Recent improvements of the LPSC Charge Breeder

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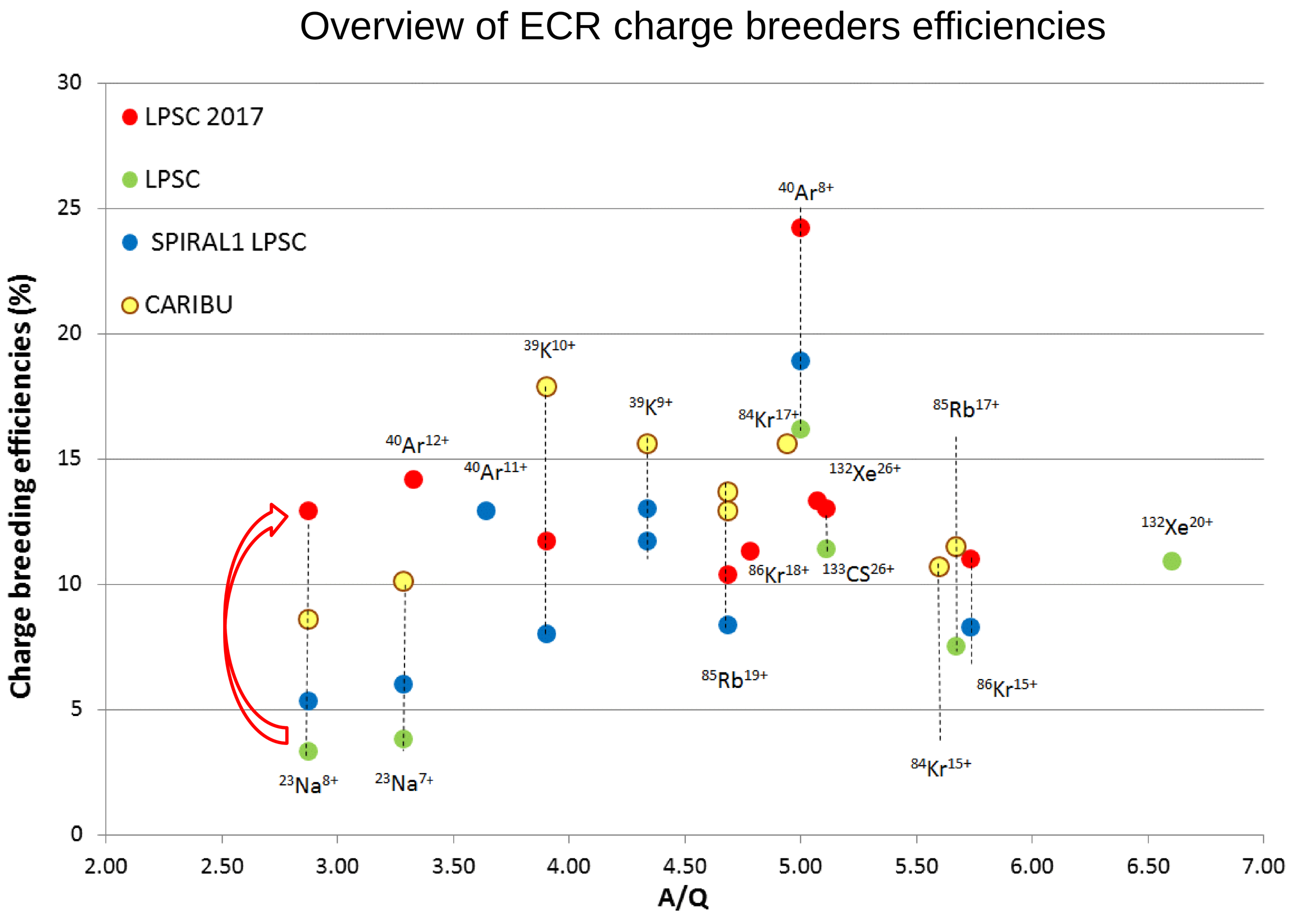
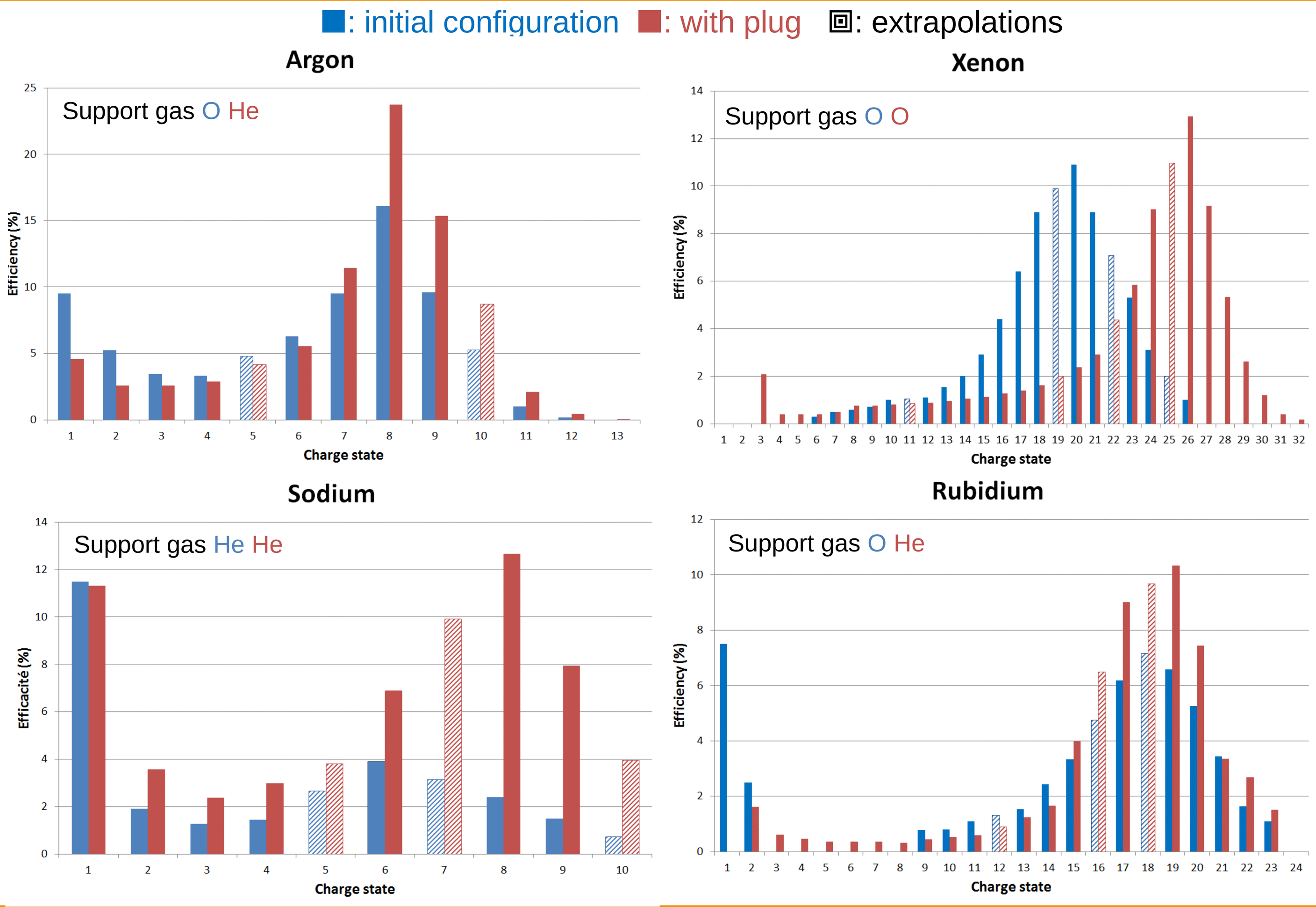
Abstract

