BES-MEMO
Sept., 1996

Measurement of the $D^{*+}(2010)$ Branching Fractions

BES Collaboration
Institute of High Energy Physics, Beijing

Abstract

D^{*+} branching fractions are determined by single tag D^+, D^0 events and double tag D^+D^- events both from production mode $e^+e^- \to \bar{D}D^*(D\bar{D}^*)$. This analysis is based on the data collected by BES detector at a center-of-mass energy 4.03 GeV, corresponding to an integrated luminosity of 22.3 pb^{-1}. Neutral and charged D meson are observed from decay modes $K^\mp\pi^\pm, K^\mp\pi^\pm\pi^\pm\pi^\mp, K^0_s\pi^\pm\pi^\mp, K^\mp\pi^\pm\pi^\pm$ and $K^0_s\pi^\pm$. Single tag events of $D^0 \to K^-\pi^+, D^+ \to K^-\pi^+\pi^+$ and double tag D^+D^- events selected through $(K^-\pi^+\pi^+$ vs $K^+\pi^-\pi^-)$, $(K^\mp\pi^\pm\pi^\pm$ vs $K^0_s\pi^\mp)$, $(K^0_s\pi^\pm$ vs $K^0_s\pi^\mp)$ are used to determine the branching fractions.

Typeset using REVTEX

I. INTRODUCTION

Vector meson D^* may decay via strong interaction to $D\pi$ final states, or via electromagnitic transitions to $D\gamma$.The latter are proportional to the magnitic moment of the constituent quarks[1], which allows an important test of the standard model for the heavy quark c. Branching fractions for D^{*+} and D^{*0} decays have also been measured in a number of expriments[2-5]. The measurement result of $BR(D^{*+} \to D^+\gamma) = 17 \pm 5$ % given by MARK III [3] and the measurement result of $BR(D^{*+} \to D^+\gamma) = 1.1 \pm 1.4 \pm 1.6\%$ given by CLEO II [4] are quite diffrent. The former cannot be accommodated by theoretical models without invoking a large anomalous charm quark magnetic moment[6], while the latter is in good agreement with theoretical predictions. Further independent measurements are called for and a clarification is also desireble because D^* branching fraction have a noticble impact on the measurements of the branching fraction of B meson decays.

In this paper, we report a measurement result of the D^{*+} decay branching fractions. The analysis is based on $22.3pb^{-1}$ of data from e^+e^- collisions at a centr-of-mass energy 4.03 GeV, taken with the BES detector during the 1992-1994 BEPC run.

The BES is a conventional cylindrical detector, which is described in detail in Ref.[7]. A four-layer central drift chamber (CDC) surrounding the beampipe provides trigger information. Outside the CDC, a forty-layer main drift chamber (MDC) provides tracking and energy loss(dE/dx) information on charged tracks over $\sim 85\%$ of the total solid angle. The momentum resolution is $\sigma_p/p = 0.017\sqrt{1+p^2}$ (p in GeV/c), and the energy loss (dE/dx) resolution is $\sim 11\%$ for hadron tracks and $\sim 8.5\%$ for Bhabha electrons. Scintillation counters which surround the MDC provide time-of-flight (TOF) measurements, with resolutions of ~ 450 ps for hadrons and ~ 330 ps for Bhabha events. Outside the TOF system a 12-radiation-length, lead-gas barrel shower counter (BSC), operating in limited streamer mode, measures the energies of electrons and photons over $\sim 80\%$ of the total solid angle,and achieves energy resolution $\sigma_E/E = 0.22/\sqrt{E}$ (E in GeV) for electrons, and spatial resolutions σ_ϕ=4.5 mrad and σ_z=2 cm. A solenoidal magnet provides a 0.4 T magnetic field in the central tracking region of the detector. Three double-layer muon counters (MUC) instrument the magnet flux return, and serve to identify muons of momentum greater than 0.5 GeV/c. They cover $\sim 68\%$ of the total solid angle with longitudinal (transverse) spatial resolution of 5 cm (3 cm).

Section.II describes the measurement of D^{*+} branching fracrions by two different methods and a brief discussion is presented in Section.III.

