PENGUINS AND FACTORIZATION IN $B \to K\pi$ DECAYS

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BASED ON WORK IN PROGRESS WITH
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1. SOME FACTS ABOUT THE THEORY OF $B \to K\pi, \pi\pi$:
   * FACTORIZATION FOR $m_b \to \infty$
   * $O(\alpha_s)$ AND $O\left(\frac{\Lambda}{m_b}\right)$ CORRECTIONS TO FACTORIZATION
2. PHENOMENOLOGY OF $B \to K\pi$:
   * PENGUIN CONTRACTIONS & FACTORIZATION
   * A SIMPLE NUMERICAL ANALYSIS
3. CONCLUSIONS & OUTLOOK

SOME FACTS ABOUT THE THEORY OF $B \to M_1 M_2$ (M_1, M_2 LIGHT)

1) FACTORIZATION HOLDS FOR $m_b \to \infty$

* "HARD" VERSION: $A(B \to M_1 M_2)$ CAN BE COMPUTED IN PQCD

Brodsky & Lepage; Li & Sterman; Szczepaniak, Henley & Brodsky; Chang & Li; Yeh & Li; Cheng, Li & Yang; ...

See Talks by Li, Keum, Brodsky
+ posters...

* "SOFT" VERSION: SOFT INTERACTIONS ARE IMPORTANT BUT FACTORIZABLE - NONFACTORIZABLE CONTRIBUTIONS ARE PERTURBATIVE

Beneke, Buchalla, Neubert & Sachrajda

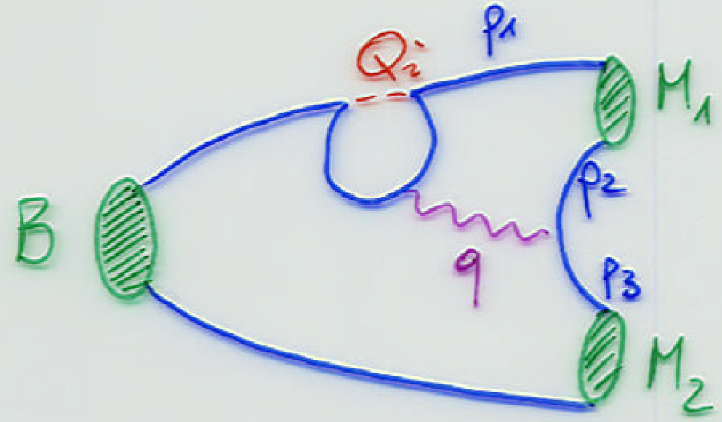
$$\langle M_1 M_2 | Q_i | B \rangle = \langle M_1 M_2 | Q_i | B \rangle_{FACT} +$$

$$+ \frac{\alpha_s(m_b)}{4\pi} r_{ij} \langle M_1 M_2 | Q_j | B \rangle_{FACT} +$$

$$+ O\left(\frac{\Lambda}{m_b}\right)$$

WITH $\langle M_1 M_2 | Q_i | B \rangle_{FACT} \propto F_{K(\pi)}, f^{+}_{K(\pi)}(0)$

2) PENGUIN CONTRACTIONS ARE NONFACTORIZABLE



* FOR $m_b \to \infty$, $\vec{p}_2$ AND $\vec{p}_3$ ARE $\sim m_b$ AND HAVE OPPOSITE DIRECTIONS $\Rightarrow q^2 \sim m_b^2$

→ THIS CONTRIBUTION IS PERTURBATIVE

BBNS

* AT $O\left(\frac{\Delta}{m_b}\right)$, $\vec{p}_2$ CAN BE SOFT $\Rightarrow q^2 \sim 0$

→ THIS CONTRIBUTION IS NONPERTURBATIVE

Ciuchini, Franco, Martinelli & L.S.

$$\langle M_1 M_2 | Q_i | B \rangle_{\text{PENGUIN}} = \frac{\alpha_s(m_b)}{4\pi} r_{ij} \langle M_1 M_2 | Q_j | B \rangle^{\text{TREE}}_{\text{FACT}} + O\left(\frac{\Delta}{m_b}\right)$$

