

Studies of $B \rightarrow K^+\pi^-\gamma$ decays at Belle and Belle II

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to

SCHOOL OF PHYSICS
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RESEARCH
THIRUVANANTHAPURAM - 695 551, INDIA

April 2026

DECLARATION

I, **Manasi Vyahalikar (Roll No: IMS21245)**, hereby declare that, this report entitled "**Studies of $B \rightarrow K^+\pi^-\gamma$ decays at Belle and Belle II**" submitted to Indian Institute of Science Education and Research Thiruvananthapuram towards the partial requirement of **Master of Science in School of Physics**, is an original work carried out by me under the supervision of **Prof. Gagan B. Mohanty and Dr. Tanumoy Mandal** and has not formed the basis for the award of any degree or diploma, in this or any other institution or university. I have sincerely tried to uphold academic ethics and honesty. Whenever a piece of external information or statement or result is used then, that has been duly acknowledged and cited.

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April 2026

CERTIFICATE

This is to certify that the work contained in this project report entitled “**Studies of $B \rightarrow K^+\pi^-\gamma$ decays at Belle and Belle II**” submitted by **Ms. Manasi Vyahalikar (Roll No: IMS21245)** to Indian Institute of Science Education and Research, Thiruvananthapuram towards the partial requirement of **Master of Science in School of Physics** has been carried out by her under my supervision and that it has not been submitted elsewhere for the award of any degree.

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April 2026

Dr. Tanumoy Mandal
Project Supervisor

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Manasi Vyahalikar

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ABSTRACT

CP violation is the violation of the combined symmetry of charge conjugation (C) and parity transformation (P) which causes a difference in the weak interaction decay rates between matter and antimatter. In the Standard Model (SM), CP violation in the quark sector arises from a single irreducible phase in the CKM quark-mixing matrix. The measurement of CP violation parameters in $B \rightarrow K_s \eta \gamma$ can be used to constrain the values of CKM matrix elements. These parameters are expected to be small in SM, and any significant deviation from the SM predictions could indicate the presence of new physics (NP) beyond the SM. Hence, this study focuses on the analysis of the control channel $B^0 \rightarrow K^+ \pi^- \gamma$ to validate the analysis strategy for the signal decay mode. We first perform the analysis on Monte Carlo (MC) simulations and then apply it to the data to obtain the data-MC correction factors. The data corresponds to an integrated luminosity of around 710 fb^{-1} for Belle and 490 fb^{-1} for Belle II collected at $\Upsilon(4S)$ resonance.

INTRODUCTION

The aim of particle physics is to understand the fundamental constituents of matter and their interactions. The SM has been the most successful theory in answering these questions. Yet, it cannot satisfactorily answer some of the fundamental questions, such as why the universe is dominated by matter. One of the necessary conditions for the dominance of matter over antimatter, according to Sakharov [1] [2], is CP violation, but the amount predicted by the SM is not large enough. The measurement of CP violation in different decay modes provides inputs to SM and acts as an important probe to physics beyond the Standard Model (BSM).

The left-handed chiral structure of the SM W bosons implies that CP violation parameters measured in radiative penguin decays of B mesons, due to the suppression of right-handed polarised photons in the final state, should be close to zero. Therefore these decays are sensitive to NP through heavy new particles in the loop that can enhance the right-handed contribution. Measurements of time dependent CP violation (TDCPV) parameters in these decays can thus be an excellent probe for NP.

Collider experiments such as Belle II stand in a unique position for measuring CP violation decays. The SuperKEKB accelerator, operating at the $\Upsilon(4S)$ resonance, collides electrons and positrons to produce mainly B meson pairs. In B meson decays, two types of CP violation are relevant: Direct CP violation, which arises from interference between multiple amplitudes in a specific decay, and Mixing-induced CP violation, which arises due to interference between decays with and without $B^0 - \bar{B}^0$ mixing.

Radiative penguin B decays are a particularly sensitive probe for NP due to the polarised photon in the final state. The transition $b \rightarrow s\gamma$ is forbidden at the tree level and is possible only at the loop level at the leading order [3] [4]. Precise measurements of such rare processes are important for testing the SM. Here we study the control channel $B^0 \rightarrow K^+\pi^-\gamma$ for Time dependent CP Violation (TDCPV) analysis of the decay mode $B^0 \rightarrow K_s\eta\gamma$. This particular control channel is used as both decays share prompt γ in the final state and similar resolution for the variables of interest, i.e. M_{bc} , ΔE and CS . Moreover, the control channel has a significantly higher branching fraction providing significantly higher statistics.

This report is organised as follows: Chapter 1 explains the motivation behind the study of $B \rightarrow K^+\pi^-\gamma$ decay mode. Chapter 2 provides an overview of the SuperKEKB accelerator and Belle II. Chapter 3 gives a detailed analysis strategy, event reconstruction and background suppression using multivariate classifiers. Finally, Chapter 4 discusses the signal and background fit modelling with the resulting the data-MC correction parameters obtained, and the summary of the study.

Chapter 1

PHYSICS MOTIVATION

This chapter serves as an introduction to the theoretical basis for the research presented in this thesis. Section 1.1 provides an overview of the Flavor Physics in SM, followed by a discussion on CP Violation in Section 1.2. The motivation behind the study of the decay mode $B \rightarrow K^+ \pi^- \gamma$ is presented in Section 1.3.

