Update on Dispersion Free Steering in the CLIC Main Linac

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- Motivation
- Bunch Compressor simulation
- Dispersion Free Steering with different Bunch Compressor settings
- Results and next developments

Dispersion Free Steering

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

⇒ A nominal beam + one or more help 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 for orbit, difference and correction terms

⇒ The energy difference of the help beams can be generated varying the RF phase.

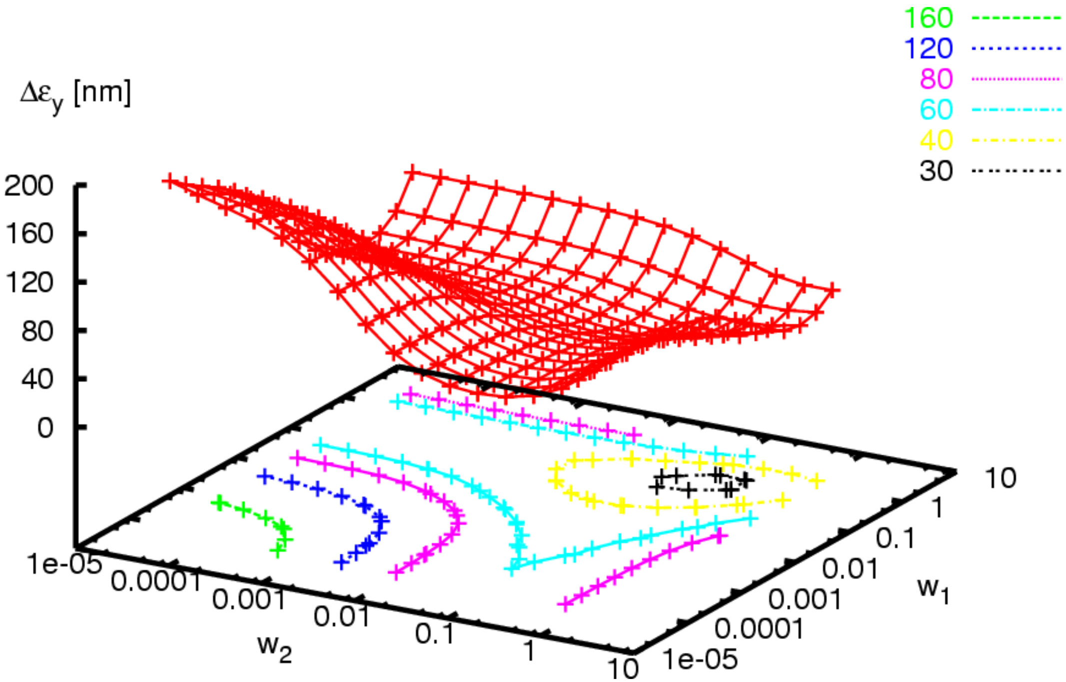
See: D.Schulte, *Different Options for Dispersion Free Steering in the CLIC Main Linac*, Proceedings of PAC 2005

Results for the ILC

Weights w_1 and w_2 for orbit and corrector strengths have been scanned:

- BPM resolution $= 10\ \mu$m

$\Rightarrow$ Target of less than 20 nm cannot be reached even for average



See: D.Schulte, P.Eliasson, *Main Linac Steering and Tuning Studies*, Proceedings of Snowmass 2005

Using Initial Energy Difference in the ILC

- need to figure out how to do it
- Optimum weights used according to individual scans
- BPM resolution $\sigma_{res} = 10\,\mu\text{m}$ (upper) and $\sigma_{res} = 1\,\mu\text{m}$ (lower table)

$\Rightarrow$ Initial energy difference helps, but

$\Rightarrow$ Even with precise BPMs barely sufficient

$\Rightarrow$ energy difference below 10% is of little help for $\sigma_{res} = 10\,\mu\text{m}$

