Production of Radioactive Beams on the Proton Dripline Using MARS

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Introduction

Exotic nuclei near the proton dripline are of interest for research in nuclear astrophysics. These nuclei's properties are important in the study of the r-p process. Radioactive beams of these nuclei can be made using in-flight techniques and individual isotopes can be separated based on charge to mass ratio and energy loss. In this project the Momentum Achromat Recoil Spectrometer[1] (MARS) at Texas A&M was used to produce and separate radioactive nuclei of interest for future experiments. Production of these exotic nuclei is commonly done at high energies[2] but the possibilities of production at low energies is of interest at this facility.

Purpose

The primary goal of this project is to identify which proton rich nuclei can be produced from a ^{58}Ni beam on both Nickel and Beryllium targets at low energy. Resulting production rates are compared to predictions from the simulation tool LISE++[3] to test the accuracy of these predictions at the energies used. The effects of the target material and a Carbon stripper foil on production rates were also measured and compared to simulations.

Methods

After the beam reacts with the target, particles are first filtered by magnetic rigidity, then separated in vertical position by the velocity filter according to their charge-to-mass ratio. A Carbon stripper foil placed immediately after the target, in theory, strips excess electrons off the products, increasing production rates. The spectrometer can be tuned for particular isotopes to increase transmission rates of those isotopes. Two Silicon detectors were used, allowing particles to be identified by position in Y and energy loss in each detector at the end of the spectrometer. Isotopes could then be counted and production rates calculated by normalizing counts to the integrated beam current.

Particle Identification

A 36 MeV/u beam was used on both a 100μm Ni target and a 304μm Be target. Nuclei can be identified in the spectra by total energy loss in the detectors and vertical position.

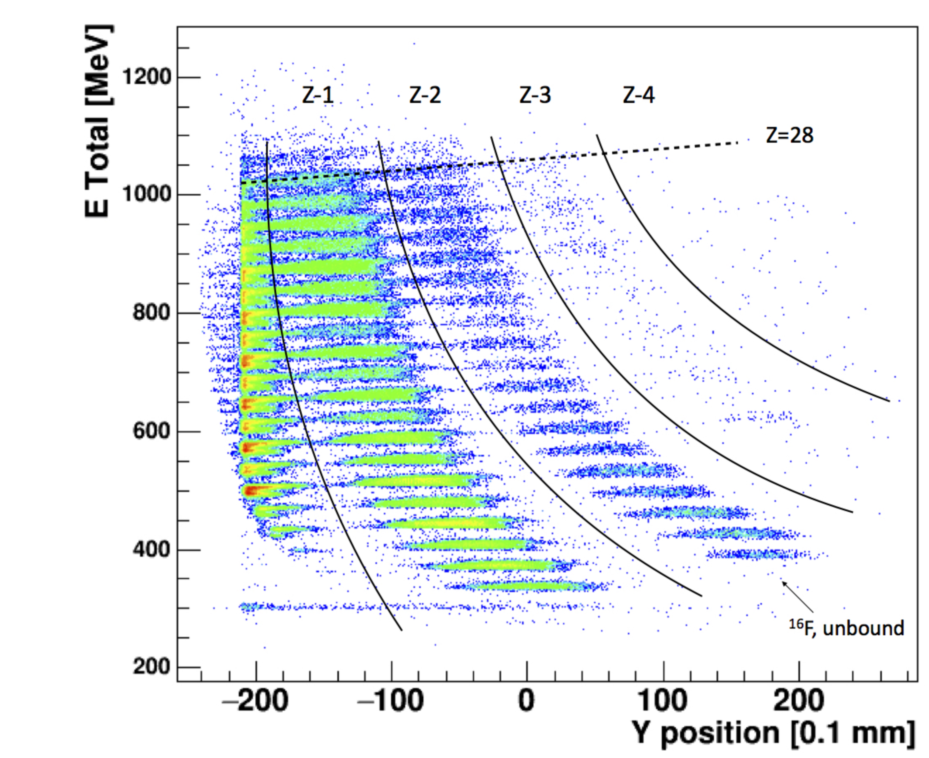

Figure 1: ^{58}Ni beam on Ni target, tuned for ^{52}Ni, after data gate to eliminate background.

