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Fermilab

More on γ from $B \to DX$ decays

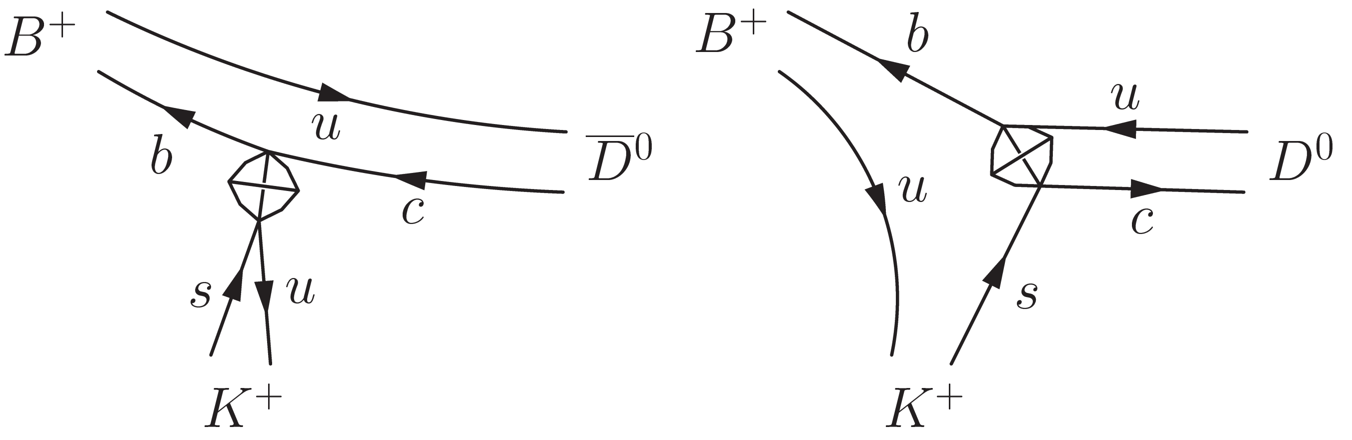
Ulrich Nierste
Fermilab

γ from tree-tree interference

Basic idea: Use interference of the two tree amplitudes $b \to c\overline{u}q$ and $b \to u\overline{c}q$ (with $q = d$ or $q = s$) to get $\gamma = \arg V_{ub}^*$. Two generic ways:

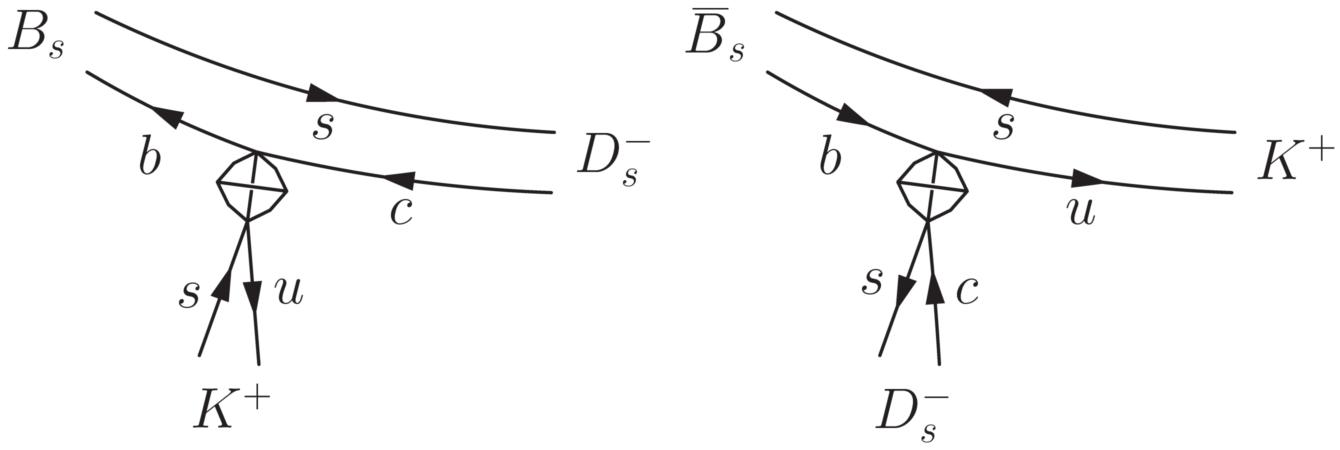
1. Interference of $B \to D^0[\to f]X$ and $B \to \overline{D^0}[\to f]X$:
   - measure only branching fractions, no tagging needed,
   - works with charged and neutral B's,
   - study different $\overset{(-)}{D^0} \to f$ decays to determine the magnitudes of the amplitudes $A(b \to u)$, $A(b \to c)$, their relative strong phase δ and the desired weak phase, e.g. γ.
2. Interference of $B \to DX$ and $\overline{B} \to DX$:
   - needs B_d's or B_s's,
   - needs either the time evolution of tagged B_d or B_s samples or the lifetime information (plus an angular analysis) of $\overset{(-)}{B}_s \to DX$ and $\overset{(-)}{B}_s \to D\overline{X}$ decays ($\overline{X} = CPX$). The untagged measurement works only, if $\Delta\Gamma_{B_s}$ is large.

