SPS Studies Working Group
Seventh Meeting - 31st August 1999

Presents: G. Arduini (secretary), H. Burkhardt, R. Cappi, P. Collier, K. Cornelis (chairman), J. Gareyte, K. Hanke, L. Jensen, P. Knaus, E. Shaposhnikova, H. Tsutsui, J. Tuckmantel, L. Vos, F. Zimmermann, M-P. Zorzano

Excused: Th. Bohl, B. Goddard, T. Linnecar, F. Ruggiero

Machine Interlocks and Beam Instrumentation (L. Jensen)

Following a request of the operation group the beam loss ring monitors will trigger the beam dump if beam losses exceed predefined thresholds. In order to provide this additional functionality and to replace the old front-ends based on Hamac crates new VME crates have been installed. The new system is running in BA3 since one month without problems and it is foreseen to complete the migration to it in the remaining BAs by the end of the next week. A thorough test of the system will be therefore performed by the end of the proton run. E. Carlier is going to connect the new beam loss ring system to the same beam dump channel presently driven by the measurement of the losses provided by a BCT. During the next shut-down a dedicated beam dump channel will be provided by recuperating a crate in BA6. The detection of large coherent oscillations that could lead to the damage of the vacuum chamber is presently guaranteed only in the horizontal plane by an analogue system not allowing any post-mortem analysis. The detection of beam oscillations in both planes is required in view of the higher intensities expected for the future. A system for the high intensity fixed-target beam (5 MHz bandwidth) and one for the LHC beam (bunch-by-bunch observation - bandwidth ~ 40 MHz) have been requested by operation. One pick-up per plane will be used. The dynamic range of the measurement should be limited to about 30 dB covering the highest intensity as oscillations at low intensity can be tolerated from the point of view of equipment safety.
Following a request from K. Cornelis a tool to measure the oscillations of different portions of a batch in a given interval of time is being studied in the BI group. This is important to study the phase relation in the motion of the different bunches (or group of bunches) in a batch and to study how an oscillation propagate from one bunch (or group of bunches) to the others in the batch. The maximum analogue bandwidth expected for such an instrument is 10 MHz and a maximum of 8 raw-data channels can be made available. A first implementation will allow setting the position of the measurement gates in steps of 50 ns with a 20 ns jitter. This instrument should be available by beginning of October 1999. It will be possible to test it on the MD segment until the middle of November. Starting on 15th November 1999, no beam will be available on the MD segment because of the expected approaching of the civil engineering to the radiation limits of the SPS.

A prototype of Q-loop (closed loop bandwidth ~ 7 Hz) for the LHC has been tested in BA2. The main problem evidenced during the tests is the difficulty to measure correctly the tune for high intensity beams where the fast damping provided by the transverse feedback introduces a large tune spread in the tune peaks. A 3-year project has been started in order to solve this problem. Because of the good reproducibility of the ramps in the SPS makes a Q-loop is not considered essential for this machine.

