# Update of the fast gas cell development for S$^3$-LEB

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ANR-21-CE31-0001

# Outline

- Project summary

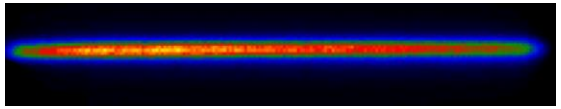
- Progress update
  - Preliminary simulation study
    - Simulation method
    - Ion extraction by electrical field and gas flow
  - Test-bench design study
    - Ion transport and separation
    - Vacuum and mecanical design

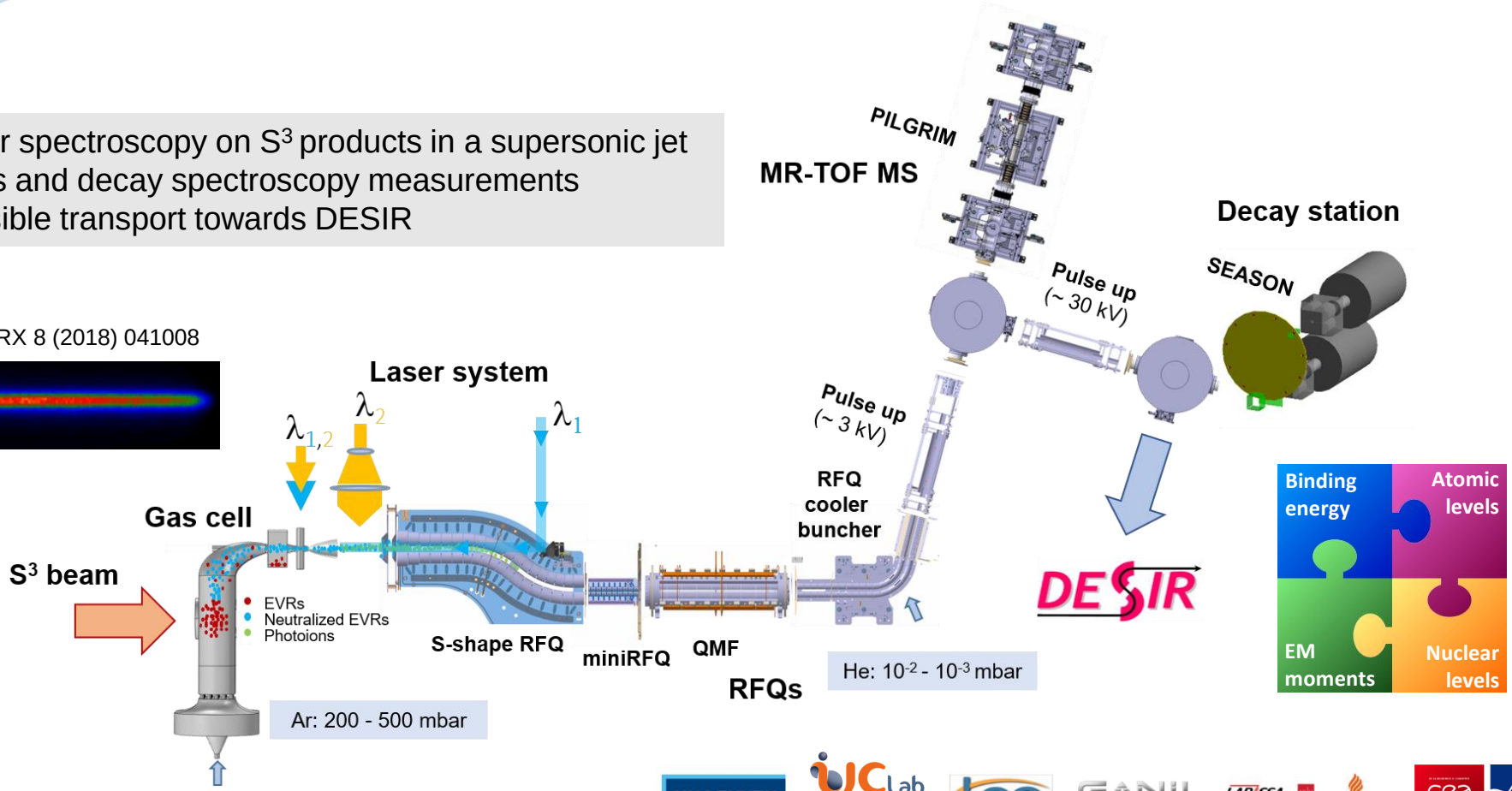
- Conclusions and outlook

# Project summary: $S^3$ Low Energy Branch

- Laser spectroscopy on $S^3$ products in a supersonic jet
- Mass and decay spectroscopy measurements
- Possible transport towards DESIR

A. Zadvornaya et al., PRX 8 (2018) 041008






R. Ferrer et al., Nucl. Instr. Meth. B 317, 570-581 (2013)
J. Romans, et al., Atoms 10, 21 (2022)

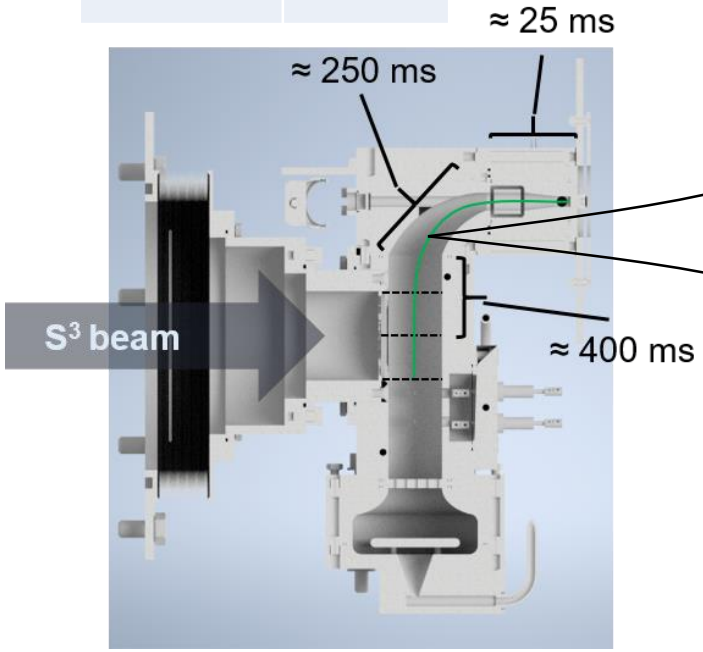
(Gas cell, laser system) (Gas cell) (RFQs) (mr-TOF-ms, laser system infractructure, safety, RFQsdetectors) (narrow band-width laser pre-studies at MARA) (decay station)

