A Comparative Study of Fast Wire Scanners, Beamscope and SEM-Grids for Emittance Measurements in the PS Booster

M. Arruat, C. Carli, A. Jansson, M. Lindroos, M. Martini, J. Olsfors, U. Raich, H. Schönauer
PS Division CERN

Abstract

The tight emittance budget, imposed on the production of the high-brilliance beams in the LHC preinjectors, demands the elimination of all possible sources of beam blow-up. A prerequisite for this is reliable instrumentation and evaluation methods for comparison of their data. We have made a study of three methods for emittance measurement in the PS Booster: fast wire-scanners, BeamScope, and SEM-grids in a measurement line. For the fast wire-scanners, a full Monte-Carlo simulation was made of the beam-wire interaction, for an energy range from 100 MeV to 1 GeV, and compared to measured values. Data from a scraping method (BeamScope) are compared to profile measurements, using Abel-type integral transformations. Results will be presented.

Introduction:

The high brilliance LHC beam has to be transferred between the injectors with a maximum emittance blow-up of 10%. To achieve this it is necessary to have precise and comparable instrumentation. In the PS Booster (PSB) emittance is today measured with a scraping method (the BeamScope) and in a measurement line equipped with three SEM-grids. In the CPS emittance can either be measured with fast wire scanners or with SEM-grids positioned in the ring. In addition the transfer line to the SPS is equipped with three SEM-grids. For the LHC era it is intended to equip the for parallel PSB rings with fast wire scanners for measurements in both planes. Presently, a prototype wire scanner is installed in PSB ring 1 in the vertical plane. We will in this paper discuss comparative measurements in the PSB , the PSB measurements line and the CPS with existing instrumentation.

Comparison of Methods

In order to calculate beam emittances the variance of the beam profile is used in conjunction with knowledge about the accelerator optics at the position of the detector. SEMgrids and wire scanners measure beam intensities at various transverse positions of the beam. A mathematical method avoding strong influence of non zero baseline and noise in the tails of near gaussian distributions is used to extract the rms width from SEMgrid and wire scanner profiles [Koz74].

SEM-grids: Since SEMgrids consist of a limited number of wires or metal strips the position resolution is rather limited (typically ~ 1mm). The positions are given by the wire position while the beam intensity is measured by means of secondary emission. The mathematical treatment of the raw data contains: suppression of bad wires, determination of baseline, spline fit or gaussian fit, calculation of variance[Mar].

Wire Scanners: The Booster wire scanner mechanics consists of three parts, i) an electric motor with a crankshaft and a connecting rod ii) a push-pull device connecting the motor in the air to the fork in vacuum by bellows and iii) the U-shaped fork with the wire stung between the prongs and hinged along the axis of its base. A resolver is connected to the motor measuring the angular position from which the linear position of the wire can be deduced by geometrical considerations. As compared to the SEM-grids the spatial resolution is very much improved using a high sampling frequency for the resolver (<0.1mm). The beam intensities can either be obtained through secondary emission from the wire or by observation of secondary particles with a scintillation detector. Again the baseline is determined and the variance extracted from the profile. A detailed discussion of the fast wire scanners in low energy accelerators can be found in [elm97]

BeamScope: The…

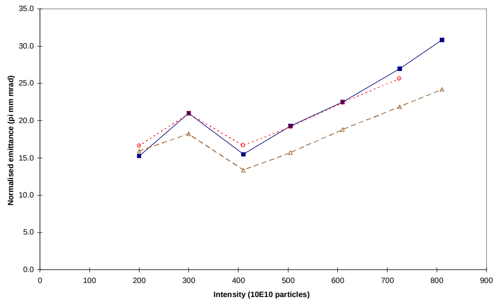
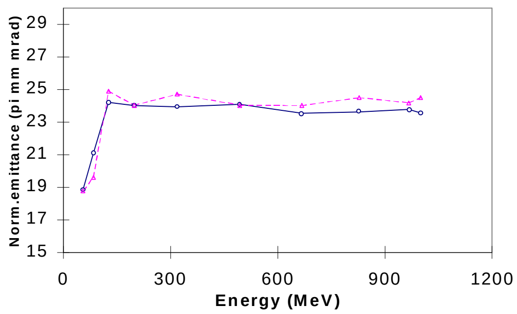
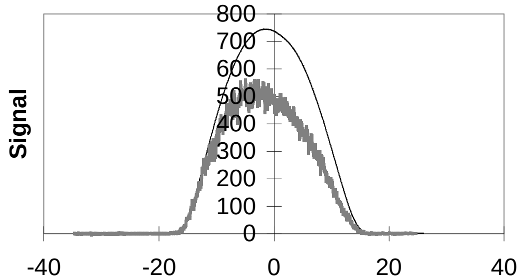


Figure 1
Normalised emittance in the PSB at different energies measured with the Wire scanner using the scintillator signal (circles), a three SEM-grid system in the PSB measurement line (squares) and the BeamScope (triangles). The measurements at 200 $10^{10}$and 300 10^{10} particles in the ring were done without Q-strips (Q-tuning power supplies) which explains the relatively larger emittance at these intensities compared to measurements at higher intensities.



Normalised emittance in the PSB at different energies measured with Wire scanner using the scintillator signal (triangles) and the secondary electron emission signal (circles). The emittance increase at low energies is expected.

Figure 3
Profiles measured with the Wire scanner at 50 MeV in the PSB with 400 1010 particles in the accelerator. The grey profile is recorded using the scintillator signal and the black profile is recorded with the secondary electron emission signal. The measurements were done on consecutive machine cycles. The asymmetry in the grey profile is due the asymmetric



secondary particle shower combined with geometric effects in the detector-wire set-up.

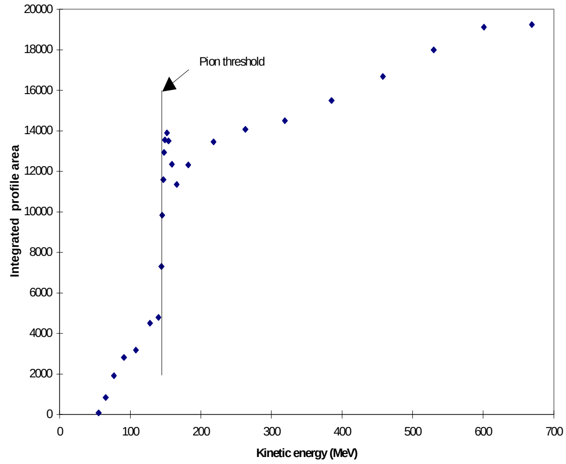


Figure 4
The integrated profile area for a fixed photo multiplier voltage as a function of the primary proton beam energy. The sharp increase in secondary particle intensity at approximately 150 MeV is due to the fact that there is sufficient enrgy in the centre of mass system to produce pions above this proton beam energy. The peak in intensity just after this threshold is probably due to Nuclear effects (see e.g. ref 2)

[elm97] P. Elmfors, A. Fasso, M. Huhtinen, M. Lindroos, J. Olsfors and U. Raich, Wire scanners in Low energy accelerators, CERN internal note: CERN/PS/OP Note 97-14 and accepted for publication in Nucl. Instr. and Meth. B.