II. BRANCHING FRACTIONS OF D^{*+}

In the 4-GeV region, three D production modes have been observed:

(1) $e^+e^- \to D\bar{D}$

(2) $e^+e^- \to D^*\bar{D}$ or $\bar{D}^*D$

(3) $e^+e^- \to D^*\bar{D}^*$

here D and D^* denote charged and neutral D meson and D^* meson respectively. Vector meson D^{*+} may decay to $D^+\gamma$, $D^+\pi^0$ or $D^0\pi^+$; D^{*0} may decay to $D^0\gamma$ or $D^0\pi^0$. Process (1) includes $e^+e^- \to D^0\bar{D}^0$, $e^+e^- \to D^+D^-$; Process (2) includes $e^+e^- \to D^0\bar{D}^{*0}$ or $\bar{D}^0D^{*0}$, $e^+e^- \to D^\pm D^{*\mp}$; Process (3) includes $e^+e^- \to D^{*0}\bar{D}^{*0}$, $e^+e^- \to D^{*\pm}D^{*\mp}$. The momentum regions of D-meson for above processes are different. We will describe it laterly. $D^{\pm}$, D^0 and $\bar{D}^0$ are reconstructed from the decay modes as follows: $K^{\mp}\pi^{\pm}\pi^{\pm}$, $K^0\pi^{\pm}$ for charged D and $K^{\mp}\pi^{\pm}$, $K^{\mp}\pi^{\pm}\pi^{\pm}\pi^{\mp}$, $K^0\pi^{\pm}\pi^{\mp}$ for neutral D. Well-reconstructed charged tracks (MFIT=2,-9,-19) were used to combine. Tracks (exclude K^0 channels)are required to come within 1 cm radialy and within ± 15 longitudinally of the measured beam crossing point. The polar angle of charged track are required to satisfy $|cos\theta| \leq 0.80$ to provide reliable tracking and barrel TOF information. The dE/dx and TOF information of a charged track are used to identify a particle. They are required to be consistent with the mass hypothesis assigned to the track. The confidence level of a track for each particle hypothesis (e, μ, π, K, P) can be calculated as $CL_i = 1 - Prob(\chi_i^2)$, where $Prob(\chi_i^2)$ is the probability of the χ^2 distribution for each partical hypothesis, $i = e, \mu, \pi, K, P$. χ_i^2 is the joint chi-square of the avilable dE/dx and TOF information for the track, defined as : $\chi_i^2 = \chi_i^2(TOF) + \chi_i^2(dE/dx)$, where $\chi_i^2(TOF) = (t - t_i)^2/\sigma_{TOF}^2$, t is the measured time of flight and t_i is expected time of flight for ith particle hypothsis. σ_{TOF}^2 is the resolution of TOF. Samillarly, $\chi_i^2(dE/dx)$ is defined as $\chi_i^2(dE/dx) = (dE/dx - dE/dx_i)^2/\sigma_{dE/dx}^2$. $CL_K > 0.01$ and $L_K/(L_K + L_\pi) > 0.5$ are required for K candidate and $CL_\pi > 0.01$ and $L_K/(L_K + L_\pi) \leq 0.5$ for π candidate, where $L_K = exp(-\chi_K^2(TOF)/2) \cdot exp(-\chi_K^2(dE/dx)/2)$ and $L_\pi = exp(-\chi_\pi^2(TOF)/2) \cdot exp(-\chi_\pi^2(dE/dx)/2)$. Further more, measured momenta of track are corrected for dE/dx losses in material traversed, and for a shift of BES magnetic field. Tracks are combined to reconstruct $D^{\pm}$, D^0 and $\bar{D}^0$ through the given decay channels. For the channel of $K^{\pm}\pi^{\mp}\pi^{\mp}\pi^{\pm}$, at least one of the two possible $\pi^+\pi^-$ combinations must have a mass within ± 150 MeV of the $\rho^0(770)$, and $K^{\pm}\pi^{\mp}$ a mass within ± 50 MeV of the $K^{*0}(892)$, to decrease the combinational background. For the K^0 channels, the invariant mass of $\pi^+\pi^-$ is limited to be 498 ± 18 MeV and the decay length in $R-\phi$ plane are required to be larger than 5 mm.

Signals from these decay chennals are observed. Fig.1 shows the invariant mass distributions of $K^{\mp}\pi^{\pm}$, $K^{\mp}\pi^{\pm}\pi^{\pm}\pi^{\mp}$, $K^0\pi^{\pm}\pi^{\mp}$, $K^{\mp}\pi^{\pm}\pi^{\pm}$ and $K^0\pi^{\pm}$. Fig.2 shows the momenta distribution of $K^{\mp}\pi^{\pm}$ and $K^{\mp}\pi^{\pm}\pi^{\pm}$ under a cut of $|M_{K\pi} - 1.865| \leq 0.05$ GeV and $|M_{K\pi\pi} - 1.869| \leq 0.05$ GeV respectively.

