**Meeting of LIU SPS-BD WG on 08/08/2013**

**Present:** Theodoros Argyropoulos, Hannes Bartosik, Nicolo Biancacci, Thomas Bohl, Fritz Caspers, Juan Esteban Muller, Roland Garoby, Wolfgang Höfle, Giovanni Rumolo, Benoit Salvant, Elena Shaposhnikova, Mauro Taborelli, Helga Timkó, Jose Varela Campelo, Carlo Zannini;

**Agenda:**

1. First results of simulations of SPS instabilities with HEADTAIL – H. Timko
2. Follow-up of the SPS vacuum flanges: measurements and simulations J. E. Varela
3. Update on the SPS impedance: ZS PMs and BPMs – B. Salvant
4. Microwave instability during the ramp – E. Shaposhnikova

**Presentations:**

**1. Helga: First results of simulations of SPS instabilities with HEADTAIL**

The presence of an unknown impedance source at 1.4 GHz has been identified in measurements when injecting long bunches with RF off. A bunch lengthening effect for increasing intensity was observed for bunched beams at flat top, which is stronger than expected from potential well distortion. This could be caused by a microwave instability, as addressed in HEADTAIL simulations.

In the simulation, the known impedances of the RF cavities are represented by 4 resonators. Another resonator accounts for the unknown impedance at 1.4 GHz. The contribution from the kickers is modeled by 5 additional resonators, which were used to fit the kicker impedance as simulated by Carlo. A good fit of the high frequency part would require that 2 resonators would have a Q lower than 1. This solution was not used for the simulations.

*The impedance behavior at high frequency is determined by the properties of the kicker ferrites.*

Another 10 resonators are added in the model to account for BPMs and the 5 ZS.

*Depending on the matching of the coaxial ports of the BPMs, the first two modes below 300 MHz could be damped and thus they might be neglected. However, the situation of the matching of the BPMs in the machine is not clear.*

The de-bunching observed in the measurements can be reproduced in HEADTAIL, using the longitudinal particle distribution as measured before extraction with the tomoscope in the PS (no bunch rotation was used in the experiment) for an intensity of 1×1011 p/b. After tracking for a few hundred turns, a modulation of the line density with a 200 MHz and a 1.4 GHz component is observed. Similar to the experiment, first the 200MHz component can be seen but the growth rate is faster for the 1.4GHz component.

Comparing simulations for different Q values for the impedance at 1.4 GHz shows that the spectrum around 1.4GHz looks very similar. It is therefore not easy to conclude which of the cases is closest to the measurement. A wide range of Q values could be compatible with the observations.

In comparison with Theodoro’s simulations, for a given Q value the obtained Rs differs by up to a factor 2 (the same conventions are used in both codes). Apart from this, the qualitative behavior is the same in both codes (the code of Theodoros is based on frequency domain calculations). Further checks will be performed and the two codes will be benchmarked against each other.

**2. Jose: update on SPS flanges**

A detailed classification of the different types of flanges and beam pipe configurations and their number of occurrences per SPS sextant has been completed (without the long straight sections). The impedance of the most common combinations has been analyzed in HFSS simulations. Flanges with QD-type vacuum chambers on both sides and enamel coating show resonances at 1.87 GHz (5.5 kΩ and R/Q=6) and 1.57 GHz (0.25 kΩ and R/Q=1.8). Without the enamel layer, the flange becomes a simple pillbox cavity with resonance frequency 1.8 GHz (78 kΩ and R/Q=8.5). Simulations for the configuration with enamel coating, MBA chambers on both sides and bellow and flange in between have been started (this configuration is very similar to the case of an MBA chamber on one side and a QF chamber on the other side surrounding the flange and the bellow). A first scan of the impedance spectrum in the frequency range around 1.4 GHz shows a resonance at 1.41 GHz (38 kΩ and R/Q=38).

*The resonance of this structure at 1.41 GHz is dominated by the beam pipe discontinuity generated by the combination of the flange + bellow and the surrounding beam pipes.*

*The effect of the enamel layer is mainly to lower the Q – the R/Q is not affected much. In view of the beam dynamics simulations, an approximate wake function could thus be calculated without the enamel layer (which makes the computation easier). However, issues with simulations of the structure in CST (instead of HFSS) have been encountered. This will be investigated together with Benoit and the Impedance team.*

The total longitudinal impedance at 1.41 GHz found so far accounts to 3.68MOhm with R/Q=3686, as generated by the 97 enamel coated flanges with either MBA-MBA or MBA-QF chambers attached. The next case to be studied as potentially contributing to this resonance frequency is the configuration with QF chambers on both sides.

New measurements of the BPH flange have been performed after shielding the attached BPH with copper tape. A big resonance at around 1.5 GHz in the transmission coefficient is measured with the wire method and so the expected impedance has been identified. A frequency shift maybe induced due to the presence of the wire.

