The REU experiment: production and separation of new rare beams ^{20}Na and ^{20}Mg with MARS

L. Trache, B. T. Roeder, A. A. Alharbi, M. McCleskey, E. Simmons, A. Spiridon,
G. Subedi,[1] and REU students
[1]*Colby College, Waterville, Maine, 04901*

This year, our research group has included, for the first time, a dedicated experiment at the cyclotron in which all the REU students were directly involved. In past years, only a few students were participating in experiments with their respective groups depending on the beam time schedule of the accelerator. The experiment was designed to give the students some "hands-on" experience with the setup and calibration of experimental equipment, as well as first-hand experience in the running of an actual experiment at the cyclotron. This also allowed the students to appreciate some of the difficulties involved in scientific research.

In the days prior to the experiment, a series of lectures were presented by the host group, including the post-docs and graduate students, to explain the operation of MARS and the physics relevant to the experiment. The principles of radioactive beam production and their application to nuclear astrophysics were presented. In addition, presentations about the specific experiment our group conducted to explain the setup, electronics and pre-run calibration techniques were given such that the

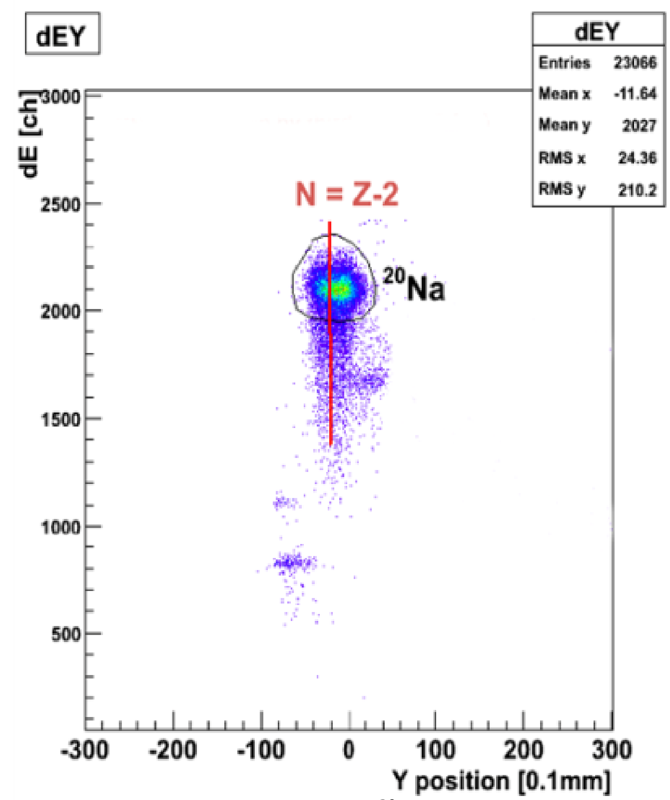

FIG. 1. Results obtained from the ^{20}Na beam production test.

students could follow what was happening in detail. As part of the preparation for the experiment, the students participated in the energy and efficiency calibration of the germanium (Ge) detector used in part 2 of the experiment.

The experiment was conducted in three parts. Part 1 consisted of the production and separation of the rare beam ^{20}Na. ^{20}Na was produced with a ^{20}Ne beam at 25 MeV/u impinging on a H_2 cryogenic gas target at a pressure of 2 atm. The resulting ^{20}Na beam was then separated with the MARS spectrometer [1]. To do this, the REU students had to apply the principles of magnetic separation and velocity filters they learned in the lectures to separate and optimize the ^{20}Na beam. The 12 students were separated into three groups that were led by members of the host group. The groups were in competition to produce the rare beam with the highest rate of ^{20}Na while minimizing the impurities in the beam. The best results were a production rate for ^{20}Na of 1900 events/nC with 11% impurities. In preparation for Part 2 of the experiment, the momentum slits of MARS were closed to ± 0.3 cm. This reduced the final production rate to 950 events/nC with 7.9% impurities. The resulting ΔE vs. Y-position spectrum for the ^{20}Na beam is shown in Fig. 1.

