SESSION 01: LESSONS FROM 2011

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REVIEW OF 2011 LHC RUN FROM THE EXPERIMENTS PERSPECTIVE

M. FERRO-LUZZI (PH-LBD)

M. Ferro-Luzzi highlighted the excellent performance of the machine and the experiments in 2011 and the fast and impressive achievements both when operating with protons and Pb ions. In a month the same luminosity as during the full 2010 proton run was delivered, and a factor 16 higher luminosity was produced with Pb ions. The excellent machine performance allowed ATLAS and CMS to make interesting observations in the context of the Higgs' boson search and LHCb found some evidence of CP violation in time-integrated D0 which could open the way for a new physics.

Special runs were dedicated to p-p collisions at intermediate energy (1.38 TeV), high β* for roman pots (optics checks, setup and data taking) and p-p luminosity calibration. A problem with the PS septum for proton extraction did not allow to accomplish the p-Pb run.

ALICE could profit of collisions between main bunches and spontaneously produced satellites. This opened the way for a successful run with an artificially increased rate of satellites from 1-2‰ up to 1-2%.

M. Ferro-Luzzi showed the evolution of the luminosity all over the year. He pointed out that, thanks to a smaller β* (from 1.5 m to 1 m) and higher brightness beams (smaller emittance and higher bunch population), it was possible to improve and speed up the luminosity production: almost 80% of the luminosity was accumulated in the second half of the year.

The 2012 run will be mainly devoted to luminosity production. No further room for improvement can be expected from the injectors but a smaller β*, higher energy and more than two years of experience could allow to reach new challenging targets.

INPUT FROM EVIAN

M. LAMONT (BE-OP)

M. Lamont presented a summary of what discussed in Evian about lessons learnt during 2011 operation and improvements foreseen for 2012.

He underlined that 2011 was a remarkable year with a continuously faster increase in luminosity production and without real show stoppers. The machine was characterized by operational robustness, a good reproducibility, stability, beam lifetime, optics control and an excellent performance of the Machine Protection system (MPs) and of the injectors.

Measurements at 3.5 TeV showed a triplet aperture better than estimates and this allowed to reduce the β* to 1 m with a consequent increase of the luminosity.

Intensity ramp-up was safely executed in 2011 but it took more than 11 weeks and several issues were encountered. The proposal for 2012 is to reduce the number of intensity steps and the time spent in stable beam between consecutive steps; three weeks should be enough to reach 1380 bunches.

Operational efficiency was quite good with 34% of the time in stable beam and an average turnaround time of $\sim$5-6 hours dominated by machine availability and injection optimization. No systematic problems were encountered after the Technical Stops (TS) and operation was re-established in less than 2 days. The performance of all the systems (cryogenics, QPS, injection and dump, transfer feedback, collimation, orbit and tune feedback, beam instrumentation, vacuum) was outstanding and important discoveries were made related to high intensity and luminosity effects (impedance, beam induce heating, Single Events Upset SEU, e-cloud, UFO). Important mitigation measures have been implemented to reduce the faults induced by the radiation on electronics: 30-50 faults are expected for next year instead of the 150 estimated without any mitigation.

Several improvements have been put in place during the 2011-2012 Christmas Stop and should enhance the performance and availability of all the systems. The plan for 2012 is to run with 50 ns beams at 4 TeV and with a β* of 60 cm in ATLAS and CMS and 3 m in ALICE and LHCb (with vertical crossing angle); this will require to close the collimators to tight settings and some optimization in particular for orbit stability during the squeeze.

Discussion

F. Giannotti asked about the option of increasing the bunch length to reduce the beam induced heating effects. In particular, she asked up to which value the bunch length could be increased and if any degradation in luminosity is expected. P. Baudrenghien answered that he would have answered these questions during his talk on Tuesday February 7^{th} (Session 03).

S. Myers asked if any aperture restriction was measured close to CMS where an insert with mis-setup RF fingers was found (see V. Baglin talk in the following). M. Lamont answered that no anomaly was observed close to IP5; S. Redaelli confirmed that no indication of bottlenecks was measured outside the triplets in point 1 and 5 but only in point 2.

THE 2011 RUN: AVAILABILITY ANALYSIS
A. MACPHERSON (BE-OP)

A. Macpherson spoke about machine availability in 2011 and gave some statistics of fills for p-p and Pb-Pb runs.

He calculated a machine availability of 76.7% and that 33% of the operation time was spent in stable beam. The Hubner factor, which gives an estimate of the luminosity production duration, was slightly bigger than the expected 0.2 value both for the proton (0.22) and lead ion (0.24) runs. Stable beams lasted in average $\sim$6 hours but about 50% of the fills were shorter than 4 hours.

