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EMITTANCE MEASUREMENT FOR SPring-8 LINAC USING FOUR SIX-ELECTRODE BPMS

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Purpose

- To measure emittances and Twiss parameters easliy like as daily (routine) operation.
- Using profile monitors is difficult to gather all signal elements for calculating r.m.s. beam size, because of signal saturation or reduction to noise level.

=>Use six-electrode BPMs and
measure second-order relative moment.

Note:
Second-order relative moment P_{g2} is
difference of square of r.m.s. beam size, $P_{g2} = \sigma_H^2 - \sigma_V^2$,
and easily derived from signal differecce.

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Contents of this talk

- Higer-order moment correction for signal difference.
- Effective aperture radius.
- Entire Calibration.
- Emittance measurement by Q-scan method.

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Higer-order moment correction for signal difference

- Correction : To minimize moment calculation error.

Roughly $-1 < \Delta P_{g2} < 1$ [mm^2] ($-\mathbf{X} < P_1, Q_1 < \mathbf{X}$ [mm])

- Definition of mth-order signal difference : C_m, S_m.

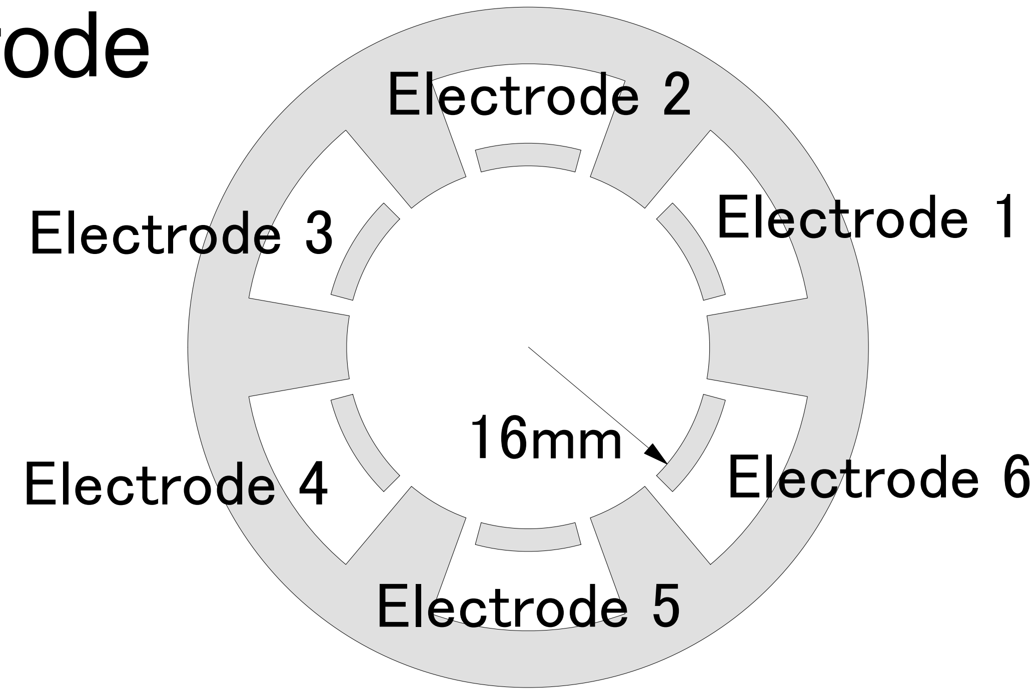
V_d : Voltage from dth-electrode

$$C_1 = \frac{V_1 - V_3 - V_4 + V_6}{V_1 + V_3 + V_4 + V_6}$$

For horizontal position P_1

$$S_1 = \frac{V_1 + V_3 - V_4 - V_6}{V_1 + V_3 + V_4 + V_6}$$

For vertical position Q_1



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Higer-order moment correction for signal difference

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- Without correction (2012)

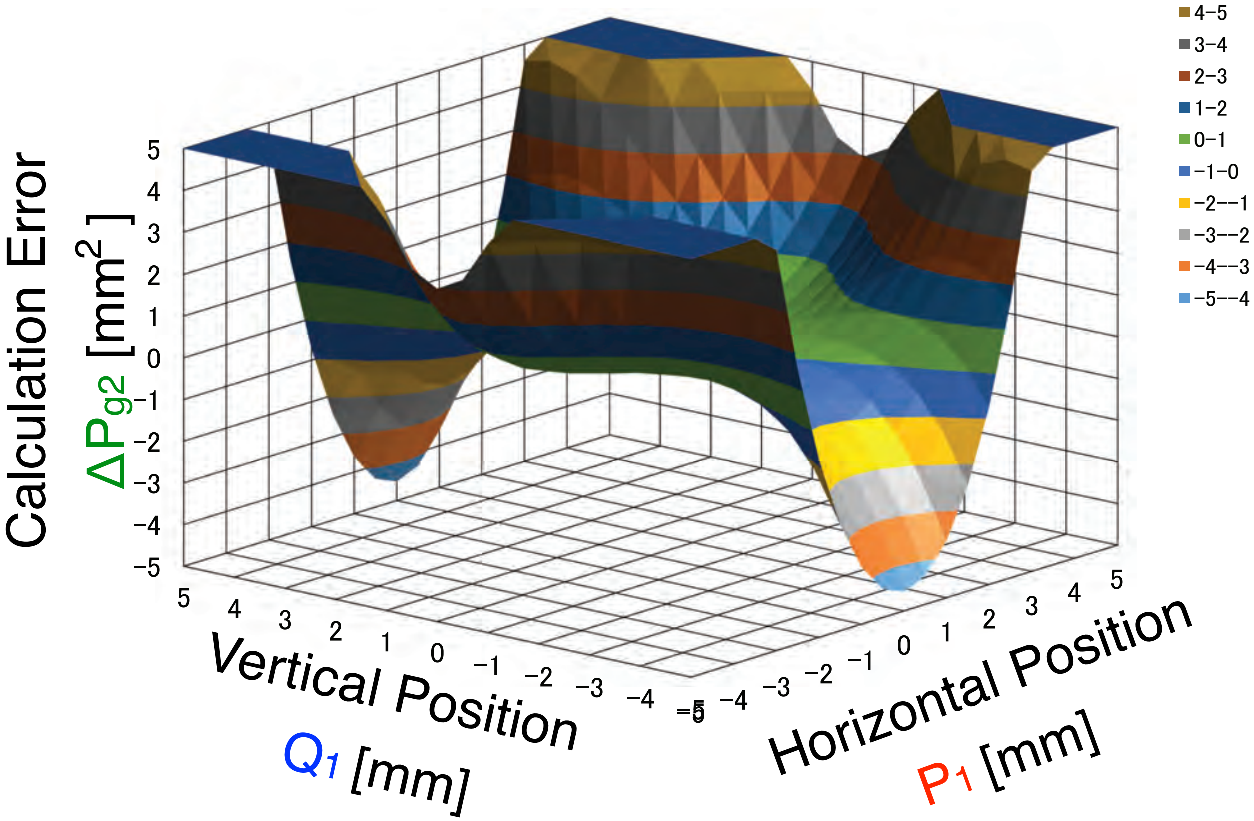
$$C_1 \approx \frac{2}{R_{C1P1}} P_1$$

$$S_1 \approx \frac{2}{R_{S1Q1}} Q_1$$

Effective aperture radius

R_{C1P1} : 18.688 [mm]

