Front end daq for the KLOE experiment

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Abstract

The KLOE experiment [1] is going to exploit the DAFNE facility in frascati.
When full luminosity will be reached we expect to have a througput of 50 Mbytes/sec. As a consequence the system has been designed to support this data rate. The target of the KLOE experiment is to measure CP violating parameters with a 10^{-4} accuracy, such an high level precision puts stringent requirements to the DAQ and trigger system. Data integrity is also checked during data acquisition in order to keep under control run-time systematic errors. To cope with this demands, specialized electronics have been designed and efficient software had to be written. The KLOE DAQ software is made of many tasks. In this paper we'll describe the front-end daq architecture and the software which deals with data collection and network sending.

[1] M. Adinolfi, F. Ambrosino, A. Aloisio, A. Andryakov, A. Angeletti, A. Antonelli, C. Bacci, R. Baldini-Ferroli, G. Barbiellini, G. Bencivegni, S. Bertolucci, C. Bini, C. Bloise, V. Bocci, F. Bossi, P. Branchini, L. Bucci, G. Cabibbo, A. Calcaterra, R. Caloi, G. Carboni, P. Campana, G. Capon, M. Carboni, C. Carusotti, G. Cataldi, F. Ceradini, F. Cervelli, F. Cevenini, G. Chiefari, P. Ciambrone, S. Conticelli, E. De Lucia, R. De Sangro, P. De Simone, G. De Zorzi, S. Dell'Agnello, A. Denig, A. Didomenico, S. Di Falco, A. Doria, F. Donno, E. Drago, V. Elia, L. Entesano, O. Erriquez, A. Farilla, F.M. Favero, G. Felici, A. Ferrari, M.L. Ferrer, G. Finocchiaro, D. Fiore, C. Forti, G. Foti, A. Franceschi, P. Franzini, A. Galli, M.L. Gao, C. Gatti, P. Gauzzi, S. Giovannella, V. Golovatyuk, E. Gorini, F. Grancagnolo, E. Graziani, P. Guarnaccia, U.v. Hagel, H.G. Han, S.W. Han, M. Incagli, L. Ingrosso, W. Kim, W. Kluge, V. Kulikov, F. Lacava, G. Lanfranchi, J. Lee-Franzini, T. Lomtadze, C. Luisi, A. Martini, W. Mei, L. Merola, R. Messi, S. Miscetti, A. Moalem, S. Moccia, F. Murtas, M. Napolitano, A. Nedosekin, P. Pages, M. Palutan, L. Paoluzzi, E. Pasqualucci, L. Passalacqua, M. Passaseo, A. Passeri, V. Patera, E. Petrolo, G. Petrucci, D. Picca, M. Piccolo, A. Pintus, G. Pirozzi, L. Pontecorvo, M. Primavera, F. Ruggieri, P. Santangelo, E. Santovetti, G. Saracino, R.D. Schamberger, C. Schwick, B. Sciascia, A. Sciubba, F. Scuri, I. Sfiligoi, S. Sinibaldi, T. Spadaro, S. Spagnolo, E. Spiriti, C. Stanescu, L. Tortora, E. Valente, P. Valente, G. Venanzoni, S. Veneziano, D. Vettoretti, S. Weseler, Y.G. Xie, C.D. Zhang, J.Q. Zhang, P.P. Zhao

