Study of CP violation at LHCb

with charmless B mesons decays

LPNHE PARIS

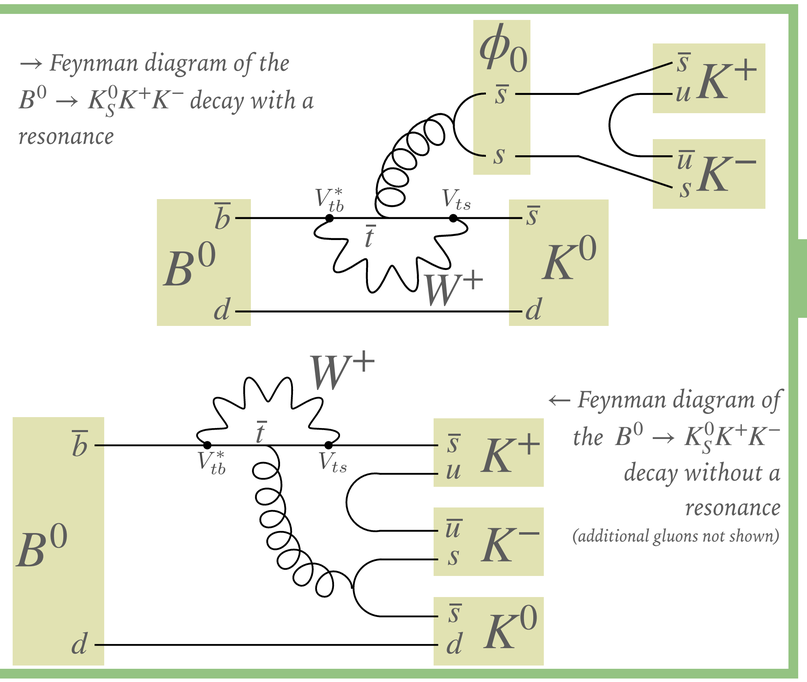
Charmless 3-body B-decays

One of the goals of the LHCb experience at CERN is to study **physics of B-mesons**.

B-meson decays allow the study of many observables: **branching fractions**, **CP asymmetries** and **CKM matrix parameters** - enabling is to probe both the weak and the strong interactions.

The LPNHE group is focused on **studying charmless 3-body B decays**. Such decays have previously shown large local asymmetries that are still to be fully understood.

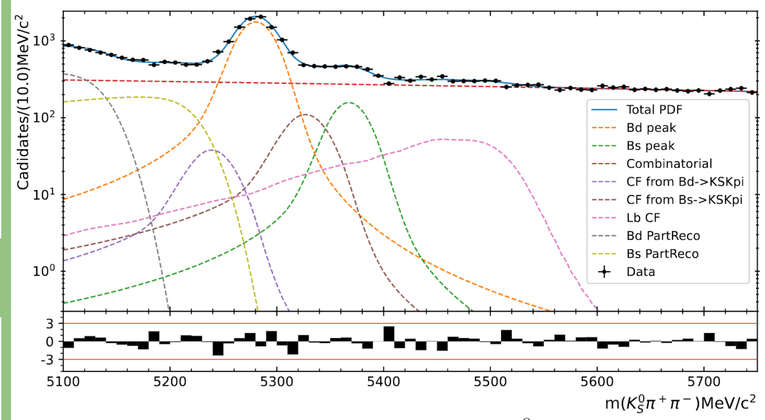
Currently two analyses are in progress involving $B^0_{(s)} \to K^0_S h^+ h'^-$ (with $h^{(\prime)} = K/\pi$, i.e. $K^0_S\pi^+\pi^-$, $K^0_S K^\pm\pi^\mp$ and $K^0_S K^+K^-$) decays.



→ *Feynman diagram of the $B^0 \to K^0_S K^+K^-$ decay with a resonance*

← *Feynman diagram of the $B^0 \to K^0_S K^+K^-$ decay without a resonance*

(additional gluons not shown)



↑ *Result of the simultaneous fit to data (DD K^0_S reconstruction, 2018 data) with the B^0_d MVA optimisation for $B^0_d \to K^0_S\pi^+\pi^-$, shown on a logarithmic scale.*

The B_d/B_s peaks are the signal descriptions, the rest are backgrounds; misidentified decays (CF, crossfeeds), partially reconstructed events (PartReco) and incorrect combinations of particules (Combinatorial).

Branching fraction measurements

This analysis aims to measure **the branching fractions of the charmless three-body B-mesons decays $B^0_{(s)} \to K^0_S hh'$** and observe $B^0_s \to K^0_S K^+K^-$, using RunI and RunII data.

