# Main Linac Simulation

## - Main Linac Alignment Tolerances

## - From single bunch effect

200508xx

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References:

TESLA TDR

ILC-TRC-2 Report (2003)

Interim reports by K.Kubo

http://lcdev.kek.jp/~kkubo/reports/MainLinac-simulation/lcsimu-20050325a.pdf

http://lcdev.kek.jp/~kkubo/reports/MainLinac-simulation/lcsimu-20050516.pdf

# *Main Linac Simulation*

- Only single bunch effects were considered
- Only vertical motion (no horizontal)
- Short range wakefunctions in TESLA-TDR were used.
- Tracking simulation using “SLEPT”.
- Considered errors:
- Offset misalignment of quads,
- Offset misalignment of cavities,
- Tilt misalignment of cavities (rotation around x axis),
- quad-BPM offset (unknown error of quad-BPM cwnter)
- BPM resolution (measurement by measurement error)
- Each quad has BPM and steering corrector
- Average of vertical emittance at the end of the linac over 100 different random seeds will be presented for each condition.

Beam parameters

| | |
|---|---|
| Initial and final beam energy | 5 GeV → 250 GeV |
| Gradient | 35 MV/m |
| Bunch intensity | 2E10 |
| Bunch length | 0.3 mm (rms) |
| Initial momentum spread | 2.8 % (rms) |
| Initial normailized emittance | 2E-8 m |

Optics (three cases)

| | (A) 3-5 | (B) 2-3 | (C) 1-2 |
|---|---|---|---|
| 5 – 125 GeV | 3 modules/quad | 2 modules/quad | 1 module/quad |
| 125 – 250 GeV | 5 modules/quad | 3 modules/quad | 2 modules/quad |
| cavities/module | 10 cavities/module | | |
| phase advance | $\pi$/6 / FODO cell | | |