Monte Carlo studies show that the momentum of D meson relies on the production mode from which it comes. These three prodution modes can be well distingwished according to the momentum of D meson produced directly or from D^* decay. The momenta range for each mode is listed in Table I. One can determine from which production mode a D meson comes by the momentum of D.

The ammounts of tagged $D^{\pm}$, D^0 and $\bar{D}^0$ can be determined by fitting the invariant-mass distributions to Breit-Weigner function. The mean value of mass and width(σ) are obtained, as listed in Table II. Numbers of tagged $D^{\pm}$, $D^0(\bar{D}^0)$ produced from each production mode are determined by fitting the inariant-mass distribution under cuts on momentum as listed in Table III. Efficiences of reconstruction via $K^-\pi^+\pi^+$ and $K^-\pi^+$ for each event type, as listed in Table IV, are determined by Monte Carlo studies.

At energy of 4.03 GeV, the momentum of the soft pion and photon which come from D^* decay are small (about 70 MeV for pion and 100 MeV for photon). It is difficult to reconstruct the D^* directly due to the low efficiency of pion reconstruction (smaller than 0.1) and high backgroud of photon. But, branching fractions can be determined from D^+ and D^0 single tag applying some theoretical constrains on branching ratio and cross sections.

Considering the mode $e^+e^- \to \bar{D}D^*$ or $D\bar{D}^*$, the numbers of single tagged D^+ and D^0 from decay modes $D^+ \to K^-\pi^+\pi^+$ and $D^0 \to K^-\pi^+$ can be written as follows

$$N_{D^+} = L \cdot \sigma(D^+D^{*-}) \cdot (\varepsilon_2 + \varepsilon_3 \cdot b_1 + \varepsilon_4 \cdot b_2) \cdot br^+ \tag{1}$$

$$N_{D^0} = L \cdot \sigma(D^0\bar{D}^{*0}) \cdot (\varepsilon_2^0 + \varepsilon_3^0 \cdot b_1^0 + \varepsilon_4^0 \cdot b_2^0) \cdot br^0 + L \cdot \sigma(D^+D^{*-}) \cdot \varepsilon_5^0 \cdot b_3 \cdot br^0 \tag{2}$$

where $br^+ = BR(D^+ \to K^-\pi^+\pi^+)$, $br^0 = BR(D^0 \to K^-\pi^+)$, $b_1 = BR(D^{*+} \to D^+\gamma)$, $b_2 = BR(D^{*+} \to D^+\pi^0)$, $b_3 = BR(D^{*+} \to D^0\pi^+)$, $b_1^0 = BR(D^{*0} \to D^0\gamma)$ and $b_2^0 = BR(D^{*0} \to D^0\pi^0)$. From PDG 1994, we have $br^+ = 9.1 \pm 0.6\%$, $br^0 = 4.01 \pm 0.14\%$. D^* branching fractions b_1, b_2, b_3, b_1^0 and b_2^0 are unknown and need to be determined.

Isospin conservation and the P^3 dependence of P-wave widths are used to constrain the cross sections. At $E_{cm} = 4.03$ GeV, we have

$$\alpha = \frac{\Gamma(D^{*+} \to D^+\pi^0)}{\Gamma(D^{*+} \to D^0\pi^+)} = \frac{1}{2} \cdot (\frac{P_{D^+}}{P_{D^0}})^3 = 0.452 \tag{3}$$

$$\beta = \frac{\sigma(D^0\bar{D}^{*0})}{\sigma(D^+D^{*-})} = (\frac{P_{D^0}}{P_{D^+}})^3 = 1.077 \tag{4}$$

$$\gamma = \frac{\Gamma(D^{*0} \to D^0\pi^0)}{\Gamma(D^{*+} \to D^0\pi^+)} = \frac{1}{2} \cdot (\frac{P_{\pi^+}}{P_{\pi^0}})^3 = 0.710 \tag{5}$$

Consider the requirements of $b_1 + b_2 + b_3 = 1$, $b_1^0 + b_2^0 = 1$ and constrains of branching ratio $b_2/b_3 = \alpha$, $b_2^0/b_3 = \gamma$ which are derived from Eqs.(3)(5), branching fraction b_3 can be calculated from Eqs.(1)(2)(4) as follows:

$$b_3 = \frac{(\varepsilon_2 + \varepsilon_3) \cdot R - (\varepsilon_2^0 + \varepsilon_3^0) \cdot \beta}{[\varepsilon_3 + (\varepsilon_3 - \varepsilon_4) \cdot \alpha] \cdot R + \varepsilon_5^0 - (\varepsilon_3^0 - \varepsilon_4^0) \cdot \beta \cdot \gamma} \tag{6}$$

where $R = N_{D^0} \cdot br^+/(N_{D^+} \cdot br^0)$. Using the numbers of $N_{D^+} = 0.5 \cdot (1722 \pm 77 \pm 9)$, $N_{D^0} = 0.5 \cdot (2090 \pm 110 \pm 107)$ and ε's in Table IV, we obtain a result shown in Table VI.

