Three-body and quasi-two-body 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.

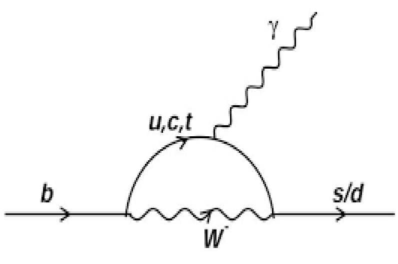

Figure 1: Penguin diagram dominating the FCNC $b \to q\gamma$ transition (q=s or d).

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/run2 and the almost complete run3 dataset, allow 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 LPCA is involved in several ongoing searches for these rare decay modes.

The purpose of the proposed internship is the reconstruction and the selection of rare radiative decays of charged B mesons that involve three charged hadrons accompanying the radiated photon, i.e. $B^+ \to (h^+h^-h^+)\gamma$ where $h^\pm$ generically represent charged pions, kaons or protons. The specific final-state with a pair of baryons, $B^+ \to (p\bar{p}K^+)\gamma$ is particularly targetted. This yet unmeasured mode has been preliminary observed during a previous internship, for the first time. In order to precisely determine the decay rate of this mode, a known normalisation mode is required as reference. The charmonium decay, $B^+ \to J\psi(p\bar{p})K^{*0}(K^+\pi^0)$, has preliminary been used as normalisation so far. It has the advantage of being rather pure and to have a final-state structure close to the one of the signal, with the two protons and the kaon. It however exhibits a small reconstructed yield of few hundred candidates, and requires a precise control of the neutral pion and photon identification. The retained internship candidate will explore alternative (or complementary) normalisation modes, like $B^+ \to J\psi(p\bar{p}\gamma)K^+$ or $B^+ \to (K^+\pi^-\pi^+)\gamma$, that benefits from significantly larger datasets.
In parallel, the reconstruction, selection and analysis of the quasi-two-body charged decay, $B^+ \to K^0_s\pi^+\gamma$, will also be considered during the internship. The goal is to prepare an amplitude analysis of the $(K^0_s\pi^+)$ hadronic system, to complement a similar analysis already completed with the isospin-companion neutral decay, $B^0 \to (K^+\pi^-)\gamma$.

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 separate radiative or charmless modes with similar topologies.
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.

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