

## LONGITUDINAL BEAM DYNAMICS - TUTORIAL

### CAS 2012 - Granada

For the Large Hadron Collider (LHC), the beam gets accelerated in the PS Booster (PSB) and transferred to the Proton Synchrotron (PS). The PS receives proton bunches ( $\Delta t_b \approx 150$  ns) during a first magnetic flat-top (i.e. no acceleration) with a kinetic energy of 1.4 GeV. When the PS machine is filled, the proton beam is accelerated up to a final momentum of 26 GeV/c and extracted to the Super Proton Synchrotron (SPS).

- 1) What are the relativistic  $\beta$  and  $\gamma$  for the protons at injection into the PS?
- 2) Calculate the magnetic field in the PS at injection and ejection.
- 3) At injection into the PS, calculate and compare the RF frequencies in the PS and in the PSB. The harmonic numbers are  $h_{PSB} = 1$  and  $h_{PS} = 8$ .
- 4) What is the synchronous phase in the PS at injection?
- 5) Assuming that the orbit remains the same during the acceleration, how does the RF frequency change between injection and ejection in the PS?
- 6) Should a phase jump system be implemented in the PS?
- 7) With the peak RF voltage in the PS at injection of  $V_{rf} = 25.6$  kV calculate the PS synchrotron frequency  $f_s$  and the synchrotron tune  $Q_s$  at injection. Does it verify  $Q_s \ll 1$ ?

#### Numerical values:

$R_{PS} = 100$ m	PS radius
$R_{PSB} = R_{PS} / 4 = 25$ m	PSB radius
$\alpha_p^{PS} = \gamma_{tr,PS}^{-2} = 0.027$	PS momentum compaction factor
$\rho_{PS} = 70$ m	PS curvature radius