IMPROVEMENT OF THE EFFICIENCY OF THE TRIUMF CHARGE STATE BOOSTER (CSB)

ECRIS WORKSHOP 2020

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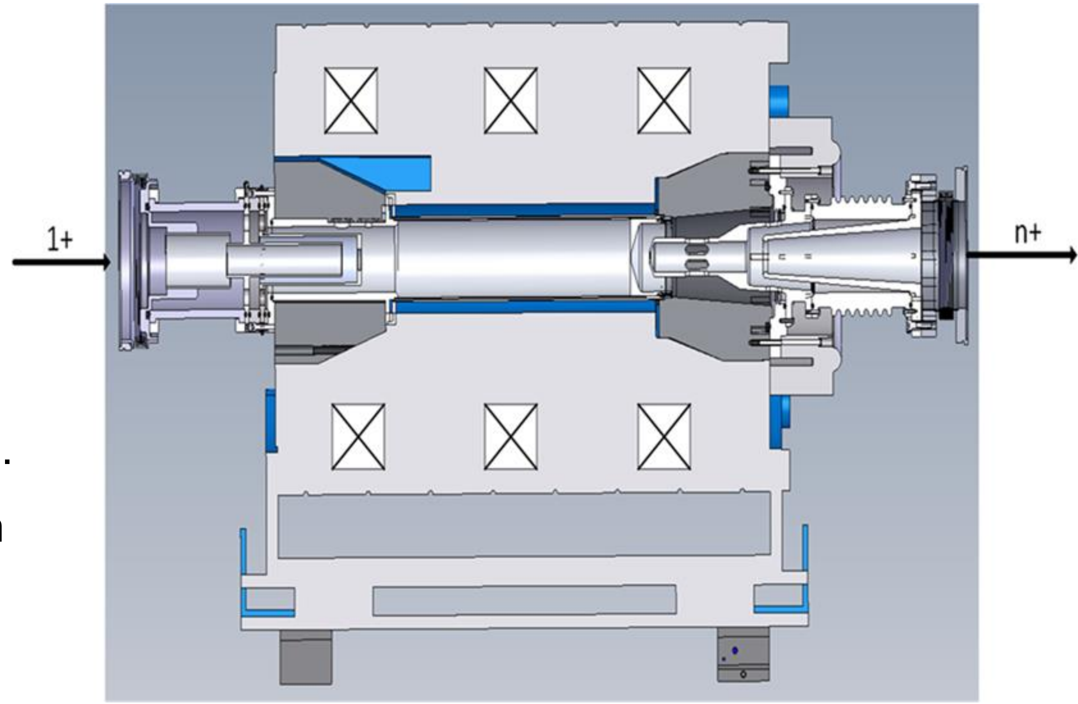
2020-09-29

