IPBPM as bunch tilt monitor ?

ATF2 Project Meeting 2014.02

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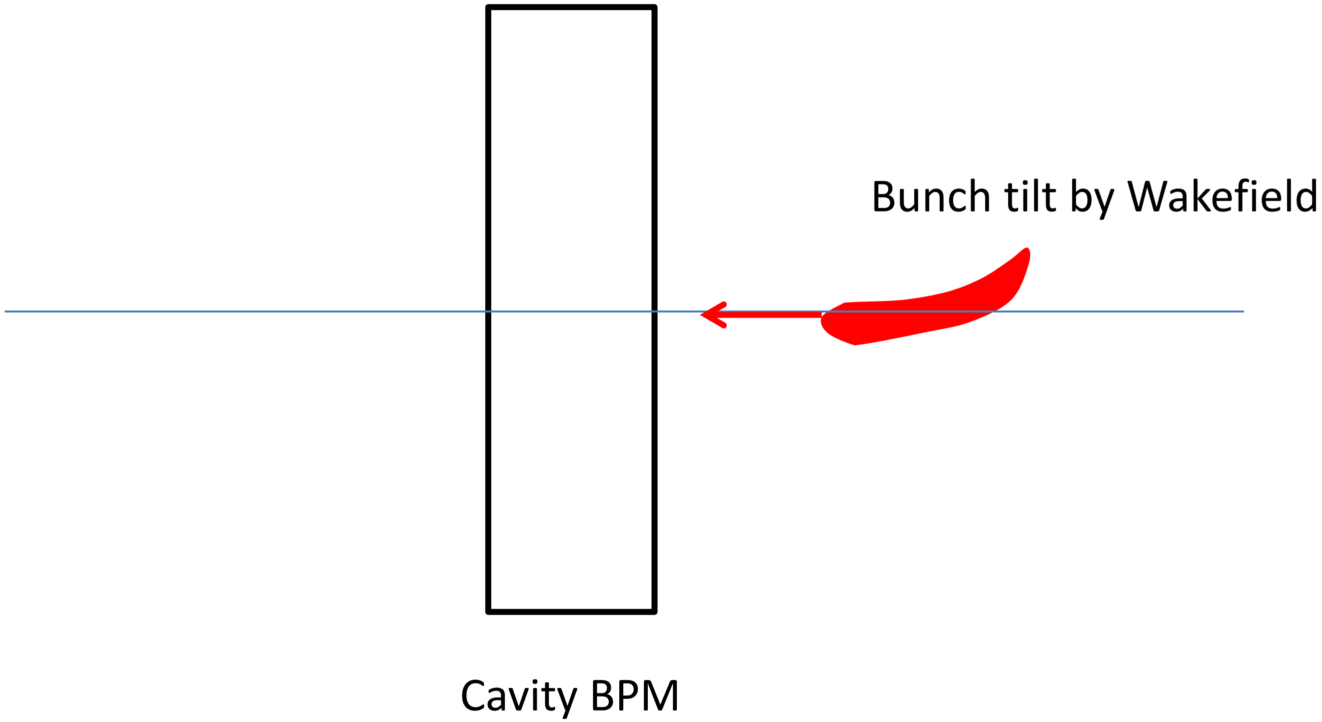

Bunch tilt by Wakefield
Cavity BPM

Sensitivity estimation by Two particle model

y : Offset of bunch center

θ : Angle of bunch center

Δy : Head - tail position difference

$\Delta\theta$: Head - tail angle difference

ω : $2\pi \times$ resonance freq. (~ 6.5 GHz)