1.1 Flavor Physics in Standard Model

The Standard Model (SM) is an effective quantum field theory which describes the fundamental particles and their interactions. It is based on the symmetry group $SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$, where $SU(3)_C$ describes strong force, $SU(2)_L$ describes weak force and $U(1)_Y$ is weak hypercharge. After spontaneous symmetry breaking, $U(1)_Y$ combines with $SU(2)_L$ to produce $U(1)_{EM}$ which describes the electromagnetic interaction. Based on their intrinsic angular momentum or spin, these particles can be broadly classified into two categories: fermions (half-integral spin) and bosons (integral spin).

The fermions are further divided into quarks (which carry a color charge) and leptons (which do not). The fermions are classified in three generations: each generation containing 2 types of distinct quark and lepton flavors. Each generation consists of an up-type quark (u, c, t), a down-type quark (d, s, b), a charged lepton (e, μ , τ) and its corresponding neutrino (ν_e , ν_μ , ν_τ). The particle content of the Standard Model is summarized in Fig. 1.1.

While the strong and electromagnetic interactions conserve particle flavor, the weak interaction mediated by $W^\pm$ bosons allows for flavor-changing processes. This happens because the quark states that participate in the weak interaction (weak eigenstates) are not the same as the quark states that have definite mass (mass eigenstates). The unitary transformation between these two bases is described by the Cabibbo-Kobayashi-Maskawa (CKM) matrix 1.1, which mathematically encodes flavor mixing in weak interactions.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} \quad (1.1)$$

The CKM matrix has 3 independent parameters: three mixing angles and one irreducible complex phase. Due to the presence of this complex phase, $V_{CKM} \neq V_{CKM}^*$, where V_{CKM} describes the weak interaction coupling for quarks and V_{CKM}^* for anti-quarks [5]. This leads to distinct transition amplitudes and hence is the source of CP violation in the quark sector.

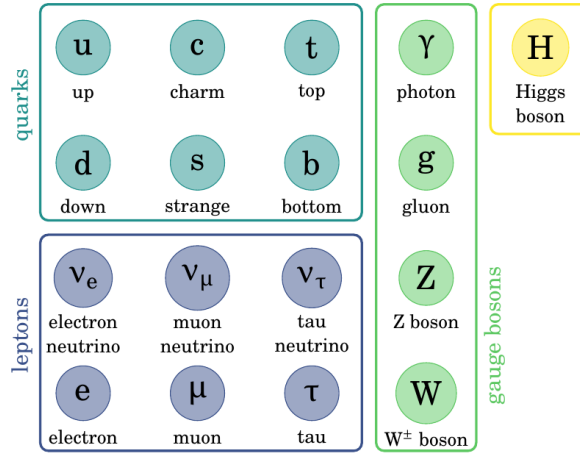


Figure 1.1: The elementary particles in the Standard Model of Particle Physics [6]

1.2 CP Violation

CP is a discrete symmetry corresponding to combined application of charge conjugation (C) and parity transformation (P), where C transforms the particle to its anti-particle, while P inverts the spatial coordinates of the particle $\vec{x} \rightarrow -\vec{x}$. For example, application of CP to a meson $M = q_1 \bar{q}_2$ results in a CP conjugate state $M = \bar{q}_1 q_2$ [7].

According to Sakharov conditions, CP Violation is one of the necessary conditions responsible for matter-antimatter asymmetry in the universe [1]. However, the amount of CP violation predicted by SM is not large enough. To account for this, there must be additional sources of CP violation beyond the SM. One of the experimental sensitive approaches is to probe Flavor-Changing Neutral Current (FCNC) processes. Because these processes are highly suppressed, virtual heavy particles can mediate in the loop. Hence, these processes are sensitive to NP.

1.3 $B \rightarrow K_s \eta \gamma$ decay mode

The decay mode proceeds via $b \rightarrow s \gamma$ flavor-changing neutral current process, which occurs dominantly through the one-loop diagram as shown in Fig. 1.2. This transition is suppressed at the tree level in SM due to Glashow-Iliopoulos-Maiani (GIM) mechanism [8]. The photon emitted in this decay is predominantly left-handed due to the chiral structure of the weak interaction in the SM. The decay $B^0 \rightarrow K_s \eta \gamma$ is of particular interest because TDCPV studies are directly sensitive to the photon polarization. Any deviations observed here could be indicative of NP contributions, such as those predicted in left-right symmetric models or supersymmetric extensions [9] [10].

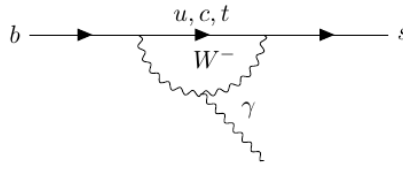


Figure 1.2: $B \rightarrow s \gamma$ decay

Reconstruction of $B \rightarrow K_s \eta \gamma$ presents challenges as it has multiple neutral particles in the final state. Due to the presence of charged particles in the final state, the reconstruction for $B \rightarrow K^+ \pi^- \gamma$ is highly efficient. Also, it has a significantly higher branching fraction, providing 100 times higher statistics. We study this channel to validate its use for extracting the data-MC correction parameters.

We use this control channel as it has the similar resolution as the signal decay mode for our variables of interest, i.e. M_{bc} , ΔE and CS . In Fig. 1.3, we can observe that both the channels exhibit comparable distributions.

