CTB Requirements Document

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<u>revA</u> RHMinor 4/9/98
<u>revB</u> RHMinor 9/1/98 per review of 6/5/98 and LED clarification.
revC LGreiner 10/21/98 addition of mechanical information/requirements
revD LGreiner 11/13/98
revE LGreiner 1/15/99
revF LGreiner 3/17/99

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CTB Requirements Document

1. Functional Requirements

1.1 Hit counting

<u>1.1.1 Requirement: Signal proportional to number of hits.</u>

Each CTB slat must provide a digital signal proportional to the number of charged particles hitting it in a RHIC strobe (RS) time period. This is expected to be approximately at 9.4 MHz or106 nsec.

Justification: This allows triggering decisions based on multiplicity to be made for the STAR detector at RHIC operating times.

1.2 Operation in level zero (L0) trigger

<u>1.2.1 Requirement: Output within 4 RHIC strobes.</u>

The number of hits on each CTB slat must be provided to the trigger decision tree within 4 RS of the beam crossing in which the particles originated.

Justification: This allows the trigger decision to be made in the 1.5 microseconds allowed for opening the gating grid on the TPC.

1.3 Coverage

1.3.1 Requirement: Coverage TBD
The CTB must be sensitive to particles in the range of -1 to1 pseudo-rapidity.

Justification: This provides coverage for the central part of the TPC and the simulations show particle multiplicities and distributions in this area suitable for triggering purposes.

2. Hardware Implementation Requirements

2.1 Location in Detector

2.1.1 Location
The location of the CTB detectors shall be in an annular ring outside of the STAR TPC.

Justification: The CTB detectors need to be located with as little mass as possible between them and the interaction. The closest practical space is located in an annular ring around the outside STAR TPC. This space has been allocated for CTB tray use by the STAR integration group.

2.1.2 Coverage
The coverage is stated in 1.3.1.

2.2 Tray Hardware

2.2.1 Requirement: 240 Scintillators
The CTB detectors shall consist of 240 scintillator slats.

Justification: The task of fast detection of charged particles with appropriate dynamic range for multiplicities expected in STAR is best addressed with plastic scintillator slats in this solid angle. See requirement 2.2.1.2

2.2.1.1 Material
The scintillator characteristics shall be appropriate in spectral output, light output and speed to the photo-multiplier tubes chosen.
Justification: We need the slats, photo-multiplier tubes and electronics to work as a system. The scintillator Bicron BC408 is suited to this task and has been chosen.

2.2.1.2 Size and shape
The scintillator slats shall cover 6 degrees in phi and 0.5 units in rapidity.

Justification: The number of 240 slats is chosen in order to meet the eta-phi coverage with the appropriate segmentation as well as provide complementary coverage to the TPC and EMC.

2.2.1.3 Coupling to tubes

The scintillator slats must be optically coupled to the PMTs.

Justification: It is necessary to gather the scintillator light into the PMTs for readout into the detector electronics.

2.2.2 Requirement: 240 photo-multiplier tubes (PMT)

Each of the 240 plastic scintillator slats shall be connected to a photo-multiplier tube.

Justification: Photo-multiplier tubes are the accepted and preferred way to read out the light generated by plastic scintillators. Each slat must be coupled to a photo-mutiplier tube.

2.2.2.1 Requirement: PMT/base in B field

The PMT/base/electronics must operate in a 5kG magnetic field oriented approximately along the length of the PMT cylindrical envelope.

Justification: This is the operating field of STAR. The Hamamatsu R5946 PMT is tested and qualified for operation in magnetic fields.

2.2.3 Requirement: At least one LED installed with each PMT-Scintillator assembly.

The LED provides a light signal for aliveness test purposes. See 3.1

Justification: This is needed to test for proper operation of the CTB tray and correct trigger system response.

2.2.4 Requirement: LED signal amplitude

This LED must provide a light signal that is reproducible in PMT ADC to allow monitoring aliveness of PMT and CDB electronics. See requirement 3.1.1

Justification: This is needed to test for proper operation of the CTB tray and correct trigger system response.

