Status of LET Steering Studies with CHEF

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Outline

- Why CHEF ? Does it work ? .
  - **The preservation of the transverse emittance is a necessary condition for high luminosity of the collider**
  - **Benchmarking results.**
- Steering Studies in CHEF (easily portable to Merlin)
  - **Only starting!**
    - With easy problem..
  - **A set of questions**
    - Focusing on Stability of steering
    - As they have to be studied in a dynamical environment

Why CHEF ?

- Other codes at FNAL :
  - **N. Solyak, K. Ranjan, Supported by Pt and Francois Ostiguy, are studying Low Emittance Transport) LET with MatLIAR. A good things, as this package is mature and trusted.**
- Other people (AD, CD) were interested in benchmark results
  - **But why don't you look at our FNAL codes!**
  - **CHEF authors (Francois Ostiguy, Leo Michellotti,…) and CHEF users (Panagiotis Spentzouris et al, e.g. Synergia) were eager to understand what it take to study LET …**
- Merlin and CHEF have similarities:
  - **Started from the same idea ~10 years ago**
  - **Evolved differently..**
  - **Implementation of physics packages, such as Short Range Wakefields can be migrate from one framework to another (current CHEF Wakefield is "borrowed" from Merlin!). ..CHEF Steering could easily put back in Merlin**

CHEF Benchmark

- Steps:
  - **Make sure the core CHEF code works with positrons.**
  - **Lattice parsing was there at the onset..**
    - Means I should be ready for the current lattices in RDR sites.
  - **Added utilities to upload misalignments, dipole settings.**
  - **Brought Merlin short range wakefield code into my CHEF User code.**
  - **Also brought the Merlin quadrupole propagator into CHEF/user**
    - -> allows to compare individual physics sub-packages.
  - **Same beam files Merlin/CHEF !**
    - Allows for individual trajectory comparisons.
  - **Same emittance calculation.**
  - **Both Framework leave the graphing up to the user.**

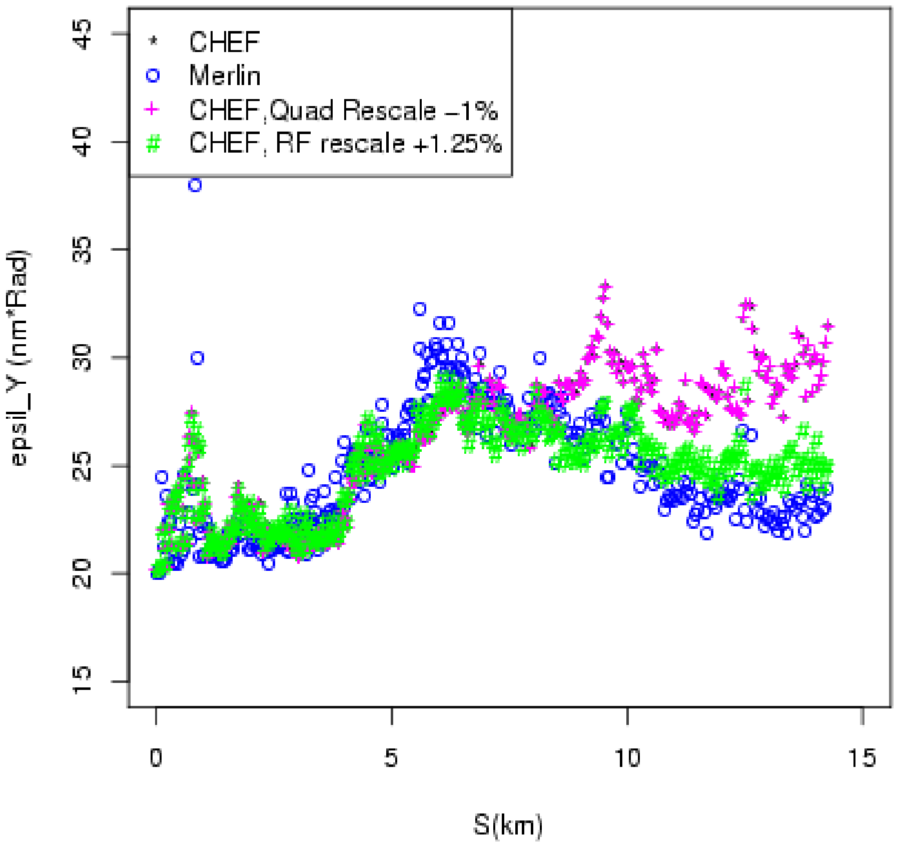
    (Unlike MatLab based codes)

