Accelerator Physics Exercises No. 1

- Work to be handed in on 28 January 2021

The aim of Hilary Term's work is to prepare a Student Design Project on the study of the primary electron beam for the electron-Super Proton Synchrotron (*eSPS*) at CERN. The facility re-enables the *SPS* as an electron accelerator, and leverages the development invested in the Compact Linear Collider (*CLIC)* technology for its injector and accelerator R&D infrastructure.

The *SPS* has, in the past, accelerated electrons and positrons from 3.5 GeV to 22 GeV when it was used as the injector to the Large Electron Positron (*LEP*) collider. It is now proposed to use the *SPS* simultaneously as an accelerator and as a very long pulse stretcher to provide an electron beam to a new experimental area. The electron injector would be a 3.5 GeV compact high-gradient linac based on *CLIC* technology injecting pulses into the *SPS*. The beam would then be accelerated to 16 GeV, using an 800 MHz superconducting radiofrequency (RF) system, similar to what is needed for the future electron-positron Future Circular Collider (*FCC-ee*). The electrons would then be extracted at 16 GeV using a slow resonant extraction. The extracted beam will be transported along an existing beamline to a new experimental area where the particle detector will be located.

The Student Design Project will concentrate on the *eSPS* and the investigation of its various components, 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 *eSPS* is available in the Conceptual Design Report (and references therein) under Tutorial 2 (Week 2) at the course INDICO page at

https://indico.cern.ch/event/983080/

Question 1.1 (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 at the *eSPS* facility.

(b) The main accelerator components of the *eSPS,* including the 3.5 GeV compact linac and its injector, transfer and injection into the *SPS*, acceleration in the *SPS*, extraction from the *SPS* and beam transfer to the detector.

(c) The main *eSPS* design considerations and electron beam parameters. This should include a discussion on the physics requirements (energy, intensity, bunch timing structure and extraction).

Question 1.2 (The Lattice)

a) Describe how the transfer of the electron beam from the linac to the *SPS* is proposed to be made for the *eSPS*. Include in your answer the new experimental requirements needed for the *eSPS* compared to what was in use for the transfer *PS*-to-*SPS* for the *LEP* collider.

b) Study the input lattice file for MAD-X available at
https://github.com/ydutheil/Transfer_lines_demo/blob/main/eSPS_injection/eSPS_injection.ipynb

   Create a MAD-X input file for the transfer line from the linac to the *SPS* and use it to calculate and plot the beam envelopes and optical functions from the linac to the *SPS* shown in the above link.

c) Electrons would circulate opposite to the direction of protons in the *SPS*. Discuss the implications on the lattice optics and whether any special measures would be required in the *SPS* for the *eSPS* facility.

For any clarification, please contact Prof. Emmanuel Tsesmelis (Emmanuel.Tsesmelis@cern.ch).

Question 1.3 (The RF Cavities)

An RF system would be used for acceleration in the *SPS*. The cavities would be installed in the long straight section SPS-LSS6 in order to exploit the existing infrastructure from the crab cavity installation for the high-luminosity LHC (*HL-LHC*).

(a) Discuss the main requirements of the RF system for the *SPS*, including the choice between normal conducting and superconducting as well as considerations for the RF system within SPS-LSS6.

(b) Discuss the various possible RF frequencies for the *SPS* and the preferred choice of a superconducting RF cavity at a frequency of 800 MHz.

(c) Using the *eSPS* parameters examined above, estimate the number of turns needed to accelerate the electron beam from 3.5 GeV to 16 GeV. What would be the minimum accelerating voltage that the RF system would be required to provide per turn?

(d) Propose a cavity design for a 800 MHz RF frequency and model it using Superfish (including tuning it to the correct frequency). Discuss your cavity choice. Assuming an accelerating gradient of 10 MV/m, estimate how many cavities would be needed to provide the required accelerating voltage per turn. Estimate the total beamline space needed for the RF system. (Hint: Superfish examples are a good starting point).

For any clarification, please contact Dr. Ciprian Plostinar (Ciprian.Plostinar@esss.se).

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