Recent Developments on the Phoenix ECR Booster at ISOLDE, CERN*

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Abstract At ISOLDE (CERN), an on-line test bench is dedicated to charge breeding experiments with a 14GHz Phoenix ion source, for the investigation of the $1+\rightarrow n+$ scenario at next generation ISOL-type facilities. This year, various technical developments have been undertaken for intensifying the tests of the on-line performances of the booster with a high diversity of stable and radioactive ion beams. This contribution will present an overview of the latest developments, the current challenges, and some perspectives for the future use of the Phoenix booster for physics experiments at ISOLDE.

Key words ion sources, charge breeding, mass and energy spectrometer

1 Introduction

At ISOLDE, CERN, a Phoenix Electron Cyclotron Resonance (ECR) ion source is installed on-line, on the heavy-mass parasitic beamline (GHM) of the General Purpose Separator (GPS)[1]. Singly charged ions are continuously injected into the charge breeder, where they are stopped by the combined effects of Coulomb collisions in the plasma and of an electrostatic deceleration. Consequently, they are stepwise ionized to high charge states by collisions with energetic electrons[2], generated by a radiofrequency wave when in resonance with the electrons cyclotron frequency in the magnetic field of the chamber (see Fig. 1).

After extraction, a 102° bending magnet allows a selection in A/q, with A the atomic mass and q the ion charge state, before ions are collected in a Faraday cup at the end of the line.

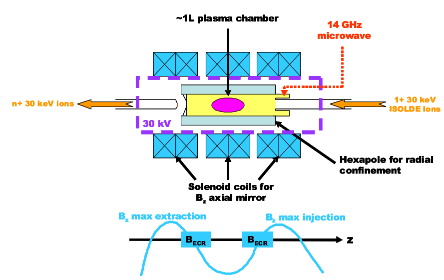

Fig. 1. The Phoenix booster used as a charge breeder: the 1+ ions are stopped and then ionized in the plasma, trapped in the minimum B-configuration.

The latest on-line charge breeding results of the Phoenix booster are described in[3]. It is currently able to charge breed a wide range of nuclides for A/q values ranging from 4 to 8, either in continuous or in pulsed mode. Efficiencies for the injected elements are similar to the ones measured for the REX beam preparation stage[4].

Due to the high diversity of exotic nuclides produced far from stability, the optimization of the

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charge breeding performances is challenging. The Phoenix Booster undergoes several technical developments to meet the requirements for rapid, efficient and high A/q charge breeding.

2 Technical upgrades

Recent developments on the ECR charge breeder aim at more flexibility of operation, and at a better purity of the beam. On the first hand, the ECR potential platform was consolidated with an upgrade from 30kV to 60kV (see Fig. 2) to allow the handling of more beams among the available ISOLDE production.

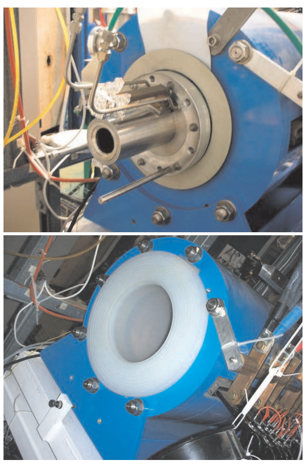

Fig. 2. Top: the plasma chamber on the injection side, surrounded by the former central insulator for a 30kV potential. Bottom: The plasma chamber has been removed and the new central insulator that can hold a 60kV potential is in place.

On the other hand, the installation of a two-step separator at the ejection side of the charge breeder is being carried out. It aims at the improvement of the resolution of the beam in mass and in energy. This latter point requires a careful study.

Previous results have shown the existence of a 10nA background in the A/q range from 3 to 7 (see Fig. 3). This level is believed to be caused by charge recombination in the extraction region of the ion source inducing energy spread on the A/q values. Therefore energy selection is to be added, after the charge breeder and before A/q separation. A design of the Nier-Johnson spectrometer type was already set up on the REX-ISOLDE facility[5] and is chosen for our purpose.

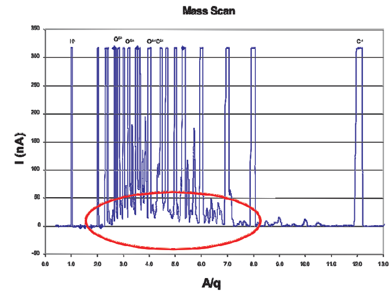

Fig. 3. Mass spectrum in a continuous mode showing a 10nA background in the range $3< A/q <8$.

