

Status of the FRIENDS³ project

FRIENDS³: Fast radioactive ion extraction and neutralization device for S³

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IJCLab, Orsay, France

March 21, 2023

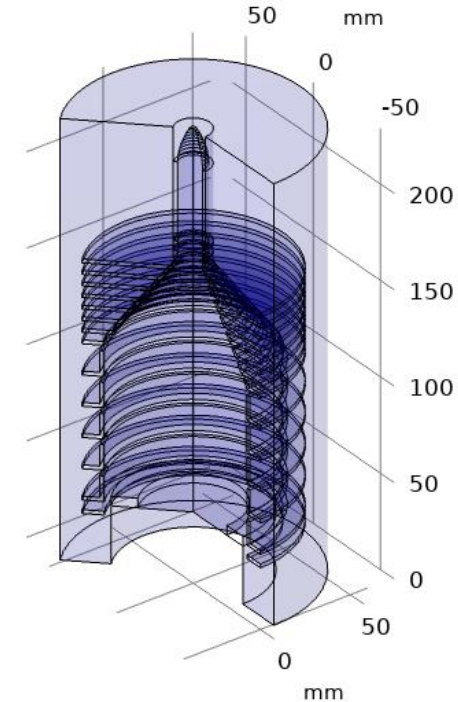


ANR-21-CE31-0001

- Project summary

- Progress update
 - Preliminary simulation study
 - Test-bench study

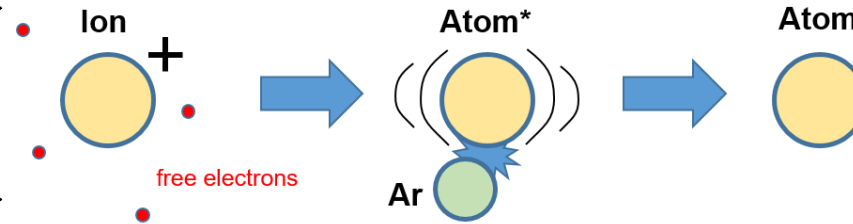
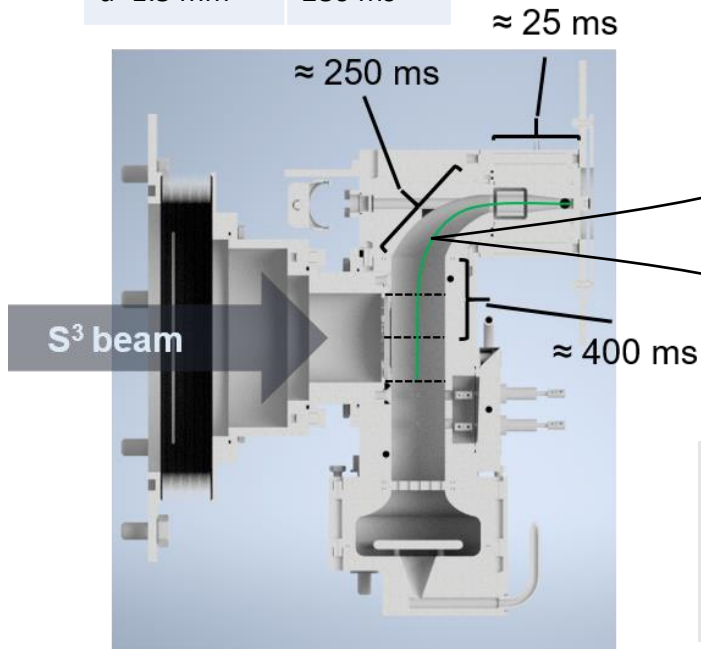
- Outlook



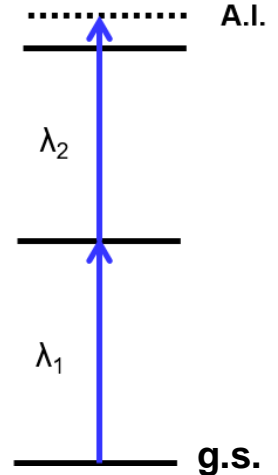
E. Mogilevskiy *et al.* (KU Leuven)

Nozzle	Wide
d=1 mm	630 ms
d=1.5 mm	280 ms

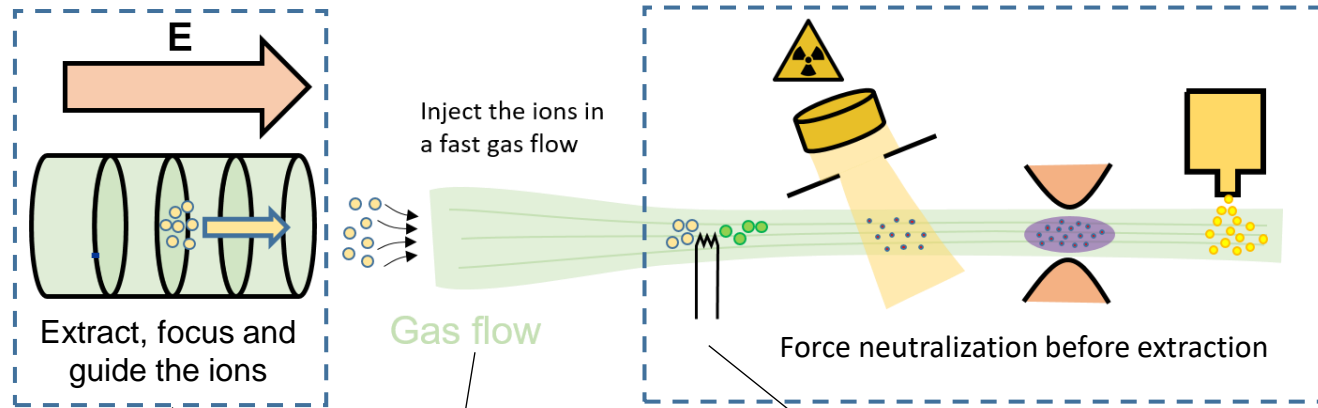
- Key roles of the S³-LEB gas cell:
 - Stop the S³ beam as efficiently as possible
 - Neutralize it by 3-body and dissociative recombination
 - Extract it as quickly as possible



