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GRUPO DE ALTAS ENERGIAS

The NA36 Time Projection Chamber. First operation and results.

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ABSTRACT

The NA 36 Time Projection Chamber is the main tracking device of the NA 36 experiment. The characteristics of the design of this TPC are tied to the physics goals of the experiment, i.e., measurement of central rapidity strange baryon production in relativistic heavy ion collisions (RHIC) at the CERN SPS. The TPC operates in a high (2.7 Tesla) magnetic field and performs no dE/dx measurements; its sense elements are composed of an array of short anode wires. The read-out electronics chain (of more than 6000 channels) terminates at a large Fastbus system. The TPC online monitoring capabilities and some preliminary results from the October 1987 heavy ion run are presented.

avalanches are created and recorded as charge induced signal on the anode wires and/or rectangular cathode pads of the MWPC, thus providing, together with the drift time information, unambiguous three-dimensional spatial measurements. For a pad readout TPC, the charge recorded on adjacent pads enables an interpolation yielding the X and Y coordinates. Particle identification is possible in addition to track reconstrution by observing the charge induced signal of the anode wires.

The electronic nature of the TPCs and their high density sense matrix make them good candidates for high multiplicity experiments such as NA 36. The combination of a magnetic field parallel to the electric field and the use of an appropriate gas mixture greatly reduces the transverse diffusion coefficient.

The high multiplicity of tracks as well as the ion fragments produced in RHIC lead to space-charge effects in the drift and sense regions of the chamber. On the other hand, the longitudinal diffusion of the drifting electrons -which can be of the order of 1 cm- and the probability of having nearby avalanches in the sense region might impact the space resolution and two track separation perfomance of a TPC. These considerations have been taken into acount in the design of the NA 36 TPC.

2. DESIGN OF THE NA 36 TPC

2.1 Geometry

The endcap of the NA 36 TPC is a matrix of 40 rows each having an array of 192 sense anode wires, 12 mm long and 20 μm diameter. The anode pitch is 2.54 mm, and the row pitch is 24 mm (fig. 3).

Defining the region where the avalanche is produced, is a planar Wire Cathode, 50 cm long and 50 μm diameter with 2 mm pitch. It is placed 3

1 INTRODUCTION

1.1 Description of the Experiment

The goal of NA 36 is to measure central rapidity strange baryon production in relativistic heavy ion collisions (RHIC) and correlate this to global event parameters, such as transverse energy flow (Et), dEt/dy and forward energy flow due to projectile fragments. The experimental setup of NA 36 (fig 1) includes a Time Projection Chamber (TPC) operating in a high magnetic field (M1), and part of the EHS spectrometer: downstream tracking chambers, electromagnetic and hadronic calorimeters, and a Forward Cerenkov counter for fragments.

The NA 36 experiment participates in the fix target heavy ion program at the CERN SPS.

1.2 Design Tied to Physics Goals

Measuring strange baryon production in RHIC - where, e.g. , a typical central collision Au - O event at 200 GeV/c/A produces about 10^3 charged particles (fig. 2) - requires a device able to achieve high multiplicity capability, and good momentum resolution for particle decay reconstruction.

A Time Projection Chamber achieves three-dimensional localization of tracks, with no ambiguities. In general terms[1)], a TPC is a high-purity gas volume embedded in a uniform electric -and, often, magnetic- field where the electrons produced by ionizing particles drift towards a MWPC, constructed on one side of the detector. In this amplifying region, the mm from the grounded anodes, allowing an electric field of several kV/cm.

The drift volume is enclosed by a field cage of dimensions 100x50x50 cm^3 filled with argon and methane at 9% (P9), and embedded in a uniform electric field (110 V/cm). This is set by the negative high voltage on the bottom of the Field Cage, as well as by the uniformly dropping voltage via divider resistors installed on the walls.

To reduce as much as possible the space charge effects, a cathode pad -Copper Cathode- is placed 2 mm underneath every row of sense wires (see fig. 3). Its negative voltage causes 66% of the positive ions of the avalanches to drift towards it. Furthemore, a plane of wires - Gate Plane- separating the drift and sense regions, 5 mm apart from the Wire Cathode, traps about 98% of the remaining ions. Given the gain at which the TPC operates, 10^4, the space charge reaching the drift region is kept below 7×10^3 ions/cm track. The signal collection efficiency on the anodes is significantly improved by the Field Wires, which alternate with the sense ones.

The charge accumulation during events in the high field region might lead to the appearance of dielectric deposits on the wires. These can cause eventual sparking between, for instance, a given Copper Cathode pad and one anode wire. To avoid fatal consequences of this problem, the maximun modularity in the high voltage distributions is desired. Every row is thus independent in terms of HV, having both the Cu Cathode and the Field Wires individual power lines, which can be disconnected if any problem of this short. In this way, the rest of the chamber is kept in normal condition, while the damaged rows can be set at lower voltages until their eventual recovery.

The HV for the Field Wires is distributed through the field wire cards, mounted on the endcap or the TPC. These cards were also used to inject a decoupled current pulse into te FW, inducing a signal on the anodes for calibration and monitoring purposes.

No dE/dx measurements are foreseen for this TPC, thus simplifying its design.

2.2 The Magnetic Field and the Gas Mixture.

The TPC is placed inside the EHS superconducting M1 magnet. The magnetic field in its center is 2.7 Tesla, the highest for any TPC up to now, and it follows the drift direction (perpendicular to the beam axis). The gas mixture is Argon and Methane at 9% (P9) with a purity greater than 99.996 %. From these two points one can extract the following consequences: the transverse diffusion gets very much reduced, and the $\omega\tau$ factor achieved for this device is high - of the order of 20.

Because the magnetic field is highly nonuniform -which is not the case in other TPCs- , the high $\omega\tau$ make the electrons follow the B lines rather than the E ones. This makes it necessary to introduced some corrections in the drift distance measurements, for which a detailed map of the magnetic field has been done.

On the other hand, the drift velocity varies significantly with the concentration of methane[2)], as shown if figure 4. The stability of the gas mixture of the NA 36 TPC is about 0.4%, which means a relative variation in the drift velocity of less than 0.2%. Higher concentrations of methane are disadvantageous due to safety aspects.

The condition at which the TPC is operated establish a drift velocity of 5 cm/μs , which corresponds to a dead time for the chamber of 10μs . Table 1 sumarizes the TPC characteristics and operational parameters.

2.3 Positioning of the TPC

The TPC is sitting between the two coils of the M1 magnet. To avoid extra space charge effects due to the beam particles and projectile fragments, it is placed 2.5 cm above the beam line. To achieve our physics goals, the central rapidity strange baryons acceptances are the most interesting. To optimize this, the target(s) have been placed around 1 m in front of the TPC, a situation which is ilustrated in figure 5 for negative pions and omegas. From this Monte Carlo calculation one can see that the strong magnetic field filters out all pions with a rapidity lower than 3, while rapidities greater that 0.76 for omegas are accepted in the TPC[3)]

3. ELECTRONICS CHAIN AND READOUT

3.1 The Preamplifiers

The signals received by the anode wires were readout by current sensitive preamplifiers -LeCroy TRA 402- mounted directly on the TPC. On every row, three preamplifier boards were plugged in, each of them containing 64 channels. These cards (motherboards) are connected to the anodes throug the front-end pins, and distributes the power to 16 subcards mounted on them. Each subcard -see figure 6- holds the 402 s (4 channels each) and contains the circuitry that optimizes the signal to noise ratio: a gain of 15 mV/μA and a noise level below 0.15 μA

The differential output signals, grouped in sets of 16 channels, were carried through 15 m long twisted pair flat ribbon cables to the electronics hut .

3.2 The Comparators

The LeCroy MVL 407 comparators receive the differential signals from the preamps and produce a digitized time-over-threshold ECL differential output. They are mounted in 64-channel boards which include some previous shaping of the incoming signals. This is done to improve the signal to noise ratio and to reduce the longitudinal diffusion effect. Figure 6.b shows the diagram of the circuit for a set of four channels of comparators. The boards are installed in 5 crates which provide the power and the computer-controlled threshold level. The threshold can be tuned via a frontal screw. During the run periods the threshold has been set at about 0.25 μA.

3.3 The TDCs.

65 modules - 96 channels each -of LeCroy 1879 TDCs were installed in three Fastbus crates contained in a water-cooled rack. The time bin size was 23 ns and both the leading and trailing edge of the signals were recorded.

With this set of electronics a total of 6224 channels have been readout from the TPC.

3.4 The FASTBUS Data Acquisition System.

The NA 36 Data Acquisition System - shown in figure 7 - contains 6 Fastbus crates; three of them were devoted to the TPC.

Each crate contains one SSP (SLAC Scanning Processor) which reads out the modules sitting on the same segment. The readout time for each of the crates cotaining TDCs is less than 1.5 ms for minimum bias events from a 200 GeV/c proton beam.

that triggers the pulser-, the threshold- set by a Fastbus DAC - and the combination of channels to be pulsed were controlled by the DAC system via a microVAX. This computer also monitors and analyses the data online.

With this scheme, several automotic tests implemented in the system were realized for every unit (64 channels) of the electronics chain: preamplifier, 18 meters of cable, comparator, DAQ. Figure 9 shows some typical results of these tests. In figure 9.a, all 64 channels of a board appear to be alive. The cable test (fig. 9.b) was done to make sure all the cabling was in order, by pulsing different combinations of channels in every set of 16 channels. A cross-talk test was done by pulsing every second channel in a board - the odds test, shown in the third plot- and checking if any of the non-pulsed channels woud fire. The tuning of the threshold was set by sending a pulse equal in amplitude to the threshold level -say, 0.5 μA- and asking that 50% of the channels fire in the comparator board.

