General Overview to the STAR Trigger - Run 2003

Version 3.0

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General Introduction

This document is meant to give a STAR collaborator a general overview of the STAR trigger capabilities for the 2003 Physics run. If one needs more detailed information than is presented here, please consult the STAR trigger Web pages:
http://www.star.bnl.gov/STAR/html/trg_l/index.html

In preparation for the STAR trigger workshop on May 5th and 6th, the reader is also encouraged to look at the presentations posted on the STAR trigger web page by clicking the link to "Workshop-2002". The convenience, the address to this page is:
http://www.star.bnl.gov/STAR/html/trg_l/workshop-2002

Overview of Trigger Operation

The STAR Trigger consists of 4 levels of analysis called Level 0, Level 1, Level 2, and Level 3. Level 0 initiates events for STAR, passing them on to the other trigger Levels for further analysis. In contemplating possible uses of the STAR trigger system it is important to understand that the only actions that the L1, L2, and L3 trigger levels can take is to either pass an event on to the next level of trigger, and eventually to DAQ, or to remove the event from the system (abort).

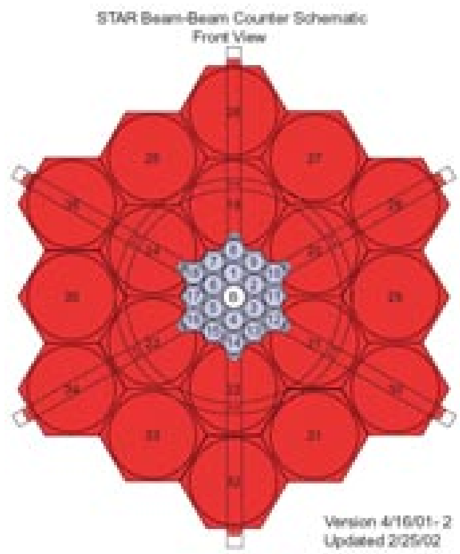
A set of scaler boards is available to record fast detector information and software counters record trigger actions for all crossings. A new Trigger Control Unit (TCU) and Trigger Clock Distribution (TCD) boards will accommodate all known current and planned upgrade detector subsystems. There will also be a new Level 2 CPU farm in the DAQ room for 2003, with the intent to use the Level 1 and Level 2 abort capability to enhance the throughput of good-events to Level 3 and DAQ.

Fast Detectors used in the STAR Trigger

The STAR trigger for the coming run will incorporate information from the following "fast" detectors:

- Zero Degree Calorimeters (ZDC): Hadronic Calorimeters, utilizing fiber readout, and primarily sensitive to the captured (totally internally reflected) Cherenkov light from the central core of the hadronic showers. Each ZDC consists of three modules, each of which is readout with a separate Photomultiplier tube. The ZDCs have transverse (to the beam) dimensions of 10 cm x 10 cm. They reside ~18 m away on either side of the interaction region (IR), at zero degrees. Note that the DX magnet resides between the IR and the ZDCs.
- Beam Beam Counters (BBC): There are two Beam-Beam Counters wrapped around the beampipe, one on either side of the TPC. The BBCs are mounted to the outside faces of the magnet poletips, and cover 2π in φ, and when complete, the range $2.2 \leq \eta \leq 5$. Each counter consists of two rings of hexagonal scintillator tiles: an outer ring composed of large tiles and an inner ring composed of small tiles. Internally, each ring is itself divided into two separate sub-rings of 6 and 12

tiles each. The timing difference between the two counters will locate the primary vertex position. The BBC also provides multiplicity (η,ϕ) information to the trigger. At present, only the inner rings are complete.



