# Meeting of LIU SPS-BD WG on 03.07.2018

Present

Elena Shaposhnikova, Patrick Kramer, Joël Repond, Hannes Bartosik, Markus Schwarz, Giulia Papotti, Alexandre Lasheen, Danilo Quartullo, Heiko Damerau, Aaron Farricker, Ezgi Sunar, Nasrin Nasresfahani, Giovanni Rumolo, Mario Stefan Beck, Christine Vollinger

Agenda

1. First results of the loss MDs in 2018 – M. Schwarz
2. The latest SPS impedance model after the LS2 – A. Farricker
3. Effect of the 80 MHz impedance – J. Repond
4. Update on slip-stacking simulations – D. Quartullo

Actions

* pending
* **N. Nasresfahani**: Study the possibility to use the new coupler design to replace all existing 630 MHz HOM couplers.
* **M. Schwarz**: Include the momentum acceptance limitation in simulations.
* **M. Schwarz**: Is it possible to understand if the instability observed with the radial-loop is real or only related to numerical problems?
* For the slip-stacking cycle, determined the aperture needed for the collimation system.
* A list of the key moments in the various cycles (slip-stacking!) is necessary to adjust the design of the collimation system.
* Measurements of the beta beating to include optics errors in simulation of the collimation system.
* Check the impedance of the new collimation system.
* New
* **M. Schwarz**: Quadrupole oscillations are observed at flat bottom with the feedforward activated. Study where this is coming from.
* **G. Papotti**: Check if it would be possible to decrease gradually the effect of the feedforward on the flat bottom and not in one turn.
* **A. Farricker**: Check with C. Zannini for the discrepancy in MKEs impedance.
* **A. Farricker**: Provide an updated longitudinal SPS impedance model for the present and future cases.
* **D. Quartullo**: Check the loss of Landau damping in Q26 for the ion cycle (are the oscillations more violent than in Q20?).
* Calculate the maximum voltage in the 800 MHz RF system due to power limitations and beam-loading.
* Ask the feedback team if it is possible to program a separated voltage program for a slip-stacking MD.
* Ask Stefan for the generation of the momentum cycle for slip-stacking in operation.

**1 – First results of the loss MDs in 2018 – M. Schwarz**

It was observed in measurements that the feedforward has an effect on the capture losses and the loss rate along the flat bottom. This talk presents the latest measurements of the losses in the SPS with and without feedforward.

* Observations from last year:
	+ Capture losses reduce with an increasing 200 MHz voltage at capture.
	+ Losses increase with the bunch intensity.
	+ It was difficult from the measurements to conclude the overall effect of the feedforward on the total losses 🡪 Does it improve the situation or does it add noise which drives particles outside of the RF bucket during flat bottom?
* Measurements this year:
	+ Beam capture with feedforward on (and feedback).
	+ Feedforward switched off after four seconds 🡪 the intensity drops.
		- The feedforward is switched off within one turn, the acceptance reduces suddenly.
			* **E. Shaposhnikova**: When you switch off the feedforward, all particles close to the RF separatrix are lost.
		- The loss rate increases.
			* **E. Shaposhnikova**: With the feedforward on, more particles are captured close to the RF separatrix which increases the loss rate.
* **E. Shaposhnikova**: I would like to stress that with the feedforward on, more particles are captured (less capture losses) but then the question is what is done with the captured particles. Due to the full bucket, these particles will be lost that is why the loss rate increases but it is not obvious that the feedforward degrades the situation (more visible for higher voltage). What is your next step in terms of MDs?
	+ **M**. **Schwarz**: Check that the feedforward significantly reduces the capture losses (scan for higher intensities).
* When the feedforward is activated a modulation appears in the bunch length along the flat bottom. The oscillations disappear when the feedforward is switched off.
	+ **E. Shaposhnikova**: You are saying that the feedforward produces instability?

🡪 Study where these oscillations are coming from.

