Status of the actual Beam Position Monitors in the Hall C Beamline

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Abstract

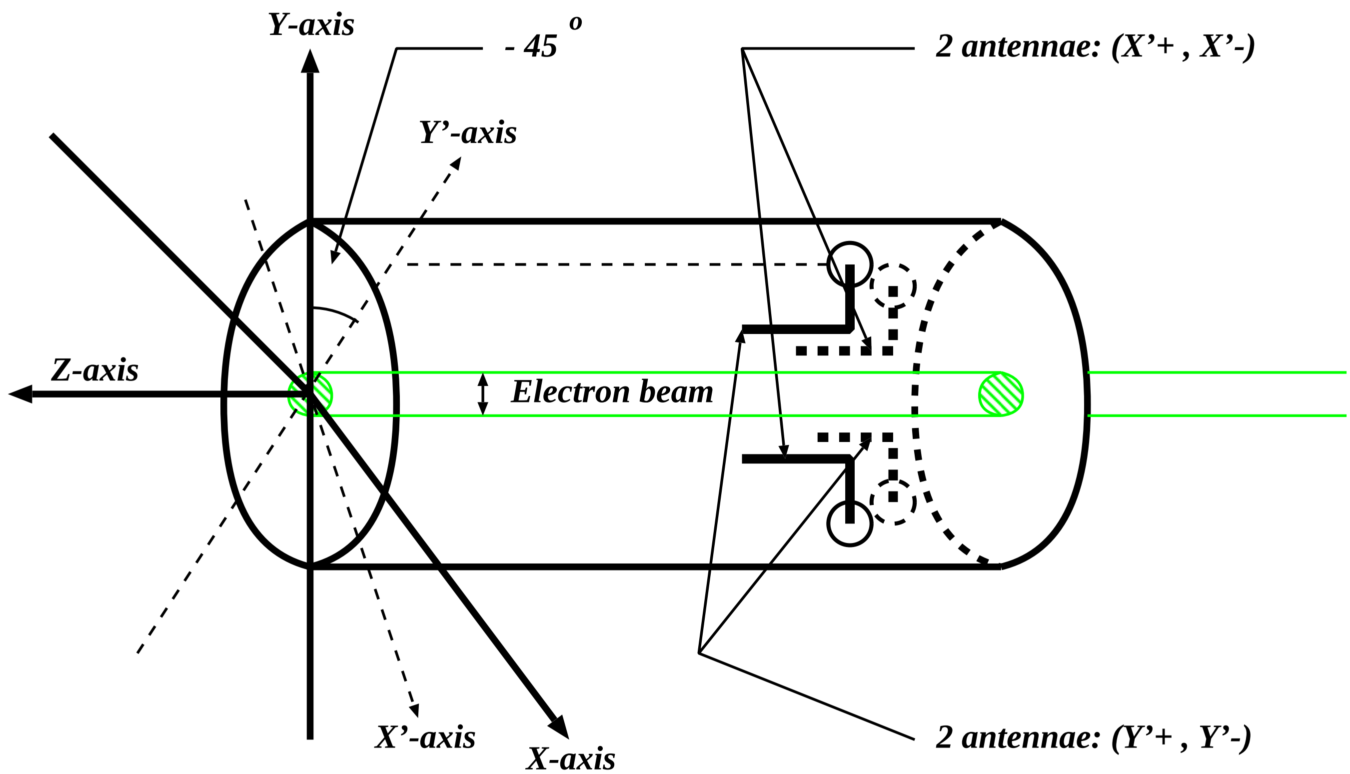
This document describes how the beam positions (horizontal-x and vertical-y) are calculated with the BPMs'four antennae signals. In addition, we have include some studies done during november 1995 which include a current dependence of the last two BPMs in the Hall C beamline (in front of the target) as well as a comparison with the last two superharps.

