

Beam background in the BELLE detector

J. Haba,

KEK, Tsukuba, Japan

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Abstract

Beam background is one of the most important issues in the KEKB/BELLE operation as well as luminosity, since the BELLE detector has a micro vertex detector surrounding a collision point where beam background is at the highest level. Electronics used there are based on CMOS technology, which is known to be radiation "soft". The current tolerance of the electronics used in the BELLE vertex detector (SVD) is as low as 200 krad.

It is, therefore, the most important task for the BELLE background control group (BCG) to keep background level well below this level with beam current stored as high as possible. In this report, the present status of the background in the BELLE detector and its gradual improvements are described.

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1 INTRODUCTION

1.1 KEKB Interaction Region

As is well known the most significant feature of the design of the KEKB complex¹ is a finite angle crossing of two beams (electron:HER and positron:LER) at the interaction region (IR). Thanks to the above scheme two beams are naturally separated away from interaction point (IP) without any special strong bending magnets sitting close to IP. We can be, therefore, free from high energy synchrotron radiation (SR) from such magnets.

Furthermore the HER beam line is designed to be completely straight in the upstream of IP after the last bend in the arc for as long as 100m as illustrated in Fig. 1. No strong bending magnets except for correctors are placed there. After passing the IP HER beam are bent outward by an off-axis Q field of QCS-R for the first time as shown in Fig. 2. This implies that all debris like lost particles or emitted photons which are generated in the

100m long upstream can reach IP and are deposited in the downstream of this bent orbit.

1.2 BELLE detector and Beam background

General description of the BELLE detector is found elsewhere². Serious effects on the BELLE detector from beam background are followings:

- ◆ High occupancy due to beam background in the detector element degrades its performance in both resolution and efficiency.
- ◆ Data transfer rate becomes huge due both to a higher (fake) trigger rate and to a larger data size per trigger.
- ◆ Preamplifier chip used in the silicon vertex detector (SVD) or CsI(Tl) crystals used in the calorimeter could be damaged by radiation dose from beam background.

Among those the SVD background is the most critical for the BELLE case since SVD is located just outside the IP beam chamber and the tolerance of the chip used is as low as 200 krad (so-called "radiation soft").