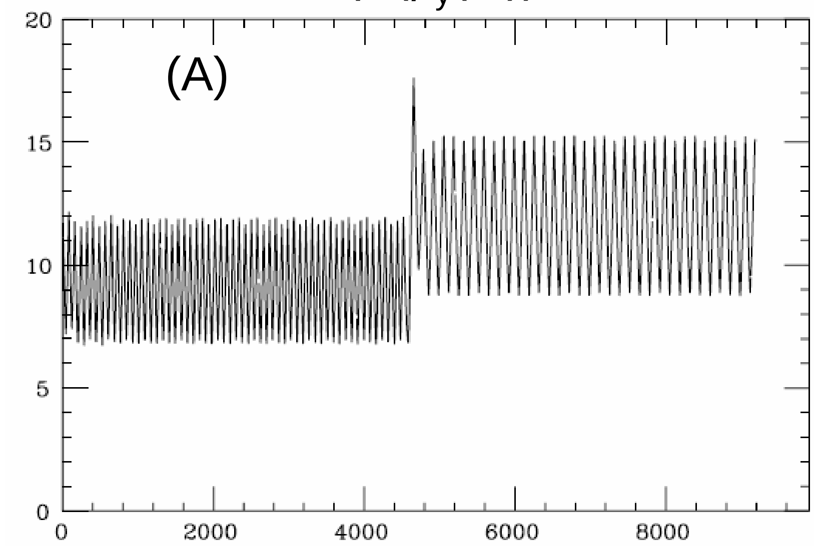
# Compare three optics

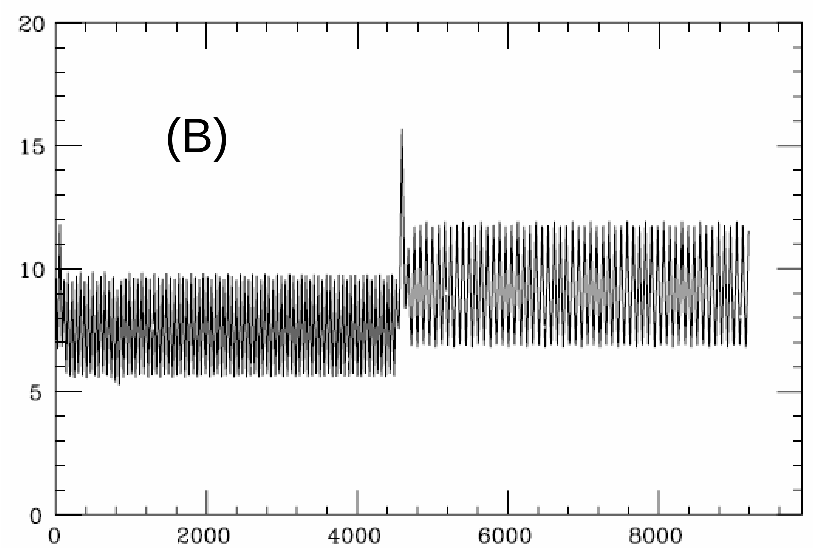
Number of modules/quad

| | 5 - 250 GeV | 250 - 500 GeV |
|---|---|---|
| (A) 3-5 | 3 | 5 |
| (B) 2-3 | 2 | 3 |
| (C) 1-2 | 1 | 2 |

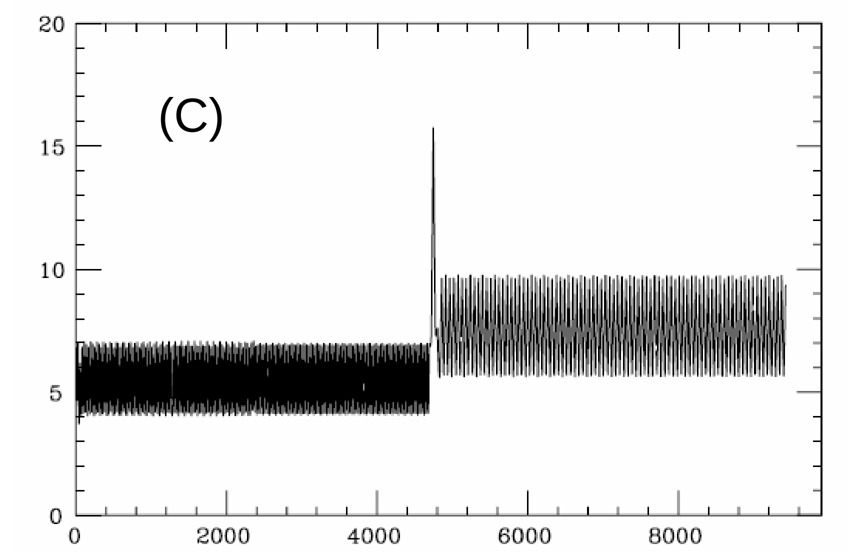
10 cavities/module, 35 MV/m

sqrt($\beta_y$(m))



