**EuroFlavour07** **November 2007**

**Orsay**

# WG2 summary

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# Overview

The WG2 parallel session contained four presentations:

1. Sascha Turczyk (U Siegen): Inclusive semi–leptonic B decays to order $1/m_b^4$
2. Sven Faller (U Siegen): $B \to D^{(*)}$ form factors from QCD sum rules with B meson distribution amplitudes
3. Robert Feger (U Siegen): Testing the left–handedness of the $b \to c$ transitions
4. Benoît Blossier (DESY Zeuthen) $1/2$ vs $3/2$ puzzle in $B \to X_c \ell \nu_\ell$

## 1. Sascha Turczyk: Inclusive semi–leptonic B decays to order $1/m_b^4$

OPE for inclusive semi-leptonic $B \to X_c e \bar{\nu}_e$ decays:

$$\Gamma = \frac{G_F^2 m_b^5}{192\pi^3}|V_{cb}|^2 \left( \hat{\Gamma}^{(0)} + \frac{\hat{\Gamma}^{(2)}}{m_b^2} + \frac{\hat{\Gamma}^{(3)}}{m_b^3} + \frac{\hat{\Gamma}^{(4)}}{m_b^4} + \dots \right) .$$

New matrix elements at order $1/m_b^4$:

$$\begin{aligned}
2M_B\ s_1 &= \langle B(p)|\bar{b}_v iD_\rho (ivD)^2 iD^\rho b_v|B(p)\rangle \\
2M_B\ s_2 &= \langle B(p)|\bar{b}_v iD_\rho (iD)^2 iD^\rho b_v|B(p)\rangle \\
2M_B\ s_3 &= \langle B(p)|\bar{b}_v ((iD)^2)^2 b_v|B(p)\rangle \\
2M_B\ s_4 &= \langle B(p)|\bar{b}_v iD_\mu (iD)^2 iD_\nu (-i\sigma^{\mu\nu}) b_v|B(p)\rangle \\
2M_B\ s_5 &= \langle B(p)|\bar{b}_v iD_\rho iD_\mu iD_\nu iD^\rho (-i\sigma^{\mu\nu}) b_v|B(p)\rangle
\end{aligned}$$

Using “guesstimates” for $s_{1-5}$ Turczyk et al. calculated moments of the charged lepton energy and of the hadronic invariant mass spectrum. The impact of the $1/m_b^4$ terms on the total rate (and the determination of $|V_{cb}|$) is

$$\frac{\delta^{(4)}\Gamma}{\Gamma} \approx 0.25\%.$$

## 2. Sven Faller: $B \to D^{(*)}$ form factors from QCD sum rules with B meson distribution amplitudes

Calculation of $B \to D^{(*)}$ form factors with Light–cone sum rules. Method applied previously to $B \to \pi, K$ and $B \to \rho, K^*$ [ Khodjamirian et al. (2007)].

Framework: Heavy Quark Effective Theory for B meson distribution amplitudes and form factors:

$$\frac{\langle D(p)|V^\mu|\bar{B}(p+q)\rangle}{\sqrt{m_B m_D}} = h_+(w)(v+v')^\mu + h_-(w)(v-v')^\mu$$

$$\frac{\langle D^*(v',\epsilon)|V^\mu|\bar{B}(v)\rangle}{\sqrt{m_B m_D^*}} = h_V(w)\epsilon^{\mu\nu\alpha\beta}\ \epsilon^*_\nu\ v'_\alpha v_\beta$$

Isgur-Wise limit $m_{b,c} \to \infty$, $\frac{m_c}{m_b} = \kappa^2 = const.$.

Result:

$$h_{+,V}^{BD,IW}(w) = \frac{\tilde{f}_B}{\tilde{f}_{D^{(*)}}} \int_0^{\beta_0/w} d\omega \exp\left\{ \frac{\omega}{\tau}\left(\frac{\kappa^2}{2} - w\right) + \frac{\bar{\Lambda}}{\tau} \right\}. \left[ \frac{1}{2w}\phi_-^B(\omega) + \left(1 - \frac{1}{2w}\right)\phi_+^B(\omega) \right]$$

and

$$h_-^{BD,IW}(w) \equiv 0$$

where $\tilde{f}_{B,D^{(*)}} = \sqrt{m_{b,c}} f_{B,D^{(*)}}$, $\beta_0 = (s_0^{D^{(*)}} - m_c^2)/m_c$ and $\bar{\Lambda} = m_B - m_b$, $\phi_-^B$ and $\phi_+^B$ are the B meson LCDAs and $M^2 = 2m_c\tau$ is the Borel parameter.

