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Performance of $2mm$ Radius Straw Tube Drift Cells. Paper and Poster Presented at the IEEE Nuclear Science Symposium, Orlando, FL, Oct. 25-31, 1992.

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Performance of $2mm$ Radius Straw Tube Drift Cells.

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Abstract

The performance of a 128 channel test module made with straw tubes of 2mm radius has been studied in a test beam and with cosmic rays. Different gases were used and for each one the time-to-distance relation and the hit efficiency was measured. Comparisons are made between results when two different electronics readouts were used. The information was recorded with $106MHz$ FADC units and also with TDCs ($50ps$ resolution). The best resolution, of 135 μm, was obtained using 50% Ethane, 50% Argon and reading out the information with the TDCs, at an operating HV of $1750V$.

1 Introduction

Detectors capable of tracking a very large number of particles have recently found renewed attention. This interest is due to the expected luminosity increase at existing accelerators or at ones under consideration. Among tracking detectors, straws tubes have been given considerable attention after the pioneering work done at SLAC and elsewhere [1]. Recent studies of straw counters with a $2mm$ radius show that position resolutions of the order of 100 μm or less can be achieved [2]. This study was part of an effort to explore tracking chamber options for the upgraded DØ collider experiment at Fermilab when the new FNAL injector becomes operational. We investigated the performance of a module made with $2mm$ radius straw counters operated under various conditions, including different gas mixtures, operating high voltages, and read out electronics.

2 Construction of Straw Module

A module with 128 channels of straws tubes [3], each $2mm$ radius and $80cm$ long, has been assembled. Figure 1 shows a cross section of the module. Eight layers of 16 straws each are separated by a $4mm$ thick sheet of Rohacell. The tubes in alternating layers are staggered by half of a straw's diameter. Each straw tube is made by winding a ribbon of aluminized mylar on a mandrel and then gluing a second layer on top. The total wall thickness is 50 μm and the layer of aluminum, which covers only the inside surface of the straw, is 2 μm thick. The tubes were cut to the same length within 100 μm. An aluminum insert (see details in fig. 1) is glued with conductive epoxy to each end of the tube. These inserts center a wire-positioning sleeve (CERN design, I-100-5-J) relative to the straw tube. Two slots in each aluminum sleeve allows the gas to flow through the straw. The frame containing the tubes was assembled by gluing two aluminum side walls to a Rohacell-Kevlar panel. After this, layers of Rohacell spacers and tubes were stacked in this U shaped structure. Lastly, the top panel was glued in place. The spaces between the aluminum inserts, at each end of the module, were then filled with conductive epoxy. The sense wires, made of 32 μm diameter gold plate tungsten wire, were then strung. Each wire was crimped to each sleeve while under a tension of $100gr$. The positions of the feedthroughs at each end were surveyed to 50 μm. No deviation larger than 125 μm from the design position was found.

3 Operation of Test Module

We report results using 4 different gas mixtures (listed in Table 1), mixed by the supplier to an accuracy of 0.1%. The module was operated at 1 ATM with the wires at negative high voltage (HV).

These tests were conducted at the Fermilab NWA test beam area, in beams of 10-150 GeV/c pions and electrons and also using cosmic rays. The test beam trigger was supplied by three beam counters in coincidence located upstream and downstream of the module. The data from the straw module were read out together with information from a drift chamber, which is a spare module of the DØ forward drift chamber (FDC) [4, 5, 6]. Tracks are measured by the FDC module with a position resolution of 200 μm. For the cosmic ray data, the straw module and FDC module were placed horizontally, as shown in Fig. 2. The trigger was again defined by 3 scintillating counters in coincidence. The counters used for the cosmic ray trigger covered the entire length of the test module.

For the test beam data, the straw module was read out using electronics developed for DØ tracking chambers at the Tevatron [4, 7, 8]. Preamplifiers mounted directly on the module send signals to shaping amplifiers $20m$ away. The signals are digitized using $106MHz$ 8-bit FADCs, are zero-suppressed, and are then passed to data acquisition computers for analysis. The FDC module was also read out using the standard DØ tracking electronics. For the cosmic ray data, straw module signals from the preamps were also

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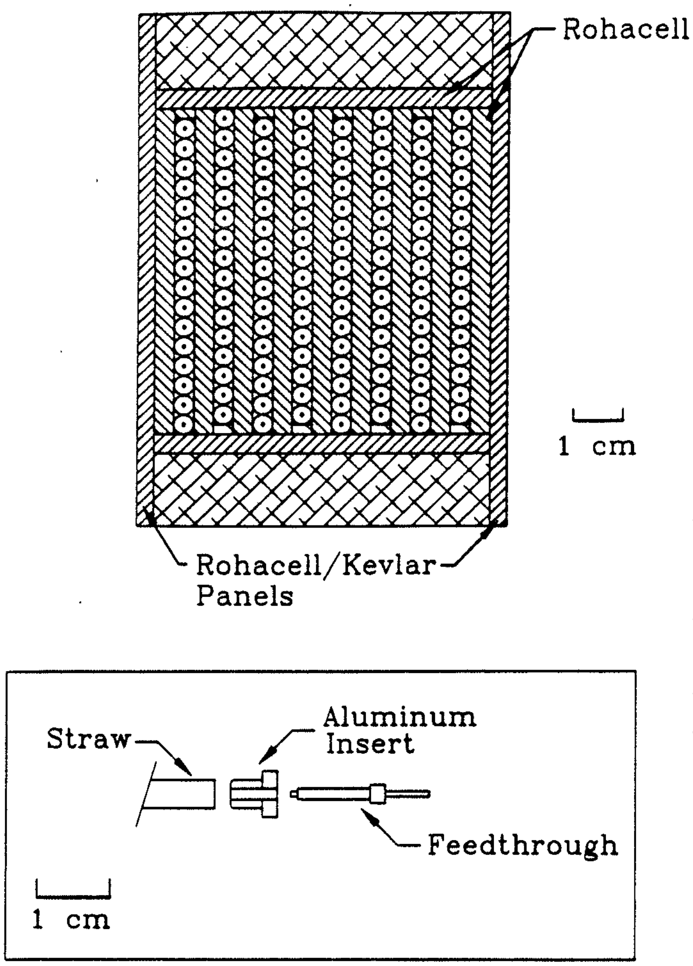

Figure 1: a) Cross section of straw module. b) Aluminum insert, which centers wire in straw tube.

sent through Lecroy discriminators (LRS623B) and then to TDCs (LRS2228A), having 50 *ps* resolution. We were therefore able to compare performance of the straw module using both FADC and TDC readout simultaneously.

