

An Alternative High P_T Electron and Hadron Trigger for LHCb

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1 Introduction

In this note we describe the present status of the Level 0 calorimeter trigger proposed in [1]. The basic idea of selecting a small number of clusters of 2×2 cells for further processing, is extended to the hadronic trigger.

The algorithm is described for both the electron and hadron triggers and projective geometry is proposed for the subdetectors involved in the calorimetric trigger, namely the Pad Chamber, Preshower, ECAL and HCAL. Geometrical constraints arising from the physical location of the front-end electronics are also considered.

After a detailed description of the hardware implementation of all the components, the performance of the trigger is presented, as obtained from simulations done with SICB. Finally, cost estimates are given.

2 Algorithm

The idea of a calorimeter trigger is to identify “hot spots”, i.e. high local deposition of energy. In fact, the relevant variable is E_T defined as the energy times the sine of the angle between the hot spot and the beam line as seen from the interaction point. A pseudo- E_T has been also proposed, giving a lower weight to the horizontal component, as it is affected by the magnetic field. A preliminary study has shown that this was not improving sensibly the algorithm, so we use the real E_T , but this can be reviewed later.

2.1 Search for “hot spots”

To search for a local maximum one can require that the cell value is higher than any of its 8 neighbours. Alternatively one can ask the cell value to be the highest in a wider area. Since the showers are sometimes centered on a cell, sometimes shared between cells, one must use the sum over neighbouring cells instead of using a single cell.

The standard LHCb algorithm requires the central cell of a group of 3×3 cells to be the highest of the 9 cells, and to have at least 40 % of the total energy. The algorithm we propose requires the sum on a group of 2×2 cells to be the highest in a large area of 8×8 cells, called a **block** in the following. The underlying idea is that the calorimeter cells are wide enough so that a shower is almost completely contained in the 2×2 area. The fraction of the shower energy lost outside this area is about 7% in the small ECAL cells, 3% in the middle ones, and zero for the big ones, and these losses can be corrected in average. Connecting together only 4 cells instead

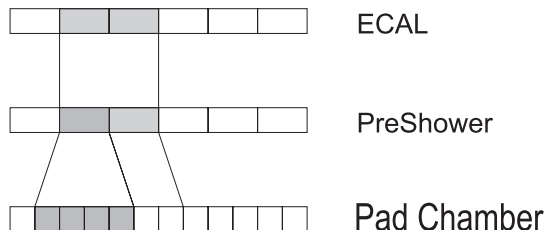


Figure 1: Schematic connection between detectors, top view.

of 9 decreases strongly the number of high speed connections. The other idea is to decrease at an early stage the number of candidates which need to be further examined. Selecting the local maximum in each **block** of 8×8 cells allows us to handle a more reasonable number of objects, typically 100 in the ECAL and 30 in HCAL, from a total of about 6000 ECAL and 1500 HCAL cells.

2.2 Use of other detectors in the ECAL trigger

For ECAL, a local maximum can be produced by a photon, an electron, or a hadron. To select electromagnetic particles, we use the Preshower detector, requiring a minimum amount of signal in the relevant area. Projective geometry is absolutely needed, to make the Preshower to ECAL connection possible. For electron identification, i.e. charged particle before the calorimeter, we use the μ_1 chamber, called **Pad Chamber** in the following, which has 12,000 pads with a similar geometry. Here also, the detector must match the calorimeter geometry, or vice-versa. In fact, the important match is between the Preshower and the Pad Chamber. The charged particle must be in front of the Preshower cell which has fired, with some tolerance in the horizontal (bending) plane. The proposed signature is then to have, in front of the 2×2 maximum in ECAL:

- Photons: No hits in the Pad Chamber, and at least one of the 4 matching Preshower cells with a signal over threshold.
- Electrons: At least one of the 4 matching Preshower cells over threshold, with a Pad Chamber hit in one of the pads matching this cell. Since the pads have the same vertical size as the Preshower cells but are two times smaller in the horizontal direction, one uses 4 pads for a Preshower cell, the two in front of the cell and the two horizontal neighbours, since charged particles are bent in the horizontal plane. Note that the OR of two pads is enough to get the 4 pads in front of each Preshower cell, so one only needs to transport 6000 bi-pads.

It seems possible to get the Preshower information in pipe-line mode for each of the maxima, as the Preshower electronics can have a similar block structure. Getting the Pad Chamber information to match the Preshower at 40 MHz is a serious challenge, as they have a different natural grouping in the electronics cards.

