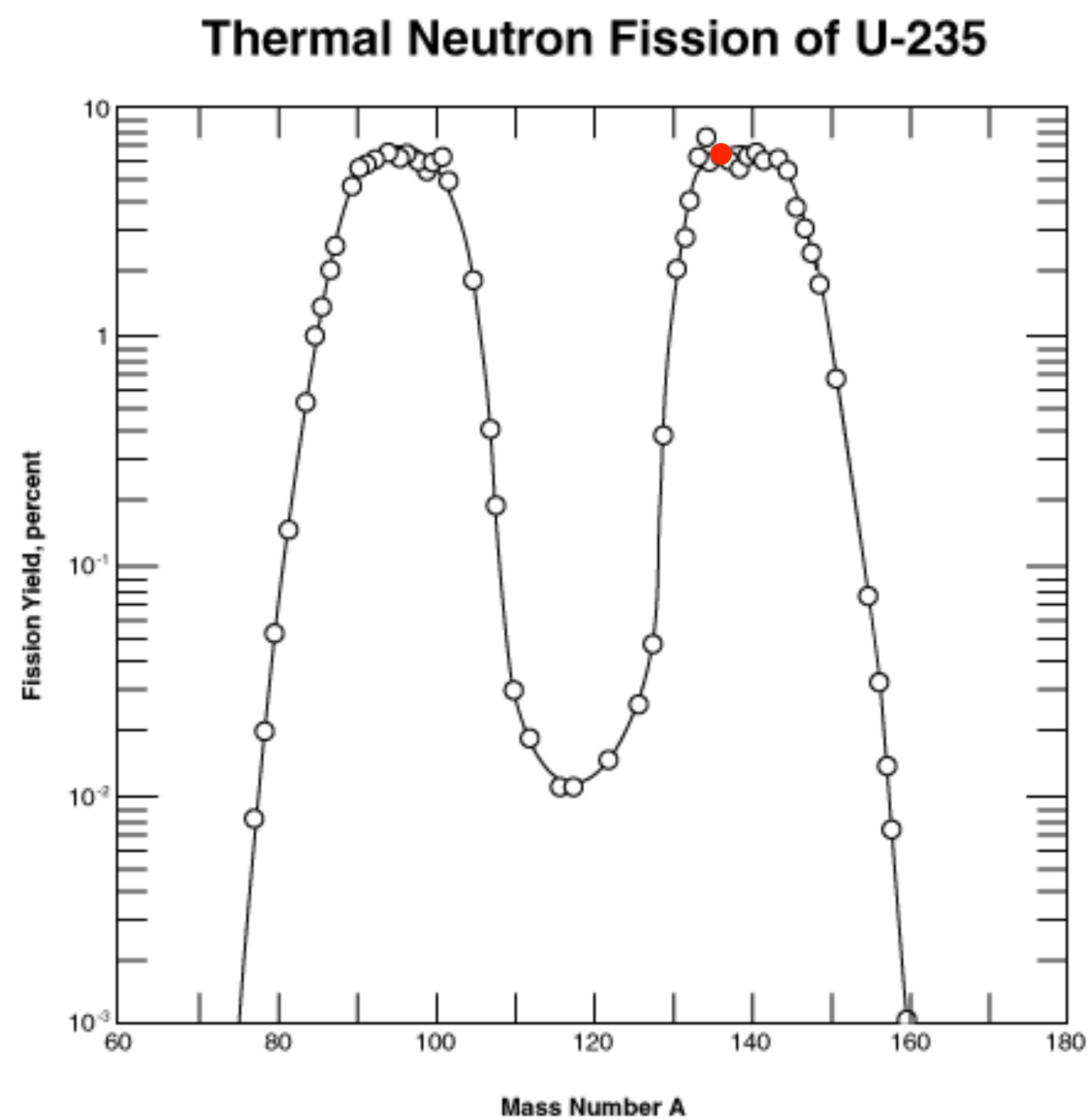
The Measurement of Cs Isotopes by Accelerator Mass Spectrometry

Cole MacDonald

Caesium Radioisotopes

- Anthropogenic
- Product of nuclear fission
- Age dating from nuclear weapons testing
- Identifying reactor products



Why AMS?

- Cs 137 has a relatively short half life (30a)
- Most has decayed since the late 50s
- Cs 135 much longer (about 2 Ma)
- The Ratios of Cs 135/137 quite useful

^{135}Cs Half Life

- N. Sugarman (1949)
  - $\text{Xe-135} \xrightarrow{\beta} \text{Cs-135} + e^- + \bar{\nu}_e$
  - 1.85 → 2.3 Ma
- Oak Ridge (1949)
  - 2.95 ± 0.3 Ma

Proposed Experiment

- Use liquid scintillation counting and accelerator mass spectrometry
- LSC: Find A_o
- AMS: find N_o

