CHEF: Recent Activity

+

Observations about Dispersion

in Linacs

Jean-Francois Ostiguy
FNAL

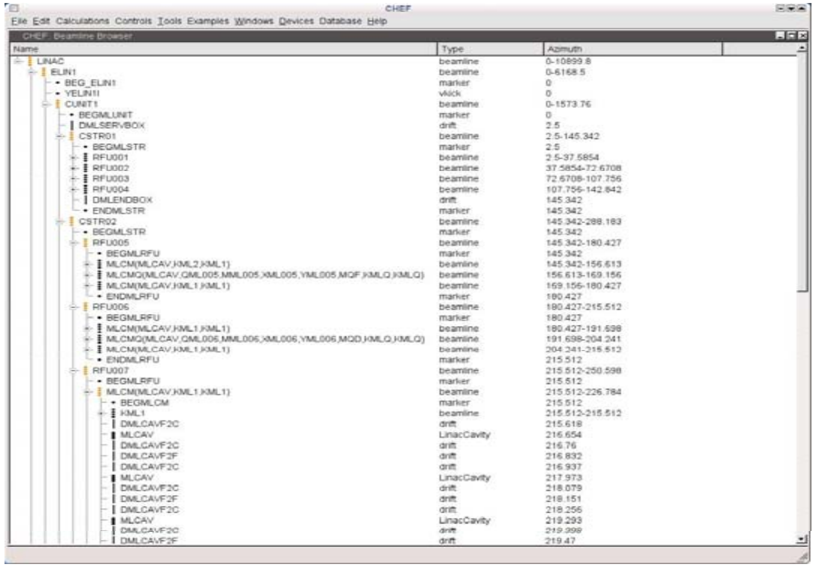
What is “CHEF” ?

- A framework for beam dynamics simulations consisting of a set of libaries organized hierarchically + python bindings + a standalone application
  - **Written in “modern” C++ (use STL and templates extensively)**
  - **Originally not written specifically with Linacs in mind.**
  - **Most C++ compiled functions are available from Python.**
  - **Main advantages: Python is absolutely free and in widespread use**

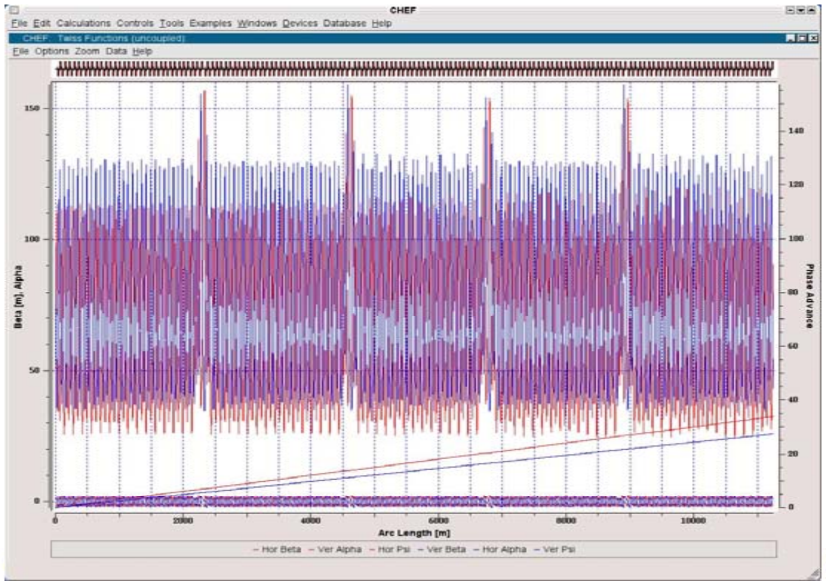
- Originally designed for proton rings and beamlines; subsequently adapted for high energy linacs
-
  - **The code provides facilities for both conventional tracking and map computions using automatic differentiation. The same generic code is used for both functions.**
  - **From time to time, features have to be implemented to accommodate special needs. Since most simulation codes are dominated by “bookkeeping” ; the philosophy was to make the “bookeeping” as generic as possible to and minimize need for “re-invention” or duplication.**

- Some Distinctive Features
  - **No paraxial approximation**
  - **Can accurately accommodate large dp/p**
  - **Internally uses 6D canonical variables (rather than optical) variables**
  - **No inherent relativistic (beta ~ 1) approximation**
  - **In principle, can track phase space “patches” using DA variables.**

Some Other Features



A browser to study the lattice and its hierarchical organization (full support for XSIF format)



User-friendly optics computations and display capabilities. Traditional (uncoupled) or generalized (coupled) lattice functions.

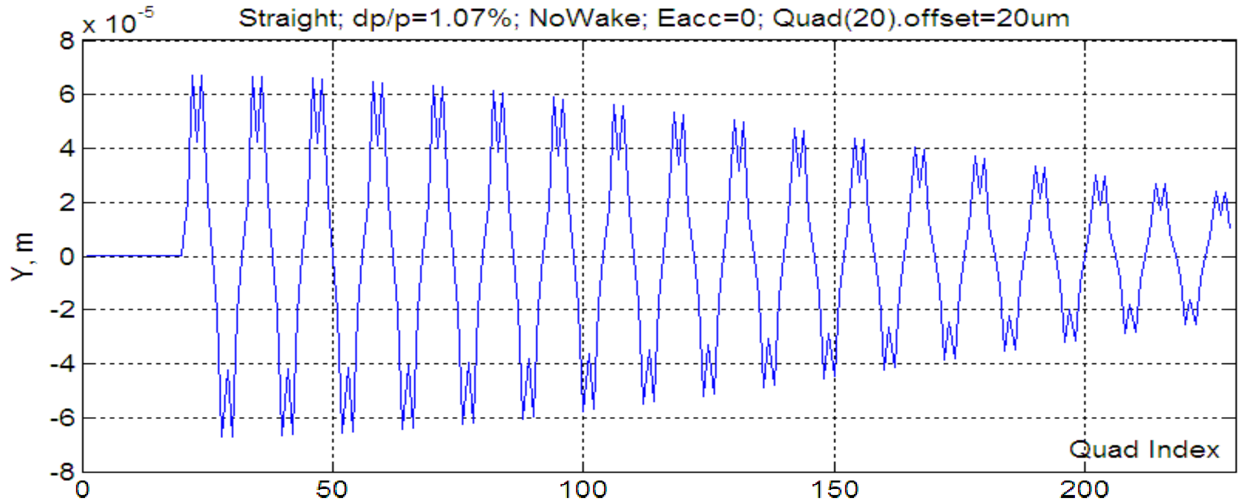
Status

- Starting early 2008, following budget problems, CHEF LC specific code development slowed down significantly.
- Earlier LET work had shown good to fair agreement between CHEF and other codes, but some differences remained.
- We are in the process of running a series of systematic, basic tests to understand these differences.

