Weak $B$ Decays into Orbitally Excited Charmed Mesons

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Weak $B$ Decays into Orbitally Excited Charmed Mesons

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1.- Introduction
1.1.- Overview

- Accuracy on the knowledge of $|V_{cb}|$ and $|V_{ub}|$ demands detailed measurements of $b$-hadron decays

- A substantial contribution to the semileptonic decay width of $b$-hadrons is provided by decays including orbitally excited charmed mesons in their final state.

- Additionally, the analysis of signals and backgrounds of inclusive and exclusive measurements of $b$-hadron decays calls for an improved understanding of these processes.

- In this scenario, data reported by Belle and BaBar offer new theoretical possibilities to test meson models as far as they include both weak and strong decays.
1.- Introduction

1.2.- Belle and BaBar measurements

|                          | Belle [1] ($\times 10^{-3}$) | BaBar [2] ($\times 10^{-3}$) |
|--------------------------|-------------------------------|-----------------------------|
| $D_2^*(2460)$            |                               |                             |
| $\mathcal{B}(B^+ \rightarrow D_2^{*0} l^+ \nu_l) \mathcal{B}(D_2^{*0} \rightarrow D^+ \pi^-)$ | $2.2 \pm 0.3 \pm 0.4$        | $1.4 \pm 0.2 \pm 0.2(*)$    |
| $\mathcal{B}(B^+ \rightarrow D_2^{*0} l^+ \nu_l) \mathcal{B}(D_2^{*0} \rightarrow D^{*+} \pi^-)$ | $1.8 \pm 0.6 \pm 0.3$        | $0.9 \pm 0.2 \pm 0.2(*)$    |
| $\mathcal{B}(B^0 \rightarrow D_2^{*-} l^+ \nu_l) \mathcal{B}(D_2^{*-} \rightarrow D^0 \pi^-)$ | $2.2 \pm 0.4 \pm 0.4$        | $1.1 \pm 0.2 \pm 0.1(*)$    |
| $\mathcal{B}(B^0 \rightarrow D_2^{*-} l^+ \nu_l) \mathcal{B}(D_2^{*-} \rightarrow D^{*0} \pi^-)$ | $< 3$                        | $0.7 \pm 0.2 \pm 0.1(*)$    |
| $\mathcal{B}_{D/D^*}$   | $0.55 \pm 0.03$               | $0.62 \pm 0.03$             |
| $D_1(2420)$             |                               |                             |
| $\mathcal{B}(B^+ \rightarrow D_1^{0} l^+ \nu_l) \mathcal{B}(D_1^{0} \rightarrow D^{*+} \pi^-)$ | $4.2 \pm 0.7 \pm 0.7$        | $2.97 \pm 0.17 \pm 0.17$    |
| $\mathcal{B}(B^0 \rightarrow D_1^{-} l^+ \nu_l) \mathcal{B}(D_1^{-} \rightarrow D^{*0} \pi^-)$ | $5.4 \pm 1.9 \pm 0.9$        | $2.78 \pm 0.24 \pm 0.25$    |

1. D. Liventsev et al. (Belle Collaboration), *Phys. Rev. D* **77**, 091503 (2008)
2. B. Aubert et al. (BaBar Collaboration), *Phys. Rev. Lett.* **103**, 051803 (2009)
2.- Theoretical framework

2.1.- Constituent quark model. Main features

- Spontaneous chiral symmetry breaking (Goldstone-Boson exchange):
  \[ L = \bar{\psi} \left( i \gamma^\mu \partial_\mu - MU^\gamma_5 \right) \psi \rightarrow U^\gamma_5 = 1 + \frac{i}{f_\pi} \gamma^5 \lambda^a \pi^a - \frac{1}{2f_\pi^2} \pi^a \pi^a + \ldots \]
  \[ M(q^2) = m_q F(q^2) = m_q \left[ \frac{\Lambda^2}{\Lambda^2 + q^2} \right]^{1/2} \]

- QCD perturbative effects (One-Gluon Exchange):
  \[ L = i \sqrt{4\pi \alpha_s} \bar{\psi} \gamma_\mu G^\mu \lambda^c \psi \]

