Simulation studies on ILC BC and ML with SLEPT

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Code upgrade-1

- SLEPT used to fix relative longitudinal position for saving time of wakefield calculations. It has been upgraded to include longitudinal motion so that we can simulate both RF section and wiggler section of 2-stage BC together. (Also ML can be included.)

Two types sections in the beam line:

- Normal section: Z does not change. Wakefields exist.
- Special section: Z can change. No wakefields. We add new element-real bending megnets.

For special section

beginning: slice beam ⟶ particle beam (add Z to each macro-particle)

end: particle beam ⟶ slice beam; reset wakefields for slice beam.

Code upgrade-2

- DFS by RF phase tuning is included in the new program.

one test beam: $$\sum_i \{ w\left(y_i(\varphi) - y_i(0) \right)^2 + y_i(0)^2 \}$$

two test beams: $$\sum_i \{ w\left(y_i(+\varphi) - y_i(-\varphi) \right)^2 + y_i(0)^2 \}$$

Code upgrade-3

- Cryomodule misalignment is included.

In the past, all the elements were aligned w.r.t. survey line or perfect beam line independently. Now the cavities, quadrupoles and BPMs in cold regions are aligned w.r.t. cryomodules, and the elements in warm regions are aligned independently.

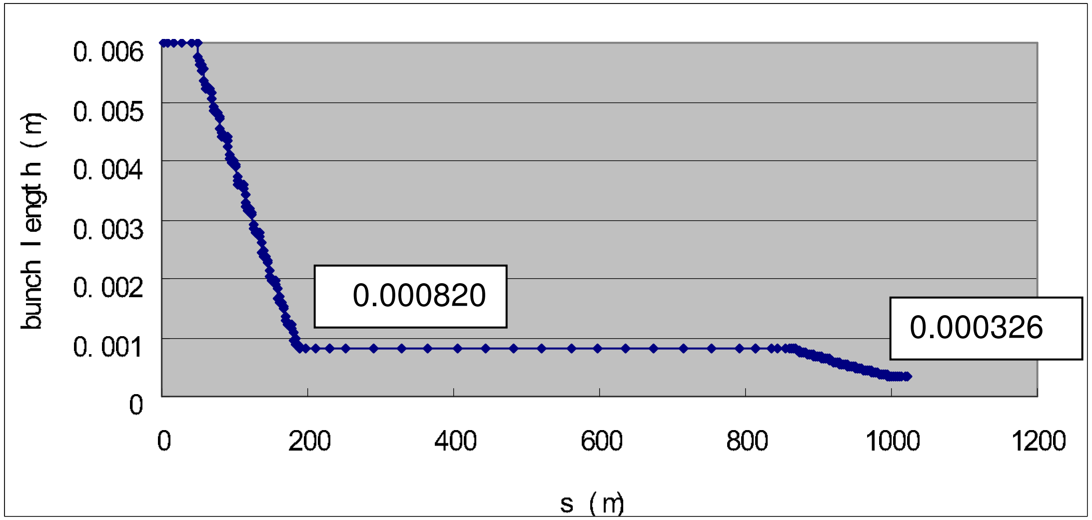
"standard" set of errors in cold regions

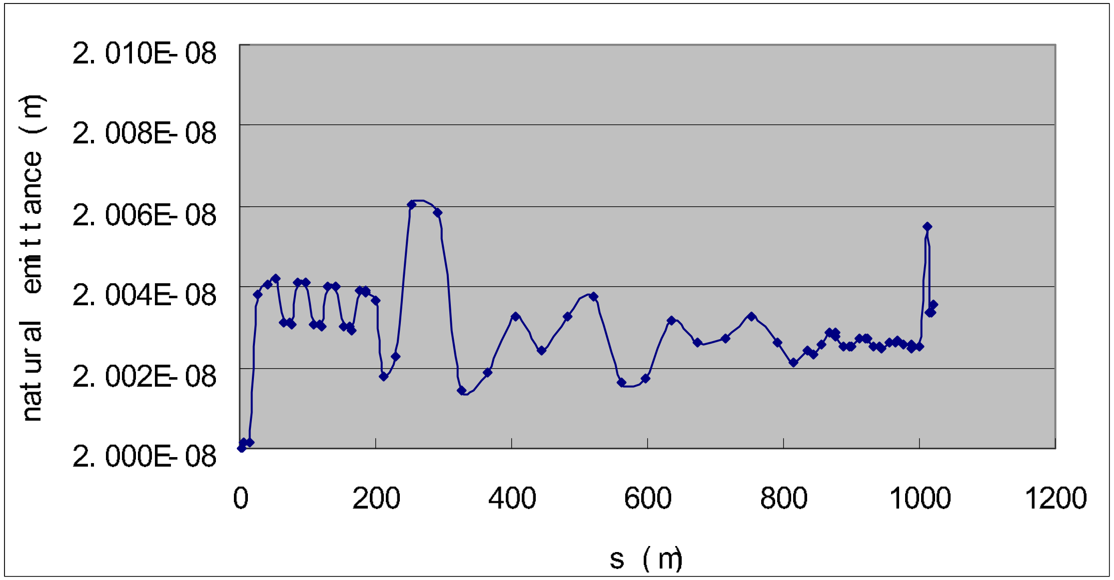
	error	**With respect to**
Quad offset	300 um	cryomodule
Quad roll	300 urad	cryomodule
Cavity offset	300 um	cryomodule
Cavity pitch	300 urad	cryomodule
BPM offset	10 um	Attached Quad
Cryomodule offset	200 um	Survey line
Cryomodule	20 urad	Survey line

1. Simulations on 2-stage BC

Bunch length and natural emittance

No error ,
no correction .





DFS by whole linac RF phase tuning-1

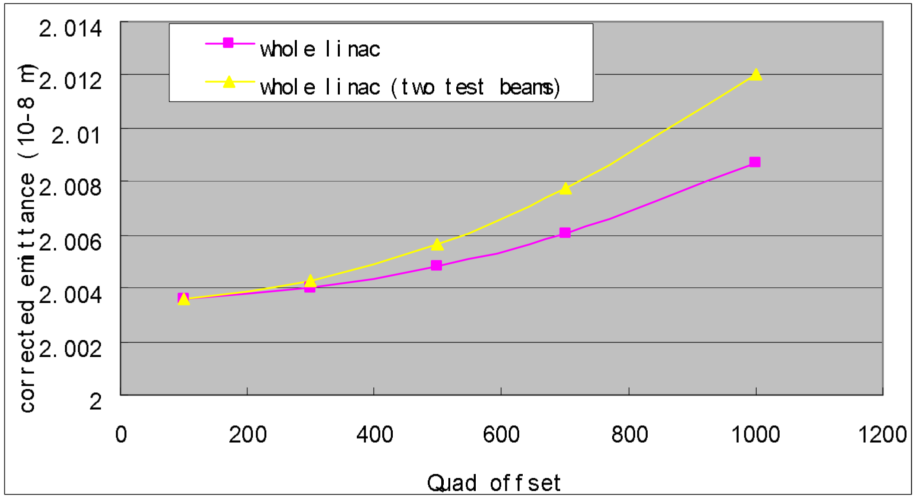
- The DFS by RF phase tuning before each section is very sensitive to BPM offset and BPM resolution.

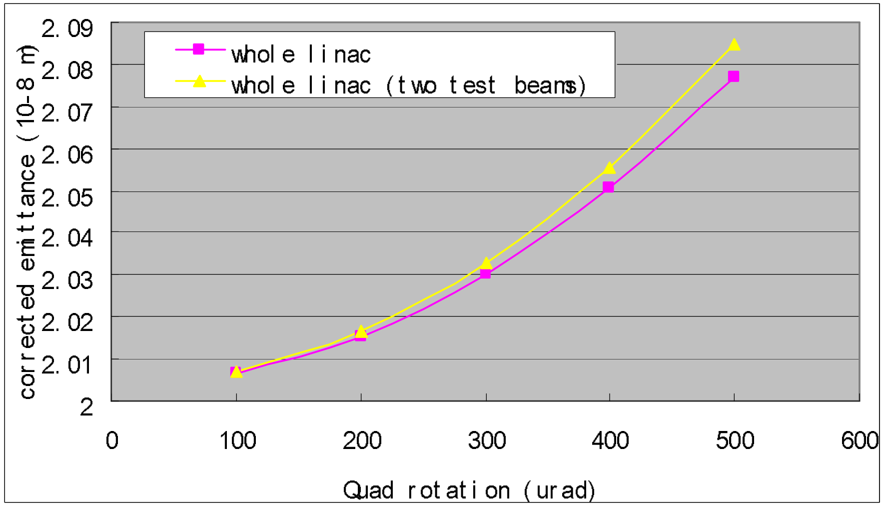
  The results are reasonable. Through changing the RF phase, the energy differrence between the normal beam and test beam is not big enough.

- Solution: changing RF phase in whole linac rather than just before each section.