The analysis of the turnaround time distribution showed an average of $\sim$13 hours between two consecutive stable beams with a most probable time of $\sim$5 hours. Injection played a dominant role in turnaround time. The possibility of using dedicated SPS cycles for filling the LHC is being explored; this would allow to recover up to 5.6 days of turnaround time. The impact on the SPS and the other SPS users has to be carefully evaluated. An improvement is expected for 2012 operation but, according to experience, a reduction to less than 2 hours is unlikely.

A. Macpherson presented also an analysis of all the faults occurred and pointed out the problem of missing documentation for several faults, in particular for the QPS failures. He proposed to add a new tool in the DB to structure and standardize the fault recording. He also suggested a regular review of the LHC-OP faults with feedbacks from the teams responsible for the different equipments.

The main contribution to machine downtime was given by cryogenics recovery ($\sim$26 days). The system had anyhow an extremely good global availability of $\sim$90%; further improvements are expected for 2012 since redundancy against SEU has been added to the PLC.

It was estimated that 78% of the dumps was non programmed and 35% happened during stable beam. Mostly all the dumps were triggered by equipment failures; QPS and cryogenic played again the main role. The effect of SEU became more and more important when increasing beam intensity and luminosity (24% dumps); the mitigation measures applied should reduce this effect.

Discussion

S. Redaelli asked if the quoted number of dumps during stable beam (35%) refers to the total or just to the non programmed ones. A. Macpherson answered that it refers to the total. S. Redaelli commented that it would be also interesting to know the percentage of beams involuntarily lost in stable beam.

G. Tonelli recalled the problem of the high sensitivity of the cryogenic system to electrical glitches and asked what are the expected effects and foreseen improvements. S. Claudet explained that if the glitches are longer than few 100 ms they can cause the stop of one or several plants; work is ongoing to try to reduce the recovery time to one day. To be kept in mind that one has to check which systems are affected and then treat them at the source; the time for the interventions and the advantages have to be evaluated. He added that it will be extremely improbable to get rid of these cuts at $>$100 ms over the next 10 years.

K. Dahlerup-Petersen commented about the QPS faults; he explained that some new failure modes and different types of SEU were discovered last year. He believes that all the possible failures are now known and solutions available.

INJECTION AND LESSONS FOR 2012
C. BRACCO (TE-ABT)

C. Bracco made a presentation on the performance of the injection system.

The injection of 144 bunches became fully operational in 2011 in agreement with what predicted during the last Chamonix workshop. Moreover 288 bunches could be injected, during MD time, for both beams with a good margin between the losses and the BLM dump thresholds. Improvements are still needed to optimize the 25 ns beam in the injector chain and accumulate it in the LHC with a good lifetime; the results are encouraging in view of operation with the designed intensity.

Several mitigations were put in place to reduce the injection losses coming from the TL collimators and uncaptured beam; supplementary measures are planned to further reduce these losses.

Injection played a dominant role in the turnaround time during the 2011 run. It was necessary to re-steer the TL every 2-3 days and steering was complicated because of shot-by-shot, bunch-by-bunch variations and long term drifts. Normally from 30 minutes up to 2 hours (excluding some big outliers) were spent at injection. About 60 hours of turnaround time have to be taken into account, for 120 days of operation, if the TL stability is not improved.

Several actions have been undertaken to reduce the different sources of instabilities and improved references will be implemented in the IQC to make the steering process easier and faster.

C. Bracco spoke also about the two injection failures which caused the only quench events observed in 2011. A number of improvements have been applied to the hardware and the diagnostics, more severe limits have been defined for the MKI interlocks and precise instructions for safer operation have been deployed.

Some other issues related to the injection system were UFOs at the MKI and problems with TDI: controls, heating, vacuum pressure increase and beam screen deformation.

Discussion

R. Losito specified that the problems encountered with the TDI controls were not due to electromagnetic noise of the LVDTs but to a temporary deformation of the jaws. R. Schmidt reminded that the TDI is a vital system and that it saved the machine already several times during injection failures. He asked if any issue can be expected from this element, in particular in case of deformation. C. Bracco answered that if the TDI is correctly set up no major issue is expected. A well defined procedure has been established last year for the angular alignment of this collimator. S. Redaelli commented on the change of thresholds needed for the drift of the TDI LVDT. He explained that 100 μm corrections were needed and that the drift was in the safe direction: smaller gap. S. Redaelli reminded that the TDI does not have a gap measurement and that it could be envisaged to implement it.

R. Assmann asked what the plans to improve the TL stability are. C. Bracco answered that it will be tried to reduce the sources of instability (minimize MSE ripple and adjust delay of the beam with respect to the MKE waveform) and that, during the commissioning, a better reference trajectory will be established that minimizes, at the same time, transverse losses and injection oscillations. V. Kain added that the TL instability is a combination of various issues and long term drifts are still expected.

