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High-P_T trigger for HERA-B experiment

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Abstract

The high-P_T trigger provides valuable extension for the physics capabilities of HERA-B fixed target experiment. Trigger performs fast and effective selection of various B meson decay modes important for CP violation and B_s mixing rate measurements. HERA-B high-P_T trigger is built up of three layers of gas detectors placed inside the magnet area. Tests with full-scale detector modules have been done in real conditions. The installation of trigger components in the HERA-B detector is nearly completed.

1. Introduction

HERA-B is a forward spectrometer using a fixed target placed in the halo of 920 GeV/*c* HERA proton beam. HERA-B detector is primarily designed to measure CP violation in "gold-plated" decays $B^0(\bar{B}^0) \to J/\psi K_s^0$. A detailed description of the detector and running conditions can be found in Ref. [1].

The high-P_T trigger is a complementary option to the basic "J/ψ" trigger used in HERA-B. It opens a variety of important additional physics possibilities, including B_s mixing rate measurement, study of CP violation in hadronic B decays and measurement of rare decays of B mesons, beauty baryons and resonant states [2].

The high-P_T trigger performs fast and effective selection of hadrons with high transverse momenta. This creates the possibility to trigger on two-prong B meson decay modes and one generic B meson decays with the second B meson in event decaying in semileptonic mode.

2. Trigger algorithm

The high-P_T trigger is a part of the HERA-B first level trigger (FLT) [3]. To ensure normal operation of the Kalman filtering procedure, used by the FLT, a limited number of candidates should be provided to the filter input. This preliminary selection ("pretrigger") is realized by the high-P_T trigger.

The trigger is based on the three layers of gas pad chambers placed inside the magnet. A charged particle traversing the detector with high momentum (and therefore with high p_T) fires projective pads in all the three layers. Several predefined coincidence combinations (see Fig. 1) of hit pads are used to define the pretrigger. The pretrigger parameters are then extrapolated downstream the beam to the tracker chambers, thus defining the input for

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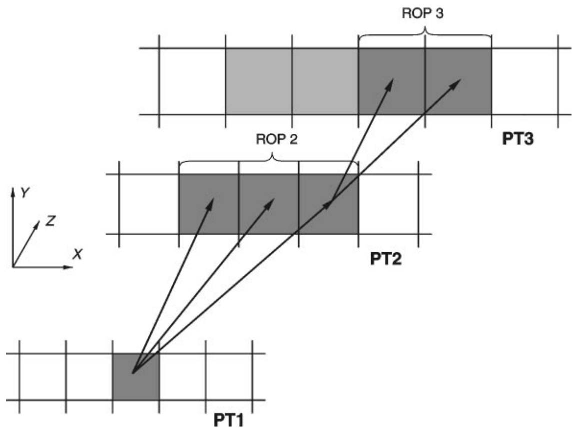

Fig. 1. Pad coincidence combinations implemented in the high-P_T trigger. PT1–PT3 are the trigger layers inside the magnet. For each pad in the first and second layers a coincidence region of pads is defined.

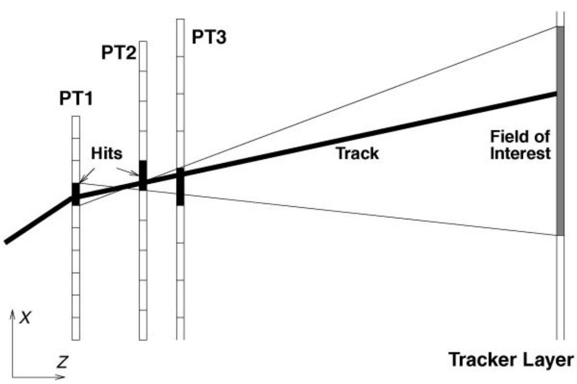

Fig. 2. The extrapolation of the pretrigger signal parameters in the Z direction to the trigger layer.

the Kalman filtering algorithm of the FLT (see Fig. 2).

