STATUS OF BEAM POSITION MONITORS FOR LIPAC*

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Abstract

The LIPAc accelerator [1] will be a 9 MeV, 125 mA CW deuteron accelerator 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. Prototypes of almost all the BPM's have been already fabricated. Acceptance tests have been carried out on each device. The output of the vacuum leak tests and electrical tests will be analyzed in this contribution. In addition, the test bench to characterize the BPM's has been upgraded and validated using some prototypes in order to obtain a better global measurement accuracy of the electrical center offset. The test bench can be used to crosscheck the simulations with the real response of each BPM. The result of the comparison will be discussed in detail.

INTRODUCTION

The LIPAC is presently under the first stages of installation and hardware commissioning in Rokkasho [2]. The beam injector is being installed during this year and the next one, and the following components -Diagnostics Plate [3], MEBT [4] and RadioFrequency Quadrupole- are to be installed late next year. As a part of the Beam Instrumentation delivery [5] and in preparation for the next commissioning step, the BPM's for the high current LIPAC prototype accelerator are in the last phase of series manufacturing and characterization. As a reminder different type of pickups have being designed for each beamline section: for the MEBT (the MBPM), for the cryomodule of the Superconducting RF linac (the CBPM) [6], for the Diagnostics Plate (the DBPM) and for the High Energy Beam Transport line (the HBPM) [7]. Most of the pickups are based in a shorted stripline design, being the ones in the SRF linac the only ones of button type to maximize the reliability of the pickups. The majority of the pickups are presently under fabrication of the first units and the characterization of those prior to launching the series manufacturing before the end of the year. Concerning the acquisition electronics, it is also being assembled as it is discussed in [8].

PICKUP STATUS

MBPM

The previous design of the MBPM's [9] has been modified following the ouput of a design review [10]. In order to increase the robustness of the pickup, the former design based in capacitive electrodes has been changed to shorted striplines. The new design (Fig. 1) has preserved the space between the electrode and the body, which is mandatory in order to install the pickup in the middle of each magnet. As a reminder, the distance between the poles of the quadrupolar magnet is 56 mm, and the inner face of the electrode is of 48 mm.

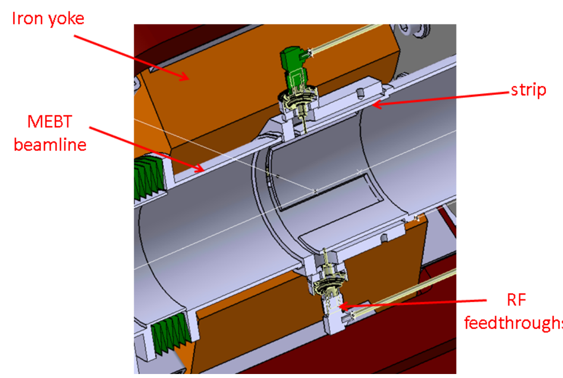

Figure 1: Section of the MEBT mockup showing the MBPM inside the first transport magnet.

The modification of the design has some consequences from the electrical point of view. The ouput signal strength is lower (Fig. 2) For a single deuteron bunch of 4.7mm and an energy of 5 mm, the maximum voltage is reduced from more than 3 V for the capacitive pickup to around 0.1 V for the shorted stripline pickup. A deeper discussion in the causes of this reduction are out of the scope of this proceeding. However, though the signal is reduced by more than one order of magnitude, the signal is still sufficient (above -10 dBm) for the acquisition electronics.

CBPM

The BPM's installed in the SRF Linac were already designed and manufactured in series [11]. However, in order to do the pairing of the buttons in each BPM a previous study of the influence of several parameters in the position error was analyzed. The study focused on the variation of two of the main parameters: the diameter of the inner surface of the button and the capacitance. Assuming a variation of $\pm 10\%$ in only the right electrode, the theoretical approach expect a bigger influence from a small change of the diameter than the capacitance (Fig. 3). However, even in the worst case, the error in the measurement region is too low to affect the accuracy of the measurements. Therefore, the pairing was performed grouping the buttons with similar inner diameter first and capacitance later on.

