Data Transmission and Online Processing in the KASCADE Data Acquisition System

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Abstract

The data transmission and online processing in the KASCADE data acquisition and control system is presented. More than 170 transputers form the data network of KASCADE, using the fast serial transputer links, partly via fiberoptic cables. They connect the various local, VME-based frontend electronics systems via Ethernet gateways (B300) with the central UNIX workstation.

1 Introduction

KASCADE [1] is an extensive air shower experiment installed at the laboratory site of the Forschungszentrum Karlsruhe. Its objective is to study extensive air showers induced by high energy cosmic ray particles above 10^{14} eV. The main goal is to obtain information on the chemical composition of the primary cosmic rays. The experimental setup consists of three main components: a detector array for the measurement of electrons/gammas and muons outside the shower core region, a central detector system for the detection of high energy hadrons and muons especially in the core and a muon tunnel for muon tracking

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outside the core. The detector array with its 252 detector stations (1120 m^2 scintillation detectors, 1392 PM's) is spread on a square of 200×200 m^2 and is grouped in 16 clusters. The central detector system consists of a segmented, 16×20 m^2 TMS-iron sampling calorimeter with 10000 liquid ionization chambers in 8 horizontal layers, of two shielded layers of multiwire proportional chambers (32 MWPCs, 244 m^2) below the calorimeter, of a trigger layer of 456 scintillation detectors in one of the gaps and – above the calorimeter – of a topcluster of 50 scintillation detectors for small central showers. In the 5.4×48 m^2 muon tunnel 600 m^2 of limited streamer tubes will be used in three layers. Data taking has started at the end of 1995. In the period from May 1996 to January 1997, more than 30 million correlated events have been measured with a typical trigger rate of about 2 Hz. In principle KASCADE consists of 21 independent experiments, which can be run alone or together from a central UNIX workstation. Signals (5 MHz, 1 Hz) from a central stabilized clock are distributed via fiberoptic cables to all parts of the experiment to correlate the data. In all parts of the experiment, the data acquisition and control system is based on transputers as local intelligence. More than 170 transputers form the data network of KASCADE, using the fast serial transputer links, partly via fiberoptic cables. They connect the various local, VME-based frontend electronics systems via Ethernet gateways (B300) with the central workstation. The total KASCADE data acquisition system, including all the hardware, will be described in detail in a forthcoming publication [2].

2 The Detector Array

A cluster is a basic subunit of the array and on its level the acquisition of the experimental data collection is organized in the form of the cluster electronics [3] and therefore it acts as a small independent air shower experiment. The cluster electronics is housed in two VME crates, both controlled by TVC (**T**ransputer-based **V**ME **C**ontroller) modules. The predicted performance of the software (1 μs interrupt latency, 30 μs dead time after showers, $\simeq$ 5 ms total time to process a shower event) was confirmed. The total uncorrelated event rate is 20–30 kHz/cluster. Data from different clusters are correlated by means of a common clock (time label). All detector signals above the hardware threshold level are converted into temporary data containing the time label. The determination of an 'event' is done by the trigger electronics [4], which generates a trigger signal when a certain multiplicity condition in the cluster is fulfilled. Triggers are distributed via fiberoptic cables to all parts of the experiment. Fiberoptic cables are also used to connect the transputers of the local DAQ (TVCs in the clusters) and central DAQ (transputer array) over the long distances. The local memories are searched for data with corresponding time labels. The selected data are sent through the transputer array

(LIM modules [3]) and a following B300 linkbox to the host workstation. The eventbuilder of the array is realized as a client-server network. The resident server program *evb* is connected to the local hard- and software of the array and is therefore the interface between the 16 clusters and the clients. The main tasks of the server are routing of data-/control-tags and eventbuilding. There are three different types of clients running on the UNIX host workstation. The control and display X11-/Motif-application (GUI) *xevdis* exists in a pure monitor version providing the user with shower data, spectra data, statistics and an on-/offline 2D-/3D-eventdisplay and a master version, which in addition is able to change hardware settings. The third type of client is the main eventbuilder of KASCADE (*xevb*).

