Hardware Verification after Installation

D0 Run IIB L1Cal Technical Readiness Review

Presented by Dan Edmunds 26-27 August 2005

The purpose of this talk is to describe to the committee how various aspects of the new L1 Calorimeter Trigger System can be tested after this system is installed in the Moving Counting House. The verification tests that are described in this talk are the following:

- BLS to ADF Cable Transition System
- ADF to TAB Cabling
- Trigger Term Generation from Analog BLS Signals
- Timing, Pedestals and Calibration of the ADF Cards

Verification of the BLS to ADF Cable Transition System

The BLS to ADF Cable Transition System receives the BLS signals from the existing long BLS cables which come from the platform. The BLS signals are received on the Patch Panel cards where they are transfered in groups of 8 Trigger Towers (TTs) to the Pleated Foil Cables. From the Pleated Foil Cables the BLS signals flow to the ADF Transition Cards (ATCs). From the ATC cards these signals flow through the P2 section of the ADF Crate backplane and into the ADF cards. All components in this transition system are passive and provide the correct impedance matching and low noise analog signal environment. Testing of this system during and after installation consists of the following 4 steps.

- The ADF cards by themselves provide a first order test of the operation of their analog input section. This test covers all components of the ADF analog section except for the input coupling capacitors and termination resistors.

- In the next step the Test Waveform Generator (TWG) is used to send signals the whole way through the BLS to ADF Cable Transition System and into the ADF cards. The TWG test signals are plugged into a 4x4 array of TTs at a time, i.e. a Patch Panel's worth at a time.. Once plugged in it takes about 10 minutes for the automated test to run. This exhaustive test checks the following characteristics of the BLS test signal after it has passed through the BLS to ADF Cable Transition System:

  - Cabling Errors
  - Signal Amplitude
  - Frequency Response
  - Noise Level
  - Signal Distortion
  - Crosstalk

  By plugging the TWG into all 80 of the Patch Panels the full signal path through the BLS to ADF Cable Transition System is tested for all 1280 Trigger Towers. In addition this test also verifies the correct operation of the analog section of all ADF cards.

- The next step of this testing is to observe signals from the long BLS cables after they flow through the BLS to ADF Cable Transition System and into the ADF cards. During the shutdown this is accomplished using the Precision Calorimeter Pulser System. The BLS signals from the Precision Calorimeter Pulser look somewhat different than the BLS signals from real Tevatron energy deposits. Because of this a little extra work is required to know that a given BLS signal from the Precision Calorimeter Pulser looks OK. For example, BLS signals from all the TTs in a ring at constant eta should look the same (although you may not be able to calculate before hand exactly what their amplitude should be).

- Once there is beam after the shutdown, the final step it to compare the Et values readout by the new Cal Trigger with the Precision Calorimeter Readout. This is done using the (expert mode) Examine program. The output from this work provides both the final confirmation of the BLS to ADF Cable Transition System and is the information that is used to tune the energy calibration of the new trigger system.

Verification of the ADF to TAB Cabling

Verification of the ADF to TAB Cabling is facilitated by being able to control what data comes out of the ADF cards and being able to see what data comes into the TAB cards. An easy way to think of this test is to imagine telling 79 of the 80 ADF cards to put out all zeros and telling the one remaining ADF card to put out some obvious pattern. You then read registers in all 8 TAB cards to verify that the correct locations are receiving the non zero data pattern.

This test can be run by the Trigger Control Computer (TCC) and loop over all the ADF cards. By itself this test quickly confirms that all 240 of the ADF to TAB cables are plugged in correctly. Extensions of this testing technique can check to verify that data is received in the TAB cards aligned on the correct "tick".

Verification of Trigger Term Generation from BLS Signals

Testing to verify that the new trigger system can go the whole way from analog BLS signals to generation of the correct Trigger Terms (And-Or Terms) is done in two distinct steps:

- The accurate digitization of the BLS signals is verified using the steps described above in the section about the BLS to ADF Cable Transition System.
- Digital data, simulating the output of the ADCs on the ADF card can then be used to test everything downstream of these ADCs. These tests can verify the operation of the ADF card Filtering, the generation of Trigger Terms by trigger algorithms running on the TAB and GAB cards, and delivery of these Trigger Terms to the D-Zero Trigger Framework.

