Main Linac Simulation studies
- Static and Dynamic tuning

Kiyoshi Kubo
“Accelerator Physics Group” or “Simulations Group”

MLI KOM 20070927

Comment

Up to Vancouver GDE meeting (July 2006), most works were on Main Linac (static) tuning.

At that meeting we agreed

- ML static tuning had been almost done (for RDR)
- We should move to Dynamic effects and other area (RTML, BDS, and e+ source undulator)

Most studies in ML tuning were summarized in the plenary talk at that meeting, by Jeff Smith.

What have been done: static tuning -1

Check effects of following earth’s curvature

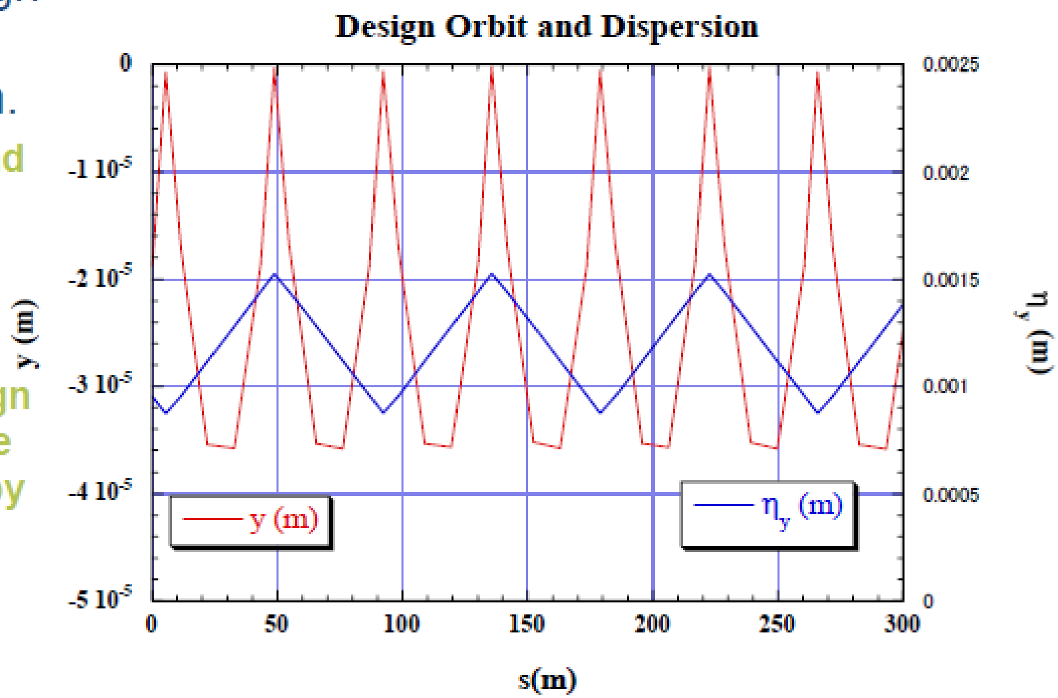
- Acceptable, if orbit and dispersions are controlled

Single bunch - static steering

- Mostly DFS (Dispersion Free Steering) has been studied
  - By many persons and many different codes
  - “Standard” errors and sensitivities to various errors.

Curved Linac Considerations

- With a curved linac there is now a design non-zero vertical orbit and dispersion.
  - The orbit was found to make an insignificant contribution to emittance growth.
  - However, the design dispersion must be compensated for by injecting a dispersive beam into the main linac



Jeff Smith, Vancouver GDE Meeting

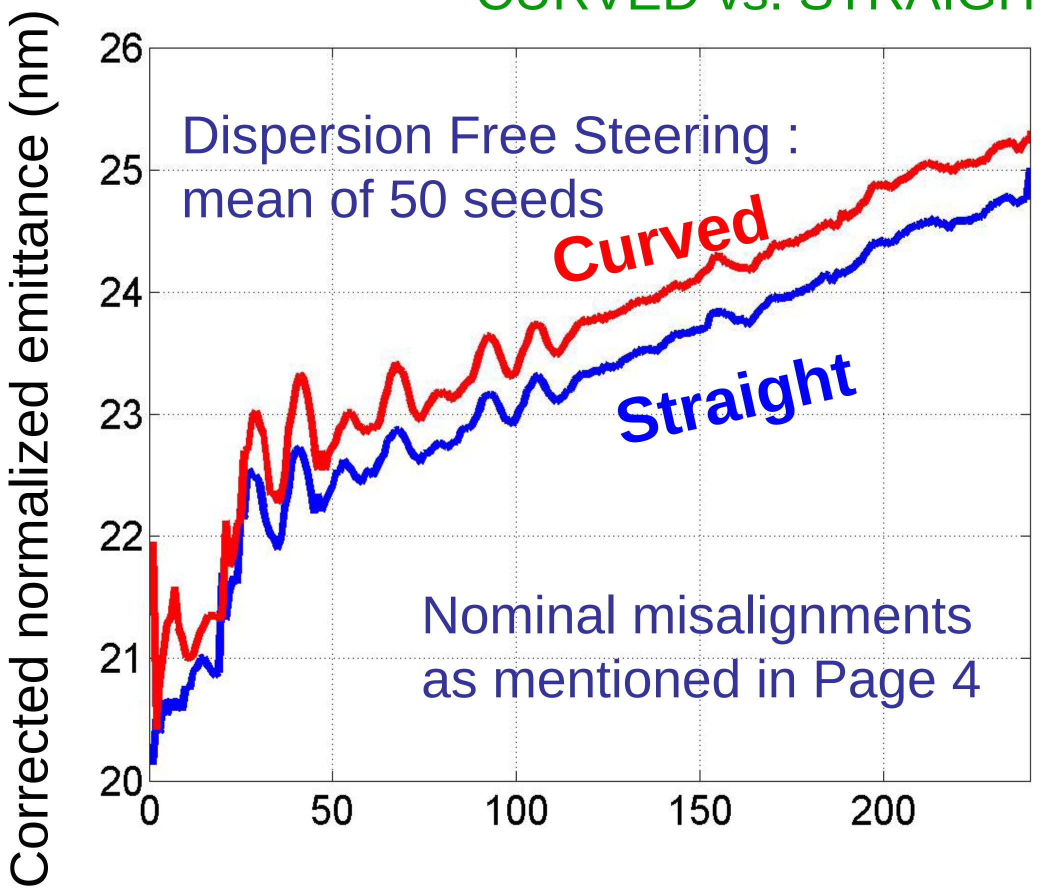
DFS (Dispersion Free Steering):