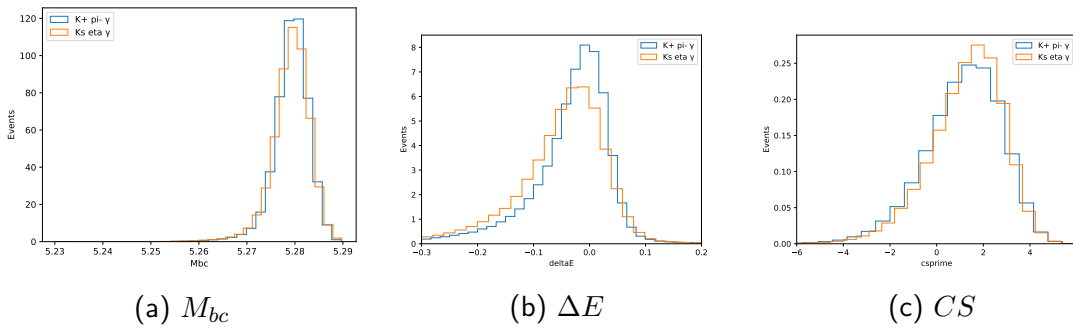


Figure 1.3: Observable comparisons in Belle II

Chapter 2

THE BELLE II EXPERIMENT

Every collider experiment has two major components, the accelerator and the detector. The accelerator here is the SuperKEKB, tuned to $10.58 \text{ GeV}/c^2$, which corresponds to the $\Upsilon(4S)$ resonance [11]. Since it is a lepton collider, it provides a clean environment with low background statistics and high precision measurements. The Belle II detector, located at the interaction point of decay of $\Upsilon(4S) \rightarrow B\bar{B}$ pairs, detects properties of the particles using various components as mentioned in section 2.2.

2.1 SuperKEKB Accelerator

SuperKEKB is an asymmetric collider located in Tsukuba, Japan. The SuperKEKB accelerator collides e^+e^- in an asymmetric fashion by circulating them in opposite directions with momentum around $7 \text{ GeV}/c$ for e^- and $4 \text{ GeV}/c$ for e^+ . This results in a COM energy of around $10.58 \text{ GeV}/c^2$ which corresponds to $\Upsilon(4S)$ resonance [11]. The $\Upsilon(4S)$ decays to B meson pairs ($B^0\bar{B}^0$, B^+B^-) which further decay through various modes. Due to its asymmetric nature, it produces a Lorentz boost to the e^+e^- system and they travel some distance before decaying. This enables precise measurements of parameters essential for TDCPV measurements. It is an upgraded version of the KEKB collider, targeting a peak luminosity 30 times higher than its predecessor. The diagram is given in Fig. 2.1.

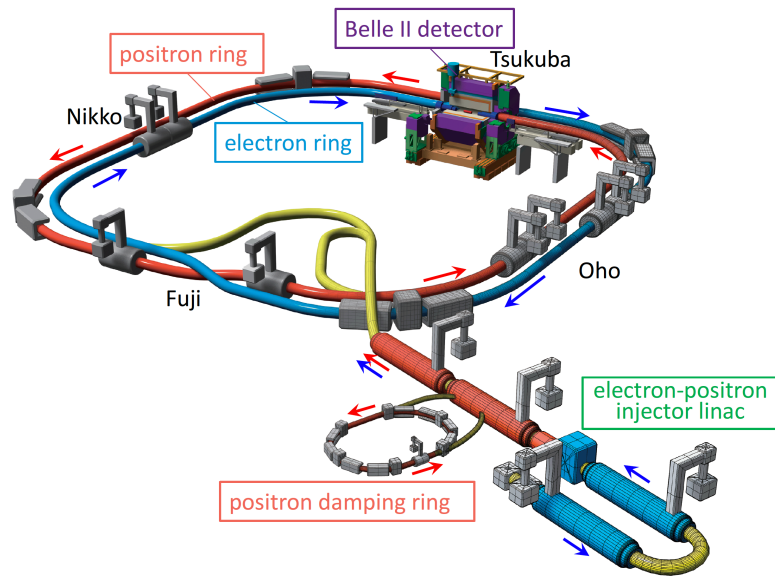


Figure 2.1: SuperKEKB Accelerator [12]

2.2 The Belle II Detector

The Belle II detector is a B-factory experiment at KEK, Japan, that collects data from the SuperKEKB accelerator [13]. It is located at the interaction point of electron and positron beams.

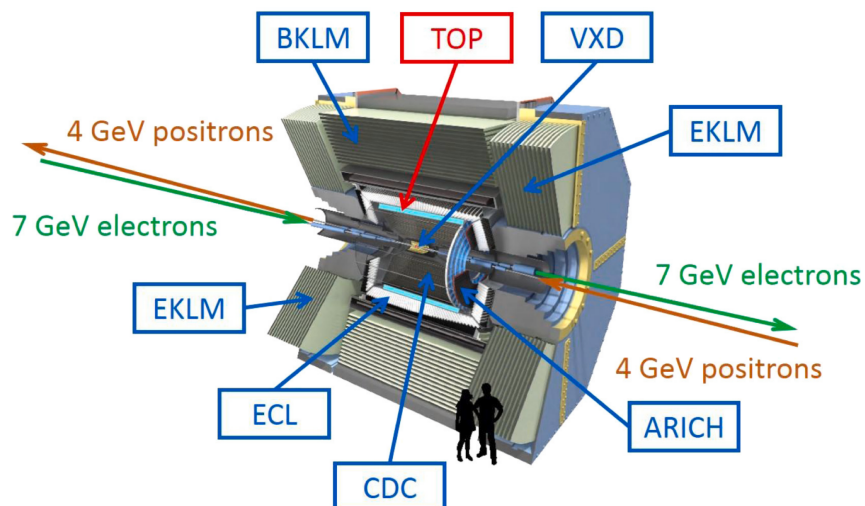


Figure 2.2: Belle II detector [14]

