Chapter 9

DAQ

9.1 Requirements

The Data Acquisition of the TOTEM experiment will perform different tasks depending on the running conditions:

- Initialisation and calibration of the front-end hardware
- TOTEM stand-alone data taking at a rate $\approx 1\,\mathrm{kHz}$;
- Data and Trigger quality monitoring;
- Data taking integrated in the CMS DAQ/Trigger system at a later stage.

9.1.1 Trigger and data rates

We consider that the upper limit of the total event size is $\approx 50\,\mathrm{kB}$. This data size is fixed since no zero-suppression is applied to the data. This choice greatly simplifies the task of evaluating the data rates and the resources needed to cope with them.

The data rate is easily computed as $50\,\mathrm{kB/event} \cdot \mathrm{TriggerRate} = 50\,\mathrm{MB/s} \cdot (\mathrm{TriggerRate/kHz})$. We consider here that the standard trigger rate is 1 kHz, with an upper limit (on redundant resources) of 2 to 3 kHz.

Two operational conditions can be envisaged:

- Calibration and Setup. The VFAT chips and related front-devices need to be initialised and calibrated before a normal run can start. The parameter space of the VFAT chip is particularly large, and its calibration procedure delicate; many different parameters need to be scanned in order to compute the optimal setting in terms of threshold and latency adjustments, taking into account the specific properties of each detector in terms of signal shape and timing. In these operating conditions the rates are typically much lower than in standard running mode, the limiting factor being the time needed to re-configure all the VFAT chips at every step of the parameter scan. We assume that a typical trigger rate in this running mode will be $\approx 100\,\mathrm{Hz}$, corresponding to $\approx 5\,\mathrm{MB/s}$

The parameters of the blocks on the Coincidence Chip can be fully configured through its I^2C interface. The VFAT chip also includes counters on the fast trigger outputs to monitor hit rates. This is achieved by a 24 bit counter which records the number of sector hits within a given time window. The duration of the time window can be selected from a list of 4 possible options (6.4 μs, 1.6 ms, 0.4 s, 107 s).

8.2.2 Trigger bit transmission to the counting-room

The trigger signals from all subdetectors are optically transmitted to the counting-room using the GOH optohybrid in the same way as the tracking data. However, the Roman Pot station RP220 is so far away from the counting-room that optically transmitted trigger data would not arrive within the latency allowed by the trigger of CMS. Therefore, in addition to optical transmission for TOTEM runs, electrical transmission with LVDS signals was implemented for commons runs with CMS. To maintain the electrical isolation between detector and counting room, optocouplers will be used to receive these electrically transmitted signals. At regular intervals of about 70 m along the total cable length of 270 m, repeaters based on a custom-designed LVDS repeater chip are inserted to preserve the electrical signal quality.

8.2.3 Trigger signal synchronisation

The large distances between the subdetectors — with RPs at up to 220 m from the interaction point — requires special attention to the synchronisation of the trigger information.

Since the trigger output from the RP220 station has the longest signal transmission time, the trigger signals from that station are the last to arrive in the counting-room. In order to minimise the latency of the combined trigger, the data from the trigger FEDs of the other subdetectors are transmitted via the VME back-plane to the trigger FED of the RP220 station where all the trigger information is merged. Thus the RP220 trigger FED acts as the master of the TOTEM trigger system, generating the global TOTEM L1 trigger decision and is also capable of sending 16 trigger bits to the CMS global trigger system [60] for common data taking with CMS in the future.

The synchronisation of the trigger generating bits is based on the BC0 signal (Beam Crossing Zero). This signal — related to the first bunch of a LHC beam revolution cycle — is issued every 3564 bunch crossings and broadcast by the TTC system. On the detector side, it is received via the control token ring and decoded by a VFAT Trigger Mezzanine (VTM) as shown in figure 7.7. It is then superimposed onto the trigger data stream transmitted to the counting-room. The trigger FEDs also receive the TTC signal including the BC0 signal. The trigger generating bits are then temporally aligned to the BCO signal. This scheme is also used for the 16 trigger bits sent to the CMS global trigger system.

Care also has to be taken in the synchronisation with respect to the transmission of the TOTEM first level trigger signal down to the “Local” and “On Detector” regions.

The level-1 trigger is transmitted to the detectors using the TTC system and the FEC card. The FEC card can adjust the phase of the fast commands and the clock. The latency of the VFAT can be adjusted to account for the differences in delay due to the spatial spread of the subdetectors and obtain synchronisation.

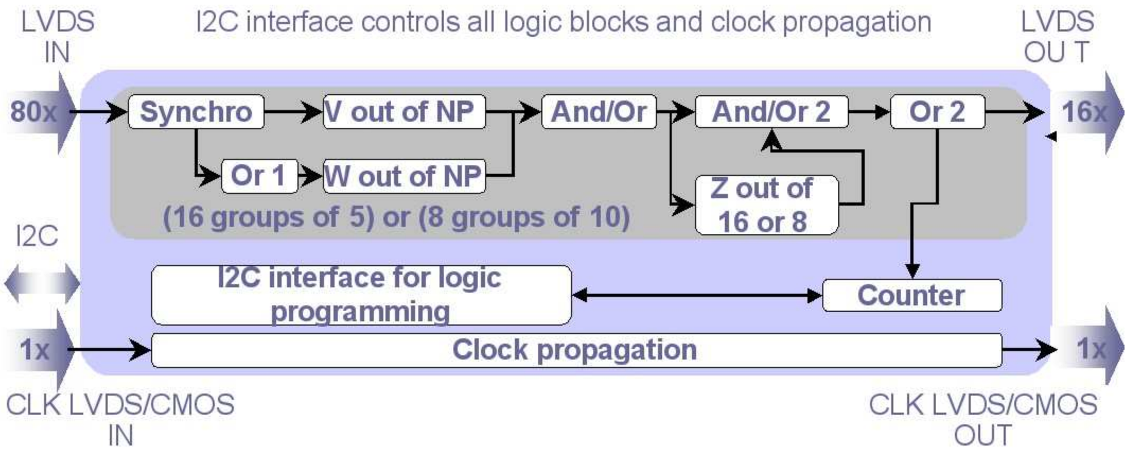

Figure 8.2: Schematic overview of the Coincindence Chip (CC).

