MINUTES OF 9th EVIAN WORKSHOP – SESSION 3, "SYSTEMS OVERVIEW"

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Abstract

This session shows an overview of the systems performance. Several LHC systems have been covered in different sessions, here we cover the performance of the LHC Beam Dump System (LBDS), the operational feedback of the LHC Dump Assembly, Power Converters and their Controls, Quench Protection System, Collimation, Transverse Damper and Observation Box, and the Machine Protection System.

C. BRACCO: LBDS PERFORMANCE

The talk covered an overview of the LHC Beam Dump System focusing on the main findings and limitations encountered during the run and which mitigations were set in place. The performance of the system with the beam is evaluated. New failure cases were identified during Run II and are presented. The abort gap keeper and XPOC were also reviewed.

Discussion

R. Steerenberg asked if, considering the actions taken to limit the extraction kicker erratic, how does the reliability of the system changes at 7 TeV. **C. Bracco** replied that the upgrades which will be applied in LS2 will allow operation at 7 TeV at the same voltage as the one used for operation at 6.5 TeV, therefore the reliability will not get worse.

J. Uythoven asked if they are going to open other magnets also to inspect them after the flash over. **C. Bracco** replied that it will not be possible to intervene on all the magnets during LS2 but, if a weakness is found, mitigation measurements will be investigated and possibly applied during the YETS.

R. Bruce asked if the estimation of asynchronous beam dumps per year has changed and if she can comment on the accuracy of the present simulations. **C. Bracco** replied that like in the past, the estimated asynchronous beam dumps are 3 per year. Regarding the simulations, the uncertainty is difficult to estimate.

S. Fartoukh asked if the tolerances of the BETS-TCDQ, in particular for the inner limit could the reconsidered and if it could be relaxed from the present 1 σ to 2 σ. **C. Bracco** replied that with the present system they can only apply symmetric limits (inner and outer jaw). **S. Redaelli** added that if the BETS-TCDQ limit is relaxed they can still rely on the position limits by OP at least for the inner limit.

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A. PERILLO MARCONE: LHC DUMP ASSEMBLY, OPERATIONAL FEEDBACK AND FUTURE PROSPECTIVE

The main evolution of the LHC dump system during Run 2 were presented. The presentation summarized the types of nitrogen leaks found during the run and the mitigation measures set in place in order to continue operations. The upgrades proposed for LS2 were presented together with their impact for operations in Run 3.

Discussion

G. Arduini asked what would be the intensity limit before YETS 21/22 when they plan to upgrade the upstream window. **A. Perillo Marcone** replied that in order to be on the safe side they can only accept nominal bunch intensities until they upgrade the window. The limitation comes from the failure scenarios.

S. UZNANSKI: POWER CONVERTERS AND THEIR CONTROL

The evolution of the LHC power converters and their control during Run 2 were described. The presentation included the experience with FGC-lite and the plans for LS2. It focused on the performance of the system in particular covering the R2E issues and mitigations.

Discussion

M. Pojer: During LS2 about 120 power converters will be replaced with harder radiation tolerance electronics, could you take into account the possibility to change more circuits affected by the zero voltage crossing? **S. Uznanski** replied that they will be building spares and that this subject should be open for discussion. **M. Pojer** added that the input from QPS team would be important in order to identify the most limiting circuits. **M. Zerlauth** commented that they have a test facility in building 272 to facilitate the integration of the new controls where the power converters lite controls automated testing is running and it would be possible to integrate the QPS controls.

S. Redaelli commented that the numbers shown correlating the failures on the power converters with the TCL6 settings need to be checked and he asked for an offline follow up in order to disentangle the failures due to TCL6 and the ones due to luminosity. **S. Uznanski** replied that the numbers shown are per luminosity unit but that indeed the failures could be within the statistical error and a closer look at the date offline would be possible.

M. Lamont pointed out that the performance shown on the 60 A power converters encourages to go beyond LS3. **R. Garcia** most of them indeed survive but he would like to remind that in some locations the failures will start to show up later, the closest to the dispersion suppressor could be reached soon after LS3.

T. PODZORNY: QUENCH PROTECTION SYSTEM

The talk described the LHC Quench Protection System (QPS) and the main evolution during Run 2. It covered the QPS performance in terms of reliability of the system and R2E issues and how to mitigate them. It showed the analysis of the main failures of the systems, trips, single-event-upset (SEU), trips during current ramp-down, communication problems and missing post-mortem data and what are the measures to solve them.

