Experiment 1

β-functions and tune

The storage ring optics are characterized by horizontal and vertical betatron tunes and the longitudinal synchrotron tune. We identify the tune by measuring the frequency of the centroid motion of the beam on a beam position monitor. In CESR, we typically operate with $Q_x \sim 10.53$ and $Q_y \sim 9.6$. We measure $f_h = f_{rev}(0.53) = 207$kHz and $f_v = f_{rev}(0.6) = 234$kHz where the revolution frequency $f_{rev} = 390.1$kHz.
The dependence of tune on quadrupole strength allows us to measure the local β-function. That dependence is given by:

$$\Delta\nu = \frac{1}{4\pi}\beta\Delta kl \tag{1}$$

We measure the average value of β at a quadrupole by finding the dependence of tune on quadrupole strength. (l is the length of the quadrupole. ($l = 60$cm for all CESR normal conducting quadrupoles.) The dimensions of k are m^{-2}.)

β-measurement

1. Fill a single bunch of positrons to about 3mA
2. Turn off electrostatic separators
3. Identify and record horizontal and vertical tunes
4. Assign the quadrupole of your choice (Q03W:Q49W, Q49E:Q03E are all good candidates) to the control panel. (RING MAGNETS $\rightarrow$ CSR QUAD CUR $\rightarrow$ Q04W)
5. Change the strength of quadrupole until the tune has changed by at least a few kHz.
6. Record the change in the horizontal and vertical tunes, and in the value of the quadrupole setting.

7. The calibration of the quadrupoles is given in the file CESR29:[CESR.CONSTANTS]QUADRUPOLE.CALS. For all except 1,2,34,48 and 49, ComputerUnits = (14972.82)E(GeV)k

8. The magnetic field in the main dipoles determines the beam energy. An NMR is use to measure the magnetic field in the dipoles. (see display) The dipole bending radius is 87.9m.

9. Compute the average value of β (horizontal and vertical) in the quadrupole and compare with the design value. Measure β at two different quadrupoles in the ring, one focusing and one defocusing. Estimate the resolution of the measurement. What systematic effects might compromise the result?

Distortion of the β-function

The β-function at positon s in the ring is distorted by a quadrupole error at s_1 according to:

$$\Delta\beta(s) = \frac{\beta(s)}{2\sin 2\pi\nu}\beta(s_1)\Delta kl\cos 2(\phi(s) - \phi(s_1) - \pi\nu) \qquad (2)$$

Using the technique mastered above, measure the change in β at one quadrupole, due to the change in k at another. Use your knowledge of the optical functions, (β and phase advances), to chose a pair that will give a good signal. Compare your findings with theory.