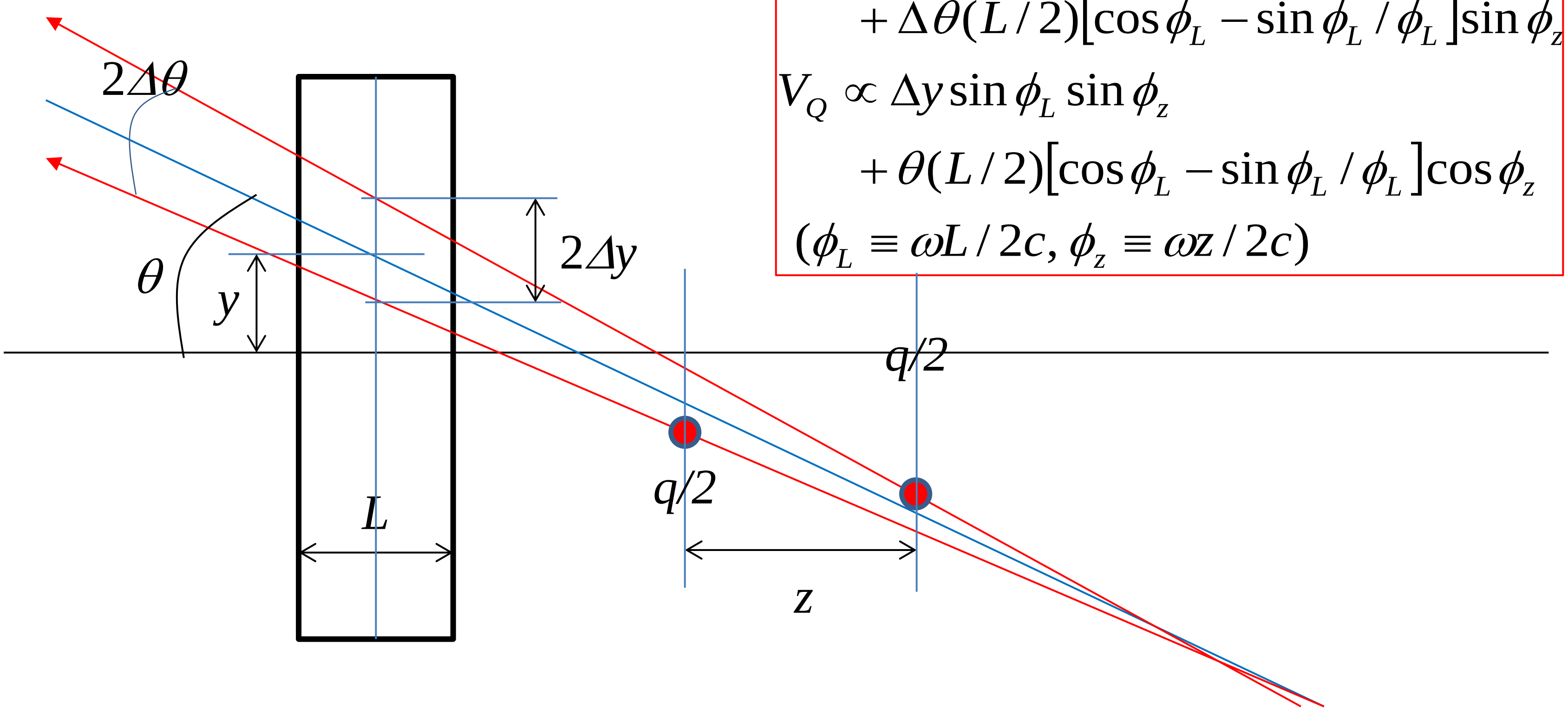
z : Distance between head and tail $\approx 2\sigma_z \approx 16$ mm

L : Effective Length of Cavity ~ 12 mm (?)

$$V_I \propto y_0 \sin\phi_L \cos\phi_z + \\ + \Delta\theta(L/2)\left[\cos\phi_L - \sin\phi_L/\phi_L\right]\sin\phi_z$$

$$V_Q \propto \Delta y \sin\phi_L \sin\phi_z \\ + \theta(L/2)\left[\cos\phi_L - \sin\phi_L/\phi_L\right]\cos\phi_z$$

$$(\phi_L \equiv \omega L/2c,\ \phi_z \equiv \omega z/2c)$$



Relative sensitivity

$$V_I = Ay_0 + B\Delta\theta$$
$$V_Q = C\Delta y + D\theta$$

$\omega : 2\pi \times \text{resonance freq.} (\sim 6.5\,\text{GHz})$

$z : \text{Distance between head and tail} \approx 2\sigma_z \approx 16\,\text{mm}$