3. Trigger hardware

HERA-B high-P_T trigger setup is described in detail elsewhere [1]. The three trigger pad-superlayers are divided into inner and outer parts. Straw chambers with cathode pad readout are used in the outer part [4]. Gas pixel chambers [5] are used in the inner part of each superlayer, covering the region of $54 \times 41\ \text{cm}^2$ near the beam pipe. The pads have different sizes varying from $4 \times 8\ \text{mm}^2$ to $3.2 \times 6.4\ \text{mm}^2$. The sizes of the chambers (and their pads) are increased projectively as the ratio of their distances to the target. In a region close to the beam pipe the granularity is higher.

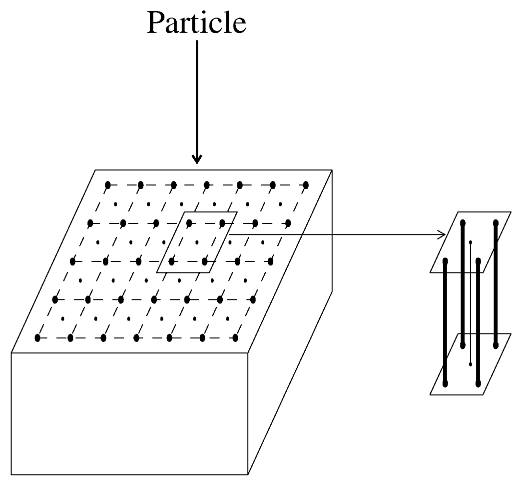

Fig. 3. Schematic view of a small region of a gas pixel chamber.

Pixel chambers have rectangular cells with the signal wire surrounded by four potential wires (see Fig. 3). Each inner layer is composed of two pixel chambers placed around the beam pipe.

In pixel chambers, 20 μm gold plated tungsten wires and 300 μm silver plated stainless-steel potential wires are stretched between two 0.2 mm thick G10 boards. Potential wires provide additional rigidity to the chamber. The wires run parallel to the beam axis. This makes the drift paths of electrons to the signal wire roughly equal along the length of the track, resulting in a sharp signal front. The chambers are attached to the support frame which is made of a light graphite structure. One of the two G10 boards has copper traces for HV distribution. Potential wires are soldered to the HV lines. The other end of the potential wires is glued into the second G10 plate. Signal wires are soldered at both sides on the G10 boards. The length of the wires is 3.5 cm, providing about 2.0 cm of fully efficient gas amplification. Preamplifiers are mounted on the frames outside the detector acceptance and connected to the chambers by the light twisted pair cables. The amount of material in a gas pixel chamber is less than 1% of a radiation length. The pixel chamber will be operated with $Ar/CF_4/CH_4$ gas mixture [6]. The maximum drift time is less than 96 ns for the maximal cell size of $1.0 \times 1.0\ cm^2$ [7].

The straw tubes are rolled out of a two-layer material: the inner layer consists of carbon-loaded kapton and the outer layer consists of mylar. The kapton layer serves as the cathode and is held at ground potential, while the mylar layer helps provide a gas seal. The thickness of the kapton is 2.5 μm, and the thickness of the mylar is 12 μm. The straws are strung with gold-plated tungsten wire having a diameter of 20 μm. The prototypes were tested with a gas mixture of 90% argon and 10% methane [4].

The pad plane consists of a two-layer printed circuit board with copper pads on one side and traces on the other. The traces connect to the pads via plated through-holes and carry signals to one end of the pad plane, where preamplifier cards are mounted. To minimize detector mass, the material used for the printed circuit board is Kapton. The thickness of the Kapton is only 14 μm (including the Cu pads and traces), which corresponds to 0.28% of a radiation length. The trace width is 14 μm.

4. Trigger electronics

The high-P_T chambers are equipped with readout electronics and a sophisticated trigger logic system which performs selection of events out of a data stream with typical rate of 10^{12} bits/s [8]. Here is presented the readout and trigger electronics scheme developed for the inner part of HERA-B high-P_T trigger. For the outer part the electronics is organized in a similar way.

