Measurement of Branching Fractions of the inclusive decay $D^0 \to \Phi X$ and of the exclusive decays of the D^0 involving a K^+K^-

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1 Introduction

The branching fractions (BF) of inclusive decay modes are notoriously difficult to measure and therefore generally not very well known. For instance, in 2006 the branching fraction of the decay $D^0 \to \Phi X$ still had an uncertainty of about 50%. A novel method of reconstructing completely events has been developped, which is especially suitable for evaluating inclusive (also useful for exclusive -) branching fractions. Since the branching fractions obtained are still highly preliminary, **we will present mainly this method**, which leads to the "best" measurement of BF($D^0 \to \Phi X$) confirming the present value of PDG2008 [1]. All exclusive decays of the D^0 involving a K^+K^- are compatible with the PDG2008 listings.

2 Data, Analysis Strategy and Event Selection

Our analysis is based on data collected by the Belle detector [2] at the asymmetric-energy KEKB storage rings [3] with a center of mass (CM) energy of 10.58 GeV ($\Upsilon(4S)$) and 60 MeV below, corresponding to a total integrated luminosity of 490 fb^{-1}.

The analysis strategy follows closely that adopted for the study on semileptonic decays $D^0 \to hl\nu$, were h=π or K [4]. We seek events of the type $e^+e^- \to D^{(*)}_{\rm tag} D^{*-}_{\rm sig} X$ $\{D^{*-}_{\rm sig} \to \overline{D}^0_{\rm sig}\pi^-\}$, where X may include additional $\pi^\pm$, π^0, or $K^\pm$ mesons (inclusion of charge-conjugate states is implied throughout this report). The D^0 is then tagged by fully reconstructing the remainder of the event. Each candidate is assembled from a fully reconstructed "tag-side" charm meson ($D^{(*)}_{\rm tag}$) and additional particles (X), with the requirement that the combination be kinematically consistent with $e^+e^- \to D^{(*)}_{\rm tag} D^{*-}_{\rm sig} X$. To the $D^{(*)}_{\rm tag}X$ is added a charged slow pion that is kinematically consistent with π^-_s from $D^{*-}_{\rm sig} \to \overline{D}^0_{\rm sig}\pi^-_s$. Candidate $D^{(*)}_{\rm tag}X\pi^-_s$ combinations passing the analysis criteria thus provide a tag of $\overline{D}^0_{\rm sig}$ and its momentum without having used any of its decay products. The $D^{(*)}_{\rm tag}$ is reconstructed in the modes $D^{*+} \to D^0\ \pi^+, D^+\pi^0$ and $D^{*0} \to D^0\pi^0, D^0\gamma$, with $D^{+/0} \to K^-(\mathrm{n}\pi)^{++/+}$ $\{\mathrm{n} = 1, 2, 3\}$. Each $D_{\rm tag}$ and $D^*_{\rm tag}$ candidate is subjected to a mass-constrained vertex fit to improve the momentum resolution. We require a successful fit of each $D_{\rm tag}$ candidate; furthermore, if this candidate is a daughter of a successfully fitted $D^*_{\rm tag}$ candidate, the event is treated as $D^*_{\rm tag}D^{*-}_{\rm sig}X$, otherwise it proceeds as $D_{\rm tag}D^{*-}_{\rm sig}X$. The candidate X is formed from combinations of unassigned pairs of pions and kaons, conserving total electric charge and strangeness. The 4-momentum of $D^{*-}_{\rm sig}$ (decaying into $\overline{D}^0\pi^-$) is found by energy-momentum conservation, assuming a $D^{(*)}_{\rm tag}D^{*-}_{\rm sig}X$ event. Its resolution is improved by subjecting it to a fit of the X tracks and the $D^{(*)}_{\rm tag}$ momentum, constrained to originate at the run-by-run average collision point, while the invariant mass is constrained to the nominal mass of a D^{*-}_{sig}. All possible combinations yielding X are tried. A candidate is rejected if the confidence level (fds2cl) of this fit is less than 0.1% (corresponding to $\pm 3.3\sigma$ of mass resolution).

In a correctly reconstructed signal event, the **remaining** particles not yet used have to be decay products of the D^0_{sig}. Since the D^0_{sig} has been reconstructed without use of any of these decay products, this method is ideal for studying various inclusive decay modes.

3 Study of the D^0 sample

Background lying under the $\overline{D}^0_{\rm sig}$ mass peak (i.e. fake-$\overline{D}^0_{\rm sig}$) is estimated using a wrong sign (WS) sample where the tag- and signal-side D candidates have the same flavor Fig.1 top left shows the invariant mass ("md0", GeV) of the D^0_{sig} candidate prior to the mass-constrained fit of the D^0_{sig}. The line is the mass distribution for the right sign (RS) sample, black that of WS. Obviously most of the background is cancelled in the difference; a possible remaining background is studied with MC below. The RS and WS m_{D^0} distributions for "good" events (confidence level of $D^0_{\rm sig} > 0.1\%$) (fd2cl) are shown in Fig.1 top right. Bottom left shows the RS-WS mass distribution representing the **canonical D^0 sample** for all present studies.

