On Cavity Tilt + Gradient Change

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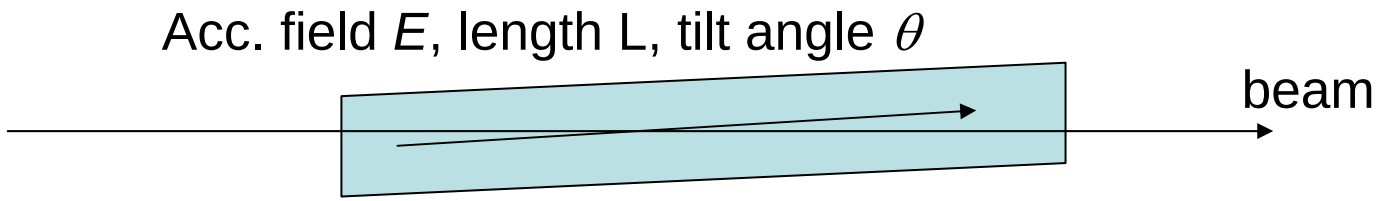
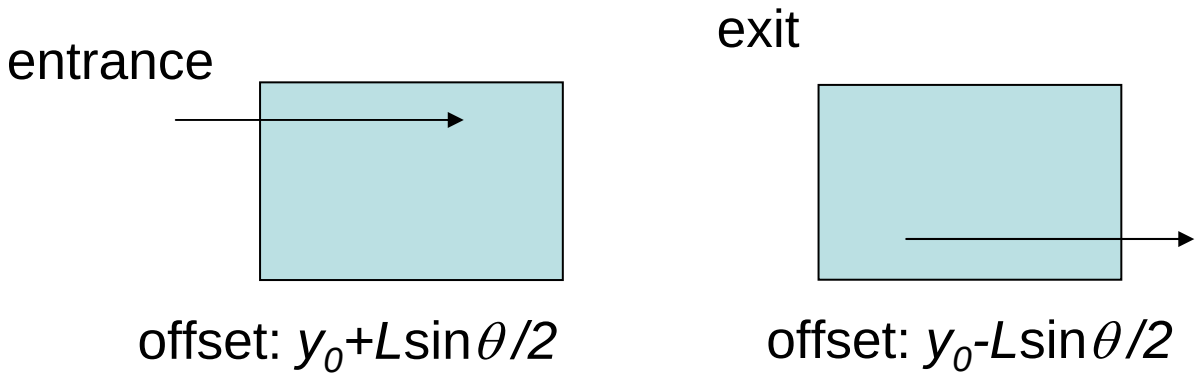
Transverse effect of acc. field with cavity tilt



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

Edge (de)focus



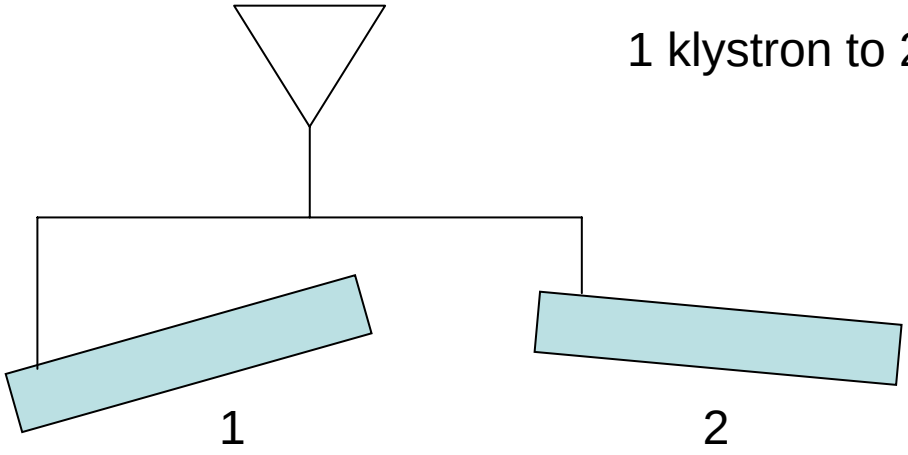
Transverse kick at the entrance: $\Delta pt = -eE\,(y_0+\sin\theta\, L/2)/2$