Introduction

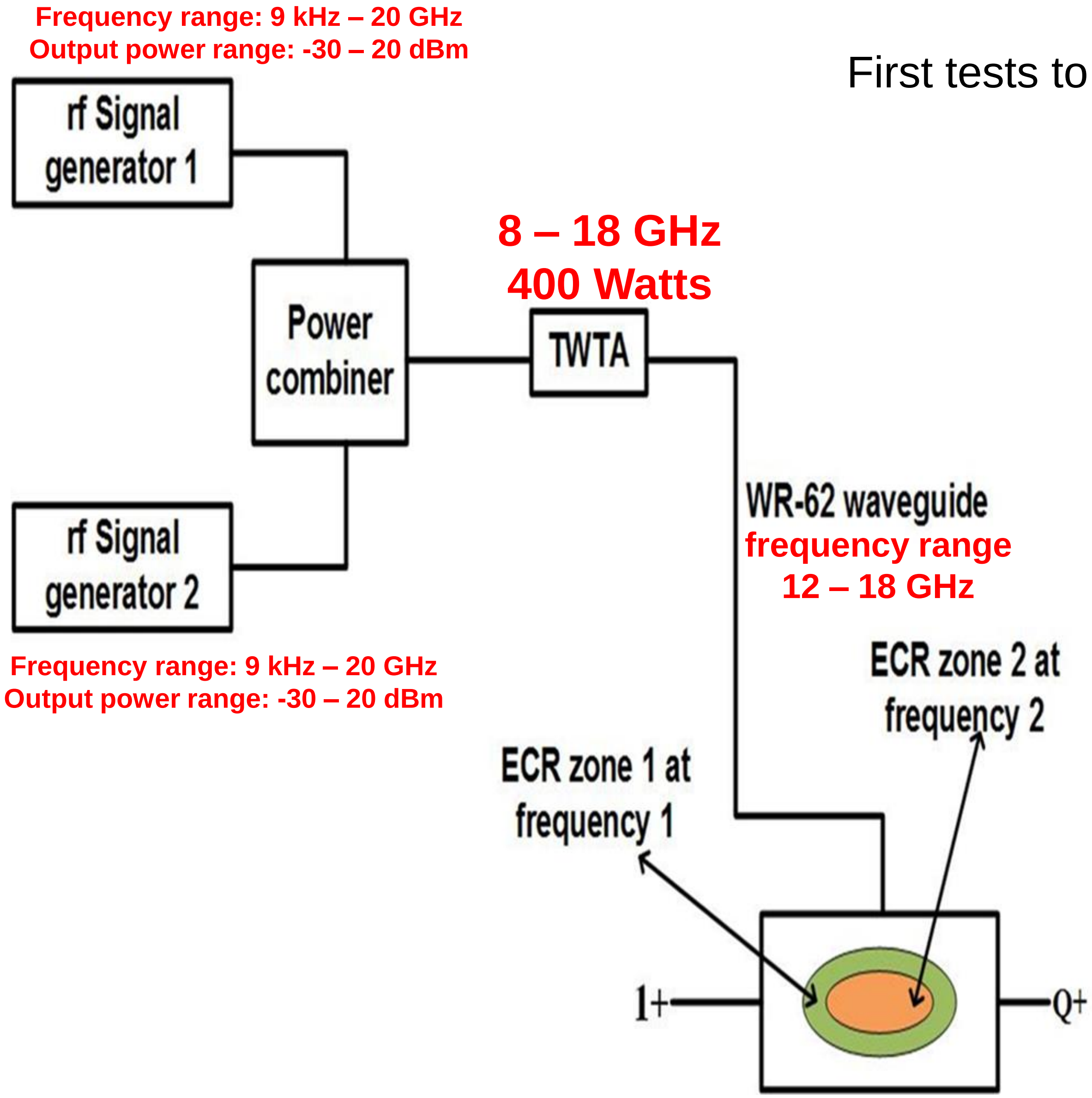
A 14.5 GHz PHOENIX ECRIS from PANTECHNIK is used at TRIUMF to boost the charge state of rare isotopes before injection into the LINAC of the Isotope Separator and Accelerator (ISAC) facility for post-acceleration.

