First measurement of polarization in $D^0 \to \omega\phi$ decay: Supplemental material

I. THE DECAY TOPOLOGY OF $D^0 \to \omega\phi$ AND THE DEFINATION OF THE DECAY ANGLES

Figure 1 illustrates the decay topology of $D^0 \to \omega\phi$ as well as the definitions of θ_ω and θ_ϕ using in the polarization analysis.

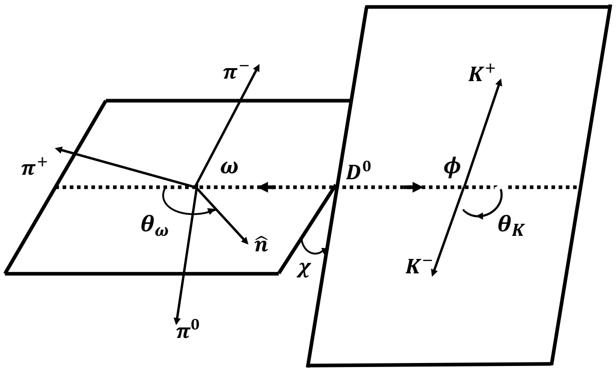

FIG. 1. The decay topology of $D^0 \to \omega\phi$ and the definitions of the decay angles.

II. THE DETAIL UNCERTAINTIES ASSOCIATED WITH THE RECONSTRUCTION EFFIENCY

The uncertainties associated with the reconstruction efficiency include tracking and PID of the charged tracks, π^0 reconstruction, ΔE requirement, and K_S^0 veto.

The uncertainty associated with the tracking efficiency is studied using a control sample of $\psi(3770) \to D\bar{D}$ with hadronic D decays via a partial reconstruction method [1, 2], where a small deviation between data and simulation is present for kaon tracks with momenta less than 0.35 GeV/c. The kaons from ϕ decay in the signal are of low momenta. Consequently, a correction factor of 1.06 for K^+K^- is applied in the detection efficiency, and an uncertainty of 0.5% is assigned for each kaon or pion. The correction factor is the ratio of the efficiencies of data and simulation weighted according to the kaon momentum distribution. We also utilize this control sample to compute the uncertainties associated with PID (0.5%) and π^0 reconstruction efficiency (2.0%) [3].

The uncertainty originating from the ΔE requirement is studied using a control sample of $D^0 \to 2(\pi^+\pi^-)\pi^0$ decays, which has a similar final state as the signal except with a pion pair instead of a kaon pair. The control sample is selected by a relatively loose ΔE requirement, *i.e.*, $\Delta E < 0.1$ GeV, and the corresponding signal yield is extracted by fitting the $M_{\rm BC}$ distribution. The nominal ΔE requirement is then implemented on the control sample, and the resultant ratio of signal yields is taken as the efficiency. The approach is implemented for both data and inclusive MC samples, and the resultant difference in the data and MC efficiencies, 1.4%, is taken as the uncertainty.

The uncertainty from the K_S^0 veto is studied by varying the K_S^0 mass window requirement within $\pm 1\sigma$, and the larger difference in the BF, 0.8%, is taken as the uncertainty.

The total uncertainties associated with the reconstruction efficiency is 3.8%, which is the quadratic sum of above individual ones.

III. THE DETAIL UNCERTAINTIES ASSOCIATED WITH THE MC MODELING

The uncertainties from the MC modeling includes those from the MC statistics (0.8%), $\omega \to \pi^+\pi^-\pi^0$ modeling, quantum correlation (QC) [4] effect, and the longitudinal polarization fraction f_L. The uncertainty due to the $\omega \to \pi^+\pi^-\pi^0$ modeling is assigned to be 0.5% on the basis of two MC samples generated with two different models [5, 6]. From the analysis, the decay $D^0 \to \omega\phi$ appears to be transversely polarized, thus it is a mixture of CP-even and CP-odd components. The uncertainties associated with the polarization is studied by an alternative signal MC sample generated with 1σ upper bound uncertainty, $f_L = 0.13$, and the resultant change in the efficiency, 3.2%, is taken as the uncertainty.

The total uncertainties associated with the MC modeling is 3.3%, which is the quadratic sum of above individual ones.

IV. THE DETAIL UNCERTAINTIES ASSOCIATED WITH 2D SIMULTANEOUS FITS

The systematic uncertainty due to the 2D simultaneous fit includes those from signal and background probability density functions (PDFs), the ratio of background between the $M_{\rm BC}$ signal and sideband regions (f), and the fit bias. The uncertainty arising from the signal PDF, 1.2%, is evaluated with an alternative fit, in which the signal PDFs are described using a different non-parameterized modeling of the simulated shape, convolved with a Gaussian function. The uncertainty of the background PDF, 0.4%, is determined by replacing the ARGUS function [7] with a modified one as used in Ref. [8]. The uncertainty from f is 0.1%, evaluated by varying its value within 1 σ when calculating the signal yield. The uncertainty due to the choice of the $M_{\rm BC}$ signal region is evaluated to be 2.7% by enlarging its region by 2 MeV$/c^2$, which is the resolution of the $M_{\rm BC}$ distribution. The fit bias, 1.0%, is estimated with a large number of pseudo-experiments. Each pseudo-experiment sample is a composition of the signal generated according to the signal PDF and background expectations from the inclusive MC sample. The resultant pull distribution for the BF is consistent with a normal distribution, and we consider the average fit bias as the uncertainty.

The total uncertainty associated with the 2D simultaneous fits is 3.2%, which is the quadratic sum of above individual ones.

[1] M. Ablikim *et al.* (BESIII Collaboration), Phys. Rev. Lett. **121**, 171803 (2018).
[2] M. Ablikim *et al.* (BESIII Collaboration), Phys. Rev. Lett. **116**, 082001 (2016).
[3] M. Ablikim *et al.* (BESIII Collaboration), Phys. Rev. D **97**, 072004 (2018).
[4] D. Asner and W. Sun, Phys. Rev. D **73**, 034024 (2006); E: **77**, 019901 (2008).
[5] P. Adlarson *et al.* (WASA-at-COSY Collaboration), Phys. Lett. B **770**, 418 (2017).
[6] M. Ablikim *et al.* (BESIII Collaboration), Phys. Rev. D **98**, 112007 (2018).
[7] H. Albrecht *et al.* (ARGUS Collaboration), Phys. Lett. B **241**, 278 (1990).
[8] M. Ablikim *et al.* (BESIII Collaboration), Phys. Rev. D **98**, 032001 (2018).