Minutes of the SPS Studies Working Group
(SSWG)

9^{th} meeting 9^{th} October 2001

Present: G. Arduini, V. Baglin, T. Bohl, R. Cappi, P. Collier, K. Cornelis (chairman), B. Dehning, J. Gareyte, N. Hilleret, W. Höfle, M. Jimenez, L. Jensen, L. Jensen, T. Linnecar, F. Roncarolo, G. Rumolo, E. Shaposhnikova, R. Tomas, J. Tückmantel, L. Vos, F. Zimmermann (secretary)

Excused: D. Manglunki, G. Roy

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1 Electron-Cloud Measurements (G. Arduini, M. Jimenez, et al.)

G. Arduini described that this year an electron cloud was observed both with the LHC and the fixed-target (FT) beam. The FT beam consists on 2.9×10^{13} protons distributed over 4200 bunches, spaced by 5 ns with two gaps of 1 μs. This corresponds to about 7×10^{9} protons per bunch. The beam is accelerated to 400 GeV. An electron cloud signal is observed on the strip detector in the last third of the store until the start of extraction.

G. Arduini showed the AEW peak detected signal, which is inversely proportional to the bunch length, and the beam sizes measured as a function of time in the cycle. Combining the data suggests that the electron cloud appears not when the bunch length assumes a minimum, which is at transition, but at the time where the total bunch volume $\sigma_z \sigma_x \sigma_y$ decreases below a threshold value. This might be in contradiction to the simulation, which usually shows a strong dependence on the bunch length, and a much weaker sensitivity to the transverse beam dimensions.

E. Shaposhnikova mentioned that without any instabilities the peak-detected signal should increase towards the end of the store much more than what has been measured.

The dynamic pressure rise seen with the LHC beam, which is ascribed to the electron cloud, is observed in all the SPS arcs, but not in the straight sections.

For the FT beam, the threshold bunch population for electron-cloud build up is about 5×10^{9}. For the LHC beam a threshold of 2×10^{10} was measured on 17/07 and 25/07 (after 7 hours effective scrubbing time). It increased to 3×10^{10} protons per bunch after scrubbing for

16 hours with the LHC beam and 48 hours with the FT beam. The threshold is about 6×10^{10} for an LHC beam with twice the nominal spacing (50 ns), as measured on 10/09. P. Collier pointed out that the three threshold values for 5 ns, 25 ns and 50 ns spacing indicate a linear dependence of the threshold bunch intensity on the bunch spacing.

G. Arduini showed various energy spectra, measured by biasing the strip detector, as a function of time in the cycle and the dipole magnetic field. The maximum electron energies detected were of the order of 100 eV. There usually was a dominant component of electrons of energy less than 20 eV. A higher magnetic field cuts the low-energy component, which may be an artifact of the detector.

In one example measurement, two strips were observed, which merged into a single strip later during the store. G. Arduini suspected that the disappearance of the two separate strips had been due to transverse beam blow up.

Energy spectrum measurements by the strip detector for the 50-ns spacing at intensities well above the threshold (up to 9.7×10^{10} per bunch) show maximum energies of only 20 eV.

K. Cornelis suggested to study the time structure between bunches for different electron energies (bias voltage), using the strip detector and a spectrum analyzer. N. Hilleret mentioned that electrons with less than 20 eV energy cannot explain the process of electron multiplication. Responding to a question by T. Linnecar, G. Arduini answers that no blow up had been observed for 50-ns spacing with a bunch population of 9.7×10^{10}.

For the 25-ns LHC and the 5-ns FT spacing, using the strip detector, maximum electron energies of 150 and 120 eV were detected, respectively. The elecron energy decreases when the beam blows up. A larger signal is observed at lower field. G. Arduini argued that this could be instrumental, and he compared the size of the holes in the vacuum chamber (2 mm diameter) with the cyclotron radius for 10 eV and 100 eV and various fields. For example, the cyclotron radius of a 10-eV electron at a field of 110 G is about 1 mm. However, the relation between normal and transverse momentum components is not measured. F Zimmermann suggested that the ratio of these two momenta can be estimated from the ratio of the vertical chamber height to the width of the (single) strip or, if present, to the distance between the two strips.

G. Arduini showed an intriguing example of local cleaning. When the beam was moved across the chamber, the electron signal disappeared in the central region, but it was clearly visible on either side of the centre. K. Cornelis stressed that the local variation of the secondary emission yield as a function of horizontal position adds a complication to the analysis of the data and to the comparison of the measured energy distribution, strip widths and strip locations with simulations.

M. Jimenez mentioned that the secondary emission yield was measured in situ and has decreased from an initial value of 2.3 to 1.8 presently.

G. Arduini then presented measurements of the electron signal as a function of magnetic field, for various intensities. The electron signal increases strongly between 2×10^{10} and 3×10^{10} protons per bunch, but for higher intensities it hardly changes. In most cases, the signal disappears at zero field. However, also 4 measurements were taken at zero field and 5×10^{10} protons per bunch (with 25-ns spacing), in which a residual signal was detected. In at least one case, the electron-strip detector signal indicated significant oscillations of the magnet power converter near zero field strength.

