Main Linac Emittance Preservation

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People Contributing to Talk

- Kiyoshi Kubo, *KEK*
- Peter Tenenbaum, *SLAC*
- Peder Eliasson, Andrea Latina, Daniel Schulte, *CERN*
- Paul Lebrun, Francois Ostiguy, Kirti Ranjan, Nikolay Solyak, *Fermilab*
- Jeffrey Smith, *Cornell*
- Freddy Poirier, Nicholas Walker, *DESY*

Areas of recent work

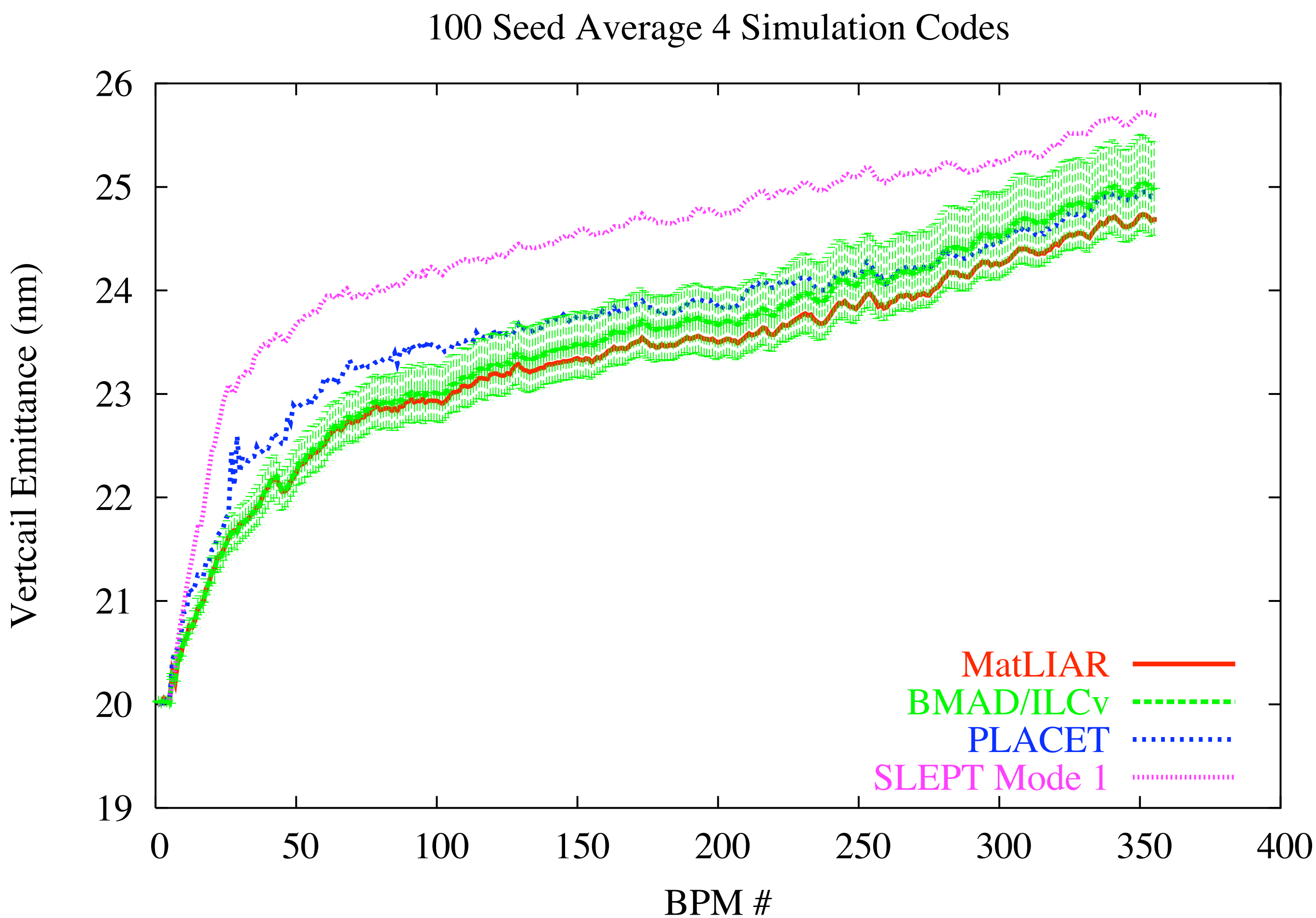
- Benchmarking/Crosschecking simulation codes
- Comparison of curved vs. straight linac
- Principally been concentrating on use of Dispersion Free Steering and Dispersion Bumps
- Failure Mode Analysis
  - failed BPMs
  - failed Steering Magnets
- Dynamic Studies
  - beam jitter
  - quadrupole jitter

Benchmarking/Crosschecking

- The Problem
  - Different simulations codes get slightly (sometime grossly) different results when performing, in particular, Dispersion Free Steering.
  - Is this due to differences in code, misalignments or algorithm?
  - Previous crosschecking studies were only performed with simple tracking simulations and not with a fully developed alignment algorithm
  - After successful completion, we will have a "benchmark" for all new simulation codes to compare to if beginning ILC LET work.

