LET Studies based on CHEF, Spring 07 Report.

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Topics (Focus: BC2, M.L.)

- Benchmark, learned lessons.
- Lattice studies (Alex V. contribution, not in this talk)
- rf Cavity Propagator Accuracy w/out Wakes.
- Dispersion Matched Steering,
  - Static: Methods, Options, Robustness.
  - Dynamic: Jitter, vibration, ground motions implementation.
- Other work at Fermilab:
  - Preserving the emittance once aligned: 1-to-1 and adaptive alignment. Related to 5 Hz feedback.
  - Ground Motion Studies, new data.
  - LET through the undulator.

Acknowledgment

- CHEF team : Leo Michelotti, Francois Ostiguy,
- Lattice expertise: Alex Valishev
- Beam Physics: Valentin Ivanov, Kirti Ranjan
- Computing Support : Lynn Garren
- Ground Motion data: Jim Volk
- Leadership: N. Solyak, P. Spentzrouris.

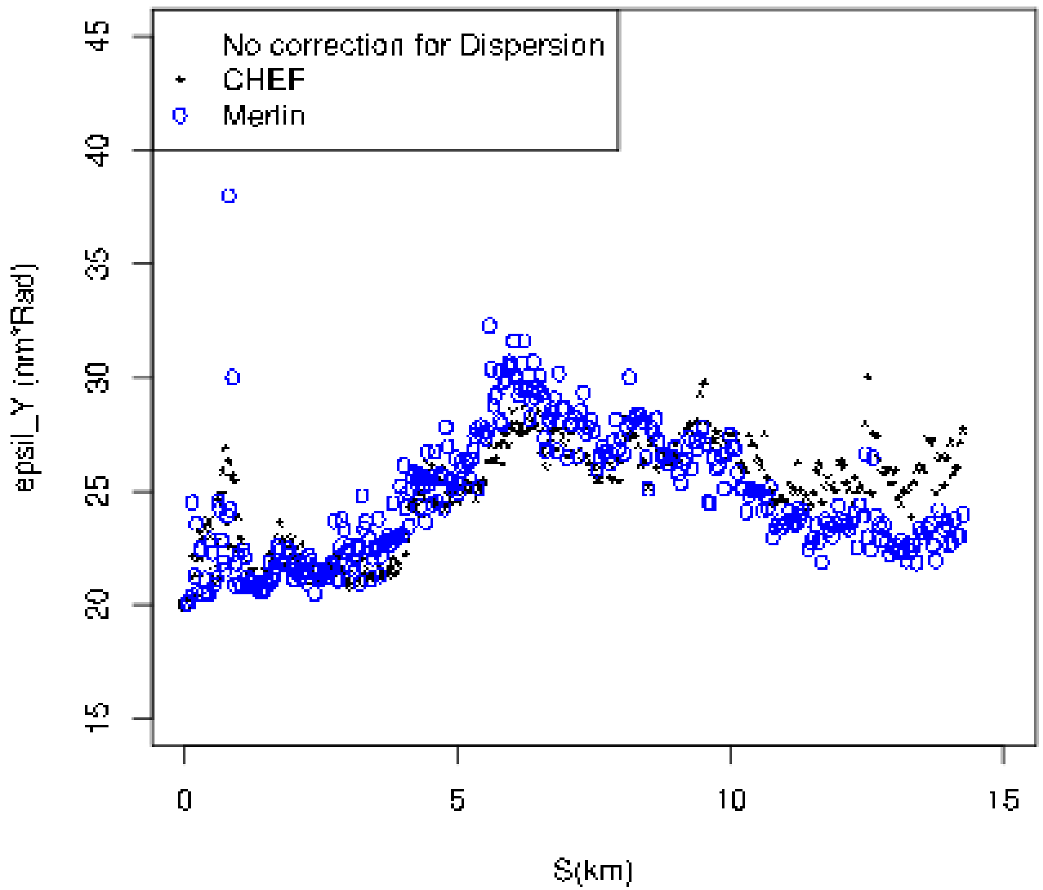
Goals of such Simulations

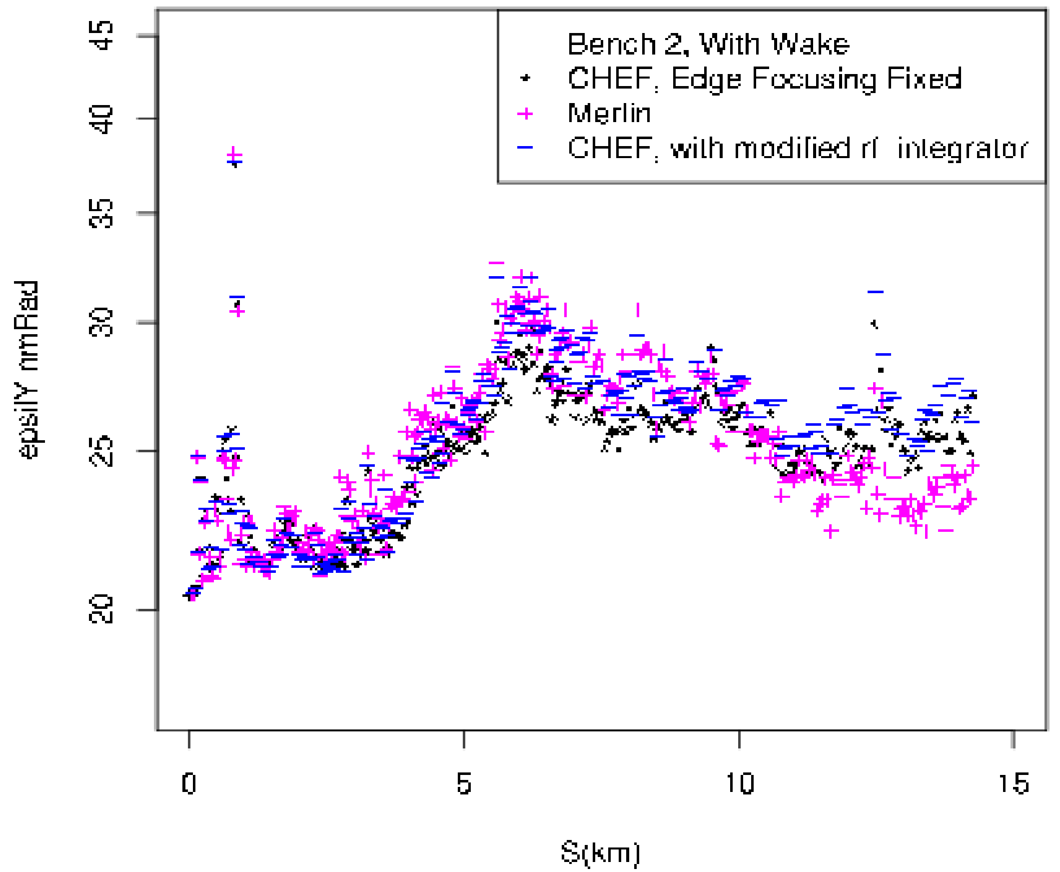
- Design certification ? Estimate performance?
- Give suggestion(s) to mitigate risk of LET under-performance. Such as :
  - Isolate Quadrupole/Corrector package from the r.f. cryostat, to improve vibration and measure motion.
  - Instrument HOM, to estimate misalignment and semi-qualitative estimates of wakes.
  - Remotely adjustable cavity couplers, so that relative cavity phases/impedance can be re-adjusted for greatly varying klystron output power and pulse length, as the rf power requirement during steering and normal operation are different.
  - *Improve rf cavity alignment tolerance, or, if not possible, suspend them on movers. (and instrument HOM)*

Benchmark Update

- After Daresbury meeting:
  - Review emittance calculation, realized that we were comparing Δ y. Δ y' to Δ y to ΔPy/P_ref (not P_z ref.) This explain most of the discrepancy, particularly at the spike at 800 m.
  - Review the rf Cavity propagator, apply the short range wake in the middle. This was a non-trivial difference... Which prompted further studies...
- => no obvious CHEF bugs were found, but concern about simulation accuracy of our code were raised.

Benchmark, Result





Discrepancy in the emittance spike, at z = 0.8 km, understood and "fixed"
"Systematic error" of ~ 1.5 nm remains, due to rf Cavity propagator.

Transport through rf Cavities.

