FIRST A/Q=3 BEAMS OF PHOENIX V2 ON THE HEAVY IONS LOW ENERGY BEAM TRANSPORT LINE OF SPIRAL2

C. Peaucelle#, CNRS-IN2P3, IPN Lyon, France
J. Angot, P. Grandemange, T. Lamy, T. Thuillier, CNRS-IN2P3, LPSC Grenoble, France
J-L Biarrotte, CNRS-IN2P3, IPN Orsay, France
D. Uriot, CEA Saclay, SACM France.

Abstract

The heavy ions low energy beam transport line (LEBT) of Spiral2 built at LPSC Grenoble is fully operational since the beginning of 2010. This LEBT has been calculated and designed to hold permanently 15 mA of multi charged ions extracted from the source at 60 kV extraction high voltage. The LEBT is shortly described. The PHOENIX V2 ECRIS is presently installed on the LEBT and first beam tests results are reported. A daily reliable beam of 1 mAe of O6+ beam at 45 kV has been obtained with a high LEBT transmission efficiency of 90. Preliminary Argon tuning shows a reproducible beam of 130 µA of Ar12+ beam. Improved currents are expected in the future. Associated emittance measurements, beam profiles are also presented. The future program, including A-PHOENIX restart, and planned improvements on the LEBT are discussed.

INTRODUCTION

The present configuration of Spiral 2 accelerator [1] features two electron Cyclotron resonance ion source (ECRIS) that produce either heavy or light ion beams. These beams are selected by a low energy beam transport line (LEBT) before being injected in an 88 MHz radio frequency quadrupole and a superconducting linear accelerator. LPSC is in charge of the assembly and commissioning of the heavy ion LEBT. This line is currently equipped with the PHOENIX V2 ECRIS, shortly described later.

THE HEAVY ION LOW ENERGY BEAM LINE

This new line, displayed on Fig. 1 was calculated and dimensioned by GANIL, CEA/IRFU and IPNO [2] to hold permanently 15 mA of total ionic beam current extracted from a heavy ion source at 60 kV voltage.

First, a solenoid is placed immediately after the ECR ion source. Then stand a quadripole triplet and a double-focusing 90° bending magnet designed with simple flat shimmed pole. An associated hexapole located before the dipole is used to reduce the non-linearities induced by such a dipole. Two faraday cups (FC) are available: one in front of the ECRIS extraction to measure the total ionic current and the second after the dipole to measure the selected beam. The overall transmission efficiency of the beam line can be deduced from these two measurements. The LEBT is also equipped with 3 profilers to centre the beams, a set of 3 motorized slits to clean the beam and perform the mass resolution through the dipole. Next, two Allison type emittancemeters are located after a second quadrupole triplet.

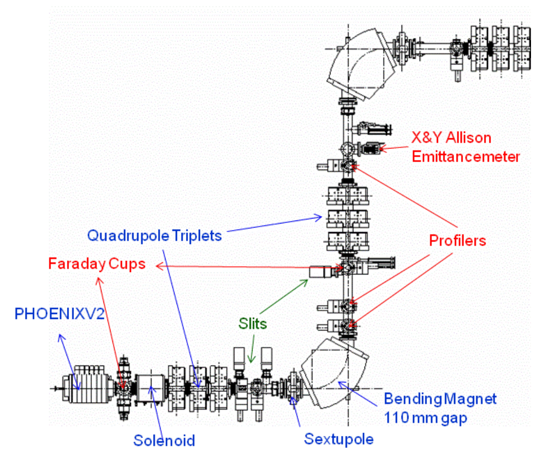

Figure 1: general sketch of the LEBT.

The LEBT uses ultra high vacuum standards for vacuum in order to minimize charge exchange in the accelerator. The pumping system is designed to reach 1.10^{-8} mbar in the whole beam line during high current production operation. Concerning the control command system, EPICS (Experimental Physics and Industrial Control System) [3] was chosen by Spiral 2 project.

