Characterization of the MARS Velocity Filter for Low-Velocity Ions

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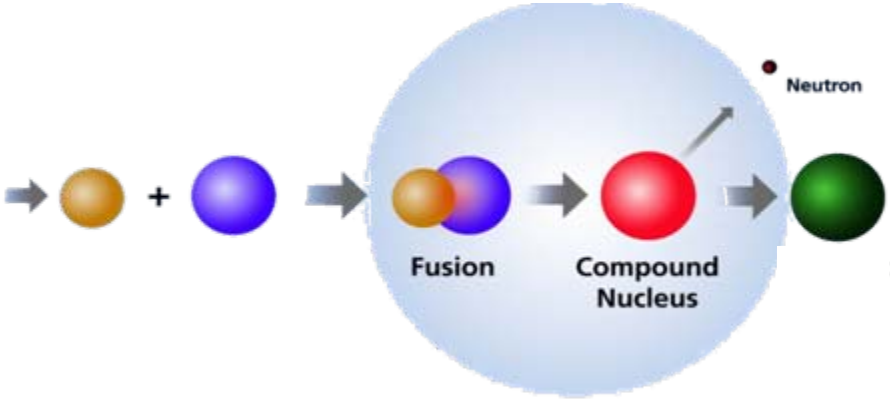
Introduction

- Our research focuses on the transactinides, the elements with atomic numbers of 104 and higher.
- We are aimed at answering some fundamental questions in nuclear science:
  - What is the heaviest element that can be formed?
  - Does the periodicity of the elements continue as we form these heavier elements?
  - How are these heavy and superheavy elements created?
- We have implemented a program to study the production, decay and chemistry of the heaviest elements.

Production of Heavy Elements



- The lighter of the two is used as the beam.
- The "excitation function" contains information on:
  - the reaction cross section,
  - the decay of the excited "compound nucleus and
  - the deexcitation of the compound nucleus.

The Excitation Function

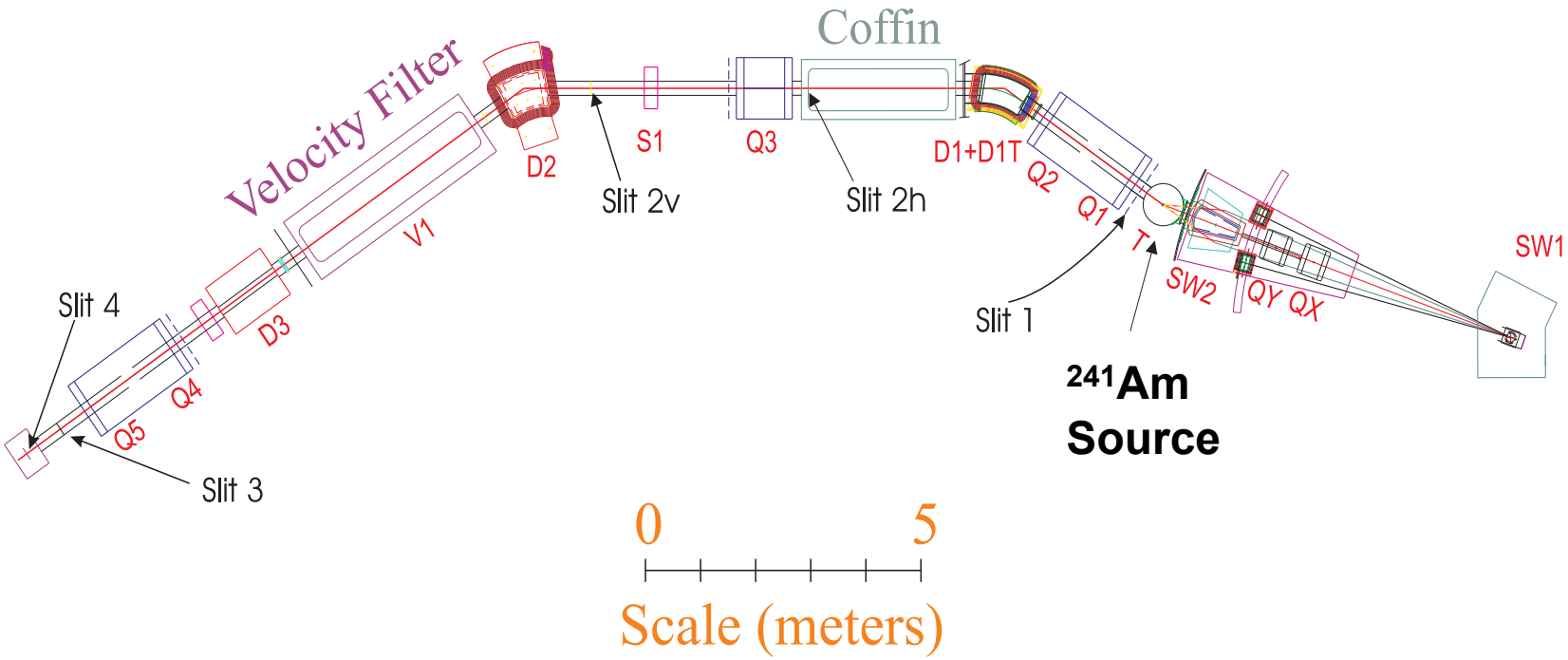
- The excitation function is narrow and specific.
- The velocity of the product is predetermined.

