EEE Project

REPORT

ON SCIENTIFIC ACTIVITY OF

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During the period from December 1, 2006 to August 31, 2007, I have performed the following work for the EEE project:

- The system for testing the MRPC in the Torino INFN laboratory has been fully mounted and checked;
- The cosmic ray telescope in the physics laboratory of the Alessandro Volta Lyceum has been mounted and tested;
- The noise characteristics and efficiencies of all the 9 MRPC, presently available in Torino, have been determined;
- New data readout and storage software has been developed on the basis of the free object-oriented library for analysis and presentation of physical data (ROOT framework). The programs developed are functional both in the LINUX and Windows XP operating systems. The format of data, obtained during our statistics collection, is fully compatible with the format [1] of data, obtained with the aid of software based on the LabView system developed at CERN for the EEE project, but in our case the data processing and presentation system is more flexible.

I. The system for testing MRPC in the laboratory of INFN.

In January 2007, within the Torino group of the EEE project, I developed and mounted a system for testing MRPC chambers in the INFN laboratory. The data acquisition system is based on the scheme proposed in ref.[2] (see fig.1). The high-voltage and gas supply systems are mounted according to the standard scheme adopted for the EEE project [3].

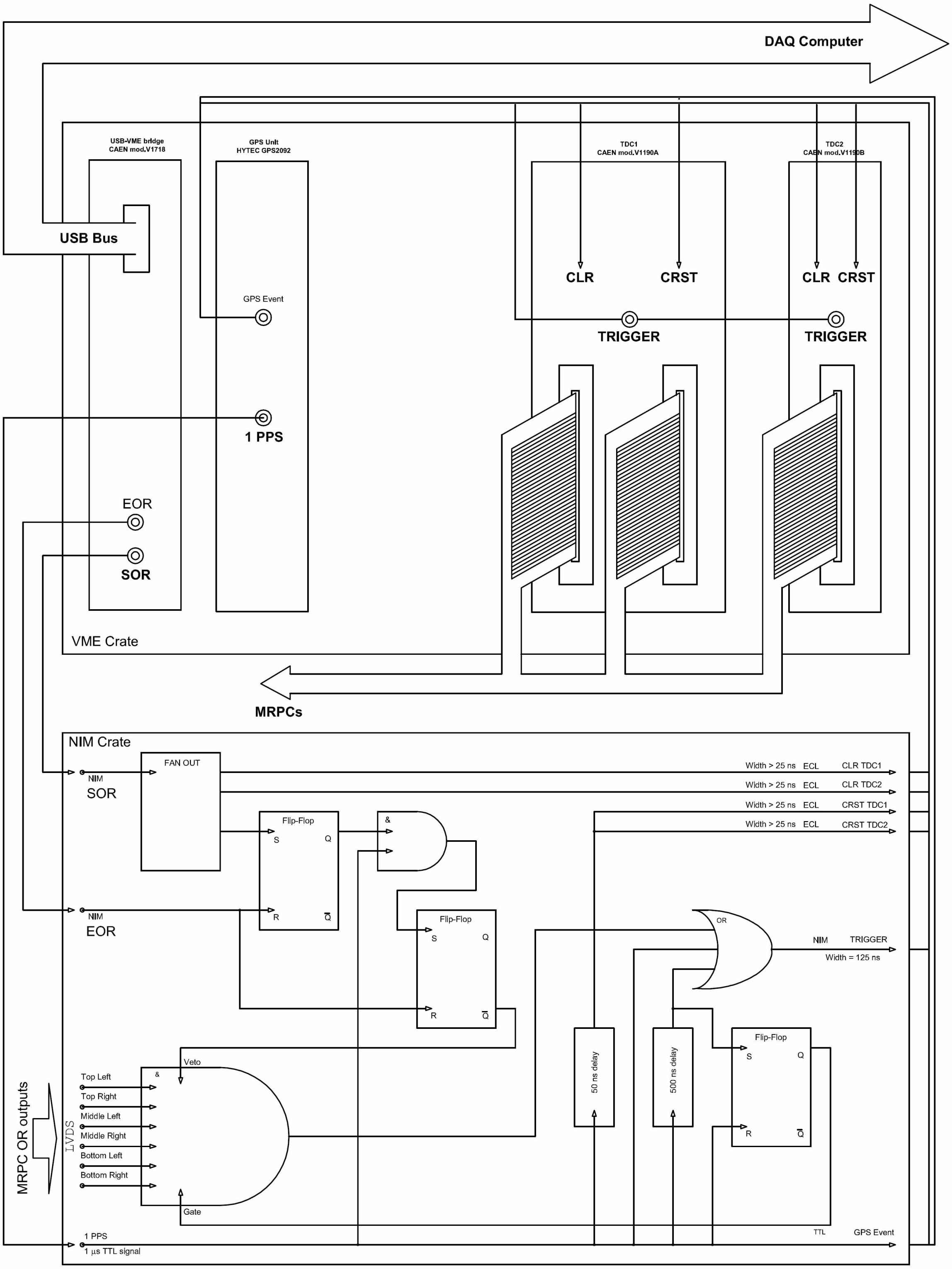

