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# Measurement of raw asymmetry in $D^0 \longrightarrow K_s^0 K_s^0$ decay at Belle II

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## Introduction

$D^0 \longrightarrow K_S^0 K_S^0$ is a Singly Cabibbo Suppressed (SCS) decay, which involves the interference of $c\bar{u} \longrightarrow s\bar{s}$ and $c\bar{u} \longrightarrow d\bar{d}$ transitions. Due to such interference, the Charge Parity asymmetry ($\mathcal{A}_{CP}$) may be enhanced to an observable level within the Standard Model [1]. Most precise experimental measurement of $\mathcal{A}_{CP}$ in this decay mode is given by LHCb in 2021, with an integrated luminosity of 6 fb$^{-1}$: $\mathcal{A}_{CP}(D^0 \longrightarrow K_S^0 K_S^0) = (-3.1 \pm 1.2 \pm 0.4 \pm 0.2)\%$, where the first uncertainty is statistical, second is systematic and third uncertainty is due to the uncertainty of $\mathcal{A}_{CP}$ of the reference mode [2]. The Belle experiment had also provided a measurement for the $\mathcal{A}_{CP}$ in this decay mode in 2017 [3]. In this work, the signal yield and corresponding raw asymmetry ($A_{raw}$) for $D^0 \longrightarrow K_s^0 K_s^0$ is measured using Belle II Monte Carlo (MC) samples at integrated luminosity of 1 ab$^{-1}$. The Belle II [4] is an experimental facility at SuperKEKB [5] located in Tsukuba, Japan. The final goal of this analysis is to measure the $\mathcal{A}_{CP}$ in $D^0 \longrightarrow K_s^0 K_s^0$ with (Belle + Belle II) dataset where, $D^0 \longrightarrow K^+K^-$ is used as a reference mode.

## Reconstruction of $D^0 \longrightarrow K_s^0 K_s^0$

Signal candidates are reconstructed using the centrally produced Belle II MC samples at integrated luminosity of 1 ab$^{-1}$. The complete decay chain reconstructed for our analysis is $D^{*+} \longrightarrow D^0(\longrightarrow K_s^0 K_s^0)\pi_s^+$, where $\pi_s^+$ denotes the low-momentum *(soft)* pions and each $K_s^0$ decays into a pair of oppositely charged pions. Candidate $K_s^0 \longrightarrow \pi^+\pi^-$ decays are reconstructed by combining the tracks of two oppositely charged pions. Pairs of $K_s^0$ candidates thus reconstructed are combined to form the decay $D^0 \longrightarrow K_s^0 K_s^0$. Finally, the $D^0$ candidates are combined with *soft* pions to form the decay $D^{*+} \longrightarrow D^0\pi_s^+$. To suppress events where the $D^{*+}$ candidate comes from B meson decays, the momentum of the $D^{*+}$ in the $e^+e^-$ center-of-mass system ($p_{cms}$) is required to be greater than 2.5 GeV/$c^2$.

## Background Study

The major background for the decay $D^0 \longrightarrow K_s^0 K_s^0$ is $D^0 \longrightarrow K_s^0\pi^+\pi^-$, as they have the same final state particles. Further they also have the same $\Delta m$ (defined as the difference in the masses of $D^{*+}$ and $D^0$ candidates) distribution. This makes it difficult to separate the signal from the background using solely the traditionally used $\Delta m$ distribution.

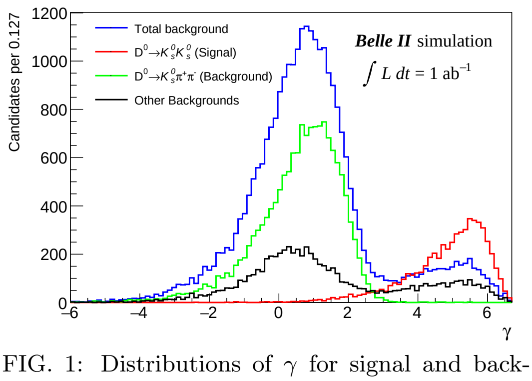


FIG. 1: Distributions of $\gamma$ for signal and background components.

The flight distance of the $K_s^0$ with respect to the $D^0$ vertex is exploited to provide a clear

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*Electronic address: `2018RPY9055@mnit.ac.in` separation of the signal and background components. A new variable $\gamma$, defined as the minimum of the flight-distance significance of the $K_s^0$ candidates is introduced as shown in 1. No selection criteria is applied to suppress the $D^0 \longrightarrow K_s^0\pi^+\pi^-$ *(Background)*.

