



## SEARCH FOR RARE 3 AND 4-BODY $D^0$ DECAYS AT FNAL E791

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Limits at the  $10^{-4}$  level are reported for rare and forbidden decays of the  $D^0$  charm meson to a pair of leptons and either a vector meson or two pseudoscalar mesons. Of these searches, 18 are investigations of decays without previous published results; several others have significantly improved sensitivity over previous results.

We have made *blind* searches for 27 dilepton  $D^0$  decays with muons or electrons.<sup>1</sup> The modes are resonant  $D^0 \rightarrow V\ell^+\ell^-$  decays, where  $V$  is a  $\rho^0$ ,  $\bar{K}^{*0}$ , or  $\phi$ , and non-resonant  $D^0 \rightarrow hh\ell\ell$  decays, where  $h$  is a  $\pi$  or  $K$ . Charge-conjugates are implied. The modes are lepton flavor-violating, or lepton number-violating, or flavor-changing neutral current decays. Box diagrams can mimic FCNC decays, but only at the  $10^{-10}$  to  $10^{-9}$  level.<sup>2,3</sup> Long range effects (e.g.  $D^0 \rightarrow \bar{K}^{*0}\rho^0$ ,  $\rho^0 \rightarrow e^+e^-$ ) can occur at the  $10^{-6}$  level.<sup>3,4</sup> Many have studied rare decays of  $-1/3q$  strange quarks. Charge  $2/3$  charm quarks are interesting because they might couple differently.<sup>5</sup>

Data is from the Fermilab E791 spectrometer.<sup>6</sup> The spectrometer has been upgraded for a series of experiments including E516,<sup>7</sup> E691,<sup>8</sup> E769,<sup>9</sup> and E791. In addition to searching for rare decays,<sup>1,10</sup> E791 has set limits on  $D^0\bar{D}^0$  mixing<sup>11</sup> and  $CP$  violation.<sup>12</sup> E791 has observed doubly cabibbo suppressed decays<sup>13</sup> and has tagged quarks as being  $c$  or  $\bar{c}$  using  $D$ - $\pi$  production correlations.<sup>14</sup> E791 recorded  $2 \times 10^{10}$  events,<sup>15</sup> which were produced by a 500 GeV/c  $\pi^-$  beam hitting a fixed target consisting of five thin, well-separated disks. Tracks and vertices use hits in 23 silicon microstrip<sup>8</sup> and 45 wire chamber planes. Kaon ID employs two Čerenkov counters.<sup>16</sup> Electron ID uses transverse shower shape plus matching wire chamber tracks to shower positions and energies in an electromagnetic calorimeter.<sup>17</sup> The probability to mis-ID a pion as an electron was  $\sim 0.8\%$ . Muon ID employs two planes of scintillation counters.<sup>18</sup> Data from  $D^+ \rightarrow \bar{K}^{*0}\mu^+\nu_\mu$  decays<sup>19</sup> were used to set cuts. The probability to mis-ID a pion as a muon decreased from about 6% at 8 GeV/c to 1.3% above 20 GeV/c.

After reconstruction,<sup>20</sup> events with well-separated production and decay vertices were chosen to separate charm candidates from background. All events having masses near the  $D^0$  mass were *masked* so that any potential signal would not cause bias. All cuts were then chosen by studying signal events from Monte Carlo (MC) and background events, outside signal windows, from real data. We normalize to topologically similar hadronic 3-body (resonant) or 4-body (non-resonant) decays.

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| $D^0$ Decay                      | $D^0$ Norm.                | Events        | $D^0$ Decay         | $D^0$ Norm.               | Events          |
|----------------------------------|----------------------------|---------------|---------------------|---------------------------|-----------------|
| $\rho^0 \ell^\pm \ell^\mp$       | $\pi^+ \pi^- \pi^+ \pi^-$  | $2049 \pm 53$ | $\pi \pi \ell \ell$ | $\pi^+ \pi^- \pi^+ \pi^-$ | $2049 \pm 53$   |
| $\bar{K}^{*0} \ell^\pm \ell^\mp$ | $\bar{K}^{*0} \pi^+ \pi^-$ | $5451 \pm 72$ | $K \pi \ell \ell$   | $K^- \pi^+ \pi^- \pi^+$   | $11550 \pm 113$ |
| $\phi \ell^\pm \ell^\mp$         | $\phi \pi^+ \pi^-$         | $113 \pm 19$  | $K K \ell \ell$     | $K^+ K^- \pi^+ \pi^-$     | $406 \pm 41$    |

