Dynamic Tuning

Selected Highlights
Freddy Poirier (DESY)

ILC accelerator physics group meeting

28th January 2008

Definition

- What does Dynamic tuning mean?
  - Steer to preserve the emittance while dynamic effects occur.
    - Maintain the “golden orbit” over time (until emittance/luminosity demands a re-application of BBA)
    - Understand/ Define trajectory correction scheme
- Burning points (Important studies)?
  - Ground motion, Feedbacks, see lists later
- What does it not include?
  - It’s ML (only?) so does not include other sections.
  - Though BDS, RTML have some inter-relation, i.e. impact of feed-back system in the other sections.
  - Start-to-End (LET) Simulation work tackle in a broader view the inter-relation of these sections (see slide later).

Workpackage 6
Dynamic Tuning

Work package definition (C. Adolphsen)

a) Specify acceptable fast and slow quad motion in terms of amplitudes and correlations. For the latter, determine the implications for the 'static' tuning system.

b) Specify a fast FB system to stabilize the beam orbits, including the requirements on the magnet response times.

c) Specify methods for measuring the bunch/beam energy profile, matching the quad lattice and regulating the bunch energy at the end of the linacs. Work with Controls and LLRF to have these implemented.

d) Specify system and procedures to monitor the bunch/beam emittance including the instrumentation requirements. Work with the Instrumentation group to design bunch size monitors.

Here only these subjects are addressed

Tasks list from K. Kubo, DT should incorporate:

a) Ground motion and vibration model for the ILC.

b) Time-dependent errors in the magnet settings, RF power, and BPM performance.

c) 5 Hz feedbacks, 3 MHz feedbacks, and train-straighteners feedbacks

d) Resteering or continual steering models

e) Initial beam jitter, both train-to-train and intra-train, which is expected from the results of the RTML.

f) 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.

Important points

- Time Scales
  - Frequency spectrum of perturbation is important to understand / define
  - Perturbation=
    - Quadrupole motion
    - BPM drift (mechanical? Electronic)
    - …
  - Need to understand effectiveness of slow compensation while understand impact of uncorrected fast perturbations.

Dynamic Tuning

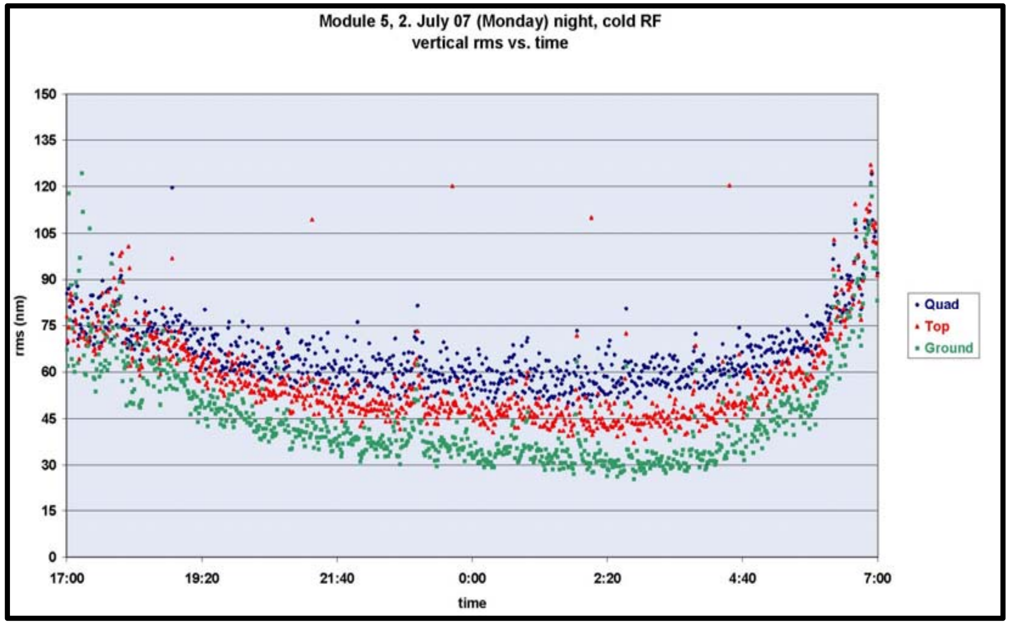
- The Beam-based feedback sets the limits. Every thing below the cut-off of the fdbk is corrected
- Choice of feedback systems:
  - Intra-train feedback systems
    - "local" systems (speed) such as across IR or over a few FODO cells
    - Effectively re-steers the beam train on every single 5Hz pulse
      - Independent from pulse to pulse – feedback loop across 1ms train.
    - Questions: how many, how often, how do they interact? (connected by the beam!)
  - Slow (5Hz pulse rate) trajectory correction
    - Effective ~0.1Hz feedback (rep. rate / 20) (hardware / controls system constraints)
    - Approaches
      - Continuous steering ("true" feedback)
      - Periodic steering
        - » Effectively "turning on" feedback for short period of time to re-steer lattice after some period of time.
      - "global" steering vs "localised" steering
        - » Steering entire lattice in one go
        - » Localised feedback/steering loops interspaced along the lattice (a la SLC)
      - Steering algorithms
        - » Simple one-to-one
        - » Mikado
        - » Others???

