EFFECTS OF THE CARIBU EBIS TRAP CONFIGURATION ON EXTRACTED ION BEAM CHARACTERISTICS

Clayton Dickerson, Rick Vondrasek, Guy Savard, Daniel Santiago-Gonzalez, and Peter Ostroumov
Argonne National Laboratory, Lemont, IL USA

17th International Conference on Ion Sources
October 15-20 2017
CERN - CICG - Geneva

INTRODUCTION

An Electron Beam Ion Source (EBIS) charge bred fission fragments from the CAlifornium Rare Isotope Breeder Upgrade (CARIBU). The ions were then accelerated in the Argonne Tandem Linear Accelerator System (ATLAS). During commissioning two configurations, offset trap fast extraction and trap-over-barrier slow extraction, were used to study the extracted beam characteristics. For fast extraction (Figure 6) the barrier was quickly lowered with a high voltage switch, while during slow extraction (Figure 2) the trap was raised over the height of the barrier with an arbitrary function generator driving a high voltage amplifier.

Table 1: Operating Parameters		
Cathode radius	2.1	mm
Cathode magnetic field	0.15	T
Cathode potential	-5870	V
SC solenoid field	5.5	T
e-beam current, I	1.18	A
e-beam potential in trap	200	V
Drift tube radius, r_{DT}	10	mm

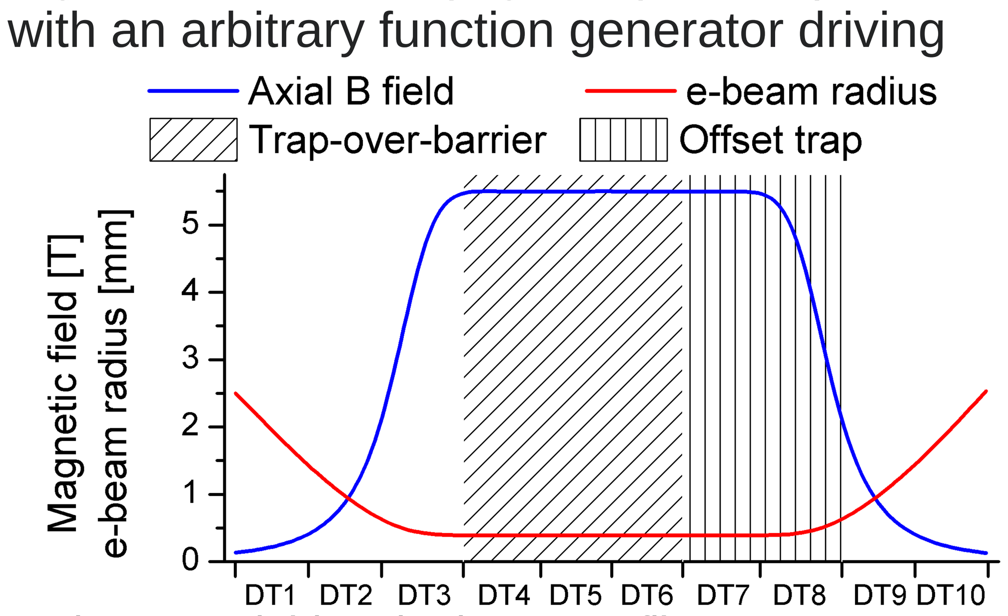

Figure 1: Field and e-beam profiles

TRAP-OVER-BARRIER EXTRACTION

The trap potential was raised over the height of the barrier potential, Figure 2. This scheme is important as a way to moderate the high instantaneous rates by elongating extracted EBIS pulses.

