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BUTTON BPM DEVELOPMENT AND PROTOTYPING FOR ALBA II

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Abstract

As part of the ongoing ALBA II upgrade, which aims to significantly enhance the performance of the ALBA Synchrotron Light Source, a new design for button Beam Position Monitors (BPMs) is under investigation. In this contribution, we present the results of a characterization study conducted on button prototypes supplied by two different manufacturers.

INTRODUCTION

In the framework of the upgrade of the ALBA machine [1], 20 buttons have been produced as prototypes by two different manufacturers [2]. The buttons were designed at ALBA [3]: It has a straight design, the button diameter is 4 mm, the gap is anticipated to be 200 µm, no sleeve is expected, the insulator material is borosilicate glass, and the selected connector is a Reverse Polarity SMA. The dimensions, tolerances, and material used are listed in Fig. 1. Each button is labeled with a Serial Number (SN) from 1 to 20.

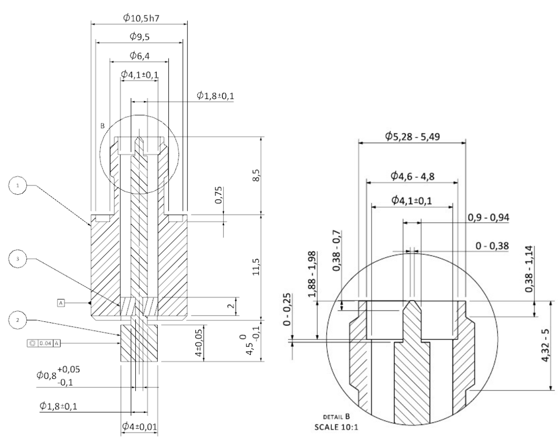

Figure 1: ALBA Button BPM mechanical design.

Materials for each part of the button are listed in the Table 1.

Table 1: BPM button material, the button material differs depending on the manufacturer.

1	Housing	SS316L
2	Button	M1: 2.4602 Alloy C22 + Au coating M2: Molybdenum
3	Insulator	Borosilicate glass

Extensive mechanical and electromagnetic characterization has been performed to verify that the prototypes were in tolerance. The buttons were then grouped and welded in 4 different blocks, produced by two different companies. Labertson method has been applied to measure the electromagnetic center of each block, and verify the grouping effectiveness. Results are presented in this proceeding.

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ELECTROMAGNETIC CHARACTERIZATION

Time Domain Reflectometry (TDR) measurements were performed using a 9 GHz Vector Network Analyzer (VNA) to assess the electronic properties of the feed-through [4]. Each button was inserted into the aperture of the BPM block for measurement. A complete VNA calibration was performed before each measurement, using the same cable throughout, to minimize the influence of cables and adapters. The obtained TDR rise time result agrees well with the one expected from the CST simulation.

To compare different BPMs we decided to use extract from the TDR the capacitance using the 10 % to 90 % rise time (τ_{10-90}) of the curve and considering the VNA load of 50 Ohm (Z_0):

$$C = \frac{Z_0}{\tau}.$$

Each button was measured 10 times after repeated extraction and insertion into the BPM block. Figure 2 shows the results for the two different manufacturers, with dots representing the mean and error bars indicating the standard deviation of the 10 measurements. Measurements were repeated two separate days to assess repeatability.

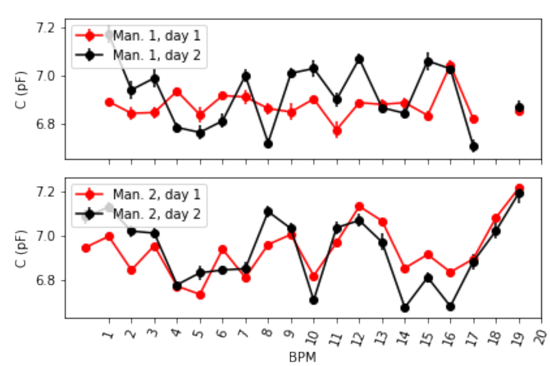

Figure 2: Capacitance measurement of the 20 buttons in two different days. Manufacturer 1: top, Manufacturer 2, bottom.

In case of Manufacturer 1, two of 20 buttons did not fit in the BPM block. The measured capacitance is close to the simulated value (7.5 pF), but measurements taken on different days showed poor repeatability, which is instead present in the case of Manufacturer 2.

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MECHANICAL CHARACTERIZATION

We then measured the diameter of each BPM button using a Palmer micrometer. We measured the diameter of top of the housing, of the bottom and the button, as depicted in Fig. 3.

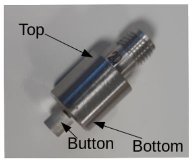

Figure 3: Diameters measured with the Palmer-Micrometer.

