PRECISION FLAVOUR PHYSICS WITH $B \to K\nu\bar{\nu}$ AND $B \to Kl^+l^-$

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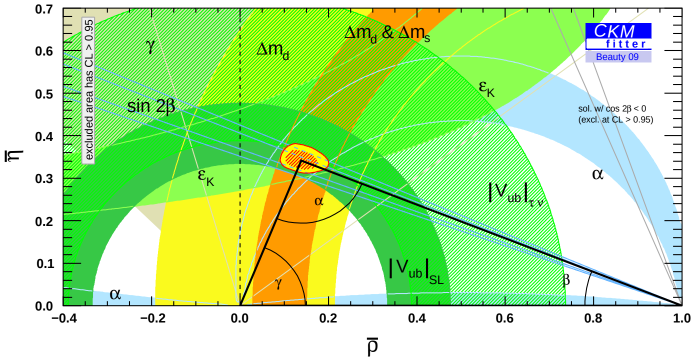
- Introduction
- Theory of $B \to K\nu\bar{\nu}$ and $B \to Kl^+l^-$
- Precision Observables
- Conclusions

Bartsch, Beylich, G.B., Gao
Hurth, Wyler

- B factories: CKM confirmed
- LHC, LHCb, SFF: precision flavour studies
- flavour physics complements
  direct collider searches for NP



B physics highlights

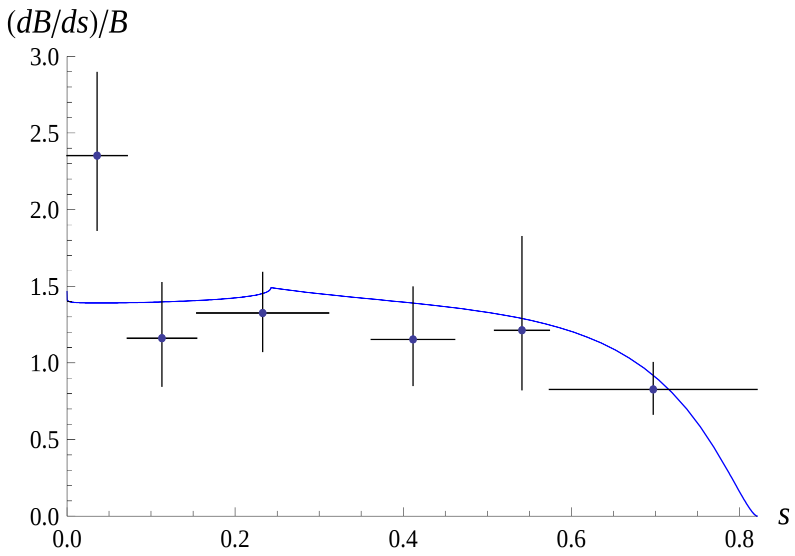
- precision CKM: CPV in $B \longrightarrow M_1 M_2$, α, β, γ
- rare decays: $B \longrightarrow K^{(*)} l^+ l^-$, $K^{(*)} \nu\bar{\nu}$, $\rho\gamma$, $\rho l \nu$, $\tau\nu$, $D\tau\nu$
- B_s mixing, CPV

