Electron Model Goals and Resulting Experimental Requirements

J. Scott Berg
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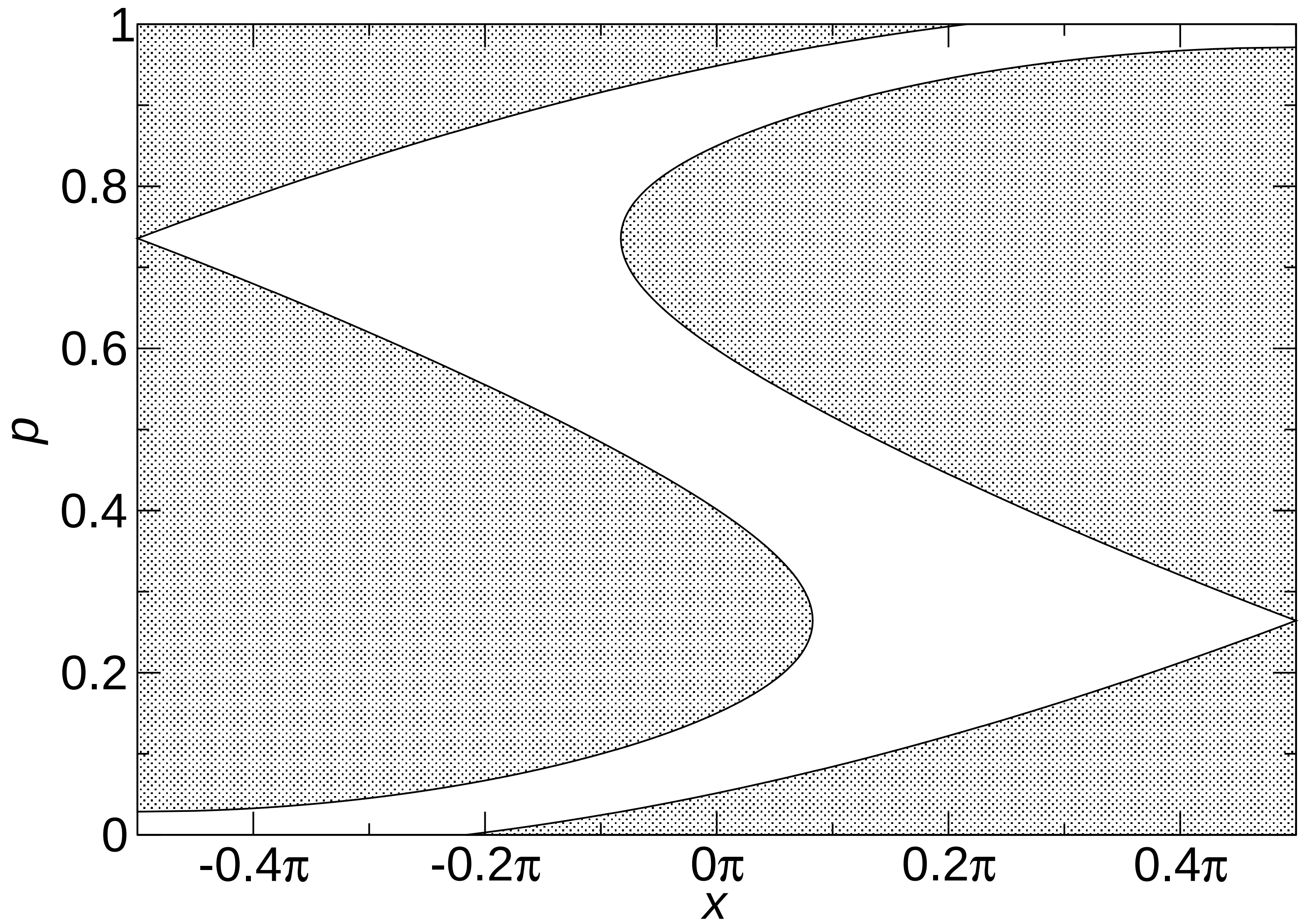
Broad Goals

- Study a linear non-scaling FFAG
- Study two types of machines
  - Muon acceleration: isochronous; high-frequency RF
  - Proton machines: non-isochronous; low-, variable-frequency RF
- Effects to look at
  - Longitudinal dynamics
  - Resonance crossing