Vibrations

- Specify acceptable fast and slow quad motion in terms of amplitudes and correlations. For the latter, determine the implications for the 'static' tuning system.
- Ground motion and vibration model for the ILC.

Contact person: P. Lebrun & D. Kruecker (Slow and fast ground motion). See talk at GDE meeting oct. 07

Night time measurements of the quadrupole (fast) vertical motion= <~100 nm



As a start, vibration can be added as white noise to quadrupole (certainly not enough, as correlation then not included)

Ground Motion

- Dynamic Tuning while a simple Ground Motion (ATL) is applied

1-to-1 steering correction in ML

Perfect alignment

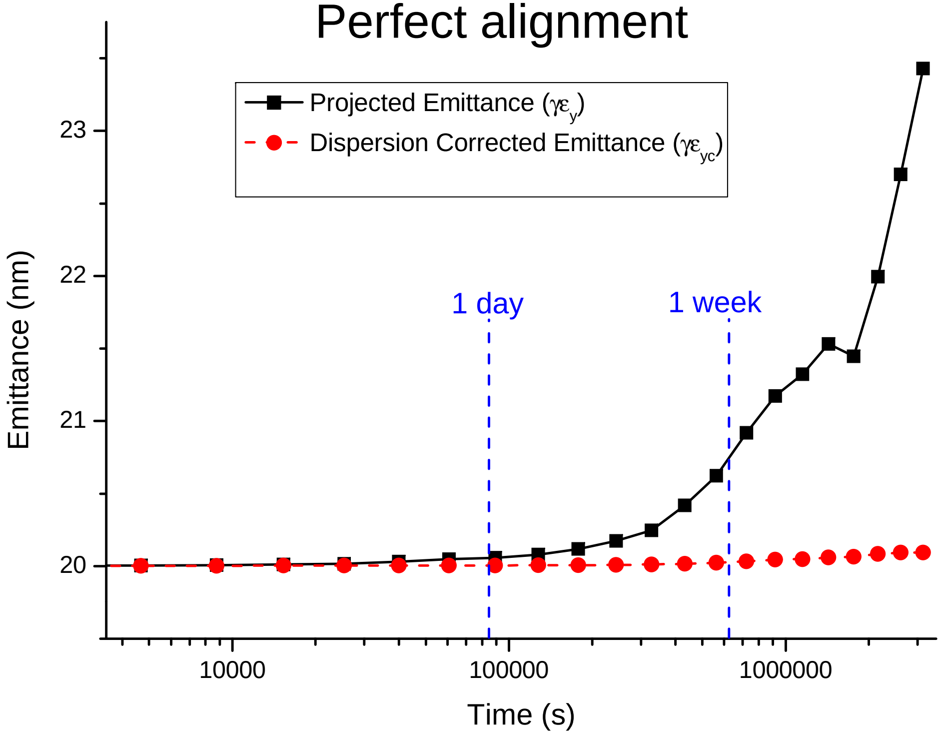
Several studies tackles ground motion effect on the ML:

Studies includes ground motion effect towards Start-to-end (with ATL or/and Seryi's model):

P. Lebrun, D. Kruecker, A. Latina, J.Lopez

A more realistic Ground Motion, Seryi's model, is on the market.

not in this model: Quasi periodic motion (tides), Hydrology, other?



