

# PROPOSAL FOR A 72.75 MHz RFQ FOR THE LINCE ACCELERATOR COMPLEX \*

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## Abstract

The low-energy part of the LINCE facility [1] can be based on a 72.75 MHz normal-conducting RFQ designed to give a 450 keV/u boost for  $A/Q=7$  ions in about 5 m length. The vanes have been electromagnetically designed to accommodate dedicated RF windows producing effective separation of the RFQ modes in an octagonal-shaped resonance chamber [2]. This article outlines the optimization of the quality factor of the cavity by using numerical methods for electromagnetic calculations. Experimental results of RF test carried out on a prototype are also discussed.

## INTRODUCTION

RFQ development, as a whole device is a very complex project which requires many iteration loops between physical concepts and engineering practices. Within the physical aspects, the development is carried out setting beam quality and specifications first. Considering a design mass-overcharge ratio  $A/Q=7$  the RFQ must yield 460 keV/u energy gain working at a maximum inter-vane voltage of 82 kV. Results of the RF modelling process carried out in COMSOL [3], are outlined along the design stages from the shape of the resonator to the final modulated vanes including windows and tuners.

## CAVITY OPTIMIZATION

Considering only two RFQ sections, the vanes and windows geometry can be optimized in order to produce the highest quality factor with a resonant frequency around 70 MHz such that adding modulation and tuners [2] would raise it in the 8 sections layout to about 72.75 MHz. This can be achieved in two stages:

- choice of the vane height and thickness in 2D with a predetermined cross-section in the beam region;
- optimization of the elliptical RF windows in 3D;

### 2D Optimization

The 2D optimization is achieved by doing a parametrization of the vane height which consists of several geometric pieces, namely a trapezoid, a rectangle, a stem and a half disk, all added on the top of the inter-vane radius  $R_0 = 6.16$  mm. While the disk radius  $r_1 = 4.8$  mm and stem height  $h_{stem} = 14$  mm are kept constant, the rectangle and trapezoid height shown in Fig. 1 are taking values between 45 mm and 125 mm in steps of 2.5 mm.

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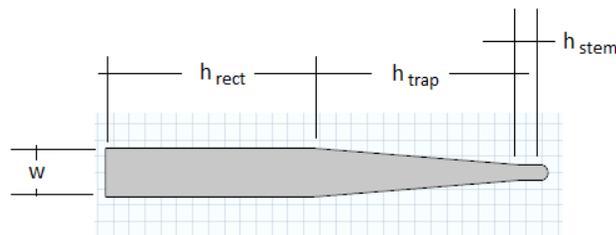


Figure 1: Transverse cross-section view of one vane.

Running the optimization process at three different values for the vane width  $w$  yields the quality factor and resonant frequency for the  $TM_{21}$  mode as shown in Fig. 2. For a given quality factor one must consider higher and thicker or shorter and thinner vanes. The trapezoid and rectangle heights are complementary in the sense that the same quality factor can be obtained decreasing any one of them and increasing the other one proportionally.

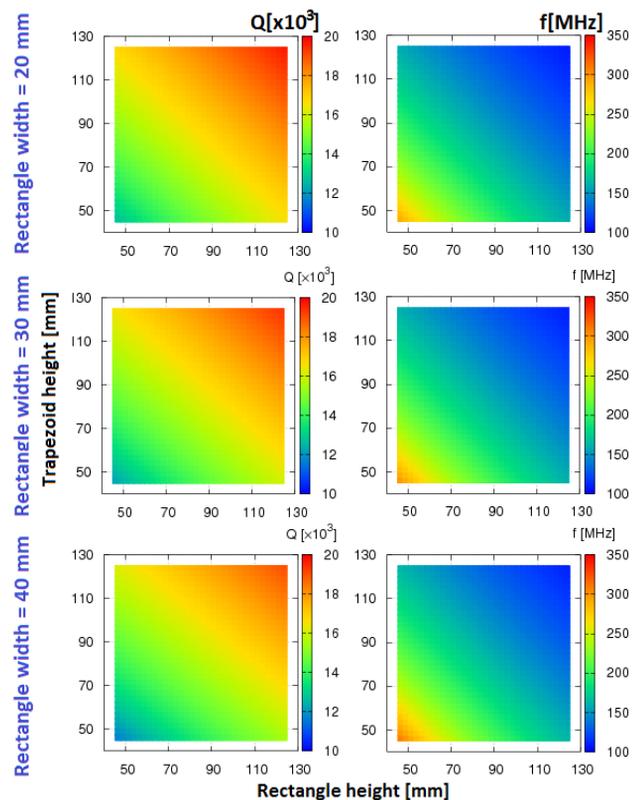


Figure 2: Evaluation of the quality factor and resonant frequency as function of rectangle and trapezoid height.

To proceed to the next stage, the parameters are set to  $w = 40$  mm,  $h_{rect} = h_{trap} = 130$  mm and this yields  $Q = 19438$  and  $f = 105.59$  MHz.

### 3D Optimization

The vane transverse cross-section is extruded for the length of two RFQ sections that is  $L = 1$  m. In a first approach an elliptical window with  $a_1$  and  $b_1$  as the minor and major semi-axes respectively is considered. Quality factor and frequency variation as a function of the two semi-axes can be seen in Fig. 3.

