A Compact Single Shot Beam Position Monitor for DELTA

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Abstract

In order to investigate the fluctuations of the injection efficiency of the DELTA booster into the DELTA storage ring a compact single shot button beam position monitor was engineered and installed in the transfer channel of DELTA. This article presents layout and characterization of the BPM and first results of its application.

1 INTRODUCTION

DELTA is a synchrotron light source with 1.5 GeV maximum electron energy and 120 mA maximum beam current. The accelerating units LINAC (75MeV), the ramped injector ring BoDo (75-1500MeV) and the storage ring Delta are connected by the transfer channels T1 and T2. Fluctuations of the injection efficiency into BoDo as well as into Delta created the requirement for better diagnostics in both transfer channels. A button beam position monitor (BPM) not only allows investigation of the beam orbit but also allows investigation of the charge distribution and bunch structure of the injected electron bunches.

2 LAYOUT

The vacuum body (69.4mm diameter, 50mm length) of the monitor is machined out of stainless steel. The outer shape is coaxial to the virtual beam axis to better than 20μm and 0.5 mrad. Four button pickups[1] are welded to the vacuum vessel at an azimuth angle of 45 degrees with respect to a flat alignment surface on the outer shape. The buttons are equipped with male SMA connectors. The whole BPM body may be aligned to the horizontal plane using the alignment surface. Two integrated conflat flanges allow the integration into the beamline vacuum system. RF noise travelling down the beamline is cut off at 5 GHz (H_{11},worst case). Frequencies up to 3 GHz are damped to less than 10% of their initial amplitude after half the BPM body length.

Figure 1: The vacuum body of the button BPM.

[1]PMB Metaceram, BUC CEDEX, France, C=4.8pF

3 CHARACTERIZATION

The interesting characteristics of the BPM are the calibration of the electrical and mechanical center, the linearity, the accuracy and the slope.

3.1 Electrical center

The electrical center of the BPMs is the beam position inside the BPM from which, in an ideal world, all four buttons see the same signal intensity. In real world the symmetry of the button signals is disturbed by slightly varying button capacities, junction and cable losses, etc. Thus correction factors for the signal intensity of each button have to be determined. This is done using the setup in figure 2.

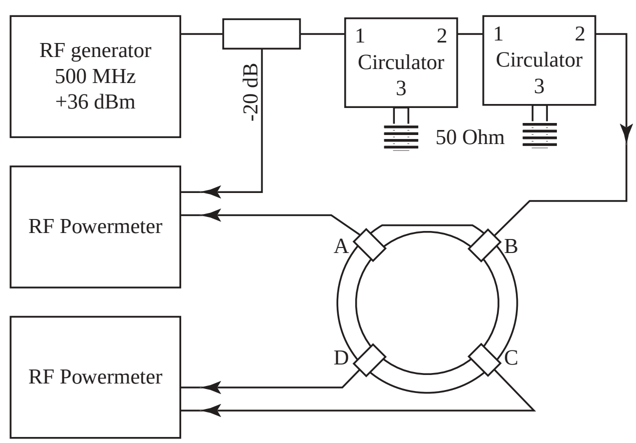

Figure 2: Setup to measure the electrical center of the BPM.

One button is connected to a RF power amplifier which provides about 36 dBm at 500 MHz, the other three buttons are connected to power measurement devices which measure the received signal strengths. The measurement is repeated four times, each button serves once as the sender button. Symmetry arguments then lead to the desired correction factors (see table 1). This calibration has to be repeated each time cables or connectors are changed.

A	B	C	D
0.981	1.000	1.028	1.003

Table 1: Typical correction factors for the BPM buttons

3.2 Mechanical center

The mechanical center is determined by the outer shape of the BPM and may be offset from the electrical center. Beamline survey usually references marks on the outer shape of the BPM body and thus the mechanical center. The typical beamline alignment precision is of the order of 0.2 mm.

In order to measure the offset between the mechanical center and the electrical center, a wire method is used: A thin copper wire is roughly aligned in parallel to the mechanical axis of the BPM, but offset from the center by some 100 micrometers. A single 1.5ns wide pulse of 25V into 50 Ohms is then applied to the wire. The four button signals are measured using a four channel oscilloscope in single shot mode. The wire position is calculated from the measured pulse amplitudes by a log-ratio method [1], taking the button correction factors into account. The BPM is then rotated around the mechanical axis and the measurement is repeated. Ideally all measured points form a circle. The center of the circle represents the mechanical center of the BPM with respect to the electric center. A precision of the center determination well below the alignment accuracy was easily achieved applying two rotations of 90 degrees.

