On Cavity Tilt + Gradient Change (Beam Dynamics)

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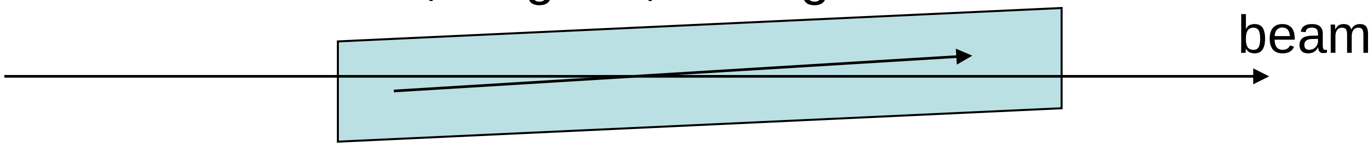
Transverse effect of acc. field with cavity tilt

Acc. field *E*, length L, tilt angle θ



Transverse kick in the cavity: $\Delta pt = \sin\theta\, eV$

Edge (de)focus

entrance

exit

offset: $y_0 + L\sin\theta/2$

offset: $y_0 - L\sin\theta/2$

Transverse kick at the entrance: $\Delta pt = -eE\,(y_0 + \sin\theta\, L/2)/2$

Transverse kick at the exit: $\Delta pt = eE\,(y_0 - \sin\theta\, L/2)/2$

→Total transverse kick by the cavity: $\Delta pt = \sin\theta\, eV/2$

Cavity tilt change (vibration) and Fixed cavity tilt + voltage change have the same effect → orbit and emittance

- 3 micro-rad. tilt angle change, cavity to cavity random

  → 0.8-sigma orbit change at the end of main linac

  $\propto$ tilt change

  → 0.5 nm (2.5%) emittance growth

  $\propto (\text{tilt change})^2$

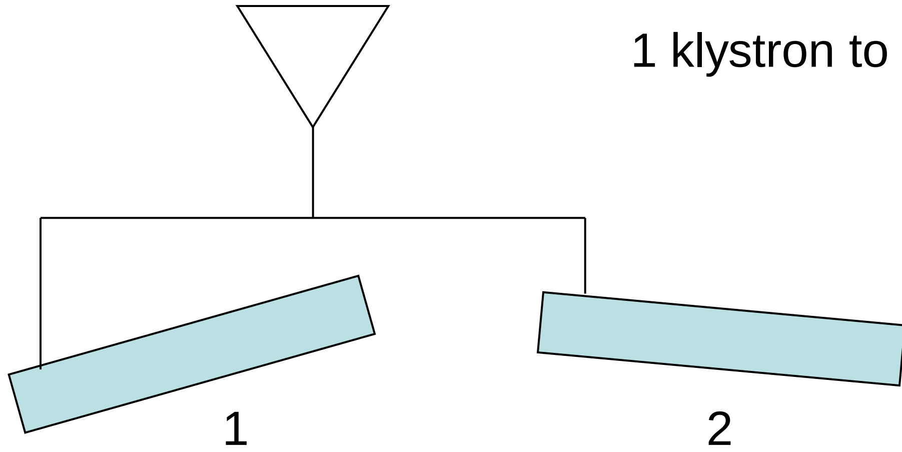
- Assuming fixed tilt angle (misalignment) RMS 300 micro-rad. 1% voltage change, cavity to cavity random

  → Same as above.

  - RF control stabilizes vector sum, not voltage of each cavity.
  - Cavities with different coupling, fed by one RF source.

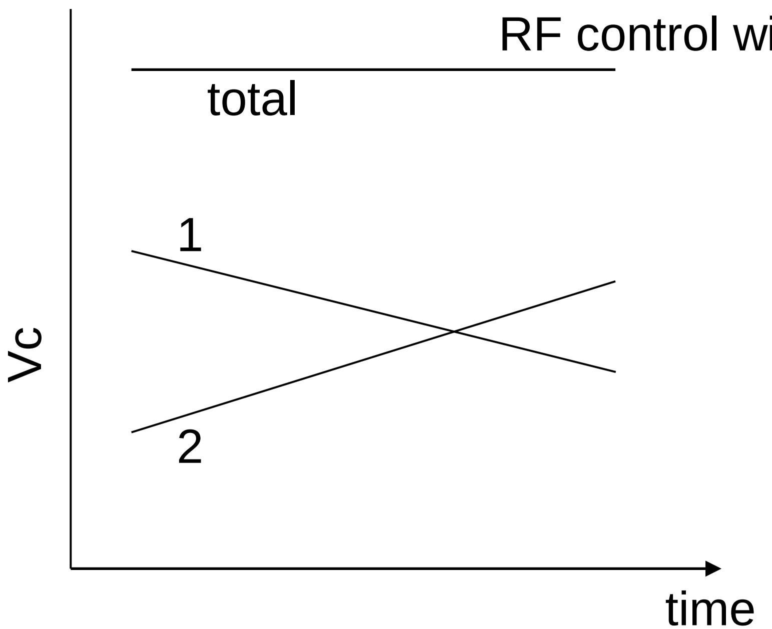
    → voltage change during one pulse.
  - Different detuning (pulse to pulse)

    → pulse to pulse voltage change

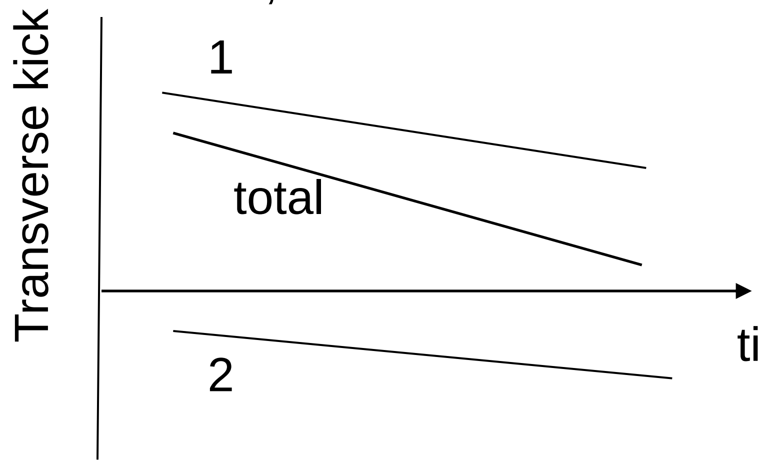


1 klystron to 2 cavities

RF control will keep total voltage flat.