BELLE, BABAR

$$B(B^- \to K^- \nu\bar{\nu}) < 14 \cdot 10^{-6}$$

$$B(\bar{B}^0 \to \bar{K}^0 \nu\bar{\nu}) < 160 \cdot 10^{-6}$$

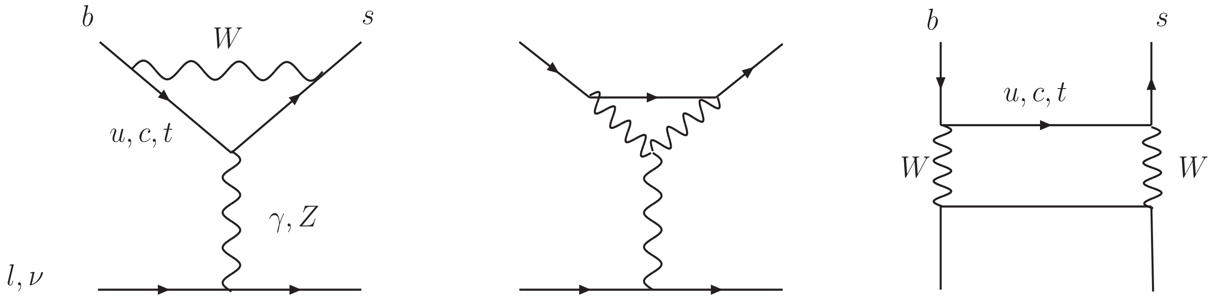
$$B(B \to K l^+ l^-) = (0.48^{+0.05}_{-0.04} \pm 0.03) \cdot 10^{-6}$$



$$s \equiv q^2/m_B^2$$

Theory

$B \to K\nu\bar{\nu}$, Kll



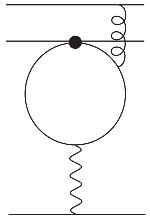
$$\frac{dB(\bar{B} \to \bar{K}\nu\bar{\nu})}{ds} = \tau_B \frac{G_F^2 \alpha^2 m_B^5}{256\pi^5} |V_{ts}V_{tb}|^2 \, \lambda_K^{3/2}(s) f_+^2(s) \, |a(K\nu\nu)|^2$$

$$\frac{dB(\bar{B} \to \bar{K}l^+l^-)}{ds} = \tau_B \frac{G_F^2 \alpha^2 m_B^5}{1536\pi^5} |V_{ts}V_{tb}|^2 \, \lambda_K^{3/2}(s) f_+^2(s) \left(|a_9|^2 + |a_{10}|^2\right)$$

m_b-scale operators

$$Q_{9,10} = (\bar{s}b)_{V-A}(\bar{l}l)_{V,A} \quad \to f_+$$
$$Q_7 = m_b \bar{s}\sigma_{\mu\nu}(1+\gamma_5)F^{\mu\nu}b \quad \to f_T$$
$$Q_2 = (\bar{s}b)_{V-A}(\bar{c}c)_{V-A} \quad \to \text{charm loops}\,\Delta$$

$$|a_9|^2 = |C_9 + \Delta|^2 = C_9^2 + 2C_9 \mathrm{Re}\Delta + |\Delta|^2$$



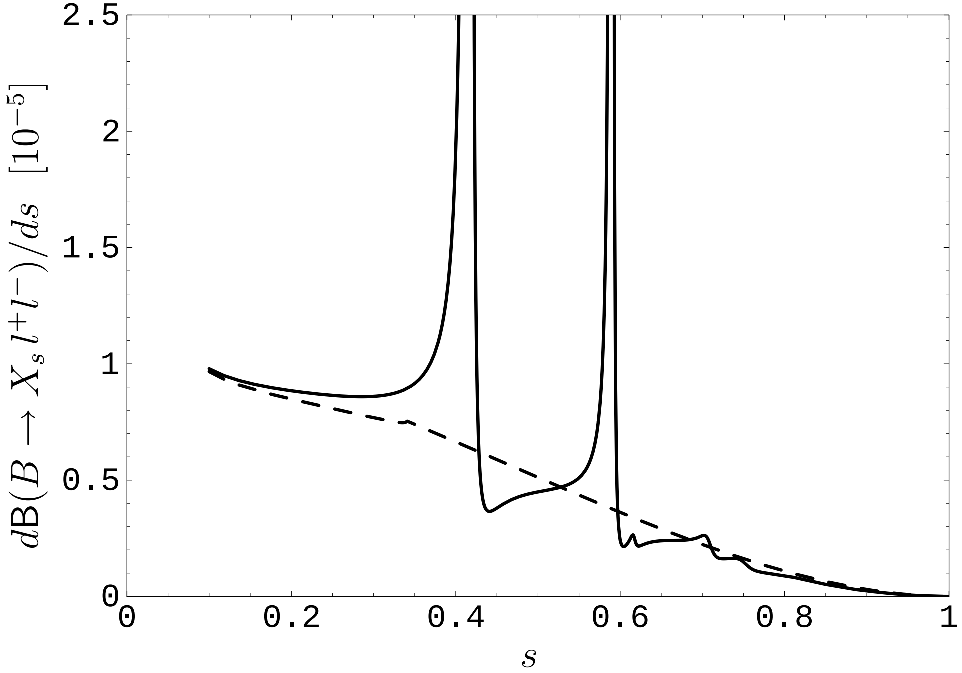
$$\Delta_{\mathrm{res}} = \frac{-f^2}{q^2 - M^2 + iM\Gamma} \qquad |\Delta_{\mathrm{res}}|^2 = \frac{f^2}{M\Gamma}\,\mathrm{Im}\Delta_{\mathrm{res}}$$