* + **E. Shaposhnikova**: Would it be possible to gradually decrease the effect of the feedforward to avoid the perturbation when it is switched off in one turn.
		- 🡪 To be check by G. Papotti.
		- **G. Papotti**: Maybe we can switch it off line by line (four lines).
		- **E. Shaposhnikova**: Or program the feedforward gain to reduce it smoothly.
	+ **M. Schwarz**: Is it possible that there is an interplay between the feedback and the feedforward?
* **H. Bartosik**: Next week high intensity MD, M. Schwarz and G. Papotti should measure losses at flat bottom.
* **E. Shaposhnikova**: This week, 12 bunches MD with high bunch intensity, we should scan the voltage ratio of the 800 MHz RF system (double RF system). Last year with 12 bunches, an injected bunch intensity of 2.5e11 was already reached but unstable because the measurements were done in a single RF system. We should try to stabilize this beam by varying the voltage ratio. We know the situation improves at flat top with an increasing 800 MHz voltage.

**2 – The latest SPS impedance model after the LS2 – A. Farricker**

This talk presents the latest impedance model after LIU upgrades with the various elements that are in the baseline of the impedance reduction campaign.

* Agreement between CST simulations and model used in simulation for the total 630 MHz HOM (2 x four-section + 4 x three-section).
	+ Small discrepancies for individual elements.
* Flanges shielding:
	+ 2 BPH-QF/QFA not in the ECR (outside of the SSS’s) but a new ECR will be written to shield them.
	+ From the 25 unshielded pumping ports, 15 will be shielded. The ten remaining need investigation because they are of non-standard type, a separate solution for shielding must be found for each piece of equipment.
* New impedance model for the ZS. Need to be included in the longitudinal SPS impedance model (will be installed after LS2).
* New impedance model for the MKE which agrees with the measurements (already included in the model).
	+ **E. Shaposhnikova**: The previous model was in agreement with measurements as well, what is different now?
		- **A. Farricker, M. Beck**: Our best guess is a misunderstanding in the impedance given in Ohm and Ohm per meter. The MKEs are 1.5 m long which could explain the discrepancy. Moreover, the material was certainly treated slightly differently in the CST simulations.
		- **E. Shaposhnikova**: Check this with C. Zannini.
	+ E. Shaposhnikova: An updated present and future (after LS2) longitudinal SPS impedance model is necessary as soon as possible to help the beam dynamics simulations.

**3 – Effect of the 80 MHz impedance – J. Repond**

Latest results for the lower harmonic RF system in the SPS for beam capture.

* **H. Damerau**: Why do you say that a fast feedback system cannot be installed in the SPS for the new 80 MHz RF cavities?
	+ **J. Repond**: Lack of space.
	+ **H. Damerau, R. Calaga and E. Shaposhnikova**: To be checked but the analysis is preliminary and requires detailed studies if this system is considered for installation.
* **E. Shaposhnikova**: A smaller number of cavity could be used depending on the bunch distribution from the PS (smaller voltage) which could reduce the requirement from the feedback system.
* **A. Farricker**: How can you have feedback at flat top if the cavity is switched off?
	+ **H. Damerau, R. Calaga**: For a large feedback reduction (>35 dB), possible but it requires a new technology, not possible with the present PS 80 MHz cavities.
* **R. Calaga**: Regarding the stability, can a higher 200 MHz voltage help (higher voltage ratio for the Landau system)?
	+ **J. Repond**: This is an open question, not studied yet.

**4 – Update on slip-stacking simulations – D. Quartullo**

The baseline scheme for the production of an HL-LHC ion beam in the SPS requires momentum slip-stacking to reduce bunch spacing and double the number of bunches in the LHC. This scheme cannot be tested before the RF upgrade (LS2) and backup scenarios are developed in parallel. However, particle simulations suggest the feasibility of the slip-stacking in the SPS with bunch rotation before extraction to the LHC or a higher transition energy optic (than Q20) to meet the HL-LHC beam parameters. New results are presented in this talk for the slip-stacking in the SPS with intensity effects.