- Required accuracy, single particle. Energy dependent. At 5 GeV, 20 nm radians, in a lattice similar to ML or BC2, σ y' ~ 280 nano-radians. Requiring a few percent of this figure seems adequate => ~10 to 20 nano-radians.
- Trajectory not dictated by beam envelope equation, but by misalignment tolerance:
  - Perfectly aligned system, 3 σ -> ~15 μm, .8 μ-rad.
  - Misalignment, 2 ~ 3 σ -> 1mm, 500 μ-rad.

R.F. Cavity propagator simple test case.

- Compare various models of edge focusing, w/out ponderomotive force, to brute force numerical integration. Very simple test
  - Propagate one ray with LIAR, 1st order, Rozenzweig-Serafini, CHEF, Numerical integration (Runge-Kutta, 4rth order, fine step, G4, ILC Tesla 9-cell cavity), with y' = 0.5 miliradians, y = 1 mm.
  - Observe 10 to 20 nm discrepancy, corresponding to 2nd order in the $(\Delta\gamma/\gamma)$ expansion.

Transport rf Cavities, Status

- Satisfactory linearity for single particle optics.
- If accurate benchmarking, and mm/mRad cavity offset/tilts, 2nd order in $(\Delta\gamma/\gamma)$ expansion recommended.
- CHEF authors are improving their cavity propagators.
  - And (unrelated), the implementation of Short-range wake, to improve CPU performance (via FFT convolution instead of brute force numerical integration).

Dispersion Match Steering

- DMS == DFS for curved lattice. Not free of Dispersion...
- Basic, + essential subtleties agreed upon..
- Progress on:
  - Tweaking existing algorithm
  - Realistic constraints (curved Linac limits $\Delta P/P$!)
  - Dynamic, i.e., doing it while the machine moves and the beam jitter.

DMS in CHEF, code status.

- Single package for Dynamic & Static studies.
  - Things are assumed to be moving, fix = negligible motion.
  - Iterate: more than one pulse required to steer the beam. Convergence criteria:
    - Closer to the nominal Dispersion Value (but what is it?)
    - Incremental kick corrections decreases and becomes small enough (~ 2.5 μT.m @ 15 GeV/c)

