MEASURING γ WITH $B_{d,s} \to K\pi\pi$ DALITZ ANALYSES

Luca Silvestrini

INFN, Rome

Introduction

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Based on:
M. Ciuchini, M. Pierini & L.S., hep-ph/0601233v4
M. Ciuchini, M. Pierini & L.S., hep-ph/0602207v2
See also M. Gronau et al., hep-ph/0608243v2,
and the talk by G. Guerrer
Special thanks to Jerome Charles!

INTRODUCTION

- One of the main goals of B physics is to measure $\gamma \approx \mathrm{Arg}(V_{ub})$
- Two main avenues from charmless B decays:
  - Use two-body decays + theoretical info on hadronic matrix elements
    - difficult to assess theoretical uncertainty
  - Use Dalitz analyses to directly access an amplitude governed by V_{ub}
    - theoretically clean, experimentally challenging

THE BASIC IDEA

The I=3/2 amplitude in $B_{d,s}$ decays is experimentally accessible

from $B_{d(s)} \to K^+\pi^-\pi^0$ Dalitz plot

$$A^0_{d(s)} = A_{d(s)}(K^{*+}\pi^-) + \sqrt{2}\, A_{d(s)}(K^{*0}\pi^0) = -V^*_{ub} V_{us(d)} (E_{1,d(s)} + E_{2,d(s)})$$

$$A^+ = \sqrt{2}\, A(K^{*+}\pi^0) + A(K^{*0}\pi^+) = -V^*_{ub} V_{us} (E_{1,d} + E_{2,d})$$

from $B^+ \to K^0\pi^+\pi^0$ Dalitz plot

The ratio of these amplitudes and their CP conjugates measures γ

$$R^0_{d(s)} = \frac{\bar{A}^0_{d(s)}}{A^0_{d(s)}} = \frac{V_{ub} V^*_{us(d)}}{V^*_{ub} V_{us(d)}} = e^{-2i\gamma} = \frac{A^-}{A^+} = R^{\mp}$$

The same argument applies to higher K* resonances

Inclusion of EW Penguins (I)

EWP's are suppressed $\sim\alpha_e/\alpha_s$ wrt strong penguins so they give very small corrections to $b\to d$ $\Delta I=3/2$ amplitudes, but are enhanced by λ^{-2} wrt $b\to s$ $\Delta I=1$ amplitudes to which they give an O(1) correction. Fortunately:

- Q_7 and Q_8 can likely be neglected, since $|C_{7,8}| \ll |C_{9,10}|$
- Q_9 and Q_{10} can be eliminated from the H_{eff} at the operator level: (q=d,s)

$$Q_9^q = \frac{3}{2}\left(Q_1^{quu} - Q_1^{qcc}\right) + 3Q_2^{qcc} - \frac{1}{2}Q_3^q; \quad Q_{10}^q = \frac{3}{2}\left(Q_2^{quu} - Q_2^{qcc}\right) + 3Q_1^{qcc} - \frac{1}{2}Q_4^q$$

$$H_{eff} \propto \left(V_{ub}^* V_{uq} C_+ - \frac{3}{2} V_{tb}^* V_{tq} C_+^{EW}\right)\left(Q_+^{quu} - Q_+^{qcc}\right) + \left(V_{ub}^* V_{uq} C_- + \frac{3}{2} V_{tb}^* V_{tq} C_-^{EW}\right)\left(Q_-^{quu} - Q_-^{qcc}\right) - V_{tb}^* V_{tq} H_{QCDP}^{\Delta I=0(1/2)}$$

Inclusion of EW Penguins (II)

The effect of the EWP's on the I=3/2 amplitudes is accounted for by the parameters

$$\kappa^{\rm EW}_{d(s)} \equiv -\frac{3}{2}\frac{C^{\rm EW}_{+}}{C_{+}}\frac{V^{*}_{tb}V_{ts(d)}}{V^{*}_{ub}V_{us(d)}}\,, \qquad r_{d(s)}e^{i\theta_{d(s)}} = \frac{\langle K^{*}\pi(I=3/2)|Q^{s(d)uu}_{-}|B_{d(s)}\rangle}{\langle K^{*}\pi(I=3/2)|Q^{s(d)uu}_{+}|B_{d(s)}\rangle}$$

The situation is completely different for B_s and B_d decays.

