EXPERIMENTAL ACTIVITIES WITH THE LPSC CHARGE BREEDER IN THE EUROPEAN CONTEXT

T. Lamy
for the collaboration

P. Delahaye, L. Maunoury – Caen, France

J. Choinski, L. Standylo – Warsaw, Poland

A. Galatà, G. Patti – Legnaro – Catania, Italy

H. Koivisto, O. Tarvainen, Jyvaskyla – Finland

T. Lamy, J. Angot, T. Thuillier - Grenoble france

Context and purpose

Accelerated RIB's with charge breeders in Europe

SPIRAL2 (RIB's phase 2 stopped)
Upgrade SPIRAL1 (ECRIS CB)

SPES (ECRIS CB)

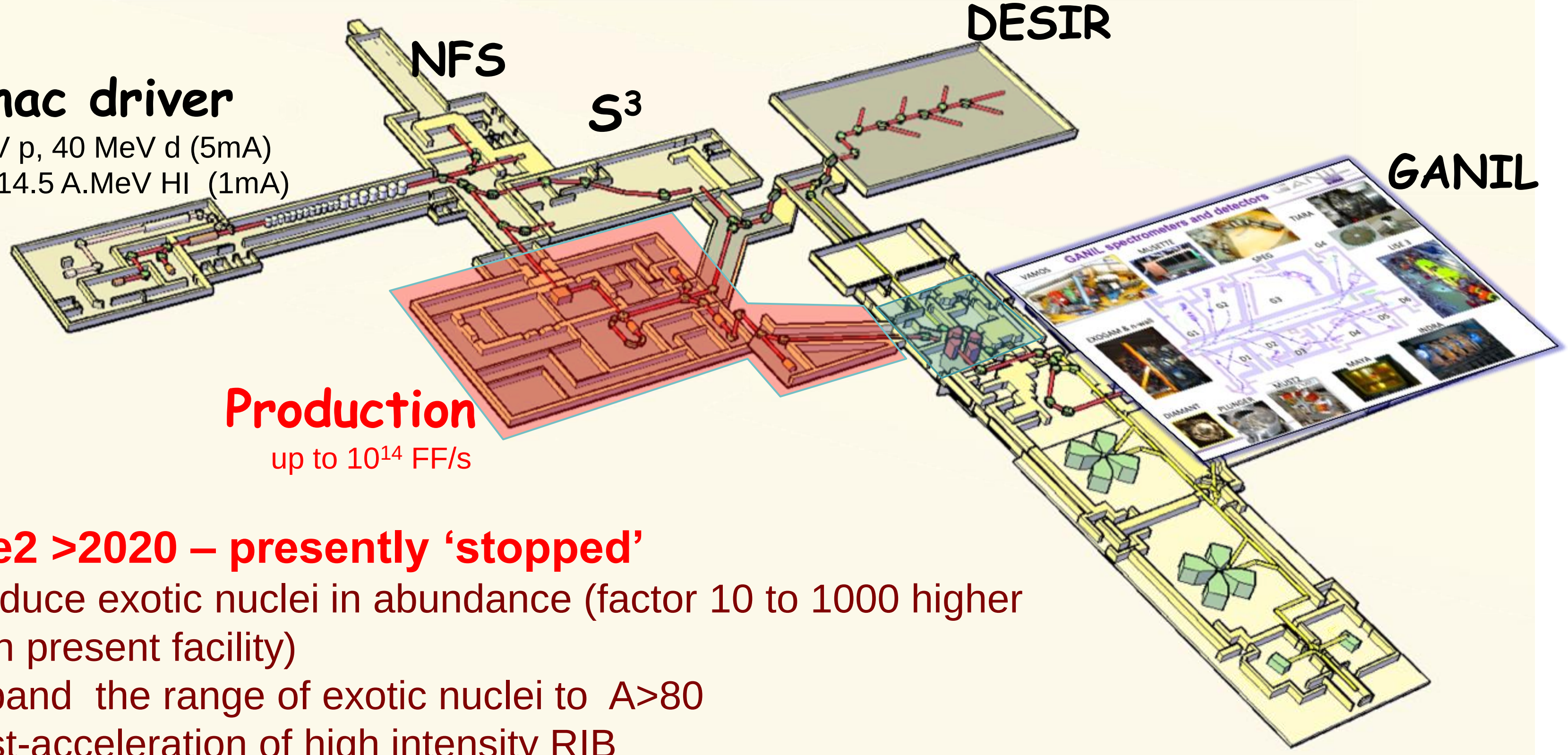
HIE ISOLDE (EBIS)

…EURISOL (possibly ECRIS + EBIS CB's in the far future)

R&D activities suported

Charge breeders in Europe

SPIRAL2



Phase2 >2020 – presently ‘stopped’

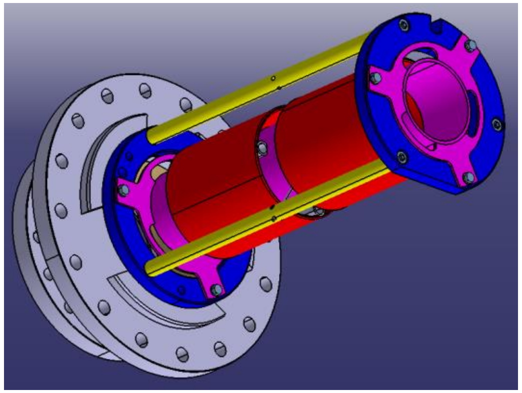
- Produce exotic nuclei in abundance (factor 10 to 1000 higher than present facility)
- Expand the range of exotic nuclei to A>80
- Post-acceleration of high intensity RIB

LPSC charge breeding activities for SPIRAL2

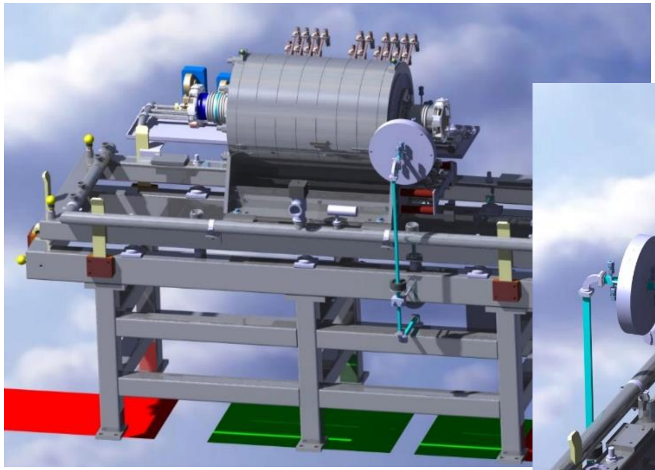
SPIRAL2

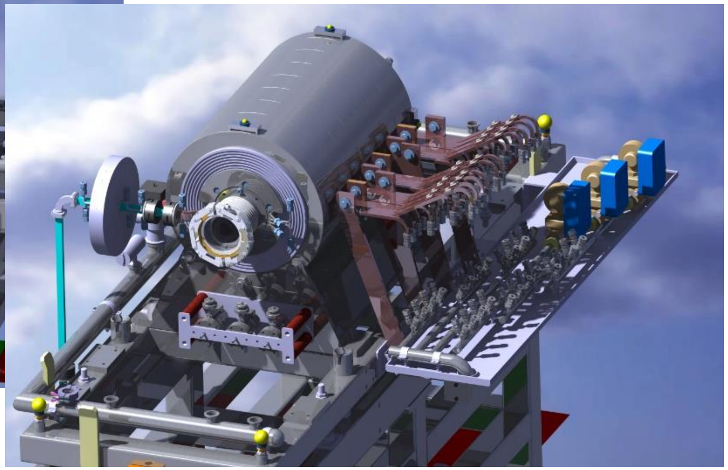
Mechanical design to

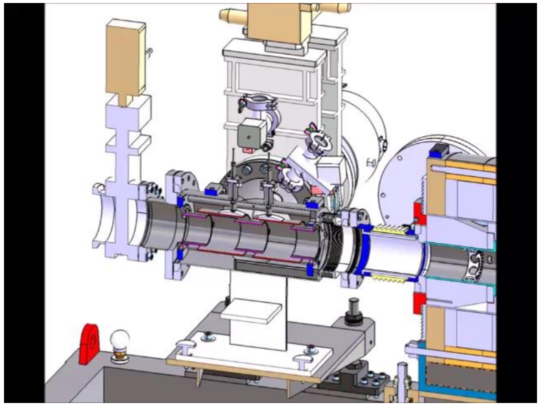
- Reduce disassembly time (radioprotection « **A**s **L**ow **A**s **R**easonably **A**chievable” principle)
- Take in account troubleshooting procedure of contaminated parts
- Guarantee precise charge breeder alignment



