ILC Main Linac Beam Dynamics Review

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Low Emittance Preservation in ILC ML

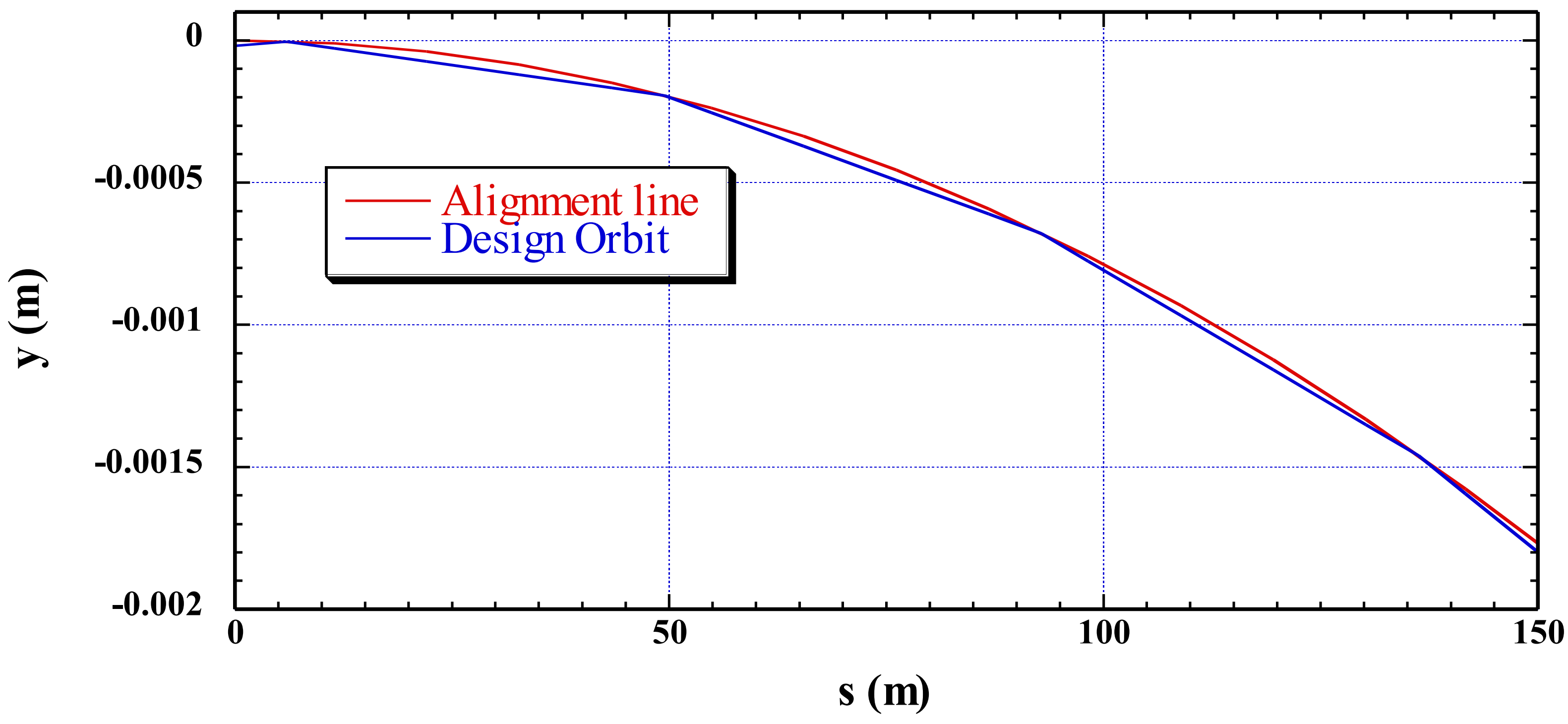
Wakefields of cavities : Not very significant because of the large aperture of the cavities. And we can reply on

- Mechanical alignment (~300 μm) and
- For multi-bunch effect, (natural) frequency spread of resonant modes (~0.1%).

