Design of a new iron plug for the TRIUMF ECRIS charge state booster

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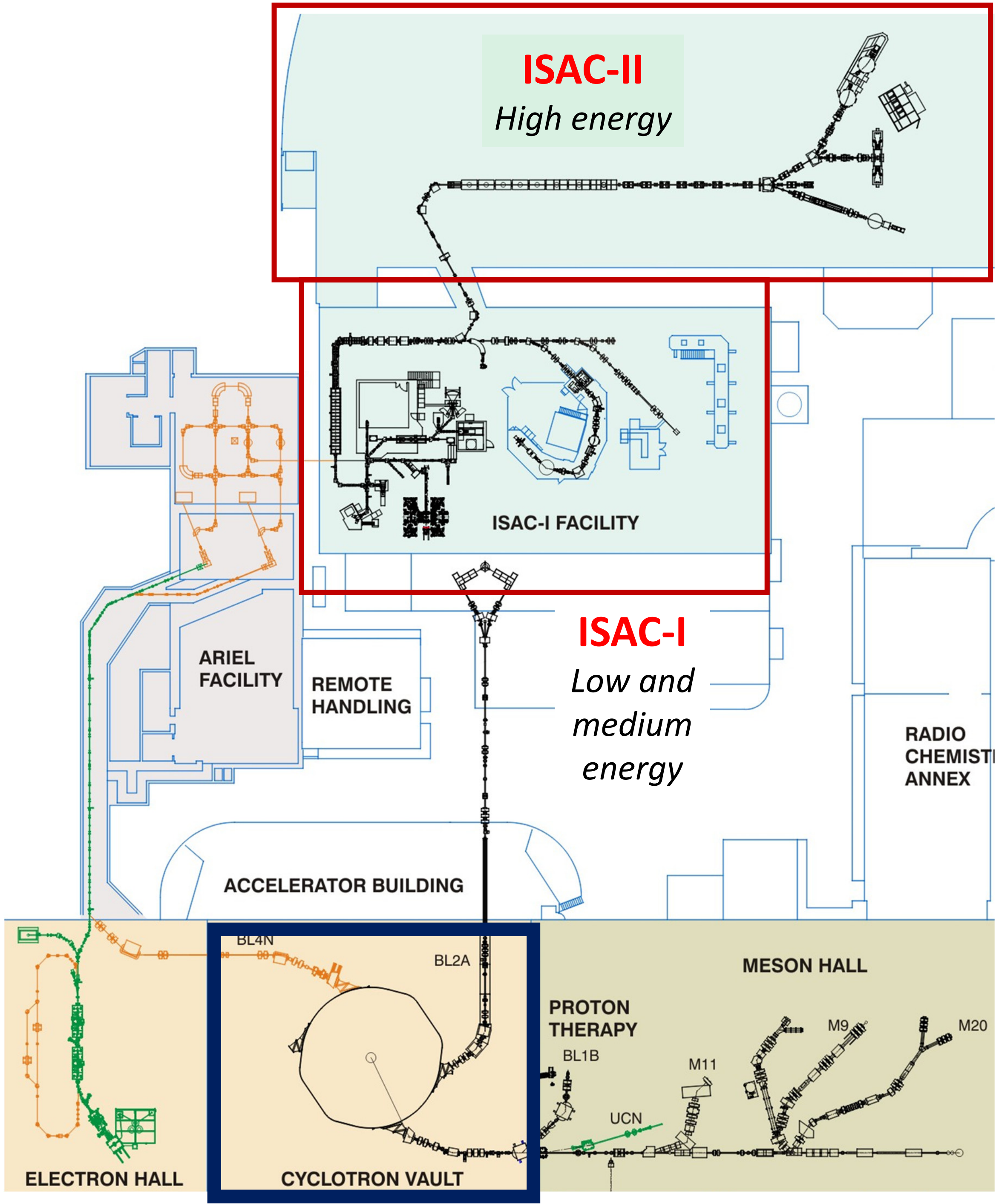
Outline

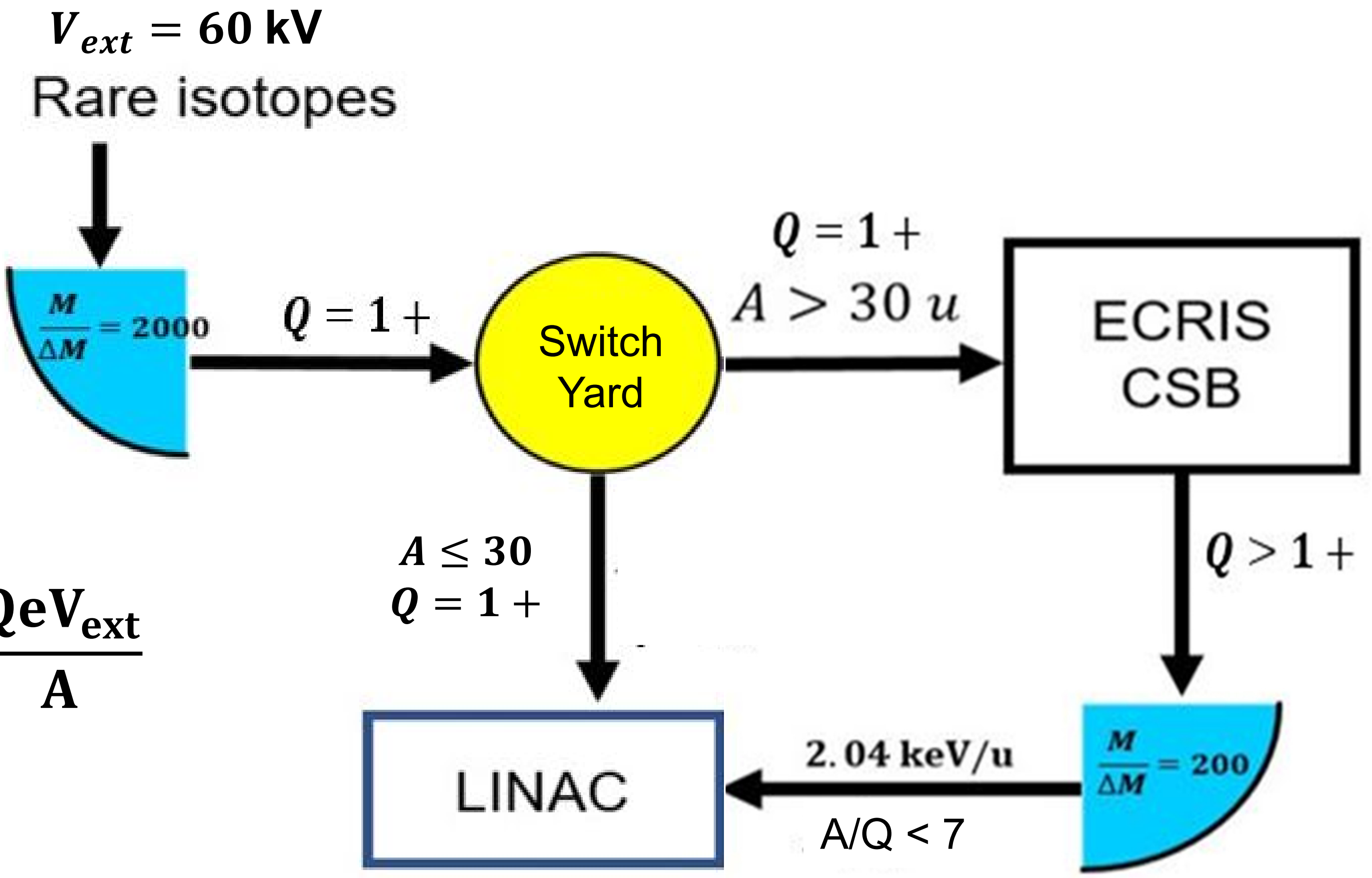
- The TRIUMF accelerator complex
- Charge breeding requirement at the TRIUMF ISAC facility
- The TRIUMF ECRIS charge state booster
- Effect of a wide gap in the injection iron plug of the booster and design of a new iron plug
- Results and Summary



TRIUMF Accelerator Complex

- Isotope Separator and Accelerator (ISAC) facility: production and acceleration of exotic isotopes.
  - ISAC I facility: Normal conducting LINAC - low and medium energy for nuclear astrophysics experiments.
  - ISAC II facility: Superconducting-LINAC - high energy for nuclear physics experiments.

