Eur. Phys. J. A **25**, s01, 115–116 (2005)
DOI: 10.1140/epjad/i2005-06-028-x

EPJ A direct
electronic only

A novel way of doing decay spectroscopy at a radioactive ion beam facility

C.J. Gross[1,a], K.P. Rykaczewski[1], D. Shapira[1], J.A. Winger[2], J.C. Batchelder[3], C.R. Bingham[4], R.K. Grzywacz[4], P.A. Hausladen[1], W. Krolas[4,5,6], C. Mazzocchi[4], A. Piechaczek[7], and E.F. Zganjar[7]

[1] Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
[2] Department of Physics and Astronomy, Mississippi State University, Mississippi State, MS 39762, USA
[3] UNIRIB, Oak Ridge Associated Universities, Oak Ridge, TN 37831, USA
[4] Department of Physics, University of Tennessee, Knoxville, TN 37966, USA
[5] Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA
[6] Joint Institute for Heavy Ion Research, Oak Ridge, TN 37831, USA
[7] Department of Physics, Louisiana State University, Baton Rouge, LA 37831, USA

Received: 9 December 2004 /
Published online: 20 April 2005 –

Abstract. A technique to enhance the purity of accelerated radioactive ion beams for decay studies is presented. The technique requires a 3 MeV/nucleon beam and a transmission ionization chamber. The gas pressure in the multi-anode ionization chamber is adjusted so that high-Z components of the beam are ranged out in the gas transmitting the more exotic, low-Z components to the measuring station. Initial tests with a radioactive ^{120}Ag and ^{120}In mixed beam indicate at least a factor of 5 relative enhancement of the ^{120}Ag decay transitions.

PACS. 23.40.-s β decay; double β decay; electron and muon capture – 29.40.Cs Gas-filled counters: ionization chambers, proportional, and avalanche counters – 27.60.+j $90 \leq A \leq 149$

1 Introduction

Beta-decay studies on nuclei far from stability have traditionally been carried out at isotope separator facilities [1] and at the focal plane of recoil and fragment separators [2,3]. The isotope separator facilities extract and accelerate beams to a few tens of kilovolts, mass analyze the beam to one part in 1000, and rely on the purity of the resulting beam to study these nuclei. Recoil and fragment separators rely on the reaction kinematics to convey enough energy to either spatially separate and/or electronically tag the ions prior to implantation and study of the decay properties. Both techniques offer advantages and disadvantages. Isotope separator facilities often use extremely thick targets and large primary beams which can produce copious amounts of isotopes. However, the chemistry of how these ions diffuse in the catcher material and are released from the surfaces inside the ion source can cause long hold-up times making it difficult to study nuclei with short halflives. Recoil and fragment separators usually produce much weaker beams but with fast separation and tracking detectors the study of very short-lived species is possible. In both cases, very weak components of the beams can be swamped by contaminants. In order to improve upon the isotope separator technique we propose to accelerate the ion beams to approximately 3 MeV per nucleon and use an ionization chamber to detect and enhance the purification of a beam of neutron-rich nuclei.

Beams of neutron-rich nuclei are produced at the Holifield Radioactive Ion Beam Facility (HRIBF) through proton-induced fission of a uranium carbide target. While many different ion sources may be used, the electron-beam-plasma ion source is presently most often used to produce neutron-rich beams. Isotopes diffuse out of the hot target and are extracted and ionized to form a beam of ions. The beam is mass analyzed and passed though a charge-exchange cell where positive ions are converted to negatively charged ions for injection into the 25 MeV tandem accelerator. Prior to injection, the ions are mass analyzed again. At the terminal potential of the accelerator, the ions are passed through a dilute gas or carbon foil and electrons are stripped off the ion. The positively charged ions have a distribution in charge; ions with one charge state are delivered to the experimental end station.

2 Technique

The experimental end station consists of a microchannel-plate-plus-thin-foil detector for counting the beam, an ionization chamber filled with CF_4 gas for identifying the

[a] Conference presenter; e-mail: `cgross@phy.ornl.gov`

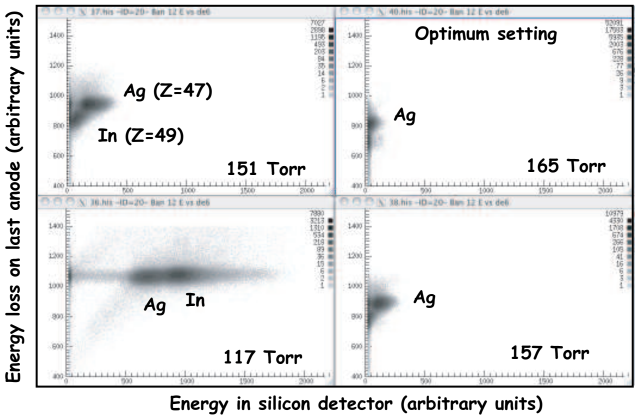

Fig. 1. Energy loss on the last anode of the ionization chamber *versus* implantation energy in the Si detector for $A = 120$ ions at the indicated CF_4 gas pressures. An analysis of γ-rays detected after the ionization chamber indicate that 165 torr is optimum to transmit ^{120}Ag and suppress ^{120}In.

