Ecole Doctorale des Sciences Fondamentales

Title of the thesis: Study of *CP* violation in three-body charmless *b*-hadron decays with the LHCb spectrometer.

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Summary :

In the Standard Model of Particles Physics (SM), the asymmetry observed between matter and antimatter behaviour is brought by the *CP*-violating phase emerging from the Cabibbo-Kobayashi-Maskawa (CKM) paradigm (1; 2) which is sufficient to describe all *CP*-violating observables measured so far in particle systems. Nevertheless, the existence of new sources of *CP*-violation in addition to that predicted by the CKM matrix is expected in most extensions of the Standard Model and the search for it constitutes an important goal of the current researches in high energy physics.

One appealing approach to search for new sources of *CP*-violation consists in studying the decay-time distribution of neutral *B*-meson decays into *CP*-eigenstates hadronic final states, when mediated by a $b \to s$ loop amplitude (so-called penguin amplitude). Many measurements have been performed by the Babar and Belle experiments in that respect, such as *B* decays to ϕK_S^0 or $\eta' K_S^0$ to cite only the most sensitive. Gathering all of these studies, the latest results provide a consistent picture with the SM predictions, commanding an improved precision to increase the sensitivity to new *CP*-violating phases.

The decays mentioned above into a final *CP*-eigenstate quasi-two body are often contributing to a three-body decay ($B^0 \to f_0(980) K_S^0$ is one of the contributing amplitude to the $B^0 \to K_S^0 \pi^+ \pi^-$ decay for instance) and experience from previous experiments has shown that **full decay-time-dependent Dalitz plot analysis of a three-body decay** is more sensitive than a ``quasi-two-body'' approach, in particular when broad resonances are contributing to the decay amplitude. On a similar note, the Dalitz plot analysis of these decays are necessary inputs in methods to determine the CKM phase γ.

The inclusive decay $B^0 \to K_S^0 \pi^+ \pi^-$ provides a rich structure of interfering amplitudes, involving both *CP*-eigenstate amplitudes ($B^0 \to \rho^0 K_S^0$, $B^0 \to f_0(980) K_S^0$, *etc.*) and flavour specific amplitudes ($B^0 \to K^{*+}(892)\pi^-$, $B^0 \to K_0^{*+}(1430)\pi^-$, *etc.*). Full time-dependent Dalitz plot analyses of $B^0 \to K_S^0 \pi^+ \pi^-$ have been performed by BaBar and Belle experiments (3; 4). These amplitude analyses rely on model-dependent parameterisation of the decay amplitudes.

Comparable studies of the decay $B^0 \to K^0_S\pi^+\pi^-$ reconstructed with the LHCb spectrometer took place in a thesis (5) defended in 2015 within our team, based on a time-integrated untagged analysis, yielding a world best measurement on the subject.

The analysis of the LHC Run II data set (corresponding to data taking periods from 2015 to 2019) should allow to reach the required statistical sensitivity to address a time-dependent measurement of these decays, thanks to the selection of the reconstructed $B^0 \to K^0_S\pi^+\pi^-$ defined with the LHCb spectrometer which results in a purer sample of signal decays than the one obtained in former experiments, and the improvements realised in the b-tagging algorithms. A PhD. thesis to be defended in 2021 contributed to the definition of the selection of the Run-II sample in view to update the branching fraction measurements of the five decay modes of interest and continue the search for the decay $B_s \to K^0_S K^+K^-$.

This PhD proposal will focus in an initial phase to the **first time-integrated Dalitz plot analysis of the decay $B_s \to K^0_S\pi^+\pi^-$**. This work will directly benefit from the current amplitude fitting technology we have at hand. A second, central and more ambitious aim of this thesis proposal consists in developing a **flavour tagged time-dependent Dalitz analysis of** $B^0 \to K^0_S\pi^+\pi^-$ relying on the current local expertise in that field, to be applied on the analysis of LHCb data from LHC Run II and Run III. The work for the two first steps will be conducted within the LHCb experiment with an international collaboration, gathering the University of Warwick (UK) and Sorbonne (F). These measurements, together with companion ones present in the literature and established by B-factories, will then be **interpreted globally in the framework of the CKMfitter group**. This part of the work is of phenomenological nature. Sensitivity studies for future experiments can be envisaged concurrently.

The selected candidate is expected to have a strong background in High Energy Physics and good computing skills. Scientific curiosity, the will to work in an international environment and hardworking abilities will be greatly appreciated.

Once the defence passed, the new doctor will have strong skills in high-level statistical data analyses and computing, a broad knowledge on tools used in HEP fields, an experience in measurement interpretation within and beyond the SM and a clear view on the subtle physics around the CP violation mechanisms.

Bibliography

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