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Beam quality of 72 bunches of 25 ns beam with Q20 optics

Observations of 2011-09-02

1 Introduction

During a dedicated MD 2011-09-02 it had been possible to obtain a first impression of the longitudinal beam quality at flat top of the SPS as seen by the BQM using a cycle with the Q20 optics and using a single batch of 72 bunches spaced by 25 ns.

Cycles with the Q20 optic had been used earlier [1], [2]. 2011-09-02 was the first time that 72 bunches of 25 ns beam were accelerated to 450 GeV/c using this optics in the SPS.

2 Observations

In the evening of 2011-09-02 there had been a moment with sufficiently good condition to asses the status of the beam parameters at flat top.

The cycle LHCMD_25ns_Q20_2011_V1 (10 860 ms long flat bottom, ramp with $\dot{B}_{\max} = 0.35$ T/s) with Timing User LHCFAST3 and RF MMI Target LHCMD3 was used.

Typical bunch intensity was $N_{\mathrm{Q}} = 1.2 \times 10^{11}$ at injection and $N_{\mathrm{Q}} = 1.1 \times 10^{11}$ at flat top, see Fig. 1. The bunch length at injection was typically between 3.6 ns and 4.1 ns, see Fig. 2.

The RF voltage programmes were as shown in Fig. 4. The longitudinal damper gain programme for the Q20 optics has to be considerably different than for the Q26 optics, see Fig. 4 (bottom). This had been already noticed 2011-07-04. Otherwise there had been no special optimisation neither of the longitudinal damper crates, nor of the feedback crates. Only the settings of the feed-forward crate of TWC200-1 had been slightly modified[1].

Without using the controlled longitudinal emittance blow-up (BUP), the bunches were stable at flat top. Typical low level signals for $t \geqslant 10\,860$ ms are shown in Fig. 5. At 14 860 ms there is small kink in the $\mathrm{AEW}_{\mathrm{pk}}$ signal. This is about the time when the maximum ϕ_{s} is reached.

The BCT data of Fig. 1 and the FBCT data of Fig. 6 look just normal.

The beam was not only stable at flat top but as far as the longitudinal bunch parameters were concerned could have been extracted straight away without any adjustment, according to the SPS BQM[2].

Fig. 7 (top) shows the BQM data for minimum, mean and maximum bunch length as function of time, acquired prior to extraction. The bunch difference between maximum and minimum bunch length is small and the standard deviation of the bunch length, Fig. 7 (centre), also. The values for OSCILLATION_DELTA_PCT and OSCILLATION_PEAK_PCT, Fig. 7 (bottom), were much lower than the threshold values, indicating that the beam had been stable before extraction. For a definition of the BQM variable names see App. C.

Fig. 8 shows the mean of the bunch length prior to extraction for all valid cycles between 20:56H and 21:29H.

Fig. 9 shows the relative bunch position versus bunch number prior to extraction for all valid cycles between 20:56H and 21:29H. The bunch position excursions were below ± 100 ps.

[1] by G. Hagmann; there had been no beam available to verify the feed-forward crates for the other feed-forward crates of the other travelling wave cavities

[2] it was only the bunch position check which failed, probably due to a BQM parameter which had not yet been adjusted for the new cycle used

At 21:13H the beam had to be cut due to an RF intervention in the CPS. It was apparently related to some unstable situation and strange RF settings[3] since about 18:21H. This had been rectified with the intervention[4] at 21:13H.

3 Conclusions

Despite the difficult circumstances when setting-up the beam on the Q20 cycle, the longitudinal beam parameters were surprisingly good at flat top. From an RF point of view, the main differences with respect to the Q26 cycle are related to the RF voltage programmes (TWC 200 MHz, TWC 800 MHz), the longitudinal damper gain programmes, and that no use of the BUP was necessary until now.

A 25 ns beam of similar bunch intensity had been used recently and was found to be more difficult to adjust to pass the BQM checks [3].

