Early physics with the LHCb detector

Dirk Wiedner
(on behalf of the LHCb Collaboration)
CERN
Route de Meyrin 385
CH-1211, Geneva 23 Switzerland

1 Introduction

The Large Hadron Collider beauty experiment [1](fig.1) is a dedicated experiment for the precision measurements of rare decays and CP-violation in the b-sector. It is currently being commissioned at the Large Hadron Collider at CERN. The experimental techniques applied allow for a highly efficient sampling of beauty events.

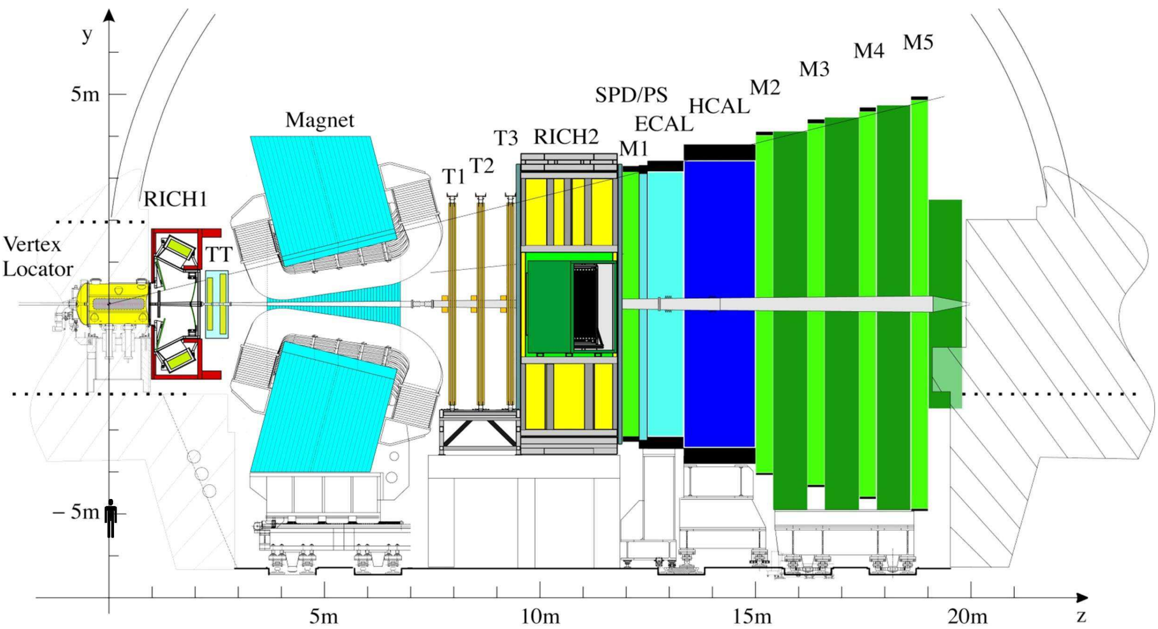

Figure 1: The Large Hadron Collider beauty experiment (LHCb)

2 Detector components

Since the $b\bar{b}$ production in pp collisions at $\sqrt{s}$=14TeV is strongly favoured in the forward region, LHCb has been constructed as a single arm forward spectrometer. The VErtex LOcator (VELO) is a silicon strip detector, see fig.2, placed at a distance of 8 mm around the interaction region. The 5 μm hit resolution allows 30 μm resolution of the impact parameter. An accuracy of about 40 fs in decay time is achieved for channel $B_s \to D\pi$ (fig.3). The good time resolution of the vertex locator permits a clean measurement of B_s oscillations. Inclusion of the impact parameter measurement in the trigger system leads to early and efficient selection of b-decays.

Figure 2: Vertex Locator (VELO)

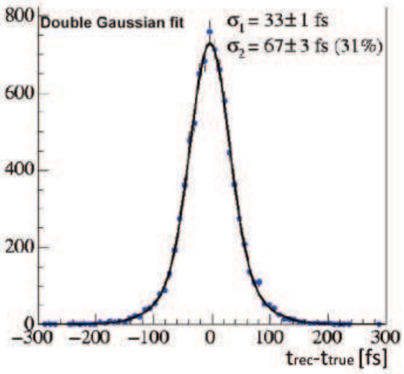

Figure 3: Decay time resolution of the VELO detector for channel $B_s \to D\pi$

The momentum and mass measurement is performed with a dipole magnet and tracking stations before and after the magnet. The dipole magnet (fig.4) generates an integrated field of 4 Tm. The VELO together with the Tracker Turicensis (Zurich Tracker, fig.5), the silicon Inner and drift tube Outer Trackers (fig.6) are used to precisely determine the particle momentum with $\delta p/p = 0.3\%$-0.5%. This leads to a mass resolution of $\sigma \approx 14$ MeV for $B_s \to \mu\mu$ allowing to efficiently suppress background.