The upper limit for each branching fraction  $B_X$  is calculated using

$$B_X = \frac{N_X}{N_{\text{Norm}}} \frac{\varepsilon_{\text{Norm}}}{\varepsilon_X} \times B_{\text{Norm}} \quad \frac{\varepsilon_{\text{Norm}}}{\varepsilon_X} = \frac{N_{\text{Norm}}^{\text{MC}}}{N_X^{\text{MC}}} \quad (1)$$

where  $N_X$  is the 90% confidence level (CL) upper limit on the number of decays for the rare or forbidden decay mode  $X$ , and  $\varepsilon_X$  is that mode's detection efficiency.  $\varepsilon_{\text{Norm}}$  is the normalization mode detection efficiency,  $B_{\text{Norm}}$  is the normalization mode branching fraction, and  $N_{\text{Norm}}^{\text{MC}}$  and  $N_X^{\text{MC}}$  are the numbers of Monte Carlo events that are reconstructed and pass the final cuts, for the normalization and decay modes, respectively. The efficiencies for the normalization modes varied from 0.2% to 1%, and the efficiencies for the search modes varied from 0.05% to 0.34%.

The 90% CL upper limits  $N_X$  are calculated using the method of Feldman and Cousins<sup>21</sup> to account for background, and then corrected for systematic errors by the method of Cousins and Highland.<sup>22</sup> Results are shown in Fig. 1.

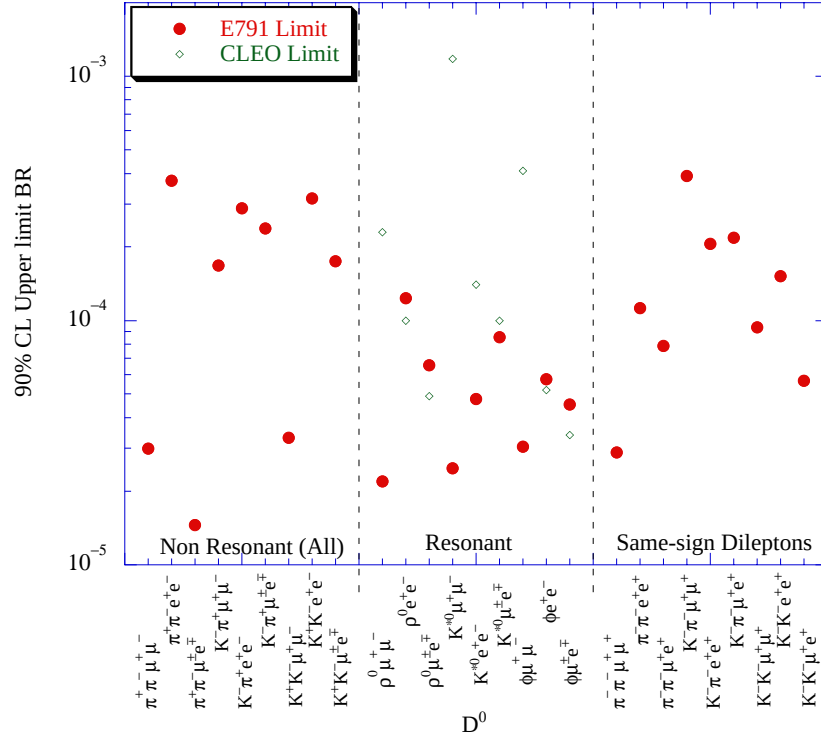


Figure 1: 90% CL branching fraction limits from E791<sup>1</sup> (•) and CLEO<sup>23</sup> (◊).

In summary, we use *blind* analyses to set 90% CL upper limits ranging from  $1.5 \times 10^{-5}$  ( $\pi^+ \pi^- \mu^\pm e^\mp$ ) to  $3.9 \times 10^{-4}$  ( $K^- \pi^- \mu^+ \mu^+$ ) for 27 FCNC and lepton-number/family violating decays of the  $D^0$ . No evidence for any of these 3 and 4-body decays is found.<sup>1</sup> Five limits are improvements over previous results;<sup>23</sup> 18 are new.

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