Part 2 of the experiment was to measure the complex (but known) β-, βα-, and βγ- decay of ^{20}Na. To do this, the ^{20}Na beam was implanted in the middle of a very thin (65 micron) Si detector using a simple energy degrading technique. Then, the decay of the ^{20}Na was observed using particle (Si for the positrons and alphas) and gamma detectors (Ge). The students participated by working in the experimental shifts and helping to identify the peaks in the α-particle and γ-ray spectra. A spectrum showing the β-delayed α decay spectrum measured in the experiment is shown in Fig. 2. The measured energies of the α-particles are in agreement with previously published work [2].

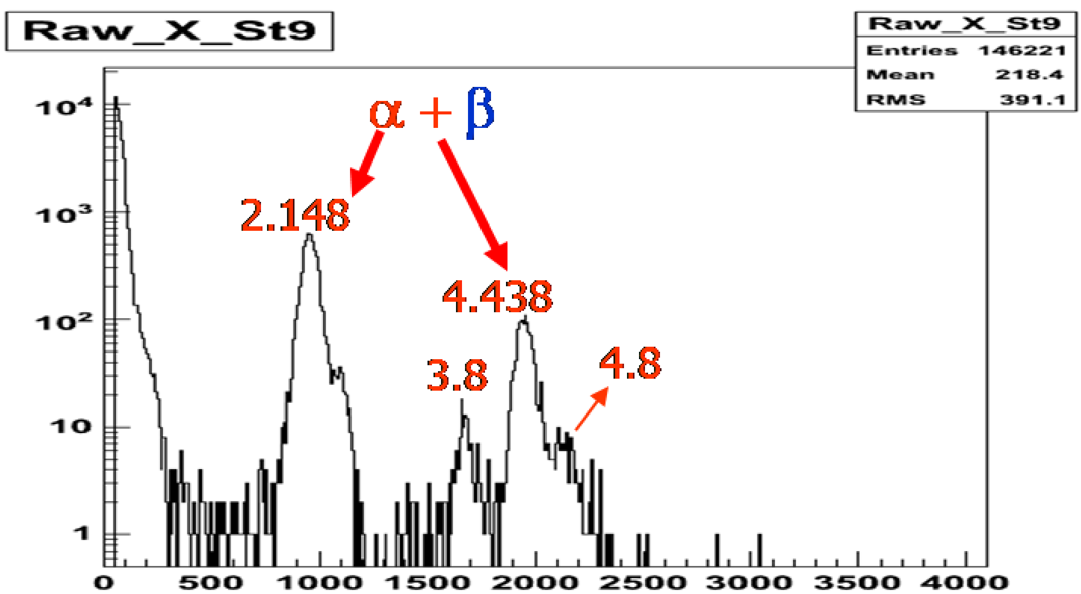

FIG. 2. β-delayed α decay spectrum measured in one strip of the thin Si detector for the ^{20}Na experiment. Energies labeled are in MeV.

Finally, part 3 of the experiment was to test the production of a rare beam of ^{20}Mg in preparation for a future experiment to measure its β-delayed proton decay. This part of the experiment did not involve the REU students, with the exception of the REU student (G. Subedi) that was working in our group. Our REU student's project was to predict the best way to produce ^{20}Mg with theoretical calculations, and to analyze the data from the production test run. The ^{20}Mg was produced with the same ^{20}Ne beam at 25 MeV/u that was used in the ^{20}Na part of the experiment, but the cryogenic gas target was filled instead with 1.5 atm of ^{3}He gas. It was found that the production rate for ^{20}Mg was much lower than the production of ^{20}Na and that there was a large, unavoidable contamination from ^{10}C. A production rate of 21 events/μC was measured for ^{20}Mg, while the ^{10}C contamination was approximately 10 times more intense. However, this method was preferred over other methods of ^{20}Mg production because the ^{20}Ne beam could be easily obtained at high intensity from the cyclotron, and the ^{10}C contamination turned out to not be a problem for the future measurement. The final ΔE vs. Y-position spectrum for the ^{20}Mg beam illustrating the contents of the beam with the MARS slits open is shown in Fig. 3.

