EXPERIENCE WITH THE GTS-LHC ION SOURCE

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Abstract

For the heavy ion programme of the LHC a new ECRIS type heavy ion source had to be designed and built for Linac3 to fullfill the intensity requirements. Experience acquired during the installation and commissioning of the source and during operation for the LEIR ring commissioning will be presented. The performance of the source and its reliability are evaluated. Further requirements for high reliability, low down time, easy maintenance and for future physics needs will be discussed.

SOURCE UPGRADING

Experiments to prove the feasibility of stacking and electron cooling of highly charged ions in the LEAR ring were successful. Phase space stacking in three planes in the ring together with electron cooling were performed. At a 2.5 Hz stacking rate at least 25% of the required number of ions per PS pulse could be accumulated in the ring [1]. Vacuum limits the accumulation. By doubling the injection rate to 5 Hz, doubling the source current and improving the LEIR dynamic vacuum, the desired number of ions per injection should be achieved [2].

An upgrade of the present CERN ECRIS was needed. A collaboration had been set up under the European Union Framework 5 research programme [3] to study scaling in ECRIS and to try to understand the parameters affecting source performance. It was felt that by increasing the frequency to 18 GHz, by accelerating Pb^{25+}, by studying and eliminating possible bottlenecks in the Linac, and by tuning to peak performance on demand rather than stability (LHC filling will be programmed) the desired number of ions could be produced. This initial scenario was pursued, in spite of some doubts being expressed as to the adequacy of the radial confinement provided by the hexapole. From the observation that the longitudinal fields used in the 14.5 GHz ECR4 in optimised afterglow mode were weaker than those expected from CW operation, it was felt that a weaker radial confinement could be an advantage.

During 2003 information became available on a prototype ECRIS that had demonstrated 200 eμA of Bi^{24+} in afterglow mode at 14.5 GHz with moderate RF power [4]. This source, the Grenoble Test Source (GTS) [5, 6], uses a modified minimum-B configuration optimised to obtain a better compromise between plasma confinement and ion losses. The principles of this optimisation were one of the spin-offs of the Innovative ECRIS collaboration [3]. This source could be adapted into the existing infrastructure in the Ion Linac building with a minimum of expenditure and modification. The final design of the source includes the possibility of an upgrade to 18 GHz or to 14+18 GHz with only very minor modifications. Two medium temperature ovens designed and constructed in collaboration with GSI are installed in the source (another spin-off of “Innovative ECRIS”). Overall, the cost of this upgrade will fall within the budget envelope defined for the earlier ideas. Additionally the source could be commissioned within the current timetable of the LHC project. Figure 1 shows the source in the present state.

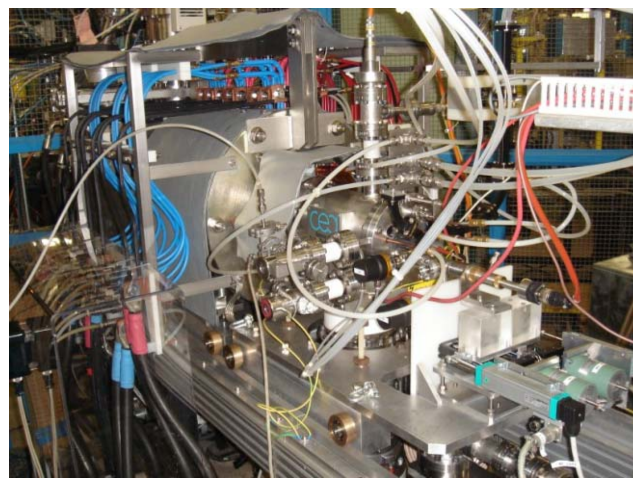

Figure 1: Picture of the GTS-LHC source.

CONSTRUCTION AND INSTALLATION

Restrictions placed on manpower due to the LHC construction programme meant that CERN had no resources to build a GTS source in-house. Thus, the decision was taken at the end of 2003 to purchase a customised version from CEA-Grenoble. During the tendering process CEA announced its intention to close its ion source service but arrangements could be made to allow the source to be built by them.

