1+/N+ method: Numerical studies and experimental measurements on SPIRAL1 charge breeder

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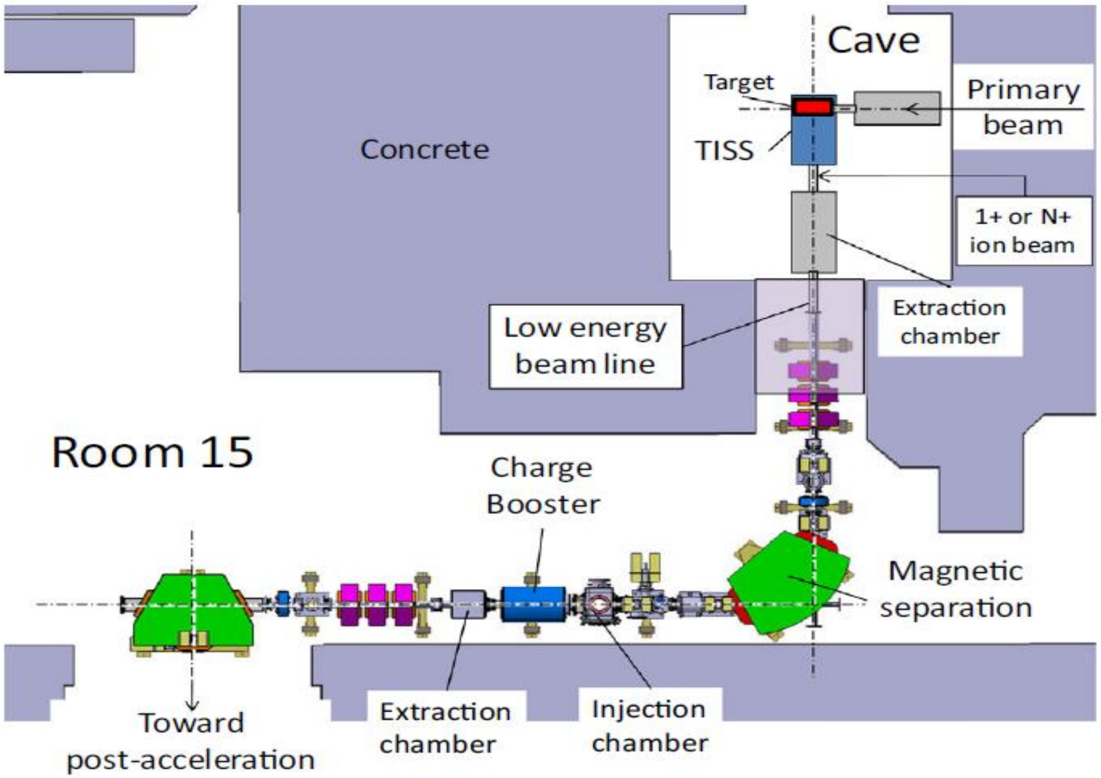
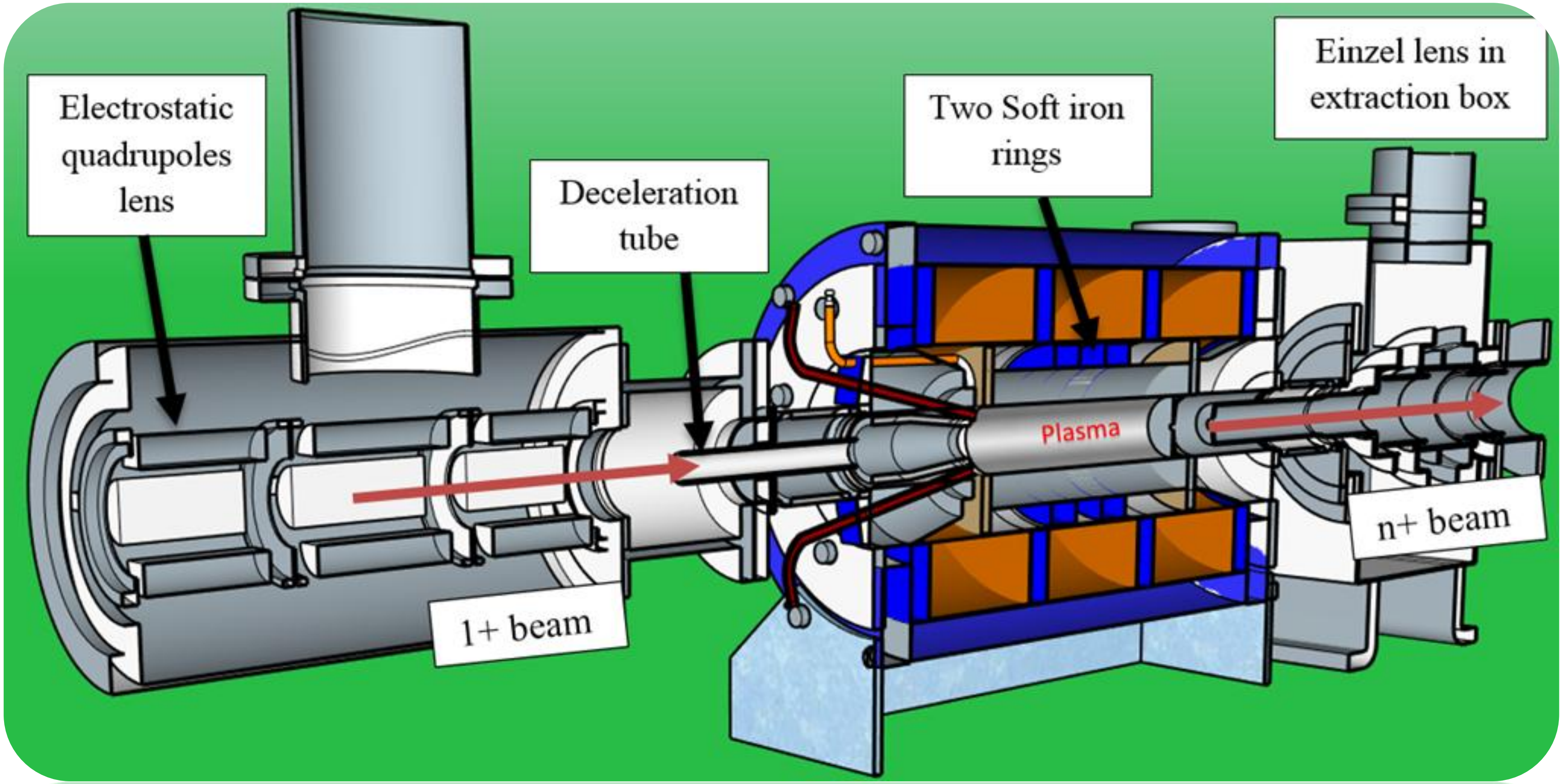
Contents

Background and Context

- At SPIRAL1, more than 30 radioactive beams mainly from gazeous elements (Ne, He, Ar, Kr, O) were delivered to nuclear experiments
- An upgrade of SPIRAL1 has been undertaken to extend the research
- 1+ beam from TISS are transported to SP1 charge breeder
- The extracted highly charged ions are mass analyzed and post-accelerated to CIME

