# Meeting of LIU SPS-BD WG on 03.11.2016

Present

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Agenda

1. Introduction – E. Shaposhnikova
2. Beam loading measurements – T. Bohl
3. Measured effects of FF/FB/LD/PL on flat bottom losses – H. Bartosik
4. Simulations of FB and FF on SPS flat top/bottom – T. Argyropoulos
5. TWC 200 MHz impedance in BLonD and its effect on beam stability – J. Repond

Foreword

* + The presentation “Models of LLRF and beam loading measurements” from T.Mastoridis/H.Timko is moved to the next meeting.
  + New 200 MHz cavities are in construction and need precise assessment of requirements for future beam stability.

1. **– Introduction – E. Shaposhnikova**

Two topics are now our first priority. The capture losses at flat bottom are critical to reach the LIU intensity from the point of view of the SPS injectors. An understanding of the mechanism behind these losses and their relations to beam loading is essential. This also includes a proper implementation of the LLRF in simulations.

* Understand how beam loading is related to losses
  + Depending on RF power (700 kW, 750 kW and 1.05 MW) at 4.5 MV, the maximum possible intensity captured properly changes from 1.5e11 to 2.4e11.
  + If losses due to insufficient voltage 🡪 wait RF upgrade, but not proven. Prediction of behavior after upgrade impossible with our current knowledge.
  + Beam loading and e-cloud effects are very similar in beam measurements 🡪 difficult to determine the dominant effect.
  + Motion of uncaptured beam after injection shows large energy loss.
* Which impedance should be included in simulations?
  + Resonator fit of 200 MHz impedance sufficient?
  + Different assumptions on FF and FB in simulations change significantly the result 🡪 a better model is necessary.

**2 – Beam loading measurements – T. Bohl**

Power and voltage measurements in the cavities after injection are presented in order to assess the beam loading compensation and see its relation with the losses.

* Increase in beam loading voltage is parabolic with time while generator voltage increases linearly 🡪 impossible to compensate exactly beam loading.
* As the feedback needs a few turns to compensate beam loading, situation is expected to be more stable in Q26 optics (larger synchrotron frequency) than in Q20. E. Shaposhnikova: the induced voltage is smaller in Q20 in comparison with Q26 (RF voltage is 4.5 MV at flat bottom instead of 2 MV for Q26).
* H. Damerau: Ask Philippe Baudrenghien about effects of delay on the feedback in beam loading compensation.
* First injection (1.25e11): power reaches 700 kW at injection, induced voltage (beam loading) as big as the designed voltage in 5-sections cavities.
* Beam loading is not fully compensated at injection
  + Uncompensated induced voltage oscillates with quadrupolar synchrotron frequency.
  + Exciting the beam with twice the synchrotron frequency 🡪 blow-up due to voltage amplitude modulation (with an odd number, blow-up die to RF phase modulation).
* Second batch expected to be worse than the first
  + Phase loop is not working for 2nd batch.
  + Longitudinal damper is not very efficient (optimized for Q26).
  + If power at injection limited, the second batch has less power available.
* During the third injection, there is still residual modulation of the voltage (at twice the synchrotron frequency) 🡪 can blow-up the beam and explain the losses.
* If FB and FF are doing the same thing (compensating beam loading), why do it separately? 🡪 The gain is limited with only one system.
* Losses expected to come from S shape of the PS bunches (impossible to fit into the SPS bucket).
* Improvement by a factor of two in beam loading compensation is expected in future from the FB, thus factor two in intensity should not be a problem for the nominal case. For transient states, predictions are not done.
* Possible simulations
  + Take a real line density from the PS.
  + Apply amplitude modulation in RF program.
  + Observe behavior of losses.
  + Simulations of transient state is very difficult. Even with cautious calibration of a given case, it will not be correct when the power changes.
* What are functional specifications for transient beam loading reduction? 🡪 Ask Philippe Baudrenghien.

**3 – Measured effect of FF/FB/LD/PL on flat bottom losses – H. Bartosik**

8 bunches and 4 empty batch configuration (8b4e) is known to minimize the electron cloud effects. Measurements have been taken with beam on SPS flat bottom to study the losses and try to discard the e-cloud effect as mechanism of these losses.

* Losses are different for the standard 25ns beam and 8b4e having the same total intensity. The two beams are not equivalent in the SPS.
* There is no e-cloud effect observed for the 8b4e beam.
* E-cloud cannot be the main effect responsible for losses for 25ns beam.
* To exclude completely e-cloud, beam with the same intensity per bunch are also needed.
* Average losses from bunch to bunch have the same pattern as the voltage modulation from uncompensated beam loading.
* Over all the LLRF, feedback has the strongest effect on losses if settings are modified.

**4 – Simulations of FB and FF on SPS flat top/bottom – T. Argyropoulos**

* Non uniform controlled emittance blow-up observed due to the 200 MHz phase variation along the batch (with FB/FF on). Better model of beam loading needed in simulations.
* The final 200 MHz impedance should be correct for stable state with formula given on the slide. Gains coefficients Hff and Hfb have to be calibrated from measurements. Moreover Hff and Hfb should be comparable from FB to FT.
* For transient states, the formula is not sufficient to describe all the beam behaviour.
* Elena: Simulations of lifetime of the beam in the stable situation (with the FF/FB compensation’s formula from Theodoros slides) can be performed to observe behavior of the beam in full bucket after injection.
* To simulate transient effects, dynamical model of feedback needed. Can be heavy computationally speaking.

**5 – TWC 200 MHz impedance in BLonD and its effect on beam stability – J. Repond**

* Different assumptions on modifications on 200 MHz impedance by FF/FB give different results on beam stability.
* Model of the FB/FF with 20dB of the 200 MHz impedance reduction is not sufficient to capture the real effect 🡪 improvement needed, see Theodoros formula.
* Phase shift due to compensation of the feedback must be reproduced as well in simulation which is not the case with 20dB reduction.
* Stability improvement from the 800 MHz RF system depends critically on the bunch phase with respect to the cavity voltage 🡪 the shift introduced by beam loading compensation in 200 MHz RF must be present in simulations.
* Simulations of thresholds with realistic phase displacement in double RF system are now needed.

Actions

* Ask Philippe Baudrenghien about effects of delay on the feedback in beam loading compensation.
* Ask Philippe Baudrenghien about specifications for transient beam loading reduction.
* Calibration of model (induced voltage obtained in simulation) versus total voltage measured in the cavities required.
* Necessary to understand if losses are due to insufficient RF power.
* Thresholds (simulated) with correct phase displacement in double RF are now needed. It includes better implementation of FB/FF (Joël).

Adding

* Should we have a better model of 200/800 MHz cavities on fundamental impedance? Jose resonators model is non symmetric.
* T. Bohl: Even if synchrotron frequency small, one turn is sufficient to observe modifications in the bunch profil. Even more pronounced with Q20 optics.
* When transfer function generator impedance is zero, feedback cannot compensate beam loading 🡪 cross-compensation between different RF cavities (4- and 3-sections) is needed.

Minutes written by J. Repond