# IMPROVEMENT OF THE EFFICIENCY AND BEAM QUALITY OF THE TRIUMF CHARGE STATE BOOSTER

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## INTRODUCTION

At the ISAC facility of TRIUMF, the electron cyclotron resonance ion source (ECRIS) is used for charge breeding of isotopes with $A/q > 7$. The ECRIS is currently operated as a single-frequency heating source. The maximum efficiency of the charge state booster is 6 % for noble gas (Argon) and 4 % for alkali metal (Cesium) while operating it in single frequency heating mode. Two-frequency heating of the plasma of the booster was recently implemented, and preliminary result showed that maximum charge state of Cesium that can measured shifted from 27+ to 30+.

### TRIUMF ECRIS Charge State Booster

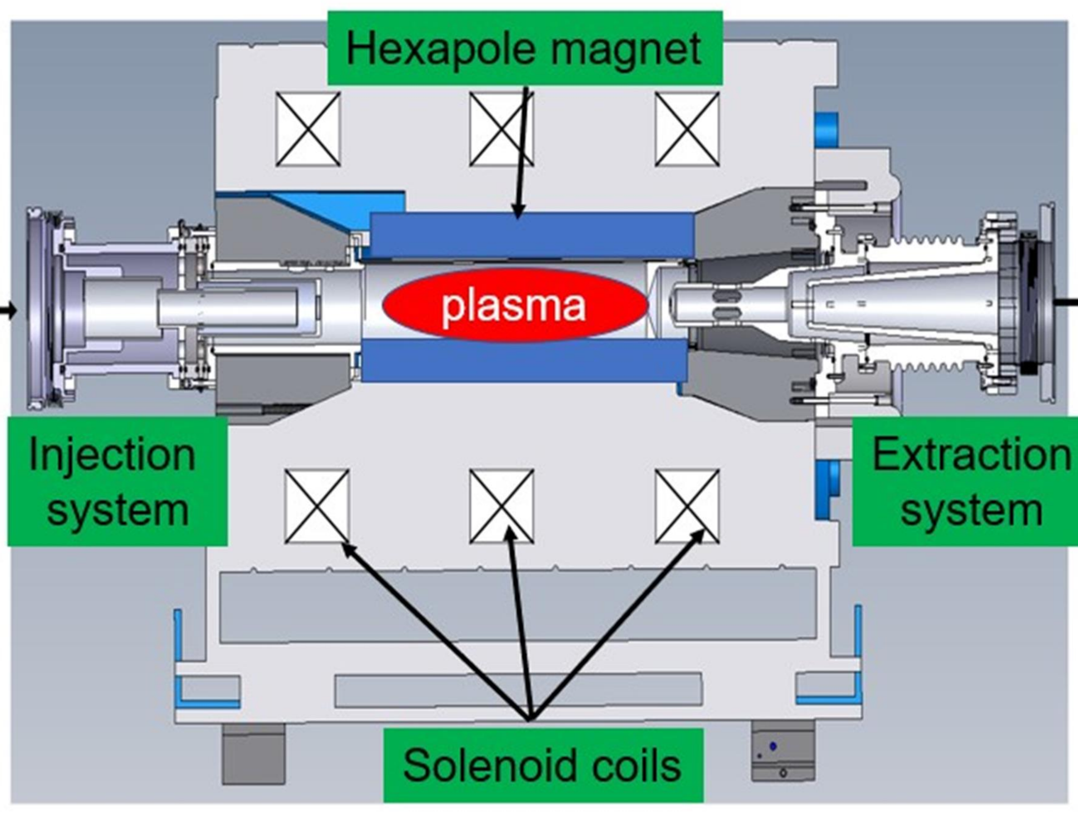


*Figure 1: TRIUMF ECRIS Charge State Booster*

Measurement conducted with the CSB high voltage bias set to 10 kV. Emittance of the CSB was determined via the quadrupole scan technique (QST). Two-frequency heating was implemented using a single waveguide. A low-power, high-frequency combiner was used to add two microwave signals operating at two separate frequencies. The combined signal was fed into a broadband travelling wave tube amplifier (TWTA), and the combined RF power is transported into the plasma chamber via a WR-62 waveguide. Figure 2 shows the TFHT set-up.

