

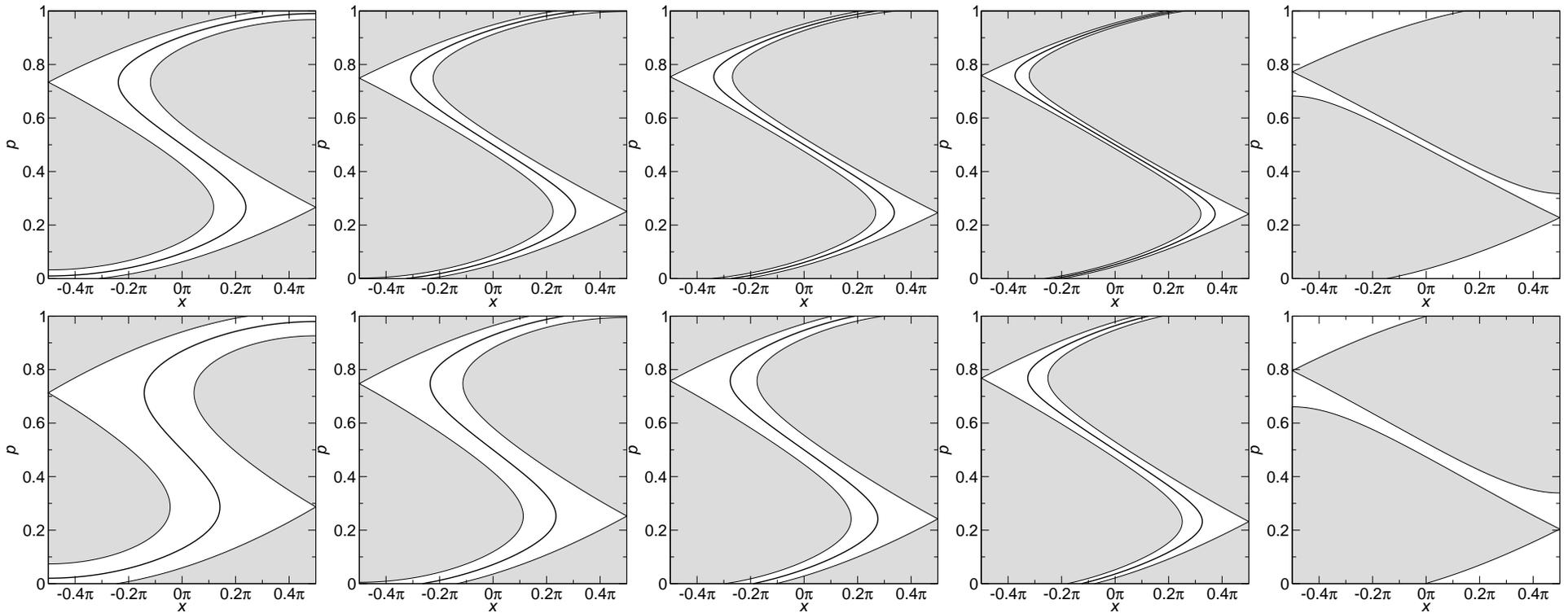
FFAG Model Goals and Parameters

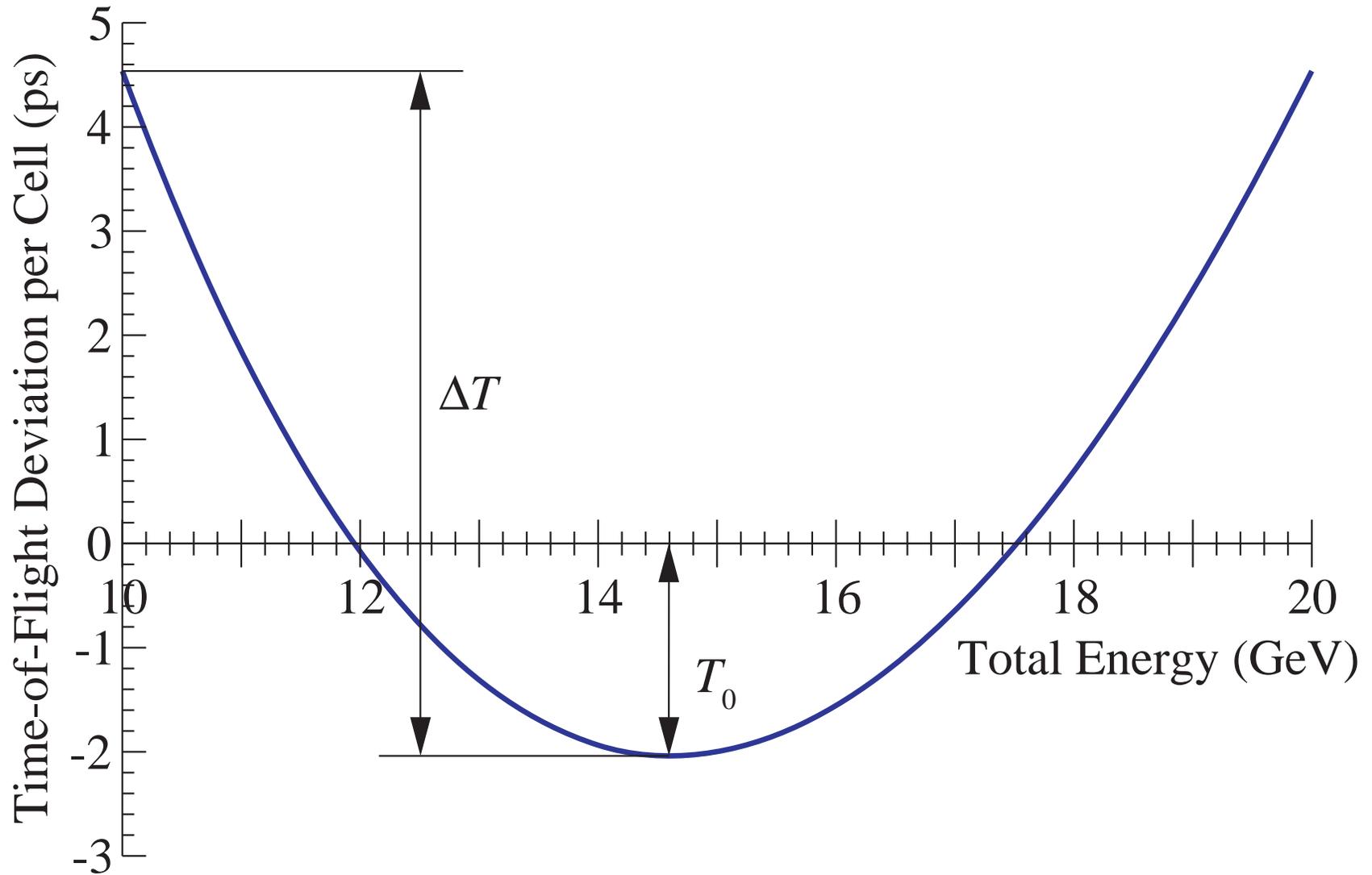
J. Scott Berg
Brookhaven National Laboratory
1 July 2005
Muon Collaboration Friday Meeting

- Linear non-scaling FFAGs
- Longitudinal dynamics in fixed, high RF frequency FFAGs
- Crossing of large numbers of resonances in (nearly) linear lattice

Fixed Frequency Longitudinal Dynamics

- Accelerate up an S -shaped channel in phase space
- Insure channel is wide enough to give acceptable distortion
- Varying machine parameters does two things
 - ◆ Pinches off the phase space channel, or makes it larger
 - ◆ Changes how energy and RF phase vary as you accelerate
- The “pure” longitudinal dynamics is determined by two parameters
 - ◆ $a = qV/\omega\Delta T\Delta E$, $b = T_0/\Delta T$
 - ◆ Oversimplified: time-of-flight is not perfectly parabolic
- V is the amount of voltage installed
- Horizontal lattices determines ΔT (and non-parabolic time of flight)
- Smaller V , larger ΔT easier, so smaller a easier
 - ◆ But smaller a squeezes channel: more longitudinal distortion
- b determined by RF frequency, cavity phasing, and cell lengths



