

Monte Carlo Modeling of a Cavity Ion Source

Pushing the Frontiers of Isotopic Sensitivity & Detection

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Isotope ratios give clues about the origin, age and history of nuclear material.

Age

$^{235}\text{U}/^{231}\text{Th}$
 $^{234}\text{U}/^{230}\text{Th}$



Origin

O isotopes
Pb isotopes
Sr isotopes

History

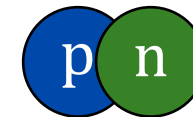
Metallic impurities
Organic impurities

Isotopes

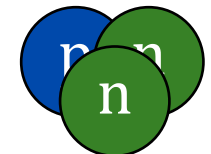
All are
hydrogen
(all form H_2O)



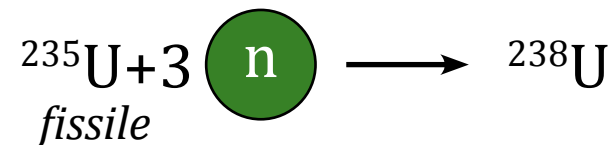
^1H



^2H



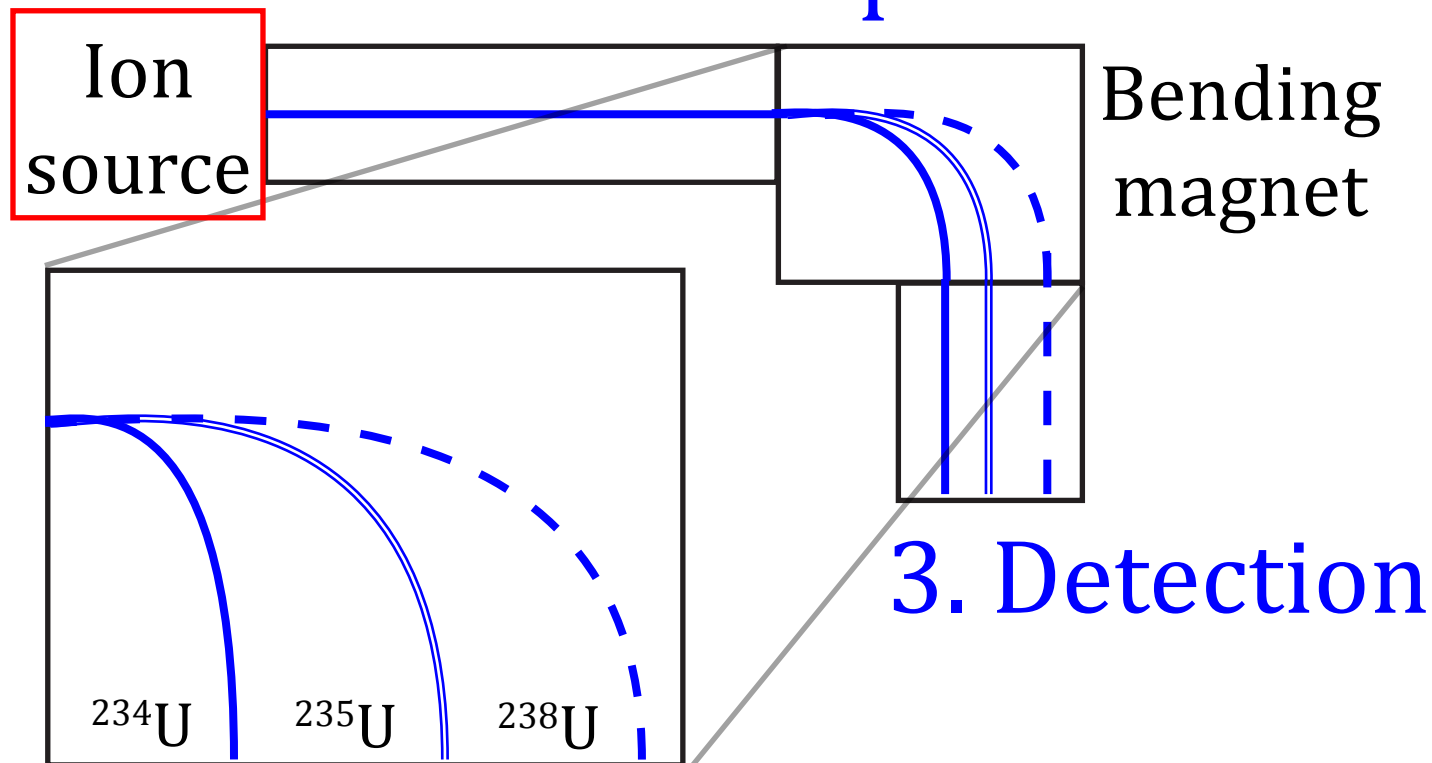
^3H



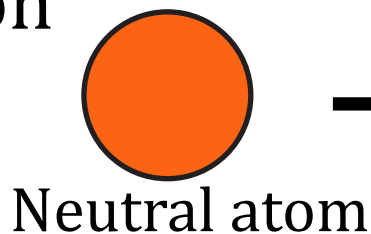
Lab **mass spectrometry** provides the most sensitive and precise isotope ratio data.

