

# Effect of a Curved Tunnel

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## Models

- A constant focusing lattice with a quadrupole spacing of 24 cavities and a phase advance of  $60^\circ$  per cell (1 TeV centre-of-mass)
  - constant focusing eases the dispersion matching
- The curvature is simulated by adding kinks between the modules
- The misalignment model is the usual one from the TRC
  - perfect alignment until the sixth quadrupole
- Focusing on dispersion free steering
  - ⇒ dispersive effects have been minimised by adjusting dispersion at the beginning and end for a perfect machine
    - they are not re-optimised for each machine

## Synchrotron Radiation

- Radiation can be calculated as

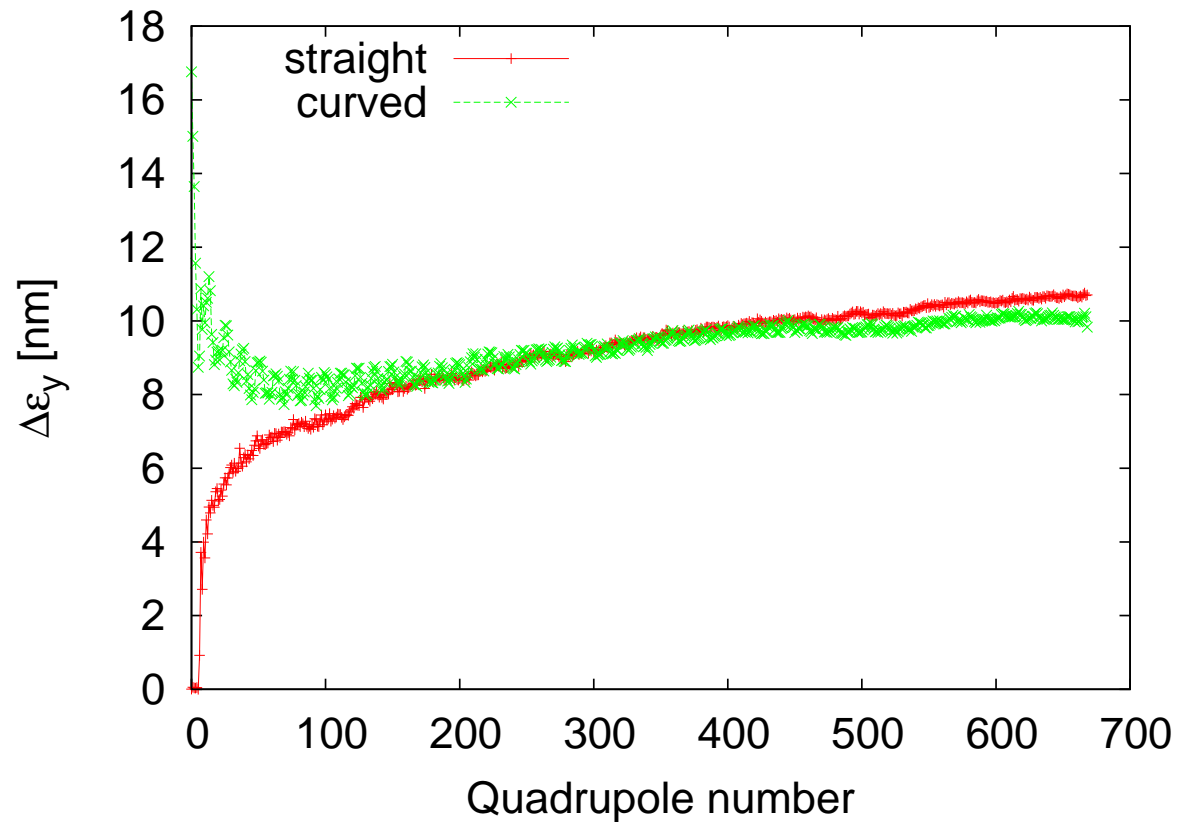
$$P \approx 90 \text{ kV} \times \frac{E^4}{\text{GeV}^4} \frac{\text{m}^2}{2\pi\rho^2} \frac{\Delta_{quad}}{L_{quad}} \times I$$

- For  $E = 500 \text{ GeV}$ , one finds  $P = 50 \text{ mW/m}$ , for 24 cavities between quadrupoles
  - $\Rightarrow$  below the acceptable heat load
  - $\Rightarrow$  but not negligible
- Note: larger quadrupole spacing leads to more radiation
- Longer quadrupoles can reduce the radiation
- Does radiation lead to problems (electron emission)?

