Chapter 1

Experimental Setup

The data used in this analysis were produced in e^+e^- collisions at the KEKB accelerator and collected with the Belle detector. The experiment was hosted at the High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan. The experiment ran from years 1999 to 2010, collecting data at and near the energy of the $\Upsilon(4S)$ resonance. This chapter briefly describes the accelerator and the detector. The descriptions are based on detailed reports from [X] and [X].

1.1 KEKB Accelerator

KEKB is an asymmetric e^+e^- collider, composed roughly of an electron source and a positron target, a linear accelerator (Linac) and two separate main rings with a circumference of about 3 km as shown in Figure X. Electrons are first produced by a thermal electron gun and accelerated in the Linac to an energy of about 8 GeV. Part of the electrons collide with a tungsten target to produce positrons, which are accelerated in the Linac to an energy of about 3.5 GeV. Electron and positron beams are injected into the high- (HER) and low energy ring (LER) where they collide at a single interaction point (IP) at an angle of about 22 mrad. The combined centre-of-mass (CM) energy of the collision corresponds to the mass of the $\Upsilon(4S)$ resonance

$$E_{CM} = 2\sqrt{E_{e^+} E_{e^-}} = m_{\Upsilon(4S)}c^2 \approx 10.58 \text{ GeV}. \tag{1.1}$$

PLOT

The $\Upsilon(4S)$ state is produced only in a fraction of all collisions, but when it is produced, it predominantly decays to a pair of charged or neutral B mesons. This setup was chosen in accordance with the main goal of the experiment, which was to study CP violation in the B meson system. In other cases the collisions of e^+e^- result in Bhabha scattering, two-photon events, muon or tau lepton pair production, and quark pair production of $q\bar{q}$, where $q = u$, d, s or c. Table X shows the cross-sections for all mentioned interactions

₂₆ in collisions of e^+e^-. In addition to the nominal CM energy, the experiment collected
₂₇ data also at energies corresponding to other $\Upsilon(nS)$ resonances, where $n = 1, 2, 3, 5$,
₂₈ and also at energies below the resonances.

₂₉

Interaction	Cross-section [nb]
$\Upsilon(4S) \to B\bar{B}$	1.2
$q\bar{q}, \ q \in [u, d, s, c]$	2.8
$\mu^+\mu^-, \ \tau^+\tau^-$	1.6
Bhabha scattering (within detector acceptance)	44
Other QED processes (within detector acceptance)	~ 17
Total	~ 67

₃₀ KEKB achieved the world-record for the peak luminosity of 2.11×10^{34} cm^{-2}s^{-1}, twice
₃₁ as much as the designed prediction, and the total integrated luminosity of 1041 fb^{-1}.
₃₂ Of the full Belle dataset, about 711 fb^{-1} of data were taken at the $\Upsilon(4S)$ energy of
₃₃ 10.58 GeV, which corresponds to about 771×10^6 $B\bar{B}$ meson pairs.

₃₄ 1.2 Belle Detector

₃₅ The Belle detector is a magnetic mass spectrometer which covers a large solid angle. It is
₃₆ designed to detect remnants of e^+e^- collisions. The detector is configured around a 1.5 T
₃₇ superconducting solenoid and iron structure surrounding the interaction point (IP). The
₃₈ 4-momentum of the decaying B mesons and it's decayed daughter particles are deter-
₃₉ mined via a series of sub-detector systems, which are installed in an onion-like shape.
₄₀ Short-lived particle vertices are measured by a silicon vertex detector (SVD) situated
₄₁ outside of a cylindrical beryllium beam pipe. Long-lived charged particle momentum
₄₂ is measured via tracking, which is performed by a wire drift chamber (CDC). Parti-
₄₃ cle identification is provided by energy-loss measurements in CDC, aerogel Cherenkov
₄₄ counters (ACC) and time-of-flight counters (TOF) situated radially outside of CDC. Par-
₄₅ ticles producing electromagnetic showers deposit energy in an array of CsI(Tl) crystals,
₄₆ known as the electromagnetic calorimeter (ECL), which is located inside the solenoid
₄₇ coil. Muons and K_L mesons (KLM) are identified by arrays of resistive plate counters
₄₈ in the iron yoke.

₄₉ The coordinate system of the Belle detector originates at the IP, with the z axis pointing
₅₀ in the opposite direction of the positron beam, the x axis pointing horizontally outside
₅₁ of the ring, and the y axis perpendicular to the aforementioned ones. The polar angle θ
₅₂ covers the region between $17° \leq \theta \leq 150°$, while the cylindrical angle φ covers the full
₅₃ range $0° \leq \varphi \leq 360°$, amounting to a 91 % coverage of the full solid angle.

1.2.1 Interaction region

1.2.2 Extreme forward calorimeter (EFC)

1.2.3 Silicon vertex detector (SVD)

1.2.4 Central tracking chamber (CDC)

1.2.5 Aerogel Cherenkov counter system (ACC)

1.2.6 Time-of-flight counters (TOF)

1.2.7 Electromagnetic calorimetry (ECL)

1.2.8 KL and muon detection system (KLM)

1.2.9 Detector solenoid and iron structure

1.2.10 Trigger

1.2.11 Data acquisition

1.2.12 Offline computing system