Wakefield effect

20130708

K.Kubo

Transverse, dipole Wakefield

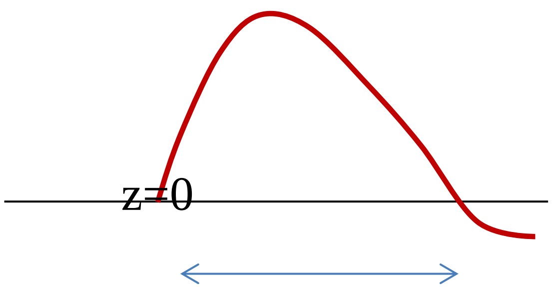
Wakepotential is integral of
wakefunction for point charge x charge distribution

$$W(z) = \int_{-\infty}^{z} W_{\delta}(z-z')\rho(z')dz' \Big/ \int_{-\infty}^{\infty} \rho(z')dz'$$

$W_{\delta}(z)$: wakefunction, or wake for point charge $(W_{\delta}(z) = 0 \text{ if } z < 0)$

$\rho(z)$: charge density of bunch (bunch head : negative z)

Wake for point charge



~ size of structure

For very long bunch, compared with size of wake source,
Wakepotential is almost resistive.

For very short bunch, Wakepotential is capacitive

Transverse, dipole Wakefield

Particle at position z change transverse momentum as

$$\Delta p_y(z) = e\int_{-\infty}^{z} y(z')W_\delta(z-z')\rho(z')dz'/c$$

$$y(z): \text{transverse offset at position } z, \text{ w.r.t. wake source}$$

Ignoring y difference along bunch (bunch shape distortion)

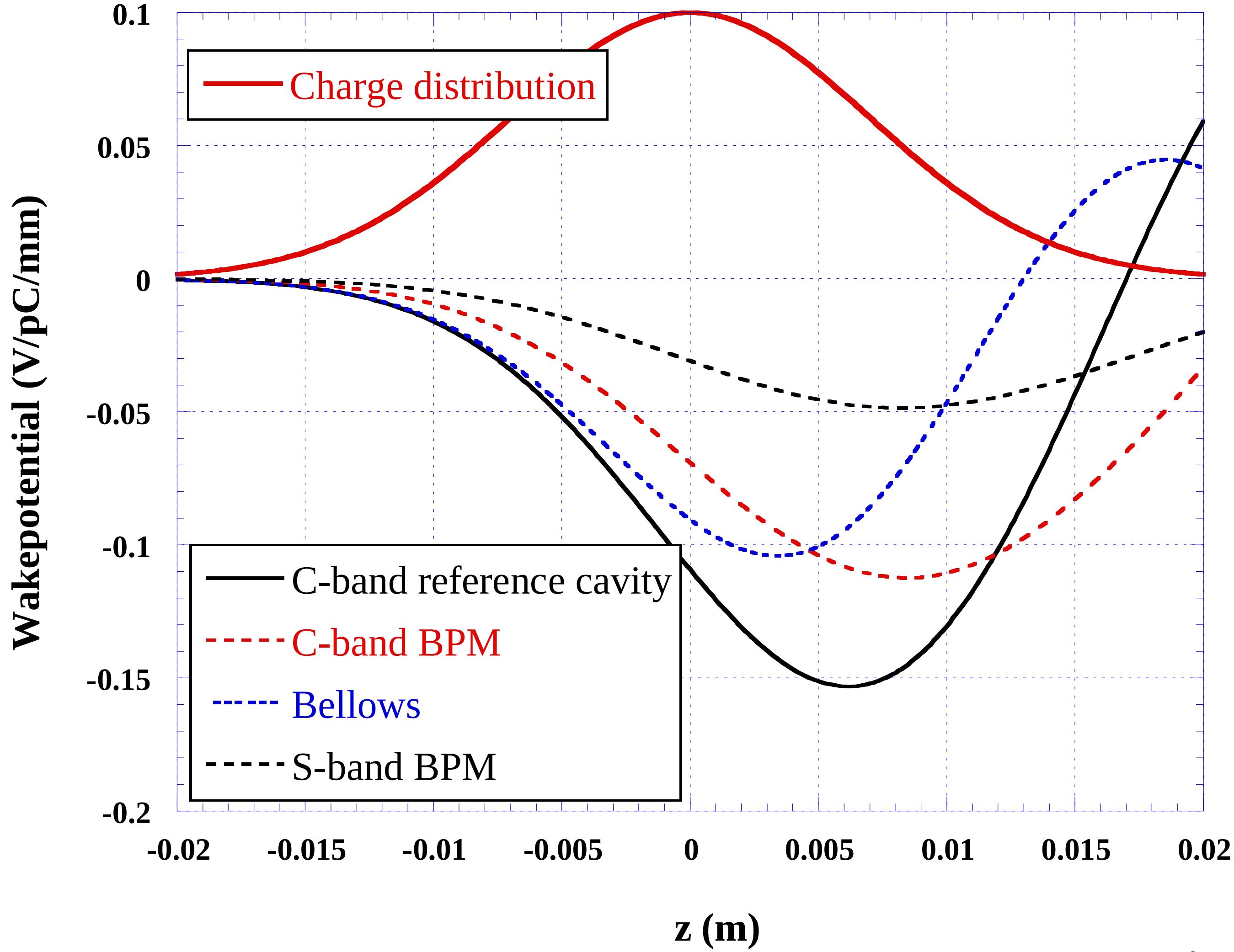
$$\Delta p_y(z) = ey\int_{-\infty}^{z} W_\delta(z-z')\rho(z')dz'/c = eqyW(z)/c$$

