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Experimental beam test of the Si-Eye2 apparatus

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Abstract

We present the experimental results obtained with the Si-Eye2 apparatus during one week test run at the PS Svedberg-Laboratoriet, Sweden. These results will be used for energy calibration of the data collected on board the MIR Space Station from July 1997. Data that will be collected with Si-Eye2 are necessary to understand the phenomenon of optical light flares (LF) in cosmonauts' eyes during orbital flights and for investigation of the nuclear fluxes in cosmic rays.

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1 Introduction

Since the Apollo missions it was known that the crews, after some minutes of dark adaptation, observed brief flashes of white light or pencil-thin streaks of light. The first observation was reported by E. Aldrin during the Apollo 11 mission. The frequency of LF depends on orbit parameters, especially on the latitude. LF are practically absent on the equator, where the charged particles' flux is minimum. The frequency of flares grows in polar areas and in the area of the South Atlantic Anomaly at orbit heights greater than 400 Km. The most probable generation mechanisms of visual effects is direct interaction of charged particles with the retina of the eye. To test this hypothesis we prepared two detectors; the first one is already on board MIR Space Station [1] and the second is scheduled for the launch in July 1997.

2 Technical description of the Si-eye apparatus

2.1 General Overview

The Si-eye detector is a unique device. It can measure simultaneously particle energy losses from 2.5 Minimum Ionizing Particles (MIPs) to 2500 MIPs and determine the coordinates of passing particles with an accuracy of ±1.8 mm. This instrument can be used for cosmic rays studies, medical-biological and technological space researches.

It can be seen as a completely software controlled solid state detector; its principle characteristics are: small dimensions, portability and low power consumption, user friendly interface, real time data analysis.

2.2 Detector & Front End Electronics

The Si-Eye2 apparatus takes all the technological advantages developed for the NINA calorimeter [2]. The main body of our detector is constituted by the silicon planes which are its active part. A silicon view is made of a square (6x6 cm^2) wafer of silicon, divided in 16 strips, each 3.6 mm wide. Two views, orthogonally attached, constitute a plane. We have three planes for a a total number of 96 strips. The distance between the silicon planes is 14 mm. Each silicon strip is 380±15 μm thick, so that we have a total active thickness of 2.3 mm. The silicon strips act like completely depleted p-n junctions, and need to be supplied by a DC tension of 36V, obtained by batteries, to completely disconnect the silicon power supply from the electronics power supply. Not all the strips are read as physical data, strips 1 and 16 of planes 2 and 3 are connected together and their sum value is read; strips 1 and 16 of plane 1 are disconnected. In this way we have (14+1)*4+14*2=88 data from the strips. We have also 8 housekeeping: 3 current meters for the 3 planes, 2 Analog Low Rate Meter (up to 400 Hz) for plane 1 (X and Y view), 1 Analog High Rate meter per each plane (up to 20 KHz). So we have 96 data per event. Each silicon couple of views is mounted on a ceramic border with appropriate electrical contacts. The Front-End board consists of the silicon planes and of the analogic preamplifiers. The analog signal from the Front-End board goes through the connector to the Read-out Board. Both the electronic boards are mounted on aluminum frames which are 1.5 cm tall, 1.5 mm thick and have appropriate holes to assemble the apparatus in vertical position. When the frames are mounted, they constitute a good shield against light coming from the sides and protect silicon and electronics. The current signals coming from the silicon strips are very fast (less than 40 ns) and very weak, 1 mip = 30400e^- = 4.86 fC. These signals go into charge preamplifiers and then into shaping amplifiers that prepare them for sample and hold.

2.3 Read-Out

All analog signals from the strips come into the Read-out board. This board has the same shape of the Front-End boards. It performs the Analog to Digital conversion of data, trigger functions and telecommands probe. A multiplexer scrolls all the strips and gives the appropriate signal to the ADC, that converts the analog signal in a 12-bit (4096 ADC Ch.) word. The ADC has a dynamic range of more than 2500 MIPs (12.2 pC), so for each channel we have: 2500 MIPs/4096 ch = 0.61 mip/ch. For the deposited charge: 12.2 pC/4096 ch = 3 fC/ch

2.4 Trigger System and Threshold

Before being converted the analog signal goes into a logical comparator that performs triggering operations; two kinds of triggers are available, by changing the appropriate telecommand. Denoting with X1 and Y1 the views of the first plane and with 2 the OR between X2 and Y2, the first (main) trigger is ((X1 AND Y1) AND (2 OR 3)), the second (low level) trigger is (2 AND 3). Triggering logic and telecommand recognizing is performed by a PAL unit mounted on the board. In these tests we used an external trigger coming from scintillators, so both these procedures where passed by.

