

Characterisation of the Ion Focusing Funnel and Assembly of the Radio Frequency Quadrupole for Further Development of RADRIS

GSI Summer School 2026

Michaela Divišová, CTU in Prague, 14. 9. 2026

Supervisor: Premaditya Chhetri

Outline

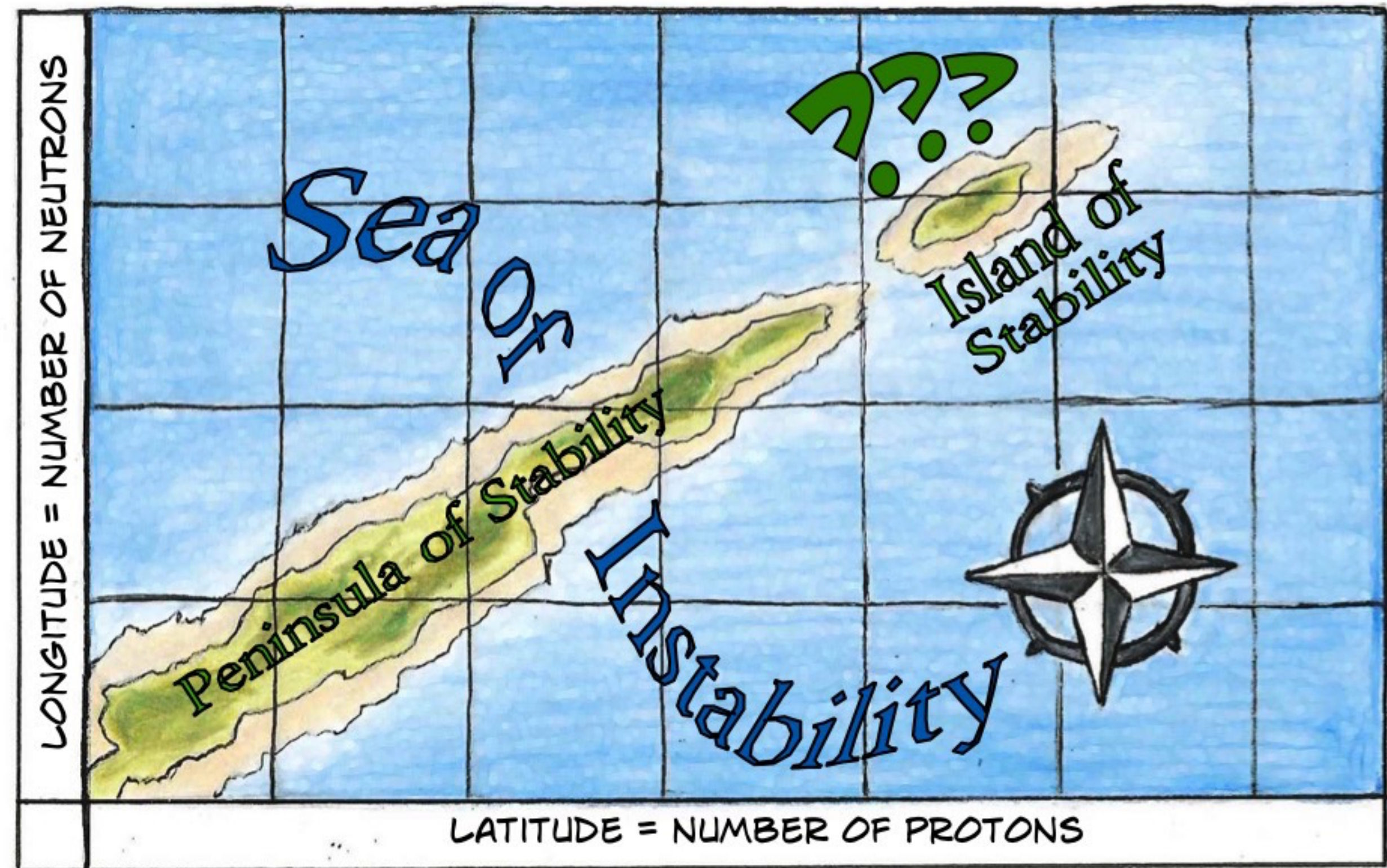
- Motivation
- Experimental setup - offline gas cell
- Experimental results
- Radio frequency quadrupole (RFQ) - assembly
- Outlook

Part 1

Motivation and RADRIS

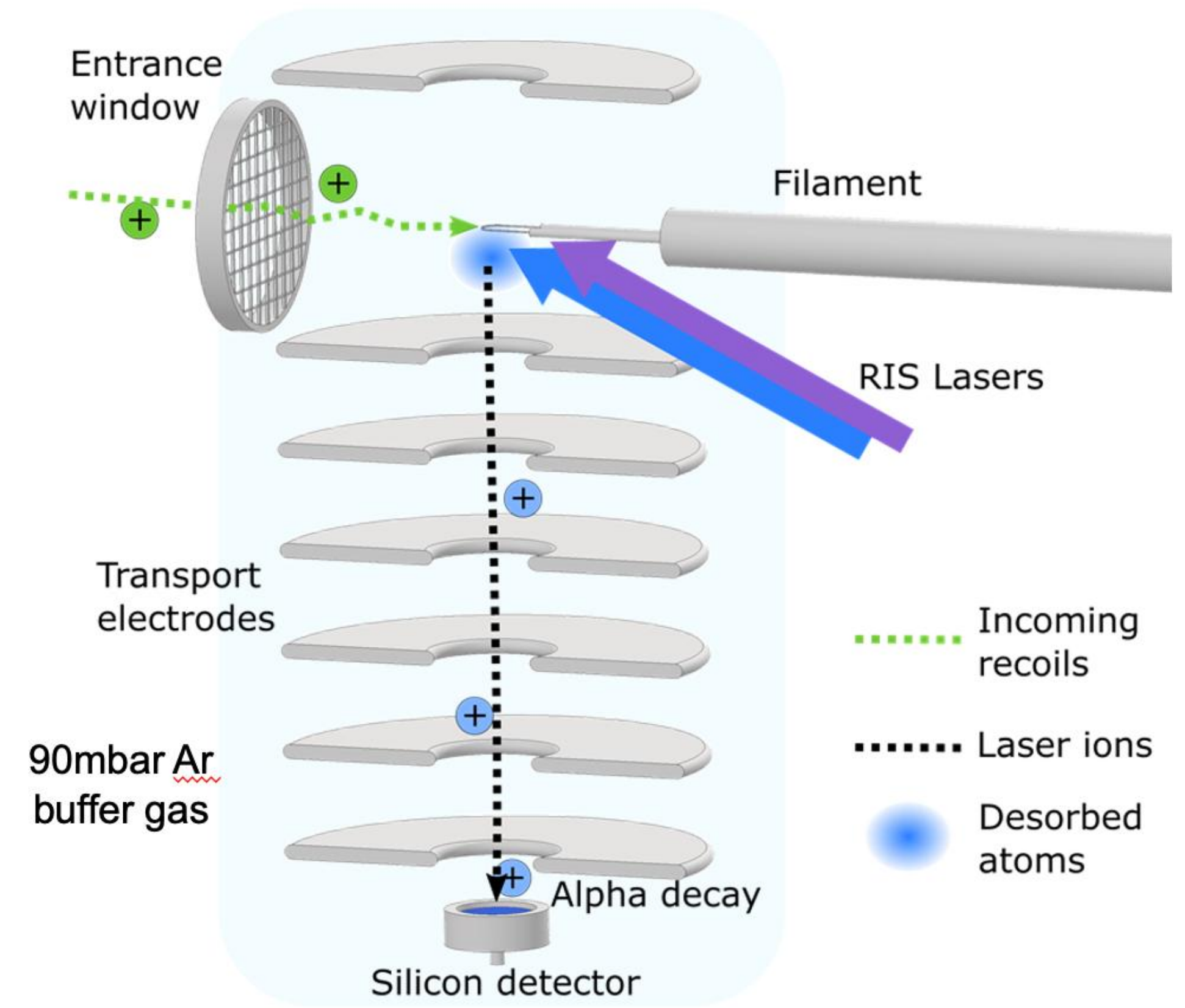
Super Heavy Elements (SHE)

- Explore the end of the periodic table - island of stability
- Atomic and nuclear structure
- Problems:
 - Complicated physics
 - Low production rates
 - Short lifetimes
 - Required precise setups