Final delivery took place in January 2005 when installation could begin. The source was measured out to establish alignment references and presented to its rail system. From this point onwards the cabling and provision of services to the source could be pursued. Thermal problems arose with the coils which limited the current to 1000A instead of 1250A. By increasing the water pressure to 19 bar, it proved possible to make the initial controls of the magnetic field alignment and polarities. An auxiliary heat exchanger was eventually required to reach nominal current, reliably, for operation.

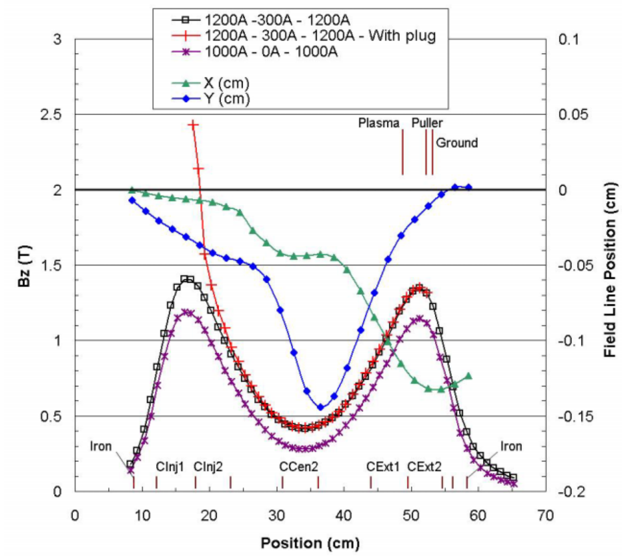

Figure 2: Magnetic field measurements in the plasma chamber of the GTS-LHC ECRIS. X and Y are the deviations from the geometric axis (scale at right).

The longitudinal field is established using the now popular three coil configuration with the central coil giving a bucking field to trim B_{min} between the two main coils. A ferromagnetic plug closes the field lines at the injection side of the source. Figure 2 shows the magnetic fields measured on the source axis for three configurations of the field. The right hand axis shows the deviation of the central field line from the mechanical axis of the plasma chamber.

This deviation of the magnetic axis was considered acceptable and the installation of the final vacuum components and infrastructure could be completed before putting the source under vacuum.

INITIAL COMMISSIONING

It had been decided to provide LEIR commissioning with beams of O^{4+}, which has nearly the same q/m as Pb^{54+}, should be easier to produce at reasonable intensities and would avoid the use of the stripper which, in any case, would give a beam of O^{8+} with some O^{7+}. This also required an extraction voltage of 10 kV to match the injection energy of the RFQ (2.5 keV/u).

The source was first set up with Oxygen at 20 kV with optimization of O^{4+} (quasi afterglow, 300 eμA) and O^{6+} (afterglow 610 eμA, normal pulse 350 eμA). This was followed by Ar^{8+} (afterglow 400 eμA) and Ar^{12+} (afterglow 50 eμA), and was finally followed by O^{4+} at 10 kV extraction, CW microwave and pulsed biased disk. It was necessary to reduce the extraction gap to overcome, partially, large transmission losses of this beam through the linac. It was noted that a high potential on the biased disk reduced the linac transmission whilst giving some increase in current. This was probably the result of emittance blow up caused by the biased disk. However, this beam was used to commission the transfer line into LEIR and the LEIR ring itself, and the images on their scintillator screen confirmed the very non-linear density distribution hinted at in some measurements at lower energies [7]. Of 300 eμA out of the source, 120 eμA was transmitted through the RFQ and 70 eμA passed the linac.

Various problems arose. Firstly, a wall thickness problem in the water cooled plasma chamber caused it to collapse. A rebuilt chamber with thicker walls was needed. Secondly, quality problems with the demineralised water resulted in partial choking of the coil pancake cooling channels with copper oxide, which gave rise to thermal problems. A wash with sulfamic acid and an improvement in water quality has eliminated this problem.

COMMISSIONING WITH LEAD

Following the Oxygen tests, the back of the source containing the Lead oven and its associated pumping system was installed. This enabled the commissioning of the Lead beams to start.

