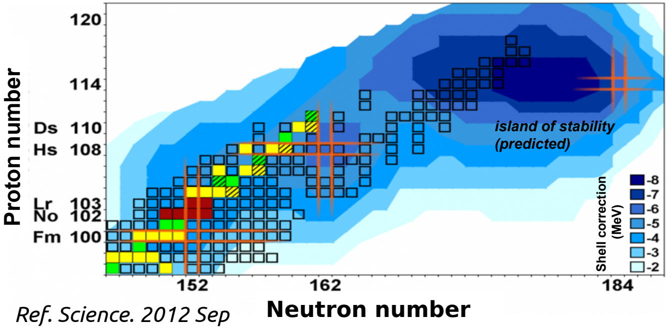
Prospects of argon as buffer gas in the stopping cell @ SHIPTRAP

Anton Roth

Supervisors: Dr. Sebastian Raeder & Oliver Kaleja

HGS-HIRe Summer Student Programme 2016

Mass measurements of heavy nuclei

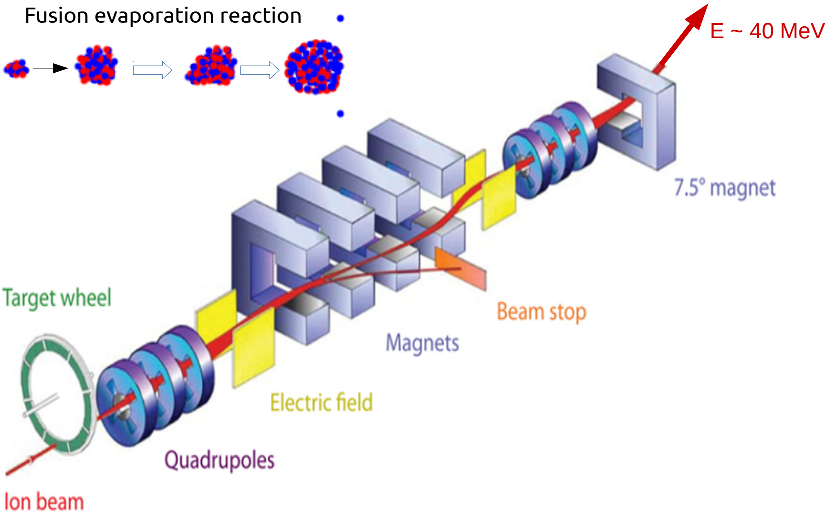


Ref. Science. 2012 Sep 7;337(6099):1207-10.

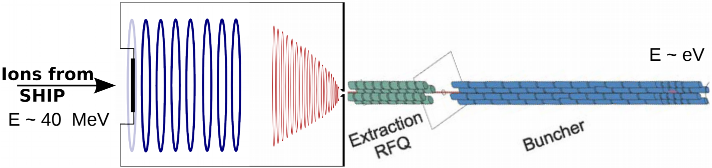
- How heavy can elements be?
- Where is the island of stability?

→ Accurate masses are needed

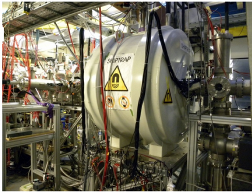
SHIP


Fusion evaporation reaction
E ~ 40 MeV
7.5° magnet
Target wheel
Beam stop
Magnets
Electric field
Quadrupoles
Ion beam

SHIPTRAP



The Penning traps



- World record: ^{256}Lr (Z = 103)
- 60 nb ^{256}Lr → 15 nb ^{257}Rf (Z = 104)
- A new stopping cell, the CryoCell
- Increased stopping and extraction efficiency

