Conceptual design of an electrostatic trap for high intensity pulsed beam

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outline

- **Background**
- **Principle of the ion trap**
- **Design of the electron gun**
- **Simulation of the ion trap**
- **Summary**

background

Heavy ion beam requirements for the next generation accelerators

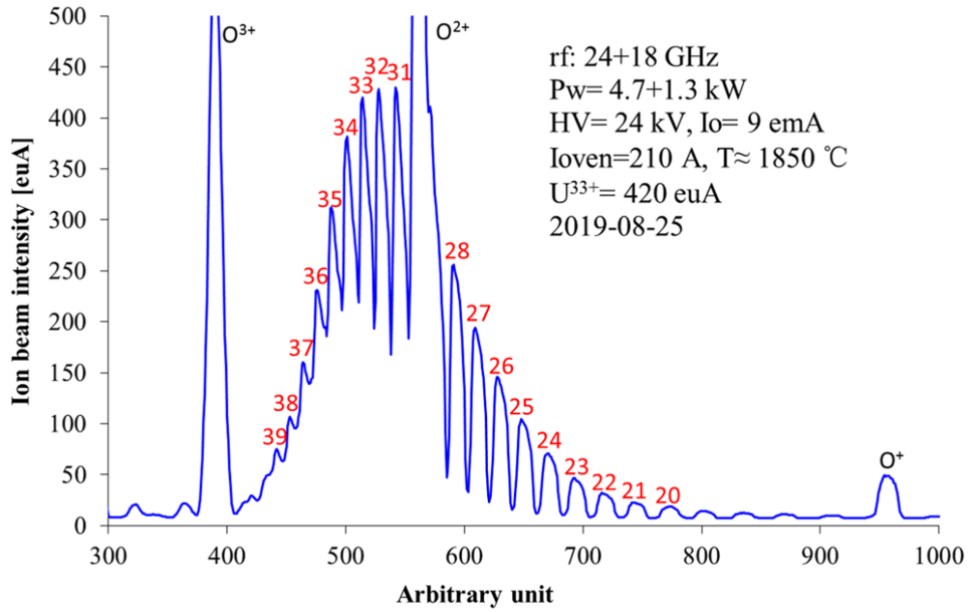
	HIAF/IMP	MEIC/JLab	FAIR/GSI	NICA/Dubna
Beam	U^{34+}	P_b^{30+}	$U^{4+\to 28+}$	U^{32+}
I (emA)	1.7	0.5	15	1.5
Ions/Pulse	1xE11	2.5xE10	3.3E11	2E9
Pulse Width (μs)	400	250	100	7
Frequency (Hz)	1	5	1	50
Ion Source	ECR	ECR/EBIS	MeVVa (X) Now ECR	ESIS
Mode	AG	AG/Pulse	Pulse	Pulse

***AG: After Glow**

Arguments on ion beam compressor, LBNL, USA, 2016

background

Present ECR performance on uranium beams in IMP



W. Lu et al., Rev. Sci. Instrum. 90, 113318 (2019).

The requirement of HIAF for U34+ is 4 times of this performance.

Solutions
- 4th generation ECR ion sources.
- Ion trap.

Principle of the ion trap

EBIS?

≤ 20% in the desired charge state distribution.

ECR?

