Measurement of Inclusive ϕ Decay Branching Fractions of Charged and Neutral D Mesons and a Search for $D^+ \to \phi e^+ \nu$

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Inclusive ϕ decays of charged and neutral D mesons have been studied using reaction $e^+e^- \to DD^*, D^*\bar{D}^*$ at $\sqrt{s}$ = 4.03 GeV. A total of 10 inclusive ϕ decay events have been observed in the recoiling system against the tagged neutral and charged D mesons. No event of the exclusive decay $D^+ \to \phi e^+ \nu$ is observed in the recoil. These lead to the charged and neutral D mesons inclusive ϕ decay branching fraction of $BF(D^+ \to \phi X) = (2.86^{+4.69+0.86}_{-1.80-0.45})\%$ and $BF(D^0 \to \phi X) = (1.16^{+1.27+0.26}_{-0.80-0.24})\%$, respectively; and an average inclusive ϕ decay branching fraction combined the charged and neutral D mesons together to be $BF(D \to \phi X) = (1.57^{+0.62+0.20}_{-0.40-0.17})\%$. With these events an upper limits on the inclusive and exclusive decay branching fractions were also determined as $BF(D^0 \to \phi X) < 3.53\%$, $BF(D^+ \to \phi X) < 11.95\%$, $BF(D \to \phi X) < 2.71\%$ and $BF(D^+ \to \phi e^+ \nu) < 1.57\%$ at 90% CL.

I. INTRODUCTION

During the last two decades a lot of progress in heavy flavour physics have been made. Up to now more and more precision measurements of exclusive decay branching fractions and inclusive semileptonic decay branching fractions of charmed and bottom measons have been performing. These make one understand the decay mechanism of heavy flavor mesons better and better. However, the measurement of inclusive ϕ decay branching fractions of charmed mesons is not available[1]. Those inclusive decay branching fractions may be served as an independent check for a sum of exclusive decay modes containing a ϕ meson in final states, which can be used to lead one to search for some new decay modes containing ϕ in final states and help one understand the decay mechanism better. The values of the decay branching fractions may also be needed as inputs to more precisely simulate the charm decay in accurate measurements of B physics in experiments such as LEP, CDF and B factories, and could be useful for background subtracting in measurements of inclusive ϕ decay branching fractions of B mesons. The measurement of inclusive ϕ decay branching fractions of B mesons would be important for studies of contribution of gluonic penguins ($b \to sg$) decay diagram to the total B decay[2] rate.

A limit on the exclusive semileptonic decay branching fraction $BF(D \to \phi e^+ \bar{\nu})$ would be beneficial to other experiment to evaluate backgrounds in studying of $B^0\bar{B}^0$ mixing and oscillation.

This paper reports on a first measurement of inclusive ϕ decay branching fractions of the charged and neutral D mesons and a new search for the exclusive semileptonic decay $D^+ \to \phi e^+ \bar{\nu}$ based on an analysis of the data collected with Beijing Spectrometer (BES) in e^+e^- annihilation at $\sqrt{s} = 4.03$ GeV.

II. THE BEIJING SPECTROMETER AND DATA SAMPLE

BES is a conventional cylindrical magnetic detector[3] operated at the Beijing Electron Positron Collider (BEPC)[4]. A four-layer central drift chamber (CDC) surrounding the beam pipe provides event trigger. A forty-layer main drift chamber (MDC) located just outside the CDC performs charged track reconstruction and ionization energy loss (dE/dx) measurement with a solid angle coverage of 80% of 4π for a charged track. Momentum resolution of $1.7\%\sqrt{1+p^2}$ (p in GeV/c) and dE/dx resolution of 8.5% for Bhabha scattering electrons are obtained for the data taken at $\sqrt{s} = 4.03$ GeV. A array of 48 sintillation counters surrounds the MDC and measures the time of flight (TOF) of the charged track with a resolution of about 350 ps for the electrons. Surrounding the TOF is a 12-radiation-length, lead-gas barrel shower counter (BSC) operated in limited streamer mode, measures the energies of electrons and photons over 80% of the total solid angle, and has energy resolution of $\sigma_E/E = 0.22/\sqrt{E}$(E in GeV), spatial resolutions of $\sigma_\phi = 4.5$ mrad and $\sigma_Z = 2$ cm for the electrons. Outsiding the BSC is a solenoidal magnet which provides a 0.4 T magnetic field in the central tracking region of the detector. Three double-layer muon counters instrument the magnet flux return, and serve to identify muons of momentum greater than 500 MeV/c. They cover 68% of the total solid angle with longitudinal (transverse) spatial resolution of 5 cm (3 cm). End-cap time-of-flight and shower counters extend coverage to the forward and backward regions.

