Bunch Compressor for Main Linac Alignment

- Idea
  - in the BC, off-phase beams gain different energy with respect to the nominal one

    $\Rightarrow$ these off-phase beams can be used as *test-beams* for DFS

- 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]

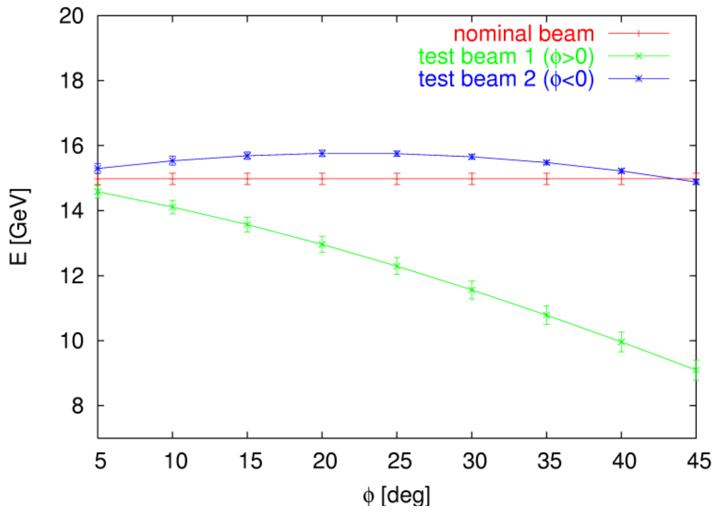
Simulation Parameters

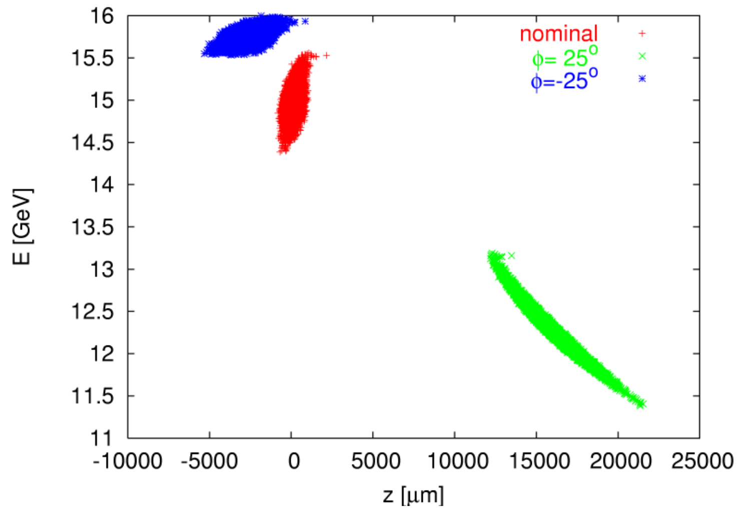
- Bunch Compressor and Main Linac:
  - ML:
    - 24 cavity spacing lattice (1 quadrupole every 3 cryogenic modules)
    - laser-straight/curved configurations
  - BC: two stages compression, configuration 300B:
    - σ_z reduced from 6 mm $\rightarrow 300\ \mu$m
    - energy increased from 5 GeV $\rightarrow$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