THE PHOENIX V2 AND A-PHOENIX HEAVY ION SOURCES

In a first step the 18 GHz ECR ion source PHOENIX V2 [4] (see Fig. 2) is installed on the LEBT to commission it. This source has already been tested with Ar, Xe, O and He beam. Several upgrades have been made to improve the performance of this ECRIS: a water-cooled bias disk was added and new design of iron yoke allows increasing the magnetic field at the injection side from 1.7 T to 2.1 T now. The new injection flange designed accepts an oven reaching 1600°C performed by GANIL to produce ion metallic beam.

A-PHOENIX is a compact hybrid ECR ion source [5, 6] with two High Temperature Superconducting (HTS) coils and an innovative large permanent magnet hexapole. The magnetic structure allows reaching 2T radial magnetic field and 3T axial magnetic confinement. A-PHOENIX is designed to operate with frequencies from 18 to 28 GHz.

Because of the weld break of one the HTS cryostat, experiments on A-PHOENIX stopped in December 2009.

#peaucelle@ipnl.in2p3.fr

After repairing, the HTS coil was tested successfully during July 2010 and A-PHOENIX is now ready to restart up its commissioning.

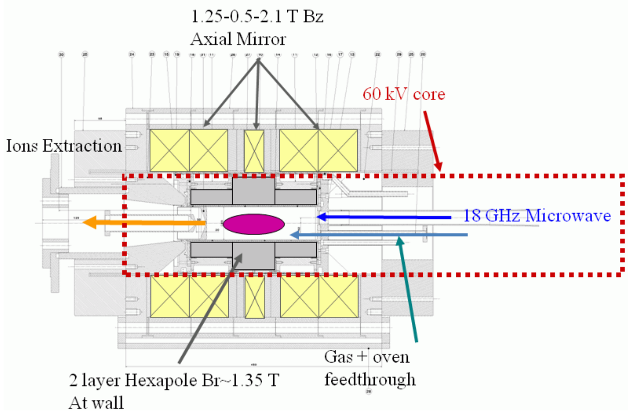

Figure 2: Phoenix V2 ion source.

The ultimate experiments done in 2009 tended to show that the low performances of the ECRIS at 18 GHz are due to a weak RF coupling. In order to improve this point, important modifications of the injection flange design have been done. The position of RF power injection was moved closer to the axis of the source; the bias disk mechanics was improved and a large welded below has been installed in order to move very easily the whole injection by 80 mm inward. Its construction is now finished and this system will be tested in late 2010.

STATUS OF THE LEBT AT GRENOBLE

The LEBT is completely assembled and operational at Grenoble since the beginning of 2010. A photo of the system is available on Fig. 3. As expected The LEBT vacuum system is able to hold ~1-2.10^{-8} mbar even at high ionic currents. Different beams such as Oxygen, Argon, Calcium and Xenon have been extracted and analyzed at a high voltage extraction up to 47 kV.

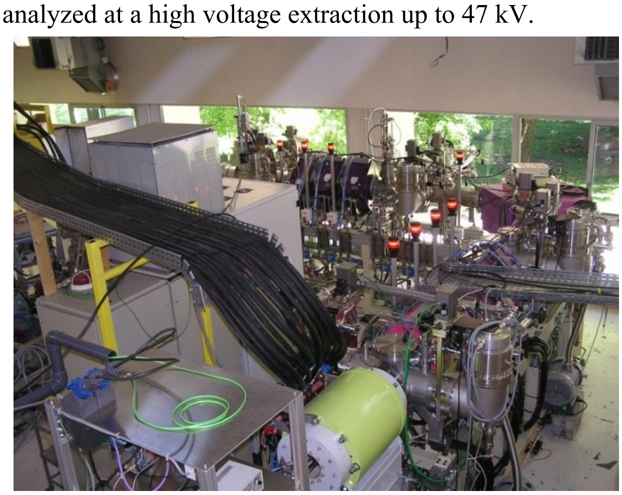

Figure 3: Phoenix V2 ion source and LEBT line at Grenoble.