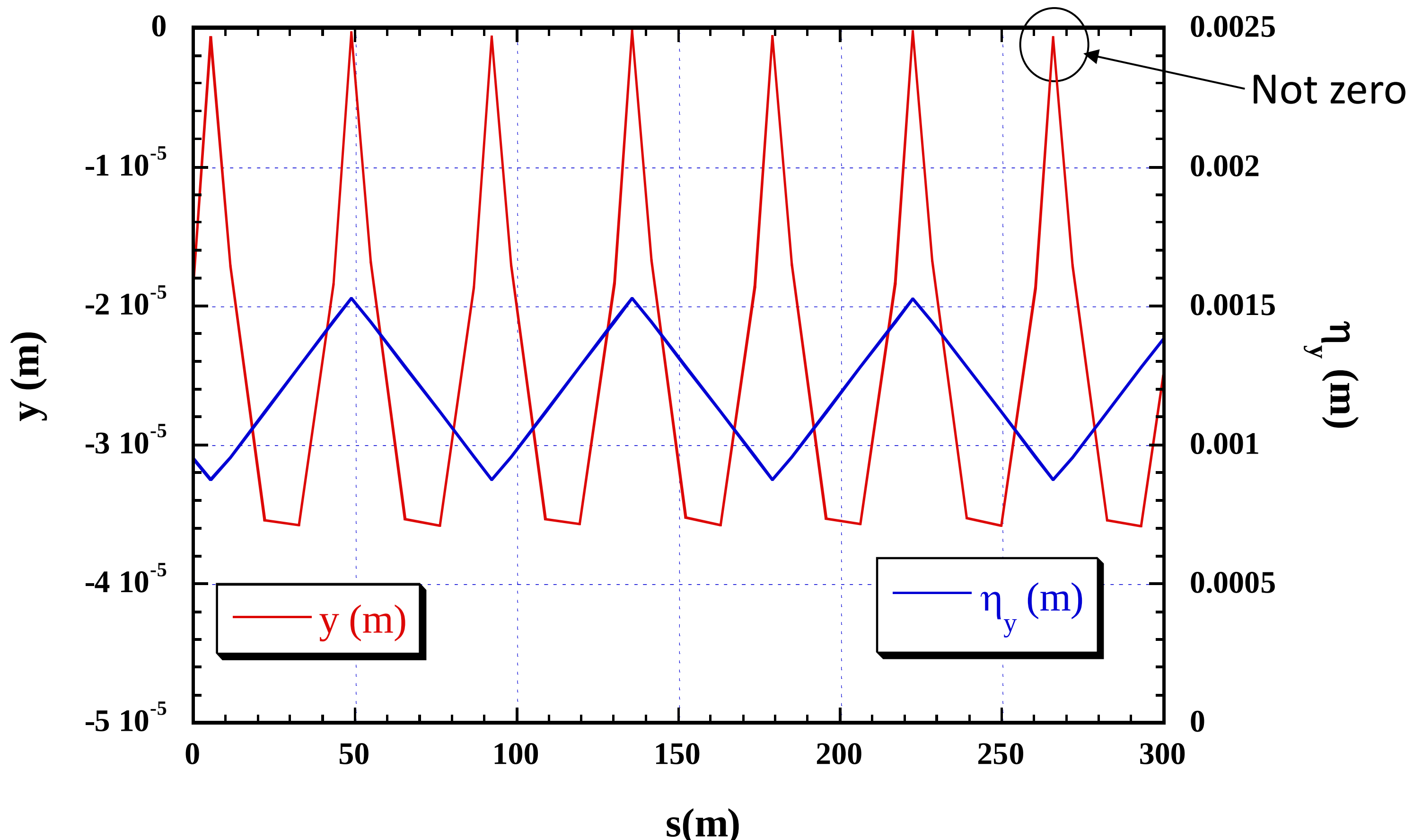
Dispersive effect, caused by Quad offset and Cavity tilt will need more careful cures.

- Static effect
- Dynamic effect

Alignment and Beam Orbit in Curved Linac, Following earth curvature



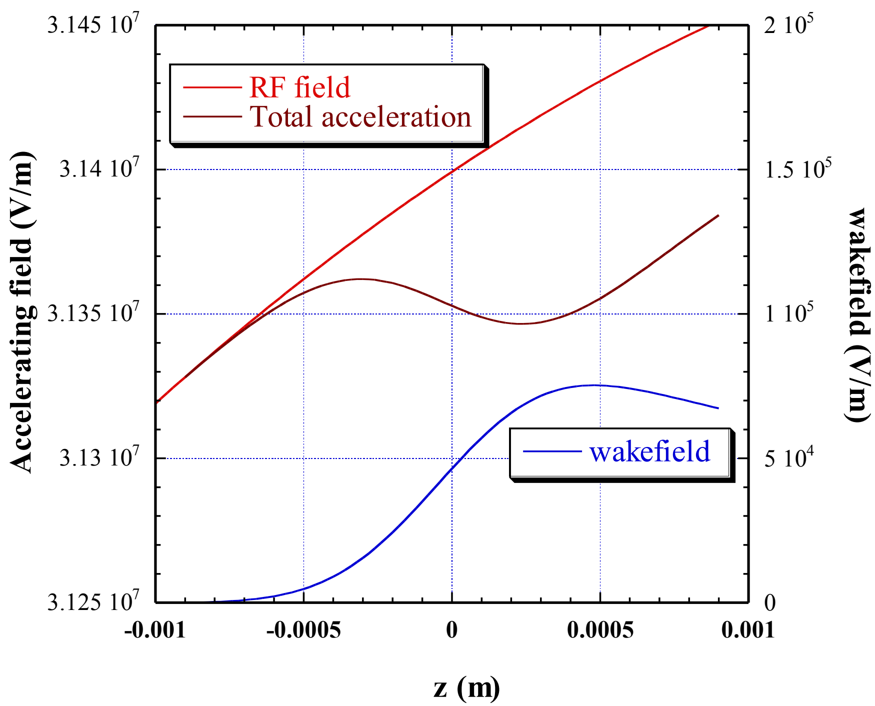
Design orbit w.r.t. the reference line and dispersion



Injection orbit and dispersion are non-zero, and should be matched to the optics.

