Particle Identification in Belle II Silicon Vertex Detector

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(On behalf of the Belle II-SVD Collaboration)

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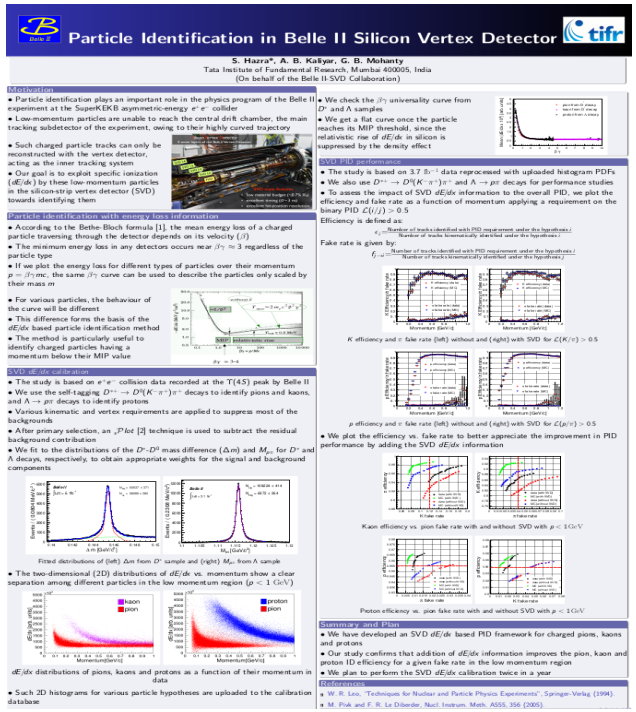
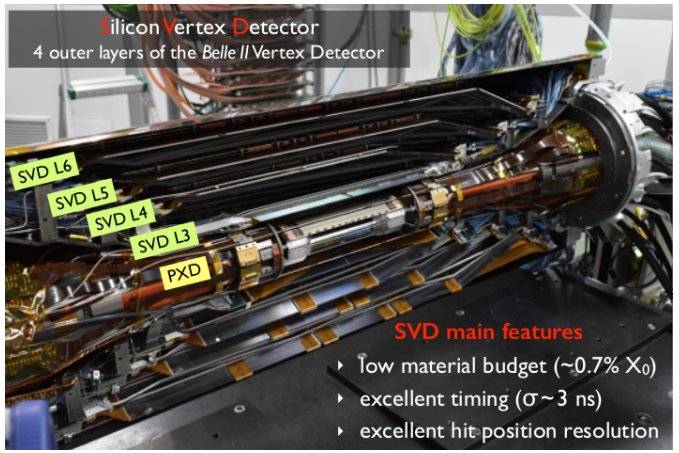


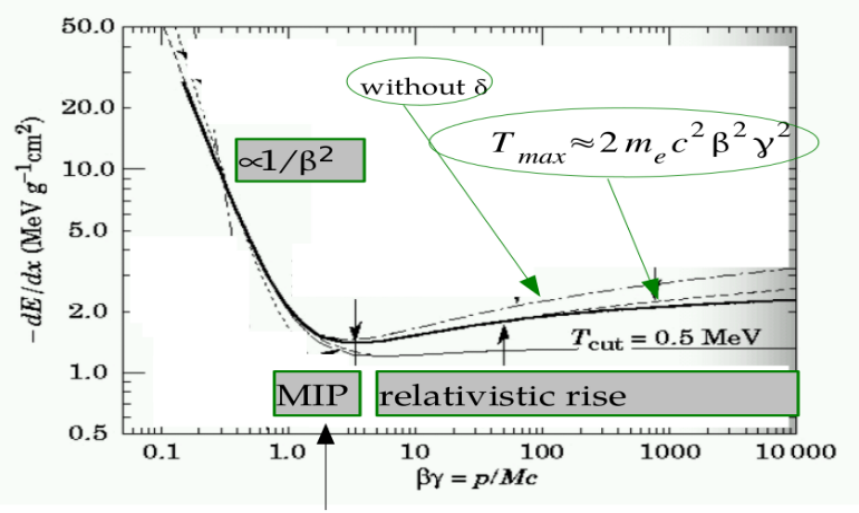
Belle II

tifr

Why and how PID with the SVD ?

