Preliminary discussion for the DESIR gas cell

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Summary

Key properties of the gas cell for DESIR:

- Universal: --> ion extraction, so He buffer gas (lower probability of neutralization)
- Fast:
  - ➢ Simple flow but small volume (high pressure for high stopping power and reduced diffusion)
  - ➢ Electrical field (lower pressure for reduced drag, so higher volume)
  - ➢ A combination/compromise of the two

Ongoing « discussion » for DESIR gas-cell -> before discussing a concrete project :

- ➢ Literature survey for identifying approaches, constraints and trade-offs
- ➢ Preliminary simulations:
  - Stopping of ions in the gas for He or lower pressures
  - Extraction by simple flow (S^3-LEB or smaller gas cell with He)
  - Extraction by electrical field (take FRIENDS^3 simulated design as starting point)
  - …

also of interest for FRIENDS^3

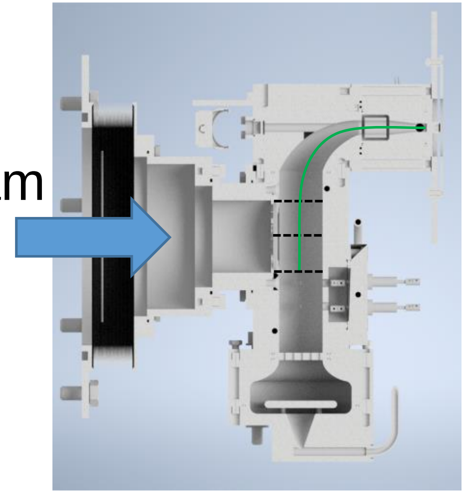
Simulation case study: ^{100}Sn, Ti window

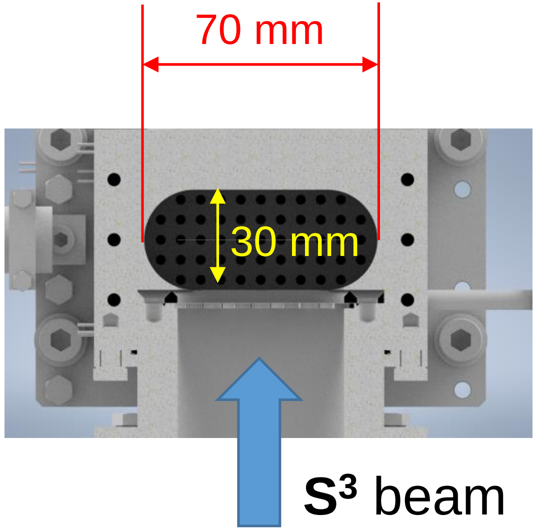
F. Déchery et al., Eur. Phys. J. A 51, 66 (2015)

2.5%

N°	Reactions	τ μ g/cm^2	E MeV	$\sigma_{\frac{dp}{p}}$ %	σ_θ mrad	Q (dQ) Mean (RMS)	$B\rho$ T·m	$E\rho$ M·V	$\epsilon_{XX'}$ mm·mrad	$\epsilon_{YY'}$ mm·mrad
1	^{46}Ti(^{58}Ni, 4n)^{100}Sn	500	84.5	2.1	25	26.4 (1.8)	0.509	6.50	13	72
2	^{208}Pb(^{48}Ca, 2n)^{254}No	600	35.0	2.2	34	18.3 (2.1)	0.755	3.89	17	98
3	^{238}U(^{22}Ne, 5n)^{255}No	170	8.3	4.8	70	8.7 (1.5)	0.736	1.85	35	202

S^3 beam





- Exploring lower pressures or He raises the question of stopping range and straggling
- Perform SRIM simulations
- Use ^{100}Sn beam as input
- SRIM overestimates stopping power
  (for simplicity this aspect is not considered at this stage)

