ILC – Main Linac Simulation
October 17 2006 Report.

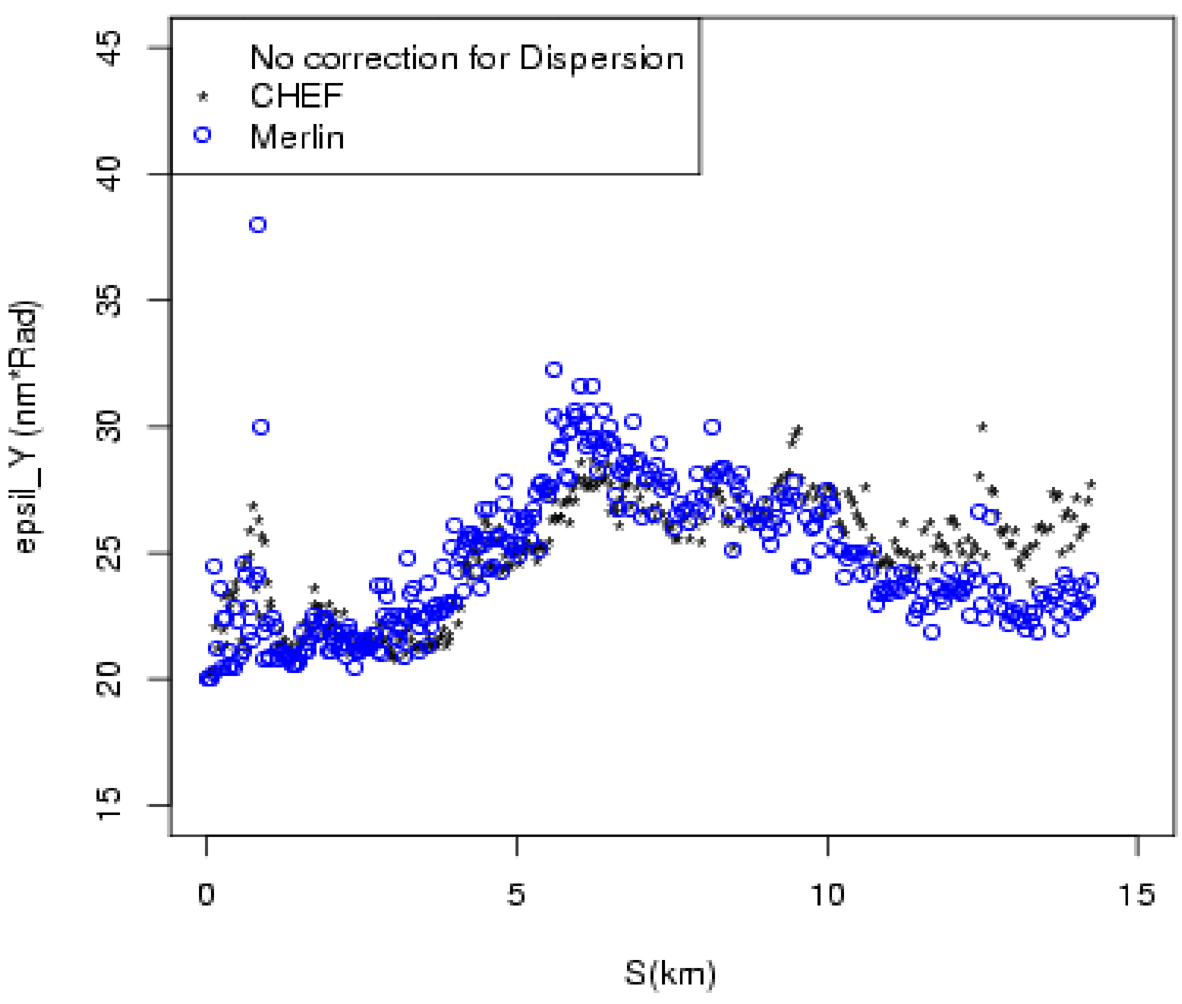
Paul Lebrun

ILC-LHC R&D in AMR

Outline

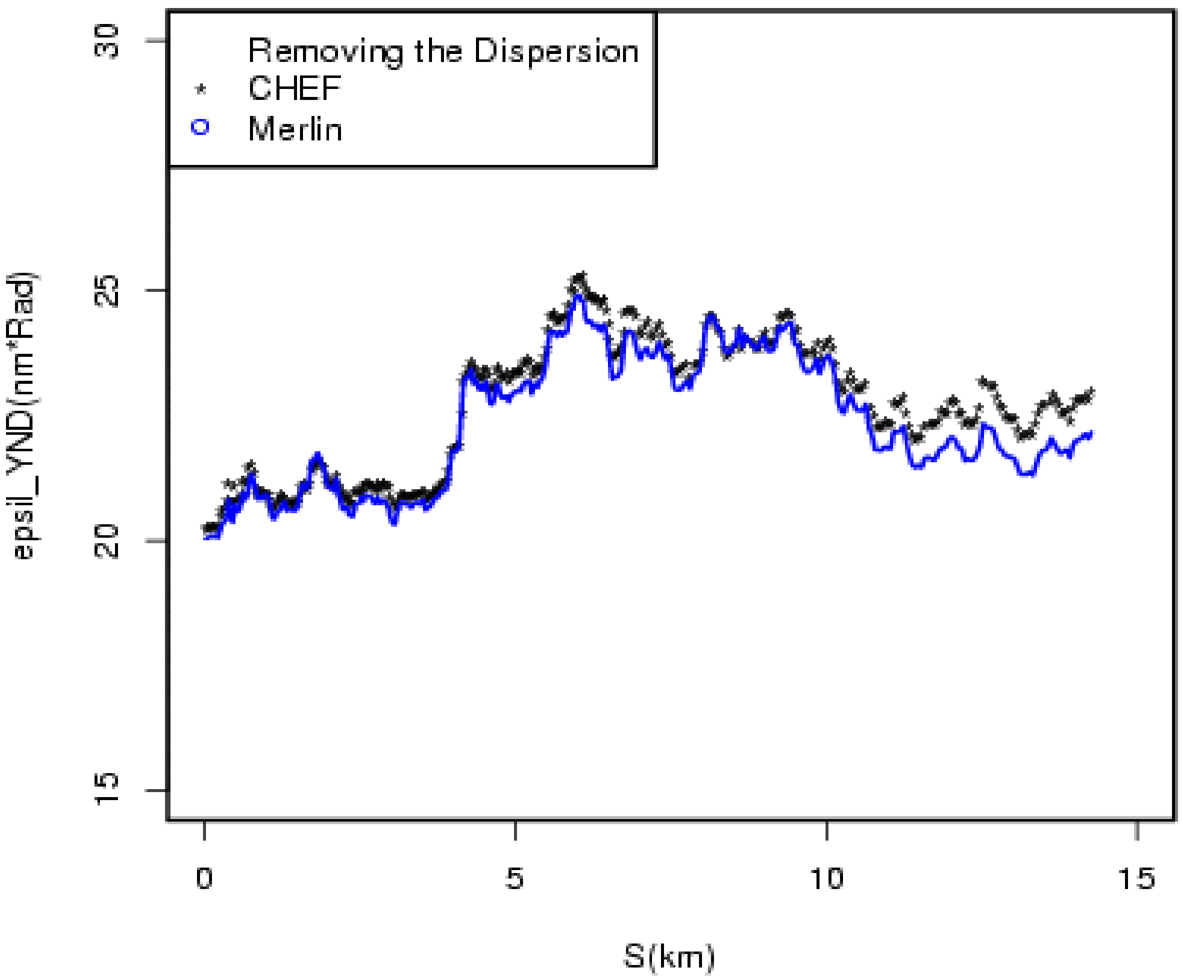
- Since many upcoming Beam Based Alignment Dynamic & Static, will be based on CHEF, a bit more on benchmark/validation.
  - Focus, this time on cavity tilts, and on integration of motion in the cavities... And
  - What do call the “answer” on Benchmark2 ?
- Progress/Comments on DFS
- Progress on RDR lattice in CHEF.