1 Introduction

The main goal of the KLOE [2] [3] experiment at the DAFNE e^+e^- collider in Frascati is to measure CP violation paraters with an accurancy of 10^{-4} in the Kaon system. Stringent conditions are imposed to keep statistical and systematic errors at such a low level.
DAΦNE peak luminosity is expected to be $10^{33}cm^{-2}s^{-1}$, which corresponds to 10 kHz estimated data rate. Half of it is due to Φ decays while 5 kHz are due to rescaled Bhabha machine background and cosmics.The estimated average event size in KLOE is 5 kBytes. Therefore the DAQ [4] and trigger system [5] should sustain a 50 Mbytes/sec bandwidth. Data rates are cosiderably higher than those of a typical collider experiment making the design of the DAQ system a real challenge. Moreover stringent requirements also come from the high level of precision of the measurement we want to perform. The DAQ system in fact should mantain dead times at a reasonable level, moreover the dead time is not a function of the event configuration. Error rates must be minimized and procedures to assure data integrity are incorporated in the system. Since bunch crossing will occur in DAΦNE every 2.7 nsec the DAQ system has to be asyncronous with respect to the collision time. Final state multiplicity on the Φ is expected to be low therefore very low channel occupancy are predicted for KLOE.
The KLOE DAQ and trigger system should therefore fulfill the following requirements:

- to sustain 50 Mbytes/s;
- to be scalable and flexible;
- to be asyncronous with respect to the trigger signal;
- to have a fixed dead time;
- to be optimized for low channel occupancies.

To keep up with this demands, the KLOE DAQ system has been designed as a mixture of custom specialized and high speed commercial electronics. Moreover an efficient software architecture has been projected and developped to deal with this complex system.

2 DAQ hardware architecture

The KLOE DAQ system has to collect data coming from roughly 23000 electronic channels: 5000 channels for the electromagnitc calorimeter ADCs and TDCs while about 13000 channel for drift chamber TDCs. A simple sketch of the readout and data acquisition system is shown in fig. 1. Data collected by the front-end electronics (FEE) [6] [7] are first buffered on a decoupling fifo on first level crates, afterwards a further bufferization occurs on the second level data concentrator, during run time, software reads data from the second level concentrator and sends data to the farm via FDDI. Sub-event building is done in hardware on first and second level crates, while farm software is in charge of performing full event-building. All the FEE boards have VME interface which is used to initiliaze the run. A fixed dead time of 2.3 μsec is hardwired on the FEE calorimeter boards this means a dead time of 2% for the KLOE experiment at DAΦNE peak luminosity. Each FEE crates hosts a read out controller for KLOE (ROCK) which upon a trigger reads all the FEE boards present in the crate and builds up a sub-event. The FEE read-out uses a custom designed bus system (AUX-bus), whose charateristcs have been optimized for low occupancies. Its peak throughput is about 50 Mbytes/sec, and implements in hardware block transfer capability. A decoupling fifo is hosted on the ROCK [8] [9] to buffer sub-events. The FEE crates are organized in chains, two busses are in charge of connecting the FEE crates with the level two crate. The first buffer is the VIC-bus which is a bi-directional bus. This is a slow commercial bus whose badwidth is 4 Mbyte/sec therefore this bus has been used to initialize the chains and check run-conditions. A fast one direction custom-bus has been developped to interconnect all the FEE crates belonging to the same chain, it can sustain up to 40 Mbyte/sec. Data flowing on the c-bus are finally collected by the chain-controller (ROCKM) whose task is to build up the chain sub-event and store it on a further decoupling local fifo. The crate which hosts the ROCKM and the VIC-controller also hosts a VME-CPU (Digital, DEC CORTEX, based on ALPHA chip) with an FDDI interface. The VIC-controller is used to issue initialization instructions to all the FEE boards, while the ROCKM FIFO is continuosly read by the processor in block-transfer mode, a packet of a set of event is built up by software and the stream is finally sent to the farm via FDDI. The crates housing ROCKM, VIC and VME-CPU are the core of the second level data concentration scheme. Fig 2 shows a sketch of the data concentrator. The maximum sustainable data throughput has been measured to be 9.5 Mbytes/sec per chain. This number includes FDDI transmission to farm using TCP-IP protocol. We have 10 chains in KLOE 4 are dedicated to the calorimeter 4 to the drift chamber and 2 to the trigger monitoring system. This means that the full system can sustain up to 90 Mbyte/sec. Data coming from

