Outline of STAR Trigger Level 2

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Introduction

This note is intended to describe the proposed Level 2 system in context with the upcoming 2003 STAR physics run. This will not get into great technical detail, but will cover some general aspects of the whole trigger system. Some mention will be made of the trigger as configured for previous runs, but emphasis will be placed on new features for the upcoming run. One should refer to other trigger documents for further details, especially technical aspects, of other parts of the trigger system.

Overview of STAR Trigger System

The STAR trigger system can be described as a set of relatively fast detectors with the associated electronics that are used to process the signals from these detectors. The primary detectors that have been used in year 1 running were the Central Trigger Barrel (CTB) and the Zero Degree Calorimeter (ZDC). The CTB consists of 240 scintillator slats arranged in an array around the STAR Time Projection Chamber (TPC) arranged with four slats in η ($-1 < \eta < 1$) and 60 in ϕ. The main function of the CTB is to measure the charged particle multiplicity in the central mid−rapidity region.

The ZDC detector is located at each of the two bending magnets nearest to the STAR interaction region. Each ZDC detector contains three modules, where each module consists of a series of tungsten plates alternating with wavelength shifting fibers which in turn have PMT's detecting the cherenkov light output. The purpose of he ZDC detector is to measure the spectator neutrons from the collision. The ZDC's were for the 2001 run equipped with a TAC to measure time difference between the two to have a fast determination of the vertex position of the triggered collision.

Four detectors were added for triggering in the 2001 run, but only two were part of the trigger system electronics. This will be explained later, but the main point is that the two that were not part of the trigger system in 2001, will be fully integrated into the trigger system for the 2003 RHIC run.

One detector present for (both the 2000 and) 2001 run was the MultiWire proportional Chamber (MWC). This in reality is not a separate detector, but uses the TPC anode wires as a fast detector. The active volume of the MWC is the region between the gating grid plane and the TPC pad plane. There are 338 anode wires per sector, but only 320 are used for triggering purposes. Electronically, the FEE are cabled so that groups of 20 wires are output into each FEE card. Each FEE card produces a five bit word which represents the number of wires within that 20 wire group that was hit. These five−bit words are transmitted from a Sector Control Board on the detector, to a Sector Receiver Board on the platform. There is one SCB per sector and four SCB's per one SRB. Once the signals arrive on the platform, they are summed in groups of four 5−bit words producing 96 8−bit MWC subsectors. These MWC subsectors, representing 80 wire groupings, are then what is available to the trigger, and then input into the DSM tree.

Another detector partially present for the 2001 run, was the Barrel

ElectroMagnetic Calorimeter (BEMC). Installation of the BEMC is continuing, and it is anticipated that half of the BEMC will be available for the 2003 run. The BEMC towers produce a twelve bit ADC value, but only the top ten bits from each tower are used for further processing to produce trigger information. Thus, for the 2003 run, there will be 150 pairs of six bit High Tower and Trigger Tower input into the trigger DSM logic tree. Details of the summing and processing of BEMC Trigger information is available elsewhere.

Two detectors that were used for proton triggering in 2001, will be incorporated into the trigger system. This means that their digitized output will be input into the trigger DSM tree for processing trigger information. The Beam−Beam Counters (BBC) consists of two counters of scintillator tiles located on either side of the TPC along the beam pipe. Each counter consists of a larger outer and smaller inner hexagonal ring of scintillator tiles. Each ring itself is divided into two sub rings of six and twelve tiles each. There are plans to also possibly add the Forward Pion Detector (FPD) into the trigger system, and details are still to be worked out.

Also to be added to the 2003 run, will be trigger information from the Endcap Electromagnetic Calorimeter. Again, details have yet to be determined on what information will be available to trigger.

Trigger System Logic

As alluded to a number of times earlier, the digitized information from all the trigger detectors is processed in the Data storage and Manipulation Board (DSM) array. The details of these boards are explained elsewhere, but the general principles will be mentioned here. Each board performs two functions. One is manipulating the multiple input data with the on−board FPGA. The manipulation is generally very simple, since it must be accomplished in the time of one RHIC crossing (~107 ns), so what one can do with the data is very limited. Generally, one is restricted to simply summing the integer input or making simple comparisons.

The other function is to store the data in cyclical buffers for later retrieval. Each buffer is 64k long, thus this information is available for ~7 ms after the initial collision of the event. This information stored in this buffer is what will eventually be available for Level 2 trigger analysis, and more will be discussed on this later.

Each DSM board is configured to input 128 bits and output 32 bits. Thus one can configure the DSM tree in layers, such that the output of four (or more) can be used as input into the next layer of boards. This is what is done for the STAR trigger system, and is described in detail elsewhere, such as DMS and Level 0 documents. The CTB and MWC boards are used to sum the charged particle multiplicity, and thus three bits eventually are output to reflect whether or not the charged particle multiplicity is greater than any of three configured thresholds.

The outputs of all the DSM trees are then used as input into the Trigger Control Unit (TCU), which is the board which makes the decision whether or not to issue a trigger. It is the only device in the entire STAR detector which issues a trigger. The TCU is highly configurable in terms of what inputs from the DSM trees are required for it to issue a trigger. It is also designed to handle special trigger requests, such as TPC laser calibrations.

As alluded to earlier, this is the so−called Level 0 of the STAR trigger system. What determines the level of the trigger are primarily two things: the allotted time available for making a trigger decision, and the data available for that particular level in making the trigger decision. The STAR trigger system is divided into four levels, 0, 1, 2, and 3. For level 0, the allotted time is ~1.5 μs after the collision, which is a fraction of the drift time of the TPC and also the time allotted for opening the TPC gating grid. The information available is the bit sets sent to the TCU, for instance, as mentioned above, one could have multiplicity information in terms of whether or not the charged particle multiplicity from the CTB and/or MWC was greater than one or more of pre–configured threshold values. The combination of TCU input bit sets composed of the output of the Last DSM (in the DSM tree) and the set of bits from the "Live" detectors, is input into the Trigger Word LUT. The Trigger Word is defined by the user, and the pre–configured bit sets are compared with the input stream by the TCU to determine whether or not to issue a trigger. Details of this process is found in TCU documentation.