Beneke, G.B., Neubert, Sachrajda

$B \to K\psi^{(\prime)} \to Kl^+l^-$ dominates by factor 10^2 $\to$ remove by cuts

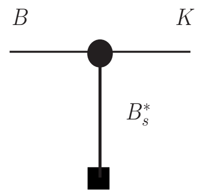
low-q^2: QCD factorization

high-q^2: OPE *G.B., Isidori; Grinstein, Pirjol*



2.5
2
1.5
1
0.5
0
0
0.2
0.4
0.6
0.8
1
$dB(B \to X_s\, l^+ l^-)/ds\ [10^{-5}]$
s

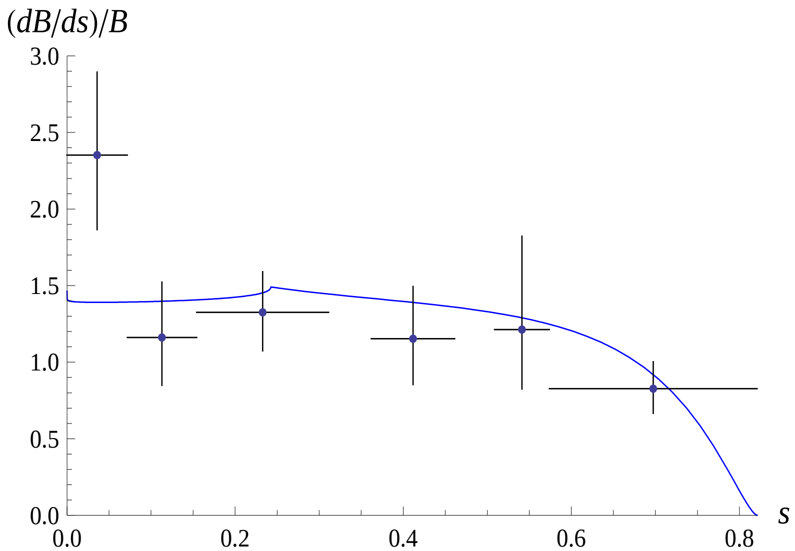
$$\frac{f_T(s)}{f_+(s)} = \frac{m_B+m_K}{m_B} + \mathcal{O}(\alpha_s, \Lambda/m_b)$$



Becirevic, Kaidalov $\qquad f_+(s) \equiv f_+(0)\,\frac{1-(b_0+b_1-a_0 b_0)s}{(1-b_0 s)(1-b_1 s)}$

$f_+(0) = 0.304 \pm 0.042$ LCSR Ball, Zwicky

shape: $a_0 = 1.6, \quad b_1/b_0 = 1.0 \qquad [1.4 \leq a_0 \leq 1.8, \quad 0.5 \leq b_1/b_0 \leq 1.0]$