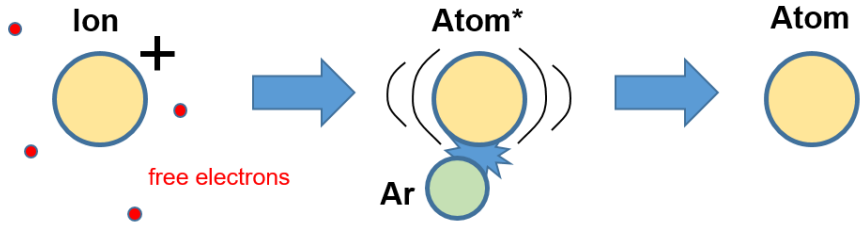
# Project summary: objectives

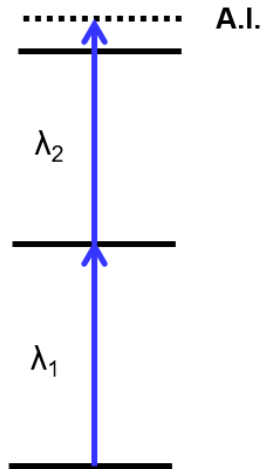
E. Mogilevskiy *et al. (KU Leuven)*

| 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



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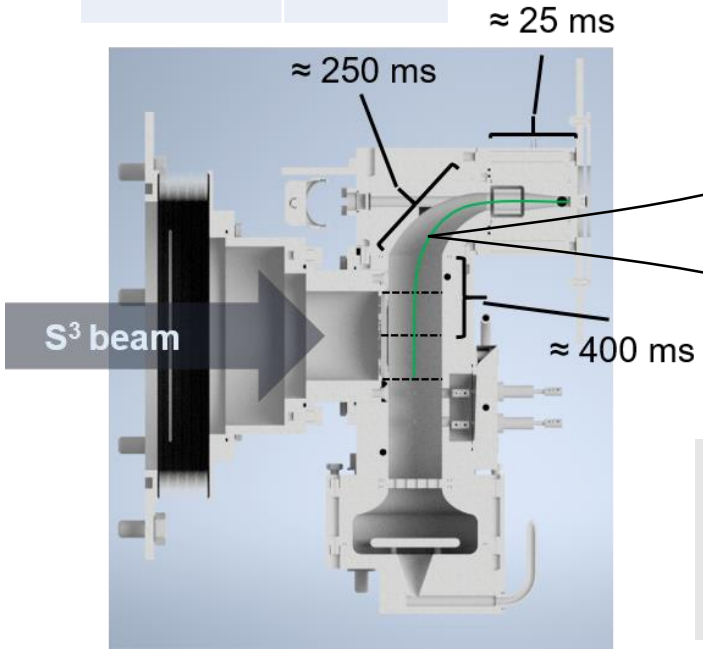


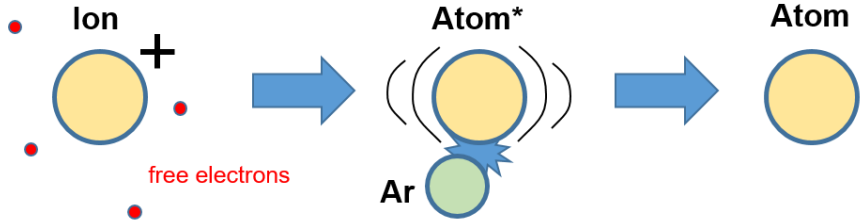


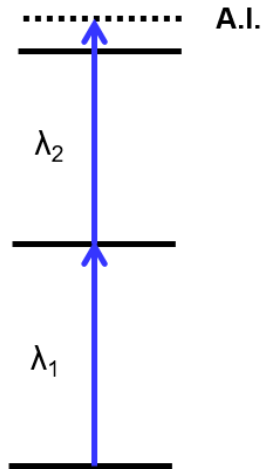


- Key roles of the S³-LEB gas cell:
  - Stop the S³ beam as efficiently as possible
  - Neutralize it by *3-body* and dissociative recombination
  - Extract it as quickly as possible