$$t_{1/2} = \frac{\ln 2}{A_o} N_o$$

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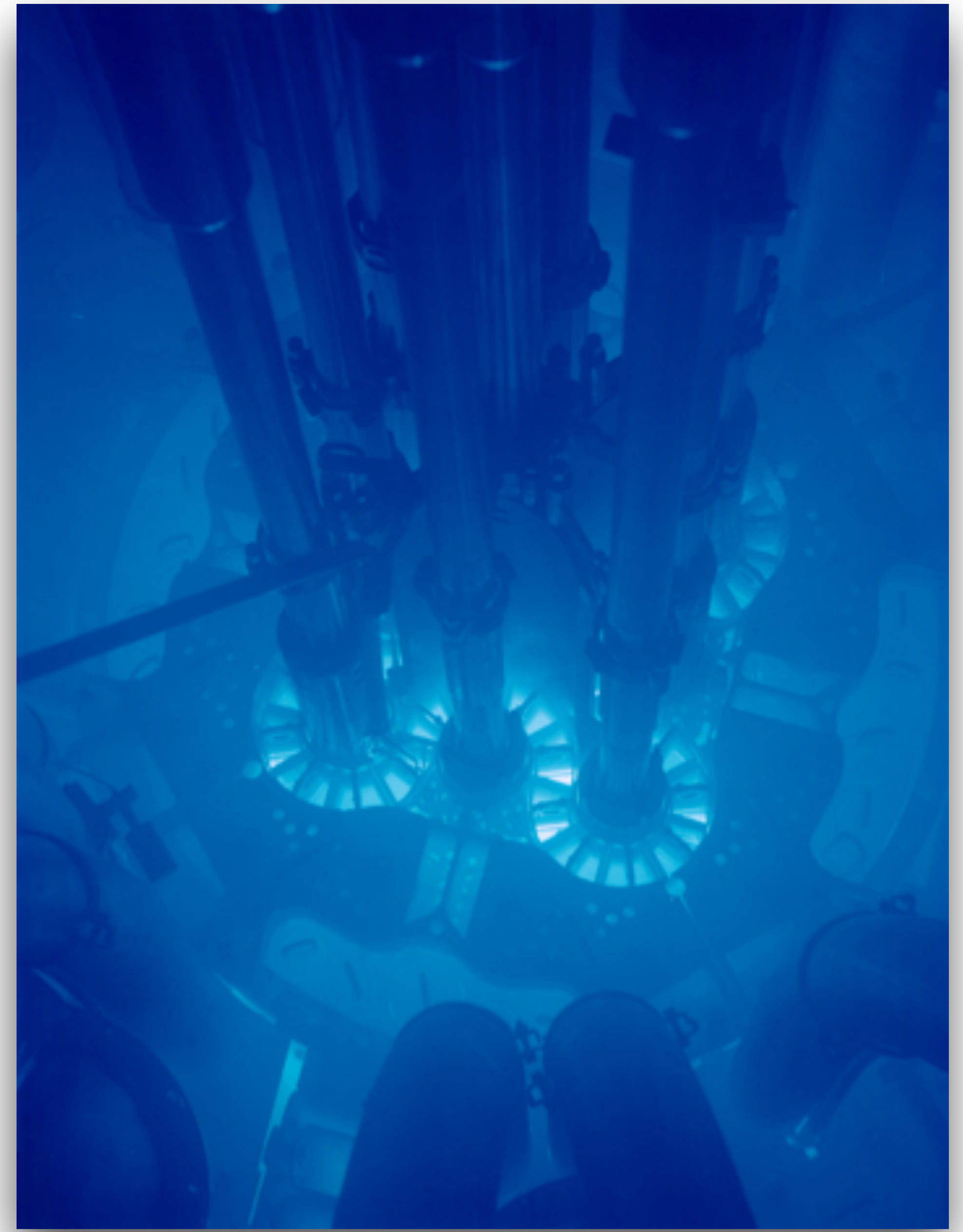
Challenges

- Purity of Cs135 and yield tracers
- Optimization of beam current
- Isobaric interferences
- Development of AMS Procedure
- Cs memory

Isotope Production

- Require sources of Cs with minimal amounts of isotope contamination
- Xenon Decay
- Neutron Capture



Creation of Cs135:
^{135}Xe Beta Decay

Bq = Becquerel = Decay/Second

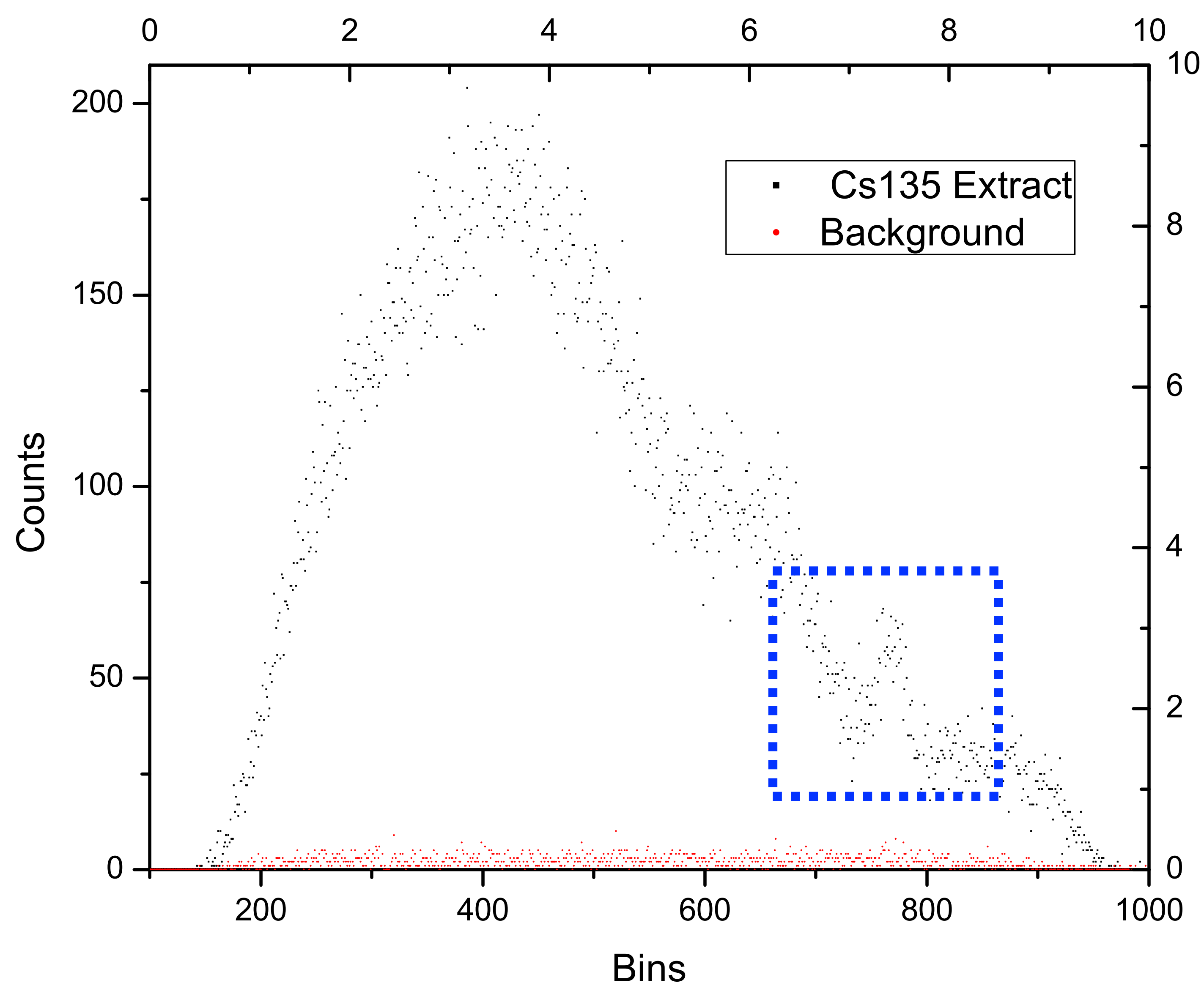
- 1 Bq of ^{135}Cs requires the decay of 2 GBq of ^{135}Xe
- Chalk River Labs supplied a section of pipe that had Xe running through it.

