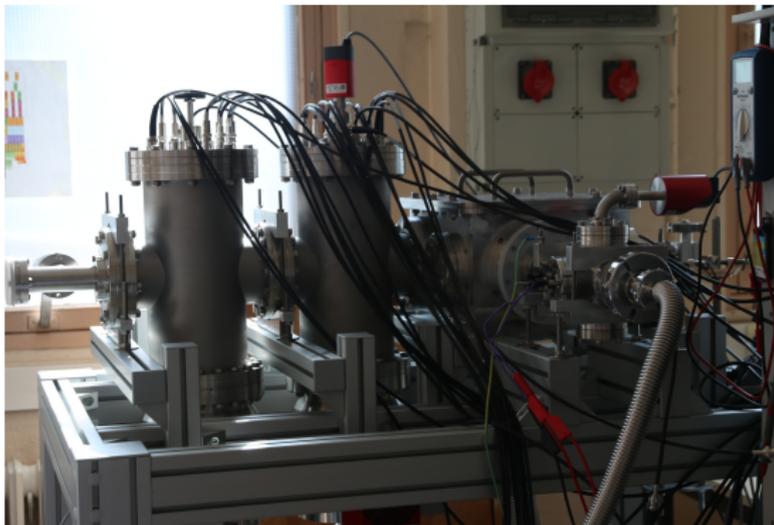


News from the FRIENDS³ project

Elodie Morin

IJCLab, Orsay France

April 4th, 2025





- 1 Design and simulation results
- 2 Test bench construction and experimental tests



- 1 Design and simulation results
- 2 Test bench construction and experimental tests

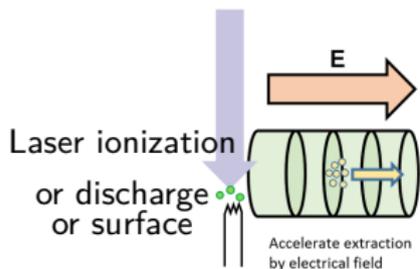


FRIENDS³ test bench

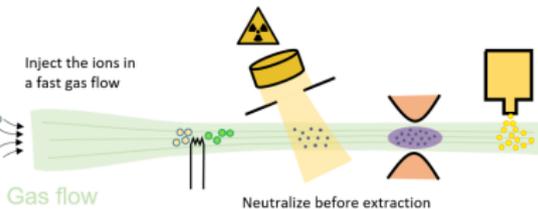
Fast Radioactive Ion Extraction and Neutralization Device for S³

- Improvement on neutralization efficiency
- Improvement on extraction time

Ion production



Neutralization



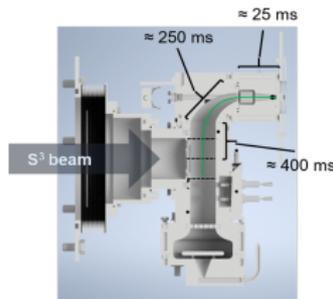
Laser re-ionization



Current gas cell extraction time : 600 ms

Our tools :

- Simulations (COMSOL and SIMION)
- Measurements with offline experimental setup

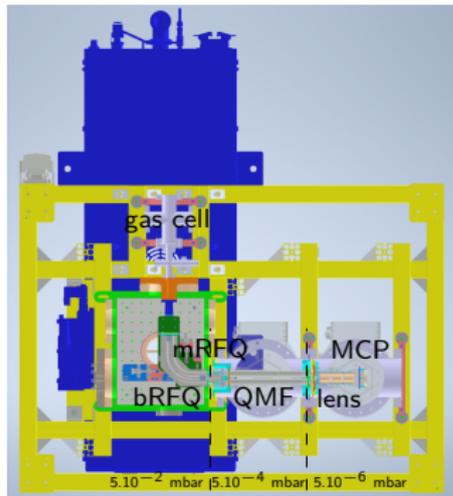
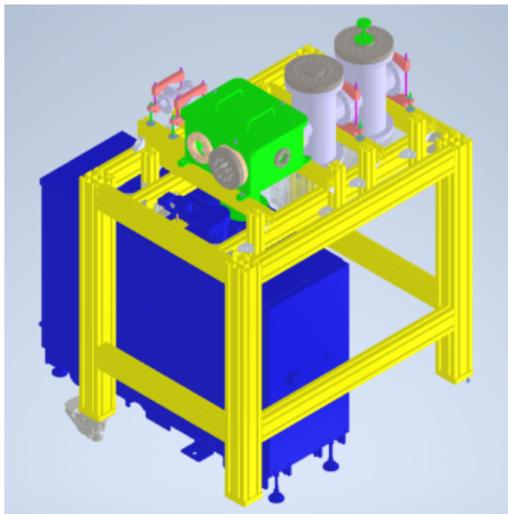