4 Position measurement

Test beam data were read out using FADCs. The hit positions were found using the software developed for DØ central tracking chambers [5]. The hit position is determined by taking the center of gravity of the FADC bin differences, but giving greater weight to the earliest bins. The drift time obtained in this way is then corrected by a reference timing pulse that was generated by the trigger. For the cosmic ray data, in addition to the above method of measuring drift times by FADCs, we also measured the drift times by TDCs, which were preceded by fixed threshold discriminators. The drift times, from either method of hitfinding, were corrected for variations in cable length and electronics time delay.

Using our test beam data, we compared the drift times

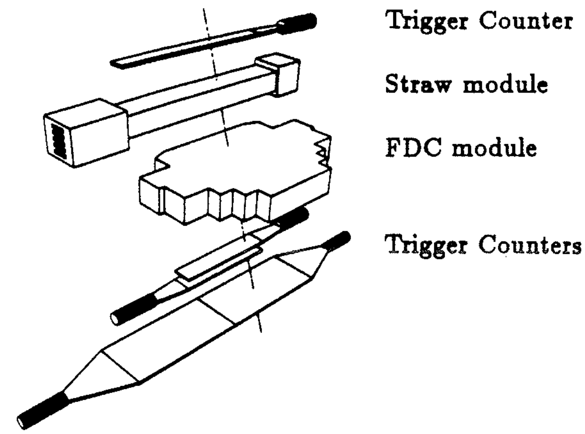

Figure 2: Data taking setup for cosmic ray trigger.

of each hit to the position of an independently measured track (from the FDC module). This allowed us to measure the time-to-distance relationship for each gas. The results are given in Table 1 and are shown in Fig. 3. The values of the measured drift velocities are similar to the ones found in the literature for similar gas mixtures. Slight discrepancies originate both from the geometry and operating parameters of our detector, and also from the hit finding methods used.

Table 1: Gas mixtures used, operating voltages at which data was taken, and time to distance relationship assumed.

Gas Mixture	Operating Voltage (V)	Time to Distance Relation Used
5% Ethane, 95% CO_2	2235	$D = a\sqrt{t}$; $a = 270\mu m/sec^{1/2}$
4% Methane, 3% CO_2, 97%Ar	1275	$D = vt$; $v = 40\mu m/sec$
20% CO_2, 80% Ar	1400	$D = vt$; $v = 80\mu m/sec$
50% Ethane, 50% Ar	1550	$D = vt$; $v = 60\mu m/sec$

The deviations of wire positions from their design positions were determined from data, by observing the average deviation of hit positions for each wire. These results were compared to the deviations measured by survey, and the two were found to agree within the survey error of 50 μm. These wire positions obtained from the data were used to correct measured hit positions in later analysis.

5 Test Module Performance

The hit efficiency and position resolution of the test module have been measured for each of the four gas mixtures, using the operating voltages listed in Table 1. These re-

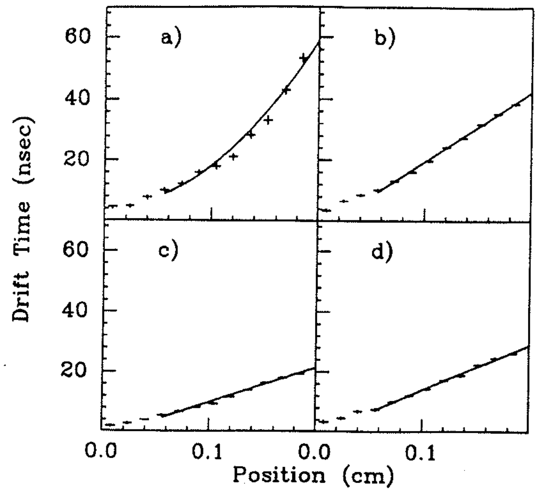

Figure 3: Average drift time of straw cell hits vs. position as measured by the FDC module, for each of 4 gases, a) 5% Ethane, 95% CO_2, b) 4% Methane, 3% CO_2, 97%Ar, c) 20% CO_2, 80% Ar, d) 50% Ethane, 50% Ar. The solid line is a fit over the range shown.

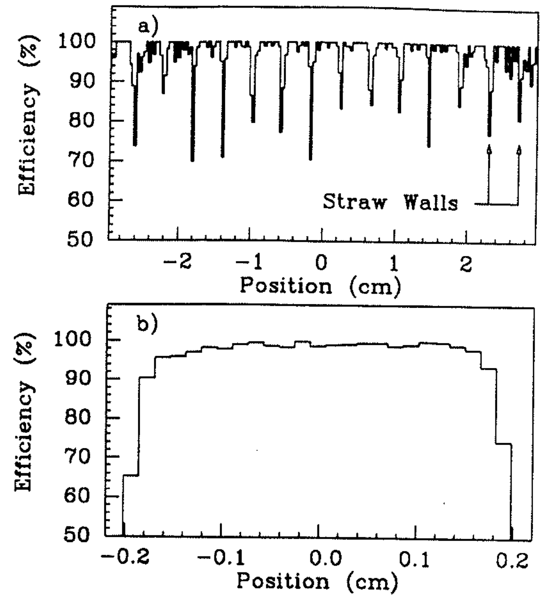

Figure 4: Hit efficiency in a straw tube versus position, a) for a single layer of straw cells, b) average for a single straw cell.

sults, obtained using test beam tracks and using FADCs to read out the module, are shown in Table 2. If a track

Table 2: Test Beam results using FADC readout.

Gas Mixture	Resolution (μm)	Hit Efficiency
5% Ethane, 95% CO_2	350	83%
4% Methane, 3% CO_2, 97%Ar	230	96%
20% CO_2, 80% Ar	280	96%
50% Ethane, 50% Ar	180	96%

is found in the FDC module, we check if a hit is found in each layer of the straw module within 1.5mm of the extrapolated FDC track. Hit efficiency is defined as the fraction of the FDC tracks for which a hit is found in the straw module. The average efficiency for single straw and for a layer of straws is shown in Fig. 4. The single hit efficiency is nearly 100% except for tracks very close to the wall of a straw. Tracks were found in the straw module using a road method, adapted from software developed for DØ central tracking chambers. We required that at least 6 of the 8 layers contributed a hit to each track. A straight line fit was then done to these hits. The position resolution is the sigma of the deviations of the hit positions from this fitted line.