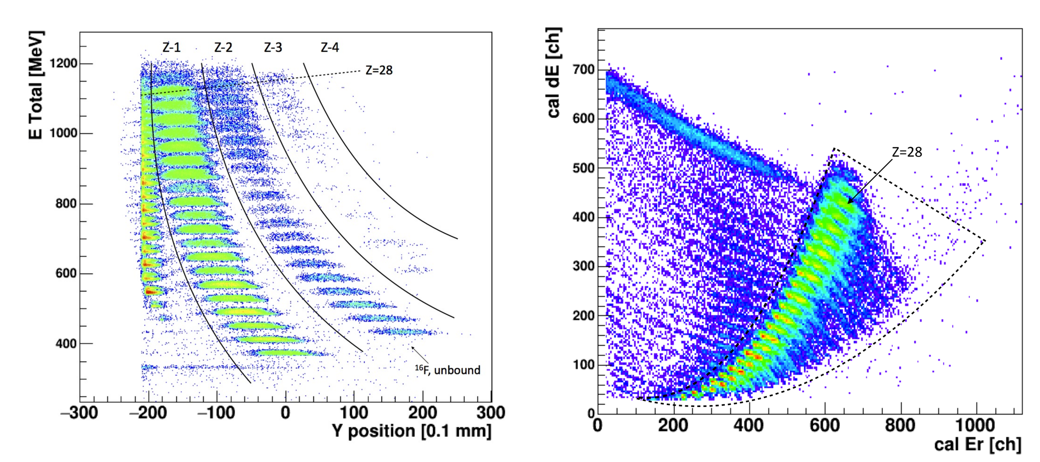

Figure 2: ^{58}Ni beam on Ni target, tuned for ^{53}Ni. A gate on the spectrum of energy loss in each detector allows background to be reduced in the energy vs position spectrum, as shown.

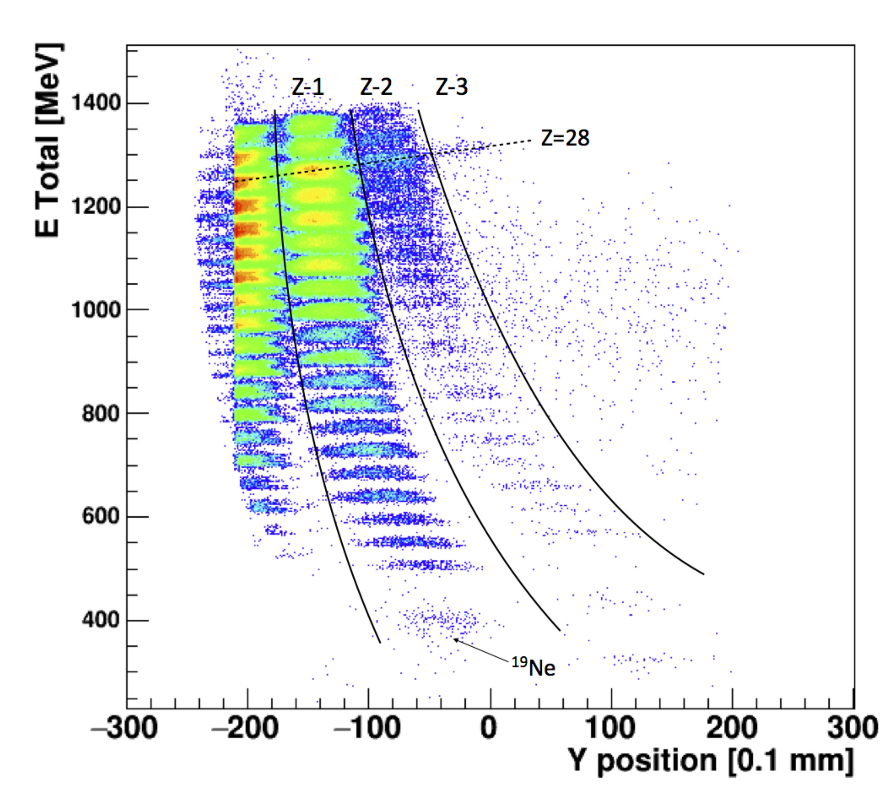

Figure 3: ^{58}Ni beam on Be target, tuned for ^{53}Ni, with data gate to eliminate background.

