# Measurement of the CKM angle $\phi_3$ using $B \to DK$ at Belle II

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**Abstract** We present the preliminary results of the physics analysis dedicated for the measurement of the CKM angle $\phi_3$ using $B^{\pm} \to D^0(K_S^0\pi^+\pi^-)K^{\pm}$ at Belle II. In this work, invariant masses of $K_S^0$ and $D^0$ are reconstructed using the Phase II data. Further, these results are compared with the Dress rehearsal data. The extrapolated results of $\phi_3$ measurement at 50 $ab^{-1}$ with imporved precision is also presented.

## 1 Introduction

The CKM angle $\phi_3$ is one of the least well constrained parameters of the Unitarity Triangle [1, 2]. The precise measurement of $\phi_3$ is highly desirable to scrutinise the consistency of the Standard Model and to detect presence of new physics. The measurement that currently dominates sensitivity to $\phi_3$ uses $B^{\pm} \to DK^{\pm}$ decays with the neutral D mesons decaying to a three-body final state such as $K_S^0\pi^+\pi^-$. As

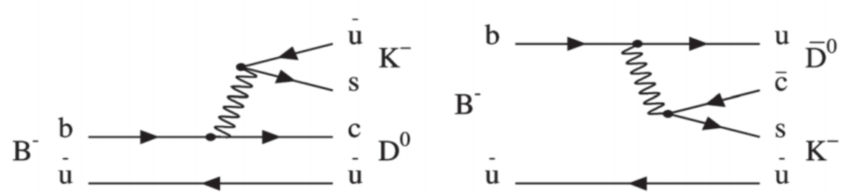


Fig. 1: Feynman diagram for $B^- \to D^0K^-$ (left) and $B^- \to \overline{D}^0K^-$ (right) [3].

the sensitivity of $\phi_3$ comes from the interference of $b \to c\overline{u}s$ and $b \to u\overline{c}s$, therefore, measurement of $\phi_3$ is performed by exploiting the difference between $K_S^0\pi^+\pi^-$ Dalitz plots for D mesons from $B^+$ and $B^-$ decay. The measurement of $\phi_3$ from $B^{\pm} \to D^0K^{\pm}$ and $B^{\pm} \to \overline{D}^0K^{\pm}$ decays is theoretically clean as they occur at the tree

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level (Fig. 1). Various methods for extracting $\phi_3$ have been proposed, from which the Dalitz plot analysis method [4] is one of the novel methods to measure the $\phi_3$. There have been many efforts by BaBar, Belle and LHCb to measure this angle but due to the small data samples so far produced, $\phi_3$ is poorly determined. Therefore, an in-

| Sr. No. | Experiment | Measurement of $\phi_3$ |
|---|---|---|
| 1 | Belle | $\left(73^{+13}_{-15}\right)^{\circ}$ [5] |
| 2 | BaBar | $\left(69^{+17}_{-16}\right)^{\circ}$ [6] |
| 3 | LHCb | $\left(74^{+5.0}_{-5.8}\right)^{\circ}$ [7] |

Table 1: Previous results for the measurement of $\phi_3$.

dependent measurement with high statistics is required to measure $\phi_3$. In this work, the experimental facility Belle II at SuperKEKB is used for the physics analysis of $B \to DK$ to measure $\phi_3$. The Belle II [8] experiment at the SuperKEKB collider [9], KEK will accumulate $e^+e^-$ collision data at an unprecedented instantaneous luminosity of $8 \times 10^{35}$ cm$^{-2}$sec$^{-1}$, which is 40 times larger than preceding experiment, Belle. Due to large statistics, an improved measurement of $\phi_3$ is expected and the extrapolated results on the measurement at 50 ab$^{-1}$ is shown in figure 2 (right) and current status is shown in figure 2 (left). In addition, Belle II will also have a better

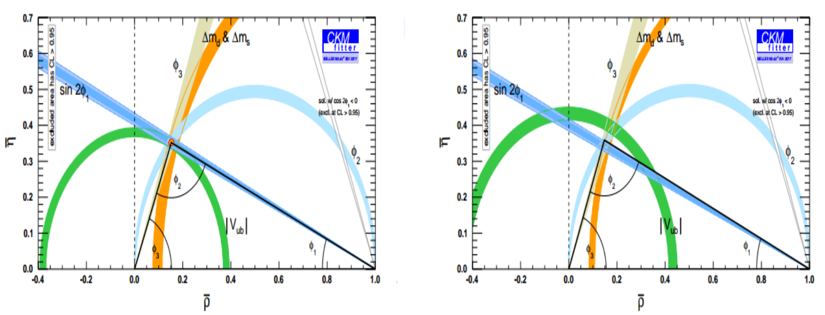


Fig. 2: UT fit today (left) and extrapolated to the 50 ab$^{-1}$ scenario (right) for an SM-like scenario and world average values [10].