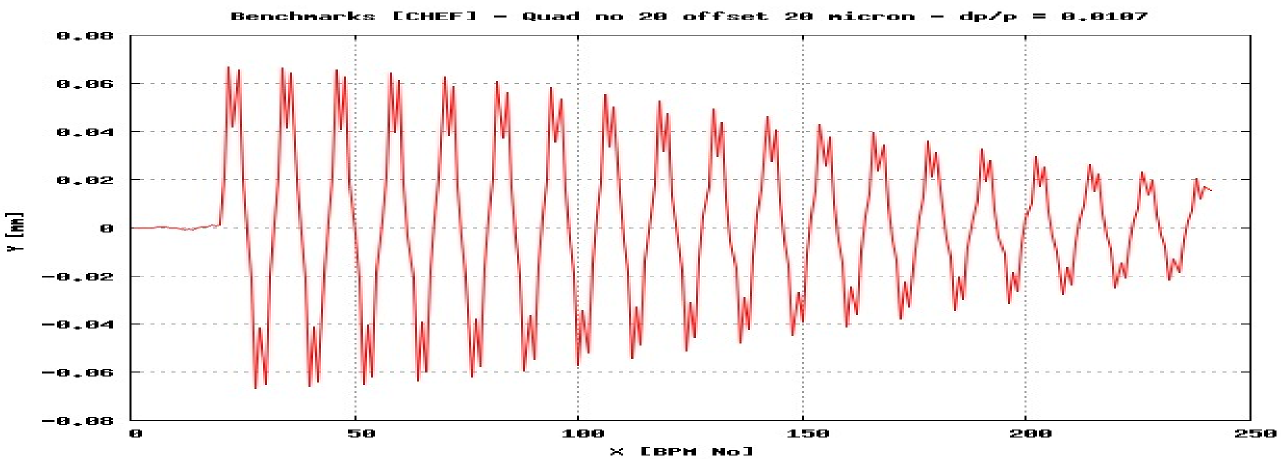
Some Sample Tests

- Assumptions (tests 1a,1b, 2a,2b)
- nominal dp/p = 0.0107
- All tests assume a “straight” linac
  (to avoid emittance correction issues)
- No girder misalignments
- No BPM misalignments

Test No 1- One Misaligned Quad

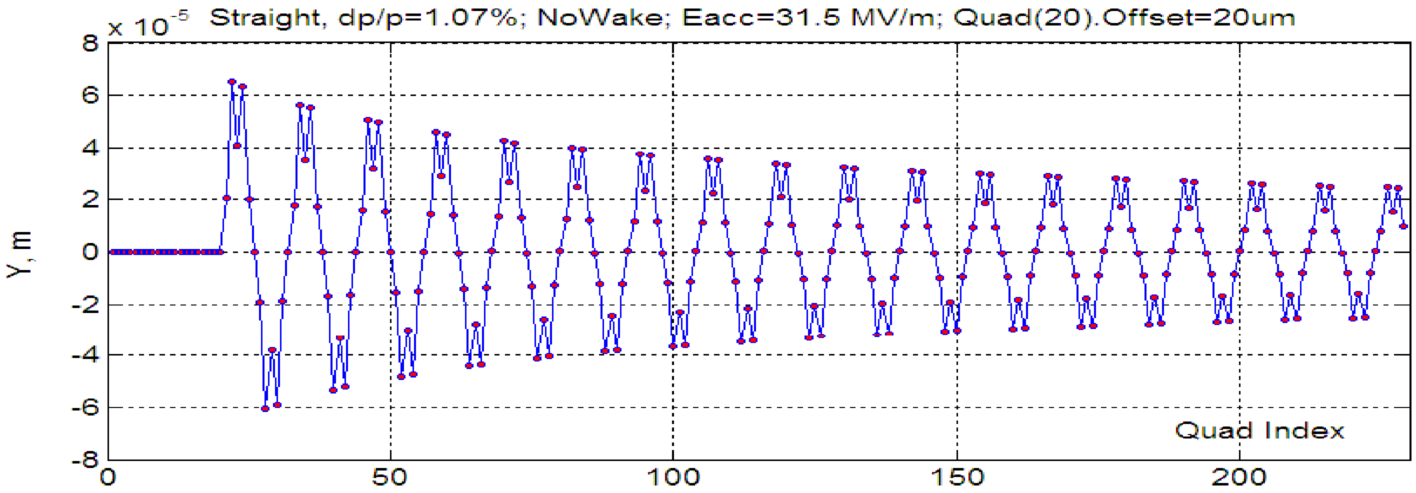


Lucretia

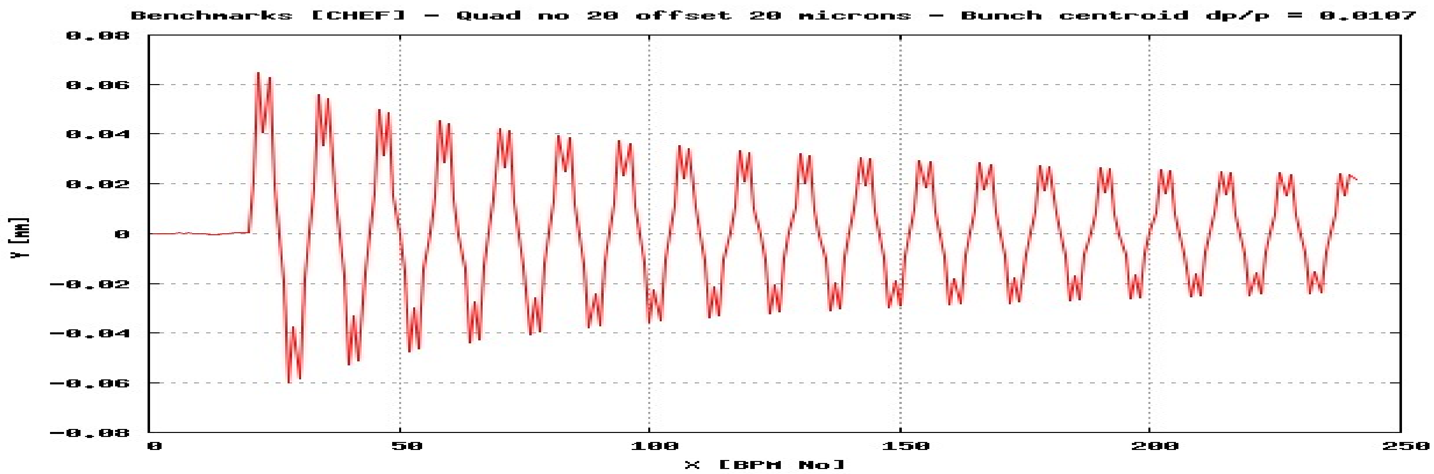


CHEF

Test 1a: <y> (With Acceleration)