Define operating conditions

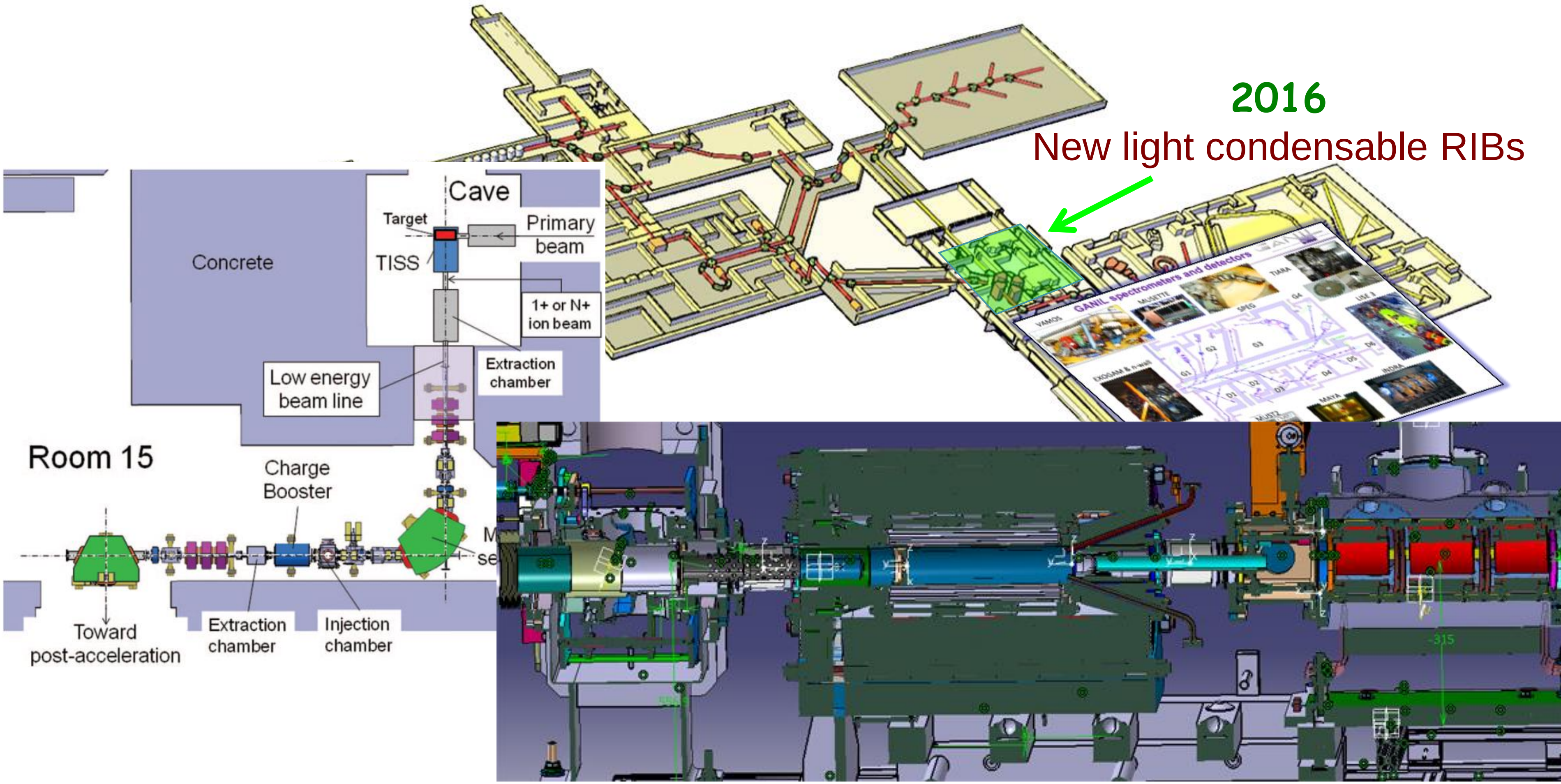






Charge breeders in Europe

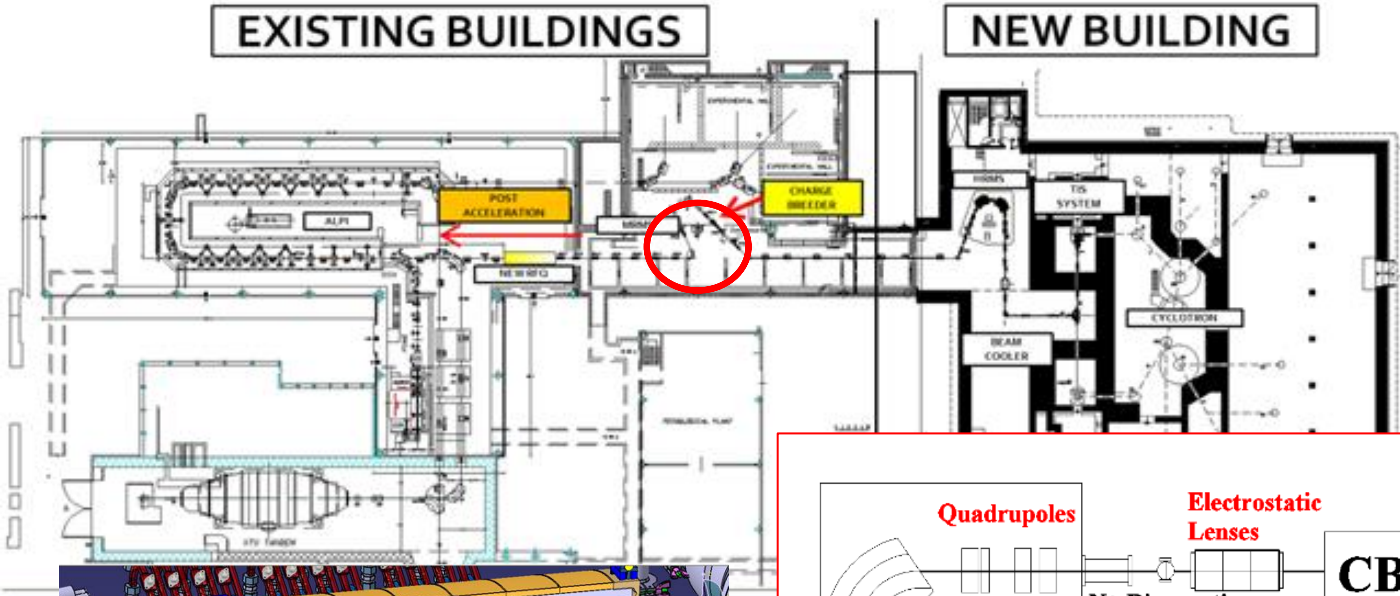
SPIRAL1 upgrade

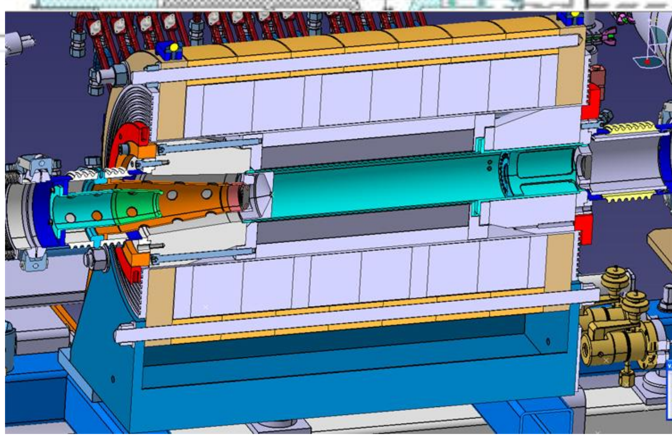


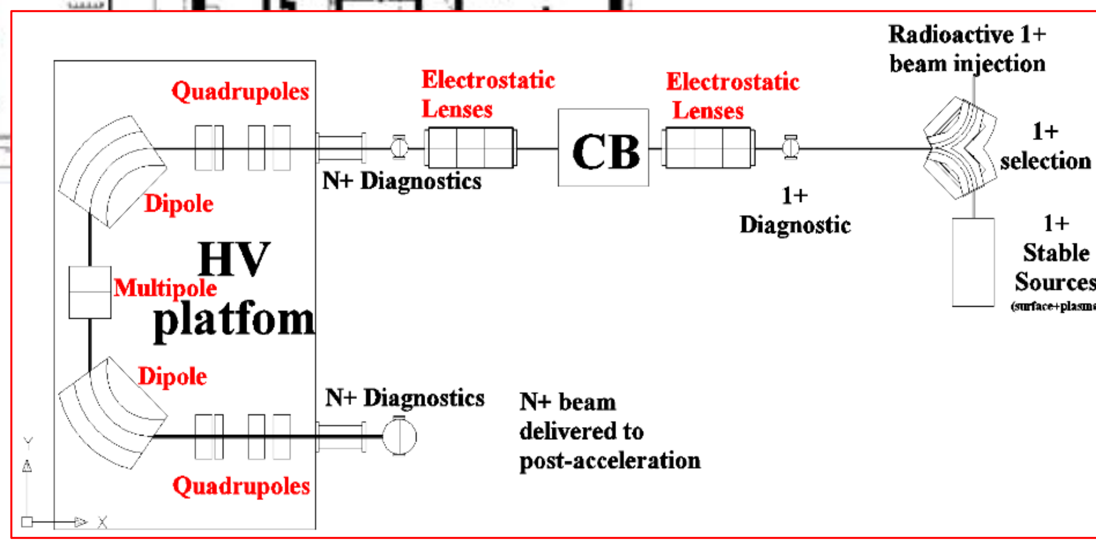
Qualification to be performed on the LPSC test bench April-September 2015