- Barrel Electromagnetic Calorimeter (BEMC): It is planned that there will be 60 fully instrumented BEMC modules for the FY03 physics run. They will be configured as a full barrel covering the West end of the STAR detector (2π in φ, and $0 \leq \eta \leq 1$).
- Endcap Electromagnetic Calorimeter (EEMC): It is expected that a portion of the EEMC will be installed and instrumented for the FY03 physics run. At this point it is expected that a maximum of 120° in φ will be installed. This would give acceptance of 2π/3 in φ, and $1.1 \leq \eta \leq 2$, on the West end of the STAR detector. The information supplied by the EEMC to the STAR trigger will be similar to that provided by the BEMC.
- Central Trigger Barrel (CTB): There will be either 118 or 119 of the full complement of 120 CTB trays in place and functional for the FY03 physics run. Please note that the TOFp takes the place on one CTB tray, and there is a proposal to replace another of the CTB trays with an MRPC TOF tray. Each CTB tray contains two scintillators, each of which cover 6° in φ and 0.5 in η. The total acceptance of the CTB will thus be 354° (348° if MRPC TOF installed) in φ, and $|\eta| \leq 1$. The CTB provides charged particle multiplicity (η,ϕ) information to the trigger.
- Multi-Wire Chambers (MWC): The MWC consists of reading out groups of TPC anode wires to extract charged particle multiplicity (η,ϕ) information. There acceptance of the MWC is 2π in φ, and $.96 \leq |\eta| \leq 2.08$. There are 24 bins of data sent to the trigger from each end of the TPC. The binning is 12 sectors in ϕ and η = .96–1.1, 1.1–1.29, 1.35-1.63, 1.63-2.08.
- Forward Pion Detector (FPD): The FPD consisted of Electromagnetic calorimeters on the East end of the STAR interaction hall that were sensitive to forward π^0s in the FY02 physics run. Portions of the detectors, and all of the electronics have been disassembled. Its status for the FY03 run is not clear as of the writing of this document.

Trigger Levels

Level 0

Level 0 analyzes every RHIC crossing in a fully pipelined architecture and decides whether to issue a trigger based on information from the fast detectors and values for prescales associated with each physics condition. The time allowed between the RHIC bunch crossing and the L0 trigger decision is currently ~1.5 μs. The L0 computations take place in field programmable gate arrays (FPGAs, located on DSM boards) located on the first level electronics platform. The information available to L0 is detailed on the trigger web pages for each detector, summarized in the Level 0 DSM Data document for the coming run, and listed in Table 1 at the end of this section. In general, the Level 0 data consists of multiplicity counts (ADC information for CTB, BBC, ZDC, hit counts for MWC), energy deposits (high tower and tower sums for BEMC and EEMC), and vertex location (timing from ZDC and BBC). Level 0 decisions are based on vertex location, multiplicity in different regions (e.g. the UPC and CENT triggers), and energy sums and/or localization (the tower sum and high tower triggers), in which multiplicities or energies are compared to a small number of thresholds.

As the fast detector data is processed through the various layers of the FPGAs it is compacted down to the following pieces of information which are available for the L0 decision.

Table 1. Information available for L0 trigger decision.

Level 0	Det	Measures	$d\eta$	$d\phi$
	CTB	$d^2n/d\eta d\phi$	2	2π
		topology	.5	$\pi/30$
	(MWC)	$d^2n/d\eta d\phi$	1	2π
	BEMC	$d^2E/d\eta d\phi$	1	2π
		(tower sum)	.2	$\pi/15$
		(high tower)	0.05	$\pi/60$
	EEMC	$d^2E/d\eta d\phi$	1	$2\pi/3$
		(tower sum)	.2	$\pi/15$
		(high tower)	.05	$\pi/60$
		(Jet patch)	1	1
	BBC	$d^2n/d\eta d\phi$	1.6	2π
			1.3	2π
		vertex loc.		
	ZDC	0^o neutral E	.1	2π
		vertex loc.		
	FPD	$d^2E/d\eta d\phi$		
	VFHC			
	RHIC	polarization		

While Table 1 above lists the information that can be available to the trigger at L0, a final decision must be made approximately two months before the start of the Physics run (Decision by September 1, 2002 for the upcoming run) on the assignment of the 16 bits that will be available for L0 during the physics run. To illustrate this point, Table 2 lists how these 16 bits were defined during the 200 GeV AuAu run and the 200 Gev proton run in FY02, as well as a possible definition of these bits for the FY03 Physics run.

