CHARGE BREEDING TIME STUDIES WITH SHORT PULSE BEAM INJECTION

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Laboratoire de Physique Subatomique et de Cosmologie

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Outline

- Introduction to ECR Charge Breeding
- Motivations for short pulse beam injection
- Experimental setup and results
- Implication on the RIB CB efficiency
- Conclusion

Introduction

- ECR CB are used in ISOL facilities (SPIRAL1, TRIUMF, SPES..) to increase the charge state of a RIB from 1+ ➔ N+
  - Radioactive production yield $10^2 - 10^{11}$ particles per second

- It is a link in the ISOL chain, characterized by
  - The efficiency $\eta = \dfrac{extracted\ particle\ current}{injected\ particle\ current}$
  - The beam purity, % of chemical contaminants included into the N+ beam
  - The time of the 1+➔N+ process = CB Time τ_{CB}

Introduction

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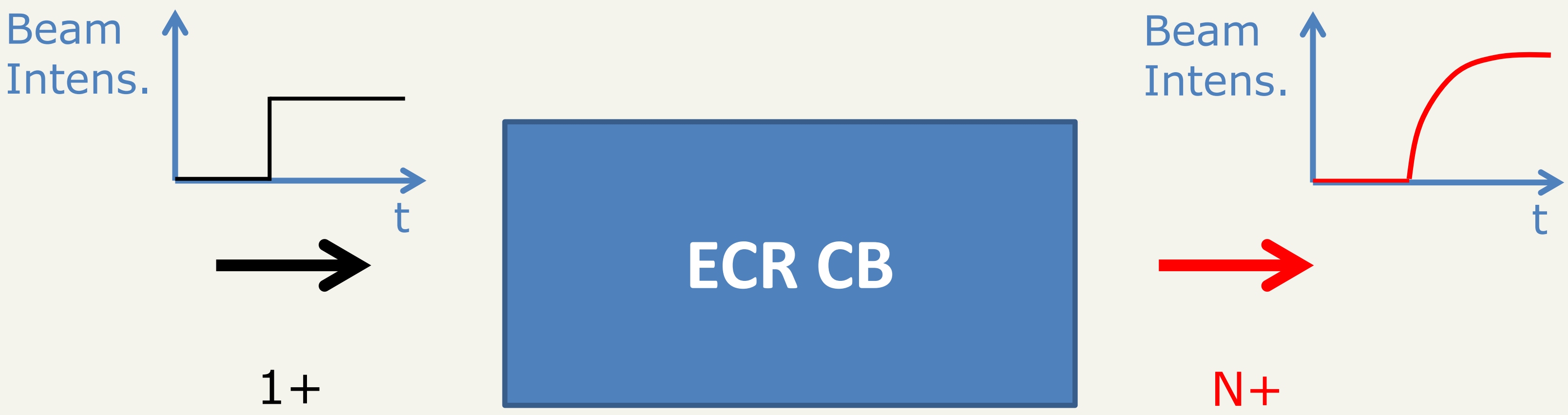
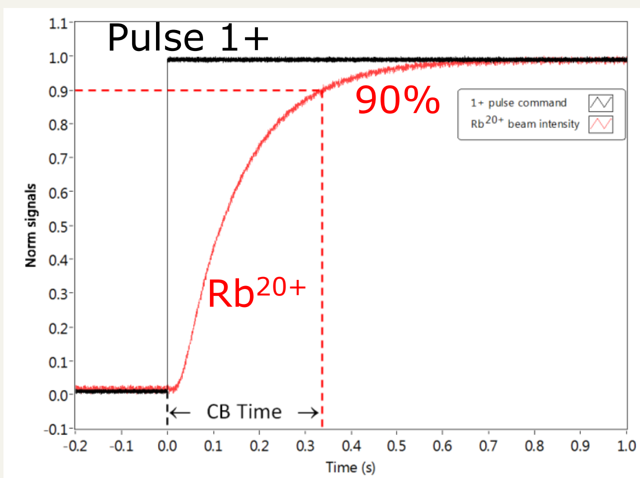
- Traditional method of CB Time measurement
  - generate a rise front with 1+ beam
  - N+ : measure the necessary time to reach 90% of the final value



- Example with Rb^{20+}
- CB Time τ_{CB} = 330 ms



Motivations for short pulses injection

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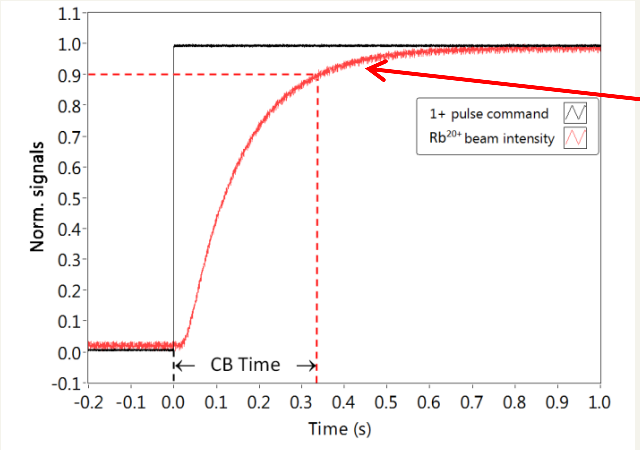
- Ambiguous measurement



At t=0.4s, Rb^{20+} signal still increasing
When were these extracted ions injected ?
At t=0 or later ?

