SCRAPING FOR LHC AND COLLIMATION TESTS IN THE CERN SPS

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Abstract

Scraping of the SPS beam prior to extraction towards the LHC will be important in order to remove the beam tails and ensure clean injection conditions. Scrapers recuperated from the ISR were installed in the SPS for this purpose. The scrapers are associated with a two stage collimation system using collimators previously installed in LEP to reduce the irradiated area in the SPS.

Tests have been performed to demonstrate that with the help of these collimators, it is possible to scrape with very little contamination outside the scraping area. Another issue was whether enough time is left for ejection towards the LHC after scraping, before repopulation of the removed tails. This was investigated with the SPS rest gas profile monitor and synchrotron radiation telescope.

The system is described and the results of these tests are presented and discussed.

INTRODUCTION

Scraping of the beam tails will be required in the SPS prior to extraction in order to maintain clean injection conditions into the LHC, hence avoiding the risk of quench in the cryo-magnets. One horizontal and one vertical scraper, recuperated from the ISR, are installed in the SPS and have been used for various tests. The questions addressed were whether enough time is available after scraping to extract before the tails repopulate and what is the achievable sensitivity of the process. The scrapers are associated with one horizontal and one vertical primary collimator installed at a phase advance of 90 degrees and complemented by two secondary collimators located again at 90 degrees from them. Each collimator consists of two moveable blocks. Photomultipliers and ionisation chambers are positioned close to the scrapers and collimators to watch the losses in comparison to the rest of the machine. Tests were also performed to try to confine the radiation induced from the scraping at these locations.

HARDWARE

Scrapers

A scraper consists in a moveable 30 mm copper jaw (Fig.1) activated linearly by a stepping motor and adjusted with a resolution of about 10 μm at a position which determines the amount of current scraped. It is then moved through the beam at a speed of 0.2 m/s by another stepping motor.
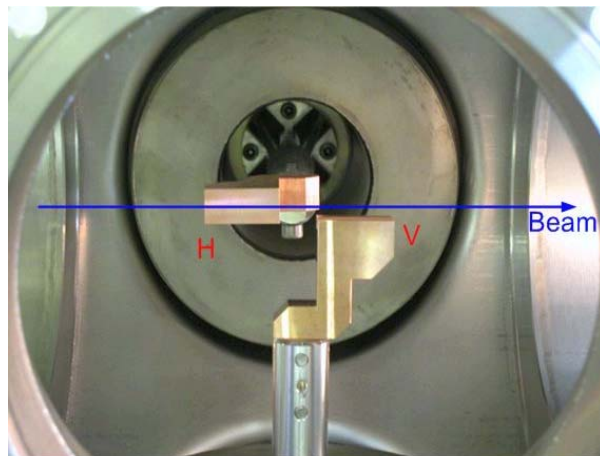

Figure 1: Side picture of the H and V scraper Cu jaws.

Collimators

Each primary collimator block is made of a 100 mm long tungsten core inserted within two transition end pieces made of copper, for RF loss minimization and heat extraction. A block has an overall length of 450 mm and can be positioned with a resolution of 5 μm [1]. The collimator blocks are aligned with respect to the beam axis with an rms precision of 0.1mm. Figure 2 shows a picture of the horizontal and vertical primary collimator assembly.
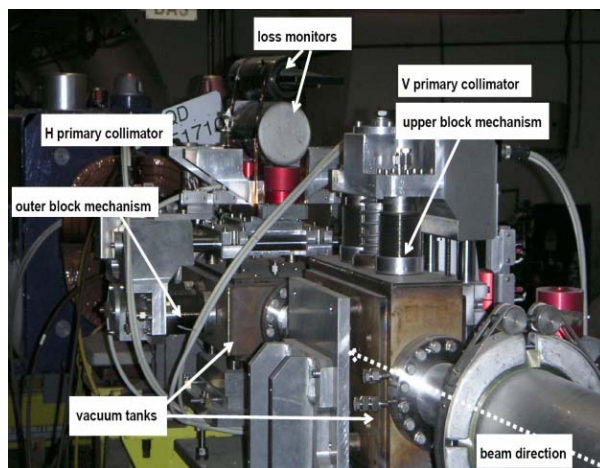

Figure 2: Horizontal and vertical primary collimator tanks and mechanisms with associated loss monitors.

The secondary collimator blocks have shorter copper transition pieces; their overall length is therefore reduced to 250 mm.

