# Meeting of LIU SPS-BD WG on 13.02.2018

Present

Elena Shaposhnikova, Patrick Kramer, Joël Repond, Hannes Bartosik, Markus Schwarz, Christine Vollinger, Giulia Papotti, Thomas Bohl, Alexandre Lasheen, Ezgi Sunar, Nasrin Nasresfahani, Danilo Quartullo, Giovanni Rumolo.

Agenda

1. News on MKE impedance model – M. Beck
2. Space charge studies in presence of power converter ripple – H. Bartosik
3. The update on the loss studies – M. Schwarz
4. Measurements of 630 MHz HOM damping with new couplers – N. Nasresfahani

Actions

* **M. Beck**: News on MKE impedance model should be presented at the next meeting.
* **N**. **Nasresfahani**: Present RF measurements of the new 630 MHz HOM damping scheme.
* **D. Quartullo**: First results of slip stacking in the SPS next meeting.
* **T. Argyropoulos**: Next meeting, beam parameters for high intensity.
* **J**. **Repond**: Next meeting, instability during ramp.
* **P**. **Kramer**: Next meeting, news from 3-sections cavity.

**1 – News on MKE impedance model – M. Beck**

The latest electro-dynamics simulations suggest that the broad-band impedance of the MKE could be underestimated by a factor almost two. Particle simulations using the new impedance of the MKE show a significant decrease in stability threshold after LS2 (10% lower intensity). During this YETS, a MKE has been removed from the machine and has been measured. The data analysis is still ongoing, more parameters need to be taken into account before concluding the agreement between the new simulations and the measurements. Results should be presented during the next meeting.

**2 – Space charge studies in presence of power converter ripple – H. Bartosik**

An unexpected beam excitation has been observed in the horizontal plan due to a resonance at Qx = 20.4. According to the resonance diagram, a systematic 5th order resonance not suppressed by periodicity exists at the corresponding tune value. Moreover, the non-linearity of the space charge potential can drive a 5th and 10th order resonance at the same tune value for off-momentum particles. The space charge seems to be responsible of the blow-up observed but simulations can reproduce the measurements only if the power converted ripples (quadrupole magnets) are taken into account. The modulations in the QF (and QD) has been measured. The corresponding variation of the magnetic field has been added in simulation. Simulations and measurements are then in good agreement which show the modulations from the power converter of the quadrupole magnets have a significant effect that should not be forget.

* Higher order resonance discovered by benchmarking a 3rd order resonance which is closed to the tune working point for ions.
* Clear emittance blow-up observed in measurements with working point just above the 3rd order resonance for a 3 sec storage time.
* Second response observed at a tune of 20.4, not expected 🡪 5th or 10th order resonance.
  + The machine contains a systematic 5th not suppressed by symmetry.
  + The strong space charge can drive a 5th and 10th order harmonic of the beam for off-momentum particles.
* The space charge has a strong effect on the bunch and should be the main contribution to the blow-up observed in horizontal plan observed in measurements.
* Simulations not in good agreement with measurements if the power converter ripples (SPS quadrupole) are not included in the 6D tracking.
* The modulation of the magnetic field due to the ripples is obtained by measuring the spectrum of the quadrupole current and applying a low-pass filter.
  + The magnets of one family (i.e. QF or QD) are all connected in series and together with the inductance of the magnet coils themselves, the chain of quadrupoles act as low pass filter.
* Simulations and measurements agree when the power converter ripples are added.
* By adding artificial modulation in the current of the quads 🡪 measurements show enhancement of the blow-up.
  + The power converter ripples have a strong effect.
  + Modulations of the tune could trap particles in the resonance and they add side-bands to the resonance.
* **E. Shaposhnikova**: The modulation at 200 Hz is almost a one third of the synchrotron frequency. Could it excite some synchrotron-betatron motion? What about losses?
  + **H. Bartosik**: More studies necessary. Concerning the losses, the dipoles do not contain so strong modulation from the power converter.
* **T. Bohl**: Did you measure the QD?
  + **H. Bartosik**: QDs are not as bad as QFs. Slightly different spectrum (which is strange) but amplitude lower by a factor 3.

**3 – The update on the loss studies – M. Schwarz**

Latest simulations of capture losses were able to reproduce the time scale of the losses and their pattern along the batch. However, the absolute numbers were off by a factor 3. Simulations with new bunch distribution simulated in the PS (shorter tails) including the phase-loop and the radial-loop are now able to reproduce the amount of losses. A strong 10 MHz modulation is observed in bunch to bunch variation of bunch length and intensity. If this modulation is included in simulations, the modulation of losses along the batch is reproduced too. First results using the new implementation of the one-turn-delay-feedback show a good agreement for the 4-sections induced voltage simulated and measured. More studies needed for 5-sections.

