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Use of the PS Fast Wire Scanner during the LHC Test Beam Machine Development of December 1993

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Preparation of the system for the MD session

The first generation of fast wire scanners was installed on the PS in 1985 in SS 54 (horizontal plane measurement) and SS 89 (vertical plane measurement). They were used with success for many years, mainly for the p-pbar runs. However, they were limited in intensity and the wire lifetime was short. An improvement project was launched in 1991 to overcome these weaknesses. Two new devices were installed in SS 64 (horizontal) and 75 (vertical) in April 93 in view of their use during the LHC test in December. First experimental measurements were done in August 1993 and a local control version was tested in September. Position calibrations were made in October and introduced in the software in November. At the beginning of that month, a mechanical breakdown occurred on unit 64, in vacuum. The unit was disabled and replaced on November 18. Two days later, the downstream scintillator in the same straight section came in contact with the vacuum chamber bellows and created a short-circuit. This resulted in a vacuum leak, which was repaired temporarily with putty since a more serious job would have taken too much time. As it was considered risky to pulse the unit near the provisional repair, it was disabled to avoid jeopardising the Physics program. Tests and improvements continued with the vertical device 75, but no position calibration with beam displacement and comparison with frequency and pick-ups could be done. The LHC type beam MD started on December 3 and on the 6, unit 64 was put back into service. Measurements started immediately with the old and new systems. The next day, the old horizontal beryllium wire of SS 54 broke. It was replaced the following night, but the beryllium spare did not hold long and a thinner carbon wire was mounted instead. The interaction with the beam was thus decreased and the horizontal profiles could not be measured at injection with the old system. Some comparison measurements were done with the old and the new system but most MD measurements were done with the new one. The Equipment Module was not implemented yet, so that the application program could not be used for measurement requests. But it could read and display the files stored at each measurement, which was very useful. Correction for momentum dispersion was introduced, giving the mono-energetic emittance once a $\Delta p/p$ is entered. An improvement was added on December 10 to allow series of measurements. When the session ended on December 17, more than 1300 measurements had been made with the two new wires.

Expected precision

Calibrations were carried out last October with a spare unit on a bench at the lab with a laser beam displaced mechanically with great precision. Correction tables were established for each of the three wire velocities available and the two directions. They correct the positions obtained from the angle resolvers and the formula which takes into account the geometry of the mechanics. At the same time, the error for a small beam was estimated provisionally to be ± 3 %, contributing to the error for the corresponding emittance by ± 6 %. Another cause of error is the uncertainty on the β function. It is calculated with the MAD modelling program. A third limit on precision, the photo multiplier non-linearity, was found to be negligible during calibration measurements with beam.

Comparison between old and new systems

On December 8 and 9, several simultaneous measurements were made on the same cycle and timing with the old and new devices. The results are listed in table 1.

Date	Plane	Timing	Energy	Old wire ε	New wire ε	Diff.
8 December	Vertical	C225	1.4 GeV	7.8π	8.4π	8%
9 December	Vertical	C220	1.4 GeV	4.8π	4.6π	- 4%
9 December	Vertical	C1400	1.4 GeV	6.03π	5.84π	- 3%
9 December	Horizontal	C2400	26 GeV/c	.57π	.52π	- 9%

Table 1: Emittances from old and new Wire Scanners (2σ emittances in μrad, no Δp/p correction).

Note that the old system had not been calibrated since its installation in 1985.

Comparison between back and forth measurements

The system allows to measure the beam twice on the same cycle on back and forth movements of the wire. Table 2 shows some of the recorded results, all measured on the injection front porch.