Cesium (Cs) ion beam was injected from a test ion source located upstream of the CSB as shown in Figure 2. The difference between the high voltage bias of the test ion source and the CSB, the delta-V value, was varied to determine the voltage at which the injected ions were efficiently captured by the plasma. Intensities of Cs+, Cs18+, Cs21+ and Cs23+ were monitored on FC16A (shown in Figure 3).

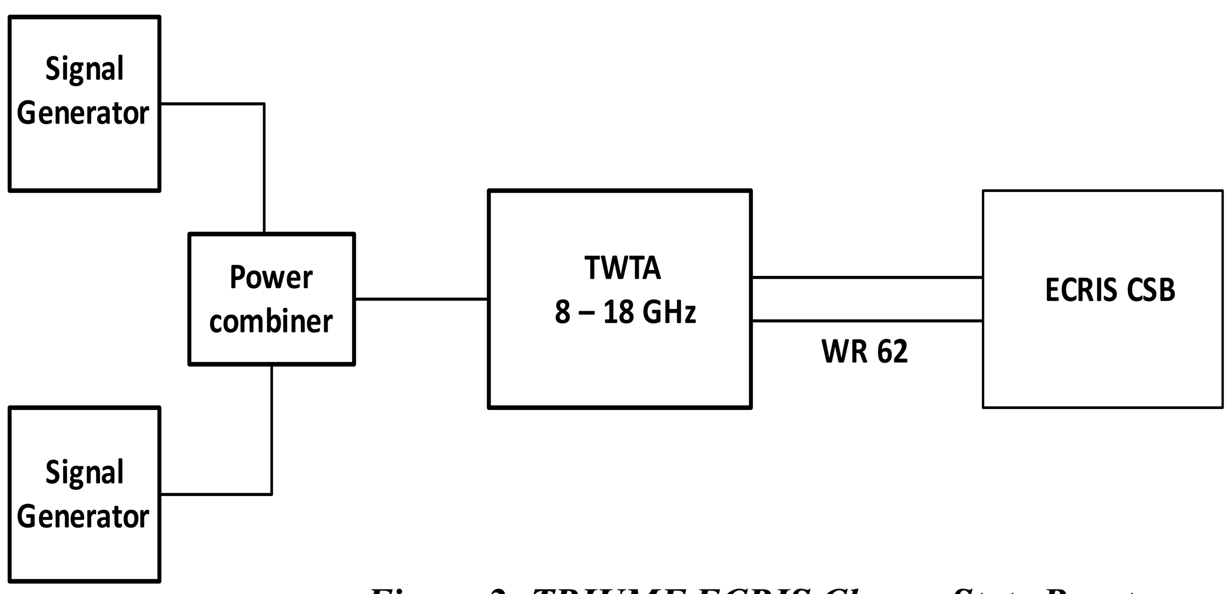


*Figure 2: TRIUMF ECRIS Charge State Booster*

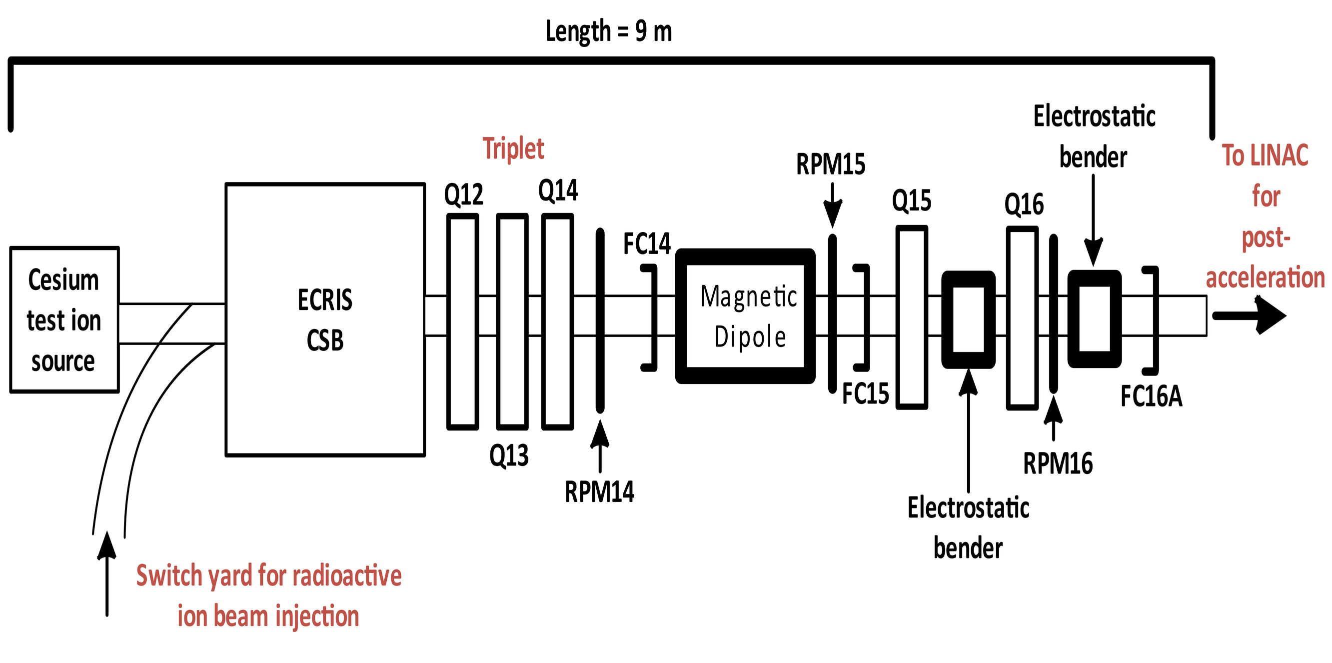


*Figure 3: Schematic of TRIUMF CSB Beamline*

