SPIRAL1 charge breeder: performances and status

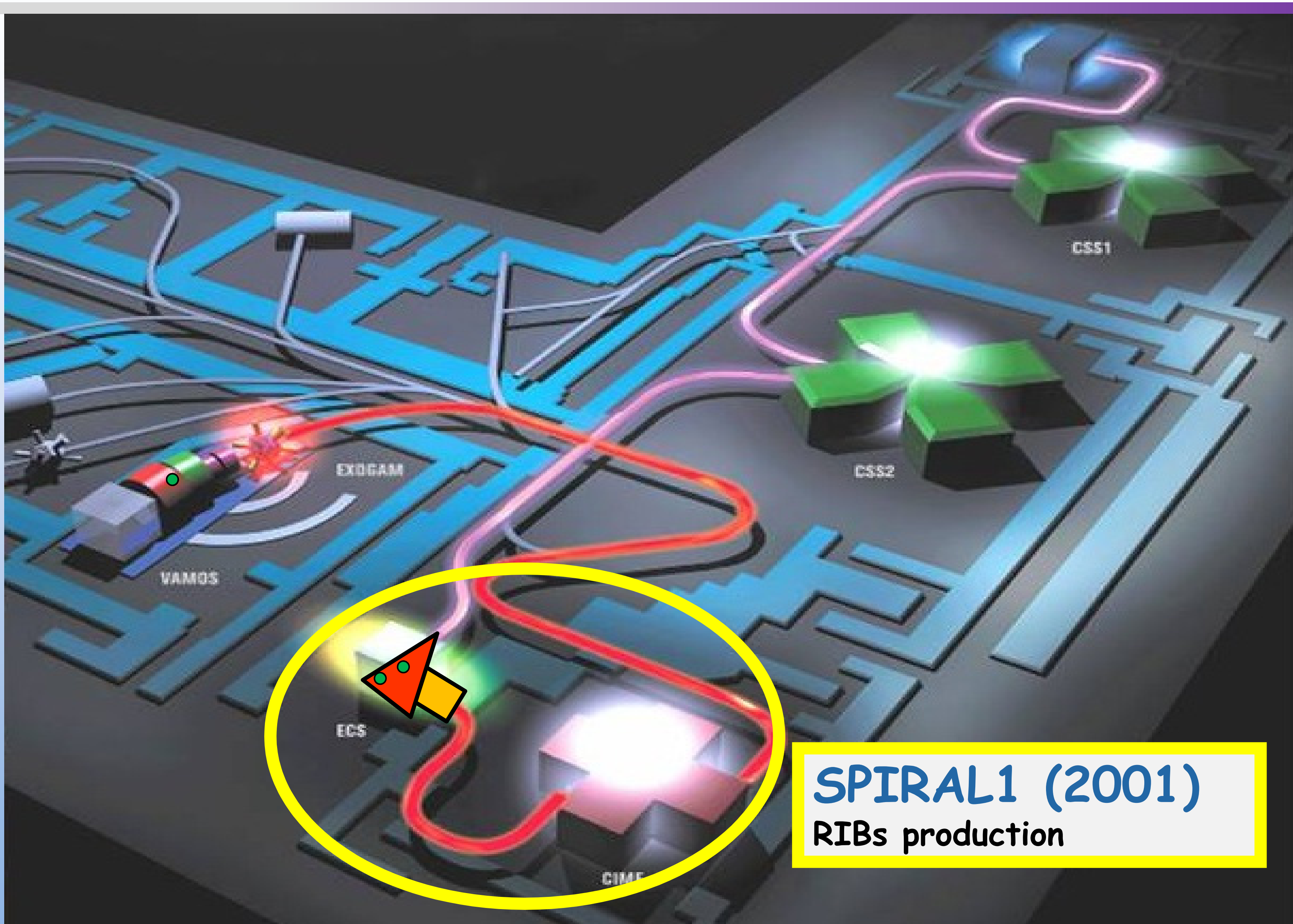
L. MAUNOURY – GANIL – Caen
on behalf of UpgradeSP1 team

Outlines

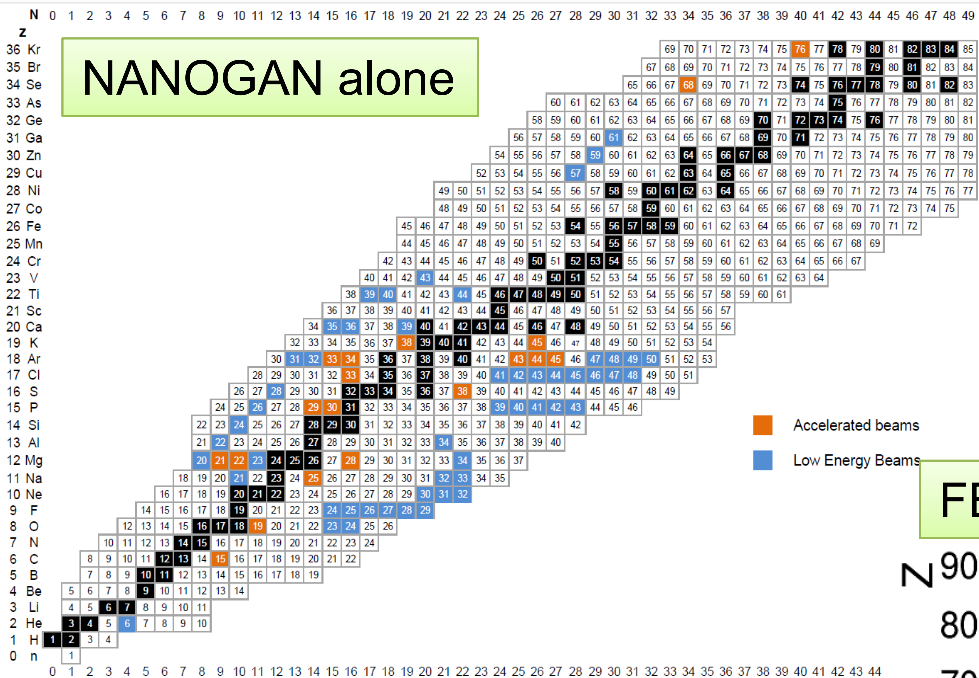
1) FRAMEWORK
2) SPIRAL1 CHARGE BREEDER
3) EXPERIMENTAL RESULTS AT LPSC
4) ION CONFINEMENT TIME
5) STATUS AND COMMISSIONING
6) CONCLUSION


SPIRAL 1
Upgrade
NANOGAN
FEBIAD
Surface
New targets

Framework

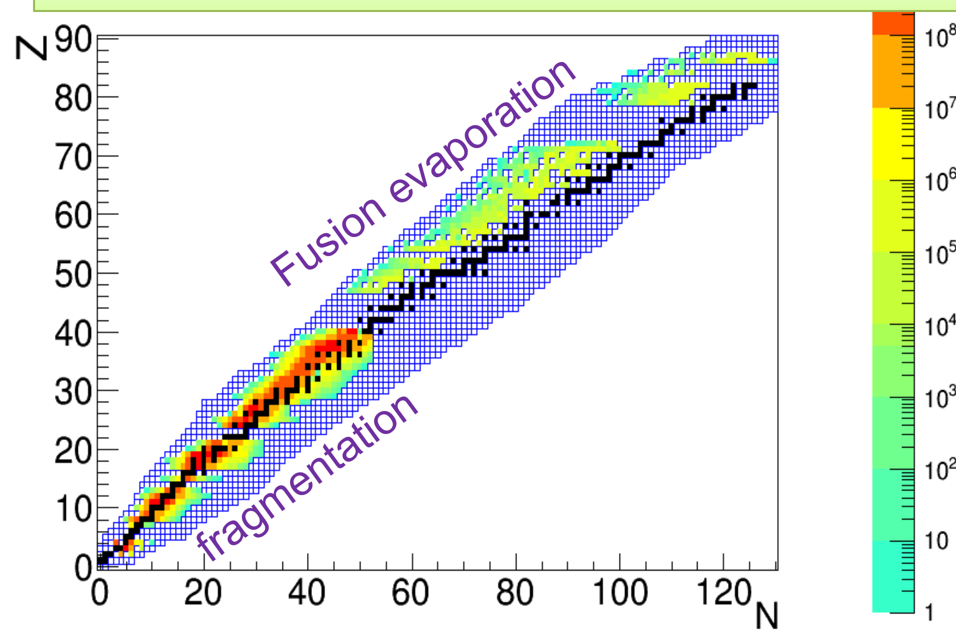

CSS1
CSS2
EXOGAM
VAMOS
ECS
CIME
SPIRAL1 (2001)
RIBs production

Framework



Since 2001 SPIRAL1 under operation
Mainly RIB's from gazeous elements
7 elements (He, Ar, Kr, O …)
35 beams provided / $T_{1/2}$ > 100ms

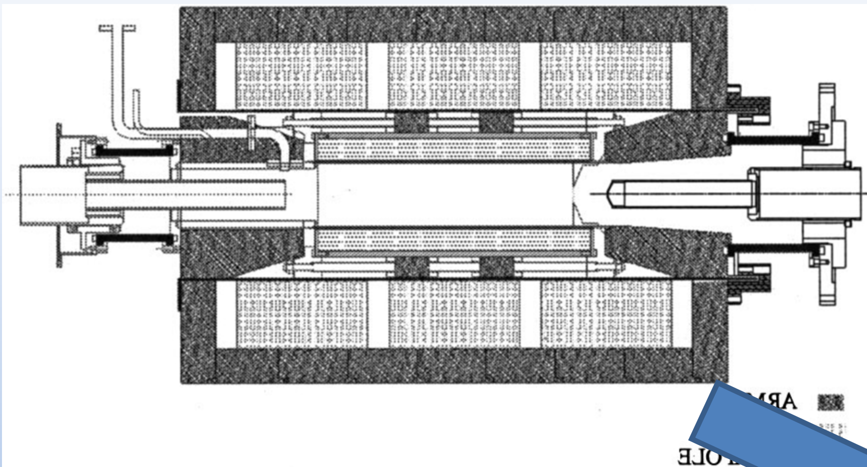
FEBIAD (or NANOGAN) + Charge breeder



Physicists need more exotic beams to study the nuclei properties
⇒SP1 should extend its RIB's palette
⇒ 1+ / n+ method
⇒ dedicated TISS (FEBIAD + C target)
⇒ Charge breeder
⇒ CIME as post-accelerator
⇒ new target m < Nb but C primary beam

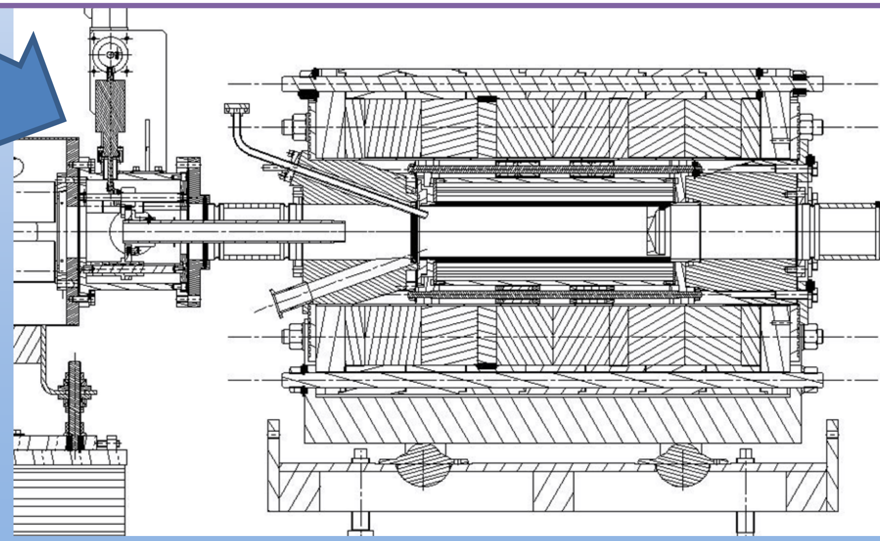
Spiral1 Charge Breeder

Based on Phoenix booster + ANL collaboration

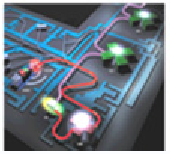


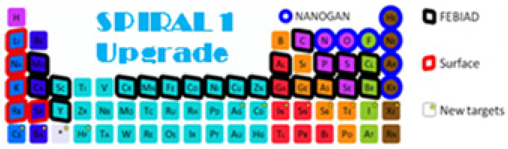
- ✓ Two RF ports 14.5 GHz and 8-18 GHz
- ✓ New design of gas and RF injection
- ✓ Symetrisation of the iron plug
- ✓ Movable deceleration tube
- ✓ Plasma chamber made of Al
- ✓ Nickel coating of the iron plug

