High precision Standard Model Physics

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Abstract. The main goal of the LHCb experiment, one of the four large experiments of the Large Hadron Collider, is to try to give answers to the question of *why Nature prefers matter over antimatter ?* This will be done by studying the decay of b quarks and their antimatter partners, $\bar{b}$, which will be produced by billions in 14 TeV p–p collisions by the LHC. In addition, as "*beauty*" particles mainly decay in charm particles, an interesting program of charm physics will be carried on, allowing to measure quantities as for instance the $D^0 - \overline{D}^0$ mixing, with incredible precision.

Keywords: Beauty physics, charm physics, LHCb
PACS: xx.x, yy.y

THE LHCB EXPERIMENT

LHCb [1] is one of the four large experiments of the Large Hadron Collider [2] (LHC), located in a underground cavern at about 100 mts beneath the French countryside. The experiment involves about 689 scientists from 48 institutions around the world.

The LHCb consists of a single arm detector (See Fig. 1) designed for high precision b-physics studies, including CP-Violation and rare decays. It is also among its objetives to look for new physical phenomena beyond the Standard Model.

The LHCb detector has good vertexing and high performance particle identification (PID). These features which make the LHCb an excellent detector for b-physics, are also those which are desirable for charm physics. As a matter of fact, along with the b-physics trigger, LHCb has a dedicated $D^\star \to D^0(hh)\pi$ trigger channel which will provide a large charm sample which can be used in mixing and direct CP-Violation searches.

LHCb has a two level trigger system. The Level 0 trigger (L0), a hardware trigger, will have an input rate of 40 MHz while its output rate will be of 1 MHz. L0 has been designed to select high transverse momentum hadrons, muons, electrons and photons, which are the signature of b-physics events. It will also reject multiple bunch crossing based on information received from the Vertex Locator (VeLo) system.

The second level, the High Level Trigger (HLT) is a software trigger which will use the full detector information. It will send the events that pass L0 to four different generic HLT alleys: muon, electron, hadron and photon. After the generic HLT confirmation, the events will continue to especific inclusive or exclusive channels. The HLT output rate of 2 kHz will be shared among 200 Hz dedicated to exclusive B selections, 300 Hz to $D^\star \to D^0(hh)\pi$, 600 Hz to $J/\Psi \to \mu^+\mu^-$ and 900 Hz to the inclusive b stream.

The estimated yield to tape of the $D^\star \to D^0(hh)\pi$ channel with an integrated luminosity of 2 fb^1, corresponding to one nominal year of data taking, is of the order of 55×10^6 events in the $D^0 \to hh$ decay channel, with $hh = K^-\pi^+;\ K^-K^+;\ \pi^-\pi^+;\ K^+\pi^-$. A

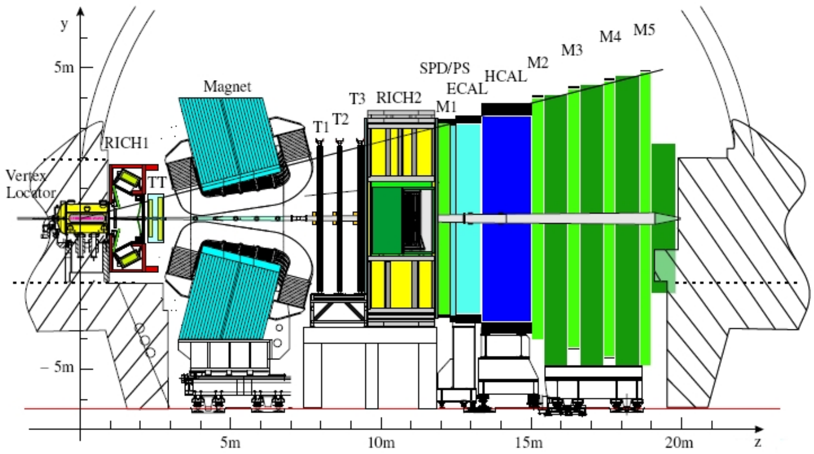

FIGURE 1. Schematic representation of the LHCb detector showing its several subsystems. The interaction point is well inside the VeLo, in the left side of the figure.

similar amount of prompt $D^\star$ is expected, rising the number of $D^\star \to D^0(hh)\pi$ events potentially usable to 10^8 per 2 fb^{-1} [3].