* Previously: The rise time of the cavity voltage was not treated accurately in simulations (rise of the voltage in one turn).
	+ This introduces dipole oscillations during slip-stacking, enhanced with intensity effects.
	+ Measurements of the rise time (June 2018, T. Bohl), ~1 $μ$s in the four-section, ~1.2 $μ$s in the five-section.
		- **E. Shaposhnikova**: From the measurements, the rise time of the four-section seems more to be ~0.8 $μ$s which is in agreement with analytical calculations.
			* **D. Quartullo**: T. Bohl gave a number with some margins but a fit of the measurements is used in simulations, this number does not affect the simulations.
* The dipole oscillations in simulations (due to the kick of the very fast increasing voltage) disappear when the correct rise time is used.
	+ **E. Shaposhnikova**: It should be mentioned the voltage pattern in simulations is now moving with the batch.
	+ **A. Farricker**: Can you use the rise time of a three-section cavity? It would be smaller and induce less perturbation during the recapture.
		- Yes it would help but the worst case scenario was used.
* The conclusions from the last meeting are not significantly modified with the new simulations (with correct rise time).
	+ In the Q20 optic, the bunch rotation is necessary.
	+ In the Q22 optic there is some possibilities of adiabatic bunch length reduction.
	+ Best case would be the Q26 optic.
* **E. Shaposhnikova**: You assume 15 MV in simulations (beam-loading small) but other constraints could reduce this value. Optics with higher transition energy would be desirable (higher than Q20) and should be tested this year in MDs with ion beams.
	+ - **H. Bartosik**: Once the ion cycles are setup for this year, tests with other optics can be achieved. But what about the instability observed?
		- **E. Shaposhnikova**: The instability appears on transition crossing, the optic doesn’t matter, and I would recommend to go to Q26. Here, the emittance is defined by the slip-stacking independent of the optics. Therefore, for a given emittance, more voltage is available in Q26 which will help.
* Study this year should show if it is possible to use Q22 or Q26 for the ion beams in the SPS.
* Dipole oscillations observed after recapture which survive through ramp and at flat top 🡪 Loss of Landau damping.
	+ **E. Shaposhnikova**: Are the oscillations more violent in Q26?
		- **D. Quartullo**: To be checked.
	+ Agreement between analytical predictions for the loss of Landau damping threshold and simulations.
* Possible cure using the 800 MHz RF system?
	+ Currently not used for the ion cycles.
	+ The bunch-shortening mode is the one suppressing the most the oscillations but very sensitive to the relative phase between the cavities.
		- **E. Shaposhnikova**: Usually it is the contrary, the bunch-lengthening mode is the one very sensitive to the phase.
		- **D. Quartullo**: Certainly due to the hollow bunches.
* **E. Shaposhnikova**: You assume 3.5 MV at 800 MHz but could be difficult to achieve. Maybe with the very small beam-loading but this should be calculated.
* The higher harmonic RF system has an effect on the hollow bunches if applied early in the cycle (before filamentation). If use after the recapture it cannot cure the loss of Landau damping.
	+ **E. Shaposhnikova**: The effects of the higher harmonic RF system on the hollow bunches can be the subject of a separated publication, very interesting.
* Possible MDs: Try the slip-stacking with one batch only (move it in phase space).
	+ **E. Shaposhnikova**: The feedback team should tell us if it is possible to program a separated frequency program for the slip-stacking (separated from the design one followed by the synchronous particle).
* **E. Shaposhnikova**: The momentum program in simulation is not realistic regarding the power supply of the magnets (it increases too fast). With a longer cycle, the transmission will decreases, all the different timing of the program should be optimized to reduce the total time of the cycle as much as possible.
* **E. Shaposhnikova**: The slip-stacking will be implemented very early after LS2. A scheme of the cycle almost final is needed now.
	+ Ask Stefan for the generation of the momentum cycle.
* **E. Shaposhnikova**, **H. Bartosik**: Beam stability should be checked (measured) in the Q26 optic. If nothing dramatic is observed, the Q26 optic should be used for the LHC ion beams.

**5 – AOB**

An instability was observed recently in single bunch on a 260 GeV plateau.

* Intensity: 1.1-1.2e11.
* Microwave-type of instability.
* Slowly growing (3 min before onset of oscillations in the bunch profile)
* **E. Shaposhnikova**: If the cycle is available, try to inject higher intensities to reduce the growth time (simulations of 5 minutes are not achievable).
* **R. Calaga**: Is it possible to use the bunch profile measured just before the onset of the instability?
	+ **E. Shaposhnikova, T. Argyropoulos**: The onset of the instability in simulation depends on the growth rate and the noise in the bunch profile. Even with the bunch profile, the initial distribution in simulations is matched with the RF with intensity effects.
	+ **E. Shaposhnikova**: This problem of noise as a seed to let the instability grow is observed in measurements as well (LHC MDs, instability can be delayed by 10 min depending on the noise).
* **E. Shaposhnikova**: What is nice in this measurements is that the instability grows from stationary conditions (during ramp too many parameters change).
* **T. Argyropoulos**: If the intensity could be scanned for this specific cycle it would be already very helpful.

Minutes written by J. Repond