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

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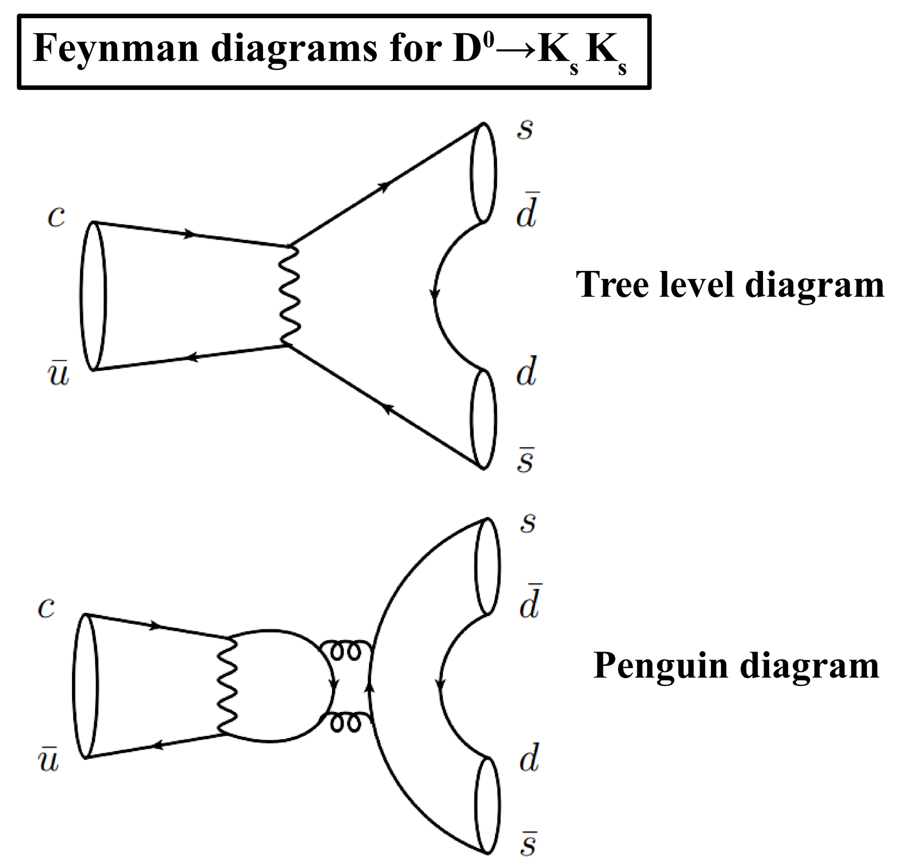
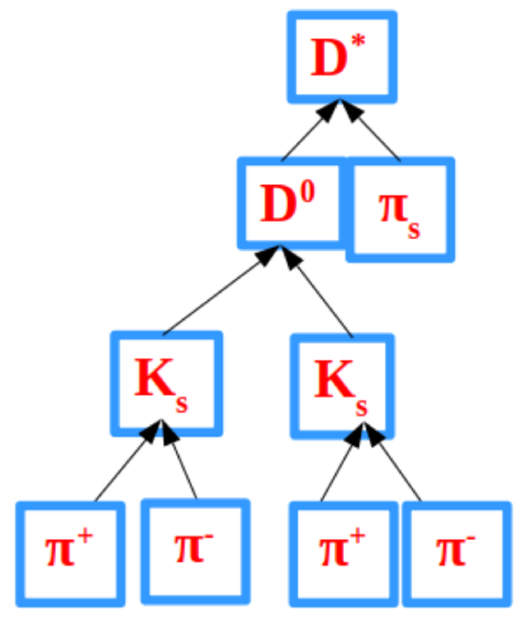
Physics motivation