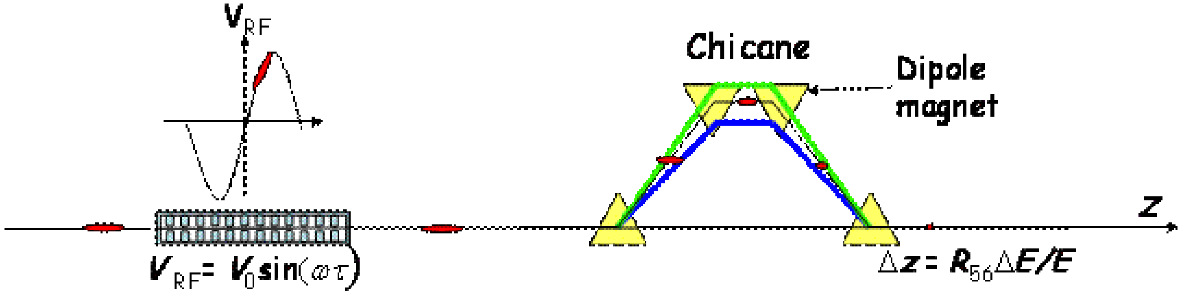
$\Delta G_1/G_0$	-0.2	-0.2	-0.2	-0.2
$\Delta G_2/G_0$	0.0	0.0	0.0	-0.1
$\Delta E_1/E_0$	0.0	0.0	0.0	0.0
$\Delta E_2/E_0$	-0.2	-0.1	-0.05	0.0
$\langle\Delta\epsilon_y\rangle$ [nm]	12	15	24	28
$\hat{\Delta\epsilon}_y(90\%)$ [nm]	53	52	69	190

$\Delta G_1/G_0$	-0.2	-0.2	-0.2	-0.2
$\Delta G_2/G_0$	0.0	0.0	0.0	-0.1
$\Delta E_1/E_0$	0.0	0.0	0.0	0.0
$\Delta E_2/E_0$	-0.2	-0.1	-0.05	0.0
$\langle\Delta\epsilon_y\rangle$ [nm]	7	8	14	26
$\hat{\Delta\epsilon}_y(90\%)$ [nm]	24	28	30	120

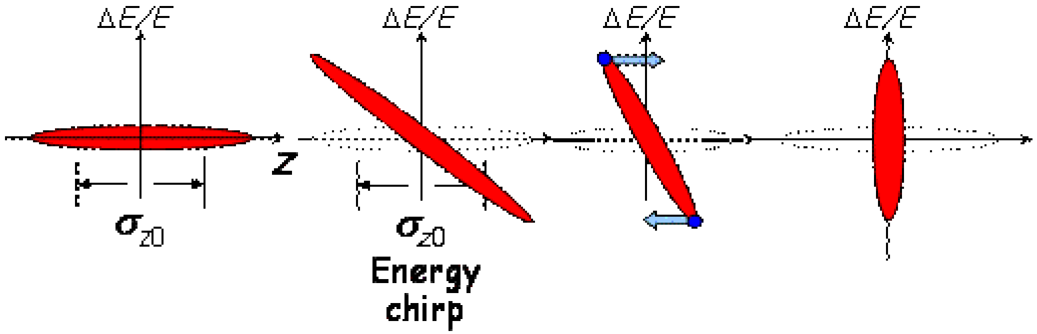
See: D.Schulte, P.Eliasson, *Main Linac Steering and Tuning Studies*, Proceedings of Snowmass 2005

Bunch Compressor

- Two components accomplish the bunch compression:
  - an accelerating structure
  - a compression chicane



- The accelerating structure and the compressing chicane reduce the rms bunch length through rotations of the longitudinal phase space of the bunch *(this reduces the rms bunch length but increases the rms energy spread)*



BC & Beam Parameters

- Beam parameters:

	unit	entrance Bunch Compression	entrance Main Linac
energy	[GeV]	9	9
energy spread	%	0.98	1.8
charge	[nC]	0.41	0.41
sigmaz	[micro m]	250	30
sigmaz	[ps]	0.834	0100
Y norm. emittance	[nm·mrad]	-	0.005-0.013
X norm. emittance	[nm·mrad]	-	0.6

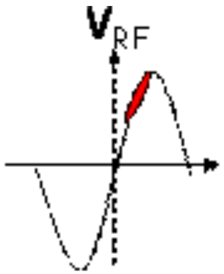
- BC parameters:
  - to compress to 30 μm the bunch length:

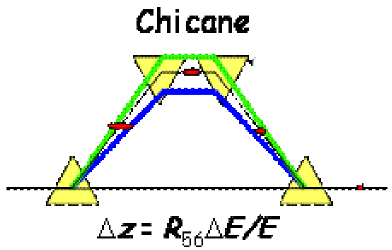
$$\mathbf{R_{56}} = \text{-0.014 m}$$
$$\mathbf{s - E}\ \text{correlation} = \text{-62.86 1/m}$$

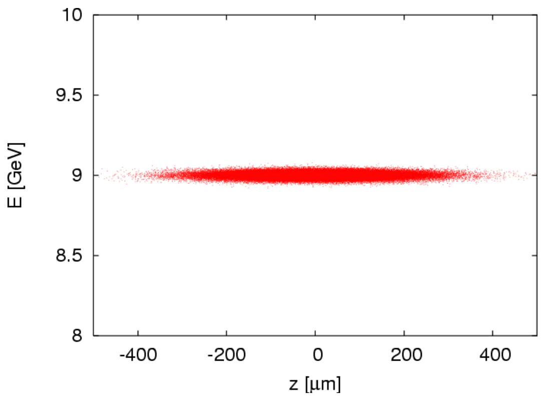
  - geometry: dipoles length 2m, bending angle 1.24deg, distance between the middle dipoles 1m, total length 40m

Bunch Compression Varying the RF Phase

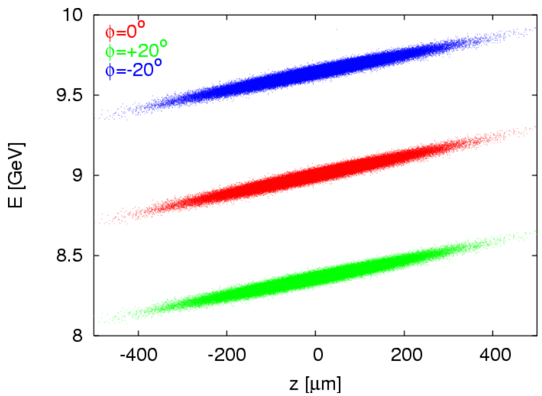
- Off-phase beams get different acceleration, therefore gain different energy.



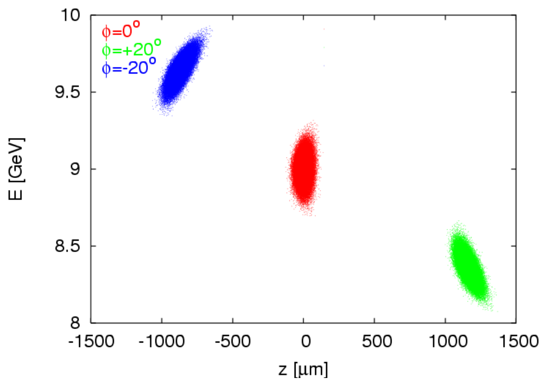




(a)



(b)



(c)

Simulation Procedure (PLACET)