- Help in understanding large discrepancies in the CB time measured values

		SPIRAL1		CARIBU		LPSC	
Ion	A/q	Efficiency (%)	τ_{CB} (ms/q)	Efficiency (%)	τ_{CB} (ms/q)	Efficiency (%)	τ_{CB} (ms/q)
$^{39}K^{10+}$	3.9			17.9	15.7	11.7	8.2
$^{39}K^{9+}$	4.33	13.0	13.0 He	15.6	16.7		
$^{39}K^{9+}$	4.33	11.7	3.9 H_2				
$^{132}Xe^{26+}$	5.07			13.5	46.1 ≠ freq	13.3	5.9
$^{132}Xe^{26+}$	5.1			10	8.8		

R. Vondrasek
RSI 77,03B107
RSI 83,113303

L. Maunoury talk
ECRIS2016

The support gas, frequency, microwave power… can have a strong influence on τ_{CB}

Motivations for short pulses injection

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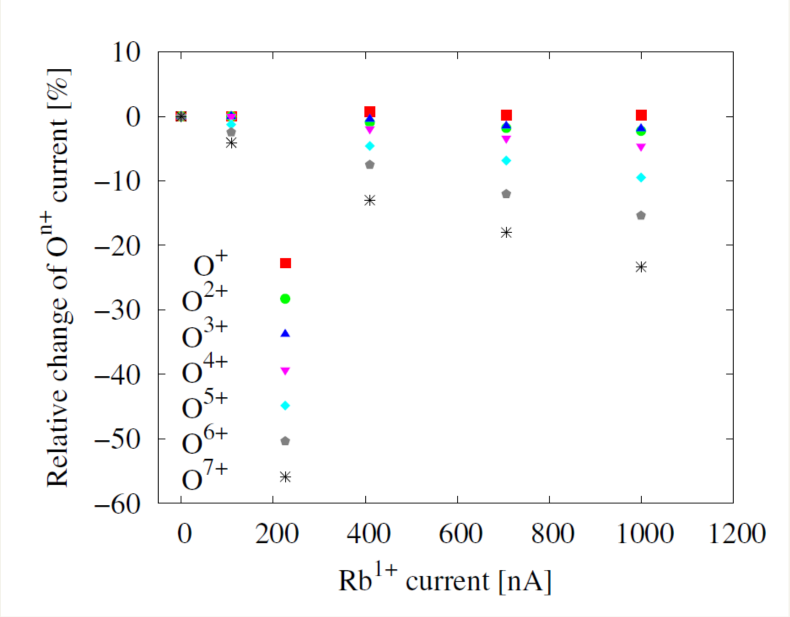
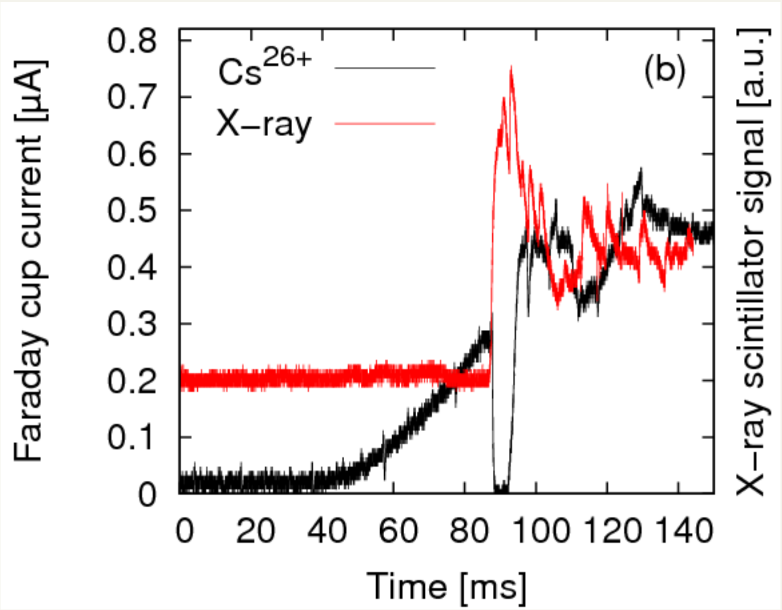
- Accumulation effect, beam injection can :

Modify the CB plasma (O_2)

Trigger instabilities in a time scale comparable to the CB time



400W, Rb^{1+} injection



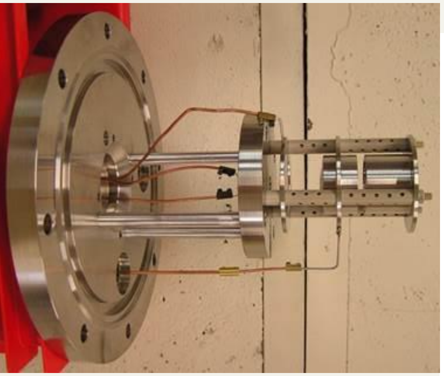
Injection at t=0, 915 nA of Cs^{1+}
Buffer gas O_2