Discussion

M. Pojer acknowledged the work of the QPS team and asked if it is foreseen to have a better synchronization of the power converters signals and the QPS signals because that will simplify the work of analyzing the data. **T. Podzorny** replied that for new installations like for the 11 T magnets it will be the case, the timing will be more precise and could be aligned with other systems. Old QPS hardware will not be updated, however the real-time application is being reviewed and if problems are found, they will be fixed.

S. Redaelli asked if they observe other issues in cells 8 and 9 around the machine or only in IP1 and IP5. **T. Podzorny** replied that they monitor when they received the PM data which indicates that radiation are higher, this is mostly observed in IP1 and IP5. **R. Garcia** commented that the numbers observed here come from SEU in the QPS system but there are other monitoring means like RADMON and BLMs that confirm those absolute values. The absolute values for the QPS were kept in 2018 below the specifications, which is 30 Gy/year. In 2016, the levels in cell 9 were similar than in 2018 because we operated with the TCL6 open. But this needs to be monitored.

N. FUSTER: COLLIMATION

N. Fuster gave an overview of the collimation performance during Run 2. She presented the achieved cleaning performances for protons and ions, together with the overall system availability. Then she described the experience gained and the changes implemented during Run 2, focusing on collimator controls and hardware aspects, before concluding with the planned upgrades for Run 3.

Discussion

J. Jowett remarked that the TCLDs in IR2 are not required for physics debris cleaning, but for the secondary ion beams. **S. Redaelli** replied that the same phenomena is meant and that he considered it a matter of terminology.

H. Burkhardt commented that the experience with crystal collimation was very promising and showed very good progress, but it should not be overstated either because the achieved improvements did not result only from crystal collimation but also from a better general understanding and from the use of new collimation schemes. He reminded that there was also one run with crystal collimation where one of the experiments was not completely happy with the achieved results.

M. SODEREN: ADT AND OBSBOX

M. Soderen presented the performance of the ADT and the ObsBox during Run 2. He reviewed the evolution of the ADT until now, and gave an overview of its use during operation and during MDs. After discussing current and possible future monitoring tools, he concluded with a summary of the planned upgrades for Run 3.

Discussion

R. Steerenberg congratulated for the nice talk and asked what the future limit would be for the amount of data stored. **D. Valuch** replied that a circular buffer on the local machine would be used. Then, when an interesting event, *e.g.* an instability, is observed, the required slice of data can be downloaded. **R. Steerenberg** asked about the size of the buffer. **D. Valuch** clarified that this depends on the amount of local storage available but that a minimum of 8 hours is foreseen.

J. Uythoven commented that the use of the ADT has to stay within certain machine-protection limits. In order to evaluate if we are intrinsically safe, we should do a fundamental check what could be the fastest and strongest kick that we can produce. **D. Valuch** agreed that this should be done.

R. Jones commented that if the bunch-by-bunch tune measurement is implemented, it will be nice to couple it with the on-demand gated BBQ, so that one also gets a BBQ measurement targeted to the excited gateway. He stated that even though it will not be possible for multiple bunches, one could get a nice measurement for the single bunch that is excited. He suggested assessing how the two systems could be combined and asked what resolution one can expect. **D. Valuch** replied that the resolution from the ADT ObsBox is already quite good. The measurement presented (Slide 16 of M. Soderen's talk) shows 180 turns data with a noise floor of about 0.02. He estimated that with a longer integration time, one could easily improve the resolution by one order of magnitude. This would allow a bunch-by-bunch measurement with a 2×10^{-3} noise floor without excitation. **D. Valuch** agreed that it is beneficial to integrate different systems to achieve the best overall result, *e.g.* as done for the coupling measurements, based on a collaboration of BI, RF, and the ADT team.

X. Buffat stressed that the ADT has been a very crucial instrument for many MDs and that it is worth to continue the effort to simplify its use for non-experts. **M. Soderen** replied that the cooperation with ABP has worked very well and that suggestions for further improvements are always welcome.

K. Fuchsberger asked about possible plans to integrate the data into NXCALS. **D. Valuch** replied that there have been discussions with the NXCALS team and the conclusion was that it is not feasible to send data with 1.3 GB/s to NXCALS. However, interesting data slices can be stored. **C. Roderick** confirmed that a constant stream of data is not feasible, but, when interesting data is identified, there is no problem in sending it to NXCALS. He reminded that the current NXCALS system is taking 2.5 TB per day.

