# Introduction to Particle Accelerators

# LONGITUDINAL BEAM DYNAMICS

# TUTORIAL 1 QUESTIONS

1. Looking at the picture below:



1. What should be the synchronous phase for particle acceleration below transition?
2. What should be the synchronous phase for acceleration above transition?
3. What should be the synchronous phase for keeping the particles at a constant energy below transition?
4. What should be the synchronous phase for keeping the particles at a constant energy above transition?
5. What are the benefits and limits of using a synchronous phase close to 𝛑/2 during acceleration?
6. What are the main differences between leptons and hadron synchrotrons in terms of longitudinal beam dynamics?

SawTooth effect at LEP:



1. The CERN SPS: The parameters for the CERN SPS (Super Proton Synchrotron) are the following:



Two types of beam are accelerated in the SPS and the parameters are:



1. Define the transition energy in one sentence
2. Compute the transition energy for both beams
3. Could transition energy be different for the LHC beam and the Fixed Target beam? Which machine optics parameter would need to change?
4. Compute the relativistic gamma and slip factor for both beams at injection energy and flat top energy
5. Does the LHC beam cross transition?
6. Does the FT beam cross transition?
7. What needs to be done when transition energy is crossed by a beam?
8. At the CERN PS machine the geometrical radius is R = 100 m, and the Bdot = 2.4 T/s (variation of the magnetic field with time during acceleration). The machine has 100 dipoles with an effective length of 4.398 m. The harmonic number is 20. Calculate:
	1. The energy gain per turn
	2. The minimum RF voltage needed
	3. The RF frequency when B = 1.23 T at extraction
9. Complete the table below for some CERN machines:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Machine | Einj (GeV) | Eflat\_top (GeV) | 𝛄tr | Etr | 𝛂c | 𝛈inj | 𝛈flat\_top |
| LHC | 450 | 7000 | 55.68 |  |  |  |  |
| SPS | 26 | 450 |  |  | 0.00192 |  |  |
| PS | 1.4 | 26 |  |  | 0.027 |  |  |

Exercise 5:

