ILC-Asia-2006-06A
Rev.A October 20, 2006
Linac, Beam Dynamics

# Simulation of Low Emittance Transport in Long Straight Line of ILC RTML

K.Kubo (KEK)

# Simulation of Low Emittance Transport in Long Straight Line of ILC RTML, which is necessary for proposed change of ILC Layout

Kiyoshi Kubo

20061018

Revised 20061020 (see next page)

# Correction (2006.10.20)

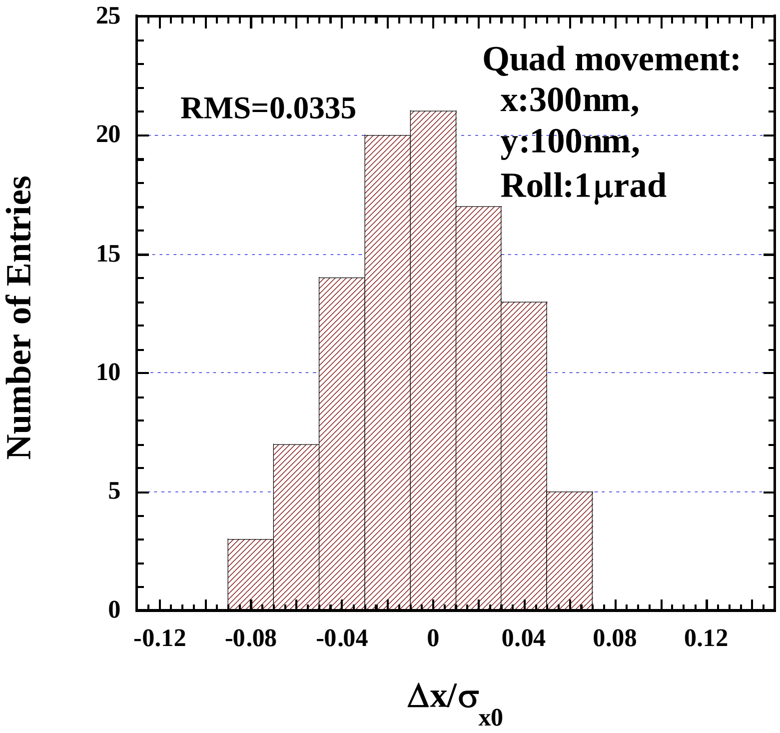
- Our design energy spread from the damping rings is about 0.15% but in the tracking simulations, it was set as 0.3% by mistake, though it was stated as 0.15% in the original version (2006.10.18).
- Then, the emittance increase due to dispersive effects (proportional to square of energy spread) is overestimated by factor 4.
- In other words, tolerances of offset errors are underestimated by factor 2.
- Tolerances of roll errors will not be affected, since x-y coupling does not related to energy spread (in first order approximation).
- New simulations setting 0.15% energy spread have not been done yet.
- Here, only the next page (simulated model) and the last page (SUMMARY) was changed.
- No need to change “PRELIMINARY CONCLUSION”.