- Confinement (screened potential):
  \[ V^C_{CON}(\vec{r}_{ij}) = \left[ -a_c (1 - e^{-\mu_c r_{ij}}) + \Delta \right] (\vec{\lambda}_i^c \cdot \vec{\lambda}_j^c) \]

\[
\begin{align*}
V^C_{CON}(\vec{r}_{ij}) &= \left( -a_c \mu_c r_{ij} + \Delta \right) (\vec{\lambda}_i^c \cdot \vec{\lambda}_j^c) \quad r_{ij} \rightarrow 0 \\
V^C_{CON}(\vec{r}_{ij}) &= \left( -a_c + \Delta \right) (\vec{\lambda}_i^c \cdot \vec{\lambda}_j^c) \quad r_{ij} \rightarrow \infty
\end{align*}
\]
2.- Theoretical framework

2.1.- Constituent quark model. Some applications

- **N-N interaction**
  - D.R. Entem, F. Fernández and A. Valcarce, Phys. Rev. C 62, 034002 (2000)
  - B. Julia-Diaz, J. Haidenbauer, A. Valcarce and F. Fernández, Phys. Rev. C 65, 034001 (2002)

- **Baryon spectrum**
  - H. Garcilazo, A. Valcarce and F. Fernández, Phys. Rev. C 63, 035207 (2001)
  - H. Garcilazo, A. Valcarce and F. Fernández, Phys. Rev. C 64, 058201 (2001)

- **Meson spectrum**
  - J. Vijande, A. Valcarce and F. Fernández, J. Phys. G 31, 481 (2005)
  - J. Segovia, D.R. Entem and F. Fernández, Phys. Rev. D 78 114033 (2008)
  - J. Segovia, D.R. Entem and F. Fernández, accepted by Phys. Rev. D

- **Molecular states**
  - P. G. Ortega, J. Segovia, D. R. Entem and F. Fernández, Phys. Rev. D 81, 054023 (2010)
2.- Theoretical framework

2.1.- Constituent quark model. Some applications (Continuation)

| Deuteron |          |          |          |          |
|----------|----------|----------|----------|----------|
| CQM      | NijmII   | Born B   | Exp.     |          |
| $\epsilon_d$ (MeV) | -2.2242  | -2.2246  | -2.2246  | -2.22475 |
| $P_D$ (%) | 4.85     | 5.64     | 4.99     |          |
| $Q_d$ (fm$^2$) | 0.276    | 0.271    | 0.278    | 0.2859±0.0003 |
| $A_S$ (fm$^{-1/2}$) | 0.891    | 0.8845   | 0.8860   | 0.8846±0.0009 |
| $A_D/A_S$ | 0.0257   | 0.0252   | 0.0264   | 0.0256±0.0004 |

Light mesons

Charmonium reactions

X(3872)

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2.- Theoretical framework

2.1.- Constituent quark model. Mass predictions involved in the reactions

| Quark masses | \( m_n \) (MeV) | 313 |
|-------------|----------------|-----|
|             | \( m_c \) (MeV) | 1763 |
|             | \( m_b \) (MeV) | 5110 |
| Confinement | \( a_c \) (MeV) | 507.4 |
|             | \( \mu_c \) (fm\(^{-1}\)) | 0.576 |
|             | \( \Delta \) (MeV) | 184.432 |
|             | \( a_s \) | 0.81 |
| One-gluon exchange | \( \alpha_0 \) | 2.118 |
|             | \( \Lambda_0 \) (fm\(^{-1}\)) | 0.113 |
|             | \( \mu_0 \) (MeV) | 36.976 |
|             | \( \hat{r}_0 \) (fm) | 0.181 |
|             | \( \hat{r}_g \) (fm) | 0.259 |

GBE taken from Ref. [1]

| Meson     | \( J^{PC} \) | CQM (MeV) | EXP (MeV)       |
|-----------|--------------|-----------|-----------------|
| \( B \)   | 0\(^-\)      | 5275      | 5279.34 ± 0.21  |
| \( D \)   | 0\(^-\)      | 1896      | 1867.22 ± 0.11  |
| \( D^* \) | 1\(^-\)      | 2017      | 2008.60 ± 0.11  |
| \( D_1(2420) \) | 1\(^+\) | 2466      | 2422.15 ± 1.6   |
| \( D_2^*(2460) \) | 2\(^+\) | 2513      | 2461.4 ± 2.3    |
| \( \pi \) | 0\(^{-+}\)   | 138       | 137.27339 ± 0.00035 |

[1] J. Vijande, F. Fernández and A. Valcarce J. Phys. G 31 481 (2005)
2.- Theoretical framework
2.2.- Weak decays. Total decay width

