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High Resolution Measurements of Lepton Beam Transverse Distributions with the LEP Wire Scanners.

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Abstract

A large number of improvements were carried-out on the LEP Wire-Scanners in preparation for the 1992 running period. They include modifications of the monitors mechanics to decrease the vibrations and the heating of the wire by the beam generated electromagnetic fields, improvements of the detector chain and a software re-organization at the various levels for better noise rejection, improved user interface and "off-line" data analysis capabilities. It is now also possible to acquire the profiles of each of the sixteen circulating bunches, electrons and positrons, during the same sweep. As a consequence of these actions the quality of the collected data is much improved. The results are presented and discussed.

I. INTRODUCTION

Four wire-scanners are installed in LEP straight section 1 [1] to provide transverse distributions in both horizontal and vertical planes. Figure 1 gives the lay-out of the monitors together with their associated detectors.



Fig 1: The LEP Wire-Scanners arrangement and Optics Parameters

One horizontal and one vertical monitor are symmetrically installed and are each associated with two detectors:

-a scintillator located behind a thin window, 75 meters downstream of the wire, receives the Bremsstrahlung resulting from the beam-wire interaction emitted at small angles (S.A.). It acquires the scan of the associated beam (i.e. e- profile from the monitors located on the e- injection side).

-a scintillator installed against the vacuum chamber near to the horizontal monitor collects the emission at large angles (L.A.) during the passage of the counter-rotating beam.

The signal received by the S.A. scintillators [1] is attenuated by 4 orders of magnitude before transmission to a photo-multiplier which has a gain 100 times smaller than that of the L.A. detectors.

II. THERMAL AND MECHANICAL OBSERVATIONS

Fourteen wires have been destroyed from 1989 to 1992, most of them in 1989 and 1990. With the exception of two 50 μ m Beryllium wires, they were 36 μ m thick carbon wires. The Be wires showed clearly [1] that the wire had melted over its full length, excluding beam energy deposition as the only destruction mechanism. This is confirmed by previous measurements at the SPS where the wires survived higher intensities at comparable speeds. Moreover, permanent wire average temperature monitoring has shown several interesting features (Figure 2):



Fig. 2: Long term recording of wire resistance (temperature) and beam current with wires retracted in the parking position

The temperature of the wires increase with the stored current and the vertical wires temperature increases less than that of the horizontal ones. This indicates that the heating is of electromagnetic origin, due to the wake fields generated in the wire scanner tanks. The vertical wires heat up less because they are retracted in a rectangular tube functioning as a waveguide below cut-off. The second evidence in favour of electromagnetic heating is the fact that the wire temperature changes when beam manipulations modifying the bunch length take place at constant circulating beam intensity. Finally wire temperature recordings during scans provide other evidence of heating by electromagnetic coupling (Figure 3).



Fig. 3: Wire resistance change during scans of 300 μ A on 300 μ A circulating beams. Calculated temperatures are indicated.

As the wire approaches the beam, a temperature increase starts at approximately 40 mm from the beam centre, mainly due to coupling to the electric field. A steady state temperature is reached again when the wire is far from the beam. This results mainly from the magnetic field created by the beam passing in the loop formed by the wire and the supporting fork. The temperature increase of the horizontal and vertical wires is inconsistent, the latter being too low compared to the former. Laboratory tests have shown that thermoemission starts at around 1000°C and shifts the resistance temperatures. towards lower equivalent measurement Electromagnetic heating of the wire being established, the fork construction was analysed for possible improvements. A coupling capacitance of a few pF was found between the wire and the fork; this was created between the aluminium arm, the wire supporting aluminium piece and the ceramic insulator (Figure 4). Two different types of supporting forks were installed in early 1991. The first design had a modified wire support piece and ceramic transition pieces to decrease the coupling capacitance (Figure 4).



Fig. 4: Wire supporting fork with original (top) and modified (bottom) wire holding and ceramic isolating pieces.

A second design was implemented with the whole supporting tubes made of ceramic. In 1992, the wire length of the combined aluminium/ceramic forks was reduced from 55 to 29 mm. The vertical wire with this design broke twice in 1992. The temperature recording of the first incident showed that it happened at a circulating current of 2.8 mA; the temperature reached was 1280° C, uncorrected for thermoemission. For 1993, a 30 μ m quartz wire has been installed in place of the broken wire. The quartz wire will definitely break any current loop leading to heating but it may experience high voltage breakthroughs when passing through the beam. Since 1991, no wires with full ceramic arms were broken.

Scans taken in 1991 and 1992 are affected by a shift of the beam centre of charge between the IN and OUT directions of the order of 100 μ m. Laboratory tests have shown that it is due to an inertia induced movement of the driving screw [1]. This effect could be reduced in the laboratory from 70 to 10 μ m by using a counter-pin pushing on the free end of the driving shaft. This modification could not be implemented for the 1993 LEP start-up.

III. LOW LEVEL AND APPLICATION SOFTWARE

The basic software design used in 1992 was unchanged from 1991. Amongst the various data structures exchanged between the local equipment server and the application, the PROFILE structures (one per profile) hold all the signals relative to a given bunch received from the photo-multiplier. If their initial analysis (sigma processing within the server) is successful, these data are trimmed to \pm 4 sigmas; otherwise the entire profile is stored for more detailed "off-line" analysis. An analysis failure usually occurs when all signals are hidden within the noise. However, even with a good signal level the fit results (mainly the standard deviation) are noise dependent. In order to cope with this, two different methods have been tested :

- a simple rms calculation over the whole profile followed by a second iteration over a limited window

- a more refined gaussian fit providing a chi-squared minimization on all data above 10% of the maximum amplitude.