DFS by whole linac RF phase tuning-2

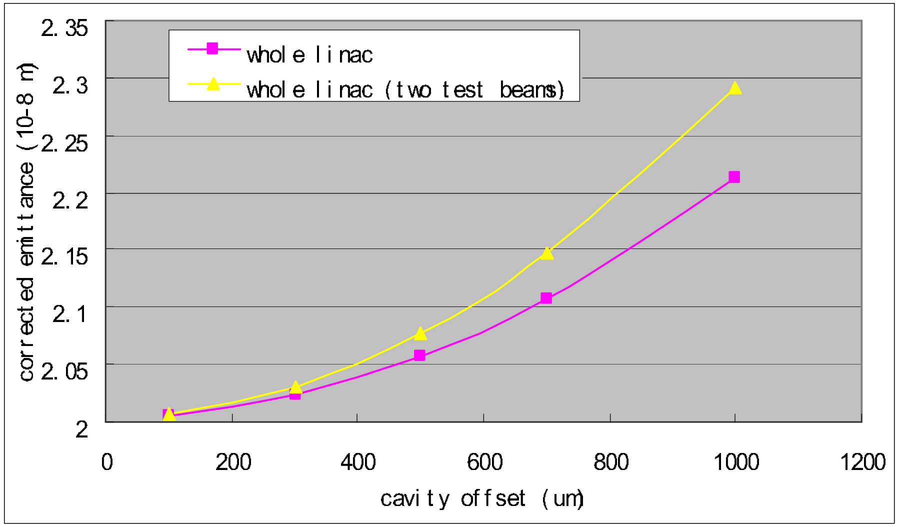
△φ=0.2 rad, weight =5000, random seeds=20

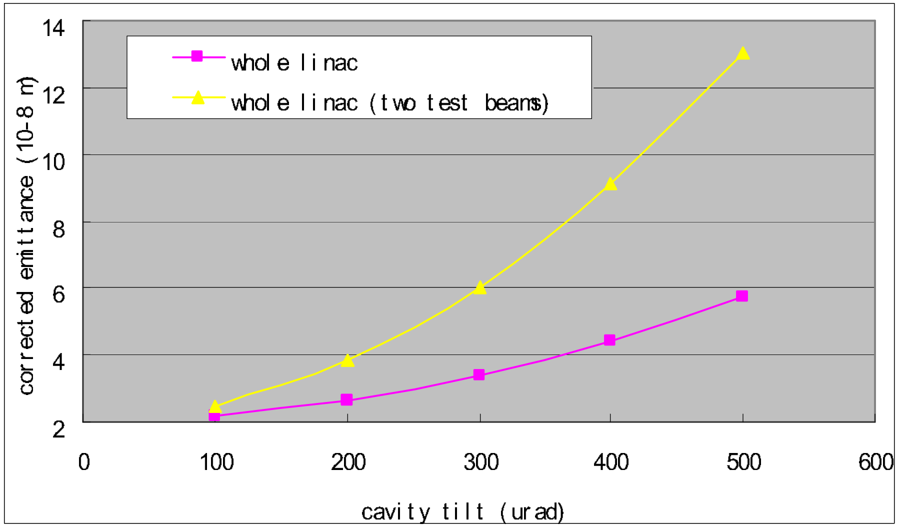




DFS by whole linac RF phase tuning-3

$\triangle\varphi$=0.2 rad, weight =5000, random seeds=20

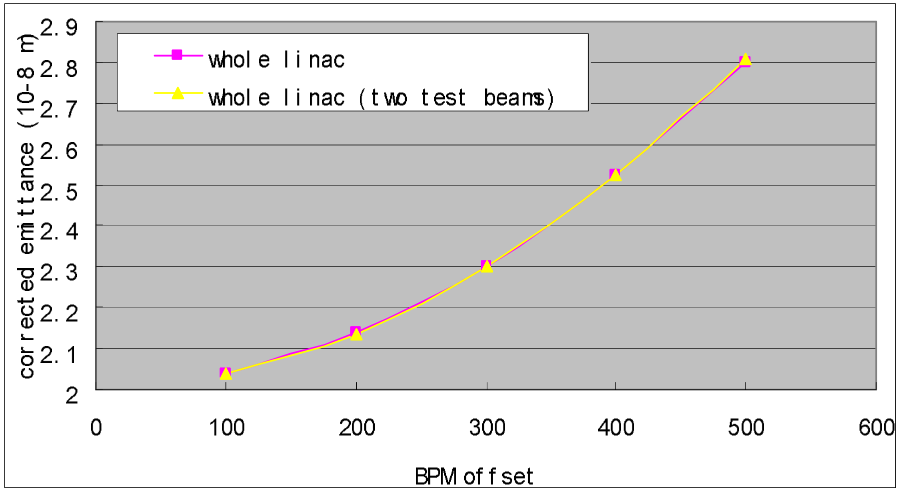


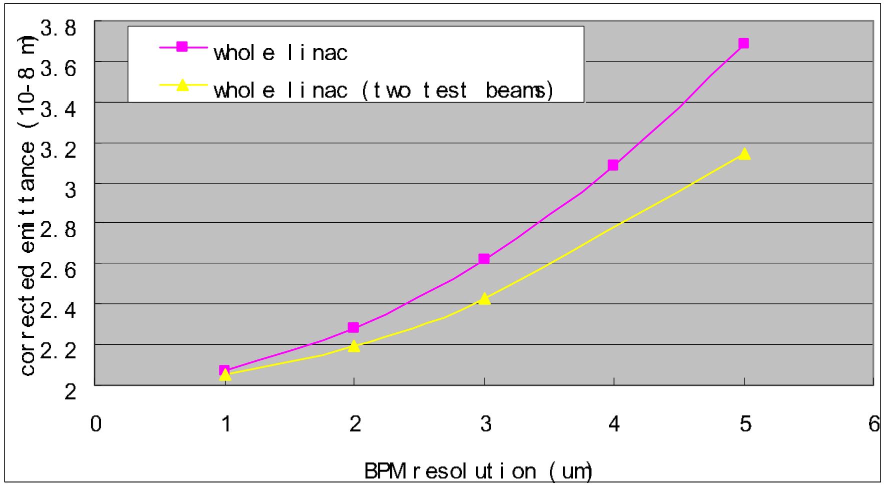


Cavity tilt can not be cured by DFS!

DFS by whole linac RF phase tuning-4

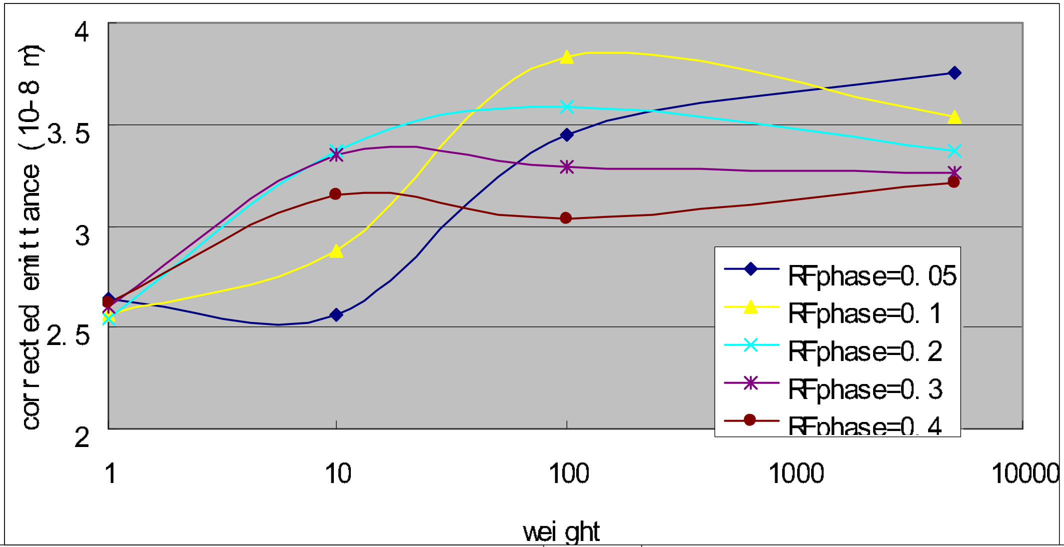
$\Delta\varphi$=0.2 rad, weight =5000, random seeds=20