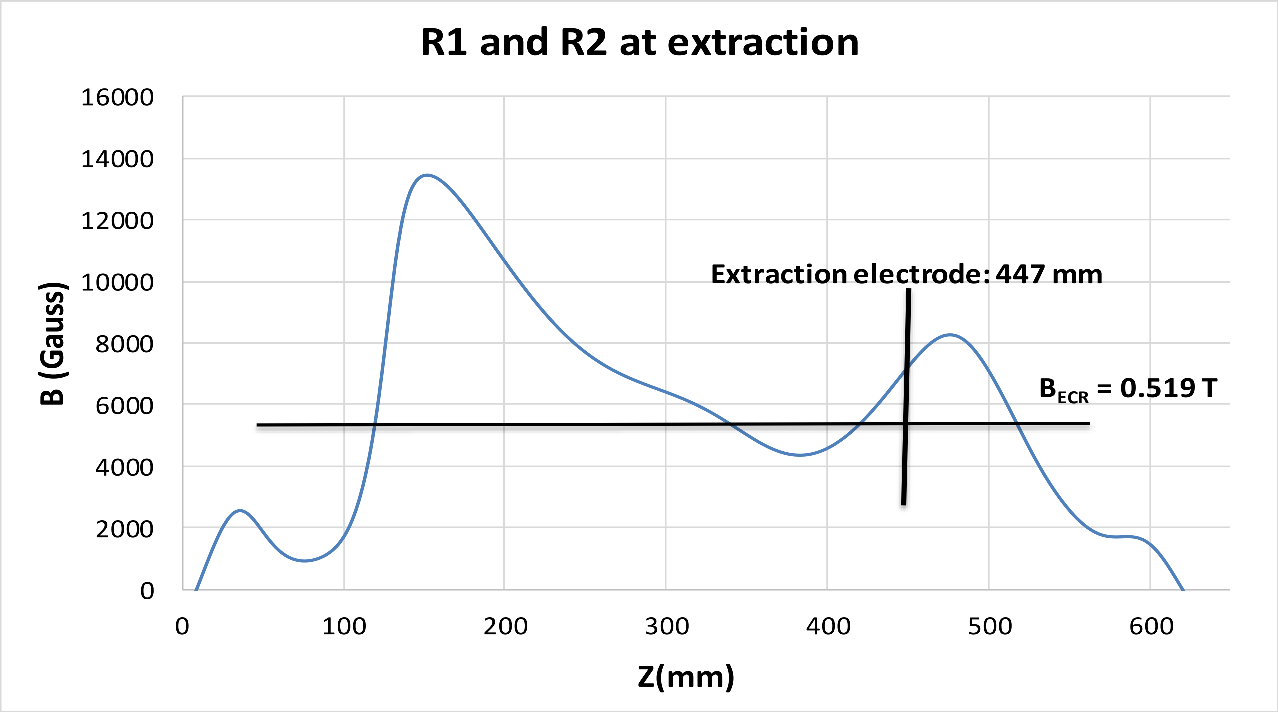


3D view of SPIRAL1 ECR charge breeder

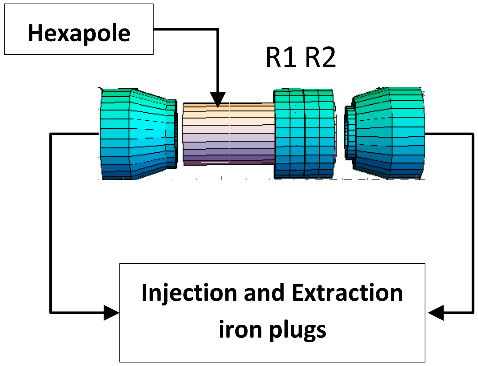


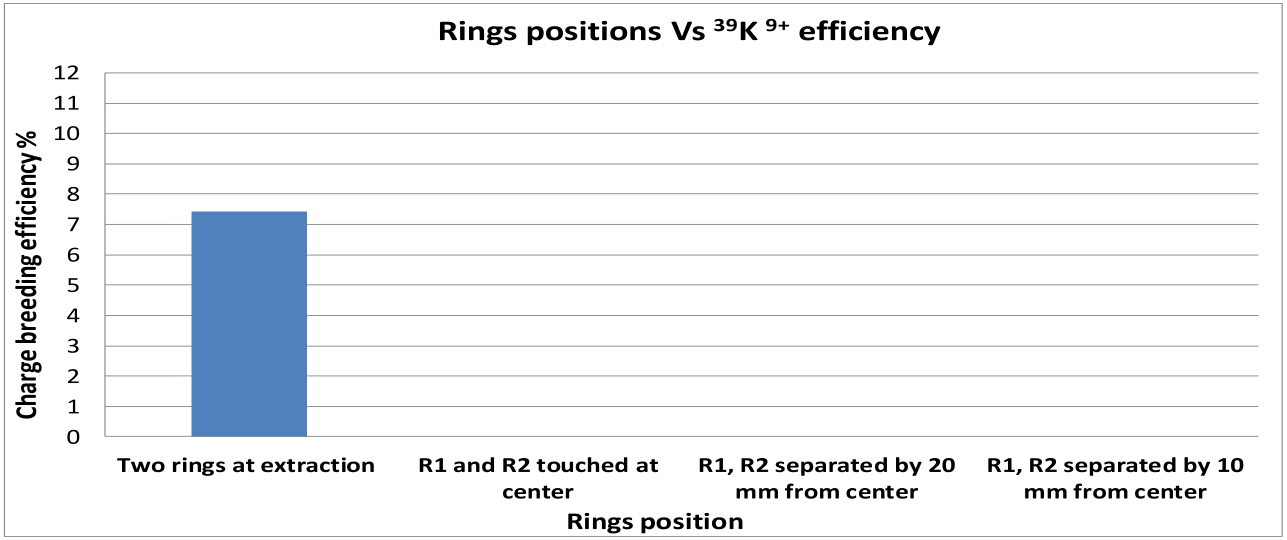
Experimental activities with SP1 charge breeder

