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CMS Global Trigger

Preliminary specifications of the baseline trigger algorithms

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Abstract

This document contains the specifications of the CMS baseline global trigger algorithms which provide the basis for the simulation and design studies and the prototype developments and tests to be carried out during the period 1997-1998. These specifications are preliminary and may be modified as a result of the foreseen tests and technical developments.

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1 Introduction

This document specifies the physics requirements, the rate capability, the design trigger conditions and the input and output data. These specifications provide the basis for further simulation studies, prototype developments and beam tests to be carried out from now until 1998 when the actual construction phase of CMS will start. They are preliminary and may be changed in accordance with the results of the foreseen tests. Important electronics, computing and data transfer developments will also imply changes to the design of the global trigger.

2 Requirements

The basic tasks of the CMS global trigger are:

- **synchronization** of the arrival times of the subdetector system data
- provision of the trigger **classification** (trigger code)
- provision of **prescaling** in case of high rate triggers
- **decision** whether to accept or to reject an event
- **communication** of the accept/reject decision to the TTC system
- **monitoring** of the different stages of the global trigger

It has to fulfill the following requirements:

Latency: < 3.2 μs total trigger processing time, including 2 x 90 m of cables to the control room corresponding to 900 ns. This is matched to the length of the tracker pipelines of 128 bunch crossings with an LHC bunch crossing time of 25 ns. 8 bunch crossings are foreseen for global trigger processing (not including the global muon trigger described in [1]). For speed reasons internal running at 80 MHz may have to be foreseen for parts of the global trigger system.

Status: total latency time still not quite certain

Dead time: not allowed. The global trigger has to run in pipelined mode and to provide a decision for each bunch crossing, i.e. every 25 ns.

Status: accepted

Maximal output rate: 100 kHz input to second level trigger. However, due to uncertainties in estimates of cross sections and backgrounds a safety factor of 3 is foreseen limiting the output rate of the level 1 global trigger to 30 kHz corresponding to a reduction factor of the order of 10^4 at the LHC design luminosity of 10^{34} $cm^{-2}s^{-1}$. In order to meet this requirement some triggers will be prescaled, e.g. low transverse energy jet triggers.

Status: accepted

Background rejection: The main backgrounds are beam halo and cosmics. These should be kept below a level of 0.1%. In addition, there are backgrounds from fake and wrongly measured physics objects. These are estimated at the subdetector levels.

Status: definition, to be discussed

Trigger requirements: The global trigger must be able to handle normal physics runs and calibration runs in standalone mode or in parallel to the physics running. A veto system has to be foreseen. A debug mode where output from every stage of the global trigger system is written to a storage medium must be available. Trigger data from the two previous and the two following bunch crossings may systematically be written.

64 trigger conditions are reserved for standard physics triggers, 32 are foreseen for calibration modes and 32

are available for any special triggers that may be required. System upgrades to handle more than 128 trigger conditions are possible.

3 Components of the global trigger

The global trigger system consists of the following items:

- PSB
- GTL
- GTF
- FED-DAQ modules
- CPU

A functional diagram is shown in Fig. 1. More detailed technical information may be obtained from [2].

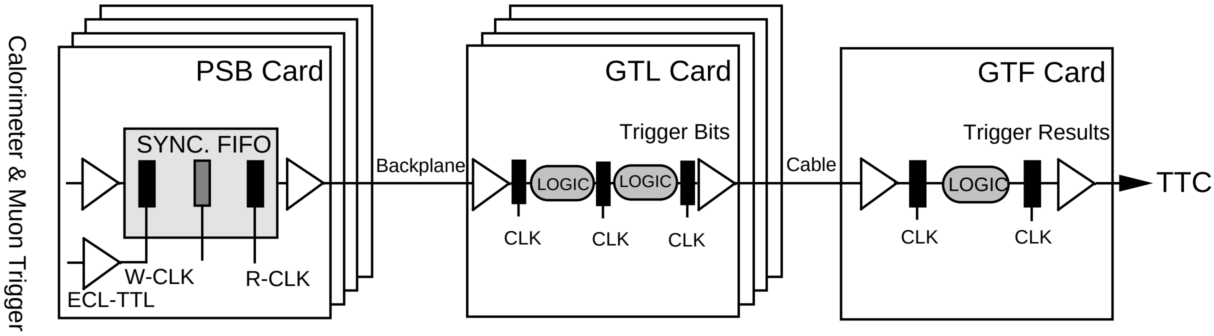

Figure 1: Functional diagram of the Global Trigger.

