# Direct measurement of B($D_s^+ \to \phi X$)

J. Z. Bai,[1] O. Bardon,[5*] I. Blum,[10] A. Breakstone,[8] T. Burnett,[11] J. S. Campbell,[10] G. P. Chen,[1] H. F. Chen,[3] J. Chen,[4] S. J. Chen,[1] S. M. Chen,[1] Y. Chen,[1] Y. B. Chen,[1] Y. Q. Chen,[1] B. S. Cheng,[1] R. F. Cowan,[5] X. Z. Cui,[1] H. L. Ding,[1] Z. Z. Du,[1] W. Dunwoodie,[7] X. L. Fan,[1] J. Fang,[1] C. S. Gao,[1] M. L. Gao,[1] S. Q. Gao,[1] P. Gratton,[10] J. H. Gu,[1] S. D. Gu,[1] W. X. Gu,[1] Y. F. Gu,[1] Y. N. Guo,[1] S. W. Han,[1] Y. Han,[1] F. A. Harris,[8] J. He,[1] M. He,[6] D. G. Hitlin,[2] G. Y. Hu,[1] T. Hu,[1] X. Q. Hu,[1] D. Q. Huang,[1] Y. Z. Huang,[1] J. M. Izen,[10] C. H. Jiang,[1] S. Jin,[1] Y. Jin,[1] L. Jones,[2] S. H. Kang,[1] Z. J. Ke,[1] M. H. Kelsey,[2] B. K. Kim,[10] D. Kong,[8] Y. F. Lai,[1] H. B. Lan,[1] P. F. Lang,[1] A. Lankford,[9] F. Li,[1] J. Li,[1] P. Q. Li,[1] Q. Li,[6] R. B. Li,[1] W. Li,[1] W. D. Li,[1] W. G. Li,[1] X. H. Li,[1] X. N. Li,[1] S. Z. Lin,[1] H. M. Liu,[1] J. Liu,[1] J. H. Liu,[1] Q. Liu,[1] R. G. Liu,[1] Y. Liu,[1] Z. A. Liu,[1] X. C. Lou,[10] B. Lowery,[10] J. G. Lu,[1] J. Y. Lu,[1] S. Luo,[1] Y. Luo,[1] A. M. Ma,[1] E. C. Ma,[1] J. M. Ma,[1] R. Malchow,[4] M. Mandelkern,[9] H. S. Mao,[1] Z. P. Mao,[1] X. C. Meng,[1] H. L. Ni,[1] J. Nie,[1] S. L. Olsen,[8] J. Oyang,[2] D. Paluselli,[8] L. J. Pan,[8] J. Panetta,[2] F. Porter,[2] E. Prabhakar,[2] N. D. Qi,[1] Y. K. Que,[1] G. Rong,[1] M. Schernau,[9] B. Schmid,[9] J. Schultz,[9] Y. Y. Shao,[1] D. L. Shen,[1] H. Shen,[1] X. Y. Shen,[1] H. Y. Sheng,[1] H. Z. Shi,[1] E. Soderstrom,[7] X. F. Song,[1] J. Standifird,[10] D. Stoker,[9] F. Sun,[1] H. S. Sun,[1] S. J. Sun,[1] J. Synodinos,[7] Y. P. Tan,[1] S. Q. Tang,[1] W. Toki,[4] G. L. Tong,[1] F. Wang,[1] L. S. Wang,[1] L. Z. Wang,[1] M. Wang,[1] P. Wang,[1] P. L. Wang,[1] S. M. Wang,[1] T. J. Wang,[1] Y. Y. Wang,[1] M. Weaver,[2] C. L. Wei,[1] W. J. Wisniewski,[7] D. M. Xi,[1] X. M. Xia,[1] P. P. Xie,[1] D. Z. Xu,[1] R. S. Xu,[1] Z. Q. Xu,[1] S. T. Xue,[1] J. Yan,[1] W. G. Yan,[1] C. M. Yang,[1] C. Y. Yang,[1] H. Yang,[10] W. Yang,[4] M. H. Ye,[1] S. Z. Ye,[1] K. Young,[11] C. S. Yu,[1] C. X. Yu,[1] Z. Q. Yu,[1] C. Z. Yuan,[1] B. Y. Zhang,[1] C. C. Zhang,[1] D. H. Zhang,[1] H. L. Zhang,[1] J. Zhang,[1] J. W. Zhang,[1] L. S. Zhang,[1] S. Q. Zhang,[1] Y. Zhang,[1] Y. Y. Zhang,[1] D. X. Zhao,[1] J. W. Zhao,[1] M. Zhao,[1] W. R. Zhao,[1] J. P. Zheng,[1] L. S. Zheng,[1] Z. P. Zheng,[1] G. P. Zhou,[1] H. S. Zhou,[1] L. Zhou,[1] X. F. Zhou,[1] Y. H. Zhou,[1] Q. M. Zhu,[1] Y. C. Zhu,[1] Y. S. Zhu,[1] B. A. Zhuang,[1]

