

INITIAL RESULTS OF THE COMMISSIONING OF THE HRIBF RECOIL MASS SPECTROMETER

C. J. Gross

CONF-961110--2

Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831
and
Oak Ridge Institute for Science and Education, Oak Ridge, TN 37831

Y. A. Akovali, M. J. Brinkman, J. Mas, J. W. McConnell, W. T. Milner, D. Shapira

Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

RECEIVED

OCT 23 1996

OSTI

T. N. Ginter

Physics Department, Vanderbilt University, Nashville, TN 37235
and
Joint Institute for Heavy Ion Research, Oak Ridge, TN 37831

A. N. James

Department of Physics, University of Liverpool, Liverpool L69 3BX, UK
and
Joint Institute for Heavy Ion Research, Oak Ridge, TN 37831

The recoil mass spectrometer at the Holifield Radioactive Ion Beam Facility is currently undergoing commissioning tests. This new spectrometer is designed to transmit ions with rigidities of $K = 100$ resulting from fusion-evaporation reactions using inverse-kinematics. The device consists of two sections: a momentum separator to provide beam rejection and a mass separator for product identification. Using normal-kinematic and symmetric reactions, the commissioning tests have shown that the A/Q acceptance is almost $\pm 5\%$, the energy acceptance is approximately $\pm 12\%$, and there has been little, if any, primary beam observed on the focal plane. Commissioning tests are presently underway with reactions using inverse-kinematics.

A recoil mass spectrometer (RMS) is currently undergoing commissioning tests at the Holifield Radioactive Ion Beam Facility (HRIBF). Similar devices, which are often used to identify exotic nuclei resulting from compound nuclear reactions, are located at many laboratories throughout the world [1-4]. The RMS at the HRIBF represents a new generation of spectrometers [5] by combining a momentum separator for primary beam rejection and a mass separator for product identification.

A. COMPONENTS OF THE RMS

A schematic of the $K = 100$ RMS is shown in Fig. 1 and has been described in-depth in Ref. [5-7]. In summary, it consists of three magnetic dipoles (D), seven quadrupoles (Q), two sextuples (S), and two electric dipoles (E). The physical properties of each element may be found in Ref. [5]. The first two quadrupoles gather the recoiling nuclei and determine the momentum focus which is located inside Q3. The first magnetic dipole separates the recoiling nuclei from the beam based on

momentum. The primary beam, originating from a tandem accelerator, has a well-defined momentum and should be focused spatially according to its charge-state distribution. The recoils have a large momentum distribution caused by the evaporation process and will thus, fill the available space. Small rods called "fingers" may be inserted through the split poles of Q3 to intercept the primary beam at its focus and still have minimal impact on the overall transport efficiency for recoil products. These "fingers" are intended for use with inverse-kinematic reactions where beam particles and recoils have similar rigidities and hence, would all be accepted by the RMS, these "fingers" could provide beam rejection factors of 10^{13} .

The second half of the momentum separator, D2-Q4-Q5, provides a second focus which serves as the object for the mass separator portion of the spectrometer. This position, called the achromat, is energy independent when Q3 is correctly adjusted. The two sextuples provide second-order corrections in the final focus.

The mass separator section contains a magnetic dipole between two electric dipoles. The electric

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

"The submitted manuscript has been authored by a contractor of the U.S. Government under contract No. DE-AC05-96OR22464. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes."

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

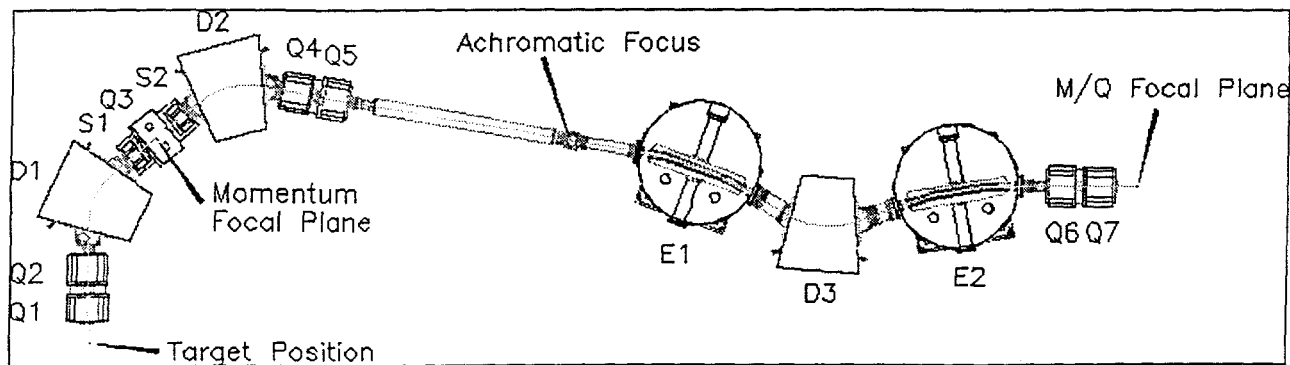


FIGURE 1 The layout of the RMS. The fingers are located at the momentum focal plane located inside Q3.