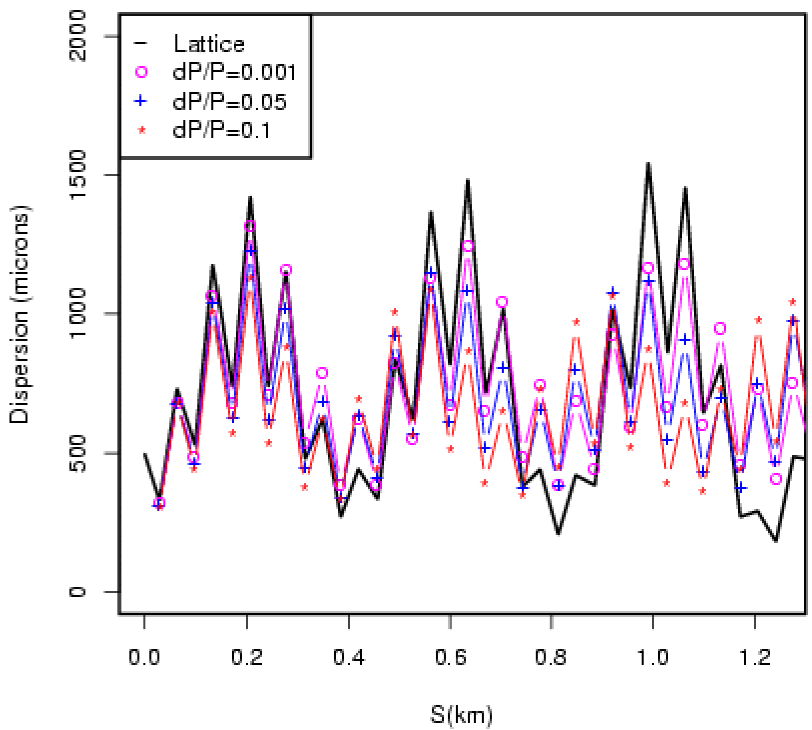
DMS: Variants

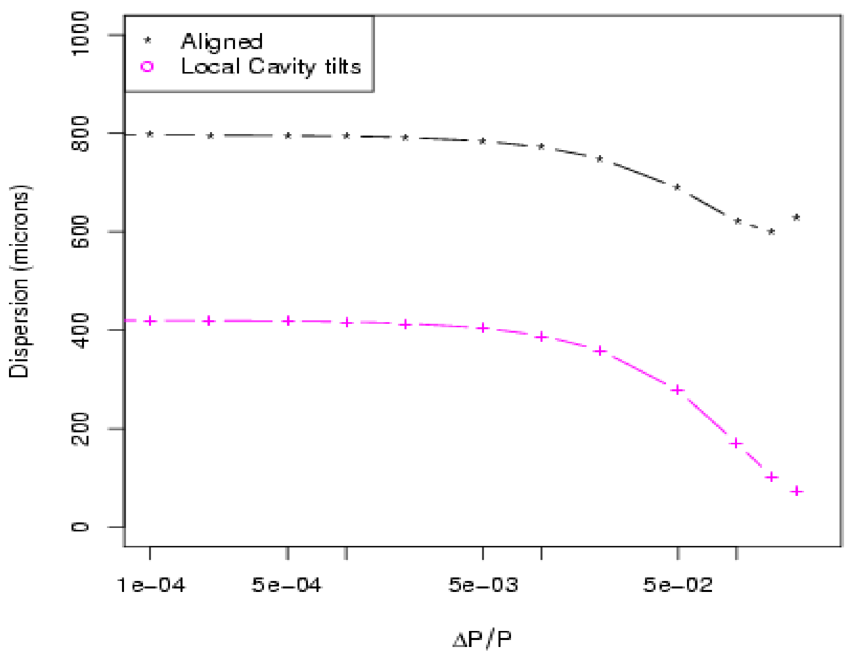
- Implemented, not extensively studied... And not exhaustive list!
  - Assume the 2nd Stage BC can decelerate by few percent. All ML structures are assumed to be misaligned.
  - Minimizing: ad-hoc weight between δ Dy (current-optimum), orbit reduction, corrector amplitude minimization.
  - SVD tuning: control of "null-space" via SVD weights.
  - Cavity tilt correction (tentative).
- Possibility of re-adjusting the Dy, Dy' at the RTML-ML matching section.. (Similar to a Dispersion bump).

DMS: Optimal Dispersion?

- To the “nominal”, perfectly aligned lattice.
  - Most sensible, in absence of additional information, probably close to what one can do.
  - But tricky: Can we determine Dy, Dy' unambiguously?
  - Keep the off-momentum bunch in the machine.
    - Either compensate energy later.
    - Small ΔP for off momentum.

Dispersion in the ML curved lattice





- Lattice RDR_V0, A. Valishev
- D only at BPM, perfect resolution!
- Machine aligned.
- DP/P not too big!

- 16 cavity misaligned by ~ 0.3 to 0.6 mRad, starting at s = 0.23 km. Big changes, but what is the optimal D, D', and path ?
- Assume it is the same as perfectly aligned...

DMS: W/Out Wakes Fields?

- Can we steer with compressed, high intensity bunches?
  - If yes, Machine protection: how do we get rid of the off momentum bunch?
  - If no, non-optimal solution, since the short range wakes deflect the beam significantly.
  - CPU time for Dynamical cases, with Wakes: tedious!.

Standard Misalignments & BPM

- Following suggestions from FNAL/PPD alignment group, added “Monument” errors, every km, 300 microns, random.
- BPM: Displaced (300 microns), but, (in the static limit), no Gaussian pulse to pulse fluctuations, as one can average over many pulses. No Slope errors for the results shown later.