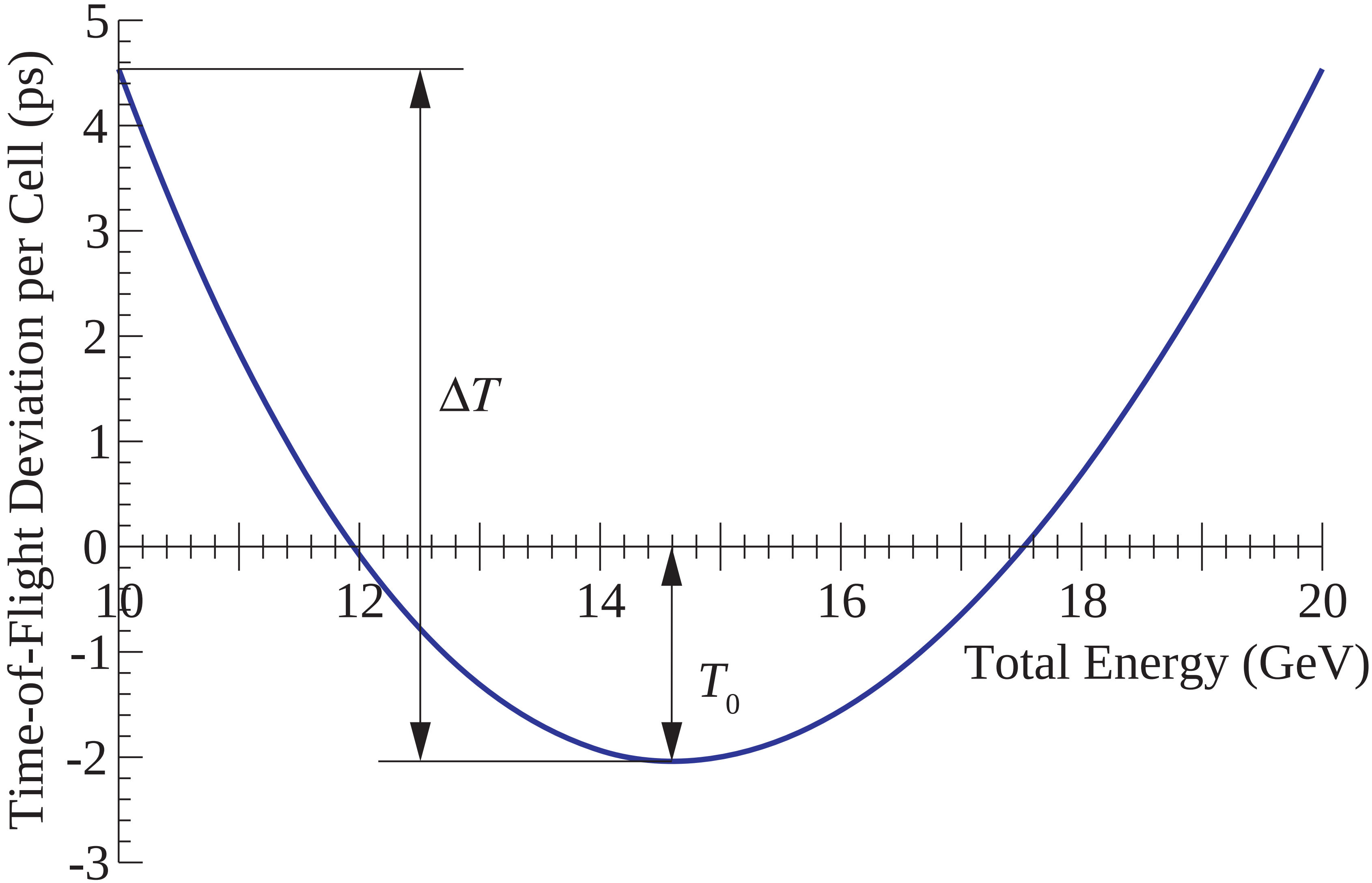
Isochronous, Longitudinal Dynamics

- Acceleration in S-shaped path in phase space
- This shape is characterized by two parameters:
  - $a = qV/(\omega\Delta T\Delta E)$: adjusted by varying the voltage
  - $b = T_0/\Delta T$: vary RF frequency, cell length, or other tricks
  - Want to survey this parameter space
- Would like to study other parameters
  - Making parabola off-center
  - Changing tune profile, particularly horizontal
- RF frequency fixed
- Accelerate in a small number of turns
- Study success of acceleration, longitudinal acceptance