R. Assmann commented that the beam screen deformation is most likely due to impedance effects and that a non conform material (Cu) was used to build the beam screen.

G. Arduini commented that during the scrubbing runs the e-cloud solenoids have to be kept off. C. Bracco confirmed that for special runs the solenoids can be off but that the interlock limits on the vacuum at the MKI should be respected to reduce the risk of flashover. P. Giubellino commented that ALICE is reviewing the state of detector during injection to limit the effects in case of failure.

Y. Papaphilippou asked if the improvement of the injector diagnostic is required for checking the beam stability or mainly tail population. C. Bracco answered that it would be mainly for tail population.

E. Chapochnikova asked what the useful part of the MKE in view of future operation with with longer extracted batches. V. Kain answered that the flat part is about 10 μs. B. Goddard added that one has to take into account also the length of the MKI flattop which is about 8 μs.

MACHINE PROTECTION
M. ZERLAUTH (TE-MPE)

M. Zerlauth introduced the architecture of the LHC Machine Protection System (MPS). He explained that this is a complex system that checks more than 10000 interlock conditions and has to evolve to follow operational changes, special runs and MD requirements.

In 2011 about 1200 dumps were cleanly executed (10% less than 2010) and no quench occurred with circulating beam (>100 MJ stored energy). The MPS worked extremely well and the majority of the dumps happened before seeing changes in the beam (no losses, orbit changes) and all the dumps were accurately analysed and documented.

M. Zerlauth explained that the needed high level of redundancy has the drawback of creating some false positives. The number of false positives coming from the QPS and due to Single Event Upset (SEU) increased in 2011 as an effect of the higher intensity and luminosity. Mitigation works done during the Christmas TS should reduce the SEU induced false positives in 2012.

Several improvements of the MPS have been implemented while other such as a beam current change monitors (DIDT), an additional software based interlock system for Power Converters (PC) for orbit correction and the Transverse Damper (ADT) bunch-by-bunch blowup remain to be made fully operational during the 2012 run. In addition new procedures for Abort Gap Cleaning (AGC) and in case of non working dump trigger have been developed and will be commissioned during the 2012 startup.

M. Zerlauth explained that the main goal of the MPS for 2012, when moving to smaller β* and tight collimator settings, is to maintain the same level of safety as in 2011 and increase the availability. He also explained in detail the plans for the intensity ramp up in 2012 and how to optimize the time for the machine protection checks.

Discussion

K. Dahlerup-Petersen commented that the number of false positive ascribed to the QPS was overestimated.

S. Myers asked when the new MPS systems and features (i.e. DIDT, ADT bunch-by-bunch blowup) will be commissioned and ready to be used. M. Zerlauth answered that almost everything will be ready for the start up. In particular, the PC interlock is under commissioning and will be connected to the BIC as soon as fully tested. Some more time will be probably needed for the DIDT current monitors. R. Jones confirmed and added that there is some issue with the position sensitivity of the Fast BCT and work has still to be done to make the system as robust as possible.

M. Aleksa asked if, thanks to the bunch-by-bunch blow up, it will be possible to avoid performing loss maps killing the beam by crossing the 3^{rd} order resonance and,as a consequence, to gain some time. J. Wenninger commented that the validation of the collimation system cannot be performed with high intensity beams. R. Assmann confirmed that, even with the new method, 2-3 fills will have to be dedicated to qualify the collimation system for all the stages of operation.

R. Assmann pointed out that since no quench happened at 3.5 TeV, even during quench tests, several BLM thresholds should be increased. He explained that a lot of time was spent in adjusting the BLM thresholds and asked if more flexibility to go towards the calculated quench limit is foreseen for 2012. M. Zerlauth confirmed and added that this presentation did not go into much detail on this as this topic will be covered by later talks during the workshop.

M. Lamont asked what is the effect of a single bad BPM on the feedback system and possible errors on closed orbit corrections. R. Steinhagen answered that this should not be a problem since no correction will be applied on the base of a single BPM readout.

W. Kozanecki asked why the abort gap cleaning has an effect on luminosity. M. Zerlauth explained that, at present, the transverse damper does not excites only the particles in the abort gap but the kick also extends (with low amplitudes) to the first nominal bunches outside the gap. Studies are ongoing to improve the hardware to leave the AGC always on also at collision.

VACUUM PERFORMANCE AND LESSONS FOR 2012

V. BAGLIN (TE-VSC)

V. Baglin presented a talk on the main vacuum observations made in 2011: dynamic effects induced by the circulating beam (synchrotron radiation and e-clouds) and unexpected local pressure spikes. He explained that the desorption yield in the cold-warm transitions was much worse (factor 50) than in the warm-warm transition due to gas load from the cold part.

