The Cosmic Ray Hodoscope for Testing Thin Gap Chambers at the Technion.

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Abstract

The cosmic ray hodoscope built at the Technion for the test of ATLAS Thin Gap Chambers (TGCs) is described. The mechanical structure, readout electronics, data acquisition and operating settings are presented. Typical TGC test results are presented and discussed.

Introduction

The detection of a charged lepton is the primary trigger for many LHC processes [1]. The high luminosity imposes rather stringent requirements on the trigger detector performance [2]. The muon trigger system has to provide a fast digital signal within a 25 ns gate imposed by the interval between beam crossings. The first level trigger is required to reduce the 40 MHz beam crossing rate to less than 100 KHz of the most interesting events.

Thin gap chambers (TGCs) [3] were chosen as the muon trigger chambers in the endcap region of the LHC experiment ATLAS. A thin gap chamber consists of a plane of closely spaced wires maintained at positive high voltage, sandwiched between resistive grounded cathode planes (Figure 1). A TGC is characterized by an anode wire to cathode plane gap distance which is smaller than the wire-to-wire spacing. ATLAS TGCs are produced with wire to cathode plane distance and 1.8 mm for the wire to wire spacing [4].

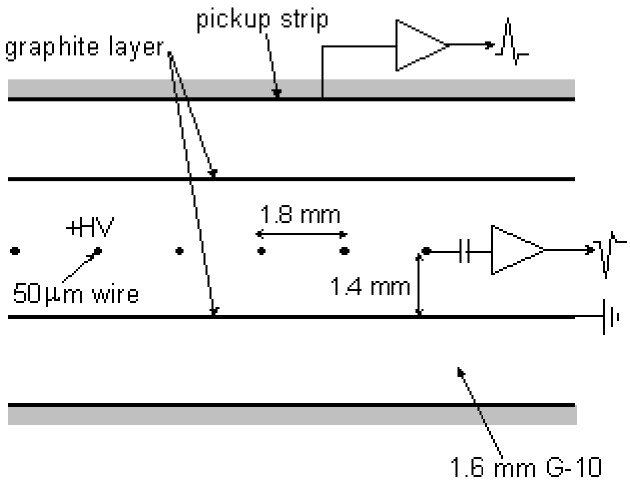

Figure 1: The structure of a Thin Gap Chamber

The TGCs are well suited for the LHC as they operate in a saturated proportional mode, giving fast signals with typical rise times below 5 ns. A saturated mode of operation leads to strong signals with reduced Landau tails and high signal–to–noise ratio. Therefore, with simple electronics, the TGC can satisfy the muon trigger requirements in the endcap region. The saturated proportional mode is achieved under a strong electric field obtained with very thin 50 microns gold plated tungsten wires and a very small gas gap. A gas mixture of 55% CO_2 and 45% n-pentane optimizes the shower amplification and quenching.

In the ATLAS detector, there will be seven layers of TGCs in the middle tracking layer of each end-cap, around z = 14 m, (z is measured along the beam axis from the center of the ATLAS detector). The TGCs will be arranged in one triplet (consisting of three wire planes) and two doublets (each consisting of two wire planes) of chambers, with separations in z of 70 cm and 30 cm.The TGC layout is described in detail in reference [4]. The trigger detectors total 3592 chambers for the two end-caps, and about 6200 m^2 of wire area.

About 2500 ATLAS TGCs are being produced at the Weizmann institute in Israel, and in Shandong University in China. Detailed testing of these chambers is performed at the Technion and at Tel-Aviv University.

We have built a cosmic ray hodoscope for testing the operation of these detectors. In this hodoscope the response of the chambers to energetic cosmic ray muons is recorded and analyzed. The hodoscope measures the exact time and space location of the cosmic ray hit and reads out the chambers which are being tested to verify that they produce a corresponding signal within the required time interval. The hodoscope has been constructed and is in operation since October 2000.

The cosmic ray hodoscope

The structure of the Technion cosmic ray hodoscope is shown schematically in figure 2. A photograph of the hodoscope is shown in figure 3.

