Main Linac Simulation

- Main Linac Alignment Tolerances

- From single bunch effect

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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

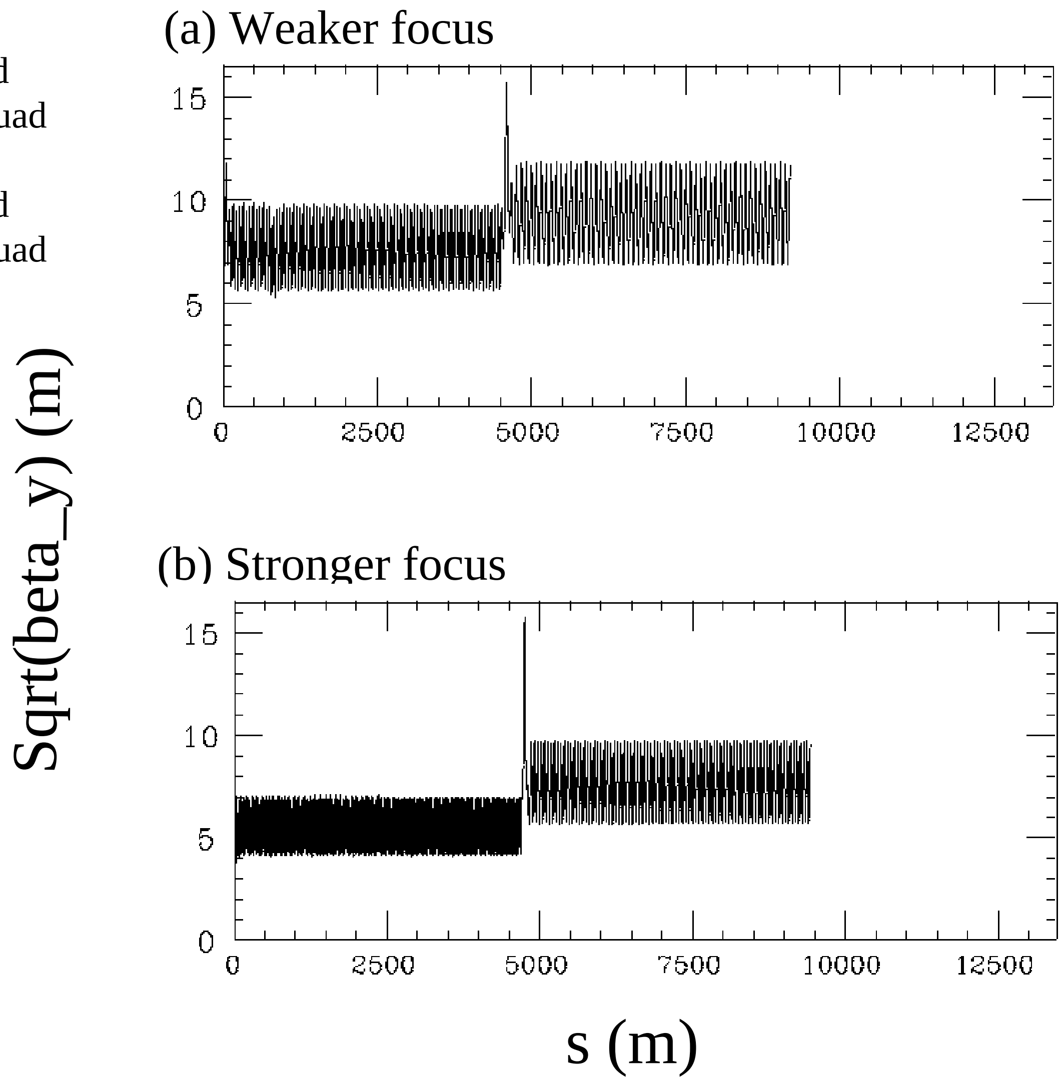
Initial and final beam energy	5 GeV → 250 GeV
Gradient	35 MV/m
Bunch intensity	2E10
Bunch length	0.3 mm (rms)
Initial momentum spread	2.8 % (rms)
Initial normailized emittance	2E-8 m

Optics (two cases)