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

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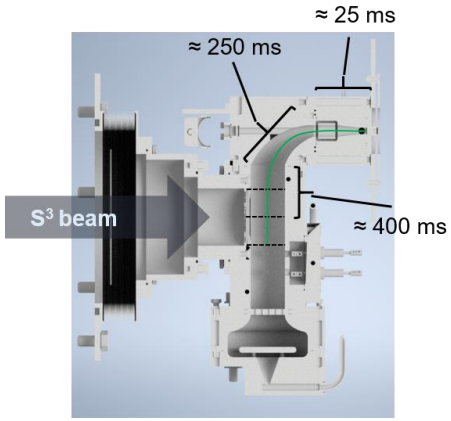
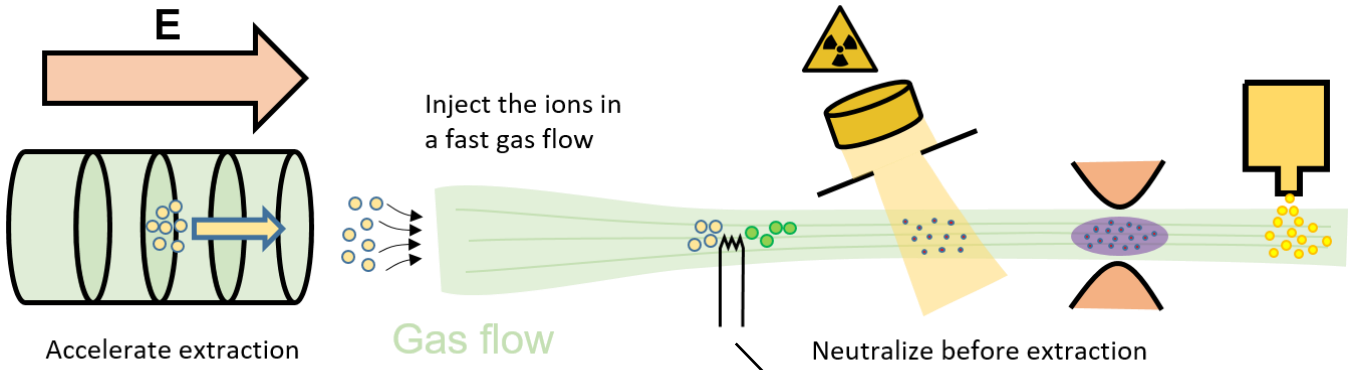
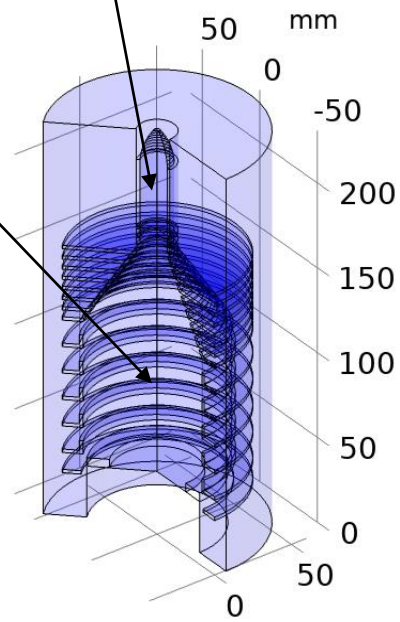
# Project summary: guiding idea




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

JETRIS collaboration

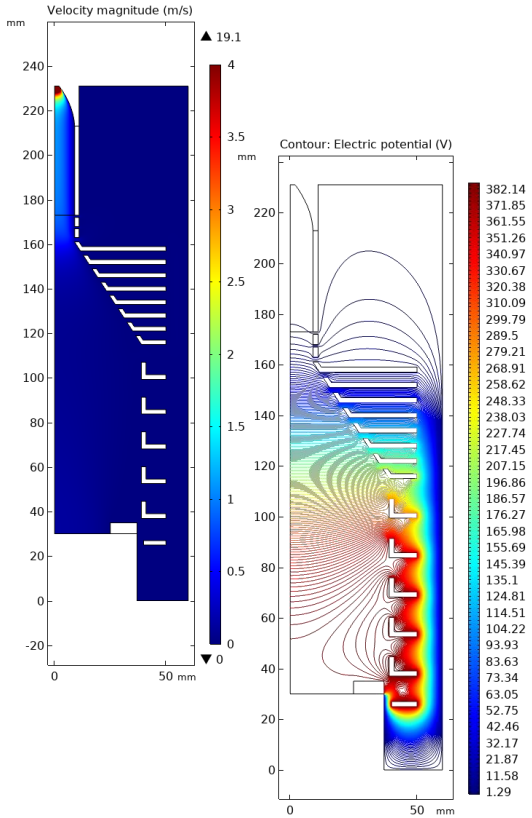
…
G. Savard et al., NIM B 204, 582-586 (2003)
S. Schwarz et al., NIM B 204, 507-511 (2003)
J. B. Neumayr et al., Rev. Sci. Instrum. 77, 065109 (2006)
J. B. Neumayr et al., NIM B 244, 489–500 (2006)
C. Droese et al., NIM B 338, 126–138 (2014)
M. Ranjan et al., NIM B 770, 87-97 (2015)
…

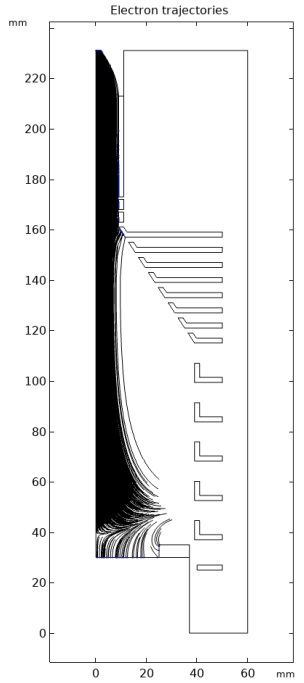
Simulations + experimental test

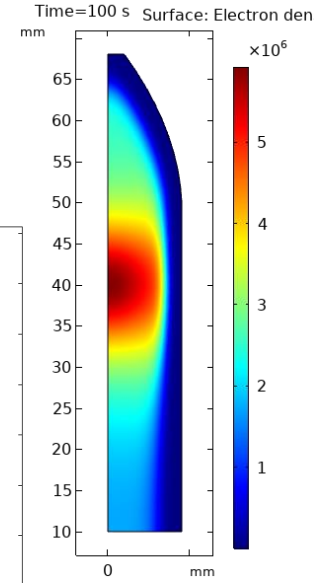
# Preliminary simulation study: multiphysics

- Study of simulation tools and methods.

- Multiphysics problem: COMSOL
  - ✓ Laminar gas flow through the cell
  - ✓ Calculation of static and dynamic electrical fields
  - ✓ Particle tracing under the action of gas flow (drag) and electrical field (drift)
  - ✓ ~~Diffusion effect in high pressures~~
  - ✓ Plasma processes (ion recombination)



