UPGRADE OF RADIATION SHIELD FOR BT COLLIMATORS

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Abstract

The beam transport line between 3 GeV Rapid Cycling Synchrotron and Main Ring has a beam collimator system in order to improve the quality of injected beam in the main ring. The beam power deposited into the collimators is required to be increased for high intensity beam operation. The tolerance of existing radiation shield becomes insufficient, even though there is no heat problem. The gate-type shield system has been preparing in order to satisfy both the radiation shielding and feasibility of maintenance. The development of movable gate-type shield system is reported here, which fully covers more than 20 meters long collimator section.

INTRODUCTION

A beam transport line between 3 GeV Rapid Cycling Synchrotron (RCS) and Main Ring is called as the 3-50BT line. In the middle of this line, a beam collimator system [1] is prepared in order to improve the beam quarity of the main ring taking off the halo component as shown in Fig. 1. The collimator system consists of 12 units. One unit which can move to horizontal and vertical direction independently has both horizontal and vertical jaws. A pair of units cuts the beam into a rectangular shape. The halo components are removed dodecagonally in phase space for both planes. The collimator jaws which hit the 3 GeV proton beam directly are covered by the iron shield at least 50 cm thick to prevent the radiation damage and activation of other components. The wall thickness of 3-50BT tunnel was determined to satisfy the limited radiation level in public area. Especially, because the above area of the collimators is the public road, iron blocks are buried in the roof part of the tunnel for the radiation shielding. The amount of the acceptable beam power deposited into the collimator system was designed to 450 W in total. On the other hand, according to the improved simulation of the extracted beam from RCS, it was found that larger tolerance of about 2 kW deposited beam power will be required for high intensity operation more than 100 kW beam in main ring. In order to solve the problem, the new radiation shield system is planned to be installed in this summer.

Figure 1: Collimator area in 3-50 BT tunnel.

SHIELD DESIGN

General

Fig. 2 shows the schematic design of the gate-type shield system which covers the existing collimator system and quadrupole magnets. Since the space between collimator shields and infrastructure such as cable racks and cooling water pipes is not wide, the width of posts is limited to less than 30 cm. The length of the shield is 24.7 meters long which covers whole collimator system. The gate-shaped iron shield is divided into 19 pieces of blocks which are 130 cm long and 21 t in weight in order to keep an accessibility to the involved components such as collimator units and quadrupole magnets for their maintenance. Shield blocks are mounted on the linear motion (LM) guide in order to locally open the specified area when it is needed. The THK JR-type LM guide is adopted for the 34 meters long main railway and HSR-type LM guide is used to the adjustment system. The tolerable mis-alignment between two rails of the railway is approximately ±2 mm/m for the vertical displacement, and ±0.4 mm for the horizontal one. Since the requirement of the horizontal alignment is severe, the adjustment system is prepared in order to accept the distance error of rails when the shield block runs on the railway. The number of LM guide blocks for running is six per one shield block, and three for adjustment. The load tolerances of LM guides whose types are called as JR55B and HSR55B are 119 kN in move and 183 kN at rest for radial, anti-radial, and transverse directions.

Cooling of Jaws

The collimator jaws are cooled by water. Jaws made of tantalum are directly bonded to inner surface of beam duct by HIP method. The outside of beam duct is attached by copper cooling plates which contain the water pipe with an outer diameter of 4 mm. A collimator unit has horizontal and vertical jaws. The present water flow is 1 l/min for each unit connecting water pipes in series. The flow will be doubled by making independent circuits for jaws. It is

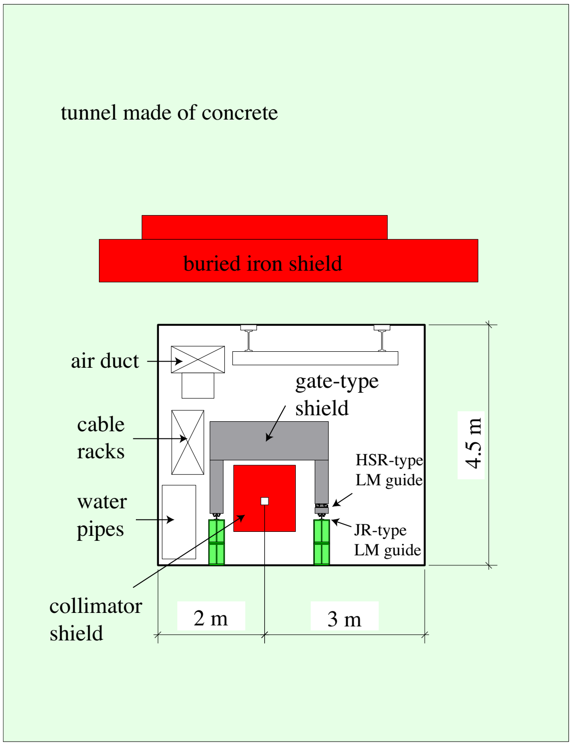

Figure 2: A sectioned drawing of 3-50BT tunnel from the upstream point.

good to avoid the danger of stuffing of water pipes though the heat load is not large even with the 2 kW depositing operation.

