The Silicon Vertex Detector of the Belle II Experiment

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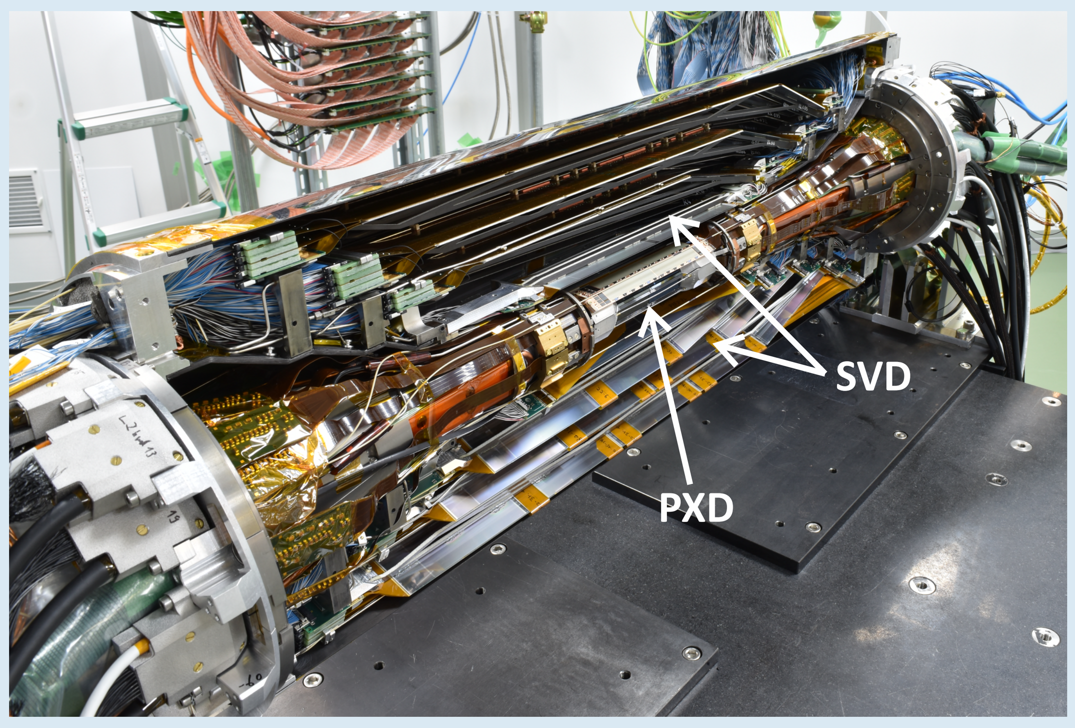
Belle II Silicon Vertex Detector

SuperKEKB

- Asymmetric collider: 4 GeV e^+ , 7 GeV e^-
- CM energy at Υ(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.

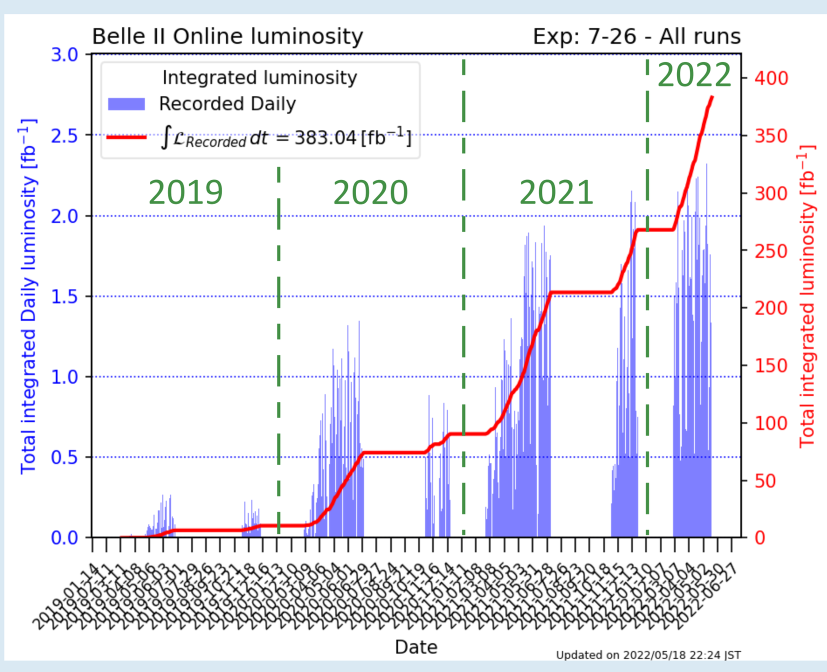
Belle II Silicon Vertex Detector (SVD)