	Weaker focus	Stronger focus
5 – 125 GeV	2 modules/quad	1 module/quad
125 – 250 GeV	3 modules/quad	2 modules/quad
cavities/module	10 cavities/module	
phase advance	π/6 / FODO cell	

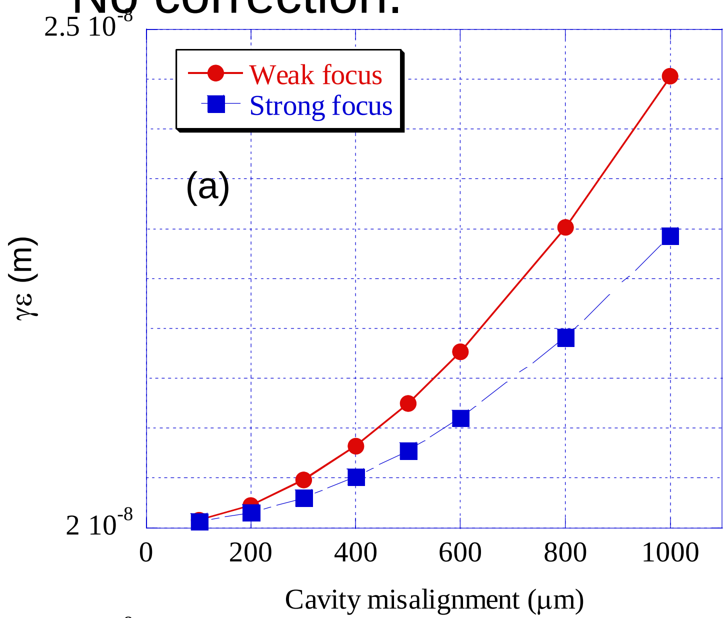
Optics

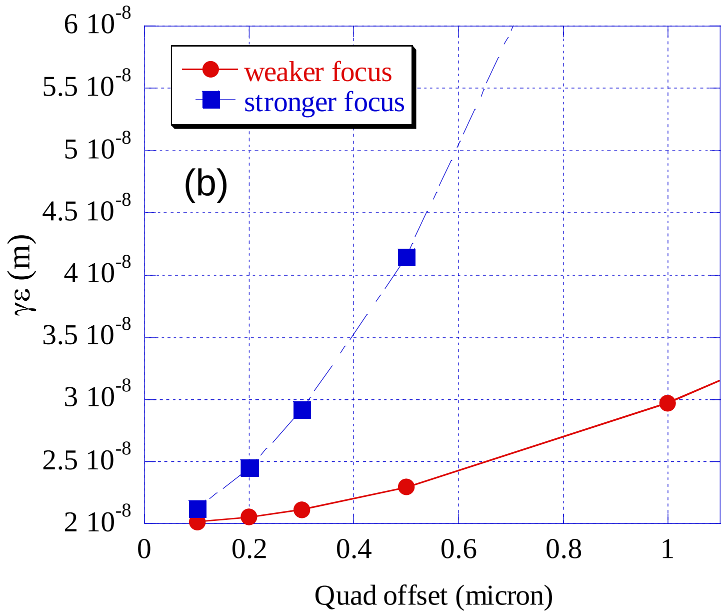
Square root of beta-function of three models;
(a) 35 MV/m weak focussing
  from 5 GeV to 125 GeV: 2 modules/quad
  from 125GeV to 250 GeV: 3 modules/quad
(b) 35 MV/m strong focussing
  from 5 GeV to 125 GeV: 1 modules/quad
  from 125GeV to 250 GeV: 2 modules/quad

