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CALCULATIONS OF THE RADIATION DOSE FROM THE SYNCHROTRON RADIATION FOR THE BELLE SILICON VERTEX DETECTOR

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Abstract

The Belle experiment has been performed at KEK using a large data sample of $B\bar{B}$ pairs produced by the KEKB accelerator in order to study CP violation in B-meson decays. The Silicon Vertex Detector, which is one of the components of the Belle multipurpose detector, is put in the vicinity of the interaction point, so that a large amount of radiation is irradiated onto this detector. EGS4 has been used in calculations of the radiation dose from the synchrotron radiation. In this article, we describe a history and a current development on the dose calculation.

1 Introduction

The Belle experiment [1] has been performed at KEK using a large data sample of $B\bar{B}$ pairs produced by the KEKB accelerator [2]. The main purpose of this experiment is to study CP violation in B-meson decays.

The KEKB is an asymmetric-energy e^+e^- collider with two colliding rings for 3.5 GeV positron (e^+) beams (Low Energy Ring; LER) and for 8.0 GeV electron (e^-) beams (High Energy Ring; HER). Peak currents are about 1.4 A for the LER and about 1.0 A for the HER (in the spring of 2002). The KEKB currently has a world record on the peak luminosity: $\mathcal{L}_{peak} = 7.35 \times 10^{33}/\mathrm{cm}^2/\mathrm{sec}$.

The Silicon Vertex Detector (SVD) [3] is one of the components of the Belle multipurpose detector, and provides precise measurements on decay-vertex positions of B mesons. The SVD consists of three concentric cylindrical layers of silicon sensors with two orthogonal-coordinate readouts as shown in Figure 1, and installed in the vicinity of the interaction point (IP). Thus, a large amount of radiation induced by the KEKB beams is irradiated onto this detector.

2 SVD1.0 Gain Drop

On July 5 in 1999, the gains on the ladders in the first layer of the SVD version 1.0 (SVD1.0) started to decrease rapidly, and for some ladders, the gains were lost in about ten days as seen in Figure 2. The cause was supposed to be the synchrotron radiation (SR) from the HER. A dose calculation was done [5] using the two software programs: SRGEN [6] and the KEK-improved version of EGS4 [7] in order to confirm the source of the gain drop. SRGEN was used to calculate beam orbits with an approximation of $\alpha \gg 1$ and with a constraint for beams to go through the nominal IP. Positions and angles of SR photons together with energy and power spectra were passed into the EGS4 simulation, where photon energies were simulated down to 1 keV. The calculated dose was found to be enough to kill the SVD1.0.

According to the results of the simulations, we have taken two steps: to limit kick angles of the HER steering magnets and to coat a 10 μm-thick gold inside the interaction-region (IR) beampipe, where the thickness was determined using EGS4 [8]. We succeeded in reducing the background.

3 A New System of the Dose Calculation

We have started a development of a new system of dose calculations from the motivations:

- the SVD1.0 gain drop due to the SR from the HER mentioned above;
- we will have more beam currents for higher luminosities, which lead to more SR;
- we will have a smaller-radius IR beampipe to improve the resolution of the decay-vertex reconstruction for B-meson decays, which leads to more beam-induced background including SR.

The policy of the development is:

- EGS4 simulations based on an exact geometry of the IR beampipe;
- fast calculations for an online monitoring of the real radiation dose from the SR

in order to make the SR background under control.

The beam-orbit calculation is based on the measurements of the beam-position monitors and some offset corrections. SR photons are simulated according to the analytical formula [9] in a Monte-Carlo (MC) method using BASES/SPRING [10]. Detailed information can be found elsewhere [11].

The exact EGS4 geometry is constructed by making modules of the basic geometrical figures: *plane*, *cylinder*, *cone*, and *leaning cone*. Fast calculations are accomplished by preparing a mapping table of the response function, which also leads to an improvement on the error from the MC statistics. Figure 3 shows examples of dose distributions in the SVD first layer, where we obtain the same distributions with and without the table, and the tail region is well simulated in case of using the table. An example of dose calculations is shown in Table 1, where we can see a good agreement between with and without the mapping table, and a significant improvement on the computing time.

4 Conclusions

EGS4 has been used in dose calculations for the Belle SVD. We have obtained an evidence on the SVD1.0 killing scenario that the SR from the HER was a dominant source for the gain drop. We have started a development of a new system of dose calculations to make the SR background under control, and cleared basic steps for an online monitoring of the SR.