Charge breeders in Europe

SPES – INFN - LNL



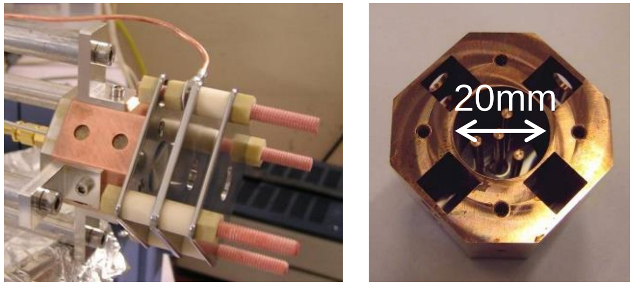




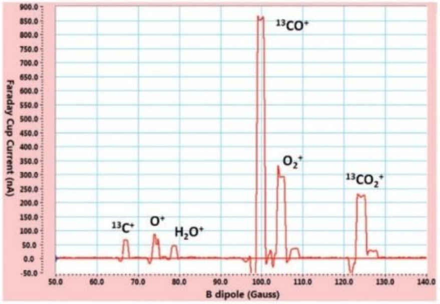
LPSC just began the construction, delivery April 2015

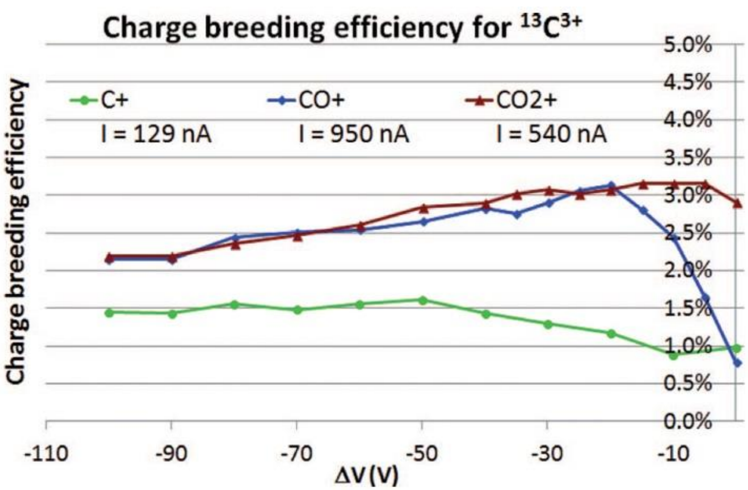
LPSC charge breeding activities for SPIRAL1 upgrade

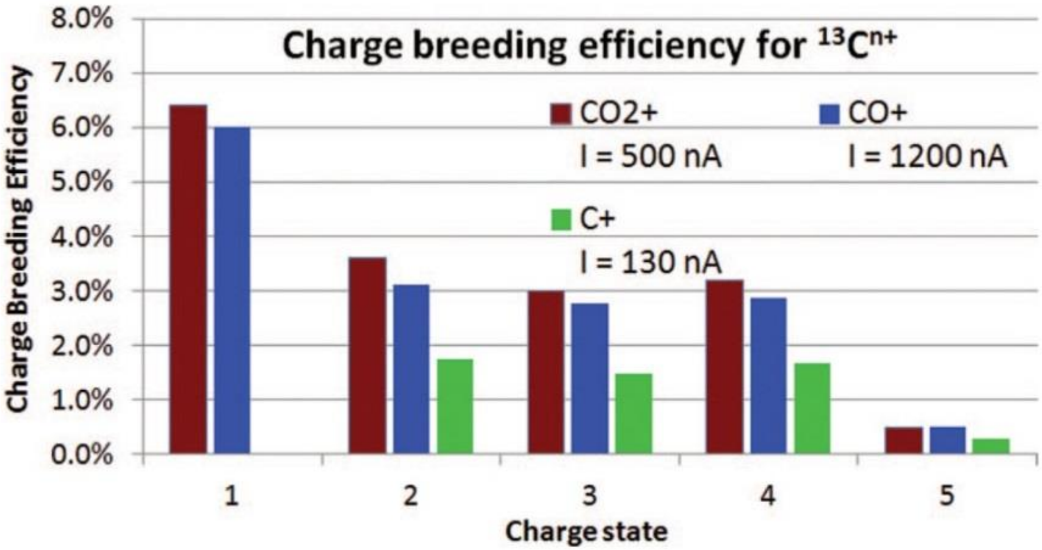
Production of charge bred carbon ions from CO_2^+, CO^+ and C^+ injection



2,45 GHz COMIC source







Rev. Sci. Instrum. 85 , 02A504 (2014)
Future carbon beams at SPIRAL1 facility: Which method is the most efficient?
L. Maunoury, P. Delahaye, J. Angot, M. Dubois, M. Dupuis, R. Frigot, J. Grinyer, P. Jardin, C. Leboucher and T. Lamy

European collaboration for charge breeding R&D

EMILIE 2012 - 2015

"Enhanced Multi-Ionization of short-Lived Isotopes at EURISOL"

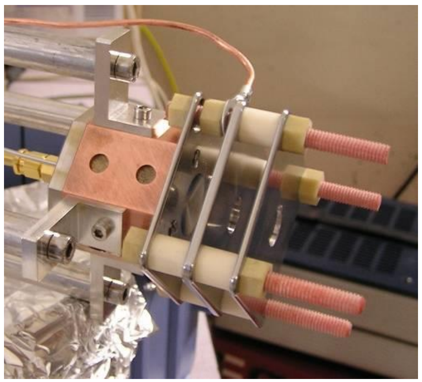
WP1	Management	France, Italy
WP2	Debuncher simulation, design, construction and test /CW EBIS test	France, Finland
WP3	**Optimization of the breeding efficiency of the PHOENIX booster** **Wall recycling and reduction of stable background in the PHOENIX booster** **Reproducibility of the performances of the PHOENIX booster**	**Italy, France, Finland, Poland**

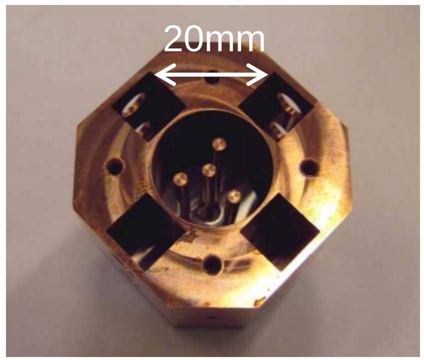
- 1+ ion source developments
- Extensive and accurate experiments to evaluate transmission, capture, charge Breeding efficiency and time for Ar, Kr, Na, Rb, Cs...
- Influence of pressure, support gas flux, fine frequency tuning, double frequency heating, magnetic field...

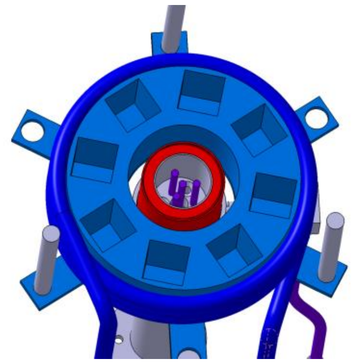
Wall recycling from 1+ sources (hot COMIC source)

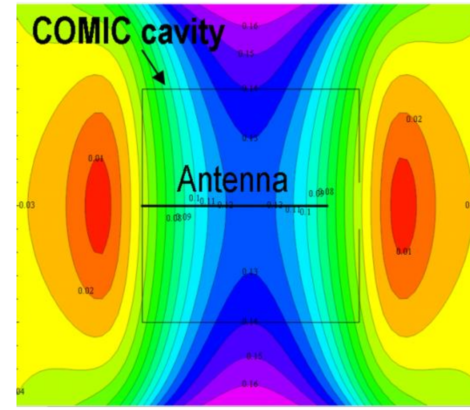
Temperature expected 650°C

- 1+ alkali ion beams with high stability and low emittance
- A second version will be developped to reach 1200 °C



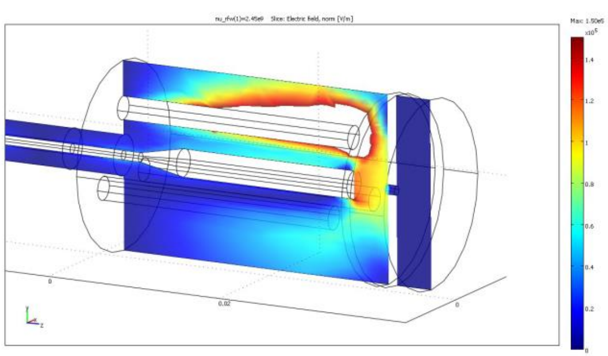




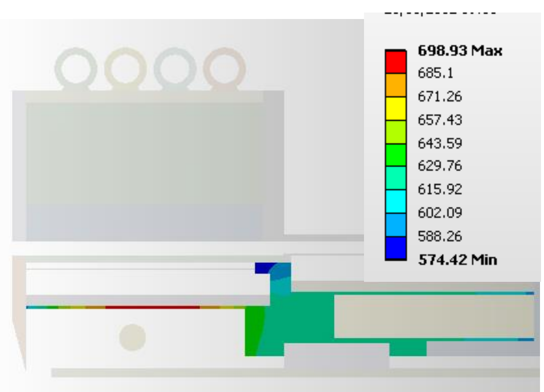


B simulation with RADIA - Mathematica

HF coupling optimization HFSS and COMSOL



Thermal simulation with ANSYS feedback to the mechanical design



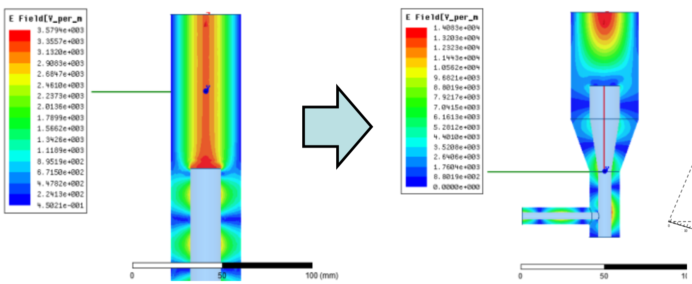
To be tested

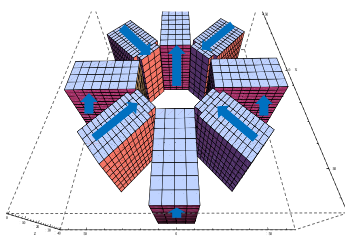
Wall recycling from 1+ sources (5.9 GHz SuperComic source)