R_{S1Q1} : 32.368 [mm]



Roughly $-1 < \Delta P_{g2} < 1$ [mm^2] (**$-1 < P_1, Q_1 < 1$** [mm])

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Higer-order moment correction for signal difference

- With up to third-order moments (2013)

nth-order absolute moments : P_n, Q_n.

$$C_1 \approx \frac{2P_1}{R_{C1P1}}\left(1-\frac{2P_2}{R^2_{C1P2}}\right)+\frac{2P_3}{R^3_{C1P3}}$$

$$S_1 \approx \frac{2Q_1}{R_{S1Q1}}\left(1-\frac{2P_2}{R^2_{S1P2}}\right)+\frac{2Q_3}{R^3_{S1Q3}}$$

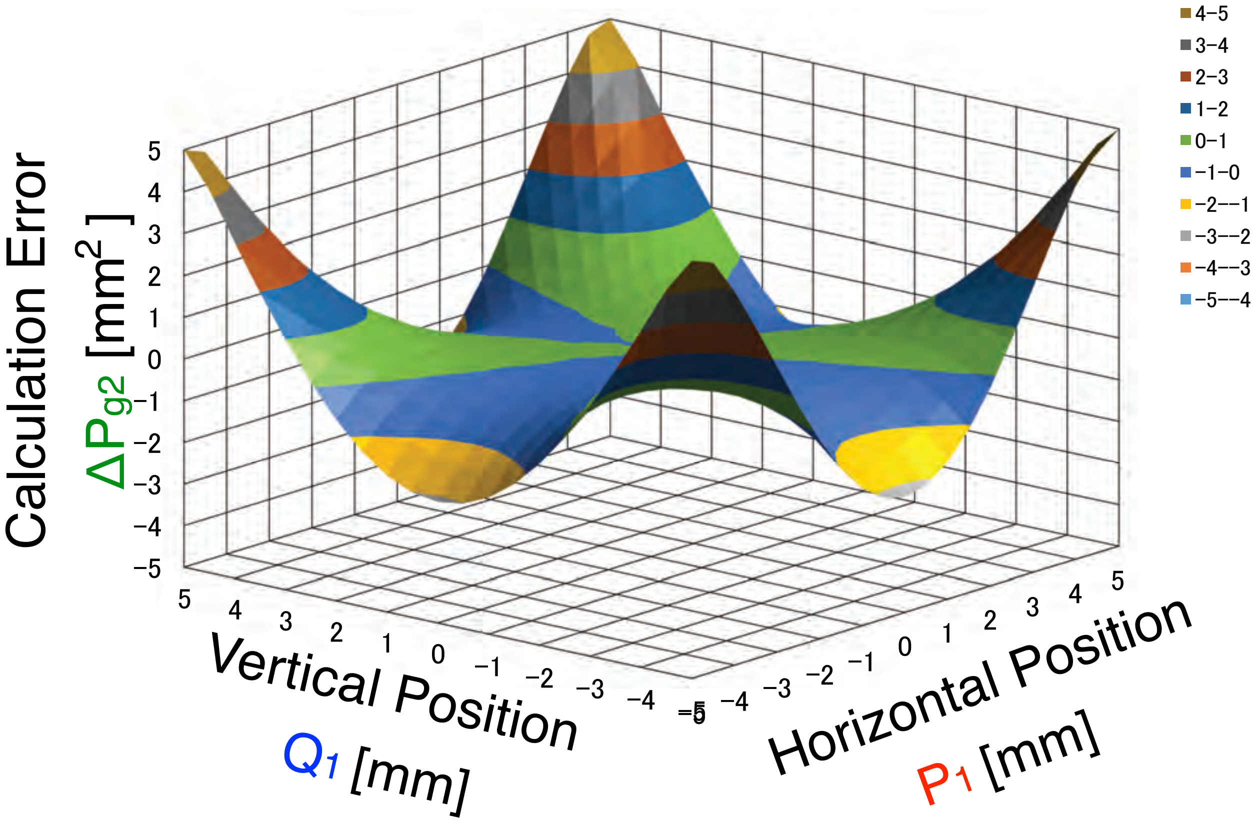
Effective aperture radius

R_{C1P2} : 23.155 [mm]

R_{C1P3} : infinity [mm]

R_{S1P2} : 23.155 [mm]

R_{S1Q3} : 16.570 [mm]



Roughly -1 < ΔP_{g2} < 1 [mm^2] (**-3** < P_1, Q_1 < **3** [mm])

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Higer-order moment correction for signal difference

- With up to fifth-order moments (2014)

$$C_1 \approx \frac{2P_1}{R_{C1P1}}\left(1 - \frac{2P_2}{R_{C1P2}^2} + \frac{4P_2^2}{R_{C1P2}^4} + \frac{2P_4}{R_{C1P4}^4}\right) + \frac{2P_3}{R_{C1P3}^3} - \frac{2P_5}{R_{C1P5}^5}$$

$$S_1 \approx \frac{2Q_1}{R_{S1Q1}}\left(1 - \frac{2P_2}{R_{S1P2}^2} + \frac{4P_2^2}{R_{S1P2}^4} + \frac{2P_4}{R_{S1P4}^4}\right) + \frac{2Q_3}{R_{S1Q3}^3} + \frac{2Q_5}{R_{S1Q5}^5}$$