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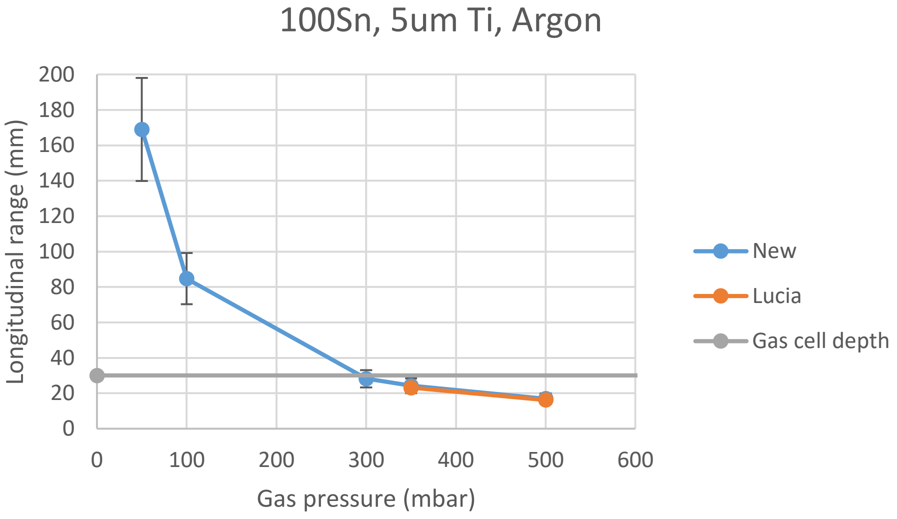

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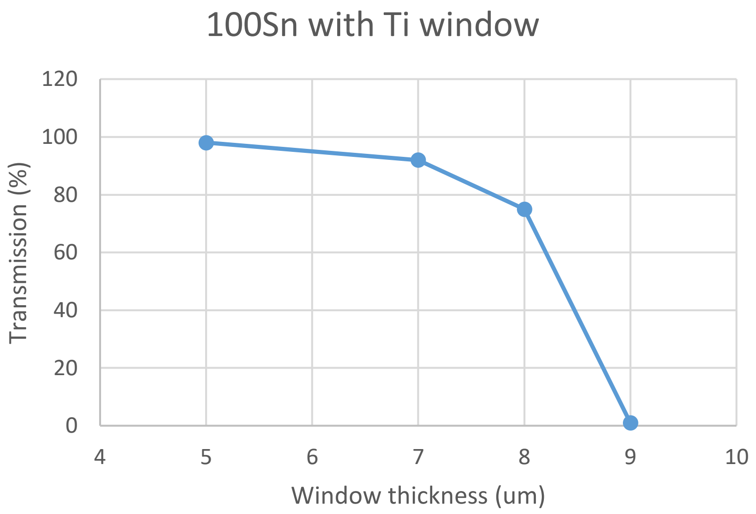

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- Perform SRIM simulations
- Use ^{100}Sn beam as input
- SRIM overestimates stopping power
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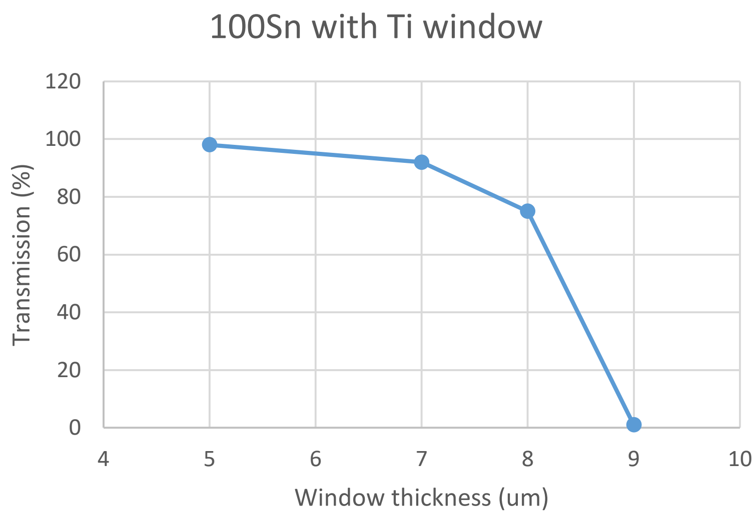
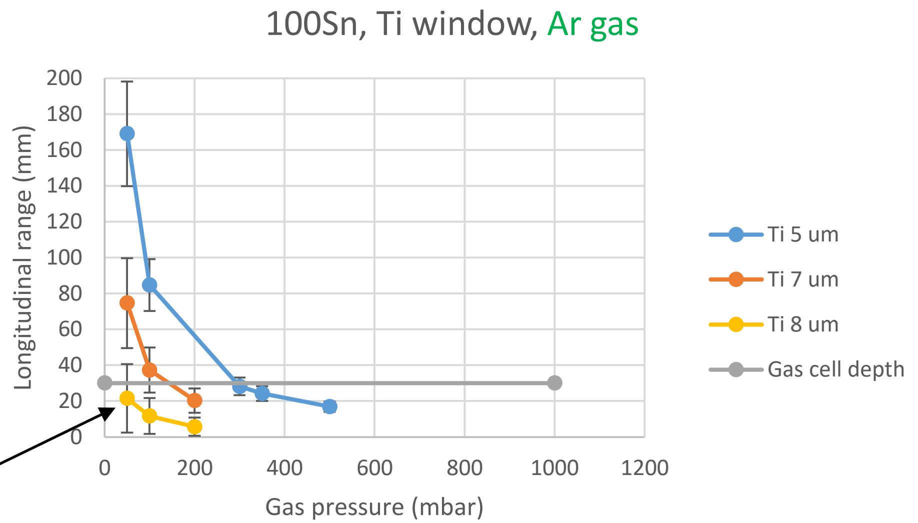
- Benchmark with Ar
- To some extent, stopping range can be adjusted by the window thickness.