Production of low charges states (1 to 4 +) and/or intense protons beams (depending on the magnetic configuration)

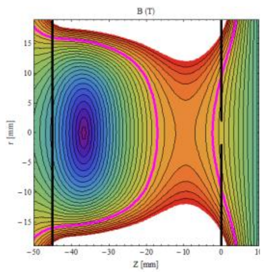
High electric field close to the plasma electrode hole

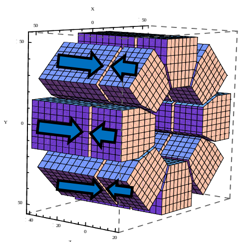
HF coupling

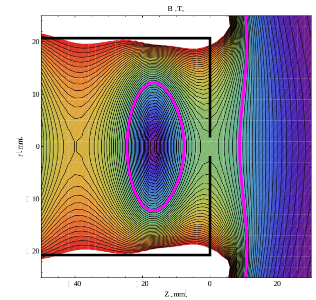


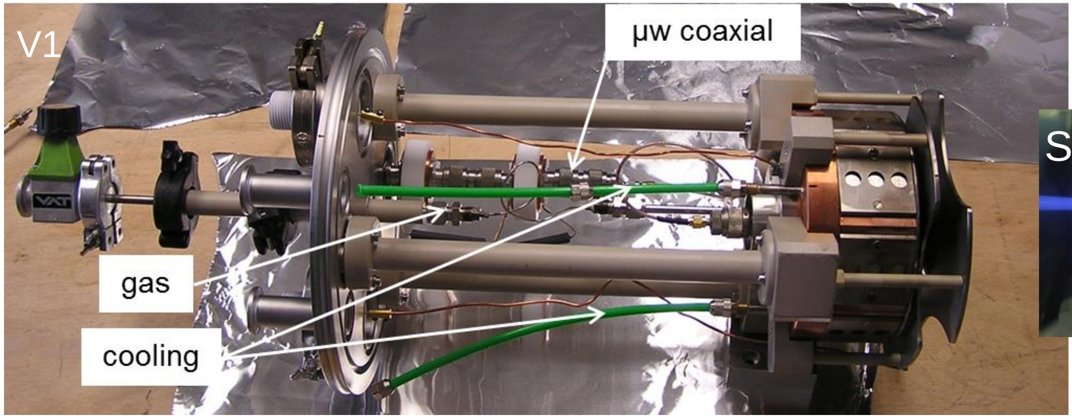


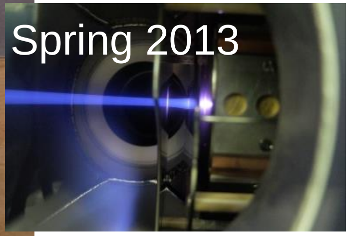
Magnetic studies

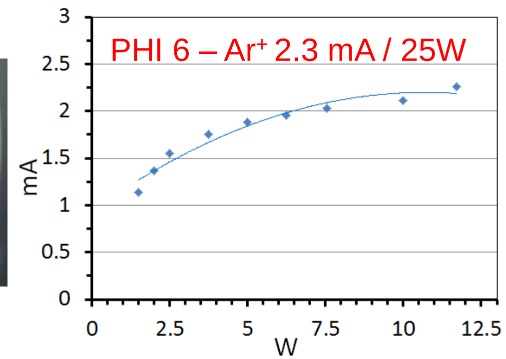








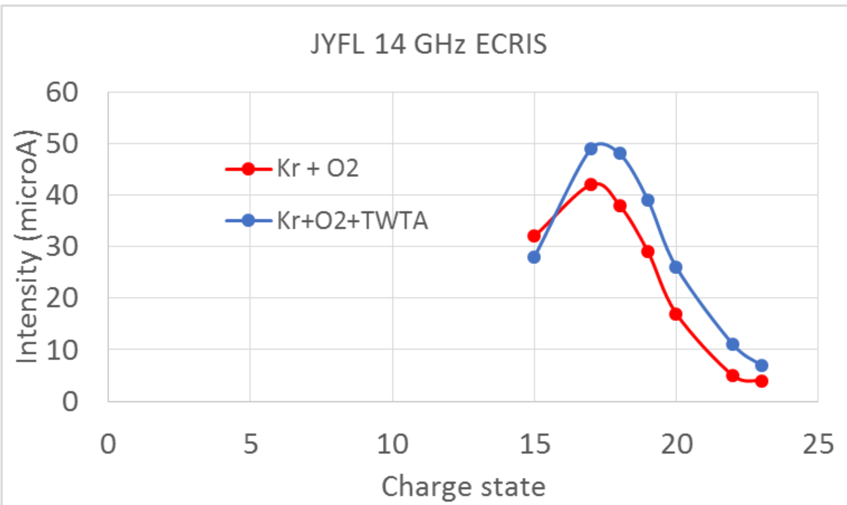


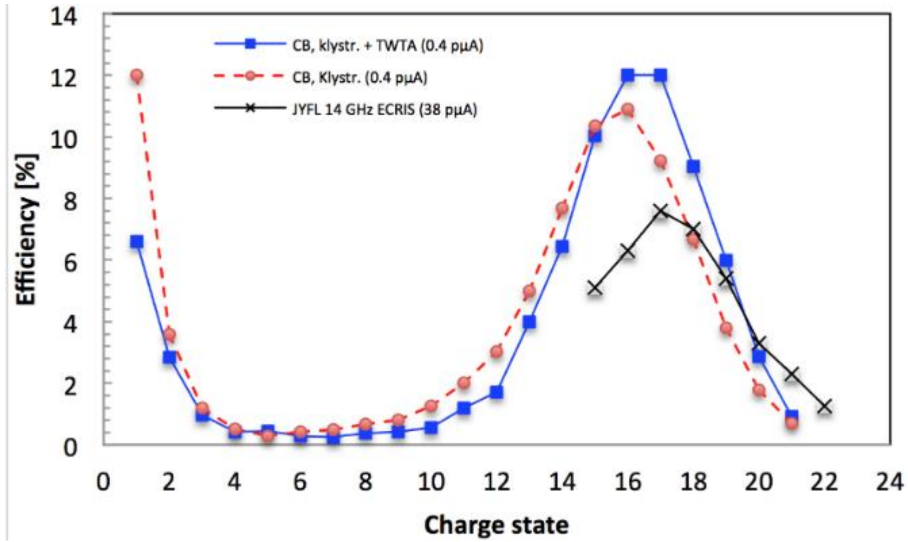


Different magnetic field configuration to be designed, adapted and tested

Double Frequency heating in ECRIS and ECR charge breeders

Rare gas (Kr) capture and ionization efficiency in conventional ECRIS or charge breeders



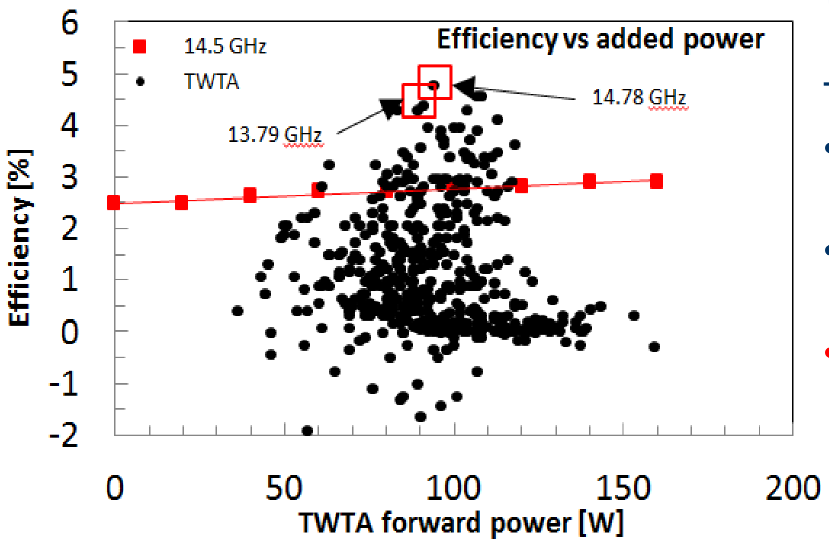


LPSC charge breeder – JYFL 14 GHz source

- No bias disc
- Axial magnetic field at Injection much lower (1.2 versus 2,2 T)
  - No significant impact on the ionization efficiency and charge state distribution

Rev. Sci. Instrum. 85 , 02B917 (2014)
Ionization efficiency studies with charge breeder and conventional electron cyclotron resonance ion source
O. Tarvainen, V. Toivanen, J. Komppula, R. Kronholm, T. Lamy, J. Angot, P. Delahaye, L. Maunoury, A. Galata, G. Patti, L. Standylo, O. Steczkiewicz and J. Choinski

