HW III.1 (3 points): Comparison of SRF and NC RF cavities for a storage ring

An electron storage ring with a beam current of 300 mA can use either one superconducting or several normal conducting cavities. A single cell Nb cavity would operate at an accelerating gradient of 7.5 MV/m. The cavity parameters are: R/Q = 90 Ohm, $Q_0 = 2.0 \cdot 10^9$. Normal conducting cavities would operate at 2.5 MV/m. Parameters of a single cell copper cavity are: R/Q = 220 Ohm, $Q_0 = 3.0 \cdot 10^4$.

(a) Calculate and compare accelerating voltages of the SRF and NC RF cavities. How many NC cavities one would need to match the accelerating voltage of the SRF cavity? Calculate RF power loss in the cavity walls for both cases.

(b) Assuming the beam phase of 80 degrees, calculate beam power delivered by the RF system. What is the total RF power required for two cases? Assume that there the cavities are ideally matched and there is no reflected power.

(c) Assuming that the SRF cavity operates at 4.5 K, calculate the wall-plug power of the cryogenic system with COP of 300. Assuming an RF power generator efficiency of 50%, calculate the wall-plug power for two cases. Compare the total AC power needed for the SRF and NC RF accelerating systems.

HW III.2 (1 point): Pillbox cavity

For a 1300-MHz pillbox cavity operating at an accelerating gradient of 10 MV/m, calculate the cavity dimensions, and accelerating voltage. Calculate an energy gain for an ultra-relativistic electron traveling: a) along the cavity axis of symmetry; b) parallel to the axis with a radial offset of 2 cm.

HW III.3 (2 points): RF power and beam loading

Consider a 350-MHz SRF cavity operating at 2 MV in a storage ring. The cavity parameters: R/Q = 100 Ohm, $Q_0 = 2.0 \cdot 10^9$. The beam current is 500 mA and the beam phase is 85 degrees.

(a) What should be loaded quality factor of the cavity so that there is no RF power reflected back to the RF power generator? What is the coupling parameter?

(b) Calculate the cavity detuning needed to compensate the reactive part of the beam loading.