(BES Collaboration)

[1] *Institute of High Energy Physics, Beijing 100039, People's Republic of China*
[2] *California Institute of Technology, Pasadena, California 91125*
[3] *China's University of Science and Technology, Hefei 230026, People's Republic of China*
[4] *Colorado State University, Fort Collins, Colorado 80523*
[5] *Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*
[6] *Shandong University, Jinan 250100, People's Republic of China*
[7] *Stanford Linear Accelerator Center, Stanford, California 94309*
[8] *University of Hawaii, Honolulu, Hawaii 96822*
[9] *University of California at Irvine, Irvine, California 92717*
[10] *University of Texas at Dallas, Richardson, Texas 75083-0688*
[11] *University of Washington, Seattle, Washington 98195*

(July 17, 1996)

The absolute inclusive branching fraction of $D_s^+ \to \phi X$ has been measured from data collected by the BES detector at a center of mass energy 4.03 $GeV$, corresponding to an integrated luminosity of 22.3 $pb^{-1}$. At this energy, direct pair production, $e^+e^- \to D_s^+ D_s^-$, has been observed. We have selected $D_s$ candidate events by reconstructing five hadronic decay modes $D_s^+ \to \phi\pi^+$, $\overline{K}^{0*}K^+$, $\overline{K}^0 K^+$, $f_0\pi^+$ and $K^0K^-\pi^+\pi^+$ and have searched for inclusive $\phi$'s in the recoiling $D_s^-$. We observed $166.4 \pm 31.8$ single tag events and 3 double tag events in the five hadronic decay modes. This leads to the absolute branching fraction $B(D_s^+ \to \phi X) = (16.5\ {}^{+13.9}_{-\ 6.7}\ {}^{+1.9}_{-4.1})$ %, and $B(D_s^+ \to \phi\pi^+) = (3.3\ {}^{+2.9}_{-1.5}\ {}^{+0.5}_{-0.9})$ %.

The main experimental difficulties in charmed particle decays are the problems of overall normalization and the precise determination of charm branching fractions. Previously, we have reported the absolute model-independent branching ratio of $D_s^+ \to \phi\pi^+$ [1]. Here we consider the absolute branching fraction of $D_s^+ \to$ inclusive $\phi$ which contributes toward our understanding of the overall $D_s$ branching fraction scale. Moreover the absolute inclusive branching fraction of $D_s^+ \to \phi X$ [2] is used in $B_s^0\overline{B}_s^0$ oscillation [3] and $B_s$ mixing [4] measurements at LEP and CDF.

In this paper we report a direct and model independent measurement of the $D_s$ inclusive $\phi$ branching fraction using the BES detector at the Beijing Electron Positron Collider (BEPC). The data were obtained using the BES detector, and correspond to a total integrated luminosity of 22.3 $pb^{-1}$ as determined by large angle Bhabha scattering events at a center-of-mass energy 4.03 $GeV$. This is just above $e^+e^- \to D_s^+ D_s^-$ threshold.

The BES detector is a conventional cylindrical detector, which is described in detail in ref. [5]. 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 $\sim 450$ $ps$ for hadrons and $\sim 330$ $ps$ 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. Surrounding the BSC, 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 $cm$).