A comparison of the resolution attained using TDC readout and FADC readout is shown in Fig. 5. This data was taken using cosmic rays, and using 50% Ethane, 50% Ar gas. If TDCs are used to read out the data, the resolution improves substantially as the HV applied to the module is increased. The best value of 135 μm was achieved at an operating HV of 1750V (the residuals to a track fit are shown in Fig. 6). In contrast, the resolution achieved with FADC readout, 180 μm at 1550V, does not change significantly over the range of operating HV from 1550V to 1750V.

Several considerations help us understand the differences between these two measurements. The amplitudes and risetimes for pulses obtained from a cylindrical drift cell have large variations due both to geometry (e.g. variations in track length), and due to the usual fluctuations in primary ionization. If a fixed threshold is used to find the hit position (as is the case when using TDCs), such fluctuations result in mismeasurement of the drift time. This mismeasurement is minimized by setting the threshold as low as possible (but still above the noise level), so that the measured time is most sensitive to the electrons first arriving at the anode wire. Since the TDCs are operated at a fixed threshold, the resolution therefore improves as the amplitudes of signals are boosted by increasing the sense wire HV. When FADCs are used to read out the module, the hit position is determined by using a weighted mean algorithm that uses information from the the rising edge of the pulse, but gives greatest weight to the earliest bins. This method is always most sensitive to the earliest electrons, even for small pulses. Consequently, even at low gas gains, the FADC hit finding method results in good resolution, but no appreciable improvement is expected with increasing HV. At higher gas gain, the FADCs become

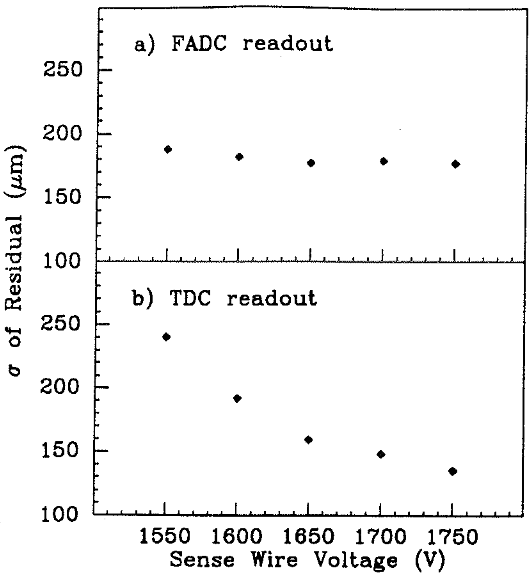

Figure 5: Straw module position resolution as a function of operating voltage, obtained from cosmic ray data, using a) FADC readout, hit positions determined by weighted mean of leading edge, b) TDC readout, at fixed threshold.

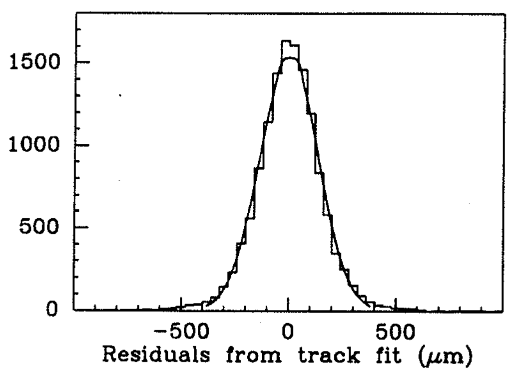

Figure 6: Deviations of hit positions from a track fit in the straw module when TDC readout is used. The module is using 50% Ethane, 50% Argon at an operating HV of $1750V$. The sigma from a gaussian fit is 135 μm.

saturated for most pulses, and information about the rising edge of the pulse is lost. The preamps themselves are also often saturated at higher gas gains. When this happens, there may be transient signals that adversely affect the time measurements made by both the TDCs and the FADCs. Additionally, although the hit finding resolution using FADCs is clearly better than the 9.4 *ns* sampling time, it is possible that this sampling time limits the resolution attainable with FADCs. Some combination of these effects may be responsible for the reduced performance of the FADCs relative to the TDCs at higher gas gains.

6 Conclusion

We have studied in a test beam and with cosmic rays the performance of a 128 channel test module made with straw tubes of 2mm radius. The information was recorded with $106MHz$ FADC units and also with TDCs (50*ps* resolution). Different gases were used and for each one the time-to-distance relation and the hit efficiency was measured. Hit finding and track finding efficiencies for single tracks exceed 95%. The best resolution, of 135 μm, was obtained using 50% Ethane, 50% Argon and reading out the information with the TDCs, at an operating HV of $1750V$. When TDC readout is used, the resolution improves substantially with increasing the HV applied to the tubes. The resolution achieved with a readout using FADCs is about 180 μm at an operating HV of $1550V$. At this voltage, the FADC readout results in a lower resolution than when was achieved when TDC readout is used. At higher gas gains, the resolution obtained with FADC readout is believed to be limited by the dynamic range of the electronics.

7 Acknowledgements

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Performance of $2mm$ Radius Straw Tube Drift Cells

Tests performed at NWA Testbeam at Fermilab, 1991-1992.

