Performance Assessment of Wire Scanners at CERN

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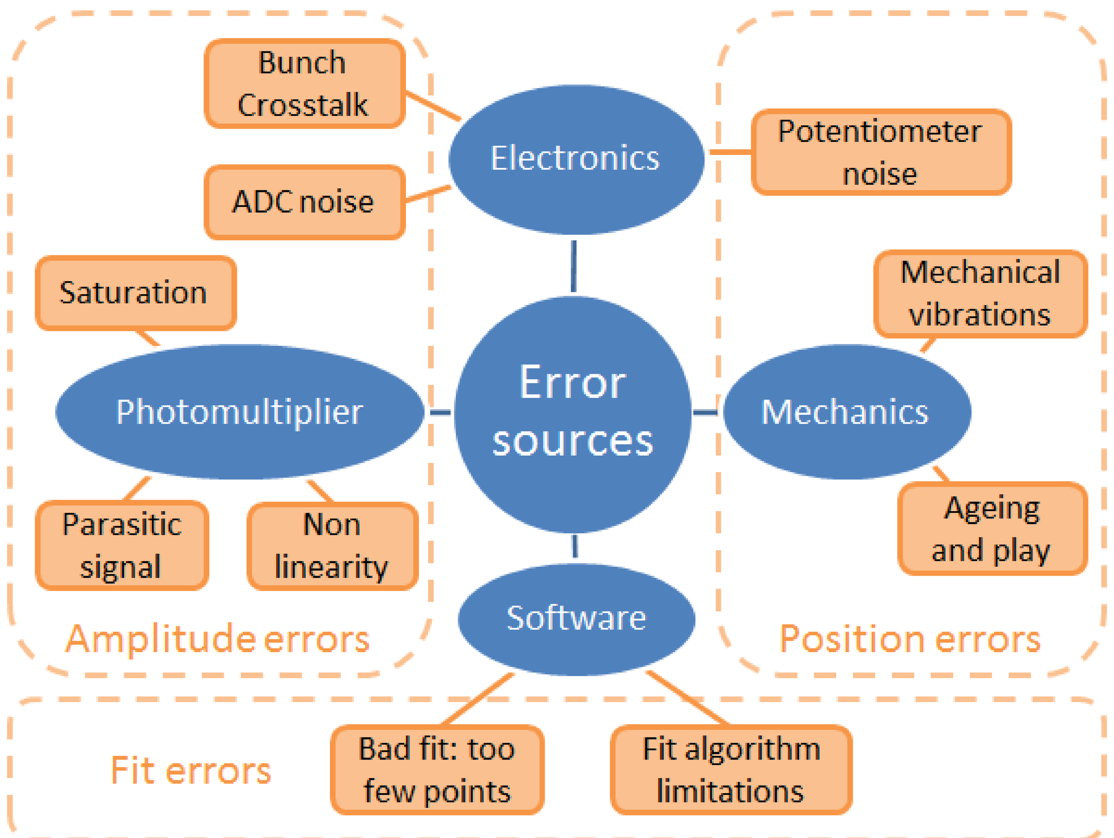
Abstract

This poster describes the current fast wire-scanner devices installed in circular accelerators at CERN with an emphasis on the error studies carried out during the last two runs. At present the wire-scanners have similar acquisition systems but are varied in terms of mechanics. Several measurement campaigns were performed aimed at establishing optimal operational settings and to identify and assess systematic errors. In several cases the results led to direct performance improvements while in others this helped in defining the requirements for new detectors.

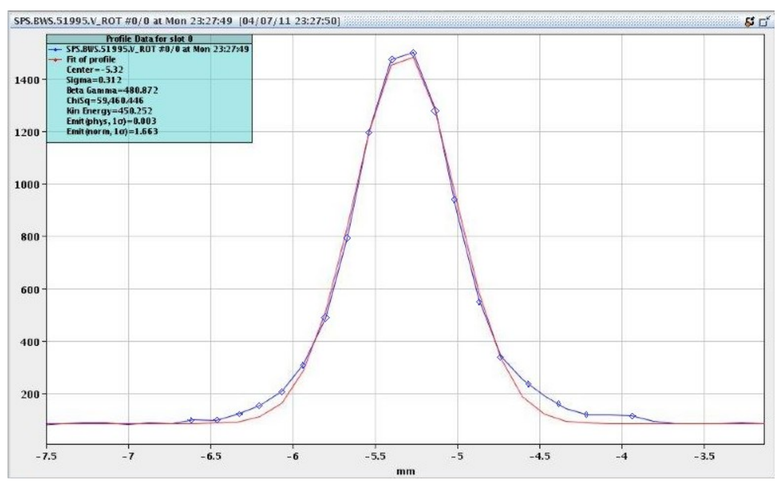
Error sources in wire scanners



Wire scanners output measurement is the beam width, expressed as the standard deviation of the beam Gaussian profile σ_{beam}.

