Simulation Studies on ILC Bunch Compressor with SLEPT

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outline

- Coupler's kicks
- DFS
- Simulations including longitudinal motion
- Summary

Coupler's Kicks

In the ILC cavities, the power and HOM couplers break the structure symmetry =>two effects

- ◇ coupler's wakefields
- ◇ RF kick

- These have been newly introduced in the code SLEPT
- Emittance growth in Bunch Compressor was simulated without errors.

Coupler's Kicks - Wake modeling-1

Simplified wake function is used in the simulations.

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

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

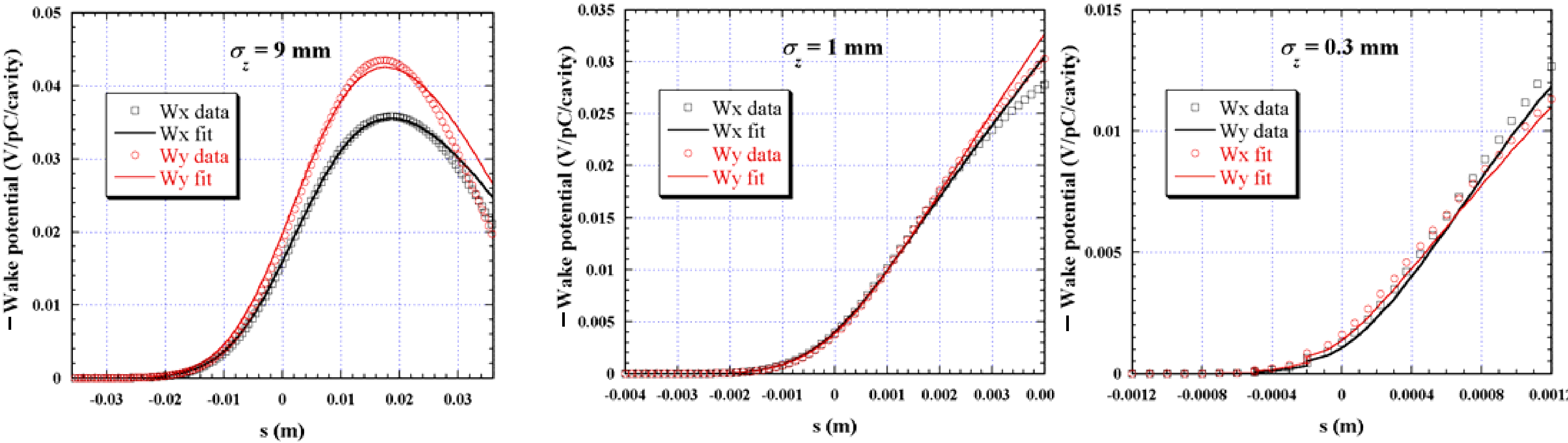


Fig. 1,2, Wake potential for 9 mm, 1 mm and 0.3 mm bunch. Data from cavity field calculation (rectangular: horizontal, circle: vertical) and from the simplified model (lines).

Coupler's Kicks - Wake modeling-2

From the numerical results of the coupler wakepotentials[1] (see Fig. 1 and Fig. 2), we get 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 simplified model have a good agreement with the data from cavity field calculation.

Coupler's Kicks - RF kick modeling

RF-kick voltage is expressed as[2] :

$$\vec{V}(s) = \left(\vec{V}_0 / V_a\right) GL \exp[i(\varphi_{rf} + \varphi_c + ks)]$$

$\vec{V}_0$: vector of transverse RF kick for on-crest particle,

V_a :accelerating voltage, k: wave number of RF, G: accelerating gradient,

L: cavity length, φ_{rf}: accelerating RF phase, φ_c :RF kick phase.)

Numerical result for an on-crest-accelerated particle in ILC cavity is[3]:

$$\vec{V}_0 / V_a = 10^{-6} \times \begin{cases} -105.3 + 69.8i & \text{(horizontal)} \\ -7.3 + 11.1i & \text{(vertical)} \end{cases}$$

Then, amplitudes and phases are:

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

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

Coupler’s Kicks - Simulations

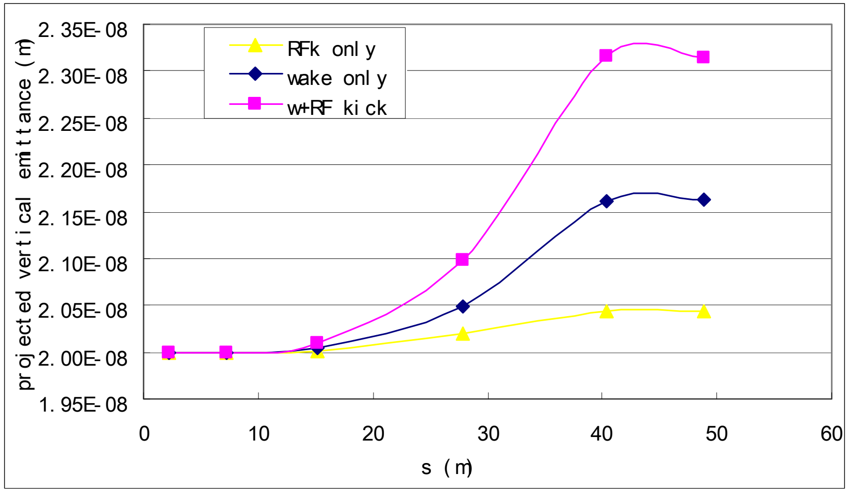
Simulations are done only in the RF sections, not in the wiggler sections.