Charge Breeding: Required for $A > 30$



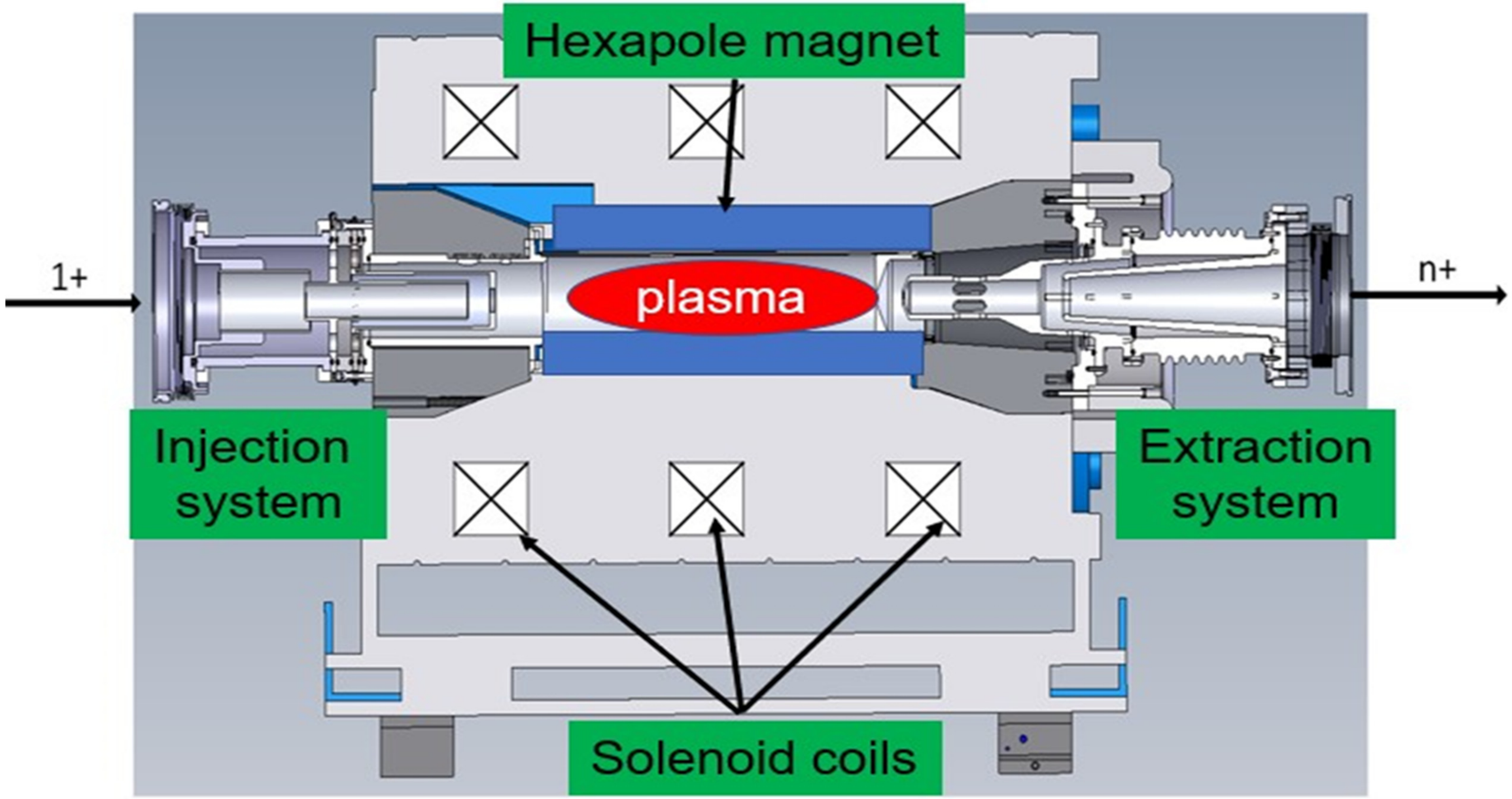
$$\mathbf{E}_i = \frac{\mathbf{QeV_{ext}}}{\mathbf{A}}$$

RFQ + DTL + SRF

Injection energy: 2.04 keV/u

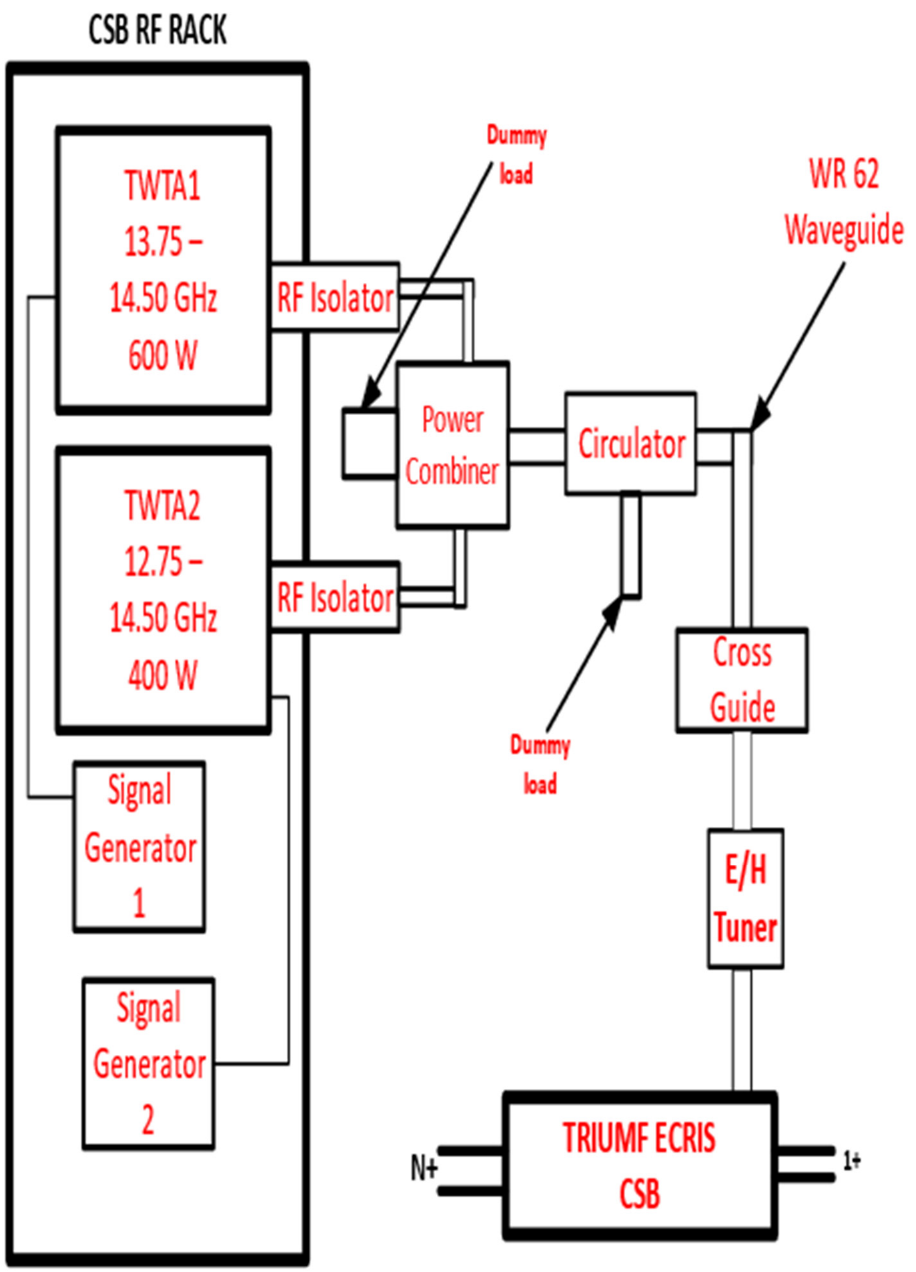
TRIUMF ECRIS Charge State Booster

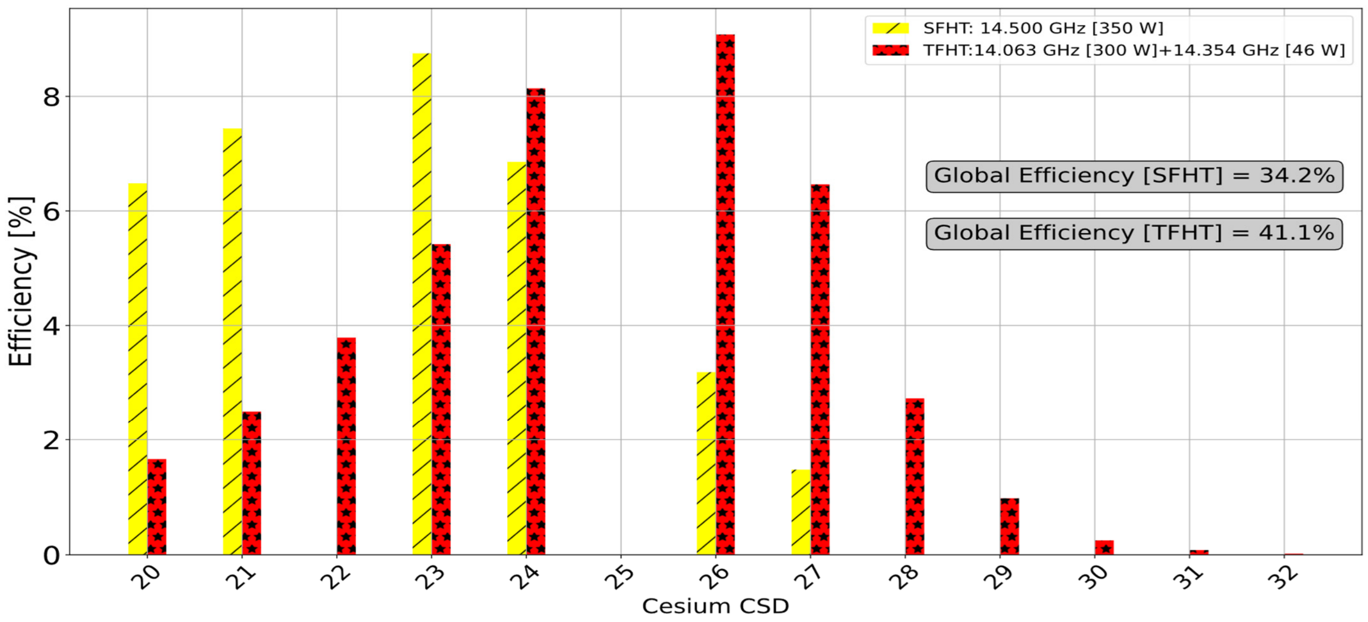
- Phoenix booster from Pantechnik
- Room temperature solenoids + hexapole permanent magnet
- Two iron plugs are installed at the injection and extraction regions to enhance the B-fields.
- Modified RF system to support two-frequency heating operation.



