Topics on non leptonic B_s decays

Pietro Colangelo
INFN - Sezione di Bari - Italy
Pietro.Colangelo@ba.infn.it

based on work in collaboration with
R. Ferrandes and F. De Fazio

Simple considerations and consequences
starting from few results obtained at the B factories

- annihilation diagrams can be sizeable
- strong phases are not always small
- several B_s non leptonic decay rates can be carefully predicted

immediate example of synergy between flavour factories
and hadron colliders (-> M.Mangano)

Flavour in the era of the LHC
CERN - 7/10 November 2005

decays induced by the $b \to c\,\bar{u}\,d$ and $b \to c\,\bar{u}\,s$ transitions

$B \to D_{(s)}P$

$B^- \to D^0\pi^-$ $\quad$ $B^- \to D^0K^-$

$\overline{B}^0 \to D^0\pi^0$ $\quad$ $\overline{B}^0 \to D^0\overline{K}^0$ $\quad$ $\overline{B}^0 \to D^0\eta$ $\quad$ $\overline{B}^0 \to D_s^+K^-$

$\overline{B}^0 \to D^+\pi^-$ $\quad$ $\overline{B}^0 \to D^+K^-$ $\quad$ $\overline{B}^0 \to D^0\eta'$

precisely measured by BaBar and Belle
(previous data from Cleo)

- Isospin analysis possible
- evidence of sizeable annihilation contribution
- sensitivity to $\eta - \eta'$ mixing

decay mode	BR
$B^- \to D^0\pi^-$	$(4.98 \pm 0.29) \times 10^{-3}$
$\overline{B}^0 \to D^0\pi^0$	$(2.91 \pm 0.28) \times 10^{-4}$
$\overline{B}^0 \to D^+\pi^-$	$(2.76 \pm 0.25) \times 10^{-3}$
$\overline{B}^0 \to D_s^+K^-$	$(3.8 \pm 1.3) \times 10^{-5}$
$\overline{B}^0 \to D^0\eta$	$(2.2 \pm 0.5) \times 10^{-4}$
$\overline{B}^0 \to D^0\eta'$	$(1.7 \pm 0.4) \times 10^{-4}$
$B^- \to D^0K^-$	$(3.7 \pm 0.6) \times 10^{-4}$
$\overline{B}^0 \to D^0\overline{K}^0$	$(5.0 \pm 1.4) \times 10^{-5}$
$\overline{B}^0 \to D^+K^-$	$(2.0 \pm 0.6) \times 10^{-4}$

$B \to DK$

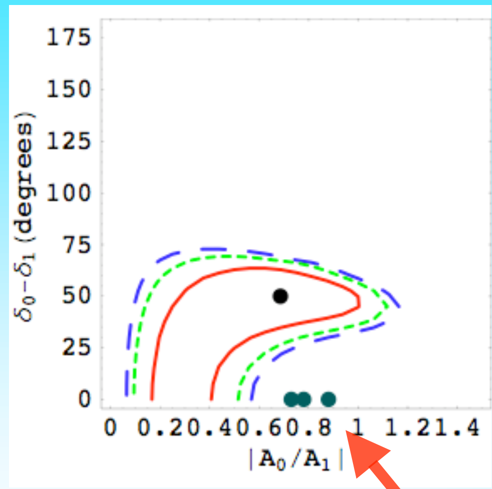
Two isospin amplitudes

$$A(B^- \to D^0 K^-) = \sqrt{2} A_1$$

$$A(\overline{B}^0 \to D^0 \overline{K}^0) = \frac{1}{\sqrt{2}}(A_1 - A_0)$$

$$A(\overline{B}^0 \to D^+ K^-) = \frac{1}{\sqrt{2}}(A_1 + A_0)$$

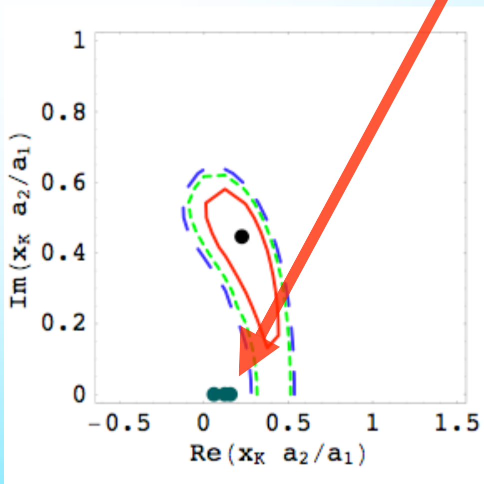
$$A(\overline{B}^0 \to D^+ K^-) + A(\overline{B}^0 \to D^0 \overline{K}^0) = A(B^- \to D^0 K^-)$$



