Main Linac DFS Simulation revisit and a little more

2007.12 LET Workshop@SLAC

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1. DFS tuning in Main Linac with static errors
2. Some dynamic effects
3. Study for Coupler wake
4. Alignment model (long range misalignment)

   → Another talk

DFS simulation of curved ILC Main Linac

- Simulation Code SLEPT.
- Curved linac, following earth’s curvature.
- Still use 4 cryomodules per bpm-magnet package: Lattice given by P.Tenenbaum [1]
- “Standard” errors are set. Horizontal misalignments are three times of vertical.
- Vertical emittance at the end of linac is looked.
- Sensitivity to each error (vertical) is also looked.

“Standard” errors (RMS)

	Vertical	Horizontal
Quad Offset (μm)	360	1080
Quad Roll (μrad)	300	
Cavity Offset (μm)	640	1920
Cavity Pitch and Yaw (μrad)	300 (pitch)	900 (yaw)
BPM Offset (μm)	360	1080
BPM Roll (μrad)	0	
BPM resolution (μm)	1	1
BPM scale error	0	0

All errors are random and independent.
This is almost (not exactly) equivalent to the “nominal misalignment” in ref. [3] (next slide).
The first three quads and BPMs are perfectly aligned.

Nominal errors from ref. [3]

Quad offset w.r.t. Cryomodule (μm)	300
Cavity offset w.r.t. Cryomodule (μm)	300
BPM offset w.r.t. Cryomodule (μm)	300
Quad roll w.r.t. design (μrad)	300
Cavity pitch w.r.t. Cryomodule (μrad)	300
Cryomodule offset w.r.t. design (μm)	200
Cryomodule pitch w.r.t. design (μrad)	20
BPM resolution (μm)	1

Simulated Algorithm of DFS, mode 1

One-to-one orbit correction (BPM reading zeroed)

・Divide linac into sections (50 quads-bpm/section, half overlapped)

In each section:

(1) Measure orbit with nominal beam energy. ($x_{0,I}$ and $y_{0,i}$ at i-th BPM)

(2) Reduce initial beam energy and accelerating gradient from the linac entrance to the entrance of the section by a common factor δ (δ= 0.1).

(3) For the second section or downstream, orbit adjusted at the two BPMs just before the section to make the position at the BPM

$$x_\delta = x_0 \text{ and } y_\delta = y_0 - \delta\eta_y$$

(x_0, y_0 are the position with nominal energy, η_y the dispersion at BPM.)

(4) Measure orbit. ($x_{\delta,i}$ and $y_{\delta,i}$ at i-th BPM)

(5) Set dipole correctors in the section to minimize

$$w\Sigma(x_{\delta,i} - x_{0,i})^2 + \Sigma x_{0,i}{}^2 \qquad \text{and}$$

$$w\Sigma(y_{\delta,i} - y_{0,i} - \Delta y_{cal,i})^2 + \Sigma(y_{0,i} - y_{cal,i})^2$$

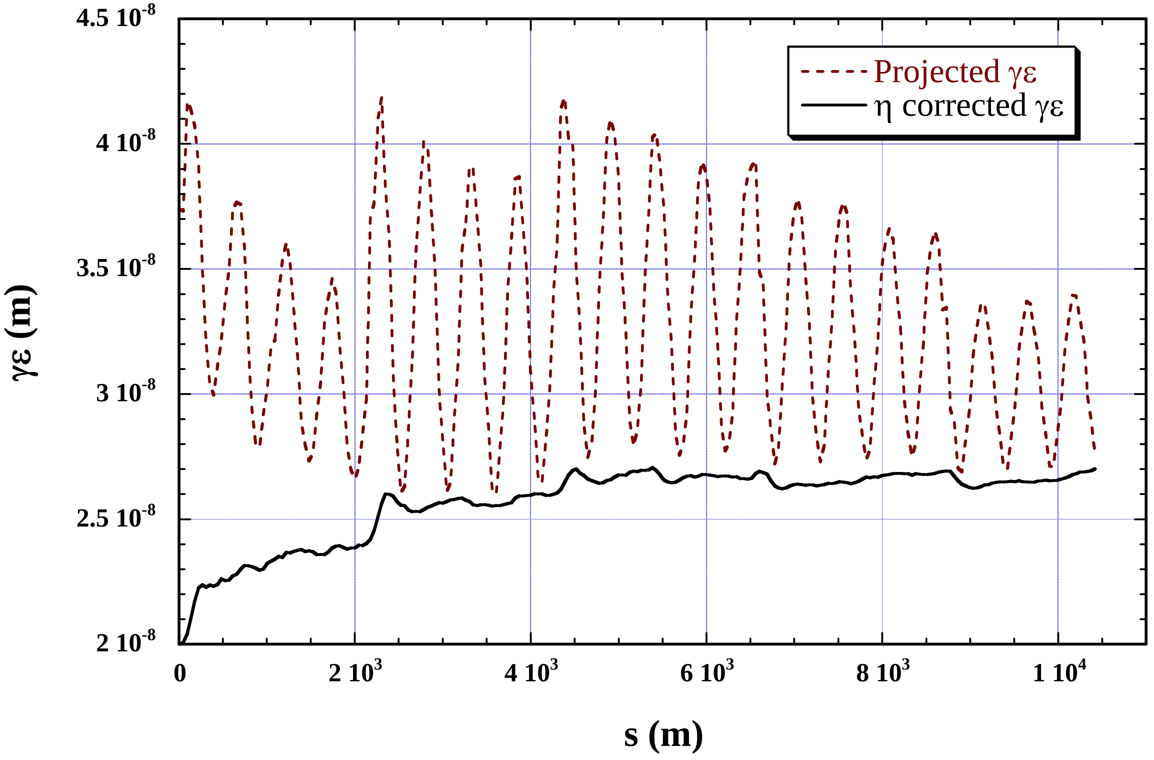
($\Delta y_{cal,i}$ is the calculated orbit difference, $y_{cal,I}$ the calculated orbit, without errors, at i-th BPM. w is the weight factor, w=5000.).