Contents

1 The Beam Position Monitor

1.1 Description

The Beam Position Monitor (BPM) is a cavity with four antennae rotated at -45^o. This angle is to prevent any damage from the synchrotron radiation:



1.2 Beam position calculation

When the beam passes through one of these cavities, the beam's fundamental frequency is picked up on each antennae. The amplitude of this detected signal is digitized and the beam's center of gravity is calculated on each axis:

$$X'_{pos}(t) = \kappa \frac{[X'_+(t) - (X'_+)^0] - \alpha_{X'}[X'_-(t) - (X'_-)^0]}{[X'_+(t) - (X'_+)^0] + \alpha_{X'}[X'_-(t) - (X'_-)^0]}$$

$$Y'_{pos}(t) = \kappa \frac{[Y'_+(t) - (Y'_+)^0] - \alpha_{Y'}[Y'_-(t) - (Y'_-)^0]}{[Y'_+(t) - (Y'_+)^0] + \alpha_{Y'}[Y'_-(t) - (Y'_-)^0]}$$

From the projection of the X' and Y' axis on the X and Y axis, the positions of the beam can be determined in two different ways:

- <u>Relative position</u>:

$$X_{rel}(t) = \frac{1}{\sqrt{2}} \times \{X'_{pos}(t) + Y'_{pos}(t)\} - X(t_0) \quad (1)$$

$$Y_{rel}(t) = \frac{1}{\sqrt{2}} \times \{-X'_{pos}(t) + Y'_{pos}(t)\} - Y(t_0) \quad (2)$$

- <u>Absolute position</u>:

$$X_{abs}(t) = \frac{1}{\sqrt{2}} \times \{X'_{pos}(t) + Y'_{pos}(t)\} - X_S - X_Q \quad (3)$$

$$Y_{abs}(t) = \frac{1}{\sqrt{2}} \times \{-X'_{pos}(t) + Y'_{pos}(t)\} - Y_S - X_Q \quad (4)$$

The absolute/relative positions of the CEBAF electron beam can be known each second ($1\ s$) and correspond to a sampling over 25 points.

Parameter	Comments
$[X,Y](t_0)$	Previous positions of the beam at t_0
$[X,Y]_S$	Offsets from the ideal trajectory of the beam
$[X,Y]_Q$	Offsets from the center of the quadrupole placed before the BPM
κ	Sensitivity of the BPM at 1497 MHz: $\kappa = 18.5\ mm$
α	Should be: $0.8 < \alpha < 1.25$
Voltage offsets	Must be: $(X'_+)^0 = (X'_-)^0 = (Y'_+)^0 = (Y'_-)^0 = 0$

1.3 Error sources

Two different kind of error sources have to be taken into account (see table below):

1. Intrinsic errors:
   - Δ_{curr}: is how far the beam position readout moves when the current changes for a same location of the beam;
   - Δ_{time}: is the smallest displacement that can be read by a BPM when the beam moves in time and for a specific frequency of the beam;
   - Δ_{rep}: is how far the beam position readout moves during a certain period of time.
2. Survey errors:
   - Δ_{ideal}: corresponds to the offset in the location of the center of the BPM's cavity versus the ideal trajectory of the beam inside the pipe;

Parameter	**BPM**	
	IPM3H00A	**IPM3H00B**
Electronic (Voltage offsets)		
$(X'_+)^0$	0	0
$(X'_-)^0$	0	0
$(Y'_+)^0$	0	0
$(Y'_-)^0$	0	0
Survey		
X_S	0.1100	0.0400
Y_S	-0.5200	-0.5600
Quadrupole		
X_Q	0	0
Y_Q	0	0
Calibration gain		
α_X	1.8192	0.7330
α_Y	1.0063	0.8935

- Δ_{quadr}: corresponds to the offset in the location of the center of the BPM's cavity versus the magnet placed just before it in the beamline.

Source	**Accuracy**
Position current dependence (Δ_{curr})	1 mm for $8 < I(\mu A) < 80$
Position time dependence (Δ_{time})	< 0.05 mm at 60 Hz
Reproducibility (Δ_{rep})	0.04 mm at 1 μA , 100 μs
Ideal trajectory of the beam (Δ_{ideal})	± 0.2 mm
Center of the quadrupole (Δ_{quadr}) (excluding IPM3H00A and IPM3H00B, in front of the target)	± 0.5 mm
Total accuracy (Δ^1_{tot}) (excluding IPM3H00A and IPM3H00B)	± 1.14 mm
Total accuracy (Δ^2_{tot}) (including IPM3H00A and IPM3H00B)	± 1.02 mm

1. Δ_{ideal} corresponds to the survey values. The number given above correspond to the survey values with the new grider installed in Hall C.