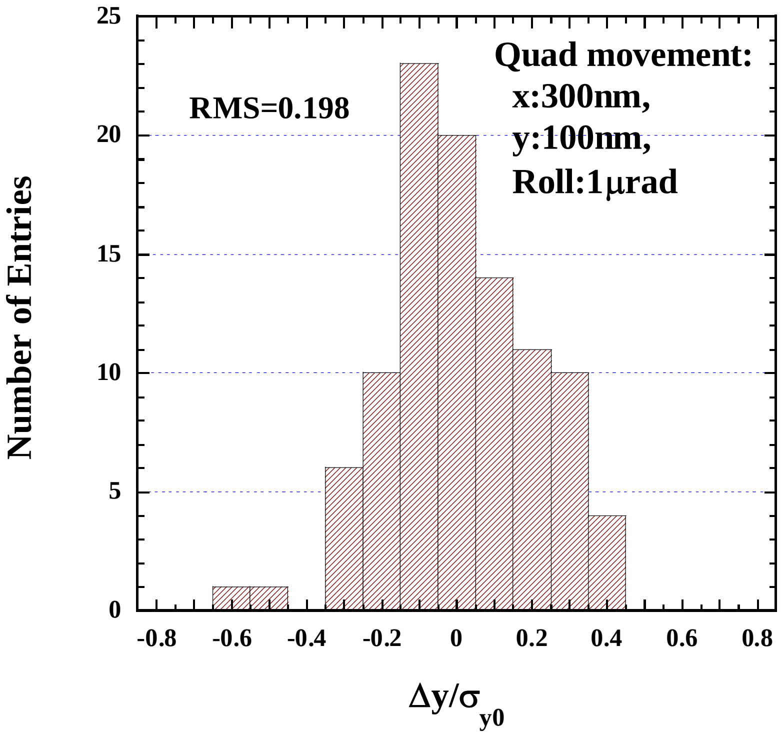
# Simulated model

- Laser Straight Transport Line, 12 km.
- FODO Lattice, Quad Spacing 36 m, Phase advance x/y = 50/45 degree per FODO cell
  - "36 m and 45 degree" are from private communication with P.Tenenbaum. Horizontal phase advance, 50 degree, is not an important parameter in this study.
- BPM and dipole correctors (x and y) are attached to every quad. (Length of a quad, BPM and steering magnet are set as 0.3 m, 0 and 0, respectively, which are not important parameters in this study.)
- Beam Energy 5 GeV, Initial normalized emittance x/y = 800/2 nm, energy spread 0.3% (it should have been set as 0.15%; see previous page)
  - Perfect initial beam (orbit, matching etc.) is assumed.
- Tracking of 10000 macro-particles using computer code SAD
- Beam center position and/or vertical projected emittance at the end of the linac are looked .

# (1) Beam center position jitter due to quad motion, No corrections

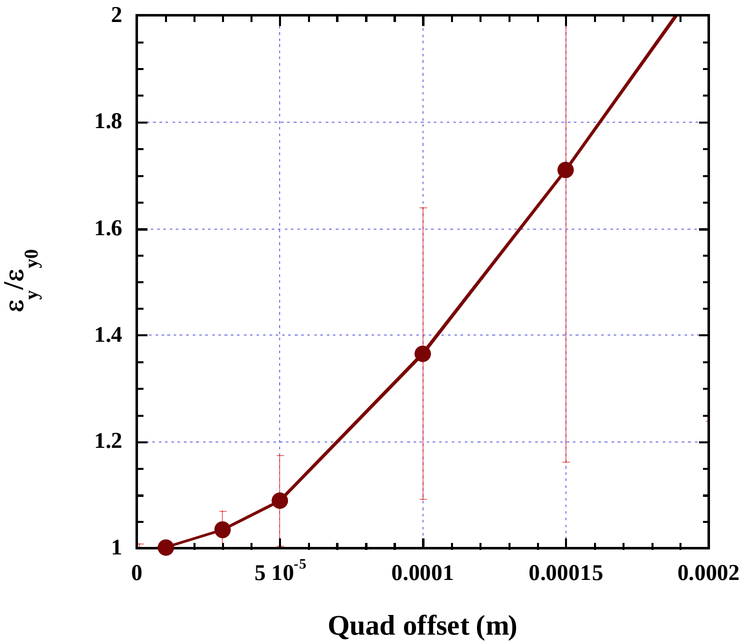
RMS Quad offset x: 300 nm, y:100 nm, Roll: 1 μrad
100 random seeds.
Figures show distribution of beam offset at the end of linac



# (2)Emittance increase due to Quad Misalignment with 1 to 1 correction: Minimize BPM reading

BPM is attached and perfectly aligned w.r.t. every quad.
Figure shows Vertical emittance vs. Quad offset,
Average of 100 seeds (error bar: standard deviation)




30 μm quad offset increases emittance by 3%.