The logical connection between ECAL, the Preshower and the Pad Chamber is show on 1.

2.3 Use of ECAL in the HCAL trigger

For HCAL, one would like to add the ECAL contribution in order to have a better estimate of E_T . If the calorimeters have a projective geometry, the correspondence is very easy between an HCAL cell and the 4 ECAL cells in front of it, as seen from the interaction point. In case of a non projective geometry, as described in the TP, it becomes very difficult, if at all possible, to add to the HCAL energy the energy in the ECAL cells crossed by the particle producing the HCAL shower. Three options can be envisaged to correct the HCAL energy for the ECAL deposition:

1. No connection. The energy of the hadron deposited in ECAL is ignored. The efficiency versus real E_T will then have a less sharp threshold, as it will depend on the shower development.
2. Connect each of the 6000 ECAL cells to the corresponding HCAL cell. This implies a large number of high speed connection between two independent detectors, which have to physically move independently, and is therefore **very** expensive.
3. Send to HCAL only the local maxima of each ECAL block, and use this information only when they are in front of the HCAL maximum. There are then only about 100 such signals to send. It is important to add the ECAL energy to HCAL only if the ECAL has a large contribution, and in this case it is probable that it is a local maximum.

The third option is the preferred one, the first one is of course simpler but less efficient, the second one requires strong arguments in order to envisage the increased cost and complexity.

2.4 Selection of the candidates

For each beam crossing, the 100 ECAL maxima and the 30 HCAL maxima will be computed in pipe-line mode. Then one has to select the highest cluster in order to be able to take a decision according to the type of particle and E_T . We need to keep more than the highest cluster, as there may be a photon with higher E_T than the electron we want to trigger on. The selection is performed by finding the value of E_T for which no more than “n” local maxima have a higher E_T . A minimal E_T cut will also be applied. The selected candidates (hadron / photon / electron) are then collected, and sent to the Level-0 decision unit. If the Pad Chamber or the Preshower information cannot be collected in pipe-line mode, it has to be obtained for the selected candidates at this level, before the final decision.

3 Geometry

As mentioned earlier, this trigger scheme requires projective geometry. This means that neutral tracks coming from the vertex cross the Pad Chamber, Preshower, ECAL and HCAL in cells with the same ‘number’. Starting from the geometry of the μ_1 Pad Chamber given in the technical proposal, i.e. a surface of 608×736 cm² with pads of 8×16 cm² for the largest ones, the external dimensions of the Preshower should be the same (scaled by the ratio of the Z position) plus one pad row, ECAL similar to the Preshower, and HCAL with a similar layout, but with 4 ECAL cells in one HCAL cell.

The Z at which the ECAL cell size should be projective (the cell is not a pyramid) is selected near the shower maximum, 15 cm inside the active volume. For HCAL, it is taken 50 cm inside the active volume. The cell size and the number of cells quoted is the size and number of the

most external cells. Middle and inner section of the calorimeters, with smaller cell size, have also to agree in size and boundary.

Detector	Z (cm)	Cell size (cm)	Number of cells	External dimensions
μ_1	1210	16.00	46×38	736.0×608.0
Preshower	1232	16.28	48×40	781.4×651.2
ECAL	1254	16.58	48×40	795.8×662.2
HCAL	1370	36.23	24×20	869.5×724.6

As can be seen, there are less cells than in the TP for the calorimeters (in the TP ECAL has 52×40 cells).

Another geometrical constraint is the localization of the electronics. The Pad Chamber electronics is located 'on the edge of each module' (TP page 93). The grouping of pads will clearly NOT match what is needed for the calorimeter trigger. The Preshower, ECAL and HCAL front-end electronics will be in racks on the top and bottom of the calorimeters. As the various detectors have to move independently from each other to allow access to the PMs, the amount of cabling between detectors has to be minimized.

One interesting idea is to integrate the Preshower to ECAL, so that they are on the same mechanical structure. In this case, the Preshower electronics can be in the same crates as the ECAL one, thus sparing many long distance links.

4 Implementation

It is clear that handling information from 6000 Preshower cells, 6000 ECAL cells, 1500 HCAL cells and 12000 Pad Chamber pads with a 40 MHz repetition rate is not easy. In particular, passing information between detectors which have to be physically moved from time to time is a challenge. The implementation proposed in this note has been carefully studied to make these connections possible and not too expensive.