FRIENDS³ test bench

Fast Radioactive Ion Extraction and Neutralization Device for S³

- Improvement on neutralization efficiency
- Improvement on extraction time



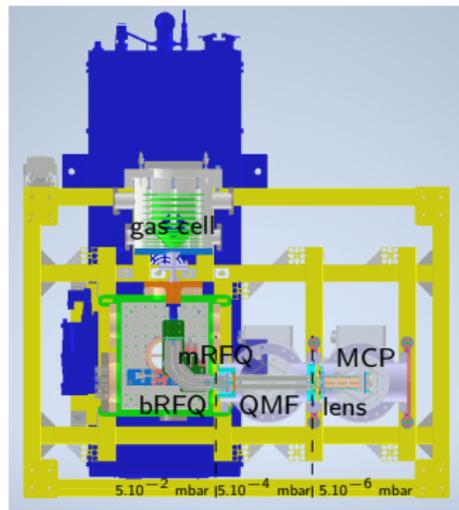
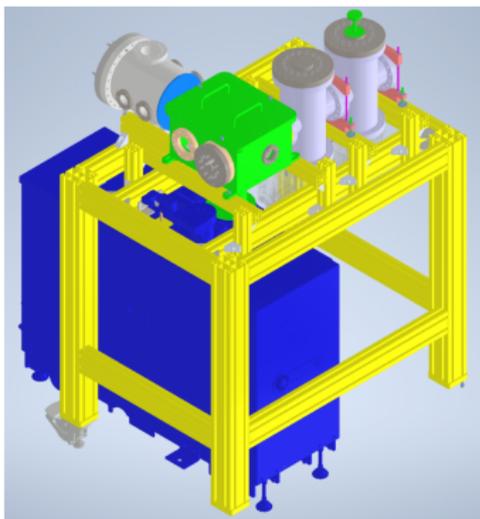
Phase 1



FRIENDS³ test bench

Fast Radioactive Ion Extraction and Neutralization Device for S³

- Improvement on neutralization efficiency
- Improvement on extraction time -> **Electrical Gas Cell**



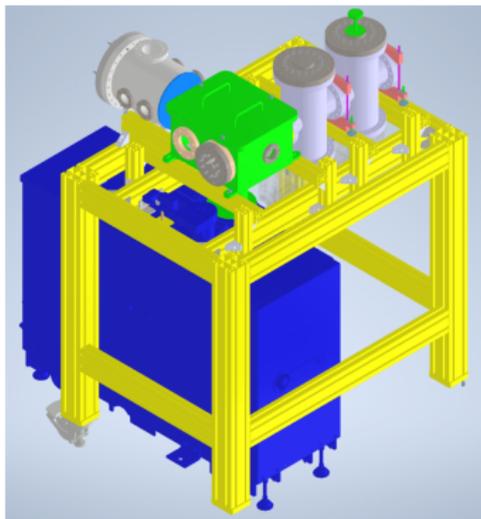
Phase 2



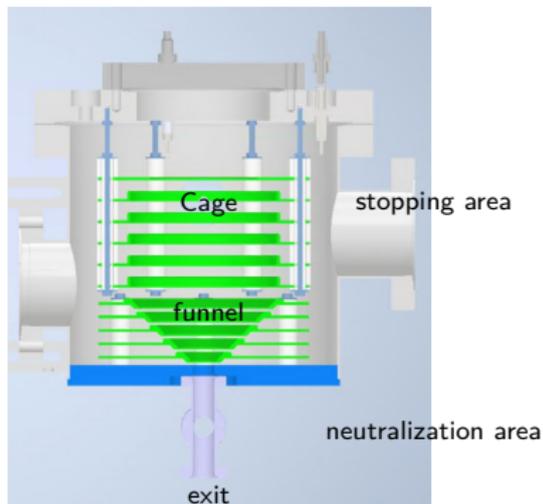
FRIENDS³ test bench

Fast Radioactive Ion Extraction and Neutralization Device for S³⁺

- Improvement on neutralization efficiency
- Improvement on extraction time -> **Electrical Gas Cell**