Fig.1. Trigger and DAQ scheme.

Test of cosmic ray detector in the physics laboratory of the Alessandro Volta Lyceum.

In May of 2007 a cosmic ray telescope was installed in the physics laboratory of the Lyceum and tests were performed of the efficiencies and noise characteristics of the chambers. The operation of the software and hardware systems was tested in real conditions. Fig. 2 shows the dependences of the efficiency and noise level upon the high voltage supplied to the MRPC.

It turned out that in conditions of poor grounding (the physics laboratory of the Lyceum is at the highest, 5-th, floor of the building) the output from the chambers is quite noisy in the case of the working high voltage. This, evidently, results in measurement errors. The said test has revealed it necessary to realize high-quality grounding in the laboratory of the Lyceum. We estimate that improvement of the grounding will permit to reduce the noise by 20-40%. Nevertheless, the test demonstrates that, when the hardware will be available, we could start measurements after a short preparation period (approximately 1 week).

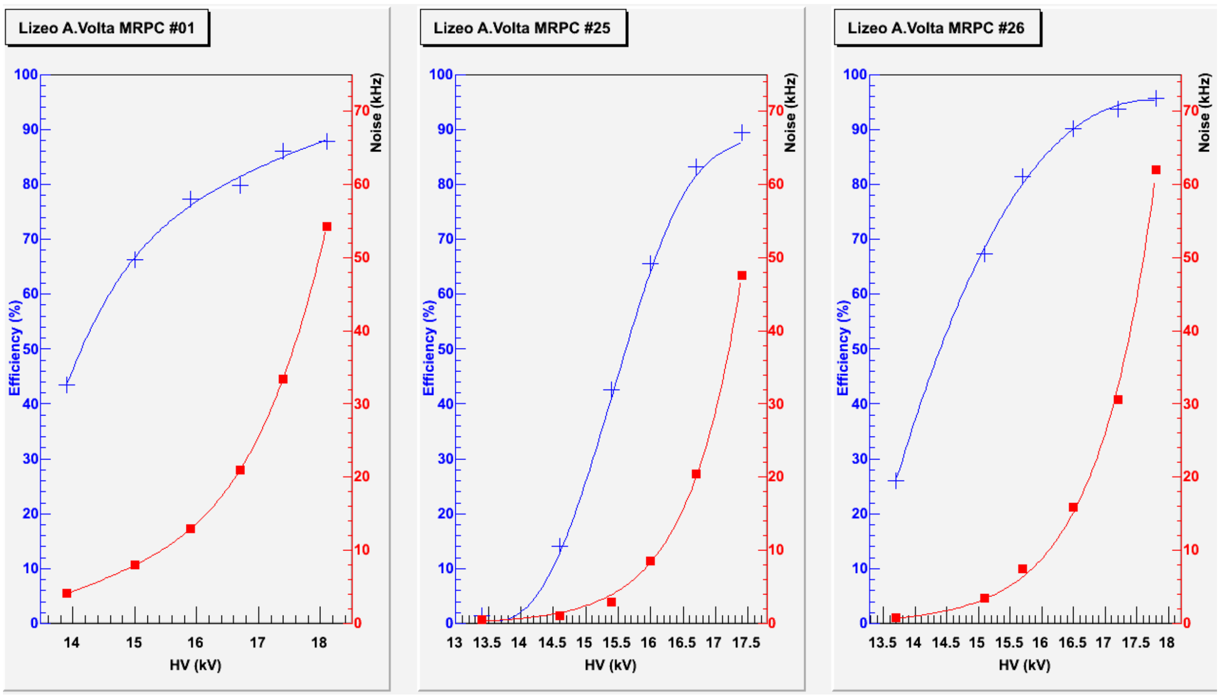

Fig.2 Efficiency (crosses) and noise level (squares) vs. HV. (A.Volta Lyceum)

At present, we lack the following equipment to be able to start operation of the detector:

1. Trigger logic module;
2. 6 Front-end cards;
3. 6 Interface cards Amphenol-TDC;
4. 7 Low voltage power supplies;
5. 6 Amphenol cables, length 4.5 m;
6. GPS unit with antenna;
7. PC with accessories.