In this experiment, the $D_s$ signal has been detected via five hadronic decay modes $D_s \to \phi\pi$, $\overline{K}^{0*}K$, $\overline{K}^0 K^+$, $f_0\pi^+$ or $K^0K^-\pi$+$\pi$+. The subresonances are detected by the decays $\phi \to K^+K^-$, $\overline{K}^{0*} \to K^-\pi^+$, $\overline{K}^0 \to K_S^0 \to \pi^+\pi^-$, and $f_0 \to \pi^+\pi^-$. Each candidate was formed using well-reconstructed track. Each track's closest approach to the origin was required to be smaller than 1.2 $cm$ in the $xy$ plane and 15 $cm$ in the $z$ direction. For the $f_0\pi$ mode, the vertexing requirements were tightened to 0.65 $cm$ in the $xy$ plane and 9 $cm$ in the $z$ direction due to larger backgrounds. Vertexing requirements were not applied to candidate pions from $K_S^0$ decay. The proper decay time of $K_S^0$ candidates was required to be between 0.01 $ns$ and 0.33 $ns$. Additionally in the $K^0K^-\pi^+\pi^+$ mode the $K_S^0$ vertex was required to have a difference in $z$ coordinate of two tracks to be within 4 $cm$ and $xy$ alignment of the parent momentum with the line from the interaction point to the $K_S^0$ vertex was required to have a confidence level $> 5$ %. A fiducial requirement, $\mid cos\theta \mid < 0.85$ was used for charged tracks. Both TOF and $dE/dx$ systems were used to reduce background from random combinations of different particles. Time of flight(TOF) and $dE/dx$ information associated with each track was required to be consistent with the assigned mass interpretation with a confidence level $> 1\%$. Kaon candidates were required to have $\chi(K)^2 < \chi(\pi)^2$. Pion candidates were required to have $\chi(\pi)^2 < \chi(K)^2$ and additionally $\chi(\pi)^2 < \chi(e)^2$ for $f_0\pi^+$ candidates. Subresonance mass criteria were $\pm 18$ $MeV/c^2$ for $\phi$, $\pm 60$ $MeV/c^2$ for $\overline{K}^{0*}$, $\pm 20$ $MeV/c^2$ for $\overline{K}^0$ and $\pm 30$ $MeV/c^2$ for $f_0$.

Additional background rejection was obtained with helicity angle cuts for the $\phi$ and $\overline{K}^{0*}$. We required $\mid cos\theta_K \mid > 0.25$ in the $\phi$ rest frame for the $\phi\pi$ mode and $\mid cos\theta_K \mid > 0.4$ in the $\overline{K}^{0*}$ rest frame for the $\overline{K}^{0*}K$ mode.

The production of $D_s$ has a $sin^2\theta$ distribution with respect to the beampipe. In single tag modes with large backgrounds the signal to noise ratio can be improved by only using tags with small values of $cos\theta$. For the $\overline{K}^{0*}K^+$ mode we required $\mid cos\theta_{D_s} \mid < 0.7$, and for both the $f_0\pi^+$ and the $\overline{K}^0K^+$ modes we required $\mid cos\theta_{D_s} \mid < 0.85$.

Candidates satisfying these criteria were subjected to a one-constraint (1-C) kinematic fit to the beam energy. Those having a fit confidence level $> 1\%$ for $\phi\pi^+$, $\overline{K}^{0*}K^+$ and $\overline{K}^0K^+$, $> 5\%$ for $K^0K^-\pi^+\pi^+$, and $> 10\%$ for $f_0\pi^+$ were retained. The unbinned maximum likelihood fit to each single tag plot (Fig. 1(a)-1(e)) gave the number of single tag events($N^i_{sngl}$), and fitting to Fig. 1(f) gave $166.4 \pm 31.8$ $D_s$ single tags above background.

Double tagged $D_s$ events were obtained by reconstructing a $\phi \to K^+K^-$ recoiling against one of the five $D_s$ single tag modes. Recoiling $\phi$'s were selected with the same track and particle identification requirements described earlier for the $\phi\pi$ single tag mode. The signal region was defined to be within $\pm 18 MeV/c^2$ which is $\pm$ 3 times the resolution for the reconstructed $\phi$ mass. A total of 3 double tag events(Fig. 2) were found, and the characteristics of these events are summarized in Table I.

A direct measurement of $B_{\phi X}$ is obtained from the number of single tag events($N_{sngl}$), the number of double tag events($N_{dbl}$), and the inclusive $\phi$ efficiency($\epsilon_{dbl}$) as follows:

$$B_{\phi X} = \frac{N_{dbl}}{N_{sngl} \times \epsilon_{dbl} \times B(\phi \to K^+K^-)}. \quad (1)$$

The inclusive $\phi$ double tag efficiency, $\epsilon_{dbl}$, was determined using Monte Carlo simulation for each of the five modes (Table II).

