

LEIR BEAM INSTRUMENTATION

C. Bal, E. Bravin, S. Burger, C. Dutriat, M. Gasior, T. Lefevre, F. Lenardon, P. Odier, U. Raich, L. Søby, J. Tan, G. Tranquille, C. Vuitton, CERN, Geneva, Switzerland

Abstract

The Low Energy Ion Ring (LEIR) is central to the "Ions for LHC" project. Its role is to transform a series of long low intensity ion pulses from Linac 3, into short high density pulses, which will be further accelerated in the PS and SPS rings, before injection into LHC. To do so the injected pulses are stacked and phase space cooled using electron cooling, before acceleration to the ejection energy of 72 MEV/u. This note describes different types of instruments which will be installed in the LEIR ring and transfer lines.

INTRODUCTION

In addition to proton operation, the LHC machine will run a few weeks per year with ions to provide collisions for heavy ion experiments. The lead ion intensities achievable with the former ion accelerator chain were far below the needs for LHC, and it has been decided to convert the previous Low Energy Antiproton Ring (LEAR) into a low energy ion ring, dedicated to accumulate and cool ions, in order to reach the required beam brilliance for LHC. The installation of the LEIR machine is underway and commissioning will start soon. A typical LEIR cycle is shown in Figure 1. At the end of each multi turn injection of 200 μ s of PB⁵⁴⁺ the beam is electron cooled and stacked. After 4-5 injections the beam is bunched and accelerated to the ejection energy, where two bunches of 4.5 10^8 ions each are created and transferred to the Proton Synchrotron (PS). The main machine parameters are resumed in Table 1.

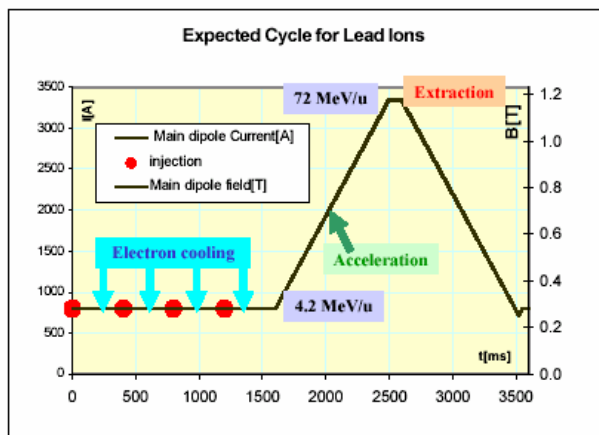


Figure 1: A typical production cycle.

Table 1: LEIR parameters.

Circumference	78.54m
Relativistic beta	0.095-0.37 ¹
Energy	4.2-72 MeV/u
Rev. Frequency	0.36-1.41 MHz
Q _H , Q _V	1.82, 2.72
Intensity range	2E8-2E11 Charges
Injection pulse	200us 50uA
Ejection bunch	2* 200ns 50mAp
Vacuum	10 ⁻¹² Torr
Bake out temp.	300 °C

INJECTION LINES

The injection line from LINAC3 consists of 3 segments: ITE, ETL which is common with the ejection line and the IE line just before the ring, see Figure 2.

Position

A total of 10 scintillating screens and cameras (MTV's) will be installed in the LEIR transfer lines. Seven are used to steer the injected beam, from which four can also be used at ejection.

Heavy ions at low energy are stopped within a few μ m and all the energy is deposited in a very small volume. Different types of screen materials were tested in Linac3 [2], in order to find a material capable of withstanding this energy deposit. The material often used in high energy accelerators Al₂O₃, showed degradation and reduced sensitivity after a few hours of beam. ZrO₂ for which a degradation of the material was visible, showed no reduction in sensitivity, and has been chosen as screen material.

A new MTV electronics hardware, consisting of a single VME 64x card, has been developed. This card is capable of controlling: all the different types of positioning mechanism for the screens, the adjustment of the illumination intensity, the different types of cameras (i.e. CCD or Vidicon tube) and the positioning of optical filters in front of the camera. Apart from the analog video signal the card provides also the digitized image.

Intensity

Three old transformers will be re-used and installed in the ETL and EI lines refurbished with new magnetic shielding and water cooling system according to the PS standard model. New front end electronics have been

¹ Will be extended to 0.9 for light ions, but not before 2009.