The signals are routed from the signal wires to the front-end (FE) cards mounted on the frames outside the detector acceptance. The readout is done using low-mass twisted pair cables. The FE readout electronics are based upon the ASD-8B (amplifier-shaper-discriminator) chips developed at the University of Pennsylvania [9].

Front-End Drivers (FED) are the interface of FE output signals both to the central data acquisition

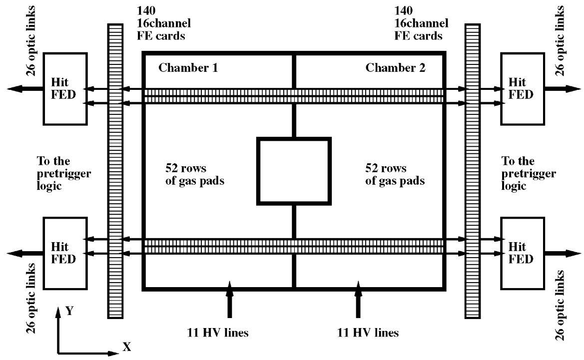

Fig. 4. Readout chain of the inner layer of high-P_T chambers. The layer consists of two pixel chamber modules. The readout schemes for the left and right modules are identical. Two serial link lines transmit hits of one row of pads to the pretrigger logic every 48 ns.

(DAQ) system and to the pretrigger logic (see Fig. 4). They are placed close to the detector. FED executes two tasks: (1) pipeline storage of digital data and transmission of the data selected by FLT to the DAQ system, (2) transmission of the data to the high-P_T pretrigger logic. Each FED handles 1000 pixel pad signals ($\frac{1}{4}$ of the inner layer) distributed between 4 daughter boards.

Every bunch crossing (100 ns) the FED's daughter board latches synchronously 256 channels of differential signals from ASD-8B cards. Data coming into the daughter boards are fanned out in two paths: they are loaded to the pipeline memory to be uploaded to the central DAQ on demand, and they are transmitted via the link boards to the pretrigger logic (see Fig. 5). Signals coming into the link board are multiplexed to fast serial link chips. This chip transfers data in serial form with the speed of two 32-bit words per bunch crossing interval. The number of 32-bit words transferred from one chamber layer in one transmission cycle is determined by the number of pad rows. In addition to pad signals a special code for synchronization is transmitted to the pretrigger logic: the 8-bit bunch crossing number and a bit, which identifies the transmission cycle number.

The pad coincidence algorithm of the inner part of the high-P_T trigger assumes that each pad of the first chambers layer projectively maps to three adjacent pads (in the horizontal plane) of the second

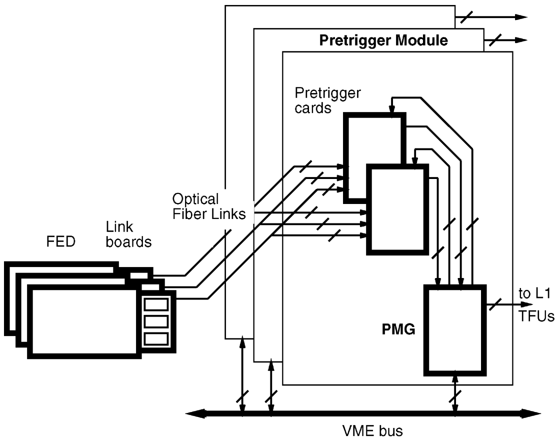

Fig. 5. Scheme of the high-P_T chambers readout and trigger logic operation.

layer, and each pad of the second layer projectively maps to two neighboring pads of the third layer. The inner area is logically divided into 10 regions corresponding to the regions of interest (ROI) of different FLT processors. The pretrigger logic distributes messages to appropriate FLT processors.

