New lattice design of Main Linac and upgrade to 500 GeV E_beam (preliminary trial)

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Introduction, motivation

- In RDR, one klystron feed cavities in 3 cryo-modules (26 cavities). (called RF unit)
  - This is a reason we chose the lattice of 3 cryomodules / quad
- 3 is no longer the unit in both DRFS and KCS scheme.
  - Consider 2, 4 or 5modules / quad
- DRFS scheme prefer even number of cavities in a cryo-module
  - Assume 8 cavities in a module

Tested lattice designs

A: 3 modules / quad (same as RDR, but 24 cavities / quad instead of 26)
- Almost the same as RDR from beam dynamics

B: 2 modules / quad in 1/3 upstream part
4 modules / quad in 2/3 downstream part
- Same number of quads in a linac as the case A
- Smaller beta-function (stronger focusing) in the low energy part.

C: 4 modules / quad
- Fewer magnets per linac than A
- Same quad strength (k-values) as A (more phase advance/cell)

D: 4 modules / quad
- Fewer magnets per linac than A
- Same phase advance/cell as A (weaker quad strength)

E: 5 modules / quad
- Fewer magnets per linac than A
- Same phase advance/cell as C

Tested lattice designs

Quad strength (in low energy region)

B > A = C > E > D

Phase advance per cell (in low energy region)

