Damping Ring and Main Linac for ILC Z-pole operation

LCWS2019 2019.10. K. Kubo

Z-pole High Luminosity Operation

- Collision at Ecm=91.2 GeV, Ebeam=45.6 GeV
- 46GeV is too low for e- beam for positron production
- TDR: RF system of ML (5Hz, Ebeam=250 GeV) can be used for 5Hz (Ebeam 46GeV) +5Hz (Ebeam 150GeV) electron operation
- New design: Ebeam 125 GeV, 5Hz correspond to
  - 3.7 Hz (Ebeam 46GeV) + 3.7 Hz (Ebeam 125GeV)

ISSUES

- Damping Ring
  - Shorter damping time required
- Main Linac
  - Emittance preservation with low accelerating gradient
  - Transport two different beam energies
- Choice of beam parameters at collision
- BDS design (focusing and collimation)

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This report

- Choice of beam parameters at collision → Yokoya's plenary talk
- BDS design (focusing and collimation) → Okugi's presentation

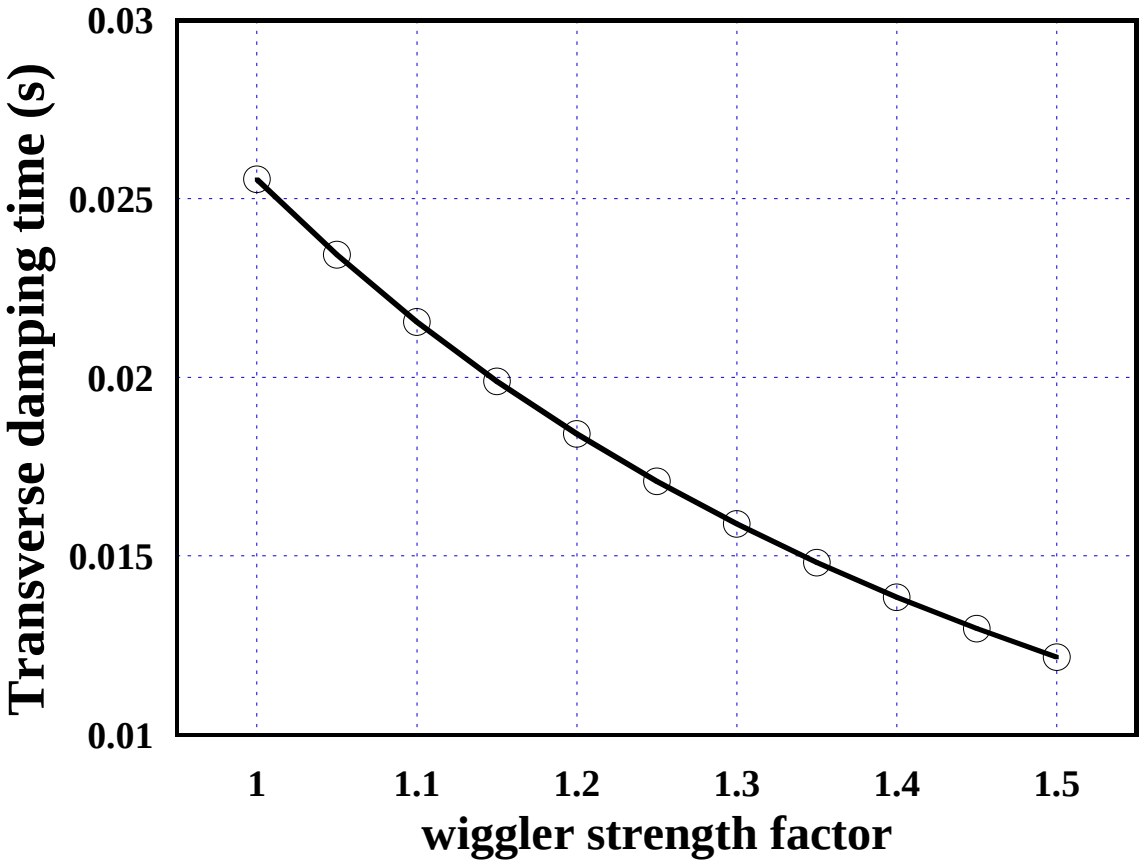
Reduce damping time of ILCDR

For z-pole operation 3.73Hz+3.73Hz

- Stored time in DR reduce from 0.2 s to 0.134 s
- Present design damping time (25ms) is too long
- Simple way to reduce damping time is strengthen wigglers
  - Equilibrium emittance may increase
  - Dynamic aperture may be affected

- Emittance and damping time calculated using SAD
- Dynamic aperture calculated using SAD.
  - With stronger wiggler
  - Add sextupole component only, no complicated field errors.