Single bunch WakeField

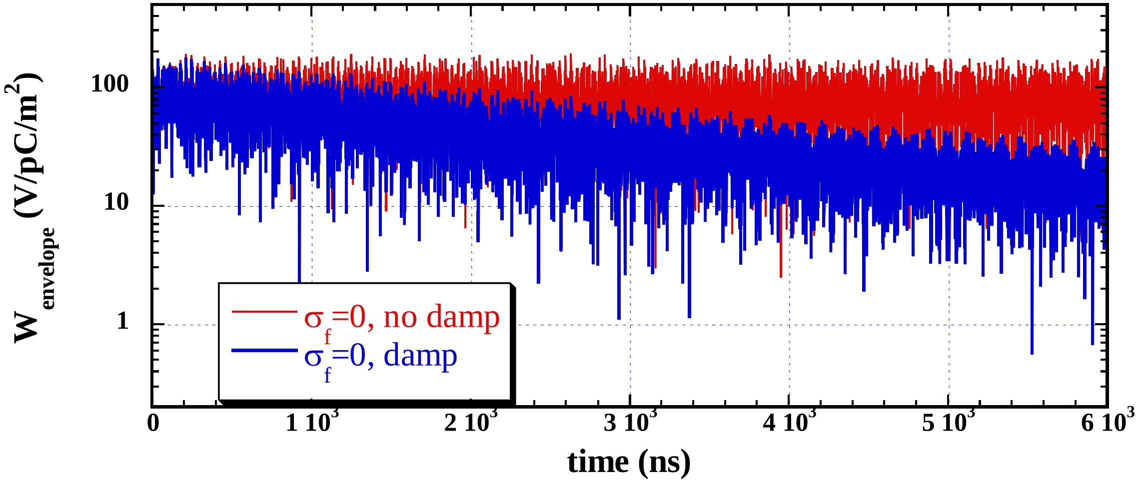
- Requiring cavity misalignment < 300 um, single bunch transverse wakefield effect is not significant.
- BBU: BNS Damping/Auto-phasing is not necessary.
  - RF phase vs. beam chosen for minimizing energy spread.
  - This choice makes the Dispersive Effect minimum.



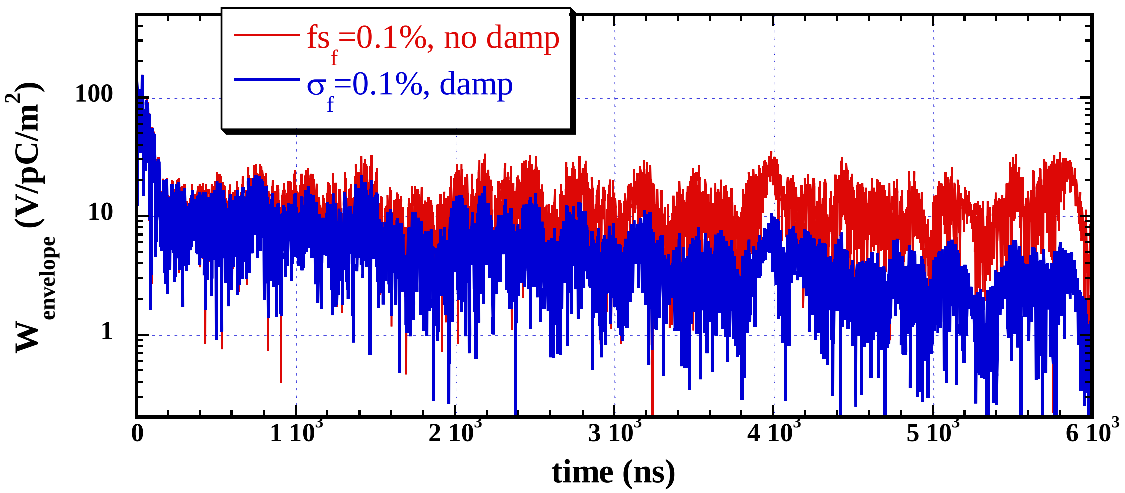
Multi-bunch Wakefield – Rely on random detuning

Wakefunction envelope from HOMs (from TESLA-TDR) with/without random detuning (50 cavities) and damping

No detuning



Random detuning σ_f/f=0.1%



ILC ML static errors and cures

- Agreed “standard” errors: Next page
  - Random Gaussian distributions are used for most studies

- DMS (Dispersion Matching Steering) correction as standard correction method
  - For dispersion measurement, change beam energy 10% ~ 20%
  - BPM scale error is important ← non-zero design dispersion
  - Simulation studies using many different codes and by different persons.
- Other methods (Kick minimum, Ballistic, wake bumps, etc.) as additional or alternative corrections.
- No serious problem expected.
  - An example shown: next-next page

Simulation code bench marking

- We rely on simulations and many codes have been developed.
- Most of them were compared and checked to be consistent.

Figure 5: Emittance dilution after performing DFS in LIAR and reading misalignments and corrector settings into the other codes.

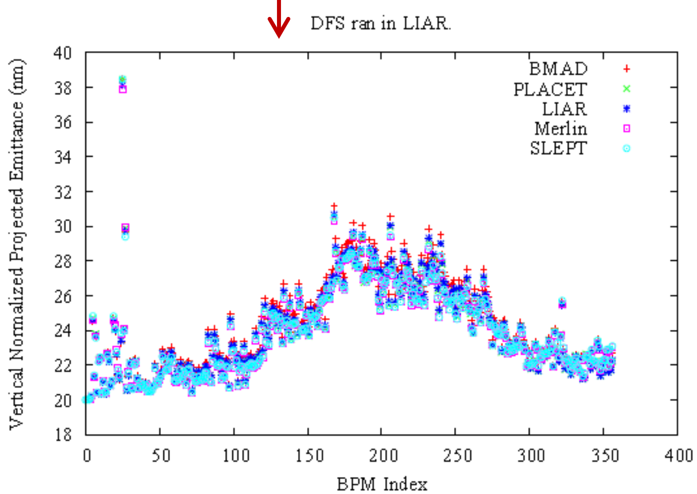


Figure 5: Emittance dilution after performing DFS in LIAR and reading misalignments and corrector settings into the other codes.