B > C = E > A = D

A: 3 modules / quad

B: 2-4 modules / quad

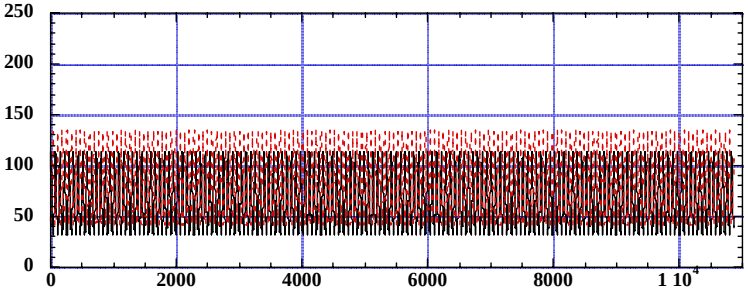
C: 4 modules / quad, strong

D: 4 modules / quad, weak

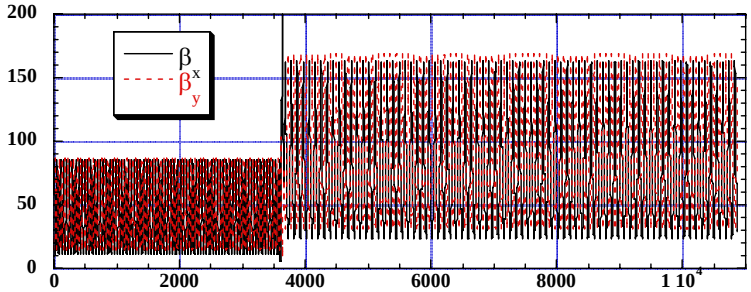
E: 5 modules / quad

Beta-functions

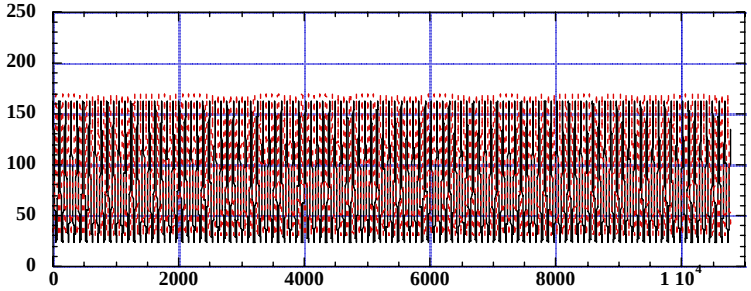
A



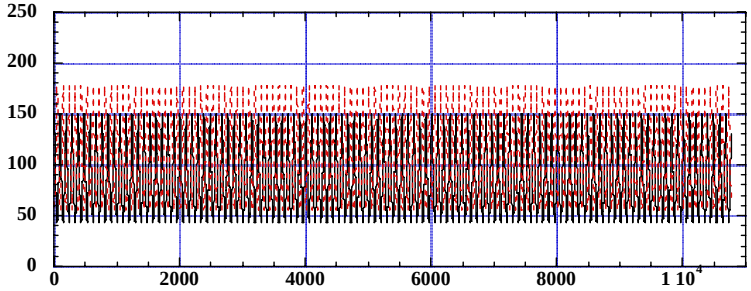
B



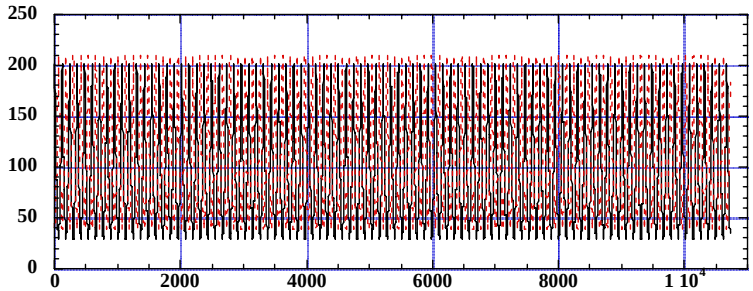
C



D

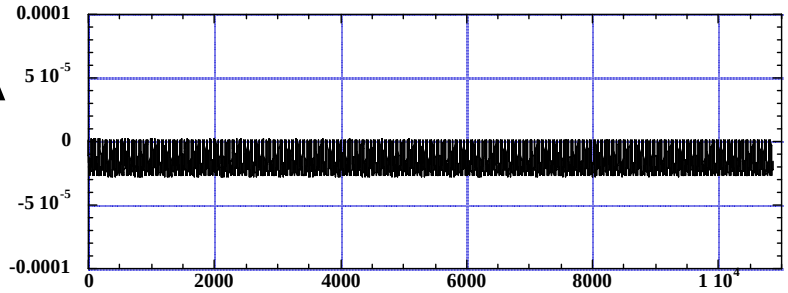


E



Vertical Orbit (offset from alignment line)

A



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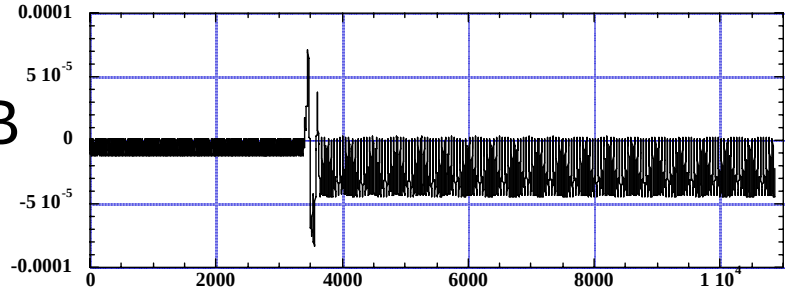

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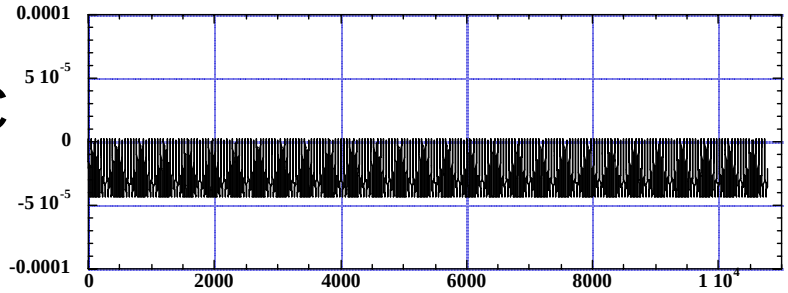

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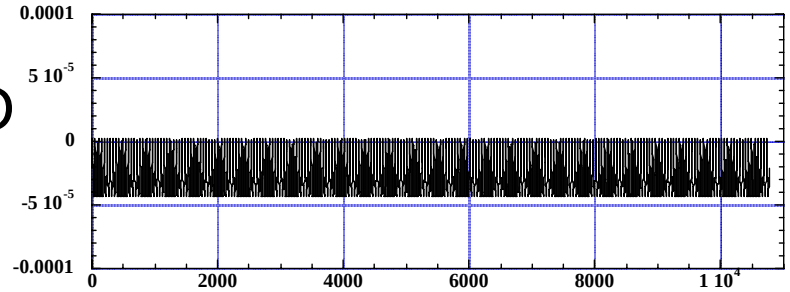
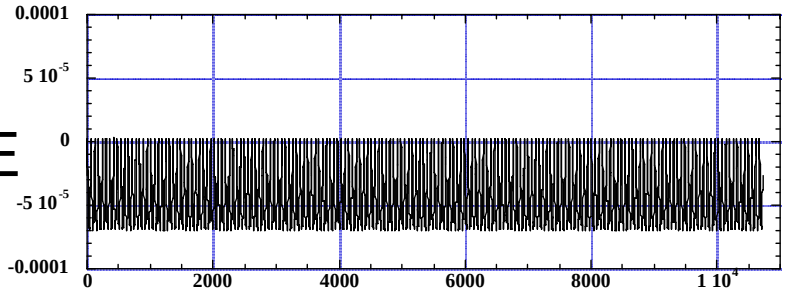
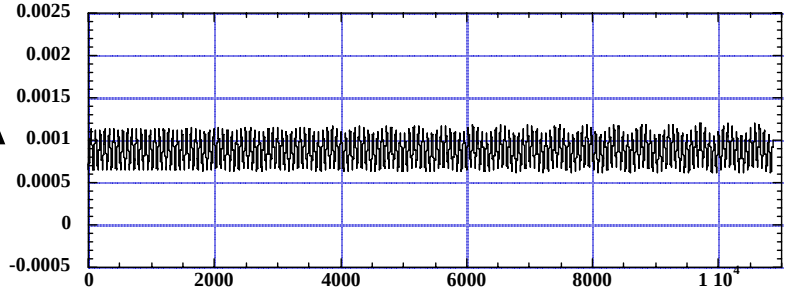