Kick angle

$$\theta(z) = eqyW(z)/E$$

$$q = \int_{-\infty}^{\infty} \rho(z')dz'$$

For 7 mm Gaussian bunch



Calc. by A. Lyapin

Effect of wake

- Average kick
  - Orbit change

    kick angle of center of mass

$$a=\int_{-\infty}^{\infty}\rho(z)\theta(z)dz\Big/\int_{-\infty}^{\infty}\rho(z)dz=\frac{ey}{E}\int_{-\infty}^{\infty}\rho(z)W(z)dz$$

- Particles at different z are kicked differently. Induce z-correlated transverse motion.
  - Beam size increase

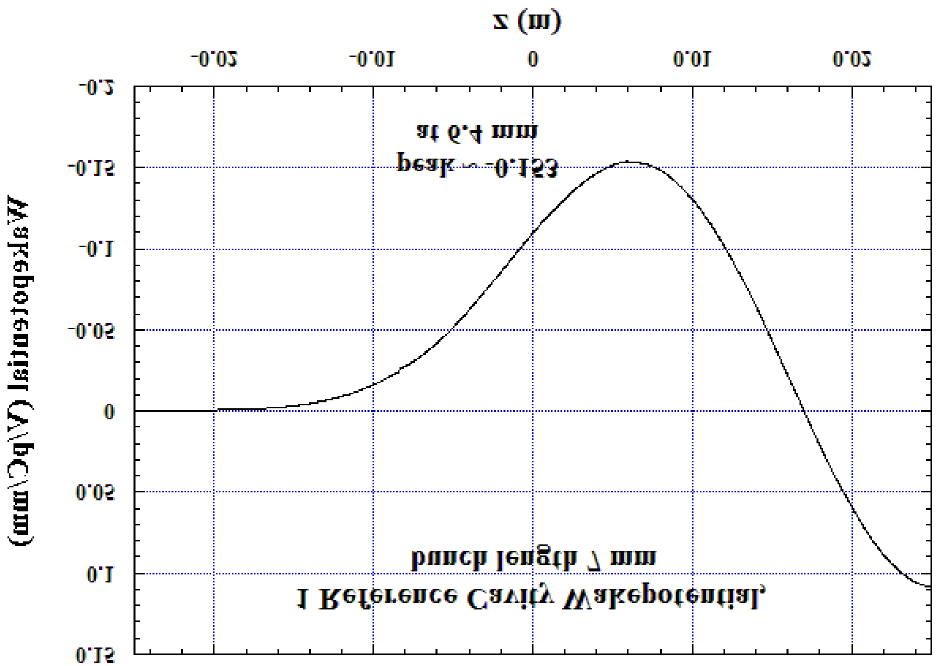
  Spread of kick angle

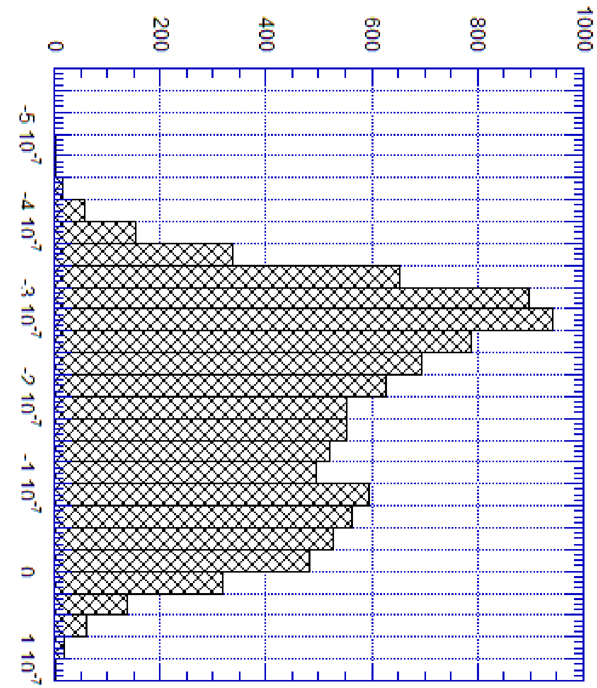
$$\sigma_\theta=\left[\int_{-\infty}^{\infty}\rho(z)\left(\theta(z)\right)^2dz\Big/q-a^2\right]^{1/2}$$

$$=\frac{ey}{E}\left[q\int_{-\infty}^{\infty}\rho(z)W^2(z)dz-\left(\int_{-\infty}^{\infty}\rho(z)W(z)dz\right)^2\right]^{1/2}$$

Resulted particle position distribution at IP
(~Projection of wakepotential)

Wakepotential





Effect of single wake source

- Center of mass position change

$$\Delta y = R_{34} a = R_{34} \frac{ey}{E} \int_{-\infty}^{\infty} \rho(z) W(z) dz = \sqrt{\beta\beta^*} \sin\varphi \frac{eqy}{E} a_W$$

- Beam size increase

$$\sqrt{\sigma^2 - \sigma_0^2} = R_{34} \sigma_\theta$$

$$= \sqrt{\beta\beta^*} \sin\varphi \frac{ey}{E} \left[q \int_{-\infty}^{\infty} \rho(z) W^2(z) dz - \left(\int_{-\infty}^{\infty} \rho(z) W(z) dz \right)^2 \right]^{1/2}$$

$$= \sqrt{\beta\beta^*} \sin\varphi \frac{eqy}{E} \sigma_W$$