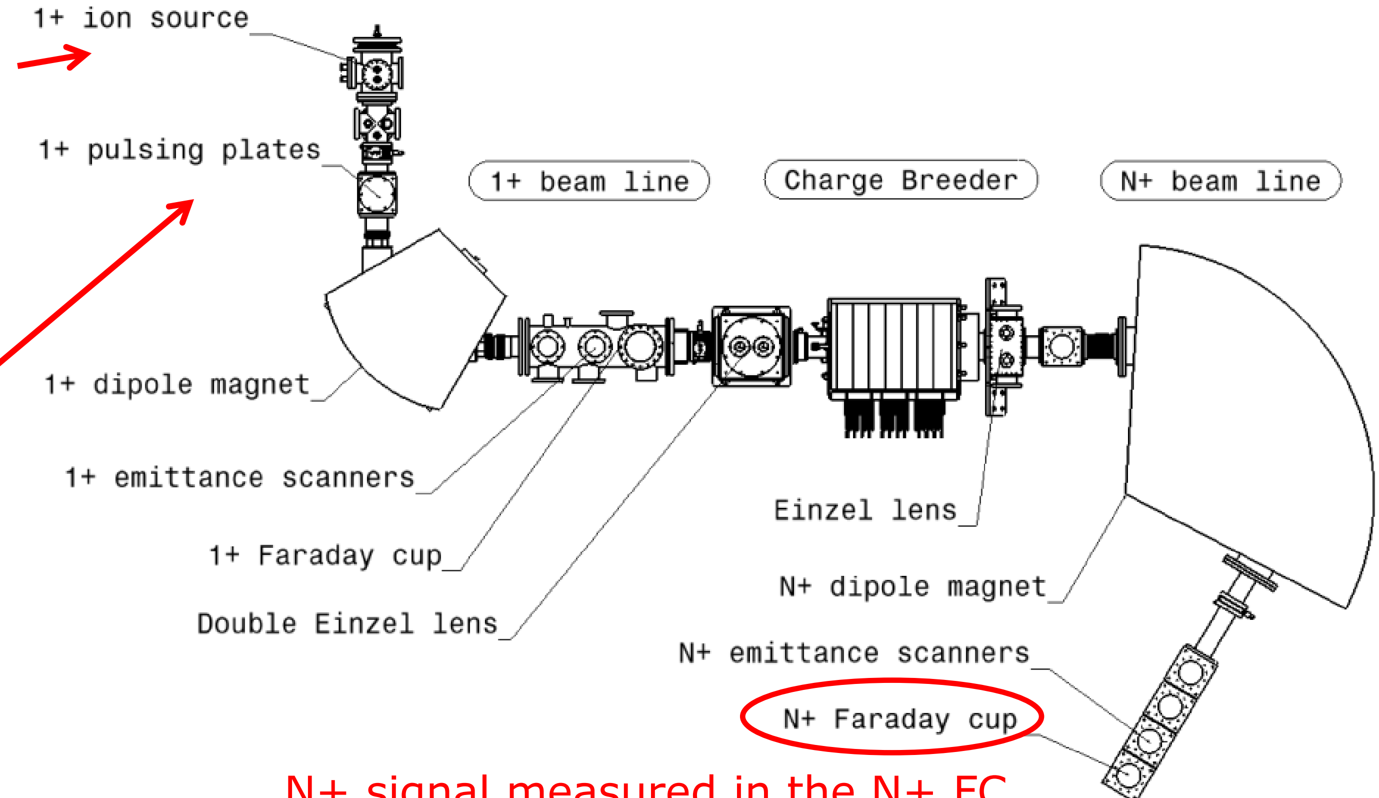
➔ Measure the CB time injecting short pulses

Experimental setup

➤ Experiments carried out on the LPSC 1+N+ beam line

Ion gun





N+ signal measured in the N+ FC

To ensure a precise pulse duration : Use of a signal generator instead of the DAQ board