The results are presented in Fig. 4: the dots are the average of 3 acquisitions, the black line is the expected diameter, and the shadow represents the tolerances. The blue dots are results from Manufacturer 1, while the orange dots are from Manufacturer 2.

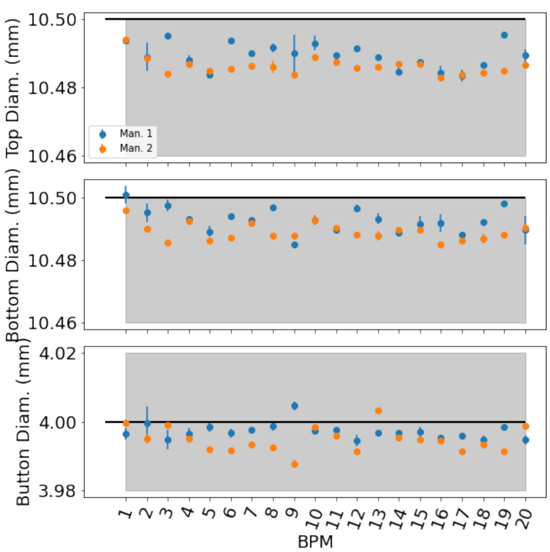

Figure 4: Results of top and the bottom of the housing and the diameter of the button.

It is clear that in case of Manufacturer 1, the bottom of the button housing SN-01 and SN-19 is out of tolerance, being larger with respect to the block hole diameter (10.5 mm). This is why these two buttons did not fit in the block.

We also measured the distance between the bottom of the button, exposed to the beam and the lower part of the housing, as depicted in Fig. 5. The measurement was performed with with FARO 3D Arm: ±30 µm repetitivity and ±30 µm length precision.

Results are presented in Fig. 6: blue dots are for Manufacturer 1, while orange dots are for Manufacturer 2. Dot represents the mean distance, calculated as the average of the maximum and minimum measured values by the FARO. The error bar shows the difference between these extremes and the shaded line is the instrumental resolution. The black line

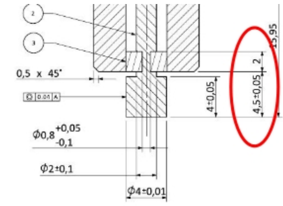

Figure 5: Distance button housing.

represents the expected value, while the darker gray filled area represents the target tolerance, and the light gray filled area represents the tolerance agreed with the Manufacturer 2.

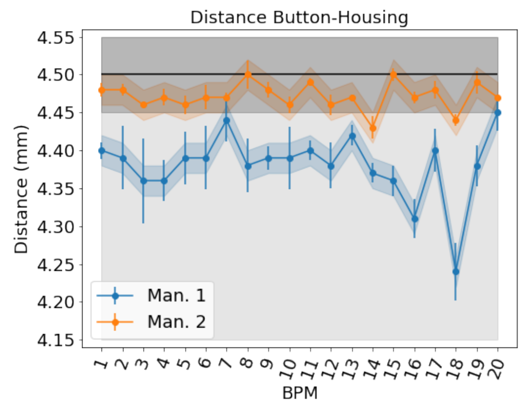

Figure 6: Measured distance button housing.

Buttons produced by Manufacturer 2 are well within the target tolerance, while the one produced by Manufacturer 1 are still within the specified tolerance but the measured distance is systematically lower. This means that buttons are retracted when inserted into the block, this could be clearly seen by eyes.

VACUUM TIGHTNESS

We finally checked the vacuum tightness of each button: leak test jig has been designed in house: buttons are inserted and kept in position by a clamp. The vacuum is ensured by a rubber o-ring. We then used a pump and we spread helium on the button. We measure the leak rate and we verify that it is lower than 10^{-9} mbar×l/s. In case of Manufacturer 2, all buttons were validated as vacuum tight, while in case of Manufacturer 1, 3 out of 20 buttons were leaky.

GROUPING

To mitigate electromagnetic offset, four capacitance-matched buttons are grouped for each BPM block. A total of 4 blocks produced by two different companies were tested, selecting two such button groups per manufacturer. Manufacturer 1 had 15 usable buttons (2 dimensionally incompatible, 3 leaky) and exhibited low capacitance measurement repeatability (Fig. 7 top, showing selected groups). All 20 Manufacturer 2 buttons were usable and free of leaks (Fig. 7 bottom, showing selected groups).

