Monitoring Beam Position in the TRISTAN AR-to-MR Transport Lines

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Abstract

A beam-position monitor (BPM) has been installed in the transport lines between the Accumulation Ring (AR) and the Main Ring (MR) of TRISTAN. This monitor can detect the beam position and its charge every passage of the beam. Variations of the beam position have been observed during the routine operation. An investigation into the AR extraction components has been carried out in order to clarify a source of the variations.

1. INTRODUCTION

The purpose of this note is to clarify a source of variations of the beam position in the transport lines, and to study the extraction process using a BPM.

The TRISTAN Main Ring (MR), an electron/positron collider, catches a bunch extracted from the Accumulation Ring (AR). The transfer efficiency, defined as the injected beam charge in the MR divided by a circulating charge in the AR, is not satisfactory. Stabilization of the beam position is necessary for improving the injection into the MR. On the other hand, the extraction process in the AR is so transitional that the beam tends to be distorted. Beam loss may occurs at that time. Study of the extraction process is also useful for understanding the injection into the MR, because the extraction is an inverse process to the injection.

2. EXTRACTION AND TRANSPORT LINE [1]

The AR accumulates an electron or positron beam of 2.5 GeV and increases the energy up to 8 GeV. The beam is then horizontally extracted from the AR by the extraction system. The extraction system has two types of magnets, i.e. kicker and septum magnets. The kicker magnet kicks the beam within one revolution period. The kicked beam passes through the outside of an effective aperture of a quadrupole magnet, QC6, and gets into an aperture of the septum. The aperture of the septum is horizontally shifted by 65 mm from the central orbit of the AR. The septum deflects the kicked beam to guide it the transport line. The beam is transported through a long line with a length of 170 m for injection into the MR. The transport lines guide electron and positron beams of 8 GeV from an AR extraction point to an MR injection point. There are two symmetrical lines: one for an electron beam and the other for a positron beam. Each line comprises eighteen dipole magnets, twenty-four quadrupole magnets and some correction magnets.

3. BPM [2]

Fig. 1 shows approximate locations of the monitor stations in the transport lines. Five monitors are installed for each line. The monitors are installed near quadrupole magnets, and are called E/P03, E/P04, E/P23 and E/P24. Letters E and P mean electron and positron line, and the following numbers called after quadrupole magnets also mean locations. The monitors at E21 and P21 are used to generate a timing pulse for detection. The monitors at E/P03 and E/P04 are mounted at the upper-stream side, and mainly watch the extracted beam from the AR. On the other hand, the monitors at E/P23 and E/P24 watch the injection condition to the MR.

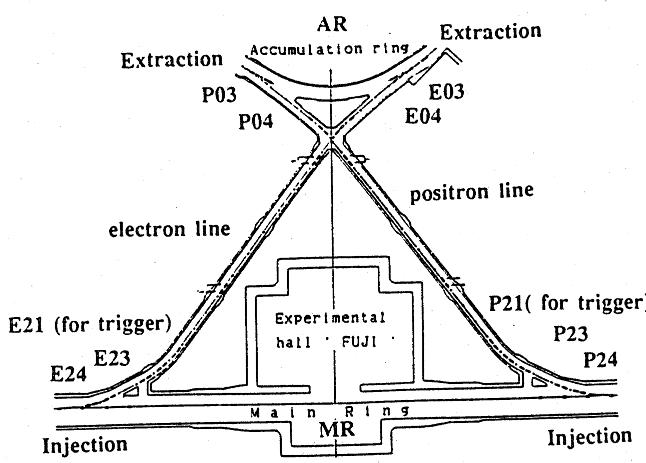

Fig. 1 Locations of the monitor chambers in the transport lines.

The performance of the BPM system is summarized below.

1) The resolution of position is 10 μm rms value at the full scale.
2) The position accuracy is about 0.3 mm over a dynamic range of 16 dB.
3) Log-time stability of position data is within 0.1 mm under constant intensity.
4) The minimum detectable beam-charge is 1.0 nC.

4. OBSERVATION

In order to fill the beams in the MR, six or seven shots of each beam are performed from the AR. The filling usually finishes within about twentyminutes. However, it takes two or three hours until the next filling. All position data in the transport lines have been reading in every shot since October 1992.