To discriminate low-level signals it is possible to set a hardware threshold on an analog comparator. For these tests this threshold was set to 200 mV = 2.5 mip. Telecommands can run various device functions: calibration, triggering, signal amplification, signal hold. Telecommands logical signals come from the interface board.

From the ADC the digital signal goes into a buffering-FIFO system and can be read by the interface.

2.5 Interface

The interface board's main work is to distribute logical signals from and to the Acquisition board, to optically decouple them and perform delays in some power supply circuits. The interface board also performs acquisition with external triggers. This board was completely projected and built in INFN laboratories.

2.6 DAQ-Card & User Software

All the I/O communications use the National Instruments DAQ-Card 1200, that allows 96 digital I/Os, 3 wave form outputs, 6 analog I/Os and is fully user-programmable with C++.

The I/O system is connected with an IBM Thinkpad 750C laptop computer. The user interface comprehends a main acquisition program and some fast-analysis routines. The acquisition procedure itself requires a laplink- controlled laptop computer that remains in the beam room. By software it is possible to control almost all device parameters and functions, like trigger, signal amplification, calibrations. The system also controls the handshaking signals like data ready and read-data involved in FIFO discharging.

3 Calibration of the device

When started, the device performs an automatic calibration in three steps: pedestal acquisition, noise test, charge injection test. In the first one the system automatically acquires 1024 lectures in standard amplification conditions. The mean values for each channel of these lectures (in number of ADC channels) are taken as pedestal values for each strip. The calculated RMS values are taken to set a software threshold to cut pedestal values and noises in the final read event. We expect fixed pedestals, whose values can vary only slightly depending on working temperature. To understand evolution of silicon strip behavior and of its noise with time, it is necessary to use the pedestals amplified 32 times as noise data. Now we have a conversion factor of (2500/32) mip/4096 ch = 0.019 mip/ch that means a charge of $3/32 \sim 0.1$ fC/ch. With these values we can do a better analysis on the silicon behavior and defects. Small capacities play a role in amplification and shaping of analog signals. For this reason gain factors between channels may differ of ±10%. This problem, together with the importance in having a system to control variations in the electronics device, required the realization of a calibration system with the injection of a known charge on the channel in order to build linearity curves for each channel. Injection capacitors have a value of 4.7 pF, so for a charge injection tension value of 1 mV we will have an injected charge of 4.7 fC (nearly 1 mip).

3.1 Technical Procedures

In the final version, Si-Eye2 will be equipped with a switching DC-DC converter supply board. For these tests we used 3 AC-DC stabilized power supplies. The system needs 3 different tensions: 2 analog (± 6.30 V, 180 mA), and 1 digital (+5.10 V).

4 Beam test performances

The calibration of the device Si-Eye2 was carried out on a proton beam of the Uppsala accelerator. The device is intended for cosmic rays research, therefore there are special requirements for the beam. The basic requirement is a low intensity of the beam, no more than 20 particles per second ($\leq$ 20 Hz) and low background radioactivity level in the experimental room. The measurements were done at two different proton energies - 48 MeV and 70 MeV. The device was placed at a distance of about 25 cm from the vacuum tube with a profile detector and two scintillation counters in between. The thickness of each scintillation counter was 0.5 cm and the sum thickness of the profile detector was ~ 0.55 g/cm^2 (see fig.1). In a 70 MeV run, the two scintillation counters were placed behind the device. In the 48 MeV runs protons stop in 5th or 6th silicon detector with big energy losses up to 50 MIP. This feature is very useful for us, because the device is intended for investigations of low energy protons and nuclei in cosmic rays. The main part of calibration stages was performed with vertically incident particles. One 48 MeV run was performed with an inclination of 5^0 and two 70 MeV runs were performed at 25^0. Additional external aluminum absorbers were installed in front of Si-Eye2 instrument during some 70 MeV runs with thicknesses of 4, 6.1 and 7 mm. Three runs with different values of aluminium absorbers were performed.

