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**SOME RESULTS FROM THE THIN GAP GAS CHAMBER DETECTOR PROTOTYPE FOR THE DELPHI END–CAPS**

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# Some Results from the Thin Gap Gas Chamber Detector Prototype for the DELPHI End-caps

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**Abstract**

Thin Gap Gas Chambers were proposed for a possible upgrade of the end-caps of the DELPHI detector at LEP. Two full prototypes were built and tested at the CERN 20 GeV/$c$ SPS pion beam. The main construction parameters of the detector and the on-board front-end electronics characteristics are reviewed. Test beam results from the full prototypes, showing the general feasibility of the detector, will be presented.

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# 1 Introduction

A detector based on Thin Gap Gas Chambers (TGGC) was proposed to improve the trigger and tracking performances in the DELPHI[1] end-cap regions at LEP200.

A large number of constraints had to be taken into account in the design of the detector, due to the necessity to fit within the actual structure of the DELPHI detector.

The TGGCs have one of their cathode planes etched with a high granularity pattern of triangular pads, to meet the trigger geometry requirement, while the other cathode plane is etched with strips either radial or transverse to the beam direction.

The chamber is made of multilayer printed circuit boards (PCB) providing a compact and reliable structure.

The same requirements also constrained the design of the front-end electronics, placed on two independent multilayer PCBs on top of the chamber, which performs a full on-board signal processing.

The tests carried out on the complete prototypes, at the 20 GeV/$c$ SPS pion beam at CERN, have shown the general feasibility of the detector. The chamber and the front-end electronics were tested and found to meet the design specifications.

With respect to previous applications this work proved the practicability of this kind of detector when a high granularity is required on a large size detector and therefore many readout channels and a VLSI electronics are involved.

As the behaviour of the DELPHI forward trigger and tracking at LEP200 turned out to be fully satisfactory, the Collaboration decided not to proceed with the detector upgrade. The working group was encouraged to proceed with the construction and full tests of the prototypes, as foreseen in the original project.

Some of the properties of TGGCs, a very thin and robust multiwire chamber providing big and fast signals, make this kind of detector an interesting solution for various applications at future experiments.

# 2 Overview and design considerations

The detector was designed to improve the redundancy and the hermeticity of the forward trigger and tracking at LEP200 and help to solve the left-right ambiguity of the forward tracking chambers. The location of the detector just after the Forward Chamber A would provide a polar angle coverage between 10° and 30° and a full coverage in azimuth.

Many constraints had to be taken into account in the design of a detector which had to be fully integrated into the actual structure of the DELPHI detector. The detector had to be thin enough to fit into the available space of about 1.5 cm and cover a large area of about 3 $m^2$ for each end-cap. A detector reproducing the present forward trigger structure, with a large number of channels, a fast and simple signal treatment and a high efficiency is required for the first level trigger. The detector should have a short radiation length to avoid adding additional material in the end-cap regions. The on-board electronics should be housed only in the region of large polar angles where the redundancy of the trigger and tracking is provided by the other tracking detectors. This space requirement constrains the total number of the detector readout channels. The detector should cover the low polar angle regions not covered by the Time Projection Chamber. The detector should be modular since it covers a large area and is very thin. The reduced amount of free space available in the end-caps must be take into account when the cabling of the detector is considered. A low power electronics is required to limit the heat dissipation.

Further details on the design and construction of the detector and the front-end electronics can be found in.[3–5]

## 2.1 The Thin Gap Gas Chamber

Thin Gap Gas Chambers[2] are thin multiwire chambers operated in high gain mode. They work in near saturated gas amplification mode with a highly quenching gas mixture and provide fast and large signals which can be directly discriminated without pre-amplification.