# (3)Another correction - Kick minimization

Set Steering magnets to minimize:

$$\sum_i w^2 \left(x_i + \theta_{xi}/k_i\right)^2 + \sum_i x_i^2 \quad \text{and}$$

$$\sum_i w^2 \left(y_i - \theta_{yi}/k_i\right)^2 + \sum_i y_i^2$$

where $x_i\,(y_i)$ is horizontal(vertical) reading of $i$-th BPM,

$\theta_{xi}\,(\theta_{yi})$ the kick angle of $i$-th steering magnet and

$k_i$ the k-value of the $i$-th quad

(inverse of focsl length, positive for horizontal focus)

(Assuming the $i$-th BPM, $i$-th Quad and $i$-th Steering are attached.)

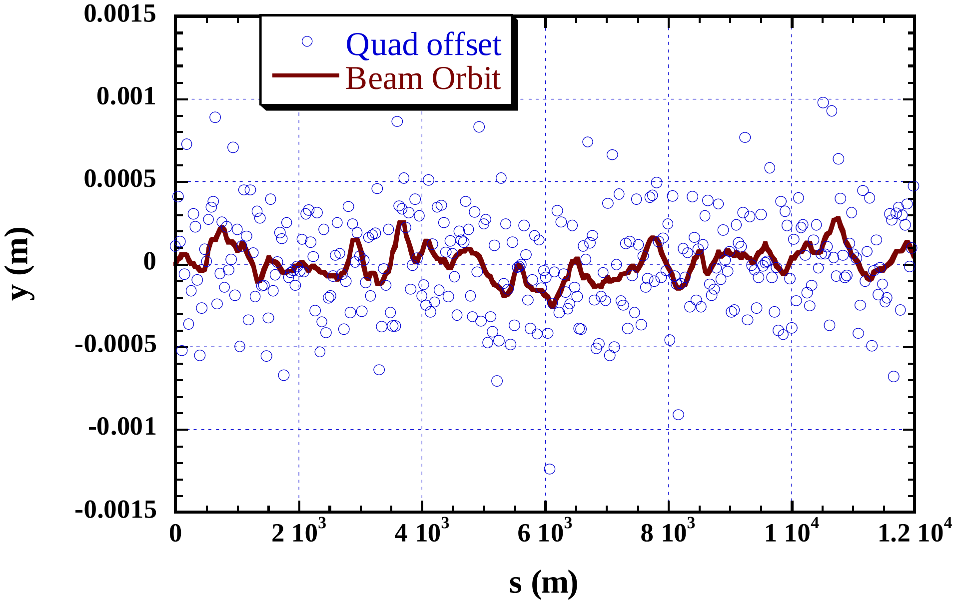
$w$ is the weight factor (here, set as 10)

This correction intends to minimize total kick by quad and steering.
Expected to be better than 1-to-1, since BPM will be aligned w.r.t. quad more accurately than w.r.t. an ideal line.
But need some iterations and more time.

# Example of Results of kick minimization

"Standard" errors:
Quad offset x and y: 300 μm, Quad roll: 300 μrad
BPM offset w.r.t. attached Quad: x and y: 30 μm,
BPM roll w.r.t. attached Quad: 300 μrad

Quad offset and Beam orbit (vertical)



