Feedback from the experiments on the 2017 run

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Abstract

This talk will cover feedback from the experiments on the 2017 run, including the high luminosity 13 TeV running, as well as the scheduled special runs that took place. It will include feedback on the 8b4e BCS scheme that was developed as a mitigation of the 16L2 issue observed during the 2017 run. In addition it will cover feedback on new operational features that were implemented for the first time in 2017, for example the RF full-detuning, crossing-angle anti-levelling, luminosity levelling, and the use of 30cm β* with ATS optics.

HIGH LUMINOSITY RUNNING IN 2017

2017 was a challenging, but ultimately very successful year for the LHC complex and the experiments, with most parts of the scheduled programme exceeding expectations. Figure 1 shows the delivered luminosity to the experiments as a function of time during the 2017 *pp* run. About 50 fb^{-1} of *pp* data at 13 TeV was delivered to ATLAS and CMS, with nearly 2 fb^{-1} delivered to LHCb and 19 pb^{-1} to ALICE, allowing a large number of searches for new physics, and physics measurements to be carried out. The luminosity production was effected by anomolous beam losses from cell 16L2, although the use of the 8b4e beam proved to be a successful mitigation for this, and gave good luminosity production, albeit with very high pileup.

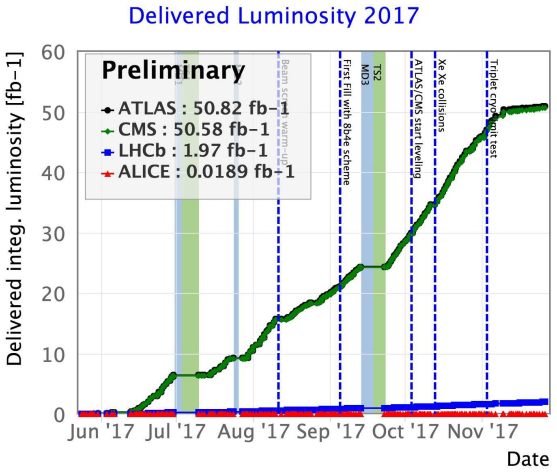

Figure 1: Luminosity delivered to the LHC experiments as a function of time during the 2017 *pp* run. The luminosity values are using a non-final offline calibration.

The high luminosity *pp* running benefited from an excellent availability with ≈50 % of the available physics time spent in stable beams. The year started with BCMS beam (2550 bunches), with which a peak luminosity of $\approx 1.75 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ was achieved. With the 8b4e beam (1960 bunches), a reduced β^* of 30cm and the reduced emittance BCS beam, the peak luminosity exceeded $2 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and the luminosity in ATLAS/CMS was levelled using beam separation to give a peak pileup of ≈60 (corresponding to $\approx 1.5 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$). This setup gave extremly good luminosity production with 25^{-1} delivered in the 7 weeks after TS2.

During regular high luminosity running the roman pot experiments CT-PPS (IP5) and AFP (IP1) were routinely inserted to 12σ+0.3mm from the beam. This did not cause any problems in terms of vacuum, impedence/heating, or beam losses. As in 2016 a bunch length levelling procedure was implemented to keep the average bunch length above 0.9 ns as requested by LHCb to reduce the pileup density during operation with their dipole in positive polarity. In contrast to 2016 running, no imbalance in the delivered luminosity to IP1 and IP5 was observed, with the luminosities agreeing within 1% (without final luminosity calibrations from the experiments).

NEW TOOLS USED IN 2017 RUNNING

During the 2017 run, new tools were commissioned and used, and feedback from the experiments related to these is given below. These tools were used to improve the performance in 2017, to prepare for HL-LHC, or to help mitigate the 16L2 problem.

RF full detuning

After a successful MD in 2016 the RF full detuning, which substantially reduces the power consumption of the RF system, and is the baseline for HL-LHC, was used in operation for all of 2017 running. The RF detuning introduces a small bunch-by-bunch modulation of the collision time in all IPs (by up to ≈100 ps), and the longitudinal collision position in IP2/8 (by up to ≈1 cm). Before running it was confirmed that these effects should not be problematic for the experiments, and indeed no adverse effects have been seen in 2017 running. The size of the modulation is measured and published in DIP, and the expectation can be seen in an LPC tool [1].

Changing the crossing angle in stable beams

Changing the crossing angle was successfully tested in MD in 2016, and shown to be able to give an increase of ≈4% in integrated luminosity for 2017 running scenarios. Before the 2017 run detailed discussions were held with the experiments to ensure that the operational changing of the crossing angle during stable beams would be acceptable

in terms of detector safety. This was then introduced into operations first in 'adjust' and then in stable beams, with no problems observed. For CT-PPS whose physics acceptance depends on the crossing angle, they requested that only a small set of crossing angles should be used in operations, but since then they have confirmed that many angles can be used for 2018 running, as they can now interpolate the effect in the data analysis.

ATS optics

The initially proposed ATS optics degraded the physics of CT-PPS, and a large effort from the optics experts was carried out to improve this situation. By adding an extra squeeze segment it was found to be able to achieve a similar CT-PPS acceptance as in 2016. No other issues were observed due to the use of ATS in 2017 running.