Adjust dispersion as design value, not zero

Dispersion Free Steering - Results

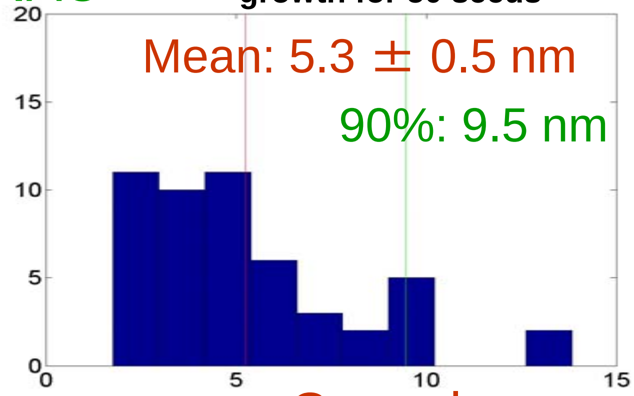
Misalign the beamline components and perform the DF steering

CURVED vs. STRAIGHT LINAC

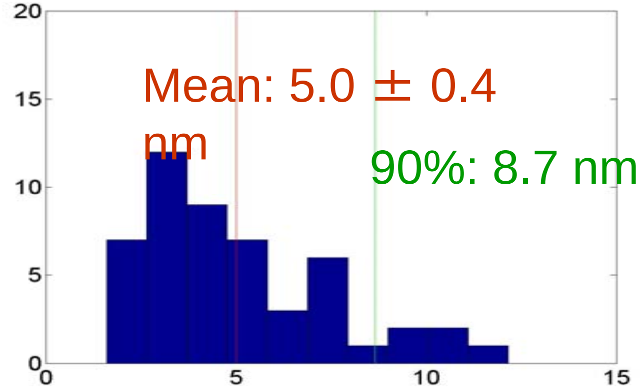


DFS parameters not optimized for Curved Linac

Distribution of emittance growth for 50 seeds



Curved



Laser Straight

Kirti Ranjan in Vancouver GDE Meeting

Nominal Errors

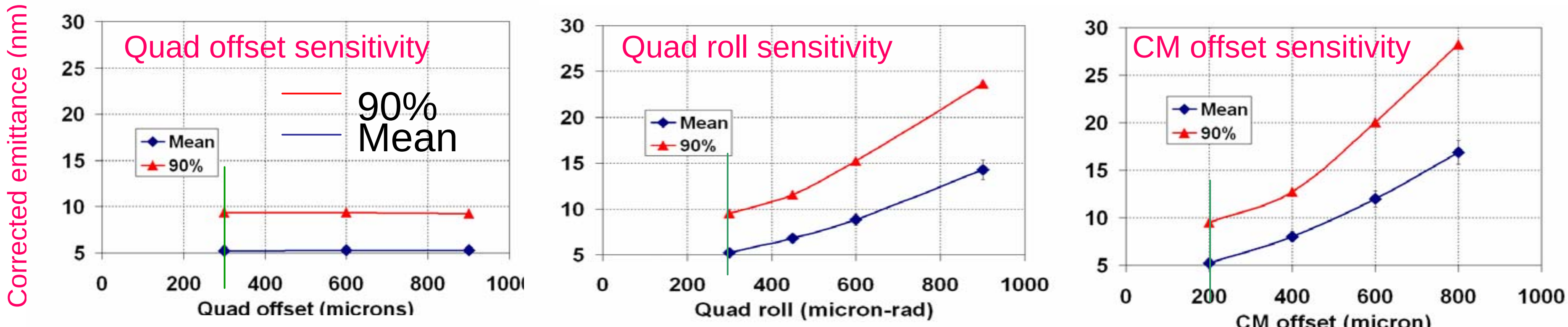
Tolerance	Vertical (y) plane
BPM Offset w.r.t. Cryomodule	300 μm
Quad offset w.r.t. Cryomodule	300 μm
Quad Rotation w.r.t. Cryomodule	300 μrad
Cavity Offset w.r.t. Cryomodule	300 μm
Cryostat Offset w.r.t. Survey Line	200 μm
Cavity Pitch w.r.t. Cryomodule	300 μrad
Cryostat Pitch w.r.t. Survey Line	20 μrad
BPM Resolution	1.0 μm

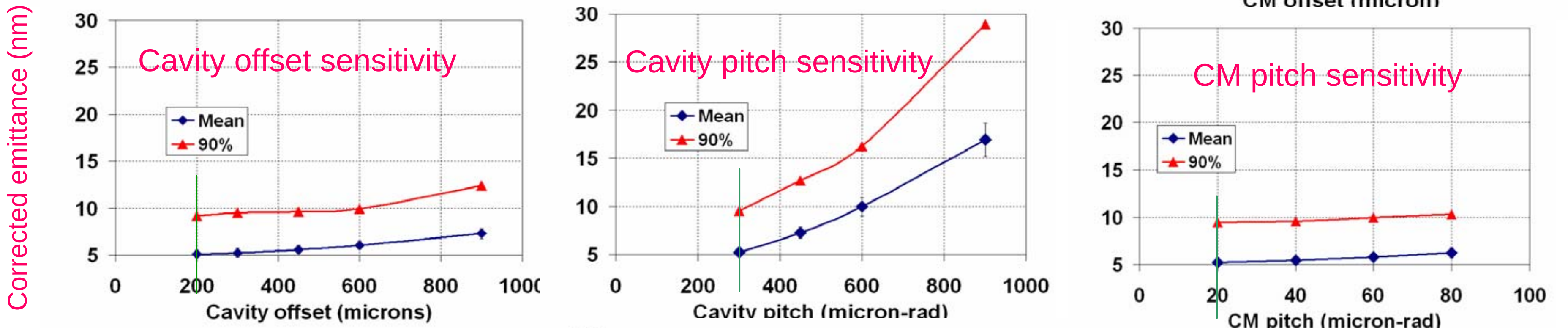
➔ **1st 7 BPMs have 30 μm RMS offset w.r.t. Cryostat**

