THE MATCHING LINE BETWEEN THE RFQ AND THE IH LINAC OF THE CERN LEAD ION FACILITY

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Abstract

The Medium Energy Beam Transport line (MEBT) of the CERN Lead Ion Facility, has been designed, constructed and commissioned by the Laboratori Nazionali di Legnaro (LNL) in collaboration with CERN. It performs a six dimensional matching of the 250 keV/u $^{208}Pb^{27+}$ beam from the Radio Frequency Quadrupole (RFQ) to the Interdigital-H structure (IH).

In this paper we review the main design characteristics of this line, and the results of the commissioning.

Introduction

The RFQ and the first IH tank of the Lead Linac operate at the same frequency (101.28 MHz) but have a different transverse focusing structure. The RFQ has a FODO structure with a period of $\beta\lambda$ while the IH has triplet focusing. Transversally the beam at the IH input plane is supposed to be convergent in both planes. As far as the longitudinal phase plane is concerned, the IH requires also a convergent beam with a small phase spread [1].

The Medium Energy Beam Transport line, which connects the above-mentioned structures, is composed of four quadrupoles and a 4-gap buncher operating at the frequency of 101.28 MHz. This set of elements guarantees the transverse as well as the longitudinal matching between the two accelerators.

The MEBT includes also a beam diagnostics system: a phase detector at the RFQ output, profile harps for the transverse planes monitoring and a Faraday cup for beam intensity measurements. Fig.1 shows the layout of the line.

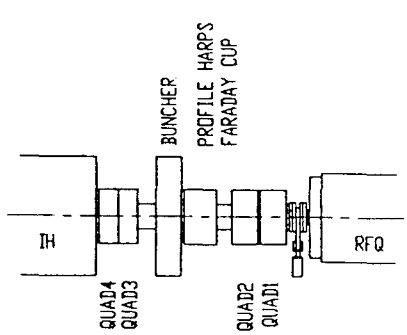

Figure 1: MEBT Layout

Beam Dynamics

The MEBT has been designed to transport without losses and match a 250 keV/u $^{208}Pb^{27+}$ beam from the RFQ to the IH accelerator. During the design phase, beam computations were carried out with the program TRACE [2] assuming the nominal conditions at the RFQ output plane. Six parameters have beam varied to achieve the matching: the position and the voltage of the buncher for the longitudinal plane, and the four quadrupole gradients for the transverse ones. There was an additional constraint: the distance RFQ-buncher was limited to avoid the longitudinal emittance growth due to the RF non-linearity in the buncher. An optimisation of the longitudinal dynamics set the length of the line to 1.6 m and determined the position of the buncher so as to have a maximum phase extension of $\pm$44deg in the buncher gaps. Once the length of the line was determined, the theoretical values of the quadrupoles for the transverse matching were found as well. The transverse acceptance of the line is 1.π mm mrad. The main beam parameters are summarised in Table 1.

TABLE 1
MEBT design beam parameters

	Input	Output	
α_x	-1.50	1.70	
β_x	0.20	0.96	mm/mrad
α_y	1.53	0.51	
β_y	0.21	0.55	mm/mrad
$\epsilon_{x,y}$	20	20	π mm mrad
α_l	0.0	-1.0	
β_l	0.02	0.02	deg/keV
ϵ_l	8500	8500	deg keV

The theoretical beam envelopes along the MEBT, calculated with TRACE [2], are shown in fig.2.

Buncher Design and Commissioning

The MEBT buncher has been designed and constructed by LNL. It is a four-gap quarter wave resonator (see fig. 3), made of copper plated stainless steel.

This resonator design has been chosen for its high shunt impedance which allows to produce the required 100 kV effective voltage, whilst keeping the power well below the 2.5 kW that the amplifier can deliver. Besides, the space available for the buncher was limited to 18 cm flange to flange. Tuning is made via two capacitive tuners, one fixed and the other movable, facing the inner conductor. A cooling system for the inner conductor and the upper cover has been foreseen to leave open the option of oper-