5 Results

We have simulated, with standard Geant Montecarlo program, all the beam conditions with different energies and absorbers (Figure 2). To obtain the calibration curve of figure 5 we compared the montecarlo simulation (fig.3) with the experimental data (fig.4). The points in fig.4 at 53, 44, 34 and 31 MeV were obtained during the 70 MeV runs with 0, 4, 6.1, and 7 mm absorber thickness respectively and scintillation counters in front of the device. The point at 69 MeV was obtained with scintillation counters behind the device. The point at 20 MeV was obtained during the 48 MeV run with scintillation counters only in front of the device. The value for the ratio MIPs/ADC Ch. is 0.63, in good agreement with the theoretical value. In figures 6 and 7, we show the beam profile on the three planes for orthogonally incident beam and 25^0 angled beam. In figure 8 the energy loss sum for single strip and all the events of run

58 (a 48 MeV run) is shown as an example of separation between pedestals and particle energy loss profiles. In this run 48 MeV particles stop in the 5th view, releasing the maximum amount of energy. Figure 9 is the same plot for the sum of all the strips. In figure 10 is shown the energy loss in the different views for a single particle for run 10 (at 53 MeV, 25^0 of inclination).

6 Acknowledgments

We wish to thank the people of LABEN, who built the front-end and the read-out board, for their effort and special interest in this experiment. We wish to give special thanks to the mechanic and the control beam people at the Svedberg laboratory accelerator in Uppsala for the help on the mechanical set up and the definition of the beam parameters. They allowed a successfull test.

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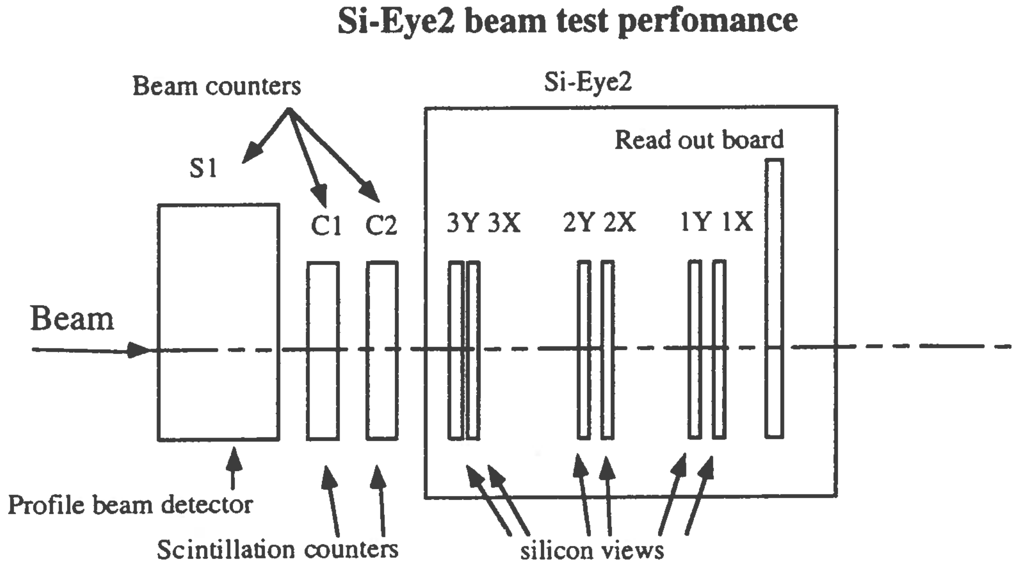

