$2\beta+\gamma$ from $B^0 \rightarrow D^+K^0 \pi^-$

Francesco Polci $^{(\S,*)}$
Marie-Hélène Schune $^{(\S)}$, Achille Stocchi $^{(\S)}$

Thanks to Troels C. Petersen for suggestions.

($\S$) LAL Orsay
(*) Universita’ degli Studi di Roma “La Sapienza” & INFN Roma
Interference of $V_{cb}$ with $V_{ub}$ amplitudes with the same final state \(\Rightarrow\) sensitivity to $\gamma$

Mixing $B^0\bar{B}^0 \Rightarrow$ sensitivity to $2\beta$


Threebody decay \(\Rightarrow\) Dalitz analysis

\[\text{FEYNMAN DIAGRAMS}\]

\[\text{Interference of } V_{cb} \text{ with } V_{ub} \text{ amplitudes with the same final state } \Rightarrow \text{sensitivity to } \gamma\]

\[\text{Mixing } B^0\bar{B}^0 \Rightarrow \text{sensitivity to } 2\beta\]


Threebody decay \(\Rightarrow\) Dalitz analysis
THE DALITZ MODEL

\[ A_{c_i(u_i)} e^{i\delta_{c_i(u_i)}} = \sum_j a_j e^{i\delta_j} BW_j(m, \Gamma, s) \]

<table>
<thead>
<tr>
<th></th>
<th>Mass (GeV/c²)</th>
<th>Width (GeV/c²)</th>
<th>J^P</th>
<th>(a(V_{cb}))</th>
<th>(a(V_{ub}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(D_s^*(2573))</td>
<td>2.572</td>
<td>0.015</td>
<td>2+</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>(D_2^*(2460)^0)</td>
<td>2.461</td>
<td>0.046</td>
<td>2+</td>
<td>0.06</td>
<td>0.024</td>
</tr>
<tr>
<td>(D_1(2420)^0)</td>
<td>2.308</td>
<td>0.276</td>
<td>1+</td>
<td>0.14</td>
<td>0.056</td>
</tr>
<tr>
<td>(K^*(892)^)</td>
<td>0.89166</td>
<td>0.0508</td>
<td>1-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>(K_0^*(1430)^)</td>
<td>1.412</td>
<td>0.294</td>
<td>0+</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>(K_2^*(1430)^)</td>
<td>1.4256</td>
<td>0.0985</td>
<td>2+</td>
<td>0.15</td>
<td>-</td>
</tr>
<tr>
<td>(K^*(1680)^)</td>
<td>1.717</td>
<td>0.322</td>
<td>1-</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>“Non Resonant”</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.07</td>
<td>0.028</td>
</tr>
</tbody>
</table>

**THE DALITZ MODEL**

Monte Carlo

\(V_{ub}\) channels

\(D_s^*\)

\(m^2(K_0^0 \pi^-)/(GeV^2/c^4)\)

\(m^2(D^+ K_s^0)/(GeV^2/c^4)\)

Monte Carlo

\(V_{cb}\) channels

\(D^{**0}\)

\(K^{**}\)

\(K^*\)
If $B^0 \rightarrow D^+ K_s^0 \pi^-$ only one r but 8 fold ambiguity:

$$\Pr \left( B^0 \rightarrow D^+ K_s^0 \pi^- \right) = \frac{A_{c_i}^2 + A_{u_i}^2}{2} e^{-\Gamma t} \left\{ \begin{array}{l} (+) \cos(\Delta m \cdot t) + D_i \sin(2\beta + \gamma + \Delta\delta_i) \sin(\Delta m \cdot t) \\ (-) \cos(\Delta m \cdot t) - D_i \sin(2\beta + \gamma - \Delta\delta_i) \sin(\Delta m \cdot t) \end{array} \right\}$$

where "i" is a bin of the Dalitz plot and:

$$D_i = \frac{2r_i}{r_i^2 + 1} \quad R_i = \frac{r_i^2 - 1}{r_i^2 + 1} \quad r_i = \left| \frac{A_{u_i}}{A_{c_i}} \right|$$

