# Meeting of LIU SPS-BD WG on 19.10.2017

Present

Elena Shaposhnikova, Patrick Kramer, Joël Repond, Verena Kain, Hannes Bartosik, Markus Schwarz, Michele Carla’, Aaron Farricker, David Amorim, Giovanni Rumolo, Benoit Salvant, Christine Vollinger, Giulia Papotti, Fritz Casper, Danilo Quartullo, Thomas Bohl, Kevin Bruce Li, Branko Kosta Popovic.

Next meeting 16th of November.

Agenda

1. Preliminary results from the high intensity run – transverse plane – H. Bartosik
2. Preliminary results from the high intensity run – longitudinal plane – J. Repond
3. Nonlinear chromaticity – M. Carla’
4. HOM damping in 3-sections 200 MHz cavities – P. Kramer
5. Update on the SPS impedance model – A. Farricker

Actions

* **P. Kramer**: Study the effect of mixing several solutions for new damping scheme of 3-section cavity.
* **P. Kramer**: Simulations with three couplers on the pumping ports should be carried out.
* **J. Repond**: Take into account missing impedance in simulation.
* Intensity scan in Q22 to find flat bottom stability threshold.
* Synchrotron frequency shift simulations should be done again using the measured impedance of the MKPs to verify if the missing source of impedance could come from the tank.
* Clarify with vacuum group that we share the same informations about the devices/flanges in the machine.

**1 – Preliminary results from the high intensity run – transverse plane – H. Bartosik**

Beam measurements have been carried out during two sessions of high intensity run on the 9th and 11th of October. This talk presents the preliminary results observed in the transverse plane.

* Temperature of the MKPs has been an issue.
	+ Observed in the past already.
	+ Reason why measurements split in two sessions.
* Nominal longitudinal parameters in PS reached for the first time.
* Limited to 48 bunches BCMS and standard 25 ns beam due to problem of second batch injection with 72 bunches and instability in the PS.
* SPS RF power limited after injection of the second batch.
* Transverse coupled-bunch instability at 20 MHz not observed anymore.
	+ Bandwidth of transverse damper now sufficient.
* Head-tail single bunch instability observed.
* The quality of the PS beam was limited.
	+ Some intensity is not extracted from PS 🡪 already longitudinal degradation of bunch coming from PS.
	+ Halo, bad splitting.
	+ Cavity reliability limited (many trips).
* Tune working point has been scanned.
	+ Degradation of losses by getting closer to resonant lines.
	+ Changing the tune does not improve the transmission.
	+ Actual working point already optimized.
	+ Not much potential for improvement.
* Increasing chromaticity or octupole strength
	+ 🡪 Losses increase.
* Single bunch instability observed with low chromaticity.
	+ Can be cured by higher chromaticity with the expanse of a degradation of the transmission.
* Vertical tune shift accumulates along the batches and can become a problem for HL-LHC intensity.
* Transverse emittance growth observed in vertical plane 🡪 has to be investigated.
	+ Growth increases with intensity.
	+ Less pronounced in horizontal plane (maybe because of momentum aperture limitation).
	+ Measurement to be done again, shot to shot variations.
* Total transmission (full intensity extracted from PS) of single and multi-batch around 92%.
	+ Higher transmission for BCMS but degrades for increasing intensity and reaches same transmission as standard beam for $2×10^{11}$ ppb.
	+ Losses increase in TT2 with intensity, 4% losses in the transfer line.
* The degradation with intensity in the transfer line is observed only with BCMS.
	+ More study needed.
	+ BCT accuracy in TT2 limited.
	+ **E. Shaposhnikova**: Could come from intensity effects in the PS, more uncaptured beam.
* **M. Schwarz**: Which BCT do you use to quantify the losses of the beam extracted from the PS?
	+ **H. Bartosik**: We compare the first trustworthy BCT point in the SPS with the one in the PS/TT2. Exact numbers have limited accuracy but trends can be measured.
* **E. Shaposhnikova**: Losses due mainly to particles close to separatrix that cannot be accelerated adiabatically.
	+ This problem will still be present after upgrade.
	+ **H. Bartosik**: Losses in the SPS before the start of the ramp does not seems to be due to intensity effects, the transmission will not degrade for higher intensity and could still be in the margin of acceptability.

**2 – Preliminary results from the high intensity run – longitudinal plan – J. Repond**

Beam measurements have been carried out during two sessions of high intensity run on the 9th and 11th of October. This talk presents the preliminary results observed in the longitudinal plane. Results from the MD Q22 vs Q20 are presented as well.

