The Software Framework of the Belle II Silicon Vertex Detector and its Development for the 2016 Test-Beam at DESY

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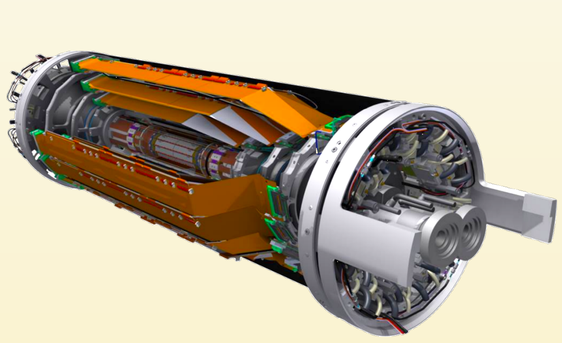
The Silicon Vertex Detector

The SVD belongs to the innermost component of the Belle II detector, designed to collect hits out of which one reconstructs the decay vertices of the B mesons. It has also a unique role of tracking neutral particles which decay after having passed the PXD (like K_S), reconstructing charged particles that don't reach the Central Drift Chamber (like slow pions), and gathering information on timing and energy loss for all hits.
The SVD is composed of 4 layers of double-sided silicon strip sensors, and has a polar angle coverage of 17-150°; this reflects the Belle II forward boost.



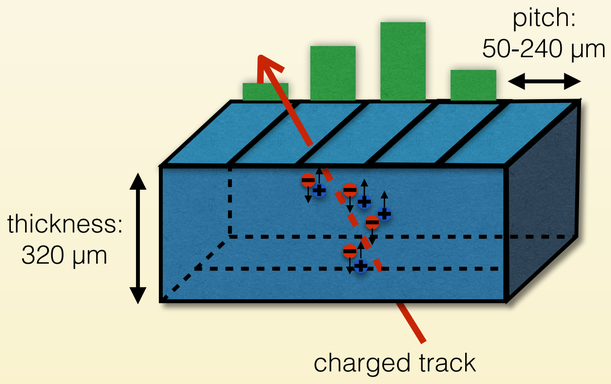


Figure 1 and 2: Left: The VerteX Detector is composed by the PXD (2 inner layers of DEPFET pixels) and the SVD (4 outer layers of DSSD). Right: This picture depicts schematically the energy loss process in the SVD silicon sensors, with the consequent drift of electrical charges that cause charge deposition on the strips.

The SVD software framework

The charge collected by the strips is read-out by APV25 chips, which sample the charge deposition creating so-called digits. These are then processed by the SVD software framework, with an eventual goal of providing spacepoints for tracking algorithms.

The *SVD Digit Sorter module* organises digits in such a way that the strip they belong to will be assigned a charge and a hit time. Then, the *SVD Clusterizer module* deals with the grouping of strips to form SVD clusters. This is done by selecting only meaningful strips while neglecting fake hits and random noise. A position with related uncertainty is subsequently assigned to the cluster with the aid of dedicated algorithms.

