TUP079

DESIGN AND BEAM TEST OF SIX-ELECTRODE BPMS FOR SECOND-ORDER MOMENT MEASUREMENT

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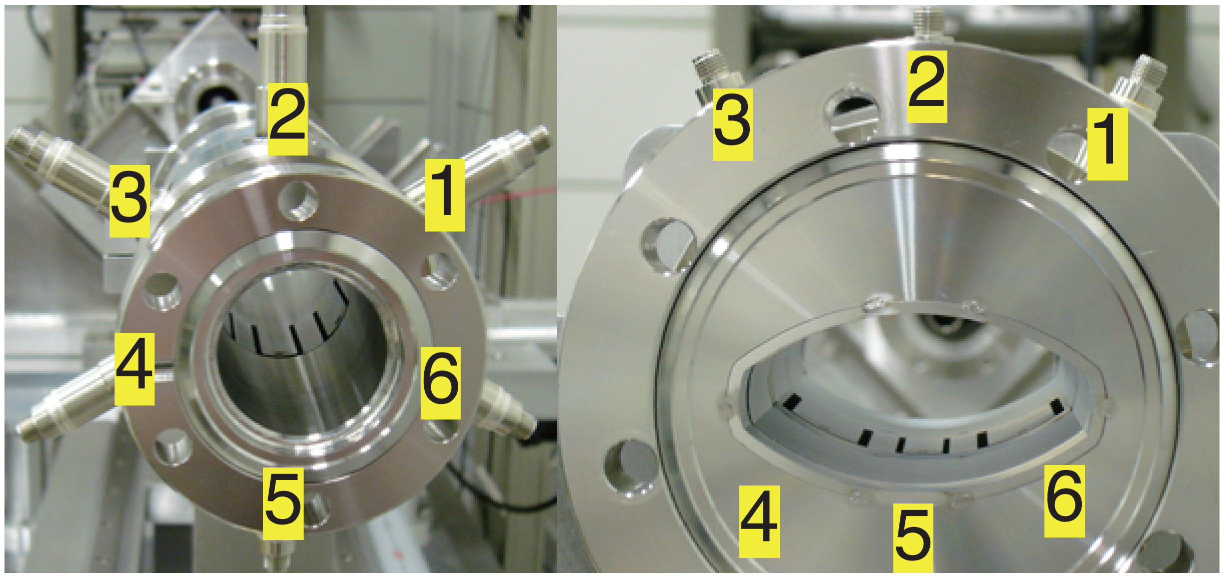
- The BPM system is being upgraded to a six-electrode BPM system in the SPring-8 LINAC.
- Purpose: To enhance the beam observation during the top-up operation
  -> Measurement of second-order moments
- We developed BPMs with circular and quasi-elliptical cross-sections.
- We present the BPM designs, the principle of the multipole moment measurement, and the beam test results.



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Absolute moments using six-electrode BPM

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- Absolute moments, **Pn**, **Qn**, are moments with respect to the duct center and obtained by taking voltage differences with nomarized moments.

$$P_1 = \frac{R_{P1}}{2}\frac{V_1 - V_3 - V_4 + V_6}{V_1 + V_3 + V_4 + V_6} \qquad Q_1 = \frac{R_{Q1}}{2}\frac{V_1 + V_3 - V_4 - V_6}{V_1 + V_3 + V_4 + V_6}$$

$$P_2 = \frac{R_{P2}^2}{2}\frac{kV_1 - 2V_2 + kV_3 + kV_4 - 2V_5 + kV_6}{kV_1 + 2V_2 + kV_3 + kV_4 + 2V_5 + kV_6} \qquad Q_2 = \frac{R_{Q2}^2}{2}\frac{V_1 - V_3 + V_4 - V_6}{V_1 + V_3 + V_4 + V_6}$$

$$Q_3 = \frac{R_{Q3}^3}{2}\frac{KV_1 - V_2 + KV_3 - KV_4 + V_5 + KV_6}{KV_1 + V_2 + KV_3 + KV_4 + V_5 + KV_6}$$

n: Order of multipole moment

Vd: Output voltage of electrode d (d = 1,...,6)