$L : \text{Effective Length of Cavity} \sim 12\,\text{mm} (?)$

$$\left.\begin{array}{l} y_0 = 100\,\text{nm} \\ \theta = 31\,\mu\text{rad} \\ \Delta y = 53\,\text{nm} \\ \Delta\theta = 16\,\mu\text{rad} \end{array}\right\} \text{same signal amplitude}$$

$$B/A = 6.26 \times 10^{-3}\,\text{m/rad}$$
$$C/A = 1.9$$
$$D/A = 3.27 \times 10^{-3}\,\text{m/rad}$$

Beam at IP

$$\sigma_y{}^* \sim 37\,\text{nm}$$
$$\sigma_{y'}{}^* \sim 350\,\mu rad$$

Single BPM (two particle model)

- Set waist at one IPBPM
- Can Q-signal be used for detecting head-tail position difference?

Probably no, or difficult?

$$\sigma_y^* \sim 37\,\text{nm}$$
$$\sigma_{y'}^* \sim 350\ \mu rad$$

$$\left.\begin{array}{l}\theta = 31\ \mu\text{rad}\\ \Delta y = 53\ \text{nm}\end{array}\right\}\text{same signal amplitude}$$

$$Q\ \text{signal from}\ \ \Delta y \sim \sigma_y^* \sim 37\text{nm}$$
$$<< Q\ \text{signal from}\ \ \theta\ \sim \sigma_{y'}^* \sim 350\ \mu rad$$

Two BPMs (Two particle model)