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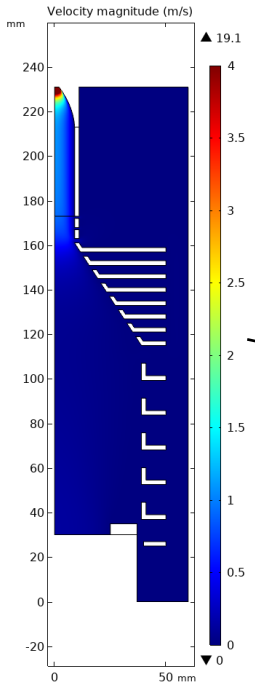
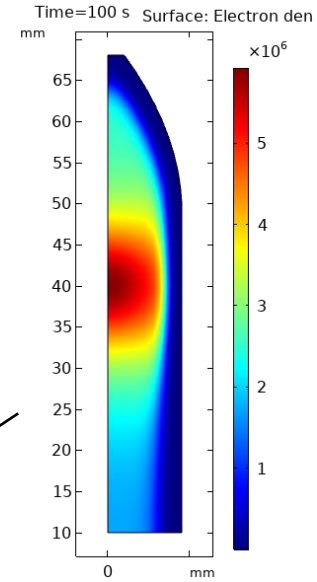



gas velocity field

- Multiphysics problem: COMSOL
  - ✓ Laminar gas flow through the cell
  - ✓ Calculation of static and dynamic electrical fields
  - ✓ Particle tracing under the action of gas flow (drag) and electrical field (drift)
  - ✓ ~~Diffusion effect in high pressures~~
  - ✓ Plasma processes (ion recombination)

- Statistical Diffusion Simulation (SDS): Simion
  - ✓ ~~Laminar gas flow through the cell~~
  - ✓ Calculation of static and dynamic electrical fields
  - ✓ Particle tracing under the action of gas flow (drag) and electrical field (drift)
  - ✓ Diffusion effect in high pressures
  - ✓ ~~Plasma processes (ion recombination)~~

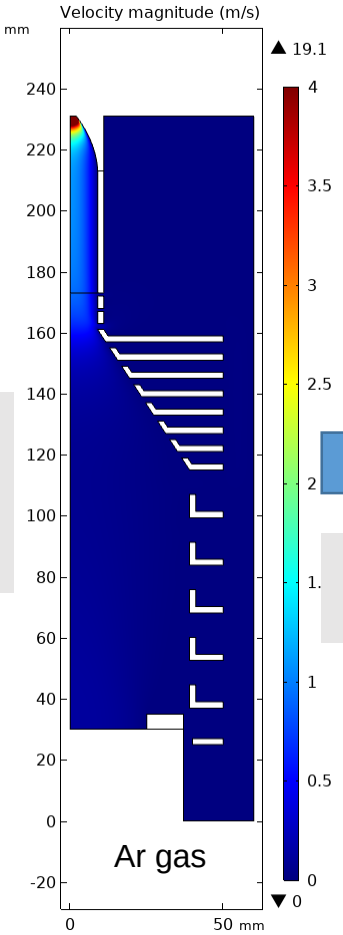
neutralization probability field



# Preliminary simulation study: method

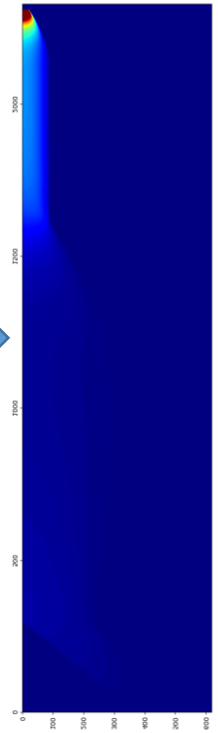
COMSOL

- ❑ Design optimization without diffusion
- ❑ Computation of fluid flow



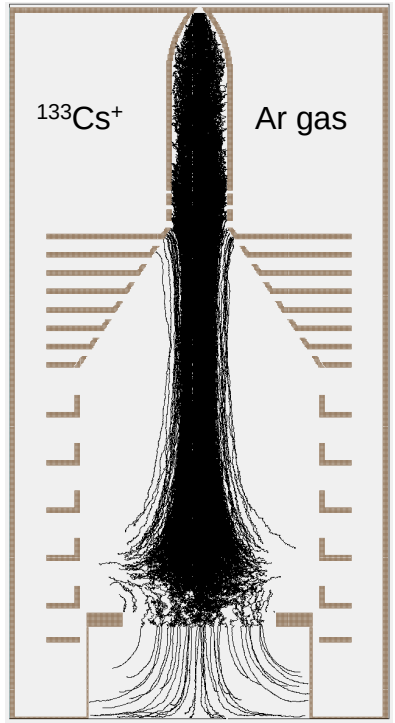

Python script

- ❑ Conversion to SIMION input file



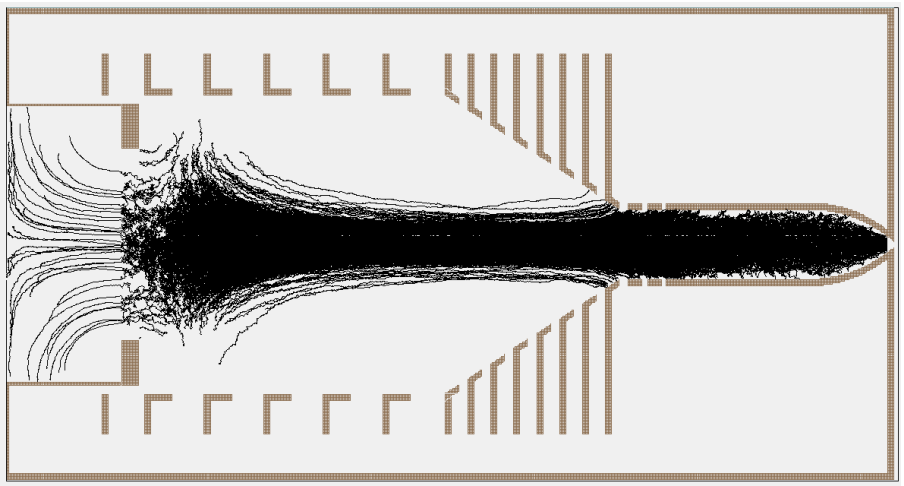
SIMION

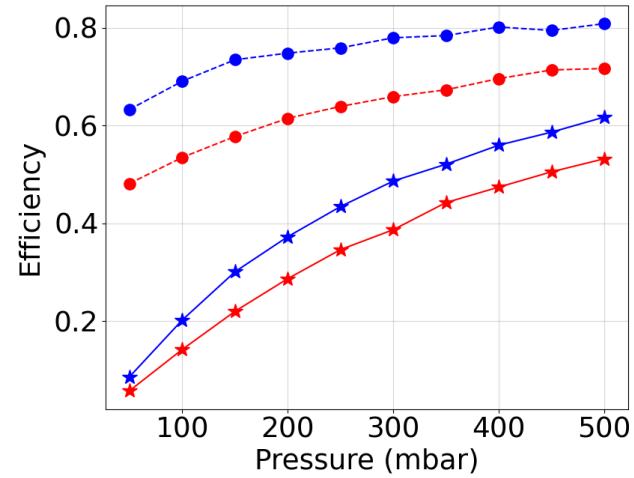
- ❑ Computation of efficiency and extraction times with diffusion