Prototype for 1.: Gronau-London-Wyler (GLW) method:



Interference if both $D^0 \to f$ and $\overline{D^0} \to f$ are allowed,
e.g. $f = \pi^+\pi^-, K^+K^{*-}, \rho^0 K_S, \ldots$

Prototype for 2.: Aleksan-Dunietz-Kayser (ADK) method:



Design measurements meeting the strengths of CDF and DØ:

Measurements based on $B \to D^0[\to f]X$ seem to be well-suited for CDF, because of the good K/π separation, which allows to distinguish e.g. $\overset{(-)}{D^0} \to \pi^+K^-, \pi^-K^+, K^+K^-$ and $\pi^+\pi^-$. No tagging is needed.

At DØ $B \to DX$ samples are tagged, because the $\mu^\pm$ from the other b is used to trigger. Decays $B \to D^{*\pm}X$ are good, because the soft π^+ from $D^{*+} \to D^0\pi^+$ helps to reconstruct the decay.

Non-flavor-specific $B \to D^0 X$ decays

Gronau, Grossman, Shuhmaher, Soffer, Zupan:

Final states like $D^0 K_S$ are accessible to both B_d and $\overline{B}_d$. Still one can solve for γ from untagged $\overset{(-)}{B}_d$ decays. The same works with $\overset{(-)}{B}_s \to \overset{(-)}{D^0} \phi$:

Consider $2N$ measurements $\overset{(-)}{B}_s \to \overset{(-)}{D^0}[\to f_i]\phi$ and $\overset{(-)}{B}_s \to \overset{(-)}{D^0}[\to \overline{f}_i]\phi$ branching fractions, where $i = 1, \ldots N$, $\overline{f}_i = CP f_i$ (and the f_i's are not CP eigenstates).

Define (neglecting CP violation in $D^0 \to f$)

$$A_f \equiv |A(\overline{D^0} \to f)|, \qquad r_f e^{i\delta_f} \equiv \frac{A(D^0 \to f)}{A(\overline{D^0} \to f)}, \qquad r_f \geq 0.$$

A_f and r_f are measured from $\overset{(-)}{D^0} \to f$ branching fractions. Then

$$\Gamma(\overset{(-)}{B_s} \to \overset{(-)}{D^0}[\to f]\phi) = A_f^2 \left[(1+r_f^2)X + 2Y r_f \cos(\delta_f + \gamma)\right]$$
$$\Gamma(\overset{(-)}{B_s} \to \overset{(-)}{D^0}[\to \overline{f}]\phi) = A_f^2 \left[(1+r_f^2)X + 2Y r_f \cos(\delta_f - \gamma)\right]$$

where X and Y are hadronic quantities related to $B_s \to D^0\phi$ and $B_s \to \overline{D^0}\phi$. For N decay modes $D^0 \to f_i$ we face the $N+3$ unknowns X, Y, δ_{f_i} and γ.

$\Rightarrow$ Need to study $N \geq 3$ different $\overset{(-)}{B_s} \to \overset{(-)}{D^0}[\to f_i]\phi$ decays to find γ from the $2N$ measurements.

