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Radiation monitoring and beam dump system of the OPAL silicon microvertex detector

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Abstract

The radiation monitoring and beam dump system of the OPAL silicon microvertex detector is described. This system was designed and implemented to measure the radiation dose over time scales varying from a millisecond to a year, and to induce a fast beam dump if the radiation exceeds a given threshold in dose and in dose rate within a very small time interval. The system uses reverse-biased silicon diodes as sensitive elements and good stability is achieved by AC coupling of the amplifiers to the sensors.

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1 Introduction

The OPAL detector is a general purpose apparatus designed to observe e^+e^- annihilations in the LEP collider at CERN in Switzerland. A description of the OPAL detector can be found in Ref. [1]. The silicon microvertex detector [2, 3] is part of the OPAL tracking system for charged particles. The microvertex detector provides precise position measurements for charged tracks resulting in excellent impact parameter resolutions and clean secondary vertex identification. During LEP operation, the inner regions of the OPAL detector are exposed to varying levels of synchrotron radiation and off-momentum beam particle radiation. LEP has been running from 1989 to 1995 at centre-of-mass energies around the Z^0 peak (LEP1 phase), and since then at higher centre-of-mass energies up to 172 GeV (LEP2 phase). For LEP2 operation, the radiation levels were expected to be higher than those at LEP1. Because parts of the present silicon microvertex detector were installed in 1993 and must remain in operation in OPAL until at least the year 2000, its desired minimum lifetime is more than eight years. The performance of the less radiation-hard version of the MX7 readout chip¹ can start to deteriorate at an integrated dose above 30 Gy and the signal-to-noise performance drops by 20% at about 300 Gy as measured with a ^{60}Co source [3]. Since in the past three years of operation the microvertex detector locally absorbed up to about 14 Gy, a maximum radiation dose of about 4 Gy per year of operation until the year 2000 should be tolerable.

The first radiation monitoring system for the silicon microvertex detector was installed in 1991. It uses four $9.5\text{ mm} \times 9.5\text{ mm} \times 400\text{ }\mu\text{m}$ semiconductor solar cells [4] located about 20 cm from the most radiation sensitive electronic components, the MX7 chips. These solar cells measure the radiation from the LEP machine in the horizontal and vertical planes. The solar cells were carefully selected and calibrated with a ^{137}Cs source before installation. They record levels of ionising radiation up to 1.6 Gy/h with a resolution of 0.1 mGy/h [2]. No bias voltage is applied to operate these solar cells. Furthermore, they are shielded from the beam pipe by a considerable amount of material, which makes them insensitive to most of the synchrotron radiation, which is always present when beams are circulating in LEP. The readout of these solar cells has a very long time constant of several tenths of a second, making the system unsuitable for recognising large radiation bursts of very short duration.

After an incident during which about 200 amplifier channels in the microvertex detector were damaged by a “pencil beam” loss (i.e., the case where the beam loss is directional and concentrated in one small region of the detector), it was decided to supplement these solar cells with a new system that responds quickly to high radiation doses. The radiation monitors described in this paper are sensitive to synchrotron radiation down to a few keV. The system is able to measure the radiation dose received at every beam crossing (every 22 μs) covering the range from one single minimum ionising particle (MIP) to 10^8 particles per beam crossing. It is able to trigger a beam dump in less than 1 millisecond, thus protecting the microvertex detector from excessive radiation exposure. Although the front-end electronics have a greater radiation tolerance when unpowered, no action is taken to power it off in the case of a radiation incident, as high radiation bursts are normally of a much shorter duration than the time required to ramp down voltages safely. Together with this new radiation monitoring system, the solar cells are still operational and their measurements are used as a cross-check and a backup system.

There exist two mechanisms for LEP experiments to stop accidental beam losses into their

¹The left side of the silicon detector is equipped with a radiation-soft version of the MX7 chips while the right side, which was built at a later stage, is equipped with a radiation-hard version [3].

Figure 1: *Schematic view of the silicon microvertex detector.*

detectors. The first is a beam dump system that activates a beam kicker that steers the circulating stored beams into a beam dump. This system is activated by breaking a current loop that runs between the LEP control equipment and each LEP experimental control room. The dump system requires about $500 \mu\text{s}$ between breaking the loop and complete removal of all beam particles. This beam dump facility was first exploited by the ALEPH Collaboration to protect their silicon microvertex detector, followed by the OPAL Collaboration which uses it to protect their silicon-tungsten luminometer [5]. The second mechanism is called the injection inhibit. Because the beam dump system only functions for circulating stored beams, it does not protect against damaging beam losses during the injection phase of LEP. Although the instantaneous currents in the machine are much smaller during injection, it is possible to continuously lose newly injected beam into sensitive areas of the experiments. To avoid this, the LEP control system has a software-based system that checks radiation levels sent to it by the LEP experiments. The system prevents beam injection if excessive radiation levels are received.