Magnetic Fields	Values [T]
B_{inj}	~1.0
B_{min}	~0.3
B_{ext}	~0.7
$B_r(r = 32\ mm)$	~0.7

Implementation of Two-Frequency heating on the TRIUMF ECRIS CSB





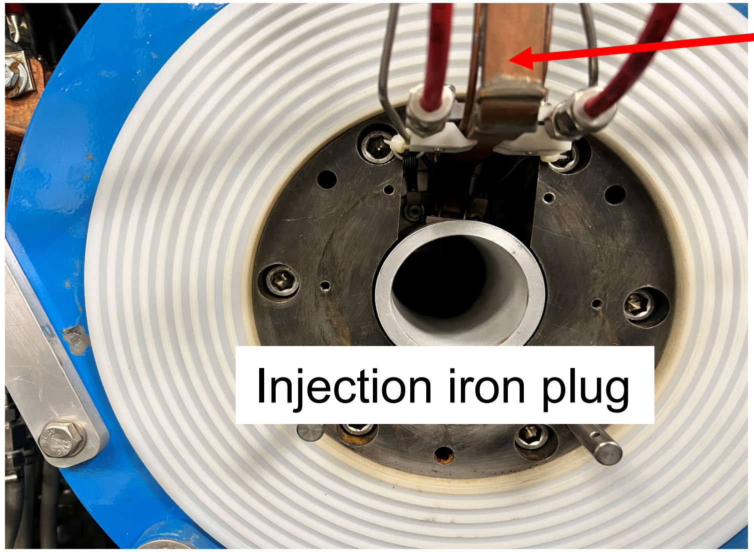
Despite the recent TFHT operation, the TRIUMF PHOENIX booster is still not performing as well as its counterpart at LPSC.

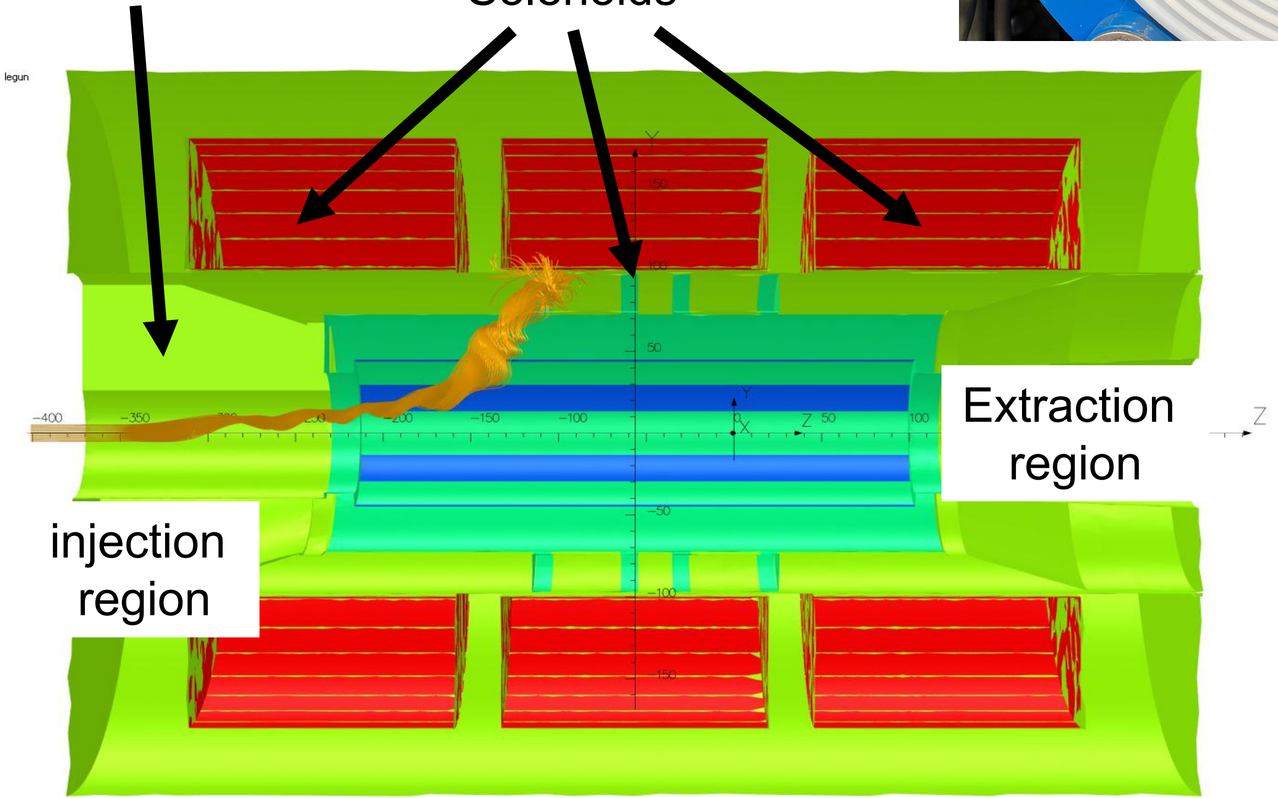
Parameter	TRIUMF Phoenix	LPSC Phoenix*
$^{133}Cs^{26+}$ Efficiency	9.1 %	14.1 %
Global Efficiency	43.2 %	91.8 %
Support Gas	He	He

* J Angot et al 2022 J. Phys.: Conf. Ser. 2244 012063

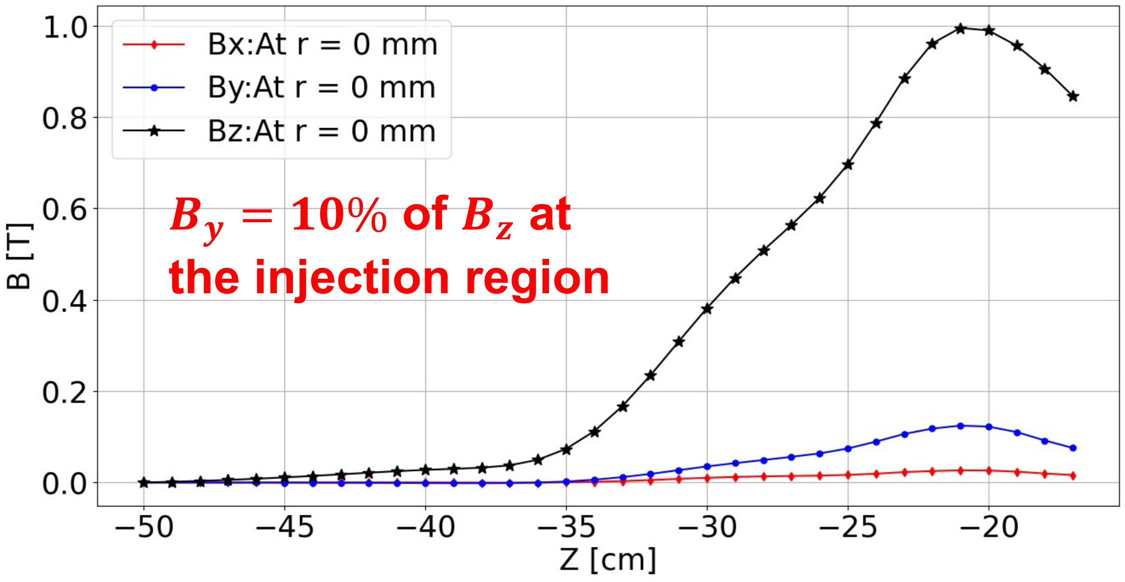
Effect of a gap in the injection iron plug of the ECRIS CSB

The gap in the iron plug at the injection region of the booster produces a dipole magnetic field.





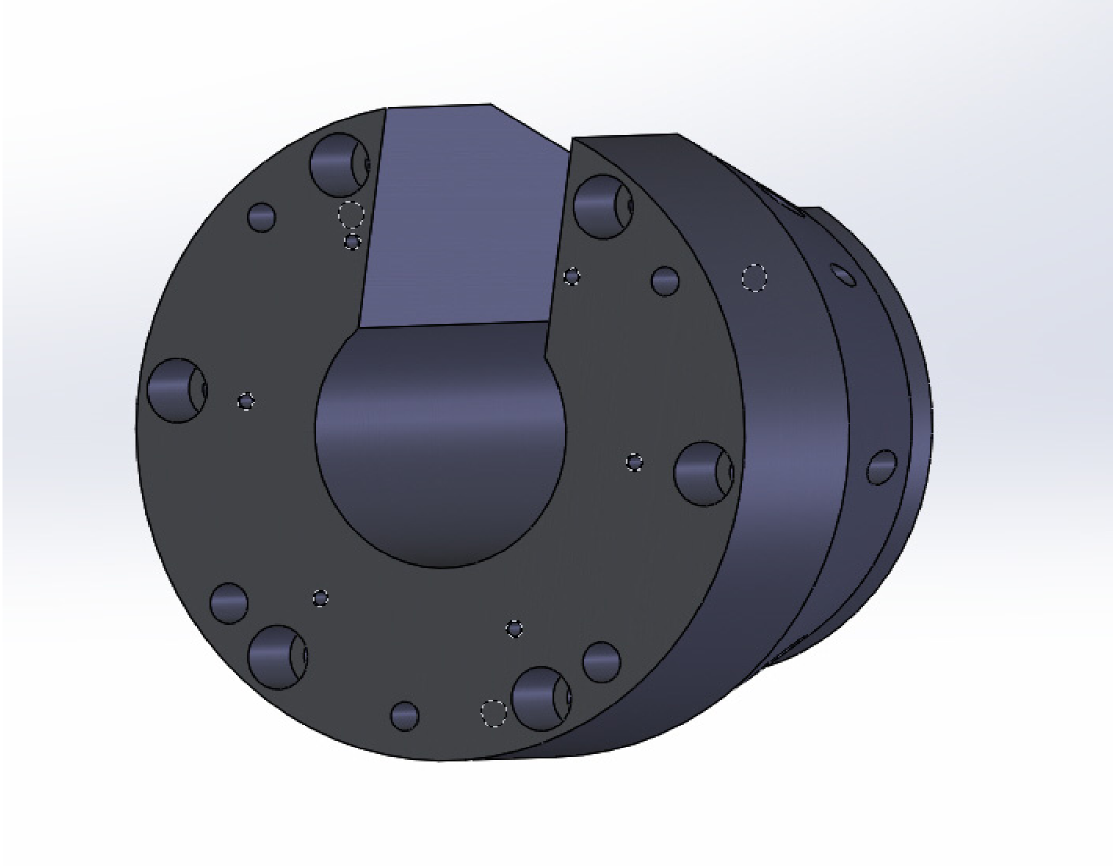
B-field in the injection region of the TRIUMF CSB