range of phase difference extends to zero

the preferred value is rather large

naive (generalized) factorization fails



$$A(B \to DK)_{FACT} \to a_i \langle P|J|B\rangle\langle P'|J|0\rangle$$

combinations of Wilson coefficients (or parameters)

matrix elements of quark currents

$$x_K = \frac{(M_B^2 - M_K^2) f_D F_0^{BK}(M_D^2)}{(M_B^2 - M_D^2) f_k F_0^{BD}(M_K^2)}$$

related analyses by
Neubert & Petrov
Xing
Wolfenstein
Rosner
Kim et al.

observation of the annihilation process $\overline{B}^0 \to D_s^+ K^-$

further evidence of the failure of naive (generalized) factorization

$$A(\overline{B}^0 \to D_s^+ K^-)_{FACT} \to \langle 0|J|B\rangle\langle D_s^+ K^- |J|0\rangle \to (M_D^2 - M_K^2) F_0^{0\to D_s K}(M_B^2)$$

small

$$\frac{A(\overline{B}^0 \to D_s^+ K^-)_{FACT}}{A(\overline{B}^0 \to D^+ \pi^-)_{FACT}} \to \frac{a_2}{a_1} \frac{(M_D^2 - M_K^2) f_B F_0^{0\to D_s K}(M_B^2)}{M_B^2 f_k F_0^{BD}(M_K^2)}$$

tiny

$$\left.\frac{B(\overline{B}^0 \to D_s^+ K^-)}{B(\overline{B}^0 \to D^+ \pi^-)}\right|_{\exp} = 1.4\ \%$$

SU(3) analysis

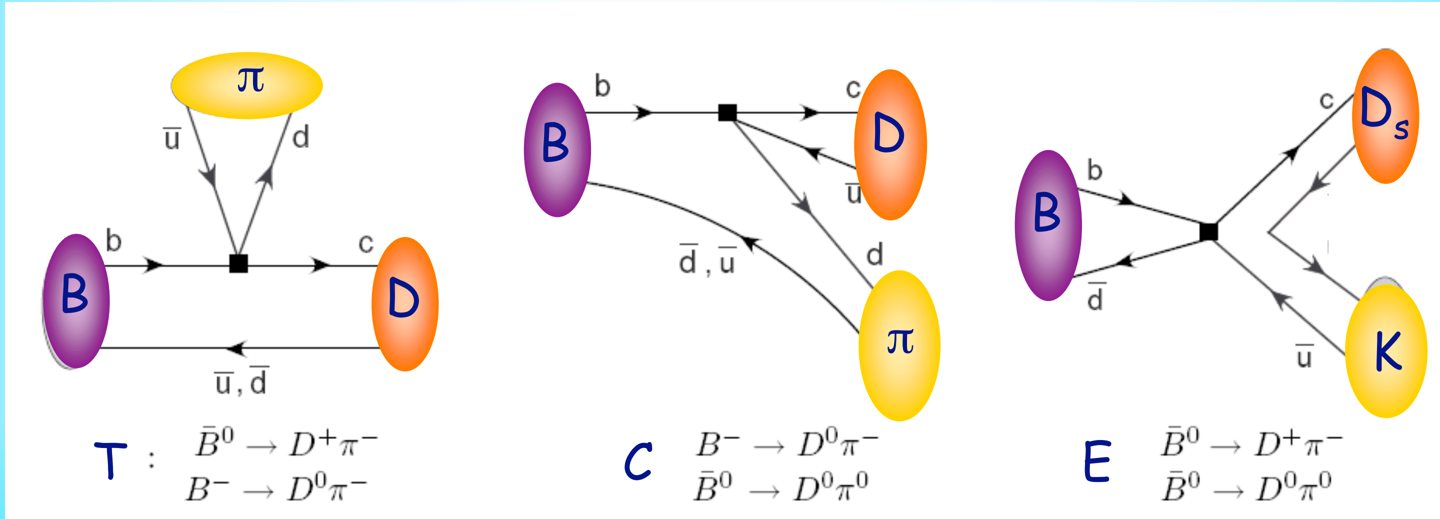
$$H_W = V_{cb} V_{ud}^* T^{(8)}_{01-1} + V_{cb} V_{us}^* T^{(8)}_{-1\frac{1}{2}-\frac{1}{2}} \qquad T^{(\mu)}_{\nu} \quad \nu = (Y, I, I_3)$$