3.5.2 The row pulser as a threshold uniformity test.

After every chain unit was tested, the preamplifier board was plugged in its final position on the TPC front-end. The so-called row pulser was then used: it consists in sending a pulse through the Field Wires Cards so that all three boards in a row would respond to it. In this way, the uniformity of the threshold along a row can be checked, as shown in figure10.a. The behaviour of the TDCs was also tested by looking at the time and cluster size spectra along all the wires in that row (fig. 10.b and 10.c).

By pulsing the whole TPC with the same method, the overall threshold, aliveness and cabling was tested again, leaving the electronics ready for real data. All this tests served also to improve the perfomance of the Fastbus and Data Acquisition System.

A large Fastbus buffer memory (4 Mbytes) reads and stores the data after each event. Between spills events are extracted from Fastbus by a VAX 750 - the main data acquisition computer- and written to standard high density tapes (6250 bpi). This can be done at speeds of up to 400 kB/s. The data rate is typically > 400 events per spill for beam events and about 80 events/spill for central collision events. A microVAX is connected to the system for control and monitoring tasks.

3.5 Electronics Tests Methods.

Testing and calibrating for gain and threshold, making uniform a set of more than 6000 channels of complex electronics is a major task. Furthermore, the goal should be to test the whole system in a configuration as close as possible to the real data taking mode.

After visual checks, using the oscilloscope, of every preamplifier and comparator channel, the following tests were done.

3.5.1 The pulse multiplexer box.

The configuration (see figure 8) used to test the whole electronics chain involved a Pulse Multiplexer Box (PMB). The Data Acquisition program, running with an artificial trigger, would trigger a pulse generator. This pulse is divided and converted into a current signal in the PMB, which is connected to the preamplifier board using a TPC connector. The box contains a set of switches which enable or disable any channel to be pulsed by means of 16 latches coming from a CAMAC Output Register. In this manner, the amplitude of the pulse - CAMAC attenuators-, the timing of the pulse relative to the trigger- delayed signal from a Fastbus 1810

4.0N-LINE MONITORING

During the run periods, The TPC behaviour has been monitored from different points of view. Its operational parameters, such as high voltages, currents, gas pressure and flow, were readout every event via CAMAC ADCs.

Wire maps, cluster size and drift time distributions were collected and displayed with Hview. Figure 11 shows such distributions for row number 38 (far end of the TPC). The higher density of hits corresponds to the bottom side of the chamber (fig 11.a), underneath which the beam was passing. The dependence of the most probable value of the cluster size on the threshold was studied along the run periods. The threshold corresponding to the distribution shown in figure 11.b was 0.25 A. In figure 11. c one can see that the drift time distribution peaks in the center of the TPC, where the beam was positioned in the Z coordinate.

Online 3-dimensional display of events were perfomed with Eview. A central collision sulphur event is shown in figure 12 (side and three dimensional views); the energy of the beam was 200 GeV/c/A. One can visualize some tracks in this event using a trick that consist of selecting a wedge cut in the Z coordinate (see figure 13.a, where a top view of the TPC shows at thin slice selected of about 2 cm).

The multihit propability for a single sense wire during one event has also been monitored, as shown in figure 14 for about 50 minimun bias events; this histogram shows how this probability drops drastically as the number of hits on a wires goes up.

In addition, a monitor board consisting in one single preamplifier channel looking at the OR of 64 channels was placed to monitor the pulse shape of signals from the TPC. These signals, after being amplified, fed an Image Chamber Analyzer (LeCroy ICA 2261) which digitized the signals with a 25 MHz frequency. A typical event of this sort is shown in figure 15.

5. RESULTS

In 1987, NA 36 has run with muons, 200 GeV/c protons, 200 GeV/c/A sulphur ion beams. From the latter beam, $1.7x10^6$ events were written to tape. The targets used were lead, copper, silver and sulphur.

Although the TPC data analysis efforts are in progress at this moment, I would like to comment here the basic outlines of the procedures we are using. The first thing to do in order to analyze the TPC data is to correct them for the non -uniformity of the magnetic field. A careful comparison of simulated and measured fields have been done. From this comparison, a detailed map of the B field in the volume of the TPC has come out. This corrections are minimal in the position where the chamber is sitting.

After having a good set of space points one proceeds to find tracks in the TPC. This is done by steeping along the rows, starting form the last one, and looking for hits that would connect with the previous ones forming a track. Simultaneously, after each step one fits a helix fuction to every piece of track. This gives us a momentun associated to each found track. Figure 16 shows an example of one sulphur event after being treated by the track finder programs. At this moment, the code is in the stage of fine tunning its parameters.

The next step in this method would be to realize actual fitting, as the trajectories of the particles swept by the M1 magnetic field aren't exactly helix functions. These just give us an initial set of momentum and position vectors from which, according to the B field map, one can calculate the trajectory of a particle under such conditions. By fitting this trajectory to the spatial points in a track, the best momentum value is obtained in terms of χ^2. All tracks pointing to the target with good fitted momentum can then be disregarded, and one starts trying to locate Vo's and associated kinks in a simplified sample, event by event. From a sample of 100 fitted tracks, an estimation of the track resolution in the Y and Z coordinates has benn computed by measuring the differences between the experimental values and the corresponding coordinates on the fitted track. By asking that the relative errors have a gaussian distribution of width equal to 1, one obtains the distribution of the estimated errors (figures 17.b and 17.c) fitted with gaussians of widths 1.5 mm and 1.2 mm for Y and Z respectively. No correlation or systematics seem to bias this procedure (figure 17.a).

6.ACKNOWLEDGEMENTS

I would like to acknowledge H. Eberley and the technicians and machinists from Cracow for their valuable effort in the construction of the TPC. Thanks also to J.C. Berset for his magnific suggestions on the design of the TPC electronics.

7.REFERENCES

(1) D. Nygren, Pes. at the International conference on experimentation at LEP, Uppsala, June 1980.

(2) I. Lehraus et al., ALEPH-TPC note 84-6.

(3) C. Gruhn, CERN/EP 86-116.

Table 1

NA 36 TPC PARAMETERS.

Magnetic field	2.7 Tesla
Drift field	110 V/cm
Drift distance	50 cm
Gas	P9
Volume	0.25 m^3
Anode wires	7680
length	1 cm
pitch along the rows	2.54 mm
40 rows, row pitch	2.4 cm
Cathode to anode wire distance	2mm
Wire cathode to anode wire distance	3mm
Gain	10^4
Special features:	
no dE/dx	
no ions from the beam or the target	
magnetic sweeping limits tracks in TPC	
single-track sense volume:	$10 \times 2.5 \times 10$ mm^3
total number of volume elements:	384×10^3
total number of frontal elements:	9.6×10^3

BT Beam Tag
U3, W2 MWPCs
D1-D6 Drift Chambers
H1, H2 Hodoscopes
M1, M2 Magnets

IGD Intermediate Gamma Detector
INC Intermediate Neutral Calorimeter
FC Forward Cerenkov
FGD Forward Gamma Detector
FNC Forward Neutral Calorimeter

