Measurements of time dependent distribution of leakage neutrons from the earth shield of KEK 12-GeV PS

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Abstract

On the earth shield of the KEK 12-GeV Proton Synchrotron, dose equivalent of leakage neutrons was measured using Andersson-Braun (A-B) rem-counters. Neutrons are produced when proton beams are lost at injection, acceleration and extraction. To know these contributions separately, time-dependent distribution of neutron dose was measured. The extraction loss was most important for leakage neutron doses. At extraction, beam was lost in wide area downstream of the extraction system. During the acceleration, the beam was lost at narrow area. Neutron dose distribution was compared with beam loss position using beam-loss monitors placed in the tunnel.

1 Introduction

Now the beam loss studies become important for KEK JAERI Joint Project of the High Intensity Proton Accelerators Complex. A beam loss rate must be kept lower to reduce the dose rate at the surface of the shielding, skyshine at the site boundary, and the activation of soil. Leakage neutrons mainly cause these problems.

On the earth shield of the KEK 12-GeV Proton Synchrotron, dose equivalent of leakage neutrons was measured [1]. The beam losses were also measured using the beam–loss-monitoring system [2] and occurred mainly during the injection, acceleration and extraction processes. It takes 3 or 4 seconds in these processes. From the booster synchrotron, 0.5 GeV protons are injected to 12-GeV PS. During the acceleration, mainly 5.6 GeV protons are lost when they make the transition to another phase. Then 12-GeV protons are extracted to two experimental halls [3]. Secondary neutrons are produced in these processes and penetrate through the 0.6-m-thick concrete and 5-m-thick earth shield. To know these contributions separately, time-dependent distribution of neutrons was measured.

2 Neutron Dosimeters

The Andersson-Braun (A-B) rem-counters, ALNOR 2202D type, were used to measure neutron dose equivalent. Because dose rates on the shield are kept lower, at most 2000 n Sv/h, counting time becomes longer. The counters are kept in containers as shown in Fig.1. Containers are placed on the point where the beam–loss-monitoring system showed losses. Two containers were used. One was used to measure the spatial distribution around the beam loss point. Another was placed at a fixed position and used as a normalized monitor for each measurement point because dose rates depend on the accelerator operation condition.

The sensitivity of conventional A-B rem-counters is smaller for high-energy neutrons above 10 MeV. They may underestimate neutron dose equivalent in the leakage neutron fields around high-energy accelerators. These A-B rem-counters were calibrated and compared with the modified A-B rem-counters [1,4]. The A-B rem-counters, ALNOR 2202D type, underestimate dose equivalent 90 ± 50 % (that is, × 1.9 ± 0.5) on the earth shield of 12 GeV PS [1].

Fig. 1 The earth shields of the KEK 12-GeV PS. Neutron rem-counters are placed in the containers.

The time-resolution of the rem-counters was 0.1-0.3 ms. Each rem-counter was connected to 5 signal-counters. The operation cycle of PS, 3 or 4 seconds, was divided to 5 periods and each signal-counter was used to see signals during 5 different periods after the timing signal of the injection kicker magnet.

3 Beam–Loss Monitoring System of 12GeV-PS

The beam–loss monitoring system of KEK-PS-Main-Ring consist of 56 detectors that are air ionization chambers (response time 0.2ms). The hardware of this monitoring system has various functions, but after changing the control computer, the new computer system did not succeed to use these functions sufficiently [2]. At this time, the beam–loss-monitoring system is modified to measure losses at difference arbitrary timings and points [5]. The beam losses observed by this system at injection and before transition and after transition are shown in Fig.2 for the slow extraction operation in July 1998. Because there are in section device for injection, beam losses are observed at 1-1F and 1-2F during the injection, Full line in Fig.2 which shows beam-loss monitor signals 0 - 600 ms after the injection start signal. At the transition during acceleration, Doted line in Fig.2, beam losses are observed at 4 different points, 1,2,3,4-5F, which correspond to higher dispersion functions location.

