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G.Chlachidze, A.Kirk*, S.Maljukov, I.Minashvili,
V.Romanovsky, N.Russakovich, A.Semenov, A.Solovjev

ELECTROMAGNETIC CALORIMETER TRIGGER FOR THE WA91 AND WA92 EXPERIMENTS

*CERN, Geneva, Switzerland

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1. Introduction

The electromagnetic calorimeter (ECal) used in CERN experiments WA91 and WA92 has a surface area of 2.5x2.7 m^2. It consists of an array of 18x19 Cherenkov lead glass counters, each with 18.5 radiation lengths in depth (lead glass type SF5 [1]). The Cherenkov light is registered with a photomultiplier tube (PMT) of type "XP-2050". In addition to the anode signals of the PMT, which are digitized by ADCs, the last dynode pulses are used for trigger purposes.

The ECal trigger performance for the WA91 and WA92 experiments and the specially designed fast electronic modules are described in this paper.

2. Selection of events containing the required number of electromagnetic (EM) showers with energy greater than a certain threshold

Experiment WA91 used the CERN Ω spectrometer to search for exotic (non-$q\bar{q}$) mesons produced in the central region in the reaction

$$pp \rightarrow p_f(X^0)p_s \tag{1}$$

at 450 GeV/c [2], where the subscripts f and s indicate the fastest and slowest particles in the laboratory and X^0 represents the centrally produced system. This experiment is a continuation of the WA76 experiment which has studied light meson spectroscopy using 85 and 300 GeV/c beams [3,4] and has reported the observation of two previously unobserved mesons, the X(1450) and X(1900), at 300 GeV/c [4]. These mesons cannot be easily interpreted as $q\bar{q}$-states and are proposed to be candidates for exotic states. One of the main aims of the WA91 experiment was to confirm the existence of these states and to determine their quantum numbers at high statistics.

The WA91 experimental layout is shown in Fig.1. A set of detectors was designed to study X^0-decays with charged particles as well as neutrals (K^0, π^0, η mesons) in the final state. Due to the relatively low mass of the centrally produced X^0 system the kinematics of reaction (1) requires two quasi-elastically scattered "slow" and "fast" protons. Therefore the basic trigger requirement is to distinguish the events with centrally produced meson states from the much larger sample of elastic pp scattering events. Several trigger conditions were used to select low-multiplicity non-elastic events with a centrally produced X^0 meson system:

- Non-elastic $p_f p_s$ kinematics: events where the transverse momenta of "fast" and "slow" protons do not balance (e.g. p_f and p_s are both on the same side with respect to the beam line). The "slow" proton was defined by requiring a hit in the Slow Proton Counter (SPC) in coincidence with a hit in the Target Box (TB) counters; the "fast" proton was defined by asking for a coincidence between the A1 and A2 (left or right) scintillation counters (see Fig.1)

- Quasi-elastic $p_f p_s$ kinematics: these events were selected by requiring a few low momentum charged particles or by requiring γs in the final state. The multiplicity of charged particles was analysed by a fast processor using information from one

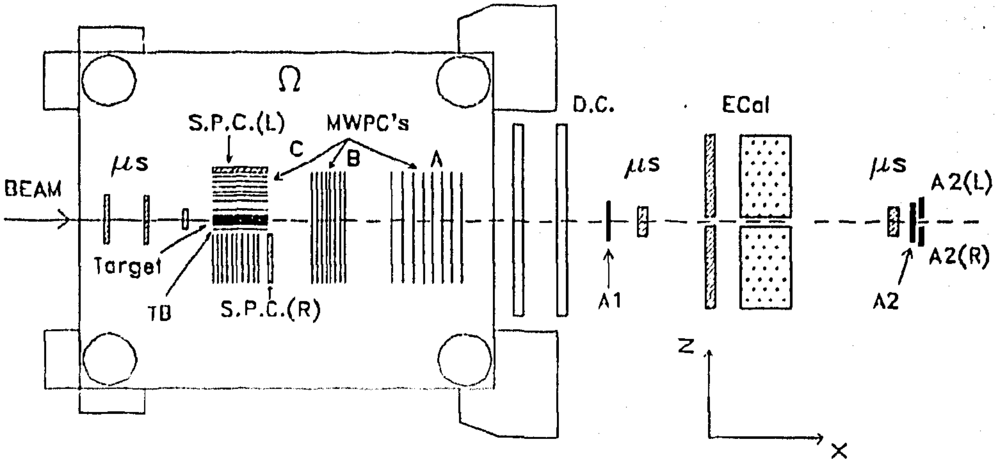

Fig.1 The WA91 experimental layout:
SPC(L) and SPC(R) - Left and Right Slow Proton Counters; TB - Target Box scintillation counters; DC - Drift Chambers; μs - Silicon microstrip detectors; ECal - EM calorimeter; MWPC - Multiwire Proportional Chambers; A1, A2, A2(L), A2(R) - scintillation counters