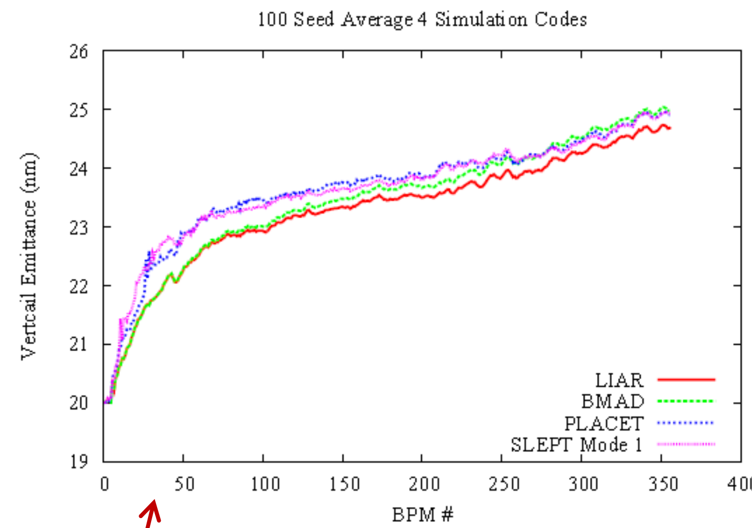


Figure 6: Each code performing DFS separately using the same 100 seeds.

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J. C. Smith, et.al., “Benchmarking / Crosschecking DFS in the ILC Main Linac” FERMILAB-TM-2373-CD, SLAC-TN-06-035

Agreed “standard” errors

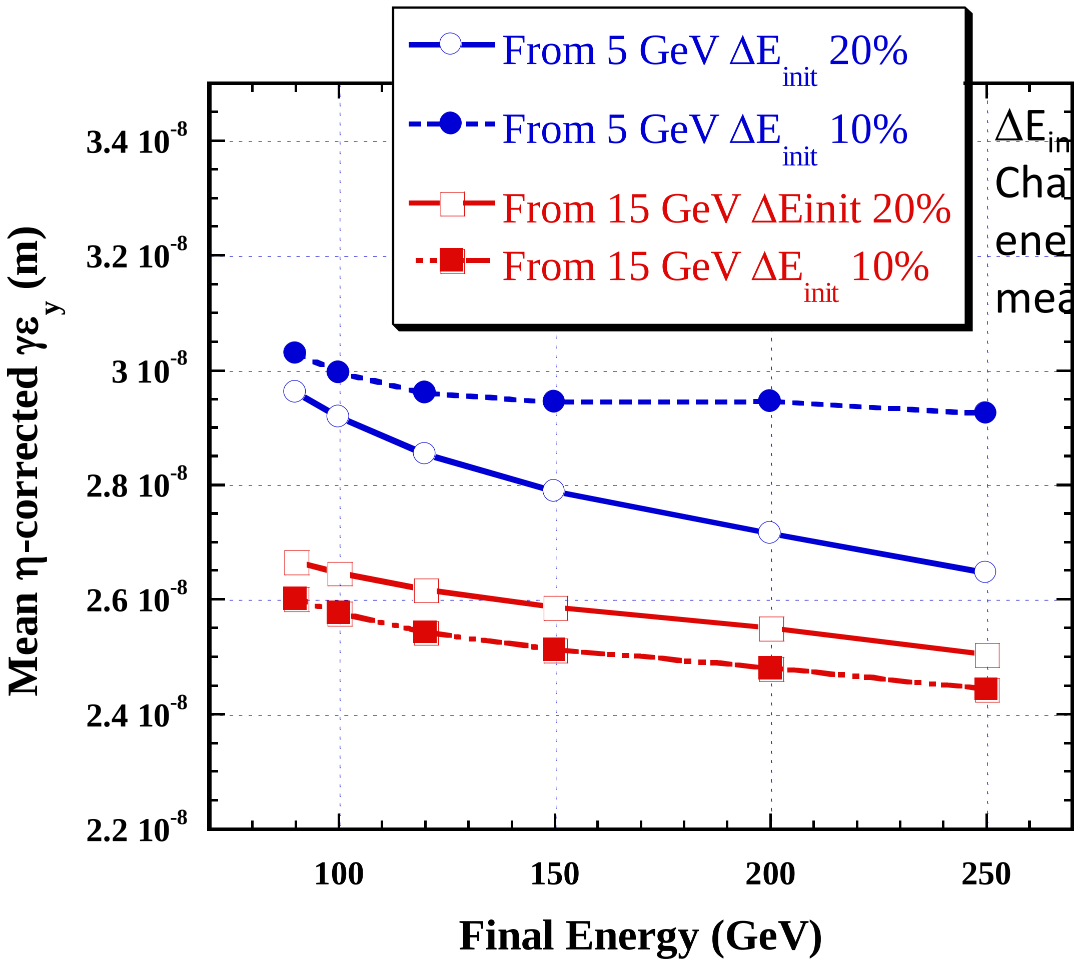
“standard” alignment errors

Error	RTML and ML Cold	with respect to
Quad Offset	300 μm	cryo-module
Quad roll	300 μrad	design
RF Cavity Offset	300 μm	cryo-module
RF Cavity tilt	300 μrad	cryo-module
BPM Offset (initial)	300 μm	cryo-module
Cryomoduloe Offset	200 μm	design
Cryomodule Pitch	20 μrad	design