Experimental setup

- Configuration of the PHOENIX ECR charge breeder

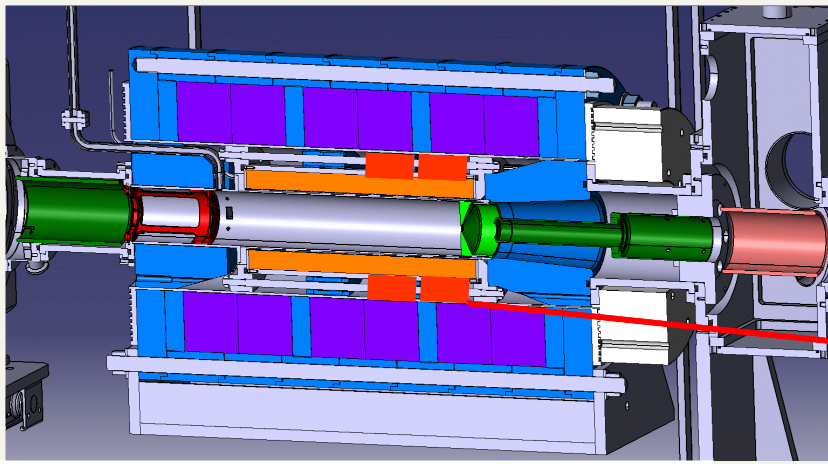
14.5 GHz 500W operation

Injection

Extraction

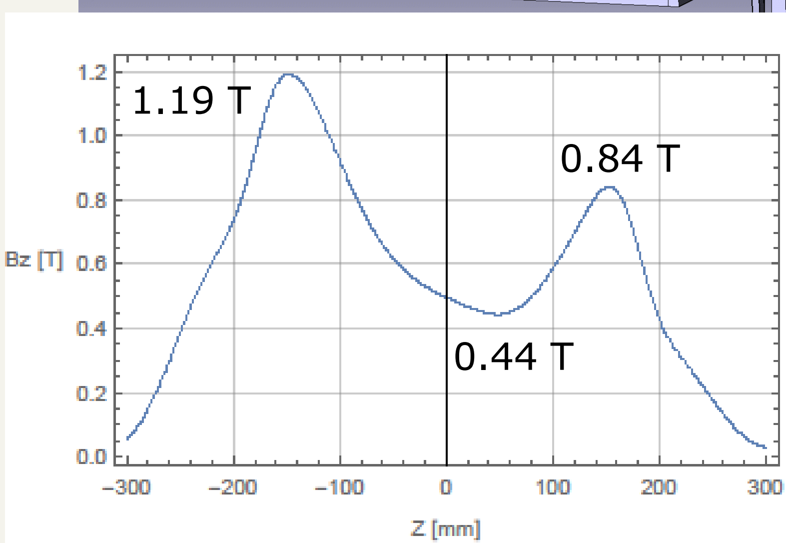
Large diameter injection electrode

HF blocker electrode



2 movable soft iron rings set at extraction

Axial field profile



Br = 0.8T at plasma chamber wall

Experimental results

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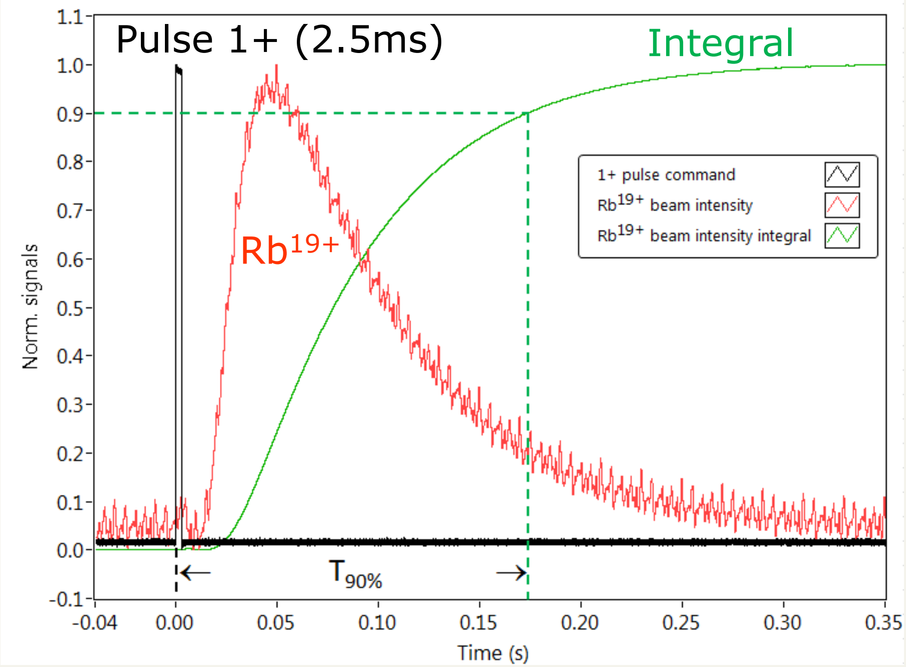
- Rb1+ beam injected in a He CB plasma
- Decrease of the pulse duration until the temporal response becomes constant



- Efficiency in pulse mode

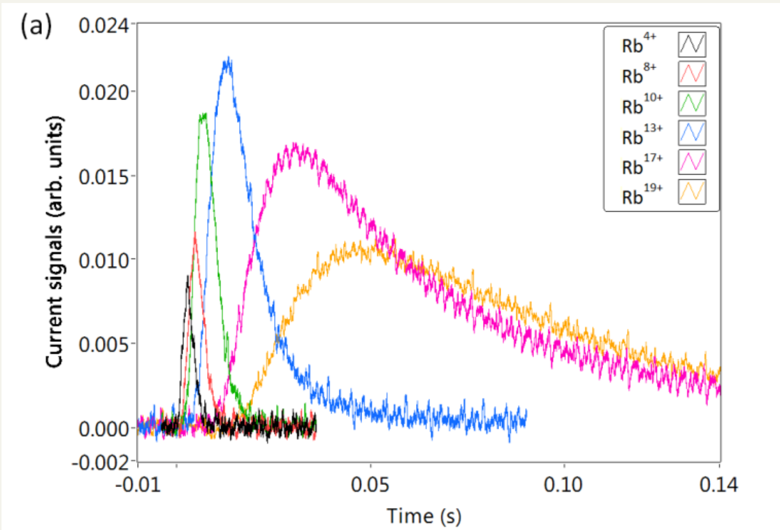
$$\eta = \frac{nb\ extracted\ particles}{nb\ injected\ particles}$$

- CB Time : the necessary time to extract 90% of the N+ particles

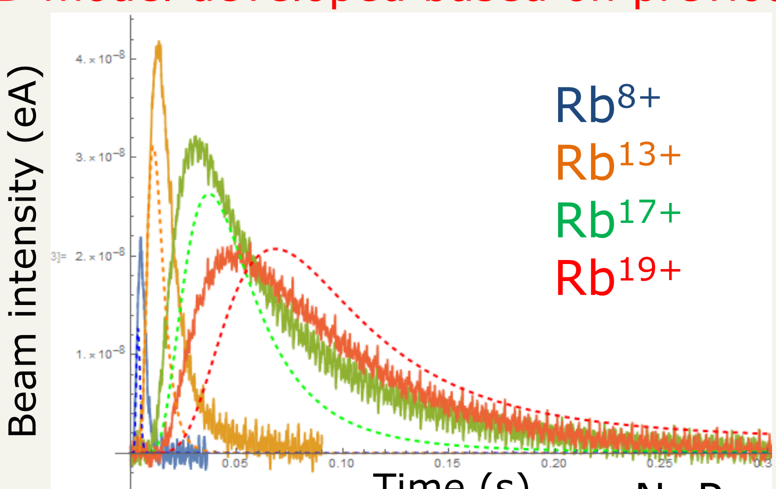
- Efficiency in pulse mode = Efficiency with traditional method
- The time to extract 90% of the N+ ions < traditional CB time by ~10%
- No noticeable accumulation effect in this configuration

