Measurement of the CKM angle ϕ_3 using B→DK with Belle II

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Abstract We present a preliminary study of using the decay $B^{\pm} \to D_{CP}K^{\pm}$ to measure ϕ_3 at Belle II, where D_{CP} represents a D meson decay to a CP even eigenstate i.e. K^+K^- and $\pi^+\pi^-$. We discuss the ϕ_3 measurement one may expect at Belle II with an integrated luminosity of 50 ab^{-1}. We also present the preliminary results on the reconstruction of B and D mesons from a Belle II data sample corresponding to an integrated luminosity of 472 pb^{-1}.

1 Introduction

The CKM angle ϕ_3 is one of the least well constrained parameters of the Unitarity Triangle [1, 2]. The measurement of ϕ_3 from $B^{\pm} \to D^0K^{\pm}$ and $B^{\pm} \to \overline{D^0}K^{\pm}$ decays is theoretically clean as they occur at the tree level [3] as shown in Fig. 1. If the D^0

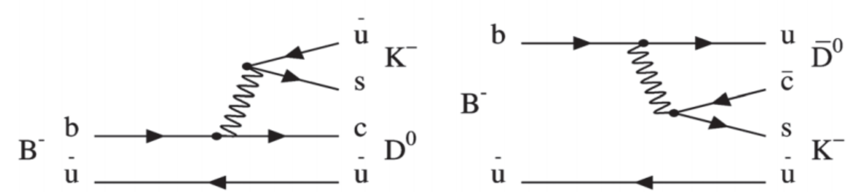

Fig. 1: Feynman diagram for $B^- \to D^0K^-$ (left) and $B^- \to \overline{D}^0K^-$ (right) [4].

or $\overline{D^0}$ is reconstructed as a CP eigenstate, the $b \to c$ and $b \to u$ processes interfere. This interference may lead to direct CP violation. To measure D meson decays to such final states a large number of B mesons is required since the branching fraction of these modes are only of the order 0.01% [5]. Then a large number of B decays are required to extract ϕ_3. To extract ϕ_3 using the GLW method [6] method, the observables sensitive to CP violation are

$$\mathcal{A}_{1,2} \equiv \frac{\mathcal{B}(B^- \to D_{1,2}K^-) - \mathcal{B}(B^+ \to D_{1,2}K^+)}{\mathcal{B}(B^- \to D_{1,2}K^-) + \mathcal{B}(B^+ \to D_{1,2}K^+)} \tag{1}$$

$$= \frac{2\text{r} \sin\delta' \sin\phi_3}{1 + \text{r}^2 + 2\text{r}\cos\delta' \cos\phi_3}, \tag{2}$$

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and the double ratios

$$\mathcal{R}_{1,2} \equiv \frac{R^{D_{1,2}}}{R^{D^0}} = 1 + \mathrm{r}^2 + 2\mathrm{r}\cos\delta^{'}\cos\phi_3 \quad (3)$$

$$\delta^{'} = \begin{cases} \delta & \text{for } D_1 \\ \delta + \pi & \text{for } D_2. \end{cases} \quad (4)$$

The ratios $\mathcal{R}^{D_{1,2}}$ and $\mathcal{R}^{\mathcal{D}^0}$ are defined as

$$\mathcal{R}^{D_{1,2}} = \frac{\mathcal{B}(B^- \to D_{1,2}K^-) + \mathcal{B}(B^+ \to D_{1,2}K^+)}{\mathcal{B}(B^- \to D_{1,2}\pi^-) + \mathcal{B}(B^+ \to D_{1,2}\pi^+)}$$

$$\mathcal{R}^{D^0} = \frac{\mathcal{B}(B^- \to D^0K^-) + \mathcal{B}(B^+ \to \overline{D}^0K^+)}{\mathcal{B}(B^- \to D^0\pi^-) + \mathcal{B}(B^+ \to \overline{D}^0\pi^+)},$$

where D_1 and D_2 are *CP*-even and *CP*-odd eigenstates, respectively. Here r = $|A(B^- \to \overline{D}^0K^-)/A(B^- \to D^0K^-)|$ is the ratio of the magnitude of the tree amplitudes and δ is their strong-phase difference. Note that the asymmetries $\mathcal{A}_1$ and $\mathcal{A}_2$ are of opposite sign.

There have been many efforts by BaBar, Belle and LHCb collaborations to measure the CKM angle ϕ_3, which are summarized in Table 1, but a measurement with a precision of 1° is desirable to compare to the indirect measurement. Therefore, determinations of ϕ_3 with high statistics are required, as the measurement is dominated by the statistical uncertainty. In this work, we present a preliminary Monte Carlo

Experiment	**Measurement of ϕ_3**
Belle	$\left(73^{+13}_{-15}\right)^\circ$ [7]
BaBar	$\left(69^{+17}_{-16}\right)^\circ$ [8]
LHCb	$\left(74^{+5.0}_{-5.8}\right)^\circ$ [9]

Table 1: Previous ϕ_3 measurements.

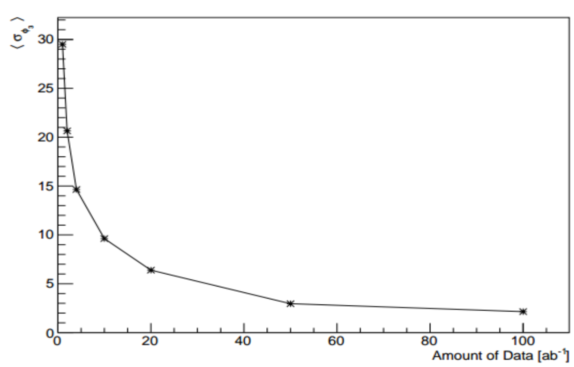

Fig. 2: Distribution between the expected ϕ_3 from $B^+ \to D(K^0_S\pi^+\pi^-)K^+$ uncertainty versus luminosity accumulated by Belle II [10].