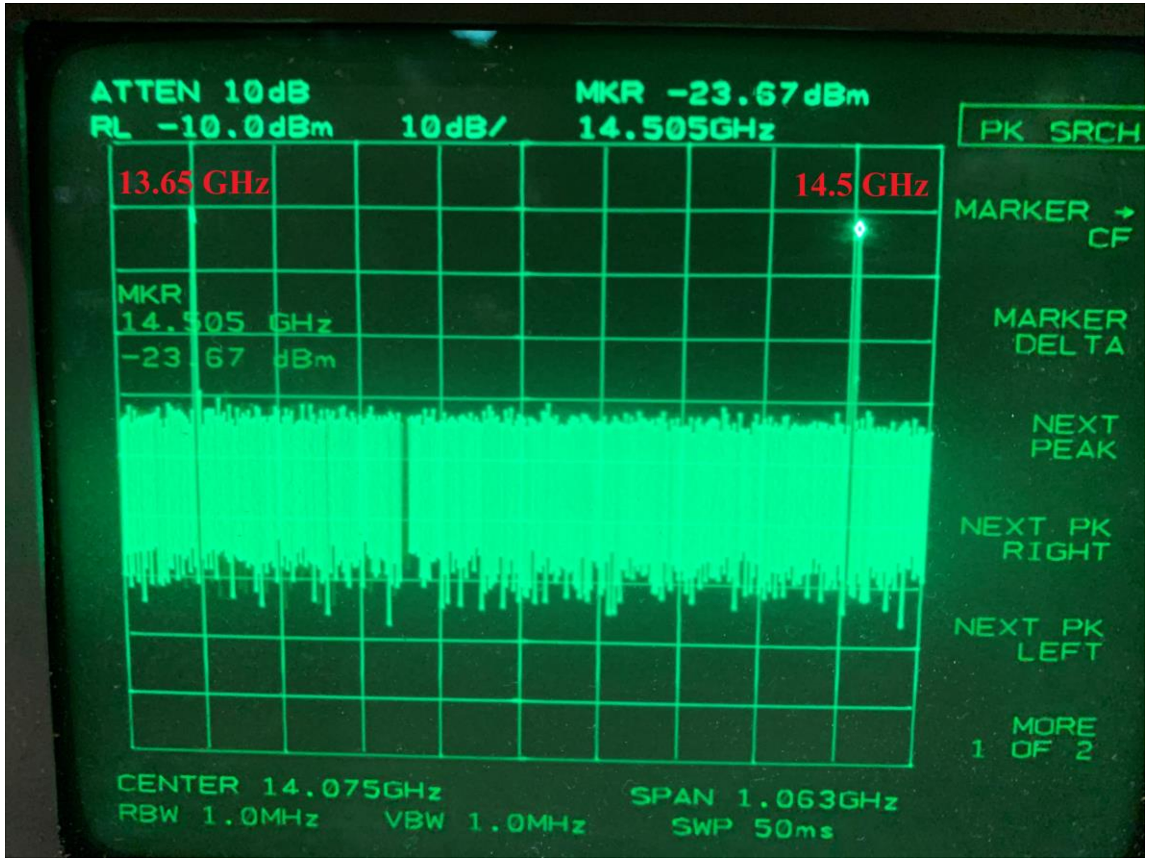
- Originally designed as a conventional single-frequency-plasma heating and a single-microwave-window source.
- Injection and extraction systems are three-electrode systems
- Plasma chamber wall, injection and extraction electrodes are Aluminum materials.
- Helium is used as support gas. Operating pressure is in $10^{-8}\ Torr$ range.
- Axial magnetic field is generated by three solenoid coils and radial magnetic field is generated by Hexapole permanent magnets. Binj=1.15 T, Bmin=0.35 T, Bext=0.87 T, Brad=1.2 T (r=37 mm).
- A Cesium test ion source is located upstream of the booster for injection of singly charged ions for charge breeding tests.
- Efficiency of the charge booster depends on the isotope that is being charge-bred. Typically between 1 and 6 %.
- The rf system of the CSB was recently upgraded to accommodate the two-frequency heating technique using a single waveguide to feed the microwave into the plasma chamber in order to improve the efficiency of the CSB.