Experimental results

➢ N+ response of several charge states was recorded

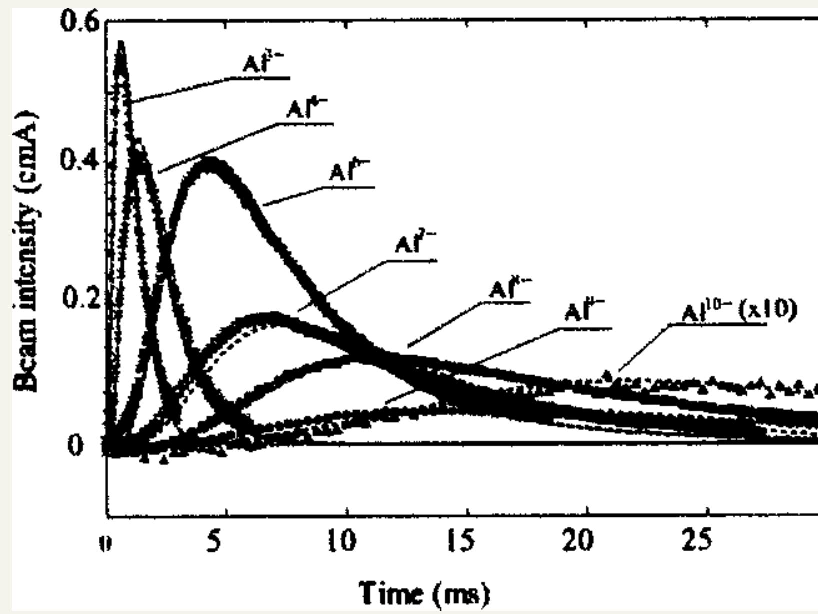


- Illustrates the step by step ionisation
- 0D model developed based on previous work



N. Preveraud

➢ Similar experiments injecting pulses of neutrals were done (RIKEN, ANL, Frankfurt..)
  - Study the plasma behavior and estimate the plasma parameters with a 0 dimension model



Nakagawa RSI 75,1394

Experimental results

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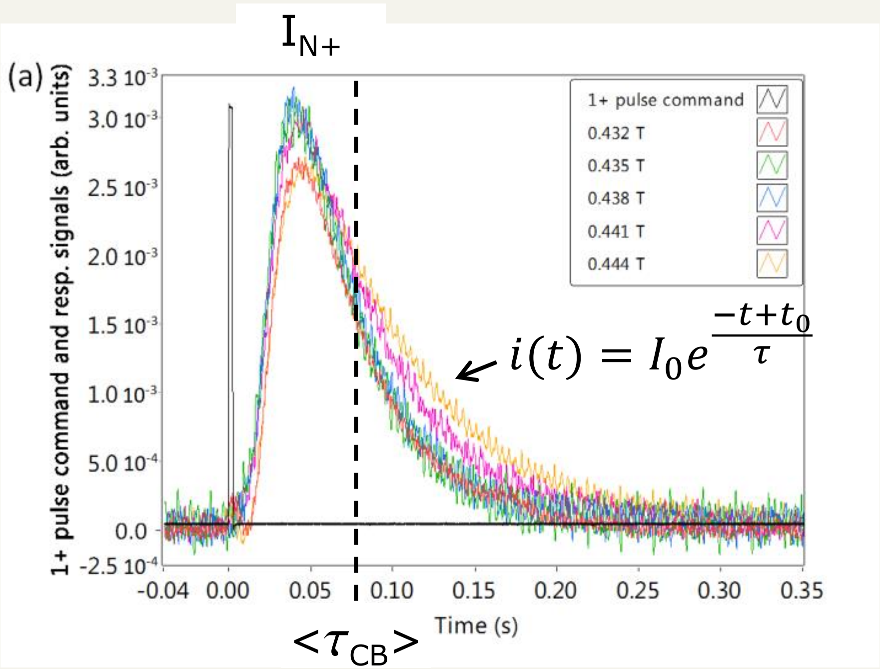
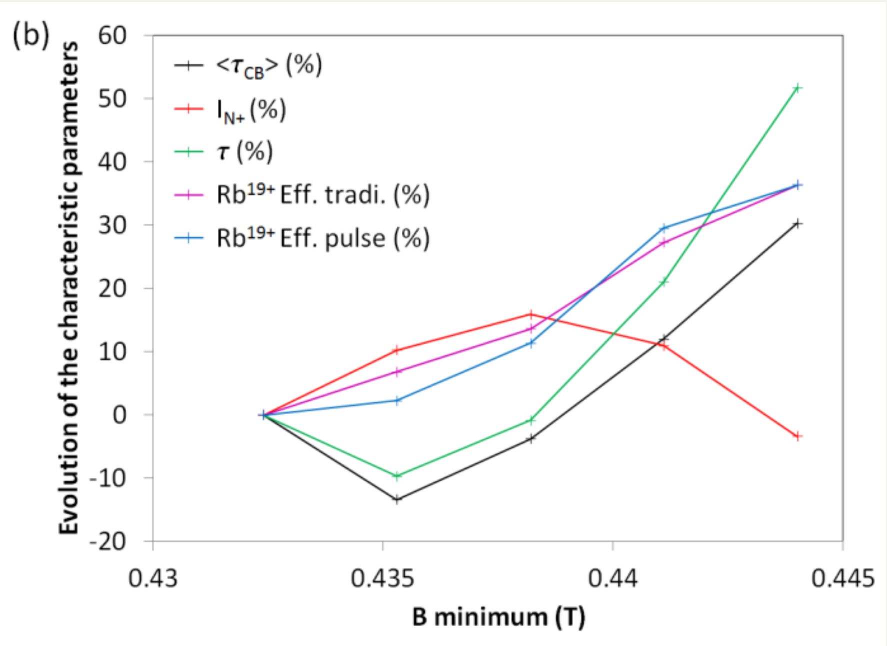
- Method used to study plasma behavior : Bmin variation
  - Linear variation 0.432 T ➔ 0.444 T gives linear increase of Rb^{19+} efficiency 4.4 % ➔ 6 %