$$a_W \equiv \int_{-\infty}^{\infty} \rho(z) W(z) dz \Big/ q$$ Average of wake potential

$$\sigma_W \equiv \left[\int_{-\infty}^{\infty} \rho(z) W^2(z) dz \Big/ q - a_W^2 \right]^{1/2}$$ Spread of wake potential

Wake potential

	C-band ref.	C-band BPM	Bellows
Peak (V/pC/mm)	-0.153	-0.1124	-0.105
a_W (V/pC/mm)	-0.0921	-0.0645	-0.0640
σ_W (V/pC/mm)	0.0492	0.0356	0.0353

Effect of single wake source at the mover, beta=6260 m, offset 1 mm, bunch charge 1 nC.

		C-band ref.	C-band BPM	Bellows
IP position (nm)	Calc. from a_W	-61	-42.7	-42.4
	Tracking	-61	-43.0	-42.7
IP beam size (nm)	Calc. from σ_W	32.6	23.6	23.3
	Tracking	32.2	23.6	22.6

IP beam size vs. mover position experiment

Effect of offset 1 mm, bunch charge 1 nC. IP beam size increase (nm/nC/mm)

Experimental data analyzed by Okugi

2 C-band ref. +2 no mask deforming bellows	1 C-band ref. +2 no mask deforming bellows	No mask Bellows +2 masked deforming bellows	Masked Bellows +2 masked deforming bellows
157	102	57	14.5

1 ref.cav. : 157-102=55
2 no mask def bellows: 102-55= 47

Assume 2 masked deforming bellows
= 1 masked bellows

1 masked bellows: 14.5/2=7
1 no mask def bellows: 57-7=50

2 no mask deforming bellows
~ 1 no mask bellows

IP beam size vs mover position experiment and calc.

Effect of wake source at the mover, offset 1 mm, bunch charge 1 nC.
IP beam size increase (nm/mm/nC)

	C-band ref.	No mask Bellows	Masked Bellows
Experiment	55	47~50	7
Calc	32.2	22.6	?