Groups of 6 to 8 TGC units (12 to 24 wire planes) equipped with front-end electronics are mounted in the hodoscope as a stack (as shown in figure 2). For each cosmic ray trajectory, the output from each channel of the front-end electronics is read by a TDC (Time to Digital Convertor).

Two arrays of scintillators (2.4 x 1.4 m^2) are placed above and below the stack, covering its entire area (as shown in figure 2). The scintillators, equipped with light guides and photo multiplier tubes (PMs) are read out. A coincidence between signals in the two scintillator planes provides a trigger for the cosmic rays.

Precision chambers (2.4 x 1.3 m^2 active area) provide a precise hit position. These precision chambers are specially designed TGCs that have thin strip readout in both x and y. The strip pitch is 3.6 mm resulting in 1024 channels per precision chamber. Along the wires, these chambers allow a determination of hit position to an accuracy of a few hundred microns, using the distribution of charge between adjacent strips. In the other direction the hit is always found at the closest wire, giving a 1.8 mm precision. The design calls for three such chambers, one between each scintillator plane and the TGC stack, and the third in the middle of the TGC stack. Fitting a straight line to the hit positions in the precision chamber allows the determination of the expected hit position in each of the stack TGCs. It will also enable the rejection of muons that had their path deflected by multiple scattering so that their precise position determination is impossible. Currently there are only two precision chambers (top and bottom) in the system. This seems to provide sufficient accuracy to resolve features like the chamber supports.

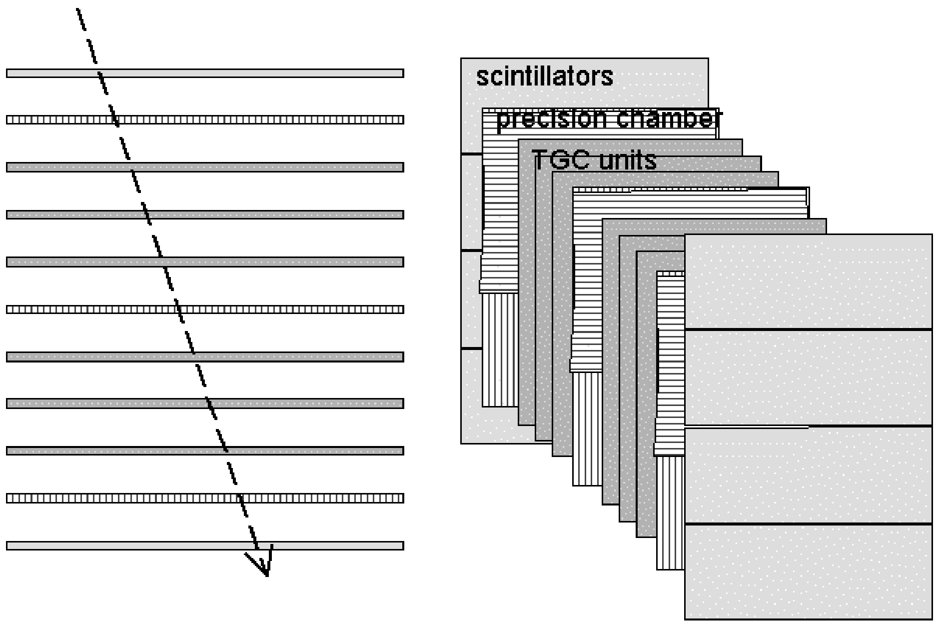

Figure: 2 A schematic structure of the cosmic ray hodoscope at the Technion

Figure 3: A photograph of the Technion testbench structure

Data acquisition

The functional schematic of the testbench data acquisition is shown in Figure 4.