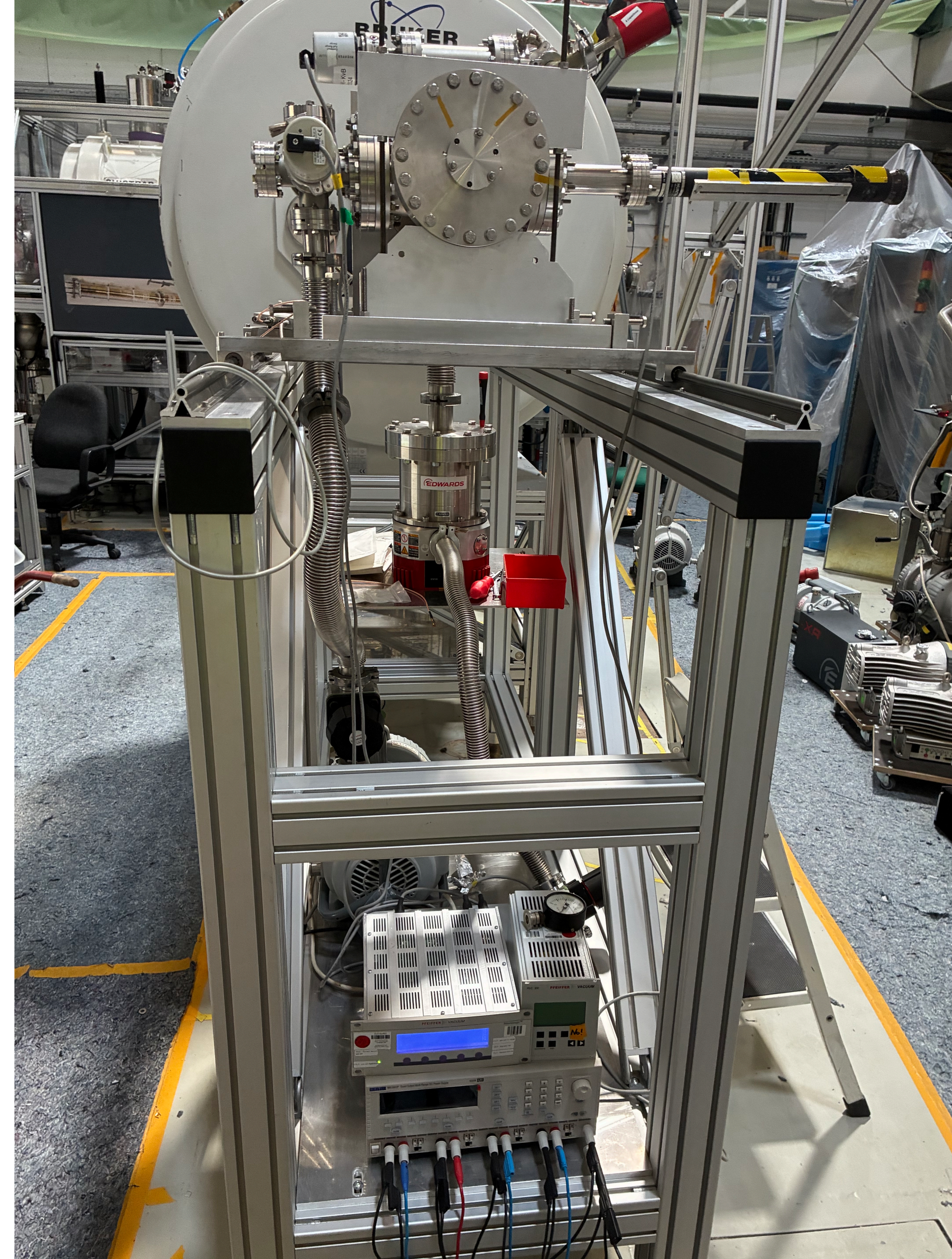
RADRIS

- Heavy nuclei produced by fusion evaporation reactions
- Separation with velocity filter Separator for Heavy Ion reaction products (SHIP)
- Thermalisation in Ar buffer gas
- Neutralisation on filament
- Desorption and RIS
- Detection by alpha decay
- BUT: restricted beam-time



Offline measurements

- Buffer gas cell
- Potentially shorter extraction times
 - Ion transport in RADRIS ~ 350 ms
 - Small cell with gas flow and guiding fields could reduce it to ~ 100 ms
- Systematic studies of spectral line-width for different buffer gas and different pressures

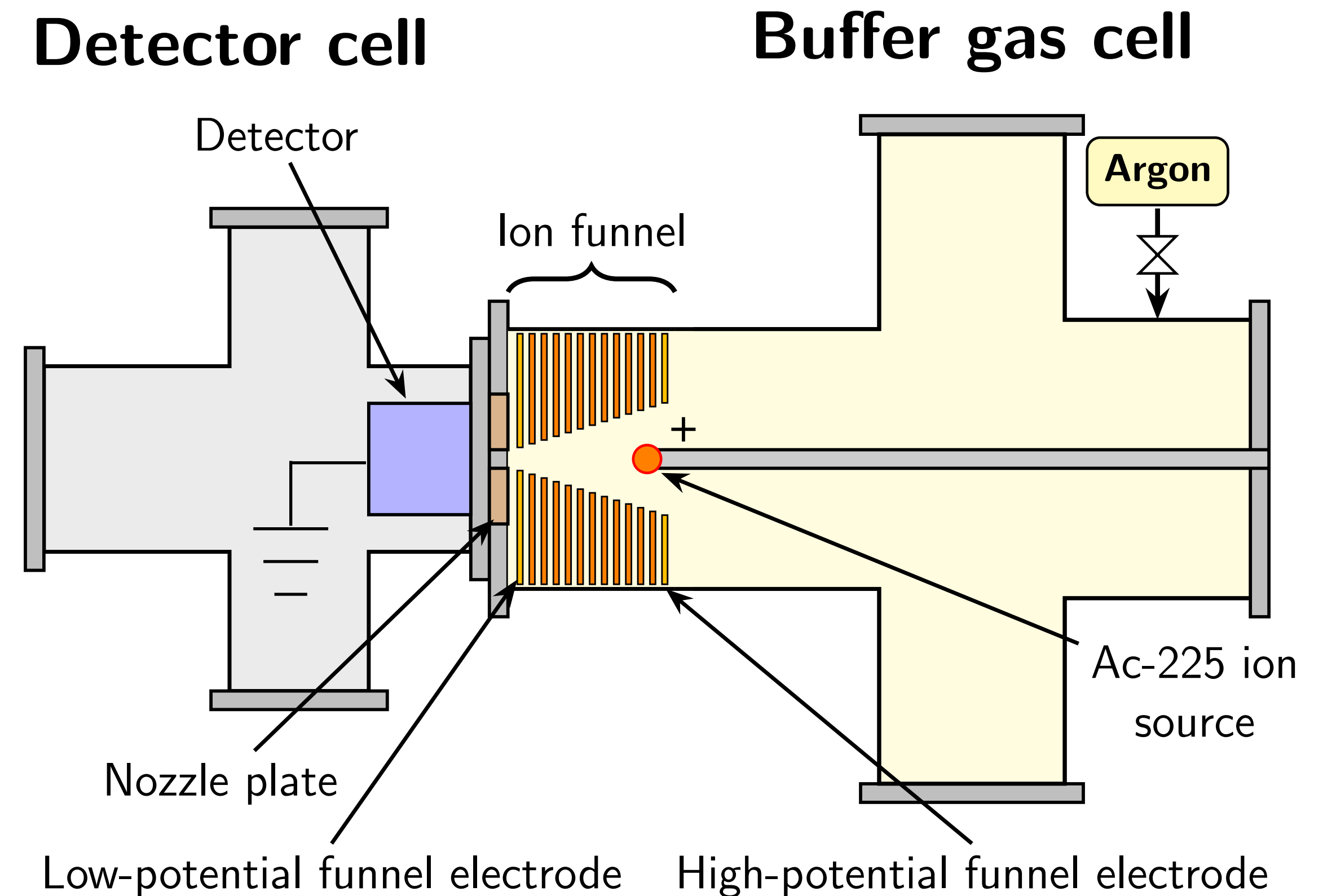


Part 2

Experimental setup

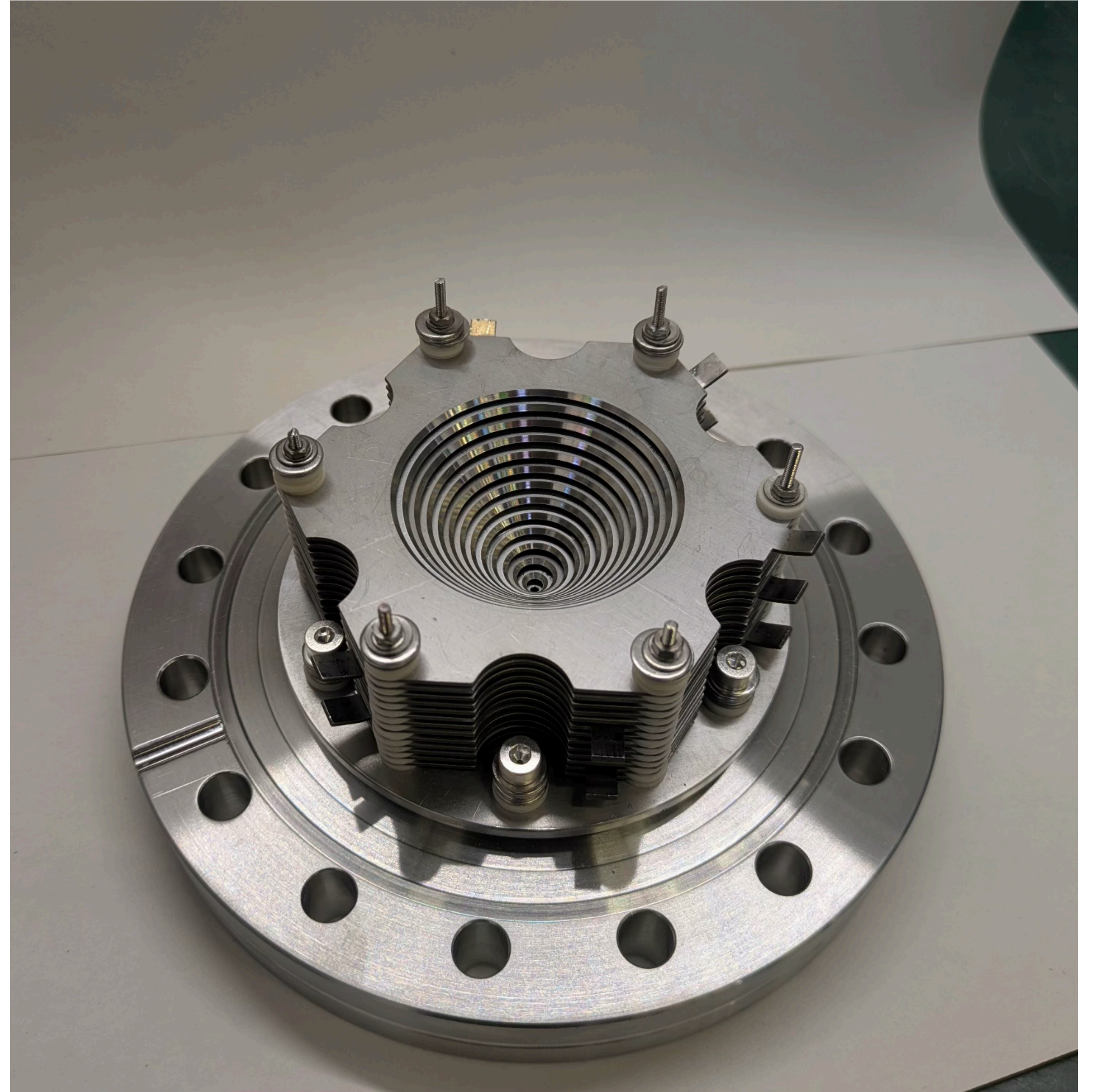
Experimental setup

- Recoil ions from the ^{225}Ac source collide with the argon buffer gas atoms
- Guided from the gas cell to the detector cell
 - Argon mass flow and DC gradients of the ion funnel focus the ions radially
- Alpha detector on a holding cap
- Signal $\rightarrow$ pre-amplifier $\rightarrow$ ADC $\rightarrow$ DAQ