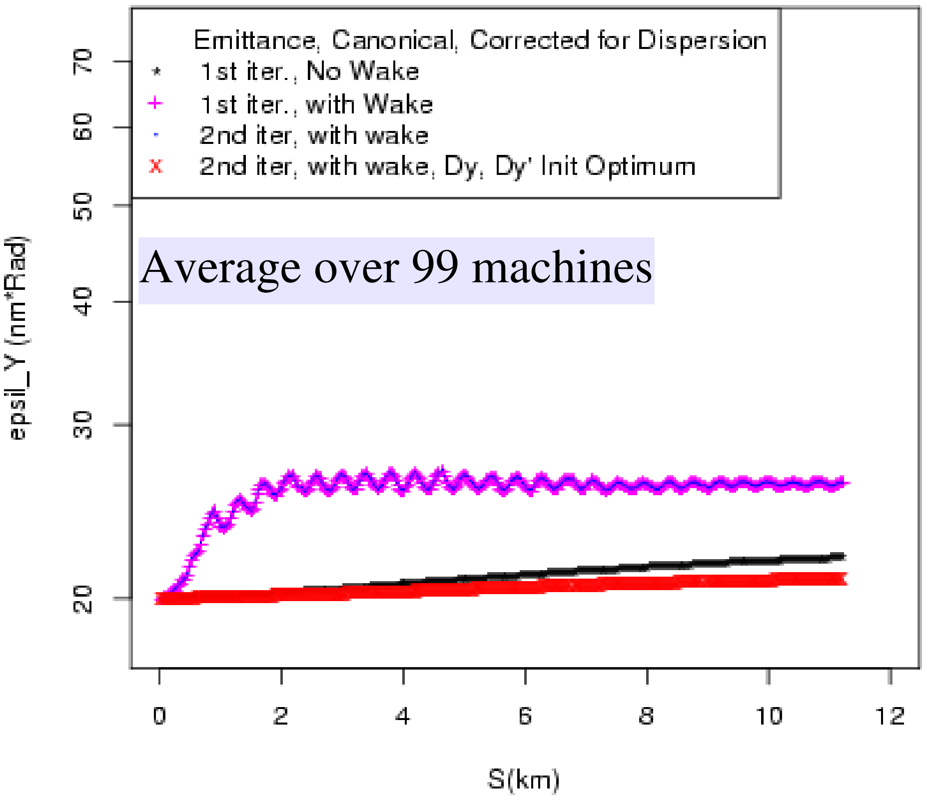
Ground Motion in LET/CHEF

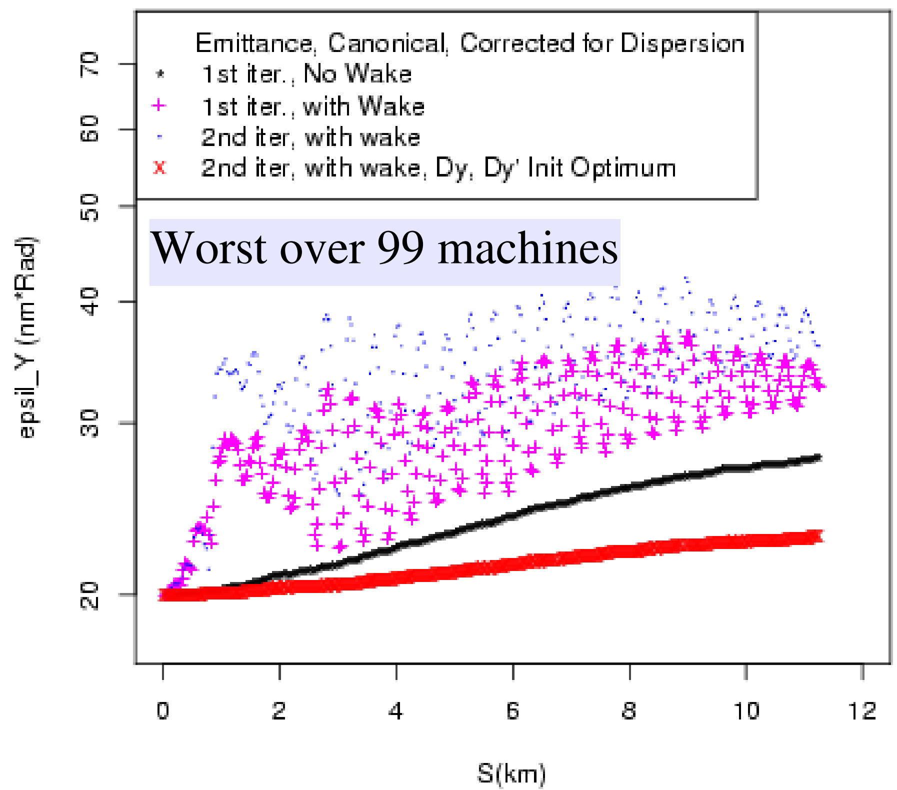
- Classic ATL+vibrations:
  - "Standard", implemented
  - But.. is wrong for selected cultural noise (pumping water our of the aquifer), moon tides (~ microns per 30 m. in FNAL/Numi tunnel)
- Using HLS data directly: mapping section and time intervals of the Numi or Aurora mine tunnel HLS relative δ to a section of our simulated ILC (suggested by V. Shiltsev) :
  - Status: implemented, running on desktop, not yet exploited on FermiGrid.

