Beam Optics Effects at the entrance of SARAF RFQ

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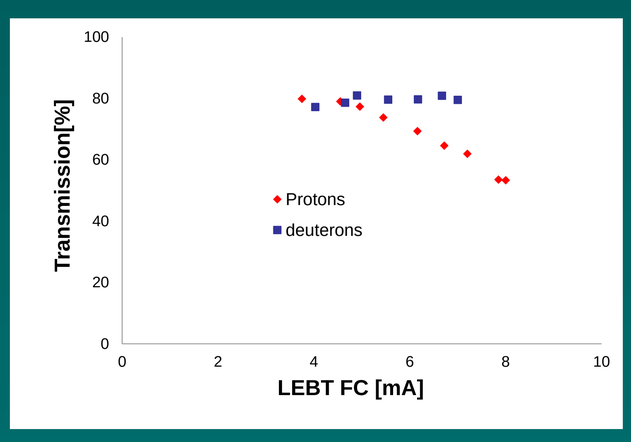
Abstract

A strong effect of the RFQ 176 MHZ RF field on the low energy beam optics was observed. The effect takes place in the Low Energy Beam Transport (LEBT) line at the vicinity of the RFQ entrance flange. The effect was studied for various LEBT protons beam energy and for the broad range of RF field. The measurements suggest that, most likely, the effect is associated with loss of the beam neutralization in the LEBT region adjacent to RFQ. Calculations of the electrical fields and beam dynamics simulations performed for the region of interest confirmed this assumption.

The SARAF RFQ transmission

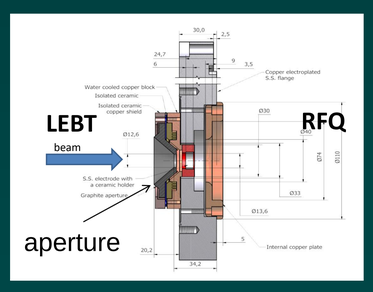


A long-standing problem of the SARAF RFQ injector is the reduction of the proton beam transmission through the RFQ as a function of the input LEBT beam current
Typically, the RFQ transmission deteriorates to 60 % for LEBT proton beam current above 5 mA. This poor transmission is not consistent with value of beam emittance measured in the LEBT beam line.

Conclusion

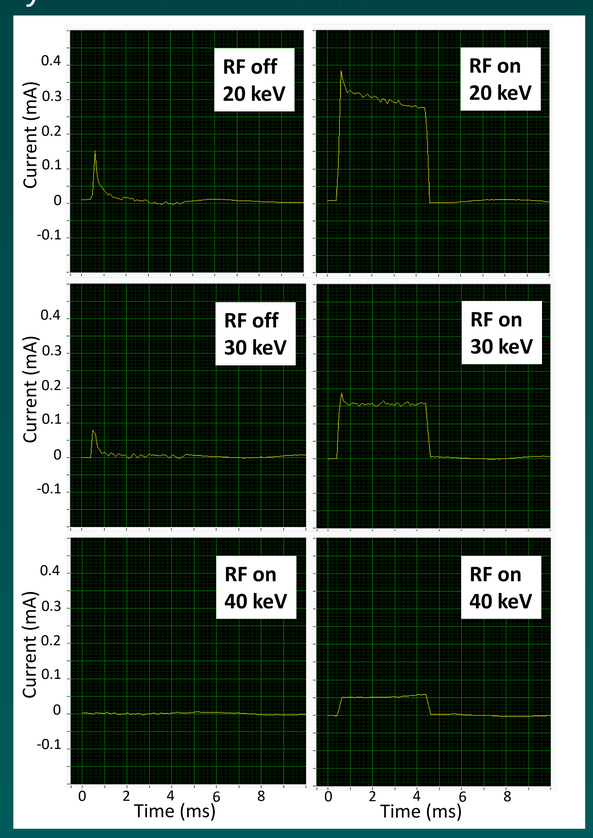
The signature of loss of the ion beam neutralization at an RFQ entrance has been observed for the first time. The initial simulations confirm that the leakage of RF field into LEBT section modifies the electron distribution and, hence, affects, the beam neutralization. It is likely that the observed phenomenon results in increased of emittance values and growth of emmitance in part responsible for modest values of the RFQ transmission.