Ion Funnel

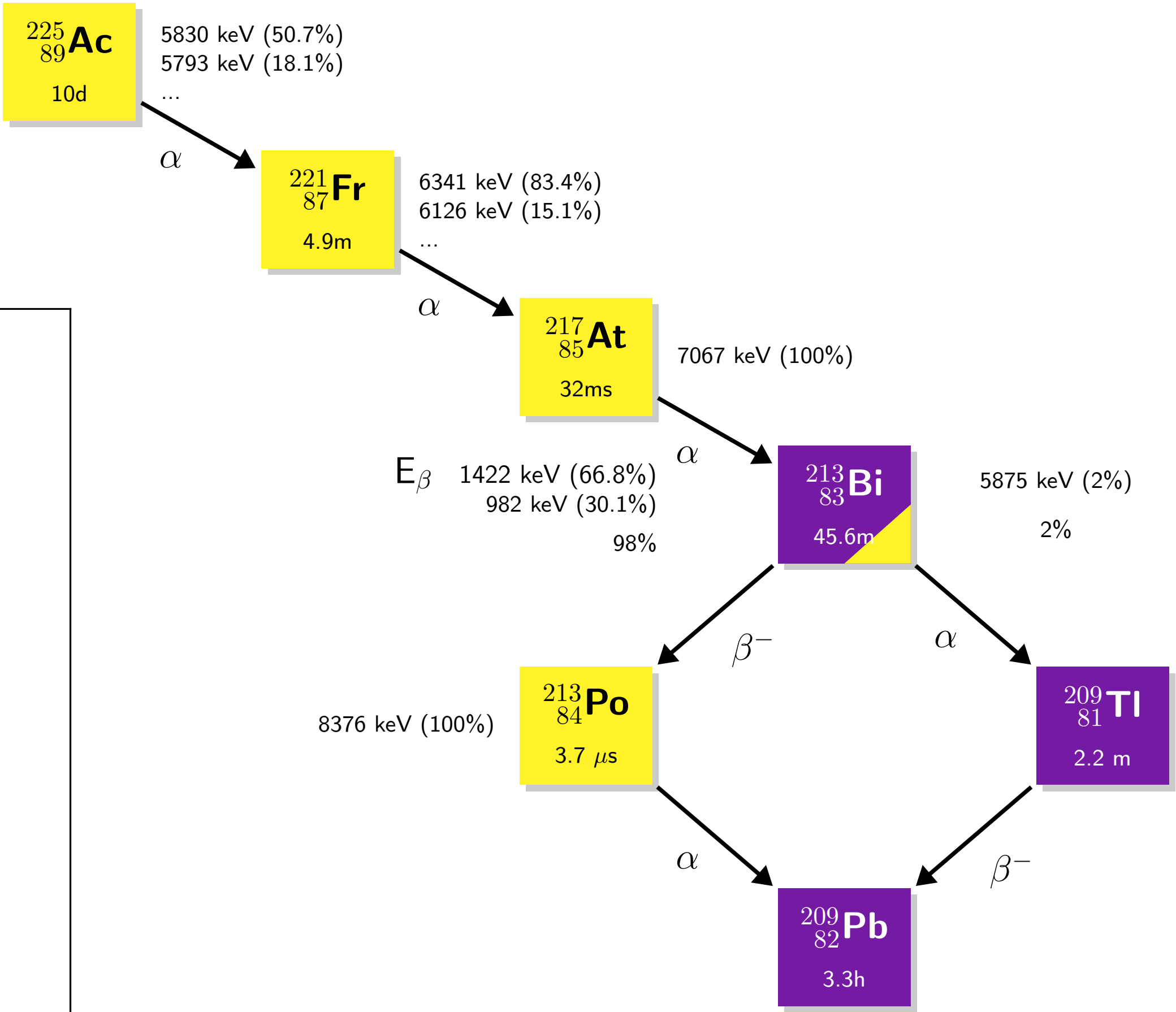
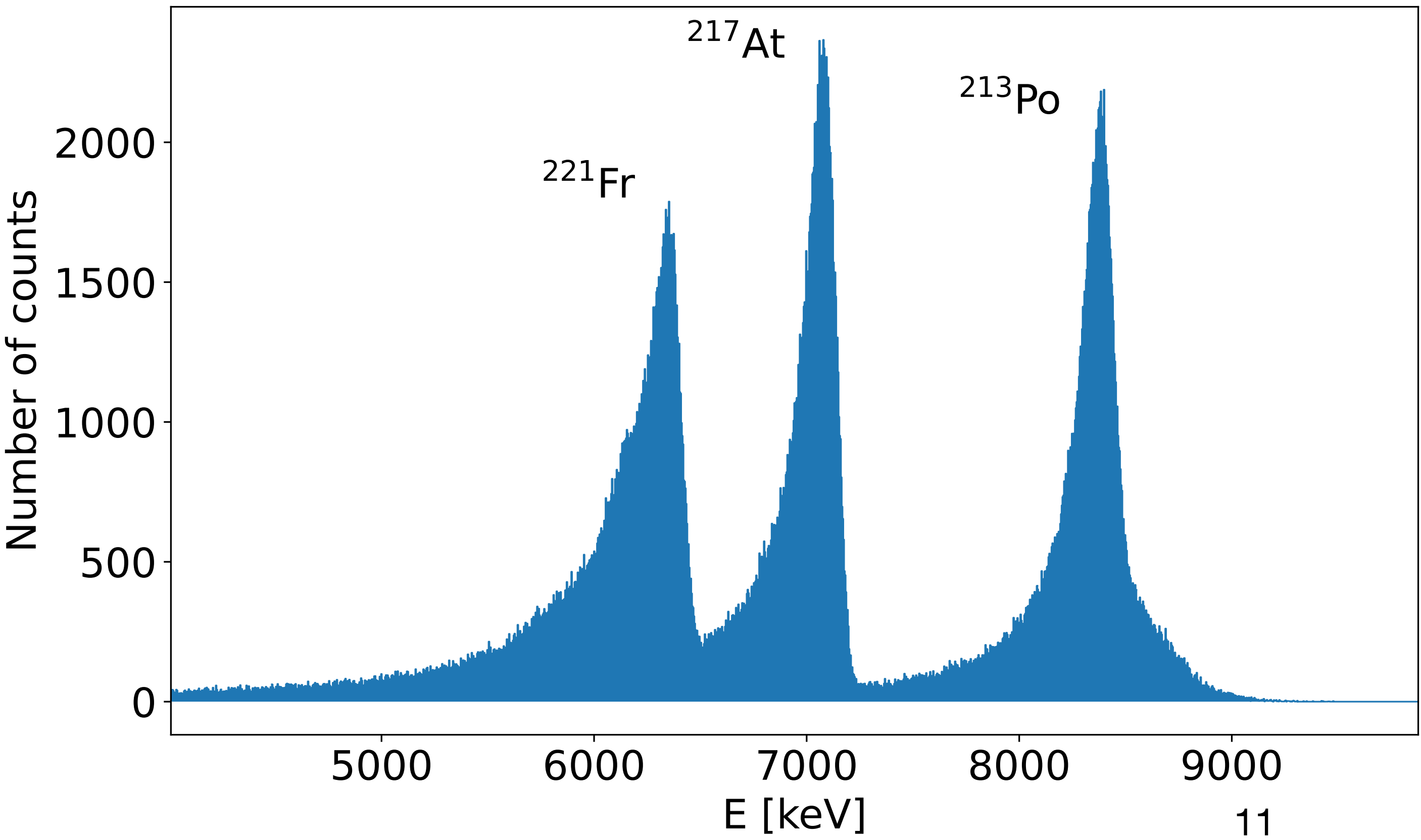
- 13 conically diverging electrodes for radial focusing + a nozzle plate
- DC voltage applied to low- and high-funnel provide axial acceleration



