SIMULATIONS OF THE BEAM LOSS DISTRIBUTION AT J-PARC MAIN RING

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Abstract

The Japan Proton Accelerator Research Complex (J-PARC) is integrated by a set of high intensity proton accelerators. At this operation level, the monitoring and control of the beam losses and residual radiation are priority for its safe performance and maintenance. At Main Ring (MR), a discrepancy appears between the beam loss signal detected by the monitors and the residual dose measured. To understand this difference and the mechanism that produces these losses, a beam simulation study is implemented using the Strategic Accelerator Design (SAD) and Geometry and Tracking (Geant4) code. The first stage of the survey uses SAD to obtain the location of the losses around the lattice per turn. Then, Geant4 produces the secondary showers in the elements. Finally, we make the extrapolation with the residual radiation and compare with the measurements. The description and results of this work are presented in this paper.

INTRODUCTION

J-PARC is a project developed between the Japan Atomic Energy Agency (JAEA) and the High Energy Accelerator Research Organization (KEK), it contains a serie of high intensity particle accelerators: Linac, the Rapid Cycling Synchrotron (RCS) and the Main Ring (MR) [1].

MR accelerates protons from 3 GeV to 30 GeV for the Hadron Experimental Hall (HD) and the Tokai-to-Kamioka (T2K) experiment [2]. Figure 1 presents the layout of the MR, its length is divided in six sections: three **ARC**s and three **INS**s areas.

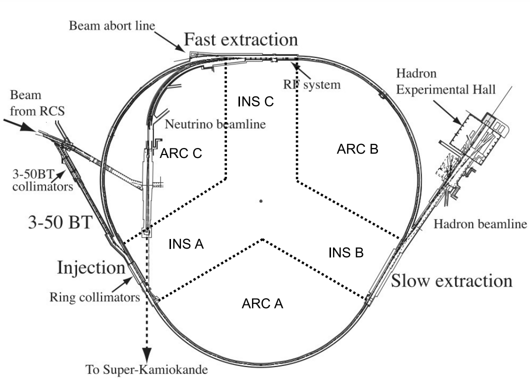

Figure 1: The description of the MR layout [2].

Due to the high beam power of 750 kW, the monitoring and the mitigation of the losses play a main role for the successfully operation of the MR [3]. However, previous reports shows a difference between the signal obtained for the beam loss monitor and the residual radiation measured inside the tunnel [4]. Thus, it is crucial to have a model which can describe with high accuracy the distribution of the lost proton, explain the mechanism that produce them and help to reduce.

SET UP

The simulations were done using the codes: the Strategic Accelerator Design (SAD) and Geometry and Tracking (Geant4). SAD is six dimensional multi-particle code developed at KEK [5], it allows to track the protons and estimated the amount and locations of the losses. For this study, a new model was developed with these features:

- Multi-tracking.
- Beam loss tools which can save the element in which the particle impact, the turns and its distribution.
- The implementation of the Closed Orbit Distorsion (COD).

Geant 4 is robust computational code used to describe the interaction of particles through matter [6]. It simulates the particle shower produced by interaction of the protons with the elements and calculated their energy deposition. The version created by Y. Kurimoto in previous study [7] was update for this survey, additionally, a script for the energy deposition was developed. Figure 2 shows the simulation scheme for this work.

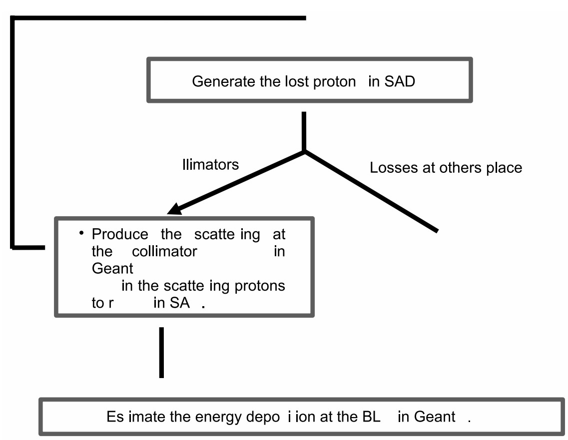

Figure 2: Flow chart describes the process to obtain the lost particles and estimate their energy deposition.

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During the Fast Extraction (FX) operation, in December of 2015, a collimation study at the MR was performed. The survey consisted in scrapping the beam with one collimator jaw and retracted the others jaws. The model was testing for the case in which the beam impact the collimator **A** horizontal (Shot 417192). Table 1 presents the important settings of the simulation.

Table 1: Relevant Parameters of the Simulation

Parameters	Units	Value
Energy	GeV	3
Q_x,Q_y	–	22.40, 20.75
ϵ	mm mrad	3
Position of collimator **A**	μm	700 (in)
Position of collimator **B, C, D, 3**	mm	5 (out)

The beam distribution used in the study were: halos in the horizontal plane, a Gaussian distribution in vertical, and the output data of the RCS for the longitudinal plane. The reason to use halos was to increase the statistics for the horizontal tails. The percentages of the halos were estimated for a Gaussian tails.

RESULTS

The primary lost protons obtained by SAD are located in the horizontal jaw of the collimator **A**. Figure 3 presents the scattering distribution produced by Geant 4. Particles beyond 1 mm of the edge were simulated, because the percentages of scattering protons for more deep particles are below 10.

