COMMISIONING OF BEAM POSITION AND PHASE MONITORS FOR LIPAc *

I. Podadera †, A. Guirao, D. Jiménez, L. M. Martinez, J. Molla,
A. Soleto, R. Varela, CIEMAT, Madrid, Spain

Abstract

The LIPAc accelerator is a 9 MeV, 125 mA CW deuteron accelerator [1] which aims to validate the technology that will be used in the future IFMIF accelerator. Several types of Beam Position Monitors –BPM's- are placed in each section of the accelerator to ensure a good beam transport and minimize beam losses. LIPAc is presently under installation and commissioning of the second acceleration stage at 5 MeV [2]. In this stage two types of BPM's are used: four striplines to control the position at the Medium Energy Beam Transport line (MEBT), and three striplines to precisely measure the mean beam energy at the Diagnostics Plate. The seven pickups have been installed and assembled in the beamlines after characterization in a wire test bench, and are presently being commissioned in the facility. In addition, the in-house acquisition system has been fully developed at CIEMAT. In this contribution, the results of the beam position monitors characterization, the tests carried out during the assembly and the status of the electronics system are reported.

PICKUP MANUFACTURING

MBPM

Four striplines are installed along the MEBT (Fig. 1) to track the beam from the RFQ to the MEBT. The BPM's chambers are installed in the middle of the combined magnets (quadrupole and two steerers) as seen in Fig 1. This makes the design, installation and assembly quite challenging, due to the very tight space available. In addition, all the materials should be non-magnetic to avoid any perturbance in the quality of the magnetic field.Three vacuum chambers were manufactured: two containing one BPM each, and a longer one containing two BPM's located in consecutive magnets. Compact welded bellows are inserted, shielded inside to protect them to the spray particles of a high CW current hadron accelerator, and welded to rotating flanges. Due to the compact design the fabrication (realized by Vacuum Projects in Spain) was quite complicated. The feedthroughs were very prone to crack due to overheating during TIG welding, although the feedthrough manufacturer supported this technique. After many attempts and empirical studies, laser welding had to be used for the first welding whereas the welding of other pieces in the chamber was kept by TIG. Once each BPM body was fabricated, it was welded to the rest of the vacuum chamber. This was also a challenging process, especially in the last chamber with two BPM's, since the tolerances were quite small. During all the manufacturing process, the machined pieces were metrology controlled, taking especial care to the BPM assembly and the coordinates of the fiducial points with respect to the reference frame. Finally, the chambers underwent an ultrasonic cleaning and a vacuum leak test to verify the tightness for a proper operation in LIPAC.

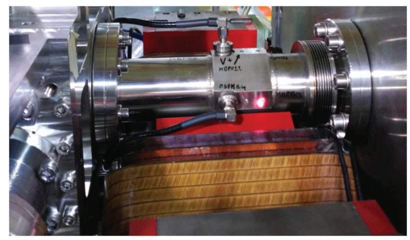

Figure 1: Picture of MBP02 mounted in the MEBT between the poles of the second MEBT magnet.

DBPM

The three units of the Diagnostics Plate BPM (DBPM) have been manufactured and tested (Fig. 2), based in the design presented in [3]. All the units have been manufactured in the CIEMAT workshops. As in the case for the MBPM, metrology was watched along all the procedures. Prior to and after the final welding assembly the unit was measured usign a 3D coordinate machine. Once the assembly was finished several acceptance tests were done. The first one was the test of the vacuum leak of the device. A leak below 10^{-12} mbar·l/s was detected, which is far beyond the requirements for the LIPAc.

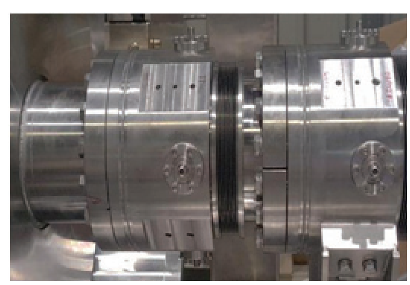

Figure 2: Picture of two of the DBPM's mounted in the Diagnostics Plate.