- Lattice of RDR base design was used.
- Only single bunch emittance growth is considered
- No error is included

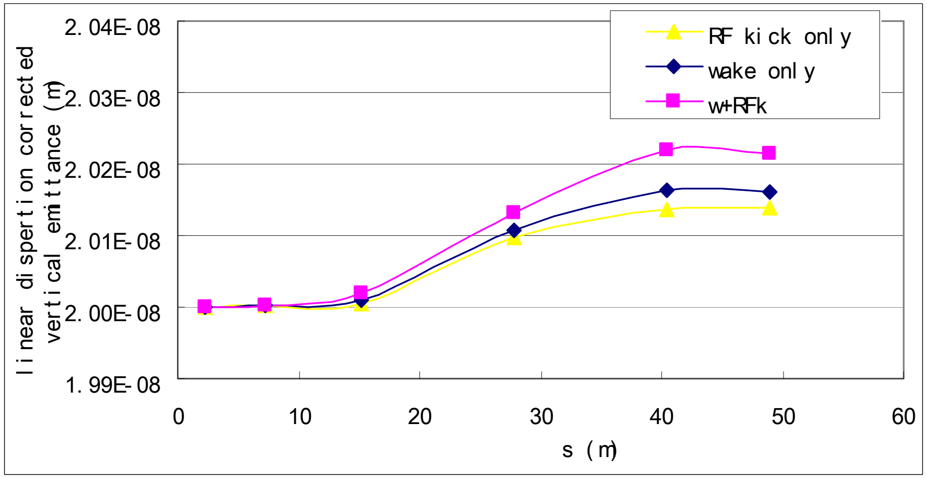
Coupler's Kicks - BC1 result

- BC1 RF section (1-to-1 correction, no misalignment)
- Final dispersion corrected emittance growth is 0.21 nm

projected vertical emittance vs. distance from the entrance



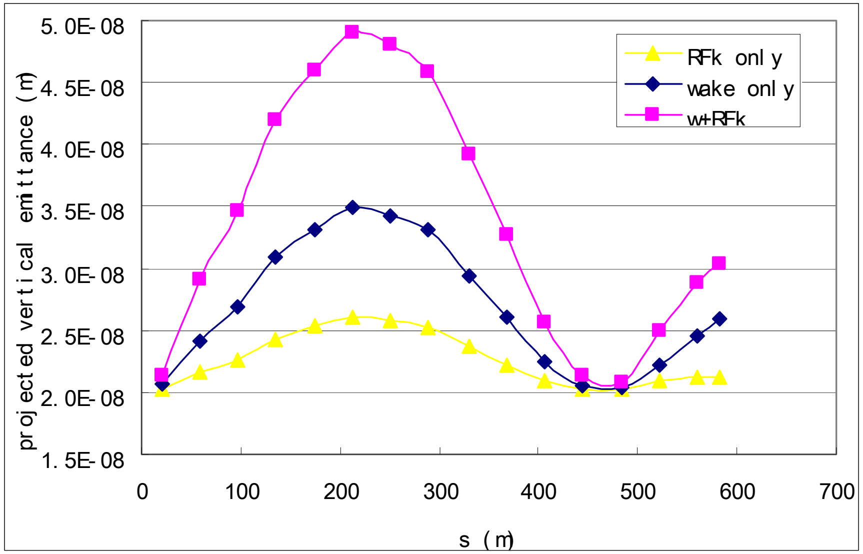
linear dispersion corrected vertical emittance vs. distance from the entrance



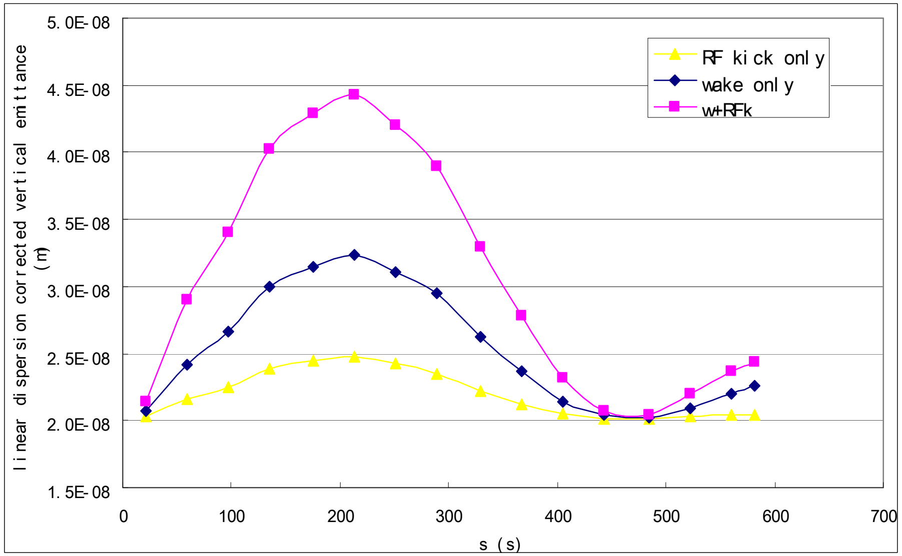
Coupler's Kicks - BC2 result

- BC2 RF section (1-to-1 correction, no misalignment)
- Final dispersion corrected emittance growth is 4.41 nm

projected vertical emittance vs. distance from the entrance



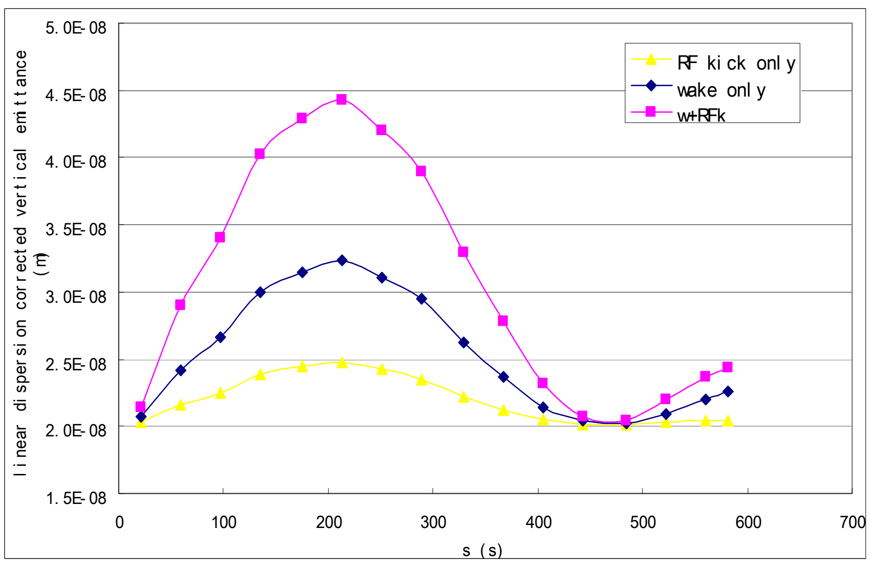
linear dispersion corrected vertical emittance vs. distance from the entrance

