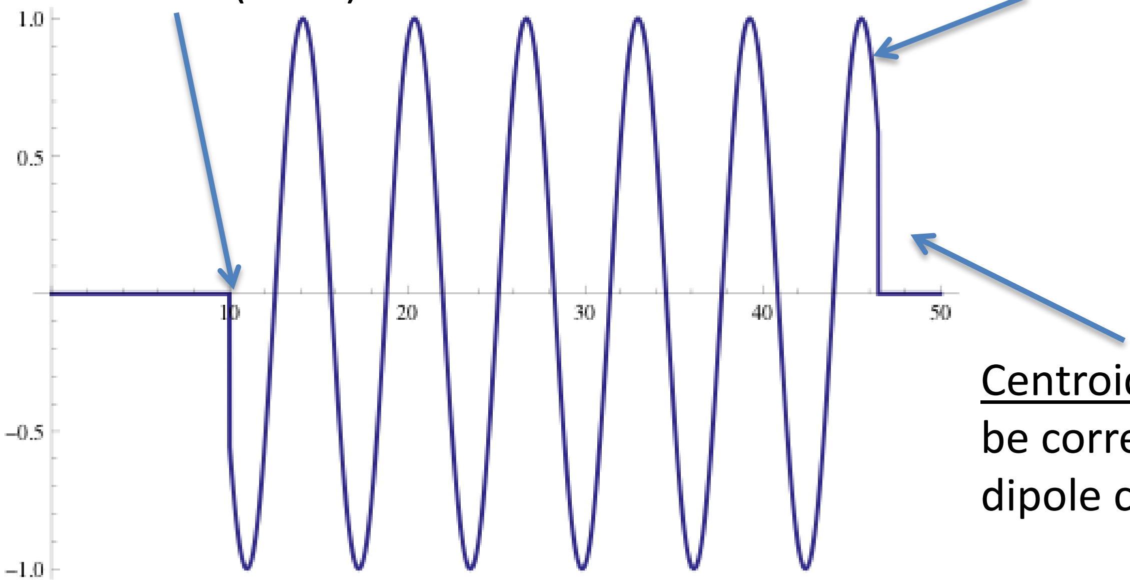
Basics I: single bunch

transverse kick (error)

coherent betatron oscillation

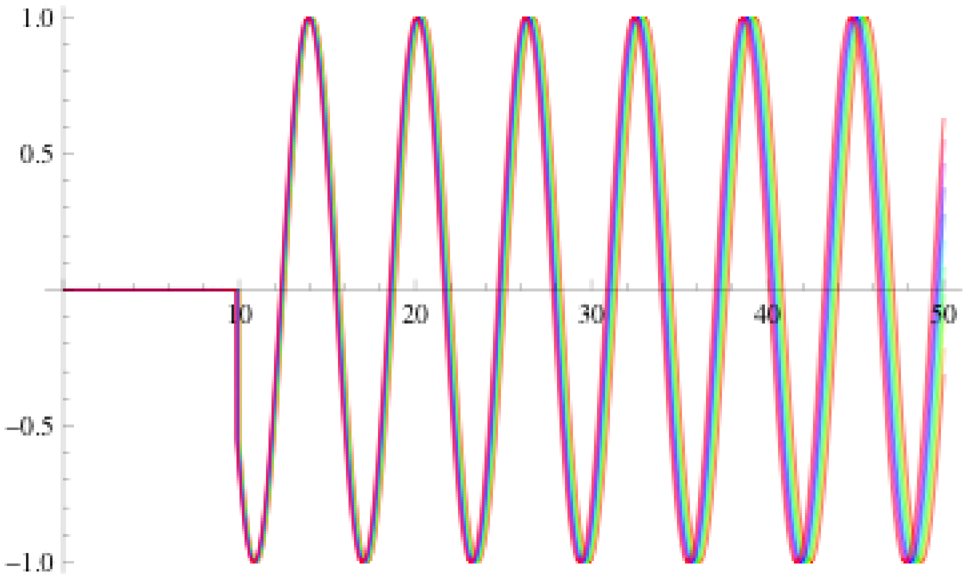


Centroid of coherent oscillations can be corrected using by steering (static dipole correctors or fast kickers)

Centroid correction is not the issue here

Errors (examples):
-static quadrupole misalignment (steering / BBA)
-quadrupole vibration (fast orbit feedback)
-*cavity pitch* / RF coupler (static and time dependent, steering and feedback)

Basics II: single bunch



Single-bunch energy spread + lattice chromaticity results in single-bunch emittance growth

Emittance growth is the problem!