BPM

BPM resolution (fraction of beam pulse)	1 μm
BPM scale error	5%

“Standard” static errors + BPM resolution 1um + DMS



ΔE_{init}:
Change of initial energy for dispersion measurement

Final Energy was changed
Keeping the total length of linac

K.Kubo LCWS 2011 Oregon

ILC ML major dynamic errors

(Affecting Transverse Motion)

ML 15 GeV to 250 GeV

Source	Assumption (Tolerance)	Induced orbit jitter	Induced emittance growth
Quad vibration (offset change)	100 nm	1.5 sigma	0.2 nm
Quad+steering strength jitter	1E-4	1 sigma	0.1 nm
Cavity tilt change	3 urad	0.8 sigma	0.5 nm
Cavity to cavity strength change, assuming 300 urad fixed tilt	1%	0.8 sigma	0.5 nm

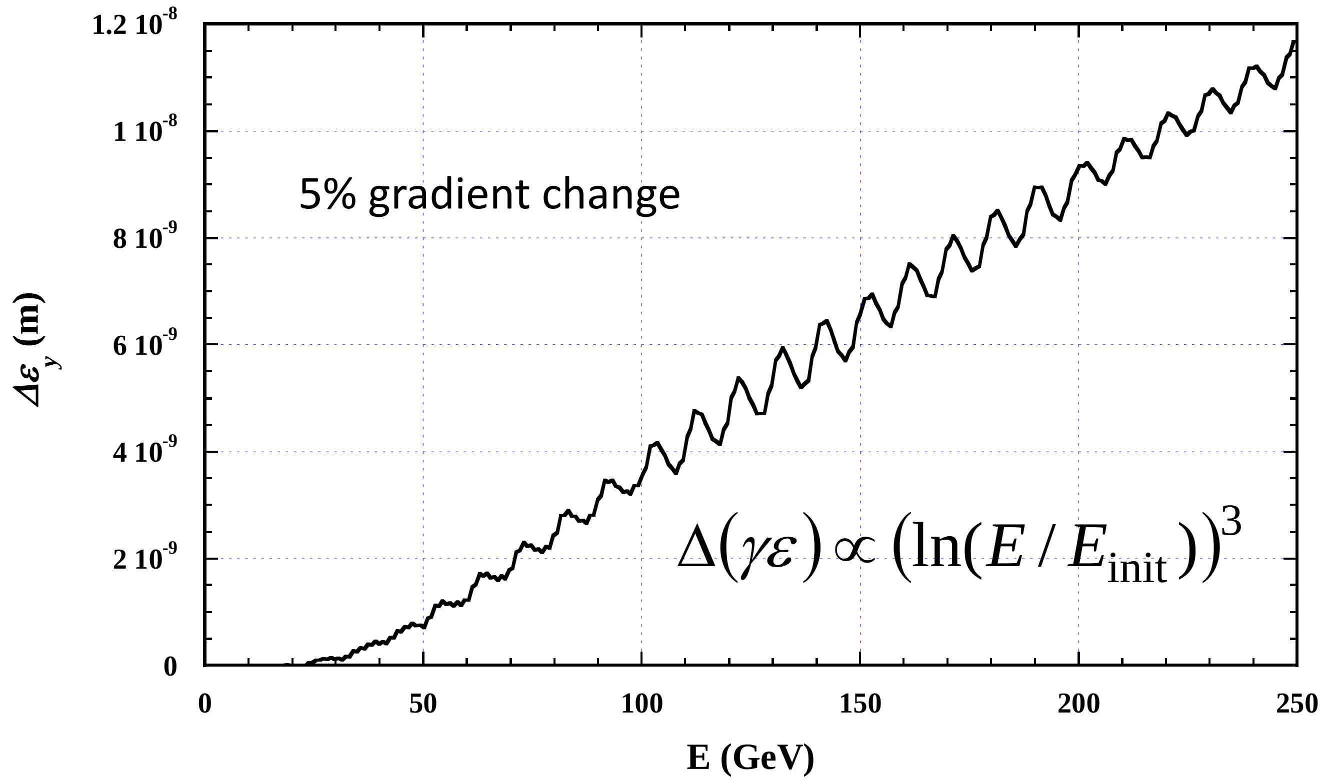
Pulse to pulse and in each pulse (flatness)