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Presented by Robert Avery

Introduction

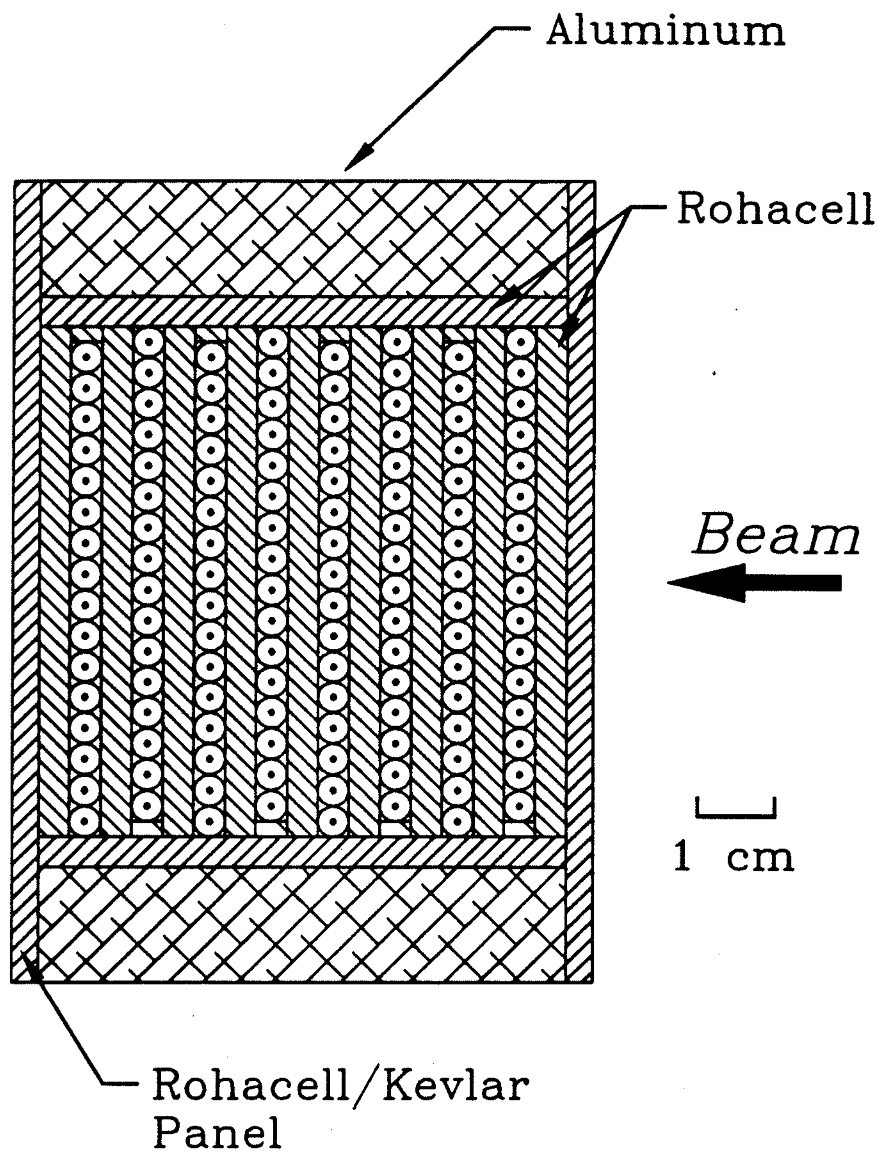
We study the performance of a **straw tube drift chamber** made with $2mm$ radius straws. These tests were conducted at the Fermilab test beam facility. Data were taken using test beam particles, and studies were continued using cosmic rays. We tested the chambers performance while varying:

- Gas mixture
- Chamber high voltage
- Read out electronics (FADCs and TDCs)

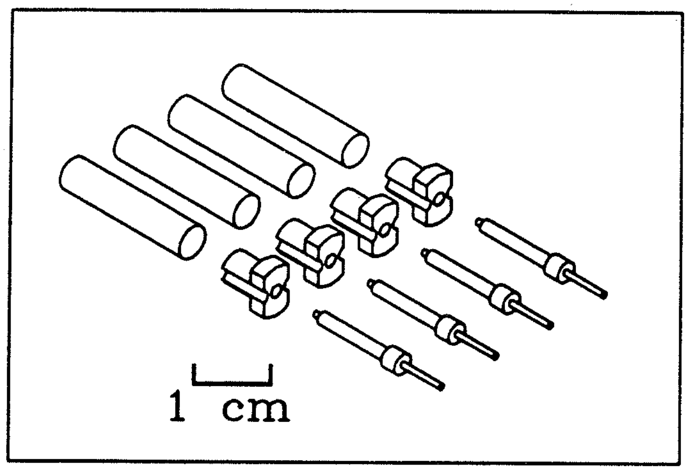
This study was part of an effort to explore tracking options for the DØ collider experiment at Fermilab when the new FNAL injector becomes operational.

Chamber Construction

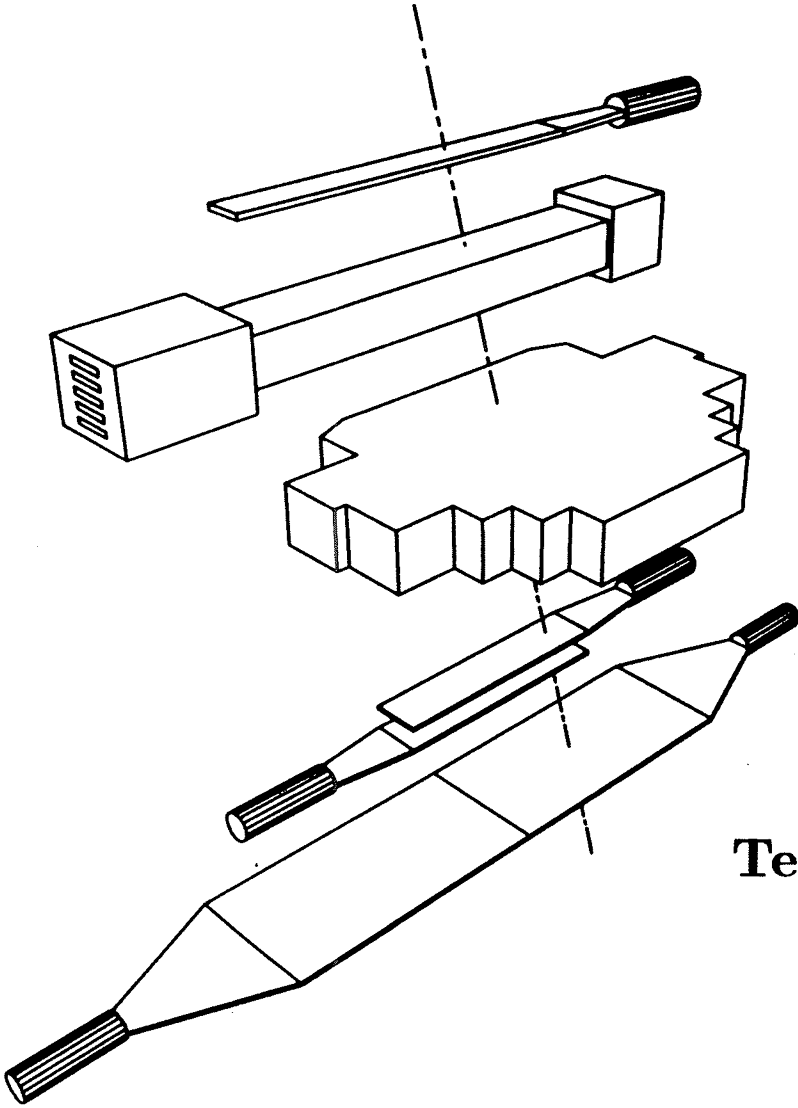
- 8 layers of 16 straws each separated by a $4mm$ Rohacell
- Alternate layers staggered
- Straws: Aluminized mylar, $50\mu m$ thick



