The 2017 REU experiment: Rare isotope beam production from the $^{58}Ni+^{58}Ni$ reaction with MARS

B.T. Roeder, R. Roundey,[1] M. Youngs, and Summer 2017 REU students
[1]*Hillsdale College, Hillsdale, Michigan*

During our Research Experience for Undergraduates (REU) program for summer 2017, a dedicated experiment for the undergraduate students was conducted using the Cyclotron Institute facilities. The experiment was designed to give the students some “hands-on” experience with the setting up and execution of a real nuclear physics experiment. The REU students received one day of introductory lectures prior to their participation in the experiment, followed by two days of experiment. During the experiment, the students aided in debugging the detector electronics, tuning rare isotope beam through the Momentum Acromat Recoil Separator (MARS) spectrometer [1], and analyzing the online data as it was collected. In addition, the REU student directly associated with the project, R. Roundey, participated in the planning of the experiment by performing simulations prior to the experiment. The student also analyzed the data in detail following the experiment and reported the results in a poster at the Fall 2017 meeting of the Department of Nuclear Physics of the American Physical Society.

Leading up to the experiment, R. Roundey conducted simulations for the experiment with the model of MARS in the program LISE++ [2]. She was instructed to study the reaction ^{58}Ni+Ni for the purpose of investigating what isotopes could be produced and separated near the proton dripline in the region near mass A=50. To maximize production of these isotopes, she performed simulations to optimize the predicted beam energy, intensity, target thickness, and whether or not a stripper foil following the target could improve the production. Following extensive calculations, it was determined that ^{58}Ni at 36 MeV/u on a nickel target 100 μm would give the best results based on the beam intensities available at the Cyclotron Institute. It was also predicted that a carbon stripper foil would increase the rate measured for the isotopes produced in the “fully-stripped” charge state. Reactions for ^{58}Ni on a ^{9}Be target were also simulated for comparison.

The ^{58}Ni+Ni and ^{58}Ni+Be experiment was conducted over two days with one day for each target. For the ^{58}Ni+Ni, a 36 MeV/u $^{58}Ni^{19+}$ beam from the K500 impinged on a 100 μm natural Nickel foil at the entrance of MARS [1]. A thin carbon stripper foil, 47.7 $\mu g/cm^2$, was also mounted after the target in an attempt to increase the reaction products in the “fully stripped” charge state. This foil was found in subsequent analysis to have a negligible effect. About 35 enA of beam was available for the measurement. To investigate the nuclei produced near the proton dripline, MARS was tuned for magnetic rigidities consistent with the production of ^{53}Ni. While this setting was not close to the proton dripline for Ni isotopes, it did allow a search for isotopes near the dripline for odd “Z” elements, such as Co and Mn. The results for a data run taken for about 12 hours are shown in Fig. 1. To remove background due to scattered primary beam, the particle identification plot ΔE vs. Y-position shown was gated with a large gate in the ΔE versus E spectrum. This ensures that only particles with the proper predicted energy losses are taken into account for the identification. As shown, isotopes in the N=Z-3 line, such as ^{53}Ni and ^{47}Mn were clearly populated. A few counts consistent with the production of N=Z-4 isotopes are also observed at the very low rate of a few counts/hour. More primary beam or more time to take data would have made the results more conclusive.

