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PLANS FOR THE UPGRADE OF CERN'S HEAVY ION COMPLEX

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LHC Injectors Upgrade

MOTIVATION

In the wake of the first two successful Pb-Pb runs in the LHC, the ALICE experiment has proposed a detector upgrade for the exploitation period following LS2. A peak luminosity exceeding 6×10^{27} Hz/cm^2 for Pb-Pb collisions is expected in order to fulfil the goal of 10 nb^{-1} integrated luminosity by the mid-2020's.

Without discussing the limitations on luminosity that will occur in the LHC, we propose a realistic baseline strategy for the injectors to achieve this ambitious goal, as well as alternative scenarios, whose feasibility will need to be studied on paper and demonstrated experimentally. A series of measures will have to be taken in the whole ion injector chain: Linac3, the Low Energy Ion Ring (LEIR), the Proton Synchrotron (PS) and the Super Proton Synchrotron (SPS).

This work is an integral part of the more general LHC Injector Upgrade (LIU) project. See THPWO077

PRESENT LIMITATIONS

The last LHC Pb-Pb run took place in 2011. With up to 358 bunches of 1.2×10^8 Pb^{82+} at 3.5 ZTeV per LHC ring, and an average spacing of 200 ns, a peak luminosity of 5×10^{26} Hz/cm^2 was obtained. Since then, during the p-Pb run, the average bunch intensity delivered by the injectors has increased, to reach 1.44×10^8 in the collider. Assuming the same performance, and scaling with the square of the energy – taking into account the adiabatic emittance shrinkage and the resulting smaller achievable β^* –, one can expect a peak luminosity of the order of 3×10^{27} Hz/cm^2 at 7 ZTeV, still a factor two below the requirements.

- The intensity per bunch, already twice the design, is a source of space charge detuning and Intra-Beam Scattering (IBS). It is therefore difficult to imagine increasing it even more in the SPS and the LHC due to their long injection flat bottoms, where RF noise also plays a detrimental role. At best one can hope to mitigate these effects.

☞ A lower tune optics, "Q20", has been implemented in the SPS, making the beam less sensitive to IBS and decreasing the space charge detuning thanks to larger transverse beam dimensions. Its drawback is a less favourable kick enhancement at injection. See TUPME046

☞ The elimination of RF noise hand has already been the subject of an extensive campaign, still ongoing.

- The number of bunches, linked to the average bunch spacing, is currently limited by:

☞ The intensity delivered by LEIR, which presently slightly exceeds the design values, but without a further splitting in the PS. This allows to deliver twice the intensity per bunch at the expense of the number of bunches.

☞ The maximum number of injections into the SPS, currently 15.

☞ The rise time of the injection kickers of the SPS (200 ns in 2011, but 225 ns with the "Q20" optics) and of the LHC (900 ns), and the length of the LHC abort gap (3.3 ms).

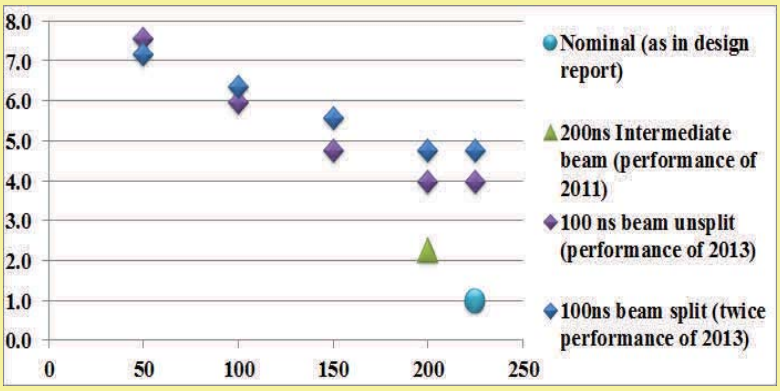
- Assuming the number of injections into the SPS can be increased to 24, which will be the case after this first long shutdown (LS1), and that the rise time of its injection kicker decreased, we estimate the peak luminosity in two cases:

☞ Keeping the current performance of the injectors, but replacing the current batch expansion to 200 ns by a batch compression to 100 ns.