III. Tests of the MRPC characteristics in the INFN laboratory.

In the INFN laboratory we have fully mounted the working cosmic ray telescope. In conditions of good grounding of the detector and electronics we obtained a very low noise level and were able to debug our software and adjust the electronics. The results of measurement of the efficiency and noise characteristics of the chambers, performed in the laboratory, are presented in fig. 3.

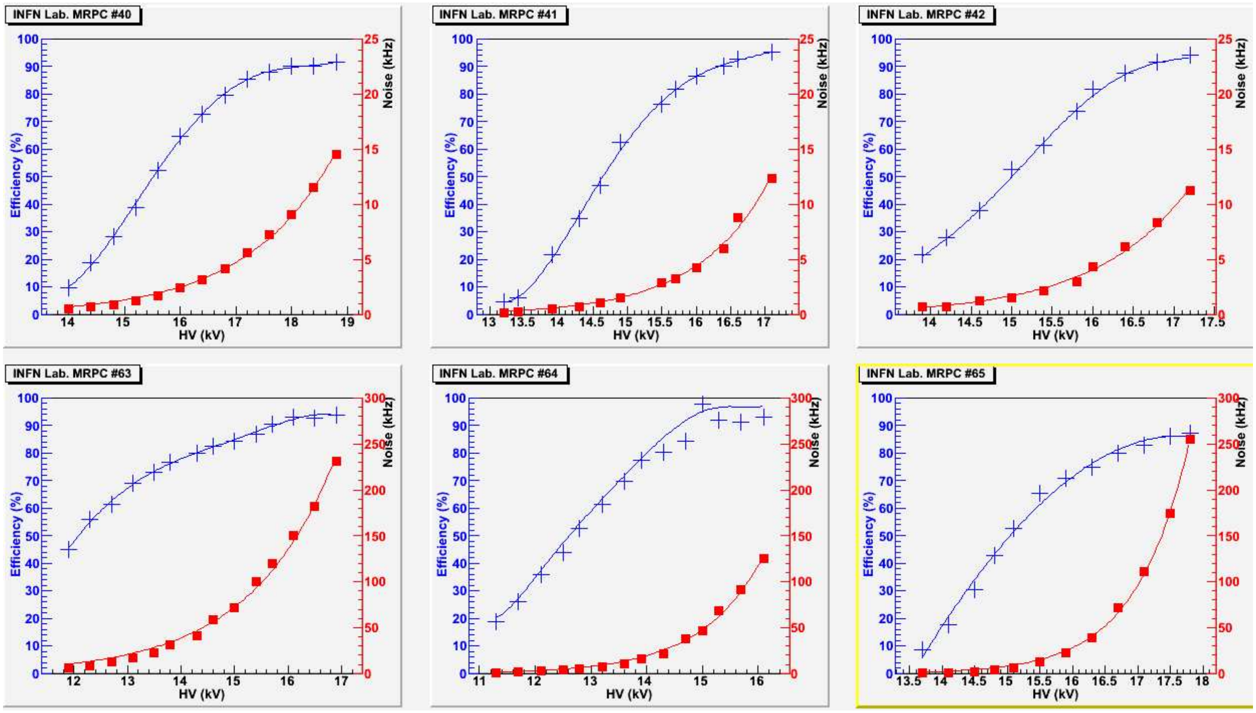

Fig.3 *Efficiency (crosses) and noise level (squares) vs. HV. (INFN Laboratory).*

The characteristics of different chambers can be seen from the figures to differ very significantly. While the chambers of series 40-42 exhibit a noise level inferior to 15 kHz with the working high voltage and an efficiency higher than 90%, the noise level of chambers from series 63-65 amounts to 250 kHz, which cannot be accepted. Moreover, for chamber #65 we were not even able to reach an efficiency above 90%. Additional studies showed that the noises characterize the chambers themselves, but not the readout electronics or the quality of its screening. Fig. 4 shows the dependence of the dark current on the high voltage supplied to chambers #40 (low noise) and #63 (high noise). It is clearly seen that the dark current in the chambers causes high noise levels.