In the following sections, an overview of the radiation monitoring and beam dump system is

Figure 2: *Schematic cross-section of the ICR cards and the radiation monitoring modules. The numbering and location of the radiation monitors are indicated.*

given; it is followed by a detailed description of the radiation monitoring detector modules, the signal transportation and the counting room electronics. The calibration of the system and its interfaces to the OPAL and LEP control and monitoring systems are then described. Lastly, a short account is given of the operational experience obtained so far.

2 Layout

The new radiation monitoring system is composed of seven detector modules placed at each end in the z direction² of the microvertex detector. The two sides are operated independently. Each module is mounted within 10 cm of the MX7 chips in the direction away from the microvertex detector. The detector modules are located on the interconnect ring (ICR) cards and face the beam pipe. The ICR cards process the signals of the front-end electronics for the microvertex detector readout system. The radiation monitors are placed within a radial distance of 2 mm from the beam pipe and have no extra material in front of them. They are exposed to the same radiation levels as the inner barrel of the microvertex detector.

Figure 1 shows a schematic view of the microvertex detector. The position of a radiation monitoring module is indicated. It is located close by the detector ladders that are also indicated in the same figure.

Figure 2 shows a schematic cross-section of the ICR cards and the radiation monitoring modules. The numbering and location of the radiation monitors are indicated. The radiation modules are placed between the beam pipe and the ICR cards. Two extra modules are mounted to the front faces of the OPAL silicon-tungsten luminometer [5] about 2.5 meters away from the interaction point in each direction along the beam pipe.

²The OPAL coordinate system is defined such that the z axis is in the direction of the electron beam.

Figure 3: Schematic drawing of the radiation monitoring and beam dump system.

Each module is equipped with five or six silicon diodes cut from the silicon wafer test structures provided with the silicon microstrip detector wafers [6]. Since they are made from the same material as the silicon detector wafers and have undergone the same processing, they are ideal for measuring the radiation dose received by the microvertex detector. The diodes, each measuring $8 \times 8 \text{ mm}^2$, are mounted on a printed circuit board (PCB) which also contains front-end electronics. The diodes are reverse-biased and are read out in parallel. Ionising radiation produces a current in the diodes that is converted to a voltage, and then shaped and amplified by a two-stage amplifier on the same PCB. In a second signal path, this current is converted to a voltage across a capacitor and transported unamplified to the electronics in the counting room. A more detailed description of the radiation monitoring modules is given in Section 3.

A schematic drawing of the overall system is shown in Fig. 3. The radiation monitoring modules send their signals to a signal receiver board located in the counting room via twisted pair cables and a patch panel mounted on the side of the OPAL magnet return yoke. Each detector side is equipped with an independent power module, receiver module and beam dump module. The two dump signals are collected in a single LEP/OPAL interface box.

The signal receiver board provides both slow signals to an ADC module and fast signals for a beam dump module. The ADC module digitises the analog signal height and the data is further processed by a CPU. The beam dump module could actuate the LEP beam dump if the thresholds on integrated dose and dose rate are exceeded. The beam dump module also provides monitoring outputs connected to another ADC, that samples the radiation level at a

Figure 4: Schematic drawing of the radiation monitoring module.

frequency of 1 kHz. If a beam dump occurs, the digital values are stored for later analysis of conditions leading to the dump. The slow digital dose rate information is also used to inhibit beam injection into LEP if sustained high radiation is detected during LEP filling.

3 Radiation monitoring modules

Each radiation monitoring module consists of a 1 mm thick PCB, $5.6 \times 2.5 \text{ cm}^2$ in size, equipped with silicon diodes, used as sensors, and front-end electronics. The electronic schematic diagram of a radiation monitoring module is shown in Fig. 4 and a photograph of the module is shown in Fig. 5.

