Determination of the CKM angle γ in $B^{\pm} \to DK^{\pm}, D\pi^{\pm}$ decays and strong phase determination of $D \to K^+K^-\pi^+\pi^-$ at BESIII

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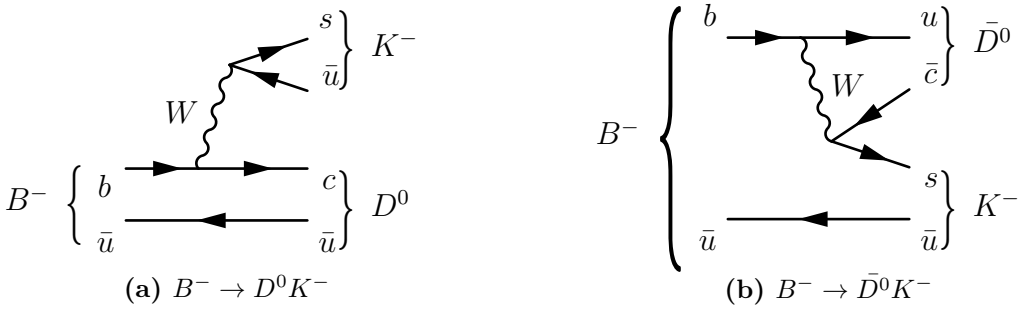
Abstract

Write abstract at the end

1 Introduction

In the Standard Model, CP-violation can occur if the CKM matrix has a non-trivial weak phase. This is studied by measuring the lengths and angles of the Unitary Triangle of the CKM matrix. In particular, the angle $\gamma = \arg(-V_{ud}V^*ub/V_{cd}V^*cb)$ is the only angle that can be measured at tree level, with negligible theoretical uncertainties. A precise determination of γ is therefore a good Standard Model benchmark which can be compared with indirect determinations from other CKM observables that are sensitive to new physics.

Sensitivity to γ can be achieved through interference between the $b \to c\bar{u}s$ and $b \to u\bar{c}s$ transitions. A powerful decay mode is $B^{\pm} \to DK^{\pm}$, where D, a superposition of D^0 and $\bar{D}^0$, subsequently decays to a self-conjugate state. This is illustrated in Fig. 1. On the left, the colour favoured decay $B^- \to D^0K^-$ is shown, while on the right is the decay colour suppressed $B^- \to \bar{D}^0K^-$. Interference is observed when D^0 and $\bar{D}^0$ decays to a common final state.



(a) $B^- \to D^0K^-$ **(b)** $B^- \to \bar{D}^0K^-$

Figure 1: Feynman diagrams of $B^- \to DK^-$ decays

A wide range of subsequent D decays has been studied. Most recently, the measurement $\gamma = (68.7^{+5.2}_{-5.1})^\circ$ from an analysis of the decay modes $D \to K^0_S\pi^+\pi^-$ and $D \to K^0_SK^+K^-$ was obtained, which is the single most precise measurement of γ. In this project, the decay $B^{\pm} \to DK^{\pm}$, where $D \to K^+K^-\pi^+\pi^-$, is considered. An initial