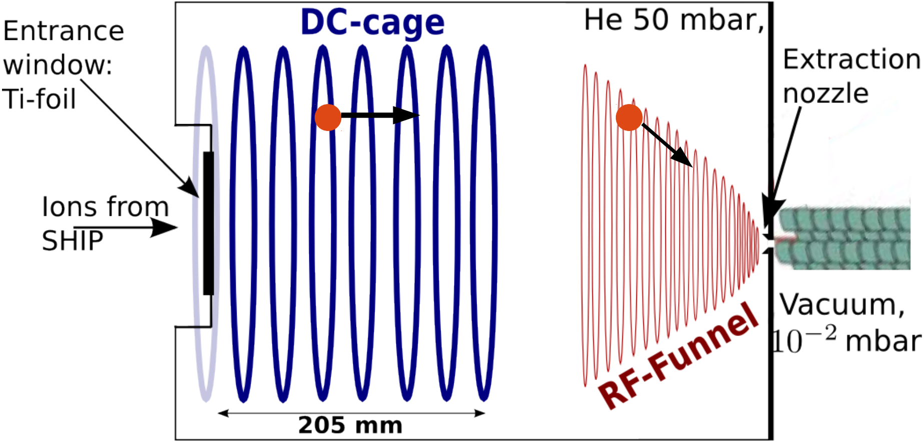
$$\omega_c = \frac{q}{m} B$$

Can argon as the buffer gas in the stopping cell improve the efficiency of SHIPTRAP?

What now...

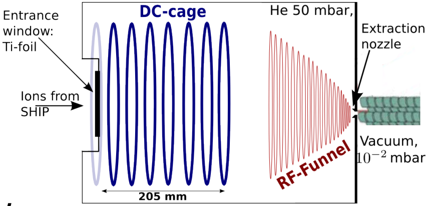
- The stopping cell
- Argon as the buffer gas
  - Stopping efficiency
  - Further properties
- Can argon improve the efficiency?

The CryoCell



The CryoCell

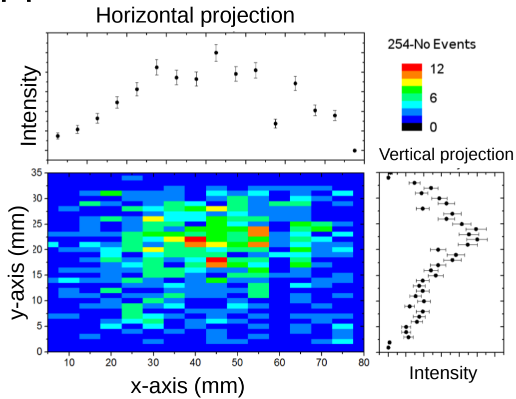
- Avoid neutralisation
- Thinner Ti-foil is foreseen
- Helium pressure limited by discharges
- Argon can potentially increase efficiency



Stopping efficiency simulations

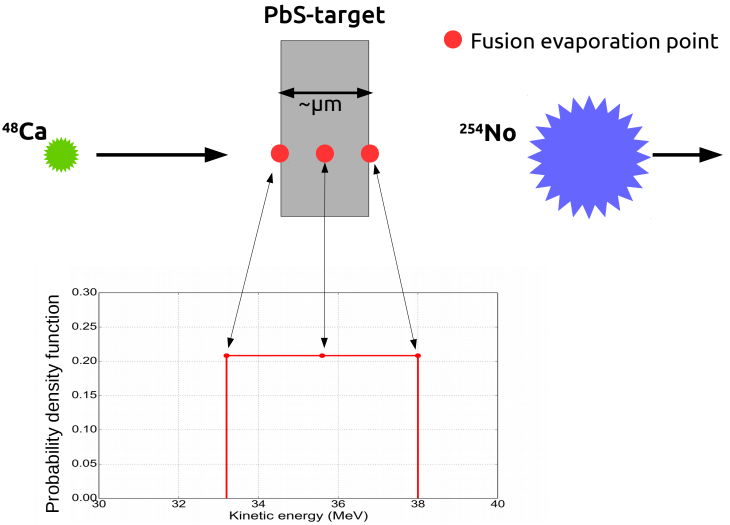
- Reaction: $^{208}Pb(^{48}Ca, 2n)^{254}No$
- Simulations with SRIM
  - Choice of ion
  - Initial kinetic energy distribution
  - Initial spatial distribution

Figure: Measured beam shape

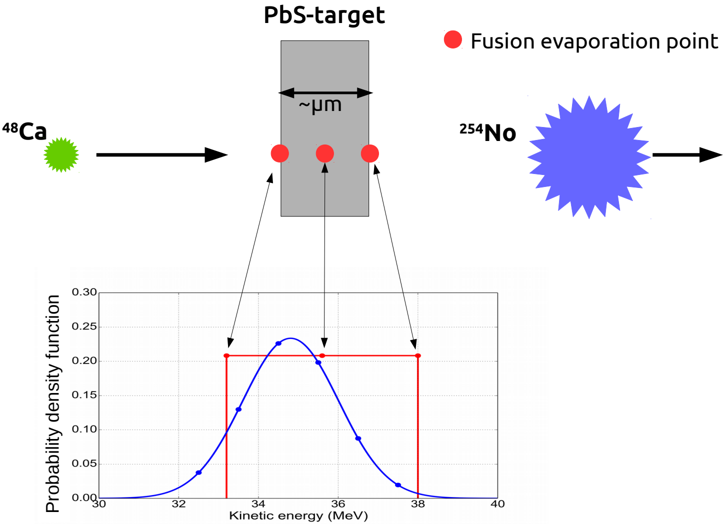


Ref. O. Kaleja, Master thesis (2016)

