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7.3
Beam and Target Monitor using thermocouples

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Abstract

In high energy physics experiments, secondary particles are produced by hitting the proton beam onto the target made of heavy metals. The target monitoring which watches the proton beam position relative to the target has been made by using a counter telescope system. This system however can not be used for the real time target monitor. A new target monitor system which measures the temperatures and temperature difference of the target are constructed and tested at the target station of one of the slow extracted beam line of KEK 12GeV-PS. The beam profile at the target station where it has small cross section(~a few mm ϕ) is also measured using a thin needle.

1. Introduction

An experiment to search for the rare decay $K^0_L \rightarrow \pi^0 \nu \nu$ (KEK-E391a)[1] is proposed to KEK 12GeV-PS. As the branching fraction of this decay is estimated to be very small($\sim 10^{-11}$), a pencil like neutral beam with less halo is needed to perform this experiment. To get a good quality neutral beam, the proton beam must have a small cross section and it must be kept at the center of the target. A target monitor system using a counter telescope can not make a real time monitoring. In order to make a real time target monitoring possible, we constructed a target monitor system using thermocouples This target monitor system worked very well and it is now used to monitor EP2-C beam at KEK. We also tried to measure the beam profile at the target station by using thin needles with K-type thermocouples welded on it. Two dimensional beam profile at the target position was measured for the first time at one of the slow extracted beam line of KEK 12GeV-PS.

2. Target Monitor

A neutral Kaon beam line (K0 beam line) was newly constructed at one of the slow extracted beam line(EP2-C) at KEK East Counter Hall. Fig.1 shows the schematic drawing of EP2-C beam line. It has two steering magnets which steer the proton beam horizontally and vertically. A counter telescope target monitor is viewing the target at 90 degree. A 8mm ϕ x60mmL platinum target is held with the aluminum support to the target driver which drives the target horizontally and vertically as shown in Fig.2. Four K-type thermocouples are welded at four points(FR,FL,RR and RL) of the target as shown in Fig.3. The proton beam hit the target with the angle of 4 degree.

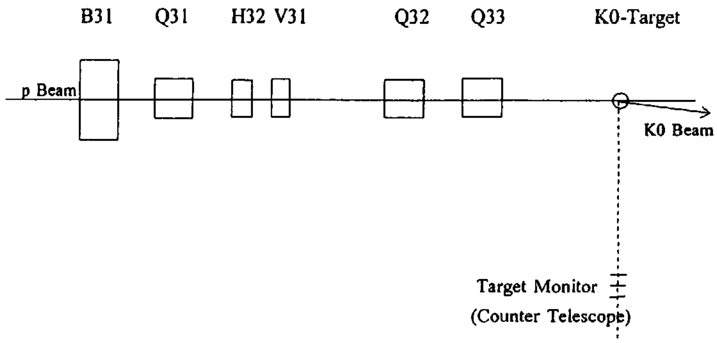

Fig.1 EP2-C Beam Line at KEK 12GeV-PS

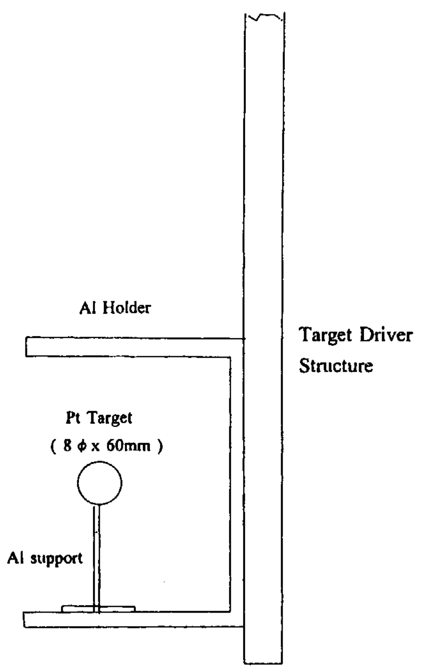

Fig.2 The Pt Target held in the target holder

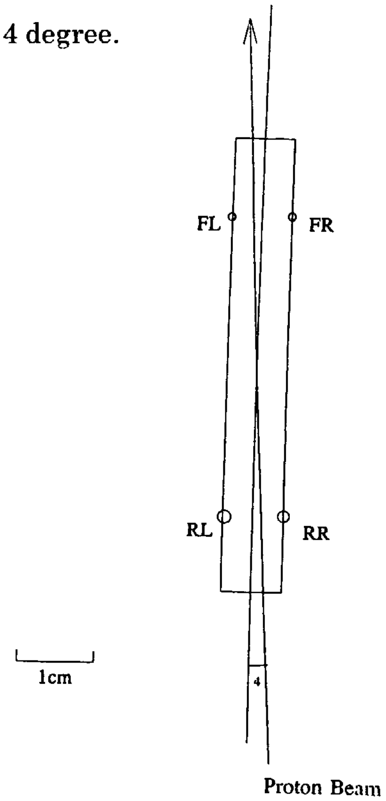

Fig.3 The Pt Target and the Proton Beam

We have made a simulation assuming thermal conduction is only the source of the heat flow. Fig.4a shows the results of the simulation for the beginning of the proton beam exposure. It is seen that the simulation results reproduce the temperature rise of the target when compared to the measured results shown in Fig.4b.