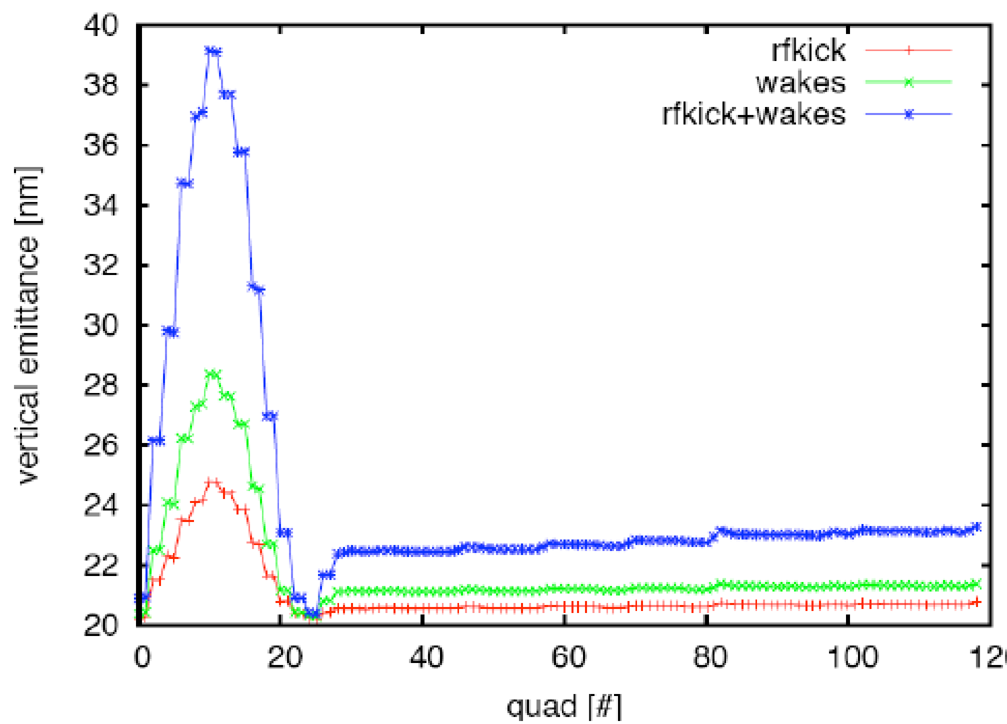


Coupler's Kicks - Comparison with past result

•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 .





DFS - method

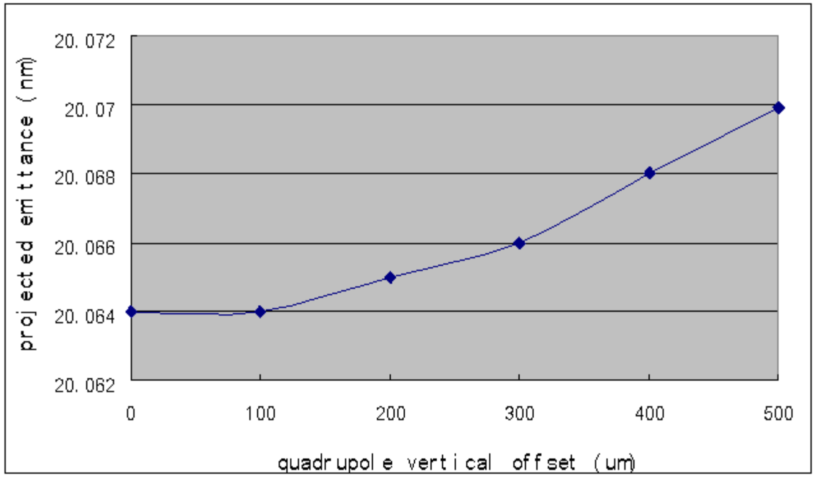
- It's impossible to change the initial energy of test beam for ILC bunch compressor.
- SLEPT DFS has been newly improved in order to change the RF phase of accelerating cavities besides of changing the initial energy of test beam.
- DFS:

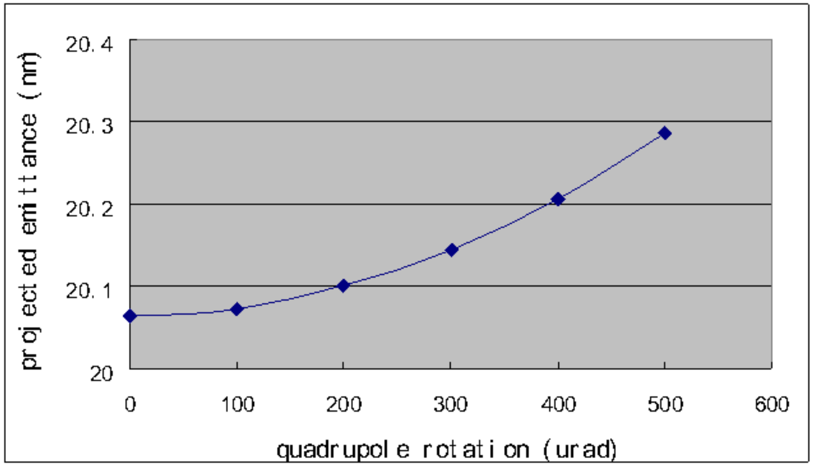
  minimize $\sum_i \{ w\left(y_i\left(+\varphi\right) - y_i\left(-\varphi\right)\right)^2 + y_i\left(0\right)^2 \}$

