Simulation of the Belle II Silicon Vertex Detector

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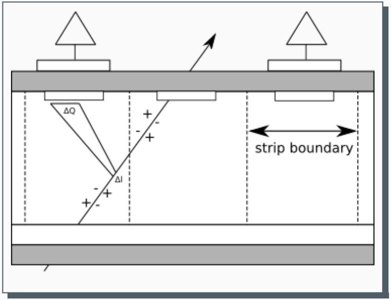
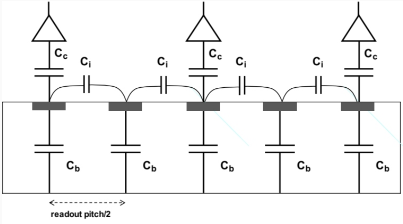
Outline

- Belle II SVD simulation framework
- Comparison with collision data
- Optimisation studies
- Summary

Belle II SVD simulation charge collection & digitization

- Drift and diffusion
  - → charge carriers drift in the combined effect of electric and magnetic fields
  - → e-h clouds generated in finite segments along the track
  - → smearing of charge clouds by $\sigma = \sqrt{D\, t_{drift}}$ (D-diffusion coeff.)
- Charge sharing and readout electronics simulation
  - → every 2nd strip connected to readout electronics: need to simulate floating strips and coupling between adjacent channels (next slides)
  - → analog waveform, noise simulation, sampling and zero suppression





- C_i - interstrip capacitance
- C_b - capacitance to the back of the sensor
- C_C - decoupling capacitance to the preamplifier input

Sensor side	$C_i[pF/cm]$	$C_b[pF/cm]$	$C_C[pF/cm]$
p	0.40 - 1.05	0.08 - 0.12	15
n	0.40 - 0.60	0.26 - 0.42	30

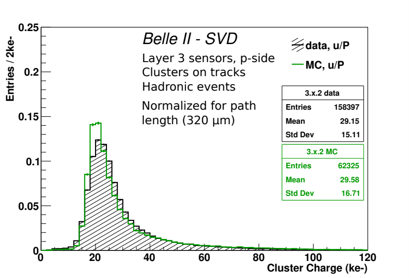
Based on simplified charge division model we define three coupling coefficients between implanted strips and preamplifier inputs. Readout charges are computed as:

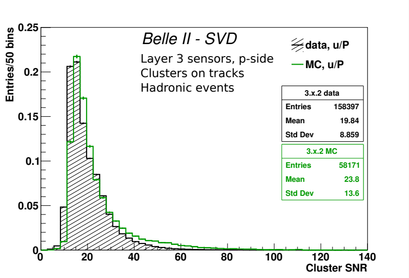
$$S_i^{READOUT} = \begin{bmatrix} C_2 \\ C_1 \\ C_0 \\ C_1 \\ C_2 \end{bmatrix}^T \begin{bmatrix} S_{-2} \\ S_{-1} \\ S_0 \\ S_{+1} \\ S_{+2} \end{bmatrix}$$

- C_0 - coupling between the readout implant and its preamplifier input
- C_1 - coupling between the floating implant and the adjacent readout channel
- C_2 - coupling between two readout channels

Sensor side	$C_0[\%]$	$C_1[\%]$	$C_2[\%]$
p	93 - 97	42 - 45	< 4
n	97 - 98	35 - 37	< 1

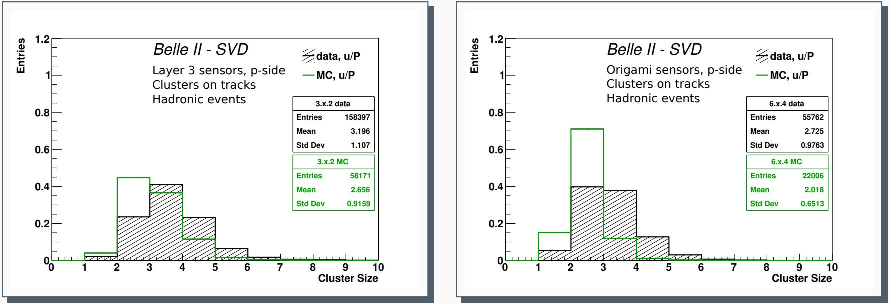
Comparison with collision data cluster charge & SNR