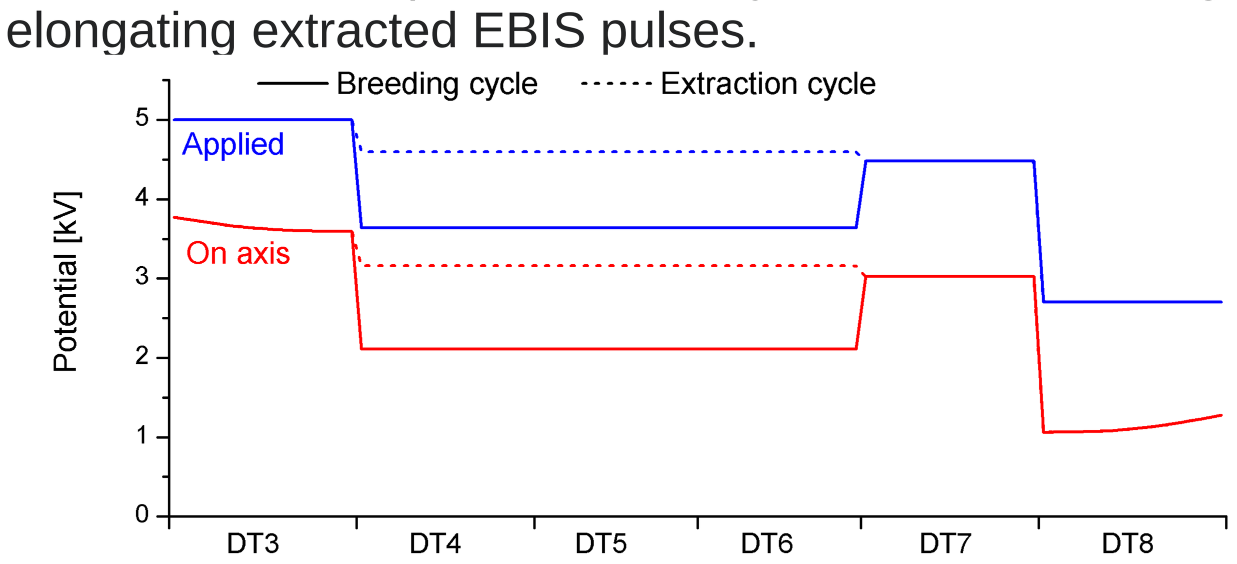

Figure 2: The applied and axial potentials used for trap-over-barrier extraction mode.

Reaccelerated radioactive ^{150}Ce/Pr timing was measured with a gas ion chamber detector, Figure 3. Multiple energy signals from the detector enabled particle identification and gating. ^{31}P was continuously extract while the heavier contaminants were only extracted by emptying the trap, Figure 4.

