# “Simulations Group” に関する報告

2007. 10. 02 久保浄

- Introduction
- これまでの仕事（RDRのために）
- これから何をやるか
  - 内容
  - 組織、進め方、、、、

# Introduction: “Simulations Group” in EDR phase

- ビームダイナミクス関係をやるグループ
  - ただし、damping ring のことはDR グループでやる。
  - 主にLET　(Low Emittance Transport: RTML, ML and BDS)
- RDR phase “Technical System Groups” の中で唯一生き残りつつあるグループ。
  - “Accelerator Physics Group” が名称変更されたもの(?)
  - 正式には10月のGDE meeting 以降？
  - Area groups と「直交」する（？）ので、仕事の進め方に難しい部分がある

# これまで何をやってきたか（主にRDRのため）
# ”Accelerator Physics Group”

- Design and simulation studies of low emittance tuning
  - Mostly simulation of each section separately
    - RTML upstream (long transport, turnaround and spin rotator)
    - RTML downstream (Bunch Compressors)
    - Main Linac
    - undulator section of e- main linac
    - BDS
  - Mostly only include static errors (時間的に変化しないもの)
  - Mostly single bunch
  - Some simulation studies of
    - inter-area issues
    - dynamic effect (時間的に変化するエラー)
    - multibunch issues
  - Set preliminary tolerances of misalignment, BPM performance, etc. (hardware specs).

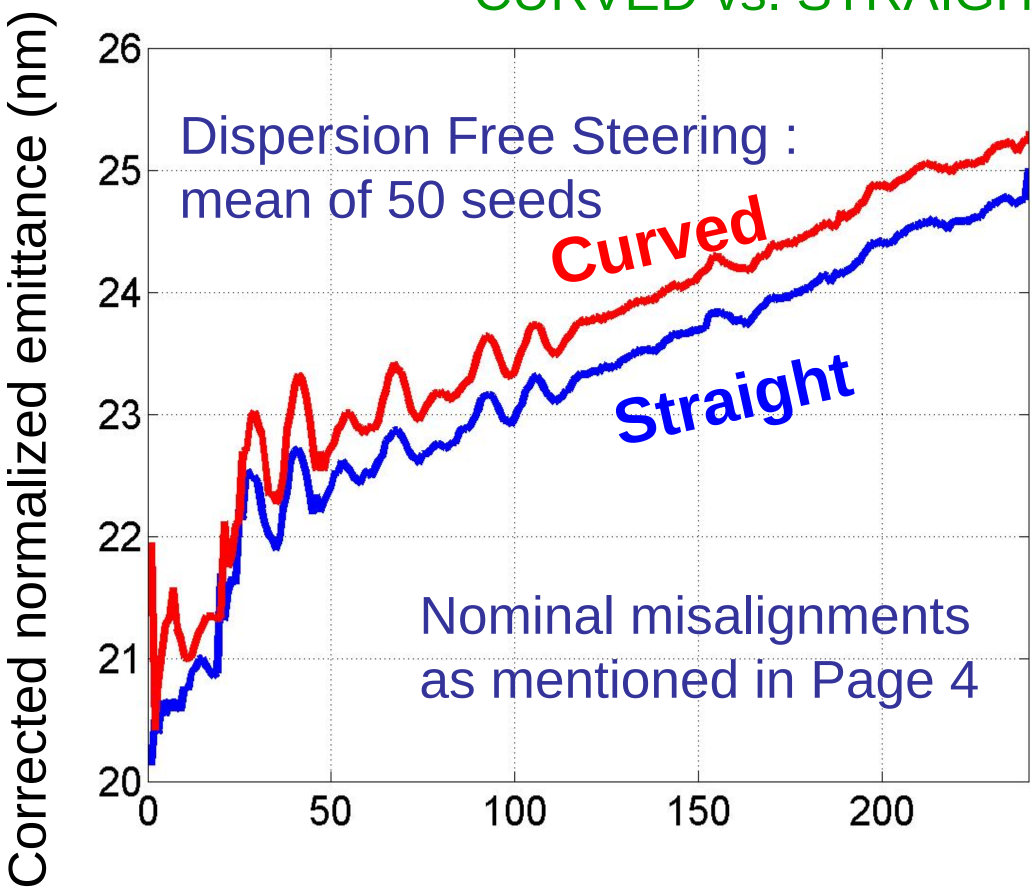
# Main Linac -1

- Dispersion Free Steering with static errors
  - Emittance increase will be acceptable with “Standard or Nominal” errors.

# Dispersion Free Steering - Results

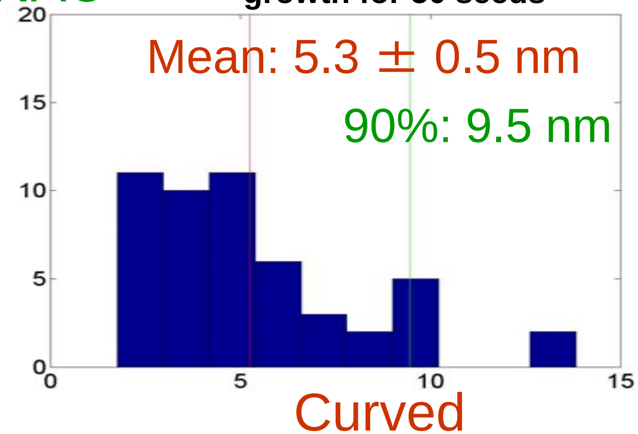
Misalign the beamline components and perform the DF steering