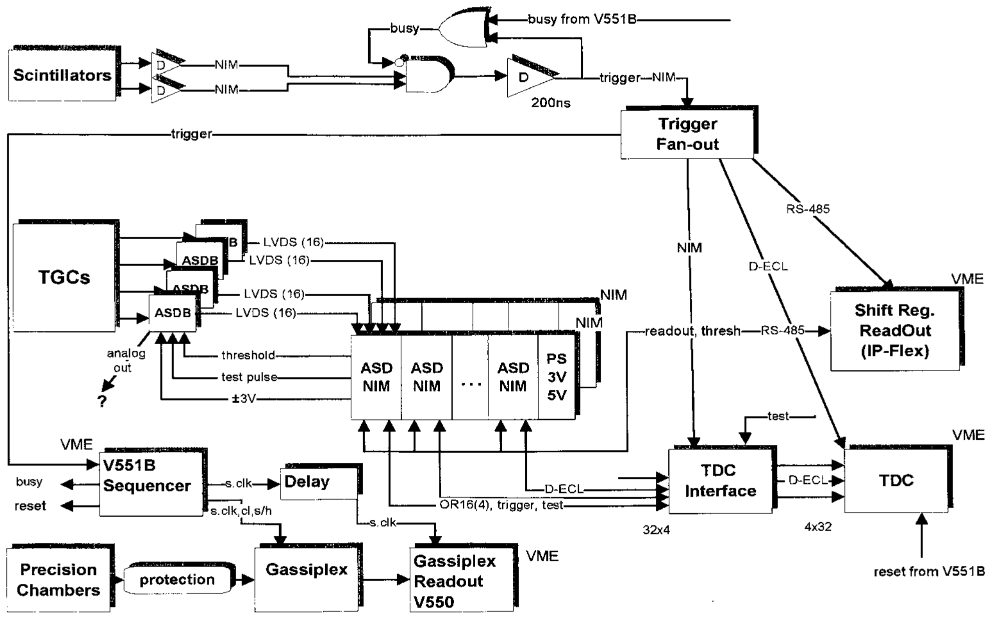

Figure 4: Testbench DAQ schematic

Each of the four scintillators in the two layers is equipped with Philips XP2262 PMs at both ends. Signals from the eight PMs in each layer are OR'd and a coincidence between the top and bottom layers is required to trigger the system. Separate signals from each end of the scintillators (OR of four front and OR of four back) are fed into a CAEN V767B multichannel TDC, to be used in the calculation of the time in which the muon entered the system.

The precision chambers are equipped with Gassiplex front end chips developed at CERN [5]. They are read into a V550B CAEN Readout for Analog Multiplexed Signals, the reading is controlled by a CAEN V551B sequencer. The readout process takes 2-4 microseconds per channel but channels are read in parallel into several ADCs (Analog to Digital Convertors).

The TGCs in the stack are equipped with ASDs (Amplifier Shaper Discriminator) with which they will be read in ATLAS[6]. The ASD signals are passed to ASD-NIM modules which were designed at the Weizmann Institute's electronics and data acquisition unit. Each of the two boards in these modules take 32 LVDS [7] inputs from 2 ASDs and outputs 2 differential ECL signals. Each output signal represents the OR of the 16 even or 16 odd inputs. These signals are fed into the CAEN V767B multichannel TDC, reading out the time of the chamber response. The identity of the channel which recorded the hit is encoded in a shift register, and is read out by a VME module, also designed by the Weizmann Institute's electronics and data acquisition unit.

TGC testing procedure

The testing procedure starts at Weizmann with the following steps [8]:

After completion of assembly, the chamber units are kept at 2900V for a day, while flowing CO_2. If successful, they are flushed with the operating gas mixture (CO_2-n-pentane) for two days, then run for one day at their nominal operating voltage and then 200V above it. The chambers are scanned with a $Ci^{90}Sr$ source to detect possible noise problems and each of the channels is checked for the presence of signals. The chambers are then flushed with CO_2, sealed and delivered to the Technion for detailed testing. These include preliminary checks, an efficiency test and validation.