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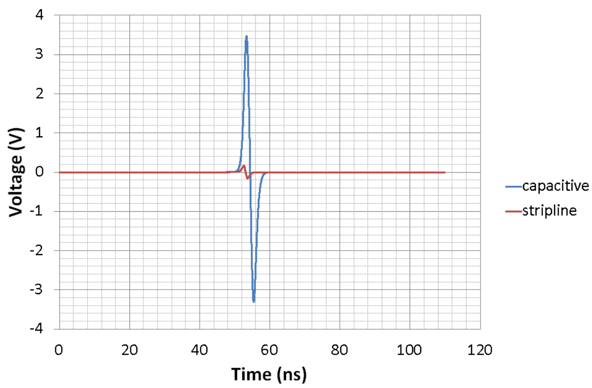

Figure 2: Comparison of the simulated signals from a capactive type BPM and from a stripline one.

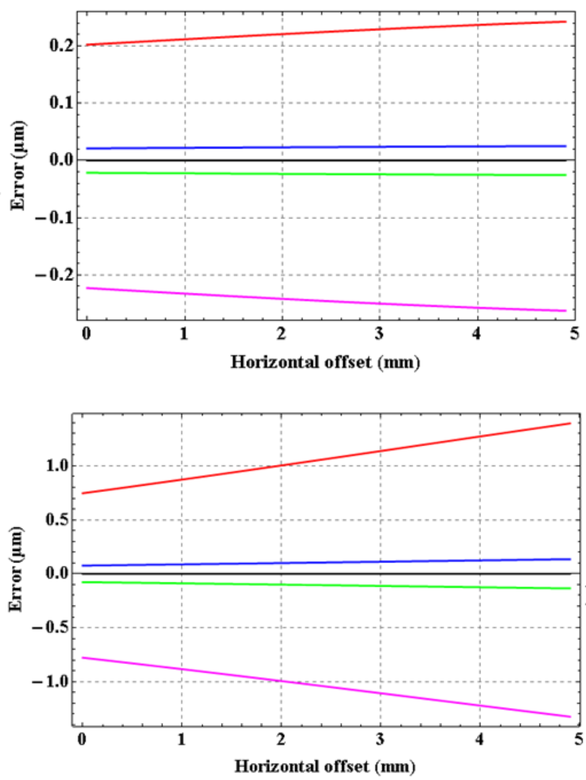

Figure 3: Influence on the variation of the $\pm 10\%$ in capacitance (top) and inner diameter (bottom) in a cbpm.

DBPM

A first unit of DBPM has been manufactured and tested, based in the design presented in [11]. The output signals from this pickup are shown in Fig. 4. The manufacturing of this first unit has been carried out satisfactory in the Fusion Lab workshop. Previous to 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.

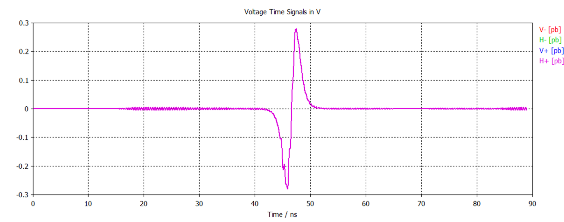

Figure 4: Simulation of the signal output from a DBPM.

The mechanical and vacuum tests to the pickup were followed by the electrical tests, to check the RF behaviour of the unit. Two types of tests were first carried out: 1) a coupling test which checks the signal detected in all the electrodes from an input RF signal in one electrode, and 2) a time domain reflectrometry analysis of each electrode channel. This tests aims to analyze the stripline impedance in each electrode. Both tests are compared with simulations performed using CST Particle Studio [12] with a similar geometry of the pickup. In the case of the coupling test (Fig. 5), the simulations of the S-parameters from opposite channels are in good agreement with the measurements, especially at frequencies below 200 MHz (see Fig. 6). The coupling from opposite channels is quite low, less than 40dB in the region of interest for LIPAc, below 350 MHz. For higher frequencies, the measurements differ more from simulations, which can be due to the modeling of the RF feedthrough or the meshing. However, the measurement of the coupling between the vertical and horizontal are in very good agreement, which shows the symmetry of each channel of the pickup.

