SUMMARY OF SESSION 2: INJECTOR STATUS AND BEAMS FOR LHC, DRY RUNS, SECTOR TESTS WITH BEAM

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Abstract

This paper summarises the presentations and the subsequent discussions during the second session of the LHC Performance Workshop in Chamonix 2014.

LIST OF PRESENTATIONS

The following five presentations were included in the second session:

- "LHC Injectors Complex Status", K. Hanke;
- "SPS Scrubbing 2014", H. Bartosik;
- "Operational beams for the LHC", Y. Papaphilippou;
- "LHC Dry Runs and Cold Checkout", D. Jacquet;
- "LHC Transfer Line and Sector Test", R. Alemany.

A brief summary of the presentations and the subsequent discussions are given in the following.

LHC INJECTORS COMPLEX STATUS

Summary

K. Hanke gave an overview of the work done in the LHC injector chain during LS1, the re-commissioning after LS1 and the present status, for both ions and protons. He highlighted the most important issues encountered and lessons learnt. The presentation represents a preliminary post-mortem of the injectors start up after a long shutdown during which substantial modifications were made to the installed hardware and software. Despite the good preparations and the dry runs it was not trivial to make all systems operational again in the time allocated and an intensive period of debugging was required. One of the major concerns has been the availability of equipment experts in the CCC to support the operation teams in order to bring the different systems into operation again, which was principally due to the high workload. Actually the items that caused most worries worked quite well whereas the more standard items were not or could not be given sufficient attention. Another point that was emphasised is that deadlines for the different re-commissioning phases could not or were not always respected, compromising, on several occasions, the schedule for machine checkout.

K. Hanke ended his presentation with a brief outlook on the 2015 YETS and the restart afterwards. He commented that only the absolutely necessary interventions will be allowed in view of a 'hot' restart of the injector complex for an early begin of the 2015 Argon ion physics run and to be ready in time for the LHC commissioning with beam, starting with a sector test on February 7th.

Discussion

F. Bordry commented that we should acknowledge all the equipment experts that made a huge effort to perform an enormous amount of work of the highest quality during LS1 and that now, during the start up of the machines, they are still required to perform at the same level, which in some cases is not possible. He would rather prefer to convey the message that now we should profit from the lessons learned and pick up those points where improvement is required. Those should then be worked out in view of future Long Shutdowns. R. Losito commented that from his point of view a more systematic approach to the commissioning phase is needed in the injectors, as it is done in LHC. This would help the equipment experts to prepare and schedule their work. M. Lamont remarked that from his perspective, the missing cable issues and similar problems mentioned during the talk could have been avoided if the operations team would have checked them before beam commissioning, as it is done in the SPS, for example. K. Hanke answered that it is the responsibility of the equipment groups to check and ensure that the equipment is ready for use from the CCC and that the missing cable actually happened in the SPS.

N. Holtcamp asked if the transverse emittance has been measured in the injectors and if it is comparable w.r.t. run 1. K. Hanke answered that it has been measured only in the booster and that it is slightly larger than in run 1. The transverse beam emittance in the SPS could not yet be measured because the wire scanners broke at the beginning of the beam commissioning.

O. Brunning asked about more details concerning the PS alignment mentioned in the talk. R. Steerenberg explained that in the PS orbit measurements were done with beam, calculations of the corrections were performed and that the proposed magnet displacements were applied. Following this beam-based realignment the orbit was measured again and was found to be different with respect to the calculated correction. The issue was traced back to a shift in the numbering of the BPMs following the insertion of three new BPMs, but not due to any magnet alignment problem. A second iteration with the correct BPM sequence provided a good orbit.

K. Hanke also mentioned that the PS Finemet cavity was found to be ringing at 40 MHz and that as a result some gaps were short-circuited to avoid potential impact on the beam performance, although presently no performance limitation have been observed. S. Gilardoni stressed that the problem is not affecting the beam production performance.

SPS SCRUBBING 2014

Summary

H. Bartosik gave a detailed presentation about the strategy for the scrubbing run in 2014, a description of the doublet scrubbing beam, together with details on the preparation of the scrubbing in 2015, including the required measurements and instrumentation readiness.

H. Bartosik started with recalling that the SPS suffered in the past from a strong limitation due to e-cloud. This situation did improve gradually thanks to scrubbing, which was done systematically every year since 2002, apart from the years 2010 and 2011

The goal of the 2014 scrubbing run is to qualify the loss of conditioning due to the LS1 activities, to recover the 2012 performance, to quantify the amount of beam and time required and finally to test the doublet beam scheme, which is foreseen to be used in the LHC in 2015.