The first item of error is statistic error caused by statistic uncertainty of ΔN_D. The second item of error is systematic error due to the uncertainty of br^+ and br^0, a variation of 2.5%L and the uncertainty of N_D via varying background function of fit. Since the uncertainties of α and β are 10^{-4} level caused by the mass uncertainties of D, D^* and π, its contribution to systematic error are ignored.

On the other hand, D^{*+} branching fraction are also determined via D^+D^- double tag. We selected double tag events through decay modes $K^-\pi^+\pi^+$ vs $K^+\pi^-\pi^-$, $K^\mp\pi^\pm\pi^\pm$ vs $K_s^0\pi^\pm$ and $K_s^0\pi^\mp$ vs $K_s^0\pi^\pm$ from the mode $e^+e^- \to D^\pm D^{*\mp}$, with $D^{*+} \to D^+\pi^0$ and $D^+\gamma$. The track selection criteria are the same as in Sec.II. The momentum of the reconstructed D^+ or D^- is required to be from 340 MeV to 700 MeV to ensure it is producted from $e^+e^- \to D^\pm D^{*\mp}$. Invariant mass of $K^\pm\pi^\mp\pi^\mp$ are required to be $1870 \pm 67(3\sigma)$ MeV. Invariant mass of K_s^0 reconstructed via $\pi^+\pi^-$ are required to be $497.7 \pm 22.5(3\sigma)$ MeV, and the flight length in $R - \phi$ plane of K_s^0 to be larger than 5 mm.

As the energy of photon from $D^{*+} \to D^+\gamma$ and $D^{*+} \to D^+\pi^0$, $\pi^0 \to 2\gamma$ is small. Impact of photon is estimated in background estimating. We observed 11 double tag events.Fig.3 shows distributions of observed signals comparing with Monta Carlo signal.

The number of observed double tag event for ith decay mode (i = 1, 2, 3) can be written as:

$$N_{D^+D^-} = 2 \cdot L \cdot \sigma(D^+D^{*-}) \cdot br_i^+ \cdot (1 - b_3) \cdot \varepsilon_{di} \tag{7}$$

where ε_{di} is the efficiency for the ith decay mode, b_3 is $BR(D^{*+} \to D^0\pi^+)$. bri^+ is the joint branching fractions for decay $(D^+ \to Hadrons)$ vs $(D^- \to Hadrons)$. From PDG 1994, we have $br_1^+ = BR(D^+ \to K^-\pi^+\pi^+) \times BR(D^- \to K^+\pi^-\pi^-) = 8.281 \times 10^{-3}$, $br_2^+ = BR(D^+ \to K^-\pi^+\pi^+) \times BR(D^- \to K_s^0\pi^-) \times BR(K_s^0 \to \pi^+\pi^-) = 8.554 \times 10^{-4}$ and $br_3^+ = (BR(D^+ \to K_s^0\pi^+) \times BR(K_s^0 \to \pi^+\pi^-))^2 = 8.836 \times 10^{-5}$.

Since there is a relation between cross section $\sigma(D^+D^{*-})$ and the number of single tagged D^+ in $e^+e^- \to D^\pm D^{*\mp}$, as described by Eqs.(1), for each double tag channel, we have

$$N_i = N_{i(D^+D^-)} = \frac{2 \cdot N_{D^+} \cdot br_i^+ \cdot (1 - b_3) \cdot \varepsilon_{di}}{(\varepsilon_2 + \varepsilon_3 \cdot (1 - b_3 - \alpha \cdot b_3) + \varepsilon_4 \cdot \alpha \cdot b_3) \cdot br^+} \tag{8}$$

where N_i is the number of double tag events via decay channel i. N_{D^+} is the number of single tagged D^+. For each double tag channel of $(Hadrons$ vs $Hadrons)_i$ (i = 1, 2, 3), the Poisson distribution function can be written as:

$$P_i(n_i, N_i + bg_i) = \frac{(N_i + bg_i)^{n_i}}{n_i!} \cdot e^{-(N_i + bg_i)} \tag{9}$$

where n_i is the number of observed events and N_i the expected number of event for decay mode i. bg_i is the background contribution for this decay mode.