$\frac{R_{Pn}^n}{2}, \frac{R_{Qn}^n}{2}$: Normalized moment

R_{Pn}, R_{Qn} : Effective aperture radius

k, K : Geometrical Factors

Calculated : analytically (circular)
numerically (quasi-elliptical)

	Circular	Quasi-elliptical
R_{P1}	18.69 mm	18.03 mm
R_{Q1}	32.38 mm	54.84 mm
R_{P2}	18.91 mm	18.42 mm
R_{Q2}	17.59 mm	22.48 mm
R_{Q3}	16.57 mm	18.55 mm
k	1.000	1.918
K	1.000	3.056

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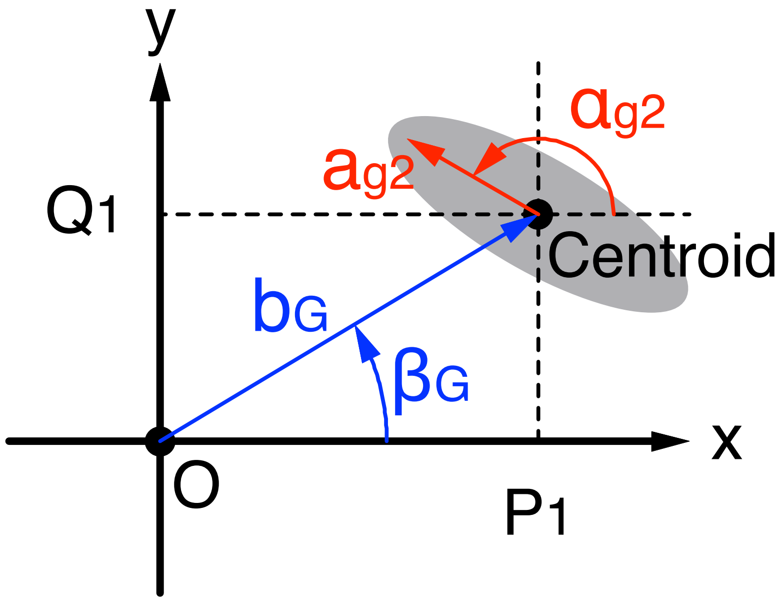
Relative moments extracted from absolute moments

- Absolute moments are complicated to compare the multipole moments taken by a screen monitor and a BPM, but relative moments are not.
- Relative moments, **P_{gn}**, **Q_{gn}**, are defined as the moments with respect to the beam centroid and extracted from the absolute moments.



$$P_1 = b_G \cos\beta_G$$

$$Q_1 = b_G \sin\beta_G$$

$$P_{g2} = a_{g2}^2 \cos 2\alpha_{g2} = P_2 - b_G^2 \cos 2\beta_G$$

$$Q_{g2} = a_{g2}^2 \sin 2\alpha_{g2} = Q_2 - b_G^2 \sin 2\beta_G$$

$$Q_{g3} = a_{g3}^3 \sin 3\alpha_{g3} = Q_3 - b_G^3 \sin 3\beta_G - 3b_G a_{g2}^2 \sin(\beta_G + 2\alpha_{g2})$$