Iron plug: New design vs current design

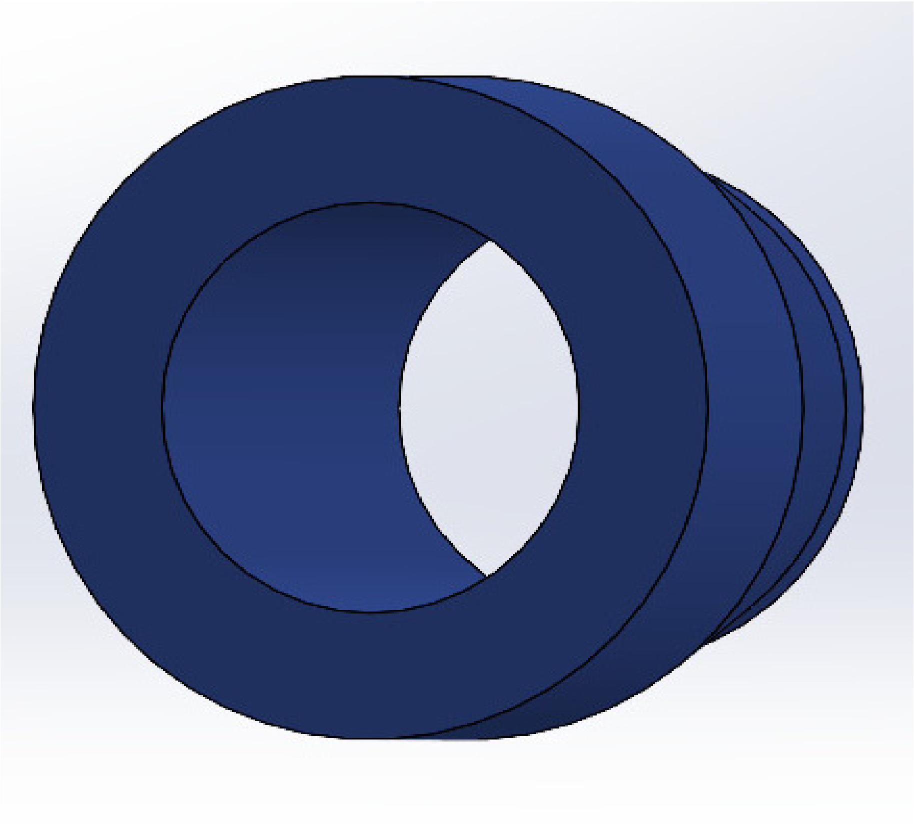
A new soft iron plug has been designed to fix the dipole field issue caused by the gap at the injection region of the CSB.

Original design



Inner diameter = 80 mm

New design

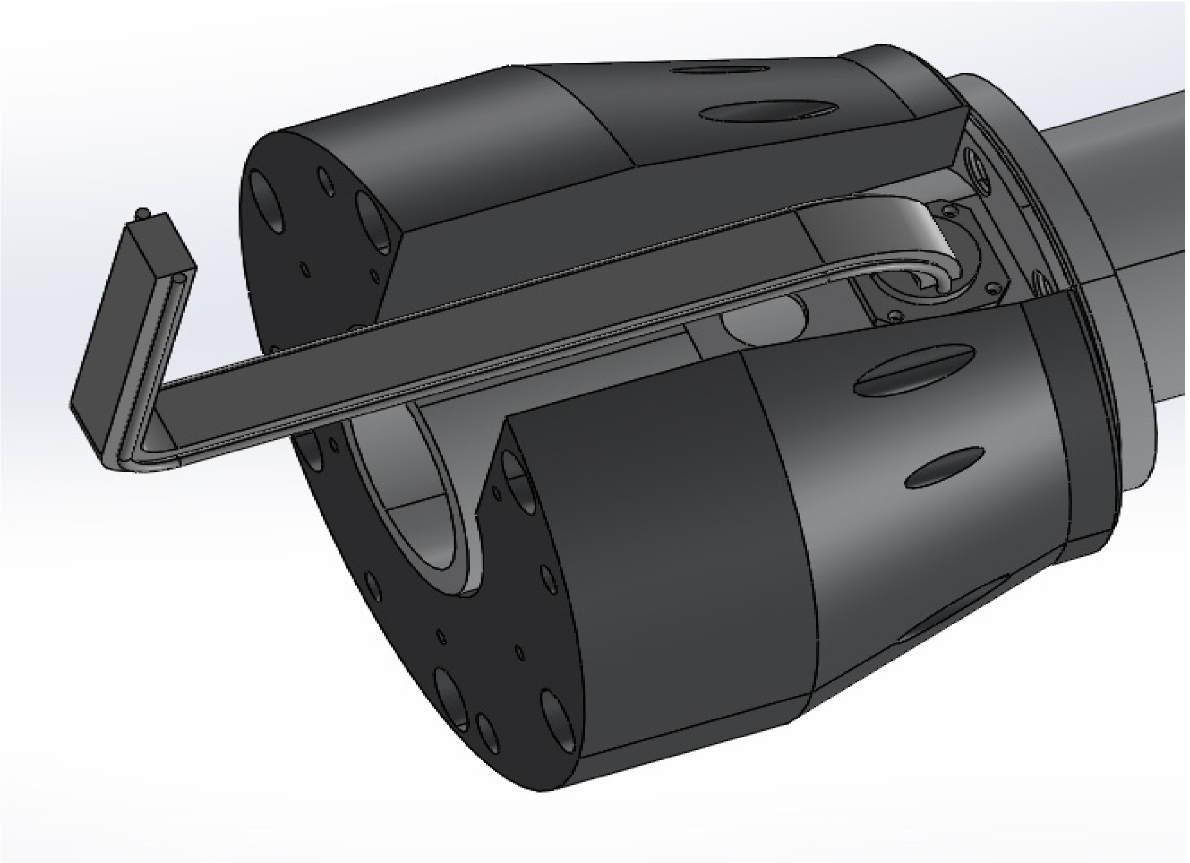


Inner diameter = 120 mm

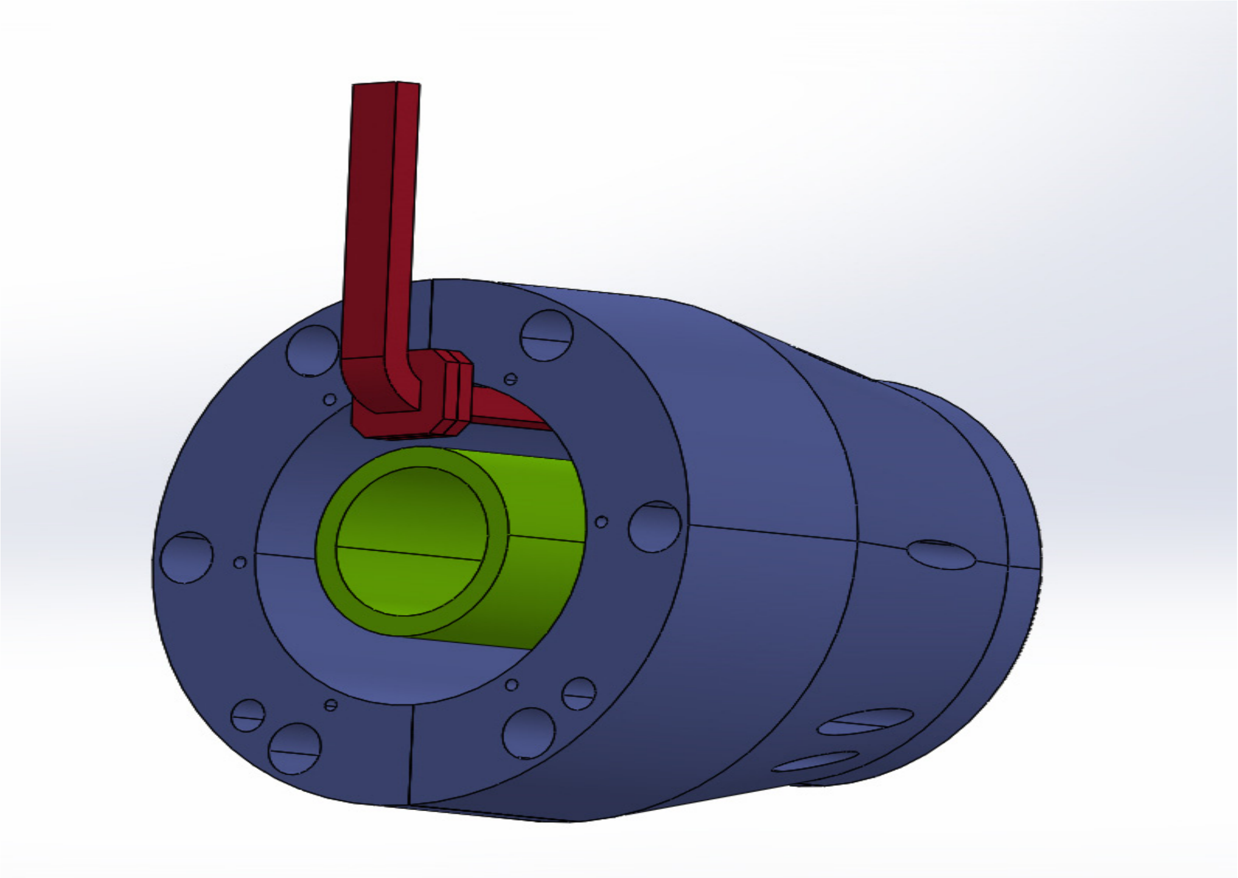
Iron Plug With Waveguide

The plasma chamber at the injection region was modified to accommodate the waveguide so that the gap, as in the existing iron plug, could be avoided.