But, total transverse kick may change.



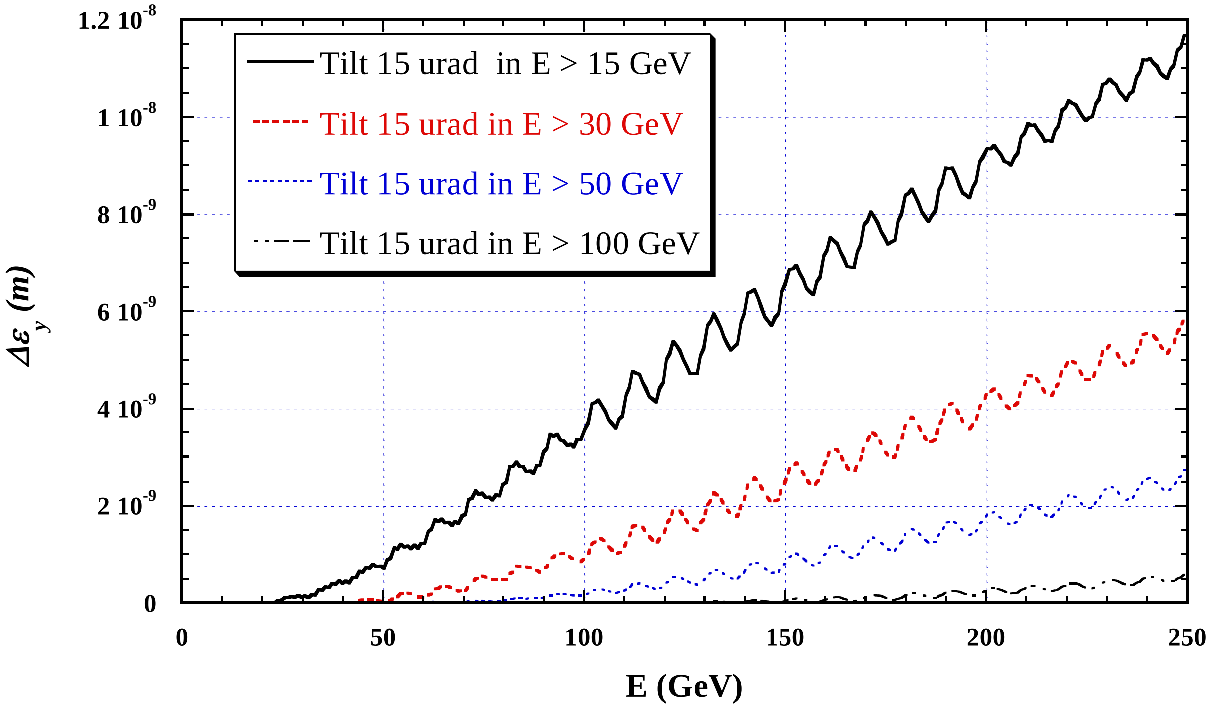
Orbit jitter sources in ML

Source	Assumption (Tolerance?)	Induced orbit jitter	Induced emittance growth
Quad vibration (offset change)	100 nm	1.5 sigma	0.2 nm
Quad+steering strength jitter	1E-4	1 sigma	0.1 nm
Cavity tilt change	3 urad	0.8 sigma	0.5 nm
Cavity to cavity strength change, assuming 300 urad fixed tilt	**1%** **Too tight !**	**0.8 sigma**	**0.5 nm**

Tolerances, tolerable timescale depend on feedback performance.

Result of simulation

Cavity tilt change 15 urad, equivalent to Fixed 300 urad + 5% gradient change (numbers are RMS)



$$\Delta\gamma\varepsilon \propto [\ln(E / E_0)]^3$$

Starting linac at different energies (to see effective ness of orbit correction)
E.g. if orbit is corrected at 50 GeV, emittance growth will be
~ 1 nm from 15 to 50 GeV plus ~ 2.5 nm from 50 to 250 GeV
Total 3.5 nm, instead of 11 nm without such correction.

Intra-pulse orbit correction will loosen the tolerance of pulse to pulse change?

- If gradient change is same for all pulses
  - Orbit change is predictable and can be corrected.
- If gradient change is a simple function of time.
  - Orbit of head part of a pulse can be used for prediction of orbit of following part.
- Gradient change is slow (~ time constant of cavity filling time)
  - Intra-pulse feedback, similar to IP feedback (but ca be much slower), can be used.

Probably possible.

- Available space in ML?

Summary

- Fast tilt change should be < 3 urad (mechanical motion)
- (Fixed tilt) x (Relative gradient change of each cavity) should be < 3 urad
- If gradient change is predicted, or slow enough, intra-pulse orbit correction will loosen the tolerance.

We assume fixed cavity tilt 300 urad, then, gradient of each cavity flatness in a pulse should be (roughly)

- < 1% for pulse to pulse without intra-pulse correction
- < 5 % with intra-pulse correction

(Numbers are RMS)