Benchmarking/Crosschecking results

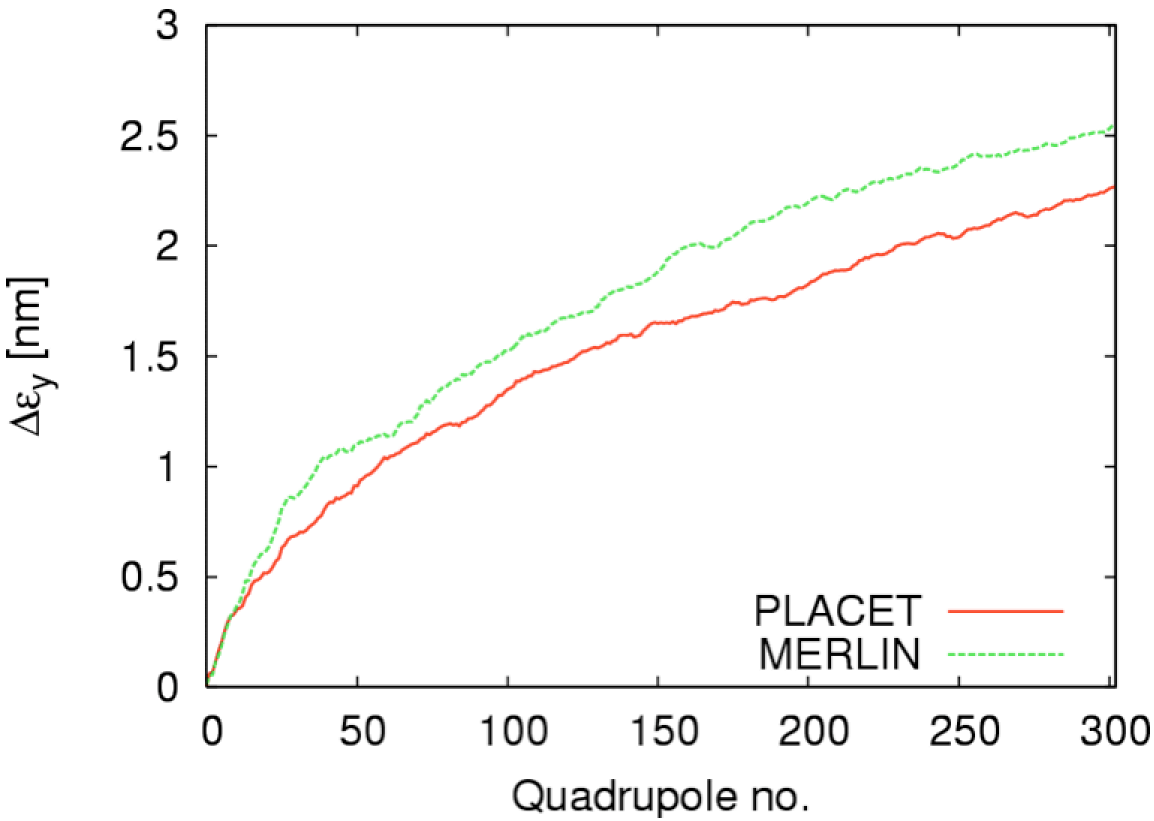
- After enough work we were able to get four codes to agree rather well.
- We now have 4 independent programs with 4 independent code bases performing very similarly with the same set of lattice conditions
- Error on mean plotted at right for one curve only



Benchmarking/Crosschecking results

P. Eliasson, F. Poirier

- A separate comparison was made between PLACET and Merlin and agreement was found to quite good.
- This was under different condition so they cannot be directly compared with results on previous slide