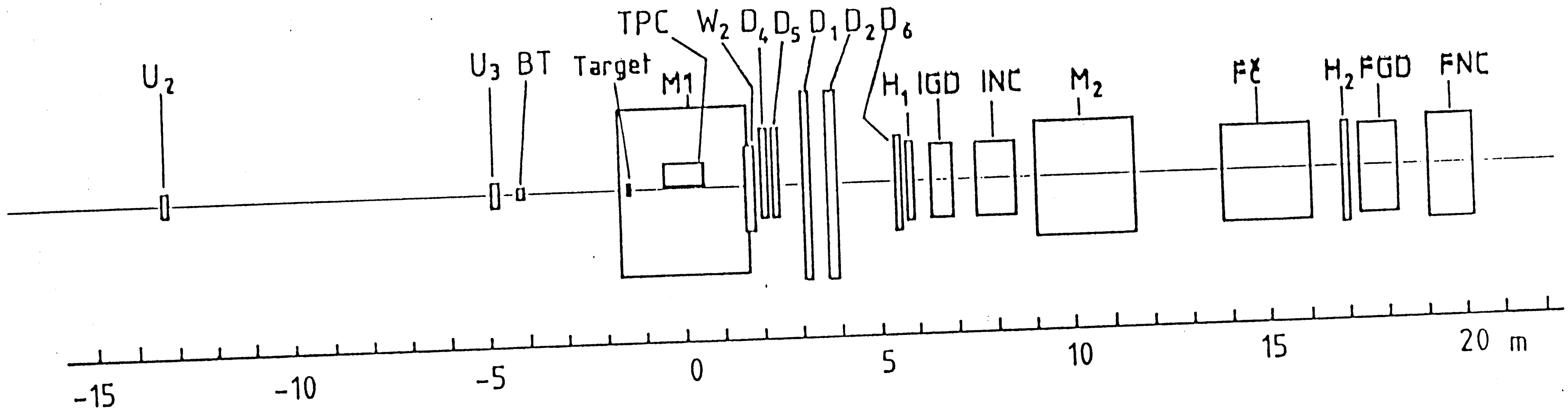


Figure 1 : NA 36 EXPERIMENTAL SET-UP

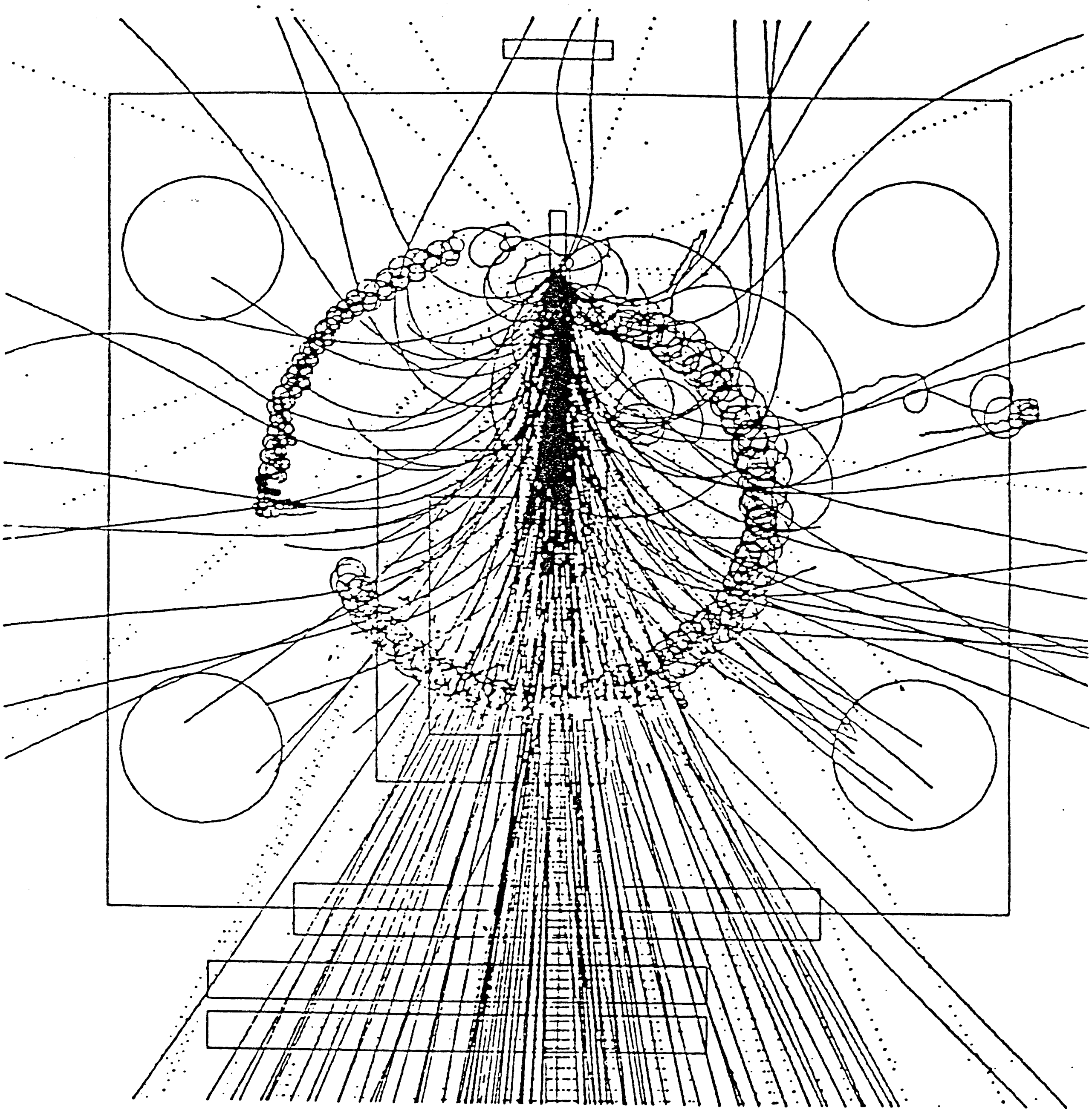


Figure 2 : A Montecarlo simulation of a Au-O event at 200 GeV/c/A in the 2.7 T M1 magnet

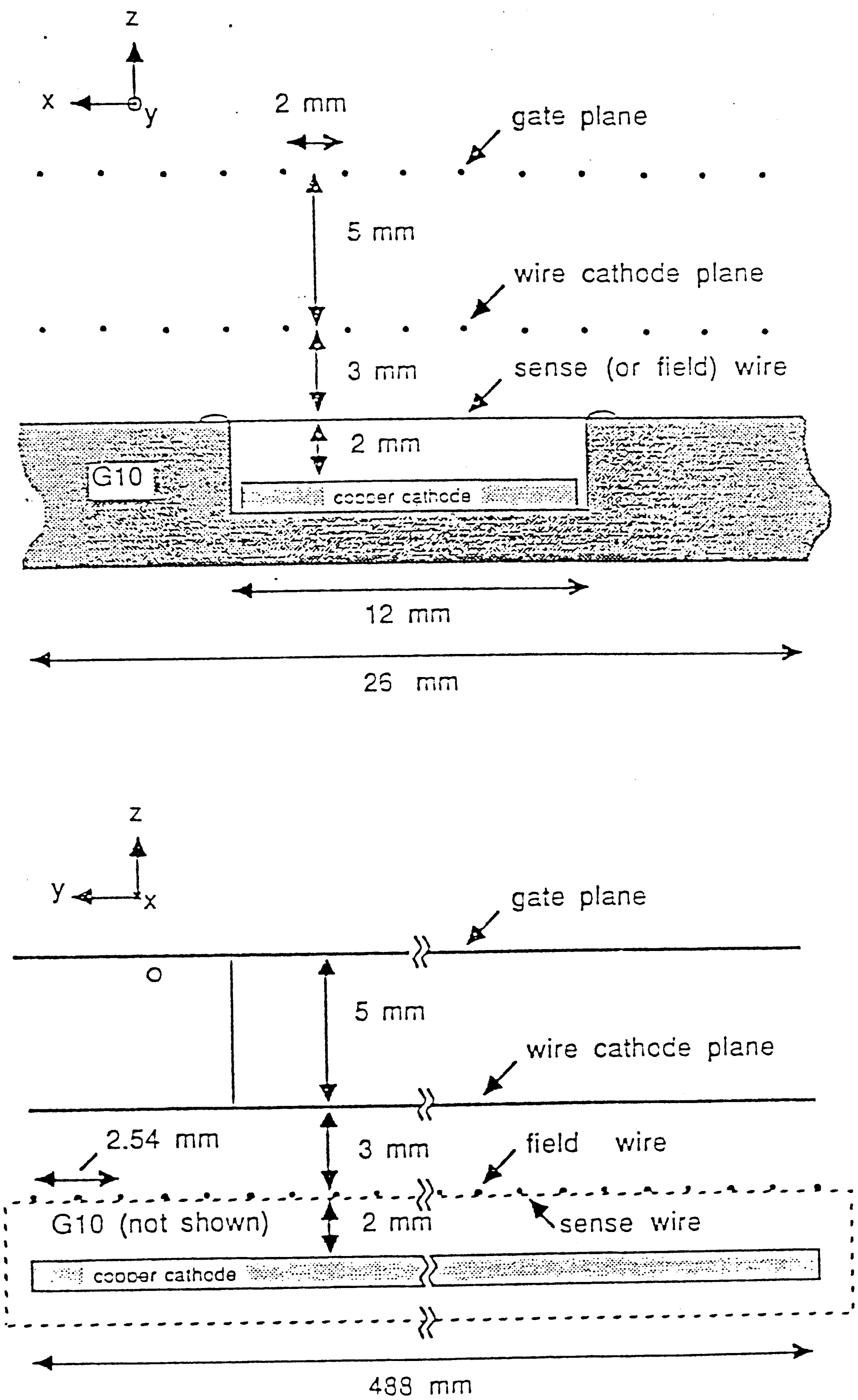


Figure 3

A schematic illustration featuring two orthogonbal views of the NA36 TPC cathode structure.

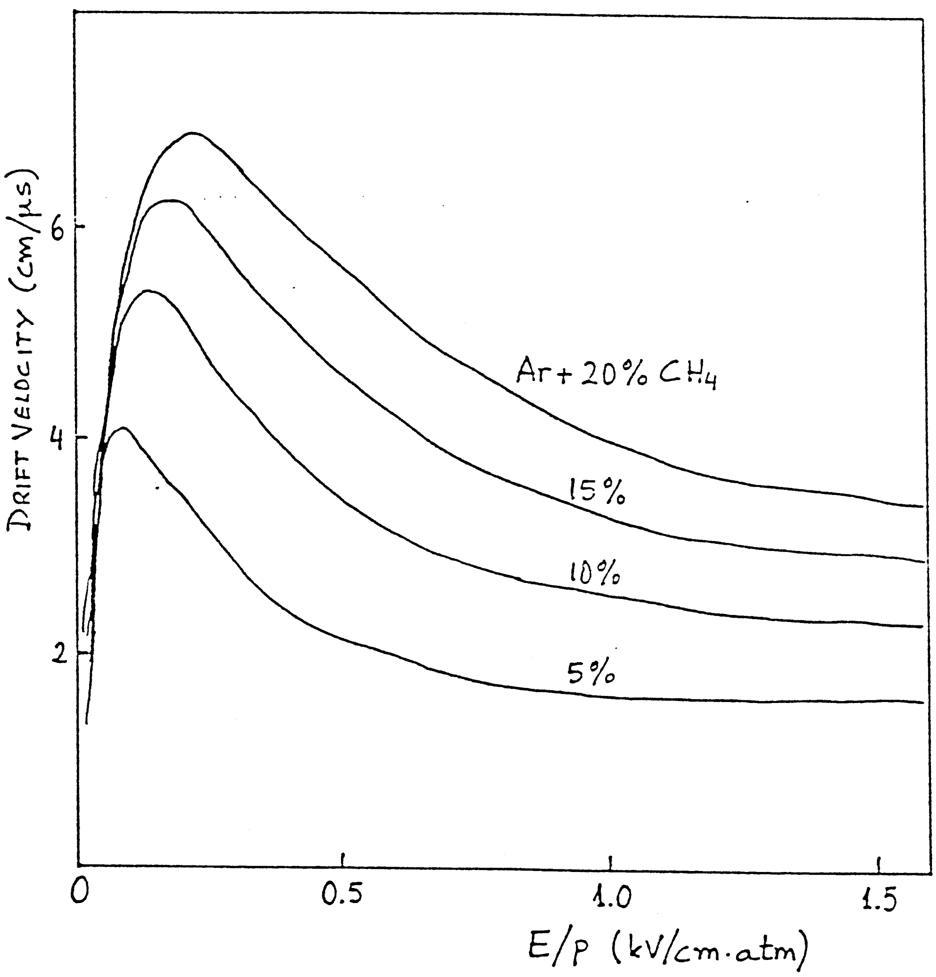


Figure 4: Drift velocity of electrons in several Argon-Methane mixtures.

