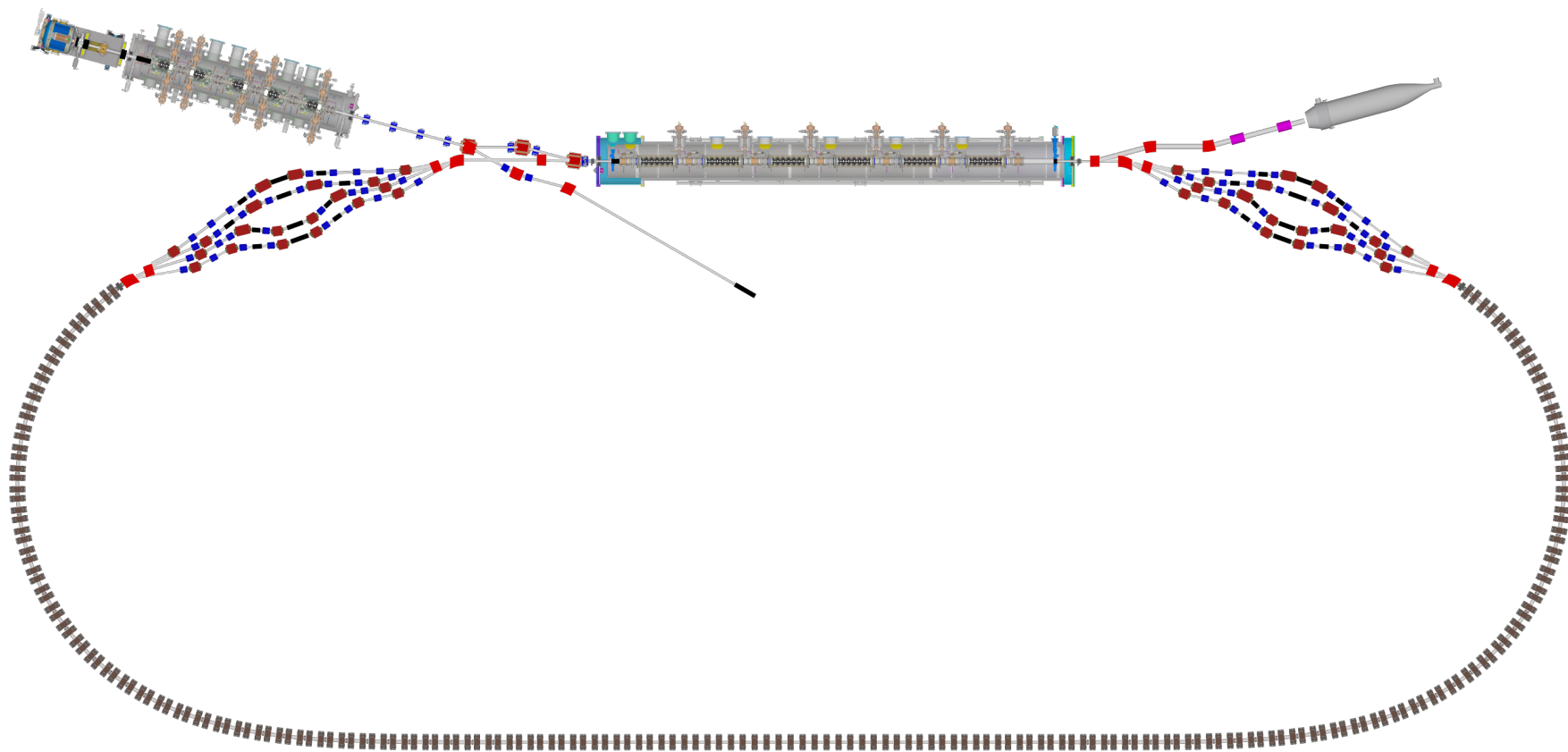


Transitioning Between FFAG Arcs

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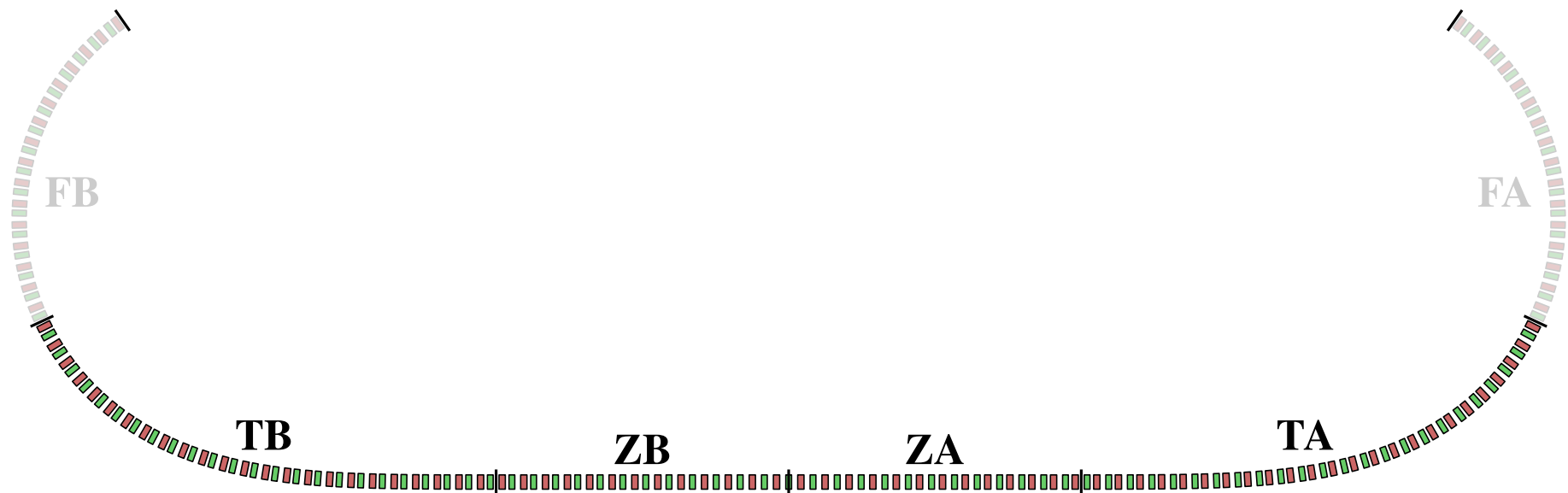




- Three sections
- Arcs (FA/FB): main building block
- Transitions (TA/TB): bring beams on-axis
- Straight (ZA/ZB): corresponds to linac opposite



- You've heard details on this from Stephen Brooks
- Tight radius to keep machine compact



- Linac and tight arcs force us to have a straight section
- Need beams on-axis in straight
- Needs to work for multiple energies
- This is what will be discussed in this talk



- Transition brings all beams on-axis at straight
- Closed orbits in arcs have different positions/angles for different energies
- Want them all on axis in straight
- Slowly change parameters from arc parameters to straight parameters

- Need to know what we are transitioning to at the straight
- Focusing from bending strong enough to make arc and straight cells different if use same parameters
- Magnet gradients the same in arc and straight
- Only parameters remaining are drift lengths
- Minimize sum beta mismatches, weighted by inverse of tunes
 - Thus transition only matching orbits
- Resulting drifts: 137 mm and 82 mm (120 mm and 70 mm in arc)

