Main Linac Tolerances What do they mean?

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1. Introduction, review of old studies
2. Assumed “static” errors and their meaning
3. Assumed some “dynamic” errors and their meaning

Simulations ILC Main Linac

- Vertical motion is concerned.
  - Horizontal tolerance is much larger than vertical, e.g. alignment tolerance should be more than 10 times larger. (proportional to sqrt. of emittance)
- We have a “Standard” error set for “static” errors.
  - They are not necessarily tolerances.
  - “Static” means not changing in time scale necessary for performing (complicated) corrections.
  - **Main purpose of this presentation is to understand what these errors can be interpreted in actual construction.**
- We use DMS (Dispersion Matching Steering, or often called DFS, dispersion free steering).

- Many Simulation Codes have given similar results. Here, I quote mostly my own results, using code SLEPT.
- Multi-bunch effect is not considered well, or supposed not to be problematic. (But it should be checked, actually.)

“Standard” errors

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

On long range alignment (survey)

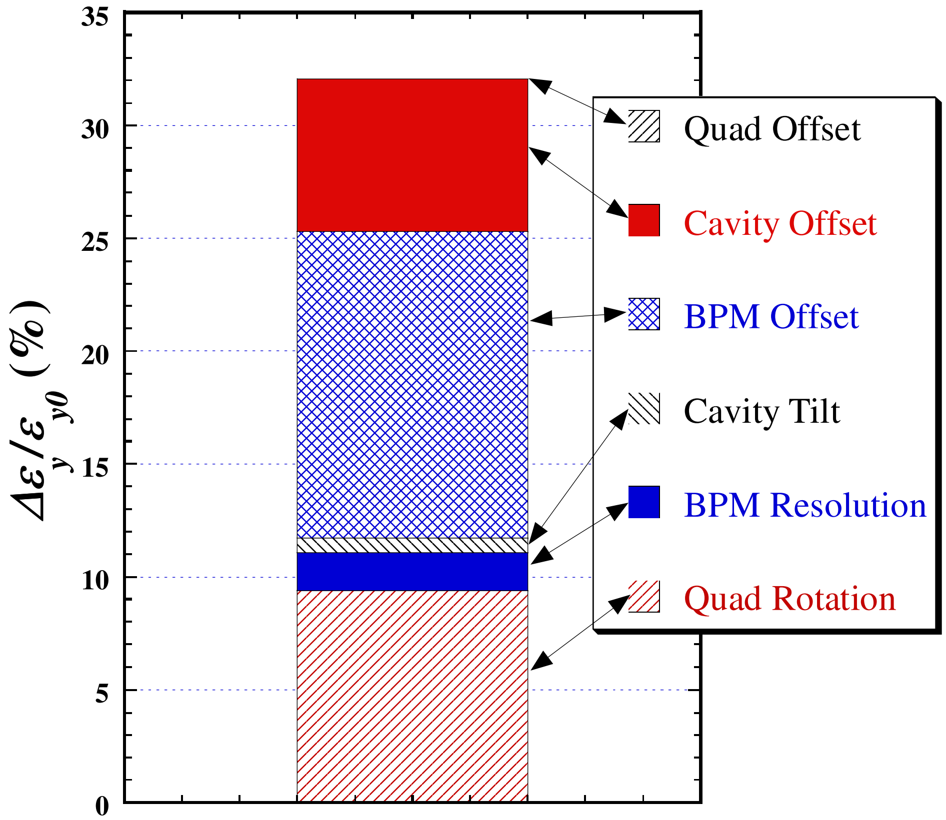
- We do not have reliable model of long range alignment (survey).
  - Need help from experts but there is no responsible group in GDE. (?)
- Here, we ignore error of survey.
  - Components are aligned with respect to a designed line. (Local misalignment only.)

Errors Equivalent to “Standard”

	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 “standard” in the previous slide.

