Development of a Gas Stopper for Fusion-Evaporation Products

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## Outline

Introduction

- Creation of fusion-evaporation products
- > Proposed Experimental Set-up
- > Gas Stopper
- Simulation Results
  - > LISE
  - > SIMION
- Onclusion
- Future Work
- Acknowledgements

## Introduction

 My research focuses on <sup>158</sup>Hf, which is a homolog of <sup>257</sup>Rf

#### • Why do we care about Rf?

Image: Product of the second secon	1	n		- 5		1.5					1.5	100	17	1.5	100	1.7			
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$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	85.468	87.62		88.906	91.224	92.906	95.94	[98]	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29
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AC TH PA U NP PU AM CM Bk Cf Es Fm Md No	* * Act	inide s	eries	89	90	91	92	93	94	95	96	97	98	99	100	101	102		
[227] 232 0.4 231 0.4 238 0.3 [237] [244] [243] [247] [247] [247] [247] [257] [257] [257] [258] [259]				Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No		
				[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]		

### Creation of Fusion-Evaporation Products

- Projectile + Target → Compound Nucleus →
   Evaporated Residue + Ejectile
  - >  $^{50}\text{Ti} + ^{112}\text{Sn} \rightarrow ^{162}\text{Hf}^* \rightarrow ^{158}\text{Hf} + 4n$

 These nuclear reactions have a low probability (<10<sup>-8</sup>%)



#### **Physical Pre-separation**

- Momentum Achromat Recoil Separator (MARS) will filter out unwanted products and beam
- Main components of my simulations: variable angle degrader, Reaction Transfer Chamber (RTC) window, & helium gas cell



## **Proposed Experimental Set-up**



### MSU Gas Stopper

- Thermalize ions
- Original design from MSU: 50 cm in length
- Designed for lighter, faster ions
- 4 concentric spherical electrodes (flower petals)



L.Weissman, et al. Nucl. Instr. and Meth. A. 540 (2005) 245-258.

### Our Proposed Gas Stopper

- Our design, adapted from MSU: 13.5 cm in length
- Optimized for heavier, slower ions
- 4 flower petals like original design
- Voltage decreases across the gas stopper



## LISE

- Simulates motion of ions through separator
- Factors that were optimized:
  - > Degrader thickness & angle
  - > RTC window thickness
  - > Gas cell pressure
- Ion energy and spatial distribution after RTC window

Projectile 5 4.46 MeV/u 30 Compound 1 Residual 1	0Ti <sup>11+</sup> ) pnA 62Hf 58Hf <sup>24+24+</sup>	
T Target	Sn 0.47 mg/cm2	
ST Stripper	C 0.05 mg/cm2	
D1 -50 H +50 -50 V +50	<b>Brho</b> 0.5757 Tm	>
S Slits #2 Coffin -80 H +80 -50 V +50	slits	.00
D2 -100 H +100 -50 V +50	<b>Brho</b> 0.5757 Tm	
Hiter           -100 H         +100           -50 V         +50	E 70 KV/m B 82.97 G DL 2.16 mm/%	
-30 H +30 -20 V +20	Br 0.5757 Tm A 5 deg DG 0 mm/%	8
S 🔲 Slit #4 Det	standard 0.5757 Tm	
M Degrader	H8C10O4 8.55118 micron	
M RTC Window	H8C10O4 2 micron	
M I Helium Gas	He	~

## Location Distribution after RTC Window

Vertical Distribution



#### Horizontal Distribution



Mean: 0 mm, σ: 17 mm

Mean: 0 mm, σ: 21 mm

## Energy Distribution after RTC Window

- <sup>158</sup>Hf is produced with ~58 MeV of kinetic energy
- 7.75 µm mylar degrader @ 25° effective thickness: 8.5 µm
- 2 µm RTC window



# SIMION

- Ion simulation program that calculates electric fields and trajectories of ions for those electric fields
- Ion energy and spatial distribution determined by LISE
- Mobility:  $(17.7 \text{ cm}^2 \text{ V}^{-1} \text{ s}^1)$  [1]
- Gas flow: 11.5 mm/sec in beam direction
- Collisions with He
- SRIM range of <sup>158</sup>Hf in
   0.3 atm of He



#### Scaling Electric Potentials

High survival rate & low kinetic energy is needed
3 different simulations



## Difference between RTC Window and 1<sup>st</sup> Ring

 Different voltages tested to determine best scenario

Forward push is needed

Survival vs. Difference in Voltage



### Stopped by 1<sup>st</sup> Electrode

#### • Too many ions stopped by 1<sup>st</sup> electrode



### Not Enough Petal Focusing

#### • Lack of petal focusing



## Addition of 5<sup>th</sup> Petal



5 Ring

98% Survival

Need for all 5 Rings?

0.143 eV average kinetic energy

## Eliminating 2 Rings



3 Ring Makes the cell smaller 96% Survival

0.146 eV average kinetic energy

## Difference between RTC Window and 1<sup>st</sup> Electrode

Like before, less of a difference proves to be better.

Survival vs. Difference between RTC Window and 1st Ring



#### Conclusions

 An RTC window voltage was optimized at 710 V, then decreased down the length of the stopper

 Can decrease ions from ~3 MeV to ~0.14 eV in just 115.5 mm

 Ion spatial distribution decreased vertically from 17 mm to 1.5 mm and horizontally from 21 mm to 1.8 mm

3 ring electrodes is sufficient in steering the ions

#### Future Work

 Further simulate the gas cell for other similar elements, such as zirconium

Fabricate and test the gas cell

More sophisticated gas flow

• Charge exchange

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