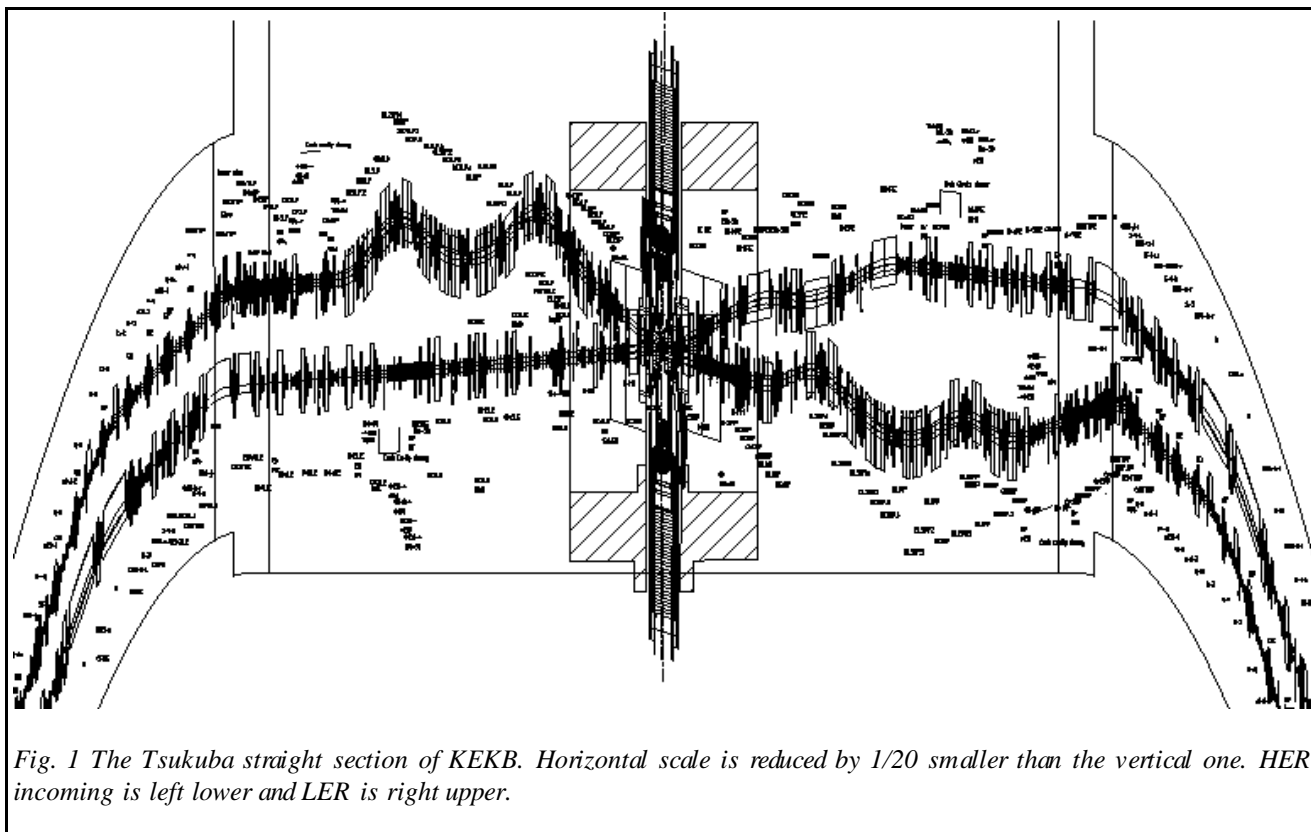


Fig. 1 The Tsukuba straight section of KEKB. Horizontal scale is reduced by 1/20 smaller than the vertical one. HER incoming is left lower and LER is right upper.

1.3 Background monitors

Several kind of background monitors are installed in the BELLE detector. Twelve PIN photodiodes are placed inside SVD system to monitor an instantaneous dose rate into the sensors and the electronics. Accumulated dose is also checked regularly by the RADFET device, which indicates the exposed dose with its threshold voltage as an FET. To get a fast response in monitoring beam loss during an injection period, we place pure CsI crystals with phototubes inside the endcap detectors.

Other than those special devices, the BELLE detector itself is also used as a background monitor in terms of counting rate, leak currents of biasing voltage, occupancy or noise level in the sensors and so on.

2 BACKGROUND IN SUMMER '99

Following the KEKB commissioning without the BELLE detector (Dec'98-Apr'99)³, the BELLE detector rolled into the beam area at the early May '99.

2.1 LER background

All the background monitors showed a clear quadratic dependence on LER beam current as shown in Fig. 3 and were improving along with an integrated beam current. It was evident that the background from "lost particle" are dominant source of background in LER operation.

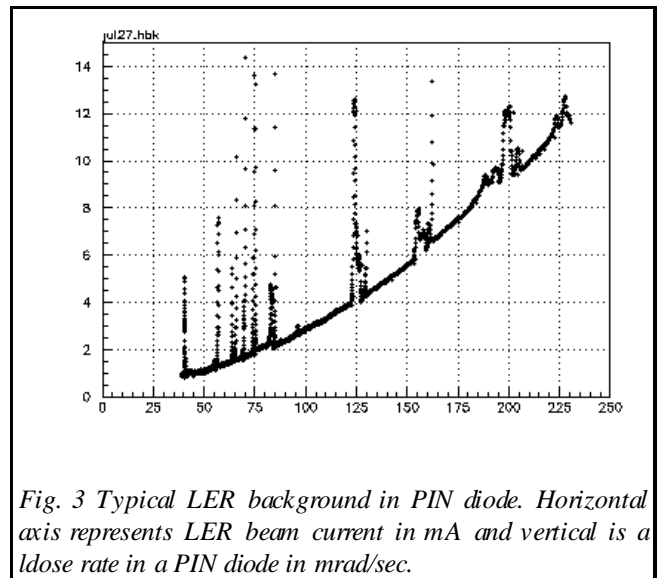


Fig. 3 Typical LER background in PIN diode. Horizontal axis represents LER beam current in mA and vertical is a dose rate in a PIN diode in mrad/sec.