THE CKM MATRIX AND THE UNITARY TRIANGLES

The required $SU(3)_c \times SU(2)_L \times U(1)_Y$ gauge symmetry of the Standard Model (SM) does not allow for fermion masses. They are instead dynamically generated in the spontaneous symmetry breaking $SU(3)_c \times SU(2)_L \times U(1)_Y \longrightarrow SU(3)_c \times U(1)_{e.m.}$ by introducing Yukawa couppling terms among the fermion and Higgs fields. Mass terms then result to be of the form

$$m_i = \frac{v\, g_i}{\sqrt{2}}\,; \;\; i = u,d,e \tag{1}$$

where u,d stands for u-type and d-type quarks and e for charged leptons. v is the vacuum expectation value of the Higgs field and g_i is the corresponding couppling constant in the Yukawa terms. The $W^\pm$ and Z^0 masses are also generated in the spontaneous symmetry breaking. The mass and flavor basis are related one another by a linear transformation of the form

$$\mathscr{U}_{u,d,e} M_{u,d,e} \mathscr{U}^\dagger_{u,d,e} = \begin{pmatrix} m_{u,d,e} & 0 & 0 \\ 0 & m_{c,s,\mu} & 0 \\ 0 & 0 & m_{t,b,\tau} \end{pmatrix}. \tag{2}$$

Transforming the fields from the mass to the flavor basis leaves all the diagonal terms of the SM Lagrangian invariant, while the quark Charged Current (CC) interactions terms, which are anti-diagonal, are changed by a factor

$$V = \mathscr{U}_u \mathscr{U}^\dagger_d \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}, \tag{3}$$

which is the so called Cabbibo-Kobayashi-Maskawa (CKM) matriz. If ν's are massles, there is no equivalent CKM matrix for the leptonic sector of the SM. Assuming three quark generations, V is a unitary matrix by construction and from its nine complex elements, only three real ones and a complex phase survive, after reducing the V matrix to a SU(3) matrix by absorbing the extra phases in a redefinition of the fermion fields. These three real numbers are the three angles governing the CC couplings while the complex phase is responsible for the CP-Violation in the SM.

There exist several parametrizations of the CKM matrix, being the most usual probably the standard parametrization, by the Particle Data Group [4],

$$V = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{i\delta} \\ -s_{12}c23 - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix} , \tag{4}$$

where $c_{ij} = \cos\theta_{ij}$, $s_{ij} = \sin\theta_{ij}$, $i, j = 1,2,3$. In eq. 4, V has been written as the product of three rotation matrices times a phase, where θ_{ij}, $i, j = 1,2,3$ are the mixing angles between generations. An alternative and very useful representation of the CKM matrix is also the Wolfenstein [5] parametrization,

$$V = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & \lambda^3 A(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & \lambda^2 A \\ \lambda^3 A(1-\rho-i\eta) & -\lambda^2 A & 1 \end{pmatrix} , \tag{5}$$

where $\lambda \sim V_{us} \sim 0.22$ is the expansion parameter, $s_{23} = A\lambda^2$ and $s_{13}e^{i\delta} = \lambda^3 A(\rho - i\eta)$. One interesting feature of the Wolfenstein parameterization is that the hierarchy between the different matrix elements is explicitly shown.

The unitary triangle

From the unitarity of the CKM matrix, six triangles are obtained in the complex plane (ρ,η) from all the possible products among different columns. From these, four are flat and two non-flat and quasi-degenerated corresponding to the B-meson system. The fact that the B-meson system triangles be non-flat and quasi-degenerated is taken as an indicative of large CP violation in the b sector of the SM.

From the product of the 1^{st} and 3^{rd} columns we get

$$\frac{V_{ud}V^\star_{ub}}{V_{cd}V^\star_{cb}} + \frac{V_{cd}V^\star_{cb}}{V_{cd}V^\star_{cb}} + \frac{V_{td}V^\star_{tb}}{V_{cd}V^\star_{cb}} = 0 , \tag{6}$$

which can be represented in the $(\bar\rho,\bar\eta)$ plane as shown in Fig. 2. The sides in the Unitary Triangle (UT) shown in Fig. 2 are given by

$$R_u = \left|\frac{V_{ud}V^\star_{ub}}{V_{cd}V^\star_{cb}}\right| = \sqrt{\bar\rho^2 + \bar\eta^2} , \quad R_t = \left|\frac{V_{td}V^\star_{tb}}{V_{cd}V^\star_{cb}}\right| = \sqrt{(1-\bar\rho)^2 + \bar\eta^2} ; \tag{7}$$

where

$$\bar\rho + i\bar\eta \equiv -\frac{V_{ud}V^\star_{ub}}{V_{cd}V^\star_{cb}} , \tag{8}$$