CHEF vs Merlin Benchmark status.



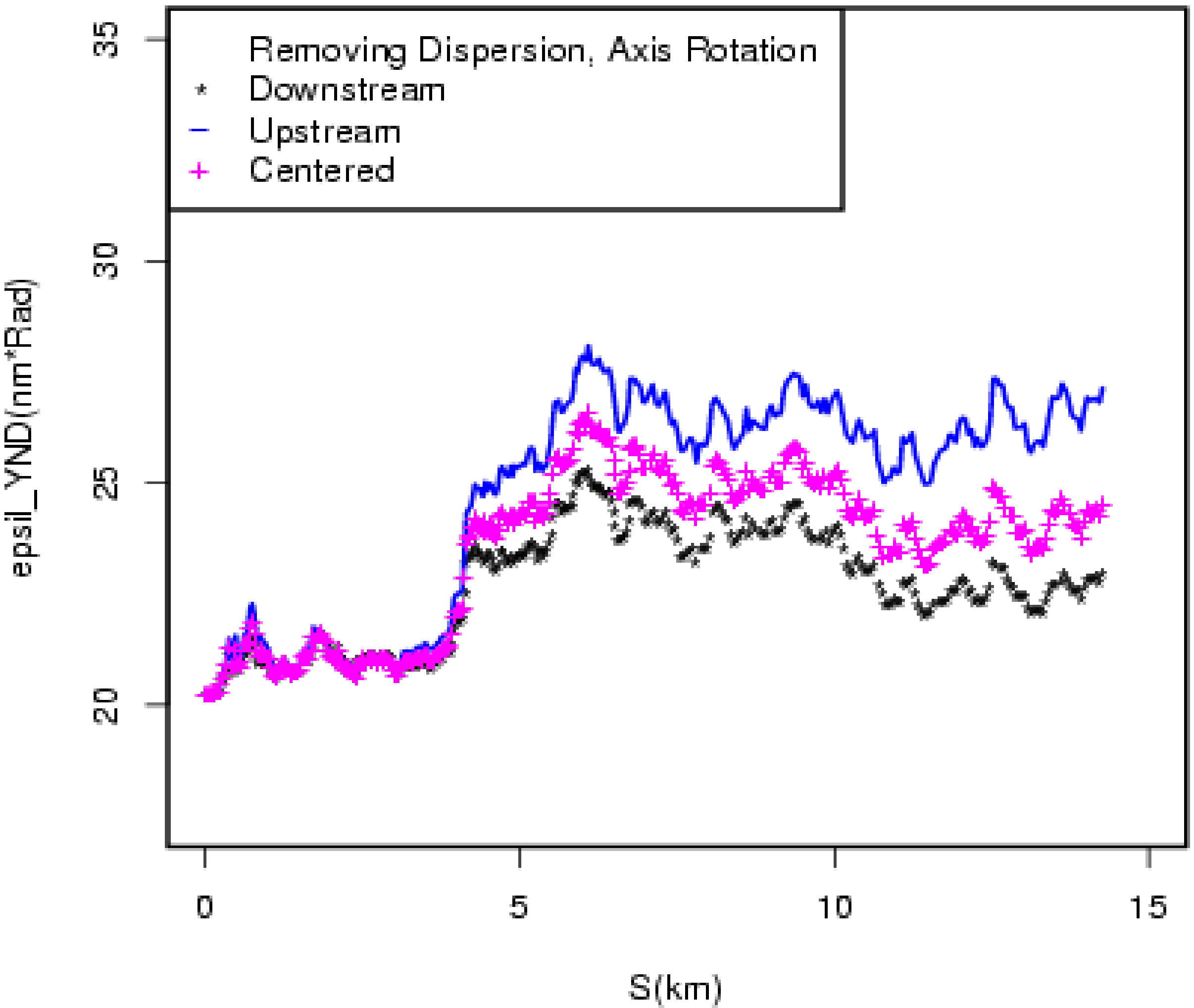
- Same bunch, sample particle thrown..
- Overall, good agreement
- Except that I don't see the spikes at s ~ 800 m.