Ions in CW mode $\xrightarrow{\text{f=1 Hz, 10 ms}}$ Accelerator

99% of the ions are wasted

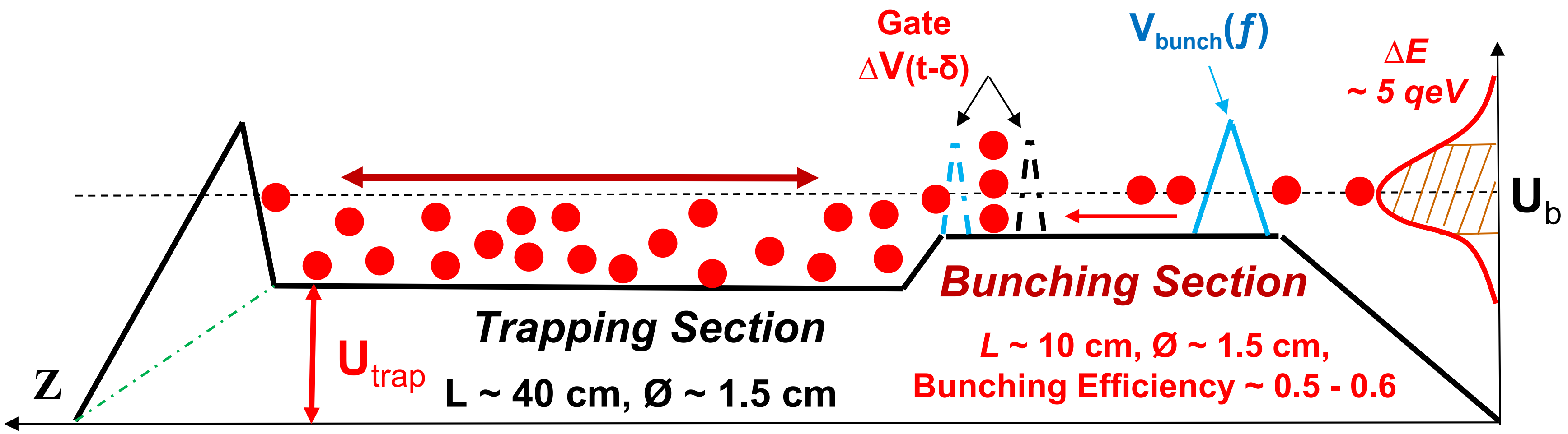
Ion trap

Ions in CW mode $\xrightarrow{\text{accumulation}}$ Ion trap $\xrightarrow{\text{f=1 Hz}}$ Accelerator

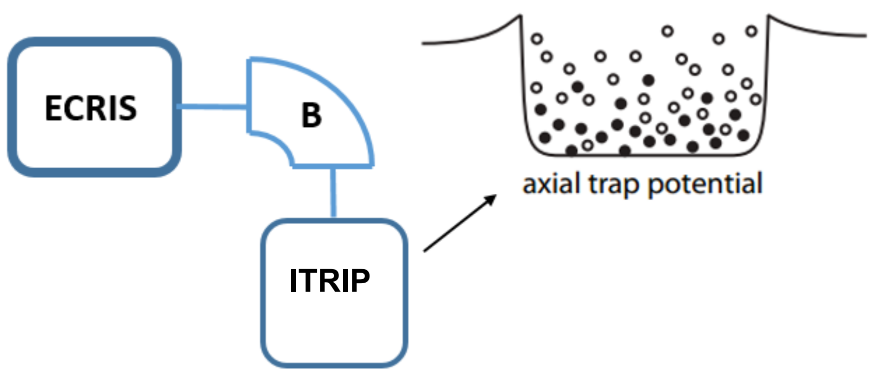
- Most of the ions are used.
- More ions are in the desired charge state.

Principle of the ion trap

An electrically confined ion beam compressor



Arguments on ion beam compressor, LBNL, USA, 2016



***ITRIP: Ion Trap for high Intensity Pulsed beams**

Principle of the ion trap

features:

1. Extraction frequency ~ 1 Hz. (requirement of the HIAF)

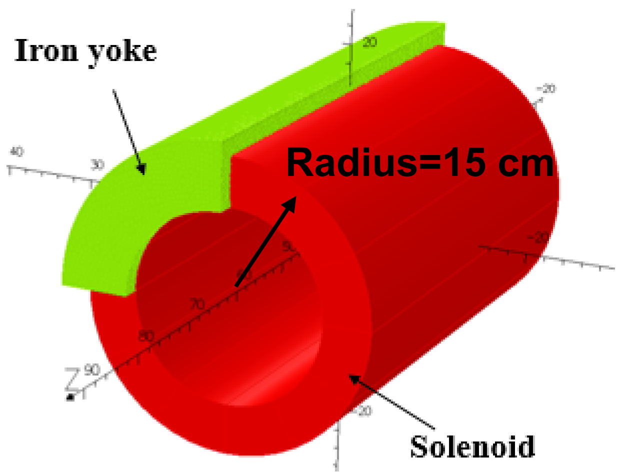
2. No ionization of the desired charge state of ion.