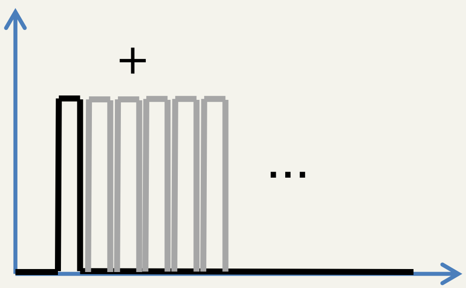


- Efficiencies in pulse mode and with traditional method are the same
- Increase of $<\tau_{CB}>$ ➔ better confinement of high charge state ions
- Short pulse injection is a tool to understand the plasma behavior

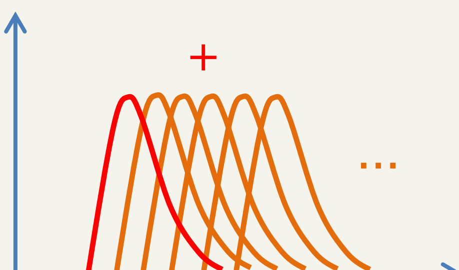
Experimental results

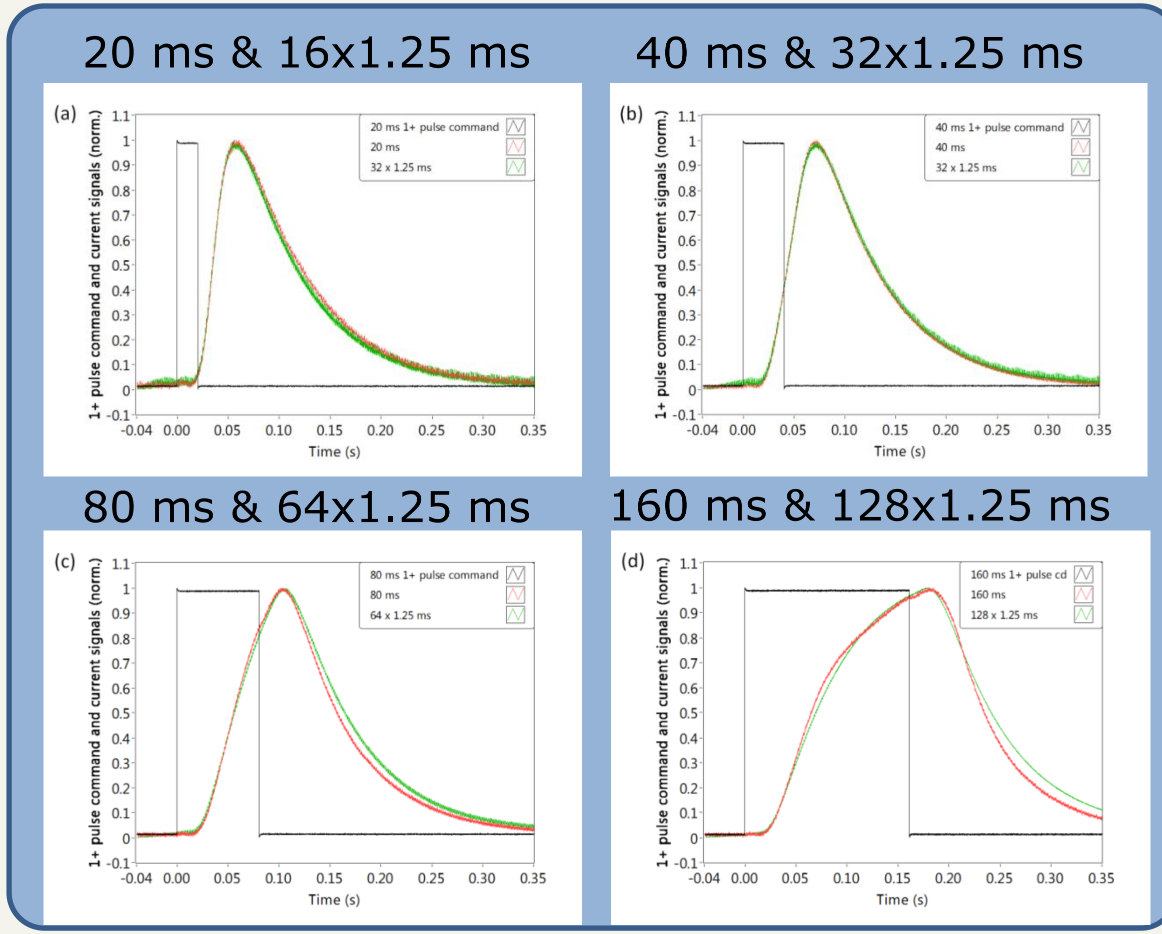
- Other studies of accumulation effect, with Rb^{19+}
  - Duplication + time shift + sum of the 1.25ms N+ response
  - Reconstructed curves compared to long pulse N+ responses