The digital data to simulate the ADC output is loaded into the ADF cards on a per accelerator turn basis. This repeating pattern of test data provides a convenient way to test the system without the need for a system wide isochronous "test now" signals.

It is easy to picture how this test can work. For example, if you want to verify the operation of the electron algorithm you can load ADC simulation data that should just barely meet or just barely fail the Et and isolation cuts that the electron algorithm has been programmed with. You can then verify that, as seen in the Trigger Framework (TFW), the And-Or Term from this instance of the electron algorithm is either asserted or not asserted as is appropriate for the current simulation data. In the case that this Term should be asserted you can verify in the TFW that it is asserted for triggering on the correct beam crossing and that it is asserted just once each turn (or whatever is appropriate to match the current simulation data).

Given the inner loop of this test procedure as described above, it is easy to loop over a full set of test conditions that moves the simulated energy deposit around in eta,phi space (for example moving the energy deposit across cards in the trigger system). The correct operation for all 36 beam crossings can also be checked with additional simulation data. Simulation data can be made that just meets or just fails the trigger algorithm cuts in various ways (e.g. meet or fail the Et cut, meet or fail an isolation cut, meet or fail a shape cut).

Timing, Pedestals and Calibration of the ADF Cards

Proper operation of the ADF cards requires that they be correctly timed with the analog BLS signals and that they have uniform pedestals and the correct Et calibration. Much of the work to establishing these operating conditions can be done before this fall's installation shutdown is over.

- The ADCs on the ADF cards sample the BLS signals several times during the BLS signal "bump" caused by an energy deposition from a given beam crossing. Because of this the precise time when a given ADC sample is taken wrt the BLS signal is not important. What is important is understanding the latency in the arrival at the trigger system of the BLS signal "bump" from a given beam crossing.

  The arrival times at the Cal Trigger of the BLS signals from different eta,phi locations in the Calorimeter are spread over a range of about 100 nsec. On the ADF cards the digitized BLS signals are all made isochronous and associated with the "Tick Number" of the accelerator beam crossing that caused the energy deposit that these digital values represent. The timing information needed to setup all the ADF cards is derived from hundreds of measurements that were taken during the installation and operation of the old L1 Cal Trigger.

  After beam returns the correct adjustment to compensate for the spread in latencies of the individual BLS signals can be verified either with a scope or by purposefully setting the timing off by 30 or 60 nsec and seeing that the response of the new Cal Trigger has gone down wrt the Precision Calorimeter Readout.

- Unlike the Precision Calorimeter Readout system where pedestal values and calibration constants can be applied offline, the trigger system needs to take care of these tasks on the fly as the data from each beam crossing is being processed.

  The pedestal of each channel in the ADF cards is adjusted automatically by a utility on the TCC called, "Find DAC". Because part of the pedestal that is seen by the trigger system is due to synchronous noise on the BLS signals, the Find DAC utility must be run when the Calorimeter PreAmp and BLS systems are powered up and running normally. All ADF channels are adjusted by Find DAC for a uniform non-zero response when there is zero energy in the Calorimeter. The non-zero ADC response to zero energy is necessary to see "negative noise". Because the ADCs on the ADF card are only 10 bit it is straight forward to design the analog circuits so that they have zero expected drift. The difference between various runs of Find DAC can be compared to verify that none of the channels have drifting pedestals.

  The initial Et calibration of the new Cal Trigger can be carried over from the old system. The Et output from all channels on all ADF cards is defined to be 0.25 GeV of Et per LSBit. The data that controls the calibration of a given channel is held

in that channel's energy to Et lookup memory. Simply put, knowing the calibration of the old Cal Trigger System means that one can work backwards through it and know how many Volts per GeV a given BLS signal is actually delivering to the old Cal Trigger System. One can then work forward through the new trigger system and calculate what data must be put into the Et lookup memory of a given channel in the new system so that it will put out 1 count per 0.25 GeV of Et. Using the calibration of the old Cal Trigger System in this way lets the new Cal Trigger System turn on with a reasonably good energy calibration.

Once the new Cal Trigger System runs in beam the calibration can be checked by comparing the Et readout from the Cal Trigger with the Calorimeter Precision Readout as described above. Information from this comparison is used to adjust the data in the Et lookup memories so that the Et data from the ADF cards is set to 0.25 GeV Et per LSBit.