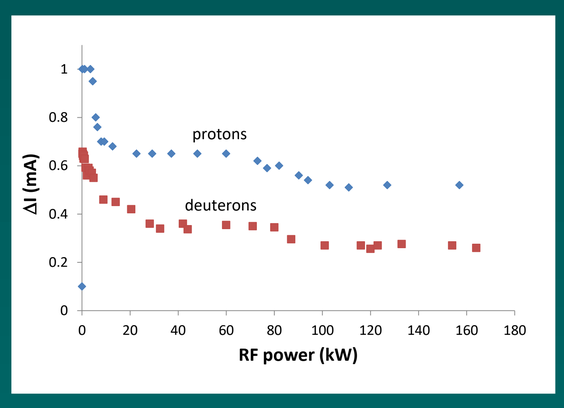
Observations



A new RFQ entrance flange has been introduced in 2014.
The flange has superior cooling and RF contacts.
In addition the flange has electrically insulated water cooled aperture allowing to measure the beam signal

It has been noticed accidentally that the signal on the aperture is significantly reduced when RF field is switched off. This phenomenon is very robust and been observed for pulsed and DC beams in the broad range of beam optics conditions. The effect takes place even at the lowest RF power values of a few hundred Watts is slightly sensitive to further increase of RF forward power. The similar measurements were performed for beam energy of 25, 30, 35 and 40 keV. It is evident from the figure that RF ON/OFF effect is significantly reduced with increase of beam energy. The observations indicate on the effect has space charge nature.





The change of beam current on the RFQ aperture with application of RF field as a function of the RF field. The effect is significantly smaller for deuterons confirming the space charge nature of the observed phenomenon.

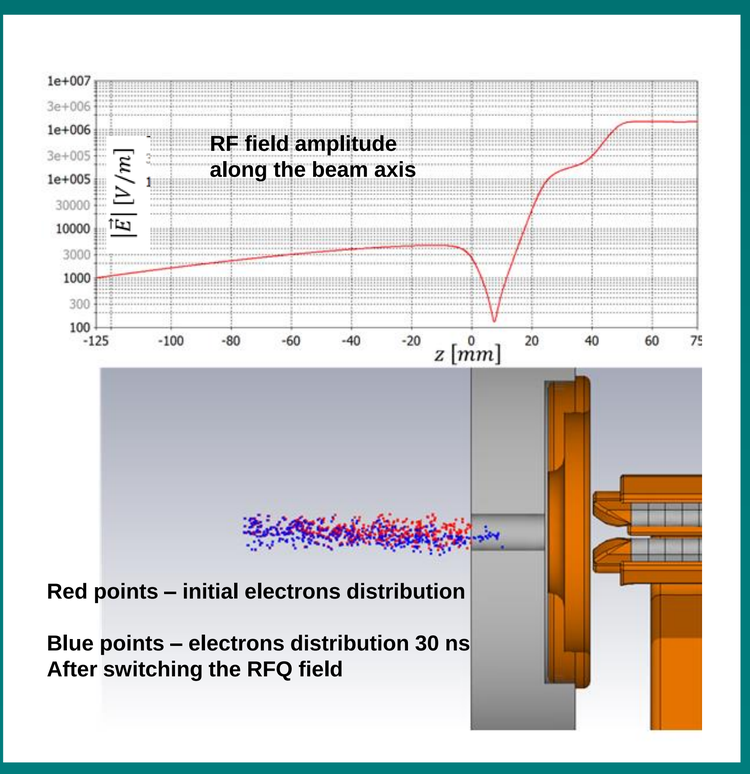
Simulations

Our understanding of this effect is the following: there is leakage of RF field from the RFQ volume via the flange entrance channel. The RF field affects the electrons in the beam modifying the level of beam neutralization and increasing the space charge interaction and, hence, changing the beam optics at RFQ entrance.

We have performed the simplified set of simulation in order to get initial idea on the RF field influence at the last LEBT section .

As the first step the electrical field in the RFQ cavity and in the downstream LEBT section was calculated using the CST software.

As the next step we have introduced a cloud of the electrons at the entrance to RFQ. The space-charge interaction between the electrons is switched off due to compensation of the proton beam. The distribution of the electron cloud as function of time was calculated after switching on RF field. The example of such distribution after 30 ns (~ 5 RF periods) is Presented in as blue points. The significant modification of the electron cloud is evident.



Thus, the effect observed at the RFQ entrance can be explained by modification of the beam optics due to leakage of the RF field. The growth of emittance and, hence, reduction of the RFQ transmission also can be explained by this effect.

ICIS 2017, Geneva,Switzerland, October 15-20 ,2017