Part 3

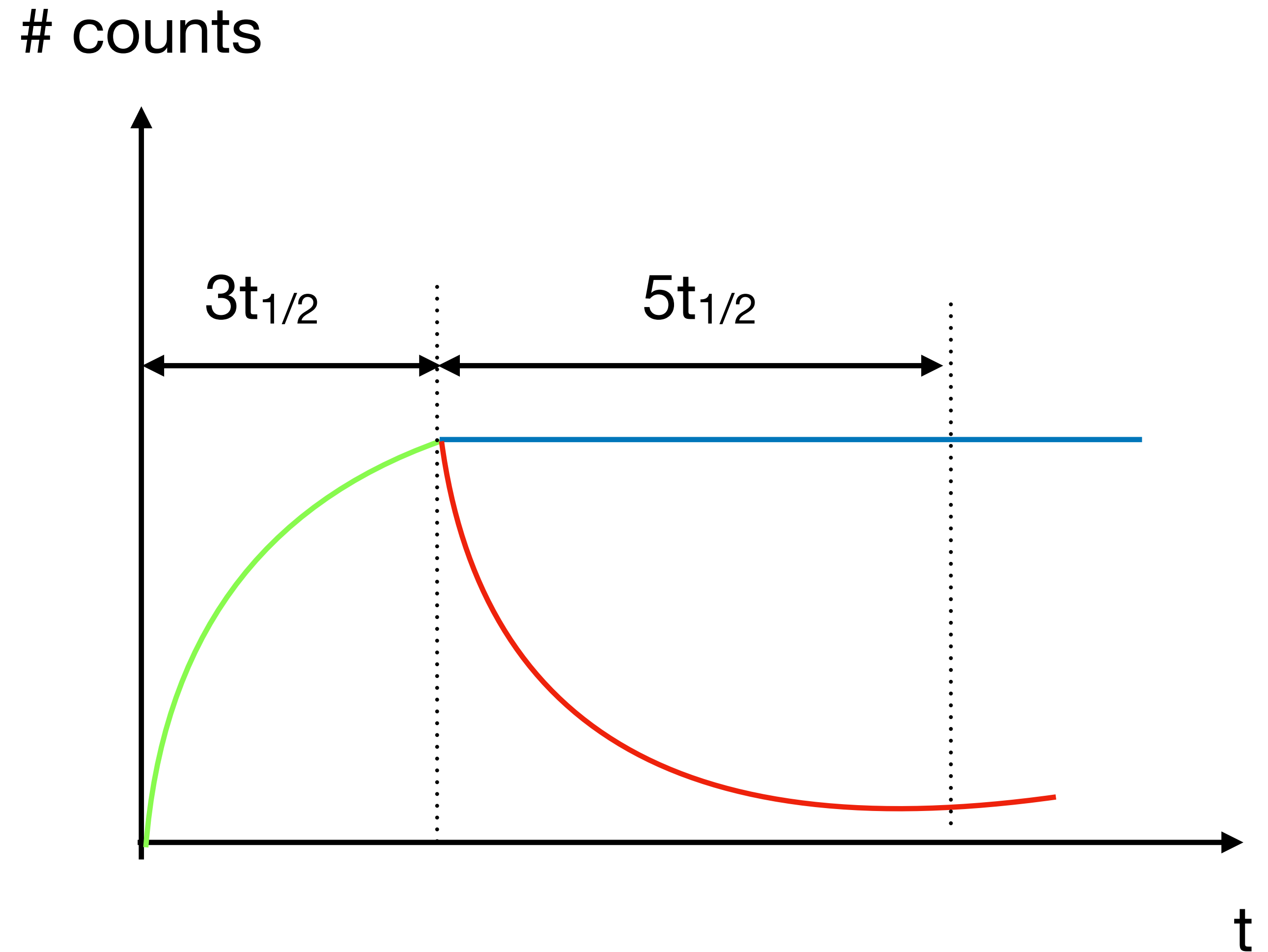
Experimental results

225-Ac recoil ion source



Measurements

- Half-life of 225-Ac: ~10 days
- Half-life of 221-Fr: ~5 min
- Measurement 15 + 25 min
- Suitable half-life for measurements
- 60 mbar

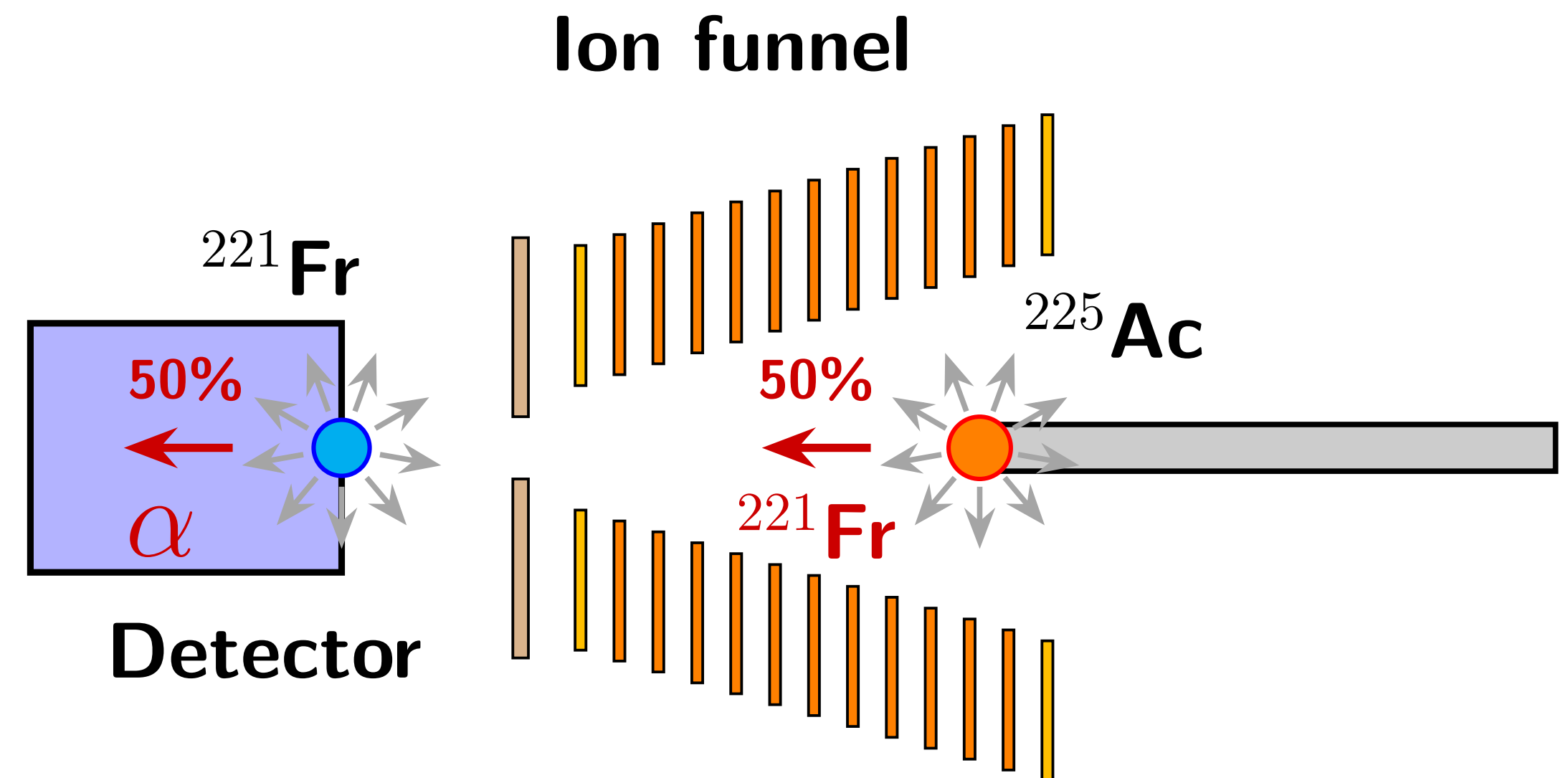
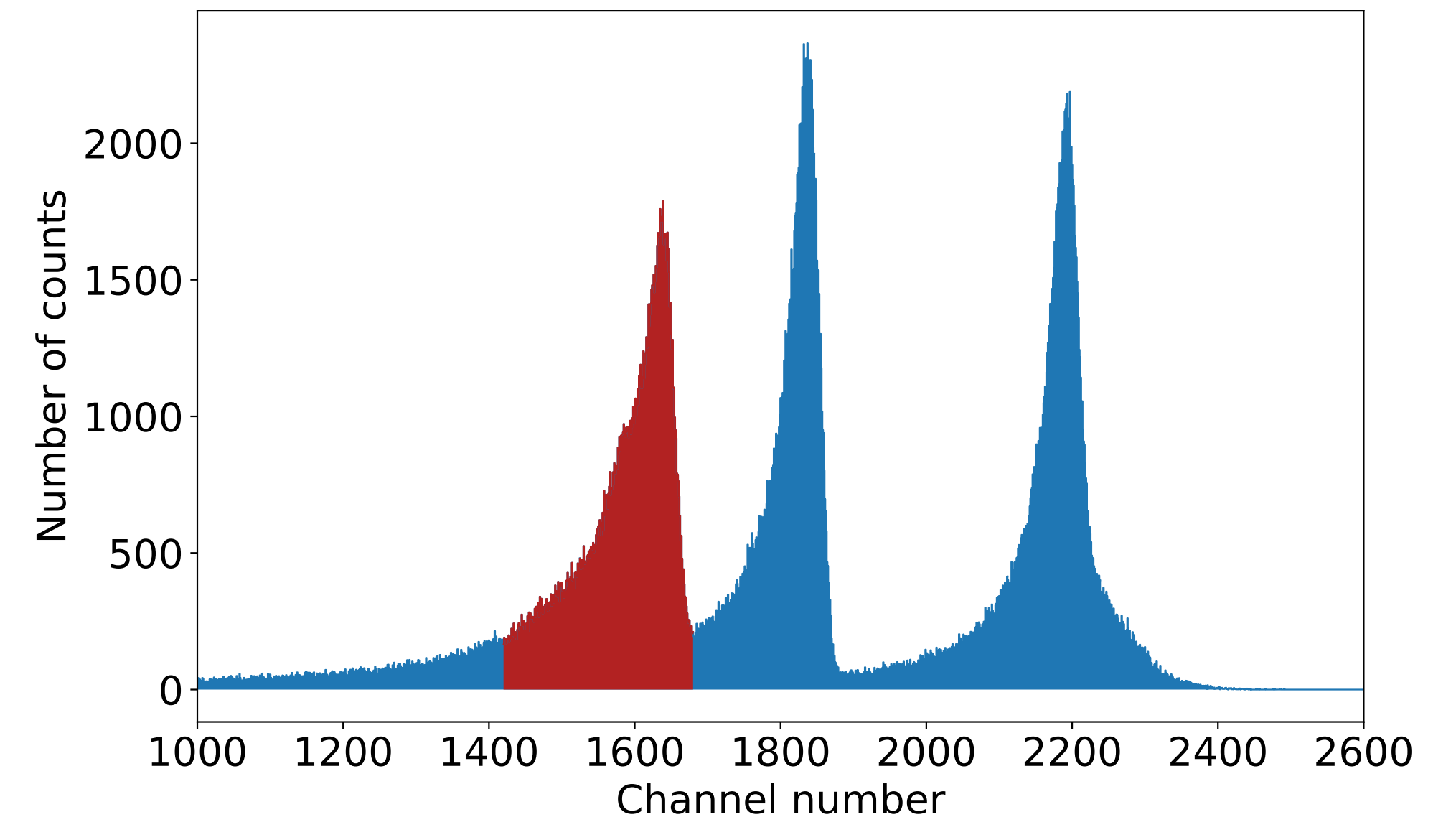