- Two aluminum inserts center wire relative to the tube
- Sense wire $32\mu m$ gold plate tungsten, $100gr$ tension
- Survey: deviations $< 125\mu m$



Cosmic ray trigger setup



Trigger Counters

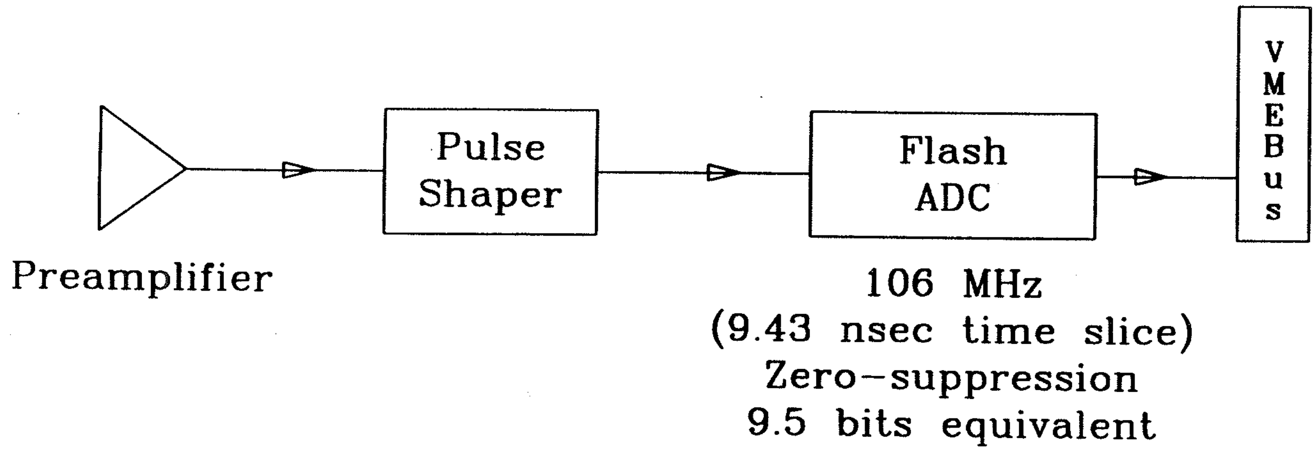
Straw Chamber

Drift Chamber, Module from DØ tracker
Provides independent position measurement

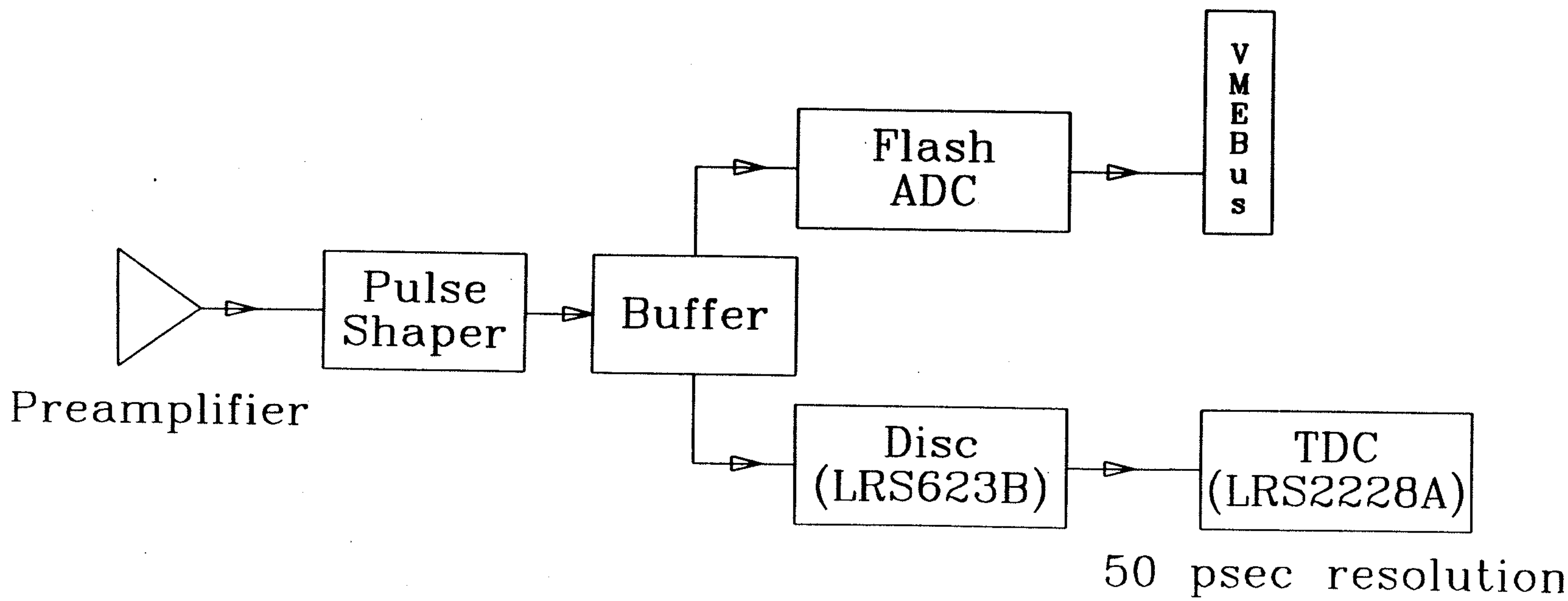
Trigger Counters

Test beam trigger setup
Essentially equivalent
(smaller counters define beam)

