FFAG Model Goals

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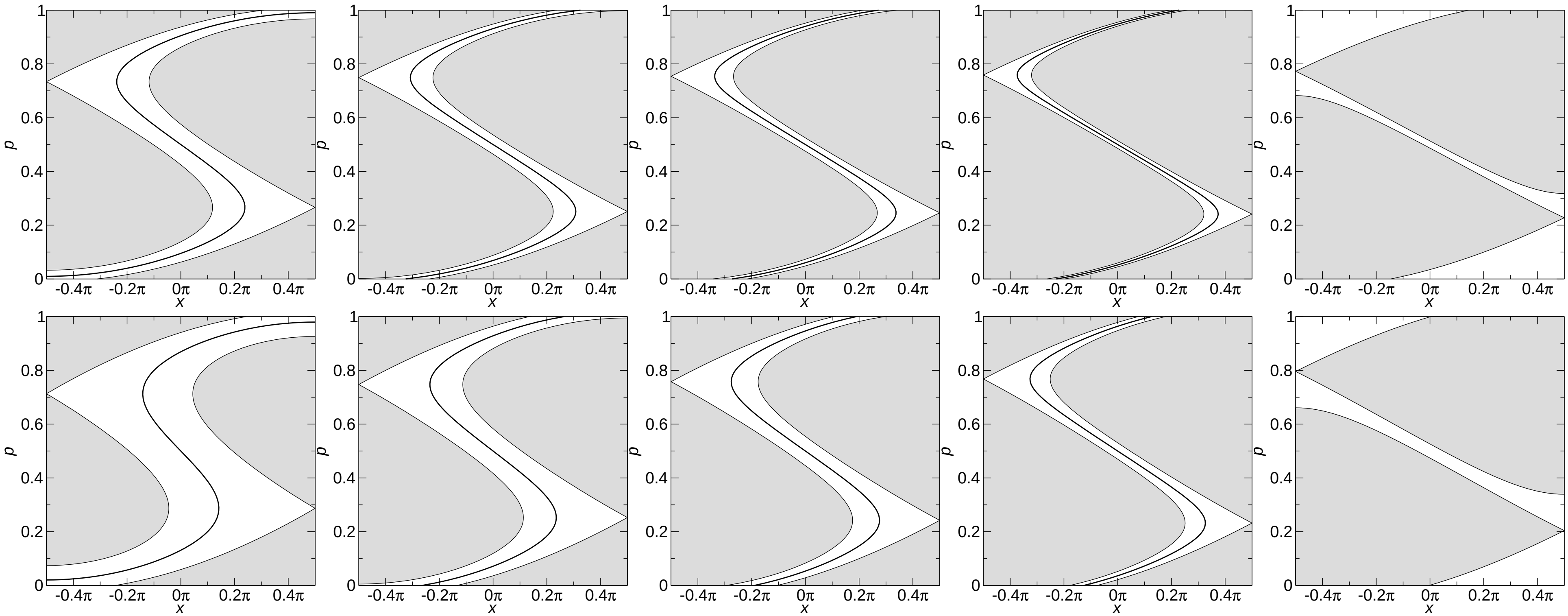
Issues to Study