PSB: The Pipeline Synchronizer & Buffer (PSB) card receives data from the Global Calorimeter and Global Muon Triggercrates. It contains synchronizing logic combined with a programmable delay for each input channel. Bus drivers will move parallel data to the GTL cards with a frequency of 40 MHz. As the number of the backplane connector pins limits the number of possible input channels there should be a possibility to transfer data from additional input channels using fast data links (option). Spy memory and a VME interface complete the board.

Status: design phase

GTL: The Global Trigger Logic (GTL) has synchronous inputs. Data is sent from one PSB via a custom backplane to two GTL's. Threshold and comparator stages follow immediately the line receivers. Algorithms are formed by programming a small array of combinatorial logic. Scalers and pipeline registers for all algorithms are included. Front panel input technical bits may be added to the algorithm. A VME interface allows for proper monitoring & algorithm downloading.

Status: design phase

GTF: The Global Trigger Final Level Logic provides a maximum of eight trigger decisions, one of which is used as the triggerword. The others are available for detector testing (partitioning) or algorithm testing prior to making them active in a run.

CPU, FED-DAQ: At the present stage commercial modules and CMS standard designs are being considered.

4 Principles of operation

The global trigger makes its decisions based on transverse momentum or energy thresholds which may be rapidity dependent. Charge-dependent triggering will also be possible. Quality bits are only relevant for muons and are already dealt with at the global muon trigger level.

5 Input/Output

Physics input to the global trigger: The inner tracker and pixel detector are not taken into account in the global trigger. Only the calorimeters and the muon system are considered. Calorimeter quiet bits and MIP bits have already been added to the muons during the global muon trigger stage [1] so that the physics input to the global trigger consists of 24 objects. Table 1 shows the details.

Status: Under discussion. For e/γ an isolation bit may be sent (included in the 8 bits). MIP bits may not be sent. 3 instead of 4 muons may be sent.

Table 1: Global trigger input.

Origin	Significance (bits)	#Links	#Bits	Information	Latency
CALORIMETER	E_T (8), φ(5), η(4)	4	68	4 highest E_T e/γ (isolated)	66 bx
	E_T (8), φ(5), η(4)	4	68	4 highest E_T e/γ (non-isolated)	66 bx
	E_T (8), φ(5), η(4)	6	102	6 highest E_T jets	66 bx
	E_T (8), φ(5), η(4)	4	68	4 highest E_T isol. hadrons	66 bx
	ΣE_T (12)	1	12	Total E_T	66 bx
	E_T^{miss} (12)	1	12	Missing E_T	66 bx
MUON SYSTEM	η(6), φ(8), sign(1),p_T (5), quality(2), isolation(1), MIP(1)	4	96	4 highest p_T muons	84 bx
TOTAL		**24**	**426**		

Technical input to the global trigger: The global trigger must communicate with a number of technical devices such as external logic, additional trigger devices, calibration triggers, DAQ-frontend, CMS-control and many others. Free PSB slots will accept parallel single input channels that will accept synchronous logical signals. Processing of these signals remains fully programmable. The PSB's used for this purpose are simplified versions of the full-feature serial-input physics PSB.

Status: design

Control input to the global trigger: The global trigger setup is communicated via a 128 bit word *(input trigger word)* containing the pattern of the required trigger algorithms. An array with the corresponding thresholds is also transmitted. Further control inputs are under discussion (Partitioning, synchronization runs, DAQ exchange).

Output to the TTC system: The final level logic consists of one GTF card. Outputs of all algorithm GTL's end up in the final level GTF card. Multiple final level configurations are supported for the sake of testing new combinations for their feasibility. The GTF card contains interface logic and cable drivers to transfer the final Level 1 Trigger decision to the TTC system.

Status: design

Output(s) to the DAQ system: The dialogue between global trigger and DAQ is not yet fully formalized. Besides the obvious "accepted/rejected" some message-passing will be performed. Typical exchange would consist of several INIT levels, interlocks, self test request, accept-on-demand, lock-during-reload, general-trigger-error, phase-error etc.

