Ecole Doctorale des Sciences Fondamentales

Thesis title: proposed for the period October 2021-September 2024

"Study of CP violation in B^- to $D^0\{K^0_S\pi^+\pi^-\pi^0\}$ K^- decays at LHCb"

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Summary & description of the foreseen thesis work:

The importance and situation of measuring the CKM angle γ

The precise measurement of the γ angle of the Cabibbo-Kobayashi-Maskawa Unitarity Triangle (CKM) is a central topic in flavour physics experiments. Its determination in open-charm b hadron decays is based on tree transitions and is theoretically clean. It provides the standard reference point for measurements sensitive to the new effects of physics potentially accessible by tests of global coherence of the KM mechanism (Nobel Prize for Physics 2008), compared to the predictions of the Standard Model of Particle Physics (SM).

In addition to the results of the B factories that operated in the decade 2000-2010 (i.e. BaBar at SLAC in California and Belle in KEK in Japan), various recent measurements of the LHCb experiment at CERN can determine the value of the angle γ with an uncertainty of about 4°. While the metrology of this fundamental parameter is in itself of great interest, an accuracy well below 1 degree is highly desirable in order to provide access to the physics energy scales beyond the SM (BSM) above 20 TeV, regardless of the BSM scenario (i.e. inaccessible by direct research to the LHC by ATLAS and CMS experiments). However, at present no single measure completely dominates the global average on determining the value of this angle, as the most accurate measurements have an accuracy of about 5 to 20 degrees. The most accurate measure has just been presented this summer by LHCb at the ICHEP 2020 conference with mode B^- into D^0 K^-, where the neutral D mesons disintegrates into $K^0_S\pi^+\pi^-$.

Alternative methods are therefore important to improve the accuracy of the global average. Among them, an analysis of the decay B^- into D^0 K^-, where the D disintegrates into $K^0_S\pi^-\pi^-\pi^0$, can have a significant impact. Recently, in 2019, the Belle collaboration published a γ angle measurement with a sensitivity of around 12 degrees using an effective model for the disintegration of the D meson from the CLEO-c experiment. During the months of May to July 2020, I demonstrated with an M1 internship student from the Orsay Fundamental Physics

Magisterium, that LHCb already has with the 2011-2018 data of a sample of beautiful mesons in this disintegration 1.5 times greater than that Belle and of which purity exceeds 80% when that of Belle does not exceed 60%.

It is on these channels that we propose to work during this thesis.

Description of the thesis subject and its environment

In the LHCb group of LPC of Clermont Ferrand, under my direction, and in close collaboration with 5 colleagues from LHCb (4 of Oxford, including the former spokesperson of LHCb, Professor G. Wilkinson who is also the author of the study of CLEO-c and 1 collaborator of the Marseille LHCb group author of the analysis of Belle, mentioned above), the PhD student will initially conduct the measurement of the angle γ with disintegration $B^- \to D^0 K^-$ with D^0 in $K^0_S\pi^-\pi^-\pi^0$ with all data from 2011 to 2018 from LHCb and after with dataset 2022-2023.

Using companion mode $B^- \to D^0\pi^-$, with D^0 in $K^0_S\pi^-\pi^-\pi^0$, more abundant, an amplitude analysis will be conducted to study the phenomenology and spectroscopy of this charmed disintegration. This analysis will accurately measure the value of the D^0 to $K^{*-}\square^+$ branching ratio, which is a replica of the excited states of the well-known (since 1976) mode D^0 in $K^-\pi^+$ and not yet known to this day. A preliminary study conducted during a Master 1 internship in 2020 showed that the branching ratio of this disintegration is in the order of 7%, with a relative statistical accuracy of 5% (6 times better than the measurement that dates from 1992 with the Mark III experiment of Stanford in California and which was not precise enough to observe this unambiguous disintegration). This study conducted with data $B^- \to D^0\pi^-$, with D^0 in $K^0_S\pi^-\pi^-\pi^0$, will be conducted in conjunction with colleagues at Oxford who are in charge of the same study with the charmed complementary mode $D^{*-} \to D^0\pi^-$ with D^0 in $K^0_S\pi^-\pi^-\pi^0$. The PhD student will conduct both a study on the phenomenology of disintegration D^0 in $K^0_S\pi^-\pi\pi^0$, which will lead to a joint publication with the Oxford LHCb group and that related to measuring the CP breach phase of the CKM matrix in mode $B^- \to D^0K^-$ with D^0 in $K^0_S\pi^-\pi^-\pi^0$ that will lead to 1 or even 2 publications, existing and future data.

The candidate will then improve these measurements by using LHC Run3 data (probably 2022-2023 data), which will allow the current statistic to be multiplied by at least 5 factors. Such a gain will be made possible by the start-up at the end of 2021 of a new *"upgraded"* version of the LHCb detector. Among the key factors for improving these measurements, the reconstruction efficiency of the tracker is essential, and at its heart the excellent operation of the SciFi scintillating fibers sub-detector. Mode $B^- \to D^0h^-$ with D^0 in $K^0_S\pi^-\pi^-\pi^0$ has a strong multiplicity of charged tracks in the final state of disintegration: no less than 5 tracks! The LPC group is involved in the construction of this detector. The student will participate very actively, upon arrival, at the end of construction, in the qualification and start-up and monitoring of the operation of this detector in cruising rhythm until the fall of 2024. To do this, he (she) will work in the LPC LHCb group with another doctoral student who began her

thesis in October 2019 and two postdoctoral fellows, one finishing in May 2022 and the other starting his 2-year contract in September 2021 (funding awarded by CNRS IN2P3). The new postdoctoral fellow will collaborate on the analysis project and the instrumental project to commission the new SciFi tracker, which is a strong responsibility for the LPC LHCb group and brings together researchers and engineers and technicians. With the current Doctoral student and the future postdoctoral fellow, under my coordination and that of Pascal Perret, head of the LHCb group of the LPC, the new doctoral student will contribute to the qualification of the SciFi tracker and to the reconstruction of the first data collected by this detector.

To do this and to ensure a good visibility of the Clermont Ferrand group within the international collaboration LHCb it would be good if the student could make one or more long stays at CERN. With this experience, the student will be able to take on the responsibility of SciFi expert in the physics analysis group of LHCb B2OC. It is within the framework of this group that the analyses related to the disintegrations $B^- \rightarrow D^0 h^-$ with D^0 in $K^0_S \pi^- \pi^- \pi^0$.

Vincent Tisserand, Aubière, Les Cézeaux, February 9, 2021.

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Note: Vincent Tisserand is the laureate of the 2019 Joliot Curie Grand Prize from the French Society of Physics (SFP) for work on these research topics.