The Silicon Vertex Detector of the Belle II Experiment

Belle II ≡ SVD

HEPHY INSTITUTE OF HIGH ENERGY PHYSICS

ÖAW

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C. Irmler* on behalf of the Belle II SVD collaboration

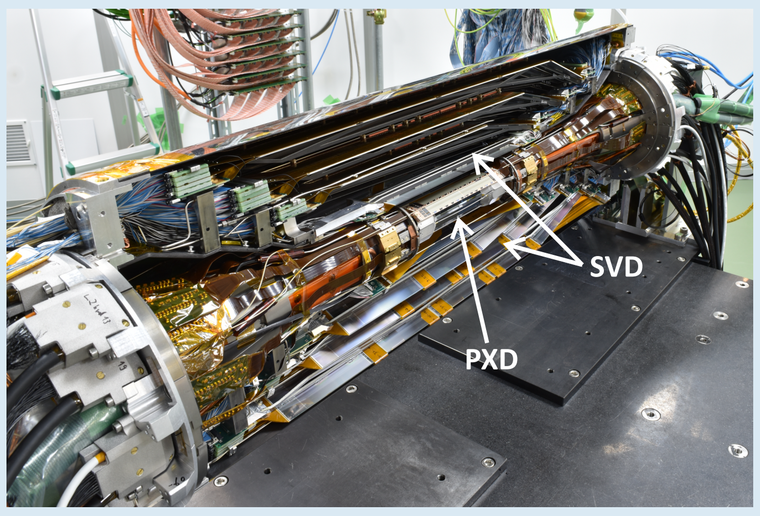
Belle II Silicon Vertex Detector

SuperKEKB

- Asymmetric collider: 4 GeV e^+ , 7 GeV e^-
- CM energy at Y(4S) resonance (10.58 GeV)
- Target integrated luminosity: 50 ab^{-1}
- Target instantaneous luminosity: 6 x 10^{35} $cm^{-2}s^{-1}$
- Luminosity record: **4.14 x 10^{34} $cm^{-2}s^{-1}$** (17 May 2022)

Belle II

- New searches beyond the Standard Model at the intensity frontier
- Start of operation in spring 2019
- Precise determination of the B decay vertices and low-momentum tracking are essential



The Belle II VXD with one half of SVD (+X half) attached.

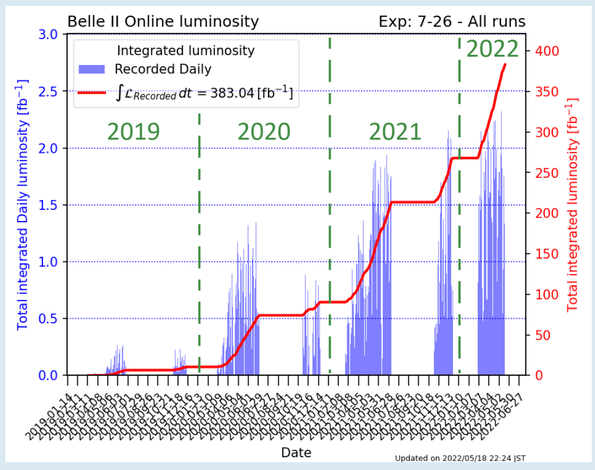
Belle II Silicon Vertex Detector (SVD)

- 4 layers of double-sided silicon strip detectors (DSSDs)
- Outside 2 inner layers of DEPFET pixel detectors (PXD)
- Radii of Layers: 39 / 80 / 104 / 135 mm
- Strip pitch: 50/75 µm (r-ϕ) and 160/240 µm (z)
- Readout: APV25 chip, 50 ns shaping time
- Cooling: two-phase CO_2 system (-20°C)