Study of the weak process based on
- E. Hernández, J. Nieves and J.M. Verde-Velasco, Phys. Rev. D 74, 074008 (2006)
- M.A. Ivanov, J.G. Körner and P. Santorelli, Phys. Rev. D 73, 054024 (2006)
2.- Theoretical framework

2.2.- Weak decays. Case \(0^− \rightarrow 2^+\)

\[
\langle D(2^+), \lambda \vec{P}_D \mid J^{cb}_\mu(0) \mid B(0^-) \vec{P}_B \rangle = \epsilon_{\mu \nu \alpha \beta} \epsilon^{\nu \delta^*}_{(\lambda)} (\vec{P}_D) P_\delta P^\alpha q^\beta T_4(q^2)
\]

\[
- i \left\{ \epsilon^{*}_{(\lambda) \mu \delta}(\vec{P}_D) P^\delta T_1(q^2) + P^{\nu} P^{\delta} \epsilon^{*}_{(\lambda) \nu \delta}(\vec{P}_D) \left[ P_\mu T_2(q^2) + q_\mu T_3(q^2) \right] \right\}
\]

\[
T_1(q^2) = - i \frac{2m_D}{m_B |\vec{q}|} A^1_{T \lambda = +1}(|\vec{q}|),
\]

\[
T_2(q^2) = i \frac{1}{2m_B^3} \left\{ - \sqrt{\frac{3}{2}} \frac{m^2_D}{|\vec{q}|^2} A^0_{T \lambda = 0}(|\vec{q}|) - \sqrt{\frac{3}{2}} \frac{m^2_D}{|\vec{q}|^3} \left( E_D(-\vec{q}) - m_B \right) A^3_{T \lambda = 0}(|\vec{q}|) \right. \\
+ \left. \frac{2m_D}{|\vec{q}|} \left( 1 - \frac{E_D(-\vec{q}) E_D(-\vec{q}) - m_B}{|\vec{q}|^2} \right) A^1_{T \lambda = +1}(|\vec{q}|) \right\}
\]

\[
T_3(q^2) = i \frac{1}{2m_B^3} \left\{ - \sqrt{\frac{3}{2}} \frac{m^2_D}{|\vec{q}|^2} A^0_{T \lambda = 0}(|\vec{q}|) - \sqrt{\frac{3}{2}} \frac{m^2_D}{|\vec{q}|^3} \left( E_D(-\vec{q}) + m_B \right) A^3_{T \lambda = 0}(|\vec{q}|) \right. \\
+ \left. \frac{2m_D}{|\vec{q}|} \left( 1 - \frac{E_D(-\vec{q}) E_D(-\vec{q}) + m_B}{|\vec{q}|^2} \right) A^1_{T \lambda = +1}(|\vec{q}|) \right\}
\]

\[
T_4(q^2) = i \frac{m_D}{m_B^2 |\vec{q}|^2} V^1_{T \lambda = +1}(|\vec{q}|)
\]

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2.- Theoretical framework
2.2.- Weak decays. Case $0^- \rightarrow 1^+$

\[
\langle D(1^+), \lambda \vec{P}_D | J^{cb}_\mu (0) | B(0^-), \vec{P}_B \rangle = \frac{-1}{m_B + m_D} \epsilon_{\mu \nu \alpha \beta} \epsilon^{(\lambda)}(\vec{P}_D) P^\alpha q^\beta A(q^2) \\
- i \left\{ (m_B - m_D) \epsilon_{(\lambda)\mu}^*(\vec{P}_D) V_0(q^2) - \frac{P \cdot \epsilon_{(\lambda)}^*(\vec{P}_D)}{m_B + m_D} \left[ P_\mu V_+(q^2) + q_\mu V_-(q^2) \right] \right\}
\]

\[
A(q^2) = - \frac{i}{\sqrt{2}} \frac{m_B + m_D}{m_B |\vec{q}|} A^1_{\lambda=-1}(|\vec{q}|)
\]

\[
V_+(q^2) = + i \frac{m_B + m_D}{2m_B} \frac{m_D}{|\vec{q}| m_B} \left\{ V^0_{\lambda=0}(|\vec{q}|) - \frac{m_B - E_D(-\vec{q})}{|\vec{q}|} V^3_{\lambda=0}(|\vec{q}|) \right\} \\
+ \sqrt{2} \frac{m_B E_D(-\vec{q}) - m_D^2}{|\vec{q}| m_D} V^1_{\lambda=-1}(|\vec{q}|)
\]

