Time-integrated raw CP asymmetry in $D^0 \rightarrow K_s^0 K_s^0$ at Belle II

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Physics motivation

- $D^0 \rightarrow K_s^0 K_s^0$ is a Singly Cabibbo Suppressed (SCS) decay, which involves the interference of $c\tau \rightarrow s\pi$ and $c\tau \rightarrow d\pi$ transitions, due to which the CP Asymmetry (AC$_\gamma$) may be enhanced to an observable level within the Standard Model.

- Using 921 fb$^{-1}$ and $D^0 \rightarrow K_s^0 K_s^0$ as the control mode, Belle measured: $A_{CP}(D^0 \rightarrow K_s^0 K_s^0) = (0.02 \pm 1.53 \pm 0.02 ± 0.17)\%$ (Phys. Rev. Lett. 119 171801).

- A more precise result of is obtained by LHCB using 6 fb$^{-1}$ with $D^0 \rightarrow K^+ K^-$ as the control mode: $A_{CP}(D^0 \rightarrow K^+ K^-) = (3.1 \pm 1.2 \pm 0.4 \pm 0.2)\%$ (Phys. Rev. D 104 L031102).

- The final goal is to measure the time integrated $A_{CP}$ in $D^0 \rightarrow K_s^0 K_s^0$ decays using the decay $D^0 \rightarrow K^- K^-$ as the control mode, with (Belle + Belle II) data-set.

- Here, we show the measurement of the signal yield time integrated raw CP asymmetry ($A_{raw}$) in $D^0 \rightarrow K_s^0 K_s^0$ using Belle II simulation.

Reconstruction & Selection criteria

- Belle II Monte Carlo sample of integrated luminosity 1 ab$^{-1}$ is used to reconstruct $D^0 \rightarrow K_s^0 K_s^0$ decay.

- $K_s^0 \rightarrow \pi^+\pi^−$ is reconstructed using tracks of two oppositely charged pions in the mass range [0.45, 0.55] GeV/c$^2$.

- Pairs of $K_s^0$ are combined to form $D^0 \rightarrow K_s^0 K_s^0$ candidates. The $m(K_s^0 K_s^0)$ signal region is [1.85, 1.88] GeV/c$^2$.

- The $D^0$ thus reconstructed, is combined with low momentum (soft) pions to form a $D^{*+} \rightarrow D^0\pi^+$ decay.

- To suppress the $D^0$ candidates from $B$ decays, we require the centre-of-mass momentum of $D^{*+}$ to exceed 2.5 GeV/c.

γ for background rejection

The major background for our signal mode comes from $D^0 \rightarrow K_s^0 \pi^+\pi^−$ decay. To provide signal-background separation, the flight distance of both $K_s^0$ (with respect to the $D^0$ vertex) is exploited, and a new variable $\gamma$ is defined as:

$$\gamma = \log \left( \frac{L}{\sigma_L} \right)$$

where, $L$ is the flight distances of $K_s^0$ and $\sigma_L$ is the error on $L$, both with respect to the $D^0$ vertex.

Fit strategy & Results

- An unbinned maximum likelihood fit to ($\Delta m$, $\gamma$) (where $\Delta m = m(D^*) - m(D^0)$) is performed to measure $A_{raw}$ defined in Eqn.2, where, $N(D^0)$ is the yield of the $D^0$ decay and $N(D^*)$ is that of the corresponding $D^{*+}$ decay.

$$A_{raw} = \frac{N(D^0) - N(D^*)}{N(D^0) + N(D^*)}$$

- Except the yields and corresponding raw asymmetries, all fit parameters, are fixed to the values obtained from separate fits to the signal and backgrounds. The Probability Distribution Functions (PDF) used for the components are given in the table below, where $\Delta m_0$ is 0.13957039 GeV/c$^2$.

<table>
<thead>
<tr>
<th>Components</th>
<th>$\Delta m$</th>
<th>$\gamma$</th>
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<tbody>
<tr>
<td>$D^0 \rightarrow K_s^0 K_s^0$ Johnson’s SU</td>
<td>Johnson’s SU</td>
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<tr>
<td>$D^0 \rightarrow K_s^0 \pi^+\pi^−$ background Gaussian + Johnson’s SU Johnson’s SU</td>
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<tr>
<td>Combinatorial background $\Delta m$ ($\Delta m_0$) + $\alpha$($\Delta m$ − $\Delta m_0$)$^{3/2}$ Double Johnson’s SU</td>
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- Distributions of $\Delta m$ (left) and $\gamma$ (right) are shown only for candidates populating the $m(K_s^0 K_s^0)$ signal window. The fit projections are overlaid and pull distributions are shown in the bottom panels of each plot.

Summary

- $D^{*+}$-tagged $D^0 \rightarrow K_s^0 K_s^0$ decays are reconstructed in Belle II simulation of integrated luminosity 1 ab$^{-1}$.

- A new variable $\gamma$ is defined to separate the signal $D^0 \rightarrow K_s^0 K_s^0$ and the major background $D^0 \rightarrow K_s^0 \pi^+\pi^−$ decays.

- Total signal yield and $A_{raw}$ are measured in Belle II simulation, using a simultaneous fit to ($\Delta m$, $\gamma$).

- Reconstructed value of $A_{raw}$ for the decay $D^0 \rightarrow K_s^0 K_s^0$ is consistent with 0.

- The measured signal yield is 5853±83 and the corresponding $A_{raw}$ is (0.7±1.4)%. The uncertainty is statistical only.