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

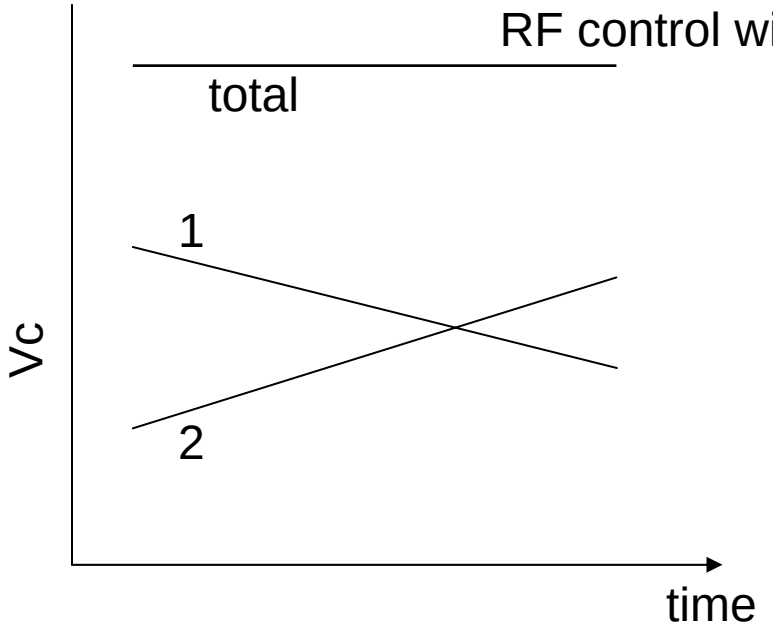
- 3 micro-rad. tilt angle change, cavity to cavity random
  → 0.8-sigma orbit change at the end of main linac
  $\propto$ tilt change
  → 0.5 nm (2.5%) emittance growth
  $\propto$ (tilt change)^2
- Assuming fixed tilt angle (misalignment) RMS 300 micro-rad. 1% voltage change, cavity to cavity random
  → 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

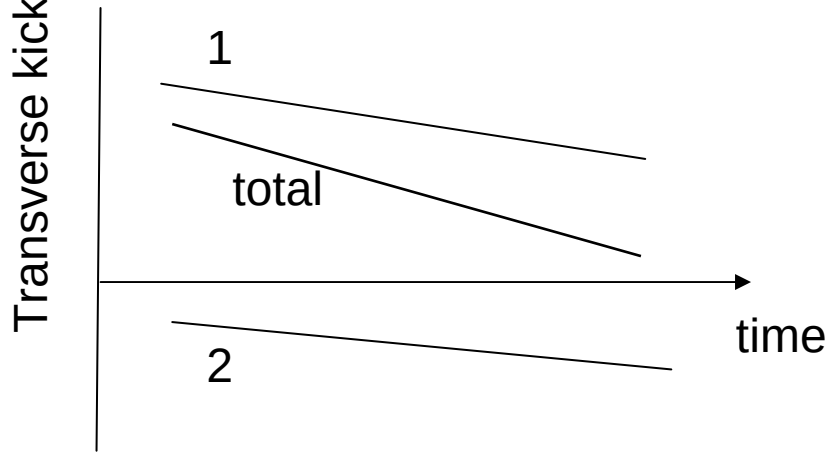


1 klystron to 2 cavities

RF control will keep total voltage flat.

But, total transverse kick may change.