E

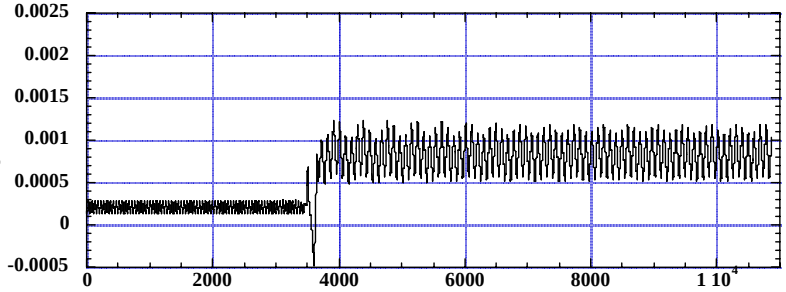


Vertical Dispersion

A



B



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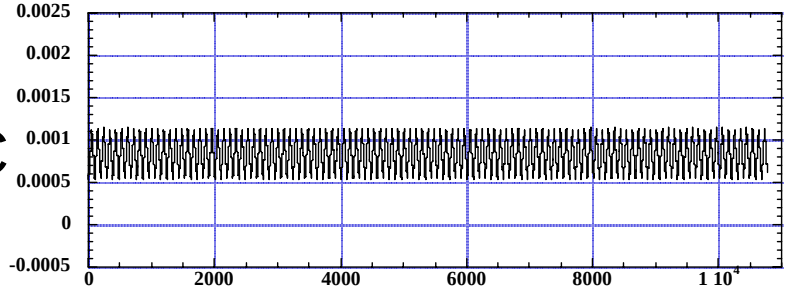
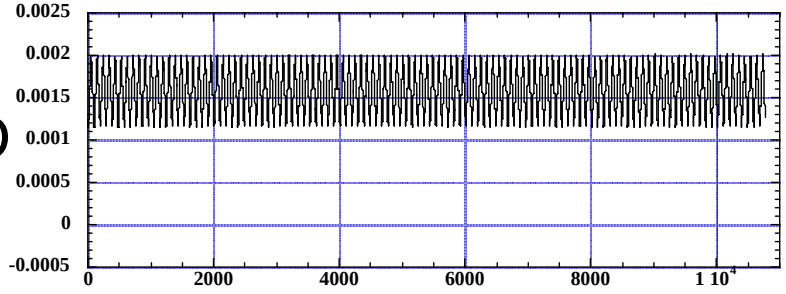


