ISBN: 978-3-95450-215-8 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2022-TUPORI17

EMITTANCE MEASUREMENT FROM THE PROTON TESTBEAM AT KAHVELab

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Abstract

A test beam using a Radio Frequency Quadrupole (RFQ) operating at 800 MHz, to accelerate a 1.5mA proton beam to 2 MeV energy has been designed, manufactured and is currently being commissioned at KAHVELab, Istanbul. The beam from the microwave discharge ion source (IS) must be matched to the RFQ via an optimized Low Energy Beam Transport (LEBT) line. The LEBT line consists of two solenoid magnets, two stereer magnets and a beam diagnostics station named MBOX. All the beamline compo- nents are locally designed, simulated manufactured and tested with local resources. The MBOX should be able to measure the beam current and profile, as well as the beam emittance, to ensure an accurate match between IS and RFQ. It includes a number of diagnostic tools: a Faraday Cup, a scintillator screen, and a pepper pot plate (PP). An analysis software is developed and tested for the PP photo analysis. This contribution will present the proton beam- line components and will focus on the MBOX measurements, especially on the PP emittance analysis.

This study is supported by Istanbul University Scientific Research Commission Project ID 33250 and TUBITAK Project no: 119M774.

INTRODUCTION

The proton beamline at KAHVELab consists of an ion source, a low energy beam transport (LEBT) section and a radio frequency quadrupole (RFQ). A simplified schema of the proton beamline can be seen in Fig. 1 [1].

The ion source consists of 3 sections: a transmission line to transfer 2.45 GHz microwaves from magnetron to the plasma chamber, a plasma chamber where ions are produced and an extraction system which transfers ions from plasma chamber to the beam line for a current of about 1.5 mA.

In this 140 cm LEBT line, there are two water-cooled solenoid magnets with the same physical dimensions and designs, different number of turns, two identical steerer magnets and a measurement box (MBOX). The sensors in the MBOX are moved into and out of the beam line by means of pneumatic motors. The solenoids are used to focus the beam to fit into the RFQ acceptance, and steerers are used

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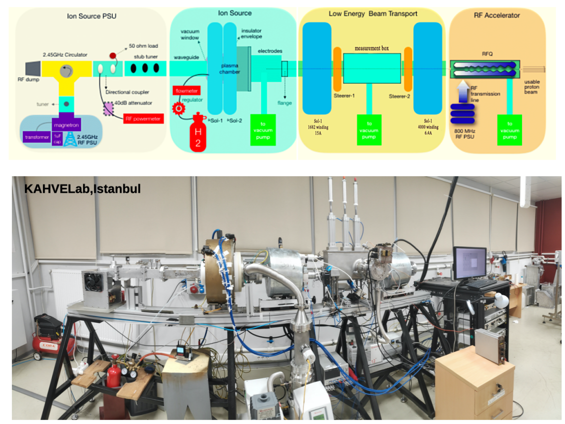

Figure 1: The schematic (Top) and the picture (Bottom) for the Proton test beam line at KAHVELab.

to direct the beam into the reference line of the RFQ. Simulation studies were carried out with DemirciPRO [2] and in-house software in Python3 [3] to optimize the solenoid positions and fields.

The MBOX vacuum chamber is designed and manufactured to keep the vacuum volume as small as possible, with a wall thickness of 5 mm and a polygonal geometry of 369 × 130 × 215 mm from stainless steel alloy material. The MBOX upper cover houses the pneumatic controls. One can see the design of the system in Fig. 2. MBOX is used to measure the beam profile, beam spread, and the beam current. The Pepper Pot method is used for emittance measurement as it allows measuring beam emittance, both the X and Y components at once, simultaneously [4].

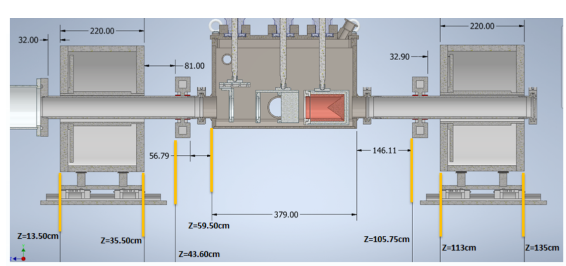

Figure 2: LEBT line components and their positions.

