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Analysis of the decays $D^0 \to \pi^- \mu^+ \nu$ and $D^0 \to K^- \mu^+ \nu$ in FOCUS

LORENZO AGOSTINO*

Department of Physics, University of Colorado, Campus Box 390
Boulder,CO 80309, USA

We present a new measurement of the branching ratio of the Cabibbo suppressed decay $D^0 \to \pi^- \mu^+ \nu$ relative to the Cabibbo favored decay $D^0 \to K^- \mu^+ \nu$ and an improved measurement of the ratio $|f_+^\pi(0)/f_+^K(0)|$. We also report a new measurement of the q^2 dependence of the form factors for $D^0 \to \pi^- \mu^+ \nu$ and $D^0 \to K^- \mu^+ \nu$.

1. Data Selection

This analysis is described in references [1] and [2] and is based on data collected by the FOCUS experiment during the 1996–97 fixed target run at Fermilab. FOCUS is a photoproduction experiment which collected a large sample of charm decays.

The selection criteria have been tuned for the $\pi^- \mu^+ \nu$ sample. We reconstruct the semileptonic decays $D^0 \to \pi^- \mu^+ \nu$ and $D^0 \to K^- \mu^+ \nu$ requiring a D^{*+}-tag where the D^{*+} is reconstructed in the $D^0\pi^+$ final state. The signal and normalization samples are selected requiring two opposite charged tracks form a good vertex with a confidence level greater than 1%. One of the two tracks from the D^0 decay vertex must be identified as a muon and must have momentum greater than 10 GeV/c. The other track must satisfy a Čerenkov requirement. To reduce non-charm background, the candidate hadron must have a momentum greater than 14 GeV/c. The primary vertex is required to be isolated from other tracks and for each hadron-lepton combination, another track coming from the primary vertex must be found as the candidate "soft" pion from the D^{*+}. The π_s^+ candidate must not have the pion hypothesis strongly disfavored over all other particle hypotheses from the Čerenkov system. It must also have a momentum greater than 2.5 GeV/c. We place a lower cut on the hadron-lepton invariant mass of 1.0 GeV/c^2. Contamination from $D^0 \to K^-\pi^+$ is eliminated by requiring the visible mass to be less than 1.7 GeV/c^2. Since the neutrino is not reconstructed we constrain the $K^- \mu^+ \nu$ ($\pi^- \mu^+ \nu$) mass to the D^0 mass and the $K^- \mu^+ \nu\ \pi_s^+$ ($\pi^- \mu^+ \nu\ \pi_s^+$) mass to the D^{*+} mass and we determine the angle between the neutrino and the π_s^+ direction. We then sample the azimuthal angle and choose the one that gives the direction of the D^0 most consistent with pointing to the primary vertex.

*On behalf of the FOCUS collaboration.

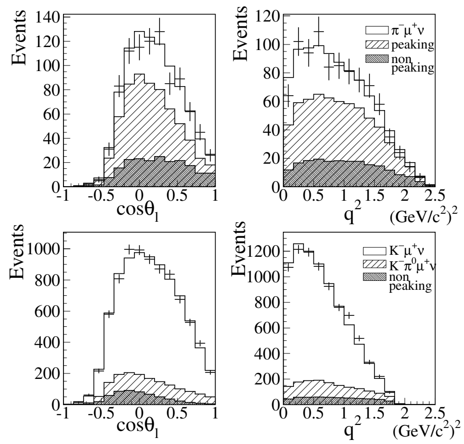

Fig. 1. Fit projections for $D^0 \to \pi^- \mu^+ \nu$ and $D^0 \to K^- \mu^+ \nu$. The fit is performed on a two-dimensional distribution of q^2 and $\cos\theta_\ell$. In the $D^0 \to \pi^- \mu^+ \nu$, the peaking background contribution is defined as the sum of the contributions from $D^0 \to K^- \mu^+ \nu$, $\rho^- \mu^+ \nu$ and $K\pi\mu^+\nu$.