Reducing the pressure for Ar gas cell



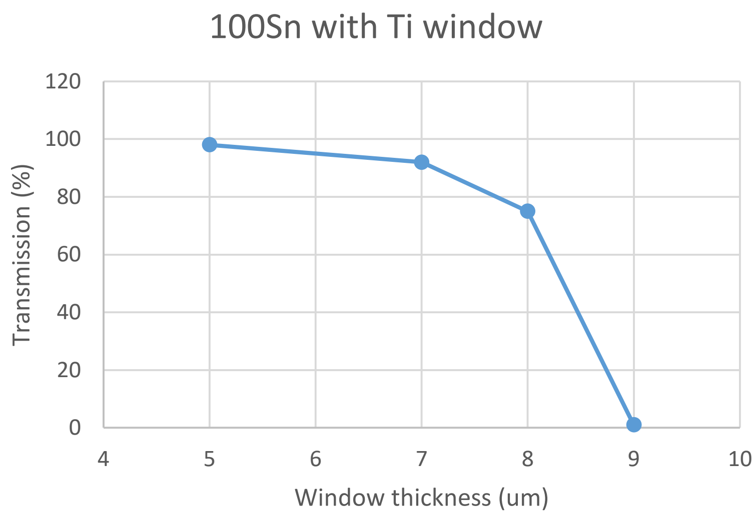


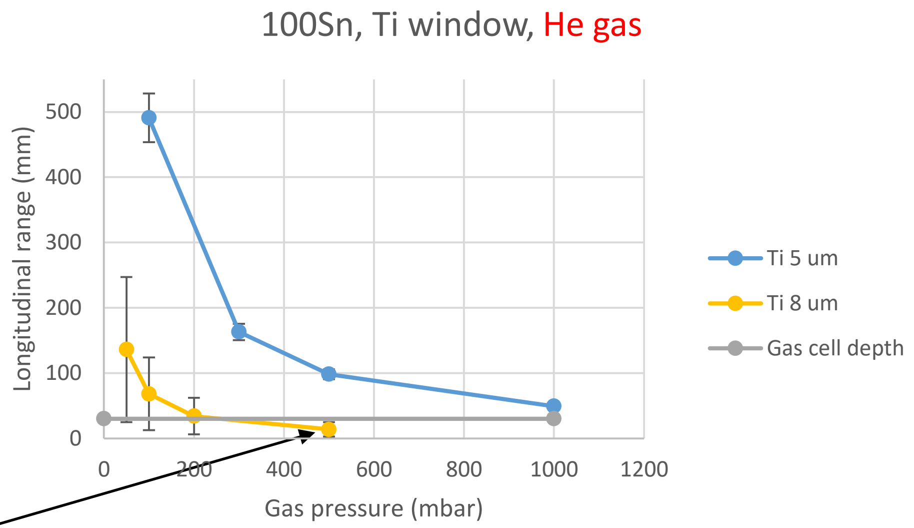
(y error bars are 1-sigma longitudinal straggling)

About 50% stopped in Ar gas for 8 um window thickness and 50 mbar pressure.

- Straggling is an issue for low pressures.

Stopping ions in He





(y error bars are 1-sigma longitudinal straggling)

About 70% stopped in gas for 8 um window thickness and 500 mbar pressure.

- Stopping power of He is much lower: larger stopping range and straggling
- ^{100}Sn can be stopped in existing gas cell at 500 mbar He pressure.