The analysis is based on a total integrated luminosity of 22.3 pb^{-1} data which was collected in e^+e^- annihilation at $\sqrt{s} = 4.03$ GeV at BEPC during the 1992, 1993 and 1994 runs.

III. METHOD OF COMBINING D^+ AND D^0 DOUBLE TAGS TOGETHER

At $\sqrt{s} = 4.03GeV$ the charm mesons are produced as

$$e^+e^- \rightarrow D_s^+D_s^-, D^+D^-, D^0\bar{D}^0,$$
$$\rightarrow D^{\pm}D^{*\mp}, D^0\bar{D}^{*0}(\bar{D}^0D^{*0}),$$
$$\rightarrow D^{*\pm}D^{*\mp}, D^{*0}\bar{D}^{*0}.$$

Since the $D^{*\pm}$ can decay to $\pi^{\pm}D^0$ and $\pi^0(\gamma)D^{\pm}$, it is impossible to know whether a $D^+(D^0)$ or $D^-(\bar{D}^0)$ appears in recoiling side against a tagged D meson. But, if one combines single and 'double' tags for the two mesons to measure their inclusive particle 'P' decay branching fractions together, he can obtain values of the decay branching fractions independently.

Suppose one wants to measure inclusive particle P decay branching fractions of the D^0 and D^+, he should search for the particle P and count the numbers ($N^P_{D^0_{tag}}$ and $N^P_{D^+_{tag}}$) of the particle P appeared in the recoiling side against the tagged D^0 and D^+,respectively. The $N^P_{D^0_{tag}}$ is related to $N^{D^-}_{D^0_{tag}}$ and $N^{\bar{D}^0}_{D^0_{tag}}$, which respectively are numbers of D^- and $\bar{D}^0$ produced in the recoiling system against the tagged D^0 sample, by

$$N^P_{D^0_{tag}} = \epsilon_1 N^{D^-}_{D^0_{tag}} BF(D^- \rightarrow PX) + \epsilon_2 N^{\bar{D}^0}_{D^0_{tag}} BF(\bar{D}^0 \rightarrow PX), \quad (1)$$

where ϵ_1 and ϵ_2 are detection efficiencies for the particle P, $BF(D^- \rightarrow P\,X)$ and $BF(\bar{D}^0 \rightarrow PX)$ are decay branching fractions to be measured. Similarly, for D^+ tags one has

$$N^P_{D^+_{tag}} = \epsilon_1 N^{D^-}_{D^+_{tag}} BF(D^- \rightarrow PX) + \epsilon_2 N^{\bar{D}^0}_{D^+_{tag}} BF(\bar{D}^0 \rightarrow PX), \quad (2)$$

The $N^{D^-}_{D^+_{tag}}$ and $N^{\bar{D}^0}_{D^+_{tag}}$ are the numbers of D^- and $\bar{D}^0$ produced in the recoiling system against the tagged D^+. A Monte Carlo study shows that the detection efficiencies are nearly the same, which allow to take the $\epsilon \approx \epsilon_1 \approx \epsilon_2$. By using the numbers ($N_{D^0_{tag}}$ and $N_{D^+_{tag}}$) of the D^0 and D^+ single tags, the numbers of the $\bar{D}^0$ and D^- produced in the recoiling side against the single tags can be calculated as following

$$N^{\bar{D}^0}_{D^0_{tag}} = (1-\eta)N_{D^0_{tag}}, \qquad N^{D^-}_{D^0_{tag}} = \eta N_{D^0_{tag}},$$

$$N^{\bar{D}^0}_{D^+_{tag}} = \beta N_{D^+_{tag}}, \qquad N^{D^-}_{D^+_{tag}} = (1-\beta)N_{D^+_{tag}},$$

where the η and β are the probabilities of D^- and $\bar{D}^0$ appeared in the recoiling side against the tagged D^0 and D^+, respectively. By using the values of D^*D^* and D^*D production cross section measured by the BES experiment[5], the probabilities are obtained to be $\eta = 0.1768 \pm 0.0175$ and $\beta = 0.5460 \pm 0.0622$.