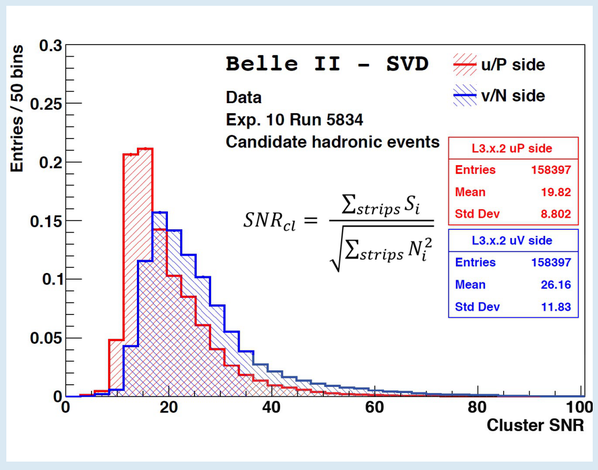
Main features of Belle II SVD:

- Extrapolate tracks to PXD
- Standalone tracking for low p_T tracks
- Precise vertexing of K_S
- PID with dE/dx

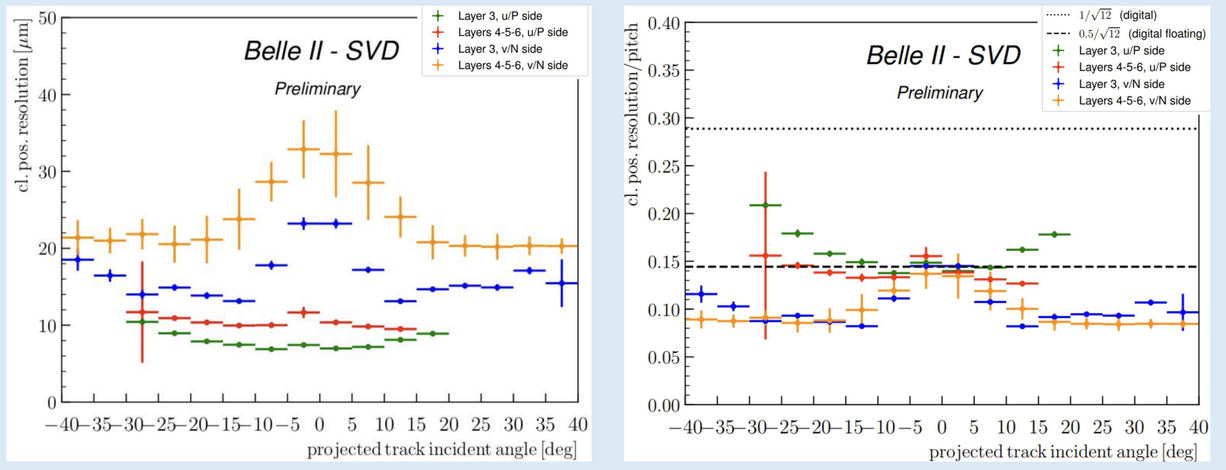
SVD Operation and Performance



Recorded ingegrated luminosity of Belle II since start of operation in spring 2019



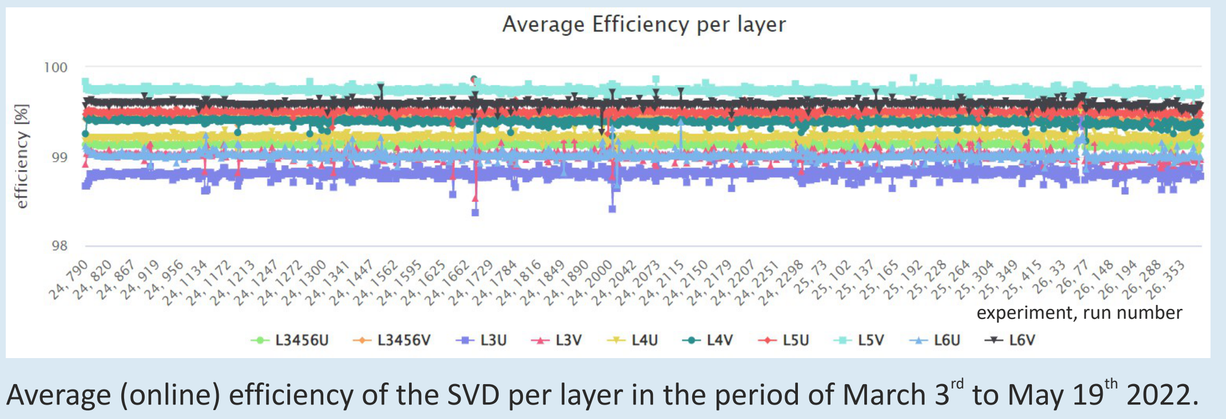
Cluster SNR of a layer 3 ladder. Difference between u/P and v/N sides results from different strip pitch and length.