Hard to correct

The orbit jitter will be corrected in post-linac fast feedback

Emittance growth by Cavity tilt

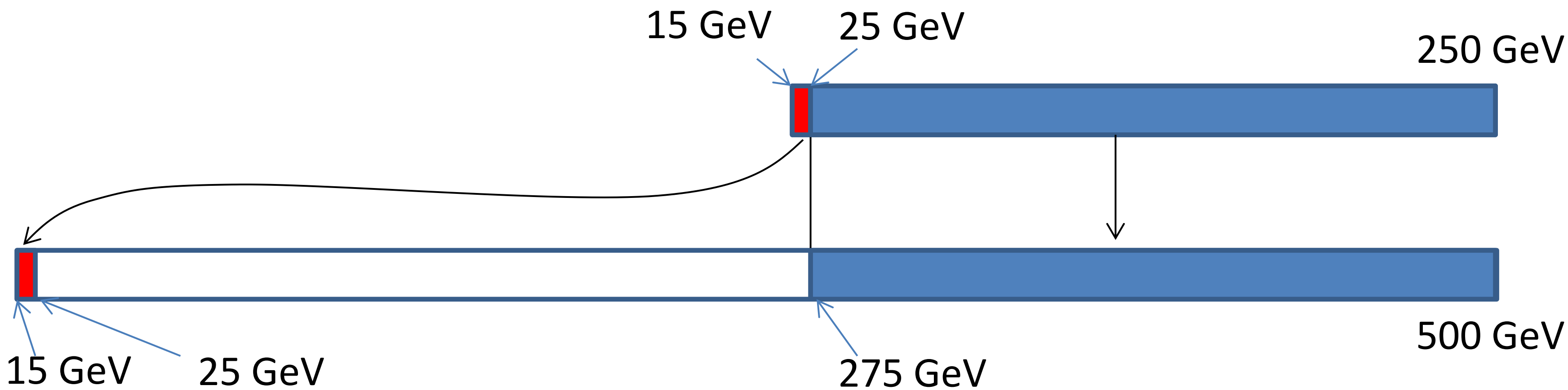
Emittance growth along ML
Cavity tilt random change 15 urad,
equivalent to Fixed 300 urad + 5% gradient change
Emittance growth proportional to square of the change



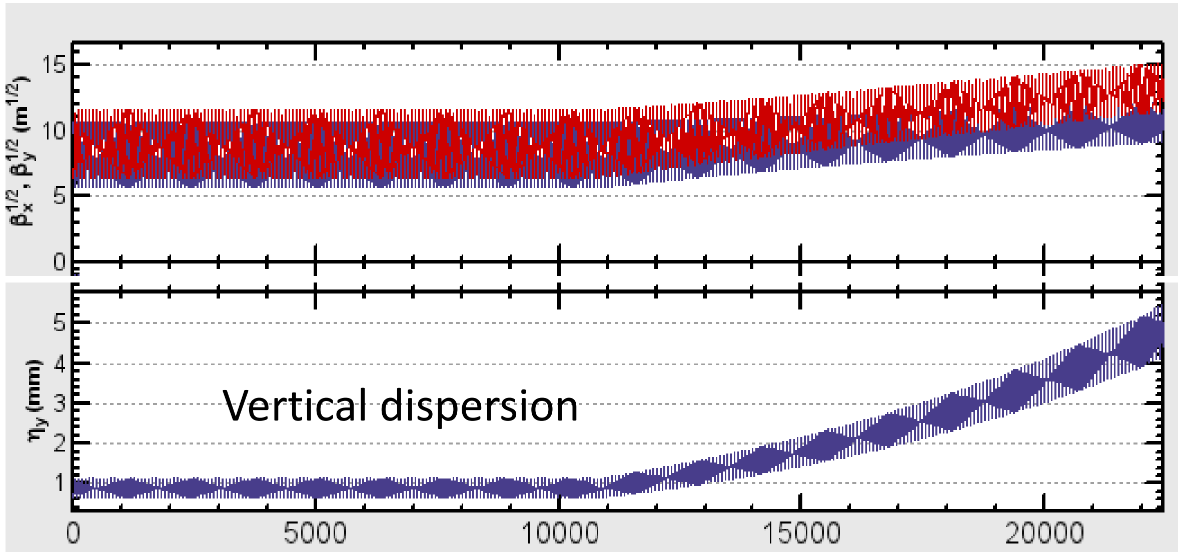
Gradient change 1% → emittance growth 1/25 of this figure.