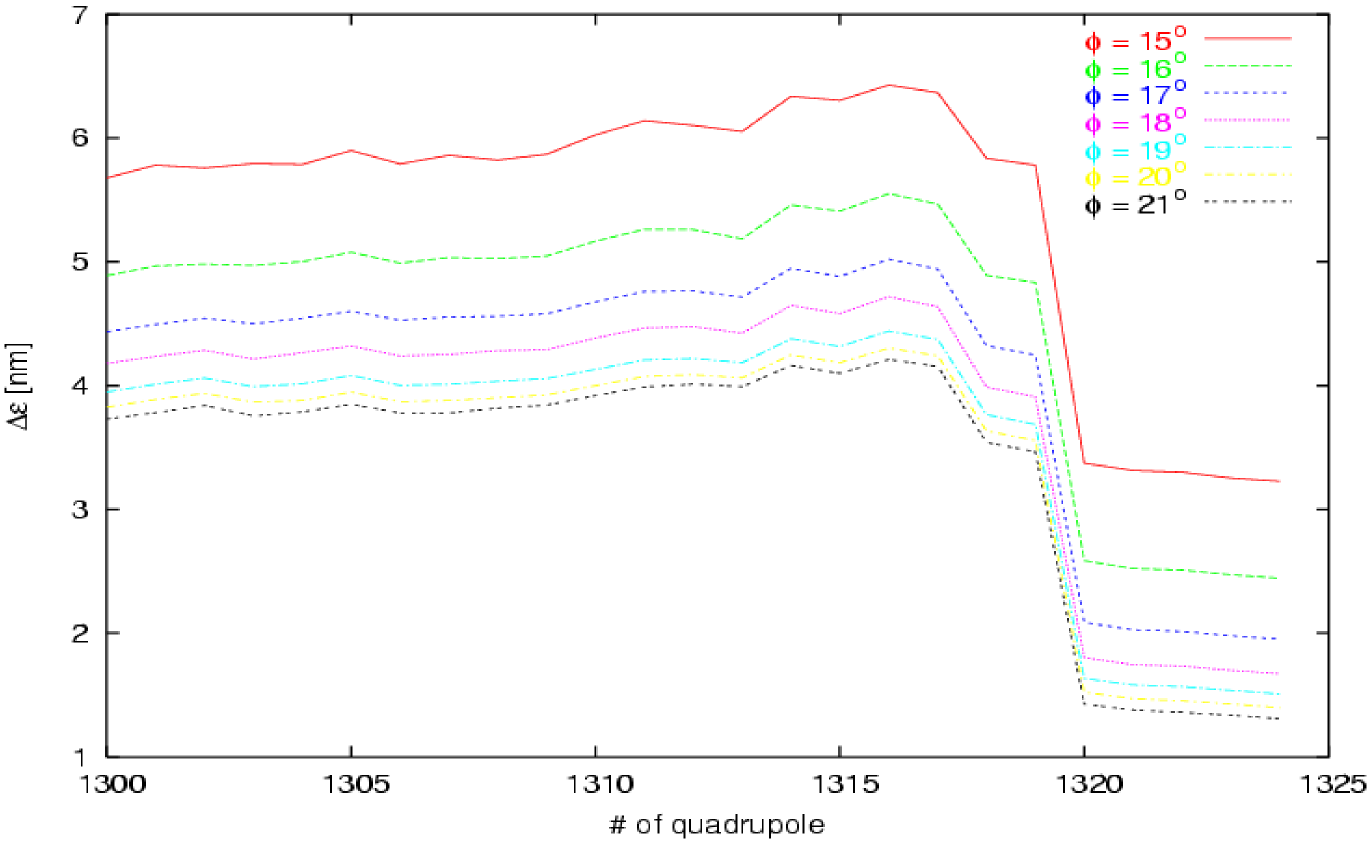
- Bunch Compressor:
  - Full 6^{th} dimensional tracking in the BC
  - Incoherent Synchrotron Radiation Emission is considered

- Dispersion Free Steering and Optimization:
  - Scan for the phase that gives the best results
  - Reduction of the emittance growth:
    - 1. One-to-One Correction
    - 2. Dispersion Free Steering
    - 3. RF Alignment
    - 4. Corrections using Wakefield Bumps

Simulation Procedure (PLACET)

- Misalignment model:
  - $\sigma_{quad} = 50\,\mu\mathrm{m}$ Quadrupole position error
  - $\sigma_{cav} = 10\,\mu\mathrm{m}$ Cavity position error
  - $\sigma'_{cav} = 10\,\mu\mathrm{rad}$ Cavity angle error
  - $\sigma_{BPM} = 10\,\mu\mathrm{m}$ BPM position error
  - $\sigma_{res} = 0.1\,\mu\mathrm{m}$ BPM resolution
- Dispersion Free Steering:
  - $\Phi_0 = 0$, nominal beam
  - $\Phi_{1,2} = \pm\Delta\Phi$, help beams
  - $\omega_{1,i} = 1$, orbit correction
  - $\omega_{2,k} = 100$, difference of the trajectories (test value, can be optimized)