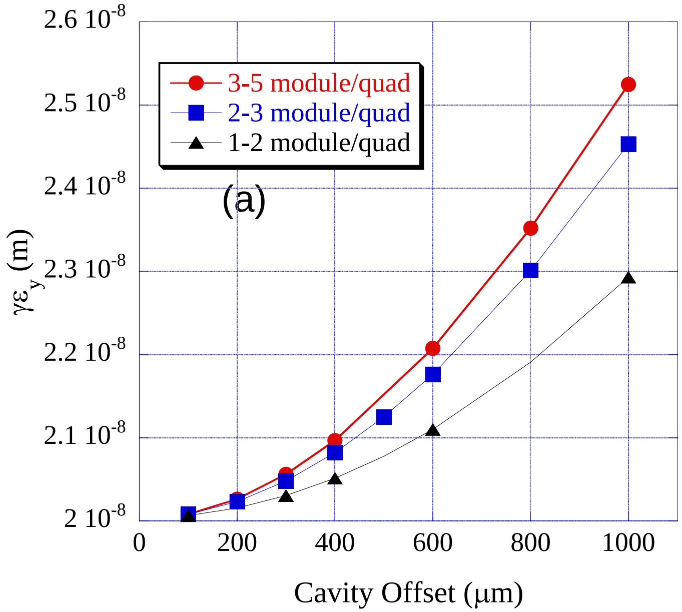



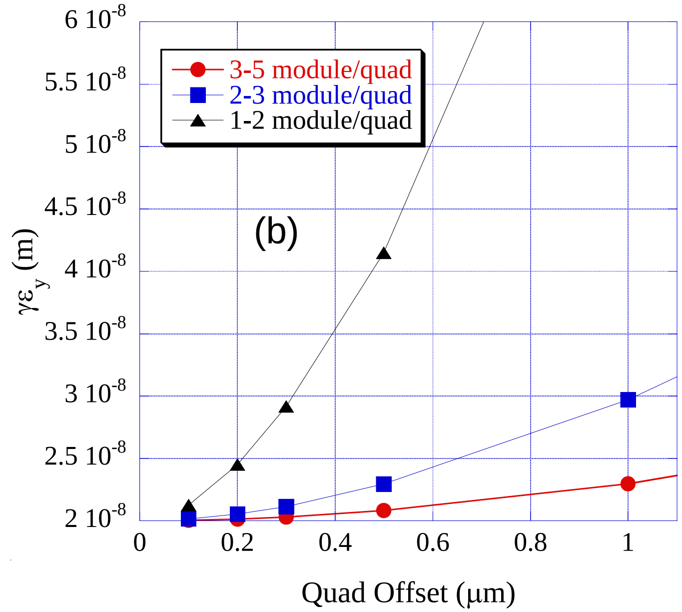

S (m)

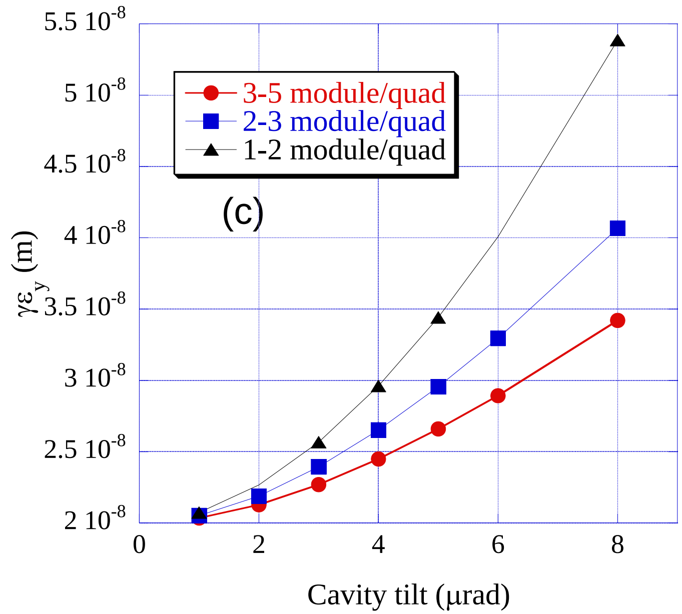



S (m)

# Emitttance vs. cavity offset, quad offset and cavity tilt. No correction.




These give tolerances in time scale faster than corrections in the main linac and slower than orbit feedback at IP.

# Steering corrections

Use steering, or correction coils of quads.
Every quad has a BPM and a correction coils.

Correction (A): One - to - one

Minimize BPM readings.

Correction (B): Kick minimization

Minimize $\sum_i (\theta_i - k_i y_i)^2$,

$\theta_i$ : kick angle of steering at $i$-th quad

$y_i$ : BPM reading at $i$-th quad

$k_i$ : K-value of the $i$-th quad

Correction (C): Combined (A) and (B)

Minimize $\sum_i r^2 y_i^2 + \sum_i (\theta_i - k_i y_i)^2$,

$r$ : Weight ratio. $= 10^{-3}$

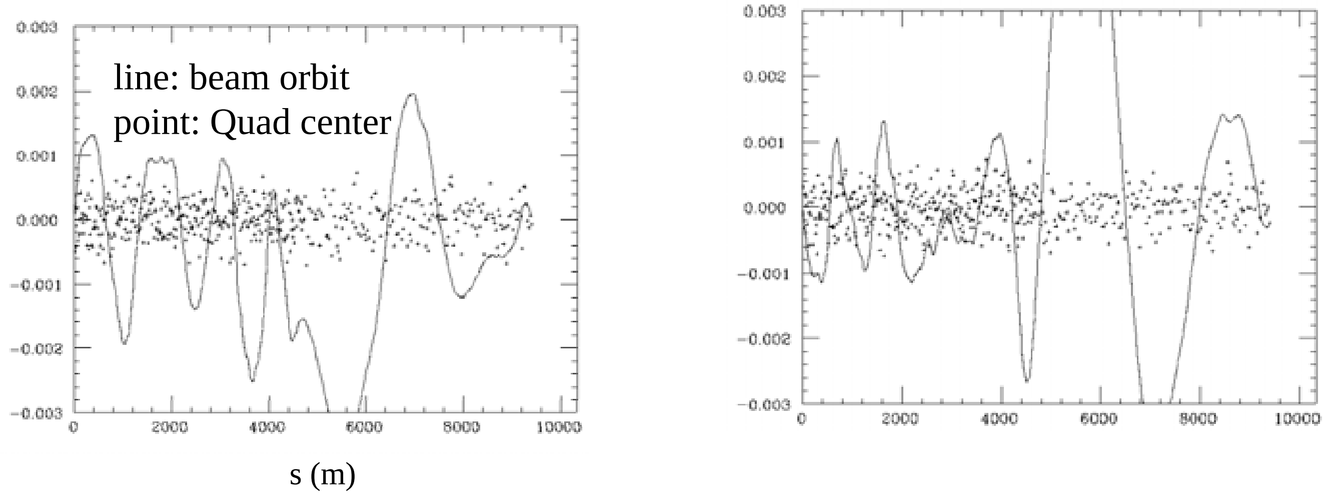
(A) is too simple
(big emittance dilution)
(B) and (C) give similar emittance, but
(B) gives big orbit

