IMPLEMETATIONS ON THE RF CHARGE BREEDER DEVICE BRIC WITH TEST MEASUREMENTS

Vincenzo Variale, Antonio Boggia, Tarcisio Clauser, Antonio Rainò, Vincenzo Valentino,
INFN-Bari and Physics Department of Bari University (Italy)
Petr Bak, Gennady Kustenzov, Boris Skarbo, Michael Tiunov
Budker Institute of Nuclear Physics, Novosibirsk (Russia)

Abstract

The "charge state breeder" BRIC (BReeding Ion Charge) is based on an EBIS source and it is designed to accept RIB with charge state +1, in a slow injection mode, to increase their charge state up to +n. BRIC has been developed at the INFN section of Bari (Italy) during these last 4 years with very limited funds and it has been assembled at the LNL (Italy) laboratory.

The new feature of BRIC, with respect to the classical EBIS, is given by the insertion, in the ion drift chamber, of a Radio Frequency (RF) - Quadrupole aiming to filtering the unwanted masses and then making a more efficient containment of the wanted ions.

The RF test measurements seem confirm, as foreseen by simulation results that a selective containment can be obtained. Most accurate measurements, however, are needed to study with more details that effect. For this reason, few implementations of the system have been studied to improve the accuracy of the measurements. The main implementation carried out on BRIC is given by the new and more efficient ion extraction system that recently has been mounted on our device. On this contribution we will shortly discuss the test measurements problems we had to face with our implemented device.

INTRODUCTION

The Radioactive Ion Beam (RIB) production with ISOL technique should require a charge breeder device to increase the ion acceleration efficiency and reduce greatly the production cost.

The European project EURISOL_DS has the aim of studying a design of the next-generation European facility for the production of intense RIB with the ISOL technique. It will provide exiting perspectives in several scientific disciplines including nuclear physics, astrophysics and fundamental interaction.

Meanwhile, in the framework of the EURISOL project, several intermediate national RIB facilities project are in progress. Among them, there is SPES. It is the project of a new facilities for the production of RIB accelerated up to several MeV/u [1]. It is in an advanced phase of study at the Legnaro National Laboratory (LNL) (Padua, Italy) . Also this kind of project is based on the ISOL technique. In general the cost of an accelerator is roughly related to the inverse of the charge state of the beam to be accelerated, a higher ion charge state beam can allow a sensitive lowering of the accelerator cost. For that reason, before the post-acceleration of a RIB, an appropriate device capable of increase the ion charge state of the radioactive element that must be accelerated can be used. In the framework of the LNL SPES project, our INFN group, in Bari, has been involved in the development and testing of a "*charge state breeder*" device based on an EBIS source type: BRIC. The BRIC features have been already presented in ref. [2]. The main new feature of BRIC is the using of a RF quadrupolar field to obtain a selective containment of the wanted ions to reach, in this way, a more efficient high charge state ion production.

The main purpose of our experiment is to test the BRIC device only as stand alone high charge ion source to verify the idea of the RF selective containment and then study its effect on the ion production. The first test measurements have already shown that the RF quadrupole field application to BRIC device gives a ion selective containment [3] as foreseen by numerical simulations shown on ref [4] where a proper code to study the ion behaviour in BRIC has been presented. In order to improve the measurement quality (better charge over mass resolution and higher peak amplitudes) few implementation have been applied on BRIC device [5].

In this paper measurements to test the new implemented device will be presented and discussed.

THE BRIC DEVICE

The detailed design of BRIC device has been already presented in ref. [2], [3]. However, for sake of clarity, a shortly description of the device here will be done to recall its main features. In fig.1 is shown the implemented experimental set up of the BRIC device. It is practically the same of a classical Electron Beam Ion Source (EBIS). In fact, , as in an usual EBIS, you can see the electron gun, the ion drift chamber and the typical electron collector where usually there is a hole for the ion extraction. Recently, however, a more complex ion extraction system, shown on the figure has been mounted on the device to obtain a more efficient ion pulse extraction.