LSC

$$t_{1/2} = \frac{\ln 2}{A_o} N_o$$

- Mix aliquot of solution with scintillating agent and count the beta's

- Small Cs^{137} peak.
- Can't use 137 for tracer
- Use of surrogate beta emitter for efficiency

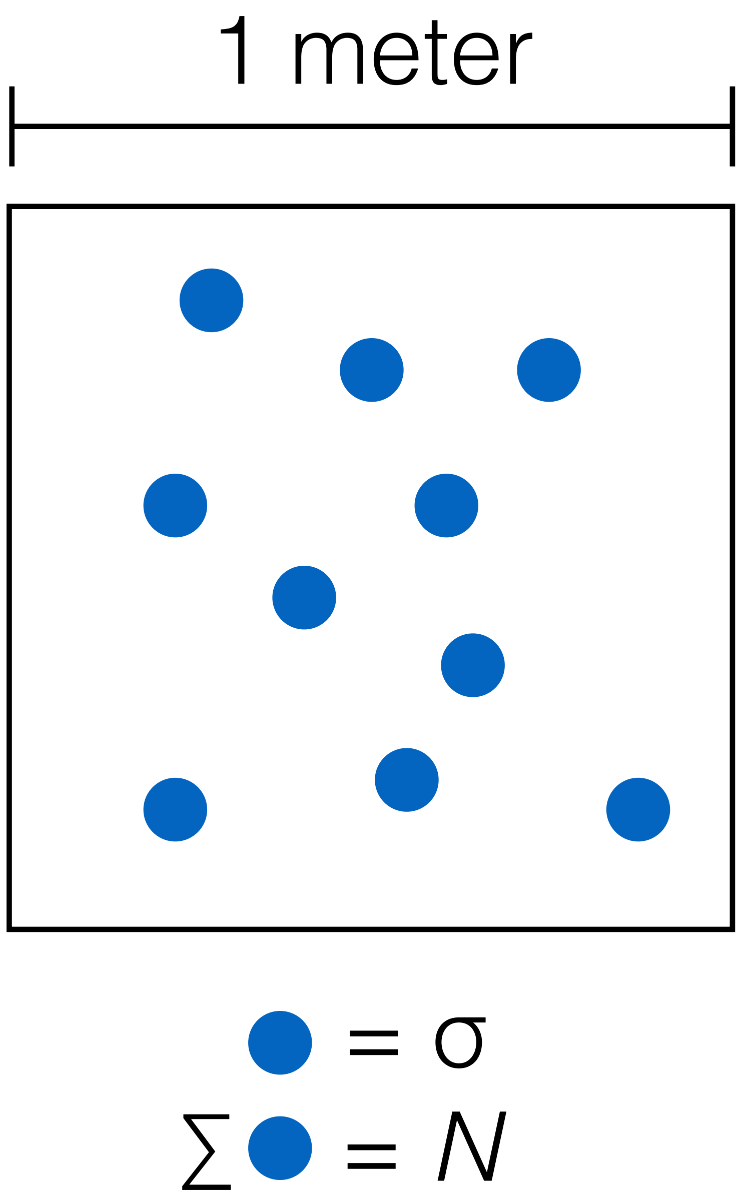


Neutron Capture

$$\boxed{\mathrm{N}_{A+1} = \mathrm{N}_A \sigma_A \phi t}$$

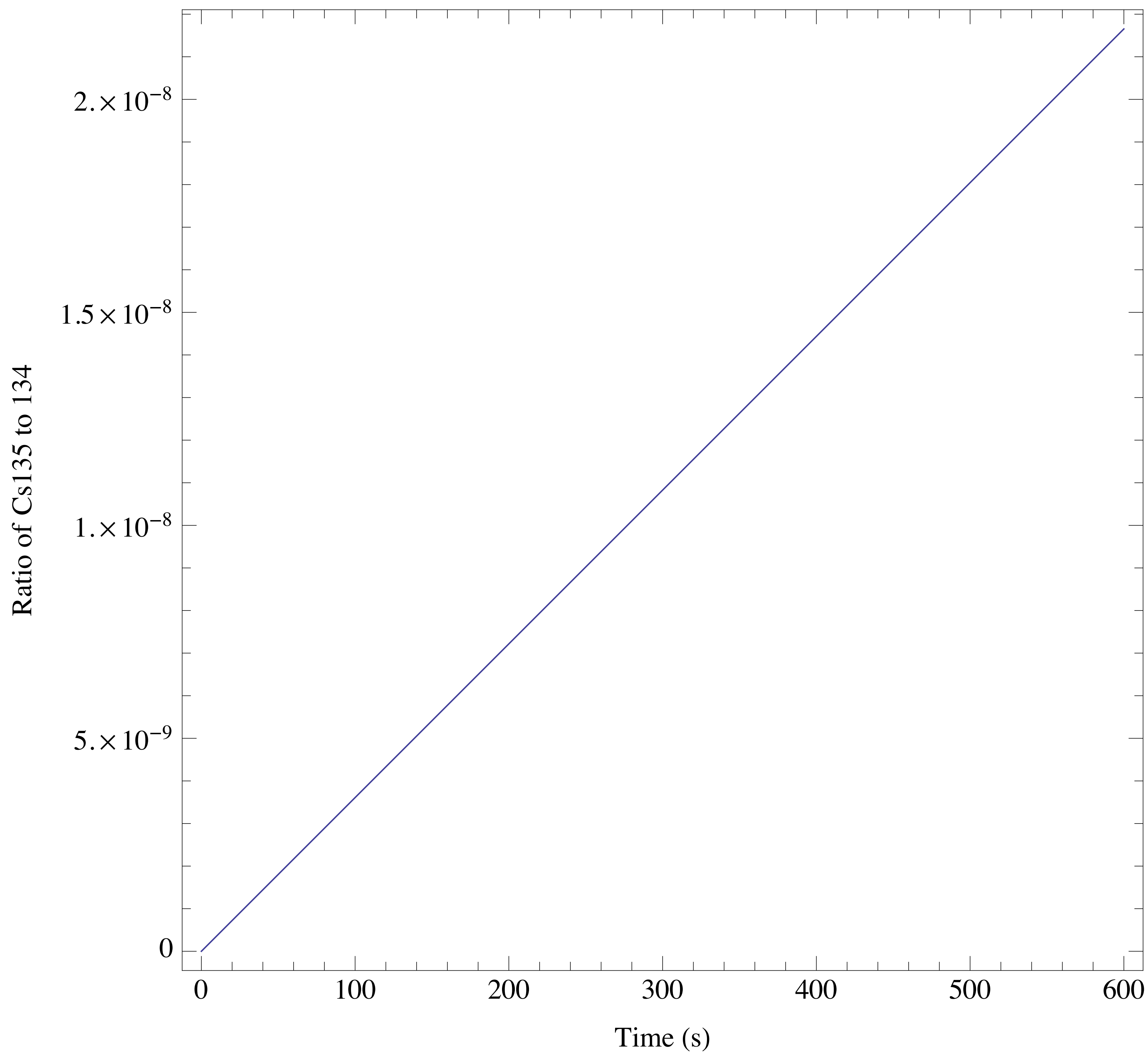
$$\mathrm{N}_{A+2} = \frac{1}{2}\mathrm{N}_A \sigma_A \sigma_{A+1} \phi^2 t^2$$