The Q factor of this resonance is determined by measurements of the reflection coefficient with a probe (simple SMA cable). The Q factor is around 110.

The next steps will be to complete the simulations for all possible flange combinations. Further measurements, also on other flange configurations will be performed. The effect of damping material positioned inside some of the bellows in the machine should also be studied in more detailed.

*There is not much information about these damping rods in the layout drawings. However, they detune the resonance and depending on orientation also damp the resonance. They are thus important for the overall impedance.*

*A strategy for a first step of a possible impedance reduction campaign could be to install a prototype of a shielded flange in the machine during LS1. This prototype and another bare flange could be equipped with probes and the beam induced signal for the two cases could be compared. Similar prototypes were installed in preparation of the impedance reduction campaign for the pumping ports.*

**3. Benoit: Update on the SPS impedance: ZS PMs and BPMs**

The pumping modules installed in the transition between the electrostatic septa ZS have a cavity like shape caused by the abrupt change of beam pipe dimensions. The real structure has a complex geometry with different tapers inside. In simplified models, the longitudinal impedance of the pumping module has a resonance at 1.18 GHz with a very high Q. There are a few of these pumping modules installed in the SPS (5 close to the ZS and a few more).

*The impedance of this structure could be reduced by shielding the inside of the tank, combined with bellows that have a racetrack shape like the adjacent vacuum chambers. However, such racetrack shaped bellows are not easy to fabricate and are not very common.*

There are 2 conventions for the definition of the shunt impedance. In order to be compatible with the beam dynamics simulations, the shunt impedance given by CST (and shown by Benoit) and thus also the R/Q have to be divided by a factor 2. This applies also for the calculations for the ZS. The impedance calculations of the kickers performed by Carlo are already corrected for this. Work within the impedance team is presently ongoing to clarify this and to establish procedures.

In simulations of the SPS horizontal beam position monitors BPH, the importance of the matching of the coaxial ports has been realized. As compared to the situation without matching, a clear damping of modes is observed in broadband excitation with a perfect matching layer at the coaxial ports. Modes below 200 MHz are only observed if not matched.

A mistake was discovered in the calculations of the transverse modes of the BPH, as presented in the SPSU-BD in March 2011. The contribution of the ~100 BPH to the total vertical impedance becomes important and should be included in beam dynamics simulations.

There are many resonances beyond 1 GHz for most of the SPS equipment due to the large beam pipe apertures. Single shunt impedances can reach 1 MΩ. Further checks of the impedance calculations will be performed.

**4. Elena: Microwave instability during the ramp**

The microwave instability (MW) was limiting the SPS intensity for many years at flat bottom. The instability was identified to be caused by the impedance of the pumping ports. No microwave instability was observed after the shielding of the pumping ports. Recent measurements with long bunches revealed a peak in the impedance at 1.4 GHz, as already seen directly after the shielding (i.e. it was already there in 2001). A strong bunch lengthening with intensity was observed during measurements with high intensity single bunches for the AWAKE project and in preparation for LHC MDs. The bunch lengthening was probably caused by an instability. Up to a certain energy, this instability could be cured by lowering the RF voltage probably due to the increased Landau damping. At some point, strong losses necessitated to increase the RF voltage again.

An overview of the SPS longitudinal impedance budget shows that the 5 ZS pumping modules together have a larger impedance than the main SPS RF cavities, even after division by 2 in order to correct for the different definition of the shunt impedance in CST. Similarly, the R and R/Q values of the BPMs shown here need to be divided by 2. Nevertheless, their impedance represents an important contribution to the total SPS impedance. The R/Q of the unknown impedance at 1.4 GHz is probably also quite high.

A comparison of the instability thresholds along the cycle shows that all instability thresholds drop down at flat top when using a voltage program for constant bucket area. In operation, the RF voltage is raised at flat top in order to shorten the bunches for the transfer to the LHC. In this case, the threshold for the MW instability is raised, however at the same time the threshold for Loss of Landau Damping is decreased. In general the threshold for the coupled bunch instability has a very low threshold, and it is even further decreased at flat top when raising the voltage. However, the real coupled bunch instability threshold could be higher due to the phase loop, feed forward and feed back that are acting on the beam in the machine.

The question is, if the experimental observations could be an indication for a microwave coupled bunch instability: The instability starts at an energy proportional to 1 over the total intensity, the threshold does not depend on the number of batches, the threshold for the 50 ns beam at flat top is 5 times lower than for single bunches. The parameters of the known impedances such as the BPMs fit well with these observations (for example their wake covers a few bunches and decays in between batches).

Next steps

* Should try to get reasonable numbers for the impedance of the ZS pumping modules 🡪 Benoit will develop a model that is more realistic, taking into account also the shielding inside
* The main contributions to the longitudinal multi-bunch instability should be revised
* A first investigation on the possibility to develop a longitudinal damper for this high frequency instability could be done: it would be required to damp microwave instability bunch-by-bunch

Minutes written by Hannes Bartosik