Each radiation monitoring module has two different output channels, allowing a large dynamic range. The high-gain channel uses the signal generated in the diodes passing through a two-stage operational amplifier (IC1 and IC2 in Figure 4). This signal ("the amplifier signal") is used to produce a "time history" and a "total integral" of the radiation dose received in a range from about 0.25 mGy/h to 2.5 Gy/h.

The resistor R15 is used to offset the output of the second amplifier stage by -2.5 V , which increases the dynamic range from 3.5 V to 6.0 V , if the amplifiers are powered at their nominal value of $\pm 6 \text{ V}$. This baseline shift of 2.5 V also provides a means to check that the radiation monitoring modules are functioning once installed inside OPAL when no direct access is possible. The low-gain channel uses the signal generated over the filter capacitors in the backplane bias voltage path (C1 and C11 in Fig. 4). This signal ("the backplane signal") is

Figure 5: *Photograph of a radiation monitoring module (actual size). The cut out in the bottom left corner allows the placement of a thermistor on the ICR card, monitoring the local temperature near the radiation monitoring module.*

sent to the beam dump module to generate a fast beam dump trigger. The low-gain channel covers a range from about 0.5 Gy/h to 5 kGy/h. The combined high- and low-gain channels provide a continuous dose rate measurement from 0.25 mGy/h to 5 kGy/h with an overlap between the ranges covered by each channel. The beam dump signal is derived from several low-gain channels and has a minimum sensitivity threshold of 36 Gy/h. The decay time of each low-gain channel is 2.4 μ s, while the rise time is much faster. The rise and decay times of the high-gain channels are similar to those of the low-gain channels.

The original design of the radiation monitoring modules used five individual 8×8 mm² silicon diodes. In the second production batch, two 8×24 mm² triplets of diodes are used. They were originally test structures on the same wafers that contained the strip detectors used in the microvertex detector. By using these diode triplets without cutting them further into 8×8 mm² individual diodes, the dicing operation was made easier. Two 8×24 mm² triplets could be glued on the radiation monitoring module instead of five 8×8 mm² diodes without modification of the module, thereby increasing the sensitive surface. A probe station and an LCR meter were used to measure the depletion voltage for each diode by means of CV curves. In addition, the leakage current was measured at a reverse-bias voltage of 40 V. A triplet of diodes was retained if all three diodes had similar (± 1 V) depletion voltages of about 15 V and if they had a leakage current smaller than 1.5 nA at 40 V bias voltage. All the triplets were also optically inspected to ensure that no visible surface damage, such as scratches or cracks, was present. After being cut, the triplets were cleaned with alcohol and the diodes of one given triplet were bonded together so that they could be tested in parallel. A long-term stability test was performed with the triplets, selecting them on the basis of a stable leakage current smaller than 1.5 nA. Two such triplets were glued and bonded on each radiation monitoring module. The assembled radiation monitoring modules were functionally tested both with a LED flasher and a radioactive source.

4 Signal transport and counting room electronics

The cables to transport the signals from the radiation monitoring modules to the patch panel consist of individually shielded twisted pairs, with a total diameter smaller than 1 mm [7]. This choice is imposed by the constraint on the space available for the cables in the microvertex detector region. Electrically passive patch panels located on either side of the OPAL magnet return yoke re-distribute the various signals to a second set of cables with larger cross-section

Figure 6: Circuit diagram of a backplane channel in the receiver module.

that transport the signals to the receiver electronics located in the counting room. The custom-made PCB connectors were well shielded electrically to avoid pick-up from the LEP radio-frequency system.

Two 6U Euro standard crates, each with a custom-made backplane, located in the counting room, serve the radiation monitoring modules each for one side of the detector. Each of these contains a power module, a signal receiver module and a beam dump module.

The low voltage power module supplies the eight radiation monitors with two floating voltages for the two-stage amplifiers, nominally set at ± 6 V. These voltages can be adjusted to optimise dynamic range versus power dissipation and to adjust the amplifier output offset. Each low voltage channel is individually fused.

The receiver module consists of eight identical channels for the backplane signals (high radiation) and eight identical channels for the amplifier signals (low radiation), all treated in the same way, although different component values are used for amplifier and backplane signals. In the receiver module, the signals are amplified, shaped, rectified and filtered with a time constant of about 0.5 seconds to achieve integrated dose measurements. The schematic circuit diagram of the receiver module is shown in Fig. 6.