Improvement of our charge breeder according to the feedback of EMILIE collaboration



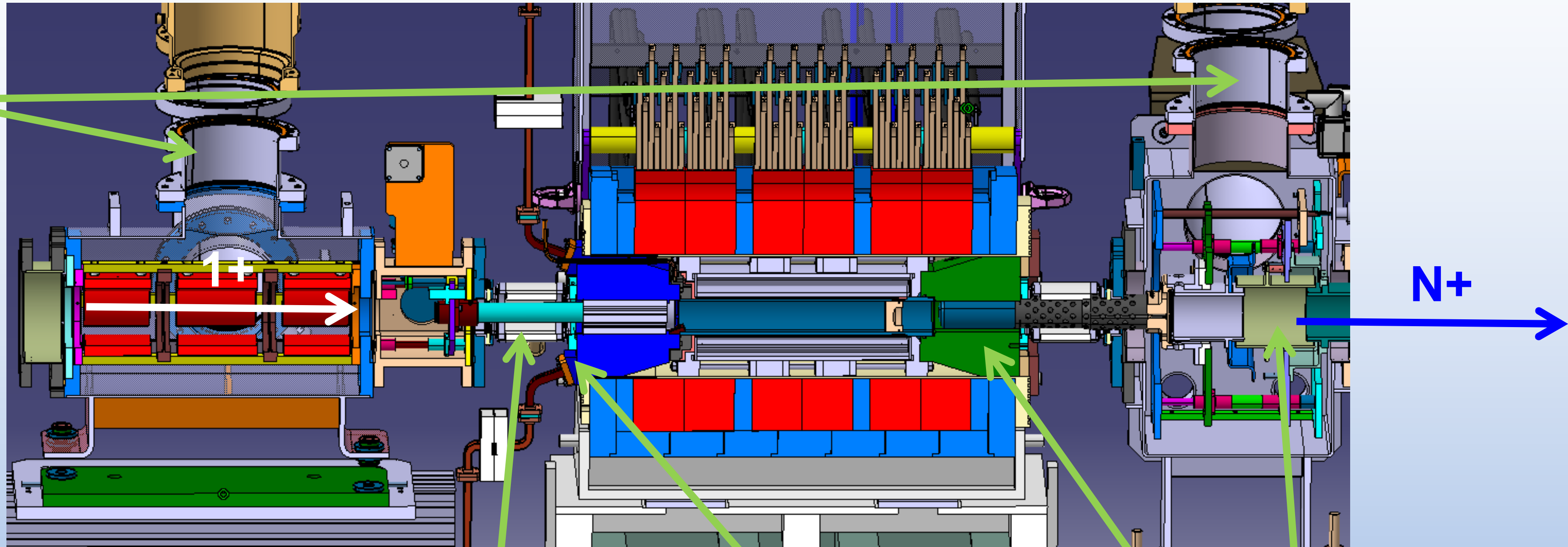
The research leading to these results has received funding from the European Union's Seventh Framework Programme under grant agreement n°262010