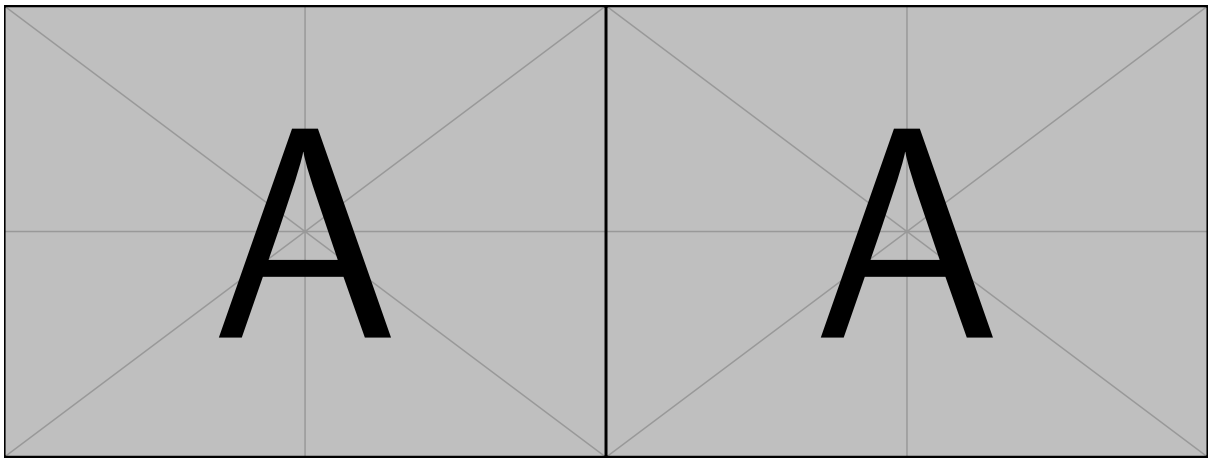
study showed that a precision of 14° is achievable with a sample of 1000 $B^{\pm} \to DK^{\pm}$ candidates. From similar decay channels, it is estimated that 2000 candidates can be reconstructed from the combined Run 1+2 LHCb dataset.

A significant challenge with this analysis is that the $D \to K^+K^-\pi^+\pi^-$ decay is a multi-body decay, so the strong phase difference between the D^0 and $\bar{D}^0$ decays varies non-trivially across phase space. Moreover, with four particles in the final state phase space becomes five-dimensional. To predict this strong phase difference, a decay model, such as one developed by LHCb, may be used. However, such a model introduces systematic uncertainties due to modelling.

In this analysis, a model-independent approach is chosen, in which strong phases are determined at a charm factory, BESIII. Here, quantum correlated $D^0\bar{D}^0$ pairs are produced at the $\psi(3770)$ resonance. The amplitude-averaged strong phases are measured in bins of the $D \to K^+K^-\pi^+\pi^-$ phase space. The choice of binning scheme may enhace the sensitivity to γ. However, a poor choice of binning scheme may only decrease the statistical sensitivity, but not bias the result. With a model-independent approach, one therefore eliminates the systematic uncertainty due to modelling.

2 LHCb detector

Briefly describe the VELO and RICH



(a) LHCb detector overview **(b)** LHCb detector overview

Figure 2

3 Binning scheme

Describe the binning scheme developed and toy studies for testing it

4 $B^{\pm}$ candidate selection

4.1 Signal candidate requirements

Explain how signal events are selected

Table 1: Requirements

Letter	Numerical value
c	$299\,792\,458\,\mathrm{m\,s^{-1}}$
G	$6.673\,84 \cdot 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
$\hbar$	$1.054\,57 \cdot 10^{-34}\,\mathrm{J\,s}$
k_B	$1.380\,65 \cdot 10^{-23}\,\mathrm{J\,K^{-1}}$
e	$1.602\,18 \cdot 10^{-19}\,\mathrm{C}$

4.2 Background from $D^0 \to K^-\pi^+\pi^-\pi^+$

Show studies of $K3\pi$ contamination

4.3 Charmless backgrounds

Show how flight significance cut removes $B \to KKK\pi\pi$ and mention that $B \to KK\pi\pi\pi$ is insignificant

5 Fit to extract CP observables

5.1 Global fit and invariant mass spectra

State the fit procedure for global fit and show results of global fit for Run 2, including yields

5.2 Binned CP fit and CP observables

Explain the binned CP fit to extract CP observables

5.3 Validation of fit procedure with toy studies

6 External strong phase input from BESIII

Describe how to extract strong phases at a charm factory and show some initial plots of single tag yields and double tag yields

7 Discussion of future work

Discuss the plan further

8 DPhil thesis plan

Discuss DPhil thesis plan with Guy first!