Simulation Studies on Coupler Wakefield and RF Kicks in ILC Bunch Compressor with SLEPT

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Coupler's wakefields (I)

- In the ILC cavities, the power and HOM couplers break the structure symmetry =>transverse wakefields are excited by the beam even if it goes through the center of cavities, which are different from usual dipole mode wakefield.

- Coupler wake has been newly introduced to SLEPT.

- We need a short-range δ wake function for point charge in order to get the transverse wakepotential $W_t(s)$.

$$W_t(s) = \int_{-\infty}^{s} \lambda(s')W(s-s')ds' \Big/ \int_{-\infty}^{\infty} \lambda(s')ds'$$

We try to use the simplified model for δ wake function of couplers of ILC cavity.

$$W(s) = as + b\sqrt{s}$$

Coupler's wakefields (Ⅱ)

- Numerical results of the coupler wakepotentials for three different bunch lengths (0.3mm, 1.0mm and 9.0mm) were provided from Andrea Latina [1] (see Fig. 1 and Fig. 2).

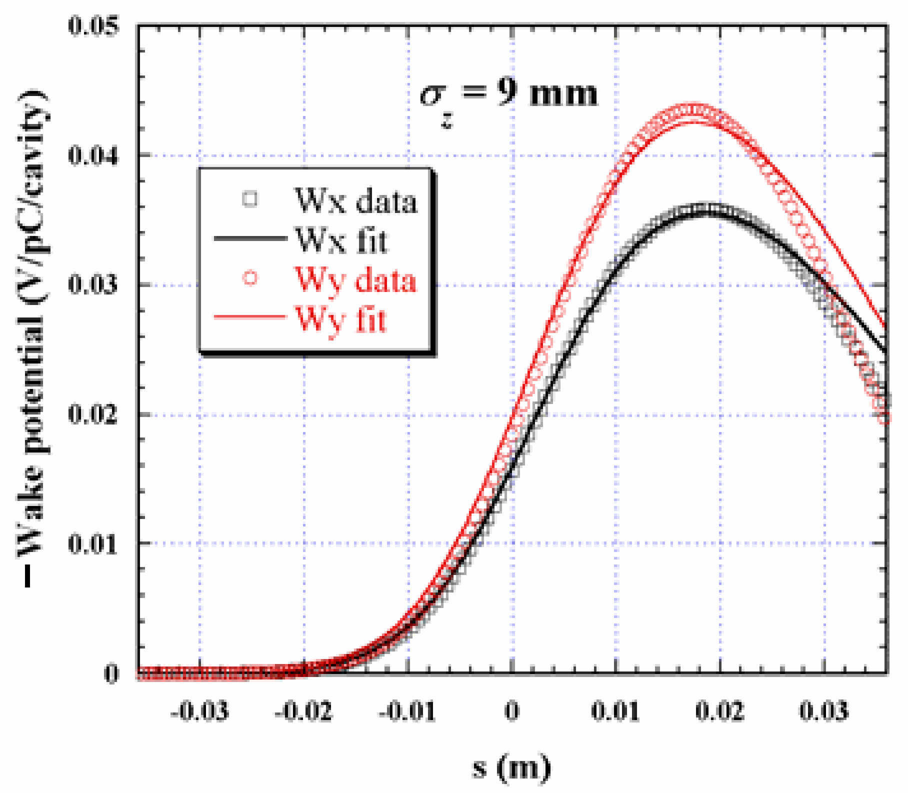


Fig. 1, Wake potential for 9 mm bunch. Data from cavity field calculation (rectangular: horizontal, circle: vertical) and from the simplified model for long bunch (lines).

Coupler's wakefields (III)