[3] see CPS eLogbook http://elogbook.cern.ch/eLogbook/eLogbook.jsp?shiftId=1038178
[4] see CPS eLogbook http://elogbook.cern.ch/eLogbook/eLogbook.jsp?shiftId=1038190

References

[1] T. Bohl. Long SPS MD period of Week 19. Note 2011-20, CERN, Geneva, May 2011.

[2] T. Bohl. Single bunch in coast at 270 GeV/c with Q20 optics. Observations of 2011-08-29. Note 2011-40, CERN, Geneva, August 2011.

[3] T. Bohl. Beam quality of the 25 ns LHC beam in the SPS. Observations of August 2011. Note 2011-39, CERN, Geneva, August 2011.

A Low level signals

Low level signals shown in some Figures are:

$\Delta\Phi_{PD}$ Phase Loop phase discriminator output

$\Delta\Phi_{SLA}$ Synchro Loop Amplifier Output

CVORG noise output of CVORG VME card used to inject noise into the phase loop, measured at Linear Gate In

AEW_{pk} bunch peak amplitude measured with peak detector; often low-pass filtered

B SPS BQM settings

Typical SPS BQM settings are shown in Fig. B.1

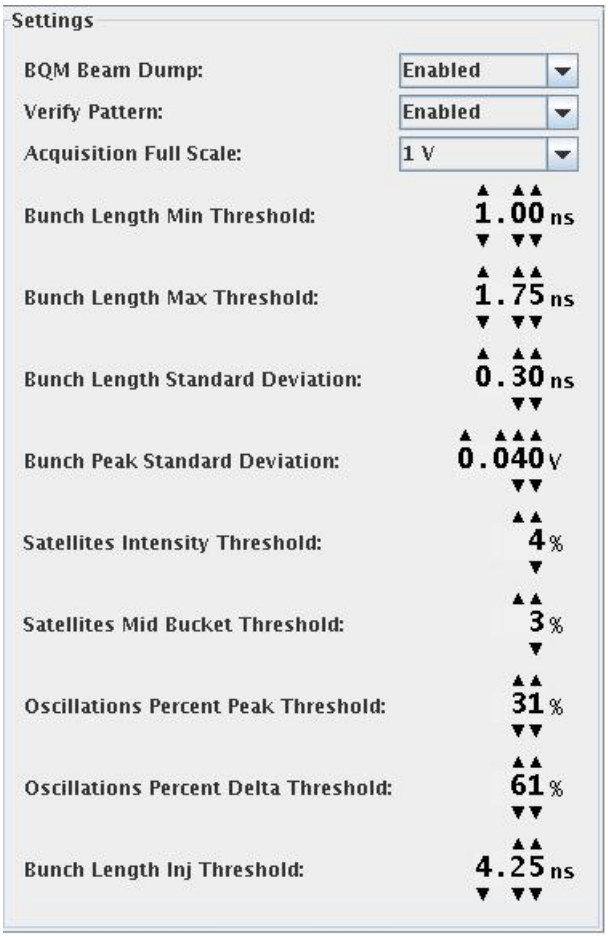

Figure B.1: Typical SPS BQM settings. September 2011.