Combining the equation (1) and (2) together by inserting the $N^{\bar{D}^0}_{D^0_{tag}}$, $N^{D^-}_{D^0_{tag}}$, $N^{\bar{D}^0}_{D^+_{tag}}$, and $N^{D^-}_{D^+_{tag}}$ into them, the inclusive particle 'P' decay branching fractions of $\bar{D}^0$ and D^- are given by

$$BF(\bar{D}^0 \rightarrow PX) = \frac{1}{\epsilon(1-\beta-\eta)}((1-\beta)\frac{N^{PX}_{D^0_{tag}}}{N_{D^0_{tag}}} - \eta\frac{N^{PX}_{D^+_{tag}}}{N_{D^+_{tag}}}) \quad (3)$$

and

$$BF(D^- \rightarrow PX) = \frac{1}{\epsilon(1-\beta-\eta)}((1-\eta)\frac{N^{PX}_{D^+_{tag}}}{N_{D^+_{tag}}} - \beta\frac{N^{PX}_{D^0_{tag}}}{N_{D^0_{tag}}}). \quad (4)$$

IV. DATA ANALYSIS

A. Event Selection

For each event it is required that at least 2 (but not more than 10) charged tracks were well reconstructed in MDC with good helix fits. Each track is required to have impact parameter less than 1.2 cm in the xy plane and 15.0 cm in the Z direction. Further more, the track is required to have a normalized chsquare of less than 9 per degree of freedom. In addition, in order to optimize the momentum resolution and charged particle identification, a geometry cut ($|\, cos\theta\, | \leq 0.8$, where the θ is polar angle of the track) is applied. For the charged particle mass assignment, one (or two) level(s) of particle identification is (are) applied. First a combined particle confidence level calculated using the dE/dx and TOF measurements is required to be greater than 1% for $\pi(K)$ hypothesis; then a normalized likelihood ratio $LR(K) > 50\%$ is required for the K hypothesis. If the track pass the particle identification cuts, the $\pi(K)$ mass is assigned to the track.

B. Single tag of $D^0(\bar{D}^0)$ and $D^{\pm}$

After the particle mass assignments, an invariant masses of different combinations for the three weak hadronic decay modes $\bar{D}^0(D^0) \rightarrow K^{\pm}\pi^{\mp}$, $K^{\pm}\pi^{\mp}\pi^{\mp}\pi^{\pm}$ and $D^{\mp} \rightarrow K^{\pm}\pi^{\mp}\pi^{\mp}$ are calculated using corrected momenta components for a small value of shift of magnetic field and ionization loss of the particle in the material interior to the MDC gas.

Figure 1a-c shows the distributions of the momenta of the $K^{\pm}\pi^{\mp}$, $K^{\pm}\pi^{\mp}\pi^{\mp}\pi^{\pm}$ and $K^{\pm}\pi^{\mp}\pi^{\mp}$ combinations whose invariant masses are within ± 87, ± 51 and ± 65

MeV/c^2 ($\sim \pm 3\sigma_{M_D}$ cut) of the D^0 and D^+ nominal masses, respectively. In the figure the three lowest peaks correspond to the D mesons from the $D^*\bar{D}^*$; the peaks in the middle respect to the D mesons from the $D\bar{D}^*(D^*\bar{D})$ and the peaks at high momentum position reflect the D mesons from the $D\bar{D}$.