The later technique is less noise sensitive but is also less accurate when the distribution is not gaussian. For the future runs the results of both the rms processing and the gaussian fit will be forwarded to the application for systematic comparisons.

The application interface has also been upgraded for 1993 owing to the availability of more powerful graphic tools. It will be possible to display simultaneously up to eight circulating bunch profiles (of the same beam or of the two e+/e- beams) and to display IN and OUT profiles relative to a given scan on the same plot. These modifications added to better "off-line" analysis facilities will ease the interpretation of results.

IV. RESULTS AND DISCUSSION

A scan is systematically performed in the IN(beam) and OUT(of beam) directions. As a result, two profiles are measured and can be compared each time a sweep is triggered in a given plane. The wire position (x axis) is in millimeters whereas the y scale unit is arbitrary and depends on the monitor gain setting.

HORIZONTAL PLANE:

In this plane the signal received by the S.A. detectors is excellent and provides good gaussian fits of the bunch profiles. This is illustrated on Figure 5 in the case of a positron bunch analysed with the monitor located on the positron side. Standard deviations from both scan directions are in agreement within +/-1.3%.



Fig 5: IN and OUT profiles and fit results of a positron bunch scanned with the He+ monitor and analysed with the S.A. detector at the window

Another S.A. detector (chateau) located fifteen meters downstream from the Bremsstrahlung radiation extraction window was also used in order to investigate eventual acceptance problems and effects of background close to the vacuum chamber. This detector was shifted radially which gave better shielding. Its response is given on Figure 6 for the same bunch.



Fig 6: IN and OUT profiles and fit results of the same bunch from the S.A. detector located 15 meters downstream from the window

Between the IN and OUT directions the agreement is +/-2% and both S.A. detectors give the same standard deviation within +/-2.1%

The response of the L.A. detectors is less good. The signal to noise ratio at large angle is less favourable and a compromise must be found between the shielding depth protecting the scintillator from background and the signal level to be analysed. In order to reduce the background noise 10 mm of Lead was necessary. However some saturation then started to affect the photomultiplier in the peak region (Figure 7)



Fig 7: IN and OUT profiles and fit results of the same bunch scanned with the He-monitor and analysed with the L.A. detector.

The fit results provided by both directions agree very well but lead to standard deviations 5% higher than the S.A. detectors. The different average positions indicate that the beam trajectory is different at the e+ and at the e- monitors.

VERTICAL PLANE :

Typical profiles performed using the vertical monitors are shown on Figure 8 for the S.A. detectors.



Fig 8: IN and OUT profiles and fit results of an electron bunch scanned with the Ve- monitor and analysed with the S.A. detector at the window.

Vertical profiles are usually affected by blow-up effects resulting from Coulomb Scattering of the beam through the wire. Taking the emittance ratio in LEP and the present monitor performances these effects can now be neglected in the horizontal plane at 46 GeV. They dilute mainly the second half of the vertical scan (positive and negative sides for respectively the IN and OUT directions) as can be seen on Figure 8. Hence, a direct gaussian fit provides a too pessimistic result. By modelling this effect and analysing the nonperturbed halves of the IN and OUT profiles [1], it is possible to reconstruct the initial distribution. An example of the results is given on Figure 9. A reduction of the rms value by 10% to 20% is then observed with respect to the fit of the entire measured distribution. However this method still suffers from the random mechanical effects (section II) and from timing imprecisions. Therefore it cannot be used systematically.

The L.A. detectors suffer from a lack of signal in the case of vertical profiles as they are located near to the H monitors (Figure 1) five meters downstream from the vertical ones.



Fig 9: Initial distributions from IN and OUT profile analysis : +: IN direction, •: OUT direction, -----: fitted profile.

The gaussian fits of profiles from the S.A. detectors provide emittance values of 0.9nm to 1 nm in the vertical plane and 14nm to 15 nm horizontally. The precision achieved is a few per cent in the horizontal plane. Vertically the results are not so accurate as long as blow-up effects are not properly eliminated.

V. COMPARISON WITH S.R. MONITORS

These figures, can be used to calibrate the U.V. telescopes [2]. The agreement between the two devices is disturbed by parasitic effects which must be considered; they are at locations in the machine where the optics are not the same and where beam dynamical effects are different (for example coupling). This can account for discrepancies of around 20%. Some 50Hz noise also disturbs the two devices differently as they have different modes of acquisition

VI. FUTURE UPGRADES AND CONCLUSION

Several steps will be taken to improve wire-scanner performances in addition to the ones discussed in section II. The mechanics will be modified to reduce the shift between the two directions. It has also been considered to add to each monitor a wire rotated by 45 degrees. This will allow a better evaluation of the tilt effects. The electric noise level will be reduced in the wire scanners environment by installing filters on adjacent motorised devices. These improvements are foreseen for the 1994 runs. Both the S.A. and L.A. detectors have been modified. The former will have a better acceptance in particular close to the vacuum chamber whereas the shape of the later has been reconsidered to increase its acceptance and hence have better signal to noise ratio.

Several software modifications will be implemented apart from the availability of the new application (section III). An interlock will prevent any scans above a given circulating beam current and temperatures will be systematically recorded during wire sweeps. The timing will be upgraded so as to lower the uncertainty in the absolute position reference between IN and OUT scans from 50 μ m down to 10 μ m (rms). The wire status will also be monitored in permanence.

Resulting from these modifications we expect to have the same level of performance in both the horizontal and vertical planes.

VIII. REFERENCES

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