Performance Studies of Belle II Silicon Vertex Detector.

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The Belle II experiment at the SuperKEKB asymmetric-energy e^+e^- collider in KEK, Japan will operate at an instantaneous luminosity of $8 \times 10^{35} cm^{-2}s^{-1}$, which is about 40 times larger than that of its predecessor, Belle. It is built with the aim of collecting a huge amount of data corresponding to an integrated luminosity of about 50 ab^{-1} by 2025 for the precise CP violation measurements and searches for new physics. At this high luminosity, Belle II will face harsh backgrounds. To validate the performance of a key component of Belle II, the silicon vertex detector (SVD) at such high rate and harsh background environment, a detailed systematic performance study is essential using offline software reconstruction. In this work, performance of the Belle II SVD is validated using commissioning data for each sensor/side. These studies help us to understand and optimize the operation parameters of the SVD.

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1. Introduction

The Belle II experiment [1] is an intensity frontier experiment, whose main goal is to search physics beyond the Standard Model (BSM) through indirect means. The Belle II experiment is installed at an interaction point of the SuperKEKB [2] collider at KEK, Tsukuba, Japan. The SuperKEKB is an asymmetric e^+e^- collider, which will be operated at the center of mass energy of 10.58 GeV, which is near to the mass of $\Upsilon(4S)$ resonance. The collider is designed to operate at an instantaneous luminosity of $8 \times 10^{35} cm^{-2} s^{-1}$, which is 40 times larger than the previous KEKB collider. The Belle II is expected to collect the data corresponds to an integrated luminosity of $50ab^{-1}$, which is 50 times higher as compared to its previous experiment, Belle [3]. At such high luminosity of SuperKEKB, the Belle II will observe harsh background environment. Therefore it is extremely important to validate the performance of the key element of the Belle II detector: the SVD in offline software reconstruction. The excellent performance of the Belle II SVD will provide the measurements of CP asymmetry in the B-meson system with higher precision. In order to achieve the physics goal, reconstruction of tracks with high efficiency and a good resolution are required. The reconstruction of charged particle positions close to the interaction point is provided by the Belle II sub-detector, Vertex Detector (VXD), which is further composed of two sub-detectors: Pixel Detector (PXD) [4], made of two layers of sensors based on DEPFET pixels, and of the Silicon Vertex Detector (SVD) [4, 5], composed of four layers of double sided silicon strip detectors. In this paper, our aim is to validate the performance of the Belle II SVD using the commissioning data, which will help us to optimize the operation parameters of SVD in offline software reconstruction.

2. Overview of the Belle II SVD

The SVD is one of the main track finding devices of the Belle II detector. It consists of 4 layers, namely, L3, L4,, L5 and L6 made of ladders. These ladders are further comprised of several double-sided silicon strip detectors (DSSDs). The two sides of silicon sensors provides the x and y coordinates of hits with z coordinate is defined by sensor position.

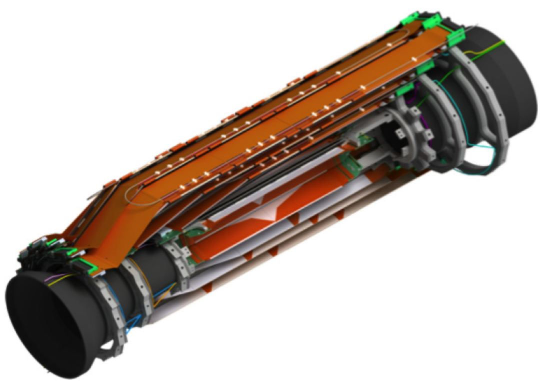

Figure 1: A 3D cut-off view of the Belle II Silicon Vertex Detector.

The 4 SVD layers are placed at different radii of 39mm, 80mm, 104mm and 135mm from the interaction point and covers the angular range of 17^0 to 150^0. This asymmetry in angular coverage improves the acceptance and precision of forward boosted particles in the experiment. The figure 1 shows the 3D cut-off view of the Belle II SVD. The sensors in SVD comes in different dimensions.

No. of Strips	Rectangular sensor	Trapezoidal sensor
# of p-strips	768	768
p-strip pitch (μm)	75 (L3: 50)	50...75
# of n-strips	512 (L3: 768)	512
n-strip pitch (μm)	240(L3: 160)	240
Active area (mm^2)	7030 (L3: 4738)	5890

Table 1: Specifications of DSSDs.