Figure 5: Image of the first DBPM during the coupling tests.

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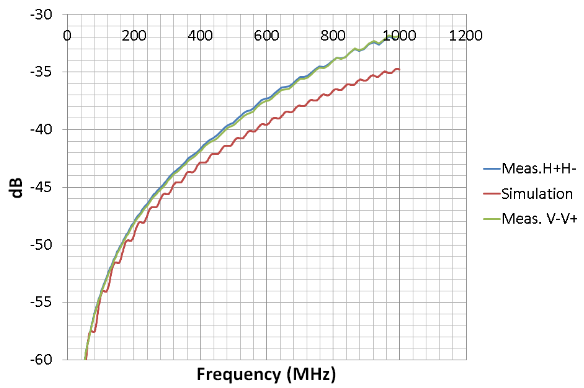

Figure 6: Comparison of the S-parameters of opposite electrodes from the real DBPM and the simulations.

The TDR test was performed using the Network Analyzer in order to study the response to RF signals from each electrode channel. The results are compared in Fig. 7. It has to be pointed out that the model for the simulations was not so detailed as in the real device. Therefore, many of the transitions appearing in the feedthrough and after the gap of the stripline are not seen in the simulation curve. Apart from that, and as can be seen in the major peaks, the curves are comparable. It is difficult to analyze from these curves the impedance of the coaxial lines.

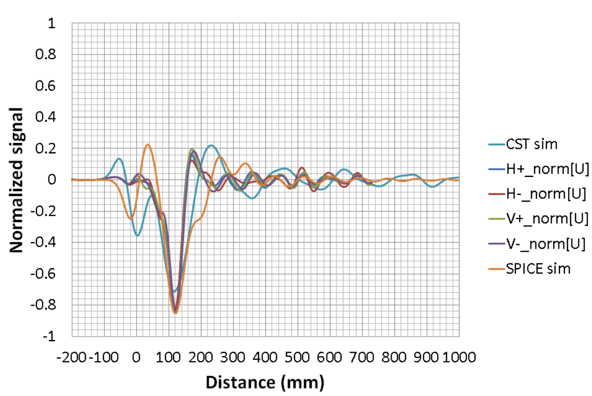

Figure 7: Comparison of the Time Domain Reflectometry results and the simulation ones.

TEST BENCH UPGRADE

Absolute Calibration

Due to beam dynamics requirements [13], target absolute accuracy of less than 100 μm for the MBPM's, 250 μm for the CBPM's and 300 μm for the DBPM's and HBPM's are searched. The absolute accuracy between the theoretical beam axis and the real beam position readout from the beam position monitors is a quadratic sum of errors from different sources: the alignment error of the BPM with respect to the building network, the metrology error between the alignment targets and the mechanical center of the BPM, the offset between the mechanical and the electrical center of the BPM and the error in the positioning map of each BPM. The first study shown that all the errors could be kept below 50 μm except for the error between the mechanical and the electrical center. This error could be split in two terms: the error in the positioning of the wire center in the middle of the mechanical center, and the knowledge of the error between the mechanical and the electrical center itself. The first term was too big due to method used for the positioning of the driven stages in the mechanical center [9]. To minimize this error source, a new setup based in a photointerrupter (as used in LINAC4 test bench [14]) have been used to improve the knowledge of the wire position (in the coordinate system of the motors) in the mechanical center. As shown in Fig. 8, the photointerrupter is attached in one side to the interface plate of the test bench and to the other side to the BPM to be measured, using positioning pins to ensure the best accuracy. The sensor can be placed in four positions around the mechanical axis which minimizes the error in the measurement of the central axis position. A Labview code has been programmed to scan the motors and obtain the maximum sensor signal and the motor position to obtain the best possible calibration and analyze the repetivity of the measurements.