# Examples of orbit after correction (B) and (C).

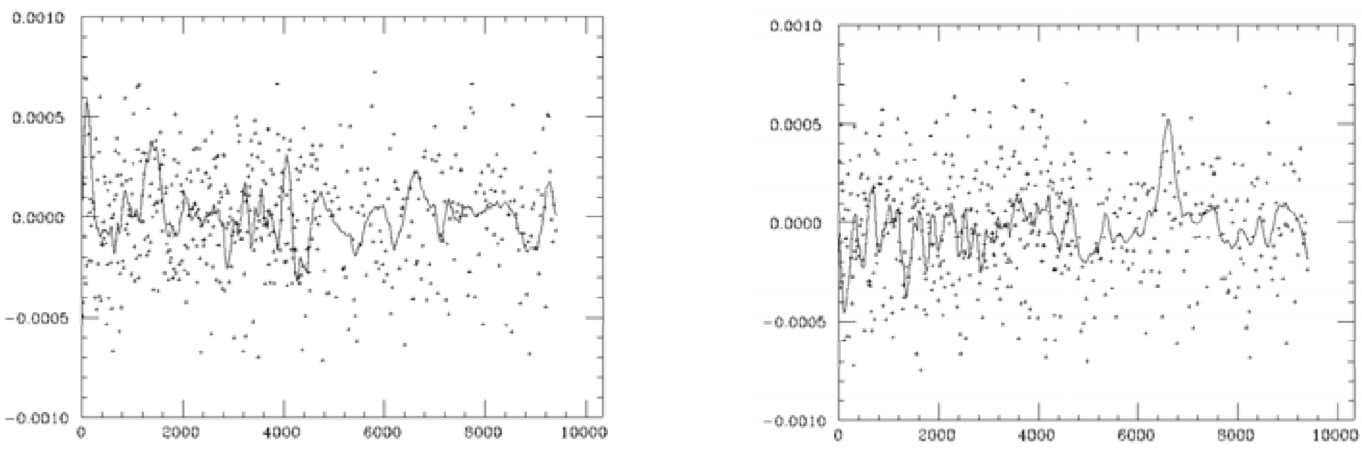
Quad misalignment 0.3 mm, Quad-BPM offset 20 μm

Fig.3

Orbit correction (B)