2.2.5 Requirement: HV must be provided to each PMT

The HV on each PMT must be computer controllable - both setting and reading the HV value.

Justification: The gain adjustment is needed to reach the required 1 Mip signal level. Reading of the high voltage is needed to confirm the high voltage value.

2.2.6 Requirement: Separate base for each phototube

A separate base shall be provided for each photo-multiplier tube.

Justification: A separate base for each tube is required to provide high voltage and signal connections.

2.2.6.1 Requirement: Gain

The PMT/base gain shall generate a 1 Mip output signal of an amplitude consistent with a digitized value of 5 ADC counts.(In this document, 1 Mip is defined as the signal produced by a relativistic singly charged particle passing perpendicularly through the slat at the center.)

Justification: The Scintillator has been designed to provide a reasonably uniform light output. It is needed to have the 1 Mip signal appear in channel 5 of the 8 bit ADC. This allows for a measure of the particle multiplicity in the slat to be made with the ADC value.

2.2.6.2 Requirement: stability

Gain variation of the PMT/base system due to noise, ripple, instability, etc. must be less than 5%.

Justification: The signal for central AuAu collisions is ~10 Mip. Variation is ~30%. We need to have the gain variation small with respect to this variation.

2.2.6.3 Requirement: Dynamic range

The PMT/base must have a dynamic range in charge output of greater than the expected multiplicities + 4 sigma in charge output with a gain matched to the noise and sensitivity of the accompanying ADC (below) and be monotonically related to the light input over this range (non-saturating).

Justification: The output of the PMT/base should be proportional to the number of particles that pass through the Scintillator. This output is used in the level 1 trigger to determine multiplicity. Each tube sees typically 8.3 particles and the sum is typically 2000 particles (Au on Au). If we assume 10 charged mip tracks / collision and sigma = 3 than the PMT/base dynamic range needs to be 10 + 4(3) = 22. Accuracy of the sum of the PMTs needs to be at the 3-4% level with each tube at the 35% level from statistics.

2.2.6.4 Requirement: Analog output

Each PMT must provide an anode or last dynode analog signal on a connector at the end of the tray capable of driving the signal over 100' of RG58 cable terminated at 50 ohms. A single minimizing particle traversing the attached Scintillator (a Mip signal) will produce a negative going pulse of approximately 100MV with a FWHM of < 30 nsec. with the STAR magnetic field OFF. We expect the PMT current amplification to fall by 50% with the STAR magnet turned on. Thus the mip signal seen at the CDB board during the normal running condition is expected to be ~50 mV. (Note. Scintillator rise and fall times are < 1 nsec).

Justification: This output feeds the CTB digitizer board (CDB). This level is matched to the gain of the CDB board.

2.3 CTB Digitizer Board (CDB):

<u>2.3.1 Requirement: CDB definition</u>
A CDB board will exist to accept analog input from trays and provide digitized output to the remainder of the trigger system.

Justification: This is necessary so that the digitized data can be manipulated by digital trigger system.

<u>2.3.2 Requirement: Functionality</u>
The CDB electronics will contain the following functions:

- 16 channel input on standard 9U VME hardware.
- Slow control interface for control and monitoring via VME
- 16 Gated integrators with individually adjustable start and stop timing.
- 16 Signal discriminators for time-based rejection with individually adjustable start time.
- 16 channels of ADC for digitization.
- Latching for the output(s) of the ADC(s).
- Logic circuitry to use the 8th ADC bit as a timing indicator for peripheral collisions (remotely switched). All channels will be in same mode on each card.
- LED driver system with individual channel masking but simultaneous operation at identical levels.
- 10 tick minimum deep temporary store for trapping of LED signal (read out by Slow Controls).
- Power fuses and regulation.
- Analog monitor, ADC gate timing monitor outputs on front panel, and discriminator output monitor on P2.

Justification: The above components are needed for functionality and stand alone capabilities.