## Simulation Procedure

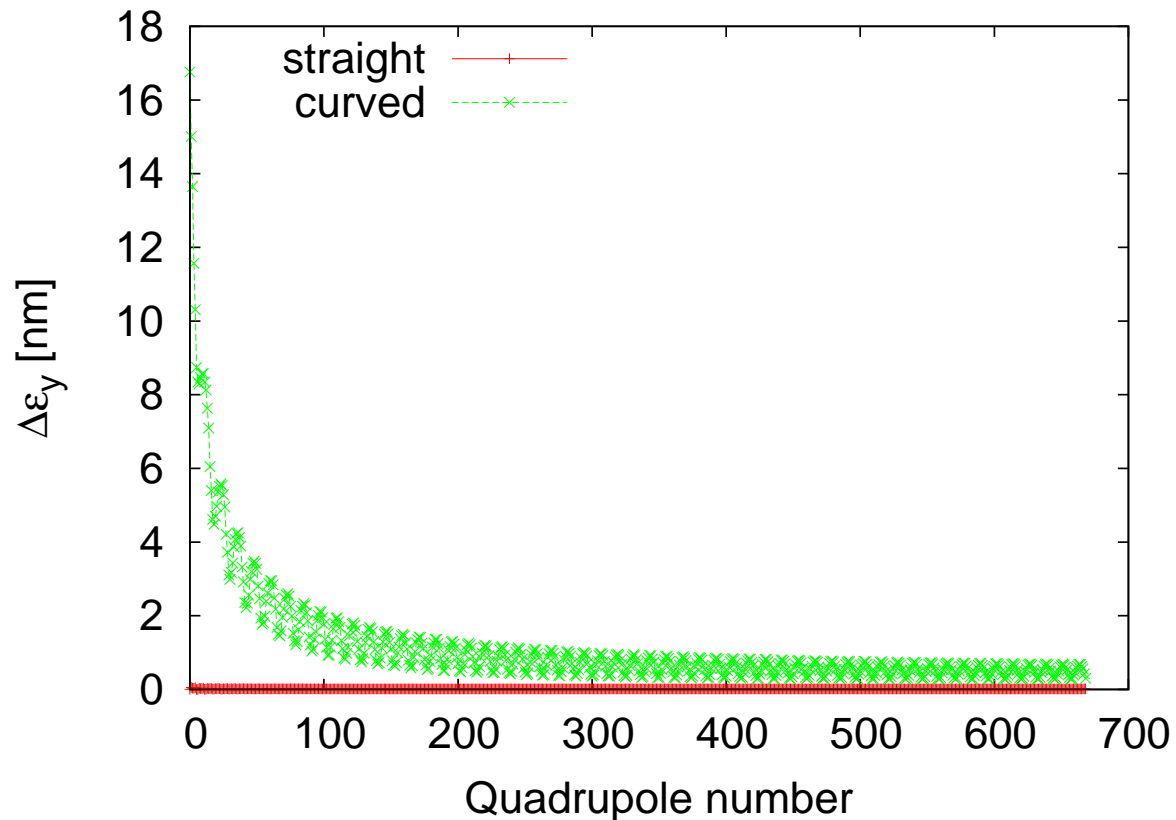
- The average emittance growth of 100 machines is calculated using PLACET
- The dispersion free steering is performed using one test beam and the nominal one
- The test beam is accelerated with a gradient that is reduced by 20%
- The target dispersion in each BPM is determined
- The weights have not been optimised, a generic value of  $w_1 = 100w_0$  is used
- Perfect knowledge of lattice is assumed