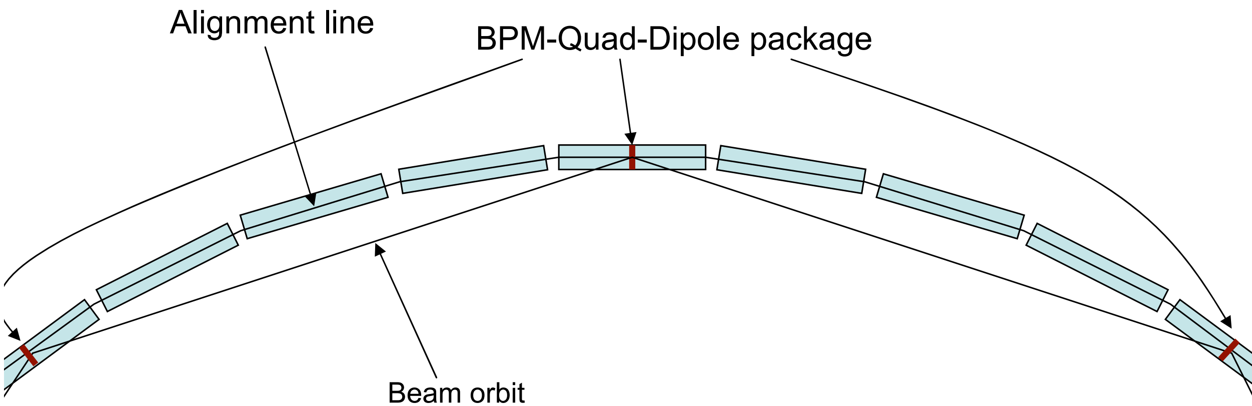


Curve Linac Anaylsis

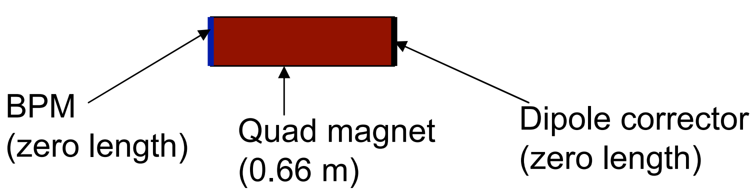
K. Ranjan, F. Ostiguy, N. Solyak, K. Kubo, P. Tenenbaum, P. Eliasson, A. Latina, D. Schulte

- Laser straight best for emittance preservation
- Earth curvature following best for cryogenic system and helium distribution, and possibly for civil engineering.
  - **But what about emittance preservation?**