RF CHARACTERIZATION

A series of electromagnetic tests were performed to validate each pickup prior to the installation in the beamline. The two main tests that are done to characterize the pickup are: the coupling between the channels in the frequency range of

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† ivan.podadera@ciemat.es

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interest, and the time domain reflectometry response of each electrode. Both are compared with the simulation and the other pickups. Figures 3, 4, 5 and 6 show respectively the comparison between the measured coupling values between adjacent and opposite electrodes of the DBPM's and the simulated ones. At the regions of interest, around 175 MHz and 350 MHz, the discrepancy between the measured and simulated values is less than 2 dB. It should be noticed than the dispersion is lower for DBPM's, where the coupling is higher.

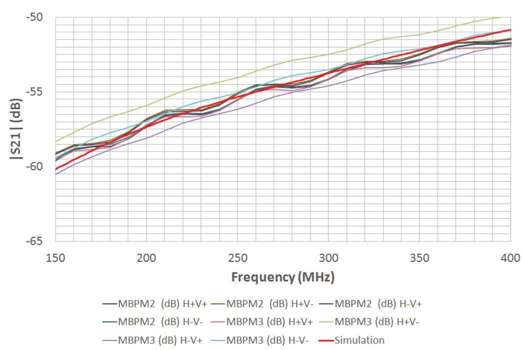

Figure 3: Comparison of the measured adjacent electrode coupling of the MBPM's with the simulation.

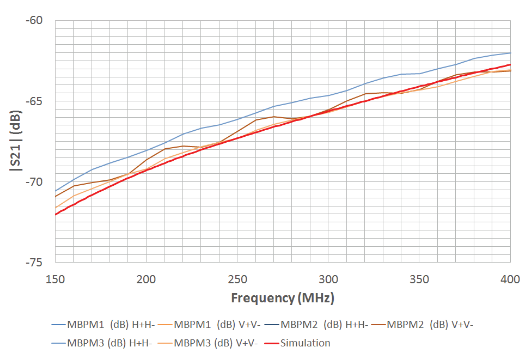

Figure 4: Comparison of the measured opposite electrode coupling of the MBPM's with the simulation.

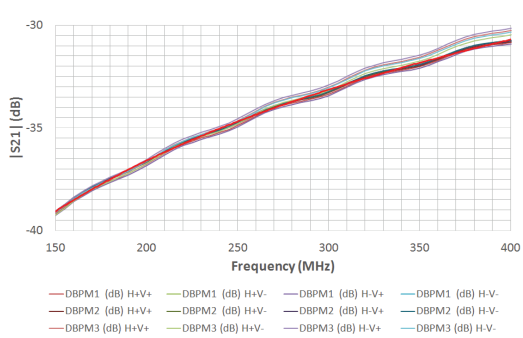

Figure 5: Comparison of the measured adjacent electrode coupling of the DBPM's with the simulation.

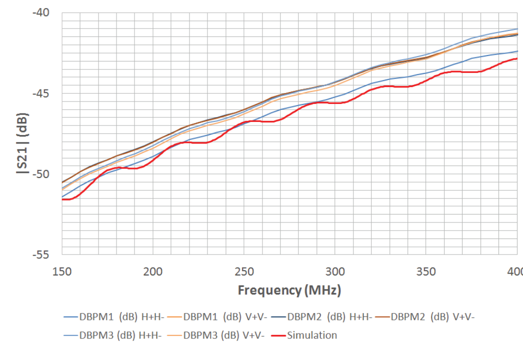

Figure 6: Comparison of the measured opposite electrode coupling of the DBPM's with the simulation.