A global view of the proposed readout and trigger electronics is shown on figure 2 for the ECAL, a very similar system with a quarter of the electronics is needed for HCAL. Note that the connections to the other detectors are not shown on this figure.

4.1 Front End cards

A complete block diagram of the proposed Front-End card is given in figure 3. Each physical card will have 16 channels.

Each channel of the calorimeter (Preshower, ECAL, HCAL) has to be read out. The photomultiplier (or APD) signal will arrive to a front-end card, situated in electronics crates on the top or bottom of the detector. Each channel will have an analog shaping section, followed by a 40 MHz ADC with 12 bits for ECAL and HCAL, probably less for the Preshower. This raw digitization will be converted to an energy value by a 4k 12 bit look-up table, for pedestal subtraction and gain correction. The result is stored in a FIFO, to wait for the Level-0 decision.

4.1.1 Conversion to E_T

This raw digitization is also sent to another 4k 8 bit lookup table, to obtain the E_T needed for the level-0 processing. As this conversion to E_T is done with a look-up table, any correction

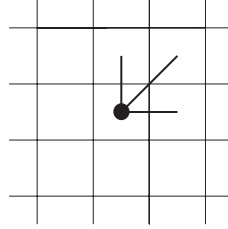


Figure 4: Neighbours of each cell.

to the simple formula (multiply the energy by the sine of the angle) can be applied, including leakage corrections, lower weight for the x component,... Note that the conversion to E_T will be saturated just over the maximum reasonable threshold, to keep the best accuracy: 10 MeV per count will be obtained with a saturation at 2.56 GeV of E_T . This basic function of the front-end card has been shown in the Technical Proposal, section 10.5.2.

4.1.2 2×2 sums

The first steps of the trigger algorithm are to perform the 2×2 sums, and to select the highest cluster in an 8×8 block. This is performed essentially in the front-end cards, thus minimizing the number of cable connections. It can be easily seen that one needs 9×9 channels to compute the 8×8 sums of 2×2 cells. A first approach for accessing the 9th row or column is to split the PM's output, and digitize twice, with a different gain on the photomultipliers. Note that in this case one cell in every block of 64 cells would have to be split in 4. This is not elegant, and requires extra readout channels to check and calibrate the split information. The solution we propose is to send the corrected (digital) E_T value of the neighbouring block when needed.

For each cell in the block, one adds the cells above, to the right, and above and right, as indicated on 4.

The 8 cells in the same column are on the same card. The addition of the cell above requires two external connection per column, the "above" of the first cell has to be received from another card and the lower cell has also to be sent to the card below. The 8 partial (vertical) sums are then added to the partial sum on the right, which will be passed by the backplane. In fact, one can fit 16 channels on a single front-end card, which will handle 2 columns of 8 cells, and then for one column the neighbours are on the same card, for the other they are on the neighbouring card, accessed by dedicated lines on the backplane. As one can most probably fit 4 blocks in the same crate, the horizontal neighbours are always in the same crate, except in the vertical separation of the two halves of the calorimeter. For this case, either we do NOT connect the neighbours, or we use special cards to send the 8 partial sums between two distant crates. The gain in performance due to this connection has to be weighted by its implications in terms of costs (special cards plus fast link, extra slot in each crate) and delay (pipe line) to add in every card to wait for this special case.

Connecting the neighbours between cells of different size is NOT implemented in this scheme, as it is too complex, and induces only a small inefficiency, when the shower is split between cells of different size.

4.1.3 Selection of the highest cluster

Once the sums are obtained, the highest cluster is selected in the front-end crate, using fast comparators. It is possible to select the highest cluster out of 8 (one column) and get its address in one clock cycle using a dedicated ASIC. The highest value and its address in each of the 8 columns will be sent via dedicated backplane lines to a “Summary Card” where the highest cluster of the block will be selected, using the same ASIC.

Note that the cards are identical for ECAL and HCAL. For the Preshower, the card will be different. First, because we don't probably need 12 bit ADC's, 8 bits may be enough and less expensive. Second, the information needed for the trigger is only one bit per cell, a comparison with a threshold. Third, there is no sum to perform. The individual bits must be made available to the ECAL decision, to select electromagnetic showers by the presence of a signal in the Preshower.

The operations performed so far require one wait cycle to get the data from the above cell, one cycle to add the above cell, one cycle to add the vertical sum to the right. One or two extra wait cycles would have to be added if the horizontal neighbours come from a dedicated inter-crate link.