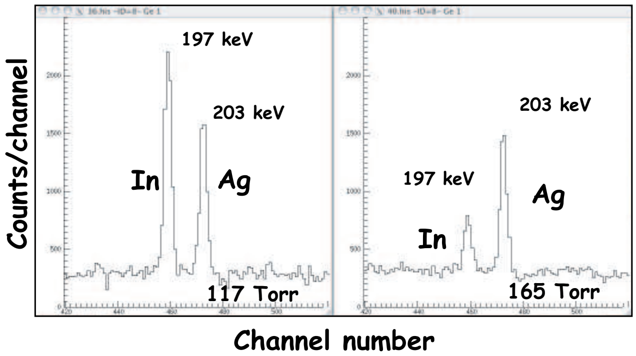

Fig. 2. Ungated γ-ray spectra for $A = 120$ ions at 117 torr and 165 torr gas pressure in the ionization chamber. Note the enhancement of the 203 keV, $T_{\frac{1}{2}} = 0.3$ s isomeric transition in ^{120}Ag. A factor of 5 enhancement is observed.

various isobars, and whatever equipment is required for decay spectroscopy. In our test runs described here, we used a 25 cm^2 square position sensitive Si detector and a single, unshielded Ge detector. For actual experiments we will use a thick double-sided Si detector (DSSD) for halflife measurements or a compact four clover Ge detector array surrounding plastic β-detectors and a tape system for removal of unwanted decay products.

The key to our technique is the energy-loss difference between ions of the same energy [4] as they travel through matter; at our energies, high-Z nuclei lose more energy than low-Z nuclei. Thus, it should be possible to stop some ions in the CF_4 gas and thin mylar exit window while transmitting lower-Z ions to the measuring station. This ranging-out of ions requires a well-defined beam (good emittance as is typical of tandem beams), careful adjustment of the gas pressure, and some signal such as decay-γ-rays which are not dependent on the low-energy thresholds of the ionization chamber and the Si implantation detector. Spectra showing the influence of gas pressure on a beam of ^{120}Ag and ^{120}In ions are shown in fig. 1. Although excellent suppression of the In component of the beam appears possible, these spectra are sensitive to the signal threshold of the ionization chamber electronics and do not indicate that the In ions have been stopped in the chamber or its exit window.

In order to better judge the effectiveness of this technique, we look at the characteristic $A = 120$ γ-rays [5] emitted at the Si detector position. Portions of the spectra taken at 117 and 165 torr are shown in fig. 2. A suppression factor of 5 has been measured for the radioactivity of ^{120}In relative to ^{120m}Ag. While not as dramatic as the electrical suppression had indicated, we will continue to explore this technique's potential.

In these tests, the Si detector was approximately 15 cm from the 1.6 cm diameter exit window of the ionization chamber. The ions traversed approximately 7.8 cm of gas in the ionization chamber. The single-crystal Ge detector was unshielded, located at a small angle directly behind the flange holding the Si detector. The implantation width of the ions is estimated to be 3 cm full-width half-maximum; these widths are well-suited to 25 cm^2 square DSSDs and our 35 mm wide tape. We are considering using a smaller tape located at the exit to the ionization chamber and moving it at 0.25 s intervals. Other improvements include lead shielding, thinner dead layers on the Si detectors, and possibly gas catching and transport of the ions to the tape.

3 Conclusion

We have established a ranging-out technique to study the radioactive decay of neutron-rich beam components. By using an ionization chamber and adjusting its gas pressure, we have reduced the contaminants of the transmitted beam by a factor of 5 for isobars with $\Delta Z = 2$ for $Z \approx 50$. This reduction of contaminants should offset the loss in statistics due to the typical 10% overall beam transmission through the tandem accelerator. Our first experiments will explore Cu, Ga, and Ge isotopes near doubly magic ^{78}Ni and the r-process path.

This work was supported by the U. S. Department of Energy under contracts DE-AC05-00OR22725 (ORNL), DE-FG02-96ER41006 (MSU), DE-AC05-76OR00033 (ORAU), DE-FG02-96ER40983 (UT), DE-FG05-88ER40407 (VU), DE-FG05-87ER40361 (JIHIR), and DE-FG02-96ER40978 (LSU). Oak Ridge National Laboratory is managed by UT-Battelle, LLC.

References

1. E. Roeckl, Nucl. Instrum. Methods B **204**, 53 (2003).
2. C.J. Gross *et al.*, Nucl. Instrum. Methods Phys. Res. A **450**, 12 (2000).
3. D. Morrissey *et al.*, Nucl. Instrum. Methods B **204**, 90 (2003).
4. U. Littmark, J.F. Ziegler, *Handbook of Range Distributions for Energetic Ions in All Elements* (Pergamon Press, New York, 1980).
5. K. Kitao, Y. Tendow, A. Hashizume, Nucl. Data Sheets **96**, 241 (2002).