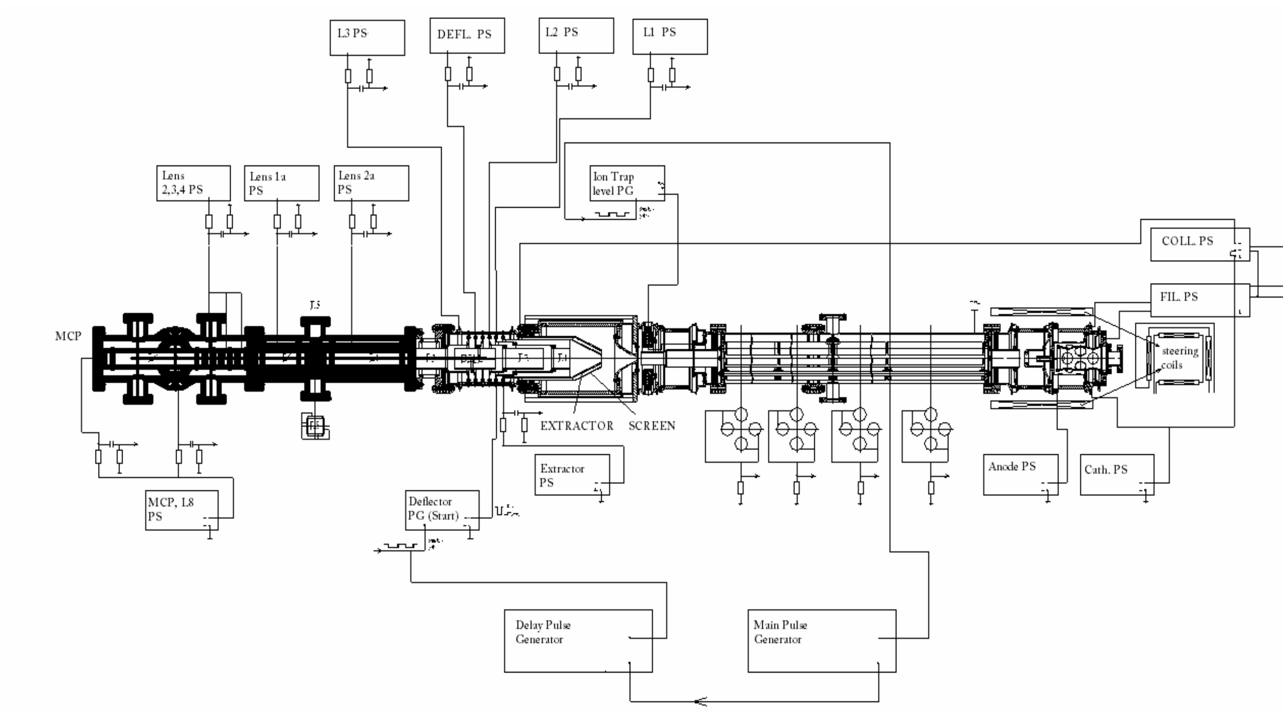

Figure 1: The modified BRIC Experimental set-up with mechanical scheme. MCP indicates Micro Channel Plates detector. In the ion chamber section are shown the quadrupole electrodes which give the RF field.

The main difference between BRIC and the usual EBIS can be observed by looking at the inside of the ion drift chamber shown in fig.1. In the ion chamber, RF electrodes of cylindrical shape, placed around the symmetry axis in such a way to give a practically pure quadrupolar RF field, are shown. That RF field, which is added to the electron beam space charge potential, gives the above mentioned transverse selective containment of the wanted ions. The anode and the electrode placed at the end of the cylindrical shaped RF electrodes are used to create the longitudinal trap for the ions, needed for the ion charge state breeding.

The implementations designed and carried out on the device have been already discussed in ref. [5]. They had the aim to improve the quality of the measurements, that is, to get a higher amplitude signal and a better charge over mass (e/m) resolution for the TOF system. In the old TOF system we had a short TOF base of flight and an ion extraction electrode that could extract only a small fraction of the ion pulse produced in the BRIC trap. Then, the main implementation in BRIC have been a new more efficient ion extraction system and a longer TOF base of flight.

The main pulse generator, shown in fig. 1, drives the trap PG that gives a negative voltage (about 0.8 kV) to the trap electrode in order to extract form the BRIC trap the ions produced by the electron beam. That trap electrode in the old version of BRIC was not able to give a negative voltage but only a zero voltage. Then in the old system the trap were emptied very slowly giving very long ion pulse that deteriorates going towards the TOF system. After the electron collector, inside the new ion extraction system, there is the TOF start electrode driven also by the main PG through a proper delay given by the delay PG. Then, at the end of the TOF line, there is a fast MCP detector.

CHARGE STATE TEST MEASUREMENTS

The main BRIC design parameters used have been: a current density, J_e, of about 10 A/cm^2 and an electron beam energy of about 5 keV [3]. For that current density, a "breeding parameter" [3]: $J_e \bullet \tau_c \approx 3 \div 4$ [A•sec/cm^2] can be obtained by using the Lotz formula as ionization cross section. Further parameters used in our test measurements are shortly described in the following. The power supply connected to the collector, needed to recover the electron beam power, was set to, V_{coll}=2 kV. The electron current recovered on the collector has been about 230 mA with a power recovery efficiency more than 99.9%. The ion extraction potential voltage from the electron collector has been set to -3.6 kV. The TOF start electrode pulse had an amplitude of about -2.6 kV and a pulse width of 400 ns. At the end, the delay time between the BRIC ion trap emptying and the TOF start time was 40 μs. In this way a large fraction of heavier ions could be analysed from the TOF MCP detector [3].

In fig. 2 are shown measurement results given by the TOF MCP in the case of using the above parameters. However, in spite of the implementations applied to the device to get higher signal amplitudes and a better e/m ion resolution, the results given in fig . 2 show, practically, the same amplitudes obtained before the device modification and even a worst resolution. Then, we have tried to understand what could be the problems that prevented better measurement results.