Pulse



N+ response



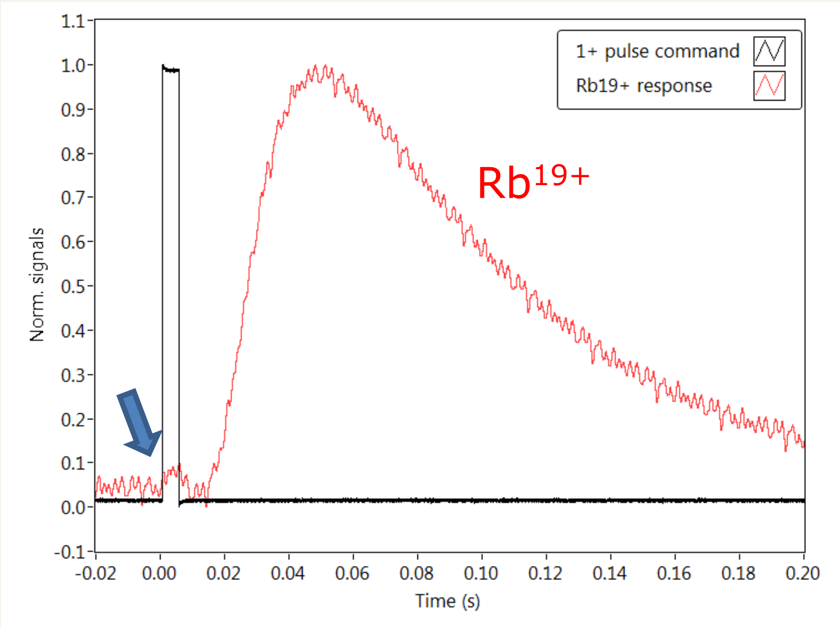


N+ responses well reproduced ➔ small cumulative effect

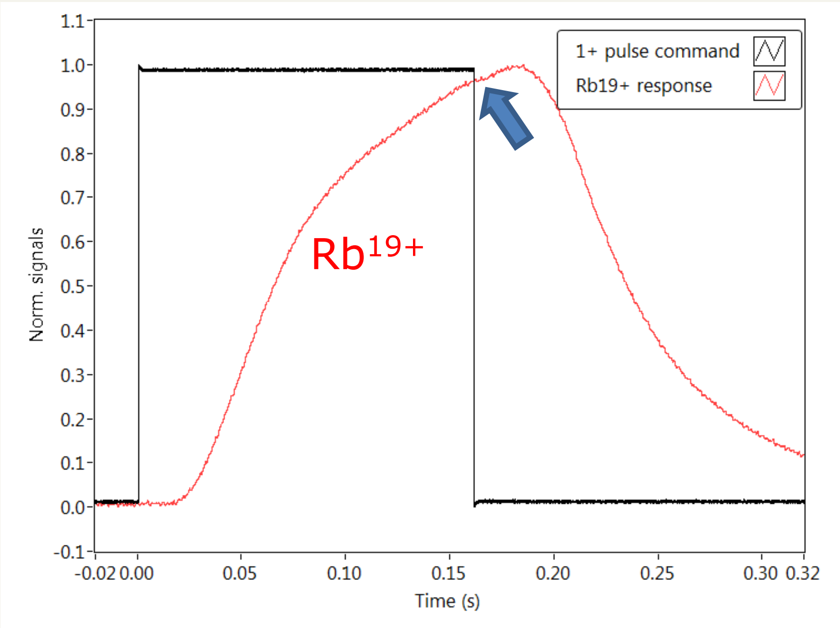
Experimental results

➤ Interaction between the injected beam and the high charge state plasma ions

10 ms pulse, 0.4 Hz



160 ms pulse, 0.4 Hz



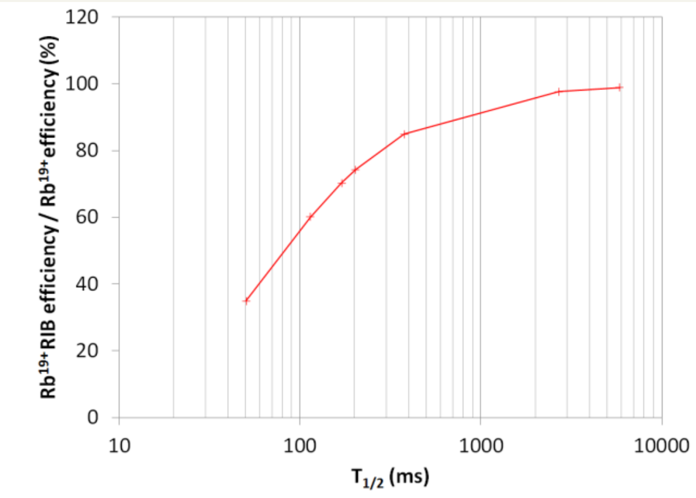
Reasons ?

