UPGRADE OF THE H1 LIQUID ARGON CALORIMETER TRIGGER

R. MARAČEK, A. BABAEV, H. BRETTEL, T. CARLI, B.DULNY, J. FENT, G. GRINDHAMMER, W. HABERER, C. KIESLING, J.H. KÖHNE, A. OSTHOFF, W. PIMPL, B. REISERT, K. RÜTER, T. SCHÖRNER, A. WEGNER, P.WEISSBACH

Max Planck Institut für Physik, München, Germany

K. BORRAS, M. FLEISCHER, D. LÜKE, H. RICK, J. SPIEKERMANN, K. WACKER, D. WEGENER

Institut für Physik, Universität Dortmund, Dortmund, Germany

B.HEINEMANN

Deutsches Elektronen-Synchrotron, DESY, Hamburg, Germany

G. TSIPOLITIS

Institut für Teilchenphysik, ETH, Zürich, Switzerland

In order to face the new physical requirements of the H1 collaboration and the luminosity upgrade of the HERA accelerator in the year 2000 the H1 liquid argon calorimeter trigger is being upgraded. The two steps of the upgrade program, the noise reduction in the pre-amplification of the trigger signals and the introduction of a new digital part, the so called "jet trigger", are presented.

1 Introduction

In this paper we firstly introduce the H1 liquid argon calorimeter (LAr) and its trigger. Then we briefly summarize the motivations for the upgrade of the LAr calorimeter trigger. The following two sections we devote to the description of a two-step upgrade program, the noise reduction in the pre-amplification of the LAr calorimeter and trigger signals and the design of an additional digital trigger signal processing, the so-called "jet trigger". In the last section we summarize the obtained results.

2 H1 liquid argon calorimeter and its trigger

The H1 detector[1] is a multipurpose apparatus built to investigate the high energy interactions at the HERA facility which consists of two independent accelerators designed to store and collide 820 GeV protons and 30 GeV electrons or positrons[2]. The experimental program of the H1 collaboration requires a detector having a good identification of electrons, a high degree of hermeticity with high granularity and excellent energy resolution, as well as the best possible hadron calorimeter. In addition a large solid angle tracking is demanded. The efficient use of all these components is provided by sophisticated trigger and read-out systems.

The LAr calorimeter provides smooth and hermetic calorimetric coverage over the polar angular range ($4° \leq \theta \leq 154°$). A single liquid argon cryostat is used, containing calorimeter stacks structured in 8 wheels in z, each of which is divided into octants in ϕ. The separation between electromagnetically and strongly interacting particles is feasible by dividing the LAr calorimeter in two sections, the inner electromagnetic (EMC) and outer hadronic (HAC) part. The structure of EMC sampling cell consists of 2.4 mm lead absorber and 2.35 mm liquid argon with one read-out plane and one high voltage plane per gap. The HAC cell consists of 19 mm stainless steel, i.e. 16 mm absorber and twice 1.5 mm independent read out cell plates, and a double gap of 2.4 mm liquid argon. The energy resolution of LAr has beam measured in test beams to be[3] $\sigma_E/E = (11.16 \pm 0.05) \oplus (0.64 \pm 0.07) \times 10^{-2}$ (with E in GeV) for electrons and for pions $\sigma_E/E = (46.1 \pm 0.7) \oplus (2.6 \pm 0.2) \times 10^{-2}$ (with E in GeV).

The LAr calorimeter trigger, see Fig. 1, is divided into an analog and a digital part. In the analog part the signals from the 45 000 read-out channels are reordered and combined into 256 projective towers, so-called “big towers” (BT), which are divided into electromagnetic and hadronic sections. The primary input of the trigger system, “a trigger cell” (TC), is an analog sum of pad signals in either EMC or HAC. The electromagnetic and hadronic TC’s are summed, shaped and used to build a “trigger tower” (TT). In order to suppress noise the TT signals are gated by fast analog switches. The BT is a sum of TT’s, where the finest granularity is realized for small polar angles with respect to the proton beam. The 2×256 BT’s are synchronized with the bunch crossing frequency, digitized with FADC’s and fed into the digital summing electronics yielding various energy sums, e.g. transverse energy, missing transverse energy, energies in different parts of the calorimeter. These sums are discriminated using programmable threshold functions, providing the trigger bits for the central trigger logic. The electron triggers can be derived by counting the BT’s with an enegy deposition above a given energy minimum in the electromagnetic part. In addition, the exact bunch crossing of the energy deposition (“t_0”) is determined by means of a pulse delay and crossing technique of the TT’s in the analog part.