## Results



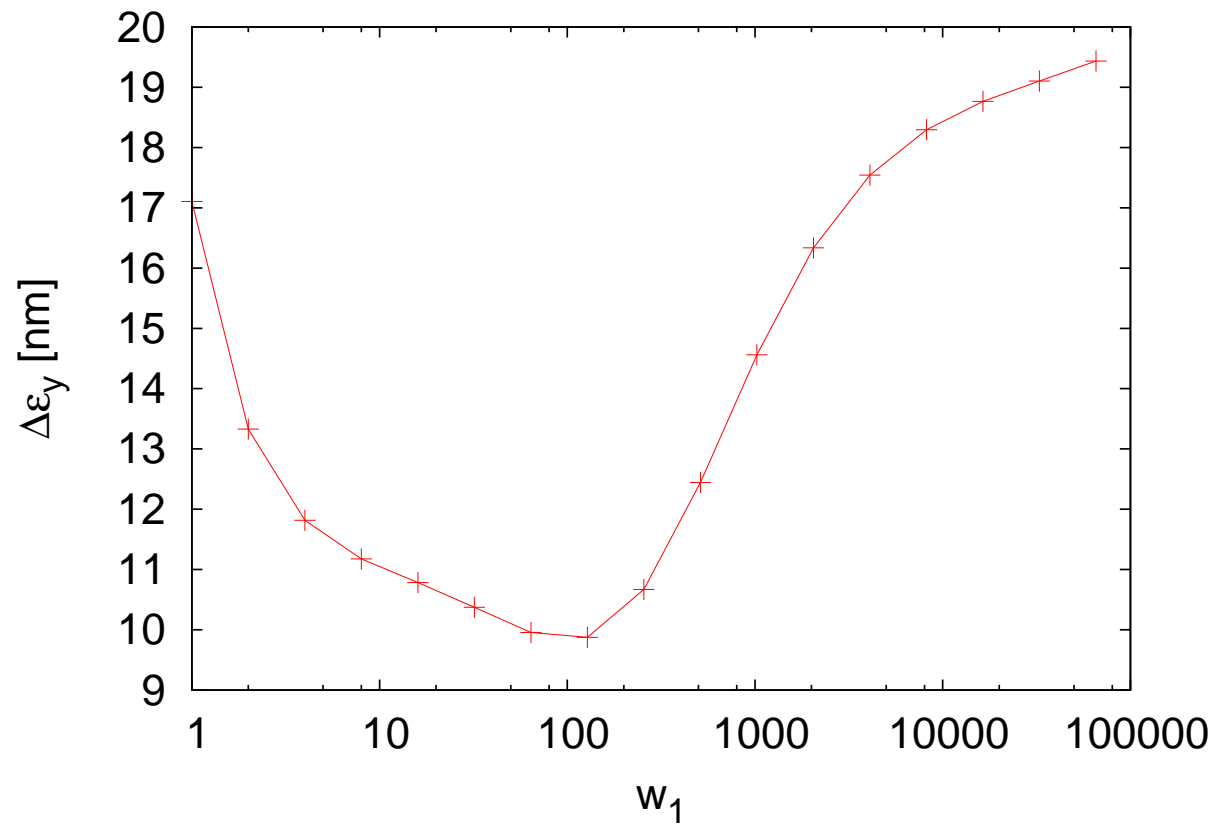
- Full static misalignment and BPM resolution are taken into account
  - Projected emittance without dispersion correction shown
- ⇒ Two cases are quite close

## Results (cont.)



- Perfect machine, with perfect BPM resolution
- Zero emittance growth for laser-straight machine
- ⇒ No emittance growth for laser-straight machine
- ⇒ Very small emittance growth for curved machine

