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Probing Ions from deeply embedded plasmas: Energy Distribution Analysis and Comparison of Ion Transfer Units

Financial support within the 14AMI project funded by the BMBF (16MEE0370) and the EU-CHIPS JU (101111948) is gratefully acknowledged.

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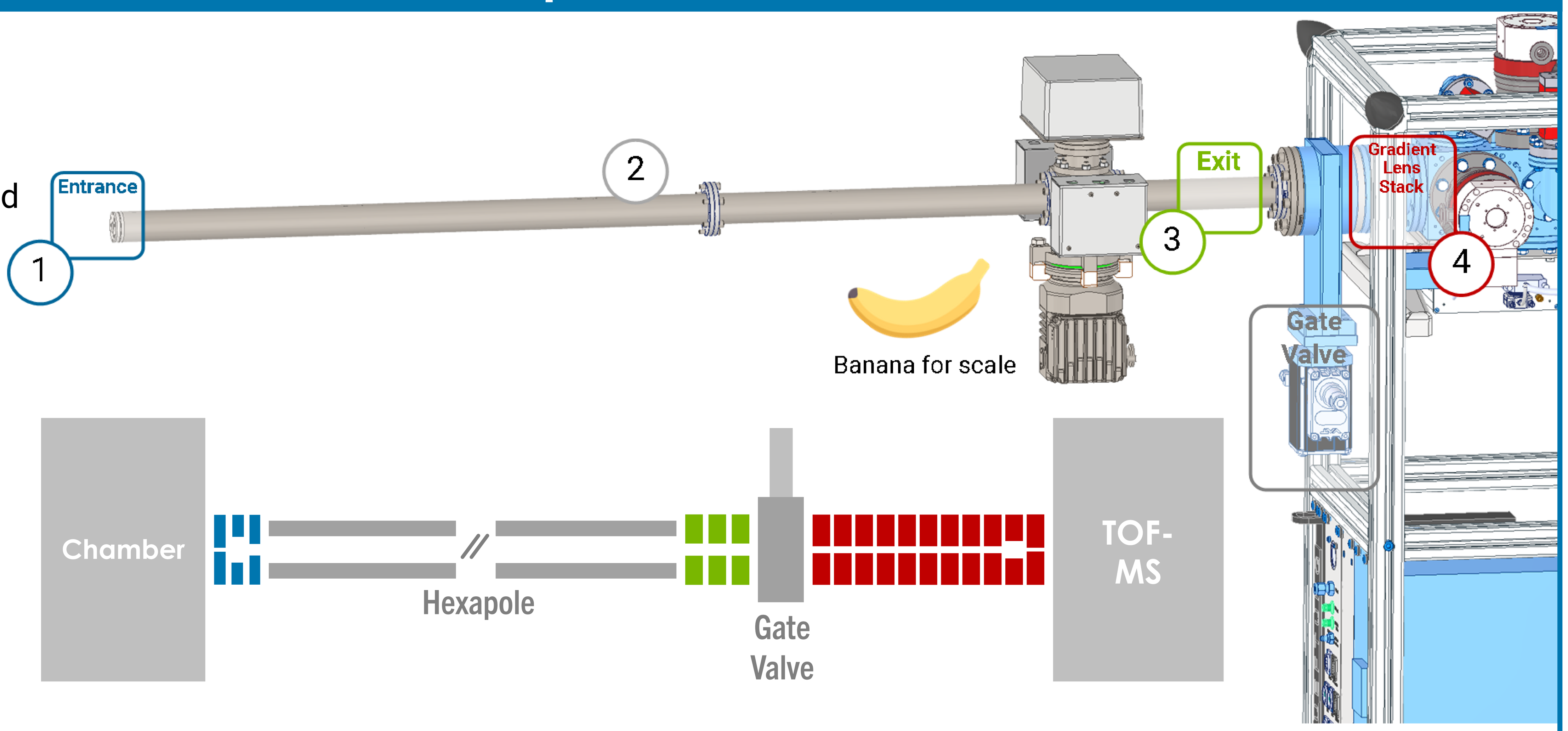
Introduction and Setup

An ion optical transfer system is necessary to efficiently sample "distant" ions.