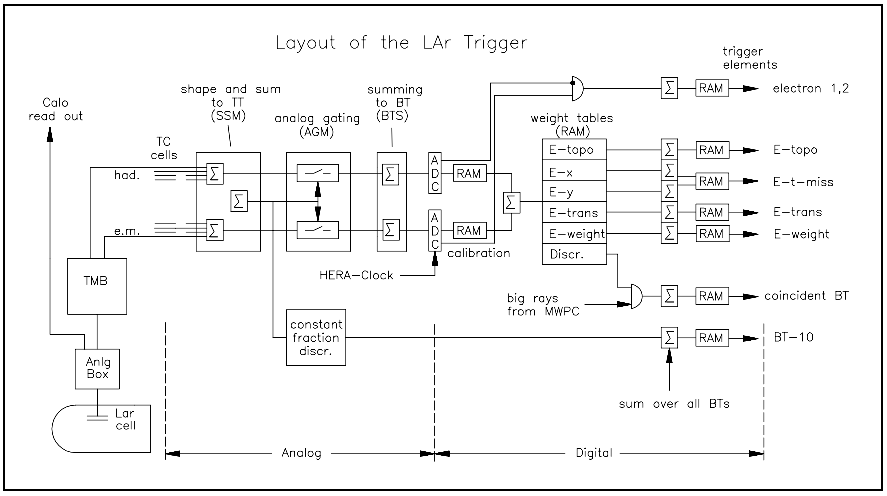

Figure 1. Schematic layout of the H1 LAr calorimeter trigger.

3 Motivations for the upgrade of the H1 LAr calorimeter trigger

The primary task of the LAr calorimeter triggers is to provide a fast identification of a "hard scale" in deep inelastic scattering events, i.e. events with high values of momentum transfer or with high p_T^2.

With the HERA luminosity upgrade the contribution to the trigger rate is predicted to increase by a factor of 5, with significant increase of the background rates. The acceptable H1 data acquisition rate gives the requirements on the all sub-detector trigger systems.

For the LAr calorimeter trigger such requirements amount to the lowest possible energy thresholds together with the most efficient use of the topological information provided by the determination of the energy depositions.

Using the Monte-Carlo simulations[4] of the upgraded LAr calorimeter trigger some physics examples, such as jets with and without heavy flavour production, hidden charm and beauty production, deep inelastic electron-proton scattering with charged current and with high momentum transfer, were studied and showed significantly higher efficiency of the LAr calorimeter triggers in the selectivity of signal to background over enlarged kinematical domains.

4 The upgrade program

4.1 Analog part – Low noise pre-amplification

Since the startup of the H1 experiment, the thresholds for triggering the LAr calorimeter have been decreased several times, mainly following the detection and removal of noise sources outside of the LAr trigger system. Already the data from the 1994 running period showed that the thresholds have reached their lower limit determined by the white noise in the pre-amplifier electronics.

Applying the white noise model[6,7] of the junction field-effect transistor (JFET) to the amplification chain of the LAr calorimeter signal showed that the noise contribution of the first transistor is dominant and could be significantly reduced[5]. In this model the white noise of a typical JFET is represented by the fluctuation σ^2 of the signal charge on the sensing electrode of the capacity (C_D):

$$\sigma^2 = 4kTa_n \frac{(C_D + C_G)^2}{g_m} , \tag{1}$$

where k, T, C_G are the Boltzmann constant, temperature, capacitance between gate and source of the JFET, respectively, and a_n is the "technology" parameter ($\approx 2/3$ for JFET's). More formally:

$$\sigma_{\text{noise}} = a + bC_D , \tag{2}$$

with

$$a = \sqrt{\frac{4kT}{g_m}} C_G \quad \text{and} \quad b = \sqrt{\frac{4kT}{g_m}} , \tag{3}$$

where g_m is the transconductance of the JFET. Provided that the detector granularity is kept unchanged, the basic parameters to optimize for low noise are the temperature and the transconductance g_m. As a substantial reduction of noise by means of lowering temperature is achievable only at cryogenic temperatures the option based on lowering the later parameter was chosen.

