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Belle II status and prospects

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Summary. — This paper is intended to describe the Belle II experiment, its status and physics prospects. Belle II is situated in Japan, at the KEK Laboratory and it is the upgraded version of the Belle experiment. It uses a new collider named SuperKEKB, a new generation of B-factory based on the innovative Nano-Beam scheme technique, which is expected to collect an integrated luminosity of 50 ab^{-1}. Using this huge amount of data, together with improved detector performances, it will be possible to provide important contributions about several flavour physics topics (*i.e.*, UT angles, CKM matrix elements, FCNC processes, LFV studies, etc.) through high-precision measurements, in order to investigate new physics scenarios and validate highly suppressed SM predictions. The experiment took the first data without the vertex detector in place while the data taking will start in February 2019.

1. – Introduction

Heavy flavour physics has a crucial role in the understanding of the Standard Model (SM) and its mechanisms. In the past, other experiments at B-factories investigated deeply this field (BaBar using PEP II and Belle using KEKB) producing important discoveries concerning the B-meson physics. Belle II is an international Collaboration, composed of more than 700 researchers from 25 countries and it takes advantage of the largest Japanese laboratory for particle physics KEK, in Tsukuba. There, the new SuperKEKB collider has been made together with an improved detector system, with respect to its predecessor Belle, in order to collect data up to a total integrated luminosity of $50\,\text{ab}^{-1}$ and to take under control the increased background coming from the higher instant luminosity $\mathcal{L}_{max} = 8 \cdot 10^{35}\,\text{cm}^{-2}\,\text{s}^{-1}$ (fig. 1).

The Belle II experiment successfully completed Phase 1 in 2016 (commissioning of SuperKEKB) and some physics data have been already collected with a partial detector installed (Phase 2, ended in July 2018) which will provide first physics results, mainly in the dark sector field. The data taking (Phase 3) will start in February 2019 and will end in 2025, when the whole statistic will be used to investigate some highly suppressed processes that will be introduced later [1].

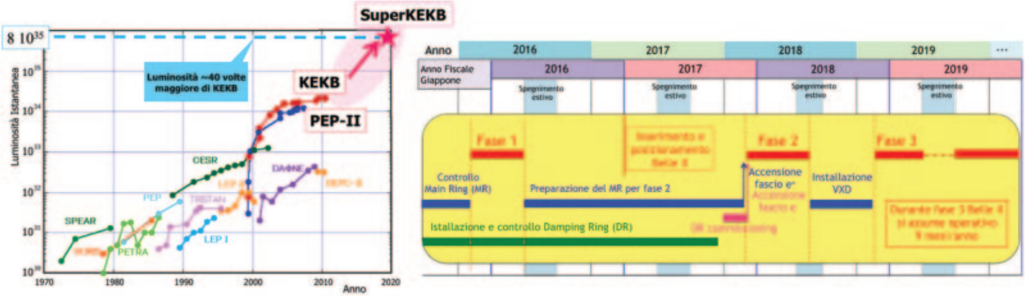

Fig. 1. – Luminosity comparison between SuperKEKB and colliders of the past (left) and status of the experiment (right).

2. – Collider and detector

In SuperKEKB, asymmetric beams of e^+ (4 GeV) and e^- (7 GeV) collide at the $\Upsilon(4S)$ resonance which predominantly decays into $B\bar{B}$ couples (fig. 2). In order to increase the statistics collected by the experiment, SuperKEKB uses an innovative technique named Nano-Beam scheme which allows to reach a 40 times higher luminosity with respect to KEKB. The luminosity of the machine depends on the following quantities:

$$\mathcal{L} \propto \frac{I_{\pm}\xi_{y\pm}}{\beta_{y\pm}}, \tag{1}$$

where the $\pm$ signs distinguish the positron $(+)$ from the electron $(-)$ while $I_{\pm}$ is the total beam current (increased by a factor $\sim$2), $\xi_{y\pm}$ is the vertical beam-beam parameter (slightly increased) and $\beta^*_{y\pm}$ is the vertical beta function at the IP (decreased by a factor $\sim$20). The Nano-Beam scheme allows to squeeze the beams at the interaction point up to $\sim$50 nm along y and $\sim$5 μm along x as shown in fig. 2. As a consequence, the machine background increased, thus, in order to compensate this effect, the Belle II detector has to be improved. The detector, starting from the interaction point, is made of the vertex detector (VXD), composed by 2 layers of the completely new PiXel vertex Detector