Spiral1 Charge Breeder

Total pumping speed of 3000 L/s

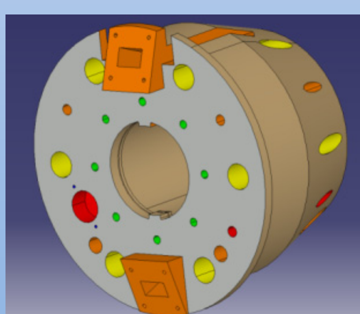


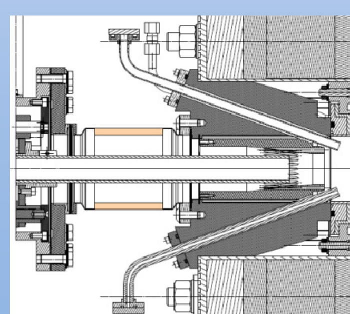
Electrostatic QPole Focussing/steering

Mobile deceleration tube

HF : 14,5GHz + 8/18 GHz

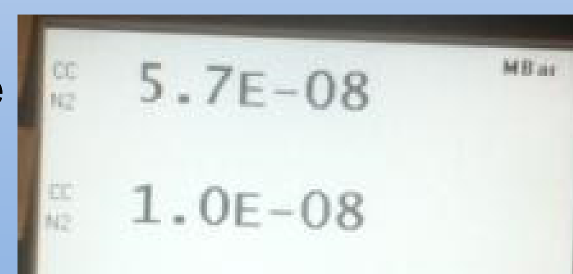
Puller and Einzel lens movable

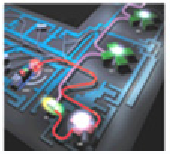


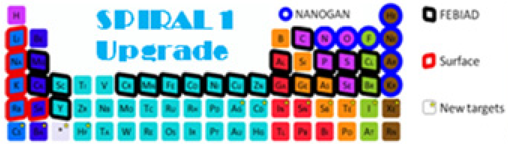


Extraction side

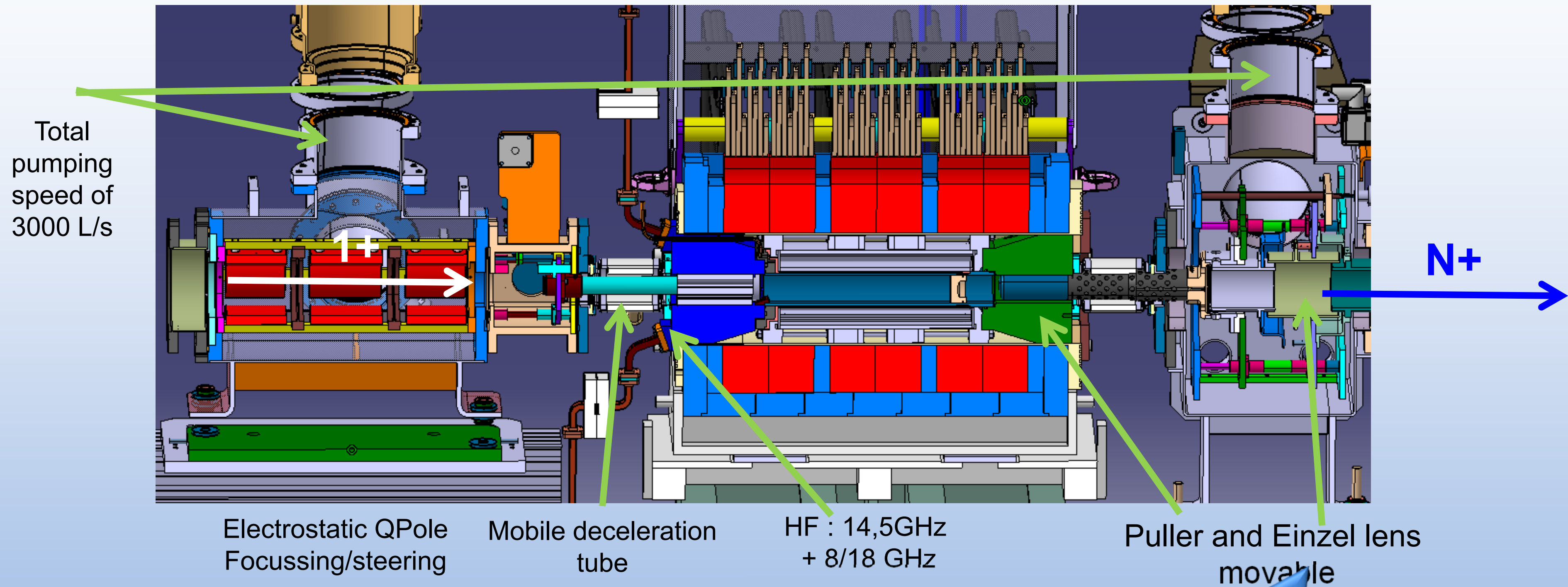
Injection side

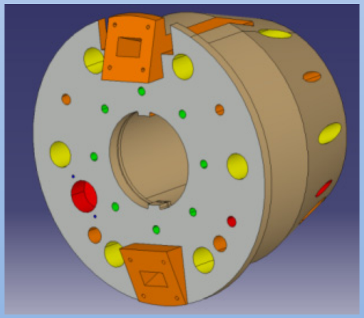


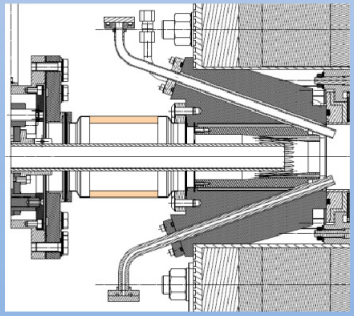




Spiral1 Charge Breeder



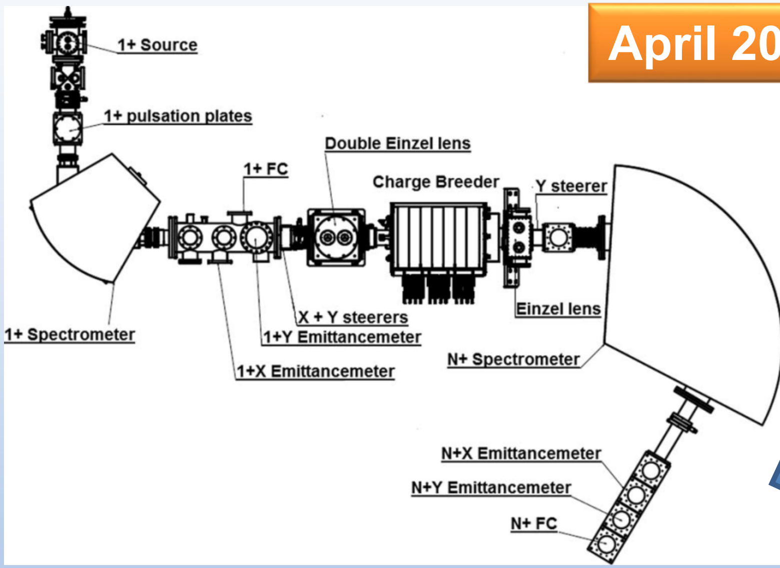


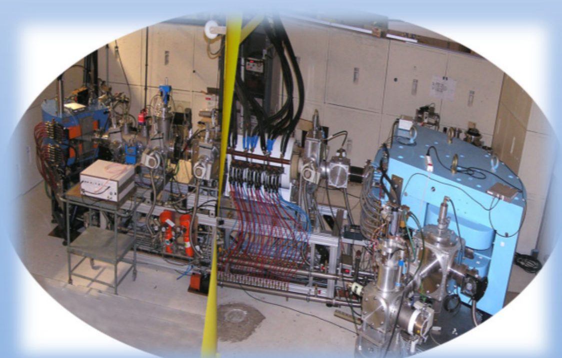


Experimental results at LPSC

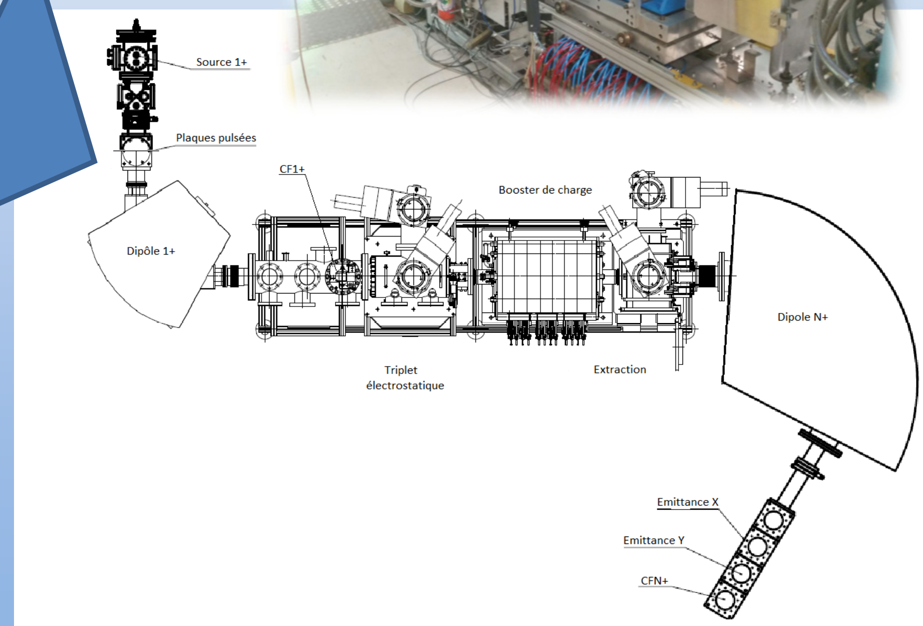
Tests on the LPSC 1+/N+ test bench

April 2015 => December 2015



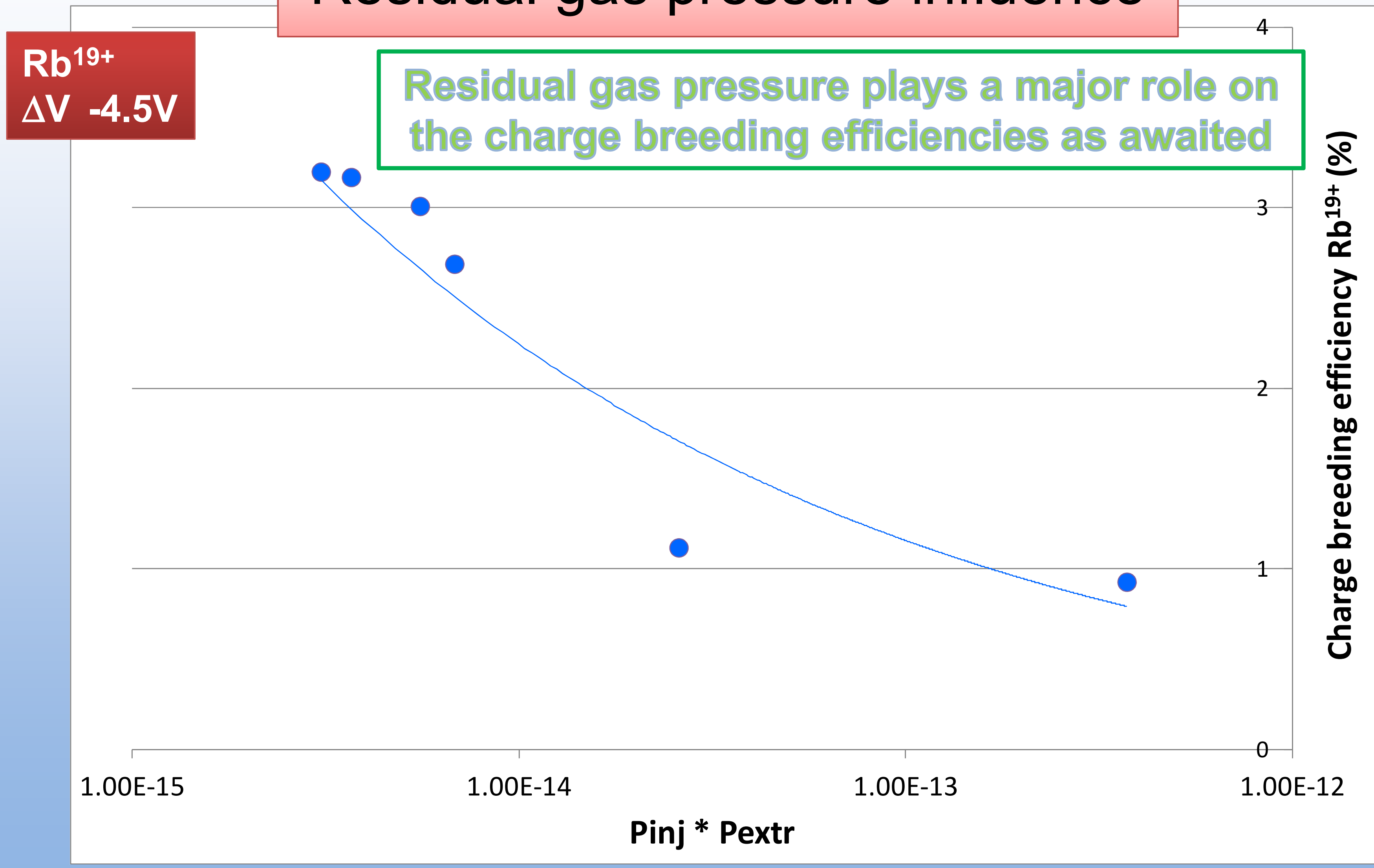


Beam line changes



Experimental results at LPSC

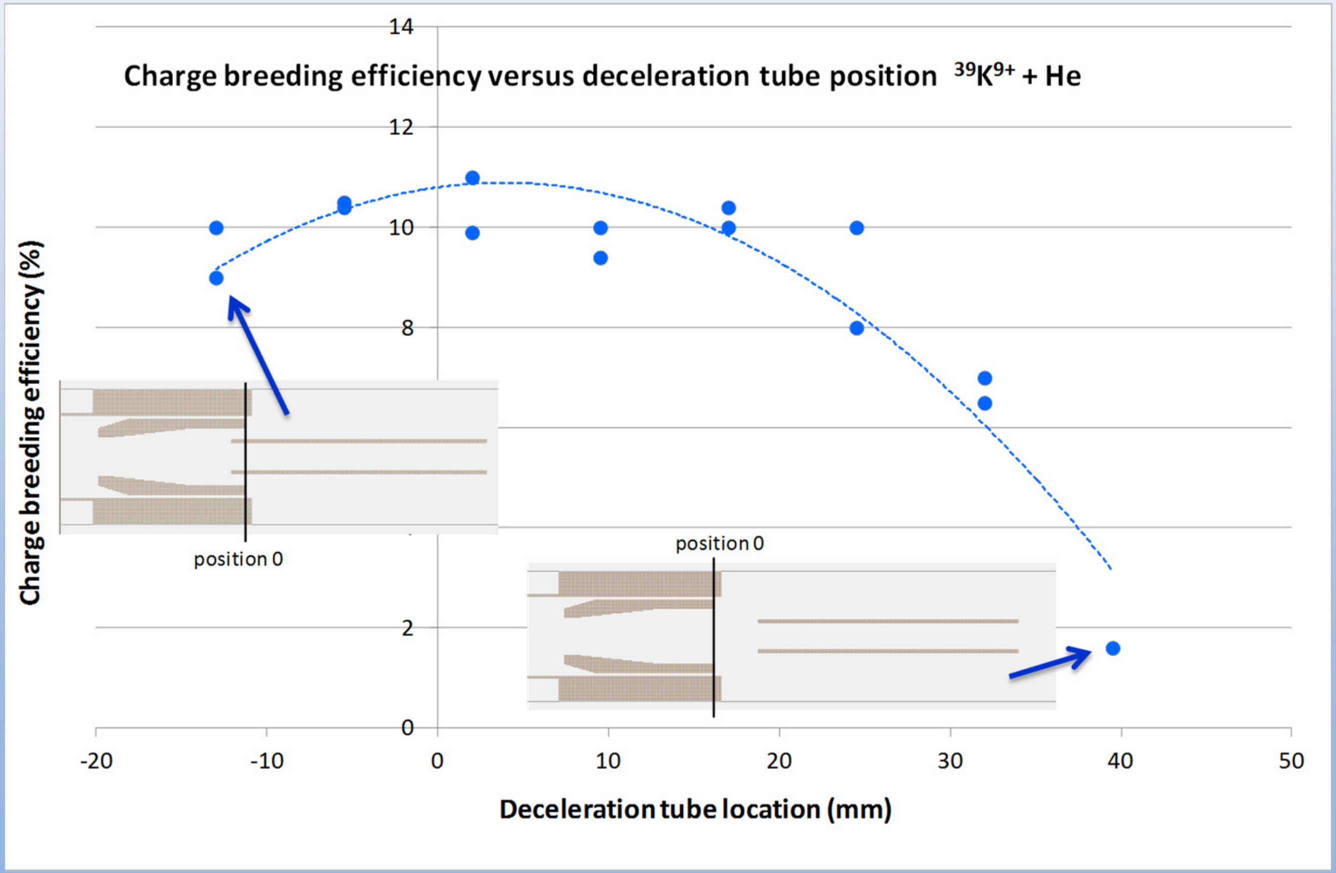
Residual gas pressure influence



Experimental results at LPSC

Movable tube influence

Charge breeding efficiency has a smooth evolution with the position of the deceleration tube



Experimental results at LPSC

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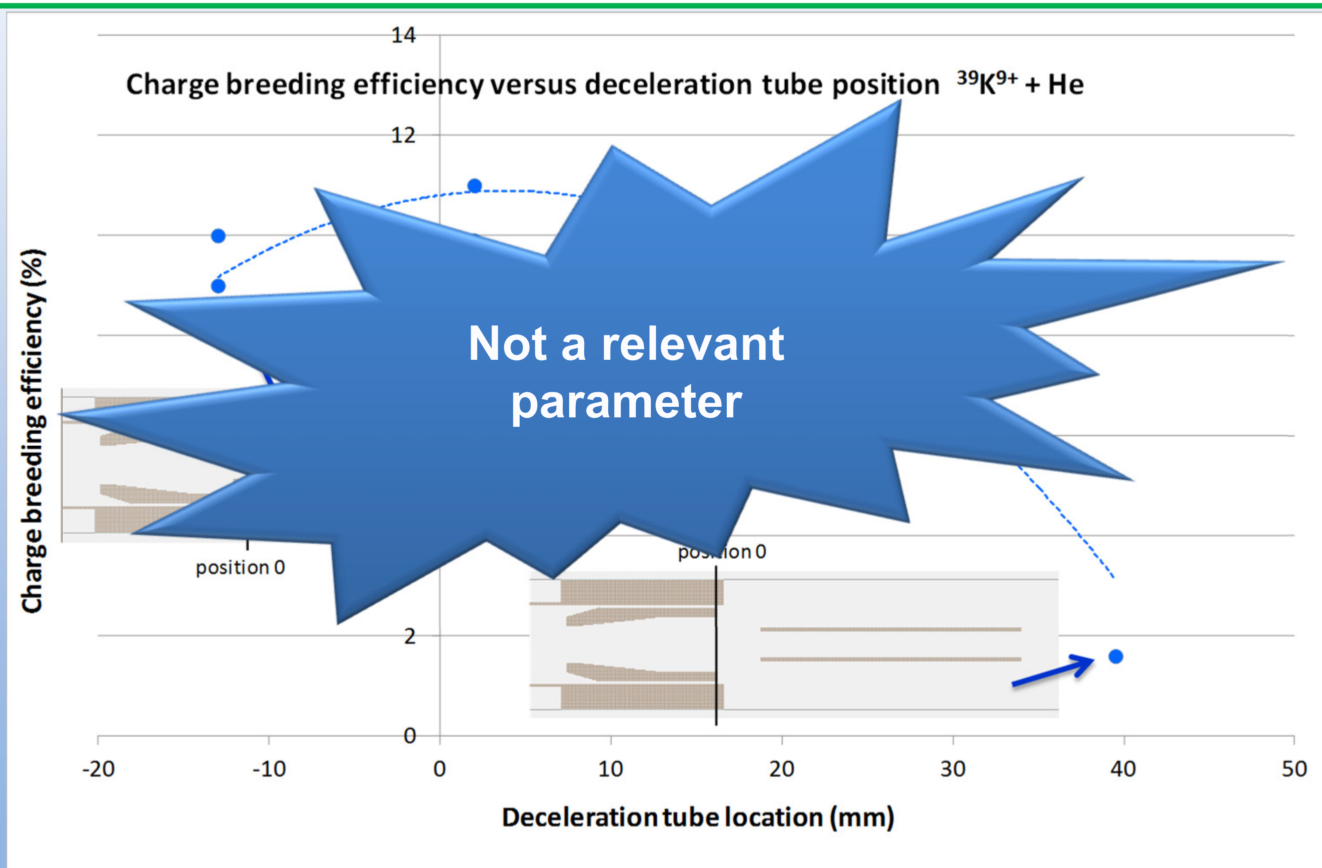
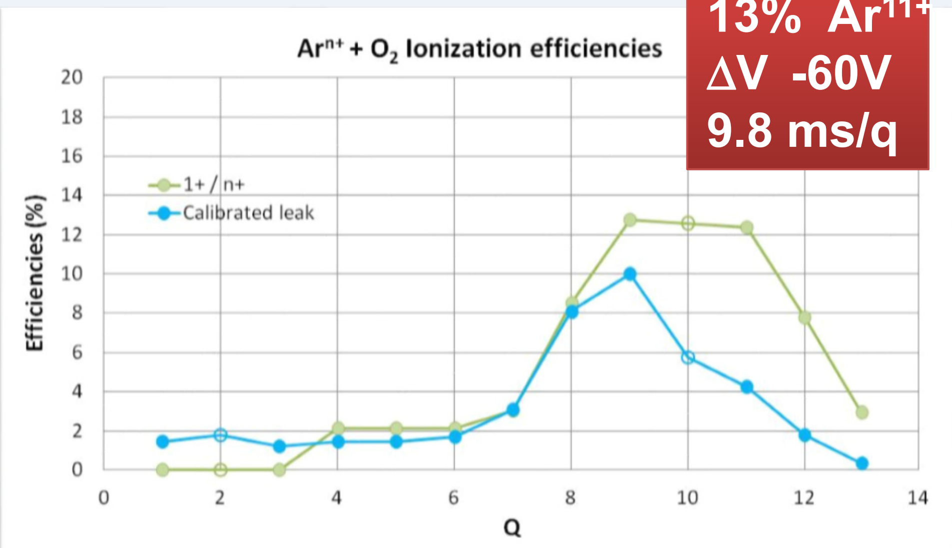