Three types of the position variations with different time scale have been observed so far. One is the shot-to-shot or the fill-to-fill variation, the next is the diurnal variation and the last is the drift with time scale of about two days.

Fig. 2 shows an example of a shot-to-shot variation in the horizontal direction. A position variation of about 0.8 mm can be seen. There was a correlation between the upper and the lower stations in the horizontal direction, however, no correlation in the vertical. When time scale is extended, a clear diurnal variation in the horizontal and vertical directions has been observed at the electron line as seen in Fig. 3. The maximum and the minimum values occur at dawn and in the evening. On the other hand, a different movement can be seen just after starting the operation. Fig. 4 shows the vertical drift of the positron beam. A horizontal drift of 0.5 to 0.6 mm was also observed at that time.

Since these variations are correlated among the monitor stations in the line, a source should be in the AR and in the extraction system. Especially, the diurnal variation has a correlation to the outdoor temperature. This variation is similar to the displacement of the photon beam observed in the KEK-PF.[3]

5. INVESTIGATION INTO THE AR EXTRACTION COMPONENTS

The orbit at 8 GeV beam in the AR corresponds to an initial value to determine the beam position in the transport lines. A vertical bump of ±2 mm was made on the normal orbit around the septum magnet, the beam position in the line was then measured. A half deviation of the vertical was observed in the horizontal in spite of setting only vertical bump. This means a strong horizontal-vertical coupling in the extraction process.

Next, in order to study on the coupling, the kicker field was changed with and without the bump. Fig. 5 shows displacements of the horizontal and vertical positions detected at the E03. One can see the vertical displacement by the kicker depends on the vertical position in the AR. The vertical displacement is greatly reduced by the +2 mm bump as seen in Fig. 5 (c). Finally, the septum field was changed within ±0.2 %. A linear horizontal displacement with no apparent vertical displacement was measured. These results suggest that the candidate for making the coupling is neither the kicker nor the BPM itself but the QC6 near the septum.

Since the BPM can detect the beam position with single passage, a correlation coefficient technique is used. The position displacement between two stations was obtained using a linear fitting, when the kicker and the septum fields were changed under the normal orbit in the AR. The correlation coefficients are given in Table 1. On the other hand, the observed linear correlation coefficients based on the

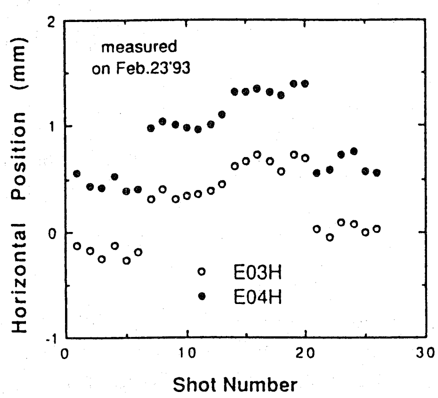

Fig. 2 Shot-to-shot variation of horizontal position at E03 and E04.

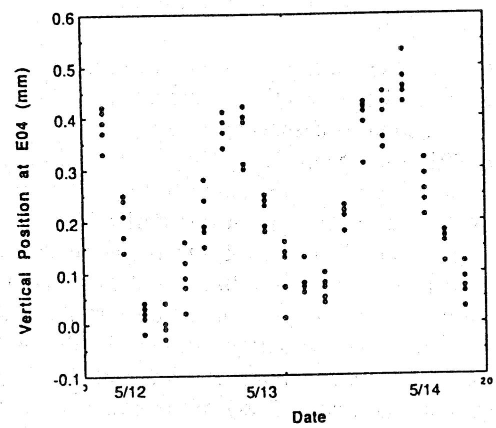

Fig. 3 Diurnal vertical variation observed at E04.