Energy upgrade Ebeam 250 to 500 GeV

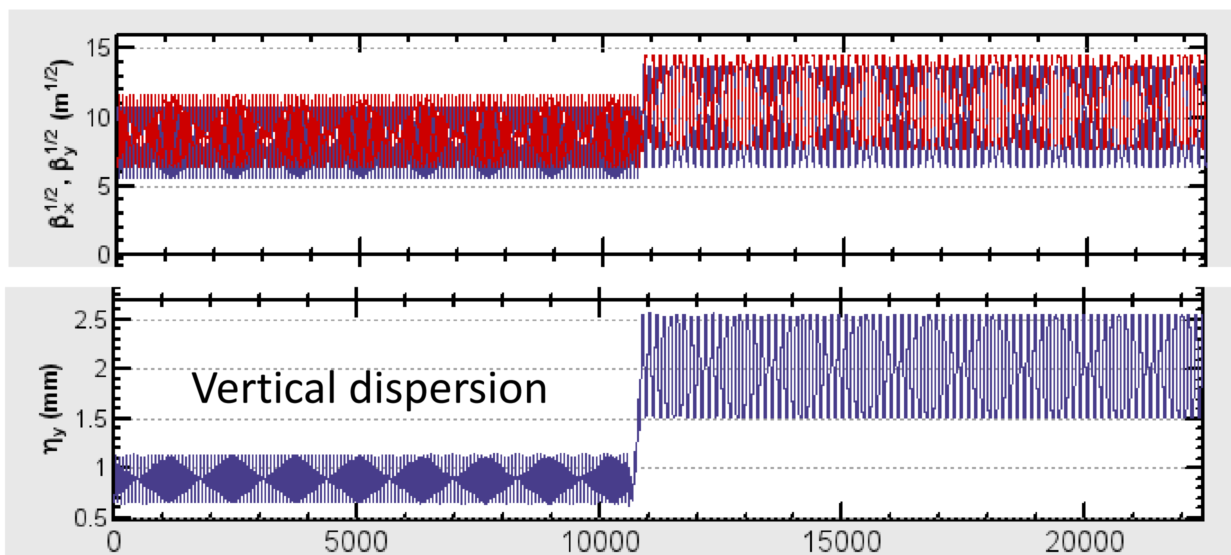
- ML starts from 15 GeV in both old and new linac.
- Special quad magnets for low energy part, 15 to 25 GeV.
- Keep most part of old linac (25 to 250 GeV) as downstream part of new linac (275 to 500 GeV).
  - Strength is limited. Strength at 250 GeV of old linac.
- Upstream part of new linac (15 to 250 GeV) identical to the old linac (FODO).
- FOFODODO for E_beam > 250 GeV
  - For keeping vertical dispersion small (following earth curvature).



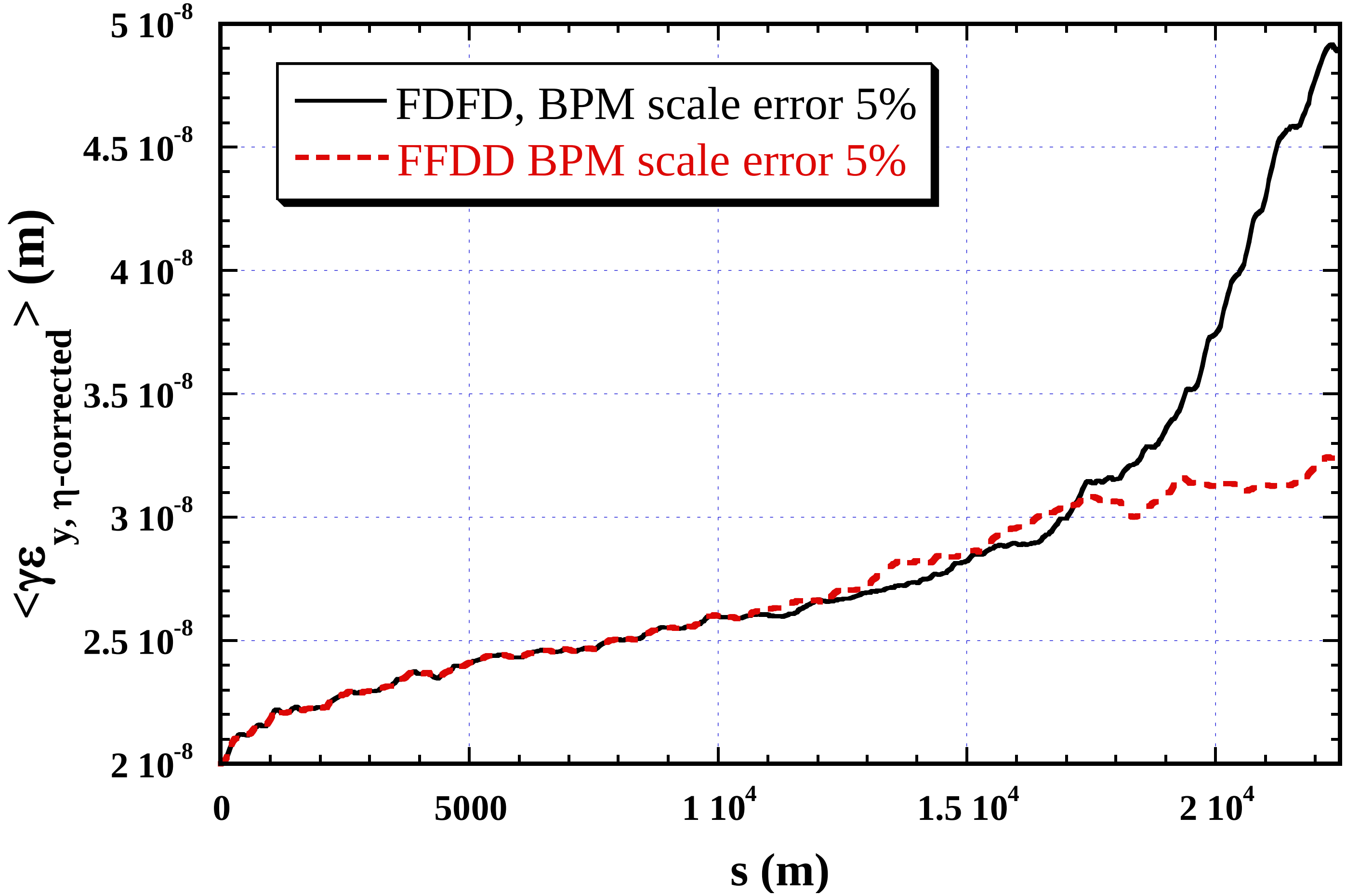
FODO



FOFODODO



Simulation results of DFS with “standard” static errors + BPM Scale error 5%



average of 40 seeds

Other considered issues, examples

- Coupler wake and RF transverse kicks
  - No problem because of short bunch length (compare with in RTML)
- Emittance dilution in undulator for e+ production
  - Dispersive effect will be small, with orbit correction.
  - Wakefield in the narrow beam pipe can be significant.
    - No problem with movers.
- Specification of magnet change speed
  - For BBA, or startup after shutdown, etc.
  - Required speed will be achievable without serious R&D.
    - Quadrupole: 0.01 T/m*m/s (0.033%/s)
    - Steering: 3E-4 Tm/s (0.6%/s)