- Particle identification (PID) plays an important role in the physics program of the Belle II experiment at the SuperKEKB asymmetric-energy e^+e^- collider
  - Low-momentum charged particles are mostly unable to reach the drift chamber and reconstructed with the silicon vertex detector (SVD)
  - Our goal is to identify those particles using energy loss information in the SVD.
  - According to the Bethe-Bloch formula [1], the mean energy loss (dE/dx) of a charged particle traversing through the detector medium depends on its velocity (β)



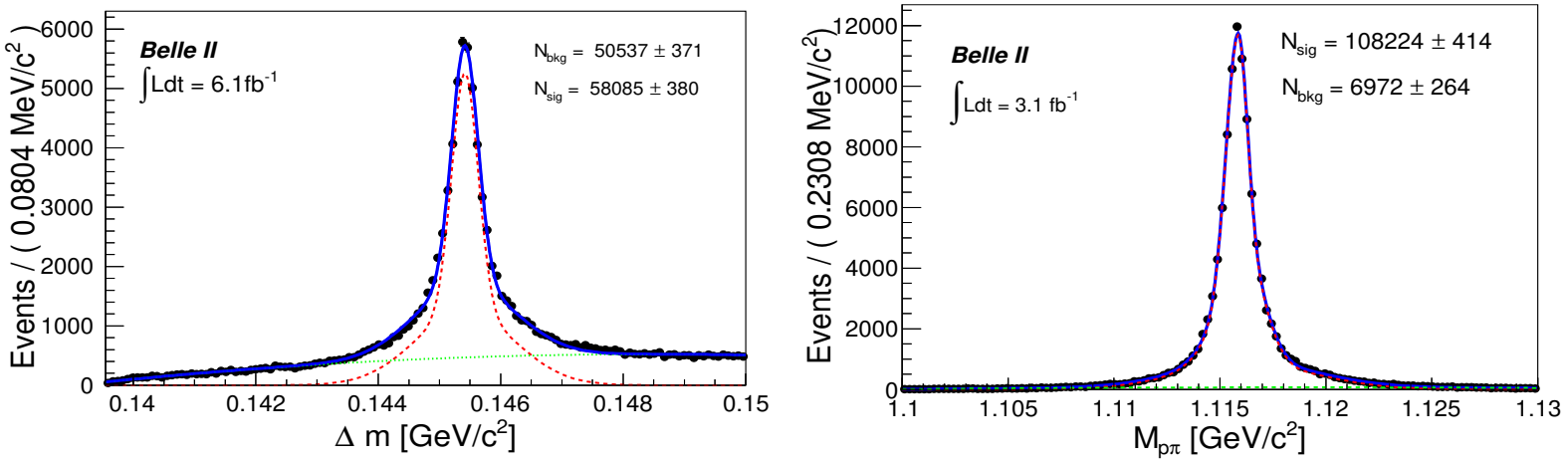


$\beta\gamma \cong$ 3-4

[1] W. R. Leo, "Techniques for Nuclear and Particle Physics Experiments", Springer-Verlag (1994).

SVD *dE/dx* calibration

- The study is based on e^+e^- collision data recorded at the $\Upsilon(4S)$ peak by Belle II
- We use $D^{*+} \to D^0(K^-\pi^+)\pi^+$ decays to identify pions and kaons, and $\Lambda \to p\pi$ decays to identify protons
- Various kinematic and vertex requirements are applied to suppress most of the backgrounds
- The ${}_s\mathcal{P}lot$ [1] technique is used to subtract the residual background contribution