The simulated data taken at the exit location of the ion source was generated via IBSIMU program.Simulated with

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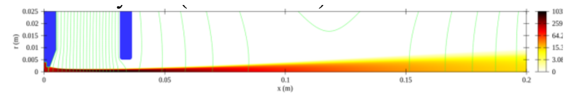

Figure 3: Simulation of ions withdrawn from plasma using a two-electrode system (with IBSIMU).

a two-electrode system you can see Fig. 3 [5]. The beam profiles and phase space of the data were demonstrated as in Fig. 4) and the normalized emittance with Twiss parameters are given in Table 1.

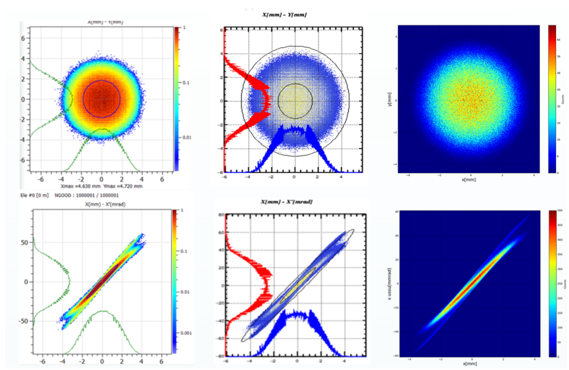

Figure 4: Beam profile and phase space simulation graphics at the entrance to the LEBT line [6].

Table 1: Emittance and Twiss Parameter Values

	PlotWin	DemirciPro	Python
ε_n (π mm.mrad)	0.0299	0.0297	0.0298
α	-6.41	-6.41	-6.41
β (mm /π.mrad)	0.47	0.47	0.47

PEPPERPOT EMITTANCE MEASUREMENT

The main components of the Pepper Pot are the pinhole mask, a phosphorus screen, a plane mirror, and a camera attached to the glass window. The pinhole mask is made of a 250 um thick stainless-steel by UFOLab at Bilkent Univ. Pinholes with a diameter of 100 um are spaced 2 mm horizontally and vertically and cover an area of 50×50 mm.

To prevent thermal deformation of the pinhole mask, it is sandwiched between two frames of 500 um thick aluminium. The phosphor screen was made in the laboratory on 300 um thick glass with 60×60 mm dimensions using fluorescent powder. The mirror was mounted at the behind of the phosphor screen with a 45° angle. The image reflected from the mirror through the glass window was taken by the camera [7].

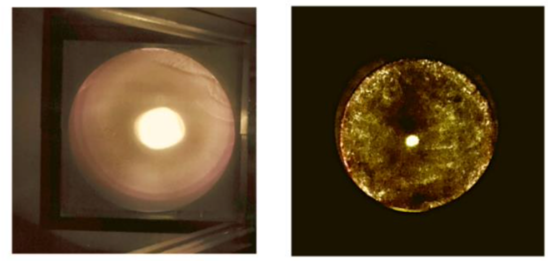

Figure 5: Beam spot in diagnostics station (left) and after Sol-2 (right).

PROFILE & EMITTANCE MEASUREMENT

The real images of the beam spots as shown in Fig. 5 were taken from the inside of the MBOX and the exit of the LEBT line, respectively. The diameter of the beam spot was calculated with the method of finding the FWHM and the results are shown in Fig. 6. The simulation and measurement results are given in Table 2.

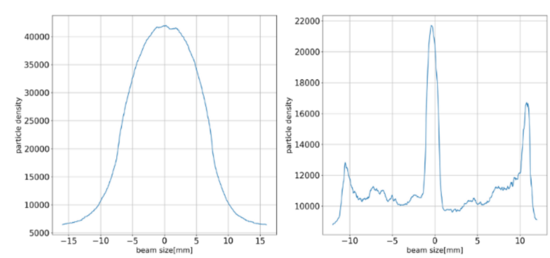

Figure 6: The analysed graphs for the real beam spot.

Table 2: Comparison of the Simulated Data Emittance and Twiss Parameter Values

	Simulation	Measurement
ε_n (π mm.mrad)	0.031	0.0297
α	-4.5	-18.9
β (mm /π.mrad)	1.33	2.13
BeamSizembox	14.8 mm	15 mm
BeamSize after sol-2	2 mm	2 mm

IMAGE PROCESSING FOR EMITTANCE MEASUREMENTS

An image processing analysing program was developed in-house. The process for a pepper pot measurement was done in 3 stages (as shown in Table 3). The first stage was to take two density profiles in x and y-directions from the image as shown in Fig. 7. As the center locations of holes on the plate were mechanically fixed, the mean positions of the peaks at the profiles were assumed as the gaps' centers on the plate. The following step was to reconstruct transversal phase spaces and to calculate emittance and Twiss parameters with the help of these position information. The last

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stage was the comparison of the computed essential parameters from the image and simulated data, as seen in Fig. 8.