Tuning

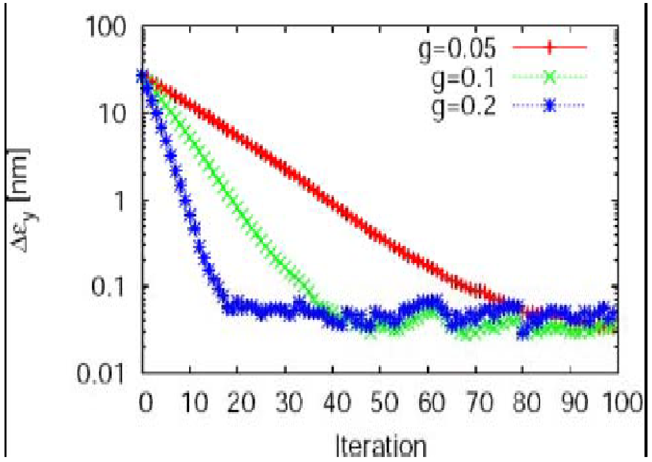
- On the effectiveness of the slow feedback system:

e.g. A. Latina, "Feedback Studies" – PAC07

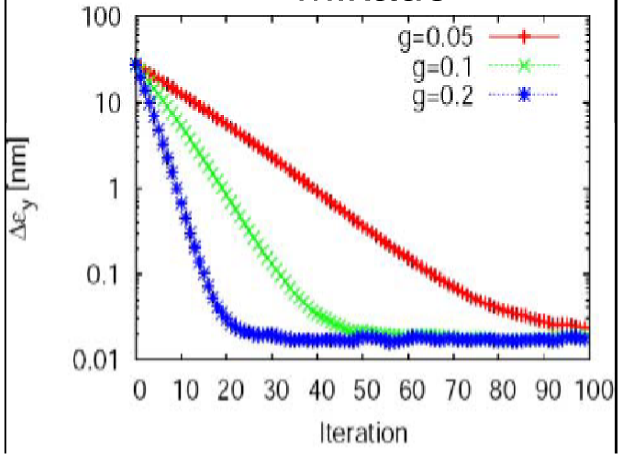
- Orbit feedback applied to a perfectly aligned linac (?).
- 1-to-1 steering compared to Mikado
  - Mikado performed better:
    - Reduces the emittance growth to smaller values
    - More stable over longer lapses of time
    - Good convergences
  - 1-to-1 magnify BPM noise

The MICADO method makes use of *optimal set* of correctors and BPMs, extracted from the system response matrix via an eigenvalue analysis.