2. Parametric Analysis

After setting the level of combinatoric background with a fit to the $D^{*+} - D^0$ mass difference, a fit is made to the two-dimensional distribution q^2 vs. $\cos\theta_\ell$ (where $\cos\theta_\ell$ is defined as the cosine of the angle between the neutrino direction and the D^0 direction in the rest frame of the lepton-neutrino system). The fit is first performed on the $K^-\mu^+\nu$ sample and the results from this fit are used to set part of the background in the $\pi^-\mu^+\nu$ sample. To measure pole masses and the form factor ratio $f_-^K(0)/f_+^K(0)$ we apply an event-by-event weighting procedure [3]. From the fit to the $\pi^-\mu^+\nu$ ($K^-\mu^+\nu$) distributions (Fig. 1) we find 288 ± 29 $\pi^-\mu^+\nu$ (6574 ± 92 $K^-\mu^+\nu$) events. Using the yields from the fit we measure the ratio of the form factors $f_+^\pi(0)/f_+^K(0)$ by computing a numerical integration of the differential decay rate modulated by the reconstruction efficiency as a function of the q^2 [4].

Several studies have been performed to search for possible systematic uncertainties. The fitting procedure was tested on a Monte Carlo set and we checked for possible biases as well as the accuracy of our statistical error by performing a fit on fluctuated data distributions. We also performed study to establish how well our fit function described the data. We investigated the stability of our results by changing a variety of selection criteria and we further investigated fit variations. Since the Monte Carlo is used to determine the amount of $K^-\mu^+\nu$ background in the $\pi^-\mu^+\nu$ sample, we are sensitive to the simulated misidentification rate. We used the high statistics modes $D^0 \to K^-\pi^+$ and $D^0 \to K^-\pi^+\pi^+$ to measure the $K \to \pi$ misidentification rate and we used the statistical error on the combined sample to assign a systematic uncertainty. From the parametric fit we find the following results: $\Gamma(\pi^-\mu^+\nu)/\Gamma(K^-\mu^+\nu)$ =0.074 $\pm$ 0.008 $\pm$ 0.007 and $f_+^\pi(0)/f_+^K(0)$

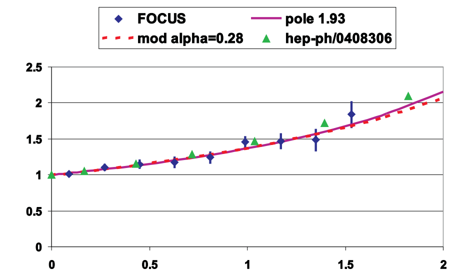

Fig. 2. The background subtracted $f_+(q^2)$ (diamonds with error bars) is compared to a pole form with $m^K_{\rm pole} = 1.93$ (solid curve), a modified pole form with $\alpha = 0.28$ (dashed curve), and the unquenched, Lattice QCD, calculations (triangles with no error bars). This form factor is for the process $D^0 \to K^- \mu^+ \nu$. The α and $m_{\rm pole}$ used for the plots are obtained using the two-dimensional parameterized fit.

$=0.85 \pm 0.04 \pm 0.04$, $f_-^{(K)}(0)/f_+^{(K)}(0) = -1.7^{+1.5}_{-1.4} \pm 0.3$, $m^K_{\rm pole} = 1.93 \pm 0.05 \pm 0.03$ and $m^\pi_{\rm pole} = 1.91^{+0.30}_{-0.15} \pm 0.07$.

3. Non-parametric analysis of $f_+^K(q^2)$.

We also performed a non-parametric analysis of the q^2 dependence of $D^0 \to K^- \mu^+ \nu$ where we used loser selection criteria [2]. This analysis is based on a sample of $\approx 13,000$ decays of the form $D^{*+} \to D^0 \pi^+$, where $D^0 \to K^- \mu^+ \nu$. We implement a method to correct for the effects of acceptance and q^2 resolution and produce a set of $f_+^2(q_i^2)$ that represents measured $f_+(q^2)$ values - each averaged over the (narrow) width of the q_i^2 *reporting* bins. Our charm background correction is based on a Monte Carlo, which incorporates all known charm decays and charm decay mechanisms. In Fig. 2 we show the comparison between the non-parametric analysis of $D^0 \to K^- \mu^+ \nu$ and recent unquenched, Lattice QCD, calculations [5].

For this analysis it was important to test the simulation of our resolution. To do this, we studied tagged, fully-reconstructed $D^0 \to K^- \pi^+ \pi^+ \pi^+$ decays where one pion was reconstructed using the neutrino cone closure. We then compared the q^2 obtained using the neutrino closure to the magnetically reconstructed q^2. The difference between these two q^2 values provided a resolution distribution. From a comparison between data and Monte Carlo we found that the Monte Carlo resolution distribution was a good match to the observed resolution distribution.

References

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