Minutes of the SPS Studies Working Group (SSWG)

6^{th} meeting 20^{th} August 2002

Present: G. Arduini (chairman), V. Baglin, T. Bohl, H. Burkhardt, R. Cappi, B. Dehning, W. Höfle, N. Iida, L. Jensen, M. Jimenez, A. Koschik, D. Manglunki, F. Roncarolo, G. Rumolo, E. Shaposhnikova, J. Tückmantel, J. Wenninger, F. Zimmermann (secretary)

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1 Chromaticity during the Ramp (J. Wenninger)

The 20-year old model used by the control system to describe the variation of the chromaticity during the cycle is of the form $\xi_{\rm mod} = a + b/p + c\dot{p}/p$, where p is the beam momentum, and a, b, and c are constants. The second term represents the remanent fields, and the last the eddy currents. In reality the measured chromaticities differ from the model prediction and, for compensation, trims are applied. These trims are often copied from cycle to cycle, which may not always be appropriate.

The goal of the recent study was to recover the trims by measuring the chromaticity during the cycle. A bug was found in the 'target function setting', which delayed the analysis. The recorded magnet current are correct, however.

Comparing the model and the trims, discrepancies in the values by up to a factor of about two are found. Not even the slope (variation with time) is consistently described, and sometimes of opposite sign. To correct for these shortcomings, J. Wenninger empirically introduced additional terms to the model, which are of the form $\Delta\xi = d(p - p_0)$ for $p < p_0$ and and $\Delta\xi = e(p - p_0)$ for $p > p_0$, respectively, where p_0 is a constant momentum, and d, e constant coefficients. This modification permits a good fit to the measured variation. G. Arduini suggested that this term might represent the saturation effect at high energy.

Using the SPS optics model with b_3 (etc.) errors in the dipoles, developed by A. Faus-Golfe, the magnitude of the sextupole components b_3 in MBB and MBA dipoles during the full cycle were inferred from the measured chromaticities. The values found at 26 GeV are consistent with those previously obtained by A. Faus-Golfe et al. on the p2 cycle.

As a next step, J. Wenninger plans to repeat the same study for the fixed-target beam. It will be interesting to compare the fit parameters a–e with those for the LHC beam. The absolute value of the eddy current contribution will be much larger in case of the fixed-target beam (larger $\dot{p}$).

2 Recent Long MDs: Beam Parameters (G. Arduini)

There were two recent long MDs. The first was held on July 17/18, the second on August 7/8.

In the first MD, up to 4 LHC batches were injected with nominal intensity and nominal batch-to-batch spacing (225 ns). The transmission was 86%. Major losses were observed at the start of acceleration; other (slow) losses occurred in the high-dispersion regions. The fractional tunes were changed to 0.19 and 0.13 (previously 0.19 and 0.22, and originally 0.62 and 0.58). The lower vertical tune was chosen, since the tune strongly increases along the batch(es). the tune is attributed to the electron cloud. Asa consequence for a basetune of 0.22, the vertical tune at the end of the batch approached the quarter integer resonance. The new working point is further away from low-order resonances.

Vacuum in the beam dump area was a problem, and the beam operation was stopped by 3 vacuum interlocks. M. Jimenez stressed that the strong pressure rises observed in the beam dump (TIDVG) vacuum sector, which triggered three times the closure of the sector valves, should remind us of the difficulties to be expected when using graphite under vacuum. This material has a strong outgassing rate (1e-10 mbar.l/s.cm2 after bake out) and is difficult to degas. He summarized the conditioning of the dump as follows. The dump has been baked at 150C during 48 hours in the laboratory, vented to atmosphere using dry nitrogen, installed in the SPS and then baked again, this time in situ, at 150°C for 48 hours. Since its installation, this vacuum sector has never been vented. The ”conditioning” of the dump can be considered as being at its maximum and nevertheless limitations arise, if the dump is extensively used with LHC type beams at nominal intensity and energy (1.1e11 p/b and 400 GeV). This is the reason why the Vacuum Group recommends to use alternative materials in the LHC UHV systems and in the long straight sections close to the experiments (background).

