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EXPERIMENTAL LIMIT ON THE DECAY $D^0 \rightarrow e^\mp \mu^\pm$

The ACCMOR Collaboration

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ABSTRACT

A search has been carried out for the decay of $D^0 \rightarrow e^\mp \mu^\pm$ in single electron trigger data recorded with the ACCMOR spectrometer equipped with a high resolution Si vertex telescope. No significant signal has been found. An upper limit of $1.0 \cdot 10^{-3}$ (90% C.L.) has been set using as normalisation the sample of D's decaying to other channels observed in this experiment.

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Although the standard model of electroweak interactions describes with remarkable completeness all available experimental facts, it has several limitations which, according to commonly accepted opinion, disqualify it from bearing the trademark of a really fundamental theory. It is rather to be viewed as an effective low energy theory which is a consequence of some more fundamental interactions occurring at very high energies. These interactions would manifest themselves at low energies through small deviations from the standard model. Experimental searches for these deviations provide valuable constraints on the scale of new interactions [1,2] and help to discriminate numerous theoretical approaches (supersymmetry, substructure, grand unification, superstrings. . .). One of the promising low energy windows to new physics are non-diagonal inter-family transitions [1,3,4,5]. Searching for decays of $D^0 \rightarrow e\mu$ we study here the transitions involving (e,μ) leptons and (c,u) quarks. The corresponding transition involving (s,d) quarks has been studied in $K_L^0 \rightarrow e\mu$ decays [6,7,8] which yielded an upper limit of : $Br(K_L^0 \rightarrow e\mu) < 6 \cdot 10^{-6}$ [9]. In general both transitions can be of different strengths, and in theories with flavour changing neutral currents it is often difficult to have a simultaneous strong suppression of $K_L^0 \rightarrow e\mu$ and $D^0 \rightarrow e\mu$ [1].

The experiment reported here was designed to study charmed particles in hadronic interactions through the observation of semileptonic or hadronic decays with a measurable decay path. The sample of D mesons selected in this experiment for lifetime and production mechanism studies consists of about 50 $D \rightarrow K\pi$, $K2\pi$ and $K3\pi$ events [10,11] and 75 events of $D^+ \rightarrow \bar{K}^{*0}(892)e^+\nu_e$ decays [12] (in the following D^+ , D^0 stand for both D^+/D^- and $D^0/\bar{D}^0$). The experimental apparatus has been described in detail elsewhere [13]. Briefly, interactions of a 200 GeV/c π^- beam incident on a 20 mm long Be target leading to prompt electrons originating from the semileptonic decay of charmed particles were selected using a multicell Cerenkov counter and a lead-scintillator electromagnetic calorimeter. Background due to hadrons, photons and conversion pairs is suppressed by a second stage trigger. Further background rejection is achieved offline after full reconstruction of the electron track in the drift chambers and silicon counters. Hadrons produced in the forward direction are measured and identified in a large acceptance forward spectrometer consisting of forty eight drift chambers, two spectrometer magnets and three large multicellular Cerenkov counters. Energy and position of forward going photons are measured with an electromagnetic calorimeter. The average mass resolution of the spectrometer at the D meson mass is 15 MeV. A high resolution vertex telescope consisting of six microstrip silicon detectors ("MSD") [14,15] allows a reconstruction of the primary and secondary vertices with an accuracy of 150 μ m in the beam direction. The

measurement accuracy of tracks extrapolated to the primary vertex is $10\ \mu\text{m}$ perpendicular to the beam. The strategy of pattern recognition in the MSDs is described elsewhere [10,16].

A secondary vertex search is performed in the region between the interaction point and the first MSD plane (50 mm). The decay $D^0 \rightarrow e\mu$, if present, would result in an enhancement at the D^0 mass in the $e\mu$ invariant mass spectrum of events with a secondary vertex formed by an electron and a muon. Our spectrometer does not distinguish between pions and muons. Therefore we search for vertices of an electron and a track of a particle x (either pion or muon) and calculate their invariant mass assigning the muon mass to the ambiguous particle. The $e\mu$ invariant mass distribution for events with an $e^\mp x^\pm$ secondary vertex, satisfying the condition that the vector sum of the momenta of the 2 particles points back to the primary vertex with good precision is shown in Fig. 1a. The same distribution for the control sample of events with $e^\mp x^\mp$ vertices (net charge $Q = \pm 2$) is shown in Fig. 1b. There are in the order of 200 events more in the sample with $Q = 0$ than in the control sample (631 vs 414 events). The mass peak $m(e\mu) = 0.440\ \text{GeV}$ is due to $K_S^0 \rightarrow \pi^-\pi^+$ decays with one pion misidentified as an electron. From the observed signal of about 20 $K_S^0 \rightarrow \pi\pi$ events and the cross-section $\sigma(\pi p \rightarrow K_S^0 X) = 3.74 \pm 0.24\ \text{mb}$ at 200 GeV [17], we estimate the overall π/e rejection factor achieved in this analysis to be better than 10^4 .