A cross-section of the TGGC is shown in figure 1. A plane of 50 $\mu$m diameter wires with 2 mm spacing is placed between two cathode planes made of multilayer PCBs and separated by a 3.2 mm gap. The surface facing the wires is made of 200 $\mu$m glass fiber reinforced epoxy (FR4) and is covered with graphite. The graphite layer has a typical surface resistance of $\approx 5\ \mathrm{M}\Omega/\Box$. The signal induced on the resistive cathodes is picked-up by the underlying copper pads or strips. Transmission lines between pads or strips and the electronics PCBs are built in the outer PCB layers. This solution provides a compact and reliable structure for the electrical connections from the pads and strips to the front-end electronics. It has the further advantage of using standard industrial multilayer PCB techniques. The total thickness of the chamber is 7.4 mm and about 0.1 radiation lengths. The chambers were operated with a $65\% - 35\%$ gas mixture of $CO_2$ and $\mathrm{n-pentane}$. Applying a typical voltage of $3.8 \div 4.0$ kV the operation is in a nearly saturated mode with a gas amplification of the order of $5 \cdot 10^6$.

## 2.2 Chamber design

Each end-cap can be instrumented with two planes of six trapezoidal chambers covering 60° in azimuth. The two planes are staggered in order to improve the geometrical acceptance. They fit the $\sim 1.5$ cm gap between the present Forward Chamber A and the Forward Ring Imaging Cherenkov detector.

The proposed detector had to comply with the DELPHI trigger structure. Each plane of chambers has therefore to provide three coordinates to be realized with a single cathode plane. This is obtained by etching the cathode plane in equilateral triangular pads, as shown in Figure 2, and properly combining the pad rows. Below about 17° polar angle the small pads have a height of 3.14 cm while above this angle the chamber granularity may be safely reduced using bigger triangular pads with double height. Only one of the two cathode planes of the TGGC is shaped with triangular pads while the other cathode plane is etched with either radial or transverse strips giving a $\phi$ and $\theta$ information on the track. Each strip is placed at a defined angle and the pitch between two strips is $\delta\phi = 0.22°$ or $\delta\theta = 0.1°$. This point is useful for solving the left-right ambiguities in the drift chambers. The wires of the chamber run along the direction of the basis of the trapezium.

## 2.3 The readout electronics

The front-end electronics for both pads and strips is placed in two independent multilayer PCBs connected to the upper part of the chamber.

The 273 pad and 266 strip channels per chamber are discriminated and digitally processed to produce prompt trigger information which is then transmitted through the serial optical link to the Fastbus data acquisition system.

The functional scheme is shown in Figure 3. The discriminated signals from the pads and strips are processed by programmable circuits to compute the trigger coordinates in a format compatible with the DELPHI first level forward trigger processor. An optical link is used to transmit the control signals and the data between the detector and the counting room. This choice is mainly motivated by the severe space limitations. It avoids adding unnecessary material into the detector volume and has the advantage of being immune to electromagnetic pick-up. Particular care has been taken in the electronics design to avoid electromagnetic interference between channels and external noise collection.

A dedicated Fastbus module was designed and built to interface the front-end electronics with the Fastbus based DELPHI data acquisition system.

# 3 Test beam results

To study the behaviour of the chamber a series of tests were carried out using a 20 $\mathrm{GeV}/c$ pion beam at the CERN SPS. The trigger came from the coincidence between two scintillation counters. The data were readout and written to disk by the Fastbus data acquisition system, allowing immediate analysis of the data set.

A display of a few events is shown in figure 4. The hit pads are hatched and the lines show the position of the hit strips. The signal rise-time was measured to be $\approx 20$ ns.

A comparison of the frequency of multiple hits with the frequency of single hits, taking into account the different geometry of pads and strips, showed that the cross-talk is essentially compatible with pad-pad and strip-strip charge sharing.

The pad efficiency was found to be compatible with a loss of efficiency due to charge sharing among pads. In fact, due to the particular pad layout which is necessary for trigger purposes, up to six pads can share the same charge. This was checked by using the strip information to localize the particle. The largest loss of efficiency of the pads is concentrated in the region where the particles are close to the border between two pads, as shown on the top left event in figure 4. The relative efficiency of a small pad is shown in figure 5 as a function of the chamber high voltage and for different thresholds. The presence of a few inefficient strips did not allow to calculate the efficiency of the strips. Applying a correction to take into account the inefficient strips, the strip efficiency at 3.8 kV and with a 3 mV threshold can be estimated to be bigger than 90%. Under these conditions the fraction of particles which are detected by one single strip is of the order of 10%. Therefore the loss of one isolated strip affects in a limited way the global efficiency. The uncorrected strip efficiency as a function of the chamber high voltage is shown in figure 6 for different thresholds.