D



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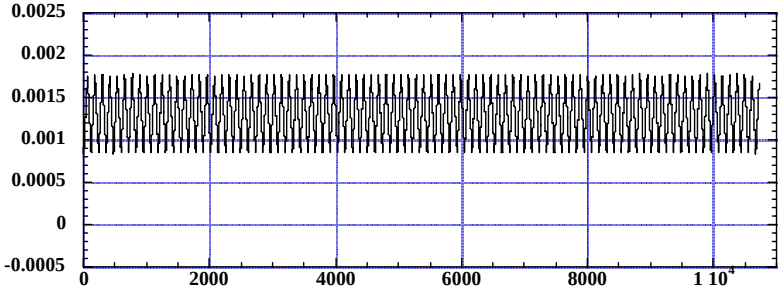
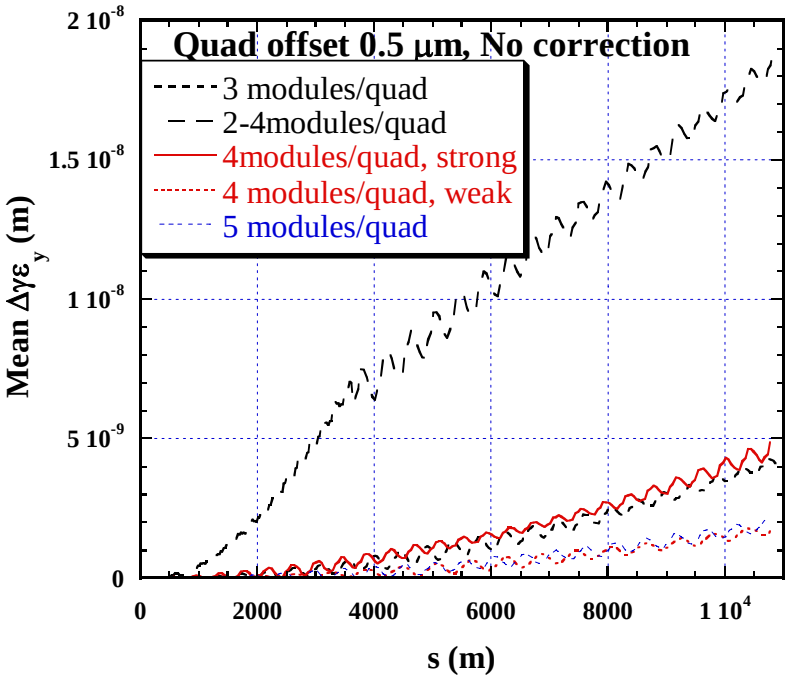
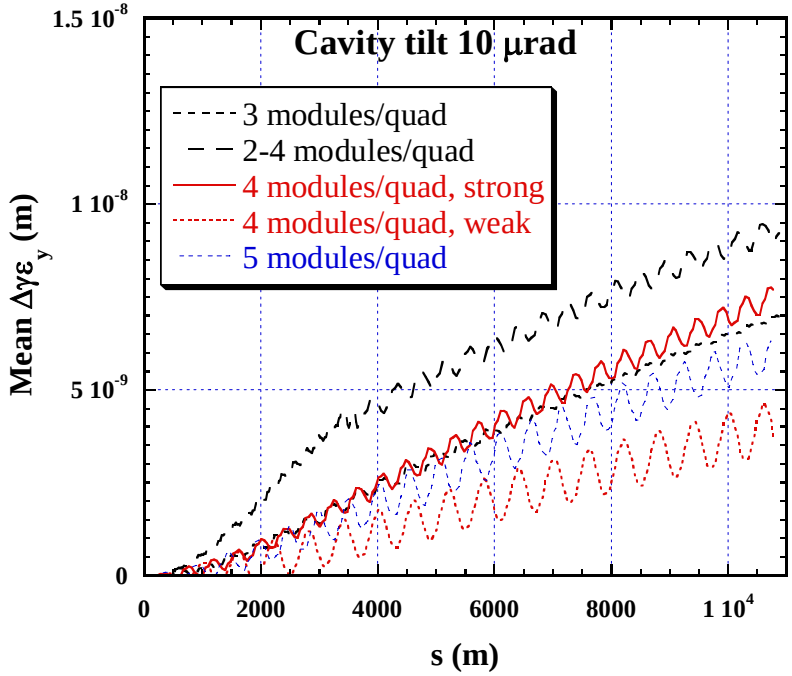


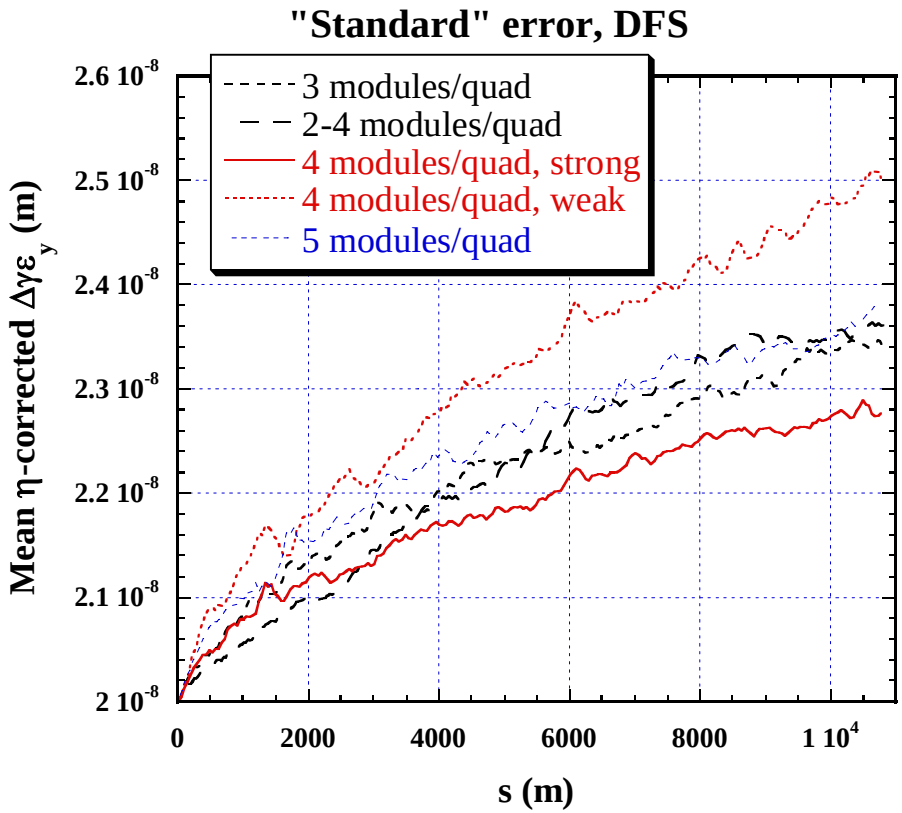
Simulation results of effects of dynamic errors (no correction)