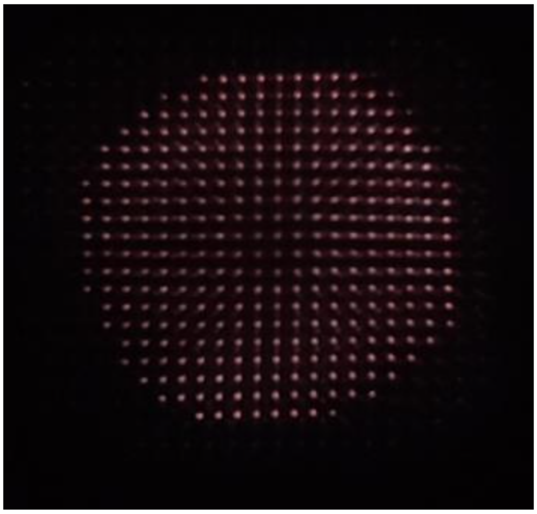

Figure 7: Beam image after the pepperpot plate.

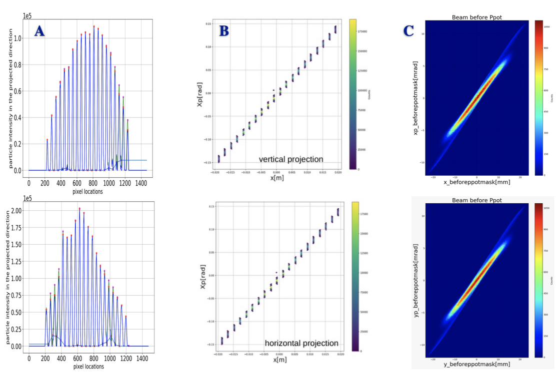

Figure 8: Image processing for the pepper pot measurement. The column with label A is the plots of density profiles in X and Y directions. The mid column with label B shows the re-constructed phase spaces in transverse directions. The graphs at the right, label C, are the simulated transversal phase spaces.

Table 3: Comparison of Simulation and Image Analysis

	Simulation X - Y		Measurement X - Y	
ε_n (π mm.mrad)	0.029	- 0.033	0.029	0.030
α	-18.9	-13.54	-6.38	-6.37
β (mm /π.mrad)	2.13	1.83	1.34	1.33

CHARGE MEASUREMENT

The outer cover of the Faraday container used for beam current measurement is made of Teflon material to provide insulation, and the inner part is made of copper. An oscilloscope is used for signal monitoring, and a voltage divider

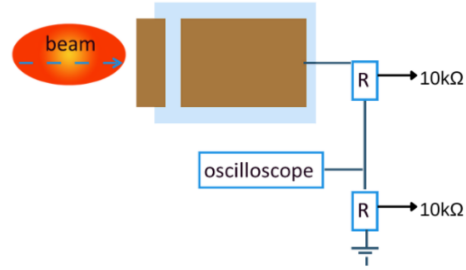

Figure 9: The schematic of the charge measurement.

circuit is used to protect the oscilloscope device while measuring (Fig. 9). Figure 10 shows that each pulse width is 8 ms and the pulse duration is 20 ms in the image taken from the oscilloscope. Therefore, the duty factor can be calculated as d.f. = 8/20 = 0.4. Similarly, the instantaneous current was 0.03 mA and the average current was 0.012 mA.

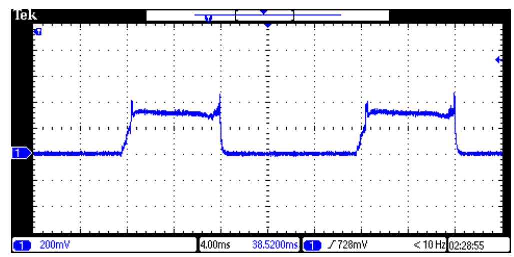

Figure 10: FC signals on the oscilloscope screen

RESULT AND OUTLOOK

Simulations and measurements were performed for the 20 keV proton beam. The beam profile and charge measurements from the LEBT line are consistent with their simulations. The Pepper Pot emittance calculation software results were compatible with DemirciPRO predictions. The beam profile measurements were taken with the handmade phosphor screens. LEBT line measurements showed that the beam could match the RFQ [8] with the specified configurations. The RFQ [9] is being manufactured for beam tests in late 2023.

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