Minutes of the SPS Studies Working Group
(SSWG)

14^{th} meeting -26^{th} September 2000

Present: G. Arduini, H. Burkhardt, R. Cappi, Yu-Chiu Chao, K. Cornelis (chairman), G. Collazuol, W. Hofle, L. Jensen, J. Klem, T. Linnecar, E. Shaposhnikova, F. Schmidt, R. Tomas, J. Tuckmantel, L. Vos, F. Zimmermann, M.P. Zorzano (secretary)
Excused: T. Bohl,

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1 The Spill structures seen by NA48 (G. Collazuol)

The aim of the NA48 experiment is to measure the direct CP violation parameter by evaluating the double ratio of the decay widths: $R = \frac{\Gamma(K_L \to \pi^0\pi^0)/\Gamma(K_S \to \pi^0\pi^0)}{\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_S \to \pi^+\pi^-)}$. The measurement of R is performed by counting the number of events in each of the four decay modes. The K_L and K_S decays are distinguished by a proton tagging detector, upstream of the K_S target. The time of each proton is recorded and is compared with the time of the decay as measured in the main detector. The presence (absence) of a proton in coincidence with the event defines the event as K_S (K_L).

Most of the systematic effects (inefficiencies, dead times, ...) cancel out in the double ratio R, but it is of extreme importance to measure and to have the deepest knowledge about the residual effects. We must keep under control the accidental activity effects and the variations of detection efficiency which are proportional to the fluctuations of the beams intensity. Low frequency structures are particularly dangerous because they are coupled with K_s/K_L intensity variations. Higher frequency structures result in high level of inefficiencies, in the beginning of the spill. Besides they are responsible for systematic effects in the K_S decays tagging.

A number of studies have done to determine the stochastic and modulation component in the intensity of the fluctuations.

A measurement based on the K_L beam counter on 1998 suggests a total fluctuation of the intensity with variance $< \eta^2 >= 30\%$.

An analysis based on the Fourier transform of the signal of secondary emission monitor (SEM) of a typical pattern of a slow extraction spill in 1980 shows the low frequency fluctuations. The spectrum shows a noisy background and harmonics of the 50 Hz frequency. The noisy component is $< \eta^2 >= 2/3 < \eta^2 >_{mainfreqs.}$ (Note SPS-89-21, 1989). We would like to have an update of these measurements (now we do no have the SEMs) and disentangle the different contributions. Another method, different from FFT, consists in exploiting for each event the number of protons m that are in the tagger region at the trigger instant as estimator of the beam intensity. The events distribution as a function of m yields $< \eta^2 > \approx 21.5\%$. A similar estimate is obtained using the number of particles through AKL muon veto. Plotting $< \eta^2 >$ from the protons through the tagger as a function of the main phase one can estimate the low frequency component in $< \eta^2 >$ to have an amplitude of 3%. Following the relation $< \eta^2 > = 2/3 < \eta^2 >_{mainfreqs.}$ would mean a 5% low frequency noise induced variation. Plotting this as a function of the SPS phase (SPS revolution period 23 μs) shows a contribution of 5%.

About the higher frequency structures:

- Plotting the number of protons through the tagger as a function of time at the beginning of the spill (burst time 100-150 ms) one sees a 200 MHz modulation, and at the end of the spill (burst time 2200-2250 ms) one sees a 100 MHz modulation. The first one decays due to debunching, the second one is excited slowly in time.

  (T. Linnecar, E. Shaposhnikova) This 200 MHz signal is due to the cavities. The excitation of the second one might be a slow instability or might be due to the active damping that is used for these cavities. Next year there should not be such effect.

- In fact the modulation is seen at roughly 203 MHz, another component at 2.4 MHz is present.

  (E. Shaposhnikova, K. Cornelis, G. Arduini) This might well be the beating of two frequencies: 200 MHz and a multiple of the tune.

- The spill shape had lower intensities at the beginning of the spill in 1999 than in 1998 even though in 1999 there was no neutrino F.S. extraction.

  (K. Cornelis) Without neutrino extraction the slow resonance structure generates a spike in intensity at the start. In order to compensate this the resonance is approached extremely slowly, as a result the number of extracted particle is reduced.

- There is a shift in the $23\mu s$ phase of the bunched train structure of about 1μs from the beginning to the end of the burst.

  (K. Cornelis, T. Linnecar) This is due to the fact that the rf is switched off and the bunched beam longitudinal profile may change slowly.

Even if a deep knowledge of the fluctuation structures did not reduce much the error on the result of NA48 (which have to fight against relative errors down to the level of some 10^{-4}), it would enforce the confidence on the systematics and could result in better running conditions for the next years.

2 120 MHz synchronous detection system (W. Hofle).

The SPS transverse feedback/damper is working in both planes using the 120 MHz synchronous detection that 'ignores' the electron cloud component - as far as known to date - and measures only the bunched proton component. The bandwidth is of 20 MHz in the V plane and of 8 MHz in the horizontal one. The following studies were done on a LHC beam of 1 batch (1.2 μs long) with 48 bunches and $3 - 4 \times 10^{12}$ p/batch. The dipole oscillation was measured in both planes when the feedback was acting. The measurements were done on the last hours of the MD 10/09/00, with the very high chromaticity settings from the electron cloud instability studies.