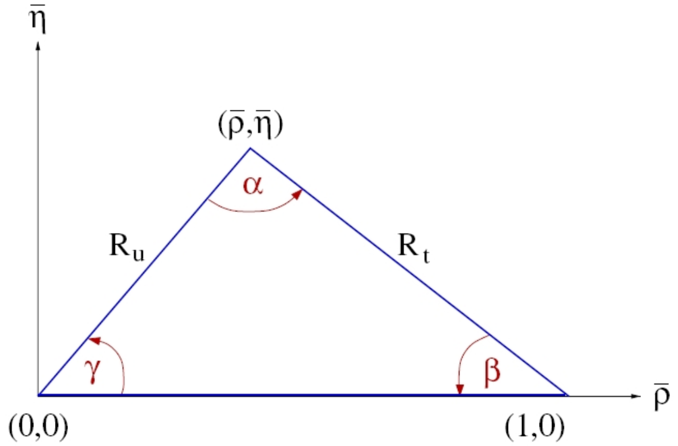

FIGURE 2. Rescaled unitary triangle in the Wolfenstein representation. Angles α, β and γ can be measured in B meson decays.

and

$$\rho + i\eta = \frac{\sqrt{1-A^2\lambda^4}(\bar{\rho}+i\bar{\eta})}{\sqrt{1-\lambda^2}[1-A^2\lambda^4(\bar{\rho}+i\bar{\eta})]}\ , \tag{9}$$

to all orders in λ. Eq. (9) relates the (ρ,η) to the $(\bar{\rho},\bar{\eta})$ planes. The angles in the UT, which given by

$$\alpha = \arg\left[-\frac{V_{td}V^\star_{tb}}{V_{ud}V^\star_{ub}}\right]\ ,\quad \beta = \arg\left[-\frac{V_{cd}V^\star_{cb}}{V_{td}V^\star_{tb}}\right]\ ,\quad \gamma = \arg\left[-\frac{V_{ud}V^\star_{ub}}{V_{cd}V^\star_{cb}}\right]\ , \tag{10}$$

are typically measured in B meson decays. However, other ingredients like ε_K, Δm_d and Δm_s, the mass splitting among the B^0_d and B^0_s meson systems, the $B \to \tau\nu$ decay, etc, are called for to constraint the UT.

The current status on the determination of the parameters of the UT [6] is shown in Fig. 3. Parameters in the Wolfenstein representation are [7] $A = 0.796^{+0.024}_{-0.017}$; $\lambda = 0.2253 \pm 0.0008$; $\bar{\rho} = 0.214^{+0.031}_{-0.104}$ and $\bar{\eta} = 0.308^{+0.061}_{-0.025}$, with errors still of the order of 10% or bigger in most cases.

WHAT'S NEXT ?

The main goal of present and future experiments in flavor physics is to make measure-ments of CKM coefficients as precisely as possible. Note that, for instance, the angle γ is known with an error of the order of 50%. Other parameters in the UT triangle are better determined, but still with large error bars. On the other hand, over-constraining the CKM matrix is relevant to validate the three generations in the SM.

Consistency checks of the UT are also called for to look for New Physics (NP) effects which can appear at the tree and loop level. Deviations of SM predictions can be made by comparing diferent measurements of the same quantity, one sensitive and another

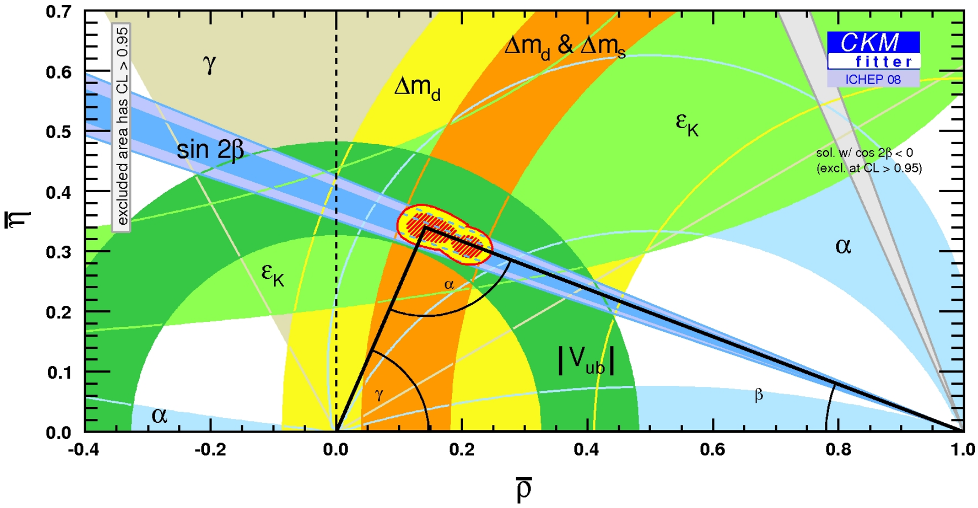

FIGURE 3. Current status of the UT from fits by the CKM-Fitter group [6].

one insensitive to NP, by looking for $|\Delta F| = 1$ and $|\Delta F| = 2$ rare decays and mixing respectively, etc.

