PROPOSAL OF A DUMMY SEPTUM TO MITIGATE RING IRRADIATION FOR THE CERN PS MULTI-TURN EXTRACTION

H. Bartosik, D. Bodart, J. Borburgh, R. Brown, S. Damjanovic, S. Gilardoni, M. Giovannozzi, B. Goddard, C. Hernalsteens, M. Hourican, M. Widorski, CERN, Geneva, Switzerland

Abstract

High activation of the magnetic extraction septum of the CERN PS machine was observed due to the losses of the continuous beam extracted via the Multi-Turn Extraction (MTE) method. The resulting activation is however incompatible with safe operation so a mitigation measure was required and found, namely the installation of a passive dummy septum to protect the actual one seems to provide the required reduction in activation in the extraction area. The shielded dummy septum is intended to absorb particles during the rise time of the MTE extraction kickers, avoiding the beam impact on the blade of the active magnetic extraction septum. The principle of the proposed modifications of the PS layout will be presented together with the studies aimed at finalising the new configuration.

INTRODUCTION

The proposed CERN PS multi-turn extraction (MTE) is based on transverse splitting by means of resonance crossing [1]. The longitudinal beam structure is to a large extent independent from the transverse beam manipulations. Originally, it was envisaged to deliver a bunched beam to the SPS. Several experimental studies, however, have indicated that a de-bunched structure is the best option for the SPS performance. During the early stage of the MTE beam commissioning an increase in the activation of the magnetic extraction septum in straight section (SS) 16 of the PS ring was observed [2]. This observation triggered a number of studies aimed at finding mitigation measures to the irradiation of the neighbourhood of the extraction region. A detailed analysis was done [3] and one of the two possible solutions is presented here, namely the use of a dummy septum installed in the PS straight section 15 with the role of shadowing the magnetic septum blade. This corresponds to creating a well-localised loss location with the possibility to provide the appropriate shielding such that the rest of the ring is maintained free of losses, or at least, well protected. A number of issues need consideration as the extraction region contains significant amounts of equipment. Specifically, in SS15 a dipole used to correct the high-energy closed orbit distortion and to generate the slow bump for beam extraction is located. Furthermore, a quadrupole used to generate the gamma-jump gymnastics for transition crossing is also installed there [4]. The proposed solution requires in the first place the relocation of these elements, taking into account the optical constraints, but also the space available elsewhere in the ring. A suitable location for the dipole corrector in its function of closed orbit corrector was found in SS03, while an additional quadrupole was installed in SS99 during the last winter shut down. Beam tests are foreseen with the newly installed dipole and quadrupole during the 2012 physics run.

Most critical is the definition of the transverse position of the shadowing blade. Indeed, such a blade should provide protection to the blade of the magnetic septum, while avoiding any aperture restriction for other types of extracted beams apart from the MTE one. In Fig. 1 the beam envelopes (at 3 σ) of the various beam types during extraction are shown in SS15. The transverse space for placing the dummy septum blade (in black) is clearly very limited. Nevertheless, a solution seems to be possible.

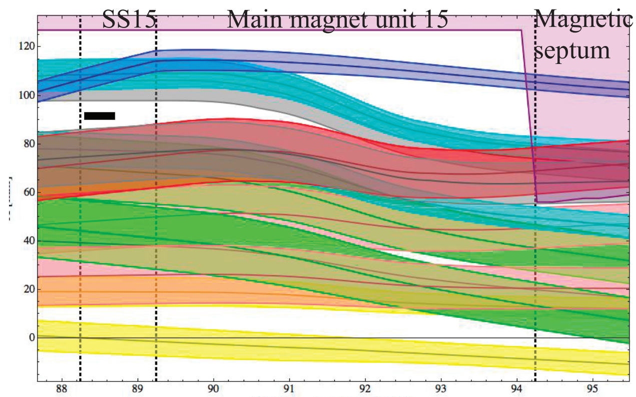

Figure 1: Various beams' envelopes during the extraction process. The location of the dummy septum blade is also shown (black rectangle) as well as the horizontal aperture on the outer side of the PS ring (in purple).