Scrubbing runs first with 50 ns and then with 25 ns beams were performed and had a clear effect in cleaning and reducing the e-cloud pressure. V. Baglin affirmed that pre-scrubbed vacuum chambers will need 10 times less scrubbing after air exposure than new chambers. New vacuum chambers have been installed in IP2; scrubbing and e-cloud solenoids will help to reduce the background in ALICE. For 2012 operation, the need for dedicated scrubbing runs will depend on the planned beam intensity: for 50 ns beams with $1.45{\cdot}10^{11}$ ppb scrubbing could be done in the shadow of intensity ramp while for $1.6{\cdot}10^{11}$ ppb a couple of days with 25 ns beam scrubbing will be required. A dedicated run would be mandatory in case of operation with 25 ns beams.

Pressure spikes were observed in IP2 and IP8 close to D1 and near CMS. In all these cases x-ray investigation revealed a bad contact of the RF fingers. A new design was developed for the RF insert in point 2 and 8 but recent studies showed that the vacuum issue could show up again during the 2012 run. Further improvement solutions are being analyzed. Interventions were done during the Christmas TS in the CMS region; the problem has been fixed and vacuum conditions reestablished.

Discussion

R. Assmann asked if any problem with RF fingers is expected at other collimator locations. V. Baglin answered that this should not be the case.

M. Aleksa commented that if scrubbing is not needed below a certain bunch intensity it would probably be better to start with lower intensity beams and, if really needed, increase the intensity later during the year. G. Arduini replied that one first needs to check if this is really the case and added that scrubbing run scenarios for different operation options will be presented the following day by G. Rumolo.

F. Zimmermann said that the dependence of the Secondary Emission Yield (SEY) on the number of monolayers absorbed gas is not clear. The plot on slide 7 indicates a minimum SEY, even lower than in case of no monolayer, for about 3 monolayers. V. Baglin replied that the plot refers to unconditioned copper. The result could be different for conditioned copper but no measurements are available.

J. Jowett asked if any desorption from local losses was measured in the dispersion suppressor during high intensity runs. V. Baglin answered that nothing dramatic was observed in this region.

EMITTANCE PRESERVATION

V. KAIN (BE-OP)

V. Kain spoke about emittance preservation all along the injectors chain up to collisions in the LHC. She explained that injectors behaved extremely well in 2011 and, for the 50 ns beams and a bunch population higher than nominal, an emittance blowup of 0.4 μm was measured from the PS to the SPS (from design report: 0.5 μm were estimated for 25 ns beams). On the other hand a 20-30% emittance growth is observed between the SPS flattop and LHC collisions. Several methods are used for emittance measurements (wire scanner, BSRT and luminosity) and all methods present some limitations. Moreover measurements in the SPS and in the LHC are not synchronized and refer to different beams.

In the LHC, no emittance blowup due to injection mismatch was observed while an increase of 10% in 20 minutes was measured during the flat-bottom at 450 GeV (compatible with IBS but slightly faster). During the energy ramp a 20% blowup was measured for both beams in both planes. A possible source could be the fact that a reduced gain of the transfer feedback has to be used during the ramp but further investigation is needed. Finally an unexplained growth is measured only for Beam 1 in the horizontal plane when squeezing from 5 m to 1 m β*. An analogous behavior was found when operating with ions.

Several improvements in the instrumentation, measurement methods and data analysis is foreseen for 2012. An intense campaign of measurements will be performed to understand and eliminate the source of the emittance growth with a consequent potential performance gain of 20%.

Discussion

B. Holzer asked why no emittance blowup due to injection mismatched is observed even in presence of injection oscillations. V. Kain answered that injeciton oscillations are immediately damped by the transverse damper.

O. Bruning asked which parameters were used to calculate the emittance growth induced by the IBS scattering at 450 GeV. V. Kain answered that she used the parameters measured during operation.

S. Fartoukh asked if the fact the off momentum beta beating is worse in the horizontal plane for Beam 1 could explain the blowup during the squeeze. V. Kain answered that this is not clear especially because such effect is not present for Beam 2

S. Myers asked if any study was performed on the dependence of the emittance blowup on the bunch length. V. Kain replayed that this was not explicitly done; the fact that the blowup happened always at the same point of the squeeze seems to show that no direct dependence on the bunch length exists.

E. Todesco asked if the blowup at the beginning of the ramp could be explained by the snapback. V. Kain excluded this option since the blowup is continuous during the ramp. R. Assmann commented that the movement of the collimators during the ramp and the consequent change in impedance could have an effect on the emittance. To check that, he suggested to compare ramps with low and high intensity beams. This could be a crucial point for operation with tight collimator settings and high intensity beams.

G. Papotti proposed to make measurements with one additional non-colliding bunch since this would allow to distinguish between beam-beam effects and the natural emittance growth at flat top.