At present, a formidable effort in this direction is being made by the Belle and BaBar Collaborations, with important contributions coming also from CDF and D0. In the near future, the LHCb experiment at CERN is expected to play a key role constraining the UT with high precision measurements in the b sector of the SM.

Beauty physics

Measurements of CP asymmetries in the proper time distribution of B^0s going to a common final state give us direct information on the angles of the UT. These CP asymmetries are defined as

$$A_{CP}(t) = \frac{\Gamma(\overline{B}^0(t) \to f) - \Gamma(B^0(t) \to f)}{\Gamma(\overline{B}^0(t) \to f) + \Gamma(B^0(t) \to f)} = S_f \sin(\Delta m_d\, t) - C_f \cos(\Delta m_d\, t)\ , \qquad (11)$$

where

$$S_f = \frac{2\, Im(\lambda_f)}{1 + |\lambda_f|^2}; \ \ C_f = \frac{1 - |\lambda_f|^2}{1 + |\lambda_f|^2}; \ \ \lambda_f = \frac{q}{p}\frac{\bar{A}_f}{A_f}\ . \qquad (12)$$

In eqs. (11)-(12), q/p describes the $B^0 - \overline{B}^0$ mixing and $A_f(\bar{A}_f)$ is the $B^0 \to f$ ($\overline{B}^0 \to f$) decay amplitude. If f is a CP eigenstate and amplitudes with one CKM phase dominate the decay, then $|A_f| = |\bar{A}_f|$, $C_f = 0$ and $S_f = \eta_f \sin(2\phi)$, with η_f the CP eigenvalue of f and ϕ the corresponding angle of the UT. Contributions of amplitudes with different CKM phase to the decay makes the value of S_f sensitive to the relative strong interaction phases between the decay amplitudes.

In addition, measurements of $B_s - \overline{B}_s$ mixing, in combination with the $B^0 \to D_s^+ + K^-$ decay can allow for a clean determination of the β_s mixing phase and the angle γ with a

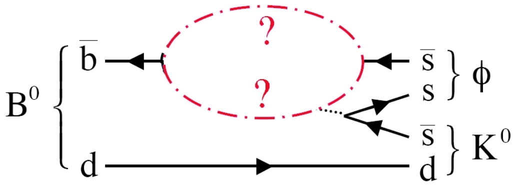

FIGURE 4. $B^0 \to \phi + K^0$ decay. NP could appear in penguin diagram through the contribution of new particles in loops.

good precision, allowing also for searches of NP. Rare decays are also called for when looking for deviations of SM predictions.

Measurement of the angle α

Only CP asymmetries in the $b \to u\bar{u}d$-dominated modes can directly measure $\sin(2\alpha)$. The determination of α is however complicated because $b \to d$ penguin amplitudes have a different CKM phase than the $b \to u\bar{u}d$ one, but magnitude of the same order in λ. Thus, for instance, the time dependent $B^0 \to \pi^+\pi^-$ asymmetry does not measure $\sin(2\alpha)$, but $\sin(2\alpha + \Delta\alpha)$, where $\Delta\alpha$ comes from the penguin amplitude.

An alternative mode to measure α is the $B^0_d \to \pi^+\pi^-\pi^0$ decay. In fact, assuming that the decay proceeds mainly through $\rho \to \pi\pi$, there are six interfering modes, $B^0_d \to \rho^+\pi^-$; $\rho^-\pi^+$; $\rho^0\pi^0$ and their c.c. The proper time evolution of tagged Dalitz distributions can provide enough information to determine simultaneously α and the strong phases among all the transitions [8]. Note however that both, tree and penguin transitions contribute to each mode. This method allows a clean extraction of α in the range $[0;\pi]$.

Combined results from the three decays [9], $B \to \pi\pi$, $B \to \rho\rho$ and $B \to \rho\pi$, where the last includes the proper time evolution of the tagged Dalitz plot of the $B^0_d \to \pi^+\pi^-\pi^0$ decay, constraint the angle α to $\alpha = \left(88^{+6}_{-5}\right)^\circ$.

