Use of an FPGA to identify electromagnetic clusters and isolated hadrons in the ATLAS Level-1 Calorimeter Trigger

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At the full LHC design luminosity of 10^{34} cm^{-2} s^{-1}, there will be approximately 10^9 interactions per second. The ATLAS level-1 trigger is required to select events at a level of only 1 in 1000. This is achieved by identifying interactions containing candidate high transverse energy muons using muon trigger chambers, and electrons, photons, single hadrons/taus, QCD jets, and non-interacting particles using calorimeters. The level-1 trigger must not generate any deadtime, and takes the form of real-time custom-built pipelined processors.

The calorimeter trigger covers the region, $|\eta| \leq 5.0$, and $\phi = 0$ to 2π. On the detector, calorimeter cells are combined to form trigger towers, with a granularity of $(\Delta\eta \times \Delta\phi) =$

(0.1 × 0.1) over the region $|\eta| \leq 2.5$ and a somewhat coarser granularity elsewhere. The total number of trigger towers is 7200; 3600 in the electromagnetic calorimeters and 3600 in the hadronic calorimeters. The analogue signals are conveyed to the trigger hardware via dedicated trigger cables, then scaled from energy to transverse energy, and digitised at 40 MHz with 8-bit precision before being input to the trigger processors.

The distribution of transverse energy over the trigger phase space is analysed to identify candidates for electrons/photons, isolated hadrons/taus, QCD jets, and non-interacting particles via missing transverse energy. The Cluster Processor of the Level-1 Calorimeter Trigger uses algorithms based on the trigger tower energies to identify transverse energy clusters associated with the first two of these.

In the original design of the Cluster Processor, it was envisaged that an ASIC would be required to implement these algorithms. Critical considerations here are: the evaluation time for the algorithm (latency), the number of trigger towers that can be processed by a single chip, and its I/O bandwidth. The subsequent evolution of FPGA performance in each of these areas, together with their inherent flexibility, means that they now represent a more attractive solution.

The algorithms used to identify electromagnetic clusters and isolated hadrons are presented and discussed. The reasons for selecting a particular FPGA are given. Its performance has been fully simulated, and the expected latency has been shown to be within the allocated time limits of the cluster trigger. These results, together with measurements made with real data into a fully configured FPGA, are presented and discussed.

Finally some observations are made on the continuing increase in FPGA performance, and the implications of this on the design of future level-1 triggers.