- 4 layers of double-sided silicon strip detectors (DSSDs)
- Embracing two 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, 50ns shaping time
- Cooling: two-phase CO_2 system (-20°C)

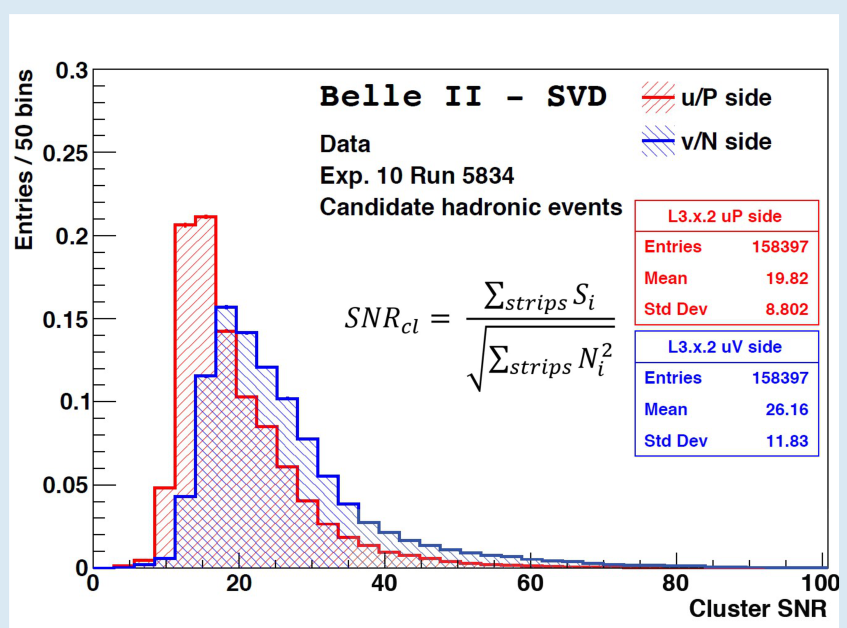
Main features of Belle II SVD:

- Extrapolate tracks to PXD
- Standalone tracking for low p_T tracks
- Precise vertexing of K_S
- PID with d*E*/d*x*