CURVED vs. STRAIGHT LINAC

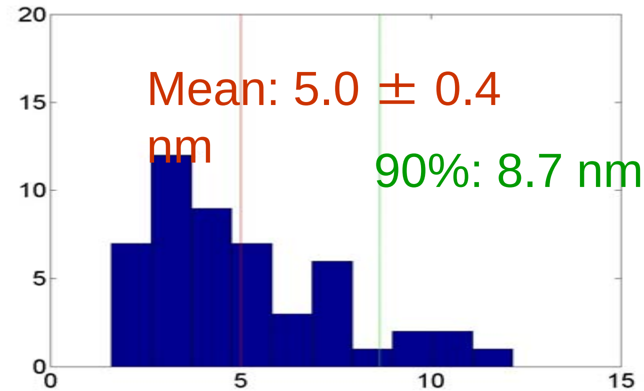



DFS parameters not optimized for Curved Linac

**Distribution of emittance growth for 50 seeds**




Curved



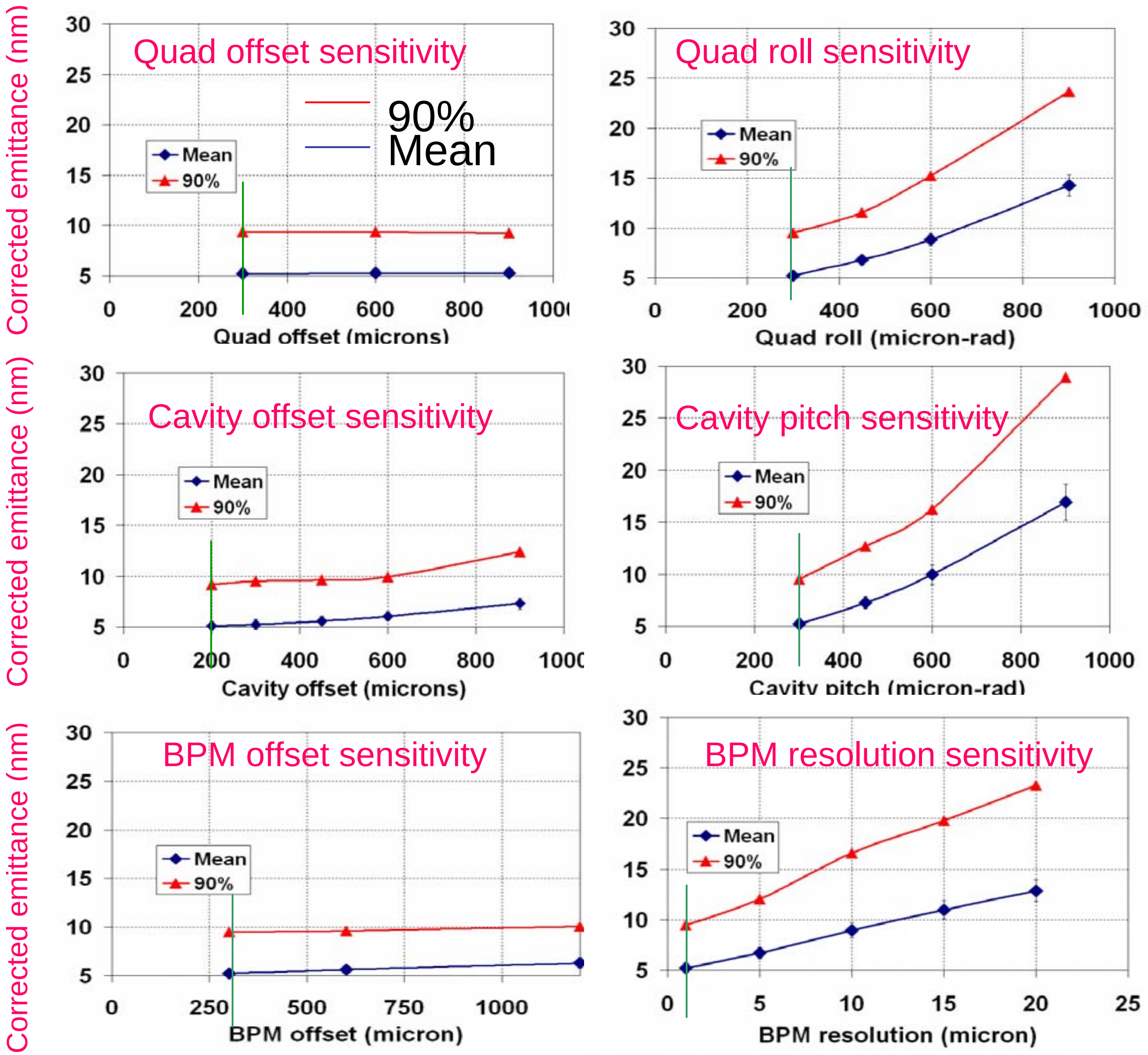

Laser Straight

# Nominal Errors

| Tolerance | Vertical (y) plane |
|---|---|
| BPM Offset w.r.t. Cryomodule | 300 $\mu$m |
| Quad offset w.r.t. Cryomodule | 300 $\mu$m |
| Quad Rotation w.r.t. Cryomodule | 300 $\mu$rad |
| Cavity Offset w.r.t. Cryomodule | 300 $\mu$m |
| Cryostat Offset w.r.t. Survey Line | 200 $\mu$m |
| Cavity Pitch w.r.t. Cryomodule | 300 $\mu$rad |
| Cryostat Pitch w.r.t. Survey Line | 20 $\mu$rad |
| BPM Resolution | 1.0 $\mu$m |

# 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***

Kirti Ranjan in Vancouver GDE Meeting

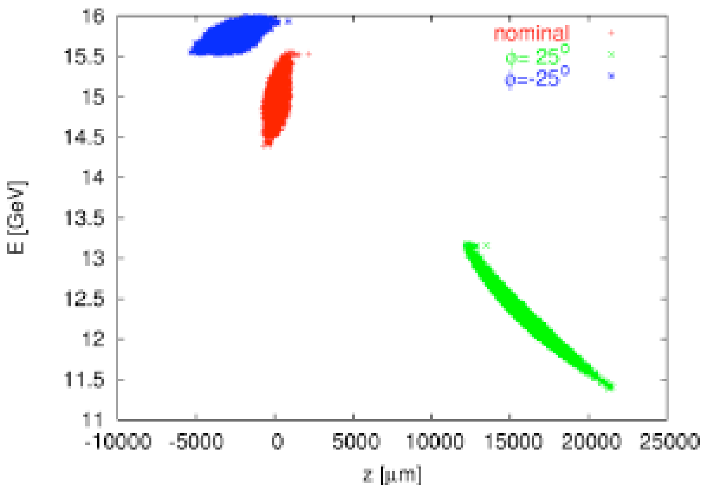
# Main Linac -2

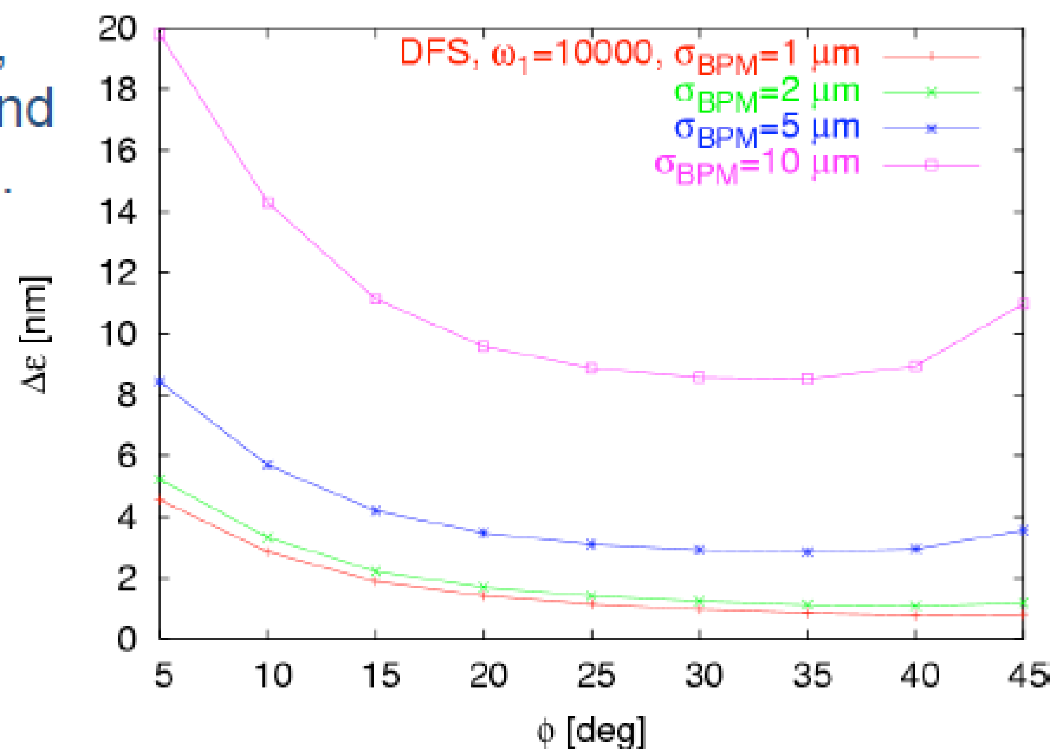
- More Realistic, Inter-area DFS (Bunch Compressors + Main Linac): Change BC RF setting to change beam energy in ML
  - Results were promising

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.