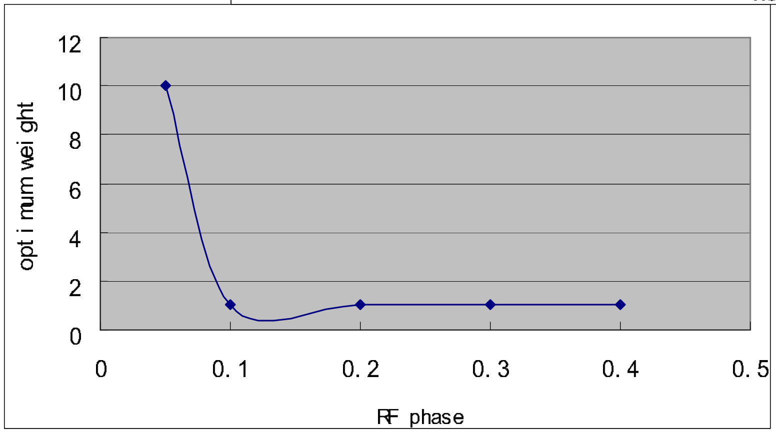


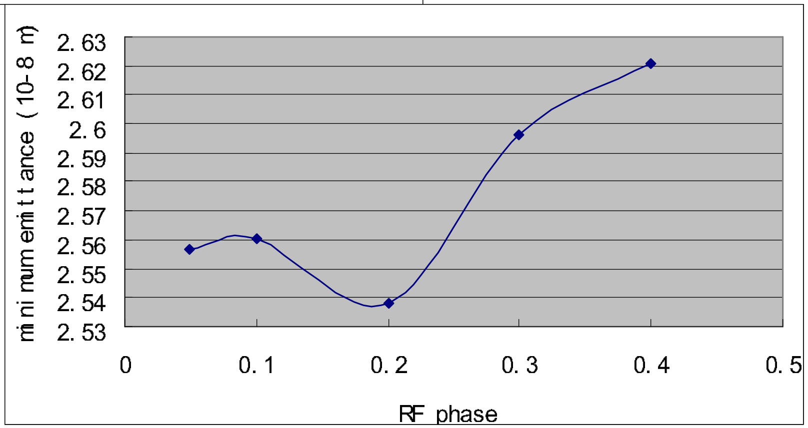


DFS with only cavity tilt

RF phase tuning (one test beam) , cavity tilt =300 um, random seeds=20





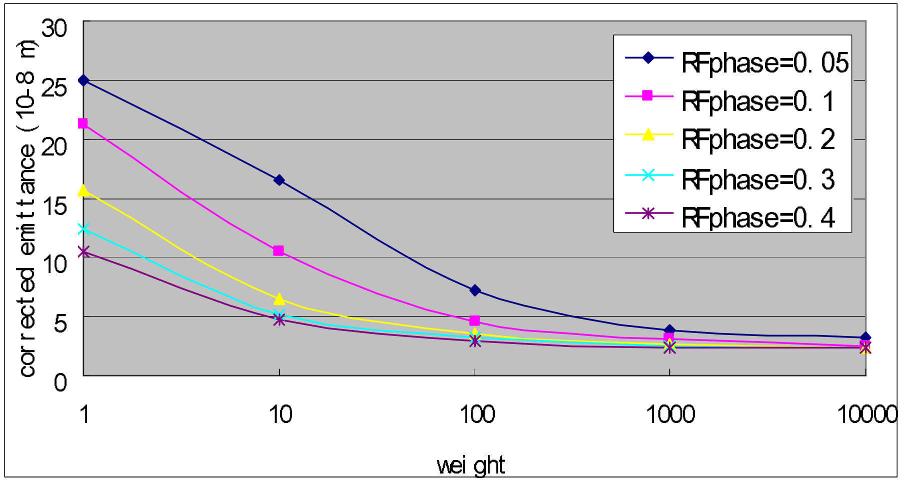


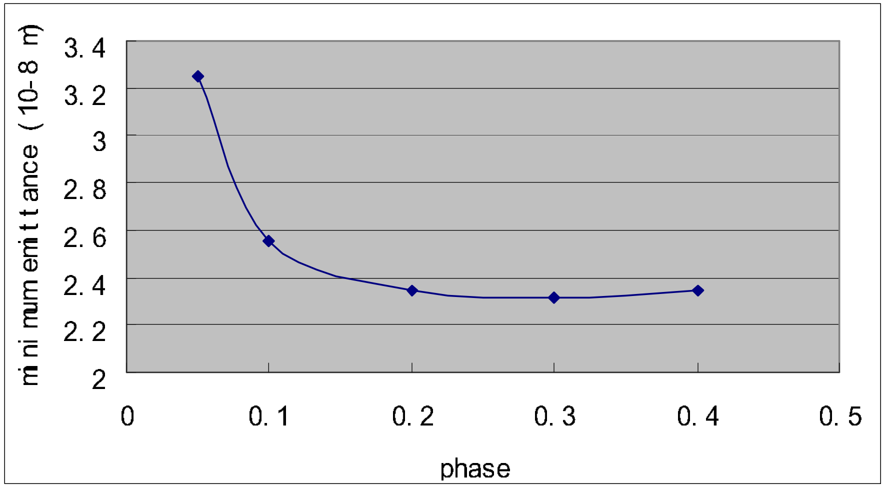
Cavity tilt reject large weight.

DFS with all errors except for cavity tilt

RF phase tuning (one test beam)，random seeds=20

- Quad offset error=300 μm
- Quad rotation=300um
- Cavity offset error=300 μm
- BPM offset=300 μm
- BPM resolution=1 μm





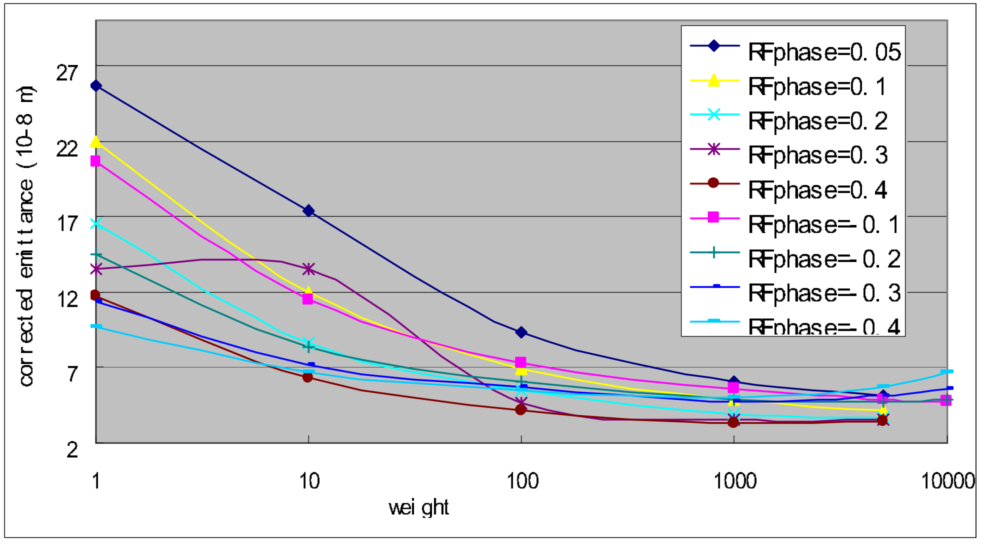
Without cavity tilt, the final corrected emittance can be controlled to 3.2 nm for BC.

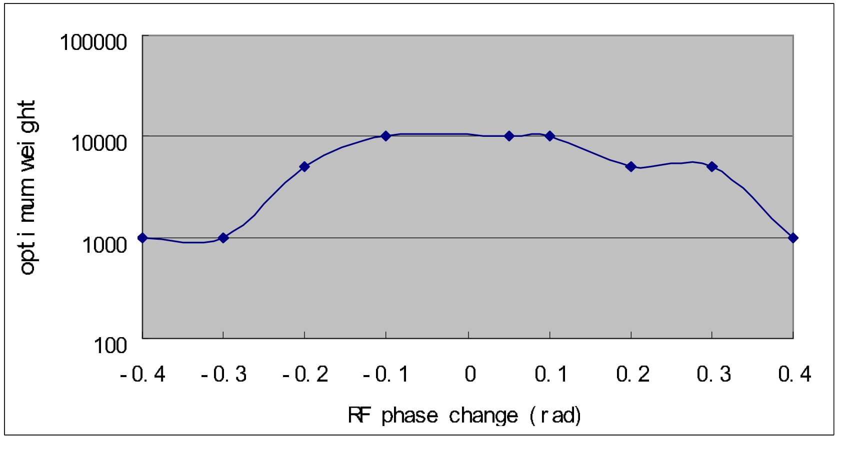
DFS with all errors-1

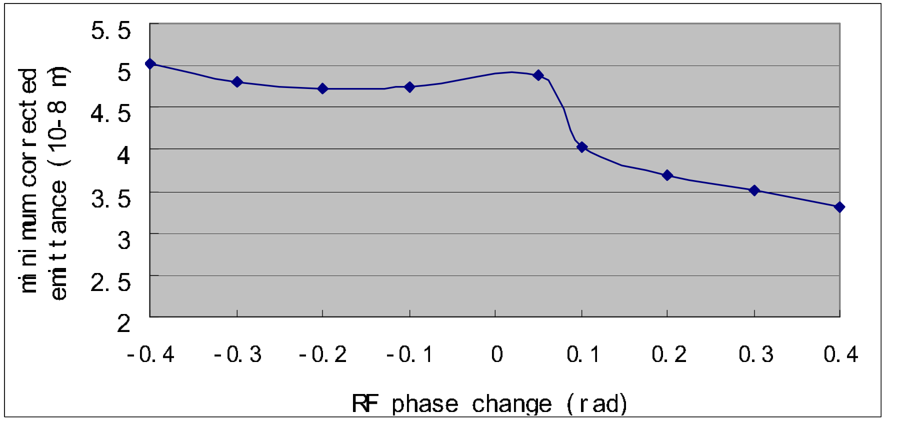
RF phase tuning (one test beam) , random seeds=20

Standard errors:

- Quad offset error=300 μm
- Quad rotation=300um
- Cavity offset error=300 μm
- Cavity tilt=300 μrad
- BPM offset=300 μm
- BPM resolution=1 μm

