Particle Identification in Belle II Silicon Vertex Detector

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Outline

- Introduction
- PID in Belle SVD
- SVD $dE/dx$ calibration
- SVD PID performance
- Summary
• Particle identification (PID) plays an important role in the physics program of the Belle II experiment at the SuperKEKB asymmetric-energy $e^+e^-$ collider

• Uses a likelihood based method

• Sub-detectors: CDC, TOP, ARICH

• Including SVD info would improve performance in the low-momentum region

• Would benefit studies such as $D^{*+} \rightarrow D^0 \pi^+_S$, $B \rightarrow D^* (\rightarrow D \pi_S) \ell \nu$...

Detector coverage for hadron ID:

- SVD
- TOP, ARICH
- CDC
PID in SVD

- Ionization energy loss ($dE/dx$) information in the SVD can be used to identify different particle types.
- This talk focuses on hadron ID
  → (see Rahul’s talk on lepton identification)

- SVD: four layers of double-sided silicon microstrip detectors
- Low momentum tracks that fail to reach the CDC are reconstructed in SVD

![SVD main features]

- Low material budget (~0.7% $X_0$)
- Excellent timing (σ ~ 3 ns)
- Excellent hit position resolution
Sample preparation for the calibration

Pions and kaons

- We use $D^{*+} \to D^0(K^-\pi^+)\pi^+$ decays to identify pions and kaons.
- Various kinematic and vertex requirements are applied to suppress most of the backgrounds.
- Fit to $\Delta m (D^*-D^0$ mass difference) for the signal extraction.
- The $sP$lot [1] technique is used to subtract the residual background contribution.

![Fitted $\Delta m$ distribution](image)

$Belle\ II$

$\int Ldt = 6.1 fb^{-1}$

$N_{bkg} = 50537 \pm 371$

$N_{sig} = 58085 \pm 380$

[1] M. Pivk and F. R. Le Diberder, Nucl. Instrum. Meth. A555, 356 (2005).
Sample preparation for the calibration

Protons

- We use $\Lambda \to p\pi$ decays to identify protons
- Various kinematic and vertex requirements are applied to suppress most of the backgrounds
- Fit to $M_{p\pi}$ for the signal extraction
- The $sP$lot technique for the background subtraction

### Belle II

$\int L dt = 3.1 \text{ fb}^{-1}$

$N_{\text{sig}} = 108224 \pm 414$

$N_{\text{bkg}} = 6972 \pm 264$

**Fitted $M_{p\pi}$ distribution**

**Background subtracted momentum**
The two-dimensional (2D) distributions of $dE/dx$ vs. momentum show a clear separation among different particles in the low-momentum region.

These background subtracted 2D histograms are used as probability density functions for various particle hypotheses and uploaded to the database.
PID performance studies

- Using reprocessed data including the uploaded 2D histogram PDFs
- Control samples: \( D^{*+} \rightarrow D^0(K^−\pi^+)\pi^+ \) and \( \Lambda \rightarrow p\pi \) decays
- The identification is done applying on a selection on the likelihood ratio:

\[
\frac{L_i}{L_j} = \frac{L_i}{L_i + L_j}
\]

Kaon ID distributions

SVD alone
PID performance studies

PID efficiency is defined as:

$$\epsilon_i = \frac{\text{Number of tracks identified with PID requirement under the hypothesis } i}{\text{Number of tracks kinematically identified under the hypothesis } i}$$

Fake rate is given by:

$$f_{j \rightarrow i} = \frac{\text{Number of tracks identified with PID requirement under the hypothesis } i}{\text{Number of tracks kinematically identified under the hypothesis } j}$$

$K$ efficiency and $\pi$ fake rate with $L(K/\pi) > 0.5$
PID performance studies

- Efficiency vs. fake rate:

- Data-MC difference in performance is due to the known difference in cluster energy distributions

[BELLE2-NOTE-PL-2020-028]
• We have developed an SVD $dE/dx$ based PID framework for charged pions, kaons and protons.

• Our study confirms that addition of SVD PID improves the pion, kaon and proton ID efficiencies in the low-momentum region.

[BELLE2-NOTE-PL-2020-028]

Thank You!
SVD PID performance relies on its $dE/dx$ information which is proportional to the energy deposited by a charged particle (cluster energy) divided by its path length.

There is a known difference between data and MC in cluster energy that translates to a data-MC difference in the SVD PID performance.

Fair DATA/MC agreement on cluster charge on u/P side, worse on v/N side. Tuning on MC to improve matching ongoing.