$$E_{CN} = E_P\left(\frac{m_P}{m_{CN}}\right) \approx E_P\left(\frac{A_P}{A_{CN}}\right)$$

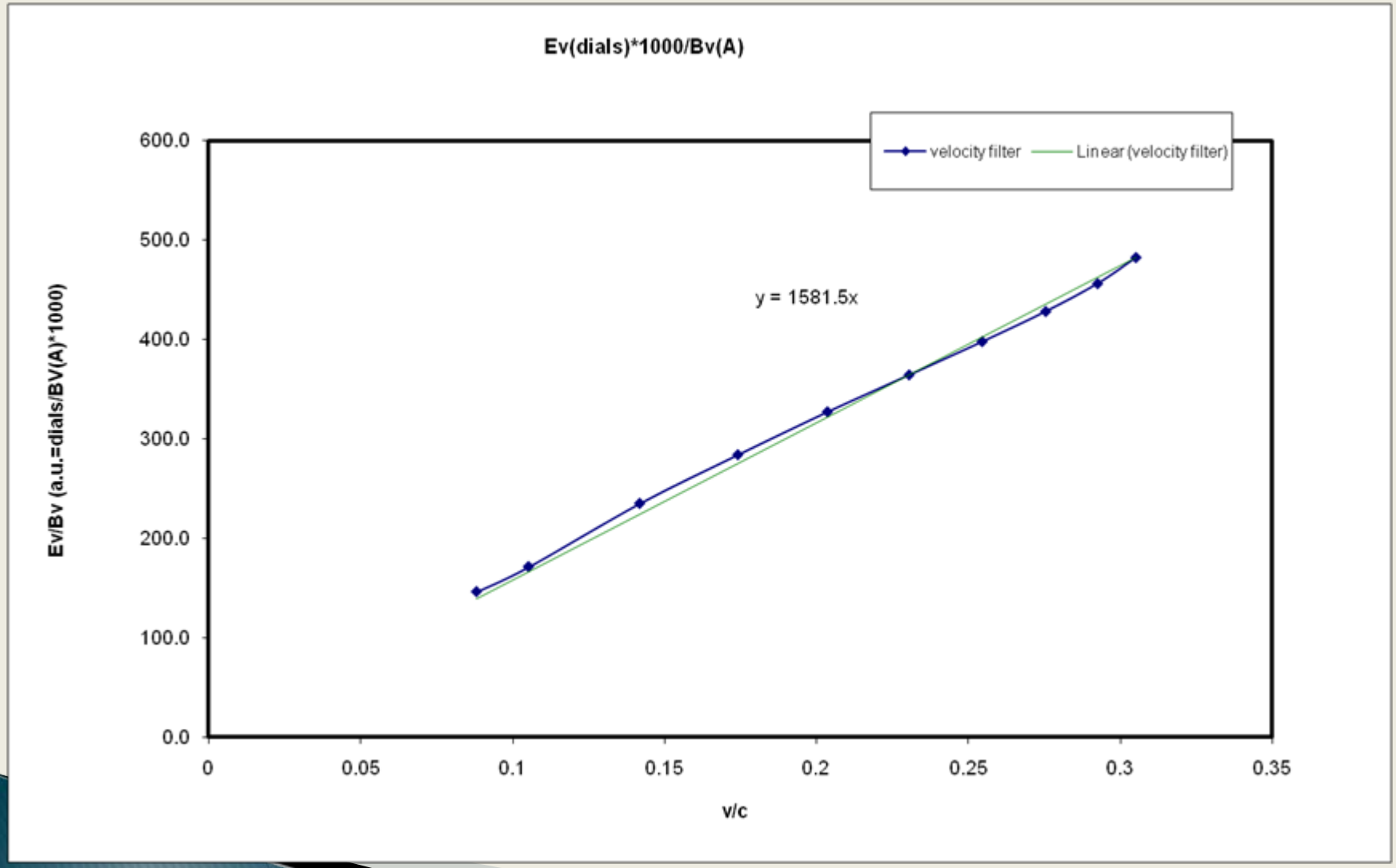
$$E = \frac{mv^2}{2} \Rightarrow v = \sqrt{\frac{2E}{m}}$$