Strong quad strength at low energy → sensitive to dynamic errors

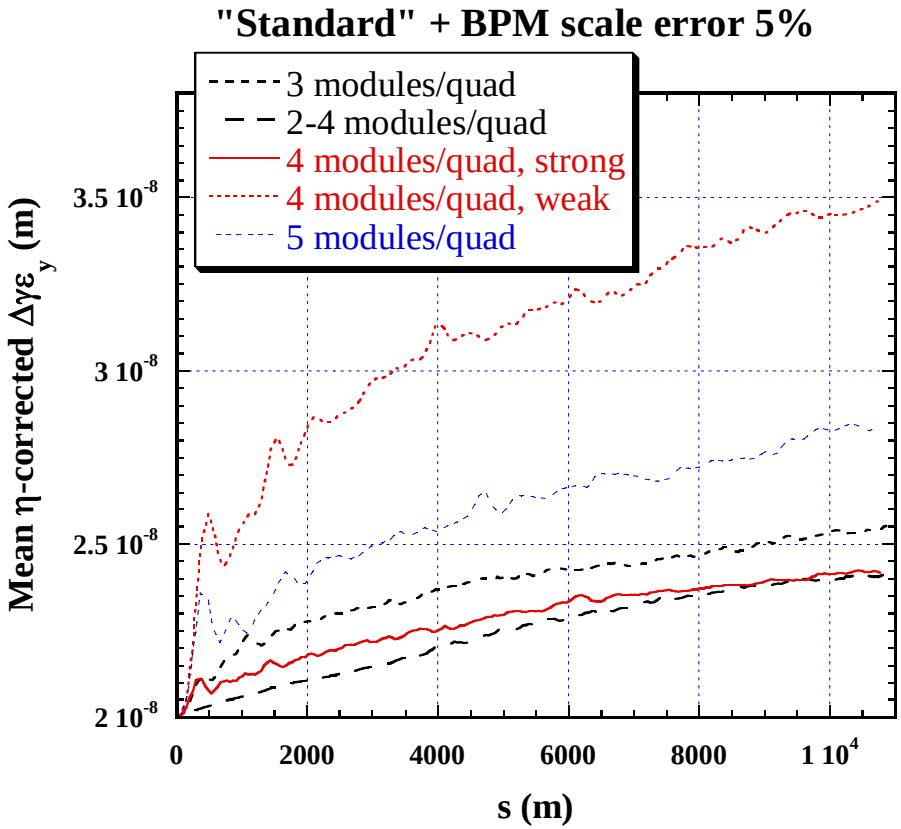
Simulation results of DFS with “standard” static errors



Errors: Quad offset 360 um, Cavity offset 640 um, BPM offset 360 um
Cavity tilt 300 urad, Quad rotation 300 urad, BPM resolution 1 um
DFS (DMS) correction changing beam energy by 10%.

Stronger focus seems better.

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



Smaller designed dispersion is better.

