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Trigger Electronics for Muon RPC Chambers in CMS.

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Abstract

The first level muon trigger of the CMS detector will be based on precise muon chambers (Drift Tubes and Cathode Strip Chambers) and on fast dedicated trigger detectors (Resistive Plate Chambers). Here we describe the RPC based part of the system. Its goals are to identify a muon, estimate its transverse momentum and determine the bunch crossing in which it was originated. A programmable pattern comparator trigger (PACT) is proposed for this task.

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I. INTRODUCTION

One way of selecting interesting events in the 10^9 /sec interactions of CMS is to look at high transverse momentum (p_t) muons. The bandwidth allowed for this channel is about 1-10 kHz and thus a reduction factor of 10^{-5} - 10^{-6} is required. The trigger should not introduce any dead time and it has to be able to examine every consecutive bunch crossing.

A large uncertainty in the estimate of physics rates, background and noise levels, as well as the possibility of surprises due to "new physics" forces us to make the trigger system very flexible with large safety margins. Therefore we plan to have a system based on two complementary muon trigger systems: one based on dedicated fast detectors like Resistive Plate Chambers (RPC) [1,2,3,4,5] and a second one using the muon chambers like Drift Tubes and Cathode Strip Chambers [2].

RPC based muon trigger system characterize precise timing, unambigous position detection and crude momentum measurement. Muon PAttern Comparator Trigger system (PACT) is described in general and PAttern Comaparator (PAC) - main decision making part of PACT is discussed in detail.

II. PATTERN COMPARATOR TRIGGER

A. General idea

General idea of PACT is to identify the muon momentum with the track of muon in four layers of detectors located in the return yoke of 4T superconducting solenoidal magnet. Detectors - RPC chambers will be arranged in four stations interleaved with magnetized iron providing the field up to 1.8T. Muon track passing through the four RPC stations will be recorded in form of a pattern of hit RPC strips (Fig.1). Bending of this track is function of muon momentum. PACT will compare the track with the set of valid patterns programmed into the PAC [6].

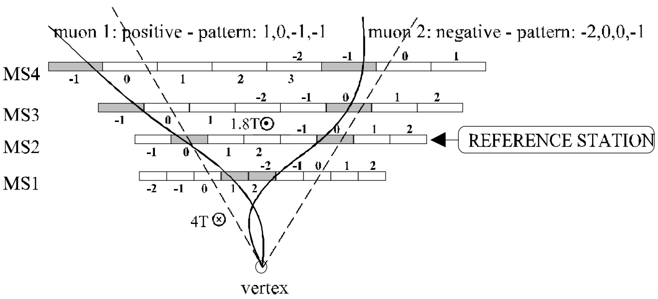

Fig.1 RPC PACT: Examples of muon tracks and patterns

B. Segmentation

The RPC trigger of CMS is foreseen to cover an area up to η = 2.1 with a possibility of upgrade up to η = 2.45. The smallest logical unit of PACT is called a segment. A segment is assumed to be 1 strip long and 8 strips wide and it covers 2.5 degrees in φ and ~ 0.1 unit in η (Fig.2). These numbers determine double muon resolution of the trigger, i.e. two muons within the same segment will be seen as one (one with bigger momentum). The information from all triggering planes within a given segment of the detector is first processed by the segment trigger processor. The main function of the segment processor is to recognize a muon and measure its momentum. It is performed by the Pattern Comparator (PAC) described in the next section.

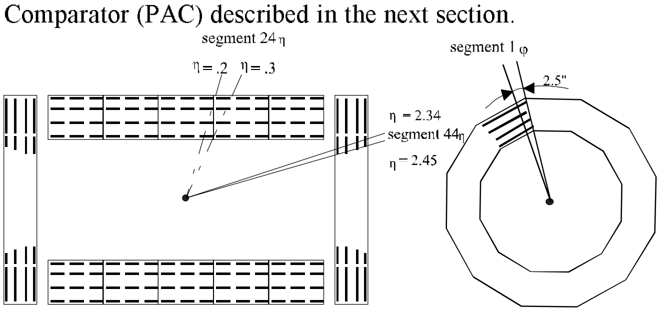

Fig.2 RPC PACT: Segment view in η and φ

To make the decision PAC needs a number of signals coming from several muon stations. Most of these signals are used in several PAC's.

To reduce the length of interconnections we plan to place certain number of segment processors (PAC's) with synchronisation and pipeline memory ASIC's and the first level of sorting ASIC's [see next subsections] on one trigger and readout board (TRB). The TRB's will be groupped into the trigger and readout module (TRM) and equipped with the next step of sorting tree ASIC's and necessary service circuits, like DAQ interfaces, timing system interface, control system interface, test pulse generator and test processor.