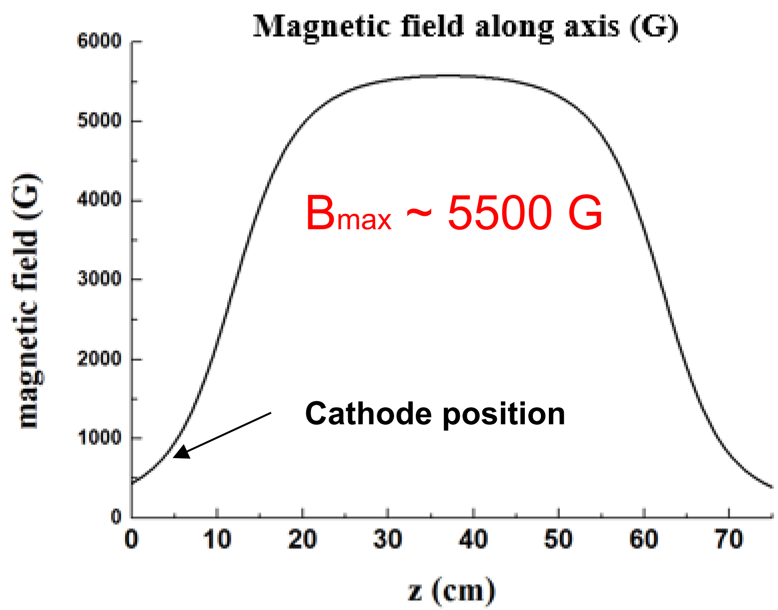
3. Hollow structure of electron gun to extract the ions.

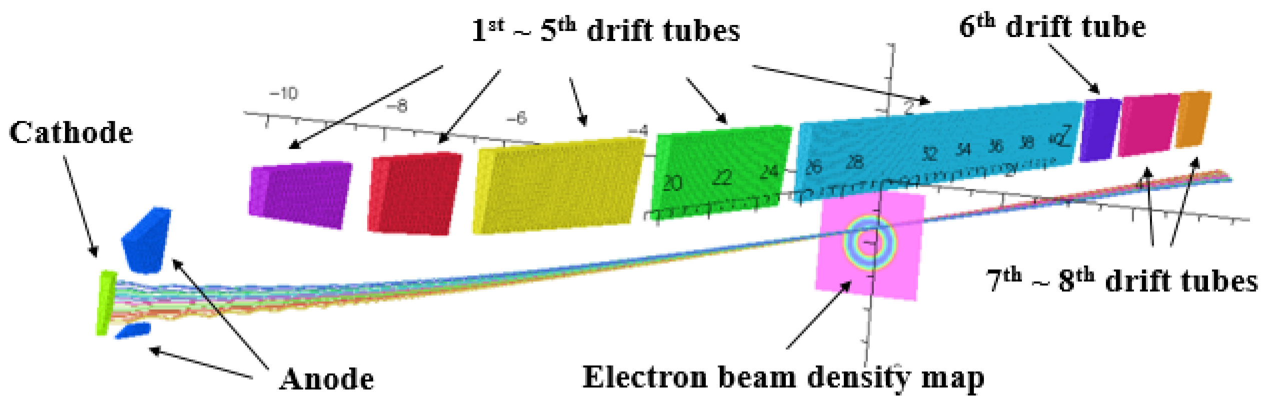
e.g. U^{34+}

Design parameters	value
Length	0.5 m
Magnetic field	~ 0.5 T
Ee	< 1.2 keV (ionization threshold of U^{34+})
Ie	<1 A
Ion trapped (charges)	~ 3E10
U^{34+} ions	~ 1.5E10