Phase 2



Design from JETRIS gas-cell model

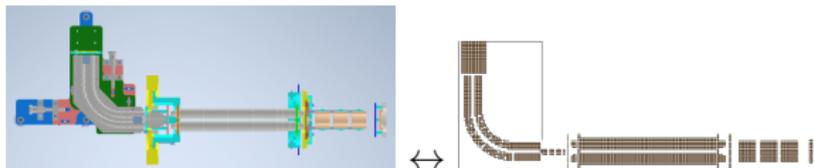
S. Raeder et al., NIM B 463, 272-276 (2020)



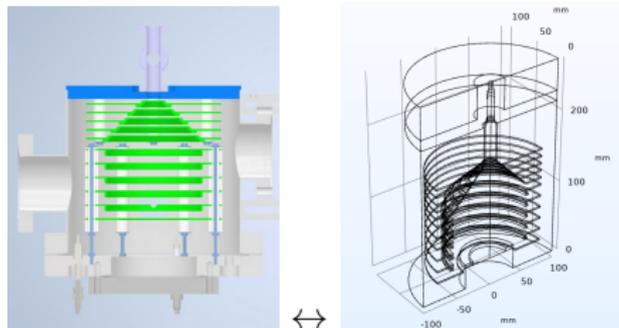
Separated simulations of the gas cell and the transport line

- Transport line to detection (SIMION), collisions with gas

- Transmission
- Mass filter
- Bunching

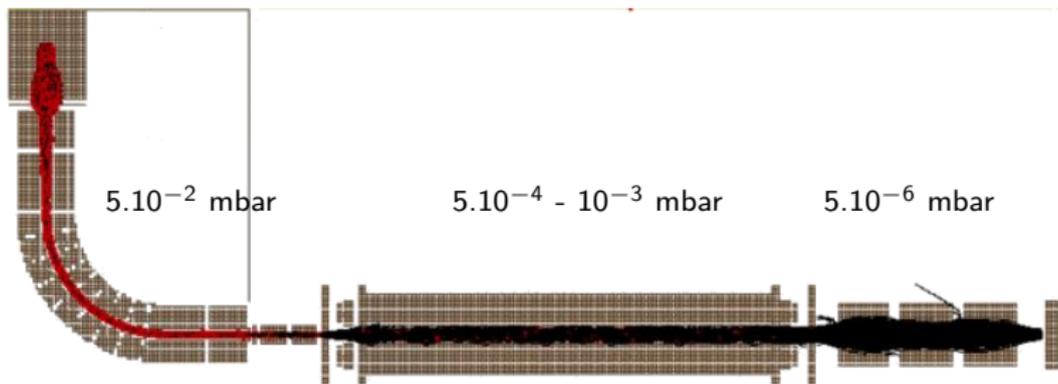


- Electrical gas cell : ion transmission in electric field and gas flow (combination of COMSOL and SIMION)