Four methods were used to estimate the background in the double tag sample: $D_s$ tag side band, recoil $\phi$ side band, tag subresonance side band, and Monte Carlo background studies.

The $D_s$ tag side band regions (Fig. 2) were defined from (1.79-1.957) GeV/$c^2$ and from (1.981-2.105) GeV/$c^2$. One $\phi$ was found recoiling from a sideband of the $\overline{K}^{0*}K^+$ tag and another was found recoiling from a sideband of the $K^0K^-\pi^+\pi^+$ tag. Since no $K^0K^-\pi^+\pi^+$ vs. $\phi$ double tag was observed, the estimate background level for this tag channel doesn't affect the value obtained for $B_{\phi X}$. No background event was detected in the $\phi\pi$ side band region. For both $\phi\pi$ and $\overline{K}^{0*}K^+$ channels we have normalized the tag side bands by the ratio of single tag events in the signal and side band regions. Poission errors for a single event in the $\overline{K}^{0*}K^+$ side band region implies an estimated background of 0.13 $^{+0.30}_{-0.04}$. In order to express the uncertainty of the $\phi\pi$ mode background we have used the 84.1 % confidence level upper limit for zero events giving 0.0 $^{+0.26}_{-0.0}$.

The recoil $\phi$ mass side band (Fig. 2) contains one event from the $K^0K^-\pi^+\pi^+$ mode; this has no effect on the shape of the likelihood function since there are no signal events with this tag.

All analyses were repeated using the side bands of the tag subresonances, (0.965-1.001 and 1.037-1.073) $GeV/c^2$ for $\phi$, (0.712-0.832 and 0.952-1.072) $GeV/c^2$ for $\overline{K}^{*0}$, (0.4376-0.4776 and 0.5176-0.5576) $GeV/c^2$ for $\overline{K}^0$, (0.89-0.95 and 1.01-1.07) $GeV/c^2$ for $f_0$. No event passed the selection criteria, leading to an estimate of zero background events in our double tag sample.

Finally, large Monte Carlo samples of $D^{*+}D^-$, $D^{*0}D^0$, $D^{*+}D^{*-}$, and $D^{*0}D^{*0}$ were used to estimate backgrounds from these sources. These samples correspond to 6.4, 5.9, 5.3 and 5.0 times the real data sample respectively. All Monte Carlo background events in the double tag signal region were rejected.

Combining all four different methods, gives an estimated backgrounds 0.0 $^{+0.26}_{-0.0}$ events for the $\phi\pi$ mode and 0.13 $^{+0.30}_{-0.04}$ events for the $\overline{K}^{0*}K$ mode. The background uncertainties contribute $^{+1.0}_{-22.1}\%$ $\times B_{\phi X}$ to the systematic error for the branching fraction $B_{\phi X}$.

The value of $B_{\phi X}$ is obtained using a maximum likelihood method. The likelihood function, $L^i(B_{\phi X}, N^i_{sngl}; \epsilon^i_{dbl}, N^i_{dbl}, N^i_{bg})$, is constructed from Eq.(1) using a Poission distribution to describe the number of double tag events and a Gaussian distribution to describe the single tag sample.

$$L(B_{\phi X}) = \prod_i L^i_{mar}(B_{\phi X}), \qquad (2)$$

where $i$ refers to the single tag mode. The marginalized likelihood function for each of the five different $D_s$ modes is obtained by integrating out the single tag uncertainty.

$$L^i_{mar}(B_{\phi X}) = \int d\tilde{N}^i_{sngl}\, L^i(B_{\phi X}, \tilde{N}^i_{sngl})\, \frac{e^{-\frac{1}{2}\left(\frac{N^i_{sngl}-\tilde{N}^i_{sngl}}{\delta N^i_{sngl}}\right)^2}}{\sqrt{2\pi}\,\delta N^i_{sngl}}.$$

The likelihood function $L^i$ is given by

$$L^i = \frac{A^{N^i_{dbl}}}{N^i_{dbl}!} \times e^A,$$

where

$$A = B_{\phi X} N^i_{sngl} \epsilon^i_{dbl} B(\phi \to K^+K^-) + N^i_{bg}.$$

The value of the likelihood function, $L(B_{\phi X})$, is shown in Fig. 3. The maximum likelihood solution is $B_{\phi X}$ = (16.5 $^{+13.9}_{-6.7}$) %, where the statistical errors are obtained by integrating the function; the area under the curve between the peak value and $-1\sigma(+1\sigma)$ corresponds to 68% of the total area below(above) the peak position.