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

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

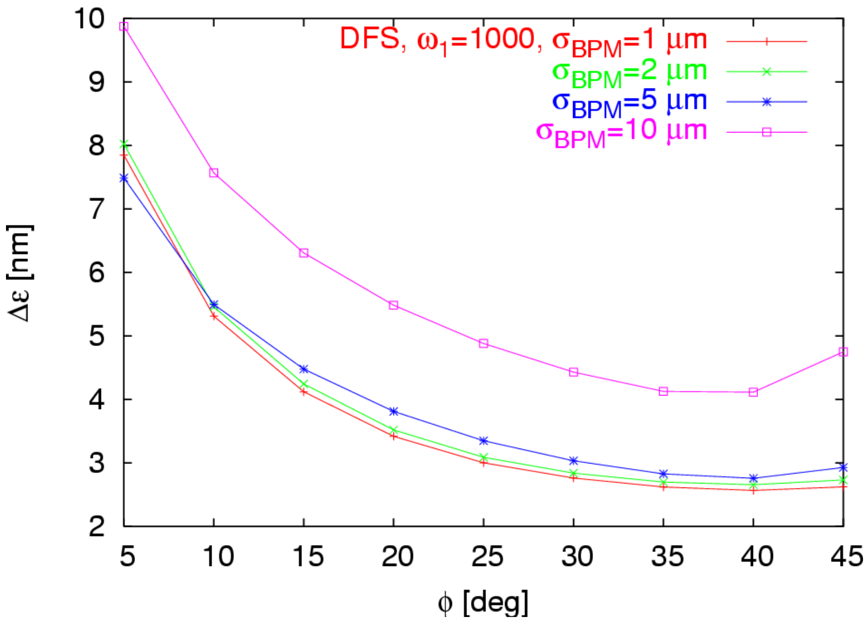
Bunch Compression of off-phase beams

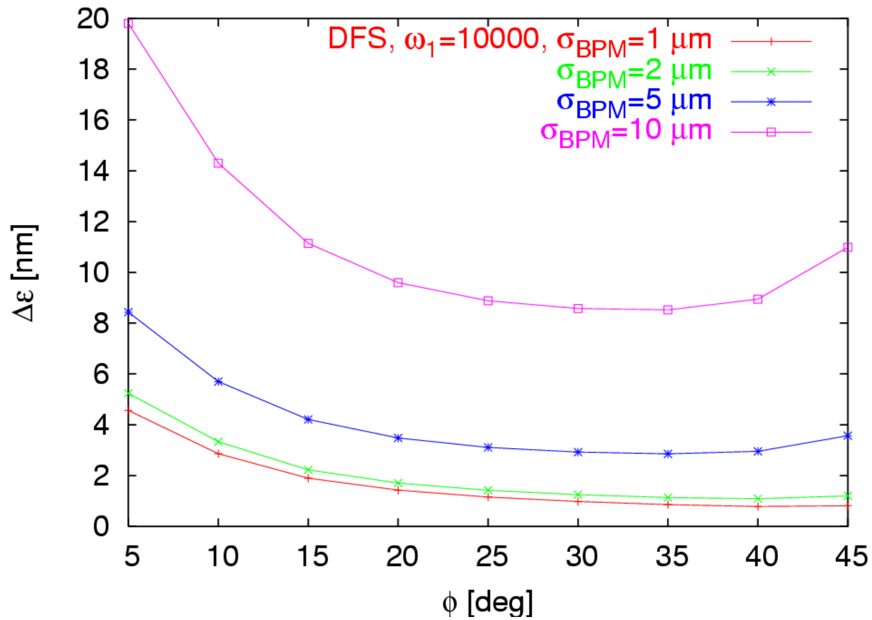




- with respect to the nominal beam, off-phase beams have:
  - different energy spread
  - greater bunch length
  - phase out of sync
- their phase must be synchronized with the ML accelerating phase