2. Δ_{curr} has been studied in 11/19/95 for $5.3 < I(\mu A) < 23$. The results are listed below for the last two BPMs (see section 3):

Position	**IPM3H00A**	**IPM3H00B**
X (mm)	$5.9 \Rightarrow 5.5$	$6 \Rightarrow 5.5$
ΔX (mm)	-0.4	-0.5
Y (mm)	$-5.0 \Rightarrow -5.0$	$-4.3 \Rightarrow -3.0$
ΔY (mm)	0	-1.3

1.4 Electronic problems

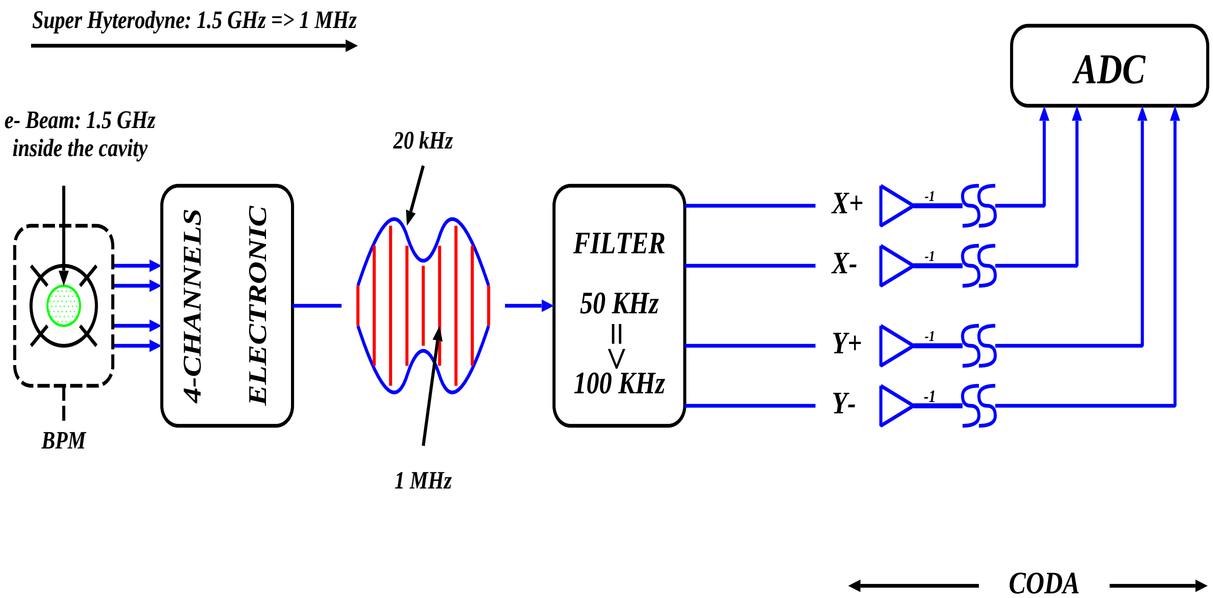
A study of the position dependence versus the frequency has been made on the 4 channel-BPMs. Different triangular wave frequencies were injected in the cavities. The results (readout from the BPMs) show a phase-shift frequency dependence (which is constant for each channel):

Frequency (kHz)	1	5	10	20
Phase-shift (Deg)	1.1	7.2	11.5	15.8
Uncertainty (μs)	< 2	< 2	< 2	< 2

2 Improvements

2.1 Electronics

The CEBAF electron beam passes through a BPM, the frequency which is excited is the 1497 GHz. The electronics beside the BPMs converts this 1.5 GHz to a modulate 1 MHz with a 20 kHz enveloppe (due to the raster system). This conversion (high frequency to low frequency) is possible via a super hyterodyne. For a triangular or a cubic wave (raster system), higher order harmonics contribute up to 100 kHz. **The previous** 50 kHz **filter** has been improved and has a band width of 100 kHz.