## 3. Robert Feger: Testing the left-handedness of the $b \to c$ transition

Ansatz: "Michel parameters" to parameterise New Physics in semi–leptonic $b \to c$ transitions:

$$J_{h,\mu} = c_L \bar{c} \gamma_\mu P_L b + c_R \bar{c} \gamma_\mu P_R b + g_L \bar{c} \frac{iD_\mu}{m_b} P_L b + g_R \bar{c} \frac{iD_\mu}{m_b} P_R b + d_L \frac{i\partial^\nu}{m_b} (\bar{c}\, i\sigma_{\mu\nu} P_L b) + d_R \frac{i\partial^\nu}{m_b} (\bar{c}\, i\sigma_{\mu\nu} P_R b),$$

$c_{L/R}$: left/right-handed vector current

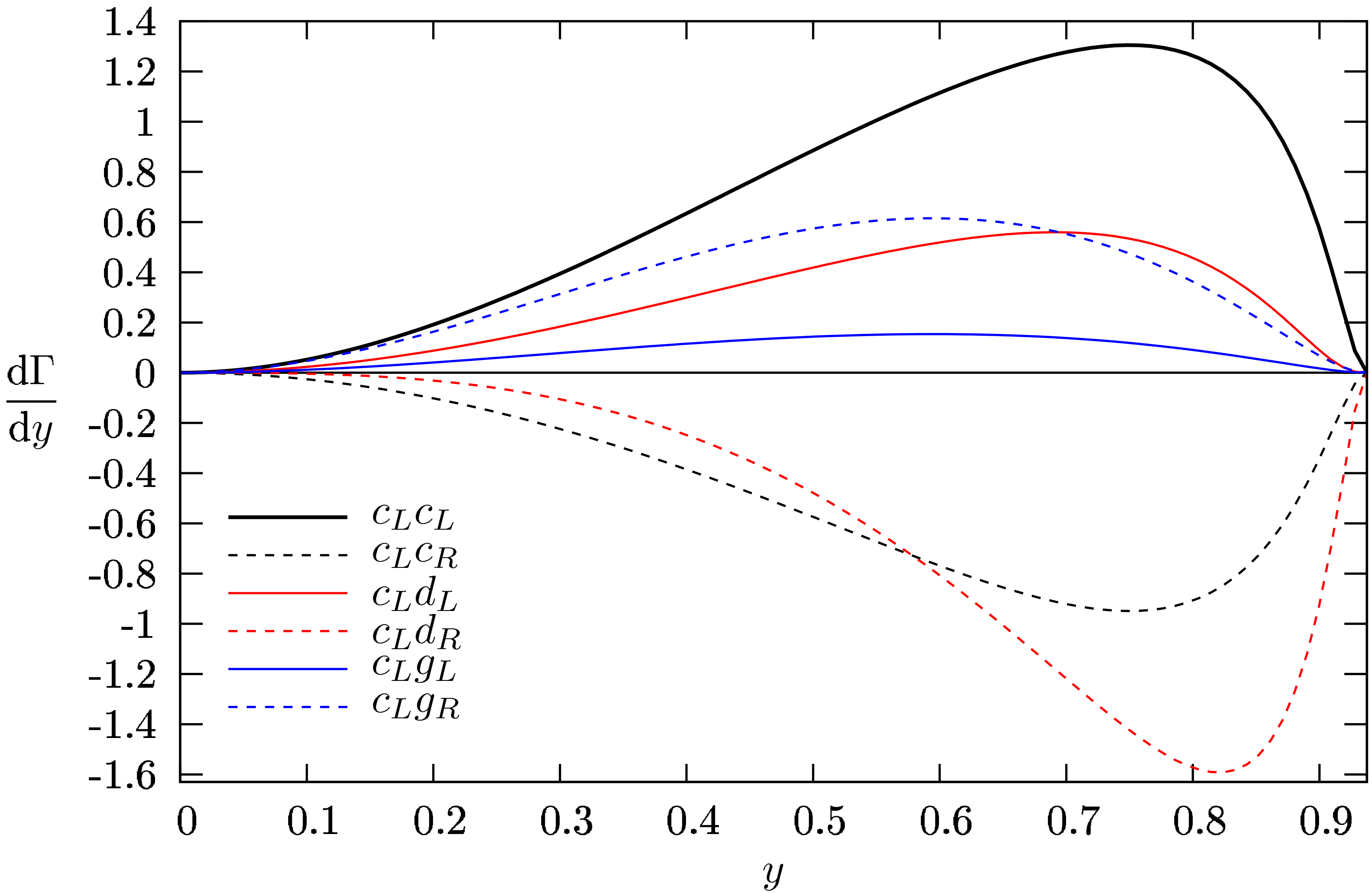
$g_{L/R}$: left/right-handed scalar current