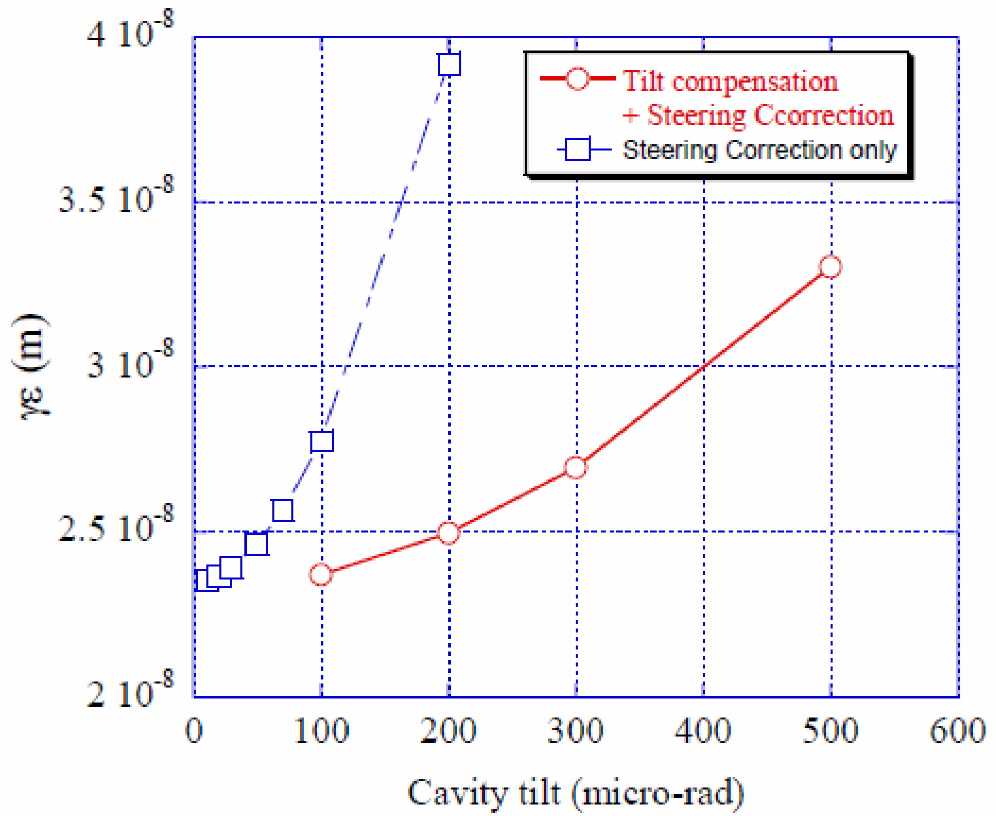



# Main Linac -3

- Other Steering methods: e.g. Kick Minimizatin
  - Good, with additional correction for cavity tilt error.

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

# Main Linac -4

Steering Tuning with dynamic effects

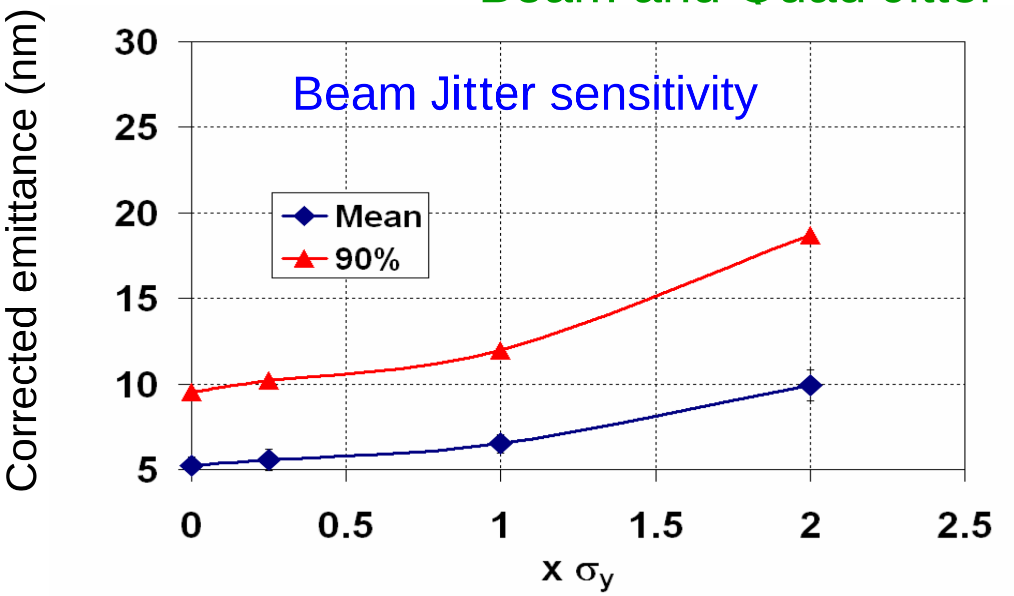
- Quad vibration (random, independent)
- Injected orbit jitter
  - Some studies exist but still much more to do.

Tuning with failure

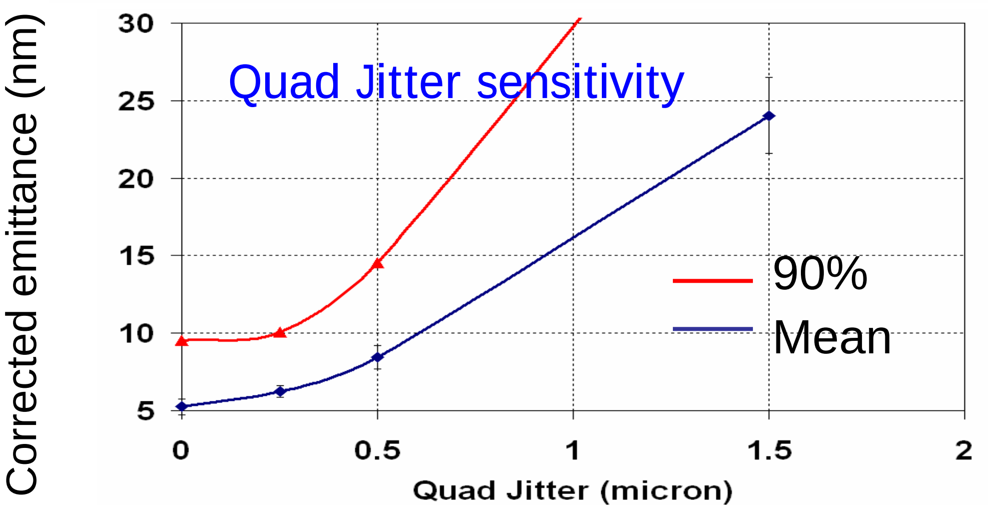
- Missing/Failed BPM, Correctors
  - Some studies exist.
  - Need realistic model for further studies.
  - How to find failed components.