$$\mathrm{N}_{A+3} = \frac{1}{6}\mathrm{N}_A \sigma_A \sigma_{A+1} \sigma_{A+2} \phi^3 t^3$$



Creation of Cs134:

Cs133 (n, γ) Cs134



$$t_{1/2} = \frac{\ln 2}{A_o} N_o$$

Challenges

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Cs Current Optimization:
The Study of Ion "Sourcery"

- Choosing anion
  - CsF_2^-
- Homogenous mixing
  - Chemical vs Mechanical

$$t_{1/2} = \frac{\ln 2}{A_o} N_o$$

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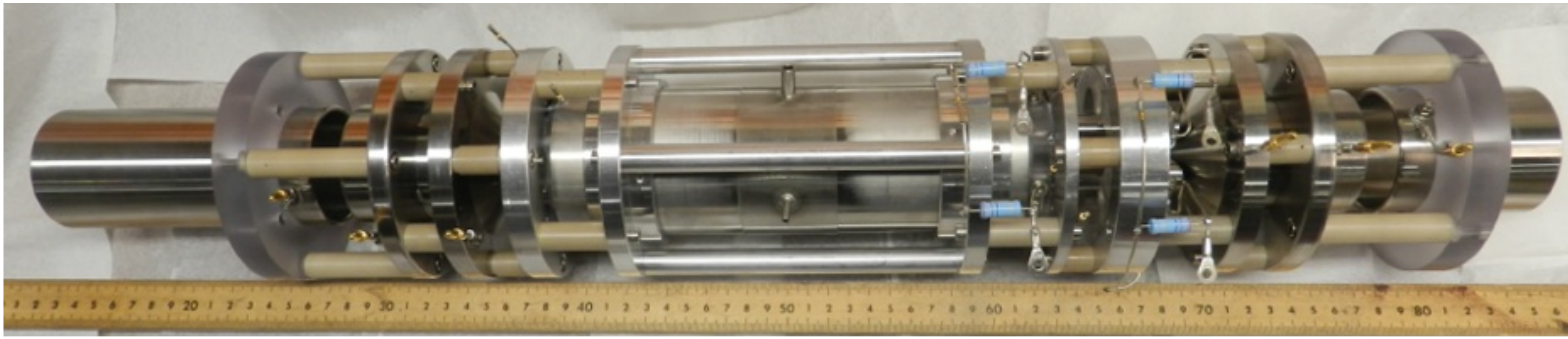
Isobaric Interferences

