# THE NEW LNL INJECTOR PIAVE, BASED ON A SUPERCONDUCTING RFQ

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*Abstract*

The new positive ion injector PIAVE for the ALPI Complex upgrading is under construction. The aim of the injector is to accelerate ions with masses up to 238 and mass over charge ratio up to 8.5 from 0.04 to 1 MeV/u. The chosen structures are two superconducting RFQ's operating at 80 MHz, followed by 8 QWR's at the same frequency. The paper will discuss the main design choices and technological challenges. At present many components have already been built and the first generation prototypes of the cavities are under test.

## 1 INTRODUCTION

At LNL a new positive ion injector for the super conducting linac ALPI is under construction [1][2]. The new linac, named PIAVE, will have an equivalent voltage of about 8 MV and will allow for ALPI the acceleration of ions up to U above the nucleus-nucleus barrier.

In this paper, after a general overview of the parameters of PIAVE (Tab. I), we report on the status of the project, started in June 1996 as an INFN "progetto speciale".

Table 1 *PIAVE main parameters*

| | | | | |
|---|---|---|---|---|
| **Source and LEBT** | | | | |
| Ion source | ECR | 14 GHz | | |
| Mass to charge ratio | 8.5÷2 | | | |
| Platform voltage* | 315 | kV | | |
| Energy | 37.1 | keV/u | ($\beta$=.0089) | |
| Beam emittance | 0.5 | mm mrad | (norm.) | |
| Bunching system | 3H | 40÷80÷120 | MHz | |
| **RFQ Accelerator** | | | | |
| Radio Frequency | 80 | MHz | | |
| Input Energy | 37.1 | keV/u | ($\beta$=.0089) | |
| Output Energy | 586 | keV/u | ($\beta$=.0355) | |
| Max. Sur. E field* | 25 | MV/m | | |
| Max. stored energy* | <4 | J/RFQ | | |
| | SRFQ1 | SRFQ2 | | |
| Vanes length | 137.8 | 74.61 | cm | |
| Voltage * | 148 | 280 | kV | |
| Tank diameter (approx.) | 65 | 65 | cm | |
| Max. surface B field* | 280 | 295 | G | |
| Shunt impedance $R_{sh}$/Q | 3.2 | 3.2 | KΩ/m | |
| Estimated Q | 7e8 | 9e8 | | |
| Power dissipation (4K)* | <7 | <7 | W | |
| **QWR Section** | | | | |
| Number of resonators | 8 | | | |
| Output energy* | 1.2 | MeV/u | ($\beta$=.051) | |
| Radio Frequency | 80 | MHz | | |
| Optimum $\beta$ | 0.047 | | | |
| Accelerating Field | 3÷5 | MV/m | | |
| Shunt impedance $R_{sh}$/Q | 3.2 | kΩ/m | | |
| Quality factor Q | $10^9$ | | | |
| Power per cavity (4K) | <7 | W | | |
| **Matching Line to ALPI** | | | | |
| Number of bunchers | | 2 (room temperature) | | |
| Buncher Eff. Voltage | VT | <200 | kV | |

* The values are referred to a mass to charge ratio 8.5, ($^{+28}U^{238}$).

## 2 THE RFQ DEVELOPEMENT

The superconducting RFQ's are being built in full Nb (3 mm thick everywhere besides the thicker modulated vanes) electron-beam welded. A first stainless steel model of SRFQ2 has been built to check the critical production steps before using the costly final material. The results of this test, including mechanical and RF measurements, are presented in ref. [3].

The consequent construction of the Nb version of SRFQ2 has started; at present the four electrodes have been assembled and welded to the supports, and are ready to be modulated (Fig. 1). The end of the construction is foreseen for the end of the year and the rf tests in the cryostat for the first part of next year.

A test cyostat, with the 80 K screen and the liquid helium reservoir made in titanium, will be used for the 4 K test on the Nb SRFQ2 and for some preliminary cooling test (70 K) on the SS model. The tests are foreseen for the fall 1998.

At the same time SRFQ1 has been defined; the geometry chosen is with four supports for each electrode; as a consequence, since SRFQ1 is roughly twice as long as SRFQ2, the RFQ cross section can be done almost in the identical way. The construction will be done with two separate RFQ halves, very similar to SRFQ2, so that the stainless steel prototyping experience and even some welding jigs will be reused. These two halves will be eventually connected at the end by welding the two external tanks. The consequences of this construction on the field distributions have been studied with MAFIA simulations and with the construction of a half scale aluminum model of SRFQ1. Most of the measurements on the model are now concluded and have demonstrated the feasibility of this solution.

*Figure 1*.Bulk Nb electrodes of SRFQ2 after EB welding, ready to be modulated.