Following the identification of the location for a dummy septum, it will be verified that the losses can really be localised and confined within the shielding of the dummy septum in SS15.

FLUKA STUDIES

To quantify the effectiveness of the shadowing method in reducing the activation in the region of the straight section 16, comparative simulations of the radiation field in this region induced by beam losses in the dummy septum 15 and in the true septum 16 have been performed using the Monte Carlo code FLUKA [5]. The complete geometry of the PS ejection region as implemented in the code, including the two septa and the objects in between, is shown in Fig. 2, while a more detailed description can be found in [6].

An experimental mapping of the residual ambient dose equivalent rates along the SS16 was performed in

ISBN 978-3-95450-115-1

December 2009, 40 days after the end of operation with the MTE scheme at a beam intensity of 10^{13} p/s and beam losses of ~1 % in this region. The first part of the simulations addresses exactly this case, assuming an irradiation time of 180 days and the measured beam loss intensity of 10^{11} p/s.

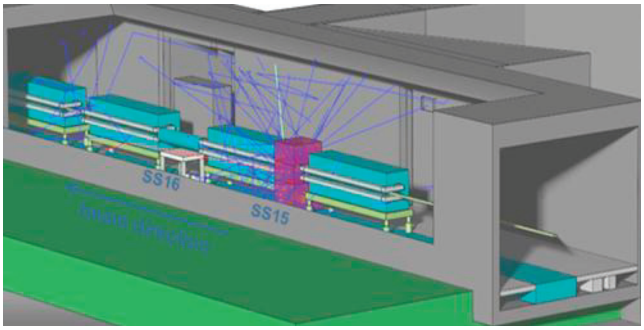

Figure 2: PS ejection region with the dummy septum in SS15 surrounded by a local shielding (in purple). The magnetic extraction septum surrounded by a vacuum tank inside the SS16 is also visible. The tracks are generated by a single interaction event in the dummy septum blade.

Several cooling times were considered, including 40 days. The second part of the simulations is performed similarly, assuming now the beam losses of 1 % to occur in the dummy septum 15. Figure 3 shows the results in the form of two-dimensional maps of the residual ambient dose equivalent rates in a plane of z (beam direction) vs. y (lateral direction) for beam losses in the dummy septum 15 (left) and septum 16 (right).

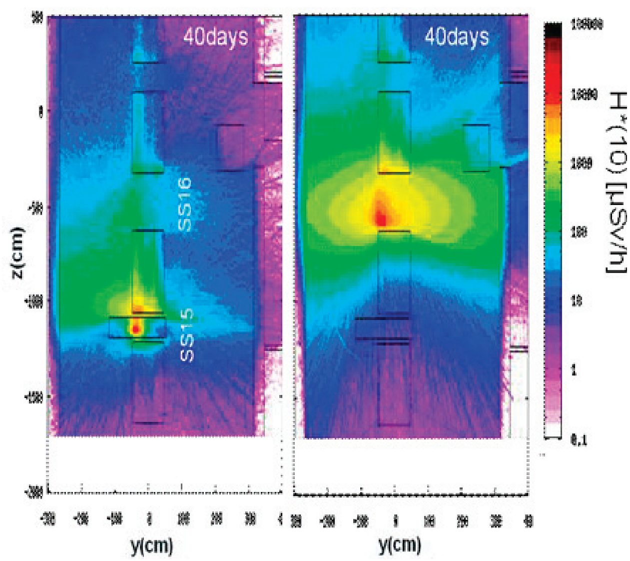

Figure 3: Comparative results on the residual ambient dose equivalent rates in µSv/h for beam losses induced in the dummy septum 15 (left) and in the septum 16 (right) for cooling times of 40 days.

One-dimensional projections of these results along the magnets (external to the PS ring) for the two beam loss locations are shown in Fig. 4.