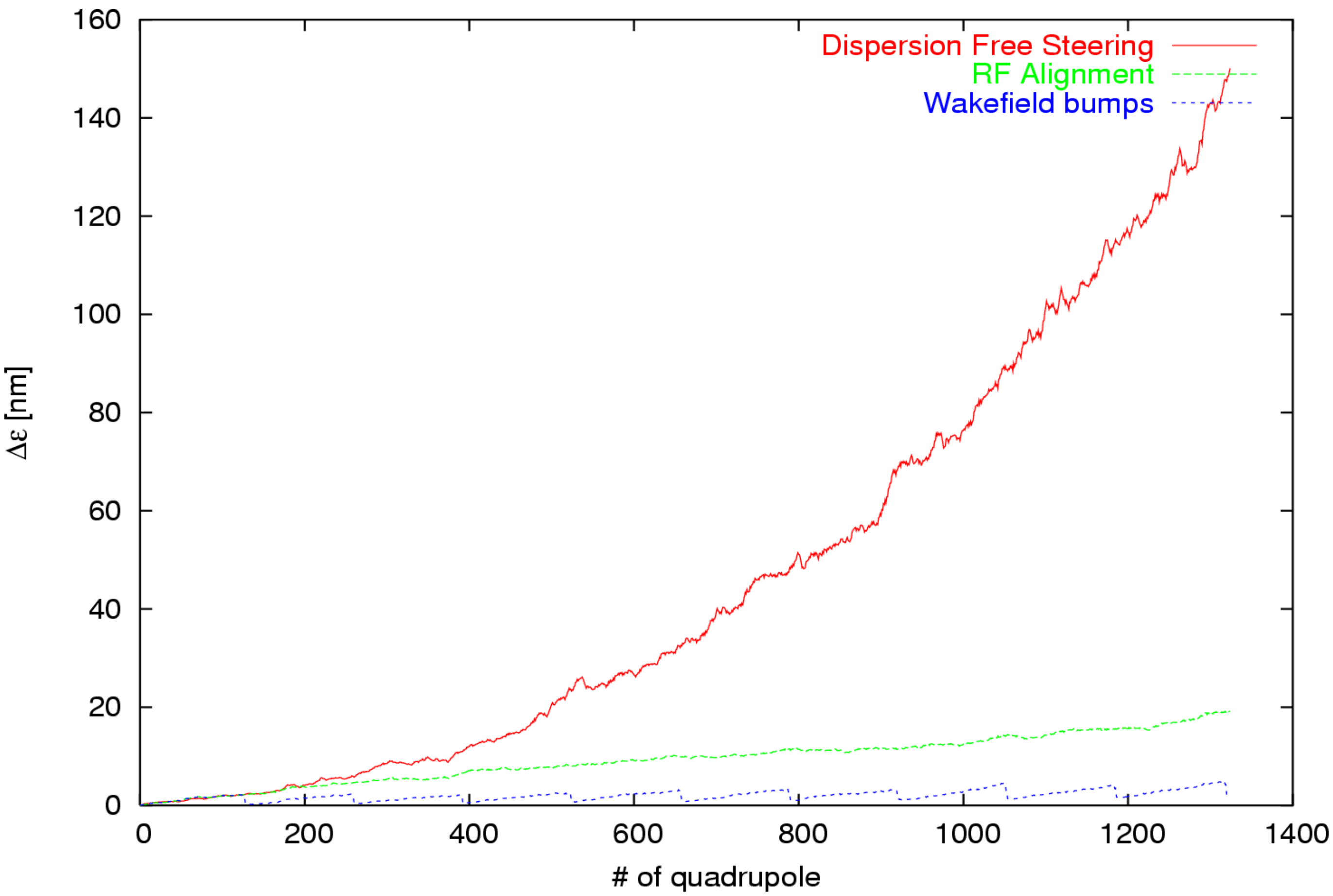
Emittance Growth as a function of Φ_{RF}



(average of 20 machines)

