News on γ from $B \to DK$

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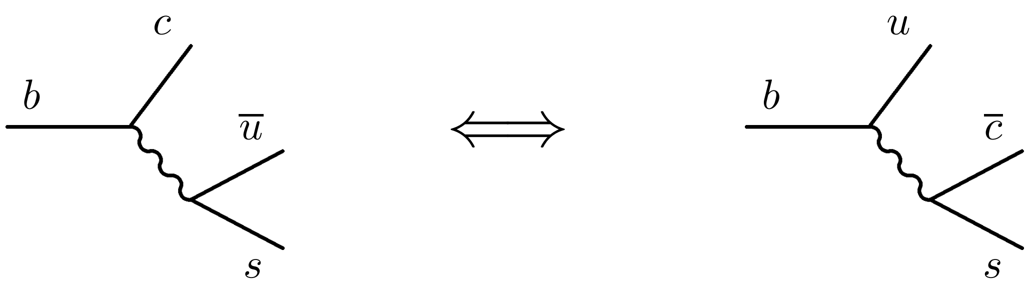
Introduction and outline

- We all know that $B \to DK$ can be used to get γ, basically with no hadronic uncertainties
- On the theory side, what are the errors?
  - Charm mixing (old)
  - CPV in charm decay (new)
  - CPV in K_S decay (new)

The basic of $B \to DK$

Gronau and Wyler

Use interference between $b \to c\bar{u}s$ and $b \to u\bar{c}s$



Interference between

$$B^+ \to DK^+ \quad \text{follows by} \quad D \to f$$

$$B^+ \to \overline{D}K^+ \quad \text{follows by} \quad \overline{D} \to f$$

f can be any common final state to D and $\overline{D}$

Factorization and interference

Why is $B \to DK$ so clean?

Factorization and interference: they are both needed

- Interference: we need it in order to get CP violation
- Factorization: it helps us calculating

$$A(B \to \psi K_S \to (\mu^+\mu^-)_\psi(\pi^+\pi^-)_{K_S}) =$$
$$A(B \to \psi K_S) \times A(\psi \to \mu^+\mu^-) \times A(K_S \to \pi^+\pi^-)$$

Usually, these two do not come together

$B \to DK$: both

$B \to DK$ is clean: we have factorization and interference

- $B \to DK$ and $D \to f_D$ amplitudes factorized
- $B \to DK$ and $B \to \overline{D}K$ interfere
- Look for n different f_D states
- Look for k different $B \to DK(X)$ decays
- $n + k$ amplitudes and $n \times k$ observables

All hadronic parameters can be measured

$$\Downarrow$$

No hadronic uncertainties

Assumptions

- Naively, there are several assumptions that are good to few $\times 10^{-3}$
  - No charm mixing
  - One D decay amplitude
  - K_S is a CP eigenstate
- How good these assumptions are?
- Can we correct for them?

Charm mixing

Effect of charm mixing

YG, Soffer, Zupan, hep-ph/0505270; Bondar, Poluektov, Vorobiev, arXiv:1004.2350

- We assume the SM (always!)
- We expect correction of order x_D and y_D

$$x \equiv \frac{\Delta m}{\Gamma} \sim 10^{-2} \qquad y \equiv \frac{\Delta\Gamma}{2\Gamma} \sim 10^{-2}$$

- For CP conserving mixing, the effect is much smaller
  - $O(x^2, y^2)/r_D$ for ADS
  - Very small in Dalitz. $r_B\, x$ if charm data is used
- It can be corrected for
- Overall, it does not seem to be a problem

CPV in charm decay

Direct CPV

- CP violation in SCS decays is of order few $\times 10^{-3}$
- Again, we assume the SM, and assume that the data is explained by the SM
- We expect corrections of order $a_{\rm CP}$
- Relevant only to cases when the D decays to a SCS final state
- The effect is enhanced by $1/r_B$
- While the effect is at the 1% level it not a big worry:
  - In principle it can be corrected (GLW becomes ADS)
  - The effect cancels to a large degree when we add K^+K^- and $\pi^+\pi^-$

CPV in kaons

Kaons CPV

Before we get to $B \to DK$, look at $\tau^- \to K_S \pi^- \nu$. We define

$$A_\tau \equiv \frac{\Gamma(\tau^+ \to \pi^+ K_S \bar{\nu}_\tau) - \Gamma(\tau^- \to \pi^- K_S \nu_\tau)}{\Gamma(\tau^+ \to \pi^+ K_S \bar{\nu}_\tau) + \Gamma(\tau^- \to \pi^- K_S \nu_\tau)}$$

- Babar reported an $O(3\sigma)$ deviation from the SM

$$A_\tau = -(3.6 \pm 2.3 \pm 1.1) \times 10^{-3}$$

- The SM prediction is

$$A_\tau = +(3.6 \pm 0.1) \times 10^{-3}$$

- The discrepancy is not due to an odd numbers of sign mistakes

Kaon induced CPV

What we have is

$$\tau^+ \to K^0 \pi^+ \bar{\nu} \qquad \tau^- \to \overline{K}^0 \pi^- \nu$$

We detect the kaon as K_S

$$\langle K_S | K \rangle = p \qquad \langle K_S | \overline{K} \rangle = q$$

Then we get an asymmetry

$$a_{\rm CP} \propto |p|^2 - |q|^2 = 2Re(\epsilon_K) \approx 3.3 \times 10^{-3}$$

- What about K_L?
- Both $\tau \to K_S$ and $\tau \to K_L$ have the same asymmetry. What is going on?

Interference, K_S and CPT

- We cannot tag a K_S. We just see two pions
- There is a CPV effect due to the interference between K_S and K_L
- Recall, K_S and K_L are not orthogonal states
- The CPV effect due to the interference is exactly twice that of K_S but with opposite sign. CPT is restored
- Experimentally, the effect due to K_S and interference terms are what was measured
- The SM prediction depends on the time cut. For Babar it is small correction, but can be important for LHCb

Back to $B \to DK$

- This effect is important when we have K_S somewhere
  - $B^0 \to DK_S$
  - $D \to K_S \pi^+ \pi^-$
- We expect it to be of order ϵ_K
- Depend on the cut
- Can be corrected for

Thus, while interesting theoretically, kaon CPV effects are not a big issue for γ determination

Conclusions

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- $B \to DK$ is unique: theory errors are still much smaller than the experimental ones
- There are few theoretical uncertainties that are below the 1% level
- The only news I could think about is that these sources of uncertainties are much larger than what I used to think, but they are still negligible