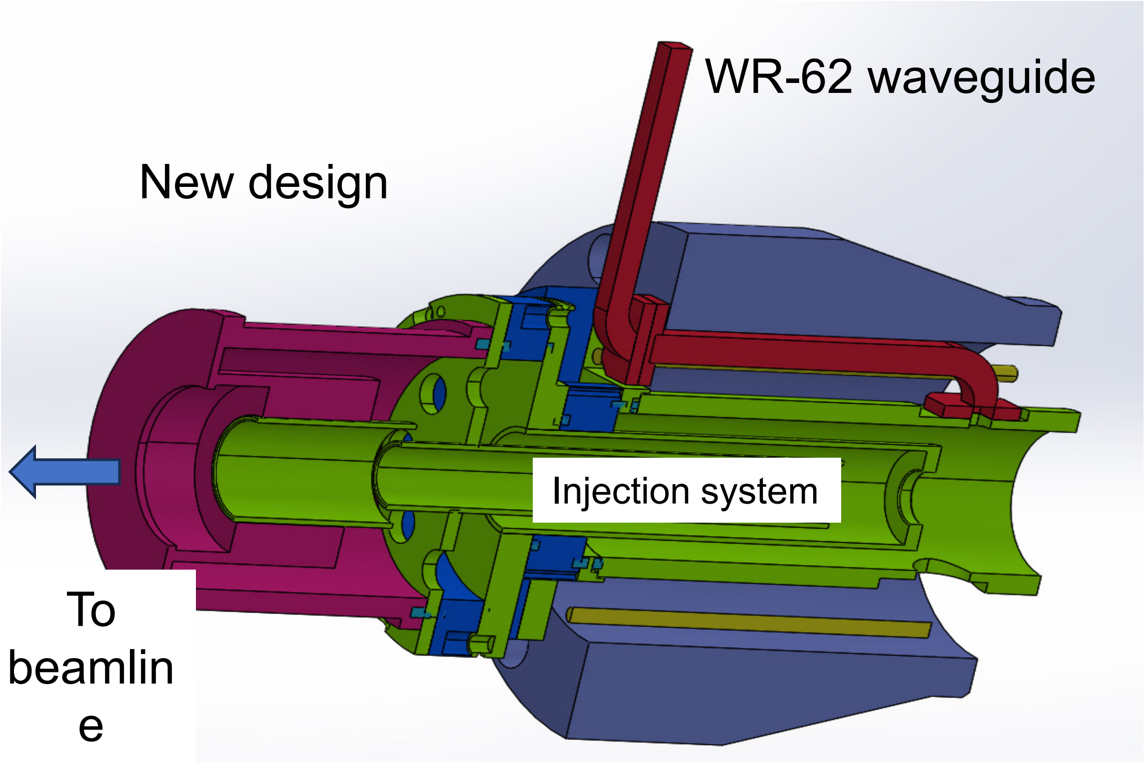
Existing iron plug

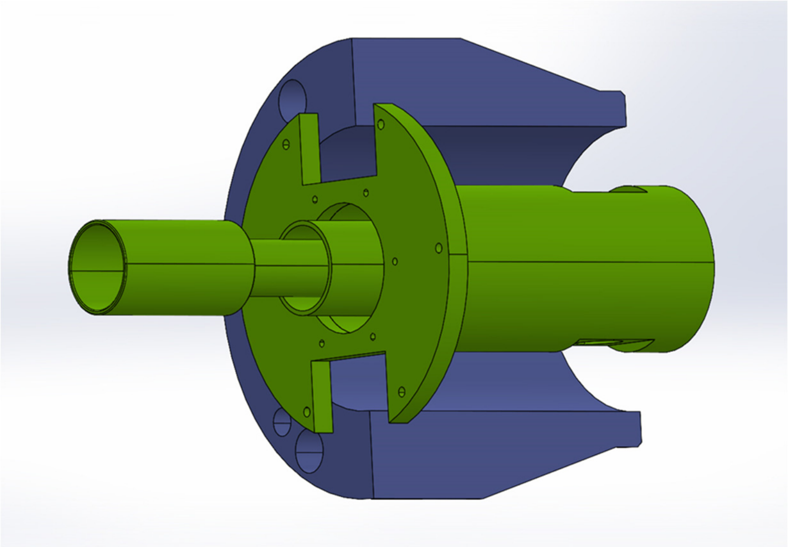


New Iron plug

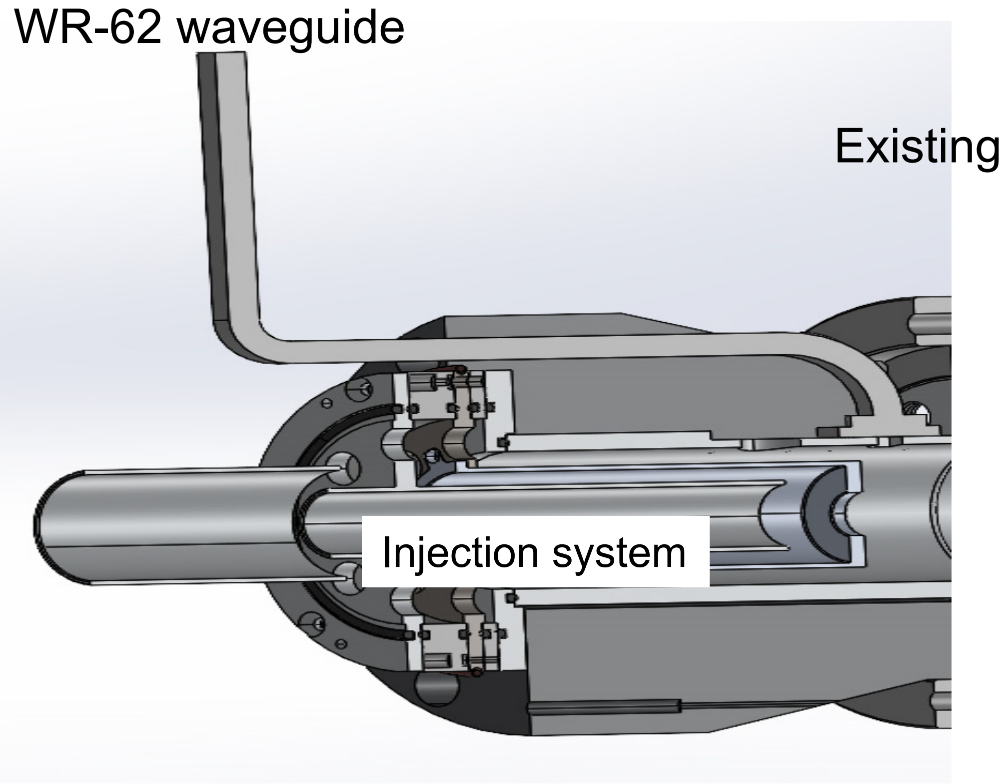


Comparison between existing and current with Flanges



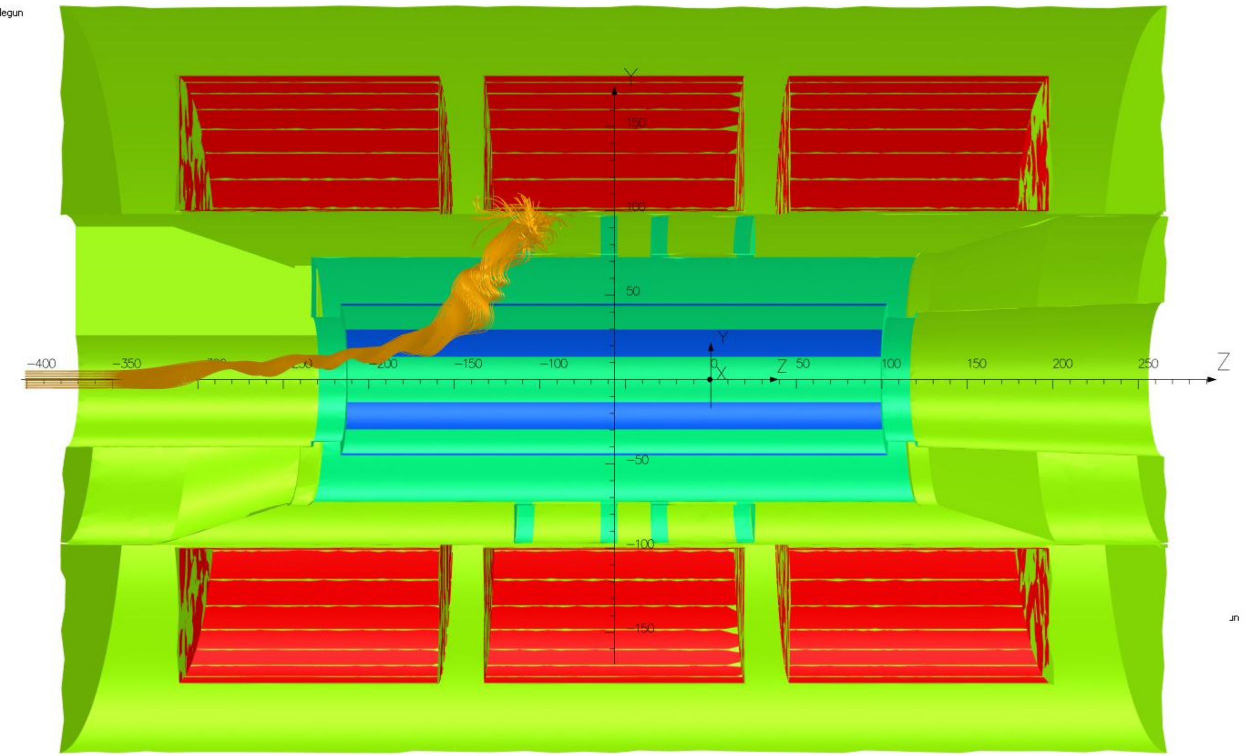


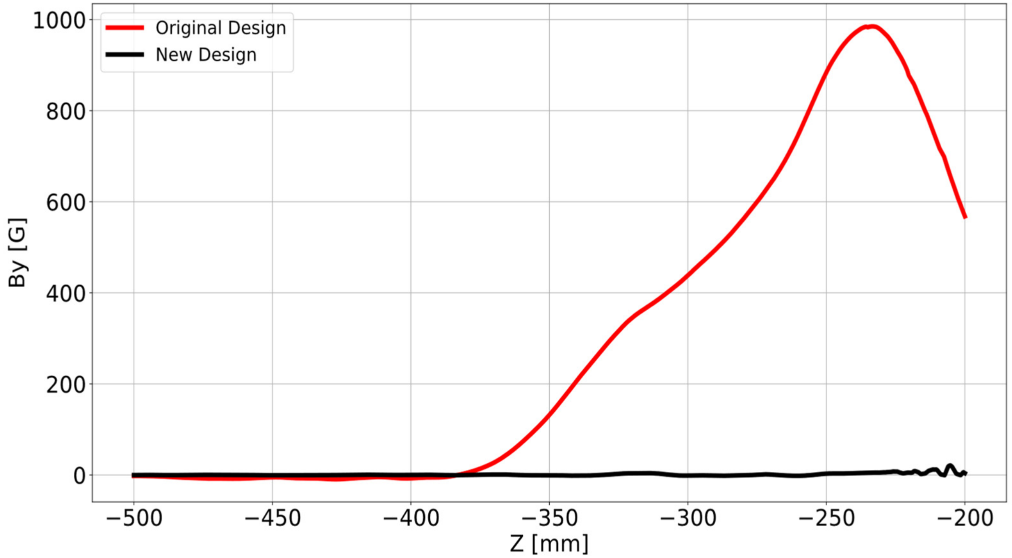
The plan was to modify only the iron plug, but like dominoes, things