Design of the electron gun



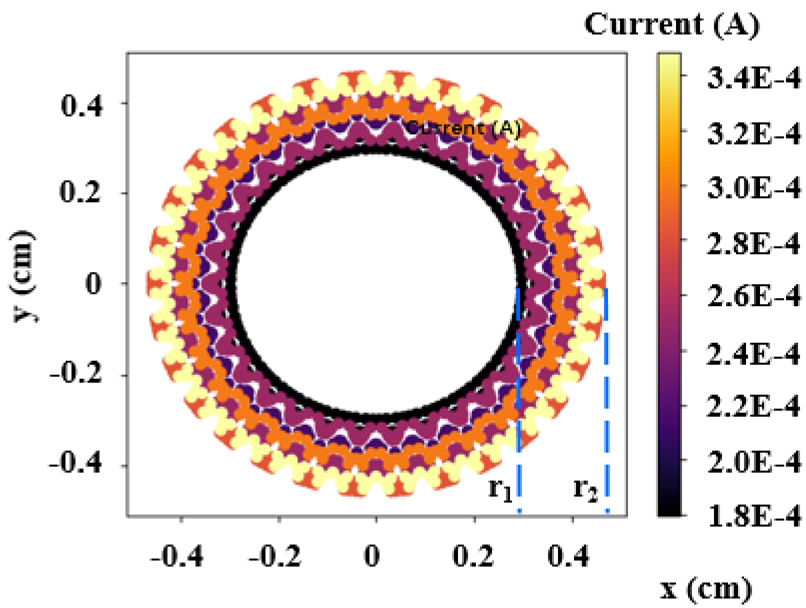


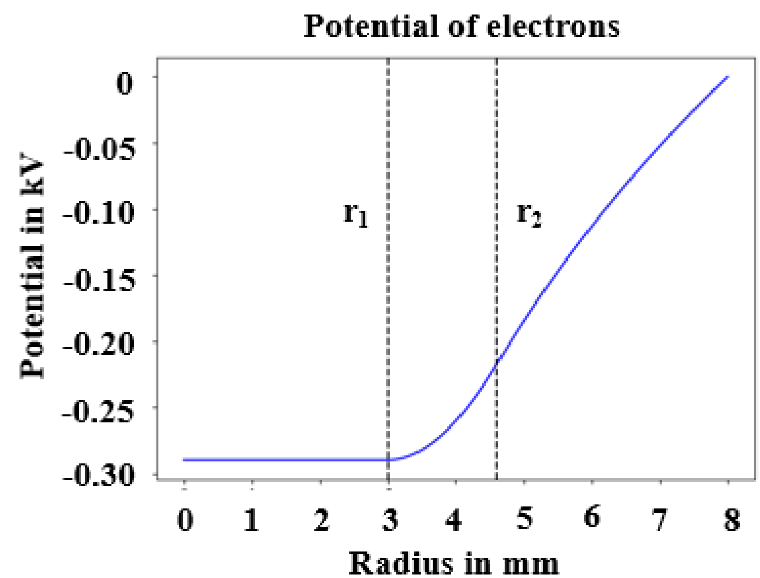


Energy of electron ~ 1 keV, current ~ 440 mA.

