Slow-pion Relative Tracking Efficiency Studies at Belle II (On behalf of the Belle II Collaboration)

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Abstract. We study the slow-pion relative tracking efficiency by using $B^0 \to D^*\pi^+$ and $B^0 \to D^*\rho^+$ decay modes. Owing to its limited phase space, the pion from D^* decay is traditionally referred to the slow-pion due to a small mass difference between the D^* and D^0. We report herein a measurement of the relative tracking efficiency in the low-momentum region of 50-320 MeV performed using $B^0 \to D^*\pi^+$ and $B^0 \to D^*\rho^+$ decay modes, where the D^* further decays to $\bar{D}^0\pi^-$ and ρ^+ decays to $\pi^+\pi^0$.

Keywords: Belle II, tracking efficiency, slow-pion

1 Introduction

Track finding efficiency is a vital input to various sources of systematic uncertainties in analyses involving charged particles. Especially, the track finding efficiency of slow pions emitted from D^* decays plays a key role in $R(D^*)$ measurements [1]. Our aim is to measure the relative tracking efficiency in the low-momentum regions and related systematic uncertainty using $B^0 \to D^*\pi^+$ and $D^*\rho^+$ decays. An earlier measurement of the slow-pion reconstruction efficiency was performed by the Belle experiment using about 29.1 fb^{-1} data and 0.2 million Monte Carlo (MC) events. High-momentum tracking efficiency measurement using partially reconstructed D decays was also carried out by Belle .

We study the decay samples of $B^0 \to D^*\pi^+$ and $B^0 \to D^*\rho^+$ with D^{*-} further decaying to $\bar{D}^0\pi^-$ and ρ^+ to $\pi^+\pi^0$. D^* mesons are reconstructed using the decay chain $D^* \to \bar{D}^0\pi^-$, where the $\bar{D}^0$ decays into the following three final states: $K^+\pi^-$, $K^0_S\pi^+\pi^-$ and $K^+\pi^-\pi^+\pi^-$. We aim to measure the track finding efficiency of the charged pion in the low-momentum range coming from D^* decays, referred to as the slow pion (π_s). So, we obtain the reconstruction

Charge conjugate processes are included unless stated otherwise.

efficiency in the following four bins of π_s momentum: 0.05 - 0.12, 0.12 - 0.16, 0.16 - 0.20, and 0.20 - 0.32 GeV/c. We keep the binning same for both the modes so that at the end we can combine two modes for more statistics.

2 Data sample and event selection

The analysis uses 57.9fb^{-1} e^+e^- collision data collected at center-of-mass energy corresponding to the Υ(4S) resonance by the Belle II detector in the year 2020 [2]. We perform an MC study to calculate efficiency and identify various sources of background. Charged tracks are selected by applying a selection criteria $|dr| < 1$ cm and $|dz| < 3$ cm, where dr and dz are the distance of closest approach in the transverse and longitudinal directions, respectively. We reconstruct K_S^0 from two oppositely charged pions and select the candidates whose invariant mass lies between 450 to 550 MeV/c^2. The charged tracks are identified as pion or kaons from the Particle identification detector information. We apply the $\bar{D}^0$ mass window, $|M_{D^0} - M_{D^0}^{\rm PDG}| < 40$ MeV/c^2 to suppress combinatorial background. Further we constrained D^* momentum to be less than 2.5 GeV/c to ensure the event coming from $B^0\bar{B}^0$. We then introduce a variable $\Delta M = M_{D^*} - M_{D^0}$, which is required to lie between 0.143 and 0.147 GeV/c^2 to suppress combinatorial background. We use the beam-energy-constrained mass ($M_{\rm bc}$) and beam-energy difference(ΔE) to extract yields, where $M_{\rm bc} = \sqrt{E_{\rm beam} - (\Sigma p_i)^2}$, $\Delta E = \Sigma E_i - E_{\rm beam}$ and $E_{\rm beam}$ is beam energy. We require $M_{\rm bc}$ to be within 5.2 to 5.29 GeV/c^2 and ΔE within -0.2 to 0.2 GeV. A vertex fit is performed in order to ensure so that the B^0 daughters originate from a common vertex. We calculate efficiencies by fitting both $M_{\rm bc}$ and ΔE to check whether the obtained values are consistent or not.

The main background in our analysis is from the $e^+e^- \to q\bar{q}$ (q = u, d, s or c) continuum events. This background is suppressed by utilizing an event topology variable(R2), which is different for $B^0\bar{B}^0$ events. Among the other background coming from $B^0\bar{B}^0$ events, they are mostly contributed by semileptonic B decays, which is taken care by a dedicated background PDF for $B^0 \to D^*\pi^+$. For the $B^0 \to D^*\rho^+$ mode, we see a tiny peaking contribution in the $M_{\rm bc}$ mostly from its nonresonant modes. We model this peaking contribution based on the signal MC study.