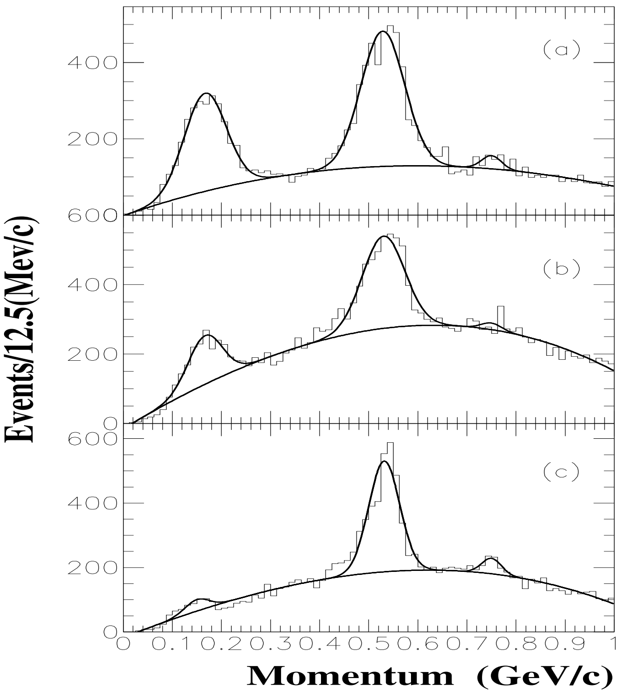

FIG. 1. Momentum distribution of (a) the $K^{\mp}\pi^{\pm}$, (b) the $K^{\mp}\pi^{\pm}\pi^{\pm}\pi^{\mp}$, and (c) the $K^{\mp}\pi^{\pm}\pi^{\pm}$ combinations for events of which the charged tracks passed selection criteria and mass cuts mentioned in the text.

In order to reduce combinatorial background for accumulating the single tagged D meson sample, a 2.5σ cut on the momenta is used. In the analysis only the D mesons from the $e^+e^- \rightarrow \bar{D}D^*(D^*\bar{D}), D^*\bar{D}^*$ reactions are selected. Figure 2a, 2b and 2c show the invariant mass distributions for events which the combinations passed the momentum cuts for the three hadronic decay modes, respectively. Using a binned maximum-likelihood fit to those three mass distributions with one Gaussian function and three order polynomial background give the measured masses, widths and observed numbers of D mesons reconstructed in the three hadronic decay modes.

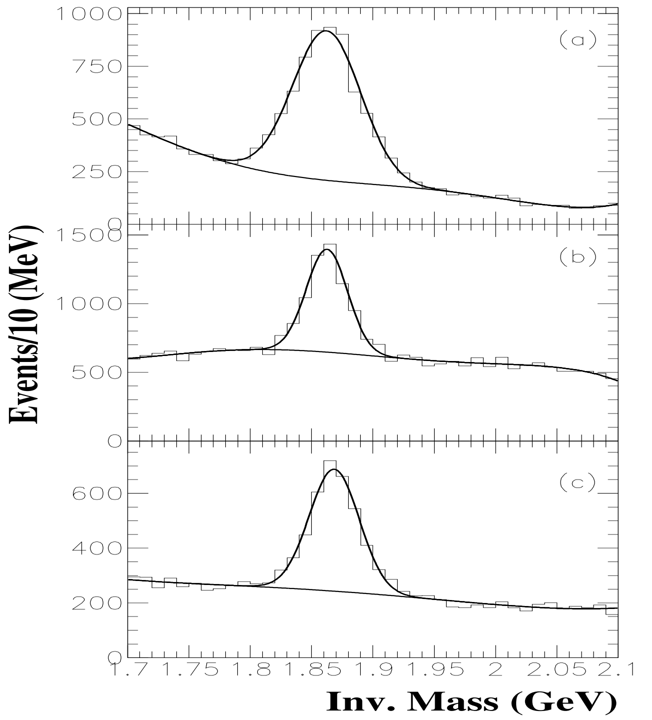

FIG. 2. Distribution of invariant masses of selected (a) $K^{\mp}\pi^{\pm}$, (b) $K^{\mp}\pi^{\pm}\pi^{\pm}\pi^{\mp}$, and (c) $K^{\mp}\pi^{\pm}\pi^{\pm}$ combinations.

Table I lists the fitted results for the three mass spectra. A total of 10371 ± 357 single tagged events is obtained. After subtracting double counting tags per event, a total of 9054 ± 308 charged and neutral D mesons are selected. These yield 2215 ± 70 $D^{\pm}$ and 6839 ± 214 $D^0(\bar{D}^0)$ mesons appeared in the recoil.