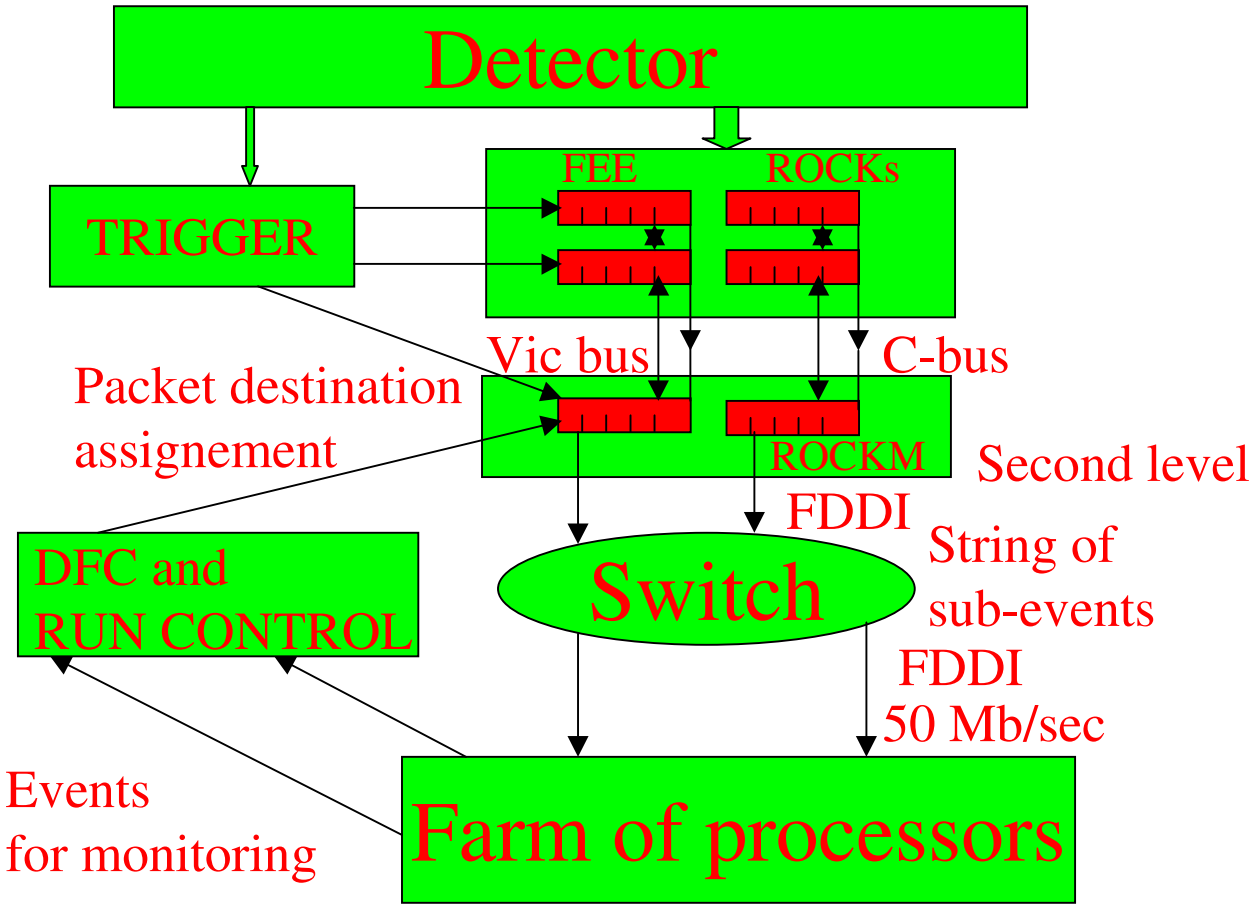

Figure 1: System architecture.

each chain must be sent to the same farm to do final event-building operations and checks. Which means that all the second level processors must send the sub-event streams to the same farm processor. A Data Flow Controller or DFC process has been developped to perform this task. All the processors share the DFC tables via a VIC-bus which horizontally interconnects all the chains.