WITH NO $O(1)$ CONTRIBUTIONS

SOME FACTS ABOUT THE PHENOMENOLOGY OF $B \to M_1 M_2$

* IN THE REAL WORLD,

$$\frac{\alpha_s(m_b)}{4\pi} \sim 0.02 \qquad \frac{\Lambda}{m_b} \sim 0.05-0.2$$

$\Rightarrow$ FACTORIZATION IS OK, EXCEPT WHERE

* $O\left(\frac{\Lambda}{m_b}\right)$ CORRECTIONS ARE CHIRAL OR CABIBBO ENHANCED

Ex. $\langle Q_6 \rangle_{\text{FACT}} \propto \frac{2 m_\pi^2}{m_b (m_u + m_d)} \sim 1$

AND/OR

* $O(1)$ TERM IS ABSENT

Ex. PENGUIN CONTRACTIONS

$\Rightarrow$ WE EXPECT FACTORIZATION TO FAIL IN PENGUIN-DOMINATED CHANNELS

CHARMING PENGUINS IN $B \to K\pi$ DECAYS

Ciuchini, Franco, Martinelli & L.S.

$$-\frac{\sqrt{2}}{G_F} A(B \to K^+\pi^-) =$$

a) $V_{us} V_{ub}^* \left(a_1 \langle O_1 \rangle_{FACT} + a_2 \langle O_2 \rangle_{FACT} \right) +$

b) $V_{ts} V_{tb}^* \sum_{i=3}^{6} a_i \langle O_i \rangle_{FACT} +$

c) $V_{cs} V_{cb}^* \left(C_1 \langle O_1^c \rangle_{PENGUIN} + C_2 \langle O_2^c \rangle_{PENGUIN} \right)$

a) IS OF ORDER $\lambda^4 \cdot 1 \cdot 1 \sim 2 \cdot 10^{-3}$

b) IS OF ORDER $\lambda^2 \cdot 10^{-2} \cdot 1 \sim 10^{-3}$

c) IS OF ORDER $\lambda^2 \cdot 1 \cdot \frac{1}{m_b} \sim 4 \cdot 10^{-3}$

CHARMING PENGUINS ARE $O\left(\frac{\Lambda}{m_b}\right)$
BUT DOUBLY CABIBBO ENHANCED
IN $B \to K\pi$ DECAYS

$\longrightarrow$ THEY CAN DOMINATE THESE BR's

A SIMPLIFIED ANALYSIS OF $B \to K\pi$

(FULL ANALYSIS OF $B \to K\pi$ & $B \to \pi\pi$ IN PROGRESS)

1) APPLY BBNS FACTORIZATION AT LO IN $\frac{\Lambda}{m_b}$

PARAMETERS: F_π, F_K, $f_\pi^+(0)$, $f_K^+(0)$ $+ \lambda_B$ IN $O(\alpha_s)$ CORRECTIONS

2) ADD CHIRALLY ENHANCED $\frac{\Lambda}{m_b}$ TERMS

IN $\langle Q_6 \rangle \propto \frac{2 m_\pi^2}{m_b (m_u + m_d)}, \frac{2 m_K^2}{m_b (m_s + m_d)} \sim O(1)$

3) ADD CHARMING PENGUINS: A SINGLE COMBINATION ENTERS ALL $B \to K\pi$ DECAYS

PARAMETERIZE IT WITH g COMPLEX

4) NEGLECT ALL OTHER $\frac{\Lambda}{m_b}$ CONTRIBUTIONS

FOR SIMPLICITY, SET ALL HADRONIC PARAMETERS TO LATTICE CENTRAL VALUES, AND TAKE ρ AND η FROM UT ANALYSIS:

Ciuchini et al

$\rho = 0.22$ $\eta = 0.32$

FIT THE CHARMING PENGUIN g PARAMETER FROM $B \to K^+\pi^-, K^0\pi^0, K^+\pi^0, K^0\pi^+$