MonteCarlo (MC) studies by LHCb seems to indicate that the experiment has low sensitivity to this measurement, with a estimated statistic error of about $\sigma(\alpha) < 10^\circ$ [10] for 2 fb$^-$1, which is the amount of data expected in one nominal year of data taking.

Measurement of the angle β

In contrast to $\sin(2\alpha)$, several methods can directly measure $\sin(2\beta)$. The $b \to c\bar{c}s$ decays to CP eigenstates, as for instance $B^0 \to J/\Psi + K^0_{S,L}$, are the cleanest decay modes to extract $\sin(2\beta)$ through a direct measurement of S_f in eq. (12). The $b \to c\bar{c}d$ transitions, shuch as $B^0 \to J/\Psi + \pi$ can also be useful to mesure approximately $\sin(2\beta)$, however, the dominant component of the $b \to d$ amplitude has a different CKM phase than the tree amplitude, both with magnitudes of the order of λ. Consequently, penguin

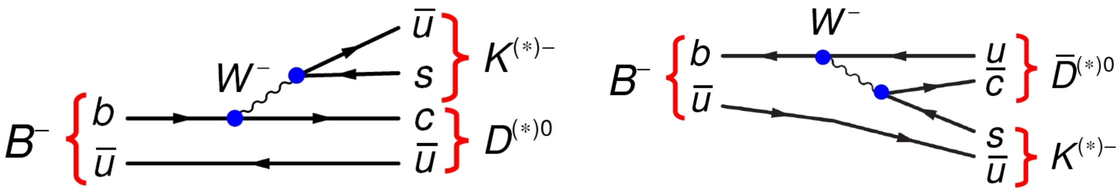

FIGURE 5. $B^- \to D^{(\star)0} + K^{(\star)-}$ decay and its c.c.

effects could be large, resulting in $S_f \neq -\eta_f \sin(2\beta)$ and $C_f \neq 0$. Other modes, like the $b \to s\bar{q}q$ penguin dominated ones, could provide measurements of $\sin(2\beta)$ but, the main interest in these modes is the search of NP which can emerge through new particles appearing in loops. This is the case of the $B^0 \to \phi + K^0$ decay (see Fig. 4).

The world average by the Heavy Flavor Group (HFAG) [11] $\sin(2\beta) = 0.672 \pm 0.024$ which translates into a value $\beta = (21.1 \pm 0.9)^\circ$ is dominated by BaBar [12] and Belle [9, 13].

LHCb expects of the order of 236×10^3 events in one nominal year of data taking, pussing the statistical error in $\sin(2\beta)$ down to $\sigma(\sin(2\beta)) \sim 0.020$ in the decay mode $B^0 \to J/\Psi + K_s$ [14]. Note that for the B-factories, it is now of the order of $\sigma(\sin(2\beta)) \sim 0.025$. The LHCb can also select ~800 $B^0 \to \phi + K_s$ events after trigger in one year of data taking [15]. This leads to a statistical uncertainty on $\sin(2\beta)$ of about 0.27 - 0.41 at 90% CL.

Measurement of the angle γ

The angle γ is the only one that does not depend on CKM elements involving the top quark (see eq. (10), then it can be measured in tree level B-meson decays. Note also that because of that, γ is unlikely to be affected by physics beyond the SM.

Several precision measurements of γ are possible, among them those involving the $b \to c\bar{u}s$ and $b \to u\bar{c}s$ transitions, as for instance the interference between the $B^- \to D^{(\star)0} + K^-$ and $B^- \to \overline{D}^{(\star)0} + K^-$ decays (See Fig. 5), which can be studied in final states accesible to both, the $D^{(\star)0}$ and the $\overline{D}^{(\star)0}$ [16]. Note that the first goes through a dominant $b \to c$ transition, while in the second, the $b \to u$ transition is color suppressed. However, in principle it is possible to extract the B and D decay amplitudes and the angle γ from data by using several method. For instance, the GLW [17] method considers D decays to CP eigenstates like $D^{(\star)0} \to \pi^+ + \pi^-$, the ADS [18] method, which looks for Cabbibo-allowed $\overline{D}^0$ and doubly-Cabbibo-suppressed D^0 interfering decays, etc. The expected sensitivity in LHCb is of $\sigma_{stat}(\gamma) \sim 9^\circ$ in one year of data taking [19].