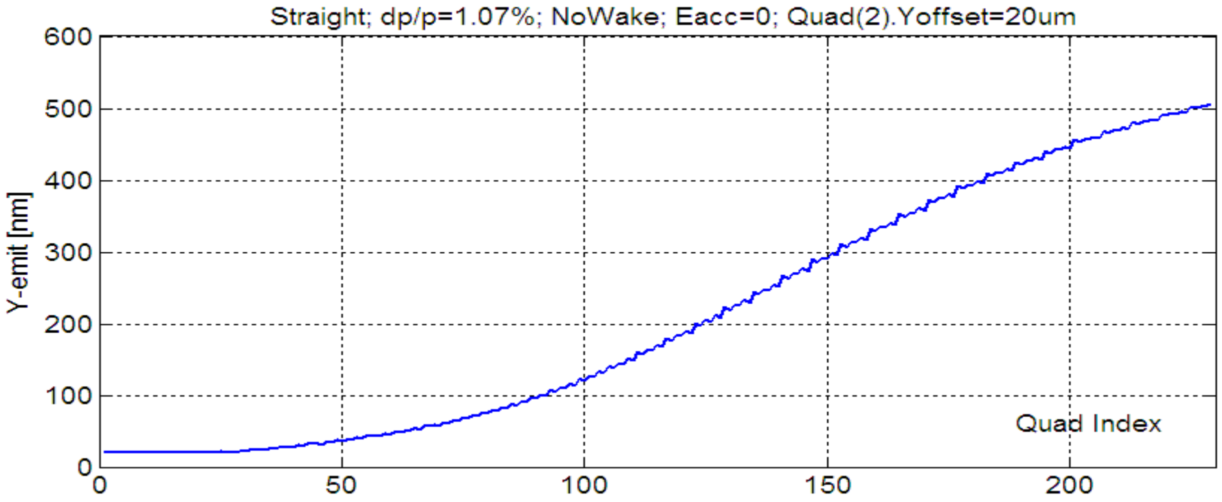


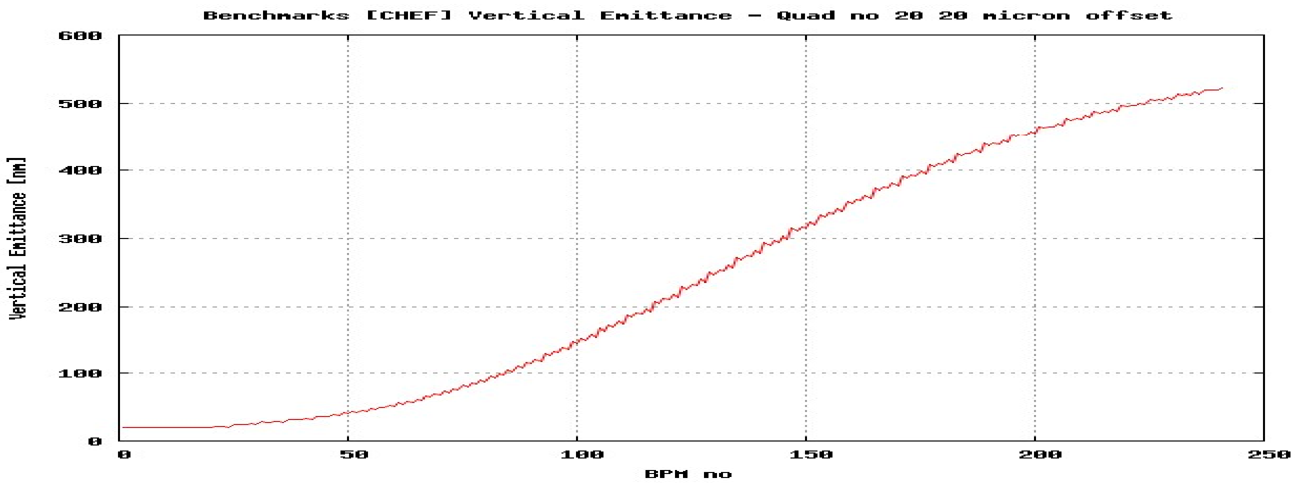
Lucretia



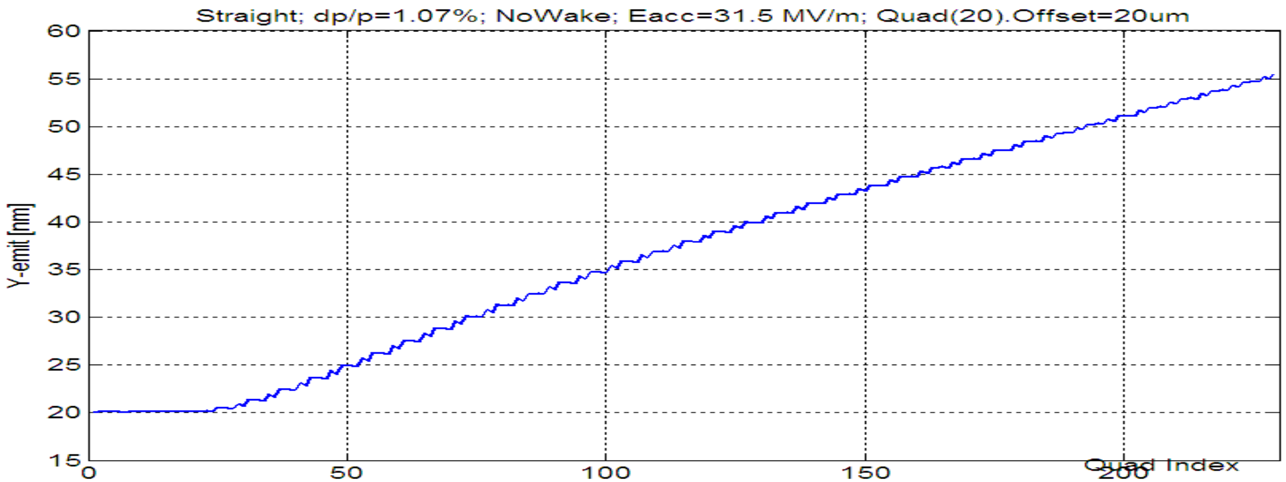
CHEF

Test No 1 – Vertical Emittance

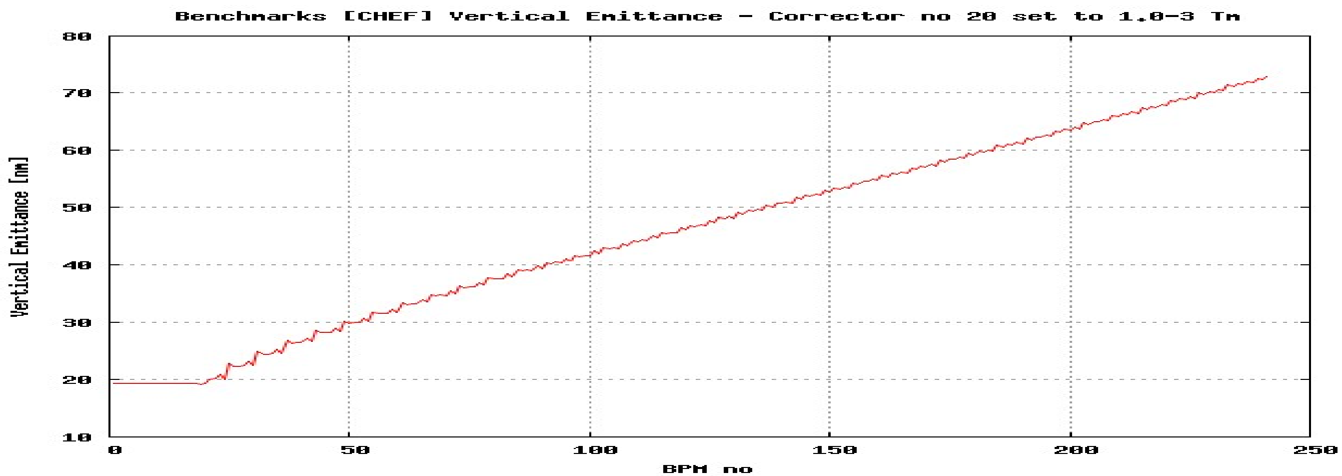




Test 1a: ϵ_y (with acceleration)