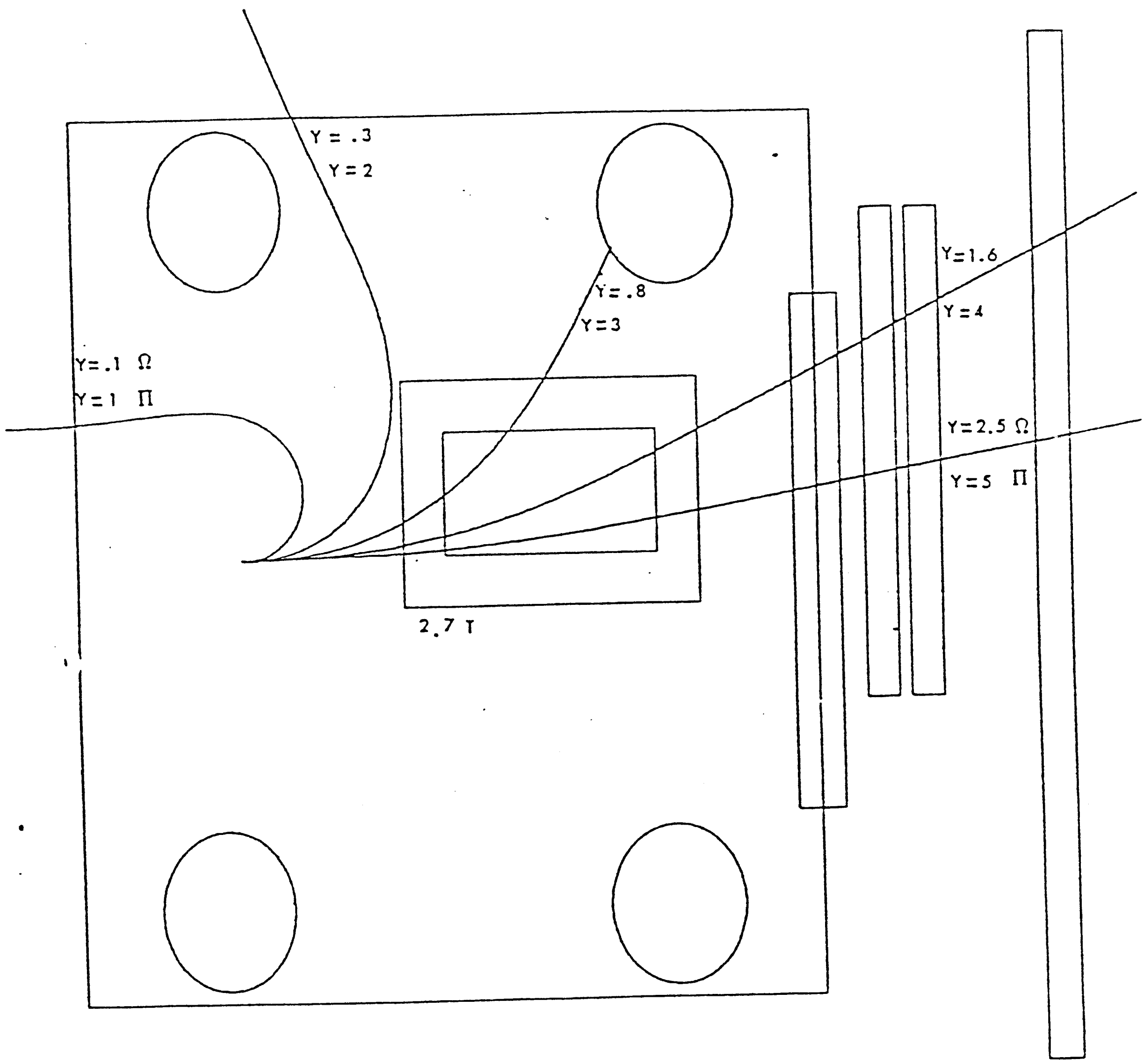
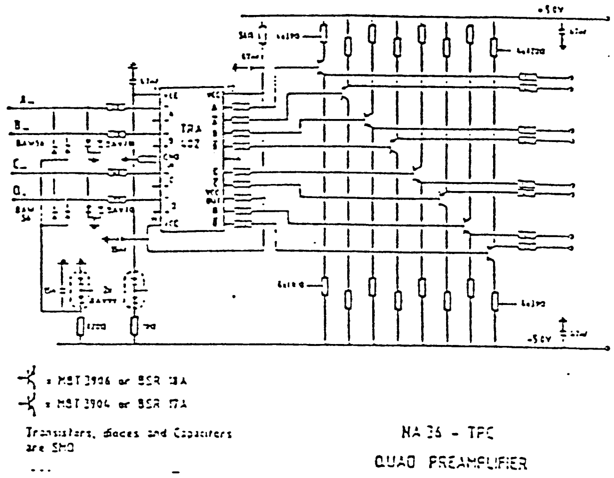


Figure 5 : Sweeping effect of the M1 Magnet for low rapidity pions according to a Monte Carlo calculation.

a)



b)

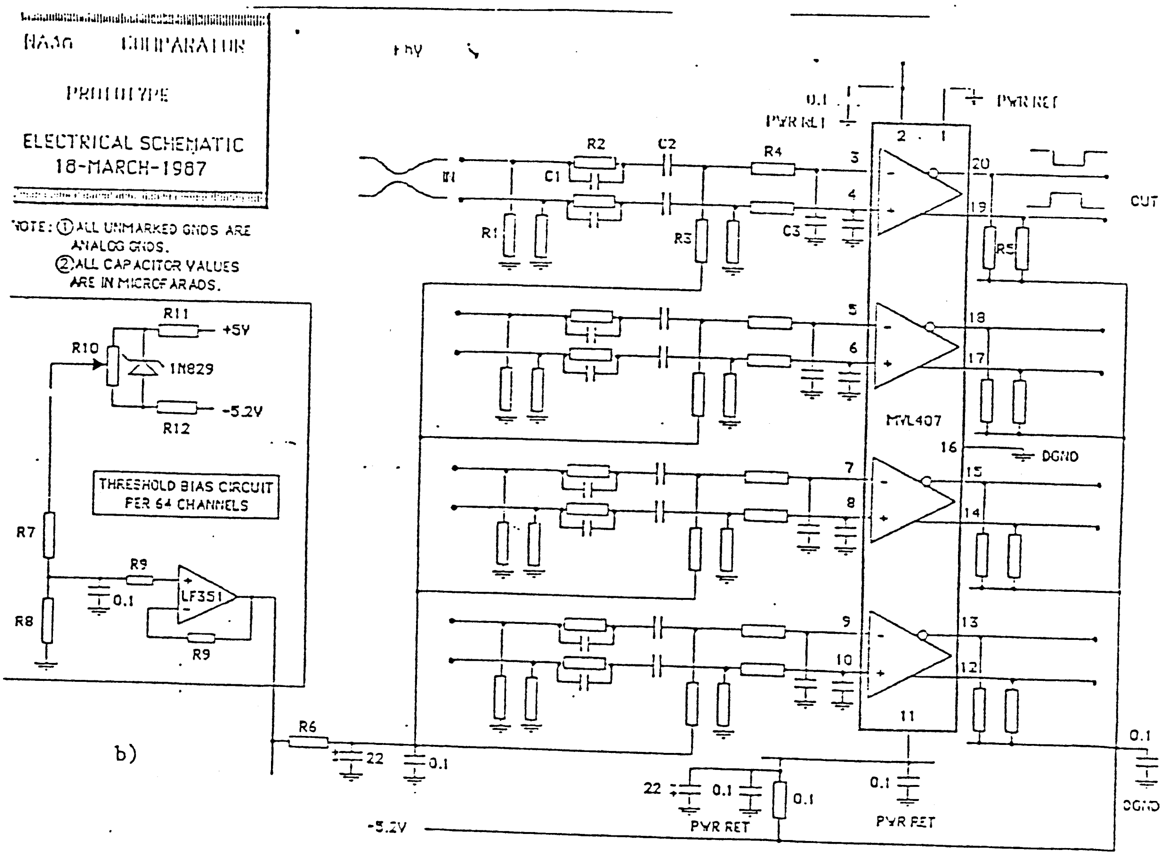


Figure 6 : The TPC preamplifier circuit (a) and comparator circuit (b).