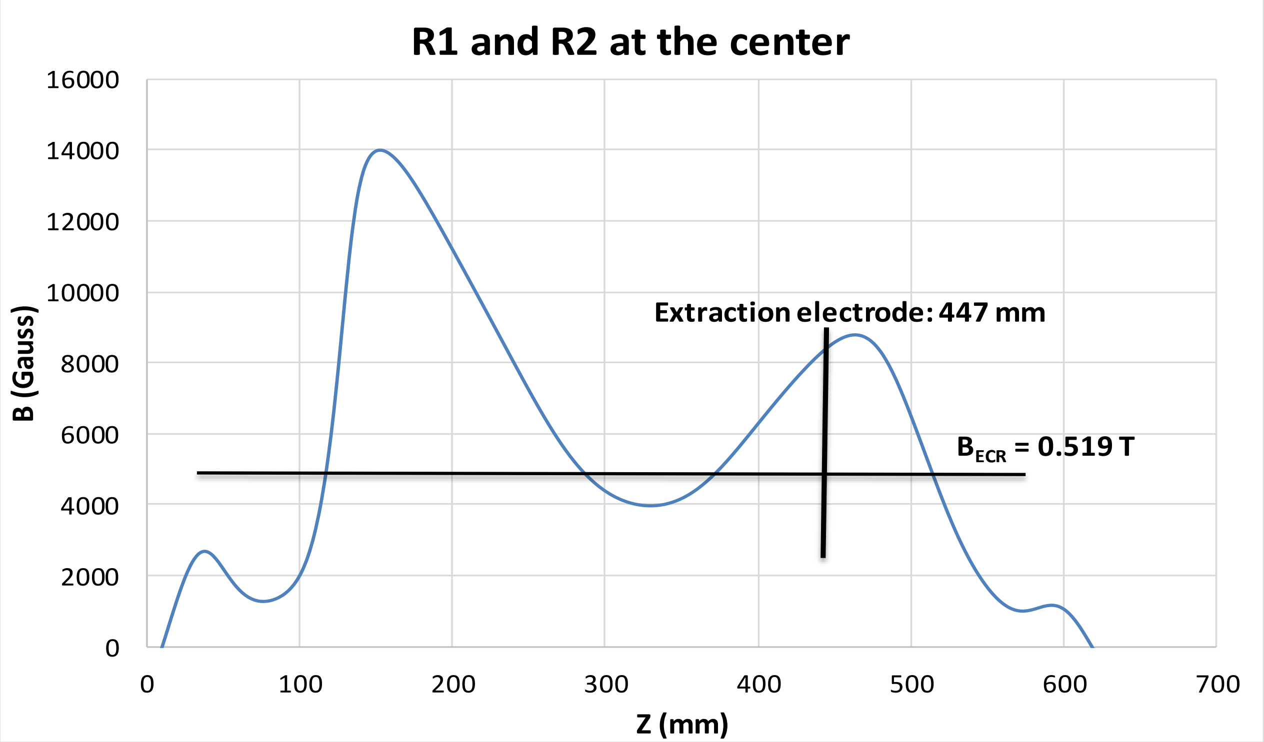
Modification of Axial Magnetic field



Center of plasma chamber = 320mm







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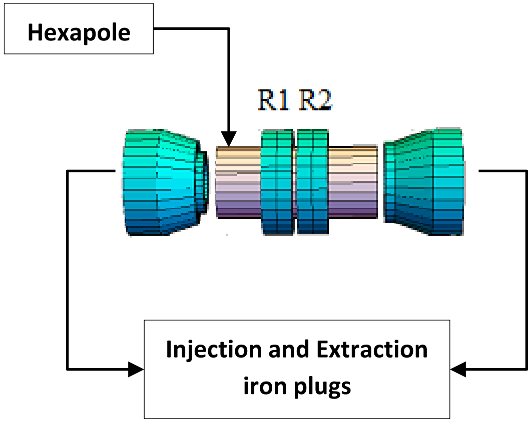

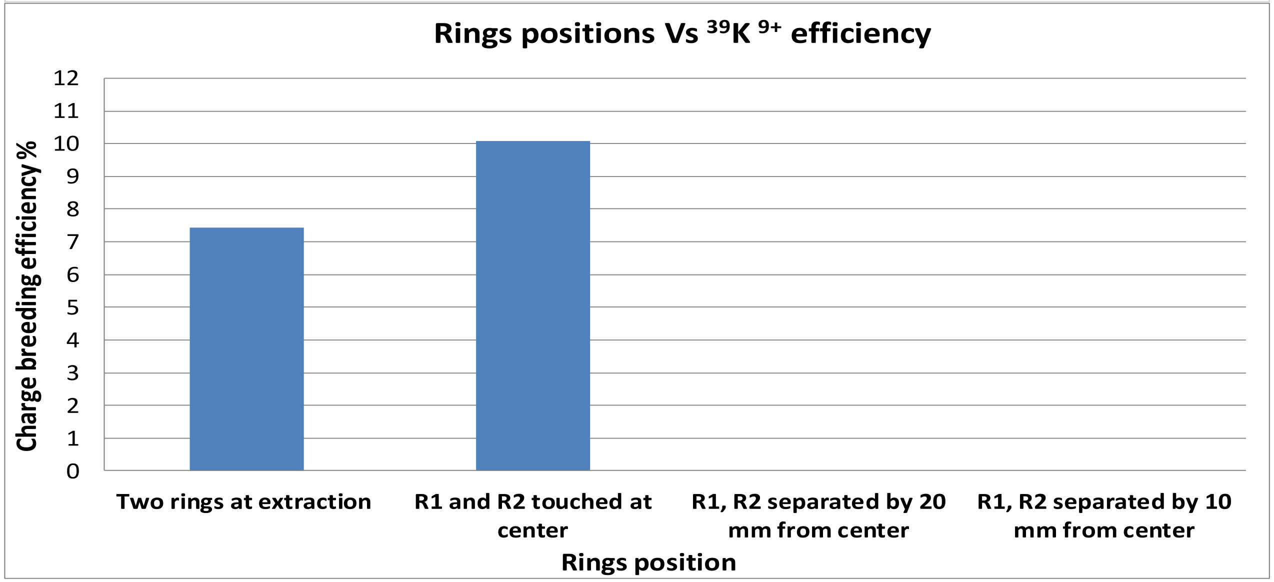

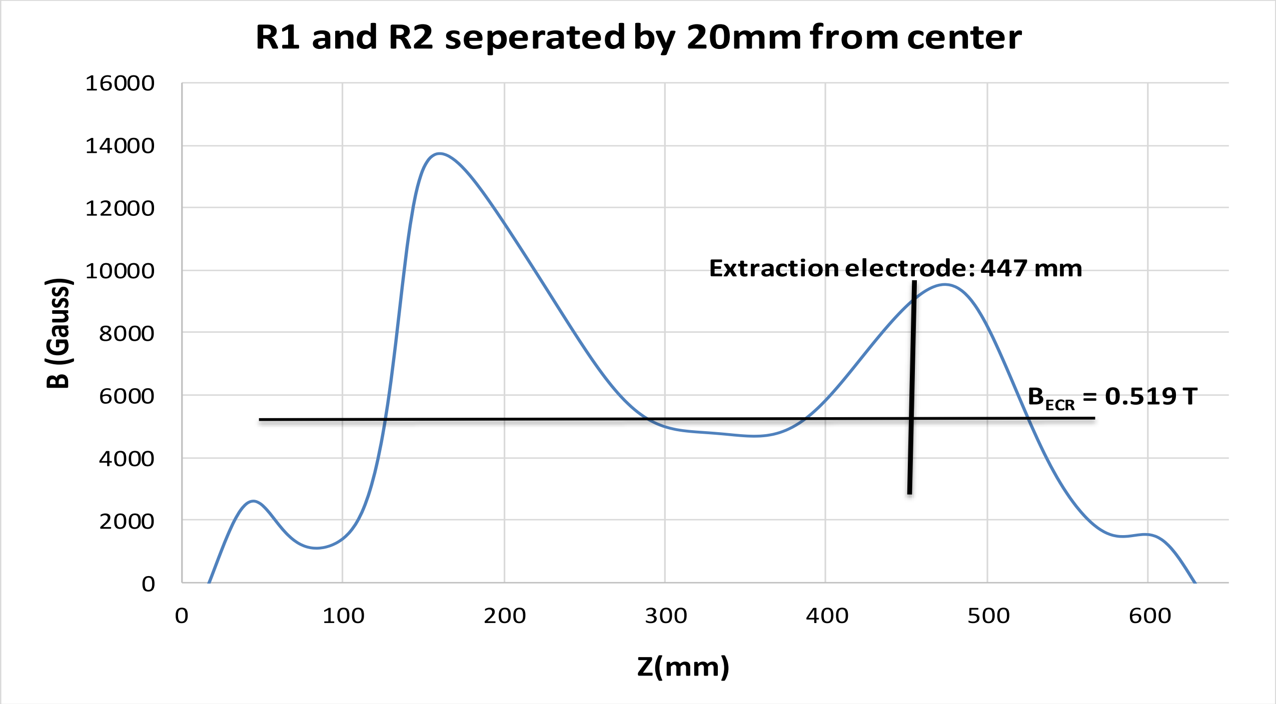

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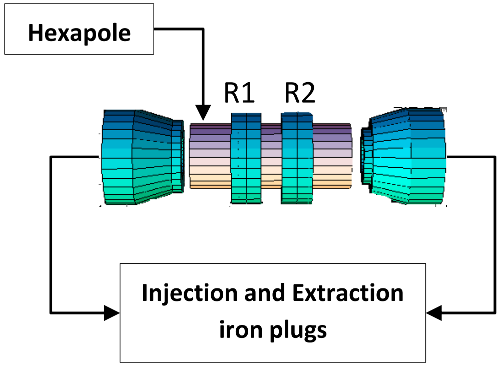