A special second level VME crate houses the Trigger Supervisor module whose main task is to interface the trigger decision system with the DAQ system. First level trigger are distributed [10] to the FEE by the trigger distributor whose task is also to synchronize the trigger with the DAΦNE radio-frequency. Second level trigger is distributed to the FEE by the Fan In/Out modules (FIOs), which distribute trigger coming from the trigger supervisor to the ROCKs and ROCKMs present on each chain and from the ROCKs and ROCKM receive back the busy and the halt signal these two control signal have been exploited also to implement real-time debugging tools.

3 DAQ software architecture

Many specialized tasks running on different platform are the core of the KLOE software architecture. These tasks are resposible of taking care and checking the full data flow [11], from VME front-end electronics down to tape recording devices. Fig 3 shows the DAQ software architecture. Tasks can be split in different categories, depending on whether they run on second level VME-CPUs or on on-line farm. The first level of the data concentrator system needs only initialization software, since the transfer protocol on AUX-bus is hardwired implemented on ROCKs. Tasks running on the second level VME CPUs take care of the initialization procedures. Moreover since also the trigger and its monitoring system is acquired the same tasks on the trigger chain are in charge of setting the proper running conditions. The initialization procedures, at the beginning of a run, are performed through the

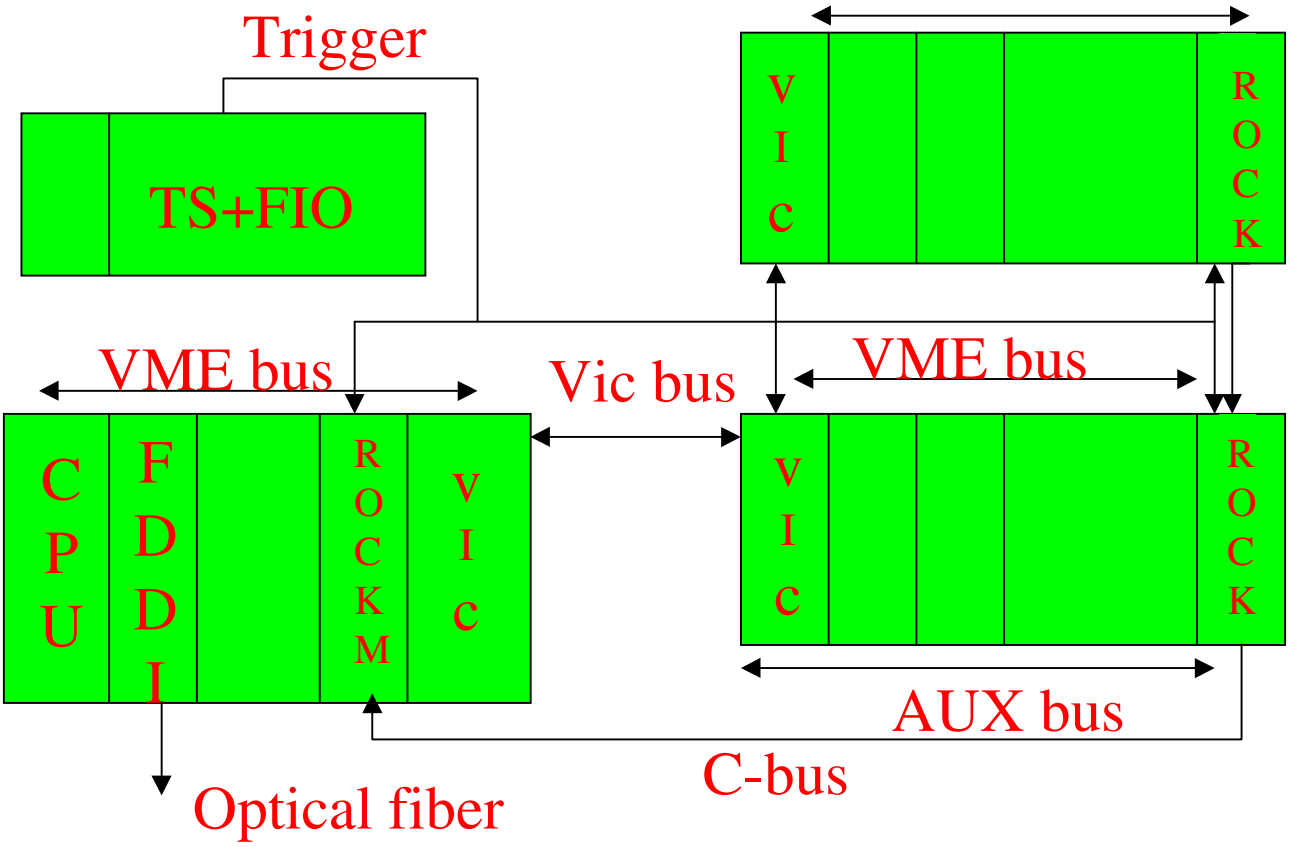

Figure 2: Second level data concentrator scheme.

VIC bus channel and concer both FEE boards and ROCKs. During the normal data taking, data (stream of sub-events) corresponding to a set of triggers are read out by the ALPHA VME second level processors from the ROCKM FIFOs though VME in block transfer mode. Block transfer parameters can be dinamically optimized according to the effective throughput in the chain. The software process (collector) puts