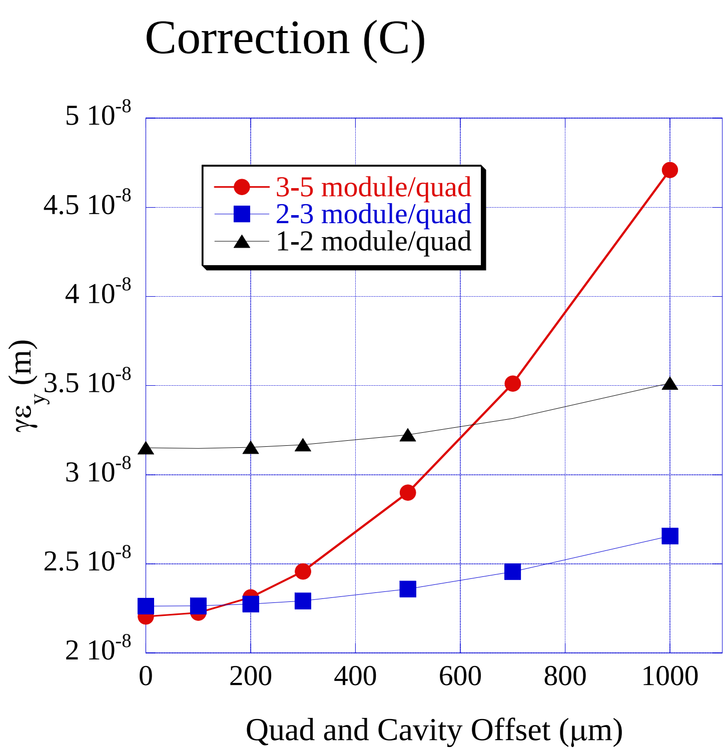


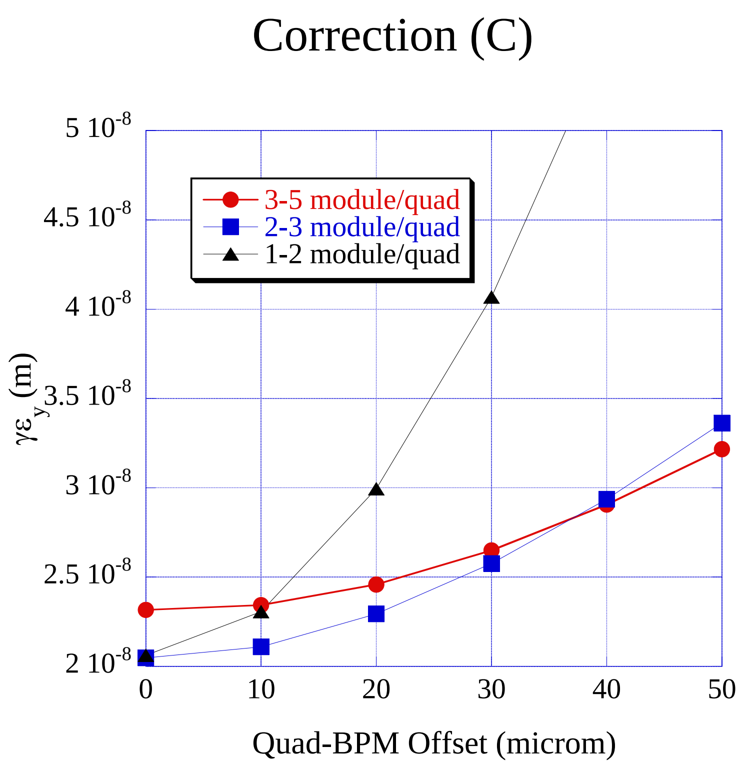

Orbit correction (C)



Emittance vs. Quad and Cavity misalignment (the same rms for quads and cavities). Quad-BPM offset 20 μm.

Emittance vs. Quad-BPM offset. Quad and Cavity misalignment 0.3 mm (the same rms for quads and cavities).




These give static alignment (offset) tolerances.

# Steering Correction

Use steering, or correction coils of quads.
Every quad has a BPM and a correction coils.

$$\text{Minimize } \sum_i r^2 y_i^2 + \sum_i (\theta_i - k_i y_i)^2,$$

$\theta_i$ : kick angle of steering at $i$-th quad

$y_i$ : BPM reading at $i$-th quad

$k_i$ : K-value of the $i$-th quad

$r$ : Weight ratio. $= 10^{-3}$

Not very effective for cavity tilt.

# Tilt Compensation + Steering Correction

(1) Perform steering correction

(2) Turn off RF of cavities in one FODO cell (40 or 60 cavities for weaker focus optics), scale the strength of magnets and accelerating voltage of downstream RF cavities to the beam energy, and measure orbit difference from nominal orbit.

Then, set two steerings (at quad in the cell) to compensate the difference.

Perform this for every cell.

