Production of Nuclei on the Proton Dripline

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Introduction

- Exotic radioactive beams are of interest in a multitude of fields in physics such as Nuclear Astrophysics.
- In order to study the properties of these beams they must be created in a laboratory.
- These beams have been previously produced at beam energies of >77MeV/u using projectile fragmentation.
40Ca beam at 40 MeV/u because that is the maximum beam energy K500 could make with reasonable beam intensity

Using 100µm Ni, 254µm Al, and 456µm Be targets

Using LISE++ assuming projectile fragmentation reaction

In projectile fragmentation product velocity is $\approx$ the beam velocity, so

$$\frac{B\rho_2}{B\rho_1} \propto \frac{q_1/m_1}{q_2/m_2}$$

Goal is to determine how much $^{35,36}$Ca can be made with a 40MeV/u beam and compare to LISE++
Method: MARS

- Beam reacts with target and products are separated by $B\rho = \frac{mv}{q}$
- Faraday cup in coffin reads beam current
- Velocity filter filters products by $\frac{q}{m}$
- $\Delta E$ vs. $E$ Si telescope detects energy deposited as a signal which is recorded by DAQ
- Tuned MARS for particular isotopes using LISE++
**Method: Calibration**

**Figure:** Peaks are used to calibrate detector. Each peak represents -.4cm, 0, .6cm respectively which is controlled by the slits before the beam hits the detector.

**Figure:** Our $^{40}$Ca beam is assumed to be the largest blob on the $N=Z$ line which is used to make a energy per channel calibration. Gaps in spectrum are used to confirm the energy calibration.
Particle Identification

**Figure:** Particles Identified for the $^{40}$Ca beam on Ni target with MARS tuned for $^{35}$Ca. Full spectrum is shown. Particles are identified by the energy loss in the Si telescope using the physical calculator in LISE++.  

**Figure:** Gated spectrum for the energy loss in $\Delta E$ detector vs. energy loss in $E$ detector for the Ni target which is used to eliminate background from the Etot vs Y spectrum.
**Figure:** Particles Identified for the $^{40}\text{Ca}$ beam on Al target with MARS tuned for $^{35}\text{Ca}$. Spectrum is cut to Mg.

**Figure:** Particles Identified for the $^{40}\text{Ca}$ beam on Be target with MARS tuned for $^{35}\text{Ca}$. Spectrum is cut to Mg.
Results

- Plots are shown as $\frac{\text{pps}}{\text{enA}}$ as a way of normalizing results, where pps is particles per second.
- 60 enA of beam on target throughout experiment which gives production rates.

**Figure:** Yields for $^{40}\text{Ca}+\text{Ni}$ reaction compared to LISE++ predicted rates using the projectile fragmentation reaction mechanism. The particles per second per enA when multiplied by the beam current gives the production rates for $^{35,36}\text{Ca}$. 
Results

Figure: Yields for a 60enA $^{40}$Ca beam on the Al target compared to the LISE++ predicted rates. The Al target in experiment underperforms in comparison to the LISE++ predicted results.

Figure: Yields for a 60enA $^{40}$Ca beam on the Be target compared to the LISE++ predicted rates. The Be target in experiment vastly underperforms in comparison to the LISE++ predicted results.
Found that the Ni target has a higher production rate than what LISE++ predicted.

Need only few counts per hour for experiments.

Ni target produced $\sim 82$ $^{35}\text{Ca}$ and $\sim 1295$ $^{36}\text{Ca}$ every hour.

Al and Be targets failed to populate $^{35,36}\text{Ca}$ to what LISE++ predicted.

Al and Be targets made $\sim 40$ $^{35}\text{Ca}/\sim 933$ $^{36}\text{Ca}$ every hour and $\sim 10$ $^{35}\text{Ca}/\sim 328$ $^{36}\text{Ca}$ every hour respectively.
We seek to explore other nuclei that can be produced such as $^{39,40}\text{Ti}$.

Production of $^{35}\text{Ca}$ can let us study its $\beta$-delayed proton and $\beta$-delayed two-proton emission.
References and Acknowledgements

R.H. Burch R.E. Tribble and C.A Gagliardi.

O.B. Tarasov and D. Bazin.

The Stopping and Range of Ions in Solids.

M. Lewitowicz et al.
Beta-Decay of Light Nuclei Close to the Proton Drip-Line: $^{40}$Ti and $^{35}$Ca.

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