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An Upper Limit on the Decay $D^0 \rightarrow \mu e$ *

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ABSTRACT

A search for the lepton family number violating decay $D^0 \rightarrow \mu e$ is reported. No signal is observed in a data sample of 9.3 pb^{-1} collected at the $\psi(3770)$ resonance with the Mark III detector, where $0.18 \pm 0.06 \pm 0.05$ background events are expected. A 90% confidence level upper limit on the branching fraction $\text{B}(D^0 \rightarrow \mu e)$ of 1.5×10^{-4} is obtained.

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Motivated by the interest in lepton family number violating processes[1] and the lack of experimental information the decay mode[2] $D^0 \rightarrow \mu e$ is investigated. This decay could be induced by massive leptoquarks which are predicted in various extensions of the Standard Model.[3] We present the most sensitive search to date for the decay $D^0 \rightarrow \mu e$.

The data, 9.3 pb^{-1}, were taken with the MARK III detector at the SLAC e^+e^- storage ring SPEAR at a c.m. energy of 3.77 GeV. This luminosity corresponds to $41400^{+3100}_{-2700} \pm 2700$ produced D^0's.[4] The data are first searched for events containing at least two lepton candidates: one muon and one electron. The kinematics of the two-body D^0 decay require that both leptons have momentum $p > 0.75\,\mathrm{GeV}/c$ in the laboratory frame. Leptons are selected on the basis of the energy deposited in the shower counter, the momentum as determined with the drift chamber, the time-of-flight measured with scintillation counters, and range in the muon system.

The two main sources of background to the decay $D^0 \rightarrow \mu e$ are hadronic charged two-body D^0 decays, and $\tau^+\tau^-$ pairs. The rejection of $D^0 \rightarrow K^-\pi^+$, $\pi^+\pi^-$ decays through the lepton selection described above is augmented by use of the two-body decay kinematics. The invariant mass M_{inv} of each two-body combination is calculated using electron and muon masses. The $K^-\pi^+$ decays of the D^0 contaminating the sample are kinematically reflected to lower masses (fig. 1). All candidate pairs with M_{inv} differing from the D^0 mass by more than $0.05\,\mathrm{GeV}/c^2$ are rejected. This cut does not reject the Cabibbo-suppressed decay $D^0 \rightarrow \pi^+\pi^-$. Thus, although the absolute rate of $D^0 \rightarrow \pi^+\pi^-$ is small, it remains a significant

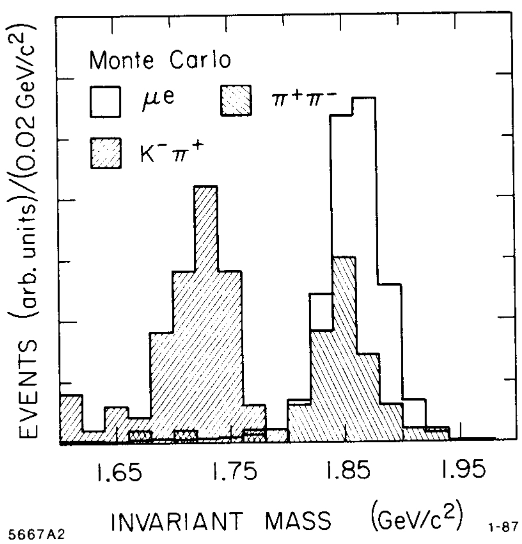

Fig. 1. Monte Carlo generated distributions of M_{inv} for the μe signal and for the $K^-\pi^+$ and $\pi^+\pi^-$ backgrounds. The invariant mass is required to lie within $\pm 0.05\,\mathrm{GeV}/c^2$ of the D^0 mass. Lepton selection criteria have already been applied.

background. The second major background source stems from τ pair production. Since this τ background consists mainly of two-prong events accompanied by undetected neutrinos, a cut on the missing energy E_{miss} in two-prong events *only* eliminates this contamination. Figure 2 shows the expected E_{miss} distribution from Monte Carlo simulations of $D^0\bar{D}^0 \to (\mu e +$ no charged tracks) and $\tau^+\tau^-$ production. By rejecting two-prong events with $E_{miss} > 1\,\text{GeV}$, the τ events are removed, with a 2% reduction in μe efficiency.