1-to-1



Mikado

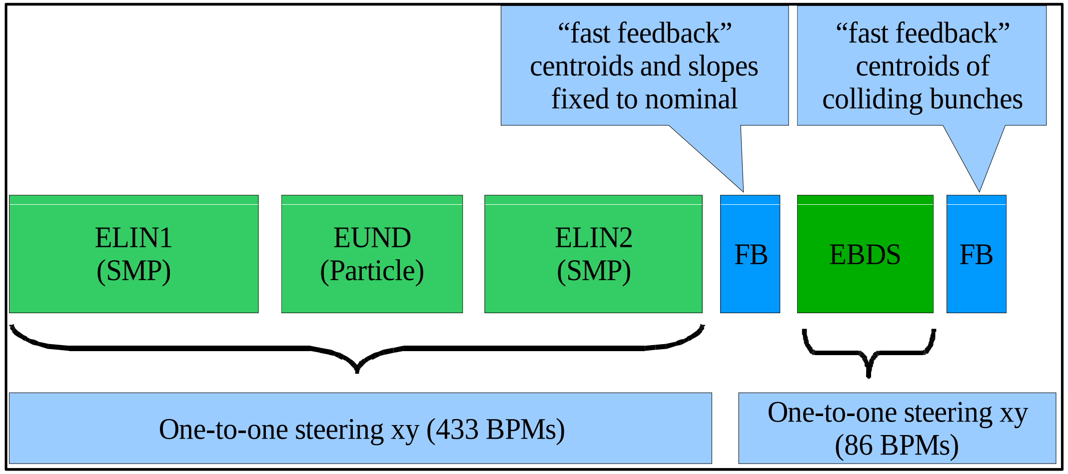


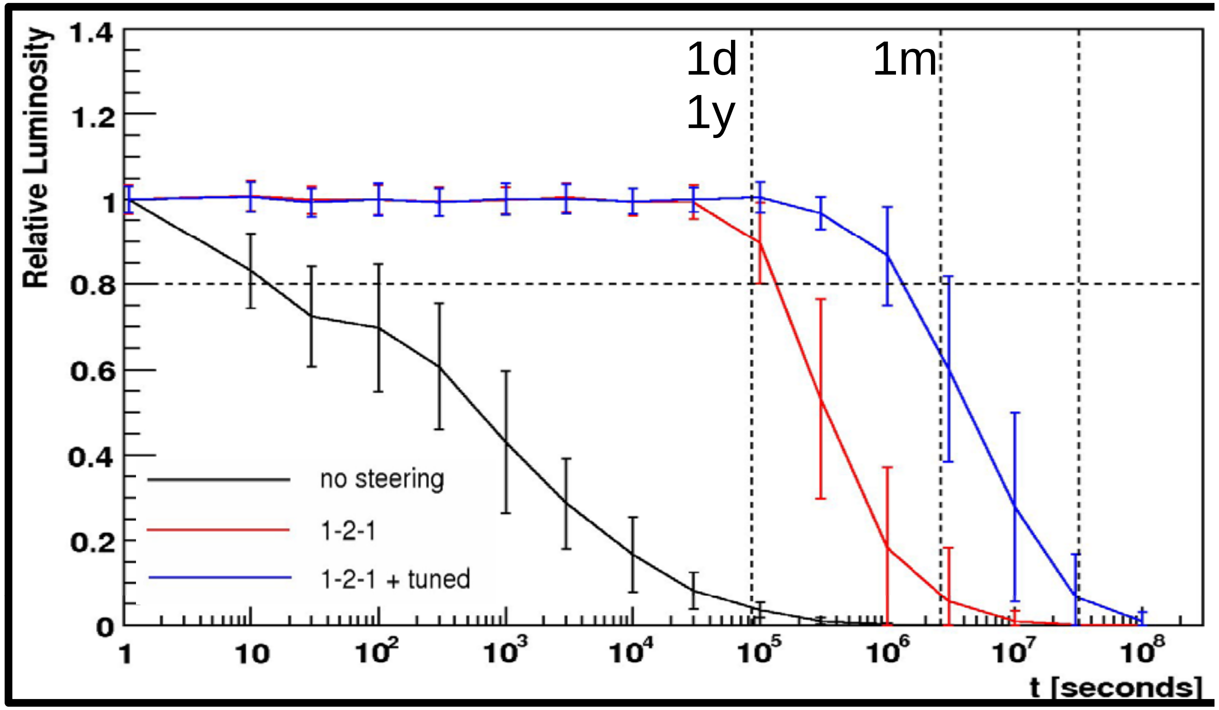
Start-to-end simulation with GM

Additional work from P. Lebrun, A. Latina for start-to-end simulation (see refs). Here only D. Kruecker's work shown.

- $\gamma\varepsilon_x$ = 10 μm
- $\gamma\varepsilon_y$ = 0.02 μm
- ATL in x and y
  A = $4 \cdot 10^{-18}$ m/s
- 1-2-1 steering
- Idealistic feedback and beam tuning
- 5 linear "tuning knobs"
  w_x, w_y, d_x, d_y, c_{xy}
- Cross section by GUNIEAPIG with

In our model the luminosity can be kept above 80% of the nominal values for about 15 (-7+15) days. Luminosity needs to be re-established then by a re-application of beam-based alignment.





