A FAST SECOND LEVEL TRIGGER BASED ON Λ MASS IDENTIFICATION

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abstract

A fast second level trigger based on on-line lambda particle mass identification is presented. The trigger hardware analyses hit patterns from three wire planes behind the momentum-analysing Ω spectrometer. Track directions are calculated and corresponding charges and momenta are derived. Combinations of two tracks with opposite charges provide a determination of the invariant mass. The trigger design and its performance are reported.

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I - INTRODUCTION

The trigger system described in this paper was designed for the WA89 experiment at CERN [1]. The physics program of this experiment includes the study of the spectroscopy of charmed-strange baryons such as the Ξ_c , and of exotic hadrons such as the U (dimeson) particle, the H dibaryon and the pentaquark P (mesobaryonium), expected in interactions of the Σ^- beam with a nuclear target. All these hadrons decay weakly or may decay into strange particles and may have a Λ particle in their final products. A second level trigger based on Λ identification (decaying in the $p\pi^-$ channel) should thus provide an efficient way of selecting the wanted events out of the huge hadronic background.

The layout of the experimental set-up is depicted in figures 1a and 1b. The incident (secondary) beam is produced upstream of a magnetic channel by the 450 GeV proton beam of the CERN SPS bombarding a production target [2]. The beam is composite and contains mainly π^- and Σ^- particles, with smaller populations of other negative particles, Ξ^- , Ω^- , K^- , $\bar{p}$. The hyperon beam momentum was 360 GeV/c with a nominal spread of $\Delta P/P = \pm 15\%$.

Upstream of the target, a transition radiation detector is used to reject beam pions. Six silicon microstrip detectors (beam microstrips) allow an accurate determination of the trajectories of incident particles. Plastic scintillators are used to provide the beam trigger. The target is made of about 2.5% interaction length of natural carbon and copper. Downstream of the target, another set of microstrip detectors helps with the reconstruction of charm decay vertices. These detectors are followed by a 10m long decay path equipped with 36 planes of drift chambers (Λ chambers). At the energies considered here, strange particles decay dominantly in this region and the tracks of their decay products can be analysed. The particles enter next the Omega spectrometer magnetic field and pass through 36 planes of multiwire proportional chambers (A and B chambers) [3]. The field-dispersed particles emerging from the magnet then cross the large area drift (DC1 and DC2) and proportionnal (MY1-2, MY3-4) chambers, the scintillator hodoscopes H1 and H2, and the RICH detector, the latter providing particle identification. The electromagnetic calorimeter provides the energy information on γ 's and π^0 's produced in interactions and decays.

The first level trigger of the experiment is obtained from geometrical and topological multiplicity conditions, as well as momentum cuts involving the hodoscopes H1, H2, the MY2 chamber, the transition radiation detector, the beam and vertex microstrip detectors and the beam scintillators. This trigger decision is taken

within the first 550 ns after the event occurred. It gates ADCs and TDCs and strobes the readout of the wire chambers. This trigger is described in a separate document [4].

The analog to digital conversion of signals can take up to 300 μ s, depending on the electronic device used. During this time, additional calculations can be made and the readout of the event can be stopped, cleaning the event sample going onto tape and reducing the dead time of the apparatus. It is where the second level trigger described in this paper will act.

The paper is organised as follows. Section II briefly recalls the kinematical basis of the operation principle of this trigger and provides an outlook of the general architecture of the system. Section III deals with a more detailed description of the set-up. Section IV describes the setting and testing procedures used and the results of the trigger simulation. Results obtained with real data samples of the WA89 experiment are discussed in sections V-VI. A conclusion is given in section VII.