CHEF Benchmark, hurdles

- Documentation
  - **Merlin: some web-pages.**
  - **CHEF: Author next door**
  - **Much needed: Reference Manual, with detailed description of the beam physics**
    - Learn the beam physics by reading code ! *Not really optimum*
- My own sloppiness in writing user part of the code… a particular bug in setting the K factor for the quads lived on for a long time!

CHEF Benchmark, Results

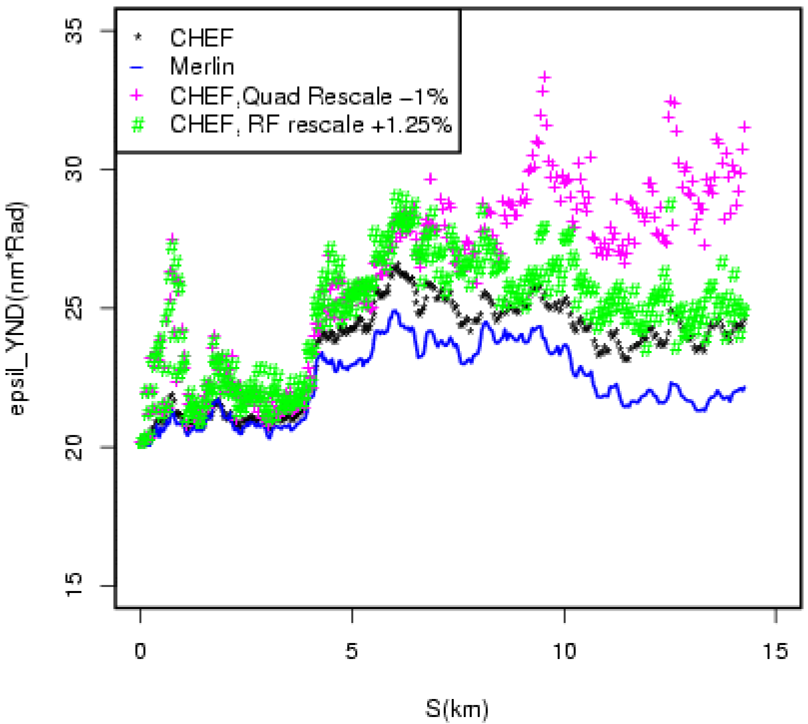
Normalized Emittance
Dispersion not taken out



- CHEF/Merlin comparison.. (Could have done also CHEF/MatLIAR.. One is enough..)
- Seemingly insensitive to quad rescaling of constant factor. (* and + nearly on top of each other)
- But sensitive to rescaling of the effective gradient => beam loading still different in the two codes.