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



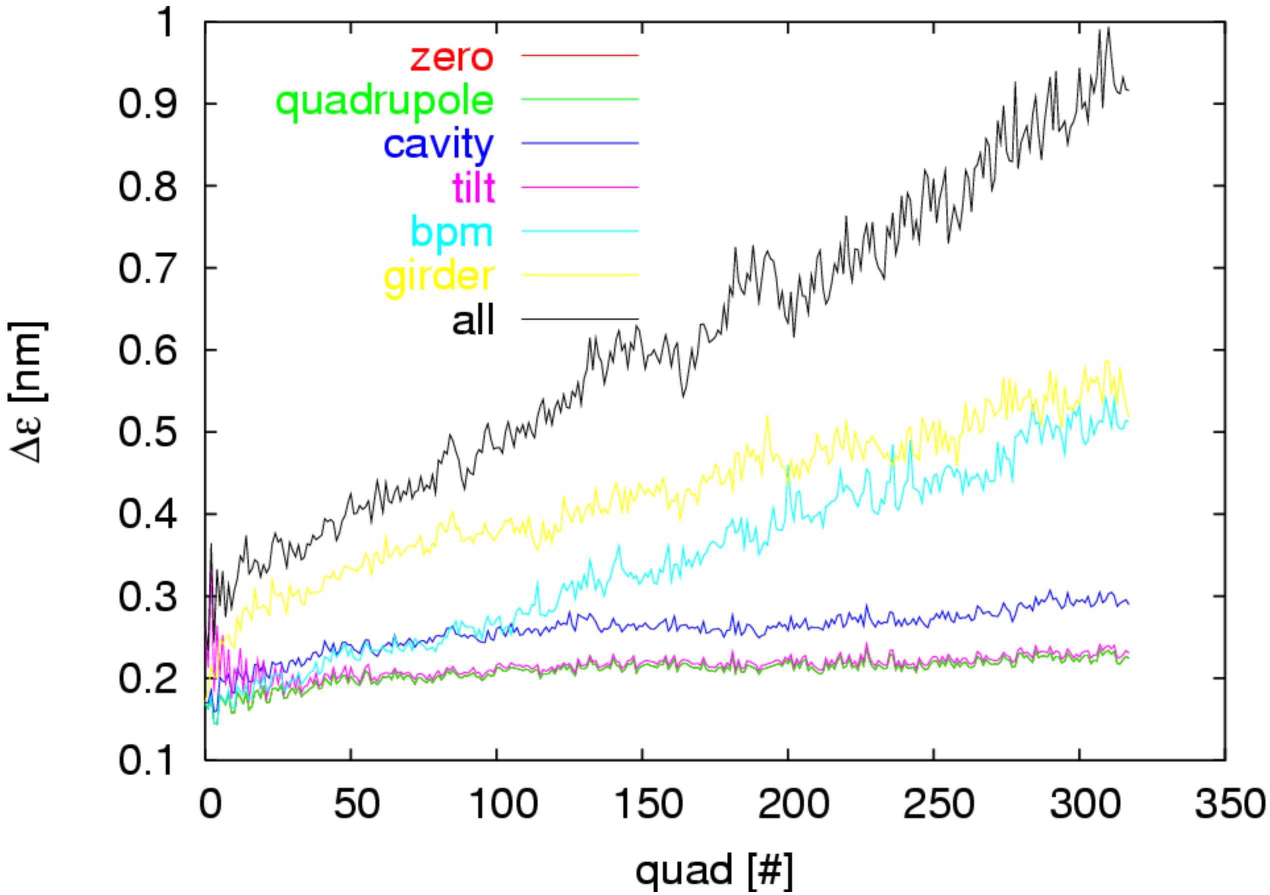


- two cases are shown: ω_1 =1000 and ω_1 =10000 (second gives better results)
- each point is the average of 100 machines