1. Ionization

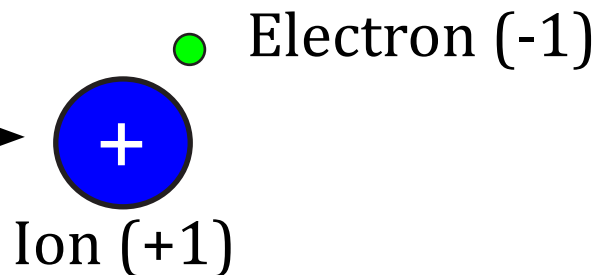
2. Separation



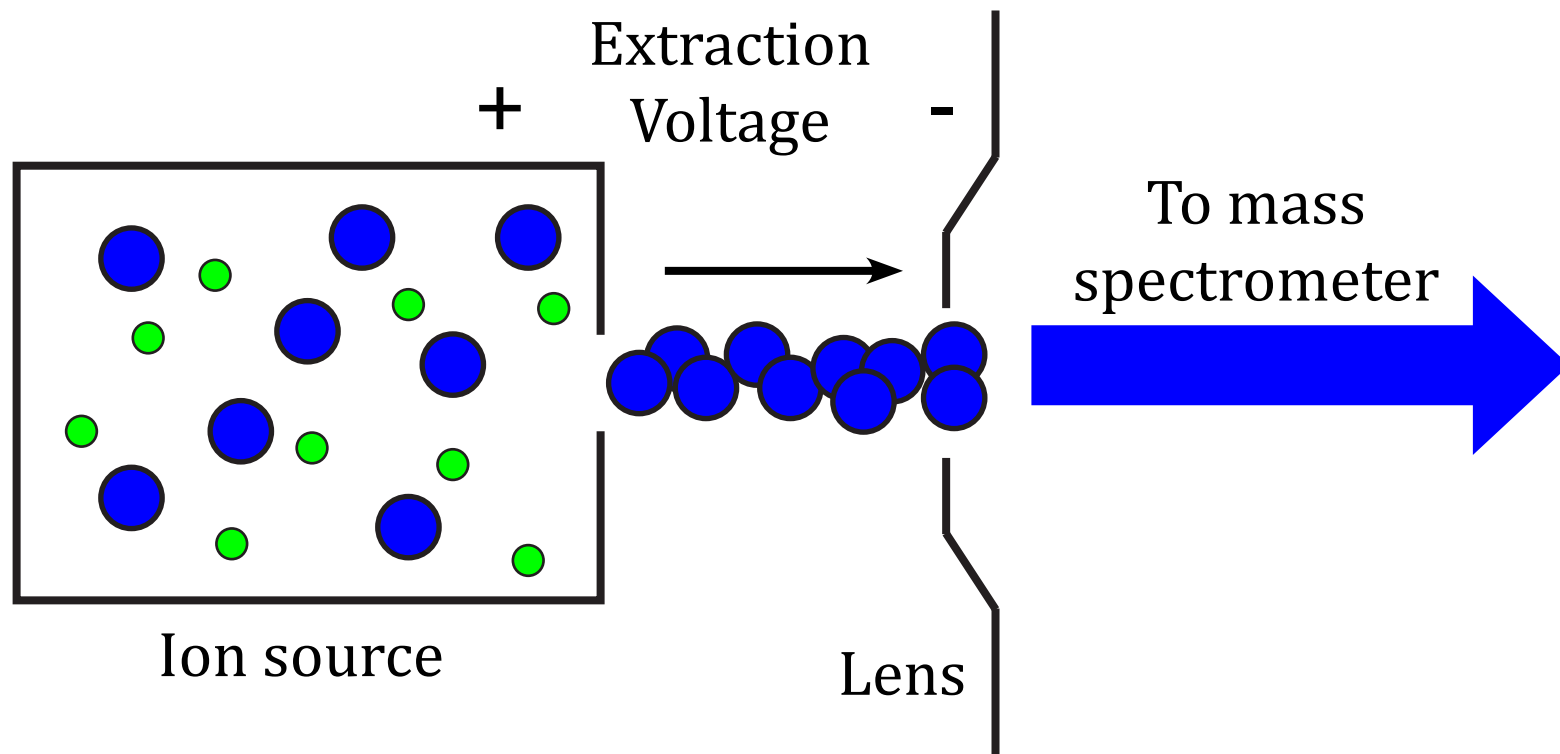