CHEF Benchmark, Results

Normalized Emittance Dispersion **is** taken out



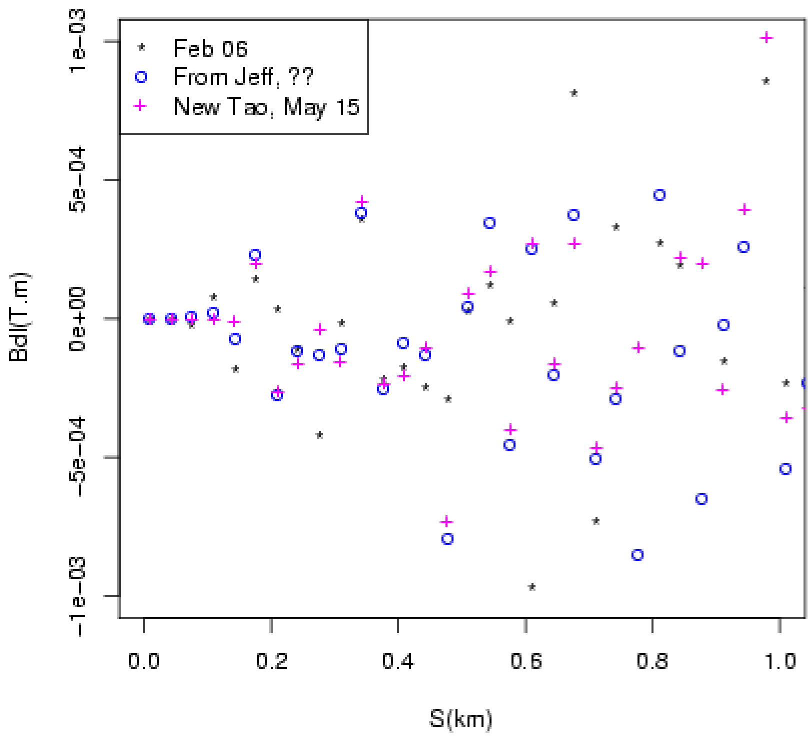
- Conclusion changes if the dispersion is taken out..
- Merlin still preserves emittance better than CHEF
- Residual bug, or genuine feature?
- What is the precision requirement? Does one nmRad matters on this benchmark?

Note On Benchmark History…

- Conclusion changes if the dispersion is taken out..
- Merlin still preserves emittance better than CHEF
- Residual bug, or genuine feature?
- What is the precision requirement? Does one nmRad matters on this benchmark?
- And one more caveat….

Dipole corrector settings are fixed, package independent

On dipole corrector settings..