Preliminary checks at the Technion

The preliminary checks screen out chambers damaged during transportation. After being inspected by eye for damage, they are flushed with CO_2 for 48 hours and checked for leaks. The chambers that pass the preliminary checks are transferred to the TGC Cosmic Ray Hodoscope Test Bench for the efficiency test. The chambers are filled with the operating gas mixture for 48 hours, and tested for sparking under high voltage before starting the cosmic ray test. The positions of the unit alignment markers are measured with respect to the testbench coordinates, to enable a transformation of hit positions from precision chambers coordinates to TGC unit coordinates. Information about the unit is entered in a testbench database[9]. This web based database allows to communicate the information about the unit disposition to the construction site at Weizmann.

Cosmic ray test

The goal of the test is an efficiency map of the detector wires and strips over the whole active fiducial area. The position resolution for each hit is more than sufficient to resolve the inactive areas caused by the inner supports of the detectors. The statistical uncertainty on the efficiency per cm^2 is required to be less than 10%. Additionally, the statistical uncertainty on the efficiency per cm in the projections of the map in the x and y directions, is required to be less than 1%. Three days of data taking supply sufficient statistics.

A provisional evaluation of the performance of each counter is done after a few hours of data taking. If the preliminary efficiency is high enough, the test is continued until sufficient data is collected. If the efficiency is too low, the signal threshold is lowered by 10% and the efficiency test is continued for another period for re-evaluation. If a chamber does not pass the test, it is removed from the hodoscope for offline local repairs if possible, or sent back to the Weizmann institute for repair.

Hit position reconstruction

The hit positions in the precision chambers are calculated as the weighted mean of the strip charge, as measured by the ADC. Typical charge distribution from muon hits spread over five to ten strips. An event is required to contain one hit in the x coordinate and one in y in each precision chamber. Muons with certain trajectories produce hits in only one precision chamber, such events are rejected. The muon trajectory is calculated and projected onto each TGC and scintillator plane.

Hit time reconstruction

Given the hit coordinates in the scintillator, the time when a muon passed through each scintillator plane can be calculated from the time of the PM response and the propagation time of photons in the scintillator. Figure 5 shows the distribution of time differences read from the two sides of the scintillators as a function of the difference in distance from the scintillator ends. We obtain from this the propagation time in the scintillator.
There are two estimates of the time when the muon hit each scintillator plane. There is also an estimate of the time of flight between the planes. It is thus possible to select the first measured time when the muon entered the system. The uncertainty in this time is 1.5 ns and it serves as the reference point for the

hit times in the planes of the TGCs. Figure 6 shows a distribution of signal arrival times from a TGC chamber.