C SPS BQM variable names

The definition of some BQM variable names is as follows

BUNCH_LENGTH_MIN minimum bunch length measured at flat top

BUNCH_LENGTH_MEAN mean bunch length measured at flat top

BUNCH_LENGTH_MAX maximum bunch length measured at flat top

OSCILLATION_DELTA_PCT a measure of dipole stability at flat top

OSCILLATION_PEAK_PCT a measure of quadrupole stability at flat top

Figures

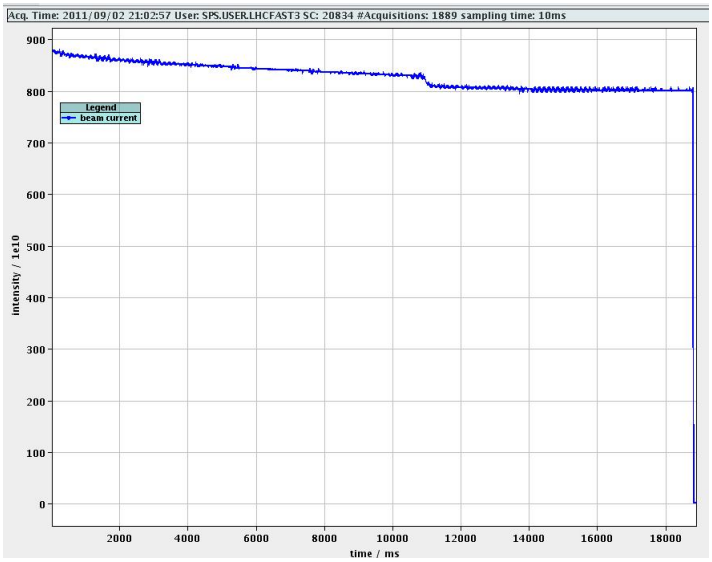

Figure 1: BCT screenshot. 72 bunches of 25 ns beam, Q20 optics. 21:03H, 2011-09-02.

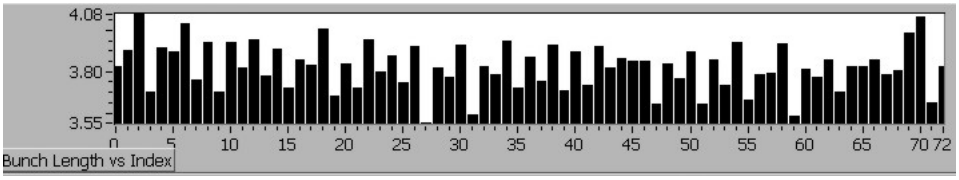

Figure 2: Bunch length at injection measured with the APWL wall current monitor via a fibre-optic link. 72 bunches of 25 ns beam. 21:28H, 2011-09-02.

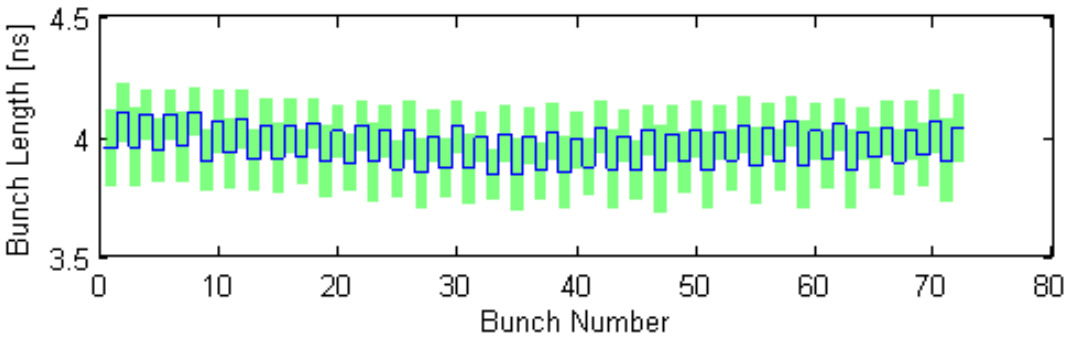

Figure 3: Mean bunch length at injection and its std (green) versus bunch number. Based on BQM data acquired between 20:56H and 21:29H, 2011-09-02.

