and a question is still opened on how to account for degraded modes. Injector AFT will address some of these issues. Categories are organised, LSA contexts will be used, so statistics by context or group of context can be done, an elogbook interface context dependent will be done and it is planned to separate warnings from faults. Injector downtime appears to be correlated by a few longer uncorrelated breakdowns.

Discussion

J. Jowett commented that the consideration of only the proton run has hidden some issues which were observed during the P-Pb run. Although there were other injectors used for the Pb injection.

M. Lamont asked how come that the LHC was not adversely effected by poor LINAC availability. **B. Mikulec** answered that the LHC never asked for beam during these problems, and therefore no fault was logged.

M. Lamont wondered if the breakdowns are really uncorrelated if it could be correlated with maintenance activities needing some improvement. **B. Goddard** noted that sometimes the maintenance has led to lower availability (e.g. water valves).

L. Ponce commented that the tracking of degraded modes was abandoned in the LHC. AFT was not adapted to track, and so was not done, but following 2016 experience with the limitation on bunch numbers imposed by injectors, the question can be asked on how to try to track degraded modes. **R. Steerenberg** added that having this degraded information for the whole period would make things clearer, at the moment the reality is obscured due to the incomplete capture of the degraded mode. **L. Ponce** agrees, in addition, injector "downtime" can be flagged in AFT, for example, "prevents injection". Following MKI problem this was added, this was not used in 2016. For example the 35h fill, for example, was kept so long to avoid injector issues.

CRYOGENICS - K. BRODZINSKI

There are four cryogenic islands, 8 cryogenics plants (A = Low Load, B = High Load). During run 1 two cryogenic plants could be stopped. In 2015 all plants were activated to compensate electron cloud heat load, there was still some operations margin. In 2016 a new configuration was used, switching off one cold compressor unit, moving capacity between A and B systems. This can be safely done as LHC is running below ultimate values. During LS2 some valves will be replaced to allow even further sharing of load between A and B systems. Cold boxes were tuned, achieving 175 W per half cell capacity on the worst performing sectors (around point 8). In sectors 2-3 the beam screen heat load cooling capacity can reach 195 W. The general limit is 160W.

In 2016, cryogenics system reached 94.4% availability. If you exclude users (Quench) and supply (mains), it achieves 98.6%. In 2016, the total downtime was 79 hours, to be compared with 273 hours in 2015. This improvement comes from four effect:feed forward logic for beam screen heating, points 2 and 8 optimisation, point 8 cold box repairs and DFB level adjustment. Overall around 60% of downtime was due to PLC failures, this is a known issue for some time. During YETS 2015/16, an anti crash program was added, it has still some issues, then during EYETS 2016/17, a further upgrade will be applied by BE/ICS on 50% of the equipment. The faults on the 4.5 K are due to 1 human factor and 2 PLC problems. For the 1.8 K, 1 mechanical failure and 1 AMB CC.

The Helium Losses have been reduces to 17 tons (9 operational) to be compared with 40 tons (29 operational) in 2010. The Beam Screen Heat Load was on average 120W per half cell, 160 W is the general limit.

The plans for 2017 are in the EYETS, update 50% of the PLCs to attempt to deal with code crashing issues, same operational scenario as 2016, the limit is still 160W per half cell, the inner triplet cooling will be OK provided the load is ¡250 W per inner triplet. In 2016 200 W per inner triplet was seen, at 6.5 TeV and 1.5e34 peak luminosity, so a maximum possible is 1.7e34.

Discussion

J. Wenninger insisted on the limit on peak lumi and asked if the triplet limit is 2.0e34 or 1.7e34. **K. Brodzinski** clarified that the limit is really 1.7e34. After the tests carried out, a baseline of 300W heat load on triplet was expected, but once the re-calibration correcting factor was added, the actual load managed was only 240-250W. There is still room for improvement, 1.75e34 is something that is known, and can be done. To reach 2.0e34 tuning is needed.

SOURCES OF PREMATURE BEAM ABORTS - I. ROMERA / M. ZELAUTH

In 2016, 86 fills were aborted, a Pareto of these has three large contributors: Technical Services (27 events), Power Converter (15 events) and Beam Losses/UFO (14 events). Premature dumps attributed to Technical Services are comprised of 23 electrical network perturbations (22 FMCM, 1 QPS XL5, XR5), 3 water pumps and flows and 1 water infiltration (cooling and ventilation) . 12 FMCMs are installed in LHC, designed to interlock on current change as 250 mA change at RD1 changes the orbit 1.5 sigma. 9 of the FMCM events were global, big enough to effect other parts of the complex, FMCM on the 18 kV network observe more glitches, being closer to the 400 kV line. After the EYETS, four SATURN supplies will replace the four converters on the 18kV

The 15 events due to Power converters are comprised of 6 SEU candidate events, 4 internal / external converter failures, 2 communications issues, 2 orbit dipole corrector issues and 1 interlock interface, which has not been solved in 2015. No significant correlation between events.

The 14 Beam Losses / Unidentified Falling Objects (UFOs) are distributed as 6 in the IRs, 3 in sector 12 since threshold changes in August and the rest in the arcs. No magnet quenches due to UFO have been observed since July 2016 but we have low statistics.

The remaining premature dumps have small counts, the interesting cases are: Collimation - LVDT measurement (3events), QPS - I_{DCCT} current measurement likely screen grounding issue (3 events), Training Quenches of MQ.22L8 (2 events at the beginning of the year) and Cryogenic - Cry Maintain lost (2 events). There is no correlation obvious. In conclusions, everything looks random, bottom of the bathtub curve!

Discussion

G. Arduini noted that for the power converters which have a possible radiation effect, five out of six are in point 5 RRs. **M. Zerlauth** confirmed that this is the case, these are planned to be changed, first by replacing the controller (FGClite) and then the converter power part. **S. Danzeca** added that the events in RR53 / 57, happen when the TCL settings are "closed", when the TCL are opened there are no events.

A. Lechner mentioned that concerning the UFO for the IR, thresholds have already been increased for the year.

B. Goddard commented putting the last presentations together, it's remarkable that there was only one dump from the dump kickers, and the dilution systems. This is due to the reliability run, which has shown to be clearly beneficial.