In this work, **a distance of 170 cm** between a plasma chamber and a high-resolution time-of-flight mass spectrometer (TOF-MS) is bridged.

The main flight distance is overcome by employing a segmented **hexapole**, which is equipped with fitting upstream apertures (**entrance**) and downstream ion optics (**exit**), to facilitate ion transport through a mandatory gate valve into the TOF-MS (**Gradient Lens Stack**).

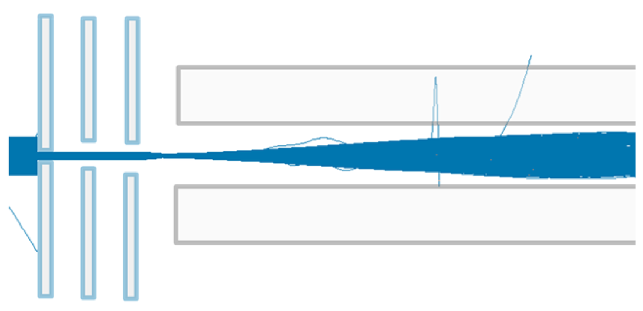
This setup aims to transfer plasma generated ("native") ions over large distances with minimal mass discrimination and ion loss.



Entrance

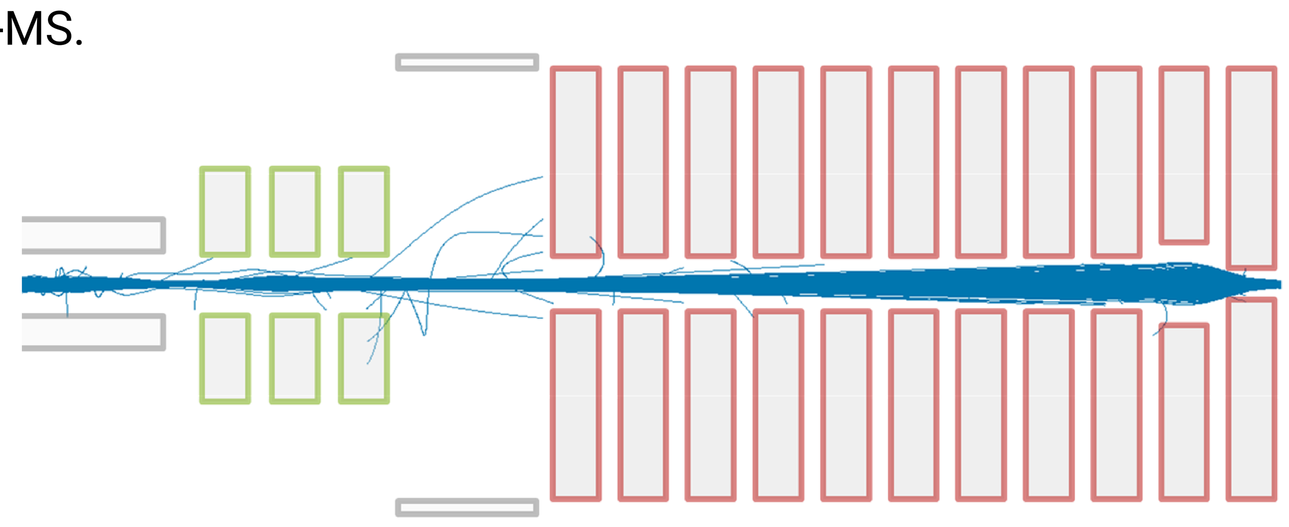
An **Einzel lens** consisting of three eletrodes to

1. **focus and guide** Ions into the hexapolar field and
2. **restrict gas flow** through first electrode to reduce pressure inside the hexapole.



Gradient Lens Stack

A Gradient Lens Stack with integrated **Einzel lens** collecting ions downstream of the gate valve.
Reduction of kinetic energy of the ions and focusing of the ion beam into the TOF-MS.

