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Data Acquisition System for RPC Testing

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Abstract

The Data Acquisition (DAQ) System of the Compact Muon Solenoid (CMS) RPC test station was built in National Centre for Physics (NCP) during the year 2004-2005 with joint efforts by NCP and PAEC groups. The system is based on the NIM, VME and CAMAC technologies which allowed users to test 10 RPCs simultaneously. With the help of our facility more than 300 RPCs were tested and finally shipped to CERN.

This note describes different components of the DAQ in detail and presents a few results from the online DAQ.

1 Introduction

An experimental setup of Data Acquisition System (DAQ) was developed in Pakistan to test the endcap Resistive Plate Chambers (RPCs) [1], which are installed in the Compact Muon solenoid (CMS) experiment at the Large Hadron Collider (LHC). In our experimental setup the DAQ System was developed to handle the signals generated by the RPCs. The DAQ system was based on VME and NIM standards. A VME crate housed fifteen 64-channel TDC modules sampled by a 40 MHz clock (which corresponded to 25 ns time sensitivity). Each TDC processed the Low-Voltage Differential Signaling (LVDS) signals coming from three FEBs. TDCs were programmed in a "common stop" configuration. A NIM crate was housing different logical units. A VME bus was used as a common interface between the online computer and the DAQ system. The computer was used to control the measurement and to store the data.

The acquisition program for the experiment was a modified version of a pre-existing acquisition program developed in C++ and some classes of ROOT [2]. The pre-existing acquisition program was designed to readout the data from TDCs. The whole setup was based on a trigger generated by scintillators and readout electronics. When the trigger was generated the data was transmitted to a personal computer (PC) for storage and analysis. Readout electronics was connected to a computer via a VME crate controller which handled all the digital modules installed in a crate to get data from detectors and scintillators in digital mode. A schematic DAQ electronics is shown in Fig. 1.

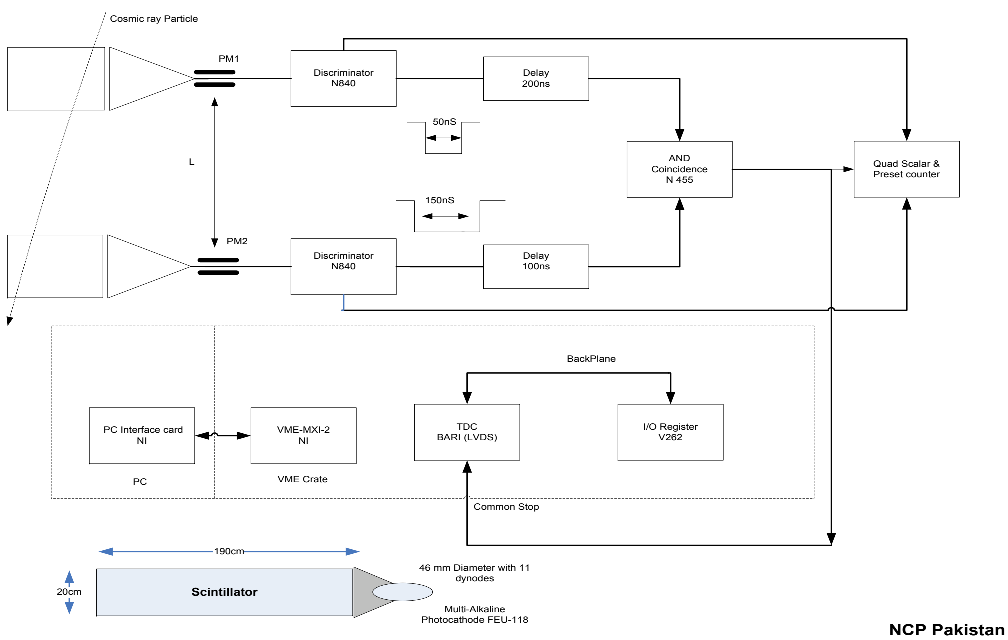

Figure 1: Schematic diagram of DAQ electronics

2 Test Setup

The test setup consists of the following:

- Trigger Setup
- Trigger Logic
- Trigger Electronics

- Readout Electronics
- High/Low Voltage Power Supply
- Cables

2.1 Trigger Setup

Working with the trigger we have to remember the following aspects:

1. Accidental Coincidence
2. Noise
3. Rare Trigger

The trigger setup is shown in Fig. 1. The accidental coincidence caused by noise in the scintillator counters may generate a fake trigger (mimic the presence of a cosmic ray muon). For good determination of RPC efficiency it is important for the accidental coincidence to be as small as possible. Number of accidental coincidences is determined by the equation:

$$N_a = N_t \times N_b \times 2T$$

Where N_a is number of accidental coincidences, N_t is number of hits in the top counters, N_b is number of hits in the bottom counters and T is time resolution of the coincidence scheme. The rate of accidental coincidence is directly related to the noise rate in a given counter. Following simple example may explain the whole scenario in a better way:

Consider a situation where we have 400 cosmic ray particles and use 20 counters (10 on top and 10 on bottom) for generating a trigger. Signals from counters have a width of 30 nsec and we need accidental coincidence less than 1% then the number of accidental coincidences must be less than 4. i.e

$$4/s = N_t \times N_b \times 2 \times 30 \times 10^{-9} s$$

if top and bottom surfaces have identical flux i.e $N_t = N_b = N$ then,

$$2 \times 10^9 Hz^2/30 = N^2$$

This gives $N = 8165/s$ for 10 counters. For a single counter, flux of particles must be less than 816/sec. Our DAQ system used 8 counters in each surfaces. In our case average number of events from one counter must be less than 1020.

Noise contribution for scintillator counters comes from ambient light or electronic noise. The efficiency of scintillator counters is affected by noise. The number of cosmic muon triggers is smaller than the noise in these counters. For the noise three steps were followed to form a trigger:

1. Testing of all equipment (pre-amplifiers, scintillators, cables)
2. Division of tested counters in groups according to high voltage and noise level
3. Completion of full scale stand and forming muon trigger

2.2 Trigger Logic

Practically in all physics experiments, one is generally faced with a situation where one would like to select a particular signal from background and/or other competing events/hits which occur simultaneously. To do this, one must impose certain criteria which could identify the signal from background. Events satisfying a certain imposed criteria in turn may activate other operations in the system. The electronic logic based on this criteria is called the trigger. In many high energy experiments, several different triggers are often present allowing an experiment to record more than one type of signal at the same time [4].

The trigger logic used in our system was based on scintillator counters. We have operated these counters between $1.0 - 1.4$ kV. To readout the signals from these counters custom made preamplifiers were used. Two voltage distribution boards were used to power these counters. The LEMO connectors used for these counters were also custom made; we needed 40 such connectors.

The RPCs were placed between two scintillator planes, each plane consisted of eight scintillator counters. The trigger signal was formed by taking the logical "AND" of the signals from upper and lower plane of counters whereas the signal from a given plane was obtained by a logical "OR" of the counters.

2.3 Trigger Electronics

Trigger is generated using the following electronic modules:

- Pre-amplifier
- Discriminator (Model N840) [3]
- Coincidence Logic Unit (Model N455) [3]
- Scaler (Model N145) [3]
- Time Delay Unit

Fig. 2 shows various trigger modules used in our system. All the triggers modules are of NIM type.