Figure 1: *Beam test set-up*

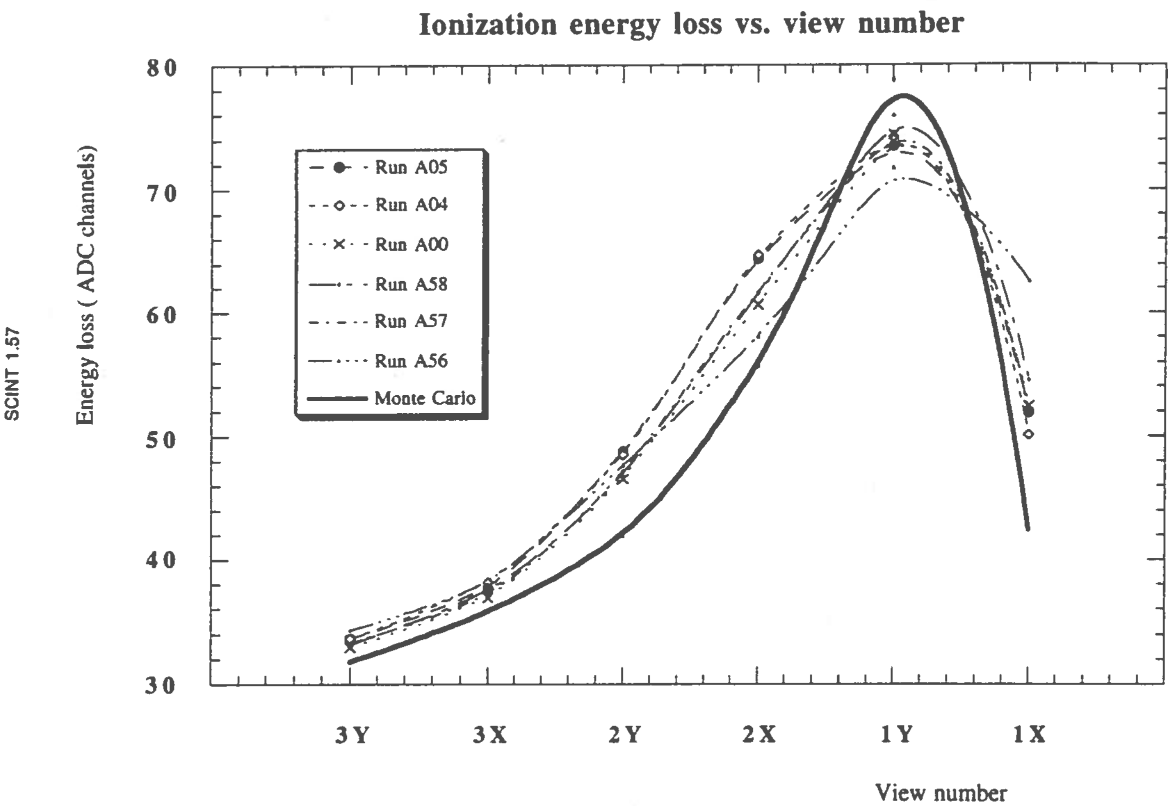

Figure 2: *Ionization energy loss vs. view number for six different runs. Comparison of data and Monte Carlo simulation (the Monte Carlo takes into account all the material in front of the detector)*

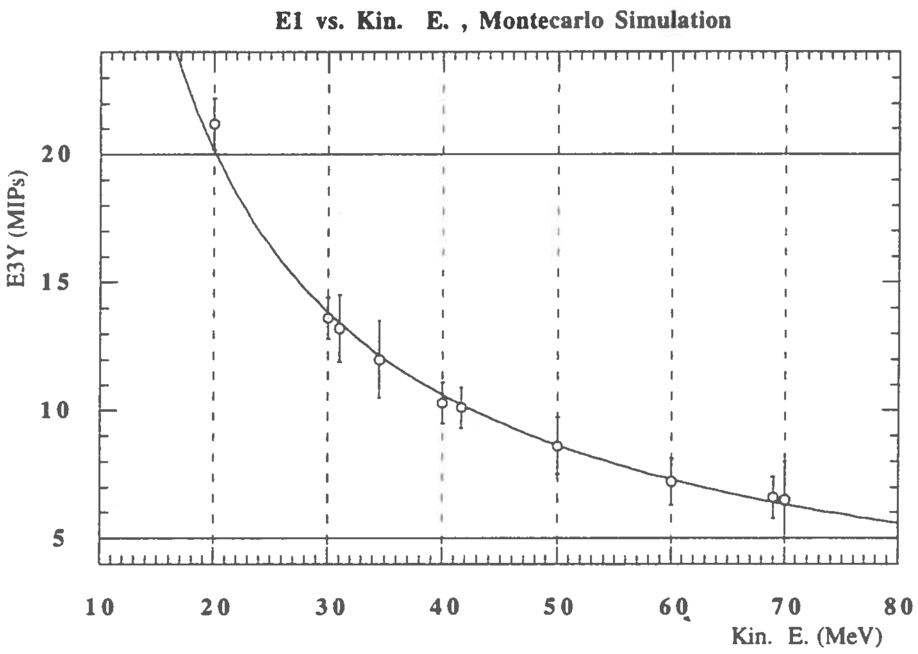

Figure 3: *Monte Carlo simulation of the energy loss (in MIP, 1 Mip=105 KeV) in the first view, for different particle Kinetic energies*