Transfer line simulations

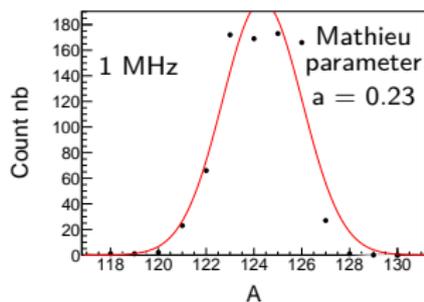


- Transmission

- 1 MHz : 88-90 %
- 500 kHz : 73-75 %

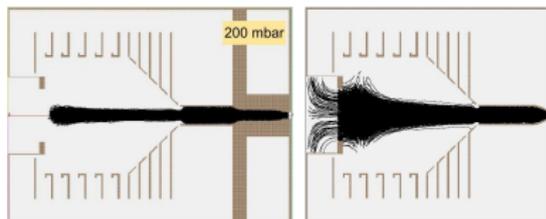
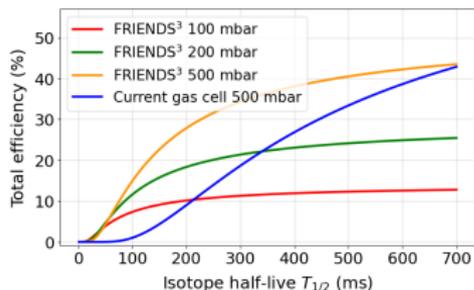
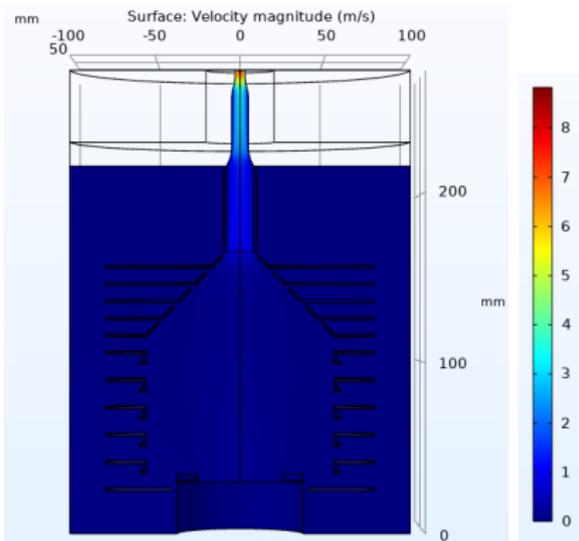
- Mass filtering

- 1 MHz : 17 %, $\frac{m}{\Delta m}(1 \text{ MHz}) = 31$
- 500 kHz : 11 %, $\frac{m}{\Delta m}(500 \text{ kHz}) = 25$





Electrical Gas Cell Simulations



Heated filament

S³ convergent

Beam size	Heated filament		S ³ convergent	
Gas pressure	100 mbar	200 mbar	100 mbar	200 mbar
Transmission	17 %	42 %	14 %	29 %
Average ToF (ms)	97.3	130.6	93	132

W. Dong's PhD Thesis, 2024

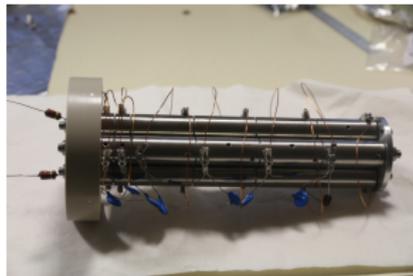
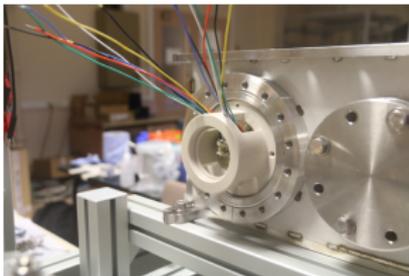
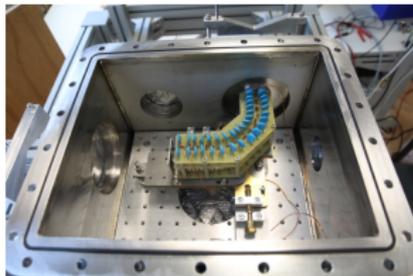


- 1 Design and simulation results
- 2 Test bench construction and experimental tests**



Test bench

- Step by step construction with tests



RFQs

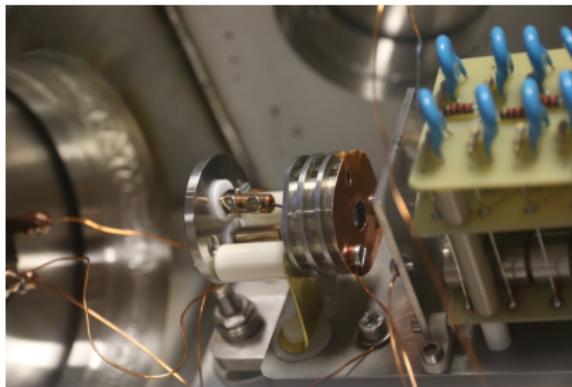


Detection system with Einzel lens



Test bench

- Step by step construction with tests
- Ions produced with alkali source
- Optimization in non-definitive conditions (-28 V biased Faraday cup, 10^{-2} mbar vacuum)



