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Radioactive Ion beams in Brazil (RIBRAS)*

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Abstract. A double superconducting solenoid system is being installed at the Pelletron Laboratory of the University of São Paulo, Brazil. This system allows the production of secondary beams of light exotic nuclei like ^{8}Li, ^{6}He and others. The first results using this facility are presented.

PACS. 28.52.Lf Components and instrumentation – 41.85.Lc Beam focusing and bending magnets, wiggler magnets, and quadrupoles – 29.27.-a Beams in particle accelerators – 25.60.-t Reactions induced by unstable nuclei

1 Introduction

The Pelletron Laboratory of the University of São Paulo installed the first South America Radioactive Ion beams device (RIBRAS) [1,2]. This facility extends the capabilities of the original 8 MV Pelletron accelerator by producing secondary beams of unstable nuclei. The most important components in this system are the two new superconducting solenoids. The solenoids have 6.5 T maximum central field (5 T · m axial field integral) and a 30 cm clear warm bore, which corresponds to an angular acceptance in the range of $2 \leq \theta \leq 15$ degrees in the laboratory system. The solenoids were built by Cryomagnetics INC [3] and were designed to operate in connection with the Linac post-accelerator, presently under construction. With the Linac, the energy of the primary beam will be about 2–3 times larger than the maximum energy of the present Pelletron Tandem of 3–5 MeV · A. The presence of two magnets is very important to produce pure secondary beams [4,5]. The first solenoid makes an in-flight selection of the reaction products emerging from the primary target in the forward angle region. As the first magnet transmits all ions with the same magnetic rigidity mE/Q^2 the radioactive secondary beam can be rather contaminated. With two solenoids, it is possible to use differential energy loss in an energy degrader foil, located at the crossover point between the magnets. This degrader foil will allow the second solenoid to select the ion of interest by moving the contaminant ions out of its bandpass. An additional future possibility of the two solenoid system is the production of tertiary beams using a secondary target in the middle scattering chamber. The second solenoid can be tuned to select a different magnetic rigidity producing low-intensity (1–100 /s) tertiary beams like ^{9}Li, ^{8}He. [6] This is in principle possible with secondary beams of 10^7 /s and assuming a typical conversion efficiency of 10^{-5} for the production reaction.

2 Recent developments

The RIBRAS beam line is presently mounted in the experimental room of the Pelletron accelerator Laboratory (fig. 1).

The production system consists of a gas cell, mounted in a ISO chamber followed by a tungsten Faraday cup which suppress the primary beam and measures its current. The gas cell was mounted with a 2.2 μm Havar entrance window and a ^{9}Be vacuum tight exit window 12 μm thick which plays the role of the primary target and the window of the gas cell at the same time. The gas inside the cell has the purpose of cooling the Berilium foil heated by the primary beam and can also be used as production target. In case we want to use a gas target to produce secondary beams, the berilium foil can be replaced by another Havar foil and the pressure inside the cell can be increased up to several bars. In table 1 we present some typical production rates and reactions used at Notre Dame [5] and at RIBRAS, São Paulo.

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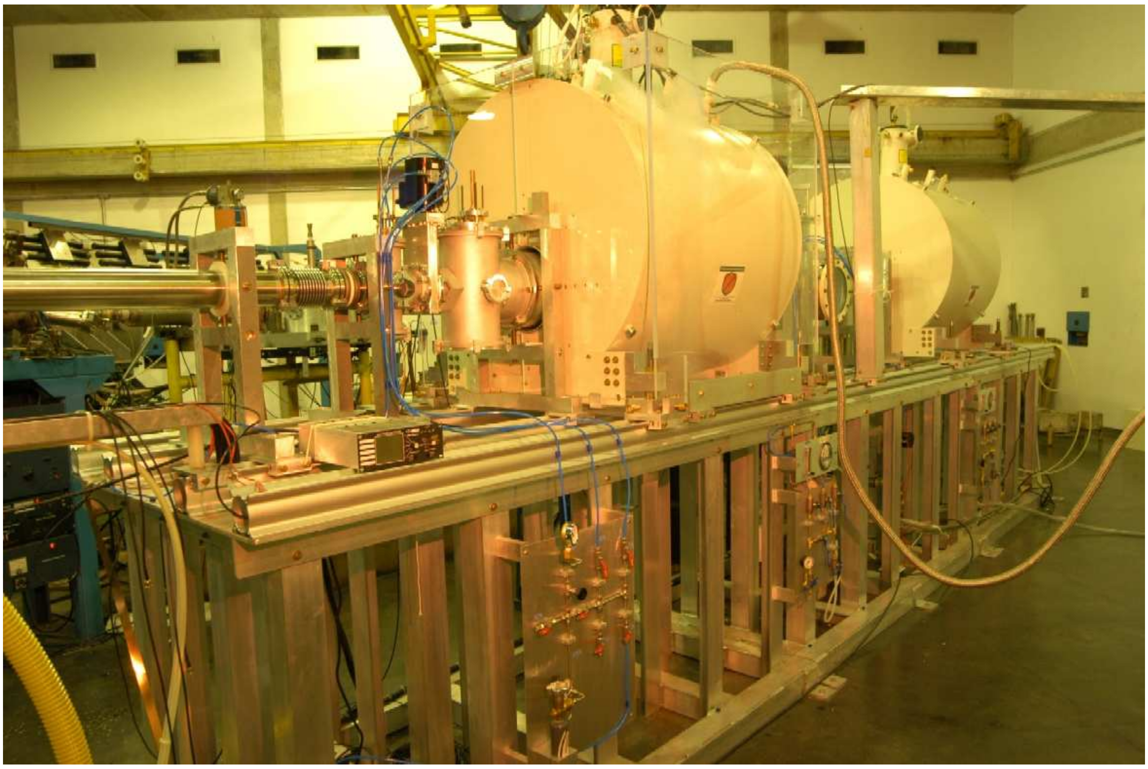