(6) Iterate from (1) to (5) once.

(7) Go to next section.

Vertical Emittance along linac

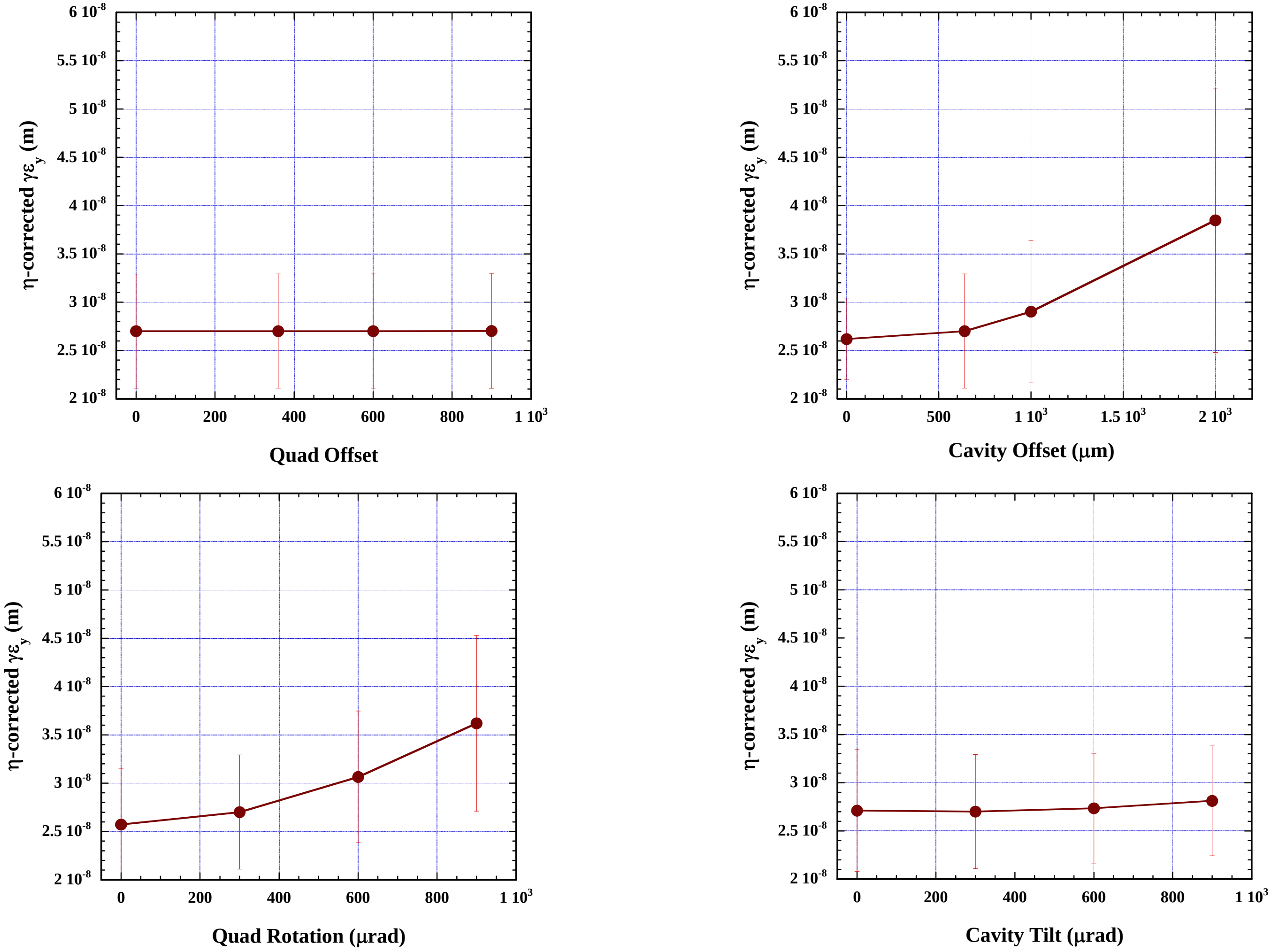
DFS with “standard” errors.
Average of 40 random seeds



Sensitivity to each error-1

Other errors are kept as "standard". Initial $\gamma\varepsilon$=2E-8 m.