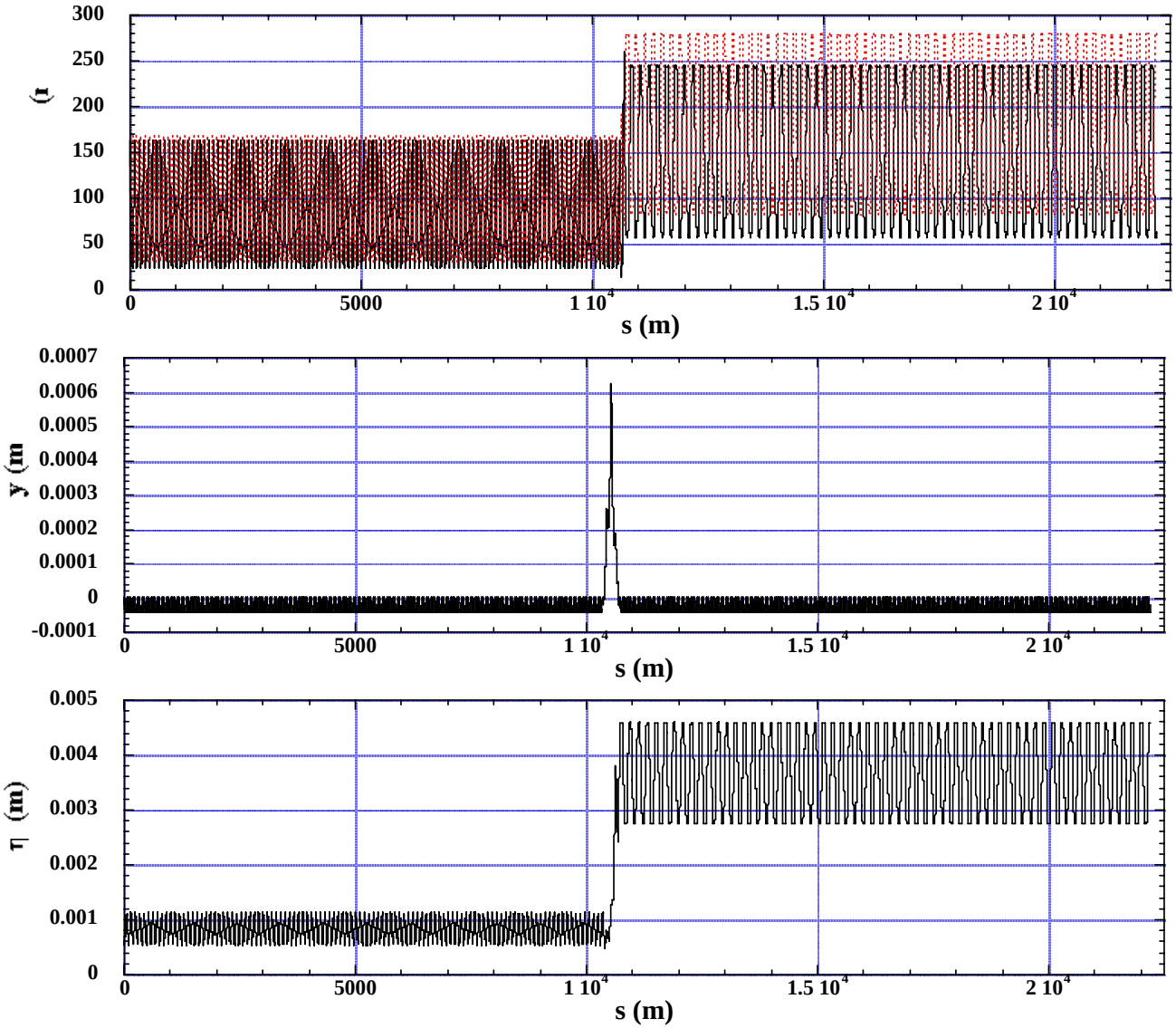
Summary for E_beam 250 GeV

- 5 lattice designs, with 8 cavities/cry-module, are tested.
  - 2-4, 3, 4 or 5 modules / quad
- Effects of dynamic errors:
  - Stronger focus lattice is more sensitive
- Effects of static errors:
  - Lattices with strong quads seem better, but not very different for all designs after DFS corrections, without BPM scale error.
  - Lattices with strong quads (with smaller designed vertical dispersion) are better, after DFS, with BPM scale error.
- 4 modules / quad will be good
  - Similar or better than 3 modules / quad with the same quad strength (larger phase advance per cell).
  - Can reduce number of magnet-BPM sets
- Need to survey more parameters?

