The Trigger and Data Acquisition System of the KLOE Experiment

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Representing the KLOE Collaboration [1]

Abstract

The requirements on the trigger/DAQ system of the KLOE experiment are a challenge in this field: this system has to deal with data rates of the order of 10^{11} events/year while rejecting background rates at least 10^3 times larger. Moreover, since the major aim of KLOE is to perform CP violation studies at sensitivities of $O(10^{-4})$, very stringent conditions are imposed on it, to insure that no biases are introduced at such level.

1. Introduction

The KLOE detector [1,5], at present under construction for operation at the Frascati ϕ-factory DAϕNE, is a general purpose detector, whose major aim is to perform CP violation studies at sensitivities of $O(10^{-4})$. The expected data rate will be of $O(10^{11})$ events/year, all of which are of physics interest or are needed for detector calibration. For these reasons the requirements on the trigger and data acquisition system represent a challenge in the field. Inefficiencies and error rates must be minimized to insure that no biases are introduced at these levels. Particular care must be taken in order to insure that the channels involved in the measurement of the CP violating parameters are triggered and acquired with very high and equal efficiencies.

2. The trigger system

At the maximum achievable luminosity (i.e. 10^{33} cm^{-2}s^{-1}) DAϕNE will produce $\sim$5000 ϕ per second, and a number about 2000 times larger of Bhabha events at angles $>3°$. Moreover, machine background, arising from interactions of the beam particles with the residual gas in the beam pipe, is expected to produce fluxes of particles inside KLOE of $O(10^6)$ Hz. For a typical event size of 5 kbytes, the DAQ system is designed to accept an event rate of about 10 kHz, with some safety margin [4]. Therefore the trigger has to reject these backgrounds as much as possible, while remaining highly efficient for ϕ decays.

A second requirement on the trigger system is that it has to be fast. Laboratory measurements have shown that the

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calorimeter's TDCs, to which the trigger has to provide the *start* signal, can maintain the expected accuracy in the time measurement, provided that the trigger arrives within $\sim$200 ns from the ϕ decay. Since the photons' arrival time measurement is crucial in the reconstruction of the events, and therefore in the correct determination of Re(ϵ'/ϵ), this requirement is of the utmost importance.

A trigger based on the total energy deposited in the calorimeter by an event cannot satisfy the first requirement. On the one hand, ϕ decays with charged particles in the final state have an average energy deposition sizeably less than the ϕ mass, because of the different response of the calorimeter to charged pions and to electromagnetic showering particles. Also, the presence of obstructions, in particular the quadrupoles of the low β insertion, leads to losses in visible energy for all types of events. On the other hand, most of the low angle Bhabhas, as well as part of the machine background particles, would produce showers in the quadrupoles which could eventually reach the calorimeter, with a total energy distribution ranging from nothing to 1020 MeV.

