DESIGN STATUS OF BEAM POSITION MONITORS FOR THE FAIR PROTON LINAC

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Abstract

Beam Position Monitors (BPM) based on capacitive buttons are designed for the FAIR Proton-LINAC at GSI [1]. This LINAC is aiming to produce a maximum design current of 70 mA at the 70 MeV energy with an operating frequency of 325 MHz. At 14 locations, the BPMs will measure the transverse beam position, the relative beam current and the mean beam energy by time-of-flight method. Depending of the location, the BPM design has to be optimized, taking into account an energy range from 3 MeV to 70 MeV, a short insertion and a beam pipe aperture changes from 30 mm to 50 mm. Some of BPMs will be mounted very close to the CH cavities and special care must be taken to suppress the pickup of the strong rf-field from that cavities. In this contribution, the status of the BPM design will be presented.

INTRODUCTION

Beam Position Monitors (BPM) are essential diagnostics for the FAIR Proton LINAC. A capacitive button type was chosen for its easy mechanical realization and short insertion length to fit into the inter-tank sections of the CH-cavities [2]. This device is composed of 4 electrodes called "buttons" mounted on a vacuum pipe. One of challenges of the FAIR Proton LINAC BPM design is that the same type of electrode is foreseen along the LINAC with an energy varying from 3 MeV to 70 MeV and a change of vacuum chamber geometry.

The main measurement is to determine the beam displacement, with a spatial resolution of 0.1 mm averaged on a macro pulse of 36 µs duration, by calculating the ratio of the difference over sum voltage between two opposite buttons. The sum signal from a BPM can be also used as a relative measurement for the beam current. An important application at a proton LINAC comprising of novel CH-cavities is the determination of the beam energy after each DTL tank which can be calculated via the time of flight determination of a bunch between two BPMs. For this time measurement, an accuracy of 8.5 ps has to be achieved corresponding to a phase resolution of 1°.

The main parameters are summarized in Table 1.

Table 1: FAIR Proton LINAC BPM Parameters

Parameter	**Value**
Beam pipe diameter	30 mm intertank section, 50 mm transfer lines
Length	50 mm
Beam energy	From 3 MeV to 70 MeV
Bunch frequency	325.225 MHz
Beam pulse length	36 µs nominal
Bunch length	150 ps average
Average Current	35 mA nominal, max 70 mA
Position resolution (RMS)	100 µm averaged on a macro pulse of 36 µs
Operation range	± 5 mm
Phase resolution	1° averaged on a macro pulse of 36 µs

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To optimize the BPMs design for these three purposes at all locations along the accelerator, 3D electromagnetic software was used to simulate the BPM signal generated by the beam.

LAYOUT

Fourteen Beam Position Monitors (BPMs) will be installed along the Proton LINAC as shown Fig. 1.

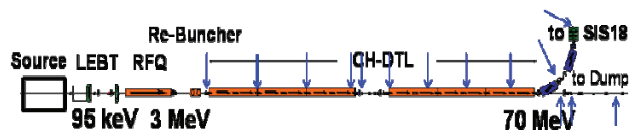

Figure 1: Distribution of Beam position Monitors along the LINAC.

The vacuum chamber aperture is 30 mm. But due to different requirements at each section, monitors installed in the transfer section, the dump and between the two dipoles will have a vacuum chamber aperture of 50 mm. Beam dynamics requirements and compactness of the beamline require that some Beam Positions Monitors (at six locations) will be an integral part of the inter-tank section between the CH cavities.

In this context and after having performed some preliminary estimations of BPM properties, a button type Pick-up BPM was chosen [3].

ELECTROMAGNETIC SIMULATIONS

To improve and extend calculations of the signal response of the monitors, numerical simulations were continued by using the code CST PARTICLE STUDIO with the wake-field solver [4]. The excitation source was defined by a Gaussian-shaped longitudinal charge distribution.

