Minutes of the LIU-PS BD WG #34 on the 28th of August 2019

***Agenda* (https://indico.cern.ch/event/842736/)**

1. *Barrier Bucket Studies*
2. *AOB*

Present:

Branko Popovic, Alexander Huschauer, Mihaly Vadai, Carlo Rossi, Ben Woolley, Heiko Damerau, Frank Tecker, Simon Albright

1. Barrier Bucket Studies (M. Vadai, pdf)

Mihaly Vadai presented the results of the beam loss reduction studies for Multi-Turn Extracted (MTE) beams using barrier buckets in the CERN PS. This topic is indirectly related to the LIU Project as it uses LIU equipment, the Finemet cavity of the longitudinal coupled-bunch feedback to produce the single sinusoidal pulses required to generate barrier buckets. Mihaly introduced the concept of the barrier bucket and the Hamiltonian describing the longitudinal motion. The potential barrier allows to reduce the longitudinal line density at a given azimuthal position, effectively generating a gap in a coasting beam. Triggering the extraction kicker for the 5-turn extraction removes the beam loss which would normally occur during the rise time of the kicker. The main motivation of the study is the removal of the present intensity bottleneck for the transfer of MTE beams from PS to SPS in view of a future intensity increase of the fixed target beams in the SPS. The initial challenges, as illustrated by Mihaly, was the generation of individual, beam synchronous pulses with sufficient voltage using the existing Finemet cavity in the PS. This was first tested with low-intensity beams at flat-bottom. Thereafter the combination of the barrier bucket manipulations has been exercised. Priorities were driven by the accelerator schedule since all measurements with beam had to be completed before LS2.

The LLRF system for the generation of beam synchronous single sinusoidal pulses in the PS mainly consists of a beam synchronous arbitrary waveform generator based on the Multi-Harmonic Source (MHS). Pre-distortion of the drive pulse optimises the pulse shape at the cavity gap. The LLRF hardware has been installed next to the LLRF of the coupled-bunch feedback and allows pulse-to-pulse switching between longitudinal feedback and barrier bucket operation.

Following first tests of injecting a low-intensity bunch into the barrier bucket to observe the de-bunching at flat-bottom, Mihaly performed beam measurements with barriers moving in phase. These measurements allowed to demonstrate a bunch can be adiabatically stretched and recompressed almost without blow-up of the longitudinal emittance, as expected.

At flat-top the 16 bunches are handed over from the conventional RF system (h =16) to the barrier bucket through an adiabatic re-bucketing. Since the duration available at the flat-top is insufficient for an adiabatic de-bunching, the potential barriers must be placed between two adjacent buckets of the conventional RF system. Comparing the flatness of the beam profile after re-bucketing to the barrier bucket, the situation interestingly improves with increased intensity. As shown by Mihaly at $1.9 \cdot 10^{13}$ p/b, the long bunch is much flatter than at $4 \cdot 10^{12}$ p/b. The duration of the gap has been scanned and a particle free region of about 200 ns was found to be optimal. In all cases shoulders of the long bunch with larger longitudinal line density close to the barriers are observed.

In combination with the MTE a significant reduction of the extraction losses by almost an order of magnitude is achieved. The losses in the extraction region have been measured versus the duration of the gap, confirming the beneficial impact of the barrier bucket.

Mihaly then presented his first simulations using BLonD. The barrier pulse is synthesized in frequency domain as a combination of about 25 sinusoidal RF systems. To assure correct initial conditions in terms of longitudinal emittance for the simulations, Mihaly performed longitudinal tomography with the tracked distribution confirming comparable initial conditions (at the start of re-acceleration from the 3.5 GeV/*c* intermediate flat-top). With these parameters the evolution of simulated and measured beam profiles during the re-bucketing process and the subsequent de-bunching becomes very similar.

The tracking simulations also allow to explain the shoulders of the bunch close to the barriers. The de-bunching time is by far too long for full filamentation, hence only few of the initial bunches are reflected at the barriers to larger momentum offset. They cause the locally higher line density. In case one could have a much longer flat-top (irrelevant for operation, but to be studied in MDs after LS), the bunch profile should become flatter, however at the cost of increased longitudinal emittance due to the filamentation.

Mihaly concluded that the beam tests with his barrier-bucket set-up were very successful, removing almost the entire beam loss at extraction with MTE beams. The behaviour of the beam at low-intensity is well reproduced by his initial tracking simulations. As next steps he will include the intensity effects in simulations, as well as a continuation of the tracking simulations in the SPS. Furthermore, the correct timing of the gap with the PS extraction kickers and the SPS injection kickers has not yet been achieved in the absence of a synchronization mechanism. Mihaly will therefore study possible options. This will be a challenging task since, due to the low RF voltage and the insufficient time at the flat-top, a conventional synchronization scheme cannot be applied.

Heiko asked whether one could measure the transfer function of the gap voltage divider of the Finemet cavity. Carlo confirmed that these measurements can be done during the shutdown. Simon questioned whether the Finemet cavity would act as a kind of Landau cavity at high intensity. Mihaly replied that the dependence of the beam induced voltage on intensity would need to be checked carefully. Heiko remarked the higher losses at higher intensity. Alexander explained that this could also be transverse losses, independent of the longitudinal manipulation. Heiko asked how the residual extraction losses for the combination of MTE and barrier bucket would compare to the extraction losses of an LHC-type beam. Alexander will check the available measurements. Heiko remarked that the shoulders of the bunch were actually due to reflected particles with larger energy offset. He suggested to check this in the SPS. Simon asked if the re-bucketing process, in particular the reduction of the RF voltage at h=16, could be made faster. Heiko suspects there would be more issues with particles at large amplitudes in the longitudinal phase space. Furthermore the question of the impact of the additional gaps in the batch on the SPS and its experiments was raised. Alexander commented that there was anyway a de-bunching at the SPS flat-top before the slow extraction and that already now the experiments would not use the first 300 ms of the spill. The spill date from NA42 during the 2018 barrier bucket experiment remains to be analysed.

2. AOB

- No item was raised.

Minutes by H. Damerau