Damping time vs. wiggler strength factor
(compared with “present” design, “factor” = 1)



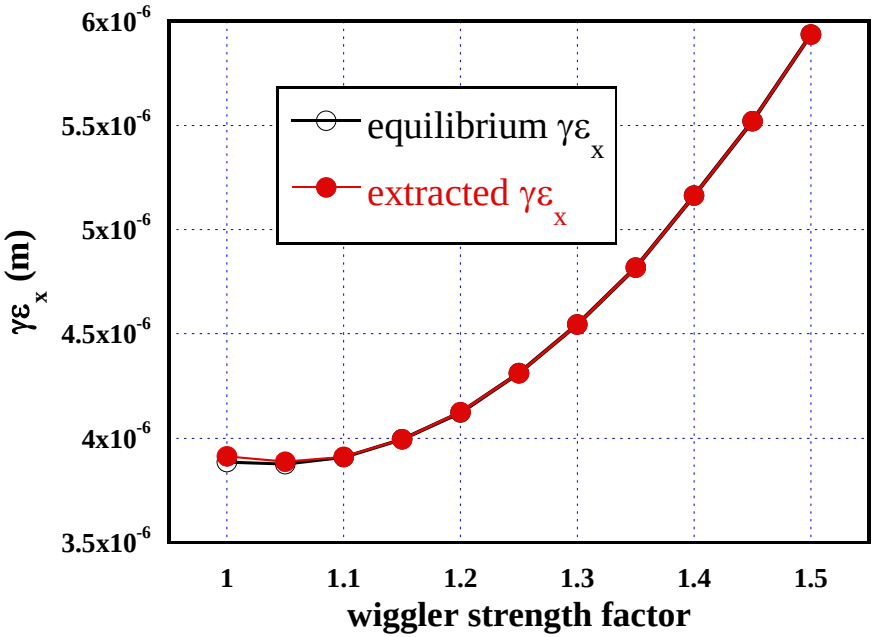
(Wiggler strength Factor=1: 1/rho = 0.07745 1/m, B = 1.29 T)

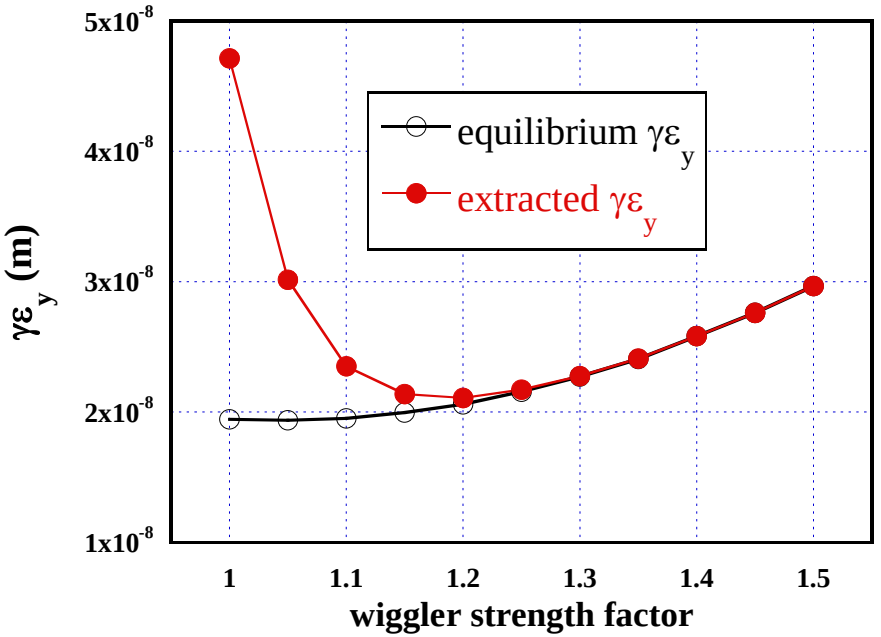
Equilibrium and extraction emittance of e+ DR

