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Accelerator Physics WS24/25

Exercise sheet 3 (Submission: 26.11.2024)

Exercise 1: KARA Synchrotron (5 points)

The synchrotron radiation source KARA (**Ka**rlsruhe **R**esearch **A**ccelerator) has a local bending radius of $\rho_{\mathrm{KARA}} = 5.559\,\mathrm{m}$ and a circumference of $U_{\mathrm{KARA}} = 110.4\,\mathrm{m}$. Typically, beam energies of 1.35 GeV or 2.5 GeV are used.

(a) Calculate the total energy loss per revolution W_{s} for an electron at both energy levels. (1)

(b) What is the orbital frequency f of the electrons? (0.5)

(c) Specify the total emitted power for a beam current of $I = 200\,\mathrm{mA}$ in each case. (1)

(d) Calculate the characteristic frequencies of the synchrotron radiation spectra ω_{c}.
Determine the photon energies corresponding to these frequencies. What do these result mean for the storage ring? (1)

(e) Compare the total energy loss per revolution for an electron in LEP with that of a proton in LHC and an electron as well as a proton in FCC.
LEP: $\rho = 3.2\,\mathrm{km}$, circumference $= 26.7\,\mathrm{km}$, beam energy $= 100\,\mathrm{GeV}$,
LHC: $\rho = 2.8\,\mathrm{km}$, circumference $= 26.7\,\mathrm{km}$, beam energy $= 7\,\mathrm{TeV}$
FCC: $\rho = 10.5\,\mathrm{km}$, circumference $= 100\,\mathrm{km}$, beam energy $= 100\,\mathrm{TeV}$ (1.5)

Exercise 2: Synchrotron radiation (4 points)

To compensate for the energy loss due to synchrotron radiation, how much power must be supplied to the accelerators listed below?

(a) ESRF: Electron beam with a beam energy of 6 GeV, beam current of 200 mA. The deflection magnets generate a field of 0.85 T at the beam. (2)

(b) LHC: Two proton beams of 7 TeV each. The bending radius of the dipole magnets is 2803.95 m, the circumference is 26 658.883 m, and 2808 bunches containing 1.1×10^{11} protons are stored per beam. Is the literature value for the 'classical electron radius' applicable? (2)