Design of a 72.75 MHz RFQ for the ECOS-LINCE Project

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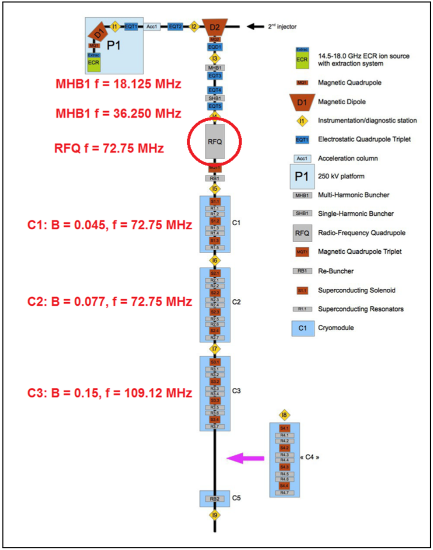
Outline

ECOS-LINCE: European LINAC CENTER

- Energy: protons (45 MeV/u) up to Uranium (8.5 MeV/u)
- High intensity beam: 1mA for light ions and 10 pμA for heavy ions
- Current stability $< 1\%$
- Beam loss $< 1 nA/m$
- Transverse emittance (rms) $< 1\pi \cdot mm \cdot mrad$
- Longitudinal emittance (rms) $< 4ns \cdot keV/u$
- Bunch length $< 1ns$



RFQ Structure

- RFQ is a small linear accelerator.
- Focuses, Bunches and accelerates.
- Modulation: Minimum distance from the axis (a), modulation factor (m), Average radius (R_0) and Length cell (L_C).

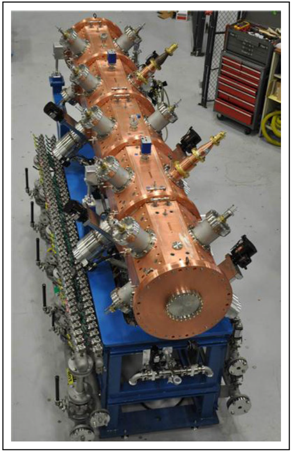


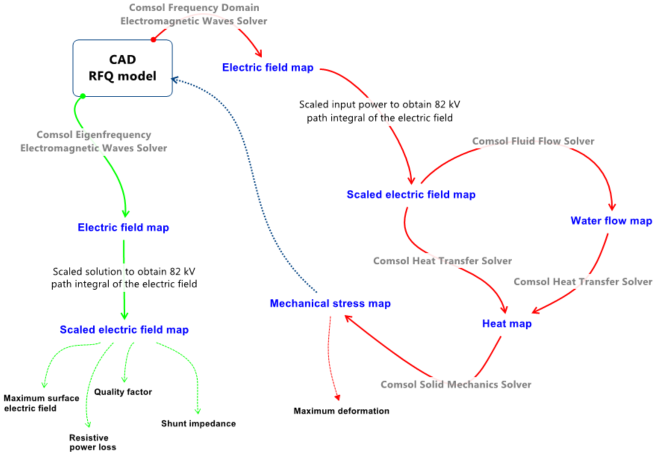
Figure: Atlas RFQ

Objective

Parameter	Value	Units
Frequency	72.75	MHz
Average radius	6.0	mm
Input kinetic energy	40	keV/u
Output kinetic energy	500	keV/u
Inter-vane voltage	82	kV
Design mass-to-charge ratio	1 / 7	

The aim of the RFQ design is the structure development with a high quality factor as well efficiency in acceleration, bunching and focusing process.

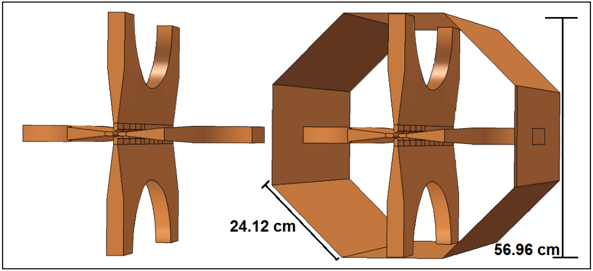
Materials and Methods



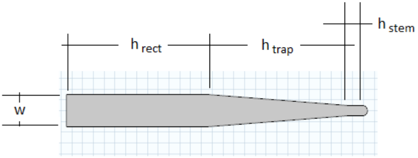
- DESRFQ, TRACK, COMSOL Multiphysics, Solid works, Inventor