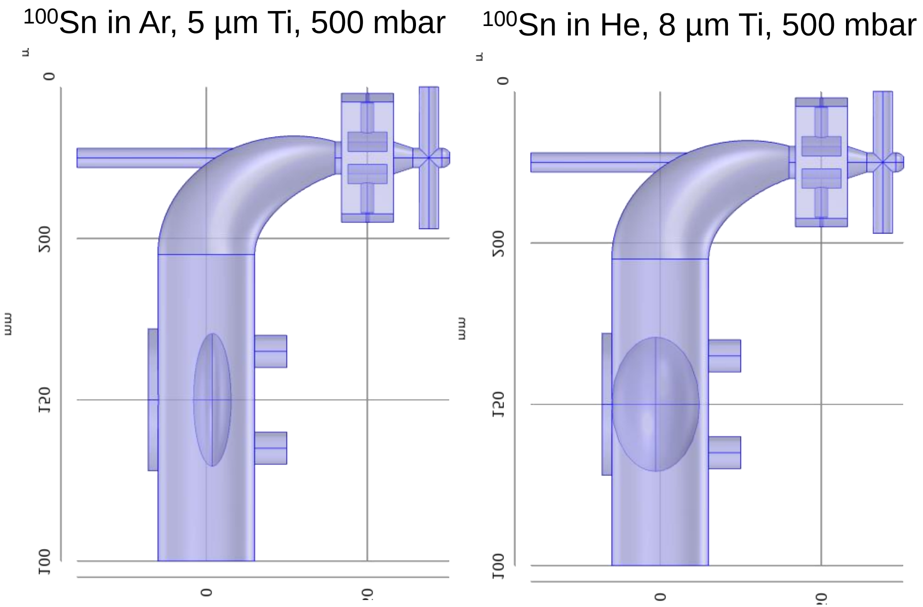
Using the S3-LEB gas cell with He

- S3-LEB gas cell in two configurations:
  - Ar, 500 mbar, 5 µm Ti
  - He, 500 mbar, 8 µm Ti

- Stopped ^{100}Sn modeled as ellipsoidal source domain

- Calculate efficiency and extraction time as a function of exit hole diameter.

- Simulations based on KU Leuven file (Evgeny Mogilevskiy et al.)



Using the S^3-LEB gas cell with He

- S^3-LEB gas cell in two configurations:
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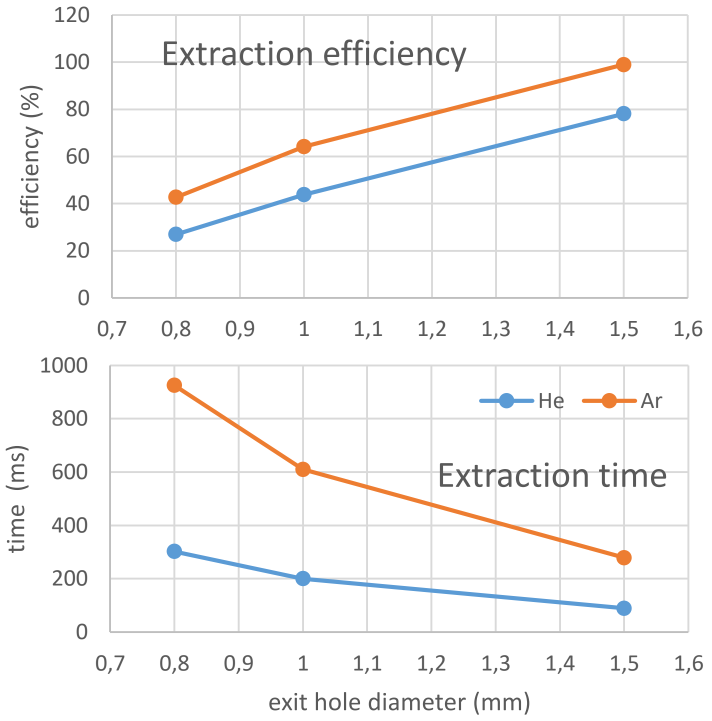
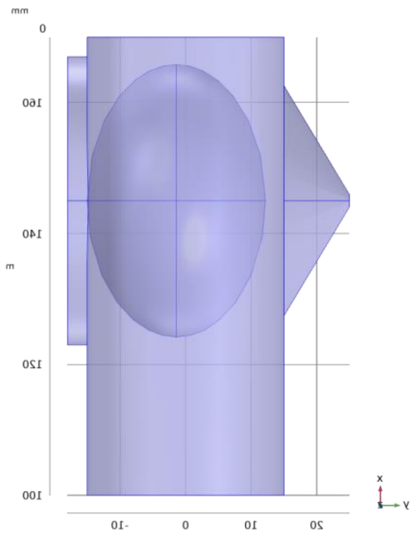
- Stopped ^{100}Sn modeled as ellipsoidal source domain
- Calculate efficiency and extraction time as a function of exit hole diameter.
- Simulations based on KU Leuven file (Evgeny Mogilevskiy et al.)
- Good agreement with KU Leuven results on Ar simulations.