# DFS: Sensitivity studies

Beam and Quad Jitter Sensitivity




Inject different beam for every measurement/corrections



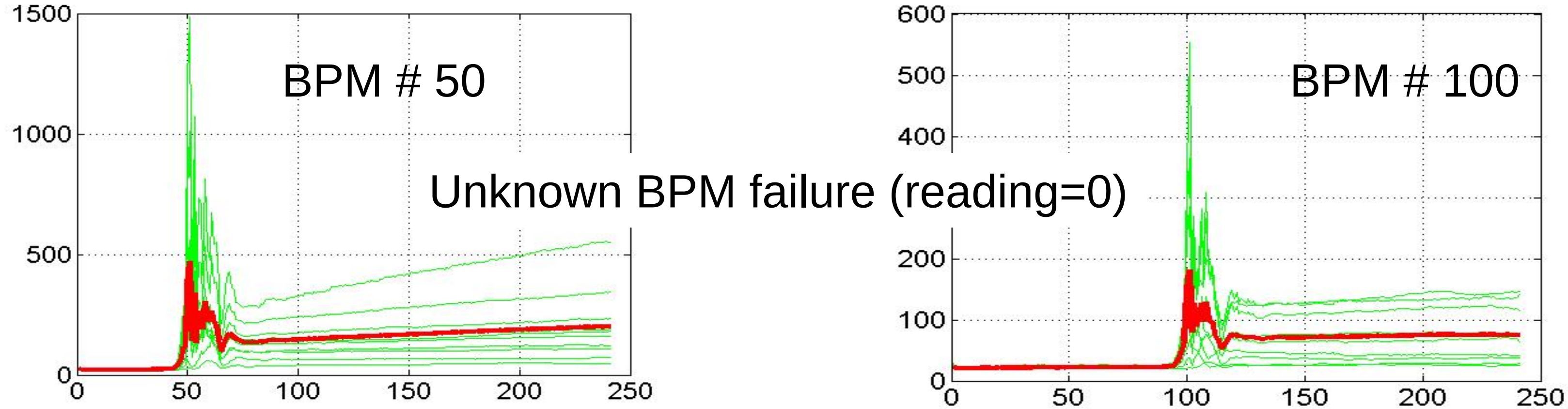

Set different quad offset for every measurement/corrections

Kirti Ranjan in Vancouver GDE Meeting

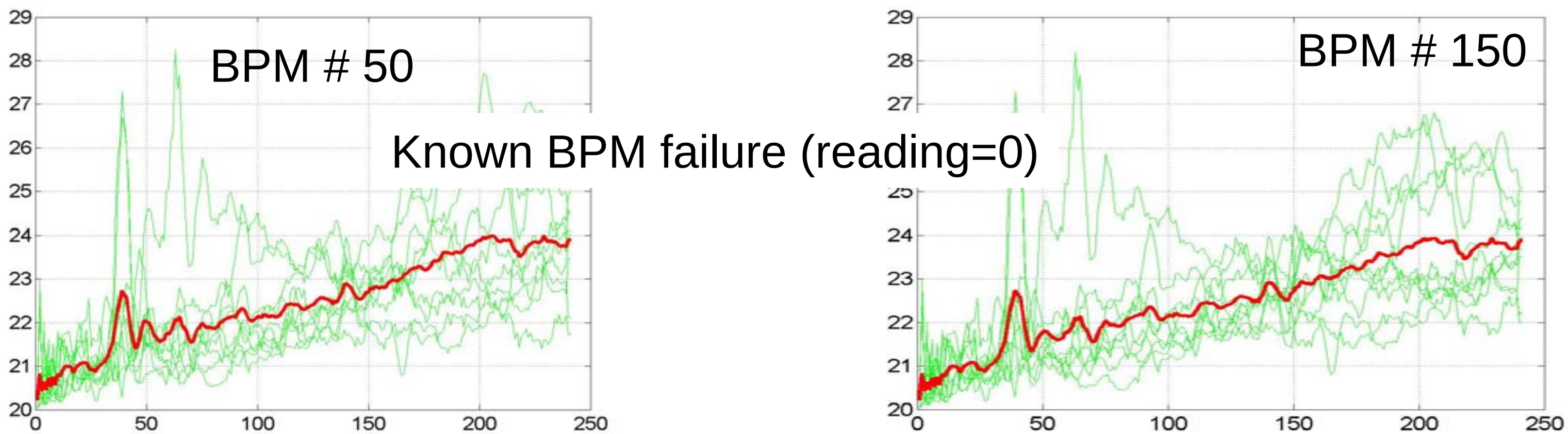
# Failure Mode Analysis (ILC BCD Curved Linac)

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

# RTML

- Study of emittance preservation tuning in
  - Long Transport from DR to Turnaround
    - Probably OK
  - Turnaround+Spin Rotator
    - Probably OK
  - Bunch Compressors
    - DFS may work well, but need more studies