He then detailed the schedule and the choices made with respect to dividing the scrubbing run in shorter blocks. For each of the scrubbing blocks clear strategies and goals have been defined.

H. Bartosik explained in detail the production of the doublet beam, its structure in the SPS together with the advantages of using this beam rather than the standard 25 ns beam, which is the increased e-cloud production, hence enhanced scrubbing. Simulation results show that the scrubbing profile depends on the beam intensity and is very different w.r.t. the standard 25 ns beam. In fact the scrubbing takes place around the centre of the MBB dipole, in contrast with the standard beam that is more efficient at the extremities of the dipole section. This will require the modulation of the beam orbit in order to cover a sufficiently large area of the vacuum chamber. First tests with beam in 2012 showed a nice agreement between simulations and measurements and confirmed a substantial increase of the dynamic pressure for the doublet beam in the SPS arcs.

Regarding the preparations H. Bartosik gave an overview of the beam characteristics requirements out of the PS together with the setting up of the cycle in the SPS. He also listed the measurements that are required and requested the devices to be operationally available.

Discussion

P. Collier asked that given the doublets scrub different surfaces of the magnets, what is it planned to steer the beam around in order to cover the whole surface? H. Bartosik answered that the cleanest way is using the orbit correctors.

M. Lamont asked what the capture efficiency is for a beam intensity of 1.7 10^{11} p+ during the non-adiabatic splitting in the SPS? H. Bartosik replied that they have measured efficiencies in the order of 90% at injection, but remarked that this beam has not yet been accelerated.

R. Steerenberg noted that as soon as beam is put in the SPS machine, the machine is being scrubbed; therefore this should be quantified and taken into account for the scrubbing results.

OPERATIONAL BEAMS FOR THE LHC

Summary

Y. Papaphilippou gave a clear review of the performance expectations for all the LHC beams, protons and ions, which have to be set-up for LHC operation. He started with an overview of the LHC restart schedule as it was discussed in the LMC of September 9th. From that schedule he then deduced which beams will have to be prepared and in what order. The first requirement is the single bunch beams: LHCPROBE (also called LHCPILOT), with intensities $\leq 10^{10}$ p/b and the LHCINDIV beam with up to 4×10^{11} p/b. The production scheme of these beams was consolidated in 2012, allowing the preservation of the 6D phase space volume for different intensity values and an excellent shot-to-shot reproducibility together with good control of the intensity and the longitudinal emittance.

Y. Papaphilippou then presented the different production schemes for the multi-bunch LHC beams, together with their pre-LS1 status. These schemes can be divided in the standard scheme, as it was used operationally in 2012 for the 50 ns beam, and the BCMS (Bunch Compression, Merging and Splitting) scheme, which resulted in smaller transverse emittances for similar bunch intensities. Both production schemes are very close to the performance limit of the present injectors.

Post-LS1 the aim is first to recover the performance that was obtained in 2012 followed by potential performance improvements that are within reach ensuing some hardware modifications made during LS1 and possible improvement on the production scheme, as proposed and discussed during the RLIUP workshop.

Y. Papaphilippou then compared the performance of the standard production scheme and the BCMS scheme with some potential improvements from optimised PSB-PS transfer and an intensity increase in the SPS, reminding the audience that these performances will depend highly on the success of the SPS scrubbing.

He also briefly addressed the less standard beams such as the doublet scrubbing beam and the 8b+4e beam. The successful Pb-Pb ion beam performance in 2011 and the P-Pb run in 2013 were briefly reviewed. From this the 2015 Pb ion performance was projected, addressing the changes to the production scheme. For the injectors the main change will take place in the PS where the bunch spacing will be reduced from 200 ns to 100 ns, which together with a reduction of the β^* in the LHC should result in an increase of the luminosity by a factor ~ 10.

Y. Papaphilippou concluded his presentation with the revised 2014 injector schedule to which he added the setting up sequence of the different LHC beams.