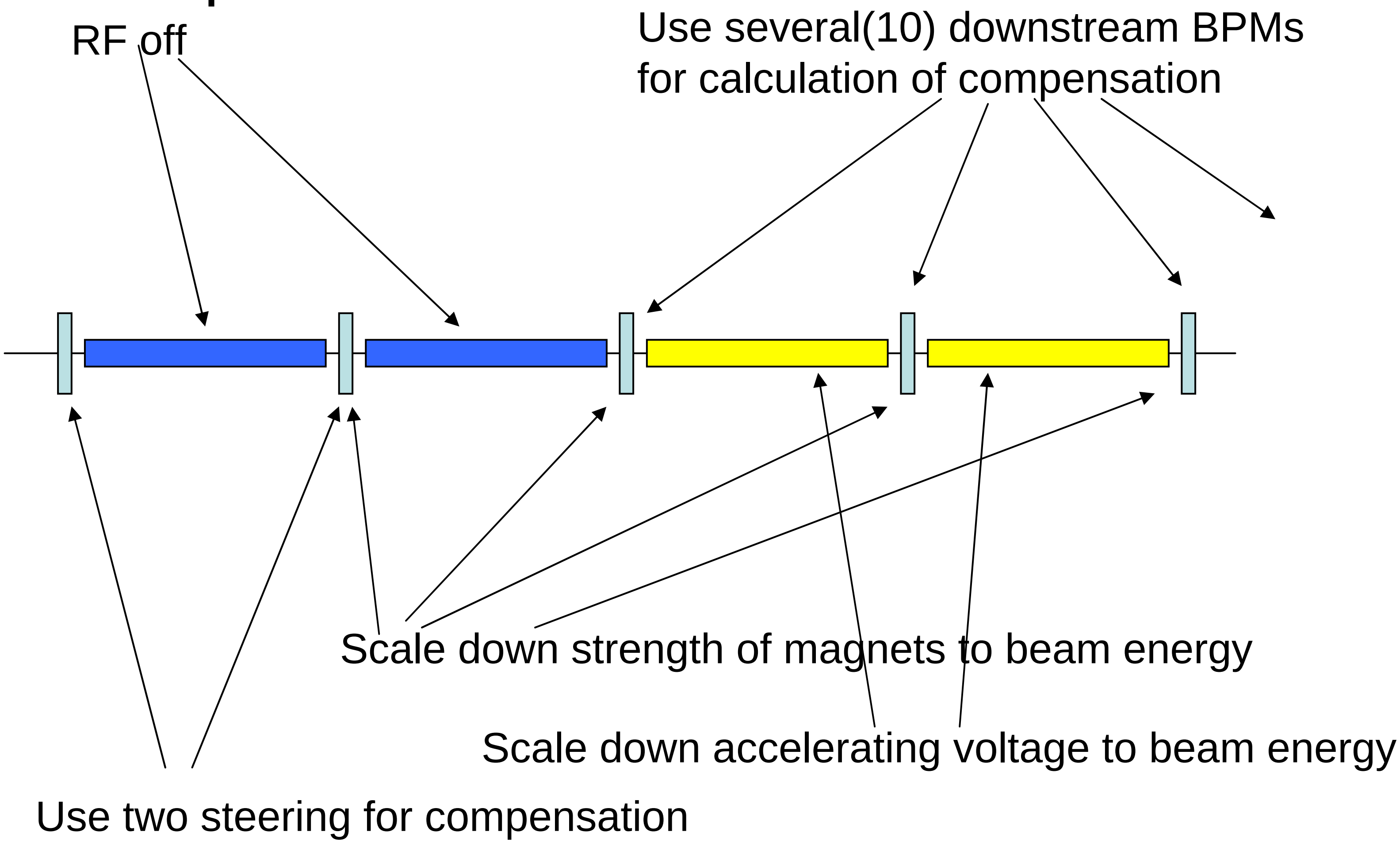
(3) Perform steering correction again keeping the compensation,

$$\text{Minimize } \sum_i r^2 y_i^2 + \sum_i \left(\theta_i - \theta_{ti} - k_i y_i\right)^2,$$

