Bunch Compressor for Main Linac Beam-Based Alignment

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- Conclusions and Outlook

Introduction

- DFS attempts to correct dispersion and trajectory at the same time

⇒ A nominal beam + one or more *test beams* with different energies are used to determine the dispersion along the linac. The nominal trajectory is steered and the differences between the nominal and the off-energy trajectories are minimized:

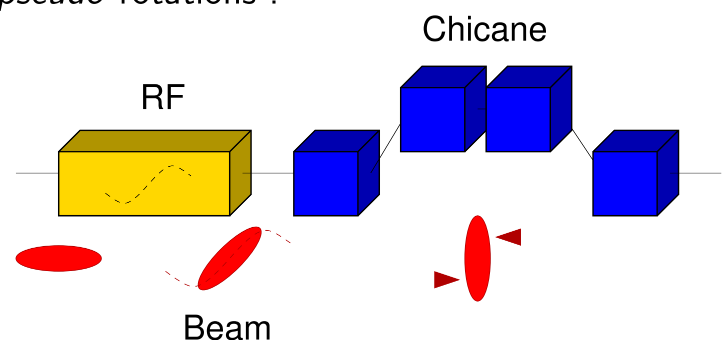
$$\chi^2 = \sum_{i=1}^{n} \omega_{1,i}\, y_{0,i}^2 + \sum_{j=1}^{m} \sum_{i=1}^{n} \omega_{2,j} \left(y_{j,i} - y_{0,i}\right)^2 + \sum_{k=1}^{p} \omega_{3,k}\, c_k^2$$

$i = 1..n$	BPMs	$y_{i,j}$	position of beam j in BPM i
$j = 0..m$	beams ($j = 0$ for nominal beam)	c_k	strength for the corrector k
$k = 1..p$	correctors	$\omega_{1,i}$, $\omega_{2,j}$, $\omega_{3,k}$	weights

- We want to use the Bunch Compressor to generate the energy difference.

Bunch Compression

- In order to compress a bunch longitudinally we need to impress a "rotation" in the longitudinal phase space
- this is achieved by two *pseudo*-rotations :



for which we need :

1. a RF system, working at a phase equal to $k\pi$, that linearly correlates the momentum with the z-position of the particles in the bunch

2. a magnetic chicane that provides a convenient R_{56}. The magnetic chicane consists of two pairs of rectangular dipoles, one being the mirror image of the other, separated by a drift space (see Frank Stulle's talk, CLIC Meeting, October 6, 2006)

Simulation Procedure

- Simulation Procedure
  - Tracking with PLACET
    - 1 nominal beam
    - 2 off-phase beams through the BC (phase offset introduced in the second stage of compression)

  - Main linac alignment:
    - 1. One-to-One Correction
    - 2. Dispersion Free Steering
    - [3. Dispersion Bumps Optimization]

Simulation Parameters

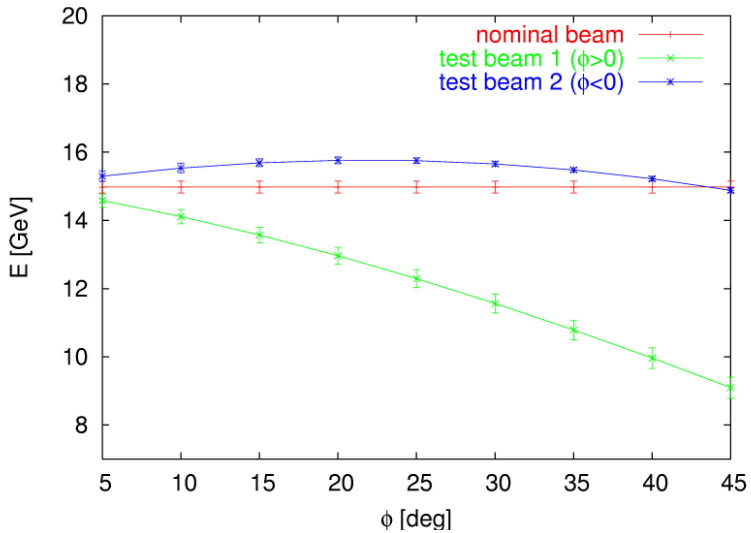
- Bunch Compressor and Main Linac:
  - ML:
    - 24 cavity spacing lattice (1 quadrupole every 3 cryogenic modules)
    - laser-straight/curved configurations
  - BC: two stages compression, configuration 300B:
    - σ_z reduced from 6 mm $\rightarrow 300\ \mu$m
    - energy increased from 5 GeV $\rightarrow$ 15 GeV