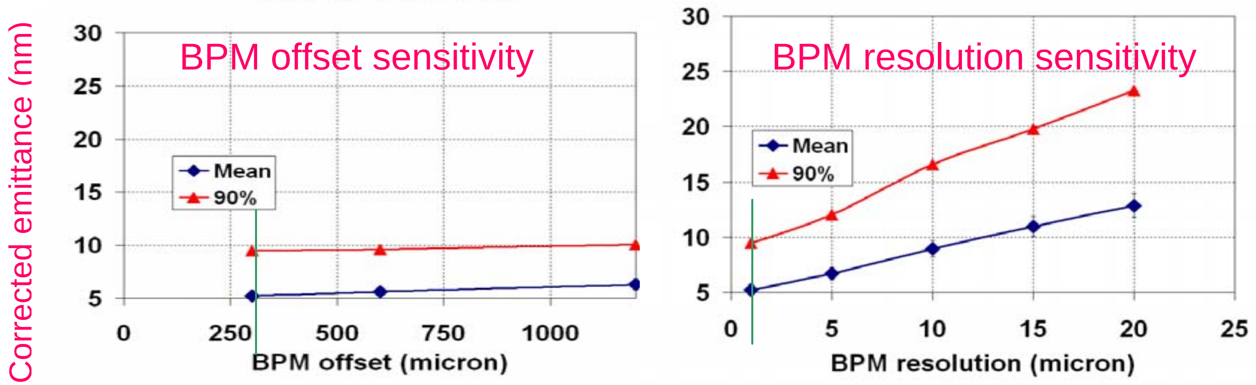
- **BPM transverse position is fixed, and the BPM offset is w.r.t. Cryostat**
- **Only Single bunch used**
- **Steering is performed using Dipole Correctors**

DFS: Sensitivity studies

Vary one misalignment from its nominal value - keeping all other misalignments at their nominal values







Sensitive to
Cavity pitch**,**
BPM resolution**,**
CM offset**,**
Quad roll

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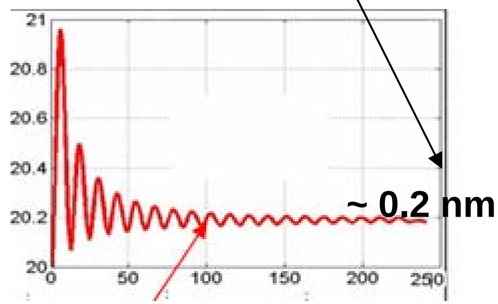
DFS: Contributions

50 seeds	mean	90%	
Nominal	**5.26 ± 0.38**	**9.47**	
Dispersion only	**1.99 ± 0.24**	**4.22**	**Switch off wakes & quad roll**
Wakes only	**1.8 ± 0.17**	**3**	**Cavity offset & wakes only**
Quad roll only	**1.47 ± 0.13**	**2.83**	**quad roll only**
Total	**5.26**	**10.05**	

Individual misalignment (30 seeds)	**mean**	err	**90%**
CM pitch only	**0.25**	0.036	0.56
***Cavity pitch* only**	***2***	*0.35*	*4.3*
Front bpm offset only	**0.41**	0.0493	0.77
Quadroll only	**1.39**	0.13	2.37
***Cavity offset* only**	***1.67***	*0.18*	*2.98*
BPM resolution only	**0.43**	0.0548	0.76
BPM offset only	**0.2**	0.0107	0.28
Quad offset only	**0.17**	0.0026	0.19
Sum	**6.52**		**12.2**

A **systematic contribution** seems to add up in each case, which is added only once when we perform the nominal run



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DFS: Sensitivity studies

Quad Strength error

Quad strength error (dK)	Mean	90%
0.5 e-3	7.43±0.46	11.7
1e-3	7.44±0.46	11.5
2.5e-3	7.50±0.46	11.5
5e-3	7.70±0.46	11.9

What have been done: static tuning -2

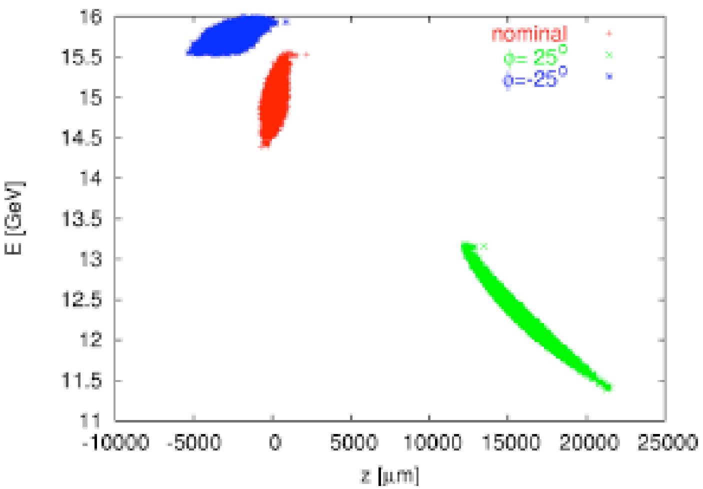
- More Realistic, Inter-area DFS (Bunch Compressors + Main Linac)
  - Change BC RF setting to change beam energy in ML