- $D^0 \longrightarrow K_s^0 K_s^0$ 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 which the CP Asymmetry ($\mathcal{A}_{CP}$) may be enhanced to an observable level within the Standard Model.
- Using 921 fb^{-1} and $D^0 \longrightarrow K_s^0 \pi^0$ as the control mode, Belle measured: $\mathcal{A}_{CP}(D^0 \longrightarrow K_s^0 K_s^0) = (-0.02 \pm 1.53 \pm 0.02 \pm 0.17)\%$ (Phys. Rev. Lett. 119 171801).
- A more precise result of is obtained by LHCb using 6 fb^{-1} with $D^0 \longrightarrow K^+K^-$ as the control mode: $\mathcal{A}_{CP}(D^0 \longrightarrow K_s^0 K_s^0) = (3.1 \pm 1.2 \pm 0.4 \pm 0.2)\%$ (Phys. Rev. D 104 L031102).
- The final goal is to measure the time integrated $\mathcal{A}_{CP}$ in $D^0 \longrightarrow K_s^0 K_s^0$ decays using the decay $D^0 \longrightarrow K^+K^-$ 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 $D^0 \longrightarrow K_s^0 K_s^0$ using Belle II simulation.**



Reconstruction & Selection criteria

- Belle II Monte Carlo sample of integrated luminosity 1 ab^{-1} is used to reconstruct $D^0 \longrightarrow K_s^0 K_s^0$ decay.
- $K_s^0 \longrightarrow \pi^+\pi^-$ 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 $D^0 \longrightarrow K_s^0 K_s^0$ 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 $D^{*+} \longrightarrow D^0 \pi_s^+$ decay.
- To supress the D^0 candidates from B decays, we require the centre-of-mass momentum of D^{*+} to exceed 2.5 GeV/c.



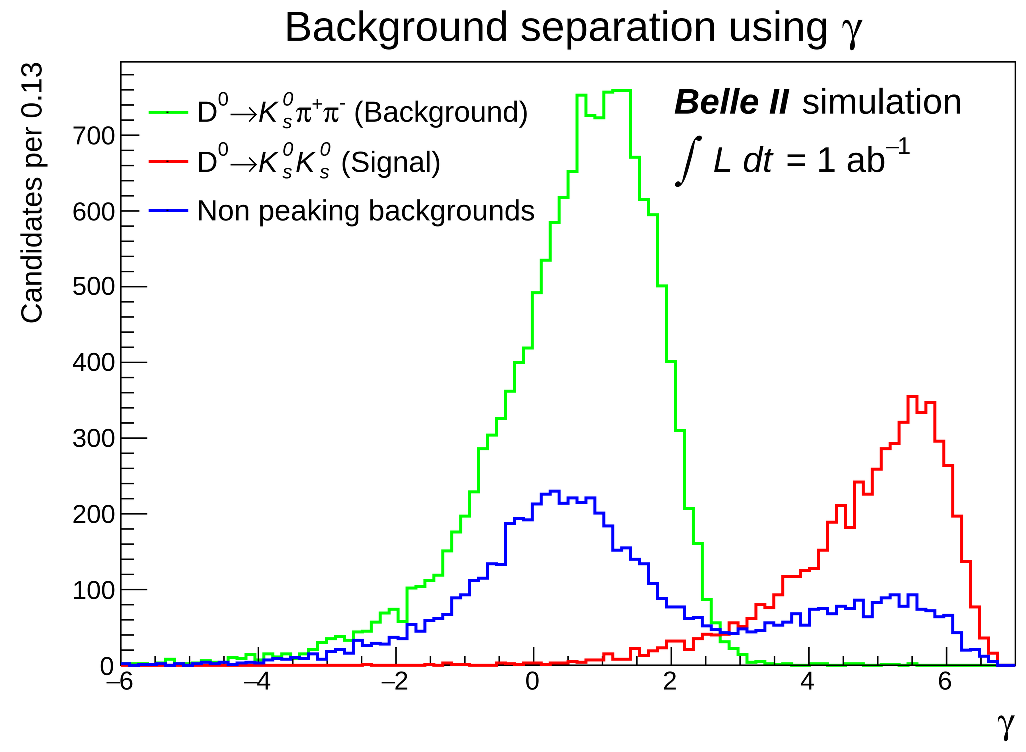
γ for background rejection

The major background for our signal mode comes from $D^0 \longrightarrow K_s^0 \pi^+\pi^-$ 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 γ is defined as:

$$\gamma = log\left(min\left(\frac{L}{\sigma_L}\right)\right) \qquad (1)$$

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

Background separation using γ



Summary

- D^{*+}-tagged $D^0 \longrightarrow K_s^0 K_s^0$ decays are reconstructed in Belle II simulation of integrated luminosity 1 ab^{-1}.
- A new variable γ is defined to separate the signal $D^0 \longrightarrow K_s^0 K_s^0$ and the major background $D^0 \longrightarrow K_s^0 \pi^+\pi^-$ 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 $D^0 \longrightarrow K_s^0 K_s^0$ is consistent with 0.