\[
V_-(q^2) = - i \frac{m_B + m_D}{2m_B} \frac{m_D}{|\vec{q}| m_B} \left\{ - V^0_{\lambda=0}(|\vec{q}|) - \frac{m_B + E_D(-\vec{q})}{|\vec{q}|} V^3_{\lambda=0}(|\vec{q}|) \right\} \\
+ \sqrt{2} \frac{m_B E_D(-\vec{q}) + m_D^2}{|\vec{q}| m_D} V^1_{\lambda=-1}(|\vec{q}|)
\]

\[
V_0(q^2) = + i \sqrt{2} \frac{1}{m_B - m_D} V^1_{\lambda=-1}(|\vec{q}|)
\]

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Weak $B$ Decays into Orbitally Excited Charmed Mesons
2.- Theoretical framework

2.3.- Strong decays. $^3P_0$ and microscopic models

- $^3P_0$ decay model

\[
H_I = g \int d^3\bar{\psi}(\vec{x}) \psi(\vec{x})
\]

- Microscopic decay model

\[
H_I = \frac{1}{2} \int d^3x d^3y J^a(\vec{x}) K(|\vec{x} - \vec{y}|) J^a(\vec{y})
\]
2. Theoretical framework

2.3. Strong decays. $^3P_0$ and microscopic models (Continuation)

$^3P_0$ decay model

- L. Micu, Nucl. Phys. B 10, 521 (1969)
- A. Le Yaouanc, L. Olivier, O. Pène, and J.C. Raynal, Phys. Rev. D 8, 2223 (1973)
- R. Bonnaz, and B. Silvestre-Brac, Few-Body Syst. 27, 163 (1999)

Microscopic decay model

- E. Eichten et al. Phys. Rev. D 17 3090 (1978); 21 203 (1980)
  → update: Phys. Rev. D 73 014014 (2006)
- E.S. Ackleh et al. Phys. Rev. D 54, 6811 (1996)
- Yu.A. Simonov arXiv:1103.4028v1 [hep-ph] 21 Mar 2011
- Bao-Fei Li et al. arXiv:1105.1620v1 [hep-ph] 9 May 2011

\[
\Gamma_{A\rightarrow BC} = 2\pi \frac{E_B E_C}{M_A k_0} \sum_{J_{BC}, I} |\mathcal{M}_{A\rightarrow BC}(k_0; J_{BC}, I)|^2
\]

\[
\mathcal{M}_{A\rightarrow BC} = \mathcal{M}_{A\rightarrow BC} + (-1)^{I_B + I_C - I_A + J_B + J_C - J_{BC} + I} \mathcal{M}_{A\rightarrow CB}
\]

\[
\mathcal{M}_{A\rightarrow BC} = \mathcal{I}_{color} \mathcal{I}_{flavor} (\mathcal{I}_{signature} \mathcal{I}_{spin-space})
\]
2.- Theoretical framework

2.3.- Strong decays. Factors for the $^3P_0$ model

- Color term $\Rightarrow$

$$I_{\text{color}} = \frac{1}{\sqrt{3}}$$

- Flavor term $\Rightarrow$

$$I_{\text{flavor}} = (-1)^{t_\alpha + t_\beta + l_A} \delta_{f_\alpha f_\delta} \delta_{f_\beta f_\rho} \delta_{f_\mu f_\lambda} \delta_{f_\nu f_\epsilon} \sqrt{(2l_B + 1)(2l_C + 1)(2t_\mu + 1)} \begin{pmatrix} t_\beta \\ l_C \\ t_\alpha \\ l_A \end{pmatrix}$$

- Spin-space term $\Rightarrow$

$$I_{\text{spin-space}} = \frac{1}{\sqrt{1 + \delta_{BC}}} \int d^3K_B d^3K_C d^3p_\alpha d^3p_\beta d^3p_\mu d^3p_\nu \delta^{(3)}(\vec{K} - \vec{K}_0)$$

$$\delta^{(3)}(\vec{K}_B - \vec{P}_B)\delta^{(3)}(\vec{K}_C - \vec{P}_C)\delta^{(3)}(\vec{p}_\mu + \vec{p}_\nu)\delta^{(3)}(\vec{P}_A) \frac{\delta(k - k_0)}{k}$$

$$\langle \{ [\phi_B(\vec{p}_B)(s_\alpha s_\nu)S_B] J_B [\phi_C(\vec{p}_C)(s_\mu s_\beta)S_C] J_C ] J_{BC} Y_l(\hat{k}) \} J_A |$$

$$\{ [\phi_A(\vec{p}_A)(s_\alpha s_\beta)S_A] J_A [\gamma_{\mu + (1)} \left( \frac{\vec{p}_\mu - \vec{p}_\nu}{2} \right) (s_\mu s_\nu) 1 \} 0 \} J_A \rangle$$
2.- Theoretical framework
2.3.- Strong decays. Factors for the microscopic model