Calculation of efficiency

- Region of interest is only the Fr peak
- Suitable half life for measurements

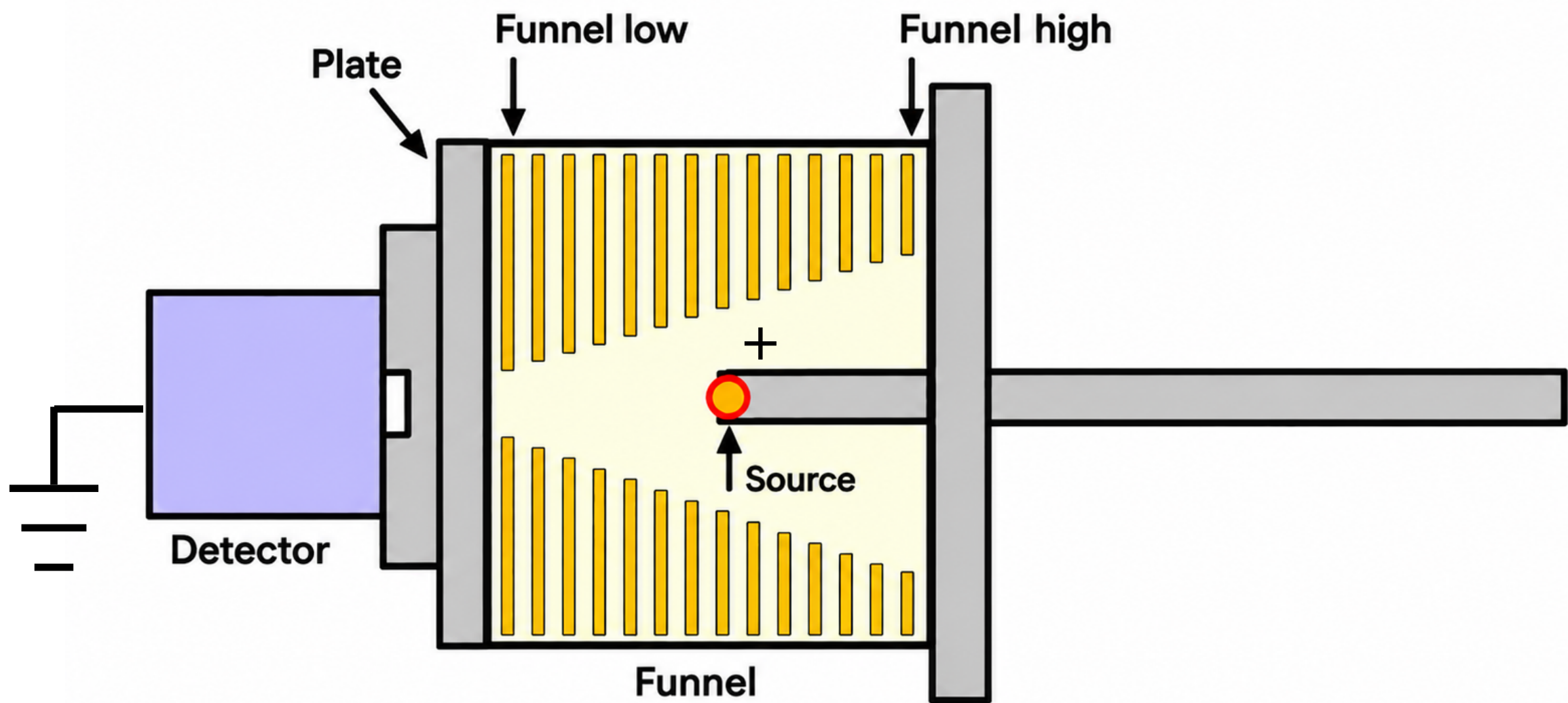
$$A(t) = A_0 \cdot 2^{-\frac{t-t_0}{T_{1/2}}}$$

$$\text{Efficiency} = \frac{2 \cdot 2 \cdot \text{Counts in ROI}}{A(t) \cdot (15 \cdot 60)} \quad [\%]$$



Extraction efficiency of the ion funnel

- Find the best voltage configuration
- Different potential gradients to different parts of the setup



Picture by Premaditya Chhetri

V_P [V]	V_L, V_H [V]	V_S [V]
Funnel Scan		
20	20, 20–60	V_H
Plate Scan		
0–20	20, 60	60
Source Scan		
20	20, 25	10–50
20	20, 40	25–65

Funnel scan

V_P [V]	V_L, V_H [V]	V_S [V]
20	20, [20, 30, 40, 50, 60]	V_H

- Decreasing efficiency for higher funnel gradients ΔV_F
- Source placed inside the funnel
- Too high acceleration $\rightarrow$ ions hit the funnel