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 $N(\overline{D}^0)$ is that of the corresponding $\overline{D}^0$ decay.

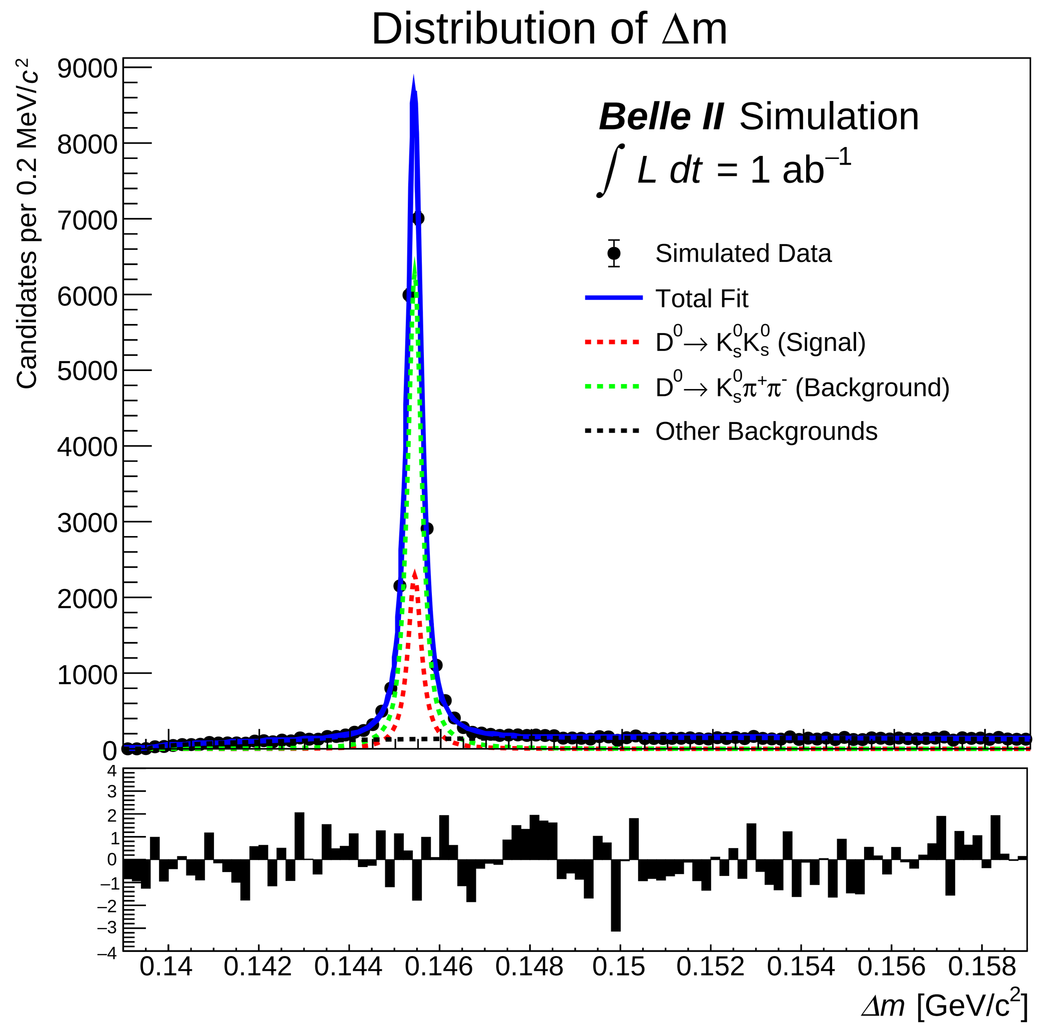
$$A_{raw} = \frac{N(D^0) - N(\overline{D}^0)}{N(D^0) + N(\overline{D}^0)} \qquad (2)$$

- 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 Δm_0 is 0.13957039 GeV/c^2.