Injected emittance 1E-3

Extract 0.134 s after injection

Emittance ratio (emit_y/emit_x) = 0.005 assumed. Include Intra-beam scattering





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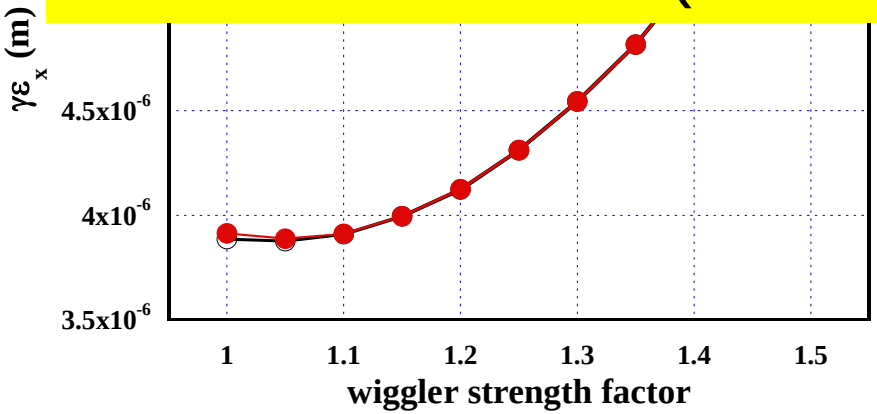
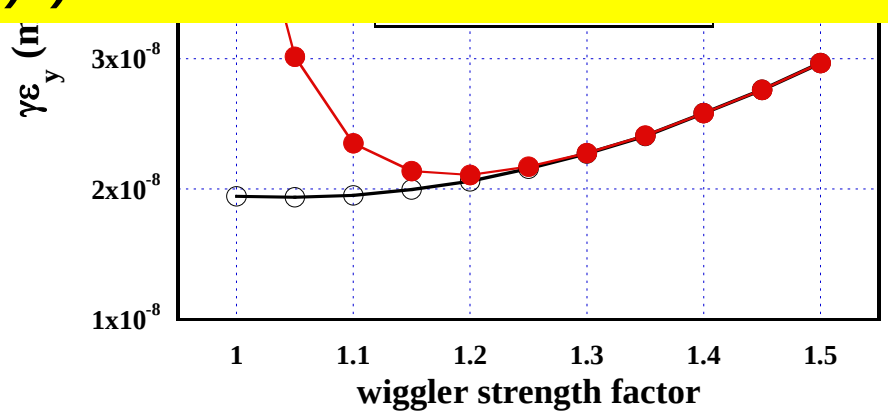
Emittance ratio (emit_y/emit_x) = 0.005 assumed. Include Intra-beam scattering

Strengthen wigglers by 15% will reduce extracted emittances acceptable.
(Slightly better emittance ratio needed for design vertical emittance (20 nm).)