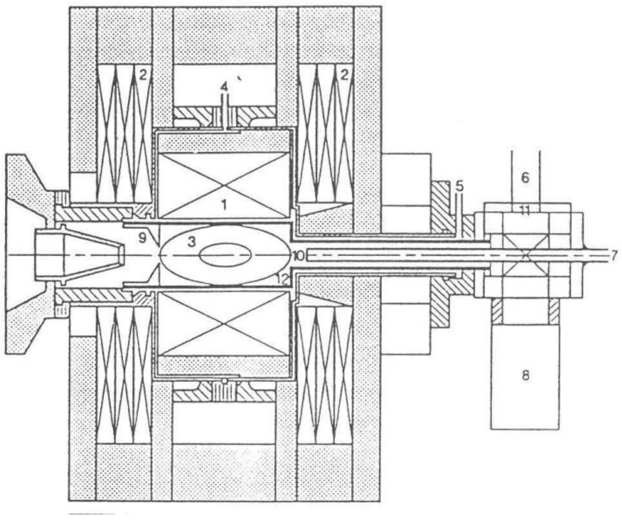
Fine frequency tuning in ECRIS



$Ar^{1+} \rightarrow Ar^{11+}$

TWTA vs Klystron

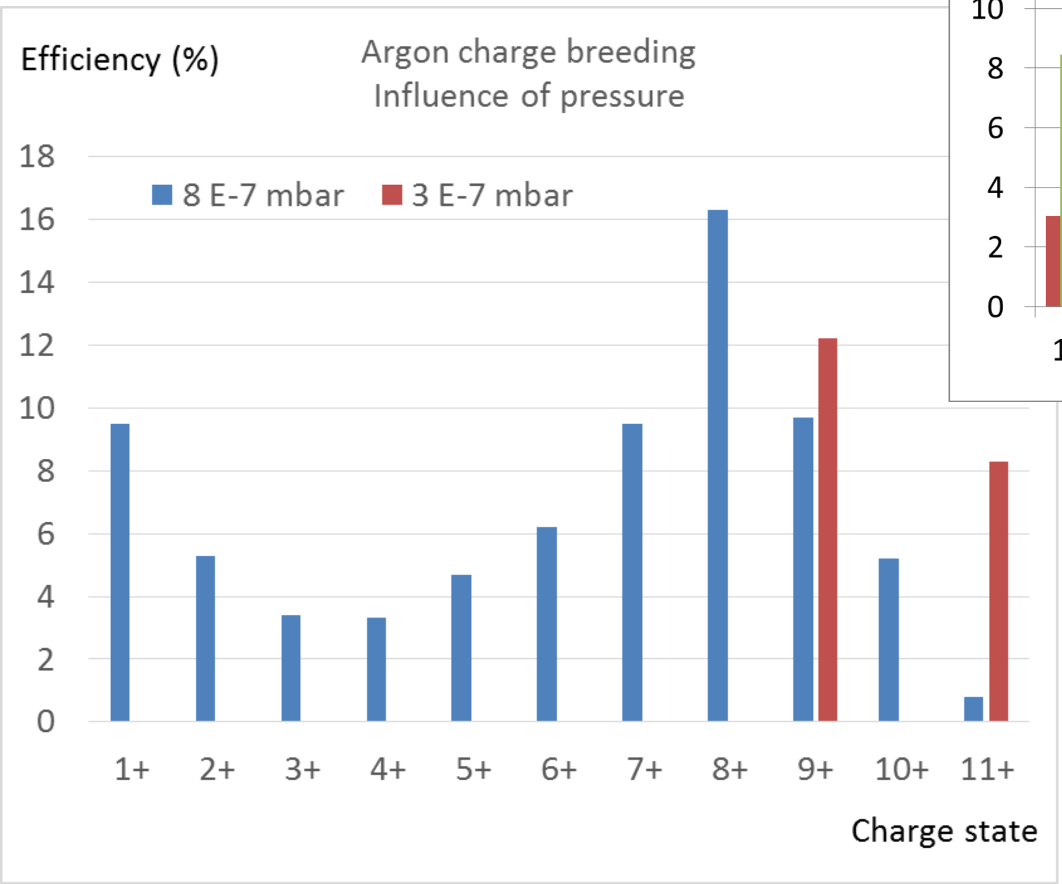
- TWTA: Higher efficiencies at some specific ECR frequencies
- Frequencies lead to plasma instabilities ('negative' efficiencies)
- Klystron alone: best result (8.4% Ar11+), like seen for many species and charges

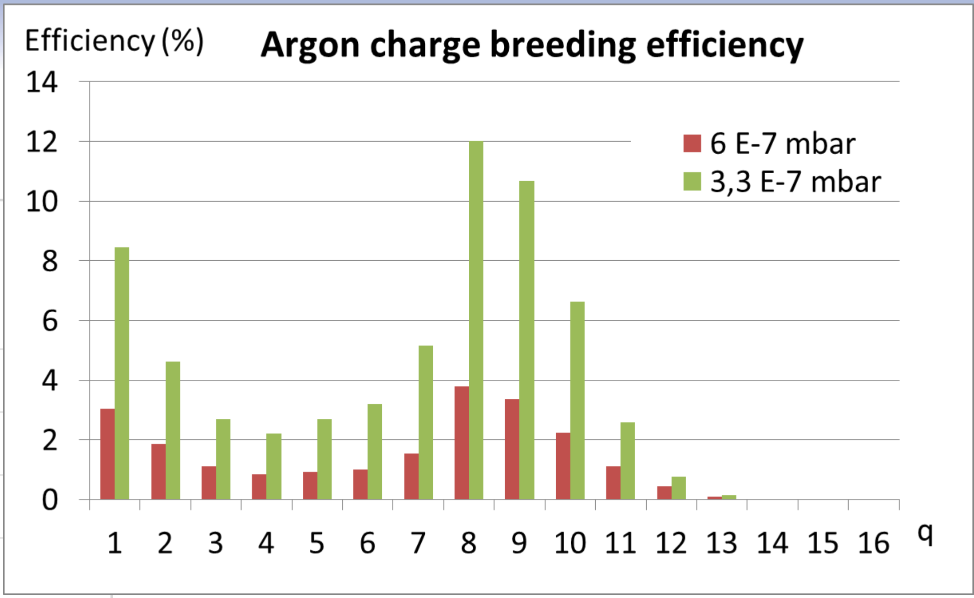


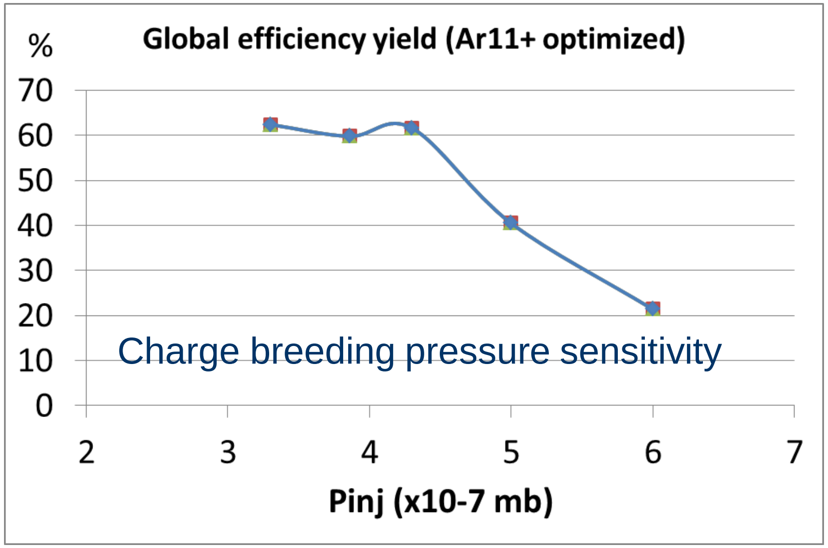
- In 'CAPRICE-like' sources, the waveguide to coaxial Injection is extremely sensitive, fine frequency tuning may optimize the transmission of waves
- In 'direct injection', large volume sources we have much less chance to need coupling optimization due to multi mode cavity

Beam line and or charge breeder improvements (1)

Vacuum improvement



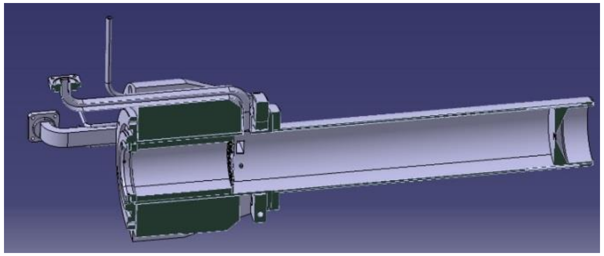
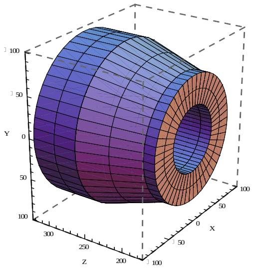