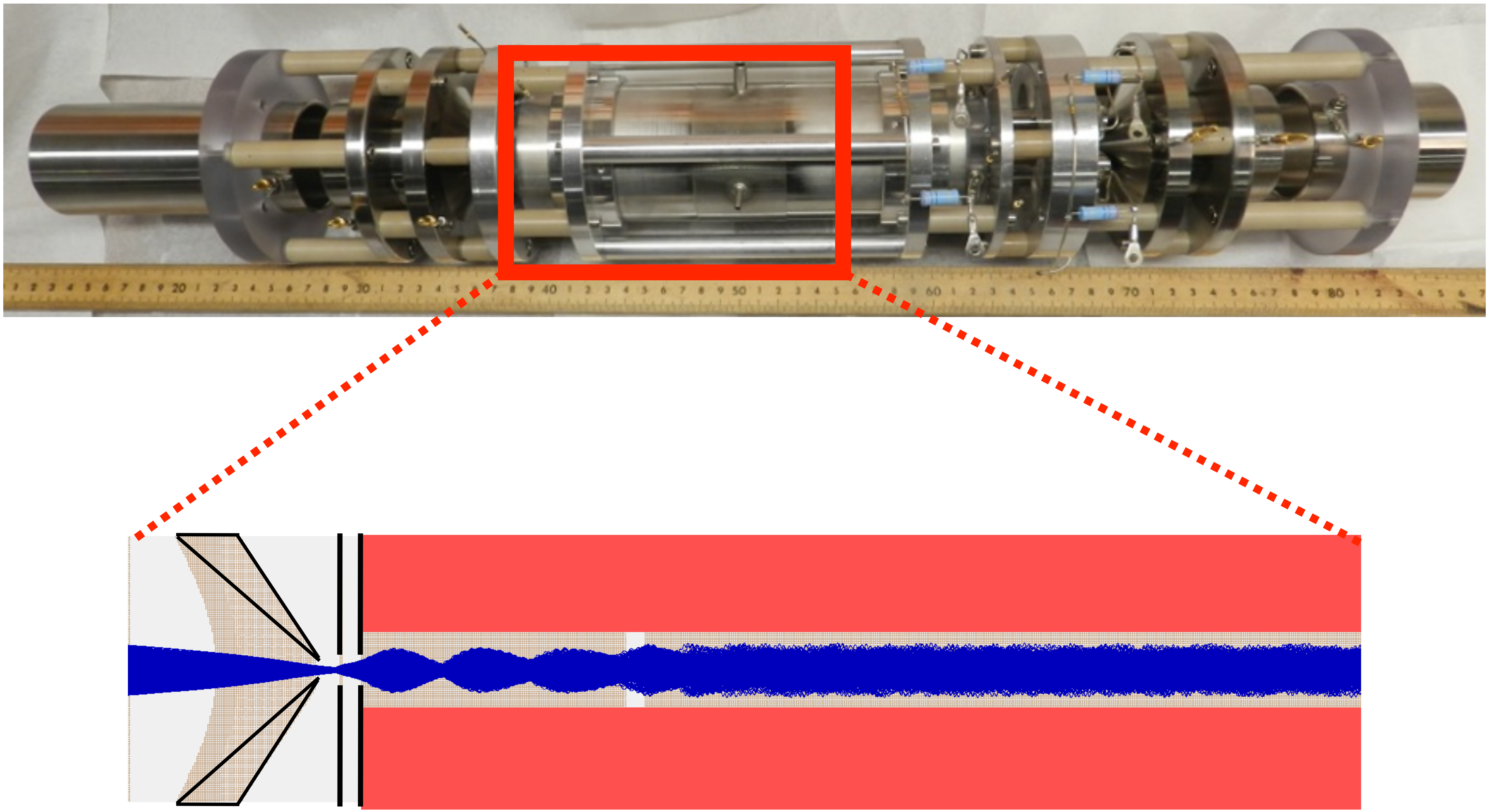
- Barium
  - Masses 134→138
- Zn Dimers
  - Masses 128→140