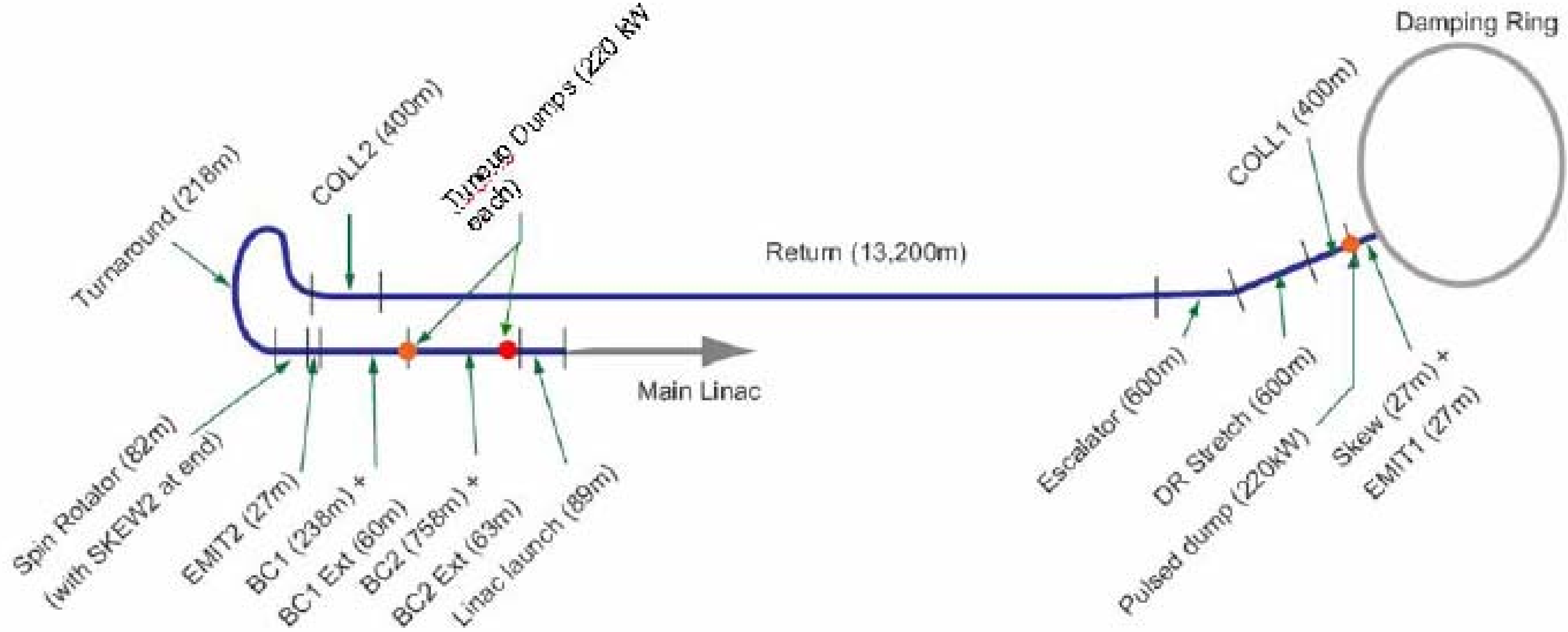



**Figure 1.3-4: Schematic of the RTML**

# Result of kick minimization

RTML Long transport

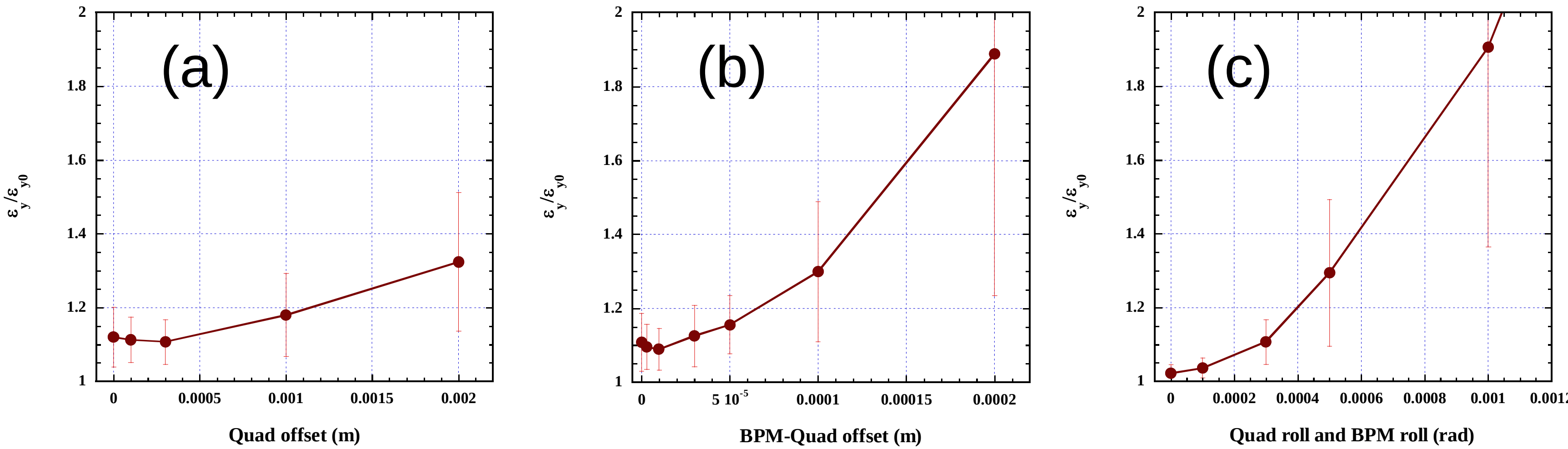
Sensitivity to different errors (average of 100 seeds)

(a) Quad offset (same in x and y)

(b) BPM offset w.r.t. attached Quad (same in x and y)

(c) Roll of Quad and Roll of BPM w.r.t. attached Quad (Same value for both roll errors)

In each figure, other errors are kept as "standard"




"Standard" set errors (Quad offset 300 μm, roll 300 μrad, BPM-Quad offset 30 μm) will increase the emittance about 10%, mostly due to Quad roll error.

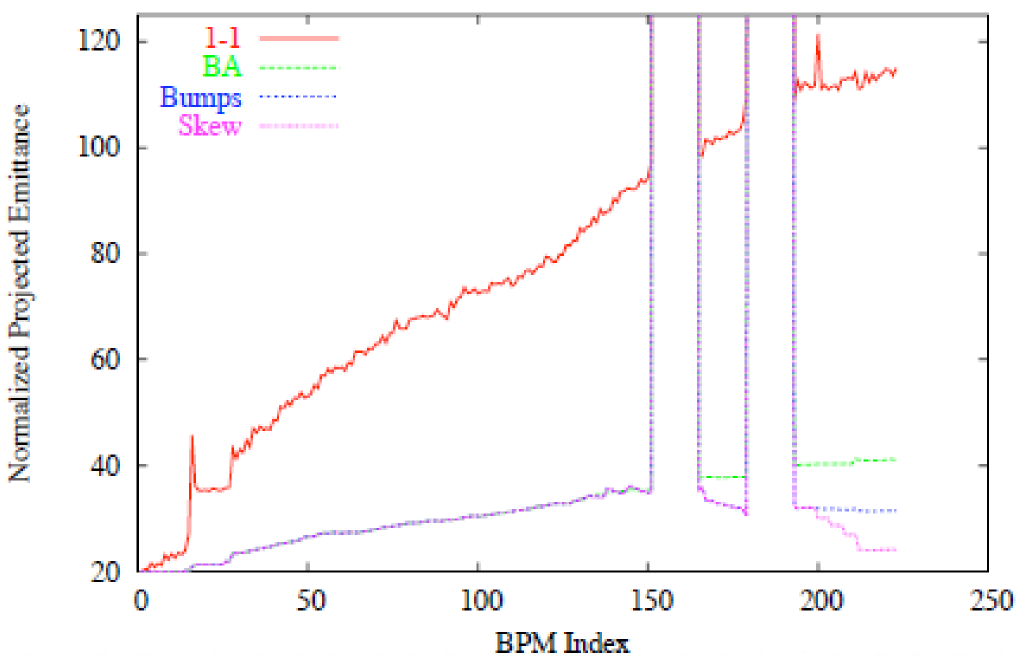
K.Kubo 20061024

# Tuning of RTML turnaround - spin rotator section

## Performance much be better

- The skew correction is now a local correction.
- Also found that simple scans works very well in this case.