- Color term ⇒
  \[ I_{color} = \frac{2^2}{3^2} \]

- Flavor term ⇒
  \[ I_{flavor} = (-1)^{t_{\alpha}+t_{\beta}+I_{A}} \delta_{f_{\alpha}f_{\delta}} \delta_{f_{\beta}f_{\rho}} \delta_{f_{\mu}f_{\lambda}} \delta_{f_{\nu}f_{\epsilon}} \sqrt{(2l_{B} + 1)(2l_{C} + 1)(2t_{\mu} + 1)} \left\{ \begin{array}{ccc} t_{\beta} & l_{C} & t_{\mu} \\ l_{B} & t_{\alpha} & l_{A} \end{array} \right\} \]

- Spin-space term ⇒
  \[ I_{spin-space} = \frac{-2}{\sqrt{1 + \delta_{BC}}} \int d^{3}K_{B}d^{3}K_{C} \sum_{m, M_{BC}} \langle J_{BC} M_{BC} | \text{Im} | J_{A} M_{A} \rangle \delta^{(3)}(\vec{K} - \vec{K}_{0}) \delta(k - k_{0}) \]
  \[ \frac{Y_{Im}(\hat{k})}{k} \sum_{M_{B}, M_{C}} \langle J_{B} M_{B} J_{C} M_{C} | J_{BC} M_{BC} \rangle \int d^{3}p_{\delta} d^{3}p_{\epsilon} d^{3}p_{\lambda} d^{3}p_{\rho} \delta^{(3)}(\vec{K}_{B} - \vec{P}_{B}) \]
  \[ \delta^{(3)}(\vec{K}_{C} - \vec{P}_{C}) \phi_{B}(\vec{p}_{B}) \phi_{C}(\vec{p}_{C}) \delta_{\rho \beta} \delta^{(3)}(\vec{p}_{\rho} - \vec{p}_{\beta}) \delta^{(3)}(\vec{p}_{\lambda} + \vec{p}_{\epsilon} + \vec{p}_{\delta} - \vec{p}_{\alpha}) \]
  \[ K(|\vec{p}_{\lambda} + \vec{p}_{\epsilon}|) \lim_{v/c \rightarrow 0} [\bar{u}_{\alpha}(\vec{p}_{\lambda}) \Gamma v_{\epsilon}(\vec{p}_{\epsilon})] \lim_{v/c \rightarrow 0} [\bar{u}_{\delta}(\vec{p}_{\delta}) \Gamma u_{\alpha}(\vec{p}_{\alpha})] \]
  \[ \int d^{3}p_{\alpha} d^{3}p_{\beta} \delta^{(3)}(\vec{P}_{A}) \phi_{A}(\vec{p}_{A}) \]
3.- Results

3.1.- Semileptonic $B \rightarrow D_2^* l \nu_l$ decay

Semileptonic decay widths

$\Gamma(B^+ \rightarrow \bar{D}_2^{0*} l^+ \nu_l) = 1.3388 \times 10^{-15}$ GeV $\Rightarrow B(B^+ \rightarrow \bar{D}_2^{0*} l^+ \nu_l) = 3.3320 \times 10^{-3}$

$\Gamma(B^0 \rightarrow D_2^{*-} l^+ \nu_l) = 1.3454 \times 10^{-15}$ GeV $\Rightarrow B(B^0 \rightarrow D_2^{*-} l^+ \nu_l) = 3.1172 \times 10^{-3}$

Some results about strong decays

| B               | Exp.          | $^3P_0$    | Microscopic |
|-----------------|---------------|------------|-------------|
| $\frac{\Gamma(D_2^{*+} \rightarrow D^0 \pi^+)}{\Gamma(D_2^{*+} \rightarrow D^{*0} \pi^+)}$ | $1.9 \pm 1.1 \pm 0.3$ | 1.80 | 1.97 |
| $\frac{\Gamma(D_2^{*0} \rightarrow D^+ \pi^-)}{\Gamma(D_2^{*0} \rightarrow D^{*+} \pi^-)}$ | $1.56 \pm 0.16$ | 1.82 | 1.97 |
| $\frac{\Gamma(D_2^{*0} \rightarrow D^+ \pi^-)}{\Gamma(D_2^{*0} \rightarrow D^{(*)+} \pi^-)}$ | $0.62 \pm 0.03 \pm 0.02$ | 0.64 | 0.66 |
3.- Results

