IL NUOVO CIMENTO **40 C** (2017) 42
DOI 10.1393/ncc/i2017-17042-5

Colloquia: IFAE 2016

The LHCb trigger in Run II

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received 17 October 2016

Summary. — In the last years the LHCb experiment has performed great precision measurements in heavy flavour and electroweak physics. This was made possible thanks to its versatile real-time reconstruction and selection system (trigger), which is responsible for reducing the rate of proton-proton collisions which need to be saved for offline analysis by approximately three orders of magnitude. In this proceeding the LHCb trigger redesigned during the 2013–2015 long shutdown will be presented. The entire data processing framework has been modified to enable a single, coherent real-time detector alignment and calibration as well as real-time analyses using purely trigger information.

1. – The LHCb trigger

The LHCb detector [1] is a single-arm forward spectrometer covering the pseudorapidity range $2 < \eta < 5$, designed for the study of particles containing b or c quarks. Due to the high collision rate provided by the LHC only a fraction of events reconstructed in LHCb can be retained. The decision of whether to keep or discard any given event is made by the trigger system. LHCb trigger is organized in three levels: the hardware Level-0 (L0) trigger and the software High Level Triggers HLT1 and HLT2. The software trigger has been redesigned during the long shutdown to allow the most possible wide and precise physics program during the Run II. During Run I the lack of very low-momentum charged particles and full particle identification information limited the performance in particular for c hadron physics. In addition, resolution differences between the on-line and off-line reconstructions led to difficulties in understanding efficiencies with a high degree of precision. For these reasons the aims of the new trigger are firstly to enable the full off-line reconstruction to run in the trigger greatly increasing the efficiency with which charm and strange hadron decays could be selected, secondly to achieve the same alignment and calibration quality within the trigger, enabling the entire analysis to be performed at the trigger level. These two objectives are correlated: increasing the efficiency for charm and strange decays increases the physics reach of the experiment but the resulting signal yields are too high to be entirely saved for analysis.

2. – The High Level Trigger in Run II

Events selected by the L0 hardware trigger are transferred to the Event Filter Farm [2] to perform the event reconstruction. The EFF consists of approximately 1700 nodes with 27000 physical cores; 800 of which were added for Run II. The LHCb High Level trigger (HLT) is written in the same framework as the software used in the off-line reconstruction of events for physics analyses. For Run II has been implemented in the EFF a total disk buffer of 5 PB, distributed in such a way that farm nodes with faster processors get a larger portion of the disk buffer. At an average event size of 55 kB passing HLT1, this buffer allows for approximately 150 hours of HLT1 datataking before HLT2 has to be executed. It is therefore large enough to accommodate both regular running and to serve as a safety mechanism to delay HLT2 processing in case of problems with the detector or calibration. The trajectories of charged particles traversing the full LHCb tracking system, called long tracks, with a transverse momentum larger than $500\,\mathrm{MeV}/c$ are reconstructed in HLT1. The goal of the track reconstruction in HLT2 is to reconstruct all tracks without any minimal transverse momentum requirement. The momentum resolution is about 0.5% for p_T below $20\,\mathrm{GeV}/c$, rising to about 0.8% for p_T around $100\,\mathrm{GeV}/c$.

3. – Real time analysis

The increased computing power in the EFF allows for automated alignment and calibration tasks [3], giving off-line quality information inside the trigger software. In order to align and calibrate the detector, dedicated samples from the first software trigger level are used. The resulting alignment or the calibration constants are updated if they differ significantly from the currently used values. Thanks to all these improvements, in Run II it is possible to perform physics analyses with the information calculated by the HLT event reconstruction. A new software, the Tesla application [4], has been developed to process the information calculated by the trigger, with the resulting output used to directly perform physics measurements without the need for further offline reconstruction. Reaching the ultimate precision of the LHCb experiment already in real time as the data arrive has the power to transform the experimental approach to processing large quantities of data. A clear advantage is that the event size is an order of magnitude smaller than that of the standard stream as all sub-detector information may be discarded. This allows to collect data with a higher rate increasing the precision of the measurements.

The whole system has already been tested and it has led to two the measurement of the open charm [5] and J/ψ [6] cross section at $\sqrt{s} = 13\,\mathrm{TeV}$.

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