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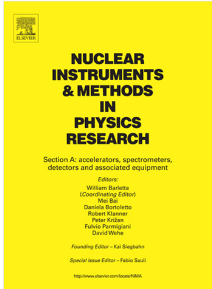

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Detectors for extreme luminosity: Belle II

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Abstract

We describe the Belle II detector at the SuperKEKB electron-positron accelerator. SuperKEKB operates at the energy of the $\Upsilon(4S)$ resonance where pairs of B mesons are produced in a coherent quantum mechanical state with no additional particles. Belle II, the first Super B factory detector, aims to achieve performance comparable to the original Belle and BaBar B factory experiments, which first measured the large CP violating effects in the B meson system, with much higher luminosity collisions and larger beam-induced backgrounds.

1. Introduction

The B factory experiments, Belle and BaBar, discovered large CP violating effects in the B meson sector and provided experimental confirmation of the Kobayashi-Maskawa hypothesis: a single complex phase can explain all the CP violating effects in the weak interaction. This was recognized by the 2008 Nobel Prize in Physics. The emphasis in particle physics has now shifted to the possibility that there may be New Physics that appears in flavor physics. There is a broad range of possibilities including new CP violating (matter-antimatter) asymmetries, unexpected rare decays, and violations of lepton flavor universality in B meson decays or τ lepton decays. The tool for the next round of discoveries at the next generation electron-positron (super) B-factory SuperKEKB [1] will be the Belle II detector (Fig. 1).

While the new detector clearly fits in the same envelope as its predecessor, the superconducting solenoid magnet with its iron return yoke, all components are either new or considerably upgraded [2]. The CsI(Tl) crystals are re-used although their readout electronics were upgraded.

Compared to Belle, the Belle II detector will be taking data at an accelerator with 40 times higher luminosity, and thus has to be able to operate at 40 times higher physics event rates, as well as with background rates higher by a factor of 10 to 20 [2]. To maintain the excellent performance of the spectrometer, the critical issue will be to mitigate the effects of higher background levels, which lead to an increase in occupancy levels and radiation damage, as well as to fake hits and pile-up noise in the electromagnetic calorimeter, and to neutron induced hits in the muon detection system. Higher event rates also require substantial modifications of the trigger scheme, data acquisition system and computing. In addition, improved hadron identification is needed, and a hermeticity at least as good as in the original Belle detector is required.

The requirements for a B factory detector can be summarized as follows. The apparatus should meet the following criteria:

– Excellent vertex resolution ($\approx 100\ \mu$m);
– Very high reconstruction efficiencies for charged particles and photons, down to momenta of a few tens of MeV/c;
– Very good momentum resolution over the entire kinematic range of the experiment, i.e. up to ≈ 7 GeV/c;
– Precise measurements of photon energy and direction from a few tens of MeV to ≈ 7 GeV;
– A highly efficient particle identification system to separate pions from kaons, and to identify both electrons and muons over the full kinematic range of the experiment;
– Coverage of (nearly) the full solid angle;
– A fast and efficient trigger system,
– A data acquisition system capable of storing and recording large quantities of data, and,

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