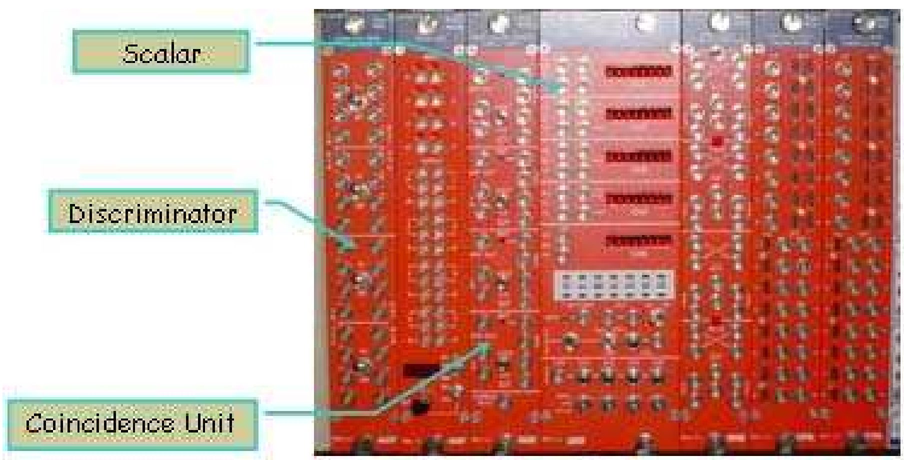

Figure 2: NIM modules used in our DAQ system.

2.3.1 Coincidence

Fig. 3 illustrates a simple coincidence measuring scheme. The basic technique is to convert the analog signal from the detectors to a logic signal and send these pulses to a coincidence module. If the two signals are, in fact, coincident, then a logic signal is produced at the output as shown in Figure 4.

In order for this setup to work, however, it was necessary that the electrical path of each branch leading to the coincidence module be of equal length. This could be ensured by adding adjustable delays to each line. In principle, only a single delay is needed on the faster branch, however, one on each branch provides a bit more flexibility when adjusting the circuit.

2.4 Readout Electronics

Elements of readout electronic system is based on:

- Front-End Board

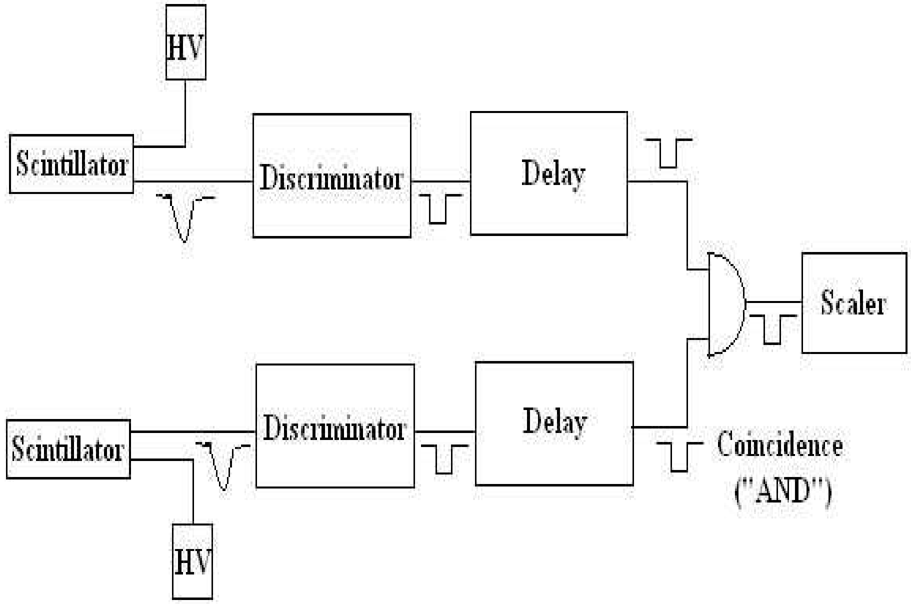

Figure 3: The coincidence logic.