(MC) study of $B^{\pm} \to D^0K^{\pm}$ to extract ϕ_3 using the 50 ab^{-1} data to be accumulated by the Belle II detector. The Belle II [11] experiment at the SuperKEKB asymmetric e$^+$e$^-$ collider [12], will accumulate collision data at an unprecedented instantaneous luminosity of 8×10^{35}cm^{-2}sec^{-1}, which is 40 times larger than the Belle experiment. Fig. 2 shows how the expected uncertainty on ϕ_3 scales with luminosity based on toy Monte Carlo studies for the mode $B^+ \to D(K^0_S\pi^+\pi^-)K^+$. It shows that the expected uncertainty is approximately 3° and the overall ϕ_3 projection is 1.6° after including GLW/ADS [13] and D^* modes with an integrated luminosity of 50 ab^{-1}. In this work, we present the study of $D^{*\pm} \to D^0(K^-\pi^+)\pi^{\pm}$ using the Phase II data of Belle II experiment collected with in integrated luminosity of 472pb^{-1}. This decay is an important control channel for GLW and ADS analyses at Belle II. Here, Phase II data is incorporating single ladder per layer of the vertex detector, which is approximately $\frac{1}{8}^{\text{th}}$ of the complete vertex detector and all other subdetectors. We also show the study on $B^{\pm} \to D^0K^{\pm}$ with MC simulation.

2 Preliminary results from Phase II data

We reconstruct the decay of $D^{*\pm} \to D^0(K^-\pi^+)\pi^{\pm}$ using Phase II data, corresponding to an integrated luminosity of 472 pb^{-1}. To select $c\bar{c}$ events, the center-of-mass momentum of D^* is required to be greater than 2.5 GeV/c. The distribution of ΔM

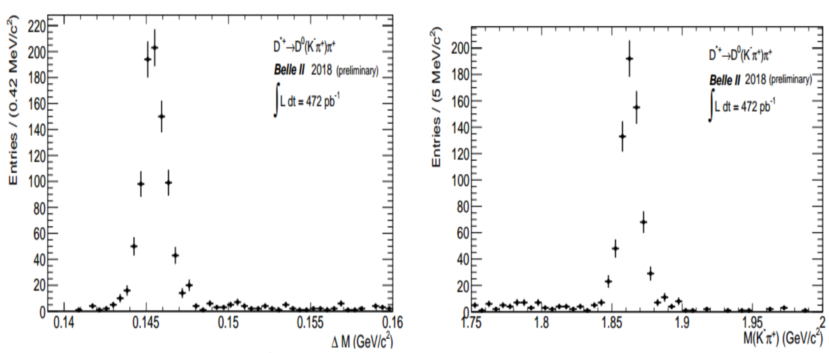

Fig. 3: ΔM (left) and M_D (right) distribution in Phase II data for $D^0 \to K^-\pi^+$ final state.

is shown in Fig. 3 (left), where ΔM is the difference between the invariant mass of $D^{*\pm}$ and D^0 meson. The invariant mass distribution of D^0 from $K^-\pi^+$ is shown in Fig. 3 (right).

Further, the reconstruction of B mesons is carried out with a MC data sample of 2×10^6 $B^{\pm} \to D^0(K^+K^-)K^{\pm}$ events. In order to select B mesons, two important variables, the energy difference, $\Delta E = \sum E_i - E_{\text{beam}}$ and the beam-constrained mass, $M_{bc} = \sqrt{(E_{\text{beam}})^2 - \sum(\overrightarrow{p_i})^2}$, where E_{beam} is the center-of-mass (CM) beam energy, E_i and p_i are the CM energies and momenta of B candidate's decay product. Fig. 4 shows the M_{bc} and ΔE distributions reconstructed from the MC sample; work is in progress to reconstruct B mesons in the Phase II data.

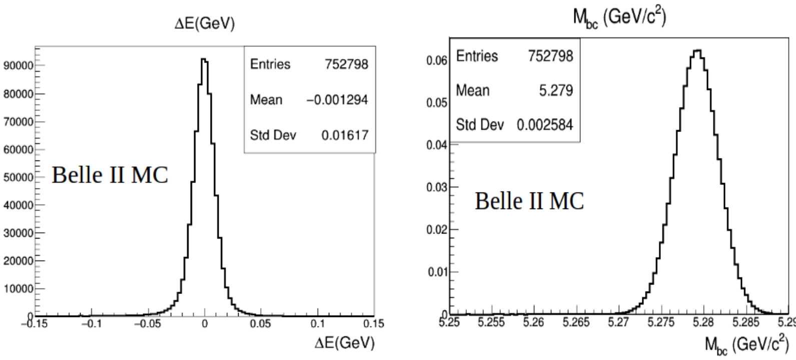

Fig. 4: ΔE (left) and M_{bc} (right) distribution from MC simulation.

3 Summary

The full 50 ab^{-1} data sample to be collected by Belle II at SuperKEKB will provide a substantial improvement in the precision measurement of ϕ_3. A clear signature of $D^{*\pm} \rightarrow D^0(K^-\pi^+)\pi^\pm$ is observed in Phase II data corresponding to an integrated luminosity of 472 pb^{-1}. Further the reconstruction of B mesons using M_{bc} and ΔE is carried out with MC simulation and the same is in progress with data.

4 Acknowledgements

The authors are thankful to the Belle II Collaboration for providing the opportunity to present this work. We are thankful to MNIT Jaipur and SERB, DST Delhi for providing the funding support from the research project (EMR Project File No:EMR/2016/007519) to participate and present this work in this symposium held at IIT Madras.

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