Ionization



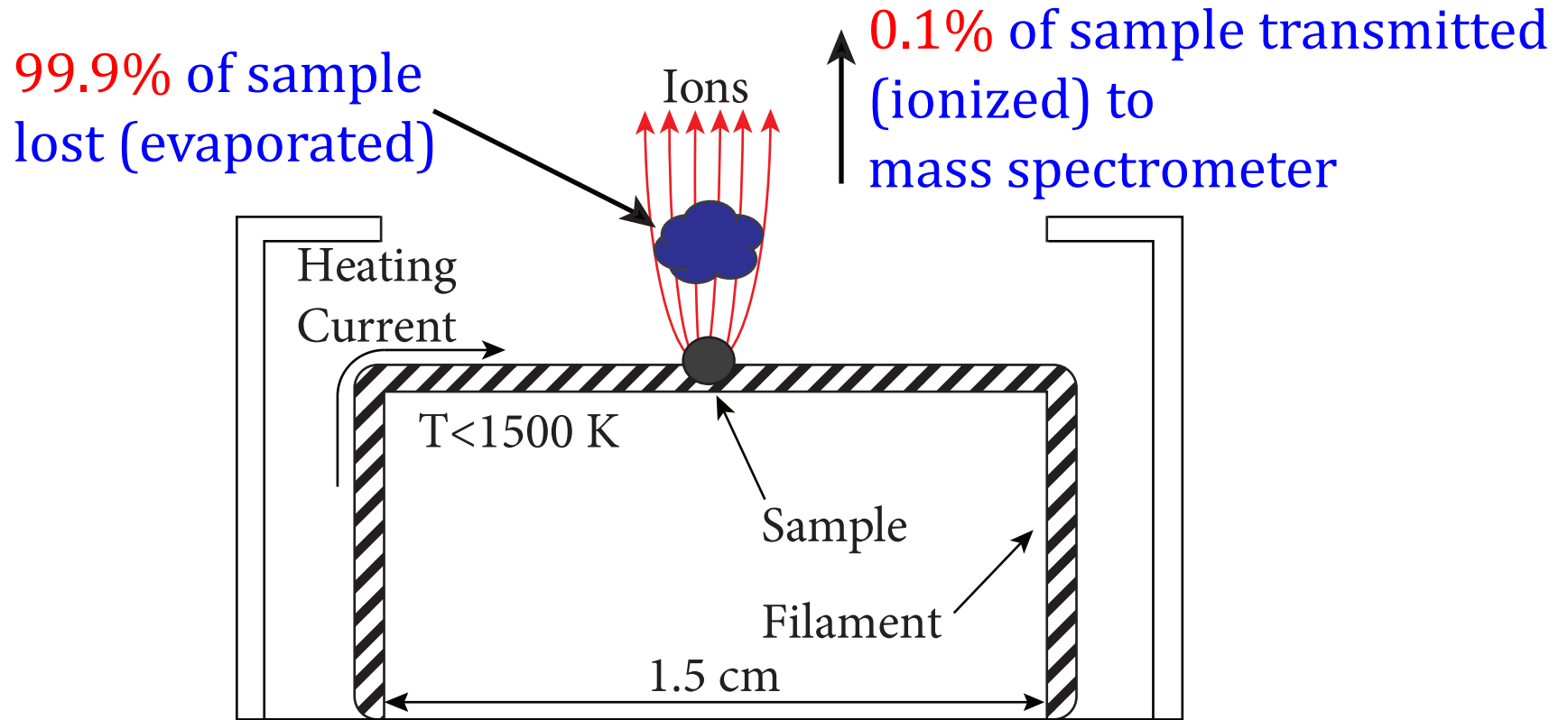
Ionization



The ion source is the **heart** of every mass