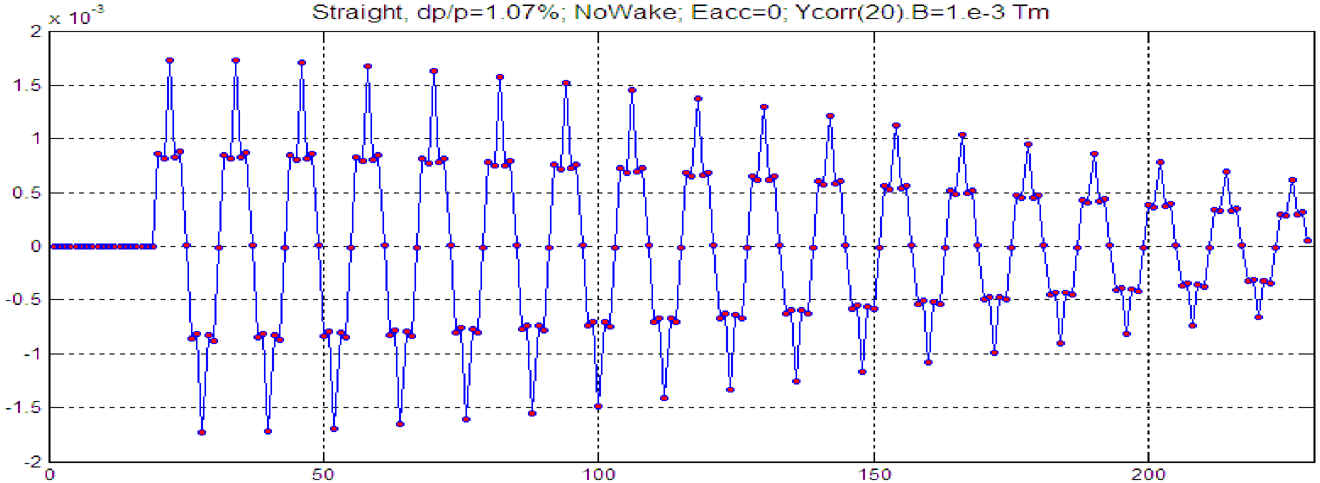


Lucretia

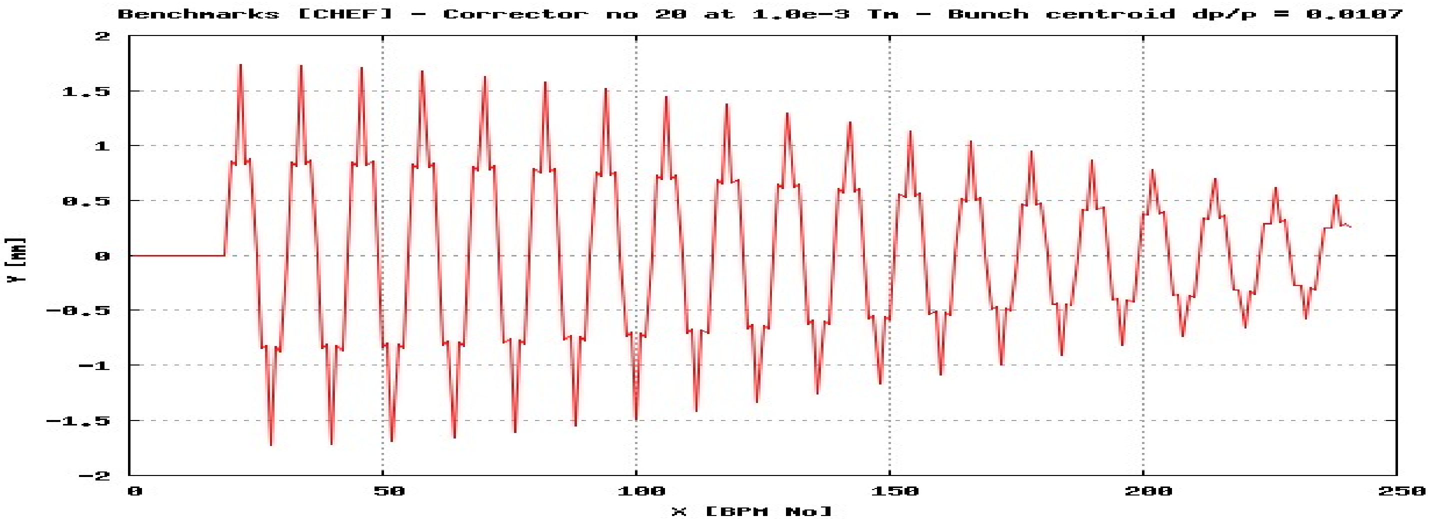


CHEF

Test 2: a single corrector @ 1.0-3 Tm

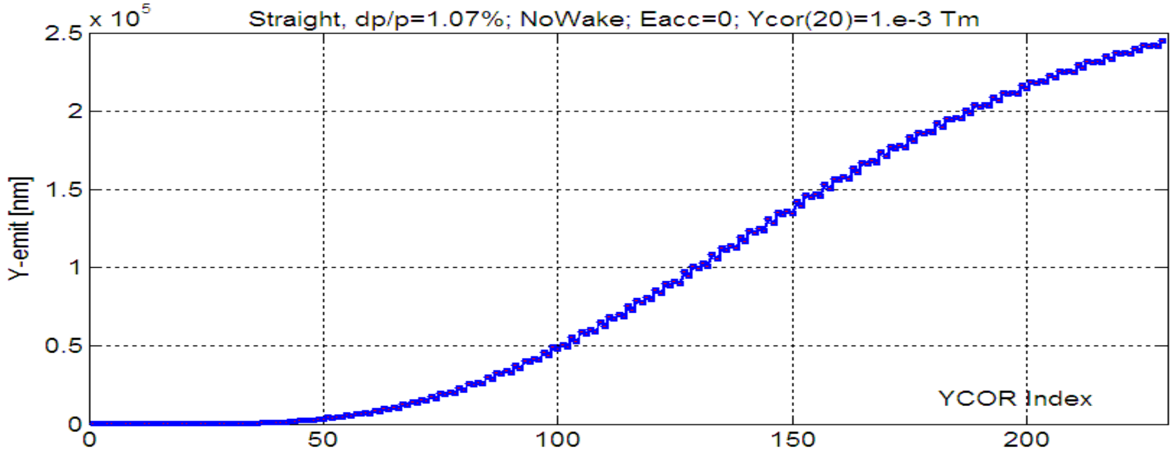


Lucretia