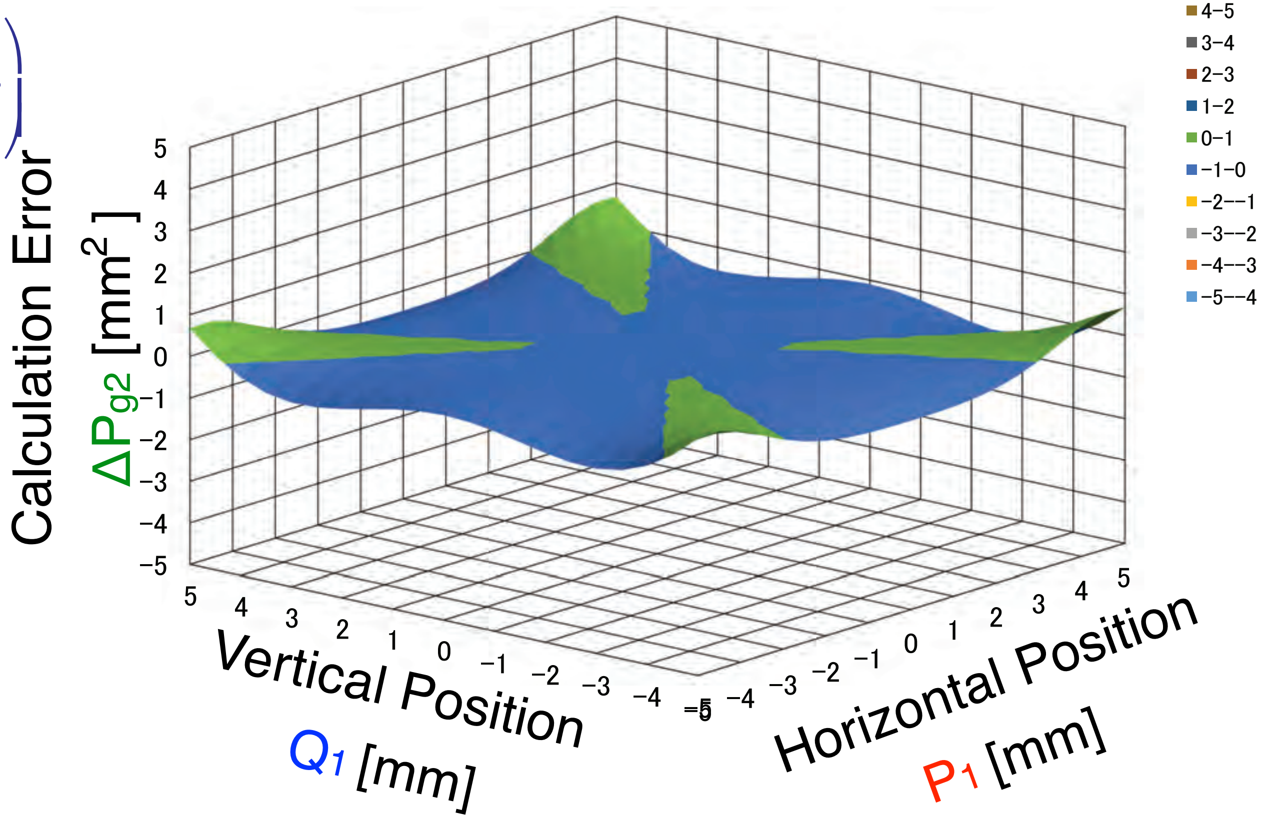
Effective aperture radius

R_{C1P4} : 19.953 [mm]

R_{C1P5} : 17.499 [mm]

R_{S1P4} : 19.953 [mm]

R_{S1Q5} : 19.531 [mm]



Roughly $-1 < \Delta P_{g2} < 1$ [mm^2] (**-5** $< P_1, Q_1 <$ **5** [mm])

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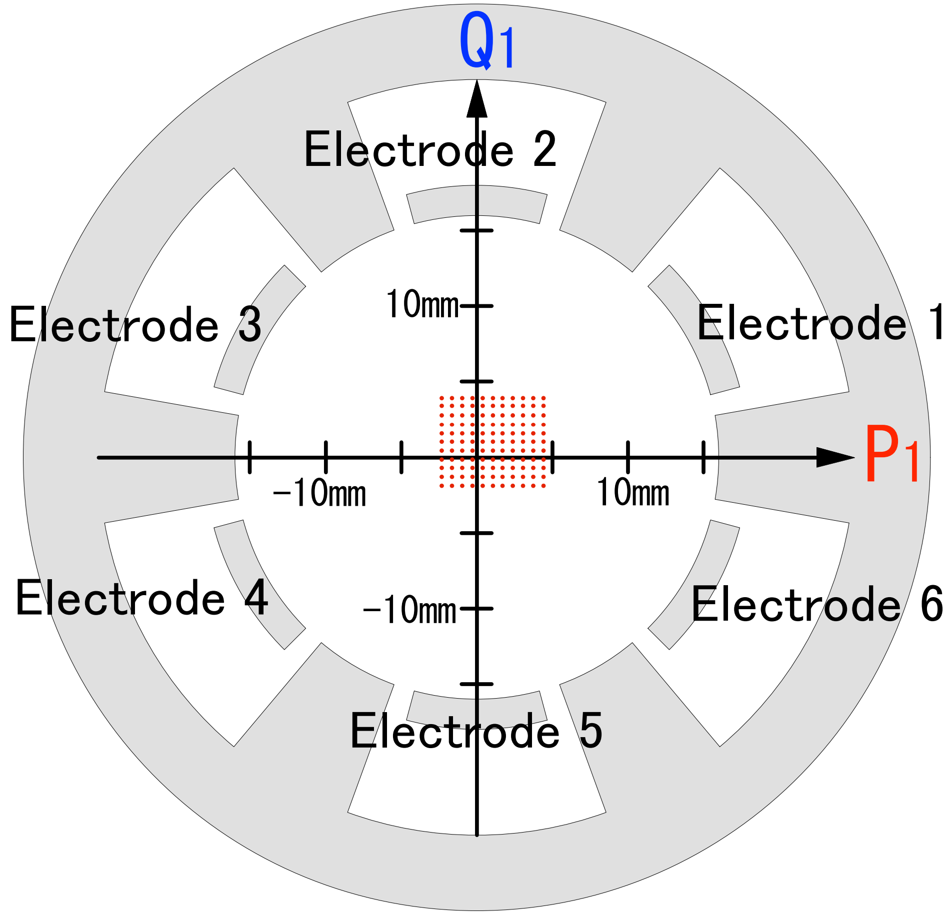
Entire Calibration

- The concept was presented at LINAC2012.
- Absolute moment was **changed** by steering magnet.
- Relative moment was **not changed** by steering magnet.
- We deduce the relative attenuation factors between electrode channels.



