Radiative Decays of B Hadrons at LHC*b*

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LHC*b* is a dedicated B physics experiment at the Large Hadron Collider (LHC) at CERN. The experiment aims to look for New Physics at energy scales much higher than those reachable through direct production, by measuring effects from the New Physics particles in rare beauty and charm decays. Radiative penguin decays of B mesons are an important part of the LHC*b* physics programme, and the detector is well positioned to harness the large statistics of these decays available at the LHC luminosity. Even with a small integrated luminosity of 100 pb^{-1}, 5% of what LHC*b* would collect in one nominal year of LHC, it can make a competitive measurement of the CP asymmetry in the decay $B_d \to K^*\gamma$.

1 Introduction

Radiative pengiun decays of B mesons are an example of Flavour Changing Neutral Currents, which are forbidden at tree level in the Standard Model (SM). Such decays can only occur due to loop diagrams, and the one corresponding to $b \to s\gamma$ is shown in Fig. 1. The contribution of all the known particles to the loop can be calculated, and hence the branching ratio of such decays can be predicted in the SM.

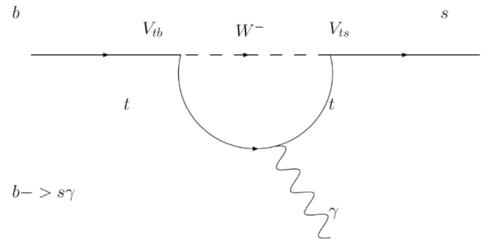

Figure 1: The loop diagram for a $b \to s\gamma$ transition

The current average experimental value of the inclusive $\mathcal{B}(B \to X_s\gamma)$ is $3.56 \pm 0.26 \times 10^{-4}$ [1], which is in agreement with the latest theoretical predication of $3.15 \pm 0.23 \times 10^{-4}$ [2]. The newest measurement by the *Belle* colaboration [3] is also in agreement with theory.

However, New Physics (NP) can have more subtle effects than a change in the branching ratio, for example the CP asymmetry in the decay $B_d \to K^*\gamma$. Another interesting way to look for deviations from the SM is to probe the chiral structure of the possible NP operator in $b \to s\gamma$ decays, by measuring the photon polarization.

The decays $B_u \to K^*\pi\gamma$, $B_u \to \phi K\gamma$, and $\Lambda_b \to \Lambda\gamma$ can provide sensitivity to the photon polarization by an angular analysis of the decay products. The decays $B_s \to \phi\gamma$ and $B_d \to K^*\gamma$ can also be used for such a study, but $B_s \to \phi\gamma$ offers much more sensitivity than $B_d \to K^*\gamma$ due to the large decay width difference ($\Delta\Gamma$) between the B_s and $\overline{B}_s$ mesons, as compared to the B_d system. Further, it is a flavour blind final state, so the photon polarization analysis can be done without flavour tagging aswell [4]. The decays $B_d \to \rho\gamma$ and $B_d \to \omega\gamma$ are very useful in constraining the ratio of $|V_{td}|$ and $|V_{ts}|$ [5] [6].

In 2010, the first year of physics operation of the LHC, an integrated luminosity of 100 pb^{-1} is foreseen. In the following, we focus on $B_d \to K^*\gamma$ and $B_s \to \phi\gamma$, in particular the very early measurements possible with these decays, at LHC*b*.

2 $B_d \to K^*\gamma$ at LHC*b*

With quite modest integrated luminosities, LHC*b* can perform measurements competitive to the current B Factory results, as the statistics available to the experiment are quite large. Table 1 lists the expected number of triggered and selected $B_d \to K^*\gamma$ and $B_s \to \phi\gamma$ decays for a range of luminosities.

Decay mode	$100\,\text{pb}^{-1}$	$500\,\text{pb}^{-1}$	$2\,\text{fb}^{-1}$
$B_d \to K^*\gamma$	4×10^3	2×10^4	7×10^4
$B_s \to \phi\gamma$	550	3×10^3	1.1×10^4

Table 1: Expected number of triggered and selected $B_d \to K^*\gamma$ and $B_s \to \phi\gamma$ decays at LHC*b*

The direct *CP* asymmetry in $B_d \to K^*\gamma$ decay $\mathcal{A}^{\text{dir}}_{\text{K}^*\gamma}$, is predicted to be less than 1% in the SM. It is defined as

$$\mathcal{A}^{\text{dir}}_{\text{K}^*\gamma} = \frac{\mathcal{B}_{\text{B}_d \to \text{K}^*\gamma} - \mathcal{B}_{\bar{\text{B}}_d \to \bar{\text{K}}^*\gamma}}{\mathcal{B}_{\text{B}_d \to \text{K}^*\gamma} + \mathcal{B}_{\bar{\text{B}}_d \to \bar{\text{K}}^*\gamma}}.$$