Fig. 1. RIBRAS facility installed in the 45B Pelletron beam line.

Table 1. (*) Production reactions measured at RIBRAS using only 1 solenoid.

Production reaction	Secondary beam (part/s/μAe)
^{9}Be(^{7}Li, ^{8}Li)$^{(*)}$	10^6
^{9}Be(^{7}Li, ^{6}He)$^{(*)}$	10^5
^{3}He(^{7}Li, ^{7}Be)$^{(*)}$	10^5
^{3}He(^{6}Li, n)^{8}B	10^5
^{12}C(^{17}O, $^{18\text{m}}$F)	10^3

The first radioactive beams produced by this system were delivered during the XIII J.A. Swieca Summer School on Experimental Nuclear Physics on February/2004 using only the first solenoid. The ^{8}Li and ^{6}He particles produced by the reaction of the ^{7}Li primary beam on the ^{9}Be primary target were focused by the first solenoid in the scattering chamber located at the crossover point between the two solenoids. The secondary-beam profile (x-y) was measured by a Paralell Plate Avalanche Counter (PPAC) placed in the crossover point. A triple $\Delta E(20\,\mu\text{m}) - E1(150\,\mu\text{m}) - E2(150\,\mu\text{m})$ silicon telescope placed at zero degrees and 5 cm after the PPAC allowed the identification of the atomic number, mass and the energy of the secondary-beam particles.

The secondary-beam spot measured at the PPAC position was of about 7 mm in diameter which is consistent with a primary-beam spot size of 4–5 mm multiplied by a magnifying factor of 1.5 of the first solenoid. Figure 2 and fig. 3 show the telescope spectra with the solenoid 1 tuned to select ^{8}Li and ^{6}He ions, respectively. The production rates measured at RIBRAS for these two exotic ions were about 10^5 p/s and 10^6 p/s, respectively, per microampere of primary ^{7}Li beam.

The second solenoid is mounted and in place waiting for the secondary scattering chamber to complete the system.

3 Scientific program with RIBRAS

The proposals of experiments for RIBRAS approved in the last PAC of the São Paulo Pelletron Laboratory for the year of 2005 consist basically of elastic scattering studies with exotic projectiles on several targets. Measurements of elastic scattering angular distributions using projetiles like ^{6}He, ^{8}Li and ^{7}Be are in progress with RIBRAS. Three systems are being studied at the moment, ^{6}He + ^{27}Al, ^{6}He + ^{208}Pb and ^{7}Be + ^{120}Sn at energies around the Coulomb barriers. The main interests are in the effect of nuclear and Coulomb breakup on the elastic scattering and the threshold anomaly behaviour in systems with weakly bound projectiles. Elastic scattering measurements with these radioactive ion beams are feasible with the present intensities of the Pelletron primary ^{7}Li beam which are in the range of 100–300 ηAe. In a second stage, with the new ionizer for our SNICS ion source, we expect to have primary intensities above 1 μAe. This will permit the measurement of transfer reactions. The