Using MARS

Momentum Achromat Recoil Separator



The Velocity Filter

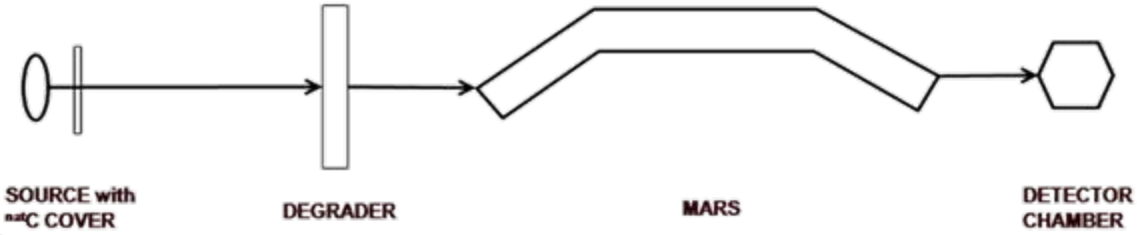


Methodology

- Calculated the energy distribution of alpha particles.
  -  Simulated alpha particles going through different degraders using SRIM/TRIM.
- Calculated the velocity of particles after going through ^{nat}C cover and ^{nat}Al degraders.
  - Using LISE program's physical calculator.
- Measured the acceptance of the velocity filter.
- Determine the ratio of dials to ExB needed to transmit ions of various velocities.

Experimental Methods

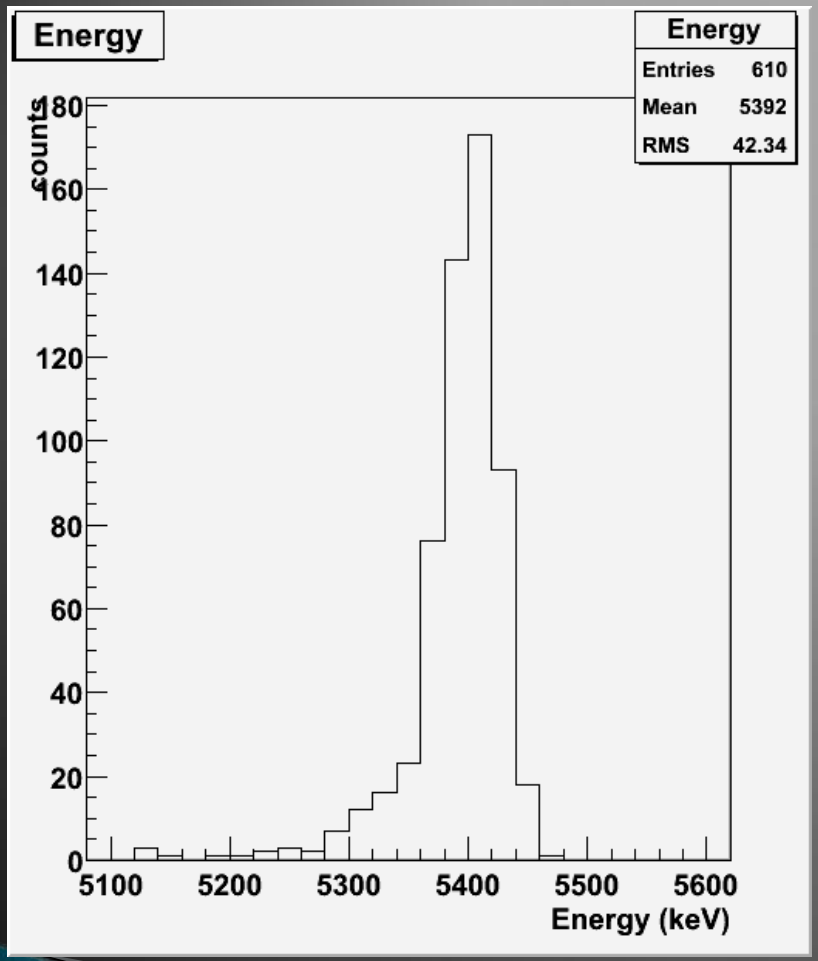
- We conducted two offline experiments, using Americium-241 as the source.
- We used aluminum degraders of various thicknesses, (6.1 μm, 12.3 μm, and 18.4 μm) to slow down particles.
- We used different electric field (dials) settings and varied magnetic field (ExB) to determine optimum settings.