In the horizontal plane, right after injection, the injection oscillations can be seen all along the batch (pick-up at a location with dispersion). Measuring 100 ms later, the horizontal injection oscillation is well damped but a longitudinal oscillation persists (synchrotron tune). This is very reproducible and should be further studied.

Removing the synchrotron oscillation part using a notch filter and measuring the spectrum after injection, one finds the betatron tune at the beginning of the batch. There is a coupling of the tunes along the batch towards the end so that both planes tunes change along the batch until they reach a common value. (K. Cornelis) With head-tail monitor and no damper one finds a 0.01 variation in Qv towards the end of the batch. (F. Zimmermann). This is in agreement with simulations. (W. Hofle) In this measurement Qv seems to increase up to a value similar to QH, the difference being much bigger than 0.01. Applying the same procedure 100 ms after injection, in the H plane no betatron tune can be seen (probably due to limited bandwidth of 8MHz) and in the vertical plane the tune can be seen about 0.63 and fixed along the batch (coarse analysis).

Note: In a more detailed analysis the exact tune value of the vertical oscillation 100 ms after injection is 0.623. The whole batch seems to oscillate *in phase*. The reason why this oscillation is not suppressed by the feedback system, can be that at a tune of 0.623 the phase error of the feedback is already $23°$ for the case that the set-up is done for 0 phase at the nominal fractional tune of 0.58.

High frequency analysis 100 ms after injection shows components with frequencies of the order of 9 MHz in the vertical plane. This is somewhat in contradiction with the above described analysis where it was found that the oscillation is in phase along the batch, i.e. dominately low frequency. More measurements are required in order to evaluate if the high frequencies are intensity fluctuations or true betatron oscillations.

Plans for future MDs include increasing the observation bandwidth in H to 20 MHz, correlating observations with machine parameters (tunes, chromaticities..), scaning through cycle, re-adjusting feedbacks and observing intensity signals.

3 Single long bunch MD 25/07/00 (E. Shaposhnikova)

Single long bunches injected at 26 GeV are used for impedance studies, by measuring the spectrum of the line density profile that develops in time once the rf system is turned off. The lines in the spectrum are associated with impedance sources. The instability rises in the first 20 ms when the beam is debunching.

This year measurements were done with a bunch length of 21 ns, $\epsilon = 0.24$ eVs and up to 10×10^{10} protons per bunch. A peak is detected in the spectrum at 200 MHz corresponding to the travelling wave cavites. Another peak is detected at 400 MHz, for high bunch intensities this instability is the first to appear. Plotting the amplitude of these modes as a function of intensity we find that for $I < 2 \times 10^{10}$p the 200 MHz peak is dominant but beyond $I = 4 \times 10^{10}$ p the 400 MHz peak is the leading one. The fact that 400 MHz dominates beyond a certain intensity rules out the possibility of this mode to be a second harmonic of the 200 MHz. For longer bunches (40 ns) the 400 peak has smaller amplitude for every bunch intensity. The first candidates for the strong 400 MHz component were the MSE septum and the MST septum, whose frequencies lie in this region and they are very numerous (16). This year they all are shielded (some increment in the threshold of instability can be observed in measurements done in 2000 in comparison with 1996) and other impedance sources in this frequency range should be studied. Recent measurements with MKE and MKP (F.Caspers et al, 2000) show that these elements (at the moment we have 3 of each in the ring) have significant impedance around 400 MHz.

One can also extract information from the growth rate of these modes as a function of bunch population. The 400 MHz growth rate is always bigger than the 200 MHz one. For instance, for a bunch length of 21 ns, $I = 10 \times 10^{10}$ and $\epsilon = 0.24$ eVs, the growth rate is 2.5 1/(ms) for 400 MHz and 0.2/(ms) for 200 MHz. One can then obtain R/Q and get families of R and Q parameters. From the preliminary analysis we expect R/Q more than 10 kOhm.

It would be interesting to repeat the same study as a function of bunch population below transition, at 20 GeV. In the only MD done last year below transition bunch intensity was fixed (3.5×10^{10}). The most strong instability was detected at 1500 MHz, being the first one to rise. This signal is less strong in comparison with 200 MHz and 400 MHz above transition.

4 1000 turns measurements (J. Klem)

The dependence of betatron phase advance on beam current has been measured using the SPS multiturn software. Data measured on the 2nd of June 2000 was presented together with error estimates. The results are similar to 1999 results. There is some scatter in the points, possibly due to phase beating, but the results seem to indicate that most of the tune shift is located around the region 118-119 close to the injection area in the SPS.

5 MD planning (G. Arduini)

Possible planning:

- Th-Fr. 39 th week, Mo-Tu-Wed. 40th week dedicated to single bunch at 26 GeV (transfer line studies, impedance measurements, resonance driving terms).

- Mo-Tu-Wed 42th week, Mo-Tu-Wed 44th week dedicated to MD LHC and 20 GeV single long beam.

- Th 44th week, long SPS MD, is the last opportunity for intrabeam scatering studies on lead (coast at 30 GeV). Check that rf noise is not dominant. This long MD could be shared with an LHC beam with a longer plateau at injection.

Ps could deliver LHC 72 bunches by the 26th of October, but this should be run parasitically to LEP, which is not practical.

6 Next meeting

The next meeting is scheduled for Tuesday 10th October, at 09:15, Room 865-1D17. A reminder will be sent by email in due time and the agenda will be announced on the web page of the working group

http://cern.ch/sl-mgt-sps-swg

M.P. Zorzano 27th September 2000