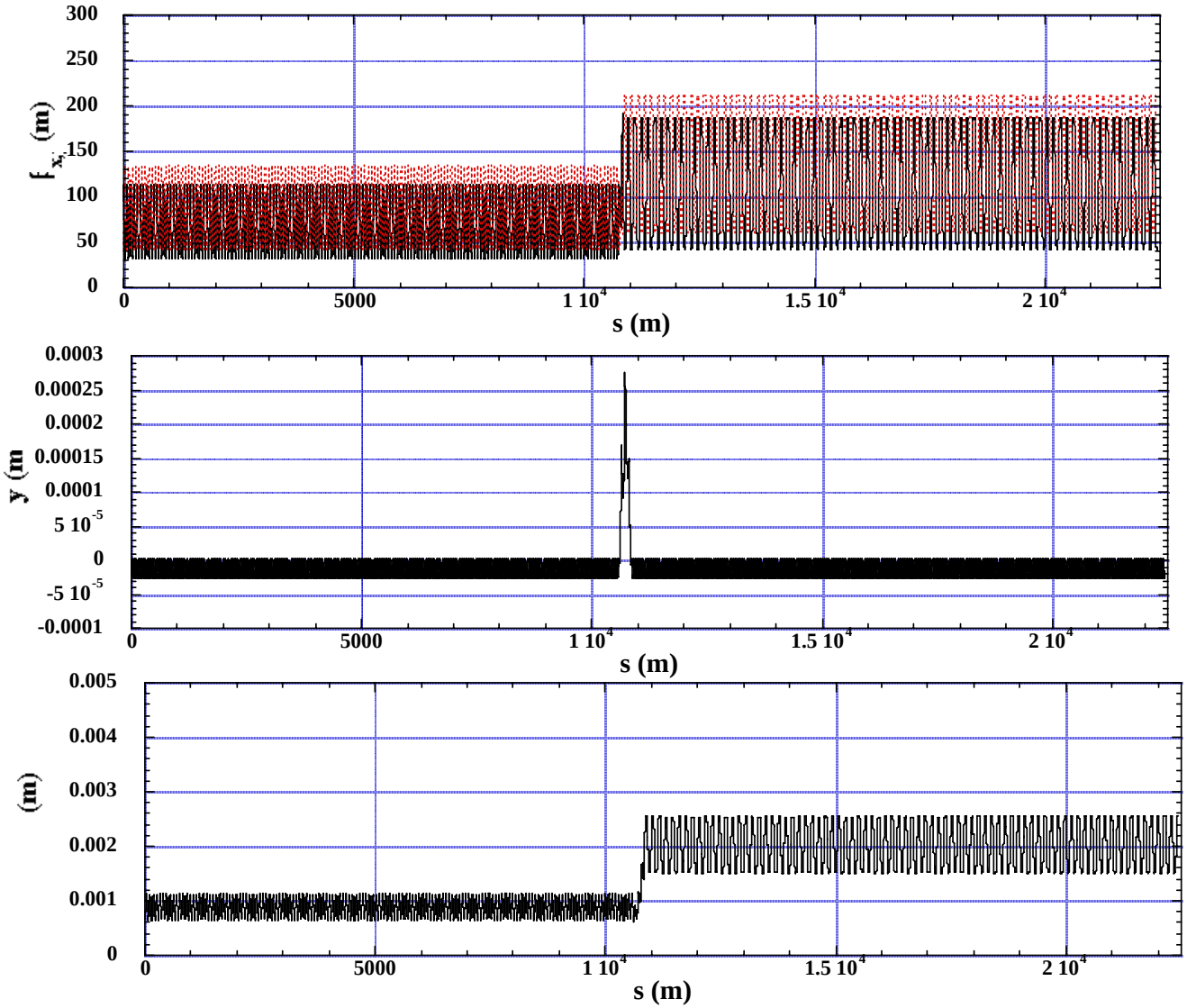
Test upgraded linac, ECM 1 TeV

- Uniform hardware configuration along the linac.
- In upgrade from 250 to 500 GeV beam energy, the old 250 GeV linac (15 to 250 GeV) is assumed to be used as the last part of the new 500 GeV Main Linac (265 GeV to 500 GeV).
- Tried FODO cell from 15 to 250 GeV, FOFODODO cell from 250 to 500 GeV. Max. quad strength at 250 GeV
- Two cases:
  - 4 modules (32 cavities) / quad in whole linac
    - Same phase advance / cell for FOFO and FOFODODO
      - Energy-normalized Quad strength (K-value) in FOFODODO is 0.35 of FODO
  - 3 modules (24 cavities) / quad in whole linac
    - Energy-normalized Quad strength (K-value) in FODO is same as FODO of 3 modules /quad
    - Phase advance / cell in FOFODODO is the same as in FOFODODO 4 modules / quad.
      - Energy-normalized Quad strength (K-value) in FOFODODO is 0.47 of FODO

