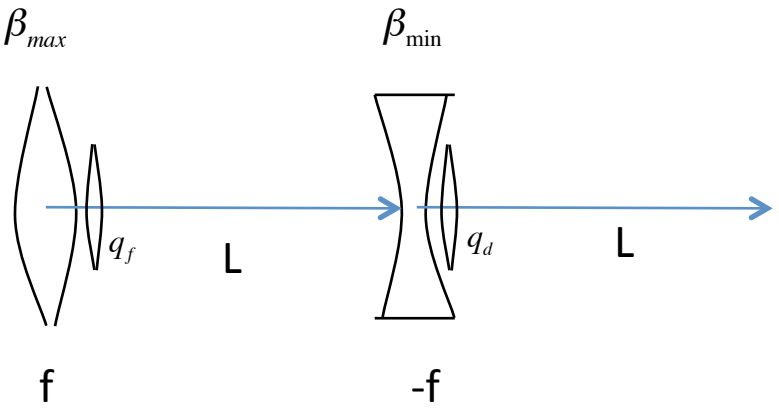
Accelerator Fundamentals Homework 6

1. We have our standard FODO cell



with a small corrector ("trim") quadrupole next to each of the main quadrupoles (you may assume that they are close enough that they see approximately the same beta functions as the quad they are next to). Each of these has a normalized strength given by $q = B'l/(B\rho)$, with the designations shown in the figure. Assume that q_f and q_d can be varied independently.

   a. Write an expression for the change in tunes in each plane $\Delta\nu_x$ and $\Delta\nu_y$ as a function of q_f and q_d. Express this as a matrix.

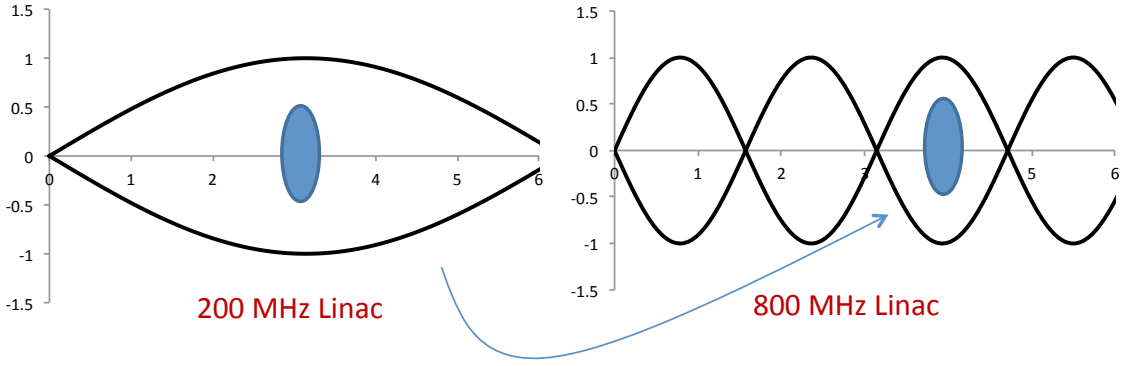
$$\begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \end{pmatrix} = \begin{pmatrix} ? & ? \\ ? & ? \end{pmatrix} \begin{pmatrix} q_x \\ q_y \end{pmatrix}$$

   where the elements of the matrix depend only on the lattice functions β_{min} and β_{max}.

   b. Invert this matrix to find expressions for the values of q_f and q_d which will give a tuneshift *only* in the x plane; that is, $\Delta\nu_x = \Delta\nu_0$ and $\Delta\nu_y = 0$.

2. A longitudinal particle distribution is described by σ_t and σ_E. Assuming we are adiabatically accelerating these bunches, how does each of these values scale with energy for $\gamma \gg \gamma_T$?

3. We want to do a bucket-to-bucket transfer from a 200 MHz linac section to an 800 MHz linac section, as we discussed in class



What is the ratio of the two peak voltages V_{800} / V_{200} that will match the bunch shapes in the two sections?

4. Why doesn't the LHC use antiprotons? The design luminosity of the LHC is 1×10^{34} $cm^{-2}s^{-1}$. Most of the particles in the ring "burn up" by undergoing simple and completely uninteresting nuclear interactions. The total nuclear cross section at this energy is roughly 100 millibarns (1 barn = 1×10^{-24} cm^2) for both proton-proton and proton-antiproton interactions.
    a. At what rate do protons burn up at the design luminosity [particles/second]
    b. The most intense antiproton source ever built was the Fermilab antiproton source, which reached a maximum production rate of about 2.5×10^{11} antiprotons/hour. By what factor would this have to be increased to substitute antiprotons for protons in part (a)?
    c. Just for fun… Assume the antiprotons from the Fermilab antiproton source were combined with a positron and converted to anti-hydrogen with 100% efficiency. How long would it take to make the "half gram" of antimatter mentioned in Dan Brown's "Angels and Demons".