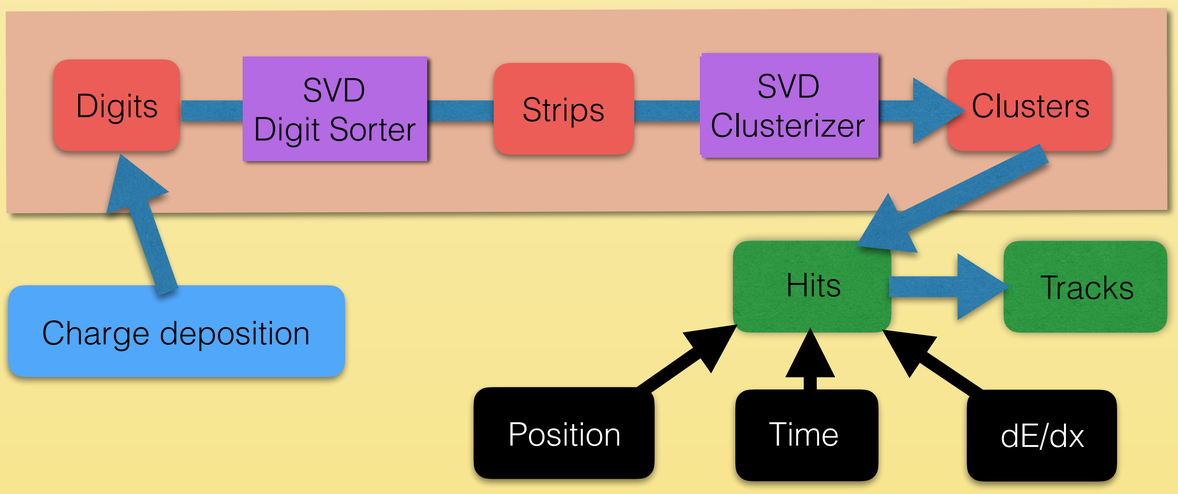
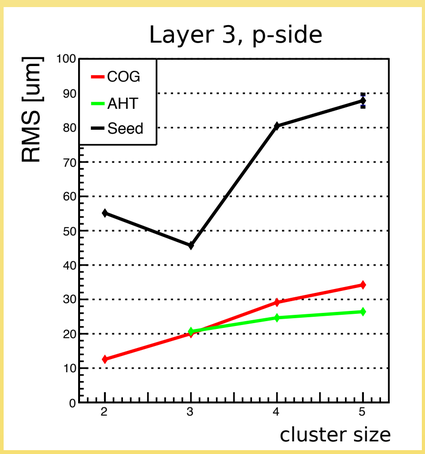
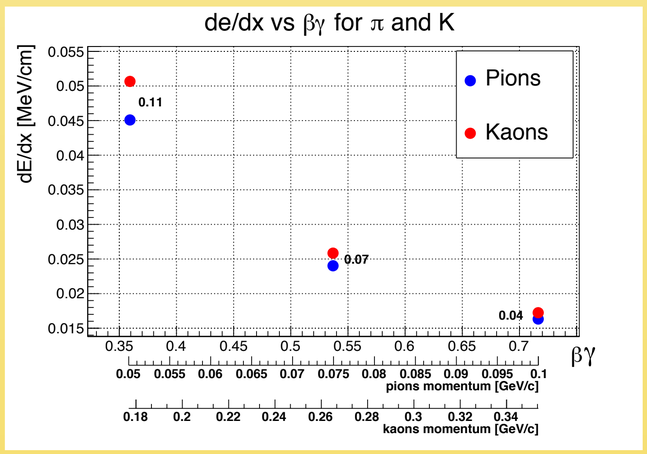


Figure 3: This image shows how the SVD software framework (highlighted pink region) plays the role of filling the gap between the production of hits in the sensors and the creation of tracks composed by these hits.





Figures 4 and 5. Left: The SVD cluster position resolution, measured as RMS of the residuals distributions, is shown as a function of the number of strips in the cluster, for different clustering algorithms. Right: The verification of the energy loss universality for different particles passing through the SVD, while having same βγ values, is shown in this graph.

Signal to noise thresholds for the clustering algorithm

The *SVD Clusterizer module* selects clusters based on three criteria:

- each of the cluster's strips has to pass a Signal to Noise threshold SNT_{noise} ;
- at least one of the cluster's strips has to pass a special SNT_{seed}, normally higher than SNT_{noise} ;
- the whole cluster has to pass a SNT_{cls}.

Given that the background radiation will have a fundamental importance in the collisions at SuperKEKB, these SNTs have to be carefully chosen. This sections describes a method that can test any combination of the three clustering SNTs, and provide clustering efficiency and fake hits ratio as output.