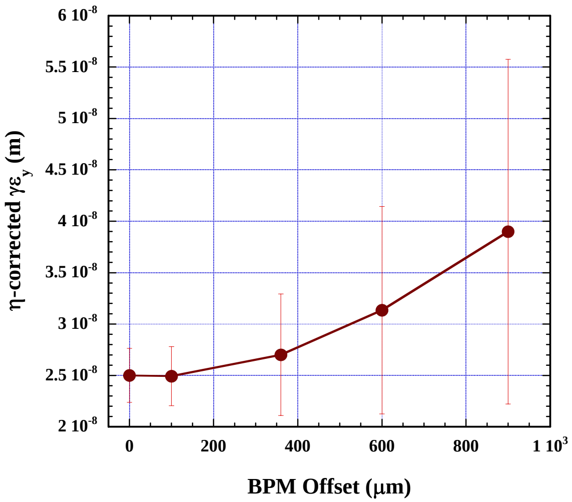
Average of 40 random seeds. Error bars indicate standard deviations.

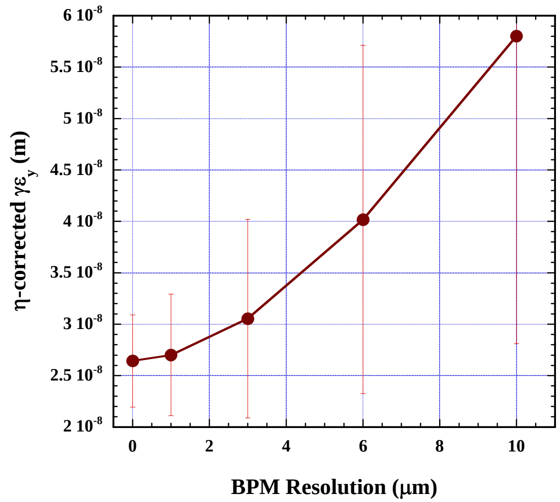


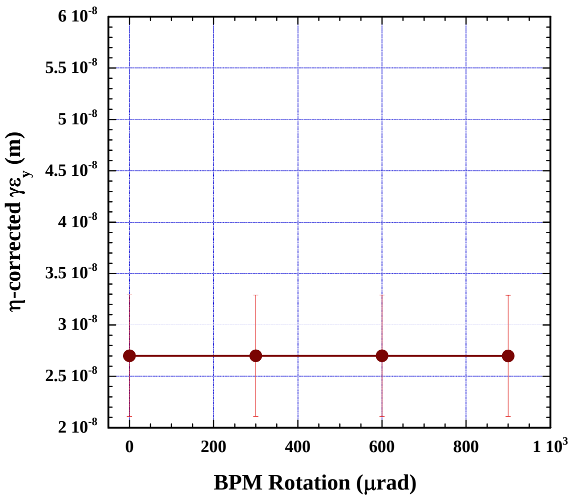
Sensitivity to each error-2

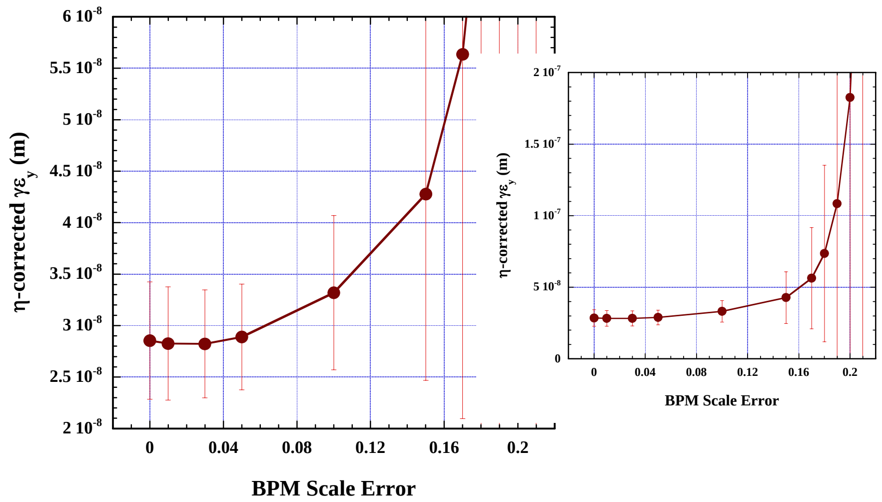
Other errors are kept as “standard”. Initial $\gamma\varepsilon$=2E-8 m.

Average of 40 random seeds. Error bars indicate standard deviations.









Sensitivity to each error

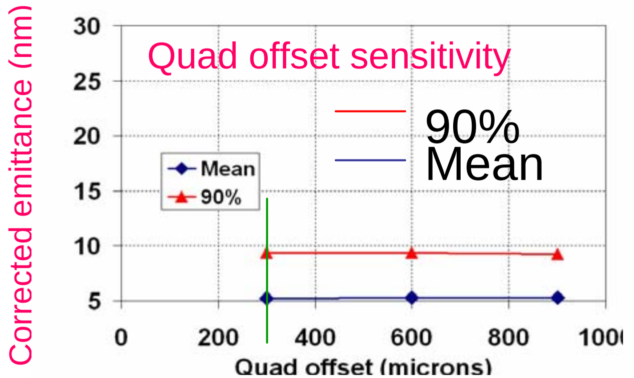
- BPM resolution is very important
  - Directly affects dispersion measurement.
- BPM scale error is very important
  - DFS tries to adjust the dispersion to non-zero designed value. BPM scale error affects this adjustment.