# Result of kick minimization

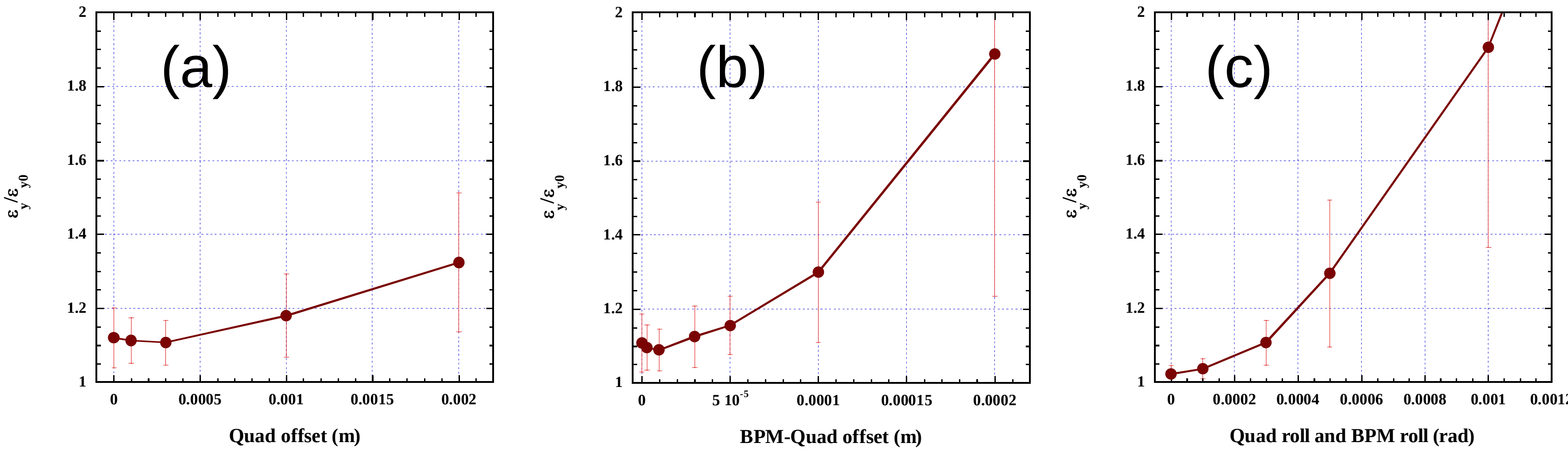
Sensitivity to different errors

(a) Quad offset (same in x and y)

(b) BPM offset w.r.t. attached Quad (same in x and y)

(c) Roll of Quad and Roll of BPM w.r.t. attached Quad (Same value for both roll errors)

In each figure, other errors are kept as “standard”




“Standard” set errors (Quad offset 300 $\mu$m, roll 300 $\mu$rad, BPM-Quad offset 30 $\mu$m) will increases the emittance about 10%, mostly due to Quad roll error.

# SUMMARY - 1

For long straight section of RTML, low emittance transport of 12 km straight line was simulated.

- Following the earth curvature is not expected to be a serious issue, from experiences in the main linac studies.
- Transverse position error of the quadrupole magnets are considered. Two cases:
  - No correction. Relevant for fast movements (vibrations) which can not be corrected by feed back. Note the different time scales of the pulse to pulse feedback (this is necessary) and the intra-pulse feed back (this may not be needed).
  - With corrections using steering magnets. One to one correction and Kick minimization are considered. Relevant for slow movements, much slower than the 5 Hz repetition rate.

Fast movements of quadrupoles (no corrections, faster than feedback) :

- 100 nm RMS movements will cause beam position jitter about 0.2 sigma of the nominal beam size at the end of the beam line, which will be tolerable, considering the orbit feed-forward in the turnaround after this line.
  - Note that emittance increase due to this level of movements will not be significant.

# SUMMARY - 2

Quadrupole misalignment (static misalignment and movements slow enough to perform the corrections):

- 30 μm RMS Quad offset will be tolerable, using "one to one correction".
  - Emittance increase less than 3% of nominal, without roll errors.
  - This correction can be used to correct movements of quad magnets which is slower than the repetition rate.
- 300 μm RMS Quad offset and 30 μm RMS BPM-Quad relative offset error will be tolerable, using "Kick Minimization".
  - Emittance increase less than 3% of nominal, without roll errors.
  - This correction can be used to correct initial alignment and slow movements of quad magnets.
- 300 μrad Quad roll will increase emittance about 10%.
  - Kick Minimization does not correct x-y coupling
  - Making Quad roll smaller than 100 μrad will be desirable.
  - Corrections using skew quadrupoles (with good monitors) will mitigate the effect. (This correction is not studied here)

Note: By mistake, the initial energy spread was set as 0.3%, where our design is 0.15%. The emittance increase due to dispersive effect is overestimated by factor 4.

PRELIMINARY CONCLUSION

- The long low emittance transport will not be a serious problem.