- Objectives of FRIENDS³ project:
 - Reduce extraction time
 - Improve neutralization efficiency
 - Ideally both at the same time

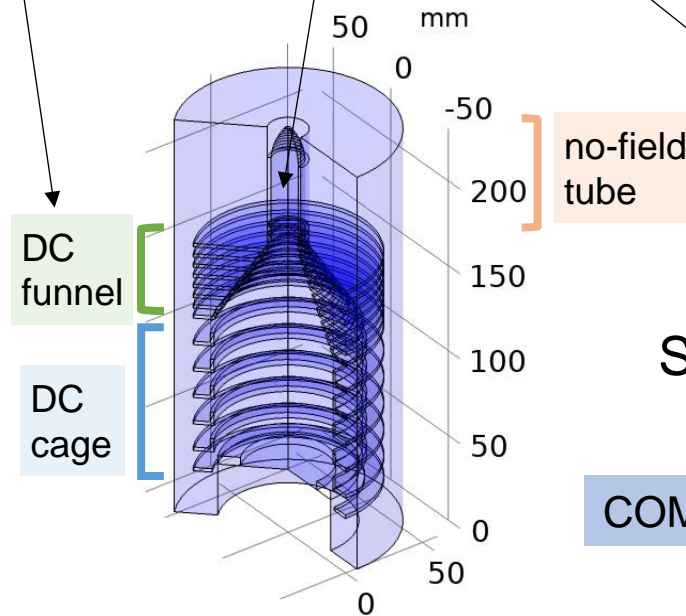


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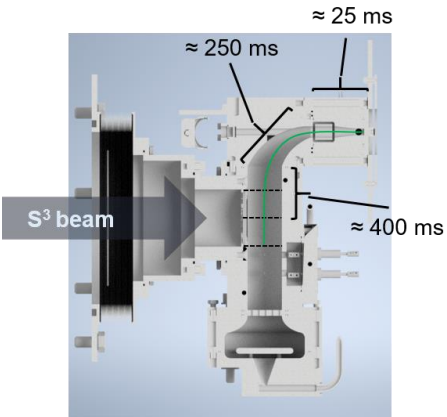
S. Raeder et al., NIM B 463, 272-276 (2020)

JETRIS collaboration



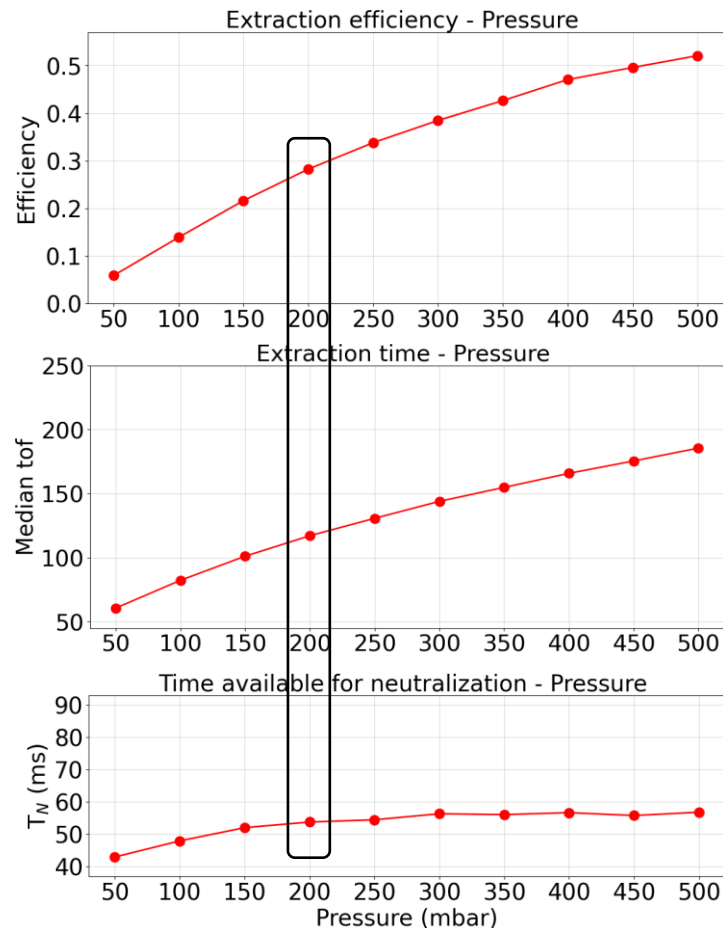
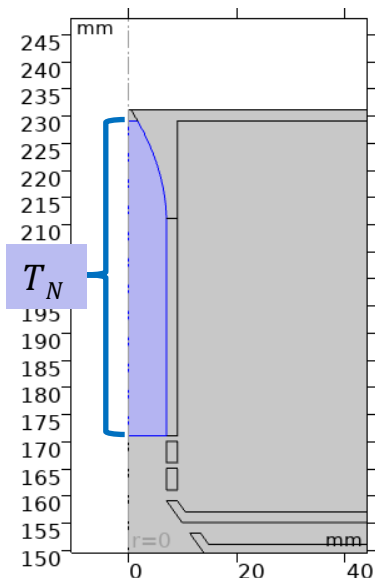
Simulations + experimental tests

COMSOL + SIMION



- ...
- G. Savard et al., NIM B 204, 582-586 (2003)
- S. Schwarz et al., NIM B 204, 507-511 (2003)
- J. B. Neumayr et al., Rev. Sci. Instrum. 77, 065109 (2006)
- J. B. Neumayr et al., NIM B 244, 489-500 (2006)
- C. Droese et al., NIM B 338, 126-138 (2014)
- M. Ranjan et al., NIM B 770, 87-97 (2015)
- ...