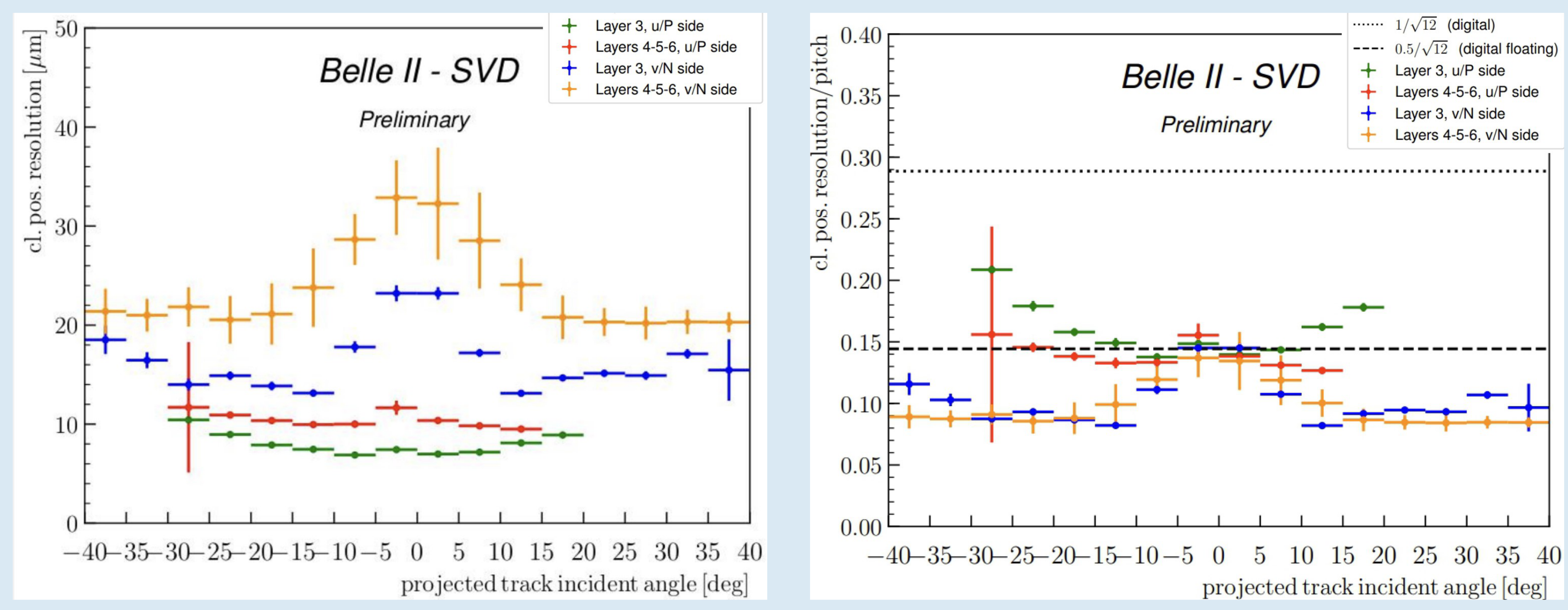
SVD Operation and Performance



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



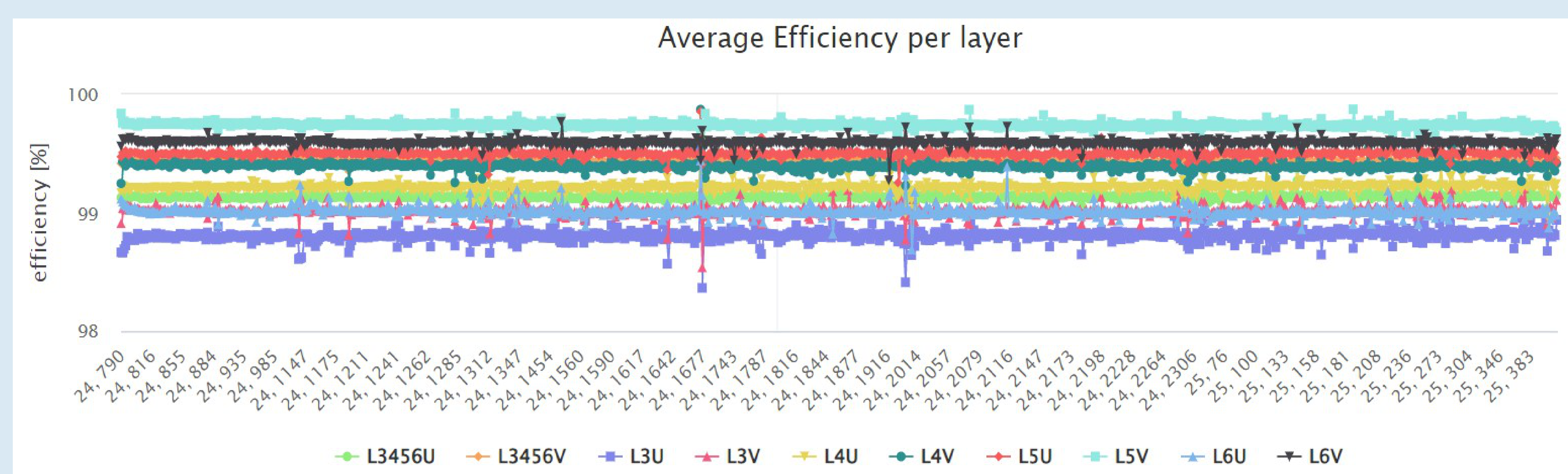
Cluster SNR of a layer 3 ladder. Difference between u/P and v/N sides results from different strip pitch and length.



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 $e^+e^- \rightarrow \mu^+\mu^-$ 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
- Resolution



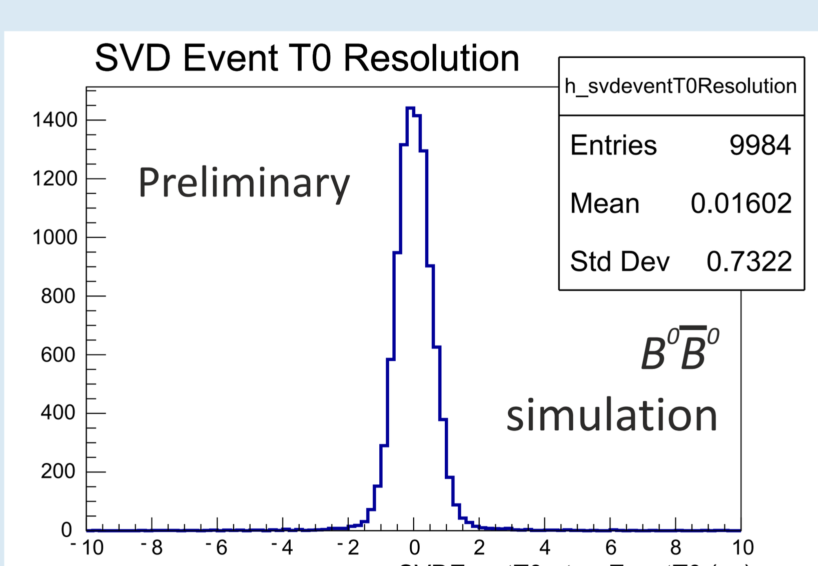
Average efficiency of the SVD per layer in the period of March 3rd to May 10th 2022.