Isobar Separator for Anions



Photograph and diagram provided by Chris Charles

Isobar Separator for Anions



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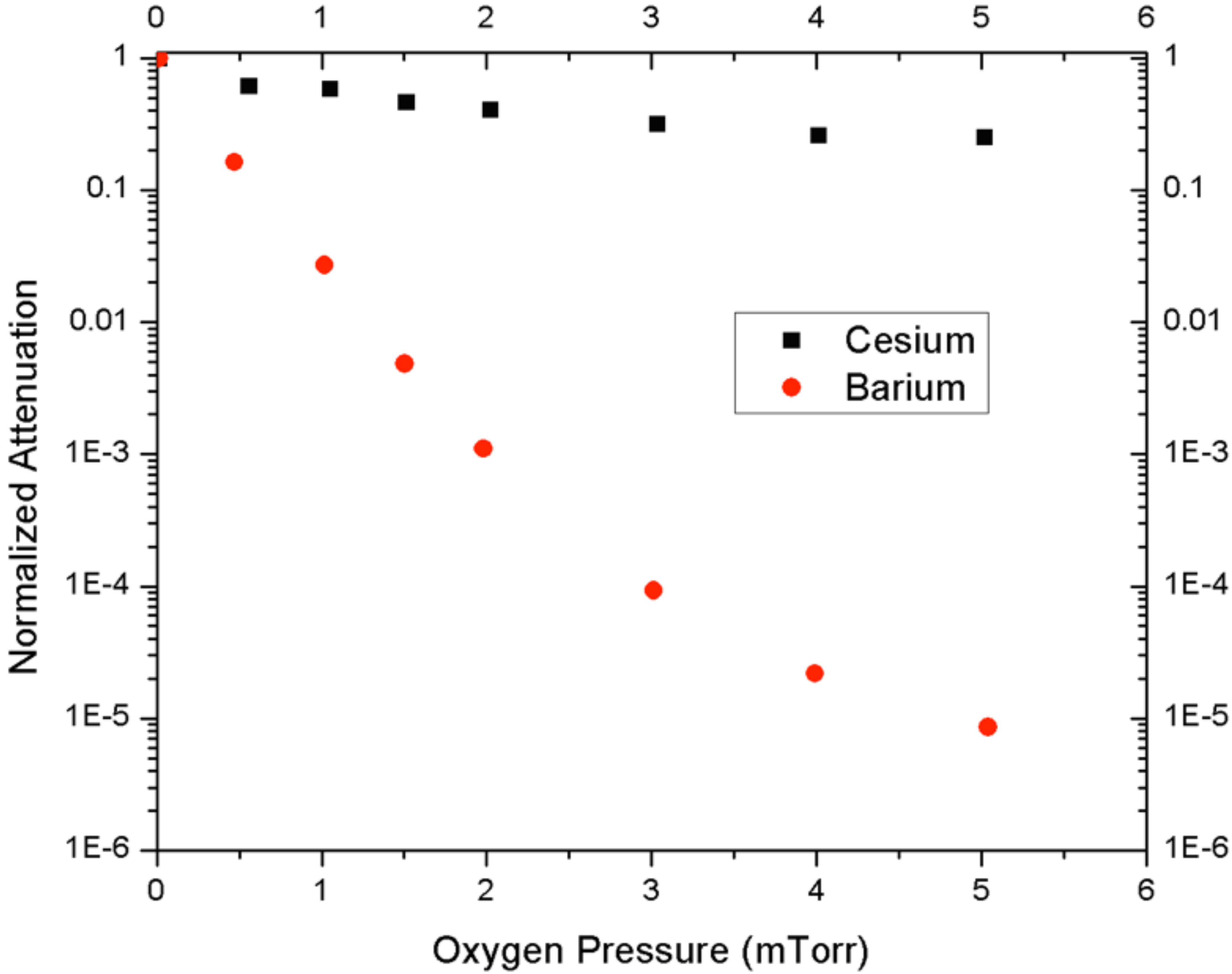
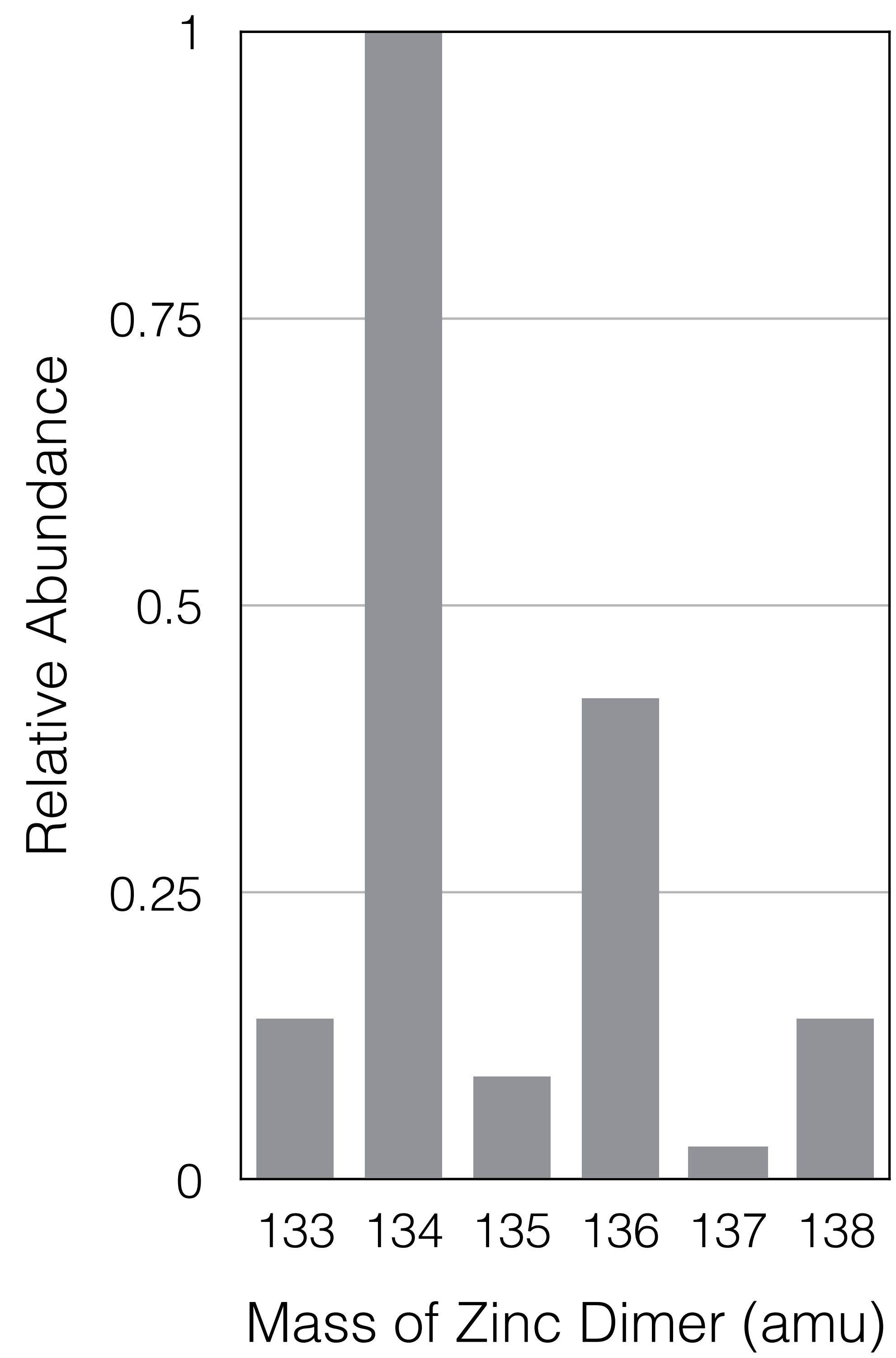
Ba Suppression



Zn Dimer Interference

- Noticed counts at mass 136 and 138
- No counts at 137 so not Barium
- Measure mass 136 and increase stripper pressure