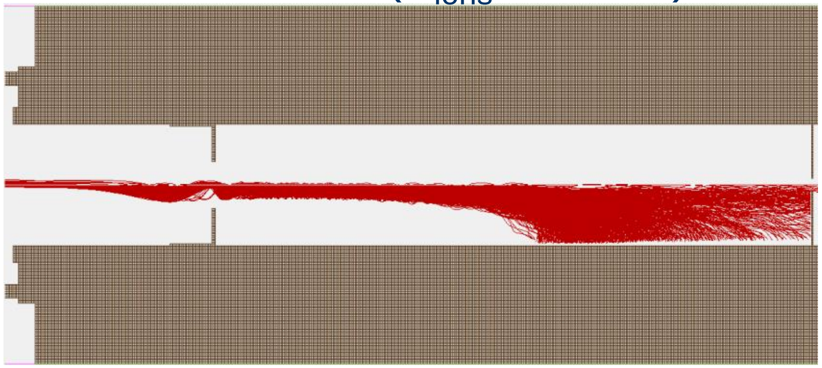
Charge breeding pressure sensitivity

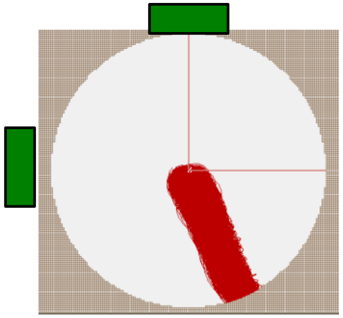
Beam line and or charge breeder improvements (2)

Magnetic field symetrization at the injection

SIMION 3D (E_{ions}=100 eV)

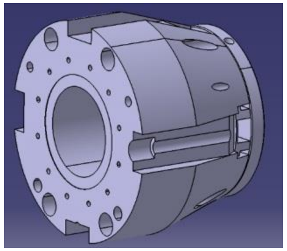
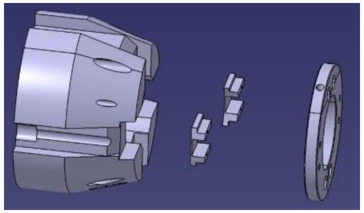
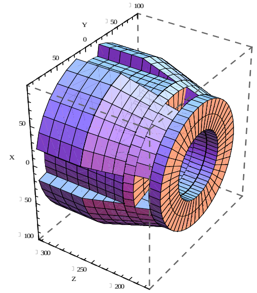


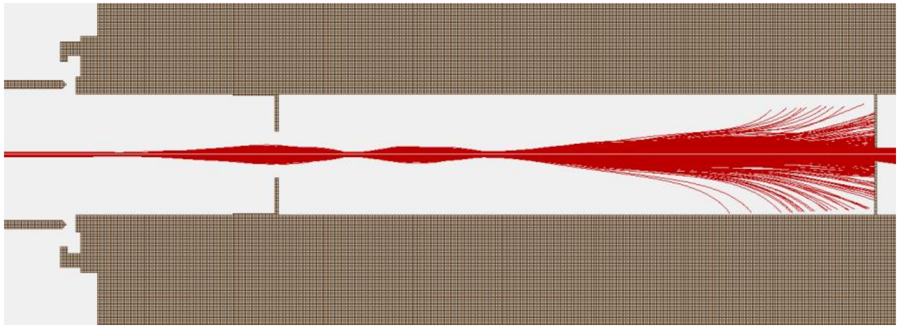


$Na^{+} \rightarrow Na^{6+}$ 3 %

$Na^{+} \rightarrow Na^{7+}$ 1.47 %

6 ms/charge



$Na^{+} \rightarrow Na^{6+}$ 3.7 %

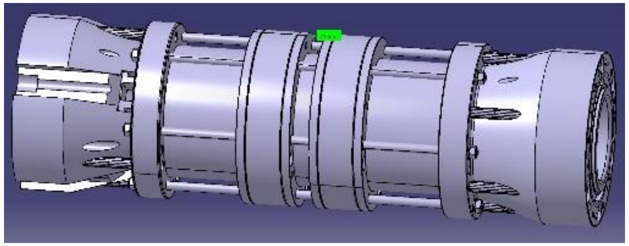
$Na^{+} \rightarrow Na^{8+}$ 2.6 %

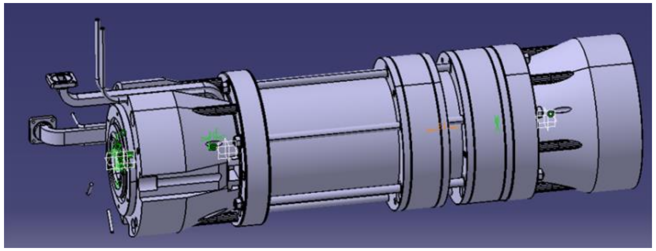
Easier injection optics tuning

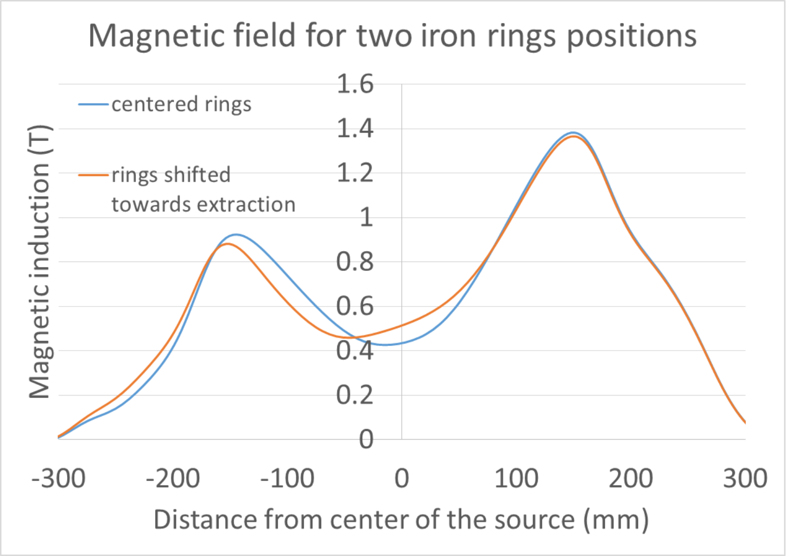
No improvement on heavy ions (Rb)

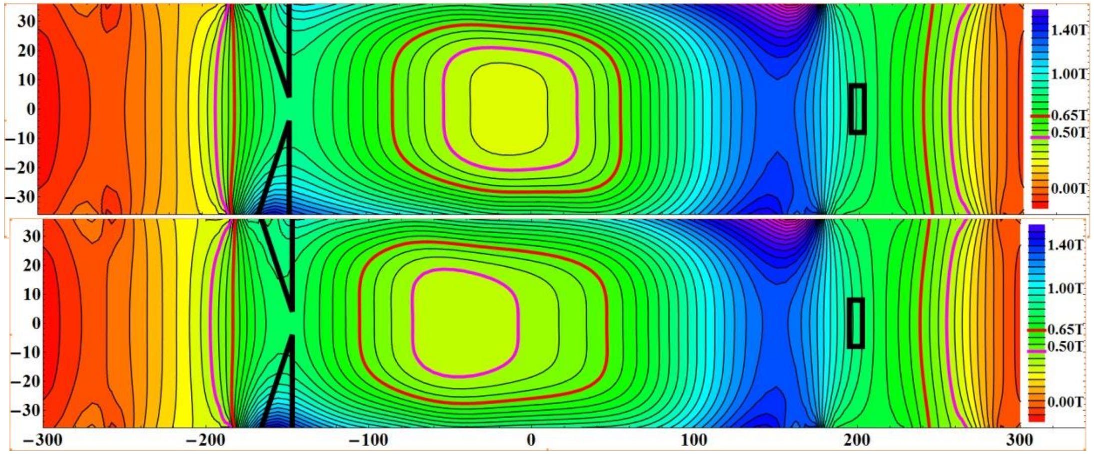
Beam line and or charge breeder improvements (3)