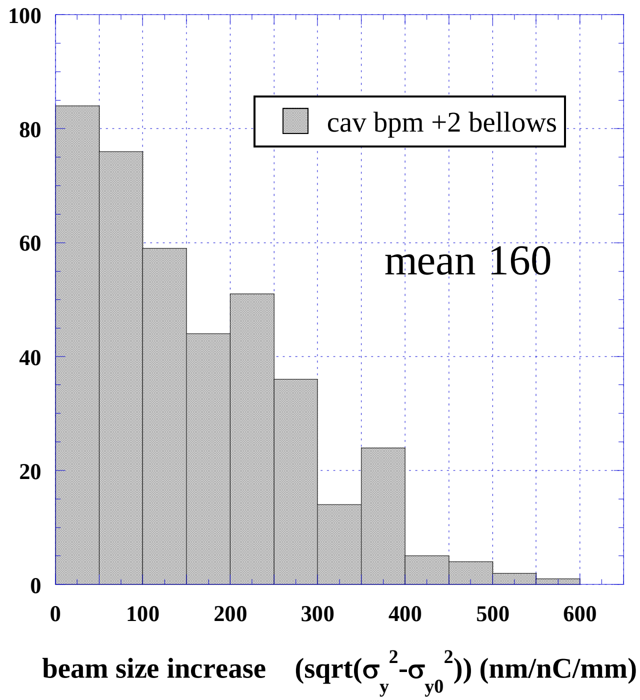
More discussion later by Jochem

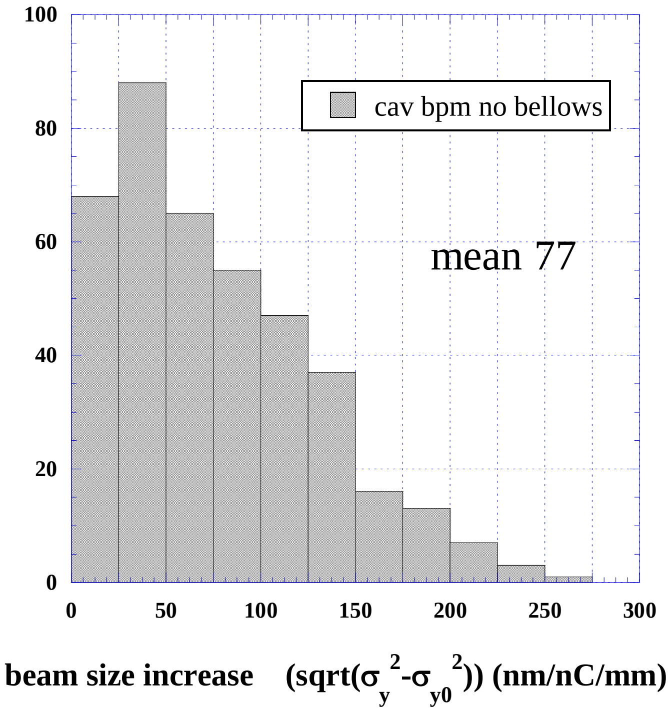
Effect of many wake sources

- Can be estimated by adding effect of each source.
- Depend on $\sin\phi$ but almost +1 or -1 for all structures in large beta region

- Random misalignment
  - Effects are random
  - Proportional to sqrt(beta)
- Orbit deviation:
  - Effect of every source is added with the same phase.
  - Proportional to beta.
  - Depend on phase of orbit

beam size increase by random misalignment





Experiment: ~120 nm/ nC (?)

No clear improvement after mask bellows . (?)

