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Belle II Experiment: Status and Upgrade

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Abstract The Belle II experiment at the asymmetric e^+ e^- SuperKEKB collider will start its operation in 2018 and will collect the data of the integrated luminosity of $50ab^{-1}$. This high luminosity will shed light on new physics beyond the Standard Model via high precision measurements of heavy flavor decays and searches for rare signal events. In this work, we present the status of the SuperKEKB and the Belle II detector construction. The expected sensitivity to new physics of the Belle II data set will also be discussed.

Keywords Belle II · SuperKEKB · CP Violation · Lepton Flavor Violation · Rare B Decays

1 Introduction

The two first generation B factories using e^+ e^- asymmetric colliders are the Belle experiment [1] at the KEKB collider in KEK [2] and the BaBar experiment [3] at the PEP-II collider in SLAC. Together, the Belle and Babar experiments have collected a total data sample of over 1.5 ab^{-1} at the center of mass energy of the $\Upsilon(4S)$. These two experiments have achieved many important results, including experimental evidence of the CKM mechanism as the source of CP violation (CPV) in the Standard Model (SM), which confirms the structure of the quark flavor sector proposed by N. Cabibbo, M. Kobayashi and T. Maskawa [4][5]. However, there is still room for contributions from new physics, for example, flavor-changing neutral currents (FCNC),

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lepton flavor violation (LFV), and new sources of CPV, which requires a large statistics in the experiment. For this, upgrade of both the KEKB and the Belle detector to the SuperKEKB collider [6] and the Belle II detector [7] are in progress, where currently 750 international collaborators from 23 countries are involved in various upgrade activities, for example, detector, electronics, software, computing, Monte Carlo (MC) simulations and physics programs. The designed luminosity of the SuperKEKB is $8\times10^{35}\text{cm}^{-2}\text{s}^{-1}$, which is 40 times higher than that of KEKB. The expected integrated luminosity of the Belle II is 50ab^{-1}, which is 50 times higher than that of the Belle. This high luminosity will help us to discover the new physics beyond SM via high precision measurements of heavy flavor decays and searches for rare signal events. The upgrade to the SuperKEKB collider has been completed and testing of the collider is going on. The detector, electronics, software, and computing systems are all being substantially upgraded. In the following sections, status on the Belle II detector and the SuperKEKB construction will be discussed. In addition, important highlights on the physics program at Belle II will also be discussed.

2 Experimental Facility

2.1 SuperKEKB

In order to achieve the designed luminosity of SuperKEKB, a new scheme based on the nano-beam is proposed by P. Raimondi from Frascati [8]. The reduced beam size is achieved by decreasing the beam vertical beta function at the interaction point by 1/20 as compared to KEKB and by increasing the beam current by a factor of 2, while keeping the same beam parameters. The luminosity of this rate will also result in much higher background rates, leading to greater detector occupancy and radiation damage. To cope up with

Table 1 Important Beam Parameters for KEKB and SuperKEKB.

S. No.	Parameters	KEKB	SuperKEKB
1	Beam energy (GeV)	3.5/8.0	4.0/7.0
2	Crossing angle (mrad)	22	83
3	Vertical beta functions at IP (mm)	5.9/5.9	0.27/0.30
4	Beam currents (A)	1.6/1.2	3.6/2.6
5	Luminosity ($\text{cm}^{-2}\text{s}^{-1}$)	2.1×10^{34}	8×10^{35}

this higher event rate, the data acquisition system (DAQ) and computing resources have also been upgraded at KEK. The detailed design parameters of existing KEKB and SuperKEKB are compared and listed in the Table 1.

2.2 Belle II Detector

To handle the high luminosity condition of SuperKEKB, the upgrade of detector system and its electronics are in progress. The most challenging experimental requirement is the detection of the decay point of the short-living B-mesons, relying on a high-performance vertex detector. Therefore, the first sub-detector is placed very close to the interaction point and surrounding the beam-pipe are the upgraded silicon vertex detectors, including two pixel layers (PXD) based on DEPFET sensors and four layers of double-sided silicon vertex detector (SVD). Next detector system is a large central drift chamber (CDC) which will provide tracking with precise momentum measurements as well as clear particle identification (PID) through the measurement of ionization energy loss. The CDC is surrounded by the upgraded barrel PID system, which consists of an imaging time-of-propagation counter (TOP). A focusing aerogel

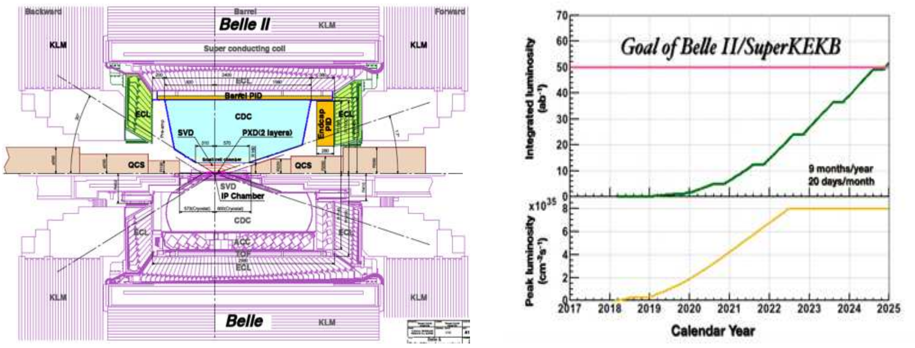

Fig. 1 A schematic view of the Belle II detector [9] (left) and SuperKEKB Luminosity Projection (right).

ring imaging Cherenkov detector (ARICH) provides PID measurements in the endcap region. The electromagnetic calorimeter (ECL) has been equipped with upgraded electronics to suppress the much higher beam-related backgrounds expected at SuperKEKB. The barrel region of the K_L and muon detector (KLM) consists of resistive plate chambers. The innermost layers of the barrel region is made up of plastic scintillators to cope with the high neutron flux both from the interaction point and from the beam line. A schematic view of the Belle II detector and its comparison with Belle is shown in Figure 1 (left).

3 Physics at Belle II

The large integrated luminosity of SuperKEKB will provide the precise measurement of the CKM Unitarity Triangle (UT) parameters [10]. As we know lepton flavor violation (LFV) decays are highly suppressed in SM, in a branching fraction of 10^{-25}. The large statistics of Belle II will improve the sensitivity for LFV decays and hence the precision measurement of the branching fraction (NP predicted 10^{-8}) [11] will be achieved. In addition, the physics program at Belle II will also include the investigation of rare B decays, charm physics, dark sector and spectroscopy.

4 Status and Schedule

The operation schedule of Belle II at SuperKEKB is divided into following three phases:

1. Phase 1 (2016): Simple commissioning detector "BEAST" was used.
2. Phase 2 (2018): First data taking (without vertex detector) will start in 2018.
3. Phase 3 (2018 - 2024): Full physics program will start using the complete detector system from 2018 to 2024.

An overview of the projected luminosity of SuperKEKB is shown in Figure 1 (right).

5 Summary

At the SuperKEKB collider, e^+ and e^- collisions will reach the unprecedented instantaneous luminosity of 8×10^{35} cm^{-2} s^{-1}. The upgraded Belle II detector will face the higher level of backgrounds with improved tracking and particle identification. The collider commissioning has started in 2016 (phase 1) with first collision expected in February 2018 (phase 2, without the vertex detector) and full physics program at the end of 2018 (phase 3, the full detector). The full dataset of 50 ab^{-1} will be collected between the years from 2018 to 2024. The physics program will include the new sources of CP violation, rare B decays, LFV, charm physics, dark sector and spectroscopy

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