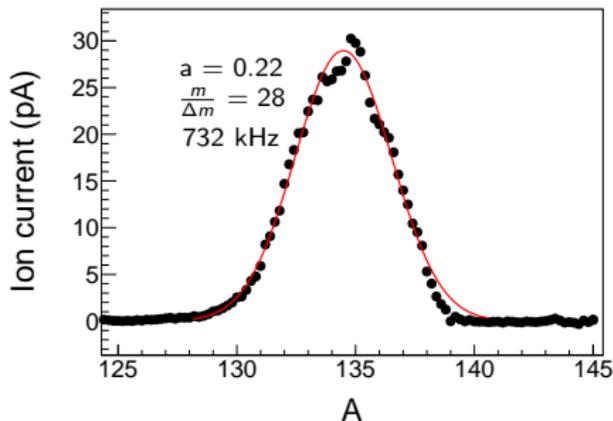
Transport line transmission : $> 25\%$ (quasi-definitive vacuum conditions, no gas cell)



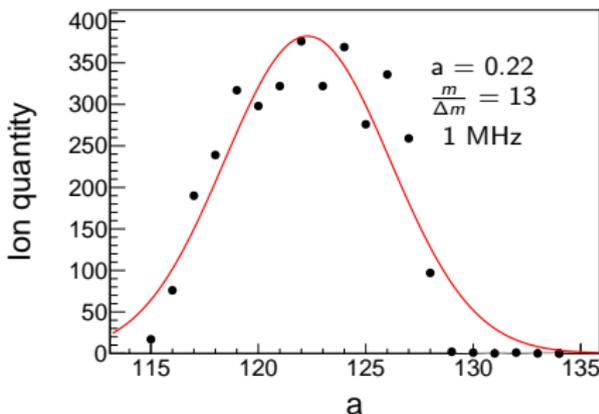
Mass filtering with FRIENDS³ test bench

Reality V.S. Simulation

Test bench



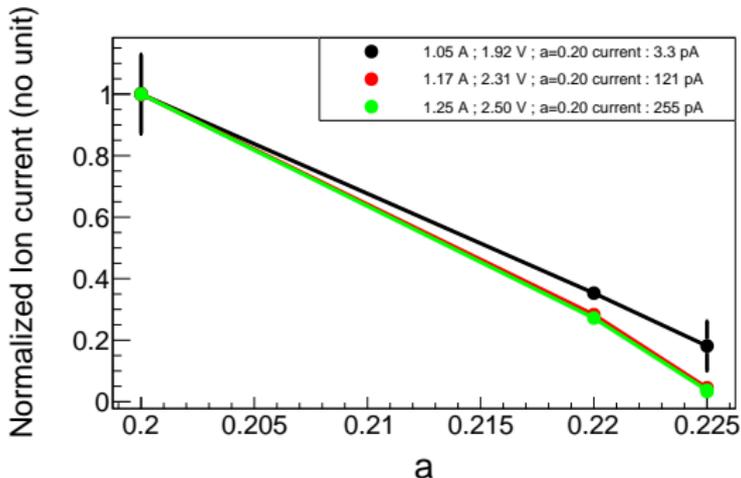
Simulations



- Difference in $\frac{m}{\Delta m}$ to be investigated
- Recalculation of QMF radius
- Investigation on masses and RF amplitude



Transmission V.S. Production

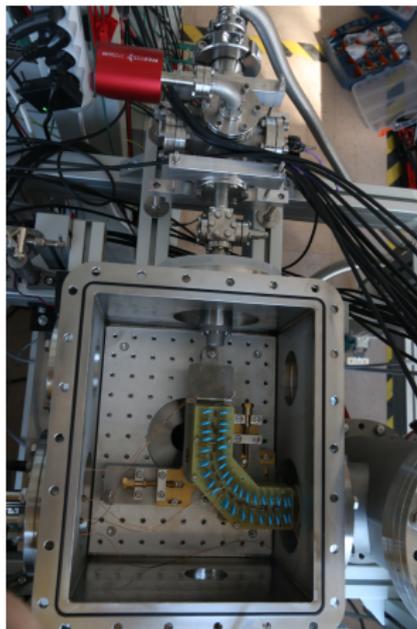
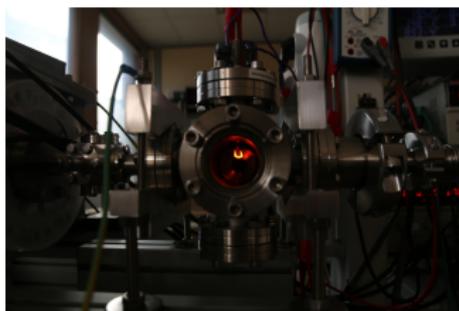
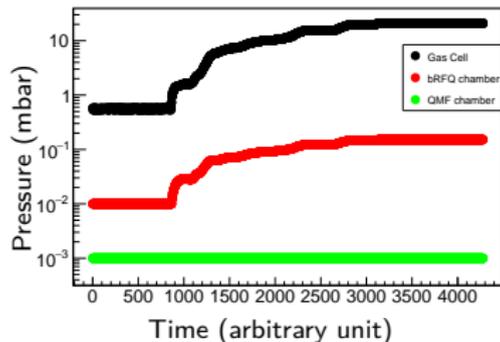