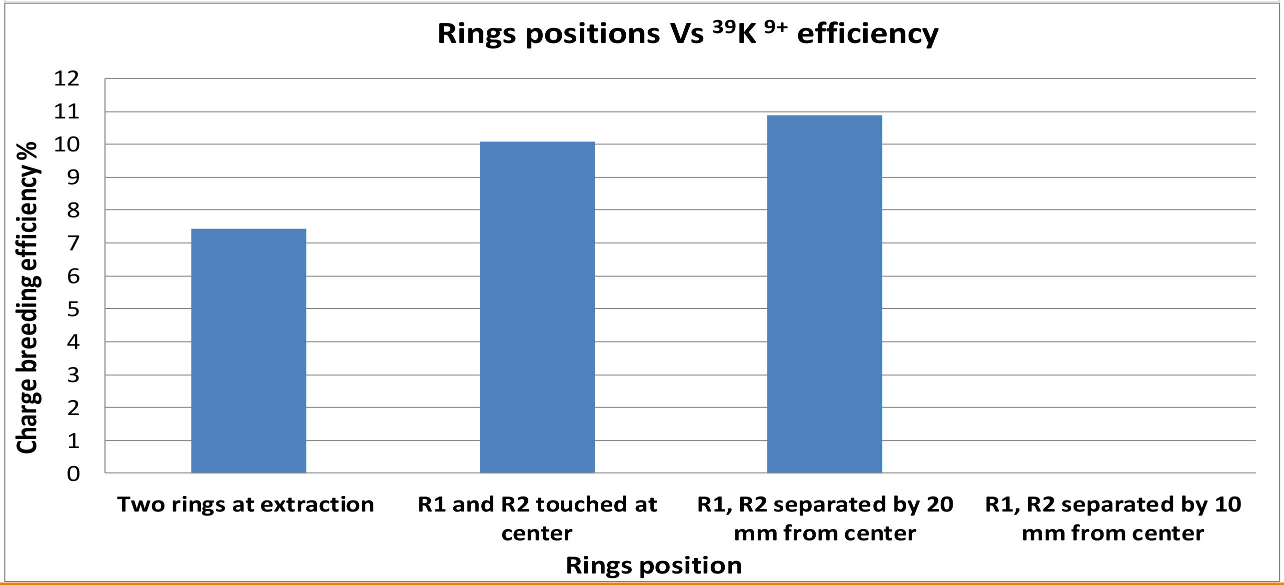

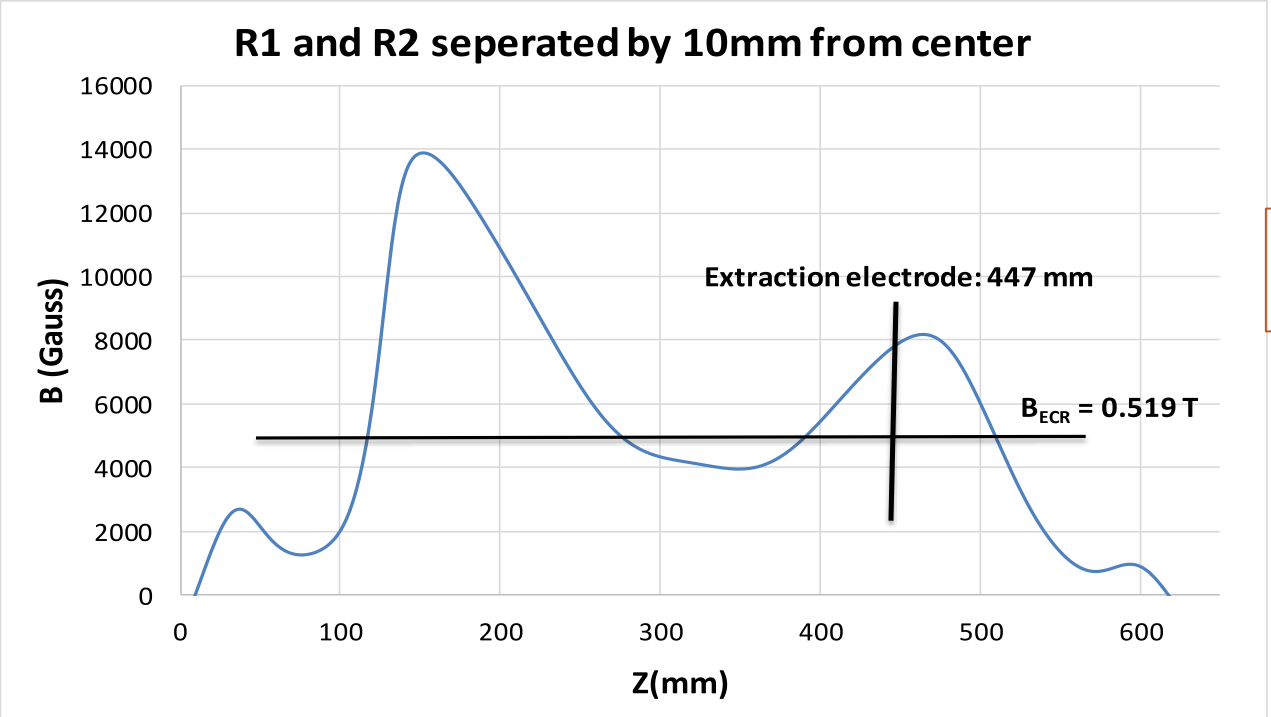

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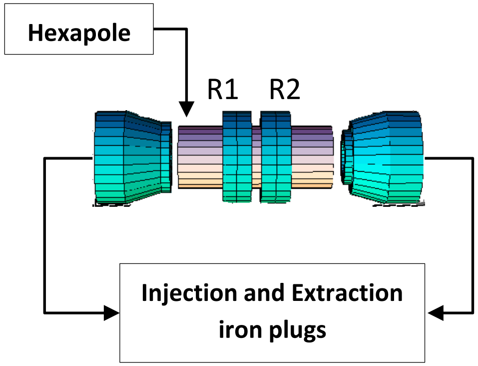
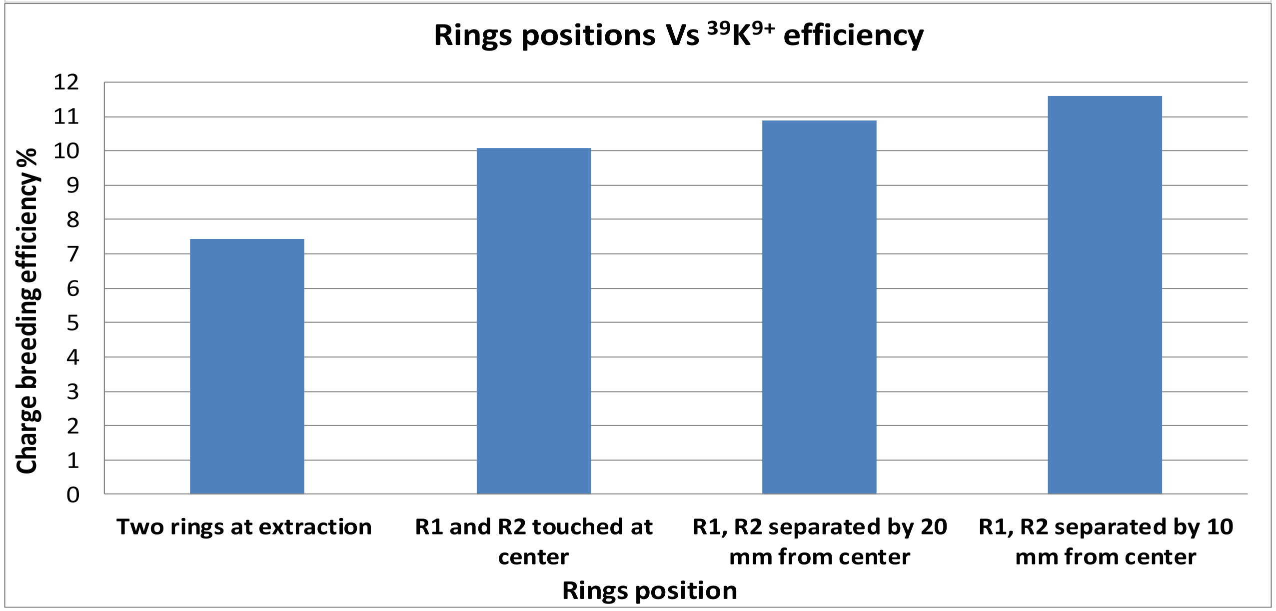