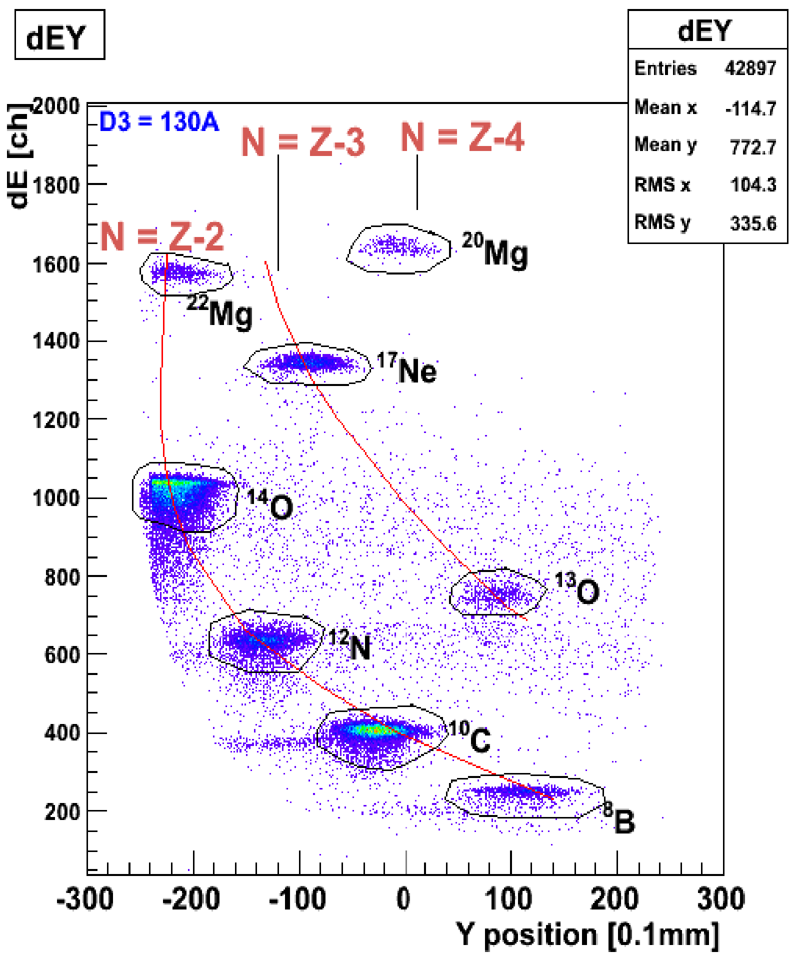

FIG. 3. Results of the ^{20}Mg beam production test run.

The results of the ^{20}Na production and decay measurements, as well as the ^{20}Mg production measurements, were presented by our group's REU student (G. Subedi) in a poster at the CEU conference at the Joint APS DNP/JSPS meeting in Hawaii in October 2009. Overall, the REU students enjoyed the experience of participating in a real experiment. Also, this experiment was beneficial to the host group as the post-docs and graduate students learned not only details about the setup and preparations for the experiment, but also how to explain what they were doing to the REU students. Because of these mutual benefits for both the host group and the REU students, future runs for the REU students are going to be planned.

[1] R.E. Tribble, R.H. Burch, and C.A. Gagliardi, Nucl. Instrum. Methods Phys. Res. **A285**, 441 (1989).
[2] E.T.H. Clifford *et al.*, Nucl. Phys. **A493**, 293 (1989).