Influence on the position of the two iron rings around the hexapole









$Na^{+} \rightarrow Na^{6+}$ 3.7 %

$Na^{+} \rightarrow Na^{8+}$ 2.6 %

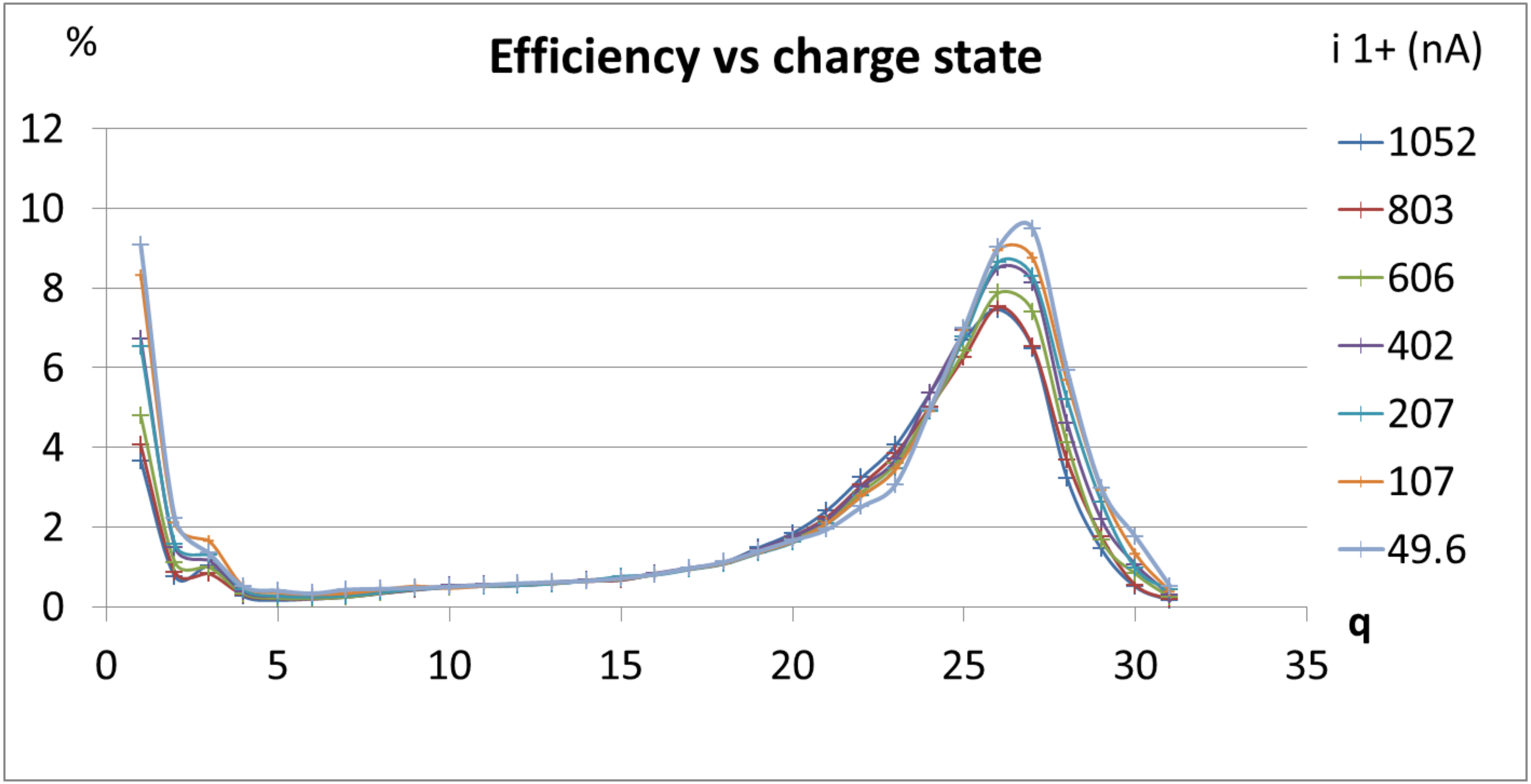
$Na^{+} \rightarrow Na^{6+}$ 3.8 %

$Na^{+} \rightarrow Na^{7+}$ 3.7 %

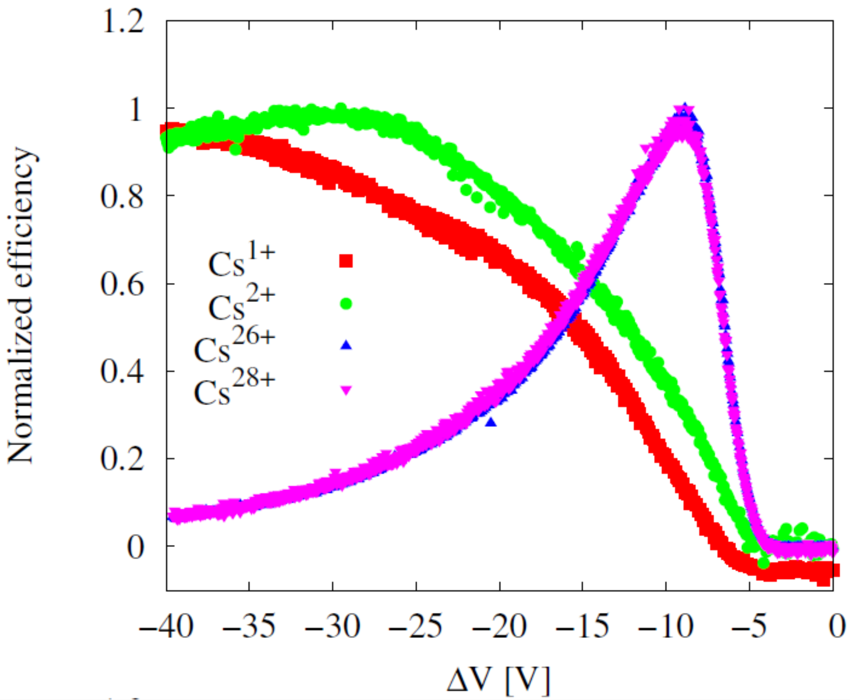
$Na^{+} \rightarrow Na^{8+}$ 3.2 %

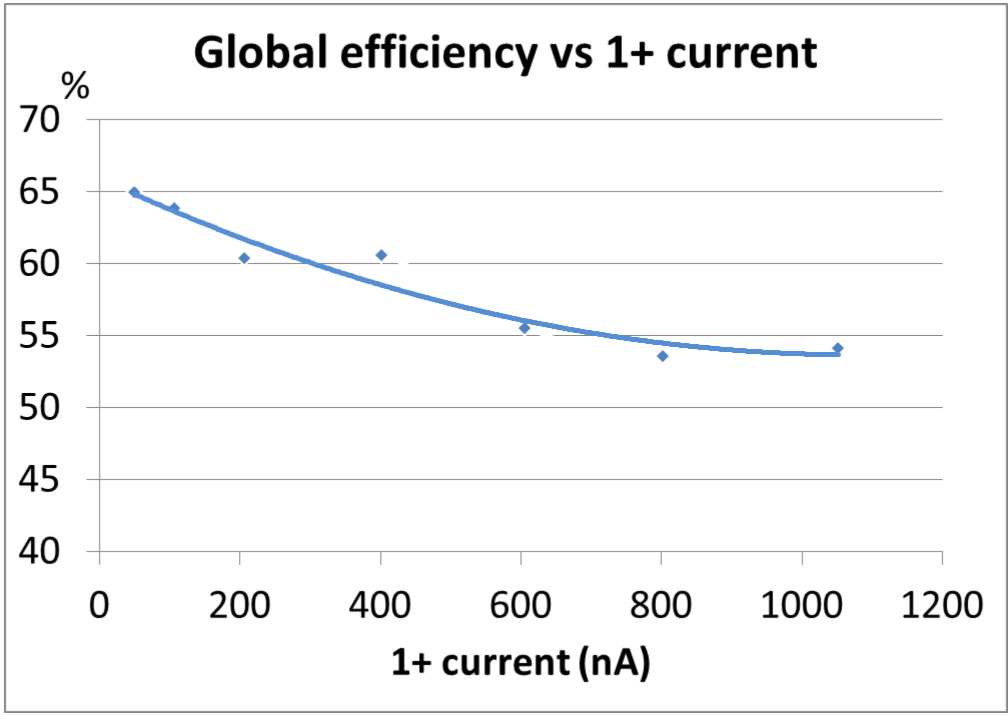
Caesium charge breeding

10 ms/charge

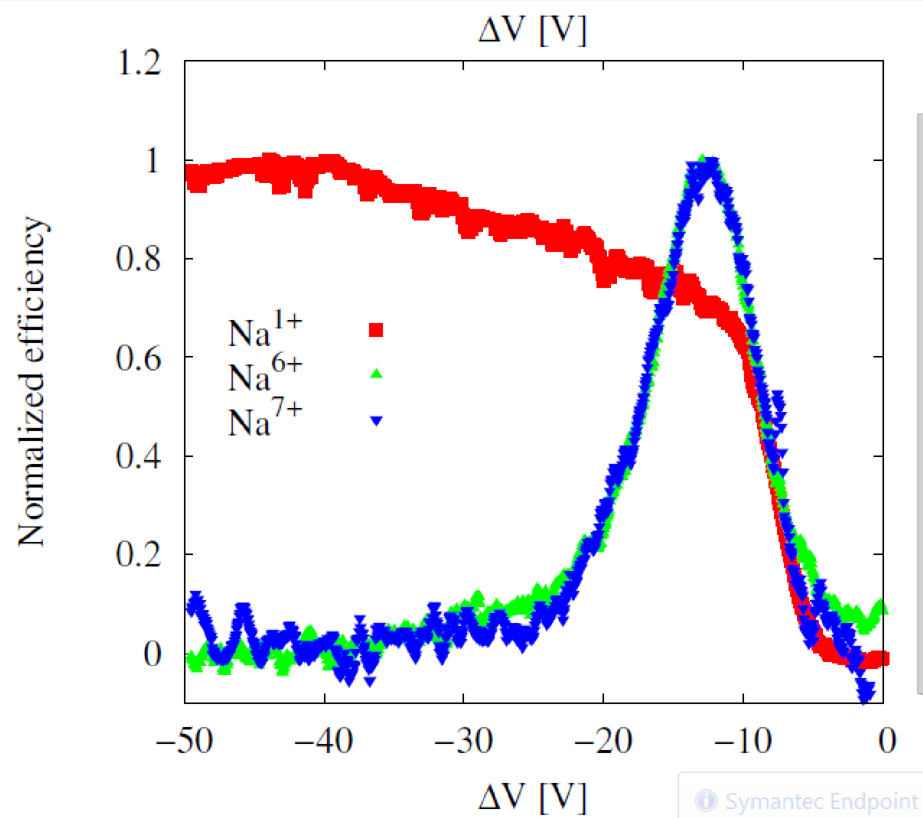