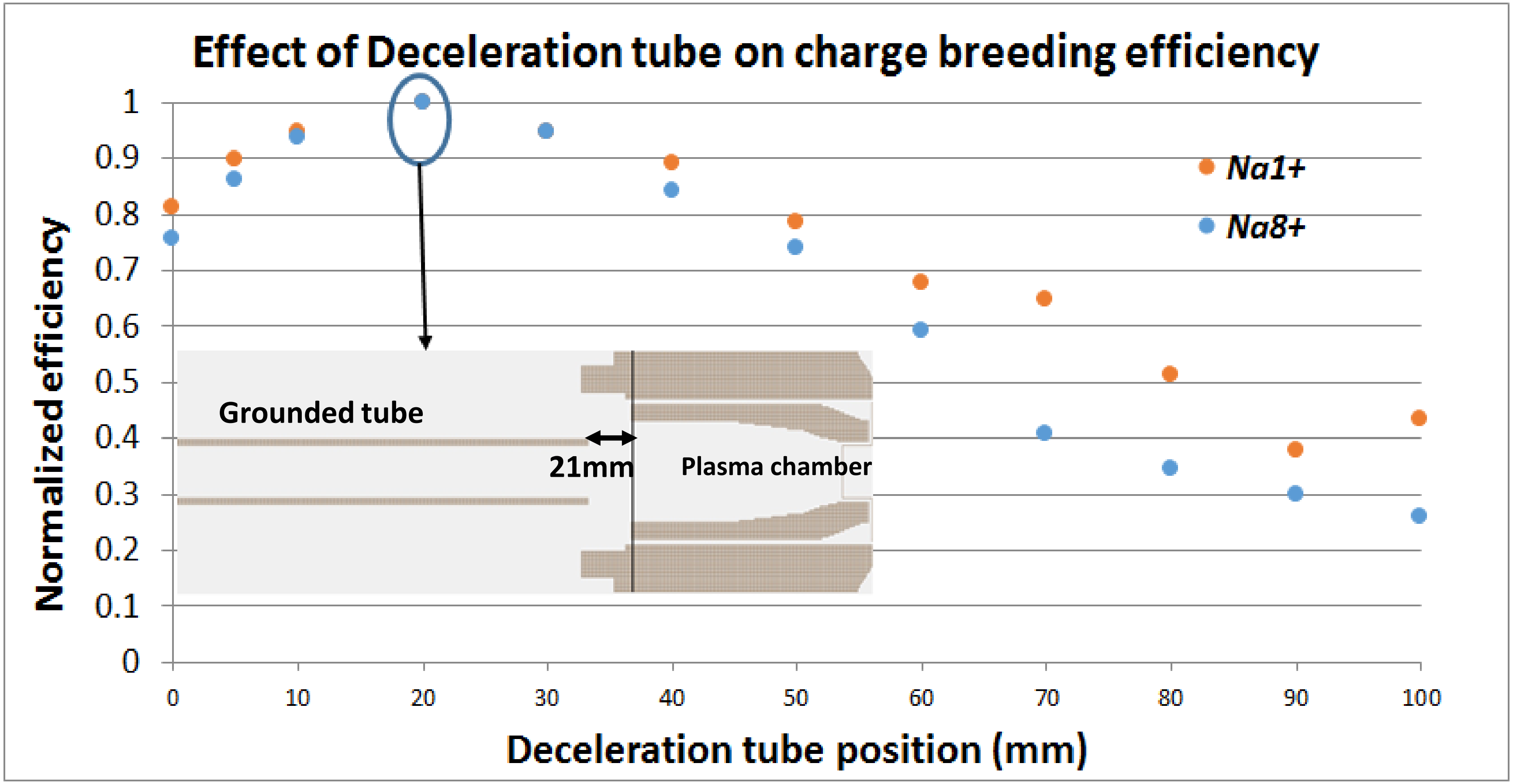
Transmission efficiencies of $^{39}K^+$ and $^{23}Na^+$

- The tuning for beam optics in LEBT has been defined by using TraceWin simulations in order to achieve high transmision efficiencies
- By turning OFF the charge breeder (no plasma, no HV), the following transmission efficiency were recorded
- For charge breeding measurements, the 1+ beam transported through charge breeder is maximized in order to minimize the losses