It is worth noting that the simulated dose distribution for beam losses in the magnetic septum describes the measured data in absolute terms. The comparison with the results for the dummy septum is very encouraging. By shifting the beam losses to the dummy septum, the associated radiation field and resulting activation is also shifted upstream of septum 16 where no sensitive equipment is present, reducing the radiation level around SS16 by more than one order of magnitude. Although the total beam losses are not reduced, but only shifted, a local shielding around the dummy septum tank (see Fig. 2, [4]) which is not possible in SS16, also reduces the residual activation in the region of SS15, by a factor of about 8. For example, after a cooling time of 40 days the new method shifts the residual dose rate of ~2 mSv/h to SS15 and the local shielding around the dummy septum reduces the rates further to on average of 250 µSv/h. From systematic studies, marble was found to be the optimal choice for the local shielding [6].

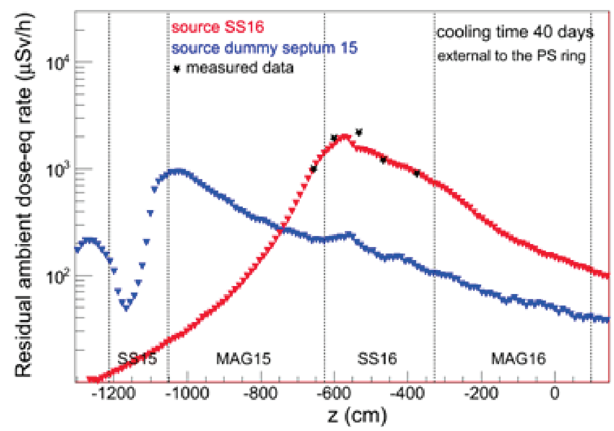

Figure 4: One-dimensional projections of H*(10) shown in Fig. 3 along the magnets (external to the PS ring) for beam losses in the dummy septum (blue) and beam losses in the magnetic septum (red). The measured data (black stars) are also shown.

Further studies help to identify the most suitable material for the blade in the dummy septum 15. Selection criteria were minimal production of secondary particles towards the magnetic septum, and best resistance to the blade heating generated by the strong and inhomogeneous local energy deposition. The simulations for the latter covered the whole region of SS15, including the parts of vacuum chambers at the extremities of the vacuum tank, the inner beam screen (possibly needed for reducing the transverse impedance), and the dummy septum tank. The differences between the three materials considered for the blade, namely W, Cu, and GLIDCOP® were found to be only of the order of 20-30 % and hence not particularly relevant for the final choice of the material. Finally, the response of LHC type beam loss monitors close to the dummy septum as a diagnostic tool for alignment of the blade was also studied, showing sensitivity in the sub-degree range.

HARDWARE SPECIFICATIONS

The dummy septum will consist of a remotely movable blade that will be located inside a vacuum vessel. The blade will be 3 mm thick, i.e., the same width as the magnetic septum conductor in SS16. However, further studies still have to determine the precise cross section (the magnetic septum conductor has a non uniform cross section). It will cover the full height of the PS vertical acceptance (70 mm) and be 40 cm long. The energy deposition rate in the blade has been estimated to be on average 0.9-1 W/cm^3, depending on the material [7]. This amounts to ~40 W for a blade of 3×70×400 mm. To avoid blade temperatures exceeding 50°C, active cooling is foreseen. A copper conductive part can be linked to the centre of the blade, which will be cooled on either side of the vacuum tank, outside of vacuum. Using two 50 mm diameter copper bars each 250 mm long, the thermal gradient over these bars would be 6.4 K. The extremities of these bars can be air cooled or water cooled to regulate the temperature at the blade centre. Assuming no radiation, and neglecting conduction via the blade supports, would yield maximum blade temperature increase at the upstream and downstream extremity of $\Delta T = 25$ K for a copper blade of 3×70 mm cross section, while $\Delta T = 61$ K for a Tungsten blade.

A remote displacement system will be installed to adjust the absorber blade's position and angle with respect to the circulating beam. Two modes can be distinguished: i) operational position (adjustable within a certain range); ii) parking position (fixed position outside the PS machine acceptance). In case of failure of the remote positioning system, the possibility to retract the blade into its parking position manually (hand driven or battery powered) is foreseen.