The steering magnet(H32) drives the proton beam horizontally. We drove the proton beam horizontally by changing the current of H32.

The results are shown in Fig.5. Fig.5a shows the counting rates of the counter telescope target monitor. The counting rate reaches its maximum when the proton beam is brought to the center of the target. Fig.5b shows the temperatures of the target(at FR and RL).

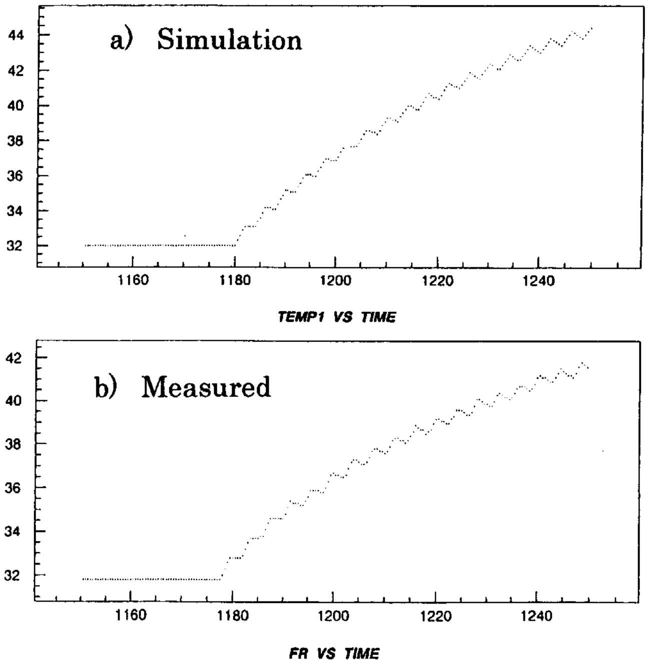

Fig.4 The temperature rise of the target

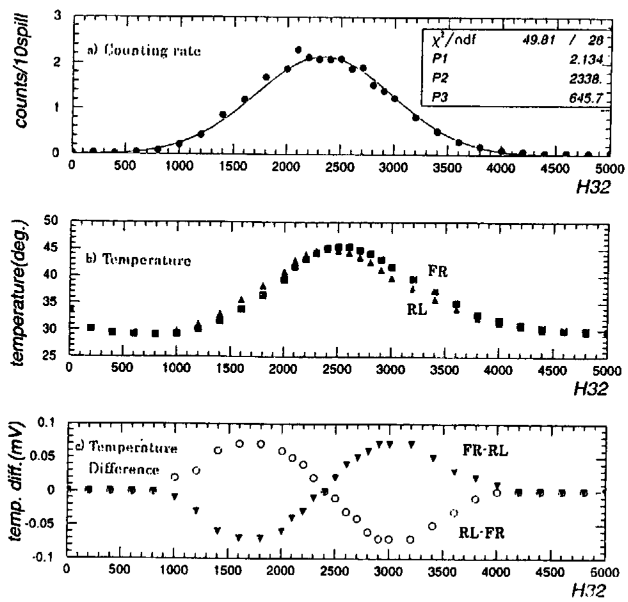

Fig.5 Horizontal scan of the target using H32 steering magnet

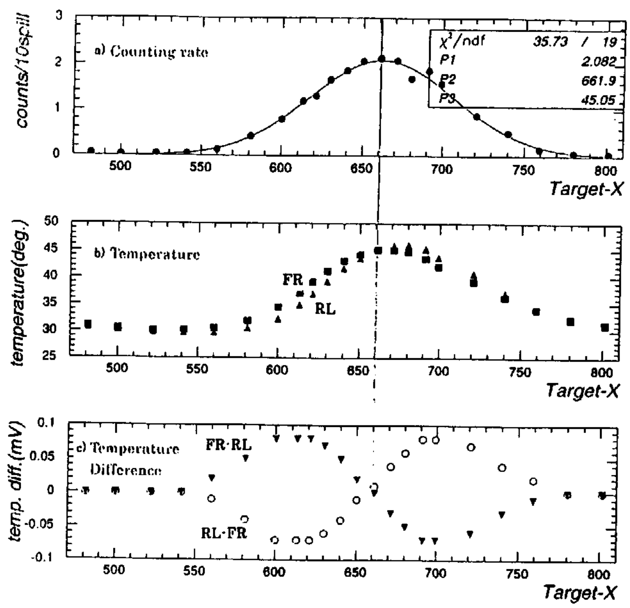

Fig.6 Horizontal scan of the target using the target driver

They also reach their maxima when the proton beam is centered. Fig.5c is a direct measurement of the temperature difference between surface points FR and RL. Because the proton beam is incident onto the target with angle of 4 degree, the temperatures of front face and rear face get different when the proton beam deviates from the target center. The zero point of the temperature difference agrees with the maximum of the counting rate of the counter telescope. When we move the target across the proton beam horizontally, the same behavior as Fig.5 is seen in Fig.6. The horizontal axes of the graphs are in unit of 0.1mm. The temperature difference reaches its maximum when the proton beam hit the edge of the target. These measurements were performed with the proton