Level 1 is defined by the drift time of the TPC or ~100 μs. The Level 1 does not issue triggers, but issues accepts or aborts on the triggered event. The analysis of the event is performed by a VME Motorola 2306 CPU. The data available for processing and analysis, is the data coming into the Level 0/1 crate that also holds the TCU. This is in general the last layer of the DSM tree and consists of data in the following list:

Detector	***Array Size***	***Coverage***	***Pixel Size***
CTB Multiplicity	4X4 (η,ϕ)	$-1<\eta<1$, 2π in ϕ	$0.5\ \eta$ X $0.5\ \pi$
MWC Multiplicity	Two 2X4 (η,ϕ)	$\|1\|<\eta<\|2\|$, 2π in ϕ	$0.5\ \eta$ X $0.5\ \pi$
BEMC , jet patches(?)	1 X 3 (η,ϕ)	$0<\eta<1$, 2π in ϕ	$1.0\ \eta$ X $2\ \pi/3$
EEMC ?	?	?, 2π in ϕ	?
BBC	N/A	$\|2.1\|<\eta<\|5\|$, 2π in ϕ	N/A
All ZDC information	N/A	N/A	Individual modules

Level 2 is defined by the digitization time of the slow detectors, or ~5 ms. As with Level 1, the information is analyzed and processed on a VME Motorola 2306 CPU, but for the 2003 physics run, there are plans to upgrade this to a fast Linux PC. The information available to the Level 2 processor for analysis, are all the trigger data described in the overview section of this note as well as information available at Level 0 and Level 1. With a fast processor, one can in principle do any integer or floating point operation on the data that is available. A summary of the data available for processing is:

Detector	***Array Size***	***Coverage***	***Pixel Size***
CTB MIPS per slat	4 X 60 (η,ϕ)	$-1<\eta<1$, 2π in ϕ	$0.5\ \eta$ X $\pi/30$
MWC Multiplicity	Two 4 X 48 (η,ϕ)	$\|1\|<\eta<\|2\|$, 2π in ϕ	$0.5\ \eta$ X $\pi/6$
BEMC Trigger Towers and High Towers	5 X 30 (η,ϕ)	$0<\eta<1$, 2π in ϕ	$0.2\ \eta$ X $\pi/15$
EEMC	?	?	?
BBC Charge and Timing	Two 1 X 16 and 1 X 8 (η,ϕ)	$\|2.1\|<\eta<\|5\|$, 2π in ϕ	$1.6\ \eta$ X $\pi/8$ (inner ring) $1.3\ \eta$ X $\pi/4$

Detector	***Array Size***	***Coverage***	***Pixel Size***
FPD	?	?	?

These data represent what is available in the first layer of the DSM tree, but one should keep in mind that all data in all layers of the DSM tree is available to the Level 2 analysis CPU. In summary, the available data represents all the digitized data available to the trigger from the fast detectors, in the finest pixel size – before the summing process in the DSM tree.

What will not be discussed here is the Level 3 processing. This is done after the slow detector data has been digitized, and thus has available to it TPC cluster information. Thus Level 3 does fast tracking, and has much more information (and time) available to it. For further details on Level 3, one should review appropriate documentation from the Level 3 group.

Level 2 Analysis

The current plan for Level 2 analysis, is to have a common module that can be used in the trigger real time software, and also for off–line analysis. Any given L2 analysis maker that will be written needs to inherit from a standard L2 analysis maker (trgL2Algorithm). This maker will do general analysis tasks common to all other analysis modules, such as handling input parameters, counters, pre/post scaling, and generation of summary data. It is anticipated that pre/post–scaling will be useful, where only every Nth event is analyzed in Level 2 (pre–scale) and every Mth event that passes a Level 2 algorithm will be issued an accept (post–scale). The values of N, M can be different for the different Level 2 algorithms. Each algorithm can have up to 32 input parameters, and this will be configurable at the start of a run. The trgL2Algorithm class will contain methods which will map the Level 2 raw trigger data and make it available in (Z, ϕ) arrays for analysis. Details of the trgL2Algorithm class will be made available elsewhere. The users analysis module only need be concerned with the available L2 data, and needs to run under a time budget of ~4 ms on a 1.5 GHz AMD processor running Redhat 7.2 Linux.

The issue of counters needs to be addressed in context of all trigger counters. The TCU for the 2003 run will be of a new design compared to the one used in the previous runs. The TCU produces, among other things, a Trigger Word that classifies each event as belonging to a specific class. There will be two counters on the TCU, the Live Counter and the Trigger Word Counter. The Live Counter will monitor the TCU performance (Live Time). The Trigger Word Counter will count the number of times each Trigger Word occurs when the TCU is Live.

The anticipated Level 2 counters will count the number of Level 2 accepts and aborts for each Trigger Word, and for each Level 2 algorithm. It is assumed that there could be multiple algorithms in a given run, and algorithms will be called based on the Trigger Word for the triggered event and the pre–scale value for the given algorithm. What is not clear is whether it is necessary to make provisions for two simultaneous analyses being performed on a given event. This situation will occur if there are multiple analyses modules configured, and more than one is configured to do analysis on the same Trigger Word. In any case, the values of all counters at the end of a run, will be stored in the database for use in off–line analysis. The database information will then be available