Curved Linac, 1-quad/4-cryomodules

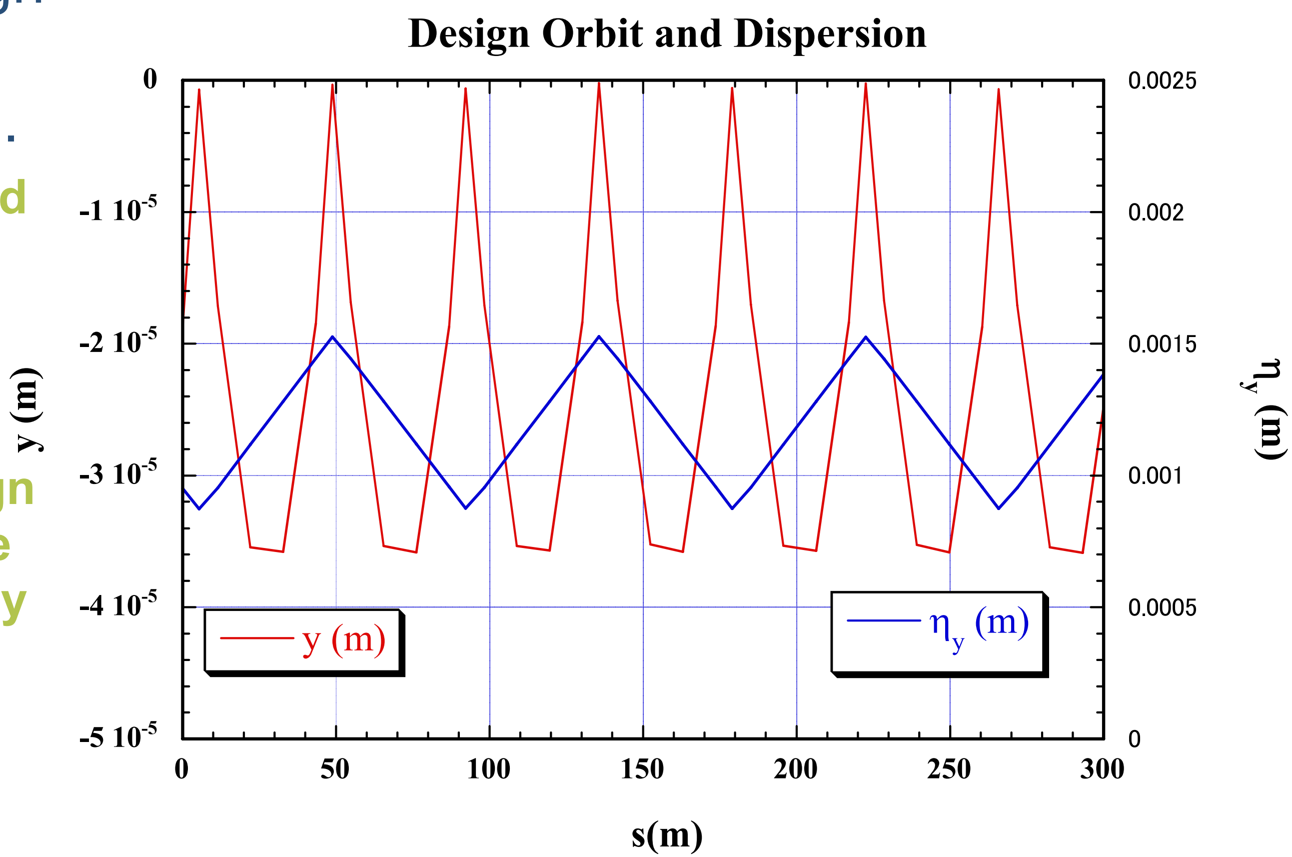


BPM-Quad-Dipole package



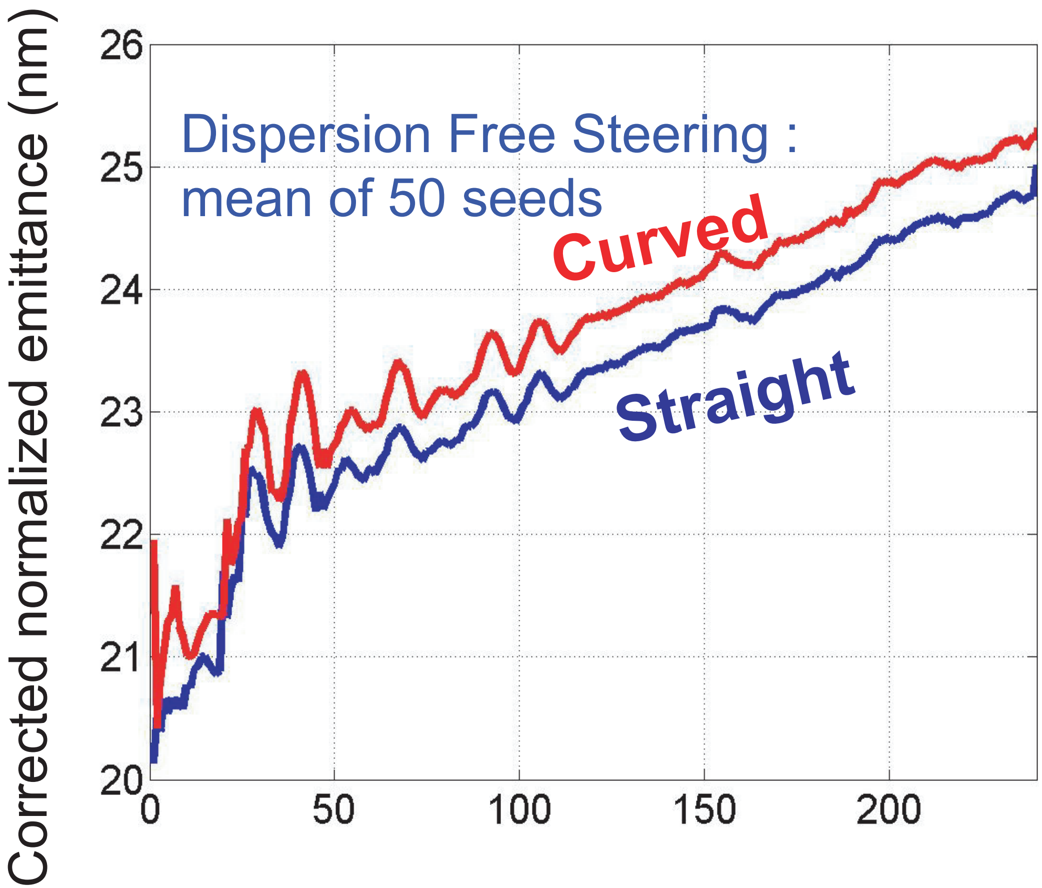
Curved Linac Considerations

- With a curved linac there is now a design non-zero vertical orbit and dispersion.
  - The orbit was found to make an insignificant contribution to emittance growth.
  - However, the design dispersion must be compensated for by injecting a dispersive beam into the main linac



Curved Linac Analysis Results

- Using similar component misalignments, but not including BPM scale errors, all participants found insignificant difference in DFS performance between straight and curved linacs.
- MatLIAR results to the right