The input signals from the radiation monitoring modules are AC coupled to the receiver amplifier by capacitors giving an appropriate time constant such that the output is the differentiated input signal. AC coupling eliminates sensitivity to baseline shifts in the radiation monitoring module output signals, e.g., due to changes in leakage current or temperature. The output of the receiver amplifier is also AC coupled, to remove DC level shifts, and rectified in a two-stage amplifier that also allows the input and output offsets to be adjusted for calibration purposes. The last amplifier filters the signal with a 0.5 s time constant, appropriate to feed a slow ADC. In addition, the fast and amplified backplane signal is picked off before the filter and sent to the beam dump module. The only functional difference between the backplane and amplifier channel circuits is the supplying of the reverse-bias depletion voltage over the diodes on the radiation monitoring modules. The amplifier gains are adjusted such that 1 V at the filter output corresponds to a dose rate of 0.25 Gy/h for the amplifier signal and 500 Gy/h for the backplane signal.

Figure 7: Circuit diagram of a channel of the beam dump module.

The beam dump module integrates the fast backplane signal from the receiver module. The circuit diagram for one of the eight channels in the beam dump module is shown in Fig. 7. The signal is received differentially and the amplification and baseline shift can be chosen to guarantee stable operation of the integrating circuit.

The integrated voltage decays linearly with an adjustable slope but never falls below zero. The adjustable decay rate is currently set to 0.01 Gy/s. Therefore, radiation levels above 0.01 Gy/s will integrate to produce a rising output resulting in an alarm or a dump signal when the output exceeds a certain level. If there is a coincidence of several fast backplane signals passing the low threshold (alarm) and at least one of them also passing the high threshold (dump), a beam dump signal is generated and sent to the LEP/OPAL beam dump interface box located in the OPAL control room. The multiplicity (up to 7) for the low threshold requirement can be adjusted by a front panel potentiometer. Any individual channel can be disabled from the dump logic by removing a jumper at the front panel. The action of the beam dump signal on the LEP current loop interlock can be disabled from the OPAL control room. If the beam dump system is enabled, the dump signal is sent to the LEP control system by breaking the LEP control current loop. A beam dump actuated from the radiation monitors also gives rise to acoustic and visual alerts in the OPAL control room.

5 Calibration and adjustment

Calibration measurements are performed by injecting a charge into the front-end amplifier input. This is done by a voltage step on a 150 pF capacitor that simulates the response of the diodes. For the 250 μm thick silicon diodes, a radiation dose of 1 μGy corresponds to a charge deposit of $Q_I = 4.1 \times 10^{-11}$ C for the boards with five diodes (150 pF). For an instantaneous radiation dose of 1 μGy , the peak output voltage V_{peak} is therefore 273 mV. The same procedure is followed for the boards with two diode triplets.

The components of the backplane channel were chosen such that an output signal of 1 mV corresponds to about 0.5 Gy/h. With this calibration and knowing that the ADC dynamic range is from 1 mV to 10 V, the low-gain channels cover the high radiation range from 0.5 Gy/h to 5 kGy/h. For the amplifier channels, the components were chosen such that an output signal

Figure 8: *Schematic drawing of the components involved in the digital signal processing.*

of 1 mV corresponds to about 0.25 mGy/h. With this calibration, the high-gain channels cover the low radiation range from 0.25 mGy/h to 2.5 Gy/h.

The adjustment of the beam dump module is similar to that of the receiver module. The components have been adjusted so that 1 V corresponds to 0.01 Gy and the decay corresponds to 0.01 Gy/s.

6 Digital signal processing

A schematic drawing of the components involved in the digital signal treatment is shown in Fig. 8. The slow, 0.5 s time constant, output signals of the receiver boards are fed into a 12-bit ADC module [9]. This ADC module is situated in a VME crate controlled by a MVME167 VME CPU module [8] (SIMON in Figs. 3 and 8), that runs the OS9 operating system [10]. In the same crate, all other electronics for controlling and monitoring of the OPAL microvertex detector are housed under the control of the same CPU module. The effective ADC resolution of 2.5 mV, corresponding to 1 count, is enhanced to about 1 mV by the averaging of several independent samplings per reading. The effective dynamic range of this ADC is then 10^4 . Readings are made at a rate of 4 Hz, matching the 0.5 s decay time constant of the signal. A

pedestal subtraction algorithm is applied to the readings, and averages are formed over 1 minute intervals and are permanently stored. Averages over a 30 second time interval are transmitted to the LEP injection inhibit software. The injection inhibit is activated when more than one of the 30 second averages exceeds 0.1 Gy/h, blocking any beam injection in LEP for 5 minutes. This prevents the situation in which beam injected into LEP is continuously lost in the vicinity of the microvertex detector, giving rise to a virtually unlimited radiation dose jeopardising the detector. In addition, the monitoring software constantly checks the dose rate. If a certain threshold dose rate is exceeded, a trace of all readings with a 1 second sampling rate is stored including a number of samples in time before and after the incident.

