Thesis proposal :

Measurement of time-dependent CP asymmetry in the charmless B decay $B^0 \to \eta' K^0_S$ and contribution to the PicoCal calorimeter for LHCb Ugrade II

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The **LHCb experiment** , operating at the Large Hadron Collider at **CERN**, has successfully recorded proton collisions during the LHC Run 1 and 2 before undergoing a major upgrade before the restart of the LHC in 2022 for Run 3, allowing the detector to accumulate high quality data at a rate increased by a factor ~ 5. Thanks to a robust and flexible trigger system, the integrated luminosity at the end of Run 2 reached the level of $9\,\mathrm{fb}^{-1}$, with a target of $\sim 50\,\mathrm{fb}^{-1}$ by 2033. While Run3 is ongoing, the LHCb collaboration is targeting to further increase the luminosity by a factor ~ 10 compared to current conditions. The LHCb Upgrade II detector is expected to take data during the LHC Run 5 allowing to accumulate $\sim 300\,\mathrm{fb}^{-1}$ by the end of the LHC. To cope with the archer data taking conditions many sub-detectors will need to be upgraded, including the current calorimeter, essential in the reconstruction of electromagnetic and neutral particles such as π^0 and photons.

The Physics objectives of the LHCb experiment consists in the high **precision studies of rare decays and CP violation phenomena** in the heavy flavours (b, c, and τ) sector.

The charged current quark flavour transitions are described in the **Standard Model (SM)** by the **Cabibbo-Kobayashi-Maskawa (CKM) matrix**, which relates the quark mass eigenstates to the electroweak eigenstates. This is **intimately linked to the spontaneous symmetry breaking** of the electroweak symmetry. The existence of a non vanishing phase in that matrix is the unique source of CP violation in the SM and most of what we can learn experimentally on this quantity is brought by the observables belonging to the b-hadron decays and mixing phenomena.

The LHCb experiment started at the moment when the B-factories experiments (BaBar and Belle) completed their Physics program. The science produced at these facilities is simply impres-

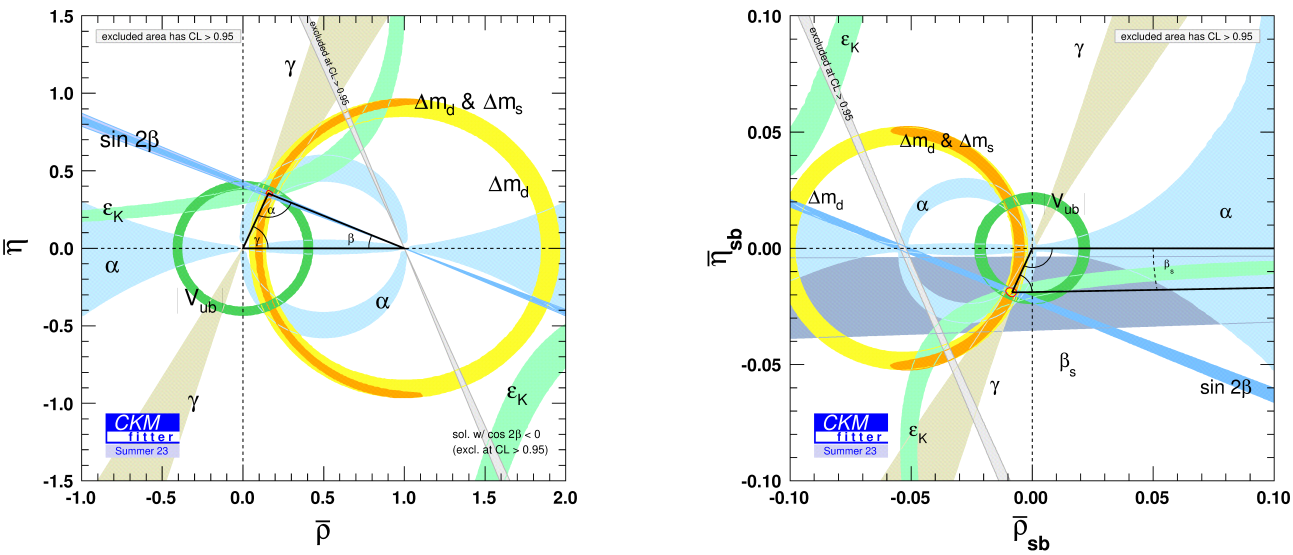

FIGURE 1 – Unitarity triangles related to β (left) and β_s (right).

sive. The **KM paradigm** is actually established as the **main source of CP violation at the electroweak scale**. Yet, there are strong indications (mostly driven by cosmological observations) that **new sources of CP violation must exist**. The LHCb experiment is expected to **improve the precision on CKM parameters** in particular (it already did in some respects) and constrain further if not unravel these new CP violation sources. The Physics analyses developed in our group belong to this framework.

Our team aims at measuring the weak phases which govern the amplitudes of the B_d^0 and B_s^0 mixing phenomena, which can be identified in the SM with the CKM angles β and β_s (Fig. 1). This can be realised by means of **time-dependant analyses of the charmless B decays** such as $B^0 \to \eta' K_S^0$. These measurements are experimentally challenging due to the multiple decay modes considered for the η' reconstruction including photons and π^0 in the final state. An important ingredient, which is **key for all CP and mixing analysis** performed in LHCb, is the determination of the flavour of the decaying neutral B meson, often referred to as flavour tagging (FT). The precision on the measured physics parameters are ultimately directly linked to the FT performances. **Advanced Deep Machine Learning techniques** appear promising to improve the FT performances, which would have a major impact on a wide range of measurements performed in the LHCb collaboration.

The Thesis will primarily focus on analysing the data collected by the LHCb detector during Run 3. Significant contributions are also expected to the study of flavour tagging improvements, as well as to the PicoCal calorimeter for the Upgrade II of the LHCb detector.

The mobility scheme for this co-tutelle is, to date, planned as : the first year and a half will happen in Clermont followed by a year in Bologna ; the selected student will return in Clermont for the last 6 months, where the defence of the thesis will be held. This proposal is the first co-tutelle project initiated with Bologna University.

Keywords : LHCb, LHC, ElectroWeak Standard Model, CP violation, B Mesons Mixing, Flavour Tagging, Deep Machine Learning