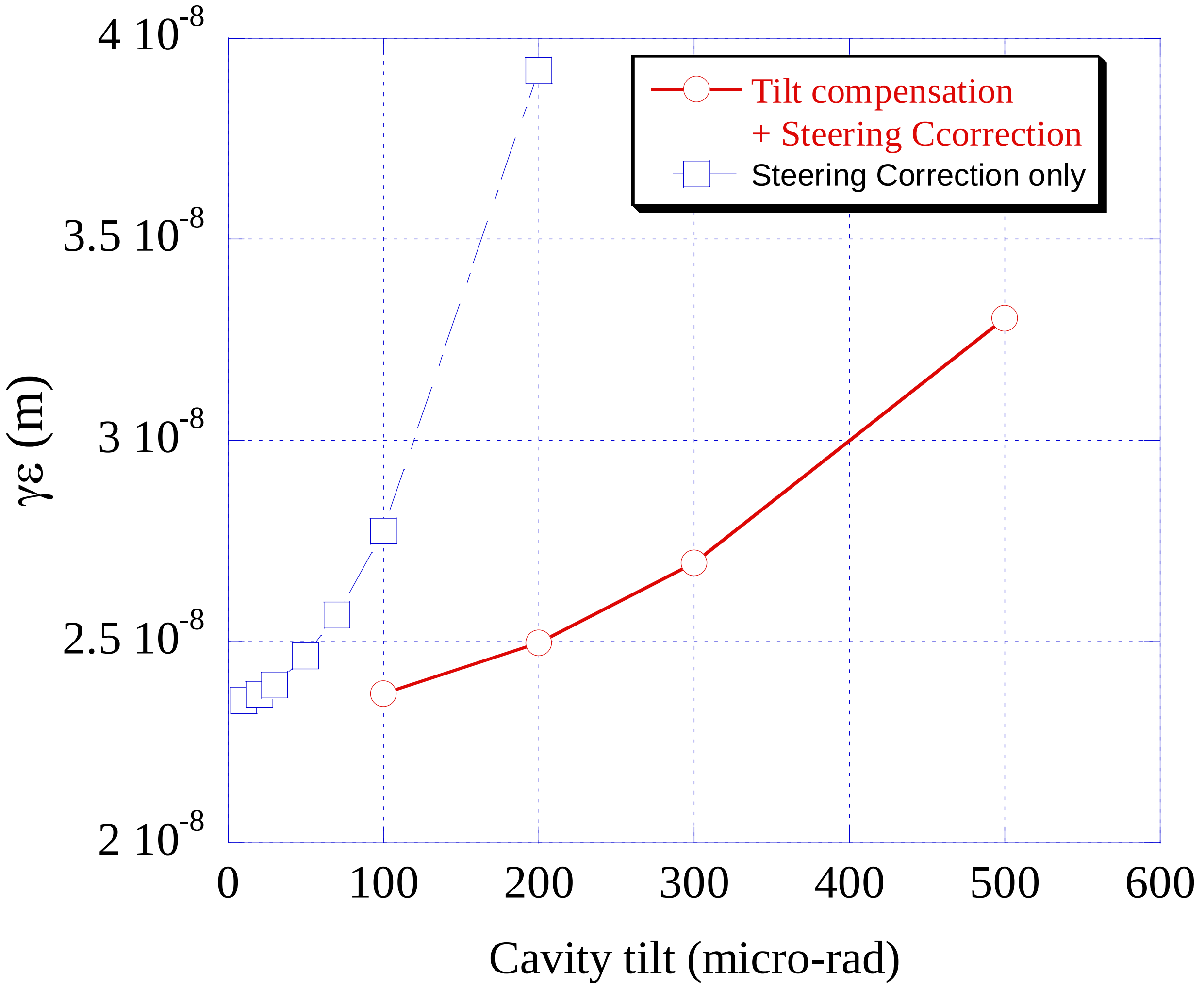
$\theta_{ti}$ : kick angle for cavity tilt compensation at $i$ - th quad