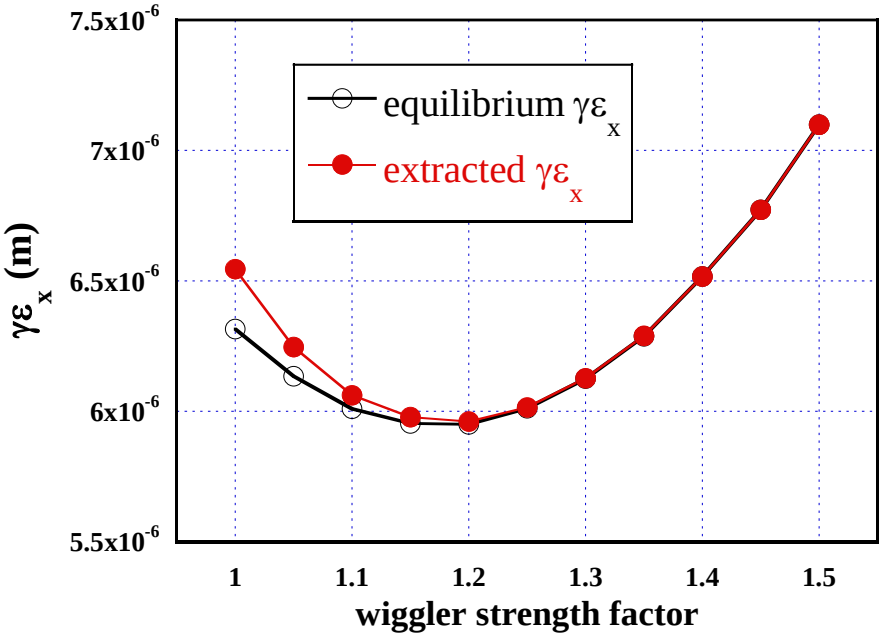


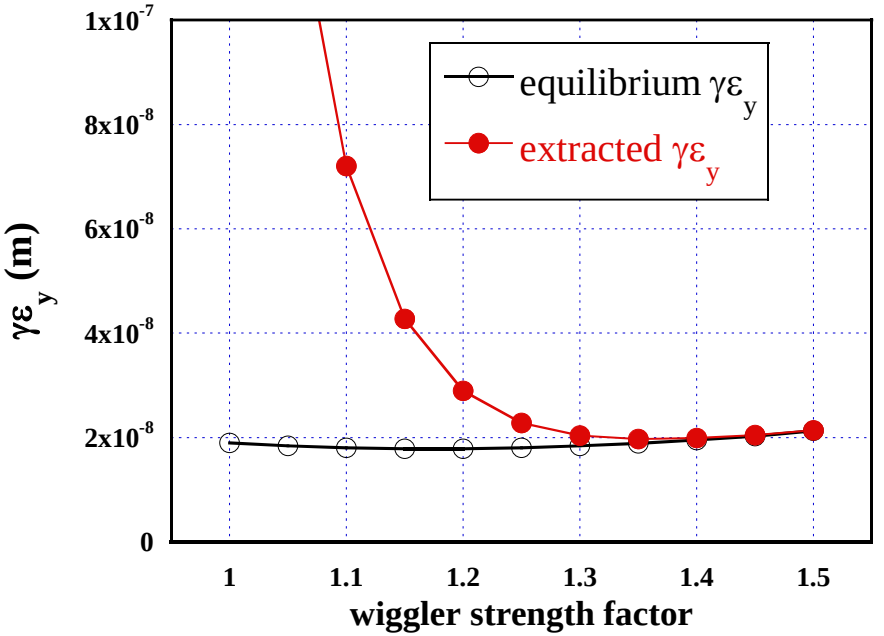
(Wiggler strength Factor=1: 1/rho = 0.07745 1/m, B = 1.29 T)

TDR optics design.
5+5 Hz operation required ~30% stronger wigglers

Equilibrium and extraction emittance of e+ DR

Injected emittance 1E-3
Extract 0.1 s after injection
Emittance ratio (emit_y/emit_x) = 0.003 assumed. Include Intra-beam scattering





Dynamic aperture

Tool prepared by SAD is used

- Set initial orbit and energy deviation
- Perform tracking

- “Accepted”, if survived after 1000 turns

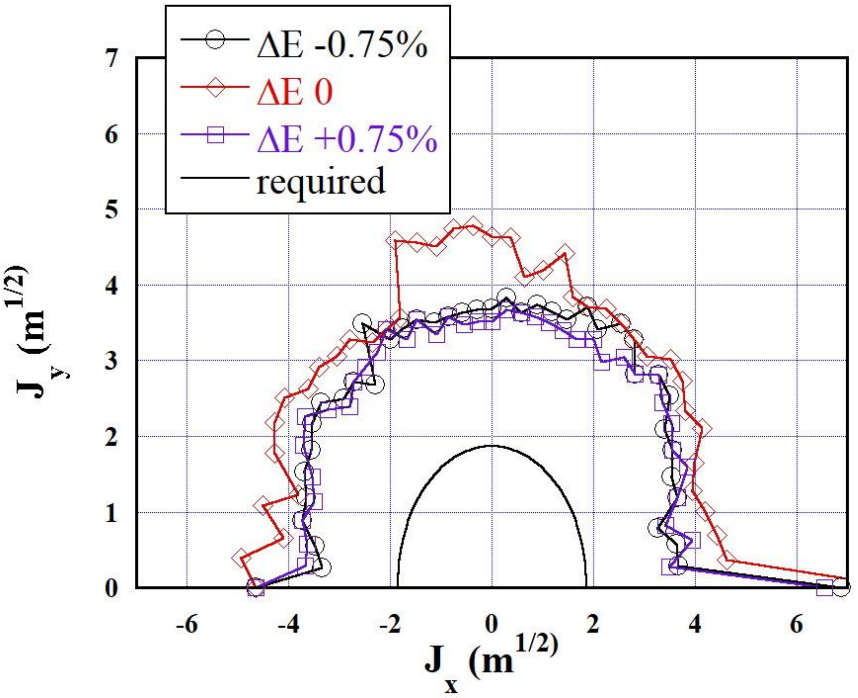
Requirement

- Norm. betatron amplitude: Ax + Ay < 0.07 m
  - gamma (Jx + Jy) < 0.035 m
- Energy deviation: 0.75%