combing with the initial B mesons (3*) one obtains 3*, 6 and 15* reprs.
which coincide with the multiplets obtained combining P and $D_{(s)}$

only three independent amplitudes

they can be rearranged to reproduce three quark topologies: T, C and E

Zeppenfeld
Chau
Grinstein & Lebed

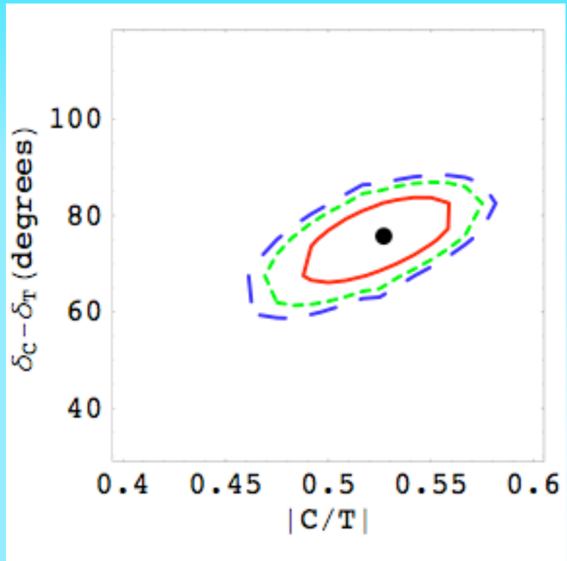


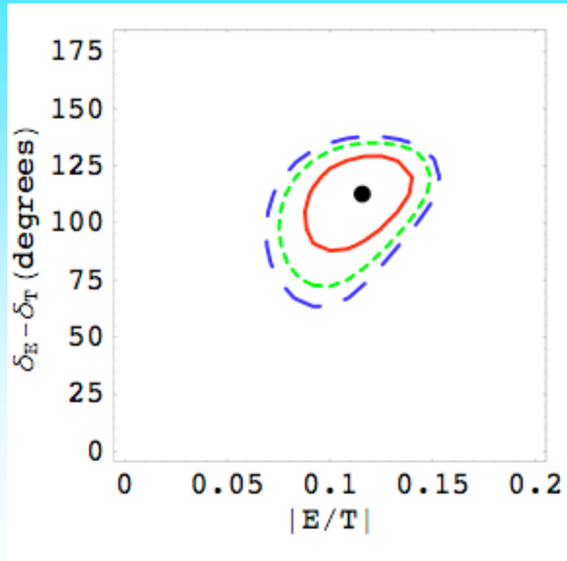
decay mode	amplitude	BR
$B^- \to D^0\pi^-$	$V_{ud}^* V_{cb}\ (C+T)$	$(4.98 \pm 0.29) \times 10^{-3}$
$\overline{B}^0 \to D^0\pi^0$	$\frac{1}{\sqrt{2}} V_{ud}^* V_{cb}\ (C-E)$	$(2.91 \pm 0.28) \times 10^{-4}$
$\overline{B}^0 \to D^+\pi^-$	$V_{ud}^* V_{cb}\ (T+E)$	$(2.76 \pm 0.25) \times 10^{-3}$
$\overline{B}^0 \to D_s^+ K^-$	$V_{ud}^* V_{cb}\ E$	$(3.8 \pm 1.3) \times 10^{-5}$
$\overline{B}^0 \to D^0\eta_8$	$-\frac{1}{\sqrt{6}} V_{ud}^* V_{cb}\ (C+E)$	
$\overline{B}^0 \to D^0\eta_0$	$V_{ud}^* V_{cb}\ D$	
$\overline{B}^0 \to D^0\eta$		$(2.2 \pm 0.5) \times 10^{-4}$
$\overline{B}^0 \to D^0\eta'$		$(1.7 \pm 0.4) \times 10^{-4}$
$B^- \to D^0 K^-$	$V_{us}^* V_{cb}\ (C+T)$	$(3.7 \pm 0.6) \times 10^{-4}$
$\overline{B}^0 \to D^0\overline{K}^0$	$V_{us}^* V_{cb}\ C$	$(5.0 \pm 1.4) \times 10^{-5}$
$\overline{B}^0 \to D^+ K^-$	$V_{us}^* V_{cb}\ T$	$(2.0 \pm 0.6) \times 10^{-4}$