Running LET at Fermilab.

- Despktop: commissioning, short studies.
- FermiGrid (Condor/Globus,..)
  - Parallelism at the level of “misaligned machine” and/or ground motion seed.
  - About 100 “jobs slots” allocated to ILC-Accelerator VO
    - for Lucretia/Dynamic (in the process of being debugged, installed)
    - CHEF/LET Steering: in operation.
  - Numerous scripts for submitting, monitoring, retrieving and collecting results.

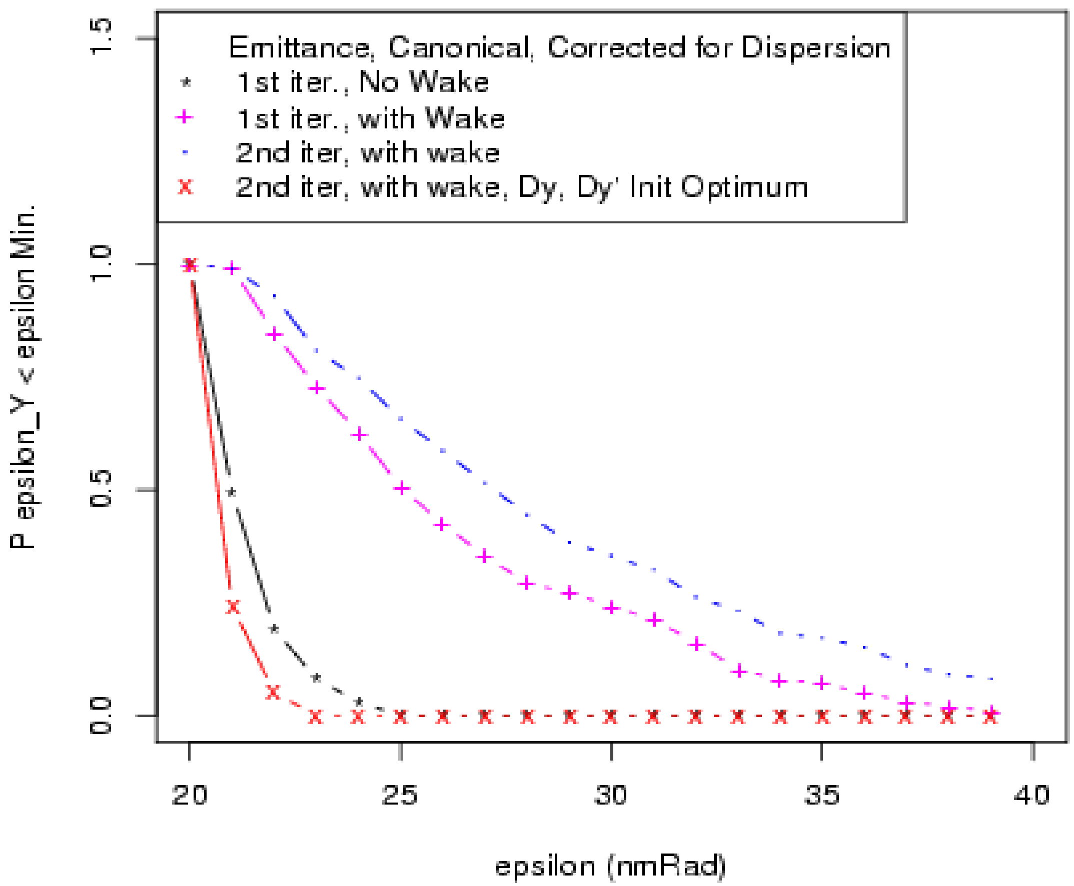
DMS, Static: ε_y vs s





- Tuned without wake (i.e., bunches with low charge)
- With large number of pulses, i.e., perfect BPM resolution

