Comment on “A possible explanation of the D0 like-sign dimuon charge asymmetry”

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Comment on "A possible explanation of the D0 like-sign dimuon charge asymmetry"

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We show that a contribution due to a second order amplitude with intermediate $\bar{u}d$ in a loop, which was claimed by Descotes-Genon and Kamenik to dominate the CP asymmetry in $b \to c\ell\nu$, vanishes.

In a 2013 paper by S. Descotes-Genon and J. F. Kamenik [1] (discussing the D0 like-sign dimuon asymmetry [2]) the authors presented a Standard Model calculation of a contribution claimed to dominate the direct CP asymmetry $A^{b,\,\mathrm{SM}}_{\mathrm{dir}}$ in inclusive semileptonic decays $b \to c\ell\nu$ ($\ell = \mu$). Their result was stated to be an order of magnitude larger than a value, $A^{b,\,\mathrm{SM}}_{\mathrm{dir}} \equiv A^b_{sl} = -3.2 \pm 0.9) \times 10^{-9}$ calculated by us in collaboration with S. Bar-Shalom and G. Eilam [3]. In this brief comment we wish to clarify this point of discrepancy.

As argued in Ref. [3] using CPT, a nonzero asymmetry in $b \to c\ell\nu$ requires interference of a tree level amplitude described in Fig. 1 with an amplitude which is second order in weak interactions. In order to produce an asymmetry, the second amplitude

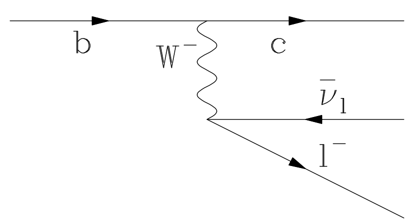

Figure 1: Tree diagram for $b \to c\ell^-\bar{\nu}_\ell$

must involve a CKM factor with a *different weak phase* and a nonzero CP-conserving phase. A second-order amplitude fulfilling these two requirements is drawn in Fig. 2, consisting of a product of a penguin amplitude for $\bar{b} \to \bar{c}c\bar{s}$ involving $V^*_{tb}V_{ts}$ and a tree amplitude for $c\bar{s} \to \ell^+\nu_\ell$ involving V^*_{cs}. A relative CP-conserving phase of 90° between the two amplitudes follows by taking the absorptive part of the second-order amplitude. The absorptive part is described by a discontinuity cut crossing the $\bar{c}s$ lines

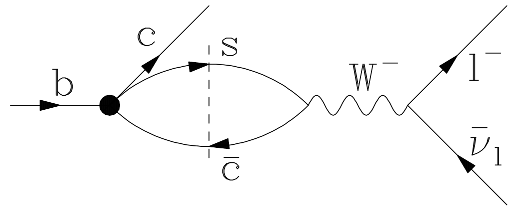

Figure 2: Second-order diagram for $b \to c\ell^- \bar{\nu}_\ell$.

in the second-order diagram, which amounts to summing over corresponding on-shell intermediate states. A detailed calculation, using a value for the weak phase difference between the two amplitudes [4], $\mathrm{Arg}\,(V_{tb}V^\star_{ts}V_{cs}V^\star_{cb}) \equiv \beta_s = 0.018$, and including uncertainties in b and c quark masses, led to the above-mentioned asymmetry result.

Ref. [1] proposed an alternative mechanism claimed to dominate the asymmetry, replacing the intermediate $\bar{c}s$ in Fig. 2 by intermediate $\bar{u}d$ coupled by a tree amplitude for $b \to c\bar{u}d$. Interference of this second order amplitude with the tree amplitude in Fig. 1 was stated to involve a weak phase factor $\mathrm{Im}\,(V_{ub}V^\star_{ud}V_{cd}V^\star_{cb})$ [see Eqs. (21a) and (22) in [1]]. This factor would seem to describe a second order amplitude involving intermediate $\bar{d}u$ which violates charge conservation. The actual imaginary part of the CKM factor for intermediate $\bar{u}d$ vanishes:

$$\mathrm{Im}\,(V_{cb}V^\star_{ud}V_{ud}V^\star_{cb}) = 0 \ . \tag{1}$$

Thus this interference term vanishes and does not contribute at all to the asymmetry.

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