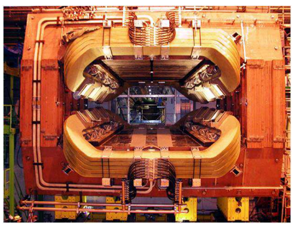

Figure 4: Magnet

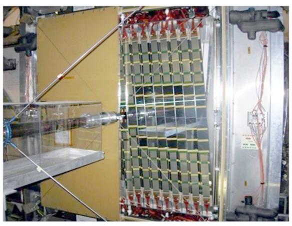

Figure 5: Tracker Turicensis

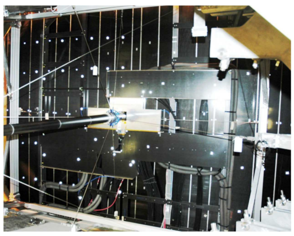

Figure 6: Outer and Inner Tracking detectors

The K-π separation is achieved by two Ring Imaging Cherenkov detectors: RICH1 (fig.7) has two different radiators, 5 cm aerogel with a refractive index n=1.03 and 4 m^3 gaseous C_4F_{10} with n=1.0014, to cover lower and middle momentum range. RICH2 (fig.8) covers the highest momentum range using 100 m^3 CF_4 with n=1.0005. As charged particles traverse the medium they emit photons in a cone around their trajectory. The emission angle of the cone depends on the velocity of the particle. If the velocity from the RICH and the momentum from the trackers is known, the particle mass and therefore its identity is determined. The expected kaon identification performance P(K→ K) is 97.29±0.06% with a fraction of pions misidentified as kaons of P(K→ π)=5.15±0.02%, see fig.9.

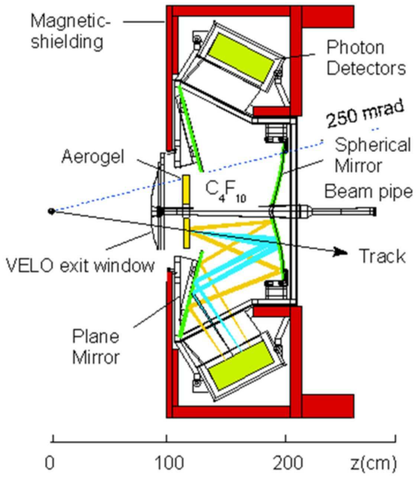

Figure 7: Ring Imaging CHerenkov detector one (RICH1)

Figure 8: Ring Imaging CHerenkov detector two (RICH2)

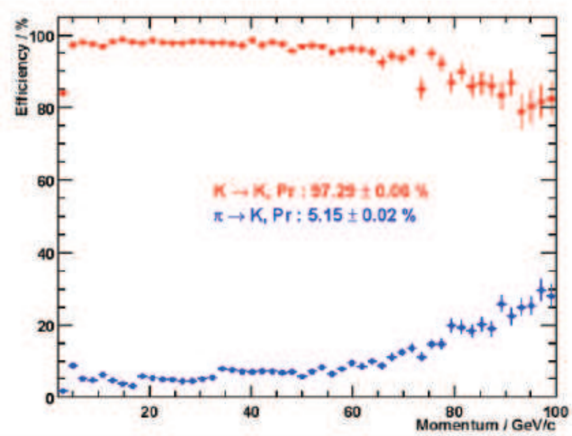

Figure 9: Kaon identification performance

The LHCb calorimeters (fig.10) identify photons, electrons and hadrons by converting them into showers. They supply the Level 0 trigger for high E_T electrons, photons and hadrons. The rejection of a high background of charged pions requires longitudinal segmentation of the electromagnetic shower detection, i.e. a preshower detector (PS) followed by the main section of the ECAL. The electron trigger must also reject a background of π_0's with high E_T, provided by a scintillator pad detector (SPD) plane in front of the PS. The thickness of ECAL was chosen to be 25 radiation lengths for optimal energy resolution, while the hadronic colorimeter has 5.6 interaction lengths. For all calorimeters scintillation light is transmitted to a Photomultiplier (PMT) by wavelength-shifting (WLS) fibers.

The muon system is used for the muon identification and the Level 0 trigger on high p_T muons. It is composed of five layers of wire chambers (M1-M5), see one layer in fig.11. In M1 also GEM chambers are used in the inner region, where the highest occupancy is expected.

Figure 10: Calorimeter

Figure 11: One layer of muon chambers

The trigger system, designed to efficiently select the events of interest, has two stages. The Level 0 (L0) trigger is implemented in hardware and selects events with high p_T (μ, e, γ, h) at a rate of 1 MHz from an input rate of 40 MHz. The higher level trigger is implemented in software. After L0 confirmation it associates L0 objects with large impact parameter tracks and performs inclusive and exclusive selections. The rate to storage is 2 kHz at an event size of $\approx$30 kB.

