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Measurement of D^0 decays into $\overline{K^0}\,\omega$, $\overline{K^0}\,\eta$ and $\overline{K^{*0}}\,\eta$

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Abstract. Using the ARGUS detector at the electron-positron storage ring DORIS II at DESY, we have measured the branching ratios of the D^0 meson decays into $\overline{K^0}\omega$, $\overline{K^0}\eta$ and $\overline{K^{*0}}\eta$ relative to the $K^-\pi^+$ mode. Using the known branching ratio $\mathrm{Br}(D^0 \to K^-\pi^+)=(4.2\pm0.4\pm0.4)\%$ we find $\mathrm{Br}(D^0 \to \overline{K^0}\omega)=(4.2\pm1.6\pm0.9)\%$, $\mathrm{Br}(D^0 \to \overline{K^0}\eta)<2.7\%$ (90% CL) and $\mathrm{Br}(D^0 \to \overline{K^{*0}}\eta)<2.9\%$ (90% CL).

The observation of the D^0 decay mode $\overline{K^0}\phi$ with a branching ratio of about 1% by ARGUS [1], MARK III [2] and CLEO [3] was originally considered as evidence for the existence of non-spectator processes by Bigi and Fukugita [4]. More recently however, in some models rescattering effects produce this D^0 decay even in the absence of weak annihilation [5–7]. The D^0 decay modes $\overline{K^0}\omega$, $\overline{K^0}\eta$ and $\overline{K^{*0}}\eta$ should also be sensitive to final state interactions in these models. Table 1 lists predictions of various models including the QCD sum rule predictions of Blok and Shifman [8], which do not contain final state interactions. Measurements of the D^0 decays into $\overline{K^0}\omega$, $\overline{K^0}\eta$ and $\overline{K^{*0}}\eta$ are therefore of theoretical interest.

Table 1. Branching ratio predictions for the studied decay modes

	$\overline{K^0}\omega$	$\overline{K^0}\eta$	$\overline{K^{*0}}\eta$
Bauer, Stech and Wirbel [5]	3.0%	0.4%	3.0%
Donoghue [6]			>2%
Kamal [7]		1.5%	
Blok and Shifman [8]	1.5%	0.4%	0.3%

The data sample used for our study corresponds to an integrated luminosity of 189/pb, obtained with the ARGUS detector on the $\Upsilon(2S)$ and $\Upsilon(4S)$ resonances and in the nearby continuum. A short description of the ARGUS detector, its trigger conditions and the method of charged particle identification can be found in previous publications [9]. The D^0 decay into $K^-\pi^+$ was used* to normalize the other decays; the mass distribution of these candidates is shown in Fig. 1a. Since the fragmentation of charmed quarks produces a hard D^0 momentum spectrum we required the scaled momentum $x_p = p(K^-\pi^+)/p_{\max}(D^0)$ to be greater than 0.55 for all measured D^0 decays. This cut reduces the combinatorial background considerably as shown in Fig. 1b. From a fit with a gaussian and a second-order polynomial background we find the signal at a mass of $(1863.8\pm1.3)\,\mathrm{MeV/c^2}$ with a width, consistent with expectation, of $\sigma=(31.4\pm1.6)\,\mathrm{MeV}$. We observed 3323 ± 170 D^0 mesons in this decay mode.

The K^0 mesons from the D^0 decays into $\overline{K^0}\omega$ and into $\overline{K^0}\eta$ are reconstructed in the K_s^0 decay mode $\pi^+\pi^-$. A cut on the angle δ between the momentum vector of the $(\pi^+\pi^-)$-system and the direction from the interaction point to the decay vertex, $\cos\delta>0.9$, provides us with an almost background free K_s^0 sample. The ω meson is reconstructed through its $\pi^+\pi^-\pi^0$ mode, the η meson in the same mode and through the decay into $\gamma\gamma$. Based on the number of shower counters set by an incoming particle, the amount of energy deposited in the shower counters, and the lateral distribution of the energy, a cut was used to reduce the background from hadronic showers in the photon identification [10]. The energy of the photons was required to be greater than 40 MeV. To improve the resolution on the ω and η mass in