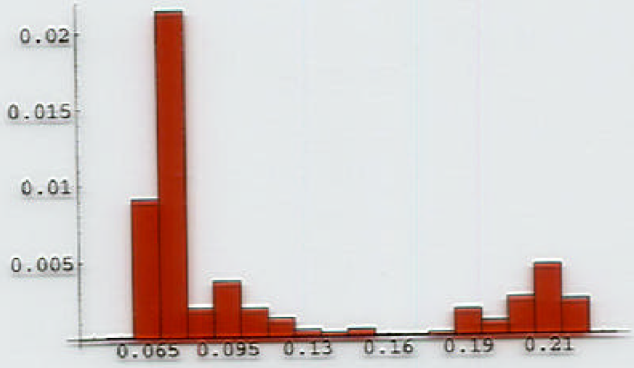


Figure 1: $|g|$.

$|g|$

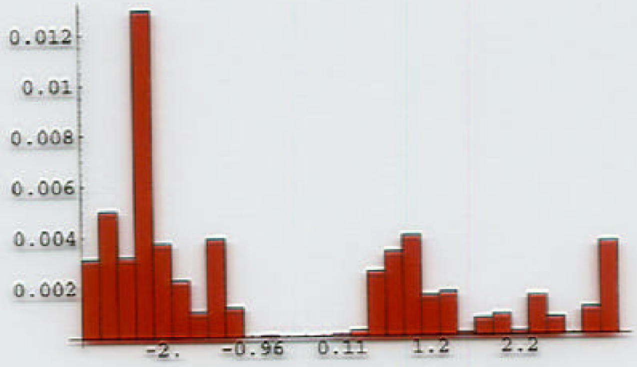


Figure 2: Arg(g).

Arg(g)

p.d.f FOR $BR(B \to \bar{K}^0\pi^0) \cdot 10^5$

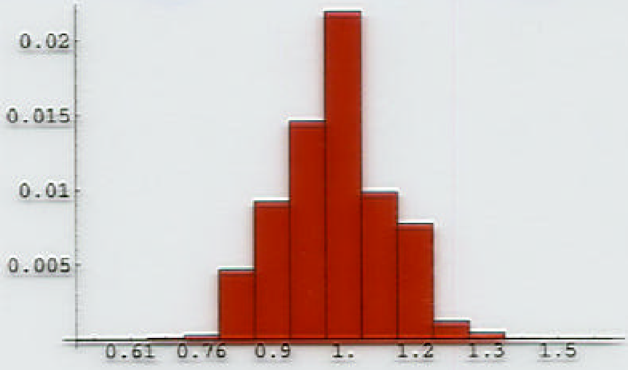


Figure 3: $\mathrm{BR}(B_d \to \bar{K}^0\pi^0) \times 10^{-5}$.

p.d.f. FOR $BR(B^- \to K^-\pi^0) \cdot 10^5$

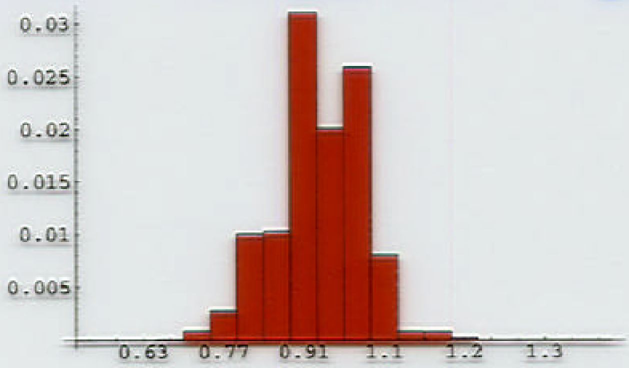


Figure 4: $\mathrm{BR}(B^- \to K^-\pi^0) \times 10^{-5}$.

