BNL-105663-2014-TECH

BNL/SNS Technical Note No. 095;BNL-105663-2014-IR

The Collimation System of the Ring to Target Beam Transfer (RTBT) Line

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USDOE Office of Science (SC)

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1 Introduction

The beam circulating along the Ring to Target Beam Transfer (RTBT) line of the SNS has the full beam power and a considerable size compared to the line aperture. Besides, a full pulse transported along the line with a large closed orbit deviation may damage the target vessel. A collimation system is provided to protect the line and the target from accidental losses mainly due to potential failure of the extraction kickers [1]. The system consists of two collimators [2, 3, 4] of fixed aperture with a relative phase advance of 90 degrees. Initially they were located after quadrupoles QH16 and QH18 after the bend.

Since the last technical note on the RTBT line [5], the design has evolved significantly. In particular the collimation system has been revisited to improve its efficiency against kicker failure. New locations for the collimators have been identified for optimum collection of the missteered beam. In this note, we report the main reasons for this change and compute the efficiency of the redesigned collimation system.

2 One-pass absorption efficiency

In a transfer line such as the RTBT or HEBT line in the SNS, the final efficiency of the system is defined by the first and only passage of the beam through the collimators. When the impact parameter is small, as is typically the case inside the accelerator, the probability of the proton escaping the collimator after suffering Coulomb scattering is non negligible. Monte Carlo simulations are used to estimate the path of the particle inside the material and predict the final absorption efficiency. Fig. 1 shows the percentage of protons absorbed in the only passage through the collimator system depending on impact parameter. From this figure, it is clear that the optimum situation is to hit the collimator front face with an impact parameter of several millimeters to obtain efficiencies over 90%. If the protons hit the inner tube of the collimator instead, even high impact angles are necessary.

The combination of aperture and position of the collimator, together with the optics of the line and the kickers misfired, defines the impact parameter of the protons and if they hit the front face of the collimator. The aperture of the collimators has been set to 400πmm·mrad to allow the passage of the beam in normal conditions. The optimization of the collimation position has been done to maximize the average impact parameter in the front face of the collimator during faulty conditions.

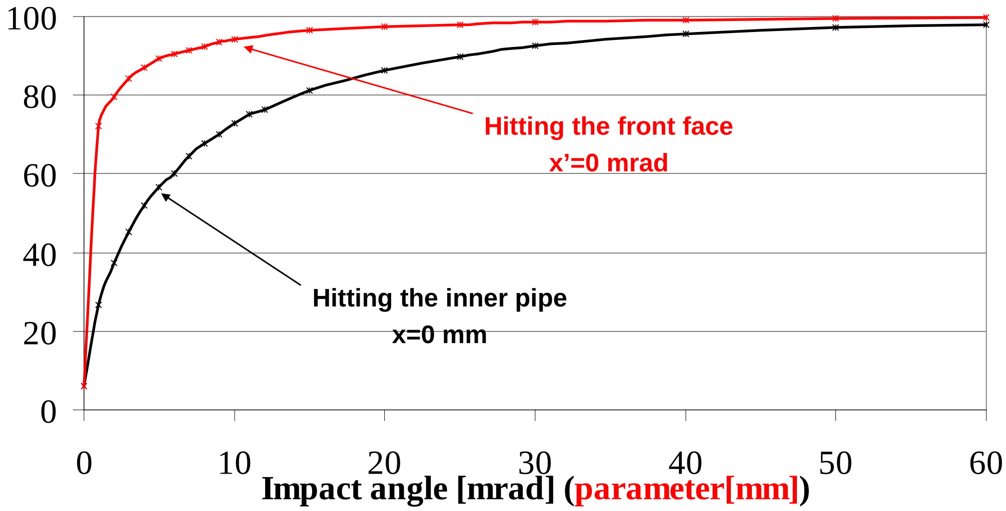

Figure 1: One-pass absorption efficiency in % of a collimator block depending on impact parameter and angle. The red line corresponds to protons hitting the collimator front face while protons hitting the inside vacuum pipe are represented by the black line.