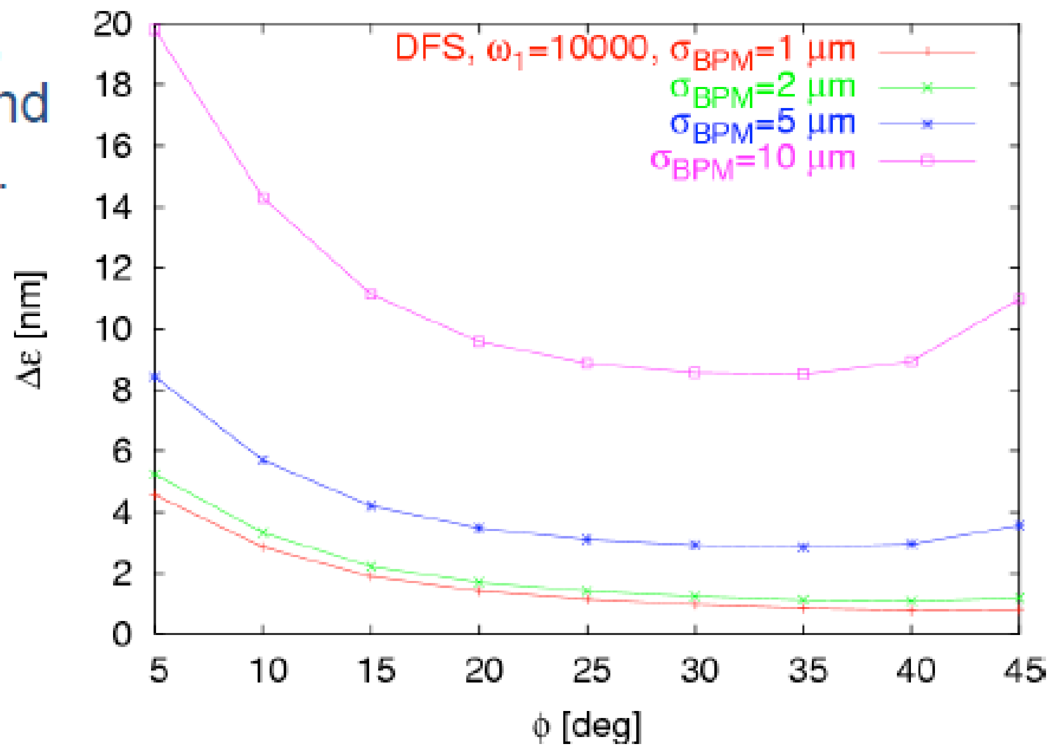
- Other steering/beam based alignment methods
  - Kick minimization
  - Ballistic alignment
  - Adaptive alignment

A. Latina

More Realistic DFS

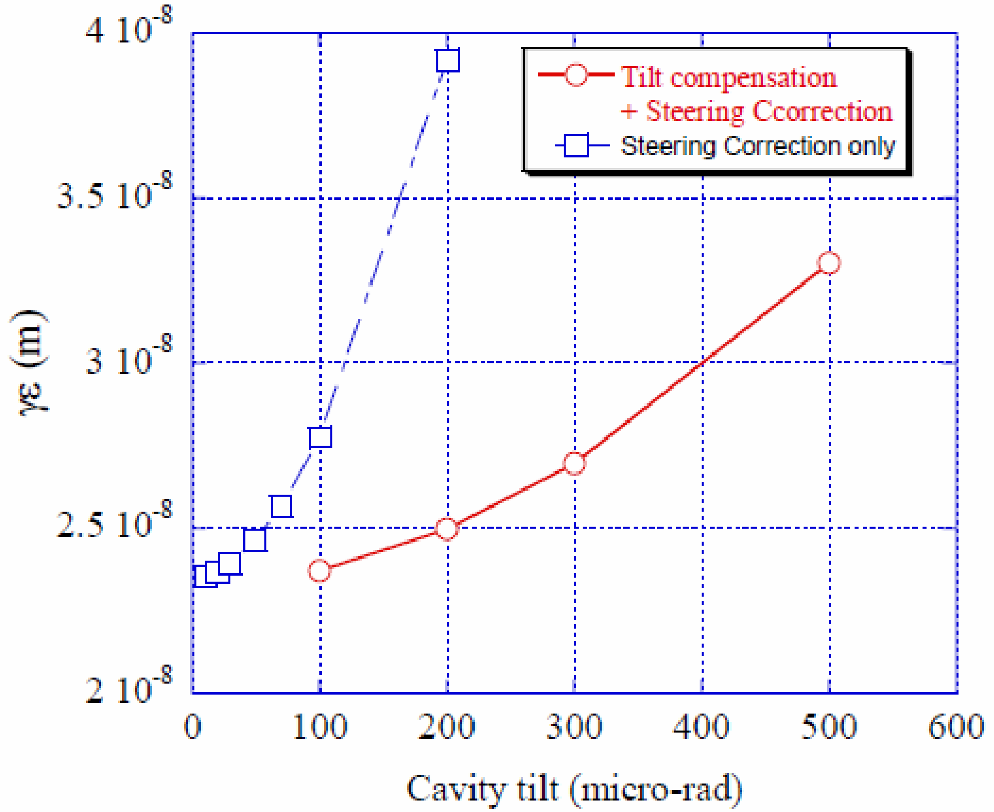
- Off-phase beams in BC gain different energies, so these beams can be used for DFS instead of changing ML cavity gradients.
- With a phase offset of about 25 degrees, this method was found to be very promising.