LPSC has developed the PHOENIX electron cyclotron resonance Charge Breeder since 2000. The performances have been improved over time acting on the 1+ and N+ beam optics, the base vacuum and the 1+ beam injection. A new objective is to update the booster design to enhance high charge state production and 1+ N+ efficiencies, reduce the co-extracted background beam and improve the ion source tunability. The first step, consisting in increasing the peak magnetic field at injection from 1.2 to 1.6 T was implemented and significant improvement in 1+N+ efficiencies are reported : 12.9% of $^{23}Na^{8+}$, 24.2% of $^{40}Ar^{8+}$, 13.3% of $^{132}Xe^{26+}$ and 13% of $^{133}Cs^{26+}$. The next steps of the upgrade are presented: modification of the axial magnetic structure, significant increase of the plasma chamber radius (72 to 90 mm), plasma heating at 18 GHz (instead of 14 GHz), reduction of chemical elements composing the plasma chamber wall and the surrounding beam line.

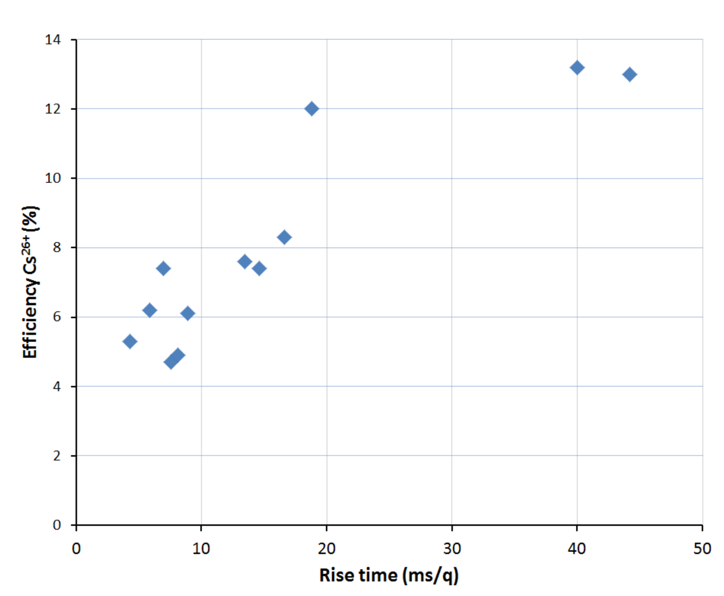
Latest performances of the LPSC PHOENIX ECR Charge Breeder

Overview of ECR charge breeders efficiencies





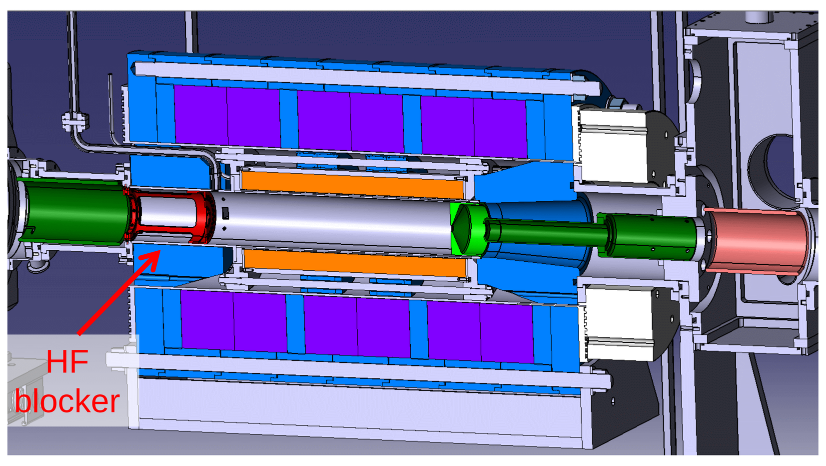
$^{133}Cs^{26+}$ efficiency vs rise time for stable plasma regimes