There are four events with masses in the interval $\pm 45\ \text{MeV}$ around the D^0 mass. For these events and for events from the side bands below and above the D^0 mass region, we examined a possible shower development of the π/μ track in the electromagnetic calorimeter. One of the four events has a shower clearly compatible with originating from a hadron interaction in the forward calorimeter. From three remaining candidates and the estimated background of 3 events in the reference mass interval we obtain a limit of $4.2\ D^0 \rightarrow e^\mp \mu^\pm$ decays (90% C.L.). The corresponding upper limit on the branching ratio can be obtained by normalisation to $D^+ \rightarrow \bar{K}^{*0}(892)e^+\nu_e$ decays observed in this experiment, according to

$$\text{BR}(D^0 \rightarrow e^\mp \mu^\pm) = [(N(e\mu) \cdot \text{Acc}(K^{*0} e \nu) \cdot \text{Br}(D^+ \rightarrow \bar{K}^{*0} e^+ \nu)) / (N(K^{*0} e \nu) \cdot \text{Acc}(e\mu) \cdot k)]$$

where $k = \sigma(\pi^- \text{Be} \rightarrow D^0 X) / \sigma(\pi^- \text{Be} \rightarrow D^+ X)$. This ratio has been measured in this experiment to be $k = 1.5 \pm 0.5$ [11]. For the branching ratio $\text{Br}(D^+ \rightarrow \bar{K}^{*0}(892)e^+\nu_e)$

with $\bar{K}^{*0}(892) \rightarrow K^- \pi^+$ we take the value of $3.9 \pm 1.1\%$ as determined by Mark III [18]. The observed number of $D^+ \rightarrow \bar{K}^{*0}(892) e^+ \nu_e$ is $N(K^{*} ev) = 74.3 \pm 8.6$ [12]. The acceptances $Acc(e\mu)$ and $Acc(K^{*} ev)$ were obtained from Monte-Carlo calculations assuming $(1-x_F)^n \exp(-bp_t^2)$ distributions with $n = 3$ and $b = 1$ as measured in this experiment [11]. They are respectively: $Acc(K^{*} ev) = 1.5 \cdot 10^{-2}$ and $Acc(e\mu) = 2.5 \cdot 10^{-2}$. Combining the above factors we find

$$Br(D^0 \rightarrow e^{\mp} \mu^{\pm}) < 9 \cdot 10^{-4} \text{ (90\% C.L.)}$$

The main uncertainties in the calculation of this limit are in the branching ratio for $D^+ \rightarrow \bar{K}^{*0}(892) e^+ \nu_e$ and in the ratio of the $\sigma(D^0)/\sigma(D^+)$. The uncertainty due to production mechanism assumed for the calculation of both acceptances should mostly cancel out because no differences are observed in the production mechanisms of neutral and charged D mesons. We repeated the above calculations using for normalisation $D^0 \rightarrow K^- \pi^+$, $K^- \pi^+ \pi^+ \pi^-$ decays observed in our apparatus. In this case the errors on the branching ratios are small and the ratio $\sigma(D^0)/\sigma(D^+)$ does not enter the calculation, but the uncertainty due to the acceptance can be big. This is mainly due to the fact that a model for $D\bar{D}$ correlations is needed to determine the acceptance [11]. Using $\sigma(\pi^- Be \rightarrow D^0 X)$ as determined in [11] we get

$$Br(D^0 \rightarrow e^{\mp} \mu^{\pm}) < 1.0 \cdot 10^{-3} \text{ (90\% C.L.)}$$

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Figure Captions

Fig. 1 : The $e\mu$ invariant mass distributions for $e^{\mp}x^{\pm}$ (a) and $e^{\mp}x^{\mp}$ events (b).

Fig.1a

Fig.1b