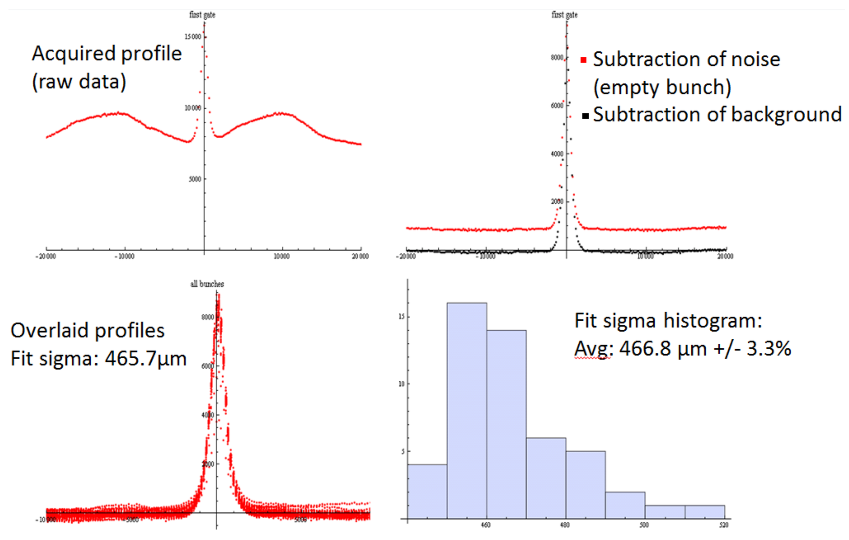
Error sources in wire scanners have various origins and will influence in different ways the determination of σ_{beam}, by adding position errors, amplitude errors, or by creating conditions under which the fitting algorithm will perform poorly.

Fit errors



SPS beam profile fit with less than 3 points per σ

(estimated σ is 312 μm while steps are 120 μm)



Bunch overlaying and associated data pre-processing

Fitting process biggest issue is having too few points in the Gaussian profile to obtain good result.

Experience shows that fitting algorithms need at least 3 points per σ of the Gaussian curve to perform well.

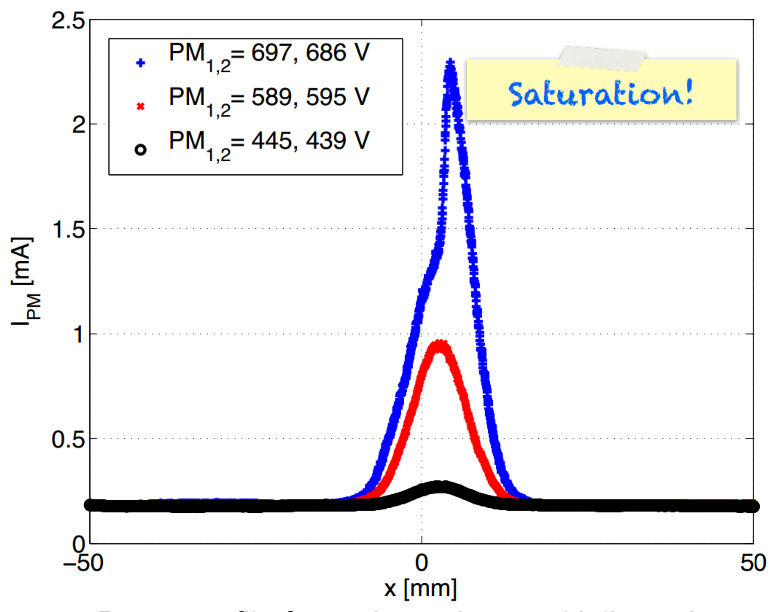
A solution to have more points is to use bunch-by-bunch acquisition to construct a profile by overlaying all bunches, correcting them for noise and offsets, and taking into account the motion of the wire between turn-by-turn position acquisitions.

Amplitude errors

Photomultiplier saturation

Saturation of the photomultiplier is currently the biggest issue for wire scanner performance.