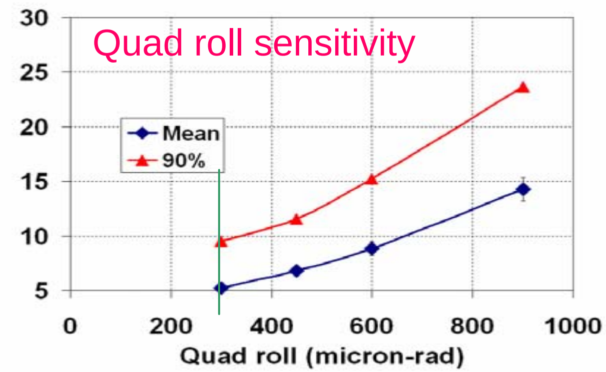
- Cavity offset error and BPM offset error have some effect
  - DFS does not correct effects of cavity wake fields.
- Quad rotation error has some effect
  - DFS does not cure the x-y coupling.

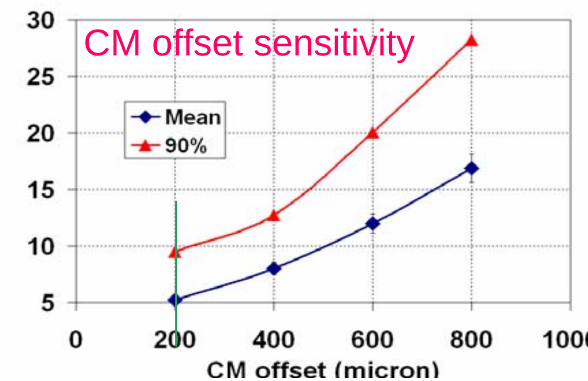
- Dependences on Cavity pitch and BPM offset do not quite agree with another work by Kirti Ranjan, reported in 2006.
  - Should be checked.

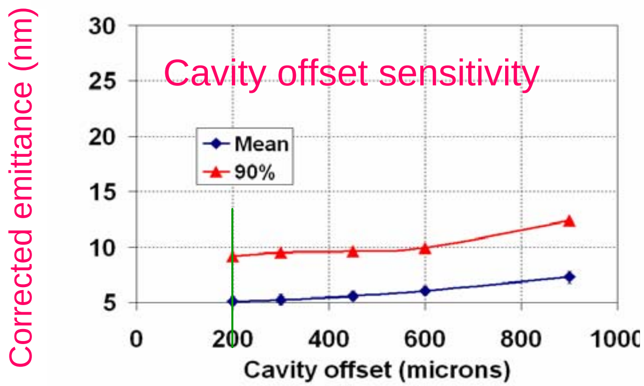
DFS: Sensitivity studies

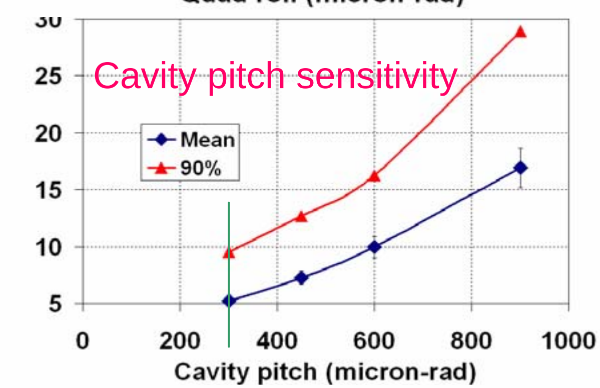
Vary one misalignment from its nominal value - keeping all other misalignments at their nominal values

