Implementation of the HERA-B First Level Trigger

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The main goal of the HERA-B first level trigger is the identification of decays in the B meson system to measure CP violation. It reduces a 10 MHz input rate by a factor of 200 with a latency of 5 to 10 μs. Using Kalman filtering it searches possible lepton and hadron tracks from a location given by particle identification devices through up to 7 layers of tracking chambers. The trigger decision is based on the momenta and masses of track pairs.

Key words: HERA-B; First Level Trigger Processor; Kalman Filtering.

1 Introduction

HERA-B [1,2] analyzes interactions of 820 GeV protons with a fixed target. With an interaction rate of 40 MHz and a time between two bunches of 96 ns, the first level trigger (FLT) has to reject background by 3 orders of magnitude, and select the signal with high efficiency. To measure CP violation, the neutral B decays into $J/\psi K_s^o$ followed by $J/\psi \rightarrow l^+l^-$ and $K_s^o \rightarrow \pi^+\pi^-$ are examined. The FLT system is designed to find this channel with very high efficiency while limiting the overwhelming background rate. This can be achieved by track following and reconstructing J/ψ candidates on this early level.

2 First level trigger strategy

The track reconstruction uses a Kalman Filtering [3] inspired method. The required track seeds (pretriggers) are obtained from an electromagnetic calorimeter, a muon detection system or a high-P$_T$ track identification system. The tracking proceeds from the back of the detector to the front (magnet). In a tracking chamber superlayer three layers of straw chambers with different orientations are

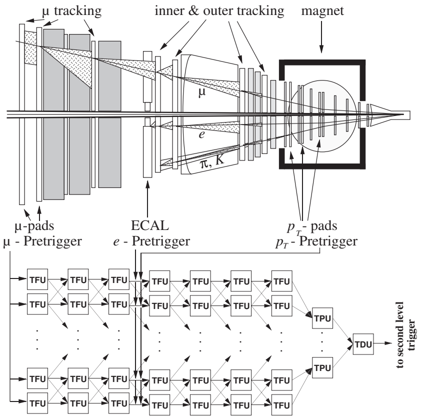

Fig. 1. *HERA-B detector and corresponding FLT structure.*

combined. Up to seven superlayers are used by the FLT. The track information obtained so far is used to predict a region of interest (ROI) in the next superlayer. The found hits are used to update the track information and so on. Finally the track parameters are calculated and the invariant masses are obtained from track pairs.

3 Implementation

The filter process needs a total amount of about 100,000 bit information which is produced every 96 ns (1 Terabit/s). For each of these events only a small part of the information (about 200 bit) is actually used. However in each event a different part of the event data is needed. The implementation concept therefore moves the filter process (its process data) to the stored event data rather than all the data to one processing unit. The filtering is performed by specialized track finding processors which communicate by means of messages. A message represents a track candidate and contains all necessary tracking information [4]. It is started by a pretrigger and updated in each superlayer by a track finding unit. The FLT is a parallel and pipelined hardware processor consisting of 60 track finding units (TFU), 4 track parameter units (TPU), and a trigger decision unit (TDU). Figure 1 gives an overview of the HERA-B detector and the corresponding FLT structure.

A track finding unit is a synchronous pipeline that can process a track hit every 20 ns. For the current bunch crossing, a coincidence matrix identifies track hits in the search region using the three stereo views of the assigned tracking chamber section. The improved search region, extrapolated to the next tracking chamber, is read from a lookup table and transmitted to one or more track finding units assigned to the next tracking chamber or, eventually, to the track parameter units. A track parameter unit determines from the transmitted track information the kinematic parameters of the particle candidate to accept or reject it. Finally the tracks are collected in the trigger decision unit. By using lookup tables to obtain the trigger decision, the mass of a pair as well as the kinematical parameters of single or double leptons are taken into account. The output of the trigger decision lookup table codes different types of triggers (pair-mass, high-P_T, etc.). Additionally triggers can be generated on count conditions of several combinations of tracks. To allow investigations of the background also prescaling is supported for frequently occurring triggers.

4 Conclusions

The HERA-B FLT is a very fast and flexible system. The system is modular and can be assembled according to the detector demands. In total only three different types of boards are needed.

The FLT accepts new data every 96 ns. It reduces the event rate by a factor of 200 which yields an input data rate of the second level trigger of 50 kHz. The FLT is realized in hardware using programmable logic devices and fast SRAMs in a highly pipelined design with a clock frequency of 50 MHz. The total latency sums up to about 5 μs for electrons and high-P_T or 7 μs for muons (without time for the pretriggers).

The FLT track finding algorithm is very flexible, because of the widely use of lookup tables. Many parameters of the algorithm as well as geometrical constants can be changed by simply reprogramming these lookup tables. Also the trigger decision unit provides a great flexibility in the trigger decision especially for additional physical topics beyond the $B^0 \rightarrow J/\psi K_s^o$ decay. The system is in the prototype stage.

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