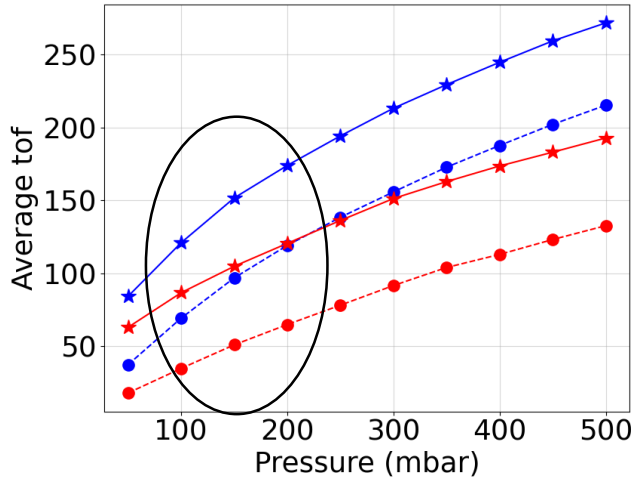


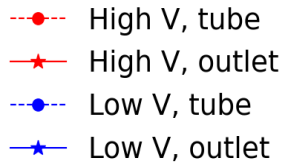
# Preliminary simulation study: results

- Preliminary simulation study:
  - Efficiency and extraction time
  - Time available in the neutralization tube
  - Sensitivity of performance to design choices





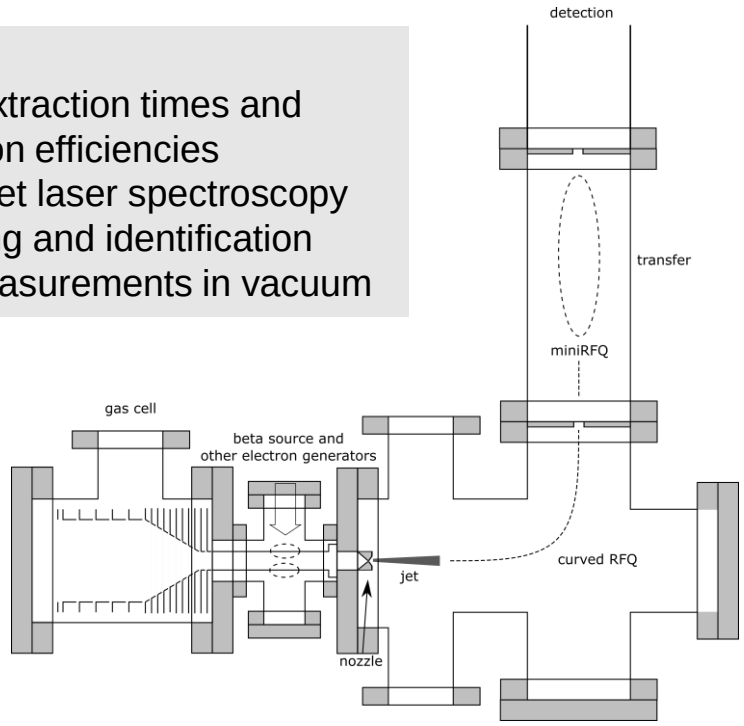



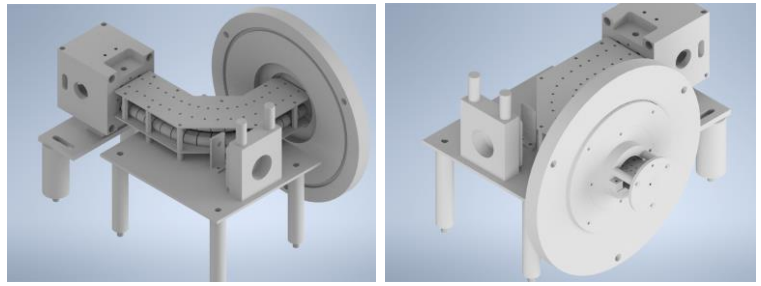

Simulation work by Wenling Dong

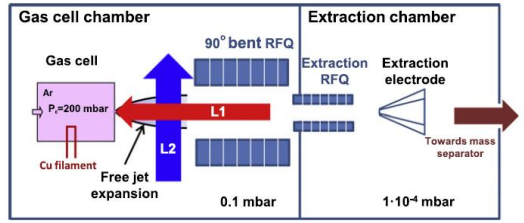
# Test-bench design study

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




Curved RFQ and miniRFQ from KU Leuven






Configuration in Louvain la Neuve, (Kudryavtsev et al., NIMB 297, 2013)