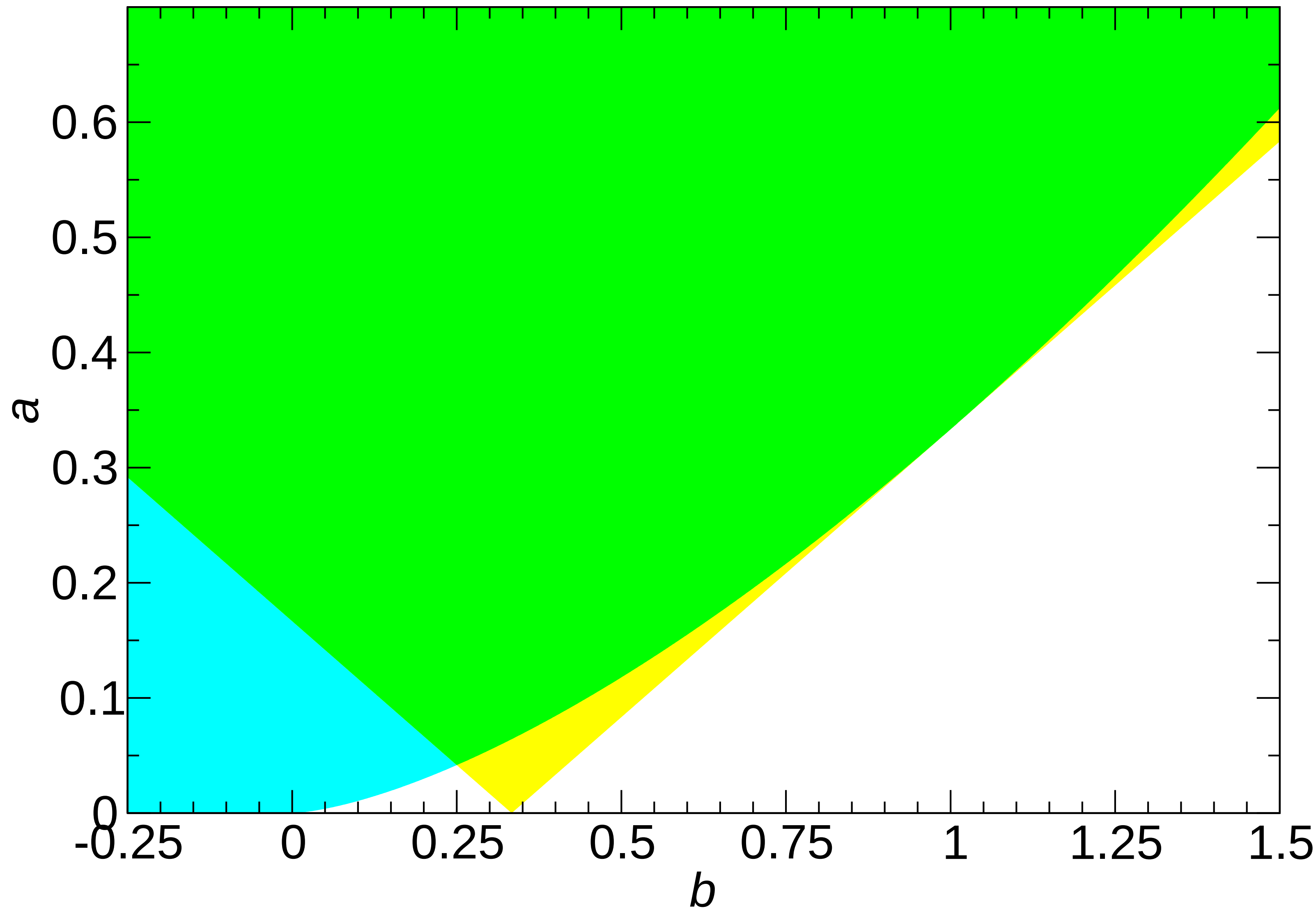
Longitudinal Phase Space



Time-of-Flight vs. Energy



Parameter Space



Non-Isochronous, Longitudinal Dynamics

- Model what occurs with velocity variation with energy, but at high energy
- Machine should not be isochronous anywhere in the range
- Use low-frequency RF
- Vary frequency to match time-of-flight
- Momentum compaction is far from constant
- Can’t look at space charge effects

Resonance Crossing

- Want to observe the crossing of a large number of resonances that occurs in a linear non-scaling FFAG
- Isochronous machine: what primarily matters is the number of cell-turns
  - Try to make at least 500 for reasonable a parameter: muon machines vary from 500 to 1500
  - Interested in large emittances
  - Will tune profile have an effect on this???
- Non-isochronous machine
  - Accelerating slowly: take 100s of turns
  - More sensitive to imperfections, etc.
  - Small emittances