The innermost layer (L3) has small rectangular sensors of thickness 320μm and width of 3.8cm, while other layers are composed of two types of sensors: (a) Large rectangular sensors having the thickness of 320μm and width of 5.8cm and (b) Slanted sensors having the thickness of 300 μm and their width varies from 3.8cm to 5.8cm in trapezoidal shape. The specifications of SVD sensors are listed in table 1. In order to cope with the high particle rates expected at

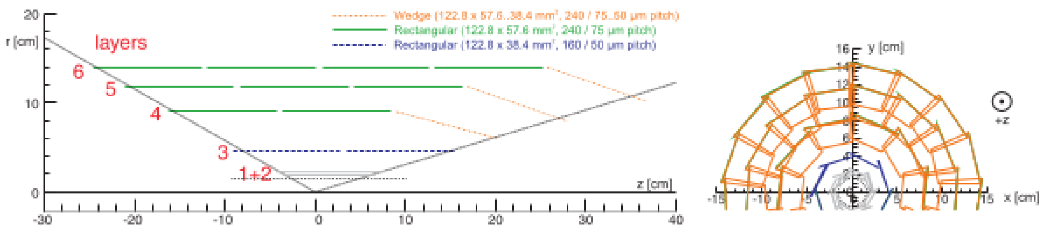

Figure 2: Cross section view of VXD with emphasis on the SVD in r-z plane (left) and x-y plane (right, top view) [6].

Belle II, the DSSDs require fast readout electronics with a short shaping time. Therefore APV25 readout chips are used in Belle II SVD. In SVD sensors, two directions of the strips are defined: U side (parallel to the beam direction with large strips and small pitch) and V side (perpendicular to the beam direction with small strips and large pitch). Figure 2 shows the cross-sectional view of SVD in r-z plane. The Belle II SVD will provide the better vertex resolution, low p_T track finding efficiency and improved K_s^0 reconstruction efficiency. Along with the PXD, SVD improves

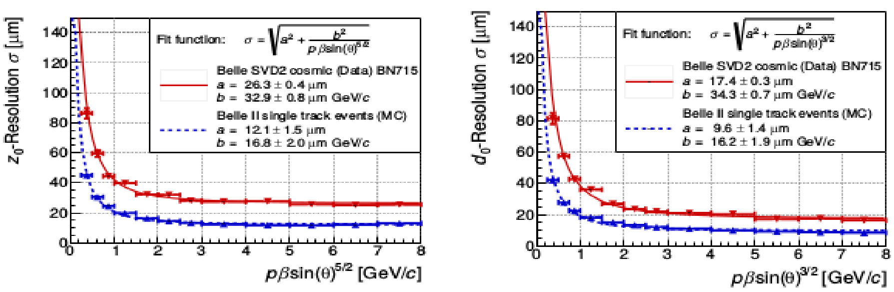

Figure 3: Impact Parameter Resolution (a) Longitudinal (b) Transverse [7].

the impact parameter resolution in Belle II as compared to Belle [7] and is shown in figure 3 (a) Longitudinal impact parameter resolution and (b) Transverse impact parameter resolution.

3. Performance Studies of the SVD

The performance of the SVD is validated in offline software reconstruction (based on BASF2 [8]) using the commissioning data, taken at KEK, Japan. The set-up of commissioning data consists of two SVD half shells, which have been assembled at KEK. The testing of these SVD half shells is carried out with cosmic rays from July 2018 to September 2018. We have collected total 30×10^6 cosmic events during the commissioning period. The complete SVD half shells are shown in figure 4 (a) and first cosmic event taken on August 17, 2018 is shown in figure 4 (b).

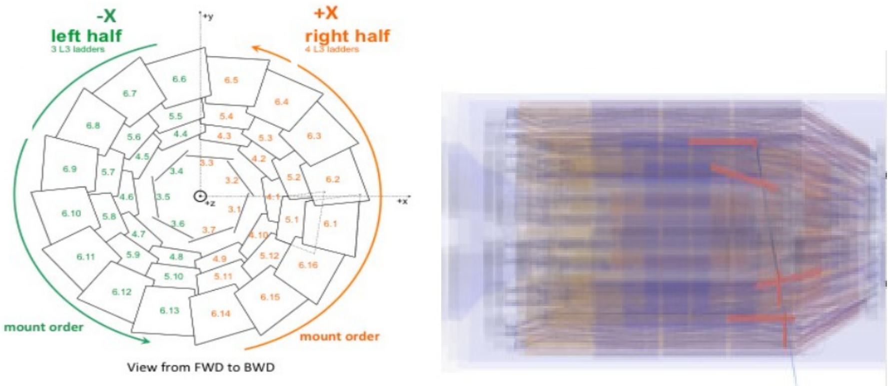

Figure 4: (a) Complete SVD half shells (b) First cosmic event recorded on August 17, 2018.

Using the commissioning data, the cluster energy is reconstructed for those clusters, which are related to the tracks for both U and V side of the sensors. Figure 5 (a) shows the reconstructed cluster energy in Layer 3, Ladder 3 and sensor 2 for both U (red color) and V side (blue color). We can see clearly that the cosmic track is perpendicular to the Horizontal sensors. As the clusters are correctly reconstructed on both sides (U, V). Hence cluster energy are in agreement for both U and V side.