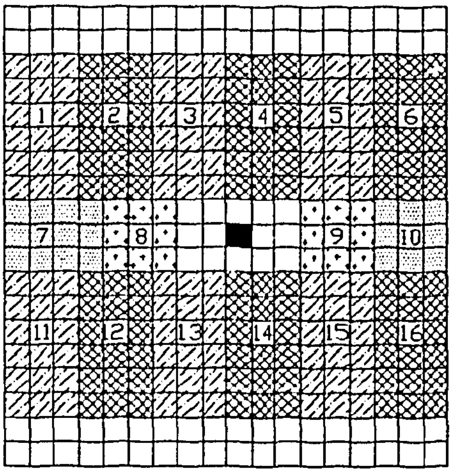

Fig.2 The ECal trigger groups in the WA91 experiment

plane of the A MWPC's (see Fig.1). The trigger on the γs in the final state and its performance based on the estimation of the EM shower multiplicity is described in detail below.

The ECal trigger has been developed to select events containing the required number of EM showers (1, 2 or more) with energy greater than a certain threshold. In order to estimate the number of γs the calorimeter cells were combined into 16 trigger groups (Fig.2). The photon occupancy of the ECal elements and the geometrical topology of clusters have been taken into account when trigger groups were composed. Since the last two rows at the top and bottom of the detector are weakly exposed to γs, these cells have not been used for trigger purposes. The ECal elements around the hole in the centre of the detector have not been included in trigger either, since they were mostly affected by charged hadron interactions. In the case of low photon multiplicity the number of ECal trigger groups with deposited EM energy greater than a threshold corresponds approximately to the number of γs.

The ECal trigger system was developed on the basis of 16 CAMAC modules. Each of them contains (Fig.3):

- a 20-input current analog adder,
- a linear gate,
- a pulse-height discriminator,
- an output pulse shaper.

The module decision time is about 15 ns. The summation accuracy including the time spread in ECal responses is less than 10%. The threshold can be adjusted by a front-panel potentiometer in the 10 — 1000 mV range corresponding to the 0.1—15 GeV energy range of ECal responses from photons. Adjustment of thresholds in the electronic modules was done during the test measurements on a muon beam.

The PMT signals from each ECal trigger group are received by a single electronic module; the sum of these signals is sent to a majority logic unit. The designed electronic modules are also able to trigger on events with total energy deposition in ECal exceeding a certain threshold. This could be provided by entering the linear outputs from all trigger modules to an additional one, where the total energy deposition threshold is set.

The general requirement for all trigger components in the WA91 and WA92 experiments is to minimize the dead-time losses. In order to reduce the execution time of the ECal trigger algorithm as well as signal delays the trigger electronics is placed adjacent to the detector.

The ECal trigger required the presence of one or more EM showers, each with energy greater than 2 GeV. It provides significant rejection of elastic scattering events in reaction (1). For non-elastic $p_f p_s$ kinematics, when p_f and p_s are both in the left hemisphere, the elastic pp-scattering events are reduced by a factor of 8. The trigger system described operated reliably in the 1992 data-taking run. During that period the WA91 experiment collected ~40 million triggers and 12% of them were selected by the ECal trigger system.