elements separate the recoils as a function of kinetic energy and charge (E/Q) and the magnetic dipole separates as a function of momentum and charge (P/Q). The net result are recoils separated as a function of mass and charge (A/Q). The magnitude of the mass dispersion is determined by the last pair of quadrupoles, Q6 and Q7. Together with Q4 and Q5, the position of the final focal plane is determined.

The performance parameters of the spectrometer, such as the size of the final image and the mass dispersion, often depend only upon specific groups of elements of the RMS. These elements may be adjusted together without affecting the field values of the other elements. Thus, several "knobs" have been incorporated into the control system so that users may adjust these parameters according to the requirements of the experiment.

B. DESIGN PERFORMANCE PARAMETERS

Various acceptances govern the performance of the RMS and its efficiency to detect recoil products. The RMS is a zero degree device and has an asymmetric, overall solid-angle acceptance. The horizontal acceptance is ± 30 mrad and the vertical acceptance is ± 115 mrad and is determined by the positions of Q1 and Q2. The target-to-Q1 distance is 75 cm. However, other apertures in the system affect the effective overall solid angle which ranges between 10- and 15 msr. The primary beam spot on target should be a vertical line 0.5 mm in width and 2 mm in length. The energy acceptance is determined, in part, by the length of the plates of the electric dipoles and is estimated to be some $\pm 15\%$ at the base. The A/Q

acceptance, reflecting the various apertures throughout the flight path is near $\pm 5\%$. Overall mass resolution ($M/\Delta M$) has been calculated to be 540 although through collimation, it is estimated that this value may approach 1000 (including software corrections).

C. COMMISSIONING DETECTORS

The mainstay detector of the RMS is the position-sensitive avalanche counter (PSAC) located at the final focal plane of the RMS. This detector has an active area of 36 cm by 10 cm and is filled with isobutane gas. The arrangement of planes with respect to the beam is cathode, horizontal sensing plane (electrically split in half), anode, and vertical sensing plane. The anode and cathode have 20 μm gold-plated tungsten wires spaced 1 mm apart. The position sensing planes have the same wires which are spaced 2 mm apart and are connected to delay-lines using 2 ns taps per wire. The overall position resolution attainable with this device is approximately 2 mm. The total PSAC efficiency (defined as those events which cause an anode signal) is better than 90%.

Behind the focal plane, several detector systems may be used. Double-sided silicon-strip detectors (see contribution by K. S. Toth, *et al.*), an ionization chamber, and a moving tape collector have been constructed and will undergo commissioning tests this year. At the target position, a germanium detector array consisting of segmented-Clover detectors (4 Ge detectors in a single housing) and conventional Ge detectors will be used. In the present tests, only four conventional Ge detectors have been used in conjunction with the PSAC to confirm mass identification.

D. INITIAL PERFORMANCE

An alpha source and four reactions have been used to commission the RMS and these are listed in Table 1.

TABLE 1. Reactions used in the initial commissioning tests of the RMS.

Beam	Energy (MeV)	Target	Thickness ($\mu\text{g}/\text{cm}^2$)	Goal
^4He	5.8			initial parameters
^{32}S	120	^{58}Ni	300	mass identification
^{58}Ni	250	^{98}Mo	900	strip detectors ¹
^{58}Ni	250	^{92}Mo	500	strip detectors ¹
^{58}Ni	220	^{60}Ni	300	mass separation

¹Attempts to identify ground state alpha and proton decays from the reaction products using double-sided silicon-strip detectors. See the contribution to these proceedings by K. S. Toth, *et al.* for information about these tests.

The highest mass resolution achieved so far has been $M/\Delta M = 450$ using the Ni+Ni reaction and is shown in Fig. 2. The energy acceptance of the spectrometer has been measured to be at least $\pm 12.5\%$. This value is smaller than similar devices ($\pm 20\%$) due to the longer plates of the electrostatic dipoles. The A/Q acceptance has been measured to be in excess of 4.5%. A total reaction efficiency has been estimated to be 1-2%. Because this efficiency is for all fusion-evaporation recoils, individual channel efficiency will vary with pure nucleon evaporation channels being more efficient than alpha evaporation channels. These efficiencies will increase when inverse-kinematic reactions are used.