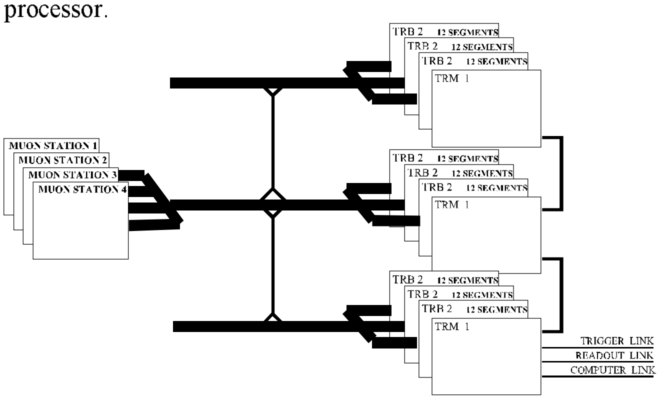

Fig.3 RPC PACT: Schematic layout of trigger electronics

C. Front-end analog electronics

Aim of this part of electronics is to provide low jitter digital signals which could be transmitted over the distance up to 10 meters into the TRB board without signal quality degradation. In the CMS detector the RPC's may be exposed to particle rate close to 1 kHz/cm^{-2}. In order to maintain high efficiency they have to be operated in so called low gain mode [4,5]. This implies usage of a fast, high gain amplifier followed by a discriminator. In this mode one can obtain a time resolution σ = 1-2 ns.

We plan to equip our front-end electronics (placed on the detector) with test facility which will be controlled from the TRM. It is foreseen to use test pulses to check all channels and perform preliminary time calibration. Final time calibration will be done with real muons. To reduce the number of interconnections between TRB's (and facilitate resynchronisation task) part of chamber signals will be send to two neighbour TRB's.

D. Synchronisation and Pipeline Memory (Fig.3)

The purpose of the synchronization block is to synchronize the signals coming from 4 different muon stations and to provide signals related to one specific bunch crossing for PAC trigger processors. The same signals will be stored during the time when the first level trigger (FLT) decision ("Accept "signal) is elaborated . In the case of CMS the time needed for FLT decision will be of order of 128 * 25 ns. If the FLT decision will be positive - coresponding stored data will be shifted to the derandomizer memory. Present DAQ simulations shows that the depth of the derandomizer buffer has to be at least 16. Derandomizer buffer will be accessed by zero suppresion circuit and followed by DAQ intarface.

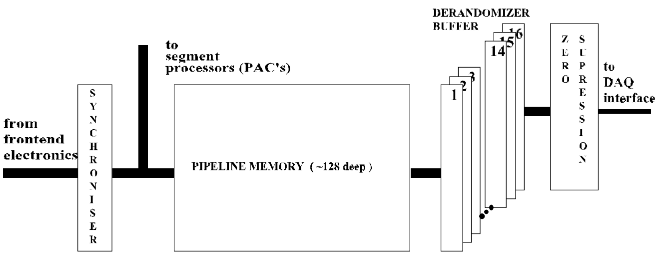

Fig.4 RPC PACT: Synchronization and pipeline memory ASIC

E. Pattern Comparator (PAC)

PAC is the main part of TRB. The PAC provides the information about the highest momentum muon crossing the segment volume. The output of the processor will be a 6 bit code of the muon momentum. The most significant bit defines the sign of the muon. Code "H00" is reserved for situation where was no muon in the segment (or its momentum was below the lowest threshold).

PAC uses as its inputs data from the segment synchronization chip as well as the synchronized data coming into the segment from neighbour TRB's (Fig.5). The first part of PAC increase the quality of the input data :

- by seting to "0" noisy strips in case they cause a lot of false triggers,
- by seting to "1" dead strips in case they cause significant efficiency losses,
- by replacing the cluster with his center of gravity. The simulation shows significant increase of trigger quality when simple declustring function replace cluster of 3 hits with his center.

Only the highest momentum muons will be recognized using single strip signals. At low momentum precision of the measurement is dominated by multiple scattering and full granularity is not needed therfore lower momentum muons will be recognized using the 2-fold, 4-fold or 8-fold OR's of strip signals. It coresponds to increase of the strip size [2]. The second part of PAC prepare the OR signals needed to recognize muon tracks of lower momenta.

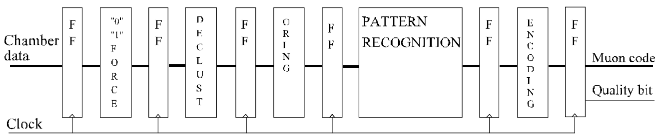

Fig.5 RPC PACT: Pipelined PAC structure

Pattern recognizing part of PAC will be divided into parts using single strips, 2-fold OR's, 4-fold OR's and 8-fold OR's. Each of these parts will provide an unique muon momentum code. Single strip part will have 8 identical blocks devoted to recognize muon tracks starting with one out of eight reference strips in a segment. Similarly 2-fold OR's part will contain 4 blocks, 4-fold OR's part will contain 2 blocks and 8-fold OR's part will contain 1 block. Figure 6 shows the construction of the pattern recogition part for single strips, containing 8 blocks. MS1-MS4 coressponds to the muon stations, hatched boxes represents programmable circuits, Ai -j box defines one muon pattern. The rest of the scheme allow us to find the highest momentum muon and to code its momentum. Each of the blocks will be able to find up to 100 programmed positive or negative tracks coressponding to one reference signal (strip, or n-fold OR). We shall accept tracks defined with four points ("quality bit" will be set to "1") or in absence of four point tracks - tracks defined with three points (in this case "quality bit" will be set to "0"). Last part of PAC selects the track with the highest code out of set of all tracks found in different blocks.