Red circles : Scanned beam positions P_1, Q1

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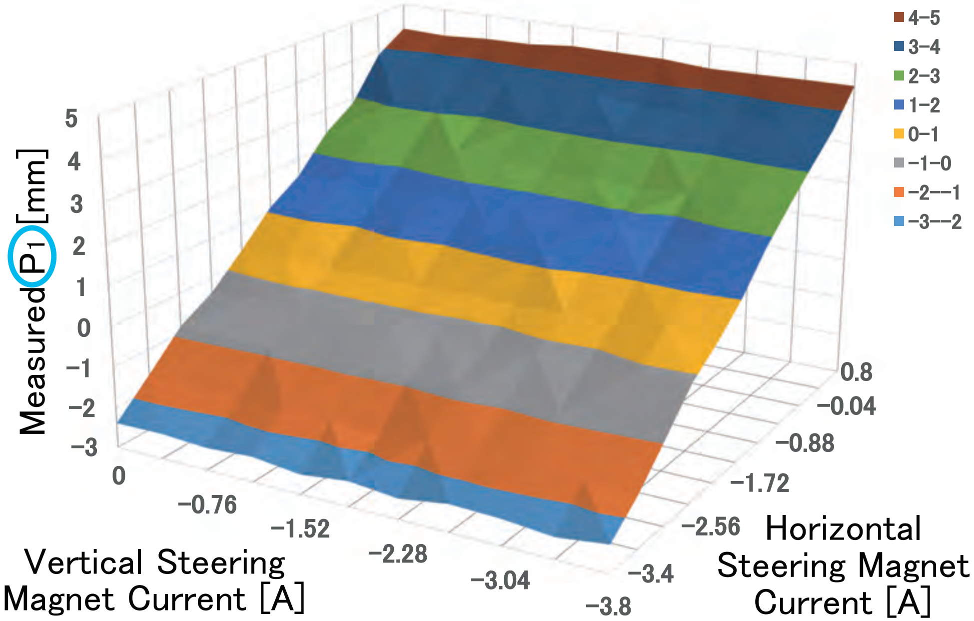
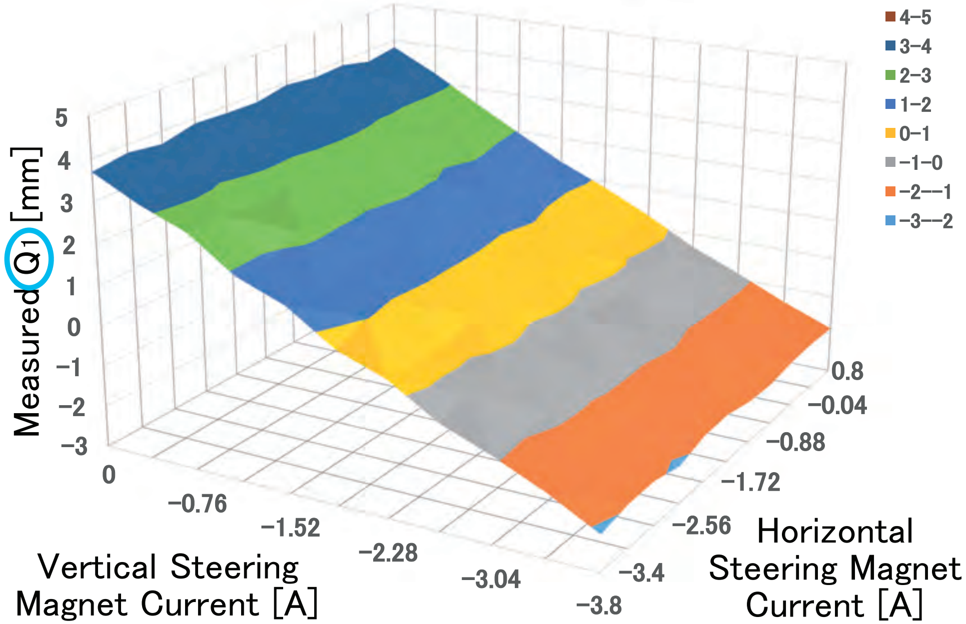
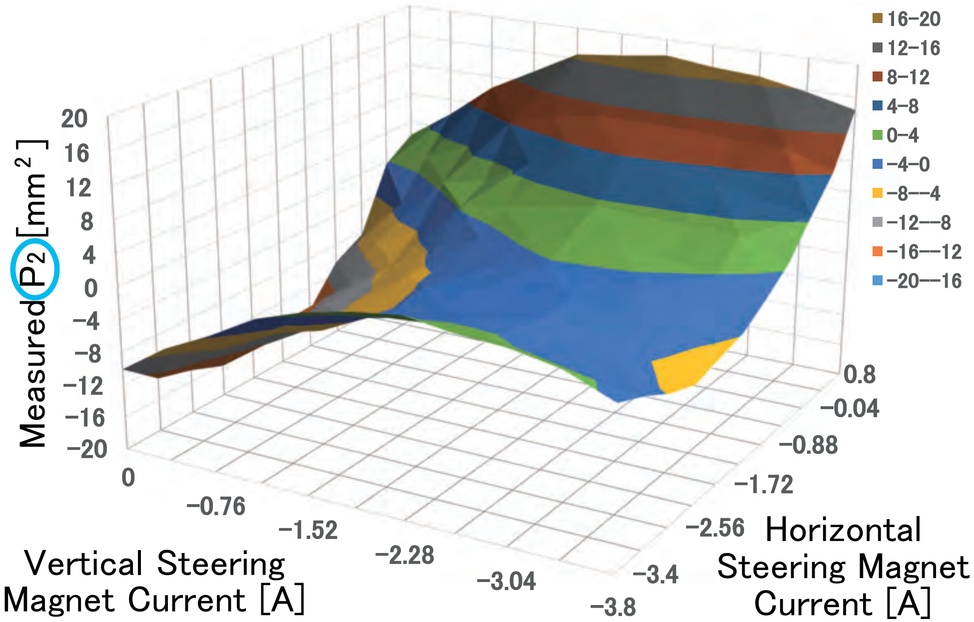
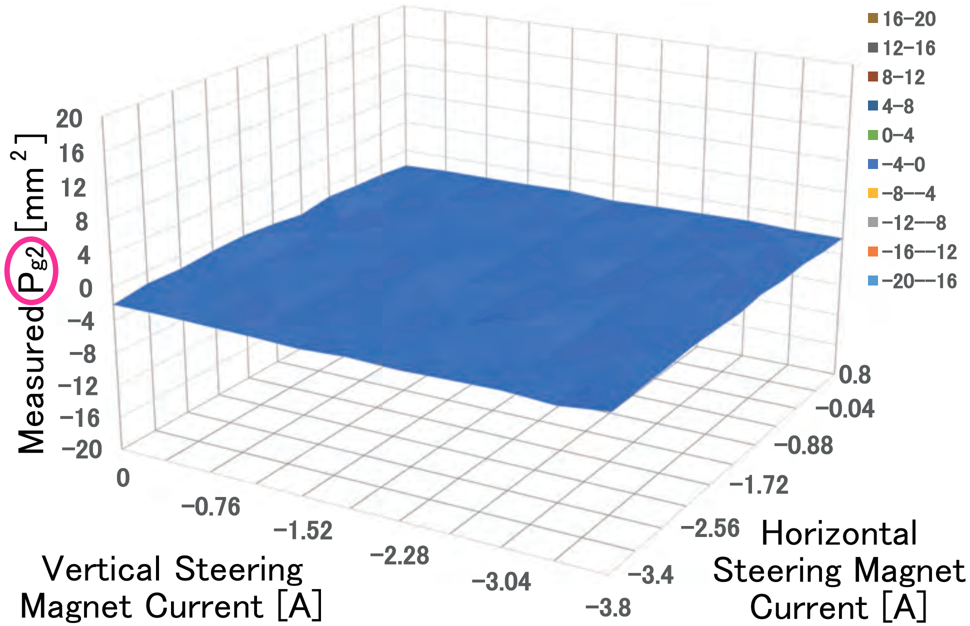
Entire Calibration

- Typical measured moments in entire calibration.