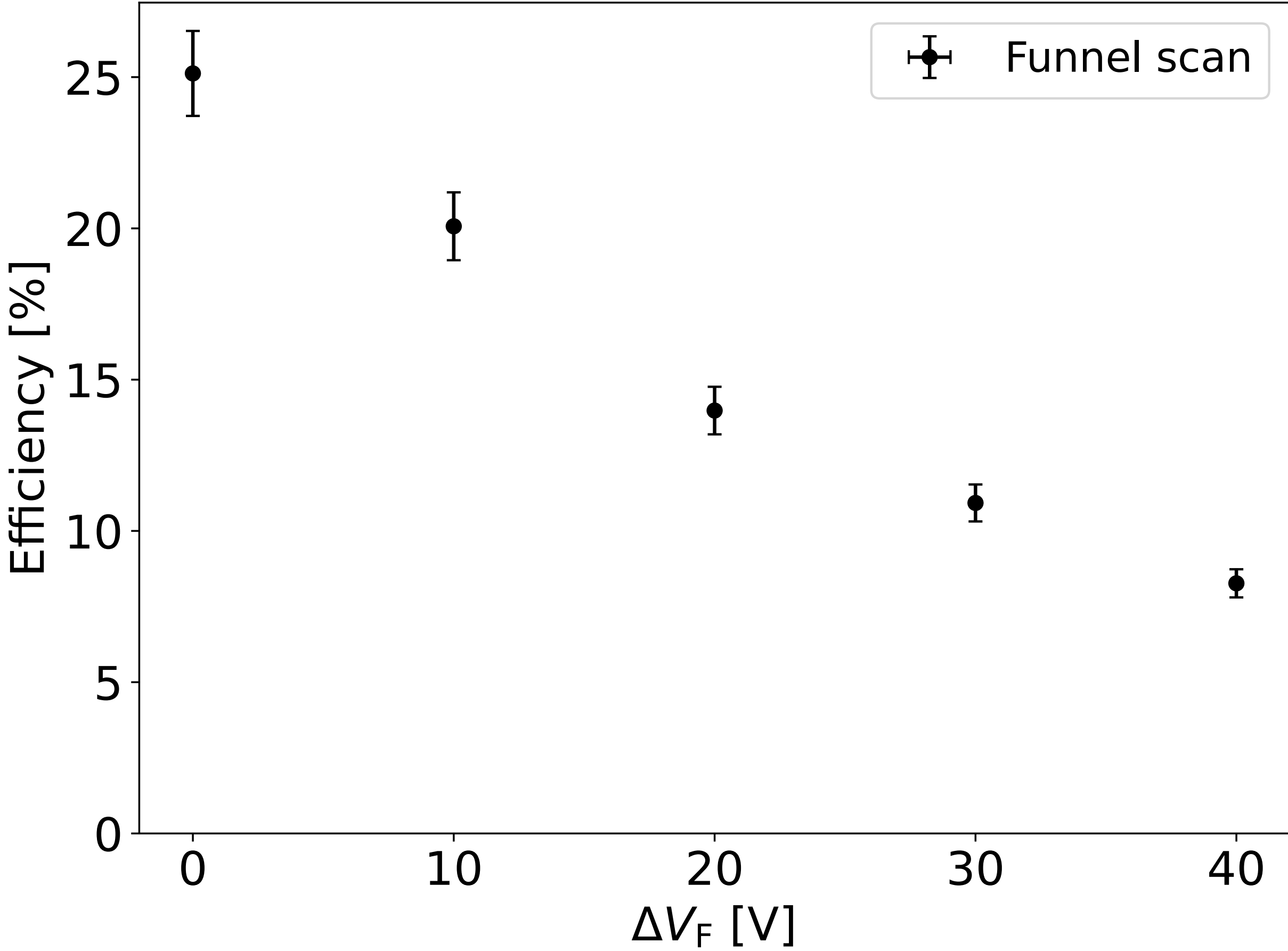
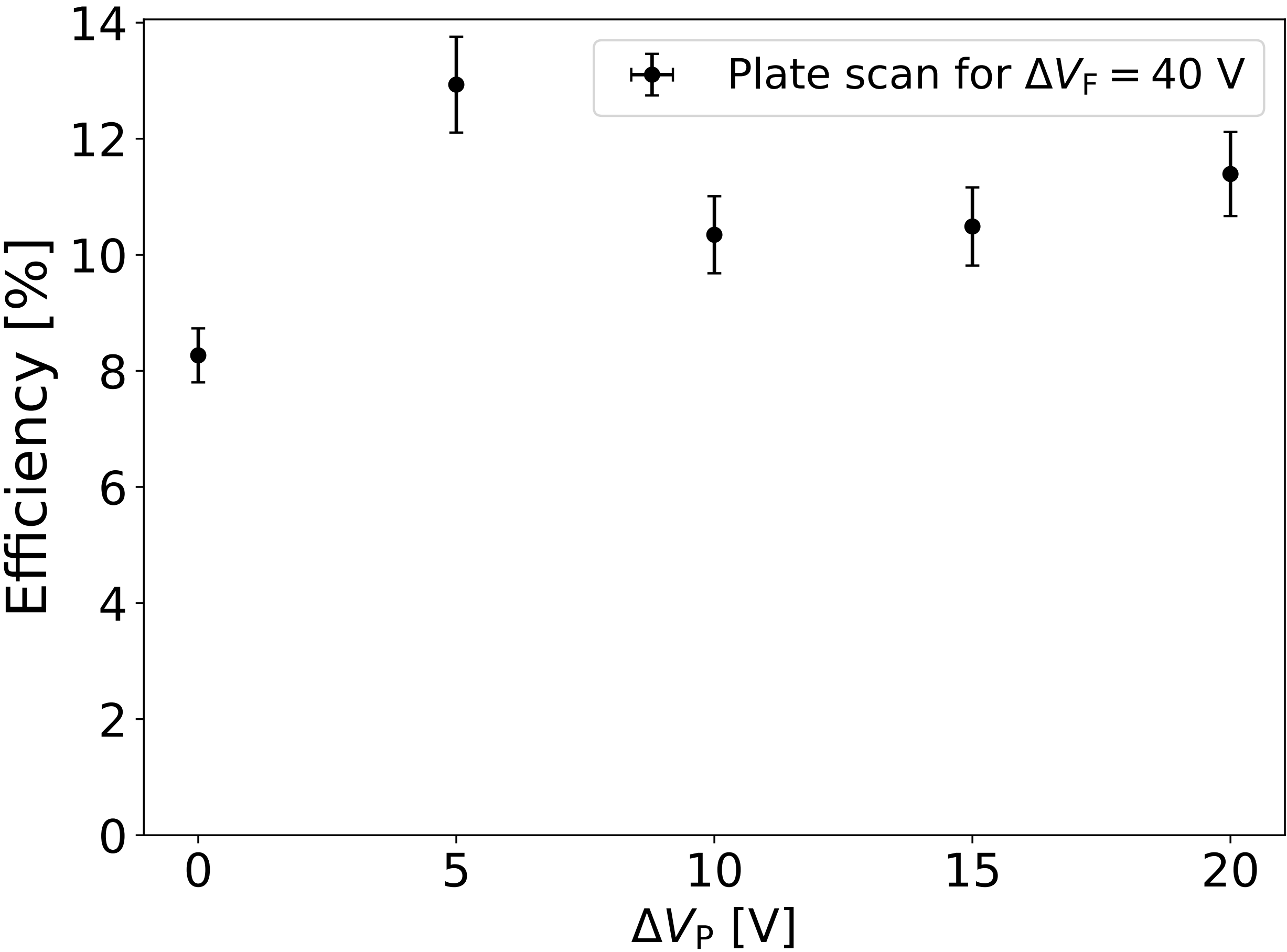


Plate scan

V_P [V]	V_L, V_H [V]	V_S [V]
[0, 5, 10, 15, 20]	20, 60	60

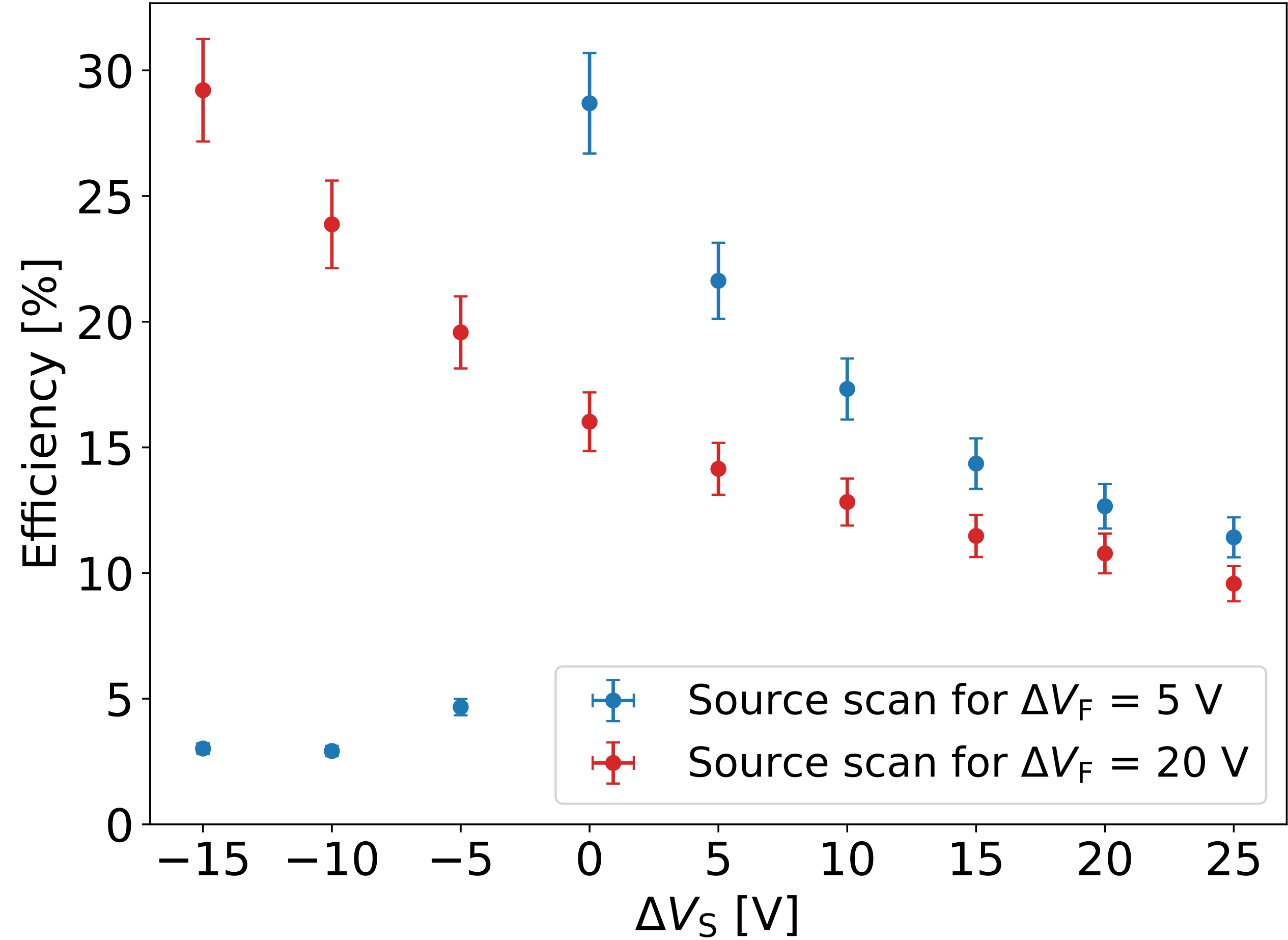
- V_P varied from 0-20 V
- Constant 40 V funnel gradient ΔV_F
- Constant efficiency observed
- V_P has small influence on the extraction efficiency



Source scan

V_P [V]	V_L, V_H [V]	V_S [V]
20	20, 25	[10, 15, 20, 25, 30, 35, 40, 45, 50]
20	20, 40	[25, 30, 35, 40, 45, 50, 55, 60, 65]

- Two different funnel gradients
- Also negative source gradients applied(!)
- Similar behaviour to funnel scan
- 5 V
 - Negative ΔV_S stops the extraction
- 20 V
 - Negative ΔV_S increases the extraction
 - Max. efficiency of around 30 %