$$t_{1/2} = \frac{\ln 2}{A_o} N_o$$

Challenges

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- Cs memory

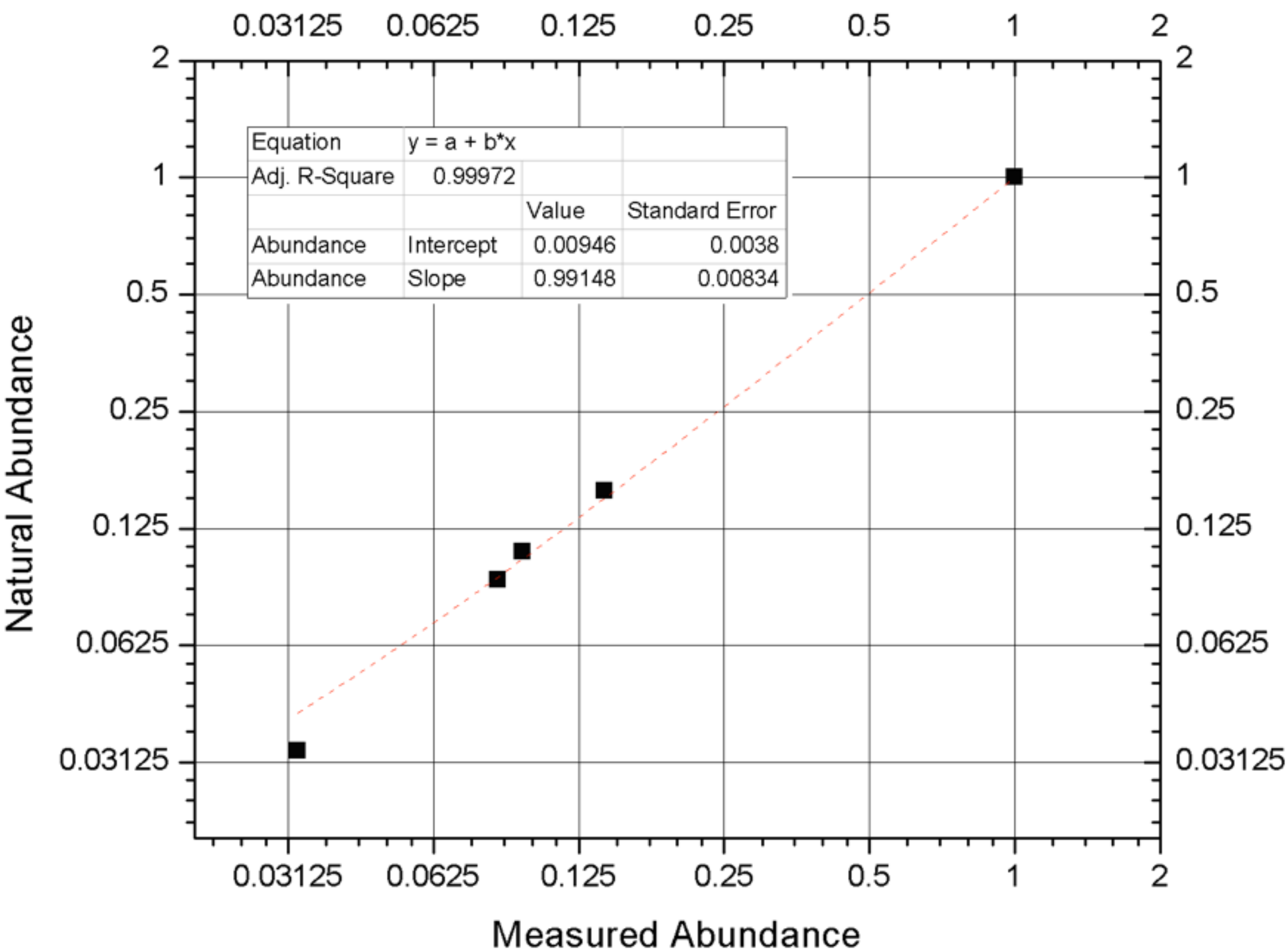
Development of AMS Procedure

- Isotope scanning
  - Monitor isotopes during analysis
- Yield Tracer
  - Ensure no fractionation

Masses Monitored During Analysis

- Require # of Cs134 atoms as yield tracer (134 amu)
- Require # of Cs135 atoms as analyte (135 amu)
- Ensure no Barium contamination (136 amu)
- Check mass 137 for Barium/Caesium (137 amu)