* References to a specific particle state should be interpreted as implying the charge-conjugate state also

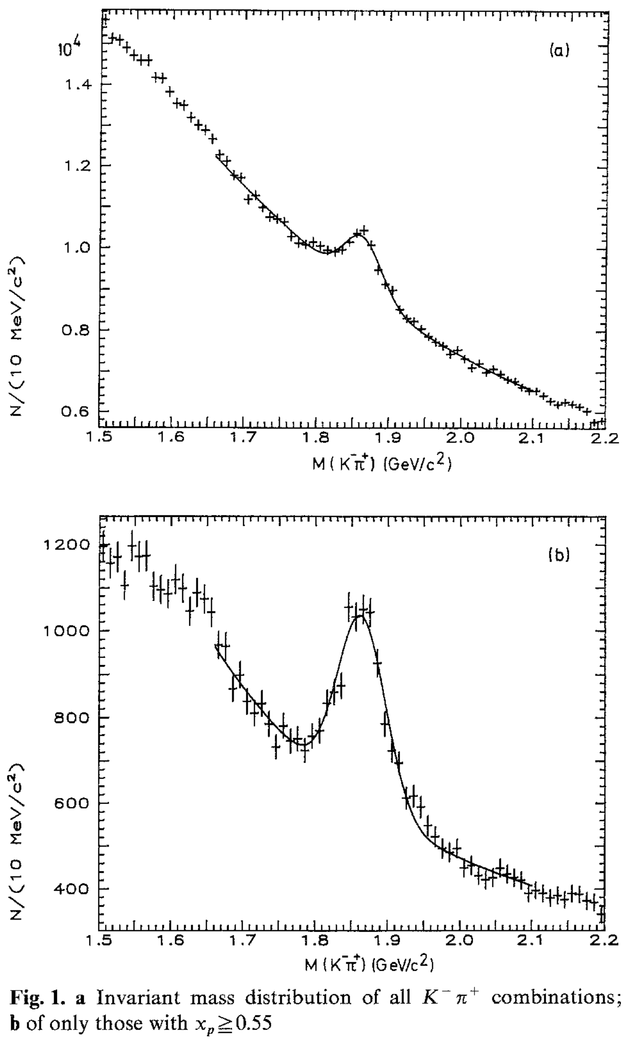

Fig. 1. a Invariant mass distribution of all $K^-\pi^+$ combinations; **b** of only those with $x_p \geq 0.55$