# 4 Summary

A detector based on Thin Gap Gas Chambers was designed to improve the trigger and tracking capabilities in the DELPHI end-caps at LEP200. Two full prototypes were built and tested. Technical problems due to the many constraints have been faced and solutions have been described. The chamber multilayer PCBs and on board VLSI electronics allowed to satisfy the design requirements. The test beam results have shown stable operating conditions. The front-end electronics has been tested on the chamber signals and found to meet the design specifications. With respect to previous application of TGGCs our tests showed the practicability of this detector when a high granularity for a large size detector as well as a fast on-board processing are required. The tests carried out on the complete prototypes have shown the general feasibility of the detector.

# 5 Acknowledgments

We would like to thank G. Mikenberg for his advise and the Weizmann Institute of Science for the help given with the chamber graphite layer; G. Leder of the HEPHY Institut für Hochenergiephysik for many useful discussions and suggestions, I. van Vulpen of NIKHEF for the help given with the tests. We express our gratitude to L. Gatignon and collaborators for their help in the set-up of the beam line. We wish also to thank J.E. Augustin, H. Foeth and D. Treille for initiating this work.

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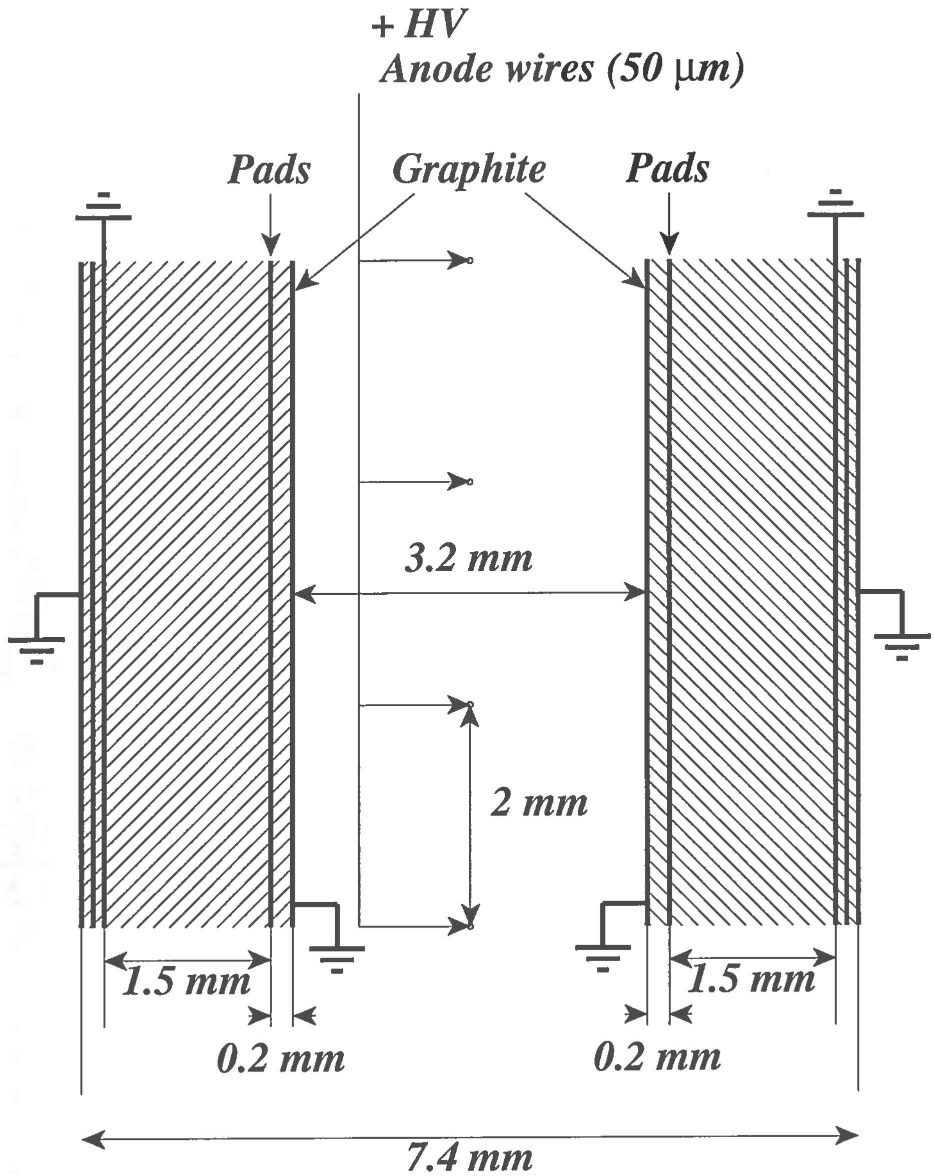