Estimation of Radiation

As the area above the collimator system is a public road, the radiation level must be low enough compared to the background one. The amount of materials between the road and collimator system is listed in Table 1. Fig. 3 shows the sectioned drawing of collimator area along the beam line. 3-50BT tunnel has an expansion joint at the downstream of collimator system in order to absorb the stress occured between RCS area and main ring area. Iron shield included in the tunnel concrete has a discontinuance due to this expansion joint. Though the maze structure was prepared to prevent the outgoing neutron, a streaming path remains there.

Table 1: Materials to the public area of upward direction. The thickness of gate-type shield will be 720 cm at the minimum above collimators.

Name	Thickness (Prsent)	Thickness (Upgraded)
Concrete	475 cm	475 cm
Iron	185 cm	257 cm
Sand	30 cm	30 cm
Air	264 cm	192 cm

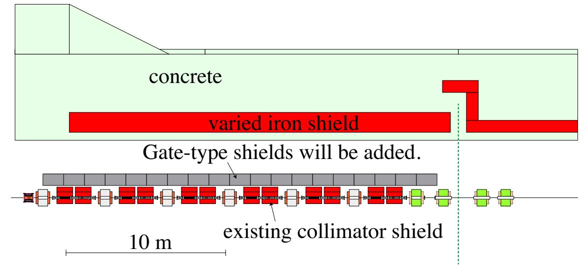

Figure 3: A sectioned drawing of collimator area along the beam line.

The beam simulation using the Monte Carlo code is necessary to estimate the accurate neutron stream passing through the maze, though the radiation level on the outside surface of the tunnel is expected to become 1/20 by Moyer's simple estimation. Fig. 4 shows the neutron stream in yz sectioned view calculated by PHITS [3] code when 3 GeV proton beam hits the jaw No.12 which belongs to the last collimator unit and closest to the streaming path. The radiation level in public area has been confirmed to be small enough compared to the background one with required beam power, also by using MARS [4] code. In simulation, the component list 'Type 02-a concrete' in ANL-5800 specified in Table 2 was used as the concrete of 3-50BT tunnel which has low radiation activity.

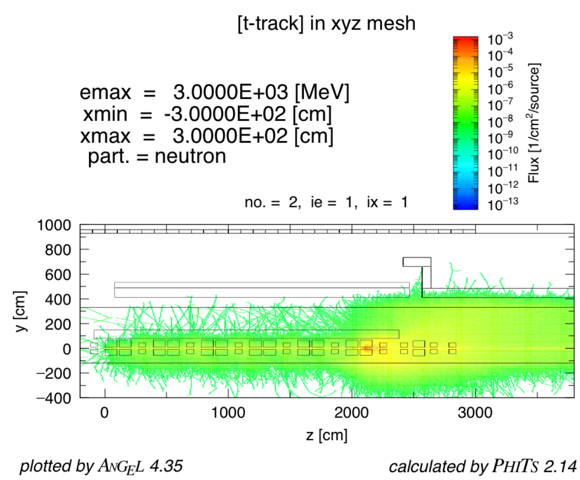

Figure 4: Neutron stream in yz-view when 3 GeV proton beam hits the jaw No.12 by PHITS code.

CONCLUSIONS

The gate-type shield system was proposed in order to increase the beam power tolerance of 3-50BT collimator system. This system has a large feasibility of maintenance to the covered components. The acceptable beam power depositing to the collimator system will increase up to 2 kW in total. The shielding ability is confirmed that the radiation level in public area is low enough. This shield system is planned to be installed in this summer.

Table 2: Composition of a concrete wall. (Density: 2.2 g/cm^3)

Element	Library ID (JENDL)	Density $\times 10^{24}$ cm^{-3}
H	1001.37c	1.345E-02
C	6012.37c	1.121E-04
O	8016.37c	4.459E-02
Mg	12000.37c	1.203E-04
Al	13027.37c	1.690E-03
Si	14000.37c	1.614E-02
K	19000.37c	4.487E-04
Ca	20000.37c	1.459E-03
Fe	26000.37c	3.352E-04

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REFERENCES

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