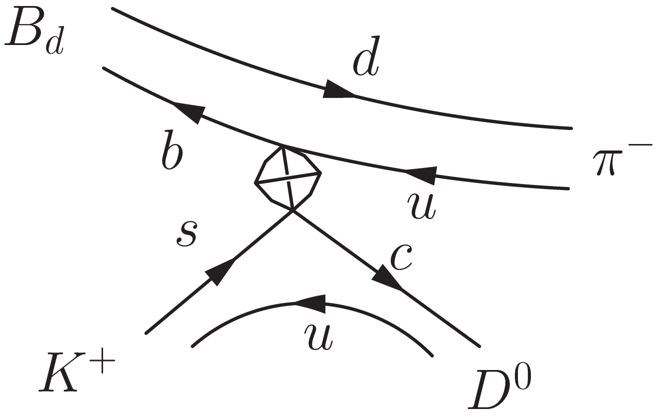
Three-body decays

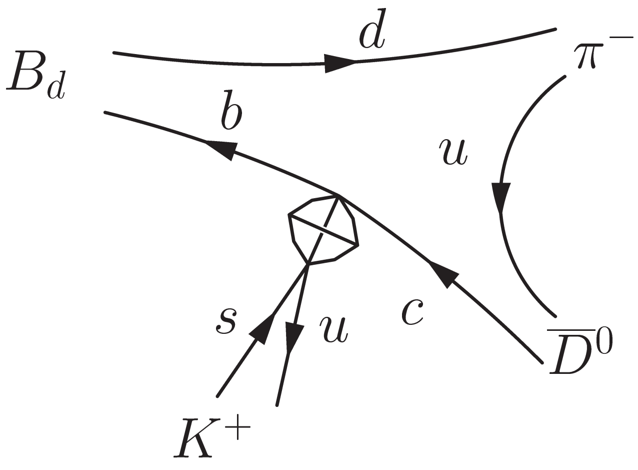
The GLW method comes with the drawback that the smaller $A(b \to u)$ amplitude has an extra $1/N_c$ suppression.

In certain three-body decays both $A(b \to u)$ and $A(b \to c)$ are color-favored. Aleksan, Petersen, Soffer proposed $B^+ \to \overset{(}{\overline{D^0}}\overset{)}{} K^+ \pi^0$. One can easily extend their findings to decay modes which are better suited for the Tevatron:

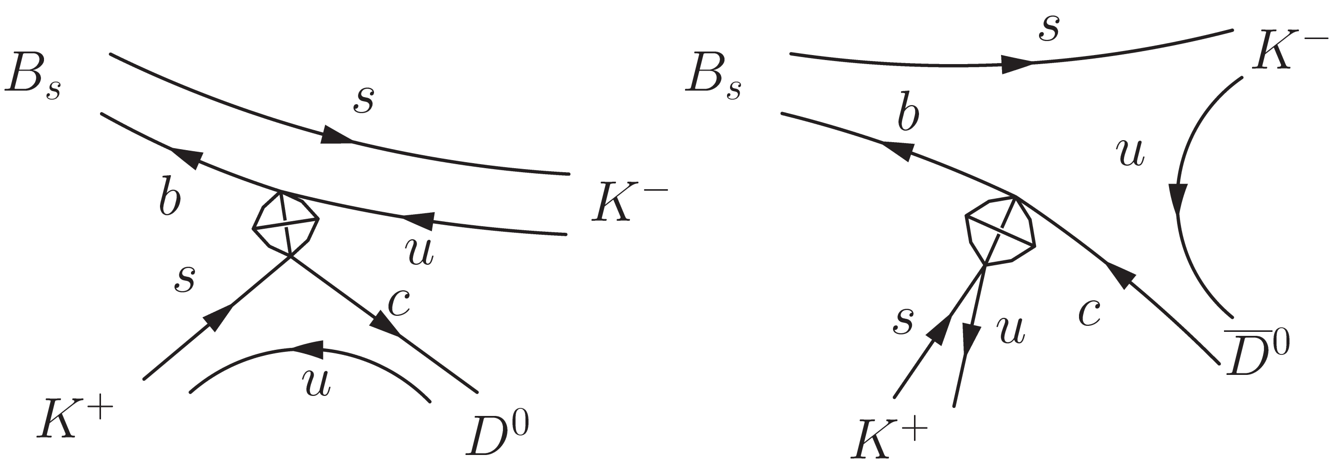
$B^+ \to \overset{(-)}{D^0} K^+ \rho^0$, $B_d \to \overset{(-)}{D^0} K^+ \pi^-$, $B_s \to \overset{(-)}{D^0} K^- \pi^+$,...