For the investigation of the position sensitivity, the position of the simulated beam was moved horizontally and vertically. Figures 2 and 3 show the sensitivity map obtained by plotting the delta-over-sum values from signals of two opposite buttons for the first harmonics of the accelerating frequency i.e 650 MHz at β = 0.08 and β = 0.37. The calculation is performed for a 30 mm beam pipe aperture as foreseen between the CH-cavities and a 50 mm aperture at the transfer line to the synchrotron and the beam dump.

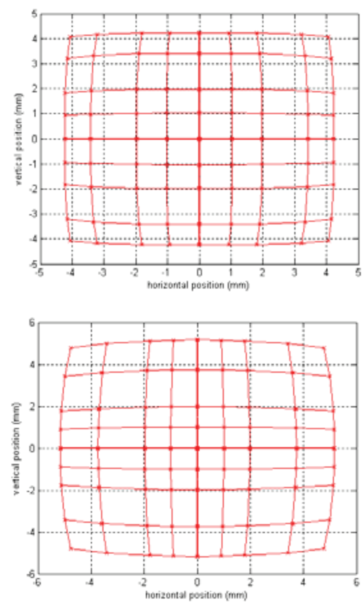

Figure 2: Sensitivity map of the button pick-up at 650 MHz and β = 0.08 and β = 0.37. Vacuum aperture: 30 mm, button diameter:14 mm.

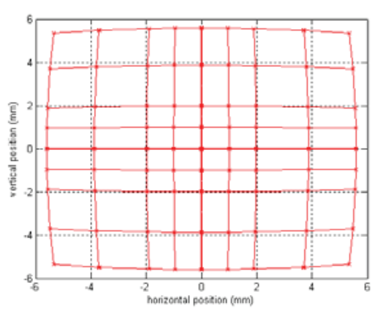

Figure 3: Sensitivity map of the button pick-up at 650 MHz and β = 0.37. Vacuum aperture: 50 mm, button diameter: 14 mm.

The influence of the button position is also an important parameter. To avoid charge accumulation on the BPM electrodes due to scattered ions, a gap has to be installed between the electrode and the beam chamber. Simulations presented on the Fig. 4 compare signals with no gap, a gap of 0.5 mm and 1 mm and show that signal read by one button decreases with the depth of gap.

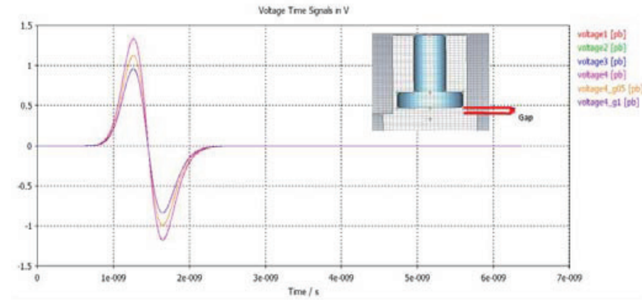

Figure 4: Signal read by a button depending of the electrode position.

Following those estimations, a preliminary design (Fig. 5) is presented with a button diameter of 14 mm and a button position with a gap of 0.5 mm. The choice of the button diameter is guided to keep the required performances for the 14 BPMs located at different energies and with two different beam pipe apertures.

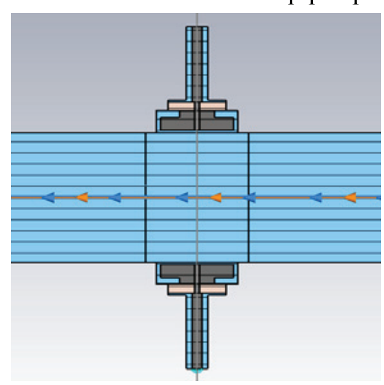

Figure 5: Design of the button BPM.