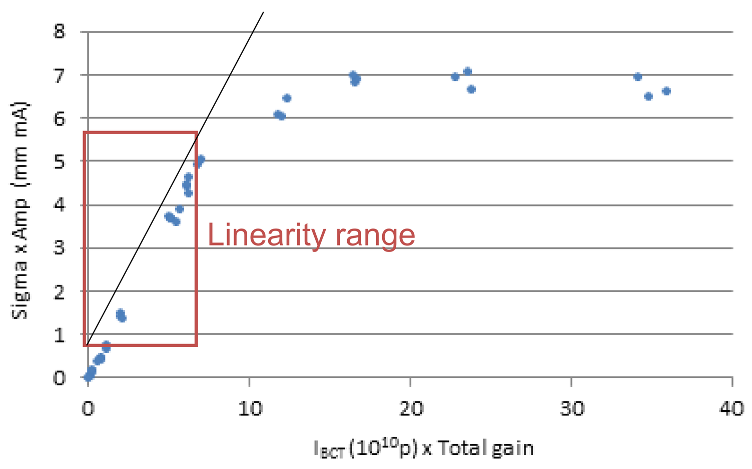
It occurs when incoming light intensity is too high, and all local charges of the supply capacitors are consumed in a few μs. This may create distorted profiles:



Beam profile for various photomultiplier gains

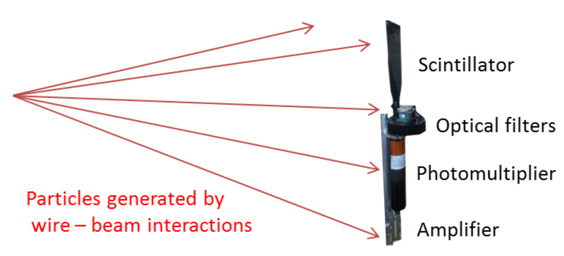
Unfortunately, the saturation of the photomultiplier is not always easy to see on beam profiles as on the one used as example.

Some studies needed to be carried out to determine limits of linearity with respect to beam intensity and total gain of photomultiplier.



Photomultiplier intensity response (in PSB)

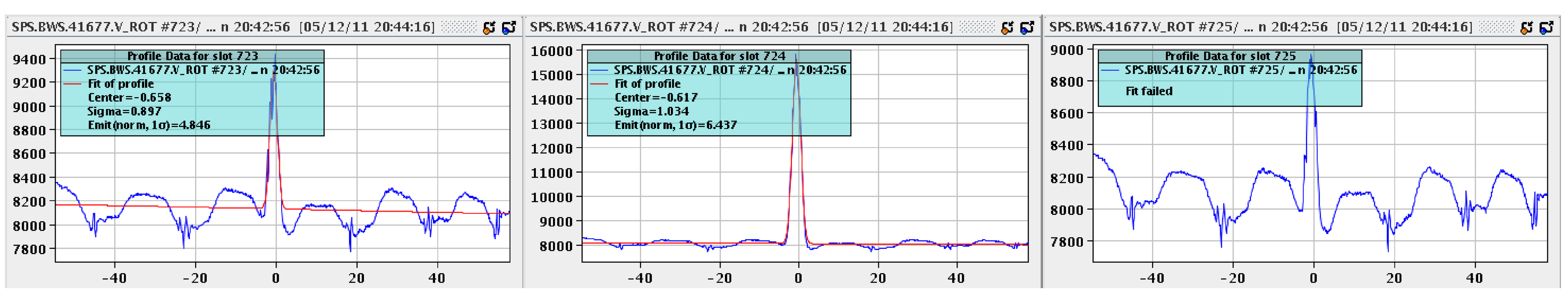
Parasitic photomultiplier signal



Secondary particle shower have a direct impact on the photomultiplier, by adding to the signal received by scintillator and transmitted by optical filters a parasitic signal, which can be of the same order of magnitude when the attenuation is large.

This has been solved in PS an PSB by shielding photomultipliers with lead, and in SPS, by moving them further away.

Cross talk between bunches



Consecutive bunch acquisitions in SPS:

Only the center bunch has an actual beam, while the ones before and after are due to cross-talk (about 12%)

Position errors

Potentiometer reading noise

Wire scanner	Read error in ADC bins (rms)	Projected position error (rms, μm)	Typical beam width (1σ, μm)
PS (rotational)	1.5	45	600 - 15280
SPS (rotational)	0.5	17	180 - 11600
LHC (linear)	6 (2 after filtering)	27 (9 after filtering)	240 - 1700