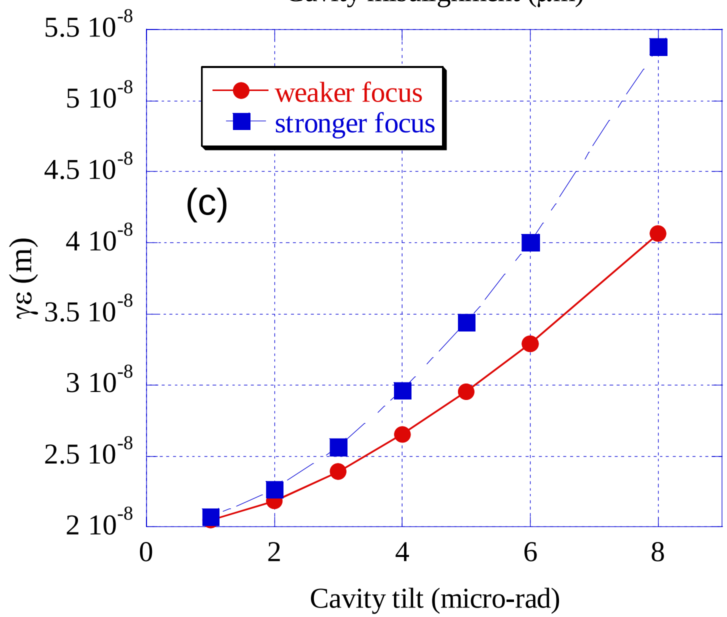


(a) Will be better

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 for static misalignment

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

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

θ_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)

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

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

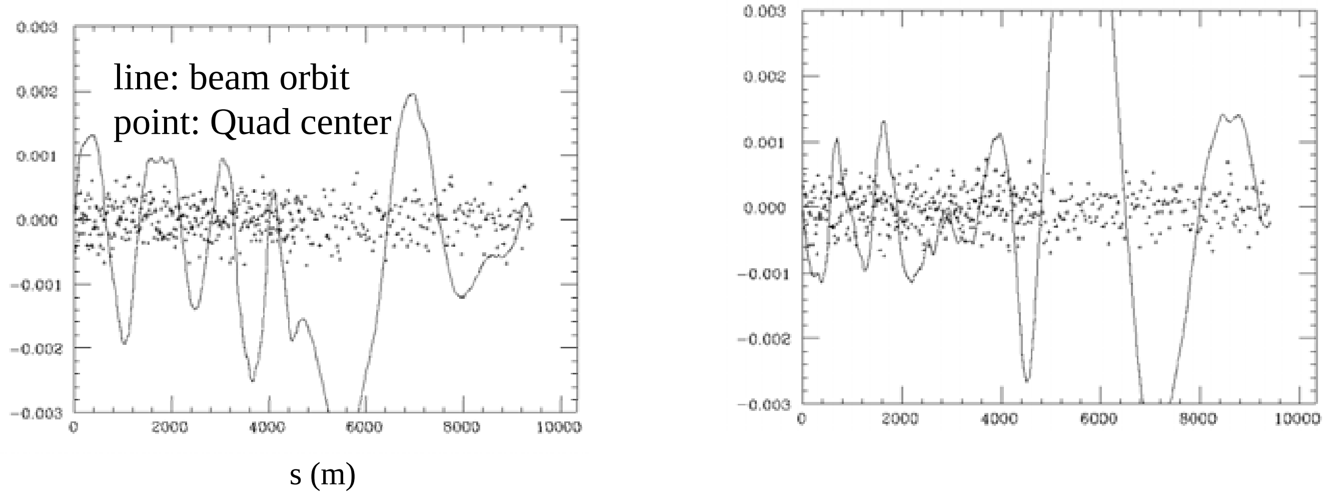
(A) is too simple
(big emittance dilution)
(B) and (C) give similar emittance, but
(B) gives big orbit