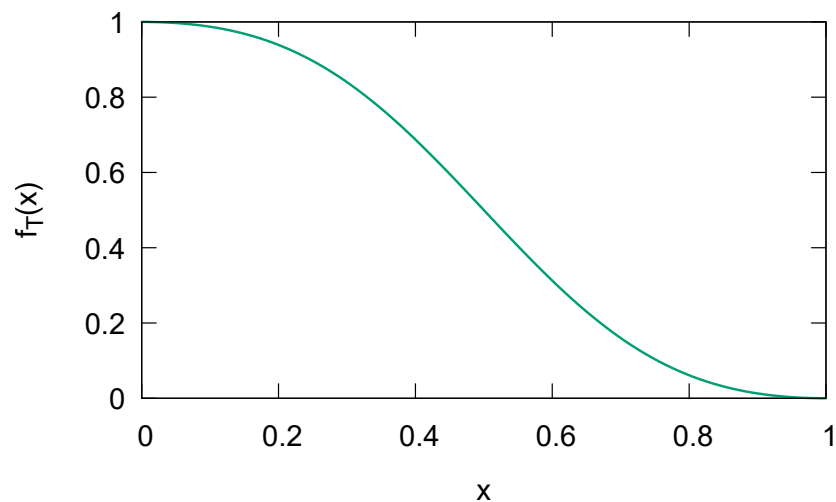
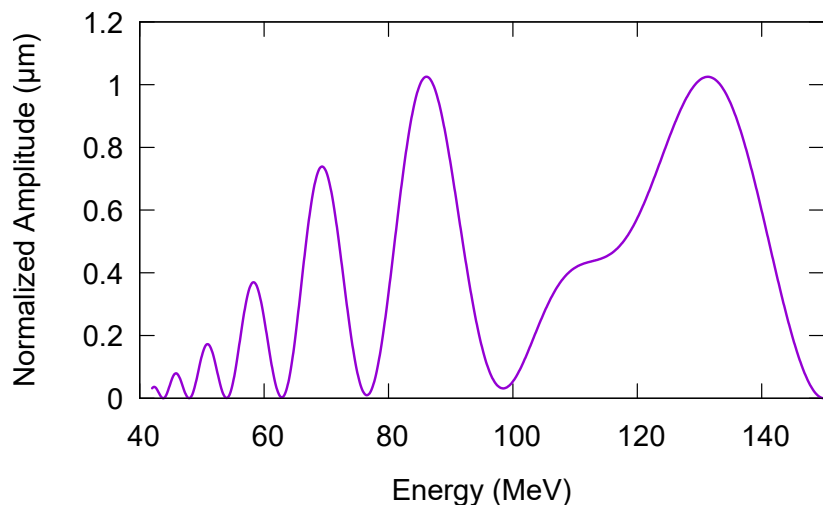
- Transition has 24 cells
- Each parameter p has value p_i in cell i :

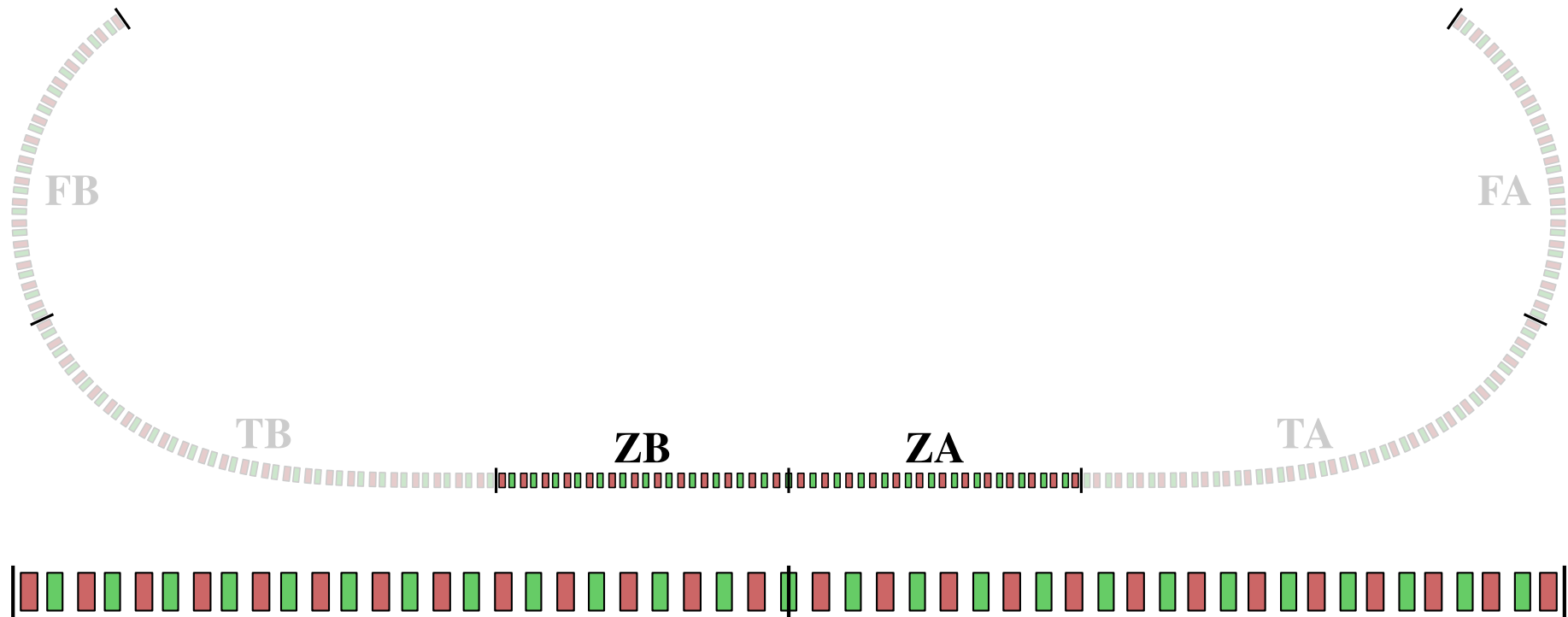
$$p_i = p_0 f_T \left(\frac{i}{n_T + 1} \right) + p_{n_T+1} f_T \left(\frac{n_T + 1 - i}{n_T + 1} \right)$$