The pretrigger electronics is structured into sections. Each section contains one Pretrigger Message Generator (PMG) card and several Pretrigger Boards (PB). The PB performs the filter procedure on raw data and decreases the output data rate to acceptable level. Each PB processes two complete row of pads in the three detector layers. It receives three bit-strings (one string per chamber layer) every 48 ns, applies the pretrigger coincidence algorithm and stores (for the necessary number for cycles) the data that matches the coincidence requirements. The data is then transmitted to the PMG.

The PMG acquires data from a group of pretrigger boards, transforms it (by means of look-up-tables) into a set of track parameters and transmits them to the appropriate FLT processors. The input rate of the PMG is limited to one track candidate per bunch crossing. This restricts the number of PBs served by one PMG. The detector acceptance is logically subdivided into several areas with roughly equal occupancy of pretrigger candidates determined from the Monte Carlo simulation. Each area corresponds to one PMG.

5. Trigger tests

The prototype of the pixel chamber with $10 \times 10\ \text{mm}^2$ cells was tested in the 2.5 GeV/c proton beam of the ITEP accelerator in 1995. The measured efficiency was 99.6% and the signal collection time was found to be less than 96 ns for 99% of the signal. The description of the experimental setup, procedure and results can be found in Ref. [7]. Tests of the straw modules prototypes are described in Ref. [4].

In 1996, a set of tests were performed at the HERA proton beam. Several prototypes with square cells of $8 \times 8\ \text{mm}^2$, $9.5 \times 9.5\ \text{mm}^2$ and $10.4 \times 10.4\ \text{mm}^2$ were installed near the beam pipe. The prototypes operated at 40–60 MHz interaction rates. The occupancy was measured and it agreed with Monte Carlo expectations. Hit correlations produced by tracks coming through several prototype chambers were observed.

The prototypes with rectangular cells were tested in 1997, including chambers with $4 \times 8\ \text{mm}^2$ and $6 \times 8\ \text{mm}^2$ cell sizes. In 1998, a first module (out of six) of the inner part of the high-P_T trigger was installed at the nominal position inside the magnet. About 1000 channels were equipped with readout electronics. The chamber readout was included in the common DAQ of HERA-B. The data was analyzed along with the information from other sub-detectors. The chamber efficiency was measured using track seeds from the Silicon Vertex Detector. The readout delays were synchronized with common DAQ system. The chamber occupancy clearly shows the HERA bunch structure.

Final versions of the pretrigger logic components were tested in 1999. The PBs and PMGs were tested in stand-alone mode using embedded self-testing facilities. The data transmission from link board to PB was tested by uploading of 0.2 Tbits of data via fiber links of nominal 55 m length. No errors occurred during the transmission.

During the 1996–1999 HERA runs full-scale gas pixel chamber modules were operating in the real HERA-B environment. No degradation of the performance was observed. Additional aging tests were also done using a setup with a radioactive source [6].

6. Conclusions

Detector components and electronics have been developed, tested and produced. Challenging performance requirements have been completely met. The installation is nearly completed. Full system test is scheduled to commence in early Spring 2000.

Acknowledgements

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References

[1] E. Hartouni et al., DESY-PRC 95/01.
[2] R. Chistov et al., Proceedings of the 3rd International Conference on B physics and CP violation, Taipei City, Taiwan, December 99, to be published.
[3] J. Flammer et al., Proceedings of the 5th Workshop on Electronics for LHC Experiments, Snowmass, USA, September 99, CERN/LHCC/99-23, p. 576.
[4] A. Schwartz, C. Lu, Nucl. Instr. and Meth. A 427 (1999) 465.
[5] V. Balagura et al., Nucl. Instr. and Meth. A 379 (1996) 404.
[6] I. Tikhomirov, ITEP Preprint, in preparation.
[7] V. Balagura et al., Nucl. Instr. and Meth. A 368 (1995) 252.
[8] V. Popov et al., Proceedings of the 4th Workshop on Electronics for LHC Experiments, Rome, Italy, September 98, CERN/LHCC/98-38, p. 447.
[9] F.M. Newcomer et al., IEEE Trans. Nucl. Sci. 40 (1993) 630.