DMS, Static, Performance over 99 machines

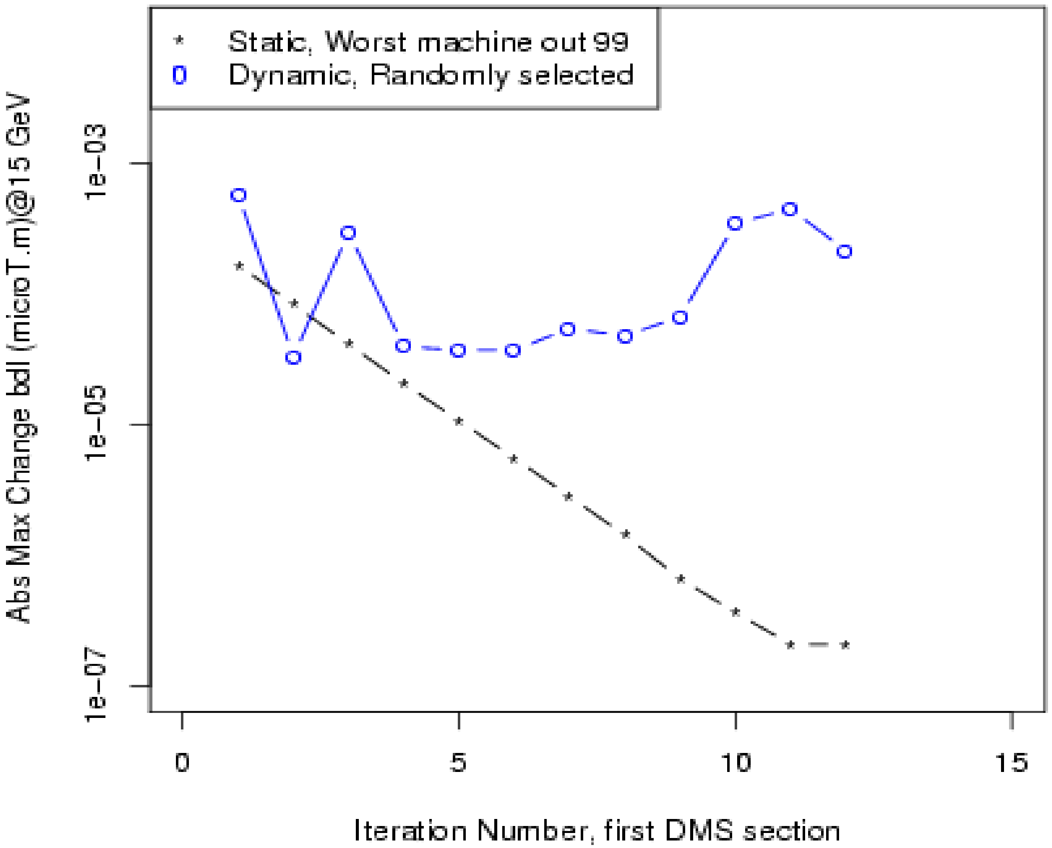


- Tuning must be optimize with wake fields on, i.e., bunch rotated and nominal charge.
- If not, can improve by re-adjusting the initial Dy, Dy'. This is a "non-local", i.e. "bump equivalent" corrections.
- Further simulation with wakes and bunch charge variation needs to be done, and
- With quadrupole rotations, X-Y coupling from cavities...