From D.Kruecker

Feedbacks

- Specify a fast FB system to stabilize the beam orbits, including the requirements on the magnet response times.

- 5 Hz feedbacks, 3 MHz feedbacks, and train-straighteners feedbacks.

4 (local) fast feedback/foreward systems are in the literatures (see refs) and are potentially located in/at:

- RTML (gives input to the Main Linac)
- End of linac so-called train straightener (intra-train fdbk)
- 2 in BDS (IP-angle, IP-position)

slow feedback systems (5 Hz), dealing with the ML and BDS

- to control the orbit while slow ground motion occurs (<~0.1 Hz).
- chain of Fdbk are dependent (so each of these should know what the other fdbk is doing)

Questions here:

Coupling effects between feedback systems (?)

Latency, requirements (magnet)

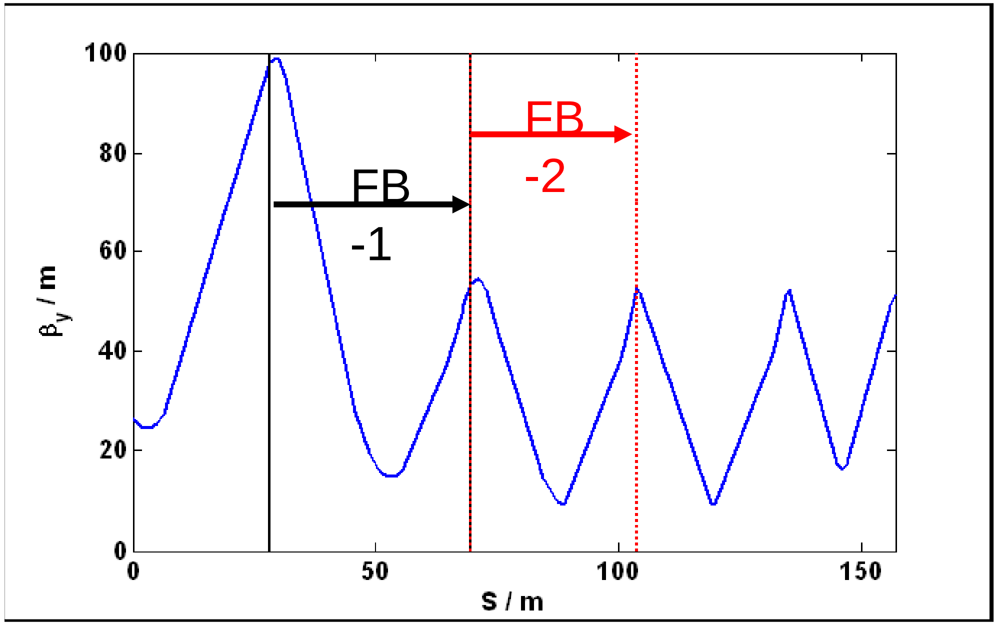
This is beyond the ML only. It is part of the BDS studies and ultimately start-to-end studies.

Fast Feedback

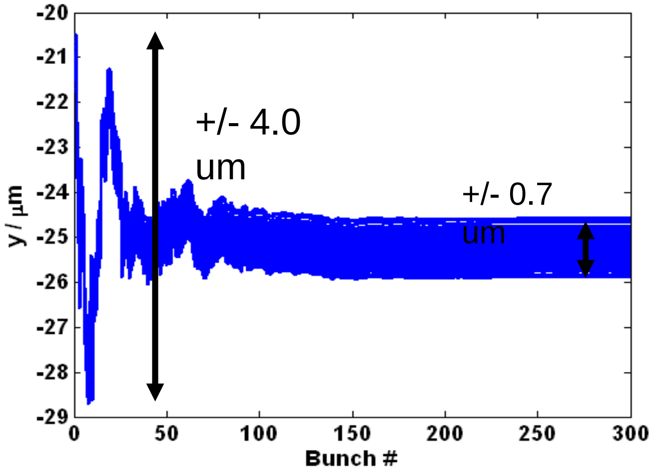
- G. White "DESIGN AND SIMULATION OF THE ILC INTRA-TRAIN ORBIT AND LUMINOSITY FEEDBACK SYSTEMS" – EPAC 2006 + talks (see ref.)