To find a way of dealing with the high noise levels, we also studied the dependence of the efficiency and noise on the front-end electronics threshold. These studies resulted in quite a paradoxical conclusion: reduction of the threshold lowered the noise level (noise reduction by 20-40%). This effect was achieved, because when the threshold was lowered, the chamber reached the efficiency plateau at a lower high voltage, the dark current also being lower. Regretfully, the above effect requires a very good grounding of the chambers, signal cables and electronics, which is not always possible in conditions of the physics laboratories of schools, where the detectors are to be installed.

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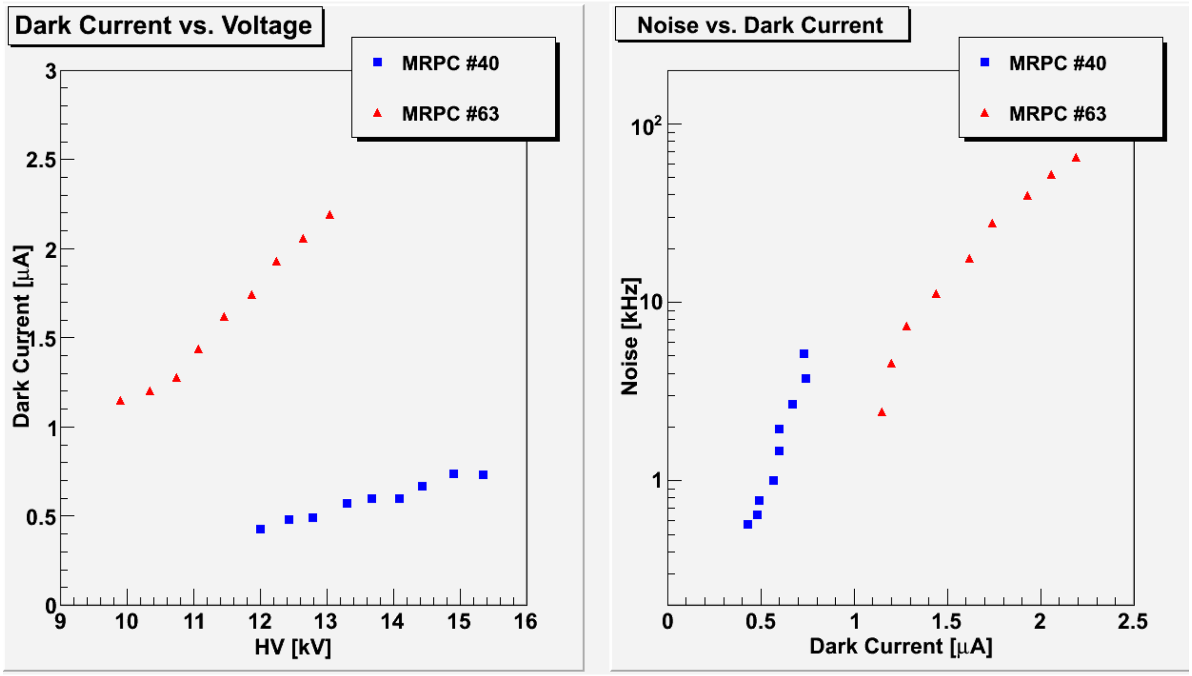

Fig.4 *Dark current level vs. HV for MRPC#40 (squares) and MRPC #63(triangles), and dependences of the noise level vs. dark current for these chambers.*

IV. Software.

From the very beginning, owing to the absence of part of the electronics, we could not start testing the chambers using the official software, based on LABVIEW and developed at the CERN laboratory especially for the EEE project. For this reason I had to develop a DAQ system for LINUX making use of the library for analysis and presentation of physical data ROOT.

As electronics arrived in our laboratory, this program underwent transformation into a full-scale DAQ system, completely compatible, at a hardware and data format level, with the official DAQ software. We decided that since an independent DAQ version could not hinder development of the EEE project and, also, since open source software is more flexible and friendly to experimental physicists, to further develop our own software.

Moreover, since the LINUX operating system requires much working experience with computers, our DAQ system has been made to operate on computers with Windows XP, too.