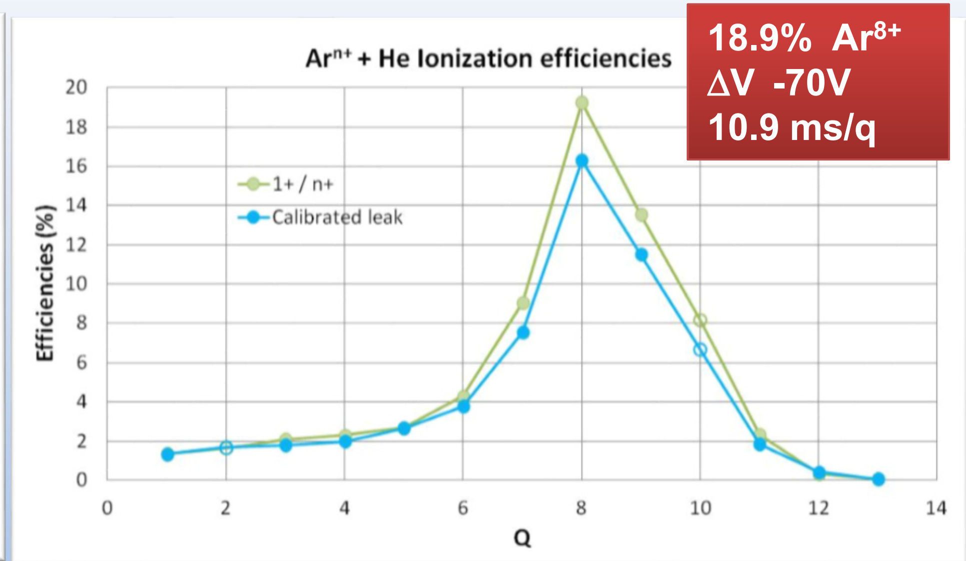
Experimental results at LPSC

Comparison of direct ionization with 1+/n+ method

13% Ar^{11+}
ΔV -60V
9.8 ms/q



18.9% Ar^{8+}
ΔV -70V
10.9 ms/q



$\Sigma(Ar^{n+})_{1+/n+}$ ~ 66%

$\Sigma(Ar^{n+})_{calibrated\ leak}$ ~ 42%

Flux of the calibrated leak ~ 15 µAp

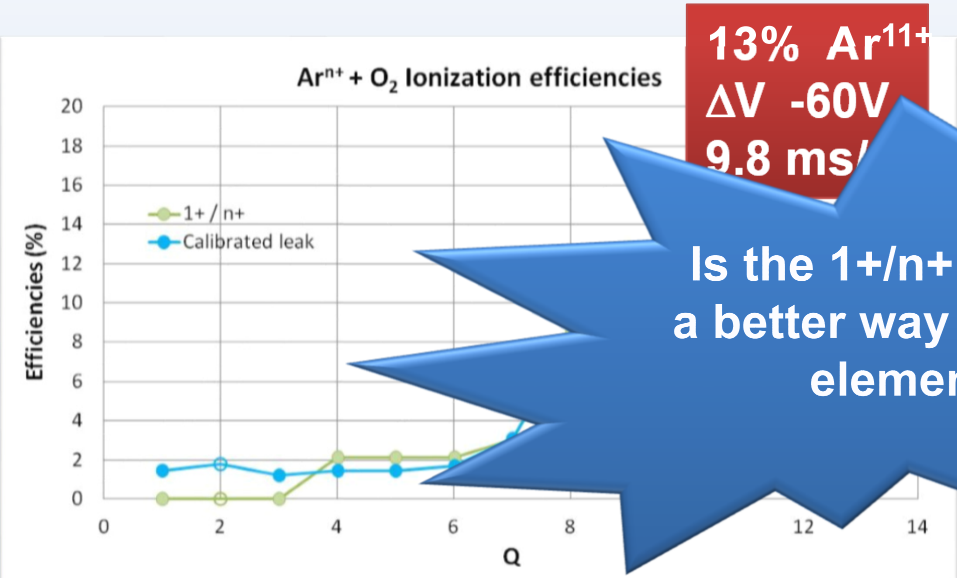
$\Sigma(Ar^{n+})_{1+/n+}$ ~ 67%

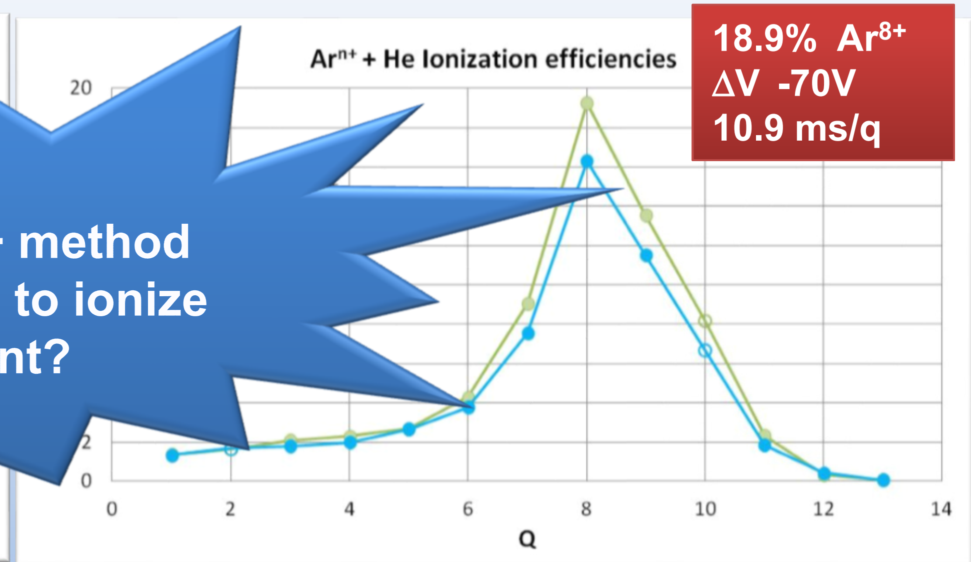
$\Sigma(Ar^{n+})_{calibrated\ leak}$ ~ 55%