Studies of several fast feedback systems

Exemple from G.W's talk: BDS FFB (Train Straightener)



2 kicker/BPM pairs to straighten train and remove jitter at entrance of BDS.



0.2s model 'K' GM + 100nm Quad jitter

Latency of each feedback =~ <400ns

Feedback possible every-other bunch

BPM Resolution Requirements: BPM1<200nm, BPM2<265 nm

Comment from G. White: When running both fast feedback: Fine if the end-of-linac FFB is at a much lower gain than the IP Fast Feed-Back

Errors

- Time-dependent errors in the magnet settings, RF power, and BPM performance.
- Initial beam jitter, both train-to-train and intra-train, which is expected from the results of the RTML.

- **Beam jitter (Communication with N. Solyak/ P.Tenembaum) at entrance of linac:**
  - bunch -to-bunch Vertical/horizontal jitter ~ 0.2 sigma (0.1 sigma in wiki) with feedforward system
  - Train-to train stability ~1 sigma probably is acceptable
  - Time jitter ~0.7ps
- **BPM performances**
  - Resolution - several studies 1-10um
  - Linear scale error (<10% acceptable?)
  - Time dependence: No studies
- **Magnet errors: No studies for Dynamic tuning in ML**

  Most studies concern the BDS and/or BBA

  It has an impact on the convergence of the feedback systems
- **RF power: No studies with DT in ML**

Conclusion

- Quite a few studies which include dynamic effects
  - Ground Motion & Vibration
  - Slow correction (1-to-1, Mikado)
- More to be done:
  - Strategy of the slow correction has to be reviewed (continuous steering or periodic, on entire lattice or sections)
  - Effectiveness of steering with Ground motion
    - With machine initially tuned
    - More realistic GM (?)
  - Effectiveness of fast feedback for ML
  - Coupling action of fast Feedback
    - Application strategy of several FFB (e.g. gain)
- Will have to integrate the above effect into the start-to-end simulations
  - Steering in the undulator (?)
- **Missing here:**
  - **Complete review of what has been done**
  - **Concrete step by step plan for the work**

Somes References

- C. Adolphsen "**Beam dynamics issues in Main Linac**", LET Beam Dynamics Workshop at SLAC Dec. 2007.
- D. Kruecker "**MERLIN-Based Start-to-End Simulations of Luminosity Stability for the ILC**", THPAN024 - PAC 2007
- K. Kubo " ", LET Beam Dynamics Workshop at SLAC Dec. 2007.
- A. Latina "**Feedback Studies**" – THPMN059 - PAC 2007
- A. Latina "**Dynamic Effects During Beam-Based Alignment**" – THPMN062 – PAC 2007
- P. Lebrun " **Recent Studies of the Dispersion Matched Steering for the ILC Bunch Compressor and Main Linac**" - THPMN104 - PAC 2007
- P. Lebrun, D. Kruecker, "**Ground Motion and Vibration for LET Simulation, "Point of Contact" – ILC/GDE meeting**
- F. Poirier "**Evaluation of the Component Tolerances for the ILC Main Linac Assuming Global Linear Corrections**", THPAN025 – PAC 2007
- F. Poirier "**DFS with dynamic effects**", LET Beam Dynamics Workshop at SLAC Dec. 2007.
- N. Solyak, private communication
- G. White **"Design and Simulation of the ILC Intra-Train Orbit and Luminosity Feedback Systems"** – EPAC 2006 - http://www.eurotev.org/e158/e1365/e1378/e2687/EUROTeV-Report-2006-088.pdf
- G. White "**BDS Front-End FFB System**", http://www-project.slac.stanford.edu/lc/bdir/Meetings/beamdelivery/2006-09-05/BDS%20Front-End%20FFB%20System.ppt
- + Private communications (G. White, D. Kruecker, P. Lebrun, N. Solyak, A. Latina)