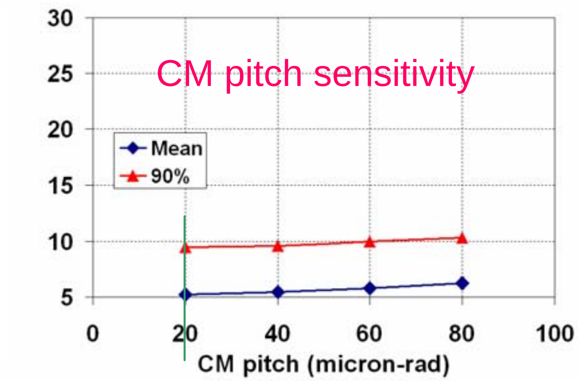


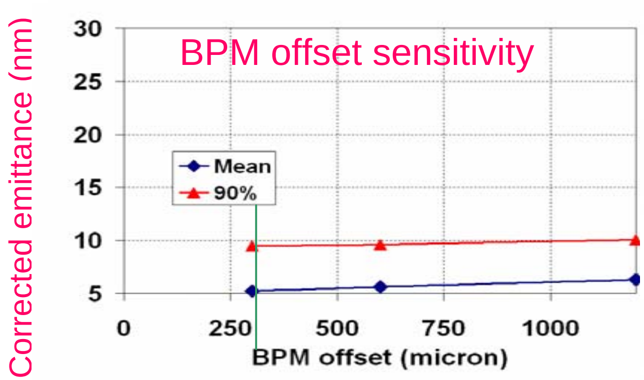


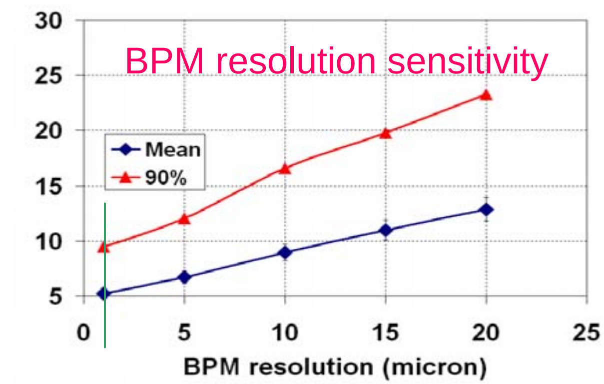










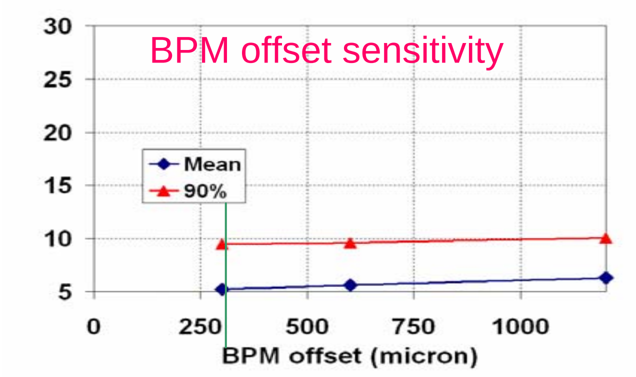


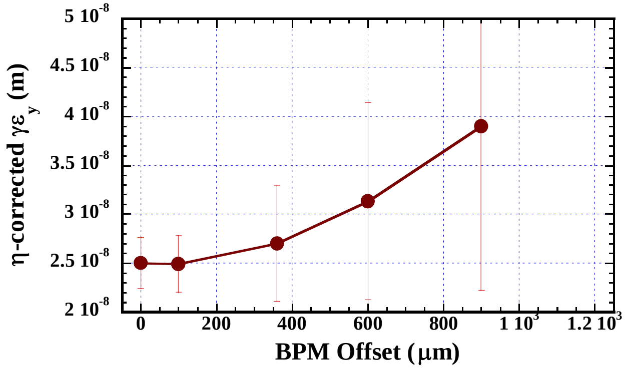
Sensitive to
***Cavity pitch*,**
***BPM resolution*,**
***CM offset*,**
Quad roll

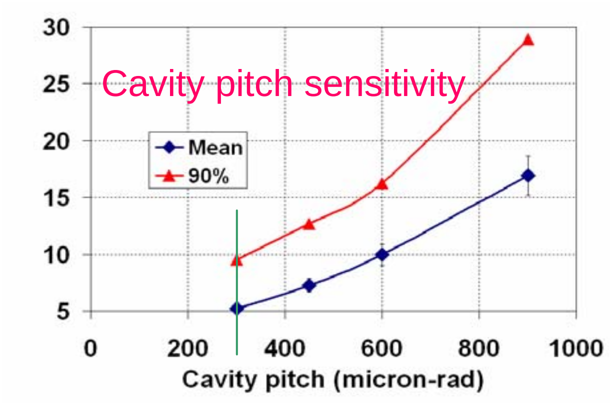
Kirti Ranjan in Vancouver GDE Meeting,2006