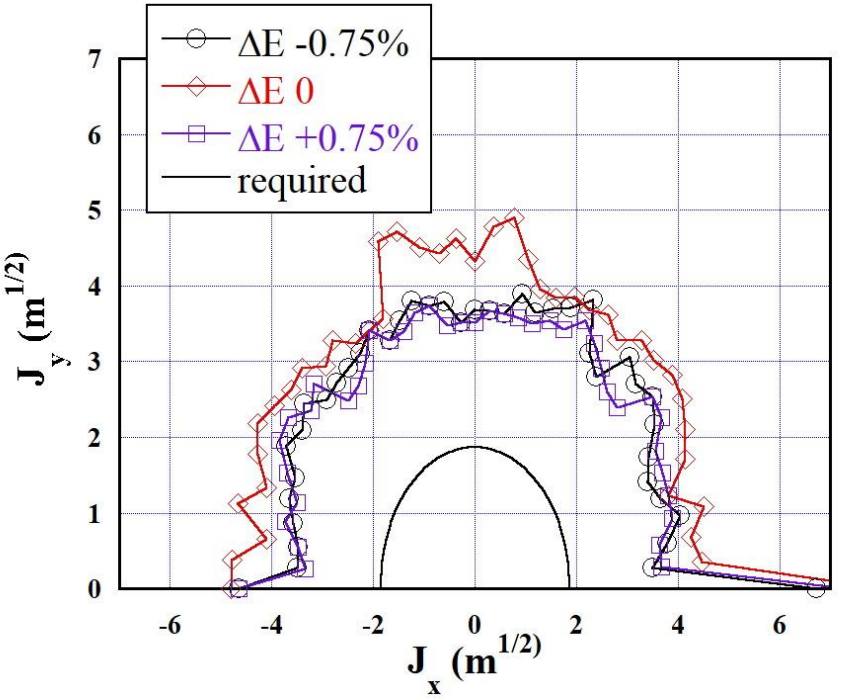
Dynamic aperture

Wiggler strength factor 1.15 (1/rho = 0.0891 m^{-1})

No sextupole field of wiggler



Add sextupole field: $(\Delta B/B)_{x=10mm}=0.066$
(TDR vol3 partII, p115)



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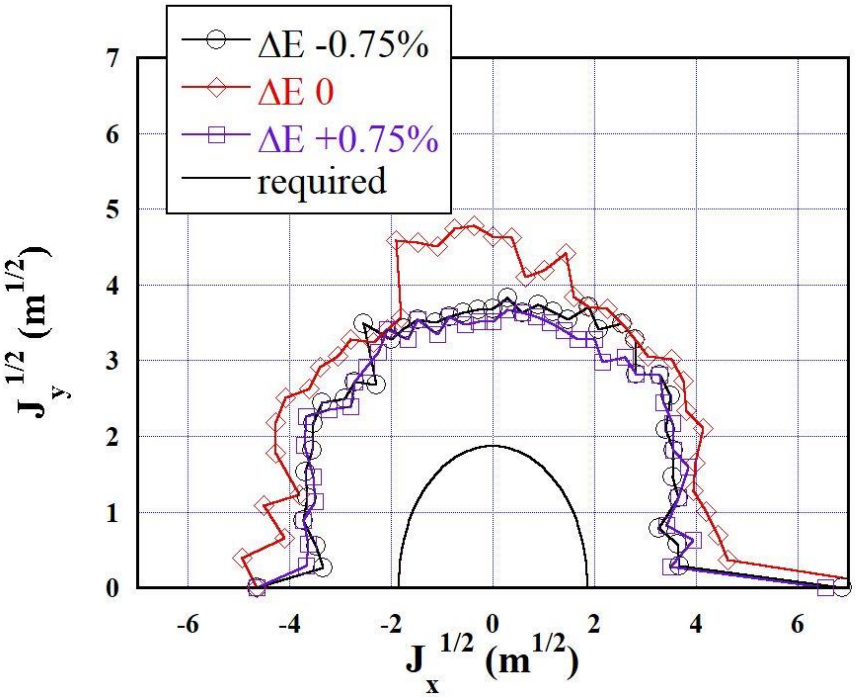
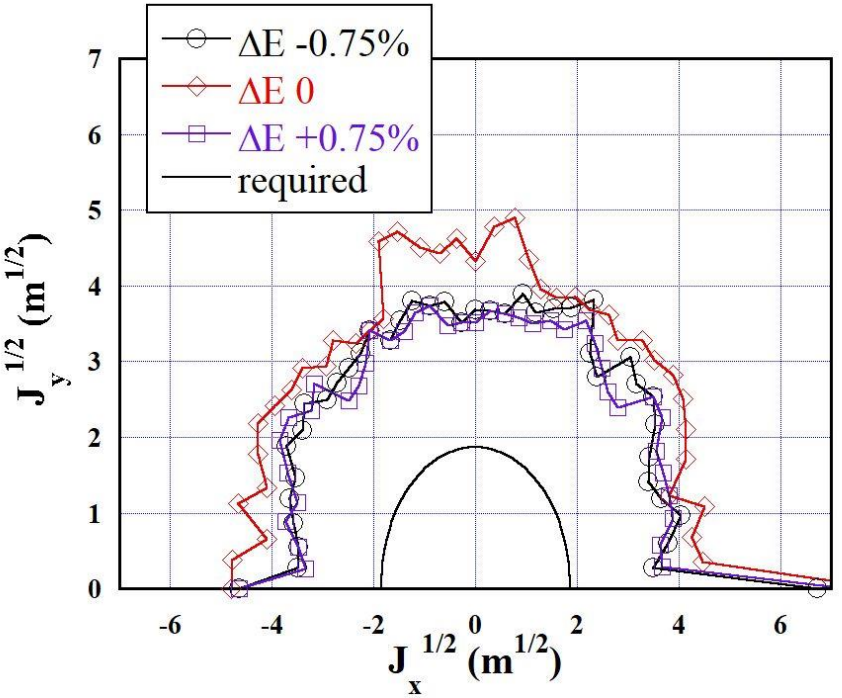