The interference among $b \to u$ and $b \to c$ transitions can be also studied in $B^0 \to D^{(\star)\pm} + \pi^\pm$ decays. Since there are no penguin contributions to these decays, it is possible to extract the magnitudes of the hadronic amplitudes, their relative strong phases and the weak phase $2\beta_s + \gamma$. However a complication, shared with the previous decays, is the smallness of the ratio of the interfering amplitudes which affects the

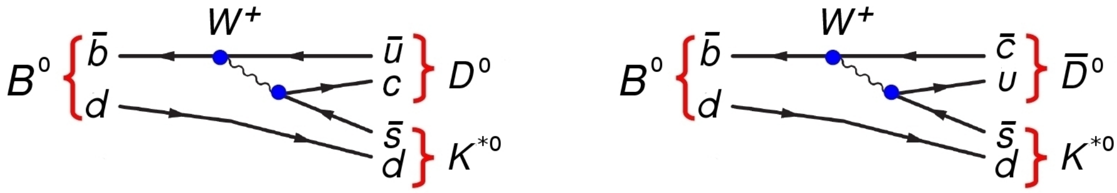

FIGURE 6. $B^0 \to D^0 + K^{(\star)0}$ decay and its c.c.

precision of the measurement.

A better alternative seems to be the $B_s^0 \to D_s^{\pm} + K^{\mp}$ decays, for which the amplitude ratio is much larger, allowing to extract in a model independent manner $\sin(2\beta_s + \gamma)$. LHCb expects a sensitivity of $\sim (9-12)^\circ$ for $(2\beta_s + \gamma)$ in this mode, thanks to its excellent PID, with $\Delta m_s \sim 20$ ps^{-1} [20].

Other interesting modes are $B^0 \to D^0 + K^{\star 0}$ and $B^{\pm} \to D^0 + K^{\pm}$. In the first one, two tree level diagrams interfere via D^0 mixing as shown in Fig. 6. This means that there are six decay rates to be measured depending on the D^0 decay mode, $K\pi$, KK or $\pi\pi$ and c.c. The LHCb expectation for one year of data taking is $\sigma(\gamma) \sim 8^\circ$. In the second decay, $B^{\pm} \to D^0 + K^{\pm}$, the relative rates for the B^- and B^+ decays should be measured and then the ADS method can be used to extract the angle γ. This decay is the candidate for the most precise determination of γ by LHCb. In one year of data taking $\sigma(\gamma) \sim 5^\circ$ is expected [19].

The current world average by the CKM-Fitter group is $\gamma = (70^{+27}_{-29})^\circ$ [6], being it by far the worse determined parameter of the UT.

β_s mixing phase and rare decays

The B_s mixing phase, β_s, in the decay $b \to c\bar{c}s$ is also an important measurement because it can signal the presence of NP. The golden mode for this measurement is the decay $B_s \to J/\Psi + \phi$, being the SM prediction [21]

$$\beta_s = \arg\left(-\frac{V_{ts}V_{tb}^\star}{V_{cs}V_{cb}^\star}\right) = -0.019 \pm 0.001\ . \tag{13}$$

The CP asymmetry for this mode is given by

$$A_{CP}(t) = \frac{-\eta_f \sin(2\beta_s)\sin(\Delta m_s\, t)}{\cosh(\Delta\Gamma_s\, t/2) - \eta_f \cos(2\beta_s)\sinh(\Delta\Gamma_s\, t/2)}\ , \tag{14}$$

from which β_s and $\Delta\Gamma_s$ can be extracted. The current values, $2\beta_s = -0.57^{+0.24}_{-0.30}$ and $\Delta\Gamma_s = 0.19 \pm 0.07$ ps^{-1} are dominated by data from the D0 Collaboration [22]. The LHCb experiment expects approximately 130×10^3 events for one nominal year of data taking which translates into a sensitivity of the order of $\sigma(2\beta_s) \sim 0.023$ and $\sigma(\Delta\gamma_s/\Gamma_s) \sim 0.009$ respectively [23], with an improvement of one order of magnitude. $B_s - \overline{B}_s$ mixing is also a sensitive probe for new physics since new particles can

TABLE 1. D^0 tagged signal yields per 2 fb^{-1} estimates from the $B \to D^\star + X$ decay channel.