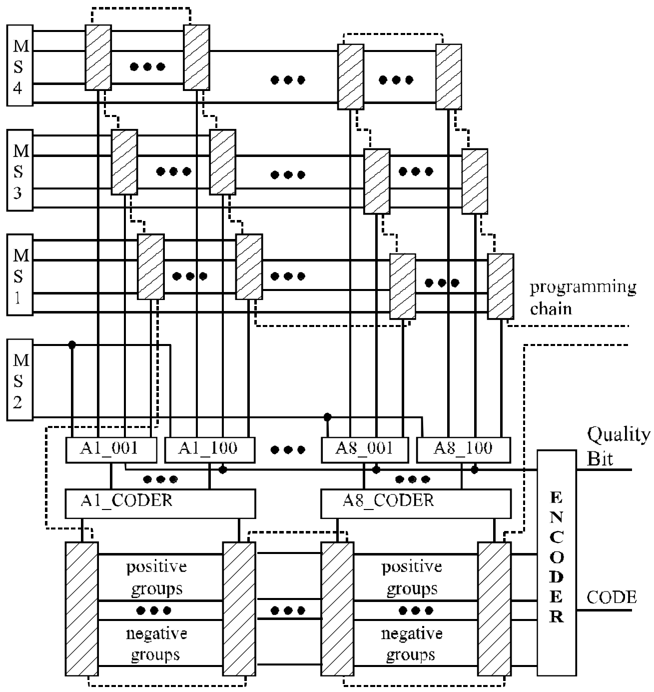

Fig.6 RPC PACT: PAC - pattern recognition

PAC operates in a pipelined mode, which means that each operation which involves more than 25ns will be devided into several suboperation each of which could be made in less then 25 ns. It will allow us to provide the trigger decision for every bunch crossing. Estimated time needed to make the muon momemtum identification in the PAC is 6 * 25ns. The PAC ASIC will be equipped with a self test facility and boundary scan test (BST) circuit. BST will be used to testing of TRB and also for programming of the PAC.

Patterns will be given first by the simulation of the muon tracks in the detector and of detector response. Later they will be updated using real muon tracks reconstructed with the help of precise muon chambers. Information about dead and noisy strips can be also included in the patterns.

F. TRM services

A group of several TRB's will form Trigger and Readout Module and will be equipped with various service devices:

- interface to the timing receiver ASIC (distributing the clock and control signals),
- controller for boundary scan test system (all ASIC's will be equipped with BST circuit),
- on board processor to fulfill TRB's, TRM tests as well as calibration and programming tasks,
- test pulse generator - to provide test pulses for the frontend electronics.

G. Sorting Tree

The basic goal of the sorting tree is to reduce the amount of data to be sent to the global trigger. This function will be performed by a tree of dedicated VLSI sorter circuits each of which will find the four highest p_t muons out of eight candidates and it will propagate the segment addresses of selected muons [2,11].

We plan for each of 14 η sectors of CMS to send 4 muon momentum codes (with relevant segment address) to global muon trigger processor.

H. Tests and developements

An ALTERA 7000 (EEPROM) prototype of the PAC was built and tested with the muon beam in the framework of the RD5 experiment at CERN [8]. Momentum measurement to 100 GeV was demonstraited [9].

First attempt to put PAC on the silicon done in Mannheim University has shown a possibility to put over 6000 pattern on surface of 1.5cm^2 using 1.0 μm standard cell technology [10].

Next ASIC is under design by the Microelectronics group of the Warsaw University of Technology. This version will utilize full custom technology in order to take the adventage of a specific architecture of PAC while preserving its flexibility. The demonstrator chip will be realized in 1.0 μm technology and will contain only a single strip block for 8 bit segment (but no 2,4,8-fold OR's) and BST circuit.

Sorter demonstrator ASIC is under design[11]. A XILINX model of the sorter will be used in a PACT test bench device.

The modular PACT test bench device is under construction. Aim of this developement is to start parallel work on different aspects of RPC based PACT trigger system, namely:

- tests and calibration procedures for RPC,
- boards and system tests (boundary scan),
- ASIC's (PAC, sorter, timing receiver, synchronizer) testing,
- preparing the software tools for the PACT environment.

III. ACKNOWLEDGEMENTS

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