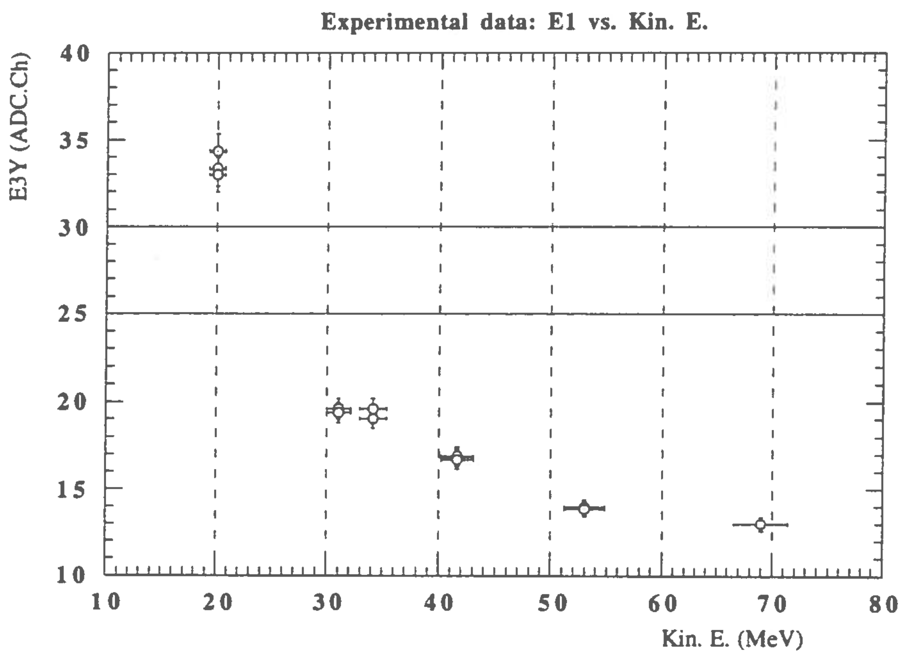

Figure 4: *Experimental results for number of ADC channels vs. incoming particle Kinetic energies in the first encountered view*