II - BASIC PRINCIPLE OF OPERATION AND GENERAL FEATURES OF THE SET-UP

The Λ decays into proton and pion with a branching ratio 0.642 ± 0.013 [5]. At typical energies around 100 GeV the decay occurs upstream of the spectrometer and the decay products are dispersed in magnetic the field according to their momenta. The invariant mass of a Λ in terms of the kinematic parameters of its decay products in the $\Lambda \rightarrow p \pi^-$ channel, assuming the masses to be small with respect to the momenta ($\frac{m_i}{P_i} \ll 1$), is given to a good approximation by the relation:

$$m_{\Lambda}^2 = P_+ P_- \theta^2 + m_+^2 \frac{P_-}{P_+} + m_-^2 \frac{P_+}{P_-} + m_+^2 + m_-^2 \quad (1)$$

where P_+ and P_- stand for proton and pion momenta and where θ is their relative angle in the laboratory.

This relation constitutes the formal basis of the trigger operation. The kinematic variables P_+ , P_- , θ and the particle charge, can be derived from the hit pattern of the Omega spectrometer detection system as described below.

II.1- Track identification and angle determination

A sketch of the geometrical arrangement of the detector elements involved in the

trigger together with the variable definitions is given in figure 2. A track is defined by its absolute momentum P , its charge and its emission angle at the vertex. P is determined from the (horizontal) deflection angle measured downstream of the Omega spectrometer using the Y coordinates of the hits (see figure 2 for the definition of coordinates) from the 3 detector planes, namely AY7 inside the field and MY2 and MY4 after the magnet. The horizontal bending angle θ_b of a particle trajectory deflected by the spectrometer field is related to its momentum by the first order approximation

$$\theta_b = \varphi - \varphi_0 = \frac{2.205 \text{ (GeV/c)}}{P}.$$

The sign of θ_b gives the charge of the particle. Let us specify by Y_2 and Y_1 the horizontal (Y) hit coordinates of the track in the MY2 and MY4 chambers located at X_2 and X_1 along the beam axis, respectively. The angle φ of the track with respect to the beam axis after the magnet is

$$\varphi = \text{atan} \left(\frac{Y_2 - Y_1}{X_2 - X_1} \right)$$

The extrapolation of the downstream trajectory back onto the plane normal to the beam axis at the Omega magnet centre ($X=0$) provides a coordinate value Y_0 (figure 2) from which one can estimate the horizontal trajectory angle φ_0 before the magnet:

$$\varphi_0 = \text{atan} \left(\frac{Y_0}{X_t} \right)$$

where X_t is the target position with respect to the Omega center. This latter relation assumes that the origin of the track lies inside the target. This is of course not true for Λ -decay products and this approximation results in an underestimation of φ_0 , which itself leads to a corresponding underestimation of the first term in relation (1). The resulting invariant mass spectrum is thus expected to exhibit a tail trailing on the low mass side. However, the effect is rather small ($\Delta M_\Lambda^2 \leq 0.082 \text{ GeV}^2$) and not damaging too much the efficiency of the Λ identification function. For the same reason it has been estimated acceptable not to determine the vertical trajectory angle and to use only its horizontal component.

In order to eliminate fake associations, Y_0 , φ , and φ_0 have been restricted to a range of values corresponding to possible tracks according to a Monte-Carlo simulation. Although the numerical values are not of general interest, we give them here for convenience: $Y_0 = \{-176, +176 \text{ (cm)}\}$, $\varphi = \{-0.3, +0.3 \text{ (rad)}\}$, $\varphi_0 = \{-0.01, +0.01 \text{ (rad)}\}$.

II.2 - Trigger design

The trigger operates in a sequence of two main steps:

1) - The first step aims at identifying particle tracks from the three (AY7, MY2, and MY4) chambers hit patterns. It consists of a triple loop over the three sets of hits (referred to as track-loop in the following) from the chambers. Hit combinations resulting in parameters outside the cuts are rejected. For each track, identified following a procedure detailed further below, the computed kinematical parameters are stored into buffers. Positive and negative tracks are stored separately.