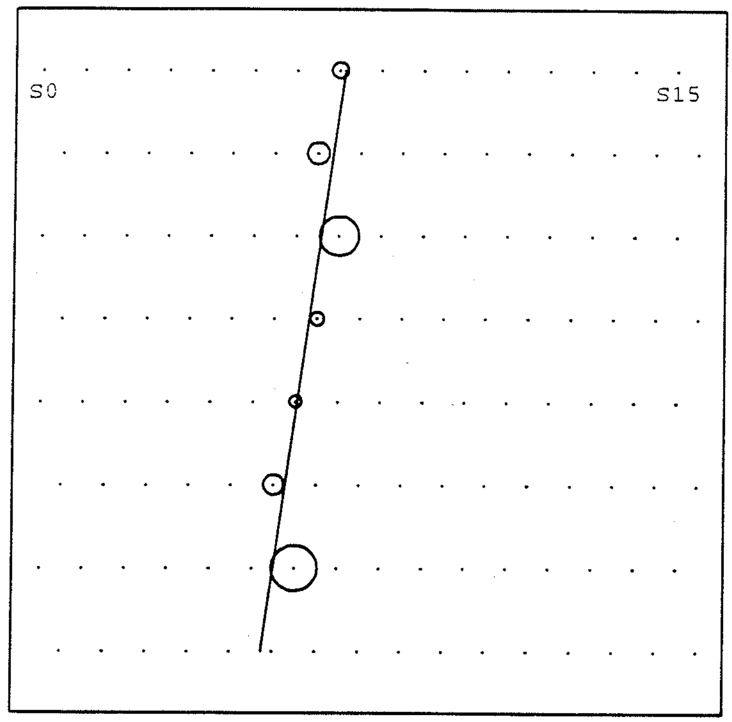
FADC Readout of Straw Chamber Used for Test Beam Data



Combined TDC & FADC Readout of Straw Chamber Used for Cosmic Ray Data



Cosmic Ray Track in Straw Chamber



Drift times of hits indicated by circles around wires

Straw Chamber, Test Beam Results

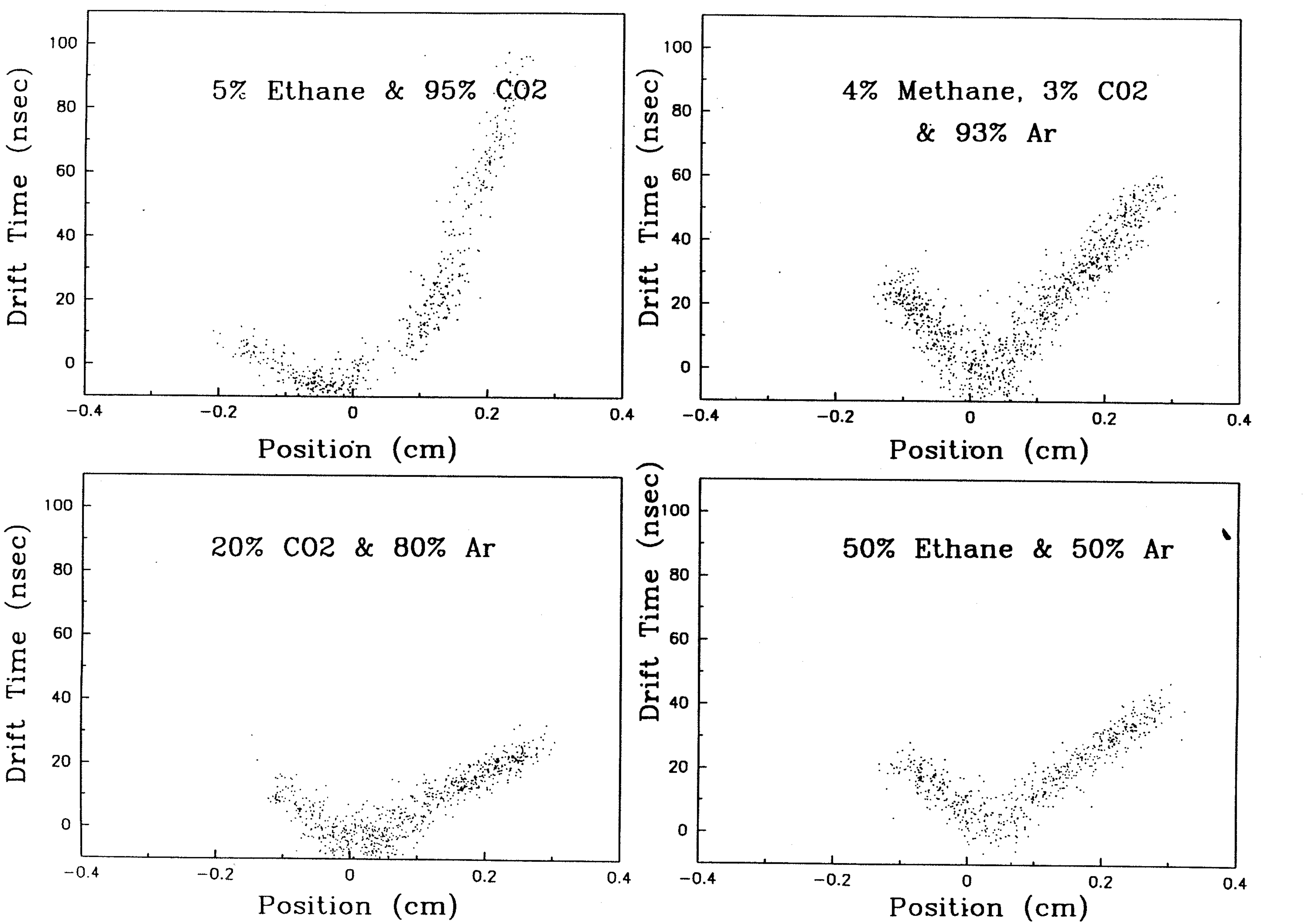
Operating Parameters

Gas Mixture	Operating Voltage (V)	Time to Distance Relation Used
5% Ethane, 95% CO_2	2235	$D \propto \sqrt{t}$
4% Methane, 3% CO_2 , 97%Ar	1275	$D \propto t$
20% CO_2 , 80% Ar	1400	$D \propto t$
50% Ethane, 50% Ar	1550	$D \propto t$