Flux of the calibrated leak ~ 15 µAp

Experimental results at LPSC

Comparison of direct ionization with 1+/n+ method





$\Sigma(Ar^{n+})_{1+/n+} \sim 66\%$

$\Sigma(Ar^{n+})_{calibrated\ leak} \sim 42\%$

Flux of the calibrated leak ~ 15 µAp

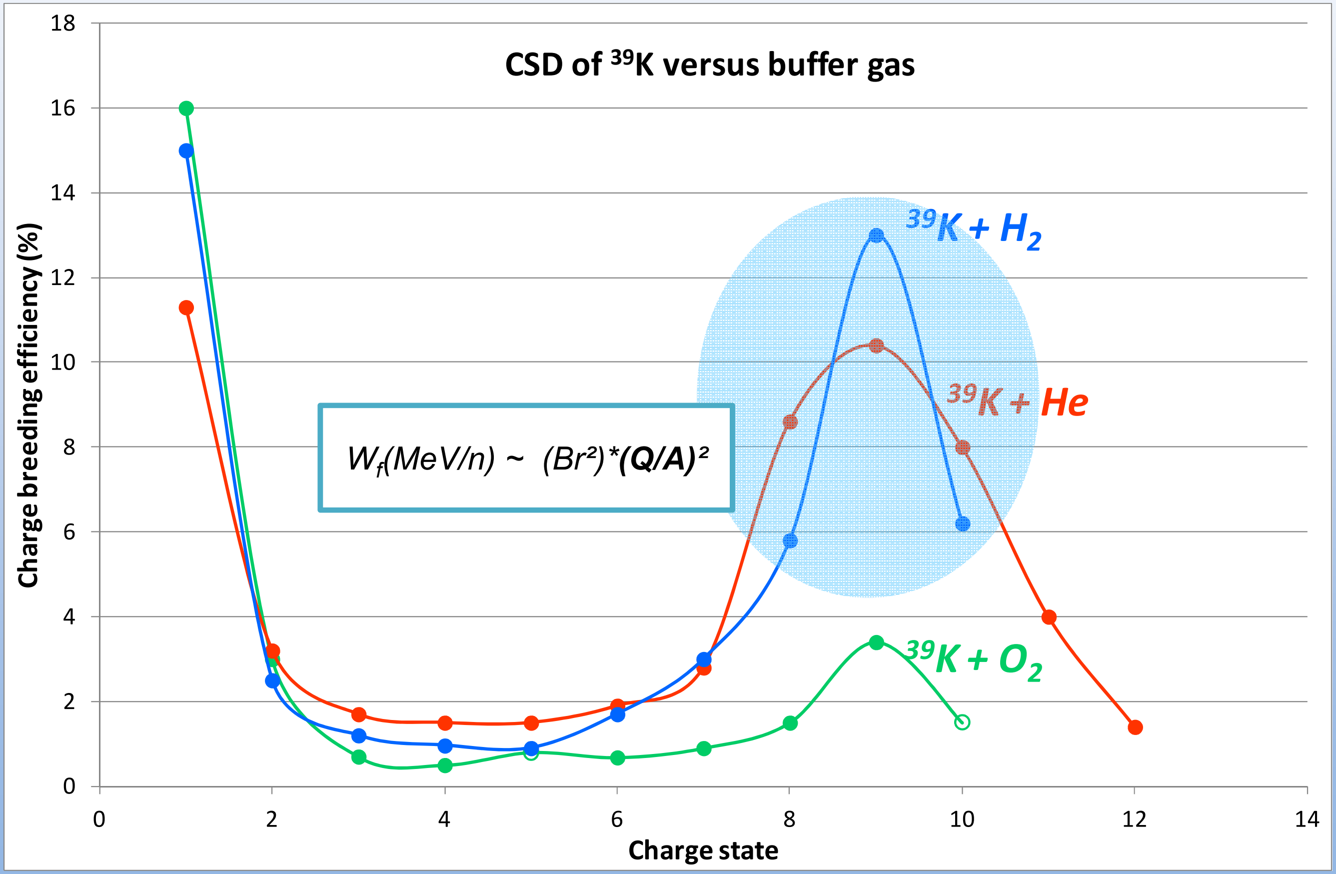
$\Sigma(Ar^{n+})_{1+/n+} \sim 67\%$

$\Sigma(Ar^{n+})_{calibrated\ leak} \sim 55\%$

Flux of the calibrated leak ~ 15 µAp

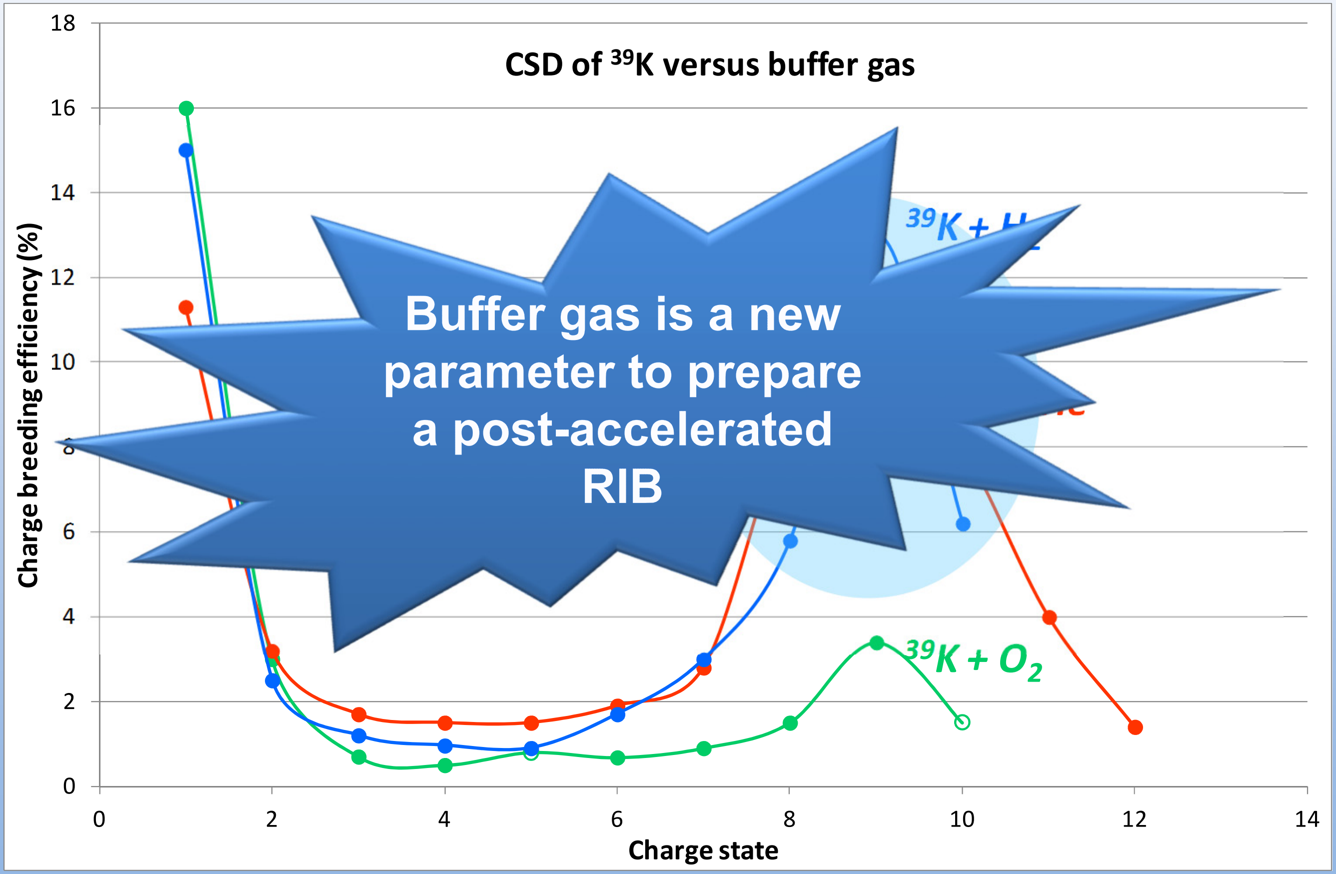
Experimental results at LPSC

Buffer gas influence



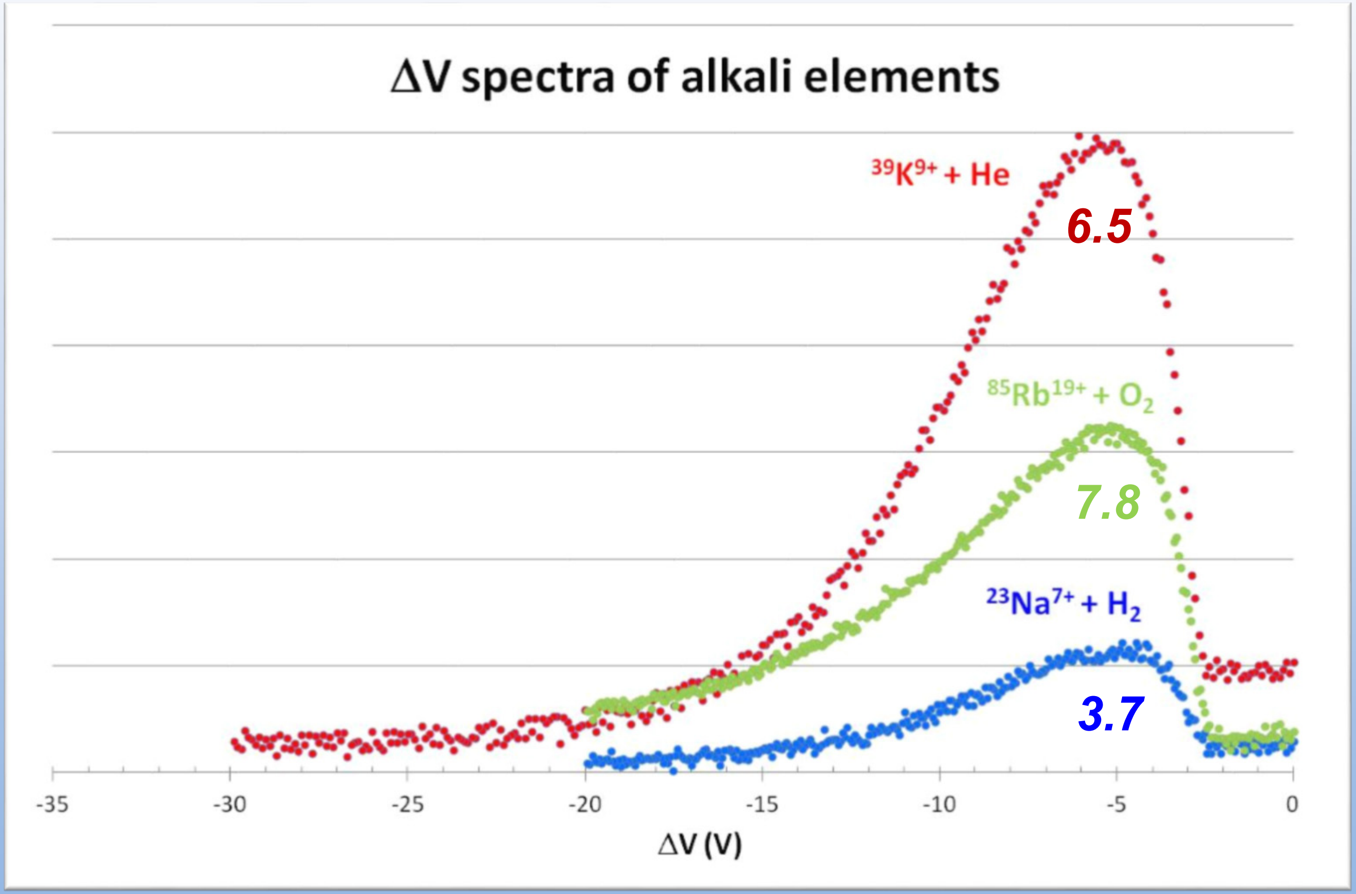
Experimental results at LPSC

Buffer gas influence

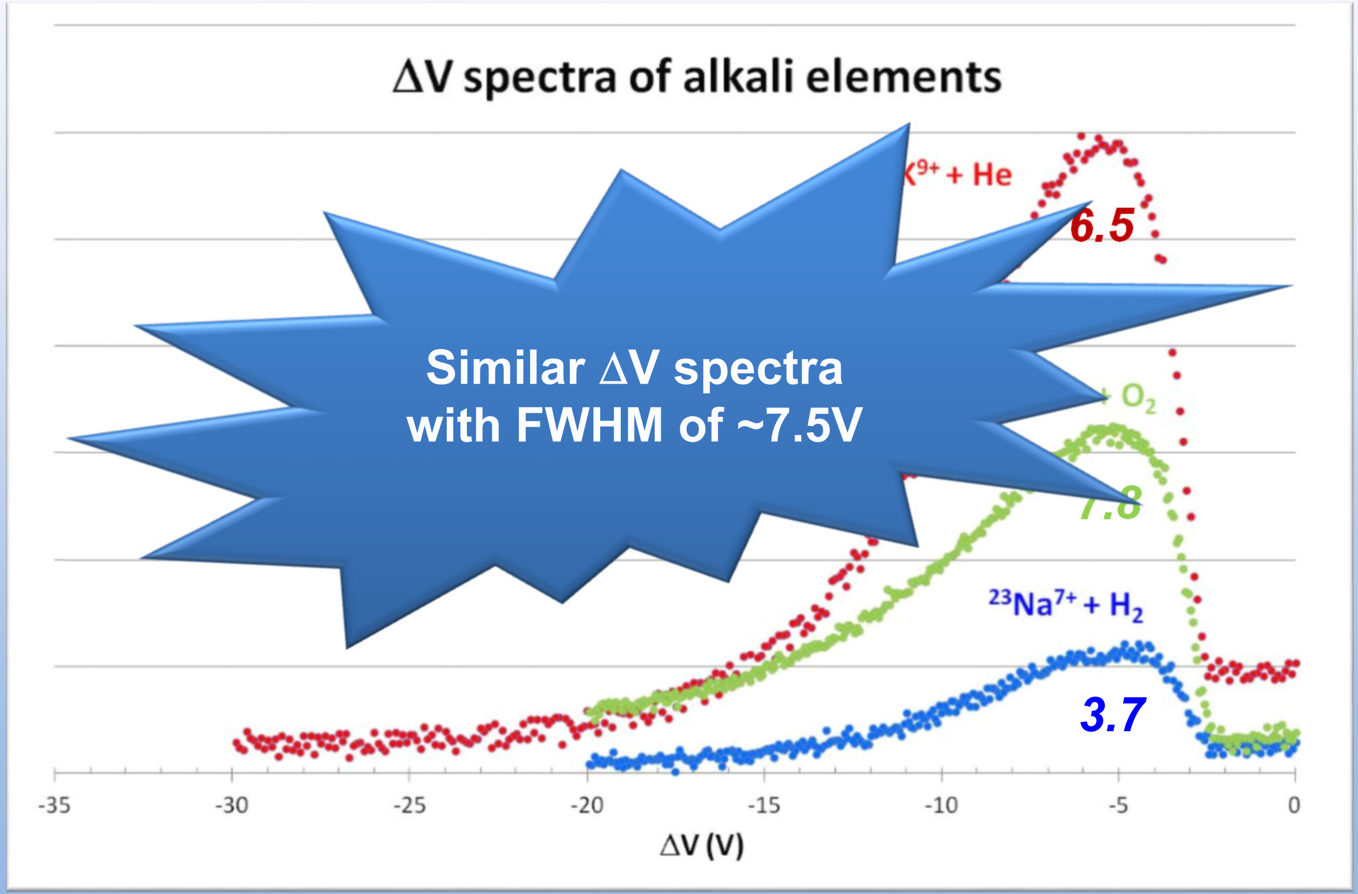


Experimental results at LPSC

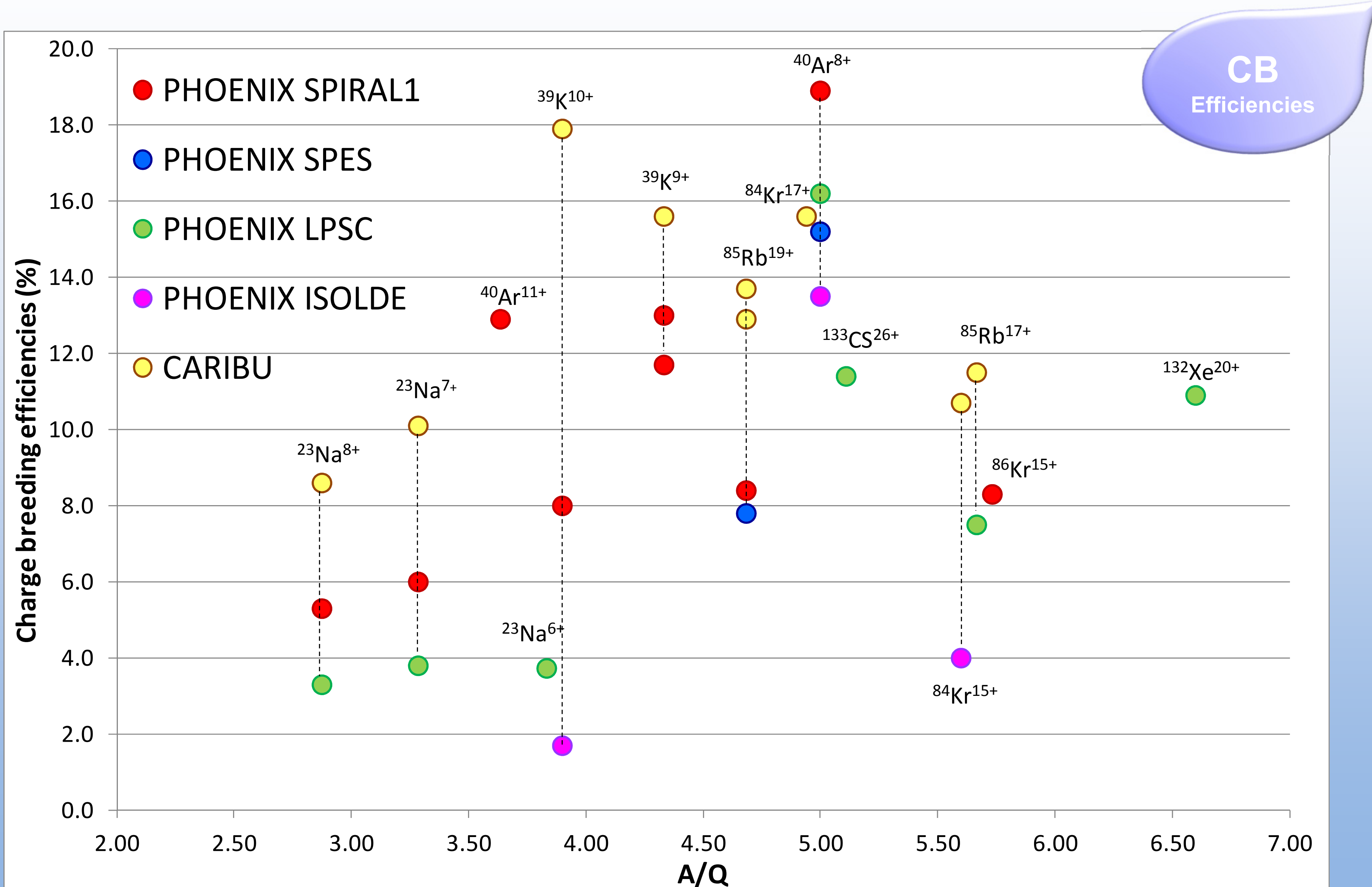
ΔV spectra evolution



ΔV spectra evolution

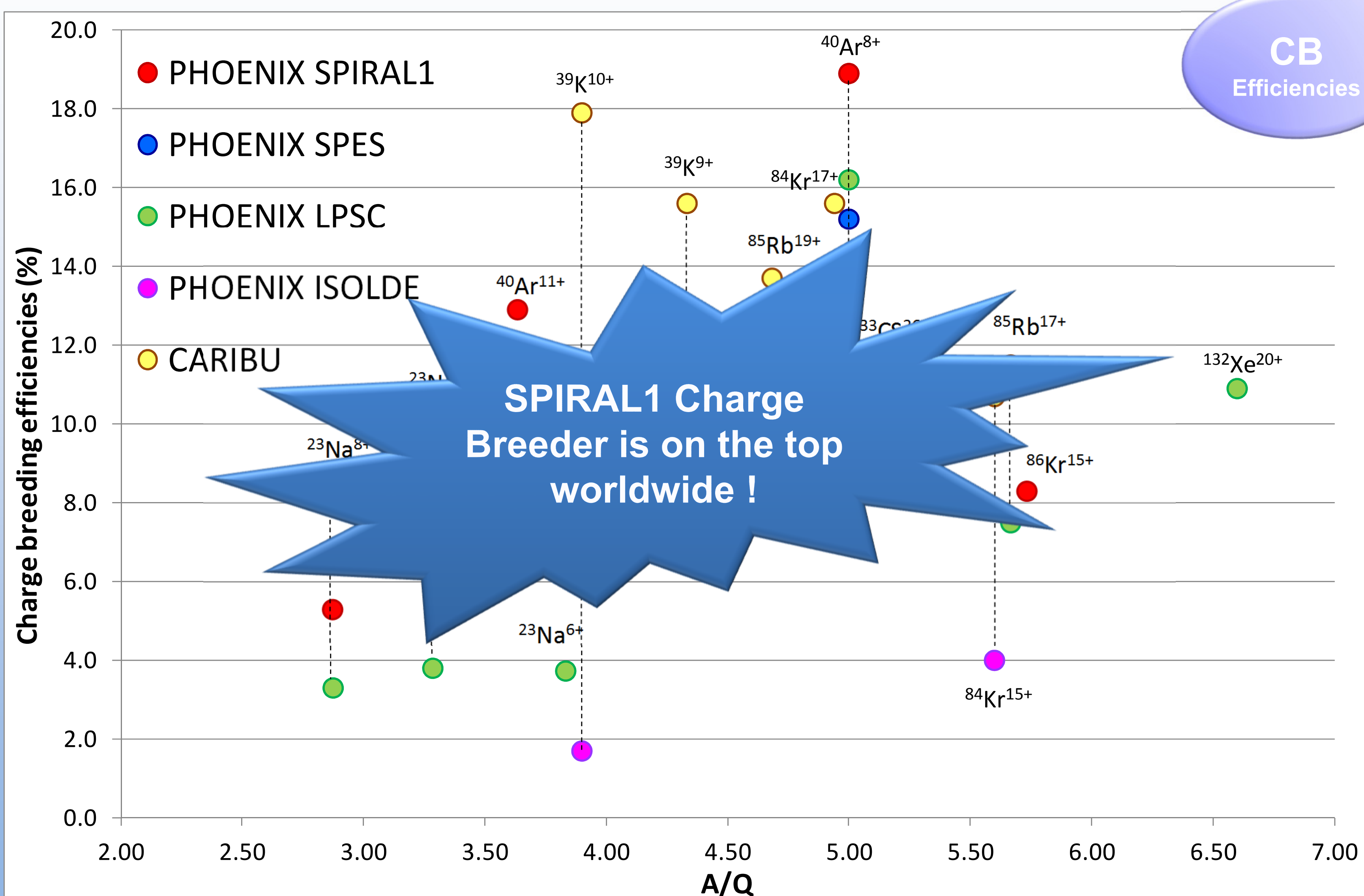


Experimental results at LPSC



Experimental results at LPSC

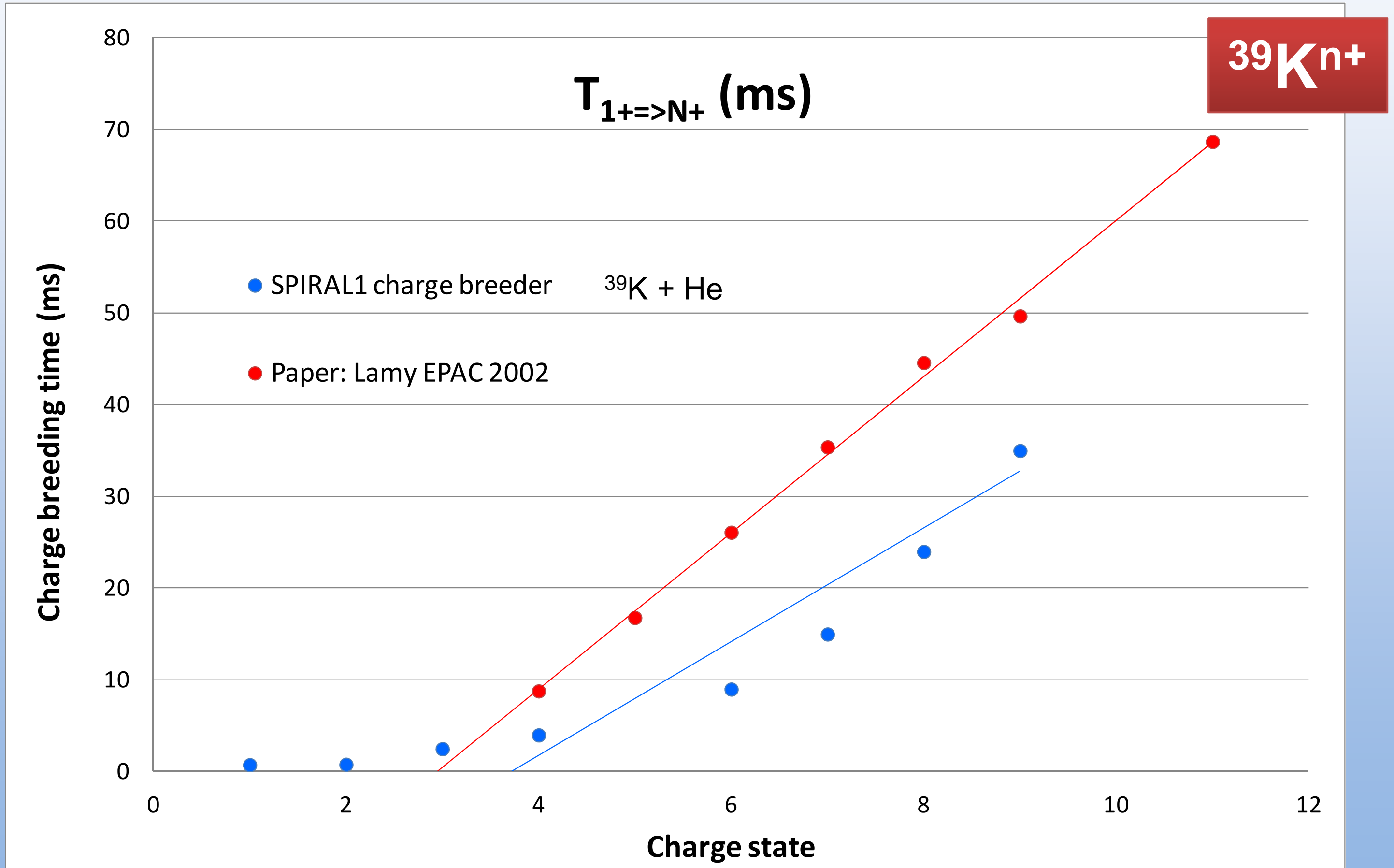
CB
Efficiencies



Experimental results at LPSC

Charge breeding time evolution

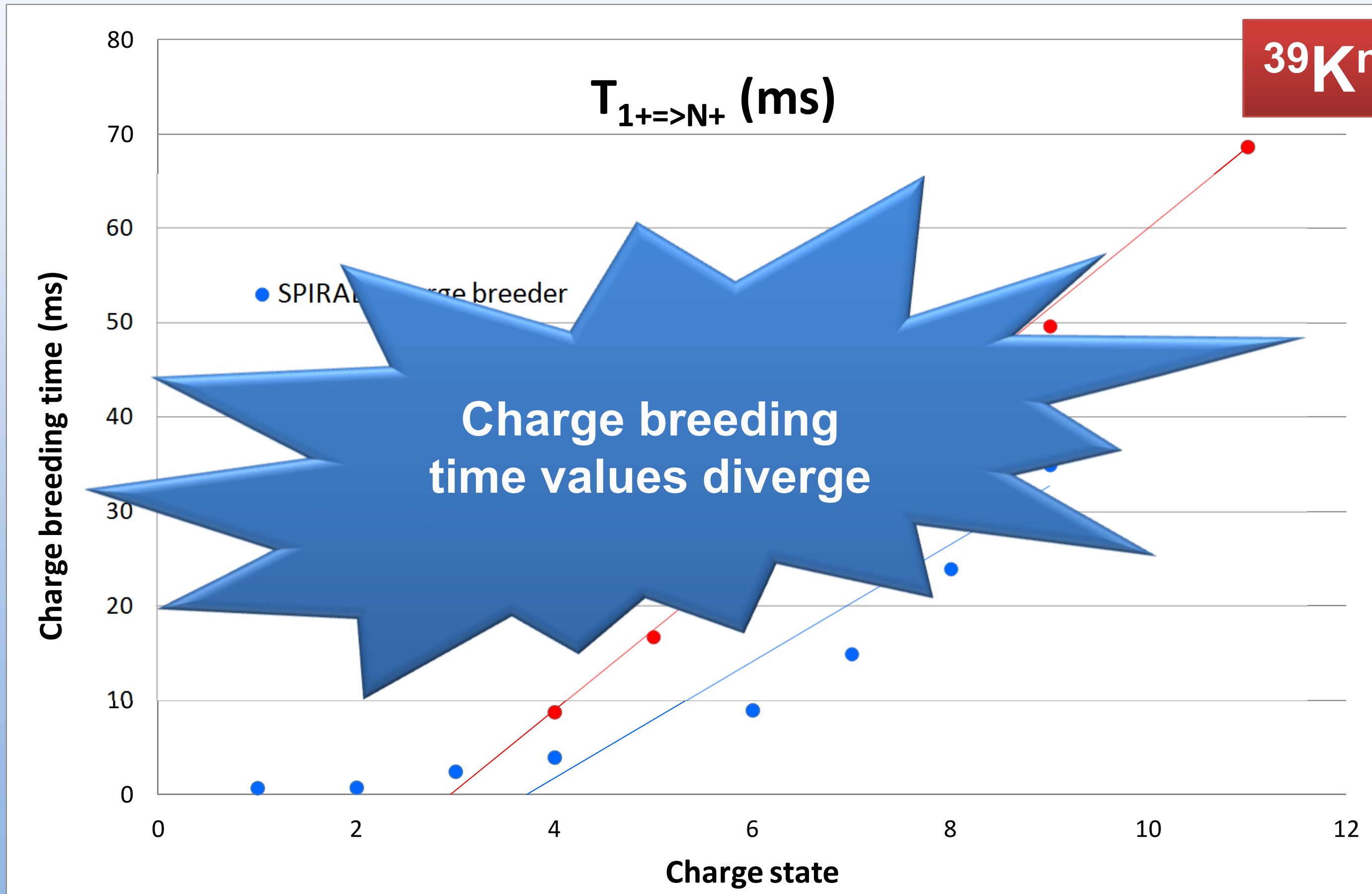
CB
Time



Experimental results at LPSC

Charge breeding time evolution

CB
Time



$^{39}K^{n+}$

Experimental results at LPSC

CB Time

Ion	A/Q	SPIRAL1 Efficiency (%)	SPIRAL1 Charge Breeding Time (ms / q)	SPES Efficiency (%)	SPES Charge Breeding Time (ms / q)	CARIBU Efficiency (%)	CARIBU Charge Breeding Time (ms / q)	LPSC Efficiency (%)	LPSC Charge Breeding Time (ms / q)	ISOLDE Efficiency (%)	ISOLDE Charge Breeding Time (ms / q)
$^{23}Na^{6+}$	3.83							3.7	6.0		