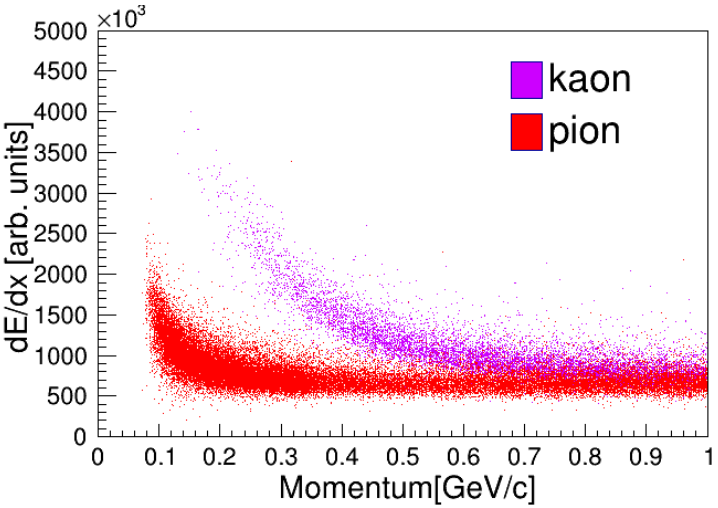


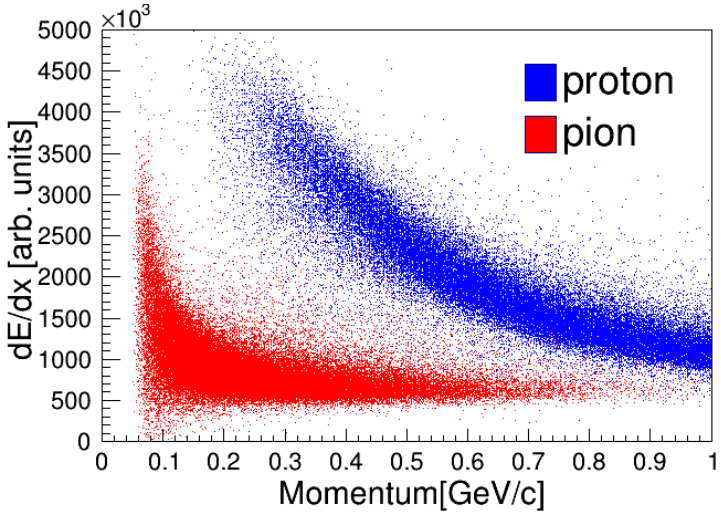
Fitted distributions of (left) D^*-D^0 mass difference (Δm) from D^* sample and (right) $M_{p\pi}$ from Λ sample

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

SVD *dE/dx* calibration

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

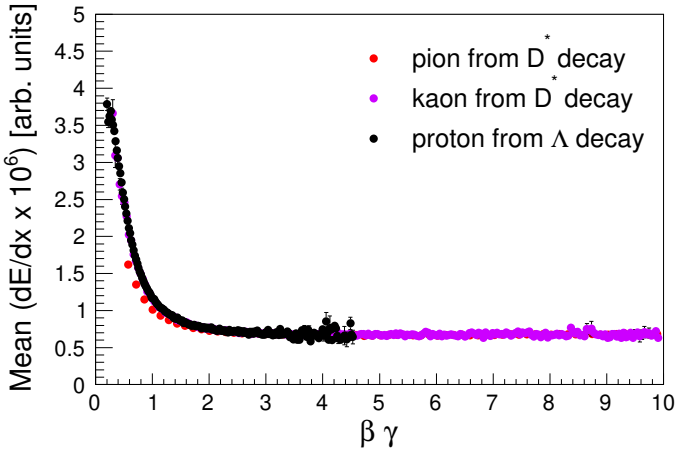




dE/dx distributions of pions, kaons and protons as a function of their momentum in data

• We check the $\beta\gamma$ universality curve from D^* and Λ samples

• We get a flat curve once the particle reaches its MIP threshold



SVD PID performance

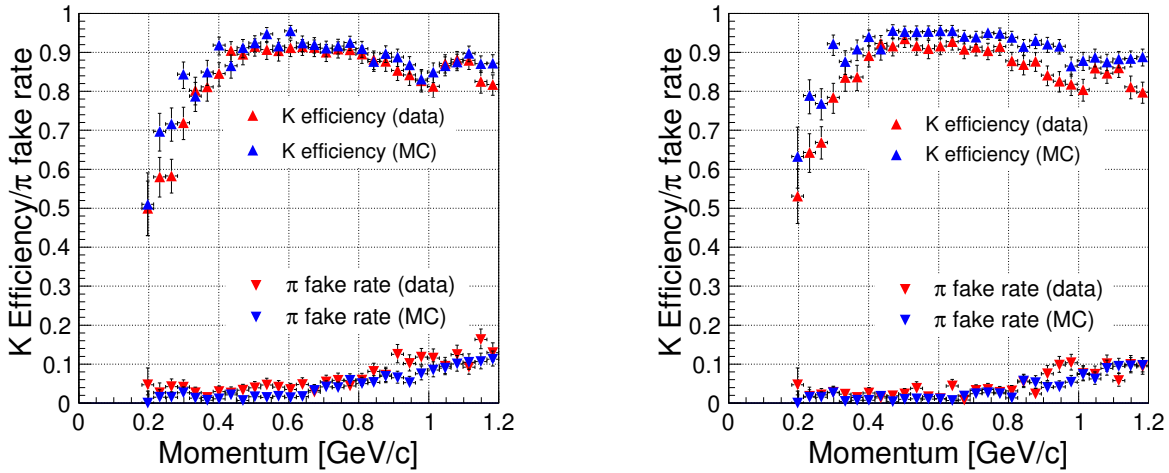
- The study is based on data reprocessed with uploaded histogram PDFs
- Again we use $D^{*+} \to D^0(K^-\pi^+)\pi^+$ and $\Lambda \to p\pi$ decays for performance studies