One persistent feature of the commissioning tests so far, has been the absence of beam on the focal plane. The momentum separator is clearly preventing scattered beam from reaching the PSAC allowing high primary beam

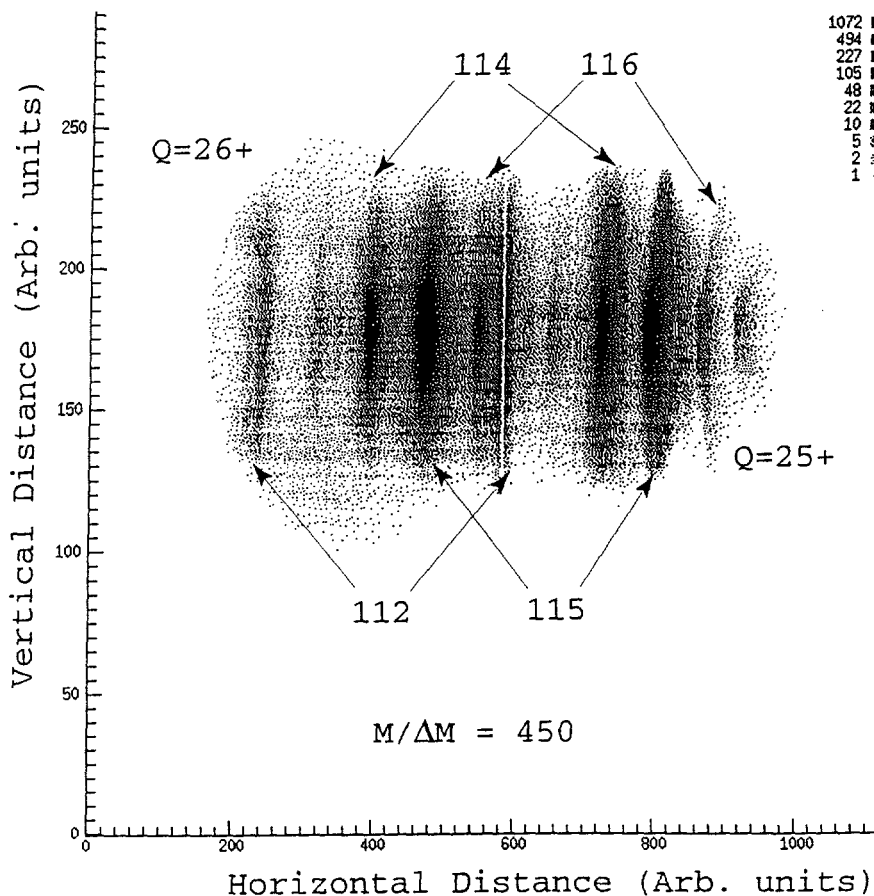


FIGURE 2 The focal plane image resulting from the reaction Ni+Ni reaction. The mass resolution $M/\Delta M = 450$. The spectrum was generated from the PSAC requiring that the sum of each delay-line signal falls within a relatively small gate and the entire range is shown. This spectrum has no other gating conditions. Notice the absence of beam in this spectrum.