The vacuum vessel of the absorber should be as short as possible to allow the installation of a maximum of shielding around the beam pipe. The vacuum vessel will be positioned as much as possible on the upstream side of the straight section to allow for the maximum amount of shielding on the downstream side (see Fig. 5).

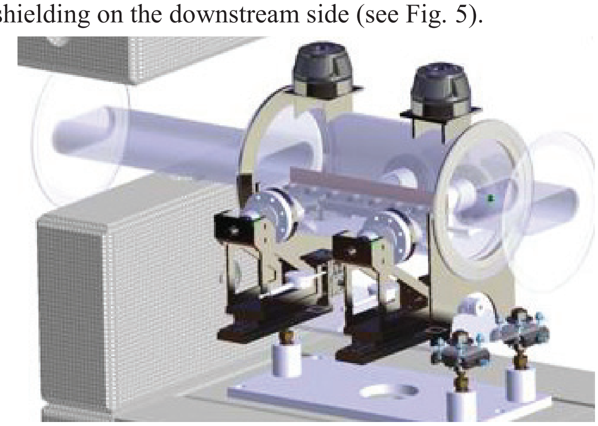

Figure 5: Basic concept of the proposed dummy septum in PS straight section 15.

Mechanical support of the dummy septum will allow for the exchange of the device in case of failure, without the need for re-alignment. The space above the PS main dipole bus bars is kept clear by the mechanical support and the shielding. A platform will be installed which will be higher than the bus bars and allow for the eventual dismantling of these bus bars in the event of the failure of either the main dipole upstream or downstream. Supports for removable alignment targets will be provided on the top of the vacuum vessel.

CONCLUSIONS AND OUTLOOK

The success of the proposed approach strongly depends on the geometrical masking of the magnetic septum blade by the dummy septum blade. Such a masking should be achieved providing a reduction of the beam interactions in the magnetic septum by at least the same factor of 10. For this reason, an on-going tracking campaign is in progress to optimize the best position for the blade and to assess the actual performance. After final validation of the proposed concept, in particular the feasibility to free up the straight section of the existing equipment (and the re-installation elsewhere in the PS ring) and the confirmation of the beam trajectories as calculated, detailed beam-based studies will be carried out to confirm the key design assumptions. Based on the outcome of these studies, the design and construction of the dummy septum 15 will be launched. Its installation is presently foreseen during the long shutdown in 2013.

ACKNOWLEDGMENT

We would like to thank Y. Bernard, N. Baddams, C. Bertone, J.-M. Lacroix, M. Lazzaroni, S. Mataguez, M. Migliorati, M. Poehler, and S. Rösler for several useful discussions and V. Mertens for constant support.

REFERENCES

[1] M. Giovannozzi (Ed.) *et al.*, "The CERN PS multi-turn extraction based on beam splitting in stable islands of transverse phase space: Design Report", CERN-2006-011, 2006.

[2] E. Benedetto *et al.*, "Results from the 2009 Beam Commissioning of the CERN Multi-turn Extraction", IPAC'10, THOBMH02, p. 3619, 2010.

[3] M. Giovannozzi, S. Gilardoni, C. Hernalsteens, G. Métral, "A Modified Extraction Scheme for the CERN PS Multi-Turn Extraction", MOPPD064, these proceedings.

[4] S. Gilardoni, D. Manglunki (Eds) *et al.*, "Fifty years of the CERN Proton Synchrotron: Volume 1", CERN-2011-004.

[5] http://www.fluka.org/fluka.php

[6] S. Damjanovic *et al.*, "Radiological impact study of a protective device for the septum PE.SMH16", CERN-DGS-2011-003-RP-TN, 2011.

[7] S. Damjanovic, "Energy deposition in dummy septum blade", MTE meeting 54, http://ab-project-mte.web.cern.ch/AB-Project-MTE/Minutes/Index.html

ISBN 978-3-95450-115-1