## RESULTS

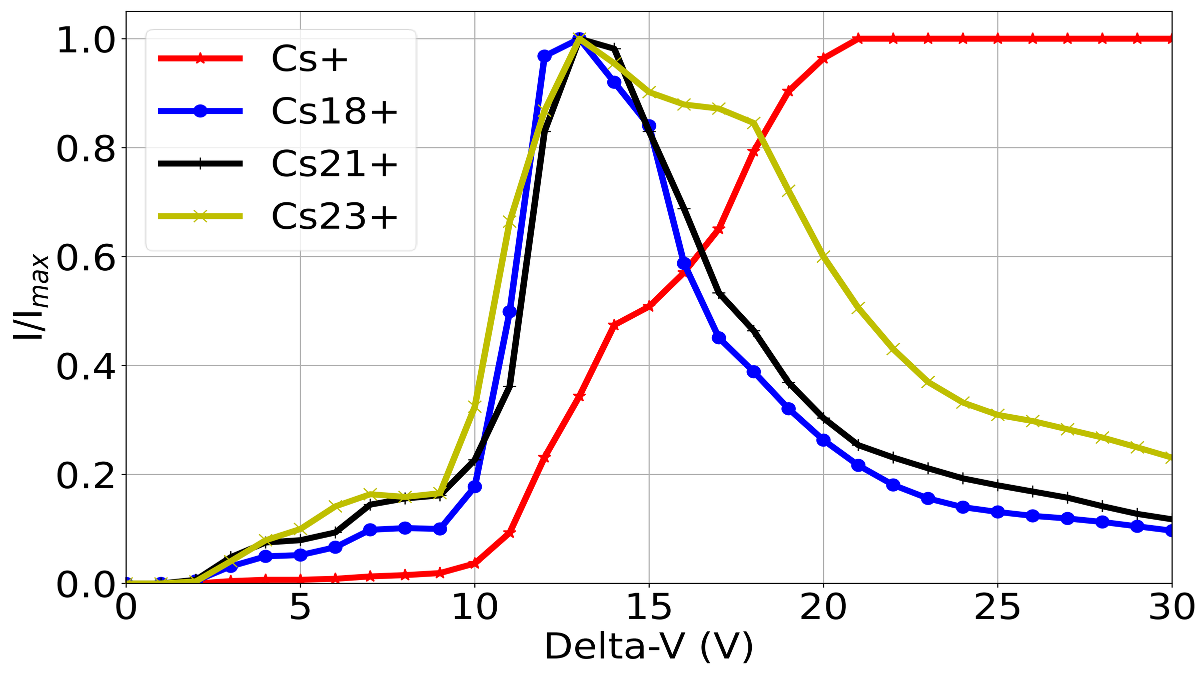


*Fig. 4: Normalized Beam intensities of some selected Cs Charge State Versus Delta-V*

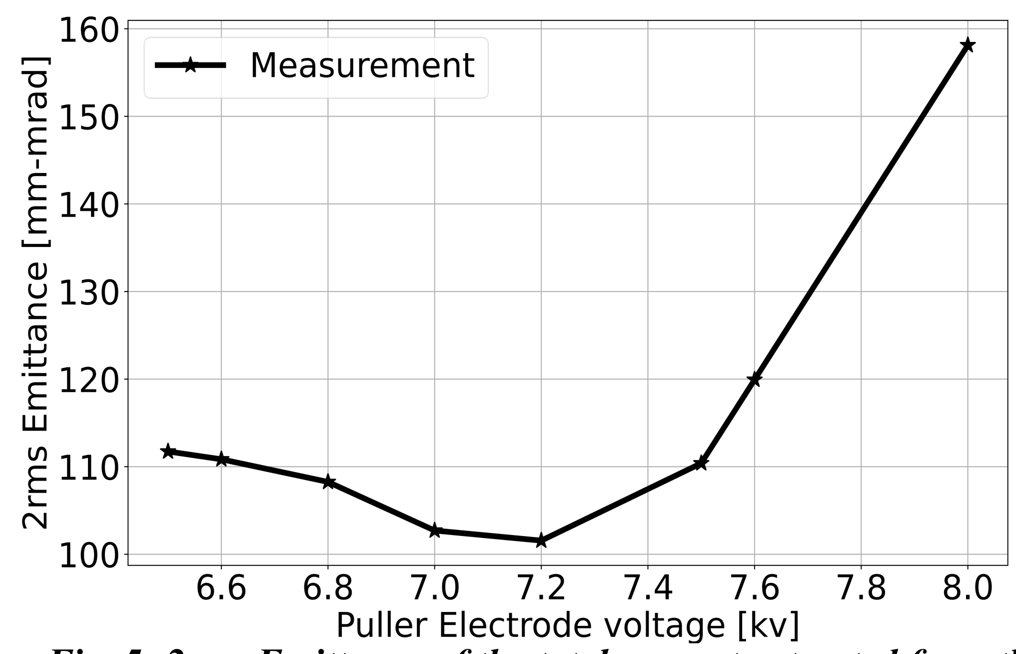


*Fig. 5: 2rms Emittance of the total current extracted from the TRIUMF ECRIS CSB using QST*