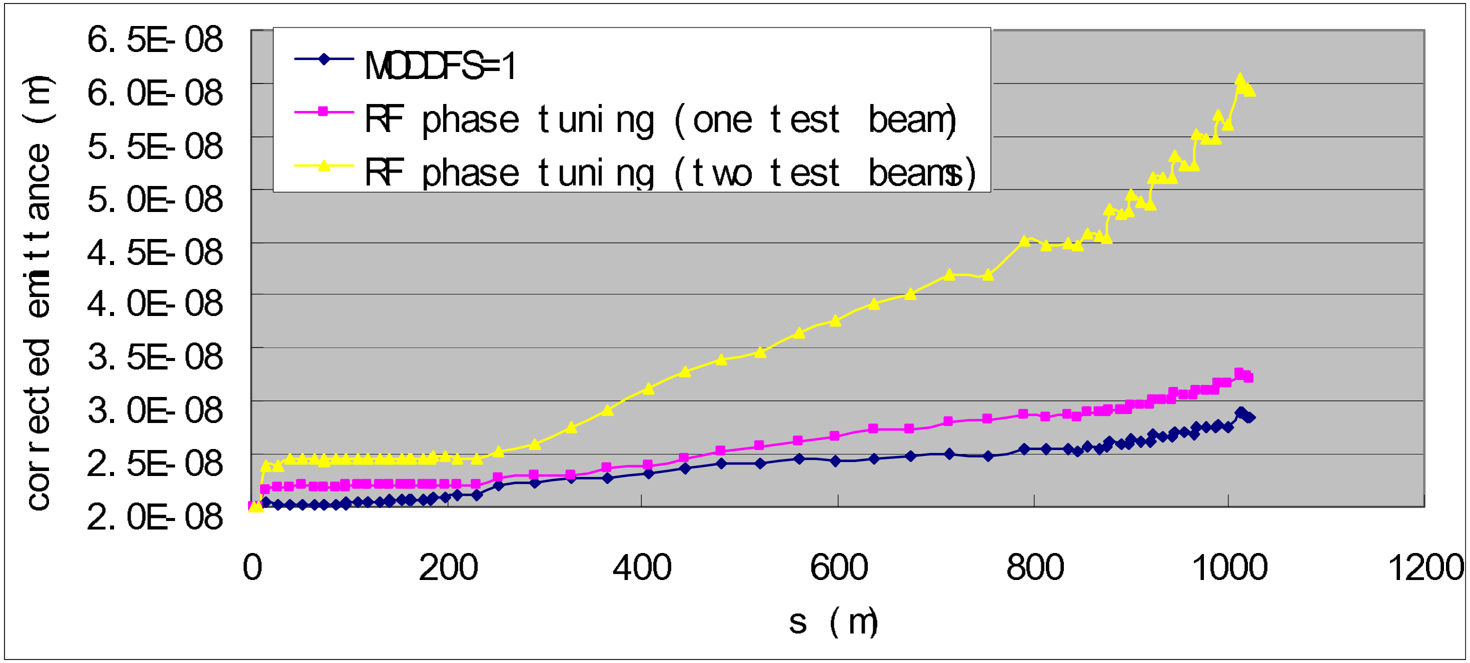






DFS with all errors-2

△φ=0.4 rad, weight=1000.

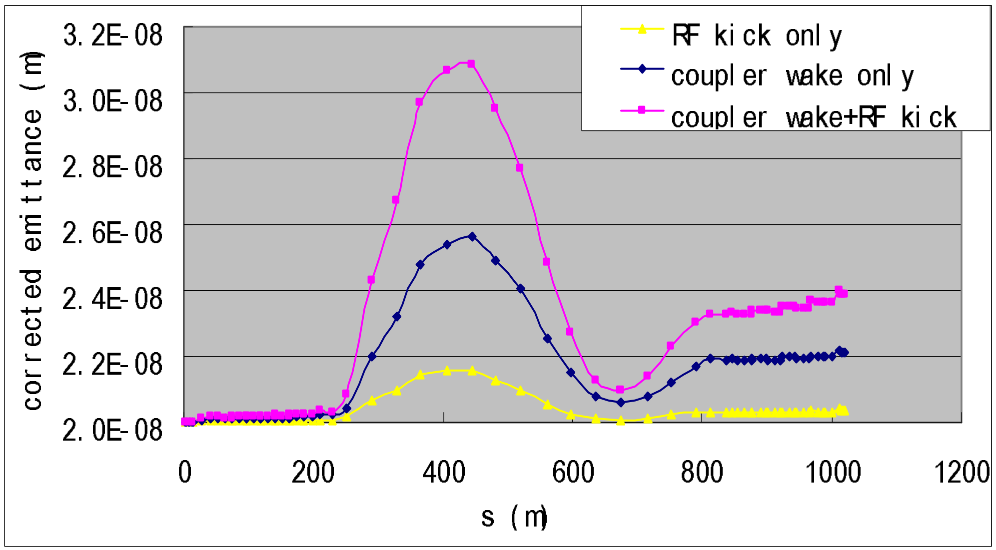


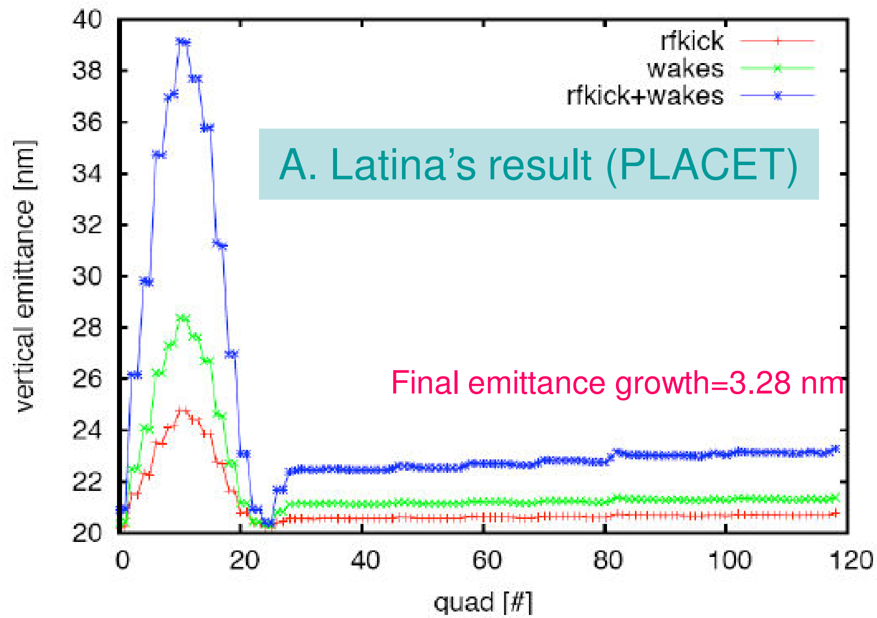
* MODDFS=1: Both initial beam energy and accelerating gradient are reduced by 10%

With all the errors, the final emittance growth will be 13 nm for BC.

The effect of coupler RF kick and coupler wakefield on BC-1

1-to-1 , no misalignment, random seeds=40

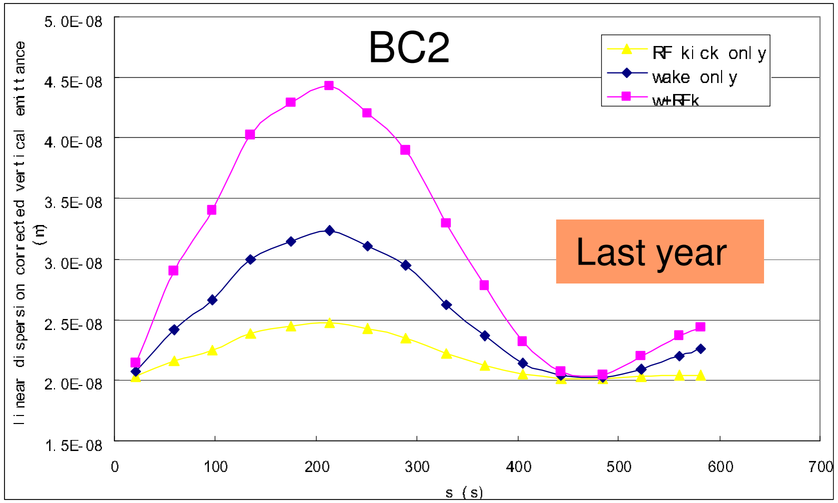


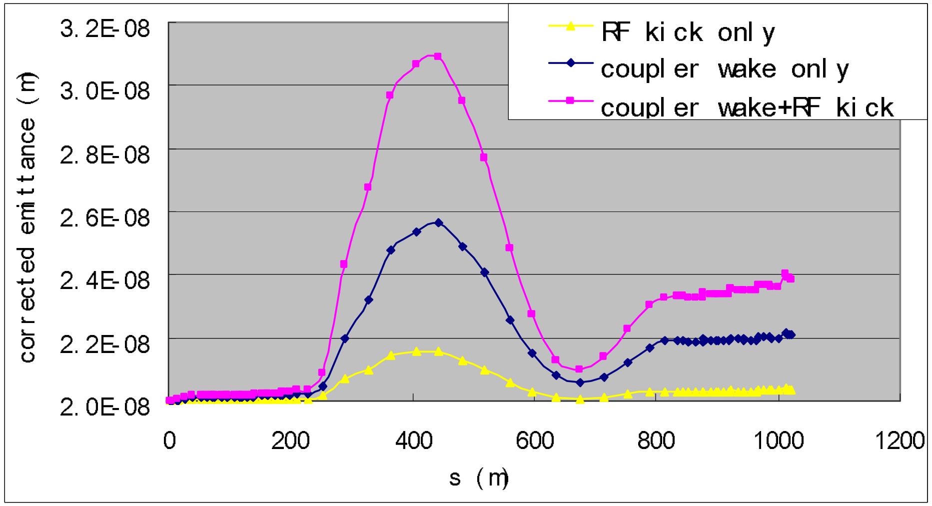


Our results for the peak are smaller than A. Latina's. ??

The final emittance growth is 3.86 nm by our result.