References

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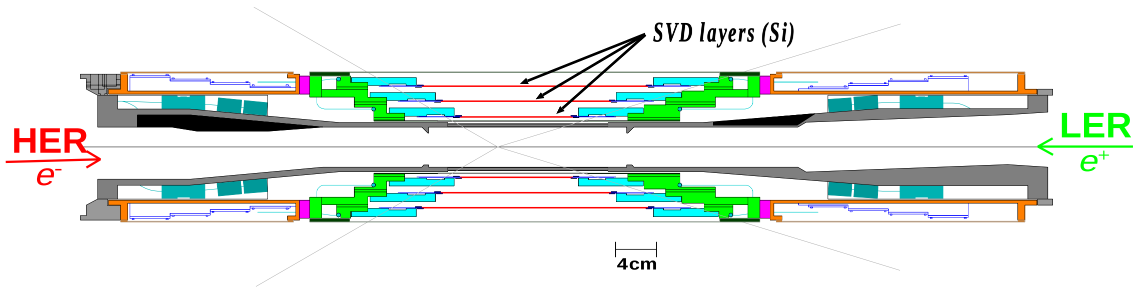

Figure 1: A cross section of the Belle SVD (version 1.4).

Table 1: An example of dose calculations. The first errors indicate statistical ones in the photon generation, and the second ones indicate the precision of the mapping table. Note that the parameters used in this calculation is not realistic, just for calculations. *'INNER'* and *'OUTER'* are defined in Figure 3.

	Dose in the SVD 1st layer [kRad/min/A]		CPU time
	INNER	OUTER	
W/o the mapping table	4.55 ± 0.31	19.5 ± 0.9	13 hours
W/ the mapping talbe	$4.63 \pm 0.11 \pm 0.02$	$13.84 \pm 1.60 \pm 0.06$	5 sec

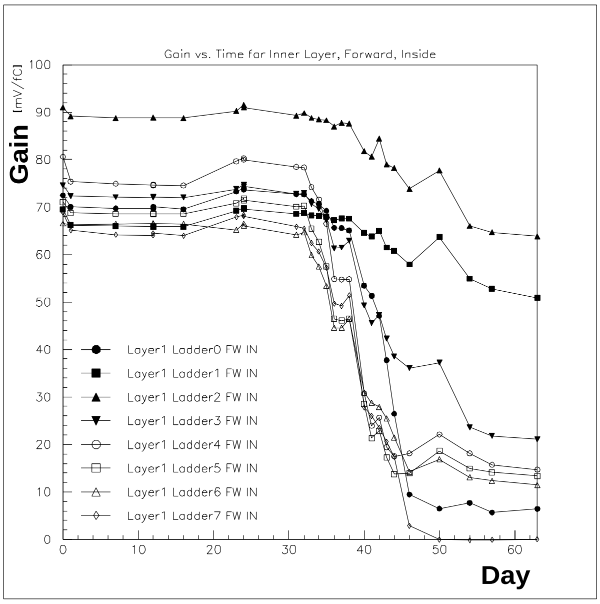

Figure 2: SVD1.0 gains as a function of time from Jun. 3 to Aug. 5 in 1999, extracted from [4].

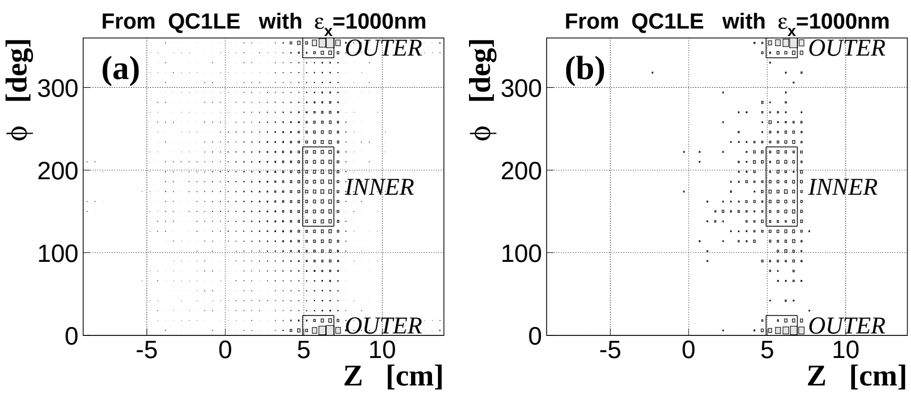

Figure 3: Examples of dose distributions in the SVD first layer (a) with and (b) without the mapping table. The Z axis is defined as an opposite direction of the LER (e^-) beam. *'INNER'* (*'OUTER'*) corresponds to the inner (outer) region of the KEKB rings.