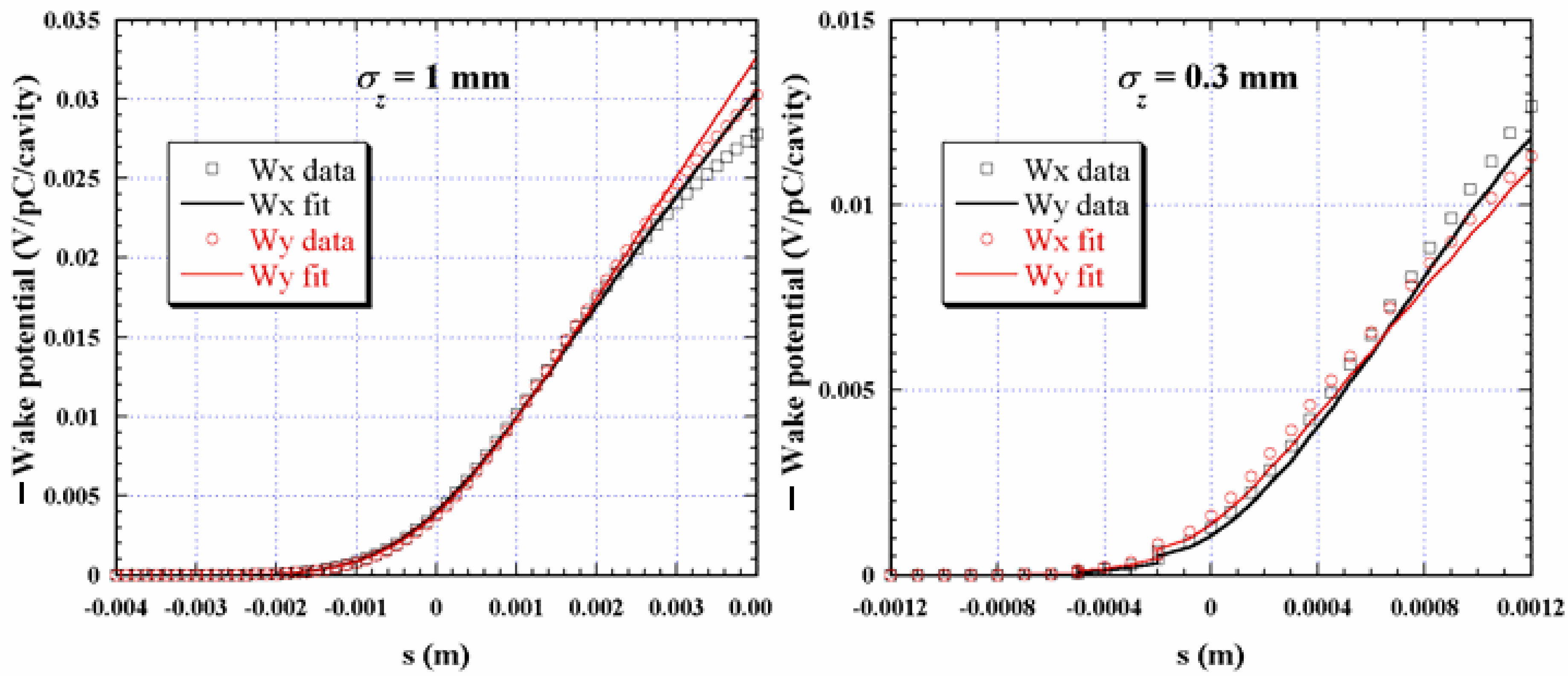


Fig. 2, Wake potential for 1 mm bunch and 0.3 mm bunch. Data from cavity field calculation (rectangular: horizontal, circle: vertical) and from the simplified model for short bunch (lines).

Coupler's wakefields (Ⅳ)

- The approximate wake function in SLEPT:

Long bunch (9 mm) :

$$\begin{cases} W_x(s)[V/pC] = 2.862s[m] - 0.6786\sqrt{s[m]} \\ W_y(s)[V/pC] = 3.731s[m] - 0.8545\sqrt{s[m]} \end{cases}$$

Short bunch (0.3 mm and 1 mm) :

$$\begin{cases} W_x(s)[V/pC] = -5.928s[m] - 0.1500\sqrt{s[m]} \\ W_y(s)[V/pC] = -6.770s[m] - 0.0894\sqrt{s[m]} \end{cases}$$

- Within 3-sigma of the bunch lengths, the calculated wakepotentials from this simpified model have a good agreement with the data from cavity field calculation.

RF kick (Ⅰ)

- The couplers also introduce an asymmetry into the accelerating RF field and thereby additional transverse field components. —RF kick

- RF-kick voltage is [2] :

$$\vec{V}(s) = (\frac{\vec{V_0}}{V_a})GLe^{i(\varphi_{rf}+\varphi_c+ks)}$$

($\vec{V_0}$ -vector of RF kick on axis, V_a-accelerating voltage on axis, k-wave number of RF field, G-accelerating gradient on axis, L-cavity length, φ_{rf} –RF phase, $\left|\frac{\vec{V_0}}{V_a}\right|$ -RF kick amplitude, φ_c-RF kick phase.)

