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TPS BEAM TRIP ANALYSIS AND DOSE DISTRIBUTION

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Abstract

Failure analysis during TPS users operation is important to improve the performance of the TPS storage ring. In this report, we discuss the particular radiation dose patterns, relevant to different beam trips, and the development of a tool to help us analyse this dose distribution. We will use this analysing tool to train our ability for future failure analysis to shorten the time it takes to find the problem.

INTRODUCTION

The Taiwan Photon Source(TPS) is a third generation 3 GeV light source operating at a low emittance and full energy injection. Standard, well defined procedures [1-3] are followed during the operation of the Linac, the Linac to Booster (LTB) transfer line, the Booster-Ring (BR), Booster to Storage ring (BTS) transfer line and the Storage Ring (SR), to assure stable delivery of beam current and synchrotron radiation light to users. Upon the occurrence of a beam trip, we not only observe the alarm messages but also rely on recording software of each sub-system to identify its cause. To be able to do this, a variety of accelerator analysis tools [4] are available at the TPS facility. Radiation detectors nearby machines and sub-systems provide relevant radiation dose information during a beam loss. knowledge of the dose distribution allows to define user protection measures and to make adjustments to TPS parameter settings. In this study, we analyse beam trips and code a radiation dose pattern program to enhance the ability of TPS failure analysis.

VARIETY OF BEAM TRIP

For beam trips during SR operation, we may analyse the reasons from information provided by the machine main page including warning lights, numerical values and alarm messages. The machine status includes information from the magnet system, the superconducting radio frequency (SRF) system, the feedback system and the machine protection system (MPS). The magnet system includes dipoles, quadrupoles, sextupoles, correctors and related power supplies. The SRF system includes the cavity and transmitter. The feedback system consists of the fast-orbit feedback (FOFB), bunch-by-bunch feedback (BBF) and RF feedback system for beam position corrections. The most important machine protection system is composed of four monitoring signals: (1) the orbit interlock from x-y beam position, (2) the utilities for the SR vacuum status, (3) the utilities for the front-end (FE) vacuum status, and (4) the beam line (BL) status from the radiation shielding hutch. When any one of these abnormal status signals are triggered, the machine protection system initiates the immediate SRF shut down and the electron beam will be lost at the same time. In addition, events like an injected beam not matching the stored-beam due to miss firings in the SR kicker pulser system (K1-K4), or occurrence of a vacuum burst, or power supply instability because of electric power perturbation, safety interlock trigger to protect machines during an earthquake, will all cause beam loss because of safety triggers. A fishbone diagram causing beam trips is shown in Fig. 1.

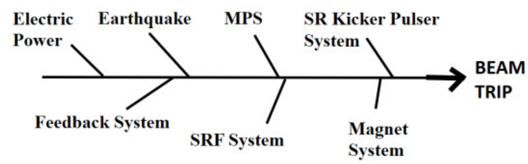

Figure 1: Cause and effect diagram of beam trips.

DOSE DISTRIBUTION AND ANALYSIS PROGRAM

For the analysis program, as shown in Fig. 2, we use the MATLAB based GUI (Graphical User Interface) script and labCA suite [5] to extract information from the dose distribution. The analysis tool functions include data comparisons, saving, monitoring and data access for each of the events. When a beam trips, the locations of maximum gamma radiation dose rates are identified. Gamma dose rates are more suitable than neutrons for analysis of different beam trip events as will be verified in the next section. For the data verification, Ion chambers (Thermo Fisher, FHT 192-10) are chosen for gamma (G)-ray detectors and ^{3}He counters (Thermo Fisher, FHT762 WENDI-2) for neutron (N) detectors. These sensors are distributed around the walls and main machines of the TPS system for which a schematic layout is shown in Fig. 3. The radiation detection consists of 19 areas (#) located at the TPS to measure the dose rate in (μSv/hr) during a beam loss. Among them are 13 areas: #06, #10, #11, #12, #14, #15, #16, #17, #18, #19, #20, #21, #22 in each BL station(outside wall), #01 is located at the TPS control room (CR), #05, #07, #13 are located along the LTB, the gateway of the Linac and the BR RF, respectively on the inside wall. The last detectors #8, #9 are located on the top of the BTS and the inside wall of the BTS (i.e. nearby the kicker pulser system). All of the survey areas are shown in the schematic diagram of Fig. 3.