3 First Data

In the first days of data taking starting in 2008, a sample of 10^8 minimum bias events is expected to be taken. Only four bunches will be filled leading to a luminosity of $L=1.1\text{x}10^{29}\text{cm}^{-2}\text{s}^{-1}$. This initial data can be used to calibrate the detector [2] and study inclusive particle production, see fig.12. When the detector components are well understood, the decay $Z \to \mu^+\mu^-$ can be used for luminosity measurement with an expected accuracy of 5% already at $5\,\mathrm{pb}^{-1}$. The differential cross section of the decays $Z \to \mu^+\mu^-$ and $W^\pm \to \mu^\pm\nu$ will allow the measurement of the Parton Density Function in a phase space priorly inaccessible [3].

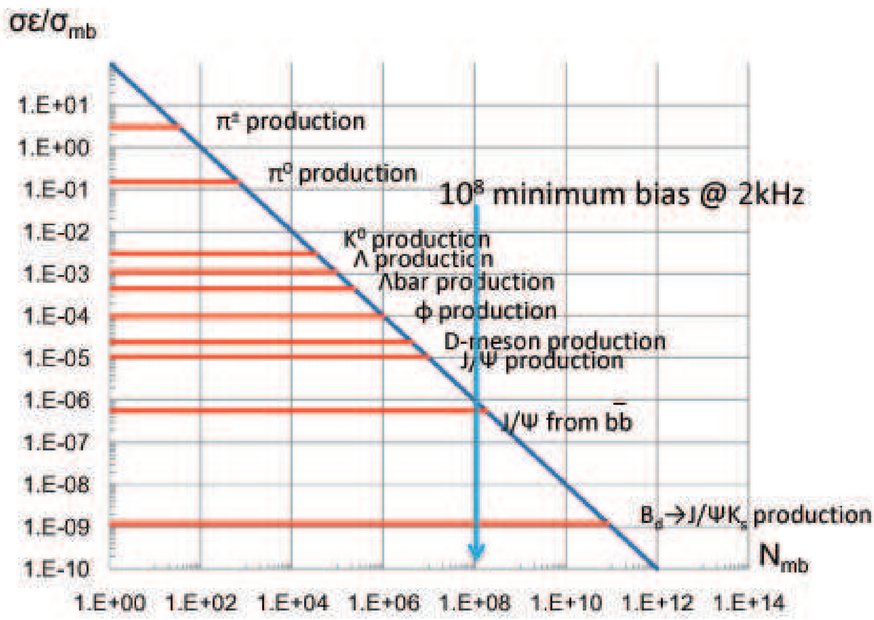

Figure 12: Physics reach vs. integrated luminosity

In the following phase of running with increasing luminosity from 2 x $10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ to 2.4 x $10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, the beauty cross section will be determined amongst others. For this a working muon system, main tracker and VELO will provide the necessary basic information. After measurement of the relative fraction of the prompt and detached J/Ψs, the absolute production of J/Ψ can be determined. From the non prompt J/Ψ yield the $b\bar{b}$ cross section will be derived.

This will be followed by the core program of search for new physics in CP-violation and rare decays including very interesting measurements with the expected first $0.5\,\mathrm{fb}^{-1}$ of data:

- $B_s \to J/\Psi\phi$ will allow to determine B_s mixing phase $2\beta_s$ with ≈0.05 precision
- $B_s \to \mu\mu$ will give the BR limit down to SM value
- $B_d \to K^{0*}\mu\mu$ will have a statistics competitive with B-factories (≈ 1800 events)

4 Summary and outlook

The LHCb detector is ready to take data in 2008. It combines good decay time resolution to resolve B_s oscillations, good mass resolution to efficiently suppress background, an excellent particle identification for K-π separation and an efficient trigger for many B-decay topologies. Inclusive low p_T physics will be investigated from day one with a data sample of 10^8 minimum bias events. During the subsequent time of increased luminosity, determination of the b-cross section is envisaged.

The core physics program will make use of $2\,\mathrm{fb}^{-1}$ per year addressing CP violation and rare decays. CP violation measurements include the UT angle γ from trees with a precision of 5° - 10° and from Penguins with ≈10° precision, the B_s mixing phase with an error of $\sigma(2\beta_s)$ ≈0.023 and β_s^{eff} from Penguins. As mentioned before, examples of the most interesting rare decays which will be studied are $B_d \rightarrow K^{0*}\mu\mu$, $B_s \rightarrow \phi\gamma$ and $B_s \rightarrow \mu\mu$.

References

[1] The LHCb Collaboration, "The LHCb Detector At The LHC," JINST **3** (2008) S08005.

[2] G. Corti, Nucl. Phys. Proc. Suppl. **170** (2007) 278.

[3] S. de Capua, "Large mass dimuon detection in the LHCb experiment," CERN-THESIS-2006-035.