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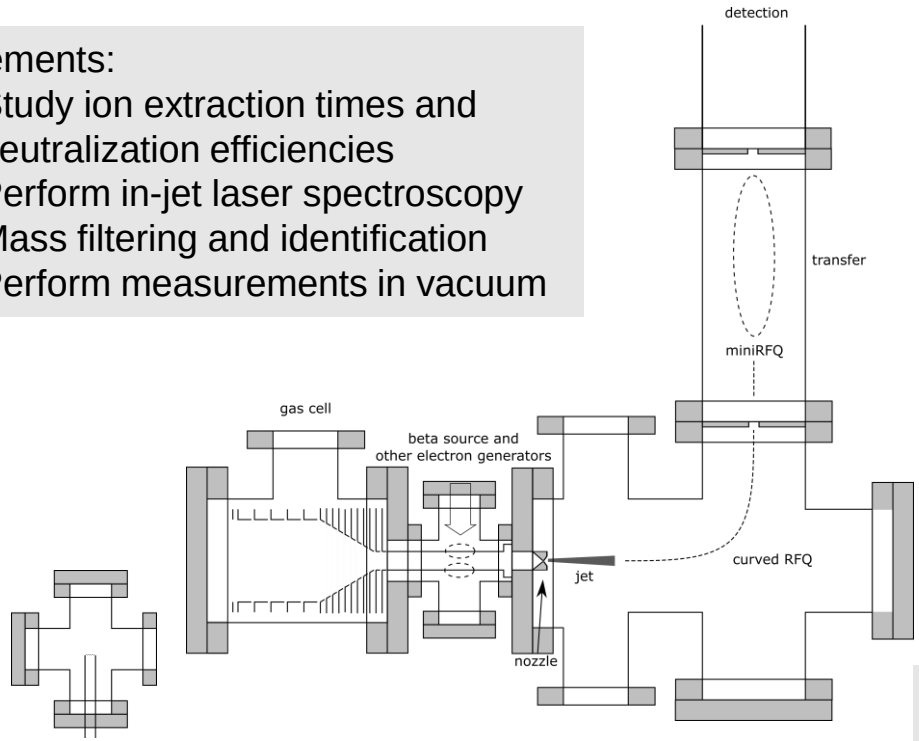
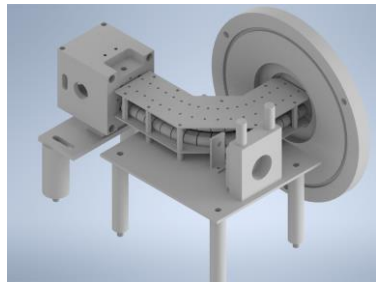
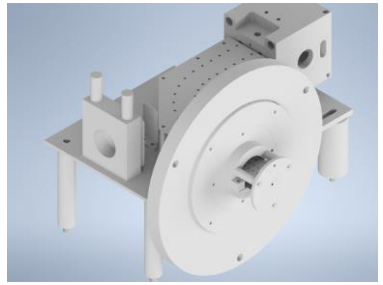


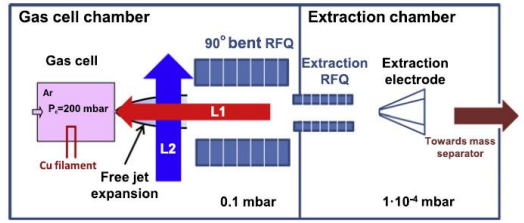

- Start with simple gas cell

Curved RFQ and miniRFQ from KU Leuven





KU LEUVEN

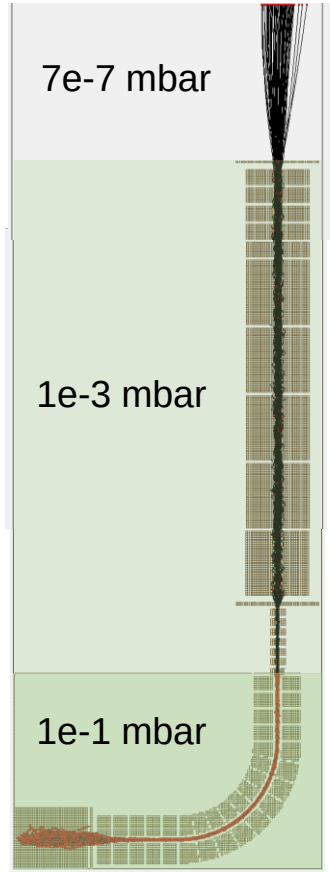



Configuration in Louvain la Neuve, (Kudryavtsev et al., NIMB 297, 2013)

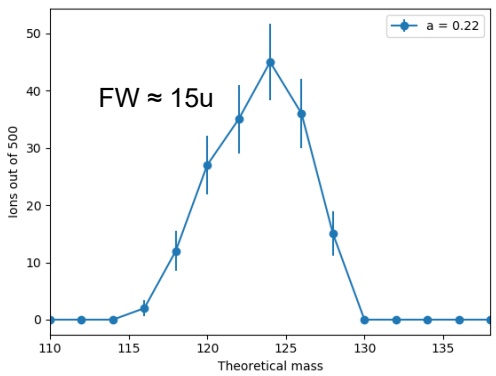
- Study integration
- Design an additional ion guide for transporting low-energy ions in intermediate pressure.

# Test-bench design study: ion guide

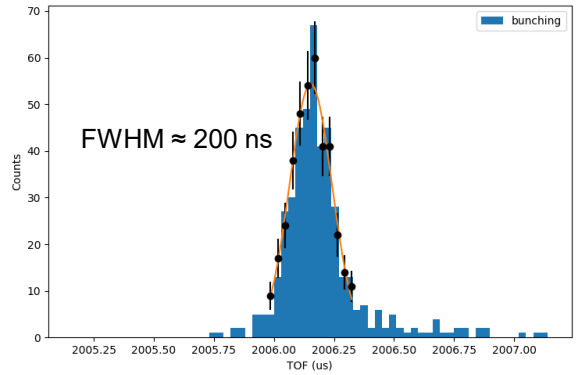
- Existing segments in stock
- Simulations with hard-sphere collisions
- Simulated total efficiency:
  - ion-guide mode: ~ 70%
  - buncher mode: ~ 40%
  - mass filter mode: 5-10%