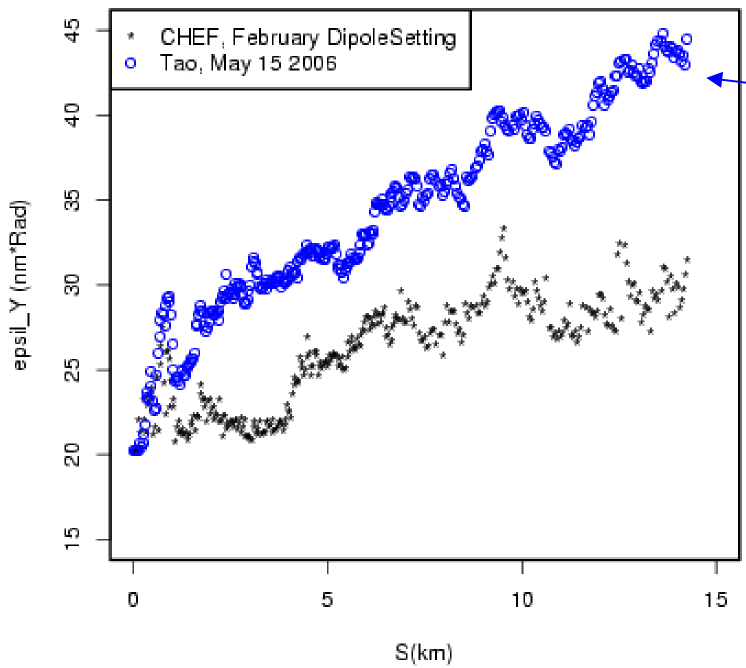


Blue “o” refers to intermediate results… Probably from MatLIAR

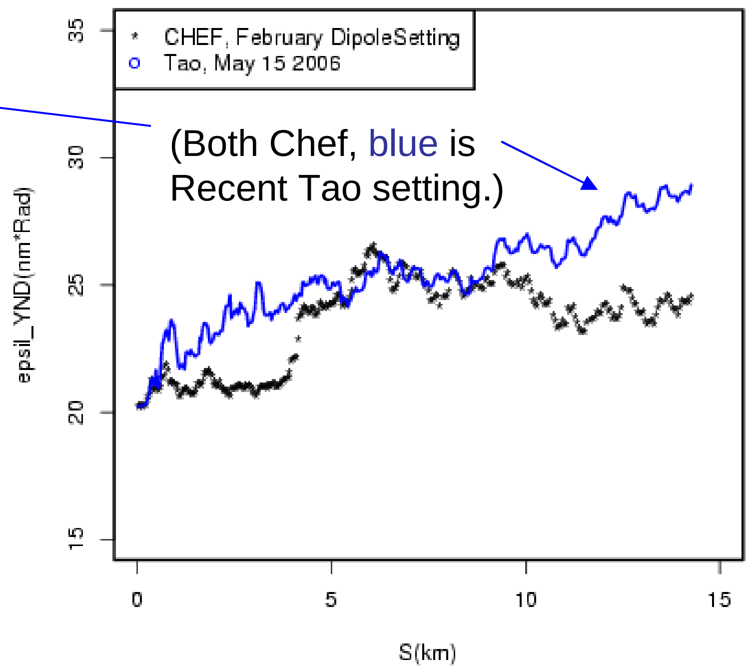
- DFS “results” changed slightly during the benchmarking process, as improvments were made both in Tao and MatLIAR.
- And different set of corrector were used..
- Although these changes produced relatively small differences in the final emittance growth, the relative changes between these solution is big, and for a given dipole, the sign of the correction changes.

Different Corrector settings…

NOT corrected for dispersion



corrected for dispersion



The Tao settings gives worse performance, for the emittance growth, not corrected for dispersion…

Is CHEF "OK" ?

- Probably..
  - **But I would agree that more detailed comparison and exchange of algorithms between package could be very useful (and detailed description of the approximation being made…)**
- Worth starting to look at Steering algorithms, may be CHEF needs just a slightly different set of dipole corrector values, and performance will be as good as in the other codes.
  - **Let's get going with LET itself!**