spectrometer.



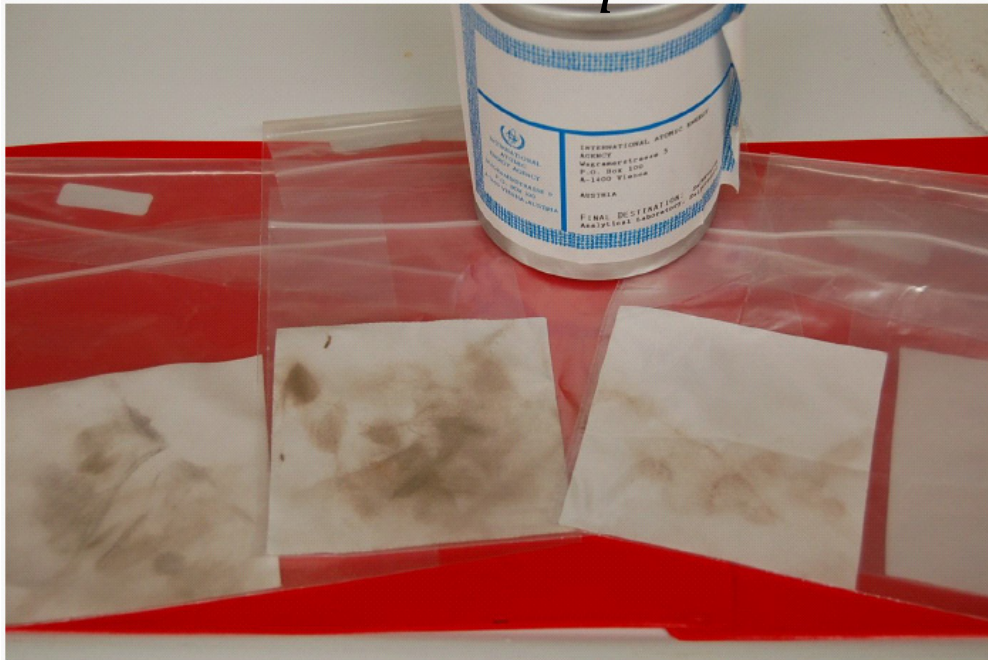
Most of the sample is **lost** in the ion source.