2.2 HER background

There seemed to be three different kinds of background in HER operation. One was an anticipated lost-particle background, which was clearly seen in EFC (Extreme Forward Calorimeter mounted on the tip of QCS's cryostat), ToF (Time of Flight scintillation counter located 1m away from the beam line) or CsI (CsI crystal

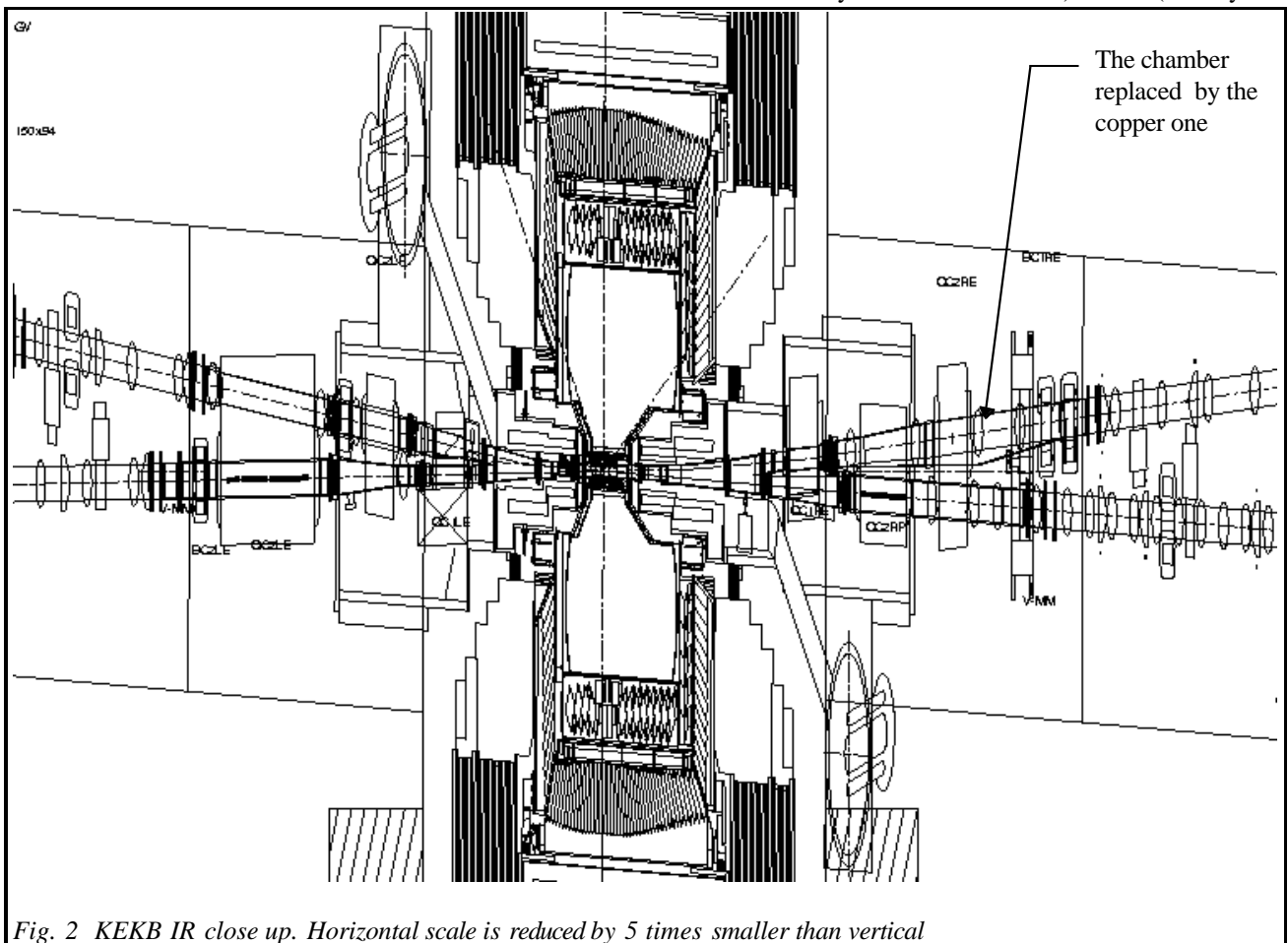


Fig. 2 KEKB IR close up. Horizontal scale is reduced by 5 times smaller than vertical

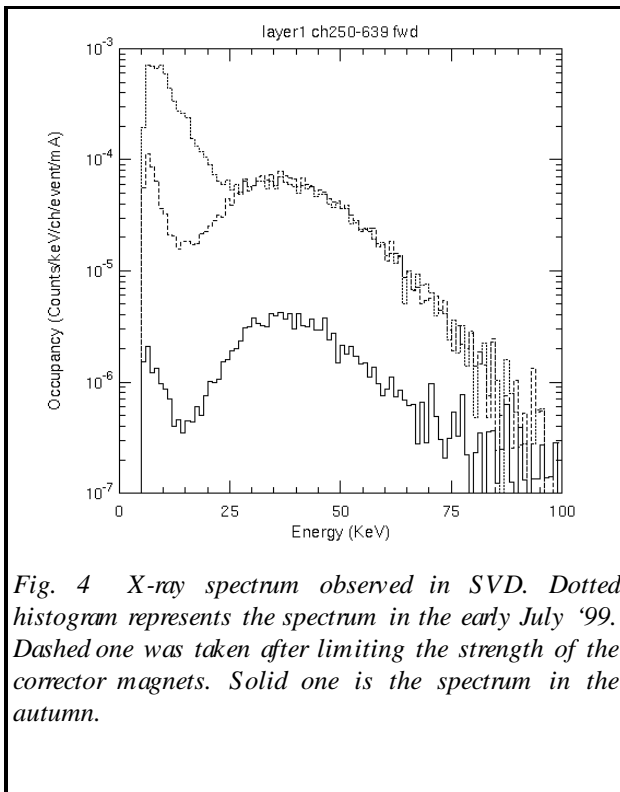


Fig. 4 X-ray spectrum observed in SVD. Dotted histogram represents the spectrum in the early July '99. Dashed one was taken after limiting the strength of the corrector magnets. Solid one is the spectrum in the autumn.

calorimeter 1.5 m away). They showed a quadratic dependence on beamcurrent .

On the other hand, there were some background indicators which showed almost linear dependence on HER current. They are CDC (Central Drift Chamber) or PIN diodes located forward part of the IP beam pipe. By analyzing low energy deposits in SVD with a single bunch operation of HER, it was found that there were two components of x-rays, low energy ($\ll 5$ keV) one and high energy (~ 30 keV) one as shown by a dotted histogram in Fig. 4. A linear dependence of the background on HER current could be understood if we assume they come from SR in some HER magnets.

Since the threshold of the above spectrum measurement is as high as 5 keV, the intensity of the lower energy x-ray could be too high for the SVD preamplifier chip to survive. When we recognized the situation, the gain of the SVD chips had already fallen to the ground as shown in Fig. 5. We found in the beam study after the incident that some of bump orbits in the upstream of IP can illuminate onto the IP beam pipe with SR which is generated in the corrector magnets with a kick angle around 0.5 mrad. Once we limited the strength of the magnet, the peak at low energy region disappeared as shown by a dashed histogram in Fig. 4.