$B^- \to \tau^- \bar{\nu}$ Background

Kamenik, Smith

Bartsch, Beylich, G.B., Gao

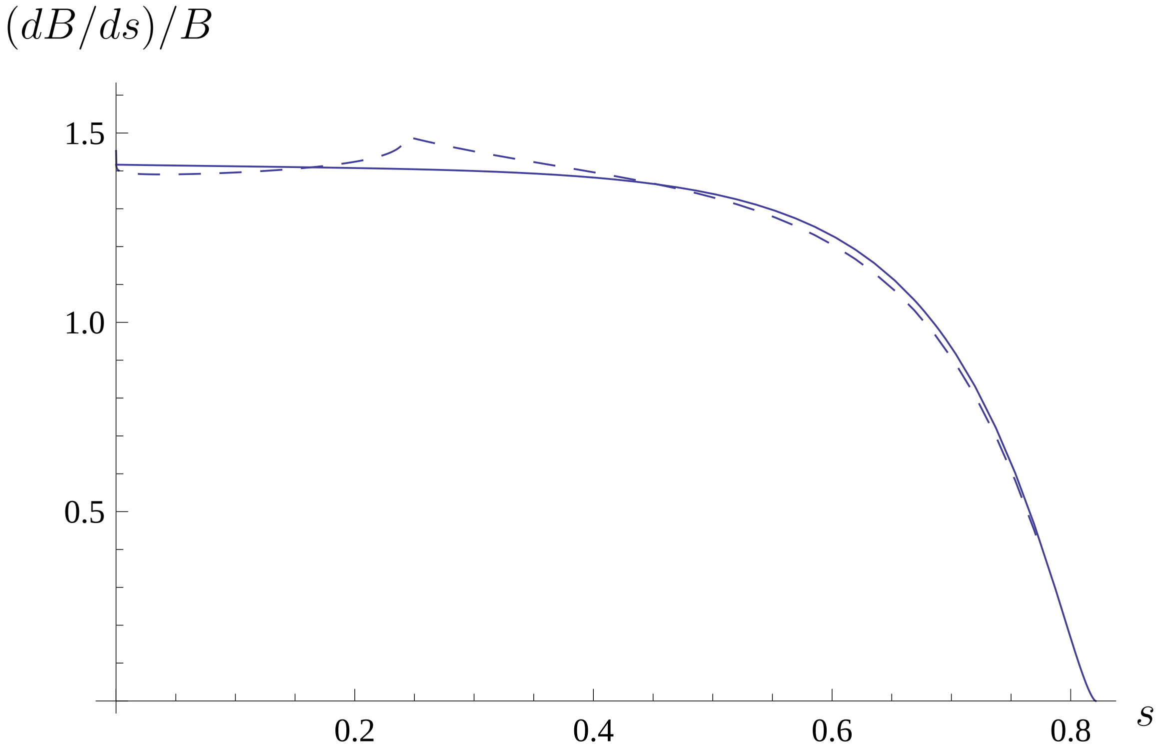
$$B^- \to \tau^- \bar{\nu}_\tau \to K^- \nu_\tau \bar{\nu}_\tau$$

$$\begin{aligned} B(B^- \to \tau^- \bar{\nu}_\tau) &= \tau_B \frac{G_F^2 m_B m_\tau^2 f_B^2}{8\pi} |V_{ub}|^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \\ &= 0.87 \cdot 10^{-4} \left(\frac{f_B}{0.2\,\text{GeV}}\right)^2 \left(\frac{|V_{ub}|}{0.0035}\right)^2 \qquad [exp: (1.43 \pm 0.37) \cdot 10^{-4}] \\ B(\tau^- \to K^- \nu_\tau) &= \tau_\tau \frac{G_F^2 m_\tau^3 f_K^2}{16\pi} |V_{us}|^2 \left(1 - \frac{m_K^2}{m_\tau^2}\right)^2 = 7.46 \cdot 10^{-3} \end{aligned}$$

$$\frac{B(B^- \to K^- \nu\bar{\nu})_{\text{bkgr}}}{B(B \to K\nu\bar{\nu})_{\text{SD}}} = \frac{B(\tau^- \to K^- \nu)}{B(B \to K\nu\bar{\nu})_{\text{SD}}} \cdot \begin{cases} B(B \to \tau\nu)_{\text{th}} \\ B(B \to \tau\nu)_{\text{exp}} \end{cases} = \begin{cases} (15 \pm 4)\% \\ (25 \pm 6)\% \end{cases}$$