RTML: 1-1, BA, bumps, skew LM, BA, bumps, skew LM LOCALSKEW 20060824




Jeff Smith, LET meeting/EuroTev meeting, Daresbury, Jan. 2007

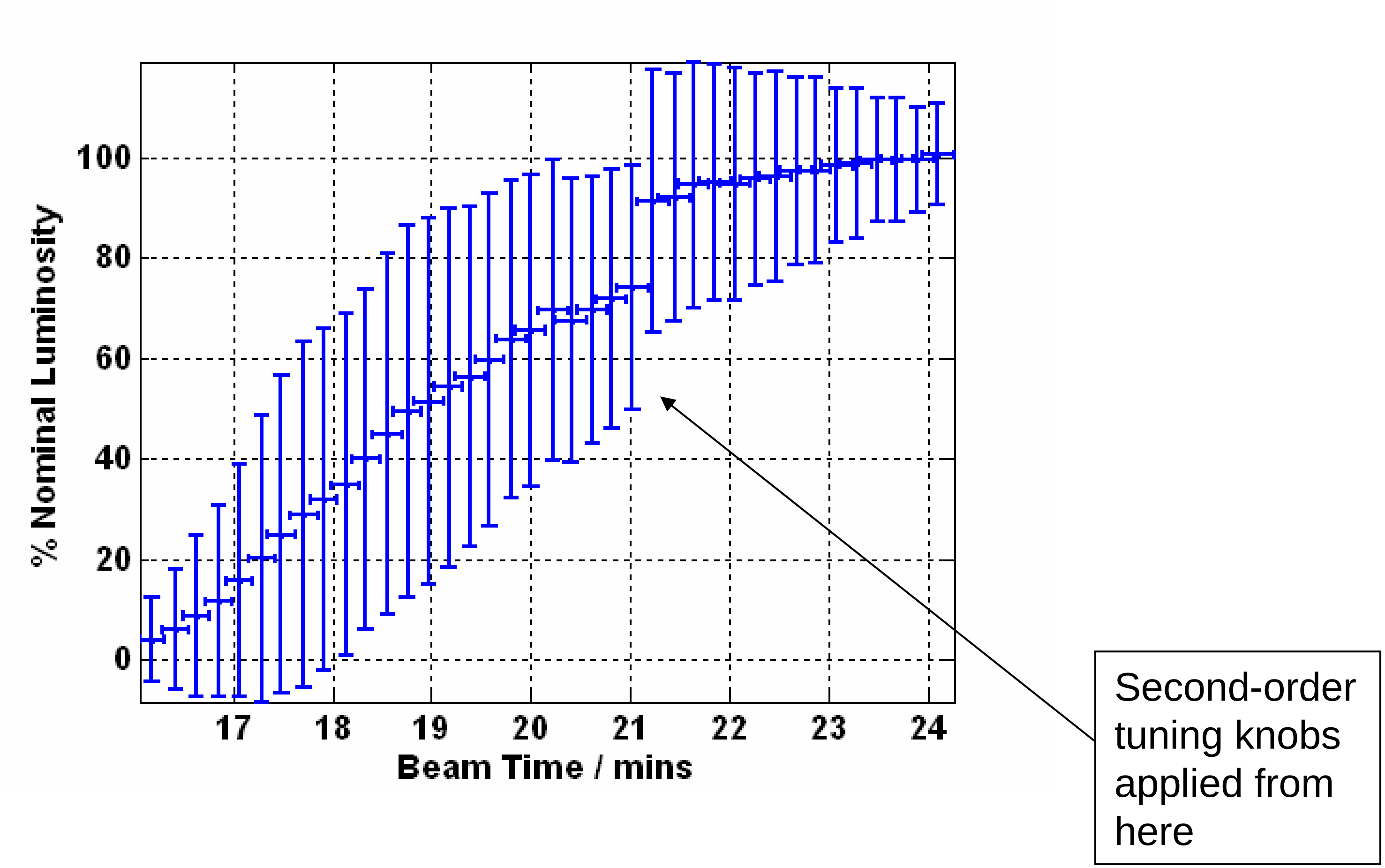
# BDS

- Study of emittance (and luminosity) preservation tuning
  - Include static errors (misalignment, magnet strength etc.)
  - Include some dynamic effects
    - Orbit jitter at BDS entrance
      - Some studies including orbit feedback
    - magnet position jitter (vibration)
    - Ground motion

# Alignment and Tuning Strategy

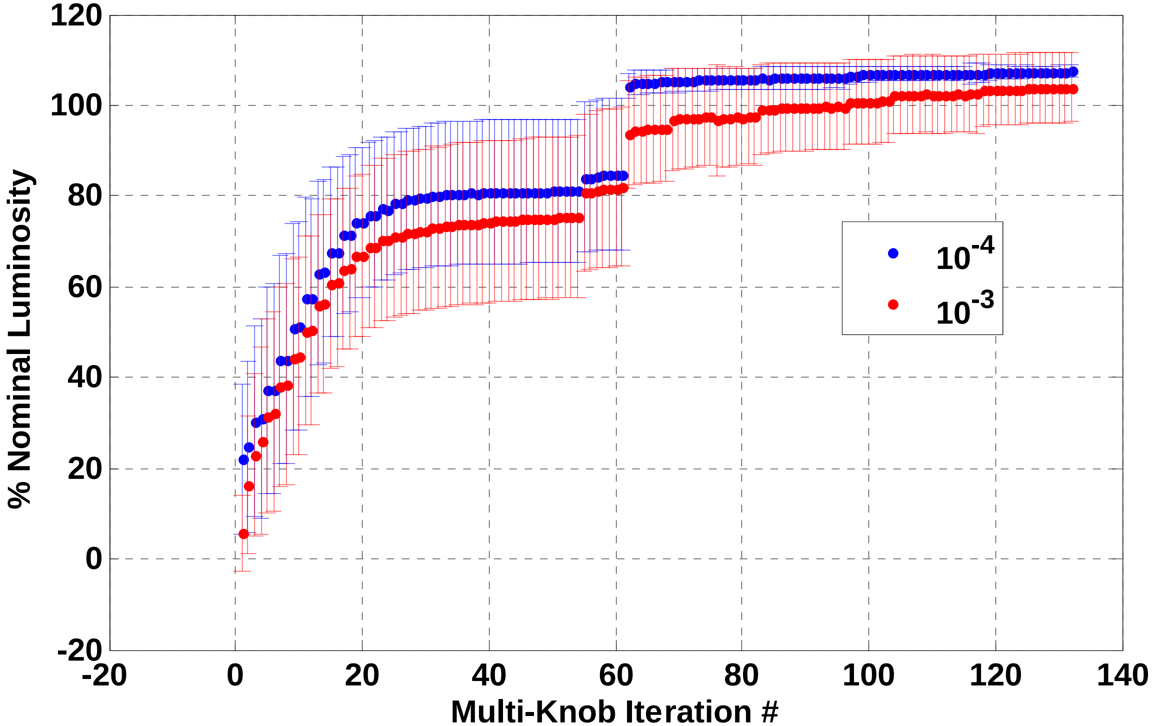
1. **Switch off sextupoles & octupoles, get rough initial alignment in Quads with movers.**
2. **Use nulling Quad-shunting technique to get BPM-Quad alignments.**
3. **Use Quad movers and global alignment algorithm to put Quads in a straight line in x and y with beam going through Quad field centers, use linear move of whole BDS to align e- beam with e+ beam.**
4. **Get BPM-sextupole/octupole alignment with movers using a fit to downstream BPM responses.**
5. **Switch on sextupoles/octupoles and use sextupole multi-knobs to tune IP waist, dispersion and coupling (first and second order knobs required).**