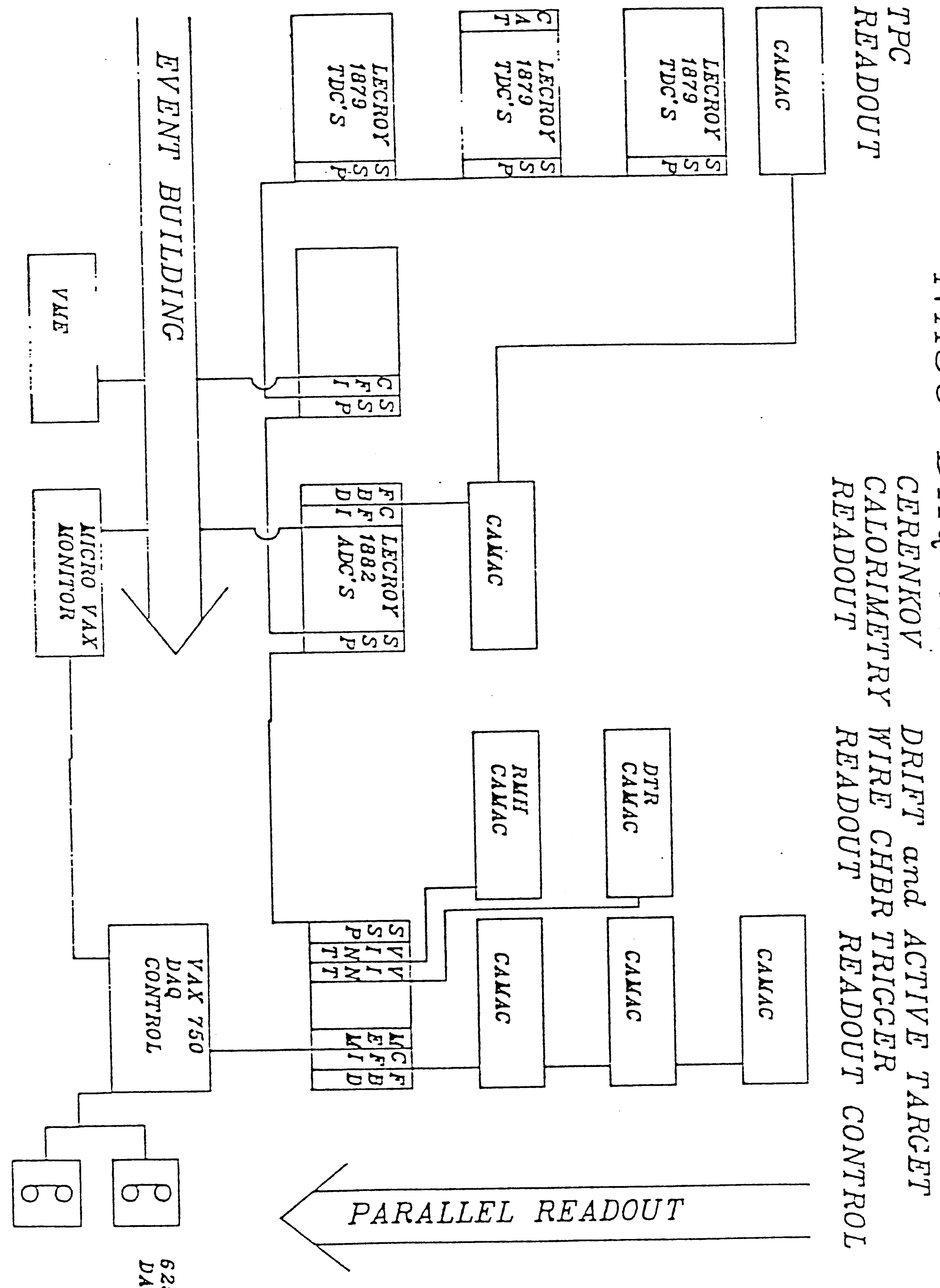


Figure 7 : The Na 36 FastBus Data Acquisition System.

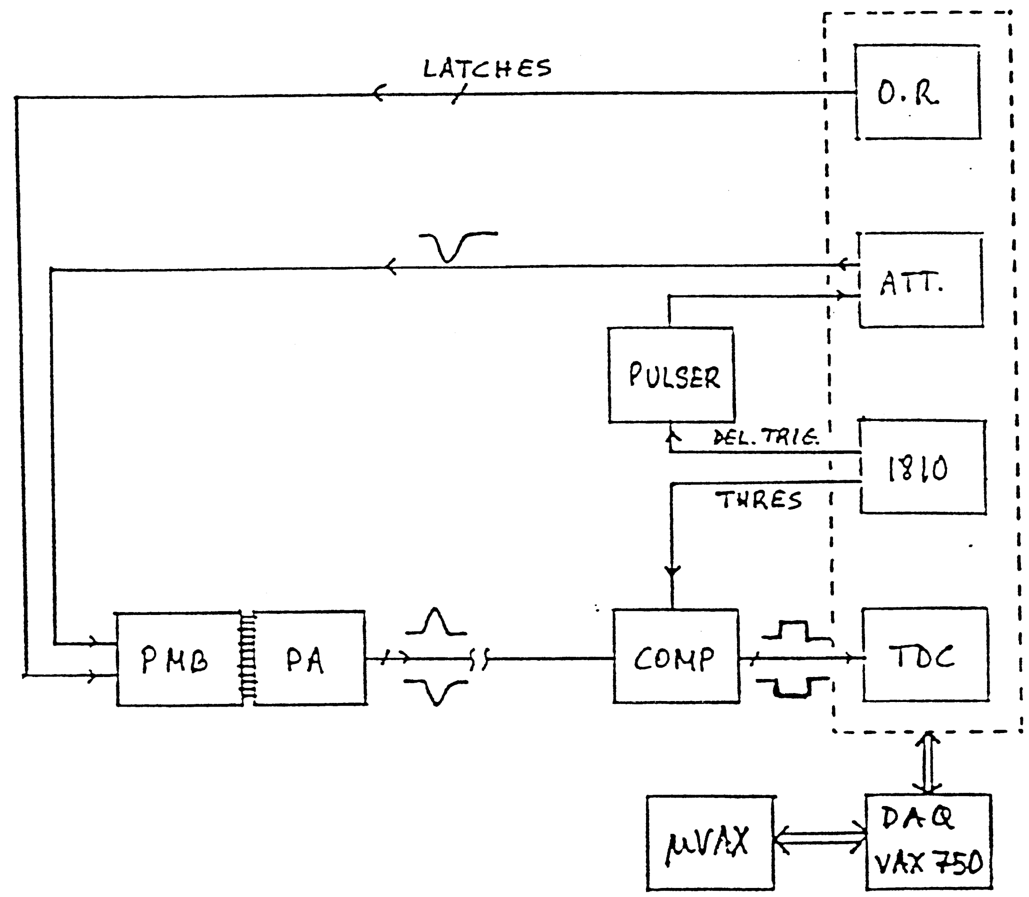
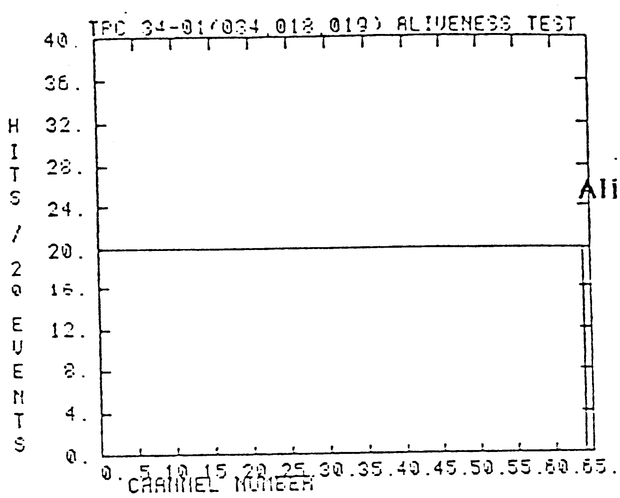
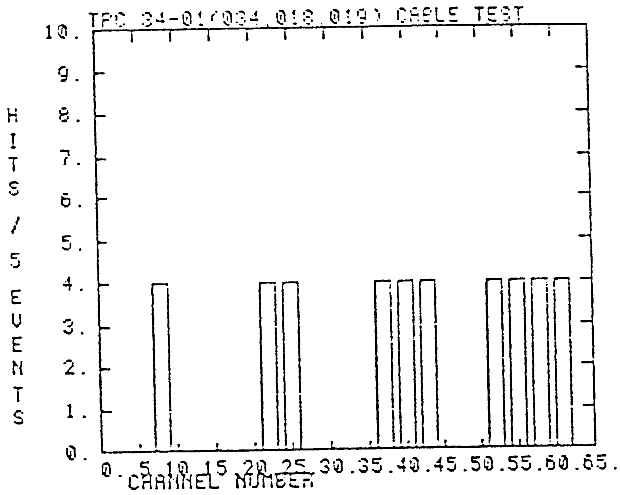


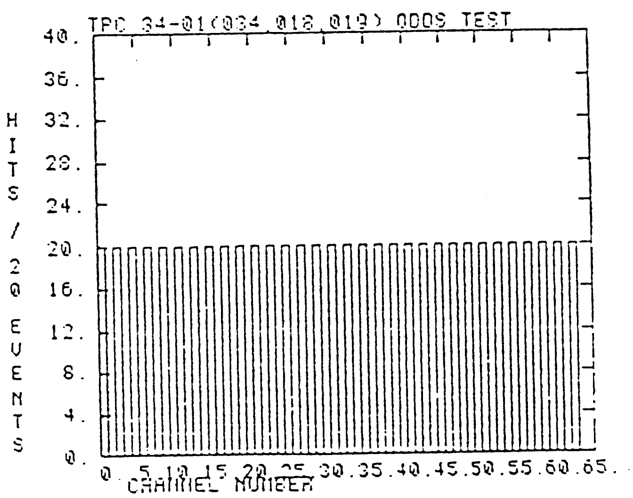
Figure 8 : The configuration used to test the TPCelectronics with the use of the Pulse Multiplexer Box.