DMS, Dynamic: Example Run

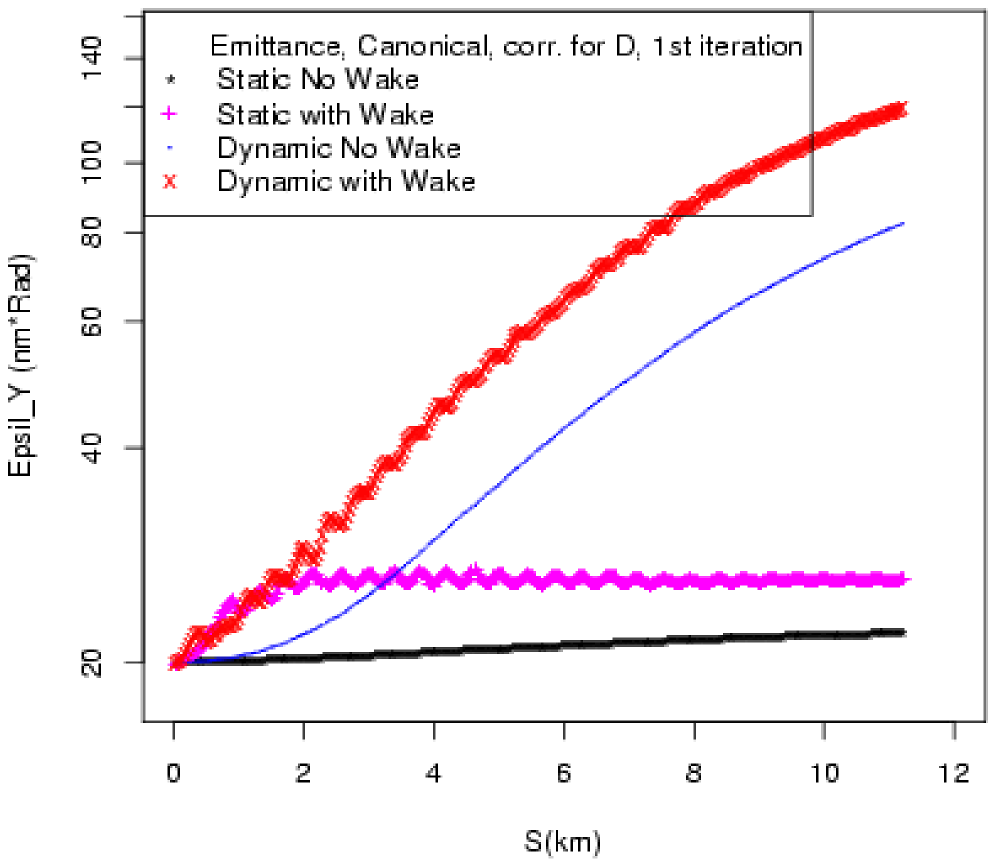
- Beam jitter: 1 micron, 0.1 micro-radians at injection
- Klystron Voltage jitter = 0. (.5% expected..)
- Ground motion: ATL, A = 5 10^-17 m^2/sec^2 + vibrations
- BPM resolution = 0.5 microns
- Running at 5 Hz, max 12 iterations per 20 BPM long DMS sections, (overlap 10 BPM), 30 sec. between local DMS iteration, 5 min. between global iterations. (one iteration through the entire Linac takes in real time only 29*33 sec = 16 min..)
- ... (i.e., details need to be documented!)

DMS, Dynamic: Local Convergence Issue



- In the static case, the maximum incremental change to the dipole correctors decreases exponentially, for a gain of 0.5. The optimization is well behaved, convergence toward the an acceptable solution (albeit not necessarily unique) occurs in ~12 steps, or less.
- This is not the case in the dynamic case specified in the previous slide. To save time, no more than DMS steps are taken, no point trying further, as the solution keeps "jittering".

DMS, Dynamic: Example



- Obtained for over 25 machines.
- Significant degradation compared to the static case
- Wake still play a big role.
- The re-optimization of D, D' at injection might not bring emittance dilution to an acceptable level.
- Suspected “bad parameter”: beam jitter (not BPM resolution). One micron is too much.

Outlook: CHEF development & LET Static

- Keep exploiting existing code, bug fixes and upgrade
  - Better XSIF parser.
  - rf Cavity Propagator Accuracy.
  - Faster implementation of Wake fields
- LET, Static
  - Keep searching for better static tuning without non-local corrections (need ideas!!?)
  - Revisit Balistic alignment? Need to know more about tolerances, “mechanical hysteresis” ?
  - Run with different wakes. (ICHIRO, re-entrant.. cavities..)

Outlook : Dymanic Steering

- DMS Dynamic, towards a realistic simulation of the process:
  - Lots of running/studying to do!: more DMS tuning, establish parameters critical values.
  - Improve Ground Motions :
    - More data will be available
    - Better Analysis: Distinction between "Random" vs "predictable" (tides, scheduled cultural noise)

This proposed work is consistent
with Nikolay S. & Pt work list.