INTRODUCTION

PIAVE superconducting RFQ was dismounted for maintenance [1], after two years of operation as the new injector of the LNL superconducting heavy ion linac ALPI. This occurrence offered enough time for accelerator alignment improvement. PIAVE injection line into ALPI and PIAVE low energy beam transport line were realigned. After RFQ re-installation, reference phases of the two cavities were tuned during commissioning with $^{22}\text{Ne}^{4+}$ beam. Doublet in front of RFQ was realigned in November 2006. We obtained a very important increase in transmission after these operations.

L-BEND REALIGNMENT

Two years of beam transport confirmed a lot of losses in the bend line injecting PIAVE beam into ALPI linac. The maximum transmission through the bend obtained with accelerated $^{40}\text{Ar}^{9+}$ beam was only 45.1%. Bend line is constituted by two triplets (3PQ4 and 3Q1), two 45º dipole magnets (PD3 and PD4) and a singlet (1PQ2) for dispersion matching (see figure 1). Considering the absence of critical elements, the first hypothesized cause of losses was system misalignment. The alignment was therefore checked before summer stop. As foreseen, a strong misalignment was found between the linac plane and the injector plane. Although PD4 and 3Q1 were on ALPI plane, PD3, 3PQ4 and 1PQ2 were down by 2 mm, 0.5 mm and 1 mm respectively.

Considering that PIAVE injector was aligned using PD3 dipole as reference plane, the less invasive operation was shifting the whole L-bend on ALPI plane and adding two steerer magnets at the end of injector in order to lift the beam by 2 mm. These operations concluded in the late September 2006.

PHASE TUNING

The first $^{22}\text{Ne}^{4+}$ beam transported through RFQs was characterized with energy and phase measurements for phase tuning. A silicon detector positioned out of the beam line was used to measure the energy and phase distributions of a scattered beam produced by a thin foil of gold. The acquisition time for each spectrum was adjusted in order to acquire a constant counts number. Because of the short time available for cavities tuning, only few measurements were taken at different phase shifts. Three harmonic buncher were turned on during the measurements. For phase values allowing complete separatrix overlapping, energy distribution consists of a single peak with a small tail towards the low energy end. Completely wrong phases can be simply separated, because of the production of an additional peak centered at the first RFQ energy. The presence of this pick increases the rms energy deviation calculated in the energy distributions (see figure 2). In phase range of overlapping separatrix, comparison between mean energy calculated by simulations and that calculated on measured energy spectra (see figure 3) can provide the right phase.

![FIG. 2: Energy spread measured after the SRFQs as a function of the phase shift.](image-url)

From analysis it appears that higher phase shifts correspond to smaller energy spread, since below 192° a
second peak starts growing. Comparison between simulations and measurements is possible only above this value. Considering that simulations foreseen the right phase shift value is 12º far from the value providing the mean energy maximum (196º), the right value provided by this analysis should be 208º. However, the measured phase range is too narrow and it is not possible to define if the mean energy maximum is a relative or an absolute one.

It was then decided to realign the last LEBT doublet respect to the RFQ, checking with best beam transmission (see figure 2). For various positions of the last LEBT doublet, each point corresponds to the best transmission optimized respect to the values of many parameters, like steerers fields and three harmonic buncher phases. At the end of this process, operative transmission was recovered and overcame. Final transmission was very similar to 68% predicted by simulations.

RESULTS

Results obtained by alignment operation and RFQ tuning appear even more impressive if compared with that obtained before RFQ maintenance (see table 1). As concern the table, PM and DI are the faraday cups. PM1 is located after HV platform, PM5 at the entrance of RFQ, PM8 after injector acceleration and DI9 at the entrance of ALPI linac (see figure 5).

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LEBT transmission is comparable in the two cases, while RFQ and L-bend transmission increased both by a factor 2. In other words overall transmission of PIAVE injector raised by 12.5% to 56.8%.

2PQ4 DOUBLET REALIGNMENT

First beam commissioning after tuning showed a poor transmission through RFQ cavities. Measured transmission (38%) with three harmonic buncher switched on, was very similar to the value measured in January 2004 [2]. This value was far from the 60% of transmission routinely obtained in operation.