STATUS AND PLANNING OF THE "PS IONS FOR LHC" PROJECT

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Abstract

The overall modifications of the PS complex (Linac3, Lear, PS) to produce the LHC ion beams will be described. While the main emphasis will be put on lead, some considerations will be given on the other ion species which are or can be requested in the future. The status of the project and the planning of the conversion and commissioning will be discussed.

1 INTRODUCTION

To reach the desired luminosity for the lead experiments in LHC the required number of ions is $0.7x10^8$/bunch at 2.7 TeV/nucleon in normalised emittances (1 σ) smaller than 1.5µm. The emittance budget has been settled to 1.2µm at the exit of the SPS, 1 µm at the end of the stripper in TT2 line and 0.7µm at the exit of LEAR. To fulfil this request, it has been proposed to add an accumulator ring to the present lead source [1](fig. 1). For the future an improved ECR Ion Source (from 100µA to 300µA of Pb^{27+}) is foreseen to fed the Linac3 pulsing at up to 10Hz. At the end of the Linac3 a first stripping takes place to obtain a beam of Pb^{54+} (~60µA, 450µs). In LEAR a combined longitudinal-transverse multiturn injection is performed. About $5x10^8$ ions are then cooled and stacked per injection. Further injections followed by cooling and stacking take place until the number of ions required is reached. To obtain fast cooling and stacking, the electron cooling device has an interaction length of 3m and a current of up to 600mA. To avoid the losses by charge-exchange with the residual gas the vacuum has to be very good and particularly the outgassing of the chamber walls by the lost ions has to be reduced. The improvements foreseen on the source, on the injection efficiency, on the vacuum in LEIR and on the cooling and stacking efficiency contribute to the objective of reaching the large of number of ions per bunch in the small emittance and in a time as short as possible. The beam is then accelerated and extracted toward the PS, where the 4 bunches are captured by an rf-voltage at harmonic 32. The transfer energy chosen

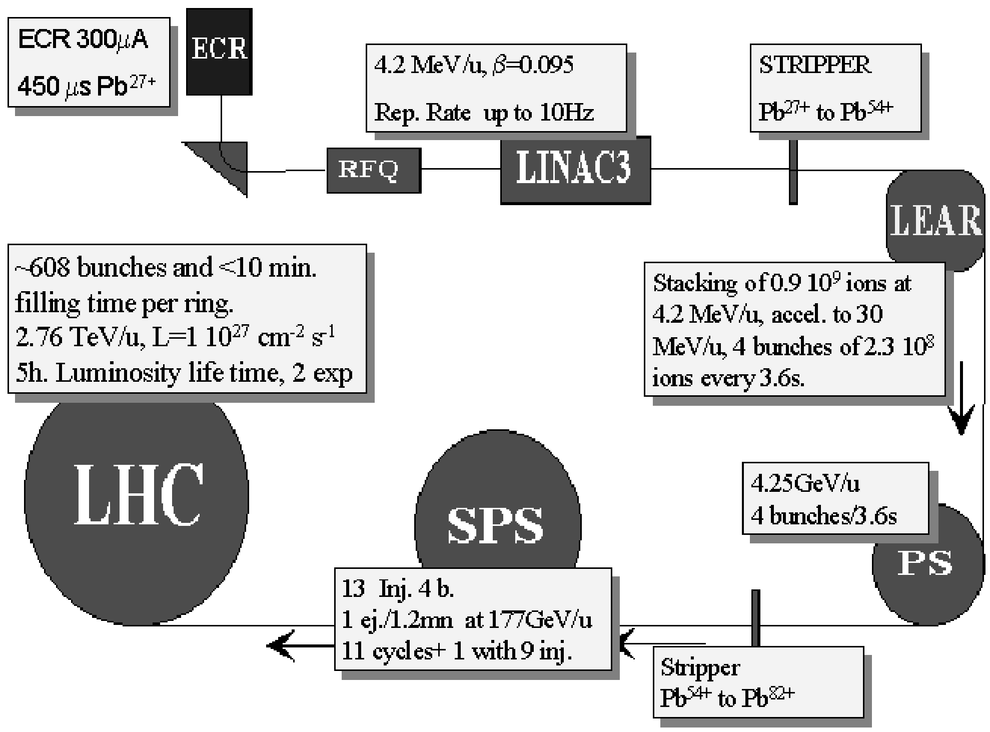

Figure 1: The LHC filling scheme with ions.

