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Direct Measurement of Branching Fraction for Inclusive Semimuonic Decay of Neutral D Mesons *

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Using a data sample of about 33 pb^{-1} collected at and around $\sqrt{s} = 3.773$ GeV with the BES-Ⅱ detector at the BEPC, we have directly measured the branching fraction for inclusive semimuonic decay of neutral D mesons to be $BF(D^0 \to \mu^+ X) = (7.2 \pm 1.5 \pm 0.8)\%$.

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Recently we have directly measured the absolute branching fractions for D^0 and D^+ inclusive semimuonic decays.[1] The Feynman diagram for these decays is shown in Fig. 1, which indicates the light quark $\bar{q}$ does not participate in the decay, while the heavy quark c decays into quark s or d emitting a μ^+ and μ-neutrino. Measurements of the branching fractions for the inclusive leptonic decays of D mesons are important to understand the D decay mechanism. Moreover, it first validates that neutral and charged D mesons have equal semimuonic decay widths. In the corresponding analysis we use four decay modes($\bar{D}^0 \to K^+\pi^-$, $\bar{D}^0 \to K^+\pi^-\pi^-\pi^+$, $\bar{D}^0 \to K^+\pi^-\pi^0$ and $\bar{D}^0 \to K^0\pi^+\pi^-$) to reconstruct the singly tagged $\bar{D}^0$ mesons, but the decay mode $\bar{D}^0 \to K^0\pi^+\pi^-$ cannot express the charge of the single tag, resulting in charge conjugation as the single tag and the recoiling side cannot meet. In this work we ignore this decay mode and measure the branching fraction for inclusive semimuonic decay of neutral D mesons.

We report the direct measurement of the branching fraction for the inclusive decay $D^0 \to \mu^+ X$ (X=any particles) based on a data sample of about 33 pb^{-1} collected with the BES-Ⅱ detector[2–4] at and around the center-of-mass energy 3.773 GeV.

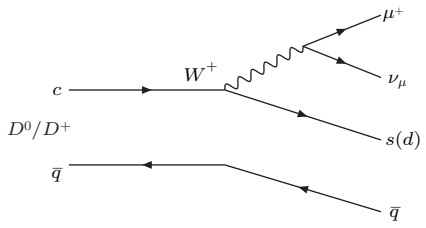


Fig. 1. Feynman diagram for the decay $D^0/D^+ \to \mu^+ X$.

Around $\sqrt{s} = 3.773$ GeV, the $\psi(3770)$ resonance is produced through e^+e^- annihilation. It lies just above the open charm pair production threshold and decays predominantly into $D^0\bar{D}^0$ or D^+D^- pairs, which provide us with a unique method to directly measure the branching fractions for the decays of D mesons. The singly tagged $\bar{D}^0$ sample used in the analysis were reconstructed from three hadronic decay modes of $Kn\pi$ ($n = 1, 2, 3$) in the previous work,[5] which gives the number of the singly tagged $\bar{D}^0$ events to be $7033 \pm 193 \pm 316$.[5] Throughout this study, charge conjugation is strictly implied.

Candidates for the decay $D^0 \to \mu^+ X$ are selected from the tracks except those reconstructed for the singly tagged $\bar{D}^0$ meson. It is firstly required that the tracks should be well reconstructed in the MDC with good helix fits and expected charges. Secondly, the polar angle θ must satisfy $|\cos\theta| < 0.67$. Thirdly, the transverse momentum of each track is required to be greater than 0.52 GeV/c. To reject the muon decayed from the kaon or pion, the charged track should originate from the interaction range, which requires that the distance of its closest approach should be less than 2.0 cm in the xy plane and 20.0 cm in the z direction. Because the number of hitting layers on the Muon Counter depends on the transverse momentum of the particle, the muon is selected by requiring that the number of hitting layers should be at least one, two and three for tracks with transverse momentum p_T in the range of 0.52–0.75 GeV/c, 0.75–0.95 GeV/c and $p_T > 0.95$ GeV/c, respectively. The electron, kaon or pion is identified by dE/dx, TOF and BSC information, with which the combined confidence level for the electron, kaon or pion hypothesis (CL_e, CL_K or CL_π) is calculated. An electron candidate is required to have $CL_e > 0.1\%$ and

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$CL_e/(CL_e + CL_K + CL_\pi) > 0.8$, a kaon candidate is required to satisfy $CL_K > CL_\pi$ and $CL_K > 0.1\%$, and that which does not satisfy the above criteria is regarded as a pion.