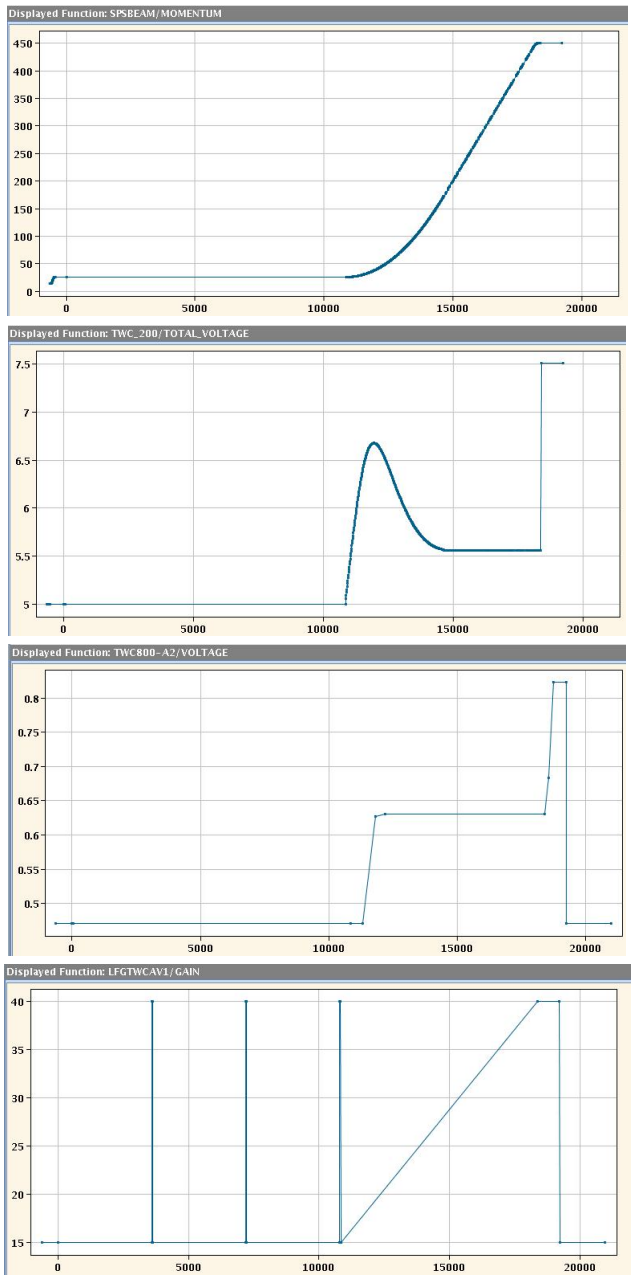

Figure 4: Top: $p(t)$ for the cycle CY LHCMD_25ns_Q20_2011_V1, followed by 200 MHz RF voltage programme, the 800 MHz RF voltage programme and the longitudinal damper gain programme (bottom) which is considerably different for the Q20 optics in comparison to the Q26 optics. 2011-09-02.

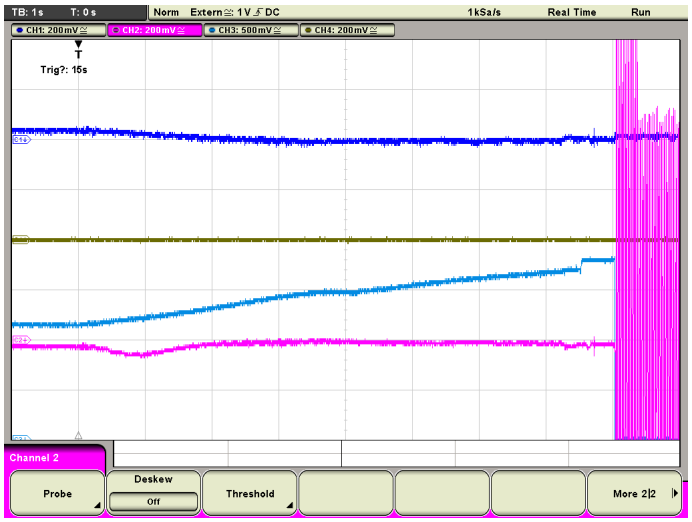

Figure 5: CH1 (blue): $\Delta\Phi_{\mathrm{PL}}$, CH2 (pink): $\Delta\Phi_{\mathrm{SLA}}$, CH3 (light blue): $\mathrm{AEW}_{\mathrm{pk}}$, CH4 (green): CVORG noise (off). Trigger at $t = 10\,860$ ms. 72 bunches of 25 ns beam, Q20 optics. See App. A for details. 20:58H, 2011-09-02.

