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Time calibration of the LHCb Muon System

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The LHCb Muon System consists of about 122,000 readout channels. It plays a basic role in the first trigger level. The trigger requires 95% efficiency in Muon tracks detection. It is then necessary to reach a system time alignment at the level of about 2 ns. This alignment must be monitored against possible fluctuations due to changes in the detector operating conditions. We describe the custom instrumentation implemented at system level for time calibration, the strategy adopted, the procedure to be followed both for system alignment and monitoring, the control program realized for this purpose. We also illustrate first results obtained during the detector commissioning in the LHCb pit.

Summary

The LHCb Muon detector plays a crucial role in the first trigger level. It is realized by means of Multi-Wire-Proportional-Chambers and Gas-Electron-Multipliers and consists of about 122,000 front-end channels.
High efficiency is necessary both at detector and front-end level to satisfy the trigger requirement of 5 hits per 5 Muon stations (layers of detectors) with an overall efficiency of 95%. This corresponds to having a single front-end channel detection efficiency of 99% within a time window of 20 ns and poses the problem of an accurate time calibration of the whole detector.
The Muon trigger processes the binary information coming from the Muon detectors according to a pipelined architecture, starting to process a new event every 25 ns (Bunch Crossing –BX). The Muon trigger expects Muon data being tagged with an identifier of the specific BX they originate from. However, considering the width of time distributions due to the intrinsic detector resolution, in order to reach the requested trigger efficiency, it is necessary to calibrate the internal system delays at the level of about 2-3 ns.
Starting from the above requirements, the Muon System has been conceived and realized containing specific tools for time calibration at the channel level. Several reasons cause the system channels to be naturally misaligned in time: time of flight of particles through detectors, different cable lengths, different number of electronics stages to be crossed.
The basic strategy for system time calibration is to measure the hit time of arrival at the ODE board level, just before the hits are dispatched to the muon trigger.
Inside the SYNC chip, placed on the ODE, time spectra can be built on each input channel. SYNC is a custom chip, containing eight Time-to-Digital-Converters, one per channel. Two kinds of time spectra can be built: a coarse-time histogram, based on the current BX number, and a fine-time histogram, based on the hit phase with respect to the rising system clock edge. The first histograms have bins of 25 ns, while the second ones have bins of 1.5 ns. Also the fine-time histograms must be centered to reach the requested detector efficiency. Two different adjustments are possible:
• The SYNC BX counters, which allow moving time in steps of 25 ns clock cycles;
• The programmable delays, placed on the front-end boards (DIALOG chip), which allow moving time in 32 steps of 1.6 ns.
A first rough system alignment can be obtained using a system pulsing network, which we have embedded in our electronics. However, an accurate System calibration is possible only by measuring the time of arrival of detected

particles coming from beam interactions and building time histograms with significant statistics.
The information gathered on the SYNC histograms is the basis for a system-wide analysis aimed at finding the general alignment of the detector. The alignment procedure of all the 122000 front-end channels is the basis for a System Control Program aimed at system time calibration, which is presently being used during system and detector commissioning.

Primary authors: LAI, Adriano (INFN Cagliari); DEPLANO, Caterina (INFN Cagliari); CADEDDU, Sandro (INFN Cagliari); DE LEO, Vincenzo (Universita‘ di Cagliairi)

Presenter: DEPLANO, Caterina (INFN Cagliari)

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