New Physics effects on leptonic decays of \( D^\pm/D_s^\pm \) mesons

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- \( D^\pm/D_s^\pm \rightarrow l^\pm \nu \)
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- Enhancement of \( D^\pm/D_s^\pm \rightarrow e^\pm \nu \)


Collaborator: S. Recksiegel (Munich)
CLEO-c Charm factory

Until 2002 CLEO was a $\sqrt{s} = 10.6$ GeV B factory
→ charm physics programme CLEO-c

- Charm threshold region: $3 \text{GeV} < \sqrt{s} < 5$ GeV
- Started operation in September 2003
- Charm physics studies complementary to those at hadron colliders and $e^+e^-$ B factories
- Advantages of lower backgrounds

Target:

- $\sqrt{s} = 3.77$ GeV: $3 \times 10^7 D^+D^-$ and $D^0\overline{D}^0$ (2004)
- $\sqrt{s} = 4.14$ GeV: $1.5 \times 10^6 D^+_sD^-_s$ (2005)
- Up to 100 times larger than existing data samples in the charm threshold region
Purely leptonic decays of $D^\pm$ and $D_s^\pm$ mesons

CLEO-c suitable to search for $D^\pm/D_s^\pm \rightarrow l^\pm\nu$

No spectator quark. Meson is annihilated via $W^\pm$, followed by $W^\pm \rightarrow l\nu$

Other examples are $\pi^\pm \rightarrow \mu^\pm\nu$, $e^\pm\nu$ and $K^\pm \rightarrow \mu^\pm\nu$, $e^\pm\nu$

Helicity suppression: proportional to $m_i^2$

$$\Gamma(D_q^+ \rightarrow l^+\nu_l) = \frac{G_F^2 m_{D_q} m_i^2 f_{D_q}^2}{8\pi} |V_{cq}|^2 \left(1 - \frac{m_i^2}{m_{D_q}^2}\right)^2$$

Main motivation for searching for these decays at CLEO-c is to measure $f_D$ and $f_{D_s}$

(Lattice gives $\approx 15\%$ error)
Experimental searches for $D_{(s)}^{\pm} \rightarrow l^{\pm}\nu$

i) Observed
ii) Upper limits
iii) No limits

<table>
<thead>
<tr>
<th>Decay</th>
<th>SM Rate</th>
<th>Current Exp.</th>
<th>CLEO-c</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D^+ \rightarrow e^+\nu_e$</td>
<td>$8.2 \times 10^{-9}$</td>
<td>$\times$</td>
<td>yes</td>
</tr>
<tr>
<td>$D^+ \rightarrow \mu^+\nu_\mu$</td>
<td>$3.5 \times 10^{-4}$</td>
<td>$(8^{+16}<em>{-5}^{+5}</em>{-2}) \times 10^{-4}$</td>
<td>3.8%</td>
</tr>
<tr>
<td>$D^+ \rightarrow \tau^+\nu_\tau$</td>
<td>$9.3 \times 10^{-4}$</td>
<td>$\times$</td>
<td>no</td>
</tr>
<tr>
<td>$D_s^+ \rightarrow e^+\nu_e$</td>
<td>$1.2 \times 10^{-7}$</td>
<td>$\times$</td>
<td>yes</td>
</tr>
<tr>
<td>$D_s^+ \rightarrow \mu^+\nu_\mu$</td>
<td>$5.2 \times 10^{-3}$</td>
<td>$(5.3 \pm 0.9 \pm 1.2) \times 10^{-3}$</td>
<td>3.2%</td>
</tr>
<tr>
<td>$D_s^+ \rightarrow \tau^+\nu_\tau$</td>
<td>$5.1 \times 10^{-2}$</td>
<td>$(6.1 \pm 1.0 \pm 1.3) \times 10^{-2}$</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

CLEO-c plans to measure 3 of the 6 decays

- Direct measurements of $f_D$ and $f_{D_s}$
- Important check of Lattice calculations

Question: Room for new physics at tree-level in these decays?

- $H^\pm$ (MSSM, 2HDM)
- $\tilde{\ell}^\pm$ (R parity violating MSSM)
Effect of $H^\pm$ on $D^\pm_s \to \mu^\pm \nu$ and $D^\pm_s \to \tau^\pm \nu$

$$\Gamma(D_s \to l^\pm \nu) \to r \Gamma(D_s \to l^\pm \nu)$$

$$r = \left[1 - R^2 m_{D_s}^2 (m_s/m_c)\right]^2$$

with $R = \tan \beta/M_{H^\pm}$

- Destructive interference
- $r$ independent of lepton flavour
- Maximized for large $R$ and $m_s/m_c$

For observable $D^\pm \to \tau^\pm \nu, \mu^\pm \nu$ can reach $r = 0.85$
non-negligible correction to the SM rate

- Larger than CLEO-c expected error (2% $\to$ 3%)
- Larger than electroweak corrections ($< 2\%$)
- Affect the measured valued of the decay constant $f_D$.
Enhancement of $D^\pm/D_s^\pm \to e^\pm\nu$

Cleanest channels to look for new physics are $D^\pm/D_s^\pm \to e^\pm\nu$.

Tree-level slepton contributions in R parity violating MSSM

SM suppression of $G_F m_e$ is replaced by:

$$\lambda_{ijq}^* \lambda_{inl} / m_l^2$$

Optimal combinations:

- For $D^\pm \to e^\pm\nu_\tau$: $\lambda_{221}^* \lambda_{231}$
- For $D_s^\pm \to e^\pm\nu_\tau$: $\lambda_{222}^* \lambda_{231}$

Correlation with lepton number violating decays $\tau^\pm \to e^\pm K_S^0$ and $\tau^\pm \to e^\pm\eta$
$\text{BR}(D^\pm \rightarrow e^\pm \nu) \text{ against } \text{BR}(\tau^\pm \rightarrow e^\pm K^0)$

$\text{BR}(D_s \rightarrow e\nu_e)$

$\text{BR}(D_s^\pm \rightarrow e^\pm \nu) \text{ against } \text{BR}(\tau^\pm \rightarrow e^\pm \eta)$
Conclusions

- CLEO-c has started operation
- Purely leptonic decays of $D^\pm/D_s^\pm$ mesons can be probed
- New physics ($H^\pm, \tilde{t}^\pm$) can affect some of these decays
- No experimental limits for $D^\pm/D_s^\pm \rightarrow e^\pm\nu$ 
  → mere observation would an unambiguous signal of new physics
- R Parity violating slepton contributions can enhance $D^\pm/D_s^\pm \rightarrow e^\pm\nu$ to experimental sensitivity 
  → BR $\approx 10^{-4}$
- Correlated with $\tau^\pm \rightarrow e^\pm K^0_S$ and $\tau^\pm \rightarrow e^\pm \eta$
- CLEO-c are interested in searching for $D^\pm/D_s^\pm \rightarrow e^\pm\nu$