TABLE I. Results fitted to mass spectra of the neutral and charged D mesons

Decay Modes	Mass GeV	σ_{M_D} GeV	No. of D observed	Pure No. of D
$K^{\pm}\pi^{\mp}$	1.862	0.028	4946 ± 287	4243 ± 247
$K^{\pm}\pi^{\mp}\pi^{\mp}\pi^{\pm}$	1.863	0.017	3152 ± 178	2652 ± 148
$K^{\pm}\pi^{\mp}\pi^{\mp}$	1.869	0.021	2273 ± 118	2159 ± 112
In Total			10371 ± 357	9054 ± 308

C. Double Tagged Events

1. Candidates of ϕ production in decays of D mesons

The inclusive ϕ meson from D decay is reconstructed in its $\phi \to K^+K^-$ mode in the recoil system against the D tags. Figure 3c shows the invariant mass distributions of the K^+K^- pairs selected in the recoils of events whose invaraint masses of $K^\pm n(\pi^\pm$ or $\pi^\mp)$ ($K^\pm\pi^\mp$, $K^\pm\pi^\mp\pi^\mp\pi^\pm$ and $K^\mp\pi^\pm\pi^\pm$) combinations are required to be within $\pm 2.5\sigma_{M_D}$. Breaking down the events in the figure 3c into two groups and histograming them for the neutral and charged D tagged events separately, we obtained figure 3a and 3b. The mass region 1.00-1.04 GeV is considered as the signal region. The mass regions from 1.7 to 2.1 GeV , but outside $\pm 3\sigma_{M_D}$ of the fitted D^0 and D^+ masses for each of the three tag modes as shown in figure 2, are defined as sideband background control regions. After subtracting both D and ϕ sideband background, we obtained 10 ± 3.5 inclusive ϕ events from the total D tags, 7 ± 2.9 inclusive ϕ events from the neutral D tags and 3.0 ± 1.9 inclusive ϕ events from the charged D tags.

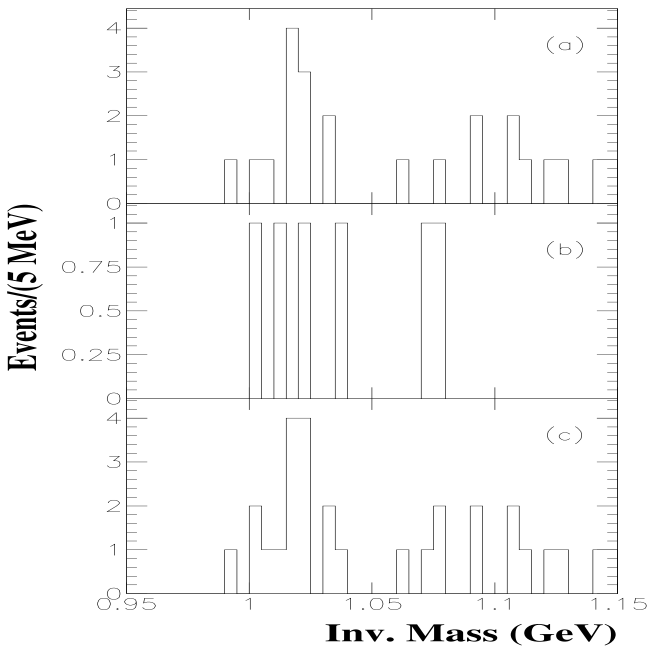

FIG. 3. Distributions of the invariant masses of K^+K^- combinations in the recoiling system against the tagged (a) neutral D, (b) charged D, and (c) combined the neutral and charged D mesons together.

2. Search for candidates of $D^+ \to \phi e^+ \nu$

In the recoil, a total of 16 tagged ϕ events are observed. 7 of the 16 tagged ϕ are accompanied by another charged track in the recoil. Each of the 7 events is examined for electron candidate accompanied by a ϕ. But no electron candidate is observed. So no $D^+ \to \phi e^+ \nu$ event by using the 2241 charged D mesons produced in the recoiling side against the D tags is obtained.

V. RESULTS

A. Inclusive ϕ decay branching fractions of the charged and neutral D mesons

The values of the inclusive ϕ decay branching fractions of the neutral and charged D mesons were obtained by means of a maximum likelihood fit. A joint likelihood function is constructed to fluctuate the numbers of the inclusive ϕ events observed. It is a product of two Possion distributions ($P^{\phi}_{D^+_{tag}}$ and $P^{\phi}_{D^0_{tag}}$) describing the probabilities of observing the inclusive ϕ events in the recoils of the tagged neutral and charged D mesons:

$$L(BF, N^{\phi}_{D^+_{tag}}, n^{\phi}_{D^+_{tag}}, N^{\phi}_{D^0_{tag}}, n^{\phi}_{D^0_{tag}}) = P^{\phi}_{D^+_{tag}} \times P^{\phi}_{D^0_{tag}},$$

where the $N^{\phi}_{D^+_{tag}}$ and $N^{\phi}_{D^0_{tag}}$ are numbers of the inclusive ϕ events observed, and the $n^{\phi}_{D^+_{tag}}$ and $n^{\phi}_{D^0_{tag}}$ are parameters for the $N^{\phi}_{D^+_{tag}}$ and $N^{\phi}_{D^0_{tag}}$. Using the relations of decay branching fraction (3) and (4), the numbers of the inclusive ϕ events observed in the recoil side, the number of the charged and neutral D tags, the efficiency $\epsilon = 0.0706 \pm 0.0035$ estimated by Monte Carlo simulation, and the probabilities η and β, for a given value of the decay branching fraction, the likelihood function L is maximized by varying the two parameters $n^{\phi}_{D^+_{tag}}$ and $n^{\phi}_{D^0_{tag}}$ for both cases of the charged and neutral tagged D mesons, respectively. Figure 4a and 4b show the likelihoods L as functions of inclusive ϕ decay branching fractions of the D mesons.

Figurge 4c shows a dependence of the probabilities on the average inclusive ϕ decay branching fraction of the charged and neutral D mesons.

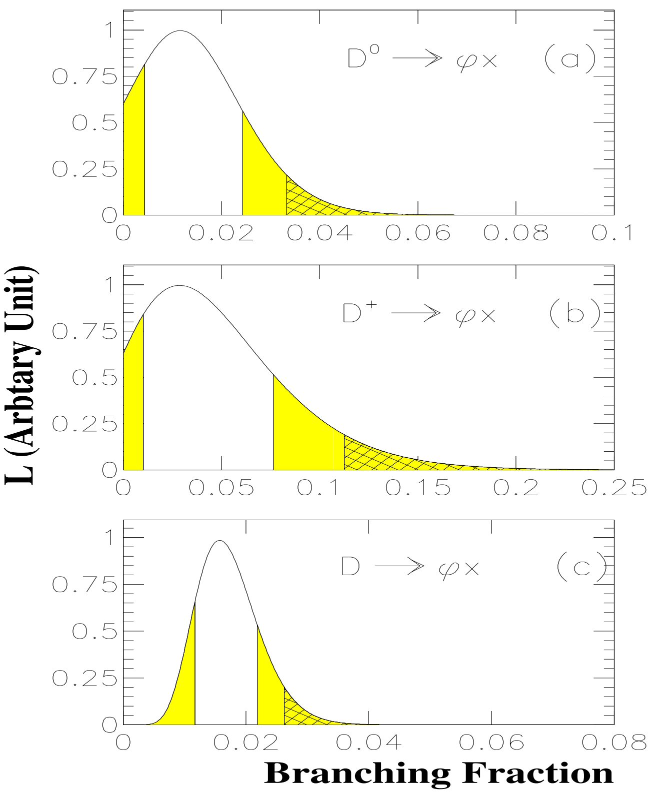

FIG. 4. Likelihoods as functions of the inclusive ϕ decay branching fractions of the neutral (a), charged (b) and the averaged neutral and charged (c) D mesons; the unshaded areas correspond to the one standard deviation errors described in the text, and the area shaded cross corresponds to the 10% of the total area in each of the plots.

By integrating the likelihoods from two sides of the peak positions to $\pm 1\sigma$ values corresponding to 68.3% (unshaded areas as shown in the figures) of the total areas below and above the peak positions, the statistical errors are obtained. Finally we obtained the inclusive ϕ decay branching fractions for the neutral, charged and for the both mesons produced at $\sqrt{s} = 4.03\ GeV$ to be