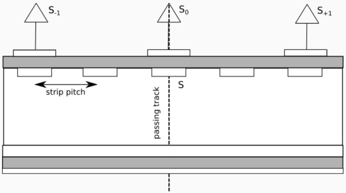
- We observe good match between simulated events and collision data for cluster charge and cluster signal-to-noise-ratio distributions ($SNR_{cl} = S_{cl}/N_{cl}$, where S_{cl}, $N_{cl} = \sqrt{\sum_{i=1}^{nstrips} N_i^2}$ are the total charge and noise of a cluster)

Comparison with collision data cluster size



- Average cluster size underestimated in simulation, indicating that simplified charge division model does not describe charge sharing accurately
- This level of disagreement was not observed in test-beam data, previously used to tune the simulation. Test-beam data had only perpendicular tracks, additional difference could be due to a different zero-suppression selection applied during physics runs ($SNR > 3$) with respect to test-beam ($SNR > 5$)
- Based on these observations we decided to use data-driven method to better estimate inter-channel signal coupling

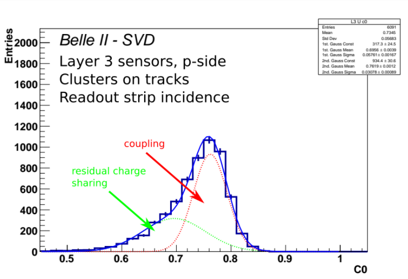
We use perpendicular tracks (large angle on other side) with readout strip incidence to estimate signal coupling from readout implants to readout channels.

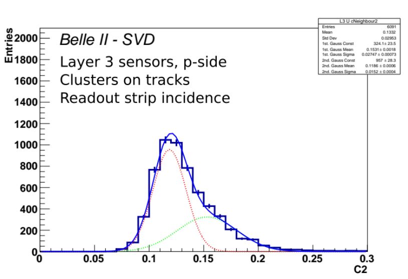


$$C_0 = \frac{S_0}{S}, \quad C_2 = \frac{1}{2}\frac{S_{-1} + S_{+1}}{S}$$

where:

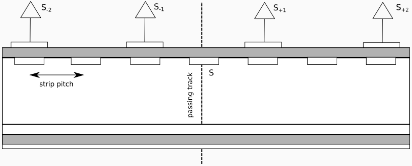
- S_i - measured readout charges
- $S = \sum_i S_i$ - total measured charge





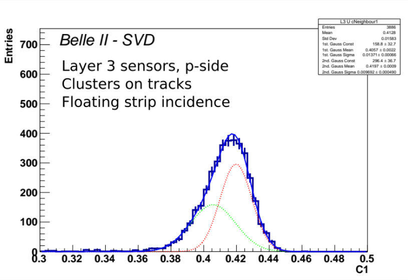
Optimisation studies

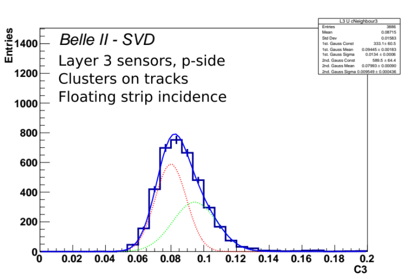
Tracks with floating strip incidence are used to estimate signal coupling from floating implants to readout channels.



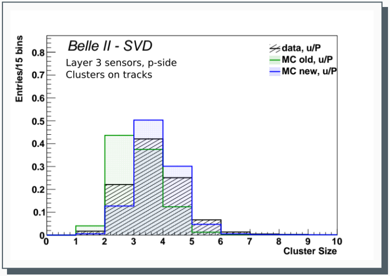
$$C_1 = \frac{1}{2}\frac{S_{-1}+S_{+1}}{S}, \quad C_3 = \frac{1}{2}\frac{S_{-2}+S_{+2}}{S}$$

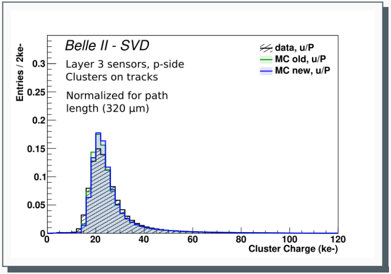
where C_3 is an additional coupling to further neighbour not used previously in simplified charge division model.





Optimisation studies





- With improved charge-sharing parametrisation we are able to model cluster size distribution more accurately, while the total charge of a cluster remains unchanged

Summary

- We presented Belle II SVD simulation framework overview and its tests against collision data
- We observe a good match in cluster charge and signal-to-noise-ratio distributions, but found some discrepancies in terms of cluster size
- Using data-driven method we are able to improve charge sharing parametrisation that provides better agreement in cluster charge distribution