- Main performance criteria:
- extraction efficiency
 - extraction time
 - time available for neutralization

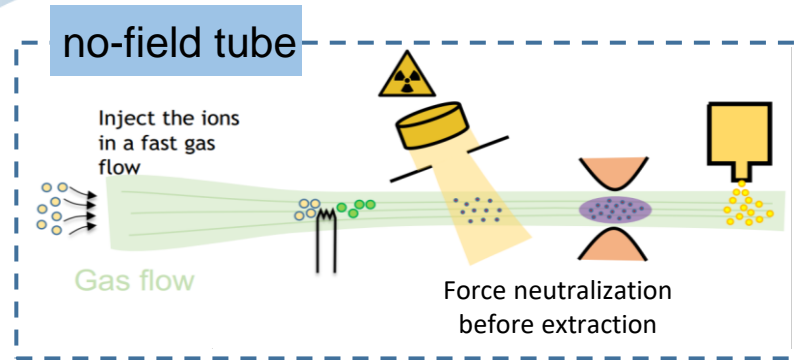


200 mbar

~ 30%

~ 120 ms

~ 55 ms



COMSOL Plasma module

Method:

Specify species and reactions in the neutralization tube



Generate the electron by a certain process



Calculate the electron distribution and density in the tube



Trace the ions through the electron clouds, calculate the neutralization efficiency

Ar, e⁻, Ar⁺, Ar_{excited}

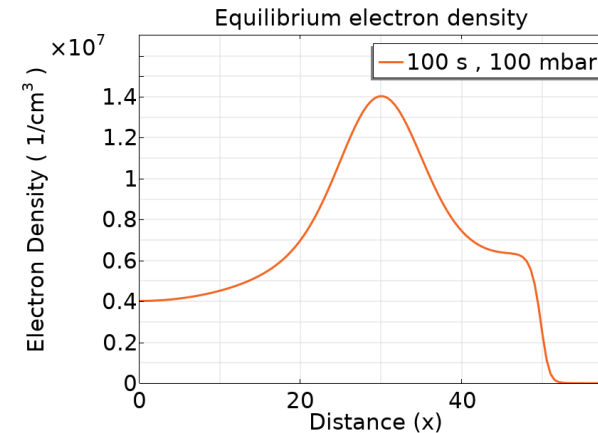
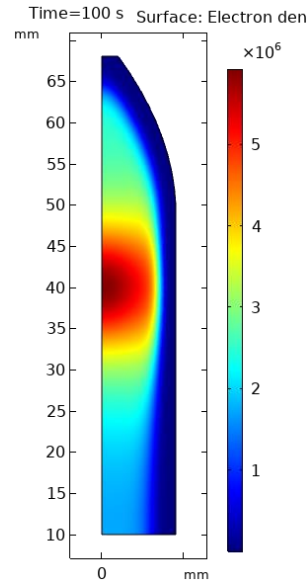
Input a production rate

Convection, migration...

Step 1:

Only consider ionization and recombination processes in the gas: $\text{Ar} \rightleftharpoons \text{Ar}^+ + e^-$.
 Estimation without any dynamics of the gas, ions and electrons.

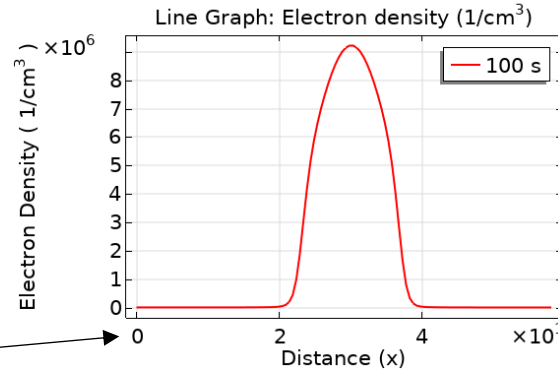
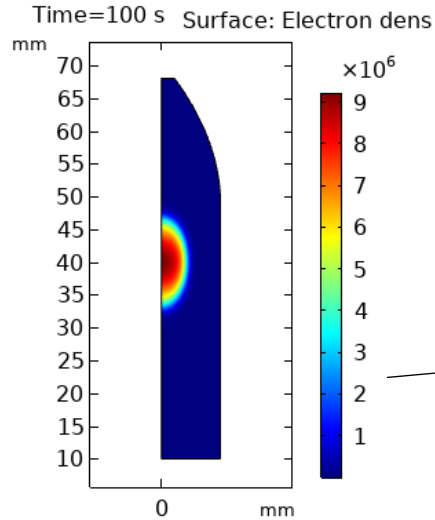
	Maximum equilibrium electron density ($1/\text{cm}^3$)
Python	2.0×10^7
COMSOL	1.4×10^7



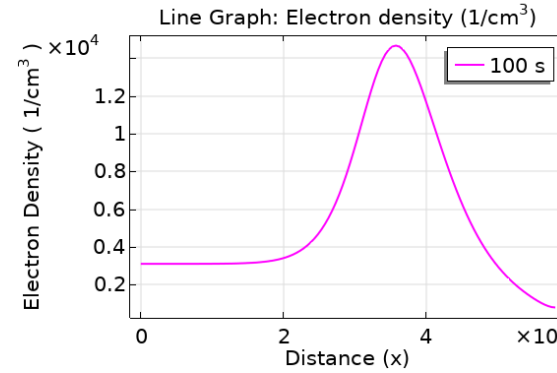
Source activity 40 MBq, gas pressure 100 mbar

More realistic simulation: consider all the species and electron impact reactions,

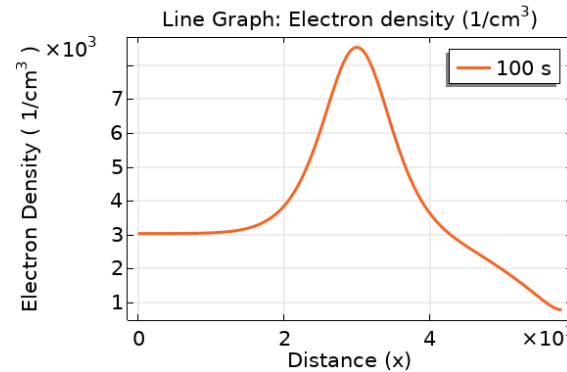
 consider convection due to gas flow and charge migration in electric field.



