September 5, 2014 **Questions for Tutorial**
Friday

Electron Dynamics with Synchrotron Radiation
Lenny Rivkin, EPFL & PSI
Introduction to Accelerator Physics Course
CERN Accelerator School, Prague

---

1. Synchrotron radiation in LHC: spectrum and dynamics

The Large Hadron Collider (LHC) is designed to collide 7 TeV protons in the same tunnel (circumference 27 km) where the Large Electron Project (LEP) operated with 100 GeV electrons. Assuming for simplicity the same bending radius in dipole magnets of 2900 m, calculate the following synchrotron radiation parameters for the three cases: for protons at the injection energy of 450 GeV, at the design energy of 7 TeV and for the electrons at 100 GeV:

- typical ('critical') photon energy of emitted synchrotron radiation
- energy loss per turn
- the damping times for energy and transverse betatron oscillations

The proton mass is 0.938 GeV and the electron mass is 0.511 MeV.

2. Future circular hadron collider (FCC).

New superconducting materials may allow in the future to build 20 Tesla dipole magnets for this recently proposed 100 km proton collider. Assuming bending radius of 10 km, calculate

To what maximum energy will FCC be able to accelerate protons?
What will be the typical photon energy emitted by protons and how much energy will proton lose per turn to synchrotron radiation?
Estimate the damping time and the equilibrium emittance of the protons stored at the top energy.

3. Synchrotron light source that never was: LEP at 5 GeV

The equilibrium electron beam emittance at 100 GeV at LEP was about 0.06 mm·mrad. If we tried to operate LEP at 5 GeV, how small an emittance could one hope to achieve using the same lattice? What would be the damping time at this energy (a few milliseconds at 100 GeV). Find the length of wiggler magnets you would need to install in the straight sections of the ring (assume wiggler field of 2 Tesla), in order to reduce the damping times at 5 GeV by a factor of 1000?