began to fall apart, and everything at the injection region of the booster had to be redesigned.



Comparison of particle trajectories

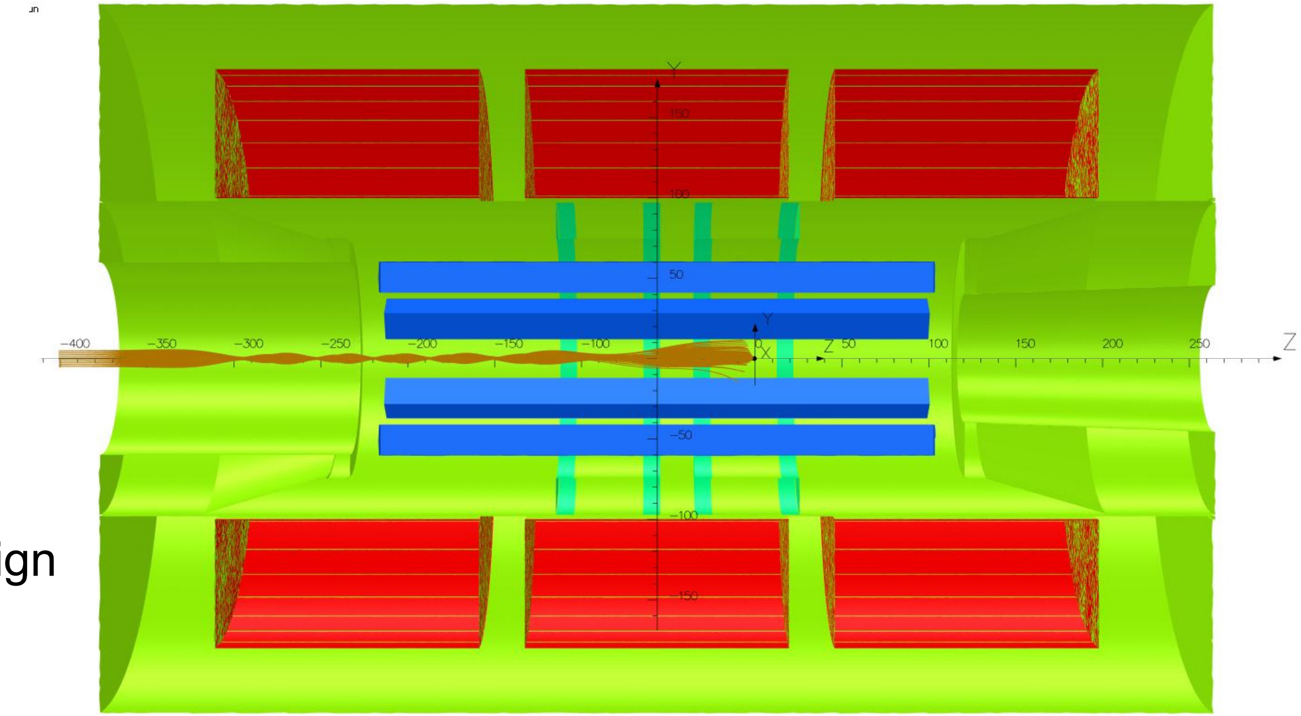
Original design





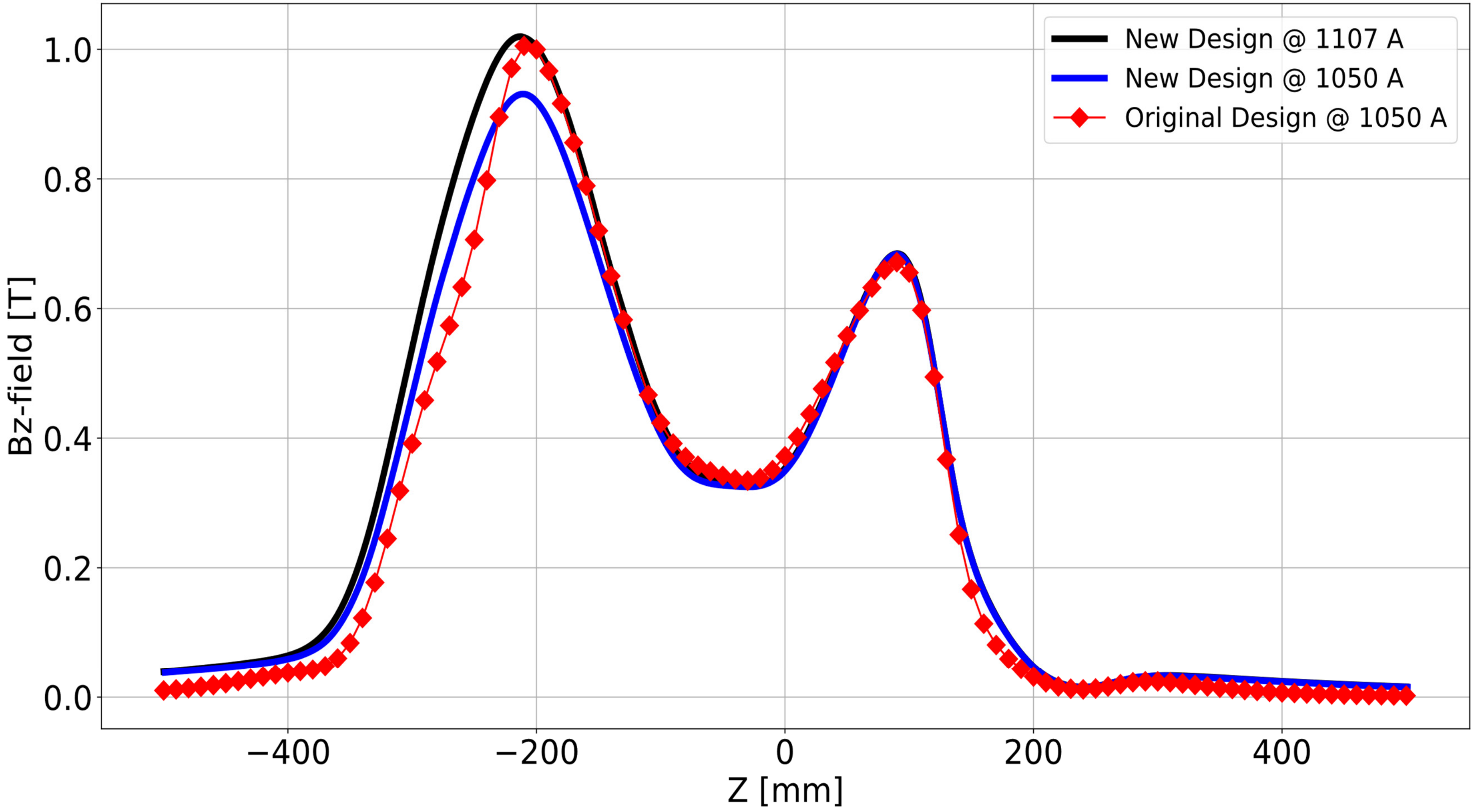
Eliminating the gap effectively got rid of the undesirable transverse field at the injection region of the TRIUMF charge breeder.