data are sufficient to determine T, C and E in moduli and phase differences

input: $\left|\frac{V_{us}}{V_{ud}}\right| = 0.226 \pm 0.003$

and to determine D input: ϑ_{mixing}





large phase differences

precise determination of the T, C and E independent amplitudes

see also Chua & Hou

the singlet amplitude D determined using an $\eta - \eta'$ mixing angle of -15.4°
(in a one angle mixing scheme)

Feldmann

$$\left|\frac{D}{T}\right| = 0.41 \pm 0.11$$

$$\delta_D - \delta_T = -(25 \pm 11)^\circ$$

consequences for B_s :

in the SU(3) limit $B_s \to D_{(s)} P$ amplitudes in terms of T, C and E

decay rates precisely predicted

Decay mode	Amplitude	BR
$\bar{B}_s^0 \to D_s^+ \pi^-$	$V_{ud}^* V_{cb} T$	$(2.9 \pm 0.6) \times 10^{-3}$
$\bar{B}_s^0 \to D^0 \bar{K}^0$	$V_{ud}^* V_{cb} C$	$(8.1 \pm 1.8) \times 10^{-4}$
$\bar{B}_s^0 \to D^0 \eta_8$	$\frac{1}{\sqrt{6}} V_{ud}^* V_{cb} (2C - E)$	
$\bar{B}_s^0 \to D^0 \eta_0$	$V_{ud}^* V_{cb} D$	
$\bar{B}_s^0 \to D^0 \eta$		$(4.1 \pm 2.3) \times 10^{-4}$
$\bar{B}_s^0 \to D^0 \eta'$		$(1.9 \pm 1.6) \times 10^{-4}$
$\bar{B}_s^0 \to D^0 \pi^0$	$-\frac{1}{\sqrt{2}} V_{us}^* V_{cb} E$	$(1.0 \pm 0.3) \times 10^{-6}$
$\bar{B}_s^0 \to D^+ \pi^-$	$V_{us}^* V_{cb} E$	$(2.0 \pm 0.6) \times 10^{-6}$
$\bar{B}_s^0 \to D_s^+ K^-$	$V_{us}^* V_{cb} (T + E)$	$(1.8 \pm 0.3) \times 10^{-4}$

(Ferrandes et al., PLB 05)

information useful to the physics programmes for B_s at LHC and Tevatron

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(Ferrandes et al., PLB 05)

observed mode for B_s

$$\frac{\Gamma(B_s^0 \to D_s^- \pi^+)}{\Gamma(B^0 \to D^- \pi^+)} = 1.05 \pm 0.24$$

$$\frac{\Gamma(B_s^0 \to D_s^- \pi^+)}{\Gamma(B^0 \to D^- \pi^+)} = 1.32 \pm 0.18 \pm 0.38$$

CDF Coll. hep-ex/0508014

information useful to the physics programmes for B_s at LHC and Tevatron

consequences for B_s :

in the SU(3) limit B_s -> $D_{(s)}$ P amplitudes in terms of T, C and E

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(Ferrandes et al., PLB 05)

sensitive to $\eta - \eta'$ mixing
important for CP violation studies through the modes

$$\overline{B}_s^0 (B_s^0) \to D_\pm \eta^{(\prime)}$$

(Fleischer)

information useful to the physics programmes for B_s at LHC and Tevatron

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← purely annihilation processes

(Ferrandes et al., PLB 05)

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bckg

important channel to determine γ

(Aleksan et al., Fleischer)

O. Schneider's talk

(Ferrandes et al., PLB 05)

information useful to the physics programmes for B_s at LHC and Tevatron

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(Ferrandes et al., PLB 05)

information useful to the physics programmes for B_s at LHC and Tevatron

SU(3) breaking terms involve additional parameters (Rosner et al.)