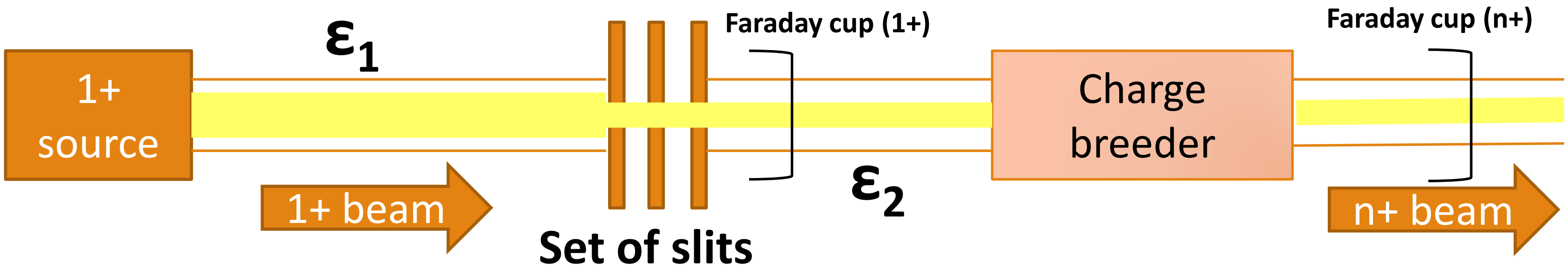
Transmission efficiencies

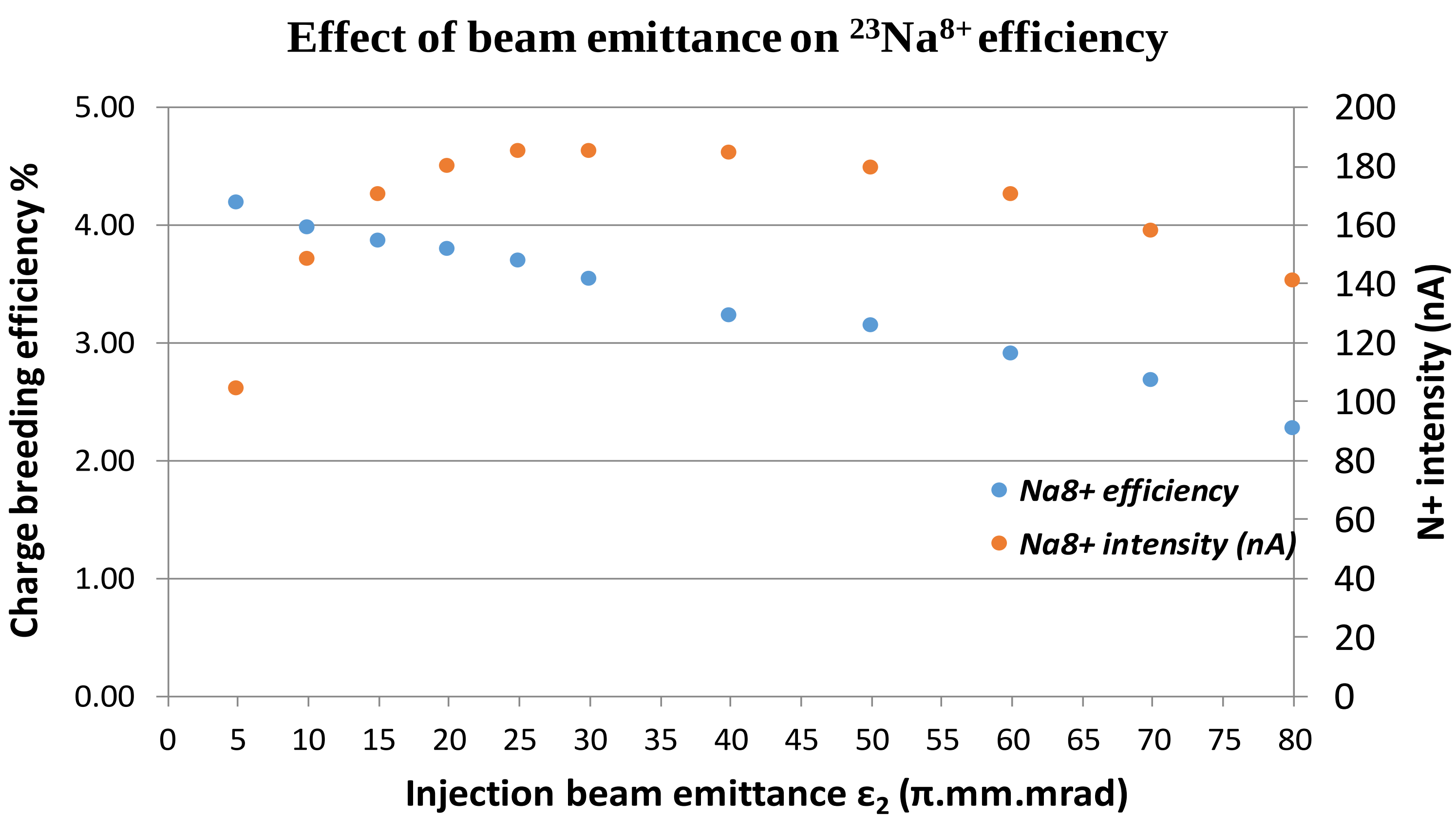
For $^{39}K^+$: 80% (10 kV with 50.π.mm.mrad)
For $^{23}Na^+$: 78% (15 kV with 50.π.mm.mrad)

Effect of deceleration tube on charge breeding efficiency



Effect of injection beam emittance on charge breeding efficiency

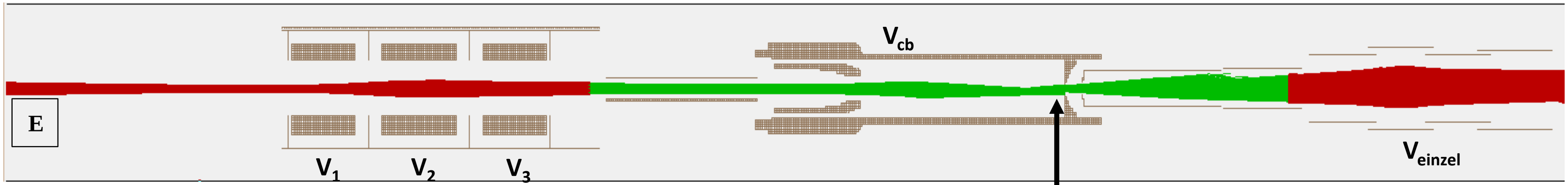




Numerical simulations on Ion transport through the charge breeder with and without plasma

Ion transport through the charge breeder without plasma

- 3D Magnetic field and potential parameters are given as an input
- Initial beam conditions at point E is defined from the experiment



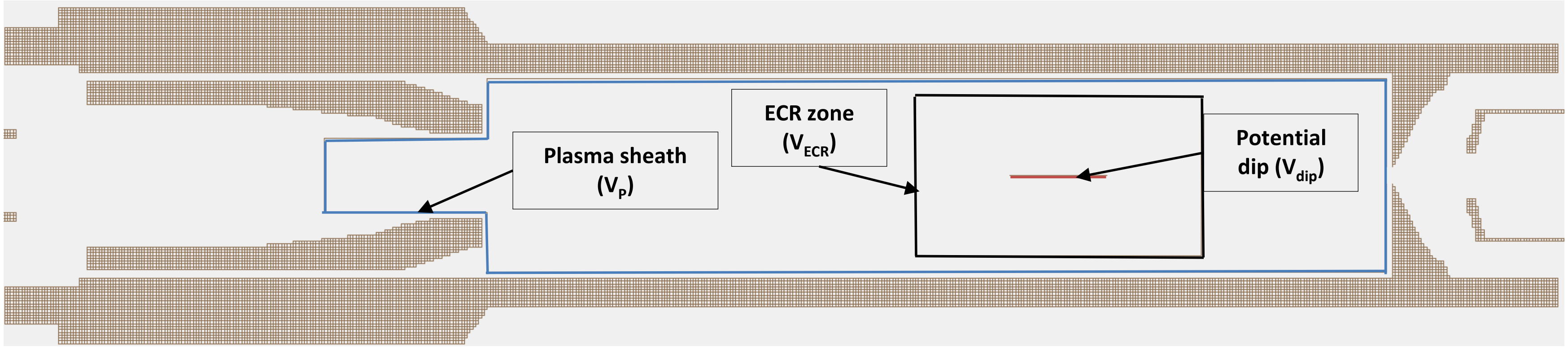
Beam Parameters	$^{39}K^{+}$	$^{23}Na^{+}$
Initial beamEmittance	50.π.mm.mrad	50.π.mm.mrad
No of simulated ions	10000	10000
Initial beam Energy (keV)	10 keV	15 keV

Ion	Simulated results	Experimental results
$^{39}K^{+}$	85%	80%
$^{23}Na^{+}$	79%	78%

- Ion losses were recorded only at extraction aperture of CB
- Losses mostly due to beam oscillations in charge breeder