3 Collimation area layout

When more than one of the fourteen extraction kickers fail at the same time, the external part of the beam may be lost along the RTBT line. The collimation system should intercept the beam partially or totally to protect the line as well as the target vessel. The optics and aperture have been readjusted so that, if one of the fourteen extraction kickers fails, the beam is transported through the line without scraping and the deviation on the target is under 2 mm (see Fig. 2).

After rematching of the optics to minimize the deviation in the target, the original position of the RTBT collimation was found to be non optimal with respect to the orbit deviations produced after kicker misfire. In particular, the phase advance between the extraction kickers and the first collimator was such that the closed orbit at the collimator front face was very small and even zero in most of the cases.

By using the TRANSPORT code [6], we calculated the central orbit deviation along the RTBT line with every kicker set to zero. The resulting orbits are shown in Fig. 2. The same procedure was done for any combination of two kickers and the maximum and minimum excursion at every position along the line was recorded. This corresponds to the thick line on Fig. 2.

The final position of the collimators was chosen between the locations with large orbit deviation and is shown in Fig. 2 superimposed to the closed orbit deviation. The phase advance between them is $\approx 135^\circ$. Note that we can not use any two maxima of the deviation as they corresponds to a relative phase advance of $n\pi$ and makes one of the collimators redundant.

The new positions correspond to right after quadrupole QV19 and right after QH22. Fig. 3 shows the actual layout of the RTBT and the proposed location of the collimators. The new locations are presently occupied by diagnostics boxes and contain wire scanners and can be relocated along the RTBT. The only requirement is that the four boxes should be put in different phase advance locations covering a total range of 2π. The two displaced diagnostic boxes may be located between Q18 and Q19 and between Q23 and Q24 as indicated in Fig. 3.

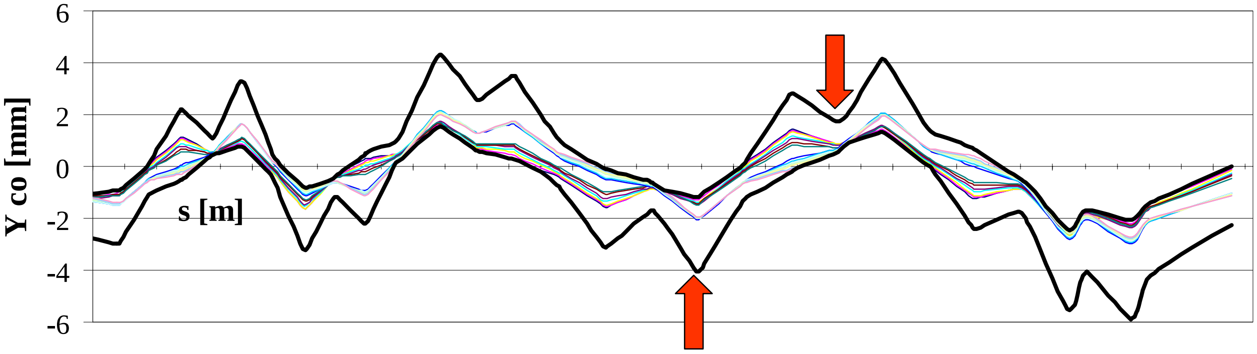

Figure 2: Vertical closed orbit deviation along the RTBT. Thin lines correspond to one kicker misfire. Bold lines are the maximum and minimum closed orbit deviation when two kickers fail simultaneously.

4 Estimated performance

Using TRANSPORT, we calculate the closed orbit deviation and beam size at the collimator front face for every failure scenario including one (14), two (91) and three (364) kickers. The results for the proposed position of the collimators is shown in Fig. 4.

We calculate the initial conditions hitting the collimator front face assuming a uniform beam of 160 πmm·mrad total emittance. Assuming that all failure scenarios have the same probability, the average impact parameter and angle in the absorbers are 3.4 mm and -4.8 mrad in the first absorber and 1.6 mm and 3.7 mrad in the second one. Using these impact parameters, we have simulated the absorption efficiency of the collimators using a Monte-Carlo simulation [7]. The average absorption efficiency is 99.8% for the first collimator and 83.5% for the second one. We obtain an average efficiency of 91-92% for the whole system. Only the case of two kickers failure is taken into account as it has the highest probability between the scenarios producing beam loss. For three kickers simultaneous failure, the impact parameters should be larger and the efficiency higher.