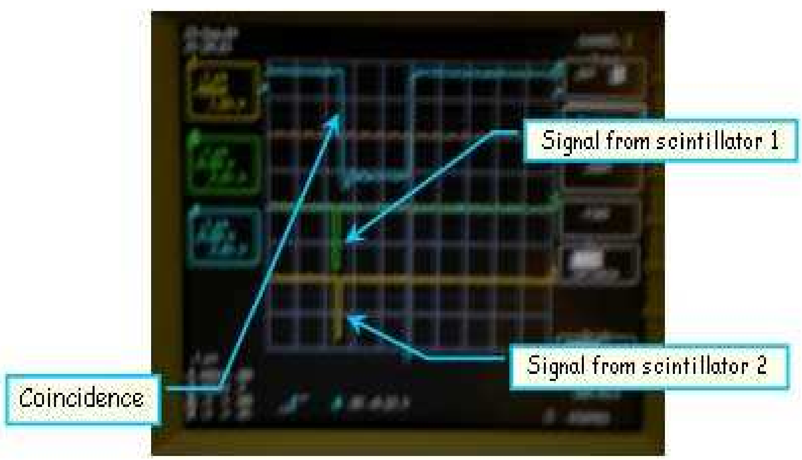

Figure 4: Three coincidence signals from two scintillator planes and a chamber.

- VME Crate Controller [4]
- VME bin or VME crate: National Instrument Crate Controller which was directly connected with the computer with MXI 2 cable and a PCI card. Crate controller acted as a communication center managing the flow of information on the crate dataway [4]
- Libraries and drivers (available both in Linux and Windows for crate controller).
- BARI TDC to readout the information from 64 channels of RPC.

The readout electronic system is shown in Fig. 5.

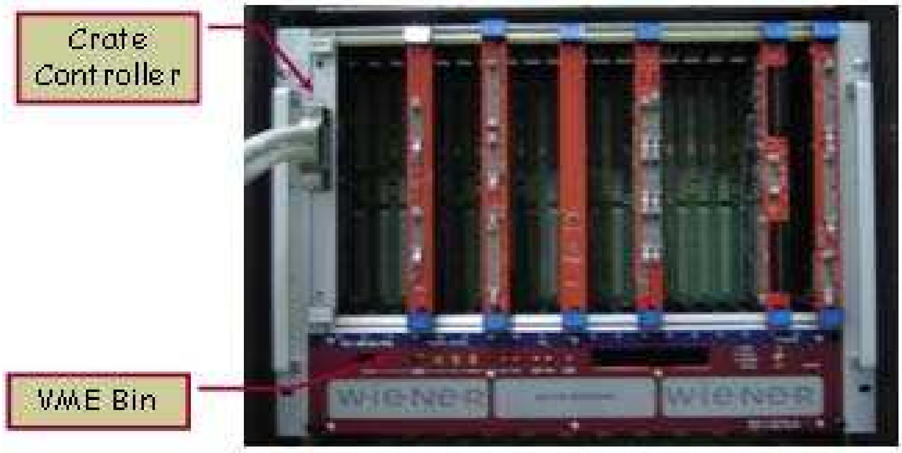

Figure 5: The VME crate houses one crate controller and maximum of 15 TDCs

2.4.1 Front-End Board

The purpose of the FEB is to house the electronics that produces a signal for high level processing. The input (information from the RPC) is processed and delivered to the trigger system via FEBs. Each RPC consists of 3 FEBs. The FEB is directly connected to the RPC and contains 32 channels of RPC front-end electronics. A photograph of FEB used is shown in Fig. 6.

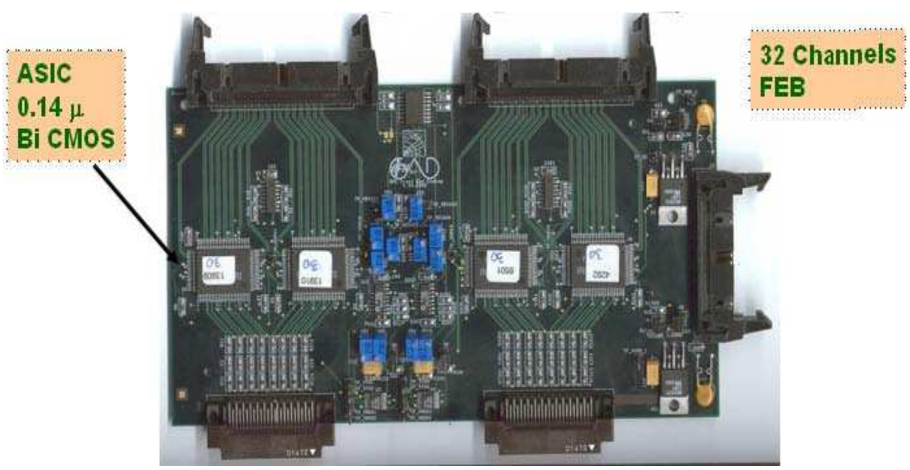

Figure 6: A Front end board with 4 ASICs .