D. WOLLMANN: MACHINE PROTECTION SYSTEM

D. Wollmann summarized the performance of the Machine Protection System (MPS). He started by giving an overview of the main machine-protection challenges, the observed failure cases, and the key events during R 2. Then he discussed the role of the (r)MPP, and presented the evolution of the intensity ramp-ups with focus on issues discovered during the ramp-ups. He concluded that, even though several issues have been experienced during Run 2, no damage has occurred thanks to the vigilant experts and the diverse redundancy in the MPS.

Discussion

B. Salvachua remarked that during the intensity ramp-up many experts have to analyse their systems fill by fill. Therefore, she asked if the possibility exists to unify the checks for the different teams in one tool and to have more automatic checks. **D. Wollmann** replied that this would be very beneficial, but requires the input from the hardware experts from the different teams. A good occasion to discuss this question would be the foreseen Machine Protection Workshop in May 2019.

E. Metral asked what the most critical case had been and what could have been the consequence. **D. Wollmann** responded by illustrating the example of the accidental injection of a nominal bunch into the empty machine. The interlock that should have prevented the injection of high-intensity beam into the empty machine was not working as expected. Therefore, the injection of a nominal bunch was not blocked, and even higher intensities could have been injected. He explained that, *per se*, this does not cause a problem because we have multiple redundancy, *i.e.* unless we have additional failures as large orbit excursions or non-detected problems in a magnet circuit, no damage would be caused. However, if we inject while an important magnet is not working properly and at the same time another protection system does not work, then the beam can be lost on the aperture. He summarized that in the cases presented we mainly lost one protection layer, sometimes two layers, but never all layers. However, the loss of one protection layer clearly increases the probability of causing a damage to the machine. That is why we have to ensure the redundancy of the protection layers. In the case of the triplet quench in 2018, we were protected by the BLMs. The next protection layer would have been the collimation system, and then we would have been left without protection.

E. Metral asked if the intensity ramp-up procedures should be reviewed based on the experience from Run 2. **D. Wollmann** answered that he considers it a successful strategy so far. Nevertheless, the procedures can still be optimized and made more efficient, which requires the input from the system experts. Therefore, the procedures should be reviewed in the foreseen Machine Protection workshop.

R. Steerenberg reminded that the whole system went through a big evolution with many changes implemented during Technical Stops but also during the run. He asked if there is a regular discussion on reviewing these changes, especially for the changes that are implemented on a more ad-hoc basis. **D. Wollmann** replied that in general we do not implement changes into critical systems during the run. In general, changes should only be made during a longer stop, followed by a re-validation of the system. An exception was the change of the variable Abort-Gap Keeper, which was considered an acceptable change because the core part of the LBDS was not touched and the worst case would have been an acceptable failure without damage to the machine. He summarized that the core elements of safety-critical system should not be touched during a run. If they have to be touched, a full recommissioning is required. However, if an unknown failure case is discovered during the run, a short-term solution can be to implement a software interlock that restores the previous protection level while mitigating the failure on a hardware level during a following longer stop.

R. Steerenberg asked how long the newly implemented SIS interlocks stay active. **D. Wollmann** replied that indeed the SIS interlocks have to be reviewed regularly to check if they are still necessary or if instead a hardware interlock is required. He announced that this topic is also on the agenda for the Machine-Protection Workshop.

S. Redaelli reminded that, so far, we never had an asynchronous beam dump with full machine, which implies that we did not probe our settings, as beta star or aperture, for the worst case. He asked if we should still consider our present, very time-consuming validation to be sufficient. **D. Wollmann** replied that we perform the validation to the best of our knowledge. He added that the validation clearly relies on the stability of the beam and the optics, which has to be ensured by various interlocks, including the newly introduced phase advance interlock. Therefore, even though a single interlock might fail or can be bypassed, it is unlikely that all fail.

S. Redaelli commented that the question of machine protection during MDs has not been mentioned. **J. Uythoven** clarified that he would cover the topic in his talk about the MDs.

P. Collier commented on the list of machine-protection issues presented by **D. Wollmann**, and remarked that we need quality assurance and rigor in documenting these events. He suggested that, whenever we have an incident that the rMPP considers serious, we should issue a major event document that includes a clear analysis of what went wrong and of what has to be done to avoid the issue in the future. If necessary, this document should then be brought to the LMC for decision and action. **D. Wollmann** agreed that this should be done.