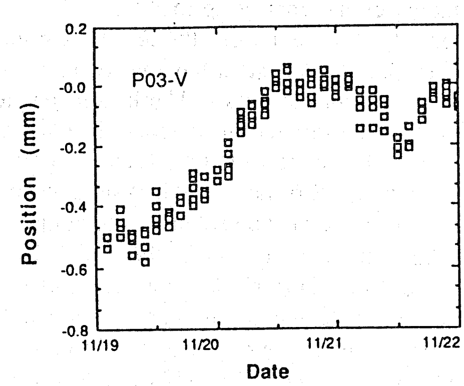

Fig. 4 Drift of vertical position at P03.

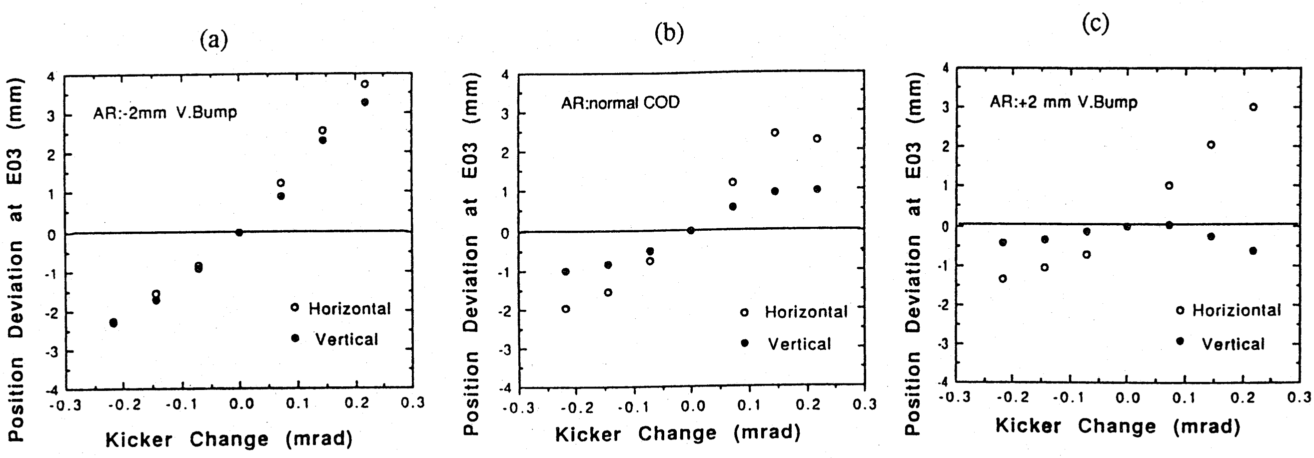

Fig. 5 Position deviation at E03 as a function of kicker field.
(a) with -2 mm vertical bump in the AR
(b) without vertical bump
(c) with +2 mm vertical bump in the AR

data in Fig. 2 are shown in Table 2. The clear coincidence can be found between the artificial change by the septum and the observation in Table 2. They are common with no vertical correlation. Though a component with the betatron phase separation of 2π is also a candidate for the variation, there is not such a horizontal deflector in the machine. The septum will be the actual source. The observed variation of 0.8 mm corresponds to a change of ±0.06 % in the septum field.

Table 1 Correlation coefficient obtained by artificial change

	----Septum----		---- Kicker ----	
Stations	Horizontal	Vertical	Horizontal	Vertical
E03-E04	+1.22		+0.51	+1.38
E03-E23	-2.83	no	+0.40	-0.31
E03-E24	-0.70	corre-	+0.62	+0.36
E04-E23	-2.32	lation	+0.78	-0.22
E04-E24	-0.57		+1.12	+0.26
E23-E24	+0.25		+1.50	-1.13

Table 2 Correlation coefficient observed on Feb.23 '93

Stations	Horizontal	Vertical
E03-E04	+1.06	
E03-E23	-2.49	no
E03-E24	-0.64	corre-
E04-E23	-2.35	lation
E04-E24	-0.61	
E23-E24	+0.26	

6. SUMMARY

1) Three types of the position variations with different time scale have been observed so far. The candidates for the variations are the outdoor remperature and the septum. It is required to study the orbit stability of the AR.
2) It was found that a horizontal-vertical coupling occurs in the extraction process, which heavily depends on the vertical position in the AR. Multipole fields of the QC6 installed near the septum may affect the coupling [4].

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