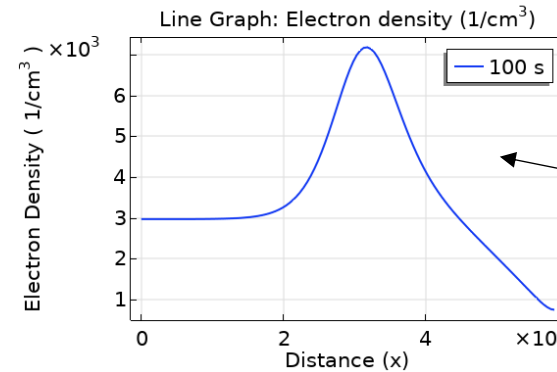
without any setting



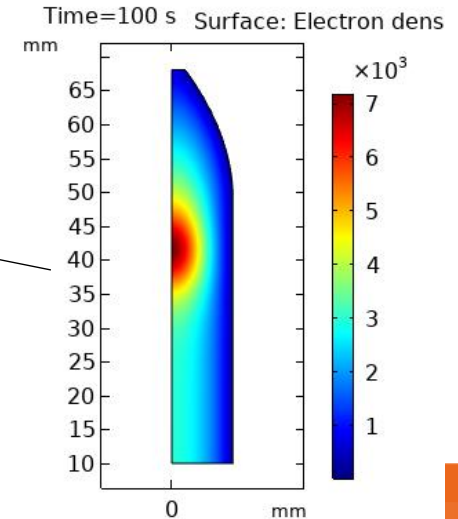
+ convection



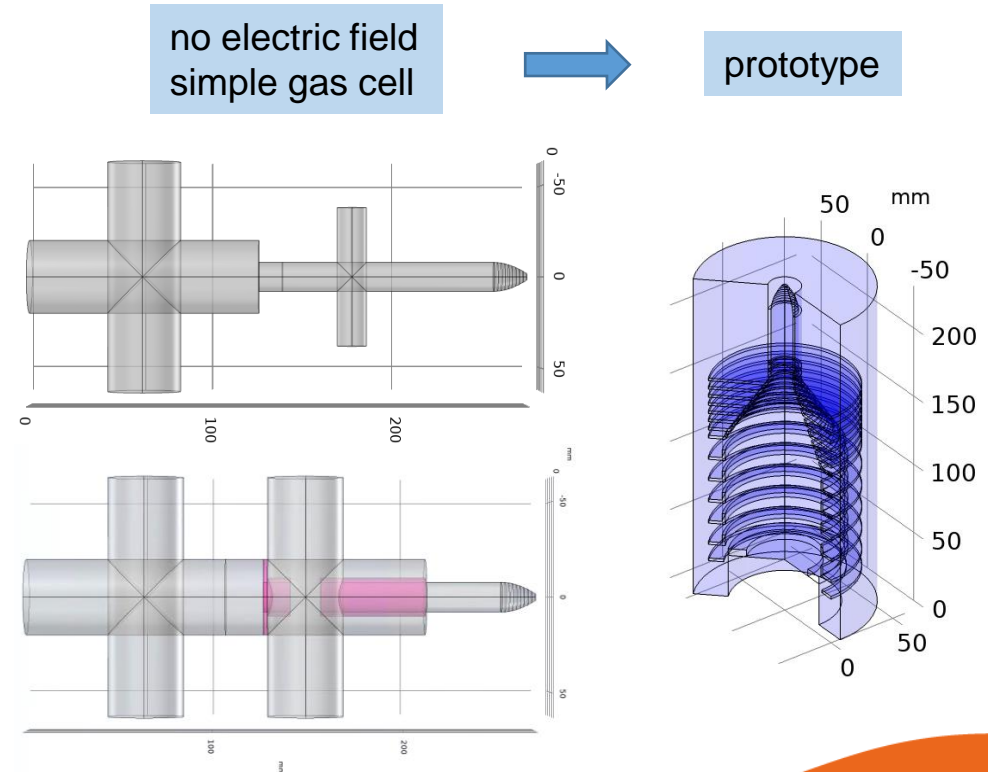
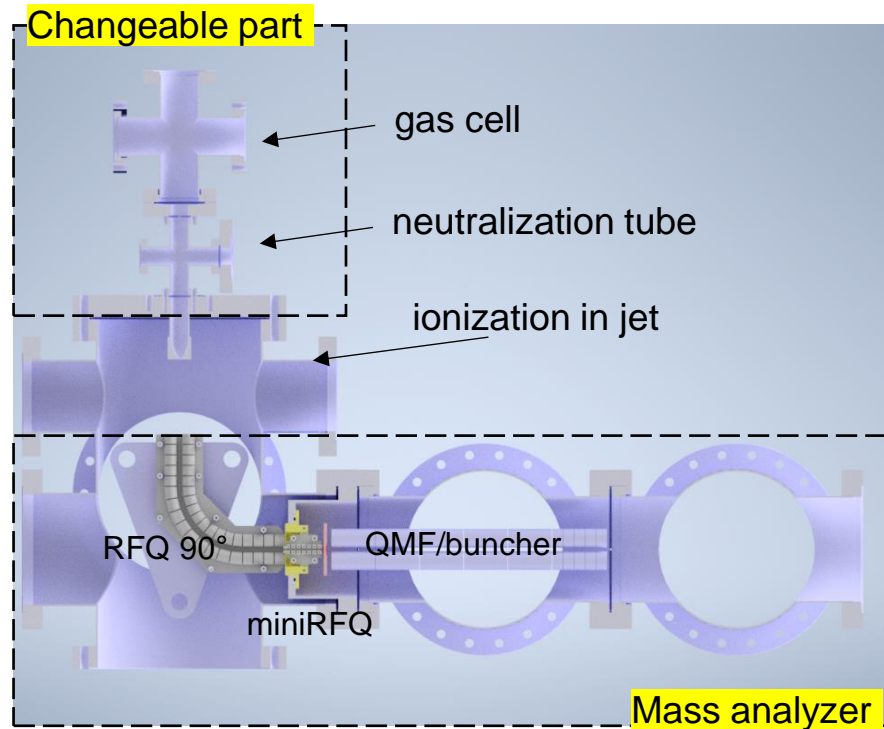
+ migration in electric field