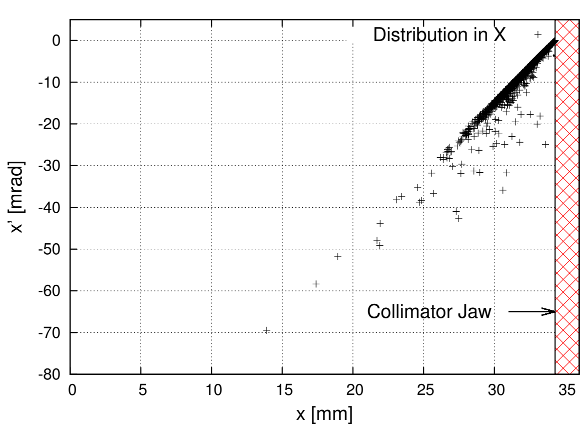

Figure 3: The horizontal phase space distribution after impacted the horizontal jaw of the collimator **A**.

The beam loss signal obtained by the Proportional Beam Loss Monitors (P-BLM) and the lost particles for the corresponding case are compared in the collimators area (See Figure 4). The data shows the first 16 ms (> 3000 turns), on the other hand, the simulations describes 20 turns (about 106 μs). The values of the simulations were normalized for a beam intensity of $3{\times}10^{13}$ protons.

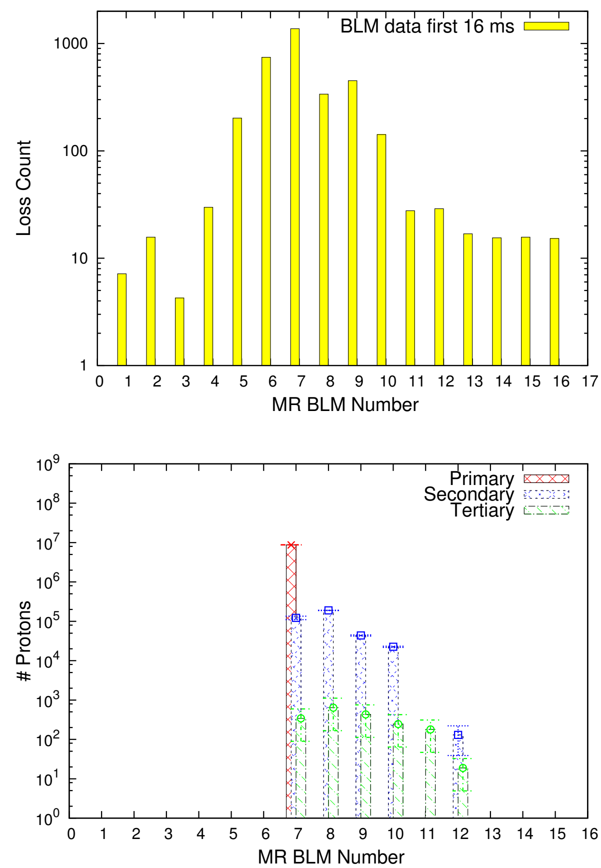

Figure 4: The comparison between the loss count for the P-BLMs (top) and the lost particles obtained by using the programs SAD and Geant 4 (bottom) at the **INS A** of the MR. The statistical errors are included.

Finally, the average energy transfer only by the scattering protons in the collimators is shown in Figure 5.

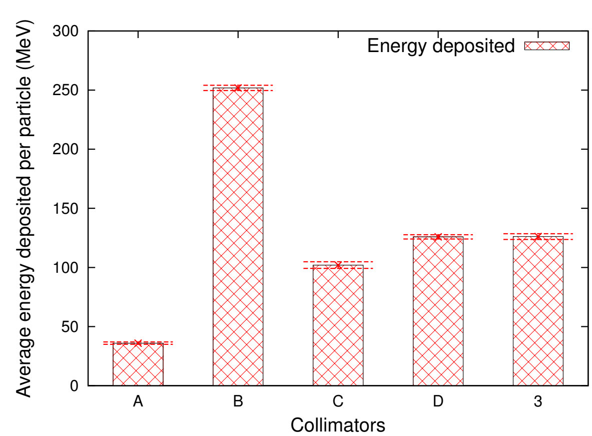

Figure 5: The average energy deposited by the scattered particles in the collimators jaws estimated by Geant 4. The statistical errors are included.

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CONCLUSION AND OUTLOOK

A beam loss model which contains multi-tracking, the COD correction and jaw scattering was implemented. It was tested using the corresponding settings for the collimation study at Main Ring in December of 2015. The code generated until tertiary particles, because all of them are absorbed after interact with the jaws.

The distribution of the lost particles estimated by the simulations are in good agreement with the beam loss count signal obtained for the **INS A**, (See Figure 4). Additionally, other regions as the **ARC A** section is roughly described by the model. However, due to the limited statistics and a noteworthy difference in the interval of time, two order of magnitude, another regions show a poorly concordance.

The particles transfered in average more energy at the collimator **B**, because it is the next element with narrow aperture after the protons are scattered. This result only takes into account the particles that are scattering at the jaws, the energy deposited by the absorbed ones was not taken into account.

The last step of the simulation, the energy deposition, was not calculated because the model is under develop and the lack of time. Nevertheless, a preliminar version which include: dipoles, steering magnets, quadrupoles and proportional beam loss monitors is tested, furthermore, a model for the collimator area is under process.

For the future studies, the estimation of the energy deposition will be included, in addition, an increase in the beam distribution and tracking turns are planning.

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