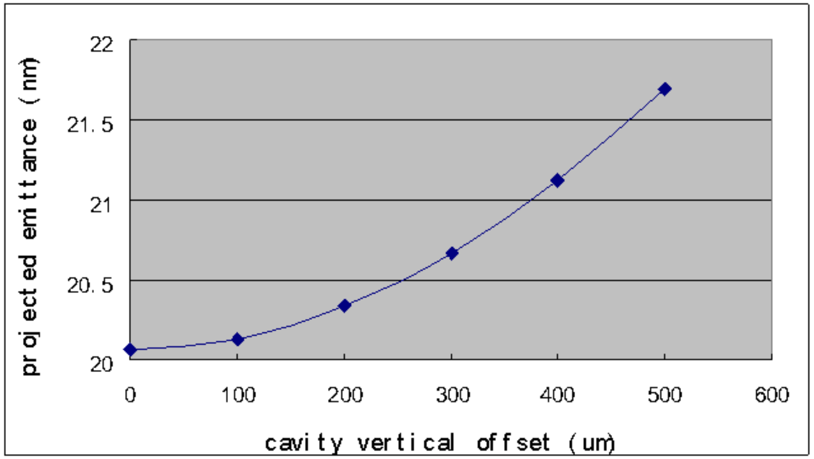
- DFS was tested on the RF section of ILC BC2.

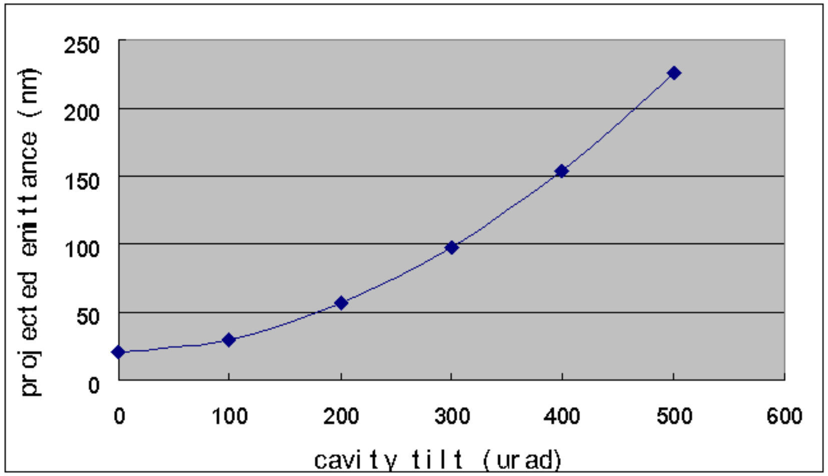
DFS result - sensitivity to each error -1