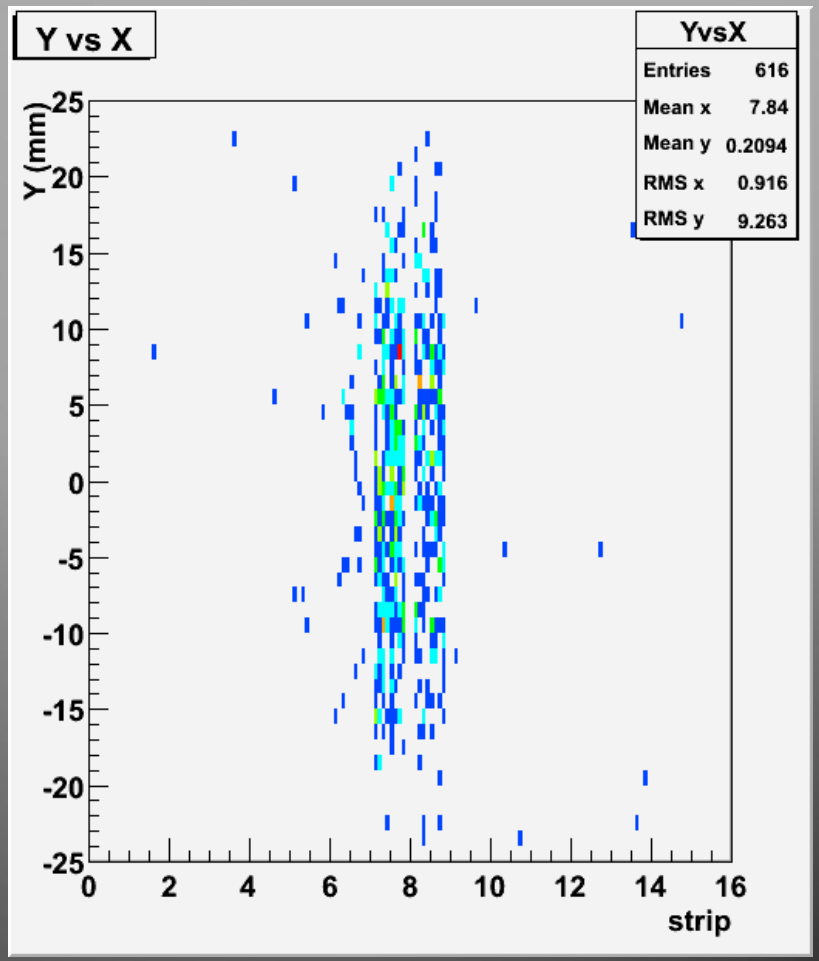


Energy Distribution for $\alpha(^{241}Am)$

Degrader (μm Al)	v/c	Energy Remaining (MeV)	$\Delta v / v_o$
0	5.40%	5.45	±0.02%
6.1	4.89%	4.47	±0.20%
12.3	4.21%	3.30	±0.40%
18.4	3.13%	1.83	±1.05%

