**Meeting of LIU SPS-BD WG on 22/11/2012**

**Present:** Theodoros Argyropoulos, Hannes Bartosik, Chandra Bhat, Fritz Caspers, Heiko Damerau, Juan Esteban Muller, Steve Hancock, Wolfgang Höfle, Gianni Iadarola, Kevin Li, Elena Shaposhnikova, Mauro Taborelli, Helga Timkó

**Presentations:**

**Gianni: First tests with a 25ns “doublet” beam at SPS injection**

The motivation for having a special scrubbing beam with a lower multipacting threshold comes from the fact that scrubbing becomes very inefficient for a low SEY and thus more dose is needed while at the same time the beam produces less e-cloud. Injecting a 25ns beam with long bunch length from the PS (around 10ns) and raising the voltage quickly at injection allows to capture the bunches in two neighboring SPS buckets and thus creating a “doublet” beam. It is expected from simulations that this beam has a lower multipacting threshold. During a first MD using a short cycle, the beam was captured nicely with a good transmission even with a short ramp. Increased pressure rise in the arcs and enhanced signals on the electron cloud monitors were observed. Further studies need to be performed with more than one batch. In particular a modification of the transverse damper will be needed in order to enable correct functioning with this special bunch spacing.

*The idea for creating this doublet beam by capturing long bunches from the PS in 2 SPS buckets comes from the fact that a bunch spacing smaller than 25 ns cannot be achieved easily with the present RF systems in the PS. Furthermore simulations show that this doublet beam creates more electron cloud compared to previously anticipated scrubbing beams based on high intensity fast extracted “CNGS-like“ beams.*

*A more efficient electron production is achieved with the doublet beam compared to the nominal 25ns beam, since there is less time between two subsequent doublets in which the electron cloud can decay. This allows for a better accumulation of electrons along the bunch train and thus leads to a lower multipacting threshold (for intensities larger than 0.8e11p/b, i.e. 1.6e11p per doublet). On the other hand, the electron distribution is concentrated more in the center rather than in two stripes like for the usual 25ns beam. Therefore, scrubbing with the doublet beam would have to be used in combination with a systematic radial beam displacement for scrubbing the required region of the chambers. The scrubbing beam could be used in the last stage of the scrubbing, when the nominal 25ns beam becomes inefficient for producing electrons.*

*The first experimental test with injections of 25ns bunch trains with long bunch length was done with only one batch and the beam was stabilized transversely by increasing chromaticity. Using more batches will certainly require the transverse damper to work for the special bunch train configuration of the doublet beam. The functionality of the damper in this configuration is however tricky, due to the down-conversion to 120Mhz used for LHC beams. Studies with beam are needed to find possible solutions.*

🡪 Action W. Höfle: study possible ways of making the damper work with the doublet scheme after LS1. Therefore the requested beam types required to enhance the scrubbing effect have to be defined as soon as possible.

*Measurements on the dedicated e-cloud monitors show the differences between the two beams on the liners: Electron cloud signal is observed in the MBA like chamber (StSt) for the doublet beam but not for the nominal 25 ns beam; a higher signal for the doublet beam compared to the nominal 25ns beam is observed in the MBB like chamber (StSt), but concentrated in the center around the beam rather than in two stripes; e-cloud signal in the MBB like chamber (Copper) only for the doublet beam. Furthermore, increased pressure rise is observed all along the SPS circumference for the doublet beam (2x72 bunches) with around 0.8x1011ppb compared to the standard 25ns beam (72 bunches) with around 1.6x1011ppb, i.e. for similar total beam intensity. No e-cloud signal was observed on the carbon-coated liner for both beams.*

*Further tests of the doublet scheme need to address the efficiency of multiple injections (first tests of lowering the voltage on the flat bottom and a sudden voltage rise did not cause significantly more uncaptured beam with single bunches).*

*A possible application of the doublet scheme to the LHC should be investigated.*

*The possibility of using a similar technique for producing a triplet beam should be studied in simulations, regarding the capture of long bunches in three buckets (using ESME for example) and with respect to the electron cloud production efficiency (using PyECLOUD).*

**Theodoros: 25ns beam longitudinal studies**

A summary of recent MD studies with high intensity 25ns beams in the SPS with the Q20 optics showed an improvement of the achievable intensity (up to 1.3x1011ppb at flat top) and the beam quality at flat top. Several RF voltage programs were tried in order to optimize beam stability and transmission. Furthermore, the effect of a larger longitudinal emittance at PS extraction was studied. For high intensity with 4 batches, fast losses at the tail of the fourth batch right after injection were observed and improved by increasing (horizontal) chromaticity. In general, the transmission was lower compared to previous MDs.