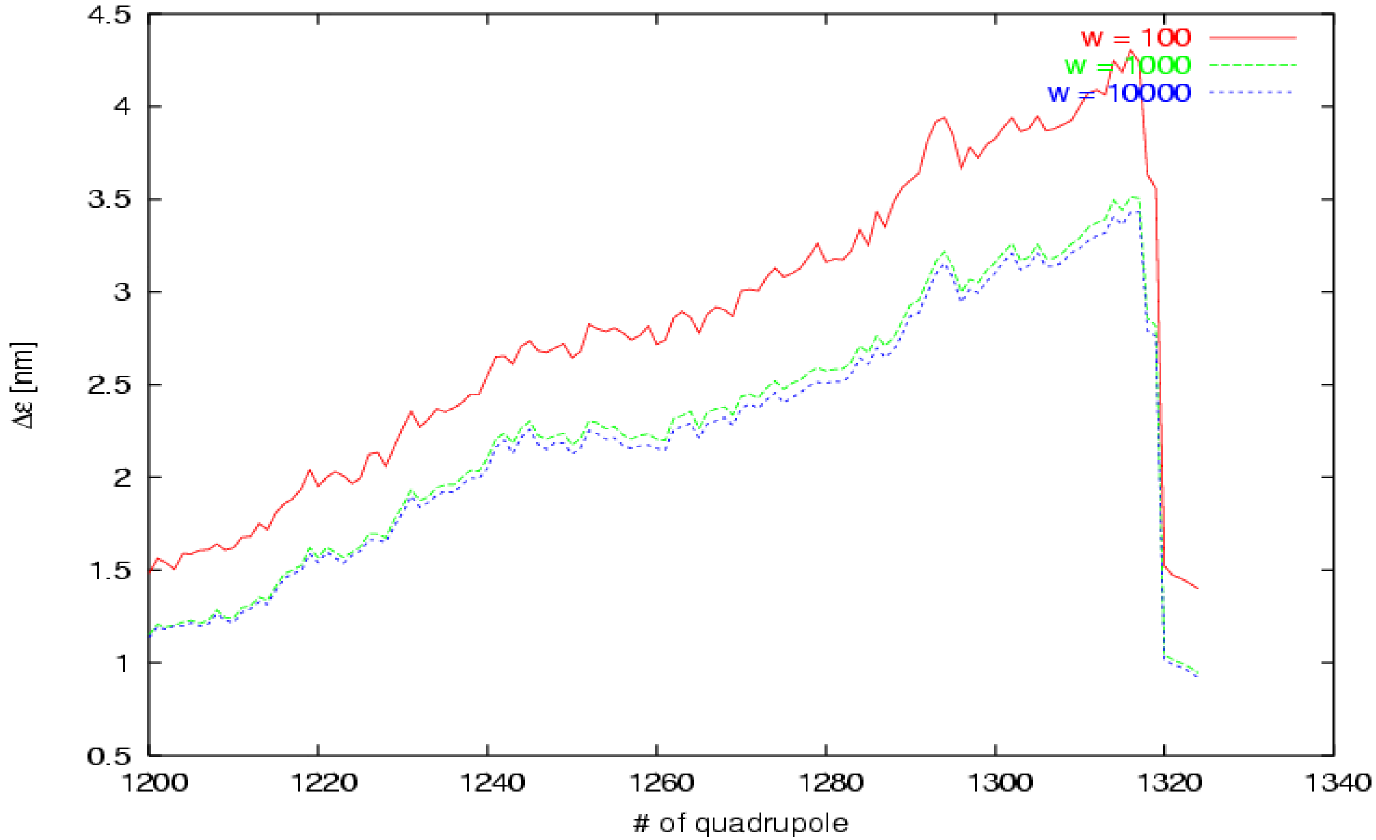
When $\Phi_{RF} > 25^o$ the emittance growth explode.