The pre-amplifier used in the FEB is of charge sensitive type with a threshold control available. The threshold could be adjusted between $10 - 300$ fC.

2.4.2 VME Crate Controller

There were various types of modules connected in the VME crate. We had different types of input data to the modules of the crate. These inputs came from RPCs and scintillator counters. Each and every module of the crate had its own function to handle these inputs. The VME crate controller handled all modules and was connected through a PCI card with the computer.

The Crate controller contained the information of all modules connected in the crate, and also data registers in which data coming from the detector(s) and hodoscope was stored temporarily. We had a task to get this (hexadecimal format) data from these registers and to store it permanently on a computer. For this purpose we used LINUX based software for the PCI card which enabled us to read data from various modules.

2.4.3 Time-to-Digital Converter

- **Inputs and Outputs**

The module has two frontal NIM inputs for the clock and trigger. These **2** signals are distributed by the Master module on **ECL** levels to the crate backplane.

- **Clock**

The module needs a clock signal which is not faster than 50 MHz. Inside the module there is a PLL, that duplicates the clock frequency in order to catch up the maximum temporal resolution of 10 ns.

The clock of the module can be taken from the frontal NIM input, or generated internally from an quartz oscillator running at 50 MHz.

- **Trigger**

The module uses this signal to stop the acquisition and works in “Common Stop” mode. Trigger is sampled at the TDC frequency (max. 100 MHz), so its width should be at least 10 ns. The acquisition of data is stopped on the rising edge of trigger signal.

- **Inputs**

The board accepts up to 64 **LVDS** inputs. The signals are sampled at the clock frequency (max. 100 MHz) so their width should be at least 10 ns.

- **Functional Behaviour**

The TDC has an internal LIFO (Last In First Out) memory comprising of 128 words $\times$ 64 bits. The acquisition starts with setting bit 0 of the RUN register. During the acquisition, every time that a rising edge on one input is detected, the status (1 is ON, 0 if OFF) of all the 64 inputs is written into the memory. In order to store the temporal position of the events, there is a $128-$bit shift register that shifts every clock cycle and a bit 1 is added when a word is written, that is when there is an event. When the trigger arrives, both the LIFO and shift register are frozen and they are reset at the next start.

The correct procedure is:

- Start acquisition writing 0×01 in RUN (0×00);
- Wait for trigger, reading bit 0 of RUN (0×00);
- When the trigger arrives, read the shift register, that is made of 4 VME registers: SR0-SR3 ($0 \times 04 - 0 \times 10$);
- Count the number of “1”$=$ nwords in the shift register;
- For every “1” in the shift register, read one $64-$bit word from the LIFO, that is two $32-$bit words (the first is $0 - 31$, the second $32 - 63$). The address of the LIFO is 0×400.

2.5 High Voltage Power Supply

A high voltage power supply was required for the operation of RPCs and scintillator counters, which could provide a wide range of varying voltages and currents. For scintillator operation we used a power supply with range of $1.0 - 1.4$ kV and to power up RPCs we used a power supply with maximum range of 10 kV.

The HV power supply distribution was based on the Universal Multichannel CAEN-SY1527 [3] unit which had internal processor and network connection. A dedicated software with Graphical User Interface (GUI) was developed to monitor the high voltage channels and selectively record the values. Each chamber was supplied by two HV channels. The setup used for testing is shown in Fig. 7. One high voltage channel supplied voltage to the top cut gaps and other to the bottom full gap.

Figure 7: Setup used to supply HV to chambers.