which can be experimentally measured by counting the number of reconstructed $\text{B}_d \to \text{K}^*\gamma$ and $\bar{\text{B}}_d \to \bar{\text{K}}^*\gamma$ decays. The systematics introduced due to production and detector asymmetries can be cancelled, to leading order, using $\text{B}_d \to \text{K}^*\text{J}/\psi$ as a control channel and building the ratios $\mathcal{R}$ and $\bar{\mathcal{R}}$:

$$\mathcal{R} = \frac{\mathcal{N}_{\text{B}_d \to \text{K}^*\gamma}}{\mathcal{N}_{\text{B}_d \to \text{K}^*\text{J}/\psi}}, \quad \bar{\mathcal{R}} = \frac{\mathcal{N}_{\bar{\text{B}}_d \to \bar{\text{K}}^*\gamma}}{\mathcal{N}_{\bar{\text{B}}_d \to \bar{\text{K}}^*\text{J}/\psi}}, \quad \text{and} \quad \mathcal{A}_{\mathcal{R}} = \frac{\bar{\mathcal{R}} - \mathcal{R}}{\bar{\mathcal{R}} + \mathcal{R}}.$$

In the ratios $\mathcal{R}$ and $\bar{\mathcal{R}}$, the production and detector asymmetries cancel to first order, and the asymmetry $\mathcal{A}_{\mathcal{R}}$ is a function of the direct asymmetries $\mathcal{A}^{\text{dir}}_{\text{K}^*\gamma}$ and $\mathcal{A}^{\text{dir}}_{\text{K}^*\text{J}/\psi}$.

The explicit expression for $\mathcal{A}^{\text{dir}}_{\text{K}^*\gamma}$ becomes

$$\mathcal{A}^{\text{dir}}_{\text{K}^*\gamma} = \frac{\mathcal{A}_{\mathcal{R}} + \mathcal{A}^{\text{dir}}_{\text{K}^*\text{J}/\psi}}{1 + \mathcal{A}_{\mathcal{R}}\mathcal{A}^{\text{dir}}_{\text{K}^*\text{J}/\psi}}.$$

With $100\,\text{pb}^{-1}$, $\mathcal{A}_{\mathcal{R}}$ can be measured to less than 2% accuracy, hence the measurement of $\mathcal{A}^{\text{dir}}_{\text{K}^*\gamma}$ will be limited by the current $\mathcal{A}^{\text{dir}}_{\text{K}^*\text{J}/\psi}$ measurement [7].

3 $B_s \to \phi\gamma$ at LHC*b*

The decay $B_s \to \phi\gamma$ can be used to extract the photon polarization in the $b \to s\gamma$ transition. With $500\,\text{pb}^{-1}$, it is possible to perform an unbinned maximum likelihood fit on $B_s \to \phi\gamma$ events. With that data sample, the uncertainty on the photon polarization result will be comparable to the the present one, if the parameter is computed from the current results of the *CP* violating parameters [7]. However, even with $100\,\text{pb}^{-1}$, an interesting measurement of the ratio of $\mathcal{B}_{\text{B}_s \to \phi\gamma}$ to $\mathcal{B}_{\text{B}_0 \to \text{K}^*\gamma}$ can be made.

Here the important uncertainties arise from various trigger efficiencies which can be different for the two channels, and also from the uncertainty on the production rates of B_s and B_d mesons (due to the poor knowledge of the fragmentation constants f_b and f_s). Again, one can use $\mathrm{B}_s \to \phi\mathrm{J}/\psi$ and $\mathrm{B}_d \to \mathrm{K}^*\mathrm{J}/\psi$ as normalization channels to reduce these uncertainties, and construct the ratio

$$\mathcal{R}^{B_s\to\phi\gamma} = \frac{\mathcal{B}_{B_s\to\phi\gamma}/\mathcal{B}_{\mathrm{B_s}\to\phi\mathrm{J}/\psi}}{\mathcal{B}_{B_d\to K^*\gamma}/\mathcal{B}_{\mathrm{B}\to\mathrm{K}^*\mathrm{J}/\psi}}. \tag{2}$$

Most systematic uncertainties are expected to cancel in this ratio, and the statistical error is about 5% for $100\,\mathrm{pb}^{-1}$.

4 Conclusion

Radiative decays of B mesons are loop processes and are extremely sensitive to NP phenomena. In this area, the existing experimental measurements agree with the theoretical predications of the SM, and act as efficient constraints of NP models.

Large statistics of radiative decays will help in making these constraints even more strict, and LHC*b* will contribute to the improvements in the current B Factory results and make new measurements in the field of radiative decays. In this document, an overview of the radiative physics programme of LHC*b* was given with emphasis on early measurements which may already be feasible in the 2010 run of the LHC.

The physics reach of LHC*b* can surpass that of the B Factories with only $100\,\mathrm{pb}^{-1}$. With this integrated luminosity, the experiment can make interesting and important measurements of the direct *CP* asymmetry in $B_d \to K^*\gamma$ decay and also of a ratio of the branching fractions of $B_s \to \phi\gamma$ and $B_d \to K^*\gamma$.

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