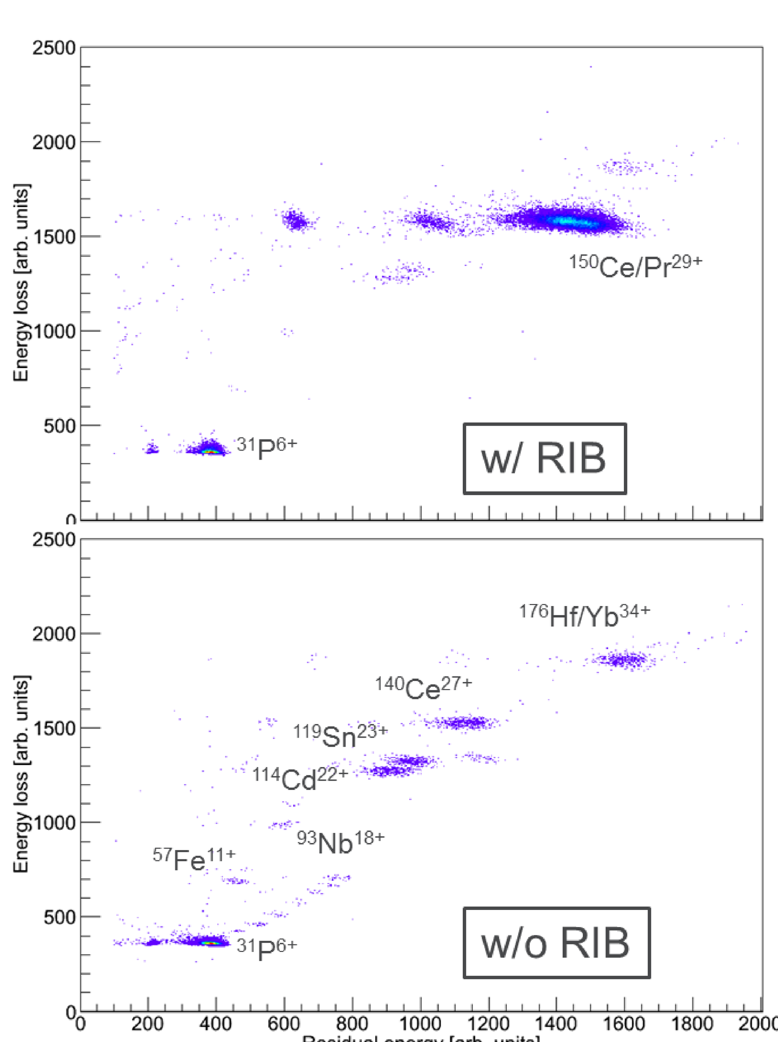

Figure 3: Particle ID spectra of the extracted EBIS beam constituents

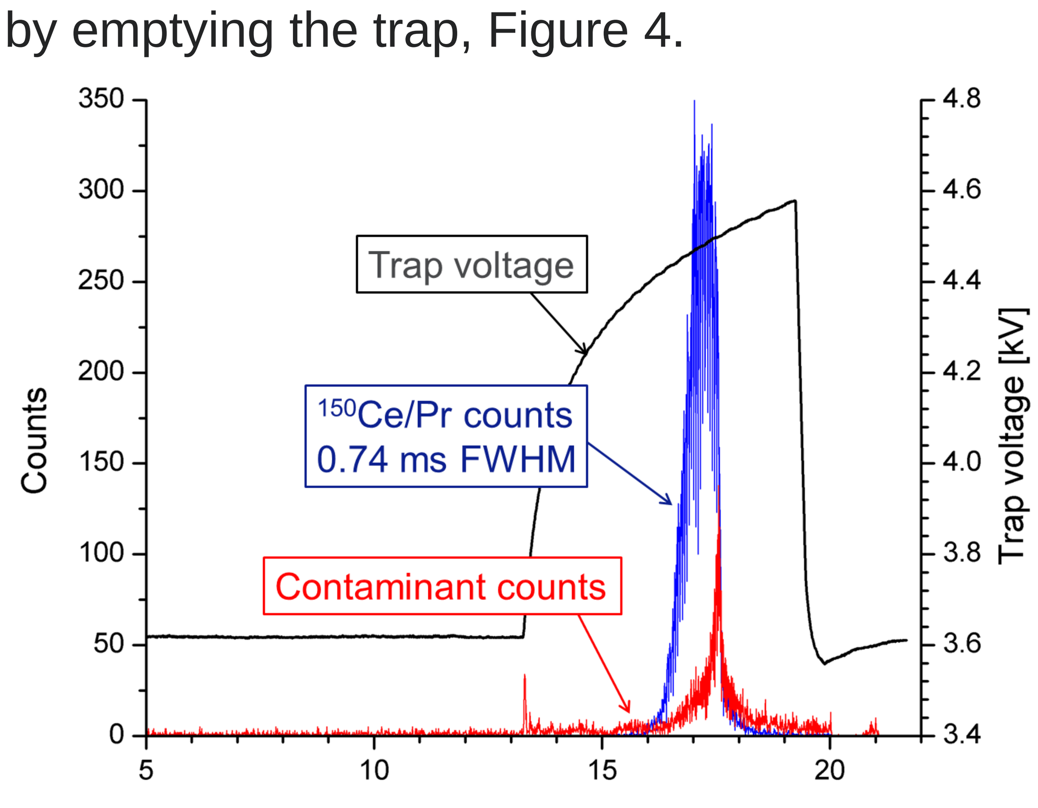

Figure 4: Extracted EBIS pulse timing along with the applied trap voltage

The timing of the extracted pulses and the trap voltage ramp, Figure 4, were correlated, enabling the determination of the energy of the ions in the trap, Figure 5. Injected ions had a larger energy spread and were higher energy than trapped residuals.