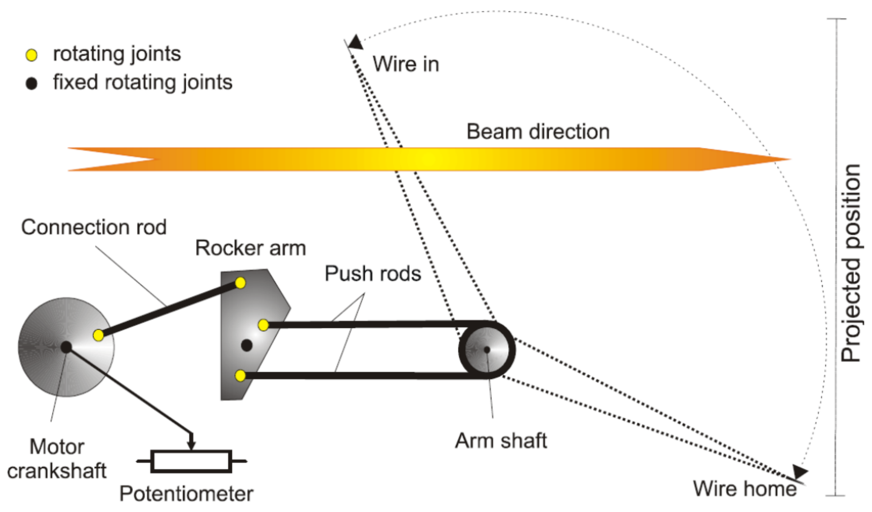
Estimations of potentiometer read noise have been made by repeated reads whilst in parking position, and converted into projection errors.

Averaging filters are used to reduce this noise, when appropriate.

Mechanical play

All mechanical elements will have play and vibrations due to large accelerations applied.

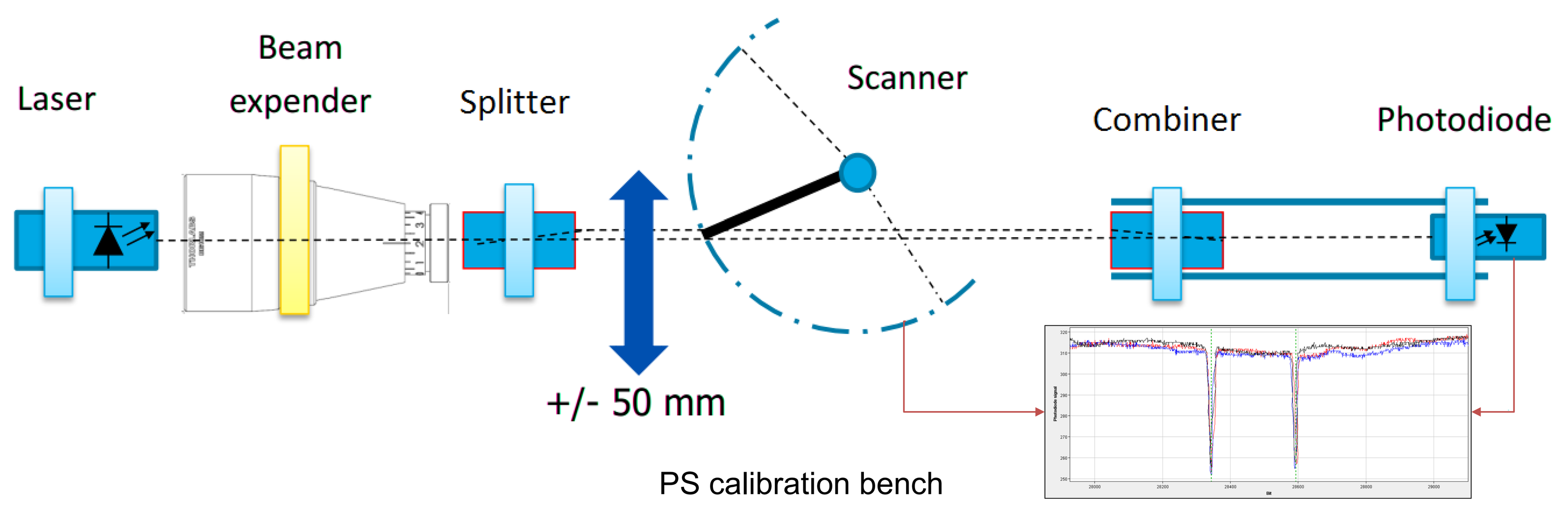
Those have been studied in order to minimize them for the next generation of wire scanner.



PS and PSB rotational wire scanner schematic

In PS and PSB, a complex kinematic is used to move the wire through the beam. This leads to a complex relationship between potentiometer value and actual projected position of the wire, subject to many mechanical plays, requiring offline calibration.

Calibration test benches have been setup for PS and PSB. Latest calibrations in PS have a precision of 80 μm.



PS calibration bench

Conclusion

Wire-scanners are deployed at CERN in the LHC and all its injector chain and need to cover a large range of beam characteristics (size, energy and intensity). Actions have been taken to correct systematic errors using calibration techniques and defining empirical optimal ranges with respect to intensity and photomultiplier gain. Some improvements are still needed for the SPS to achieve the expected accuracy and precision.

A new generation of rotational wire-scanner is now also under development and a prototype will be installed in SPS for the next run (2014). Mechanical uncertainties with the new design have been thoroughly studied. It will use an optical position sensor to replace the potentiometer, with diamond detectors considered to replace the photomultipliers.