p.d.f. FOR BR$(B^- \to \bar{K}^0 \pi^-) \cdot 10^5$

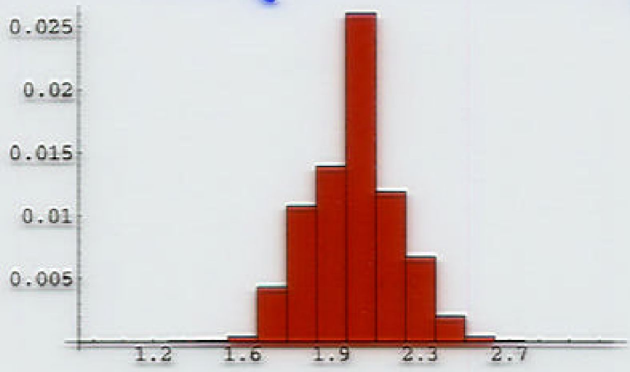


Figure 5: BR$(B_d^- \to \bar{K}^0\pi^-) \times 10^{-5}$.

p.d.f. FOR BR$(B \to K^- \pi^+) \cdot 10^5$

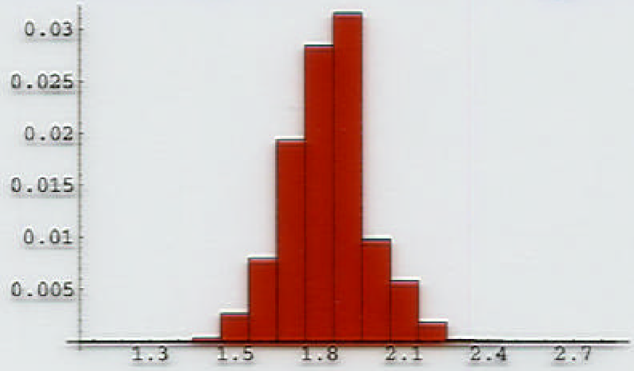


Figure 6: BR$(B_d \to K^-\pi^+) \times 10^{-5}$.

PRELIMINARY NUMERICAL RESULTS

① ALL PARAMETERS TO CENTRAL VALUES

$\gamma = 55^\circ$

$BR \times 10^{-5}$	$\pi^0 \bar{K}^0$	$\pi^0 K^-$	$\pi^- \bar{K}^0$	$\pi^+ K^-$
WITH CHARMING PENGUINS	0.9	0.9	1.9	1.8
NO CHARMING PENGUINS	0.3	0.3	0.7	0.5

② ALL PARAMETERS TO CENTRAL VALUES

γ FITTED

$BR \times 10^{-5}$	$\pi^0 \bar{K}^0$	$\pi^0 K^-$	$\pi^- \bar{K}^0$	$\pi^+ K^-$	γ
WITH CHARMING PENGUINS	0.9	0.9	1.9	1.8	$(70 \pm 20)^\circ$
NO CHARMING PENGUINS	0.3	0.6	0.6	1.1	$(170 \pm 10)^\circ$

CONCLUSIONS

① CHARMING PENGUINS IN $B \to K\pi$ DECAYS ARE DOUBLY CABIBBO ENHANCED CORRECTIONS TO BBNS FACTORIZATION → NUMERICALLY DOMINANT (RELEVANT)

② A (TOO) SIMPLIFIED ANALYSIS SHOWS THAT:

* FOR $\gamma = 55°$ AS GIVEN BY UT FITS AND VALUES OF ORDER $\frac{\Delta}{m_b}$ FOR CHARMING PENGUINS, CAN REPRODUCE EXP. VALUES FOR $B \to \pi K$ DECAYS

(WITH "PENGUIN" PATTERN $\pi^0 \bar{K}^0 \simeq \pi^0 K^- \simeq \frac{\pi^- \bar{K}^0}{2} \simeq \frac{\pi^+ K^-}{2}$)

* FACTORIZATION WITH NO CHARMING PENGUINS GIVES A MUCH WORSE FIT TO $B \to K\pi$, EVEN FOR VERY LARGE γ

③ FULL ANALYSIS IN PROGRESS...