$^{23}Na^{7+}$	3.29	6.0	7.4			10.1		3.8	7.4		
$^{23}Na^{8+}$	2.88	5.3				8.6		3.2	8.8		
$^{39}K^{9+}$ (50%)	4.33	13.0	13	+ H_2		15.6	16.7	8	5.4		
$^{39}K^{9+}$ (50%)	4.33	11.7	3.9	+ He							
$^{39}K^{10+}$	3.90	8.0				17.9	15.7	5.2	6.0	1.7	10
$^{40}Ar^{8+}$	5.00	18.9	10.9	15.2	9.1			16.2	9.8	13.5	
$^{40}Ar^{11+}$	3.64	12.9	9.8					8.4			
$^{84}Kr^{15+}$	5.60					10.7		10.0		4.0	
$^{84}Kr^{17+}$	4.94					15.6		12.0	8.5		
$^{85}Rb^{17+}$	5.67					11.5	10.6	7.5	13.3		
$^{85}Rb^{19+}$ (56%)	4.68	8.4	15.8	7.8	28.2	13.7	77.9	7.3	12.0		
$^{85}Rb^{19+}$	4.68					12.9	12.1				
$^{86}Kr^{15+}$	5.73	8.3	3.4								

Experimental results at LPSC

CB
Time

Ion	A/Q	SPIRAL1 Efficiency (%)	SPIRAL1 Charge Breeding Time (ms / q)	SPES Efficiency (%)	SPES Charge Breeding Time (ms / q)	CARIBU Efficiency (%)	CARIBU Charge Breeding Time (ms / q)	LPSC Efficiency (%)	LPSC Charge Breeding Time (ms / q)	ISOLDE Efficiency (%)	ISOLDE Charge Breeding Time (ms / q)
$^{23}Na^{6+}$	3.83							3.7	*6.0*		
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$^{23}Na^{8+}$	2.88	5.3				8.6		3.2	*8.8*		
$^{39}K^{9+}$	4.33	13.0	*13*						*5.4*		
$^{39}K^{9+}$	4.33	11.7	[illegible]								
$^{39}K^{10+}$	3.90	8.0							*6.0*	1.7	*10*
$^{40}Ar^{8+}$	5.00	[illegible]						[illegible]	*9.8*	13.5	
$^{40}Ar^{11+}$	3.64	12.9						8.4			
$^{84}Kr^{15+}$	5.60					[illegible]		10.0		4.0	
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$^{85}Rb^{17+}$	5.67					11.5	*10.6*	7.5	*13.3*		