After the MD, it was impossible to recover the high voltage on ZS5 West. The source of the breakdown was not clear.

In the second MD, the vacuum in LSS5 proved the main limitation. Here the machine had been vented, for installations of the BBLR and work on the IPM. An ion pump in this region was also broken, and, in addition, a sector valve was leaking. Hopefully, the latter two problems were fixed on 14/08.

Longitudinal (dipole or quadrupole) oscillations at injection adversely affected the performance of the damper. Two acceptable solutions were found (see below). One of these consisted in injecting into a mismatched rf bucket. The resulting fast blow up enhances the Landau damping.

3 Recent Long MDs: RF (E. Shaposhnikova)

During the first long MD, new hardware was commissioned. The outcome may be reported by P. Baudrenghien in a later meeting.

For the second long MD, on August 7–8, the beam consisted of 1 LHC batch, for most of the time, with a total intensity of about 7×10^{12}. Several different set ups were studied. For example, in one case, the rf voltage was increased from the matched value 0.75 MV at injection to 2 MV later on. In another set up, the rf voltage was kept constant at 2 MV. The voltage program for the ramp was optimized for a longitudinal emittance of 0.5 eVs, with a total 200-MHz voltage of 4.2 MV, from

14.5 s onwards, and with 3.2 MV after 18 s. In some cases, the 800 MHz rf system was turned on as well. The higher harmonic rf can provide Landau damping and it also blows up the beam emittance.

The desired target values at extraction towards the LHC are a longitudinal emittance of less than or equal to 0.9 eVs, a full bunch length smaller than 2 ns, and, in particular, a stable beam.

With the initial matched 200-MHz rf voltage of 0.75 MV, and no higher harmonic rf, the beam was always unstable at extraction. The timing jitter between bunches was of the order of 0.2 ns. Higher voltages resulted in larger emittances. Reducing the rf voltage on the flat top stabilized the beam oscillations. R. Cappi commented that this behavior is expected and may reflect an increased Landau damping. The bunch length was recorded for the last 5 bunches in the batch, which were most unstable.

Among the several combinations tried, only two resulted in a stable beam at extraction. One employed the 800 MHz system, the other a mismatched capture voltage of 2 MV. Final bunch lengths and emittances were of the order 1.75 ns and 0.46 eVs, which suggests a comfortable margin for further controlled emittance increases.

Increasing the longitudinal emittance with the square root of the beam energy is thought to be the ideal case, from the point of view of longitudinal dynamics. G. Arduini pointed out that longer bunches tend to suppress the electron-cloud build up at injection, and in this respect a fast emittance blow up might be beneficial.

It is not clear whether the case with 2 MV capture voltage or the use of the 800 MHz system are preferable. The beam distributions in the two cases are different.

4 Recent Long MDs: Digital Hilbert Filter (W. Höfle)

The signal for the transverse damper can be obtained either from 2 BPMs with 90° spacing (SPS standard procedure) or alternatively from a single BPM sampled over successive turns. The second option, being considered for the LHC, uses a digital Hilbert filter. This filter can be realized by a finite impulse response (FIR) architecture. The performance depends on the order m of the filter. A version with $m = 3$ was implemented in the SPS this year as a preparation for the LHC. The Hilbert filter is about 3 times more sensitive to the betatron tune than a 2-BPM system, and without adjustments the present system accommodates a tune range of at least ± 0.01. W. Höfle presented the results of first successful tests at the SPS, indicating that the damping of injection oscillations was about the same for the 2-BPM scheme and for the Hilbert-filter scheme.

