THE MECHANICAL DESIGN OF THE BPM INTER-TANK SECTION FOR P-LINAC AT FAIR

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Abstract

At the planned Proton LINAC at the FAIR facility, four-fold button Beam Position Monitor (BPM) will be installed at 14 locations along the 30 m long FAIR p-LINAC. The LINAC comprises of crossbar H-mode (CH) cavity to accelerate a 70 mA proton beam up to 70 MeV at frequency of 325 MHz. At four locations, the BPMs will be an integral part of the inter-tank section between the CCH and CH cavities within an evacuated housing. As the BPM centre is only 48 mm apart from the up-stream cavity boundary, the rf-background at the BPM position, generated by the cavity must be evaluated. In this paper the mechanical design of the BPM for the inter-tank section is presented and the rf-noise at the BPM location is discussed.

INTRODUCTION

The proton LINAC at FAIR will provide the primary beam for the anti-proton production chain. It will serve as an injector for the existing synchrotron SIS18, delivering 35 mA of beam current within macro-pulse length of 36 µs and a typical bunch length of 150 ps. It is designed to accelerate the beam to 70 MeV with an operating frequency of 325 MHz [1,2]. Beam Position Monitors (BPM) will be installed at 14 locations along the LINAC, as schematically shown in Fig. 1. Two different beam pipe apertures (30 mm and 50 mm) have to be considered. The BPM system will be a key diagnostic tool. It will be used to determine the beam displacement with a spatial resolution of 0.1 mm, the mean beam energy and the relative beam current. The beam energy is recorded from the time-of-flight of bunches between two successive BPMs with an accuracy of 8.5 ps corresponding to a phase difference of 1° with respect to the accelerating frequency of 325 MHz. The relative beam current is determined from the sum signal of the four BPM plates. The basic layout for the BPM system and relevant calculations are described in [3-5].

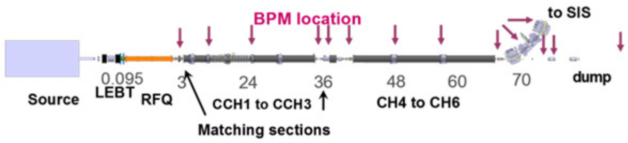

Figure 1: Layout of the proton LINAC including BPM locations.

RF COUPLING TO BPM

The mechanical design of the BPM at the inter-tank locations is most critical. The tight space allows only 60 mm insertion length between CCH cavity and magnet walls as shown in Fig. 2. Therefore, the rf-field propagation from the cavity into the beam tube and the BPM's co-axial signal path must be considered. The design of the inter-tank BPMs is based on previous numerical simulations as well as on the given inter-tank dimensions [3-5]. The device performance was optimized by simulation calculations. Special attention is paid to the reduction of the rf-background from the nearby cavity.

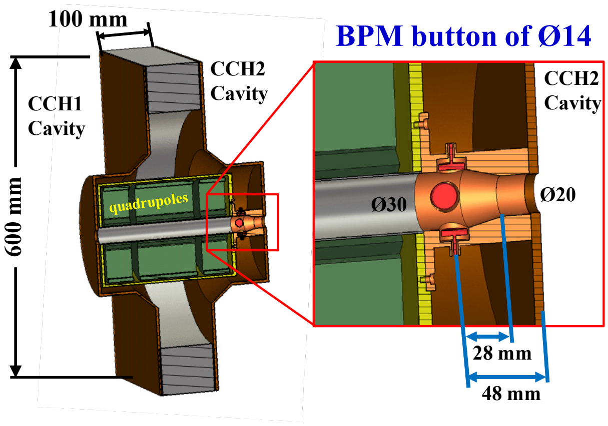

Figure 2: The technical layout of the inter-tank section

The BPM (tube diameter of 30 mm) is connected to the CCH entrance flange (20 mm) by a conical section with a length of 20 mm in order to reduce the rf- background signal to max. 5mV [5] as shown in Fig. 3. This value is satisfactory compared to the signal voltage of ~ 1V for a nominal beam current of 35 mA. On the other hand, in order to suppress the rf-leakage contribution a band-pass filter matched to the second harmonic (650.5 MHz) of the accelerating frequency is placed into the analogue chain of the BPM electronics. The signals are processed by under-sampling technology to obtain the beam position from the difference of the plates' amplitude and the mean energy from the phase value compared to the accelerating frequency [5].

