Time-integrated WS-to-RS ratio of the $D^0 \rightarrow K^+\pi^-\pi^0$ decay at Belle II

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**Physics Motivation**

- In the standard model, mixing and CP violation in the charm sector are expected to be very small. Thus, they constitute a sensitive probe for potential new physics contributions.
- The “wrong-sign” (WS) $D^0 \rightarrow K^+\pi^-\pi^0$ decay is one of the most promising channels at Belle II, as this can be produced through two interfering processes: a direct doubly Cabibbo-suppressed decay of the $D^0$ meson, or through $D^0 - \bar{D}^0$ mixing followed by a Cabibbo-favored decay of the $D^0$ meson.
- Measuring the decay-time-dependent rate of wrong-sign decays allows us to separate the two processes and measure the mixing rate.
- The goal of this analysis is to measure the time-integrated WS-to-RS ratio of the “wrong-sign” (WS) $D^0 \rightarrow K^+\pi^-\pi^0$ decay at Belle II.

**Efficiency Variation**

- Due to the different amplitude models for RS and WS samples, the reconstruction efficiency over the Dalitz plot is required.
- The efficiency is evaluated as a function of $m(\pi^+\pi^-\pi^0)$ invariant mass and helicity angle $\cos(\pi^+\pi^-)$ (i.e., the angle between the $\pi^0$ and $K$ directions in the rest frame of $\pi^+\pi^-$ and $\pi^0$).
- The efficiency of the Dalitz plot can be parametrized as $N_{rec}/N_{gen}$.
- To correct the efficiency variation over this plane, we reweighted the generic MC events with 1/efficiency, where the efficiency is the relative efficiency over this plane.

**Reconstruction of $D^0 \rightarrow K^+\pi^-\pi^0$**

**Dataset and Selection Criteria:**

- Monte Carlo (MC) Simulation: 1 ab$^{-1}$.
- Candidate $D^0 \rightarrow K^+\pi^-\pi^0$ are formed using charged kaon, and pion has at least one hit in Silicon Vertex Detector (SVD) and at least 20 hits in Central Drift Chamber (CDC), combined with $\pi^0 \rightarrow \gamma\gamma$, satisfying the range [0.12, 0.145] GeV/c$^2$.
- The $D^0$ thus reconstructed is combined with low momentum pions, have at least one hit in CDC to form $D^{*+} \rightarrow D^0\pi^+$ decay.
- Center of mass momentum of $D^{*+} > 2.5 GeV/c$ to remove D from B decays.

**Results**

- Identified all the background components of $D^0 \rightarrow K^+\pi^-\pi^0$ decay to separate from signal.
- The Probability Density Function (PDF) for every component corresponding to $m(D^0\pi_s)$ and $m(K^+\pi^-\pi^0)$ shown with different colors.
- Used a 2D fit PDF that is the product of the corresponding $m(D^0\pi_s)$ and $m(K^+\pi^-\pi^0)$ PDFs to determine signal yield.
- All fit parameters are fixed to the values obtained from separate fits to all components.

<table>
<thead>
<tr>
<th>Components</th>
<th>$m(D^0\pi_s)$</th>
<th>$m(K^+\pi^-\pi^0)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D^{*+} \rightarrow D^0 K^+\pi^-\pi^0$</td>
<td>Johnson + Double Gaussian</td>
<td>Johnson + Double Gaussian</td>
</tr>
<tr>
<td>$D^{*+} \rightarrow D^0 SM(signed)$</td>
<td>same as signal</td>
<td>Double Gaussian</td>
</tr>
<tr>
<td>$D^{*+} \rightarrow D^0 multi-body$</td>
<td>Johnson</td>
<td>1st order Chebyshev</td>
</tr>
<tr>
<td>$D^0$ signal + random pion</td>
<td>$(x-x_0)^{1/2} + \alpha (x-x_0)^{1/2} + \beta (x-x_0)^{1/2}$</td>
<td>same as signal</td>
</tr>
<tr>
<td>Combinatorial</td>
<td>same as $D^0$ signal + random pion</td>
<td>1st order Chebyshev</td>
</tr>
</tbody>
</table>

**Fit strategy**

An binned fit to $(m(K^+\pi^-\pi^0), m(D^0\pi_s))$ is performed to determine the signal yield.

The variable $m(D^0\pi_s)$:

- $m(D^0\pi_s)$ is the mass of the $D^*$ but with no mass hypothesis on the $D^0$ daughters.

**Summary**

- Estimated the efficiency over the square Dalitz Plot.
- Efficiency corrected time-integrated WS-to-RS Ratio in the reconstruction is in agreement with the generation.

- Signal Yield for WS $D^0 \rightarrow K^+\pi^-\pi^0 = 14322 \pm 262$.
- Signal Yield for RS $D^0 \rightarrow K^-\pi^+\pi^0 = 671521 \pm 4030$.
- Reconstructed time-integrated WS-to-RS ratio $(2.13 \pm 0.04) \times 10^{-3}$ is consistent with the value used in generation $2.12 \times 10^{-3}$.

16th International Conference on Heavy Quarks and Leptons (HQL2023)