Barium Natural Abundance



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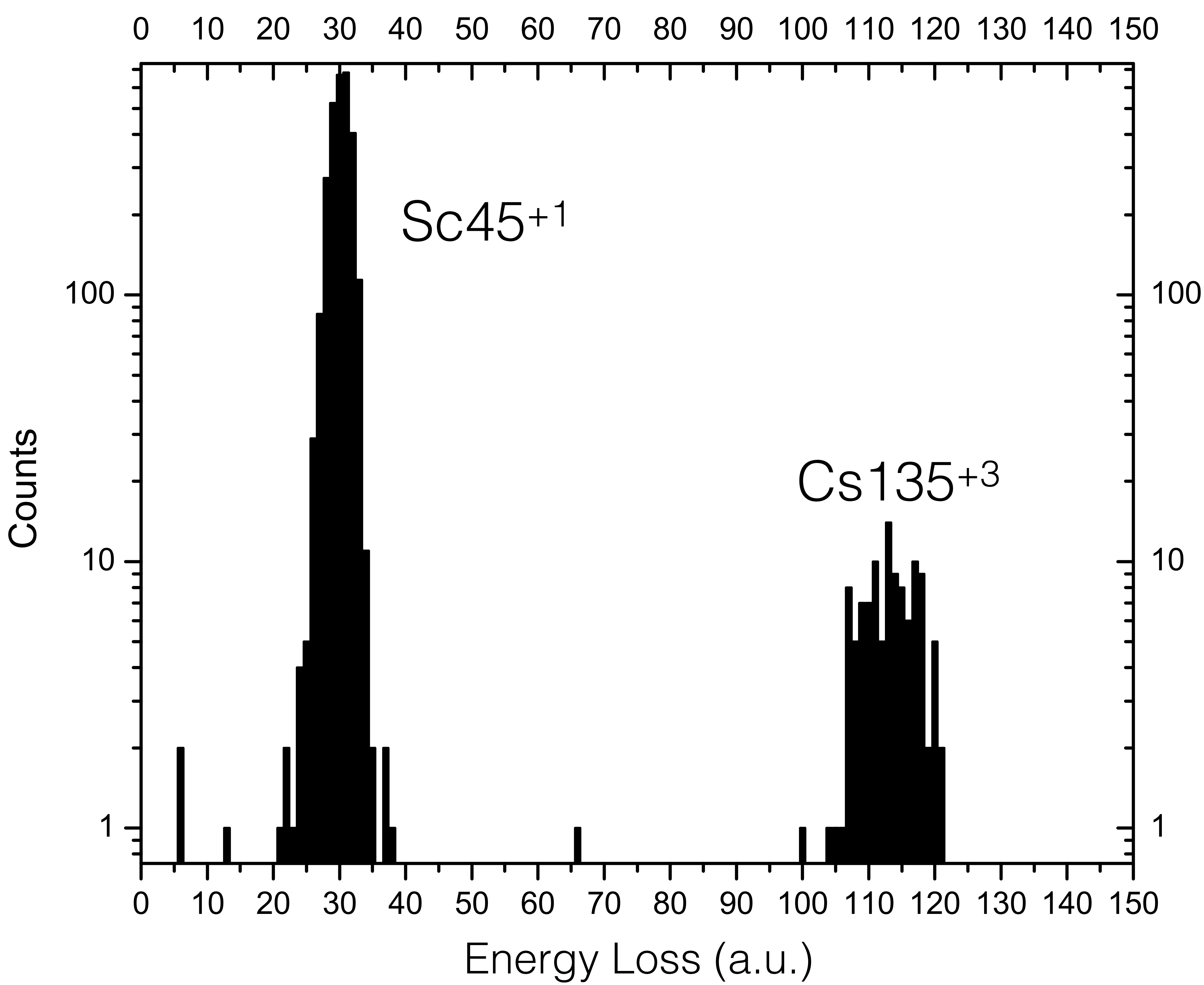
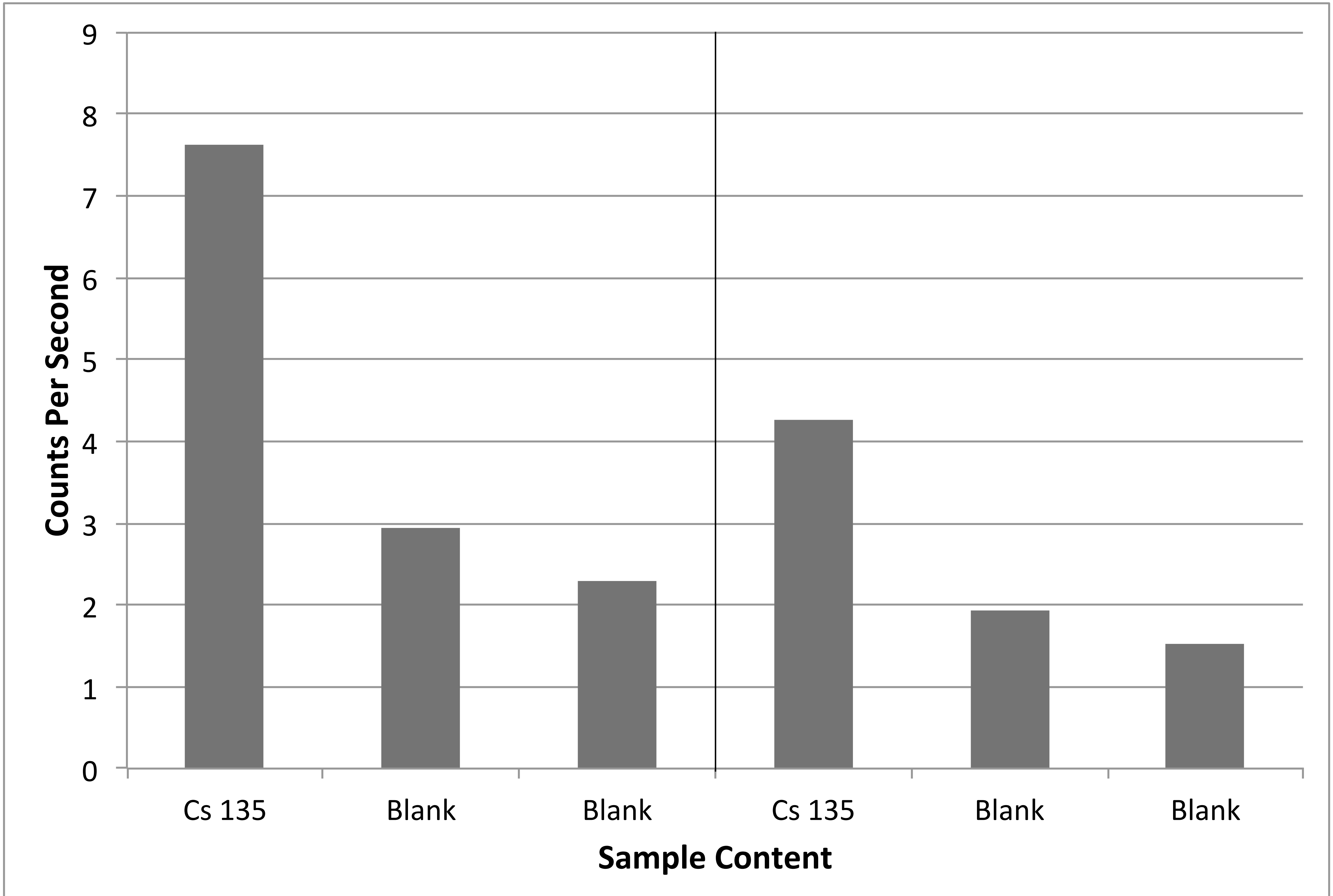
RadioCs Measurement



Cs Memory


9
8
7
6
5
4
3
2
1
0
Counts Per Second
Cs 135
Blank
Blank
Cs 135
Blank
Blank
Sample Content

Predicted vs Observed

$$t_{1/2} = \frac{\ln 2}{A_o} N_o$$

	Measured Half Life (Ma)	Uncertainty (%)
Sugarmann (1949)	1.85	-
	2.3	-
ORNL (1949)	2.95	10%
C. MacDonald (2014)	0.69	42%
	0.63	45%

In Summation

$$t_{1/2} = \frac{\ln 2}{A_o} N_o$$

- Eliminated isobaric interferences
- Demonstrated the effectiveness of ISA-AMS routine
- Successfully measured rare Cs isotopes by AMS

Acknowledgments

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Isobarex