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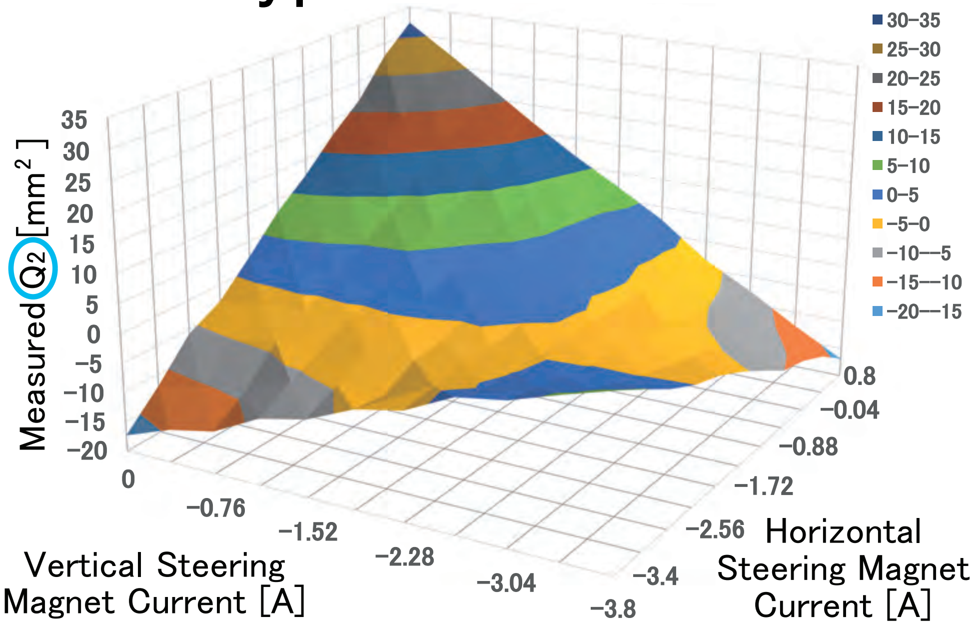
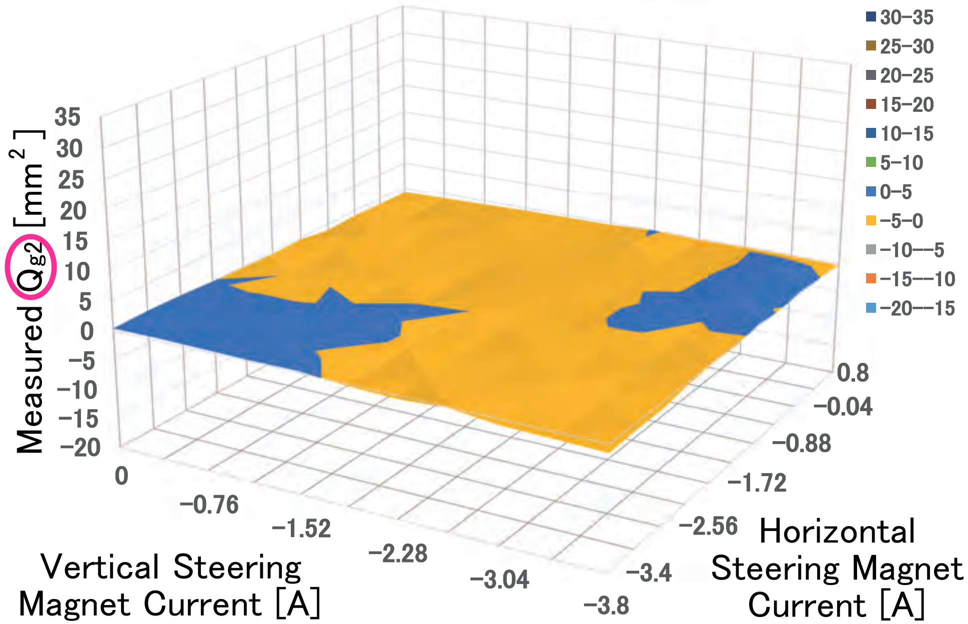
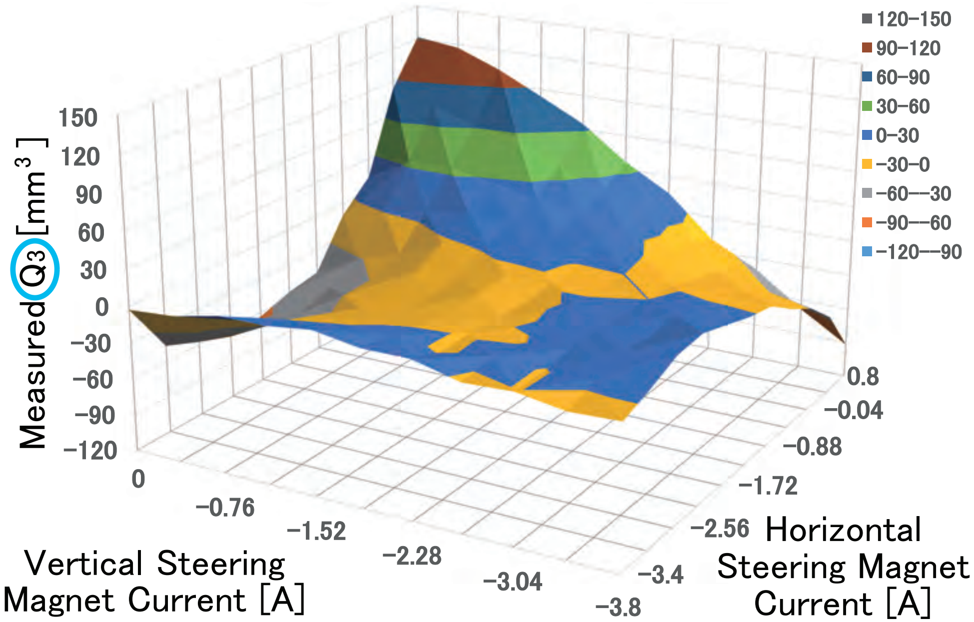
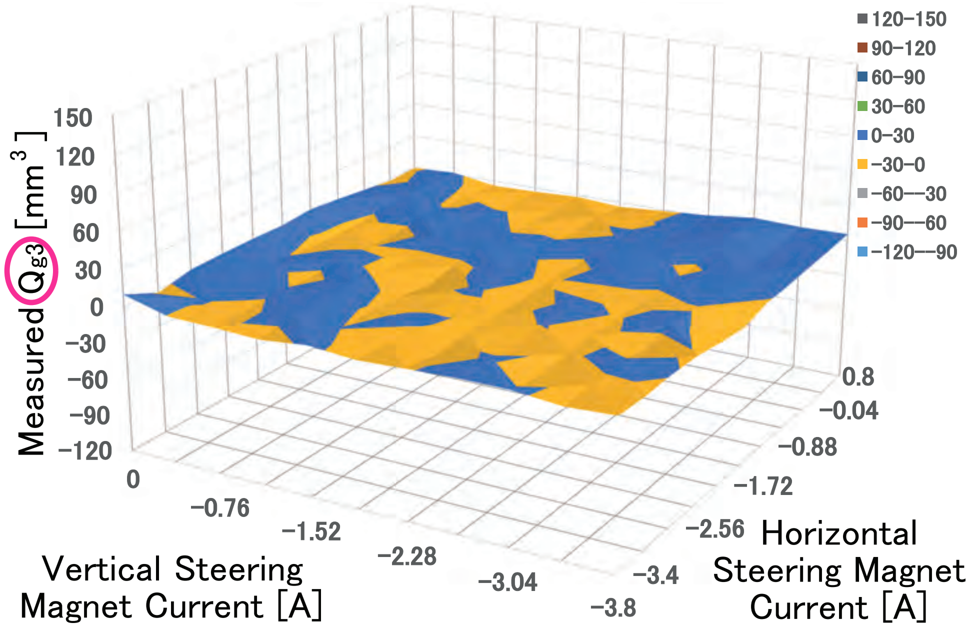
Entire Calibration

- Typical measured moments in entire calibration.