Energy and Position Spectrum

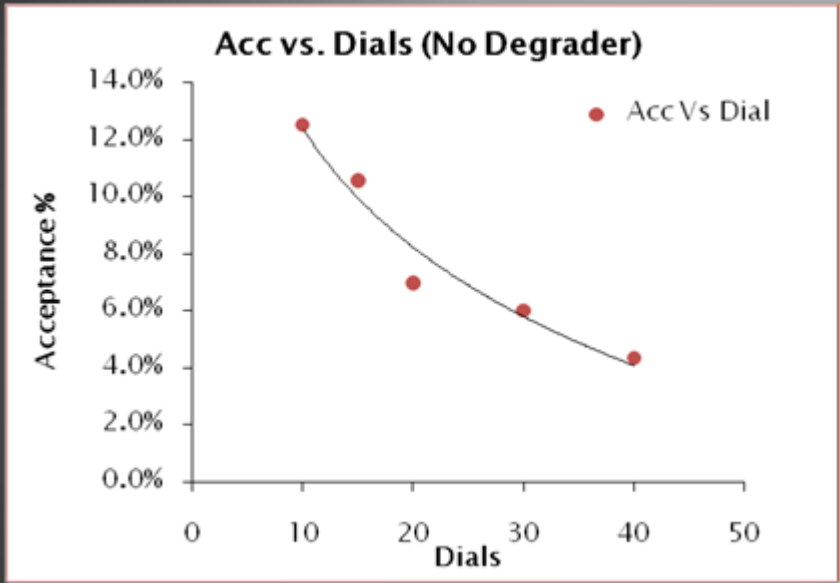


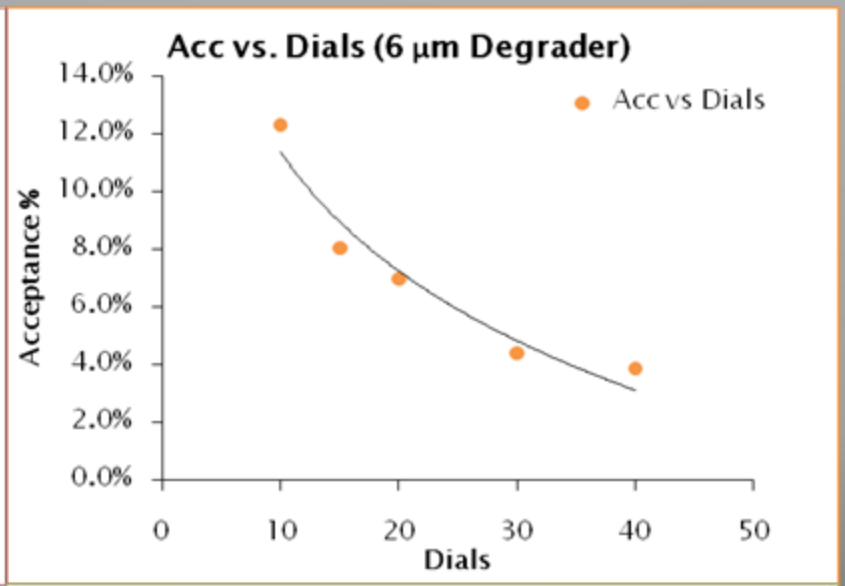


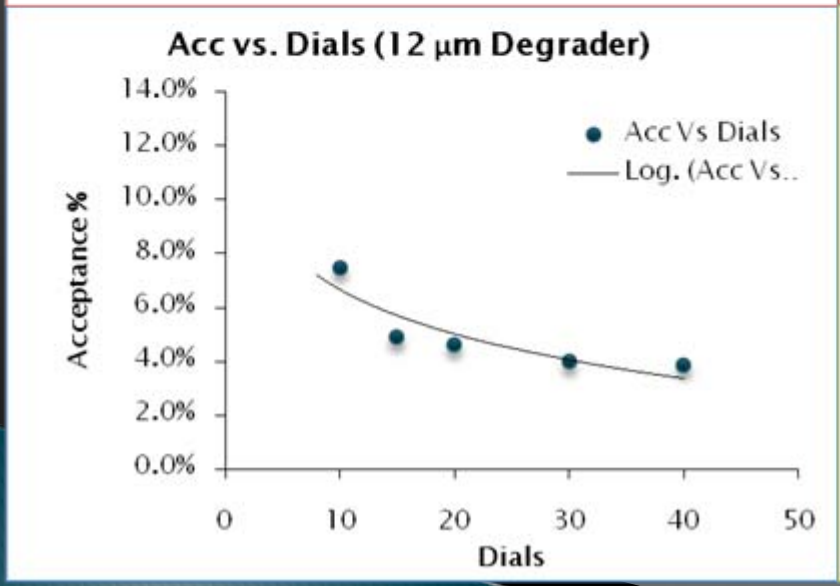
Velocity Filter Acceptance

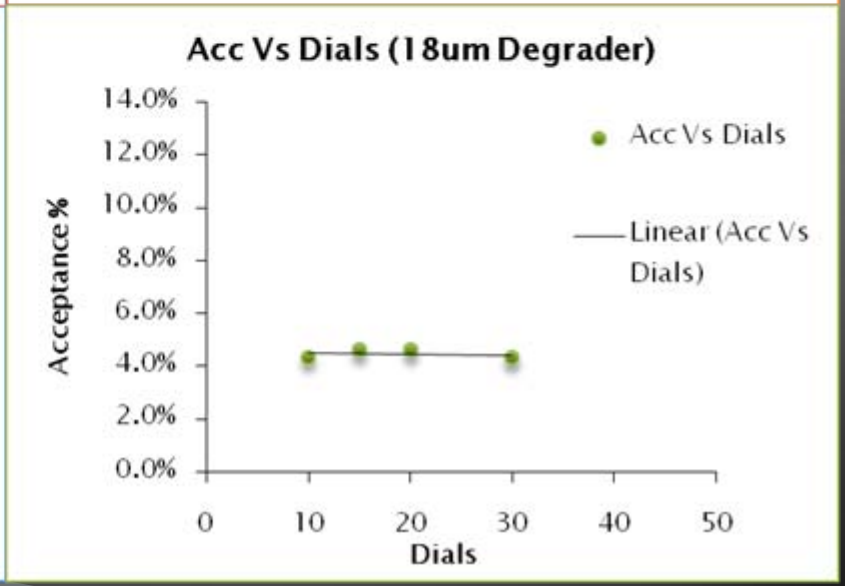
Dials	No Degrader	6.1μm Degrader	12.3μm Degrader	18.4μm Degrader
10	±6.3%	±6.2%	±3.7%	±2.2%
15	±5.3%	±4.0%	±2.4%	±2.3%
20	±3.5%	±3.5%	±2.3%	±2.3%
30	±3.0%	±2.2%	±2.0%	±2.2%
40	±2.2%	±2.0%	±1.9%	—

Velocity Filter Acceptance (2)