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

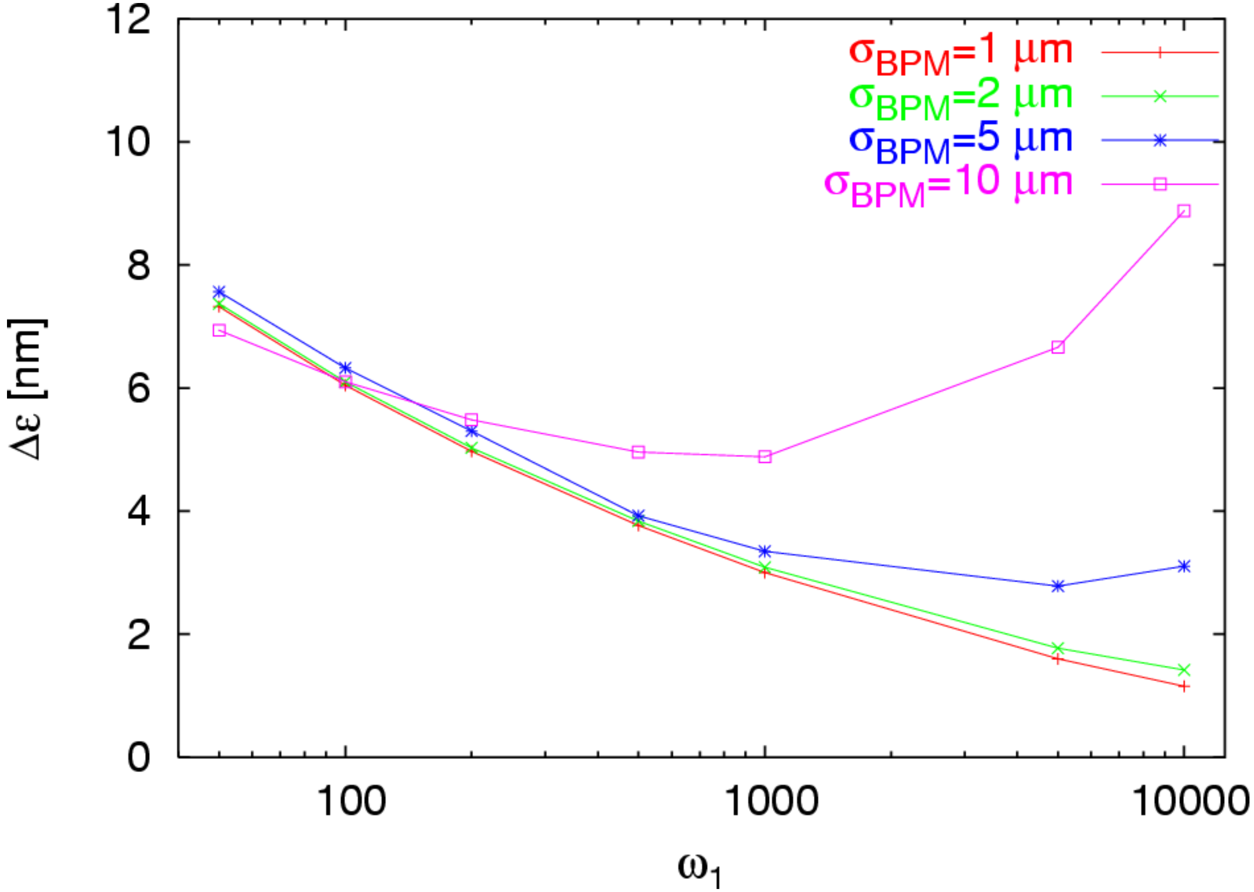
- from now on we focus on Φ=25^o

Emittance growth along the machine after DFS



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

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

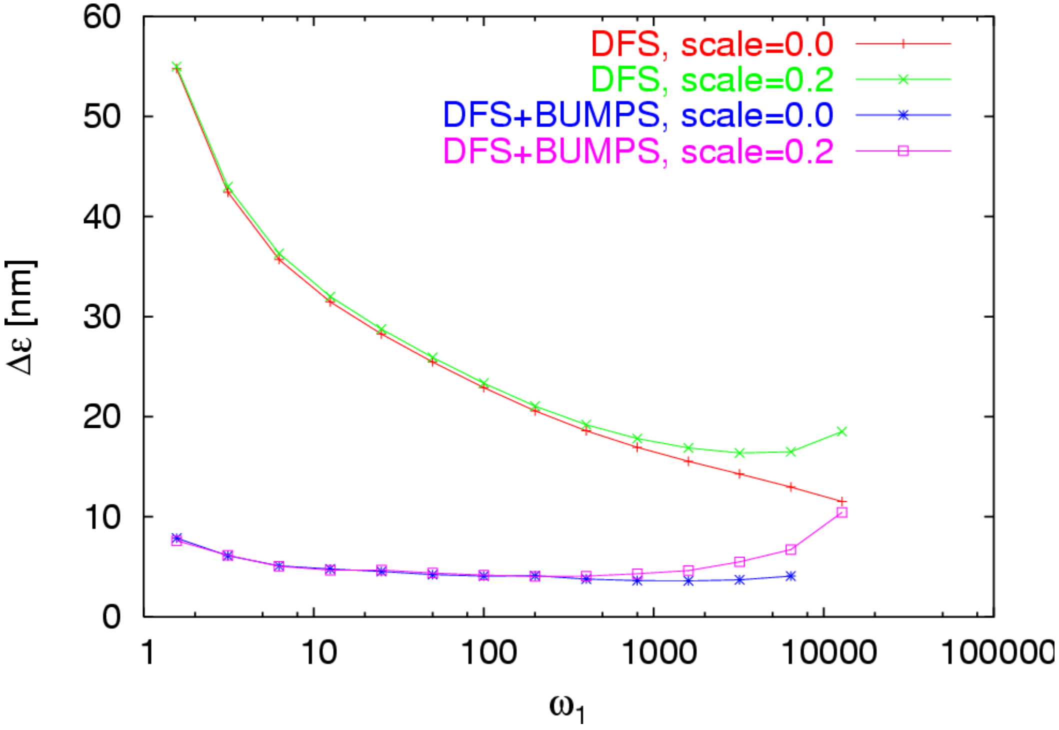


(average of 100 machines)

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 limit $\rightarrow$ dispersion bumps are necessary

- Future studies:
  - how to align the bunch compressor?
  - Does the bigger energy spread in the BC2 constitute a problem (apertures...) ?