Figure 1: Cross section of the Thin Gap Gas Chamber.

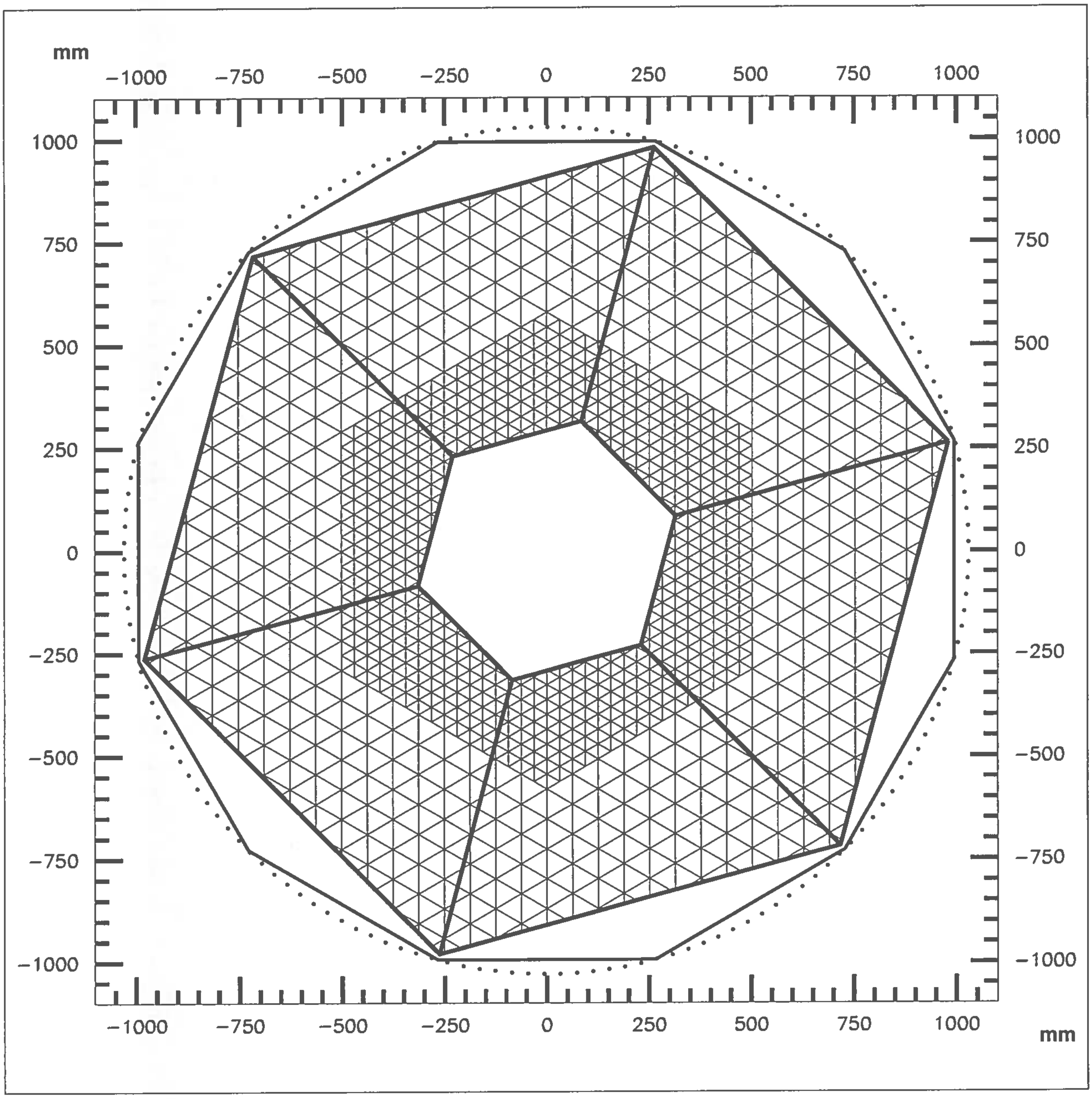


Figure 2: Layout