Level-0 Trigger Algorithms for the STAR-Spin Program

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In 2002, several detectors were commissioned, upgraded and incorporated into the level-0 trigger system for the STAR spin program:

- Fully azimuthal and East-West symmetric beam-beam counters (BBC), consisting of hexagonal scintillator patches, read out by optical fibers connected to photomultiplier tubes (PMT).
- Top-Bottom/East-West symmetric forward pion detectors (FPD), consisting of 7x7(Left/Right) and 5x5(Top/Bottom) led glass calorimeter arrays and a shower max detector.
- The West half of the Barrel Electromagnetic Calorimeter (BEMC) consisting of 2400 led-scintillator sandwich calorimeter towers.
- Half of the End-cap Electromagnetic Calorimeter (EEMC) consisting of 360 calorimeter towers.

The trigger electronics acts as a data acquisition system for the FPD and the BBC: photo-tube signals are passed through digitizer boards into a multilayer system of data storage and manipulation boards (DSM). For the BEMC and EEMC only a sub set of trigger information is passed to DSMs for trigger purposes. A DSM consists mainly of a field programmable gate array (FPGA) which can be configured by using a hardware description language (VHDL). The DSMs are arranged in a four layer tree structure. The physics algorithms implemented into the FPGAs reduce the data along the tree structure yielding a final trigger decision, which can be combined from the data of several detectors. The trigger system as a whole is acting as a data pipeline, where the trigger data remains for 104 ns (one RHIC bunch crossing) in each DSM layer. The implementation of complex trigger decisions bears the challenge to meet the strict time constrains and the restrictions given by the available number of data transfer bits (16 or 32) between the DSM layers. The trigger system is highly flexible, since DSM algorithms, thresholds and certain logic selections can be configured on-line. The following main trigger algorithms were designed, implemented, and successfully applied for the 2003 dAu and pp data taking period:

BBC: The BBC trigger is the main 'minimum bias' trigger for data taking in polarized proton-proton collisions. Each PMT is separately tested for a minimum digitized (ADC) signal arriving within a 40 ns window w.r.t. the RHIC bunch crossing. All valid PMT ADC signals are added. A trigger is issued when a minimum multiplicity, i.e. ADC sum, in both BBC East and West is reached. A vertex position requirement is imposed through cut on the arrival time difference between the signals in East and West.

FPD: The FPD detects the two-photon decay of π^0, produced in the forward direction. The sum of the PMT signals is built separately for each of the eight calorimeter modules. If the energy deposit in one of the modules is above a certain threshold, a trigger is issued. Additional thresholds are available for monitoring purposes in the scaler boards, discussed below.

BEMC/EEMC: The main purpose of the calorimeter triggers is to select particles with high transverse momentum and jets. The calorimeter towers are combined to groups of 6, 8 or 10 (EEMC) or 16 (BEMC) in the calorimeter front end electronics. For each group, the energy sum and the largest signal within the group (high-tower) is available. Available calorimeter trigger algorithms are:

- The total energy deposit in the calorimeter is above a certain threshold.
- The energy deposit in any calorimeter (high-)tower is above three programmable thresholds.
- The tower groups are combined to $\eta \times \phi = 1 \times 1$ jet patches, fitting the average jet radius of 0.7, their energy sums is compared to three thresholds.
- A topology trigger for back-to-back energy deposits in the calorimeter is implemented to enhance the di-electron J/ψ decay events.

The cross section for hard processes is rapidly falling with increasing transverse energy E_T. Three thresholds on the high-tower and jet-patch energy allow to sample different regions of the cross section with different pre-scale factors: while only a fraction of high-rate low E_T events is sampled every event at high E_T is recorded.

The FPD and BBC are symmetric around the beam axis. During data taking with longitudinal polarized proton beams, both will be used as local polarization monitors. Residual transverse beam polarization components will be visible through left/right top/bottom asymmetry measurements. For this purpose the FPD and BBC are subdivided into top-bottom/left-right symmetric parts. Thresholds are placed on this sub-components and the hit patterns are recored for each bunch crossing in scaler boards. The statistics collected is large and even small asymmetries of the order 10^{-3} can be used for local polarimetry.