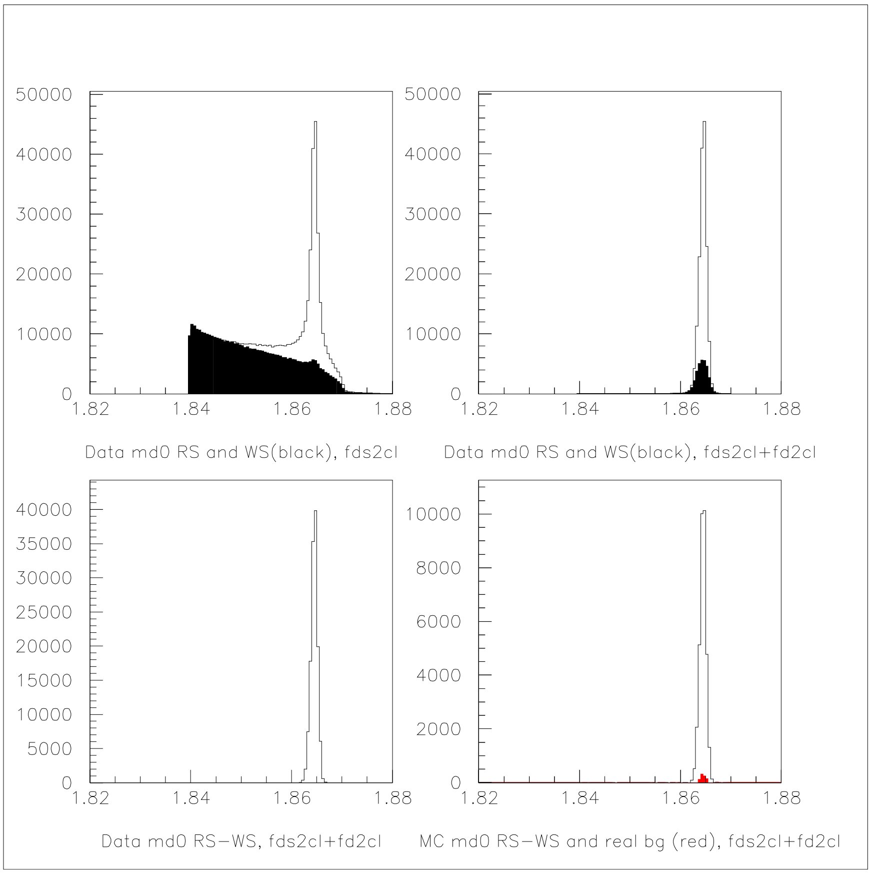

Figure 1: **Unfitted D^0 masses ("md0"), GeV**. Explanations in the text.

To evaluate the amount of possible background ("no D^0_{sig} events") still contained in the RS-WS D^0_{sig} sample (bottom right part of Fig.1) a MC sample of $e^+e^- \to \gamma \to q\bar{q}$, where $q = c, s, u, d$, containing about 35% of the data statistics, is used. The line is the canonical distribution, which can be compared to bottom left. Using generator information the true identity and origin of the particles supposedly coming from D^0 subsamples can be identified: Fig.1 bottom right red shows this (very small) background of "no D^0 events" amounting to about 3.5%, i.e. no particle originates, directly or indirectly, from a D^0_{sig}.

4 Evaluation of branching fractions of D^0 decays

Invariant mass m(K^+K^-) and missing mass spectra of K^+K^- are studied. In order to understand the background the charm MC is used. In Fig. 2 it is demonstrated that