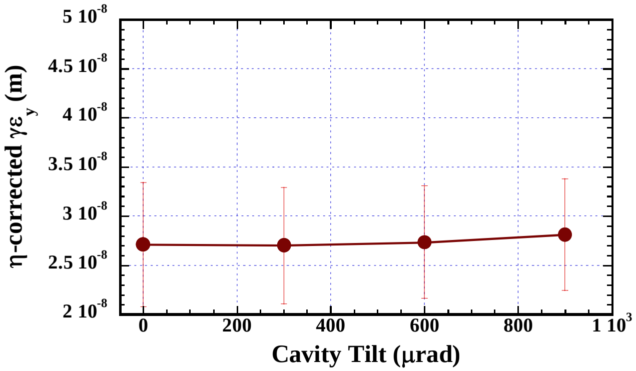
By K.Ranjan

This work



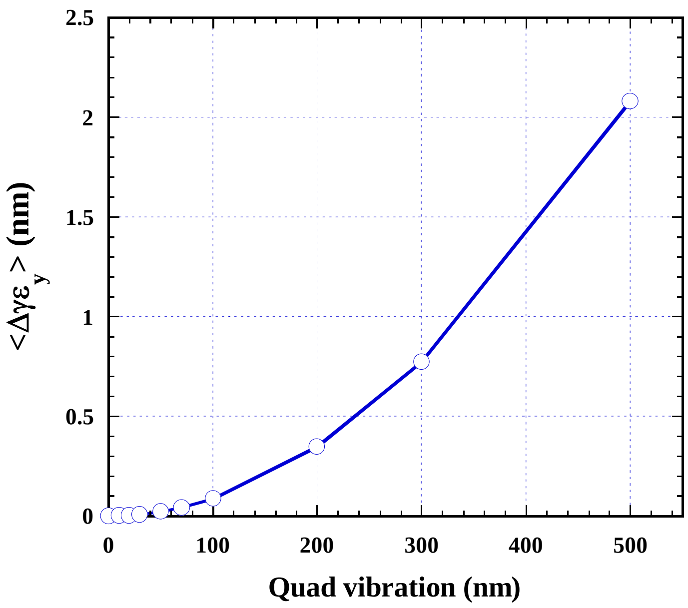


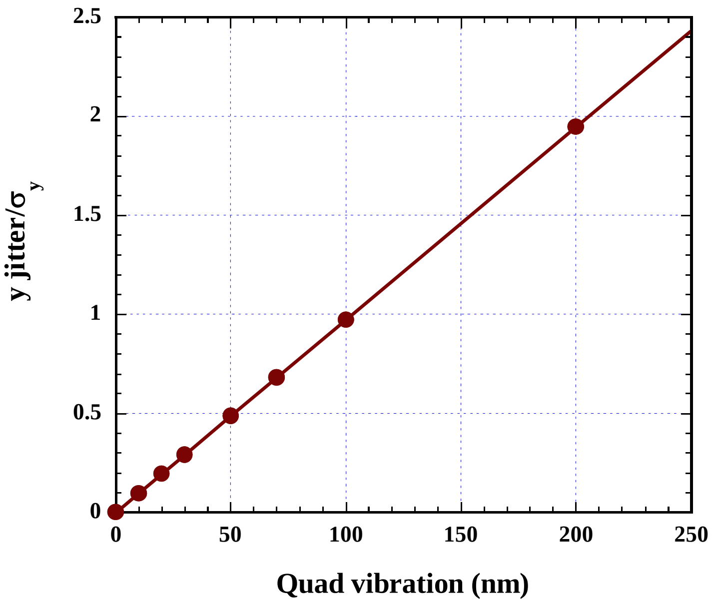




Effect of quad position jitter (vibration) -- emittance and orbit --

Apply 100 sets of random quad position error to a perfect linac.
Average of emittance growth and RMS beam orbit jitter

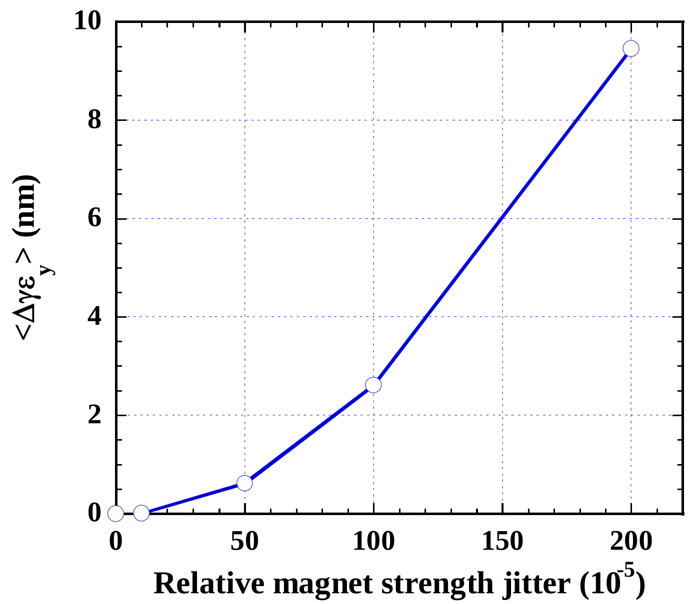


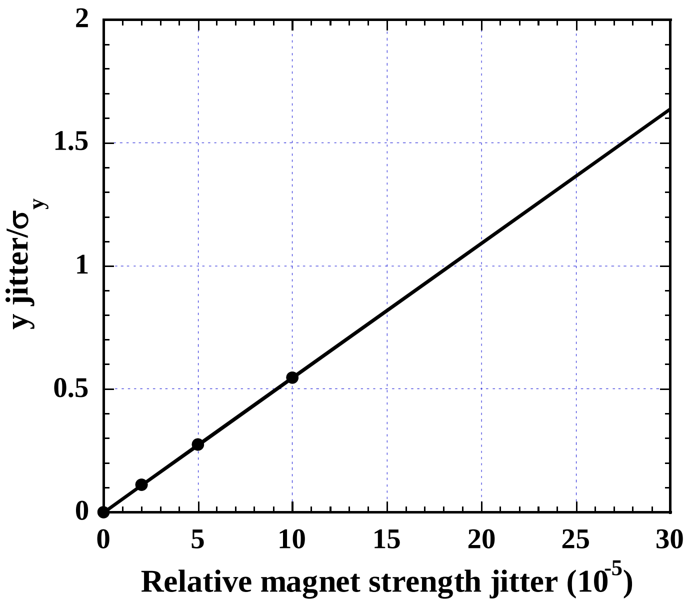


100 nm jitter → 0.1 nm emittance growth, 1 σ orbit jitter

Effect of magnet Strength jitter
-- emittance and orbit --

Apply 10 sets of random strength error of quad and dipole corrector magnets to each of 10 linacs after DFS with “standard” errors. (total 100). Average of emittance growth and RMS beam orbit jitter