Evaporated atoms are instantly lost to the environment.

Improving the efficiency of the ion source equals improving the **sensitivity**.

IAEA Swipes



Detect lower concentrations

Interdicted HEU sample



Or, analyze smaller samples

A **whole new** ion source must be created from the ground up.



Modeling

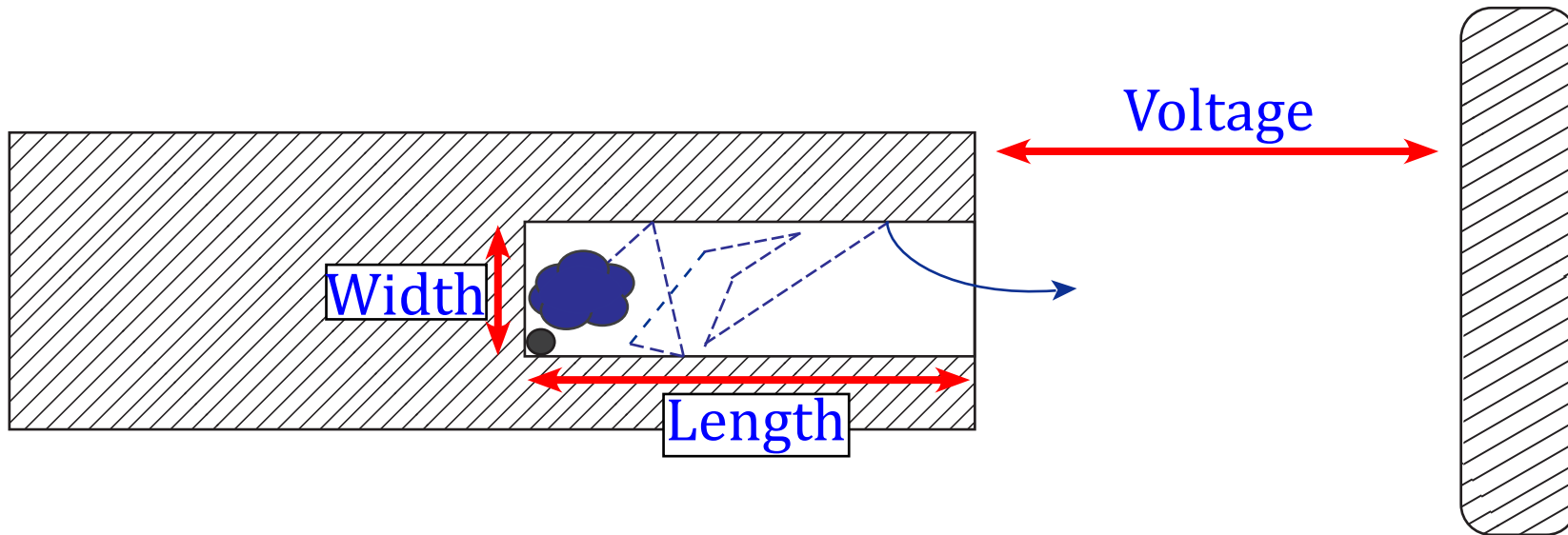


Prototype



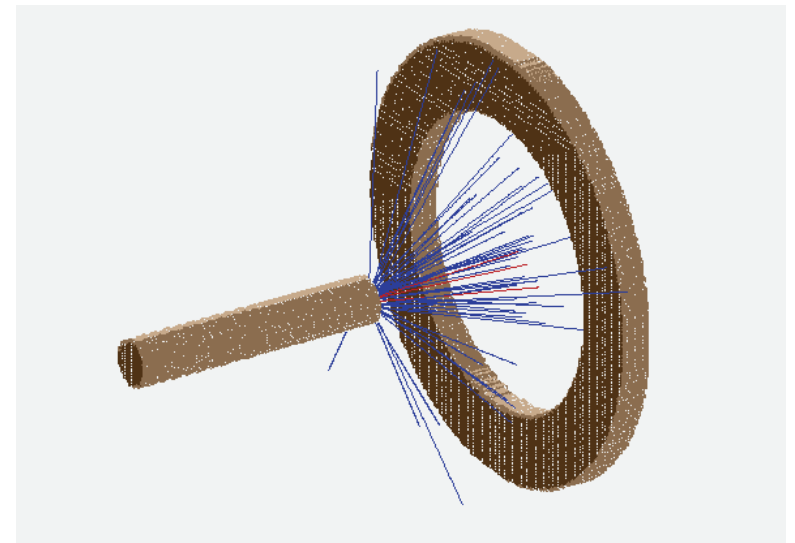
Product

We are designing an ion source that improves efficiency (sensitivity) by **100x**.