the data in a circular buffer which is readable by another process (sender). The sender send them via FDDI to the on-line farm using TCP/IP protocol. The information allowing stream syncronization is taken from Data Flow Control (DFC). This task, which runs, on a dedicated HP VME processor, implements a modified round-robin protocol to assign the right farm address to packets of events. Another task, running on a second-level CPU, manages the Trigger Supervisor module and the FIOs. Both the trigger and the collector process implement real time debugging tools which upon interrupt are able to diagnose an error and suggest a recovery operation. Error diagnosis logic flow is triggered by a long lasting busy signal or by an halt signal received from trigger supervisor from FEE boards. Should such event occur the trigger process starts a first level diagnosis by interrogating FIOs. In this way the trigger process retrieves the information of the chain and the crate which triggered a long lasting busy or an halt. When such information is known to the trigger process a software interrupt is broadcasted to the second level processes and the collector starts a deep diagnostic procedure which leads to identify the source of the problem. Farm processes will be described elsewhere [12]. All these processes are coordinated by a run-control process and a specific message passing system, based on SNMP[13] protocol, has been developped for KLOE.

4 DAQ present status

All the second level processors and chains have been installed on the detector toghether with the FEE reading the electromagnetc calorimeter and the drift chamber. Various test have been performed on the system. The dead time of the system has been checked by distributing and external clock of 430 kHz which was vetoed only occasionally by the busy signal. Since FDDI transmission from second level to farm was not enabled the daq system could sustain a rate of 390 kHz. The peak rate compares directly with the dead time of the system which is 2.3 μsec. Moreover, in order to check the data trasmission