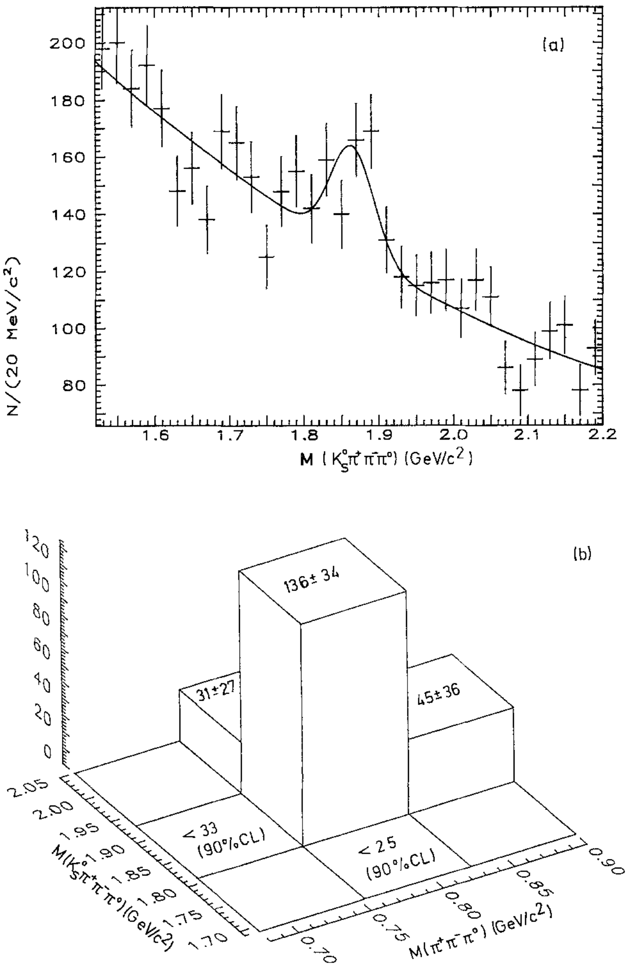

Fig. 2. a Invariant mass distribution of all $\overline{K^0}\pi^+\pi^-\pi^0$ combinations with $x_p \geqq 0.55$ and $0.76\ \mathrm{GeV/c^2} < m(\pi^+\pi^-\pi^0) < 0.83\ \mathrm{GeV/c^2}$. **b** Sideband analysis for the D^0 decay into $\overline{K^0}\omega$

the final state $\pi^+\pi^-\pi^0$ we applied a π^0 mass-constraint fit to all $\gamma\gamma$ combinations with an invariant mass within 44 MeV/c² of the π^0 mass.

The mass spectrum for the combinations $\overline{K^0}\pi^+\pi^-\pi^0$ with the $(\pi^+\pi^-\pi^0)$-mass in the ω mass band, $0.76\ \mathrm{GeV/c^2} < m(\pi^+\pi^-\pi^0) < 0.83\ \mathrm{GeV/c^2}$, is shown in Fig. 2a. From a fit with a gaussian and a polynomial background we obtained 136 ± 34 D^0 candidates which corresponds to a significance of 4 standard deviations above the background level. The width of the signal agrees with the expected value from a Monte Carlo simulation of about 30 MeV. A sideband analysis is necessary to show that we really did observe the D^0 decay into $\overline{K^0}\omega$ and not the decay mode $\overline{K^0}\pi^+\pi^-\pi^0$ which has a large branching ratio of $(11.5 \pm 2.2 \pm 2.8)\%$ measured by MARK III [11]. For this purpose the number of ω mesons in the D^0 meson sidebands and the number of D^0 mesons in the ω meson sidebands were fitted (Fig. 2b). The number of D^0 mesons found in the ω sidebands is 7 ± 23 which leads to 129 ± 41 D^0 decays into $\overline{K^0}\omega$. The signal still has a significance of more than three standard deviations. To reduce systematic errors in