RESULTS

Rest gas monitor observations

The effect of scraping the vertical beam distribution was investigated with the SPS rest gas monitor [2].
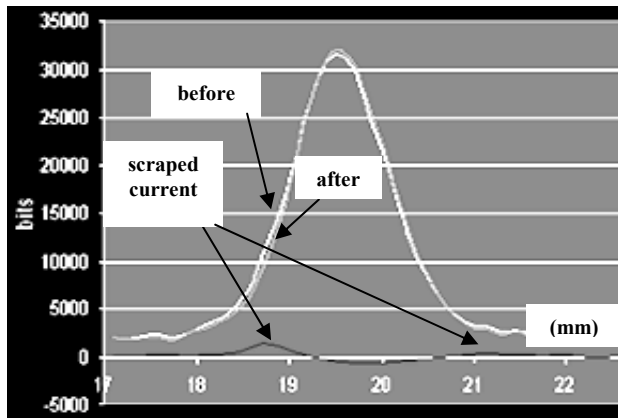

Figure 3: Results of scraping vertically 1% of the distribution of a beam of 2.6 10[12] protons as seen by the Rest Gas Monitor.

Vertical beam distribution profiles integrated over 20 ms (800 SPS turns) are acquired every 40 ms with the SPS rest gas monitor. For this test the last profile measured before scraping, was compared to the profiles taken after. This was performed for various degrees of scraping, down to 1% of the circulating current, which is the resolution limit of the present current transformers. The results are presented in this last case in Figure 3, showing the distribution before and after scraping, The removed distribution (black curve), obtained by subtraction of these two profiles, although just emerging from the measurement noise, can still be appreciated for this level of scraping.
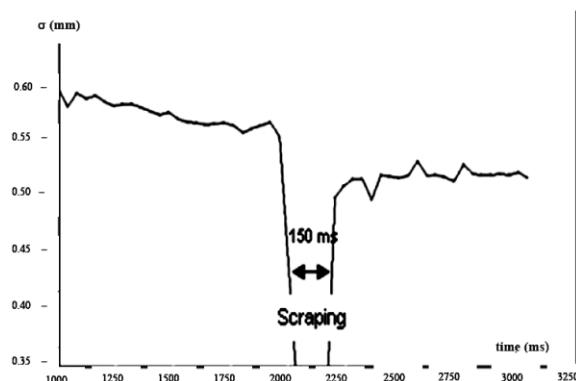

Figure 4: Recording of the vertical beam distribution rms value at a sampling rate of 25 Hz, before and after scraping 7% of the current.

The nominal SPS acceleration cycle to 450 GeV for the LHC ends up with a flat top of 1 second. Scraping lasts typically 100 ms, (Fig.4), on this flat top in order to overcome problems related to instabilities and orbit drifts occurring during the beam acceleration (Fig.5). A repopulation time of 100 ms or less would have been critical, as not enough time would have been left to proceed to the extraction towards the LHC. By increasing the flat top duration at 450 GeV to 2 seconds and by monitoring the beam distribution every 40 ms, the repopulation time constant was investigated. It could be verified that the reduction of the beam distribution rms value resulting from the scraping is kept for at least one second, as shown in Figure 4.

Synchrotron light telescope observations

The Synchrotron Radiation telescope uses the light emitted by the edges of two adjacent bending magnets. This light is extracted horizontally at 14m by a mirror into a telescope equipped with a Peltier-cooled CCD sensor. The CCD can either be operated in TV mode or in digital mode, where a fast projection scheme is available. In this mode, after a chosen integration time, the charges in the CCD are shifted down and compressed in the readout register, where the beam projection is available within 230μs. The register is read out after each projection operation and is digitised over 14 bits. The memory will contain 576 profiles after a sequence. It is a more robust but slower version of the instrument described in [3]. For the scraping application, the integration was chosen to be 5ms, and the acquisition sequence was started at the end of the acceleration ramp to 450GeV, which provided an acquisition time of ~3s covering the whole flat top, including the scraping operation. The CCD was oriented to provide the horizontal projections, complementing the rest gas monitor which measures vertical distributions.
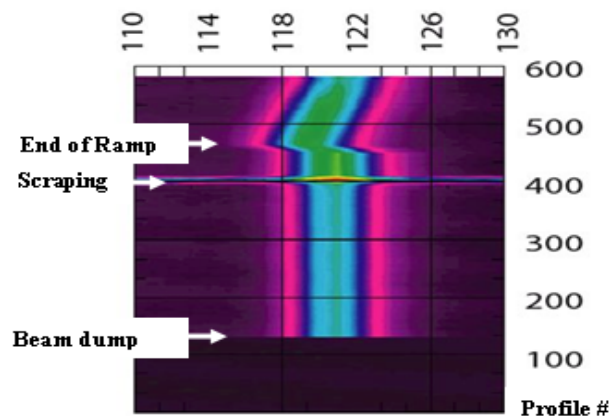

Figure 5: H profile sequence including a 30% H scraping as recorded by the CCD in projection mode.