CHEF vs Merlin.. OK?



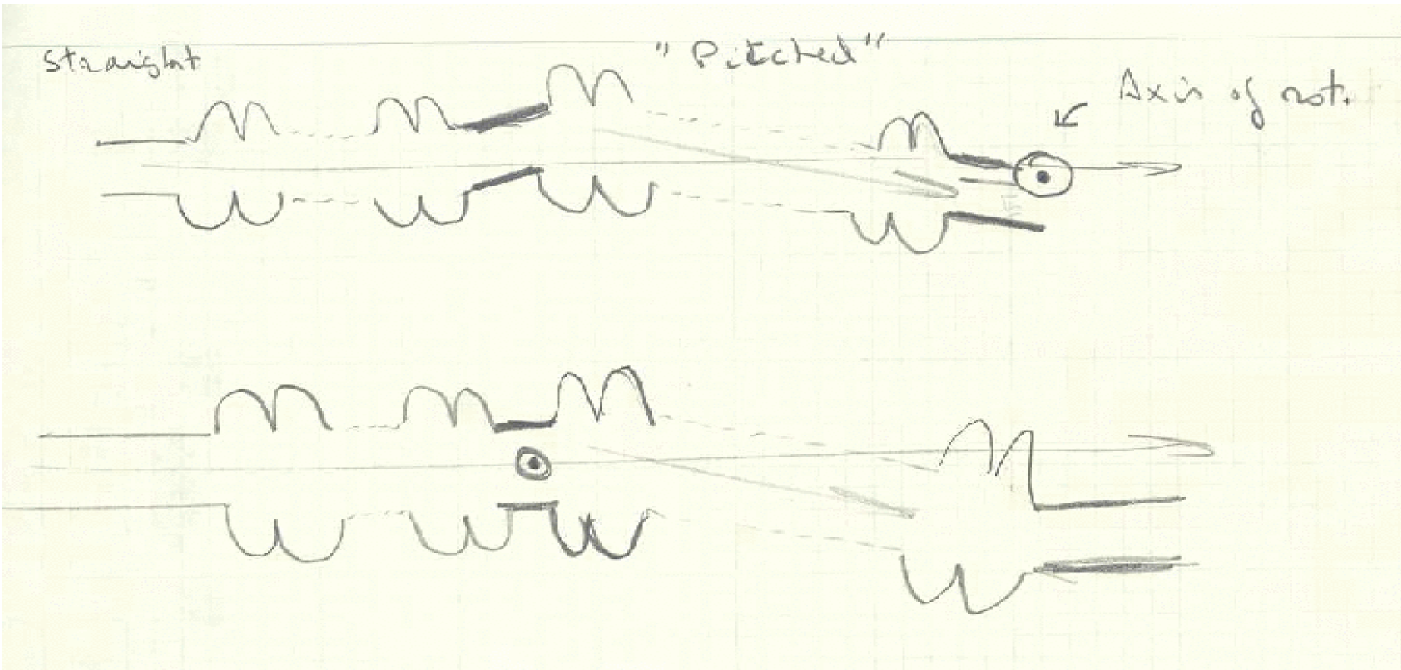
- Even better if the dispersion is removed...
- What changed in CHEF?
- Minor changes in error/warning handling..
- Assumption cavity rotation!

CHEF: Location of Axis of rotation



- Only a minor change in the user code!
- CHEF handles all coordinate transform as formal 3D translation/rotation.
- Must define where the rotation axis are located with respect to the center of the element...

How Come?