The branching fractions are measured relatively to the well-established mode $B^0 \to K^0_S\pi^+\pi^-$ (the reference mode, ref):

$$\frac{\mathcal{B}(B^0_{d,s} \to K^0_S h^+ h'^-)}{\mathcal{B}(B^0 \to K^0_S\pi^+\pi^-)} = \frac{N_{B^0_{d,s}\to K^0_S h^+h'^-}}{N_{\rm ref}} \frac{\epsilon_{\rm ref}}{\epsilon_{B^0_{d,s}\to K^0_S h^+h'^-}} \frac{f_d}{f_{d,s}}$$

In addition to cut-based selections, **two multivariate selections** (BDTs) are used, with **separate 2D optimisations** for the B^0 and B^0_s signals in each spectrum.

For each year of data taking, yields ($N_{B^0_{d,s}\to K^0_S h^+h'^-}$ and $N_{\rm ref}$) are extracted from 7 **simultaneous fits** of the eight spectra (4 final states × 2 K^0_S reconstructions). Various source of backgrounds are accounted for in the mass fits, and allow to include correlation effects between the final-state signal components.

The efficiencies ($\epsilon_{B^0_{d,s}\to K^0_S h^+h'^-}$ and $\epsilon_{\rm ref}$) are averaged over the phase space of the decay, weighted according to the signal distribution (via sWeights derived from the fits to data) to include dynamic structures in its description.

This branching fraction analysis is **well advanced** and is currently in working group review, and aiming to be **published early 2024**.

Dalitz plots analysis

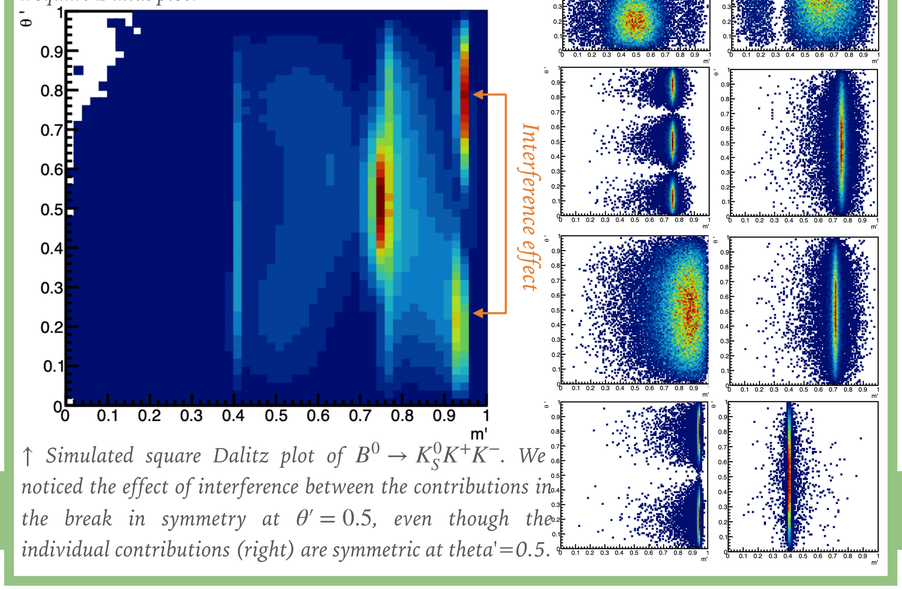
The branching fraction measurement (left) is a stepping stone to analyses that probe the internal decay mechanisms. A **time-integrated amplitude analysis** of $B^0/\overline{B^0} \to K^0_S K^+K^-$ has been started. The goal is to **model** how the decay amplitude varies across the phase space, identifying and quantifying individual contributions (e.g. **resonances**) and how they **interfere**.

Characterising the interference may allow us to **identify the presence of CP violation** and also provide information to **describe the mechanisms behind** it.

Not all parts of this phase space are fully understood yet, especially at intermediate invariant mass (away from known resonances); a full QCD-based theoretical description of these decays is still missing. This LPNHE group is working with theorists to test **new models** which should better **reflect the underlying physics** and known **mechanism of CP violation** via the CKM matrix over the full phase-space (low and high invariant mass).

Future plans are to carry out a full **time-dependent amplitude analysis** of $B^0/\overline{B^0} \to K^0_S K^+K^-$ and, once enough signal is available, a time-integrated analysis

→ *Various contributions in the $B^0 \to K^0_S K^+K^-$ decay. The bottom 6 are resonant and the top 2 are non-resonant contributions. In each case, the phase space is represented as a square Dalitz plot.*



↑ *Simulated square Dalitz plot of $B^0 \to K^0_S K^+K^-$. We noticed the effect of interference between the contributions in the break in symmetry at $\theta' = 0.5$, even though the individual contributions (right) are symmetric at theta'=0.5.*

Run 3 early measurements *(in addition to the main topic)*

The LPNHE group is contributing to the measurement of the production cross section of D-mesons with data taken with the new LHCb detector.

In addition to the measurement, such analysis helps us to understand our new upgraded detector and the **data processing pipeline**, scrutinise **data taking quality** and **validate the reconstruction**.

Our group is working on D decays to $K^0_S h^\pm h'^\mp$ final states.