* Losses increase by a factor almost two when the beam is changed from BCMS to standard 25 ns.
* A longitudinal instability is observed for a single batch of 48 bunches at an intensity of $2×10^{11}$ ppb.
	+ Center of the batch more unstable.
	+ 800 MHz RF system does not improve the stability.
	+ Cause of the instability under investigation.
* Longitudinal instability triggered at injection of the second batch
	+ Center of the batch more unstable.
	+ 800 MHz RF system inefficient to improve the stability.
	+ Dipole and quadrupole oscillations observed.
	+ Possible causes:
		- Uncompensated beam loading due to power limitation.
		- Uncaptured beam.
		- Unexpected behavior of the LLRF.
* Uncaptured beam decreases with higher capture voltage (bigger acceptance).
	+ 🡪 Limitation from injected bunch shape.
* Losses on flat bottom increases with the voltage.
	+ 🡪 Momentum aperture limitation.
* 800 MHz RF system does not improve the transmission.
* Phase of the 800 MHz RF system giving the smallest losses correspond to a shift of 45° with respect to the bunch shortening mode used in operation.
* Capture voltage giving the best transmission
	+ Q20: 4.5 MV
	+ Q22: 4.0 MV
* In Q22, the longitudinal damper improves the transmission by 30%.
* No noticeable effects on transmission was observed with the feedforward
* **E. Shaposhnikova**: In future, the injection energy in the PSB will rise and the space charge limit will be reduced 🡪 smaller transverse emittance, closer to actual BCMS.
* **V. Kain**: We experienced recently problems with the phase module, could the dipole oscillations observed at flat bottom be related?
	+ **T. Bohl**: No, they cannot be related.
* **E. Shaposhnikova**: Is this instability driven by the main harmonic at 200 MHz for single and multi-batch?
	+ Difficult to reproduce in simulation. An accurate model of the LLRF would be needed as well as a model of the power limitation and its impact on the LLRF.
	+ Actually we do not have the clear picture of the beam stability and losses after LS2 due to power limitation.
	+ The Landau cavity at 800 MHz is a cure for instability in the SPS but not efficient on flat bottom.
	+ **T. Bohl**: After LS2, longitudinal damper and phase-loop will be different.
		- Longitudinal damper efficient only if instability driven by 200 MHz main harmonic.
	+ **T. Bohl**: Concerning the power limitation, after LS2 we will not have 5-sections anymore which will lower the power limitation.
	+ Momentum aperture improvement with Q22: 1 sigma.
	+ Is it worthwhile to operate in Q22?
		- More margin to play with voltage according to the total transmission measured (transmission deteriorates more quickly in Q20 moving from the voltage of 4.5 MV)
		- **H. Bartosik**: Given the fact that only a limited number of MDs have been done in Q22, a relatively good results of transmission is reached and there is room for improvement (not yet the optimal working point of the Q22).
		- TMCI threshold in Q22: $2.5×10^{11}$ ppb.
		- A beam with an intensity of $1.5×10^{11}$ ppb has already been accelerated to flat top in Q22.
		- Strong instabilities have been observed in Q20 for $2.0×10^{11}$ ppb which correspond to $1.5×10^{11}$ ppb in Q22 by simple scaling.
			* 🡪 Intensity scan needed (threshold).
			* If limitations are related to power limitation, Q22 is more favourable as long as no instability has to be cured.

**3 – Nonlinear chromaticity – M. Carla’**

The magnetic model of the main SPS magnets is not available. Therefore effective nonlinear models are developed based on beam measurements. These models are needed to study the beam stability. This talk shows the model for the Q20 and Q26 optics together with the new calculation done for the Q22 optic, extending the momentum scan.

* Fit the model of the machine in Q22 to reproduce the chromaticity measured.
* Systematic multipole errors on SPS main magnets mainly due to remnant fields (from ramping to top energy).
	+ Necessary to introduce remnant fields in sextupoles and octupoles to reproduce measurements.
* Larger momentum scan achieved by lowering intensity, RF voltage and chromaticity.
* Fits agree well for Q20 and Q22. Difference with Q26, measured with a different supercycle
	+ 🡪 Should be done with same supercycle.
* Tune foot-print during the high intensity run for an relative moment spread of $\pm 5.5×10^{-3}$.
	+ Helpful for understanding particle stability and losses at large $δp/p$.