## Results

Two variables $\Delta m$ and $\gamma$ are used to discriminate between the signal and the background components for the $D^0 \longrightarrow K_s^0 K_s^0$ decay and to measure its yield and $A_{raw}$.

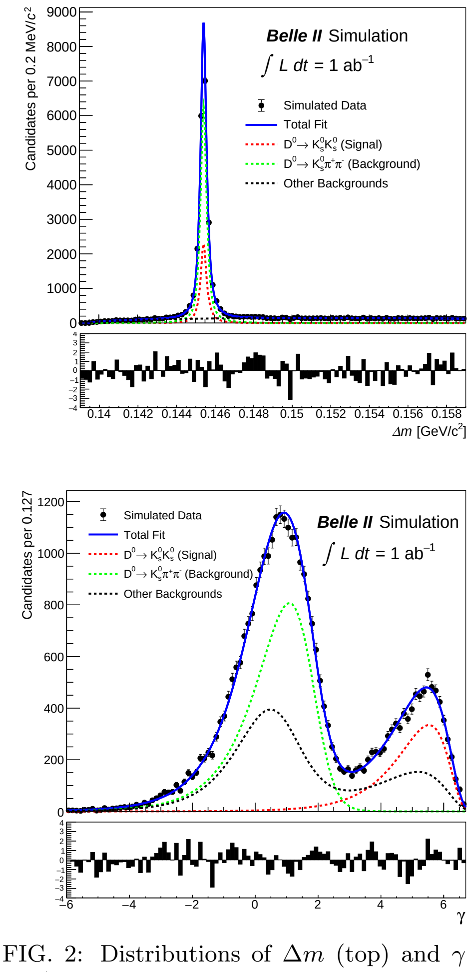


FIG. 2: Distributions of $\Delta m$ (top) and $\gamma$ (bottom), with fit projections overlaid. The normalized residuals (pulls) are also shown in the lower panel of each plot.

A simultaneous, unbinned maximum likelihood fit to $(\Delta m,\ \gamma)$ is performed for candidates populating the $m(K_s^0 K_s^0)$ signal window [1.85, 1.88] GeV/c$^2$. As shown in 2, the signal shape in both dimensions is modelled using a Johnson's $\mathrm{S}_U$ [6] distribution. The $D^0 \longrightarrow K_s^0\pi^+\pi^-$ *(Background)* component is modelled in the $\Delta m$ dimension using the sum of a Gaussian and a Johnson's $\mathrm{S}_U$ [6] distributions, both with the same mean. In the $\gamma$ dimension, it is modelled using a Johnson's $\mathrm{S}_U$ [6] distribution. *Other background* components in the $\gamma$ dimension are modelled using the sum of two Johnson's $\mathrm{S}_U$ distributions. In the $\Delta m$ dimension, it is modelled using $((\Delta m\text{-}\Delta m_0) + \alpha(\Delta m\text{-}\Delta m_0)^{3/2})$, where $\Delta m_0$ is 0.13957039 GeV/c$^2$. All shape parameters of the fit are fixed to their values obtained from the separate fits to the components in MC. The yields corresponding to the three components, the corresponding raw asymmetries and $\alpha$ is left free to float. Same shapes are assumed to hold for the $D^0$ and $\overline{D}^0$ samples.

The measured signal yield is $5853 \pm 83$ and the corresponding $A_{raw}$ is $0.007 \pm 0.014$.

## Summary

Using an MC sample at integrated luminosity of 1 ab$^{-1}$, the signal yield for the decay mode $D^0 \longrightarrow K_s^0 K_s^0$ is measured. The corresponding $A_{raw}$ is consistent with 0.

## References


[1] Ulrich Nierste and Stefan Schacht , CP violation in $D^0 \longrightarrow K_s^0 K_s^0$, Phys. Rev. D **92** 054036 (2015).

[2] R. Aaij et al., Measurement of CP Asymmetry in $D^0 \longrightarrow K_s^0 K_s^0$ decays, Phys. Rev. D **104** L031102 (2021).

[3] N.Dash et al., Search for CP violation and measurement of the branching fraction in the decay $D^0 \longrightarrow K_s^0 K_s^0$, Phys. Rev. Lett **119** 171801 (2017).

[4] E Kou. et al., The Belle II Physics Book, **2019** 123C01 (2019).

[5] Akai et al., SuperKEKB collider, Nucl. Instrum. Meth., **907**, 188-199 (2018).

[6] N. L. Johnson, Systems of frequency curves generated by methods of translation, Biometrika **36**, 149-176 (1949).