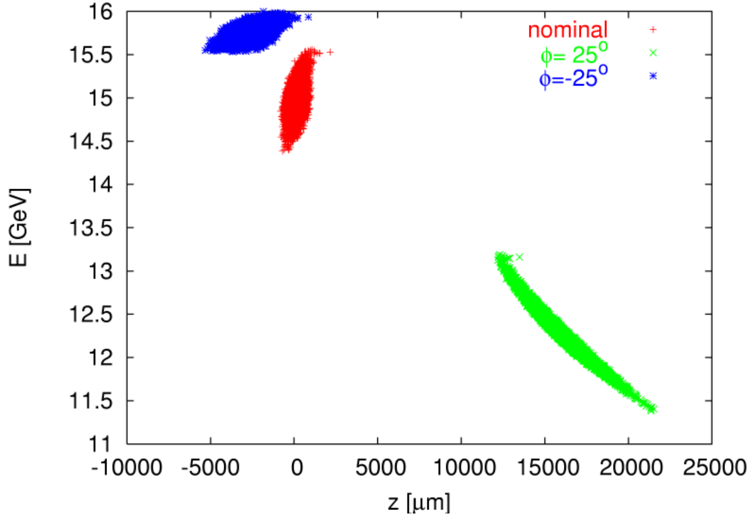
- Misalignment model in the ML:
  - $\sigma_{quad} = 300\,\mu\text{m}$ Quadrupole position error
  - $\sigma_{cav} = 300\,\mu\text{m}$ Cavity position error
  - $\sigma'_{cav} = 300\,\mu\text{rad}$ Cavity angle error
  - $\sigma_{BPM} = 200\,\mu\text{m}$ BPM position error
  - $\sigma_{res} = 1 - 10\,\mu\text{m}$ BPM resolution

- Dispersion Free Steering:
  - 1 nominal beam, 2 help beams
  - $\omega_{1,i} = 1$, orbit correction
  - $\omega_{2,k} = 1000 - 10000$
  - $\sigma_{res} = 1 - 10\,\mu\text{m}$ BPM resolution

Bunch Compression of an off-phase bunch

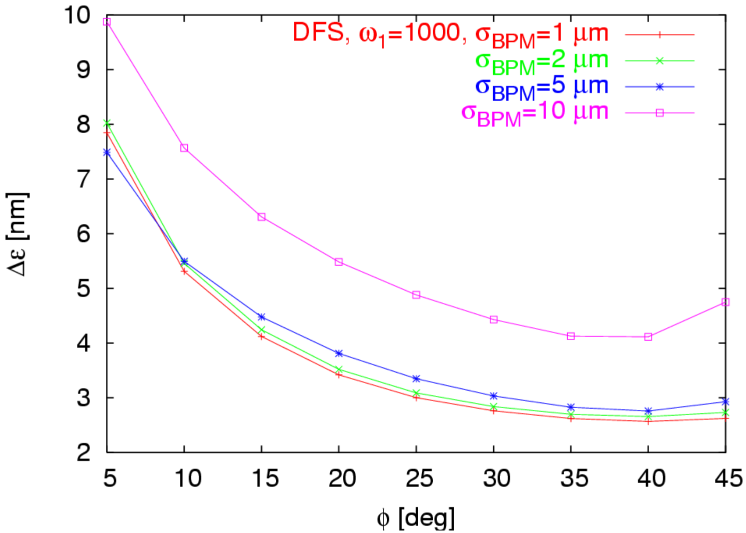
Energy difference as a function of the phase:

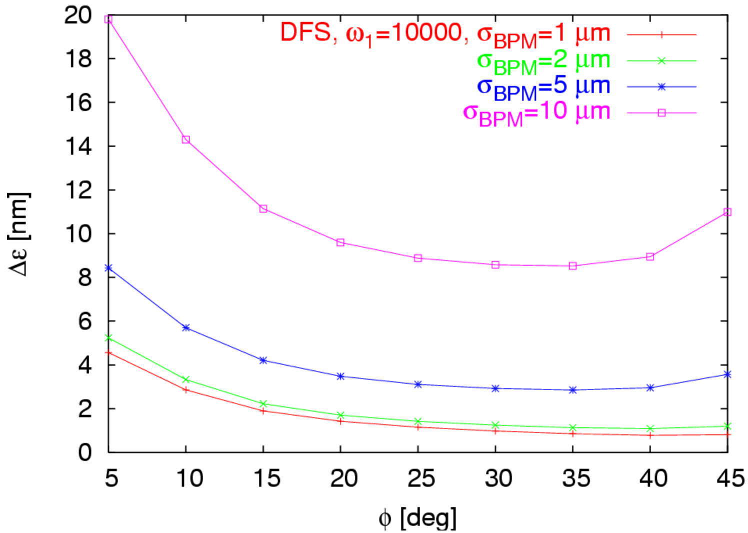




- with respect to the nominal beam, off-phase beams have:
  - different energy spread
  - greater bunch length
  - phase out of sync
- their phase must be synchronized with the ML accelerating phase

Final Emittance Growth after Dispersion Free Steering as a function of Φ





- two cases are shown: ω_1 =1000 and ω_1 =10000 (second gives better results)

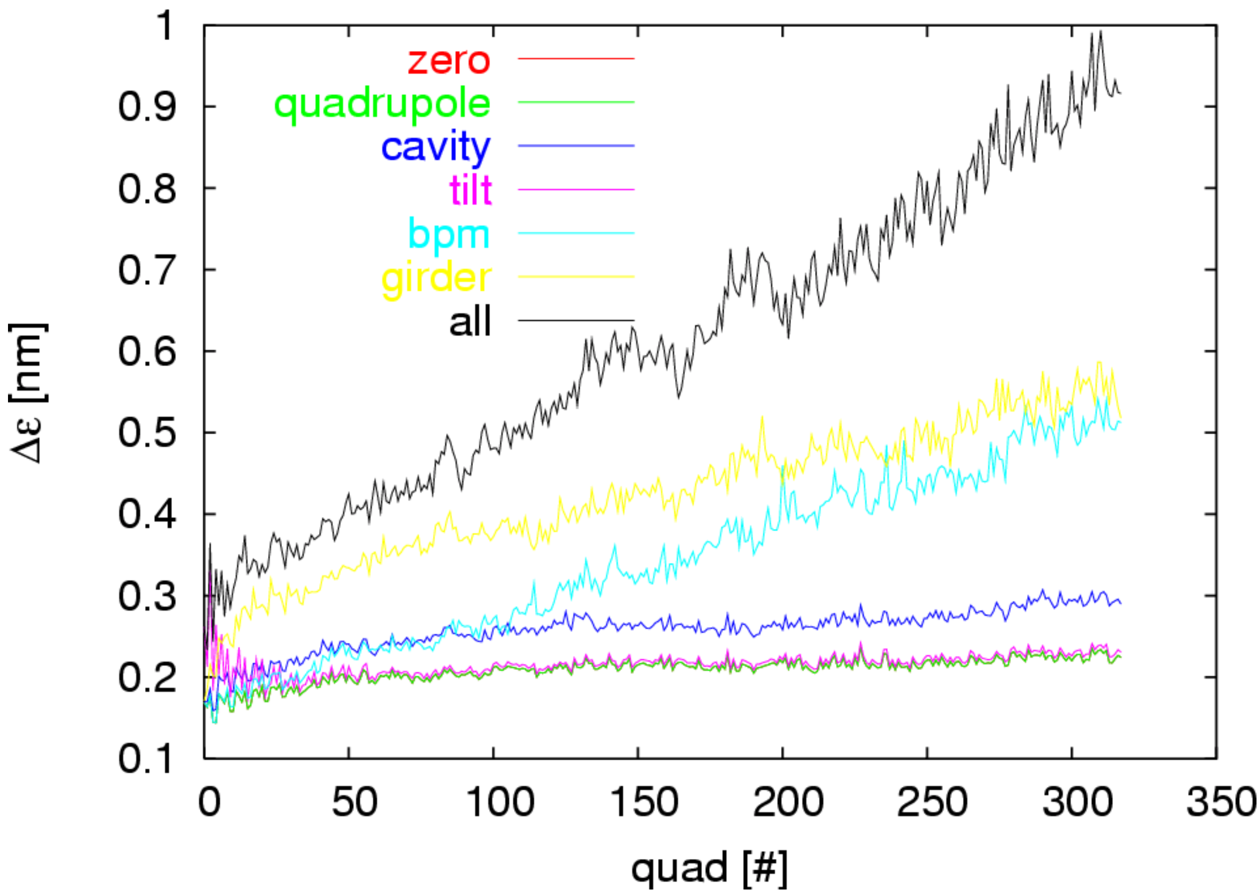
- each point is the average of 100 machines