a)
Aliveness test



b)
Cable test



c)
Cross-talk test

Figure 9

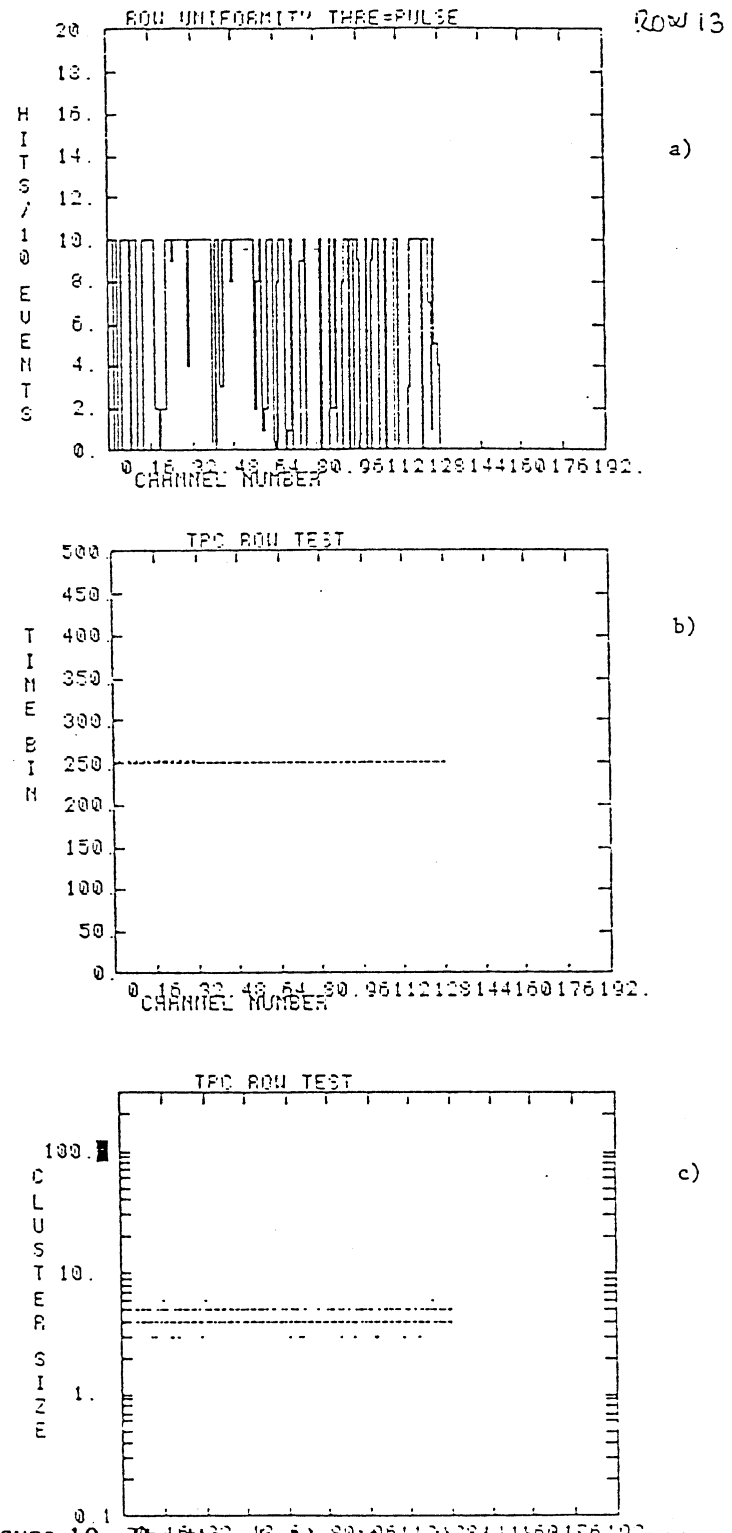
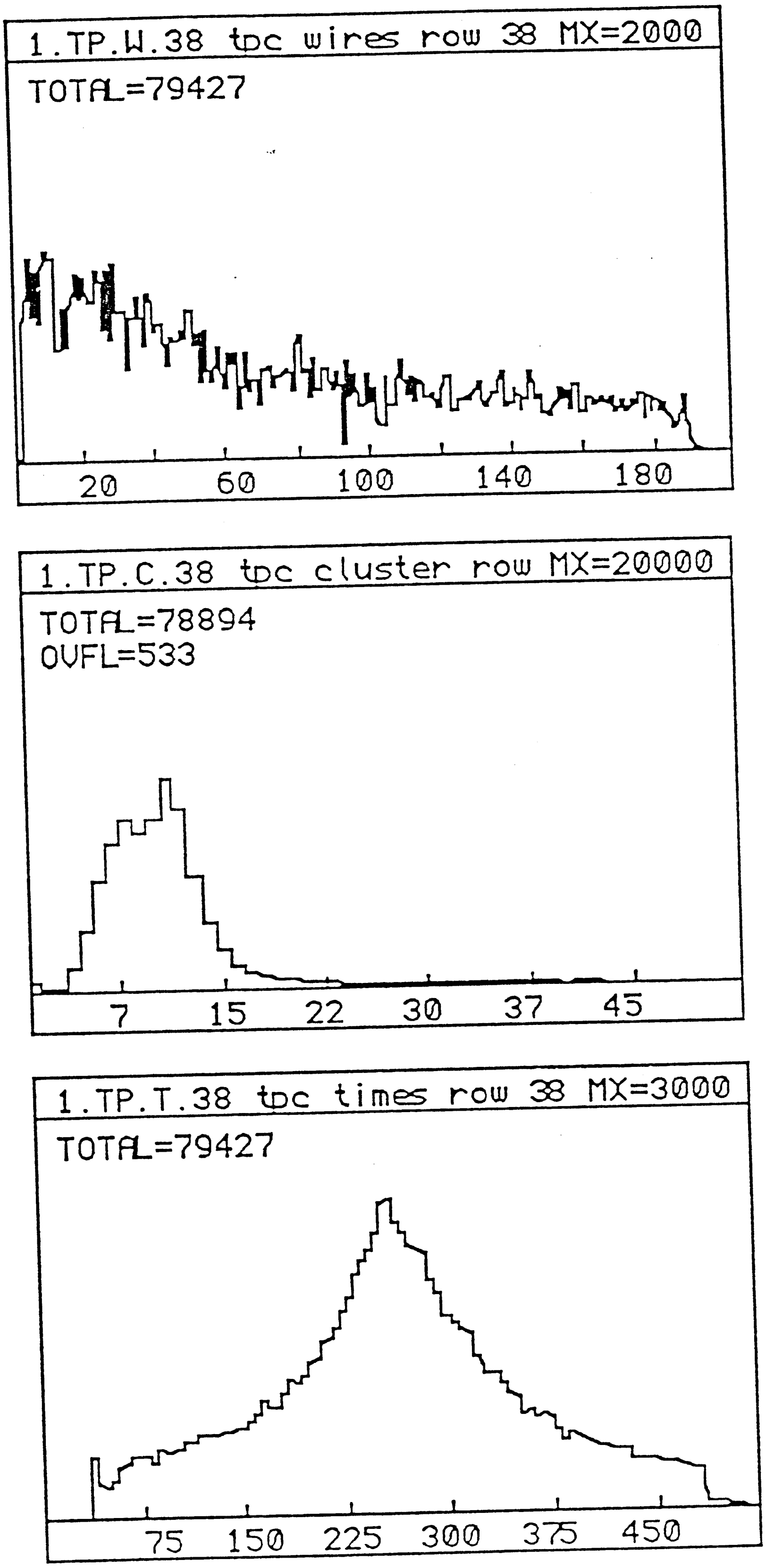


Figure 10 : The threshold uniformity test (a), and time (b) and cluster size (c) distributions tests within a row.



a)

b)

c)

Figure 11: On-line wire map (a), cluster size (b) and drift time distribution (c) in a TPC row.