Cluster position resolutions (left) and resolutions normalized to the pitch (right) as a function of the incident angle of tracks traversing the sensors. The measurements are performed on $e^+e^- \to \mu^+\mu^-$ events obtained from from 98 pb^{-1} collision of 2020 run data.

SVD performance

- Recorded integrated luminosity: 383 fb^{-1} (until May. 18th 2022)
- Reliable and smooth operation since spring 2019 without major issues
- All 1748 APV25 readout chips functional
- Less than 1% masked strips
- Stable noise levels and calibration constants; long-term evolution as expected
- Cluster SNR between 13 and 30 depending on sensor position and side
- Excellent efficiency of > 99% in most sensors
- Cluster position resolution: 9 (11) µm for layer 3 (4, 5 and 6) u/P side
  20 (25) µm for layer 3 (4, 5 and 6) v/N side



Average (online) efficiency of the SVD per layer in the period of March 3rd to May 19th 2022.

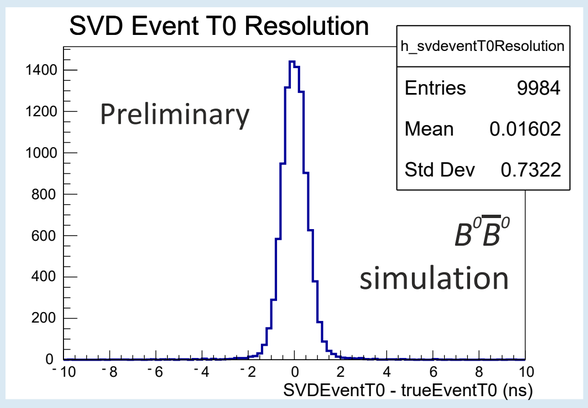
Event T0 Estimation from SVD Data

- Precise measurement of the time of the collision (event T0) allows to reduce the beam background from SuperKEKB quasi-continuous bunch crossings
- The event T0 is estimated for the first time with the SVD, as the average of the time of the clusters associated to selected good tracks:

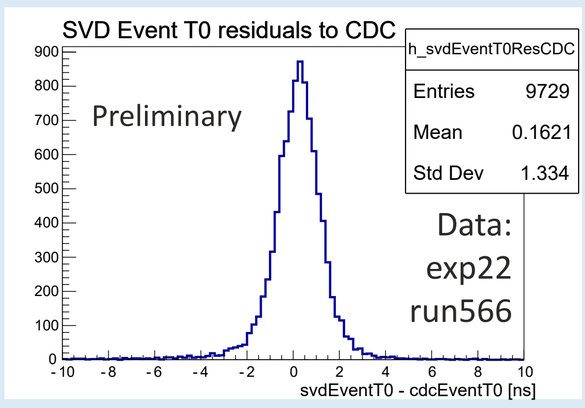
$$\text{event } T_0^{\text{SVD}} = \frac{1}{N_{cls}} \sum_{i=1}^{N_{cls}} t_i^{cls}$$

where t_i is the timing of a cluster and N_{cls} is the number of clusters.

- This event T0 computed from SVD data has been tested against the currently used T0 estimation based on data of the central drift chamber (CDC) with MC simulations and on data.



Achievable SVD T0 resolution from MC simulation.



SVD T0 residuals from data compared to CDC T0.