$$BF(D^0 \to \phi X) = (1.16^{+1.27+0.26}_{-0.72-0.24})\%,$$

$$BF(D^+ \to \phi X) = (2.86^{+4.80+0.86}_{-1.81-0.45})\%$$

and

$$BF(D \to \phi X) = (1.57^{+0.62+0.20}_{-0.40-0.17})\%.$$

Where the first errors are statistical and second systematic. The systematic errors arise from uncertainties ($^{+0.07}_{-0.04}\%$, $^{+0.22}_{-0.19}\%$ and $^{+0.03}_{-0.02}\%$) in the numbers of single tagged D mesons due to uncertainty in background, uncertainties ($^{+0.13}_{-0.13}\%$, $^{+0.31}_{-0.31}\%$ and $^{+0.07}_{-0.07}\%$) in efficiency, uncertainties ($^{+0.21}_{-0.20}\%$, $^{+0.77}_{-0.25}\%$ and $^{+0.18}_{-0.15}\%$) in number of background in tagged ϕ mass region and uncertainties ($^{+0.03}_{-0.02}\%$, $^{+0.09}_{-0.06}\%$ and $^{+0.02}_{-0.01}\%$) of η and β which are due to uncertainties in values of production cross section measured (for neutral, charged and the total D mesons). The combined effect of these sources is obtained by adding in the uncertainties in quadrature, which yields a total systematic errors of $^{+0.26}_{-0.24}\%$, $^{+0.86}_{-0.45}\%$ and $^{+0.20}_{-0.17}\%$ for the D^0, D^+ and the total of the D^0 and D^+, respectively. For estimate of the systematic error, the uncertainty in luminosity is also taken into account (in η and β). Considering 1σ systematic error, the upper limits on the inclusive branching fractions of the D mesons are set to be

$$BF(D^0 \to \phi X) < (3.33 \times 1.06) = 3.53\% \qquad 90\%\ CL,$$

$$BF(D^+ \to \phi X) < (11.27 \times 1.06) = 11.95\% \qquad 90\%\ CL$$

and

$$BF(D \to \phi X) < (2.63 \times 1.03) = 2.71\% \qquad 90\%\ CL.$$

Here the factors, 1.06, 1.03 and 1.16 are corresponding to upper shifts of the decay branching fractions due to 1σ systematic error.

B. Exclusive semileptonic decay branching fraction

For the zero event $D^+ \to \phi e^+ \nu$ observed, an expected number of the events can be calculated based on a possion distribution and the upper limit can be obtained from the expected number, $n^{expect}_{D^+ \to \phi e^+ \nu}$, the total number, $N^{Rec}_{D^+}$, of the D^+ appeared in the recoil for the total tagged D mesons and the detection efficiency $\epsilon^{MC}_{D^+ \to \phi e^+ \nu}$, by

$$BF(D^+ \to \phi e^+ \nu) = \frac{n^{expect}_{D^+ \to \phi e^+ \nu}}{\epsilon^{MC}_{D^+ \to \phi e^+ \nu} N^{Rec}_{D^+}}.$$

The detection efficiency $\epsilon^{MC}_{D^+ \to \phi e^+ \nu}$ is estimated to be $\epsilon^{MC}_{D^+ \to \phi e^+ \nu} = 0.0684$ by Monte Carlo simulation.

Figure 5 shows the dependence of probabilities for an expected number of events for the zero observation on the decay branching fraction. The upper limit on the branching fraction including 1σ systematic error is

$$BF(D^+ \to \phi e^+ \nu) < (1.35 \times 1.16) = 1.57\% \qquad 90\%\ CL.$$

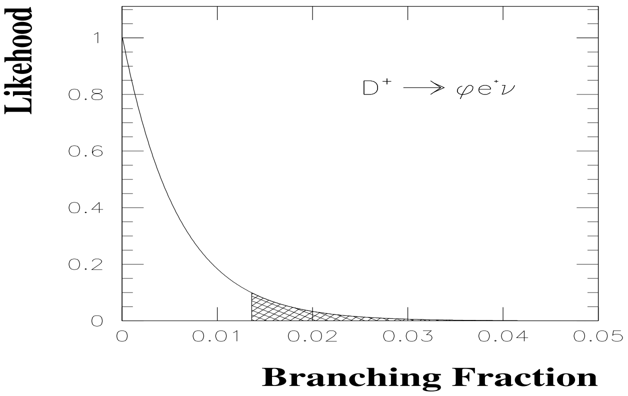

FIG. 5. Probability as a function of the exclusive semileptonic decay branching fraction of charged D; the unshaded area correspond to the 90% CL described in the text.