$s_B < 0$: distance from IP to IPB

$s_C > 0$: distance from IP to IPC

$a_{B,C}$: offset misalignment

$\theta_{B,C}$: angle misalignment

y : average y at IP

$2\Delta y$: y difference at IP

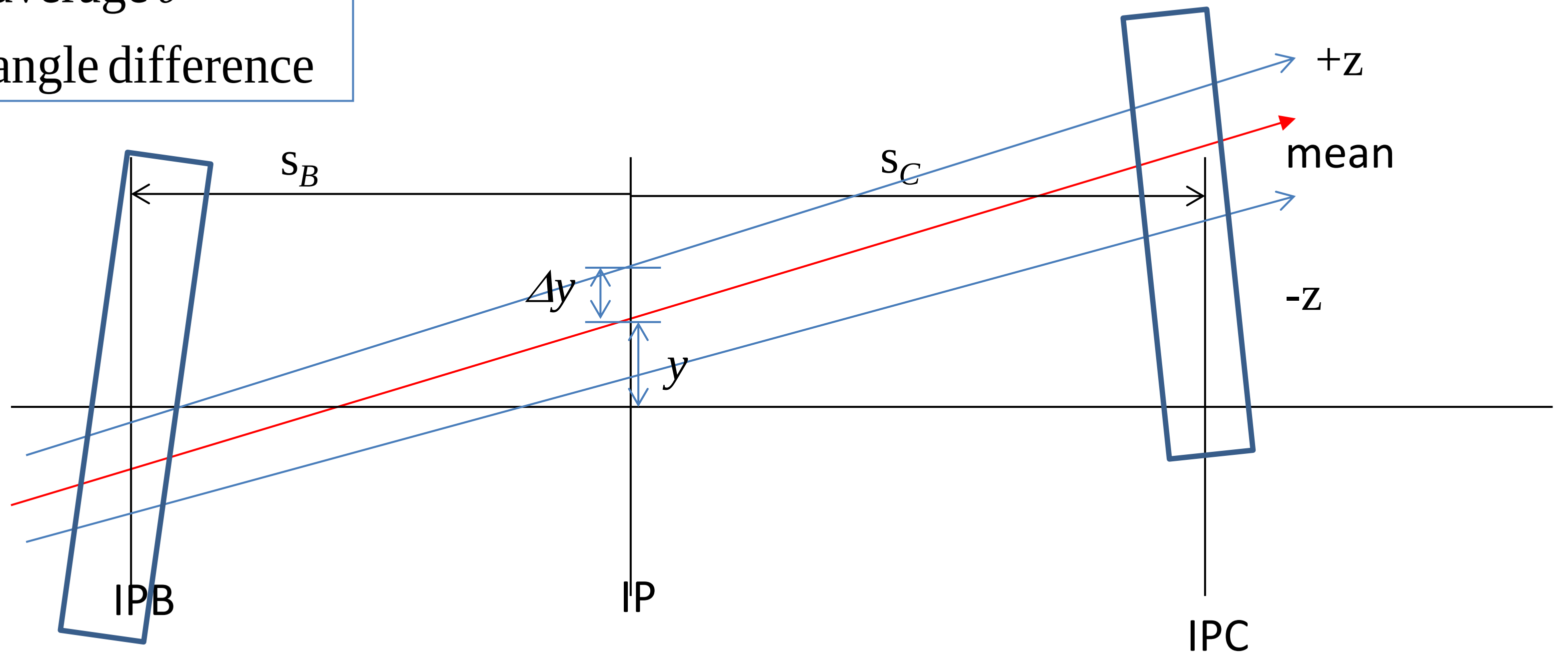
θ : average θ

$2\Delta\theta$: angle difference

$$V_{I,(B,C)} \propto (y + s_{(B,C)}\theta - a_{(B,C)})\sin\phi_L \cos\phi_z + \\ + \Delta\theta(L/2)[\cos\phi_L - \sin\phi_L/\phi_L]\sin\phi_z$$

$$V_{Q,(B,C)} \propto (\Delta y + s_{(B,C)}\Delta\theta)\sin\phi_L \sin\phi_z \\ + (\theta - \theta_{(B,C)})(L/2)[\cos\phi_L - \sin\phi_L/\phi_L]\cos\phi_z$$

$$(\phi_L \equiv \omega L/2c, \phi_z \equiv \omega z/2c)$$



Take data with two different beam conditions (changes: denoted δ) and look at difference.
Assuming IPB and IPC have the same response (or, difference is only a common sensitivity factor),

$$\delta\theta(\text{from}\, V_{I,B} \text{ and } V_{I,C}) = \frac{\delta V_{I,C} - \delta V_{I,B}}{\sin\phi_L \cos\phi_z (s_B + s_C)} = \delta\theta$$

$$\delta\theta(\text{from}\, Q_{I,B}) = \frac{\delta Q_{I,B}}{(L/2)\left[\cos\phi_L - \sin\phi_L/\phi_L\right]\cos\phi_z}$$

$$= \delta\theta + \frac{\sin\phi_L \sin\phi_z}{(L/2)\left[\cos\phi_L - \sin\phi_L/\phi_L\right]\cos\phi_z}\delta\Delta y$$

Change of offset difference can be evaluated.

Possible problem: If $\delta\theta$ is too large, effect of $\delta\Delta y$ cannot be cleary detected.

Possible procedure

- Use 2 BPMs (IPA or IPB and IPC)
- Calibration using movers, averaging many pulses
  - $I - Q$ phase (this may be affected by beam tilt)
  - I vs. Offset and Q vs. Angle

- Check sensitivity to wakefield
  - Change position of ref.Cavity, or OTR chamber
  - Change bunch charge
- Look at pulse to pulse change
  - Wakefield affect beam size at IP, tilt will be also detected. (?)

Need more considerations

- More quantitative information
- Practical issues
- Etc.