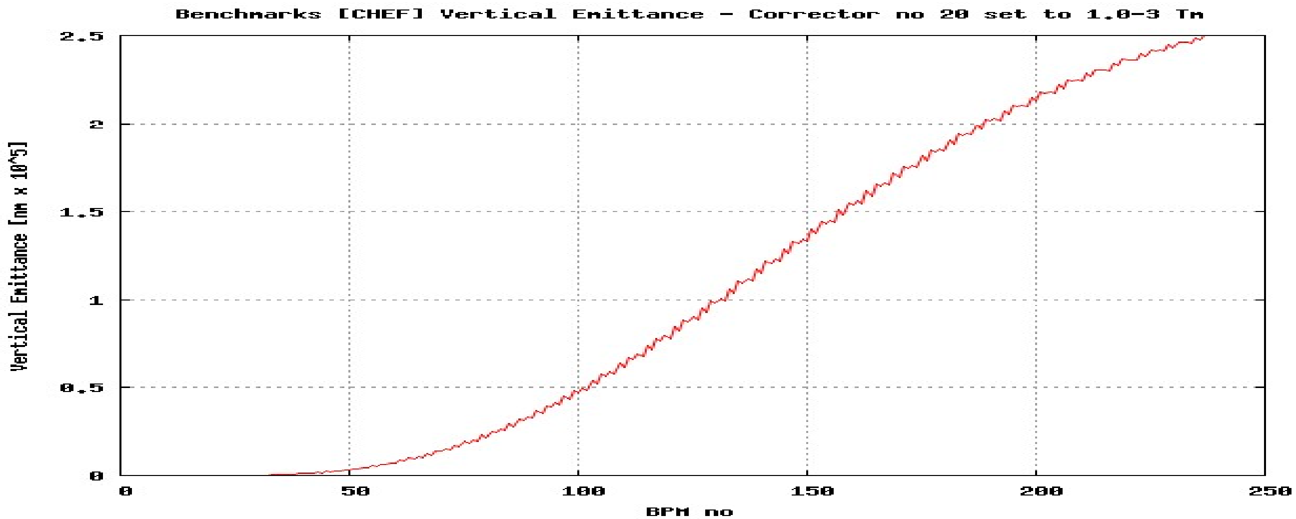


CHEF

Test 2: emittance

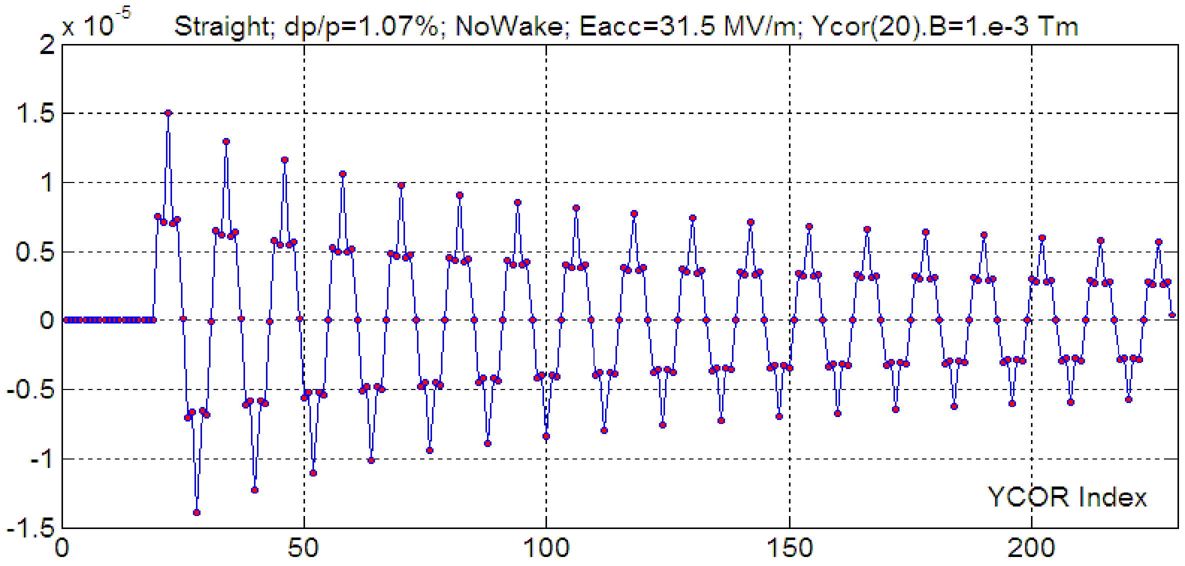


Lucretia

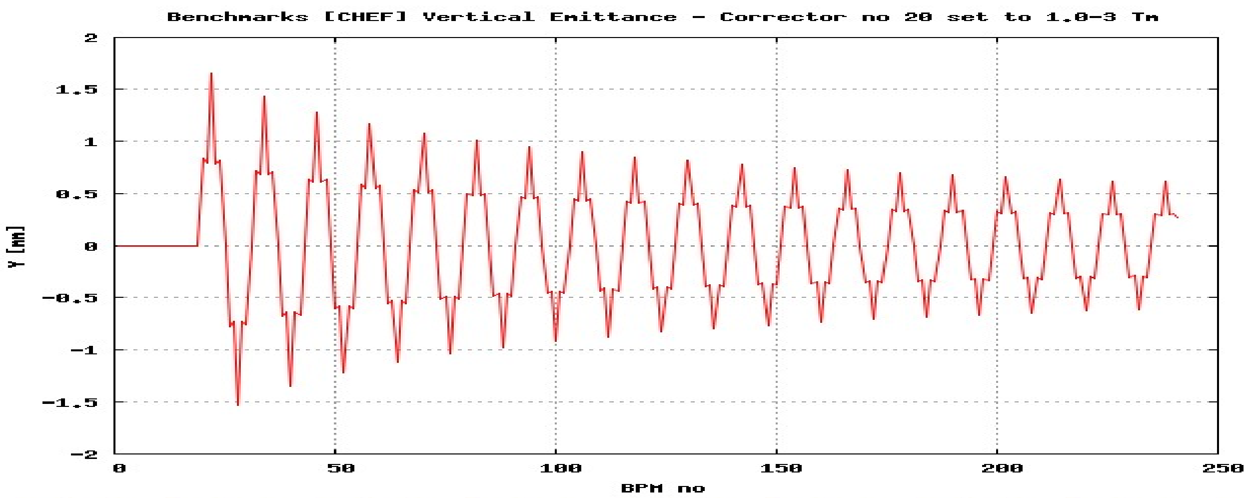


CHEF

Test 2a (with acceleration)

