

## Ecole Doctorale des Sciences Fondamentales

### SUJET DE THESE

#### Titre de la thèse : Study of charmless $b$ -hadron decays with the LHCb spectrometer

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#### Résumé :

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. The LHCb experiment is currently the only running experiment which can address this subject.

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  $b \rightarrow s$  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  $\phi K_S^0$  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 ( $B^0 \rightarrow f_0(980)K_S^0$  is one of the contributing amplitude to the  $B^0 \rightarrow K_S^0 \pi^+ \pi^-$  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  $\gamma$ .

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The inclusive decay  $B^0 \rightarrow K_S^0 \pi^+ \pi^-$  provides a rich structure of interfering amplitudes, involving both  $CP$ -eigenstate amplitudes ( $B^0 \rightarrow \rho^0 K_S^0$ ,  $B^0 \rightarrow f_0(980) K_S^0$ , etc.) and flavour specific amplitudes ( $B^0 \rightarrow K^{*+}(892) \pi^-$ ,  $B^0 \rightarrow K_0^{*+}(1430) \pi^-$ , etc.). Full time-dependent Dalitz plot analyses of  $B^0 \rightarrow K_S^0 \pi^+ \pi^-$  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  $B^0 \rightarrow K_S^0 \pi^+ \pi^-$  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  $B^0 \rightarrow K_S^0 \pi^+ \pi^-$  defined with the LHCb spectrometer which results in a purer sample of signal decays than the one obtained in former experiments, and the improvements realized in the b-tagging algorithms.

The successful candidate will have to develop a flavour tagged time-dependent Dalitz analysis relying on the current local expertise in that field, to be applied on the analysis of LHCb data from LHC Run II. The first step will be a physics reach sensitivity study based on pseudo-experiments accurately reproducing the LHCb spectrometer performances. This work will be conducted within an international collaboration, including short trips to CERN for data-taking activities and meetings.

The candidates are expected to have a strong background in High Energy Physics and good computing skills. Scientific curiosity, the will to work in an international environment, curiosity 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, and a clear view on the subtil physics around the CP violation mechanisms.

### Bibliographie

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Key word : LHCb, CKM matrix , Dalitz plot, flavour tagged analysis