SUMMARY OF SESSION 5 ON ION OPERATION DURING HL-LHC

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Abstract

The session goal was to review the LHC upgrade plans related to the ion operation and to discuss the related machine updates for LHC RunII and RunIII and during the HL-LHC operation period.

INTRODUCTION

The session discussed machine upgrade plans particularly relevant for the ion operation during the HL-LHC operation period and had a look at options for extended ion runs during the LINAC4 connection to the PSB. In this context the session reviewed the current baseline ion operation schedule of one month of dedicated ion run per year and discussed alternative operation options for the ion beam operation. The session featured 5 talks covering the topics of:

1) The Experiments perspective by Emilio Meschi;
2) The performance projections of the LHC injector complex with ion beams by Django Manglunki;
3) Options for running the LHC with ions during the LINAC4 connection by Jean-Babtist Lallement (most of this presentation was already addressed in the previous session);
4) Options for running the source and Linac3 with ion beams in the future by Detlef Kuchler;
5) Future heavy-ion performance projections of the LHC after LS1 by John Jowett.

EXPERIMENTS PERSPECTIVE

The experiments perspective talk first discussed the physics highlights of the LHC RunI operation (Quark-Gluon plasma measurement and Jet suppression in p-Pb collisions). The presentation highlighted the need for regular 'control experiments' (e.g. p-p data taking and p-Pb runs at intermediate beam energies [e.g. Pb-Pb @ 5 TeV and 5.5 TeV and p-Pb at 5 TeV and 8.2 TeV]) in addition to the core ion schedule and the implied configuration changes for the asymmetric p-Pb collision (requiring additional workload and schedule time for the machine operation) and a regular polarity reversal for the ALICE spectrometer magnet. The p-p data taking at ALICE during the LHC RunII operation requires 5 orders of magnitudes lower luminosities as compared to the General Purpose (GP) experiments ATLAS and CMS which might imply additional operational challenges as compared to the LHC RunI period. Furthermore, for background reduction, ALICE requires a vacuum of 10^{-9} mbar or better which might be challenging to achieve during RunII with the 25ns bunch spacing and its associated electron cloud activities.

The ALICE RunII wish list consists of:

- 2015: Operation with p-p collision for minimum bias measurements over a period of about 24 weeks with a luminosity between 10^{29} and 10^{30} cm^{-2} s^{-1} and Pb-Pb collisions for 4 weeks with a levelled target luminosity of 10^{27} cm^{-2} s^{-1}.
- 2016: Operation with p-p collisions for rare triggers over a period of about 24 weeks with a luminosity of 5-10 10^{30} cm^{-2} s^{-1} plus a 4-week dedicated data taking run with Pb-Pb collisions and a levelled luminosity of 10^{27} cm^{-2} s^{-1}.
- 2017: Operation with p-p collisions over a period of about 24 weeks with a luminosity of 5-10 10^{30} cm^{-2} s^{-1} plus a 4-week dedicated data taking with p-Pb with a levelled luminosity of 5-10 10^{27} cm^{-2} s^{-1}.

The ATLAS experiment would like to accumulate an integrated luminosity of 3 nb^{-1} by LS3 and all experiments would like to collect at least 1 nb^{-1} by LS2. ALICE will undergo a major detector upgrade during LS2 and aims at a total integrated luminosity of 10 nb^{-1} after LS2. ALICE will require a levelled luminosity for both Pb-Pb and p-Pb operation while ATLAS and CMS will not and LHCb would like to have the p-Pb operation ***not*** scheduled at the end of the LHC RunII period, which is currently the baseline scheduling for the ALICE experiment.

All experiments look at the operation with different ion species (e.g. Pb-Pb, p-Pb, Ar-Ar and p-Ar) after LS2 (there is even an expression of interest in the operation with N and O beams by LHCf but the physics case still needs to be approved by the LHCC) and all experiments prefer a regular annual running with ions beams and are ***not*** in favour of an extended ion run as part of an extended technical stop for the LINAC4 connection with reduced ion operation after the LINAC4 connection.

