SU(3) Analysis of D-Meson Decays

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Based on:

D. Pirtskhalava and P. U., arXiv:1112.5451 [hep-ph].

D. Pirtskhalava and P. U., In Progress

The Measurements

Recently LHCb and CDF reported the measurement of $\Delta A_{CP} \equiv A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$:

ΔA_{CP}	
LHCb	$-(0.82 \pm 0.24)\%$
CDF	$-(0.62 \pm 0.23)\%$
W.A.	$-(0.67 \pm 0.16)\%$

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Direct CP Violation Primer

Direct CP violation in decay

$$A_{CP}(D \to f) = \frac{\Gamma(D \to f) - \Gamma(\bar{D} \to \bar{f})}{\Gamma(D \to f) + \Gamma(\bar{D} \to \bar{f})}.$$

Typical decay amplitude

$$\mathcal{A}(D \to f) = \tilde{a}\Sigma + \tilde{b}\Delta,$$

$$A_{CP}(D \to f) \approx -2 \,\mathrm{Im}\left(\frac{\tilde{b}}{\tilde{a}}\right) \,\mathrm{Im}\left(\frac{\Delta}{\Sigma}\right).$$

Why Should We Care?

- Significant CP violation in D^0 meson decay.
- It is commonly believed that Standard Model predicts a small ΔA_{CP}.
- It's tempting to attribute ΔA_{CP} to new physics
  - 1111.3987, 1202.2866, 1202.5038, ...
- However, we don't have a solid SM prediction for ΔA_{CP}. Need a better SM calculation.
  - 1111.5000, 1112.5451, 1201.2351, 1201.0785, ...
  - Use flavor $SU(3)$ to gain information about D-meson decays.

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  - Use flavor $SU(3)$ to gain information about D-meson decays.

Flavor $SU(3)$ Analysis

- Light quarks (u, d, s) form a triplet of $SU(3)$.
  - Light mesons (pions, kaons, etas) transform as $1 \oplus 8$.
  - D-meson $(\bar{c}q)$, $q \in (u, d, s)$ transforms as a 3.
  - Effective H_W $(c\bar{q}q\bar{q})$ transforms as $\bar{3} \oplus 6 \oplus \bar{15}$.
- Identify all possible $SU(3)$ invariant matrix elements, $\langle out|H_{eff}|in\rangle$ (7 in $SU(3)$ limit).
- Flavor $SU(3)$ relates invaraint matrix elements in different decay amplitudes.
- Introduce $SU(3)$ breaking effect by $m\lambda_8$
  - Generate (too) many new invariant matrix elements.
  - Require some working assumption to make progress.

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The Ansatz

- Assume matrix elements associated with the small rep. of H_{eff} are enhanced by $\sim \mathcal{O}(10-50)$.
  - Only need to retain matrix elements associate with small rep of $SU(3)$ breaking H_{eff}.
- This can be justified by:
  - The $\Delta I = 1/2$ rule in kaon system.
  - Practicality.
- Extract infomation about these matrix elements from the measured rates and CP asymmetries.
  - This is equivalent to working to first order in electroweak and all orders in QCD.

