A local/global architecture for level 2 calorimeter triggers

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Introduction

A major problem in triggering and data acquisition at LHC is the quantity of data which must be moved and stored at each stage of the selection process. The architecture proposed here, see Fig.1, restricts the data flow to manageable rates and allows sufficient time for programmable devices operating sophisticated algorithms to process data for a level 2 trigger. Using the example of a calorimeter based isolated electron trigger we present some initial results of a system simulation.

For a first level trigger, most proposals [1] assume that data are stored in a pipeline with a depth of at least 64 elements. This allows approximately 1 µs for the collection of the trigger information, its processing by hardware units and distribution of the accept/reject signal to all parts of the experiment. The level 1 system must produce a decision for each machine bunch crossing i.e. at intervals of 15 ns. It is believed that the rate for level 1 acceptance can be restricted to about $10^9$ Hz at the highest luminosities proposed for LHC while keeping a high efficiency for retaining 'interesting' physics events. Level 2 is required to reduce the acceptance rate by at least two orders of magnitude.

In order to achieve the very short decision time at level 1, information is grouped with a granularity significantly larger than the detector basic cell size. For our estimates we have considered an electromagnetic calorimeter with a basic cell size of 0.02 in phi ($\phi$) by 0.02 in pseudorapidity ($\eta$) with 2 depth samples and $2.10^5$ channels. Based on Isajet studies [2], a level 1 trigger calorimeter granularity of 0.2 by 0.2 in $\phi\eta$ space with no electromagnetic depth information appears capable of providing a satisfactory trigger rate while maintaining the number of electronic channels and stages in the trigger to a feasible level.

If level 2 is to produce a substantial reduction in the level 1 trigger rate then, where appropriate, information must be processed at the basic cell size, additional information on depth or timing profiles added and more sophisticated algorithms used to evaluate the data. Total energy, jet and missing $P_t$ triggers are formed at level 1 using large granularity and relatively coarse energy bins and only marginal improvements can be made in these triggers at the second level by making use of finer details. For the isolated electron trigger, however, a significant improvement can be obtained by using more detailed information. Where possible, data from several detectors should be correlated but, for this exercise, we have only considered the problems associated with analysing calorimeter data.
Local and global processing

For the calorimeter described above and assuming that the data from each channel has been formed into a digital word of two bytes, the calorimeter data occupies $4.10^9$ bytes and transferring this data to level 2 processors would require a bandwidth of $4.10^9$ bytes/s. Zero suppression could be used to reduce the transfer requirements but would result in a more complex data format and a concomitant increase in processing time.

We propose to use the level 1 information to indicate areas of interest in the calorimeter and to transfer data only from those areas to level 2 processors. Allowing for edge effects, an isolated electron trigger at level 1 specifies the position of a cluster to an area of about 0.3 by 0.3 in $\phi\eta$ space. For each cluster, only data from 0.2% of the calorimeter, about 1 kbyte, need be transferred to level 2 for validation, and the data transfer rate has been reduced to $10^8$ bytes/s/cluster.

Sustained transfer rates of a few $10^8$ bytes/s are possible but not trivial and are unnecessary if data are transferred to a processor connected to a restricted part of the calorimeter i.e. a local processor. For a local processor covering an area of 0.3 by 0.3 in $\phi\eta$ space, the local trigger rate is about 200Hz and the local data transfer rate is only $2.10^7$ bytes/s. Under these circumstances, transfer rates of only $10^7$ bytes/s and processing times approaching 1 ms can be considered. Note that, when overlaps are taken into account, about 1000 local processor are needed at level 2.

To correlate information from several areas and to add information, from other detectors, which cannot be supplied to the local processor, global processors are used. The volume of data to be transferred from the local to the global processor can be limited to a few words providing, for example, the position of the cluster, its energy and fit quality. The accept/reject decision is made at the global processor level (see Fig.2). Because memory uses silicon efficiently, front end storage of data for long level 2 decision times is not a serious problem. In the multi-chip module design of Goggi and Lofstedt[3], a derandomizing buffer, a memory for data storage and all the level 2 and readout interface logic has been included on the

![Diagram](image-url)
front end card. In Fig.2 all the items inside the hashed line are incorporated onto the front end card. Only 2 kbytes of memory are needed to store data from 10 channels for 100 level 1 triggers.

Simulation

Data loss due to dead time is acceptable if the loss is kept small but, with significant quantities of data held in buffers, it is important that no part of the trigger system saturates. If saturation occurs, data taking must be stopped until the blockage is cleared and queued data in front of the blockage must be flushed. Returning the system to a coherent state after saturation is time consuming and wasteful and results in an unacceptable level of dead time. As well as designing a system which has the correct size buffers to minimize dead time, it is important to incorporate into the design the ability to inhibit global level 1 triggers before saturation occurs.

We have modelled [4] the performance of a level 2 system with local and global processors using SIMSCRIPT [5]. The performance of the system has been evaluated for a range of values of selected parameters. Fig.3 shows the model used and standard parameter values.

A level 1 rate of $10^5$ Hz is assumed with an exponential distribution in time between triggers which are locked to the LHC bunch separation of 15ns. The fast FIFO and the large FIFO correspond to the buffer and level 2 memory of Fig.2. Local level 2 processors are assigned on the basis of information provided by level 1 but, as they are assigned randomly, global processors share a common queue. To simplify the electronic reality, the level 2 memory is assumed to be a circular buffer and, therefore, the read/clear operations must be kept in input order. This requirement is imposed on the simulation by not releasing the global processor for an event until all previous events have been completed.

Running on a SUN SLC the program takes about 11 minutes to process $10^5$ triggers i.e. 1 second of data taking. A summary is produced for each run giving the overall performance and showing where resources have become saturated as well as their average utilization. Fig.4 shows results obtained from runs varying the number of global processors and the local level 2 processing time but keeping the total level 2 time constant at 1 ms; other parameters were kept at their default
values. Dead time becomes significant only when the number of global processors is reduced below 125 or the local processing time is greater than 500 μs. Fig. 5 shows the effect of varying the number of clusters for total level 2 processing times of 300 μs and 1 ms. For the shorter processing time, the dead time only becomes unacceptable when the 4-cluster trigger rate approaches 10^3 Hz, but the longer processing time can operate successfully only on one cluster triggers at that rate.

Implementation

As shown in Fig. 2 and discussed above, the data buffers and level 2 interface, can be incorporated into the front end card [3].

Several possibilities exist for the local and global processors. Tests have been made on an FDPP module [6] used as a local processor connected to 100 channels. Using data from the SPACAL test calorimeter [7] and standard benchmark algorithms [8] the module finds the position of maxima in 42 μs; total energy and width parameters take another 15 μs for each cluster. Allowing for data transfer times, the total local level 2 latency would be less than 100 μs.

For clusters which straddle boundaries to be treated correctly, it is necessary to have fixed connections and local processing areas which overlap or to build in the facility to select the information to be sent to the local processor. The second option could be accomplished using HIPPI links [9] and crossbar switches. Such a system allows local transfers of 1 kbyte of information in about 12 μs. Similar links or a bus system could be used to transfer data from local to global processors.

Conclusions

We have shown that a level 2 trigger is feasible using current technology. Simulation languages make it possible to assess the performance of a system at an early stage and system models can be easily and rapidly changed to accommodate new ideas on architectures. We intend to develop our model to include greater detail on proposed implementations of level 2 architectures. A considerable amount of work, at both the physics and detector simulation level, is required before estimates of the efficacy of the isolated electron second level trigger can be obtained.

References

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