$^{85}Rb^{19+}$	4.68	8.4	*15.8*	7.8	*28.2*	13.7	*77.9*	7.3	*12.0*		
$^{85}Rb^{19+}$	4.68					12.9	*12.1*				
$^{86}Kr^{15+}$	5.73	8.3	*3.4*								

50%

56%

Not only charge breeding efficiency BUT also charge breeding time !

Ion confinement time

CB
Time

RIB	1+n+ Conversion Time (ms)	T1/2 (ms)
$^{30}Na^{7+}$	51.8	48
$^{35}K^{9+}$	117	190
$^{35}K^{9+}$	35.1	190
$^{32}Ar^{8+}$	87.2	98
$^{74}Rb^{19+}$	300.2	64.8
$^{71}Kr^{15+}$	51	100

(green)	Day 1 RIB
(orange)	Radioactive decay losses
(light green)	Behavior as stable

PhD under progress

1+n+ conversion time plays a major role

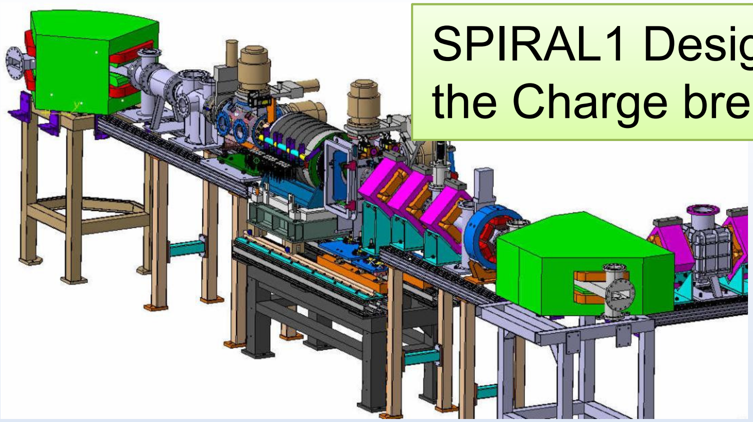
1+n+ conversion time should be controlled

Experimental study => more systematic data collection depending on CB operation conditions
Theoretical work => creation of code based on coulomb force

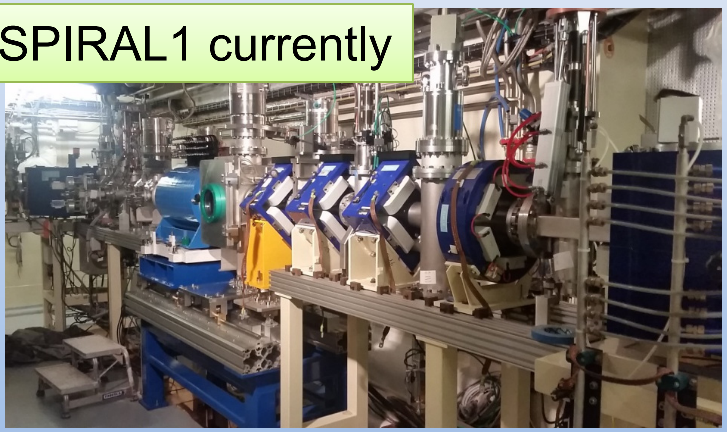
Status and commissionning

SPIRAL1 last year

SPIRAL1 Design with the Charge breeder



SPIRAL1 currently

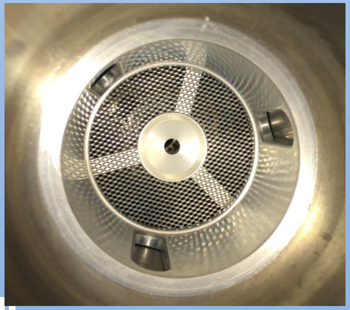


New features on our Charge breeder

✓ Coating of a pure Al layer 99.999% => **beam purity**

✓ Plasma electrode using a grid => **better residual gas pressure**

✓ Deceleration as well as puller electrodes with holes => **better residual gas pressure**

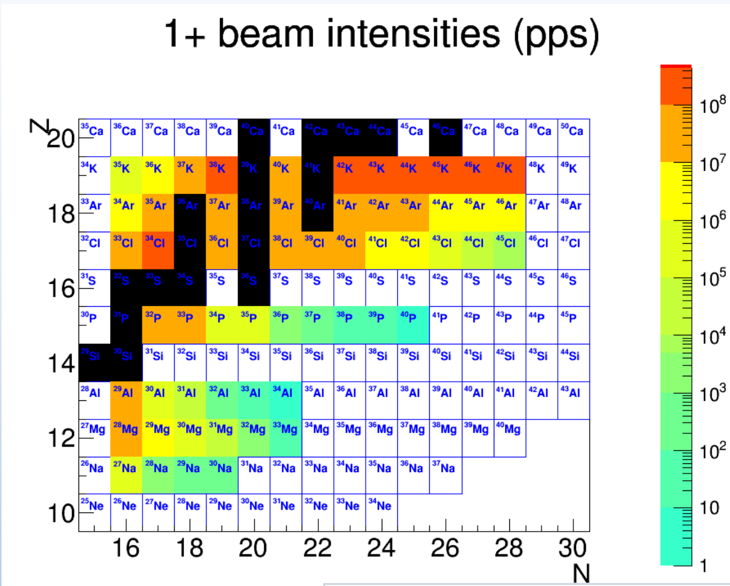


Plasma electrode

→ ANL advice

Status and commissionning

Towards the Day 1 RIB



Post-accelerated beams

^{38m}K ($T_{1/2}$=924.2ms) 9 A.MeV
Coulomb excitation experiment
Primary beam ^{40}Ca
~10^6 pps