$\Rightarrow$ there is an optimum (which seems to vary with the weight)

- from now on we focus on Φ=25^o

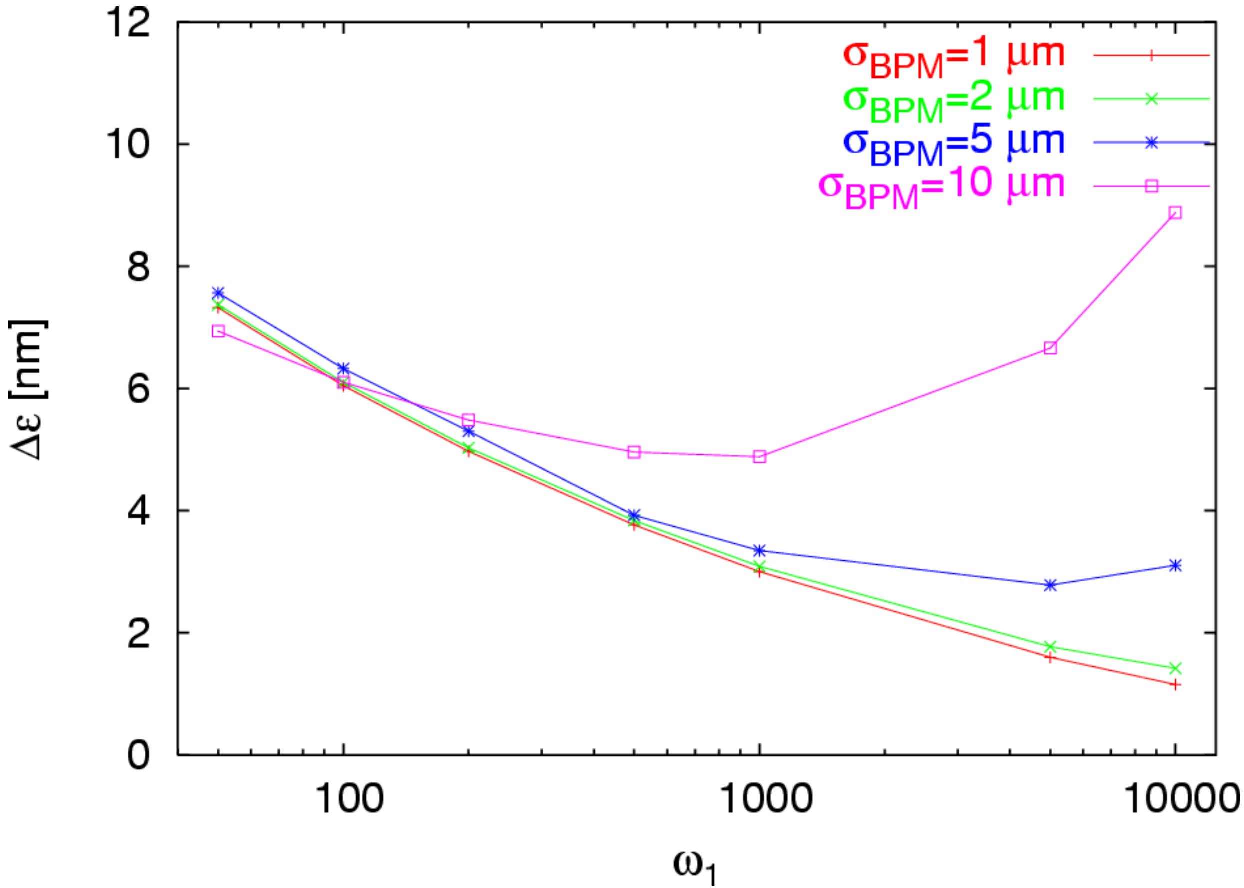
Emittance growth along the machine after DFS