2) - In the second step a double loop (referred to as mass-loop) is performed over the positive and negative tracks stored in the first step. For each combination of one positive (assumed to be a proton) and one negative (assumed to be a pion) track, the invariant mass is computed according to relation (1). A window set on the invariant mass around the Λ mass value ($1.107 \text{ GeV}/c^2 < m_{\text{inv}} < 1.120 \text{ GeV}/c^2$) selects Λ candidates and provides either the second level trigger or a Λ tag of the event.

The associated decision logic also incorporates further kinematical criteria for event selection.

Figure 3 shows a schematic view of the general trigger architecture. The set-up has been realized using the MBNIM electronic standard developed in the CERN-Omega group [6,7]. All the required functions could be found in the standard modules available or in modules developed for specific purposes [7]. Some of the modules used in this work are described in the appendix, for convenience.

III- DESCRIPTION OF THE SET-UP AND TRIGGER OPERATION

III.1 - Chamber read-out

The three chambers used in the trigger are equipped with a fast read-out system (FASTRO) associated to fast encoding modules (FASTEN) [7,8]. The chamber hit patterns are also read in parallel (but sequentially) by SIREN modules together with all the other chambers of the Omega spectrometer, to be written on tape [7,8]. The FASTEN modules load the encoded coordinates into a built-in FIFO register where the information is available for the event processing. After completion of the loading process a ready signal (RD) is delivered on the front panel of the FASTEN modules and the first set of data are put on the front end MBNIM bus [6]. A "NEXT SET" signal forces the next register data to be ready on the bus if the "FROM PREVIOUS" input is active,

otherwise the same register data are put on the bus. A "TO NEXT" signal is generated when the register stack is exhausted, for looping purpose. The module restarts automatically after it has reached the last register address written, or it can stop thereafter. The RD signal is then set low. Otherwise, the RD signals are kept at active level as long as a RETURN signal has not been sent to the module to signal the end of operation. The RETURN is generated from the trailing edge of the RD signal of the module corresponding to the outermost loop, namely AY7 in the present case. The RETURN can alternatively be generated externally by the decision logic (time-out, etc..) to stop the process (see section III.4). Provided with these features, the FASTEN modules offer the flexibility of delivering their data to the electronic processing chain in loop sequences. The set-up of the FASTEN loop used here is given in figure 4 for the handshake mode and the pipeline mode. In addition, it is possible to define an input acceptance window, set by internal switches, to reject hits outside a given interval, thus allowing a geometrical cut on the data at the very early stage of the processing.

III.2 - Track loop

As mentioned above, the purpose of this step is to associate sets of hits recorded in the 3 chambers to (likely) particle trajectories and to store their kinematical parameters into buffers (track buffers).

All the $N_{MY2} \times N_{MY4} \times N_{A7}$ combinations of hits in the acceptance window of the FASTEN modules, are processed in this sequence unless the process is stopped by the control logic when a rejection or validation decision is made. The criterium used to identify a given combination of hits as a good track requires that the linear extrapolation based on the two hit coordinates ($Y1, Y2$) onto the AY7 chamber plane inside the Ω field, points to a coordinate which has a corresponding AY7 hit in its close neighbourhood ($-2.1 \text{ cm} < Y3 - Y_p \leq 1.1 \text{ cm}$, determined from the simulation). The asymmetry of the bounds accounts for the small bending of the trajectory in the magnetic field after AY7. Positive particles with $P^+ \leq 40 \text{ GeV}/c$ and negative particle tracks outside the range $6 \text{ GeV}/c \leq P \leq 100 \text{ GeV}/c$ were rejected.

The relevant kinematical quantities are calculated for each combination, i.e. the particle momentum P and the particle emission angle ϕ_0 before the spectrometer magnet. The charge of the particle is determined and the kinematical quantities $P_{\pm}$, $\phi_{0\pm}$, are stored in the track buffers when the track identification criteria are satisfied.

Some kinematical conditions are also involved in the track selection. They will be discussed in section III-4.

Organisation of the sequence:

Figure 5 shows the organisation of the control logic, and a functional block diagram of the set up is given in figure 6.