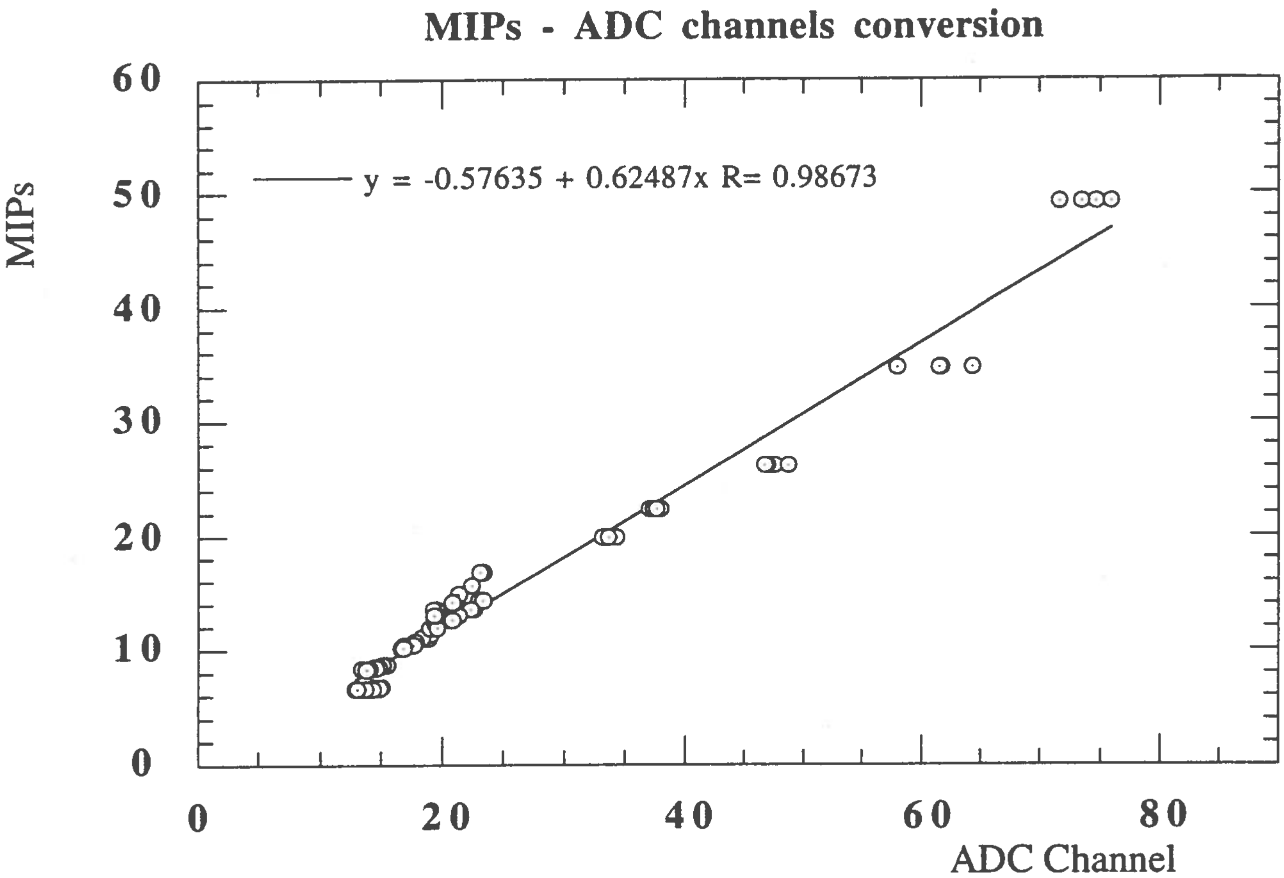

Figure 5: *MIPs vs. Number of ADC channels for all the runs (different energies and absorber thicknesses).*

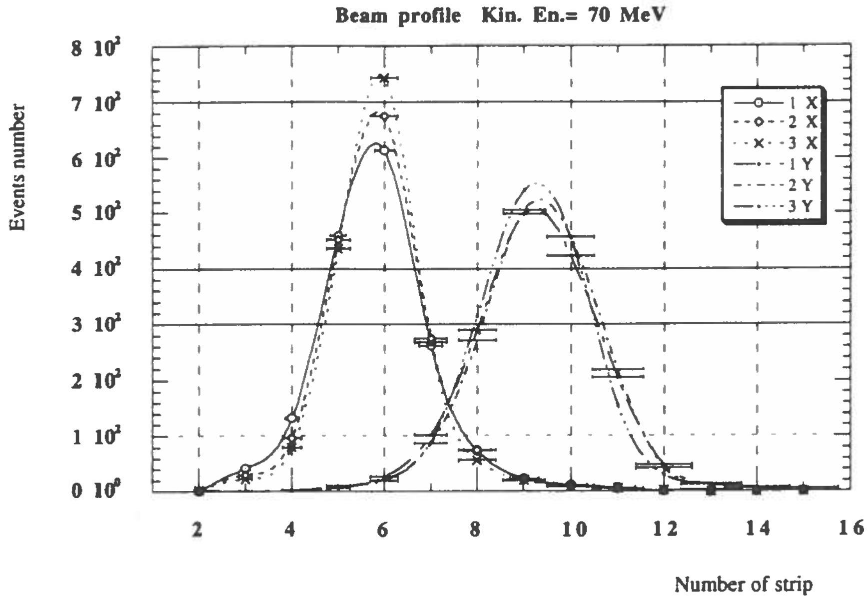

Figure 6: *Beam profile for proton energy of 70 MeV. This picture with the next one illustrate the possibility of our device to determine the coordinates of the passing particles.*