## Weight Optimisation



● BPM resolution  $10 \mu\text{m}$

⇒ Optimum  $w_1 \approx 100$

## Effect of Scale Errors

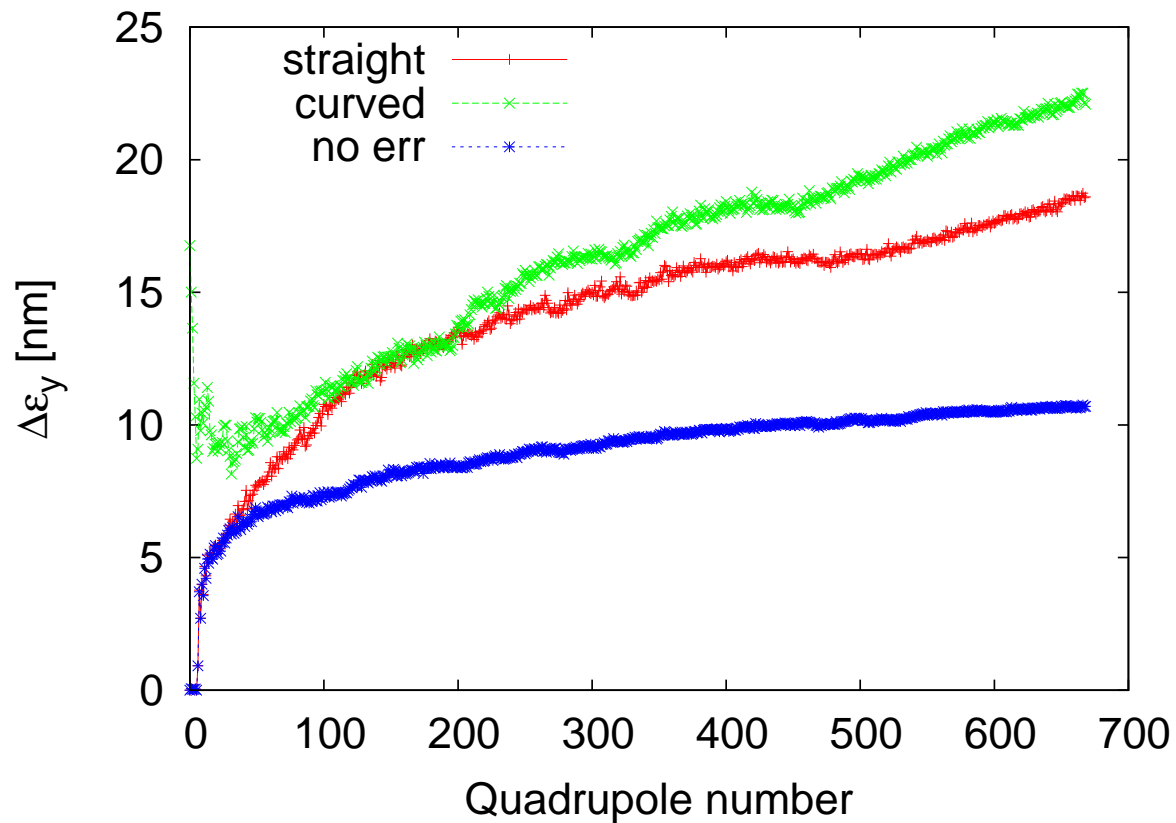
- Errors in the linear response of the BPM signal to beam offsets can affect the correction

$$x_i^{(read)} = (1 + a_i)x_i^{(actual)}$$

- In the following it is assumed that this error is different for each BPM but constant from pulse to pulse
- $a_i$  is drawn from Gaussian distribution with width  $\sigma_a$