- Parameters are
 - Bend angle for cell
 - Drift lengths
 - Dipole fields at reference axis
- Remaining work is to determine f_T
- Minimize normalized amplitude at straight

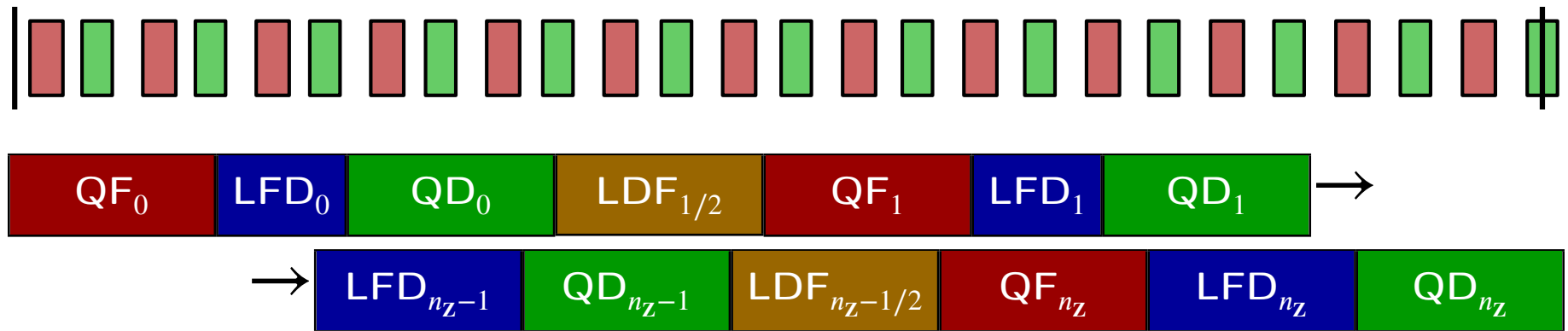
$$\frac{1}{2m_e c} \left(\gamma_x p x^2 + 2\alpha_x x p_x + \frac{\beta_x}{p} p_x^2 \right)$$

- Full energy range: robust against errors/changes
- Choice of f_T
 - High continuity at ends: adiabatic, good at low energy
 - Not too much continuity: would force middle too steep
 - Adjust additional parameters to limit maximum values
- Can make perfect at design energies: use correctors
 - Displacements to fix in design tiny
- Results for Nov. 17 Baseline lattice:



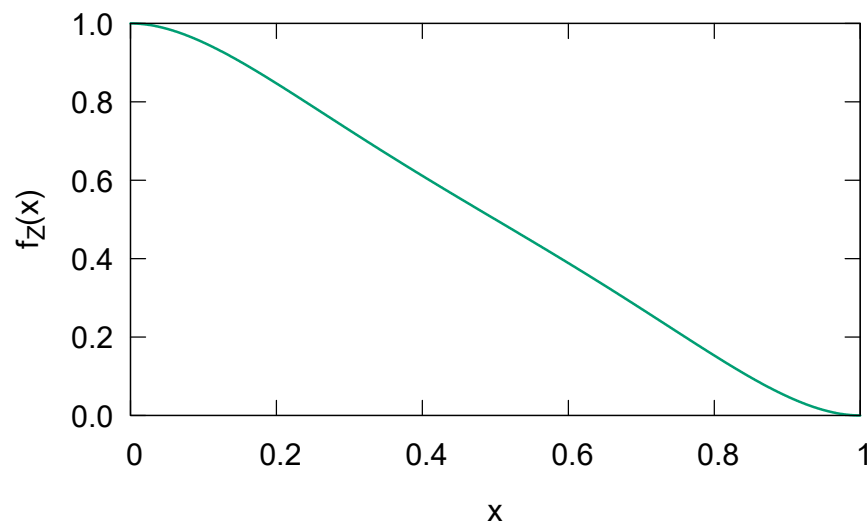
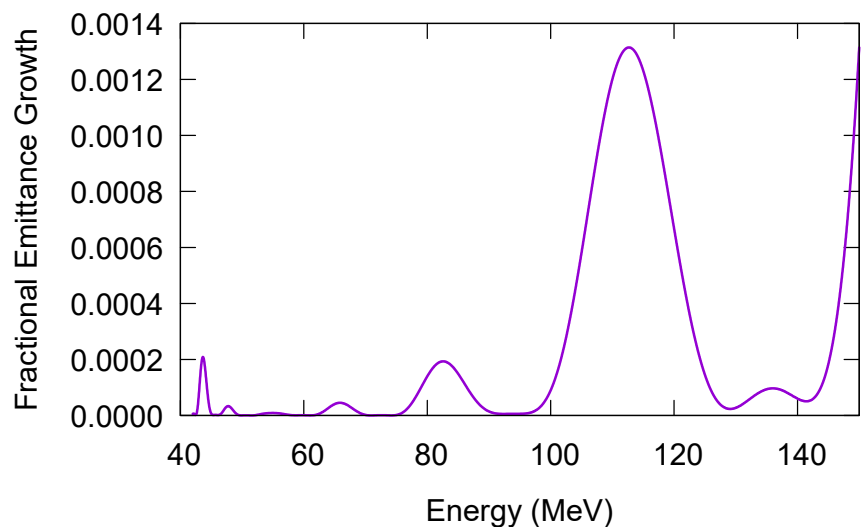


- Reflection symmetric machine
- Slowly switch direction of doublet, FODO at center
- Goal to have $\alpha = 0$ at center
- Central cell, both drifts at least 120 mm



- Parameters vary from end to center, like transition
 - Different tapering function
 - Drift lengths
 - Gradients (actually, inverses)
- Central cell: sum of cosines of cell tunes same as end cell
- Minimize fractional emittance mismatch: $2\alpha^2$ at center, summed over design energies and planes

- Half straight about half transition length, so taper function less flat at ends
- Effective emittance growth small over entire energy range
- Requires gradient reduction of about 17% at center
 - Push magnets out using shims, as for correction
- Results for Nov. 17 baseline lattice:



- Have FFAG lattices that get from one arc to the other
- Transition brings beam onto axis of straight
- Straight transitions from one doublet to its reflection
- Use smooth variation of parameters so designs work across entire energy range
 - Tuned to balance smoothness at ends with rate of change in center
 - Works for all energies to be robust against errors
- Transition performance good, can be tweaked to be perfect on design energies with correctors if desired
- Straight mismatch tiny