Concerning transport beam dynamics, simulations was validated experimentally by measurements on FCs, profilers and emittancemeters with Argon, Xenon and Oxygen beams. Transverse emittance between 0.15 and 0.4 pi.mm.mrad normalized RMS depending of the beam is usually measured in both planes (see Fig.4).

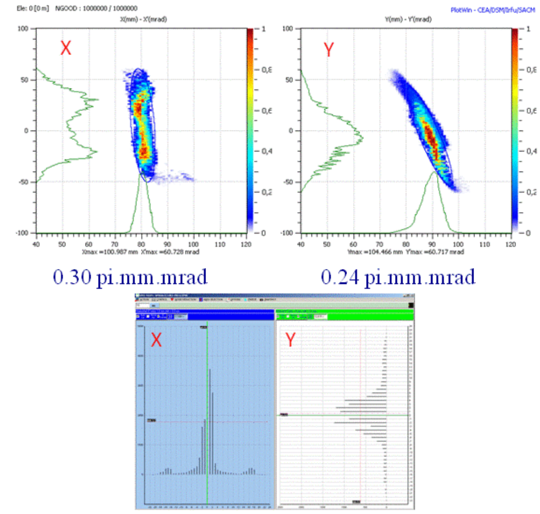

Figure 4: emittance measurements (up) and profiles (bottom) for 800 µAe O^{6+} at 45 kV.

The whole optic devices are tuned through an automatic algorithm developed from the TraceWin code [7] so that the LEBT can be optimized in two modes [8]: the first one corresponds to the smallest size on the profiler immediately after the dipole (optimized beam selection) while the second corresponds to the highest current on the second FC. Once the optics is optimized, the LEBT transmission reaches 90% in most cases. Besides, Phoenix V2 produces a very stable and reliable beam. The resolving power of the dipole has been studied and validated using a Xenon beam at 40 kV: $^{132}Xe^{25+}$ and $^{16}O^{3+}$ beams are not fully separated when slits between the dipole and the second FC are completely opened. Helped with the beam dynamic algorithm, it was possible to tune the optics and get rid of the oxygen keeping only Xenon beam with the analysis slits being opened at ± 5 mm (see Fig.5).

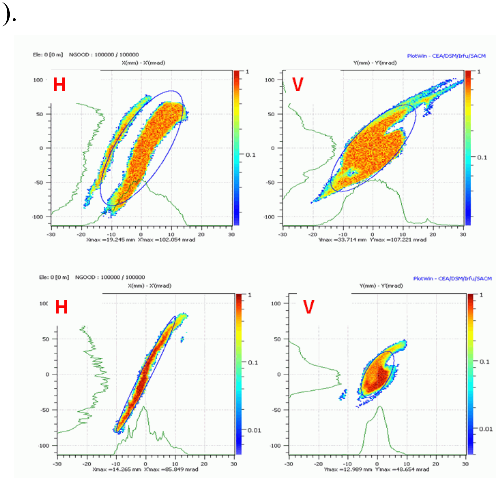

Figure 5: resolving power of the dipole validated with emittance measurements when slits are fully opened (up) and opened at ± 5 mm (bottom) for $^{132}Xe^{25+}$ at 40 kV.

The nominal performance in Oxygen beam was obtained in July 2010 at 45 kV and 1 kW of RF power: a $^{16}O^{6+}$ beam of more than 1 mA was produced with a very good transmission (95%). The associated ionic spectrum is displayed on Fig. 6. Measured transverse emittance was 0.3 pi.mm.mrad norm. rms in horizontal plane and 0.24 pi.mm.mrad norm. rms in vertical plane.