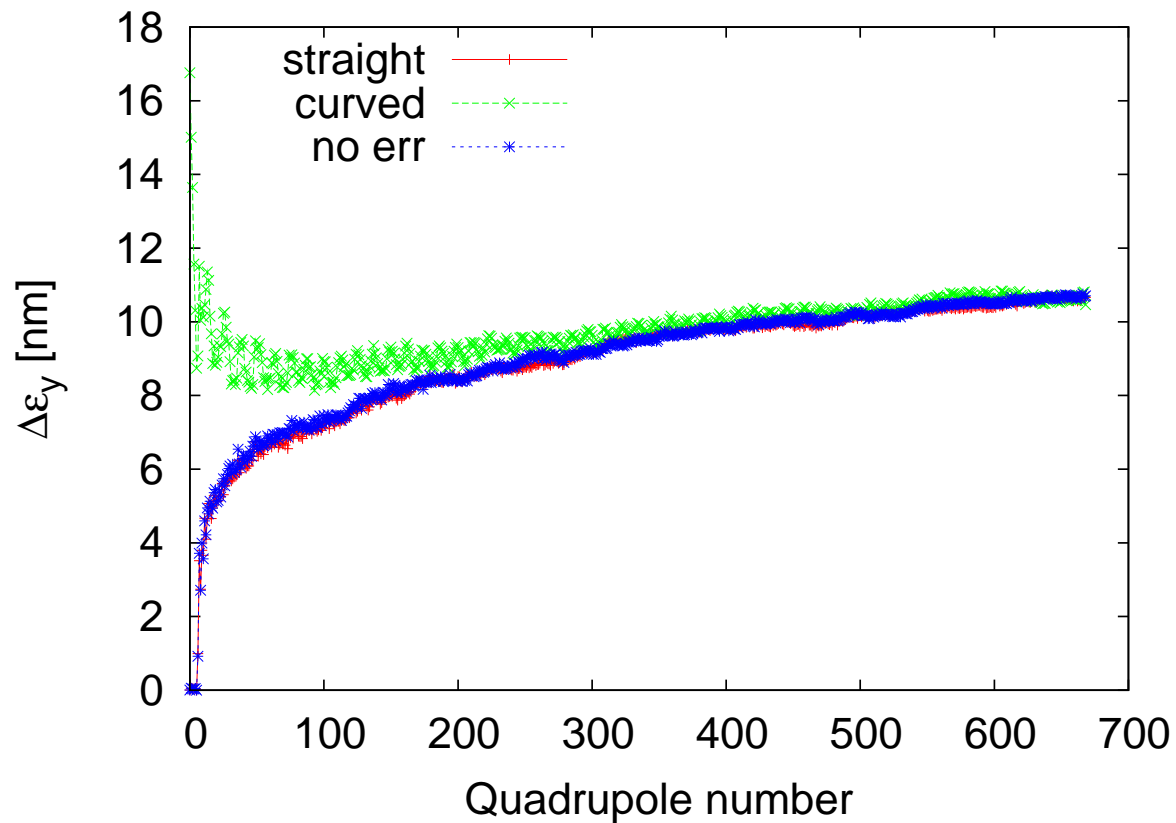
## Results for $\sigma_a = 0.04$



- Static misalignments, BPM resolution, one iteration of correction

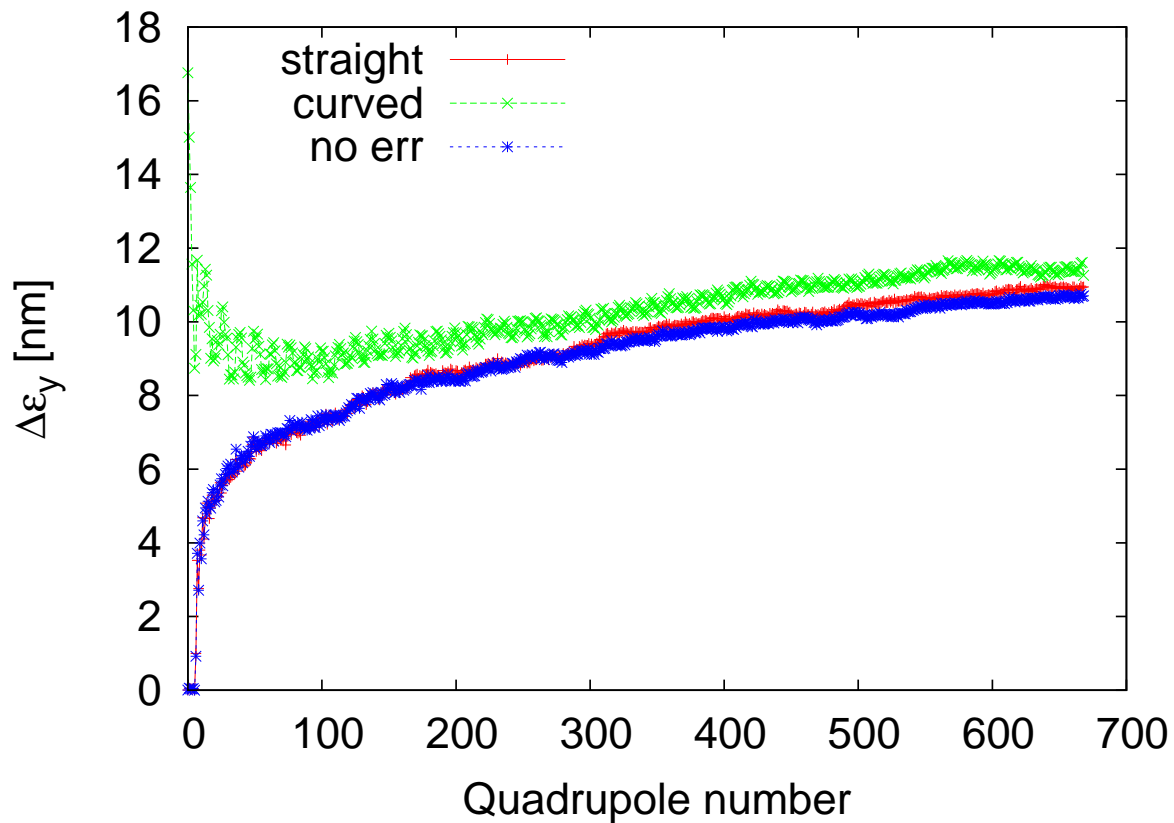
⇒ Significant effect for straight and curved tunnel