Design of the electron gun

Density distribution of electrons



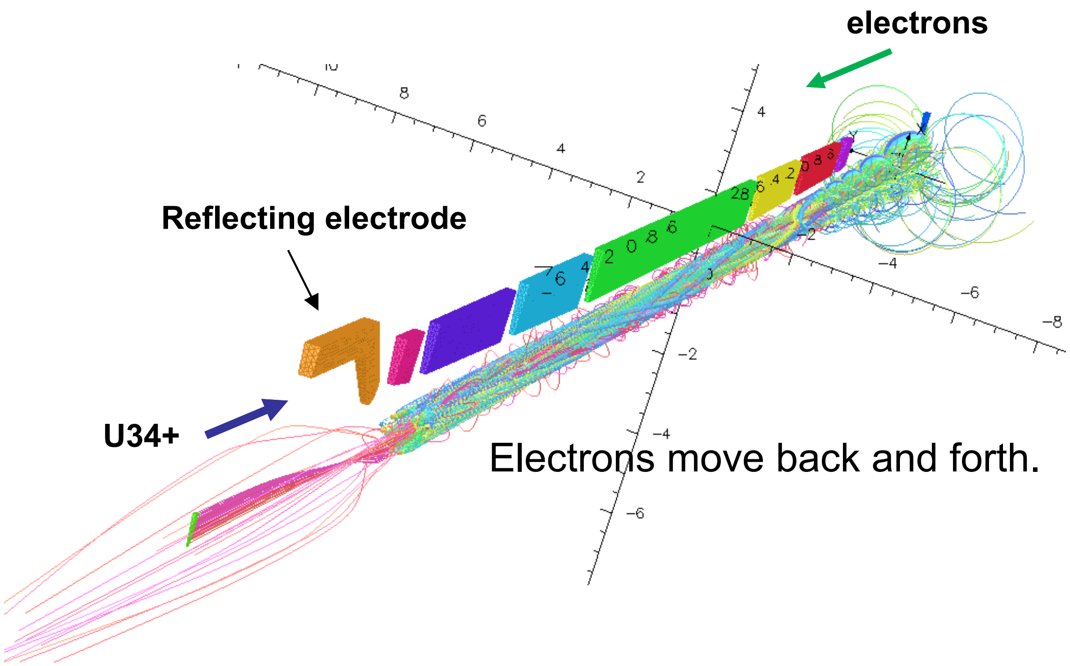


r_1 ~ 3 mm, r_2 ~ 4.5 mm.

The depth of electron potential is ~ 0.3 kV.