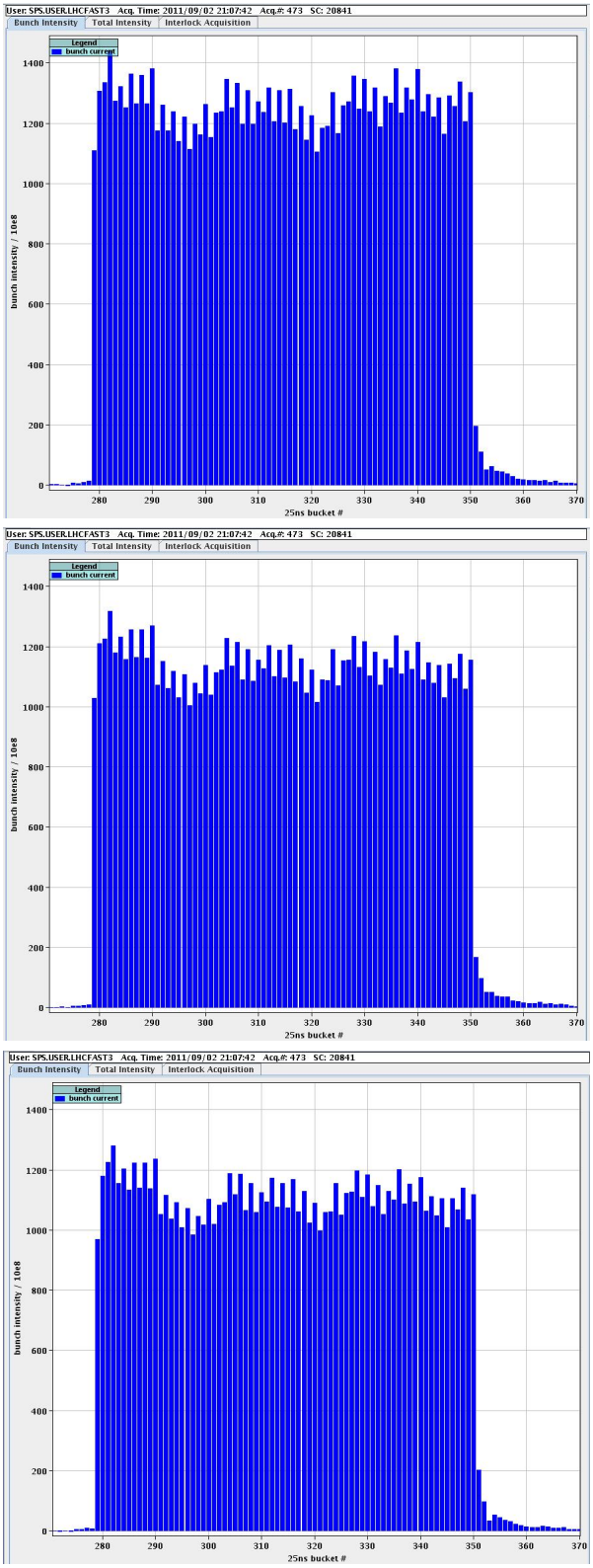

Figure 6: FBCT data. 72 bunches, 25 ns beam, Q20 optics. Top: at injection ($t = 0$ ms). Centre: at $t = 11\,000$ ms. Bottom: at $t = 18\,760$ ms. All data of the same SC 20841, 21:07H, 2011-09-02.