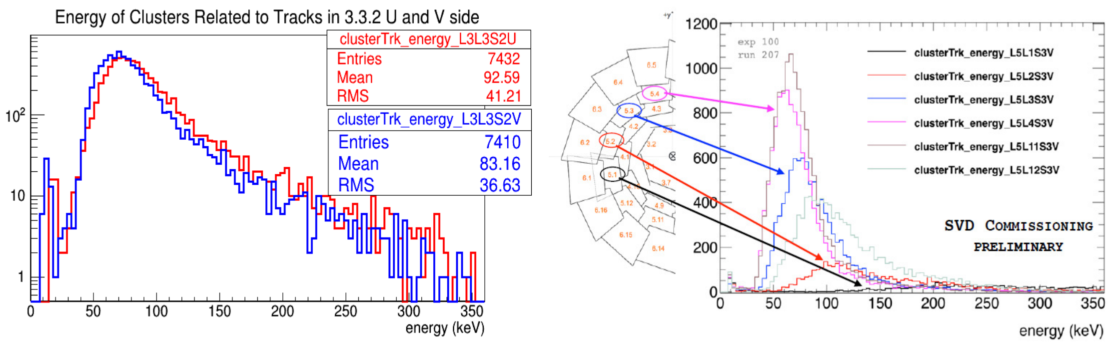

Figure 5: (a) Distributions of Cluster energy (b) Cluster energy vs Azimuthal angle (commissioning data).

In addition, we have also seen the dependency of the cluster energy on incident angle of cosmic rays on sensors. Figure 5 (b) shows the cluster energy distributions for different sensors, which are positioned along the parallel and perpendicular to the beam direction. We can clearly see that the cosmic rays incident at large angle on vertical sensors as compared to the horizontal sensors. Hence relatively high energy is deposited in the vertical sensors. In addition, The cluster signal to noise ratio (S/N) is also reconstructed for each sensor/side and is shown in figure 6 (a). The S/N is measured to be larger than 25 for N side, slightly lower on P side due to the longer strips and larger capacitance load to the pre-amplifier. Further, the signal hit time is also reconstructed and results are shown in figure 6 (b). The RMS of the signal hit time corresponds to a bunch crossing is found to be in the order of 5ns.

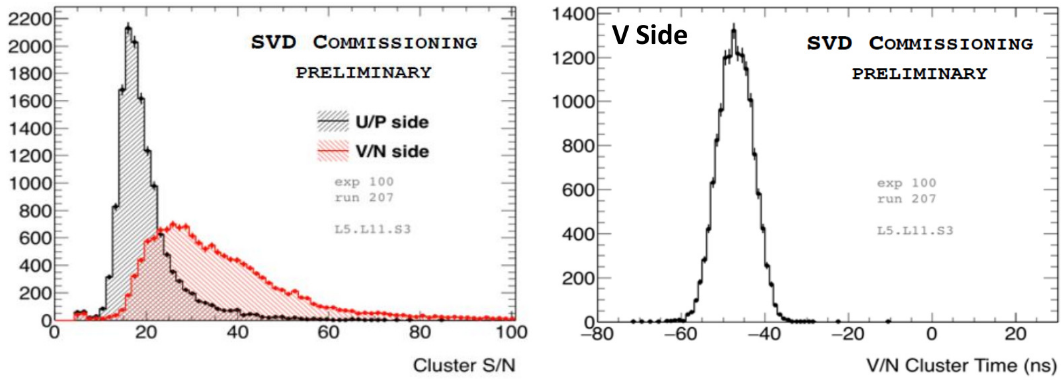

Figure 6: (a) Cluster S/N ratio (b) Signal Hit time (commissioning data).

4. Summary

The Belle II SVD is currently running smoothly during the commissioning period, where two SVD half shells are assembled at KEK. The performance of SVD is evaluated with cosmic runs for each side/sensor in offline software reconstruction and we have extracted the fundamental information from SVD hits, for example, cluster energy, cluster signal to noise ratio and signal hit time. After analyzing the commissioning data, it is found that the SVD provides the excellent performance in the framework of software reconstruction. First physics run at Belle II is expected early in 2019.

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References

[1] T. Abe et al., Belle II Technical Design Report, [arXiv:1011.0352].

[2] Boqun Wang, The Belle II Experiment and SuperKEKB Upgrade, [arXiv:1511.09434].

[3] J. Brodzicka et al. (for the Belle Collaboration), PTEP 2012, 04D001.

[4] J. Schieck et al., DEPFET Pixels as a Vertex Detector for the Belle II Experiment, [arXiv:1304.0870v1]

[5] K. Adamczyk et al., The silicon vertex detector of the Belle II experiment, Nuclear Instruments and Methods in Physics Research, Section A, 824, 406-410 (2016).

[6] M. Friedl et al., The Belle II Silicon Vertex Detector. Nucl. Instr. and Meth. in Phys. Res. A, 732, 8386 (2013).

[7] J. Bennett et. al., Belle II Reconstruction Software, Prog. Theor. Exp. Phys., 00000 (2015).

[8] T.Kuhr et. al., The Belle II Core Software, Computing and Software for Big Science, 3:1 (2019).