Precision Observables

normalized spectrum: $B \to K\nu\bar{\nu}$ (solid), $B \to K l^+ l^-$ (dashed)



$$B(B^- \to K^- \nu\bar{\nu}) \cdot 10^6 = 4.4\,^{+1.3}_{-1.1}\,(f_+(0))\,^{+0.8}_{-0.7}\,(a_0)\,^{+0.0}_{-0.7}\,(b_1)$$

$$B(B^- \to K^- l^+ l^-) \cdot 10^6 = 0.58\,^{+0.17}_{-0.15}\,(f_+(0))\,^{+0.10}_{-0.09}\,(a_0)\,^{+0.00}_{-0.09}\,(b_1)\,^{+0.04}_{-0.03}\,(\mu)$$

$$R = \frac{B(B^- \to K^- \nu\bar{\nu})}{B(B^- \to K^- l^+ l^-)} = 7.59\,^{+0.01}_{-0.01}\,(a_0)\,^{+0.00}_{-0.02}\,(b_1)\,^{-0.48}_{+0.41}\,(\mu)$$

$$\Rightarrow B(B^- \to K^- \nu\bar{\nu}) = R \cdot B(B^- \to K^- l^+ l^-)_{exp} = (3.64 \pm 0.47) \cdot 10^{-6}$$

$0 \leq s \leq 0.25$ (low s) $\quad 0.6 \leq s \leq s_m = 0.82$ (high s)

$$R_{256} \equiv \frac{\int_0^{s_m} ds\, dB(B^- \to K^- \nu\bar{\nu})/ds}{\int_0^{0.25} ds\, dB(B^- \to K^- l^+ l^-)/ds + \int_{0.6}^{s_m} ds\, dB(B^- \to K^- l^+ l^-)/ds} =$$

$$14.60\,^{+0.28}_{-0.38}\,(a_0)\,^{+0.10}_{-0.02}\,(b_1)\,^{-0.80}_{+0.62}\,(\mu)$$

New Physics

- modified Z-penguin (SUSY) could suppress R_{256}

  Altmannshofer et al.

modification of $B \to K\nu\bar{\nu}$

- $B \to K\,SS$ light invisible scalars *Bird et al.*
- $B \to K\,\tilde{\chi}_1^0\tilde{\chi}_1^0$ light neutralinos *Dreiner et al.*
- Z' models *Altmannshofer et al.*
- $B \to K\nu_\tau\bar{\nu}_\tau$
  topcolor assisted technicolor
  Z' with FCNC at tree level *G.B., Burdman, Hill, Kominis*

Conclusions

- $B \to K l^+ l^-$ reliably calculable in terms of f_+:
  charm loop with factorization/OPE; $f_T \leftrightarrow f_+$
- $B \to K \nu \bar{\nu}$ precisely known in terms of f_+,
  $B^- \to \tau^- \bar{\nu}_\tau \to K^- \nu_\tau \bar{\nu}_\tau$ bkgr no problem
- f_+ cancels in ratios $\to$ few percent precision
- prediction: $B(B \to K \nu \bar{\nu})/10^{-6} = 3.64 \pm 0.47$
- ratios of $B \to K \nu \bar{\nu}$ and $B \to K l^+ l^-$ rates
  sensitive to New Physics

Backup

Fit of form factor shape parameters a_0, b_1

b_1/b_0, a_0	1.0	1.2	1.4	1.6	1.8	2.0
0.5	20.2	14.7	11.0	8.8	7.5	7.1
0.6	20.2	14.2	10.3	8.0	6.9	6.7
0.7	20.2	13.5	9.4	7.1	6.2	6.4
0.8	20.2	12.7	8.3	6.2	5.7	6.4
0.9	20.2	11.8	7.1	5.3	5.5	7.0
1.0	20.2	10.5	5.7	4.7	6.2	9.2

$$\chi^2(a_0, b_1) = \sum_{i=1}^{6} \frac{(y_i - F_i(a_0, b_1))^2}{\sigma_i^2} \qquad y_i = \Delta B_i / B$$