of one plane of six chambers.

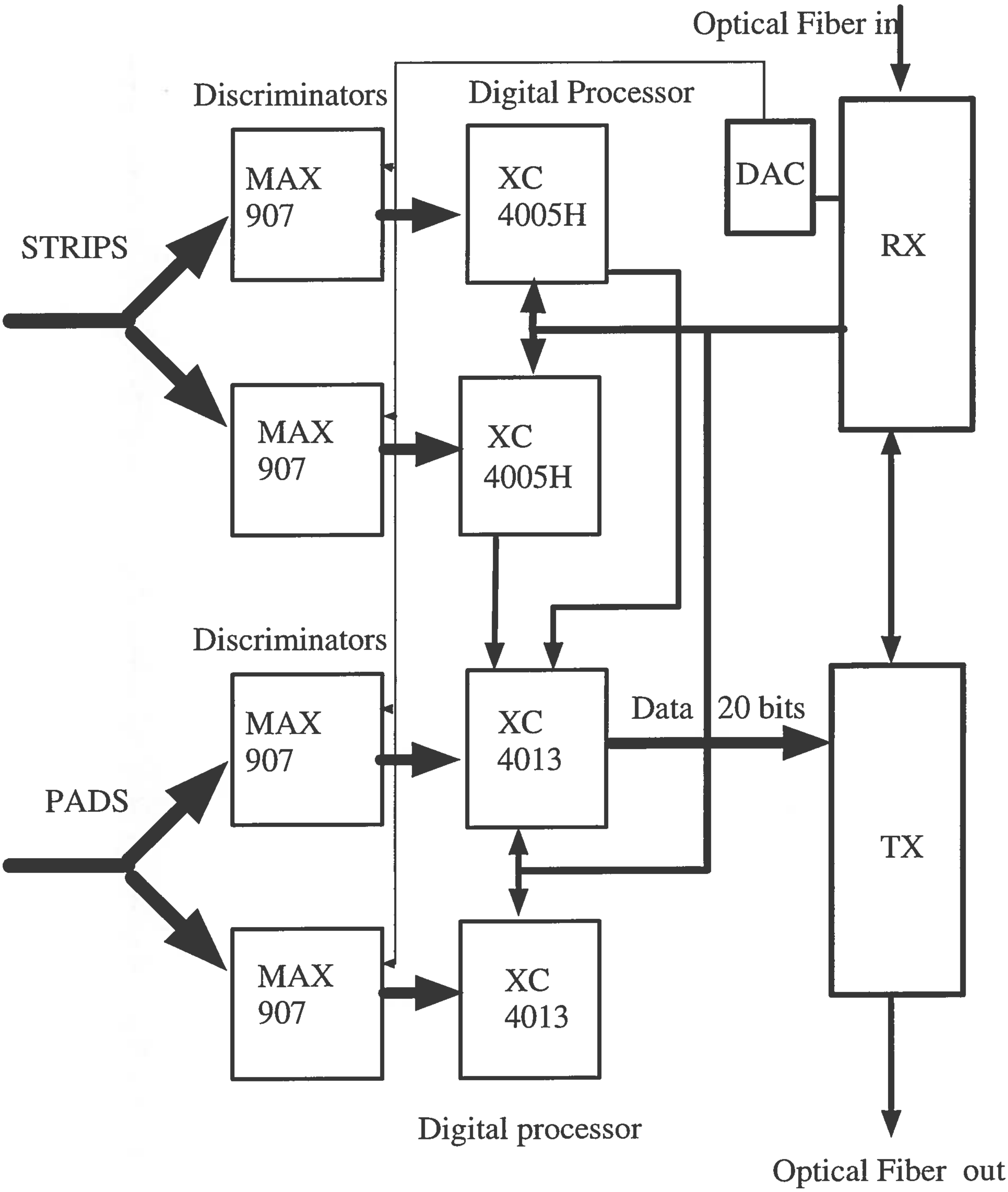


Figure 3: Electronics functional scheme.