Several systematic uncertainties affect this measurement. The inclusive $\phi$ efficiency, $\epsilon_{dbl}$, introduces systematic error for $B_{\phi X}$ of 6.8 % $\times B_{\phi X}$. The choice of a background functional form and fit interval for the single-tag sample introduces a 9.0 % $\times B_{\phi X}$ uncertainty. Finally, the double-tag background estimate is responsible for a $^{+1.0}_{-22.1}\%$ $\times B_{\phi X}$ uncertainty. After combining the systematic errors in quadrature, the final result for $B_{\phi X}$ is

$$B_{\phi X} = (16.5\ ^{+13.9}_{-\ 6.7}\ ^{+1.9}_{-4.1})\ \%.$$

This is the first direct measurement of the $D_s$ inclusive $\phi$ branching fraction which is model-independent. The present world average value from indirect or model-dependent procedures is $B_{\phi X} = (17.1\pm4.1)$ %(Table III).

LEP experiments [3] and CDF [4] have used a theoretically inspired method to estimate $B_{\phi X}$ from $B_{\phi\pi}$. The theoretical $D^+_s$ branching fractions are evaluated from the BSW model [6], giving $B(D^+_s \to \phi X) = (4.84 \pm 0.51)\ b_s$ [7] where $b_s$ is the measured branching fraction of $D^+_s \to \phi\pi^+$. Using the PDG(1994) [8] value yields $B_{\phi X} = (16.9 \pm 1.9)$ %. The PDG(1994) value itself relies on theoretical estimates of semileptonic form factors. The theoretical estimate of $B_{\phi X}$ is consistent with our direct measurement of $B_{\phi X}$.

A measurement of $B_{\phi\pi}$ can be obtained from $B_{\phi X}$ using the sum of exclusive measurements shown in the Table III under the assumption that no significant decays of the $D_s$ to $\phi$ remain unmeasured. Scaling $B_{\phi X}$ by the sum of the world average values of $\Gamma_i$ / $\Gamma_{\phi\pi}$ gives $B_{\phi\pi} = (3.3\ ^{+2.9}_{-1.5}\ ^{+0.5}_{-0.9})$ %. This value is consistent with the previous BES result $B_{\phi\pi} = (3.9\ ^{+5.1}_{-1.9}\ ^{+1.8}_{-1.1})$ % [1].

We would like to thank the staffs of the BEPC accelerator, the Computing Center at the Institute of High Energy Physics (Beijing). This work was supported in part by the National Natural Science Foundation of China under Contract No. 19290400 and the Chinese Academy of Sciences under contract No. KJ85 (IHEP); by the Department of Energy under Contract Nos. DE-FG03-92ER40701 (Caltech), DE-FG03-93ER40788 (Colorado State University), DE-AC02-76ER03069 (MIT), DE-AC03-76SF00515 (SLAC), DE-FG03-91ER40679 (UC Irvine), DE-FG03-94ER40833 (U Hawaii), DE-FG03-95ER40925 (UT Dallas); by the U.S. National Science Foundation, Grant No. PHY9203212 (University of Washington).

* Present address: Northeastern University, Boston, MA.
[1] J. Z. Bai *et al.*, Phys. Rev. D **52**, 3781 (1995)
[2] Throughout the paper, reference to a particular charge configuration implies reference to the charge conjugate configuration as well.
[3] Prospects for $B_s^0\overline{B_s^0}$ Oscillation Measurement at LEP *X. C. Lou* **Proceeding of B Physics at Hadron Accelerators Workshop, 1993**,
[4] Prospects for Measuring $B_s$ Mixing at CDF *John E. Skarha and A. Barry Wicklund* **Proceeding of B Physics at Hadron Accelerators Workshop, 1993**
[5] J. Z. Bai *et al.*, Nucl. Instr. and Methods **A344**, 319 (1994); J. Z. Bai *et al.*, Phys. Rev. Lett. **69**, 3021 (1992)
[6] M. Bauer, B. Stech, M. Wirbel *Z. Phys. Particles and Fields*, C34 (1987) 103-115
[7] Inclusive Branching Fractions of $D^0$, $D^+$ and $D_s$ into $\phi$ meson *P. Roudeau - A. Stocchi* LAL93-03, September, 1993
[8] L. Montanet *et al.* (Particle Data Group), *Review of Particle Properties*, Phys. Rev. **D50**, 1173 (1994).