During the track loop, the track parameters are stored in dedicated (+ or -) track buffers (RAHMs). Two sets (for + and - tracks) of two modules [7]: COUNTER, a counter to increment the track-buffer memory address, and SPACER, a register for storage of the last memory address in the track loop, are used to handle the storage process.

The track loop is initialised by the first level trigger. COUNTER and SPACER modules are then set to start values and RAHMs are set to write mode. The start up of the loop is controlled by a triple coincidence between the RD signals from the three FASTEN modules MY2, MY4, AY7 (figure 4). The data are then pipelined through the electronics at a rate determined by the propagation time of the "data-ready" (DTRD) signal through the processing chain on the MBNIM bus. For each piece of data processed, the current counter output is given as memory address to the buffer and the track parameters are stored at this address. When a track is identified, then the address counter is incremented by one unit (leaving the validated track parameters at the previous memory address). It is also stored in parallel in the spacer so that this register will contain the last buffer address after completion of the loop. This information will be used in the inner mass loop as a start address for the decrement process. The whole loop ends naturally or is interrupted on the occurrence of the RETURN signal as already mentioned.

In the first part of an elementary cycle of the loop the following operations are performed in parallel (see figure 6):

- a) - the emerging trajectory angle ϕ is calculated, using the relation given previously, from the hit coordinates Y1 and Y2 from the MY4 and MY2 chambers (ALU1, RAHM's 5, 15).
- b) - the angle ϕ_0 of the trajectory entering the spectrometer is obtained from the extrapolated Y_0 value (RAHM's 3,4, ALU2, RAHMs 6,16)
- c) - the emerging trajectory is extrapolated onto the detection plane AY7 (RAHM's 1,2, ALU3), providing a predicted hit coordinate Y_p .

The triple loop over the FASTEN data contents is organised in such a way that, in the innermost loop, all Y_{3i} coordinates are compared to Y_p . When Y_{3i} is found within the accepted error (RAHM9), a flag is set to identify the current set of hit coordinates $\{Y_{1i}, Y_{2i}, Y_{3i}\}$ as belonging to a physical trajectory. In parallel to this, the

charge of the particle is obtained from $\phi - \phi_0$ (ALU6), the corresponding sign flag is set (RAHM14) and the particle momentum (Log) is calculated (RAHM's 12, 13). When all selection criteria are satisfied, the track parameters are stored (RAHM's 22,23 (+), and RAHM's 27,29(-)).

More technical and functional details on the set-up are given below for convenience. The MY2 and MY4 wire chamber planes consist of 768 wires with 4 mm spacing. The AY7 chamber has 760 wires with 2 mm spacing. The FASTEN modules are configured so as to cutoff wire numbers outside the region of interest. The look-up table (RAHM) modules must be addressed using bit numbers 1 to 10, corresponding to the range 0-1023 in decimal value. A RAHM can be configured so as to use negative addresses. The electronic chain had to be designed so that all RAHM inputs are scaled to fit the address range. In figure 6:

- the arithmetic and logic unit ALU1 performs a subtraction. If the output value is positive, RAHM5 is addressed, whereas RAHM15 is addressed in case of a negative value.

- For a given output of ALU2 (sum), the output of RAHM16 is the same as that of RAHM6 plus an offset so as to get always a positive address to RAHM34 in the mass loop.

- The contents of RAHM's 5,15,6, are set to have positive ALU6 outputs for the allowed range of values of $\phi - \phi_0$ (then RAHMs 14,12,13 are addressed), otherwise ALU6 delivers negative addresses accepted by RAHM17.

- RAHM's 12 and 13 provide the momenta of positive and negative tracks respectively.

- ALU5 performs the Y3-YP(-1) operation; the MINIMA module is configured to convert the negative ALU5 output to a (large positive) value such that RAHM9 is addressed in any case and provides a flag if Y3-YP is within the window of acceptable values. This validates the set of hits being treated as a physical track.