A typical acquisition sequence is given in Fig.5. The sequence starts with profile #576 taken during the end of the energy ramp, where a position drift is observed. The scraping operation, which is clearly visible due to the production of secondary particles, takes place around profile #400, and is followed by a stable period until the beam is dumped around profile #110. The change in beam size before and after scraping is clearly visible on

this picture of a 30% scraping. To assess the effectiveness of the scraping and check the repopulation of the scraped tails, profiles were compared before and at different times after scraping.
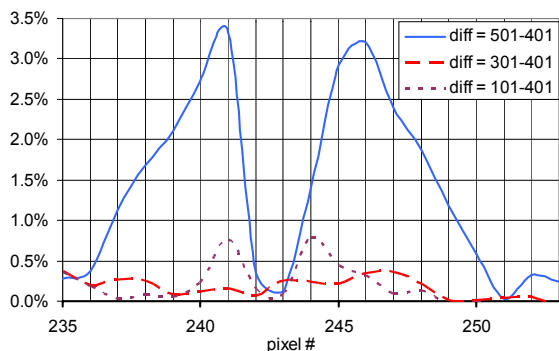

Figure 6: Effect of a 5% horizontal beam scraping as seen by the Synchrotron Radiation telescope.

Such a comparison can be seen in Fig. 6, taken for a 5% scraping and a 5ms integration time. The scraping took place at profile #420 and profiles were compared just before (#501) and just after (#401) scraping to assess the tail scraping effectiveness. To evaluate the tail evolution after scraping, profiles #101 and #301 where compared to profile #401. It can be seen that the tails were effectively scraped (501-401) and that a partial repopulation took place after a relatively long time, as small tails re-appear only after 300 profiles, i.e. 1500ms.

Collimation effectiveness

The achievement of clean scrapings with the help of the associated two stage collimation system was also investigated. The aim was to scrape while confining the losses at the scraper and collimator locations.
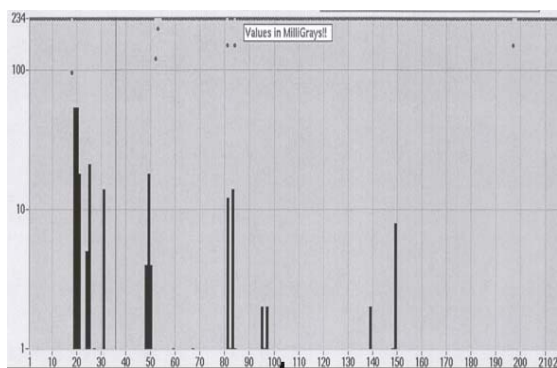

Figure 7: Loss monitor pattern around the SPS without scraping.

Beams of $3 \cdot 10^{12}$ protons were injected, ramped in energy from 26 to 450 GeV and then scraped in the last 0.5 second of the cycle flat top. The vertical scraper position was adjusted to remove 10% of the current.

The primary horizontal and vertical collimator jaws were progressively moved IN by steps of 1 mm, and followed by their corresponding secondary jaw retracted

by an additional 1 mm opening. During this exercise, the basic criterion was the reading of the beam loss monitors positioned all around the SPS circumference, Figure 7 and 8, trying to concentrate the losses at the scraper and collimator locations and to minimize them elsewhere.
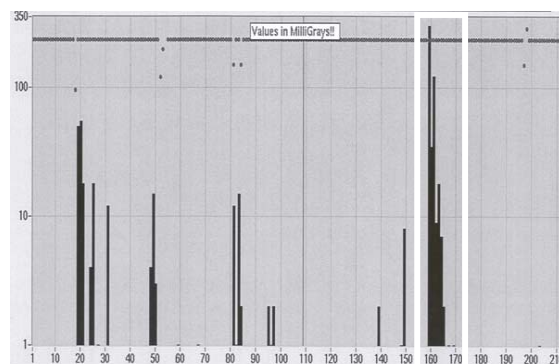

Figure 8: Loss monitors when scraping 10% of beam with collimators adjusted.

Figure 7 shows the loss distribution around the SPS during a normal cycle, without beam scraping. It can be observed by comparison with Figure 8 that additional losses resulting from the scraping are confined at the scraper and collimator locations, white rectangle, and that the loss pattern is unchanged outside these locations, demonstrating the effectiveness of the collimation.

SUMMARY

Scraping tests down to 1% of SPS beams accelerated to 450 GeV have been performed.

The repopulation time constant was measured to be longer than 1 second, long enough to ensure clean extraction conditions towards the LHC.

With a two stage collimation system associated with the scrapers, the radiation induced by the scraping is concentrated at the scraper and collimator locations, without irradiating other parts of the accelerator.

ACKNOWLEDGMENTS

REFERENCES

[1] R. Jung, R. Perret, R. Valbuena: Design of a New Generation of Collimators for LEP 200, Proc. PAC 1993, Washington, DC, p. 2202-2204.

[2] C. Fischer et Al., Design and Tests of a New Rest Gas Ionisation Profile Monitor installed in the SPS, BIW04, May 2004, Knoxville, TE and CERN-AB-2004-031-BDI.

[3] R. Jung: Image Sensor Technology for Beam Instrumentation, BIW 1998, CERN SL 98-061 BI.