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

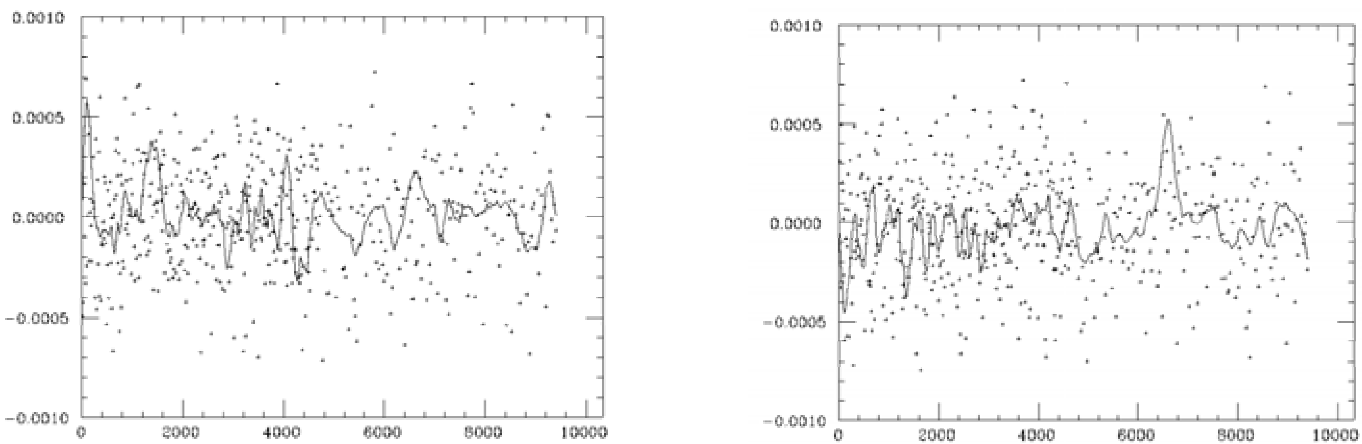
Quad misalignment 0.3 mm, Quad-BPM offset 20 μm

Fig.3

Orbit correction (B)

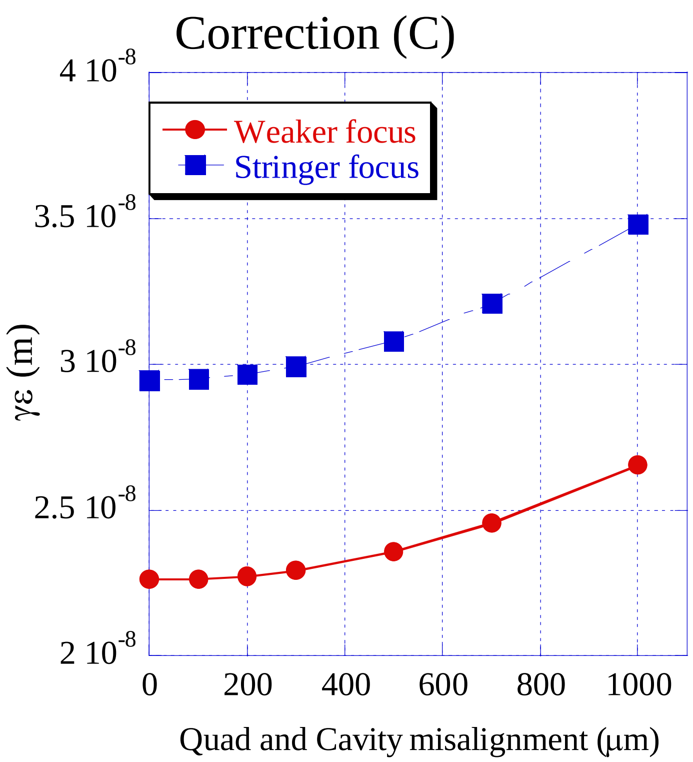


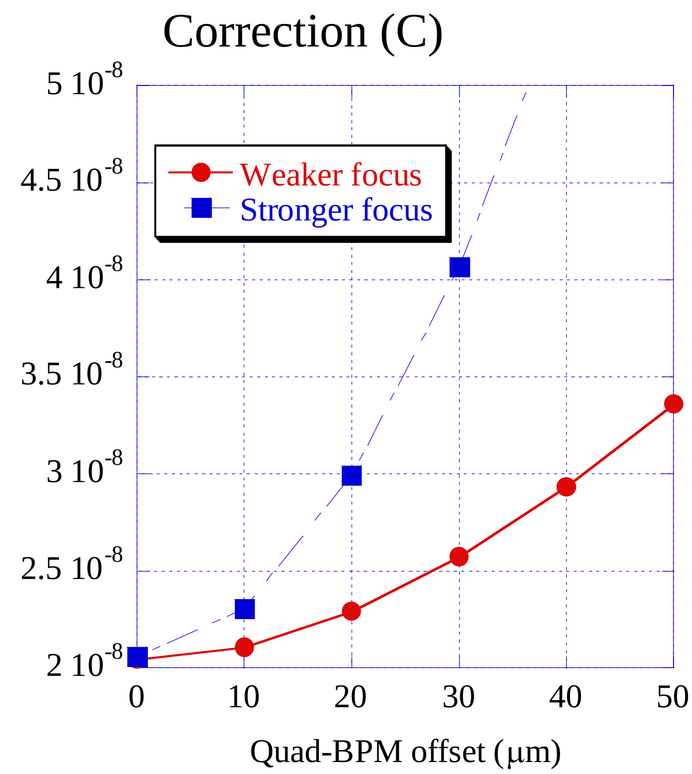
Orbit correction (C)



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.