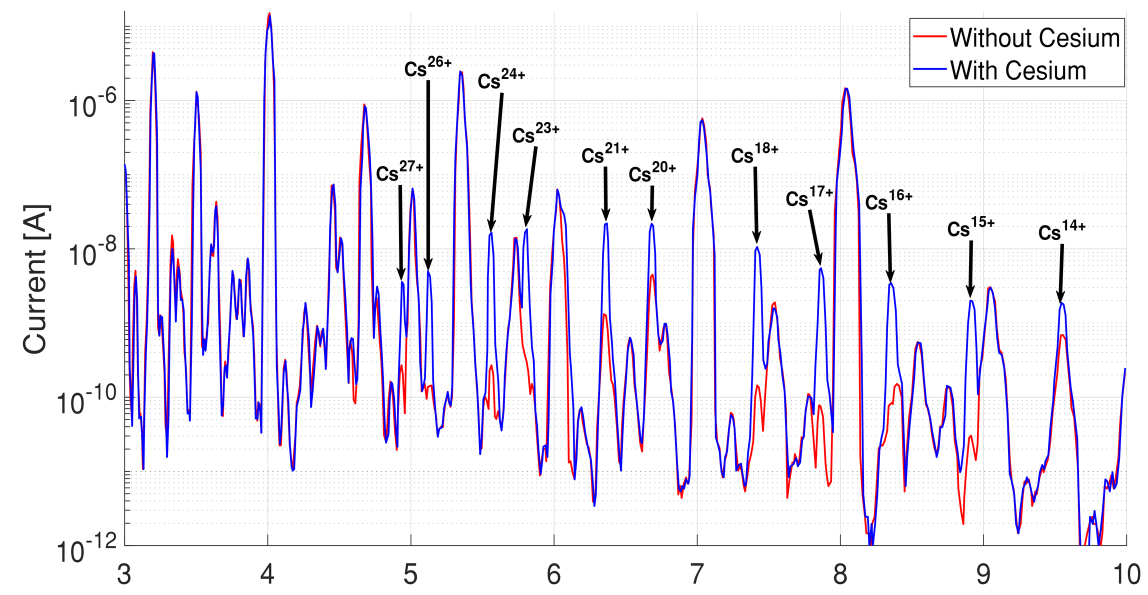


*Fig. 6: Mass Spectrum of the CSB with and without Caesium*

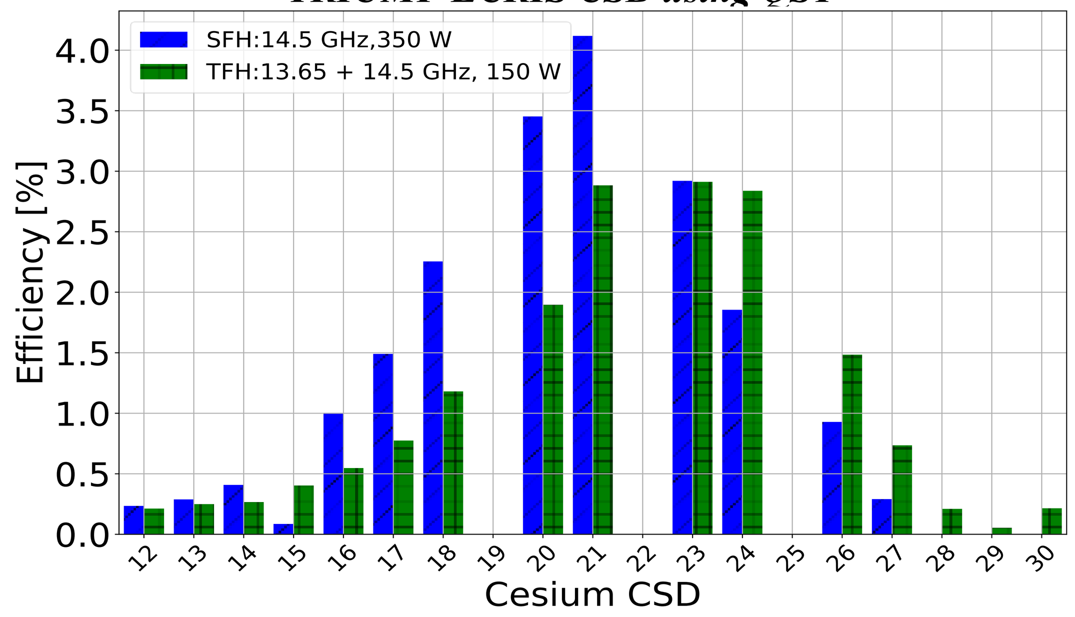


*Fig. 7: Efficiency of Cs with Single and Two-frequency Heating*

Figure 4 shows that the plasma potential is of the order of 13 V as the injected ions appear to be efficiently captured by the plasma at that delta-V value. The shape of the plot of measured 2rms emittance versus the puller voltage (Fig. 5) shows that as the potential on puller electrode is varied, the plasma boundary is changed from convex to planar and to concave (high extraction field). This behavior has been observed in IGUN simulations. Figure 6 shows the mass-to-charge spectrum of the CSB with and without Cs between A/q of 3 and 10 in single frequency operation. This A/q region is mostly dominated by residual ions from C,N and O. The maximum charge state of Cs that can be measured in the single frequency heating mode is 27+. Figure 7 shows the efficiency of Cs in single frequency heating mode compared with the efficiency of Cs in a preliminary measurement of the operation of the CSB in two-frequency heating mode. The maximum charge state of Cs that can be measured shifted from 27+ for single-frequency heating to 30+ for two-frequency heating.

