Performance of the Outer Tracker Detector of LHCb

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Abstract. The LHCb experiment is a single arm spectrometer, designed to study CP violation in B-decays at the Large Hadron Collider. The Outer Tracker is part of its tracking system and consists of ~ 55000 straw tubes. It is now fully installed and partially equipped with readout electronics. After a short description of the detector, the read-out electronic performances are discussed. Some results about the detector ageing are also presented. Finally the performance of the final detector has been checked with a beam test at DESY and some results are shown.

1. Description of the Outer Tracker of LHCb
The LHCb tracking system is composed of the vertex locator [1][2] (see Figure 1), the trigger tracker (TT) [2] and three tracking stations T1-T3 downstream the dipole magnet. These three last stations are divided in two part : a silicon detector [3] close to the beam pipe, in the highest particle flux region, and a gaseous straw tube detector (with a counting gas mixture of Ar(70%)/CO2(30%)), Outer Tracker (OT) [4], covering most of the LHCb acceptance (~ 98%).

The OT has been designed in order to fulfill the following performance requirements :

- a cell efficiency ~ 98%, in order to get a tracking efficiency close to 95% (to reconstruct, for instance, all the tracks of B_{S} \rightarrow D_{S}K decay channel with an efficiency ~ 80%).
- a resolution ~ 200\mu m, in order to get a momentum resolution \frac{\Delta p}{p} ~ 0.4% (to get, for instance, a mass resolution of 16 MeV/c^2 for B_{S} \rightarrow D_{S}K decay channel).

The OT is modular design and consists of 168 long F-modules (500 x 34 cm^2) and 72 short S-module around the beam pipe. One F-module consists of two staggered layers of 64 straws, electrically floating at the center and read out at the two ends. The anode is 25 \mu m thick gold-plated tungsten wire; the cathode is made of a carbon-doped (XC) kapton straw with a diameter of 4.9 mm on the inside, and aluminium at the outside for electrical shielding. The modules are assembled in three stations containing each four planes (of which two vertical, and two with stereo angles \pm 5°) with an overall size of 6 m x 5 m. The module production is now complete and all the modules are installed in the pit.

2. Outer Tracker readout system and its performances
The charge signals from 128 straw tubes are collected in shielded metal Front-End boxes positioned at both ends of the OT modules. The Front-End boxes contains four types of boards : HV board (decoupling the analog signal from the high voltage), ASDBLR board (amplifier, shaper and discriminator) based on ASDBLR amplifier from ATLAS [5, 6], OTIS board (measuring the drift time) [7] and the GOL board (data transmission) [8]. All these
elements are now produced and roughly half of them are assembled and being installed. Once assembled, the FE boxes are tested at Nikhef. The test includes threshold (see Figure 2), pulse amplitude, delay, latency and dark noise scans for each single channel. At 1.1 MHz L0 accept rate, hits within a 75 ns window from 4 TDCs runs to the GOL chip which serializes 32 input bits to a 1.6 Gbit/s output. The data are then sent to a board common to many LHCb detectors, the TELL1 board [9] through 90 m optical fibers. TELL1 FPGAs are programmed to synchronize, zero suppress and reformat the data. Event are then transmitted through multiple Gigabit ports to a more than 1000 CPU computing farm. First commissioning tests including the full readout chain have been performed using test pulses sent through the ASDBLR chips. These tests have shown that the drift time resolution is as good as expected (~0.4 ns).

3. Ageing of the Outer Tracker
During R&D phase, high rate ageing tests were performed on 1 m prototype detector modules using 11 MeV proton beams and a X-ray facility (9 KeV). These studies on long term effects with high irradiation dose (0.5-3 C/cm) did not show any ageing phenomenon. However, mass production modules showed unexpected gain deterioration with β and γ sources. Many investigations have been done and carbon deposits have been identified on the wire in the damaged region. The cause of the ageing have been traced back to outgassing of the glue used in the module assembly and to recover the gain loss, flushing, HV training and heating of the modules have shown beneficial effects.

4. Test Beam results
Final modules and electronics were tested using a 6 GeV electron beam at DESY [10]. The purpose of these tests was to determine the main performance parameters of the detector, such as efficiency, coordinate resolution and noise. The dependence of these quantities on the gas gain and the preamplifier threshold was investigated. The schematic set-up is shown in Figure 3 and
comprised four short modules. On one hand the knowledge of the position of the beam particle was known using a silicon strip telescope. On the other hand, the number of OT modules were sufficient to reconstruct track using OT data only. The trigger signal, which served also as time reference, was produced by coincidence of two scintillator counters (S4 and S5) installed downstream of the OT modules. In runs with Si-telescope, additional small scintillators counters (S1, S2 and S3) were used. These tests showed good OT detector performance in agreement with the design requirements. For example, with $HV=1550$ V and a amplifier threshold at $800$ mV, a high efficiency ($\sim 98\%$), a coordinate resolution better than $200$ $\mu$m, a acceptable noise ($< 10$ kHz/wire) and crosstalk level ($< 4\%$) were obtained. These results were confirmed by three different and independent analyses, using different methods. Within the range of $700$-$800$ mV and high voltage range between $1520$-$1650$ V the detector performance meets the desing requirements.

![Side View:](image)

**Figure 3.** Schematic picture of test beam set up.

**References**

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