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Measuring $\mathcal{B}(D^+ \to \mu^+\nu)$ and the Pseudoscalar Decay Constant f_{D^+}

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In 60 pb^{-1} of data taken on the $\psi(3770)$ resonance with the CLEO-c detector, we find 8 $D^+ \to \mu^+\nu$ event candidates that are mostly signal, containing only 1 estimated background. Using this statistically compelling sample, we measure the value of $\mathcal{B}(D^+ \to \mu^+\nu) = (3.5 \pm 1.4 \pm 0.6) \times 10^{-4}$, and determine $f_{D^+} = (198 \pm 41 \pm 17)$ MeV.

1. Introduction

Measuring purely leptonic decays of heavy mesons allows the determination of meson decay constants, which connect measured quantities, such as the $B\bar{B}$ mixing ratio, to CKM matrix elements. Currently, it is not possible to determine f_B experimentally from leptonic B decays, so theoretical calculations of f_B must be used.

Measurements of pseudoscalar decay constants such as f_{D^+} provide checks on these calculations and help discriminate among different models.

The decay rate is given by[1] $\Gamma(D^+ \to l^+\nu) = \frac{G_F^2}{8\pi} f_{D^+}^2 m_l^2 M_{D^+} \left(1 - \frac{m_l^2}{M_{D^+}^2}\right)^2 |V_{cd}|^2$, where M_{D^+} is the D^+ mass, m_l is the mass of the final state lepton, V_{cd} is a CKM matrix element equal to 0.224,[2] and G_F is the Fermi coupling constant.

2. Analysis Technique and Event Selection

In this study we use 60 pb^{-1} of CLEO-c data recorded at the ψ'' resonance (3.770 GeV) with the CLEO-c detector[3] at the Cornell Electron Storage Ring (CESR). We fully reconstruct one charged D meson of the produced D^+D^- pairs as a tag. Tagging modes are fully reconstructed by first evaluating the difference in the energy of the decay products with the beam energy ΔE. We then require the absolute value of this difference to be within 0.02 GeV of zero, approximately twice the r.m.s. width, and then look at the reconstructed D^- beam constrained mass defined as $m_D = \sqrt{E_{beam}^2 - (\sum_i \overrightarrow{p}_i)^2}$, where i runs over all the final state particles. We then search for $D^+ \to \mu^+\nu_\mu$ candidates with charge opposite to the charge of the tagged D^-. The charge-conjugate modes are always used.

The m_D distributions for all D^- tagging modes considered in this data sample are shown in Fig. 1. We have a total of 28574±207 tags.

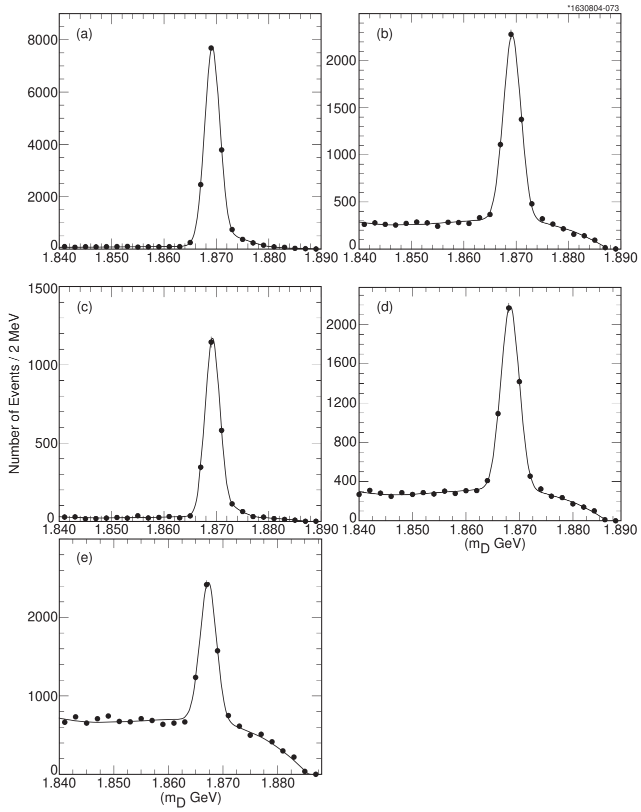

Fig. 1. Beam Constrained Mass distributions for different fully reconstructed D^- decay candidates; the curves show the sum of Gaussian signal functions and 3^{rd} order polynomial background functions. A single signal Gaussian is used for all modes except for (a) and (c) where two Gaussians are used. (a) $D^- \to K^+\pi^-\pi^-$, (b) $D^- \to K^+\pi^-\pi^-\pi^0$, (c) $D^- \to K_s\pi^-$, (d) $D^- \to K_s\pi^-\pi^-\pi^+$ and (e) $D^- \to K_s\pi^-\pi^0$.

To select $D^+ \to \mu^+\nu_\mu$ events we first reconstruct D^- event candidates and then search for events with a single additional charged track presumed to be a μ^+. Then we infer the existence of the neutrino by requiring a measured value near zero (the neutrino mass) of the missing mass squared (MM^2) defined as MM^2 = $\left(E_{beam} - E_{\mu^+}\right)^2 - \left(-\overrightarrow{p}_{D^-} - \overrightarrow{p}_{\mu^+}\right)^2$ where $\overrightarrow{p}_{D^-}$ is the three-momentum of the fully reconstructed D^-. We reject events with extra charged tracks besides the muon candidate and maximum extra shower energy above 250 MeV.

3. Results

The MM^2 distribution for our tagged events is shown in Fig. 2.[4] We see a signal near zero containing 8 events within a $\pm 2\sigma$ interval, -0.056 GeV^2 to +0.056 GeV^2. This signal is due to the $D^+ \to \mu^+\nu_\mu$ mode we are seeking. The large peak centered

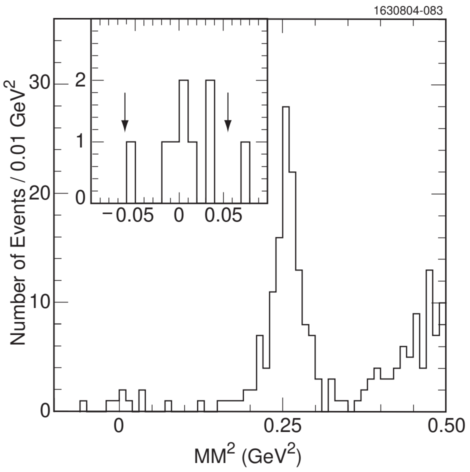

Fig. 2. MM^2 using D^- tags and one additional opposite sign charged track and no extra energetic showers (see text). The insert shows the signal region for $D^+ \to \mu^+\nu$ enlarged, $\pm 2\sigma$ range is shown between the two arrows.

near 0.25 GeV^2 is from the decay $D^+ \to \overline{K}^o\pi^+$ that is far from our signal region.

Backgrounds from $D^+ \to \tau^+\nu$, $\tau^+ \to \pi^+\nu$, $D^+ \to \pi^+\pi^0$ and other smaller sources are estimated as summing to 1.07 events. Subtracting the background from our 8 events in the signal region, we determine a branching fraction using a detection efficiency for the single muon of 69.9% and 28574±207 $D^\mp$ tags. We find $\mathcal{B}(D^+ \to \mu^+\nu_\mu) = (3.5\pm1.4\pm0.6)\times10^{-4}$ and the decay constant is $f_{D^+} = (198\pm41\pm17)$ MeV.

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References

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