For B_s we are lucky:

- κ^{EW}_s=(0.4+2.8i) 10^{-2}, completely negligible
- r_s=0 due to isospin (Gronau et al.)

forget about EWP's in B_s case

Inclusion of EW Penguins (III)

For B_d decays we are not so lucky:

- κ^{EW}_d=(-0.35+0.53i), an O(1) correction
- r_d not zero by flavour symmetry, but small in factorization: $r = \left| \frac{f_{K^*} F_0^{B\to\pi} - f_\pi A_0^{B\to K^*}}{f_{K^*} F_0^{B\to\pi} + f_\pi A_0^{B\to K^*}} \right| \lesssim 0.05$

The ratios R now given by

$$R^{\mp}, R_d = e^{-2i\left(\gamma+\arg(1+\kappa_d^{\mathrm{EW}})\right)} \frac{1 + \frac{1-\kappa_d^{\mathrm{EW}*}}{1+\kappa_d^{\mathrm{EW}*}} \frac{C_-}{C_+} r_d e^{i\theta_d}}{1 + \frac{1-\kappa_d^{\mathrm{EW}}}{1+\kappa_d^{\mathrm{EW}}} \frac{C_-}{C_+} r_d e^{i\theta_d}}$$

Inclusion of EW Penguins (IV)

We obtain a linear relation between ρ and η:

$$\bar{\eta} = -\tan\left(\frac{1}{2} Arg\, R^{0}\right)\left(\bar{\rho} - \bar{\rho}_{0}\right)$$

with

$$\bar{\rho}_0 = -\left[\frac{3C_+^{\rm EW}}{2C_+ + 3C_+^{\rm EW}} - \frac{12 C_+^{\rm EW} C\_r_d \cos\theta_d}{(2C_+ + 3C_+^{\rm EW})^2}\right]\frac{1-\lambda^2}{\lambda^2} + \mathcal{O}(\lambda^2)$$

for phenomenology, vary r≈0-0.3

DETAILS OF THE DALITZ ANALYSIS

The method requires to extract both B and B decay amplitudes from $B_d \to K^+ \pi^- \pi^0$, $B_s \to K^- \pi^+ \pi^0$ or $B^+ \to K_S \pi^+ \pi^0$ and the CP-conjugated channels. Need to fix the relative phase of B and anti-B decay amplitudes!

For B_d decays, time-dependent $\overset{(-)}{B}_d \to K_S \pi^+ \pi^-$ fixes the relative phase, exploiting interference of $K^{*+}\pi^-$ and $K^{*-}\pi^+$ with $\rho^0 K_S$ and other $\pi^+ \pi^-$ resonances. Then use isospin to fix the relative phase of B^+ and B^- amplitudes.

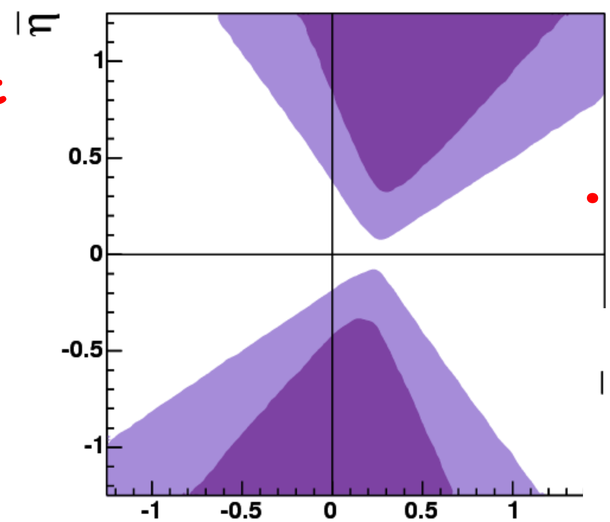
Bound on CKM from Arg(R^0)

BaBar, hep-ex/0408073

Arg(R^0) is already measured with an error of 18°.