TRIUMF ECRIS RF system upgrade: layout and preliminary test

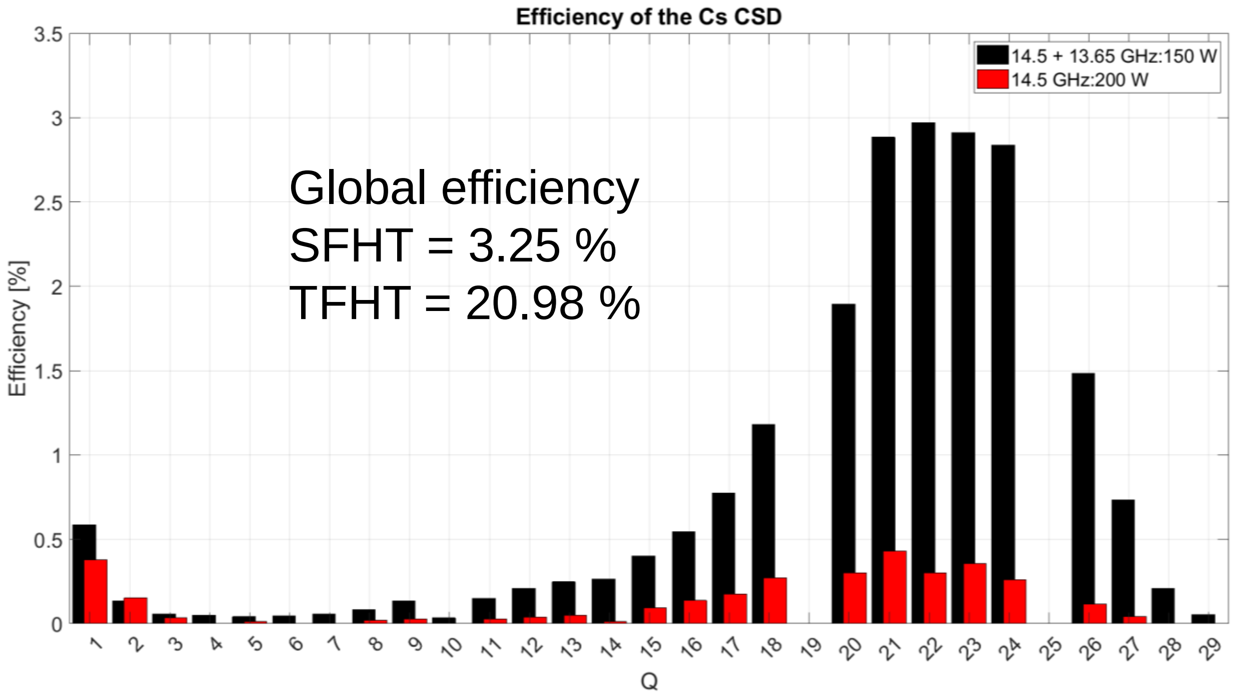
First tests to heat plasma with two RF-frequencies have been performed.





Initial charge breeding result

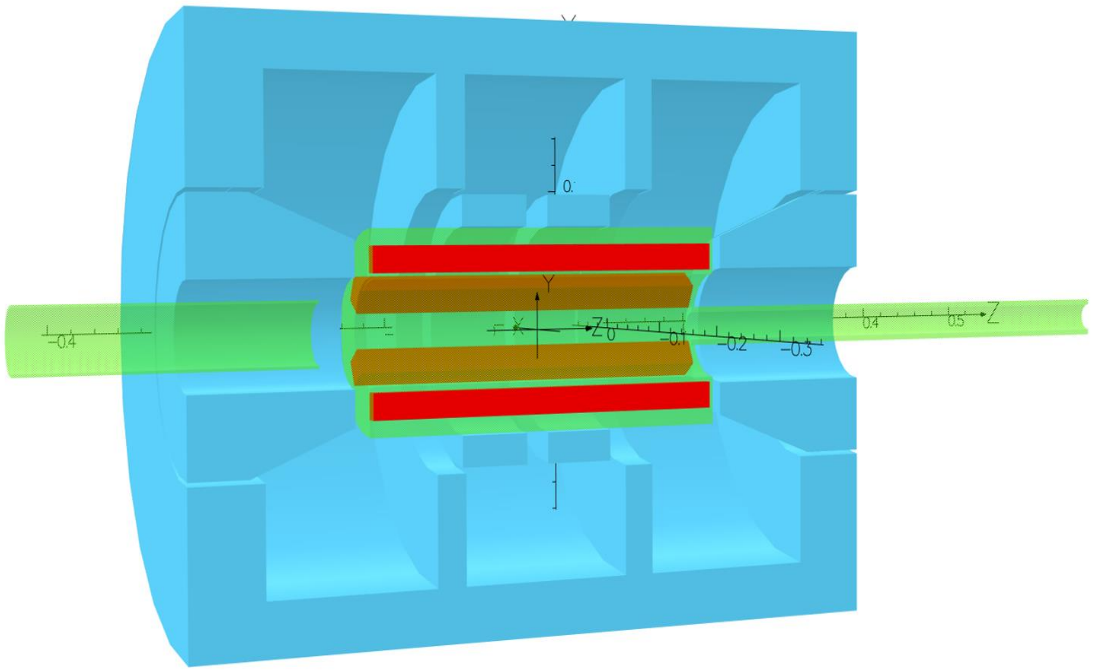
- Upgrade of the rf system was completed on February 28, 2020.
- $^{133}Cs^{1+}$ beam of about 11 nA was injected from the test ion source located upstream of the booster.
- The booster and the beam optics were tuned for the extraction of $^{133}Cs^{29+}$.
- One of the rf signal generator's frequency was set to 13.65 GHz and output power of -20 dBm while the other signal generator was set to a frequency of 14.5 GHz and output power of -15 dBm. The TWTA output power was set to 150 W, and the Cs charge state distribution (CSD) was measured.
- Single frequency heating: 133Cs1+ beam of about $\mathbf{9\ nA}$ was injected, rf frequency was set to $\mathbf{14.46\ GHz}$, rf power was set to $\mathbf{200\ W}$. Beam optics were optimized for the extraction of $^{133}Cs^{27+}$.
- The test result showed that Cs charge states could be detected up to 29+ with the two-frequency heating compared to the single frequency heating with Cs charge state up to 27+.
- The optimization of the booster for two-frequency heating is ongoing and Investigation of the effect of two-frequency heating on the intensity, efficiency and emittance of extracted beam from the booster will follow soon.