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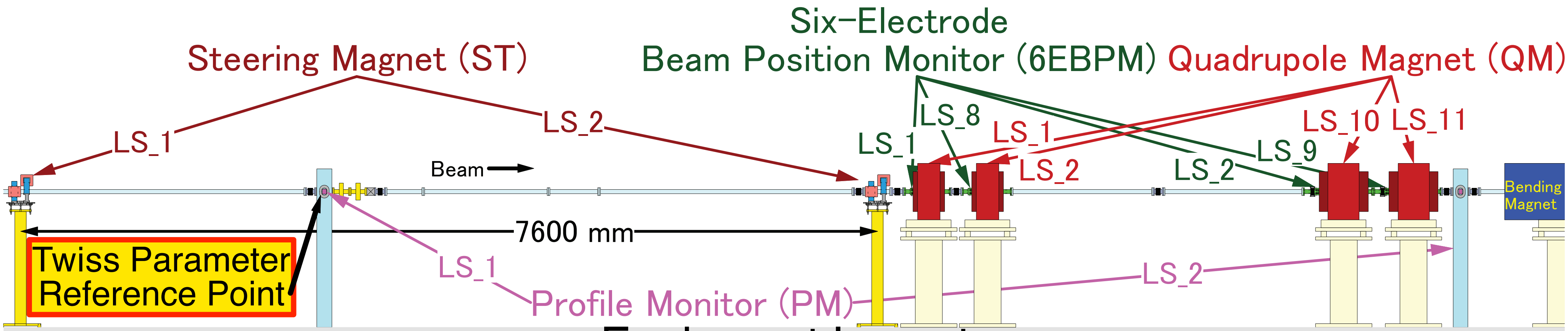
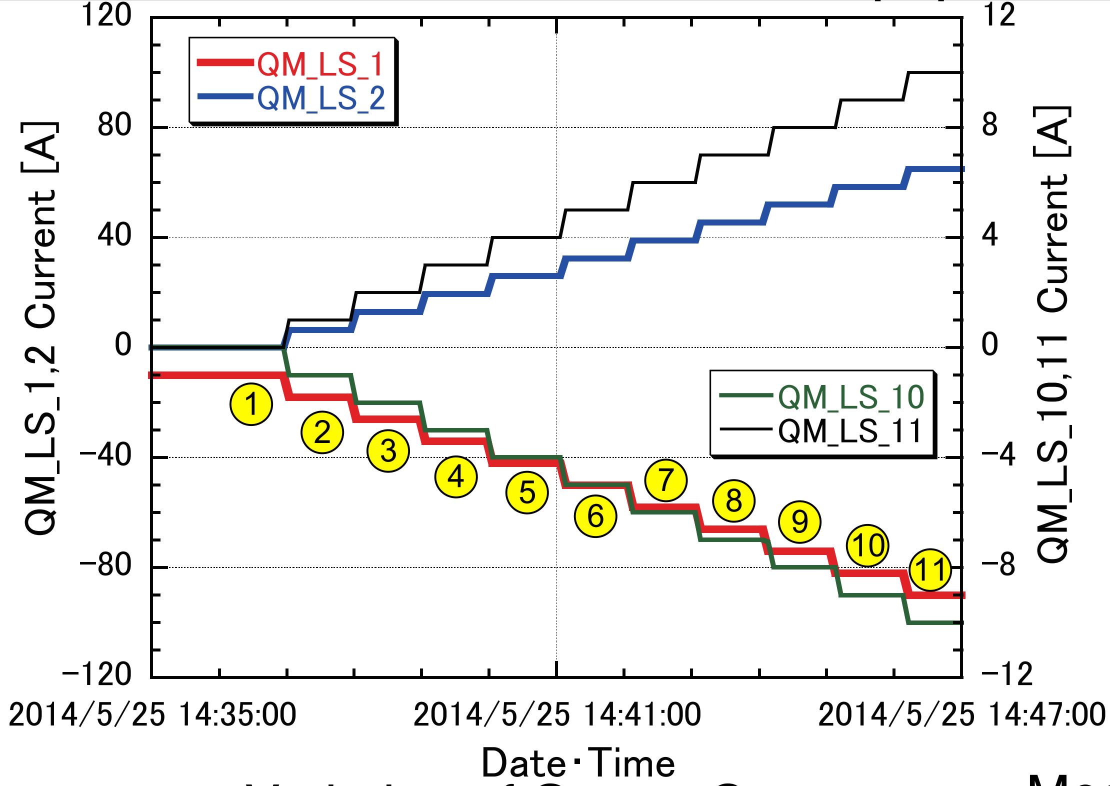
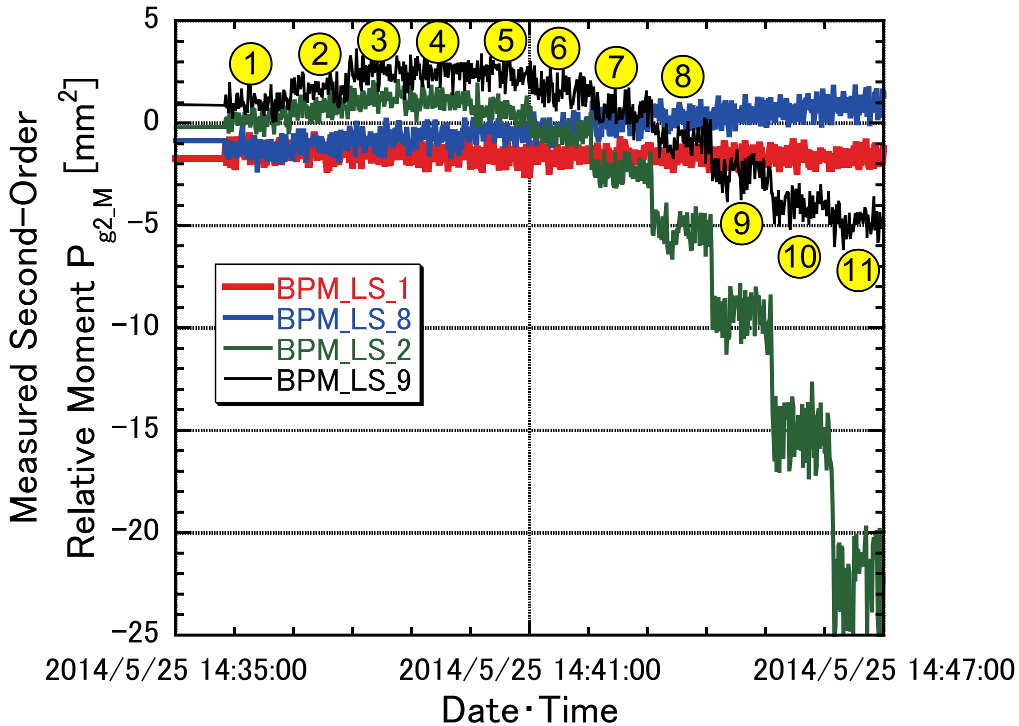