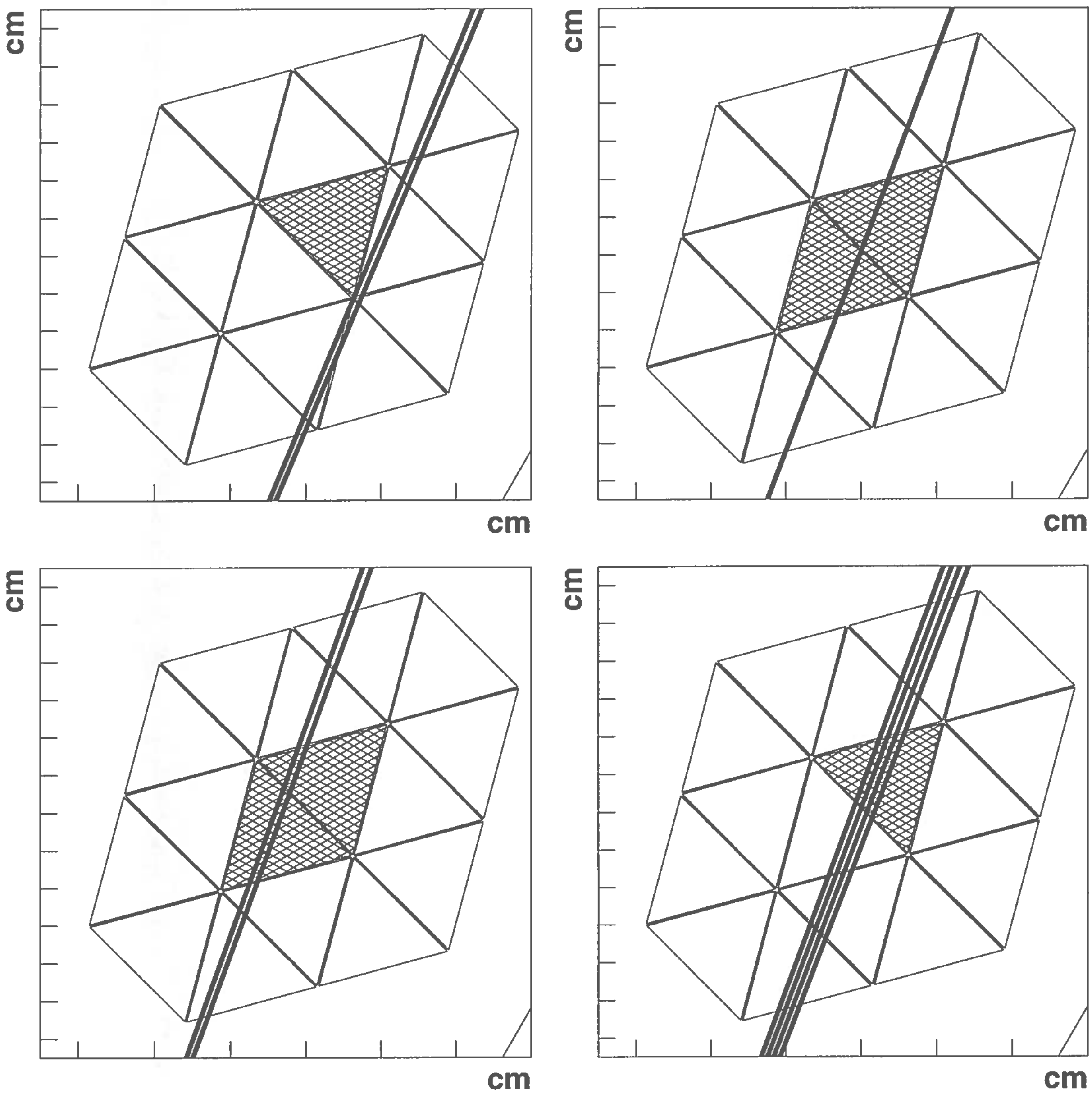


Figure 4: Display of some events.