R. Cappi pointed out that the tune sensitivity could be a critical point for the LHC, where reproducibility might be compromised, and that the feedback could result in antidamping. T. Bohl replied that precise numbers have to be inserted, in order to judge the tolerances for the LHC.

5 Recent Long MDs: Transverse Profile Measurements (F. Roncarolo)

On-line and off-line analysis of wire scanner results are consistent to within $\pm 10\%$. Measurements for two wire scanners, in BA5 and BA4, were compared with data from the ionization profile monitor

(IPM). In and out scans were performed 1 s and 18 s after injection. A few parameters were varied, among these the gate length of the wire, and the MCP voltage for the IPM. For 9×10^{10} protons per bunch, good agreement between the wire scanners and the IPM was achieved for an MCP voltage of 2100 V. With 1900 V the IPM profile was about 50% smaller; the ratio between initial and final emittance still appeared similar to that at higher voltage. It was also observed that the disagreement between wire scanner and IPM increased for decreasing beam intensity.

Given the sensitivity of the IPM measurement to the MCP voltage and beam intensity, the IPM must be calibrated against the wire scanners. C. Fischer commented that working towards such a calibration had been the purpose of the MD.

G. Arduini mentioned that in principle the MCP voltage could be varied during the acceleration.

6 Recent Long MDs: Calorimeter and Pressure (V. Baglin)

The circular WAMPAC1 in BA4 has an inner diameter of 140 mm and no magnetic field. A heat load of 10–20 mW/m was measured, presumably unrelated to the electron cloud.

The flat WAMPAC2 calorimeter is installed in BA5. Its dimension correspond to an MBA chamber. Data were taken on 17–18 July with 10^{11} protons per bunch. Here, even for a single batch the heat load was considerably larger, of the order of 400 mW/m for a 100-G magnetic field, and 100 mW/m without field. The value of $\delta_{\rm max}$ measured in a different field-free region was 2.1 initially, and 1.55 after the MD.

7 Recent Long MDs: Strip Detectors (M. Jimenez)

Strip detector measurements show the injection of 1, 2, 3 and 4 batches. For 4 bunches, a 3rd strip becomes visible at the center of the chamber. The electron cloud activitiy increases during the ramp. One of the strip detectors was modified in July. A retarding field was added, by which the energy distribution can be be measured in addition to the spatial distribution. Fields up to 300 V were applied and varied during the cycle. The measurements suggest that the central strip contains higher-energy electrons.

8 2002 Schedule (G. Arduini)

A scrubbing period is foreseen in week 38; and low-energy MDs in week 39. In both cases beam is available 24 hours per day. A short (2-day) MD period in October is assigned to the SPS energy calibration.

G. Arduini posed two main questions:

- Should the cycle for the scrubbing run include a ramp to 50 GeV?
- In week 39, can/shall we decelerate below transition to either 20 GeV or 14 GeV, or both in two steps? This deceleration is of interest for exploring the regime of high-space charge with a single bunch. The decelerated beam can also be used for studies by the rf group (although

for the latter, the required beam intensity is modest, and the beam could possibly be directly injected at 14 or 20 GeV, according to E. Shaposhnikova).

The updated 2002 schedule has been posted on the web by G. Arduini, on the SPS MD planning page.

9 2003 Draft Schedule (G. Arduini)

At the start of the 2003 SPS run, 1.5 weeks of beam scrubbing (including set up) are foreseen, around week 19. The indium ion run starts in week 37.

In 2003, there will be 6 long MDs, plus two additional dedicated MDs for TT40 extraction tests at low intensity. In addition, 5 Wednesday MDs are planned. The schedule also includes two days of reserve for LHC beam extraction studies at the very end of the run.

G. Arduini asked for comments on this draft schedule.

10 Next Meeting

The next meeting of the SPS SWG will be announced in due time. The agenda will be posted on the web page of the working group http://cern.ch/sl-mgt-sps-swg, and an invitation will be sent by email.

F. Zimmermann, 21st August 2002