As mentioned before, HER has no strong bending magnet in the upstream of IP. The potential source of the higher energy x-rays is the QCS-R which serves a bending field for HER beam after IP. High energy x-ray flux illuminates the aluminum beam chamber in the downstream and some significant fraction of it can be

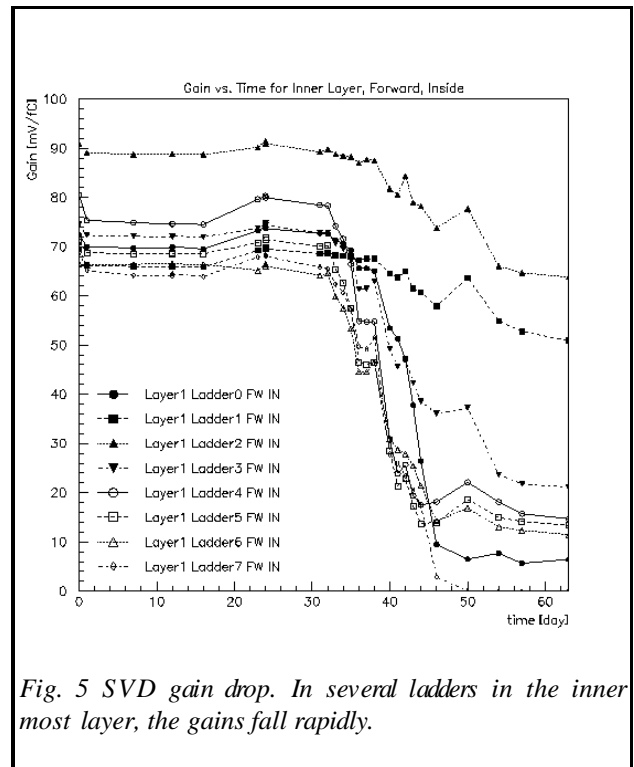


Fig. 5 SVD gain drop. In several ladders in the inner most layer, the gains fall rapidly.

reflected back to the IP chambers. Background energy spectra observed in CDC, where a shoulder around 5 keV was seen, could be explained easily by a Compton scattering of 30 keV x-ray mentioned above inside CDC volume. Due to this higher energy x-ray, CDC can't be operated stably with HER current higher than 200 mA.

3 MODIFICATION IN SUMMER SHUTDOWN

As mentioned above, we had three serious problems in HER background. Our effort for the improvement is, therefore, three folds.

3.1 Effort against lost particle background

We recognized that there were holes which were not shielded well from shower particles generated by lost particles hitting on the beam pipe wall. Presumably the first place to be fixed is the hole between EFC detector and the existing tungsten mask as illustrated by shadowed areas in Fig. 6. We have added new tungsten masks as indicated by hatching in the figure.

3.2 Reduction of higher energy x-ray background

As mentioned above, the higher energy x-ray is thought to come from a reflection of SR photons generated at the QCS-R. To reduce the flux of the x-ray we modified the beam chamber which would be illuminated by the primary SR photon in two points;

the material used is changed from aluminum to copper in order to reduce reflection probability by a factor of ten.

the shape is modified so as to make a reflecting surface farther away from IP. Reduction of a factor of two is expected due to a smaller solid angle.

In Fig. 2 the old chamber shape are drawn by thin curves while the new shape is illustrated by thick ones.

The new beam chamber has been fabricated and installed at the end of September.

3.3 Protection against lower energy x-ray

In the beam study at the end of the last run period, we found that an upper limit on the kick angle in some of the corrector magnets were effective to prevent a lower energy SR x-ray to illuminate the IP chambers as described before. We, therefore, decided to have a definite restriction to every IR upstream corrector magnet of HER on its kick angle as follows;

- i) all the corrector magnets 10 m or farther upstream of HER IR have a limit of 0.3 mrad in its kick angle.
- ii) further limitation is applied on $s \cdot \theta$ to be less than 15mm where s is a distance of the magnet from IP and θ is a kick angle.

Condition i) limits a critical energy of x-rays emitted at the magnets and ii) prevents the x-rays to hit the IP chamber directly.

To avoid such a low energy x-ray to damage the electronics of SVD by all means, we wrap the IP beampipe with a kapton film coated with 20 μm thick gold. Furthermore 300 mm thick gold plates are put in front of the electronics of SVD.

