Commissioning and first efficiency measurements of the cryogenic gas stopping Cell at SHIPTRAP

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Motivation

Direct mass measurements are an important tool to

• to obtain absolute nuclear binding energies

\[ M(Z,N) = ZM_p + NM_n - B(N,Z) \]

• to gain informations about the nuclear shell structure

• to benchmark nuclear models

• to obtain anchor points to fix alpha-decay chains
Motivation

Up to now the masses of $^{252-255}$No$^1$ and $^{255-256}$Lr$^2$ were directly measured at the Penning-trap mass spectrometer SHIPTRAP.

$^{256}$Lr: reaction cross section = 60nb

Mass determination with 50 ions took 4 days

Measurement of superheavy elements envisaged

(next $^{257}$Rf = 15nb)

SHIPTRAP Experimental Setup

Reaction products from SHIP

\[ \approx 50 \text{MeV} \]

GasCell Extr. RFQ Buncher

\[ \approx \text{eV} \]

Overall efficiency approximately \( \approx 2\% \)

Bottleneck: gas stopping cell (stopping + extraction efficiency \( \approx 10\%)^{[1]} \)
(stopping efficiency \( \approx 40\% \))

Setup of a second generation gas stopping cell with a higher efficiency

Advantages compared to 1st generation gas cell:

- Larger stopping volume
- Coaxial injection of reaction products
- Higher cleanliness
- Larger gas density at a smaller absolute pressure

Efficiency Boost from 10% to 35%[1]

Inner and outer chamber

Inner chamber:  
- copper plated with a 2mm layer  
  - cooled with 20K single-stage cryo cooler (100W at 77K)  
  - fixed with 12 stainless steel rods of 1.6mm thickness to outer chamber  
  - wrapped in multilayer insulation foil
RF-Funnel

- 76 ring electrodes
- Diameter: from 266mm down to 5mm
- Total capacity of 2.6nF
- 1mm distance between electrodes (0.5mm at last 20 segments)

RF with 180° phase shift between neighboring electrodes superimposed with DC gradient

Tested in UHV and 50mbar He at 300K and 45K:

\[ f_{res} = 1017 \text{kHz} \]
\[ U_{out,pp} = 320 \text{V} \]
DC-Cage and Entrance Window

- 8 ring segments with a DC gradient of >10V/cm
- Diameter of 260mm
- Extraction Time ≈ ms

- beam diameter behind SHIP of 60mm
- electrical insulated
  -> increase homogenity of DC potential
- currently 3µm Ti foil + gold sealing
- 90% energy loss of reaction products
Efficiency measurement setup

**Test chamber**
- determine initial activity via determination of number of $^{223}\text{Ra}$ decays

**CryoCell**
- Same foil-/detector-arrangement installed (same DAQ electronics)
- Extraction RFQ installed
- placed $^{223}\text{Ra}$ source inside the inner chamber
- determine number of $^{219}\text{Rn}$ decays
Offline efficiency determination

Efficiency determination

- count number of $^{223}\text{Ra}$ decays and take the ratio between the spherical angle and detector surface into account
- take half-life of the $^{223}\text{Ra}$ into account (11.43 days)
- count number of $^{219}\text{Rn}$ decays behind CryoCell and take the ratio between foil surface and detector surface into account

Preliminary efficiency: 75%
Summary and Outlook

- Cryogenic gas stopping cell will lead the way to mass measurements of SHE
- All major parts tested separately -> working
- First extraction tests successfully performed, preliminary efficiency = 75%
- Further offline tests with $^{223}\text{Ra}$ will be performed
- Final efficiency needs to be determined in an online experiment -> Ready for beamtime!!!
Thank you for your attention

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