Energy Distribution vs. Velocity Acceptance

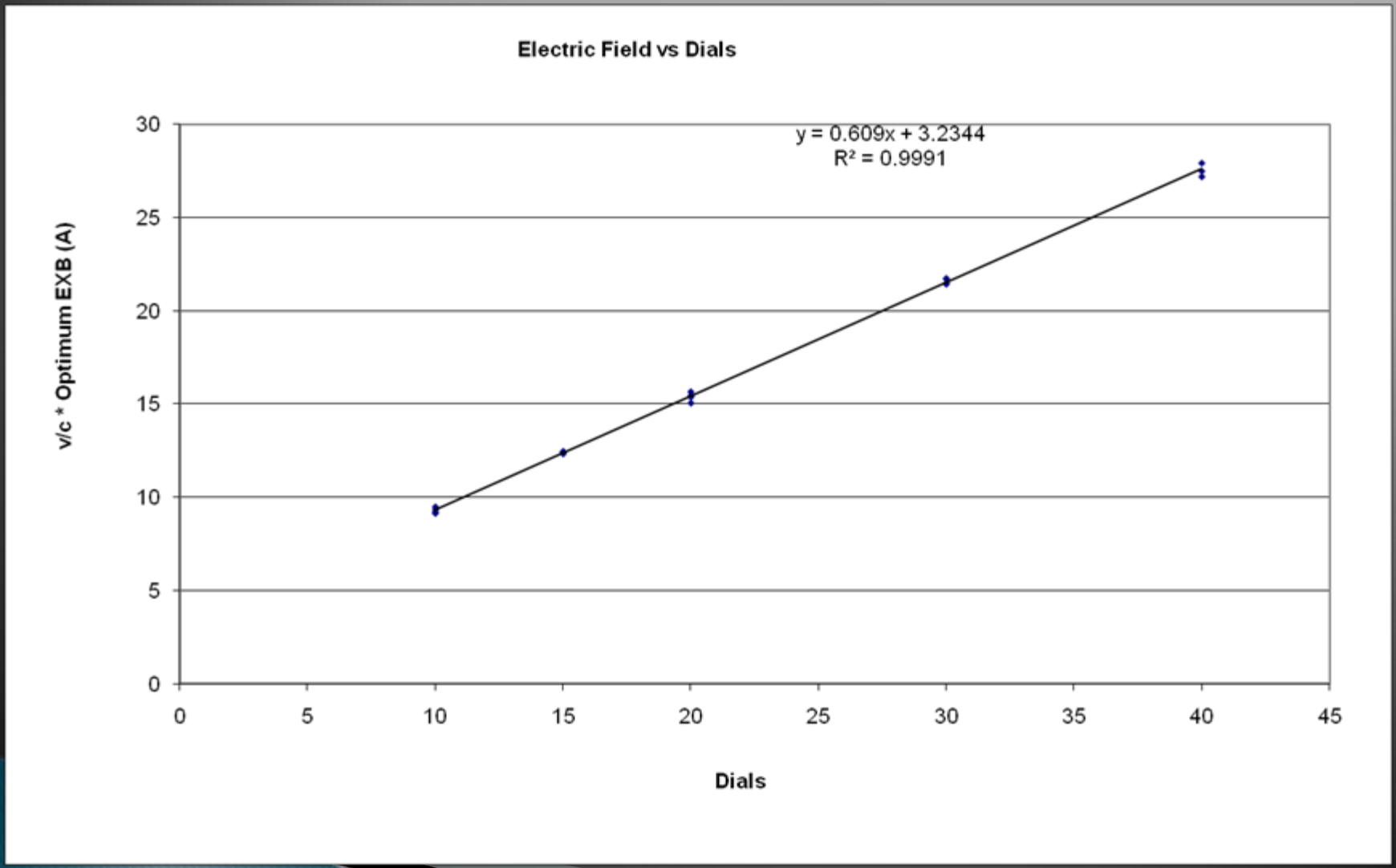
^{241}Am at initial energy 5.485 MeV w/Cover (μg/cm^2 ^{nat}C)

Degrader (μm Al)	v/c	Energy Remaining (MeV)	$\Delta v/v_o$
0	5.40%	5.45	±0.02%
6.1	4.89%	4.47	±0.20%
12.3	4.21%	3.30	±0.40%
18.4	3.13%	1.83	±1.05%

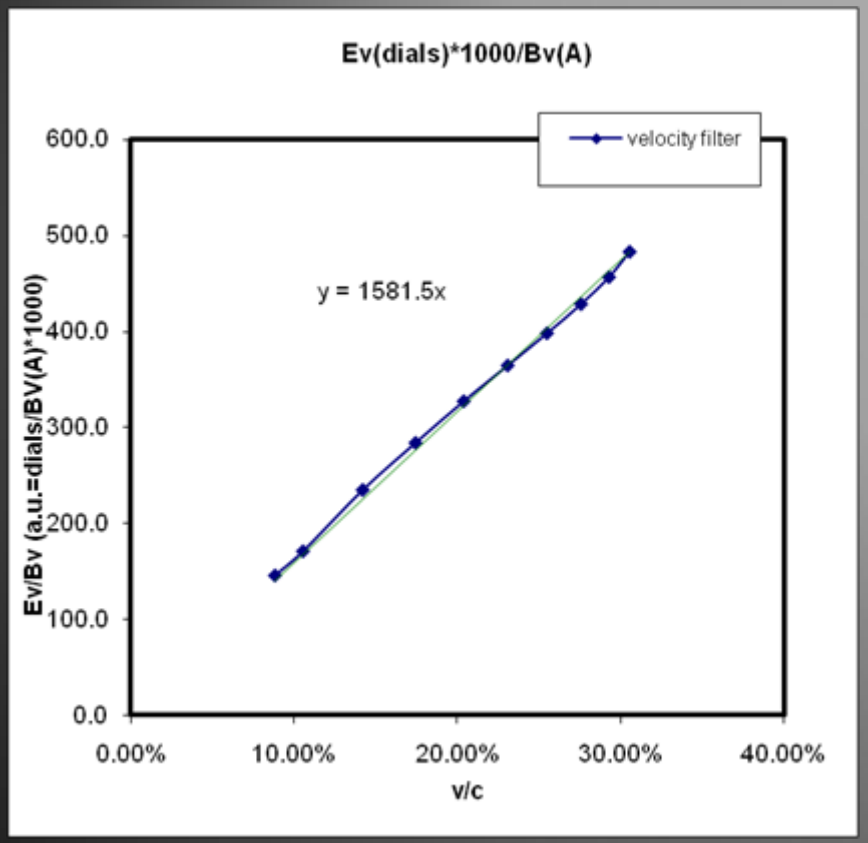
Change in acceptance as the electric field changes.