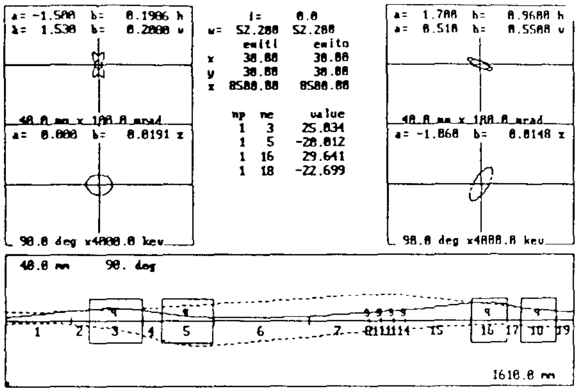

Figure 2: Beam envelopes in the MEBT

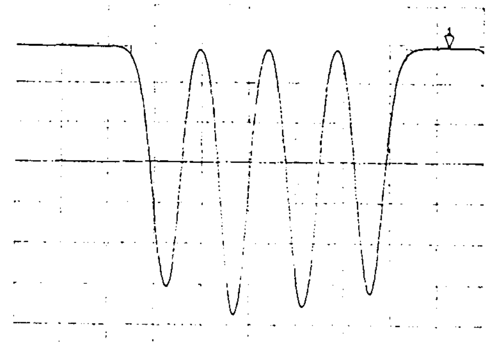

Figure 4: E^2 profile measured along the buncher axis

ating the cavity at a duty cycle higher than the nominal 0.4%. RF power is fed to the input loop through a 1"5/8 EIA coaxial connector, to allow future operation at higher voltage levels. Table 2 summarises some measured RF parameters of the buncher.

TABLE 2

Buncher RF Parameters

Resonant Frequency	101.28	MHz
Tuning range	125	kHz
Q	5450	
TTF	0.775	
R_{sh}	8.25	MΩ

The electric field shape on the beam axis has been checked with a bead-pull measurement, and the result is reported in fig. 4.

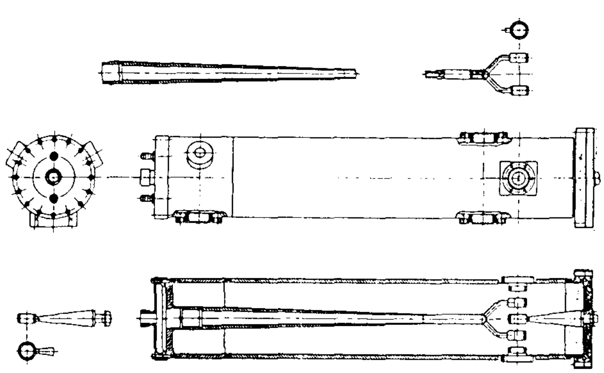

Figure 3: MEBT Buncher technical drawings

During the high power RF tests, the buncher showed a high multipactoring rate typical of this kind of cavities. After conditioning of the cavity at low power and high repetition rate for about one week, multipactoring disappeared almost completely. Nevertheless, during beam tests the multipactoring rate increased drastically and the number of pulses lost became as high as 30%. This multipactoring was triggered by the few nA of ion beam that the ECR source produces before the afterglow pulse and that pass through the RFQ before the start of the RF pulse. This beam arrives at the buncher completely defocused and hits the cavity wall producing secondary electrons which then start the multipactoring process. To stabilise the buncher, a modulation of the source extraction voltage has been implemented, in order to reduce it before the afterglow, thus loosing the unwanted beam in the LEBT spectrometer [3] . This allowed to reduce the number of pulses lost due to buncher multipactoring to less than 1%. Some improvements to the cavity are foreseen in the future, in order to reduce its sensitivity to multipactoring.

Beam Commissioning

For the beam commissioning, a temporary measurement line consisting of a single slit emittance measurement device and a bunch length and velocity detector (BLVD) [4] [5] was installed at the end of the MEBT.

During the two weeks of commissioning, the objectives were mainly to find out the beam parameters at the RFQ output, to calibrate the quadrupoles, to match the beam to the IH structure and to get a feeling for the sensitivity of the matching to the upstream parameters, like the LEBT settings [6] and the RFQ RF level.

The first set of emittance measurements was taken with the buncher switched off, in order to separate the transverse and longitudinal dynamics. Backtracing these measurements with TRACE allowed us to find the transverse conditions of the beam at the RFQ output plane and to have a rough calibration of the magnetic elements of the line. Good agreement was found between the expected and the measured values.