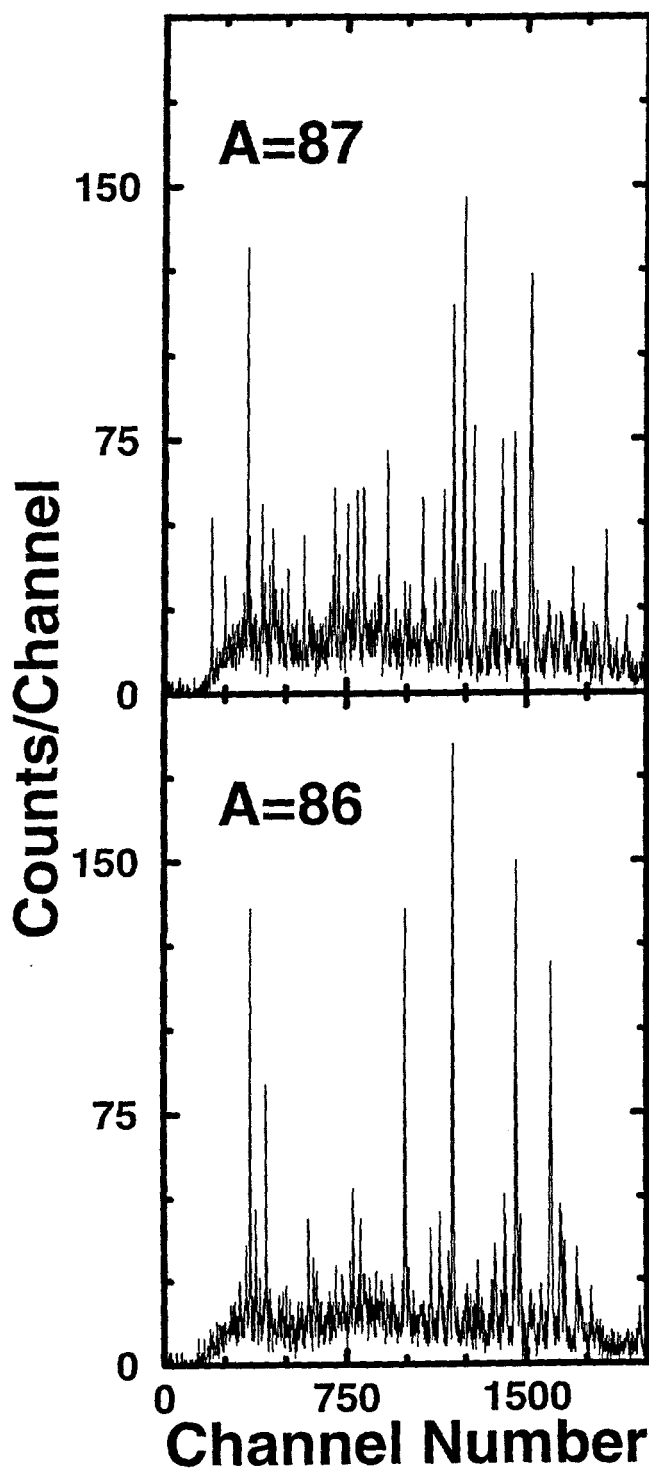


FIGURE 3 Mass 86 and 87 gated γ ray spectra from the S+Ni reaction.

currents to be used. Most tests have been conducted with 15 pA, or more, yet the PSAC has always run at less than 1 kHz.

Mass 86 and 87 γ ray spectra are shown in Fig. 3. These data were taken with the S+Ni reaction and demonstrate the channel selection sensitivity of the RMS. Only those known transitions in ^{86}Nb , ^{86}Zr , and ^{87}Nb can be observed in their respective mass-gated spectrum.

Further commissioning tests will be continuing throughout this year and in 1997. Inverse-kinematic reactions and the successful use of the "finger" system will constitute a large portion of our future efforts. Our upgraded Ge array will become available in 1997, as well as, a 4π charged particle ball located at the target position. Neutron detectors will also augment this in-beam spectroscopy system. The ionization chamber and tape collector plus pair spectrometer plus Clover Ge system will also be tested in the coming months. As radioactive ion beams become available for nuclear structure studies, the RMS stands ready to investigate nuclei far from stability.

E. ACKNOWLEDGMENTS

We would like to acknowledge the work performed by P. F. Mantica, J. J. Das, and R. L. Auble on the installation of the RMS. One of us (J. Mas) acknowledges support from the SERS program administered by Oak Ridge Associated Universities. Research sponsored by the Oak Ridge National Laboratory, managed by Lockheed Martin Energy Research Corporation for the U.S. Department of Energy under contract number DE-AC05-96OR22464. This work was also supported by the U.S. DOE under contract number DE-AC05-76OR00033 (Oak Ridge Institute for Science and Education).

F. REFERENCES

- [1] Cormier, T. M., *et al.*, Nucl. Instrum. Methods **212**, 185 (1983).
- [2] James, A. N., *et al.*, Nucl. Instrum. Methods in Phys. Res. **A267**, 144 (1988).
- [3] Spolaore, S., *et al.*, Nucl. Instrum. Methods **A238**, 381 (1985).
- [4] Davids, C. N., *et al.*, Nucl. Instrum. Methods in Phys. Res. **B70**, 358 (1992).
- [5] Cole, J. D., *et al.*, Nucl. Instrum. Methods in Phys. Res. **B70**, 343 (1992).
- [6] Cole, J. D., *et al.*, in *Exotic Nuclear Spectroscopy*, edited by C. McHarris, (Plenum Press, New York, 1990), p 11.
- [7] Mantica, P. F., Nucl. Instrum. Methods in Phys. Res. **B99**, 338 (1995).