On the display of power supply there were many columns, but few of them were of our prime interest. The first column showed the number of channels which corresponded to chambers and scintillator counters to be tested. Second column showed the input voltage, which we gave to the chambers and the scintillator counters. During the testing process, the voltage of the scintillators was fixed whereas the voltage of the chambers was varied as mentioned in the testing procedure. Third column showed the maximum current which we fixed for the chambers and the scintillators separately. We fixed the threshold for current at a value of (15 μA) and whenever the current increased from this threshold value, the chamber and/or the scintillator was automatically switched off. Fourth column showed how much current was flowing through the chambers and the scintillators.

2.6 Cables

- All input channels were terminated to match a 50 Ω signal cable or terminator. One end of the scintillator signal cable was connected with the scintillator and other with NIM module. There were 16 LEMO connectors on the scintillator counters and 16 LEMO connectors on the NIM modules (8 for scintillator counter in top plane and 8 for scintillator counters in bottom plane).

- To power up the scintillators, 16 high voltage power cables were used. Maximum operating voltage for these cables was 5 kV with a maximum current upto 1 A. Scintillator counters were operated between $1.2 - 1.6$ kV.

- Data cables and ribbon cables were used to take data from RPCs to TDCs. 40 pin connectors were used for these cables.

- To power up the 10 RPCs, 20 high voltage power cables were used. One for each cut gap and one for each full gap. These cables could operate below 15 kV with a maximum current of 1 A. The RPCs were operated between $8.0 - 9.8$ kV.

- Length of each signal cable, power cable for scintillator, data/ribbon cable, power cable for RPCs was 20 ft approximately.

Signal and high voltage cables used for scintillator counters are shown in Fig. 8.

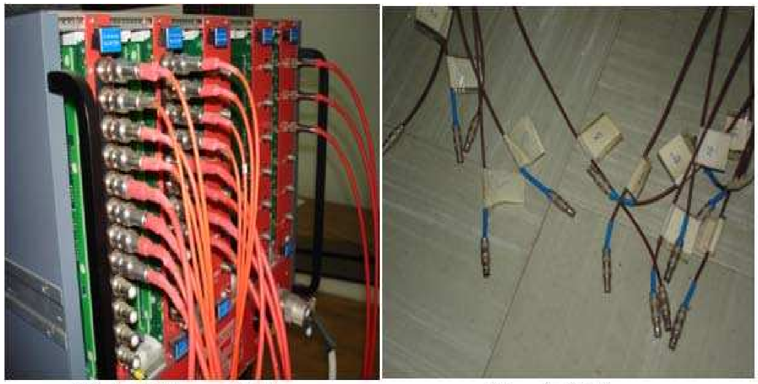

Figure 8: high voltage cables (left) and the signal cables (right) from the chamber.

3 DAQ online

DAQ online was a tool developed using java [5] and web services technology [6]. The main feature of DAQ online was to provide the user a facility to process data and create plots by sending requests to remote servers. Since DAQ online was based on web services technology it was very easy to do distributed data processing. Data received from an RPC was converted into "xml" format using an "xml" conversion tool which was provided with DAQ online. These "xml" files were stored on one of many servers. Users could connect to any of the servers and process the data. DAQ online also provided a caching facility of a particular $“runnumber''$ so next time the user did not have to go through the network to view or create plots for a given run number which was already been processed in the past. This facility was very useful when we had a limited network bandwidth or unstable network resources.

3.1 Details and Usage

The main window consisted of two split panels one on the left contain the run number and all the RPCs that were tested during that run. Right panel contained different graphs that were obtained after running the online analysis. On top there was a menu bar which had different options to analyze data. At the bottom there was a status bar which had information about the current status of the software. A user could select a desired chamber number and applied voltage value from a drop down list. As soon as the value of applied voltage was selected by the user, DAQ started to process the corresponding data residing on the web server. After processing, a user could see graphs of the following types:

- The strip occupancy plot of a chamber is shown in Fig. 9.
- Cluster size of a chamber plot as shown in Fig. 10.