4 BACKGROUND IN AUTUMN

3.1 LER background

Due to the exposure of the IR components to atmosphere during the summer shutdown for the replacement work of the damaged SVD, LER vacuum and therefore the background from LER was not good in the early days of the autumn operation. It is improving along with an accumulation of LER beam current.

3.2 HER background

At the beginning of the autumn operation, we made the measurement of x-ray spectra in SVD with 10 mA current as done in the last period. The solid histogram in Fig. 4 represents the spectrum observed in the autumn. Thanks to the replacement of the down stream beam chamber the yield of higher energy x-ray is now reduced by a factor of 20 as expected. The absence of sharp peak in the lower energy region implies that the orbit control in the upstream with the new limitation on the steering (corrector) magnets works fine.

The reduction of the higher energy x-ray is clearly seen in the leakage current of CDC as shown in Fig. 7, where the leakage current are plotted as a function of HER beam current. Also found in the figure is that the dependence on the beam current is quadratic in the autumn run while it is

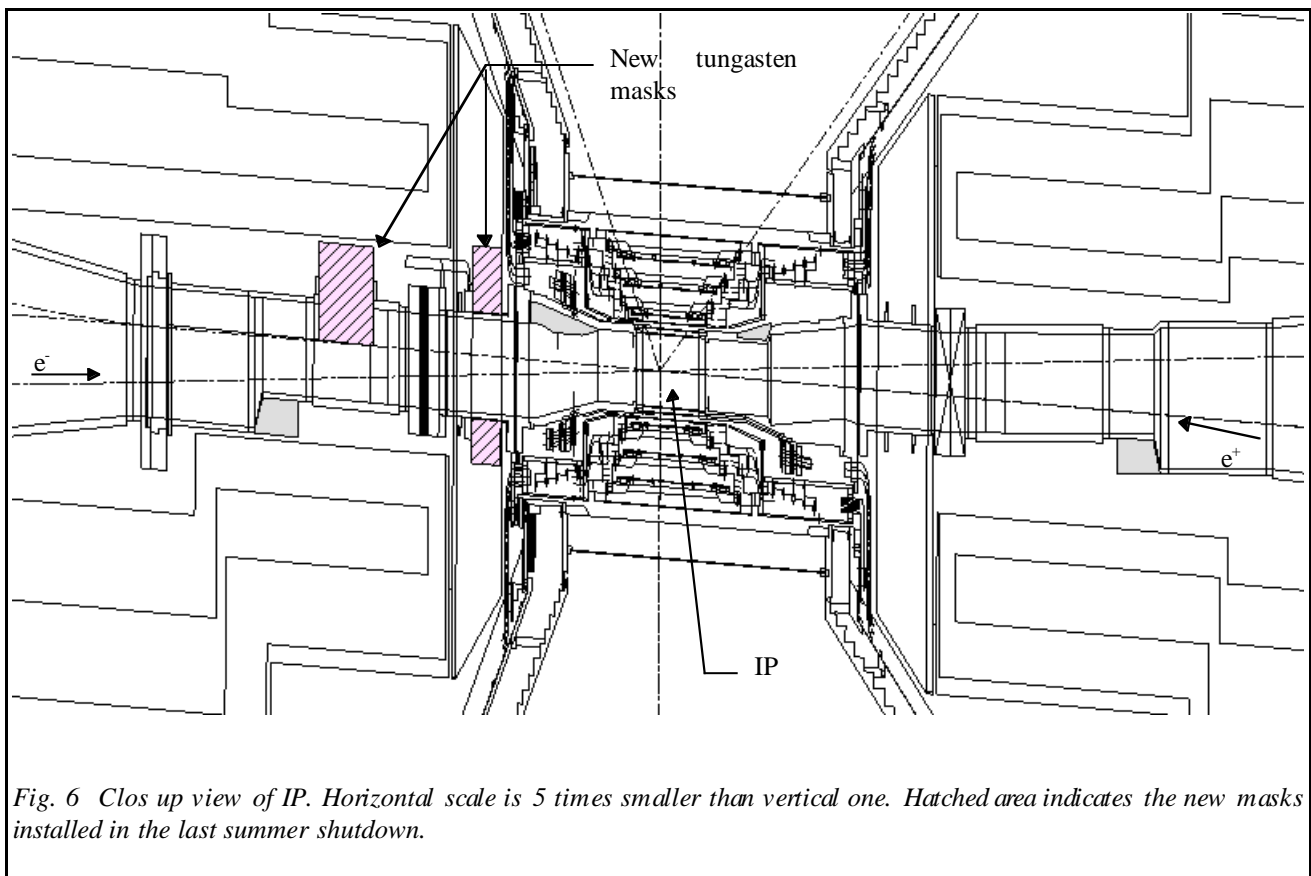