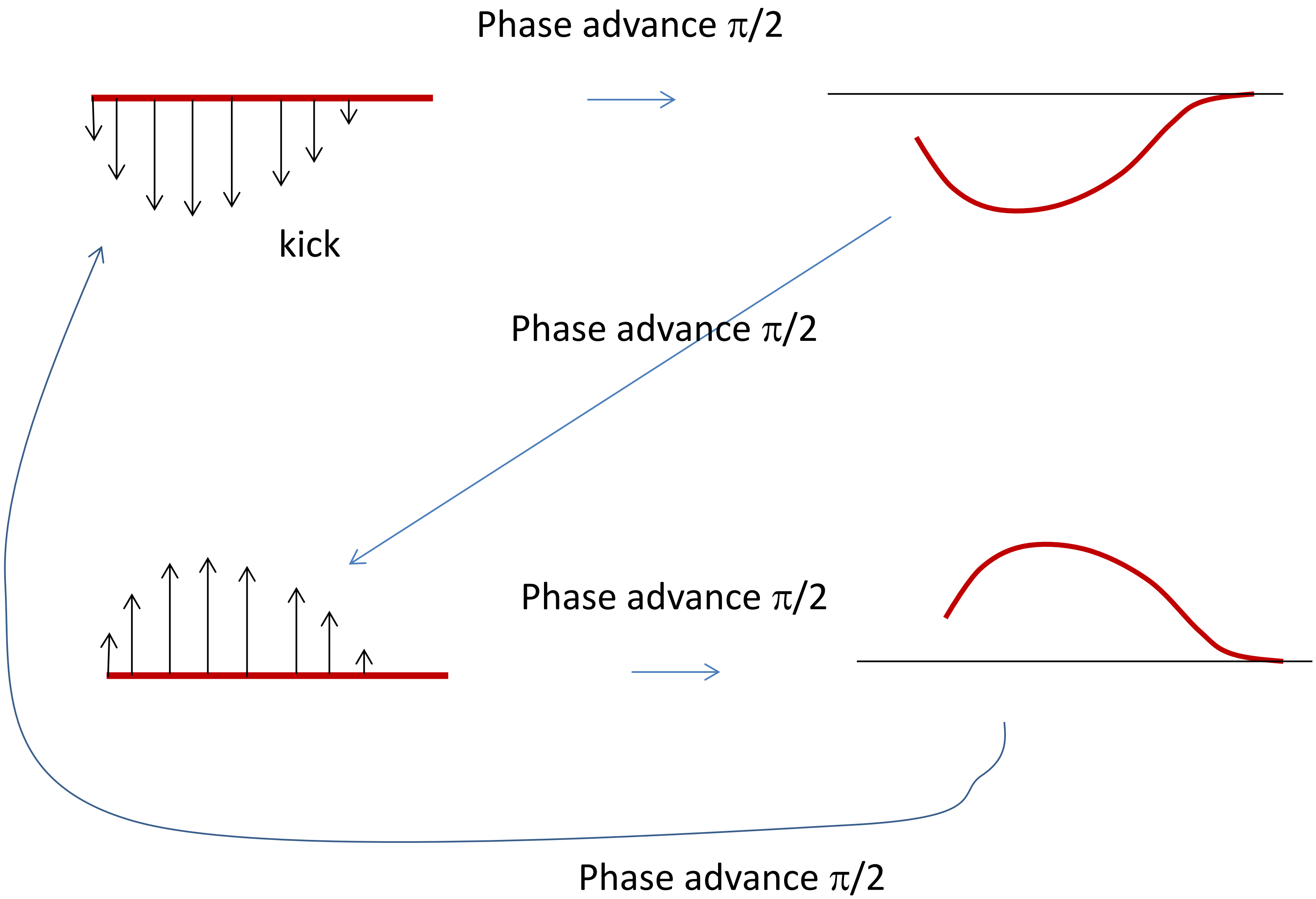
→ **random misalignment 1.3 mm and 0.6 mm.**

For bellows, 1 mm does not seem too large.

But they were shielded in May-June.

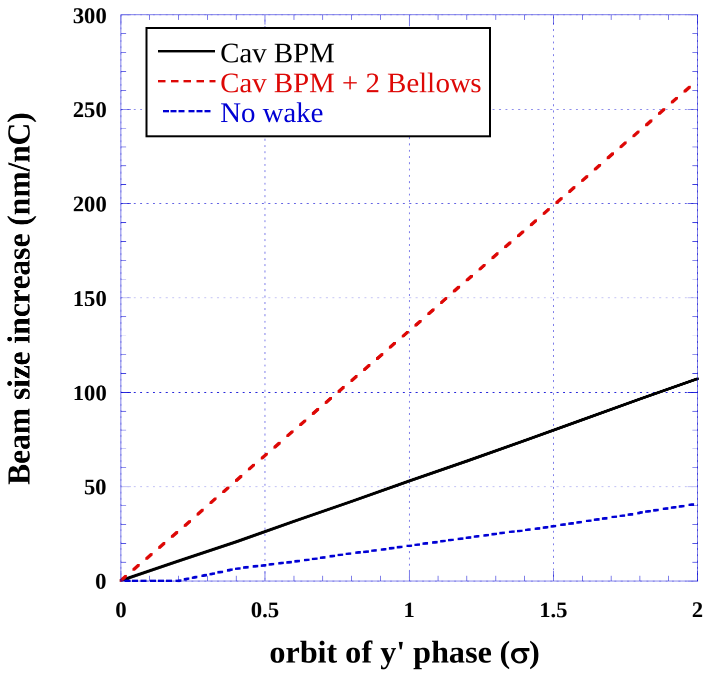
mover position was optimized in most cases (fixed offset was compensated?).