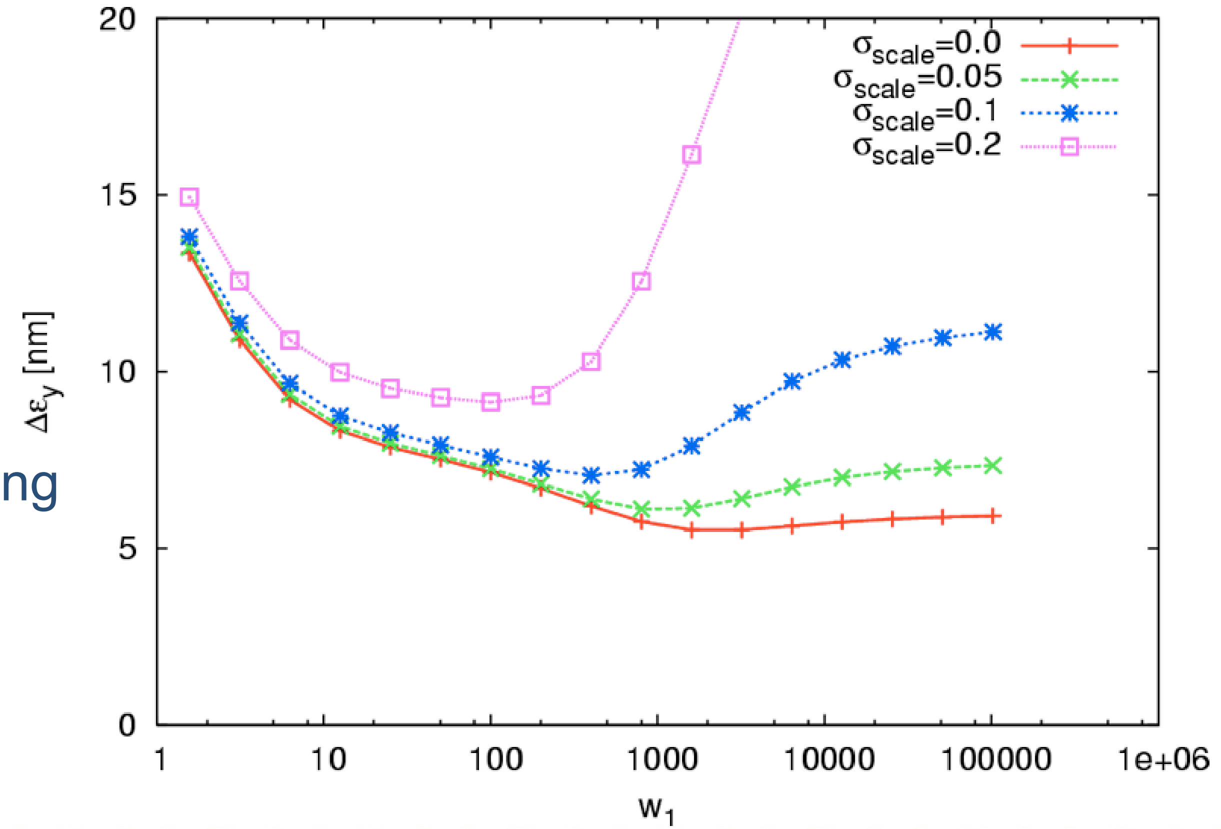


DFS parameters not optimized for Curved Linac

Curved Linac and BPM Scale Errors

P. Eliasson

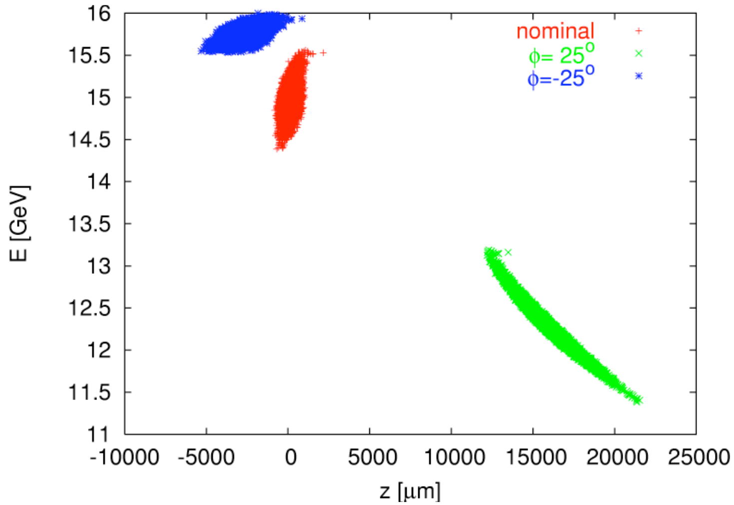
- BPM scale errors: $x_{\text{reading}} = a\, x_{\text{real}}$
- Without calibration, the scale errors can be on the order of 20%
- This plot shows the effect the scale error has on DFS performance. A 20% scaling error dramatically decreases DFS performance for a curved linac.
- However, dispersion bumps were found to mitigate the effects.
- The horizontal axis at right is the weighting function for DFS