Discussion

T. Roser asked what are the disadvantages of BCMS beams? V. Kain answered that from a machine protection point of view, the current LHC – Transfer Lines protection devices cannot cope with such dense beams and added that she will address this during her talk in

session 5. E. Metral recalled that the small beam sizes the BCMS provides might trigger more beam instabilities. Y. Papaphilippou completed the answer by reminding that the 25 ns BCMS beams, with the complete number of bunches injected and ramped in LHC, have not been proven yet, so there are still many unknowns and one first needs to learn how to operate those beams. The eventual increase of pile-up in the experiment is not an argument, as was reminded by CMS, since the experiments are prepared to take 1.5 10^{34} $cm^{-2}s^{-1}$ after LS1, but not during the firsts weeks though.

S. Gilardoni gave, in contrast, some arguments in favour of BCMS beams: they provide more aperture margin due to the smaller emittance, and if instabilities are an issue, the beams can be blown up with a relative small loss in luminosity since they imply less number of bunches as compared to standard 25 ns. On the other hand, if e-cloud is still an issue, the smaller emittance leave margin in case of e-cloud induced blow up.

P. Collier asked how much time is needed to recover a good vacuum for ion operation in SPS and if sublimation pumps are active? P. Chigiatto answered that the amount of time depends on the length of the vacuum sector, but gave ~ 2 weeks as a typical duration. He added that sublimation pumps are not active, however, they could be activated if needed, but with a significant cost in time. M. Jimenez commented that there are no pressure problems in SPS with the fully stripped ions and that sublimation pumps are useless in the SPS. B. Goddard added that discussions are on going to reduce the length of the vacuum sectors in order to reduce the time needed for conditioning.

John Jowett corrected the number concerning the integrated luminosity for the Pb-Pb run in 2011, which was 150 μb^{-1} instead of 100 μb^{-1}.

LHC DRY RUNS AND COLD CHECKOUT

Summary

D. Jacquet presented the systematic approach that LHC operation has adopted since 2008 to tackle the complexity of LHC in view of the preparation for beam commissioning, dry runs of equipment and software, coordinated with the equipment experts and performed from the CCC at an early stage, followed by a thorough cold machine checkout when the whole machine is practically handed over to operations.

She started by stating that during LS1 besides consolidation, many modifications were made to the LHC and added that there were also non-negligible changes to the team operating the LHC. This has lead to a similar level of preparation for beam commissioning as was applied during the 2008/2009 start up.

One of the main messages was that the testing from the control room should start early (i.e. May 2014), even though not all systems are fully deployed or stable. The reason for this is the early detection of issues and it allows allocating sufficient time for corrective actions. She mentioned that the restart of the LHC injectors made that experts were not always available to help and solve arising issues immediately. A prerequisite for successful testing is that the basic controls environment has to be in place in the CCC.

D. Jacquet then provided examples of tests made so far and results obtained. Although a new timing system will be deployed in October many tests related to the telegram, timing tables, etc. were performed. Similar approaches were used for other systems such as RF synchronisation and frequency map, handshakes and beam modes, post-mortem events, etc. The available time was also used to perform reliability runs on the beam dump systems, using the BETS simulator for the energy ramp.

She then presented a list of tests that have to take place until the beam commissioning. The pre-conditions for the final machine check were clearly listed together with the organisation of the check out period.

Discussion

R. Steerenberg acknowledges that the strategy of early start of dry runs is very beneficial and that the injectors could potentially benefit from a similar approach.

LHC TRANSFER LINES & SECTOR TEST

Summary

R. Alemany presented the motivation and goals to perform a transfer line test and sector tests in LHC. She showed the proposed schedule, which are an update of the previous ones following a major LHC schedule revision.

She started by explaining that the transfer line and sector test will allow testing a substantial number of systems across its different layers. These tests are then representative for the same systems in the ring, such as BLM, BTV, BPM, etc. It will also allow testing and confirming the optics models and will allow probing the aperture available. The sector tests are now foreseen for 7 and 8 February for sector 2-3 and 21-22 February for sectors 6-7, 7-8 and the beam dump. These tests need to be carefully planned, as partial closure of the LHC and the ALICE and LHCb experiments are required. For these tests the LHCPROBE (also called LHCPILOT) beam is required with an intensity of $2–5 \times 10^9$ p/b.

R. Alemany then concluded by presenting the stepwise strategy for the sector test together with the list of systems to test together with a preliminary, but detailed, schedule for beam in both directions.

Discussion

M. Lamont asked if it makes sense to do a sector test just before the machine checkout starts. R. Alemany answered that experience has shown that even if the sector test was performed the day before beam commissioning, as it was done for the sector tests in 2008, it brought very positive results. M. Lamont emphasised that he fully agrees with this approach.