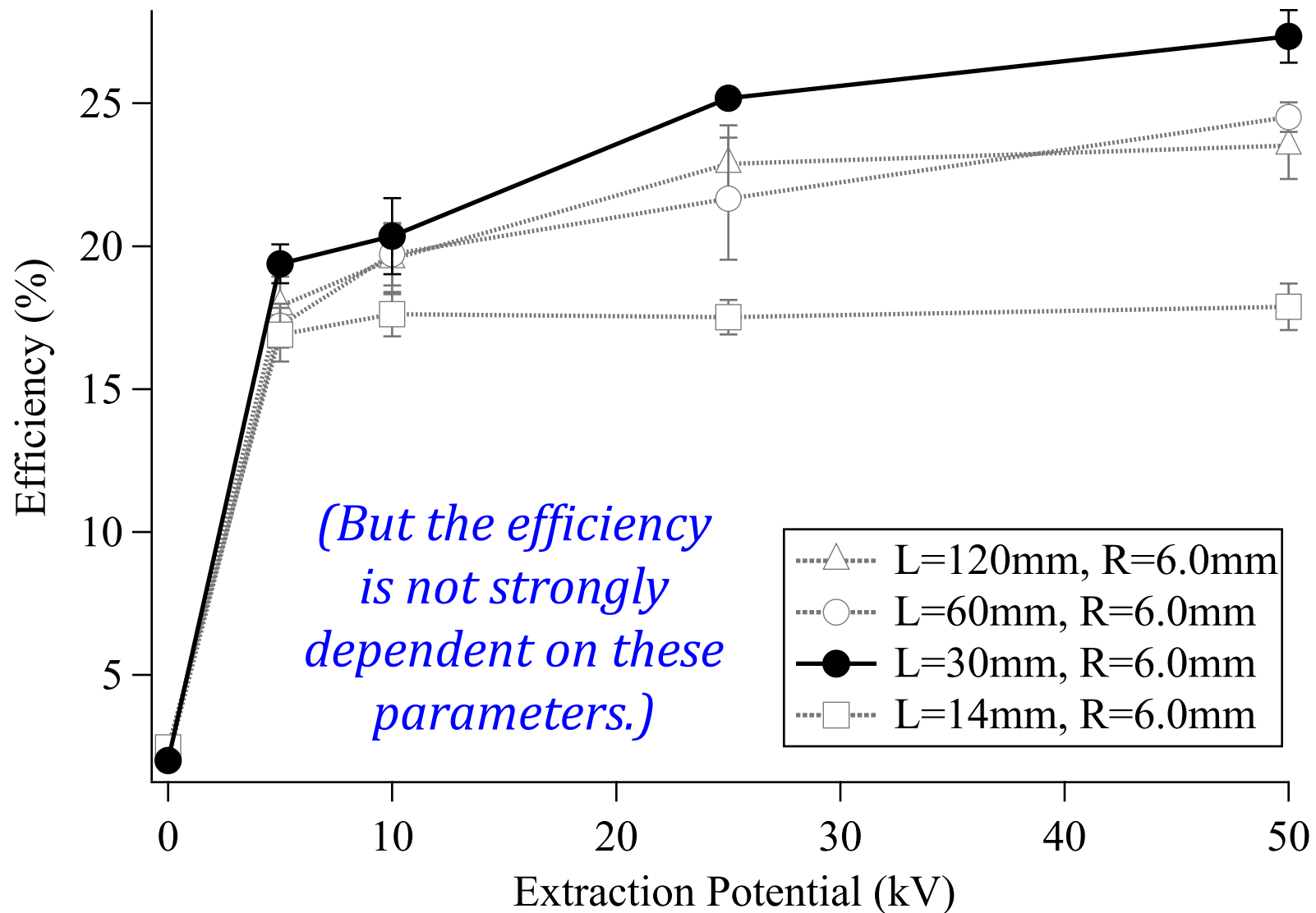


Evaporated atoms must travel down the cavity length to escape.

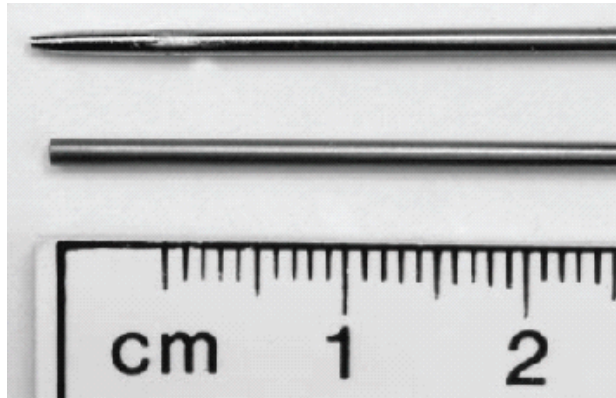
Our goal: Model the cavity and