A new pre-amplifier hybrid using the JFET NJ3600 by InterFet Corporation[8] with higher transconductance g_m = 200 mSi with respect to 60mSi of the originally used Toshiba JFET[9] has been designed and tested at MPI Munich and finally installed on the existing analog cards in the H1 experiment.

In order to profit from the low noise electronics, a new analog gating module (AGM) unit was designed. The characteristics of these new modules are: Separated discrimination of electromagnetic and hadronic channels, precision of setting the AGM threshold of 1 mV, which corresponds to 125 MeV on the electromagnetic scale, read-out of AGM threshold via on-board ADC with a precision of 0.5 mV.

A comparison of measurements of the average values of the trigger cell noise for the analog cards equipped with the new hybrids with respect to the old analog cards as a function of the TC capacity is presented in Fig. 2. In order to determine the obtained final noise reduction factor a fit of both sets of experimental data using Eq. (2) was performed. The obtained value of the noise reduction factor was 1.65.

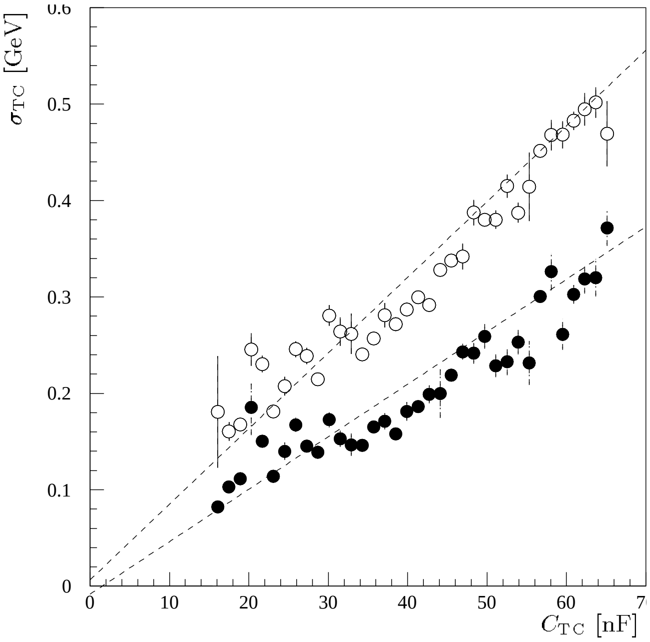

Figure 2. Comparison of the measurements of the trigger cell noise (σ_{TC}) for the new analog cards equipped with the upgraded hybrids with respect to the old analog cards as a function of the capacity of the trigger cell (C_{TC}). The dashed and dashed-and-dotted lines stand for the fits, see Eq. (2).

In Fig. 3 the LAr calorimeter trigger efficiency for electrons in the central barrel part of the LAr calorimeter is presented, determined from 1998 and 1997 neutral current deep inelastic scattering events at high momentum transfer. In 1998, as a consequence of the described above upgrade, the effective electron trigger threshold has been reduced by 1.4 GeV. The threshold behavior is steeper indicating a more complete summing. Since despite the lowering of thresholds the noise rates are seen to be still one order of magnitude lower with respect to the pre-upgrade situation further optimization is foreseen.

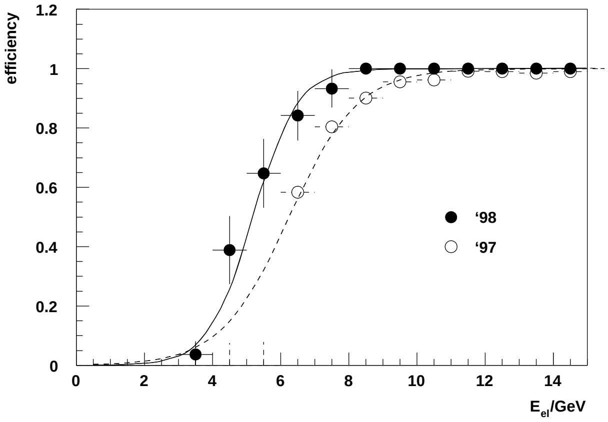

Figure 3. LAr calorimeter trigger efficiency for electron energy (E_e) in the central barrel for data in 1998 (closed circles) and in 1997 (open circles).