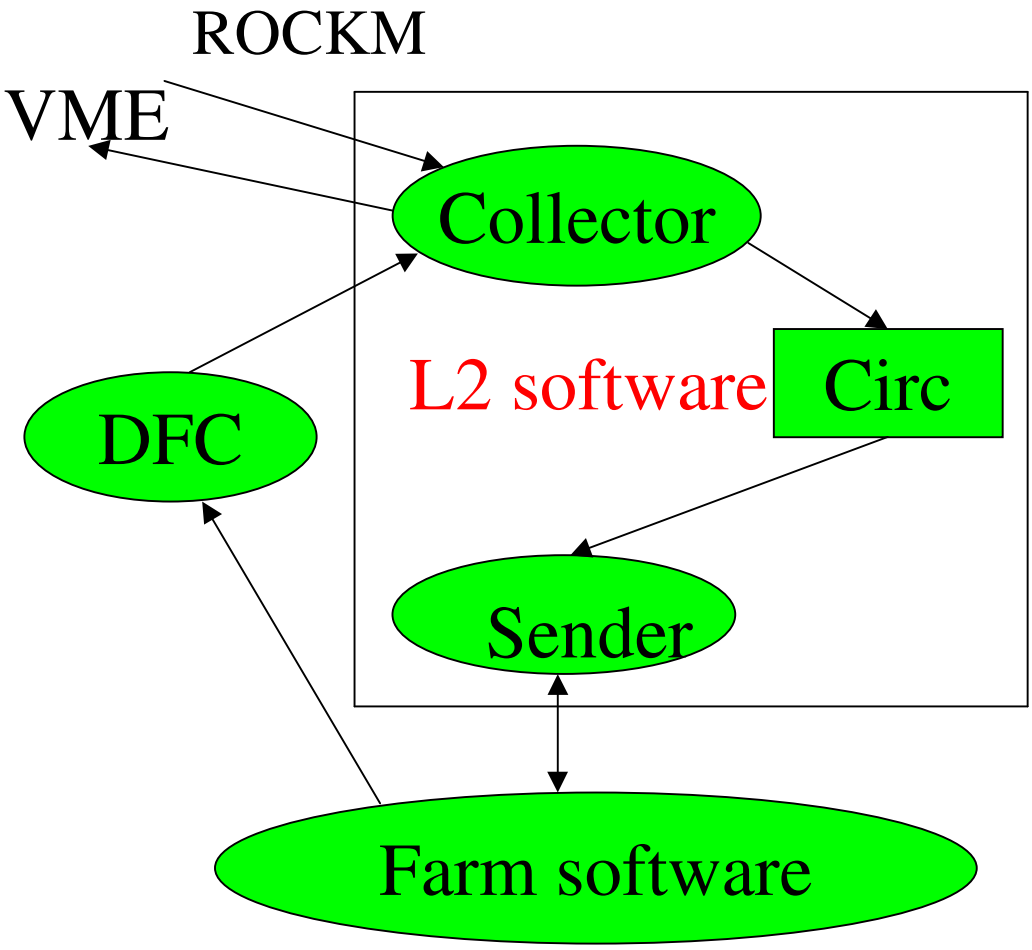

Figure 3: DAQ level two software architecture.

quality, random generated patterns have been loaded into the FEE boards. This patterns have been acquired using the standard daq chain and compared. In this way data consistency in each chain for each channel in each board has been checked during at least a 24 hour long run. By enabling the FDDI trasmission to the on-line farm, rate as high as 30 kHz per chain with an occupancy which is the one we expect in normal running condition can be sustained. The KLOE DAQ and trigger system is now running using cosmic rays as input. Long term tests of the full system have been performed the measured sustaind rate is about 3 kHz. A typical event is shown in fig 4.

5 Conclusions

The KLOE experiment now can profit of a flexible and scalable trigger and DAQ system. The trigger and DAQ fulfill all the requirements needed by the experiment. The trigger and DAQ system can handle data bandwidth up to 90 Mbytes/sec. The system has been extensively tested and proved to be efficient and reliable over long period of tests. The trigger and DAQ system is now installed on the detector and running using cosmic rays as input.