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

θ_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.

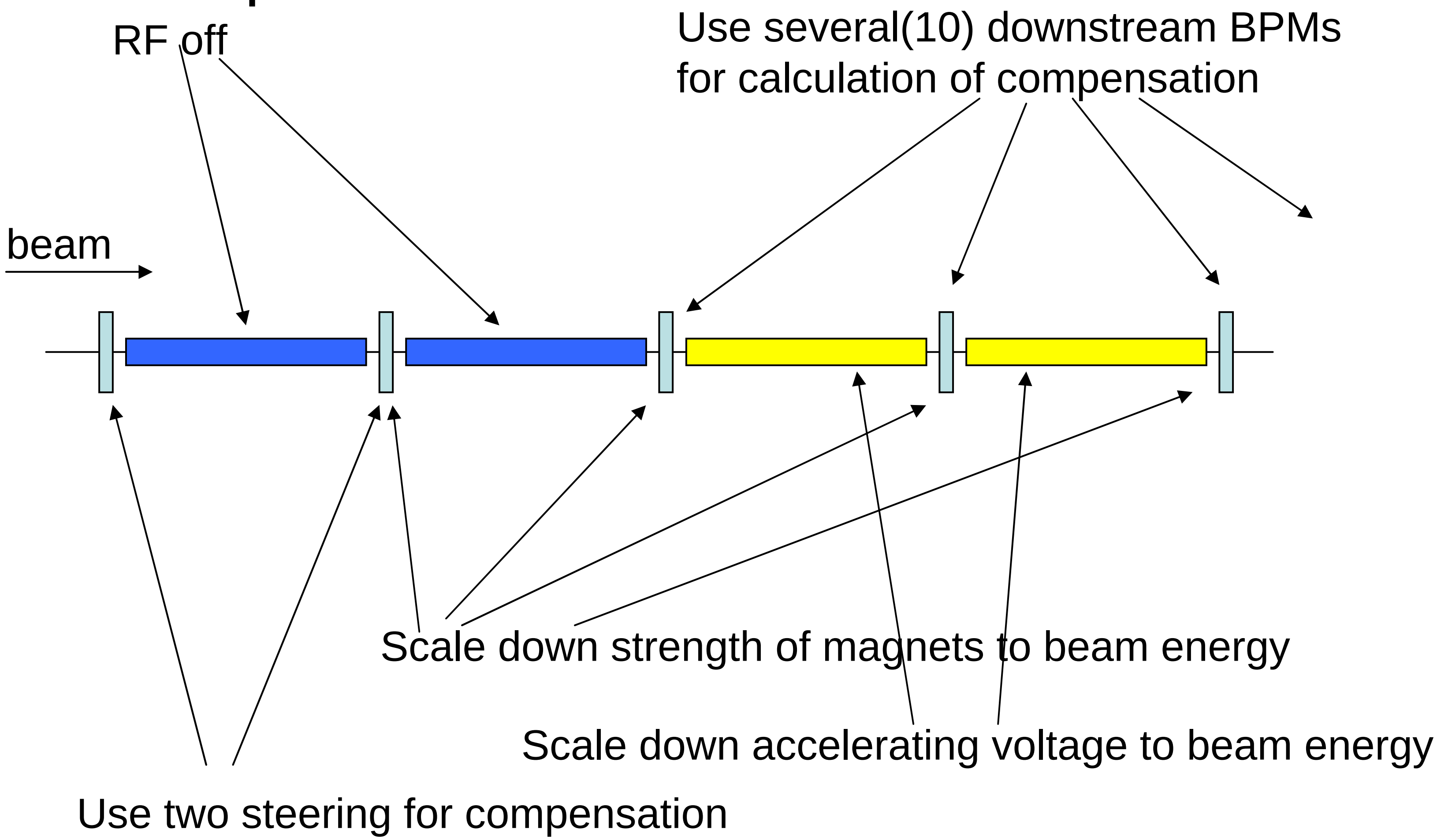
(3) Perform steering correction again keeping the compensation,