Once the beam parameters at the output of the RFQ were found, a finer calibration of the first two MEBT quadrupoles was achieved with the help of the profile harps. The method consisted in comparing the theoretical size of the beam with the width measured on the profile harps for different settings of the quadrupoles. The results are reported in four plots, see fig. 5. By imposing that the theoretical and measured values overlap, the calibration factor of the quadrupoles and the emittances (in the two planes) of the beam could be found. This technique gave emittance values consistent with the ones measured at the emittance device. The second set of quadrupoles

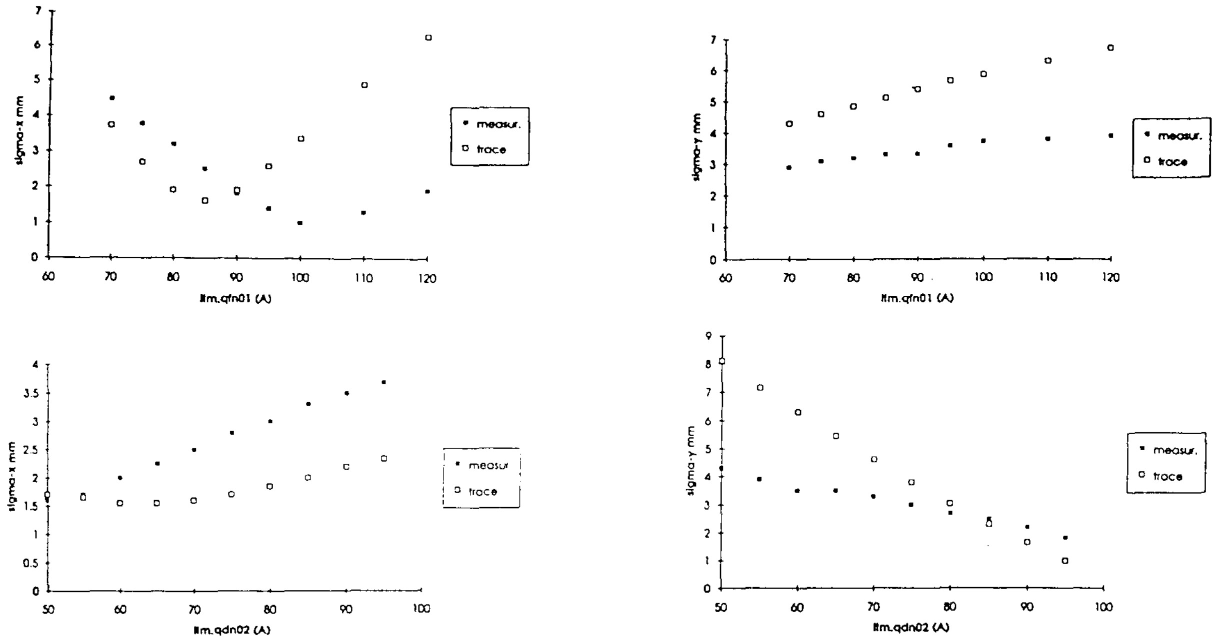

Figure 5: Comparison between calculated and measured beam size (2 sigma) at MSF04

was calibrated against the emittance device.

The values of the quadrupoles that would bring the transverse emittance in the IH acceptance were then theoretically found and set on the machine. After some empirical optimisations the matched transverse emittance, shown in fig. 6, was obtained. The matching to the IH is not sensitive to changes of RF level in the RFQ and to variations of the source extraction voltage of the order of 10%.

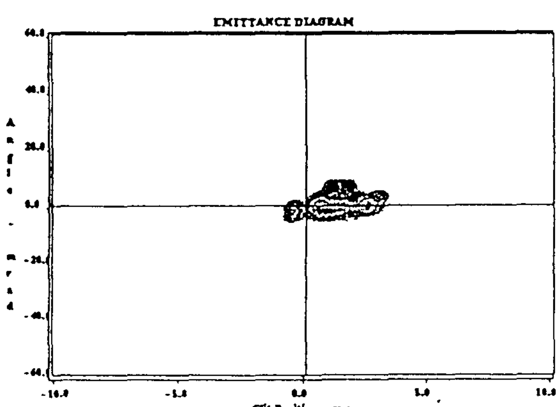

Figure 6: Measured transverse emittance

Longitudinal matching was achieved with the theoretical setting of the buncher [7]

Conclusions

The MEBT of the CERN Lead Ion Linac Project has been successfully commissioned. It performs the matching of the beam between the RFQ and the IH structure as expected. The line is operational since April 94.

Acknowledgements

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