Excellent results achieved both on data and simulated events:

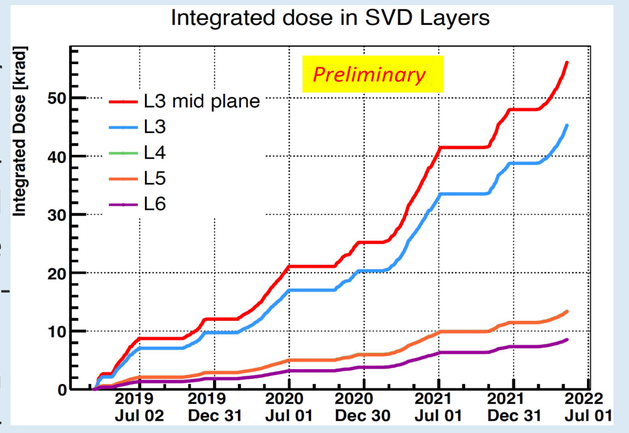
- SVD event T0 efficiency >99% on hadron events (data) and on simulated $B^0\overline{B}^0$ with nominal background, and >96% on tau-tau events (low track-multipicity events)
- Resolution compatible with CDC estimation, 0.7 ns on $B^0\overline{B}^0$ simulations and 1 ns on hadronic events
- Computation of the SVD event T0 is 2000 times faster than the CDC based one, allowing to speed up the High Level Trigger (HLT) reconstruction and therefore cope with the higher trigger rate expected at higher luminosity

The plan is to replace CDC event T0 computation with the one based on SVD data in the next official Belle II software release.

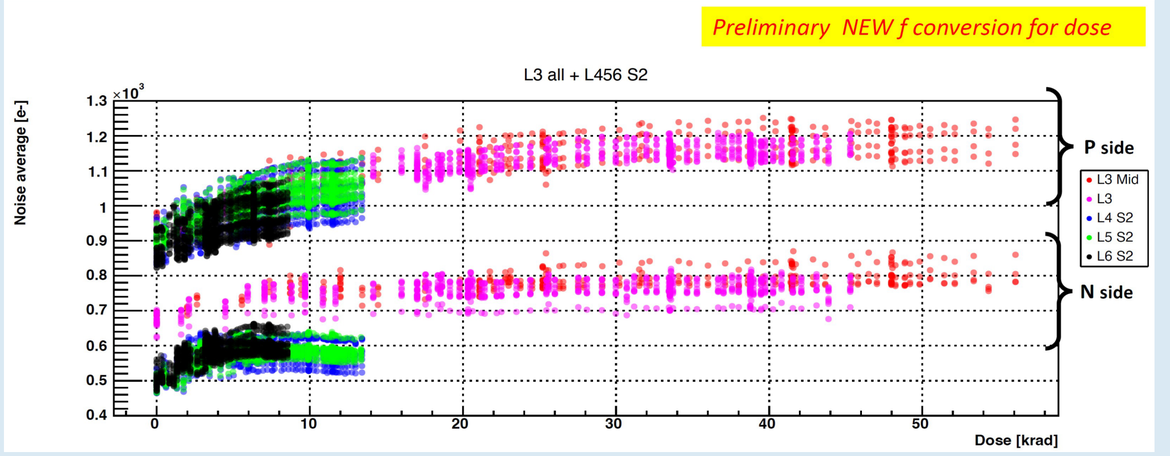
Integraded Dose and Radiation Effects

SVD integrated dose

- Diamond sensors used to monitor radiation dose
- Correlation between SVD occupancy and diamond dose is used to estimate the SVD sensor dose (several assumptions and large uncertainty)
- Conversion factor obtained from data and verified with MC simulations
- Recent analysis showed that SVD dose was overestimated in the past
- New, corrected conversion factors calculated and applied
- So far **~500 Gy** (50 krad) accumulated in **layer 3 sensors**
- First observable effects on sensor currents, noise and calibration constants, but so far without degradation of the SVD performance



Integrated dose per SVD layer. The dose in layer 4 and 5 is very similar, thus they overlap in this plot.



Evolution of the average noise vs. accumulated dose per layer. Saturation of noise in layer 3 already observed.

Summary

- Belle II SVD reliably takes data since March 2019
- Excellent performance w.r.t SNR, efficiency and position resolution
- Estimation of event T0 from SVD data with similar precision as CDC, but with three orders of magnitude faster execution time
- First effects of radiation damage observable, but so far no degradation of detector performance

* Email: christian.irmler@oeaw.ac.at

http://www.hephy.at