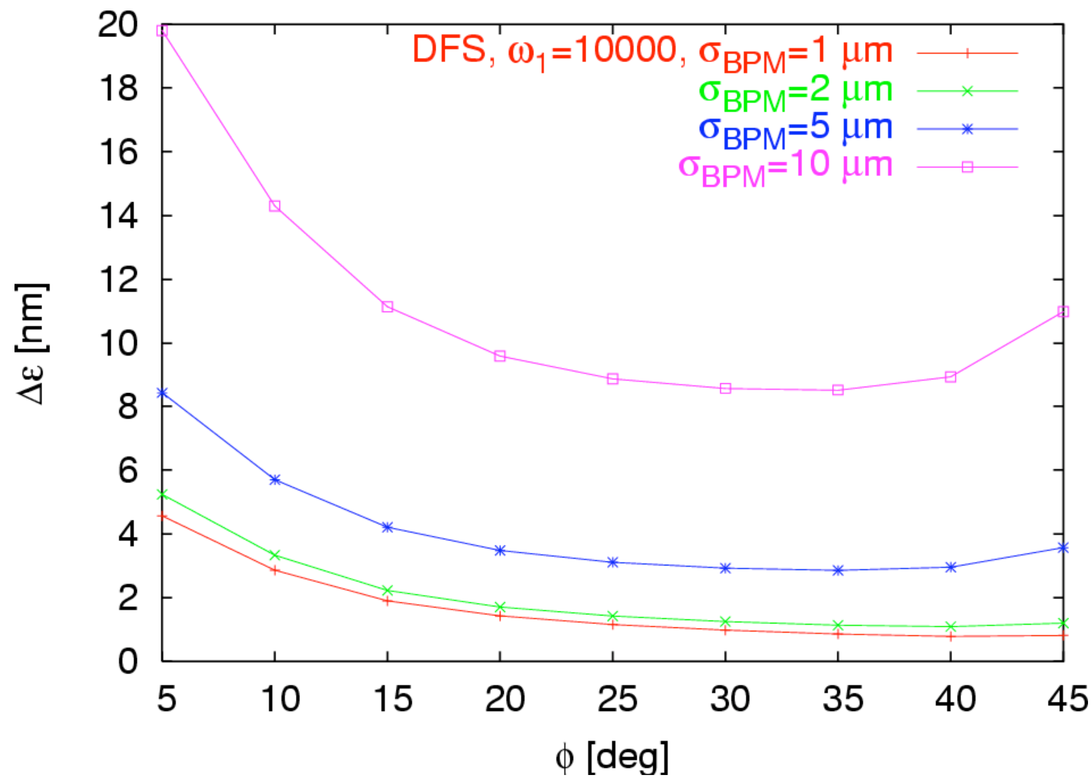


Using Bunch Compressor for DFS

A. Latina

- Off-phase beams in BC gain different energies, so these beams can be used for DFS instead of changing ML cavity gradients.
- With a phase offset of about 25 degrees, this method was found to be very promising.
- We intend on studying this method further





Failure Mode Analysis

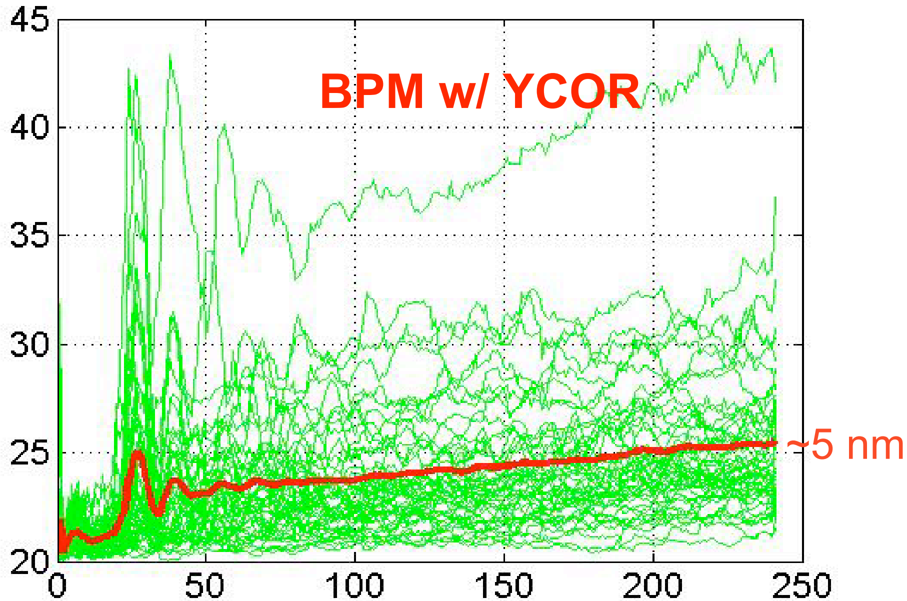
K. Ranjan, F. Ostiguy, N. Solyak, J. Smith

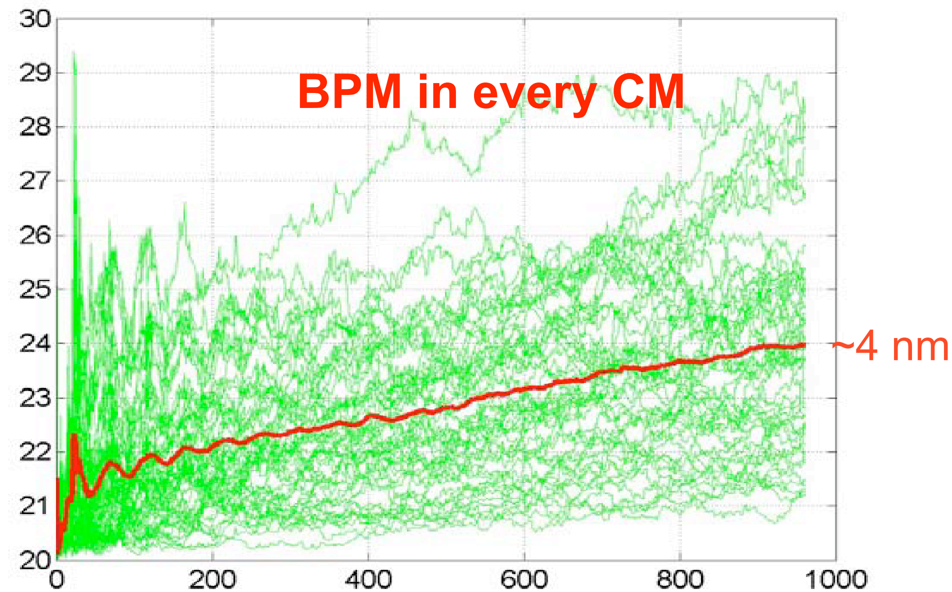
- Examined faulty BPMs and Steering Magnets.
- Effects on DFS:
  - DFS performs well even in the presence of several (few %) failed BPMs and steering magnets, provided the faulty BPMs and magnets can be identified. This is true even if there are several failed BPMs and steering magnets back to back (decrease in performance begins when about 4 or more consecutive components fail).
  - However, if DFS is performed while being unaware of faulty components then the emittance dilution is significant
  - Compared to other alignment algorithms, DFS is very robust to BPM and Steering Magnet failure. It's much more of a serious issue for BA and KM.
  - However, in the presence of noisy, but still operational, BPMs and steering magnets DFS performs more poorly than BA and KM