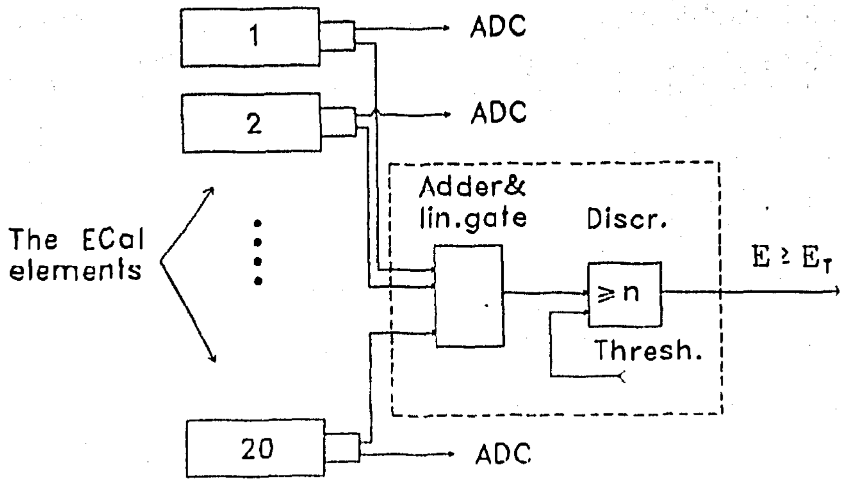

Fig.3 The block diagram of the ECal trigger electronics in the WA91 experiment

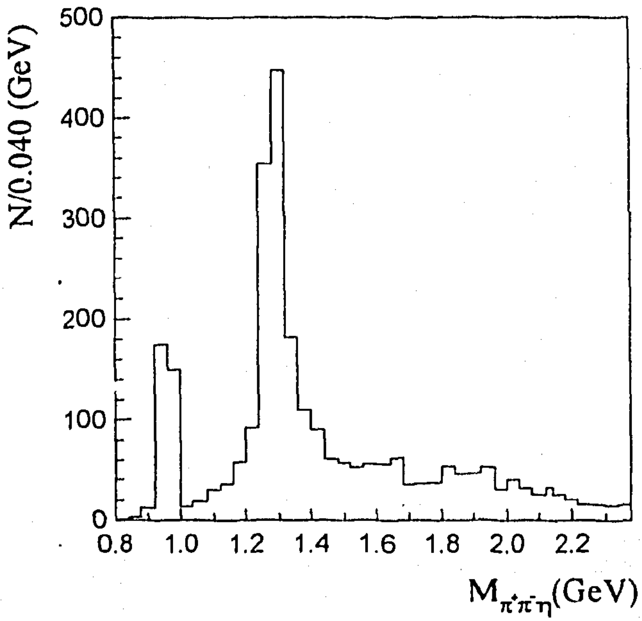

Fig.4 The $(\pi^+\pi^-\eta)$ effective mass spectrum, where $\eta \to \gamma\gamma$

As an illustration of the ECal operation, the $\pi^+\pi^-\eta$ mass spectrum obtained, where $\eta \rightarrow \gamma\gamma$, is shown in Fig.4.

3. Selection of events with high transverse electromagnetic energy in the WA92 experiment

The WA92 experiment [5] used a 350 GeV/c π^- beam interacting on a Cu and W target to study the hadroproduction of B mesons. The schematic view of the experimental layout is shown in Fig.5.

A selective trigger with high background rejection is necessary for the investigation of beauty hadroproduction on fixed targets at this energy ($\sigma_{b\bar{b}}/\sigma_{tot} \approx 10^{-6}$ at $\sqrt{s} = 26$ GeV). The two-level trigger system in this experiment consists of several independent trigger components. The high mass of the B-meson favours decay products with high transverse momenta P_T. The high-transverse momentum trigger based on the "Butterfly" scintillator hodoscopes (BH) selected events with charged particles at P_T >0.6 GeV/c. A large fraction of B-decays results in a muon or electron in the final state. The muon trigger [6] is based on the Resistive-Plate Chambers situated behind the Iron absorbers. The muon tracks coming from the target region are selected in time for level-1 trigger (~250 ns after the beam interacted in the target). Electron identification and triggering was performed using the ECal signals. The ECal trigger system, which was designed to select events with high transverse EM energy, will be discussed below. The secondary-vertex trigger [7] allowed separation of events containing B-decays from the background using the peculiar topology of beauty events. Its algorithm is executed by the parallel processor in 35 μs. Signals from the muon, electron and high-P_T triggers are combined with the secondary-vertex trigger to form a Level-2 trigger.

The ECal elements are combined into 14 trigger groups to estimate the number of EM showers (Fig.6). The central rows of Cherenkov lead-glass counters do not participate in the ECal trigger because they are mostly affected by charged particles. The Monte-Carlo simulation has shown that the last two rows at each edge of detector do not improve the acceptance for beauty production and hence these elements have not been used for the trigger purposes either. Individual threshold energy deposition for each lead-glass block is defined according to its position in the array and corresponding to a threshold transverse energy E_T for EM showers.