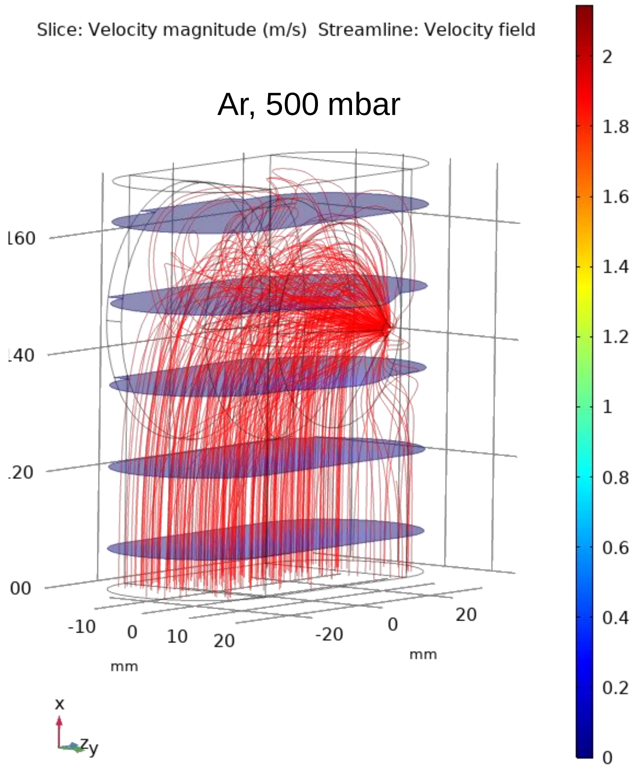


- Extraction times scale as $\sqrt{A}$ and $1/d^2$
- For He, 0,8 mm is currently the upper limit due to the required decay time in the evacuation delay line

An even smaller S^3-LEB gas cell

« What if we just put the exit in front of the gas-cell window? »





- « Small gas cell» (theoretical limit): extraction cone in front of window
- Having a bit of room on the gas injection side helps

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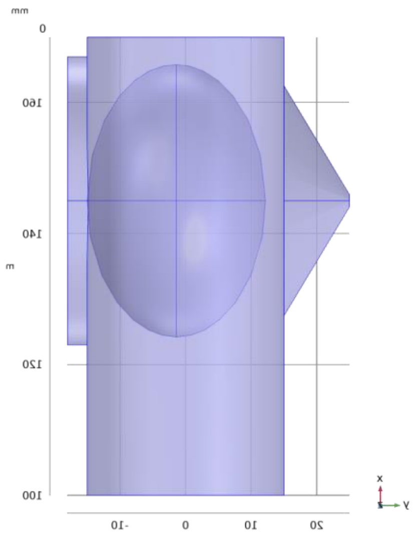
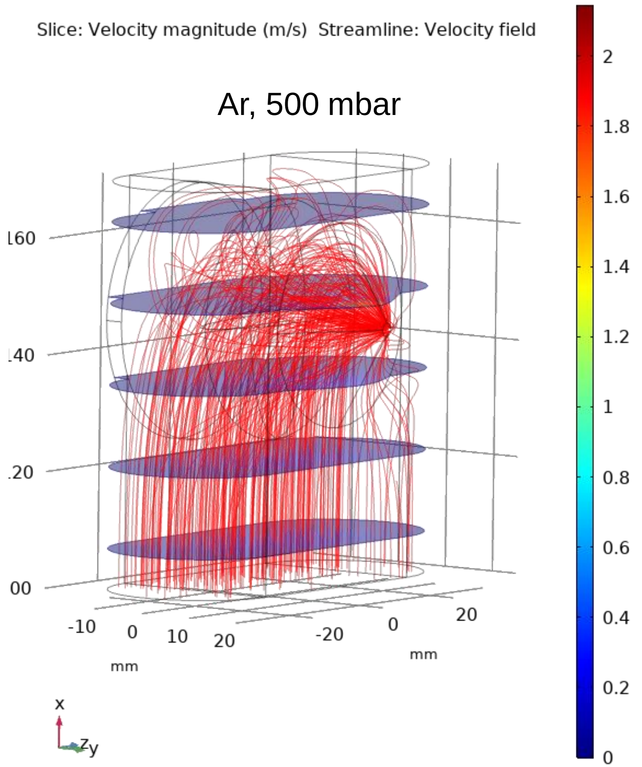
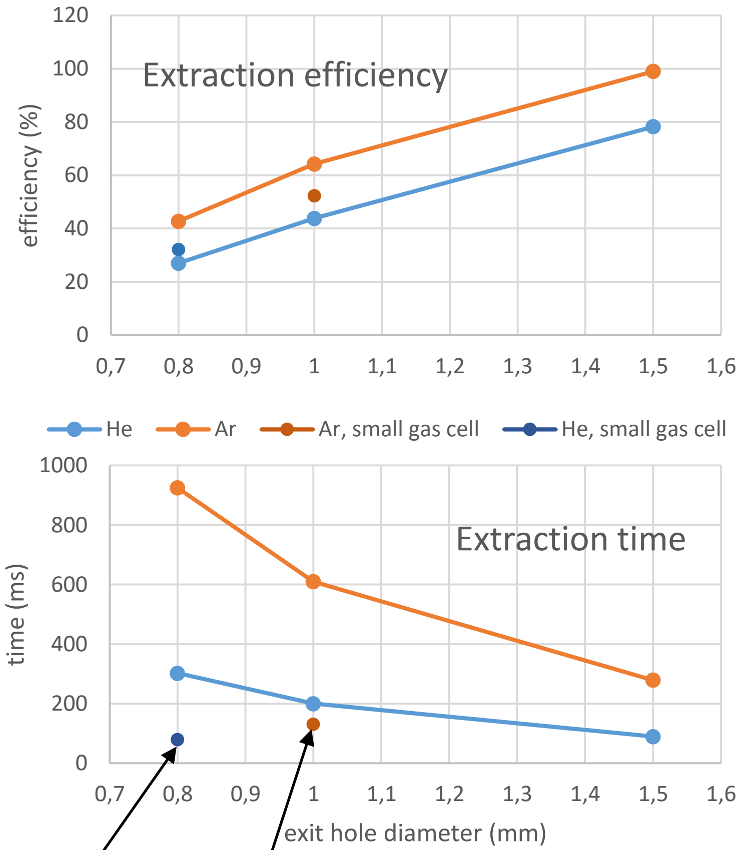