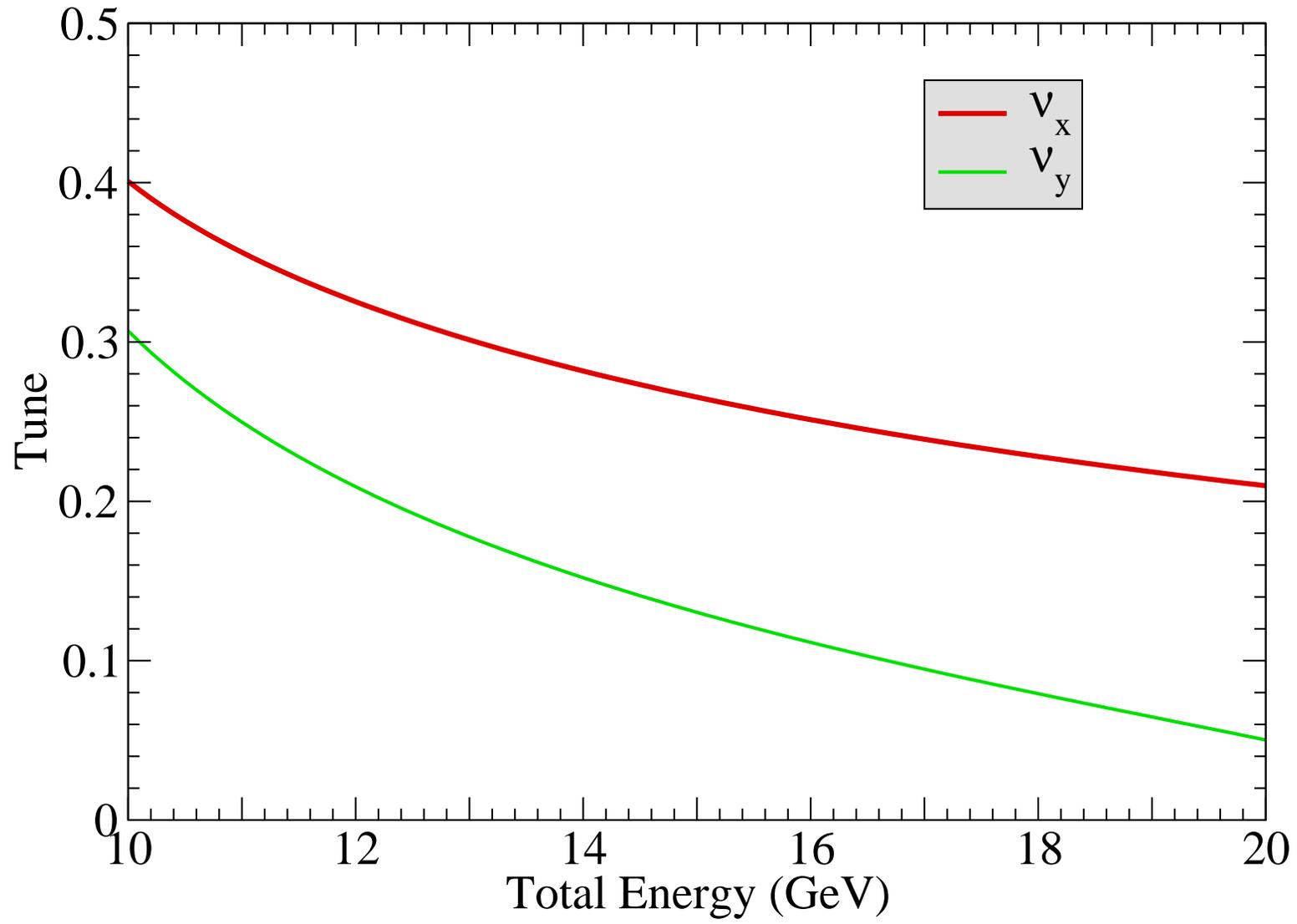


Longitudinal Dynamics

Things to Study

- As we vary a and b , do we get the expected behavior?
 - ◆ Do we lose transmission at the expected parameter values?
 - ◆ Is the emittance growth what we predict?
 - ◆ What happens when we deviate from the model?
 - ★ Does the machine behave as predicted when we move the minimum of the parabola?
 - ★ Does the non-parabolic nature of the time of flight behave as expected
- The horizontal lattice determines the time of flight behavior
 - ◆ Do we get the predicted time-of-flight behavior as a function of energy?
- Effect of errors on transmission, longitudinal emittance growth
 - ◆ Phase errors in cavities
 - ◆ Lattice errors (as they affect time of flight)

- During acceleration, we cross large numbers of (hopefully) weakly-driven “resonances”
- Result is emittance growth and/or beam loss
- In fixed-frequency acceleration: rate of resonance crossing depends on energy
- Resonance crossing will depend on tune/energy profile



Resonance Crossing Things to Study

- As we vary the resonance crossing rate (overall acceleration rate), do we get expected growth rates/losses?
- As we vary the tune range, how does the emittance growth vary? Check predictions.
- As we vary b , which changes where the high and low acceleration rates are, how does the emittance growth change?
- Introduce magnet displacements and field errors; how does this affect the emittance growth?
- Introduce low, variable-frequency RF system to study
 - ◆ Uniform rate of crossing resonances
 - ◆ Slower resonance crossing rates than we can have with the high-frequency system.