The ECal trigger electronics was placed close to the detector to reduce signal delays. As access to the experimental setup was limited, a remotely controlled ECal trigger system was designed.

The programmable 20-input electronic module (Fig.7) was made in the CAMAC standard and contains:

- a programmable pulse-height discriminator,
- a mask scheme to enable or disable signal discrimination,
- a programmable majority logic scheme,
- an output shaper

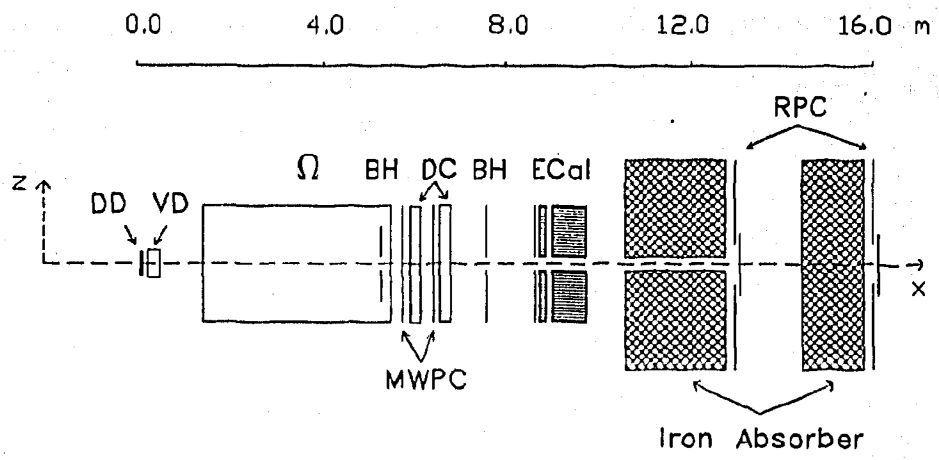

Fig.5 The schematic view of the WA92 experimental layout:
DD – Microstrip Decay Detector; VD – Microstrip Vertex Detector; DC – Drift Chambers; MWPC – Multiwire Proportional Chambers; BH – "Butterfly" Scintillator Hodoscopes; ECal – EM calorimeter; RPC – Resistive Plate Chambers

