# Meeting of LIU SPS-BD WG on 13.02.2018

Present

Patrick Kramer, Joël Repond, Hannes Bartosik, Markus Schwarz, Christine Vollinger, Giulia Papotti, Alexandre Lasheen, Danilo Quartullo, Heiko Damerau, Mario Stefan Beck, Aaron Farricker, Heiko Damerau, Marcin Patecki, Thomas Bohl, Ezgi Sunar, Kevin Shing Bruce Li, Verena Kain

Agenda

1. Simulations of long-term losses – M. Schwarz
2. Parameters of the low-frequency capture RF system in the SPS – J. Repond
3. Correction of the 2nd order chromaticity by octupole reconfiguration – H. Bartosik
4. First results of horizontal aperture measurements after modification of QD apertures in YETS – V. Kain

Actions

* pending
* **M. Beck**: News on the MKE impedance model.
* **P. Kramer**: Measurements of effects on the fundamental passband of the new 3-section HOM damping scheme.
* **N. Nasresfahani**: Study the possibility to use the new coupler design to replace all existing 630 MHz HOM couplers.
* **D. Quartullo**: Slip-stacking with intensity effects.
* New
* **Markus**: Include the momentum acceptance limitation in simulations.
* **Markus**: Is it possible to understand if the instability observed with the radial-loop is real or only related to numerical problems?

**1 – Simulations of long-term losses – M. Schwarz**

Update on the capture losses simulations. Instabilities were recently observed in simulations when the radial-loop implemented in BLonD is used. This instability is not anymore present if the radial-loop is replaced by the frequency-loop much less computationally intensive. The mechanism of this instability is not yet understood. A further study would be needed to identify if the instability in simulations is related to numerical problems or if it is a real effect of the radial-loop.

* Summary of the two types of losses encountered on SPS flat bottom.
	+ Capture losses 🡪 Bunch-shape, uncaptured beam.
	+ Losses on flat bottom 🡪 Momentum aperture and transverse emittance, full bucket.
* **H. Bartosik**: How do the distributions used in simulations compare with measurements?
	+ **A. Lasheen**: The distributions are generated using the measured bunch length with a binomial distribution as line density. The parameter $μ$ of the distribution is then adjusted to generate more or less tails.
* **H. Bartosik**: The beam in simulations is generated using 72 identical bunches?
	+ **M. Schwarz**: The same bunch distribution with 4M macro-particles is used but a subset (1M macro-particles) is chosen randomly for every bunch.
* The simulations of the capture losses with phase-loop and frequency-loop are now in better agreement with measurements than without any loops.
* The radial-loop gives an unexpected contribution where an instability grows on the long-term flat bottom (1 sec).
	+ Instability does not appear if radial-loop exchanged by frequency-loop.
	+ Radial-loop could be more sensitive to the initial conditions because it uses the average energy inside the bunch where the frequency-loop does not depend on the beam.
* **H. Bartosik**: Simulations are done without aperture limitation?
	+ **M. Schwarz**: Yes. The physical momentum aperture can be included in simulations by removing particles reaching a fixed momentum amplitude.
	+ **T. Bohl**: The dynamical aperture should be smaller?
		- **H. Bartosik**: Not necessarily. In the normal working point, the transverse momentum aperture should not be a problem.
	+ **A. Lasheen**: Be careful by removing particles from the simulation. It has been seen in simulations of the booster (D. Quartullo) that a numerical instability can start due to the removal of particles.
	+ **D. Quartullo**: When you remove particles the line density changes. This was not investigated further but it should be done carefully.
* **H. Bartosik**: In the bunch-by-bunch loss pattern, the fact that the losses in simulations are higher (animation, time evolution) is an indication that you overestimate the tails.
* **H. Bartosik**: Is the frequency-loop a key ingredient in the results? If you do not have it, do the simulations give the same results?
	+ **M. Schwarz**: For the moment the radial-loop is not used anymore since it creates instability. Difficult to comment.
	+ **H. Bartosik**: It would be interesting to know if the frequency-loop is a key ingredient compared to the radial-loop or if the discrepancies are due to a numerical problem.
	+ **M. Schwarz**: At least the phase-loop is definitely needed to reproduce measurements, it was shown in my previous talk.
* **H. Bartosik**: The next critical step is to include the momentum acceptance limitation in simulations.
* **A. Farricker**: Is the impedance of the 800 MHz cavity included without any reduction from the feedback (no voltage in 800 MHz 🡪 no feedback)?
	+ **M. Schwarz**: Yes there is no feedback reduction on the impedance of the 800 MHz. However it seems that the losses observed with the full SPS impedance model are very comparable to the one with the 200 MHz impedance only.
* **H. Bartosik**: What about future measurements?
	+ **M. Schwarz**: It has been observed that the feedforward (FF) reduces the losses but after the transient when the beam-loading is compensated to its maximum, the FF add noise to the RF. A measurements with FF on at injection and switched off after a few ms would be interesting.
	+ **H. Bartosik**: Any measurements planned with the 800 MHz activated?
		- **M. Schwarz**: We tried at the beginning to have the smallest number of parameters that can vary. For the moment no measurements with 800 MHz scheduled.

