TUTORIALS for the course of
"Collective Effects in Beam Dynamics" (EM) – 3rd day

COASTING-BEAM TRANSVERSE COHERENT INSTABILITIES

1) Derive the equation of motion of page 3.

2) What would be the instability rise-time (see page 10) in the following conditions?

- Horizontal tune: $Q_{x0} = 6.25$.

- Resonator impedance: $f_r = 1\,\text{GHz}$, $R_x = 3\,\text{M}\Omega/\text{m}$ and $Q = 1$.

- $\gamma = 6$.

- Number of protons: $N_b = 10^{14}$.

- Machine radius: $R = 100$.

Draw the shape of the resonator impedance (from - ∞ to + ∞).

3) In the case of betatron frequency spread through momentum spread only (see page 50), what happens if the slip factor is $\eta = -0.1$ and the chromaticity $\xi = +0.1$? What do you propose to improve the situation?

What happens right at transition?

4) What happens in the case of betatron frequency spread through momentum spread only (see page 52) if the real part of the coherent tune shift is –0.9E-3, the imaginary part of the coherent tune shift -0.7E-3 and the tune spread is $\Delta Q_p = \frac{4}{3} 10^{-3}$ (the revolution frequency is 471 kHz)? Is the beam unstable? If yes, what is the instability rise-time and by how much should we increase the tune spread to stabilize the beam? How could we do that?

BUNCHED-BEAM TRANSVERSE COHERENT INSTABILITIES

1) Applying Sacherer's formula (page 51) to the impedance of the previous exercise 2), what would be the horizontal coherent tune shift for the first 3 head-tail modes in the same conditions as exercice 2) with in addition an horizontal chromaticity $\xi_x = 0$ and a full (4 σ) bunch length $\tau_b = 500\,\text{ns}$.

Hint: It is a simple computation.

2) Will the instability of page 56 be faster if the chromatic frequency is doubled? How will the signal at a Beam Position Monitor look like (assuming that the instability is not damped by another mechanism)?

3) Looking at the figures of pages 79 and 80, explain why in the first case the coupling between modes 0 and -1 will be weak and will lead to mode couplingdecoupling, whereas in the second picture the coupling between modes 0 and -1 will lead to a strong instability.