Decay channel	Expected sample
$D^0 \to K^-\pi^+$ (RS)	$\sim 50 \times 10^6$
$D^0 \to K^+\pi^-$ (WS)	$\sim 0.2 \times 10^6$
$D^0 \to K^+K^-$	$\sim 5 \times 10^6$
$D^0 \to \pi^+\pi^-$	$\sim 2 \times 10^6$

appear in internal lines of the box diagrams. In particular, large contributions are expected if there exists a fourth generation, meaning that β_s is no longer proportional to $-\arg(V_{ts}V_{tb}^\star/V_{cs}V_{cb}^\star)$, either $\Delta m_s \neq \Delta m_s^{SM} \propto \left|V_{ts}^2\right|$. LHCb could impose severe constraints to NP even in the first year. Further searches for NP can be done by looking for rare decays like $B_s^0 \to \mu^+\mu^-$ for which the SM predicts a suppression of about $\sim m_\mu^2/m_B^2$ giving a $BR = 3.4 \times 10^{-9}$. Current limits from the Tevatron are $BR < 5.8 \times 10^{-8}$ and $BR < 9.3 \times 10^{-8}$ at a CL of 95% from CDF and D0 respectively. MC studies shown that LHCb can do better than CDF and D0 with only 0.05 fb^{-1} and reach a 5σ observation of the SM signal with 6 fb^{-1} [24].

Bonus track: charm physics

B-mesons decay to $D^\star + X$ with a BR = 22.5 % and charged $D^\star \to D^0 + \pi$ with BR $\gtrsim$ 60%. $D^\star$s are also produced at the interaction vertex, giving a total of the order of 10^8 $D^\star \to D^0(hh)\pi$ [3] potentially usable events per 2 fb^{-1} for charm physics (See Table 1). This large charm sample will be suitable for precision studies in time dependent measurements of $D^0 - \overline{D}^0$ mixing as well as direct CP-Violation measurements in D^0 two body decays. Time integrated $D^0 - \overline{D}^0$ mixing in $D^0 \to Kl\nu$ decays, three body charged and neutral D meson decays and four body D meson decay studies are also possible.

In what follows I will explore the potential of LHCb in searches for $D^0 - \overline{D}^0$ mixing.

$D^0 - \overline{D}^0$ mixing

The $D^0 - \overline{D}^0$ mixing is expected to be small in the SM. However several recent results have shown that indicate mixing to a level from 2.7 to 3.9 σ [25]. Among these recent results, BaBar has performed a $D^0 - \overline{D}^0$ mixing analysis that can be done by LHCb using the WS decay $D^0 \to K^+\pi^-$.

In absence of CP-Violation, the $D^0 - \overline{D}^0$ mixing is described by the parameters

$$x = \frac{m_1 - m_2}{\Gamma} = \frac{\Delta m}{\Gamma}, \quad y = \frac{\Gamma_1 - \Gamma_2}{2\Gamma} = \frac{\Delta\Gamma}{2\Gamma}, \tag{15}$$

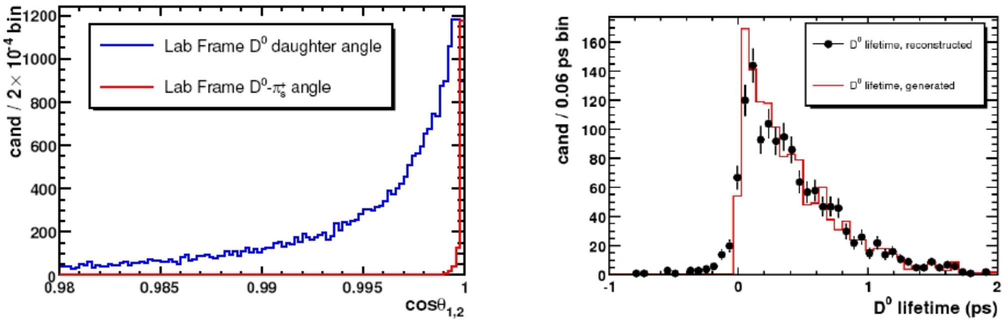

FIGURE 7. Left: MC study showing the D^0 daughter angle (blue line) and the $D^0-\pi$ angle (redline) in the laboratory frame. As can be seen in the figure, the D^0 and π coming from the $D^\star$ decay are almost collinear. Right: Reconstructed compared to the generated D^0 lifetime using the technique of partial reconstruction of the mother B meson.

where $m_{1,2}$, $\Gamma_{1,2}$ are the masses and decay widths of the mass eigenstates and $\Gamma = (\Gamma_1+\Gamma_2)/2$.

