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A second-level trigger, based on calorimetry only

G.Klyuchnikov*, R.K.Bock, A.Gheorghe, W.Krischer, M.Nessi, A.Watson

Abstract

This note gives some results, derived from Monte Carlo calulations, of the effect of an inclusive second-level triggering on electrons. It is based on algorithms using fine-grained calorimeter information alone. The assumed dominant background consists of QCD jets with the pathological property of passing a first-level trigger condition. Of events which pass the first level trigger it is shown that, at a 95% electron efficiency, a jet rate reduction by a factor of larger than 6.5 (10) is achieved with (without) pileup. Implementations of such algorithms with today's technology have been shown previously to be possible at the predicted rates (Badier et al., CERN/ECP 92-7).

Background data

We have used PYTHIA to generate a large sample of QCD jets (about 500K) in the pseudorapidity range $|\eta| \leq 0.5$ for both partons, with a parton momentum cutoff at 15 Gev. The corresponding cross section is $\sigma = 33.08\ \mu b$, corresponding to an event rate of 661 KHz at $2x10^{34}/cm^2/s$ ('peak') luminosity.

In order to save the CPU time needed for full MC simulation, events were selected by a 'pretrigger'. It requires that an event contains a total energy of all particles greater than 14 Gev in a space cone of the size .12 x .12 (in η–Φ space). It can been shown separately that the 1st level trigger algorithm will not accept events failing this criterion. The pretrigger selected about 53K events. These were fully calorimeter-simulated, using CERN's SNAKE computer farm. Figure 1 shows the overall behaviour of the background (and the signal) data.

Signal data

As signal events, we have generated in PYTHIA single electrons in the same η-range as the QCD jets, simulating an electron energy distribution close to that of the QCD sample, as shown in Figure 1. This was done in an attempt to avoid in the filter algorithms the use of unjustified differences in basic variables for discrimination, as would undoubtedly and uncontrollably happen with neural-network based algorithms.

Detector

We used the detector description known in simulations as 'EagleB' (EAGLE Note /Tec-003). Cells are of basic size .02 x $2\pi/300$ in η x Φ. Electromagnetic and hadronic cells are of the same size, and precisely aligned. Only barrel cells are considered, mostly to avoid the much longer computing time necessary for the higher energy jets at larger η.

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First-level trigger

The trigger algorithm that was used to filter events corresponds to what has been proposed for implementation in DRDC proposal P37 (ATLAS/DAQ note 005) and is now under hardware implementation in project RD-27. Non-overlapping groups of 5 x 5 calorimeter cells are formed into level-1 cells of roughly 0.1 x 0.1 (in η x Φ). A 4 x 4 square of these cells is considered as the trigger window which slides in steps of 0.1 in both variables over the entire calorimeter range. A *cluster region* is defined to consist of two adjacent electromagnetic cells both not touching the edge of the 4 x 4 square. An *isolation veto region* is defined to comprise all electromagnetic cells along the edge of the square (i.e. 12 level-1 cells), and all 16 hadronic cells. The criterion used is a minimum of 25 GeV for clusters AND a maximum of 5 GeV for the sum of all veto cells (after thresholding individual level-1 cells at 1 Gev). In case of adjacent windows giving rise to triggers, only the window with the highest cluster energy is retained.

The accepted cross section of background events after the first-level selection is 14.3 nb, corresponding to 2.87×10^3 events/s at peak luminosity, for $|\eta| \leq 0.5$. In the case that the primary partons are restricted to the range $|\eta| \leq 3$, the event rate can be shown to be about 30 times higher, close to the assumed 100 KHz rate. For this extrapolation, we assume the performance of the first level trigger to be dependent only on transverse energies, hence independent of η.

Pileup

The addition of pileup was done after the first-level selection, for both signal and background events. Events were generated as minimum bias in PYTHIA. An average of 20 of these were combined for high-luminosity. The level-1 trigger condition was then verified again. Out of 1057/1634 background/signal events, 62/9 failed the isolation veto test when pileup was added. The effect of added energy in the cluster, which could add events failing the cluster criterion previously, was ignored. Pileup distorts only slightly the energy spectrum, in equal ways for signal and background events, as shown in Figure 2.

Second-level trigger algorithms and results

To discriminate between different particles we extract some characteristic features as decision variables, and perform the classification either by using look-up tables or with neural network (NN) algorithms, depending on the architecture used. In this particular example our input consists of two images of 20 * 20 cells (of original size) each. The two images correspond to the electromagnetic ($em_{i,j}$) and the hadronic ($ha_{i,j}$) part. When we use a NN we can, in principle, feed it directly with these 800 input pixels. Instead we use some space-, rotation- and/or scale-invariant features. This shortens the training phase and reduces the complexity of the neural network processing system by several orders of magnitude.

We show here the results of an algorithm, which we consider as a first iteration. Similar results have also been shown, on equivalent data, by J.Carter et al. (private communication, ATLAS note in preparation), and results on the same data set can be improved using different (e.g.luminosity-dependent) algorithms. For the results below, we add up the two input images pixel by pixel, $et_{i,j} = em_{i,j} + ha_{i,j}$, and determine the maximum (MAX) of the combined image, which represents the total energy. A radius of ≤ 6 pixels around the center of this maximum cell defines a near-circular neighbourhood, in which we compute the following features :

1.second moment : $\sum (et_{i,j} * r_{i,j}^2) / (\sum et_{i,j} - \mathrm{MAX})$

where the $r_{i,j}$ are the Euclidean distances from the maximum position (cell centers).

2.peak / total, where by "peak" we mean the sum of MAX and its four vertically and horizontally adjacent neighbours, and the total is the sum $\sum et_{i,j}$.

Figures 3 - 6 show scattering plots of these features for electrons and jets, with and without pileup. From these figures we derive Figure 7, where we plot the accepted fraction of electrons against the accepted fraction of jets, again for low and high luminosity. For this diagram, the two features have to be combined into a single discrimination variable. We did this by optimizing the linear combinations, and found that the decision quality is quite robust with respect to changes in the projection angle. From this figure we can see e.g. that for 95 % of electrons we accept ≤ 10 (15) % of jets in the case of pileup of 0 (20) minimum bias events.

Data availability

Original background events as well as signal and minimum bias events can be found on EAGLE MC tapes (see the file PROD_LOI TAPES on the disk PUBZP 197 on CERNVM). Regions of interest after first-level trigger, i.e. the 20 x 20 pixels for em and had cells, are available in ASCII form, on the disk RKB 402. The file README 1ST on the same disk contains the brief description of the files available and their format.

Figure's captions

Figure 1. Distributions of the main features of events before and after the first -level trigger algorithm (see ATLAS/DAQ Note 005) :

ETcluster	electromagnetic energy of a 2 x 1 cluster
EMisol	electromagnetic energy of the isolation ring
EHad	total hadronic energy deposited in a window

Histograms in rows 1 and 3 present distributions for jet events , before and after the first-level selection, for single electron events see rows 2 and 4.

Figure 2. Distributions of the main features with/without pileup for jet events (rows 1 and 2) and for single electron events (rows 3 and 4). Variables as in Figure 1.

Figure 3,4 and **5,6** Scattering plots of single electron events and jet events in the feature space. Low luminosity means the absence of pileup, high luminosity means pileup addition with the average 20.

Figure 7. The curves represent the best separation that can be achieved using an optimal linear conbination of the second momentum and peak/total features, for low (solid line) and high (dashed line) luminosity.