3 TMS Calorimeter

The calorimeter has 40 000 electronic channels with a resolution of 13 bit and is controlled by a transputer network which consists of 59 processors and 93 Mbyte memory, executing about 550 processes in parallel in total. An asynchronus, connectionless interprocess communication system for arbitrary transputer networks allows to connect and disconnect parts of the network during normal operation. The multi–user operating system MONIKA supports the management of the transputer network and allows to control all parameters of the ADC system, the voltage setting and several peripherical devices, including control monitors. Complex functions, like the calibration of the ionizing chambers or the well–regulated increase of the high voltage at the detectors are integrated in MONIKA. The necessary complex numerical and analytical fits to the experimental data are done in parallel by several processors. The program enables data–taking, including zero–suppression and eventbuilding, and checking the stability of the detector. The transputer network is booted via a DOS-PC, which works as the console of the parallel computer. In addition, the network is connected to the UNIX workstation. A UNIX based server allows to connect up to 50 user interfaces via Berkeley sockets to the parallel computer and to transport the data to the central event builder. The calorimeter can be controlled from different operation positions. For the UNIX socket connections and the connections inside the transputer network a uniform multi–user communication protocol is used, extending from the UNIX user interfaces up to the crate controllers.

4 Topcluster, Triggerplane and MWPCs

The data acquisition of triggerplane and topcluster of the central detector use similar electronic schemes developed at the University of Tübingen [5]. These systems are based on T805 transputers and generate an m-out-of-n (n=50/456) and a 1-out-of-n coincidence trigger signal, which can act as trigger source for MWPCs, calorimeter and array. Programmable trigger units ease the change of trigger conditions and sources. Besides readout the online software has to perform different monitoring tasks which include control of the discriminator thresholds and temperature drifts of the time conversion system. Furthermore, a pulser system designed to measure time offsets in the whole trigger system is controlled by this software. Each of the 32 large area MWPCs is equipped with a T805 transputer. Two MWPCs are linked together via RS422 interface whereas the connection to a transputer array is done via fiber optic links. Presently, this transputer array has the task to perform local event building, trigger synchronization and to link the MWPC part via ethernet to the host computer. The used handshake protocols for trigger locking between the MWPC setup and an additional trigger crate entail a data readout dead time of 20 ms but can be improved. The readout systems of MWPC, triggerplane and topcluster are linked via the B300 interface and the TCP/IP protocol using BSD socket calls to the central host workstation. On this level a user defined protocol layer common for all components is used. To control these parts of the experiment from host side a Motif based program is run on host. It loads hardware parameters and trigger conditions to the hardware and provides possibilities to inspect frontend generated control spectra and other useful quantities.

5 The Central KASCADE Eventbuilder

The main task of the Motif-based central KASCADE eventbuilder package (*xevb*, *xkernel*, *xmerge*) is the on-line data merging while the experiment is running. The event data reveived by the different experimental parts contain time information of the 5 MHz/1 Hz clocks in their headers. Blocks with differences of less than 10 μs are regarded as belonging to the same event. The user control interface *xevb* starts the processes *xkernel* and *xmerge* after successful initialization. After completion of the experimental setup and the connection to all active parts the data acquisition (DAQ) can be started. Dynamical adding and removing of components by the user during DAQ is supported. *xmerge* is the process that is directly connected to the KASCADE components. After having established and initialized the network connections it takes the data from the experiment and forwards them to *xmerge* when the DAQ is active. The incoming event data blocks at *xmerge* are stored in linked lists arranged by arrival times and sorted by their origins. Data will only be merged if events of all active components are present. This condition shall avoid the building of incomplete events. Blocks belonging to the same event are converted and written to ZEBRA banks by user defined routines that enable non-blocking writing to files within working procedures. When *xmerge* notifies an event timeout, it makes *xkernel* disconnect from the refering component and starts a new run. Finally *xmerge* creates WWW pages with information about run conditions and the present KASCADE run status.

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