4.2 Summary Cards

The summary cards for ECAL and HCAL have to perform the selection of the highest cluster of the 8 columns, as described earlier. They will also be the place to collect the information from other sub-detectors, i.e. the Pad Chamber for the Preshower, the Preshower (and Pad Chamber) for ECAL, the ECAL for HCAL, and also to send the information to the next stage in the case of the Preshower and of ECAL. There will be three different types of cards, since they have different functions. When adding information from different detectors, a timing adjustment is needed to add the information from the same beam crossing. At least one of the informations has then to wait (pipe-line) for the other to arrive.

4.2.1 Preshower Summary Card

The purpose of this card is to send to the ECAL summary card the Pad Chamber and Preshower information required for the selected ECAL local maximum. Three solutions can be envisaged:

- In the first solution the Preshower Summary card receives and handles the information coming from the Pad Chamber. As mentioned earlier, the 6000 bi-pads should be sent via high speed long distance cables to the Preshower crates, where a complex re-ordering has to take place.

The pads are then available in the crate via short distance (i.e. inexpensive) connections, for example via the backplane. The way to validate the “charged” signature, i.e. to associate pads to Preshower cells, has to be somewhat flexible if possible. Our current view is that a Preshower cell will be validated by the OR of 4 pads, the two in front and the two neighbours in the x (bending) direction, which is the OR of two adjacent bi-pads. This will double the number of informations sent from the Preshower crate to the ECAL crate, as each cell will then send two information: “electromagnetic” which means over a threshold, and “electron” which is “electromagnetic” and “charged”. Finally, the 9×9 bits of Preshower information and the same number for the Pad Chamber are sent to the ECAL summary card every 25 ns. This also means that the neighbours have to be obtained. A simplification would be to send only the 8×8 bits directly available, inducing a small loss in efficiency which has to be compared to the increased cost and complexity.

Globally, the Preshower will send about 12,000 bits to the ECAL summary cards. This is again a long distance high bandwidth connection. A Fast Serial Transceiver with an optical link can transmit 1 Gbit per second, i.e. 24 bits per BX, at a cost of about 1000 CHF per link. The Preshower to ECAL connection requires about 500 such links. The Pad Chamber to Preshower connection requires 250 links. A less expensive method using e.g. copper cables is being investigated, to decrease this cost.

- Another approach is to keep the Preshower and Pad Chamber data on the detector, and to let ECAL interrogate the detector for the wanted information. This clearly decreases the number of links, 2 (question-answer) per block, but increases the complexity of the answer: One has to store the data in a memory indexed by the bunch ID, access this memory and extract the 4 wanted bits, and send them back. The amount of information per link is small (6 bits address, 4 bits answer, plus a bunch ID) so one could use less expensive links, however this solution is probably more difficult to implement and to test.
- Finally, the Preshower front-end cards can be located in the same crate as the ECAL front-end, if the two detectors are on the same supporting structure. In this case the Preshower information can be added tower by tower to the ECAL information, adding one bit to the 8 bits of E_T , and then very simply merged and selected with the previously describe mechanism. Access to the Pad Chamber has still to be implemented if this solution is chosen.

4.2.2 ECAL Summary Card

The ECAL summary card selects the highest cluster of the 8 columns as indicated earlier. It also receives the 2 (“electromagnetic” and “electron”) times 81 (or 64) bits of the Preshower, and extracts the two flags for the local maximum: A “photon” and an “electron” flags, defined from the two times four bits in front of the ECAL local maximum. A look-up table can define these 2 bits from 8 inputs, typically OR of the “electron” bits flags an electron, while the OR of the “electromagnetic” bits in absence of any “electron” bit flags a photon.

In the case of the interrogation approach, the 2 bits will be received after a request, with several cycles of wait due to cable length. A small pipe-line is then needed in the Summary card.

The address and E_T of the local maximum are sent to the corresponding HCAL summary card. And the same information plus flags is sent to the **ECAL Selection Crate** in charge of selecting the highest clusters of the ~ 100 maxima. One has to send 14 bits to HCAL (8 bits E_T and 6 bits address), and 16 bits (the same plus flags) to the ECAL Selection Crate, both on long distance (optical fiber) links. Note that if the candidate is neither a photon nor an electron, one could “erase” it at this level, by sending a null E_T .

4.2.3 HCAL Summary Card

The HCAL summary card selects the highest cluster of the 8 columns as indicated earlier. It also receives 4 ECAL local maxima, as there are 4 ECAL blocks in front of one HCAL block. From the address of the ECAL and HCAL maxima, it is easy to compute (12 bit look up table) whether the addresses match. The highest of the matching ECAL maximum is then added to the HCAL E_T to obtain the best estimate of the hadron E_T . This value, and its address, is then sent to the **HCAL Selection Crate** using again a fast optical link.