+ convection and migration

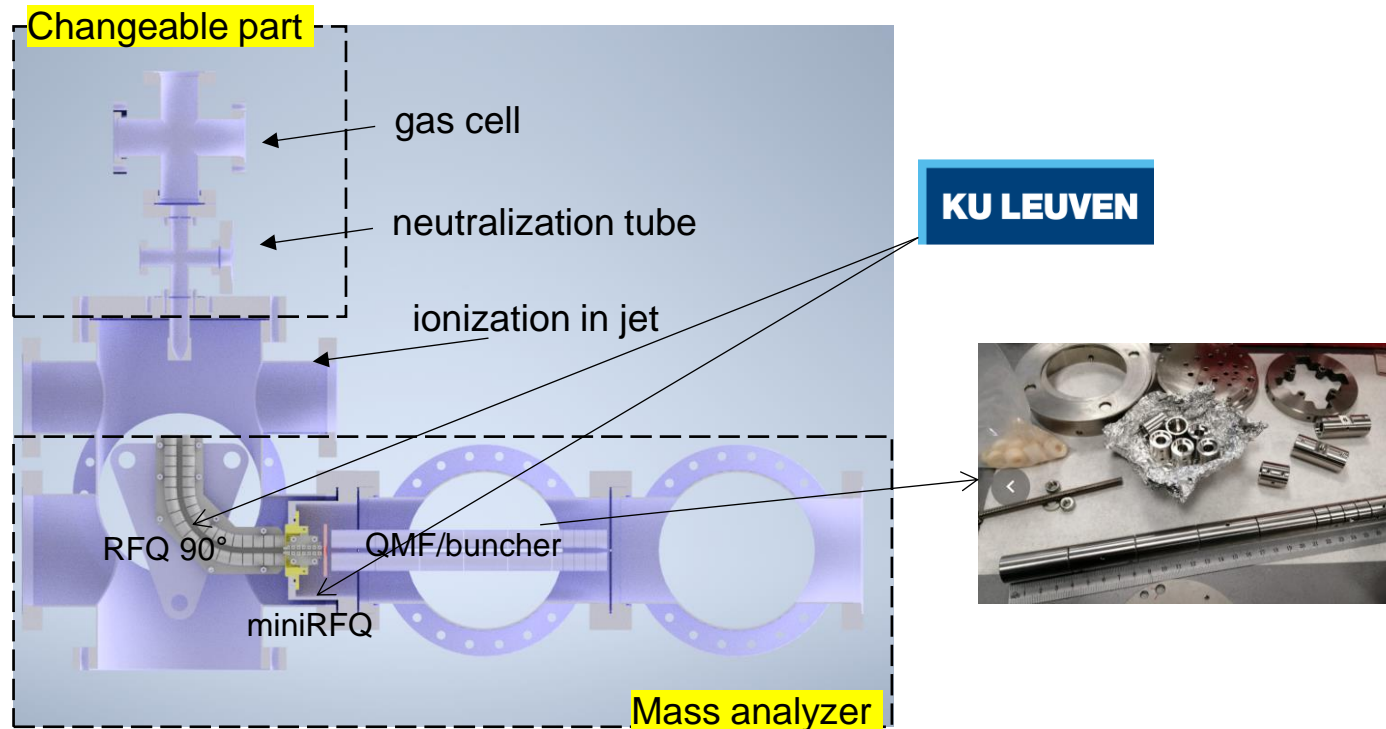


- Requirements:
 - Study ion extraction times and neutralization efficiencies
 - Perform in-jet laser spectroscopy
 - Mass filtering and identification

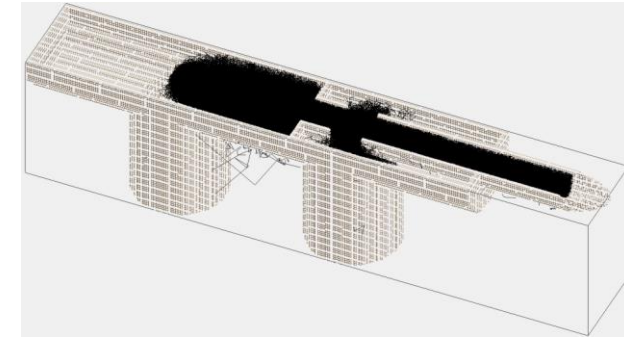
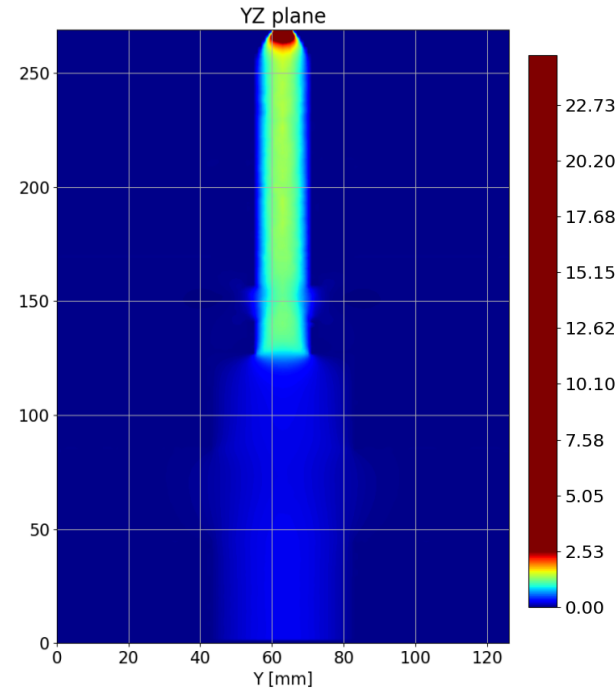
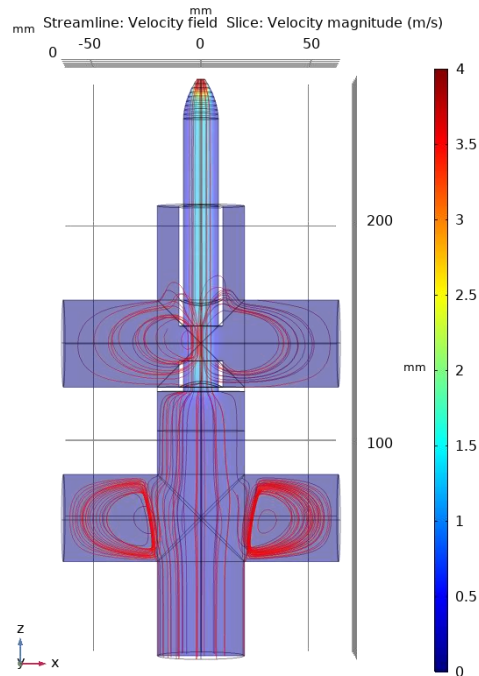