intensity of 10^{11}ppp. The rare K decay experiment will be done with the intensity of 10^{12}ppp. We have simulated the temperature rise of the target for the intensity of 10^{12}ppp as shown in Fig.7a. The rise is around 200℃ and it is still manageable. Fig.7b shows the measured temperature rise for the intensity of 10^{11}ppp for comparison.

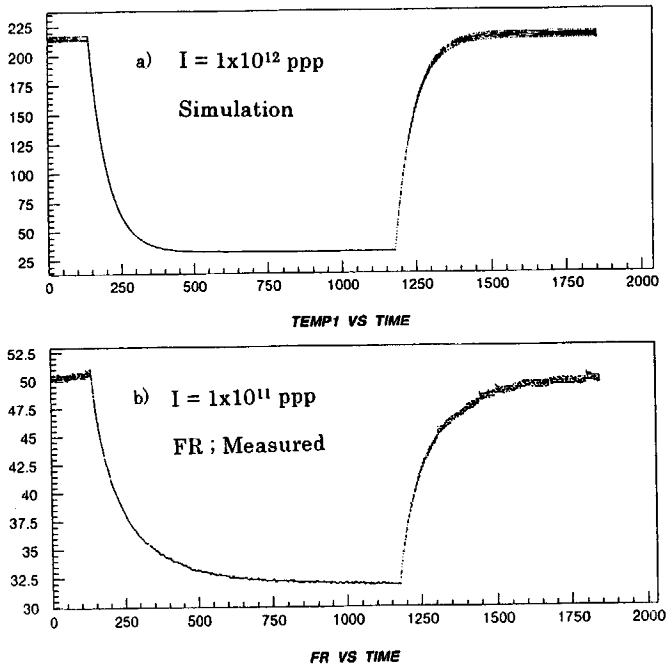

Fig.7 Temperature fall and rise with proton beam exposure

3. Beam Profile Monitor

During the course of the Target Monitor test, we realized that the temperature measurement of a thin needle would be used to measure the small profile of the proton beam at the target position. Thin needles(1mm ϕ x30mmL) made of Cu, SUS and Pt were prepared and set to the target holder as shown in Fig.8. Prior to the measurement using these needles, we made a simulation to estimate the temperature rises of these needles when they are exposed to the proton beam of the intensity of 10^{11}ppp. Fig. 9 shows the results of the simulation.

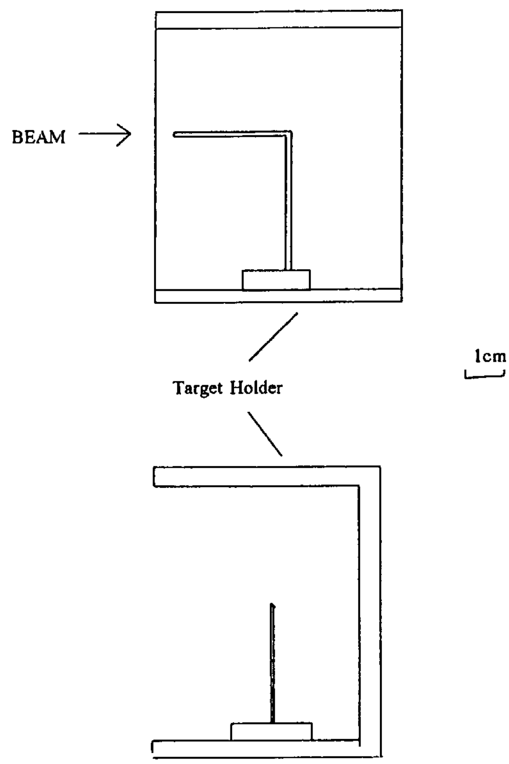

Fig.8 Thin needle held in the target holder

The simulation tells us that we have sizable temperature rise for the thin needles made of various materials. The Pt needle was driven horizontally and vertically across the proton beam using the target driver system. Fig.10 shows the results of the measurements. Fig.10-a and b shows the horizontal and vertical beam profiles at EP2-C target station.

