

Characterization of the MARS Velocity Filter for Low-Velocity Ions

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Introduction

A program to study the production, decay and chemistry of the heaviest elements using the MARS^{[1][2]} separator at the Cyclotron Institute at Texas A&M University has been implemented. To produce these heavy elements, also known as transactinides, we induce a fusion reaction using two lighter elements. Due to the kinematics of the nuclear reaction, we use the lighter of the two elements as the accelerated beam and the other as the target. The production process gives rise to many unwanted particles due to other reactions. The transactinide of interest has certain properties including magnetic rigidity and velocity, which are used to direct it through MARS and filter out the unwanted particles. The transactinides produced are low-energetic ions with low velocities on the order of 0.02c.

The MARS has several filtration mechanisms including: slits, dipole magnets, quadrupole magnets and the velocity filter (Figure 1). However, MARS is typically used for the production of energetic light ions which travel at high velocities (>0.08c). This project is aimed at determining the acceptance of the velocity filter and the ratio for electric to magnetic field necessary to transmit low-velocity ions.



Figure 1. MARS separator: indicating the different filtration mechanisms. The dipoles (D1-D3) filter particles based on magnetic rigidity. The sits physically block unwanted particles and the velocity filter determines what is transmitted based on the velocity of the particles.

Calculations

Alpha particles emitted by a 241 Am source were simulated going through 50 μ g/cm² of nat C and nat Al degraders of various thicknesses including 6.1 µm. 12.3 µm and 18.4 µm (Figure 2).

The energy remaining and velocity of α -particles after going through $50\mu g/cm^2$ of nalC cover and each degrader were calculated using LISE program's physical calculator [3] (Table 1).

The energy distribution was then calculated for the different degrader thicknesses (Figure 3).

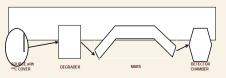


Figure 2. The path taken by particles emitted by the source. The ^{™C}C cover is placed over the source to prevent contamination. The particle then travels through the degrader, through the MARS separator including the velocity filter then into the detector chamber where it is detected.

Calculated Energy Distribution of Source Particles

The distribution of α -particles as they travelled through the ^{nal}C cover and aluminum degraders of various thicknesses were simulated using SRIM /TRIMI⁴¹ (Figure 3).

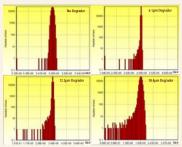


Figure 3. The energy distribution of the alpha particles emitted by ³⁴¹Am source. The energy distribution width increases as the thickness of the degrader increases. **Note:** Graphs are not on the same scale.

Degrader (µm Al)	v/c	Energy Remaining (MeV)	Δνίν.	
0	5.40%	5.44	±0.02%	
6.1	4.89%	4.47	±0.20%	
12.3	4.21%	3.30	±0.40%	
10.4	2 129/	1.02	+1 0EW	

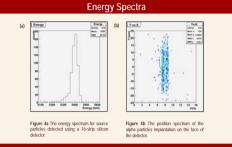
Table 1. Summary of properties of the energy distribution of alpha particles emitted by a ²⁴¹Am source as shown above

Source Experiments

Aluminum degraders were used to slow the particles down closer to that of the velocity of the transactinides (0.02c) that we are interested in producing. The particles are transmitted through MARS using specific settings for the magnets and velocity filter.

- With the experimental set-up in place, the velocity filter was turned off and the separator was tuned for no degrader. An energy peak was detected at approximately the expected energy of 5.45 MeV (Figure 4a).
- The velocity filter was then turned on. The electric field was set and the magnetic field was scanned and the rate was measured.
- The electric field was set to another value and the magnetic field was scanned again.
- 4. Steps 1-3 were repeated for the various degraders.

The goal of the experiment was to measure the acceptance of the velocity filter. The ratio of electric field to magnetic field was measured for ions of specific velocities.



Analysis

The velocity filter has two independent settings, one for the electric field (E) and another for the magnetic field (B). The electric field steers particles downwards. The magnetic field steers particles upwards. Together these two fields transmits ions where,

$$v = \frac{1}{B}$$

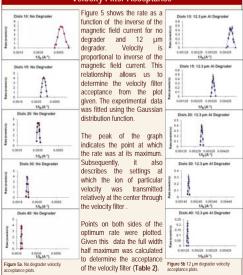
 $v \propto \frac{1}{B}$ or $v \propto \frac{1}{I_B}$

where I_B is the magnetic current.

therefore,

The acceptance of the velocity filter was determined by fitting the data (rate vs. $11_{\rm b}$) acquired from the experiment using a Gaussian fit and calculating the full width half maximum to determine the velocity acceptance (**Figure 5**).

Velocity Filter Acceptance



Calculated Velocity Filter Acceptance

The acceptance of the velocity filter was calculated for each degrader including no degrader at each electric field setting (Table 2). The acceptance was plotted as function of the electric field setting (Figure 6).

Dials (Electric Field)	No Degrader	6.1 µm Degrader	12.3 μm Degrader	18.4 µm Degrader
10	±6.3%	±6.2%	±3.7%	±2.2%
15	±5.3%	±4.0%	±2.4%	±2.3%
20	±3.5%	±3.5%	±2.3%	±2.3%
30	±3.0%	±2.2%	±2.0%	±2.2%
40	±2.2%	±2.0%	±1.9%	-

Table 2. Acceptance for the different electric field settings and different degraders used. The increase in dials implies an increase in the electric field for the velocity filter.

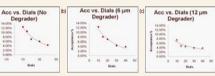


Figure 6a. Acceptance as a function Figure 6b. Acceptance as a function of plectric field for no degrador.

or 6 µm degrader of electric field for 12 µm deg

Conclusion

The acceptance of the velocity filter decreases as the electric field increases. In addition, the rate detected decreases as the electric field increases.

Future Work

We intend to use ¹⁴⁸Gd source to achieve lower velocities closer to 0.02c and determine settings necessary to transmit those ions. Using information gathered from offline experiments, we will conduct beam experiments to more precisely calibrate MARS for low-energy, low-velocity ions.

Acknowledgements

This REU program was funded by the National Science Foundation (NSF). The project was funded by Department of Energy and The College of Science, TAMU. Special thanks to Dr. Sherry Yennello, Ms. Leslie Spiekes, Dr. Charles M. Folden III, Marisa Alfonso and Paul Cammarata.

References

[1] R. E. Tribble, C. A. Gagliardi, and W. Liu, Nucl. Instrum. Methods Phys. Res. B56/57, 956 (1991).

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

[3] O. B. Tarasov and D. Bazin, Nucl. Phys. A 746, 411c (2004) available at http://www.nscl.msu.edu/lise.

[4] J. F. Ziegler, Nucl. Instrum. Methods Phys. Res. B 219, 1027 (2004) available at http://www.srim.org.