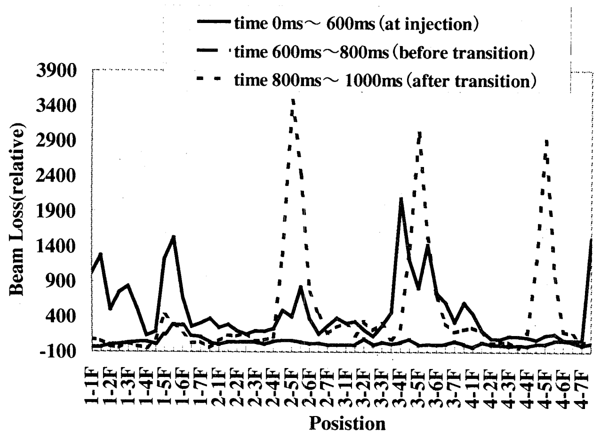

Fig. 2 Typical beam loss measured using beam–loss-monitoring system [2,5]. Fill line: Beam-loss at injection. Doted line: at transition.

4 Neutron Doses on the Earth Shield of PS

As shown in Fig.2, beam-losses are seen at the injection point, 1-1F,2F, and at the transition, 2-5F. Neutron doses were measured on these points and also on the shield of the fast extraction beam line for N-Hall shown in Fig. 1.

4.1 Injection Point

Neutron doses were measured on the shield around 1-2F magnet. The beam-loss position is not directly seen on the shield and it is difficult to place on the exact location.

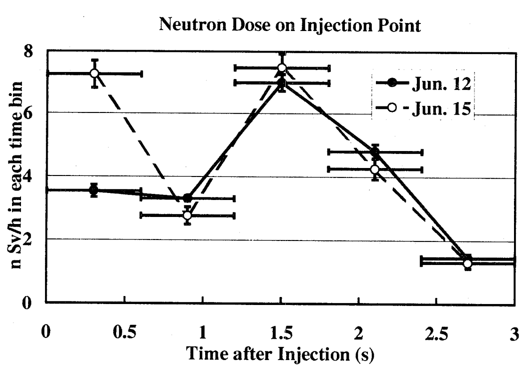

Fig. 3 Time dependent distribution of neutron dose rate on the injection point. Dose rate is shown as a function of the time after the injection start signal.

Neutrons were also measured at 2 m downstream and the count rate was about a half. So the measurement point was close to the maximum position. Typical time distributions of neutron doses are shown in Fig.3. During the injection, 0 - 0.6 s in Fig.3, 25 % of the total doses were measured. During the acceleration, 0.6 – 1.2 s period, dose rate was reduced. At the extraction, 1.2 – 2.4 s, doses were increased up to 55 %. The beam loss at the injection was dominant at 1-2F. But these neutrons attenuated rapidly in the shield than those produced by 12 GeV protons at the extraction.

4.2 Transition during the Acceleration

At the transition during the acceleration, 5.6 GeV beams were lost at 4 distant positions, as doted line shows in Fig. 2. Measurements were done on the shield above 2-5F. On May 20 – 28, 55 % of the total doses were due to transition loss, 0.6 – 1.0 s after the injection. The extraction loss contributed 37 % to the doses because measurement point was close to the extraction system. Dose equivalent rate due to the loss at the transition was between 18 and 400 n Sv/h.

Spatial distributions of neutron dose are shown in Fig. 4. One rem-counter was placed at the position on 2-5B magnet. Another counter was used to measure the spatial distribution around 2-5B. To know neutrons by 5.6 GeV beam loss, neutron counts 0.6 – 1.0 s after the injection were shown subtracting the background in 0 – 0.6 s period. A peak was seen on 2-5B. Steep distribution was seen in the backward direction because many neutrons are produced for the forward direction.