3.3 Linearity, accuracy and slope

The linearity, accuracy and slope of the BPM are also measured with the wire setup. The BPM is firmly positioned on the support and the alignment surface is adjusted to be horizontal. The wire is connected to the pulser which provides pulses of 1.5ns duration and 25V Amplitude into 50 Ohms. It is aligned in parallel to the BPM axis and moved horizontally in steps of 0.5mm. At each position the four button signals are measured with a single shot oscilloscope. The position is calculated from the signal amplitudes using the log-ratio method [1]:

$$x = K_x(\log(A/C) - \log(B/D))\sin(\varphi) \quad (1)$$

$$y = K_y(\log(A/C) + \log(B/D))\cos(\varphi), \quad (2)$$

with A, B, C, D=signal amplitudes, φ=pickup rotation angle, here $K_x \sin(\varphi) = K_y \cos(\varphi)$ arbitrarily set to 1. The range within 3mm of the BPM center is measured in steps of 0.1mm. This data is used to generate a linear fit and to calculate the measurement accuracy. The slope results as $s = \log(A/C) - \log(B/D) = 0.135mm^{-1}$. The statistical error of the measurement results as 74μm. It is dominated by the oscilloscope accuracy (66μm). At wire positions in excess of 3mm off-center the data start showing a deviation from the linear behaviour. The systematic error due to nonlinearity is shown in table 2.

Offset from center	0-3mm	6mm	9mm
Nonlinearity error	$\leq$1%	4.5%	7.5%

Table 2: Linearity error of the BPM.

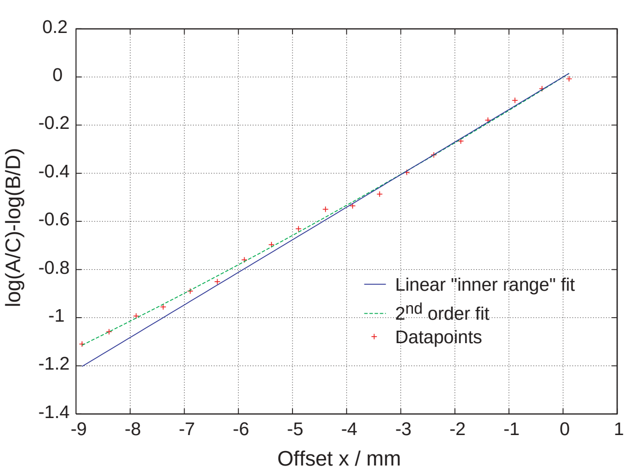

Figure 3: The linearity of the BPM. The error bar of a single measurement is 0.01 corresponding to 74μm.

4 BPM ELECTRONICS

In order to serve in the DELTA transferchannel T2 the BPMs will be used as single shot BPMs. Every 7 to 10 seconds a charge of 0.5 to 1.5nC distributed over 7-20 bunches spaced by 2ns pass the transfer channel. The BPM bodies are thus equipped with BERGOZ[2] LR-BPM electronics which are capable of measuring an averaged beam position for each shot. The electronics are jumpered to Sample and Hold mode in which they hold the beam position for up to

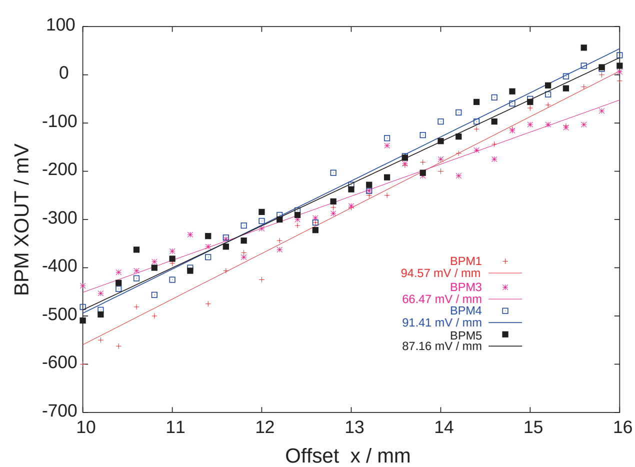

Figure 4: Calibration of the BPM electronics (BERGOZ LR-BPM).