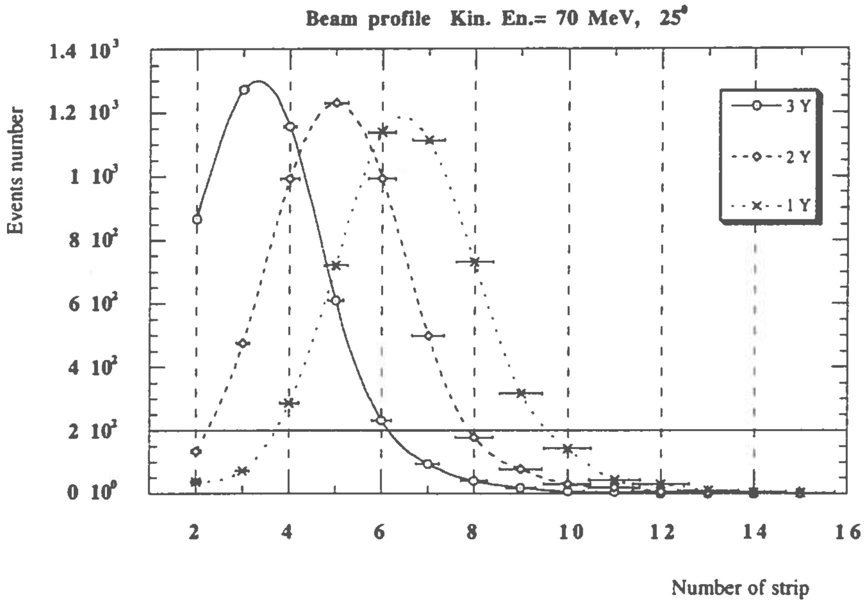

Figure 7: *Beam profile for proton energy of 70 MeV, 25 degrees of silicon planes inclination in Y direction*