$B_d \to \overset{(}{\overline{D^0}}\overset{)}{} K^+ \pi^-$:





$\overset{(-)}{B}_s \to \overset{(-)}{D^0} K^+ K^-$:



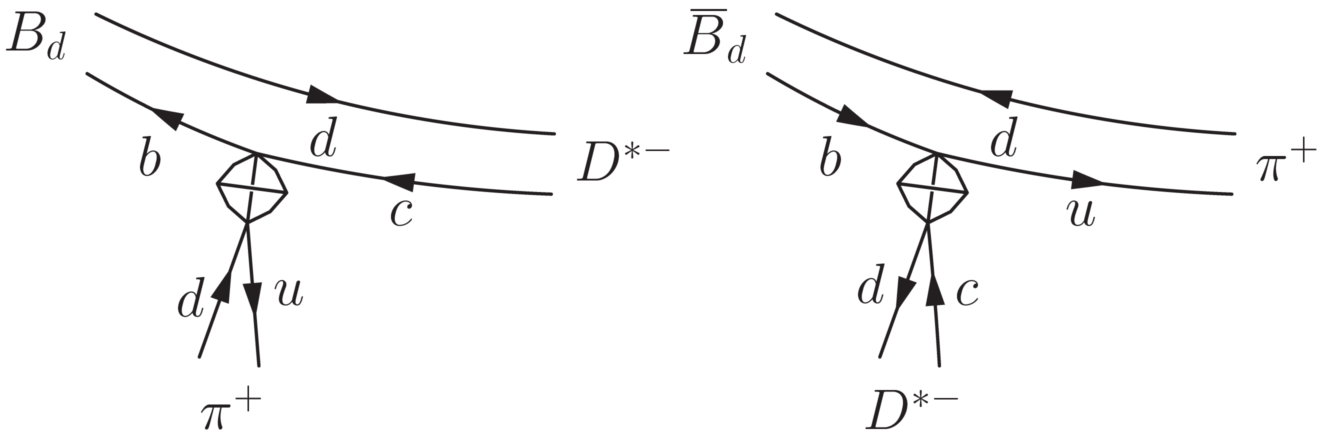
Dalitz plot: Information on CP-even and CP-odd $\overset{(-)}{D^0} K^+ K^-$ final states.

$\Rightarrow$ Lifetimes will reveal information on $\mathrm{B_s} - \overline{\mathrm{B}}_\mathrm{s}$ mixing phase.

Tagged studies with a $D^{*\pm}$

$2\beta+\gamma$ from interference of $b \to c\overline{u}d$ and $b \to u\overline{c}d$:

$B_d \to D^{*-}\pi^+$:



The interfering $b \to u\overline{c}d$ amplitude is only 0.02 of the dominant amplitude. K/π misidentification should not be a big problem: $Br(B_d \to D^{*-}K^+)$ background is 20 times smaller and does not oscillate. Also B_s/B_d separation is not an issue.

β_s and γ can be obtained from the interference of $b \to c\overline{u}s$ and $b \to u\overline{c}s$ à la ADK. If the final state shall contain a D^{*-}, one must go to three-body decays: $B_s \to D^{*-} K_S K^{*+} [\to K_S \pi^+]$ or $B_s \to D^{*-} \overline{K}^{*0} K^{*+} [\to K_S \pi^+]$.

No problem with K/π misidentification, but B_s/B_d separation matters, because of $B_d \to D^{*-} K_S K^{*+}$, which however does not oscillate.

B_s/B_d separation is no issue in $B_s \to D^{*-} \pi^+ \phi$, which however is color-suppressed.

Conclusions

- γ can be determined from untagged measurements through branching fractions of $B \to \overset{(-)}{D^0} X$, where B can be any weakly decaying b-flavored hadron.
- There are very many B decays involving the interference of $b \to c\bar{u}s$ and $b \to u\bar{c}s$ decays. One should look for decay modes which meet the strengths of the Tevatron experiments. (Likewise γ can also be found from the interference of $b \to c\bar{u}d$ and $b \to u\bar{c}d$ decays.)
- Three-body decay modes can be interesting, but require a Dalitz analysis.
- Tagged studies reveal information on $2\beta + \gamma$ and $2\beta_s + \gamma$.
- It is well possible that the measurement of γ from tree-tree interference is a "world effort", with both B factories and the Tevatron contributing to the measurements of the required branching ratios and with the study of many different decay modes.