Event T0 estimation from SVD Data

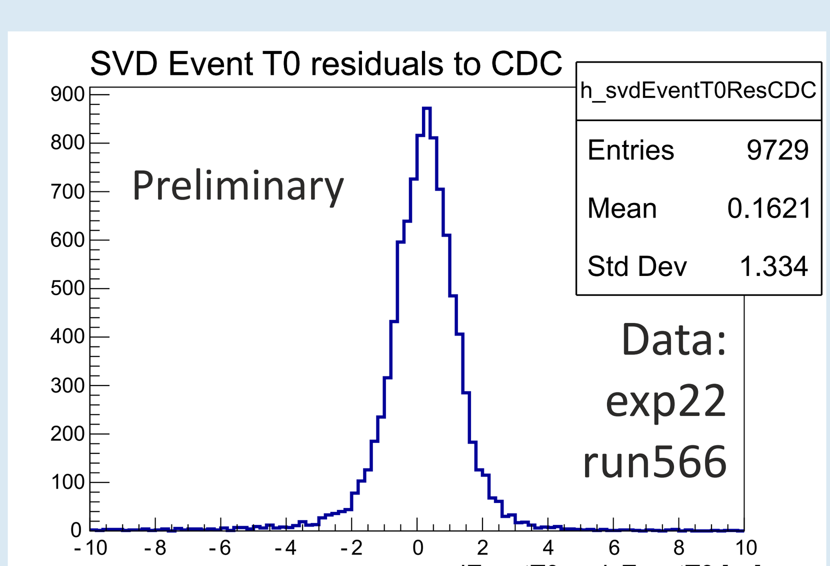
A module to estimate the event time T0 from SVD data has been implemented into the Belle II analysis software framework. It averages the cluster time t0 of all clusters associated to a track according to

$$eventT_0^{SVD} = \frac{1}{N_{cls}} \sum_{i=1}^{N_{cls}} t_i^{cls}$$

where t_i is the timing of a cluster and N_{cls} is the number of clusters.
This method has been tested against the currently used T0 estimation based on data of the central drift chamber (CDC) with MC simulations and on recorded data with very good results.



Achievable SVD T0 resolution from MC simulation.



SVD T0 residuals from data compared to CDC T0.

MC simulation results:

- $B^0\overline{B}^0$ simulation with nominal background
- Efficiency >99% on $B^0\overline{B}^0$
- SVD T0 can achieve a timing resolution of ~0.7ns
- Similar precision as CDC T0 estimation

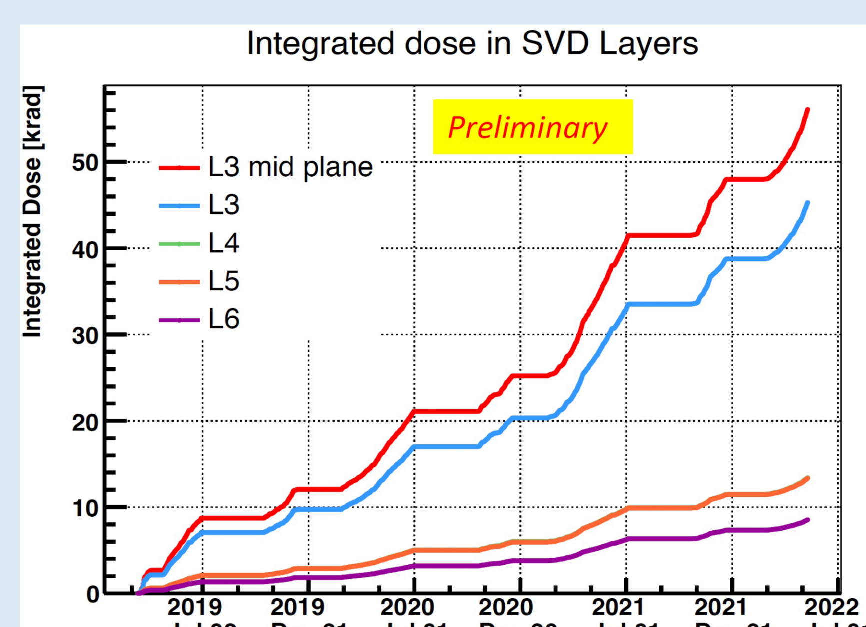
SVDEventT0 performance on data:

- Efficiency >99% on hadrons
- SVD T0 estimation has small shift (≤1ns) w.r.t. CDC T0
- Width of residuals ~1.3ns w.r.t CDC
- Execution time of SVDEventT0 is ~2000 times shorter than that of the currently used module
- Plan to replace currently used module with SVDEventT0 in future.