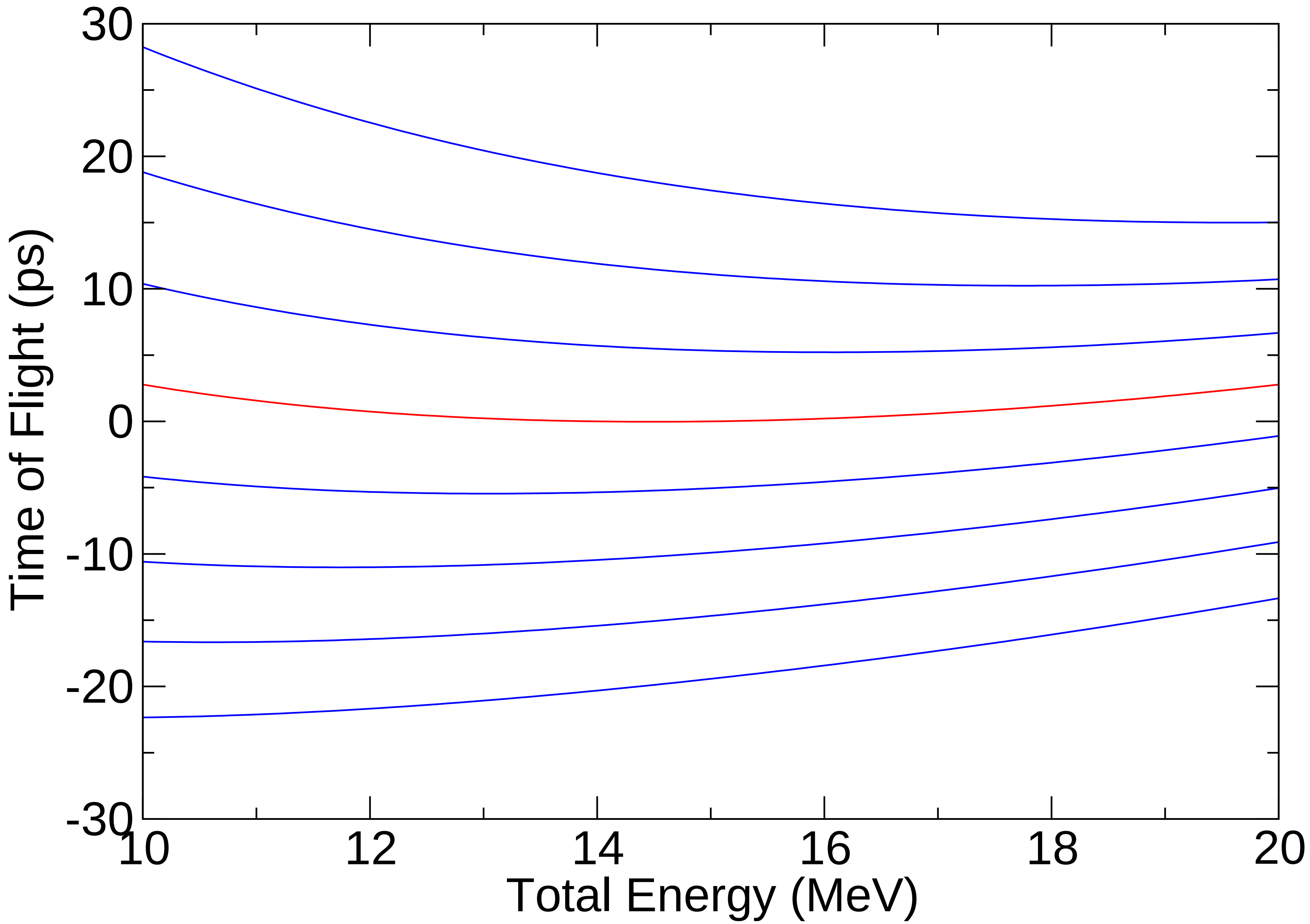
Hardware Requirements: Longitudinal Isochronous

- Must be able to survey a-b parameter space
- Varying a is easy: increase RF voltage
  - RF gradients modest: at $a = 1/12$, about 0.5 MV/m (every other cell has RF)
  - Going to $a = 1/2$ (very high) would require 3 MV/m, still a no-brainer at 1.3 GHz
- Varying b can be done a few ways
  - Adjust RF frequency: $\Delta f/f = 2.2 \times 10^{-3}$ to cover the $b = 0$ to $b = 1$ (more than you want to do)
  - Change cell length: same relative change in cell length
  - Phase relationship of one cell to the next must be well defined
    - Naïve computation: $1.3^\circ \cdot \delta_b$: but probably just need avarage
  - Tricks with magnet fields (coming up...)