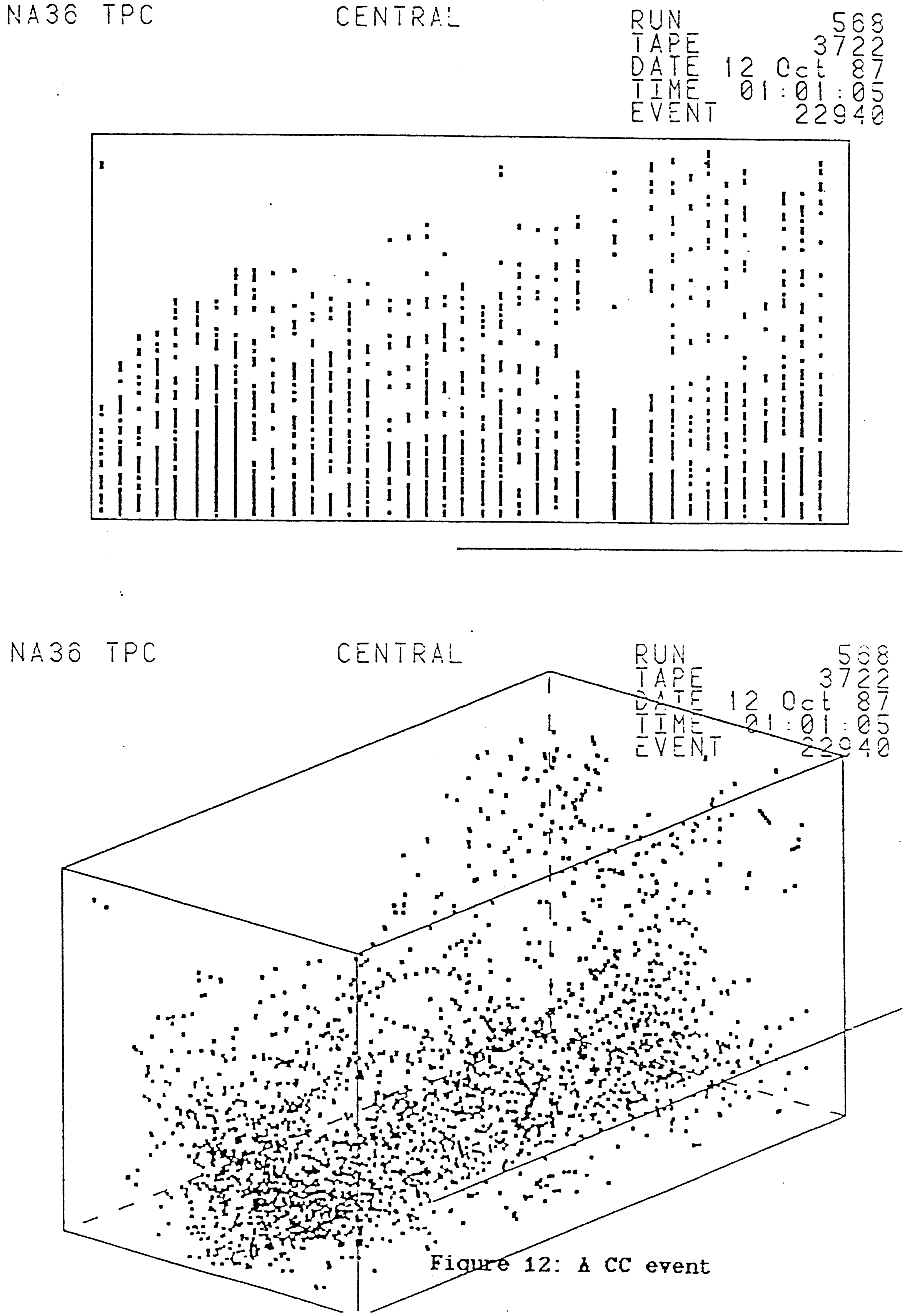


Figure 12: A CC event

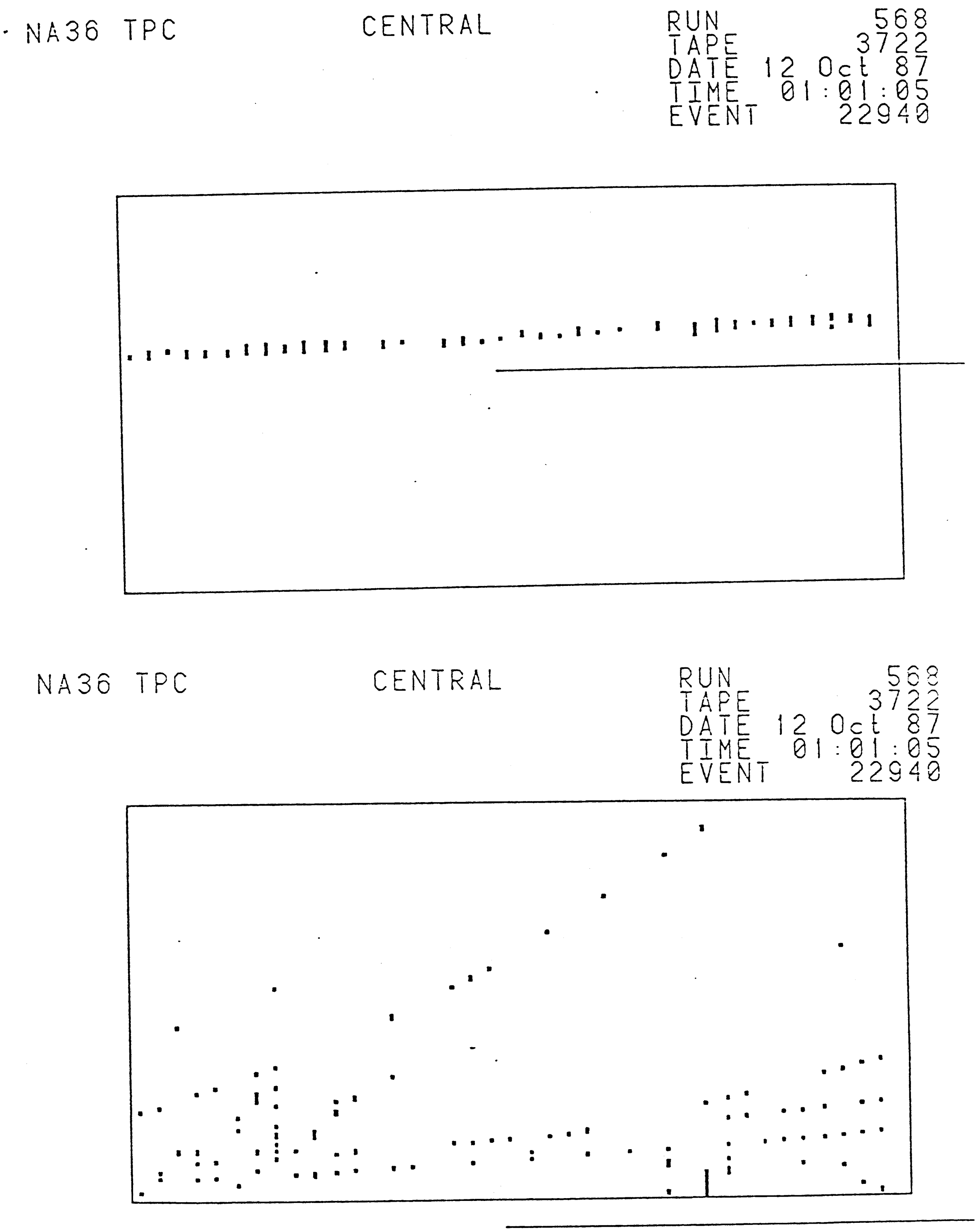


Figure 13: The same event with a wedge cut in the Z direction. Top and side views.

X-Y plane

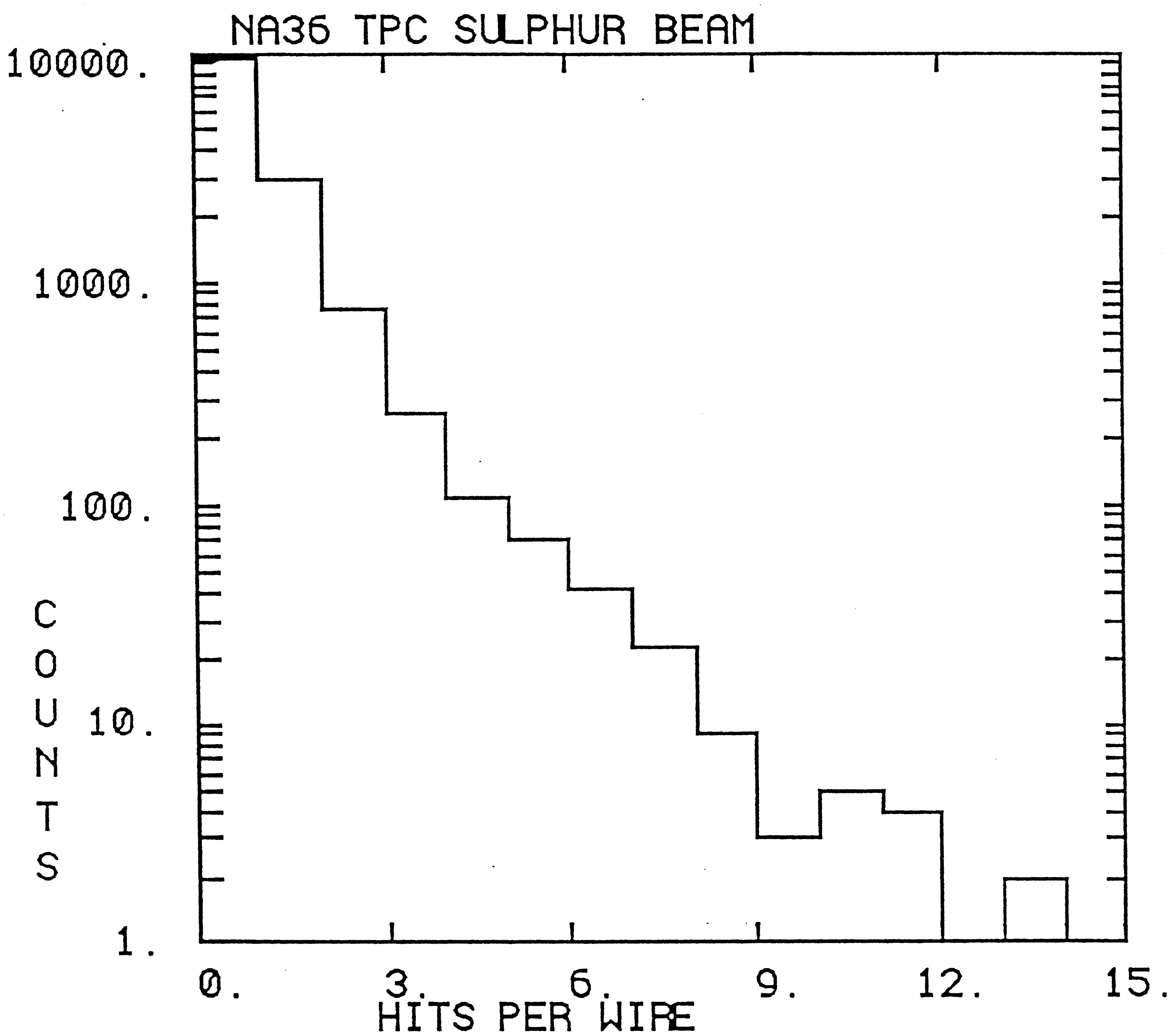


Figure 14: Multiple hit probability for a simple wire during one event.