Background contribution for each mode can be estimated by Monte Carlo simulation. bg_i can be calculated as

$$bg_i = \frac{N_i^{bg} \cdot 2 \cdot L \cdot \sigma(D^+D^{*-})}{N_{MC}} = \frac{N_i^{bg} \cdot 2 \cdot N_{D^+}}{N_{MC} \cdot (\varepsilon_2 + \varepsilon_3 \cdot (1 - b_3 - \alpha \cdot b_3) + \varepsilon_4 \cdot \alpha \cdot b_3) \cdot br^+} \tag{10}$$

where N_i^{bg} is the number of observed backgroud events from the ith tag mode in a total number N_{MC} of Monta Carlo $D^\pm D^{*\mp}$ events. We generate N_{MC}=5000 MC events in the way that $D^\pm$ decays to cocktail excluding the tag chennals and give a factor of bg_i as listed in Table V.

A joint liklihood function for three modes can be formed as follows:

$$Liklihood = \prod_{i=1}^{3} P_i(n_i, N_i + bg_i) \tag{11}$$

Using the result of double tag study in Table V, we get a liklihood function:

$$Liklihood \propto \left(\frac{11.99 - 11.42 \times b_3}{0.567 - 0.3 \times b_3}\right)^{11} \times exp\left(-\frac{14.56 - 12.57 \times b_3}{0.567 - 0.3 \times b_3}\right)$$

Fig.4 shows the liklihood function. The most probable value of b_3 are obtained. 32% of the area below and above this value gives a $\pm\sigma$ statistic error. We get $b_3 = 68.8^{+10.2}_{-24.2}\%$. Now b_1 and b_2 are calculated from $b_1 + b_2 + b_3 = 1$ and $b_2 = \alpha \cdot b_3$. the results are shown in Table VI. The systematic errors are estimated by changing event selection criteria, a variation of estimated background level by 50% and a variety of $2L \cdot \sigma(D^+D^{*-})$ by 1 standard deviation.

III. DISCUSSION

In measurement of D^{*+} via single tag event, parameters α, β, γ are used. But the result are not sensitive to the value of γ very much. A variation of γ by $\pm 50\%$ leads to $\pm$ 0.1% variation on $BR(D^{*+} \to D^0\pi^+)$. So, it is not a good idea to calculate b_1^0, b_2^0 from b_3 and γ. In the method of double tag, only α is used (α is also used in MARK III and CLEO measurements). Results from single tag and double tag agree well with each other and are consistent with the results of CLEO and theoretical predictions.

We would like to thank the staffs of the BEPC accelerator and the Computing Center at the Institute of High Energy Physics (Beijing).

REFERENCES

[1] S.Ono, Phys. Rev. Lett. **37**, 655 (1976); W. Wilcox, O. V. Maxwell, and K. A. Milton, Phys. Rev. D **31**, 1081 (1985); R. L. Thews and A. N. Kamal, Phys. Rev. D **32**, 810 (1985); G. A. Miller and P. Singer, Phys. Rev. D **37** 2564 (1988); T. M. Yan, H. Y. Cheng *et. al.*, Phys. Rev. D **46**, 1148 (1992); T. M. Yan, H. Y. Cheng *et. al.*, Phys. Rev. D **47**, 1030 (1993);

[2] G.Goldhaber *et. al.*, Phys. Lett. **69B**, 503 (1977); MarK II Collaboration, M. W. Coles *et. al.*, Phys. Rev. D **26**, 2190 (1982).

[3] Mark III collaboration. J.Adler *et. al.*, Phys. Lett. B **208**, 152(1988).

[4] CLEO collaboration, F. Butler *et. al.*, Phys. Rev. Lett. **69**, 2041(1992).

[5] ARGUS collaboration, H. Albrecht *et. al.*, ISSN 0418-9833 DESY 94-111.

[6] E. Angelos and G. P. Lepage, Phys. Rev. D **45**, 3021 (1992).

[7] J. Z. Bai *et al.*, Nucl. Instr. and Methods **A344**, 319 (1994); J. Z. Bai *et al.*, Phys. Rev. Lett. **69**, 3021 (1992);

TABLES

TABLE I. Momenta range for production modes

production mode	theoreticl momenta	experimental momenta
$e^+e^- \to D^*\bar{D}^*$	0.004-0.308 GeV	0.0-0.34 GeV
$e^+e^- \to D^*\bar{D}$ or $\bar{D}^*D$	0.368-0.664 GeV	0.34-0.70 GeV
$e^+e^- \to D\bar{D}$	P_{D^+}:0.752, P_{D^0}:0.764 GeV	0.70-0.85 GeV