Simulation of the ion trap

Injection of ions



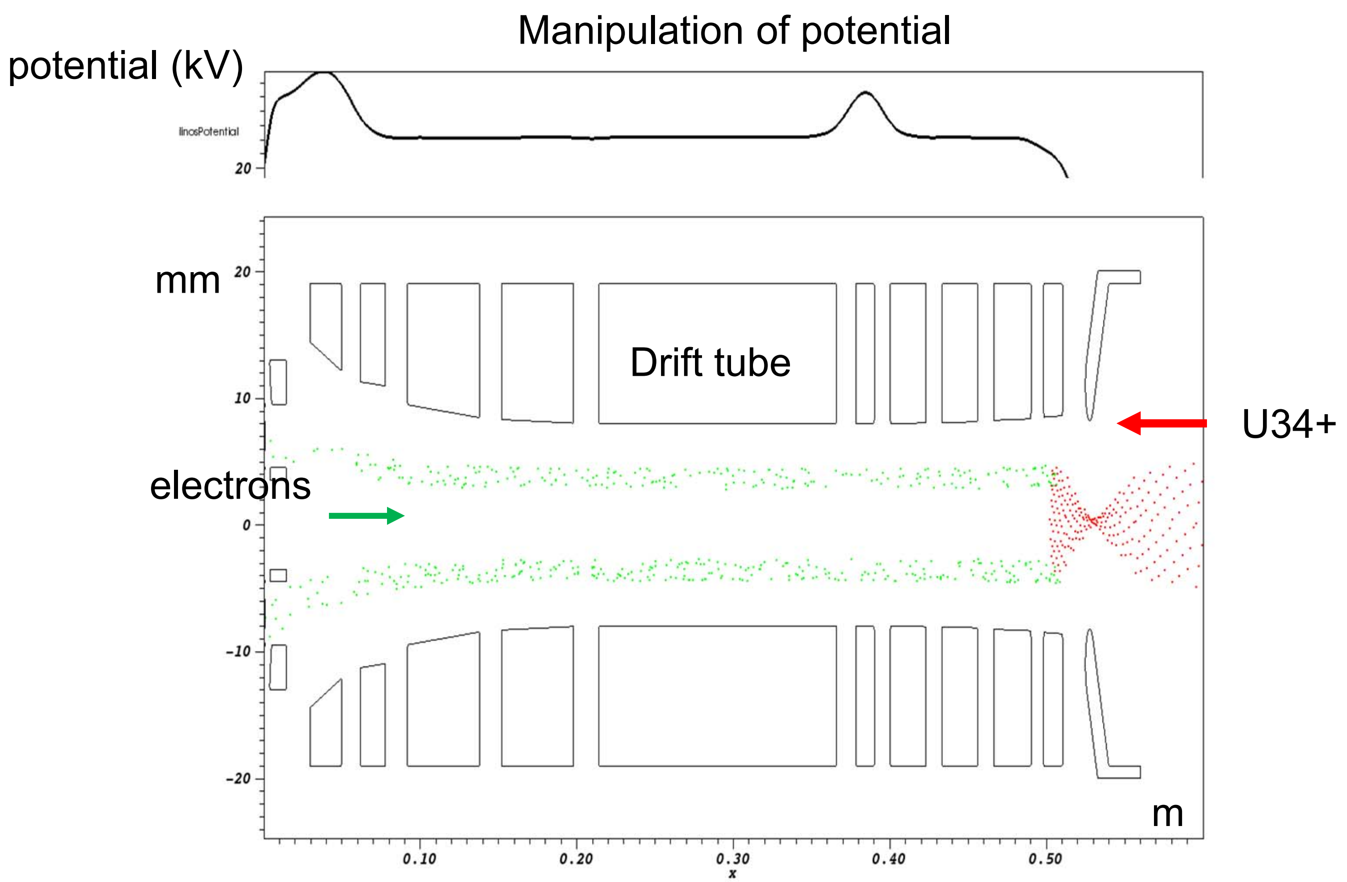
Ions parameters:
radius ~5 mm, 0.1 emA

Energy of ions in the trap: (20 ~ 50) *q eV

**q: charge state*

Simulation of the ion trap

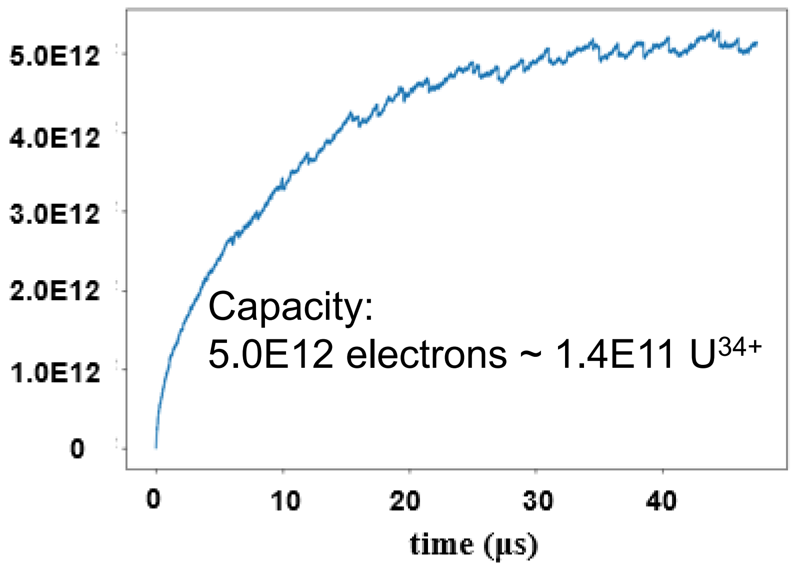
Tracking without collisions.



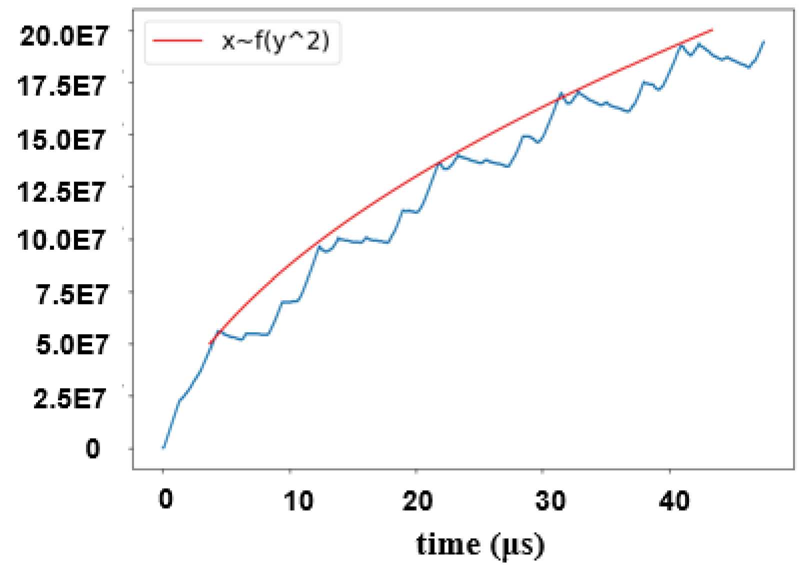
Ions can be trapped and accumulated in the trap.