Ion transport through the charge breeder with plasma

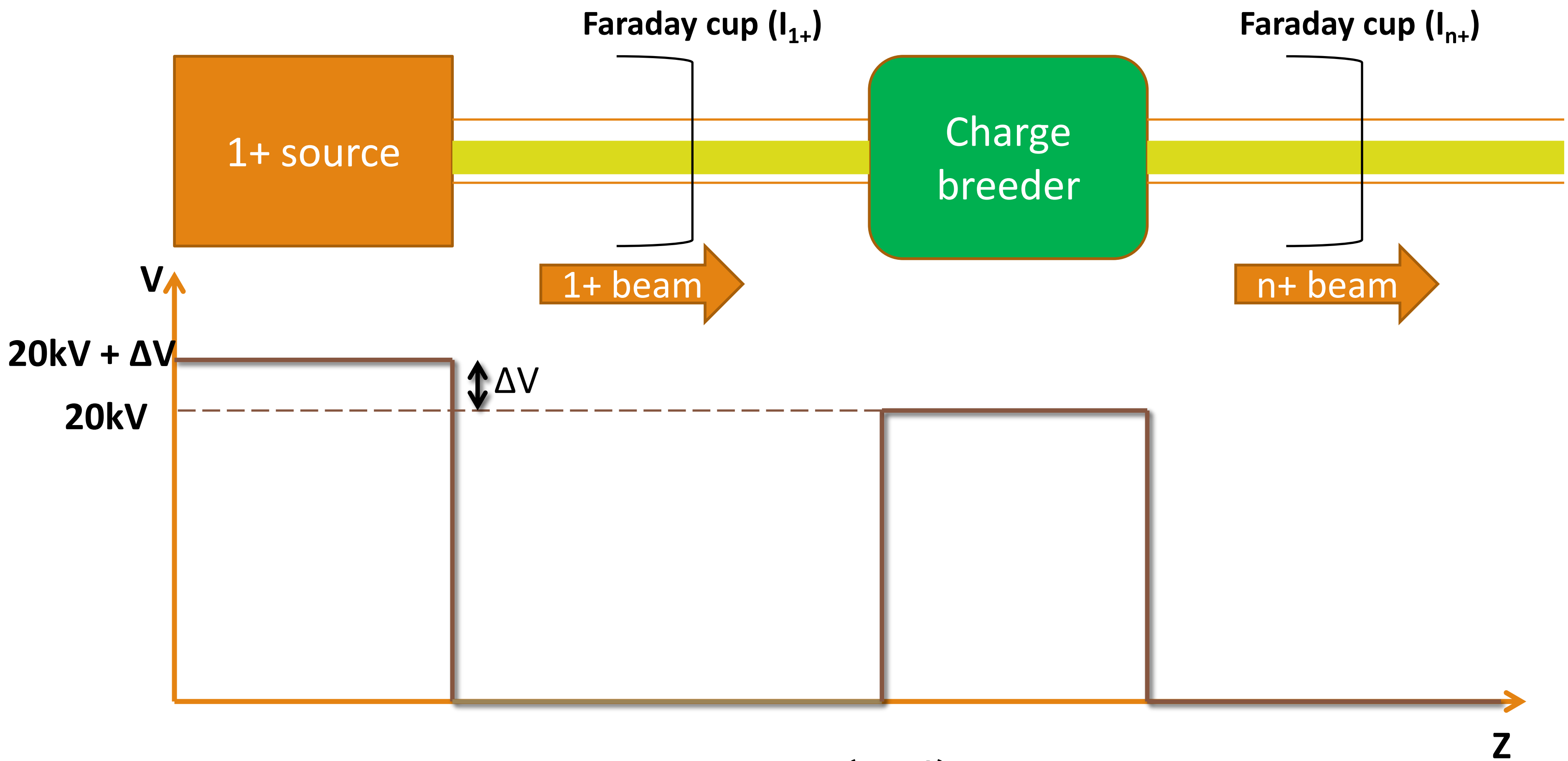
- A simplified plasma model has been introduced
- Fixed potentials are included to approximate the potential distribution in the plasma volume.
- Ion counts are monitored after the extraction system



A few assumptions were considered in the simulation

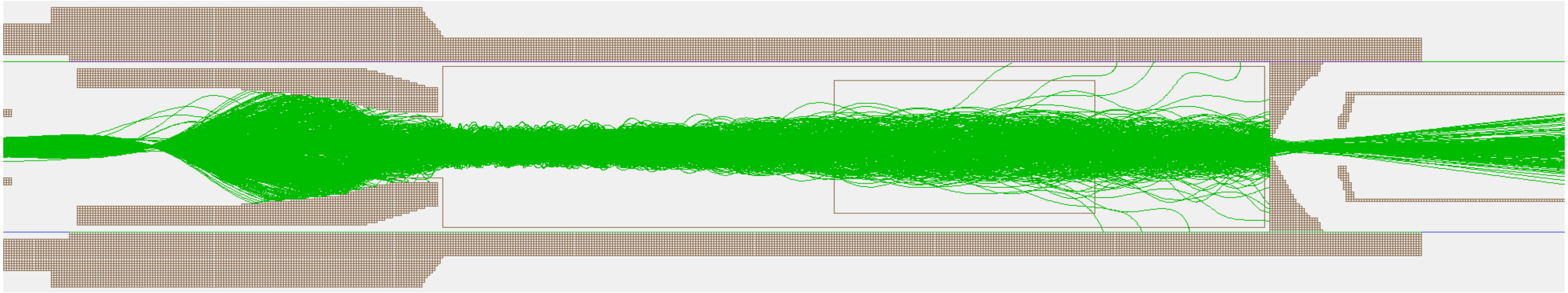
- $V_p = V_{ECR}$ in all cases to confine the potential dip
- Model does not include collisions or interactions
- Potential applied to plasma sheath is 10V

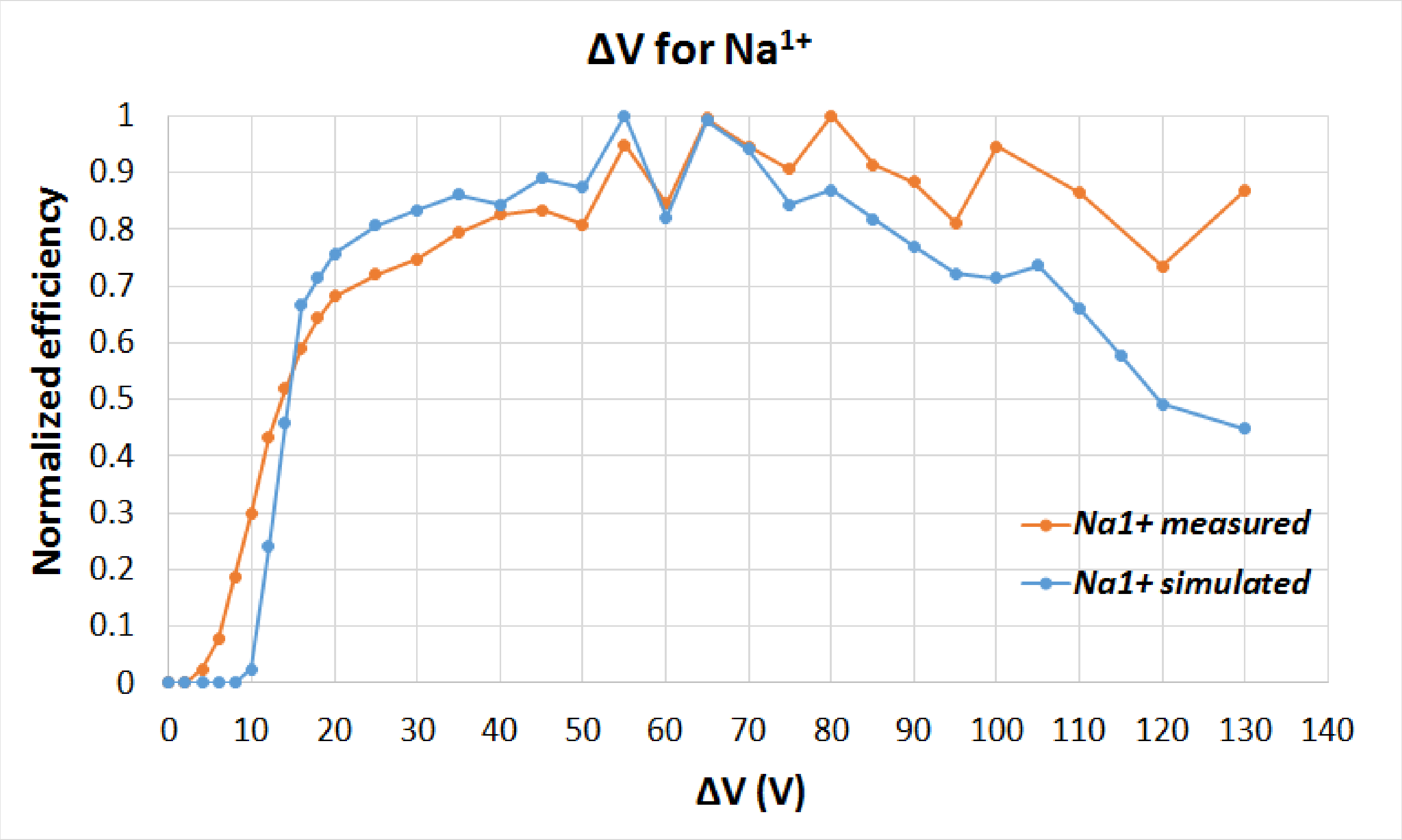
Potential difference between 1+ source and charge breeder (ΔV)