RF kick (Ⅱ)

- The RF kick on axis for an on-crest-accelerated particle in ILC cavity (from numerical calculations) is [3] :

$$\frac{\vec{V}_0}{V_a}\times 10^6 = \begin{pmatrix} -105.3+69.8i \\ -7.3+11.1i \end{pmatrix}$$

- Parameters used in SLEPT:

Horizontal:

$$\left|\frac{V_{0x}}{V_a}\right| = \sqrt{105.3^2+69.8^2} = 126.3\times 10^{-6}, \varphi_c = \pi + arctg\left(\frac{69.8}{-105.3}\right) = 2.5562$$

Vertical:

$$\left|\frac{V_{0y}}{V_a}\right| = \sqrt{7.3^2+11.1^2} = 13.3\times 10^{-6}, \varphi_c = \pi + arctg\left(\frac{11.1}{-7.3}\right) = 2.1525$$

Simulation Results (Ⅰ)

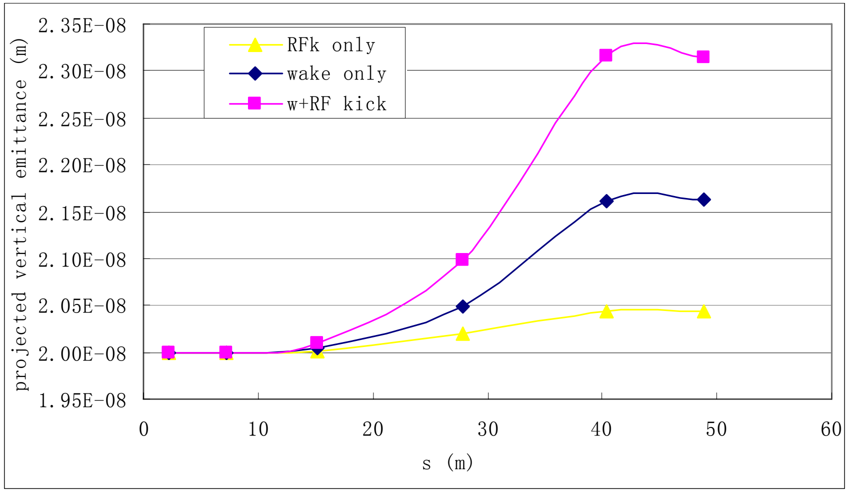
- Simulations are done only in the RF sections, not in the wiggler sections.
- Lattice of RDR base design was used.
- only single bunch emittance growth is considered

Parameter	BC1	BC2
Bunch Charge	2×10^{10} e	2×10^{10} e
Initial Energy	5.0 GeV	4.88 GeV
Initial Energy Spread	0.15%	2.5%
Initial Bunch Length	9.0 mm	1.0 mm
RF Gradient	18 MV/m	30 MV/m
RF Phase	-105°	-27.6°
Initial Emittance X/Y	8 μm/ 20 nm	8 μm/ 20 nm

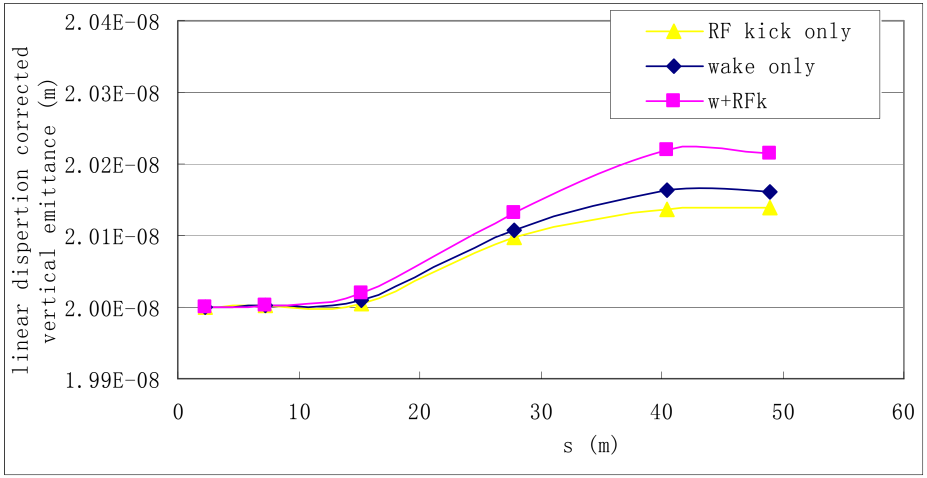
Simulation Results (Ⅱ)