Δφ=5°, weight=5000, random seeds=20

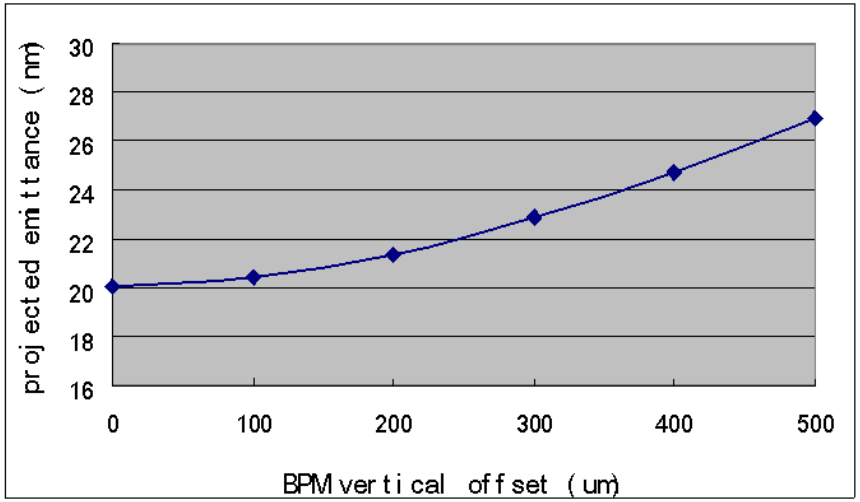


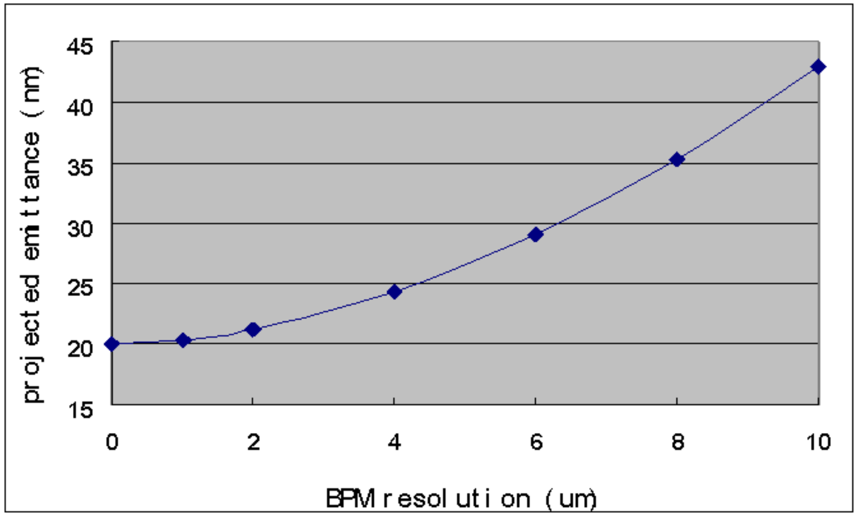






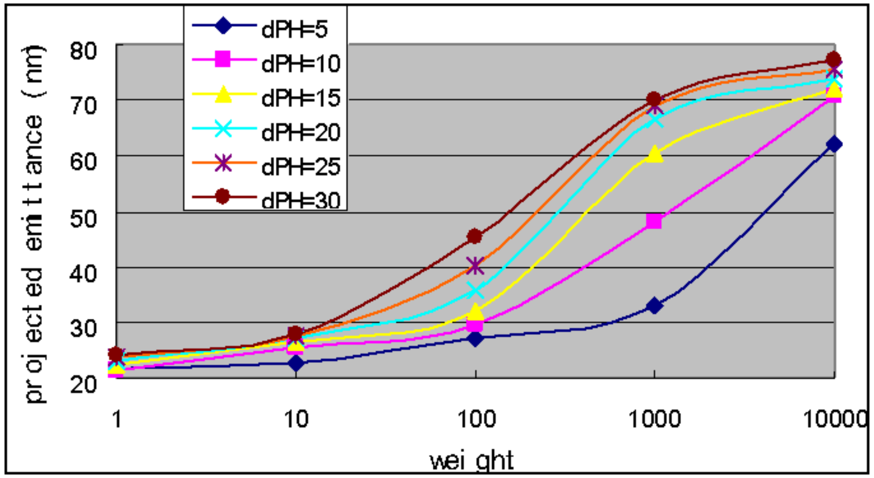
DFS - sensitivity to each error -2

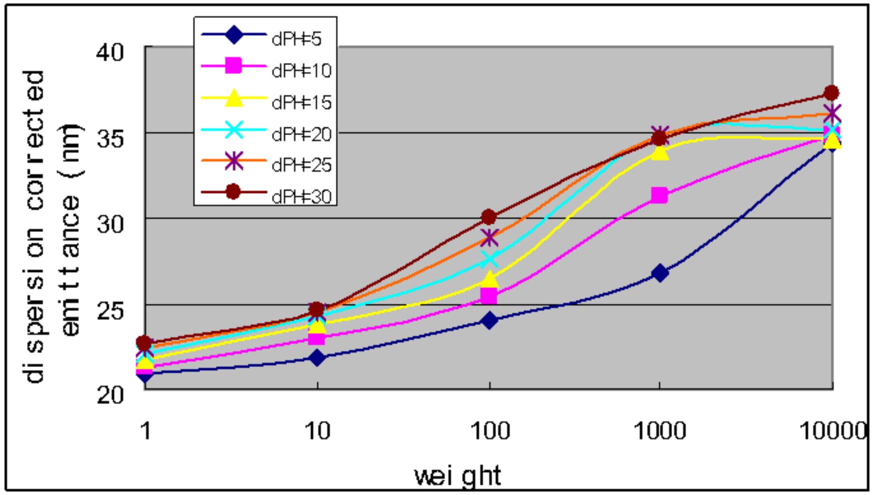




- Almost no dependence on Quad offset and Quad rotation
- Some dependence on cavity offset, BPM offset and BPM resolution
- Strong dependence on cavity tilt