**4 – HOM damping in 3-sections 200 MHz cavities – P. Kramer**

The introduction of new couplers in the three-section cavity is detrimental for one specific mode. The impedance of this mode increases if more couplers are fixed on the top of the cavity. New damping schemes are under investigation. This talk presents several solutions for the damping of this mode, achieving a factor up to 3 in damping.

* The couplers break the symmetry and for one specific mode push the field to the bottom of the cavity.
	+ Add couplers increases the impedance of this mode.
* Possible options of mitigation:
	+ Avoid the mode to rise by using smaller (or less) probes.
		- A maximum factor of 2.2 in damping can be achieved and no room for further improvement.
	+ Damp the mode in the lower half of the cavity.
* 1) Damping via vacuum pumping ports
	+ Each section contains three pumping ports, two are unused.
	+ Ports need to be machined to fix a probe.
	+ **Possible factor 2.8 damping (3.1 if two ports are used).**
	+ No impact on fundamental passband.
	+ **A. Farricker**: Lowering of the impedance is due to damping or to perturbation of the geometry?
		- **P. Kramer**: Mainly due to perturbation of the geometry.
			* It would then be possible to use a device perturbing the geometry without installing a full coupler.
	+ **F. Casper**: Couplers could be fixed on used pumping port as well.
	+ Simulations with three couplers per cavity should be carried out (one and two for the moment).
* 2) Damping via pedestal.
	+ With only one additional pedestal-coupler **🡪 factor 2.8 damping achievable**.
	+ New drift-tube would have to be machined.
	+ **C. Vollinger**: If only one pedestal-coupler is installed, only one drift tube has to be machined 🡪 can be done.
* 3) Damping via endplate HOM-port.
	+ One coupler on each endplate of the cavity can achieve a damping by a **factor 2.6.**
	+ Can couple to the fundamental passband.
* Cavity cells are not symmetric. Not possible to rotate a section by 180° to have a coupler port on the bottom.
* **E. Shaposhnikova**: What happens if several solutions are combined?
	+ **P. Kramer**: not studied yet.

**5 – Update on the SPS impedance model – A. Farricker**

This talk presents sources of impedance missing in the model and possible underestimation of the kickers’ impedance.

* From synchrotron frequency shift measurement, a possible broad-band missing impedance has been found in the 350 MHz passband. Possible source for this impedance could be:
	+ Underestimation in the kickers’ impedance (the model does not include the tank).
	+ BI equipment with big tanks.
* Focus put on MKPs (impedance closest to the possible missing one)
	+ Model significantly differs from the real geometry because the beam does not see it.
	+ Disagreement between simulations, model and measurements in 400 MHz passband
		- 🡪 Effect of the tank, not taken into account in simulations or in the model.
	+ Disagreement in the 300 MHz passband, measurement lower than the model (overestimated impedance?).
	+ The model overestimates the impedance below 300 MHz.
		- **E. Shaposhnikova**: Even more impedance sources could be missing in the model (missing elements).
	+ **E. Shaposhnikova**: Refinement of the kicker model is required. The search for missing source should continue.
		- The missing source of impedance should be added in simulation using the best actual knowledge while the search continues.
	+ **A. Farricker**: Discussing with M. Beck it seems that the missing impedance could come from the resonances of the kickers’ tank.
		- **B. Salvant**: Given the uncertainties on the measurement (~10% errorbars), it is hard to conclude this.
		- Synchrotron frequency shift simulations should be done again using the measured impedance of the MKPs to confirm the hypothesis.
* Alternative candidates:
	+ SPS wire scanner.
		- Two in the machine.
		- Not included in the model yet.
	+ Beam position monitors horizontal (BPH).
		- 39 unshielded BPH’s are included in the model as shielded.
			* 25 have damping resistors which could add broad-band contribution.
		- Significant additional source of impedance.
* **E. Shaposhnikova**: Clarify with vacuum group that we share the same informations about the devices/flanges in the machine.
	+ **C. Vollinger**: X-rays measurement may be carried out for the RF fingers 🡪 should we do X-rays to count the damping resistors in flanges?
		- **E. Shaposhnikova**: Aperture limitation can be explained by conceptual error of the SPS. The magnets are displaced by 5mm. No need of X-rays for RF-fingers.
	+ BPCE: vertical/horizontal position monitors.
		- High narrow-band impedance.
		- 12 elements in the machine.
		- Not included in the impedance model yet.

Minutes written by J. Repond