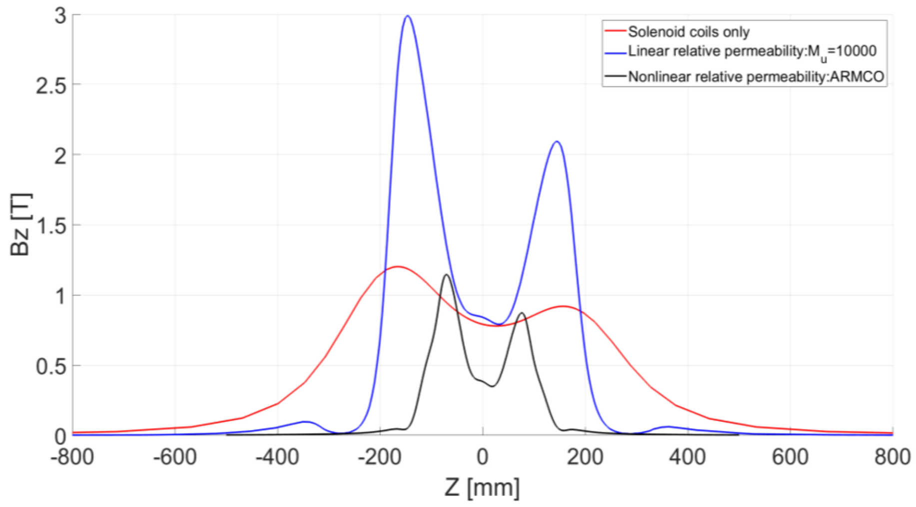


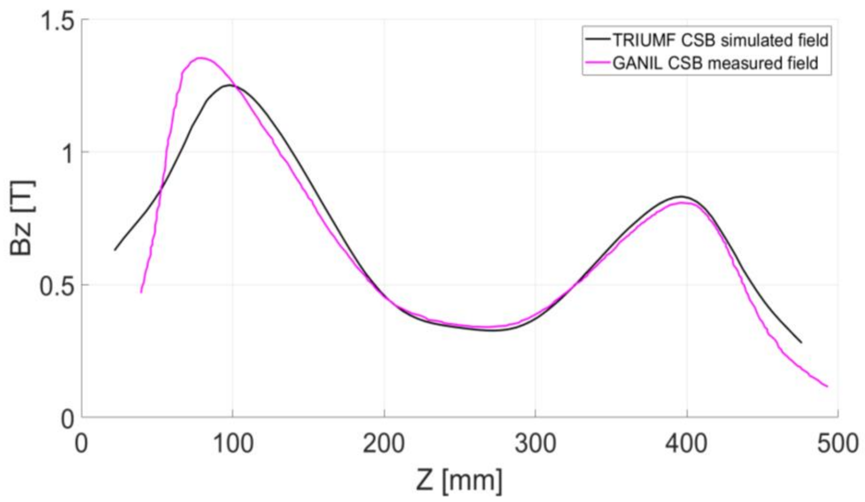
Improvement of the beam quality of the CSB: Injection and Extraction system simulation