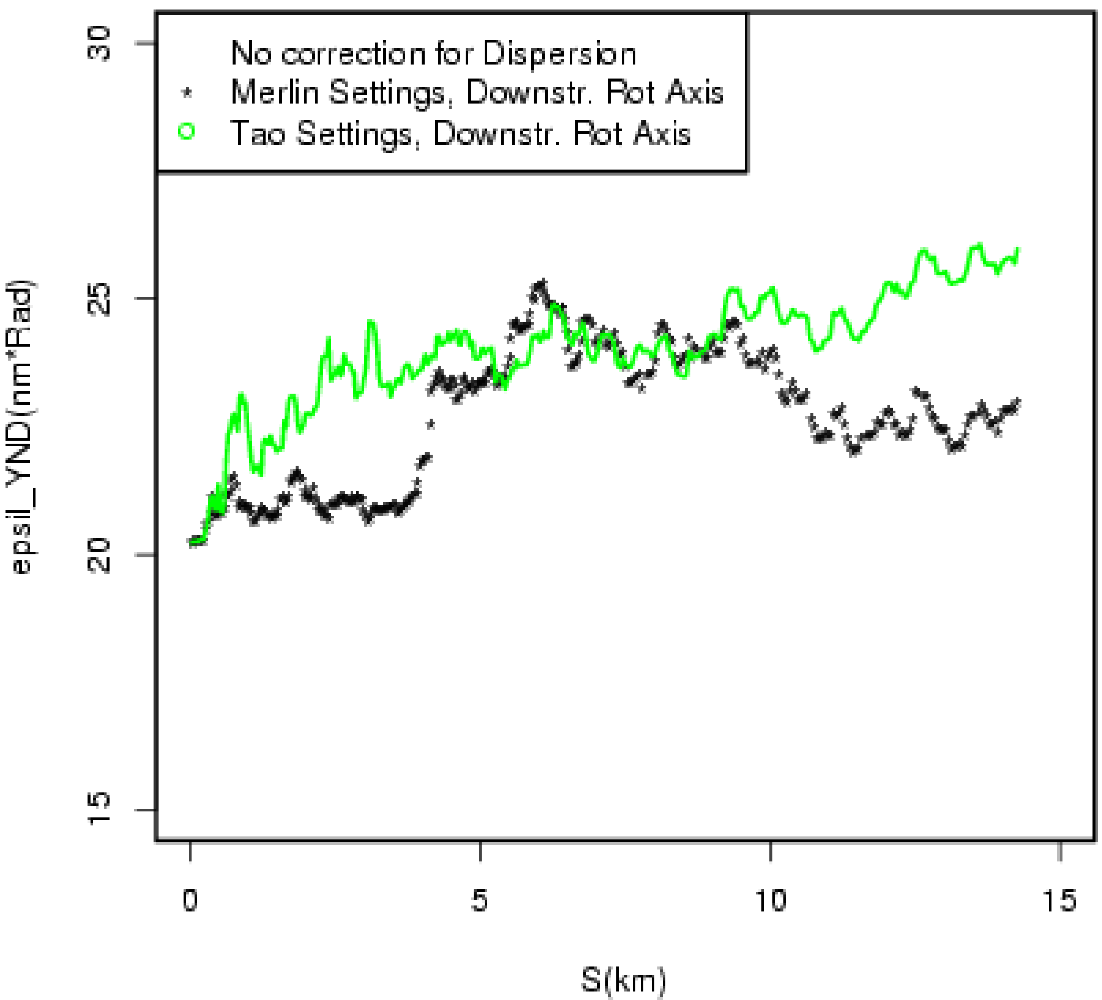


- Edge focusing leads to different trajectories!..
- Note Not any better for the RDR RTML and beginning of Main Linac: $\Delta y' \sim$ Pitch * Gradient * L
- Path integral through a perfect cavity only is only modeled, not computed exactly (in both codes!) .. Is CHEF consistent?