TABLE I. Properties of the double tag candidates

| Event | 1 | 2 | 3 |
|---|---|---|---|
| Tagging $D_s$ Decay | $\phi\pi^+$ | $\phi\pi^+$ | $\overline{K}^{0*}K^+$ |
| Subsystem mass ($GeV/c^2$) | 1.0090 | 1.0229 | 0.8345 |
| $D_s$ invariant mass ($GeV/c^2$) | 1.9723 | 1.9694 | 1.9678 |
| 1C $D_s$ fitmass ($GeV/c^2$) | 1.9662 | 1.9686 | 1.9684 |
| Recoiled $\phi$ mass ($GeV/c^2$) | 1.0068 | 1.0306 | 1.0125 |
| Number of visible charged tracks | 6 | 5 | 6 |
| Number of isolated showers | 5 | 3 | 1 |

TABLE II. Result of the measurement

| Decay Mode | $N^i_{sngl}$ | $N^i_{dbl}$ | $\epsilon^i_{dbl}$ | $N^i_{bg}$ |
|---|---|---|---|---|
| $\phi\pi^+$ | $37.5 \pm 6.7$ | 2 | $0.260 \pm 0.013$ | $0.0\ ^{+0.26}_{-0.0}$ |
| $\overline{K}^{0*}K^+$ | $66.3 \pm 14.3$ | 1 | $0.220 \pm 0.014$ | $0.13\ ^{+0.30}_{-0.04}$ |
| $\overline{K}^0K^+$ | $27.0 \pm 8.8$ | 0 | $0.160 \pm 0.009$ | NA |
| $f_0\pi^+$ | $18.3 \pm 7.0$ | 0 | $0.161 \pm 0.013$ | NA |
| $K^0K^-\pi^+\pi^+$ | $21.4 \pm 6.9$ | 0 | $0.197 \pm 0.017$ | NA |

TABLE III. Inclusive $\phi$ decay modes of $D_s$ (PDG 1994)

| Decay Mode | Branching Fraction(%) | $\Gamma_i/\Gamma_{\phi\pi}$ |
|---|---|---|
| $D_s^+ \to \phi e^+\nu$ | 1.88 ± 0.29 | 0.54 ± 0.05 |
| $D_s^+ \to \phi\mu^+\nu$ | 1.88 ± 0.29 | 0.54 ± 0.05 |
| $D_s^+ \to \phi\pi^+$ | 3.5 ± 0.4 | 1.00 |
| $D_s^+ \to \phi\pi^+\pi^0$ | 8 ± 4 | 2.4 ± 1.0 ± 0.5 |
| $D_s^+ \to \phi\pi^+\pi^+\pi^-$ | 1.8 ± 0.5 | 0.51 ± 0.12 |
| $D_s^+ \to \phi K^+$ | $< 0.25$ | $< 0.071$ |
| Total | 17.1 ± 4.1 | 5.0 ± 1.0 ± 0.5 |