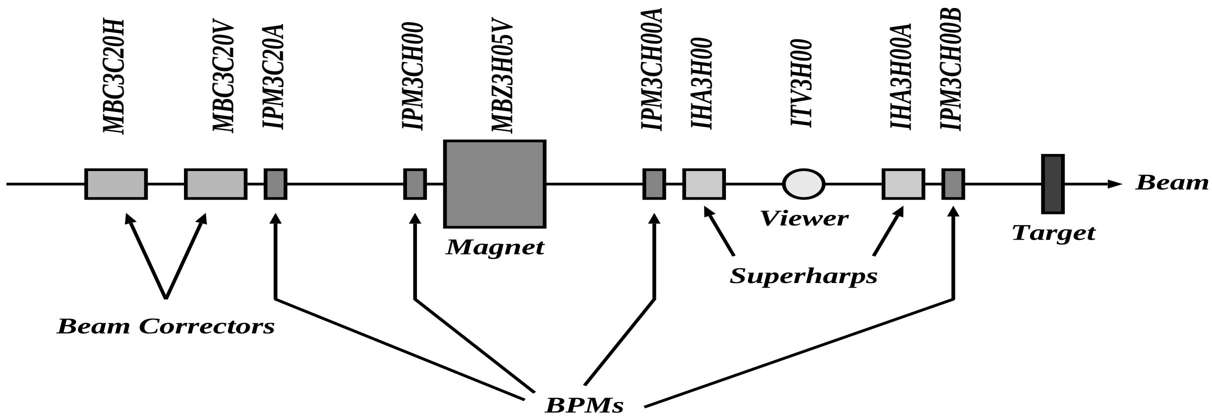


2.2 CODA

The four signals are recorded with CODA during a data acquisition task. Compare to the EPICS configuration which works at 60 Hz, the Hall C users can have a fast readout electronic up to 100 kHz.

3 Comparison BPMs/Superharps (november 1995)

In 11/19/95, a comparison has been made between the last BPMs (IPM3H00A and IPM3H00B) and the last Superharps (IHA3H00 and IHA3H00A). The X and Y positions were recorded for a current range $5.3 < I(\mu A) < 23$.



Element	Name	Distance from the target (m)
BPM	IPM3H00A	3.455
Superharp	IHA3H00	3.290
BPM	IPM3H00B	1.663
Superharp	IHA3H00A	1.473

	I (μA)	5.3	9.4	15	20	23
BPMs						
IPM3H00A	X (mm)	5.9	6.0	5.8	5.8	5.5
	Y (mm)	-5.0	-5.0	-5.0	-5.0	-5.0
IPM3H00B	X (mm)	6.0	7.0	6.8	6.5	5.5
	Y (mm)	-4.3	-45.0	-4.5	-3.8	-3.0
Superharps						
IHA3H00A	X (mm)	0.16	0.15	0.19	0.13	0.14
	Y (mm)	-0.34	-0.39	-0.37	-0.370	-0.47
IHA3H00B	X (mm)	-0.04	-014	-0.02	-0.29	-0.01
	Y (mm)	-0.23	-0.25	-0.51	-0.26	-0.44

References[1]

[1] **P. Gueye, E. Joe, R. Wallace:** *Status of the actual Beam Position Monitors in the Hall C Beamline*, **(October 1995)**

[2] **P. Gueye, C. Yan, R. Ent, D. Mack:** *Status of the actual Beamn Position Monitors in the Hall C Beamline: Electronic Fast Readout Study*, **(October 1995)**

[3] **S. Shaffner, A. Hofler:** *Software requirements for BPM control* **(june 1994)**

[4] **BPM/SEE systems:** *CEBAF Revision A* **(march 1994)**

[5] **G. Krafft, A. Hofler:** *How the Linac BPMs work*, **TN93-004 (1993)**

[1] [1] and [2] are available on $/cdaq/documents/NEWSTUFF\_HERE/bpm$