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

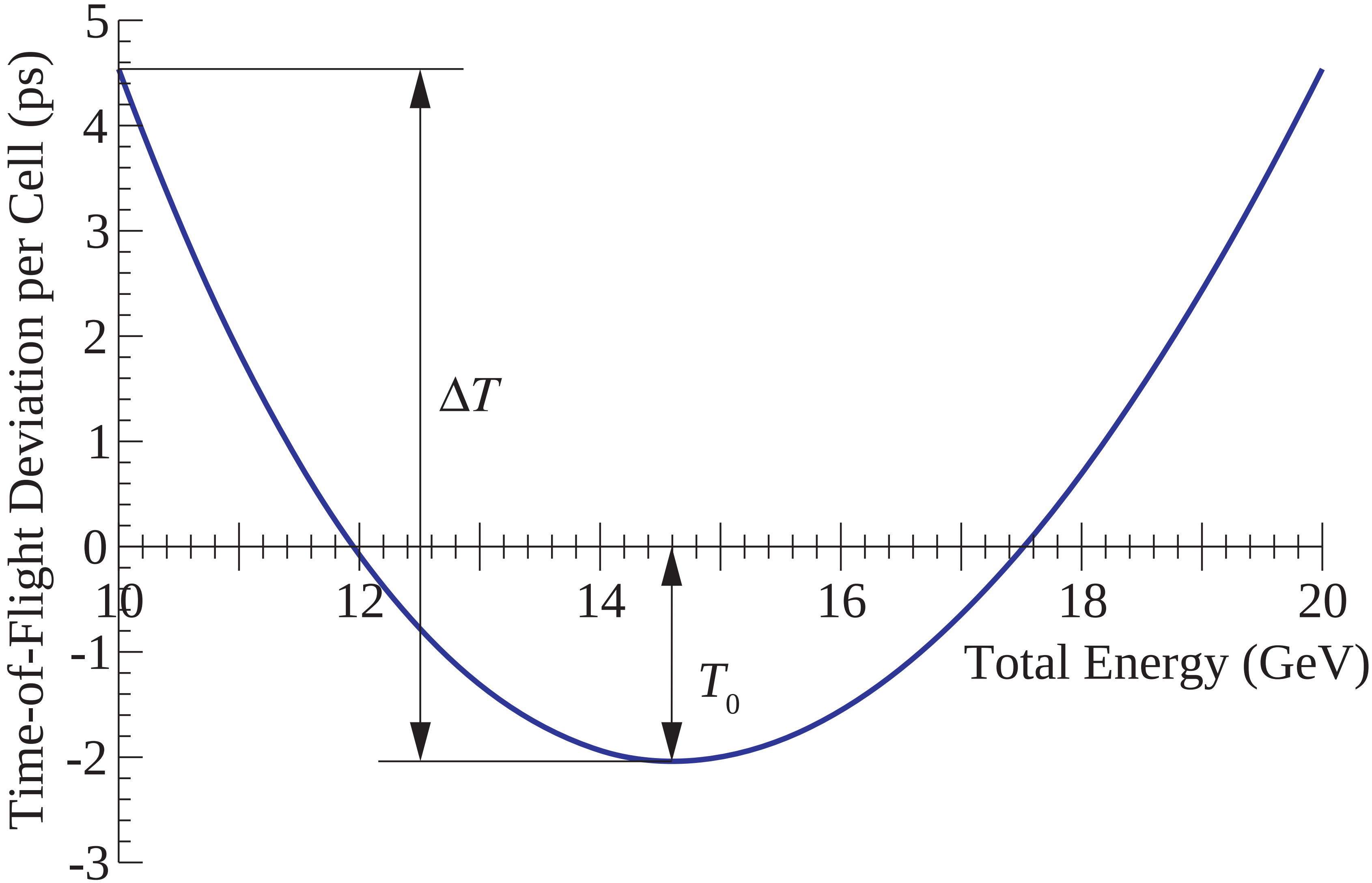
Fixed Frequency Longitudinal Dynamics

- 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 Phase Space



Time of Flight



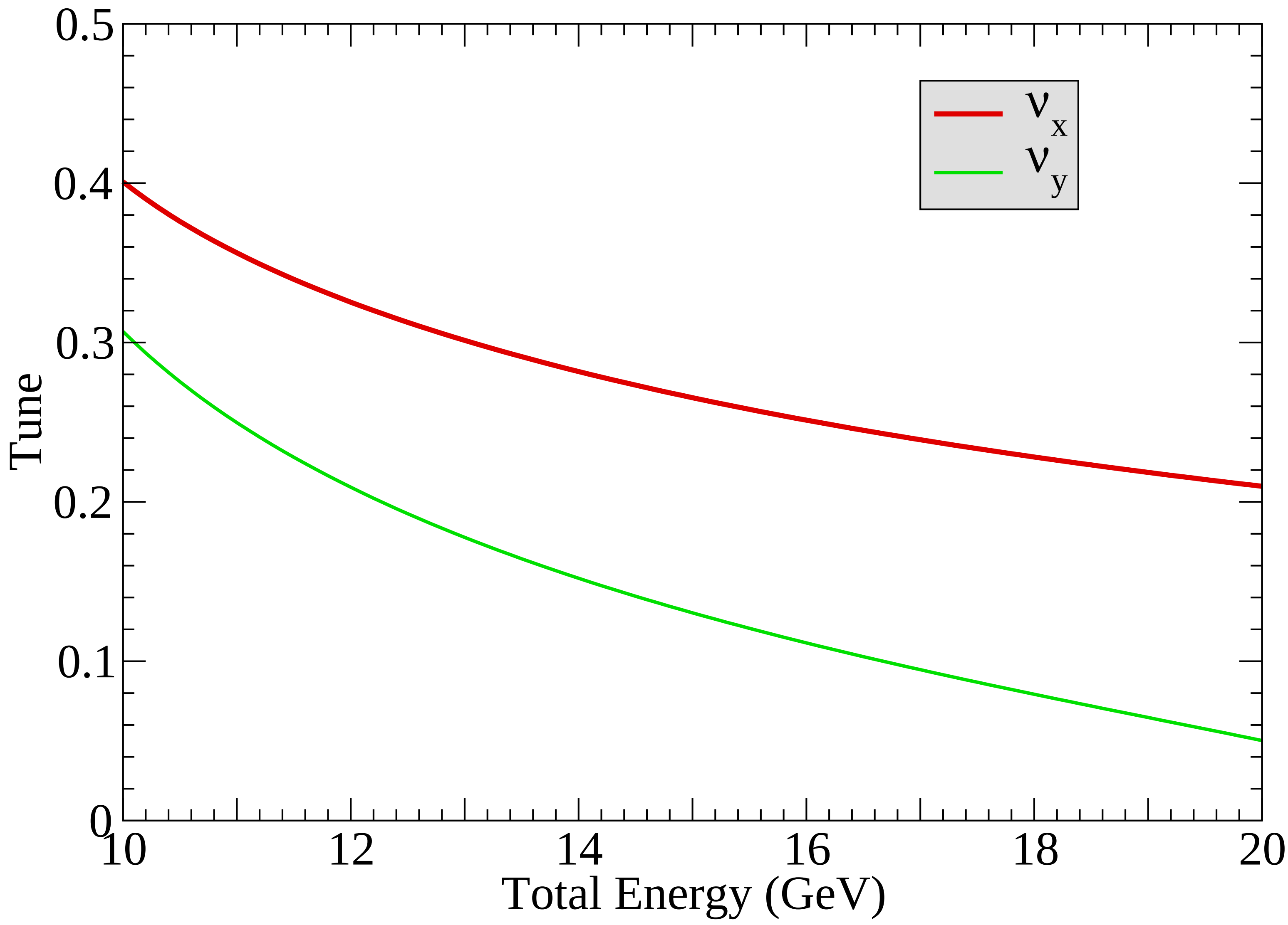
Longitudinal Dynamics
Things to Study

- 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 effors (as they affect time of flight)

Resonance Crossing

- 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

Tune 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.

Simulation

- 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

Hardware Requirements

- 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

Hardware Requirements (cont.)

- Resonace 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

Diagnostics

- 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