Accelerator Homework, Part 1

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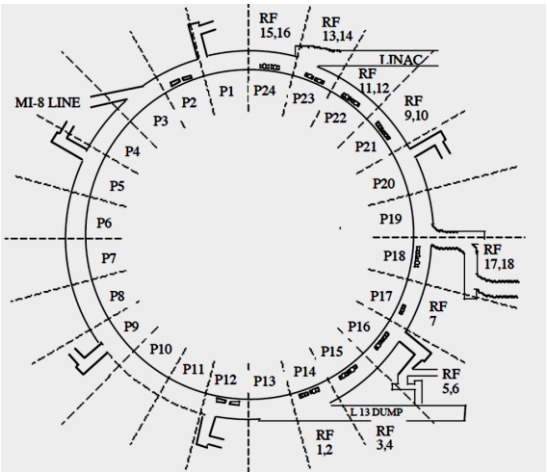
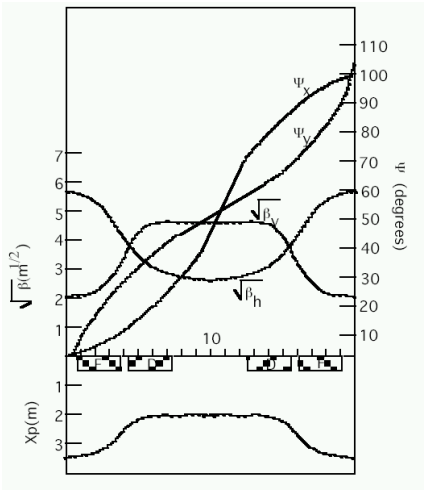
1. Quadrupoles focus in one plane and defocus in the other. Sketch the type of field you would need to focus in both planes and use Maxell's Equations to show that this is impossible using only *external* currents.
2. Beam line or accelerator "admittance" represents the area o f the maximum ellipse in phase space that can be transported. It is calculated from the limiting aperture in the same way the emittance is calculated from the transverse beam size. The radius of the aperture in the final focus quadrupoles of the LHC is 35 mm. Using the optics plots on slide 46, estimate the normalized admittance of these magnets at injection and collision energy. Recalculate the admittance at injection if they tried to inject with the *collision* optics (that is, no "squeeze" later).
3. The Fermilab "Booster" is a rapid cycling synchrotron that accelerates protons from 400 MeV to 8GeV. It has a 24-fold periodicity, where each period has the lattice functions shown below





Each period has a corrector dipoles located at the maximum beta points in *x* (horizontal) and *y* (vertical).

   a. Using the "3-bump" equation on slide 29, calculate the vertical angular bends I would need at the maximum beta points in periods 1, 2, and 3 to create a localized 1 cm vertical bump at the maximum beta point in period 2. (hint, for a *localized* bump, you can use the first equation on the slide to calculate the beam deflection).
   b. Calculate the integrated magnetic fields it would take to produce these angles at the extraction energy of 8 GeV.
4. Express the luminosity formula on slide 43 in terms of the maximum beam-beam tune shift (slide 44). Discuss the strategy for increasing luminosity if this is the limiting factor.

5. In looking for new uses for the Tevatron tunnel, some people (briefly!!) discussed building a "Z Factory" – a higher luminosity version of LEP.
    a. Assuming a uniform bend radius, show how the power lost to synchrotron radiation would scale as one went from the LEP tunnel (C=27km) to the Fermilab tunnel (C=6π km)
    b. Calculate the power loss for a 1A beam current