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

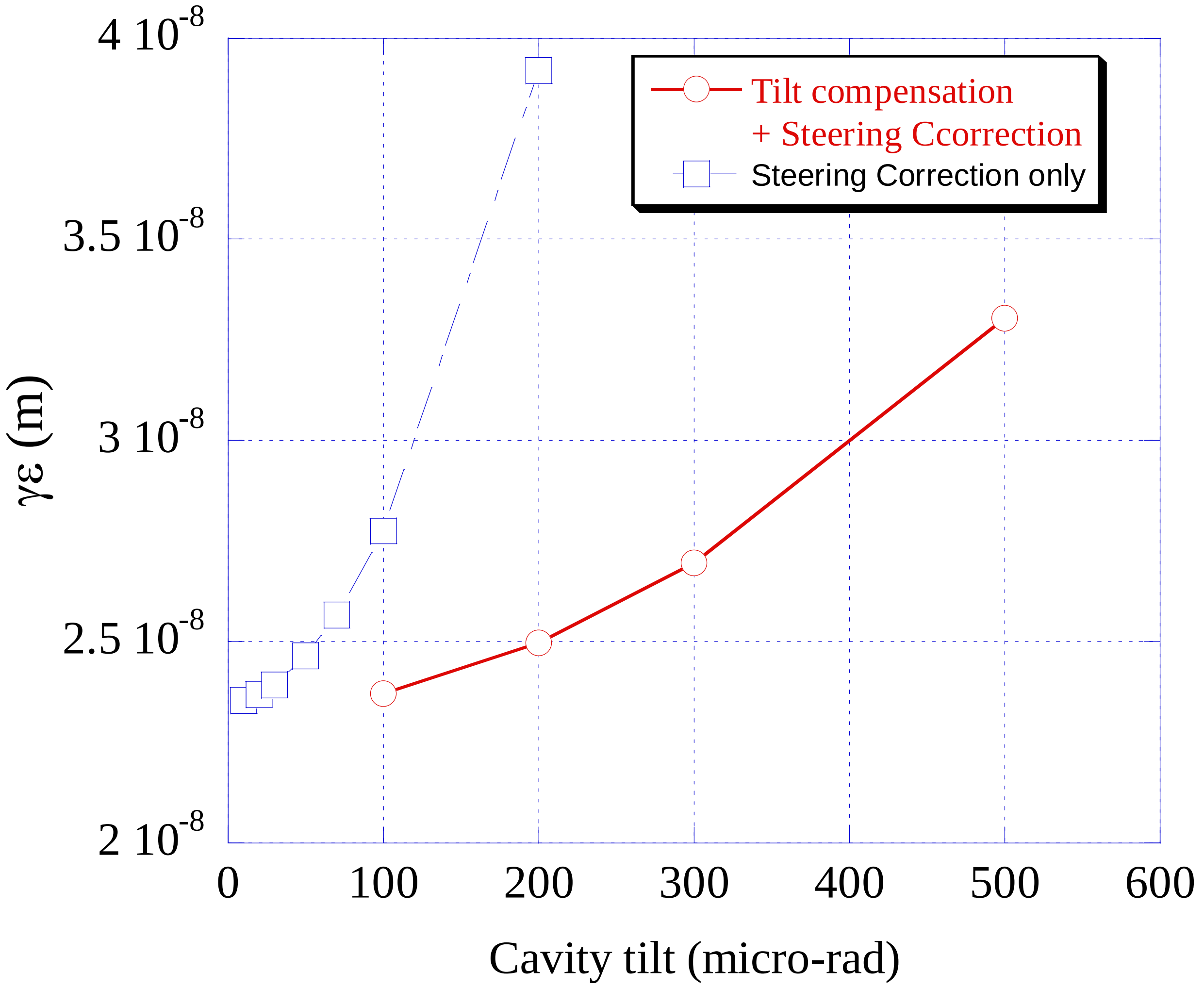
θ_{ti} : kick angle for cavity tilt compensation at i - th quad