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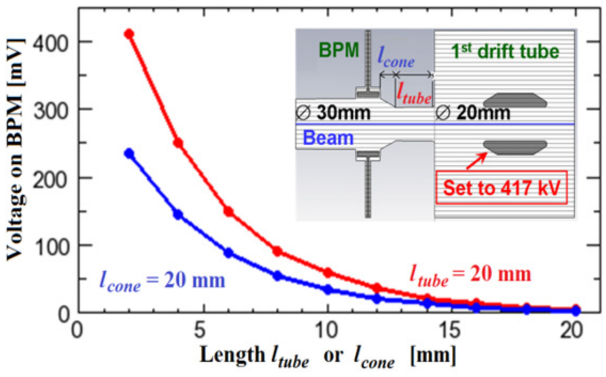

Figure 3: Shielding properties as a function of the length of the cone l_{cone} (red) for a fixed length of the tube or as a function of the cylindrical tube length l_{tube} (blue) for fixed cone length. For the electro-static solver the first drift tube is set to 417 kV.

The first CCH power prototype for the p-LINAC arrived in late 2013 at GSI and is currently under preparation for further tests. A drawing of the cavity is presented in Fig. 4. Presently, the copper plating is performed to achieve the required high surface quality at all regions of the cavity. In parallel the high power test stand will be make use of the klystron and the associated infrastructure of the CCH. At this test stand, the BPM will be installed to determine its performance under realistic conditions.

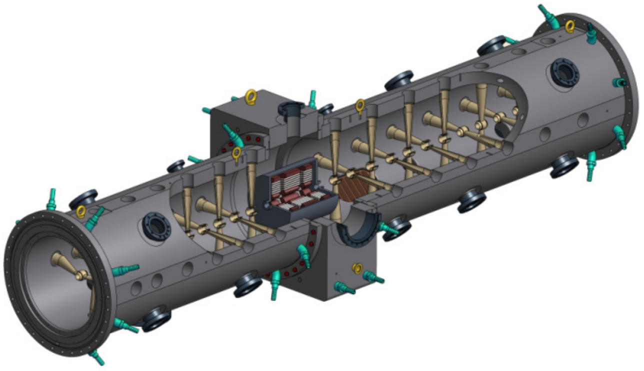

Figure 4: 3D Sketch of the CCH power prototype.

BPM MECHANICAL DESIGN

A commercial 14 mm button pick-up produced by Kyocera [6] was chosen. The button sub-assembly unit composite a titanium electrode of 2 mm thickness connected to a SMA coaxial structure as shown in Fig. 5. The assembly of the BPM consists of four buttons, a housing and a flange as shown in Figures 5 and 6, respectively. The buttons are recessed 0.5 mm from the inner radius of the tube to protect the electrode from stray beam impingement. Since the BPM is located near the quadrupole magnet, a non-magnetic design is mandatory. Therefore, the housing and the flange will be fabricated from 316LN stainless steel. The buttons will be welded to the housing and both will be joined with the flange at the final assembly.

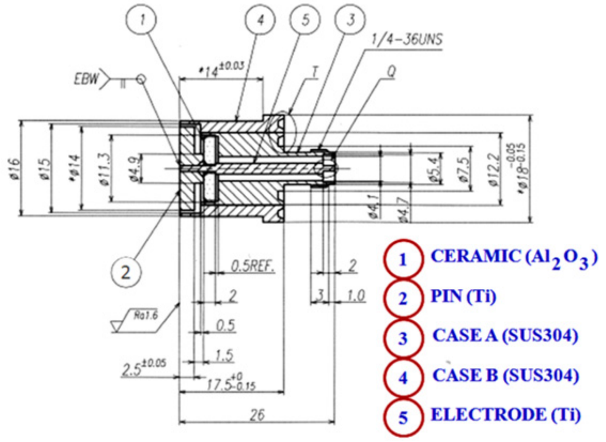

Figure 5: Scheme of 14 mm button electrode from Kyocera composites a titanium electrode of 2 mm thickness connected to a SMA coaxial structure.

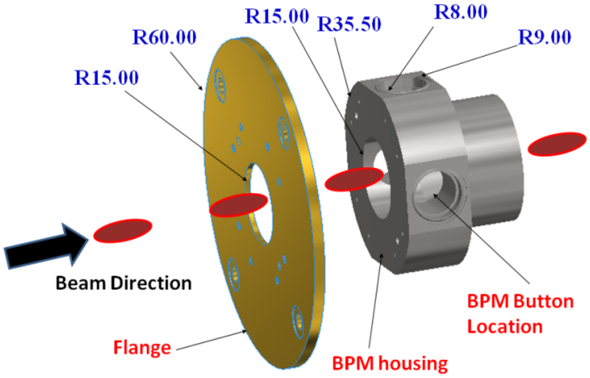

Figure 6: View of the BPM prototype parts.