On Benchmark2 solution

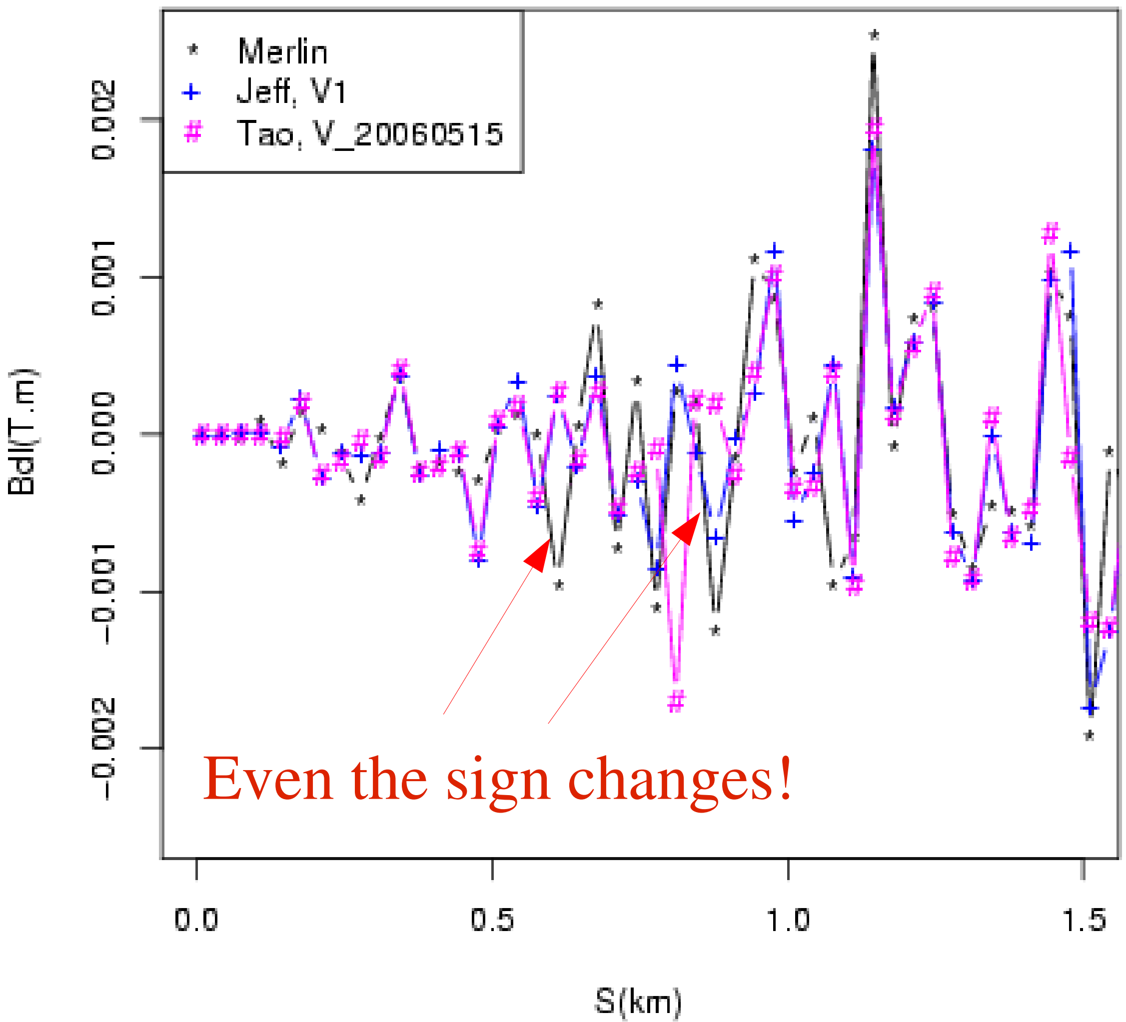
- Shown in the previous plot are the dipole corrector setting as found by Merlin (~ year ago)
- What I would call the "solution" to the Benchmark2 problem is not only the transverse emittance vs Z, but a list of B.dl values, for the dipole correctors.
- It matters!... (Operational Standpoint !)

CHEF, Tao vs Merlin settings..



- These difference are not presently not understood..
- They are significant.
- Two benchmarks in one, in fact:
  - Tracking
  - Steering.
- More work is now needed on understanding in CHEF the integration model through titled cavities..

Benchmark Solution over time and authors..



- These difference are not presently not understood..
- They are significant.
- Two benchmarks in one, in fact:
  - Tracking
  - Steering.
- => Let us distinguish...
- The problem was **not** quite fully specified..