- « Small gas cell» (theoretical limit): extraction cone in front of window
- Having a bit of room on the gas injection side helps

in He 0,8 mm hole: 79 ms

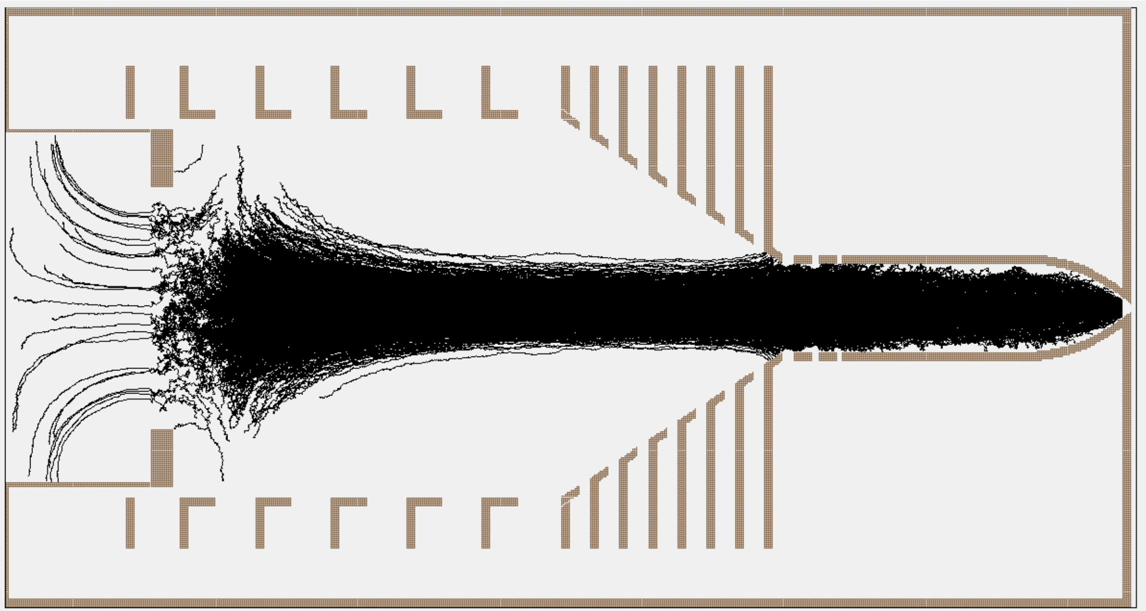
in Ar 1 mm hole: 131 ms

FRIENDS^3 gas cell with Ar

- In Wenling's work, optimization on ion cloud:

$^{133}Cs^{+}$, depth = 20 mm, σ_{depth} = 5 mm, σ_{trans} = 10 mm

- At 200 mbar:
  - Total extraction time 127 ms
  - Extraction efficiency 24%



FRIENDS^3 gas cell with Ar (SRIM distribution)

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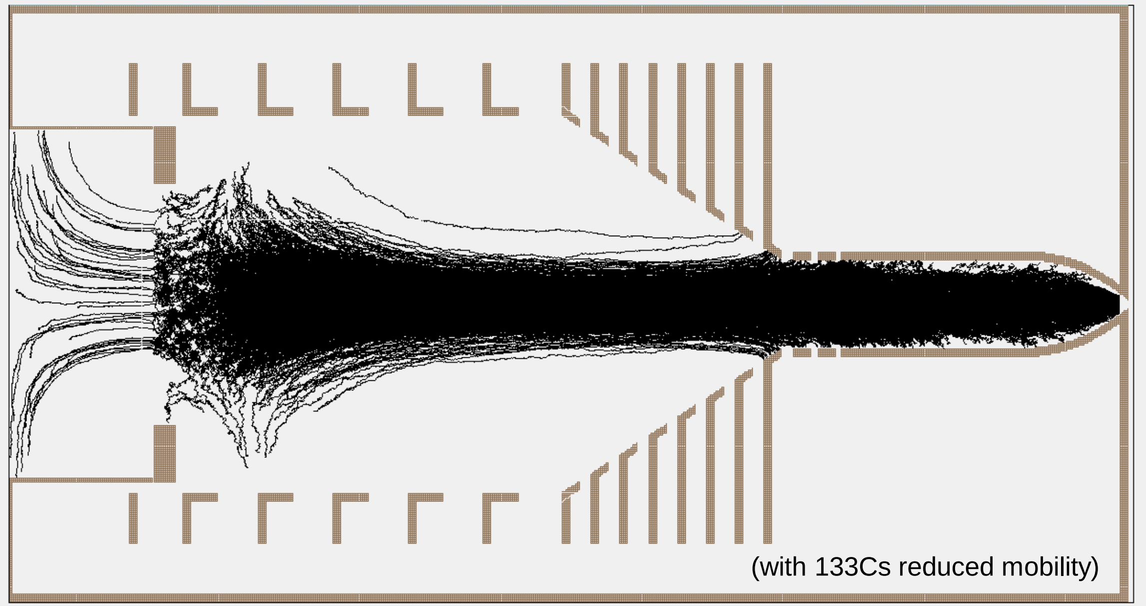
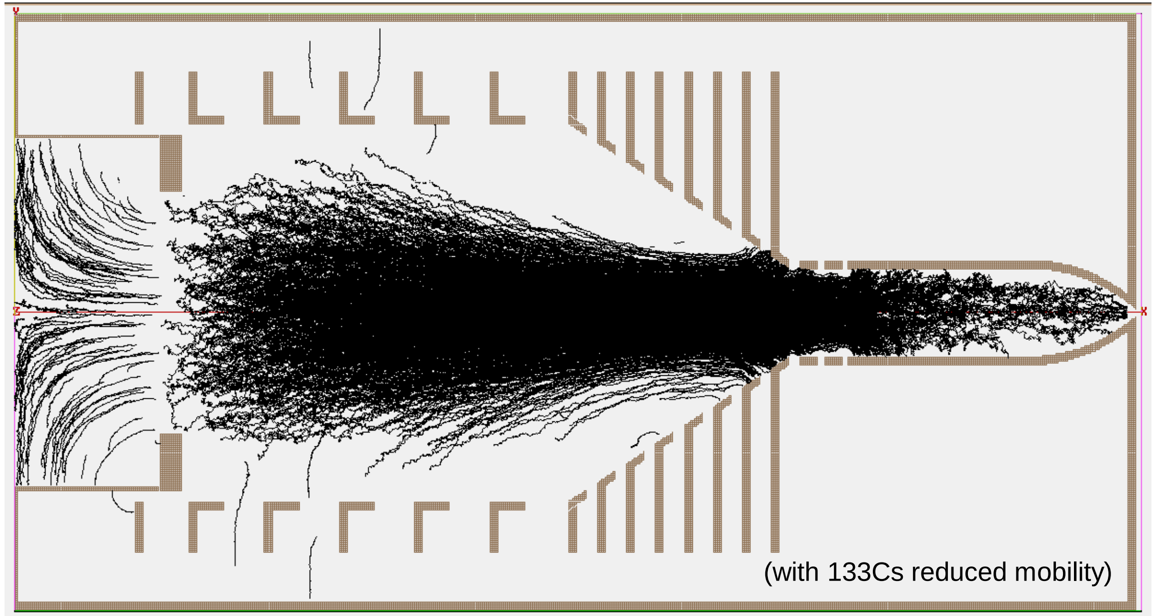
- At 200 mbar:
  - Total extraction time 127 ms
  - Extraction efficiency 24%