Normalized on $a = 0.2$ transmission

Small impact from ion current produced on QMF transmission



Non-electrical Gas-cell installed (Phase 1)



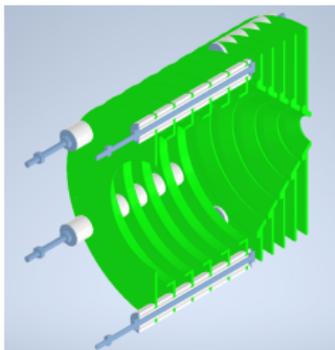
- Ions production with Ta fil, Ta + Rb deposit, pellet source
- Ions detected inside the bRFQ ; New tests in definitive pressure conditions



Conclusion

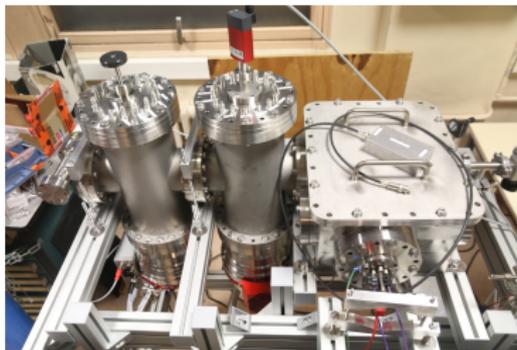
Conclusions

- Fast gas-cell designed, extraction efficiency objectives reached with simulations
- Ongoing neutralization tests, promising results with W filament e-production
- Test bench ready, operational transport line



Perspectives

- Waiting for delivery, construction of electric gas-cell
- Moving test bench to GANIL, use with lasers
- Continue neutralization tests, confirmation of results with reionization





Ready to go !





Acknowledgements

FRIENDS3 team @ IJCLab

Wenling Dong, Serge Franchoo, Thierry Hourat, David Lunney, Vladimir Manea, Valentin Marchand, Enrique Minaya Ramirez, Elodie Morin, and Samuel Roset

S³-LEB team

JETRIS (HIM, JGU Mainz, GSI) 



ANR-21-CE31-0001

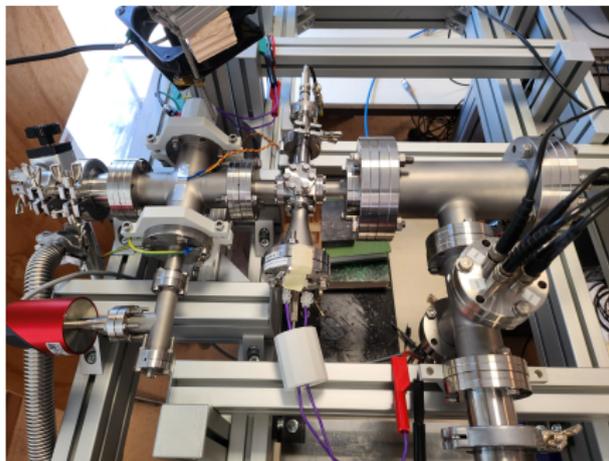


Thank you for your attention !