New design



But another issue emerged………

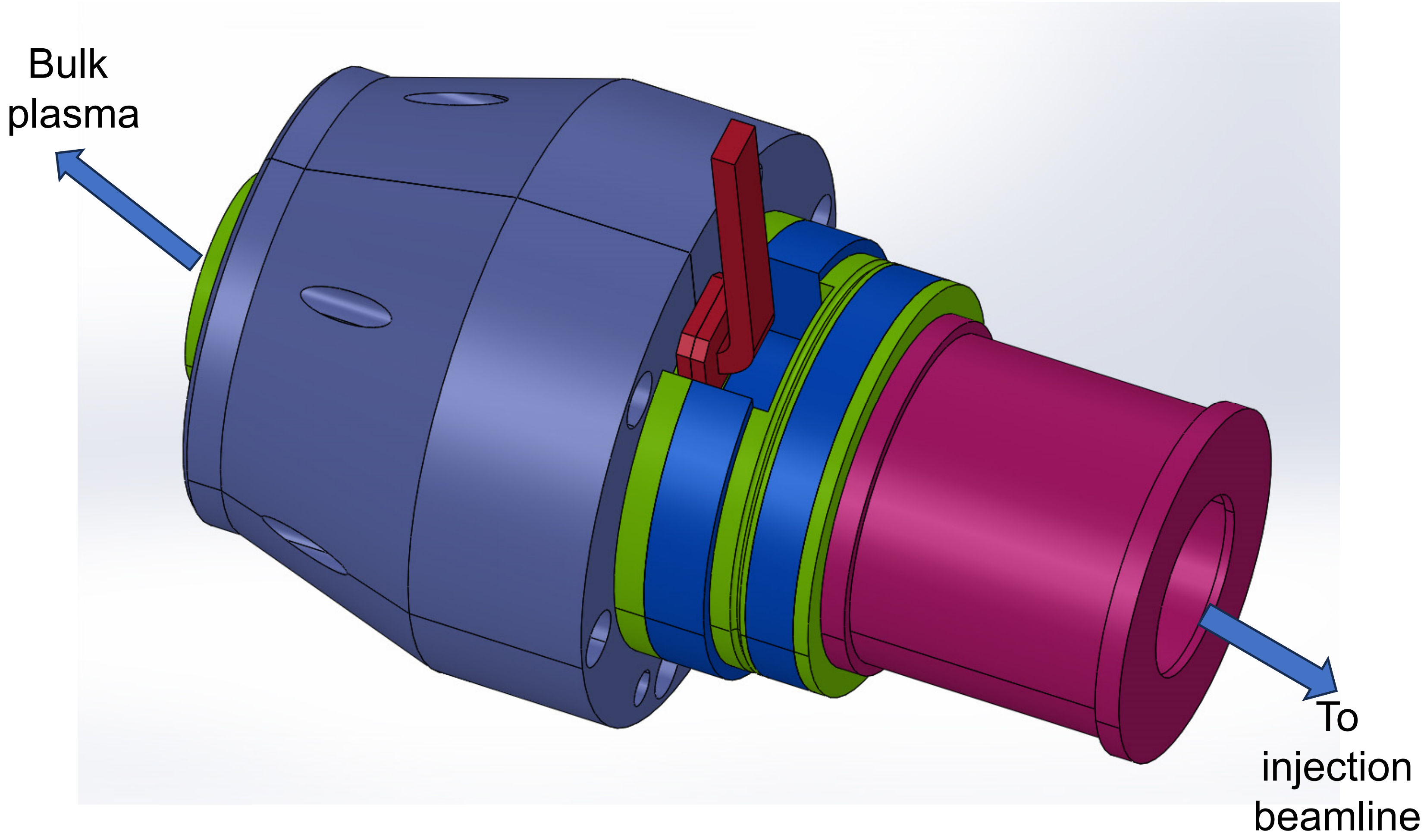
The current supplied to the solenoid coil, capable of generating a 1.0 T magnetic field with the iron plug that previously featured a gap, is inadequate for my updated design.



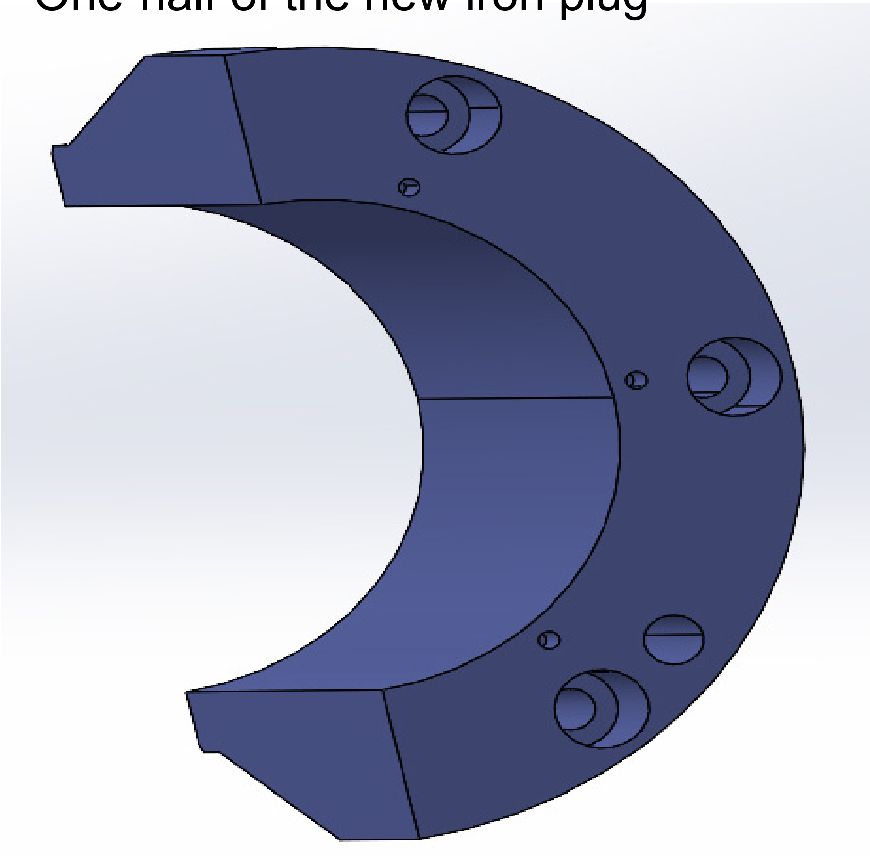
Luckily, the power supply for the injection solenoid coil can handle up to 1300 A, providing sufficient capacity for the required adjustments.

Assembly and disassembly issue……….

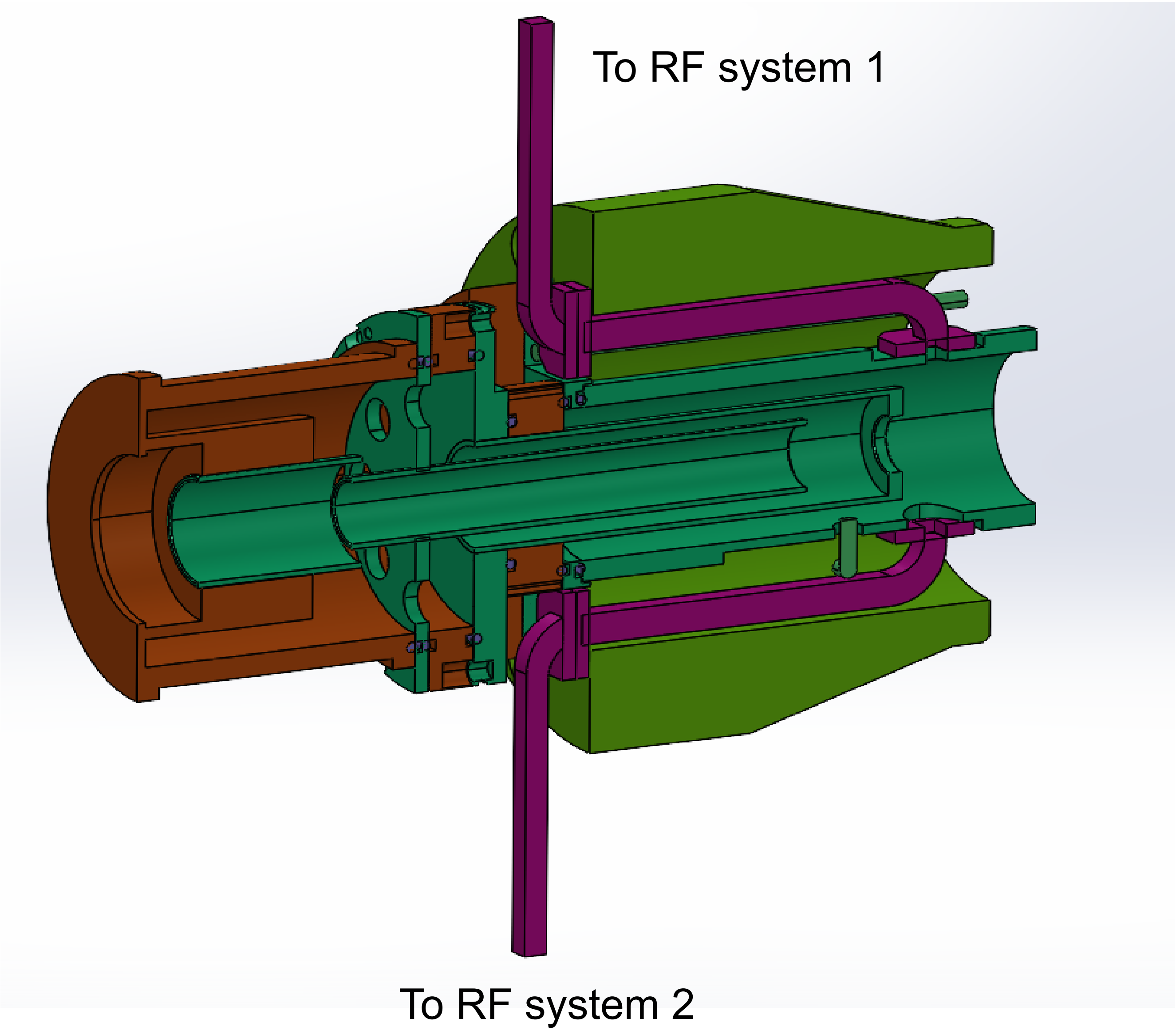
Upon assuming that the final challenge had been addressed, a subsequent issue emerged: the assembly of the components proved to be not feasible.