vary the **Width**, **Length** and **Extraction Voltage**.



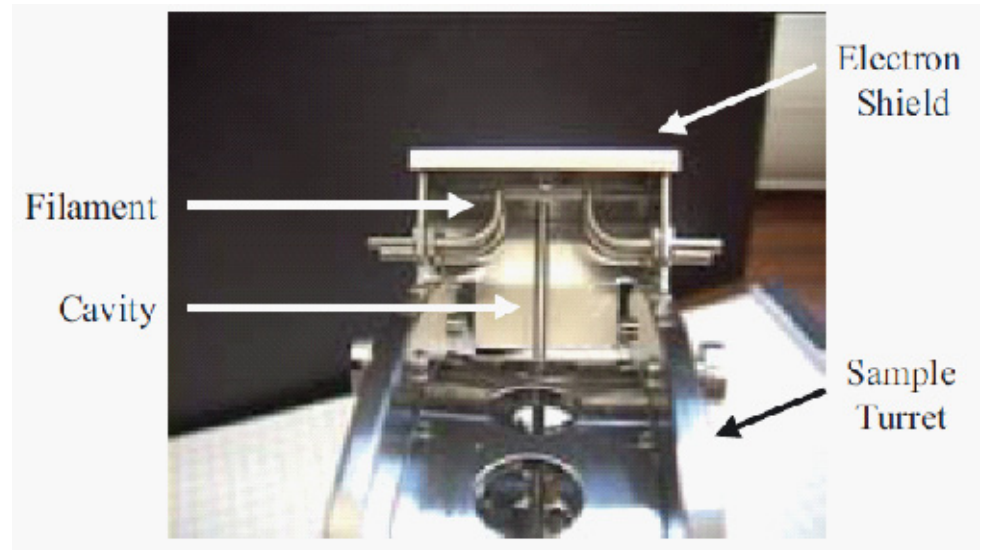
Wider cavities, higher extraction potentials and medium lengths did best.