4.2 Digital part – Jet trigger

The aim of the second part of the here presented upgrade is to complement the existing LAr calorimeter trigger with a system that avoids summing up noise distributed over large partitions of the calorimeter and that triggers on low energy deposition. The task of this "jet trigger" is to find the various localized energy depositions in the calorimeter, centered around regions in azimuthal angles ϕ and pseudo-rapidities η within a cone radius of $\Delta r = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} \approx 1$.

Since only about 800 ns are available for the jet trigger a parallel hard-wired solution is needed.

An overview of the jet trigger signal processing is shown in Fig. 4. The source signals originate from the new Big Tower Summing (BTS) modules, which provide the BT signals for the existing digital part of the LAr calorimeter trigger and in addition the higher granulated TT signals. The reassembling of the TT's into the so-called "input towers" (IT) is done in the ADC-calculation-summing (ACS) unit in order to optimize the granularity of the IT's to approximately $\Delta r = 1$ for all pseudo-rapidities. The Bump Finder

Unit (BFU) processes the IT's and finds the maxima of local energy depositions, so-called "bumps". The BFU consists of eight boards, mapping the ϕ-octants of the LAr calorimeter. Each boards delivers fifteen bumps to the Primary Sorting Unit (PSU), which transfers for each board the three bumps with the highest energy to the Secondary Sorting Unit (SSU). Here the in total 3×8 bumps are sorted by energy in decreasing order. The 16 largest bumps are sent to the Trigger Element Generator (TEG) where the trigger elements for the CTL are calculated. The flexibility of the TEG provides the optimal strategies of triggering based on e.g. discrimination of the individual jet energies, counting jets with energies above certain thresholds, determination of topological and angular correlations.

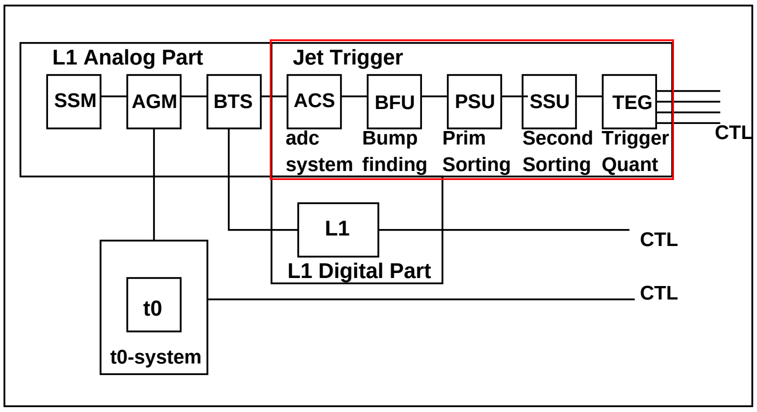

Figure 4. Schematic layout of the LAr calorimeter trigger including the jet trigger system.

5 Conclusion

The H1 LAr calorimeter and trigger electronics was partially equipped with new pre-amplifiers and new analog trigger electronics which allows separate discrimination of the electromagnetic and hadronic energy deposition at finest granularity level. As it was shown above this resulted in the final noise reduction factor of 1.65, and allowed significant decreasing of the trigger thresholds.

The here described level 1 jet trigger, which is planned to run in parallel with the existing digital part of the LAr calorimeter trigger, allows further lowering of the thresholds by summing up over limited areas of the calorimeter.

After its installation it will allow the combination of the already achieved lowered energy thresholds with the topological information and will thus substantially increase efficiency and background rejection of the H1 LAr calorimeter trigger.

References

1. H1 Collab., I. Abt et al., Nucl. Instr. and Meth. **A386** (1997) 310 and **A386** (1997) 348.
2. B. H. Wiik, HERA status, Proceedings of the workshop "'Physics at HERA"', Vol.1, ed. W. Buchmüller and G. Ingelman, DESY, Hamburg, 1991
3. B. Andrieu et al., Nucl. Instr. and Meth. **A336** (1993) 460.
4. T. Carli et al., H1 internal report, H1-01/99-560, DESY, Hamburg, Germany.
5. A. Babaev et al., H1 internal report, H1-01/96-470, DESY, Hamburg, Germany.
6. V. Radeka et al., Nucl. Instr. and Meth. **A256** (1988) 228.
7. V. Radeka et al., Ann. Rev. of Nucl. and Part. Sci. **38** (1989) 217.
8. Data book by InterFet Corporation, JFET NJ3600, Garland, Texas, USA.
9. Datasheet of JFET 2 SK 372, Toshiba Corporation, Japan.