Master 2 Internship proposal at the *Laboratoire de Physique de Clermont* - 2025

Rare Baryonic-Radiative decays of B mesons with LHCb.

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The Standard Model of Particle Physics (SM), successfully confronted to five decades of experimental tests, well describes the current quarks and leptons data. Though, fundamental open questions still remain that justify the search for New Physics (NP) phenomena beyond the SM predictions. Among the four experiments installed on the Large Hadron Collider (LHC) at CERN, Geneva, two of them, Atlas and CMS, are performing direct searches of new particles. The purpose of the LHCb experiment is to conduct indirect searches of new phenomena through accurate measurements in the heavy quarks sector.
During its first campaigns of data taking (run1: 2010-2013 and run2 : 2015-2018) LHCb has collected an unprecedently large collection of many b-hadron decays, paving the way for studying rare and very rare transitions. After a three-year shutdown and an important update of the detector, the LHCb experiment has now entered in its third period of data taking (run3), aiming at increasing the collected statistics by a factor four in the coming years.

In the SM, radiative decays of b-hadrons proceed via flavour-changing neutral current, $b \to s(d)\gamma$, that only can occur through loop-mediated transitions, as illustrated on the figure below. The dynamics of those FCNC transitions is particularly sensitive to the possible NP spectrum allowed to propagate inside the virtual loops.

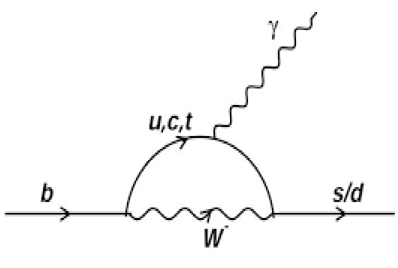

Figure 1: Penguin diagram dominating the FCNC $b \to q\gamma$ transition (q=s or d).

With a decay rate of few 10^{-5} at most, radiative decays are relatively rare. Several of the dominant modes, $B^0 \to K^+\pi^-\gamma$, $B_s \to K^+K^-\gamma$, $B^+ \to K^+\pi^-\pi^-\gamma$ or $\Lambda_b \to pK^-\gamma$, mediated by the $b \to s\gamma$ transition, have extensively been (and are still being) studied at LHCb. The full statistics of run1 and run2, now allows to explore more suppressed modes, like $B^0 \to \pi^+\pi^-\gamma$ or $B_s \to K^{*0}\gamma$. These modes, mediated by the $b \to d\gamma$ transition, have a typical decay rate of few 10^{-7}. The LHCb group at LPC is involved in several ongoing searches for these rare decay modes.

The purpose of the proposed internship is the search for unobserved decay modes that involve of pair of baryons in the final states, like $B^+ \to p\bar{\Lambda}\gamma$ ($b \to s\gamma$ transition) or even more rare $B^0 \to p\bar{p}\gamma$ ($b \to d\gamma$ transition). This kind of baryonic and radiative decay of B mesons, potentially accessible with the current statistics at LHCb, would provide interesting informations about the di-baryon mass spectrum.
The main experimental signature of the radiative decays at LHCb is driven by the high-energy photon in the final-state. The Electromagnetic Calorimeter that identifies the photon and reconstructs its momentum, plays a major role in the the reconstruction and the selection performance. The identification of the final-state hadrons (proton, kaon or pion), mostly performed by the Ring Imaging Cherenkov subdetectors (RICH), is also crucial to reject other radiative or charmless modes with a similar topology.
The retained internship candidate will analyze the existing data sample, participate to the signal selection and to the identification and the reduction of the different backgrounds that potentially contaminate the signal region. Due to the difficult hadronic environment and the potentially large background contamination, a multivariate selection (Boosted Decision Tree or Neural-Network) will have to be setup. A detailed invariant-mass model describing the signal and the remaining backgrounds, will be build to (hopefully) observe and measure these decay modes for the first time.

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