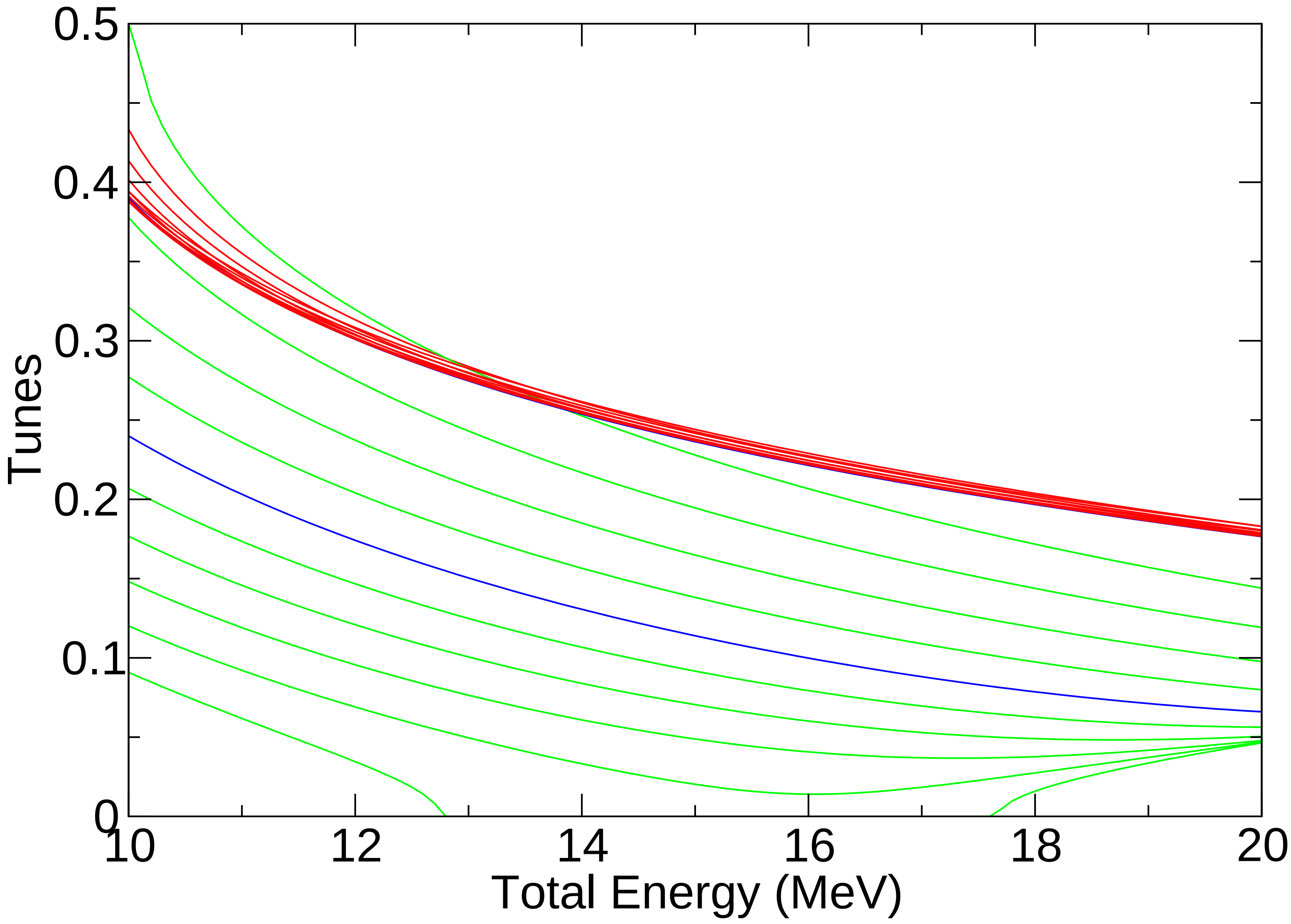
Magnet Requirements

- Question from Carol: can we do a permanent magnet plus coil?
- First, try fixed quad and vary dipole
  - Don't change energy range, to keep tune profile same
  - Can switch from isochronous to non-isochronous case doing this
  - Problem: vertical tune profile changes drastically: edge focusing
- Instead, vary quad
  - Change momentum range in proportion to quad strength
  - This will let us change b over a small range
  - Tune profile still changes, not as much
  - To keep isochronous, momentum in proportion to quad strength is wrong