Our DAQ system is organized according to the client-server scheme. Here, the server part of the system is responsible for data readout and data storage on the disk without any processing, and it operates with high priority to avoid losing data. The client part of the system is actually a separate program, which can be installed both on the same DAQ computer and on any other remote computers; it is connected with the server via TCP/IP sockets. Such an operating scheme permits several clients to simultaneously connect to the server without any loss of its performance. Thus, several persons may watch the operation of the cosmic ray telescope, even if it is installed remotely. In our opinion this will be useful for students of schools. The server part of the DAQ system is organized as follows: if its resources are insufficient to supply all data of all events to all clients simultaneously, then it will distribute the data in small samples without any risk of losing information.

In case the servers operate within LINUX, one operator will be able to work simultaneously with several telescopes on a remote computer.

The client actually represents data monitoring software and can perform simple data processing. It can also work both with Windows XP and LINUX. Below, as an example, several pictures are shown with histograms, which can be seen in the course of work with the data monitoring software.

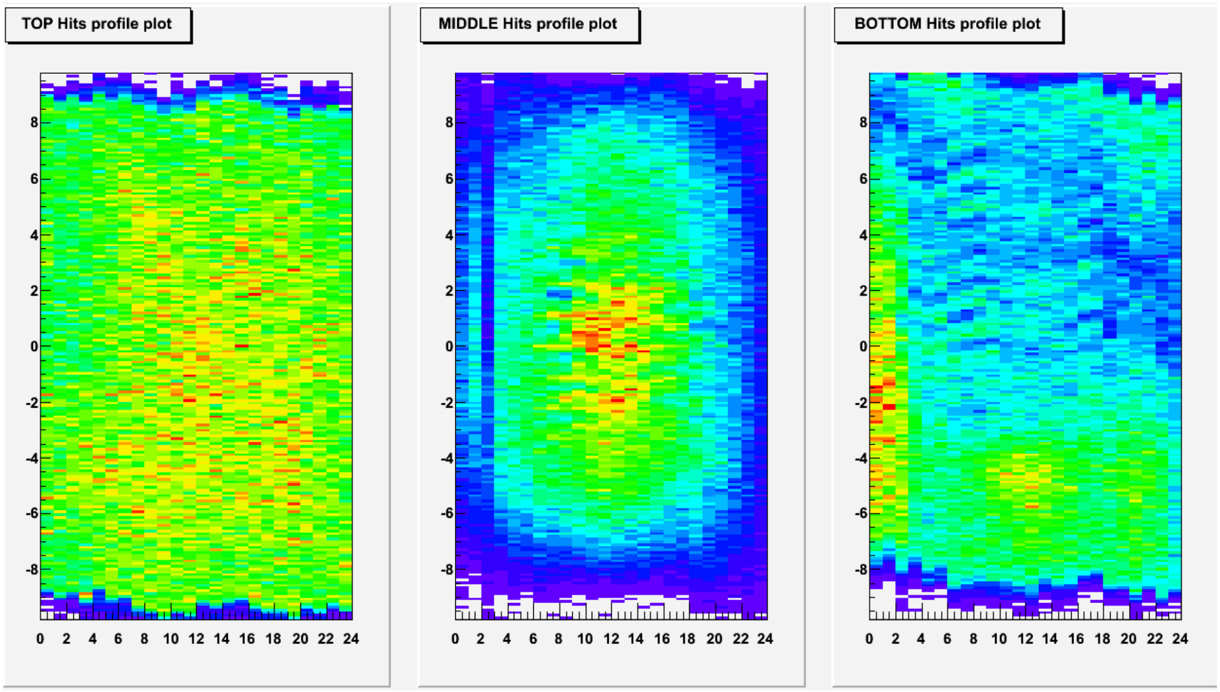

Fig.5. Hit distributions for all 3 MRPCs of the telescope.