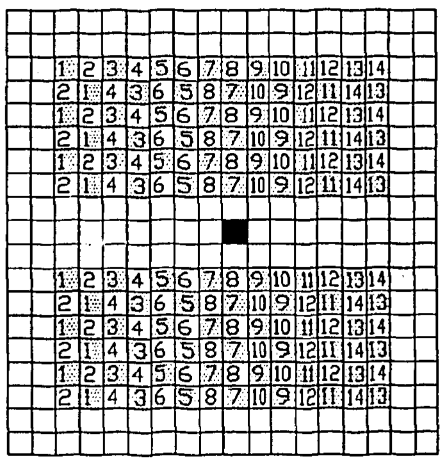

Fig.6 The ECal trigger groups in the WA92 experiment

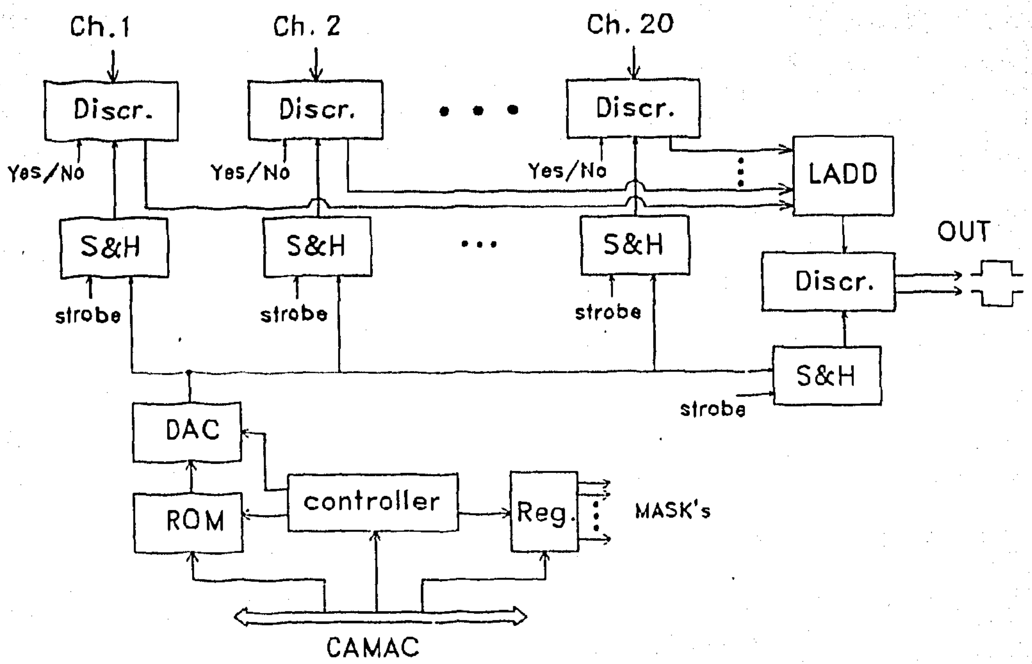

Fig.7 The ECal trigger organization in the WA92 experiment:
S&H - Sample and Hold Circuits; LADD - Linear Adder; DAC - Digital-to-Analog Converters; ROM - Read-Only Memory; Discr. - Discriminator

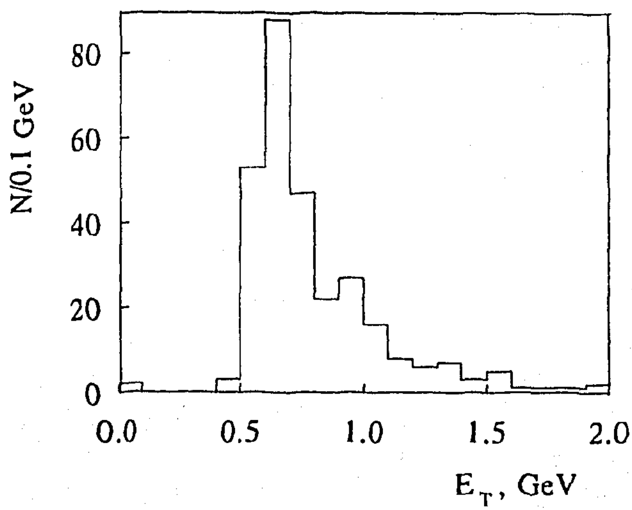

Fig.8 Distribution of transverse EM energy deposited in one Cherenkov lead-glass counter for events selected by the ECal trigger system

• and a built-in test function.

Each PMT signal from an ECal element is sent to an individual discriminator. The threshold values are first written in the internal memory of the unit through the CAMAC bus. These values are converted to analog pulses by a 10-bit DAC and are stored in the Sample and Hold circuits (S&H). Every 10 μs the threshold values are refreshed by reading the digital memory and by rewriting in the S&H circuits (see Fig.7). This solution has allowed the use of a high density of discriminator channels per unit and the construction of this module on the basis of low-cost manufactured chips.

After pulse-height discrimination and shaping the PMT signals are sent to the programmable majority logic scheme, which consists of a linear adder and a threshold discriminator. The required majority of EM showers is set by the threshold on this discriminator. All thresholds are remotely adjustable.

The built-in test function and the possibility of the trigger system operating remotely are attractive features of these modules, especially for the experiments with long-term data-taking runs. The mask scheme allowed noisy or dead ECal channels to be excluded from the trigger logic without loss of data taking time. The built-in test function allowed the simulation of pulses passing through the module and the control of the operation of all components of the trigger unit.

The software package has been designed to operate the ECal trigger system from IBM PC through the CAMAC bus. The CAMAC crates are interfaced to PC via the controller KK-011 [8]. The ECal trigger system was developed on the basis of 14 of the above described programmable electronic modules.

The trigger required two or more EM showers with $E_T > 0.5$ GeV/c. The "on-line" control of transverse EM energy deposition in each calorimeter cell was provided for events selected by the ECal trigger system. An example of this distribution is shown in Fig.8.

The ECal trigger resulted in a trigger rate of 3% of the interaction triggers while keeping 25% of beauty particles.

The ECal trigger system operated reliably and efficiently during the long-term data taking run in 1993, when some 60 million triggers were recorded.

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