Main Linac
for Ebeam 46GeV and 125 GeV

Preservation of low emittance of 46GeV beam

- “Full gradient in upstream + detune cavities downstream” will be good from beam dynamics. But switching detune – tune cavities cannot be fast enough
- Assume uniform gradient (8.9MeV/m, 28% of nominal)

125 GeV beam (for positron production) for linac with magnets adjusted for 46 GeV beam

- Orbit distortion should be suppressed
- Emittance is not an issue. (the beam is not for collision)

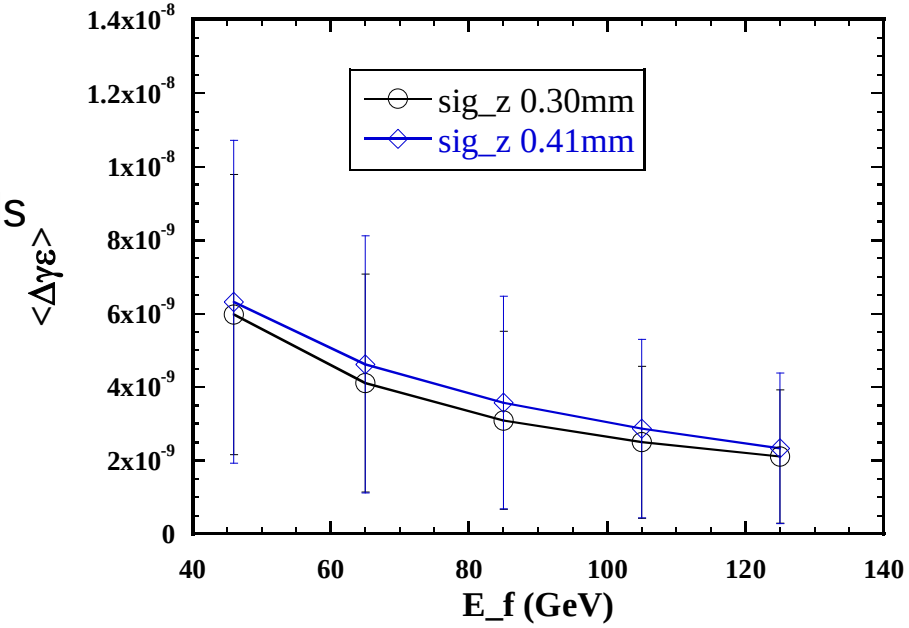
Tracking simulation for emittance

- Linac for 15 GeV to 125 GeV (full gradient 31.5 MV/m)
- Vertically curved, following earth's curvature
- Use tracking code "SLEPT"