- the rôle of RAHM14 is to provide several flags:

- the charge information if the momentum value is within the acceptance window.

- the indication that a positive track with $P > 200 \text{ GeV}/c$ has been found.

- the indication that a negative track with $P > 35 \text{ GeV}/c$ has been found.

- ALU21 collects the flags from RAHMs 9 and 14 and feeds them into a terminim module. They are then used in the control logic to make the decision on storing the track parameters.

- the DTRD signal from ALU6 is used to control the writing into the buffers and sent as a write order to the counters at the end of each cycle of the track-loop. When a trajectory has been found, a clock signal is generated from the flag coincidence module which increments the counter address to the next value, waiting for the next validated track.

III.3 - Mass loop

In this step, the invariant mass of each combination of one positive and one negative track is calculated. After completion of the track loop, identified tracks are available in the buffers. The mass-loop can then be initialised. The same trailing edge of RD signals used to end the track loop is used for that purpose: RAHMs are set to read mode, the COUNTERs are loaded with the last used memory address from the SPACERS, set to decrement mode, and the first track pair parameters are put on the bus. The mass loop is then started, operating in handshake mode via the MBNIM bus control lines. Each time the inner-loop counter reaches the address 0 (end of inner loop) the start address is reloaded from SPACER to COUNTER, the other (outer loop) COUNTER address is decremented by one unit and the loop goes on. This is done until both COUNTER modules reach the address 0. This latter configuration is detected by a coincidence between the two address 0 signals, which puts an end to the processing.

III.4 - Decision logic

The decision logic is designed so as to validate the event if one of the following criteria is satisfied:

- a Λ candidate is found within the defined invariant mass window and a negative track of more than 35 GeV/c has been found.
- a positive track of more than 200 GeV/c has been found.

Besides, for high multiplicity events, the event processing has to be timed-out to avoid an unacceptable increase of the dead time.

Some of the above conditions were dictated by specific experimental purposes else than simple Λ identification.

Thus, the decision logic (see figure 5) is set up to :

- stop the process, inhibit the event rejection, and reset the electronics

when a $P_+ > 200$ GeV track is found during the track loop, or when a time out signal occurs.

- clear the data acquisition at the end of the track loop and reset the electronics if neither a positive track with $P > 200$ GeV/c, nor a negative track with $P > 35$ GeV/c has been found.

- clear the data acquisition (validate the event) if the processing ends finding no Λ (finds a Λ), the above conditions having been already checked.

IV- SETTING AND TESTING PROCEDURE

The rather high complexity level of the set-up and the critical character of the timing of the two loops required a rigorous and flexible testing procedure. This has been made possible by means of a special module developed at Saclay [9] allowing the built-in RAM of the Fasten modules to be computer loaded. This RAM operates in parallel with the data FIFO register, and it can be read and written by CAMAC. The 3 FASTEN modules could thus be loaded either with simulated hits or with off-line generated hit data, and these data then be processed through the electronics operating under data-taking conditions. The settings of the electronics could then be performed in a safe way, the initial conditions could be varied at will, and the boundary conditions (initialization and ending of loops), together with some particular hit configurations be explored in details.

The settings of the track loop were first done with the loop operated in handshake mode. This procedure was considered as the safest way to proceed. After a correct operation was obtained in handshake mode, the driving was switched to pipeline mode and the pipeline period set at the minimum compatible with the normal operation of the loop. The final setting of the pipeline clock period had to be at least 420 ns (instead of 1 μ s in handshake mode). This number is compatible with the estimate made from the transit times in individual modules.

Various computer files of hits have been constructed and used for the settings. At the final stage of testing the ensemble, files obtained from the Monte-Carlo simulation of the events as well as files of real hit coordinates read from data tapes, were used and the resulting configuration for each event compared to the results of the trigger simulation.