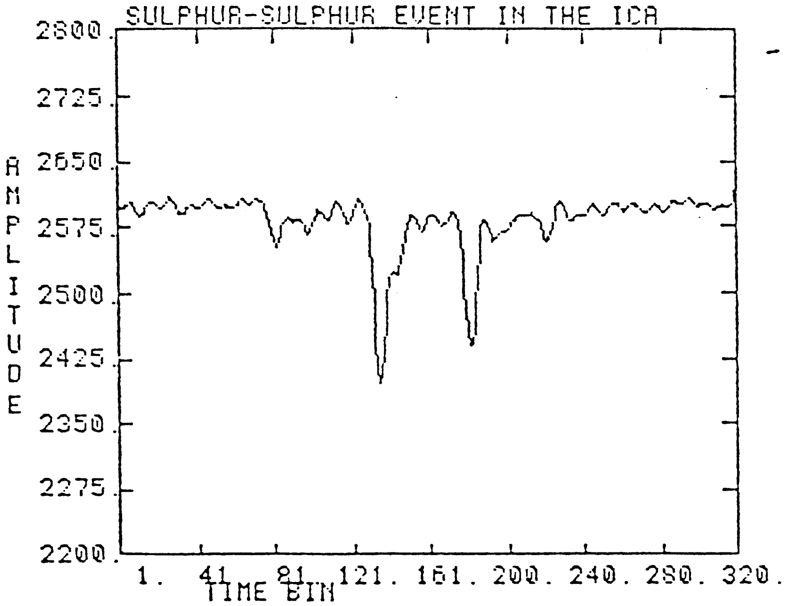


Figure 15: Hits recorded by a 2261 Image Chamber Analyser.

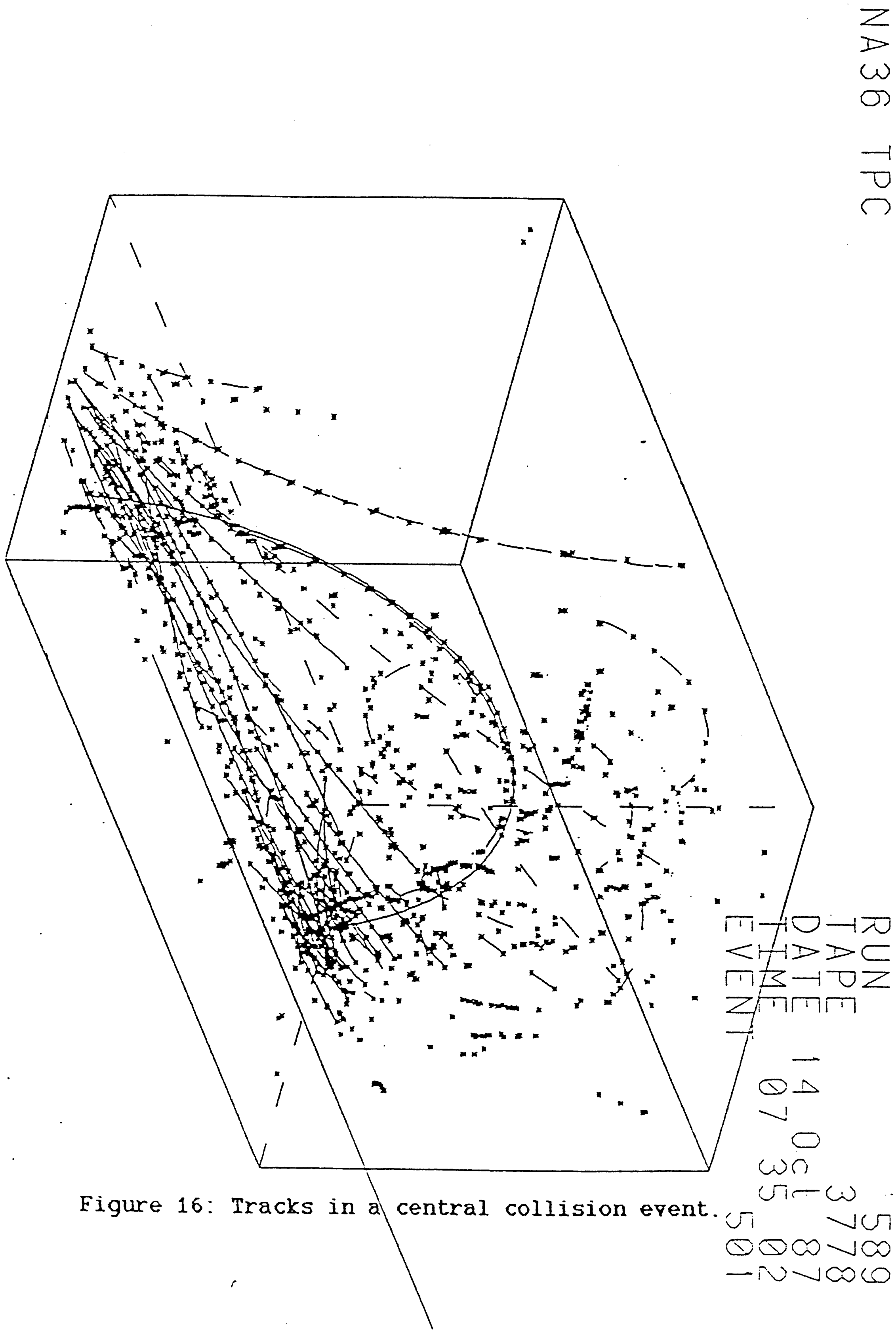
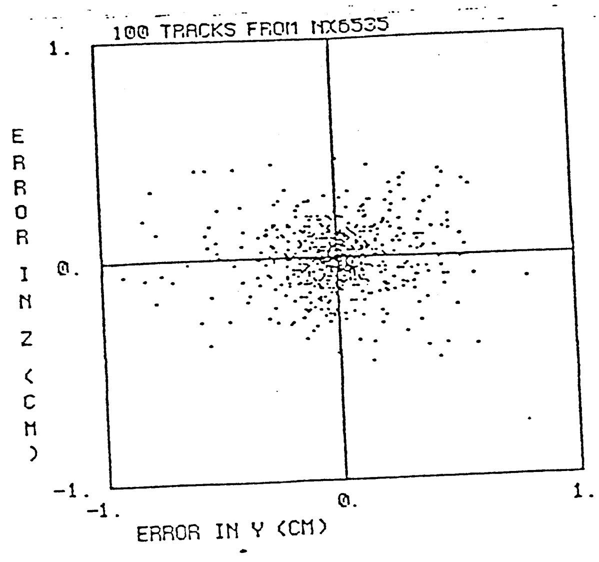
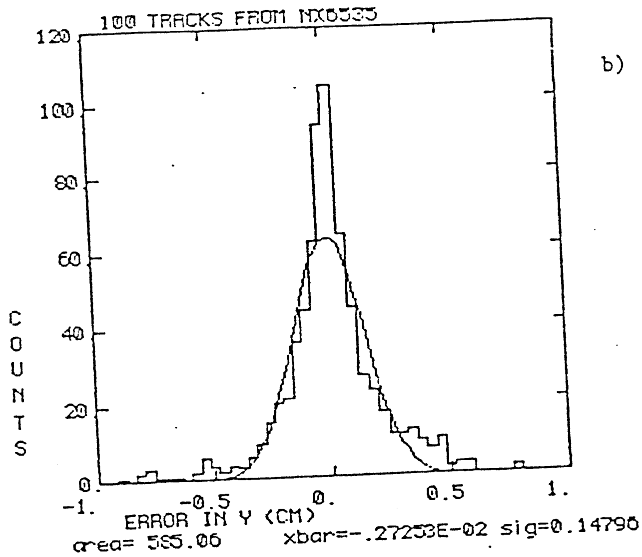


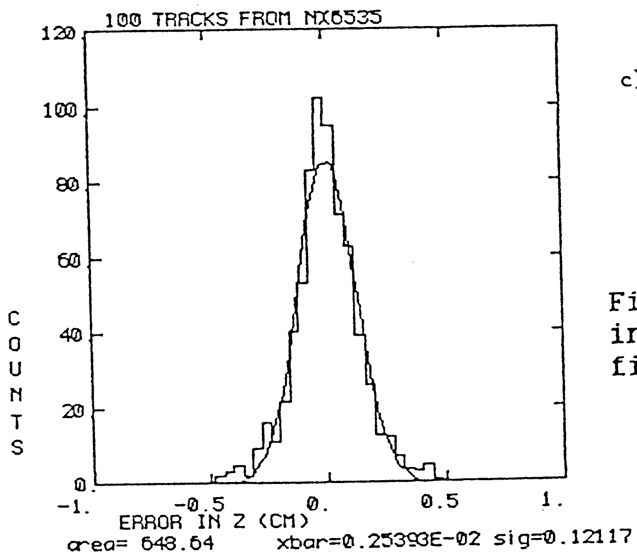
Figure 16: Tracks in a central collision event.



a)



b)



c)

Figure 17: errors in Y and Z after fitting.