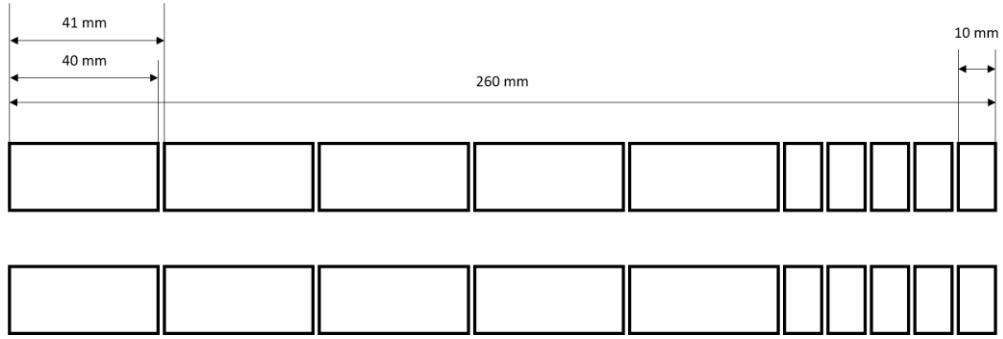



## Mass filter mode



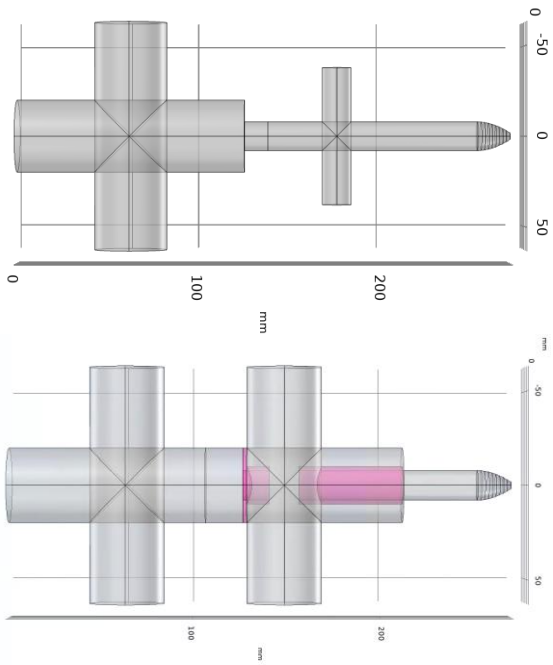

## Bunching mode

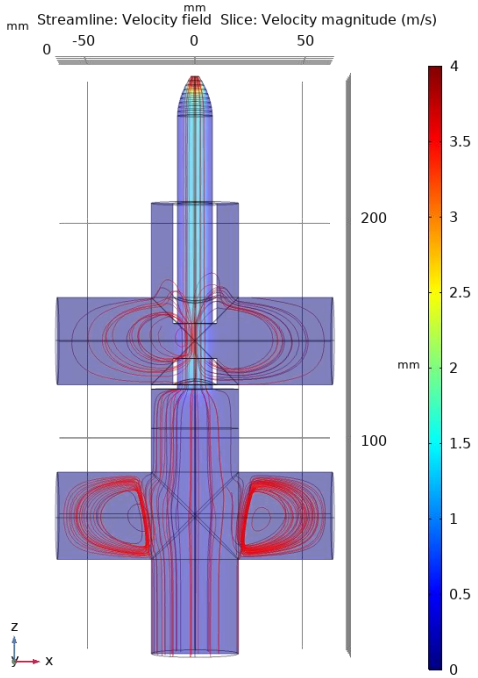


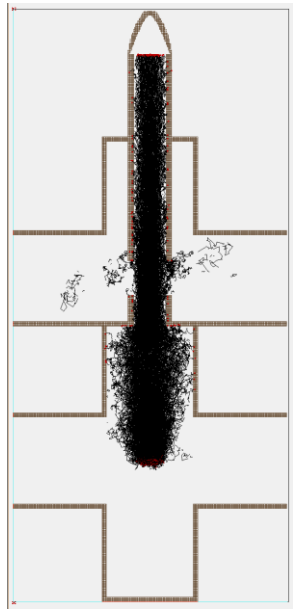



# Test-bench design study: simple gas cell

- CF40 cross as gas cell
- CF16 tube for neutralization or custom CF40 cross with inner tube
- No major disturbance of ions by cross structure



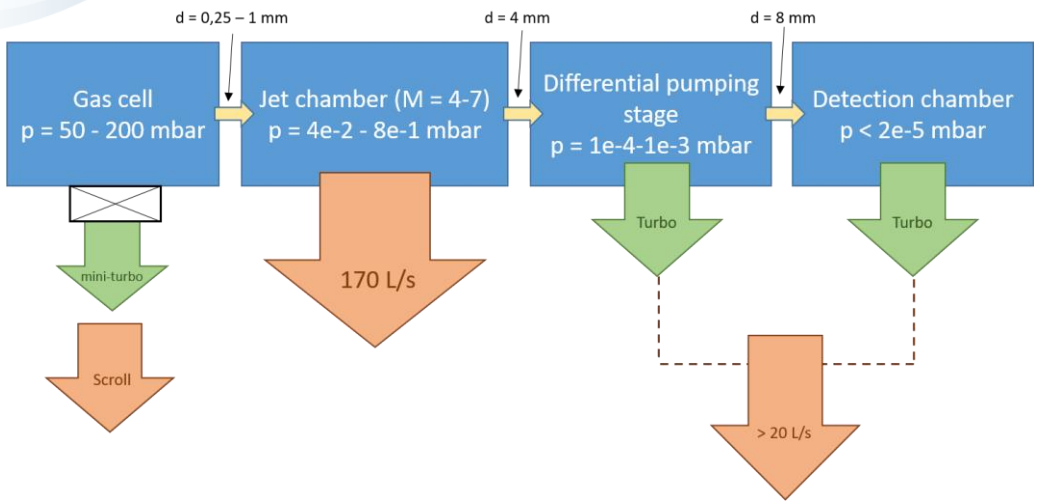



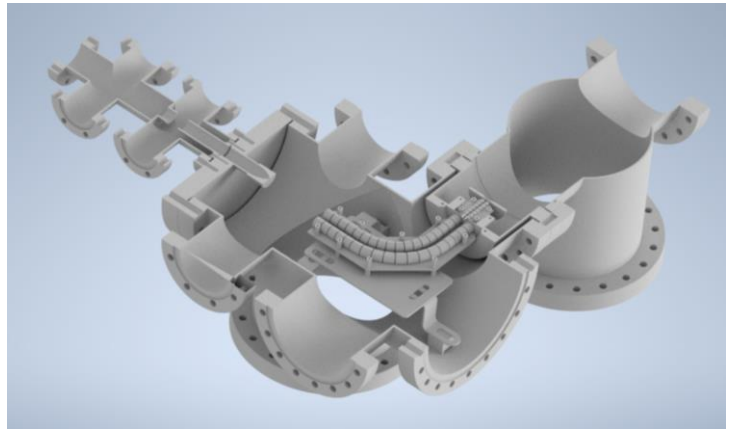
- @ 100 mbar:
  - ≈ 25% efficiency
  - ≈ 450 ms extraction time
  - ≈ 140 ms in narrow tube
- @ 200 mbar:
  - twice the efficiency