One-half of the new iron plug



Designed to accommodate two-waveguide…



The booster could be configured to accommodate two distinct waveguides.

Modification of the plasma cavity

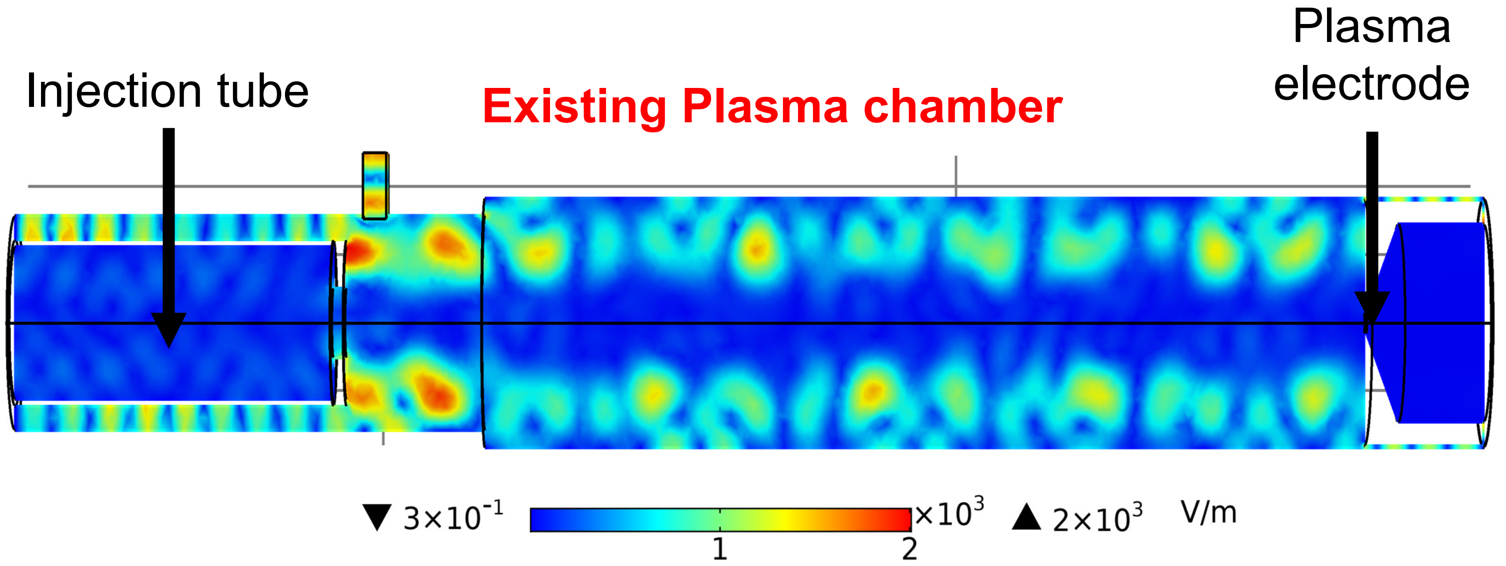
The plasma cavity was designed for an electromagnetic wave of 14.5 GHz.

Changes made to the plasma chamber should not be underestimated

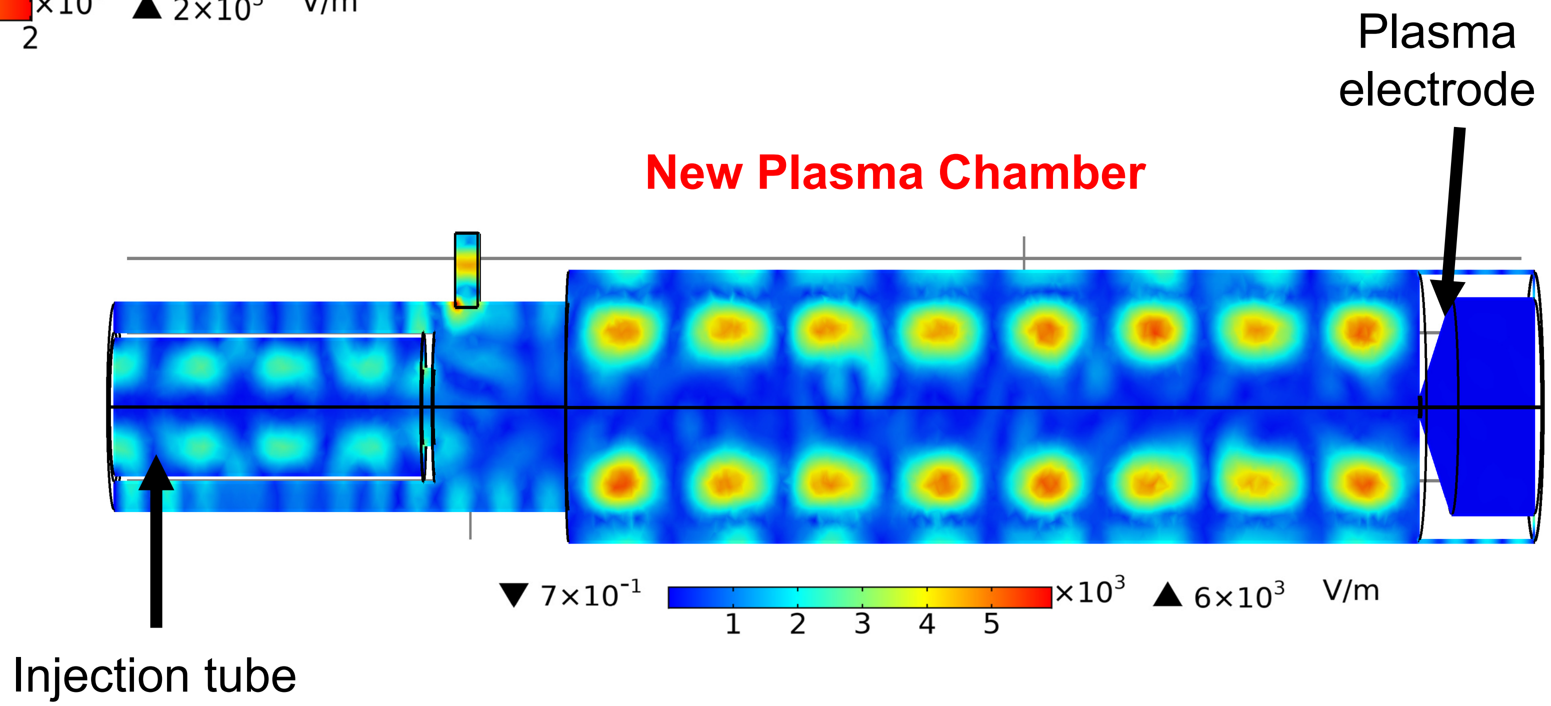
The section of the plasma chamber that was modified to achieve the final design.

Plasma electrode

Electromagnetic Mode Excitation: New vs. Existing Plasma Chamber Designs



EM wave at 14.5 GHz without plasma



Interestingly, the localized heating around the injection region disappeared in the modified plasma cavity.

Summary and Future Activities

- At TRIUMF, the Electron Cyclotron Resonance Ion Source plays a crucial role in charging breeding isotopes with atomic mass greater than 30. This process is essential to match the injection energy of the LINAC.
- The gap in the iron plug at the injection region of the ECRIS CSB creates a dipole magnetic field, causing ion deflection during injection and reducing the ion source efficiency.
- A new iron plug has been designed to replace the existing one, eliminating the gap.
- These changes necessitated redesigning the injection system and the plasma chamber.
- Pantechnik has been contracted to supply the soft iron and plasma chamber. Installation is tentatively scheduled for the next shutdown.
- The installation of the modified components is anticipated to improve the overall efficiency of the TRIUMF Phoenix booster.

Thank you