$$\eta(\%) = \frac{I_{n+}(pnA)}{I_{1+}(pnA)} \times 100$$

Normalized efficiencies of $^{23}Na^{+}$ as a function of ΔV.

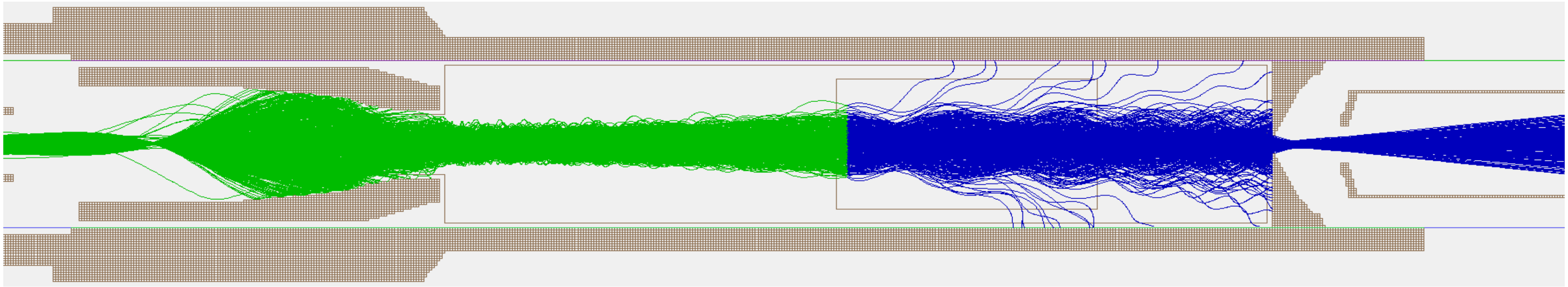


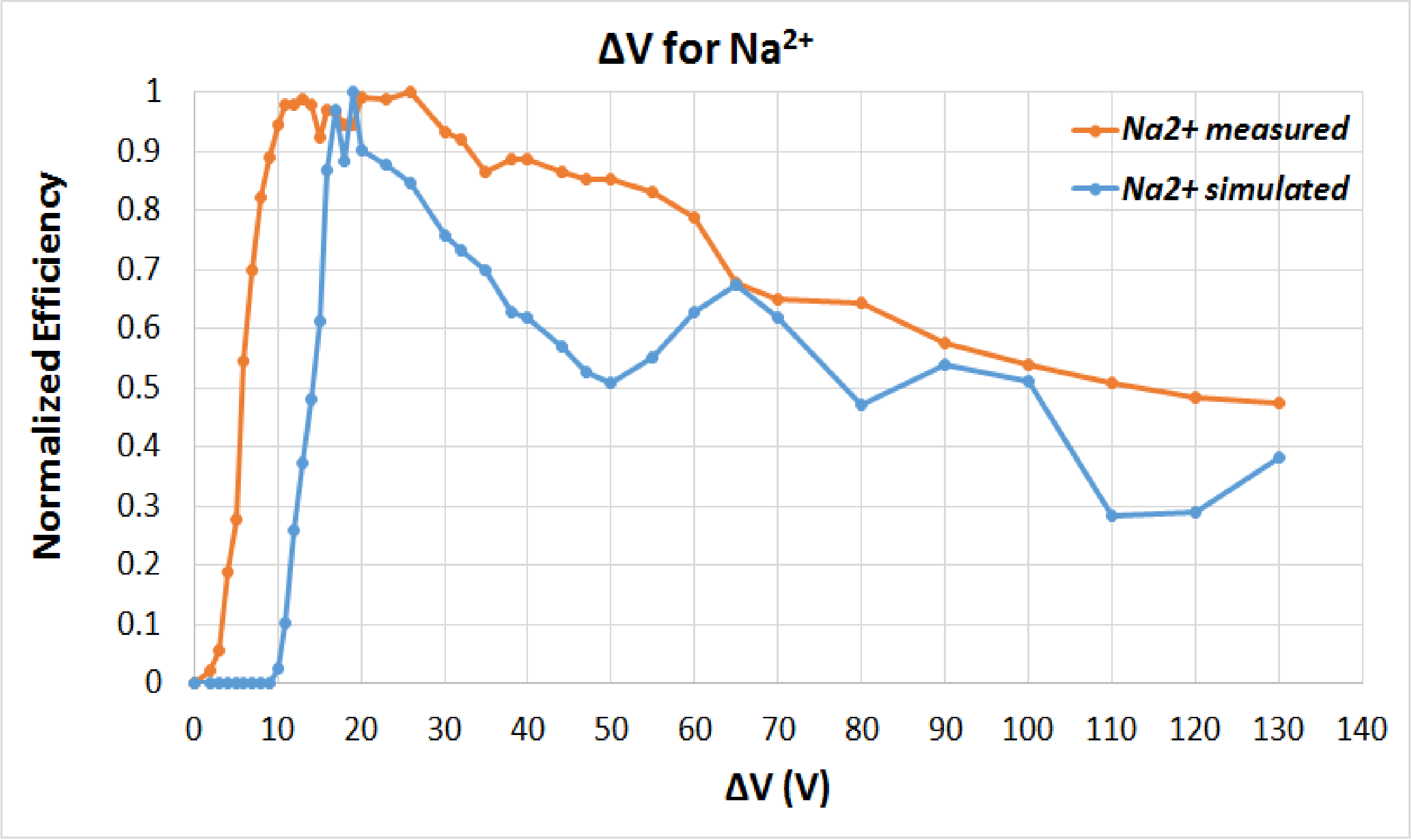


Experiment = 28%
Simulation = 27%

Maximum 1+ at
ΔV = 55V

Normalized efficiencies of $^{23}Na^{2+}$ as a function of ΔV.





Experiment = 0.9%
Simulation = 21%

Maximum 2+ at
ΔV = 19V

Perspectives

- Simulated model will be improved
- to measure charge breeding efficiency for Mg and K using He and O_2 buffer gas
- The axial field modifications will be applied on light ions
- Combined numerical simulations will be performed with MCBC (Monte Carlo Charge Breeding Code) and SIMION to determine the CB parameters which influences 1+ capture

Thank you for the attention

Charge breeding for Na (He buffer gas)

ION	Charge breeding efficiency
$^{23}Na^{2+}$	0.82%
$^{23}Na^{7+}$	3.23%
$^{23}Na^{8+}$	3.57%
$^{23}Na^{9+}$	1.2%