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

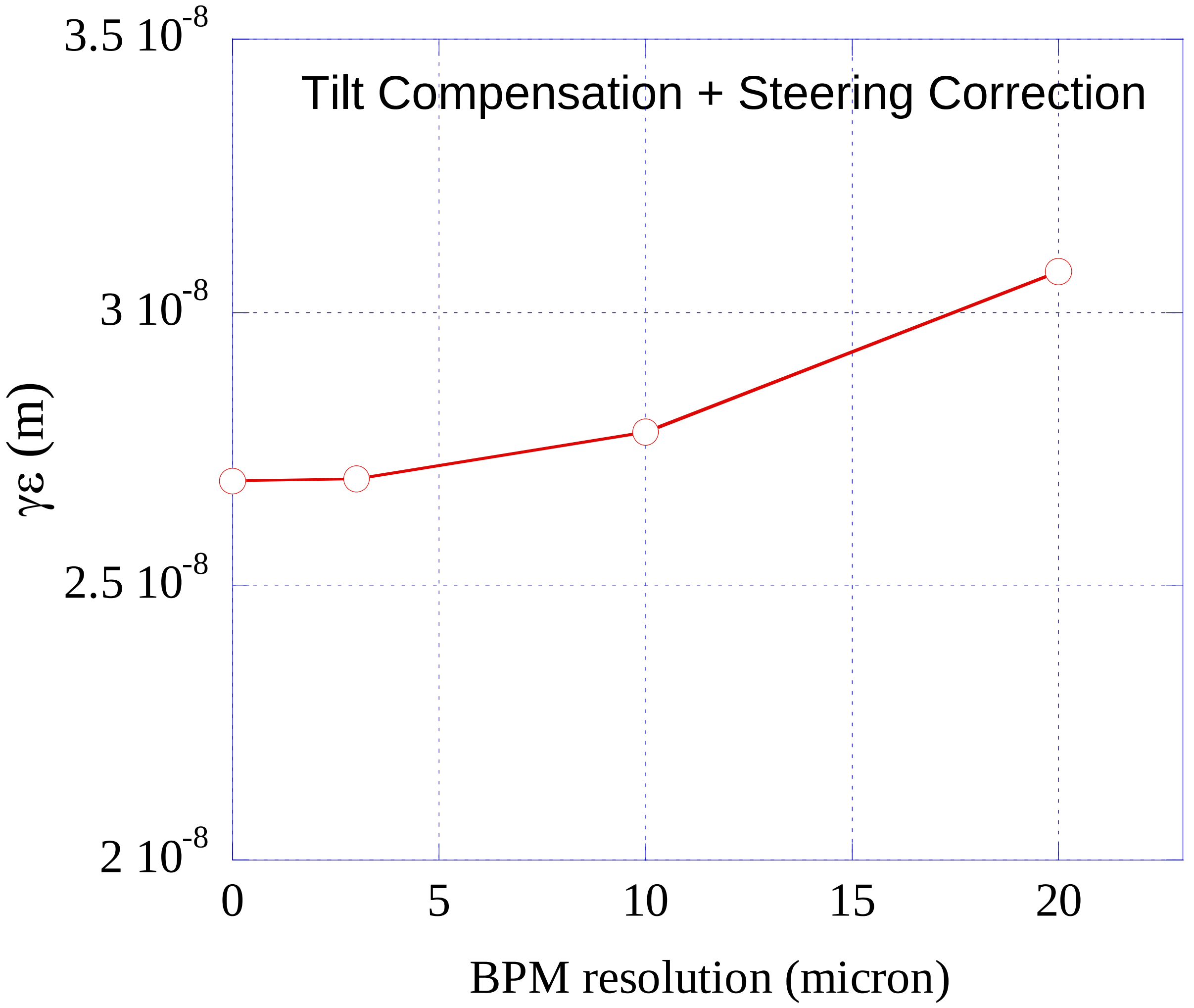
Tilt Compensation



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