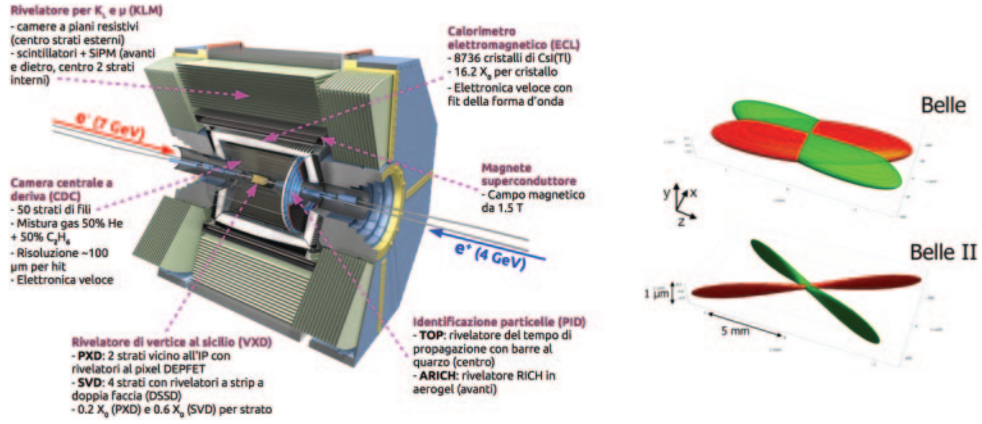

Fig. 2. – Schematic view of the Belle II detector (left) and the Nano-Beam scheme (right).

(PXD) and 4 layers of the fast Silicon-strip Vertex Detector (SVD); Central Drift Chamber (CDC) with improved resolution (smaller cell size); particles identification system made of the Time-Of-Propagation (TOP) counter in the barrel and the Aerogel Ring Imaging Cherenkov (ARICH) detector in the forward end-cap region; Electromagnetic Calorimeter (ECL), substantially the same as the one used for the Belle detector, with a faster read-out electronics; K_L and μ detector (KLM) modified by substituting all the Resistive Plate Chamber (RPC) layers with scintillators in the end-caps and the first 2 layers in the barrel region [2].

3. – Physics contributions

As a B-factory, the experiment aims to investigate with high precision several heavy flavour physics fields [1]. Part of the Belle II physics program can be summarized as follows:

- Unitarity Triangle (UT) angles and CKM matrix elements: CP-violating measurements (time dependent and time integrated) allow to discover new possible CP-violating phases that indicate the existence of SM extensions.
- Flavour Changing Neutral Current (FCNC): penguin processes described by quark transitions like $b \to s$ and mixing processes of neutral meson states allow to search for New Physics (NP) in loops.
- Leptonic decays and Lepton Flavour Violation (LFV): study of τ and leptonic B decays in order to probe NP scenarios which take into account NP models, *i.e.*, extended Higgs sector or right-handed neutrino couplings. This can be achieved thanks to the clean environment of Belle II which provides great advantages in decays with missing energy.
- Dark sector: search for dark-matter candidates, *i.e.*, dark photon. Belle II will use a dedicated single-photon trigger in order to be able to reconstruct its decay into an invisible final state (the signature is the presence of a single photon and missing energy). Some results can be obtained before the beginning of Phase 3.
- Hadronic spectroscopy and quarkonium: a different center-of-mass energy of the collider is needed in order to produce resonances like $\Upsilon(3S)$, $\Upsilon(5S)$ and $\Upsilon(6S)$ allowing to study several intermediate bounded states and their properties.

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