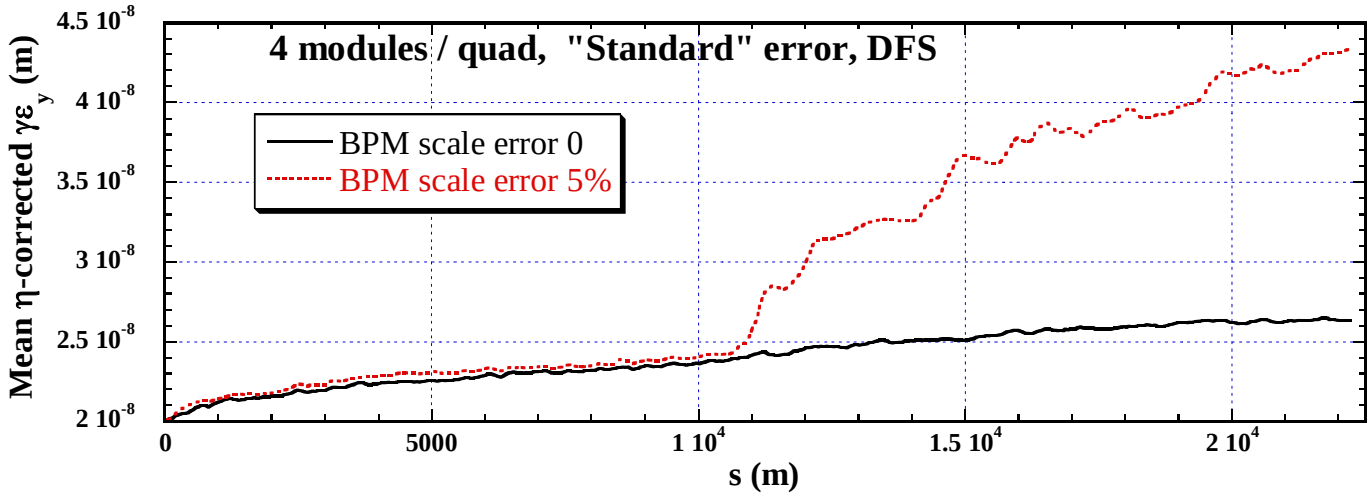
Beta, orbit, dispersion, 4 modules/q



Beta, orbit, dispersion, 3 modules/q



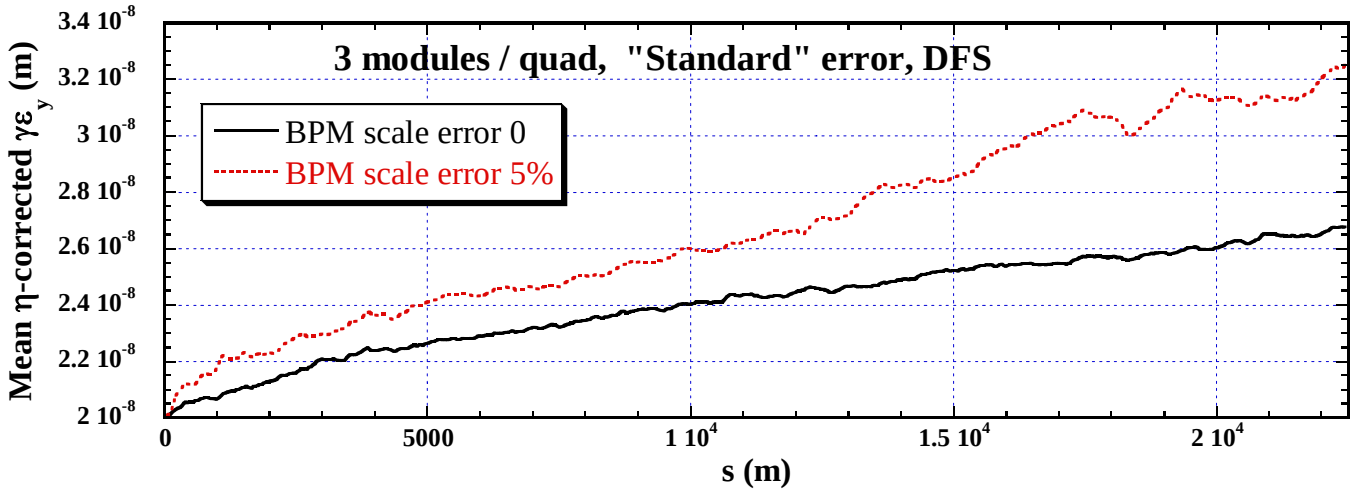
Static “standard” error + DFS , 4 modules/q



Errors: Quad offset 360 um, Cavity offset 640 um, BPM offset 360 um
Cavity tilt 300 urad, Quad rotation 300 urad, BPM resolution 1 um
DFS (DMS) correction changing beam energy by 10%.
RDR nominal beam parameter. Computer code SLEPT.

BPM Scale Error affect DFS performance significantly in FOFODODO.
(Large designed dispersion)

Static “standard” error + DFS , 3 modules/q



Still significant effects
but less sensitive to BPM Scale Error than 4 modules/quad.
(Smaller designed dispersion in FOFODODO)

Summary for ECM 1TeV upgrade

- Lattice of Main Linac from 15 to 500 GeV beam energy are designed with 4 cryo-modules / quad and 3 modules / quad.
- Old 250 GeV linac (15 to 250 GeV) is assumed to be used as the last part of the new 500 GeV Main Linac (265 GeV to 500 GeV).
- Usual FODO lattice is used up to 250 GeV, and FOFODODO lattice from 250 to 500 GeV. (FOFODODO lattice can have smaller beta-function compare with FODO with the same quad strengths.)
- Larger design dispersion of the FOFODODO lattice in the high energy part (from 250 GeV) will cause significant emittance growth with BPM scale error 5 %.
  - 3 modules / quad is better, with smaller dispersion.
- There may be better optics. E.g. smaller dispersion near de-focus quads (larger near focus). (?)
- Or, can we require accurate BPM scale?

SUMMARY

250 GeV beam energy

- Lattice of 4 cryo-modules / quad will have similar performance with lattice of 3 cryo-modules / quad
  - With the same quad strength.

Upgraded 500 GeV beam energy linac from 250 GeV

- If the old 250 GeV linac is used as the last part of the new 500 GeV linac,
  - Design vertical dispersion in high energy part (FFDD cell) will be large and
  - Tolerance of BPM scale error may be too tight.
  - 4 modules / quad seems much worse than 3 modules / quad
  - There may be better optics choice ?

IF considering the upgrade, 3 modules/quad may be better.