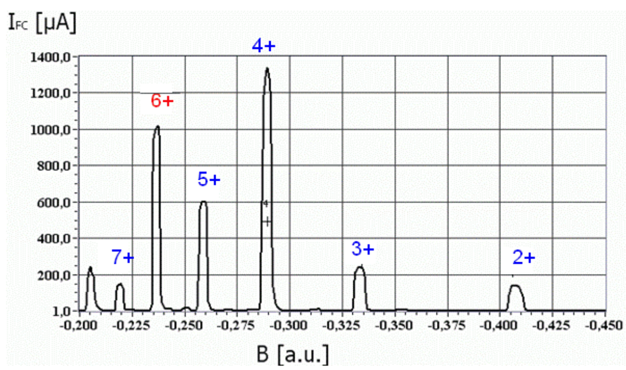

Figure 6: Oxygen spectrum at 45 kV with He gas mixing.

Tests with Argon beam have also been performed in summer 2010. 130 μA beam of $^{40}Ar^{12+}$ was produced at 40 kV. The associated ionic spectrum is presented on Fig.7. This result was obtained with few oxygen buffer gas. The $^{40}Ar^{12+}$ emittances, displayed on Fig.8, were measured to be 0.3 and 0.25 pi.mm.mrad normalized RMS in the horizontal and vertical planes respectively. One should note that the tests were done on a short time and a limited microwave power set to 1 kW. Improvement of these performances is expected in the future.

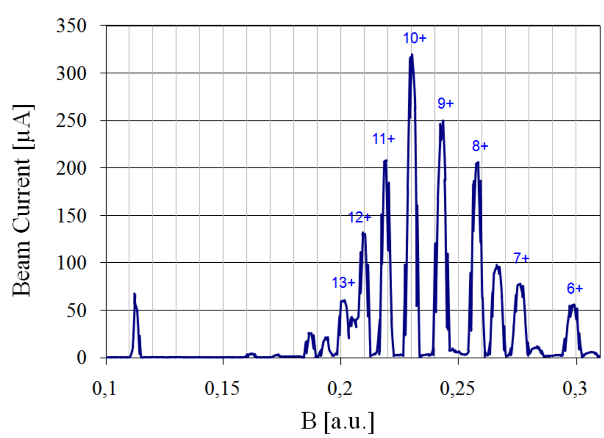

Figure 7: Argon spectrum at 40 kV optimized for Ar^{12+} production.

PROSPECTS

The LEBT beam tests will continue with PHOENIX V2 ECRIS especially with metallic ion beams using the large capacity oven (LCO) from GANIL. The present ECRIS extraction system must be modified to reach the high voltage specifications: an intermediate extraction electrode set to 30 kV will be added to safely hold the 60 kV high voltage required.

Once this last milestone is fulfilled, The A-PHOENIX research and development will restart at 18 GHz and continue at 28 GHz until mid 2011. The goal being to choose by mid 2011 the starter ECRIS to be moved in 2012 at GANIL. If A-PHOENIX shows better performance than PHOENIX V2, it will be installed on the LEBT for ultimate tests before moving to GANIL.

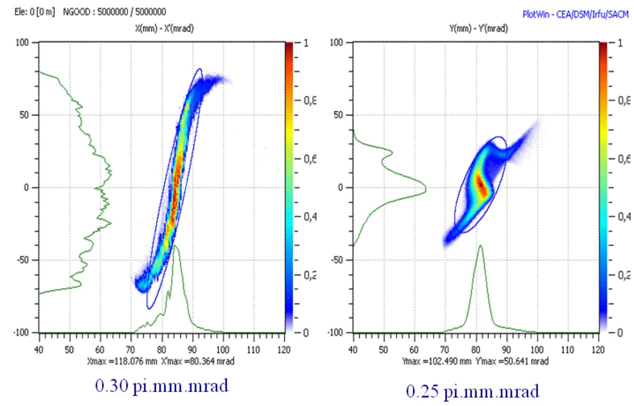

Figure 8: Argon 12+ emittance at 45 kV.

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