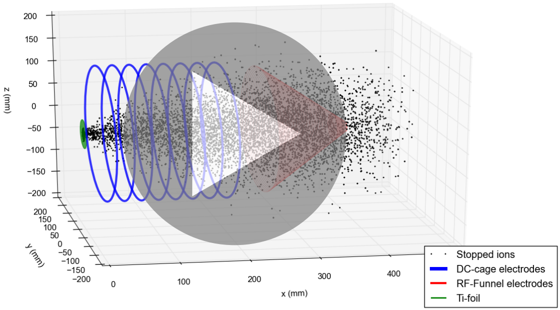
Kinetic energy distribution



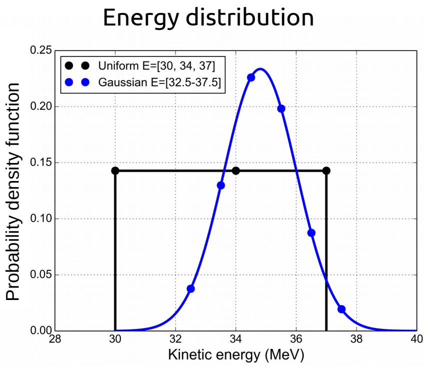
Kinetic energy distribution



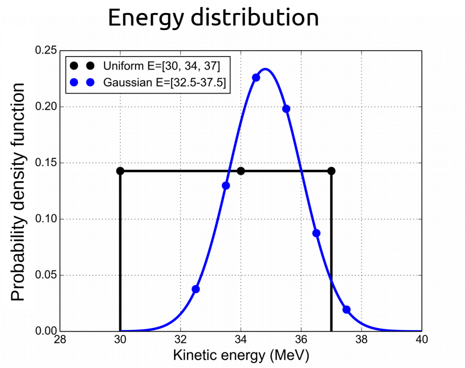
Simulation results

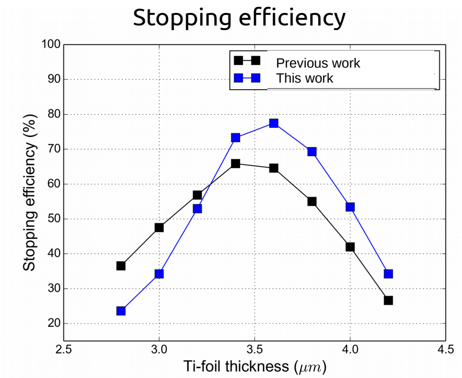


Kinetic energy distribution



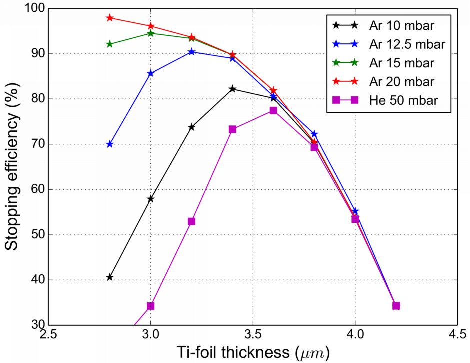
Kinetic energy distribution





- Peak is shifted towards a larger thickness
- Higher stopping efficiency

Argon stopping efficiency

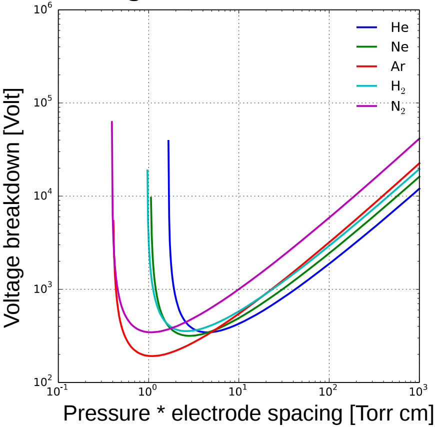


- 90 % stopping efficiency of 12.5 mbar Ar at 3.2 µm thickness

Further properties of Ar

- RF-Funnel performance
  - Focusing
- Voltage breakdown
  - Discharges

Figure: Paschen-curves



Funnel performance

- The focusing force $\boldsymbol{F_{RF}}$ depends on the ion mobility $\boldsymbol{\mu}$ and the RF-voltage $\boldsymbol{V_{RF}}$:

$$F_{RF} \propto \mu^2 V_{RF}^2$$

Ref. M. Wada, Nucl. Inst. Meth. B 204 (2003) 570–581

Table: Mobility of ^{254}No with 50 mbar He and 12.5 mbar Ar at T=300 K

Gas	$\boldsymbol{\mu}$ (cm^2/Vs)
Helium	0.033
Argon	0.016

Ref. M. Laatiaoui, PhD-thesis (2009) & H.W. Ellis et. al., Atomic data and Nuclear data tables (1976)

Funnel performance

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$$F_{RF} \propto \mu^2 V_{RF}^2$$

- For equal force with He & Ar:

$$\frac{V_{RF}(Ar)}{V_{RF}(He)} = \frac{\mu(He)}{\mu(Ar)} \approx 2$$

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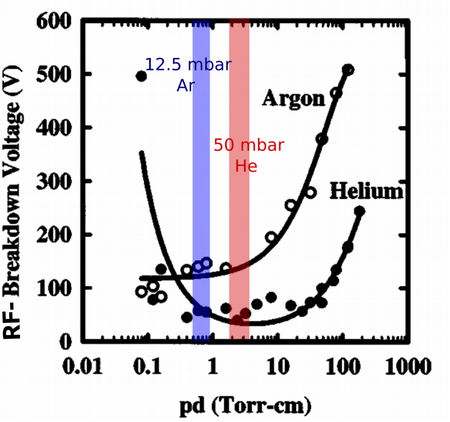
➡ Twice the RF-voltage is needed with Ar

Voltage breakdown

- RF-voltage breakdown: Ar vs. He in the CryoCell



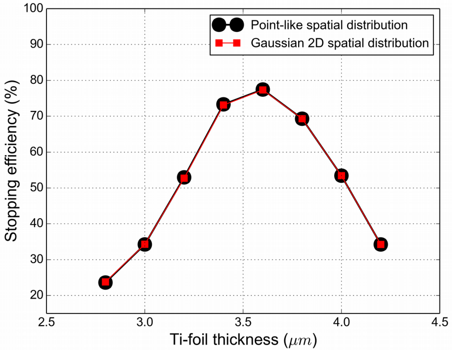
→ Twice the voltage possible with Ar

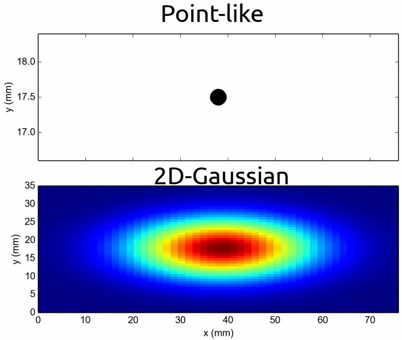
Ref. M. Moravej et. al. J. Appl. Phys., Vol. 96, No. 12, (2004)

Can Ar improve the efficiency?

- Stopping efficiency: 77 % → 90 %
- A similar RF-Funnel focusing force can be accomplished
- Ambiguities:
  - Charge state distribution
  - Real extraction efficiency

Spatial distribution

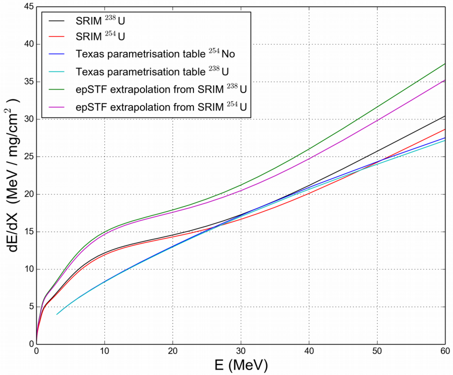




- Negligible effect
- Beam size too small compared to CryoCell dimensions

Choice of ion in SRIM

Figure: Stopping power of ^{254}No in Ti



- SRIM exaggerates stopping power
- Extrapolation models are congruent with ^{238}U