Backup

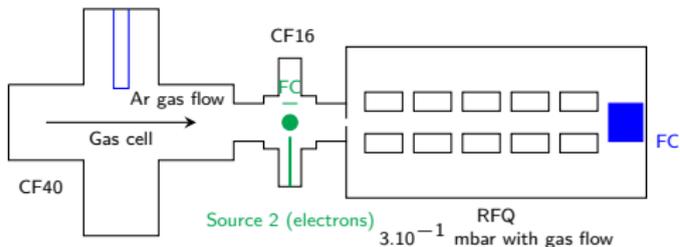


Reduced test bench



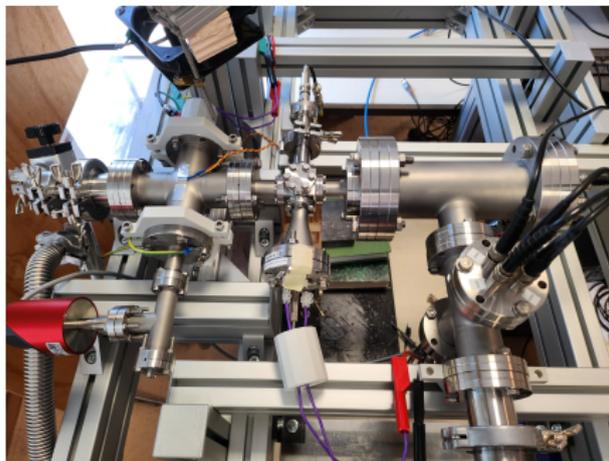
Preliminary tests on ion and electron production

Source 1 (ions)



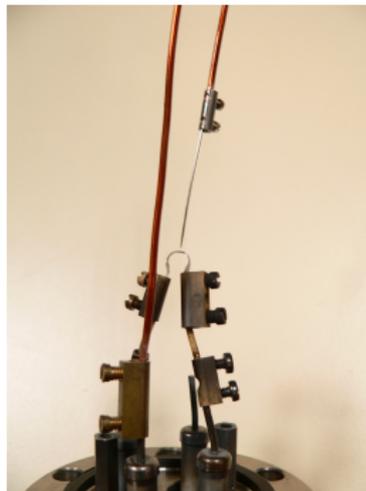
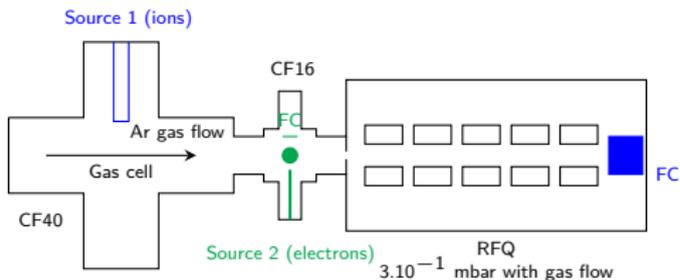