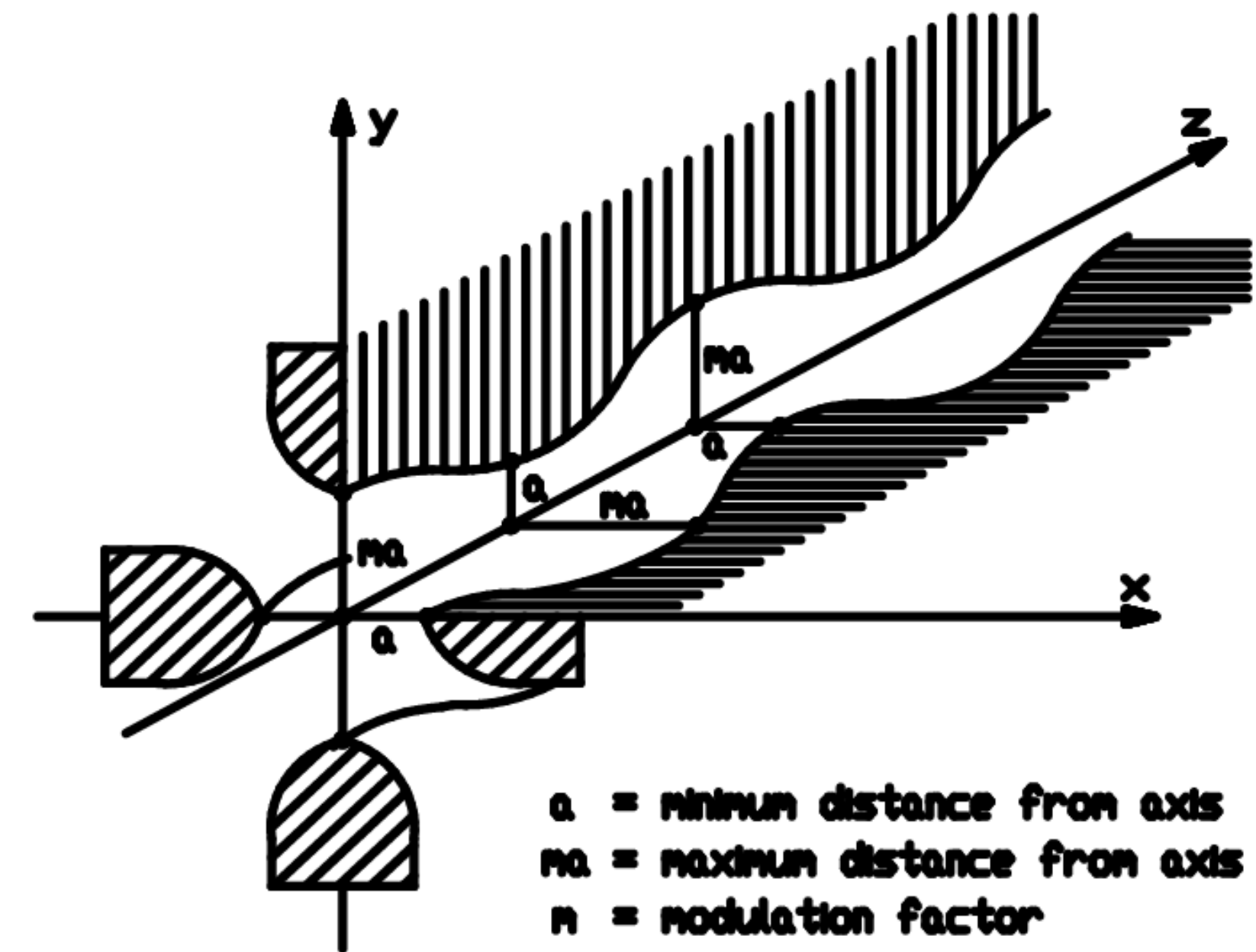
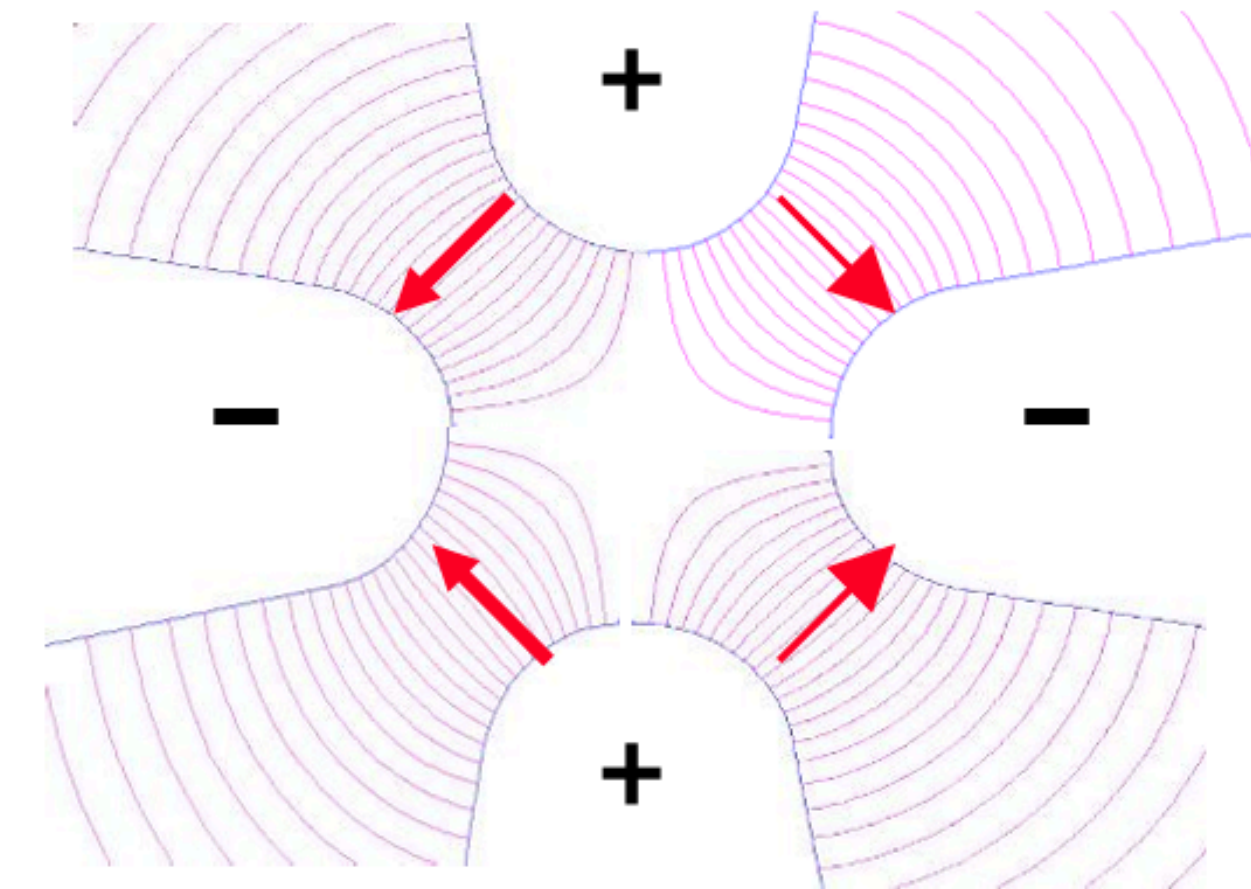