- BC1 RF section (1-to-1 correction, no misalignment)

projected vertical emittance vs. distance from the entrance



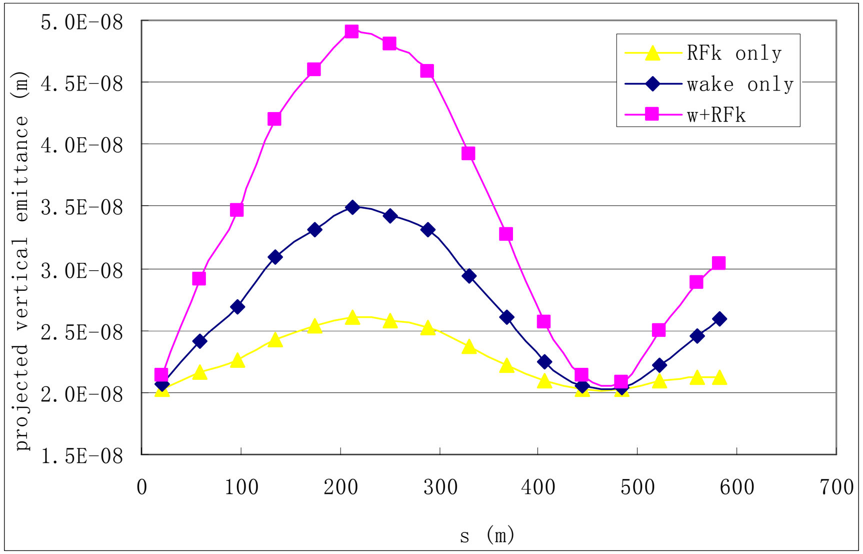
linear dispersion corrected vertical emittance vs. distance from the entrance



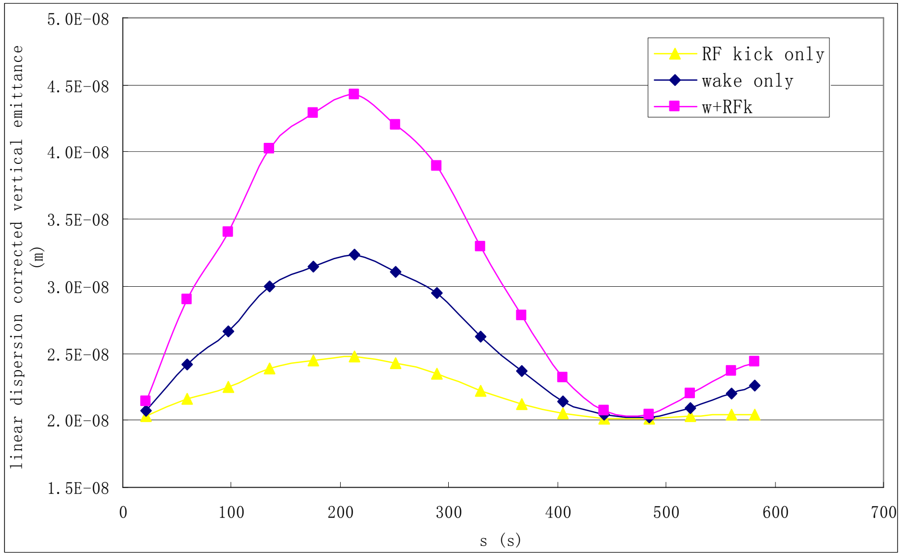
Simulation Results (III)

- BC2 RF section (1-to-1 correction, no misalignment)