Kick minimization (Minimize total kick of attached quad-dipole corrector)
+ cavity tilt compensation
(Cancel transverse kick by cavity tilt, measuring orbits with RF on and off)

Emittance vs. cavity tilt angle.
Quad offset 300 micron, Cavity offset 300 micron
Quad-BPM offset error 20 micron, BPM resolution 3 micron



Kiyoshi.Kubo ILC-Asia Note 2005-18

What have been done: static tuning -3

Single bunch - bump tuning

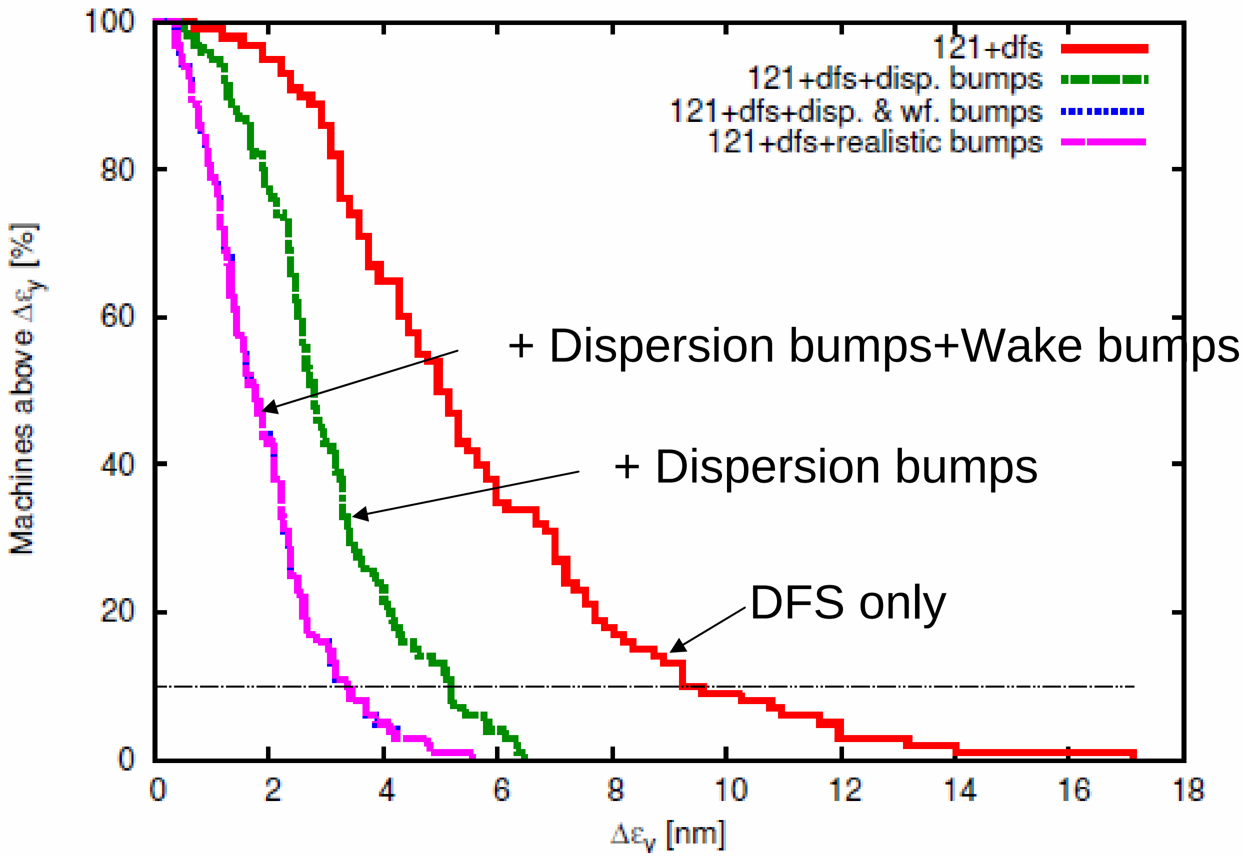
- Dispersion bumps and wake bumps
  - As additional tuning to steering
  - More realistic model of beam size (emittance) monitors should be included in the future

Multibunch simulations

- Long range wakefields
  - Works were mostly on issues of x-y mixing
  - No other problems were expected. But should be checked.

Emittance tuning bumps: (Monitoring emittance)

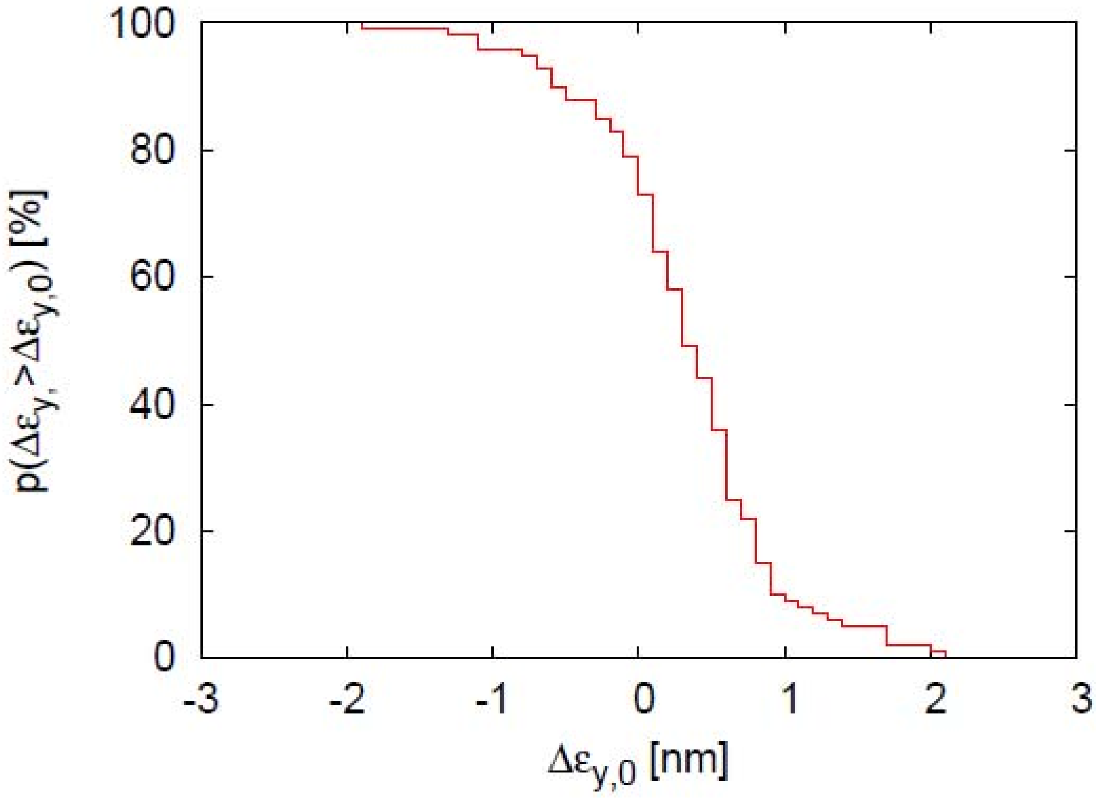
- The realistic bumps give almost exactly the same final emittance as the artificial ones. For ILC the target for emittance growth is maximum 10% of all machines above 10nm.