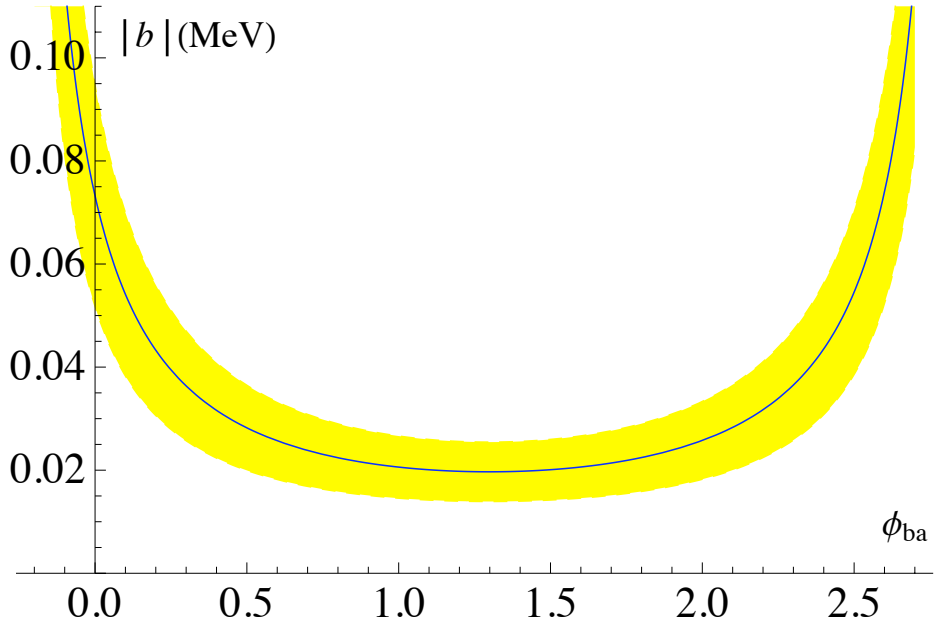
Analysis on Subset of Processes

$$
\begin{aligned}
\mathcal{A}(D^0 \to K^- \pi^+) &= a V_{11} V_{22}^*, \\
\mathcal{A}(D^0 \to \bar{K}^0 \pi^0) &= \tfrac{-a+5T}{\sqrt{2}} V_{11} V_{22}^*, \\
\mathcal{A}(D^0 \to K^+ \pi^-) &= a V_{12} V_{21}^*, \\
\mathcal{A}(D^0 \to K^+ K^-) &= (a+c)\Sigma + b\Delta, \\
\mathcal{A}(D^0 \to \pi^+ \pi^-) &= (-a+c)\Sigma + b\Delta, \\
\mathcal{A}(D^0 \to \pi^0 \pi^0) &= \tfrac{-a+5T+c}{\sqrt{2}}\Sigma + \tfrac{b-5T}{\sqrt{2}}\Delta, \\
\mathcal{A}(D^+ \to \bar{K}^0 \pi^+) &= 5T V_{11} V_{22}^*, \\
\mathcal{A}(D^+ \to \pi^+ \pi^0) &= \tfrac{5T}{\sqrt{2}}\Sigma - \tfrac{5T}{\sqrt{2}}\Delta,
\end{aligned}
$$

Decay rates depend on a, c, T.

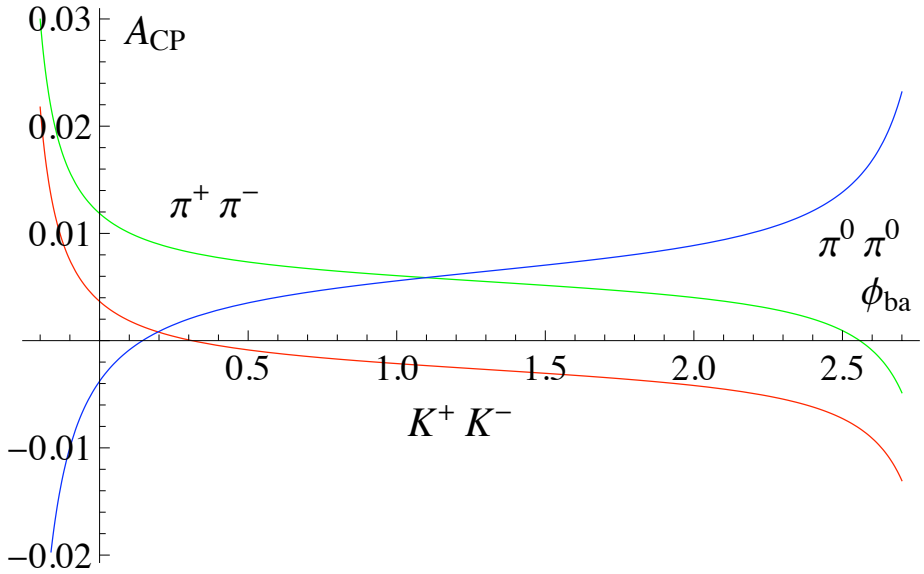
Results

- Fitting to the measured BRs and ΔA_{CP} determines a, c and T.
- The ansatz provide reasonable parameter space for explaining ΔA_{CP}.



Predictions

- Individual asymmetries can be computed.



- $A_{CP}(D^0 \to K^-\pi^+, D^0 \to K^+\pi^-, D^+ \to \pi^+\pi^0) = 0$ in this framework.

Global Fit (work in progress)

- Determine all the relevant matrix elements.
- Include the effect of $\eta - \eta'$ mixing.
  - Allow for the determination θ_η.
- Two possibilities
  - Retain only the SU(3) breaking triplets matrix elements.
  - Retain both the triplets and sextets.

Preliminary results

- Triplets
  - 22 real parameters.
  - Prefer small $\theta_\eta \approx 14^\circ$.
  - Predict $\mathrm{Br}(D^0 \to 2K_S^0) = 1.87 \times 10^{-4}$.*
- Triplets and Sextets
  - 36 real parameters.
  - Prefer large $\theta_\eta \approx 22^\circ$.
  - Predict $\mathrm{Br}(D^0 \to 2K_S^0) = 1.82 \times 10^{-4}$.*
- Both values of θ_η fall in the commonly accepted range.

$*$ This Br is measured to be $(1.6 \pm 0.1) \times 10^{-4}$. However it is predicted to be 0 in the diagrammatic analysis. [Bhattacharya, Rosner]

Summary

- Large ΔA_{CP} can be accommodated in SM taking into account flavor $SU(3)$ breaking effects.
- Global analysis of D-meson decays is under way.