➤ Requirements:

- Study ion extraction times and neutralization efficiencies
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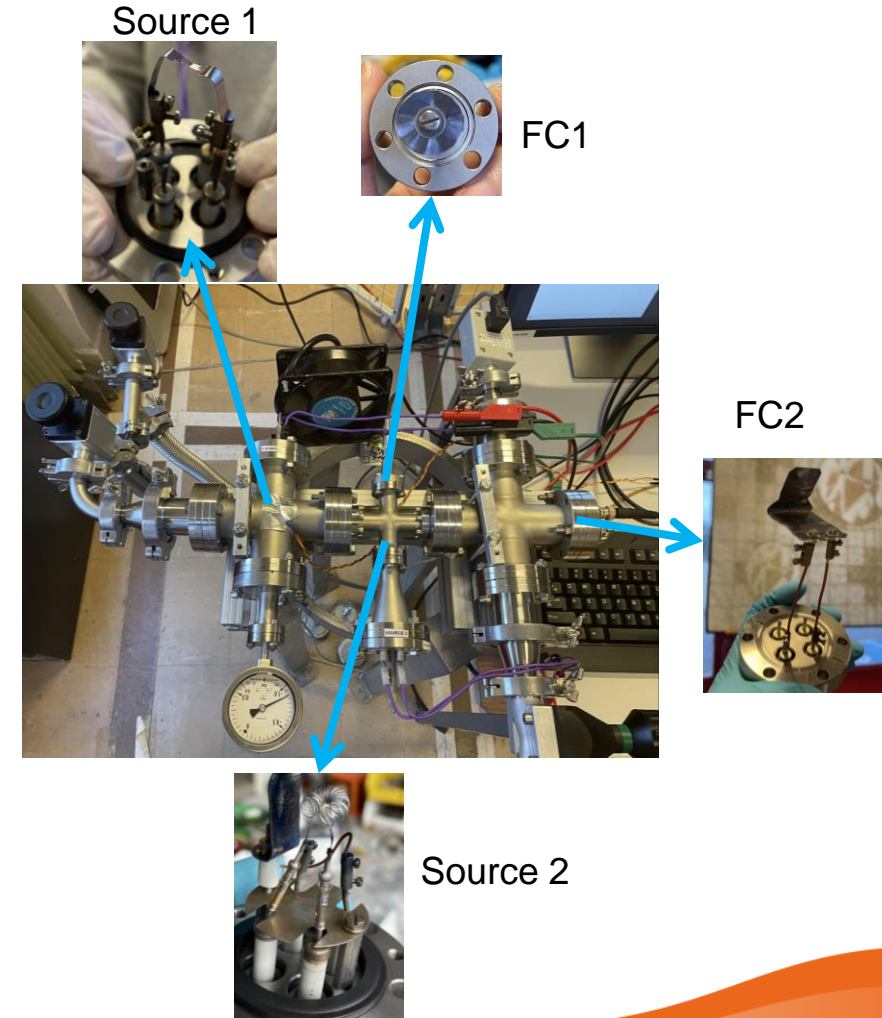
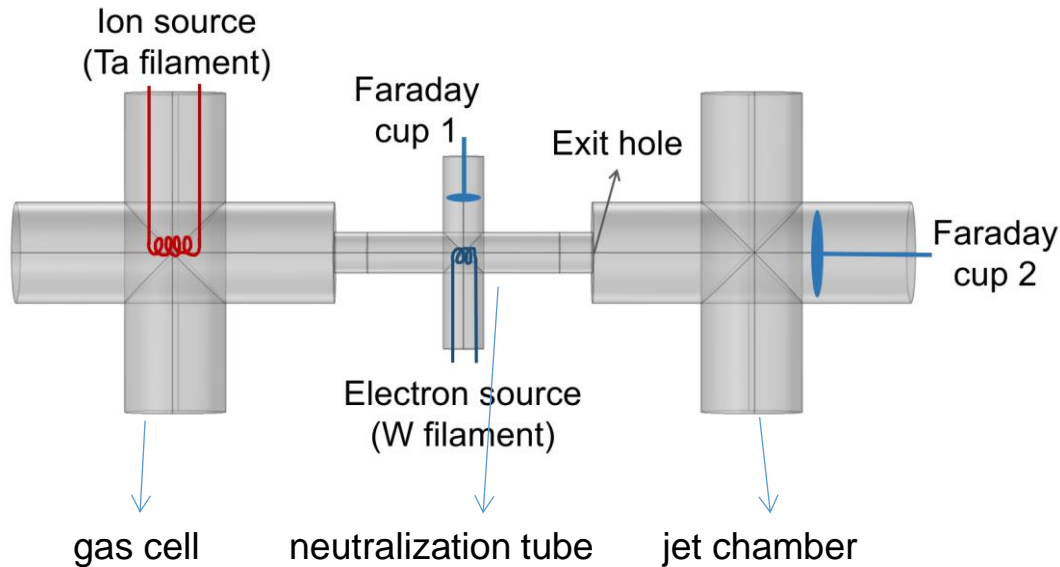
- CF40 cross as gas cell
- CF16 tube for neutralization or custom CF40 cross with inner tube



@ 100 mbar:
 ≈ 25% efficiency
 ≈ 450 ms extraction time
 ≈ 140 ms in narrow tube
 @ 200 mbar:
 twice the efficiency