The time dependent Wrong Sign (WR) ($D^0 \to K^+\pi^-$) decay rate is given by

$$r_{WS} \propto \exp(-\Gamma t)\left[R_D + \sqrt{R_D}y'\Gamma t + \frac{1}{2}R_M(\Gamma t)^2\right], \tag{16}$$

where

$$x' \equiv x\cos\delta + y\sin\delta \quad y' \equiv y\cos\delta - x\sin\delta \tag{17}$$

are the x, y parameters rotated by a strong phase δ.

R_D is the ratio of the Double Cabbibo Suppressed (DCS) to Cabbibo Favored (CF) decay rates and R_M the mixing rate is given by

$$R_M = \frac{x^2+y^2}{2} = \frac{x'^2+y'^2}{2}. \tag{18}$$

Note that the WR D^0 decay can proceed either by a DCS direct decay to $K^+\pi^-$ or via mixing followed by a CF decay. The analysis of mixing requires a precise determination of the decay time, which in turn translates into a very good determination of both, the birth and decay vertex of the D^0. As D^0s come from the $D^\star \to D^0 + \pi$ decay chain, and the D^0 and π are almost collinear (See Fig. 7, Left pannel), the birth vertex of the D^0 is poorly determined not allowing for a precise measurement of the decay time. This shows the needs of new techniques to perform the time dependent analysis using D^0s coming from the $D^\star$ decay.

The typical flight distance of the D^0 at 60 GeV energy is about $\beta\gamma\tau_c \sim 4\ mm$ whereas the $D^\star$ decays almost in the creation point. A better alternative than try to reconstruct the $D^\star$ is to partially reconstruct the mother B meson by adding a fourth track to the birth vertex of the D^0, and then use the B decay vertex as the D^0 birth vertex. MC studies[3] shown that following this procedure, the D^0 proper time resolution improves by one order of magnitude, from 0.465 ps to 0.045 ps (See also Fig 7, Right pannel). This is

TABLE 2. LHCb sensitivity compared to other experiments.

Exp.	**Data set**	N_{WS}	$x'^2(\times 10^{-3})$	$y'(\times 10^{-3})$
BaBar	384 fb^{-1}	4030	-0.22±0.30±0.21	9.7±4.4±3.1
Belle	400 fb^{-1}	4024	$0.18^{+0.21}_{-0.23}$	$0.6^{+4.0}_{-3.9}$
CDF	1.5 fb^{-1}	12700	-0.12±0.35	8.5±7.6
LHCb	10 fb^{-1}	232500	$x'^2 \pm 0.064(stat)$	$y' \pm 0.87(stat)$

due to a large improvement of the birth vertex resolution of the D^0, which is now close to the decay vertex resolution.

The sensitivity of LHCb for mixing will improves by at least one order of magnitude as compared to results from Belle, BaBar and CDF, as shown in Table 2, for 10 fb^{-1} of data [3]. As for now, Belle, BaBar and CDF have reported evidence on $D^0 - \overline{D}^0$ mixing, but there is no evidence of CP-Violation.

CONCLUSIONS

With the start of the LHC experiments in the next year, a new window into flavor physics will be opened. On one side, precision measurements in the B sector of the SM will be possible thanks to the unprecedent statistics and, consequently, an exciting search for NP beyond the SM will be possible through the search for rare decays, precision measurements to look for deviations of SM predictions in penguin dominated diagrams, supersimmetry, etc. LHCb, which is tunned for b-physics will be able to provide not only precision measurements on the CKM matrix coefficients, but also to participate in this exciting search for physics beyond the Standard Model.

LHCb will also accumulate an impresive amount of charm, both originating from B decays and coming from prompt production. In particular, a dedicated $D^\star$ trigger in LHCb will provide of the order of 10^8 tagged $D^0 \to hh$ by each 2 fb^{-1}. This sample will provide an unprecedent sensitivity to search for $D^0 - \overline{D}^0$ mixing and CP-Violation in the charm sector. Note that the SM predicts $x, y \sim \mathscr{O}(10^{-3})$, then bigger values are clearly indicative of NP. Studies of multibody decay channels and searches for rare decays in the charm sector of the SM will be also possible. In addition, the large charm sample which will be collected by LHCb will serve to callibrate the RICH performance.

In conclusion, LHCb has a very interesting potential for both, B and *charm* physics and, it is expected that in the first months of data taking, important results on flavor physics be obtained, including limits for NP.

ACKNOWLEDGMENTS

J.M would like to thanks to the Organizing Committee of the XIII Mexican School of Particles and Field for the warm hospitality and the stimulating environment to discuss physics created during the Conference. The author wish also to congratulate the

Organizing Committee for the excellent organization. J.M. aknowledges the financial support by the XIII Mexican School of Particles and Field.

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