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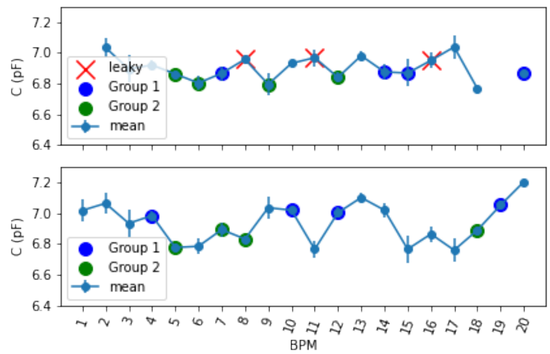

Figure 7: Manufacturer 1 (top), Manufacturer 2 (bottom): Manufacturer 1: Average and standard deviation of the capacitance measured on two different days. Red crosses represent leaky buttons, blue and green circles represent the two groups.

BPM BLOCK TESTING

A first visual inspection of the blocks reveals that laser welding, chosen by Company 1, appears cleaner than Company 2's TIG welding. However, the buttons welded by Company 1 are clearly retracted, which is not ideal.

After a visual inspection, we measured the *S*-parameters to measure the electromagnetic offset using the Lambertson method [5]. We connected each button to one of the four channels of the VNA, then recorded all *S*-parameters up to 9 GHz and visually checked for consistency. In particular, we examined the reflection parameter S_{11} on a Smith chart to check for possible absorption.

This is clearly shown in Fig. 8. For an ideal, fully reflective system, we would expect all the signal to be concentrated on the outer border of the Smith chart. The observed spiraling of the signal towards the center of the chart for Block-B unequivocally denotes signal absorption.

The presence of absorption is even more clearly demonstrated by plotting the S_{11} parameters on a Smith chart, as shown in Fig. 8. For an ideal, fully reflective system, we would expect all the signal to be concentrated on the outer border of the Smith chart, as the case of Block-A, where the Manufacturer 2 buttons are welded. The observed spiraling of the signal towards the center of the chart for Block-B with buttons by Manufacturer 1 unequivocally denotes signal absorption.

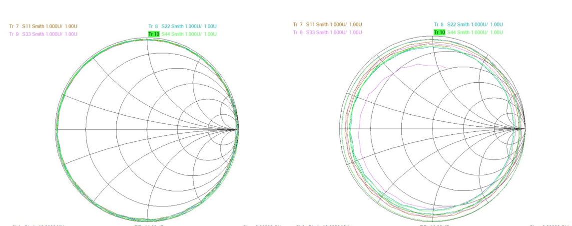

Figure 8: S_{11} for Company 1 block containing buttons from Man. 1 (top), and Man. 2 (bottom) on a Smith chart.

The same behavior appears in the Blocks produced by the other company, indicating clearly that the issue is in the button themselves.

Finally, we recorded the S-parameters at 500 MHz for a 2-second period and averaged them over time to obtain the final result. We then used the Lambertson method formula to obtain the electromagnetic offset. The S_{ij} parameters, measured up to 9 GHz, are presented in Fig. 9, along with the time evolution of the same parameters recorded at 500 MHz for one block.

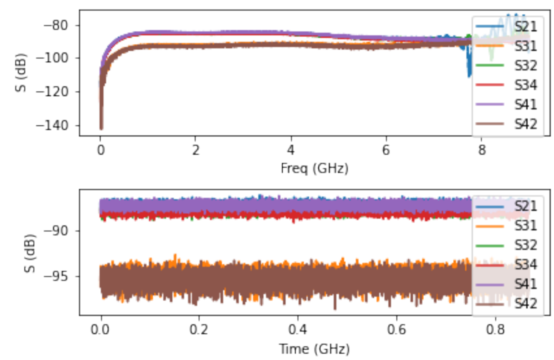

Figure 9: *Sij* at different frequency (top) and at 500 MHz as a function of time (bottom).

The average results for different days for all the blocks are presented in the Table 2: in general the results for the electric offset are consistent across different days, varying within 10 micrometers, and are generally in the order or lower than hundreds of micrometers, as expected.

Table 2: Results of Electromagnetic Offset Measured with Lambertson Method

Block & button	Δx (mm)	Δy (mm)
Comp. 1 + Man. 1	-0.062	-0.042
Comp. 1 + Man. 2	-0.090	-0.103
Comp. 2 + Man. 1	0.123	-0.095
Comp. 2 + Man. 2	-0.062	-0.028

CONCLUSION AND NEXT STEPS

BPM buttons for ALBA II were prototyped by two different manufacturers and extensively tested. The results showed that the buttons from Manufacturer 2 were superior, as they fulfilled the required tolerances and exhibited good electromagnetic behavior. We are currently in contact with the same manufacturer to produce these buttons using CuCrZn as the housing material. This presents a challenge, but significant progress has been made. The produced buttons have been welded into four blocks, which were also produced by two different companies. The results were comparable in both cases. Two of these blocks have now been returned to one of the companies for the application of NEG coating, in order to verify its effect on the electromagnetic behavior.

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