TABLE II. Event number and mass for each tag Channel

Channel	mass(GeV)	width(MeV)
$D^0 \to K^-\pi^+$	1.8659±0.0007	27.6 ± 0.9
$D^0 \to K^-\pi^+\pi^+\pi^-$	1.8644±0.0007	15.9 ± 0.8
$D^0 \to K^0\pi^+\pi^-$	1.8649±0.0023	23.1 ± 2.3
$D^+ \to K^-\pi^+\pi^+$	1.8683±0.0009	21.0 ± 1.0
$D^+ \to K^0\pi^+$	1.8693±0.0034	25.3 ± 3.6

TABLE III. Events number for each production mode ($P_D : GeV$)

Channel	$e^+e^- \to D^*\bar{D}^*$ $p_D < 0.34$	event number N_D $e^+e^- \to D^*\bar{D}(\bar{D}^*D)$ $0.34 < P_D < 0.70$	$e^+e^- \to D\bar{D}$ $0.70 < P_D < 0.85$	total
$D^0 \to K^-\pi^+$	$1809 \pm 63 \pm 53$	$2090 \pm 110 \pm 107$	82 ± 28	$3899 \pm 127 \pm 119$
$D^0 \to K^-\pi^+\pi^+\pi^-$	$898 \pm 43 \pm 9$	$1130 \pm 73 \pm 18$		$2028 \pm 85 \pm 20$
$D^0 \to K^0\pi^+\pi^-$	$192 \pm 26 \pm 5$	$268 \pm 41 \pm 20$		$460 \pm 49 \pm 21$
$D^+ \to K^-\pi^+\pi^+$	$428 \pm 43 \pm 7$	$1722 \pm 77 \pm 9$	< 95	$2150 \pm 88 \pm 11$
$D^+ \to K^0\pi^+$	< 20	$179 \pm 24 \pm 20$		

TABLE IV. Efficence for each event type

event type	efficiency (%)
$e^+e^- \to D^+D^-, direct D$	$\varepsilon_1 = 0.289$
$e^+e^- \to D^+D^{*-}, direct D$	$\varepsilon_2 = 0.265$
$e^+e^- \to D^-D^{*+}, D^{*+} \to D^+\gamma$	$\varepsilon_3 = 0.302$
$e^+e^- \to D^-D^{*+}, D^{*+} \to D^+\pi^0$	$\varepsilon_4 = 0.308$
$e^+e^- \to D^{*-}D^{*+}, D^{*+} \to D^+\gamma$	$\varepsilon_5 = 0.295$
$e^+e^- \to D^{*-}D^{*+}, D^{*+} \to D^+\pi^0$	$\varepsilon_6 = 0.312$
$e^+e^- \to D^0\bar{D}^0, direct D^0$	$\varepsilon_1^0 = 0.354$
$e^+e^- \to D^0\bar{D}^{*0}, direct D^0$	$\varepsilon_2^0 = 0.344$
$e^+e^- \to \bar{D}^0D^{*0}, D^{*0} \to D^0\gamma$	$\varepsilon_3^0 = 0.371$
$e^+e^- \to \bar{D}^0D^{*0}, D^{*0} \to D^0\pi^0$	$\varepsilon_4^0 = 0.375$
$e^+e^- \to D^-D^{*+}, D^{*+} \to D^0\pi^+$	$\varepsilon_5^0 = 0.357$
$e^+e^- \to \bar{D}^{*0}D^{*0}, D^{*0} \to D^0\gamma$	$\varepsilon_6^0 = 0.387$
$e^+e^- \to \bar{D}^{*0}D^{*0}, D^{*0} \to D^0\pi^0$	$\varepsilon_7^0 = 0.403$
$e^+e^- \to D^{*-}D^{*+}, D^{*+} \to D^0\pi^+$	$\varepsilon_8^0 = 0.394$

TABLE V. D^+D^- double tag

i	tag mode	No. of Evt. n_i	efficiency ε_{di}	background level N_i^{bg}/N_{MC}
1	$K^-\pi^+\pi^+$ vs $K^+\pi^-\pi^-$	11	0.0729	$< 3. \times 10^{-5}$
2	$K^\pm\pi^\mp\pi^\mp$ vs $K_s^0\pi^\pm$	0	0.0678	$< 3.75 \times 10^{-5}$
3	$K_s^0\pi^\mp$ vs $K_s^0\pi^\pm$	0	0.0287	$< 3.75 \times 10^{-5}$