# Luminosity vs. Tuning Time




- Application of multiknobs- mean and RMS beam time vs. geometric luminosity.

# Comparison of $10^{-3}$ / $10^{-4}$ Magnet Strength Errors




- Larger spread of initial errors and slower convergence rate for case of 1e-3 magnet strength errors.
- Only 75% of 1e-3 seeds exceed nominal lumi after tuning.
- For one seed, lumi increased beyond 100% nominal by extending # of linear tuning iterations.
- Larger spread of IP divergences in 1e-3 case suggests difference even more severe when GUINEA-PIG used for lumi calculation.

Glen White, ACC. Phys phone meeting, 2006.12.07

# これからやろうとしていること

- Include realistic error models, hardware specs
  - misalignment
  - monitor performance
  - Magnetic field errors
  - etc.
- Inter-area studies (Start to End simulations)
- Include important dynamic effects (時間とともに変化するもの)
  - Ground motion, vibration
  - RF fluctuation
  - etc.
- Orbit Feedback/feedforward (design and simulations)
- Some remaining issues
  - Multibunch effects (wake, bunch-to-bunch variations)
  - Include undulator section of e- linac
  - Longitudinal tuning, Energy regulation
  - Emittance tuning in Bunch Compressors
  - etc.

# Contact persons of items "information for simulations"

## for realistic error models, hardware specs

| List A: Information for simulations | Contact |
|---|---|
| Lattice design | (Mark Woodley (SLAC)), *Allex Valishev (FNAL) |
| Alignment model | *K. Kubo (KEK) |
| Ground motion and vibration model | *P. Lebrun (FNAL), *Dirk Kruecker (DESY) |
| RF (BC, ML) error model | *D. Schulte (CERN) |
| Magnet error model | James Jones (ASTeC) |
| BPM performance mode<br>Cold and Warm | ? |
| BSM(Beam size monitor) performance model | *G. Blair (RHUL) |
| Cavity wakefield | (Karl Bane (SLAC) Roger Jones) |
| Collimator wakefield | *Roger Barlow (Manchester) |
| Other impedance | (Karl Bane, Gennady Stupakov (SLAC)) |
| Stray electromagnetic fields | *N. Solyak (FNAL) |

# Tasks of “Information for simulations”

- Contact person is responsible to
  - Communicate with experts
  - Gather relevant information
  - Make documentation(s).
  - If suitable, make a set of data file(s) which can be used in simulation studies.
- Contact person is not necessarily an expert in each task (probably not, in most cases). But he/she should know what information are needed for simulations.
- Time schedule (?)
  - First set of out put by the GDE meeting in October
  - Can be tentative. Further update will be necessary, but we need models for simulation studies. (There may be exceptions)

これらは、「work package」ではない、というつもり。

# Simulation studies

- 実際のsimulation work、「work package」の下書になる（かもしれない）ものが準備されている。

# DRAFT: Task B (simulation studies) of ILC Simulation

200708 K.Kubo

Description of each task is based on http://www.slac.stanford.edu/~quarkpt/EDRPlan quarkpt 16-May-2007

Modified 2007.08.21

# RTML-1

**Initial Goals of the Study**

- The study will focus on the emittance tuning requirements of the Ring to Main Linac (RTML). The goal of the first phase of the study is to demonstrate that the RTML's emittance preservation goals can be achieved: the goal is to limit growth in the normalized vertical emittance to 4 nm.rad with 90% confidence, using standard assumptions of misalignment and component errors. It is preferred that multiple paths to achieve the emittance goal are demonstrated. Techniques that can achieve the necessary emittance without resorting to bumps are preferred to techniques which require bumps.
- A prerequisite to performing the tuning studies is to develop a set of simulation code benchmarks which can be used to validate, or at least cross-check, the multiple simulation codes which will be used for this set of studies. The benchmarks must include the key physics features of the RTML: misaligned quadrupoles, sector bends, and RF cavities; pitched RF cavities; quadrupole errors in the spin rotator section; transverse wakefields of uncompressed bunches; momentum compaction.

**Essential Features of the Study**

- Full and accurate lattices, including vertically-curved or laser-straight segments, and geometry matching between them
- A set of standard misalignments and errors which is considered appropriate by the relevant technical experts
- The expected beam distribution from the extraction of the DR, including the correct bunch length, energy spread, and any non-Gaussian features; both the nominal and low-charge, short-final-bunch cases should be studied
- Long-range wakefields, including any expected rogue modes or mode-rotation wakes

# RTML-2

**Later Goals of the Study**

- Once the basic study has reached a conclusion, the next steps will be: to include BPM and corrector "hard failures" in the study (failed BPMs and correctors known to have failed); to use an initial set of misalignments which include the expected long-wavelength distortions of the tunnel (if this was not included in the initial set of studies). The studies will be used to set specifications and tolerances on many parameters of the main linac, for example determining the actual requirements on initial alignment. The exact dimensions of this last part of the study will be determined later based on experience from the initial portions of the study and demands from the various area, technical, and global experts.
- In parallel with the above, incorporate dynamic features into the tuning model. These features include: ground motion and component vibration based on the accepted model; 5 Hz, feedbacks, 3 MHz feedbacks, "train-straightener" feedbacks, and feed-forward; bunch-by-bunch and train-by-train beam jitter.

**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. Additionally, datasets representing the misalignments and corrector settings for a number of "seeds," which can be loaded into other simulation programs for simulation of a misaligned, corrected beamline. These datasets, in ASCII format, would be stored on a central web server for use by any ILC LET person who wishes to use them. Finally, the data files needed for the benchmarking of RTML simulation codes, and the results from the codes which have passed the benchmark, must be made available for general use.

# ML Static tuning

**Goals of the Study**

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

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:

- Effects of long range misalignment, then, set tolerances for realistic survey-alignment models.
- , , ,

**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.

# 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.

(Note: do we need to develop benchmarks for this part of the overall study? If so, what should they be?)