- A program to improve the beam quality of the CSB has been started.
- It comprises the simulations of the injection and the extraction systems using the code IGUN©.
- In preparation for the simulations, the axial magnetic field distribution of the booster has been modelled and simulated in OPERA and benchmarked against the measured field of the GANIL SPIRAL1 CSB that is similar to TRIUMF CSB. The simulated magnetic field of the TRIUMF CSB will be benchmarked against Hall probe measurement in the future.
- Systematic scans of the injection and extraction parameters such as injection voltage, extraction voltage, extraction gap, extraction holes and magnetic field is ongoing to further improve the performance of the CSB.

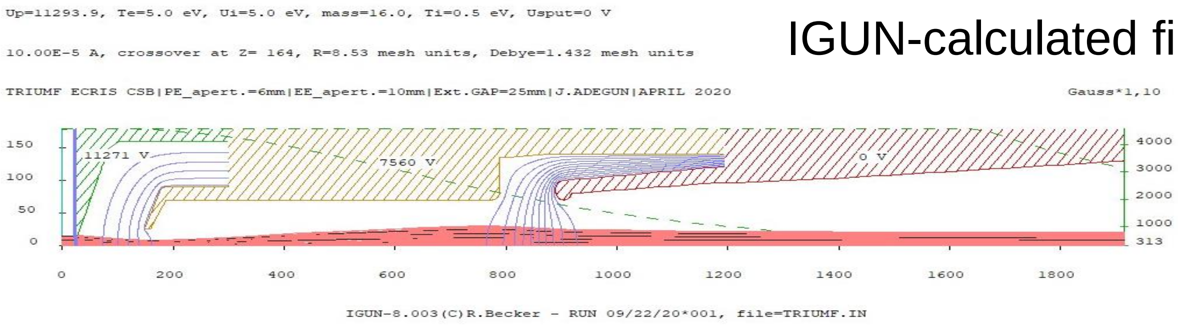
Magnetic field simulations in OPERA



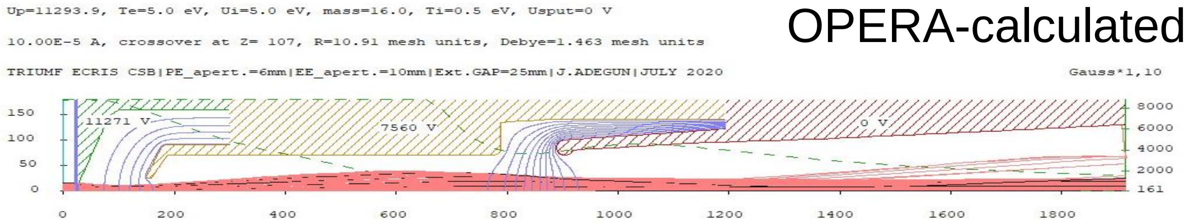




IGUN-calculated field



OPERA-calculated field



Summary

- The two-frequency heating technique has been implemented on the TRIUMF CSB using a single waveguide to improve the efficiency of the CSB. Initial result obtained shows that Cs charge states could be detected up to 29+ with the two-frequency heating compared to the single frequency heating with Cs charge state up to 27+.
- The optimization of the CSB for the two-frequency heating is ongoing and Investigation of the effect of two-frequency heating on the intensity, efficiency and emittance of extracted beam from the booster will follow soon.
- Also, a research campaign to further improve the performance of the CSB via injection and extraction simulations has started.
- The magnetic field distribution of the CSB has been modelled and simulated in OPERA to provide realistic magnetic field values for the simulations in IGUN©.
- The magnetic field distribution simulated has been benchmarked against the measured field of the GANIL SPIRAL1 charge state booster, and the simulated field matched the measured field very well.
- In the future, the simulated magnetic field of the TRIUMF CSB will be benchmarked against Hall probe measurement.
- Investigation of the extraction parameters on the extracted via simulation is currently being conducted to further improve the performance of the CSB.

Acknowledgement

The project is funded by Natural Sciences and Engineering Research Council of Canada (NSERC), TRIUMF, and the University of Victoria, BC.