(4) Iterate (2) and (3) four times for better compensation

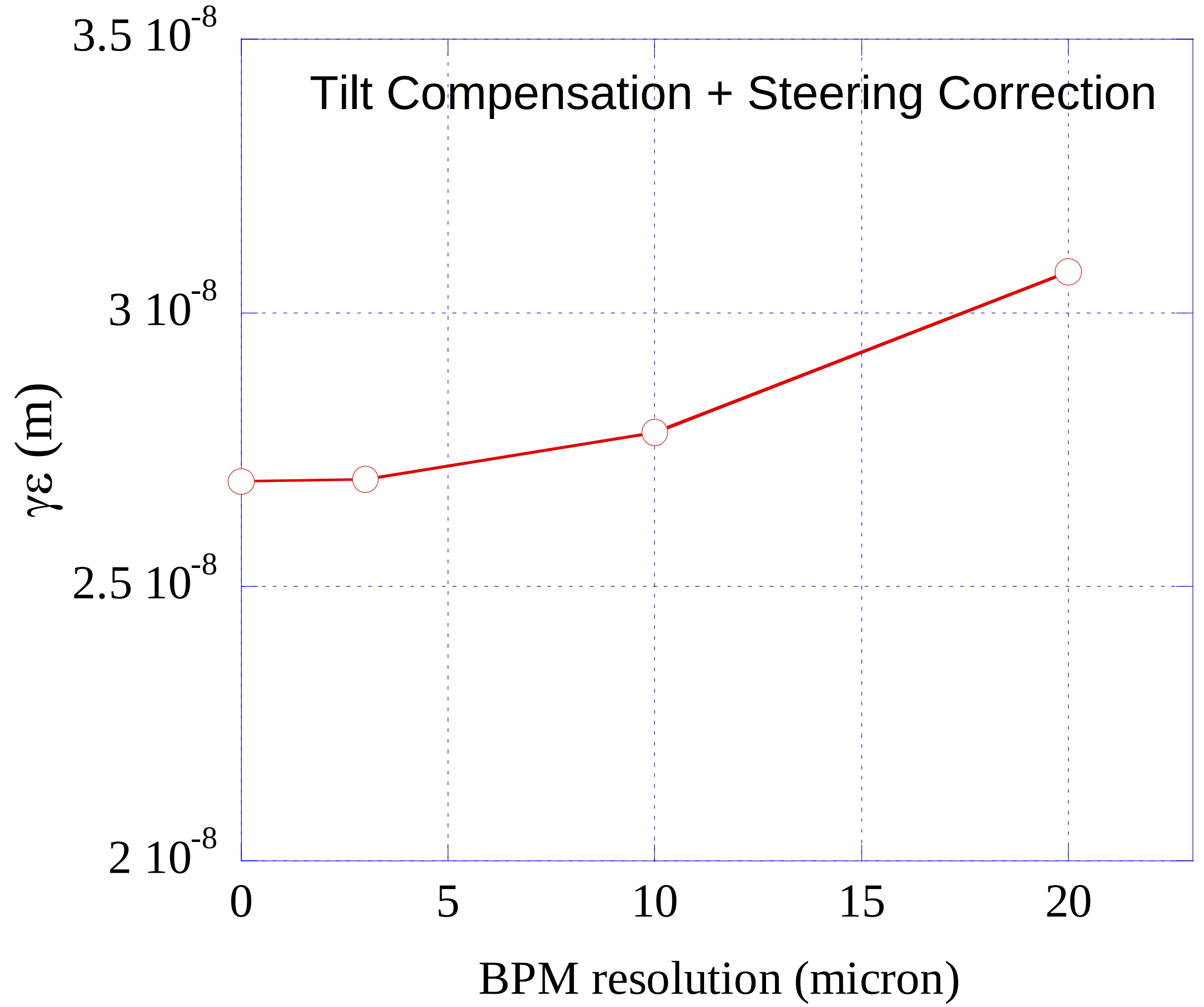
# Tilt Compensation



Emittance vs. cavity tilt angle.
Quad offset 300 micron, Cavity offset 300 micron
Quad-BPM offset error 20 micron, BPM resolution 3 micron



Emittance vs. BPM resolution.
Quad offset 300 micron, Cavity offset 300 micron
Quad-BPM offset error 20 micron, Cavity tilt 300 micro-rad



## *Rough tolerances.*

| | |
|---|---|
| Static misalignment (Slower than the correction in the main linac) [additional 5% emittance dilution] | |
| Quad offset | 400 μm |
| Cavity offset | 1 mm |
| Cavity tilt | 150 μrad |
| Quad - BPM offset | 15 μm |
| Fast movement (Faster than the correction in the main linac but slower than the orbit feedback at IP) [10% emittance dilution] | |
| Quad offset | 0.4 μm |
| Cavity offset | 600 μm |
| Cavity tilt | 2 μrad |
| Mmeasurement by measurement [additional 5% emittance dilution] | |
| BPM Resolution | 10 μm |

# *Summary*

Main Linac Simulations using “SLEPT” were performed.

Only single bunch effects are considered.

Beam energy 5 --> 500 GeV.

- Sensitivities to vibration of quads and cavities were simulated.
- Steering correction and cavity tilt compensation were demonstrated.
- From comparison of three optics:

  2 modules/quad (5-205 GeV) - 3 modules/quad (250-500 GeV) will be the best among them.
- Rough tolerances of misalignment, static and vibrations, and BPM performance, were given.

  These numbers can be given to hardware people, if we agree.