Status of BBA/Steering in CHEF/Merlin

- Merlin people released their DFS code for the EPAC 06, few moths ago.
- Started to re-implement simple DMS (Dispersion matched Steering) in CHEF prior to this release.
  - Mostly finished it. but...
- Plan to go back to Merlin and study the algorithm differences, and implement the Merlin features that are missing in CHEF...

DMS in CHEF..

- Relevant difference between this code and other implementation (perhaps)
  - Does not necessarily assume the problem in linear: allow for re-calculations of the response matrices at every iteration. (2*nDip/section, minimum, pulse required, per tuning iteration.).
  - Requires convergence, “tuning simulation” :
    - Compute or measure Responses Matrices, invert them.
    - Measure “what we got now “
    - Apply ~ 0.5 the proposed correction
    - iterate.. until settings don't change anymore..
    - (and, of course iterate over over lapping sections)

Lesson learned so far...(I out of few)

- Motivation for this simulated controlled steering: plan to study the robustness of the BBA technique in presence of dynamical defect (beam jitter, ground motion, LLRF Klystrons power fluctuations...)
  - Since I can run multiple pulses for a given setting, I can integrate out the BPM Gaussian fluctuations in the readout => insensitive to BPM “resolution”
- DFS implementation from scratch is time consuming, indeed (*Jeff Smith warned me...*)
- Not done yet, as I am not (yet) reproducing Merlin or Tao setting (order of magnitude is O.K. though...).

Lesson learned so far...(II out of few)

- If cavities are neither displace nor rotated, e.g., perfectly aligned, the problem has in principle, and in practice one preferred solution: correct the (unknown) kick given by the displaced quadrupole by an opposite kick with the dipole corrector located only ~30 cm from that quadrupole... Hyper-local correction. Good performance... (virtually no emittance growth over ~the first 2 km.
- Pure DFS gives this type of solution a broad ranger of steering parameters, such as the length of section being steered, the overlap beween successive sections, the number of downstream BPM (although the downstream BPM don't add much...)....
- => happy with this part. Algorithm converges and is found to be robust. .. Except that ~> 5% BPM scale error leads to non-convergence !..

Lesson learned so far...(III out of few)

- When cavity are displaced/rotated, at ~ 5GeV, significant spurious Dispersion is generated in between the quad/corrector package. As shown before, there are no unique preferred solution. Currently, I am running into trouble in getting to “robust” optimization:
  - Indeed pure DMS does not work. Too easily falling into a pattern of solution where successive dipoles are “fighting” each other, leading to big kicks ..
  - Fixes:
    - down-weight solution with such big kicks (not yet implemented, easy to do though..)
    - down-weight solution with large BPM readings. This helps.
    - “Pre-steer” such that the position and angle of the bunch does not depend on energy at the entrance of the section.

Lesson learned so far...(IV out of few)

- The last trick helps, but... suceptible to section edge effects? Not sure yet..
- At ~5 GeV, it is definitely possible to improve performance by correcting cavity tilts. In practice, a costly solution, but we should not reject it out of hand. Compromise: tilting the cryo-module. BBA technique: while steering through section B, vary the gradient in section A and B such that, at the beginning of section C, the energy is identical, but the spurious $\Delta y'$ kicks are different, because the gradient ratios A vs B are different.

Status of RDR lattice in CHEF..

- Running beam... Bunches are not travelling through the local center of every element after the first S-Bend -> geometry problem.. Working on it.
- As for the other codes, limited amount of work needed to run steering with this lattice. Once the above problem is addressed, plan to do most of steering studies with this lattice. Focus will be on
  - Robustness of the solution.
  - Dynamic effects while steering is done.

On Dispersion in misaligned LINAC

- The dispersion in a given section C depends on how the beam has been accelerated in previous section A & B. If section A is perfectly aligned and rans at higher than nominal voltage, section B is misaligned runs at a lower than nominal voltage, the transverse kicks in section B will be reduced compared to the case where section A runs at higher voltage than section B.