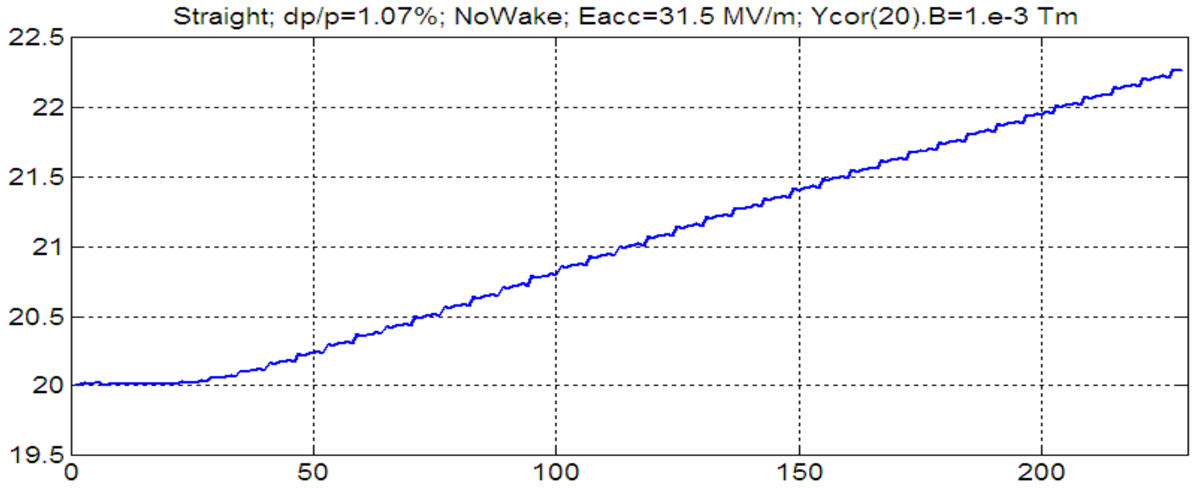


Lucretia

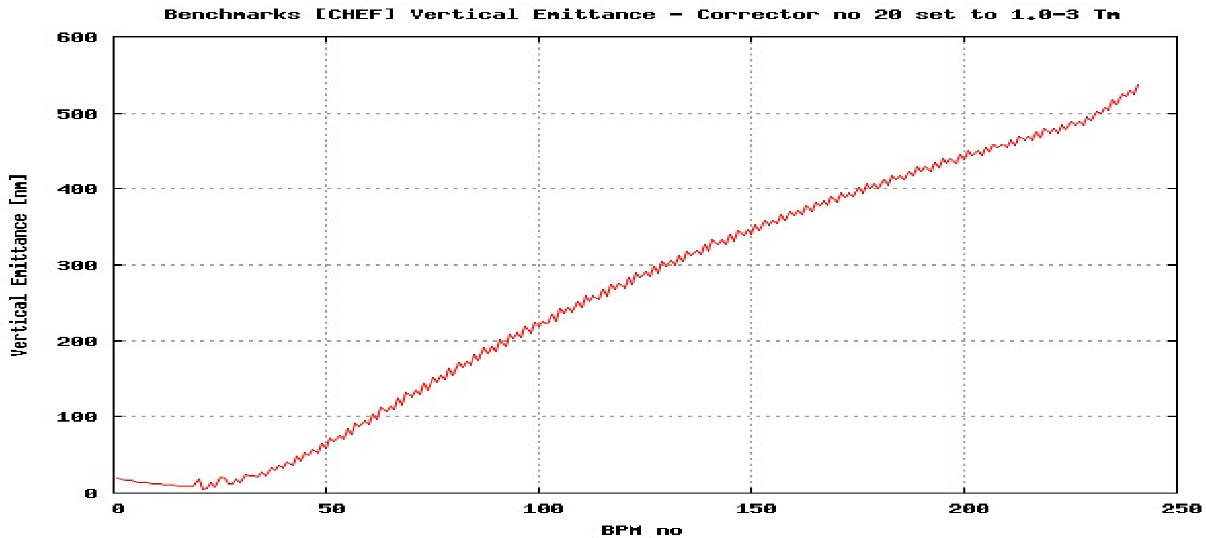


CHEF

Test 2a (Acceleration ON)