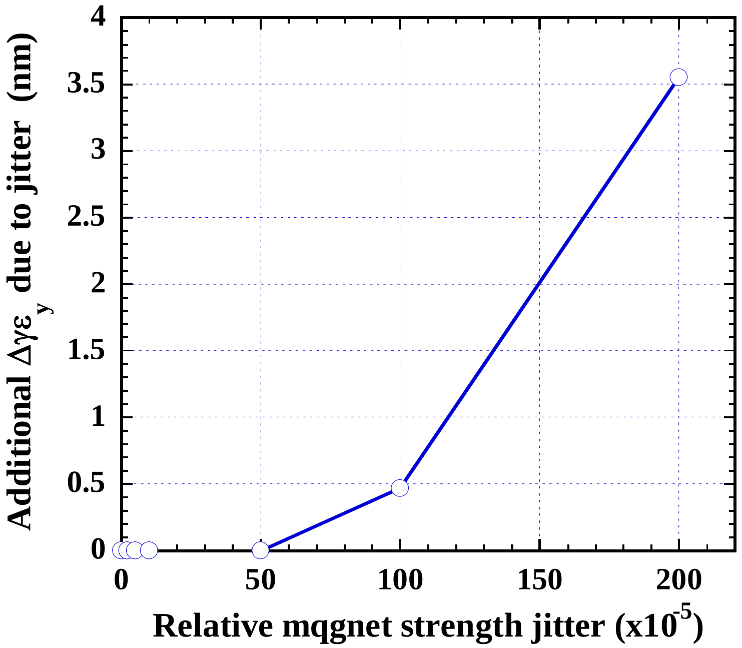
5E-4 jitter → 0.6 nm emittance growth

1.8E-4 jitter → 1 σ orbit jitter

Effect of magnet Strength jitter During DFS

Apply strength error of quad and dipole corrector magnets to 50 linacs during DFS with “standard” errors.

Average of additional emittance growth (emittance without jitter is subtracted)

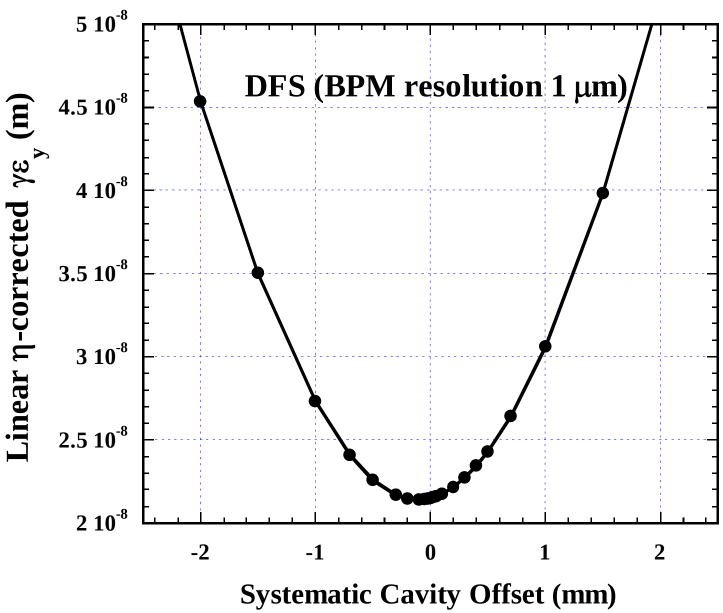


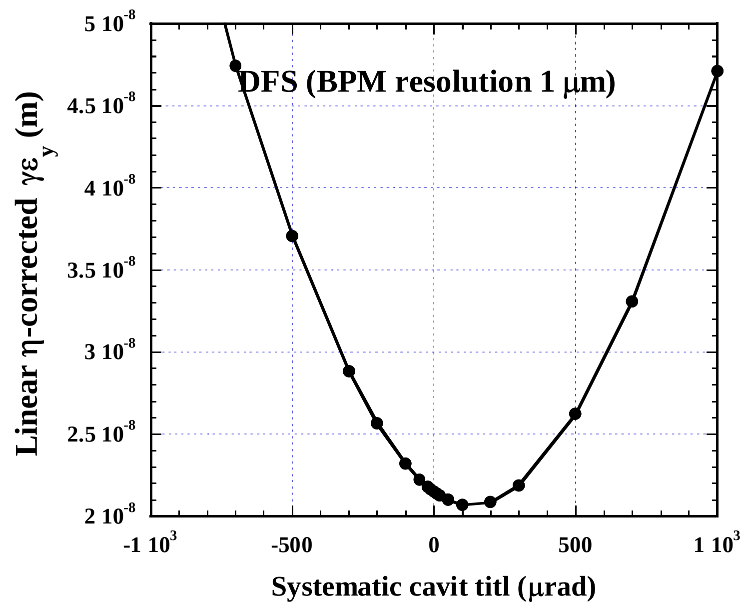
1E-3 jitter → 0.5 nm emittance growth

Systematic offset and tilt of cavities

- Effects of coupler wakefield and coupler RF kick can be simulated as systematic offset of cavities (all cavities have the same offset) and systematic tilt of cavities (all cavities have the same tilt). (Is it true?)