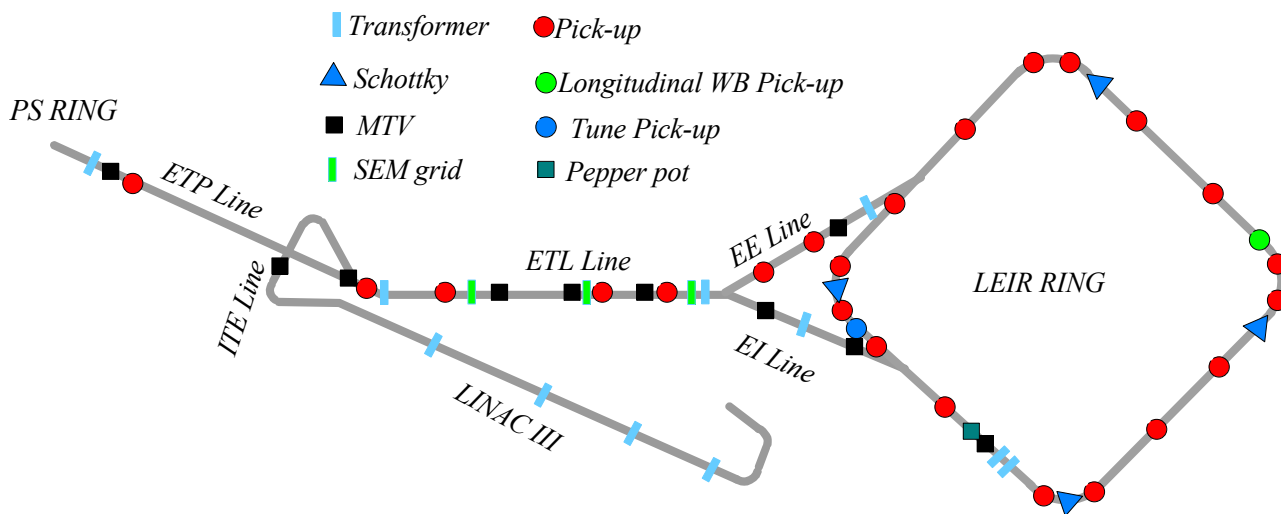


Figure 2: Layout of the LEIR complex and instruments.

developed which will in the near future be used to standardize all the transformers of the PS complex.

The two transformers installed in the ETL line, which will also have to measure the current of the two ejected bunches, will be equipped with 2 sets of electronics, one slow and one fast.

After amplification by the front end electronics and transmission to the control room the signals will be digitised with a 12 bit, 10MS/s FADC followed by digital baseline restoration and integration.

INJECTION

Injection Efficiency

For the measurement of the multi turn injection efficiency ($T_{rev} = 2.7\mu s$), a special semi fast transformer is requested. It will allow measuring every injection pulse (200 μs) with a droop less than 1%, but will also have a time constant short enough to measure the next injection 200ms later, without any current offset. This means a frequency bandwidth from 8 Hz to 500 kHz.

Schottky

The Schottky pick-ups are non perturbation measurement tools which provide a large set of informations for either coasting or bunched beams. With a spectrum analyser one can deduce: the tune, the emittance, the momentum distribution and the revolution frequency. Two existing systems, inherited from the former LEAR machine will be brought back to operation. Both consist of a succession of short strip-line pick-ups. Two of them will be connected as travelling wave pick-ups suitable only for low energy particles at injection ($b = 0.095$). The two other pick-ups are used in a parallel configuration, which will work at all particle velocities. There are two Schottky pick-ups per transverse plane but the horizontal ones also yield longitudinal informations.

Emittance

The emittance and matching of the beam injected into LEIR will be measured by means of a "pepper pot" device. This device consists of a molybdenum mask, in which a square matrix of 0.17mm holes with 1mm spacing is drilled.

The surviving particles will be observed on a scintillating screen located some 30cm further downstream and digitized using a CCD camera. By measuring the width and the center of the distribution of each beamlet, it is possible to reconstruct the transverse phase space distributions of the injected beam.

ELECTRON COOLING

Trajectory

Two H+V electrostatic pickups placed at each end of the drift space are foreseen to measure the electron and ion trajectories separately. The expected resolution is 0.1mm so as to insure that electron and ion beams are aligned within an angle lower than 1mrad.

Profiles

For the measurement of the ion beam transverse profiles and the electron cooling efficiency, two Beam Ionisation Profile Monitors (BIPM) will be installed. Both monitors consist of electrodes separated by alumina plates and a two-stage multi-channel plate (MCP) for the amplification of the ionisation signal. This amplified signal is collected on a strip readout having a resolution of 1mm.