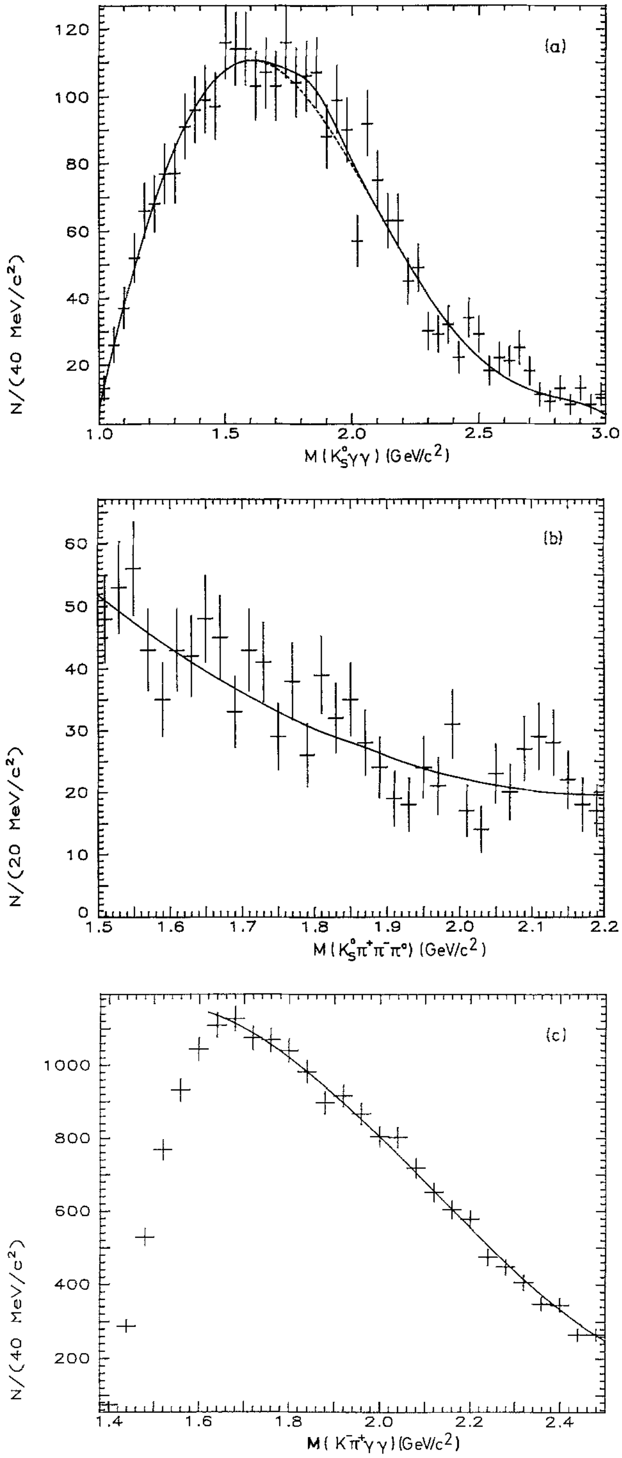

Fig. 3. Invariant mass distributions for the D^0 decay modes **a** $\overline{K^0}\eta$ with $0.48\ \mathrm{GeV/c^2} < m(\gamma\gamma) < 0.60\ \mathrm{GeV/c^2}$; **b** $\overline{K^0}\eta$ with $0.53\ \mathrm{GeV/c^2} < m(\pi^+\pi^-\pi^0) < 0.59\ \mathrm{GeV/c^2}$; **c** $\overline{K^{*0}}\eta$ with $0.48\ \mathrm{GeV/c^2} < m(\gamma\gamma) < 0.60\ \mathrm{GeV/c^2}$ and with $x_p \geqq 0.55$

the K_s^0 efficiency we applied an additional cut on the decay length of the K_s^0 mesons at 2 cm which reduces our D^0 signal finally to $94 \pm 32 \pm 15$. The errors include the uncertainty of the background from the non-resonant decay $\overline{K^0}\pi^+\pi^-\pi^0$ and the uncertainty of the parametrisation of the polynomial background function used for the fit.

For the investigation of the D^0 decay mode $\overline{K^0}\eta$ we used the η decays into $\gamma\gamma$ and into $\pi^+\pi^-\pi^0$. Using the same procedures as for the D^0 decay mode $\overline{K^0}\omega$ we found $N(D^0 \to \overline{K^0}\eta, \eta \to \gamma\gamma) = 30 \pm 27$ and $N(D^0 \to \overline{K^0}\eta, \eta \to \pi^+\pi^-\pi^0) = 2 \pm 16$ (Fig. 3a and b).

For the D^0 decay into $\overline{K^{*0}}\eta$ we found $N(D^0 \to \overline{K^{*0}}\eta, \eta \to \gamma\gamma) = -43 \pm 120$ (Fig. 3c). The less efficient η decay channel $\pi^+\pi^-\pi^0$ has not been used, since we get additional systematic uncertainties from a combinatorical background peaking in the D^0 mass region.

To obtain the detector acceptances for these decays we passed events generated by the Lund 6.2 Monte Carlo through a full detector simulation [12] and analysed the events with the same programs as used for the real data. The Monte Carlo momentum spectrum for the D^0 mesons, generated according to the fragmentation function of Peterson et al. [13], agrees with the data from the decay $K^-\pi^+$. The combined detector and selection acceptances for the different decay modes are listed in Table 2. The branching ratios of $\overline{K^0}$, $\overline{K^{*0}}$, ω and η mesons into the modes used for reconstruction reduce these acceptances further.