β^* of 30cm

Although the expriments were not pushing for reducing the β* during the 2017 run, this was done after TS2 with no problems observed. Commissioning of this change was done very quickly (as estimated by OP beforehand, and benefitting from some pre-commisisoning during the initial setup of the 2017 run), and gave a nice increase in the luminosity (coupled with the use of a more aggresive crossing angle). No drop in operational efficiency was observed due to the lower β*.

Separation levelling

Levelling the luminosity in ATLAS/CMS by beam separataion (as done in ALICE and LHCb since the start of the LHC) was tried in two test fills in 2016. Due to the high pileup from 8b4e BCS beam this was required to be used in physics operations in 2017. After some small teething problems related to getting the optimal parameters for the levelling, this worked flawlessly during 2017 running. Separation levelling to very low pileup values ($\mu \approx$1-3) was used in ATLAS/CMS at the end of the 2017 run, and again no problems were observed in this configuration.

8b4e and BCS beam

8b4e BCS beam was used after TS2 and produced very high luminosity. Such beam is not favoured in future running, as this reduces the possible number of colliding bunches and therefore increases the pileup substantially for the same luminosity. On the other hand as a mitigation for the 16L2 problems, this worked extremely well due to a large reduction of electron-cloud effects, and saved the year in terms of luminosity production for ATLAS/CMS. It should be noted that LHCb particularly suffer with this scheme as the number of bunches is much reduced and they level to a fixed pileup.

SPECIAL RUNS

Due to the problems with 16L2 a number of special runs planned for 2018 were advanced to happen in 2017, along with those originally planned for 2017 running. Below these runs are discussed.

van der Meer scans

The van der Meer scan programme went well. After a number of years this has been well optimized, and it is expected that precise luminosity calibrations should become available from the analysis of this data. One complication was introduced due to the absence of a crossing angle in this years vdM injection optics which led to long range encounters and subsequent blow-up of the beam with the original filling scheme. For the future, having a crossing angle re-introduced at injection would allow the vdM fills to be more useful for parasitic studies needing additional bunches.

Xe pilot physics run

One shift of Xe-Xe collisions was carried out, which combined with some MD efficiently provided an interesting physics dataset at little cost. This demonstrates the flexibility of the LHC machine, and bodes well for potential running with other ion species in the future, if requested by the experiments.

5 TeV run

5 TeV pp data is needed as a reference for Pb-Pb collisions at the same collision energy per nucleon. Such data was requested by ATLAS/CMS and ALICE, but the length of time for the run was dominated by the ALICE request, due to their lower readout rate. The LHCC had recommended this run should be for 11 days, which would be enough time to satisfy the ALICE request given excellent availability. The setup was well planned, and optimized to satisfy the ALICE request (as much as possible) in the given time, while also satisfying the other requests. A modest β^* (3.1m in IP1/5/8 and 10m in IP2) was used, which allowed all of the squeeze to happen during the ramp, and for the first time the fast ramp (PLPP) was used for physics. The run proceeded very well, with long fills and extremely high machine availability allowing all requests to be satisfied with a day to spare.

900 GeV high β^* run

A run to measure the total cross section and ρ parameter using elastic scattering at low energy was requested by ATLAS(ALFA) and TOTEM. Such a run is challenging and detailed discussion about the energy and β^* between the experiments and machine experts led to a configuration with energy of 900 GeV, and a β^* value between 50 and 100 (different in IP1/5 and in the H/V planes). The optics was validated in dedicated test fills, and shown to be good for physics, and could be be directly injected into. However further tests showed a large beam background in the roman pot detectors which was too large to allow a precision physics measurement. A number of different collimator settings were tested to control the beam background

but no good configuration could be found within the limited time available. Such a run may be requested in 2018, where more time to would be available to study the available data and to come up with a strategy to control the beam background.

Low-pileup run

At the end of the physics run, a few days of low-pileup running at 13 TeV were schedule, to replace the low energy high β^* run. This had the advantage of allowing cool down of the detector, allowing long fills to effectivly increase the LHCb luminosity, and provided an important dataset for W-boson physics for ATLAS and CMS. For this run luminosity levelling by separation was used to give a μ value of 1-3 in ATLAS/CMS with the usual levelling in IP2/8. No instabilities were observed due to beam separation at all IPs. Excellent availability and long fills, allowed a substantial dataset to be collected in the scheduled time, which was much appreciated by the experiments.

SUMMARY

2017 was a very good year for the LHC experiments, despite the 16L2 problems, with the machine performing very well, and with excellent availability. A number of important new tools were used in operations during the year, and no problems were observed due to these. In addition to the usual 13 TeV running special runs were successfully carried out, in particular a run at 5 TeV energy, and a low-pileup run. Commissioning of a low-energy high β^* run was carried out, althouhg the physicas run was postponed due to too large beam backgrounds, and this may be requetsed in the future. The experiments would like to thank all of the relevant groups for the successful physics run in 2017.

ACKNOWLEDGMENT

We wish to thank in particular the Run Coordinators of ALICE, ATLAS, CMS, LHCb and TOTEM for their essential input as well as our colleagues working on the LHC and injectors operations for countless explanations and discussions about machine parameters and constraints.

REFERENCES

[1] C. Schwick, https://lpc.web.cern.ch/SchemeEditor.htm