It has cylindrical symmetry with the following components [11][13]:

- **Beam Pipe:** Creates a separation between the detector and the interaction region. Absorbs soft x-rays emitted by beams to reduce the noise in the PXD.
- **Superconducting Solenoid:** Produces 1.5 T magnetic field.
- **PXD and SVD:** These "Vertex detectors" measure the decay vertex by precisely identifying the interaction point (IP).
- **CDC:** Central Drift Chamber measures the trajectory and momenta of charged particles.
- **TOP:** Time Of Propagation detector identifies particles using mass measurements made from momentum and velocity measurements by utilising Cherenkov effect produced in the quartz bars.
- **ARICH:** Aerogel Ring-Imaging Cherenkov detector is a particle identification subdetector in the forward region. It identifies particles by detecting the Cherenkov radiation produced in the aerogel.
- **ECL:** Electromagnetic Calorimeter measures electromagnetic energy of photons and electrons.
- **KLM:** KLong and Muon (KLM) system reconstructs K_L and provides muon identification.
- **TDAQ System:** Trigger and Data Acquisition (TDAQ) System selects the relevant collision events.

Chapter 3

ANALYSIS OF $B \rightarrow K^+ \pi^- \gamma$

We used 2 and 4 streams of MC each for Belle and Belle II. Each stream of MC corresponds to 790 fb^{-1} and 490 fb^{-1} of the $\Upsilon(4S)$ dataset for Belle and Belle II respectively. For Belle II, we also use signal MC sample of 1 million events. We first perform the analysis on MC and upon confirming our strategy works well in simulations, we apply it to the data collected by the experiment.

3.1 Event Selection and Reconstruction

The three-body decay of B meson is reconstructed from its decay products, namely K^+ , π^- and γ . Information from ECL, tracking systems and particle identification is used for this purpose [15]. We are interested only in the analysis of signal events, which are retained using the preselection cuts.

From the IP where e^+e^- collision takes place, the distance of the reconstructed tracks of K^+ and π^- from the beam axis (z) i.e., the distance of the closest approach (dz) must satisfy $|dz| < 2 \text{ cm}$. PID likelihood is also used to identify the charged particles. To discriminate between K and π , we use a PID based neural network. We apply the selection $\text{kaonIDNN} > 0.6$ to select $K^\pm$ and $\text{pionIDNN} > 0.6$ to select $\pi^\pm$ candidates.

The high-energy signal photon candidates are reconstructed from ECL clusters with energies $1.4 \text{ GeV} < E_\gamma^* < 3.4 \text{ GeV}$ ¹. To distinguish photons from the hadronic background, we utilize the ratio of the energy deposited on the inner 3x3 crystals to 5x5 crystals around the central crystal without corners denoted as E9/E21. For true photons, this value tends to 1 hence we apply the selection $\text{E9/E21} > 0.9$. Additionally, for Belle II, we require the photon hits ECL within 200 ns of beam crossing time.

The highest contribution for the decay mode is through $K^*(892)$ and we restrict our study to K^* resonance to enhance high signal purity. $K^*(892)$ is reconstructed by combining K^+ and π^- . To retain K^* candidates, we restrict the invariant mass of

¹The variables marked with * are calculated in the e^+e^- center of mass frame

the $K^+ - \pi^-$ system to be less than $1 \text{ GeV}/c^2$. The K^* is further combined with the prompt gamma to reconstruct B meson.

Selection cuts are applied on the kinematic variables ΔE and M_{bc} . They are defined as [15]:

$$M_{bc} = \sqrt{(E_{beam}^*)^2 - \vec{p}_B^{*2}}, \quad (3.1)$$

$$\Delta E = E_B^* - E_{beam}^* = E_B^* - \frac{\sqrt{s}}{2} \quad (3.2)$$

where $\vec{p}_B^*$ and E_B^* are the momentum and energy of the B meson, and E_{beam}^* is the beam energy. M_{bc} is the beam constrained mass and ΔE is the difference between the correctly reconstructed B meson and energy of the beam.

The beam energy is tuned to the $\Upsilon(4S)$ resonance which decays to pairs of B mesons. For correctly reconstructed B meson, $\Delta E \approx 0 \text{ GeV}$ and $M_{bc} \approx 5.279 \text{ GeV}/c^2$ (mass of B^0 meson) [16]. Hence, we perform analysis in the fit region $-0.3 \text{ GeV} < \Delta E < 0.2 \text{ GeV}$ and $5.24 \text{ GeV}/c^2 < M_{bc} < 5.29 \text{ GeV}/c^2$.

3.2 Backgrounds

Events surviving the preselection criteria other than signal events are called backgrounds. Broadly can be classified into 2 types:

1. Combinatorial Background, which are $B\bar{B}$ events that are not the signal decay mode.
2. Continuum Background, which are non-resonant hadronic events ($e^+e^- \rightarrow q\bar{q}$, where $q = u, d, s, c$).