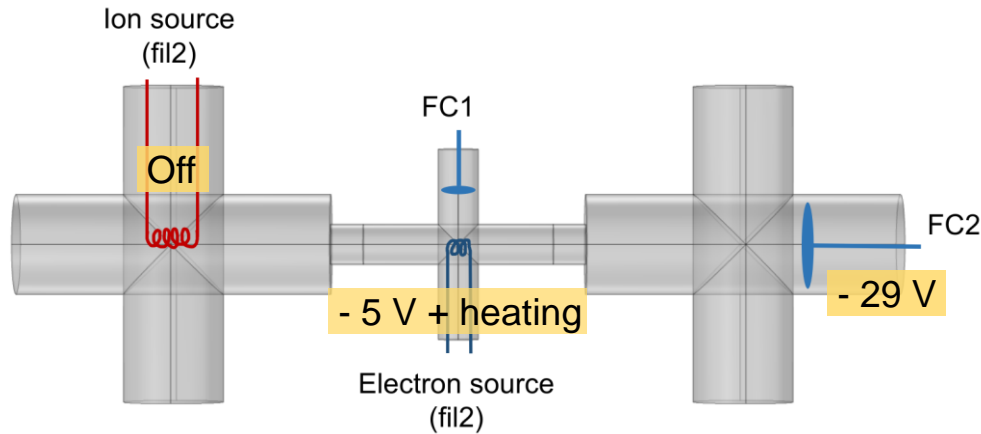
Our first test bench:

- study electron emission mechanisms in the neutralization tube.
- study the ion transport with the gas flow.

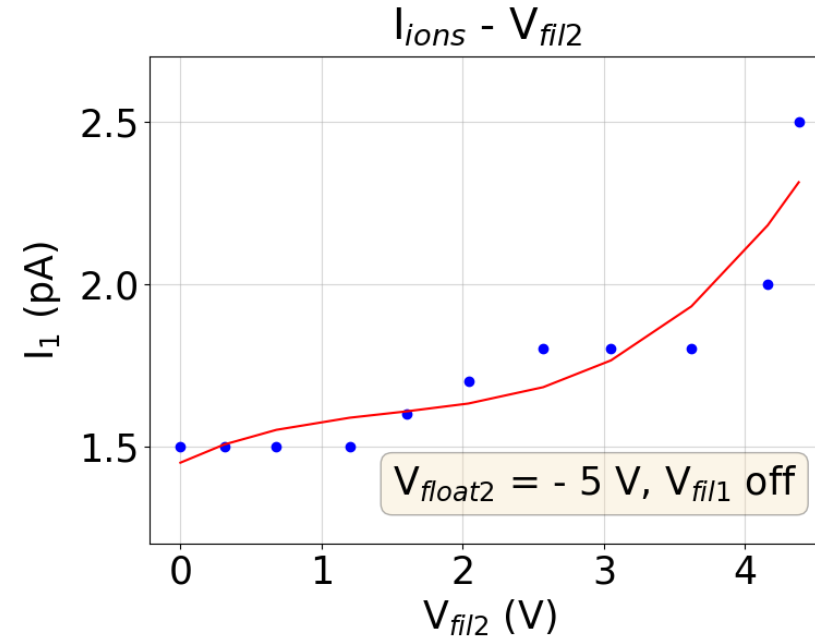


All measurements need to be corrected for two effects:

- fil2 also produces W^+ ions.
- fil2 attracts Cs^+ because of the heating voltage.

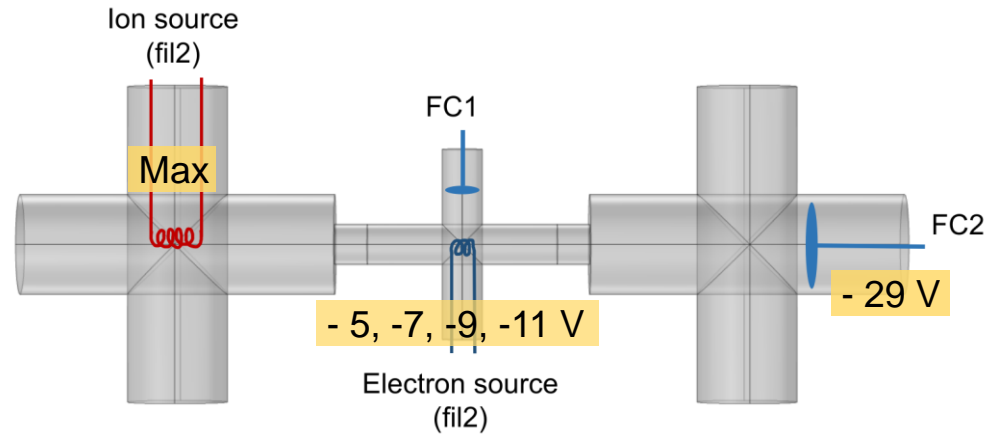


Measurement 1: Ions escaping from the electron source.