-> at present they are compatible with zero

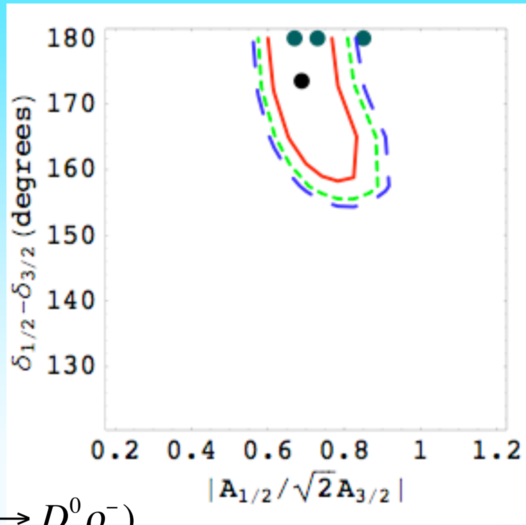
$B \to D\rho$

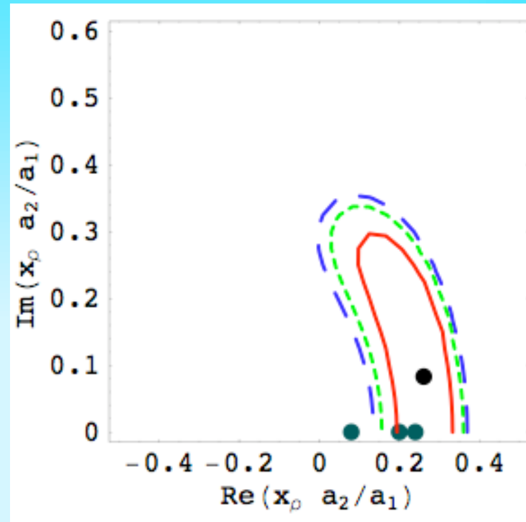
$$A(B^- \to D^0\rho^-) = \sqrt{3}A_{\frac{3}{2}}$$

$$A(\overline{B}^0 \to D^0\rho^0) = \sqrt{\frac{2}{3}}A_{\frac{3}{2}} - \frac{1}{\sqrt{3}}A_{\frac{1}{2}}$$

$$A(\overline{B}^0 \to D^+\rho^-) = \frac{1}{\sqrt{3}}A_{\frac{3}{2}} + \sqrt{\frac{2}{3}}A_{\frac{1}{2}}$$

$$A(\overline{B}^0 \to D^+\rho^-) + \sqrt{2}A(\overline{B}^0 \to D^0\rho^0) = A(B^- \to D^0\rho^-)$$