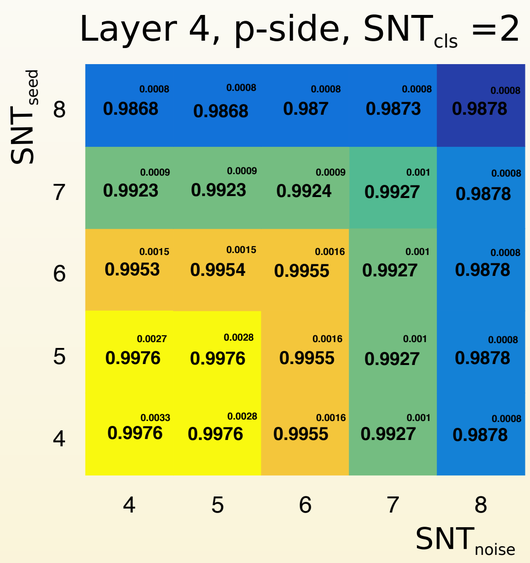
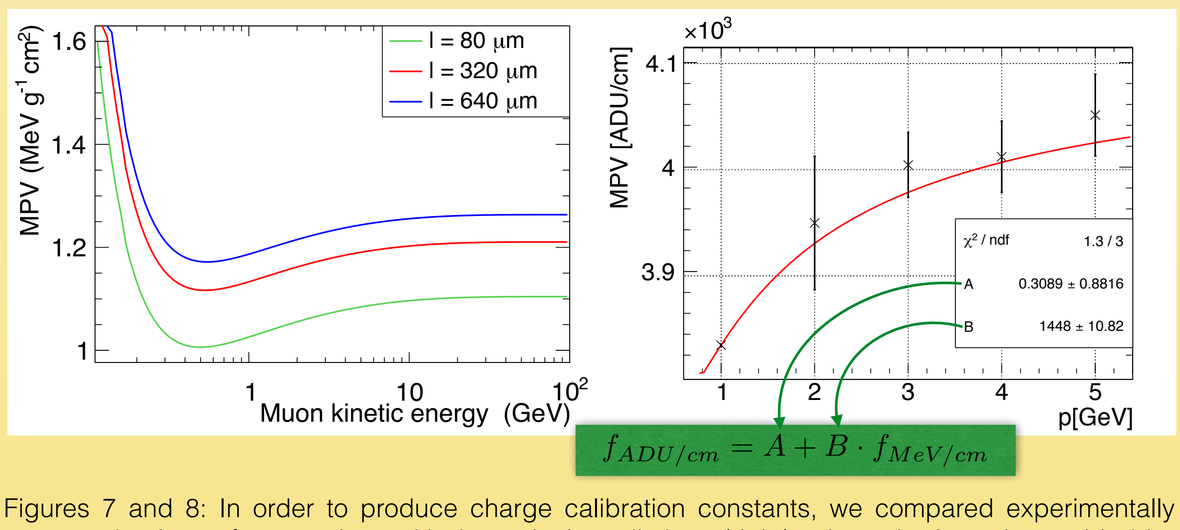


Figure 6: An example: For a fixed value of one SNT (chosen to be the SNT_{cls}), a graph of the other two variables is obtained (in this case SNT_{seed} vs SNT_{noise}), representing clustering efficiency in black, with the uncertainty as superscript.

Charge calibration

In order to extract useful information about the charge deposition, it is essential to know the number of electron-hole pairs which were created. This requires a method that creates calibration constants, allowing a conversion from the output of the electrical strips read-out to the number of electron-hole pairs produced in the sensors.

In order to produce charge calibration constants, we compared the measured values of energy loss, as a function of particles momentum with theoretical predictions. The latter is provided by the Landau-Vavilov-Bichsel function, an improved version of the standard Bethe-Bloch function, which provides the Most Probable Value (MPV) for energy loss (and not the average value) and can describe ionization loss in thin sensors with variable thickness *l*.



Figures 7 and 8: In order to produce charge calibration constants, we compared experimentally measured values of energy loss with theoretical predictions (right), where the latter is provided by the Landau-Vavilov-Bichsel function, which takes into account the sensor thickness (left).

Summary

The software framework of the Belle II SVD efficiently converts hits into spacepoints for the tracking algorithm, complete of location, time and energy loss information. New software modules, used for the study of signal to noise thresholds for the clustering algorithm and the calibration of the charge output have been developed and tested in April 2016 at DESY in Hamburg, Germany. In this occasion, the Belle II VXD was tested using an electron beam with a 2-5 GeV energy and a magnet with 0-1 T strength.

References

Talk at this conference (26/09/16, 18:00 - 19:30 session):
"The Belle II SVD detector", Katsuro Nakamura