The output of the beam dump module integrators is sent to a dedicated system consisting of an ADC module and a MVME167 CPU module (SIRAD in Figs. 3 and 8), housed in a separate VME crate and also running the OS9 operating system. This dedicated system samples the output of the beam dump module at 1 kHz and stores all the readings up to a total duration of 7.5 s in case of a (near) beam dump. This allows a detailed post-mortem analysis of beam dumps and situations in which the beam was nearly dumped.

The VME CPUs can send messages into the OPAL error message display system. These messages, which are entered in case of high radiation levels and beam dumps, are displayed in prominent places in the OPAL control room and may also trigger acoustic alarms. The OPAL error message system also archives these messages with a time stamp, such that these incidents can later be correlated with other recorded problems. All the stored time averages and recorded data of incidents are stored in Network File System mounted files that are accessible from an HP workstation. Software on such workstations can display the stored radiation levels in real-time or off-line. A real-time display is always available in the OPAL and LEP control rooms.

7 Operational experience

In 1993, the new radiation monitors were installed for the first time. During LEP operation that year, the viability of radiation dose measurements with the silicon diodes was demonstrated and the difference in sensitivity with respect to the solar cell system was studied. The time structure of radiation incidents was also examined. In 1993, the total radiation doses measured by the solar cells were about 0.3 Gy in the horizontal and lower vertical directions and about 1 Gy for the upper vertical direction [2]. It was learned at this time that the solar cell system was indeed insensitive to the synchrotron radiation background and hence underestimates the background from this source by a large factor (about 10). However, it was observed that the measurement of off-momentum beam particles and other large losses of charged particles into the vicinity gave similar readings in both the solar cell sensors and in the new diode sensors. The time structure of radiation incidents was found to vary from rise times of a few milliseconds, corresponding to only a few turns of the beams, up to hundreds of milliseconds for events that usually resulted in loss of LEP beams or produced significant radiation doses. This is illustrated in Fig. 9 showing three traces corresponding to three different beam losses recorded with an oscilloscope in 1994. This information was subsequently used to determine the necessary minimum response time of the radiation monitor electronics. The information on the typical magnitude of incidents also determined the necessary dynamic range needed for the improved radiation monitoring modules.

Figure 9: Oscilloscope traces showing the time structures of three different radiation incidents recorded in 1994. The beam losses were found to have rise times ranging from a few milliseconds up to hundreds of milliseconds.

During LEP operation in 1994, the total radiation doses measured by the solar cells were about 0.45 Gy in the horizontal and lower vertical directions and about 0.9 Gy for the upper vertical direction. A precise value for the total radiation was not computed with the new radiation monitors due to the large temperature variations affecting the long term dose measurement.

In 1995, together with a microvertex detector upgrade, the number of radiation monitors were doubled and read out on both sides. The radiation doses received by the silicon microvertex detector were measured in 1995 using the four solar cells and the operational radiation monitors 1L, 2L, 4L, 5L and 6L on the left-hand side and 1R, 3R and 7R on the right-hand side. The other monitors were not operational for the whole running period. The doses measured in 1995 by each of these monitors are summarised in Table 1.

#	1S	2S	3S	4S					Average
1995 (Gy)	0.40	0.86	0.51	0.44					0.55
1996 (Gy)	0.12	0.17	0.18	0.15					0.16
#	1L	2L	3L	4L	5L	6L	7L	8L	Average
1995 (Gy)	0.74	0.71	—	1.10	2.08	2.18	—	—	1.36
1996 (Gy)	0.18	0.23	0.13	0.20	0.58	0.32	0.16	0.23	0.26
#	1R	2R	3R	4R	5R	6R	7R	8R	Average
1995 (Gy)	1.13	—	0.89	—	—	—	1.57	41.2	1.20
1996 (Gy)	0.23	0.26	0.26	0.17	0.22	1.33	0.28	8.53	0.39

Table 1: Radiation doses in Gy measured in 1995 and in 1996 by the four solar cells (1S to 4S), the left-hand side radiation monitors (1L to 8L) and the right-hand side radiation monitors (1R to 8R). The averages are calculated excluding the monitors #8 which are not located near the microvertex detector. Modules with no entries were not operational.