A user could define the values for the time windows for the good hits and also for the spurious hits. In future we are looking to include the simulation of the chambers and hit profile to observe the chambers in a visual manner.

4 Conclusions

Using our setup we have tested 318 chambers out of which 160 were of RE2/2 type (smaller in size) while 158 were of RE2/3 type (larger in size). Our system was an essential part of quality assurance test. During the testing several chambers were diagnosed with problems. Problems identified using our setup do include high dark currents, bad connectors, broken wires at connector end, faulty FEBs and noisy strips. In most cases we were able to fix these problems.

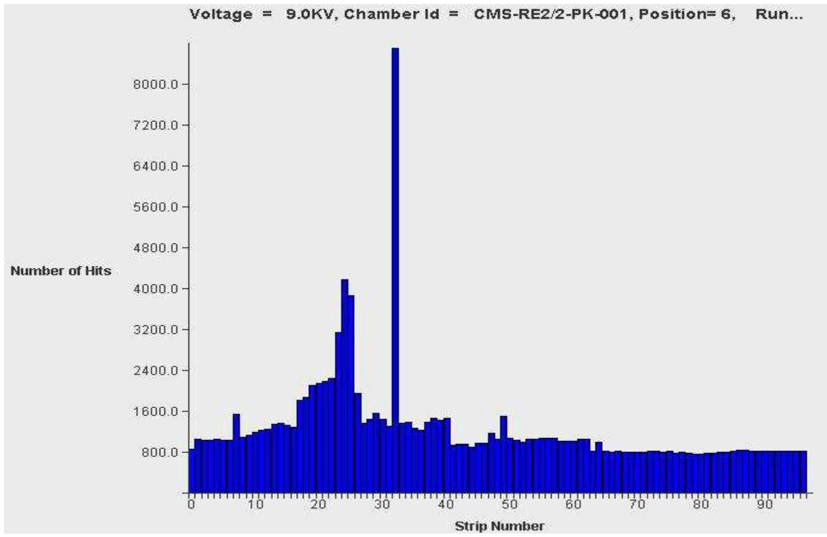

Figure 9: The strip occupancy plot generated by the online DAQ program.

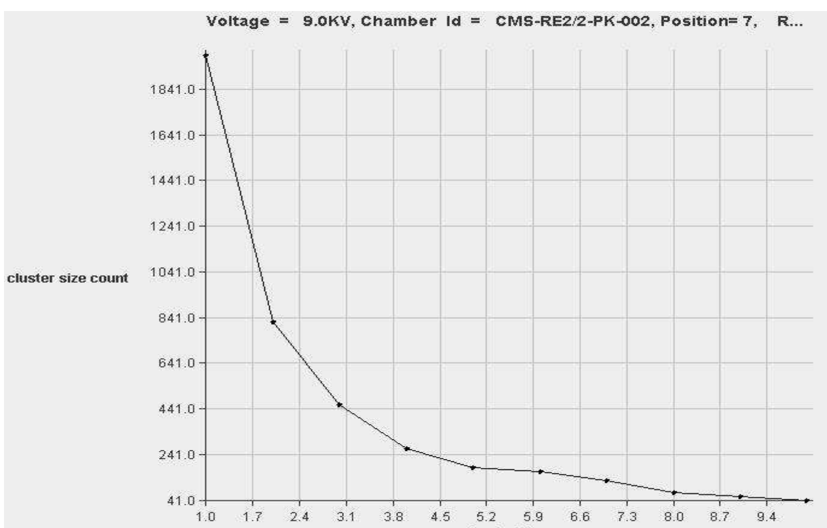

Figure 10: Cluster Size

5 Acknowledgments

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References

[1] R. Santonico and R. Cardarelli, Nucl. Instr. and Meth. A187 (1981) 377.

[2] ROOT Home Page, http://root.cern.ch

[3] http://www.caen.it/nuclear/products.php

[4] http://www.ni.com/products/

[5] “JSci - A science API for Java”, http://jsci.sourceforge.net/

[6] “Web Services-Axis”, http://ws.apache.org/axis/