The effect of coupler RF kick and coupler wakefield on BC-2



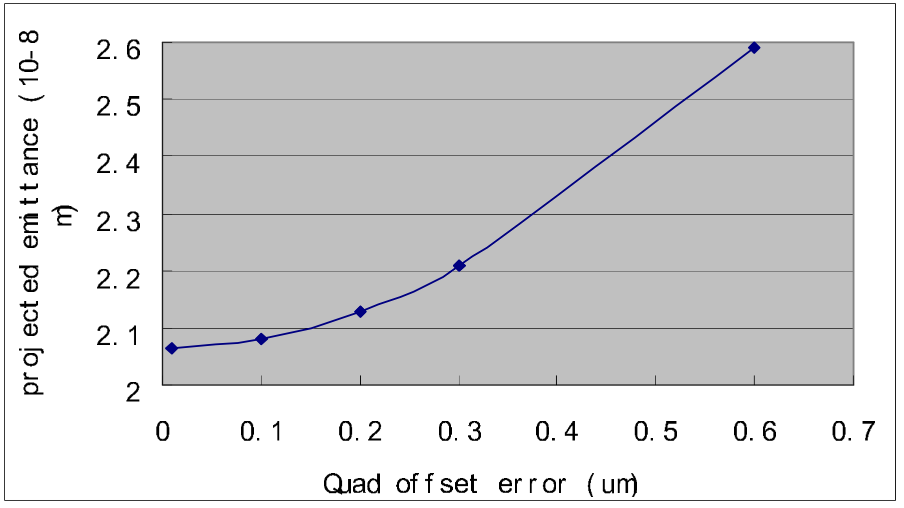


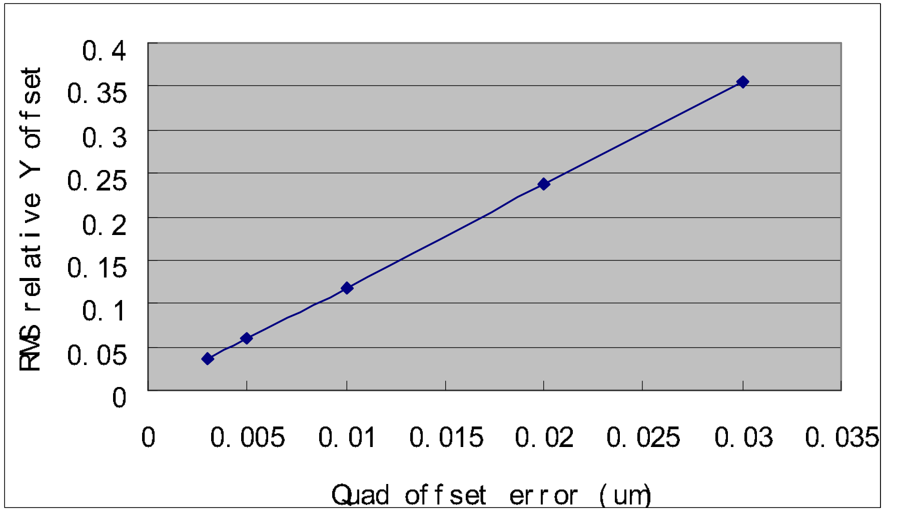
- We had different lattice this year, related to the beam loading by short-range wakefield .
- Different lattice give different results.

2. Simulations on curved ML

Fast movement-Quad position

No orbit correction , random seeds=50





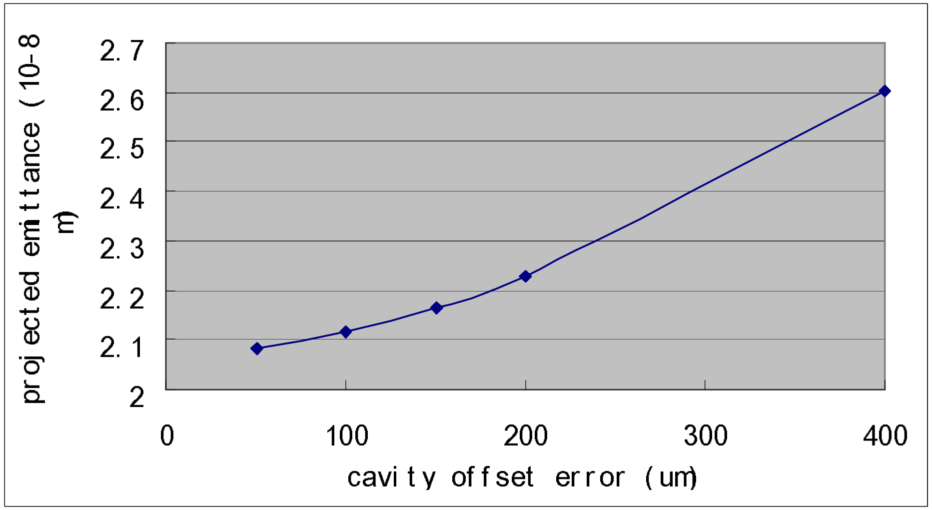
Random quadrupole position jitter torlerance (about 3% luminosity reductuion):

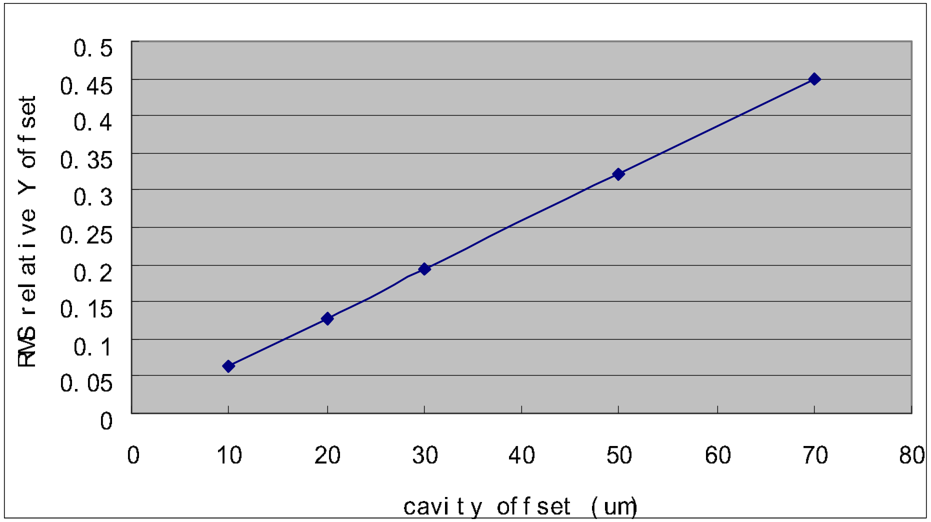
For 0.14σ RMS beam offset: 12 nm

For 0.063ε_0 emittance growth: 200 nm

Fast movement-cavity position

No orbit correction , random seeds=50



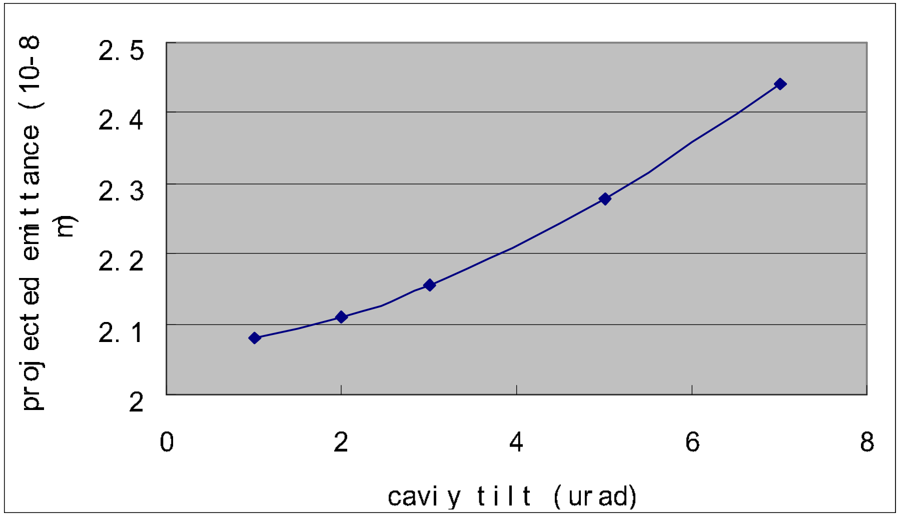


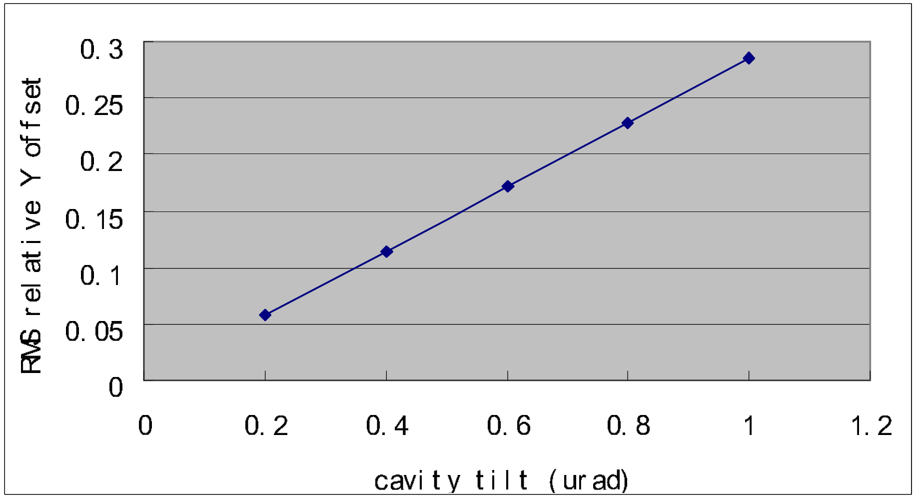
Random cavity position jitter torlerance (about 3% luminosity reductuion):