**2 – Parameters of the low-frequency capture RF system in the SPS – J. Repond**

Losses increasing with intensity are a bottleneck in the production of HL-LHC proton beams and need to be mitigated. Moreover the PS suffers coupled-bunch instability at flat top and larger longitudinal emittance bunches would be beneficial. The introduction of a lower-harmonic RF system in the SPS would increase the longitudinal acceptance and can reduce capture losses if they are mainly related to the bunch shape at injection (bunch rotation in PS). However, the beam stability in the lower-harmonic RF would be more difficult to ensure and the re-bucketing in the main 200 MHz RF system would require very large voltages if the PS bunches have large tails. Indeed the 200 MHz RF system in the SPS is necessary to accelerate both ion and proton beams to the LHC and the beams need to be transferred from the lower-harmonic RF to the main 200 MHz RF bucket. Moreover, the beam-loading and the power limitation after RF upgrade will limit the maximum emittance that can be accelerated.

* Lower-harmonic RF system considered as a possible solution to mitigate losses increasing with intensity and inject larger emittances from the PS with smaller bunch population close to the RF separatrix.
* Already studied in the past but due to collective effects the bunch rotation in the PS was the solution chosen.
* Today the situation is different because of the LIU-SPS upgrades (RF upgrade, impedance reduction) and the experience gained in stabilization using a higher harmonic RF system.
	+ The 200 MHz RF system in the SPS can be used as a Landau system with the lower-harmonic RF system.
* The 200 MHz RF system cannot be removed.
	+ Landau cavity for the low harmonic RF system.
	+ Needed for acceleration of ions and protons due to the large bandwidth of the travelling-wave cavities.
	+ Needed for transfer to the LHC (otherwise a 200 MHz RF system should be installed in the LHC).
* The PS can produce a single bunch of length 6 ns without rotation.
	+ To be confirmed this year in multi-bunch.
	+ Larger bunches would need a control of the 200 MHz voltage to a very low level.
* Only an 80 MHz RF system is suitable on the SPS flat bottom with 200 MHz as a Landau system.
* Potential issues with the 80 MHz RF system:
	+ This system would be installed principally to inject larger emittance bunches from the PS (stability in PS) but the acceptance in the SPS 200 MHz bucket will be limited by the available power after RF upgrade and beam-loading at HL-LHC intensity.
	+ Lower stability due to lower harmonic number.
	+ The population of satellite bunches must be kept as small as possible during the re-bucketing in the main 200 MHz RF bucket 🡪 large 80 MHz voltage.
	+ Impedance and beam-loading in the new system can be an issue but not treated here.
* For a filling factor in momentum $q\_{p}=0.8$, the maximum emittance that can be accelerated in the SPS after RF upgrade is about 0.45 eVs.
	+ **H. Damerau**: In the past the maximum emittance to accelerate in the SPS (after upgrade) was 0.4 eVs. Why now we can accelerate larger emittances?
		- **J. Repond**: The losses at the beginning of acceleration depend on the tails of the bunch from the PS (particles too close to separatrix). But without bunch rotation in the PS the filamentation can be minimized and it is possible to imagine to accelerate with a larger filling factor. However the evolution of the losses with the filling factor and the bunch tails is an ongoing study.
* To conserve the bunch length injected from PS with intensity effects, the 80 MHz voltage must reach 1.15 MV.
	+ **A. Lasheen, H. Damerau**: Why is there a significant increase from the matched value? uncontrolled emittance blow-up?
		- **J. Repond**: This analysis was made on the conservation of the bunch length to avoid particles at large synchrotron amplitude during the re-bucketing. The emittance may increase in this process due to filamentation.
* During the transfer to the main 200 MHz RF system, particles not captured in the main 200 MHz RF bucket create satellite bunches that can be harmful for LHC already at low intensity ratio ($10^{-3}$).
* Assumptions on the tails of the PS bunch distribution are crucial to determine the population of satellite bunches.
	+ Larger tails can change the amount of particles lost in the process by an order of magnitude.
	+ Preliminary analysis, study of the PS bunch tails necessary to determine the gain of such a system
	+ **A. Lasheen**: Concerning the tails, we see that tails extend up to 0.45 eVs by the post-acceleration shaving measurements.
		- **J. Repond**: Is it possible to obtain the parameters of the binomial distribution from the measurements to have an estimation to use in simulations?
			* **A. Lasheen**: I can try.
		- **J. Repond**: Do we have an estimation of how the tails could be modified after LS2?
			* **A. Lasheen**: In the baseline there is no changes in the machine that could modify significantly the bunch tail population. Present measurements should be representative of what will happen after LS2.
* An 80 MHz voltage above 3 MV will be necessary for the re-bucketing.
* **H. Bartosik**: It looks like this scenario would be difficult to achieve, too many open questions (stability margin, re-bucketing, impedance of the new system).
	+ **V. Kain**: Since this scenario seems problematic from the beginning is it really necessary to spent time to study this in more details?