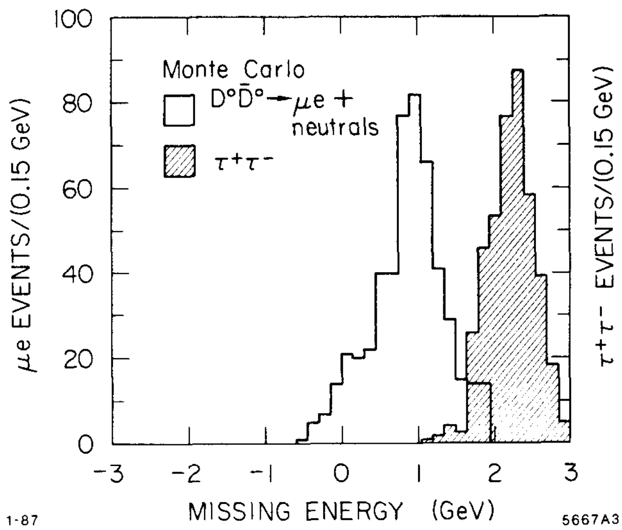

Fig. 2. Monte Carlo generated distributions of E_{miss} for *two-prong events only* from $D^0\bar{D}^0 \to (\mu e +$ no charged tracks) and from $\tau^+\tau^-$ pair production. As the former channel constitutes 6% of all $D^0 \to \mu e$ events, the cut at $E_{miss} = 1\,\text{GeV}/c^2$ reduces the $D^0 \to \mu e$ efficiency by only 2%. All lepton selection criteria have been applied.

After all particle identification and kinematic cuts have been applied, the beam-constrained mass M_{bc} is calculated for each surviving candidate pair by constraining its energy to the beam energy. Two events with $M_{bc} > 1.82\,\text{GeV}/c^2$ are found. A study of the M_{bc} distribution of $D^0 \to K^-\pi^+$ in the same data sample shows that 90% of those two-body decays lie within $\pm 0.0055\,\text{GeV}/c^2$ of the D^0 mass (fig. 3). No μe candidate falls within this range. The efficiency for $D^0 \to \mu e$ detection is found to be $0.433 \pm 0.004 \pm 0.029$, while that for $D^0 \to \pi^+\pi^-$ is $0.0024 \pm 0.0004 \pm 0.0002$. After all analysis cuts, neither $D^0 \to K^-\pi^+$ decays nor $\tau^+\tau^-$ pair production contribute significantly. The background to a μe signal is estimated to be $0.18 \pm 0.06 \pm 0.05$ originating solely from $\pi^+\pi^-$ events.[4] The observation of no events of the type $D^0 \to \mu e$ yields a 90% confidence level (C.L.) upper limit of 2.30 on the total number of signal and background events.

This results in an upper limit on $B(D^0 \to \mu e)$ of 1.5×10^{-4}, when all systematic errors are included. This bound, which is model-independent, is approximately an order of magnitude lower than other model-dependent measurements.[5]

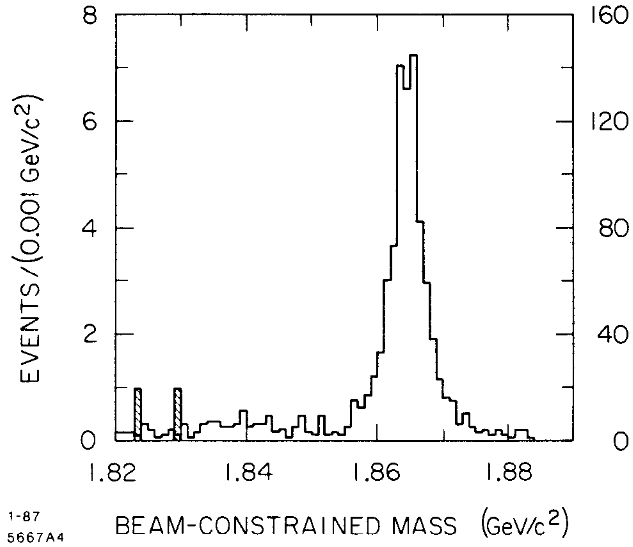

Fig. 3. M_{bc} distribution for $K^-\pi^+$ events in the data (used to determine the $\pm 0.0055\,\mathrm{GeV}/c^2$ cut on M_{bc}). Superimposed are the two closest $D^0 \to \mu e$ candidates, that pass all other cuts.

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