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Radiation monitoring at Belle

D. Žontar*

Institute of Applied Physics, University of Tsukuba, Tennodai 1-1-1, Tsukuba-shi, Ibaraki-ken 305-8753, Tsukuba, Japan

For the Belle SVD Monitoring Group

Abstract

High beam currents at the KEK B factory lead to high radiation background (order of 100 krad/y, consisting mostly of spent electrons/positrons) around the interaction point where the silicon vertex detector is located. In order to monitor the background conditions close to the interaction point a radiation monitoring system has been developed and installed. It is based on 16 monitoring modules containing RadFET chip (containing 4 sensors) for measurement of total accumulated dose and PIN diodes for measurement of instantaneous dose rate.

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Keywords: Radiation monitoring; Radiation damage; Silicon detectors

1. Introduction

High luminosity (over $4 \times 10^{33}/\mathrm{cm}^2\,\mathrm{s}$) of the KEK B factory [1], obtained by high beam currents (close to 1 A/beam), leads to significant radiation background close to the beam pipe. Belle detector [2] has a micro vertex detector [3] surrounding the interaction point and the high background has damaging effects on its performance, which are mainly due to the increase in detector occupancy or damage to the detector and the electronics. As experienced with the first version of the Belle silicon vertex detector (SVD), an undetected increase in background can lead to a sudden death of the SVD. Therefore, in order to assure a successful operation of the SVD during its designated operation period, an effective radiation monitoring system for the SVD region is of utmost importance.

Design of the monitoring system for Belle SVD 1.4 has been determined by the requirement that it should provide:

- information about total accumulated dose,
- information about instantaneous dose rate,
- fast warning signal in case of large, fast deterioration of background,
- information about the radiation field around SVD.

A modular design consisting of 16 modules, each containing three types of sensors, has been adopted.

*Tel: +386-1-477-3742 fax: +386-1-425-7074.
E-mail address: dejan.zontar@ijs.si (D. Žontar).

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2. Description of the system

Radiation monitoring module is based on a thin kapton circuit and is functionally and spatially divided into two parts: a sensor part and an electronics part. This division has been required by the limited space available at designated sensor locations.

Sensor part (Fig. 1) contains:

- one RadFET chip,
- two PIN diodes,
- one Pt100 resistive temperature device (RTD).

The electronics part contains two pre-amplifiers, connected to the PIN diodes, and provides soldering pads for the readout cable connection.

The main purpose of the *RadFET sensors* is measurement of the total accumulated dose. RadFET is a MOSFET, optimized for sensitivity to radiation [4]. Radiation damage is detected as a threshold shift of the transistor due to charge accumulation in the gate insulator. The fact that this mechanism is similar to the one causing damage to the readout electronics, combined with small dimensions and easy electrical readout, makes RadFET a very attractive choice for the integrating sensor. RadFET sensors are commercially available, with different ranges of sensitivity. RadFET chips adopted in the monitoring module contain four sensors, two with krad sensitivity (up to few Mrad) and two with rad sensitivity (up to few 10 krad).

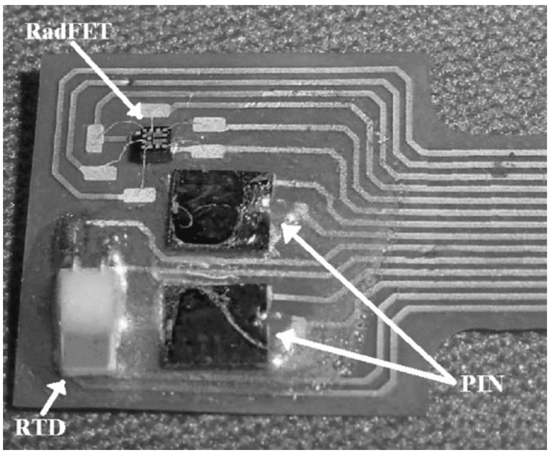

Fig. 1. The sensor part of the monitoring module, containing a RadFET chip, 2 PIN diodes and a RDT.

PIN diodes are used to detect instantaneous dose rate. Sensor part contains two PIN diodes with an active area of $2.4 \times 2.8\ \mathrm{mm}^2$, operated with no bias voltage. Diodes are connected to pre-amplifiers with gains different by a factor of 100. This construction provides very high sensitivity range, with high gain diode being used to measure dose rate during normal operation and the low one to detect fast, very high deterioration of the background.

Pt100 RTD sensors are included in the module with dual purpose. They enable temperature correction to outputs of radiation sensors and provide temperature information at different locations around SVD, thus partially integrating radiation monitoring and temperature monitoring systems.

In order to obtain good information about the shape of the radiation field in the area of the SVD, monitoring modules have been mounted on beam pipe and on the inner cover of the SVD, just outside of the acceptance region, at four azimuthal angles $(0°, 90°, 180°, 270°)$, in forward and backward direction.

Background information from RadFET and PIN sensors are displayed to experimental and accelerator crew and provide warning in case of significant increase of the dose rate. Besides, if dose rate exceeds 100 mrad/s for more than 2 s, monitoring software issues a beam abort signal. A hardware abort module, connected to low gain PIN diodes, is used to protect the detector from extreme increase of the background. When dose rate exceeds about 100 rad/s (over 10^4 average dose rate), it issues a fast beam abort signal with the total response time of the system of the order of ms (Fig. 2).

3. Performance of the system and radiation background

The described system has been operating for a year in the Belle SVD 1.4, which was installed in 2000 summer shutdown. It provided valuable information about the total accumulated dose

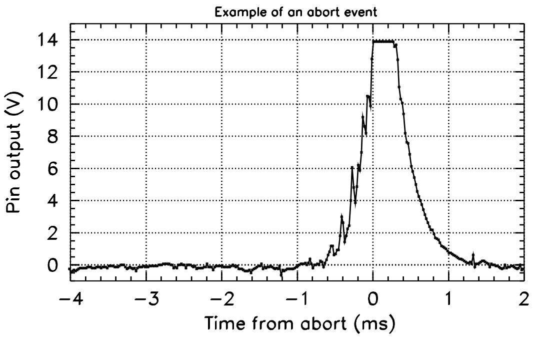

Fig. 2. An example of a SVD beam abort event. PIN signal is proportional to the dose rate. At time = 0 beam abort signal has been sent to the accelerator control.

and its geometrical dependence. Information about instantaneous dose has been a valuable guide to the accelerator crews during injections, machine studies and normal operation. Besides, fast beam abort system proved to be a successful protection against any sudden increase of the background, most often caused by the loss of the control of a beam. In beam background studies, results of the radiation monitoring system gave information about background dependence on beam currents and vacuum conditions, contributing to better understanding of the accelerator.

Average total accumulated dose in SVD 1.4 during first 10 months of operation was about 120 krad, with about 30% of that coming from beam injections and about 70% from operation with stored beams. Background field shows strong angular dependence with the dose in downward direction being more than three times the dose in the inside direction.

Studies of background dependence on the beam currents show faster than linear increase with current, indicating that background mostly consists of scattered electrons and positrons, with light contribution of X-rays from synchrotron radiation. Very effective masks are strongly reducing the contribution of spent particles generated far upstream, leaving mostly background radiation and particles, generated close to the interaction point.

4. Conclusion

A radiation monitoring system, consisting of RadFET chips and PIN diodes, has been developed for the Belle SVD. Its operation during the last year of running proved it to be very suitable for the conditions present at high luminosity electron machine. It has been providing valuable information about the radiation field close to the interaction point and also helped in keeping the background at the levels that will assure successful operation of the SVD over its designed operation period.

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