Date	Injection energy	Plane	Forward		Backward	
			Timing	ε	Timing	ε
9 December	1.4 GeV	Vertical	C220	2.75π	C1400	3.35π
9 December	1.4 GeV	Vertical	C220	2.48π	C1400	3.39π
9 December	1.4 GeV	Vertical	C220	2.53π	C1400	4.63π
9 December	1.4 GeV	Horizontal	C220	4.63π	C1400	3.87π
9 December	1.4 GeV	Horizontal	C220	4.58π	C1400	4.31π
13 December	1 GeV	Vertical	C220	3.84π	C320	4.79π
13 December	1 GeV	Vertical	C220	3.72π	C320	4.48π
13 December	1 GeV	Horizontal	C220	6.64π	C320	5.72π
13 December	1 GeV	Horizontal	C220	6.94π	C320	7.36π
13 December	1 GeV	Horizontal	C220	6.89π	C320	6.51π

Table 2: Emittances from back and forth measurement (2σ emittances in μrad, no Δp/p correction).

One notices that on the low energy front porch, there is a systematic blow-up of the vertical emittance and a decrease of the horizontal one. This was observed during a good part of the MD session and is very likely due to coupling between the two planes [2]. The horizontal and vertical Q values were set and measured to be near each other.

The expected blow-up by Coulomb scattering is, under these conditions (wire velocity of 20 m/s and 30 μm carbon wire): .07 π μrad at 1.4 GeV and .11 π μrad at 1 Gev. It is small compared to the observed differences between forward and backward sweep.

Comparison with the SEM-grids

During the ten days of the session, sets of measurements were made with four different profile measurement devices, namely: the Beam Scope in the PSB, the PS injection SEM-grids, the fast wire scanner at four different timings of the cycle (start of flat top at C220, end of flat top at C1400, soon after transition at C1620 and high energy at C2397) and finally the TT2 SEM-grids.

A more complete account of the results will be published in a PS divisional report [2] describing and discussing all the measurements in detail. As an illustration of how the results of the wire agree with the other PS emittance results, we give here (figure 1) one set of measurements [3], taken with 1.4 GeV injection and constant machine conditions. They are labelled on the curves according to table 3.

1 SEM-grid PS	1.4 GeV Injection
2 PS wire C220	1.4 GeV start flat top
3 PS wire C1400	1.4 GeV end flat top
4 PS wire C1620	3.5 GeV/c
5 PS wire C2397	26 GeV/c
6 SEM-grid TT2	26 GeV/c

Table 3: List of measurements made during the MD session with the labels used on the graphs.