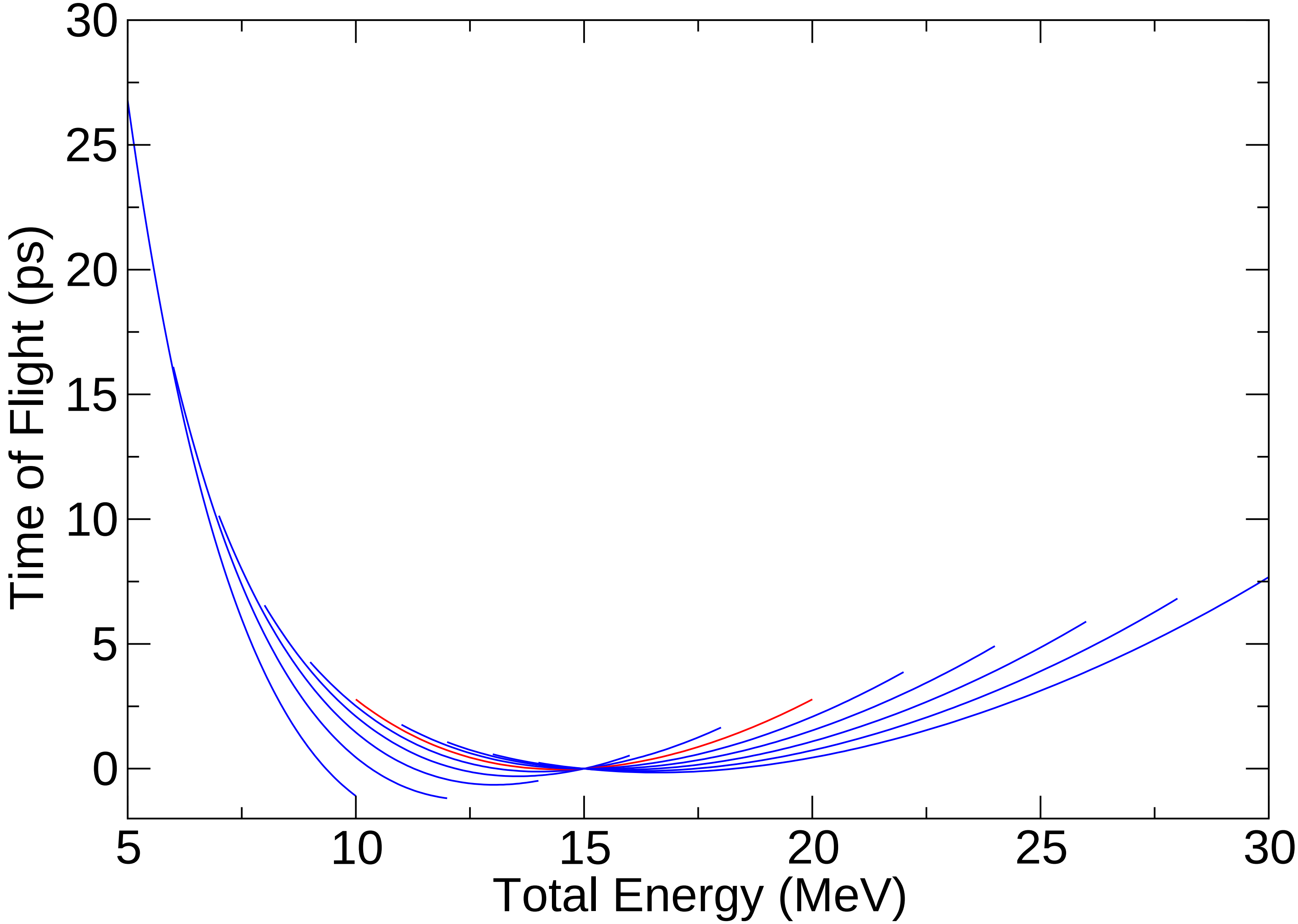
Varying Dipole Field



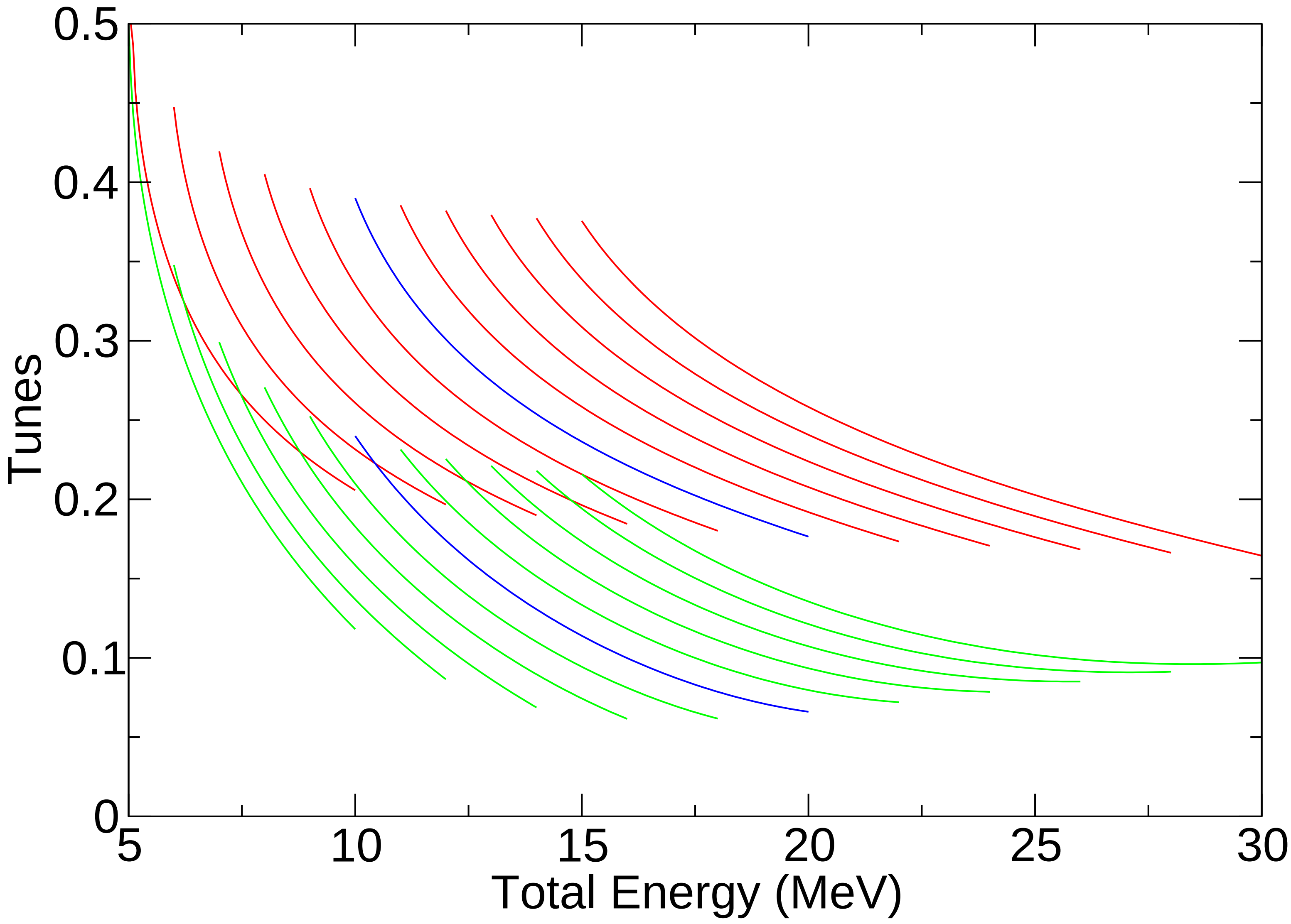
Varying Dipole Field



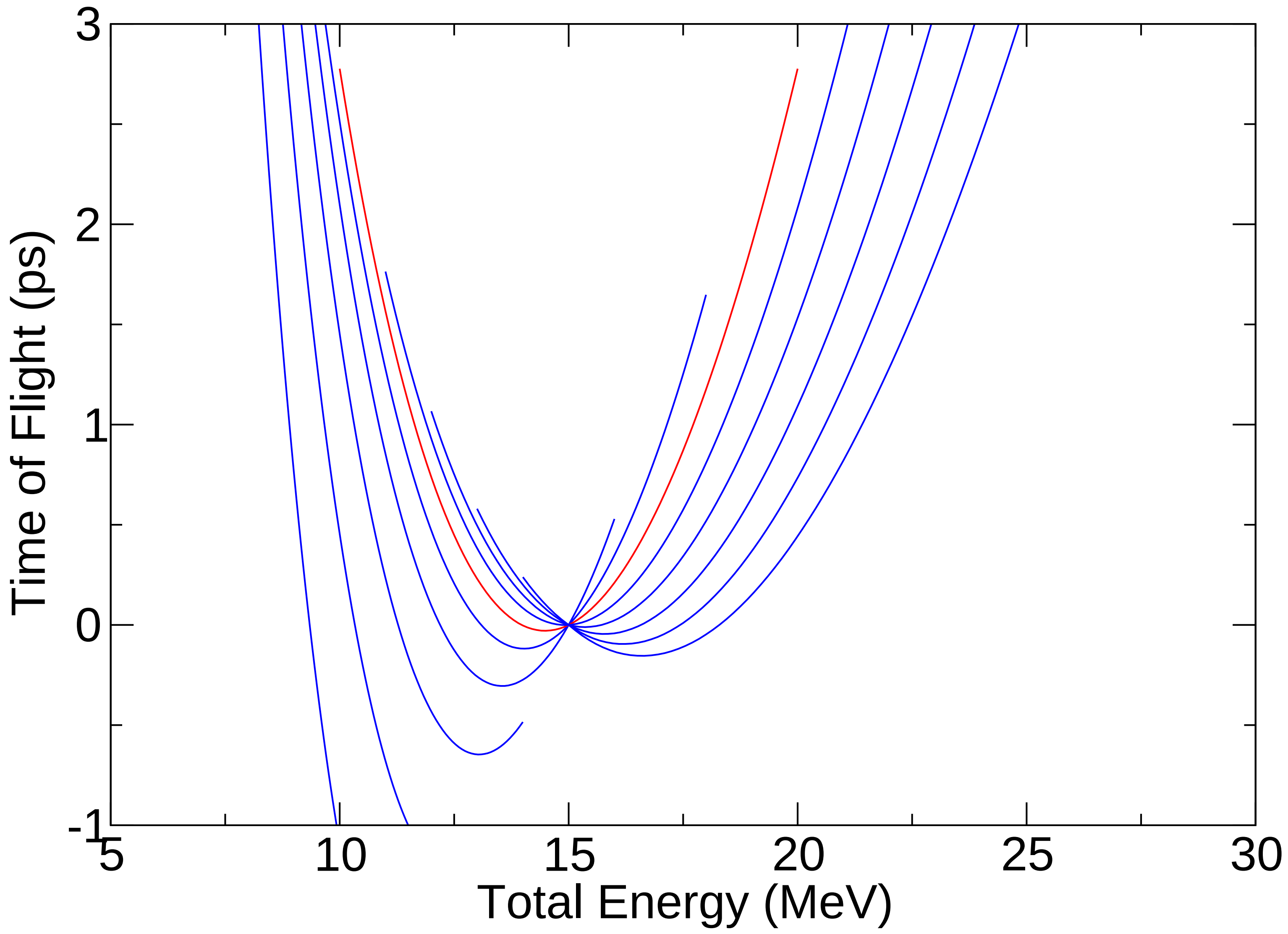
Varying Quadruople Field



Varying Quadruople Field



Varying Quadruople Field



Magnet Requirements (cont.)

- My opinion: not enough knobs with one component as permanent magnet
  - Want to adjust tune profile independently of time-of-flight profile
  - The two are strongly intertwined: varying one field component changes both
  - Reference energy range doesn't give you enough of a knob, since horizontal and vertical don't change together
- It becomes especially difficult to look at the non-isochronous scenario without varying both components
- PM dipole with variable quad seems better than other way
- Will PM mess up the coil field???
- All this variability requires extra field and extra aperture
- Maybe my scope is too ambitious?

Cell Parameters

Cells	42	48	54	36	42	48	36	42	48
Pole Tip Field (T)	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
$\Delta E/V_{\text{cell}}$	389	528	683	374	524	692	427	519	774
D Quad Length (mm)	139	122	109	78	68	61	51	45	41
D Quad Radius (mm)	18	16	15	15	14	13	14	13	13
F Quad Length (mm)	119	110	103	66	60	56	44	40	38
F Quad Radius (mm)	30	27	25	26	24	22	24	22	20
Cavity Voltage (kV)	26	19	15	27	19	14	23	17	13
Circumference (m)	21.3	23.1	24.9	14.2	15.9	17.6	12.4	14.1	15.8