3.3 Continuum Suppression

Events $e^+e^- \rightarrow q\bar{q}$ that do not produce $\Upsilon(4S)$ resonance constitute the continuum background [11]. This is the most dominant background left after reconstruction. While the B meson pair is produced almost at rest in the center of mass frame and exhibits spherical topology, continuum events exhibit jet-like topology. This is due to the fact that the masses of up, down, strange and charm quarks is significantly smaller than half the beam energy. We use this information to discriminate between the signal and the continuum.

3.3.1 Multivariate Analysis

A pre-trained XGBoost classifier, trained on topological variables, is used to separate the signal from the continuum background. An MVA score (CS_{MVA}) between 0 and 1

is assigned to each event, with a value of 1 (0) indicating the true signal (background) candidate.

We use the logarithmic transformation of CS_{MVA} , CS , as our variable of interest which is given by the formula

$$CS = \log \left(\frac{CS_{MVA} - 0.6}{1 - CS_{MVA}} \right) \quad (3.3)$$

We apply the selection $CS_{MVA} > 0.6$ to retain the signal events.

3.3.2 π^0/η veto

The decays $\pi^0 \rightarrow \gamma\gamma$ and $\eta \rightarrow \gamma\gamma$ also constitute a major background. The photons from these decays are rejected by applying π^0/η veto to select the candidates with a higher probability of coming from the B meson decay. In case of Belle, we apply $\text{pi0veto} < 0.5$, while for Belle II, we apply $\text{pi0veto} < 0.9$ and $\text{etaveto} < 0.75$.

The tables below provide a summary of the selection criteria used.

Particle	Selection criteria
K^+	• $ dz < 2$ cm, $\text{PID}_K > 0.8$
π^-	• $ dz < 2$ cm, $\text{PID}_\pi > 0.8$
γ	• $E_{\text{CMS}} \in [1.4, 3.4]$ GeV, $\text{clusterE9E21} > 0.9$ • $\text{pi0veto} < 0.5$
B	• $M_{bc} \in [5.24, 5.29]$ GeV/ c^2 , $\Delta E \in [-0.3, 0.2]$ GeV • $0.8 < \text{InvM}_{K^+-\pi^-} < 1$ GeV/ c^2 . • $\text{B_chiProb} > 0$, $\text{TagVpVal} > 0$, $\text{TagVNDF} > 0.5$ • $CS_{MVA} > 0.6$

Table 3.1: Preselection criteria for Belle

Particle	Selection criteria
K^+	• $ dz < 2$ cm, $\text{kaonIDNN} > 0.8$
π^-	• $ dz < 2$ cm, $\text{pionIDNN} > 0.8$
γ	• $\text{abs}(\text{clusterTiming}) < 200$ ns • $E_{\text{CMS}} \in [1.4, 3.4]$ GeV, $\text{clusterE9E21} > 0.9$ • $\text{pi0veto} < 0.9$, $\text{etaveto} < 0.75$
B	• $M_{bc} \in [5.24, 5.29]$ GeV/ c^2 , $\Delta E \in [-0.3, 0.2]$ GeV • $\text{InvM}_{K^+-\pi^-} < 1.8$ GeV/ c^2 . • $\text{B_chiProb} > 0$, $\text{TagVpVal} > 0$, $\text{TagVNDF} > 0.5$ • $CS_{MVA} > 0.6$

Table 3.2: Preselection criteria for Belle II

Chapter 4

RESULT AND CONCLUSION

4.1 Fit Modelling

The signal and two background components (continuum and $B\bar{B}$) are modelled using the similar models used in the analysis of $B \rightarrow K_s \eta \gamma$. First, the fit is performed on MC and then applied to data where several parameters of signal modeling are floated to obtain the data-Monte Carlo correction parameters. The variables of interest here are M_{bc} , ΔE and CS . These fit regions for the variables are summarised in Table 4.1.

Variable	Fit Region
M_{bc}	[5.23, 5.29] GeV/ c^2
ΔE	[-0.3, 0.2] GeV
CS	[-6, 6]

Table 4.1: Fit Region

4.1.1 Signal Modelling

The M_{bc} and ΔE PDFs are modelled using CrystalBall PDF defined as

$$f(x; \mu, \sigma, \alpha, n) = N \times \begin{cases} \exp\left(-\frac{t^2}{2}\right), & \text{for } t > -\alpha, \\ A(B - t)^{-n}, & \text{for } t \leq -\alpha, \end{cases} \quad (4.1)$$

where,

$$t = \frac{x - \mu}{\sigma}$$

$$A = \left(\frac{n}{|\alpha|}\right)^n \exp\left(-\frac{\alpha^2}{2}\right)$$

$$B = \frac{n}{|\alpha|} - |\alpha|$$

The CS PDF is modelled using Gaussian + Exponential PDF defined as

$$f(x; \mu, \sigma, \tau) = \frac{1}{2\tau} \exp\left(\frac{\sigma^2}{2\tau^2} - \frac{x - \mu}{\tau}\right) \operatorname{erfc}\left(\frac{1}{\sqrt{2}} \left(\frac{\sigma}{\tau} - \frac{x - \mu}{\sigma}\right)\right), \quad (4.2)$$

The fits are given in the Fig. 4.1 and Fig. 4.2.

