THE SPS AS A VACUUM TEST BENCH FOR THE ELECTRON CLOUD STUDIES WITH LHC TYPE BEAMS

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Abstract

The SPS machine has been operating with LHC-type beams with bunch intensities up to 8x10^{10} protons (70% of LHC nominal intensity). This paper will give evidence of the electron cloud phenomenon as the mechanism responsible for the pressure rises in the SPS in presence of LHC type beams. The dependence of the pressure rise and of the electron current measured with dedicated pick-ups on various beam characteristics such as proton bunch intensity, number of bunches needed to start the e^-cloud phenomenon and the effect of missing bunches will be presented. The evolution of the pressure rise with the integrated current ('beam scrubbing') will be discussed. The observed effect of the dipole magnetic field and of the treatment of the stainless steel vacuum chambers with N_2 glow discharge on the pressure rise and on its evolution with the integrated current will be also considered. Finally, the consequences of the electron cloud build-up on the SPS vacuum system for the LHC beam nominal intensity will be described.

1 INTRODUCTION

The first SPS pressure rises in presence of LHC-type beams were observed in August 1999 [1]. Pressure increases by a factor of 50 to 60 were recorded in the arcs and in the long straight sections. The maximum pressure measured was 10^{-5} Pa (10^{-7} mbar) for a proton bunch intensity of 5.8x10^{10} p/b and a duty cycle close to 62%.

The end of the 1999 running period was dedicated to studies on the effect of the bunch intensities and of the batch length [1] on the pressure rises. All these measurements showed evidence for the electron cloud as being the mechanism responsible for the pressure rises. The measurements on the scrubbing effect were not conclusive mainly due to the small duty factor used during the MD [1].

The 2000 running period was mainly used to identify whether or not a scrubbing effect could be observed in the SPS and if a modification of the filling pattern, i.e. missing bunches and bunch spacing, affect the pressure rises.

2 BEAM EFFECTS

2.1 Bunch intensity

Preliminary results [1] concerning the pressure dependence on the beam intensity showed that the pressures do not vary up to a threshold bunch intensity, above which the pressure rises increase with the bunch intensity (Fig.1 and Fig.2). The amplitudes of the signals measured on the pick-up also increase with the bunch intensity (Fig.3a and Fig.3b). In August 1999, the threshold in the long straight section (no dipole magnetic field) was about 4.3x10^{10} p/b and increased up to 6.4x10^{10} p/b in April 2000. In the arc, the dipole magnetic field affects the behaviour of the pressure versus the bunch intensity (Fig.2). In presence of a dipole magnetic field, the measurements give consistently a lower threshold value, between 3.0 and 4.0x10^{10} p/b, and higher pressure rises. This effect has not been understood, but cannot be attributed to systematic errors since the gauges are not influenced by the dipole magnetic field. One explanation could come from the simulations of F. Zimmerman [3] showing that, in a dipole magnetic field, the electrons are confined in the vertical plane. The number of electrons and their distribution in energy in the cloud will depend on the bunch intensity and therefore, the impinging surface will depend on the bunch intensity. The entire vacuum chamber will not be bombarded and recontamination should be expected.

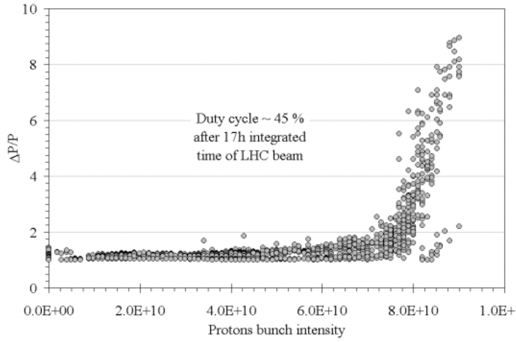

Figure 1: Pressure rise versus proton bunch intensity in a field free region.