Number of BPMs

K. Ranjan, F. Ostiguy, N. Solyak

- The nominal design has BPMs only in the Quadrupole package
- Increasing the number of BPMs results in only a slight decrease in average emittance for DFS.
- However, the spread in performance over different seeds is smaller.





Steering Magnet Jitter

D. Schulte

- Preliminary results suggest that for single bunch effects, steering magnet power supply jitter is not be a problem and the required stability for acceptable performance of a few 10^-4 is well within capability.
- However, if there is no end of linac intra-pulse feedback then steering magnet jitter could result in significant projected emittance dilution.

Other Dynamic Effects During DFS

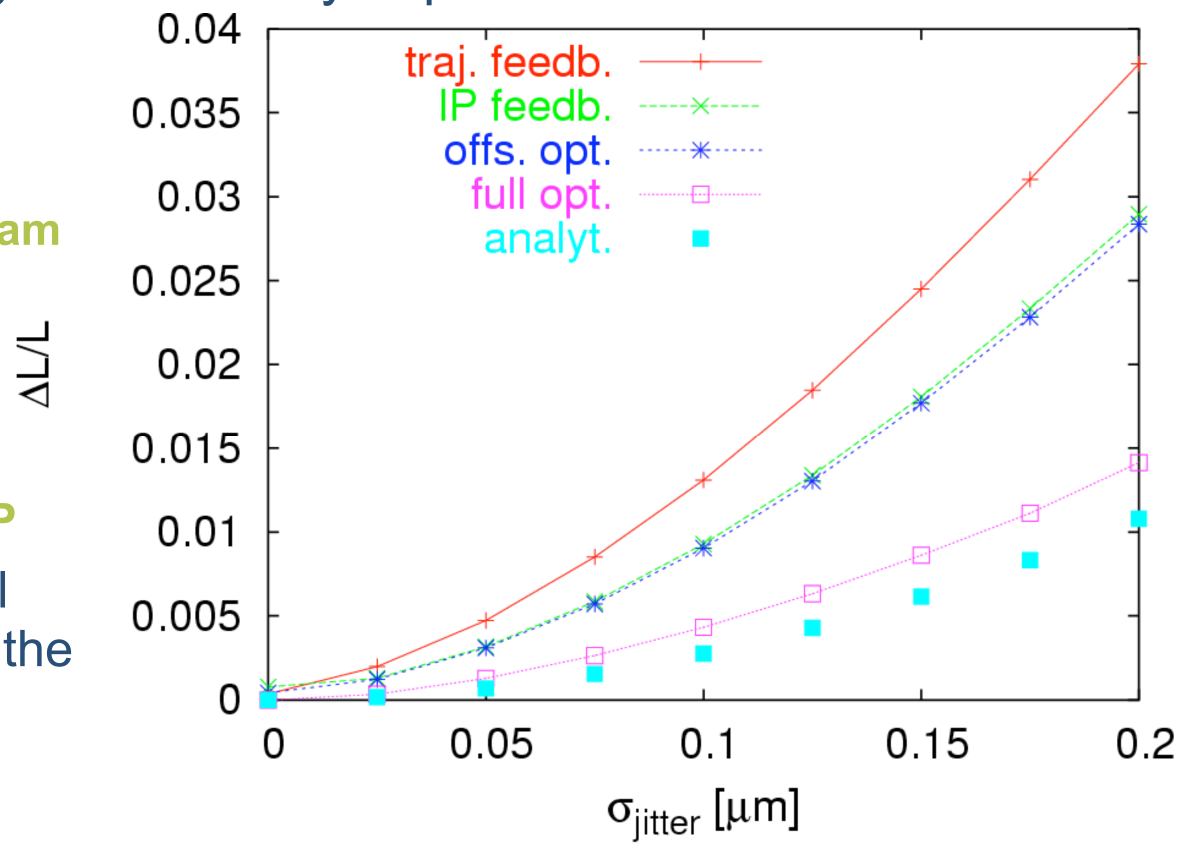
D. Schulte

- Dynamic effects during DFS can result poor performance due to the fact we are taking the different between two beam orbits.
- This beam jitter can be partially “fitted out” using upstream BPMs and the model prediction
- Method was found to work well for Quadrupole and incoming beam jitter
- However, it requires very good BPM resolution.
- Method looks very promising and would like to investigate it further