Problems with runaway leakage currents and instability due to temperature fluctuations required further modifications and prompted a much tighter quality selection of the silicon diodes and the development of the AC coupled electronics. Many of the previous sensors had to be repaired or replaced. A total of seven radiation monitors operated in 1995 were refurbished and reused in the system after extensive testing.

In 1996, all 16 radiation monitors were operational and stable. The doses received starting from July 1996 are summarised in Table 1. Figure 10(a) shows the average integrated radiation

Figure 10: (a) Integrated radiation dose in Gy averaged between the 14 radiation monitoring modules mounted near the microvertex detector. (b) Highest integrated radiation dose in Gy amongst the 14 left and right radiation monitoring modules.

dose in Gy plotted daily. This average is computed using the 14 measurements provided every day by all radiation monitoring modules mounted on the microvertex detector ICR cards. Figure 10(b) shows the highest integrated radiation dose in Gy for any of these 14 modules.

In 1995, the total radiation dose averaged over the four solar cells is 0.55 Gy (see Table 1), while the average using the measurements from the left-hand side radiation monitors is 1.36 Gy. An estimate of the average scaling factor between the measurements provided in 1995 by the solar cells and the measurements provided by the radiation monitors is therefore 2.5. This can be explained by the fact that the new radiation monitors are much more sensitive to synchrotron radiation than the solar cells. Under the assumption that the 1995 scaling factor can be applied to the radiation doses measured by the solar cells during the previous years, the highest rescaled radiation dose measurements for 1993 and 1994 are 2.5 Gy and 2.3 Gy, respectively. In 1995 and 1996, the doses measured with the new monitors were 1.36 Gy and 0.26 Gy, respectively. The radiation dose received during 1996 LEP operation (LEP2) is substantially smaller than the doses received during the previous years (LEP1) due to changes in beam currents, configuration of the accelerator, shorter run duration and new shielding in and around the beam pipe. An estimate of the total average radiation dose received since 1993 is thus 6.4 Gy. An estimate of the highest dose received locally can be determined by computing the above defined scaling factor using the highest measurement given by monitor #6L (2.18 Gy) and the smallest value provided by the solar cells (0.40 Gy). This yields a scaling factor of 5.5. Using this number, the highest rescaled radiation dose measurements for 1993 and 1994 are now 5.5 Gy and 4.9 Gy, respectively. In 1995 and 1996, the highest measurements from the new monitors were 2.18 Gy and 1.33 Gy. An estimate of the total highest radiation dose received locally since 1993 is 14 Gy.

In September 1995, a prototype system including the beam dump facility was tested during

the last week of running at LEP1 and during the three weeks of running at LEP1.5 ($\sqrt{s} = 130\text{--}136$ GeV). No spurious beam dumps were generated during the test periods. One beam dump signal was induced, but not yet sent to LEP, when the beams became unstable and were lost. Although the system's sensitivity was set to a low threshold, the system appeared to be fully functioning and stable. It was producing beam dump signals when the beams were being lost and did not produce any spurious beam dump for the complete test period. For the 1996 high energy run, the complete system including newly manufactured receiver modules, beam dump modules and the LEP/OPAL interface box was commissioned. Currently, the alarm and dump thresholds are set to 5 mGy and 10 mGy, respectively. The thresholds are higher than for the 1995 run, which was operated with a dump threshold of 2.5 mGy and an alarm threshold of 0.25 mGy. The system has been monitored since July 1996 and after some minor adjustments has shown good stability.

8 Conclusions

During the past years, uncontrolled beam losses resulted in some problems for the OPAL silicon microvertex detector. Such radiation incidents as well as unavoidable synchrotron radiation could lead to degradation of the radiation-soft MX7 chips. For this reason, a system of 16 radiation monitoring modules was designed and implemented to protect the silicon microvertex detector against excessive radiation doses. The radiation monitors are placed as close as possible to the MX7 chips. These monitors are made from the same material as the strip detectors, therefore allowing an accurate estimate of the accumulated radiation on the microvertex detector. The system provides fast warnings of high radiation levels; it also provides an accurate measurement of low level integrated doses. A beam dump system allows beams that give rise to very high radiation levels to be dumped in a controlled way on time scales of less than 1 ms. The system has proven to be accurate and reliable.

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