Single bunch DFS was applied
then, simulate multibunch beam with Long range wakefield

Multi-Bunch Emittance Growth

- Standard errors used
- DFS applied
- 100 machines simulated
  - TESLA wakefields with 0.1% RMS frequency spread
  - one-to-one alignment with full train for each machine
  - 5% bunch-to-bunch charge variations in uncorrected test beam



Daniel Schulte, in Acc Phy meeting 2007.2.26

What have been done, dynamic tuning

Steering Tuning with dynamic effects

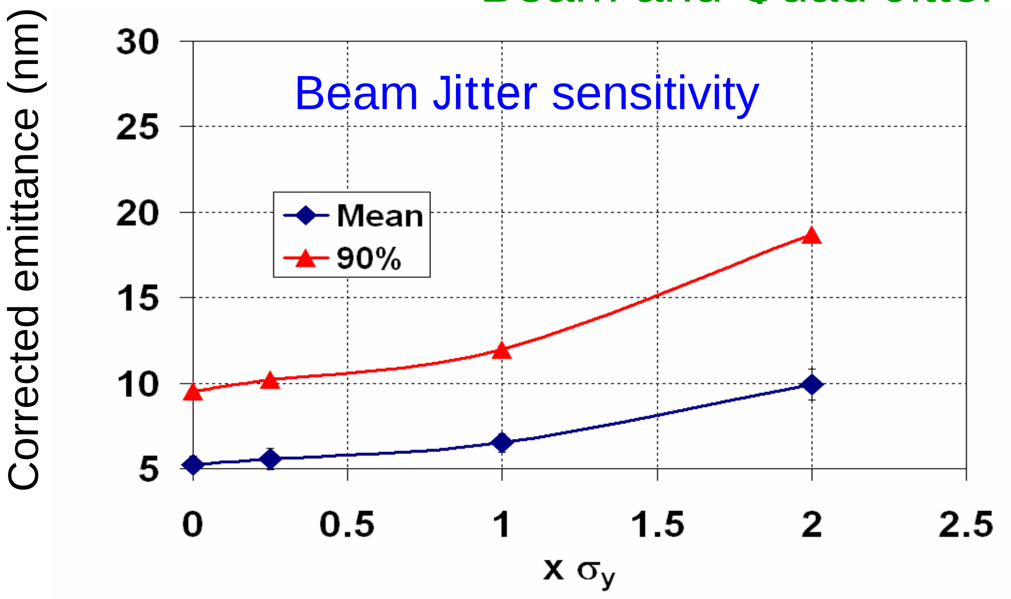
- Quad vibration (random, independent)
- Injected orbit jitter
  - Some studies exist but still much more to do.

Note: Dynamic effects have been studied mainly in BDS, where the effects are expected to be more significant than in ML or RTML.

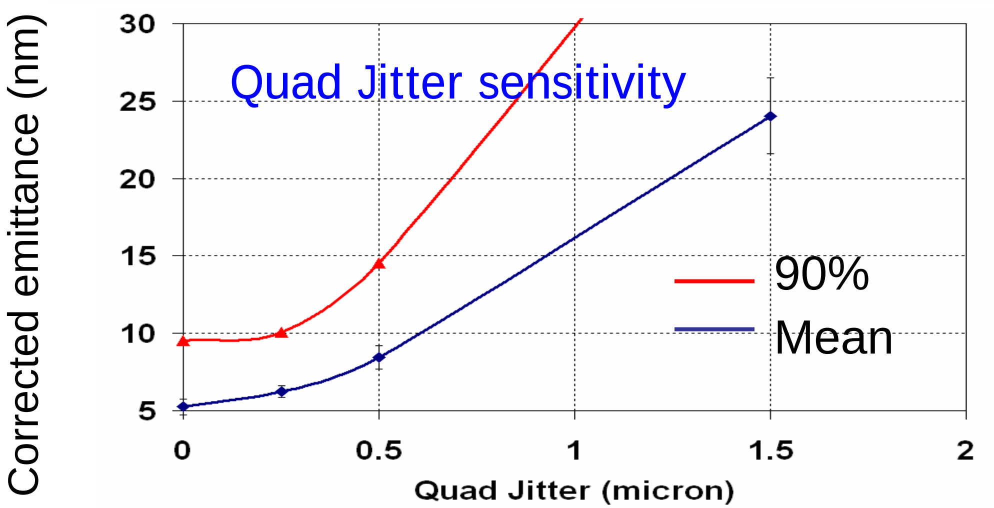
- All LET areas should be simulated in the future