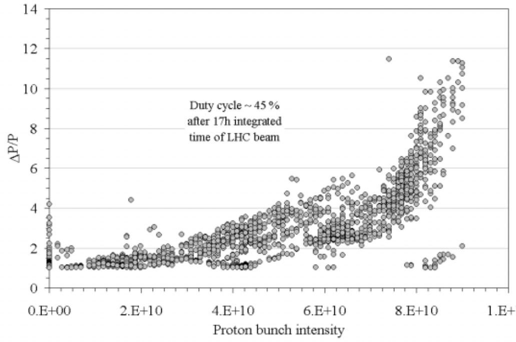

Figure 2: Pressure rise versus proton bunch intensity in a dipole region (arcs).

2.2 Filling pattern

The preliminary results presented in the "SPS & LEP Performance Workshop" [1] showed that the number of bunches needed to build up the electron cloud decreases when the bunch intensity increases. As an example, 32

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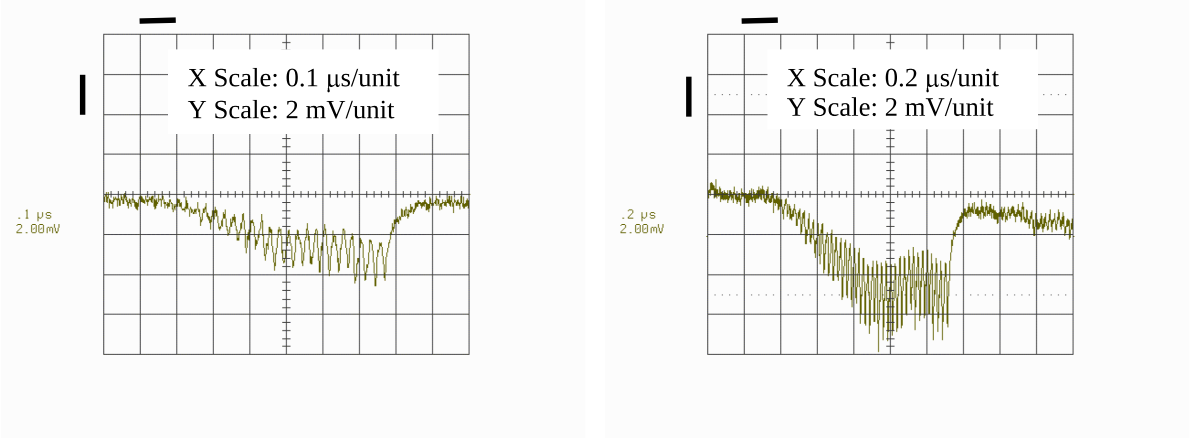
bunches are needed at 6.5x10^{10} p/b, only 20 bunches at 7.9x10^{10} p/b. These results are confirmed by recent observations on pick-ups (Fig.3a and 3b) which show that the number of detectable bunches on the electron cloud signal increases with the bunch intensity.

The 72 bunch filling pattern, made of 6 trains of 12 bunches (Fig.4), allows the suppression of one of these trains. During the measurements, the 4th and the 3rd train were removed. This shows that 12 missing bunches affect the pick-up signals and the pressure rises, which decrease by a factor 8 (Fig.5). The pick-ups showed that the missing train is more efficient in the position 4 than in the position 3 (Fig.6a and 6b). No difference in the pressure rises can be seen between the two missing trains (Fig.5).

The effect of a bunch spacing of 50 ns was not verified since intensities above the threshold of the electron cloud (6.0x10^{10} p/b) could not be injected.



a) Pick-up signal for a bunch intensity of 6.9x10^{10} p/b

b) Pick-up signal for a bunch intensity of 8.3x10^{10} p/b

Figure 3: Pick-up signals showing the effect of an increase of the bunch intensity

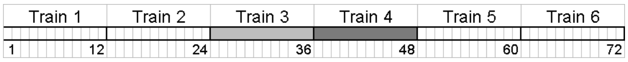


Figure 4: Filling pattern with 72 bunches made out of 6 trains of 12 bunches each.