3.2.- Semileptonic $B \rightarrow D_1 l \nu_l$ decay

- Semileptonic decay widths

$$\Gamma(B^+ \rightarrow \bar{D}^0_1 l^+ \nu_l) = 1.5490 \times 10^{-15} \text{ GeV} \Rightarrow B(B^+ \rightarrow \bar{D}^0_1 l^+ \nu_l) = 3.8552 \times 10^{-3}$$

$$\Gamma(B^0 \rightarrow D^- l^+ \nu_l) = 1.5445 \times 10^{-15} \text{ GeV} \Rightarrow B(B^0 \rightarrow D^- l^+ \nu_l) = 3.5785 \times 10^{-3}$$

Only one open-charm decay $\Rightarrow B(D^0_1 \rightarrow D^{*+} \pi^-) = B(D^-_1 \rightarrow D^{*0} \pi^-) = 2/3$
## Results

### 3.3.- Comparison with experiment

|                | Belle ($\times 10^{-3}$) | BaBar ($\times 10^{-3}$) | $^3P_0$ ($\times 10^{-3}$) | Mic. ($\times 10^{-3}$) |
|----------------|---------------------------|--------------------------|---------------------------|-------------------------|
| $D_2^*$ (2460) |                            |                          |                           |                         |
| $B(B^+ \to D_2^{*0} l^+ \nu_l)B(D_2^{*0} \to D^+ \pi^-)$ | 2.2 ± 0.5                | 1.42 ± 0.21              | 1.43                      | 1.47                    |
| $B(B^+ \to D_2^{*0} l^+ \nu_l)B(D_2^{*0} \to D^{*+} \pi^-)$ | 1.8 ± 0.7                | 0.87 ± 0.21              | 0.79                      | 0.75                    |
| $B(B^+ \to D_2^{*0} l^+ \nu_l)B(D_2^{*0} \to D^{(*)+} \pi^-)$ | 4.0 ± 0.9                | 2.29 ± 0.31              | 2.22                      | 2.22                    |
| $B(B^0 \to D_2^{*-} l^+ \nu_l)B(D_2^{*-} \to D^0 \pi^-)$ | 2.2 ± 0.6                | 1.10 ± 0.19              | 1.34                      | 1.38                    |
| $B(B^0 \to D_2^{*-} l^+ \nu_l)B(D_2^{*-} \to D^{*0} \pi^-)$ | < 3                      | 0.67 ± 0.19              | 0.74                      | 0.70                    |
| $B(B^0 \to D_2^{*-} l^+ \nu_l)B(D_2^{*-} \to D^{(*)0} \pi^-)$ | < 5.2                    | 1.77 ± 0.28              | 2.08                      | 2.08                    |
| $B_{D/D^{(*)}}$ | 0.55 ± 0.03               | 0.62 ± 0.04              | 0.64                      | 0.66                    |
| $D_1$ (2420) |                            |                          |                           |                         |
| $B(B^+ \to D_1^{0} l^+ \nu_l)B(D_1^{0} \to D^{*+} \pi^-)$ | 4.2 ± 1.0                | 2.97 ± 0.24              | 2.57                      | 2.57                    |
| $B(B^0 \to D_1^{-} l^+ \nu_l)B(D_1^{-} \to D^{*0} \pi^-)$ | 5.4 ± 2.1                | 2.78 ± 0.35              | 2.39                      | 2.39                    |
4.- Summary and conclusions

- We have studied semileptonic $B$ decays into orbitally excited charmed mesons

- These data offer new theoretical possibilities to test meson models as far as they include weak and strong processes

- Weak decays: Studied within spectator approximation and in the helicity formalism.

- Strong decays: We study these processes within the context of the $^3P_0$ and microscopic models

- Predictions for $B \rightarrow D_2^* l\nu_l$ and $B \rightarrow D_1 l\nu_l$: very good agreement with BaBar data which are the latest measurements. All theoretical results within the error bars

- In both cases the theoretical predictions are smaller than the Belle data