Individual contributions



σ_{BPM}=1 μm, Φ=25^o, ω=10000, average of 100 machines

Emittance Growth as a function of the Weight, for Φ=25

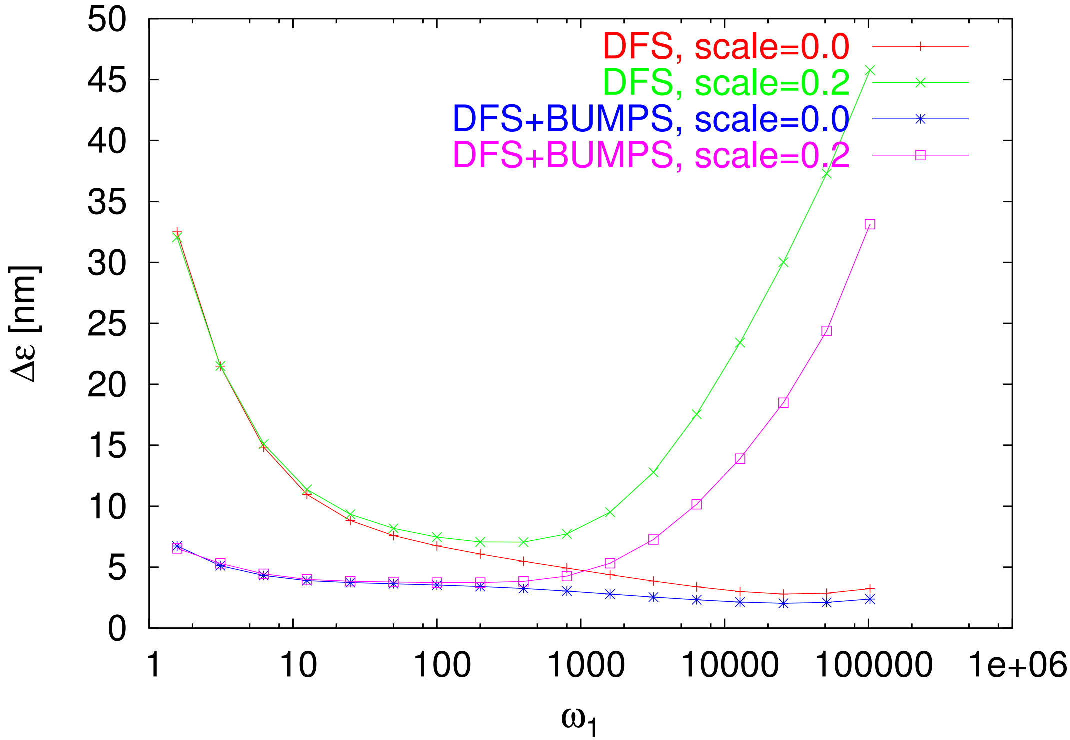


(average of 100 machines)

for a laser-straight linac, DFS (with ω "big", BPM resolution of 1 μm) leads to excellent results but...

..for a Curved Machine things are different!

In a curved linac, the BPM scale error, $\mathrm{X}_{\mathrm{meas}} = a\, X_{\mathrm{real}}$, has an impact on the DFS performances



- Scale error prevents from using “big” weights

⇒ we still need to use Dispersion Bumps to reduce the emittance growth!