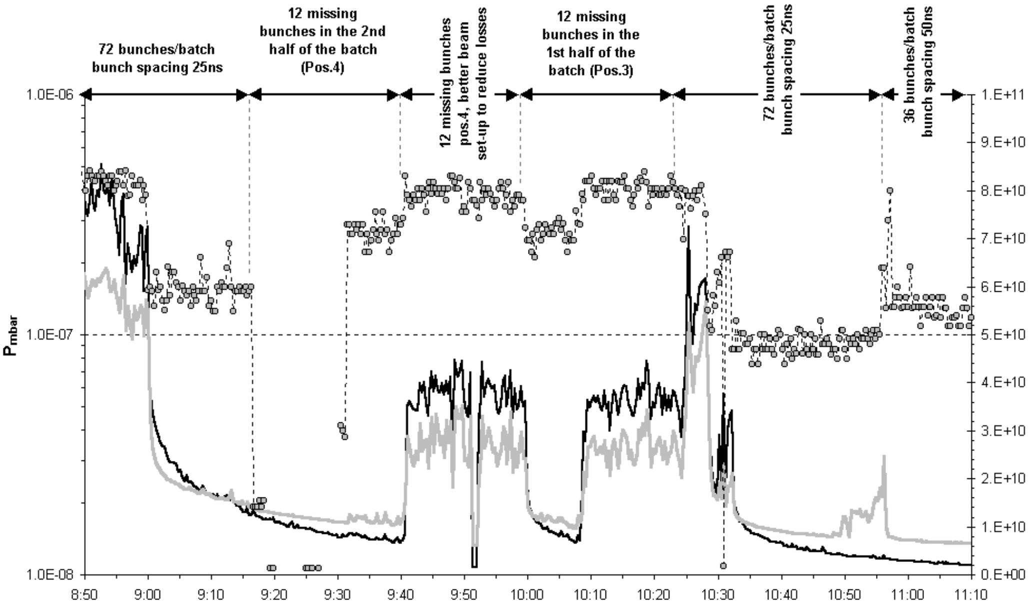
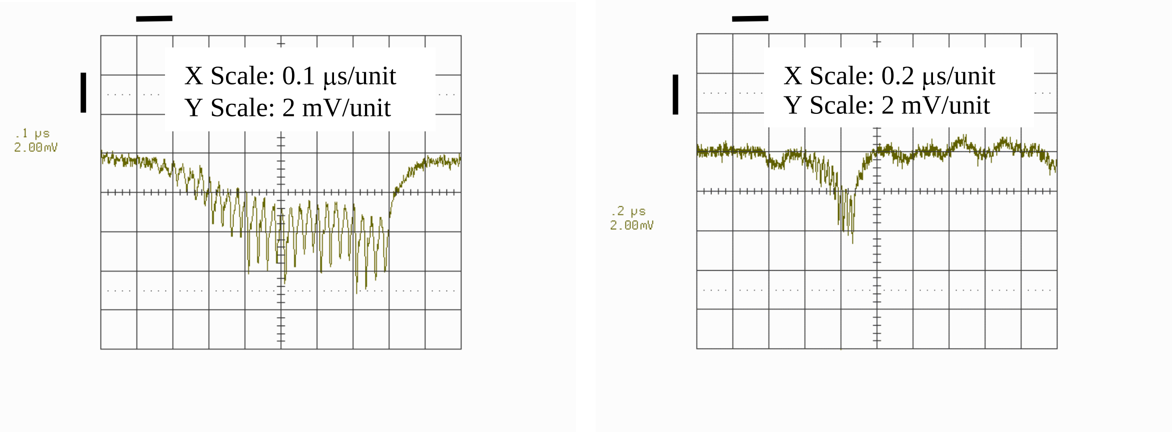


Figure 5: Pressure behaviour versus time with 12 missing bunches in pos. 3 and 4.