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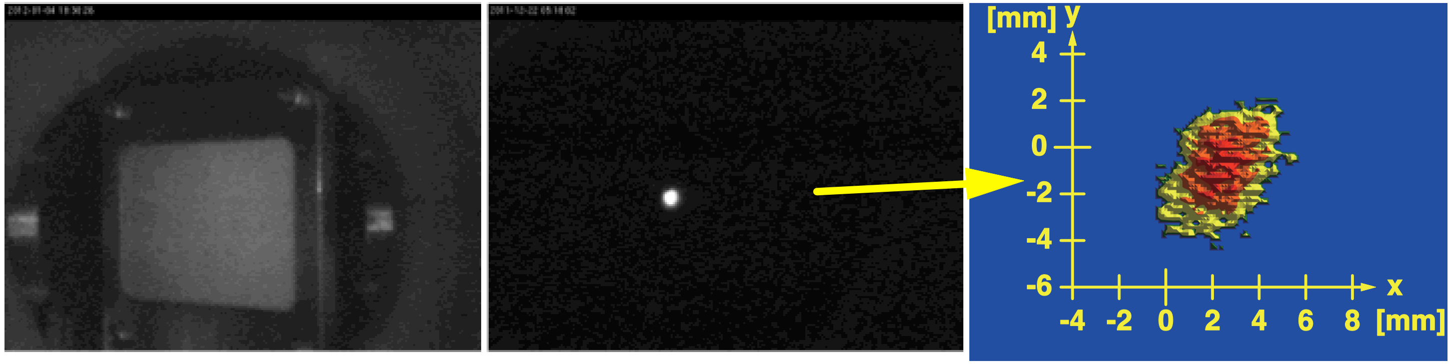
Screen monitor for relative moment measurement

- At the beam test, the relative moments were also measured by the screen monitor.
- $I(x_i, y_j)$: Intensity distribution on the screen
  (x_i, y_j): Position of data cell from screen center



P_1=2.334mm
Q_1=-0.989mm
P_{g2}=-0.391mm^2
Q_{g2}=1.366mm^2
Q_{g3}=0.161mm^3

$$m_{00} = \sum_i \sum_j I(x_i, y_j) \qquad m_{10} = \sum_i \sum_j x_i I(x_i, y_j)$$

$$m_{01} = \sum_i \sum_j y_i I(x_i, y_j) \qquad m_{20} = \sum_i \sum_j x_i^2 I(x_i, y_j)$$

$$m_{11} = \sum_i \sum_j x_i y_j I(x_i, y_j) \qquad m_{02} = \sum_i \sum_j y_j^2 I(x_i, y_j)$$

$$m_{21} = \sum_i \sum_j x_i^2 y_j I(x_i, y_j) \qquad m_{03} = \sum_i \sum_j y_j^3 I(x_i, y_j)$$

$$P_1 = \frac{m_{10}}{m_{00}} \qquad Q_1 = \frac{m_{01}}{m_{00}}$$

$$P_2 = \frac{m_{20} - m_{02}}{m_{00}} \qquad Q_2 = \frac{2m_{11}}{m_{00}}$$

$$Q_3 = \frac{3m_{21} - m_{03}}{m_{00}}$$

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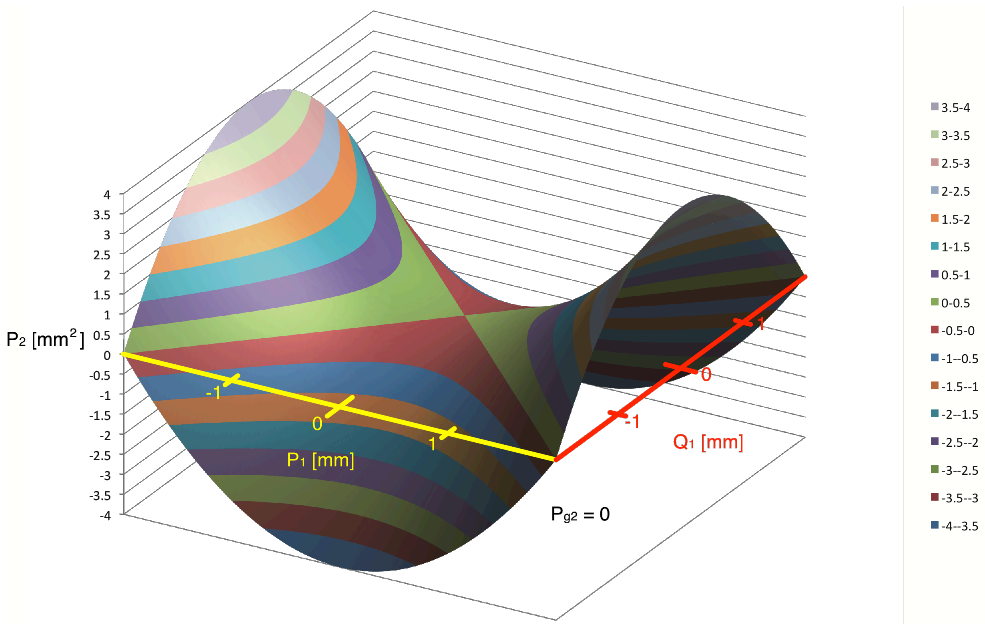
Entire calibration using electron beams