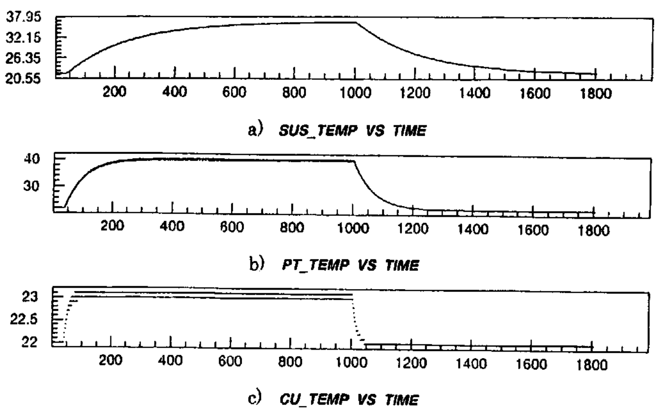

Fig.9 Simulation of temperature rise for SUS, Pt and Cu

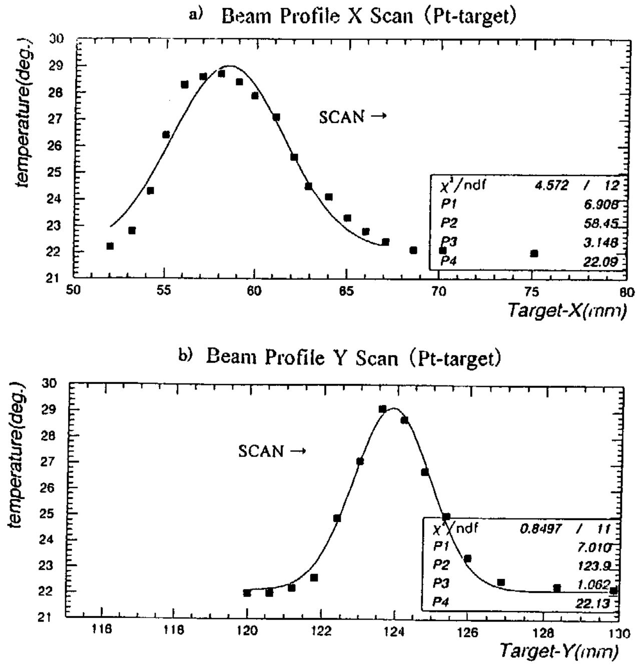

Fig.10 EP2-C Beam Profile measured with Pt needle

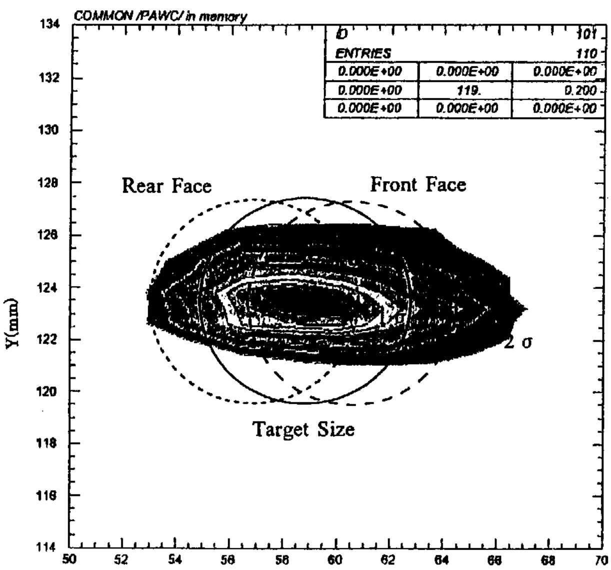

Fig.11 Two dimensional Beam Profile of EP2-C measured with Pt needle

Fig.11 shows the two dimensional measurement of the proton beam at the target station. This is the first two dimensional measurement of the slow extracted proton beam at the target position at KEK 12GeV-PS. The proton beam cross section is found to be very flat in the horizontal plane and the cross section(6.6mmx2.2mm) is suitable for our target(8mm ϕ).

We have now a tool to measure the proton beam profile at the target station. This would help to reproduce the proton beam condition at the target position after a long shut down of 12GeV-PS.

4. Summary

We have made a target monitoring system and a beam profile monitoring system by using the temperature measurements. The real time target monitoring is now available at K0 beam line of KEK 12GeV-PS. The real time target monitoring was made possible by the direct measurement of the temperature difference between front and rear faces of the target. Two dimensional beam profile measurement was made by measuring the temperature rise of the thin Pt needle. This tool would help to keep the proton beam to an appropriate size. However, the measurement takes rather a long time at present. We have to wait for a minute to measure one point. In order to improve the measurement time, we are preparing a method of direct measurement of the temperature difference between successive needles.

References

[1] T. Inagaki et.al. KEK 12GeV-PS proposal(E391a)