- Coulomb collisions between injected ions and plasma ions
- Modification of the potential dip ➔ de-confinement of high charge state ions
- Combination of the two

Implication on the RIB CB efficiency

- Population decay on the form $N(t) = N_0 e^{\frac{-t}{\tau_1}}$ $T_{1/2} = \tau_1 * \ln(2)$
- + N+ response ➔ calculation of the effic. as a function of $T_{1/2}$
- Exemple for Rb^{19+}

Isotope	^{85}Rb	^{93}Rb	^{94}Rb	^{95}Rb	^{96}Rb	^{97}Rb	^{98}Rb	^{99}Rb
$T_{1/2}$ (ms)	Stable	5840	2702	377.5	202.8	169.9	114	50.3
Rb^{19+} Efficiency (%)	5.07	5.02	4.95	4.30	3.77	3.57	3.05	1.77
Rb^{19+} RIB efficiency / Rb^{19+} Efficiency (%)	100	98.9	97.7	84.9	74.3	70.3	60.1	35

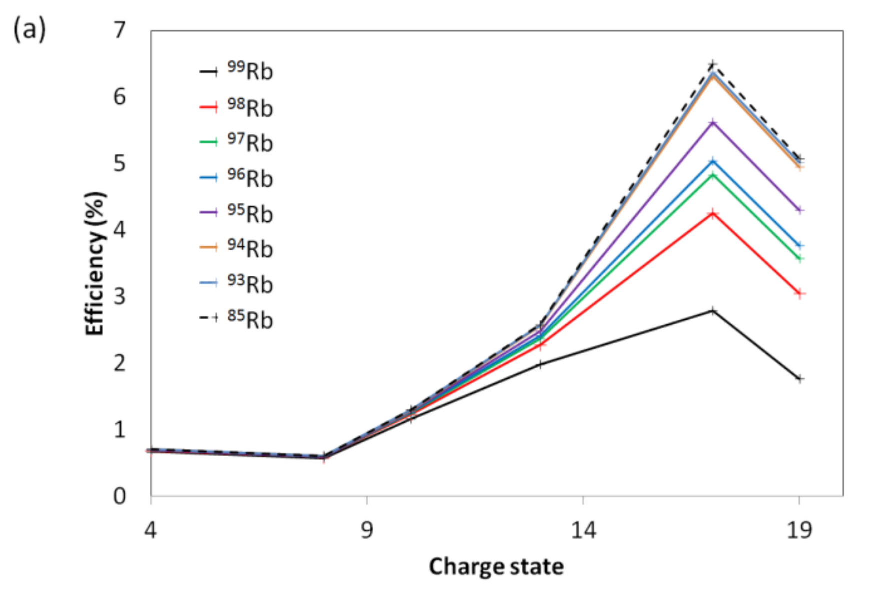


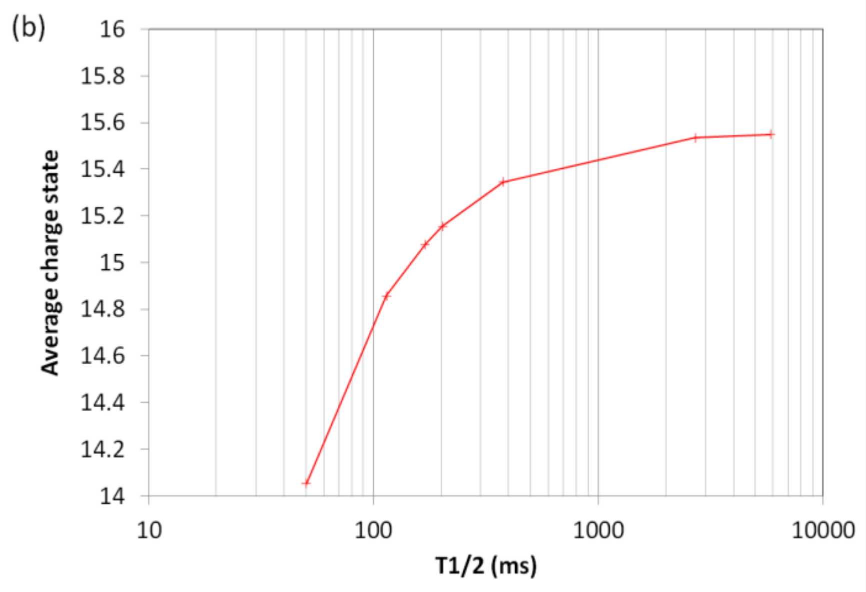
When decreasing $T_{1/2}$:

- down to 380ms : efficiency reduction limited to 15%
- Below : efficiency reduction decreases rapidly

Implication on the RIB CB efficiency

➤ Calculation for other charge states (4+, 8+, 11+, 13+, 17+) :





For short-lived isotopes such as ^{99}Rb, the CSD is shifted toward lower charge states

Conclusion

- The temporal distribution of the N+ beam extracted from the CB was measured in short pulse mode
- Efficiency in short pulse mode is comparable to the efficiency measured with the traditional method
- N+ responses provide information on the plasma behavior
  ➔ allows comparing several CB tunings and configurations
- Prompt interaction between the injected beam and the plasma ions noticed during the injection
- Allows estimating the efficiency for RIBs, as a function of the charge state and half-life

THANK YOU FOR YOUR ATTENTION

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