is a compromise between the limitation by the space charge at the PS injection($\Delta Q_{incoherent}$<0.25), the gap needed between two consecutive bunches for the rise of the extraction kicker(120ns), the cycle length and the minimum frequency available with the basic PS rf-system. After acceleration to 250 MeV/n, the bunches are gradually transferred from h=32 to h=17 in order to reach the 125ns bunch spacing in LHC. The beam is then further accelerated to 4.25GeV/n and extracted toward the TT2 line where the ions will be fully stripped. In the SPS several batches of the PS are stacked, then accelerated and extracted to the LHC at 177GeV/c. This procedure is repeated until the two rings are filled with 608 bunches each. The filling time of each ring will take about 10mn.

2 THE MAIN CHALLENGES

2.1 Linac3

The ECR ion source has to be improved. A European collaboration[2] has already shown that increasing the plasma heating frequency from 14GHz to 28GHz is the right way when the source is used in continuous mode. Tests are under way for the after glow pulse mode.

2.2 LEIR injection

The electron cooling is more efficient in the longitudinal plane than in the transverse ones. Thus a combined longitudinal horizontal injection has been proposed as it limits the transverse emittance to a reasonable value compared to the normal multiturn injection. It requires an increase of the momentum during the linac3 pulse (done by a special cavity at the end of the Linac3), a zero dispersion at the end of the line to avoid the position change of the beam, a normalised dispersion $D/\beta^{1/2}$ of more than $5m^{1/2}$ to limit the momentum spread injected and a not too large dispersion (~10m) in the machine at the injection point. Furthermore an inclined septum is foreseen to permit an improved injection efficiency (>50%) by exploiting also the vertical phase space for stacking.

2.3 LEIR Electron Cooling

The electron cooling should provide a cooling time of 0.1s for Lead ions. This could be achievable with an electron current of 0.6 A, an e-beam radius of 30mm and an interaction length of 3m. The cathode will be convex to increase the perveance to about 5µP, the gun will be immersed in a large solenoid field (up to 0.6 T). Finally an adiabatic field reduction (to 0.075 T) will be inserted between the gun and the interaction part to increase the electron beam radius to 35mm and to reduce the transverse electron temperature which could improve the cooling time. Although a small dispersion at the cooler is favourable [3] for efficient cooling, zero dispersion at the electron cooler is preferred to ease the operation. Transverse beta functions of about 5m are chosen at the cooler

2.4 The lattice

To keep symmetry 2 to the machine, injection and cooling are in two consecutive sections, The extraction is in the section where the dispersion is null. To obtain the Twiss parameter goal defined above a triplet (figure 2 and 3) instead of a simple doublet is needed in the electron cooling section.

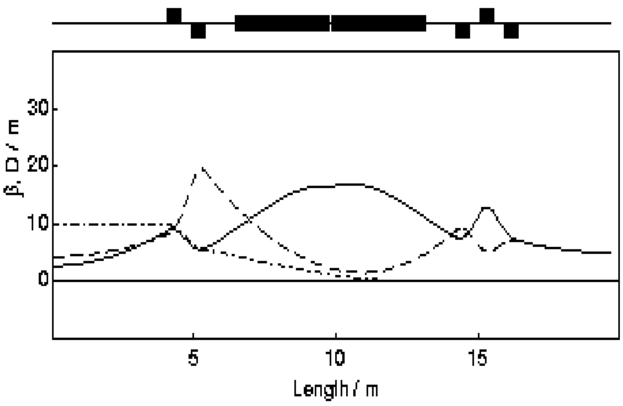

Figure 2: The LEIR lattice. One half of a period (i.e. a quarter of the machine) extending from injection to the centre of the cooler is shown