Using these results we find the following relative branching ratios:

$$\frac{\mathrm{Br}(D^0 \to \overline{K^0}\omega)}{\mathrm{Br}(D^0 \to K^-\pi^+)} = 1.00 \pm 0.36 \pm 0.20,$$

$$\frac{\mathrm{Br}(D^0 \to \overline{K^0}\eta)}{\mathrm{Br}(D^0 \to K^-\pi^+)} = 0.28 \pm 0.28 < 0.64 \quad (90\%\ \mathrm{CL}),$$

$$\frac{\mathrm{Br}(D^0 \to \overline{K^{*0}}\eta)}{\mathrm{Br}(D^0 \to K^-\pi^+)} = -0.2 \pm 0.5 < 0.7 \quad (90\%\ \mathrm{CL}).$$

For the D^0 decay mode $\overline{K^0}\eta$ the two independent results from the η decays into $\gamma\gamma$ and into $\pi^+\pi^-\pi^0$ have been combined. Using the known branching ratio $\mathrm{Br}(D^0 \to K^-\pi^+) = (4.2 \pm 0.4 \pm 0.4)\%$ [11] we calculate $\mathrm{Br}(D^0 \to \overline{K^0}\omega) = (4.2 \pm 1.6 \pm 0.9)\%$, $\mathrm{Br}(D^0 \to \overline{K^0}\eta) < 2.7\%$ (90% CL) and $\mathrm{Br}(D^0 \to \overline{K^{*0}}\eta) < 2.9\%$ (90% CL). The measured value for the D^0 decay into $\overline{K^0}\omega$ is in good agreement with the result from MARK III [11] $\mathrm{Br}(D^0 \to \overline{K^0}\omega) = (3.2 \pm 1.3 \pm 0.8)\%$.

Table 2. Detector and selection acceptances for the measured decay modes

D^0 decay	acceptances (%)
$K^-\pi^+$	$35.3 \pm 0.8 \pm 1.0$
$\overline{K^0}\omega;\ \omega \to \pi^+\pi^-\pi^0$	$3.2 \pm 0.4 \pm 0.4$
$\overline{K^0}\eta;\ \eta \to \gamma\gamma$	$6.4 \pm 0.9 \pm 1.0$
$\overline{K^0}\eta;\ \eta \to \pi^+\pi^-\pi^0$	$3.2 \pm 0.4 \pm 0.6$
$\overline{K^{*0}}\eta;\ \eta \to \gamma\gamma$	$9.2 \pm 1.0 \pm 1.1$

In summary, we have observed the D^0 decay into $\overline{K^0}\omega$ and we have found upper limits for the branching ratios of the decay modes $\overline{K^0}\eta$ and $\overline{K^{*0}}\eta$. The average of the measured branching ratio from MARK III and ARGUS for the D^0 decay into $\overline{K^0}\omega$ of $(3.7 \pm 1.2)\%$ favours the improved spectator model of Bauer et al. [5] which includes final state interactions versus the QCD sum rules calculations of Blok and Shifman [8].

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References

1. H. Albrecht et al.: Phys. Lett. 158B (1985) 525
2. R.M. Baltrusaitis et al.: Phys. Rev. Lett. 56 (1986) 2136
3. C. Bebek et al.: Phys. Rev. Lett. 56 (1986) 1983
4. I.I. Bigi, M. Fukugita: Phys. Lett. 91B (1980) 121
5. M. Bauer et al.: Z. Phys. C – Particles and Fields 34 (1987) 103
6. J.F. Donoghue: Phys. Rev. D33 (1986) 1516
7. A.N. Kamal: Phys. Rev. D33 (1986) 1344
8. B.Yu. Blok, M.A. Shifman: Sov. J. Nucl. Phys. 45 (1987) 522
9. H. Albrecht et al.: DESY report 88-80 (1988)
10. A. Drescher et al.: Nucl. Instrum. Methods A237 (1985) 464
11. D. Hitlin: International Symposium on Lepton and Photon Interactions at High Energies, Hamburg, (1987) p. 179
12. H. Gennow: DESY report F15-85-02, (1985)
13. C. Peterson et al.: Phys. Rev. D27 (1983) 105