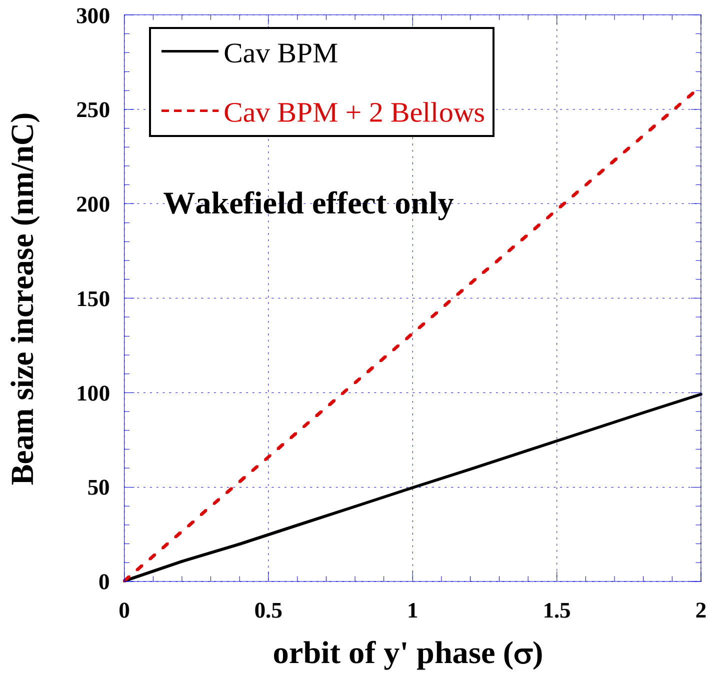
Wake of fixed offset can be corrected by on-mover wake source at other place (If shape of wake potential is same).



Simulation of beam size increase by orbit distortion

Orbit of angle-at-IP phase





Experiment: ~120 nm/ nC (from IPBSM 30 deg mode measurements

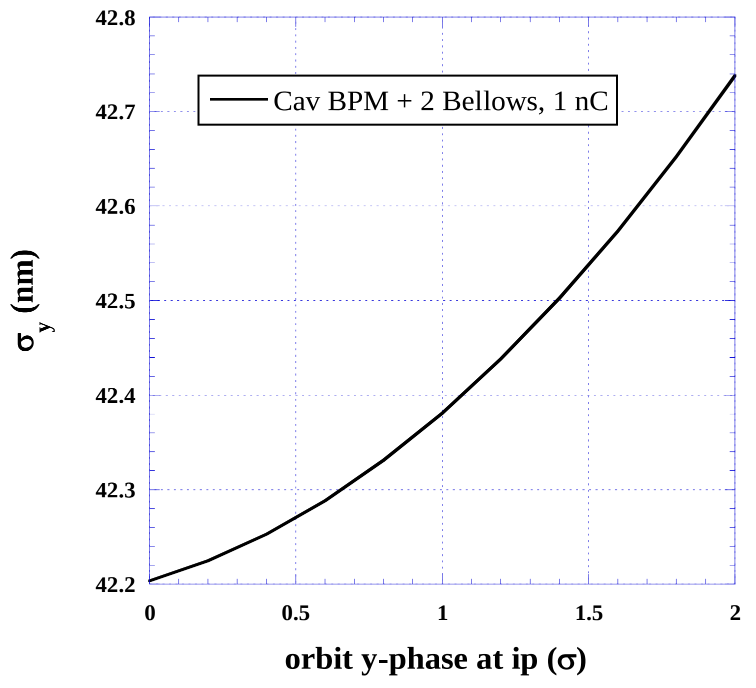
For explaining by orbit,

need orbit distortion >2-sigma of nominal (no bellows), ~1 sigma (with bellows)

(if assuming calculated wakepotentials)

Simulation of beam size increase by orbit distortion

Orbit of position-at-IP.



Orbit of position-at-IP does not induce significant wakefield effect.

Summary of this talk

- Experiments of on-mover wake source
  - Suggested larger wake than calculation
    - Factor 1.7 for C-band reference cavity
    - Factor 2 for no mask bellows
  - Wake of masked bellows was about 1/7 times of no mask bellows
- Beam size dependence on intensity ~120 nm/nC
  - Wake of cavity BPM, bellows or wake of similar shape cannot explain observations
  - Orbit distortion 1-sigma of y at IP phase may explain, assuming wake of cavity BPM + 2 bellows at every cavity BPMs (Much larger than expected from calculation with most of bellows are masked.)
- Other wake sources with much different wakepotential shape????
- More discussions by Jochem.