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Carbon Wire heating in PS and PS2 beams

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Summary

The model of the carbon wire heating in an accelerator beam is applied to the special case of PS and PS2 Wire Scanners. The result of the modelling is the maximum temperature reached by the wire during the scan. This temperature indicates what scan speeds should be used in order not to damage the wire. In case of PS beam it is recommended to use scan speeds above 10 m/s. Less then 50% fraction of the more demanding PS2 beam can be scanned with a speed of 20 m/s without damaging the wire.

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1 Results for PS

The Proton Synchrotron (PS) is one of the most demanding, in terms of beam density, machines in the CERN accelerator complex. It accelerates protons from energy 1.4 GeV to 25 GeV, which corresponds to the relativistic factor $\gamma = 25.6$. The revolution time of PS is 2.1 μs.

According to [1] a few operational scenarios predict different beam conditions for the four rotational Wire Scanners: two performing measurements in horizontal and two in vertical direction. The scanners are called:

- PR.MFWH54,
- PR.MFWH64,
- PR.MFWV75,
- PR.MFWV85

In Tables 9.5.9-9.5.12 of [1] the transverse sizes of beam in the locations of the Wire Scanners are presented. Among the variety of possible beams one of the most demanding one is the LHC-25 ns beam.

The values of the LHC-25 ns beam parameters chosen for the simulation are the most oppressive for the wire. They are summarized in Table 1. The beam intensity is chosen according to the most challenging beam parameters from Table 9.5.1 of [1]: 72 bunches of $1.7 \cdot 10^{11}$ protons each. The transverse profiles are assumed to be gaussian.

The Wire Scanners are rotational. The linear component of the speed (transverse to the beam) can be regulated in steps: 10, 15 and 20 m/s. The wires of these scanners are made of 12 carbon fibers with diameter $d_{fib} = 8\ \mu$m each. Here it is assumed that it corresponds to a single wire of $\sqrt{12} \cdot d_{fib} = 28\ \mu$m. This assumption is justified by the fact that in the first approximation the maximum temperature depends only on the heat capacity of the wire. The structure of the surface, which is important for cooling processes, can be neglected.

instrument name	σ_H [mm]	σ_V [mm]
PR.MFWH54	**0.68**	0.83
PR.MFWH64	**0.68**	0.83
PR.MFWV75	0.90	**0.60**
PR.MFWV85	0.90	**0.60**

Table 1: *Transverse beam sizes for PS wire scanners [1]. The beam widths in the direction of scan are indicated in bold.*

The energy deposition due to a single proton passing the wire center is presented in Figure 1 for injection and extraction values of beam energies. The small increade

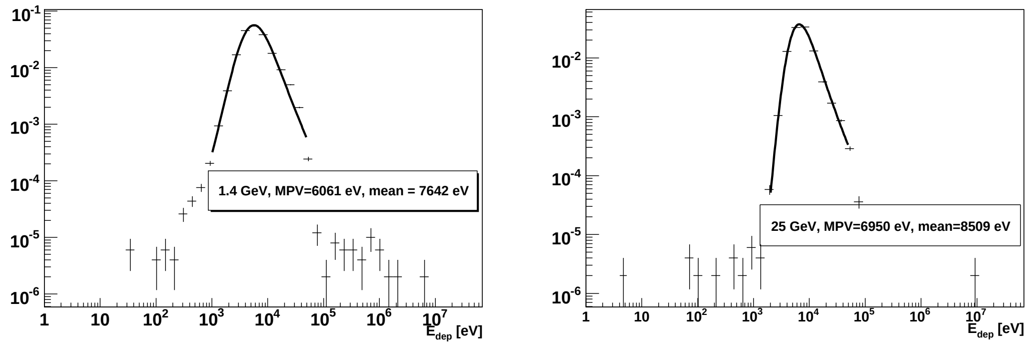

Figure 1: *The distribution of energy deposited in the* $28-\mu m$ *wire for PS protons with energy 1.4 GeV and 25 GeV. Distributions obtained with* Geant4 *with statistics of* $5 \cdot 10^5$ *protons each.*

of the deposited energy is observed. The mean value at extraction beam energy ie. 8509 eV is used further. This value is not significantly different from the mean energy deposition per proton for SPS and LHC energies. It can be explained by the fact that most of the energy deposit comes from electronic energy loss which is almost energy independent in this range.