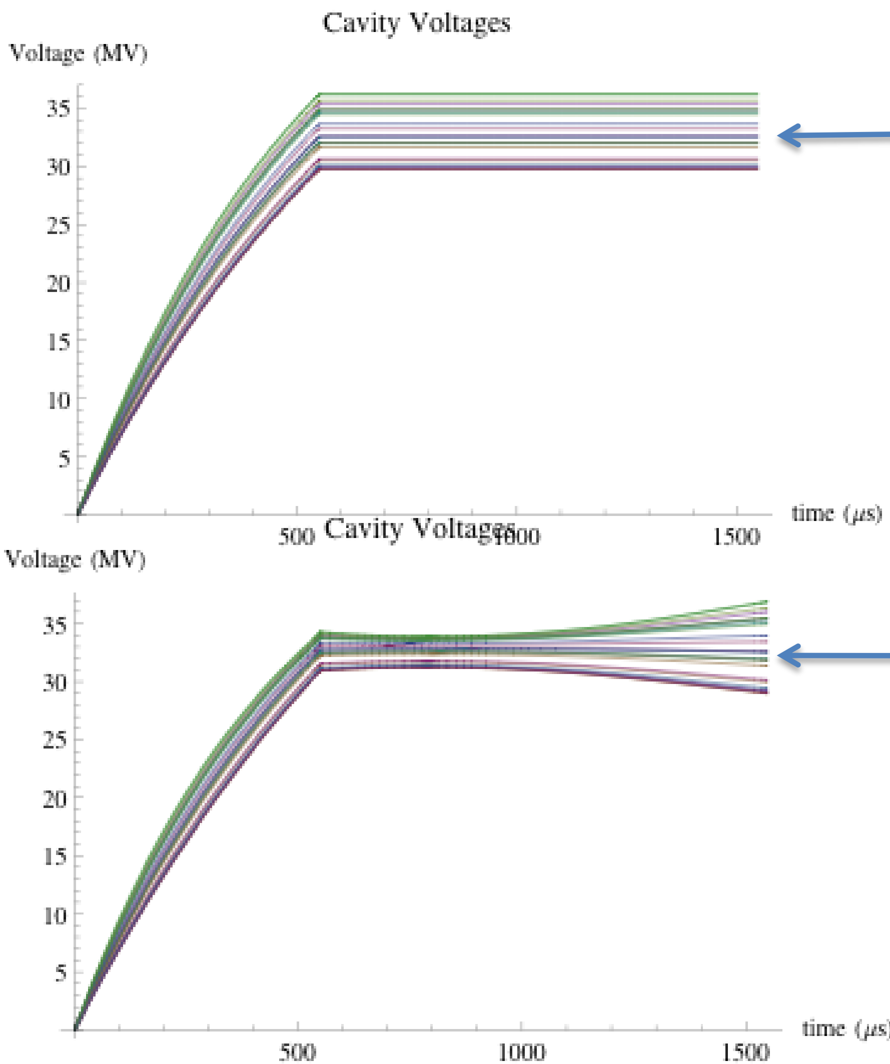
Cannot be corrected by steering / fast feedback correction

Allowable emittance growth defines *how often* trajectory needs to be corrected (along the linac)

Compare Quadrupole Vibrations

- 100 nm RMS quadrupole vibration in Main Linac
- Results in ~1 sigma oscillation at end of linac
- ~2 nm emittance growth (cf 30 nm) – considered OK
- 100 nm RMS ⇒ equivalent 20 V RMS transverse field
  - @5GeV worst case
- Assuming 300 μr RMS cavity pitches, 26 cavities per quad, then
  - $\theta = \frac{1}{2} \times 300\mu r \times 32MV/\sqrt{26} \approx 1$ kV → **~1-2% RMS stability**
  - spec on *individual cavities*, not vector sum
    - cavity pitches assumed uncorrelated and random
- Note emittance growth scales as θ^2

Our (LLRF) Problem



Ideal: flat cavity fields across beam pulse.

All bunches see “same” kick.

Pulse-to-pulse (5Hz) stability still needs to be ~1% RMS

Reality: individual cavity gradients change over the pulse

vector sum held constant to 10^{-3}

Comments

1% = 0.3% RMS

- RMS stability specified
  - Depends on how 'mean' is defined (steering)
  - *helps a little but not much!*

- Beam dynamics people also need to look at coupler kicks
  - these will also have "slopes"

- Mitigation:
  - How well can LLRF people do?
  - Impact on emittance → number of 'fast correction' stations in linac
    - currently only one foreseen at end of linac
  - (Ideas about transverse deflecting cavities in ML)
  - Review mechanical alignment and what can be achieved
    - remote adjustment / beam based alignment possibilities

Cost versus performance