Results of recent MDs

- K. Hanke reported on the tests of an improved knob for tuning the betatron and dispersion matching between the injection line and the SPS. With respect to a previous experiment performed last year a new knob using not only the TT10 quadrupoles but also the TT2 ones has been calculated. This is based on the inversion of the matrix providing the variation of the Twiss parameters, the dispersion and its derivative for small trims of the transfer line quadrupole strengths. The OTR matching monitor in the SPS ring has been used to measure the betatronic and dispersion mismatch at injection. The Twiss parameters are obtained from the measurement of the profiles in the OTR monitor at 3 different passages once the transfer matrices between any pair of points in the ring or in the transfer line are known. The dispersion D and its derivative D' at the beginning of the injection line and the momentum spread of the beam should be measured. Twiss parameters, D and D' can be determined from the measured beam size at 5 passages in the OTR monitor once the transfer matrices between any pair of points in the ring or in the transfer line are known and the momentum spread of the beam is measured. This can only be possible for the horizontal plane as there are no vertical bends in the ring. The measurement was performed with a 2 μsec batch of 8 equidistant bunches with small transverse emittance and momentum spread.
  MAD simulations already show that the knob is non-linear (as expected) for the Twiss parameters (in particular for α) and it is not completely orthogonal as some coupling between the Twiss parameters for the same plane are observed. The measured Twiss parameters (from the 3-profile method) are in fair agreement with the model though the variation of α was too small to verify the effectiveness of the knob in this dimension. The values of the dispersion provided by the 5 profile method did not give any meaningful result due to the large spread of the obtained values. During the meeting it was evidenced that misteering of the bunches of the batch could be a source of error for both the above-mentioned measurement methods. The low momentum spread of the beam and the limitation imposed by the hardware to 4 profiles/injection are sources of error for the 5 profile method. The present monitor is installed in a dispersive region (2.7 m). K. Cornelis mentioned that it could be helpful to install an additional OTR monitor in the SPS. This should be placed in a low dispersion region in order to disentangle the dispersive contribution to the beam size more easily.

- H. Burkhardt and F. Zimmermann reported on the additional measurements performed on the dependence of the coherent tune shift on intensity. These have been conducted with a 26 GeV bunch captured in the SPS. The correction of the chromaticity to about +0.01 in both planes is now satisfactory. Better precision could be achieved by considering bunches of intensity lower than 10^{10} p to minimise the tune fluctuation induced by changes in bunch length and bunch intensity form one cycle to the next. The natural octupolar component of the SPS is also quite well compensated.

In the last two MD sessions (13/08/99 and 23/08/99) all the parameters affecting the coherent tune shift (intensity, bunch length of the beam in the SPS, transverse emittances, octupolar component, chromaticity) have been measured. Discretization of the tune values has still been observed and might be related to the resolution of the FFT or to the presence of an amplitude modulation at 50 Hz. This could produce side-bands at 0.0012 from the tune peak and the peak finding algorithm might find any of the three peaks from one measurement to the next. Recent measurements have evidenced the important dependence of the coherent tune on the capture voltage (i.e. on the bunch length). Doubling the voltage almost doubled the coherent tune shift in the vertical plane. This variation of the tune shift could be due either to space charge or to impedance. No general consensus was reached during the meeting on that point. A measurement with leptons could bring some hints in that respect. P. Collier suggested that a measurement could be performed with positrons at 22 GeV. The quality of the measurement in these conditions should be verified as the measurements performed on leptons at injection where strongly affected by the ripple of the main power converters.

Bunch shape measurements evidenced quadrupolar oscillations which affect the precision of the measurement. This is probably due to a mismatch at injection. In order to avoid such kind of problems the voltage should be matched at injection and then adiabatically increased if the bunch length has to be decreased. From the present experience measurements with shorter bunches (i.e. higher voltages) should be preferred to reduce the sensitivity to the precision of the tune measurements. Transverse emittances were also measured with the rotational wire scanner in LSS4 as a function of the intensity. While during the first session the horizontal emittance was constant and the vertical emittance increased as a function of the intensity, during the second MD it was just the opposite. This means that the methods applied in the PS in order to get the different intensities were not the same in the two occasions.

The results of the measurements of the coherent tune shift for the 26 GeV bunch performed in 1999 are summarised in Table 1 together with the estimated impedance for a broad band model with resonant frequency at 1.35 GHz.

Date	Capture voltage [MV]	$\Delta Q_H/\Delta I$ [per 10^{11} p]	$\Delta Q_V/\Delta I$ [per 10^{11} p]	Z_{tH} [MΩ/m]	Z_{tV} [MΩ/m]
25/06	0.5	0.0015 ± 0.00015	-0.0089 ± 0.0004	-1.5 ± 0.2	8.7 ± 0.3
13/08	0.81	0.0029 ± 0.00014	-0.0092 ± 0.0008	-2.8 ± 0.1	9.0 ± 0.8
23/08	2.8	0.0059 ± 0.0006	-0.029 ± 0.0011	-3.8 ± 0.4	18.5 ± 0.7

Table 1: Results of the measurements performed on the 26 GeV single bunch in 1999.