We do not have the $K_s\pi\pi$ Dalitz plot yet, so the relative phase of B and $\bar{B}$ cannot be fixed.

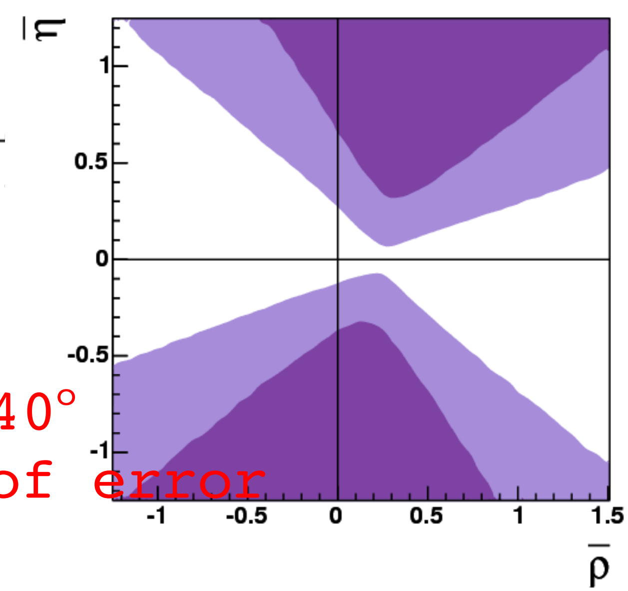
We can assume **a perfect agreement to SM and ...**



...20° of error

Precision would be already comparable to γ from DK

using r≈0-0.3



...40° of error

DETAILS OF THE DALITZ ANALYSIS II

For B_s decays, no need for a time-dependent analysis. The relevant process is again $B_s \to K_S \pi^+ \pi^-$, exploiting interference of $K^{*+}\pi^-$ and $K^{*-}\pi^+$ with $\rho^0 K_S$ and other $\pi^+ \pi^-$ resonances.

At hadron colliders, sensitivity is given by the Re $\lambda\, \Delta\Gamma/\Gamma$ term in the time-integrated rate ($\lambda = q/p\, \bar{A}/A$). Of course, a time-dependent analysis would also help.

DETAILS OF THE DALITZ ANALYSIS III

At (super-)B factories running at the $\Upsilon(5s)$, two possibilities:

untagged integrated analysis: sensitivity is given by the Re $\lambda\ \Delta\Gamma/\Gamma$ term in the time-integrated rate.

tagged integrated analysis, separating $\Delta t>0$ from $\Delta t<0$: sensitivity is given by the Re λ $(\Delta\Gamma/\Gamma)$ and Im λ $(\Gamma/\Delta m)$ terms in the time-integrated rate.

SENSITIVITY TO NP

- Extraction of γ from B_d decays:
  - independent of NP in QCD penguins
  - sensitive to NP in EWP's:
    - if only in $C_{9,10}$: observe a discrepancy with γ from tree-level decays
    - if sizable contribution to $C_{7,8}$ or new operators: also observe $|R|\neq 1$ (at present, $|R^0|=0.96 \pm 0.17$)
- Extraction of γ from B_s decays:
  - independent of any loop-mediated NP (unless huge enhancement of EWP's – already excluded)

CONCLUSIONS

- B decays to $K\pi\pi$ give us the opportunity to access directly the phase γ of V_{ub}.
- B_d decays affected by electroweak penguins, but th uncertainty still smaller than expected experimental error; can be improved with data. Sensitive to NP in EWP's
- B_s decays theoretically clean, unaffected by NP – on the same footing of $B \to D$ channels!
- Look forward to the first experimental results!