The electron, kaon or pion could hit the Muon Counter resulting in misidentification as a muon. Similarly, a muon could be misidentified as an electron, kaon or pion due to the limits of the dE/dx, TOF and BSC resolutions. The number of the total observed muons, electrons, kaons or pions consists of that of the true identified particles and that of misidentified ones, as shown in the following:

$$\begin{pmatrix} N^{\mu}_{\rm obs} \\ N^{e}_{\rm obs} \\ N^{k}_{\rm obs} \\ N^{\pi}_{\rm obs} \end{pmatrix} = \begin{pmatrix} \eta^{\mu\to\mu} & \eta^{e\to\mu} & \eta^{K\to\mu} & \eta^{\pi\to\mu} \\ \eta^{\mu\to e} & \eta^{e\to e} & \eta^{K\to e} & \eta^{\pi\to e} \\ \eta^{\mu\to K} & \eta^{e\to K} & \eta^{K\to K} & \eta^{\pi\to K} \\ \eta^{\mu\to\pi} & \eta^{e\to\pi} & \eta^{K\to\pi} & \eta^{\pi\to\pi} \end{pmatrix} \cdot \begin{pmatrix} N^{\mu}_{\rm true} \\ N^{e}_{\rm true} \\ N^{K}_{\rm true} \\ N^{\pi}_{\rm true} \end{pmatrix}, \quad (1)$$

where $N^{a}_{\rm obs}$ is the number of observed particles for a, $N^{b}_{\rm true}$ is the number of true b particles (a or b denotes μ, e, K, π), and η^{b-a} is the rate of misidentifying the particles b as a ($a \neq b$) or the efficiency of identifying the particles a ($a \neq b$).

The transverse momentum of a muon decayed from a D meson is within the range of 0.52–1.02 GeV/c. In order to obtain a more precise (mis)identification rate, we divide the range of transverse momentum into five intervals with 0.1 GeV/c steps. The (mis)identification rate $\eta^{b-a(i)}$ is determined by

$$\eta^{b-a(i)} = \frac{N_{b-a(i)}}{N_{b\,\rm sample(i)}}, \quad (2)$$

where $N_{b\ \rm sample(i)}$ is the number of b in the ith interval, $N_{b-a(i)}$ is the number of b identified as a in the ith interval, $i = 1, 2, 3, 4, 5$. The muon and electron samples are selected from the cosmic rays and the radiative Bhabha events in the $\psi(3770)$ data set, respectively; the kaon and pion samples are selected from the decays of $J/\psi \to \phi K^+K^-$ and $J/\psi \to \omega\pi^+\pi^-$ in the J/ψ data set, respectively. The (mis)identification rates are shown in Ref. [6].

The invariant mass spectra of the $Kn\pi$ combinations are shown in Fig. 2, in which the candidates for $D^0 \to \mu^+X$ are observed on the recoil side, where (a), (b), (c), (d) and (e) are for the transverse momentum of the muon candidate in the ranges of 0.52–0.62 GeV/c, 0.62–0.72 GeV/c, 0.72–0.82 GeV/c, 0.82–0.92 GeV/c and 0.92–1.02 GeV/c, respectively. The number of the observed events $N^{\mu,i}_{\rm obs}$ is obtained by fitting the mass spectra with a Gaussian function for the $\bar{D}^0$ signal and a special ARGUS background function[5] to describe the background shape. Similarly, the numbers of the observed events $N^{e,i}_{\rm obs}$, $N^{K,i}_{\rm obs}$ and $N^{\pi,i}_{\rm obs}$ are also obtained.

Inserting $\eta^{b-a,i}$ and $N^{a,i}_{\rm obs}$ into the matrix Eq. (1), we can yield the number of true muon candidates in the ith momentum interval $N^{\mu,i}_{\rm true}$. Summing $N^{\mu,i}_{\rm true}$ over five intervals, the total number of true muon candidates is obtained to be 88.4 ± 16.8. In order to estimate the background decayed from $K^+ \to \mu^+\nu_\mu$ and $\pi^+ \to \mu^+\nu_\mu$, we use a Monte Carlo sample generated as $e^+e^- \to D^0\bar{D}^0$ to pass through the same analysis process, where D^0 and $\bar{D}^0$ decay into all possible channels except $D^0 \to \mu^+X$ whose branching fractions are quoted from PDG.[7] The total number of the background is determined to be 8.1 ± 1.7. After subtracting the number of the background, we obtain the signal events to be 80.3 ± 16.9.