The most effective way to separate ϕ decays from backgrounds consists in counting the multiplicity of particles with energy above a given, moderate ($O(50)$ MeV), value. This is done by summing the analog responses of groups of adjacent photomultipliers, defining therefore trigger *sectors*, and to compare them with a set of adjustable thresholds; the values of these thresholds have been tuned to maximise signal efficiency and background rejection, and depend on the sector's position and dimensions. For instance, the thresholds for the sums of the signals of the photomultipliers nearest to the beam pipe have to be set higher with respect to those in the barrel region, because backgrounds are generally at smaller angles.
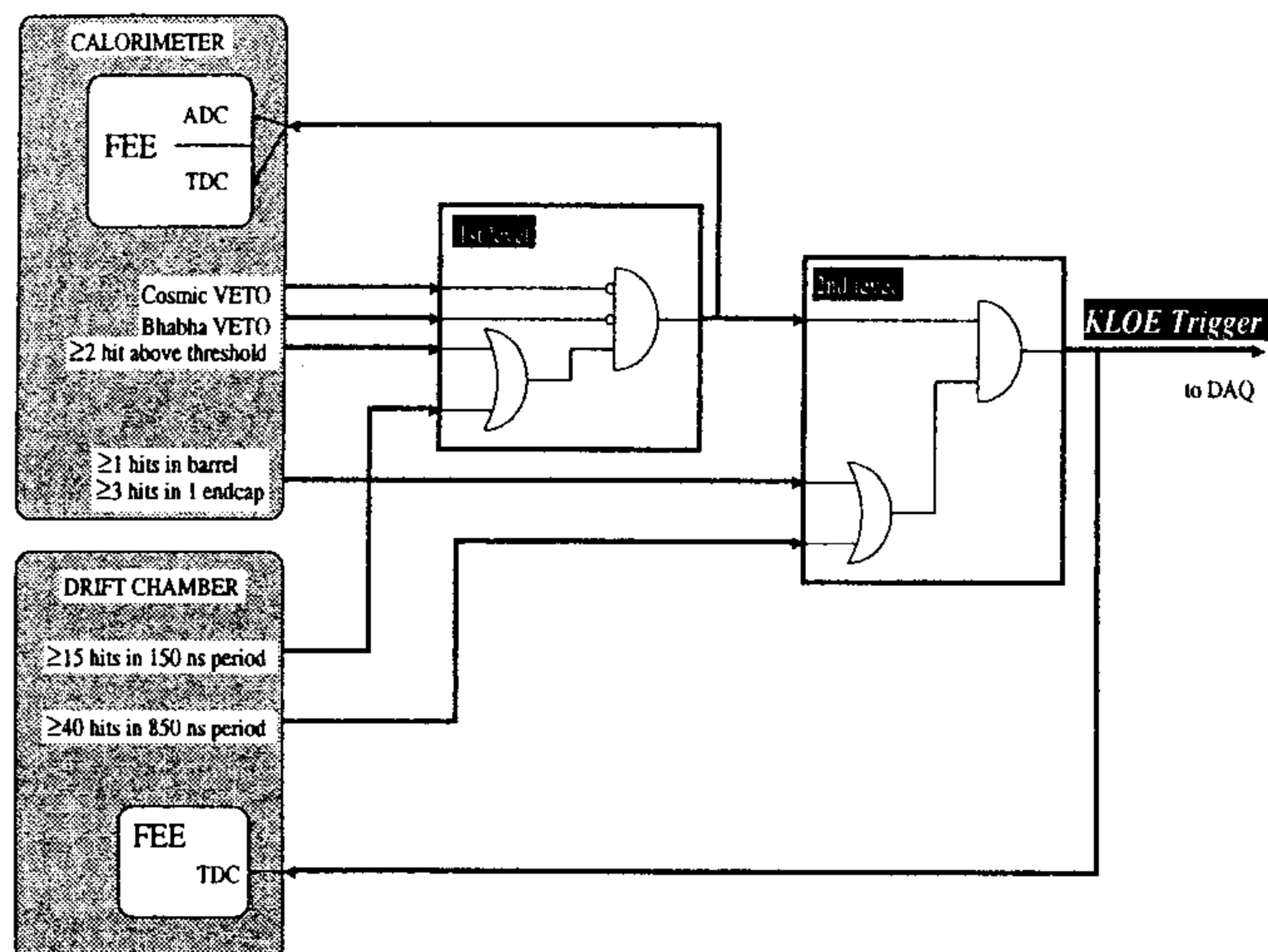
Fig. 1. Block diagram of the trigger logic. From Ref. [5].

Fig. 2. Architecture of the DAQ system.

Also the drift chamber is used for the trigger decision. In fact, for ϕ decays with two or four charged pions in the final state, the multiplicity of hit wires is much larger than that for background events. Since, however, the drift time in a single cell can be as long as 2 μs [3], a two level strategy is better suited to satisfy the requirements on both trigger velocity and background rejection efficiency.

The first level is activated by the coincidence of a low number of hits in the drift chamber (15, for example) within 150 ns, or by the coincidence of at least two calorimeter sectors above threshold. At this level, the start to the calorimeter's FEE is provided and the trigger formation is prevented for a predetermined amount of time ($O(2)$ μs). In the following 850 ns, more information is collected by the drift chamber to confirm/discard the first level decision and to start the DAQ chain or reset it (see Fig. 1).

Monte Carlo simulation has shown that, with such a strategy, all the prescriptions listed above can be safely met. In particular, it has been shown that this trigger is able to reject the machine background at such a level that it would not cause problems even if its rates were higher by a factor of ~3–4 with respect to the present estimate [5].

3. The DAQ system

The architecture of the KLOE Data Acquisition System is shown in Fig. 2.