BPM CHARACTERISTICS AND REALIZATION

A Time Domain Reflectometer (TDR) test was performed to investigate the 50 Ω impedance matching of the PU structure, which can be influenced by the inner ceramics. For these tests and also for the measurements with the Network Analyser we used an available pickup of Ø 11 mm and a thickness of the button of 2 mm. The TDR signal, as depicted in Fig. 7, displays the impedance over time showing the place and nature of discontinuities that are due to impedance changes. A significant mismatch was observed exactly at the fitting position of the ceramic backing. This causes an impedance step down to 22 Ohm and can be seen as downward peaking in Fig. 6. The direction of the reflection on the display is negative indicating that the reflection is caused by a capacity. Such disturbance on the signal propagation has minor conse-

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quences for beam position determination but for the time-of-flight (TOF) measurements such effect is critical due to the deformation of the time-domain signal and must be avoided. Therefore, the electrical characteristic of the PU must be optimised to achieve a better 50 Ω impedance matching along the whole signal path.

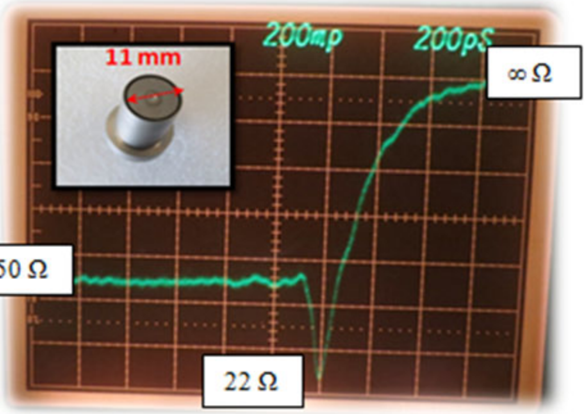

Figure 7: The TDR measurements of the 11 mm Kyocera button pickup.

In parallel to the TDR measurements the transmission line characteristics of the buttons were measured with a Network Analyser. Figure 8 shows the Smith chart derived from these measurements. The capacity of 3.47 pF determined at low frequency (marker1 @ 1MHz) corresponds to the capacity of 3.72 pF which has been calculated from a simple geometrical model.

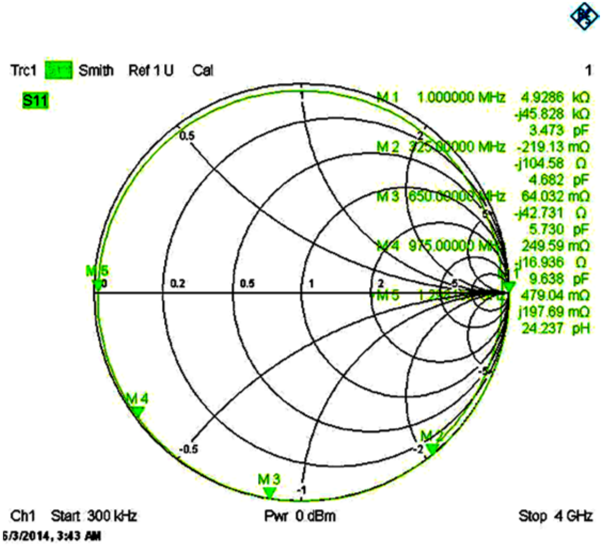

Figure 8: Smith chart of the 11 mm Kyocera button pickup shows the impedance at different frequencies.

The graph rotates clockwise, while the frequency is swept from 1 MHz to 1.29 GHz. In the interesting frequency range (marker 2, 3 and 4) the capacitive load from the button is obvious. At marker 5 @ 1.29 GHz the quarter-wave frequency is reached and the PU impedance becomes inductive reactance. This point is close to 0-end of the pure resistance line and represents a short circuit. The geometrical length of the transmission line represented by the pickup is $\lambda/4_{1.29\ \mathrm{GHz}} = 4$ cm.

CONCLUSION AND OUTLOOK

The first CCH power prototype and the high power test stand are currently in preparation. A button-type BPM has been chosen and is being fabricated. The button diameter, the gap between the button and the chamber wall as well as the button thickness are selected as 14 mm, 0.5 mm, 2 mm, respectively. The Time Domain Reflectometer measurement shows that the electrical characteristic of the button must be improved for 50 Ω matching.

The BPM prototype will be used as a test device to explore the rf-field propagation from the cavity to the BPM. Results are expected just after the commissioning of the new klystron end of 2014 and will be considered for the final BPM design.

Furthermore, CST calculation will be performed taking into account different PU geometries and beam pipe as well as bunch length at different velocities. These investigations should provide position maps for a range around 8 mm beam offset and possible position dependences concerning the time-of-flight method for non-relativistic beam velocities .

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