Results

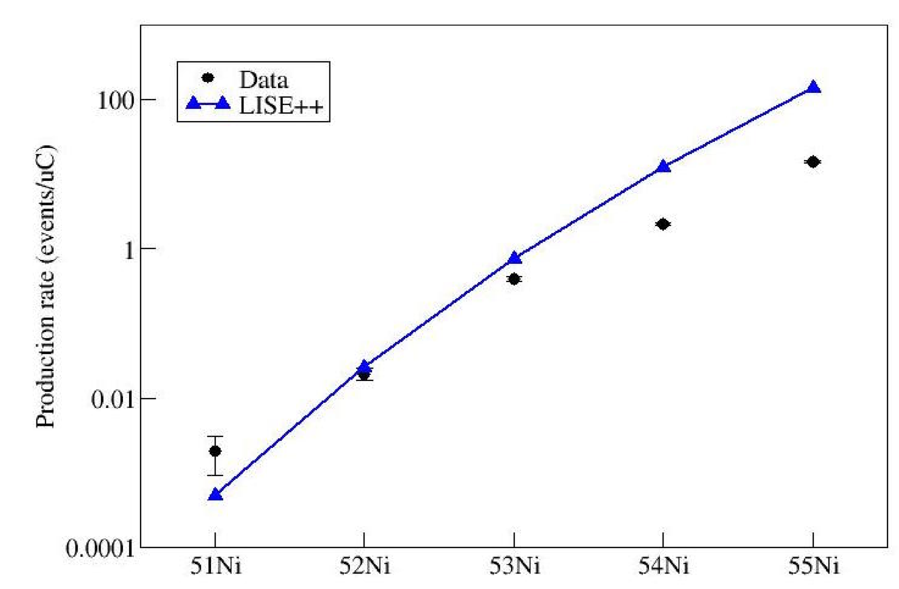

Figure 4: Nickel isotopes produced when tuned for ^{52}Ni, with stripper foil

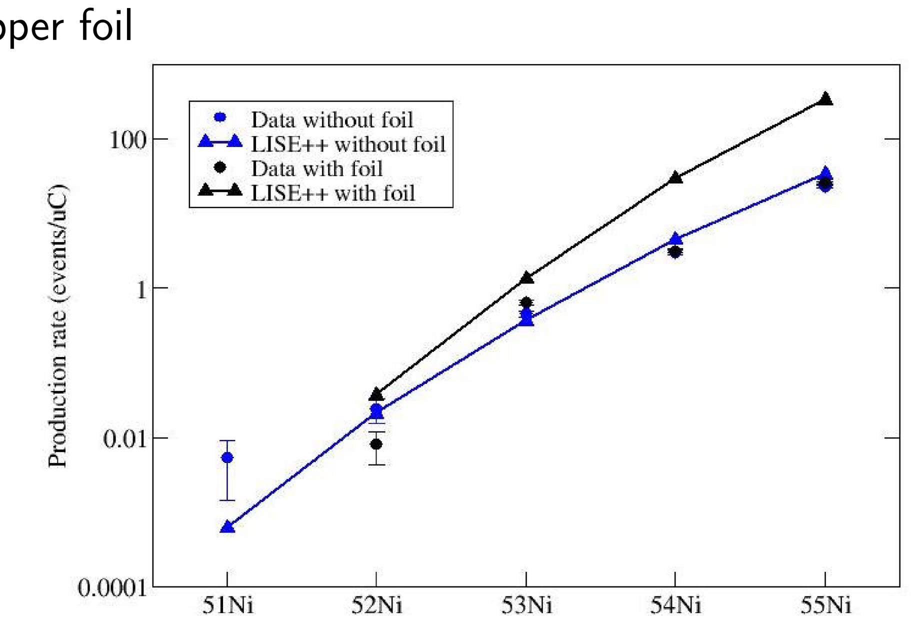

Figure 5: Nickel isotopes produced when tuned for ^{53}Ni, with and without stripper foil.