## Results for $\sigma_a = 0.04$



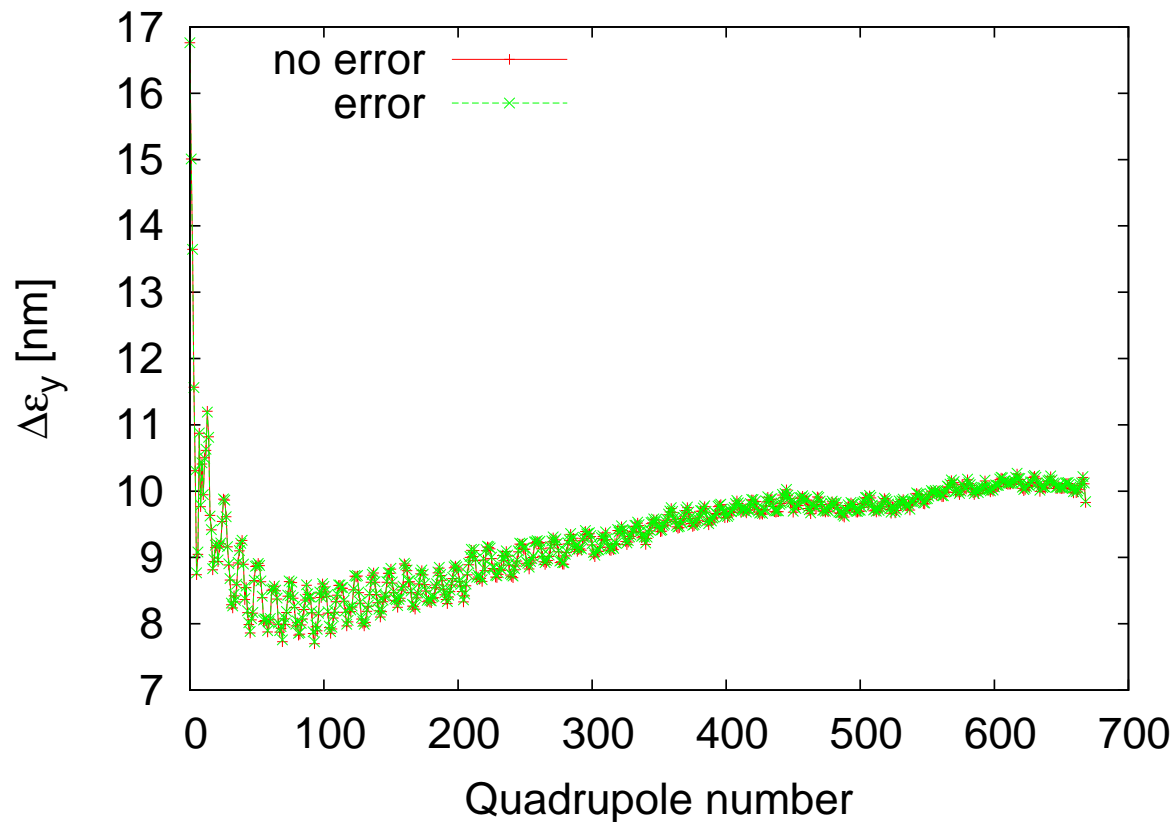
- Three iterations of correction  
⇒ almost no effect left
- Iterations of the whole beam line seem to be less efficient