DFS: Sensitivity studies

Beam and Quad Jitter Sensitivity



Inject different beam for every measurement/corrections



Set different quad offset for every measurement/corrections

Kirti Ranjan in Vancouver GDE Meeting

What have been done, others -1

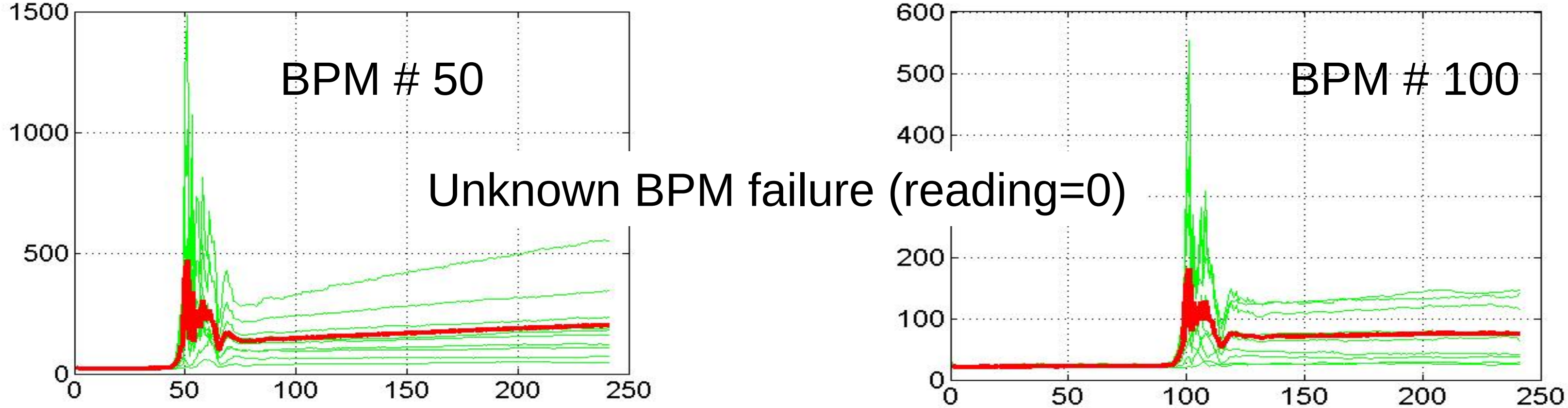
Tuning with failure

- Missing/Failed BPM, Correctors
  - Some studies exist.
  - Need realistic model for further studies.
  - How to find failed components.

Failure Mode Analysis (ILC BCD Curved Linac)

10 seeds; **Curved Linac**; **1 BPM reading = 0 and is used in the DF steering**

Dispersion corrected emittance growth (nm-rad) vs. BPM index



Case2: Faulty BPM and associated YCOR not used in steering

(1) If you know the position of faulty BPM and exclude it from the steering then the results are fine
(2) However, if you use that faulty BPM in finding the corrector settings, then the emittance dilution is significant.

Kirti Ranjan in Vancouver GDE Meeting

What have been done, others -2

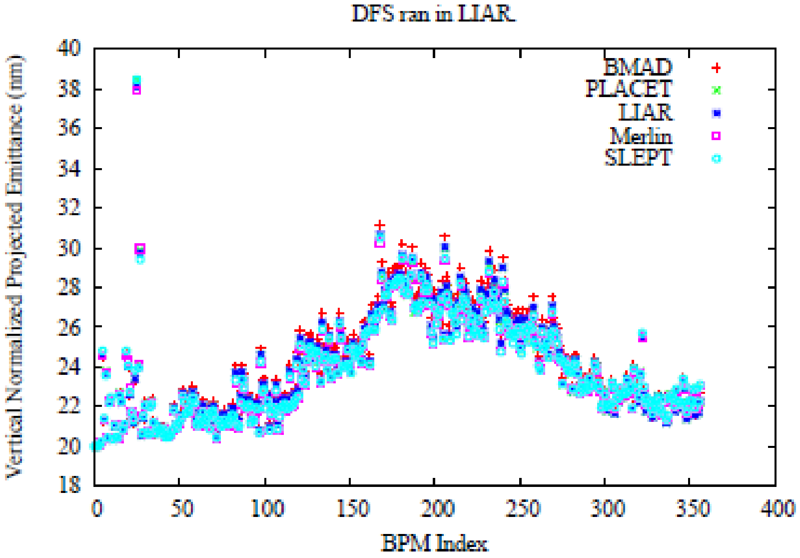
Code Benchmark, Cross Checking

- BMAD, LIAR, MAD, Merlin, PLACET, SLEPT, (CHEF and Lucretia)

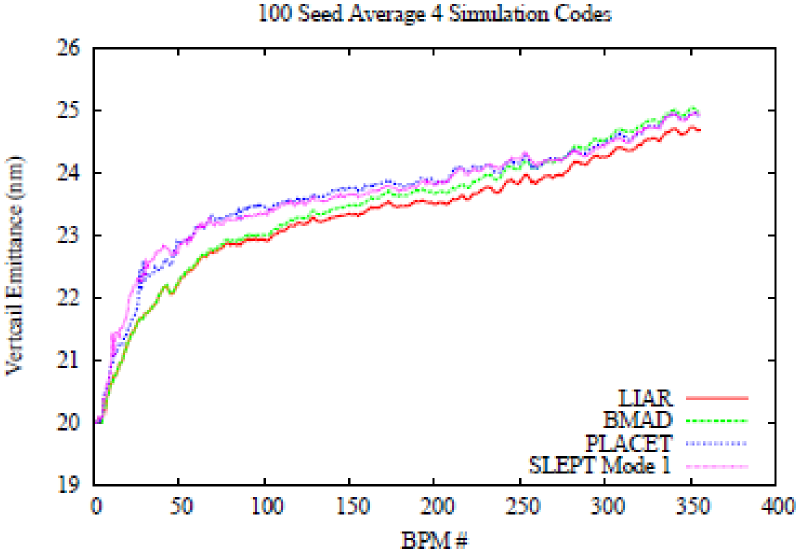
- Injection offset in a perfect linac
- With the same misalignment and the same dipole corrector setting (Generated by LIAR’s DFS)
- With the same sets of misalignment, from 100 random seeds. Perform DFS of each code.

Code Benchmark/Cross Checking

With the same misalignment and the same dipole corrector setting (Generated by LIAR's DFS)



With the same 100 sets of misalignment, from 100 random seeds.
Perform DFS of each code.