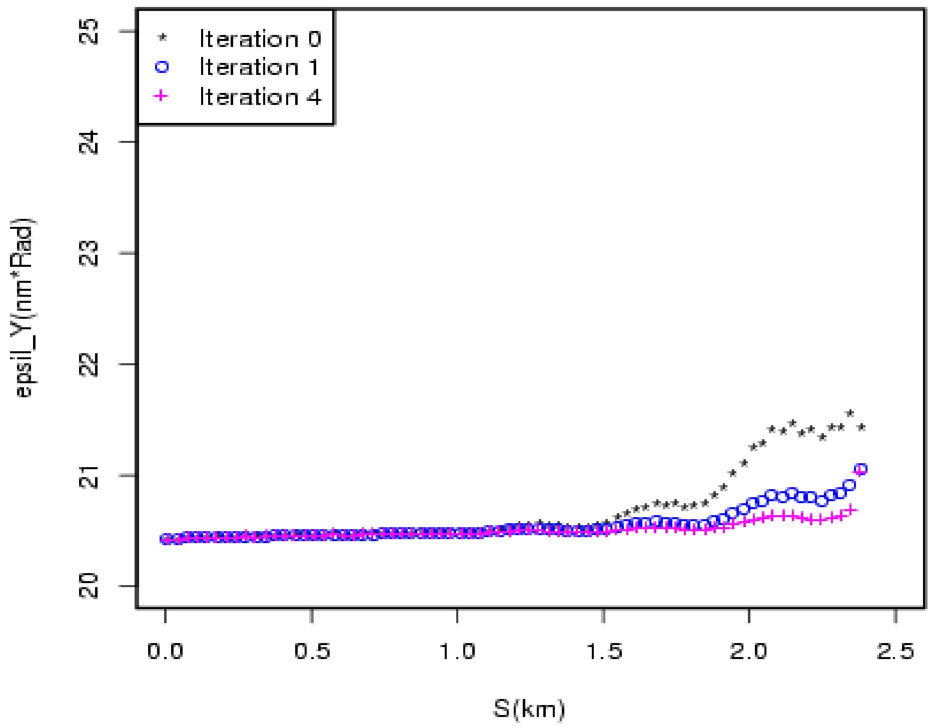
Steering Package, design

- Build on previous lectures and discussion, and experience.
  - **Coding from scratch, but concepts and algorithms not new.**
- Support many algorithms, re-use of some infrastructure
  - **In practice, iterate over the design of this software.**
- Must be able to steer while the machine is moving.
  - **Static vs dynamic? In reality, always dynamic!**
  - **=> algorithms must be robust enough to be perturbed, and recover.**
- Support numerous studies, allows for diagnostics.

Steering Package, Status

- Infrastructure written…
- 1-to-1 and DFS (or, more precisely D**M**S, “Matched”) written.
- Easy to write BBA, or mixed algorithms (“DFS” with “weights”)
- “Tested”
  - **1 – 1**
  - **DFS tested in easy case. (see few next slides..)**
  - **Many parameters not tuned yet.**
- “Tuned” :
  - **working on DFS, checking and understanding previous work by Kiyoshi, Pt, Daniel..**

Example : DFS pure and simple.



Cheats:
BPM : perfect, no scale error, infinite resolution, but misaligned.

No quad. Rotation.
No Beam jitter.
Cavity perfectly aligned.

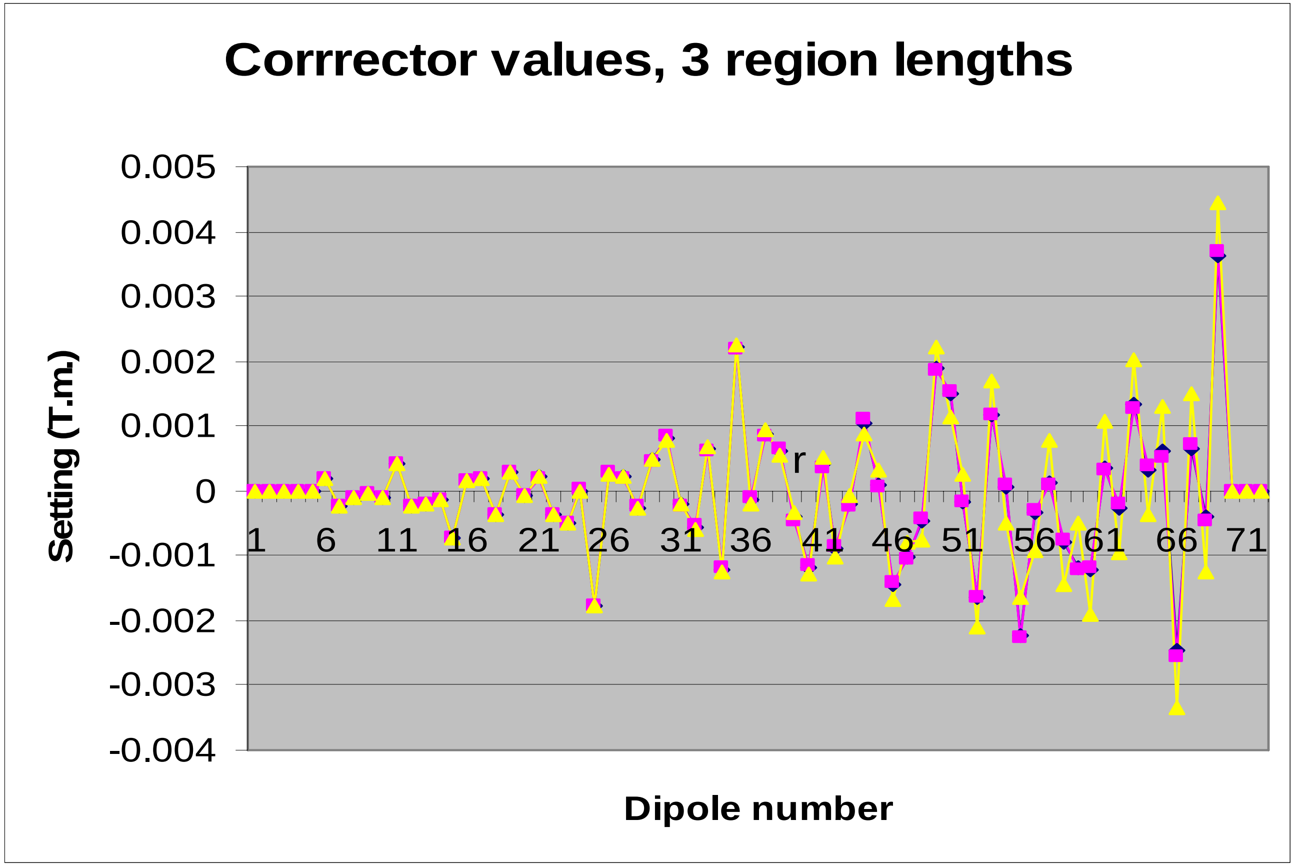
Not the whole LINAC (but the beginning is harder !)