The problems related to this type of measurement are now quite well understood, additional studies are necessary to verify the stability of the results once the

conditions of the measurement are well established and documented. Only in that way they can be used as a reference for future comparison after the planned interventions to reduce the machine impedance. The precise control of parameters such as transverse and longitudinal emittances in an orthogonal way is quite important for this type of measurement and it is generally felt that the availability of a scraping section in the injection line could be of great help. This could also be useful for the production of the pilot beam for the LHC.
F. Zimmermann concluded by showing a table containing the results of transverse and longitudinal impedance measurements performed in the SPS. An important spread can be noted as a consequence of the different measurement methods and analysis models applied.

- J. Tuckmantel reported on some new results of the study of the SPS damper pick-up DC bias problem discussed already in the last three meetings. No problem is observed for the fixed target beam with 5 ns bunch spacing at least up to intensities of about 2 x 10^{10} p/bunch. On the other hand for the LHC-type beam with 25 ns bunch spacing unusual signals are observed particularly at injection for intensities higher than 2 x 10^{10} p/bunch. A small bias voltage on the pick-up electrodes can reduce the phenomenon but no clear relation between the beam intensity and the required bias voltage. On the other hand a solenoidal magnetic field can do the job though the required intensity of the magnetic field depends on the intensity of the beam (100 G are needed for an intensity of 4 x 10^{10} p/bunch). It was also noted that one plate of the electrostatic pick-up charges positive while the other charges negative. The model of beam-induced electron cloud already studied for the LHC gives a possible explanation for all the above observations. The difference in the sign of the voltage to which the two plates charge up could be explained by the higher secondary emission coefficient of one of the two plates. J. Tuckmantel also mentioned that there is a problem of overload of the electronics at injection, which would require some improvement. Previous experiments seem to exclude that the phenomenon is due to losses at injection nevertheless it was proposed to replace pick-up 215V (which is the worst) with a well cleaned new one and to put 215V in a the test area where a different pattern of losses at injection is expected. At the end of Tuckmantel intervention K. Cornelis mentioned that the above model seem to be confirmed by additional observations performed by J.-M. Jimenez (LHC-VAC) during the last long MD (25-26/8) with the LHC beam. A generalised increase of the residual pressure has been observed whenever the intensity of the LHC beam was increased above 2-3 x 10^{10} p/bunch.

- E. Shaposhnikova reported on the observations conducted during the last long MD (25-26/8) with the LHC beam. The small emittance provided by the PS during the MD (0.25 eVs) required low capture voltage (~ 540 kV) to be matched. At this voltage a modulation (with a frequency of about 1 MHz) in the intensity of the of the bunches was observed to develop in the first 20 ms after injection for intensities of about 4 x 10^{12} p/batch. That disappeared at lower intensities and/or at higher voltages. In the latter case nevertheless larger capture losses were observed. The appearance of this modulation might be correlated to the bandwidth of the TWC RF feedback which is limited to about 1 MHz. L. Vos mentioned that similar observations were done in the transverse plane where the beam gets unstable at frequencies just outside the bandwidth of the transverse feedback. R. Cappi warned on the possibility that the small value of the emittance communicated by the PS control room crew might have been not correctly measured.

- G. Arduini presented the results of a measurement of the dependence of the strength of instabilities on the fixed target beam at 14 GeV on the working point. The horizontal and vertical dampers were switched off for 8 ms in the middle of the flat bottom (500 ms from start of the supercycle). The oscillations of the beam were recorded during this interval of time, a Fourier analysis was performed and the spectral power was determined as a function of the working point. From the data one can observe that the beam is more unstable for $Q_H \sim 26.625$ and $Q_V \sim 26.57$ which are quite near to the standard working point. These results confirm what already seen by K. Cornelis for the horizontal plane. Another unstable point occurs for $Q_H \sim Q_V \sim 26.62$. the measurement should be repeated with a larger statistics and with a finer scan of the working point.