Status: under discussion

Output trigger data (includes path to second level trigger):

The *output trigger word* of 128 bits and all 24 physics objects in the same format as on input but one additional bit set if the object was used in any one of the 128 trigger conditions. Since all 128 trigger algorithms always run the output trigger word will in general have more bits set than the input trigger word.

Status: under discussion

6 Global trigger algorithms

Presently a maximum of 128 trigger algorithms is foreseen. Normally not more than 64 physics triggers should be needed. The other 64 triggers can be used for calibration and special purposes.

24 objects serve as physics input to the global trigger and need to be considered by the trigger algorithms. According to table 1 these objects are:

- the four highest p_T muons
- the four highest isolated E_T electrons or photons
- the four highest non-isolated E_T electrons or photons
- the four highest E_T isolated hadrons
- the six highest E_T jets
- the total E_T sum
- the total missing E_T

The trigger classification **(trigger code)** is defined as:

$$\textbf{\# Object}^{\textbf{(isolation)}}_{\textbf{Threshold}}$$

For example "$2M_{20,10}$" means a di-muon trigger with thresholds 20 and 10 GeV/c for the two muons. For only one object the number 1 may be omitted, e.g. E_{35} means a single electron trigger. If two thresholds are the same they may be put only once, e.g. $2J_{100}$ means a di-jet trigger with both jet transverse energies greater than 100 GeV. Isolation may be required for leptons, e.g. $2M_{10}M^i_8$. "O" stands for a minimum bias trigger.

In the hardware each trigger condition is represented by 1 bit. 128 bits in total define the trigger setup (input trigger word) as shown in table 2. For simplicity the indices for the thresholds have been omitted. Where relevant, an "isolation and MIP mask" has to be foreseen which will be transmitted to the GTL stage. Isolation and MIP bits will be checked at the GTL level. Only the most important trigger conditions for physics running are defined at this point. Note that total E_T is not a separate trigger condition since it will in general be only be used in conjunction with other triggers.

A fast simulation of the most important trigger conditions is described in ref. [3]. Results on cumulative trigger rates have been presented and it is confirmed that these rates are within the specifications of the global trigger. More detailed simulations are under way.

Table 2: Definition of physics triggers.

Trigger bit	Trigger code	Description
0	M	Single muon
1	2M	Di-muon
2	E	Single electron
3	2E	Di-electron
4	J	Single jet
5	2J	Di-jet
6	I	Single isolated hadron
7	2I	Two isolated hadrons
8	T	Missing E_T
9	3M	3 muons
10	3E	3 electrons
11	ME	1 muon, 1 electron
12	2ME or 2EM	3 leptons (except 3M and 3E)
13	2M2E or 4M or 4E	2 lepton pairs
14	MJ or EJ	Lepton + 1 jet
15	M2J or E2J	Lepton + 2 jets
16	2M2J or 2E2J	Lepton pair + 2 jets
17	3MJ or 3EJ or 2MEJ or M2EJ	3 leptons + 1 jet
18	MT or ET	Lepton + missing E_T
19	2MT or 2ET	Lepton pair + missing E_T
20	3MT or M2ET or 2MET or 3ET	Lepton pair + lepton + missing E_T
21	3MJ or M2EJ or 2MEJ or 3EJ	Lepton pair + lepton + 1 jet
22	M2JT or E2JT	Lepton + 2 jets + missing E_T
23	M3JT or E3JT	Lepton + 3 jets + missing E_T
24	M4JT or E4JT	Lepton + 4 jets + missing E_T
25	2M2JT or 2E2JT	Lepton pair + 2 jets + missing E_T
26	MI or EI	Lepton + isolated hadron
27	LIT	Lepton + isolated hadron + missing E_T
..	..	...
63	O	Minimum bias

References

[1] **CMS TN-96/060.** *CMS Muon Trigger, Preliminary specifications of the baseline trigger algorithms*.

[2] **A. Taurok et al.,** Proceedings of the 2nd Workshop on Electronics for LHC experiments, Balatonfüred, Sept. 1996.

[3] **J. Pliszka and G. Wrochna**, presentation at Aachen CMS Week, Sept. 1996.