* Previous results show good agreement between simulations and measurements of time scale and structure of losses along the batch. Amount of losses not reproduced (3 times too much losses in simulation).
* The phase-loop has a big impact on losses 🡪 using phase-loop in simulation allows to have better agreement with measurements.
  + The phase-loop uses an average position of the 12 first bunches to modify to frequency.
* **E. Shaposhnikova**: Simulations cannot reproduce high amount of losses for the last 10 bunches.
  + Synchronous phase shift due to feedback not included in simulation.
  + **M. Schwarz**: The first and last bunches show a higher amount of losses. Losses are computed along the batch by integrating the bunch profile which contains at the center the uncaptured particles travelling with the beam. The first and last bunches do not contain these particles which could explain the difference in losses.
* **E. Shaposhnikova**: it is remarkable that now absolute numbers are close to measurements.
  + By fine tuning of the bunch distribution, the right amount of losses can be obtained.
* **E. Shaposhnikova**: More measurement at lower voltage needed to benchmark the losses with simulations. More losses for lower voltage, easier to compare.
* Strong modulation at 10 MHz in bunch to bunch variation of injected bunch length or intensity.
  + Due to splitting in the PS at 20 MHz (component at 20 MHz present as well).
  + Using this modulation of the bunch length in simulation 🡪 bunch to bunch variation of losses along the batch reproduced.
* **H. Bartosik**: The bunch to bunch variation is systematic?
  + **A. Lasheen**: The splitting in the PS is done to minimize the variation of the bunch intensity but systematic bunch to bunch variation in length observed.
    - Mechanism under investigation.
* **H. Bartosik**: What is the cure for the losses?
  + A precise control of bunch length and intensity from bunch to bunch (in the PS) would be necessary for HL-LHC intensity. The losses are very sensitive to the bunch length.
* Simulations using the baseline machine parameters after LS2 show a total amount of losses lower than 2% after a 1 sec cycle.
* One-turn-delay-feedback, new implementation in simulations.
  + Induced voltage measured and simulated agree for 4-sections cavity.
  + More study needed for the long cavity.
* **H. Bartosik**: Simulations predict 2% losses after LS2. Is it sufficiently low?
  + **E. Shaposhnikova**: Very optimistic result but other factors have to be included.
    - The flat bottom is 10 secs long not 1 sec and the noise arising from the RF system and the magnets should be included.
    - More particles will be lost at the beginning of the ramp.
    - A higher value than 2% is expected.
  + **E. Shaposhnikova**: The 10 MHz modulation should be taken into account for stability. The effect of the 630 MHz HOM will be stronger.
  + **H. Bartosik**: Does the phase-loop help?
    - **M. Schwarz**: need to look at the data

**4 – Measurements of 630 MHz HOM damping with new couplers – N. Nasresfahani**

RF measurements with beam has been conducted last year in the 4-sections cavities and show a clear contribution to the induced voltage at the frequencies 628 MHz and 629 MHz. Eight news couplers have been installed during the YETS in one 4-sections cavity. New measurements are ongoing to observe the effect of the improved damping scheme.

* Measurements of the new damping scheme will be presented next time.
* Tunnel measurements difficult 🡪 fundamental power couplers reduce the Q of the modes in the 630 MHz band which are already damped by the original couplers.
  + Three sets of measurements will be done to separate the effect of the new and the original coupler. Measurements in different positions is necessary to avoid blind spots.
* FPCs reduce the impedance.
  + Not an effect of the load but the FPCs themselves (geometry of two cells perturbed).
* Meshing in electro-magnetic simulation has to be refined.
  + Different meshing can give up to 1.6 factor difference in shunt impedance.
  + The frequency can be shifted up to 1 MHz.
* Use refined mesh provided by CST team 🡪 take 15 days to run for 4-sections cavity.
* **E. Shaposhnikova**: What do we hope to measure?
  + **N. Nasresfahani**: Reduction in S21 parameters, possibly R/Q.
* RF measurements done with beam:
  + Made on the feedback loop which does not have any filter.
  + Measurements with AWAKE and IONs cycles.
  + Narrow-band filter around 630 MHz with 1 MHz bandwidth.
    - 628 MHz and 629 MHz show the highest value of the induced voltage for IONs and AWAKE.
  + Measurements in cavity one and two with original damping scheme.
* **E. Shaposhnikova**: Cavity one and two give similar results?
  + **N. Nasresfahani**: The comparison is not yet finished.

Next meeting in 3 weeks, 6th of March 2018

Minutes written by J. Repond