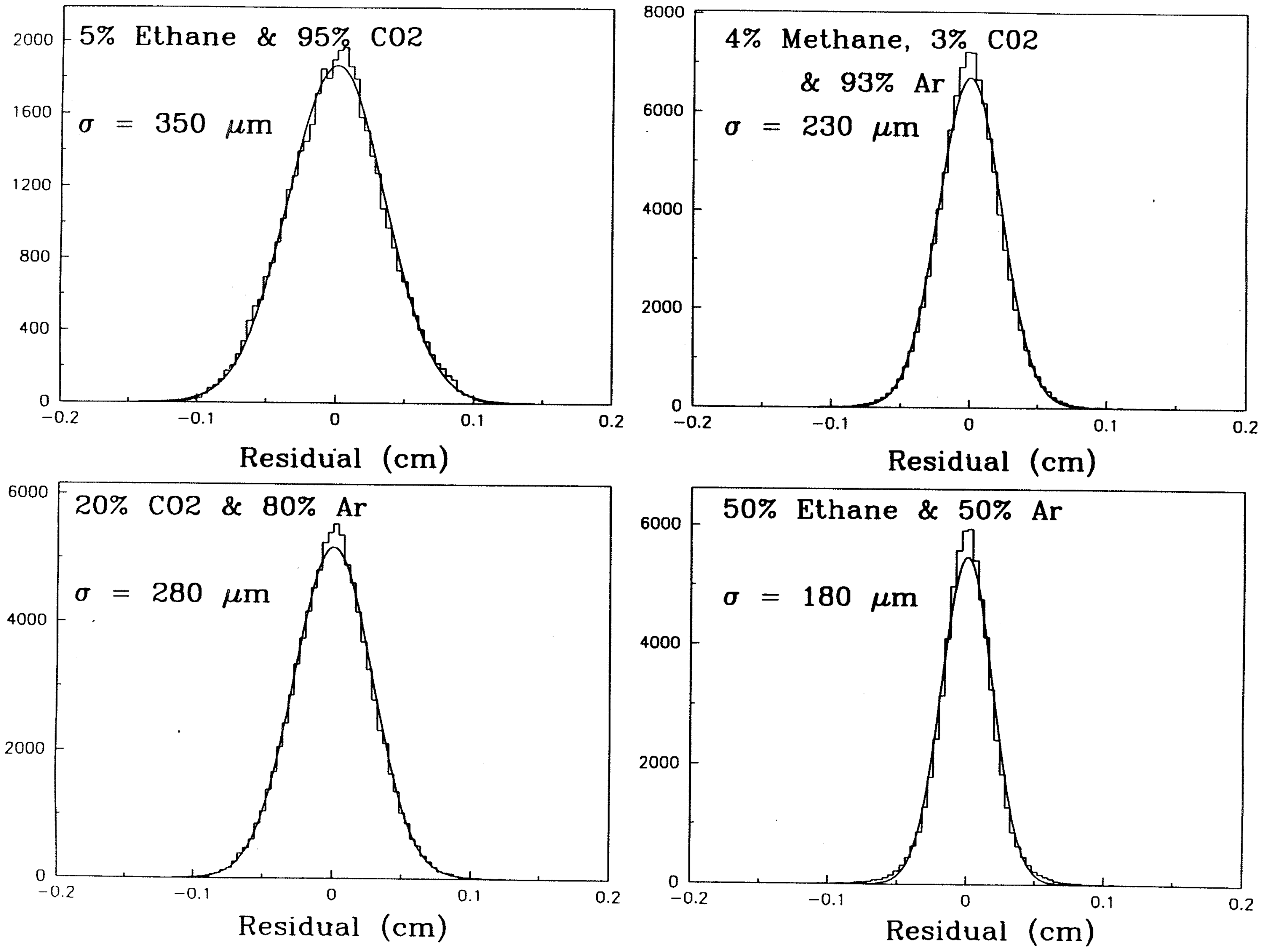
Results

Gas Mixture	Resolution (μm)	Hit Efficiency	Segment Efficiency
5% Ethane, 95% CO_2	350	83%	54%
4% Methane, 3% CO_2 , 97%Ar	230	96%	91%
20% CO_2 , 80% Ar	280	96%	78%
50% Ethane, 50% Ar	180	96%	94%

Drift Time (Straw cell) vs Position (FDC cell)