- Much of this program is a verification of results obtained through simulation
 - ◆ But we want to test how varying the parameters of a muon FFAG will affect its performance
 - ◆ We of course want to address the issue of whether it works at all!
- We must be able to simulation the full system
 - ◆ Full 6-D
 - ◆ Magnet end fields
 - ◆ Arbitrary magnet displacements
 - ◆ Correct handling of RF timing
- Real machines will have these same simulation requirements
- If results do not match simulation, our task should be to determine what went wrong in the simulation

- To test parameter space of longitudinal dynamics, for fixed transverse lattice
 - ◆ Vary cavity frequency (part in 10^3 : probably straightforward, but significant hardware required)
 - ◆ Vary cavity voltage (factor of 4 to 6: easy, since low voltages)
 - ◆ Vary individual cavity phases (with relatively high precision)
- To see the effect of the transverse lattice on the longitudinal dynamics (i.e., vary the parabola)
 - ◆ Independent variability of dipole and quadrupole components of the magnets
 - ◆ Without both components variable, the tune profile cannot be decoupled from the parabola centering

- Resonance crossing
 - ◆ Requirements as above
 - ◆ Ability to adjust magnet positions to study displacement errors
 - ◆ Individual control of magnet strengths to study gradient errors
- Without independent control of quadrupole and dipole
 - ◆ Difficult to look independently at certain effects (tune profile, parabola shape, etc.). Effects are coupled together.
 - ◆ Still will be doing simulation verification
 - ◆ Longitudinal RF parameters (a, b) can still be explored thoroughly
 - ◆ Can still look at resonance crossing rate
- Lower-frequency RF system for second stage

- To measure these effects, need extensive diagnostics
- Longitudinal
 - ◆ Can do initial experiments (e.g., look for point of pinch-off) simply by having energy distribution at extraction or in ring
 - ◆ To get longitudinal emittance growth, need more detailed diagnostics
- Resonance crossing
 - ◆ Need relatively accurate transverse emittance measurement
- Ability to extract is probably important for detailed measurements

- Rate of resonance crossing is (roughly) the product of cells and turns (cell-turns)
 - ◆ Muon acceleration: between 500 and 1500 cell-turns
 - ◆ More cell-turns requires a larger machine, so try for the low end: 500 cell-turns
- Match other parameters of muon machines
 - ◆ Factor of 2 in energy
 - ◆ Low-energy tunes: $\nu_x = 0.39$, $\nu_y = 0.27$
- Pole tip field limitation of magnets
- $a = qV/(\omega\Delta T\Delta E)$: choose 1/12, to have reasonably-sized channel
 - ◆ Can make larger if we so desire: voltages are small
- Doublet cells
- Want similar angles and fraction of aperture filled: about 3 mm normalized emittance

- RF frequency choice: with 0.2 T pole tips, 1.3 GHz requires 42 cells, 3 GHz requires 60; choose 1.3 GHz
- Pole tip field: to get 500 cell-turns

| Pole Tip Field (T) | 0.1 | 0.2 | 0.3 |
|---------------------------|------|------|------|
| Cells | 48 | 42 | 42 |
| Circumference (m) | 23.1 | 15.9 | 14.1 |
| Magnet Aspect Ratio (L/A) | 2.1 | 1.3 | 0.9 |

- ◆ At 0.1 T, ring is too long
- ◆ At 0.3 T, magnet aspect ratio is bad: ends contribute too much
- ◆ Probably prefer 0.2 T or slightly below for balance
- To achieve $a = 1/4$, need 115 kV per cavity (every other cell has cavity), gradient 1 MV/m: EASY!
 - ◆ Issue: too much stored energy extracted if high current, but need high current for diagnostics