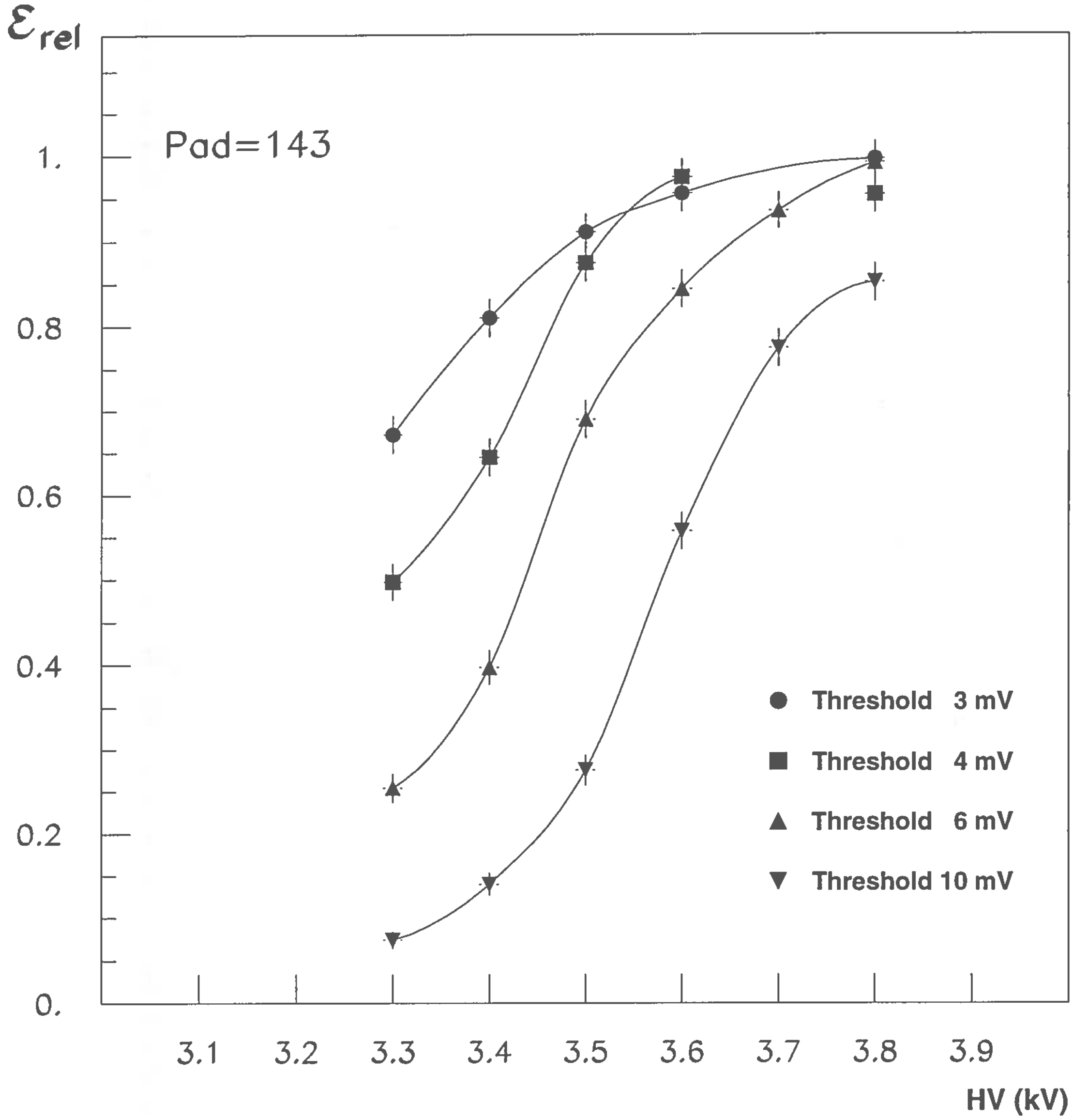


Figure 5: Relative efficiency of the pads.