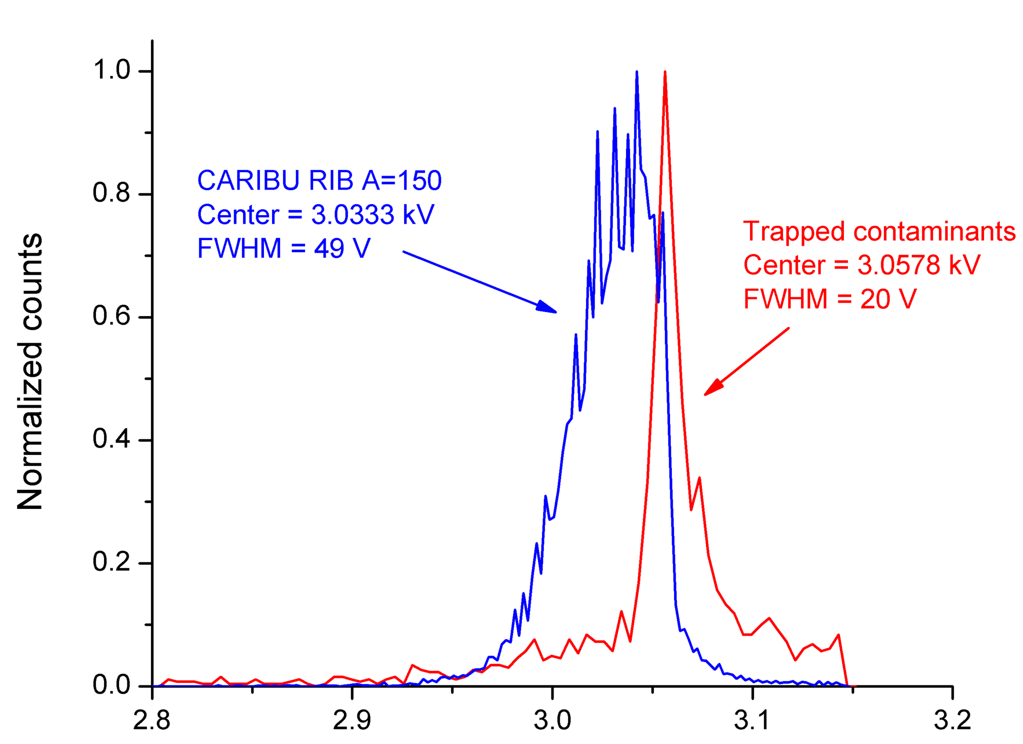

Figure 5: Axial trap potential corresponding to the intensity of extracted EBIS beam on target

OFFSET TRAP FAST EXTRACTION

The trap was configured offset from the middle of the superconducting solenoid in a region with significant variations in the magnetic field. The linear current density of the electron beam, λ_e, caused a potential drop, ΔU, along the axis of the drift tubes

$$\Delta U = \frac{\lambda_e}{4\pi\varepsilon_o}\left[1 + 2\ln\left(\frac{r_{DT}}{r_e}\right)\right]$$

The potential on axis, based on the applied drift tubes potentials and the electron beam characteristics, varied within a constant drift tube potential when the e-beam radius, r_e, changed, and created an electron beam induced trap, Figure 6.

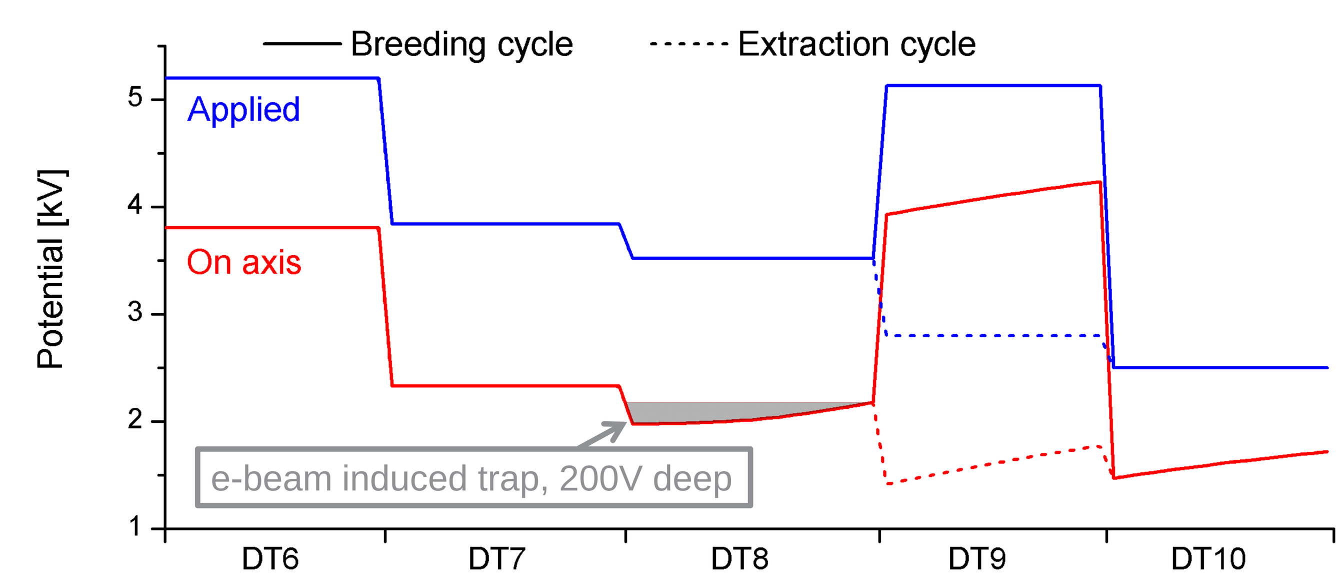

Figure 6: The applied and axial potentials used for the offset trap extraction mode.

Two pulses were extracted each cycle: one when the barrier lowered, and one when the e-beam tuned off. The intensities of ions in both pulses were measured using the beta decay rates of radioactive ^{142}Cs. The beta decay rates were insensitive to the charge state distribution which varied with breeding time. Atoms ionized sufficiently in DT8 became trapped there until the electron beam was extinguished. The likelihood of DT8 trapping increased with breeding time, Figure 7.

