CPV in charm decays into neutral kaons





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F.s.Yu, D. Wang, H.n.Li, PRL119, 181802(2017)

CP Violation can occur in $D \to K_S^0 f$



Belle: $A_{CP}^{D^+ \to K_S^0 \pi^+} = (-3.63 \pm 0.94 \pm 0.67) \times 10^{-3}$ [PRL 109, 021601 ($A_{CP}(t) \simeq \left[A_{CP}^{\overline{K}^0}(t) + A_{CP}^{dir}(t) \right]$

Indirect CPV in kaon mixing $Re(\epsilon)=10^{-3}$



[Zhi-Zhong Xing, PLB 353, 313(1995)]

Direct CPV in charm decays

D(t)

 $Im(V_{cd}V_{us}/V_{cs}V_{ud})=\lambda^{6}=10^{-5}$



[Bigi, Yamamoto, PLB 349, 363 (1995)] 3



[D.Wang, FSY, H.n.Li, Phys.Rev.Lett 119, 181802(2017)]



Time-Integrated CPV



$$\Delta A_{CP} = A_{CP}(D^+ \to \pi^+ K_S^0) - A_{CP}(D_s^+ \to K^+ K_S^0)$$
New Observable
revealing
new CPV effect
$$A_{CP}(t) \simeq \left[A_{CP}^{\mathbb{R}^0}(t) + A_{CP}^{dir}(t) + A_{CP}^{int}(t)\right]$$
Cancel some systematic errors
@ LHCb & Belle-II
[Wang, FSY, Li, '17] 10
$$\Delta A_{CP}^{\pi^+,K^*}(x) = A_{CP}(D_s^+ \to K^+ K_S^0)$$



New Physics in $D \rightarrow f K_{S^0}$

$$A_{CP}^{dir} \sim 2r_f \sin \phi \sin \delta_f$$

SM: $\phi \equiv Arg \left[-V_{cd}^* V_{us}/V_{cs}^* V_{ud}\right] = (-6.2 \pm 0.4) \times 10^{-4}$

NP: $\phi = O(1)$

Search for new physics at tree-level

$$\mathcal{A}(D \to fK_S^0) = \mathcal{A}_{CF}^{\rm SM} + \mathcal{A}_{DCS}^{\rm SM}(1 + r^{\rm NP}e^{i\phi^{\rm NP}}e^{i\delta^{\rm NP}})$$





new physics!

0.002

0.004

r_{NP}=A_{NP}/A_{DCS}

0.006

0.01

0.008

0.

Ambiguities in penguins

$$\Delta A_{CP}(K^+K^-, \pi^+\pi^-)$$

range from 10⁻⁵ to 10⁻² in literature

- @m_c~1.5GeV, perturbation theories do not work
- Tree diagrams extracted from branching fractions (Br)
- Penguin neglected in Br's

ΔAcp(KK,ππ)_{exp} <~ 𝒪(10⁻³)

uncertainties of Br's ~ $\mathcal{O}(\%)$

If CPV observed, cannot tell SM or NP



[many papers...]

Summary

- New CPV effect is found in $D \to K_S^0 f$
- It is accessible at Belle II and LHCb, and cannot be neglected
- CPV in $D \rightarrow K_S^0 f$ is promising to search for New Physics at tree level, compared to penguins in charm!

Thank you for your attention!