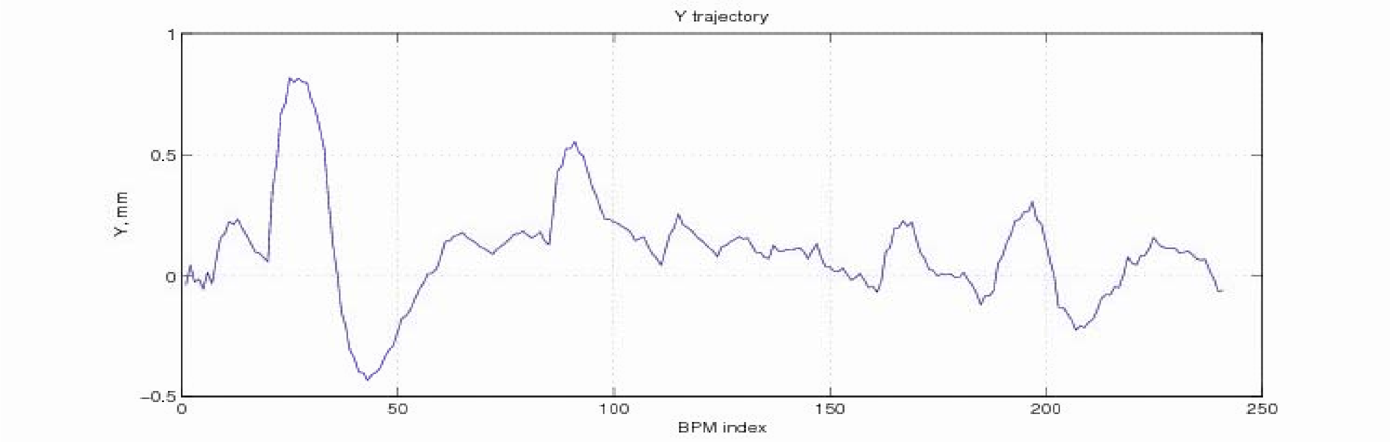


Lucretia

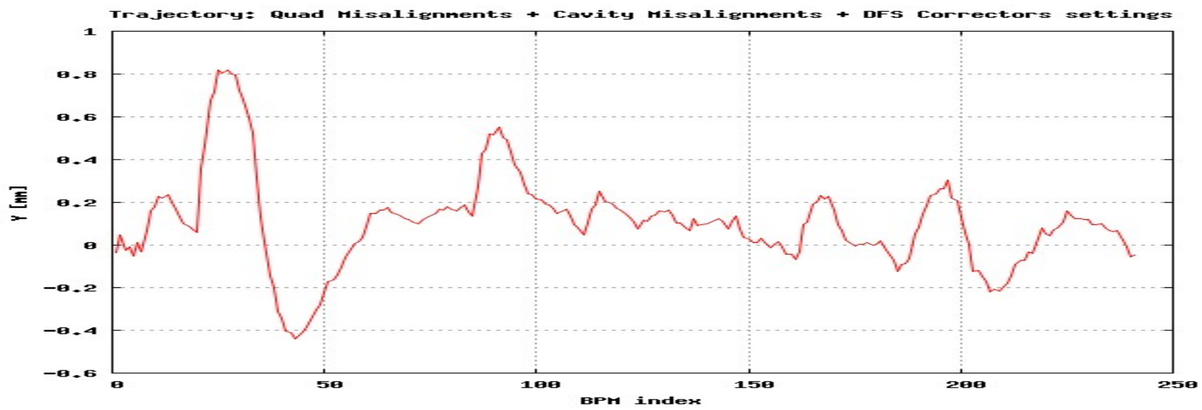


CHEF

Test 3 – DFS Corrected Straigth Linac -Trajectory



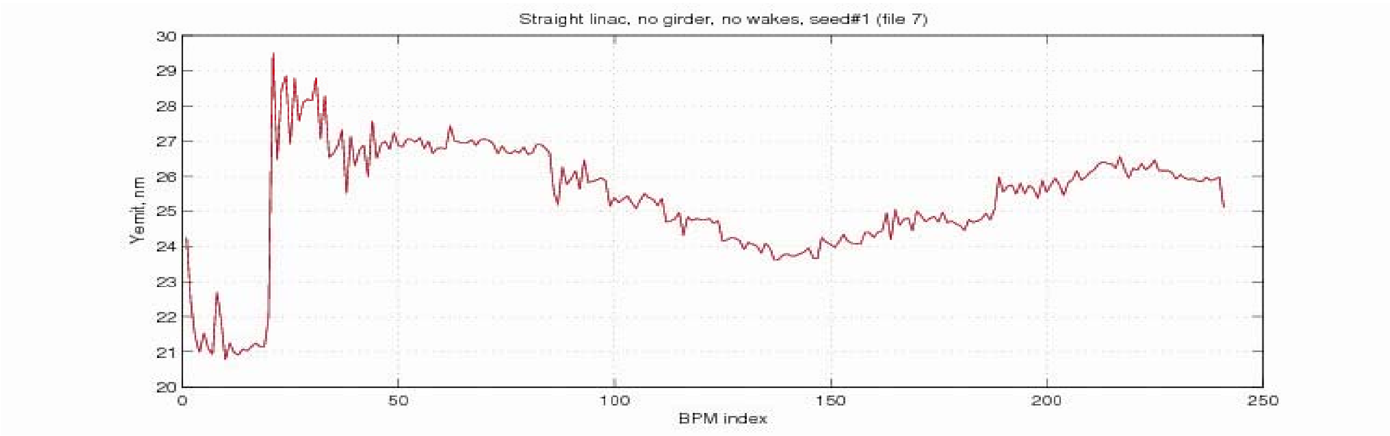
Lucretia



CHEF

Misaligned Quads, Cavities + DFS Corrector settings
Agreement is excellent.

Test 3: DFS Corrected Straigth Linac Emittance Profile



Lucretia

CHEF

Close - but nevertheless we observe some discrepancies
It is not clear yet what the source is.

Linac Dispersion

- In a ring, dispersive correction to the trajectory is fully defined by dp/p i.e. dx = eta*dp/p
- In a linac, the dispersion function depends on initial conditions.
- In a linac, magnet strength is scaled so as to make the (quadrupole) optical strength constant for the reference particle
- For a given particle, dp/p is not constant during acceleration.

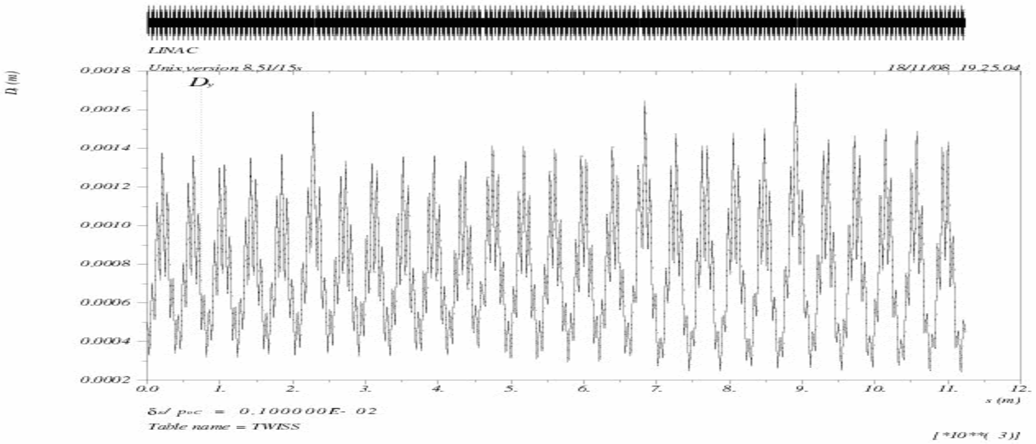
Observations

- In comparing linac dispersion with other codes we observe some differences when acceleration is present.
- Since dp/p scales like ~p/p0, linac dispersion often defined as
- $[\, x(p0+dp0) - x(p0)\,] / (dp/p)_0 \;*\; [\, p/p0]$
- Periodic dispersion is very sensitive to deviations in optical periodicity.
- In applying the DFS algorithm to a curved linac, the nominal "dispersion" is subtracted out in the quadratic objective function. The optimum corrector settings depends somewhat on which "dispersion" is used.