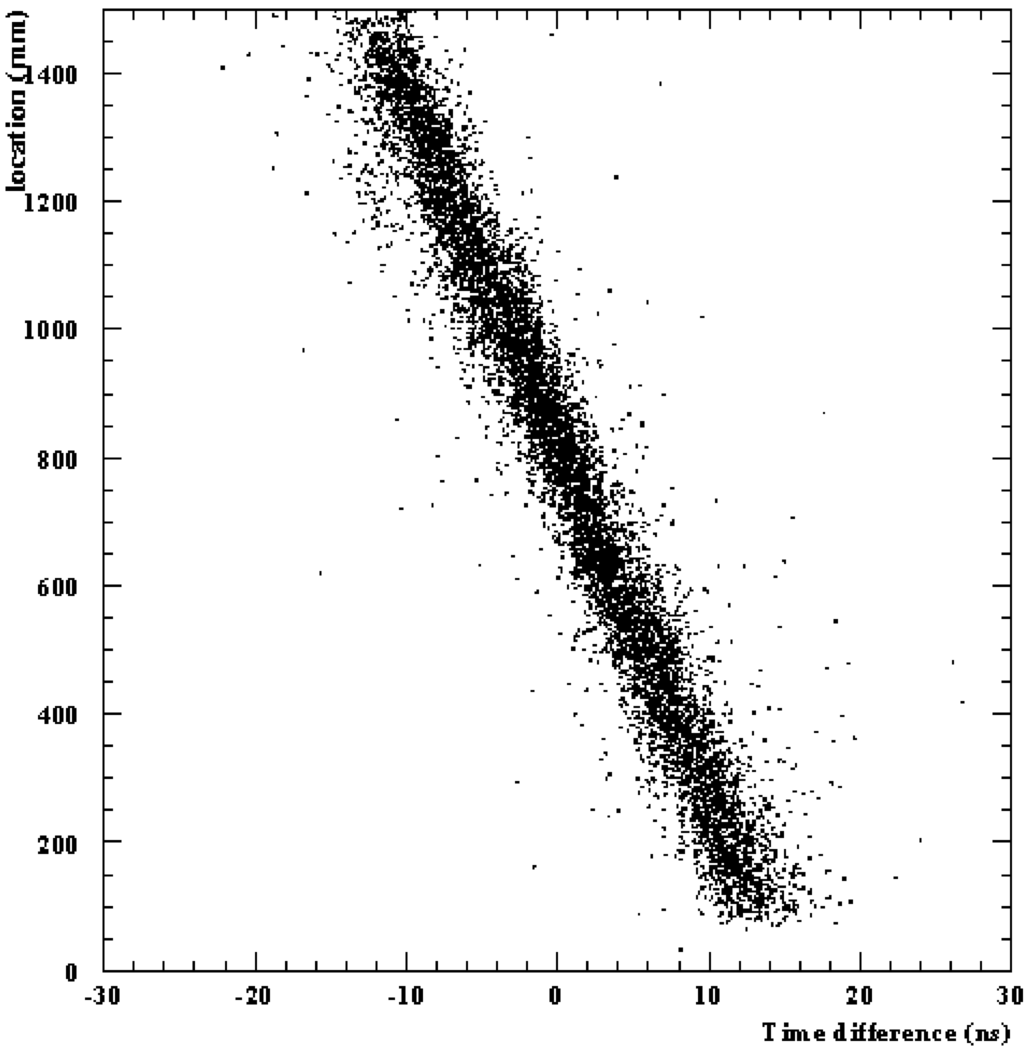

Figure 5: Plot to calculate scintillator propagation times

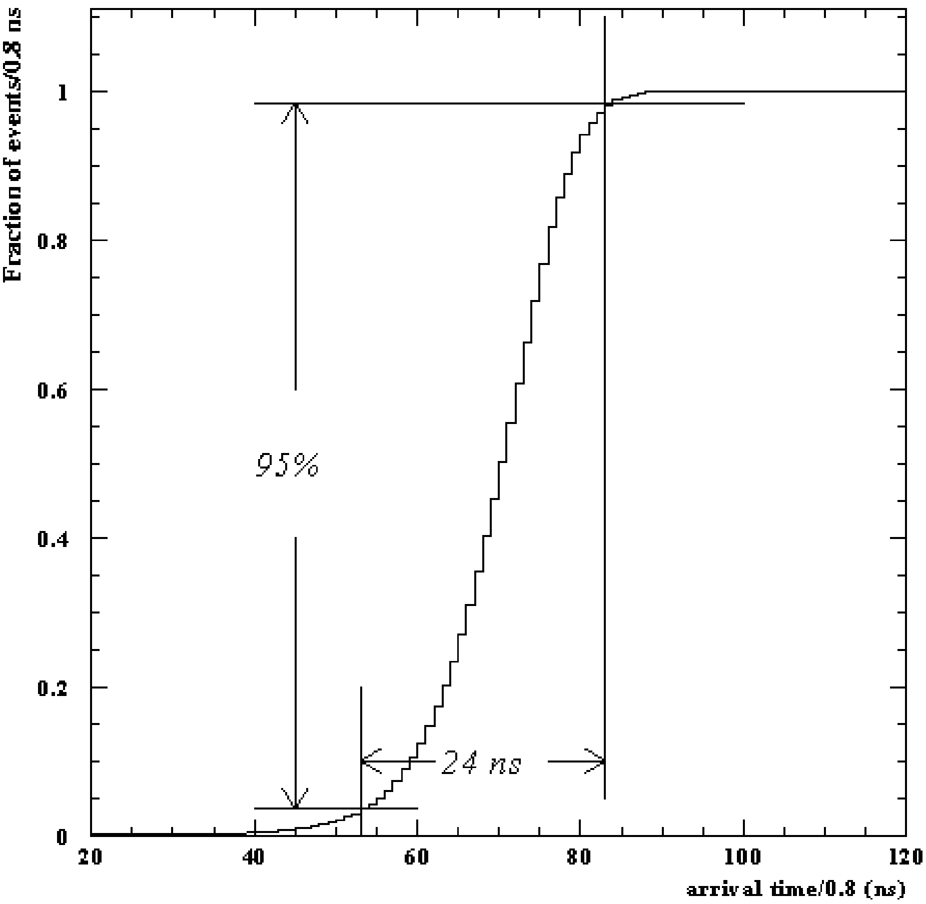

Figure 6: Arrival time of signal from TGC

Efficiency calculation

The hit time and position of a cosmic muon on a specific TGC plane are calculated from the scintillator and precision chamber data as explained above. If no signal comes within 25 ns from a TGC, the muon is counted as missed. Figure 7 shows such an efficiency map from the existing hodoscope (currently done with two precision chambers).

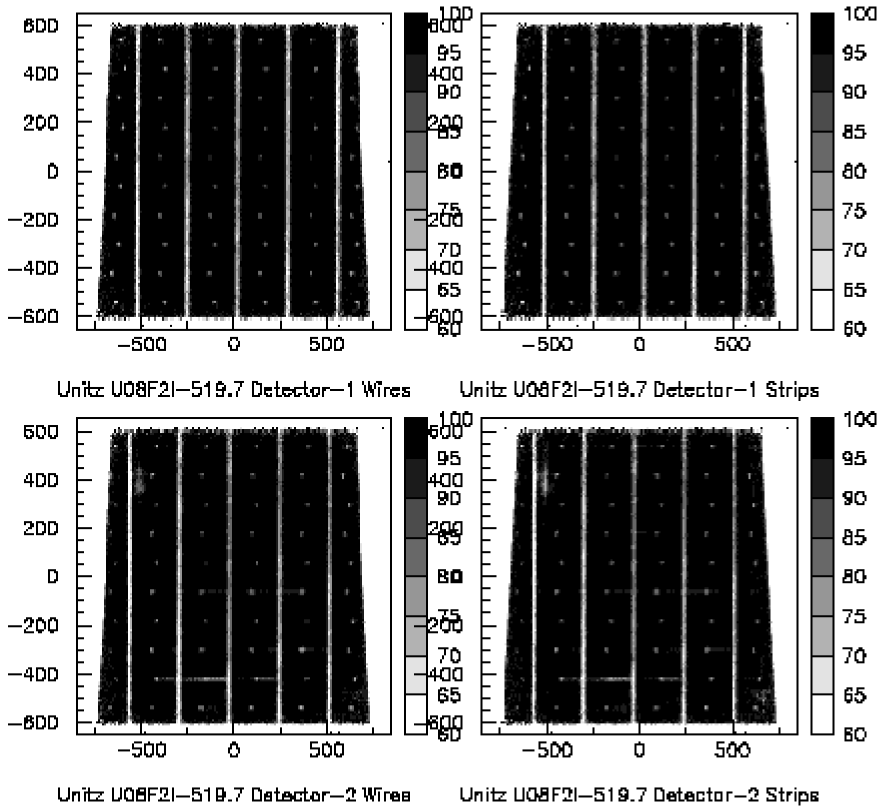

Figure 7: Unit efficiency plot

Validation

At the end of the test, the units are then flushed with CO_2, sealed and prepared for shipment to CERN. Further tests of fully assembled modules with the actual first level trigger electronics will be performed at CERN.

The efficiency maps and timing plots are stored in the TGC testbench database available on the web, together with the high voltage value and ASD thresholds applied during the test. Some post processing can be performed to define inefficient regions for ATLAS offline analysis.

Summary

By July 2002 we have tested about 30% of the total number of chambers assigned to our laboratory. Testing will continue until the end of 2005.

Acknowledgments

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