Simulations were done to design the new isotopic separator setup with elements provided after the dismantlement of the AMS facility injector[6] in Lund. The energy and mass separator is constituted of two analyzers: the electrostatic analyzer reduces interference of energy tails from nearby masses and the magnetic analyzer provides the A/q selection. An optimization routine was performed with the COSY INFINITY software to evaluate the relative positions of the analyzers and of the possible focusing elements. Two quadrupole triplets are needed in the final setup for an optimized control of the beam before and after the analyzers. Fig. 4 presents the results of the first order COSY calculations. The simulated beam has an emittance of 30π·mm·mrad for an initial extraction diameter of 4mm. Given the typical emittance of beam extracted from Phoenix-type charge breeders[7], one can consider that at least 95% of the beam extracted from the ECRIS is taken into account for the calculations. The position of the elements was optimized with beams in the range of $3< A/q <8$ and with an electrostatic acceleration around 30kV and 60kV. The resolution of the separator was evaluated for 30kV and also 60kV, giving similar results for both cases.

Two analyzed peaks were considered as resolved in energy when their position differed with more than $4\sigma_x$ at the energy slits, corresponding to a transmission of 95% of the selected peak. The same definition was used for the mass separation. The resulting resolving powers are $E/\Delta E \sim 158$ and $m/\Delta m \sim 140$, with a total transmission of 90% of the beam. As for the mass separation, the results are sufficient compared to the current value $m/\Delta m \sim 80$ obtained with the 102° bending magnet.

The choice of the needed resolving power will be mainly determined by the needs of the installation following the isotopic separator, which is the application to an experiment.

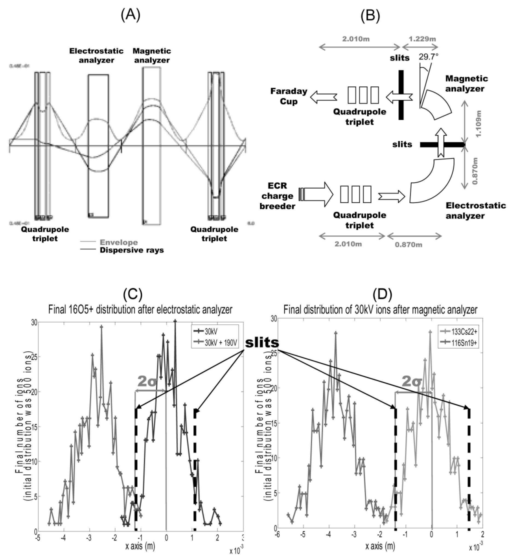

Fig. 4. The simulated beam has an emittance of 30π·mm·mrad and a potential energy of 30keV per ion. (A) Simulations of the beam envelope through the isotopic separator in the dispersive plane with COSY INFINITY. (B) Preliminary sketch of the separator setup with the calculated relative distances. (C) Resulting energy resolving power and (D) mass resolving power.

3 Perspectives for nuclear physics

The charge breeding of radioactive ions in ion sources is now commonly used for an efficient post-acceleration of the ISOL-type beams in LINAC or cyclotrons. Besides this application, it allows the production of very pure beams by suppressing the contaminants with molecular sidebands[8] or charge state distributions[9].

Additionally, charge breeding can provide a full electrostatic post-acceleration with the use of a high voltage cage, filling the gap between the energies available after the mass separation at typical ISOL-type facilities, usually from 30kV to 60kV, and the first energies accessible after a RFQ cavity, of the order of a few hundreds of keV/u. This property is of interest in perspective of "low-energy" nuclear astrophysics experiments[10], as well as for implantation experiments. A proposal is under study for half-life measurement of alpha emitters implanted in various matrices[11].

4 Conclusion

The Phoenix Booster undergoes several technical developments to intensify the tests of the on-line performances of the booster. The setup has been upgraded to a 60kV potential platform, allowing the use of more available beams at ISOLDE. The installation of an isotopic separator is being studied for the reduction of the stable background. A system consisting on the combination of an electrostatic and a magnetic bender was chosen. The first order calculations of the relative positions of the elements have been performed with the COSY INFINITY code. For a beam emittance of 30π·mm·mrad and an extraction diameter of 4mm, the resulting resolving powers are $E/\Delta E \sim 158$ and $m/\Delta m \sim 140$ for a total transmission of 90% of the beam. Emittance measurements will be needed to confirm the hypothesis on which the calculations were based. This development should hopefully lead to new possibilities for physics experiments with clean and charge bred beams.

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