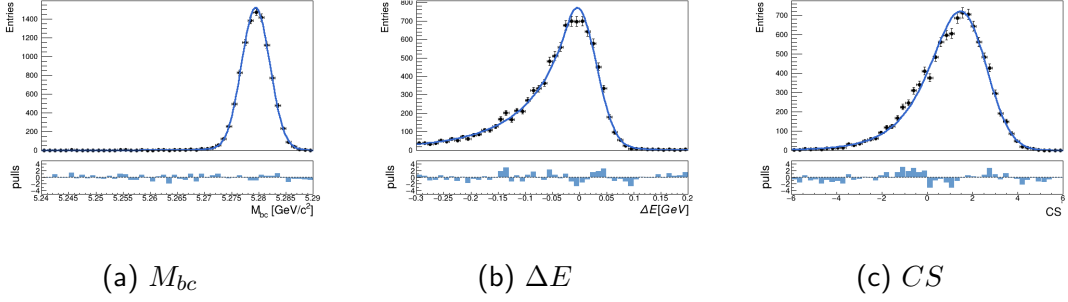


Figure 4.1: Signal fit in Belle

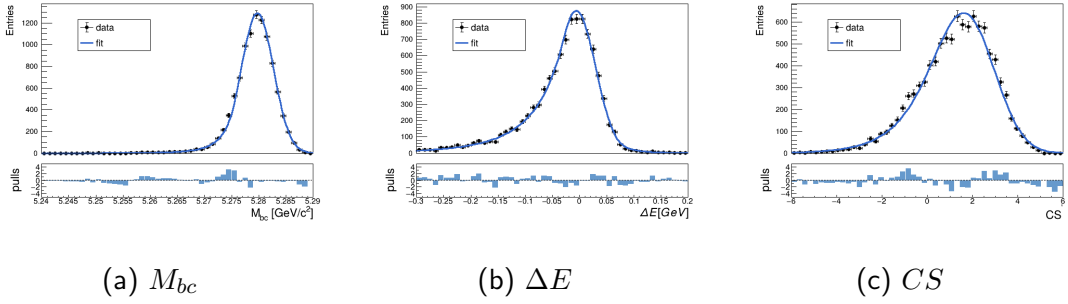


Figure 4.2: Signal fit in Belle II

4.1.2 Continuum Modelling

The M_{bc} is modelled using Argus PDF defined as:

$$f(x; x_m, c) = N x \sqrt{1 - \left(\frac{x}{x_m}\right)^2} \exp\left[c \left(1 - \left(\frac{x}{x_m}\right)^2\right)\right], \quad x \leq x_m \quad (4.3)$$

ΔE is modelled using first order Chebyshev polynomial PDF defined as:

$$f(x) = N (1 + a_1 x) \quad (4.4)$$

The CS PDF is modelled using Gaussian + Exponential PDF as defined in Eq. 4.2. The fits are given in the Fig. 4.3 and Fig. 4.4.