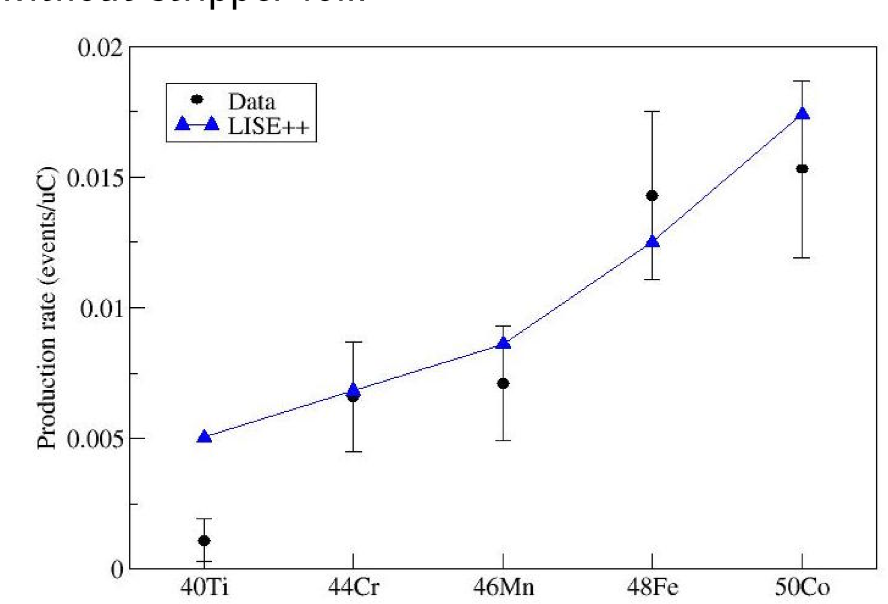

Figure 6: Z-4 isotopes produced from ^{58}Ni beam on Ni target, tuned for ^{52}Ni

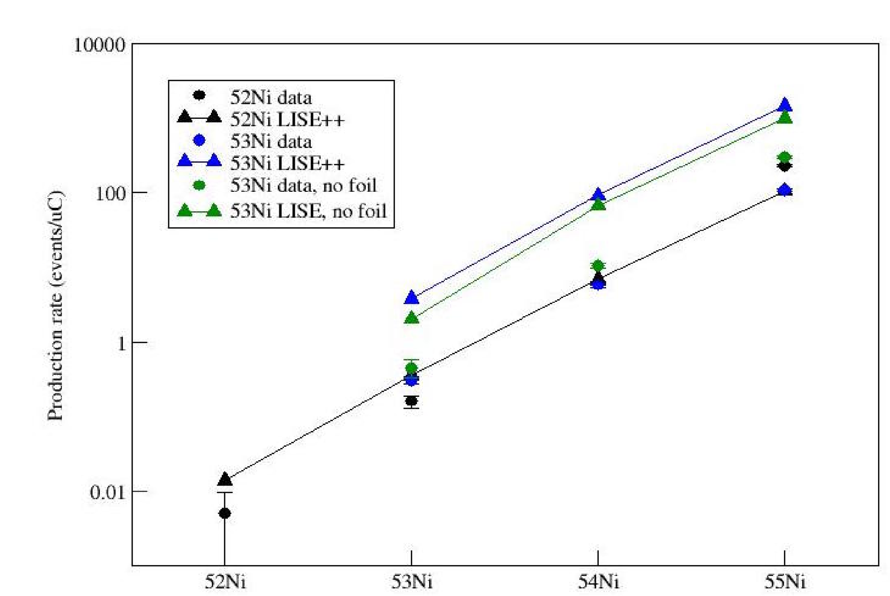

Figure 7: ^{58}Ni beam on Be Target. In general, production from the Be target was lower than the LISE predictions.

		Be target		Ni target	
		LISE	data	LISE	data
^{52}Ni tuning	^{51}Ni	.0002	0	.0005	.002
	^{52}Ni	.014	.005	.0259	.0211
	^{53}Ni	.354	.159	.731	.3956
	^{54}Ni	6.92	6.173	12.3	2.14
	^{55}Ni	105	232	141	14.7
		LISE	data	LISE	data
^{53}Ni tuning	^{52}Ni	.008	0	.037	.008
	^{53}Ni	3.81	.305	1.32	.656
	^{54}Ni	91.9	5.66	29.1	3.161
	^{55}Ni	1440	109	330	25.5

Table 1: Production rates (in events/μC) for Ni and Be targets compared

Conclusion

In general, the Nickel target had higher production rates and populated isotopes nearer the dripline than the Beryllium target. The stripper foil did not increase production rates, and in the reaction tuned for ^{53}Ni (fig. 5) decreased production rates for ^{52}Ni and ^{51}Ni. While LISE++ predictions were accurate for the magnetic rigidity tuned for (as shown in figures 4 and 6 especially), the precision decreased for isotopes farther from that rigidity.

Future Work

It is of interest to know whether isotopes in similar proximity to the dripline can be produced from other beams, such as ^{54}Fe, on a Ni target. This reaction also enables the study of β-delay proton emission in isotopes in this region.

References

[1] R.E. Tribble, R.H. Burch, and C.A. Gagliardi. *Nucl. Instrum. Meth.*, 285(3):441, Dec 1989.

[2] C. Dossat et al. *Nucl. Phys. A*, 792:18, Aug 2007.

[3] O.B Tarasov and D. Bazin. *Nucl. Instrum. Meth.*, 266:4657, Oct 2008.

[4] B.T. Roeder and O.B. Tarasov. Technical Report p. IV-40, Cyclotron Institute, 2013-2014.

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