<u>2.3.3 Requirement: Slow Controls Communication</u>
VME will be used to provide a slow control path to read and write to registers in the CDB electronics.

Justification: STARs standard slow control communication paths include VME.

2.3.4 Requirement: Gated Integrators

The anode outputs from the PMTs must be routed to gated integrators whose gate-width is remotely controllable over a range from 20 - 70 nsec with a 10 nsec granularity.
The gated integrator accuracy will be better than 4%
The gated integrator signal to noise will be better than 20:1.

Justification: We need to gate the signal on the time relevant to a collision within the diamond region, and have it be wide enough to collect the full PMT anode signal and to cover the maximum range of arrival times of the signals from fast and slow particles hitting the scintillator at either end and originating anywhere within the interaction diamond.

2.3.5 Requirement: ADC dynamic range

This ADC must have a dynamic range in charge of at least 110 channels matched to the gain of the PMT. The maximum signal will be placed at about half scale.

Justification: The components that make up the dynamic range are:
Variation in mips from path length ~ factor of <2
Average multiplicity of ~10 / slat
Sigma = ~3, 4 sigma = ~12
Total: ~10 + ~12 = ~22
Thus if 1 mip is set to channel 5 in ADC (this covers the variation in mip signal from path length and provides some headroom), the ADC needs to have 5 * 22 = 110 channels.

Therefore the dynamic range is >110

The ADC must be 8 bits to provide a safety factor of two.

2.3.6 Requirement: Discriminator

The anode signal will also be routed to a discriminator having a remotely controlled threshold. A single threshold value will be used for all channels on a card. A single time window width is sufficient for all channels on a card but the start of the window will be adjustable on a channel by channel basis. 5ns granularity is required and a 15 – 45 nsec range. The leading edge of the discriminator pulse shall be used to generate the coincidence with the timing gate with adjustment in 5 nsec steps.
The signal discriminator must detect a 1 mip signal. With an expected mip pulseheight of 50 mV for the STAR magnetic field on, this indicates that the discriminator threshold must reliably reach a lower limit of ~20 mV without triggering on noise.

Justification: This is to allow implementation of a further timing constraint on each PMT signal as a means of reducing Cosmic Ray background in the peripheral physics program.

2.3.7 Requirement: CDB Output
The ADC values must be transmitted out of the CDB to the DSM once per RHIC strobe.

Justification: The data is needed for the trigger on each beam crossover.

2.3.8 Requirement: LED control
LED firing signals shall be provided from the CDB.

Justification: The CDB is the central control and status hardware point for the CTB system.

2.3.8.1 Requirement: LED signal amplitude
Each CTB slat will have at least one LED installed with the PMT-Scintillator assembly. This LED must provide a light signal that is reproducible in PMT ADC space at the 20% level or better to allow monitoring aliveness of the PMT. A single value will be used for all LED drivers on any one card.

Justification: This is needed to test for proper operation of the CTB tray.

2.3.8.2 Requirement: LED arming
Whether or not an LED fires when given the LED trigger signal must be computer controllable (LED arming signal for each PMT). Must be able to fire individual LED's or any group of LED's.

Justification: The pattern of LED firing is needed to test trigger responses to CTB hits.

2.3.8.3 Requirement: LED firing phase
Once the timing signal is given, the LED's must be fired so that the PMT signal arrives back at the CDB overlapping the CDB gate.

Justification: The strobe signal that is transmitted to the CTB contains the timing phase that is needed to insure the proper timing of the light pulse.

2.3.8.4 Requirement: Pulser event flag.
LED firing shall generate a signal to an input of the DSM that is logical true for the duration of the LED firing and coincident with the data arriving at that level in the DSM tree.

Justification: We need to tag pulser events to distinguish them from real data.

2.3.9 Requirement: Readout register
The CDB shall include a readout register to store the ADC values corresponding to the strobes before, during, and after issuing a LED trigger. The depth of this

register must be sufficient to store the “flattop” of the LED pulse. This is expected to be at least 10 ticks. This must be readable by Slow Controls.