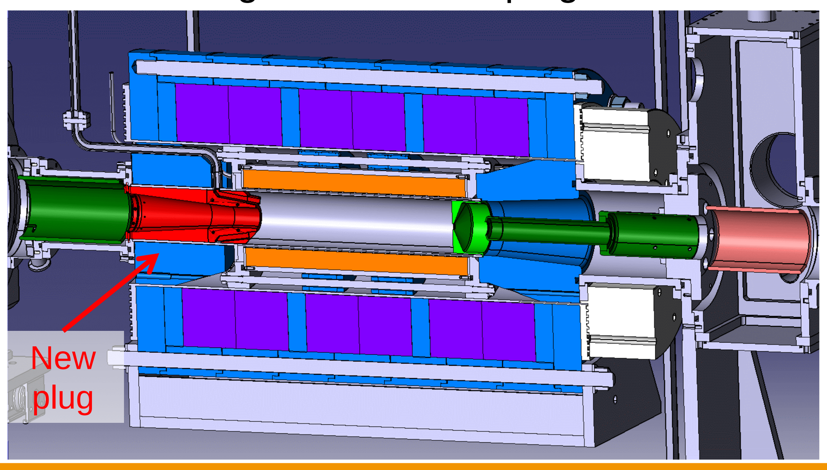
7% achievable with rise time < 10 ms/q
Additional experiments needed

Magnetic structure modification (2016)

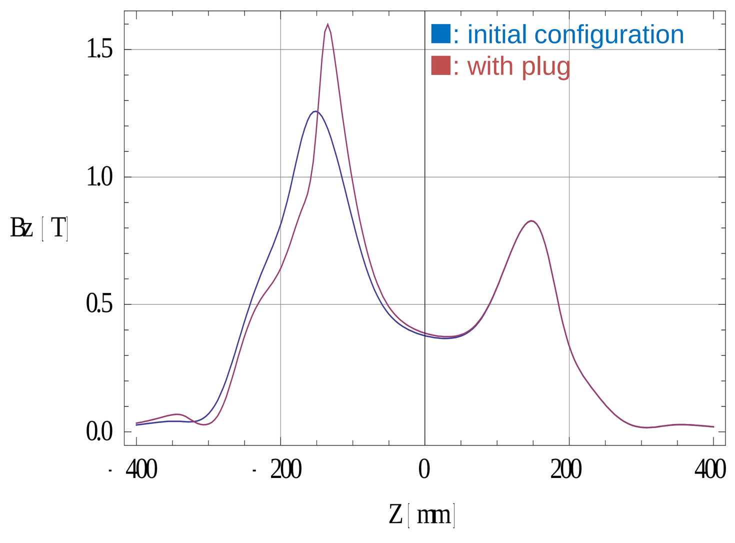
Previous configuration with the HF blocker



Modified configuration with a plug under vacuum



Axial magnetic field profiles



Additional soft iron plug parts

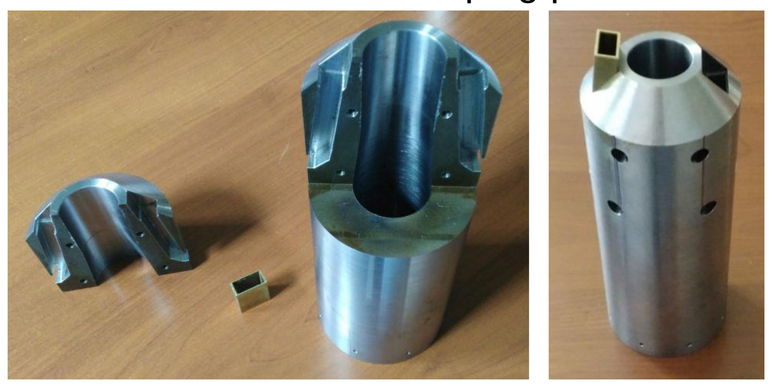


Table of results

Species	Initial configuration Efficiency (%)	Initial configuration Rise time (ms/q)	Initial configuration Total efficiency (%)	Additional plug configuration Efficiency (%)	Additional plug configuration Rise time (ms/q)	Additional plug configuration Total efficiency (%)
$^{40}Ar^{8+}$	16.2	9.8	75	24.2	8.6	84
$^{40}Ar^{12+}$				14.2	28.4	78
$^{86}Kr^{15+}$				11	8.2	
$^{86}Kr^{18+}$				11.3	14.6	
$^{132}Xe^{20+}$	10.9	12	80			
$^{132}Xe^{26+}$				13.3	5.9	
$^{23}Na^{8+}$	3.3	8.6	19	12.9	12.9	65
$^{23}Na^{7+}$	3.8		19			
$^{39}K^{10+}$				11.7	8.2	73
$^{85}Rb^{17+}$	7.5	13.3	55			
$^{85}Rb^{19+}$				10.4	29	66
$^{133}Cs^{26+}$	11.4			13	44.2	75