8.2 Implementation

8.2.1 The Coincidence Chip (CC)

The Coincidence Chip provides on-detector coincidences to reduce the trigger data sent to the counting room. It is used by the RP and T2 systems, but not by T1 where the more complex geometry made its use too difficult. Figure 8.2 shows a block diagram. The chip has 80 LVDS inputs which can be grouped in two ways:

- 16 groups of 5 inputs, for 5 detector planes (RP case).
- 8 groups of 10 inputs, for 10 detector planes (T2 case).

These groups correspond to detector sectors in a similar transverse position on different detector planes.

A synchronisation block is included to synchronise the pulses to the clock and to stretch the pulses over different clock cycles for detectors with an inherent timing spread larger than a single clock cycle. Asynchronous operation is also possible. For TOTEM only synchronised operation has been adopted.

Two types of coincidences can be performed:

- A coincidence on just one group: V hits on one track road through NP detector planes.
- A coincidence which takes into account a programmable number of neighbouring groups: W hits out of NP detector planes including X neighbouring groups.

The result of these coincidences can be logically combined in a programmable way (AND/OR with possible inversion). The possibility to include neighbouring sectors or not allows a certain programmable selectivity on the direction of incoming particles.

The total number of positive coincidence results is checked (Z out of 8 or 16) and can be logically combined with the coincidence results (AND/OR2). This can be used to impose certain occupancy limits, for instance to prevent the generation of a trigger if a detector is completely filled with artificial hits, e.g. due to noise or particle showers. Finally, signals can be grouped into a smaller number (OR2) to reduce overall signal count.

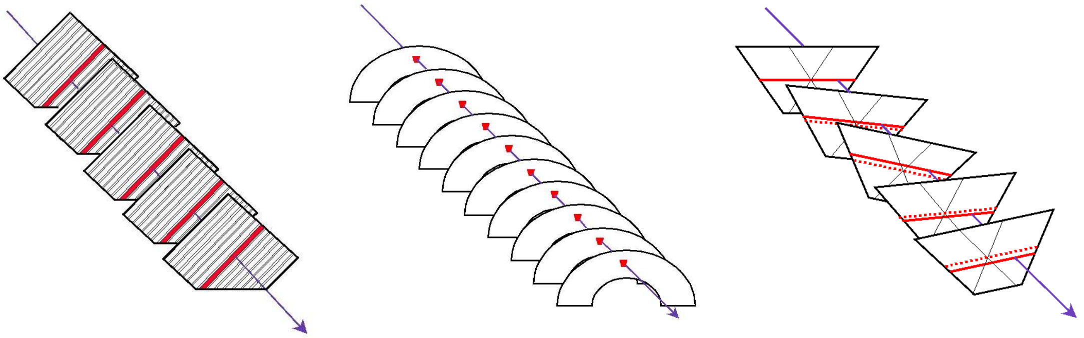

Figure 8.1: Left: RP trigger coincidence in one projection (u or v). Middle: T2 trigger coincidence in one pad. Right: due to the 3° rotation between different planes in T1 (angle exaggerated in the picture), the coincidence definition is more complicated and hence performed in the counting-room.

trigger, open the possibility to mask noisy regions, as e.g. close to the beam pipe. Cuts on hit multiplicities over larger detector areas might improve the trigger cleanliness or create a simplified trigger.

The trigger formation strategy can be explained with the aid of the principal chamber arrangements in figure 8.1.

The silicon detectors in the Roman Pots close to the beam have to trigger on protons with almost the same momentum as the beam. Consequently there is only one track that is parallel to the beam within less than 1 mrad. Altogether, 10 planes (5 planes per each strip orientation u and v), define the proton trigger in one Roman Pot station. Each detector plane is divided into 16 groups of 32 strips, defining a track road of about 2 mm per strip orientation. In a first step, the coincidence chip (CC) requires a coincidence of at least 3 out of 5 planes with hits on the same track road resulting in 32 trigger bits per pot (16 in u and 16 in v). With this loose requirement, tracks crossing the boundary of neighbour track roads are still included. Coincidences between track segments in the u and v oriented planes will further reduce the trigger rate. In the counting-room, coincidences between the two RP units with a distance of a few meters will select tracks that are parallel to the beam, and multiplicity cuts will reduce the background originating from beam-gas interactions.

For the T2 GEM chambers, the trigger is based on pads that are grouped by a fast-OR logic of 3×5 pads into 104 super-pads per half plane. To trigger on a straight track, the super-pads from the 10 detector planes are put into an adjustable coincidence (at least 5 out of 10). This loose coincidence again solves the problem of tracks crossing the superpad boundaries. 104 trigger bits per half arm of the T2 detector are sent to the counting-room for further trigger treatments.

For T1, the trigger is formed by the anodes which are read by two VFATs per plane. However, the more complex detector geometry (for acceptance reasons the chambers are rotated by 3° with respect to each other) makes it difficult to have on-detector coincidences. The 16 trigger outputs of the two VFATs per plane are therefore sent directly to the counting-room where the coincidences between the five planes will be performed in hardware. Simpler triggers based on hit activities in the chambers may lead to a less biased trigger at the expense of larger trigger rates.

This procedure results in 960 trigger bits for T1, 416 for T2 and 768 bits for the RPs.