Contributions to Emittance growth

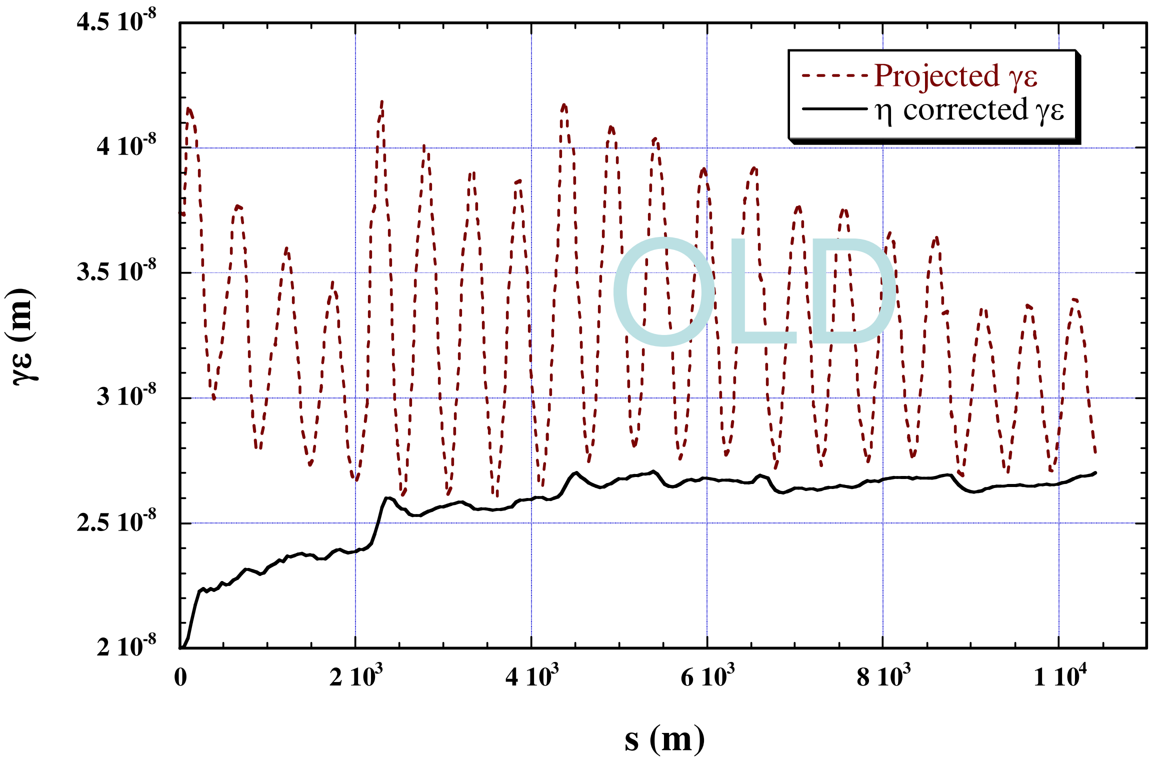


For 15 → 250 GeV ML, error set “equivqlent to standard”

The total and contribution of each error should be different if initial energy is 5 GeV.

Vertical Emittance along linac

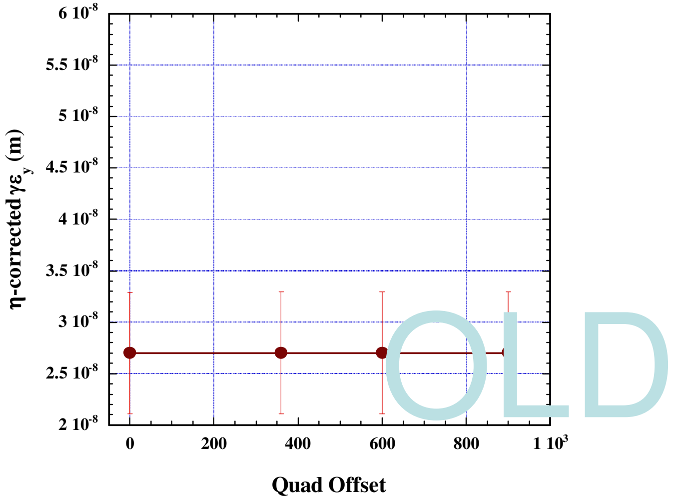
DFS with "standard" errors.
Average of 40 random seeds