PERFORMANCE OF THE INJECTORS WITH IONS AFTER LS1

The presentation on the LHC injector complex operation with ion beams started with a summary of the injector performance with ions during the LHC Run1 period. During RunI, the injectors prepared 2 bunches with 200ns spacing in the PS, injected 24 ion bunches per SPS cycle and prepared a total of 360 bunches per beam for collisions in the LHC. An increase of the bunch intensity for operation after LS1 will not be trivial as the RunI intensities were already at the limit of IBS (in the SPS) and luminosity burn-off rates would probably demand leveling. Increasing the number of PS injections into the SPS is also not favored due to the required increase in the SPS injection plateau and the associated additional beam emittance blow-up.

However, a 100ns batch compression in the SPS could already be envisaged for RunII (already planned for the PS but without the required SPS injection upgrade) leading to a maximum of 432 colliding bunches per beam in the LHC.

An upgrade of the SPS injection system could increase the number of colliding bunches in the LHC from 432 to 624 bunches. Higher bunch intensities in LEIR (which was already operating above design intensities during RunI) would require further studies before operation for the LHC.

The implementation of Slip stacking in the SPS could lead to even smaller bunch spacing, e.g. 50ns. In all cases it is necessary to operate LINAC3 at 10Hz (the LINAC3 source is already pulsing with 10Hz).

HOW TO RUN IONS IN THE FUTURE

Detlef Kuchler summarized the operational records and normal operational performance of the source and Linac3 operation during LHC RunI and highlighted the plans for upgrading Linac3 to 10Hz rep-rate. Further upgrade plans include the option for multi charge acceleration, the re-design of the oven, allowing for longer operation time between two oven refills (the optimum goal would be to achieve an oven fill length in excess of 4 weeks), and the development of a dedicated source test stand for a continuous performance improving developments.

The presentation further highlighted the wish for dedicated ion runs in 2015 for machine developments and tests.

FUTURE HEAVY-ION PERFORMANCE OF THE LHC

The presentation highlighted the need for detailed bunch-by-bunch modelling (IBS blow up at SPS and LHC injection plateaus) for the estimating the luminosity evolution and maximizing the performance in the LHC. John Jowett estimates that performance levels of 2.8 10^{27} cm^{-2} s^{-1} and 3.7 10^{27} cm^{-2} s^{-1} are within reach for ATLAS and CMS with the 2011 bunch pattern and the new 100ns bunch spacing scheme respectively. The luminosity in the ALICE detector needs to be levelled at 10^{27} cm^{-2} s^{-1} before the ALICE detector upgrade is completed during LS2.

The luminosity decay in RunII will be dominated by burn-off due to the beam collisions at the Interaction Points.

The estimated performance for asymmetric p-Pb collisions is estimated to be between 2.5 – 7 10^{29} cm^{-2} s^{-1} and 4.3 – 12 10^{29} cm^{-2} s^{-1} for operation at 4 ZTeV/c and 7 ZTeV/c respectively.

Performance levels of 6 10^{27} cm^{-2} s^{-1} are within reach for Pb-Pb operation after LS2. This value would correspond to 6 times the original design performance. The performance after LS2 will be limited by losses in the cold sections of the LHC due to Bound Free Pair Production and Electromagnetic dissociation and the emittance blow up due to IBS. The first limitation can be mitigated by the installation of additional collimators in the cold section of the dispersion suppressors (formerly called ‘cryo collimators’) or, in the case of ATLAS and CMS (less easily for ALICE), by a technique of orbit bumps that was demonstrated in 2011 for CMS.

Discussion and Conclusions

The general discussion identified the following key observations:

- ALICE highlighted the need for regularly scheduled dedicated ion operation periods on an annual base during each LHC run period and expressed the wish for a clear commitment to a ‘standard running scenario’.
- The LS2 duration with LINAC4 connection as H-injector is estimated to take 20.5 month.
- The experiments have no interest in a long dedicated ion run during an extended technical stop for the LINAC4 connection to the PSB before LS2.
- While dispersion-suppressor collimators are foreseen for installation in IR2 during LS2, these additional collimators are not yet foreseen in the baseline LS3 upgrade plan for IR1 and IR5. Should it turn out that losses from bound free pair production limit the peak Pb-Pb luminosity during Run III, the luminosity during the initial part of a fill may have to be levelled at a lower value in the ATLAS and CMS experiments as compared to ALICE. However this appears increasingly unlikely given the recent optimistic estimates of quench levels and the successful demonstration of a mitigation technique in 2011. The impact on integrated luminosity should be modest.
- Levelling the RunII Pb-Pb luminosity differently in each experiment may have to become the default way of operation.