Despite the expected ultra-high vacuum in the LEIR ring (2×10^{-12} torr), given the increased number of lead ions available from the source, it should be possible to obtain enough signal to measure profiles every 20 ms thus enabling a very precise evaluation of the electron cooling time in the horizontal and vertical planes.

ACCELERATION

Orbit

In the ring 32 ceramic based electrostatic PUs are foreseen. Eight horizontal and eight vertical shoebox type will reside inside the bending magnets, and eight combined horizontal and vertical cylindrical PUs in the straight sections, of which 2 are inside the electron cooler.

The orbit measurement system consists of head amplifiers (3 gains), which generates the Δ and Σ -signals, distribution amplifiers and an analogue normaliser module, whose output is proportional to the average beam position. These 32 signals are then fed to a multiplexing ADC.

Tunes

The LEIR system will be equipped with a strip line kicker, which can deliver large kicks needed for machine non linearity studies. Betatron oscillations will be observed on a dedicated electrostatic pick-up.

The acquisition system will be based on the Direct Diode Detection (3D) method [1], where the beam pulses from the pick-up are stretched in time, in order to increase the betatron frequency content in the base band. This can be accomplished by a simple diode detector followed by an RC low pass filter, as used in the common envelope detection technique for demodulating AM signals. The circuit can increase the betatron signal level by orders of magnitude compared to classical systems. In addition, it suppresses the revolution frequency content by a few tens of dB, which would be very difficult to achieve by other means, due to some two octaves of frequency swing.

Intensity

For the measurement of the circulating beam current, the continuous current transformer (DCCT) employed in the previous LEAR will be reused and installed in straight section 12. A new magnetic shielding is designed and the water-cooling system, needed during the bake-out, is renovated. An electronic similar to that one used in the PSB and PS will be adapted to the existing transformer, which is from a previous generation.

The β normalization will be based on the 1 Gauss B-train counting and on look-up tables calculated for the various types of ions foreseen. 3 ranges available in parallel will cover the intensity. The acquisition of the 3 ranges will be made, during all the time the beam is circulating, with a 1 kHz sampling rate by a 12 bit ADC. A post-acquisition selection is performed to choose the best range, i.e. the highest non-saturated range. A resolution of 2uA and temperature drift of 5uA per deg. C is foreseen.

Longitudinal Profile

The existing 300MHz wide band pick-up will be used for measuring the longitudinal bunch shape. The pick-up consists of a stainless steel ring (length=200mm, diameter=120mm) mounted on ceramic isolators.

The signal induced by capacitive coupling will be amplified and monitored with a fast digital oscilloscope.

EJECTION

Trajectory

In the LEIR ejection lines, 7 horizontal and 7 vertical electrostatic PUs will be installed.

The cylindrical PUs exists in three different diameters, and are made of stainless steel (316 LN) sheets. One annular electrode provides the intensity signal, and the difference signal is derived from a v-cut cylinder, forming two semi-sinusoidal electrodes.

The acquisition system consists of a head amplifier mounted close to the PU, followed by differential transmission to the control room. Here the signals are split to several users, among others a 12 bit 200MS FADC based digital acquisition system, which will digitise the position and intensity signals.

Intensity

A total of four fast transformers are used to measure the ejected beam intensity. For the fast extraction pulses 200MS FADC's are used to digitise and integrate the ejected bunches.

Profiles

As mentioned earlier four of the MTVs used to steer the injected beam will also be used at ejection. Another two will be installed in separate parts of the ejection line. Since the trajectory will be measured by the PUs, the main purpose of the MTVs will be profile measurements. Frame grapper software provides this from the digitized images.

To measure the emittance of the ejected beam three SEM grids will be installed in the ETL line. They consist of 1mm thick ceramic grids onto which 30 wires of 40um gold coated tungsten, have been soldered every 1.5mm. Each detector consists of 2 such grids mounted on independent arms, which are controlled by pneumatic motors. The acquisition system consists of 30 integrators followed by sample and hold system and ADC's.

CONCLUSION

This note describes the beam measuring instruments foreseen for the LEIR commissioning which will start in June 2005 and continue until mid 2006. Injection of lead ions into LHC is foreseen for the beginning of 2008. Results and performances of the LEIR beam diagnostics will be presented on next years conferences.

REFERENCES

- [1] M.Gasior, R.Jones, "High Sensitivity Tune Measurement by Direct Diode Detection", this conference.
- [2] C. Bal, E. Bravin, T. Lefèvre, R. Scrivens, M. Taborelli, Scintillating Screens Study for LEIR/LHC Heavy Ion Beams, this conference.