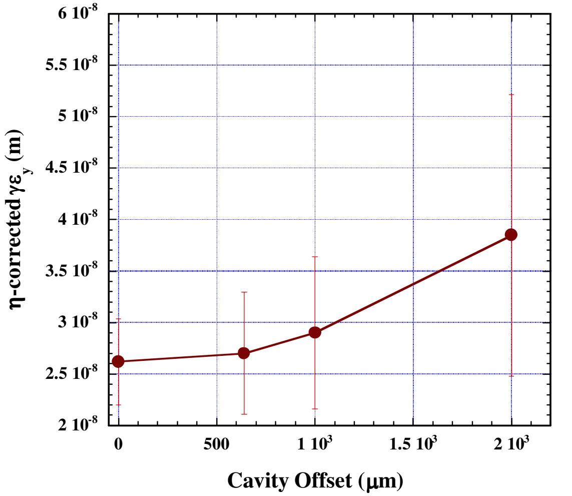


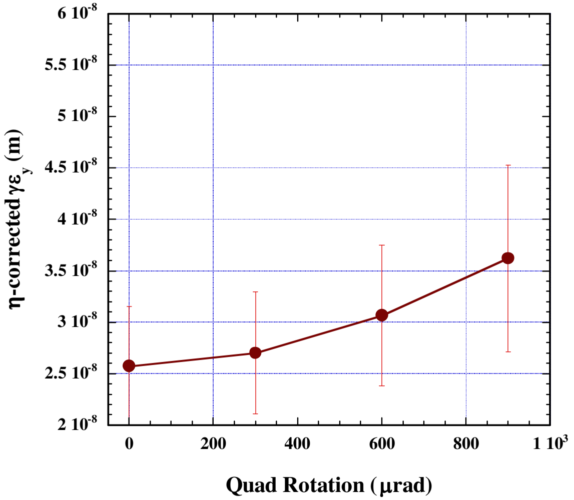
Sensitivity to each error-1

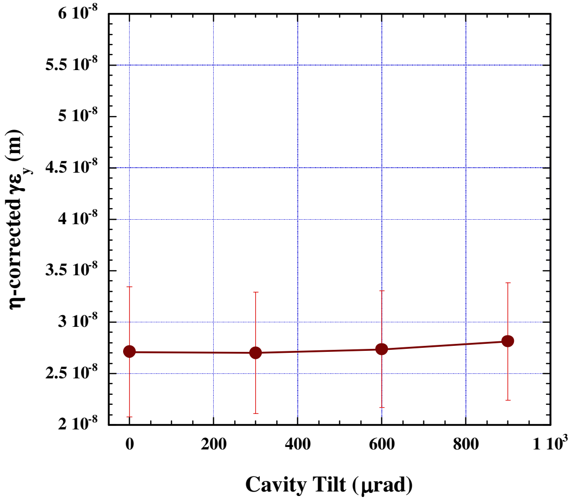
Other errors are kept as “standard”. Initial $\gamma\varepsilon$=2E-8 m.

