Charmless B-decays at BaBar

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Why Charmless?

- huge variety of physics can be found in charmless decays
  - can extract all three UT angles
  - potential New Physics can be seen in penguin transitions
  - large range of BF for these “rare” decays
  - BF and CP asymmetries are important inputs for theoretical models (e.g. PQCD, SCET, factorization etc...)

\[ \begin{align*}
\pi\pi, \rho\pi, \rho\rho \quad & V_{td}V^{*}_{ub} \\
J/\psi K^0, \phi K^0 \quad & V_{cd}V^{*}_{cb} \\
DK, K\pi \quad & \frac{V_{td}V_{ub}}{V_{cd}V_{cb}} \\
\end{align*} \]
SLAC Participation in the Charmless World

* Convenerships:
  – Charmless 2-body: A. Roodman (2007-Present)

* Analysis:
  – $h^+\pi^0/\pi^0\pi^0$: AR, M. Allen, I. Ofte
  – $K^+K^-K^0/ K_sK_sK^+$: AR, DD, J. Thompson, H. Kim, B. Lindquist
  – $K^+\pi^-\pi^0$: AR, MG, A. Wagner
  – $K_s\pi^+\pi^-$: MG
  – $K_s\pi^0\pi^0$: AR, MA
  – $\pi^+\pi^-\rho^+\rho^-$: MG
  – $pp\bar{p}h$: T. Hrynova
  – $\Lambda\Lambda h$: MG, B. Butler
\[ \sin 2\beta \] From Penguin Decays

\[ \sin 2\beta \]

\[ J/\psi \rightarrow K^0 \]

\[ \phi \rightarrow K^0 \]

• Penguin dominated \( b \rightarrow (q\bar{q})s \) decays have the same weak phase as \( b \rightarrow (c\bar{c})s \) and thus the TD-CPV parameters should be \( S = \eta \sin 2\beta \) and \( C = 0 \) in the SM.
• Other SM diagrams contribute a small shift and is expected to increase \( S \).

2-body: [Beneke; PL B620, 143 (2005)]
3-body: [Cheng, Chua, Soni; PRD72, 094003 (2005)]
Measuring $\beta$: $B^0 \rightarrow K^+K^-K^0$ Dalitz Plot Analysis

- We perform a time-dependent Dalitz plot amplitude analysis: includes $\phi(1020)$, $f_0(980)$, “$f_X(1500)$”, $\chi_c0$, and a non-resonant component.
- Interference between CP-Odd and CP-Even terms allows us to extract $\beta_{\text{eff}}$.

$\beta_{\text{eff}} = (18.9 \pm 4.6 \pm 1.7)^\circ$

Mirror solution disfavored @ 4.5$\sigma$

PRL 99, 1610802, 2007

383M B-Pairs
Measuring $\beta$: $B^0 \rightarrow \pi^+\pi^- K_S$ Dalitz Plot Analysis

- another TD-DP amplitude analysis; more going on here...
- includes $\rho(770)$, $f_0(980)$, $f_2(1270)$, “$f_X(1300)$”, and a non-resonant component
- additionally, there are self-tagging modes: $K^*(892)$, $K^*_0(1430)$

\[ \beta_{\text{eff}}(f_0(980)K_S) = (44.3 \pm 11.5)^\circ \]
\[ \beta_{\text{eff}}(\rho(770)K_S) = (18.7 \pm 10.0)^\circ \]
Status of $\sin 2\beta$ from Penguins

Naïve average of S now in excellent agreement with SM…

BUT: most of the measurements are still below the SM…the very small errors on $K^+K^-K_s$ and $f_0K_s$ help to pull the average up.
Measuring $\alpha$: The Isospin Analysis

\[ \frac{A^+}{\sqrt{2}} = A^0 \]
\[ \frac{A^-}{\sqrt{2}} = A^0 \]

\[ 2\Delta \alpha = 180^\circ \]

8-fold ambiguity from $-180^\circ \rightarrow 180^\circ$

4 ways to fold the triangles

BF, S, C
BF, S, C
BF, $A_{cp}$
Measuring $a$: $B \rightarrow \pi^0\pi^0$

154 ± 27 Events

- crucial mode for $\pi\pi$ isospin analysis
- can’t extract $S$, but can get $C$

$BF(\pi^0\pi^0) = (1.5 \pm 0.28) \times 10^{-6}$

$C(\pi^0\pi^0) = -0.49 \pm 0.35$

without $C(\pi^0\pi^0)$, the peaks here are completely unresolved!
Status of $\alpha$