4.3 Selection Crates

The purpose of these crates is to select the blocks with the highest E_T . The method is to search the value of E_T for which at most “n” blocks have a higher E_T . As E_T is coded on 8 bits, this requires 8 comparison cycles, to set the threshold bit by bit starting with the highest bit. Counting how many maxima among the 100 are over the threshold can not be done in digital electronics, but is possible using an analog sum. For each of the 100 maxima, a fixed amount of current is added on a common line when the value is over the threshold. The total current on this line is then proportional to the number of values over threshold, and a simple comparator will see if this is over or below “n”. Each comparison can fit relatively easily in a clock cycle.

The difficulty is that the 8 comparison cycles have to be done in pipe-line mode, i.e. there should be 8 copies of the hardware, each of them handling the 8 cycles of one event. For each of the 100 inputs we will have 8 registers. At each clock cycle, the data will be passed to the next register. The first register will be used for the first comparison, i.e. to set the high order bit of the threshold, needing 0 input bits, the second register will be used for the comparison setting the second bit, which requires one input bit, and so on. At the end, a ninth comparison will be performed so that each system will know if it is over the final 8 bits threshold. In this case, the value will be stored in a memory addressed by the bunch ID, and a line will be sent on the backplane indicating a valid answer for this card for this bunch ID. A first estimate indicates that one can put 8 of these systems per card, so only 14 cards cover the ECAL needs. The backplane needs 9 analog lines, for the answers of the 9 comparisons, and 36 digital input lines ($0 + 1 + 2 + \dots + 8$) for the 9 comparisons, plus 14 lines (one per card) to indicate to the Selection Controller which card has at least one valid answer. The readout of the data requires to address the card to be readout (14 individual lines or a 4 bit bus with the card number) and to specify the bunch ID (8 bits). The card will internally store the list of valid channels for this bunch ID, and output them one after the other when addressed. A signal indicating ‘no more on this card’ will allow the Selection Controller to address the next card at the next cycle. The readout bus will have less than 32 bits (8 bits E_T , 1 bit electron, 13 bits for the tower address, 8 bits for the bunch ID). The basic scheme of this receiver cards is shown in figure 5.

Each of these 100 systems will be reasonably simple, the “master” card will be more complex, with the 9 analog comparators, the pipe-line to set the threshold, and the mechanism to control the extraction of the candidates. On the ninth cycle, the master will check if any system is over threshold. At this level, one will apply a minimal threshold, of the order of 1 GeV for E_T , so that in average there is by far less than one candidate per beam crossing. The ID of the bunches with some data over threshold is stored in a FIFO, with the pattern of cards having some data. The output of the FIFO is used to access sequentially, but time ordered, the valid results on the known cards, and to send them, one after the other and at the BX clock rate, to the Level 0 Decision Unit. The main functions of this card are shown on figure 6.

For the ECAL crate, one can also envisage two copies of the control part of this selection mechanism, one for electrons and one for photons, and then directly select the highest electrons and the highest photons. In this case, one can use a low value for “n”, two is certainly a maximum, and this can make the Level-0 decision unit easier to build.

The HCAL selection crate is very similar, handling only about 30 inputs, and having of course only one type of particle to select.

4.4 Communication with the Level-0 decision

At this stage, the electron / photon / hadron candidates are selected. The time which has been used by this selection is about 20 cycles so far (6 in the front-end cards, 2 plus a few to wait