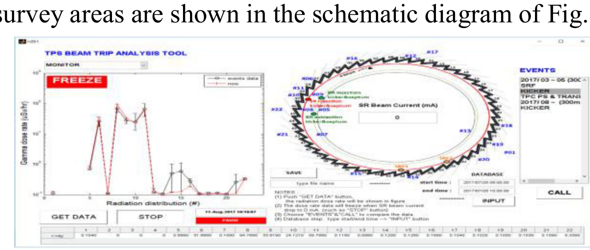

Figure 2: Analysis tool for a beam trip.

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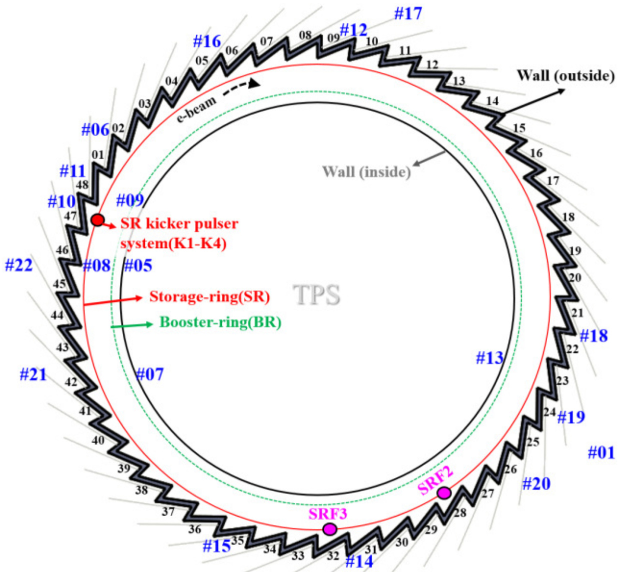

Figure 3: Radiation detection system for the TPS ring.

RADIATION DOSE PATTERN

The TPS storage-ring facilities have a precise and high stability to keep the electron beam on the same orbit. When beam trip event occur due to the same sub-system failure, it should produce a similar dose distribution. As an example, we use a manually triggered beam dump by activating the storage ring K1, K2 kicker pulser system to create an event. As experimental conditions, we chose sequentially a beam current of 30 mA, 300 mA, 150 mA in the decay mode, while the feedback system was off. The monitors display the highest dose rates when the beam current was completely lost as shown in Fig. 4. From the results of Fig. 4, the gamma and neutron intensity at the SR kicker pulser system section increase with beam current. As an example for the neutron dose, the dose rate in areas #8, #9, #10, #11 are higher than at other locations and correlate with beam current.

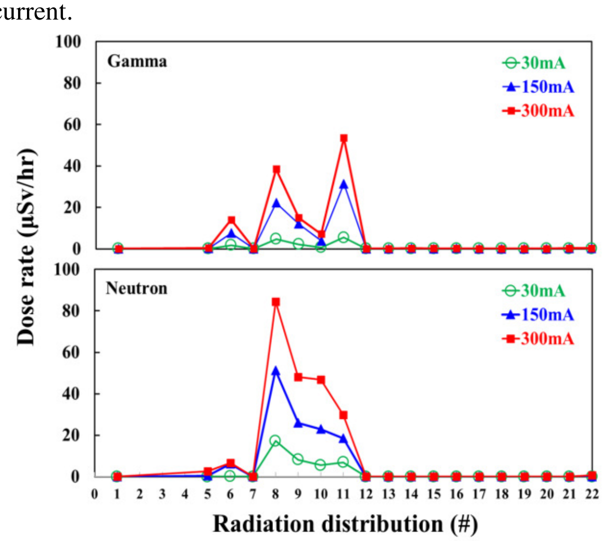

Figure 4: Dose distribution caused by a beam dump.