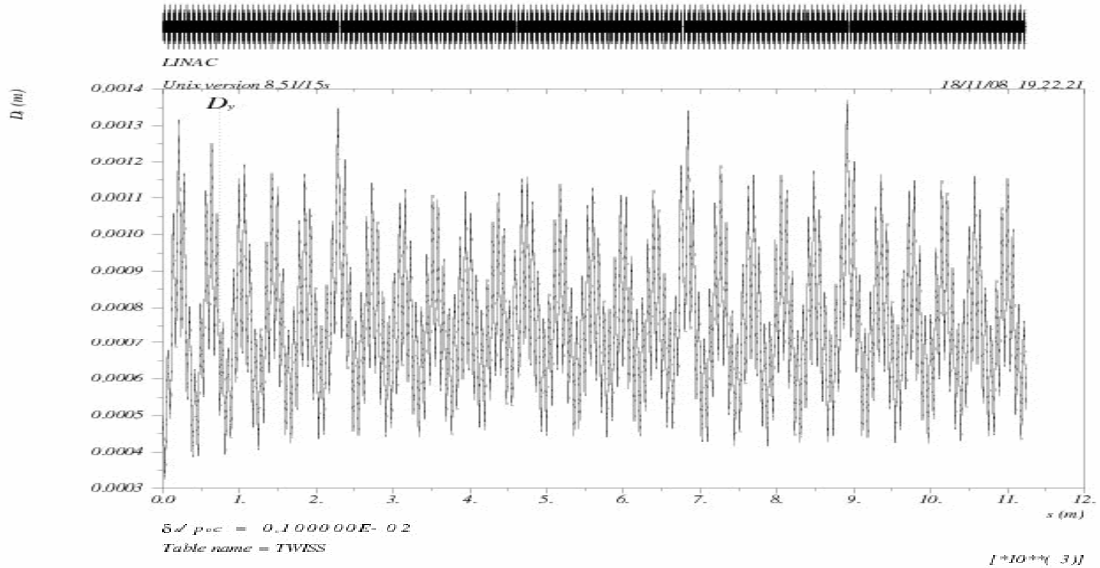
How CHEF computes dispersion

- A reference particle is sent through the linac and the magnet field are scaled so as to make the optical strengths constant for that particle.
- Method 1: A “JetParticle is tracked through the linac. A JetParticle propagates the derivative of y w/r to dp/p to machine precision. The result is scaled by p/p0
- Method2: 2 particles with momentum p and p+dp are tracked through the linac. The results is scaled by
- p/p0.
- Method3: Same as 2, but this time, the acceleration gradient is modified by a factor 1+dp/p so as to make
   dp/p constant.

Dispersion (MADacc)

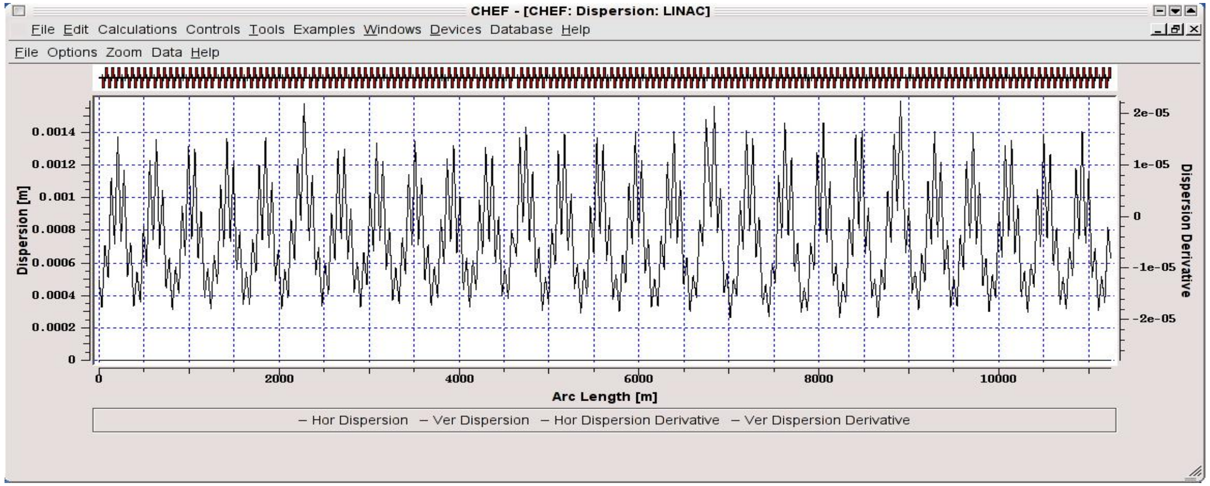


No Acceleration

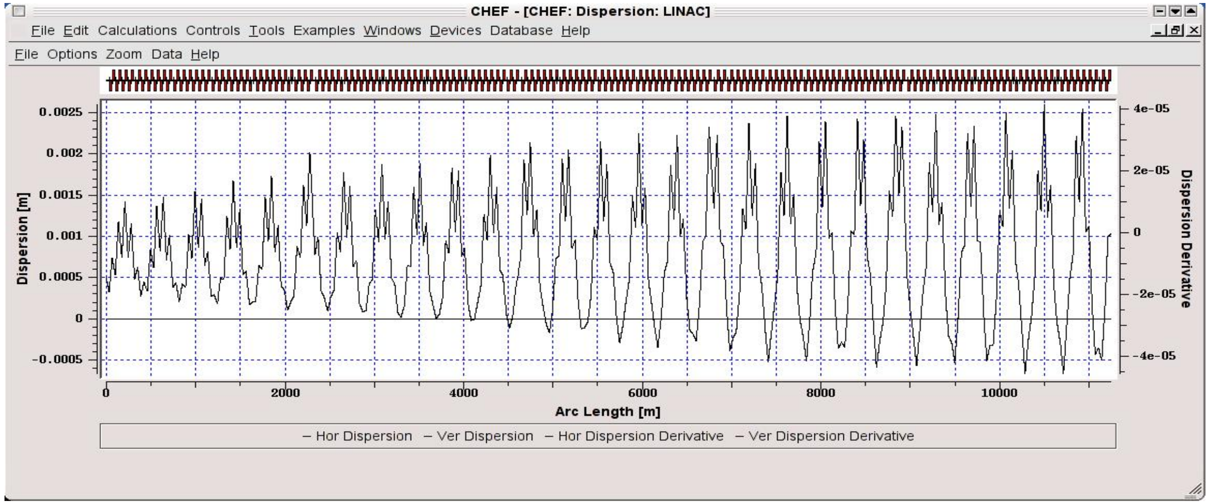


With Acceleration

Linac Dispersion



Without Acceleration



With Acceleration

Notice slow amplitude drift ..

Conclusions

- Agreement between CHEF and Lucretia is generally quite good; nevertheless, some unexplained discrepancies remain.
- Predicted dispersion with acceleration exhibits a weak amplitude drift … is this real and/or what causes that ?
- Although the manpower dedicated to this effort has been scaled back since last december, development of CHEF continues.
- For HE linacs, we intend to focus on improving the cavity representation to include asymmetric wakes (e.g RF coupler).
- Lucretia and Placet are also in regular use at FNAL; we plan to continue using - and possibly to improve - these codes and cross-check with them (A. Latina + A. Saini (GS))
- Access to > 1 code is invaluable, in particular to uncover bugs and to understand the impact of approximations which may not always be fully appreciated.