ILC School Erice Linac – Homework Problems

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1. Consider the ILC baseline cavity shown in Figure 13 of the lecture notes, and in slide 51 of the lectures. The cavity has 9 cells, with a cell period of 115.4 mm, iris radius (a) of 35 mm, and cavity radius (b) of 102 mm, and operates in the π mode at 1.3 GHz.

   Using the first-principles expressions derived in the lectures and the notes, calculate the following quantities:

   - The expected surface resistance at 2 K.
   - The expected quality factor for the cavity, assuming an operating temperature of 2 K and a surface resistance which neglects the residual resistance due to impurities.
   - The expected shunt impedance, including the correction for the cavity iris (aka "beam hole").
   - The R/Q of the cavity, including the correction for the cavity iris.
   - The expected phase velocity for the cavity.

   Note: For the impedance of vacuum, use $Z_0 \approx 377\Omega$; for the first zero of J_0, z_{01}, use 2.404; for $J_1(z_{01})$, use 0.519. Assume that the factor $z_{01}h/a$ is small enough to be approximated as zero.

2. Estimate the mean decelerating voltage experienced by a single bunch of 3.2 nC with $\sigma_z = 300$ μm passing through an idle ILC cavity (*i.e.*, a cavity with no stored energy, which is initially at $V = 0$). Estimate the induced RMS energy spread. Estimate the mean and RMS energy spread due to all of the cavities in the positron main linac.

3. At the vertically-focusing quadrupoles in the ILC, the vertical betatron function reaches approximately 140 meters. Estimate the kick voltage experienced by the tail of the bunch due to a cavity with a 1 mm vertical misalignment. Compare this to the RMS angular divergence of the beam, $\sigma_{y'} = \sqrt{\epsilon/\beta}$, at 15 GeV and at 250 GeV.

4. The integrated strength of the ILC main linac quads is approximately given by $K_q L_q \approx 0.0125$ m^{-1}. Calculate the deflection to the beam given by a quad with a 1 mm misalignment. Compare this to the angular divergence of the beam at 15 GeV and at 250 GeV.

5. In the lecture notes, we derive that the tolerance on BPM alignment required for 1:1 steering to work without any other techniques is about 85 μm. If only the first half of the linac is considered, what is the alignment tolerance? What is the alignment tolerance considering only the second half of the linac? What is the alignment tolerance considering only the second half of the linac and also reducing the phase advance per cell to 45 degrees? Note: $\Sigma 1/E_q = 3.38$ for the full linac, 2.62 for the first half of the linac, and 0.76 for the second half.