V- STUDY OF TRIGGER EFFICIENCY

V.1 - Efficiency of the track finding technique

The track finding efficiency of the trigger algorithm was evaluated comparing the results found by the trigger with the results obtained with the off-line track finding program (TRIDENT)[10] used for data analysis, taken as a reference. The tracks found by TRIDENT were selected in such a way that:

- the abscissa of the last data point along the track is in MY4 or downstream
- the momentum is inside the acceptance window
- the Y coordinates of the intersection between tracks and detector planes are within the geometrical acceptance

Using the raw data from the 1990 run, the FASTEN contents have been read back from tapes for a sample of events, and fed into the simulation program of the trigger. For track finding, TRIDENT uses the hits recorded from the SIREN modules. The track reconstruction efficiency of the Λ trigger algorithm was about 91%. A detailed analysis of this result shows that the trigger inefficiency arises mainly from the chamber + readout inefficiencies. For each chamber, the inefficiency is estimated to be 2.7 %, 3.4 %, and 2.3 % for AY7, MY2, and MY4 respectively.

Figure 7 shows the error on P and θ , obtained by comparing the values computed by TRIDENT to those evaluated by the Λ trigger algorithm. The trigger underestimates the momentum by 1.85% in average with a distribution rms of 4.5%. The angle is slightly overestimated, on the average by 0.34% with a rms of 1.17%. These results are excellent considering the approximations used in the trigger algorithm.

V.2- Efficiency of the lambda trigger algorithm

The first step of the testing procedure was to simulate the MBNIM chain, in order to check first that the Λ -trigger algorithm does identify Λ particles from their decay products and to verify the correctness of all the MBNIM module (ALU, RAHM, MINIMA) configurations and memory contents along the chain.

Using a sample of Monte-Carlo events containing Λ decays, the efficiency of the Λ trigger algorithm to find lambdas was found to be 99%. The same test was made with a sample of real events from the first run of the WA89 experiment, containing off-line identified Λ particles: when the hits of the decay products in AY7, MY2, and MY4 were available, allowing normal track reconstruction, the efficiency of Λ finding

was 98%. Figure 8 shows the invariant mass spectra obtained from the trigger simulation (right) and from a full kinematical calculation (left) using equation 1 for the same sample of Monte-Carlo (top) and real (bottom) data. For each event the invariant mass of all +/- track combinations was computed and appear in spectra. The latter show the lambda mass peak at the lower edge, followed by a combinatorial background extending to the higher mass region. The peaks appearing on the right part of spectra c) and d) correspond to events rejected by the trigger.

V.3 - Test of the electronic set-up

The hardware has been tested using hits extracted from raw data, which were loaded into the FASTEN modules as described in section IV. The tests consisted in a systematic comparison of the rates of the different trigger decisions, measured on scalers, with the values predicted by the simulation program from the same set of hits. The two right most columns in table 1 show that the agreement between counting rates from electronic processing and from simulation results is good. An event by event comparison also leads to a satisfactory agreement.

VI - STUDY OF THE TRIGGER TIMING

The duration of the trigger is determined by four factors:

- 1) - the hit multiplicity in the acceptance window,
- 2) - the length of an elementary track finding cycle,
- 3) - the number of found tracks, and
- 4) - the length of an elementary cycle in the mass loop.

The length of the track loop cycle was optimised to 420 ns, while the length of the mass loop cycle was fixed by the handshake protocol to 290 ns.

The number of hits depends on the experiment actual running conditions. In the case of WA89, it was of the order of 6x6x6 for the three chambers and with the chosen geometrical cuts.

The numbers of positive and negative tracks depend on the quality of the data and on the acceptance criteria. In the present case, table 1 shows that it was about 1.3 positive and 5.7 negative tracks per event.

Figure 9 shows the distribution of processing time of the track loop as measured on-line during the 1990 run of the experiment. The conversion time for the ADC's and TDC's of the experiment was about 300 μ s. After this time a clear could be applied to the data acquisition. With a time limit set to 270 μ s the processing finished

normally for about 87% of the events, leaving 13% unchecked.