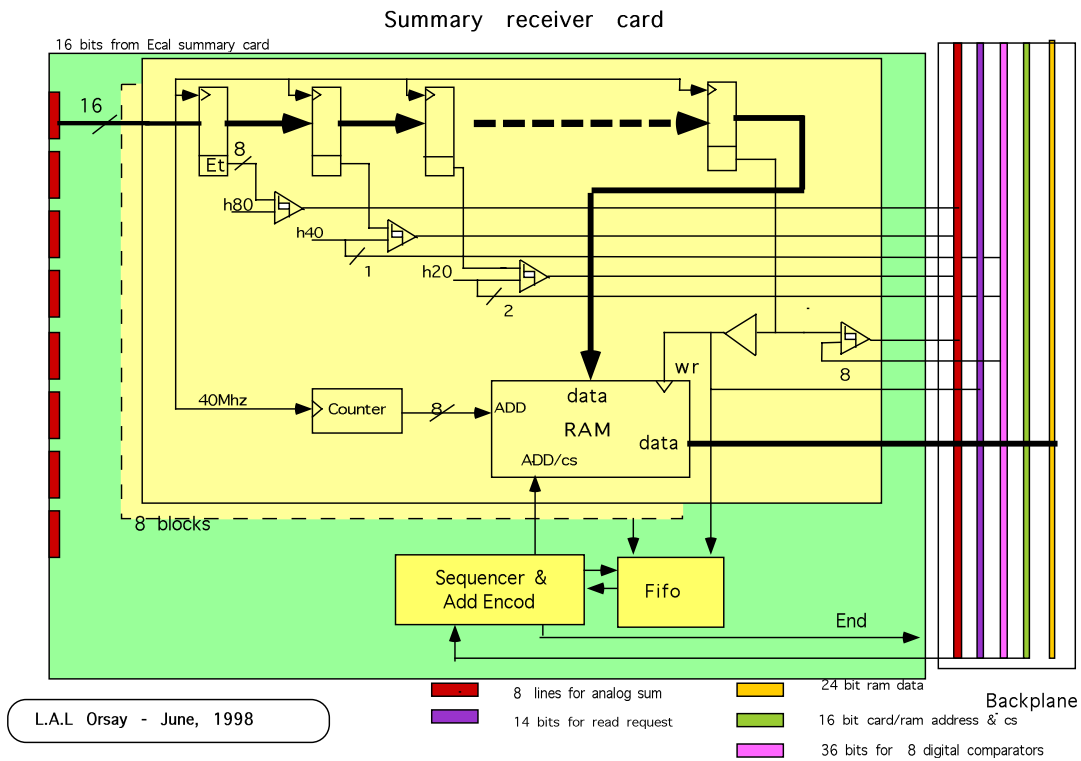


Figure 5: Receiver card in the Selection crate.

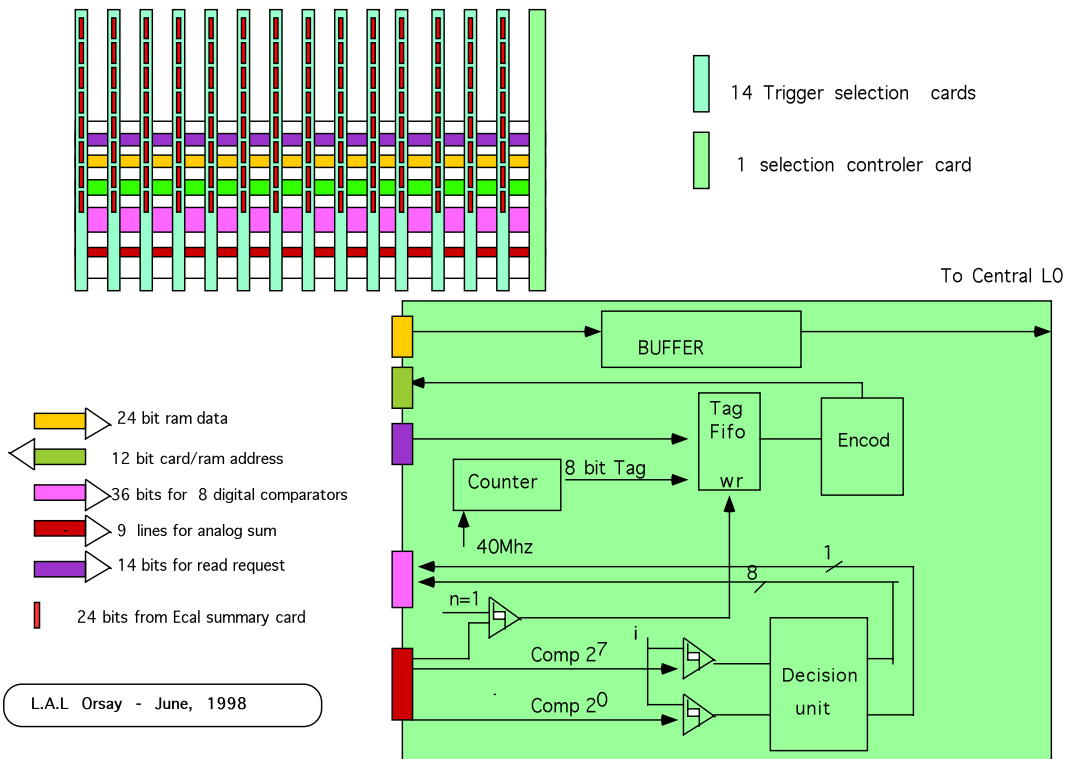


Figure 6: Selection crate, controller card.