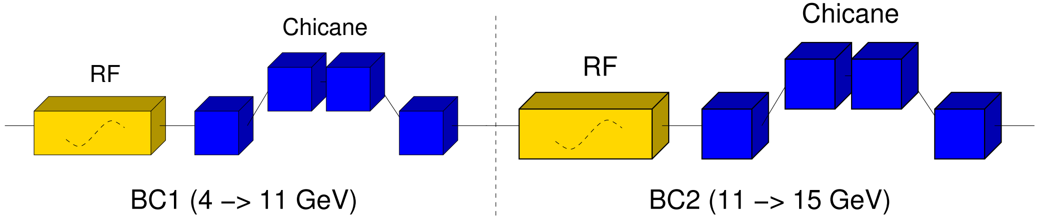
Conclusion and future developments

- BC for generating the beam energy difference needed by DFS seems to be working
- in case of a straight linac the performances are remarkable ($\Delta\epsilon < 2$ nm)
- in case of a curved linac the scale error imposes some limits $\rightarrow$ dispersion bumps are necessary

- Studies in progress:
  - how to align the bunch compressor? we want to use BC1 to align BC2
  - does the bigger energy spread in the BC2 constitute a problem (apertures...) ?

Addendum: Using BC1 to align BC2 (preliminary)

- ILC Bunch Compressor :

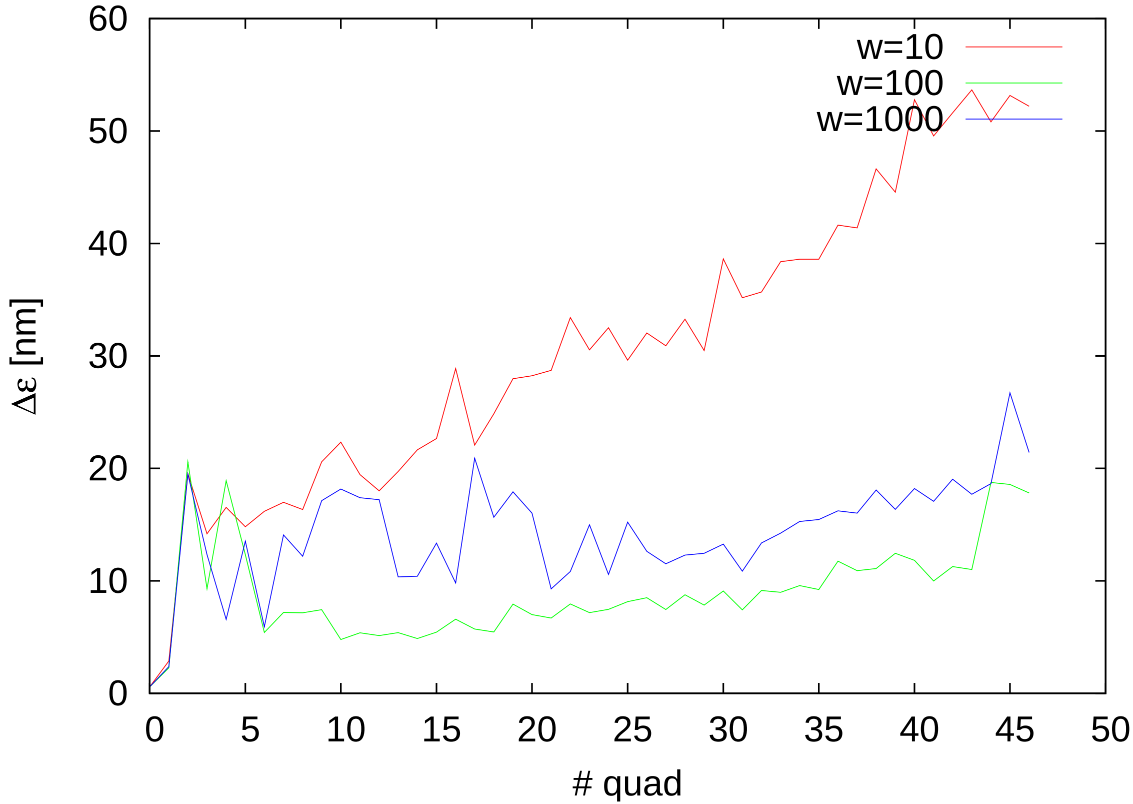


two stages, RFs **do accelerate** the bunch, σ_z from 6mm to 300μm

- We want to use the BC1 in order to align the BC2
  - we generate the test-beams with BC1, then apply DFS to BC2
  - the accelerating phase is 110^o for the BC1 and 22^o BC2

Emittance Growth in BC2 after Dispersion Free Steering

Using a phase offset of 10 degrees:



(average of 50 machines)

⇒ Dispersion Free Steering is effective but we need to apply Dispersion Bumps