VII- SUMMARY AND CONCLUSION

A second level trigger working with decision times comparable to the conversion time of standard digitizing electronics has been set up and successfully tested.

The trigger for track reconstruction has been designed to use two sets of coordinates to get the direction of particle trajectories and a third set inside a magnetic field to get the particle momenta and charges.

A simple algorithm has been developed to combine positive and negative track pairs and find their invariant mass. In the present configuration the Λ mass finding efficiency proved to be $\eta_{\Lambda} \times \eta_{+} \times \eta_{-} = 0.98 \times 0.91 \times 0.91 \approx 0.8$, mainly due to the inefficiency of the detectors used (the overall detection inefficiency is twice the individual detectors efficiencies since there are two charged tracks). With 100% efficient detectors, the loss would be less than 2%.

The main limitations of the trigger are the hit multiplicity in the tracking devices because of the limited time available for the decision and the finite momentum and mass resolution due to the limited address space in the look up units.

The main structure of this second level trigger can be used in any experiment with tracking detectors and for any invariant mass if the reconstruction from two charged particles is possible. It has proved to be a highly efficient tool in cleaning the event sample and thereby reducing the experiment dead time and the computing power needed in the off-line analysis.

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APPENDIX

We give here a brief description of some of the MBNIM modules used in the set-up. MBNIM [6,7] is a modular trigger logic system using a flat cable ECL 10K as a connecting medium. The bus may operate at up to 100 MHz. It carries 16 data bits plus four bits for handshakes on single-ended ECL lines.

- 1) - ALU-16 : a 16-bit arithmetic and logic unit in the CAMAC standard with two MBNIM bus inputs and one output. It can perform either arithmetic operations or bit by bit logical functions.
- 2) - RAHM is a 1K x 16-bit random access high speed memory for look-up table applications. It is written and checked via CAMAC. The MBNIM output channel of the RAHM can be used as input into the memory when the relevant bit of the handshake lines is set.
- 3) - COUNTER is a 16-bit up-down counter, which can be used either as a simple counter or as an address register and master device for RAHM module.
- 4) - SPACER is a 16-bit register for one single word.
- 5) - MINIMA is a bit assigner. Each bit of the input word is assigned a 16-bit word. The logical OR of the words enabled by the input makes up the output. It is a hardwired bit assignment.
- 6) - TERMINIM converts the signals on the MBNIM bus into NIM logic levels.

REFERENCES

- [1] Proposal for a new hyperon experiment at the Cern SPS, Bologna-Genoa-Grenoble-Heidelberg U.-Heidelberg MPI-Mainz-Mons-Moscow, report CERN/SPSC-87/43
- [2] P.Grafström, Σ^- Beam for the Omega Spectrometer in the West Hall at Cern, report CERN/SL/90-104 EA
- [3] W.Beusch et al., omega prime report CERN/SPSC/77-70, august 1977.
- [4] S.Paul and K.Röhrich, WA89 internal note, january 1991
- [5] Particle data group, Phys. Lett. B239 (1990) 1.
- [6] F.Bourgeois, proc. of the Nucl. Sci. symposium, San-Francisco, october 17-19, 1979 and report CERN/EF 79-3, october 1979; MBNIM user guide, F.Bourgeois edit., report CERN/EF, jan. 1984
- [7] A.Casaca and A.Corre, NIM A253 (1986) 77; A.Casaca, report CERN/OM/SPS/84-3
- [8] W Beusch et al., NIM A249(1986)391
- [9] F.Bourgeois and A.Corre, private communication
- [10] J-C Lassalle, F.Carena, and S.Pensotti, NIM 176(1980)371