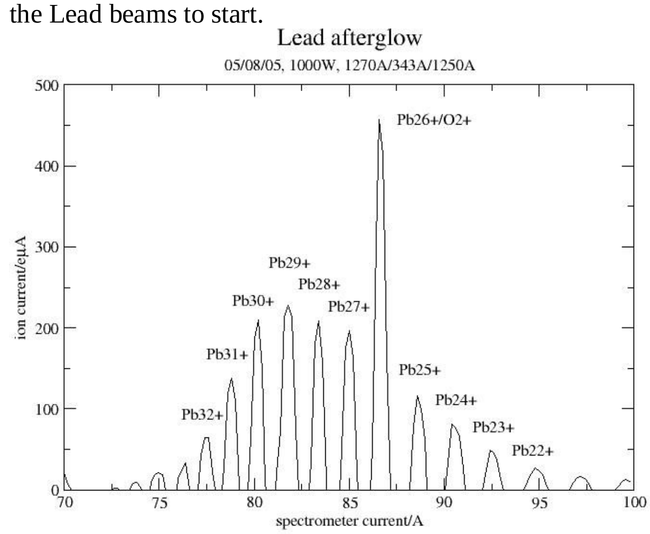

Figure 1: Lead charge state distribution from GTS-LHC.

Fairly quickly it was possible to reproduce the Pb^{27+} performance of the ECR4 source, namely around 100 eμA into the RFQ. It was possible to increase this to around 200 eμA which would be the objective for the project (50 eμA Pb^{54+} out of the Linac). Unfortunately, this beam was extremely difficult to stabilise.

During these tests a preliminary estimate of lead consumption was ~1.2 mg/hour (compared to 0.3 mg/h for ECR4). The tests were abruptly stopped by a series of vacuum problems which have been tracked down to badly toleranced ‘O’ rings and grooves on the plasma chamber near the extraction. It is possible that this problem could be the source of the instabilities.

FUTURE PROSPECTS

The commissioning of what is virtually a completely new source has proved more onerous than anticipated. As with any new device, technological problems have abounded, with only the most important mentioned above. Even so, it is necessary to prepare for the running in of the Ions for LHC injectors and for this it is now intended to use the following strategy: Firstly the Pb^{27+} beam will be consolidated to obtain at least 25 eμA of Pb^{54+} out of the Linac. This will require around 120 eμA of analysed Pb^{27+} beam at the entry of the RFQ. This beam should be stable and be fully characterized. Record intensities will be attempted only after this initial phase.

Up to now the source showed a good performance and reliability if one considers that the source is a prototype. For lead this has to be proven.

There is a need to improve reliability, which will probably require a close examination of the source design, to see the long term behaviour of the source and to gain real life operational experience. The consumption of lead has to be improved. A lack of spare parts is crucial in view of the long term operation and maintenance. One of the most crucial parts is the present 14.5 GHz microwave generator. It is a more than ten year old prototype. To replace it with a new one or by a 18 GHz generator ~100 k€ are necessary.

To study the source behaviour more in detail beside operation or to prepare for beams of other than lead a test stand would be appreciated. For a future LHC operation with elements other than lead an early enough discussion between all participating parties would be desirable.

REFERENCES

[1] J. Bosser et al. "Experimental Investigations of Electron Cooling and Stacking of Lead Ions in a Low Energy Accumulation Ring", Particle Accelerators, 63, 171, 1999.

[2]. O. Brüning et al.. (Eds), "LHC Design report, Vol 3, The LHC Injector Chain", CERN 2004-003, 2004.

[3] European Commission Framework 5 Contract HPRI-1999-50014 "New Technologies for the Next Generation ECRIS".

[4] D. Hitz, Private Communication, 2003.

[5] D. Hitz et al., "Grenoble Test Source (GTS): A multipurpose Room Temperature ECRIS", Proc. 15th Int. Workshop on ECR Sources, Jyväskylä, 2002, JYFL Research Report 4/2002, 2002.

[6] D. Hitz et al., "Production of Highly Charged Ions with the Grenoble Test ECT Ion Source", Proc. 10th Int., Conf. Ion Sources, Dubna, 2003, Rev. Sci. Inst., 75,.1403, 2004.

[7] C. Andresen et al., "Characterisation and Performance of the CERN ECR4 Ion Source". Proc. 16th Int. Workshop on ECR Sources, Berkeley, 2004 AIP Conference Proceedings 749, 161, 2005.