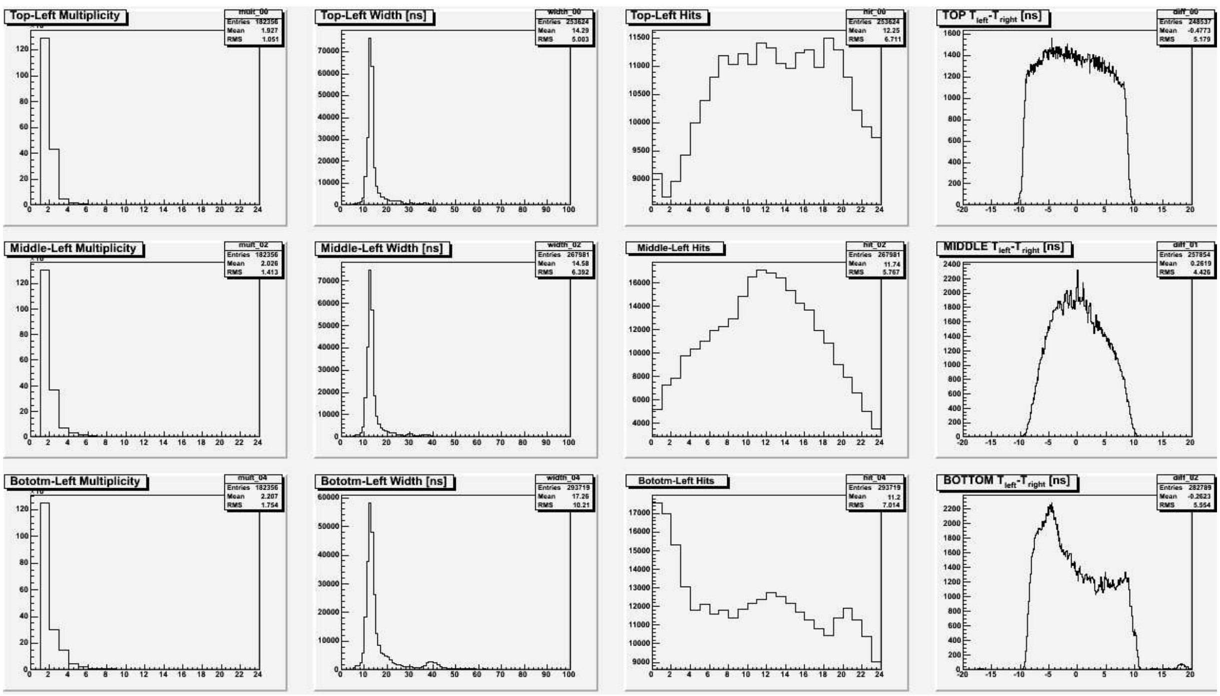

Fig.6. Examples of monitoring histograms.

Besides the histograms presented above, the monitoring program has an "Event Viewer" window, in which one may see which MRPC strips actually were hit in a given event and see on the screen of the monitor the passage of a cosmic particle through the telescope in two projections (along and across the chambers).

V. Synchronization of events.

Synchronization of an event relative to the time, determined by a GPS receiver, differs somewhat from the synchronization adopted in the EEE project. Our TDC units operate in the "disable subtraction trigger time" mode. As a result, the time a signal from a MRPC strip arrives to a TDC is synchronized with the arrival time of the CRST signal (see fig.1) . Thus, we define the precise arrival time of a signal from a MRPC by the following formula:

$$\mathbf{T_{signal} = T_{CRST}+N_{bins}*t_{bin}} \qquad [5.1]$$

In this formula $\mathbf{T_{CRST}}$ is the arrival time of a CRST signal to a TDC (synchronized with the first event after the arrival of data from the GPS receiver), $\mathbf{N_{bins}}$ if the number of TDC bins counted starting from the arrival time of the CRST signal up to the arrival time of the signal from a MRPC, $\mathbf{t_{bin}}$ is the length of a single TDC bin.

The quantity N_{bins} can be calculated by the formula:

$$\mathbf{N_{bins} = ETTT*32*N_{bins/clock} + t_{signal} - [(ETTT*32*N_{bins/clock})\&0x7FFFF]}$$

In this formula **ETTT** is the extended trigger time tag value; $\mathbf{t_{signal}}$ is the TDC leading time measurement value; $\mathbf{N_{bins/clock}}$ is the number of TDC bins per clock of the internal TDC generator, and in our case it equals 256.

The quantity $\mathbf{t_{bin}}$ in formula (5.1), which is about 98 ps in our case, depends on the frequency of the internal TDC generator and can be determined very precisely. The only problem, that remains, consists in determination of the quantity $\mathbf{T_{CRST}}$, since the CRST signal is formed by the 1PPS signal of the GPS receiver, its synchronization precision is about 100 ns, and it also exhibits additional delays, which are difficult to determine, because they are composed of delays in the cables and the delays inside the electronic modules.

References

1. Preliminary EEE Data File Format, prepared by Raman ZUYEVSKI.
2. Cosmic Ray Tests of Large Area Multigap Resistive Plate Chambers.
   Shaohui An, D.Hatzifotiadou, Jinsook Kim, M.S.C. Williams, A.Zichichi, R.Zuevski
   (Preprint submitted to Elsevier Science)
3. Progetto "La Scienza Nelle Scuole" EEE. A.Zichichi