DFS - effect of cavity tilt -1

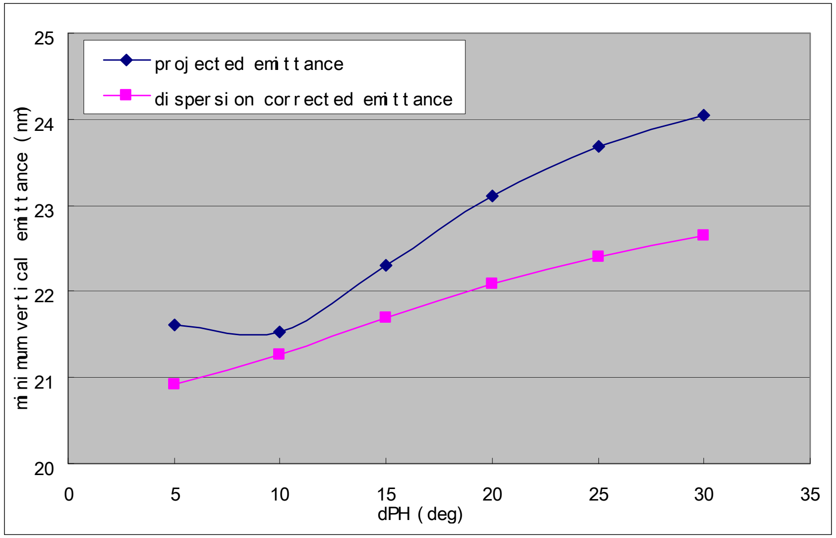




Cavity tilt only

TiltC=200urad,

random seeds=40

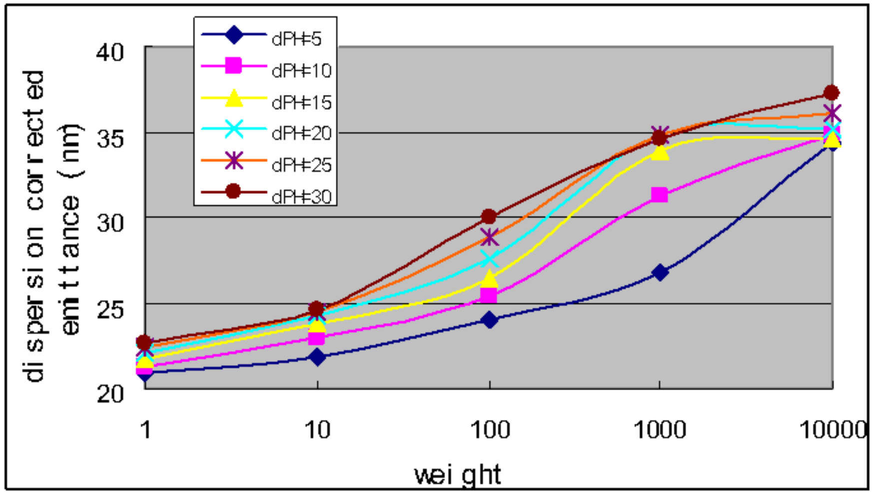


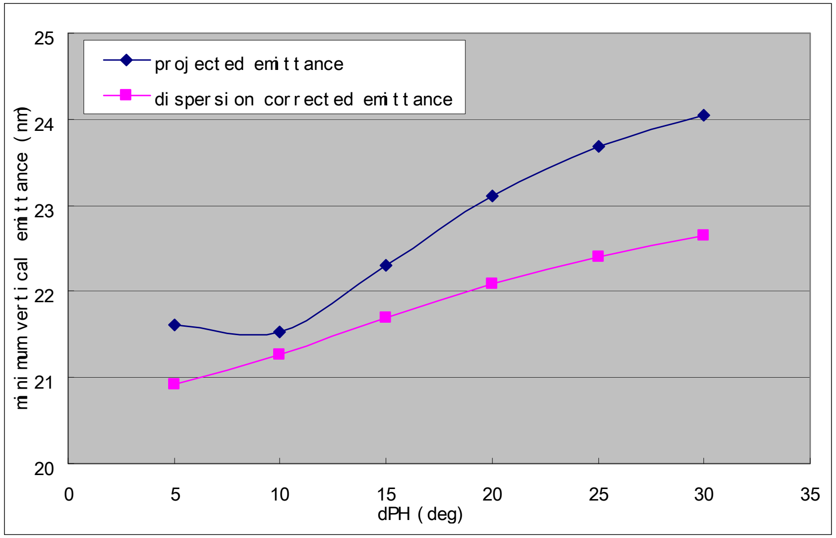
DFS - effect of cavity tilt -1

Cavity tilt only

Tilt of Cavity = 200urad,

random seeds=40





DFS - effect of cavity tilt -2

All errors except for cavity tilt.

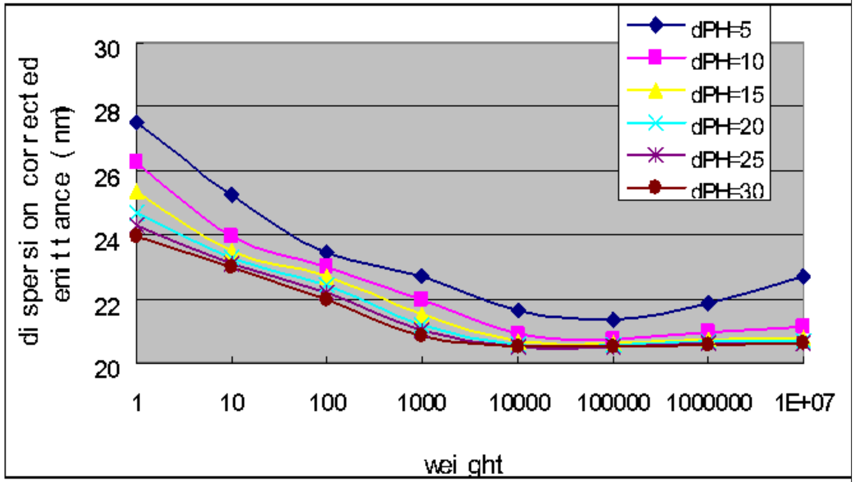
Quadrupole vertical offset: 300 um, Quadrupole rotation: 300 urad

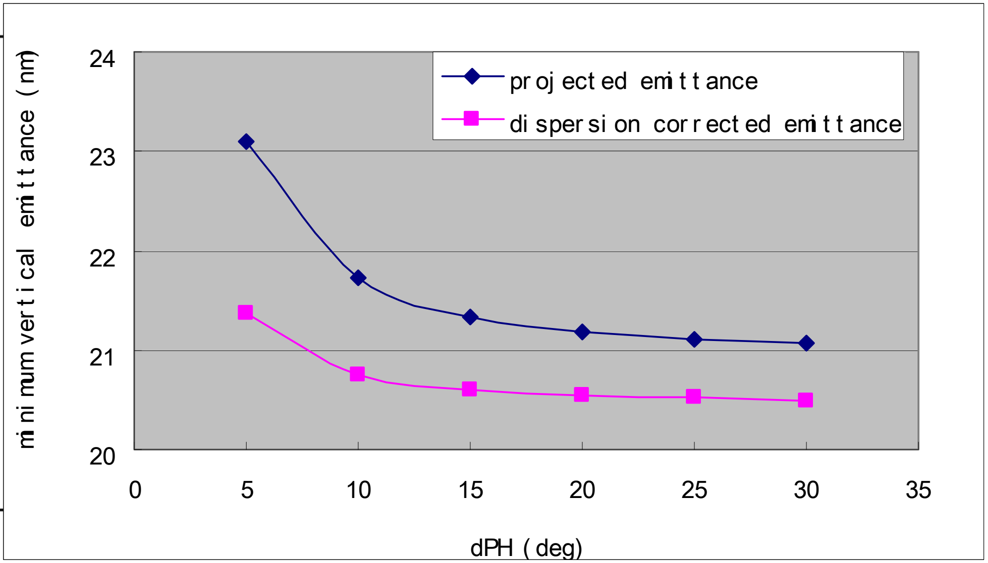
Cavity vertical offset: 300 um

BPM vertical offset: 300 um (aligned independently)