3 BEAM SCRUBBING

3.1 Duty cycle and magnetic field

The measurements presented in the "SPS & LEP Performance Workshop" [1] were made with a total integrated LHC beam time of about 3 hours due to the small duty cycle of ~3% during the measurements. A decrease of the pressure rises was noticed but the effect was small. Using higher duty cycle (45%), the decrease of the pressure rises was significant and a shift of the threshold bunch intensity to higher intensities was observed. This last observation is in favour of a scrubbing effect as a reduction of the outgassing rate by electron or ion bombardment could not explain this shift.



a) Missing train 3 (12 missing bunches)

b) Missing train 4 (12 missing bunches)

Figure 6: Pick-up signals with missing trains of 12 bunches.

In both the magnetic field free regions and in the dipole field, the shift of the threshold bunch intensity and the decrease of the pressure rises is clearly visible. But this effect is enhanced in the magnetic field free region [3]. The measurements have shown that the pressure rises decrease by a factor of 30 after about 2.5 integrated days of LHC beam.

Finally, the measurements have shown that the scrubbing effect is effective up to the bunch intensity used for the commissioning. If a beam with higher bunch intensity is injected, the pressures will increase. This observation is consistent with the displacement of the electron strips in the magnets when the beam intensity increases.

3.2 Nitrogen discharge - Memory effect

No difference in the pressure rises nor in an increase of the scrubbing effect can be seen between the non treated vacuum chambers and the two chambers treated with a N_2 discharge.

Nevertheless, the chambers treated with a N_2 discharge and submitted to a beam scrubbing show a faster conditioning compared to the non-treated chambers after an exposure to air and pressure rises are 4 times smaller.

4 CONCLUSIONS

All the measurements are in favour of the electron cloud as the mechanism responsible for the pressure rises in the SPS: pick-ups measure an electron current signal and pressure rises occur only in the presence of LHC type beams. In addition, the behaviour of pressure rises versus bunch intensity is consistent with observations made in other machine (KEKb, PEPII).

The effect of a 50 ns bunch spacing was not evidenced since intensities above the threshold of the electron cloud were not available. But the filling pattern with 12 missing bunches affect the pick-up signals and the pressure rises, which decrease by a factor of 8. The missing train is more efficient in the position 4 than in the position 3. The electron cloud is not suppressed with 12 missing bunches and this is consistent with the measurements of pressure rises and of the pick-ups which show that the electron cloud will need less than 24 bunches to build up for bunch intensities above $6.0\text{x}10^{10}$ p/b.

It appears clearly that the pressure rises decrease with time. This is consistent with a cleaning effect even if it does not imply a measurable modification of the secondary electron yield of the surface. In addition, all the measurements have shown an increase of the threshold bunch intensity from $4.0\text{x}10^{10}$ in August 1999 up to $6.6\text{x}10^{10}$ in June 2000 (data for the field free regions). This threshold increase is a clear indication of a modification of the secondary electron yield of the surface.

Concerning surface treatments against the electron cloud, only a nitrogen glow discharge has been tested in the SPS. To be more realistic, the vacuum chamber was vented to N_2 before installation (30 min.) and was not baked. At the first cycle of experiments no difference between the non-treated chambers and the two chambers submitted to a N_2 glow discharge have been observed. After an air exposure, only the treated chamber seems to have a memory of the scrubbing.

To improve our understanding of the electron cloud, more pick-up devices will be installed and the head of the batch of the LHC beam will trigger their signals. Special pick-ups will be used to study the energy and spatial distribution of the cloud in the vacuum chamber in presence or not of a dipole magnetic field. An in-situ measurement system of the secondary electron yield will be installed in the SPS to study the scrubbing effect.

5 AKNOWLEDGEMENTS

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6 REFERENCES

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