Equipment Layout



Variation of Q-mag Currents



Measured Secon-Order Relative Moments P_{g2_M}

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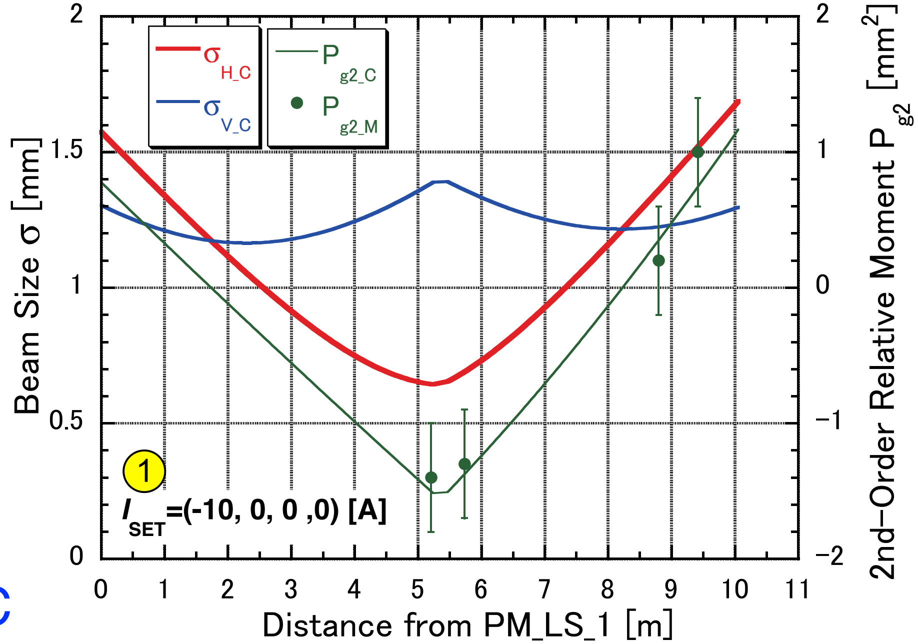
Deduced Emittances and Twiss Parameters

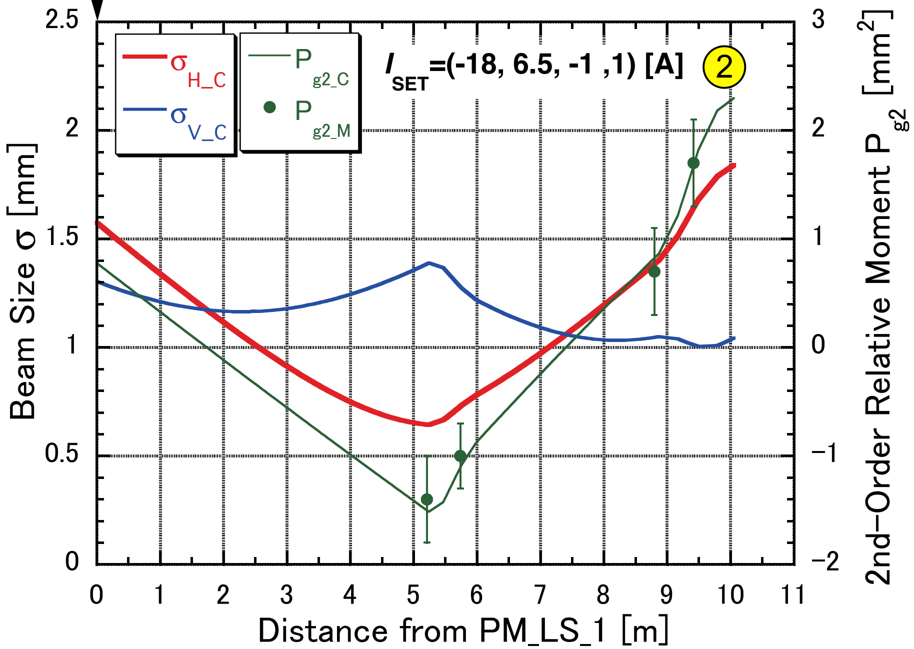
Parameter	Horizontal	Vertical
ε [πmm · mrad]	0.168 ± 0.002	0.299 ± 0.001
β [m]	14.7 ± 0.1	5.7 ± 0.2
α	2.25 ± 0.04	0.50 ± 0.03

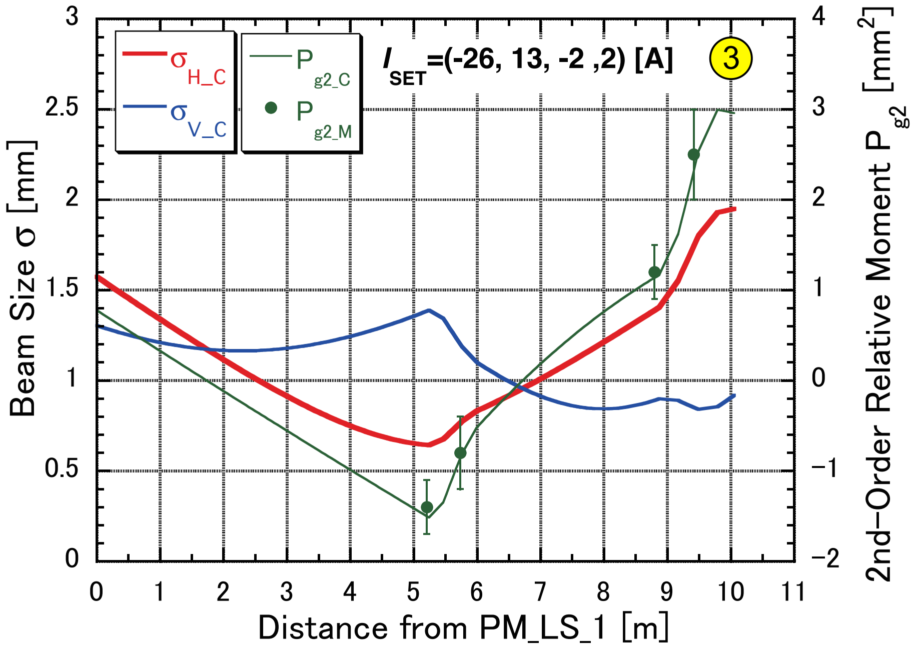


All P_{g2_C} and P_{g2_M} are agree within error bars.