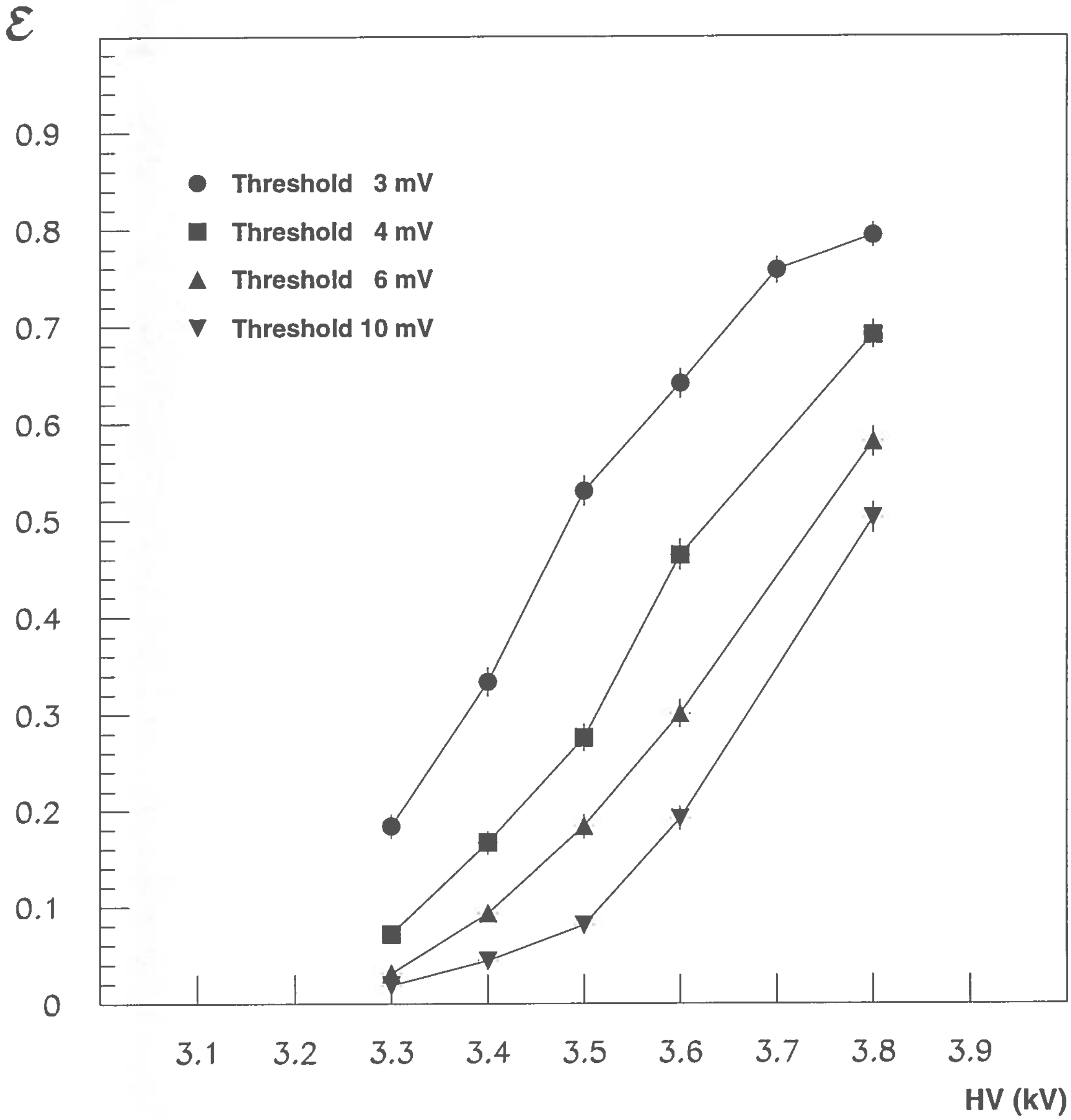


Figure 6: Uncorrected strip efficiency.