*Different voltage programs were tried in order to optimize the beam stability and transmission. The main improvement in beam quality and stability was achieved by increasing the longitudinal emittance already before injection into the SPS (by blow-up in the PS), such that the bunch length at injection was about 4.2 ns (similar to operational 50 ns beam). This was sufficient to achieve stable beam conditions with intensities up to 1.3x1011ppb at flat top, with only small dipole and quadrupole oscillations for a few bunches of the first batch. It seems however that the larger longitudinal emittance results in higher losses on the SPS flat bottom (losses increased by 2%).*

*Bunches in the first batch have a smaller longitudinal emittance due to the phase loop at injection (which acts on the first part of the first batch) and in addition they suffer from bunch shortening on flat bottom (as they stay longest on the flat bottom). Bunches of the first batch are thus observed to be the most critical with respect to stability at higher energy, as the controlled longitudinal emittance blow-up during the ramp is less effective.*

*Further studies are needed to understand how the longitudinal emittance (and particle distribution) from the PS affects the beam stability in the SPS at flat top after the controlled blow-up. In particular, how can the blow-up be optimized to achieve similar beam stability for all four batches at high energy?*

*In comparison with the previous 25 ns MD before the optimization of the low-level RF setup, bunches injected with smaller bunch length (and low intensity) are now more stable. Nevertheless, the “u-shape” of the bunch length along the bunch train is still there. When injecting bunches with enlarged bunch length, the total losses seem now larger compared to the MD before the low-level RF setup.*

**Hannes: Observations with 25ns beam in the SPS Q20 MDs in November 2012**

While good beam quality and stability was achieved for the 25ns beam with intensities up to 1.3x1011 ppb at flat top, several issues were encountered for higher intensities. In addition to longitudinal instabilities at high energy, fast losses and emittance blow-up in the last part of the fourth batch were observed right after injection. Increasing chromaticity (with steps at each injection) helped to some extent, but stable conditions at SPS injection with the high intensity 25 ns beam (1.65x1011 ppb) were not achieved yet. Furthermore, transverse emittance measurements using the wire scanners cannot be done at high energy: already 2 wires were broken due to the beam-wire interaction at flat top with 4 batches of the high intensity 25ns beam (only measurements at flat bottom are within the wire breakage limit).

*The transverse emittances measured with the bunch-by-bunch mode were around 2.5-2.8 μm for the nominal intensity (1.10x1011 ppb at flat top) and close to 3 μm for slightly higher intensity (around 1.25x1011 ppb at flat top).*

*The transverse emittance blow-up (from about 3 μm to roughly 6 μm) and losses at injection of the fourth batch for the high intensity beam need to be studied in future MDs. In particular the chromaticity and transverse damper settings need to be further optimized. It is also not clear yet, if the observed instability is caused by the impedance of the machine or by electron cloud effects: increased pressure rise and increasing slow losses were observed for higher than nominal intensities at injection. However, the pressure rise is still orders of magnitudes lower compared to the first 25ns MDs in the early years of 2000.*

*Future studies should include measurements with the high-bandwidth pickup in order to monitor the intra-bunch motion.*

*In general, beam instrumentation needs to be adapted to the future needs of measuring high intensity 25ns beams. In particular emittance measurements at high energy will require reinstallation and re-commissioning of the BSRT in the SPS.*

**Helga: Parameters of high-intensity single bunches at 450 GeV**

Since the AWAKE project requires high intensity single bunches with small transverse emittance and the shortest possible bunch length at SPS extraction, the achievable beam parameters were studied in two MD sessions. In the first session the Q26 optics was tested and the second session was devoted to measurements with the Q20 optics. In both cases, cycles with a fast ramp were used. At flat top the voltage was raised quickly in order to achieve bunch rotation and thus short bunch length. No controlled longitudinal emittance blow-up was applied.

*Strong instabilities were observed at the end of the ramp in the Q26 cycle, which result in a blow-up and thus longer bunches at extraction. This instability was enhanced by the fact that the voltage was kept constant at 7MV in the second part of the ramp, which is bad for beam stability as the synchrotron frequency spread is reduced. In fact an increase of the bunch length (corresponding to an emittance blow-up) is observed at the time when the bucket area is increasing. Future studies should be performed with a voltage program generating a constant bucket area throughout the ramp.*

*In the first session with the Q26 optics, the bunch rotation was tested only with a voltage jump from 2 MV to a maximum of 5.8 MV. The bunch length achieved (at ¼ synchrotron period after the voltage jump) was 1.52±0.12 ns. Slightly smaller bunch length might be achieved with a voltage jump to 7.7 MV as used during the second session with the Q20 optics.*

*During the second session with the Q20 optics, the voltage of the 200 MHz cavities was programmed to generate a constant bucket area during most part of the cycle. Only in the last part the voltage had to be increased slightly in order to compensate for potential well distortion. The beam was much more stable even for high intensities. Even in case of small instabilities (for intensities above 3x1011 ppb) und thus small longitudinal emittance blow-up, the bunch length after rotation increased only slightly. The average bunch length was about 1.19±0.05 ns for intensities below 2.8x1011 ppb and 1.34±0.09 ns for intensities between 2.8x1011 and 3.7x1011 ppb at flat top.*

*Systematic measurements of the transverse emittance as function of intensity were only performed with the Q20 optics. Although the measurements show a difference between horizontal and vertical plane, it is believed that the beam is round and the difference is due to the calibration of the wire scanners.*

*A fair comparison of the two optics cannot be made at this point, since the voltage program of the Q26 cycle was not fully optimized and a smaller voltage difference was used for the bunch rotation. Nevertheless, the beam is clearly more stable in the Q20 optics which results also in a smaller spread of the beam parameters at extraction.*

Minutes written by Hannes Bartosik