[2] BERGOZ Instrumentation, Saint Genis Pouilly, France

100ms. The output signals XOUT and YOUT are fed into a CAN-bus analog input module which is integrated in the DELTA control system.
In order to characterize the BPM electronics the same measurements as in section 3.3 are repeated but this time the oscilloscope is replaced by a BPM electronics. Figure 4 shows the results. All electronics were measured in the same environment with the same BPM body. With signal amplitudes of 20-30 mV, self triggering of the BPM electronics did not take place. As soon as an external trigger was provided to it and timed within 30 ns of the pickup signal pulse the position measurement became reproducible. The four measured electronics show slopes between 66 and 95 mV/mm. The statistical error of the measurement was about 250μm which is slightly more than specified. The reason for this lower accuracy is still being investigated. One possible explanation is that reflections from the poorly terminated copper wire end in the BPM teststand confuse the BPM electronics and lead to a loss in accuracy.

5 APPLICATION

Two of the BPM bodies have so far been installed in the transfer channel T2 between BoDo and Delta. Though their commissioning as position monitors is still on the way, investigations of the bunch structure have already taken place. Therefore one of the T2 BPM pickups was connected to one channel of a fast single shot oscilloscope[3] while a pickup of a Delta BPM closeby was connected to the other channel.
The bunch structure in T2 shows a strong variation with the LINAC energy. Bunch trains filled with 7 to 20 bunches were observed as a function of the pulsed linac klystron PFN voltage. We believe this is due to the large energy spread of the electron beam due to beam loading in the accelerating structure of the LINAC. Since the energy acceptance window of the booster is smaller than the offered energy spread, the maximum number of buckets in BoDo can only be filled if the acceptance window is centered on the LINAC spectrum.
Injection into Delta, on the other hand, seems to work quite well. Figure 5 shows pickup signals from a Delta BPM close to the injection point compared to signals from the T2 pickup. Each bunch in T2 can be identified with a bunch in Delta showing an increase in bunch charge. Neither in the beginning nor in the end of the bunch train charge is lost. An integrating charge monitor in T2, which is currently also being commissioned will allow the absolute calibration of the bunch charge.

6 CONCLUSION

We have engineered and characterized a BPM body for use as a single shot BPM in the DELTA transfer channels. The device was equipped with a commercially available single shot BPM electronics. Two units are currently being commissioned as beam position monitors in the transfer channel T2. Bunch studies have been undertaken which provide data for injection optimization.

[3]LeCroy WavePro 950, 1GHz, 16 Gs/s

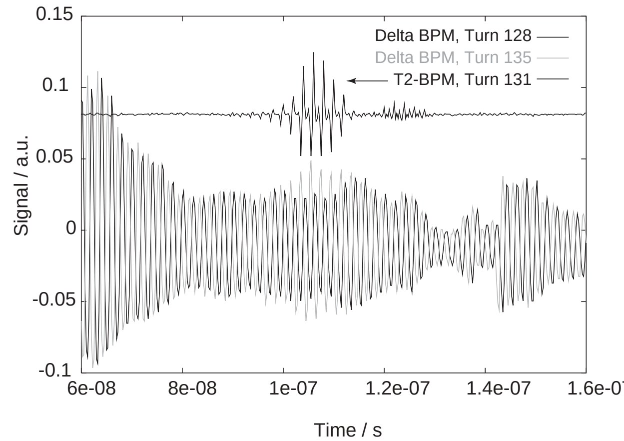

Figure 5: Injection through the transfer channel T2 into Delta. For better visibility Turn 128 is time shifted by 1ns.

7 CREDITS

The authors wish to thank the mechanical workshop of DELTA for an excellent machining job, the electronics workshop of the physics department for providing the fast scope and Miss Bea Braun for taking parts of the data during her traineeship at DELTA.

8 REFERENCES

[1] R. E. Shafer, AIP Conf. Proc. No. 281, pages 120-128

[2] Log-ratio BPM users manual, BERGOZ Instrumentation, Saint Genis Pouilly, France