for other detectors in the summary cards, 9 in the Main Selection Crates). There will be some more delay to wait for the Pad Chamber and the Preshower, as a 10 meter link can not be faster than about 50 ns, i.e. 2 clock cycles. The information sent to the decision unit is, for each selected candidate, the E_T , the type of particle (electron/photon/hadron), and the calorimeter cell number. Plus a bunch identification, as from this point we are no more synchronous. This is then about 32 bits per candidate, to be sent over a long distance as the decision unit will be situated in the electronics barracks.

5 Performances

The performance of this implementation has been simulated in SICB 113. This includes the conversion to 8 bit E_T , the 2×2 sums, the selection in 8×8 blocks, defined with the TP geometry, the validation of the Preshower and the Pad Chamber. The Preshower is not projective in SICB, but the matching by cell number was still used, inducing some small inefficiency at large angle. The Pad Chamber being recorded as hits in SICB, a virtual geometry matching the Preshower one was implemented, to have a correct matching. Sending of the ECAL maxima to HCAL was implemented not exactly as described earlier: as the geometry of HCAL is not projective in this version, the matching between ECAL and HCAL is done after computing the expected ECAL cell using straight line extrapolation from the vertex and not using just the cell number. This should not be too different from the proper implementation.

The data used are 5000 events, produced by SICB 113 for Minimum Bias events and $B_d^0 \rightarrow \pi^+\pi^-$ events, and by version 112 for $B_d^0 \rightarrow J/\psi(e^+e^-)K_s^0$ as there is no DST available from version 113. The differences between versions 112 and 113 are mainly in the HCAL geometry, and do not affect the electron trigger... Events are selected as being reconstructible using the AXACPT routine for the B decays. The efficiency number can not be directly be compared to the numbers in the TP, as here there is no selection of reconstructed, tagged events. However, we can compare the result of the official trigger as implemented in SICB with the results of the proposed one.

Figure 7 shows the efficiency for $B_d^0 \rightarrow J/\psi(e^+e^-)K_s^0$ with respect to the rejection for minimum bias as function of the threshold in computed E_T , for this implementation and for the SICB implementation of the electron trigger. For the same rejection, the E_T cut is clearly different, but the efficiency for $B_d^0 \rightarrow J/\psi(e^+e^-)K_s^0$ is very close, as can be seen from table 1 for two rejections.

Rejection	SICB		2×2	
	E_T	Efficiency	E_T	Efficiency
50	1.75	50.2	1.98	51.6
100	2.14	39.2	2.42	39.9

Table 1: Efficiency vs. rejection, electron trigger

Figure 8 shows the same comparison using $B_d^0 \rightarrow \pi^+\pi^-$ for the hadron trigger. The conclusion is similar, the efficiency is even slightly better for the same rejection, obtained at a slightly higher E_T , as can be seen from table 2.