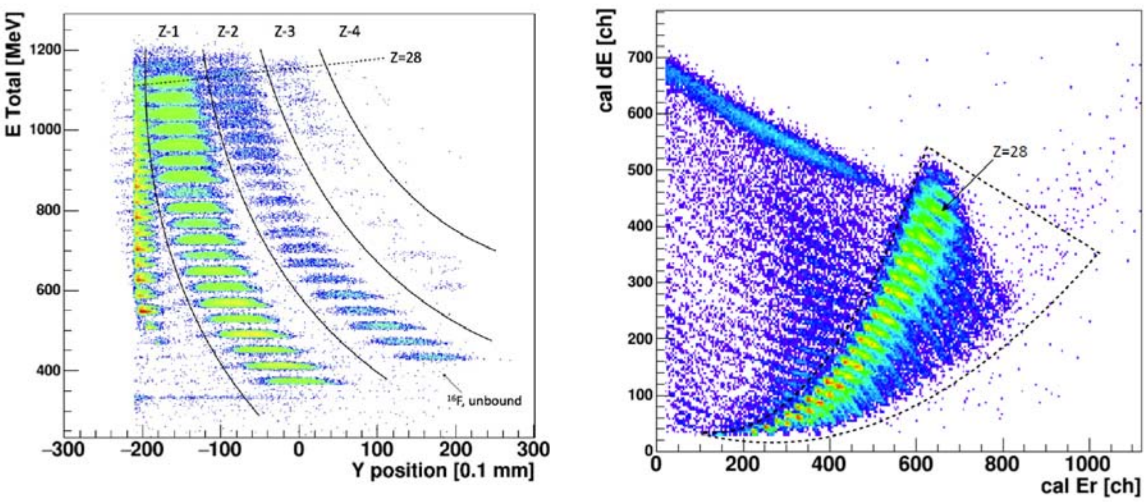

FIG. 1. Particle identification plots for the ^{58}Ni+Ni data. N=Z-3 and a few N=Z-4 isotopes were populated. See text for explanation.

For the ^{58}Ni+Be target data, the same ^{58}Ni beam at 36 MeV/u from the K500 cyclotron impinged on a Be foil 304 μm thick. The reaction was measured for about 7 hours. The result of that series of runs

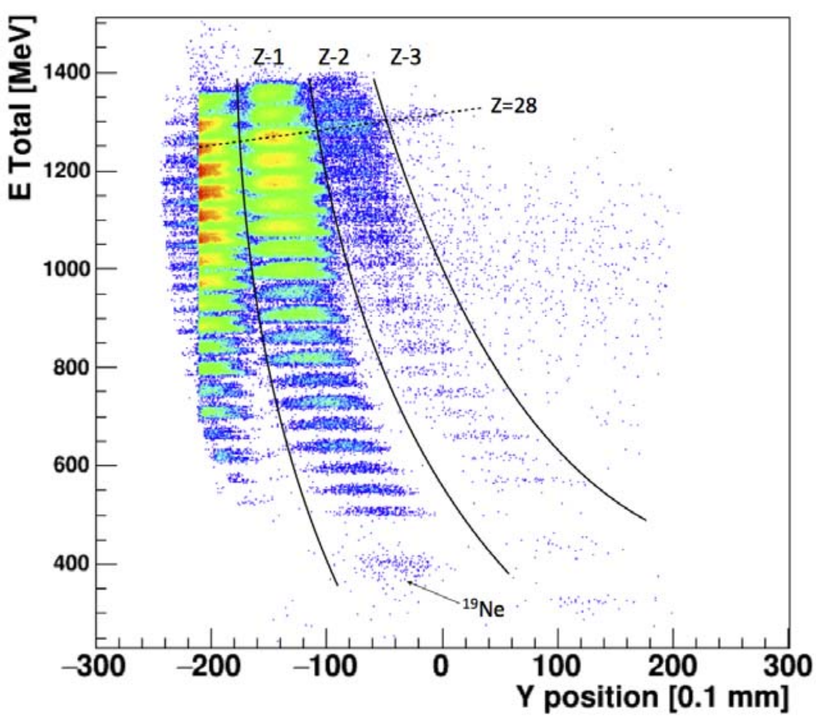

FIG. 2. Particle identification plot for the ^{58}Ni+Be data. N=Z-3 isotopes were populated, but with lower intensity than with the Ni target. See text for explanation.

is shown in Fig. 2. In this case, the only clearly observed N=Z-3 isotope was ^{53}Ni, although a few counts consistent with other N=Z-3 isotopes were noted. No counts consistent with N=Z-4 isotopes were observed.

In conclusion, N=Z-3 and N=Z-4 nuclei in the mass region of A=50 have been produced and observed using a beam, in this case ^{58}Ni at 36 MeV/u, available at the Cyclotron Institute. However, contrary to the predictions of LISE++ [2,3], more exotic isotopes closer to the proton dripline were produced with the Ni target as opposed to the Be target, as was predicted by the model. This reaction was studied as part of an on-going study that has shown that using nickel as a production target produces nuclei further from stability and removes more particles from the primary beam than a beryllium target.

[1] R.E. Tribble, R.H. Burch, and C.A. Gagliardi, Nucl. Instrum. Methods Phys. Res. **A285**, 441 (1989).

[2] B.T. Roeder *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2013-2014) p. IV-40; http://cyclotron.tamu.edu/progress-reports/2013-2014/SECTION IV.html.

[3] O.B. Tarasov and D. Bazin, Nucl. Instrum. Methods Phys. Res. **B266**, 4657 (2008).