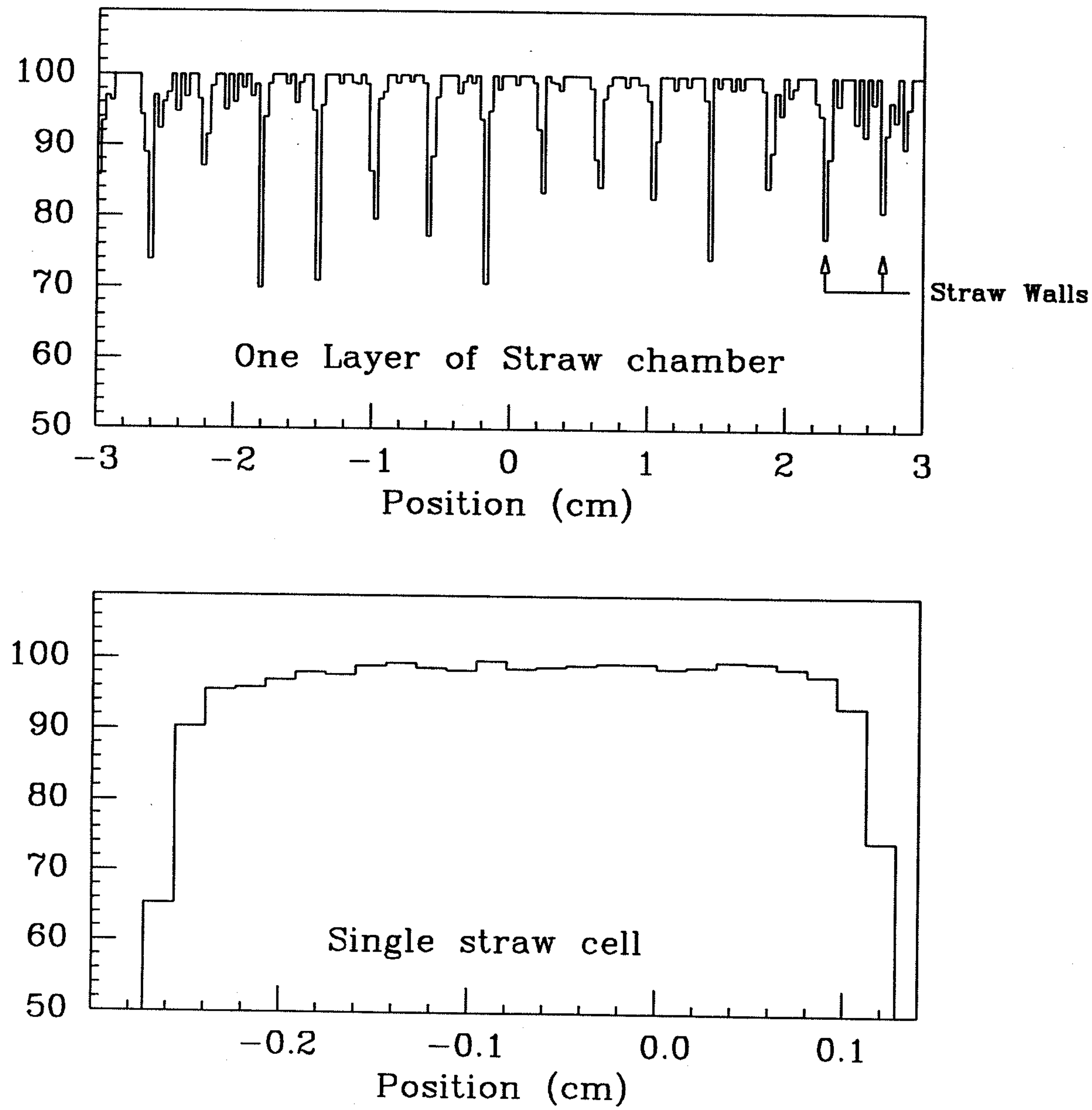


Resolution, Residuals to Track Fit



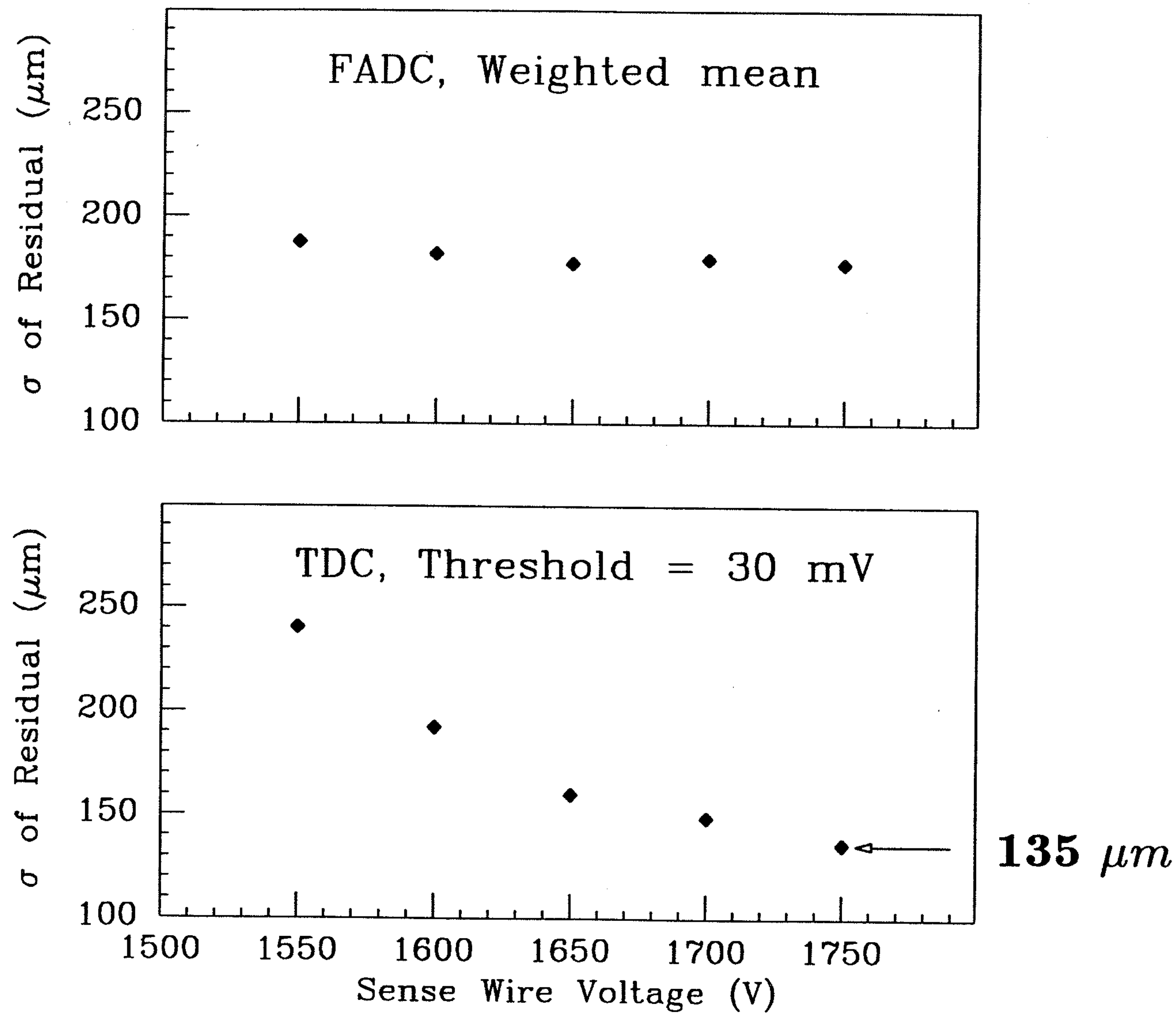
Straw Chamber

Hit Finding efficiency



Straw Chamber, Cosmic Ray Results

Position Resolution vs Operating Voltage



50% Ar, 50% Ethane

Conclusion

We have collected Test Beam data and Cosmic Ray data with a **straw tube drift chamber**. We have attained a **resolution of 135** μm using TDC readout and 50% Ethane & 50% Ar gas. **Hit finding and track finding efficiencies for single tracks exceed 95%**. We have compared resolution using TDC readout and using FADC readout. We found that for low gas gains, the FADC readout, combined with a weighted mean hitfinding algorithm, results in a lower resolution than when TDC readout is used. For larger gas gain, the TDC resolution improves, exceeding the performance with FADC readout. Adequate resolution is attained using either the TDC readout or FADC readout at moderate gas gain.