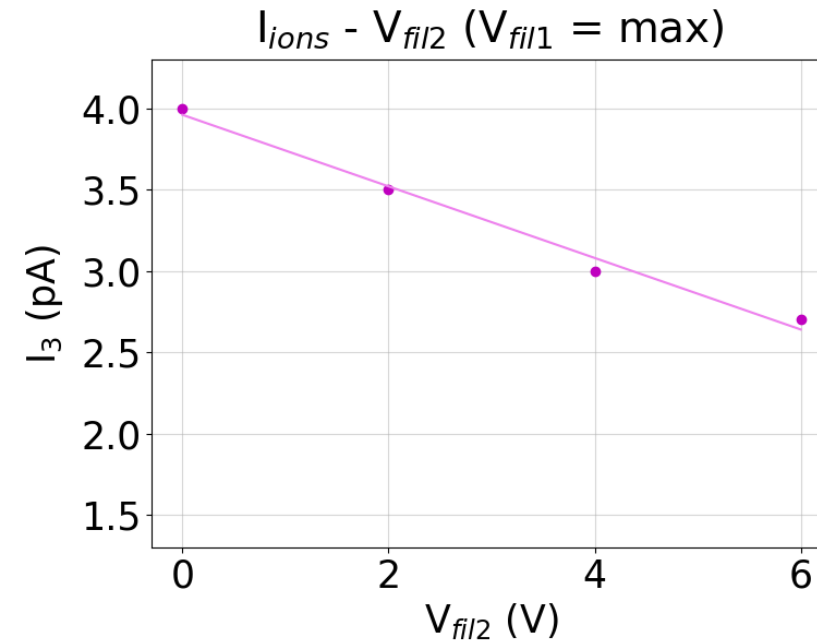


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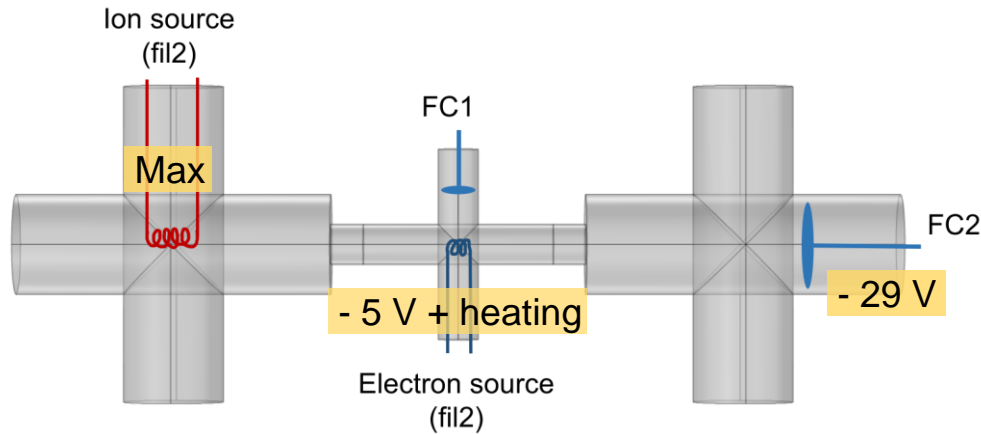


Measurement 2: lost of ions from fil1 due to pure attraction without heating of fil2.

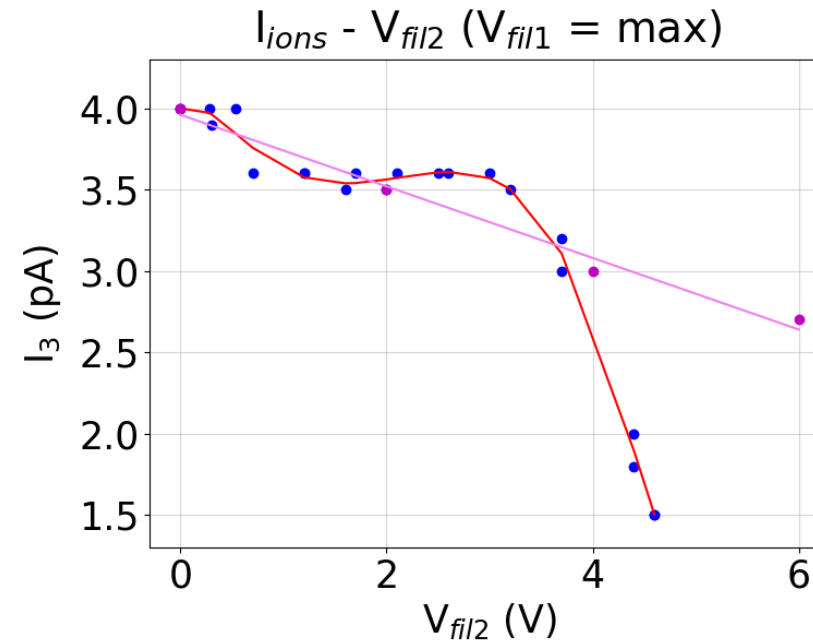


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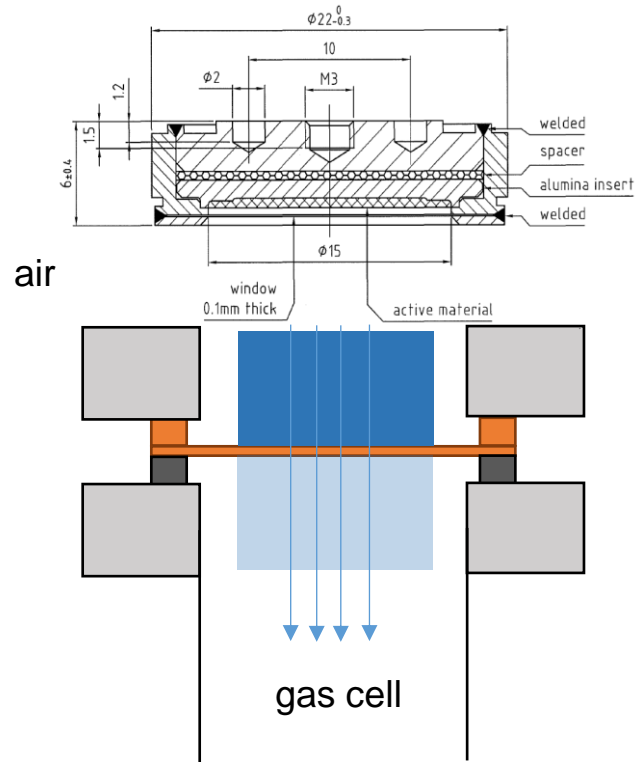
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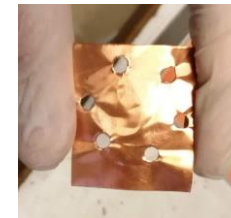
Measurement 3: lost of ions from fil1 due to heating of fil2.



- Beta source test preparation



- Window with 100 μm Cu foil, hand cut
- Perfectly leak tight
- Estimated beta transmission 35%



- simulation of the neutralization efficiency
- Vacuum system

Three pumps arrived at IJCLab, we are planning to move the setup to GANIL at the end of 2023.

Thank you for your attention !

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