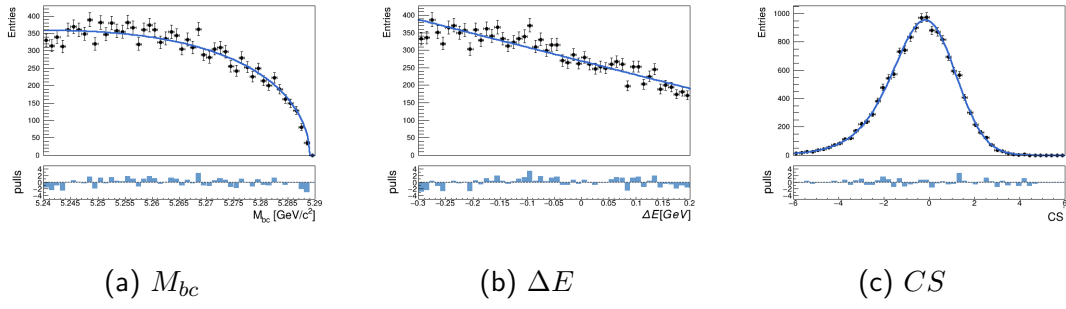


Figure 4.3: Continuum fit in Belle

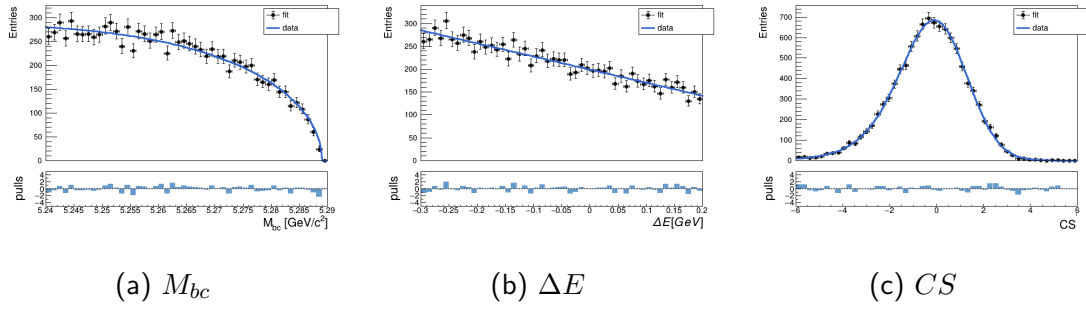


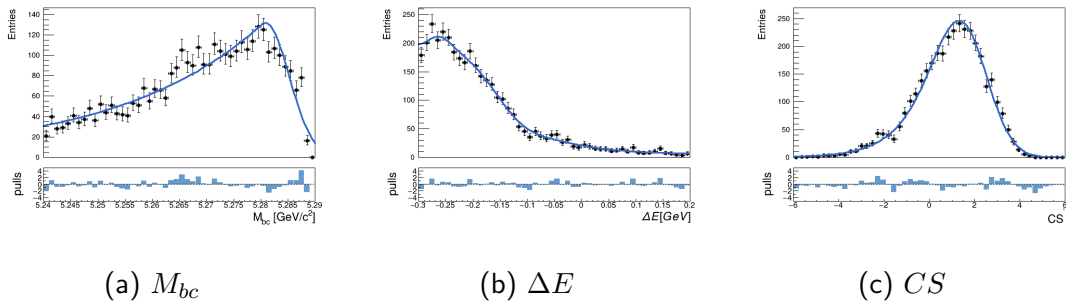
Figure 4.4: Continuum fit in Belle II

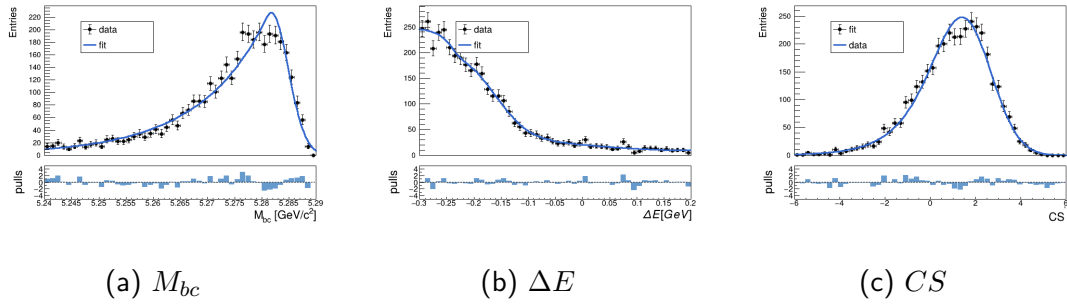
4.1.3 $B\bar{B}$ Modelling

The M_{bc} PDF is modelled using Crystalball PDF as defined in Eq. 4.1. For ΔE distribution, a Kernel Density Estimation (KDE) is used.

The CS PDF is modelled using Gaussian + Exponential PDF as defined in Eq. 4.2.

The fits are given in the Fig. 4.5 Fig. 4.6.

Figure 4.5: $B\bar{B}$ fit in Belle

Figure 4.6: $B\bar{B}$ fit in Belle II

4.1.4 Combined Fit

The combined fit model is the sum of respective component PDFs weighted by the respective yields in dataset. The PDFs used are summarised in 4.2.

Figure 4.7 and 4.8 give the fits for MC and data in Belle. Figure 4.9 and 4.10 give the fits for MC and data in Belle II. For data fit, several parameters of signal PDF are floated to obtain the data-MC correction parameters. The data-MC correction factors obtained are close to nominal values. These are summarised in Tables 4.3 and 4.4.

Component	PDF Shape ($M_{bc} \times \Delta E \times CS$)
Signal	CrystalBall $\times$ CrystalBall $\times$ (Gaussian + Exponential)
Continuum	Argus $\times$ Chebychev Poly $\times$ (Gaussian + Exponential)
BBbar background	CrystalBall $\times$ Kernel Density Estimation $\times$ (Gaussian + Exponential)