- DFS (dispersion free steering), with energy change 20%
- Look at final vertical emittance (linear dispersion corrected)
- Uniformly reduce Eacc for lower energies
- Condition
  - Initial normalized emitt_y: 2E-8
  - Initial sig_z and sig_E:
    0.3 mm and 1.2%, or 0.41 mm and 0.9%
  - Misalignment: Q-mag offset 0.36 mm*, Cavity offset 0.67 mm*, Cavity tilt 0.3 mrad, BPM offset 0.3 mm (Gaussian, cut 3-sigma).
  - BPM resolution 1 um

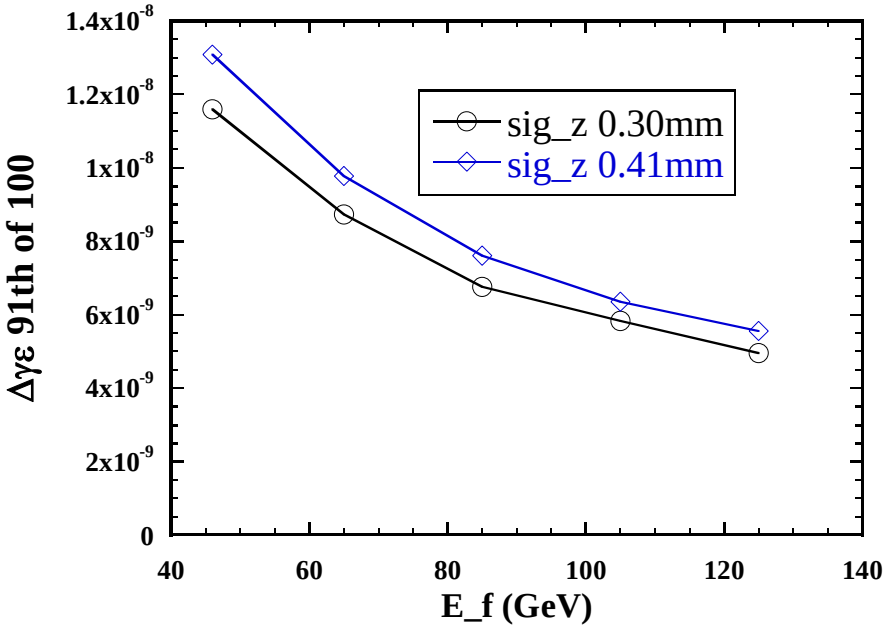
*($\sqrt{0.2^2 + 0.3^2} \approx 0.36$ $\sqrt{0.2^2 \times 9 + 0.3^2} \approx 0.67$)

Vertical Emittance growth
vs. final beam energy

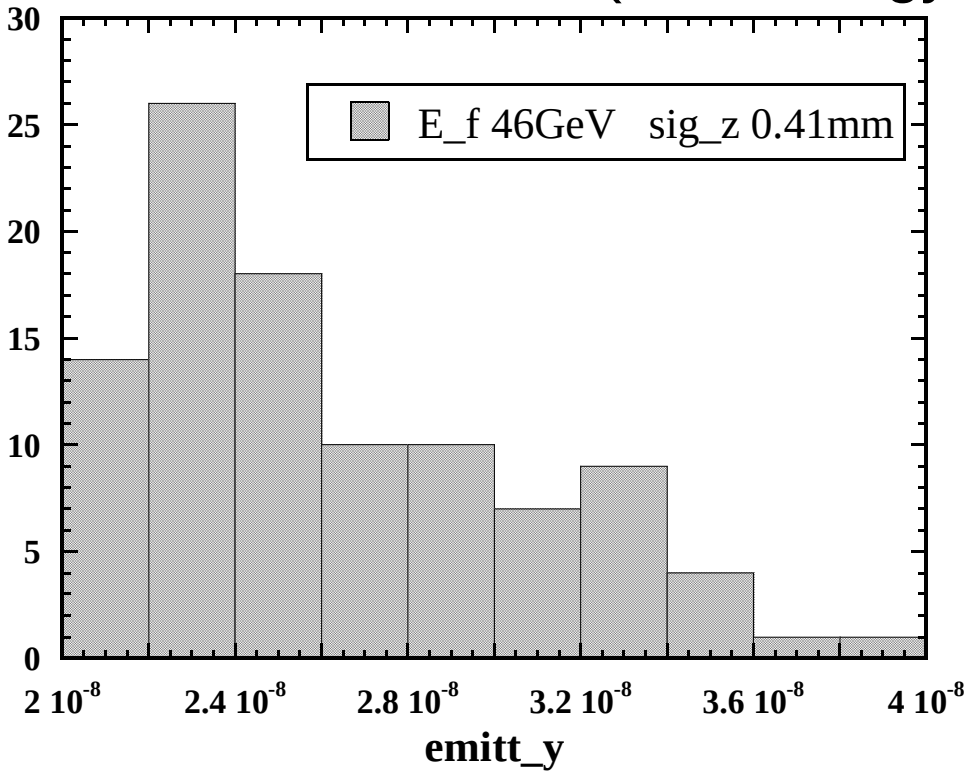
Average of 100 random seeds
error bar: standard deviation