**3 – Correction of the 2nd order chromaticity by octupole reconfiguration – H. Bartosik**

An instability in the horizontal plan was observed (2015) on the injection plateau for high intensity multi-bunch batches. This instability was cured by the transverse feedback (2017) but a single bunch instability remains. This instability can be cured by increasing the chromaticity, however, the higher chromaticity enhances the losses (larger tune excursion). The question was raised if we can cure this instability by using octupoles instead of a higher chromaticity but the octupoles create an increase of chromaticity because they are placed in regions of high dispersion in Q20 optics (the contrary for Q26). By changing the powering scheme of the octupoles already installed, it would be possible to minimise there contribution to the second order chromaticity.

* The positioning of the octupoles (activated) was chosen to minimize Q’’ in Q26 but not Q20.
	+ However, the inactivated octupoles are in regions of lower dispersion. By using them it would be possible to minimize the second order chromaticity.
		- The efficiency of the octupoles for the Q26 optic cannot be changed
	+ By re-cabling the unused octupoles it is possible to bring the chromaticity detuning to a very low level.
		- It only needs an intervention in the tunnel that can be done for an MD (all hardware already installed).
	+ The impact on the resonances is expected to be small. Ultimately it should be checked during an MD.
	+ **A. Farricker**: If you plan to relocate some octupoles (two locations), we can at the same time put in place the shield of the pumping port next to them.
	+ **M. Beck**: What about Q22?
		- **H. Bartosik**: Q22 is very similar to Q20.

**4 – First results of horizontal aperture measurements after modification of QD apertures in YETS – V. Kain**

In 2017 the horizontal aperture was measured to be smaller than expected. Asymmetric flanges have been identified as one cause of this limitation. The flanges have been fixed in three locations during YETS. Measurements have been carried out this year but however no significant changes are observed.

* Horizontal aperture in Q20 was measured to be asymmetric and smaller than expected.
	+ Problem at QD locations in high dispersion regions, asymmetry in the drawing of the flange.
	+ The flanges was exchanged in 3 locations by a symmetric one.
* Not much improvement.
* Flanges installed with RF fingers that reproduce the previous asymmetry.
* Not successful yet but might be changed during TS1 or TS2
* **H. Bartosik**: To M. Schwarz: These measurements should allow to take into account the aperture limitation in the losses simulations (compute probability of a Gaussian bunch to lose particles at the smallest value of the aperture).
* **M. Patecki**: From the collimation point of view, if we use the measured aperture the results are not very optimistic. To add 5 mm would give already a significant improvement.

Minutes written by J. Repond