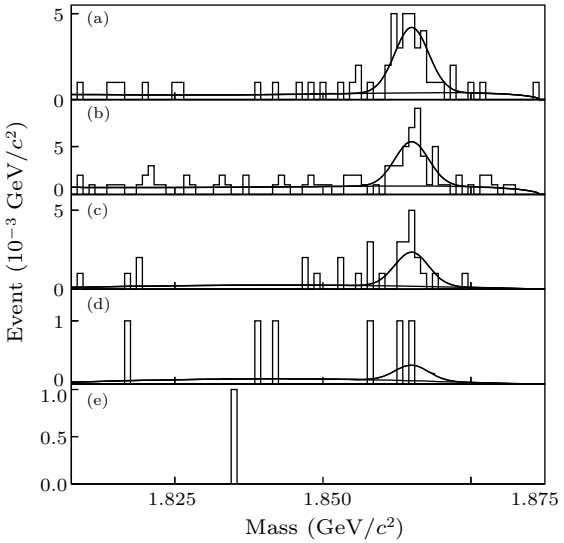


Fig. 2. Invariant mass spectra of the $Kn\pi$ combinations in which the candidates of $D^0 \to \mu^+X$ are observed on the recoil side, where (a), (b), (c), (d) and (e) are for the transverse momentum of the muon candidate in the ranges of 0.52–0.62 GeV/c, 0.62–0.72 GeV/c, 0.72–0.82 GeV/c, 0.82–0.92 GeV/c and 0.92–1.02 GeV/c, respectively.

The detection efficiency for the inclusive μ^+ decay of D^0 meson is estimated by Monte Carlo simulation. The Monte Carlo events are generated as $e^+e^- \to D^0\bar{D}^0$, where $\bar{D}^0$ decays into three hadronic decay modes of $Kn\pi$ ($n = 1, 2, 3$) and D^0 decays into μ^+X. The particle trajectories are simulated with GEANT3 based on the Monte Carlo simulation package of the BESⅡ detector.[4] Weighting the branching fractions of D^0 semimuonic decays quoted from PDG[7] and the numbers of the singly tagged $\bar{D}^0$ events, the averaged efficiency is obtained to be $(15.78 \pm 0.21)\%$.

Dividing the number of the signal events by the number of the singly tagged $\bar{D}^0$ mesons and the detection efficiency, the branching fraction for the inclusive decay $D^0 \to \mu^+X$ is determined to be $BF(D^0 \to \mu^+X) = (7.2 \pm 1.5 \pm 0.8)\%$, where the first error is statistical and the second is systematic[1].

Table 1. Comparisons of the measured branching fraction for the inclusive semimuonic decay of neutral D mesons with those measured by ARGUS, CHORUS and given by PDG.

	This work in BESII	Last work in BESII	ARGUS	CHORUS	PDG(06)
$BF(D^0 \to \mu^+ X)$	$7.2 \pm 1.5 \pm 0.8$	$6.8 \pm 1.5 \pm 0.8$	$6.0 \pm 0.7 \pm 1.2$	$6.5 \pm 1.2 \pm 0.3$	6.5 ± 0.7
$\frac{BF(D^+ \to \mu^+ X)}{BF(D^0 \to \mu^+ X)}$	$2.44 \pm 0.63 \pm 0.24$	$2.59 \pm 0.70 \pm 0.25$			
$\frac{\tau(D^+)}{\tau(D^0)}$					2.54 ± 0.02

Using the branching fraction for the inclusive semimuonic decay of charged D mesons listed in Ref. [1], we can obtain the ratio of two branching fractions to be $\dfrac{BF(D^+ \to \mu^+ X)}{BF(D^0 \to \mu^+ X)} = 2.44 \pm 0.63 \pm 0.24$.

Table 1 presents the comparisons of the measured branching fraction with those measured by ARGUS,[8] CHORUS[9] and given by PDG.[7]

In conclusion, based on a data sample of about $33\,\mathrm{pb}^{-1}$ collected at and around $\sqrt{s} = 3.773\,\mathrm{GeV}$ with the BES-II detector at the BEPC, the branching fraction for the inclusive semimuonic decay of neutral D mesons is directly measured to be $BF(D^0 \to \mu^+ X) = (7.2 \pm 1.5 \pm 0.8)\%$. The ratio of these branching fractions is obtained to be $\dfrac{BF(D^+ \to \mu^+ X)}{BF(D^0 \to \mu^+ X)} = 2.44 \pm 0.63 \pm 0.24$, which is consistent with the ratio of the lifetimes of D^+ and D^0 mesons, $\dfrac{\tau(D^+)}{\tau(D^0)} = 2.54 \pm 0.02$.

References

[1] Ablikim M et al 2008 *Phys. Lett.* B **665** 16
[2] Bai J Z et al 2001 *Nucl. Instrum. Methods* A **458** 627
[3] Ye M H and Zheng Z P 1999 *Proceeding of the XIV International Symposium on Lepton and Photon Interaction* (Stanford, California 9–14 August 1999)
[4] Ablikim M et al 2005 *Nucl. Instrum. Methods* A **552** 344
[5] Ablikim M et al 2004 *Phys. Lett.* B **597** 39
[6] Liu H H et al 2009 *Chin. Phys. Lett.* 26 041202
[7] Yao W M et al 2006 *J. Phys.* G **33** 1
[8] Albrecht H et al 1996 *Phys. Lett.* B **374** 249
[9] Kayis-Topaksu A et al 2005 *Phys. Lett.* B **626** 24