Starting point for the cavity design

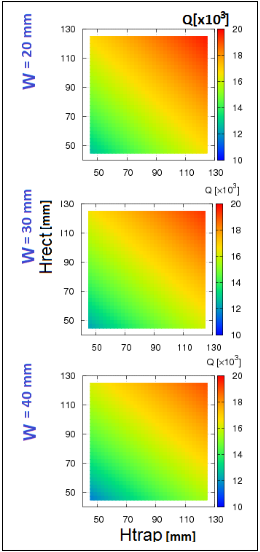
- Atlas RFQ at Argonne National Laboratory.
- Size rescaling according with the fundamental frequency.
- Structure with 2 brazing steps.
- Mechanical tolerances $\pm 20\mu$ (Cavity), $\pm 10\mu$ (Vane tip).
- Modular Design: 0.5 m long section, 4 ports for tuners, power and couplers.



2D Optimization

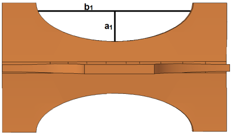


Parameter	mm
R_0	6
R_1	4.8
h_{stem}	14
$H_{trap,rect}$	45-130
W	20/30/40

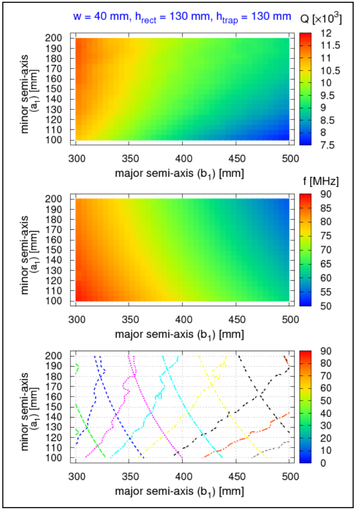


3D Optimization

- Advantages
- Reduce diameter and length, separation of frequency mode, low density RF current on the vane surface, improves the longitudinal flatness of the voltage distribution.



- $a_2 = 170mm$, $b_2 = 350mm$



RF Parameters

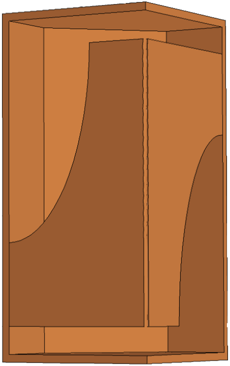
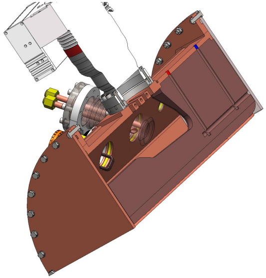
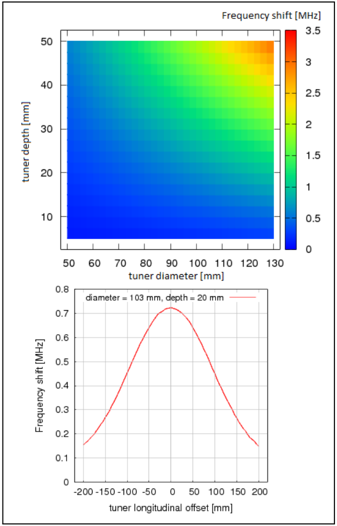


Figure: A quarter RFQ section

Parameter	Value	Units
r_s	390.43	$k\Omega - m$
f_{RF}	71.62	MHz
f_{212}	77.40	MHz
P_{loss}	92.354	kW
W_t	2.0478	J
Q	9977.8	

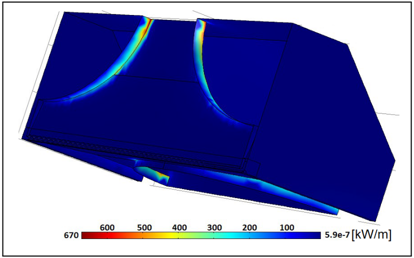
Tuners

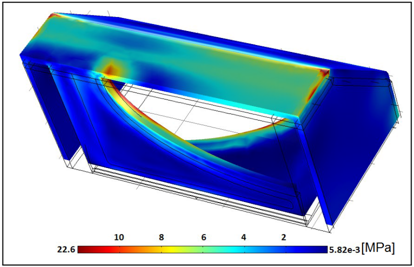


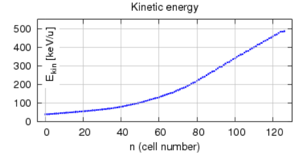


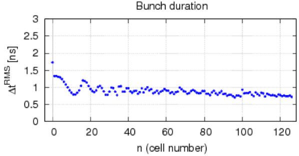
- Diameter, depth and position optimization.
- $D = 103mm$
- $d = 25mm$
- Central position

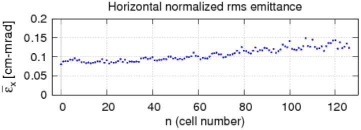
- This study is coupled with a non-isothermal pipe flow simulation in a quarter symmetry model (section) of the RFQ.
- The maximum values of the mechanical stress are in the corners ends and in the the elliptical windows with a maximum value of $22.6 MPa$.