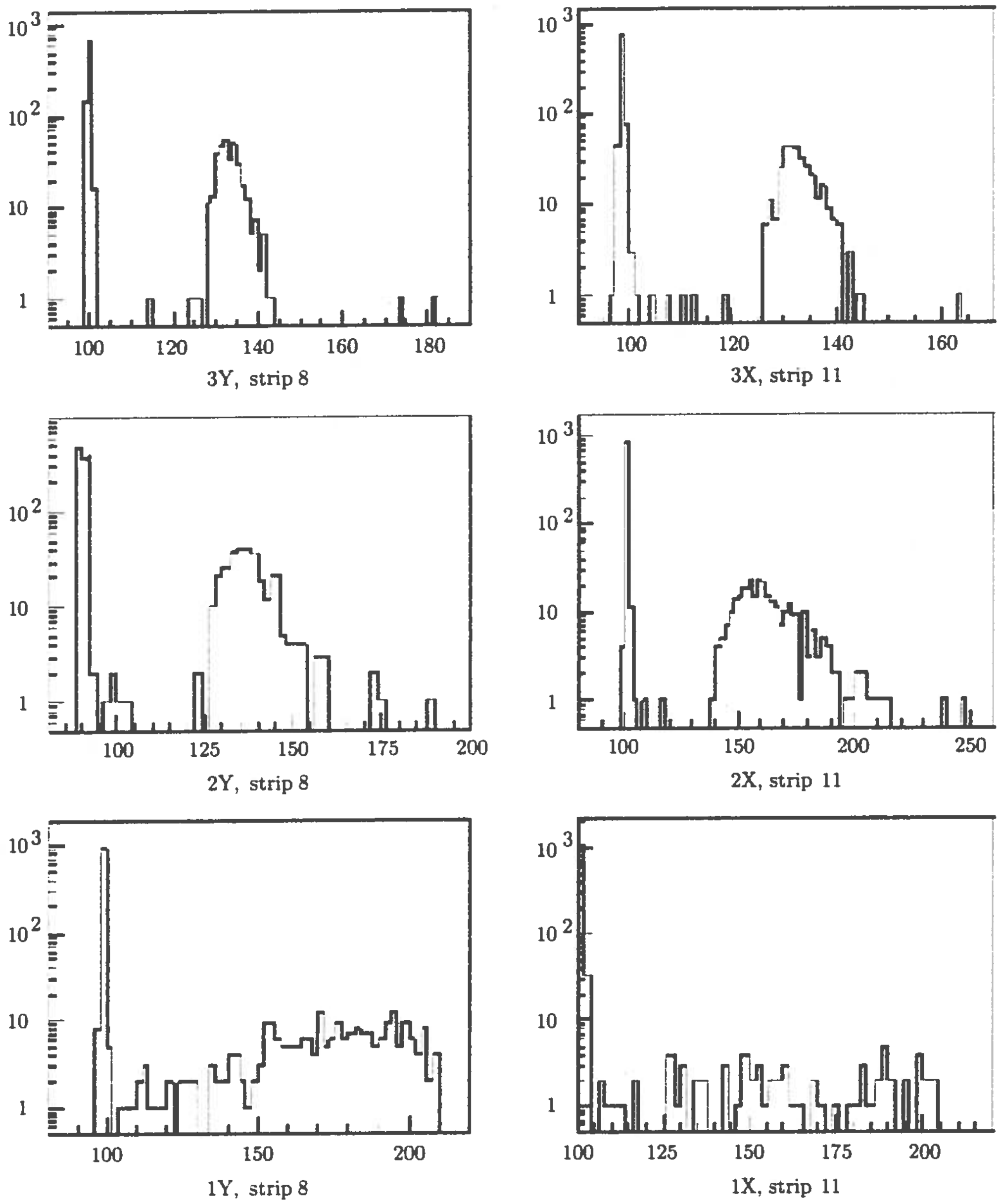

Figure 8: *Energy loss in the different views for run 58 (at 20 MeV in the first view) without pedestal substraction for single strips so one can see the degree of separation between signal and pedestal*

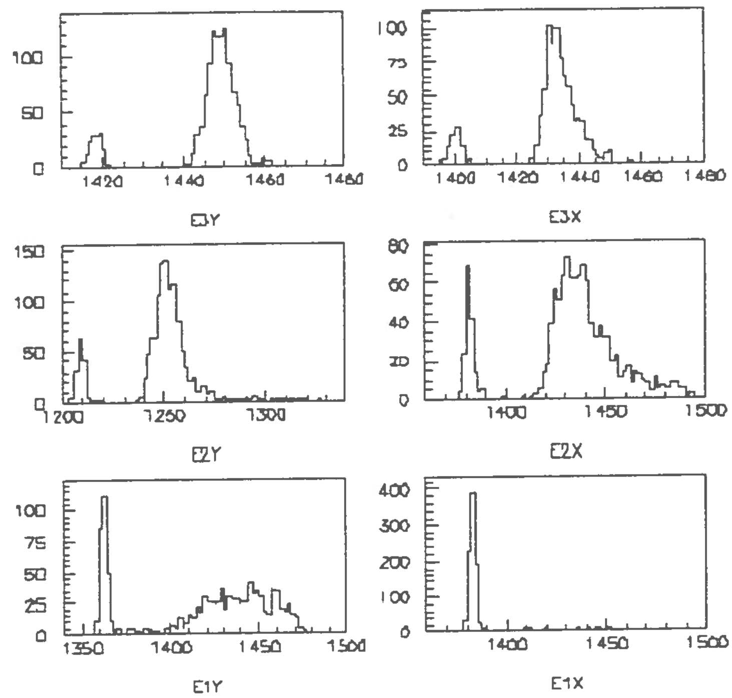

Figure 9: *Energy loss in the different views for run 58 (at 48 MeV) without pedestal substraction for the sum of all the strips*

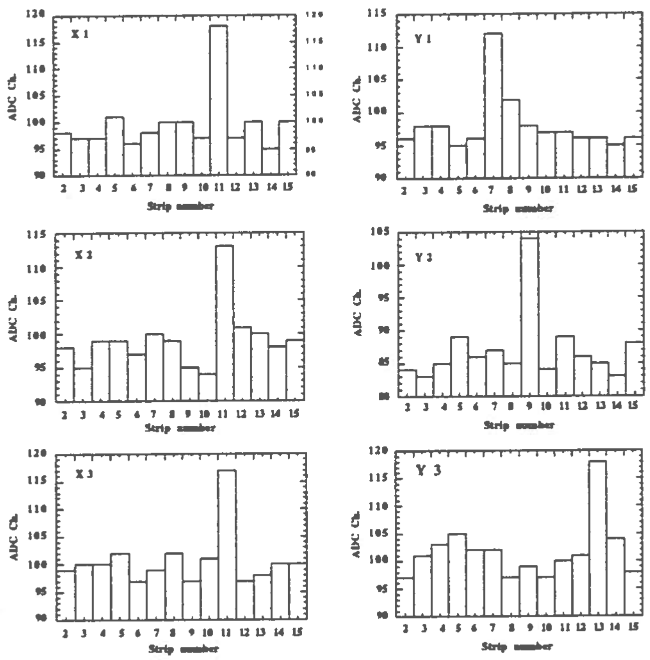

Figure 10: *Energy loss in the different views for a single particle for run 10 (at 25^0 degrees of inclination in Y direction and without pedestal) substraction*