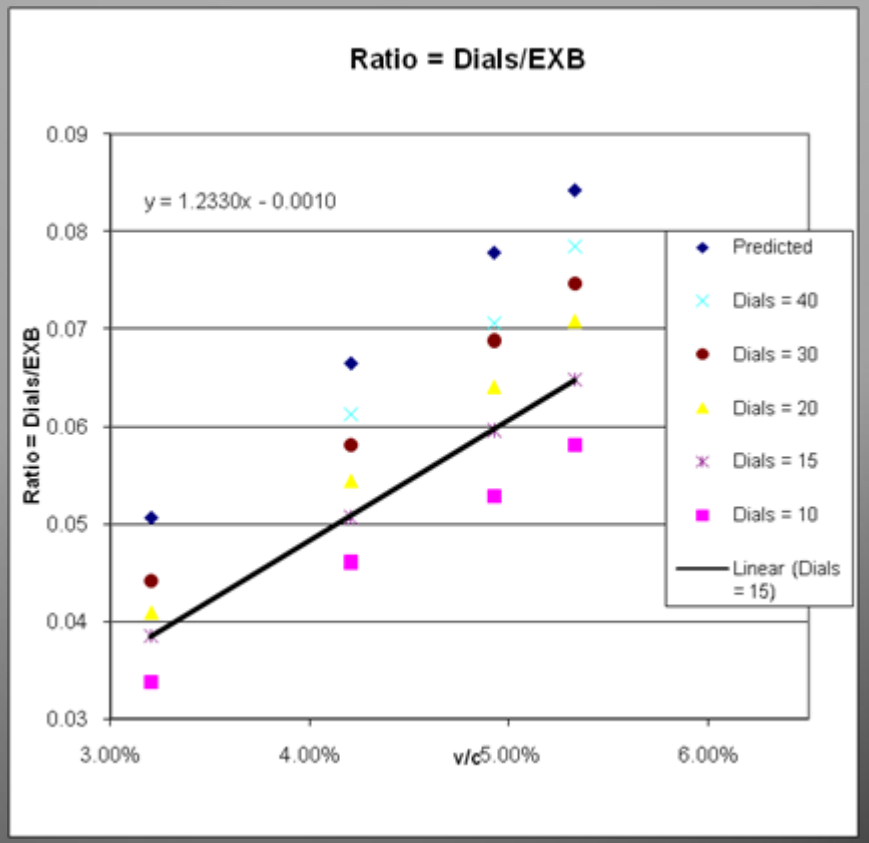
Dials	No Degrader	6.1μm Degrader	12.3μm Degrader	18.4μm Degrader
10	±6.3%	±6.2%	±3.7%	±2.2%
15	±5.3%	±4.0%	±2.4%	±2.3%
20	±3.5%	±3.5%	±2.3%	±2.3%
30	±3.0%	±2.2%	±2.0%	±2.2%

Something proportional to the Electric Field…



Ratio of Dials to ExB





Conclusion

- A large electric field off set exists and must be considered when planning for experiments
- The acceptance of the velocity filter decreases as the electric field increases (dials increases).
- Rate decreases as the electric field increases.
- Based on results, we can't actually run at 40 on the dials.

Future Work

- To determine the correlation between dials and actual voltage produced.
- Use ^{148}Gd source to achieve lower velocities closer to 0.02c and determine settings necessary to transmit those ions.
- Conduct beam experiments to more precisely calibrate MARS for low-energy, low-velocity ions.

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