Jeffery Smith, et.al., PAC07 THPMS013

Plans: Static tuning - 1

(1) A little More on single bunch steering

- More on Realistic DFS (e.g. control setting of Bunch Compressors for energy change)
- Other steering methods (e.g. Kick minimization, Ballistic alignment)
- Understand the results. (e.g. compare with analytical results)
- Well organized documentation.
- Include Realistic error models
  - Alignment
    - Small working group with Metrology group was formed.
  - BPM
    - Especially scale error seems important
  - Magnet strength and Beam energy along linac → optics mismatching
  - Failed BPM and/or correctors
- Include undulator section of e- linac

Plans: Static tuning -2

(2) Bump tuning

- Dispersion bumps and wake bumps
  - Include realistic monitors

(3) Multibunch simulations

- Different centers between short range and long range wake.
- Bunch-to-bunch injection orbit and charge variations
- x-y mixing of long range wakefields

Plans: Dynamic tuning, etc. - 1

(1) Tuning studies including dynamic effects - tolerances of them

- Ground motion and component vibration
- RF fluctuations
- Injection orbit jitter
- Stray fields
  - Some studies exist in BDS. But not much in ML.

(2) Orbit control, feedback/feedforward

- Will be studied as inter-area issue; RTML-ML-BDS
- Requirement for monitors and correctors should be specified.

(3) Energy profile monitoring along linac and energy regulation (feedback) at the end of linac

- Check whether we do not need monitoring beam energy in ML
  - Optics mismatch due to beam energy error
- Related to Bunch compressors. Control in longitudinal phase space.
  - bunch to bunch energy variation

Plans: Dynamic tuning, etc. - 2

(4) Emittance monitoring

- Check if we need monitoring emittance in ML
- Will be studied as inter-area issue; RTML-ML-BDS
  - Performance of beam size monitors (laser wire) will be critical.

(5) Background, halos

- Will be studied as inter-area issue; RTML-ML-BDS
- Halos, Dark current, Multipactoring, SR
  - Calculations of halo creation by beam-gas scattering exist
  - Dark current and MP will be studied by cavity group?

(6) Machine protection

- Work with Control Group
- Will be studied as inter-area issue; RTML-ML-BDS
- Feedback/feedforward related issues

NOTE: (5) and (6) cannot be done as extentions of past works of Acc. Physics Group.

Draft Descriptions of Work Packages related to ML Beam Dynamics

Description of some of the tasks are based on
http://www.slac.stanford.edu/~quarkpt/EDRPlan quarkpt 16-May-2007,
and modified according to
discussions in Acc. Physics Group meetings, etc..

DRAFT for WP: ML Static tuning

Goals of the Study

The study will focus on main linac emittance tuning and preservation in the presence of static effects.

A lot of works have already done. The past work should be reviewed and documented in well organized way. Also there are a few remaining issues to be studied:

- Study effects of long range misalignment, then, set tolerances for realistic survey-alignment models.
- Multibunch effects
- Undulator section of e- linac
- Include realistic error models, failed components.

Deliverables

The key deliverable is a "white paper" summarizing the results of the study. Additionally, the algorithms must be documented and made publicly available in some form, whether as source code or as a fully-developed technical note on the algorithms; this will allow other users to develop studies which take the tuning algorithms as a starting point.

Note on Time schedule

- Since this work should be followed by dynamic tuning study, the main part of this should be completed relatively early. Probably in a half year or so.

DRAFT for WP: ML Dynamic tuning

Goals of the Study

The study will focus on main linac emittance tuning and preservation in the presence of dynamical effects. It should incorporate the following refinements:

- The ground motion and vibration model for the ILC
- Time-dependent errors in the magnet settings, RF power, and BPM performance
- 5 Hz feedbacks, 3 MHz feedbacks, and train-straightener feedbacks
- Resteering or continual steering models
- Initial beam jitter, both train-to-train and intra-train, which is expected from the results of the RTML dynamic study

The study will quantify the degradation in the initial tuning due to dynamic effects, determine the optimum mitigation of the dynamic effects, set specifications, tolerances, and limits on dynamical effects, and determine the necessary procedures and equipment to maintain optimum emittance performance of the main linac over time.

Deliverables

The key deliverable is a "white paper" summarizing the results of the study, which is to be available at the time of the Engineering Design Report (ie, in early FY10). Additionally, the algorithms must be documented and made publicly available in some form, whether as source code or as a fully-developed technical note on the algorithms; this will allow other users to develop studies which take the tuning algorithms as a starting point.

DRAFT for WP: Feedback/Feedforward model and simulations

Goals of the Project

The goal of the project is to develop a model of the ILC beam-based feedback and feedforward systems and to demonstrate its performance by simulations. The model should incorporate the following components:

- Train-to-train (5 Hz) feedback loops
- Intra-train (3 MHz) feedback loops
- Intra-train feed-forward loops
- Train-straightener feedback loops
- Dither feedback loops

- To the extent possible, the developed system should include specific locations for sensors and actuators, bandwidth requirements for sensors and actuators, and descriptions of the algorithms used by each loop, and communications between them, which are adequate for a moderately-skilled LET simulation guru to incorporate into a simulation package.

Deliverables

One or more technical notes which document the design and expected performance of the system.

DRAFT for WP: Control of longitudinal phase space of the beam

Goals of the Project

The goal of the project is to develop a model of the control system in the longitudinal phase space of the beam, and to demonstrate its performance by simulations. This includes

- Monitoring, tuning and control scheme of:
  - Bunch length, timing, energy spread (tuning of the bunch compressors)
  - Measuring the beam energy profile and matching the quad lattice
  - Regulation of energy at the end of the linac

Deliverables

One or more technical notes which document the design and expected performance of the system.

DRAFT for WP: Emittance monitoring

Goals of the Project

The goal of the project is to simulate performance of emittance monitoring system, and/or estimate required performance of the system. This should include diagnostics in RTML, ML and BDS.

Deliverables

One or more technical notes which document the design and expected performance of the system.

DRAFT for WP: Backgrounds and machine protection

Goals of the Project

The goal of the project is to simulate backgrounds, and performance of background mitigation system and machine protection system, and/or estimate required performance of the system. This study includes:

- Background
  - Beam Halo
  - Synchrotron radiation
  - Dark currents, Multipactoring
- Machine protection scheme
  - Spoilers
  - Beam abort

Deliverables

One or more technical notes which document the expected background and performance of the mitigating system.

One or more technical notes which document the design and expected performance of the machine protection system.