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:

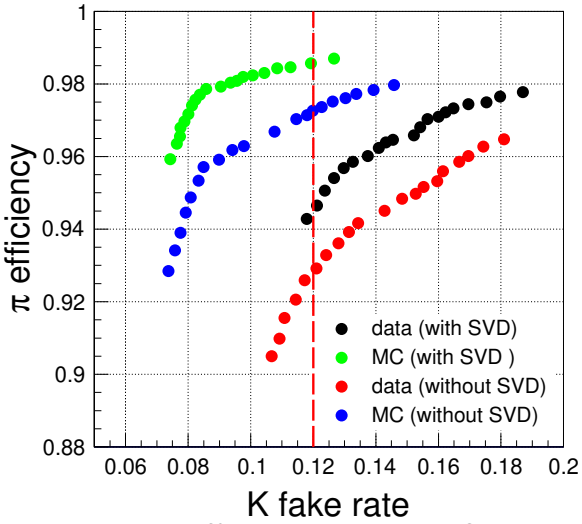
$$f_{j\to i} = \frac{\text{Number of tracks identified with PID requirement under the hypothesis } i}{\text{Number of tracks kinematically identified under the hypothesis } j}$$

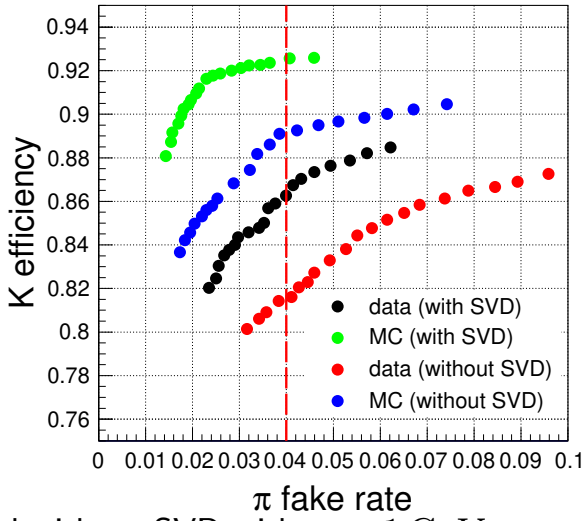


K efficiency and π fake rate (left) without and (right) with SVD for $\mathcal{L}(K/\pi) > 0.5$

SVD PID performance

• We plot the efficiency vs. fake rate to better appreciate the improvement in PID performance by adding the SVD *dE/dx* information

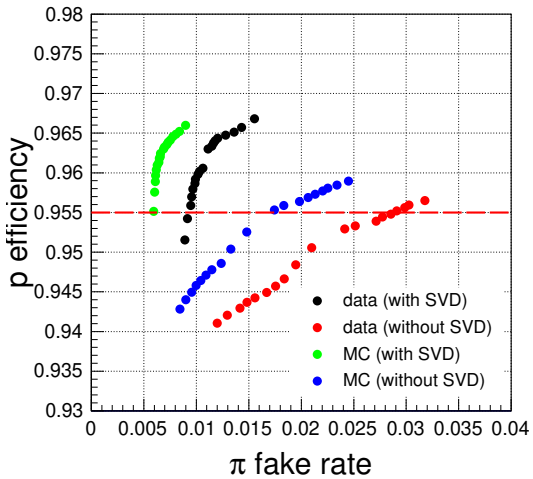




Kaon efficiency vs. pion fake rate with and without SVD with $p < 1\,\mathrm{GeV}$

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

• Our study confirms that addition of *dE/dx* information improves the pion, kaon and proton ID efficiency for a given fake rate in the low momentum region



Proton efficiency vs. pion fake rate with and without SVD with $p < 1\,\mathrm{GeV}$

Thank You

Backup: ${}_s\mathcal{P}lot$

- ${}_s\mathcal{P}lot$ is a method to reconstruct features of mixture of event components based on their known difference in a given distribution
- We have two components (signal and background) in the Δm distribution, where background is distributed as a threshold function and signal as a Gaussian function
- It gives the information about probabilities, allowing us to estimate the number of signal and background events with each bin
- From this we get the information of probability (sWeights) for each event component in each bin
- This sWeights information is used to reconstruct the distribution in another variable in that particular bin

Backup: Data/MC agreement

- 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