☞ Doubling the current performance of the injectors, and supplementing the batch expansion to 200 ns by a splitting into 4 bunches spaced by 100 ns.

The results are plotted below, as a function of the SPS injection kicker rise time. The performance of the nominal beam foreseen in the design report , and of the 3.5Z TeV "Intermediate" beam used in 2011 scaled with energy squared, are included for reference.

CHOICE OF BASELINE SCENARIO



Expected peak luminosity (10^{27} Hz/cm^2) at 7 ZTeV, with respect to batch spacing in the SPS (ns).

UPGRADES AND STUDIES NEEDED

Linac3

Improve dignostics; increase the number of ions accelerated per pulse:

☞ Emittance measurement device and correct the matching in the LEBT.
☞ Increase repetition rate from 5 to 10 Hz.
☞ Multiple charge acceleration

LEIR

☞ Implement more robust diagnostics (Schottky signals, and BIPM)
☞ Identify the cause for the loss; cure or mitigate it.
☞ Add beam dump in the extraction transfer line

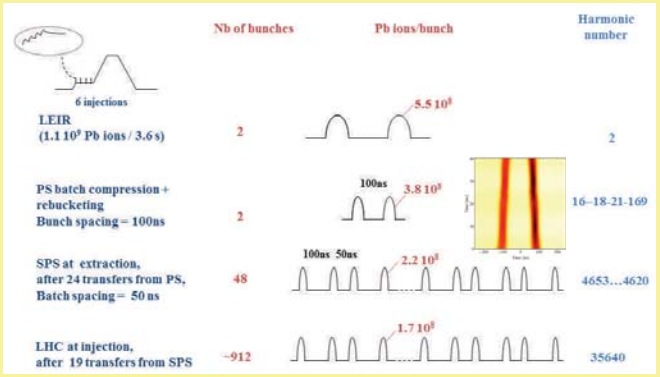
PS

☞ Operationally implement the batch compression low –level hardware.
☞ Study ways of achieving a splitting into 4 bunches spaced by 50ns, either using fast γ_t-jump optics, or acceleration hardware on 20 MHz.

SPS

☞ 50 ns rise-time ion injection system in the SPS See MOPFI052
☞ Switch from fixed harmonic to fixed frequency
☞ RF noise

BASELINE SCENARIO



ALTERNATE SCENARIOS

☞ To be tested in 2015: batch compression to 100 ns in the PS, 24 injections in the SPS, injection kicker rise time of 225 ns (Luminosity of 4×10^{27} Hz/cm^2 ?)
☞ If the intensity per bunch can be doubled, re-introducing a splitting stage in the PS can be envisaged: 4 bunches spaced by 100 ns.
☞ Splitting to 50 ns would allow squeezing up to 1400 bunches per LHC ring, but not with current hardware:
. The 20 MHz cavity cannot accelerate the beam.
. At 5.9 GeV/u, the beam is too close to transition, making splitting impossible

CONCLUSIONS and OUTLOOK

☞ In light of the performance achieved during the 2013 p-Pb run, scaling with the energy squared, a peak luminosity of 4×10^{27} Hz/cm^2 at 7 ZTeV is well within reach. However, to ensure 6×10^{27} Hz/cm^2 or more as requested by the experiments after LS2, several upgrades will need to be implemented in the injector chain, expensive both in terms of money and manpower.

☞ The proposed baseline filling scheme consists of an alternating 100 ns and 50 ns bunch spacing, yielding up to 912 bunches of 1.5×10^8 Pb^{82+} ions per LHC ring in collision. The main ingredients will be batch compression in the PS, and a new 50 ns rise-time injection system in the SPS.

☞ Alternate schemes are under study, which would need doubling the bunch intensity in LEIR, and an additional bunch splitting in the PS.