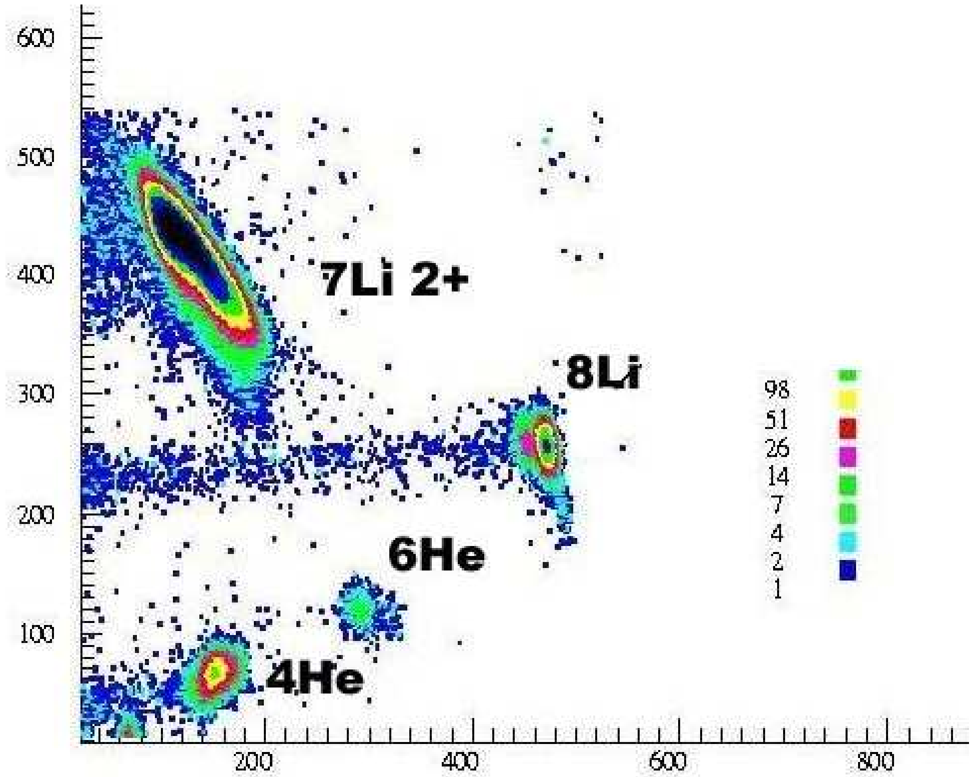

Fig. 2. ΔE-E spectrum for the ^{9}Be(^{7}Li, ^{8}Li) reaction.

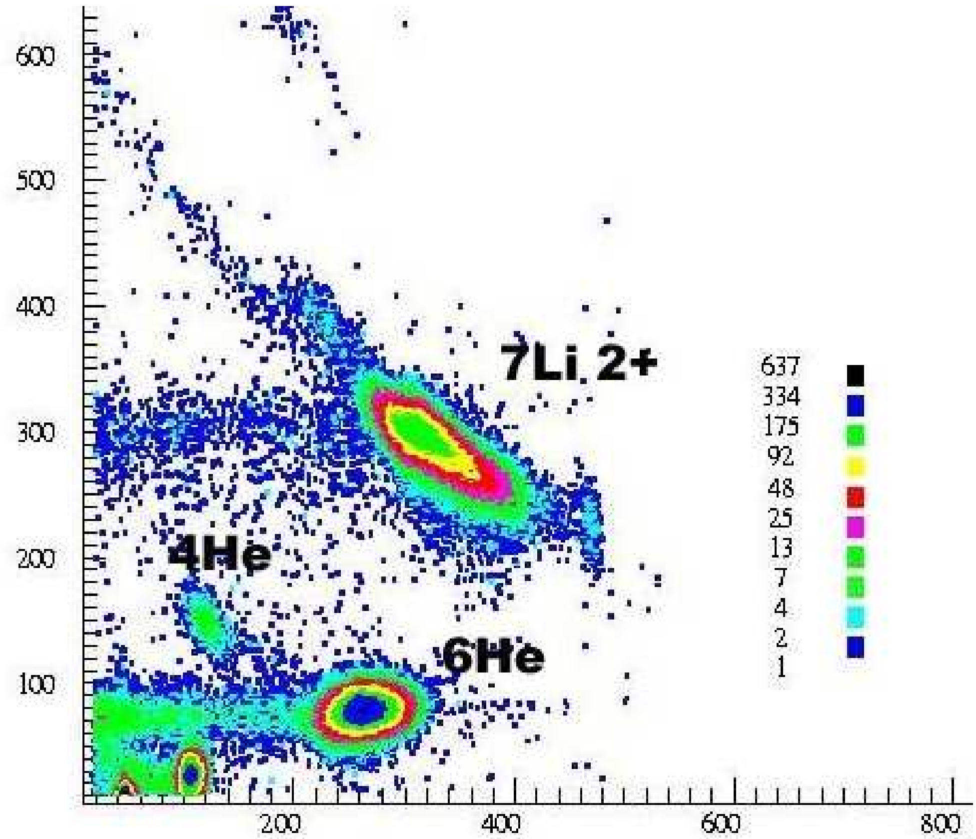

Fig. 3. ΔE-E spectrum for the ^{9}Be(^{7}Li, ^{6}He) reaction.

study of transfer and capture reactions of astrophysical interest will be possible to be performed in the near future with both solenoids.

4 Conclusions

In conclusion, a double superconducting 6.5 T facility is installed at the Pelletron Laboratory of the University of São Paulo to produce secondary beams of radioactive nuclei. The two solenoids are mounted and tested on the 45B beam line of the Pelletron experimental area. The system began its operation with only the first solenoid and using the ^{7}Li primary beam delivered by the 8 MV Pelletron Tandem. Secondary beams of ^{8}Li and ^{6}He were produced. Experiments using these secondary beams are in progress.

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