# Test-bench design study: vacuum and mechanics

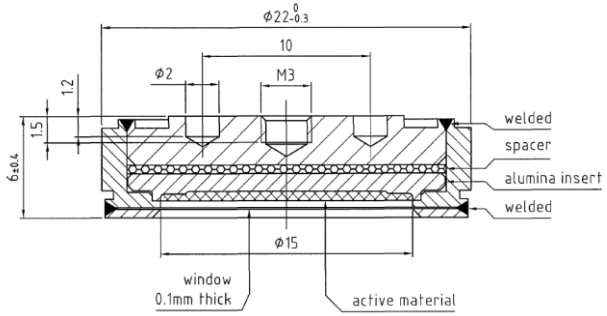
- Commercial suppliers of vacuum pumps contacted, quotations obtained




- Mechanical design of test bench started (work of Samuel Roset).



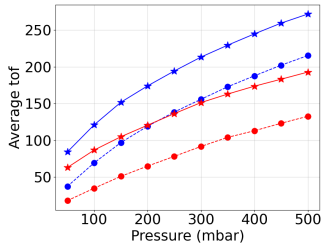
- 50 MBq beta source of $^{90}$Sr purchased (delivery today)

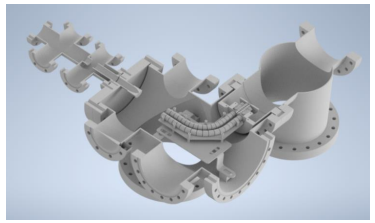


# Conclusions and outlook

- Preliminary simulation study completed, showing that the coupling of an electrical gas cell to a no-field gas flow is possible (even in a simple DC version).

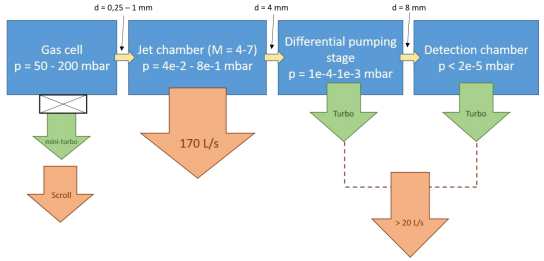
- Test-bench definition completed and simulated, with mechanical design ongoing.

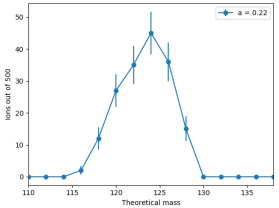


- Vacuum requirements were studied and pump purchase in progress.

- Postdoc position currently open, new postdoc will be hired beginning of next year.




- Tests will begin at IJCLab in 2023 (some simple tests already started).

- Test bench will eventually move to GANIL for coupling to the Ti:sa laser system of the GISELE lab.

# Acknowledgements


- **FRIENDS$^3$ team**

Wenling Dong, Serge Franchoo, David Lunney, Enrique Minaya-Ramirez, Samuel Roset

- **S3-LEB collaboration**

- **JETRIS collaboration (HIM, JGU Mainz, GSI)**

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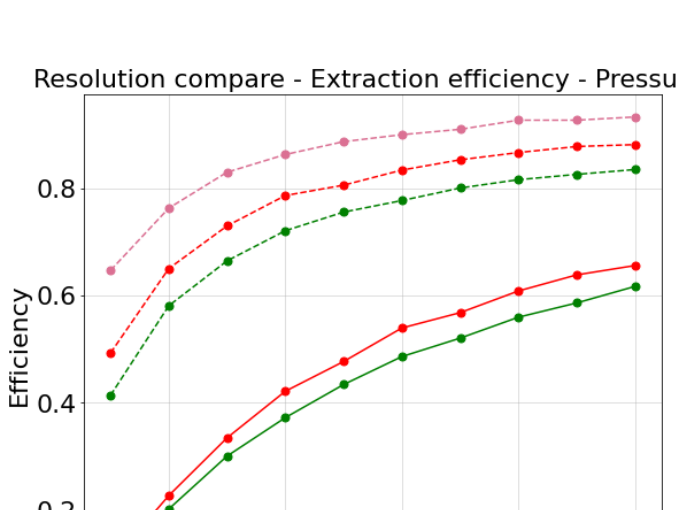
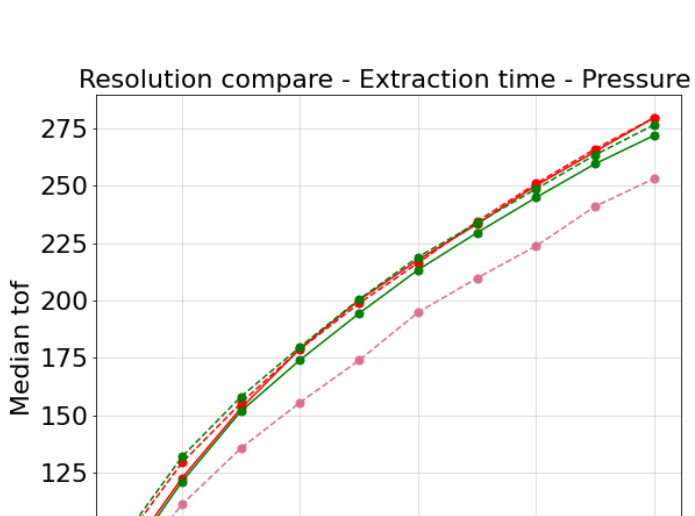
# COMSOL-SIMION comparison




SIMION 1mm grid, low voltage setting, + diff

SIMION 1mm grid, low voltage setting, no diff

SIMION 0.1 mm grid, low voltage setting, + diff

SIMION 0.1 mm grid, low voltage setting, no diff

COMSOL 1000 counts, low voltage setting, no diff