Next, we discuss three types of beam trip events: due to the SRF system, the kicker pulser system and electric power. The event reasons were confirmed by the machine main page and post-mortem system [6]. The radiation dose pattern collected from February 2017 to May 2017 during user operation are shown in Fig. 5 for the same events. A logarithmic scale is used for the *y*-axis to more clearly present lower dose rates while the minimum recording limit is set 0.1 µSv/hr to account for the background during user operation. These SRF events were triggered by the safety interlock protection system that includes the vacuum pressure, MPS, gap voltage errors and more. SRF events produce the highest gamma dose rates in areas #10 and #14 (100~1000 µSv/hr), whereas the neutron dose rate was lower at ~10 µSv/hr. The cause for kicker pulser events was a partial kicker miss firing (e.g. K1, K3, K4) during top-up injection, with gamma dose rates less than for the SRF events, and only distributed near the areas #6, #8, #9, #10 and #11. The average neutron dose rate intensity for kicker events is similar to SRF events. Electric power events belong to external factors, together with effects from magnet and transmitter power supplies. The safety interlock triggered itself to turn off the power supply causing the orbit to spiral in and electrons to be lost. As for the dose distribution, the gamma and neutron rates are of low intensity and are mostly less than 10 µSv/hr. Comparing the above results, the gamma radiation dose pattern provides a good method to identify differences in beam trip events thus helping the failure analysis.

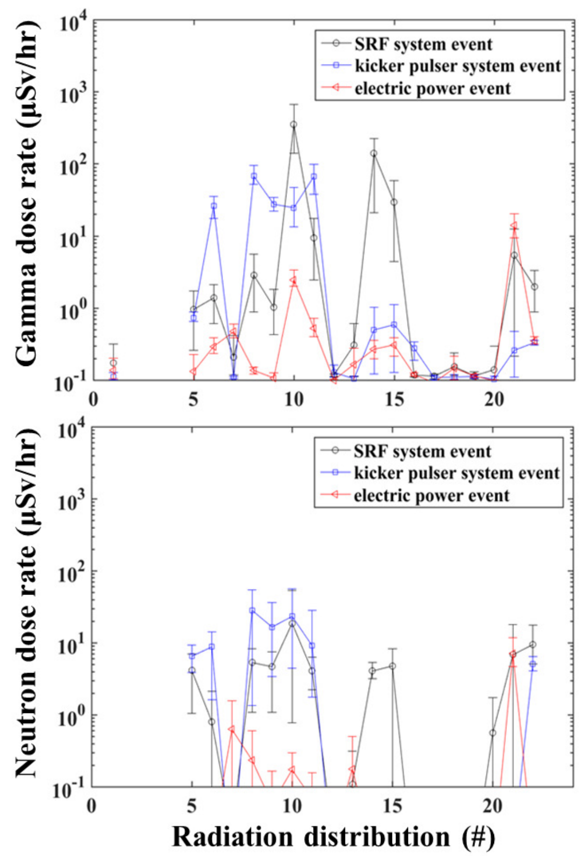

Figure 5: Radiation dose pattern caused by different events.

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SUMMARY

In this study, we have discussed gamma radiation dose pattern for three causes of beam loss: by the SRF system, the kicker pulser system and electric power. It is well suited to analyse beam trip events. As an analysis tool development, the program functions provide data comparisons, saving, monitoring and data access for each event. In the future, when the storage ring is operated at increased beam current, or the location of radiation detectors changes, the database of the radiation dose pattern needs to be re-established.

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