## 3 THE QWR RESULTS

A prototype of the QWR bulk Nb cavities of PIAVE has been built and successfully tested [4]. This cavity is a modification of the low β cavities used in ALPI [5], with a new geometry in the beam port region so to decrease $\beta_{opt}$ from 0.055 to 0.047. The measured performances of the cavity are plotted in Fig. 2 in the usual accelerating field vs. quality factor graph. The accelerating field is applied to an effective length of 0.18m.

The performances of this cavity are so good that an enhancement of the nominal field up to 5 MV/m can be conceived. These results are in good agreement with those obtained by the similar $\beta_{opt}$=0.055 resonators [6].

Beam simulations show that for many beams it is indeed possible to use this additional acceleration.

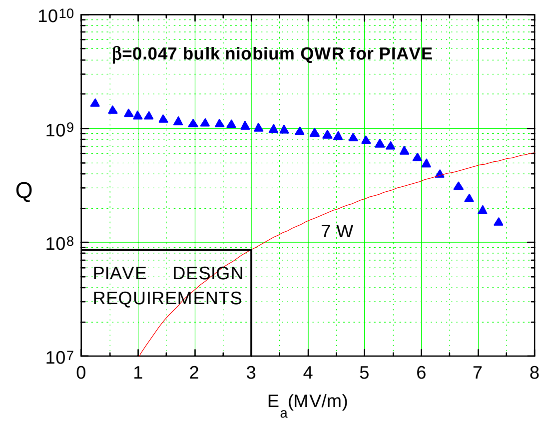


*Figure 2* Performances of the first PIAVE QWR.

## 4 THE BEAM TRANSFER LINES

Two beam transport lines are foreseen by the PIAVE project: the LEBT between the ECR source and the RFQ, and the MEBT between the superconducting RFQ cryostat and ALPI.

In the first line the particles, are bunched and matched transversally to the RFQ acceptance. In the second line they are accelerated by the 8 quarter wave resonators and matched to ALPI.

The final simulations of the complex where presented in ref [7]. All the main elements of the two lines are designed and many of them have been built during last year.

The magnets, two $45^0$ dipoles, two small $90^0$ dipoles, and quadrupoles assembled in 4 triplets, 6 doublets and 2 singlets, have been delivered in the second week of 1998, together with their power supplies. An achromatic almost vertical line ($18^0$ inclination) guarantees the beam transfer between the accelerating column axes and the RFQ axes, with two dipoles, two triplets and a singlet. The whole line is mounted on a common girder and arrived prealllined from the company (Fig.3); the beam is therefore reduced to a small spot in the buncher by means of two doublets, and matched to a smaller spot at the RFQ input by means of two similar lenses. The quadrupoles of the LEBT are characterized by a large bore aperture (120 mm diameter) and short effective length. The main difficulties in these elements came from the fringe field non linearities control (multipole components below .8% in 85% of quadrupole aperture have been obtained with a mechanical correction after preliminary measurements). In the MEBT two compact and strong doublets (0.8 T on pole tips) are placed between the cryostats, while the remaining elements are almost identical to the ones already in ALPI. This focusing structure is the key point that allows the use of 5 MV/m in the QWR's.

For what the other components of the line are concerned, the main achievements of this year are the construction of the three harmonic buncher [8] and the purchase of the main vacuum component. The beam diagnostics of the line (7 Beam Profile Monitors, 4 Faraday cups) are in advanced construction. Moreover a beam emittance measurement box has been developed and built for the precise measurement of beam characteristics at the RFQ input plane during commissioning. The construction of the two lines has begun (Fig. 2), and our plans are to assemble the LEBT line within the end of the summer '98, so to be able to do calibrate the line and characterize the ECR emittance in various conditions before the installation of the RFQ.

*Figure 3* Achromatic U bend, aligned on a common girder, that will connect the ECR and the RFQ beam lines.

## 5 CONCLUSIONS

PIAVE, which started officially in July 1996 as a four years project, is progressing with the installation of the magnetic elements, the construction of the diagnostics, the acquisition of the vacuum system components as well as the construction of the accelerating and bunching rf structures both normal and superconducting.

A large effort has been put in the construction of the rf resonators and their prototypes. The results in the stainless steel prototype of the SRFQ resonator as well as the performance of the first of the QWR has been reported. The triple harmonic LEBT buncher has been constructed and is ready for the installation.

The test cryostat for the SRFQ resonators is expected to be ready by late summer 1998.

The cryogenic plant for PIAVE has to deliver ~350 W at 4.5 K and ~600 W at 80 K. The cooling power at 80 K will be provided by liquid nitrogen. An additional cryogenic refrigerator, with respect of the ALPI system for the liquid helium, has been considered.

The Injector is foreseen to be ready for the commissioning by beginning of 2000.

## REFERENCES


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