Chapter 1

Physics motivations and requirements

LHCb is an experiment dedicated to heavy flavour physics at the LHC [1, 2]. Its primary goal is to look for indirect evidence of new physics in CP violation and rare decays of beauty and charm hadrons.

The current results in heavy flavour physics obtained at the B factories and at the Tevatron are, so far, fully consistent with the CKM mechanism. On the other hand, the level of CP violation in the Standard Model weak interactions cannot explain the amount of matter in the universe. A new source of CP violation beyond the Standard Model is therefore needed to solve this puzzle. With much improved precision, the effect of such a new source might be seen in heavy flavour physics. Many models of new physics indeed produce contributions that change the expectations of the CP violating phases, rare decay branching fractions, and may generate decay modes which are forbidden in the Standard Model. To examine such possibilities, CP violation and rare decays of $\mathrm{B_d}$, $\mathrm{B_s}$ and D mesons must be studied with much higher statistics and using many different decay modes.

With the large $\mathrm{b\overline{b}}$ production cross section of $\sim 500\,\mu$b expected at an energy of 14 TeV, the LHC will be the most copious source of B mesons in the world. Also $\mathrm{B_c}$ and b-baryons such as Λ_b will be produced in large quantities. With a modest luminosity of 2×10^{32} $\mathrm{cm^{-2}s^{-1}}$ for LHCb, 10^{12} $\mathrm{b\overline{b}}$ pairs would be produced in 10^7 s, corresponding to the canonical one year of data taking. Running at the lower luminosity has some advantages: events are dominated by a single pp interaction per bunch crossing (simpler to analyse than those with multiple primary pp interactions), the occupancy in the detector remains low and radiation damage is reduced. The luminosity for the LHCb experiment can be tuned by changing the beam focus at its interaction point independently from the other interaction points. This will allow LHCb to maintain the optimal luminosity for the experiment for many years from the LHC start-up.

The LHCb detector must be able to exploit this large number of b hadrons. This requires an efficient, robust and flexible trigger in order to cope with the harsh hadronic environment. The trigger must be sensitive to many different final states. Excellent vertex and momentum resolution are essential prerequisites for the good proper-time resolution necessary to study the rapidly oscillating $\mathrm{B_s}$-$\mathrm{\overline{B}_s}$ meson system and also for the good invariant mass resolution, needed to reduce combinatorial background. In addition to electron, muon, γ, π^0 and η detection, identification of protons, kaons and pions is crucial in order to cleanly reconstruct many hadronic B meson decay final states such as $\mathrm{B^0}\to\pi^+\pi^-$, $\mathrm{B}\to\mathrm{DK^{(*)}}$ and $\mathrm{B_s}\to\mathrm{D_s^{\pm}K^{\mp}}$. These are key channels for the physics goals of the experiment. Finally, a data acquisition system with high bandwidth and powerful online data processing capability is needed to optimise the data taking.

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