^{17}F ($T_{1/2}$=64.49s) 7 A.MeV
ACtive TARget (ACTAR) experiment
Primary beam ^{20}Ne
~10^5 pps

Commissionning steps

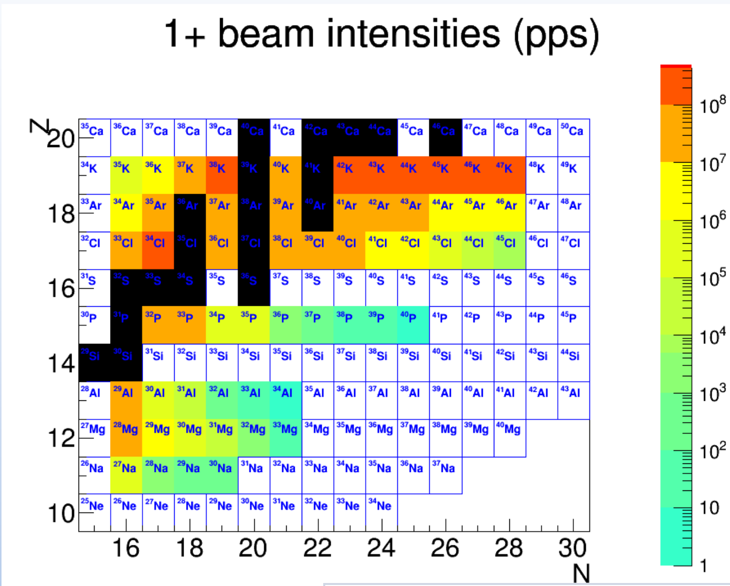
	Charge breeder alone	Going through mode	1+ n+ mode	1+ n+ post and post-accelerated beam mode
TISS				
Charge Breeder				
CIME				
Stable Ions / GAS	1			
Stable Ions / NANOGAN TISS		2	3	
Condensable - stable - Ions / Test TISS		4	5	6
Radioactive Ions / FEBIAD TISS		7		8

7: 1+ LE

8: n+ HE

Status and commissionning

Towards the Day 1 RIB



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Primary beam ^{20}Ne
~10^5 pps

Commissionning steps

	Charge breeder	Going through	1+ n+ mode	1+ n+ post and post-accelerated beam mode
TIS…				
…arge B…				
…CIM…				
…able Io…			3	
Condensable - stable - Ions / Test TISS		4	5	6
Radioactive Ions / FEBIAD TISS		7 (1+ LE)		8 (n+ HE)

First RIB for the second quarter of 2017 !

Conclusion

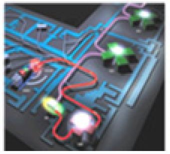
<u>In conclusion:</u>

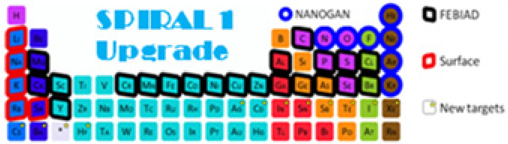
✓ The Spiral1 Charge Breeder has been modified with success

✓ Experimental results have proved the high performance of the CB

✓ Charge breeding time should be controlled => more experiment should be undertaken

✓ Margin for increasing the charge breeding efficiency especially for elements with light masses





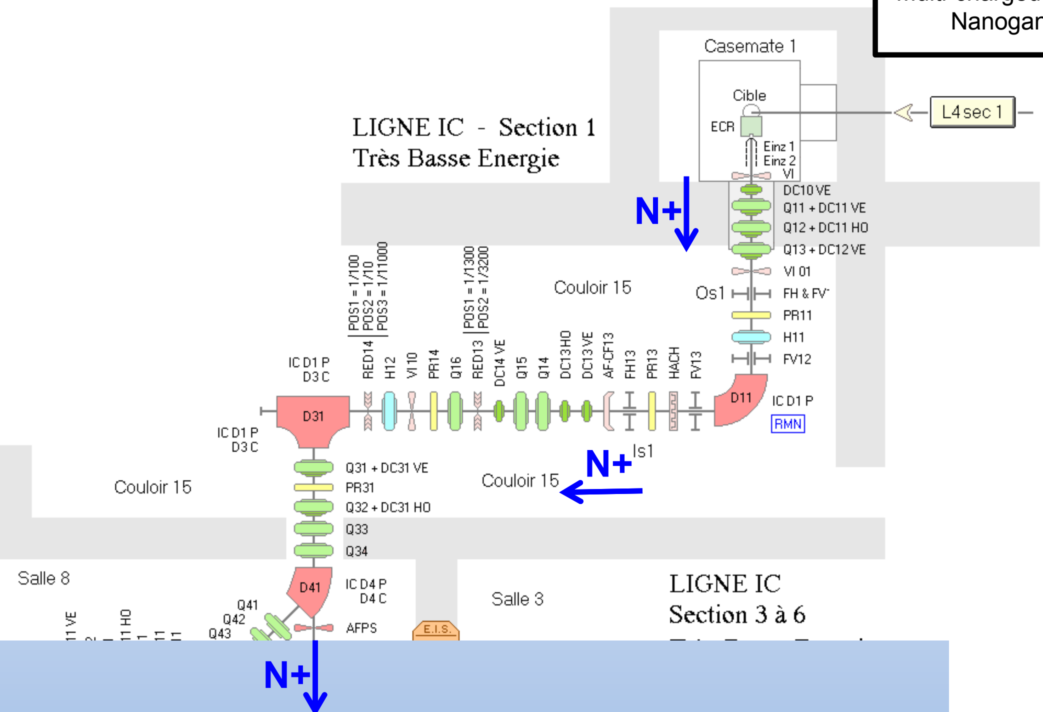
See you at the ICIS 2017 – CERN with radioactive beam results !

Thank you for your attention

Framework

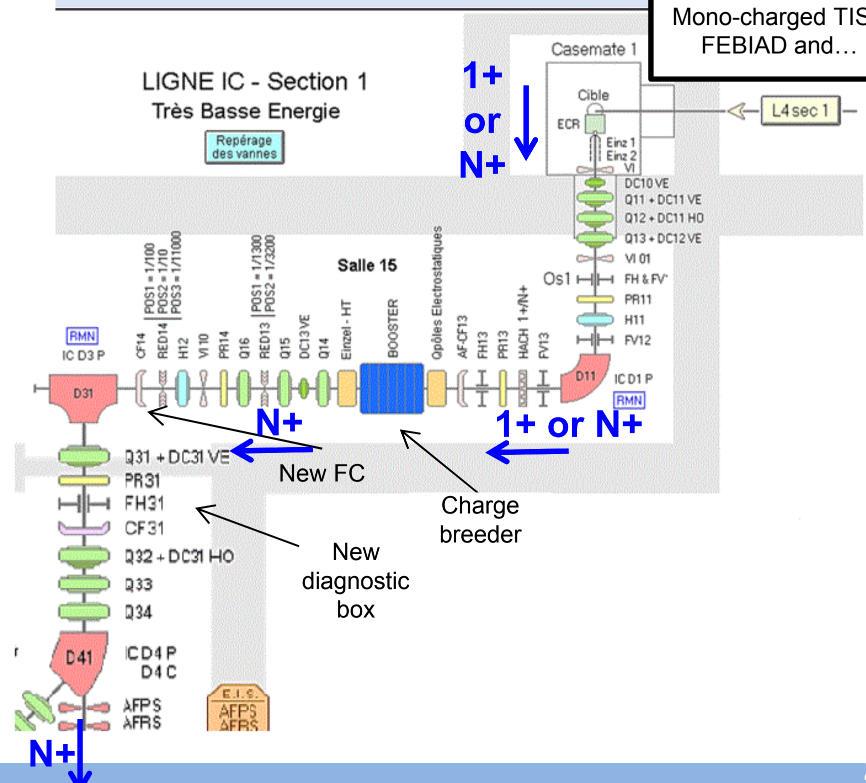
Previous SPIRAL1 scheme

Multi-charged TISS
Nanogan



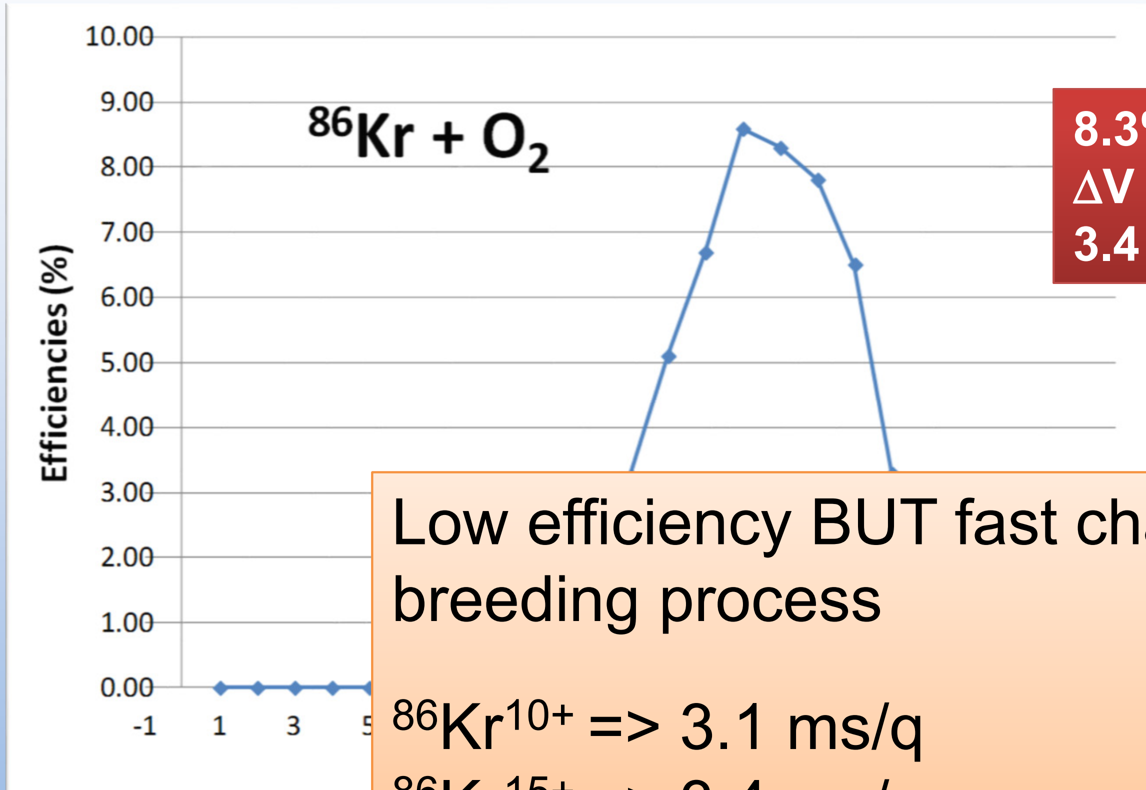
Future SPIRAL1 layout

Mono-charged TISS
FEBIAD and…



Experimental results at LPSC

CB
Time



8.3% $^{86}Kr^{15+}$
ΔV -40V
3.4 ms/q

Low efficiency BUT fast charge breeding process

$^{86}Kr^{10+}$ => 3.1 ms/q
$^{86}Kr^{15+}$ => 3.4 ms/q
$^{86}Kr^{20+}$ => 3.4 ms/q