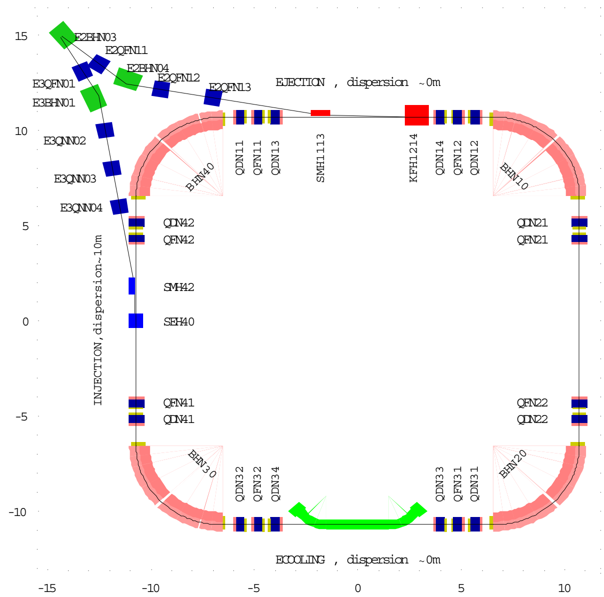

Figure 3: The main elements of the LEIR machine.

2.5 The vacuum

During the tests in 1997, it was found that the losse of ions on the vacuum chamber walls provokes an outgassing [3,4] which has been estimated from measurements (at injection energy) to about 10^5

molecules per ion lost. The lifetime of the circulating beam is then decreased and this limits the number of ions which can be accumulated in the machine. Tests using the beam of the Linac3 have been launched to find the best vacuum chamber treatment to decrease this limiting phenomenon.

2.6 The PS and TT2 line

The change of the injection elements, the RF manipulation described above and the bunch compression are the ingredients foreseen in the PS. In the TT2 line a low β insertion has to be added around the stripper[5]. A solution(4 new quadrupoles and 6 power supplies) has been found which permits to reduce the actual measured emittance growth by a factor 4 which nevertheless leads to a 0.2µm emittance increase. This value is evaluated assuming that the coherent energy and the mismatch occurring in the stripper are corrected downstream the line. This will require long MD program to establish the matching of the line to the SPS.

3 THE OTHER IONS

The Alice experiment has also asked for ions lighter than lead. Intensity limits for the LHC have been established by D. Brandt [6] (Table 1). However the PS complex has difficulties to provide this intensity due to severe space charge limitations when working with 4 bunches per PS batch as in the case of lead. It is only possible to reach the LHC-limits by reducing the number of bunches per PS-batch but then the filling time becomes longer. As an example, the filling time becomes 40 min. for oxygen in the one bunch mode required to reach this limit. **We think that the limitations in the complete(PS and SPS) injector chain have to be analysed before any final decisions are taken**. The deuteron request heavily interferes with the protons operation of Linac2. We propose to replace the deuteron by Helium, which can be furnished by the Linac3.

4 PLANNING

The assumptions are the following:

- There will be an ion run in 2007 and the lead ion beam should be ready for tests in LHC end 2006.
- The project will be financed from 2002 onwards.

The established preliminary planning shows that the LEIR commissioning can be done end 2003 and beginning 2004 will lead ions, the PS commissioning in 2004-2005 and the SPS in 2005-2006. Other ions are only foreseen in 2009.

Table 1: Ions required for LHC. The PS space charge limits are computed assuming a transfer of 4 bunches from LEIR at Bρ=4.5Tm(1.4GeV/c proton equivalent). Stripping has been applied at the exit of the Linac3.

ION / ion ch. state	"required" PS ions/bunch	space-charge limit in PS ions/bunch	ratio: obtainable/ required	bunch length [m]
Pb(82) / 54+	2.3E8	4E8	1.7	~9
In(49) / 37+	7.0E8	4.5E8	0.6	~8
Kr (36) / 29+	1.1E9	5.5E8	0.5	~8
Ar (18) / 16+	3.6E9	8.6E8	0.25	~8
O(8) / 8+	1.7E10	1.4E9	0.08	~8
He or (d)	2.5E10?	5.5E9	0.2 ?	~8

5 CONCLUSION

The scheme for the Lead ions is now well established. The main challenges are efficient electron cooling, the space charge limits, the vacuum quality, and the emittance conservation (as for protons but with the stripping in addition) through the entire injector chain. For all ions requested by Alice the limitations in the SPS have to be checked.

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[4] N. Madsen, “Vacuum changes during accumulation of Pb54+ in LEIR”,PS/DI Note 99-21

[5] M. Martini, D. Möhl, A.S. Müller, to be published

[6] D. Brandt, “Review of the LHC Ion programme”, LHC Project Report 450. See also LEMIC 42, PLC 59 and 60