For 0.14σ RMS beam offset: 22 um
For 0.063ε_0 emittance growth: 130 um

Fast movement-cavity tilt

No orbit correction , random seeds=50



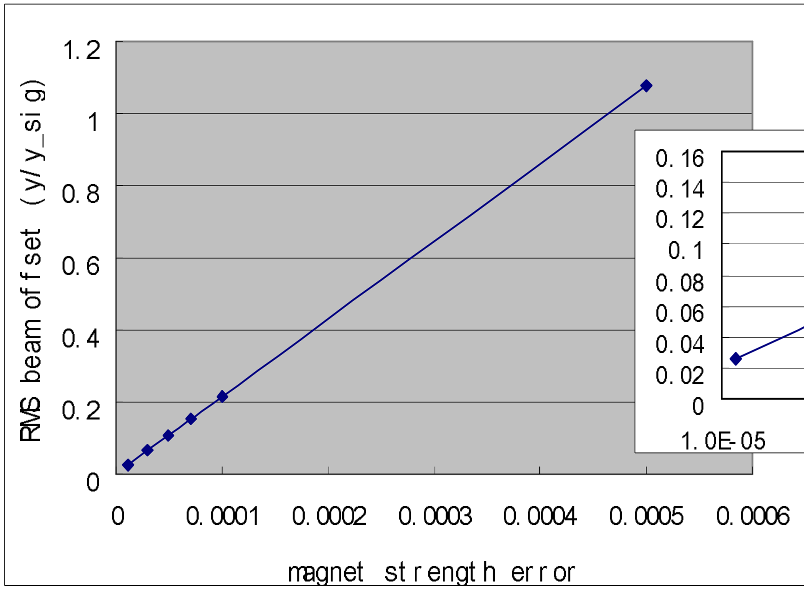


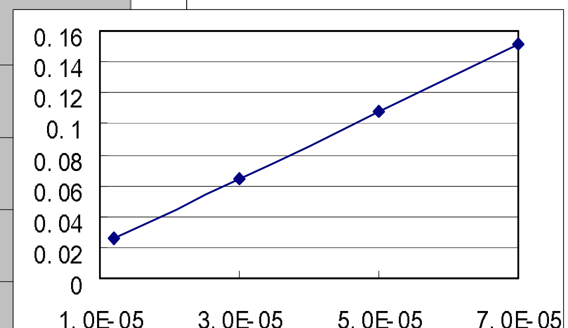
Random cavity tilt jitter torlerance (about 3% luminosity reductuion):

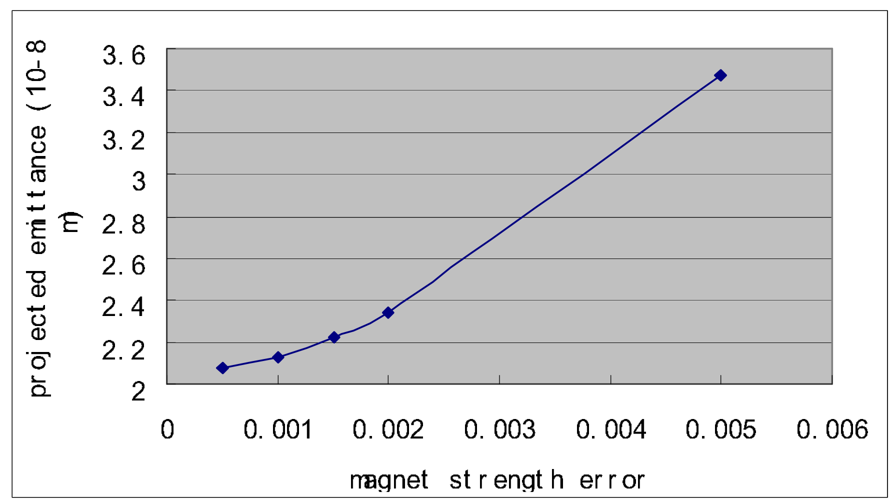
For 0.14σ RMS beam offset: 500 nrad
For 0.063ε_0 emittance growth: 2.5 urad

magnet strength jitter

No orbit correction, Random seeds=50
Same error for quadrupoles and attached correctors.



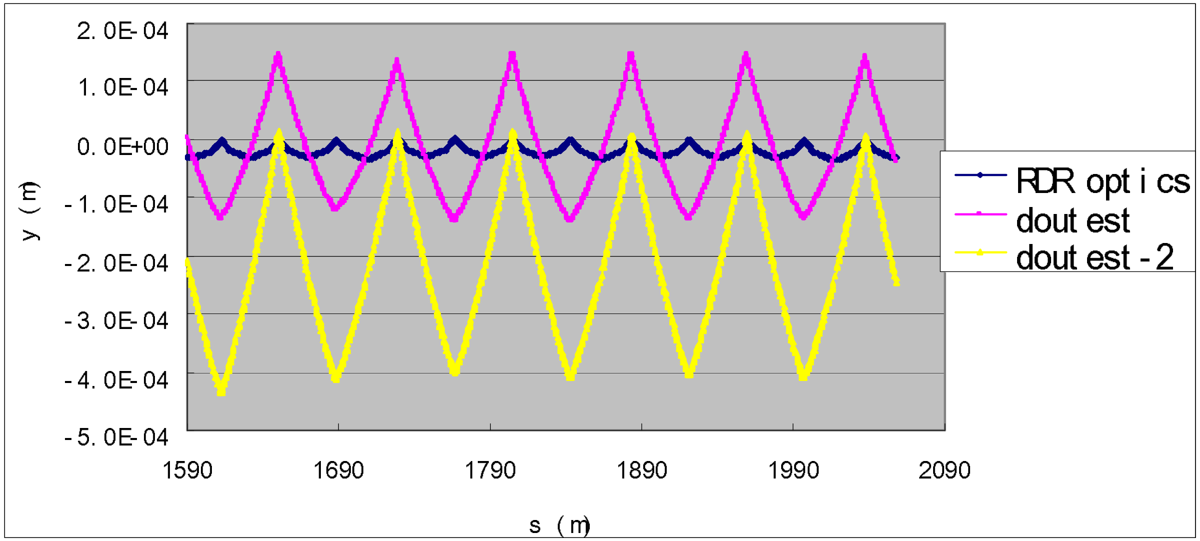


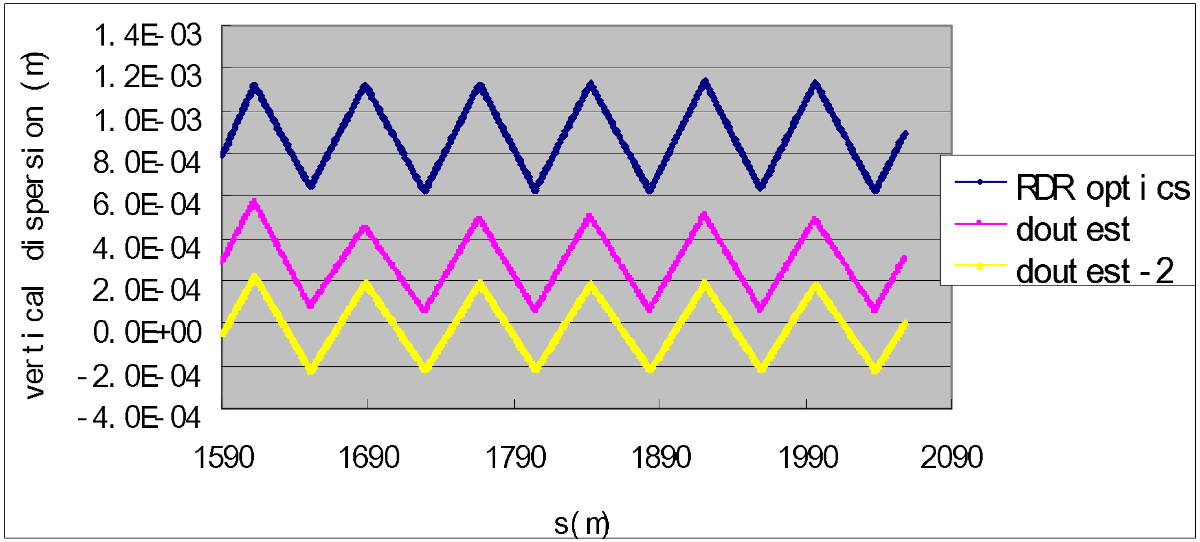


Random magnet strength jitter torlerance (about 3% luminosity reductuion):

For 0.14σ average beam offset: 0.0065%
For $0.063\varepsilon_0$ emittance growth: 0.1%

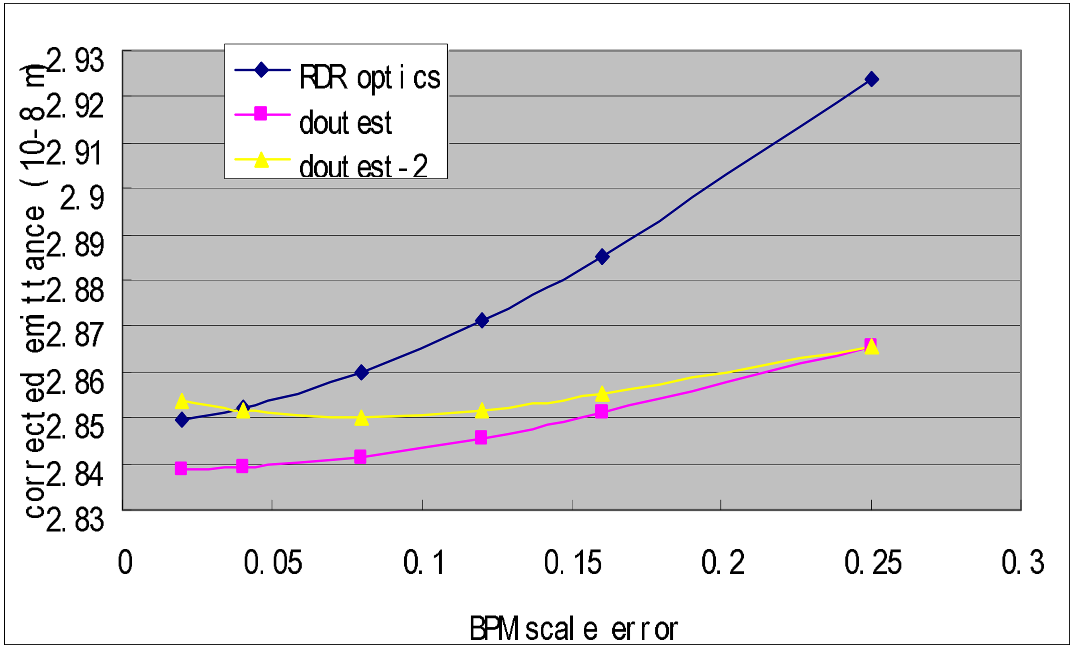
DFS with BPM scale error -1





DFS with BPM scale error-2

Random seeds=40
Weight=100
Standard errors:
Quad offset error=300 μm
Quad rotation=300um
Cavity offset error=300 μm
Cavity tilt=300 μrad
BPM offset=300 μm
BPM resolution=1 μm



- BPM scale error: $y_{read}=a_{scale}y_{real}$
- For curved ML, DFS (DMS) tries to adjust the dispersion to non-zero designed value. So BPM scale error affects this adjustment.
- New test optics have smaller design dispersion in quadrupoles, so they are less sensitive to BPM scale error.
- BPM scale error rejects the use of large weight.