Apply DFS with systematic offset of tilt. No other errors.





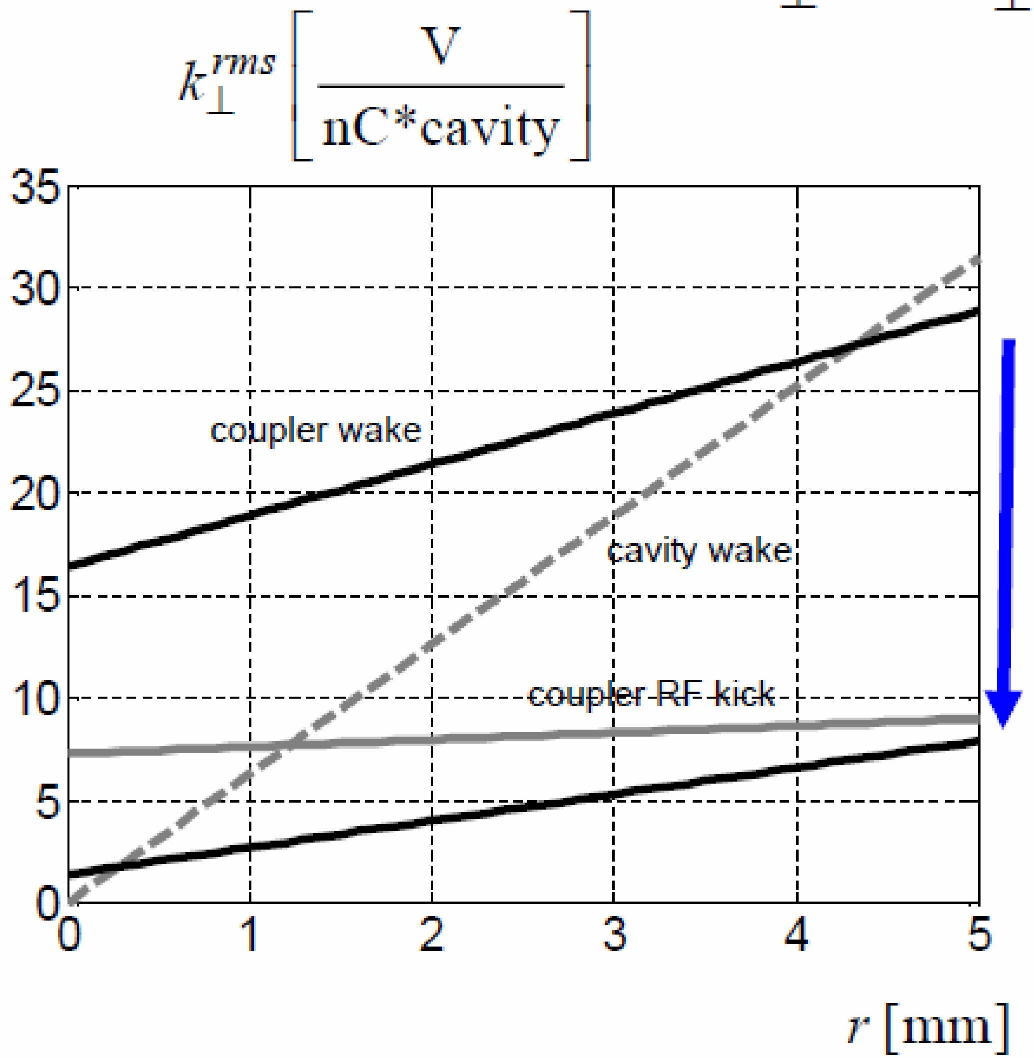
Tolerance will be a few 100 μm and a few 100 μrad.

Effective tilt may be compensated by intentional tilt.

Head-Tail Kick (ILC)

$\sigma = 300\ \mu\text{m}$

$$k_\perp^{rms} \approx k_\perp^{0,rms} + k_\perp^{1,rms} r$$



I. Zagorodnov and M.DohlusILC Workshop, DESY31 May, 2007

SUMMARY

Main Linac DFS tuning was visited again

- DFS with "Standard" errors give 35% average emittance growth, which will be (barely?) tolerable.
- Dependence on BPM offset, cavity pitch ad cavity offset looks inconsistent with K.Ranjan's result, [3].
  - Should be checked by somebody.

Some effects of Quad position jitter (vibration) and magnet (quad and dipole) strength jitter were studied

- Tolerance will be determined by the performance of post linac feedback.

Effects of coupler wake and coupler RF kick were studied.

- It looks they have to be cured.
- Probably the effects should be considered more carefully.

References

[1]: http://www-project.slac.stanford.edu/ilc/acceldev/LET/ilc_linac.xsif
[2]: K.Kubo, in ILC Beam Dynamics Meeting,
http://ilcagenda.cern.ch/getFile.py/access?resId=3&materialId=slides&confId=694
[3]: K.Ranjan, Vancouver GDE meeting parallel session,
http://ilcagenda.cern.ch/conferenceDisplay.py?confId=753
[4] Igor Zagorodnovand Martin Dohlus, "Coupler Kick", ILC Workshop, DESY31 May, 2007