Table caption

Table 1 - The table gives the average numbers of positive (negative) tracks per event, the percentage of events with $P_+ > 200 \text{ GeV/c}$, with $P_- > 35 \text{ GeV/c}$, the percentage of events containing a lambda, the rate of time-outs, and the number of rejected events. The first column provides the numbers measured directly from trigger electronics. They have to be compared to the numbers obtained from the trigger simulation using an off-line data sample (obtained from the on-line readout via the SIREN modules, see text), given in the second column. The last two columns compare the numbers obtained from the same (off-line) data sample, loaded into FASTENS and processed through the trigger hardware (column 3) with those obtained from trigger simulation (column 4). The numbers in columns 1 and 2 are to be compared to each other, as well as those of columns 3 and 4, but not between the former to the latter group of columns since they correspond to samples taken in different conditions. Similarly, the noticeable difference between the $P_- > 35 \text{ GeV/c}$ countings in columns 1 and 2 is due to a difference between the logics in the simulation and in the real set-up.

- Table 1 -

	on line data Λ trigger scalers	off line data hits in AY7, MY2, MY4	off line data hits in AY7, MY2, MY4 (SIREN read out)	
(Mean values)		Simulation of Λ trigger set up : MBNIM + logic	Electronic setup FASTEN 'fed' with hits	Simulation of Λ trigger set up : MBNIM + logic
+ tracks / event	1.3	1.5	1.5	1.48
- tracks / event	5.7	4.7	4.97	4.99
$P_+ > 200 \text{ GeV/c}$	10 %	9.3 %	10.9 %	11 %
$P_- > 35 \text{ GeV/c}$	31 %	22 %	35.9 %	36.7 %
evts with Λ	9 %	10 %		18 %
time-outs	23 %	23 %	9.8 %	8.1 %
rejected events	65 %	60 %	63.8 %	63.8 %

FIGURE CAPTIONS

Figure 1 - general schematic view of the WA89 experimental set-up (a) and details of the target region (b).

Figure 2 - Detection elements involved in the Λ -trigger and definition of the variables used to define trajectories.

Figure 3 - Lambda trigger operation principle and general architecture of the electronic set-up.

Figure 4 - Set-up of the FASTEN modules in the triple loop configuration for the handshake mode (above) and pipeline mode (below) of operation.

Figure 5 - Control logic of the second level trigger. The normal end of the track-loop, i.e., the RETURN signal provided by the TO NEXT (end of fifo stack) signal of the outermost loop FASTEN is implicit in the FASTEN block of the figure (see figure 4).

Figure 6 - Functional block diagram of the processing electronics.

Figure 7 - Errors on the momentum (a) and ϕ angle determination (b) made by the trigger with respect to the values obtained with the off-line program (Trident) in %. The trigger underestimates the momentum by 1.85 % on the average, with a distribution rms of 4.5 %. The angle ϕ is slightly overestimated on the average by 0.34 % and the distribution rms is 1.17 %. These values are acceptable for a good trigger efficiency.

Figure 8 - Invariant mass spectra obtained for all +/- track combinations from:

- 1) - Λ trigger simulation program by means of relation (1) (a and c)
- 2) - Output of RAHM36 (see figure 5), converted into GeV/c^2 . a) and b)

correspond to about 2000 processed events. c and d are from events of the same run and contain at least one lambda particle identified by an off-line analysis program. The lambda mass peak is clearly seen in all spectra around $1.11 \text{ GeV}/c^2$. The trigger simulation (b,d) provides results quite similar to the computation of relation 1 (a,c). The part of the spectra extending to higher invariant masses above the lambda mass is a combinatorial background (see text).

Figure 9 - On-line measured event-processing time distribution in the track loop. The points give the proportion of events having a processing time larger than the time-out value given in the abscissa. The track loop duration represents by far the longest part of the event processing time, the mass loop duration being only a small fraction

of it. This distribution is thus close to the full event time processing. The curve is to guide the eye.

WA89 Experiment

WA89 - target region

- Figure 1 -

- Figure 2 -

- Figure 3 -

- Figure 4 -

- Figure 5 -

- Figure 6 -

- Figure 7 -

invariant mass spectra

- Figure 8 -

- Figure 9 -