The KLOE FEE makes use of VME hardware, typically 9U cards, located in racks where a custom bus, the AUX-bus, is used for fast data transfer. At the rack level, data are collected by a custom readout controller, the ROCK. A readout manager, the ROCKM, communicates with up to 8 ROCKs via a custom Chain-bus, the C-bus, which is designed to support up to 40 Mbytes/s data transfer. The ROCKMs reside in their crates together with VME processors which prepare data from a string of sub-events, typically 100, to be given to the event building farm processors. ROCK and ROCKM work asynchronously to the trigger signal. Each acquisition
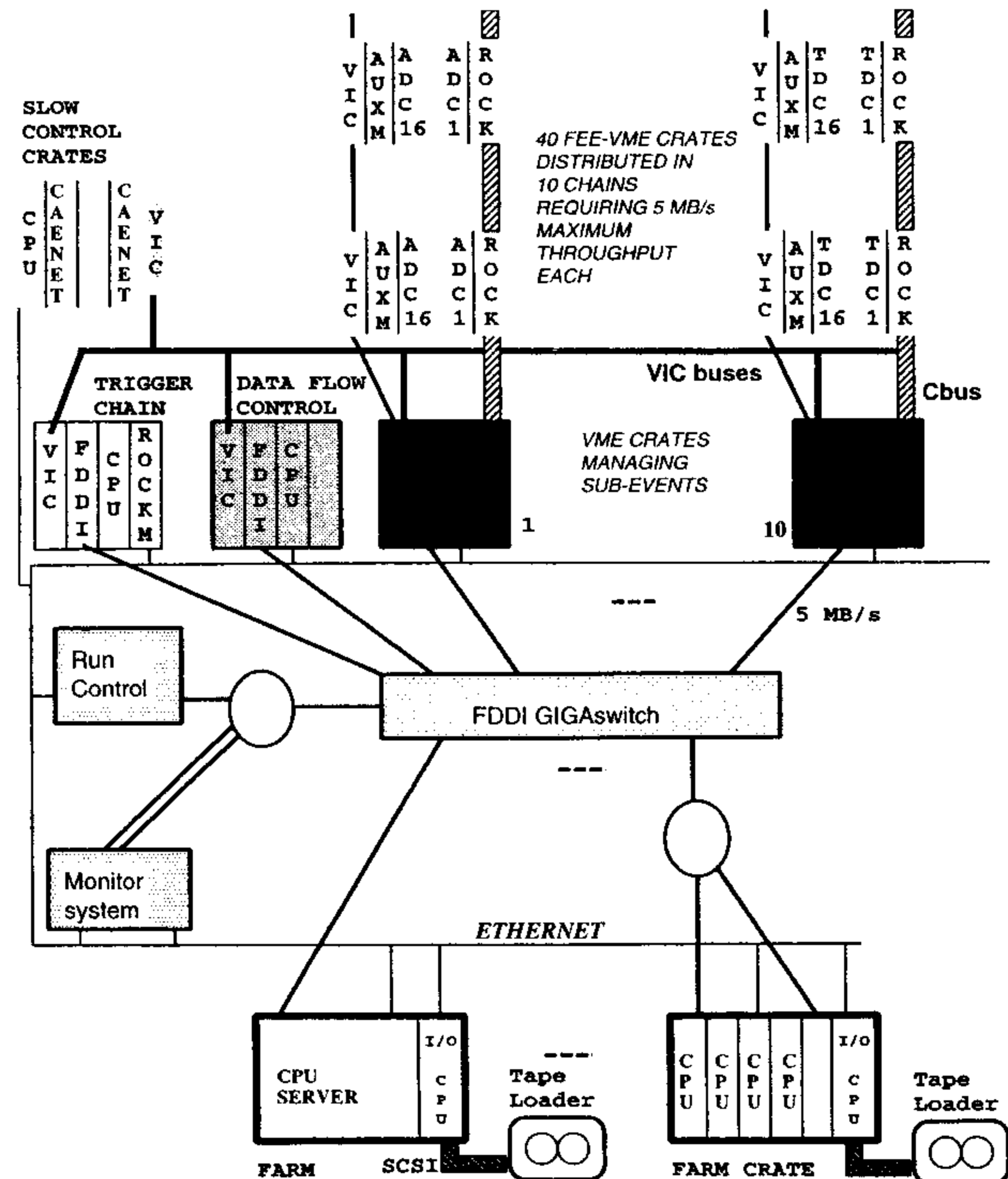
board is designed to respond to a trigger number request by sending all the data associated to it into the AUX-bus; this operation is driven by the ROCK in a sparse data scan mode, to speed up operations.

For a given event, data coming from the different VME boards must be gathered by a single board computer, SBC, where the integrity of the event is tested and the final event formatting is implemented. A commercial GIGA-switch reads data over FDDI from the VME boards, and delivers them to the proper SBC in the farm, whose address is assigned by a VME control processor, the Data Flow Control, DFC. The GIGA-switch allows for a 3.6 Gb/s total throughput (I/O), largely sufficient for the KLOE purposes. A CPU power of ~100 processors of 100 SPECint92 is needed for the farm.

A complete simulation of the performances of a readout chain has been performed using Verilog-HDL, assuming the use of standard TTL components operating at conservative speeds. The typical acquisition time, assuming 80 words/event for a calorimeter's chain and 120 words/event for a drift chamber's chain, is about 35 μs, that is satisfactory for a 10 kHz trigger rate [4].

At present, a chain made of two ROCKs in their final version, reading 16 FEE boards each, and a prototype ROCKM has been successfully tested in the laboratory. Many commercial processors are being considered for both the VME boards and the SBCs in the farm, most of which appear to be well suited for KLOE. The final decision, however, will be taken only just before the beginning of the KLOE operations, to optimize the choice as well as cost effectiveness.

The amount of data collected in a few years of operations of KLOE might exceed 1000 Tbytes, including reprocessing

and the production of large samples of Monte Carlo events. To store such a large amount of data, therefore, the use of very high density cassettes, special robotics and excellent computing organization is needed. At full luminosity, KLOE needs 10 tape units on which events are written in parallel while running, each of which has to sustain a throughput of 5 Mbytes/s.

4. Conclusions

At the beginning of 1998 the KLOE detector at DAΦNE will start its operations. The expected high data rate, and the very high efficiencies required, represent a challenge for its trigger and DAQ systems. From the successful operation of KLOE, a lot of experience can be collected in the field for the next generation colliders' experiments.

Appendix: Members of the KLOE Collaboration

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