### Extraction System Simulation in IGUN©

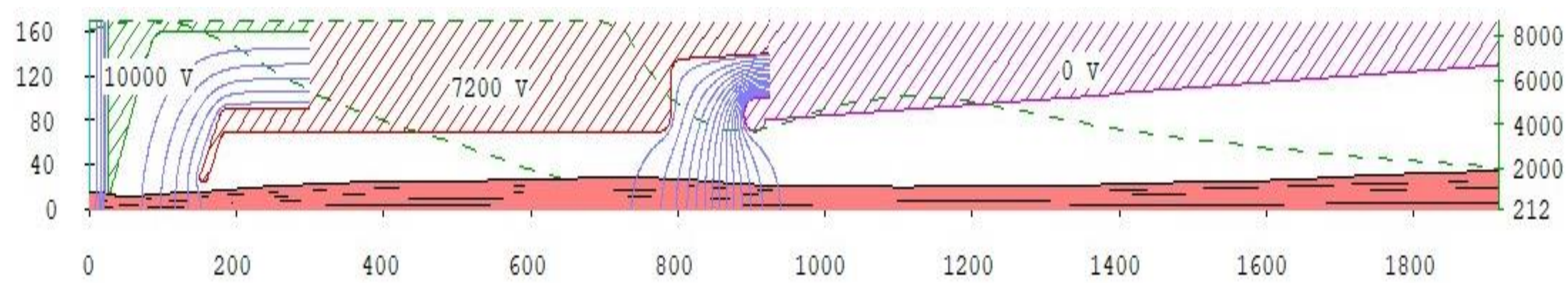


*Fig. 8: TRIUMF CSB Extraction System Simulation in IGUN*

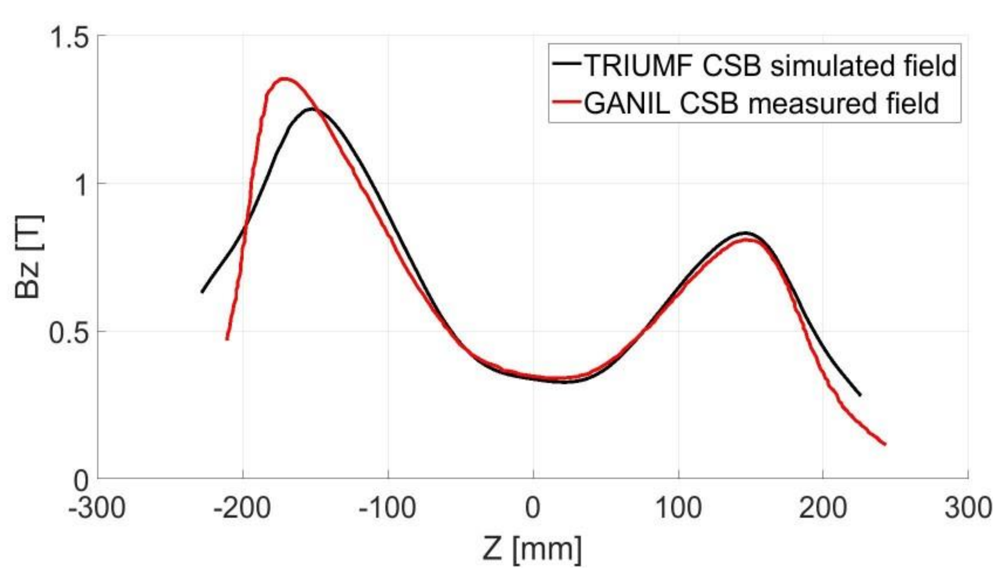


*Figure 9: OPERA simulated magnetic field distribution of the TRIUMF CSB compared with the GANIL CSB measured field*

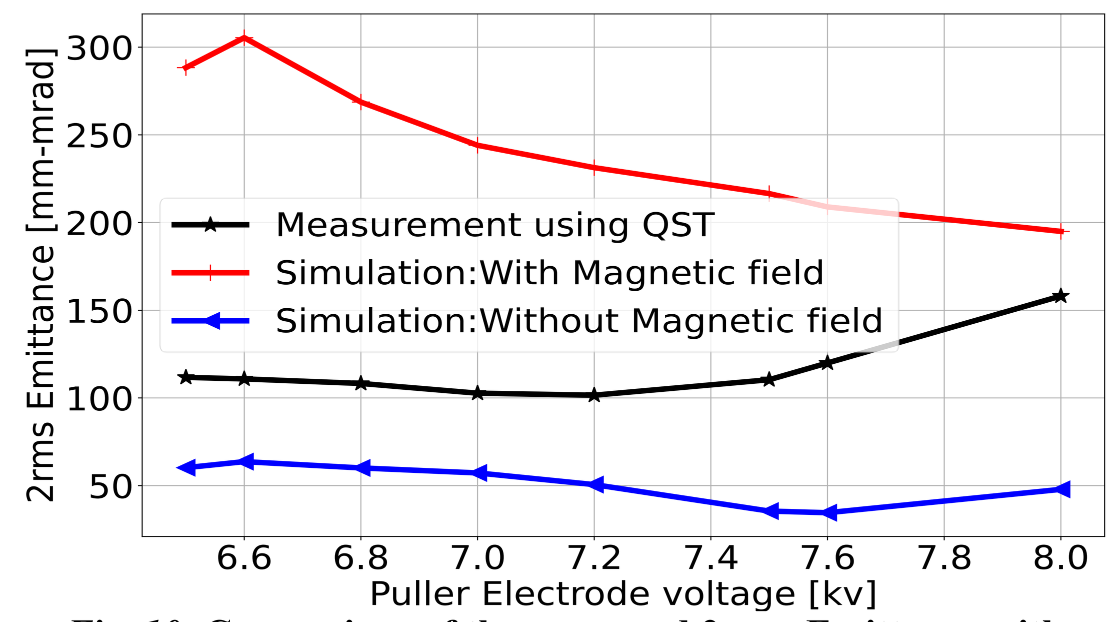


*Fig. 10: Comparison of the measured 2 rms Emittance with simulated 2rms Emittance with and without Magnetic field*

Furthermore, to improve the emittance of the extracted beam from the CSB, the extraction system was modelled and simulated in IGUN©. Figure 10 compares the measured emittance of the CSB with the simulated emittance with and without magnetic field. As it is seen, the measured emittance does not agree with the simulated emittance assuming the magnetic field simulated in OPERA© (Figure 9) and benchmarked against GANIL CSB measured magnetic field distribution.

## OUTLOOK

The two-frequency heating will be implemented using a new approach to prevent damaging the TWTA which occurred with the set up in Figure 2. The magnetic field of the CSB will be mapped in the near future to gain the real magnetic field of the CSB for extraction system simulation in IGUN.

## ACKNOWLEDGEMENT

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