**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.

# BDS

**Goals of the Study**

- The study will focus on the luminosity tuning requirements of the Beam Delivery System (BDS). The goal of the first phase of the study is to demonstrate that [the BDS's emittance preservation goals can be achieved: the goal is to limit growth in the normalized vertical emittance to 6 nm.rad with 90% confidence,] [the designed luminosity can be achieved with 90% confidence,] using standard assumptions about the initial alignment of components and the accuracy of electromagnetic fields in the devices.

  The key physical issues to be studied include:
  - The typical misalignments, rotations, and strength errors of beamline devices
  - Crab cavity effects, including wakefields, phase and amplitude errors, and xy rotation errors
  - Wakefields, including both collimators and the vacuum chamber itself
  - Dynamic effects: ground motion, technical noise (especially on the final doublet and detector), train-by-train and intra-train feedbacks
  - Beam-beam effects
- A prerequisite to performing the tuning studies is to develop a set of simulation code benchmarks which can be used to validate, or at least cross-check, the multiple simulation codes which will be used for this set of studies. The benchmarks must include the key physics features of the BDS, as outlined above.

**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. Additionally, datasets representing the misalignments and corrector settings for a number of "seeds," which can be loaded into other simulation programs for simulation of a misaligned, corrected beamline. These datasets, in ASCII format, would be stored on a central web server for use by any ILC LET person who wishes to use them. Finally, the data files needed for the benchmarking of BDS simulation codes, and the results from the codes which have passed the benchmark, must be made available for general use.

# 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.

# 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 i(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.

# 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.

# 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
- 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.

# Start to End simulation

**Goals of the Study**

This study will integrate the RTML, Main Linac, and BDS simulations into a common framework and produce direct estimates of the ILC luminosity (rather than indirect estimators such as the emittance). As such, it will incorporate the static tuning algorithms of each area, the dynamic effects and feedbacks, and the beam-beam interactions necessary to achieve a fully-realistic luminosity estimate. As a secondary goal, the study will produce estimations of the unwanted beam-beam induced byproducts (ie, backgrounds or lost beam power in various forms).

In the event that the integrated simulations predict a luminosity which is lower than what is expected from the emittance-preservation studies, the efforts will be directed towards understanding the discrepancy and increasing the luminosity.

**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. Additionally, datasets representing the misalignments and corrector settings for a number of "seeds," which can be loaded into other simulation programs for simulation of a misaligned, corrected beamline. These datasets, in ASCII format, would be stored on a central web server for use by any ILC LET person who wishes to use them.

# Code development-1

**Goals of the Project:**

- The goal of the Simulation Code Development project will be to produce a beam dynamics simulation code which is suitable for use in LET Start to End (S2E) simulations: simulations which incorporate the RTML, main linac, BDS, and collision point. Optimally, simulations of the extraction line should be supported as well.

The physics simulation requirements of an S2E code are as follows:

- Standard beam dynamics issues: drifts, bends, quads, sextupoles, octupoles, thin-lens multipoles, solenoids, dipole correctors, including errors and misalignments; bend magnet errors and rotations must be correctly treated, ie, a bend with a strength error produces an error in the beam trajectory as well as in the dispersion.
- Accelerating cavities: acceleration, focusing from fringe fields, single bunch transverse and longitudinal wakefields, long-range wakefields including mode-rotation wakes, pitched-cavity aberrations.
- Interaction region: crab cavity including collective and multi-bunch effects, IR solenoid overlapping IR beamline magnets, beam-beam effects (luminosity enhancement, disruption of the outgoing beams, crossing angle, arrival time error, kink instability).
- Capacity to incorporate the ground motion model.
- Capacity to incorporate intra-train feedbacks, train-to-train feedbacks, train-straightener feedbacks, and feed-forwards.
- Two-beamline simulation: appropriate incorporation of misalignments and errors which are correlated between the e- and e+ beamline such as bunch compressor phase errors, crab cavity errors, ground motion effects over the full site, IR girder and solenoid field error / alignment effects.
- BPM resolution limits, scale factor errors, electrical and mechanical offsets, rotations.
- Other appropriate instrumentation: profile monitors of various forms, bunch length and arrival-phase monitoring.
- The S2E codes should be developed in such a way as to maximize their use of parallel processing and grid computing capabilities of the national laboratories.

# Code development-2

- Optimally, the S2E codes should explicitly incorporate book-keeping tools for managing common girders, RF sources, power supplies, and other fixed relationships between beamline elements.

  In addition to the actual simulation codes, the S2E effort must develop a set of benchmarks which can be used by prospective codes. The benchmarks incorporate the benchmarks used by the RTML, ML, and BDS studies, and any additional benchmarks which are needed to verify the correct functioning of additional features in the S2E code.

  **Deliverables**

  The deliverables of the project are the following:

- The simulation package itself: source code, exectuables, and any makefiles or other construction tools needed to build the executables from the source.
- Documentation adequate to allow a modestly-experienced simulation guru to run the code.
- Documentation of the results of benchmarking studies.
- Ideally all of the above should be made available on a public web server, and everything should be placed under some form of version control.

QUESTION: It may not be a good idea to develop one single code in the world. I (K.K.) guess there is a project to make such a code in the US. Other regions may have different code(s)? However, every accelerator facility seems to have one standard code for simulation and operation. (It may be wrong.) ??????? So, ILC should have one?

# 進め方に関する問題点

- “Simulations group”と “area groups”が直交することにより、仕事の区分け等が明確でない。
  - 基本的に「area groups」が責任を持つ。
  - が、複数のareaにまたがるものもある。
- RDRのときにも同様の問題あり
  - 特にBDS、e+ Undulatorグループとの意思疎通に問題があった（？）

(Nick Walker の MLI KOM での presentation 参照)

# Beam Dynamics – A special case

- For Accelerator Systems, beam dynamics and Accelerator Physics still plays a critical role.
- All Accelerator Systems have identified critical “Beam Physics” issues (WPs)
- Simulation Group will provide high-level coordination across beam dynamics WPs
  - arranging workshops
  - identifying simulation work that goes across AS boundaries
  - providing resources were possible
- AS managers have responsibility to define critical Beam Dynamics WP for their specific areas
  - set priorities
  - Important that scope and timing of these activities be integrated into engineering schedule
- Special session at GDE FNAL meeting to discuss beam dynamics WPs
  - across all AS.
- NOTE: it is <u>critical</u> that all beam dynamics calculations are cross-checked by at least one quasi-independent group
  - Role of Simulation Group to monitor this.

# 今年の予定

- 電話会議（1回/2週程度）継続予定
- 10/10-12 BDS Kick Off Meeting
- 10/22-26 GDE Meeting
  - Workpackage organization will be almost done (???)
    - 誰が責任を持つかを決める必要はあるが、後から来る者のcontributionをdiscourageしないようにすべき
    - 全「package」のリストを作って、一斉にスタートするのか？　できたものからそのつど始めるのか？
- 11/5-7  Workshop at IHEP
  - ？？？
- 12/11-13 ILC LET Beam Dynamics Workshop
  - 主にscientific な議論をしたい