- K. Cornelis presented the list of the studies that remain to be conducted:
  - Evolution of the emittance of the fixed target beam as a function of intensity to evaluate the improvements due to the higher injection energy in the PS (1.4 GeV).
  - Acceleration of a 2 μs batch with 8 x 10^{12} p
  - Measurement of the momentum spread before and after transition for the fixed target beam and the 2 μs batch at different intensities.
  - Precise impedance measurements (20 % of all pumping ports will be changed during the next winter shut-down).
  - Shared slow extraction of the LHC beam in preparation of next year physics run.
  - Bucket barrier to verify the possibility of performing a fast extraction after a shared slow extraction.
  - Reduction of the ripple on the spill of the slow extracted beam at multiples of 50 Hz with feed-forward for the lead ion run
  - Test of an optics with higher horizontal tune for the lead ion run at 100 GeV.

- G. Arduini presented a list of the machine development studies performed or on-going and of those that still have to be performed.

  Performed or on-going:
  1. LHC beam injection and acceleration (setting-up, damper, …): present limitation given by the damper and the RF feedback? (see Tuckmantel and Shaposhnikova presentations)
  2. 14 GeV 2 μs batch injection up to 8 x 10^{12} p/batch
  3. TT2-TT10 optics reference measurements and test of the new matching knob. Need another matching iteration after chromaticity adjustment in the PS at extraction + verification of dispersion trims (MD segment)

4. 26 GeV Single short bunch reference measurements (see H. Burkhardt and F. Zimmermann presentation), at least 2 other sessions on the MD segment are needed by the end of the proton run
5. 26 GeV single long bunch measurement to verify the effect of the magnetic septa shielding (2 sessions performed – another needed on the MD segment)
6. 26 GeV coast setting-up
7. Instrumentation: Beam profile monitors, Q-loop setting-up (one session for Q-loop needed on the MD segment)
8. SSE with LHC beam. Some time during the Long MD on week 39 is needed to try and reduce the bunch length at extraction

Still to be done:

1. 14 GeV short batch acceleration. (Wednesday MD – 01/09)
2. LHC beam: 2-3 batch injection (Long MD – week 39)
3. 26 GeV coast for the study of the beam –induced electron cloud and beam stability (Wednesday 15/09)
4. Low tune optics for the LHC beam at tunes = 21 (second half of September on the MD segment)
5. 20 GeV single bunch for microwave instability studies below transition (week 43-44)
6. Aperture measurement (during lead-ion run on the MD segment)
7. IBS studies with lead ions (Long MD – week 48)
8. Bucket barrier to allow a fast extraction after a slow extraction (important for NGS project)
9. Chromaticity measurement from head-tail oscillations
10. Lead ions with higher tune (during lead ion setting-up)
11. Determination of the resonant terms from multi-turn measurements and the measurement of the energy loss of protons at different energies are postponed to next year. The studies on the LHC beam have priority given the possible hardware implications.

It was also mentioned that some problems with the instrumentation were observed during the machine development sessions:

- Q-meter: the measurement in the vertical plane on the MD segment fails quite often
- Wire scanner: ‘single-bunch’ electronics not available (2 cards broken) until week 36
- OTR matching monitor: need to have > 5 acquisitions/injection (see K. Hanke presentation)
- OTR monitors: calibration to be verified (it will be done on 01/09)
- On line chromaticity measurement would be a very useful tool.

Next meeting

The next meeting will take place on Tuesday 14th September 1999, at 09:15, room 865-1-D17. A reminder will be sent by e-mail in due time and the agenda will be announced on the web page of the working group http://wwwinfo.cern.ch/~ghislain/sswg/sswg.html.

G. Arduini
3rd September 1999