SLAC has also been involved in the analysis of $B^0 \rightarrow \rho^+ \rho^-$ and $B^0 \rightarrow \rho \pi$ (both MG)…

Combining all results, we have:

$\alpha = 87.5 \pm 5.8$ at 1$\sigma$

*** this doesn’t include newest $\pi^0 \pi^0$ result!!!
Measuring $\gamma$: $B^0 \rightarrow K\pi\pi$ Dalitz Plots

- Can use an isospin decomposition in the $K\pi$ system to extract $\gamma$
- Need the relative phases between the different $K\pi$ isospin states…interference!
  - can’t use the 2-body states ($K^+\pi^-$, $K^0\pi^0$)
  - must use 3-body decays $\rightarrow$ Dalitz plots

Need phases between:

\[
\begin{align*}
(K^{*+}\pi^-, K^{*0}\pi^0) & \quad B^0 \rightarrow K^+\pi^-\pi^0 \\
(K^{*-}\pi^+, K^{*0}\pi^0) & \quad B^0 \rightarrow K_s\pi^+\pi^- \\
(K^{*+}\pi^-, K^{*-}\pi^+) & \quad B^0 \rightarrow K_s\pi^+\pi^-
\end{align*}
\]

\[
A_{1, \frac{3}{2}} = \frac{1}{\sqrt{2}} A(B^0 \rightarrow K^{*+}\pi^-) + A(B^0 \rightarrow K^{*0}\pi^0)
\]

\[
A_{1, \frac{3}{2}} = \frac{1}{\sqrt{2}} A(B^+ \rightarrow K^{*0}\pi^+) + A(B^+ \rightarrow K^{*+}\pi^0)
\]

\[
R_I = \frac{\overline{A}_I}{A_I} \quad \Rightarrow \quad \gamma = -\frac{1}{2} arg\left(\begin{bmatrix} R_I \end{bmatrix}\right)
\]

Ciuchini et al., PRD 74, 051301, 2006
Measuring $\gamma$: $B^0 \rightarrow \pi^+\pi^-K_s$ Dalitz Plot

- Same analysis as the $f_0(980)K_s$ and $\rho(770)K_s$ TD-CPV results!
- Sensitivity to $\Delta\phi(K^{*+}\pi^-, K^{*-}\pi^+)$ comes (mainly) from common interference between $K^*$ and $\rho(770)$ and NR

$\Delta\phi(K^{*+}\pi^-, K^{*-}\pi^+) = (164\pm31)^\circ$

mirror solution disfavored @ 3.7$\sigma$ significance

$\chi^2$

Scan in $\Delta\phi$
Measuring $\gamma$: $B^0 \rightarrow \pi^- \pi^0 K^+$ Dalitz Plot

- Spin-off of the $\pi^+ \pi^- \pi^0$ DP analysis
- Tricky! Poorer resolution than $K_s \pi^+ \pi^-$ due to $\pi^0$; more going on in the DP than in $\pi^+ \pi^- \pi^0$
- Current result just published recently on Runs 1-4 by the Paris group; we are working on an update

No significant constraint on the phases...should do better with full dataset

Paris/MG, AW

hep-ex/0711:4417
Future Plans

* Complete the KKK Dalitz plot picture with full dataset:
  - update of $K^+K^-K_s$ time-dependent DP analysis is almost done
  - plan on doing DP analysis of $K^+K^-K^+$ (update) and $K_sK_sK^+$ (for the first time)

* Use full dataset to extract $\gamma$ in $B^0 \to K\pi\pi$
  - update of $B^0 \to K^+\pi^-\pi^0$ is almost complete
  - plan to update $B^0 \to K_s\pi^+\pi^-$ for next summer
  - investigate using $K^*_0(1430)\pi$ system to extract $\gamma$

* Use full dataset to extract $\alpha$ in $B^0 \to \pi^+\pi^-\pi^0$
  - work has begun; plan to have result for next summer
Summary

* This is an interesting and challenging time to be doing physics analysis on BaBar
* Since we won’t have more data, the results we make public from now on are likely the final word from BaBar
* Our goal is give as complete and coherent picture as possible…and extract as much information as we can!
* Our physics goals center around understanding the KKK and ππK Dalitz plot composition and use that knowledge to measure $\beta_{\text{eff}}$ and $\gamma$