BPM resolution: 1 um

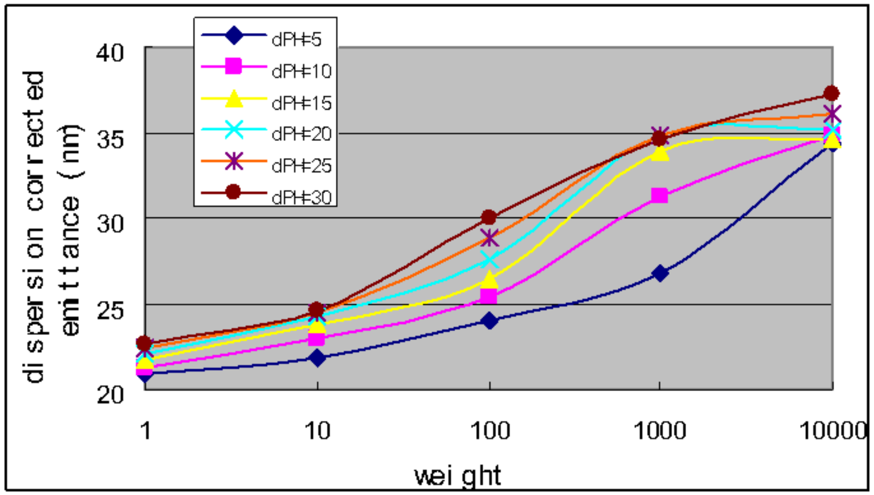
random seeds=40



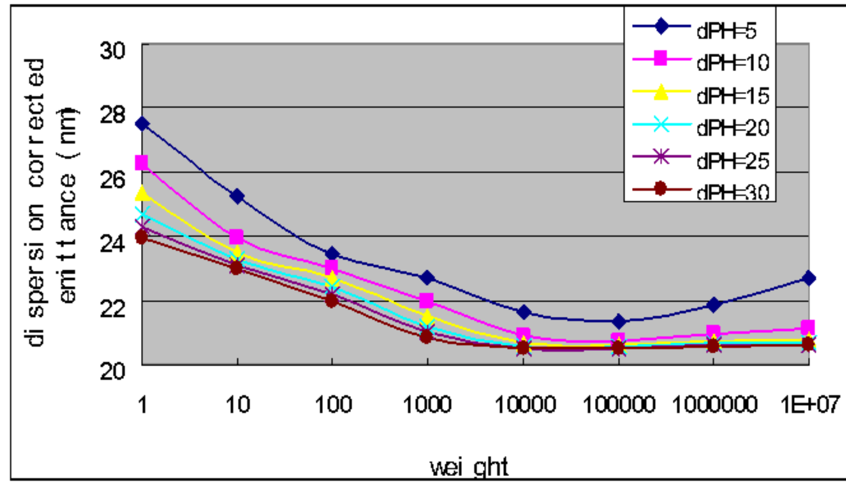


DFS - effect of cavity tilt -3

Cavity tilt only



All errors except cavity tilt



Our modified DFS is not very effective to cavity tilt.

Large emittance for large weight.

With all other errors except for cavity tilt, the final emittance growth can be controlled to 0.5 nm.

DFS - including all the errors -1

Errors:

Quadrupole vertical offset: 300um

Quadrupole rotation: 300urad

Cavity vertical offset: 300um

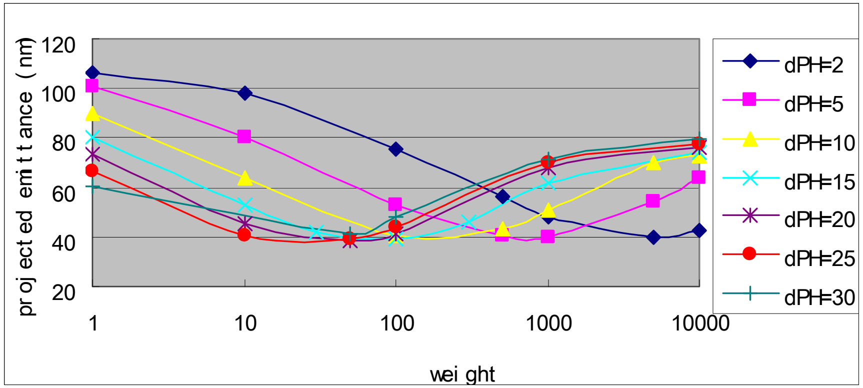
Cavity tilt: 200urad

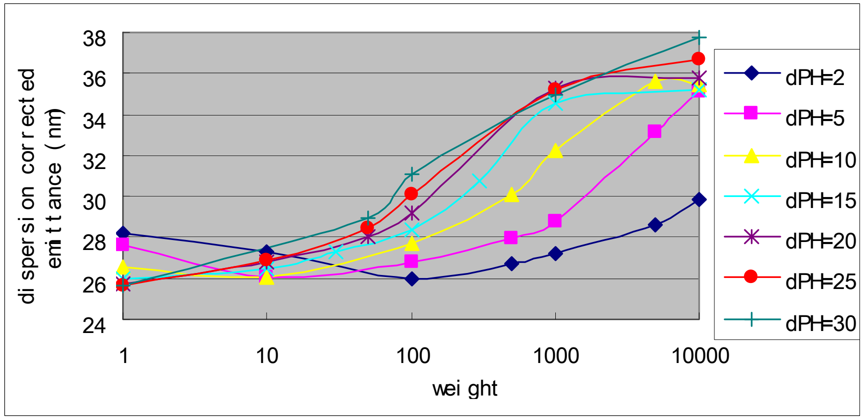
BPM vertical offset: 300 um

(aligned independently)