Part 4

Radio Frequency Quadrupole Assembly

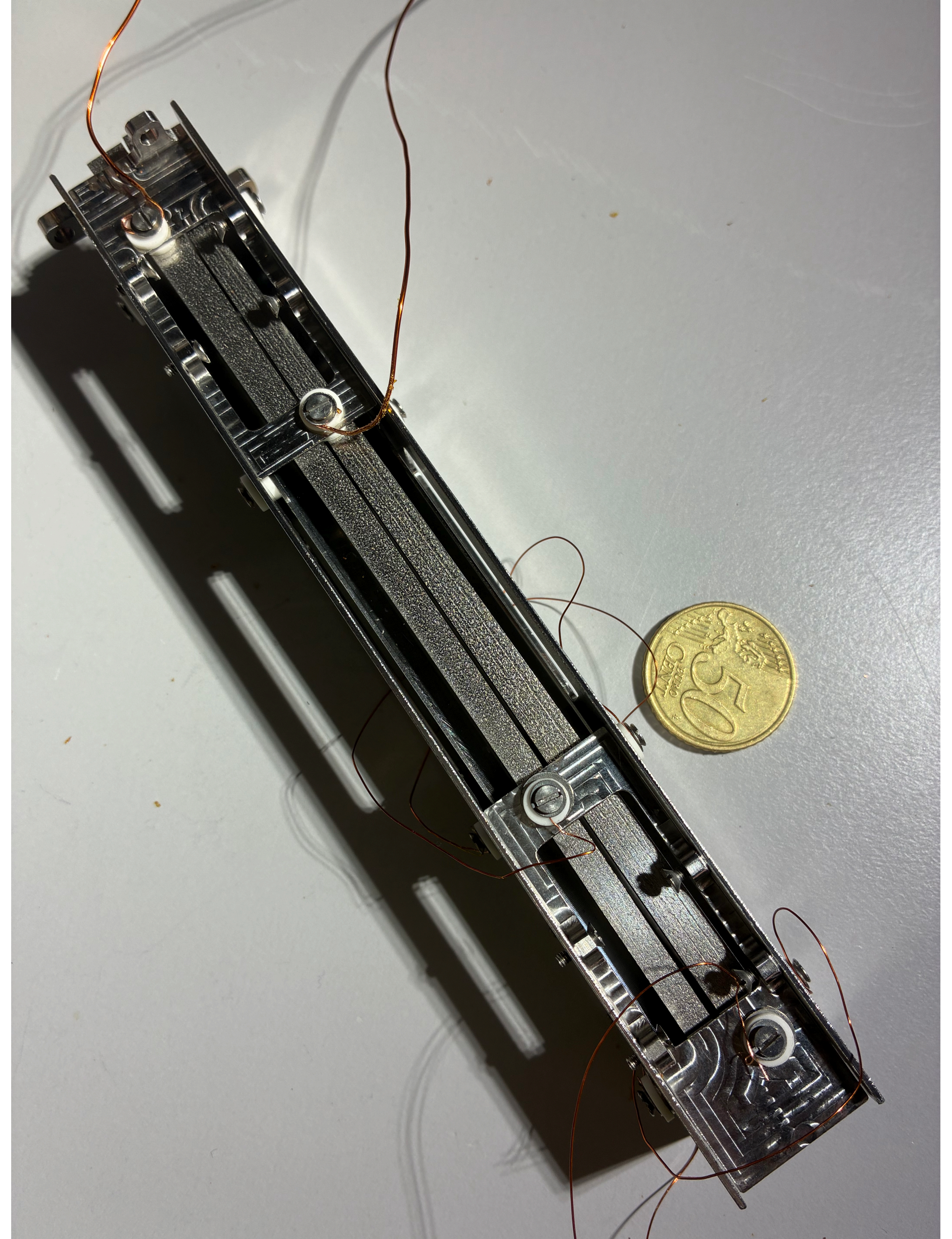
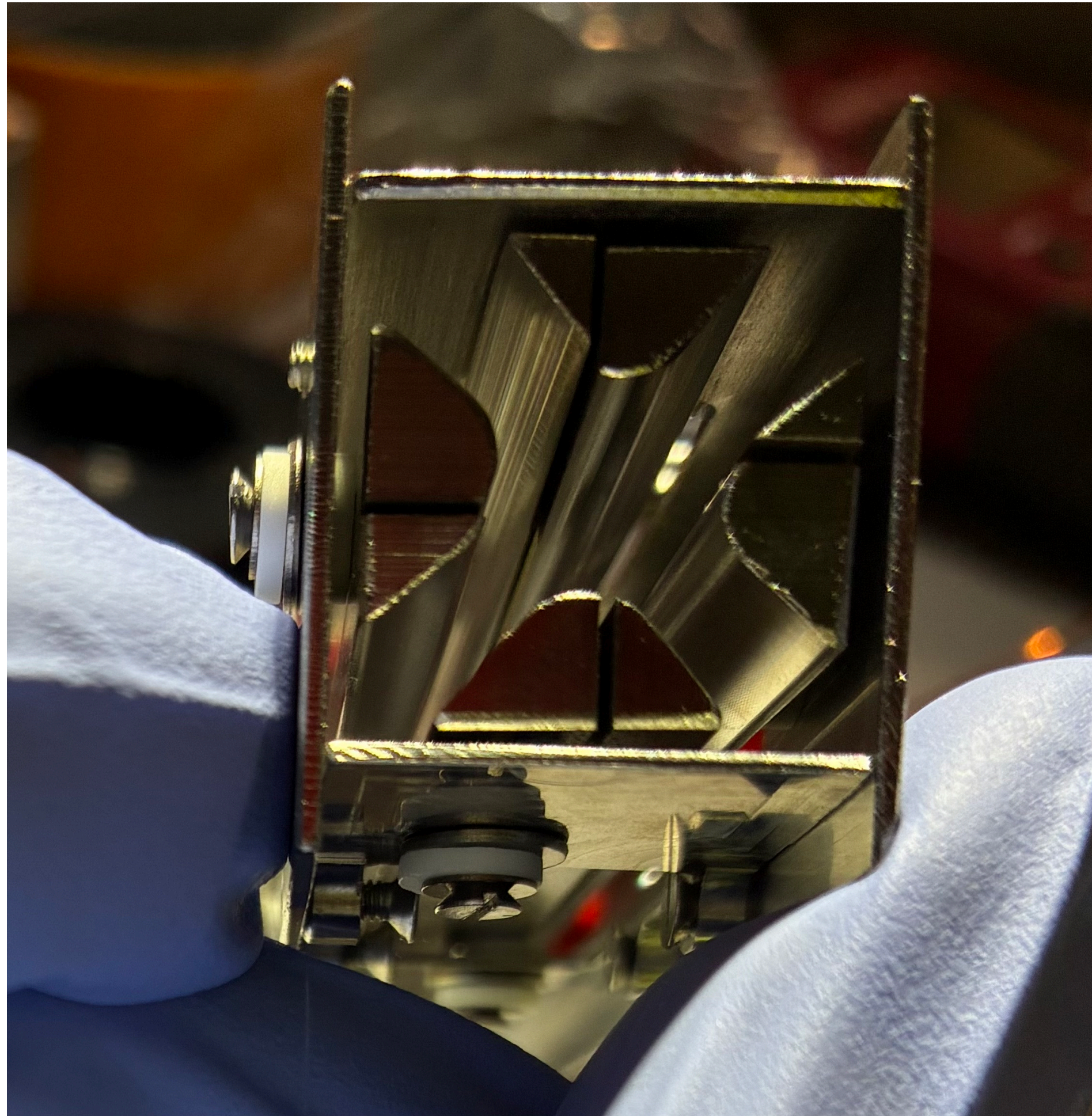
RFQ

- Ion confinement, guiding or mass separation
- 4 electrodes, 2 segments each
- RF and DC voltage
- Opposite electrodes are phase-shifted
- Hyperbolic radial confinement potential
- Ion motion governed by Mathieu's equations of motion



CERN Presentation: https://indico.cern.ch/event/432948/contributions/1929650/attachments/1124798/1605454/module7_RFQ_s2.pdf

Assembled RFQ



Conclusion

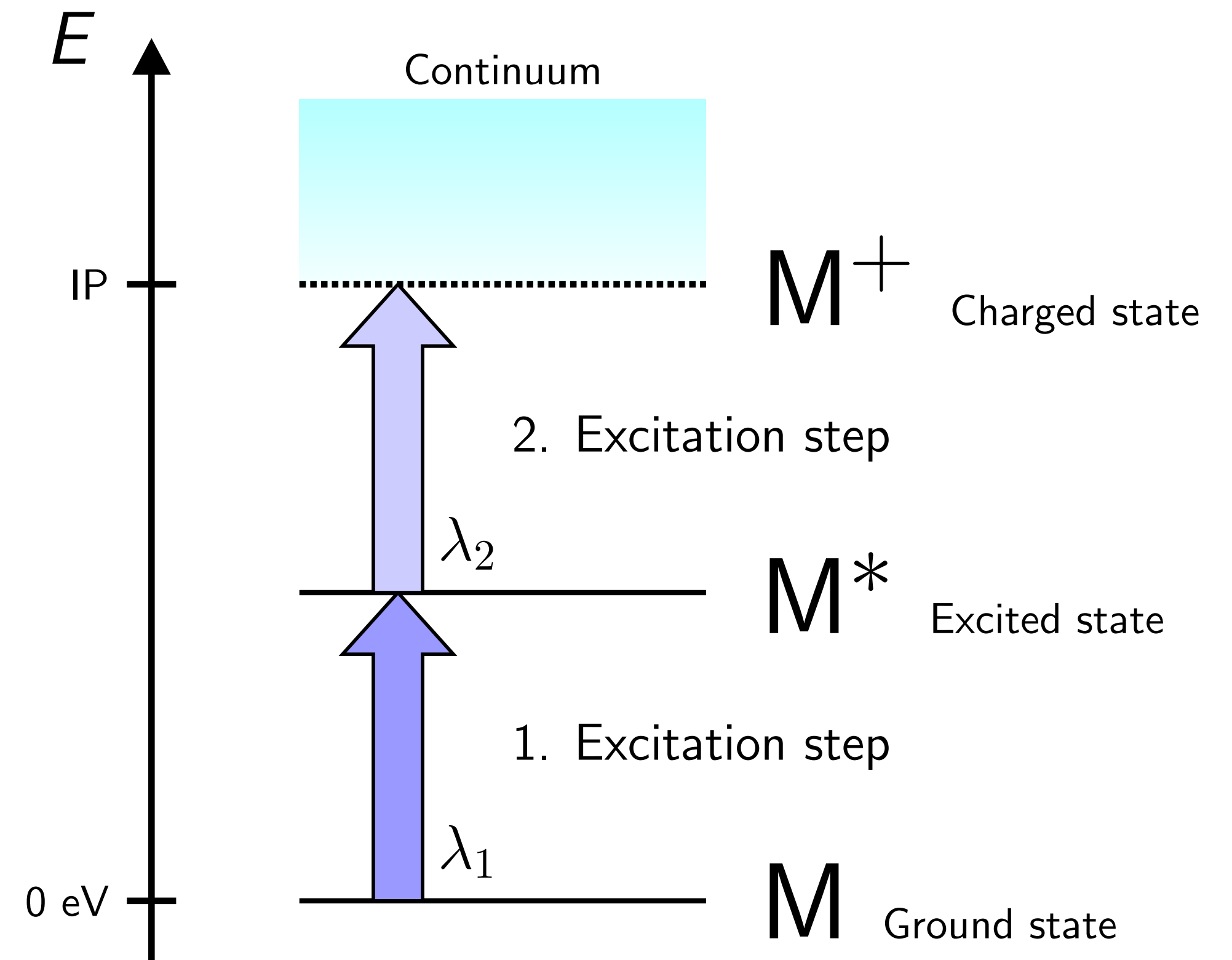
- Extraction efficiency of the ion funnel was measured for different combinations of the voltage gradients between the setup components
- The highest extraction efficiency of around 30 %
- Sufficient for the RFQ installation
- Extraction efficiency at different source positions to be measured
- RFQ is assembled and prepared for the installation

Thank you for your attention

Backup

Resonance ionisation spectroscopy (RIS)

- Two-step photoionisation
 - Lasers of different wavelengths
 - Excitation $\rightarrow$ ionisation of the electrons
 - Good selectivity



Energy spectrum

- Calibrated from the channel spectrum