If $B \rightarrow D\pi$ only one r but 8 fold ambiguity:

- $S_{\pi,2}: 2\beta + \gamma \rightarrow \pi/2 - \Delta\delta, \quad \Delta\delta \rightarrow \pi/2 - (2\beta + \gamma)$
- $S_- : 2\beta + \gamma \rightarrow -(2\beta + \gamma), \quad \Delta\delta \rightarrow \pi - \Delta\delta$
- $S_{\pi} : 2\beta + \gamma \rightarrow 2\beta + \gamma + \pi, \quad \Delta\delta \rightarrow \Delta\delta + \pi$

If $B \rightarrow D K_s \pi$ more complicated since:

- $r_i$ varies along the Dalitz plot, thus should be fitted with amplitudes;
- several resonances contributing;
- But only 2 fold ambiguities ($S_{\pi}$).

**Likelihood scan** only for $D^{*0}$ wide resonance interfering (MonteCarlo $\sim 1ab^{-1}$), as function of strong phase $\Delta\delta$ and $2\beta + \gamma$; the initial 8-fold ambiguity is almost resolved to a 2 fold ambiguity.

---

**TIME DEPENDENT DALITZ FIT**

Francesco Polci

CKM 2005, San Diego
**THEORETICAL vs EXPERIMENTAL DALITZ PLOTS**

### Theoretical Dalitz

![Theoretical Dalitz Plot](image)

$$A \left( \begin{array}{c} b \\ \bar{c} \\ \bar{d} \end{array} \right) \bar{D}^{*0} \begin{array}{c} u \\ c \\ s \\ d \end{array} K^{0} \approx \frac{1}{\lambda} \left| V_{ub} \right| V_{cb} \approx 0.4$$

### Experimental Dalitz

![Experimental Dalitz Plot](image)

$$B^{0} \rightarrow D^{\mp} K^{0} \pi^{\pm}$$

from **BaBar** data (82 fb$^{-1}$)  

(hep-ex/0412040)

Reconstruct $D^{+} \rightarrow K \pi \pi$

Total efficiency: 18%
Fix amplitudes and phases
Fit only $2\beta+\gamma$...
Get sensitivity

$$\sigma_{2\beta+\gamma} = \sqrt{\sum \frac{\partial^2 \ln L}{\partial (2\beta+\gamma)^2}}$$

Most of sensitivity due to interference
t between $D^{*0}$ and $K^*$

Error vs integrated luminosity
($"r"=0.4$)

Std Model $\times 0.7$ Amp($D^{*0}$)
Std Model
Std Model $\times 1.5$ Amp($D^{*0}$)
Vub all non-resonant

points: weight = 1

$$\text{weight} = \frac{\partial^2 \ln L}{\partial (2\beta+\gamma)^2}$$
✓ $B^0 \rightarrow DK^0\pi$ is a decay sensitive to the weak phase $2\beta+\gamma$.

✓ The sensitivity on $2\beta+\gamma$ is strongly depending on the model.

✓ A Dalitz model in reasonable agreement with data has been elaborated.

✓ A model with only non-resonant $V_{ub}$ amplitude (not realistic) turns out to be over optimistic ($\sim$ a factor 3)

✓ With a statistic of $500 fb^{-1}$, the relative error on $2\beta+\gamma$ should lie in the interval [25%, 50%]

**Improvements:**

✓ Informations on amplitudes and phases from:
  1) untagged events;
  2) several control samples

✓ Add other $D$ decay channels ($D \rightarrow K_s\pi$, with $\sim$15% gain in statistics)
BACKUP SLIDES
A model having only non resonant contribution in $V_{ub}$ amplitudes does not reproduce data.
Our model with $0.7 \cdot \text{Amplitude}(D^{**0})$

Our model with $1.5 \cdot \text{Amplitude}(D^{**0})$
Monte Carlo

\[ m^2(K^0_s \pi^-)(\text{GeV}^2/c^4) \]

\[ m^2(D^+ K^0_s)(\text{GeV}^2/c^4) \]