$d_{L/R}$: left/right-handed tensor current

Standard model: $c_L = 1$ and $c_R = g_L = g_R = d_L = d_R = 0$

Sizeable effects possible.

Tree-level coefficient functions of the lepton energy spectrum ($y = 2E_\ell/m_b$):



## 4. Benoît Blossier: "1/2 vs. 3/2" puzzle in $\overline{B} \to X_c l \bar{\nu}$

Heavy Quark Limit: The angular momentum $j_l$ of the light degrees of freedom in a charm-flavoured meson is a good quantum number.

$D$: $J^P = 0^-$ and $j_l^P = \frac{1}{2}^-$
$D^*$: $J^P = 1^-$ and $j_l^P = \frac{1}{2}^-$

$D_0^*$: $J^P = 0^+$ and $j_l^P = \frac{1}{2}^+$
$D_1^*$: $J^P = 1^+$ and $j_l^P = \frac{1}{2}^+$
$D_1$: $J^P = 1^+$ and $j_l^P = \frac{3}{2}^+$
$D_2^*$: $J^P = 2^+$ and $j_l^P = \frac{3}{2}^+$

- The composition of the final state $X_c$ in $\bar{B} \to X_c l \bar{\nu}$ has received some attention since 10 years, see e.g. I. Bigi *et al* in arXiv:0708.1621.
- Theoretically, it is expected that the odd-parity states $D, D^*$ and the 4 first parity-even $D^{**}$ states do not saturate the total width.
- Covariant quark models, the Uraltsev sum rule (extracted from the OPE in

the $m_Q \to \infty$ limit of the Heavy Quark Expansion) and an exploratory lattice QCD computation lead to the conclusion that $[\Gamma(\bar{B} \to D\left(\frac{1}{2}\right)^{+} l\bar{\nu}) < \Gamma(\bar{B} \to D\left(\frac{3}{2}\right)^{+} l\bar{\nu})]^{\rm TH}$.

- Experimentally, it was found at LEP that the total width is saturated by $D$, $D^{*}$ and the broad $D/D^{*}\pi$ component of the $D^{**}$ distribution mass; it leads to the conclusion that $[\Gamma(\bar{B} \to D\left(\frac{1}{2}\right)^{+}_{\rm broad} l\bar{\nu}) > \Gamma(\bar{B} \to D\left(\frac{3}{2}\right)^{+}_{\rm narrow} l\bar{\nu})]^{\rm EXP}$ if one interprets $[D/D^{*}\pi]_{\rm broad}$ as $D\left(\frac{1}{2}\right)^{+}_{\rm broad}$.
- That conflict between theoretical expectations and experimental measurements received the name of "1/2 vs. 3/2" puzzle. However, from CDF, Belle and BABAR analyses, it seems that the experimental verdict is not clear yet.
- An important experimental effort is demanded, in particular to have a better knowledge of the quantum numbers of those broad states.
- The answer will have an impact on the theoretical control over QCD nonperturbative dynamics of the heavy-light systems.

- On the theoretical side, taking account of $1/m_Q$ corrections is crucial, either in the analytical treatement of QCD (OPE, quark models) or in its numerical one (lattice).

## Summary

The WG2 session has covered

- $1/m_b^4$ corrections to inclusive $B \to X_c \ell \nu \ell$ decays,
- $B \to D^{(*)}$ form factors from QCD sum rules,
- a model–independent analysis of left-handed currents in semileptonic $b \to c$ transitions,

  and
- the "1/2 vs. 3/2" puzzle in $\overline{B} \to X_c l \bar{\nu}$.