Concerning future measurements, G. Arduini proposed to more precisely determine various parameter dependences of the threshold, and to upgrade the electronics of the strip monitor so as to be able to take turn-by-turn data, and thus, *e.g.*, to observe the influence of bunch-shape oscillations. The bunch length and transverse emittance are two important parameters whose effect has not been sufficiently examined so far. Also the electron-cloud evolution along several subsequent batches should be studied more thoroughly. An attempt should be made to increase the bunch intensity under controlled conditions. Local scrubbing could be explored with the FT beam, by varying the orbit bump amplitude and the magnetic field.

As for the beam instability, K. Cornelis showed an FFT tune spectrum revealing 4 or 5 synchrotron sidebands, *i.e.*, evidence for head-tail modes, possibly driven by the electron cloud. These data were taken with an increased rf voltage. Raising the chromaticity such that the chromatic tune spread overlapped the sidebands suppressed the instability.

The question was raised whether 75 ns spacing is still an official option for LHC. The tentative answer was yes.

M. Jimenez started his presentation by comparing the beam conditions of this run with those last year. The beam intensity distribution in 2001 is quite different from that in 2000, with perhaps half the beam intensity. This might explain possible discrepancies in the scrubbing behavior. K. Cornelis pointed out that the threshold of multipacting was lower this year as well. In any case, the scrubbing effect that was seen in 2001 is still consistent with that presented in Chamonix 2001 for the 2000 run, *i.e.*, 7 hours of scrubing does not lead to a detectable change in the multipacting threshold.

M. Jimenez then presented several example measurements from the strip detector, illustrating the effect of the bunch length and of the dipole field.

He pointed out an important difference between the strip detector and the triangle detector. To measure the electron energy distribution, in the first case, the vacuum chamber is biased with a positive voltage, while the detector strips located above are on ground potential. The consequence is that secondary electrons emitted from the strip detector are accelerated towards the vacuum chamber, which can result in a negative current on the strip detector, possibily annihilating the signal. By contrast, the triangular detector employs an additional filtering grid, installed between the chamber and the detector plate. The chamber and the detector are both kept on ground potential, while a negative bias voltage is put on the grid. In this configuration, any electrons emitted from the triangular detector are repelled by the grid and return to the detector.

The difference in the polarity of the bias voltage may explain the completely different energy distributions detected by the two monitors. The energy distribution from the strip detector is concentrated at very low energies (a few eV), whereas the energy distribution from the triangular detector has an average value of about 75 eV, and a maximum value of 300 eV.

The electron stimulated desorption coefficient increases strongly with electron energy. It is almost insignificantly small at energies of a few eV. M. Jimenez emphasized that only the energy distribution measured by the triangular detector is consistent with the observed pressure rise. He proposed to add a filtering grid at negative bias voltage to the strip detector, for next year. While the triangle detector can detect the energy distribution, it presently does not well measure the spatial distribution of the cloud. One reason is the large width of the electron strip; the other is the huge transparency of the vacuum chamber of 42% chosen for this detector, which easily suppresses the cloud build up already for moderate magnetic fields. Consistent with the strip detector, the triangular detector does not show any signal for zero field.

The measurements with the strip detector confirm the prediction that electron build up can occur in the vicinity of the inner layer of the LHC pumping slots.

M. Jimenez proposed to devote the next measurements with high priority to studies of the heat load (calorimeter, energy distribution) and beam scrubbing. Desirable conditions are highest possible intensities, $> 5 \times 10^{10}$ per bunch, a high duty cycle, a large number of batches, and adequate beam time.

He presented a table indicating a possible scaling from the measured heat load, scrubbing, dynamic pressure, energy distribution, and spatial distribution to the LHC situation.

V. Baglin explained that the minimum demonstrated resolution of the calorimeter is about 0.1 W (actual value, *i.e.*, without correction for duty cycle and SPS filling factor). So far no clear signal has been seen with the beam. N. Hilleret mentioned that even heat loads below the minimum detectable value for the past beam conditions may be intolerably high if extrapolated to the LHC. Both V. Baglin and F. Zimmermann recalled that the scaling with bunch intensity is not linear. A higher beam current or duty cycle appears to be needed in order to measure the heat load in the SPS. A dedicated MD might be the only chance. A measurement of the SPS heat load would yield a useful reference for comparison with simulations, and possible extrapolation to the LHC.

G. Arduini suggested to bias the strip detector with a negative voltage, in order to assess the importance of secondary electrons re-emitted from the Copper strips of the detector. He and K. Cornelis also mentioned that a bunch-to-bunch measurement of the strip detector signal would allow us to directly observe the decrease of the electron cloud between batches.

For this year, two long MDs are left, and two weeks of parasitic MDs.

2 Next Meeting

The next meeting of the SPS SWG is tentatively scheduled for Tuesday, 23rd October, at 09:15, in Room 865-1D17. 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, 10th October 2001