NSERC
CRSNG

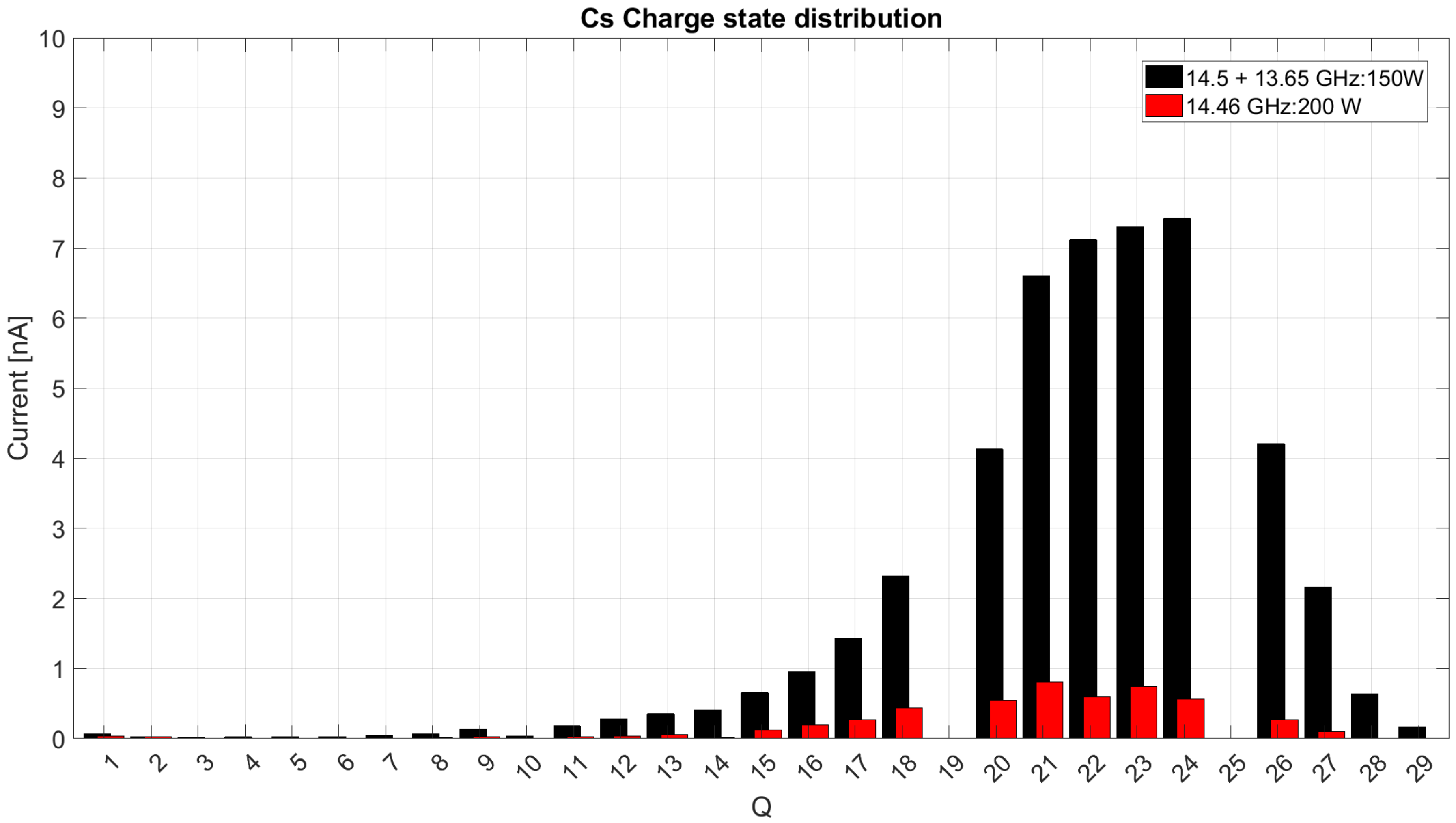
TRIUMF Canada's particle accelerator centre
Centre canadien d'accélération des particules

University of Victoria

Thank you

Back-up Slides

Preliminary Two-frequency Heating Technique Result



IGUN and OPERA-Calculated magnetic fields