Accelerator Physics Exercises

- Work to be handed in before tutorial on - 22 Jan 2015

The aim of Hilary Term's work is to prepare a Student Design Project for the Future Circular Collider (FCC) study.

The FCC study is developing options for potential high-energy frontier circular colliders at CERN for the post-LHC era. The study includes a hadron collider (*FCC-hh*), a lepton collider (*FCC-ee*) and an electron-hadron collider (*FCC-he*). It has been launched as result of the recommendation made in the update of the European Strategy for Particle Physics in 2013.

The Student Design Project will concentrate on the *FCC-hh* machine option with a centre-of-mass energy of the order of 100 TeV in a new 80-100 km circumference tunnel for the search of new physics at the highest energies. The *FCC-hh* option, along with its detectors, will determine the basic requirements for the tunnel, surface and technical infrastructures of the FCC in general.

A description of the FCC is available at:

https://espace2013.cern.ch/fcc/Pages/default.aspx

and the principle parameters of the *FCC-hh* study are available at

https://espace2013.cern.ch/fcc/Pages/Hadron-Collider.aspx

Question 5.1 (Introduction)

Imagine you are writing the introductory section of the Student Design Report. Describe clearly and in detail the following:

(a) The physics that can be addressed by the *FCC-hh*, *FCC-ee* and *FCC-he*.

(b) The motivation and uniqueness of the *FCC-hh* compared to a high-energy LHC based on the *FCC-hh* high-field magnet technology and housed in the existing LHC tunnel. Such a machine would in principle have the ability to reach 26 to 33 TeV.

(c) The *FCC-hh* performance requirements and overall configuration.

(d) The particle beam requirements for both the *FCC-hh* and *FCC-ee*. Compare the two particle beam options and elaborate the pros and cons of each.

Question 5.2 (The Lattice)

(a) Study the lattice files and *info.txt* in *Holzer_ring.zip*. Create a MADX input file with just one basic straight cell (with no bending) and one basic arc cell. Use MADX to calculate and plot the periodic beta functions and dispersion in each cell.

(b) The current ring design has 12 arcs, but there is also an idea for a racetrack version that has two very long arcs and two long straight sections, while retaining 4 interaction points. Outline what you think are the advantages and disadvantages to each approach.

(c) At such high energies even protons emit synchrotron radiation. Assuming the bending radius is roughly 10km and the magnets can go up to fields of 16T, calculate the maximum energy the *FCC-hh* could accelerate protons to. Revisiting the synchrotron radiation lectures, what is the typical photon energy emitted by the protons and how much energy is lost per turn due to synchrotron radiation?

For clarification do not hesitate to contact Suzie Sheehy - suzie.sheehy@stfc.ac.uk.

Question 5.3 (The Cavities) – TO BE UPDATED BY CIPRIAN

It has been suggested that the FCC could use an RF system similar to the one used in the LHC, but capable of providing a higher voltage.

a) Revisit the lectures on RF cavity design and modeling and look in particular at the slides showing the pillbox and the elliptical-type cavities. Considering an RF frequency of 400.8 MHz (LHC frequency), estimate analytically the dimensions of a pillbox cavity at this frequency. Model this cavity in *Superfish* and plot the on-axis electric field. Start from the examples given in the tutorial.

b) Assuming an accelerating field of 5 MV/m and a relativistic beta of unity, model a single cell elliptical cavity at 400.8 MHz. What is the Q of this cavity? Plot the on-axis electric field. How many such cavities would be needed to provide an RF voltage of 20 MV per turn? How can the number of cavities be reduced? Start from the examples given in the tutorial.

c) Starting from the single-cell elliptical cavity, model a multi-cell cavity in *Superfish*. The number of cells needs to be chosen accordingly. Present your model, and plot the on-axis electric field. What is the Q of this cavity, the ratio of peak fields (Bmax/Emax) and the peak to average electric field ratio (Emax/E0)? To model multi-cell elliptical cavities, add the "NumberOfCells" keyword to the single cell model and use the "ELLCAV.EXE" solver. Start from the examples given in the tutorial.

For clarification do not hesitate to contact Ciprian Plostinar - ciprian.plostinar@stfc.ac.uk.

E. Tsesmelis and T. Wilson, December 2014