## Results for $\sigma_a = 0.08$



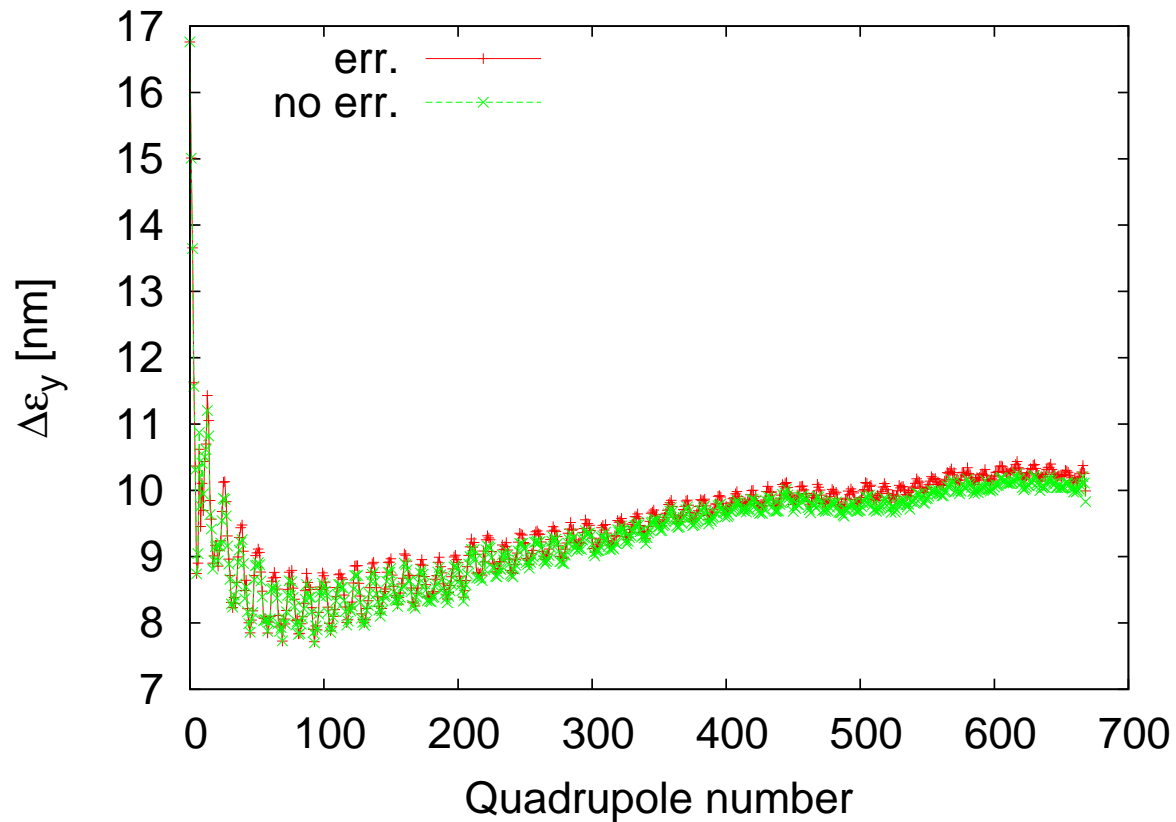
- Three iterations of correction
  - ⇒ some difference between laser straight and curved linac
  - ⇒ Residual effectg in curved linac due to non-zero dispersion

## Quadrupole Strength Errors



- Curved tunnel
  - Lattice is not perfectly known
  - Assumed quadrupole strength error 1% with respect to model
  - No strength variation from pulse to pulse
- ⇒ Effect is very small

## Gradient Errors



- Curved tunnel
  - Assumed systematic gradient error 3% RMS with respect to model for groups of 24 cavities
  - No gradient variation from pulse to pulse
- ⇒ Effect is very small

## Conclusion

- The curved tunnel seems not to significantly increase the emittance growth
- Some problems can be more severe in the curved tunnel
  - scale errors of the BPMs
  - but difference seems not very large
- Perfect knowledge of the lattice is not required