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





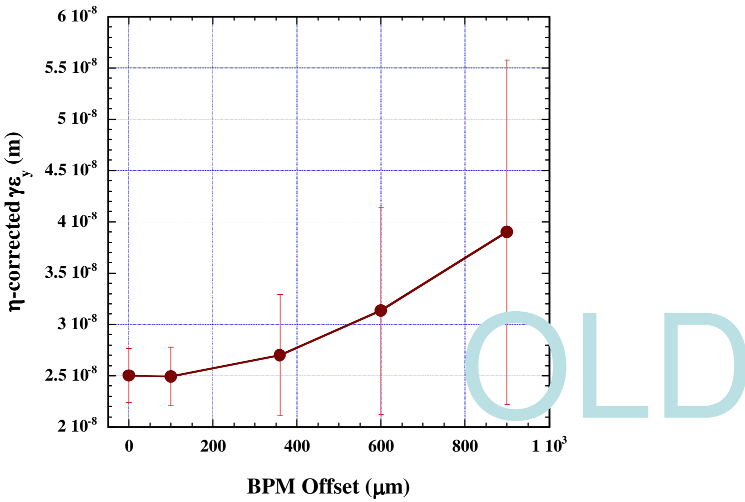


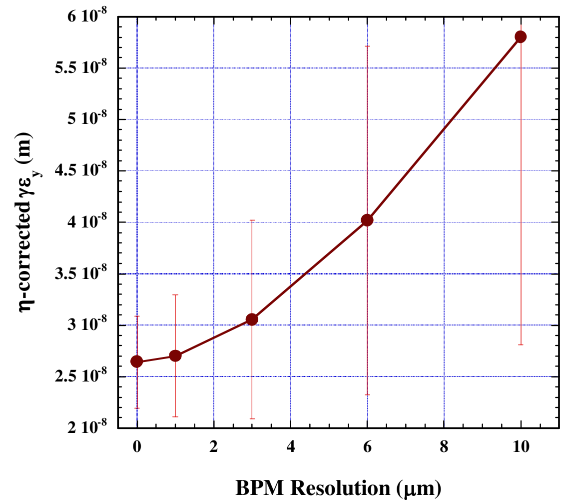


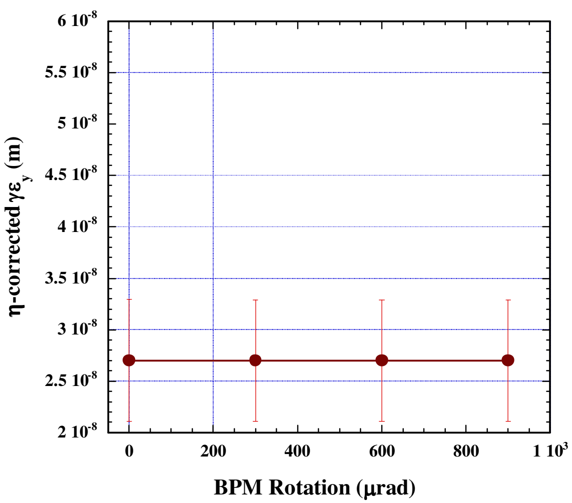
Sensitivity to each error-2

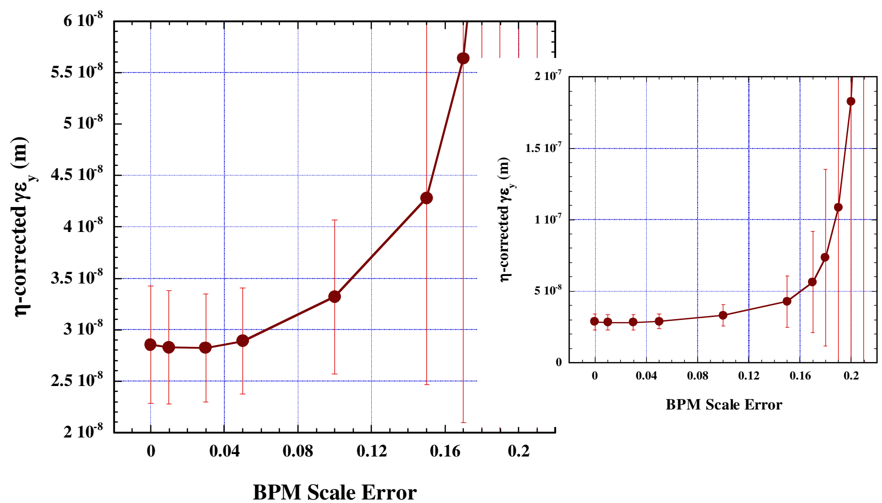
Other errors are kept as “standard”. Initial $\gamma\varepsilon$=2E-8 m.

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









On 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.

- Assumptions of some errors may be loosened, by tightening others.

Quad misalignment

- Offset
  - Relevant value: Offset of each magnet from design

(Effective RMS offset)^2 ~
(RMS offset of cryo-module)^2
+ (RMS offset of quad w.r.t. cryo-module)^2 = (360 micron)^2

- Rotation:
  - Relevant value: Rotation of each magnet from design
    RMS = 0.3 mrad

- Pitch and yew tolerances are supposed to be large enough.

Cavity misalignment - 1

- Offset:
  - Relevant value: Average offset from design (average over length comparable to beta-function ~ 100 m)
  - Effect: Wakefield

(Effective RMS offset)^2 ~

(RMS offset of cryo-module)^2*(# of cavities in a module)

+ (RMS offset of cavity w.r.t. cryo-module)^2 = (640 micron)^2

- Effect of distortion of cavity (banana, and etc.)
  - Only average is relevant (for single bunch).

Cavity misalignment - 2

- Tilt (pitch, rotation around x-axis):
  - Relevant value: Average tilt from design (average over length comparable to beta-function ~ 100 m)
  - Effect: Transverse kick by accelerating RF field

(Effective RMS tilt)^2 ~

(RMS tilt of cryo-module)^2*(# of cavities in a module)

+ (RMS tilt of cavity w.r.t. cryo-module)^2 = (300 micro-rad)^2

- Effect of distortion of cavity (banana, and etc.)
  - Only average (total transverse field) is relevant.

Comment on Effect of distortion of cavity (banana, and etc.)