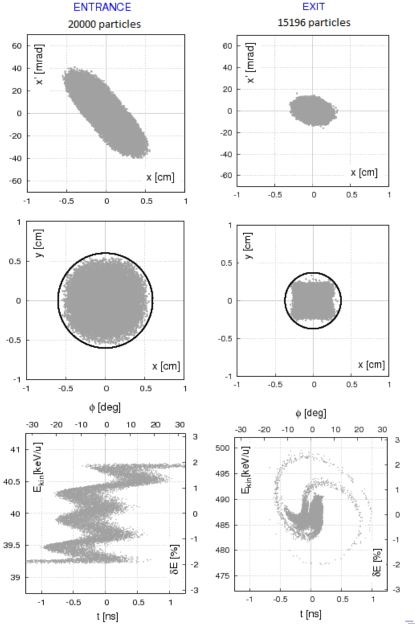





Kinetic energy
E_{kin} [keV/u]
n (cell number)

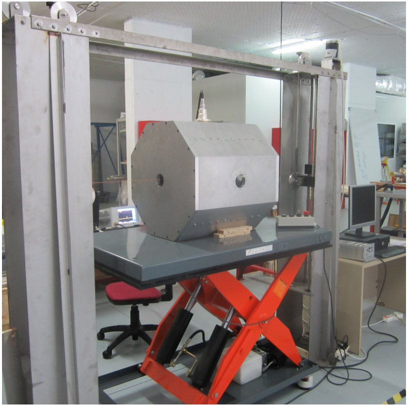

Bunch duration
Δt^{RMS} [ns]
n (cell number)


Horizontal normalized rms emittance
$\bar{\varepsilon}_x$ [cm-mrad]
n (cell number)


ENTRANCE
20000 particles
EXIT
15196 particles
x' [mrad]
x [cm]
y [cm]
ϕ [deg]
E_{kin}[keV/u]
δE [%]
t [ns]

Aluminium model

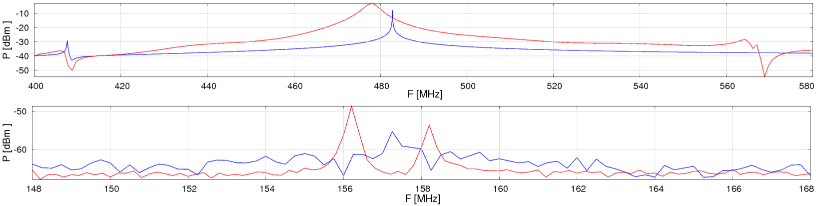
- Development and RFQ construction partially supported by the Spanish Government (MINECO-CDTI) under program FEDER INTERCONECTA.
- A RFQ section of Aluminium.
- A RFQ section of Copper - Step brazing in Laboratori Nazionali di Legnaro (LNL).



RF Laboratory at the University of Huelva

Measurements vs simulations

- The tests were performed at room temperature.
- COMSOL predicts a resonance value at 485 MHz and 157 MHz for the cavity with no vanes and with vanes, respectively.
- The simulated frequencies (blue line) are close to the experimental values (red line).



Summary

The design work carried so far jointly by University of Huelva result in a one-section RFQ prototype. This will enable calibration of the RF lab instrumentation and further improvement of the RFQ research and manufacture process.

The experimental results found are similar to those predicted by simulation, so it follows that the theoretical calculations were performed properly. Bead pull test bench will also carry out with the four vanes installed inside. Future work will focus on improving the quality of the simulations and obtain better measurements of the whole RFQ.

Summary

Beam dynamics results are to be improved using realistic field maps obtained through RF simulations. This will include suitable input matcher and trapezoidal cells at the RFQ end, finished with an output matcher.

We are still working for checking the accuracy of Beam Dynamics, RF and heat transfer simulations and to verify the behavior of the longitudinal emittance.

Thank you for your attention