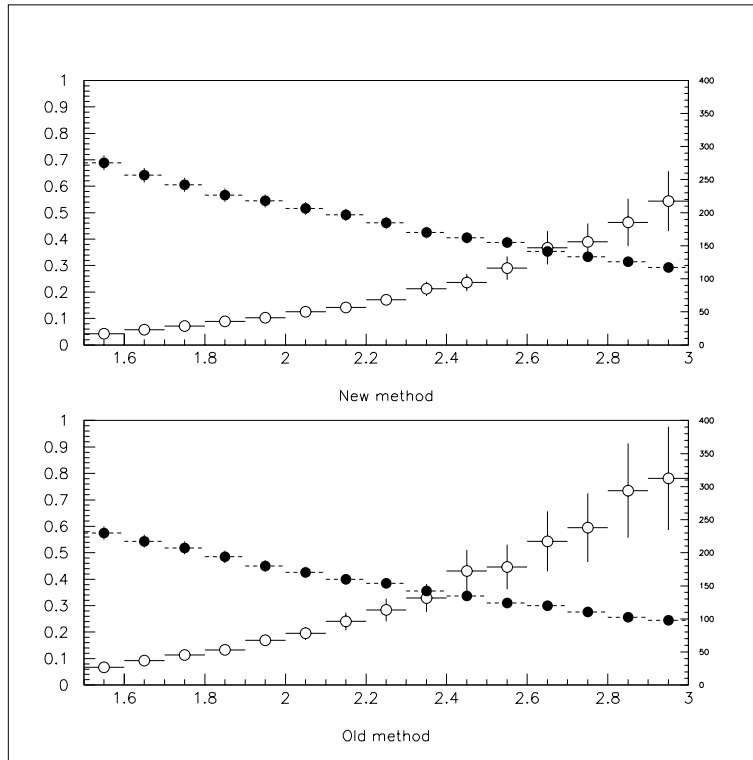


Figure 7: Efficiency for $B_d^0 \rightarrow J/\psi(e^+e^-)K_s^0$ and rejection to Minimum Bias events versus E_T for the electron trigger.

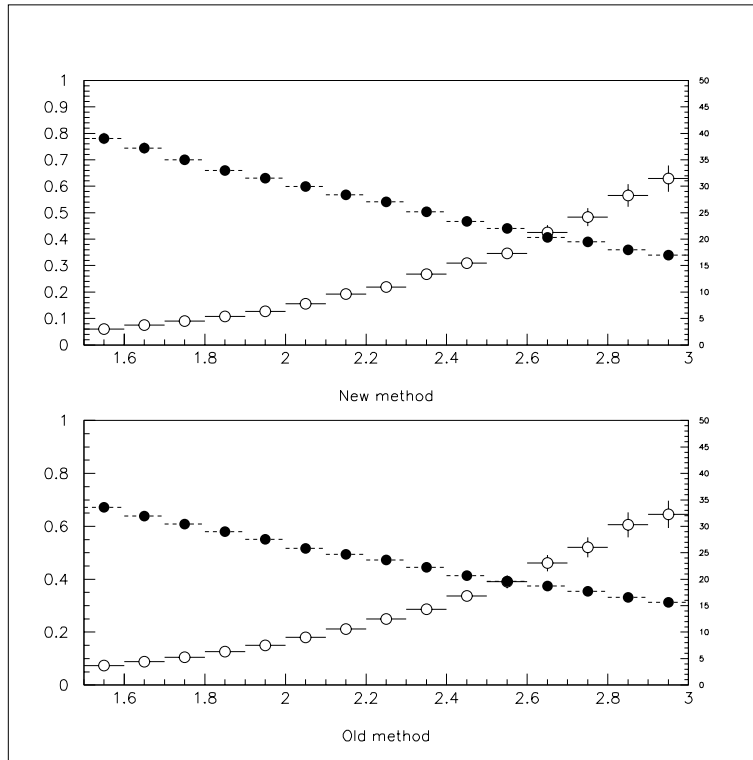


Figure 8: Efficiency for $B_d^0 \rightarrow \pi^+\pi^-$ and rejection to Minimum Bias events versus E_T for the hadron trigger.

Rejection	SICB		2×2	
	E_T	Efficiency	E_T	Efficiency
10	2.06	49.9	2.12	55.9
15	2.34	43.2	2.39	47.4
20	2.51	39.0	2.57	42.0
25	2.65	36.5	2.71	38.3

Table 2: Efficiency vs. rejection, hadron trigger

6 Cost

The system described in this note can be implemented with existing or announced commercial components. The major items have been identified and estimated.

Item	Number	unit cost CHF	Total cost kCHF
1. Pad Chamber to Preshower links	250	1000	250
2. Preshower to ECAL links	500	1000	500
3. ECAL to HCAL links	100	1000	100
4. Trigger part on the front-end card	7500 channels	45	340
5. Summary card	60	4000	240
6. ECAL Selection crate	1		160
7. HCAL Selection crate	1		100
Total			1690

The links are long distance (typically 10 m) high speed links which transmit 24 bits per beam crossing, i.e. 1 Gbit per second. Less expensive solutions are being investigated given that the links represent almost half of the cost of this implementation.

The first part of the trigger is integrated with the front-end electronics on the same board. The cost of the boards and crates is therefore included in the ECAL and HCAL electronics. Here only the cost of the specific components is considered.

The cost of the selection crates has not yet been precisely estimated, since their detailed design is still under study. At the present stage we assume 160 kCHF for ECAL Selection Crate and 100 kCHF for the HCAL Selection Crate to be safe estimates.

The Preshower and Pad Chamber parts have also to be looked at in more detail. Last, a more precise estimate of the decision part is needed.

References

- [1] An Alternative High p_t Electron Trigger for LHC-B
LHCb 97-021