- For single bunch effect
  - only average (total transverse field) is relevant.
- For multi-bunch effect
  - Long-range transverse wake should be checked
  - We just assume it will not be significant, tentatively. (?)
  - Large efforts existed for X-band LC structures. (There was a good reason why we had to studied the effect.)

BPM misalignment

- Offset
  - Relevant value:
    (A) Offset of each BPM from design
    (B) Offset with respect to attached quad magnet field center.

(A):
(Effective RMS offset)^2 ~
(RMS offset of cryo-module)^2
+ (RMS offset of BPM w.r.t. cryo-module)^2 = (360 micron)^2

(B):
Mechanical offset should be should with in BPM dynamic range.
We assume offset can be measured using beam, with accuracy of 10 micron.

Fast errors (jitters) -1

- 0.14 sigma orbit change will cause offset in collision and ~3% luminosity reduction without orbit feedback.
  - It may not determine tolerances becuase we will have intra-pulse orbit feedback at IP.
- Orbit jitter tolerance at the entrance of BDS is 0.5 sigma.
  - It will determine tolerances if we do not have intra-pulse post-ML orbit feedback.
  - It may not determine tolerances if we do have intra-pulse post-ML orbit feedback.
    - Actual tolerance will depend of the dynamic range of the feedback system. (?)
- 6.3% emittance growth cause ~3% luminosity reduction in head on collision (Assuming perfect orbit correction)

Fast errors (jitters) -2

	0.14σ RMS orbit change	6.3% emittance growth
Quad position	12 nm	200 nm
Cavity position	22 um	130 um
Cavity tilt	0.5 urad	2.5 urad
Magnet strength	6.5E-5	1E-3

[Wang Dou, This workshop, in (): old results by K.Kubo]

- 0.14 sigma orbit change will cause ~3% luminosity reduction without orbit feedback downstream.
- 6.3% emittance growth cause ~3% luminosity reduction in head on collision

Fast errors (jitters) -3

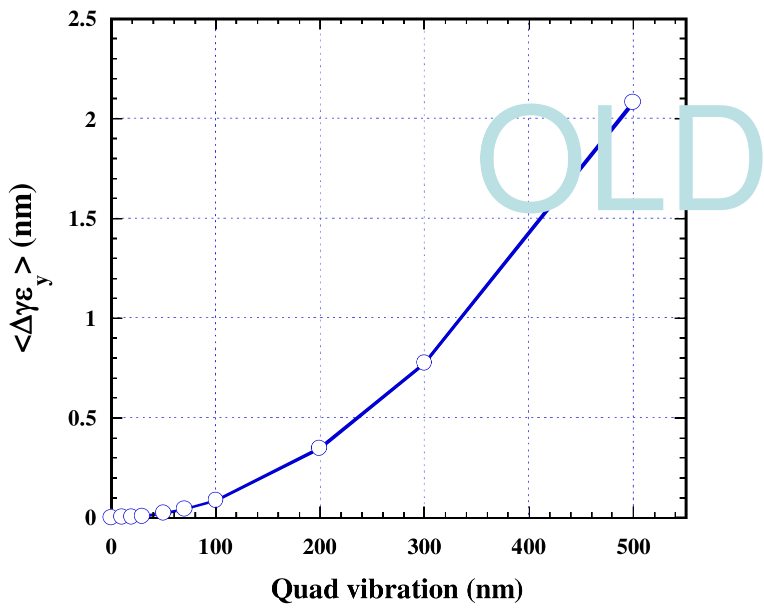
	0.5σ RMS orbit change	6.3% emittance growth
Quad position	40 nm	200 nm
Cavity position	80 um	130 um
Cavity tilt	1.8 urad	2.5 urad
Magnet strength	2.3E-4	1E-3