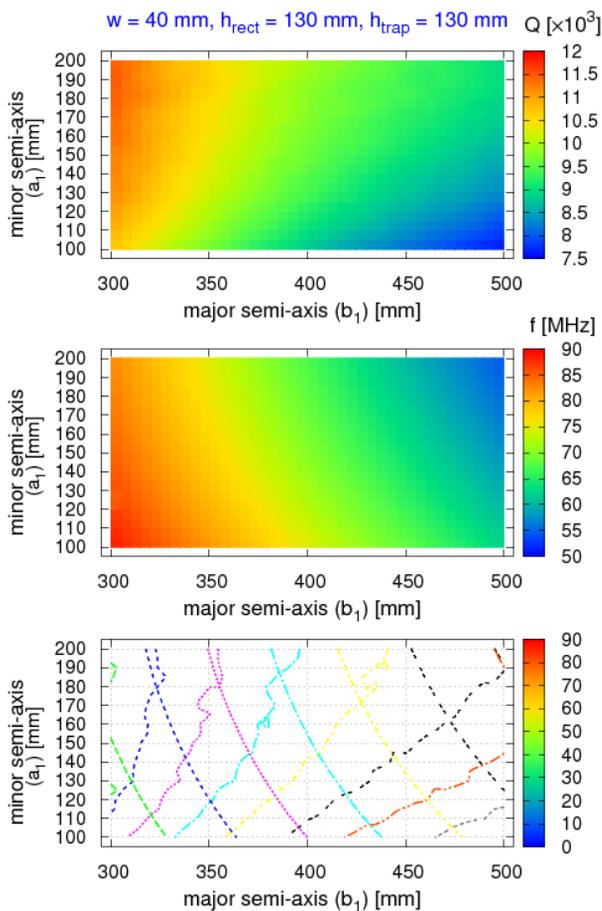


Figure 3: Evaluation of the quality factor and resonant frequency as function of the ellipse semi-axes.

Constant frequency lines are bent oppositely to constant quality factor lines and thus they intersect, though the curvatures are quite different. We choose  $b_1 = 375$  mm and  $a_1 = 200$  mm and the quality factor of 10221. The end caps volume is not used for calculations. Neither are the copper faces in the xy-plane at the two vane longitudinal limits. The RF analysis results for one RFQ section with these characteristics are show in Table 1.

Table 1: RF Characteristics of One RFQ Section

Parameter	Units	Simulation
Frequency	[MHz]	67.20
Quality factor		10221
Power loss per cavity	[kW]	17.73
Stored energy	[J]	0.40
Shunt impedance	[[kΩ–m]	237.59

## RFQ PROTOTYPE

A section of aluminum cavity RFQ has been built in collaboration with Spanish companies and tested in the RF Laboratory at the University of Huelva as shown in Fig. 4. The test was performed at room temperature, using a coaxial coupler and a pickup loop antenna connected to a Agilent N9000A CXA spectrum analyzer, using the tracking generator mode to measure the frequency response of the cavity. The test procedures are explained in this section and results are compared with the simulations in COMSOL.

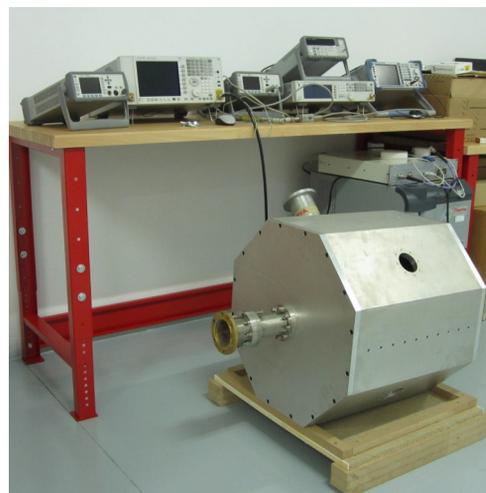


Figure 4: Aluminum RFQ section prototype.

### Measurements

The main objective of the test is to obtain the frequency modes of the cavity, which can confirm the accuracy of the design. First cavity input and output signal generated by the computer connects, that is the entrance to pick up and the output is connected to the coupler.

The empty cavity resonates at 485 MHz in good agreement with COMSOL simulations as it can be seen from the two spectra shown in Fig. 5. The resonator (without vanes) is fed by a coupler installed on one of the end caps while the pickup antenna reads the frequency spectrum for a lateral wall.

## CONCLUSIONS

The experimental results found are similar to those predicted by simulation, so it follows that the theoretical calculations were performed properly. Frequency measurements

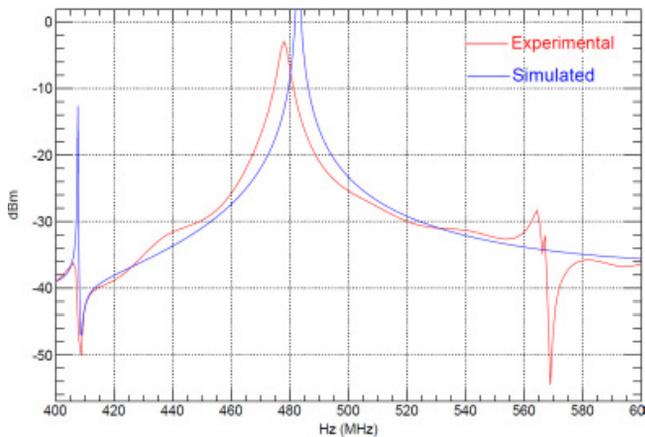


Figure 5: Experimental and simulated RFQ frequency mode.

will also carry out with the four vanes installed inside, followed by bed pull test bench. Future work will focus on improving the quality of the simulations and obtain better measurements of the whole RFQ.

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## REFERENCES

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- [3] Comsol website:  
<http://www.comsol.com>