The plots in Figure 2 present evolution of the maximal temperature of the wire during the scan. The plots are obtained from the model described in [2]. The left plot is for horizontal and the right one for vertical scanners.

For the horizontal scanner the maximum temperature is 2182 K for scans with 20 m/s, 2687 K for 15 m/s and 3563 K for 10 m/s. Vertical scanners reach respectively 2061 K, 2534 K and 3395 K. At temperatures above 3200 K the carbon sublimation rate becames important [2, 3] therefore use of scan speeds above 10 m/s is recommended.

It can be concluded that use of the PS wire scanners with the 25 ns LHC beam is possible without damaging the wire, although use of high wire speeds is recommended, especially in case of horizontal scanners.

2 PS2

The PS sucessor called PS2 [4] is planned to be comissioned in 2017. It will accelerate protons to the top energy of 50 GeV. The maximum intensity of the LHC-25 ns beam will be increased to $4 \cdot 10^{11}$ protons per bunch.

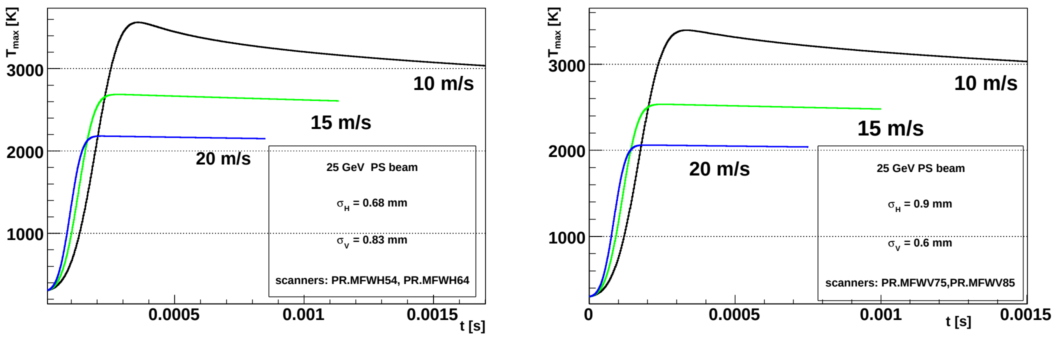

Figure 2: *Left plot: temperature evolution during horizontal scan of PS beam (with PR.MFWH54 and PR.MFWH64 scanners). Right plot: the same for vertical scanners PR.MFWV75 and PR.MFWV85.*

The PS2 circumference is planned to be more than twice of the PS one, therefore the revolution time will be 4.5 μs. Assuming the 25-ns bunch spacing the maximal amount of bunches that will increase with circumference and will be 154.

The transverse normalized emmitance is expected to increase sligthly to about 3 μm therefore, assuming that amplitude function β remains the same the beam sizes should be about 10% larger.

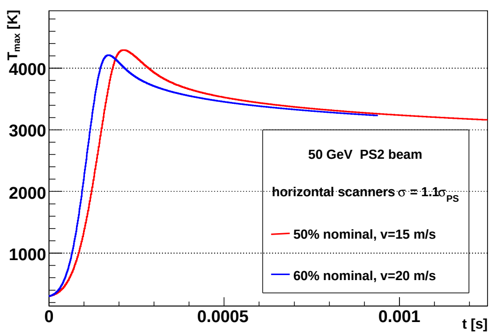

Figure 3: *Example of maximal temperature evolution during the scans of fractions of PS2 beam.*

An example of temperature evolution for the hottest point of the wire during the scan of the fractions of PS2 beam are presented in Figure 3. The maximum temperatures above 4000 K are expected to damage the wire immediately. Therefore, even with scan speed of 20 m/s the PS2 beam cannot be scanned at full intensity. It can be estimeted that only about 40-50% of the PS2 beam can be scanned with the fastest CERN Wire Scanners. Therefore scanners with higher wire speed should be developed for PS2 or different beam profile monitors should be installed in addition.

References

[1] G. Arduini et al. “ Measurement of the transverse beam distribution in the LHC injectors”

[2] M. Sapinski, “ Model of carbon wire heating in accelerator beam”, CERN-AB-2008-030-BI report

[3] M. Sapinski, B. Dehning, A. Guerrero, J. Koopman, E. Metral, “ Carbon fiber damage in accelerator beam”, proceedings of DIPAC09

[4] R. Garoby, “ Plans for upgrading the CERN Proton Accelerator Complex”, CERN-AB-2007-074 PAF