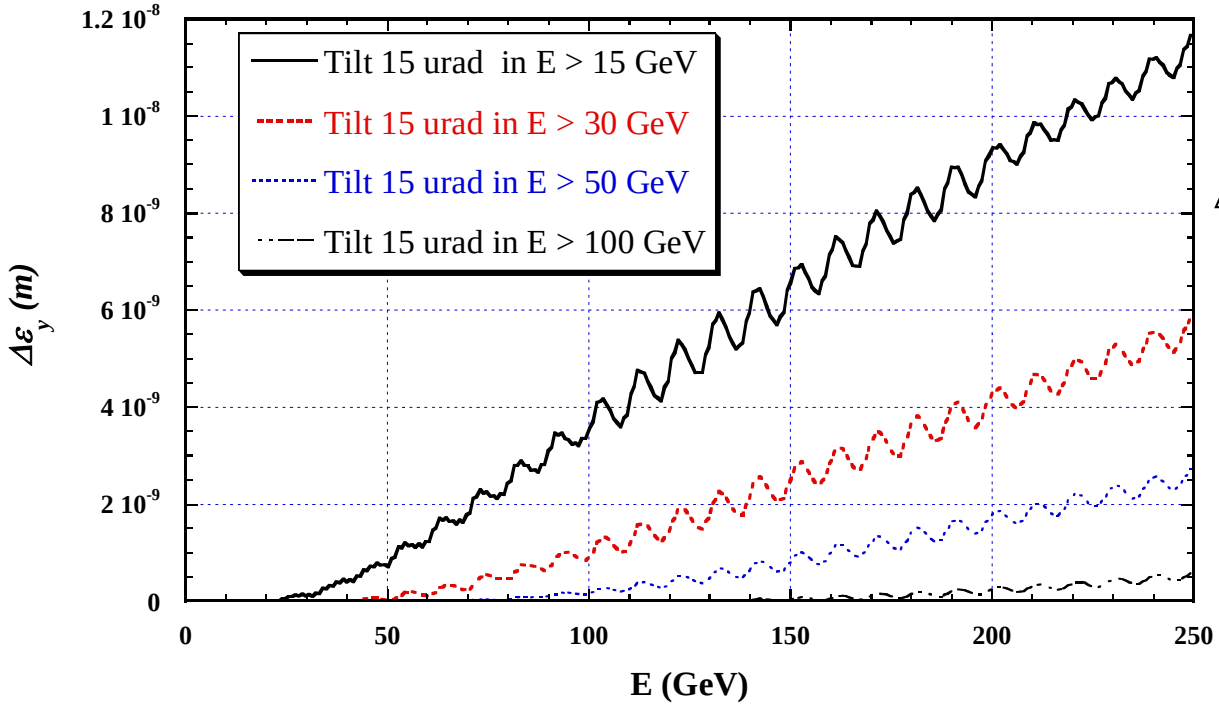
Orbit jitter sources in ML

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)



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

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.

Summary

- Fast change of tilt should be < 3 urad (this looks easy?)
- (Fixed tilt) x (Relative gradient change of each cavity) should be < 3 urad (looks tight)
  - If gradient change is same for all pulses (predictable), orbit in one pulse may be corrected in the linac. Then the toleranse will be loosened. Probably about 15 urad.
  - Pulse to pulse different change can not be corrected.
- We assume fixed cavity tilt 300 urad

As conclusion, roughly, gradient of each cavity flatness in a pulse should be less than

- 1% for pulse to pulse different
- 5 % for predictable [If we can straighten a train at certain locations in the linac.]

Discussion + comment

Feedback in each pulse will loosen the tolerance of pulse to pulse change? (suggested by Yokoya and Ross)

- Measure orbit of head part of pulse and correct following part.
  - Voltage change of each cavity during a beam pulse should be a simple function of time. (Can following voltage change be predicted from voltage of head part?)
  - It looks difficult. But may be able to correct partially ???
- Gradient change (then, orbit change) will not be so fast.
  - Intra-pulse feedback, similar to IP feedback (but ca be much slower), may be used.
  - Can feedback in ML be fast enough?