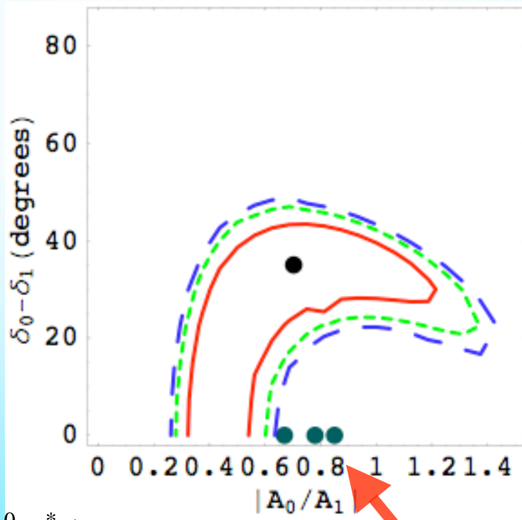
$B \to DK^*$

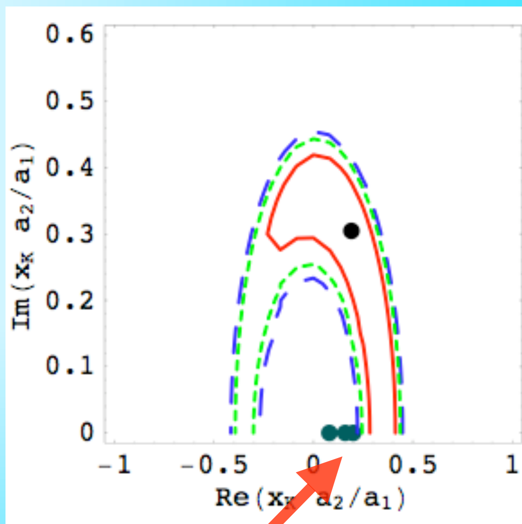
$$A(B^- \to D^0K^{*-}) = \sqrt{2}A_1$$

$$A(\overline{B}^0 \to D^0\overline{K}^{*0}) = \frac{1}{\sqrt{2}}(A_1 - A_0)$$

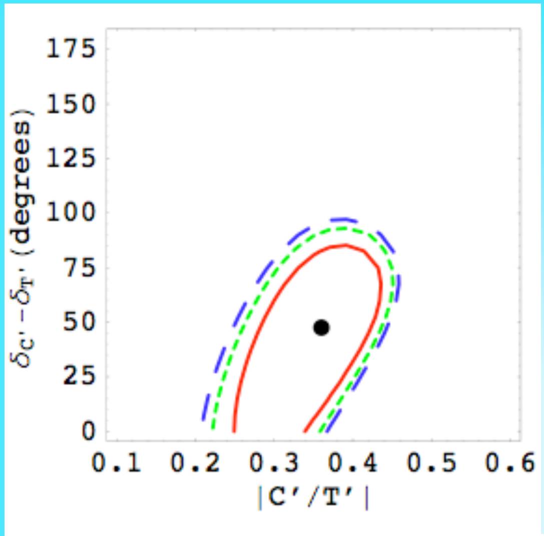
$$A(\overline{B}^0 \to D^+K^{*-}) = \frac{1}{\sqrt{2}}(A_1 + A_0)$$

$$A(\overline{B}^0 \to D^+K^{*-}) + A(\overline{B}^0 \to D^0\overline{K}^{*0}) = A(B^- \to D^0K^{*-})$$





naive (generalized) factorization marginal



predictions

decay mode	BR	decay mode	BR
$B^- \to D^0\rho^-$	$(1.34 \pm 0.18) \times 10^{-2}$	$\overline{B}_s^0 \to D_s^+\rho^-$	$(7.2 \pm 3.5) \times 10^{-3}$
$\overline{B}^0 \to D^0\rho^0$	$(2.9 \pm 1.1) \times 10^{-4}$	$\overline{B}_s^0 \to D^0\overline{K}^{*0}$	$(9.6 \pm 2.4) \times 10^{-4}$
$\overline{B}^0 \to D^+\rho^-$	$(7.7 \pm 1.3) \times 10^{-3}$		
✸ $\overline{B}^0 \to D_s K^{*-}$	$< 9.9 \times 10^{-4}$		
$B^- \to D^0 K^{*-}$	$(6.1 \pm 2.3) \times 10^{-4}$	$\overline{B}_s^0 \to D^0\rho^0$	$(0.28 \pm 1.4) \times 10^{-4}$ ✸
$\overline{B}^0 \to D^0\bar{K}^{*0}$	$(4.8 \pm 1.2) \times 10^{-5}$	$\overline{B}_s^0 \to D^+\rho^-$	$(0.57 \pm 2.8) \times 10^{-4}$ ✸
$\overline{B}^0 \to D^+K^{*-}$	$(3.7 \pm 1.8) \times 10^{-4}$	$\overline{B}_s^0 \to D_s^+K^{*-}$	$(4.5 \pm 3.1) \times 10^{-4}$

less accuracy in the predictions

✸ annihilation processes poorly determined → improvements expected in the near future

some modes are relevant for CP violation studies in B_s

$B_s \to D^*_{(s)}\pi(K)$

$B_s \to D^*_{(s)}\rho(K^*)$

present data on $B \to D^*\pi(K)$ and $B \to D^*\rho(K^*)$ are not precise enough for reliably predicting the rates of B_s decays

decay mode	experimental BR	decay mode	predicted BR
$B^- \to D^{*0}\pi^-$	$(4.6 \pm 0.4) \times 10^{-3}$	$\overline{B}^0 \to D_s^* K^-$	$(1.7 \pm 3.8) \times 10^{-4}$
$\overline{B}^0 \to D^{*0}\pi^0$	$(2.7 \pm 0.5) \times 10^{-4}$	$\overline{B}^0 \to D^{*0}\overline{K}^0$	$(3.8 \pm 8.1) \times 10^{-5}$
$\overline{B}^0 \to D^{*+}\pi^-$	$(2.76 \pm 0.21) \times 10^{-3}$	$\bar{B}_s^0 \to D^{*0}\overline{K}^0$	$(7.7 \pm 16) \times 10^{-4}$
$\overline{B}^0 \to D^{*+}K^-$	$2.0 \pm 0.5 \times 10^{-4}$	$\bar{B}_s^0 \to D^{*0}\pi^0$	$(4.6 \pm 10.2) \times 10^{-6}$
$B^- \to D^{*0}K^-$	$(3.6 \pm 1.0) \times 10^{-4}$	$\bar{B}_s^0 \to D^{*+}\pi^-$	$(9.3 \pm 20.4) \times 10^{-6}$
		$\bar{B}_s^0 \to D_s^{*+}K^-$	$(2.8 \pm 1.3) \times 10^{-4}$