Twiss Parameter Reference Point

$$P_{g2\_C} = \sigma^2_{H\_C} - \sigma^2_{V\_C}$$





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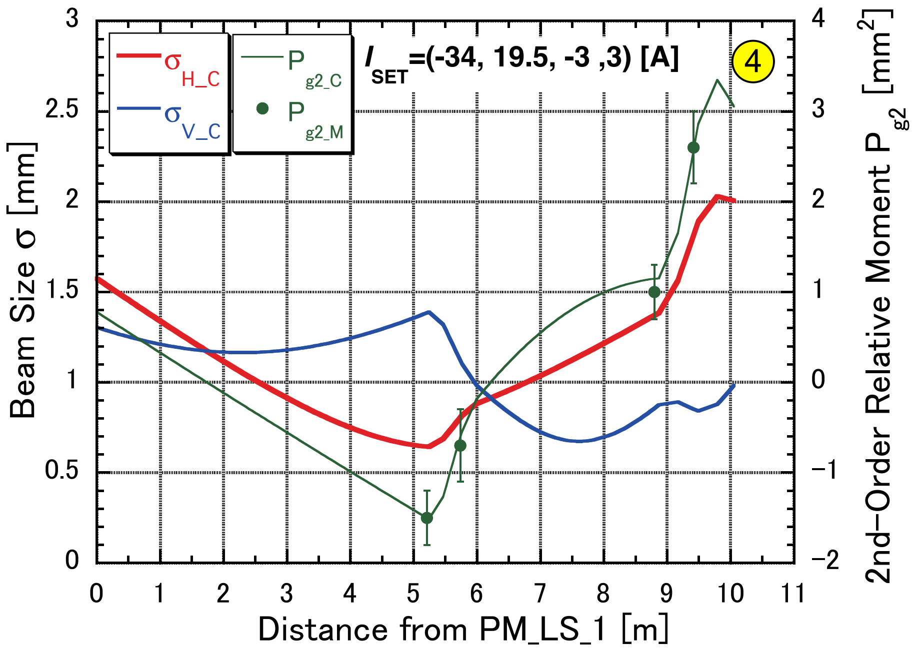

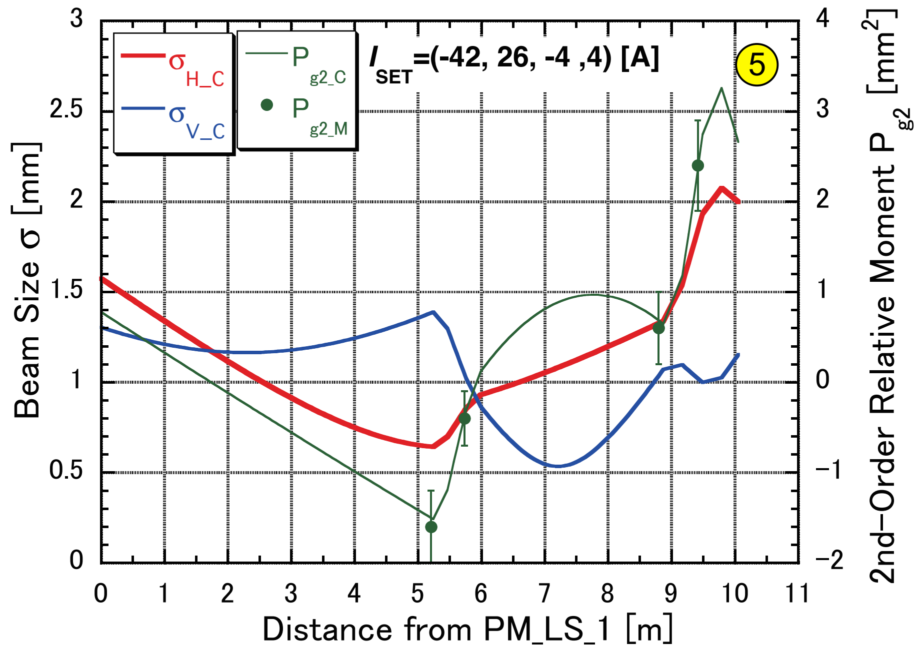

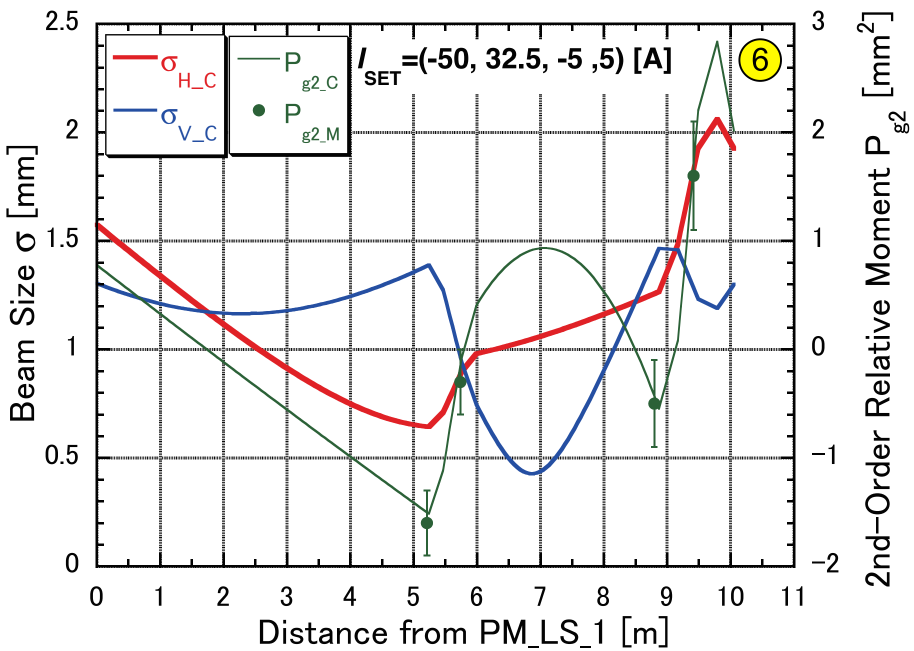

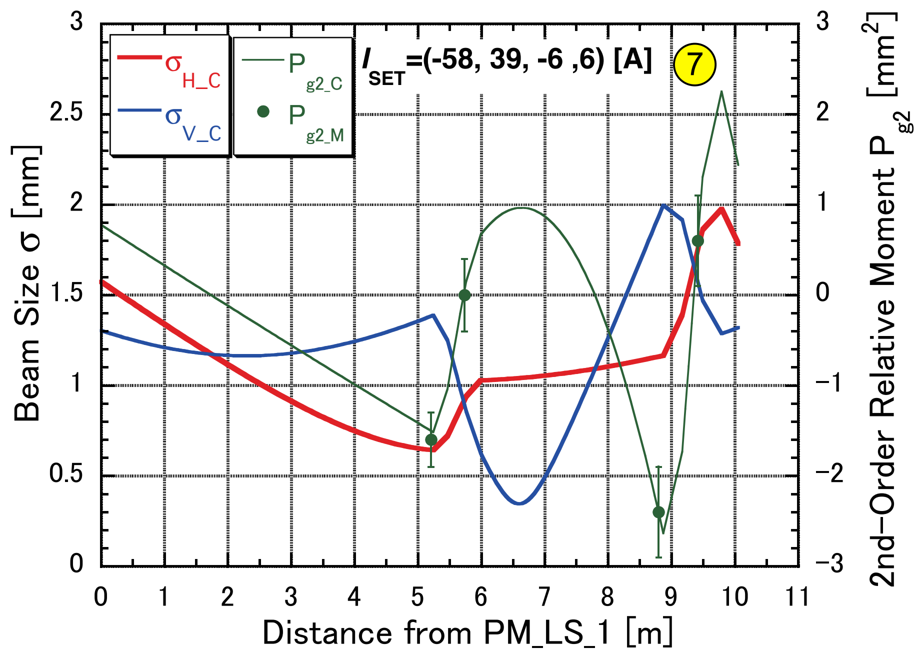

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