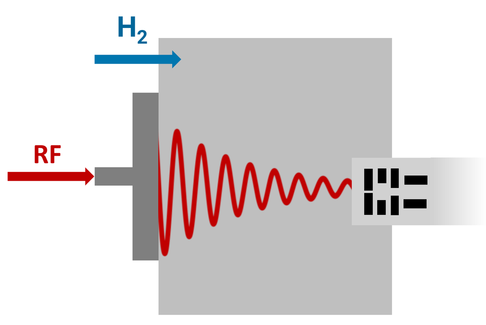


The entire transfer stage was simulated with the SIMION program package.[1]

[1] D. A. Dahl, Int. J. Mass Spectrom., vol. 200, no. 3., pp. 3–25, 2000.

Experimental Results of Kinetic Energy Scan

Methods



· RF power applied to **electrode** in **vacuum chamber.**

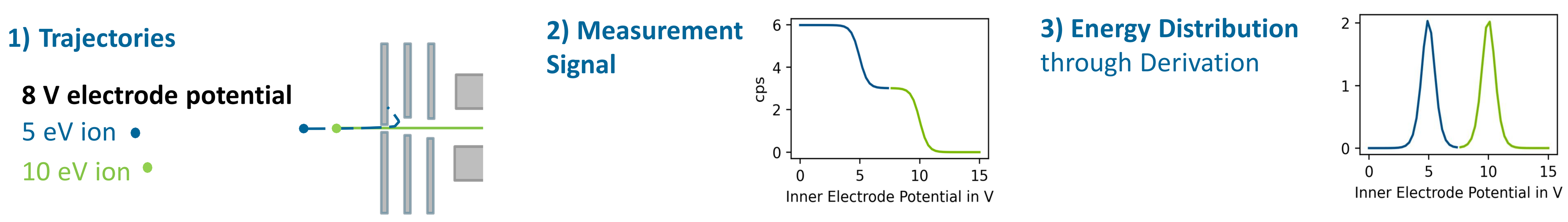
· **Alternating electric field** ionizes gas in chamber:

- · Collisions between electrons and gas atoms/molecules.
- · Plasma formed with free electrons, ions, and neutral particles.
- · Oscillating electric field sustains plasma by accelerating electrons for further ionization.

The position of the Transfer can be varied with an adjustable bellow.

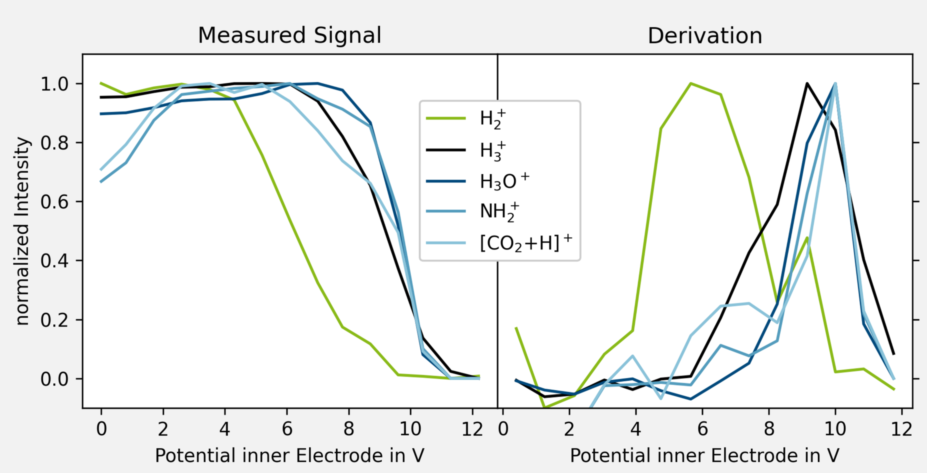
This setup allows for numerous types of analyses of different plasmas. An example is shown here, where we used the Einzel lens as an **RFEA** to perform an **energy scan** of the plasma to determine the energy distribution of the plasma ions.