Integrated Dose and Radiation Effects

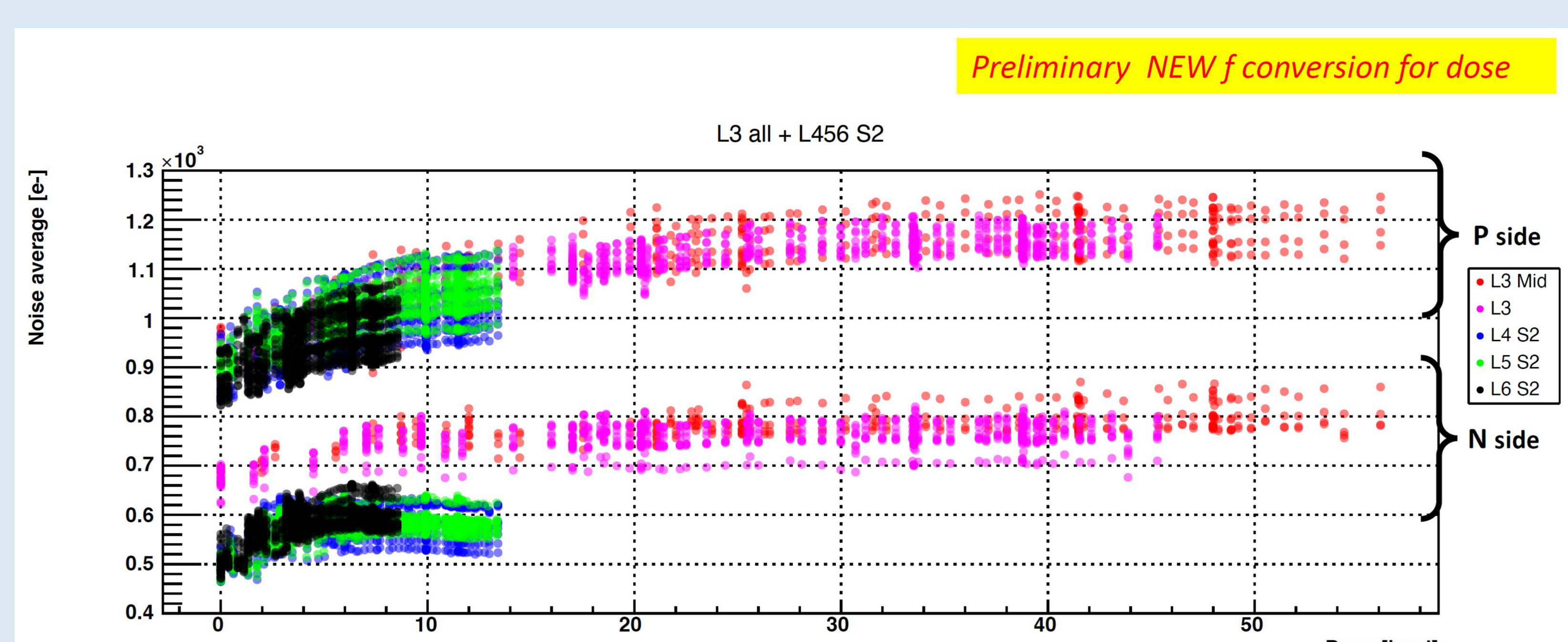
SVD integrated dose

- Diamonds sensors used to monitor radiation dose
- Correlation between SVD occupancy and diamond dose is used to estimate the SVD sensor dose.
- Conversion factor obtained from data and verified with MC simulations (several assumptions and large uncertainty).
- Recent analysis showed that SVD dose was overestimated in the past. New, corrected conversion factors calculated and applied.



Integrated dose per SVD layer. The dose in layer 4 and 5 is very similar, thus the green and orange lines overlap in this plot.

- 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.



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

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 noticeably shorter execution time
- First effects of radiation damage observable, but so far no degradation of detector performance.

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