TABLE VI. Branching fractions of D^{*+}

decay mode		branching fraction (%)	
		(D single tag)	(D double tag)
$D^{*+} \to D^+ + \gamma$	b_1	$3.2 \pm 8.5 \pm 11.2$	$0.1^{+35.1+8.0}_{-14.8-7.7}$
$D^{*+} \to D^+ + \pi^0$	b_2	$30.1 \pm 2.7 \pm 3.5$	$31.1^{+4.6+2.4}_{-10.9-2.9}$
$D^{*+} \to D^0 + \pi^+$	b_3	$66.7 \pm 5.9 \pm 7.7$	$68.8^{+10.2+5.3}_{-24.2-5.5}$

FIGURES

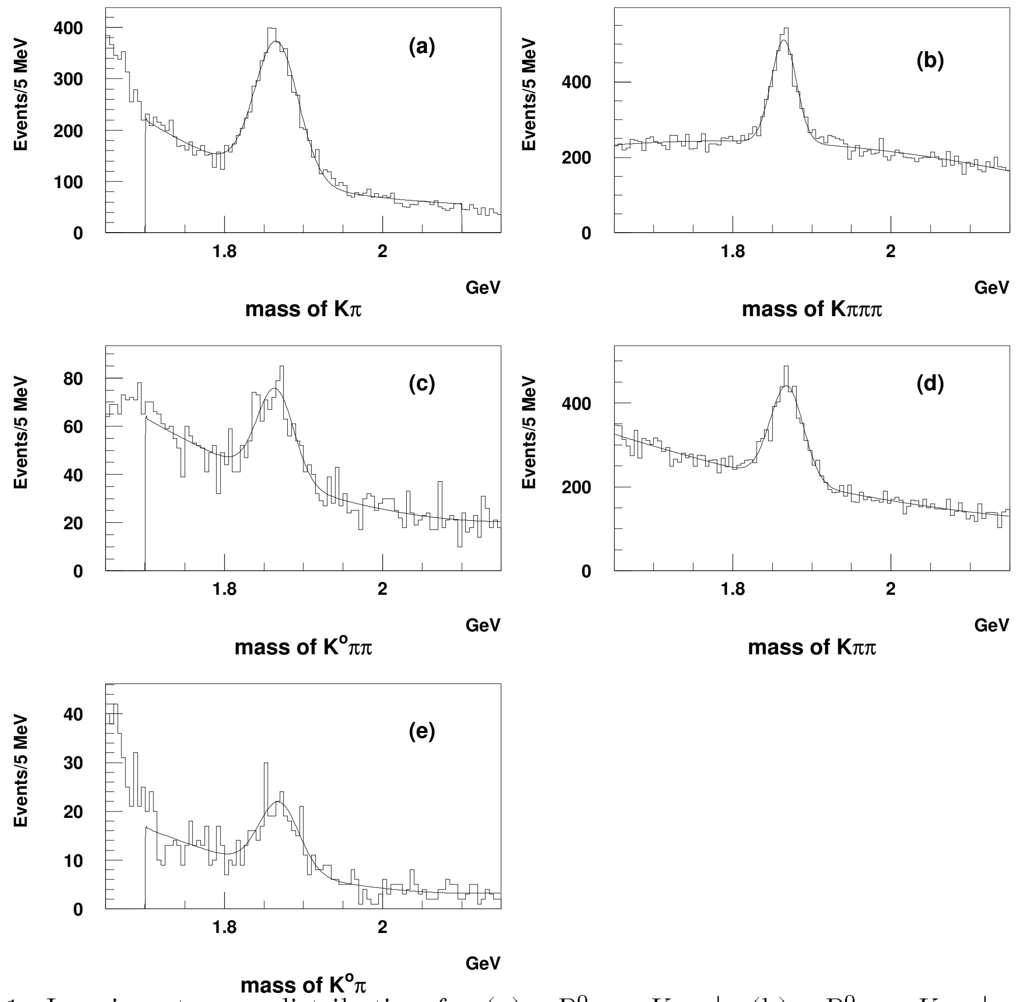

FIG. 1. Invariarant mass distribution for (a). $D^0 \to K^-\pi^+$, (b). $D^0 \to K^-\pi^+\pi^+\pi^-$, (c). $D^0 \to K_s^0\pi^+\pi^-$,(d). $D^+ \to K^-\pi^+\pi^+$, (e).$D^+ \to K_s^0\pi^+$