Table 2. Examples of L0 Bit assignments.			
bit	Run2-AuAu	Run2-pp	Run2003
0	CTB Mult. lo	CTB Mult. lo	CTB M1
1	CTB Mult. mid	CTB Mult. mid	CTB M2
2	CTB Mult. hi	CTB Mult. hi	CTB M3
3	UPC	FPD –no busy	UPC
4	Blue	Blue	Blue
5	Yellow	Yellow	Yellow
6	==0	FPD busy	BBC TAC
7	ZDC TACs	BBC –no vertex	ZDC TAC
8	ZDC sum	BBC -vertex	BBC coinc
9	ZDC coinc	HiTower –lo	ZDC sum
10	BEMC	HiTower –hi	HiTower –lo
11	special	special	HiTower –hi
12	N/A	N/A	FPD
13	N/A	N/A	Jet 1
14	N/A	N/A	
15	N/A	N/A	special

Level 1

The DSM tree of Level 0 compacts the fast detector data into a coarse pixel array which is passed to Level 1, as shown in the DSM tree diagram for the run on the STAR Web page (16 pixels for the CTB, 8 MWC, 8 BEMC, 8 for BBC, and 2 EEMC). In addition, all ZDC data is available in level 1. Level 1 then has approximately 100 μs to decide whether to reject the event based on the ZDCs and the information in the coarse pixel array, or to pass the event to Level 2. The data available for the L1 trigger decision is shown in Table 3. The L1 processing consists of simple C algorithms, which are run in VME CPUs.

Table 3. Information available for L1 trigger decision.				
Level 1	Det	Measures	dη	dφ
	CTB	$d^2n/d\eta d\phi$	0.5	$\pi/2$
	MWC	$d^2n/d\eta d\phi$	0.5	$\pi/2$
	BEMC	$d^2E/d\eta d\phi$	1	$2\pi/3$
		>thresholds		
	EEMC	$d^2E/d\eta d\phi$		
	BBC	$d^2n/d\eta d\phi$	1.6 (2.2 -3.8)	2π
			1.3 (3.8 – 5.1)	2π

	ZDC	All ZDC raw data is available. This includes individual tube and tube sum ADC values as well as E&W TAC values.

Level 2

At Level 2 all of the fast detector data stored in DSM boards is available, in addition to all the data that was available at Levels 0 and 1 (listed in Table 1 and 2). This includes the raw data for all the trigger detectors and the results of intermediate stages of DSM processing for the BEMC and EEMC.

In Level 2 all of the raw data from the fast detectors is gathered to form the fine pixel array (240 pixels for the CTB, 96 for MWC, 32 for BEMC (16 high tower and 16 tower sum), and 32 for EEMC). The data available to the trigger at Level 2 (in addition to all of the L0 and L1 data listed in Tables 1 and 2) is listed in Table 4. Jets can be localized or decay signatures for low multiplicity events may be verified in Level 2. Level 2 analysis algorithms run on a Linux farm, and have approximately 5 ms to reach decisions for each event accepted by level 1. There are discussions ongoing that may lead to all of the BEMC and EEMC raw data being made available to L2.

Table 4. Information available for L2 trigger decision.

Level 2	Det	Measures	$d\eta$	$d\phi$
	CTB	$d^2n/d\eta d\phi$	0.5	$\pi/30$
	MWC	$d^2n/d\eta d\phi$	0.25	$\pi/12$
	BEMC	$d^2E/d\eta d\phi$	0.2	$\pi/15$
	EEMC	$d^2E/d\eta d\phi$	0.2	$\pi/15$
	BBC	$d^2n/d\eta d\phi$	1.6	$\pi/8$
			1.3	$\pi/4$