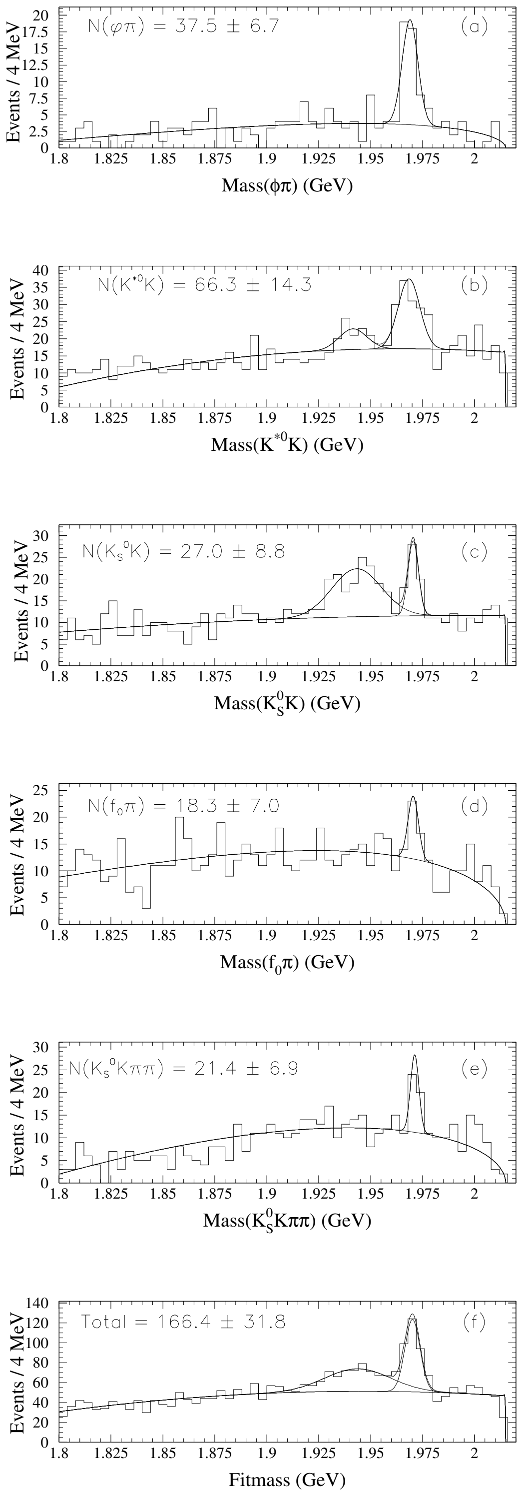


FIG. 1. Kinematically fit mass of $D_s$ candidates. The curves are the result of unbinned fits to the data.

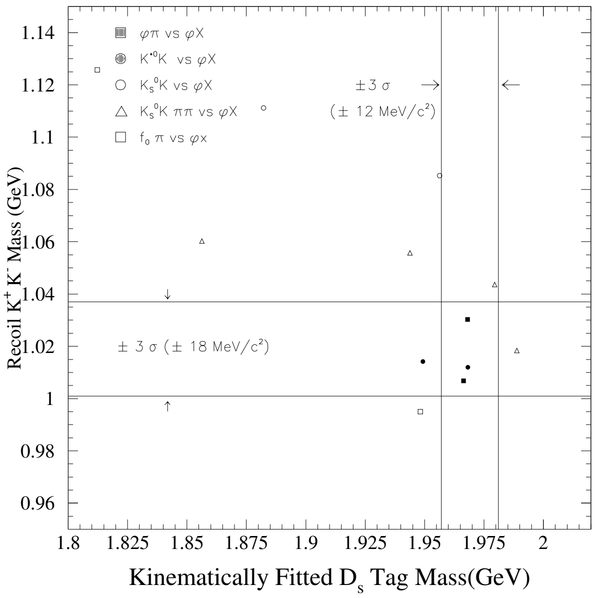


FIG. 2. Double tag candidates

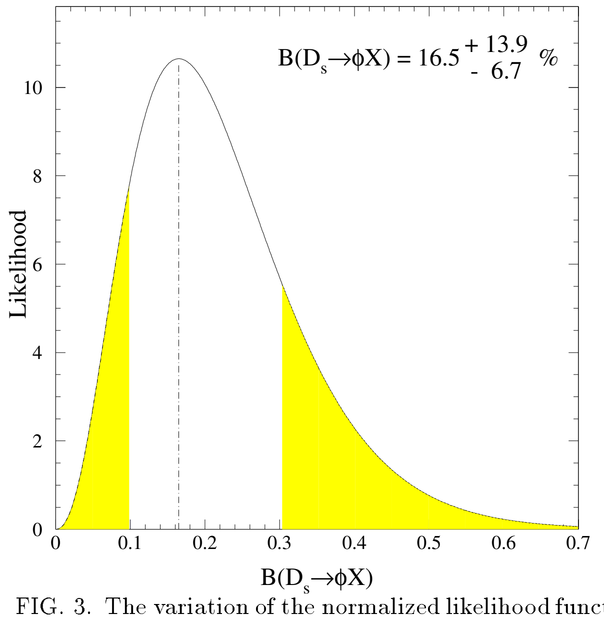


FIG. 3. The variation of the normalized likelihood function with respect to $B_{\phi X}$ ; the unshaded area under the curve denotes the 68 % confidence interval.