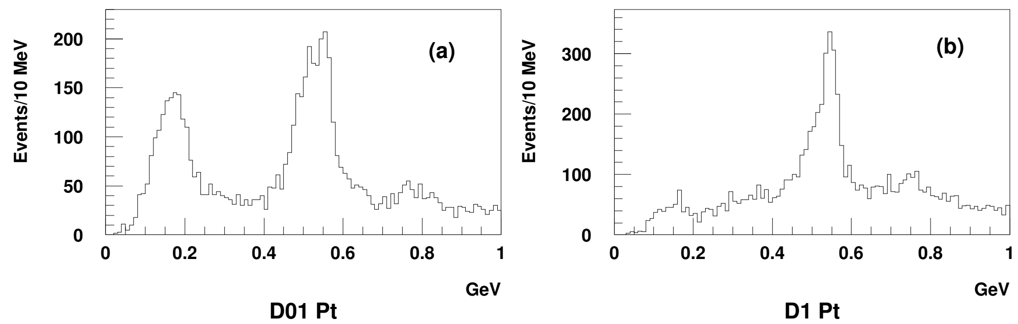

FIG. 2. Momenta distribution for (a). $D^0 \to K^-\pi^+$ and (b). $D^+ \to K^-\pi^+\pi^+$

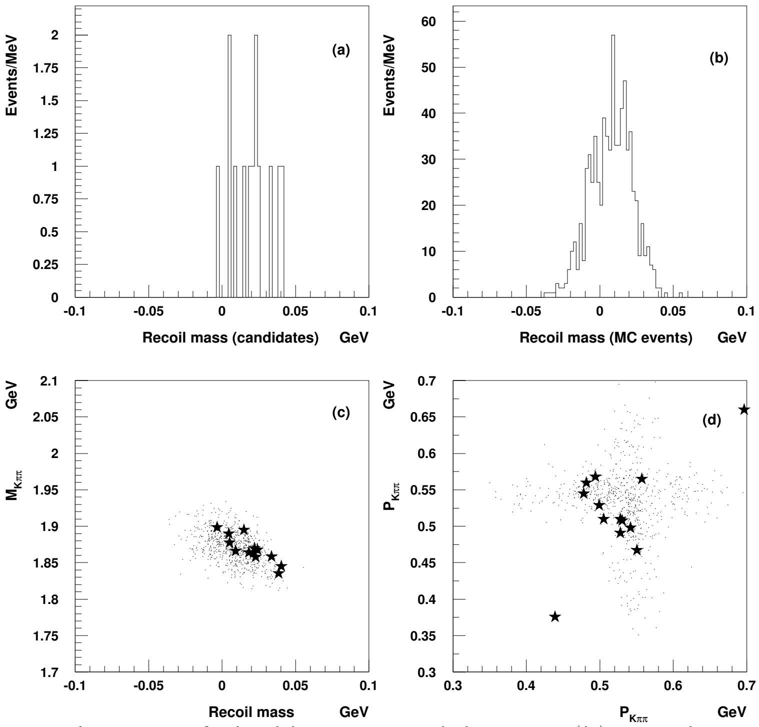

FIG. 3. (a). Recoil mass of double tag candidates. (b).Recoil mass of D^+D^- from $e^+e^- \to \bar{D}D^*(D\bar{D}^*)$ (Monte Carlo events). (c). Mass of $K^+\pi^-\pi^-$ vs Recoil mass, compared with MC events (dots: MC events, star: candidates). (d). Momenta of $K^+\pi^-\pi^-$ vs Momenta of $K^-\pi^+\pi^+$, compared with $e^+e^- \to D^\mp D^{*\pm}$, $D^{*\pm} \to D^\pm\gamma, D^\pm\pi^0$ MC events (dots: MC events, star: candidates).

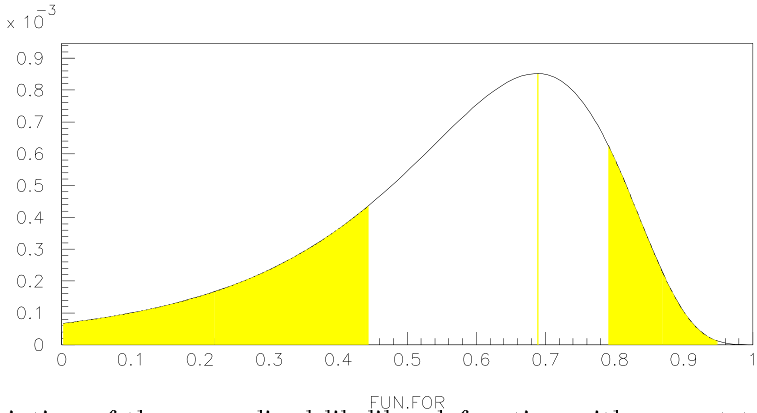

FIG. 4. The variation of the normalized likelihood function with respect to b_3 ; the unshaded area under the curve denotes the 68% confidence interval.