Fig. 6 Clos up view of IP. Horizontal scale is 5 times smaller than vertical one. Hatched area indicates the new masks installed in the last summer shutdown.

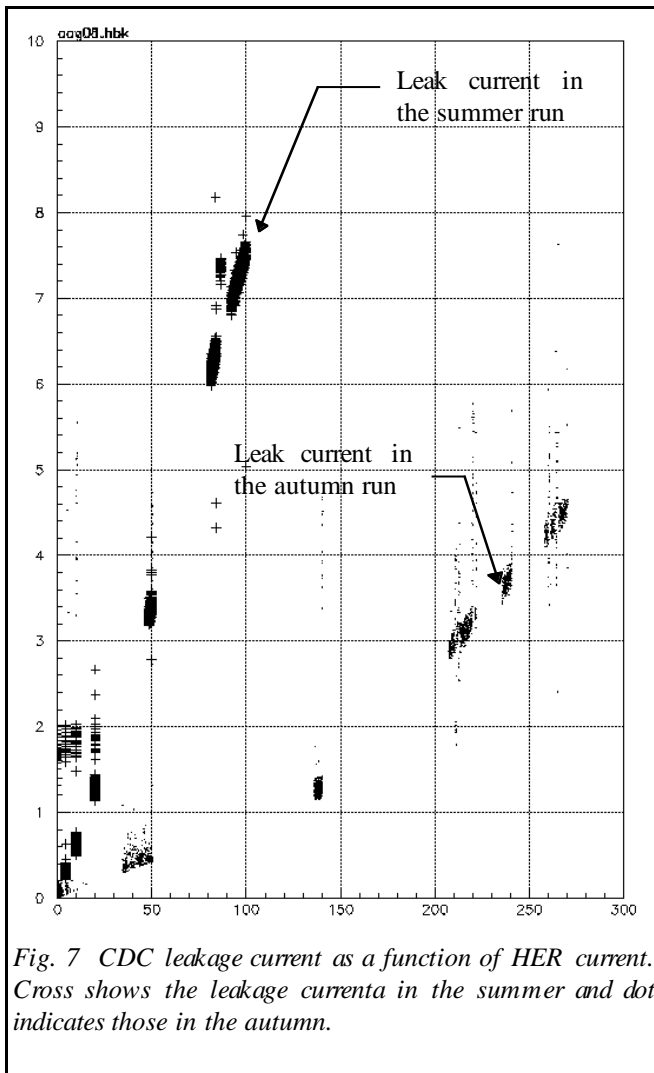


Fig. 7 CDC leakage current as a function of HER current. Cross shows the leakage current in the summer and dot indicates those in the autumn.

almost linear in last summer. Most of background now seems to come from lost particles.

5 SUMMARY

We have started the commissioning of the KEKB with the BELLE detector rolled in since the last May. The background observed in LER operation was considered to come from lost particles. Its level is relatively low and is still improving according to the improvement of vacuum level. In the last summer operation we suffer from the HER background due to SR photons. By replacing the beam chamber downstream of the IP in the summer shutdown, flux of the photons are reduced significantly. From the autumn operation, the major background source in HER can also be understood as those from lost particles.

For further reduction of background, the studies especially on the relation between the background and vacuum pressure should be very important.

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