projected vertical emittance vs. distance from the entrance



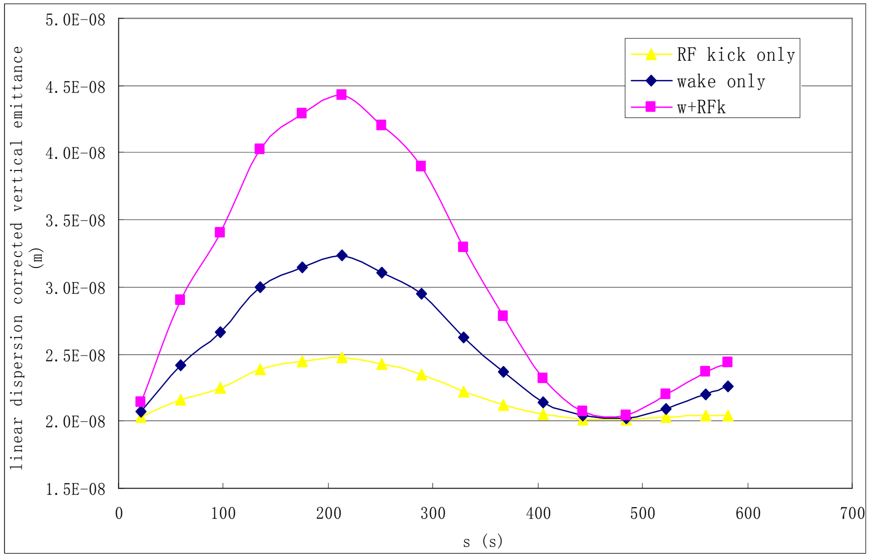
linear dispersion corrected vertical emittance vs. distance from the entrance

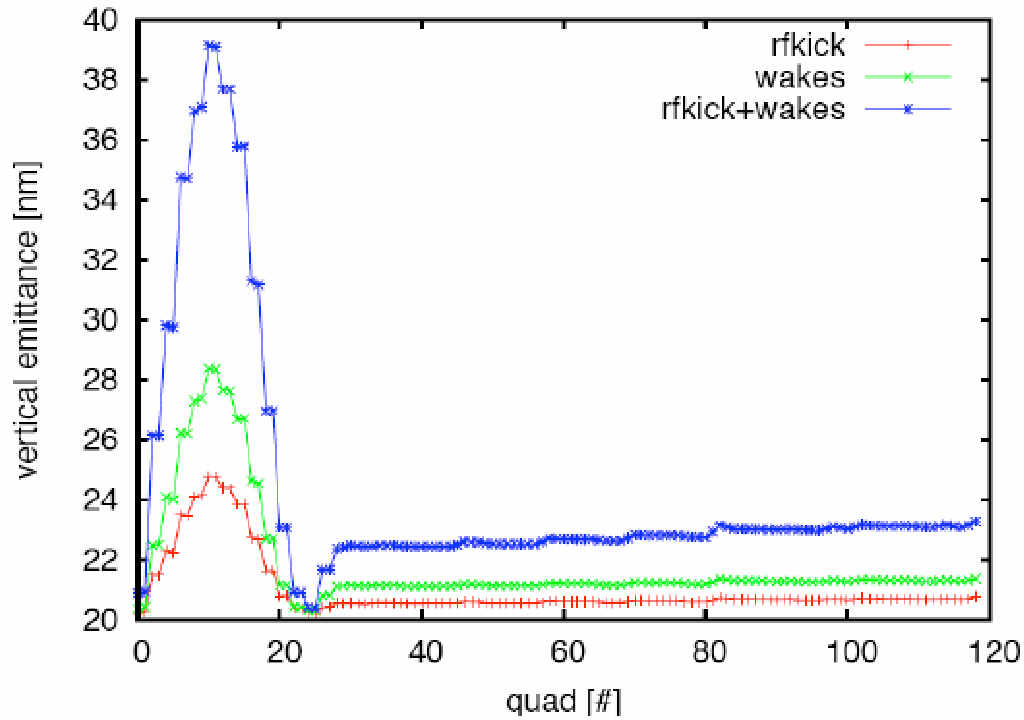


Simulation Results (Ⅳ)

- Comparison with A. Latina's result (using PLACET) for BC2 [2]

Two results about RF kick effect agree well, but the wakefield effect from our result is larger than A. Latina's .





Conclusions

- Final vertical emittance growth in ILC BC RF section including coupler RF kick and Wakes is :

  BC1: 0.21 nm

  BC2: 4.41 nm

- The emittance oscillates along the Linac according to the betatron oscillation. We can change the betatron phase advance to make the minimum coincidently at the exit.

References

[1] Andrea Latina, private communication, (2008).

[2] Andrea Latina, et al, “Emittance Growth in ML and BC with Couplers’ RF-Kick and Wakefields”, LCWS, Chicago, November 2008.

[3] N. Solyak, et al, “RF Kick in the ILC Acceleration Structure”, MOPP042, EPAC08.