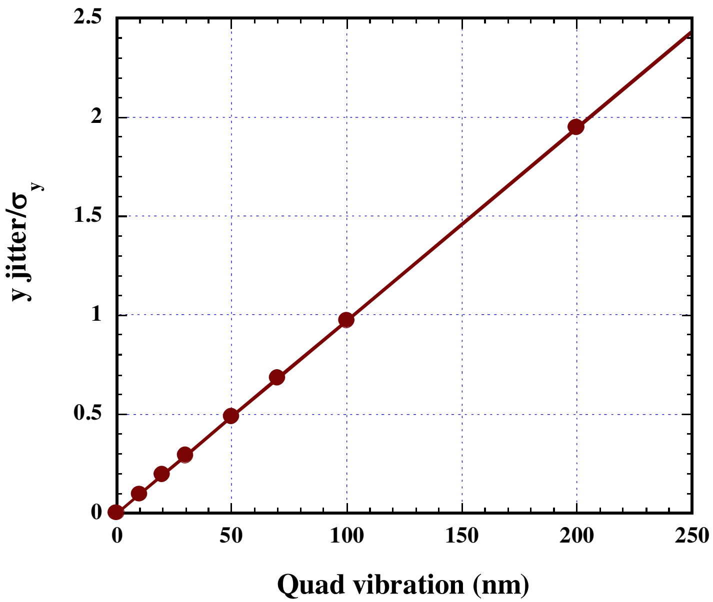
[Wang Dou, This workshop, in (): old results by K.Kubo]

- 0.5 sigma orbit change will be required at BDS entrance. May be larger assuming (intra-pulse) post ML orbit feedback
- 6.3% emittance growth cause ~3% luminosity reduction in head on collision.

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

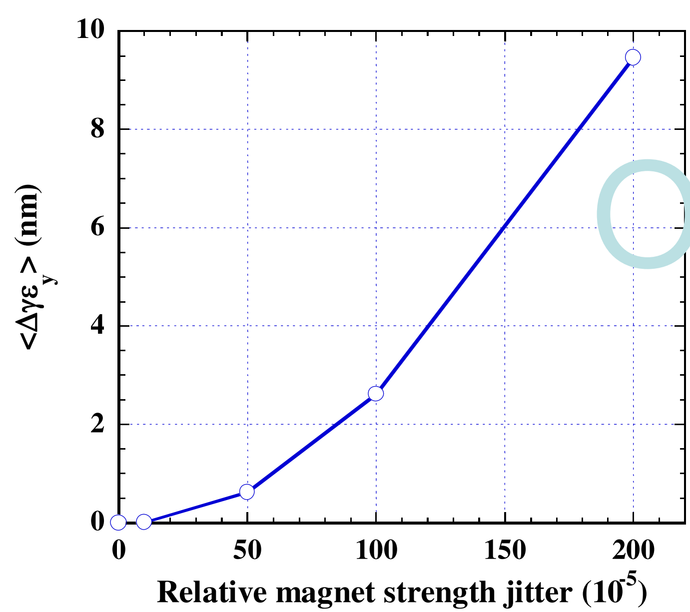


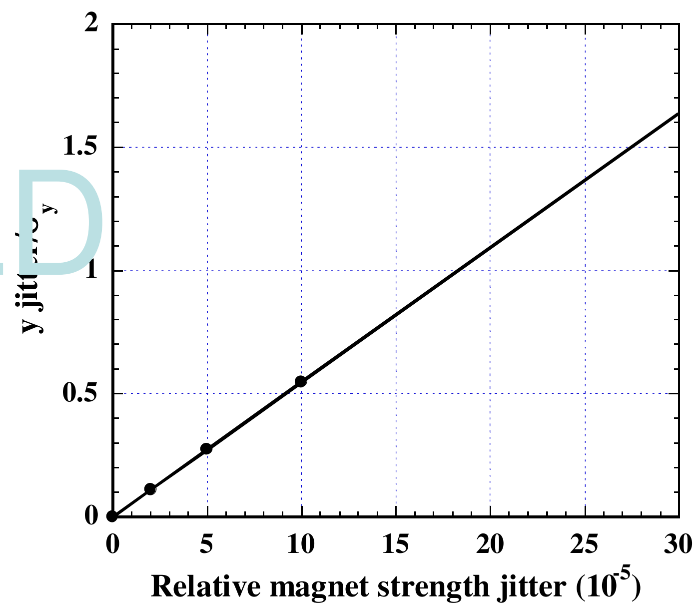


100 nm jitter → 0.1 nm emittance growth, 1 σ orbit jitter

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

Questions

- Are the assumptions reasonable?
- Are the models appropriate?
  - If not, what kind of models should be used and what parameters should be specified.

References

K.Kubo, in ILC Beam Dynamics Meeting,

http://ilcagenda.cern.ch/getFile.py/access?resId=3&materialId=slides&confId=694

K.Ranjan, Vancouver GDE meeting parallel session,

http://ilcagenda.cern.ch/conferenceDisplay.py?confId=753

W.Dou, In this workshop

etc.