Quadrupole Jitter

D. Schulte

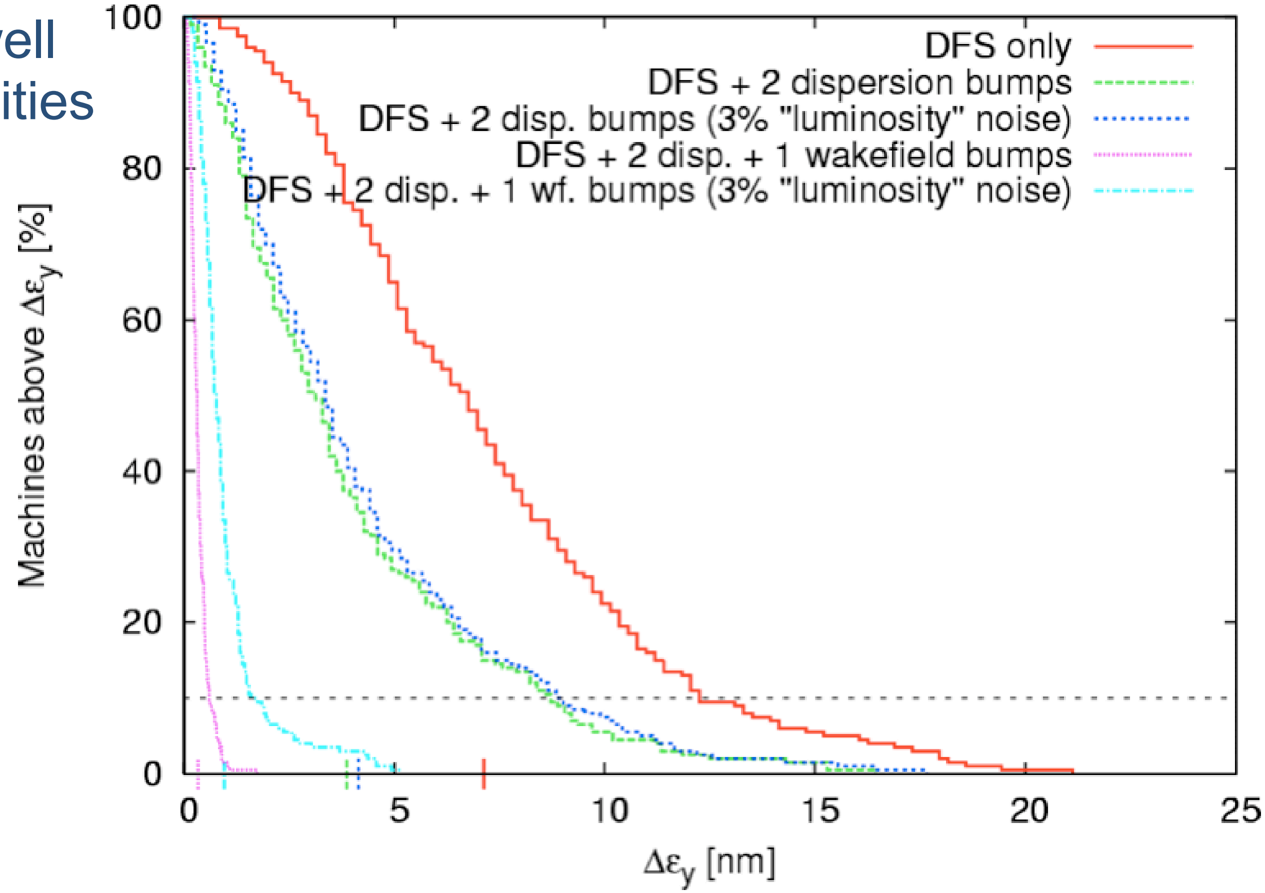
- In addition to dispersive emittance growth, quadrupole jitter also results in a beam jitter exiting the main linac resulting in luminosity degradation
- Several methods to regain luminosity in presence of Quadrupole jitter:
  - **intra-pulse trajectory feedback at end of ML**
  - **intra-pulse IP beam-beam offset feedback**
  - **beam-beam offset optimization at IP**
  - **beam-beam offset and angle optimization at IP**
- Using a combination of all four was found to restore the luminosity rather well



Dispersion and Wakefield Bumps with DFS

P. Eliasson

- Using Dispersion and Wakefield Bumps in conjunction with DFS has been found to be very effective in emittance preservation.
- Wakefield bumps were found to perform very well if a large number of cavities (144 in this case!) were on movers
- Even when including all significant sources of emittance dilution, this combination preserves emittance very well. Only the laser wire signal noise remains as a significant source of emittance dilution.



Future Work

- Look into benchmarking with other alignment algorithms (DFS most complex so we started there)
- Static studies rather well progressed so we should ramp up work on dynamic studies
  - RTML and BDS still need a lot more static studies
  - ML could still use some more too
- Fully integrated luminosity preservation studies
  - RTML, ML and BDS right now basically tuned separately (some with with ML -> BDS)
  - Start studies from DR extraction to IP and ideally use luminosity preservation as figure of merit and not emittance growth.
  - RTML lattice has only existed for a couple of months so integrated studies couldn't have started earlier!