3 Fit procedure and extraction of yields

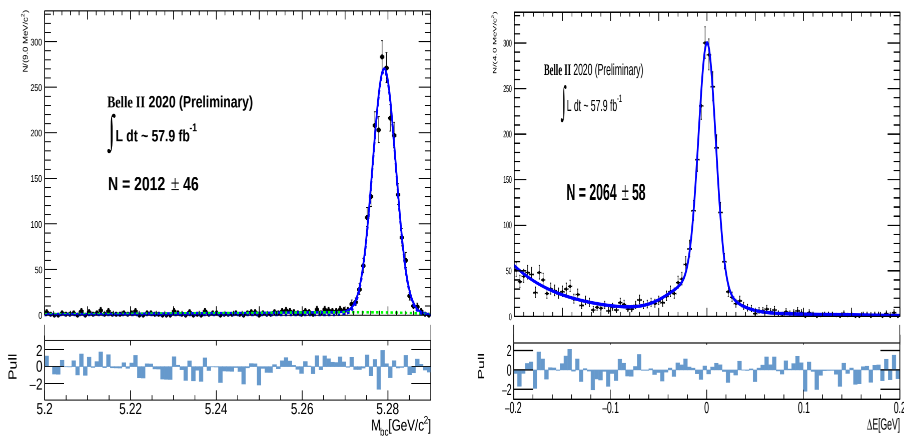

Fig. 1. Fitted distributions of $M_{\rm bc}$ and ΔE with $B^0 \to D^{*-}\pi^+$ generic MC sample.

Table 1. Slow-pion efficiency obtained for MC events in bins of slow pion momentum for $M_{\rm bc}$ and ΔE using $B^0 \to D^{*-}\pi^+$ decay mode.

	$Y_{\rm MC}$		$\varepsilon_{\rm MC}$	
p in (GeV/c)	$M_{\rm bc}$	ΔE	$M_{\rm bc}$	ΔE
0.05-0.12	309 ± 18	309 ± 18	0.15 ± 0.01	0.14 ± 0.01
0.12-0.16	551 ± 24	570 ± 25	0.27 ± 0.01	0.28 ± 0.01
0.16-0.20	422 ± 21	437 ± 22	0.21 ± 0.01	0.21 ± 0.01
0.20-0.32	727 ± 28	747 ± 28	0.36 ± 0.02	0.36 ± 0.02

We fit $M_{\rm bc}$ and ΔE to extract yield after applying all the selection criteria mentioned above. The fitted distributions in $M_{\rm bc}$ and ΔE using $B^0 \to D^*\pi^+$ are shown in Fig. 1. We fit these two variables in each bin of slow pion momentum as mentioned in section 1. Fig. 2 shows the fit to $M_{\rm bc}$ distribution to extract signal yield using $B^0 \to D^*\rho^+$ decay. We do not use ΔE fit here as the background contribution is relatively higher. When we fit $M_{\rm bc}$, we require ΔE within -0.04 to 0.04 GeV. The fitted yields ($Y_{\rm MC}$) and efficiencies ($\varepsilon_{\rm MC}$) are listed in Tables 1 and 2 for $B^0 \to D^*\pi^+$ and $B^0 \to D^*\rho^+$ modes, respectively. The efficiencies are calculated by dividing the yield in each bin by the total yield.

Looking ahead we will follow the same procedure in data to calculate the yields in each bin of slow pion momentum. We will then calculate the ratio between these yields in each bin by scaling the highest momentum bin to 1.

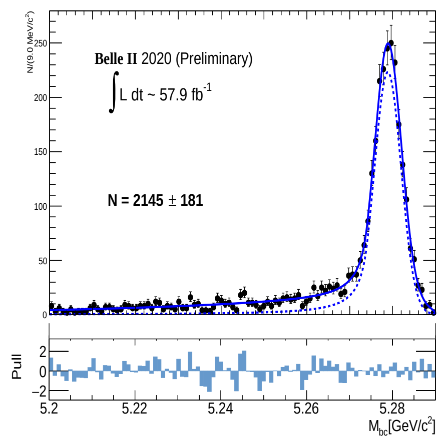

Fig. 2. Fitted distribution of $M_{\rm bc}$ obtained using $B^0 \to D^{*-}\rho^+$ generic MC sample.

Table 2. Slow-pion efficiency obtained for MC events in bins of slow pion momentum for $M_{\rm bc}$ using $B^0 \to D^{*-}\rho^+$ decay mode.

p in (GeV/c)	$Y_{\rm MC}$	$\varepsilon_{\rm MC}$
0.05-0.12	292 ± 17	0.14 ± 0.01
0.12-0.16	538 ± 23	0.26 ± 0.01
0.16-0.20	528 ± 45	0.26 ± 0.02
0.20-0.32	709 ± 53	0.34 ± 0.02

4 Summary

We have developed an analysis strategy using MC samples. We calculate the slow-pion relative tracking efficiencies using these samples having the same luminosity as data for $B^0 \to D^*\pi^+$ and $B^0 \to D^*\rho^+$ modes. We plan to do the same for data in near future before calculating the data-MC efficiency ratios. Finally, we will combine both the modes to gain more statistics and thereby obtain more precise value.

References

[1] A. Abdesselam *et. al.* (Belle Collaboration), arXiv:1904.08794 [hep-ex].
[2] T. Abe *et. al.*, Belle II Technical Design Report (2010), arXiv:1011.0352 [physics.insdet].
[3] P. A. Zyla *et. al.*(Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020)