Couplers' effects

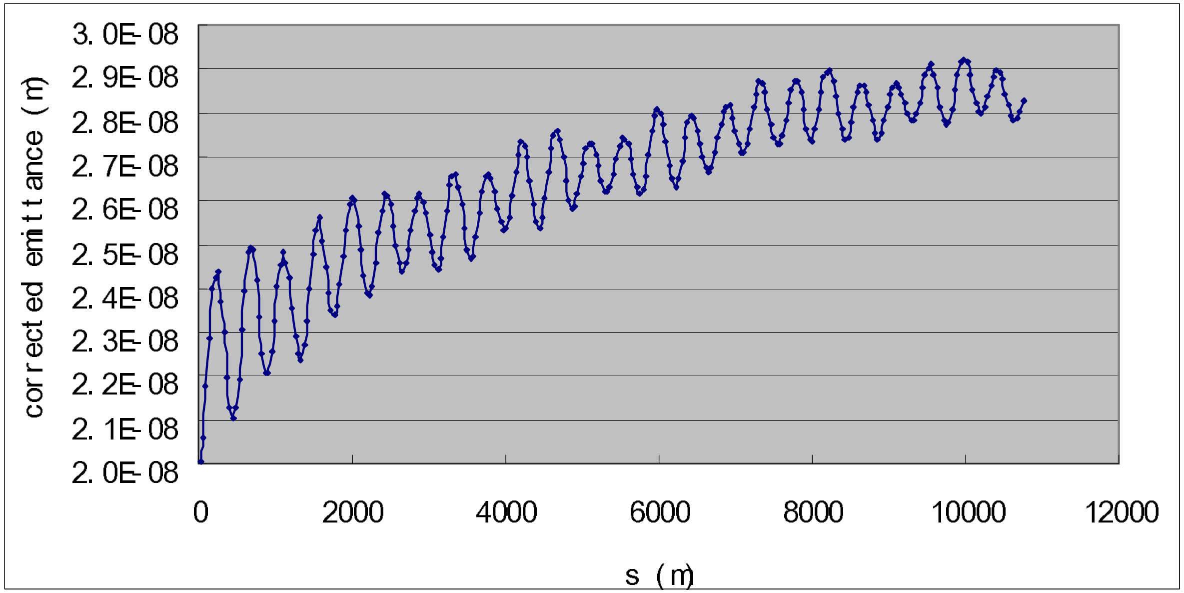
MODDFS =1(random seeds=20), with coupler RF kick and coupler wake

Survy line errors:

- Random angle: 60 nrad/step
- Random offset: 5 um/step
- Systematic angle: 250 nrad/step
- Primary reference offset: 10 mm

Local misalignment:

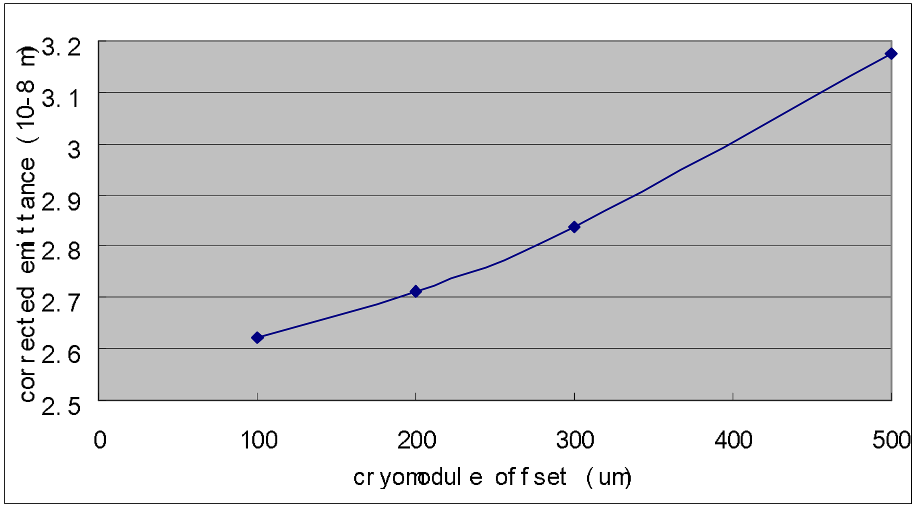
- Quad offset: 300 um
- Quad rotation: 300 urad
- Cavity offset: 300 um
- Cavity tilt: 300 urad
- BPM offset: 300 um
- BPM resolution: 1 um

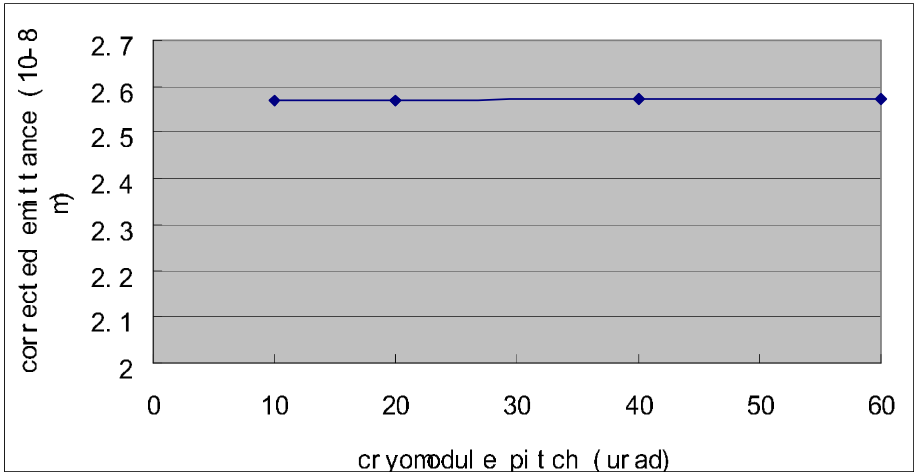


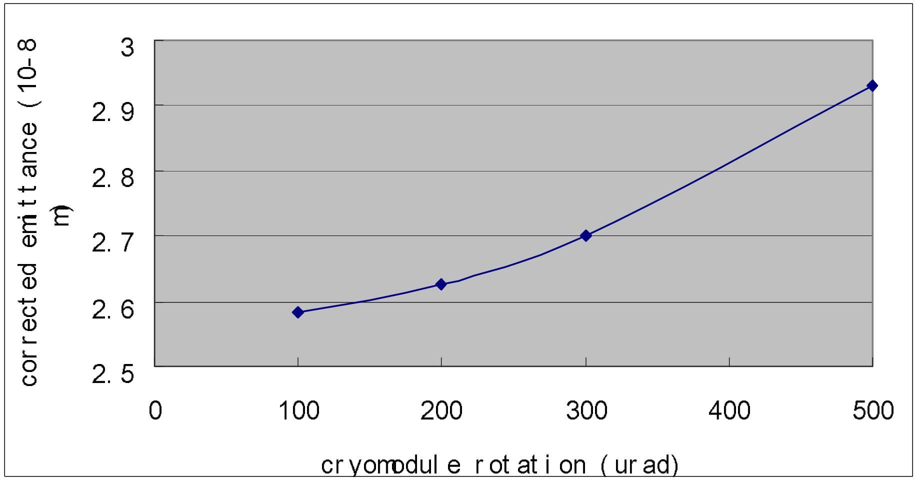
DFS with cryomodule misalignment-1

Random seeds=20, weight=5000

- Quad offset=300 um
- Quad rotation=300 urad
- cavity offset=300 um
- cavity pitch=300 urad
- Quad-BPM offset=10 um
- BPM resolution=1 um