C. Discussion of the results and comparison with that measured by other experiments

Table II summarizes the sums of all decay branching fractions, quoted from PDG96[1], for the exclusive decay modes containing a ϕ in the final states, yielding two sums of decay branching fraction of $(2.91 \pm 1.00)\%$ for D^+ and $(0.96 \pm 0.14)\%$ for the D^0. Our measured most probable values of inclusive ϕ branching fractions are all consistent with the sums well.

If we take the summed decay branching fractions of D^+ and D^0 to calculate an averag-weighted decay branching fractions weighted in $\frac{2215}{9054}$ for D^+ and in $\frac{6839}{9054}$ for D^0, respectively, we obtain the average-weighted decay branching fraction to be 1.44%. Our measured value of the averaged inclusive ϕ decay branching fraction, $BF(D \to \phi X) = (1.57^{+0.62+0.40}_{-0.40-0.30})\%$ is in good agreement with the average-weighted decay branching fractions of D^+ and D^0.

Our upper limit of the exclusive semileptonic decay branching fraction $BF(D^+ \to \phi e^+ \nu) < 1.57\%$ is a bit tighter than the value listed in PDG96[1] in which the upper limit is $BF(D^+ \to \phi e^+ \nu) < 2.09\%$.

TABLE II. Decay branching fractions of the D to final states containing a ϕ meson. The upper limits are set at 90% CL.

Decay Mode	Branching Fraction (%)	Sum (%)
$\phi\pi^+$	0.61 ± 0.06	2.91 ± 1.00
$\phi\pi^+\pi^0$	2.3 ± 1.0	
ϕK^+	$0.013^{+0.022}_{-0.019}$	
$\phi e^+\nu$	< 2.09	< 6.01
$\phi\mu^+\nu$	< 3.72	
$\phi\pi^+\pi^+\pi^-$	< 0.2	
$\phi\bar{K}^0$	0.85 ± 0.10	
$\phi\pi^+\pi^-$	0.107 ± 0.029	0.96 ± 0.14
$\phi\pi^0$	< 0.14	< 0.63
$\phi\eta$	< 0.28	
$\phi\omega$	< 0.21	

VI. CONCLUSION

In summary, the inclusive ϕ decay branching fractions of the charged and neutral D mesons have been presented. Based on a single tagged D sample of 9160 ± 278 D^0 and D^+ events in total, 10 $D \to \phi X$ (7 events of "D^0_{tag} VS $\bar{D}^0(D^-) \to \phi X$", and 3 events of "$D^+_{tag}$ VS $D^-(\bar{D}^0) \to \phi X$") events are observed. These lead to the measured inclusive ϕ decay branching fractions and their upper limits to be

$$BF(D^0 \to \phi X) = (1.16^{+1.27+0.26}_{-0.72-0.24})\%,$$

$$BF(D^+ \to \phi X) = (2.86^{+4.80+0.86}_{-1.81-0.45})\%,$$

$$BF(D \to \phi X) = (1.57^{+0.62+0.20}_{-0.40-0.17})\%,$$

$$BF(D^0 \to \phi X) < 3.53\%,$$

$$BF(D^+ \to \phi X) < 11.95\%$$

and

$$BF(D \to \phi X) < 2.71\%.$$

No exclusive semileptonic decay process of $D^+ \to e^+\phi\nu$ is observed from the 2241 D^+ events. This leads to set a new $CL = 90\%$ upper limit of

$$BF(D^+ \to \phi e^+ \nu) < 1.57\%.$$

Comparing with the sums of the existing measurements on the exclusive D decays containing a ϕ in the final states, our measured values of the inclusive ϕ decay branching fractions of the charged and neutral D mesons indecate that there is little room for searching for new decay modes containing a ϕ meson in the final states.

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[1] R.M. Barnett et al. (Particle Data Group), Review of Particle Properies, Phys. Rev. D54(1996)445, 455

[2] R.M. Barnett er al. (Particle Data Group), Review of Particle Properties, Phys. Rev. D54(1996)481. ARGUS .....

[3] J.Z. Bai et al, Nucl. Instr. and Methods A 344(1994)319.

[4] M. H. Ye and Z.P. Zheng, Proceeding of the XIV International Symposium on Lepton and Photon Interaction, Stanford, California, 1989

[5] H.W. Zhao "$D^\pm$, D^0, $\bar{D}^0$ Single Tag and the Measurement of Production Cross Section at Ecm=4.03 GeV in e^+e^- Annihilation", Oct, 1995.