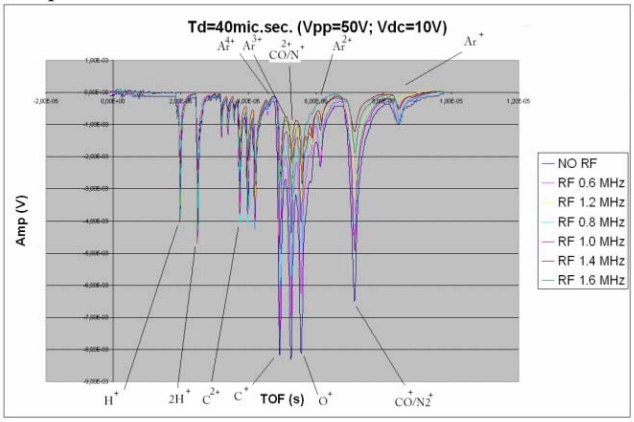

Figure 2: Ion mass spectrum with and without RF field. Vpp refers to the RF amplitude voltage and Vdc refers to DC amplitude voltage.

As first test we have checked the efficiency of the new ion extraction system by measuring the ion pulse just after it and we obtained, as expected, an ion pulse higher than that one of the old ion extraction electrode. We found the same ion pulse also on the last TOF electrode before the MCP. At the end we found that the MCP detector did not work properly. In fact, when the MCP has been dismounted from the TOF system we have verified that micro discharges had reduced the active detector surface and for that it gave lower amplitude signal.

To better understand why we obtained, in our measurements (fig. 2), also a lower e/m resolution (see for comparison ref. [3]), simulations of the ion trajectories in the TOF system have been carried out. As shown in fig. 3, when the TOF electrode 'start' voltage is V_s=0, the ions did not stop completely, as it was in the old BRIC, and few ions reach the same the MCP surface.

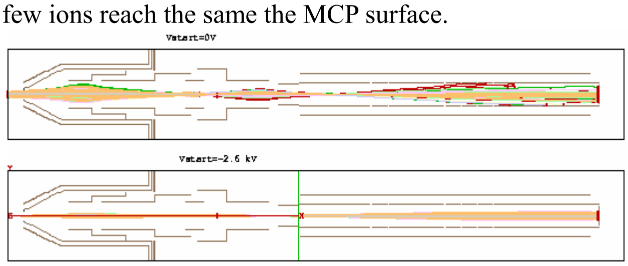

Figure 3: Ion trajectory simulations from the electron collector to TOF MCP. The upper figure refers to the case when the 'start' voltage electrode is V_s(off)=0. The lower case for V_s(on)=-2.6 kV. When V_s=0 a fraction if ions reached the same the TOF detector.

For that reason on the bottom of the peaks of fig. 2 there is a kind of common base where the ions have reached the MCP surface out of the TOF start signal have been, the same, detected.

The ions, in the collector, had an initial energy of about 0.8 keV given by the emptying BRIC trap electrode. For that reason, the ions could not be stopped by the TOF 'start' electrode when Vs(off)=0. In order to obtain that all the ions stop at the TOF 'start' electrode, it should have a voltage pulse starting from -2.6 kV (or other) up to 0.8 kV. The other possibility is to reduce the voltage of the empting BRIC trap electrode to a value close to 0 V .

The fig . 2 shows, as in ref. [3] and [5], that the application of quadrupolar RF fields gives a selective ion containment. In fact, for different frequencies we had that peak amplitudes referring to different e/m could be more or less increased by the RF field presence. In general applying the RF field we realized a kind of mass filter. That is, peak amplitudes referring to values of e/m lower than a certain value (depending on the RF parameters) are sensitively reduced by applying RF filed while peaks referring to higher values of e/m increase. However, as an example, for the frequency 0.8 MHz (cyan color in fig. 2) we have a more evident increase of only a small range of e/m values (from C^{2+} to O^{2+}). This means that our device could work not only as a mass filter (unstable all the masses greater than a certain value) but also to make stable, in the trap, only ions with a certain range of e/m values. In the case of fig. 2, the range of mass is not very small but new test experiments will be done to find RF parameters [3] that could give better results.

CONCLUSIONS

The aim of the implementations, discussed in ref. [5], was both to increase the measurement signal amplitudes, by increasing the ion beam pulses sent in the TOF system, and to improve the ion charge state resolution by using a longer TOF base of flight.

Unfortunately we have found out that our MCP detector was deteriorate. In fact, a higher ion pulse in the test did not produce higher MCP signals. For that reason a new MCP detector has been already ordered.

Furthermore, although a longer base of flight has been used in the modified BRIC the ion charge state measurement resolution decreased. That problem has been caused by the higher energy of the ion generated in the BRIC trap which prevented a complete stop to the ions when the TOF start pulse was off, that is with Vs(off)=0. That problem could be solved by setting Vs(off)=0.8 kV.

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