Table 4.2: Models of PDF shape in Belle and Belle II

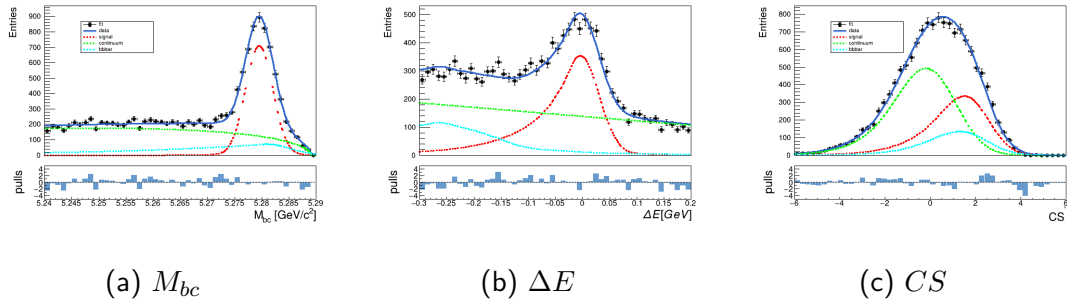


Figure 4.7: MC fit in Belle

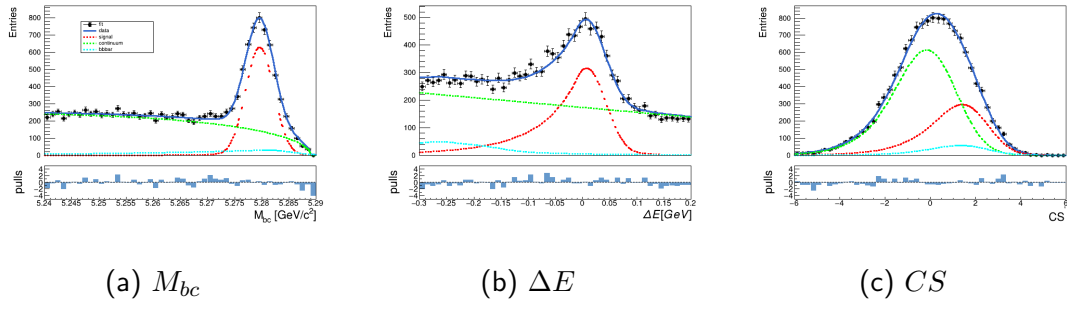


Figure 4.8: Data fit in Belle

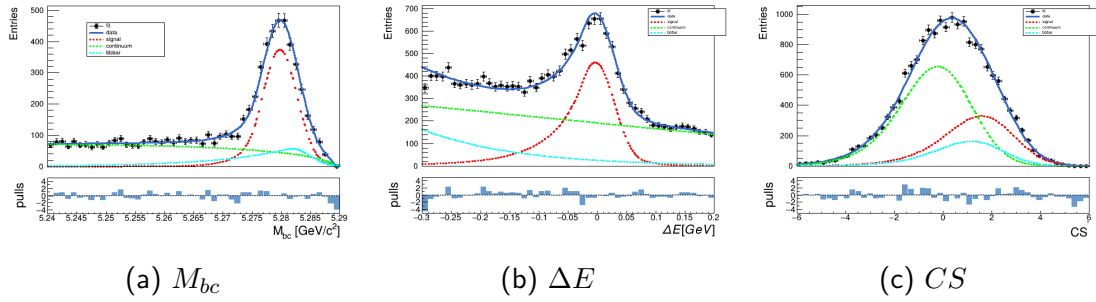


Figure 4.9: MC fit in Belle II

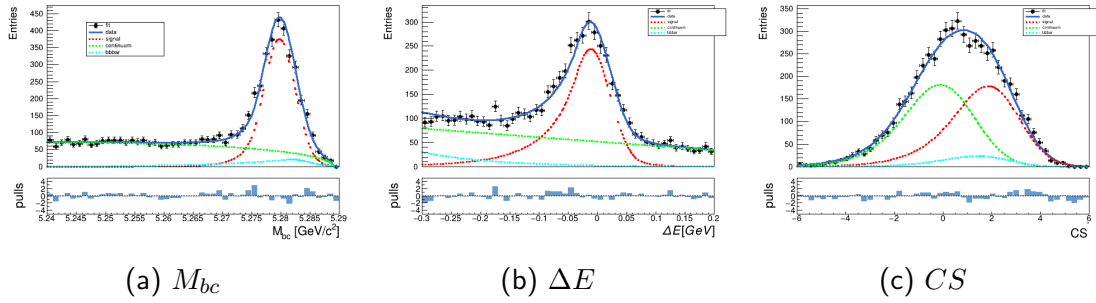


Figure 4.10: Data fit in Belle II

Parameter	Value
$\sigma_{sig}^{M_{bc}}$ scale	0.97 ± 0.01
$\mu_{sig}^{M_{bc}}$ fudge (GeV/c^2)	$(21.55 \pm 4.95) \times 10^{-5}$
$\sigma_{sig}^{\Delta E}$ scale	1.01 ± 0.02
$\mu_{sig}^{\Delta E}$ fudge (GeV/c)	0.01 ± 0.001
σ_{sig}^{CS} scale	0.97 ± 0.02
μ_{sig}^{CS} fudge	-0.08 ± 0.02

Table 4.3: Data-MC correction parameters for Belle

Parameter	Value
σ_{sig}^{Mbc} scale	0.91 ± 0.01
μ_{sig}^{Mbc} fudge (GeV/c^2)	$(3.64 \pm 6.52) \times 10^{-5}$
$\sigma_{sig}^{\Delta E}$ scale	0.95 ± 0.02
$\mu_{sig}^{\Delta E}$ fudge (GeV/c)	-0.005 ± 0.001
σ_{sig}^{CS} scale	0.93 ± 0.02
μ_{sig}^{CS} fudge	0.22 ± 0.03

Table 4.4: Data-MC correction parameters for Belle II

4.2 Conclusion

In this report, we have studied the control channel $B^0 \rightarrow K^+\pi^-\gamma$ for the TDCPV analysis of the decay $B^0 \rightarrow K_s\eta\gamma$ using the data collected at $\Upsilon(4S)$ resonance with the Belle and Belle II detectors. The data corresponds to an integrated luminosity of around 710 (490) fb^{-1} for Belle (Belle II).

These radiative penguin decays are a sensitive probe for NP due to the polarised photon in the final state and the measurement of TDCPV parameters helps constrain the values of the CKM matrix elements. Precise measurements of such rare processes are important for testing the SM.

Since the signal decay mode has multiple neutral particles in the final state and a lower branching fraction, the reconstruction efficiency is comparatively low. Hence, we use a control channel which has similar distributions for the variables of interest, i.e. M_{bc} , ΔE and CS , and a significantly higher branching fraction, providing significantly higher statistics.

We use similar preselection cuts for reconstruction and modelling PDFs for signal and background components as used for $B \rightarrow K_s\eta\gamma$. We first perform the analysis on MC simulation and then apply it to data to obtain the data-MC correction parameters. The data-MC correction obtained will be applied to the signal PDF for the TDCPV analysis of $B^0 \rightarrow K_s\eta\gamma$.

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