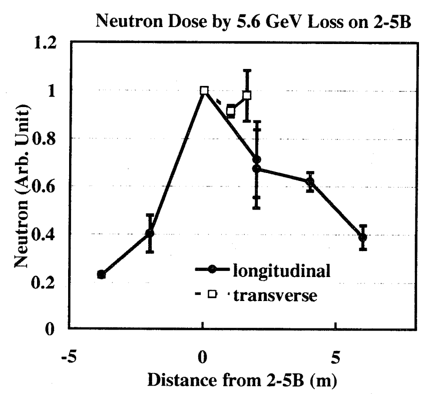

Fig. 4 Spatial distribution of neutron doses on the shield above 2-5B. Only neutrons 0.6 – 1.0 s after the injection are shown to know neutrons by 5.6 GeV beam loss at the transition. Full circle: Longitudinal distribution. Open circle: Transverse distribution.

4.3 Fast Extraction

Neutron doses were measured on the shield of the fast extraction system that is used for the beam lines in N-Hall. The N-Hall and the shield are shown in Fig. 1. Time dependent distribution was measured and more than 90 % of neutron doses were due to extraction process.

Longitudinal distribution was shown in Fig. 5 [1] as a function of distance from C-type septum magnet. Total doses were shown because doses during injection and acceleration were below 10 %. Compared with the distribution during acceleration in Fig. 4, doses due to extraction losses are higher and distributed in larger regions, more than 20-m long longitudinal distance.

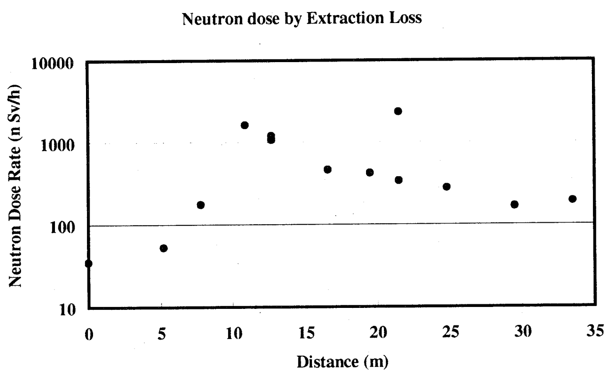

Fig. 5 Spatial distribution of neutron dose on the shield [1]. Shown as a function of the distance from C-type septum magnet in the fast extraction system.

5 Summary

On the earth shield of KEK 12GeV PS, time dependent distribution of neutron dose was measured. Neutrons were produced due to beam losses, which are measured using the beam loss monitoring system placed in the PS. During injection, acceleration and extraction process, beam losses and also neutron doses were measured separately.

The extraction loss was most important for leakage neutron doses. On the shield of the extraction system, doses were larger and distributed in wide area downstream side of the extraction septa.

The injection point and the arc area, 2-5B, are distant from the extraction system. But the extraction losses contribute 30 – 60 % to the total neutron doses.

Neutrons during acceleration were produced in narrow area. Doses due to injection losses were smaller than 30 % of the total doses even on the injection point.

Acknowledgement

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References

[1] Li Jianping et al., "Neutron Energy Response of a Modified Andersson-Braun Rem-Counter and Measurements in High-energy Stray Neutron Radiation Fields", KEK Internal 99-2 (1999).

[2] H Nakagawa, S Shibata, S.Hiramatsu, K Uchino, T Takashima, "Beam-Loss Monitoring System with Free-Air Ionization Chambers", Nucl. Instrum. Methods, 174(1980) 401-409.

[3] Y. Shoji, K.Marutsuka, T.Toyama and H.Sato, "Slow Extraction System of the KEK-PS", KEK Report 93-10 (1993).

[4] Li Jianping et al., "Neutron Energy Response of a Modified Andersson-Braun Rem Counter", Radiat. Prot. Dosim., 67 (1996) 179-185.

[5] Shinji Yamanaka, "The Study of Beam Losses in Proton Synchrotron Accelerator", Thesis of Graduate Course of Faculty of Engineering Miyazaki University, (1999).