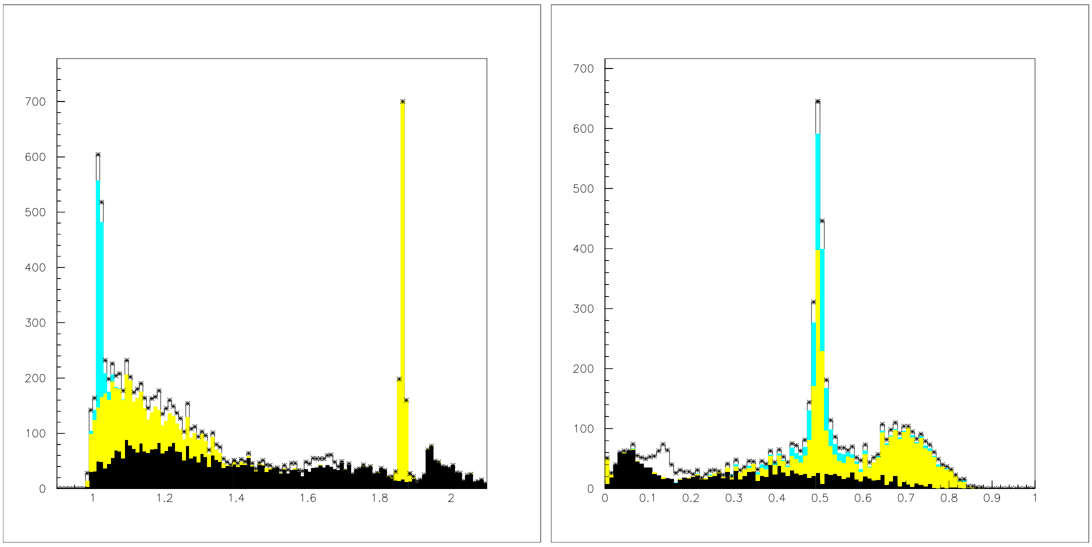

Figure 2: **MC**: Invariant mass (Left) and missing mass (Right) spectra of K^+K^-. **Yellow**: $D^0 \to K^+K^-X$. **Blue**: $D^0 \to \Phi(K^+K^-)X$. **Black**: One kaon has been wrongly identified by particle identification. **White**: Mainly $D^0 \to K^*(890)\pi^0$

the background of misidentified particles (black) consists of wrong identifications. In Fig. 2, left, m(K^+K^-) exhibits under the Φ signal a further background contribution stemming from decays $D^0 \to K^+K^-X$ (yellow, left part). The yellow signal to the right around m(D^0) comes from the exclusive decay $D^0 \to K^+K^-$. One can approximate the non-physics background in the data by purposely misidentifying a pion as a kaon. Clear background-free signals are obtained by subtracting the two kinds of backgrounds described above.

The MC simulations displayed in Fig. 2 have shown that the background of misidentified particles is smooth and non peaking. As an example we show for data in Fig. 3, that for $D^0 \to \Phi X$ similar results for the "direct fit" of Fig. 3 left (no background subtraction) are obtained compared with background subtraction as a cross-check (Fig. 3 right). Similar procedures are applied for the missing mass spectra of K^+K^- and for $K^+K^-\pi^0$. Nine different branching fractions for D^0 decays involving a K^+K^- pair have been evaluated. Since the branching fractions obtained are presently under review, we do not quote quantitative results. The procedure described above leads to the "best" measurement of BF($D^0 \to \Phi X$) confirming the present value of PDG2008 [1]. All exclusive decays of the D^0 involving a K^+K^- are compatible with the PDG2008 listings.

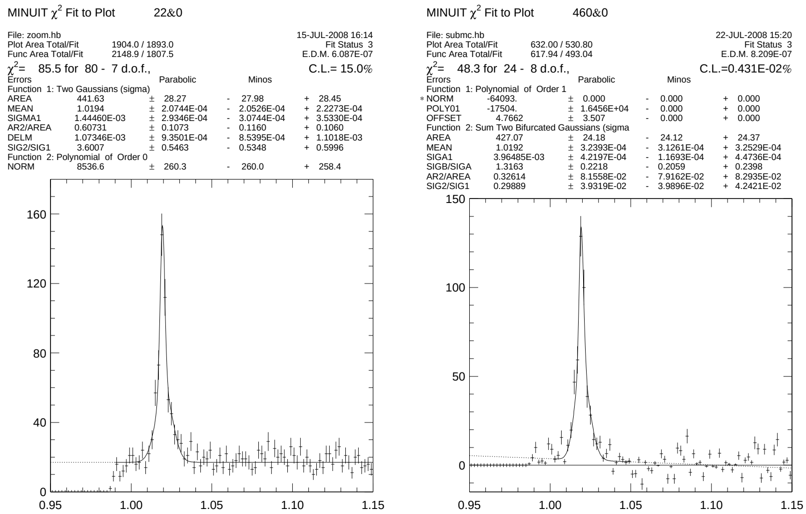

Figure 3: **Data**: **Fits** of m(K^+K^-) around m(Φ): **Left**: no background subtraction. **Right**: with background subtraction.

References

[1] Amsler et al. (Particle Data Group), Phys. Lett. **B667**, 1 (2008).

[2] A.Abashian et al. (Belle), Nucl. Instrum. Methods Phys. Res., Sect. **A 479**, 117 (2002).

[3] S.Kurokawa and E. Kikutani (Belle), Nucl. Instrum. Methods Phys. Res., Sect. **A 499**, 1 (2003) and other paper in this volume..

[4] L. Widhalm et al. (Belle), Phys. Rev. Lett. **97**, 061804 (2006).