Justification: We need to test the system for response to the LED during test phase and to assure that the system is quiet both before and after the LED firing.

<u>2.3.10 Requirement: Analog monitor and ADC Gate test point</u>
A buffered monitor output of the PMT signal shall exist on a connector on the CDB.
A copy of the integrator gate signal must be available on a connector on the CDB.
A copy of the discriminator output shall be available as an ECL signal on P2.

Justification: We want this to check internal timing as compared to the anode signal. There must be <few nsec difference between the relative timing observable at this point compared to that at the actual integrator gate input. Discriminator signal is for possible future use.

<u>2.3.11 CDB Timing</u>

<u>2.3.11.1 Requirement: RHIC Strobe (RS) Phase Control</u>
The phase of the RHIC clock input to the CDB electronics must be computer controllable over >20 ns with a granularity of 2 ns.

Justification: The main phase of the RHIC clock for the CTB is done on the platform in the fanout boards. This additional adjustment is needed to guarantee that phase adjustments can be made for card to card differences.

<u>2.3.11.2 Requirement: Timing control</u>
The adjustable timing of the electronics will be via Slow Controls.

Justification: This adjustability is needed to compensate for local variations in timing and to set operating conditions for integrators and discriminators to match STAR operation.

2.4 Interface to Level 0 Trigger Electronics

<u>2.4.1 Requirement: Maximum Signal delay</u>
The signals from each CDB card must arrive at the DSM within 4 RHIC ticks of the occurrence of the interaction. See 1.2.1

Justification: The level 0 trigger decision time budget allocates 3 RHIC ticks after the interaction to the CTB electronics.

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 0          1          2          3          4
/**********/**********/**********/**********/
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^ event occurs anywhere in this RS	DSM xfer at this strobe

<u>2.4.2 Requirement: Signal phase</u>
CDB signal input to the DSM boards must have adjustable phase with respect to the DSM RHIC clock.

Justification: The DSM boards have their own phase of the RHIC clock. The data must be stable on this clock edge meeting timing requirements as specified in interface document.

<u>2.4.3 Requirement: Signal levels</u>
The signals must be presented to the DSM boards in agreement with the DSM input specification (differential PECL; 34pin connector) as specified in interface document.

Justification: Interface specifications must be followed.

2.5 Timing and Control Electronics

<u>2.5.1 Requirement: Clock and LED trigger input</u>
The CDB's shall receive clock and trigger from the TCD system.

Justification: The CDB's must operate under timing control of the trigger system.

2.6 Power Distribution System

<u>2.6.1 Requirement: HV control and Monitor</u>
The LeCroy high voltage supply must be controlled and monitored via Slow Controls.

Justification: We need to monitor and control the HV to adjust PMT gain. 240 channels are required.
<u>2.6.2 Requirement: LV Power Supplies</u>
Low voltage Power for the CDB boards and trays will be derived from the VME back-plane.

Justification: Low voltage power is needed to power the electronics on the CDB boards.

2.6.3 Requirement: Remote Power Monitor
The status and current of all power sources shall be monitored via Slow Controls system.

Justification: This is a routine function of the STAR standard VME crates.

2.7 Requirement: Lifetime

The hardware components fabricated for the CTB detector and electronics shall be designed to have an operational lifetime of greater than 10 years.

Justification: Ten years is the expected lifetime of the STAR experiment.

3. Calibrations

Note: there are no specific hardware requirements for the calibration of the CTB system. We intend to calibrate the CTB system by associating the hits in the CTB with the tracks in the TPC. The CTB system will, however, need aliveness testing and monitoring.

3.1 LED System

3.1.1 Requirement: The CTB slats shall be provided with a LED based light pulsing system.
In order to test the scintillator -> PMT -> cable -> CDB -> DSM system chain both initially and during the lifetime of the system we will need to generate a light pulse at the scintillator end of the chain as a check of the associated hardware and electronics.

Justification: We need to monitor the integrity of the CTB system over it's lifetime. The requirements for this hardware reside in the CDB electronics. See Requirements 2.3.8.* for details.