- Taking distribution for ^{100}Sn in 200 mbar Ar, 7µm Ti window:
  - Total extraction time 133 ms
  - Extraction efficiency 23%



FRIENDS^3 gas cell with He

- Without changing the geometry, replace Ar with He at 200 mbar
- Take ^{100}Sn distribution for 8 µm Ti
- Slighly reoptimize voltages (quick):
  - Total extraction time 22 ms
  - Total efficiency 1-2 % (major loss in exit tube, but we don't need it)



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- Take ^{100}Sn distribution for 8 µm Ti
- Slighly reoptimize voltages (quick):
    - Total extraction time 22 ms
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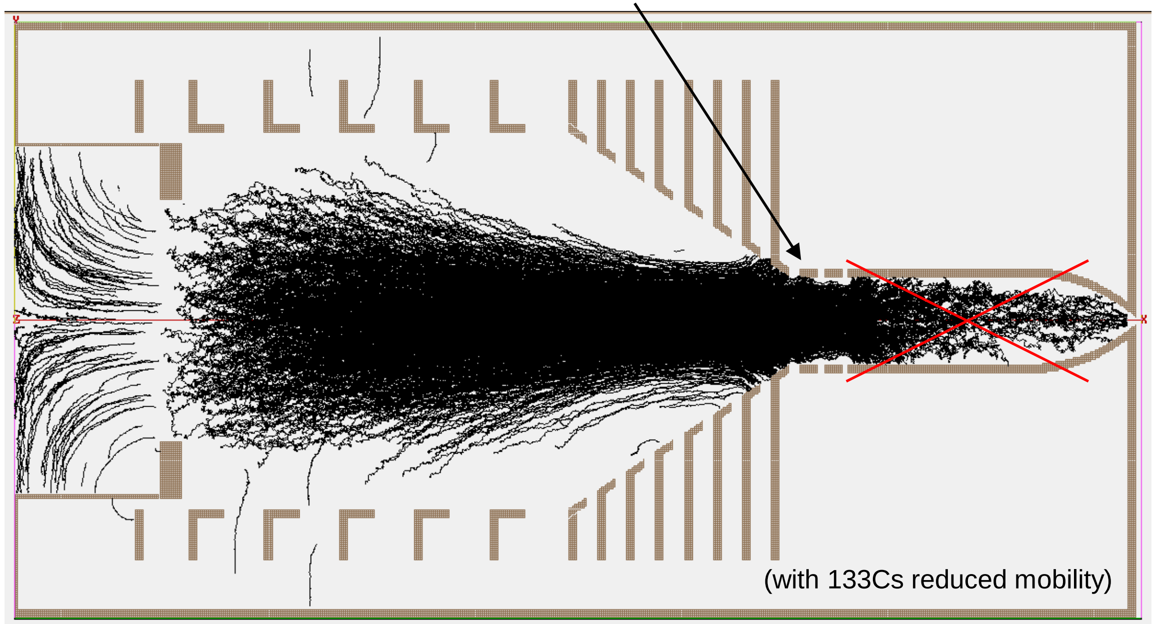
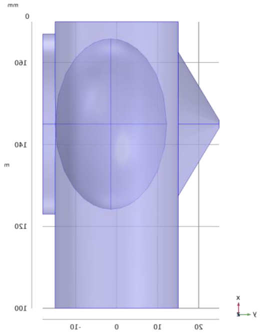
- An electrical gas cell optimized for Ar can work with He, but an RF carpet/funnel will be required at extraction.

To entrance of tube:
- Extraction time 6 ms
- Transport efficiency 38%



Conclusions



- It seems feasible to use the S^3-LEB gas cell (or similar) with He for extracting ions, but:
  - real stopping range and required pressure/window should be precisely determined.

- A minimal S^3-LEB-like gas cell gives an extraction-time limit in the 70 ms range (also considering 1,5 mm hole for Ar).

- Stopping range is a crucial aspect which should be revisited for the S^3-LEB gas cell too (the idea of a degrader too).

- FRIENDS^3 simulated design should probably be slightly increased in size even for Ar, but:
  - replacing Ar with He should be possible by adjusting window thickness and pressure and replacing the extraction tube with an RF carpet/funnel.
- …