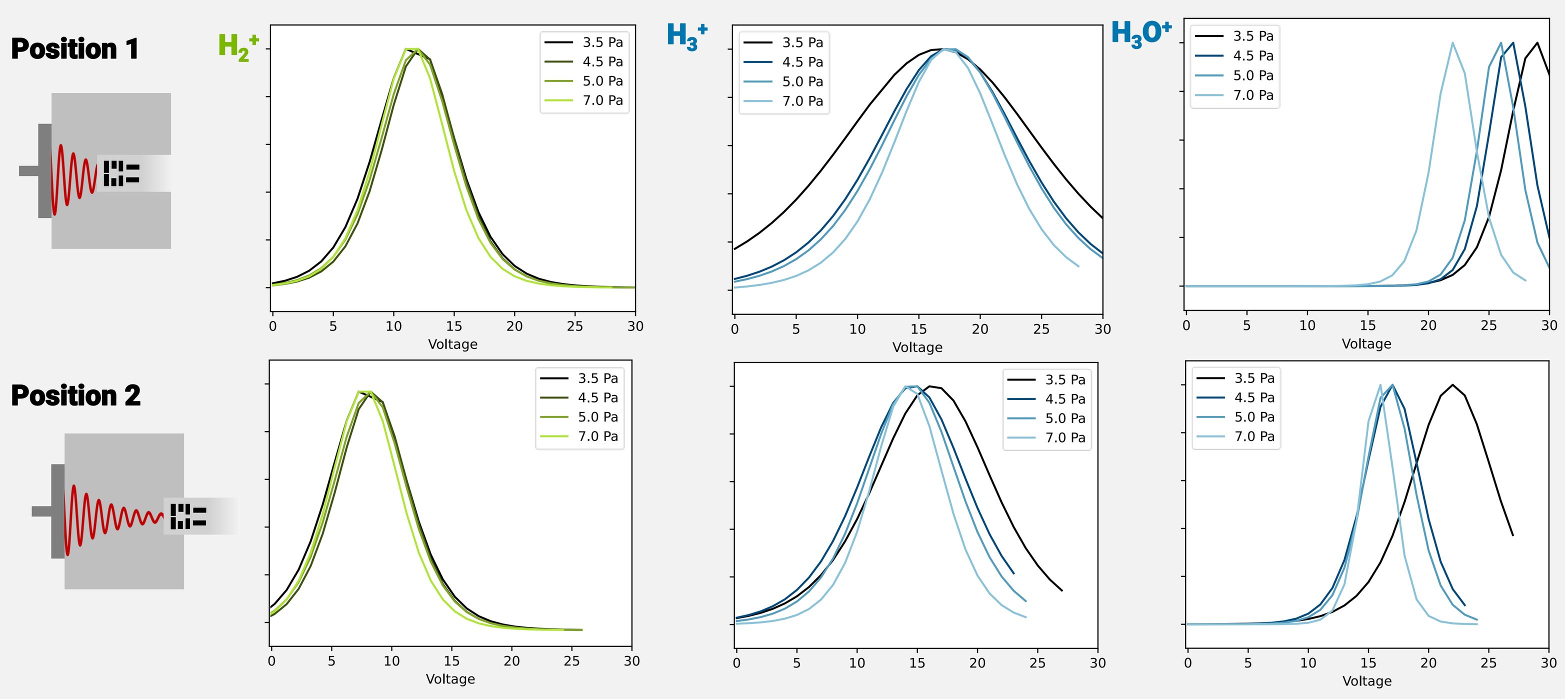
In this experiment, the potential of the inner electrode is gradually increased to positive values. Once the potential exceeds the kinetic energy of the plasma ions, the ions cannot overcome the potential energy barrier, causing the count rate (cps) to decrease. Ions with higher kinetic energy can still pass the Einzel lens and enter the hexapole.



The experimental results show, that the energy distribution depends on

1. the **formation mechanism** of the species (**primary** or **secondary** ionization product),
2. the **pressure** in the chamber and
3. the **position** within the plasma.





Comparison of Gradient Lens Stack with commercially available Units

The GLS is a **custom** transfer unit designed for **easy assembly in standard laboratory environments**. Unlike **commercially available** lens stacks (such as the one shown on the right), the GLS features a uniform electrode stack with resistors creating a gradually decreasing electric field. It operates with a total of **only four power supplies**: two power supplies for the first and last electrodes of the uniform stack, while an additional Einzel lens, controlled by two more power supplies, focuses the ions. Different commercially available units are currently being compared, and the results will be presented at this year's ASMS 2025 in Baltimore.