particle identification with the Central Drift Chamber (CDC), Time of Propagation (TOP) and the Aerogel Ring Imaging Cherenkov Counter (ARICH), which is functioning in different momentum ranges. Due to larger acceptance of the detector, an improved reconstruction efficiency of $K_S^0$ is anticipated. Recently, Belle II has collected Phase II data incorporating single ladder per layer of the vertex detector (VXD) and all other subdetectors at integrated luminosity of 250 pb$^{-1}$.

## 2 Physics Analysis of B $\to$ DK

The physics analysis of $B^{\pm} \to D^0(K^0_S\pi^+\pi^-)K^{\pm}$ is carried out using the Phase II data collected at 250 $pb^{-1}$. The analysis begins with the reconstruction of $K^0_S$ from the two charged tracks of $\pi^+$ and $\pi^-$. The invariant mass of $K^0_S$ is shown in figure

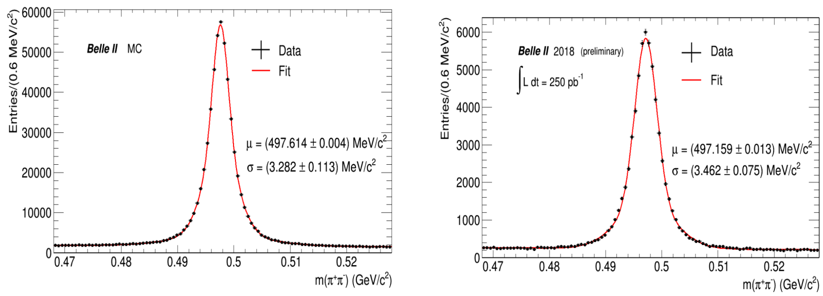


Fig. 3: Invariant mass of $K^0_S$ with DR2 (left) and data (right).

3 (left) with Dress rehearsal 2 (DR2) collected at integrated luminosity 1 $fb^{-1}$ and with Phase II data shown in figure 3 (right). Here, black points are data and red line is fitting. As can be seen from the figure, the invariant mass resolution shows

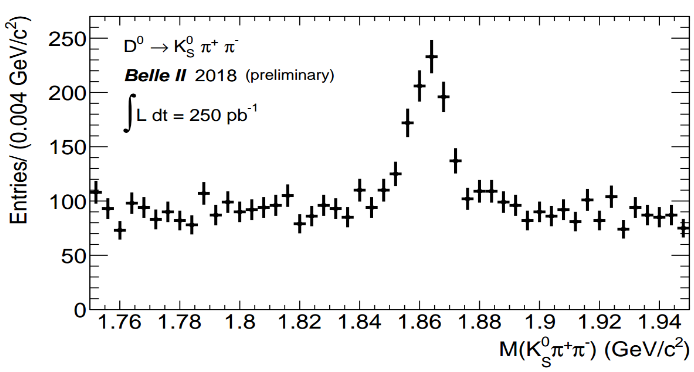


Fig. 4: Invariant mass of $D^0$ with Phase II data.

the good aggrement between data and DR2. Further, the $D^0$ is reconstructed from one $K^0_S$ and two charged tracks of $\pi^+$ and $\pi^-$ and invariant mass of $D^0$ is shown in figure 4. The reconstruction of B meson is in progress by using the two important variables, energy difference, $\triangle E = \sum E_i$ - $E_{beam}$ and the beam constrained mass, $M_{bc} = \sqrt{(E_{beam})^2 - \sum(\overrightarrow{p_i})^2}$, where $E_{beam}$ is the center-of-mass (CM) beam energy, $E_i$ and $p_i$ are the CM energies and momenta of B candidates decay product.

## 3 Summary

The large statistics with Belle II at SuperKEKB will provide the precision measurement of $\phi_3$. Extrapolated results are expected to provide a more precise measurement of the CKM angle $\phi_3$ at integrated luminosity 50 ab$^{-1}$. Recently Belle II has collected Phase II data incorporating single ladder per layer of the vertex detector and all other subdetectors. In this work, we have performed the physics analysis of $\mathrm{B}^{\pm} \to \mathrm{D}^0\mathrm{K}^{\pm}$ with Phase II data. Invariant masses of $\mathrm{K}_S^0$ and $\mathrm{D}^0$ are reconstructed and compared with DR2 and Phase II data. The reconstruction of B meson is in progress.

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