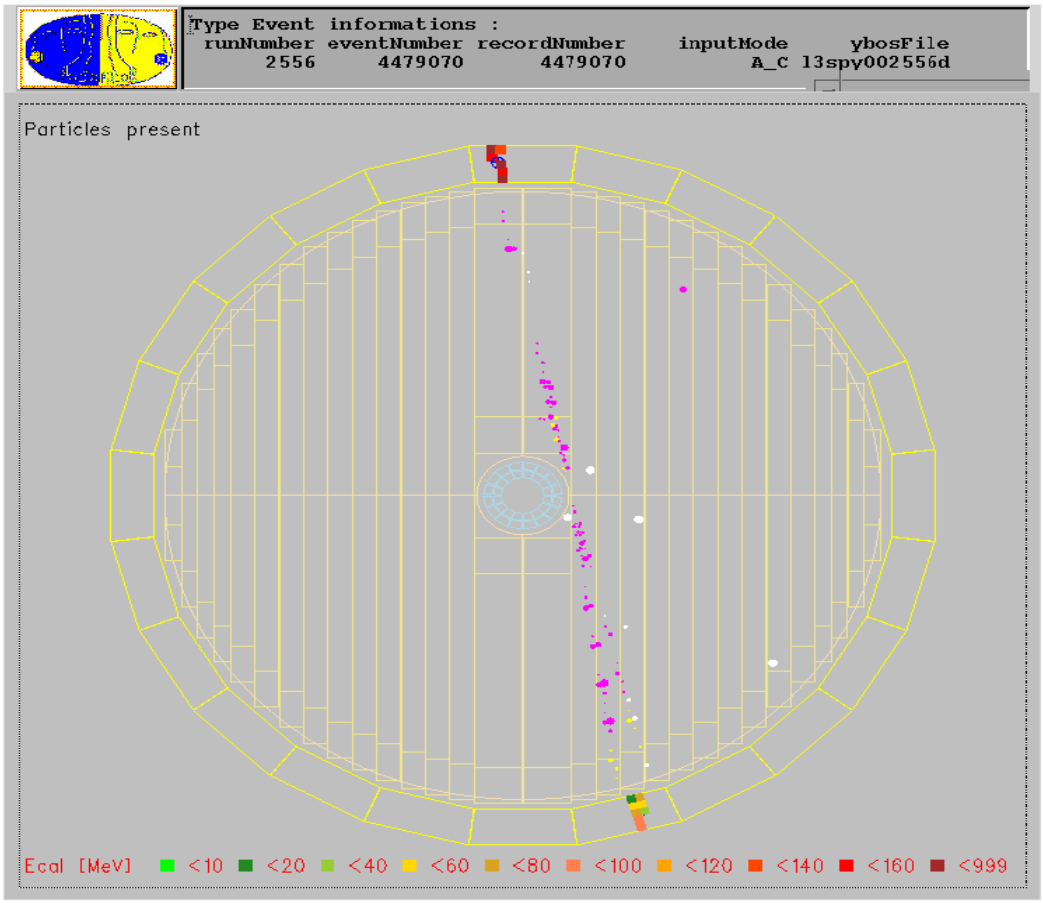

Figure 4: Event display of a cosmic ray in KLOE.

References

[1] The KLOE Collaboration. A general purpose detector for DAΦNE, LNF-92/019 (1992).
[2] The KLOE Collaboration, The KLOE Detector, Technical Proposal, LNF-93/002 (1993).
[3] The KLOE Collaboration, The KLOE Central Drift Chamber Addendum to the Technical Proposal, LNF-94/028 (1994).
[4] The KLOE Collaboration, The KLOE Data Acquisition System, Addendum to the Technical Proposal, LNF-95/014 (1995).
[5] The KLOE Collaboration, The KLOE Trigger System, Addendum to the Techinical Proposal, LNF-96/043 (1996).
[6] P.Franzini, E. Spiriti, The ADC f or the KLOE electromagnetic Calorimeter, KLOE memo n. 94 (1997).
[7] P. Franzini et al., Tests of the KLOE EMC Calorimeter TDC board, CAEN model VX569, KLOE memo n. 34 (1995).
[8] A.Aloisio et al., Fast readout system for KLOE, KLOE note n. 88 (1994).
[9] A.Aloisio et al., Custom Solution for a data readout architecture: a system level simulation, Proceeding of CHEP 1994.
[10] V. Bocci et al., Trigger Handling and distribution in the KLOE experiment, KLOE memo n. 125 (1997).
[11] E. Graziani et al., The KLOE Data Acquisition System, KLOE memo n. 153 (1998).
[12] E. Pasqualucci et al., Monitoring of the KLOE DAQ System, this proceedings.
[13] E. Pasqualucci et al., Using SNMP implementing Data Flow and Run Controls in the KLOE experiment, Proceedings of CHEP95, World Scientific (1996) 78.