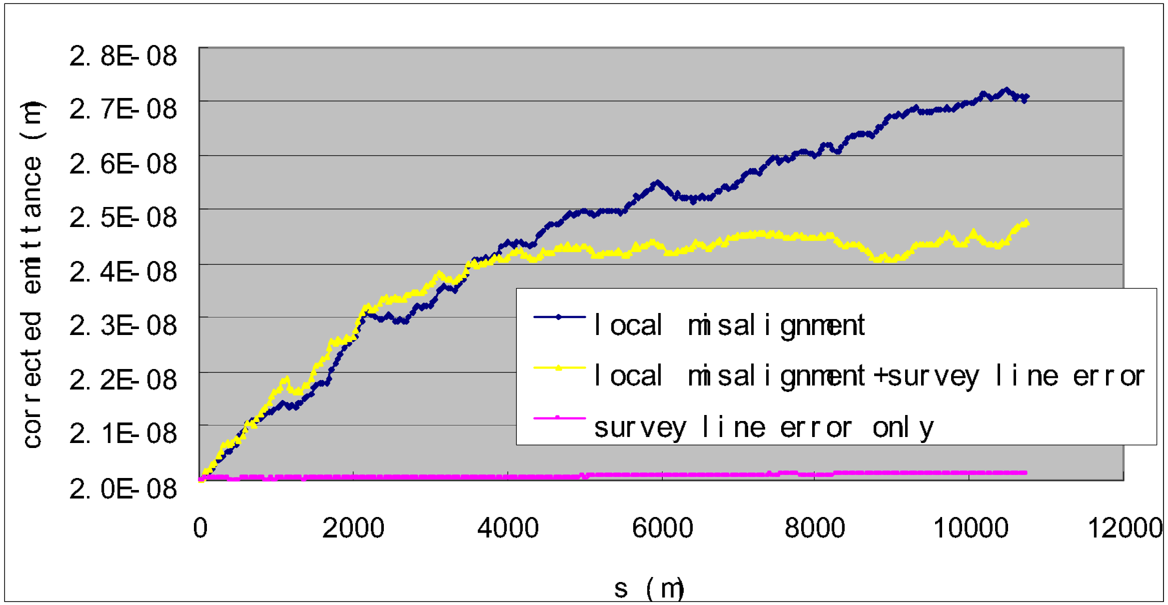
DFS with cryomodule misalignment-2

Random seeds=20, weight=5000
- Quad offset=300 um
- Quad rotation=300 urad
- cavity offset=300 um
- cavity pitch=300 urad
- Quad-BPM offset=10 um
- BPM resolution=1 um
- cryomodule offset=200 um
- cryomodule pitch=20 urad

Survy line errors:
- Random angle: 60 nrad/step
- Random offset: 5 um/step
- Systematic angle: 250 nrad/step
- Primary reference offset: 10 mm

Preliminary result !

Should be checked



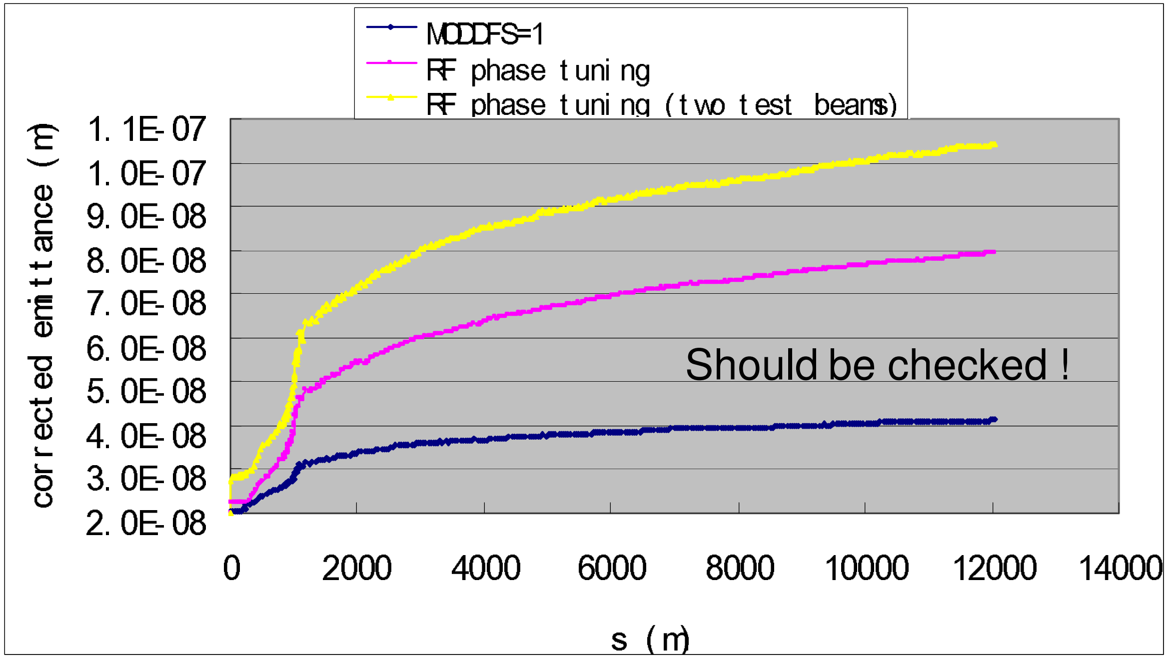
3. Integrated simulations from BC to ML

Comparison of three DFS modes

Standard errors:

- Quad offset error=300 μm
- Quad rotation=300 μ m
- Cavity offset error=300 μm
- Cavity tilt=300 μrad
- BPM offset=300 μm
- BPM resolution=1 μm

△φ=-0.3 rad , random seeds=20 , weight=5000



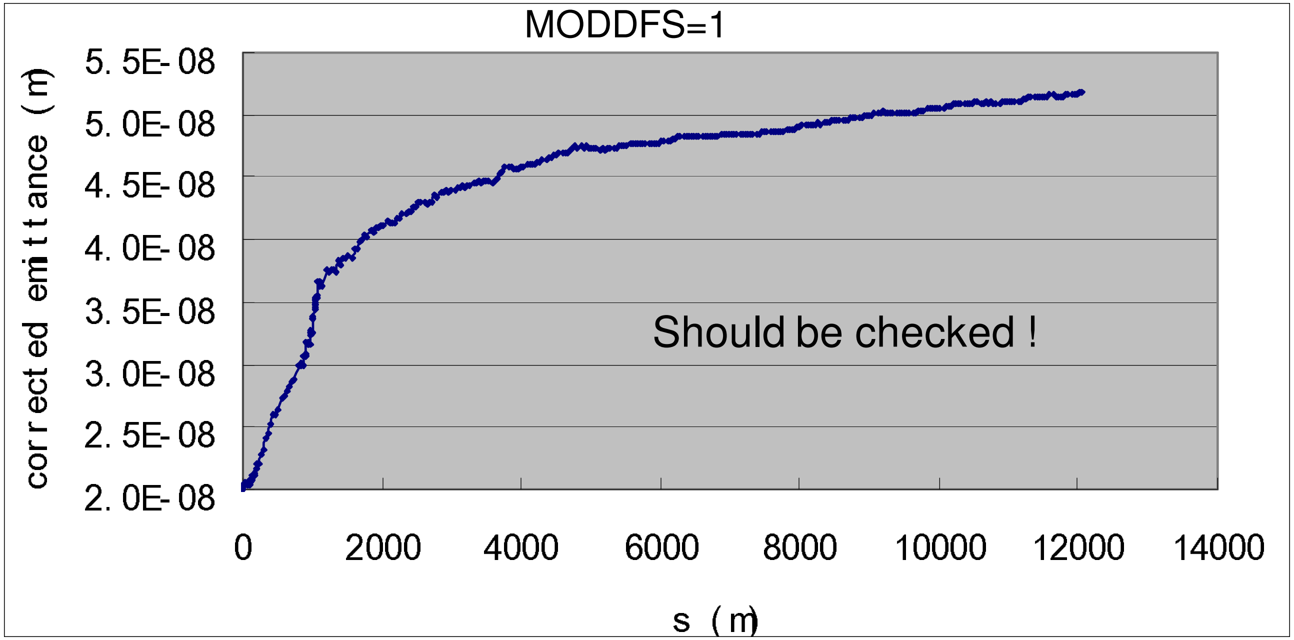
This is very preliminary.
The algorithm may still have problems.

DFS with cryomodule misalignment

Random seeds=20, weight=5000

- Quad offset=300 um
- Quad rotation=300 urad
- cavity offset=300 um
- cavity pitch=300 urad
- Quad-BPM offset=10 um
- BPM resolution=1 um
- cryomodule offset=200 um
- cryomodule pitch=20 urad

Preliminary result !



Summary -1

- Code upgrade (SLEPT)
  - Include longitudinal position change
    - slice ←→ macro-particle transformation
    - RF section + Wiggler section of BC was simulated
    - BC + ML will be able to be simulated (still working)
  - Alignment algorism:
    - Survey + Cryomodule + component
- Simulation of BC (2-stage)
  - DFS with RF phase tuning can not cure cavity tilt.
    - Emittance growth with/without cavity tilt: 13 nm / 3.2 nm.
      - Cavity tilt should be corrected in other ways.
    - Couplers' effects: 3.86 nm after 1-to-1 correction.

Summary -2

- Simulation of ML (from 15 GeV to 250 GeV), effect of fast jitter

	0.14σ RMS orbit change	6.3% emittance growth
Quad position	12 nm	200 nm
Cavity position	22 um	130 um
Cavity tilt	500 nrad	2.5 urad
Magnet strength	0.0065%	0.1%

  - 0.14 sigma orbit change will cause ~3% luminosity reduction without orbit feedback downstream.
  - 6.3% emittance growth cause ~3% luminosity reduction in head on collision

- Simulation of ML (from 15 GeV to 250 GeV), static errors
  - DFS's sensitivity to BPM scale error can be reduced by careful design of dispersion in quadrupoles (optics matching), and optimization of weight factor.
    - 20% scale error will not be a big problem.
  - Including survey line errors (given by LiCAS) , local "standard" misalignment and couplers' effects, the final emittance growth is 8.5 nm.

Summary -3

- Near future plans
  - Integrated simulations from BC to ML
    - Present results are still preliminary.
    - DFS changing RF phase in BC and changing amplitude in ML
  - Single-stage BC + ML
    - Need lattice design including matching between BC and ML (exist?)
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