91th in random 100 seeds
(~ 90% CL)



Distribution of final emittance (final energy 46 GeV)



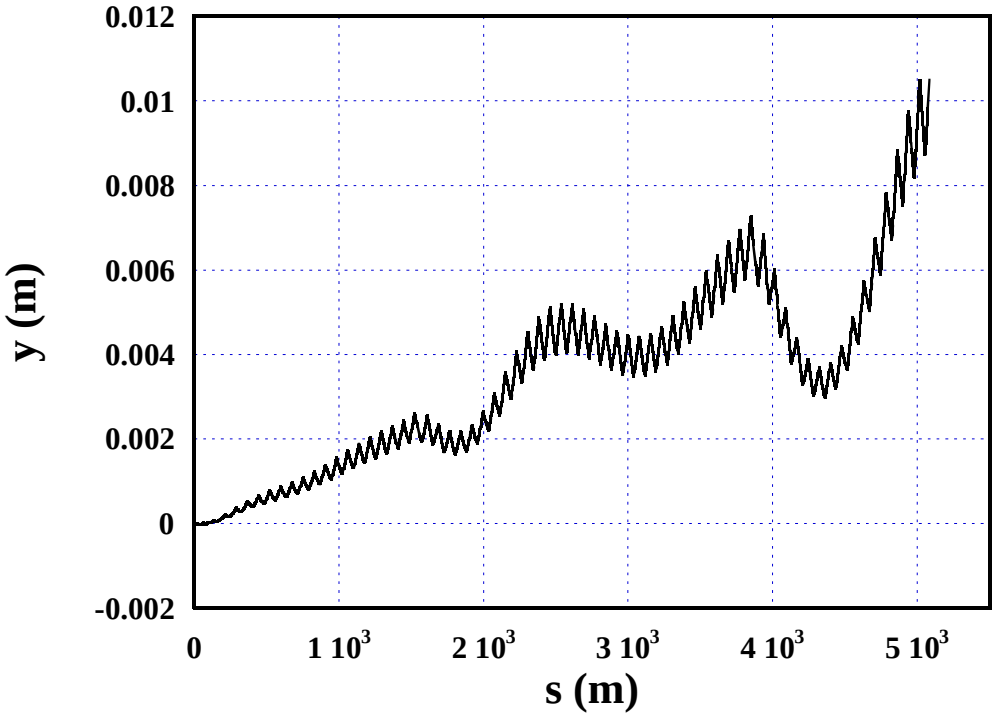
Total 100 simulated.
Average emittance growth: 6.3e-09 (32% of 2E-8)
Standard deviation: 4.4e-09
91th in 100 random: 1.31e-08 (65%)

Vertical orbit

Final beam energy 125 GeV

Magnet setting: for final beam energy 46 GeV

(no errors)



Orbit difference between two beams will be about 10 mm.
Probably acceptable.
This should be corrected by introducing 4 (2 in each direction) pulse magnets.

Summary

Damping Ring

- Strengthen wigglers by 15% will make 3.73x2 Hz operation possible.
  - Keep horizontal emittance ~4 um
  - Damping time will be barely OK.
  - Longer storage time for colliding beam is desirable (e.g. 4.5Hz+3Hz)
- Dynamic aperture with stronger wigglers.
  - Larger than requirement. (may be better than “nominal” strength?)
  - Adding sextupole field has no significant effect
  - Simulations with more realistic field errors are desirable.

Main Linac

- Emittance growth of 46GeV beam will be acceptable level
- Orbit difference of two different energy beams will not be a problem.

So far, no problem found.