Accelerator Physics Exercises No. 6

- Work to be handed in on 24 January 2019

The aim of Hilary Term's work is to prepare a Student Design Project as part of the superconducting Super Proton Synchrotron (*scSPS*), which is part of 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 2013 update of the European Strategy for Particle Physics and a Conceptual Design Report is being finalised.

The *FCC-hh* will require a High Energy Booster as injector. One option being studied is to reuse the 6.9 km circumference tunnel of the *SPS* to house a fast-ramping superconducting machine, designated as the *scSPS*. The *scSPS* would be used to accelerate protons to an extraction energy of 1.3 TeV, both for *FCC-hh* and for the fixed-target experiments in CERN's North Area.

The Student Design Project will concentrate on the *scSPS* and the investigation of this fast-ramping superconducting machine in the SPS tunnel, focusing on the general lay-out, the lattice design, the choice of magnet technology and magnet design, and the RF system for acceleration.

A description of the *FCC* in general is available at:

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

and details of the *scSPS* study are available at

https://indico.cern.ch/event/774280/.

Question 6.1 (Introduction)

Imagine you are writing an 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*.

(b) The motivation for a 1.3 TeV *scSPS*, including the requirements for both an injector for the *FCC-hh* and for fixed-target beams to CERN's North Area.

(c) The main design considerations for the scSPS and the main machine parameters.

(d) Discuss the *Tevatron*, the former superconducting proton-antiproton collider at Fermilab. Compare the *Tevatron's* general design and machine parameters with those required for the *scSPS*.

Question 6.2 (The Lattice)

(a) The *scSPS* is designed to operate from an injection energy of 26 GeV up to 1.3 TeV top energy, with 6 T bending magnets. From this, calculate the minimum and maximum rigidity, and looking up the circumference of the ring, calculate the 'filling factor' – the proportion of the circumference taken up by 6 T bending magnets.

(b) Study the *scSPS* 'sequence' lattice file, together with the 'elements' file for definitions. Create a MADX input file with just one basic straight cell (with no bending) and one basic arc cell (with bending). Note that the half-cell length is 32 m and consists of one quadrupole and two dipole magnets – we want to write down one whole cell. Use MADX to calculate and plot the periodic beta functions and dispersion in each cell. The latest lattice is available at

https://project-sps-optics.web.cern.ch/project-SPS-optics/2015/

(c) Try to recreate the plot on p. 32 of Emmanuel's introduction talkl to the project (Lecture 22 of Michaelmas Term 2018).

For clarification do not hesitate to contact Dr. Suzie Sheehy (suzie.sheehy@physics.ox.ac.uk).

Question 6.3 (The RF Cavities)

First estimates indicate that installation of the superconducting RF system can be made within a single straight section (LSS3).

(a) Discuss the current normal-conducting RF system for the *SPS*, presenting its main parameters. Elaborate on the reasons for a superconducting RF system for the *scSPS*.

(b) Propose an optimum RF frequency (or frequencies) and parameters for the *scSPS*, including that required to de-bunch the beam for the slow extraction to the North Area fixed-target experiments.

(c) Propose a cavity design for your chosen frequency and model it using Superfish (including tuning it to the correct frequency). Present your findings and discuss your cavity choice. (Hint: The Superfish examples are a good starting point).

(d) Using the *scSPS* parameters, estimate the maximum voltage requirements per turn.

For clarification do not hesitate to contact Dr. Ciprian Plostinar (Ciprian.Plostinar@esss.se).

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