Reduced test bench



Preliminary tests on ion and electron production

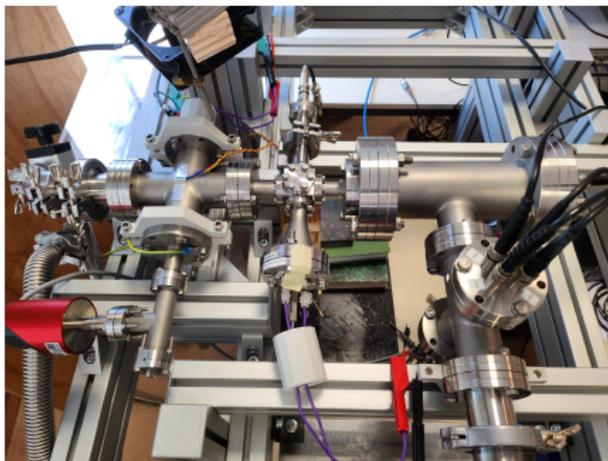
- Plasma source



Works well as ion source, to be tested for neutralization

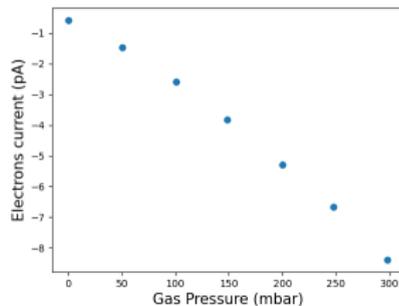


Reduced test bench

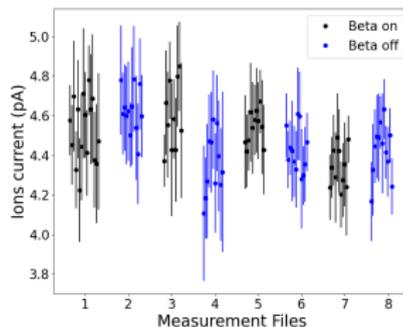
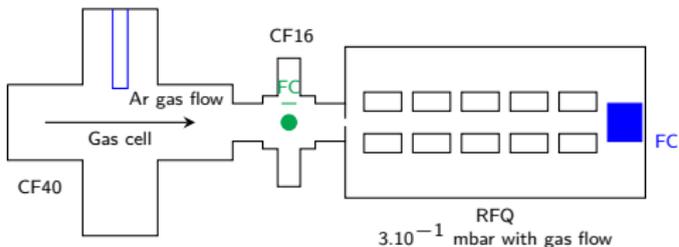


Preliminary tests on ion and electron production

- Beta source

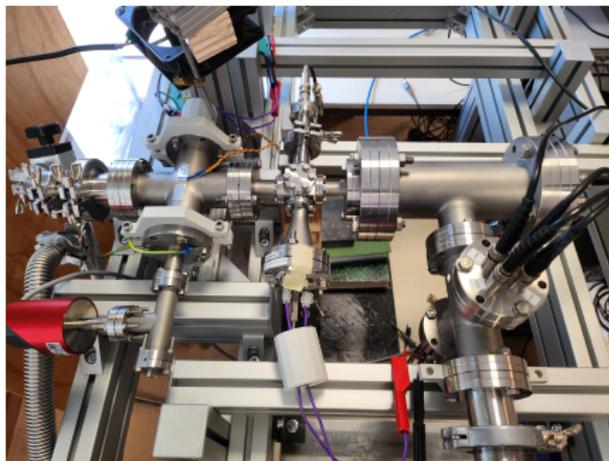


Source 1 (ions)



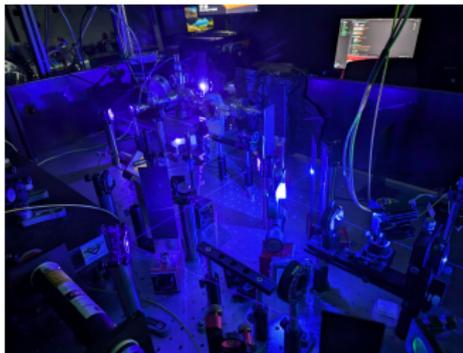


Reduced test bench

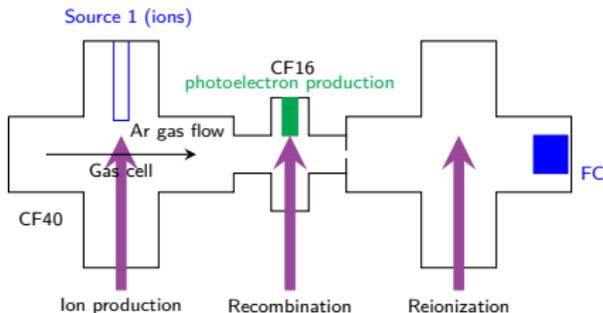


Preliminary tests on ion and electron production

- Photoelectric effect

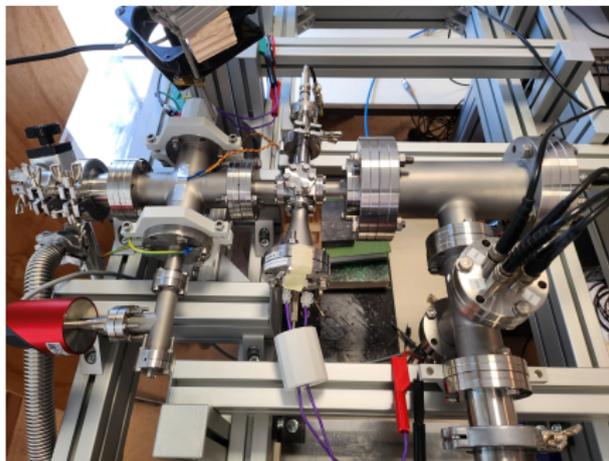


Work in progress in HIM, Mainz





Reduced test bench



Preliminary tests on ion and electron production

- W filament