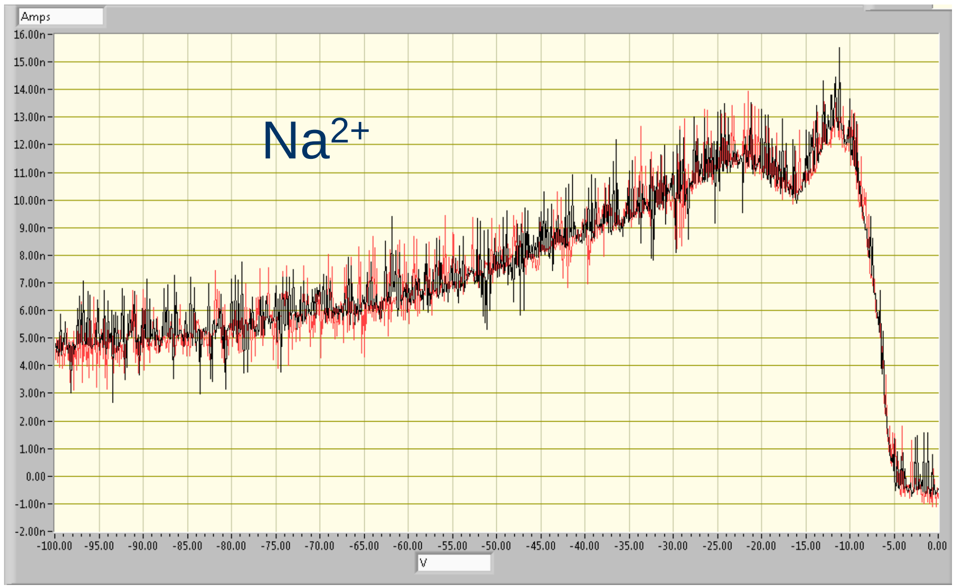
Caesium charge breeding



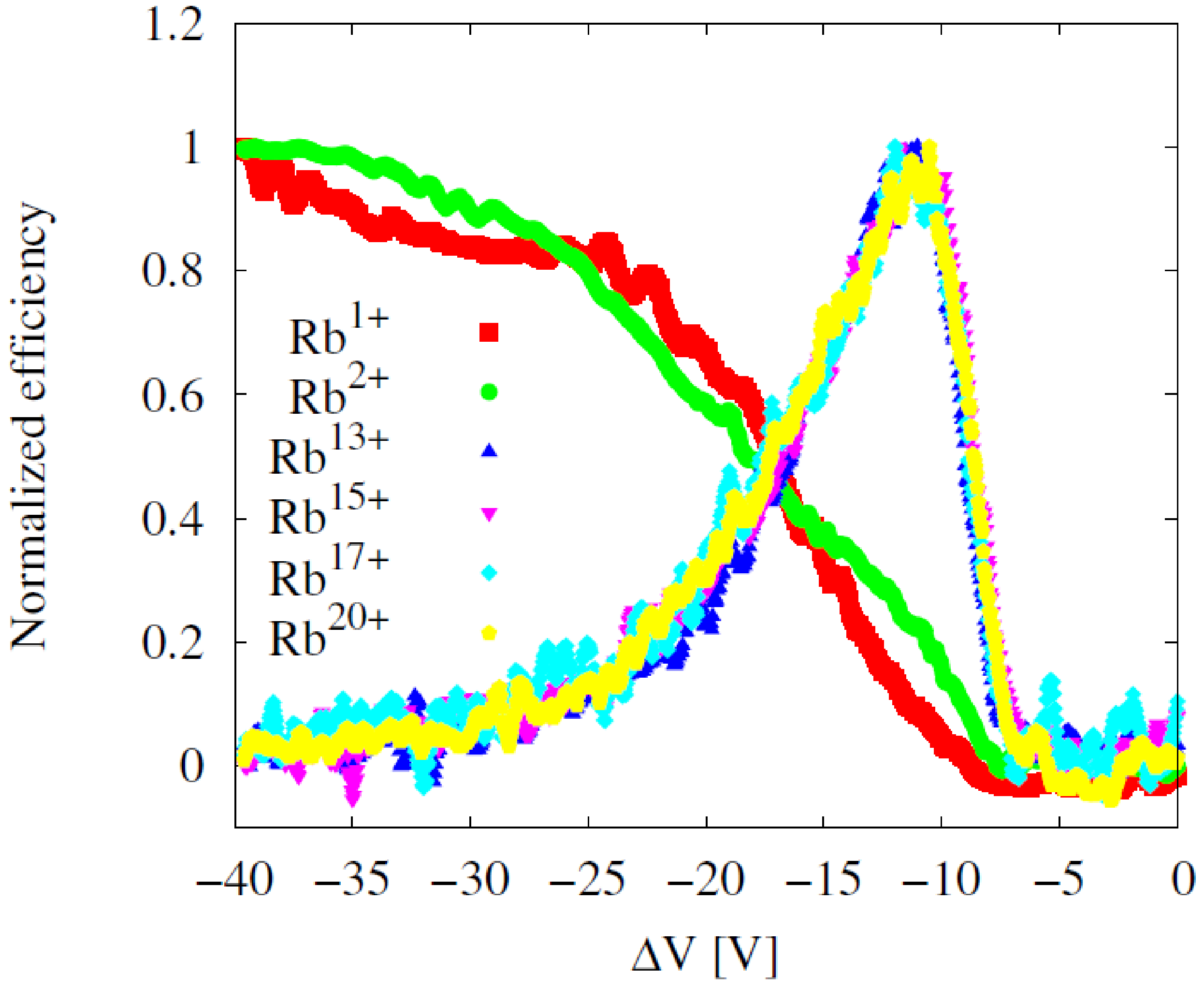


Sodium resuts

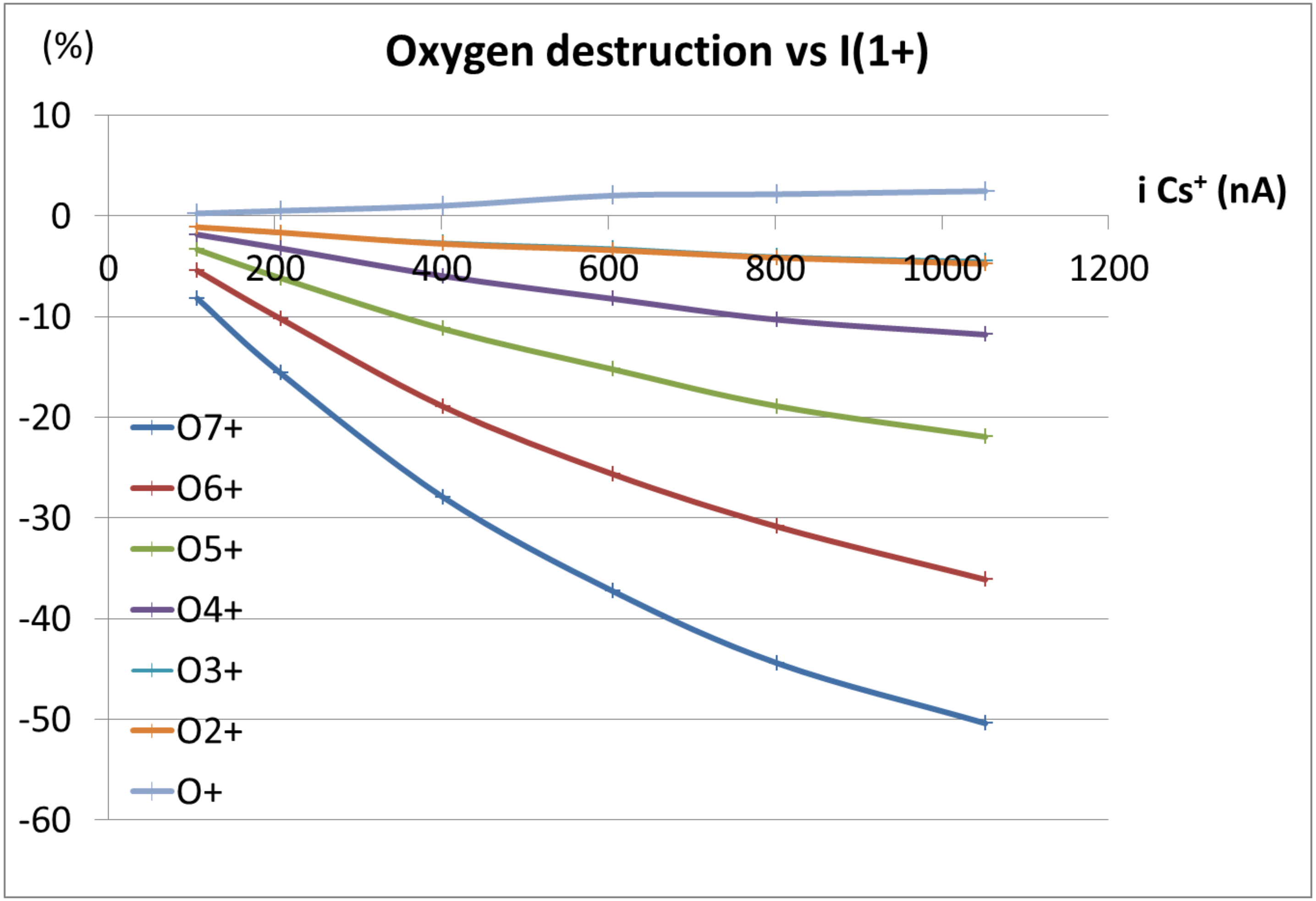




Rubidium results



Oxygen destruction injecting low energy ions



Very next future

SPES charge breeder construction and qulafication
SPIRAL1 charge breeder qualification
Plasma physics studies
LPSC charge breeder magnetic structure modification

Thank you for your attention