Emittance growth during the optimization, for $\Phi_{RF} = 20^o$



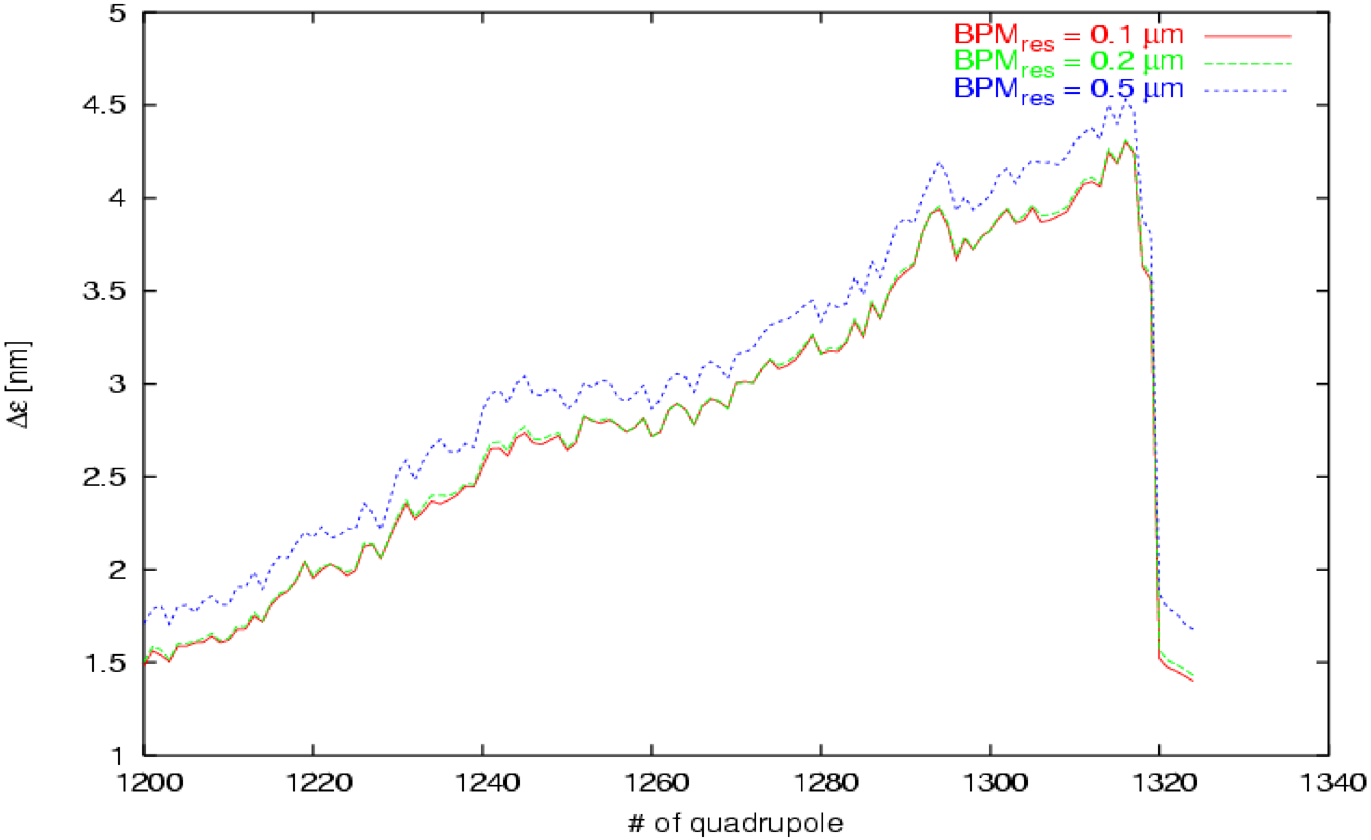
(average of 20 machines)

Emittance Growth as a function of $\omega_{2,k}$, for $\Phi_{RF} = 20^o$



(average of 20 machines)

Emittance Growth as a function of the BPM resolution, for $\Phi_{RF} = 20^o$



(average of 20 machines)

Conclusions and next developments

- How to create the energy spread necessary for the DFS

  $\Rightarrow$ varying the phase into the BC + DFS work well

- Next steps:

  - scan of the DFS weights to find the optimum
  - we have assumed that there is no dispersion in the BC

    $\Rightarrow$ we should work on a more realistic lattice to inject the beam from the BC into the ML