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LHCb VELO detector: Performance and Radiation Damage

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The LHCb experiment is dedicated to the study of New Physics in the decays of heavy hadrons at the Large Hadron Collider (LHC) at CERN.
Heavy hadrons are identified through their flight distance in the Vertex Locator (VELO), and hence the detector is critical for both the trigger and offline physics analyses.
The VELO is the retractable silicon-strip detector surrounding the LHCb interaction point. It's innermost radius is located only 7 mm from the LHC beam during normal LHC operation, once moved into its closed position for each LHC fill when stable beams are obtained. During insertion the detector is centred around the LHC beam by the online reconstruction of the primary vertex position.

Both VELO halves comprise 21 silicon micro-strip modules each. A module is made of two n+-on-n 300 μm thick half-disc sensors with R-measuring and phi-measuring micro-strip geometry, mounted on a carbon fibre support paddle. The minimum pitch is approximately 40 μm. The detector is also equipped with the only n-on-p sensors operating at the LHC. The detectors are operated in vacuum and a bi-phase C02 cooling system is used. The signals read out with analogue front-end chips are subsequently processed by a set of algorithms in FPGA processing boards.

The VELO has been performing very successfully. Operational results show a signal to noise ratio of around 20:1 and a cluster finding efficiency >99 % excluding dead channels. The small pitch and analogue read-out result in a best single hit precision of 4 μm having been achieved at the optimal track angle. The performance of the VELO during its three years of operation during the LHC physics runs will be presented, focussing on the latest studies. This will include highlights such as alignment, cluster finding efficiency, single hit resolution, impact parameter resolution and vertex resolution.

The VELO module sensors receive a large and non-uniform radiation dose having inner and outer radii of only 7 and 42 mm, respectively. A maximum dose of 1.2 x 1014 1 MeV neutron equivalent /cm2 was received in the innermost region of the sensors for the combined 2010-12 run (3.4 fb-1 of delivered data). Type-inversion of the inner part of the n-on-n sensors has already been measured. The radiation damage in the detector is monitored and studied in three dedicated ways: (1) dependence of sensor currents on voltage and temperature; (2) measurement of the effective depletion voltage of the sensors from the charge collection efficiency and from studying the noise versus voltage behaviour; and (3) cluster finding efficiency. In addition, the noise and charge collection is directly monitored over time. Results will be presented in all areas with updates based on recent results from the LHC running in 2012. The primary results presented are the first observation of type-inversion at the LHC; a comparison of n-type and p-type silicon in operation; system-wide measurement of the silicon effective band gap after irradiation; and the observation of a radiation-induced charge loss effect due to the presence of a second metal layer.

Primary author: SNOEK, Hella (NIKHEF (NL))

Presenter: SNOEK, Hella (NIKHEF (NL))

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