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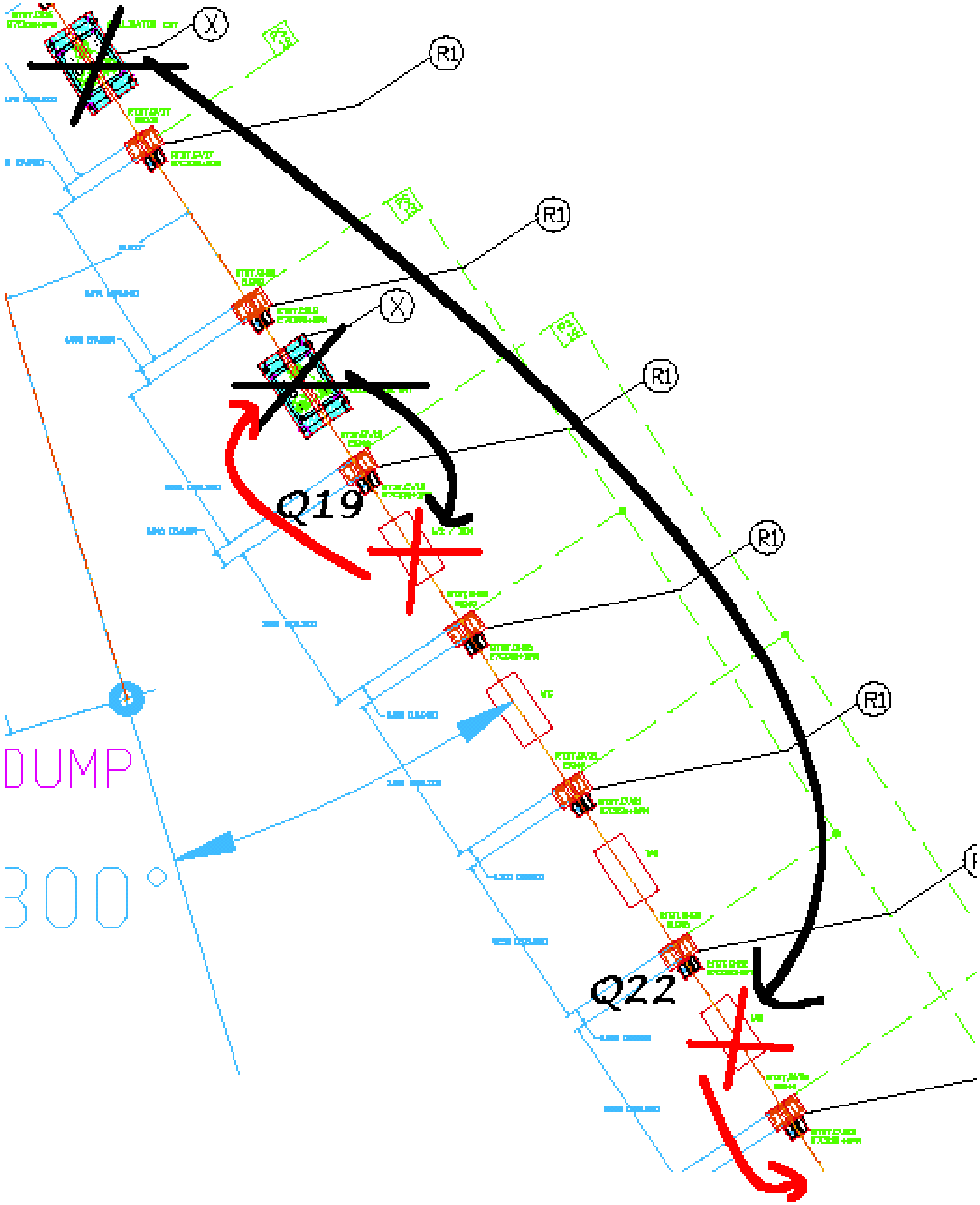
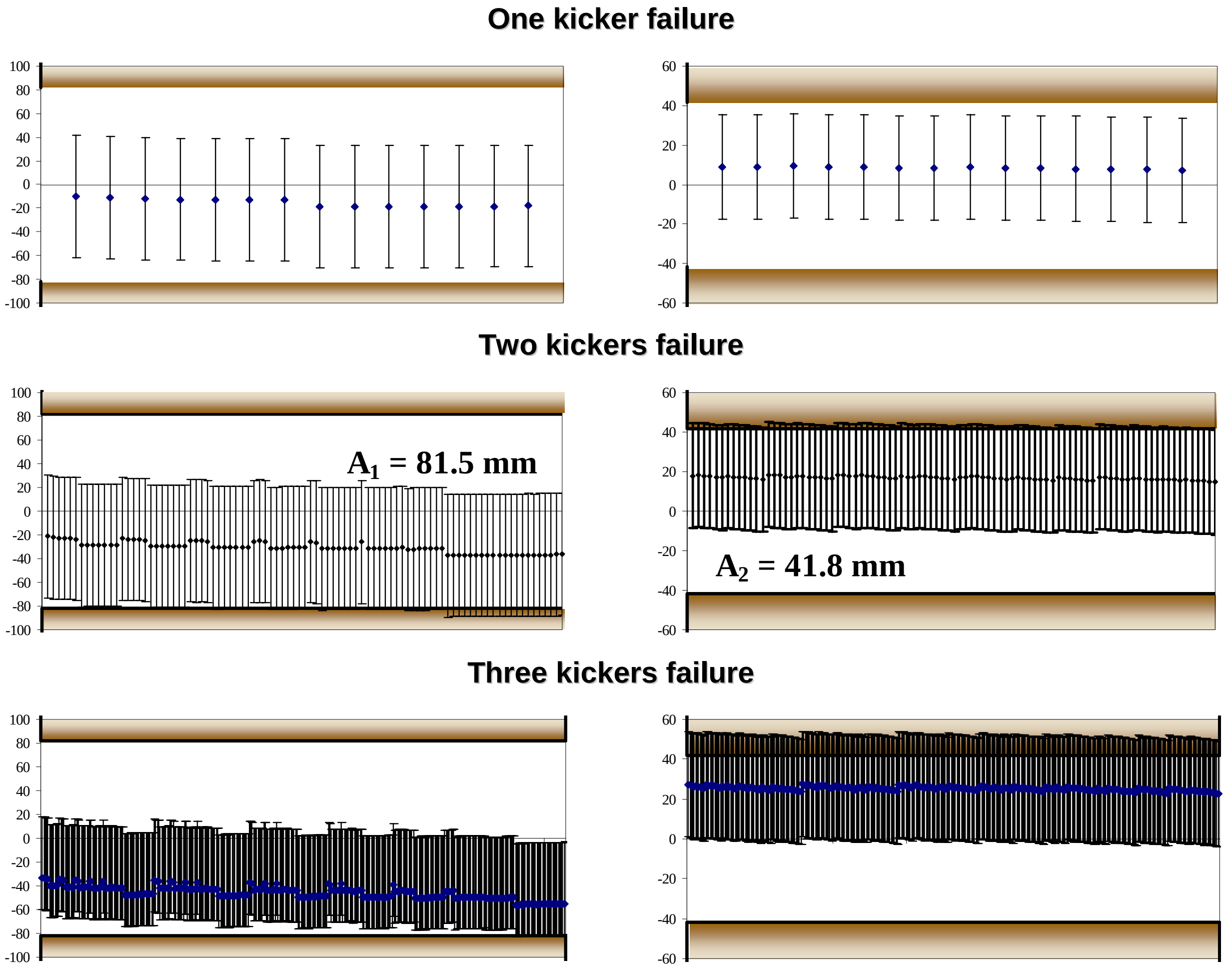


Figure 3: Actual and proposed location of the two collimators in the RTBT line. Absorbers should be located the closest possible to the end of the quadrupole to improve collimation efficiency.



One kicker failure

Two kickers failure

Three kickers failure

Figure 4: Beam position and size at the location of the two RTBT absorbers after one (top), two (middle), and three (botom) extraction kicker misfire. The beam is partially scraped by the fixed aperture collimator. The aperture of the collimators indicated in the middle figure corresponds to 400 πmm·mrad.