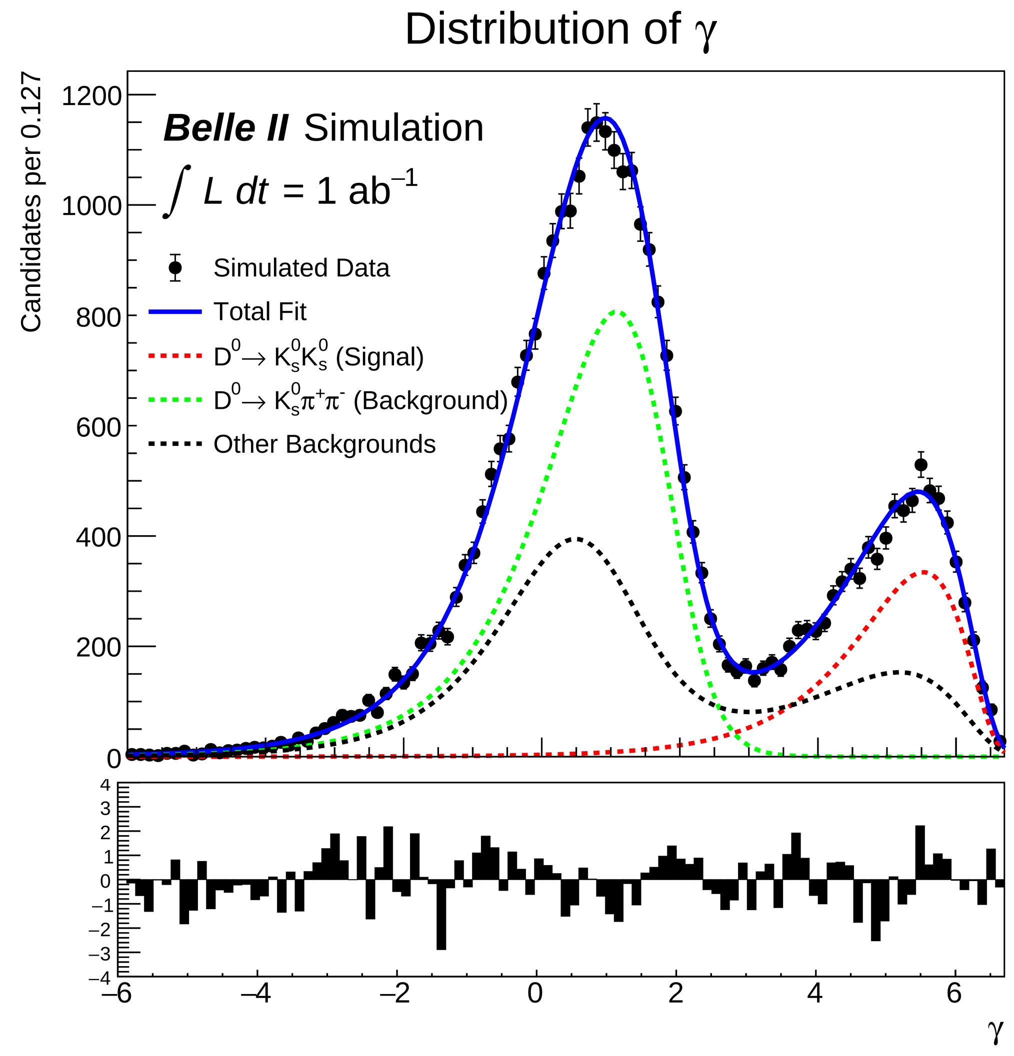
Components	Δm	γ
$D^0 \longrightarrow K_s^0 K_s^0$	Johnson's S_U	Johnson's S_U
$D^0 \longrightarrow K_s^0 \pi^+\pi^-$ background	Gaussian + Johnson's S_U	Johnson's S_U
Combinatorial background	$(\Delta m\text{-}\Delta m_0) + \alpha(\Delta m\text{-}\Delta m_0)^{3/2}$	Double Johnson's S_U

- Distributions of Δm (left) and γ (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.

Distribution of Δm



Distribution of γ



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