14.5 GHz 400 – 500W, base vacuum 3 10^{-7} mbar

- **All the efficiencies are higher than 10%**
- **high increase of efficiencies for low masses**
- **Shift of the peak charge state distribution function to higher value**

Development plan 2016 - 2020

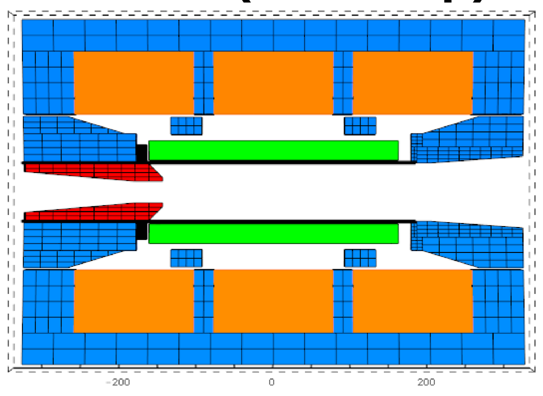
Objectives :

- Reduce co-extracted contaminants
- Improve efficiencies
- Increase charge states

Means :

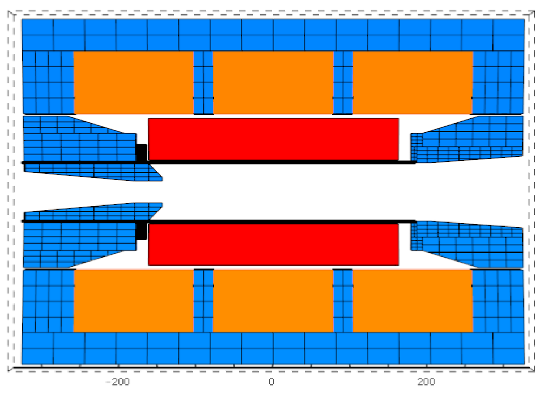
- Magnetic field structure improvement
- Plasma chamber volume increase
- Operation at 18GHz
- UHV technique for ECRIS and beam line
- Reduction of chemical elements facing the plasma, use of liners

✓ 2016 (first step)



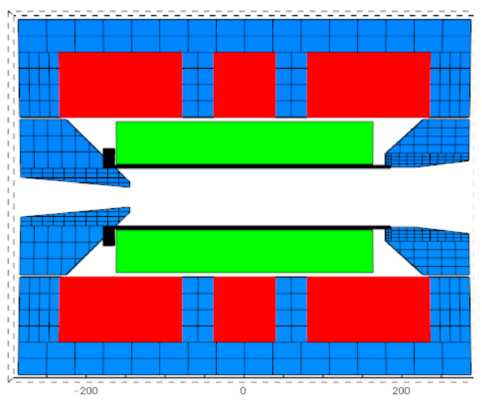
Injection axial magnetic field strength increase

2017



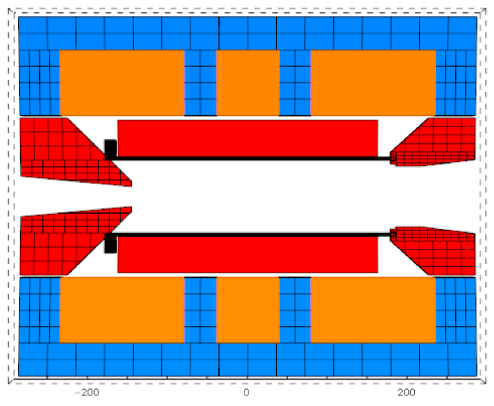
Radial magnetic field strength increase

2018



Yoke and coils redistribution

2019



Plasma chamber volume increase

18 GHz operation