**Meeting of LIU SPS-BD WG on 12/12/2013**

**Present:** Theodoros Argyropoulos, Hannes Bartosik, Thomas Bohl, Fritz Caspers, Roland Garoby, Wolfgang Höfle, Elias Métral, Juan Esteban Müller, Giovanni Iadarola, Alexandre Lasheen, Giovanni Rumolo, Benoit Salvant, Elena Shaposhnikova, Jose Varela Campelo;

**Agenda:**

1. SPS transverse mode coupling instability – H. Bartosik
2. Summary for 2013 – E. Shaposhnikova

**Presentations:**

**1. Hannes Bartosik: SPS transverse mode coupling instability**

Extensive measurements of the transverse mode coupling instability (TMCI) at SPS injection were performed with the Q26 and with the Q20 optics in 2013. The TMCI is a fast instability in the vertical plane, characterized by a travelling wave pattern of the intra-bunch motion and fast losses, It can be cured to some extent with chromaticity.

*The TMCI was observed in the SPS already with leptons during the time of LEP.*

The measurement campaign in 2013 was performed with low chromaticity ξy≈0.05 and with the double harmonic RF system where the voltage of the 800 MHz was set to 1/10th to that of the 200 MHz main RF, which had 1.4 MV for Q26 and 4 MV for Q20 (according to the ratio of the slip factor between the two optics at injection). For bunches injected with the nominal longitudinal emittance of εl=0.35 eVs, the instability threshold is more than 2.5 times higher in Q20 (i.e. around 4.5x1011 p/b compared to 1.6x1011 p/b in Q26), as expected from the scaling law of analytical models based on a broadband resonator due to the higher slip factor in Q20. An interesting observation is a slow instability for the Q20 optics for intermediate intensities (between 1.6x1011 p/b and 2.5x1011 p/b), which only occurs with small longitudinal emittance. All observations could be reproduced in HEADTAIL simulations using the present SPS impedance model (including vacuum chambers, kickers, BPMs, the 200 MHz cavities, the 800 MHz cavities and the Enamel flanges), which reproduces about 70% of the measured vertical coherent tune shift with intensity. In the HEADTAIL simulations, the two RF systems with their respective voltages and the measured linear and non-linear chromaticity up to third order were taken into account.

The linear dependence of the intensity threshold as function of longitudinal emittance observed in the measurements with the Q26 optics was reproduced with HEADTAIL, but with a slightly higher threshold. This is explained by the fact that we are still missing some impedance in the model. In the simulations, the instability is due to a coupling between azimuthal modes -2 and -3. The slope of the growth rate as function of intensity is similar as in the measurements. Furthermore, the intra-bunch pattern obtained in HEADTAIL is very similar compared to the experiment. However in the measurement the intra-bunch motion is mainly observed in the tail of the bunch while it is more symmetric in HEADTAIL.

*The difference in the intra-bunch motion might be explained by the fact that the measurements were taken during the initial phase of the instability while in the simulation the snapshot corresponds to a later moment (more turns between start of instability and snapshot).*

The two regimes of fast and slow instability observed in the measurements with the Q20 optics were also reproduced with HEADTAIL. For the slow instability, similar growth rates as in the measurements were obtained in HEADTAIL. No data of the growth rate of the fast instability is available from the experiments due to issues with the Q-meter related to the high bunch intensity (above 3.5x1011 p/b). The slow instability seems to be a weak coupling of modes 0 and -1. The intra-bunch pattern agrees well between measurements and HEADTAIL, showing in both cases a pattern with one node. Also the intra-bunch pattern for the fast instability agrees between measurements and simulations showing a travelling wave pattern typical for transverse mode coupling (in this case between modes -2 and -3, where mode -1 might also be involved). The threshold in the simulation is slightly lower than the experimental observations, which might be explained by residual amplitude detuning of the machine not taken into account in the HEADTAIL model. Another possibility could be the effect of space charge, which is presently also not taken into account in HEADTAIL.

*Further investigations should be made concerning the importance of space charge with respect to the TMCI threshold. Although the effect might be small in the case of the SPS (since the HEADTAIL model without space charge is already very close to the experimental observations), the interplay between TMCI and space charge is a long-standing question. Furthermore, there have been observations during the studies for the High bandwidth feedback in the SPS, where the bunch could not be excited with the feedback system when it had high brightness (small emittance for given intensity and therefore large space charge tune shift).*

*The source of the slow instability in the Q20 optics needs to be analyzed in more detail. Further information on the driving impedance can be obtained by analyzing the frequency content of the intra-bunch motion. Studies are ongoing.*

*The measurements relied on the SPS Headtail monitor, which became operational again only in the last two weeks of the 2013 run after a long period without availability. The Headtail monitor is an essential tool for studying TMCI and electron cloud instabilities and therefore needs to be operational. It is foreseen that a new digitizer for the HEADTAIL monitor will be installed.*

**Elena Shaposhnikova: Summary for 2013**

The main efforts during 2013 were devoted to MDs (in the first two months), the analysis of all data collected during 2012 and 2013 and their comparison/benchmarking with numerical simulations, with particular emphasis on instabilities and impedance. The main items planned for 2014 are the SPS scrubbing run (reconditioning of the SPS vacuum chambers after the long shutdown), pushing the intensity of the 25 ns beam for studying the instabilities and intensity limitations, the preparation of the doublet scrubbing beam for the LHC (acceleration to flat top, multiple batches, …), as well as further efforts on impedance identification and space charge studies.

**AOB:**

*The repair of broken BPMs and the works on the MOPOS system foreseen during LS1 are planned for the last weeks before the restart of the SPS. BI will be contacted to make sure all works will be finished before the start-up.*

Minutes written by Hannes Bartosik