Wire Test Bench

Prior to installation in the beamline, a mapping of the signals of each pickup was performed in the wire test bench constructed at CIEMAT laboratory (Fig. 7) [4]. The sensitivity, linearity and offset of the electrical signal with respect to the mechanical one are the main parameters to be analyzed. As discussed in previous works, for low-beta beams the parameters obtained in the test bench cannot be directly used in the accelerator. BPM sensitivity is energy and frequency dependent. To obtain the parameters to be used in the accelerator the mapping obtained in the test bench should be fit with the analytical function. Then, once the right values of beam radius b and electrode angle ϕ are obtained, it is possible to use them to get the sensitivity value at the right energy and frequency. For LIPAC BPM's, the interest is to get the inversed sensitivity at 5 and 9 MeV for 175 and 350 MHz. The inversed sensitivity can be defined in different ways. In this work,the inversed sensitivity k_x is defined as:

$$k_x = \frac{\Delta_x}{\Sigma} \tag{1}$$

where $\Delta_x = I_R - I_L$ and $\Sigma = I_R + I_L$, and I_R and I_L are the currents induced in the right and left electrode respectively.

Table 1: Summary of the MBPM and DBPM Wire Measurements.

	Wire meas.		Analytical
BPM Id.	k_x (mm)	k_y (mm)	k_1 (mm)
MBP01	13.54	13.46	12.58
MBP02	13.66	13.81	12.58
MBP03	14.57	13.7	12.58
MBP04	13.64	13.7	12.58
DBP01	31.9	30.4	26.19

Table 1 summarizes the sensitivity results obtained in the test bench for the MBPM's and the DBP01. For each BPM a preliminary fitting to the analytical equation has been done taking into account the mean result of the series of each monitor type. The fitting is done using the analytical

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solution for low-beta beams [5, 6]. With this approach, a half aperture value of 26.1 mm for the MBPM's and 58 mm for the DBPM's. The values obtained are bigger than the nominal half apertures of the pickups, 24 mm and 50 mm for MBPM and DBPM respectively. However, as anticipated in [6], it corresponds to the mean value of the aperture of the stripline.

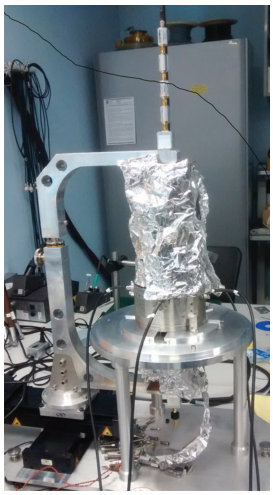

Figure 7: Picture of a DBPM's being characterized.

The inversed sensitivities at 175 and 350 MHz calculated analytically from the fitting are 11.4 and 8.14 mm for the MBPM's, and 20.7 and 12.3 mm for DBPM's. There is a small discrepancy (less than 10 % between those values and the obtained in the simulations. Further data analysis is required to investigate the source of those discrepancies.

ACQUISITION ELECTRONICS

The acquisition system (Fig. 8) has been designed and manufactured for all the LIPAC BPM's as explained in detail in [7], yet based on commercial digitizers. The system uses an analog front-end to house the system calibration switches and an intermediate frequency stage, plus ancillary boards such as timing and clock distribution, on CompactPCI. As such, all parameters for controlling the system are available for windows & Linux OS via Ethernet, and given the low event rate output of the BPM system the integration in the Central Control System is via an ASYN driver. Currently the timing boards are rather simple, consisting on a fan-out buffer with pulse generation and counting capabilities for statistics and monitoring, because the timing outputs for the BPM system from LIPAc consist only of the Trigger and Gate synchronization pulses [8]. The digitizer remains the VHS-ADC from Nutaq (formerly Lyrtech) for the first series of the prototype mainly because historical reasons. The front-end analog board is manufactured and it is in the test phase of the boards. The system is expected to be shipped to LIPAC in the following months.

CONCLUSIONS AND OUTLOOK

The beam position monitors required for the following commissioning stage of the LIPAc prototype accelerator

Figure 8: Picture of the acquisition electronics test bench.

have been successfully designed, manufactured, characterized and integrated by CIEMAT. Further data processing of the mapping of each pickup will be performed to minimize the positioning error of the beam in the accelerator. In parallel, the electronics is being commissioned to be ready before the start of the next beam commissioning phase of LIPAC next year.

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