Precise measurement of the branching ratio of
$B^0 \rightarrow D^*^- \pi^+ \pi^- \pi^+$ at $\text{BaBar}$

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Using a sample of $(470.9 \pm 2.8) \times 10^6$ $B \bar{B}$ pairs, we measure the decay branching fraction
$\mathcal{B}(B^0 \rightarrow D^*^- \pi^+ \pi^- \pi^+) = (7.26 \pm 0.11 \pm 0.31) \times 10^{-3}$, where the first uncertainty is statistical
and the second uncertainty is systematic. The measurement is 2.4 times more precise than the
current world average value. This branching fraction includes singly-charmed $B^0$ decays only
and is obtained by removing the dominant doubly-charmed $B^0$ decay contribution from the con-
taminated branching fraction of $(7.37 \pm 0.11 \pm 0.31) \times 10^{-3}$.

16th International Conference on B-Physics at Frontier Machines
2-6 May 2016
Marseille, France

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1. Introduction

The branching fraction ratio $R^{(s)} = \frac{\mathcal{B}(\bar{B} \to D^{(*)} \pi^{+} \nu_{\tau})}{\mathcal{B}(\bar{B} \to D^{(*)} \nu_{\tau})}$, where $l = e$ or $\mu$, was measured by BaBar [1], Belle [2] and LHCb [3]. The combined result is deviate from the standard model (SM) prediction by 3.9$\sigma$ [4]. A new measurement at a hadronic collider of $\mathcal{B}(\bar{B} \to D^{(*)} \pi^{+} \nu_{\tau})$ using $\tau^+ \to \pi^+ \pi^- \pi^+$, normalized to $\mathcal{B}(\bar{B} \to D^{(*)} \pi^{+} \pi^- \pi^+ \pi^-)$, may improve the precision and find more deviation from the SM. This new possibility needs a precise measurement of $\mathcal{B}(\bar{B} \to D^{(*)} \pi^{+} \pi^- \pi^+ \pi^-)$. This proceeding describes such a precision measurement at BABAR with $(470.9 \pm 2.8) \times 10^6 \bar{B}B$ pairs (the charge conjugates is implied).

2. Event selection

The $B^0 \to D^{*-} \pi^{+} \pi^- \pi^+$ decay candidates are reconstructed with $D^{*-} \to \bar{D}^0 \pi^- \to K^+ \pi^- \pi^-$. The non-$BB$ decays are suppressed. The $B^0$ candidates are required to have center-of-mass (c.m.) energies within $\pm 90$ MeV of the beam c.m. energy $E_{\text{beam}}$. Then the energy-substituted mass $m_{ES} = \sqrt{E_{\text{beam}}^2 - p_B^2}$ of the $B^0$ candidates, where $p_B$ is the c.m. momentum of the $B^0$ candidate, is shown in Fig. 1 (left) together with these of signal and background Monte-Carlo (MC) simulated samples. Then a model composed by a signal (Crystal Ball function), a non-peak background (ARGUS function) and a peaking background (Gaussian function) is used to fit the $m_{ES}$ spectrum as shown in Fig. 1 (right), and the fitted yield of signal candidates is $17767 \pm 324$.

![Figure 1](image)

**Figure 1:** Left: The $m_{ES}$ distribution of $B^0$ candidates in data and MC simulation. The points indicate the data. The solid histogram indicates the MC-simulated signal. The backgrounds are shown as stacked histograms. The $B^0 \to D^{*-} D^+_s$ decays are included in the signal histogram. Right: The unbinned extended-maximum-likelihood fit to the $m_{ES}$ spectrum of data. The total fit is shown by the solid curve, the signal component is shown by the dotted curve, and the background component is shown by the dashed curve.

3. The $3\pi$ mass and preliminary results

After a subtraction of the normalized background estimated by the sideband of $B^0$ peak on the $m_{ES}$ spectrum, the $3\pi (\pi^+ \pi^- \pi^+)$ mass of the $B^0 \to D^{*-} \pi^{+} \pi^- \pi^+$ candidates under the $B^0$ peak is...
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calculated as shown in Fig. 2. The $a_1^+$ predominate the $3\pi$ mass spectrum and the $D_s^+$ signal is also clear. The reconstruction efficiency as a function of the $3\pi$ mass is estimated by MC simulated events. After the integration of the efficiency corrected $3\pi$ mass spectrum, the number of the produced signal events in the experiment can be estimated. The result of $B^0 \to D^{*-} \pi^+ \pi^- \pi^+$ is $(7.26 \pm 0.11 \pm 0.31) \times 10^3$, where the $D_s^+$ contribution is removed, the first uncertainty is statistical and the second is systematic. The result with $D_s^+$ contribution included is $(7.37 \pm 0.11 \pm 0.31) \times 10^{-3}$.

\[ m_{3\pi} = 1230 \pm 40 \text{ MeV}/c^2 \]

**Figure 2:** The background-subtracted invariant mass spectrum of the 3π system. The indicated mass of the $a_1^+$ resonance is obtained from PDG [5].

4. Summary

A precise measurement of the branching fraction of $B^0 \to D^{*-} \pi^+ \pi^- \pi^+$ was performed at BABAR. The result is consistent with the current world average $(7.0 \pm 0.8) \times 10^3$ [5], but the precision is improved by a factor of 2.4. This result can be combined with a future measurement of $\mathcal{B}(B^0 \to D^{*-} \tau^+ \nu_\tau)/\mathcal{B}(B^0 \to D^{*-} \pi^+ \pi^- \pi^+)$ at a hadronic collider using $\tau^+ \to \pi^+ \pi^- \pi^+ \bar{\nu}_\tau$ to determine one more precise result of $\mathcal{B}(B^0 \to D^{*-} \tau^+ \nu_\tau)$, which could yield a further deviation of $R(D^*)$ from the SM prediction.

References