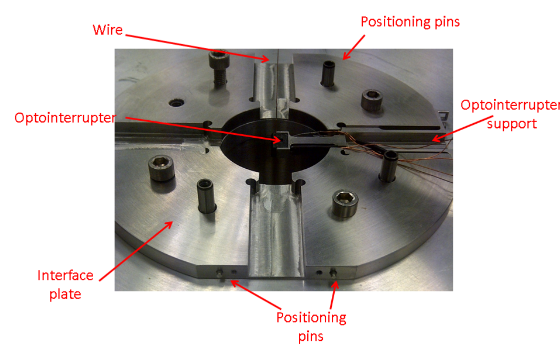

Figure 8: Picture of the mechanics for the calibration of the test bench wire simulating the beam.

Acquisition Cables

The test bench wants to simulate as close as possible the operation in the accelerator. In the final LIPAc installation, the pickups are placed up to 70 m far away from the acquisition electronics. In order to simulate the effect caused by the acquisition cable length, low-loss cables C-50-11-1 [15] of 40 m length were installed between the test bench and the electronics. The installation procedure of the cables was also simulated. Cables were measured using a hand meter with a high inaccuracy and then cut and plugged. Then, the cable length difference was measured using a network analyzer. Errors of less than 50 mm were obtained using this procedure. In order to increase the accuracy, the cables were matched by precise measurements with the network analyzer and the oscilloscope. Afterward the cable were unplugged, cut and plugged again to the

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proper length. The matching with this procedure was good enough, obtaining a phase accuracy better than the required 2^o for all the set of cables.

CONCLUSIONS

The manufacturing of the LIPAc BPM's is successfully accomplishing the schedule. If no showstoppers appear, it is expected to have the BPM's ready to detect beam for the next beam commissioning stage. Some of the pickups have been modified in order to improve the mechanical design, and the test bench has been also modified in order to improve the accuracy and characterization of the pickups.

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REFERENCES

[1] A. Mosnier, et al., The Accelerator Prototype of the IFMIF/EVEDA Project, IPAC'10, 2010.

[2] J. Knaster, et al., Installation and Commissioning of the 1.1 MW Deuteron Prototype Linac for IFMIF, IPAC'13, 2013.

[3] I. Podadera, et al., A Diagnostics Plate for the IFMIF-EVEDA Accelerator, EPAC'08, 2008.

[4] I. Podadera, et al., The Medium Energy Beam Transport Line (MEBT) of IFMIF/EVEDA LIPAc , IPAC'11, 2011.

[5] J. Marroncle, et al., IFMIF-LIPAc Diagnostics and its Challenges, IBIC'12, 2012.

[6] F. Orsini et al., Progress on the SRF Linac Developments for the IFMIF-LIPAC Project, IPAC'13, 2013.

[7] I. Podadera, et al., HEBT Diagnostics for Commissioning, Control, and Characterization of the IFMIF-EVEDA Accelerator, HB'08, 2008.

[8] A. Guirao, et al., Development of the New Electronic Instrumentation for the LIPAc/IFMIF Beam Position Monitors, IBIC'13, MOPC12, 2013.

[9] I. Podadera, et al., Developments for IFMIF/EVEDA LIPAc Beam Position Monitors: The Sensors at the MEBT and the Wire Test Bench, DIPAC'11, 2011.

[10] A. Aleksandrov et al., BI DDR review, June 2013.

[11] I. Podadera, et al., Design of Beam Position Monitors for the IFMIF-EVEDA Accelerator, DIPAC'09, 2009.

[12] CST STUDIO SUITE™, CST AG, Germany, www.cst.com.

[13] P.N.P. Nghiem, et al., The IFMIF-EVEDA Challenges in Beam Dynamics and their Treatment, Nuclear Instruments and Methods in Physics Research A 654, 63-71, 2011.

[14] J. Tan, et al., Beam Position Monitor System for the CERN Linac4, DIPAC'11, 2011.

[15] DRAKA Communications, Coaxial cables, www.draka.com

ISBN 978-3-95450-127-4