Joint University Accelerator School

Examination of Transverse Beam Dynamics

JUAS 2014

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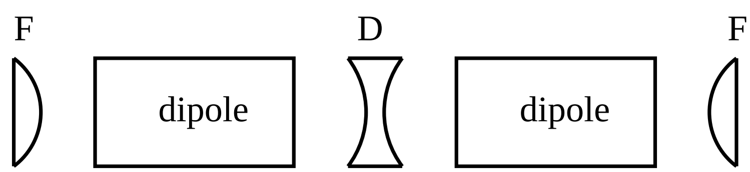
1 Exercise:

TLEP is a high luminosity circular e^+e^- collider to study the Higgs boson and physics at the electroweak scale. The TLEP project is conceived as a ring with a circumference 80 km long. Let us assume that the optics of this machine is made of identical FODO cells, each cell with the following structure:



Assuming for the calculations the thin lens approximation, and considering the following parameters:

Parameter	Value
Beam energy	120 GeV
Total FODO cell length	50 m
Quadrupole gradient G	10 T/m
Quadrupole length	1.5 m
Dipole length	21.3 m

answer the following questions:

1. Calculate: (1) for each dipole the bending angle and the necessary magnetic field; (2) the value of the focal length of each quadrupole
2. Is this lattice stable?
3. What are the vertical and horizontal tunes for this machine?
4. Compute the maximum and the minimum value for the betatron functions, and the maximum and minimum value of the dispersion
5. Calculate the natural chromaticities for this machine

2 Exercise:

Let us now assume that in TLEP there is an Interaction Point (IP) with $\beta_x^* = 0.5$ m and $\beta_y^* = 0.1$ cm. The peak luminosity available by a e^+e^- collider can be written as:

$$L = \frac{N_\mathrm{b} N_{e^-} N_{e^+} f_\mathrm{rev}}{4\pi\sigma_x^*\sigma_y^*} \; [\mathrm{cm}^{-2}\mathrm{s}^{-1}]$$

where $N_\mathrm{b} = 80$ is the number of bunches per beam (we assume the same number of bunches for both the e^- and the e^+ beams), $N_{e^-} = N_{e^+} = 5 \times 10^{11}$ is the number of particles per bunch (we assume the same number for both e^- and e^+ bunches), and f_rev is the revolution frequency. The horizontal and vertical normalised beam emittances are respectively: $\epsilon_{x,N} = 2.2$ mm and $\epsilon_{y,N} = 4.7$ μm.

1. Compute the revolution frequency f_rev, knowing that the circumference is 80 km and that the beam moves nearly at the speed of light
2. Calculate the beam transverse beam sizes σ_x^* and σ_y^* at the IP, and the luminosity L for two different beam energies: 45 GeV and 120 GeV
3. What is the value of the betatron function at position $s = 0.5$ m from the IP?

3 Exercise:

Given a dispersion suppressor based on the missing-magnet scheme, followed by a straight section with the same focusing properties, reduce the horizontal chromaticity of the system using two sextupoles.

1. Sketch the lattice with the horizontal beta functions and the dispersion.
2. Where do the two sextupoles have to be located? Why?
3. What are the requested sextupoles strength? (work in thin-lens approximation)

4 Exercise:

Orbit control: given two kickers located at the two ends of a FODO cell with phase advance 45 degrees (the two kickers are located at L_cell distance from each other), compute the strengths of such kickers (in radians) in order to give the beam, initially at $(x_i,\, x_i') = (0,\, 0)$, an arbitrary offset at the end of the cell while preserving its angle, $\left(x_f,\, x_f'\right) = (x_\mathrm{arbitrary},\, 0)$.