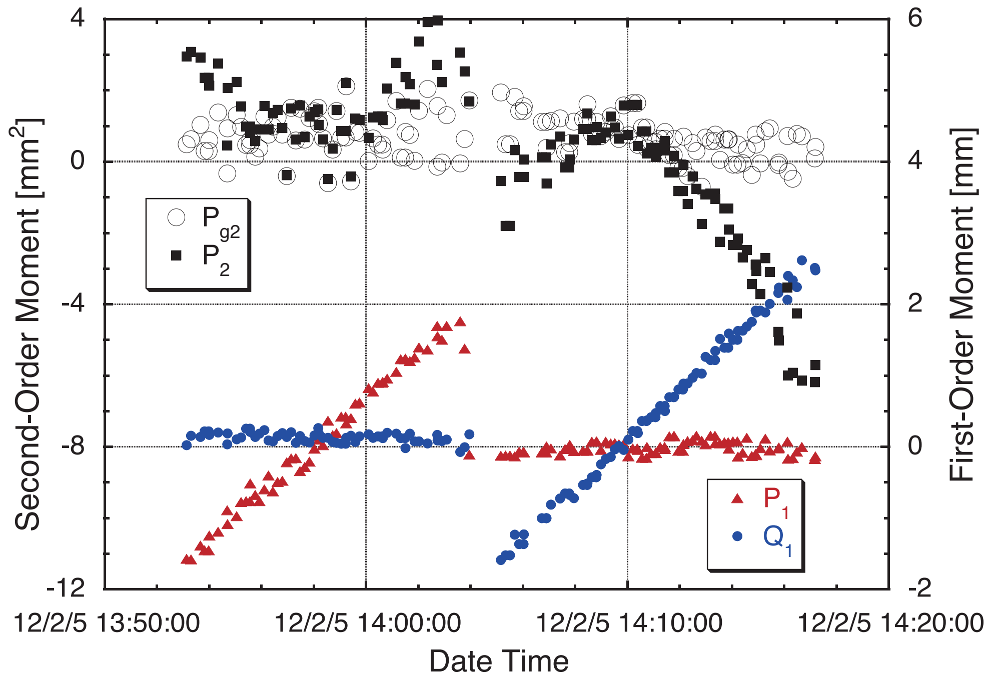
- Entire calibration: To determine relative attenuation factors between electrode channels

- Principle:

By means of steering magnets we change the position of the beam centroid.
-> Absolute moments, P_n, Q_n, vary.
But we do not change beam distribution with respect to the beam centroid.
-> Relative moments, P_{gn}, Q_{gn}, do not vary.



Simulationtion of entire cal. for P_2
$P_{g2}=0$ (constant), $Q_{g2}=0$ (constant)



Beam test result of entire cal.

Correlation measurement

- We compared the second-order relative moments taken by **screen monitor (abscissa)** to those taken by **BPM (ordinate)** when we changed beam intensity distribution by changing magnetic field of upstream quadrupole magnet.

- Correlation plot apparently indicates **direct proportionality relation** with **proportionality coefficient of 1**.

-> Important consequences

- Such BPMs with stripline-type electrodes, **normalized moments** can be **obtained accurately by analytical or maybe numerical electrostatic field calculation**.

- **Entire calibration** is **useful** as is **self-consistent method for precise calibration** to determine relative attenuation factors between electrode channels.