Simulation of the ion trap

Accumulation of electrons



Accumulation of ions



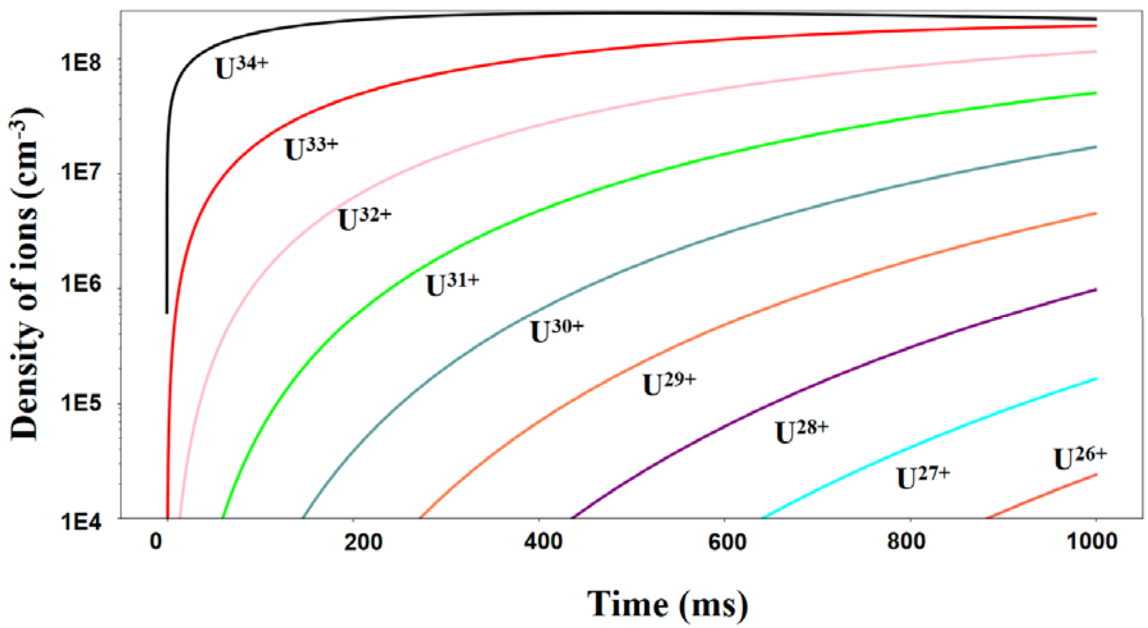
After 1 s:

In the trap	50% extraction efficiency	Intensity
3.4E10 U^{34+}	⟶	1.7E10 ions/pulse
	Without collisions	

Simulation of the ion trap

Evolution of charge state of ions

Parameters: accumulation of U^{34+} ions as fitting curve, vacuum 1E-10 Torr, electron current is 440 mA with an energy of 1 keV.
Considering only charge exchange and radiative recombination processes.



After 1 s:

In the trap	50% extraction efficiency	Intensity
1.24E10 U^{34+}	→	6.2E9 ions/pulse

Need more effort!

summary

- **An ion trap based on ECRIS is proposed for high intensity highly charged ions.**
- **The ion trap is a promising and economic device.**
- **The above discussed design can be further refined for better efficiency but should be verified with experiments.**

Thank you for your attention!