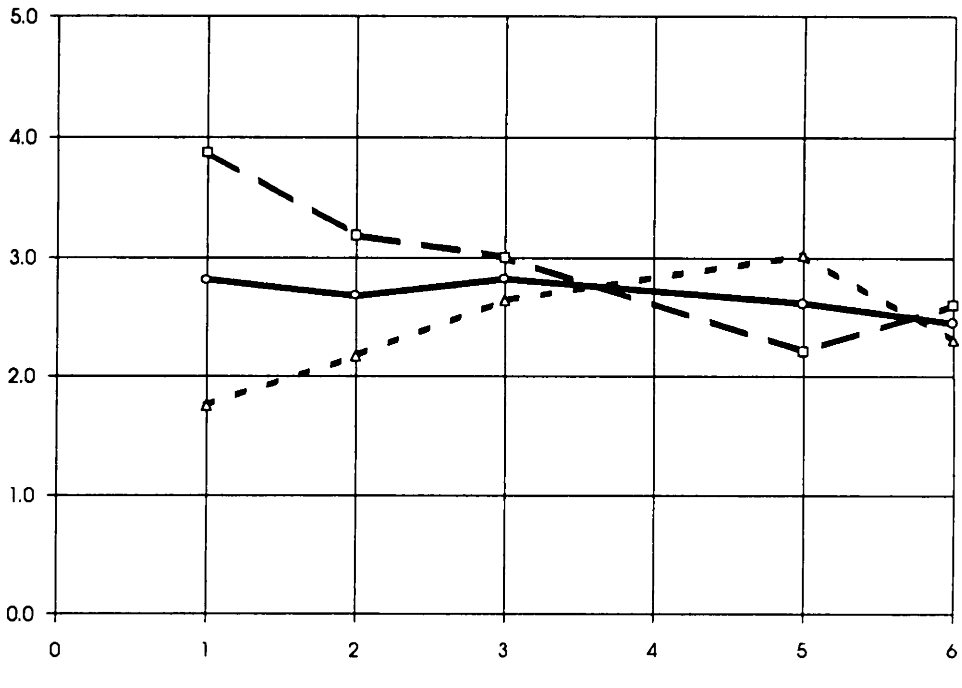

Figure 1: Mean normalised emittances of the "ultimate" LHC type beam (1.8 10^{12} protons/bunch). PS injection kinetic energy is 1.4 GeV. Dotted line stands for ε_y^*, broken line for ε_x^*, continuous line for $(\varepsilon_x^* + \varepsilon_y^*)/2$. All emittances are for 1σ, normalised, expressed in π μrad, after Δp/p correction.

We do not intend to enter into a full discussion of these measurements. However, it seems likely that coupling between planes is, again, the explanation for the apparent "exchange" between horizontal and vertical emittances. Conservation of $1/2(\varepsilon_h^* + \varepsilon_v^*)$ checks rather well between all devices.

In fact, among all measurements taken during the session, some do not agree so well. The discrepancies are not necessarily the fault of the instruments. They may be due to special beam conditions (instabilities, coupling etc...) or specific measurement causes as, for instance, the use of an erroneous value of $\Delta p/p$ for the dispersion correction [2].

Most of the profiles taken were clean and symmetrical. Figure 2 shows, as a typical example, a double vertical profile (back and forth) where emittance blow-up is apparent on the injection front porch during the 1 GeV injection operation.

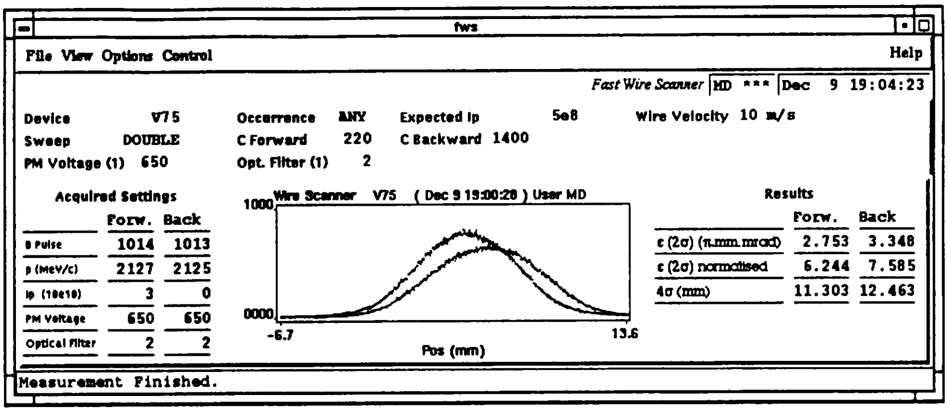

Figure 2: Display of the application program window on Work-station. The 2 vertical profiles correspond to the measurement quoted in the first line of table 2.

Conclusion

After the two accidents of November, the use of the new PS wire scanner during the LHC type beam MD session of December 93 was a success. No breakdown occurred during more than 1300 measurements. Apart from a few still not fully explained results, agreement is good with the other means of emittance measurements, namely the old wire scanner, the injection and TT2 SEM-grids. In fact, the extreme beam conditions of such a machine development session do not allow direct cross calibration of the various emittance measurement devices. We still have to further assess our system with well known stable beam conditions. We will also improve its precision, with position calibrations of each unit. However, we already have great confidence in the value of the tool and in its improved reliability as compared to the first generation wire scanner.

References

[1] Minutes of the meeting of 11 November 1993 on the PS Fast Wire Scanner project. PS/OP/Note 93-73 (Min)

[2] PS divisional report, to be published

[3] Private communications of the measurements and compilations kindly supplied by R. Cappi, M. Martini, J.P. Riunaud and B. Vandorpe.

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