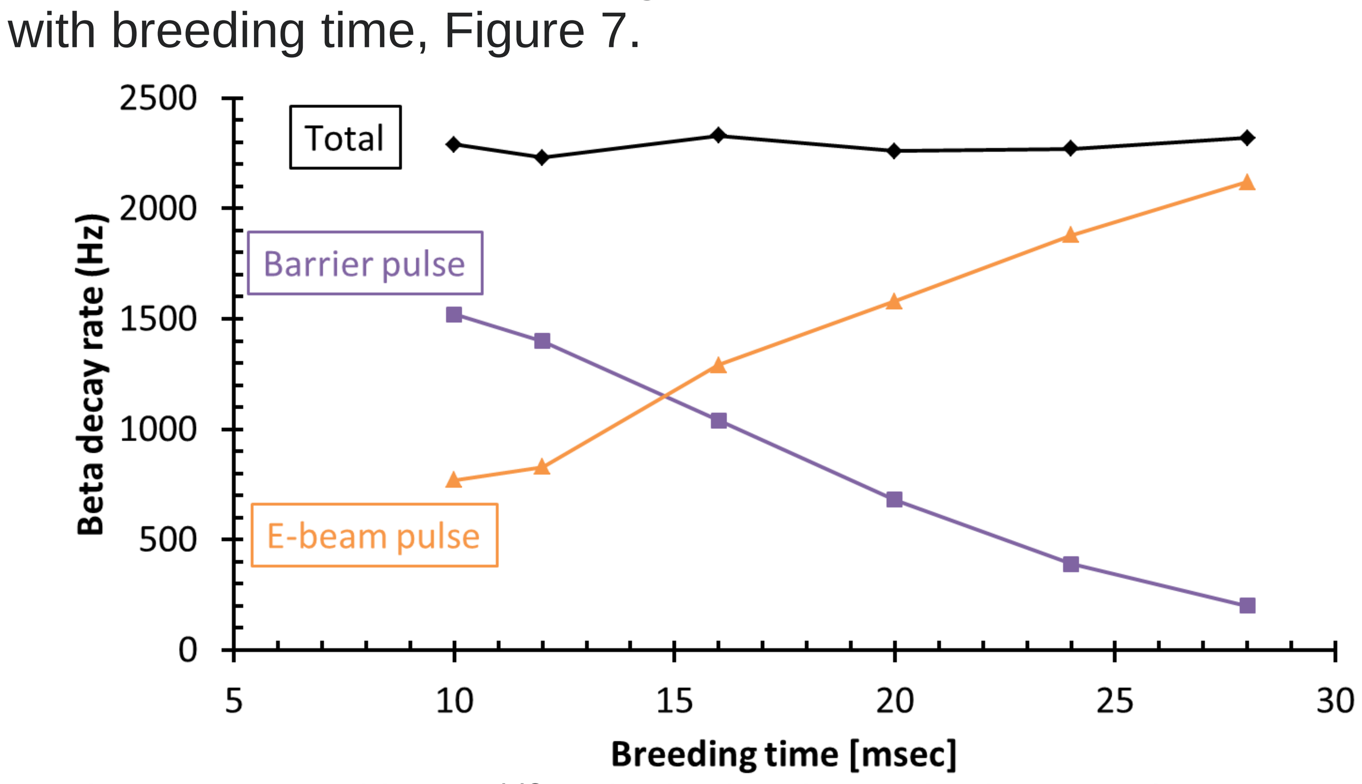

Figure 7: Intensities of ^{142}Cs in the barrier and e-beam pulses.

DISCUSSION AND CONCLUSIONS

- Trap-over-barrier extraction was only possible with uniform axial potentials, otherwise ions would be transferred to an e-beam trap.
- Light mass contaminants were sufficiently ionized without being trapped and were extracted continuously, Figure 4.
- Trapped residual contaminants, at thermal energies in the trap, were expectedly lower energy compared to injected ions, and were extracted later during the emptying cycle, Figure 5.
- Trapped radioactive ions showed signs of energy compression during the slow extraction process (Figures 4-5)
  - asymmetric timing and energy curves
  - energy spread was significantly lower than e-beam potential depth
- Elongating the extracted pulse is important to avoid pile-up and rate related issues for the experimental users.
- E-beam traps can be relatively deep, especially where the magnetic field falls off quickly, Figure 6.
- In the offset trap configuration, the ion intensity in the e-beam off extracted pulse increased for longer breeding times, Figure 7, due to an e-beam trap.

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract number DE-AC02-06CH11357, and used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.