(for $B \to D^*\rho(K^*)$ the three helicity amplitudes need to be determined for each decay mode)

Conclusions and perspectives

- SU(3) decomposition is a powerful method to classify and evaluate non leptonic decay amplitudes

  - independent of hadronic models
  - all dynamical information encoded
  - based on experimental data

the huge amount of measurements collected at the B factories can be fully exploited to make predictions for B_s

systematic numerical improvement following the improvements in the accuracy of B measurements

- all the amplitudes have to be considered on the same basis - no physical content is included in the decomposition (amplitude democracy)

Conclusions and perspectives

- However, as soon as the number of independent amplitudes increases, data can be not sufficient to determine them (B_s -> P P)

  In that case, the SU(3) approach could be complemented by arguments about the amplitude hierarchy, paying the price of degraded predictivity and numerical accuracy

- As for direct theoretical evaluation

  - old fashioned methods not always enough accurate

  - at present there is not a general approach valid for all the situations (QCDF, PQCD, SCET, QCDSR applied in selected cases)

  determinations based on SU(3) complementary tool (-> Nir's talk)

- B_s is a natural sector for applications, important for the elaboration of the physics programmes at the new experiments

Addendum (not related to non leptonic B_s decays)

The way of using existing data to make predictions for the (bq) - (bs) sectors invoking QCD symmetries is not restricted to B_s non leptonic decay amplitudes

Example: masses and strong decay widths of orbitally excited beauty mesons
input: charm data and HQET&chiral symmetry + $1/m_Q$ corrections

masses:

	$B^*_{(s)0}\,(0^+)$	$B'_{(s)1}\,(1^+)$	$B_{(s)1}\,(1^+)$	$B^*_{(s)2}\,(2^+)$
$b\bar{q}$	$5.70 \pm 0.025\,\mathrm{GeV}$	$5.75 \pm 0.03\,\mathrm{GeV}$	$5.774 \pm 0.002\,\mathrm{GeV}$	$5.790 \pm 0.002\,\mathrm{GeV}$
$b\bar{s}$	$5.71 \pm 0.03\,\mathrm{GeV}$	$5.77 \pm 0.03\,\mathrm{GeV}$	$5.877 \pm 0.003\,\mathrm{GeV}$	$5.893 \pm 0.003\,\mathrm{GeV}$

corresponding to D^*_{sJ} (2317) and D_{sJ} (2460)

observable in $B_s\,\pi^0$, $B^*_s\,\pi^0$, $B_s\,\gamma$, $B^*_s\,\gamma$

strong decay widths

Mode	Γ(MeV)	BR	Mode	Γ(MeV)	BR
$B_2^{*0} \to B^+\pi^-$	20 ± 5	0.34	$B_{s2}^{*0} \to B^+K^-$	4 ± 1	0.37
$B_2^{*0} \to B^0\pi^0$	10.0 ± 2.3	0.17	$B_{s2}^{*0} \to B^0K^0$	4 ± 1	0.34
$B_2^{*0} \to B^{*+}\pi^-$	18 ± 4	0.32	$B_{s2}^{*0} \to B^{*+}K^-$	1.7 ± 0.4	0.15
$B_2^{*0} \to B^{*0}\pi^0$	9.3 ± 2.2	0.16	$B_{s2}^{*0} \to B^{*0}K^0$	1.5 ± 0.4	0.13
B_2^{*0}	57.3 ± 13.5		B_{s2}^{*0}	11.3 ± 2.6	
$B_1^0 \to B^{*+}\pi^-$	28 ± 6	0.66	$B_{s1}^0 \to B^{*+}K^-$	1.9 ± 0.5	0.54
$B_1^0 \to B^{*0}\pi^0$	14.5 ± 3.2	0.34	$B_{s1}^0 \to B^{*0}K^0$	1.6 ± 0.4	0.46
B_1^0	43 ± 10		B_{s1}^0	3.5 ± 1.0	

(De Fazio, Ferrandes et al., 05)

useful information for the physics programmes at LHC and Tevatron