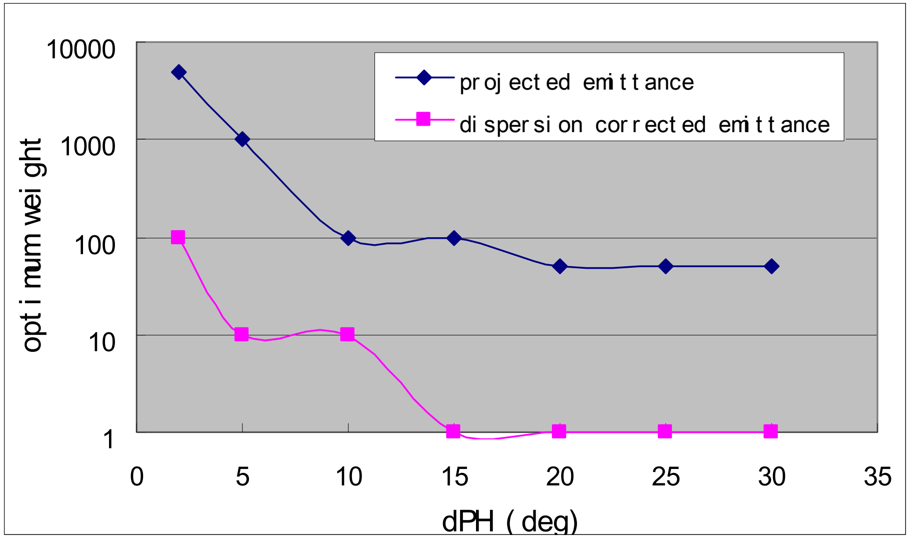
BPM resolution: 1 um

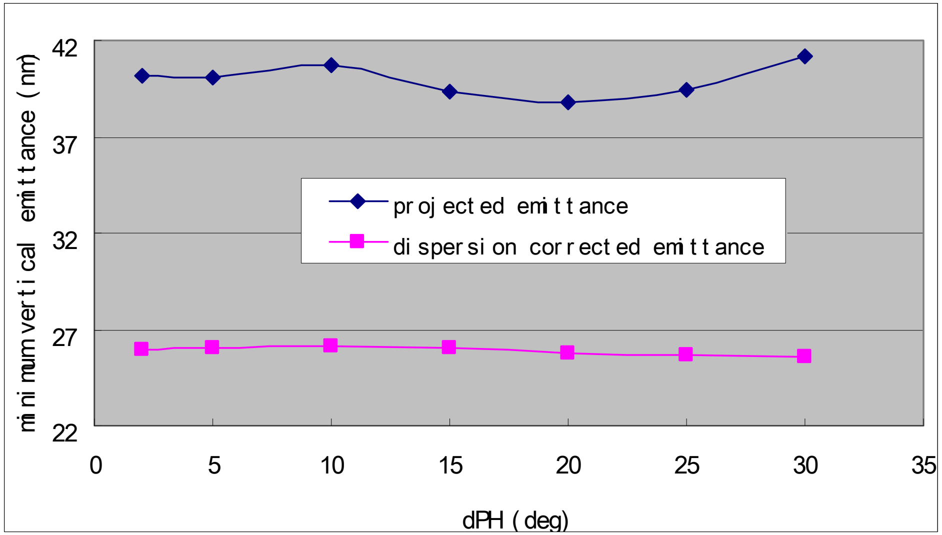
- random seeds=40





DFS - including all the errors -2





- *DFS is not very effective because of cavity tilt.*
- *The minimum final emittance growth can be controlled to 6 nm including all the errors.*

(Note: we set 200 urad, instead of “standard”, 300 urad.)

Simulations including longitudinal motion

SLEPT used to fix relative longitudinal position for saving time of wakefield calculations.

It is being improved to include longitudinal motion.

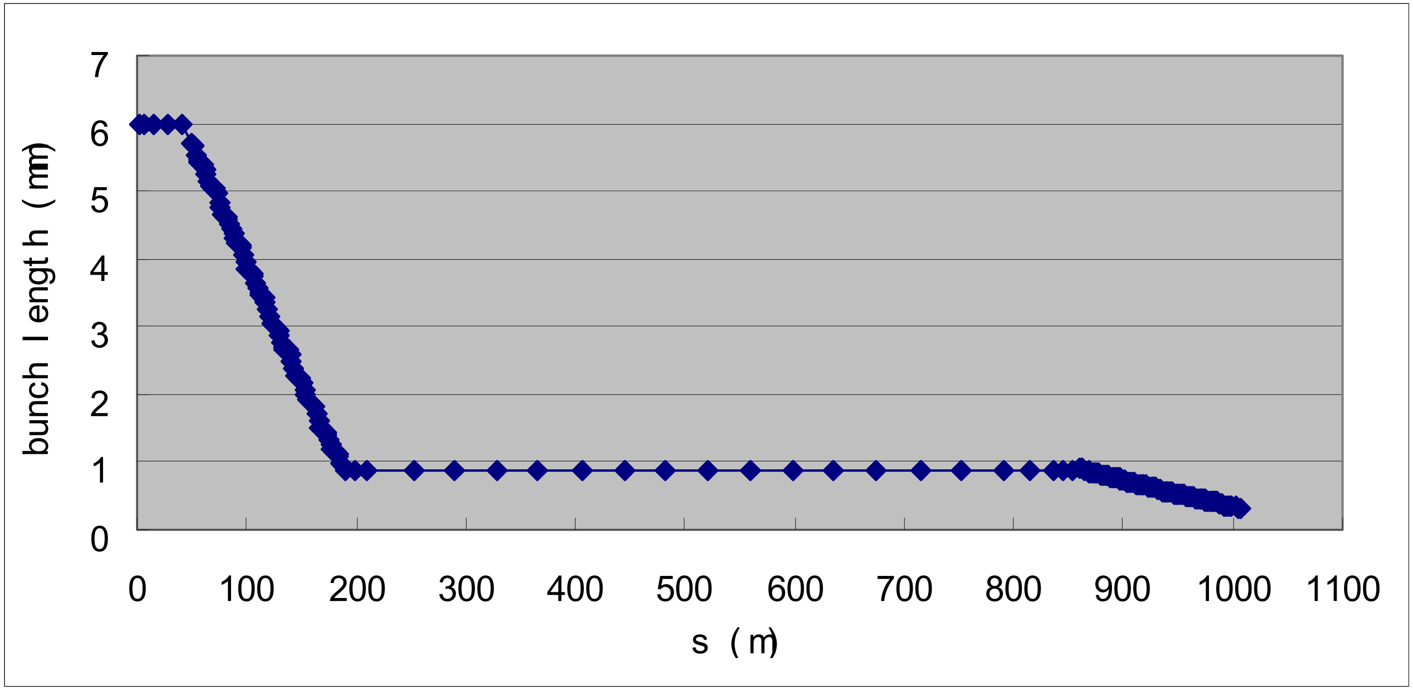
- Two types sections in the beam line:
  - Normal section: Z does not change. Wakefields exist. We use present program.
  - Special section: Z can change. No wakefields. We use new program.
- For special section

beginning: slice beam → particle beam (add Z to each macro-particle)

end: particle beam → slice beam; reset wakefields for slice beam.

Simulations including longitudinal motion - check bunch length change

- Simulation results for the whole ILC bunch compressor



W1: bunch length can be compressed from 6 mm to 0.89 mm

W2: bunch length can be compressed from 0.89 mm to 0.33 um

summary

1. Coupler wake has been newly introduced to SLEPT. Final vertical emittance growth in RDR BC RF section including coupler RF kick and wakes is :

   BC1: 0.21 nm

   BC2: 4.41 nm

2. DFS changing RF phase was introduced in SLEPT.
3. This DFS is not very effective to cavity tilt. (Should be checked.)
4. With all other errors except for cavity tilt, the final emittance growth can be controlled to 0.5 nm. But the final emittance growth will be 6 nm including 200 urad cavity tilt.
5. SLEPT is being improved to include Z-position change for BC.

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.