Figure 7: 72 bunches, 25 ns beam, Q20 optics. Top: BQM variables BUNCH_LENGTH_MAX, BUNCH_LENGTH_MEAN and BUNCH_LENGTH_MIN. Centre: BUNCH_LENGTH_STD. Bottom: OSCILLATION_DELTA_PCT and OSCILLATION_PEAK_PCT. At 21:05H there had been a bad cycle, the cycle at 21:12H occurred just before the beam was cut by the CPS at 21:13H due to an RF intervention was also a bad cycle. Data acquired between 20:56H to 21:29H, 2011-09-02.

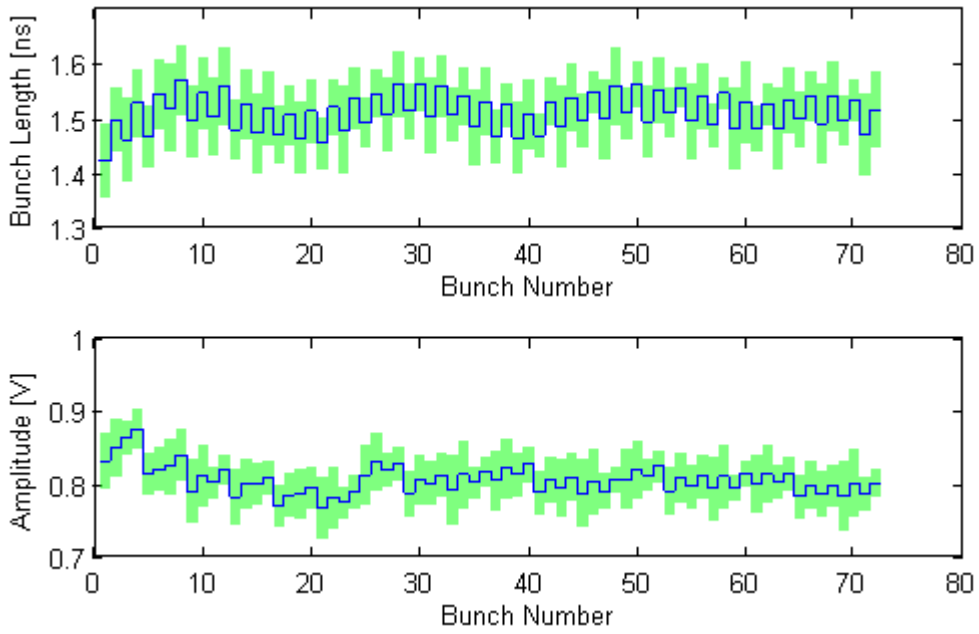

Figure 8: Top: mean bunch length prior to extraction and its std (green) versus bunch number. Bottom bunch peak amplitude prior to extraction and its std (green) versus bunch number. Based on valid data acquired between 20:56H and 21:29H, 2011-09-02.

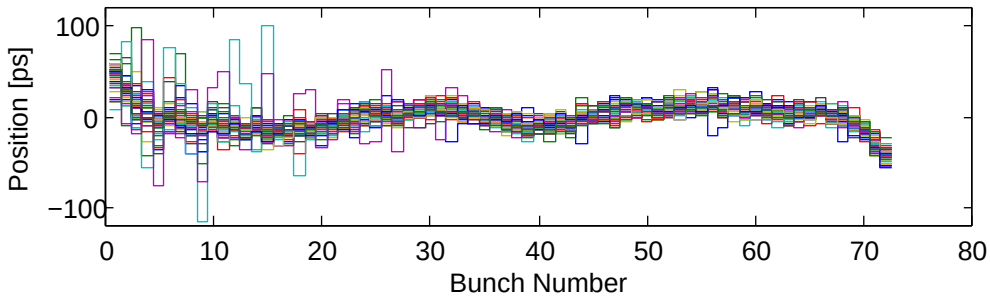

Figure 9: Relative bunch position prior to extraction versus bunch number. Based on valid data acquired between 20:56H and 21:29H, 2011-09-02.