Possible Further studies

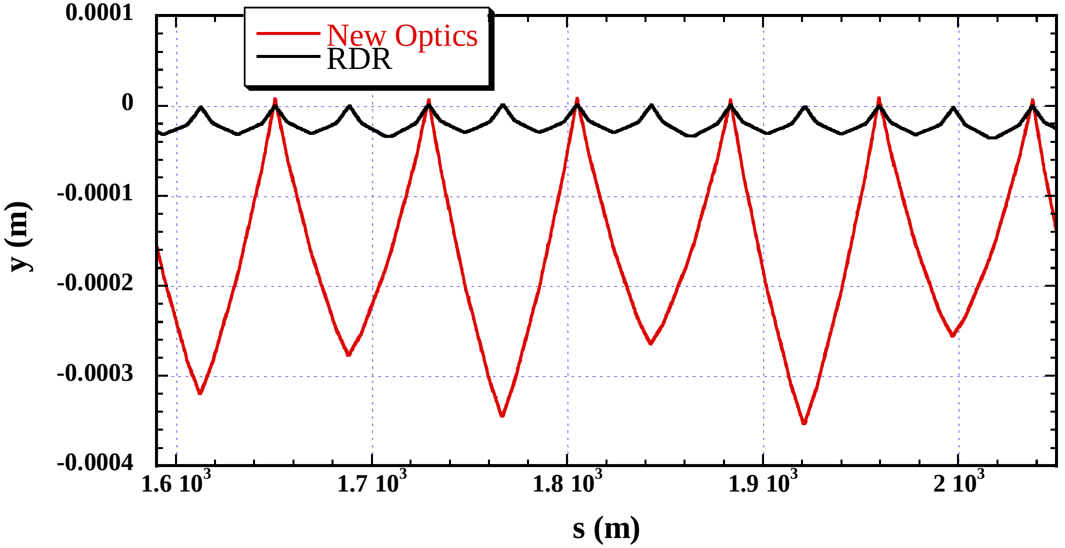
(some studies already exist but not completed)

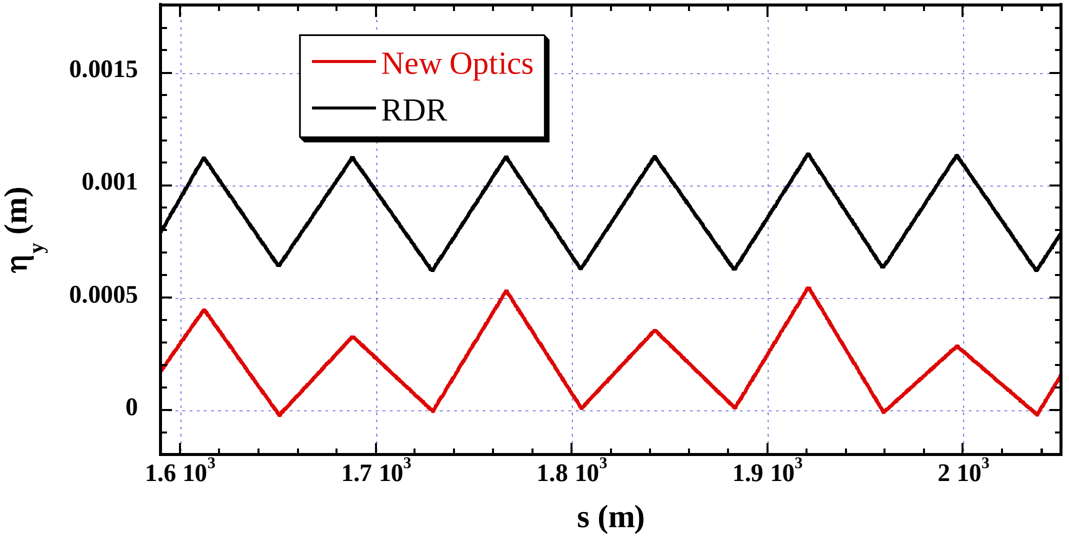
- Studies with realistic alignment model
  - Alignment engineers and beam dynamics physicists should agree.
- More realistic DMS procedure
  - E.g. Simulations combined with upstream (RTML)
- Optics choice, for making less sensitive to BPM scale error.
  - See next slide
- Simulations with failed components (BPM, Cavities, Magnets)
- , , , RTML-ML-BDS combined studies, , ,

None of these are expected to be critical.

Vertical Orbit and Dispersion

Base line optics (same as RDR) and new possible optics





K.Kubo, ILC-CLIC-LET-Workshop, 2009 CERN