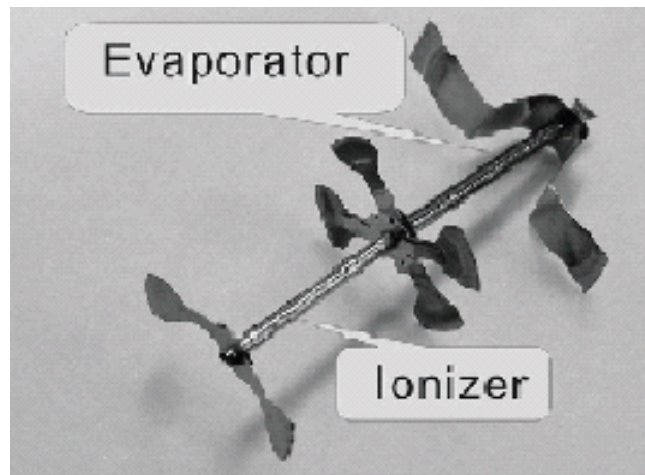
Groups have successfully built **prototypes** of cavity ion source.



Duan et al. 1999: 3.8%
Los Alamos



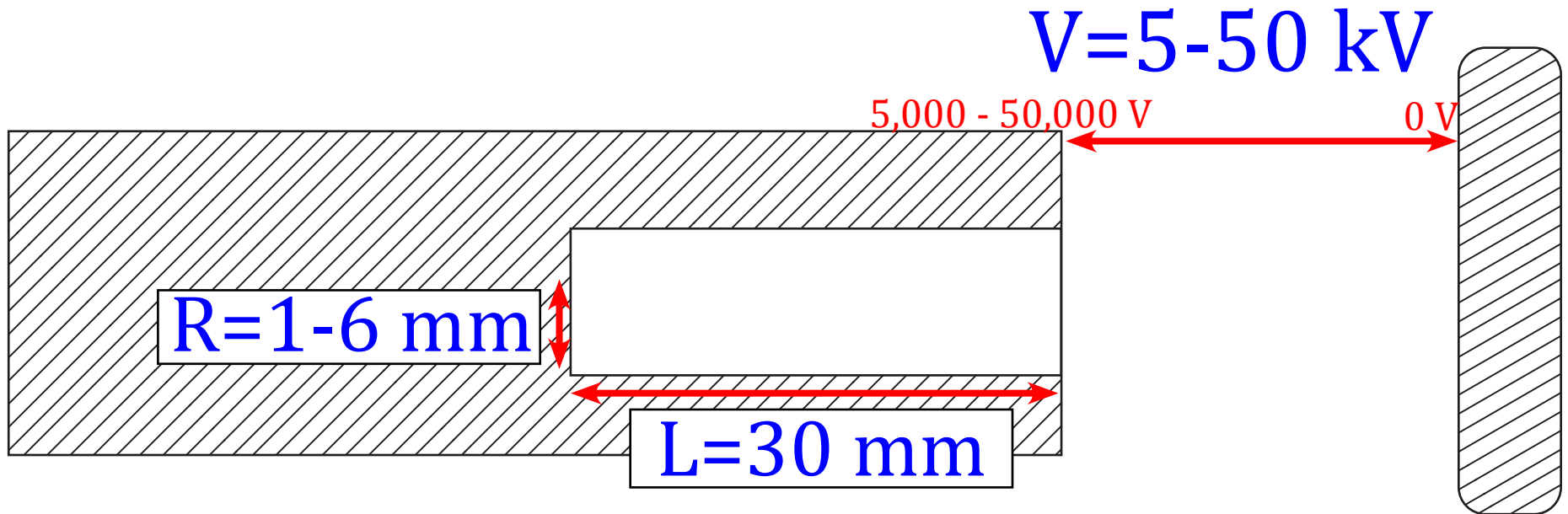
Riciputi et al. 2003: 6.2%
IAEA & ORNL



Zhai et al. 2011: 4.5%
China

Our solution: Build the spectrometer around the ion source

We will **build** the new cavity ion source around the model's predictions.



Possible 20% ionization efficiency.

Leads to an increase of 200x in sensitivity!