Going slow: section length is 12 dipoles, moving downstream by only 1 dipole for next section.

- **Easy, because there is a unique solution to this problem: for each quad kick, one can compensate with a dipole corrector.**
  - **Macro iteration do help, especially near the end.**

- No spike in emittance, smooth growth.

Pure DFS, Stability of solution.



Three different section lengths:

Diamonds 8
Squares 12
Triangles 16

Agreement is lost at the end, not BPM data was uploaded there.

- The solution is (almost) unique, and converges at each local iteration. Adding one macro iteration won't change the result much.

Questions on Steering Algorithms.

- Assumptions:
  - **Are the lattice functions known? Do we steer to the perfect lattice, or to a “to be determined” lattice, not too far away from the one we want?**
    - Do we have enough instrumentation/methods to measure all Twiss parameters?
    - *Software must be able to measure/check, even if we steer to a set of known parameters..*
  - **Do we steer with full intensity bunches?**
    - Matters for wake field effect… Final steering must be done with full intensity bunches.
  - **Do we steer as the machine moves?**
    - Yes, must be able to this!
  - **Are we subject to beam abort, wasting pulses?**
    - Yes, the Machine Protection System must also be simulated.

Steering Algorithms: Stability

- Do we require “convergence”, and, if so at each step ? Or Global iteration through, say, the Main Linac to Undulator
  - **Since we steering and correcting previously found solution (steering with dynamical machine), gain for a given set of correction should be < 1.**
  - **How long does that takes.?**
    - Keep track of real time (need to do this to simulate ground motion + vibration, in any case.)
  - **Studying nearly singular response matrices**
    - Solutions for non trivial problems where solution is not unique!

Steering: Local or Global ?

- Local:
  - **Always first step, but if no stable solution..**
  - **Tune to the peculiarity of the section:**
    - E.g. in the Main Linac, one would expect that the optimum region size is somehow related to the (~fixed) betatron period.
    - But defect to a fixed period are un-avoidable..
- Global:
  - **“bumps”: dispersion, “Wakefield” (not sure what that is…)**
    - Stability in presence of continuous adjustment of local corrections.
    - Make sure local algorithm are no fighting global ones.

Next steps

- Tentative: I'll keep listening..
- Pursue study of DMS
  - **In increasingly difficult cases.**
  - **With realistic lattice: indeed, need to move to ILC/RDR lattice,**
    - But I still can learn from simpler model.
  - **With realistic bunches**
  - **With ground motion and vibration.**
- Break the distinction between "static steering" and "dynamical studies".
- Keep studying underlying physics assumptions of the various codes.