USPAS Graduate Accelerator Physics Homework 14

Due date: Monday February 15, 2021

1 LEP electron radiation

(5 points) Consider 50 GeV electrons in LEP *(requiesce in pace)*, circulating in a nearly-circular ring with a total circumference of about 27 km. Consider also a 5 TeV electron storage ring that is built around the earth's equator. For each accelerator:

a) How much energy is radiated per electron per turn?

b) What is the characteristic damping time τ_0, in turns and in seconds?

c) What is the bending field?

2 FCC wall-plug power

(10 points) A Future Circular Collider (FCC) might circulate 50 TeV protons in a 100 km circumference tunnel with a main arc dipole bend radius of 11 km.

a) What is the arc dipole bending field?

b) What is the critical energy of photons radiated in the dipoles?

c) What is the total energy lost per turn, per proton?

d) If each proton beam has a current of 0.5 A, what is the total synchrotron radiation power, per ring?

e) Assuming that cryogenic refrigerators operate with a Carnot efficiency of 20%, how much "wall-plug" power would be required if the synchrotron radiation were absorbed at a temperature of 4 K?

3 Muon storage ring

(10 points) Consider muon storage rings.

a) What is the total power radiated in an isomagnetic muon storage ring of radius ρ with an average beam current of I?

b) How much power is emitted in a 30 GeV ring with $\rho = 250$ m that stores 1 A of electrons, or 1 A of muons?

c) What is the natural beam current lifetime decay for 30 GeV muons?

d) What is the heat load due to the decay of 1 A of 30 GeV muons?

4 RHIC longitudinal parameters during acceleration

(15 points) (See also Exercises 4.4 and 5.8.) RHIC accelerates fully-stripped gold ions in an RF system with a harmonic number of $h = 360$ and with a typical voltage of $V_{RF} = 300$ kV. Assume that transition $\gamma_T = 22.89$, and ignore synchrotron radiation.

a) If $\phi_s = 0°$ before acceleration begins, when $\gamma = 10.4$, what is the synchrotron frequency (in Hz)?

b) For a synchronous phase of $\phi_s = 5.5°$, how much energy does the synchronous particle gain per turn?

c) How long does it take to accelerate to $\gamma = 107.4$? Assume that the phase jump at transition has been performed correctly – ignore it.

d) Plot the synchrotron frequency as a function of energy, up the acceleration ramp.