The signal read by one electrode of this BPM design is shown by the green curve of Fig. 7. This calculation was done for a velocity of β = 0.22 which corresponds to a BPM installed in the inter-tank section between the quadrupole triplett and a CH cavity. This kind of monitors will be fixed to the quadrupole via a flange and will be mounted within an evacuated housing. Figure 6 illustrates by a CST model, the BPM of inter-tank section installed in its environment. This geometry is used to simulate the signals generated by the beam from each electrode.

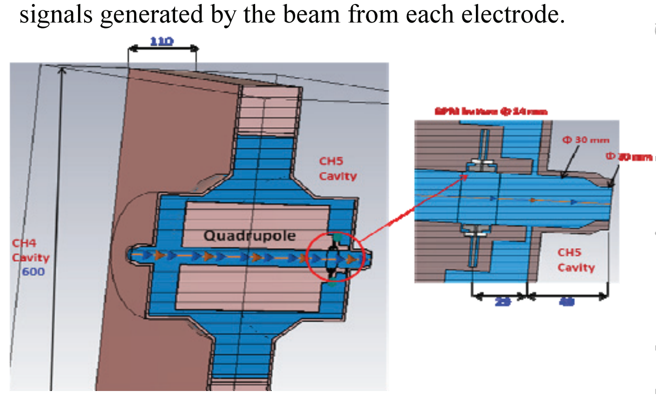

Figure 6: CST model of the inter-tank section behind CCH2 cavity housing the quadrupole triplett and the attached button BPM.

Figure 7 compares the button BPM simulated with the quadupole not inserted in the inter-tank to the monitor inserted in the inter-tank. The signals amplitudes are very similar. The gentle difference is due to the mesh which is not perfectly identical. The blue curve shows the amplitude read by one electrode in simulating the 3D model of Fig. 6, i.e with a gap between the BPM and the CH cavity. The quality of the measurement is affected by undulations at the top of the signal. To understand this phenomenon, a 3D model with no gap between the BPM and the CH cavity was simulated. Results read by the buttons did not show undulations (red curve on the Fig. 7). Undulations could be excited by wakefields which may be caused by the discontinuity of the beam pipe. In removing the gap between the BPM and the CH cavity, the undulations on the signals disappeared. That's why a slit between the BPM and the CH cavity has to be avoided.

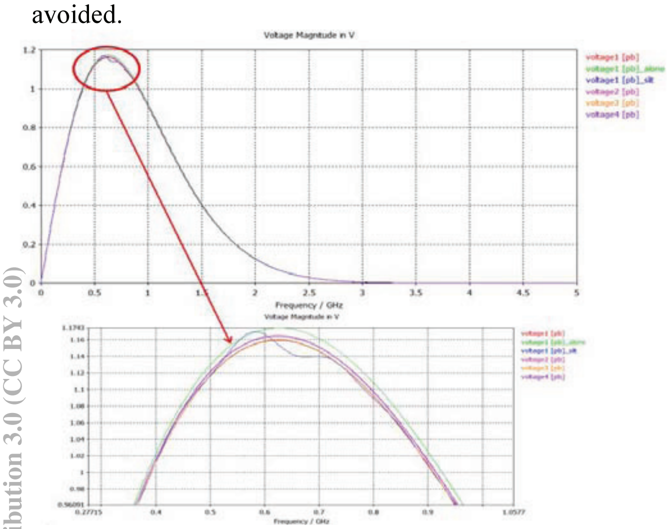

Figure 7: Voltage magnitude vs frequency from the pickups of the button BPM.

CONCLUSION

Beam Position Monitors are essential devices for the beam-based alignment and diagnostic of the FAIR Proton LINAC accelerator.

Simulations presented are encouraging and show that a BPM with a button of diameter 14 mm can be used for all locations along the LINAC. According to the simulations of BPMs installed in the inter-tank, a slit between the BPM and the CH cavity has to be avoided.

After having finished the BPM design, some prototypes will be measured on a test bench to approve the performances and compare them to the simulations.

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