LBL-31070

Physics Division

Presented at the Fifth Pisa Meeting on Advanced Detectors,
Isola d'Elba, Italy, May 26-31, 1991,
and to be published in the Proceedings

D0 Vertex Drift Chamber Construction and Test Results

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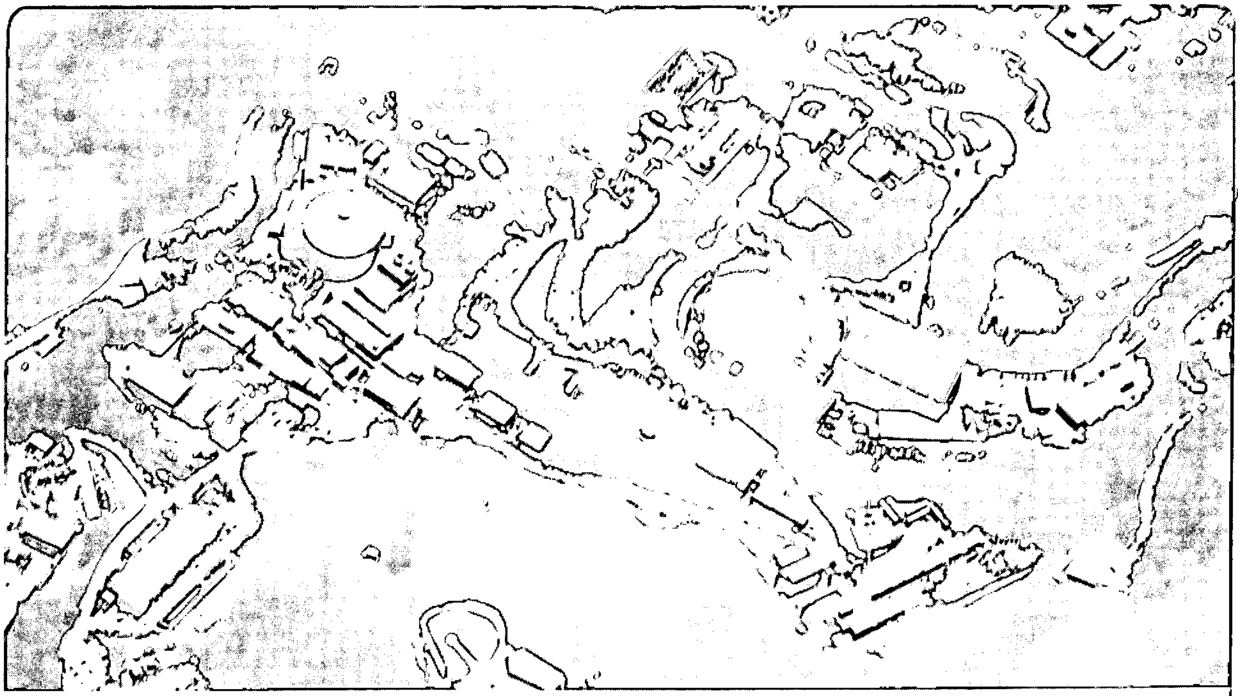

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

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This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, High Energy Physics Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

DØ Vertex Drift Chamber Construction and Test Results*

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Abstract

A jet-cell based vertex chamber has been built for the DØ experiment at Fermilab and operated in a test beam there. Low drift velocity and diffusion properties were achieved using CO_2(95%)-ethane(5%) at atmospheric pressure. The drift velocity is found to be consistent with $[9.74+8.68(|\mathbf{E}|-1.25)]$ μm/nsec where $\mathbf{E}$ is the electric field strength in kV/cm (1.0 kV/cm $< |\mathbf{E}| <$ 1.6 kV/cm.) An intrinsic spatial resolution of 60 μm or better for drift distances greater than 2 mm is measured. The track pair efficiency is estimated to be better than 90% for separations greater than 630 μm.

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*This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics, of the U.S. Department of Energy under contract No. DE-AC03-76SF00098

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1. Introduction

The general purpose DØ detector [1], designed to investigate $\bar{p}p$ interactions at the Tevatron, is now in its final assembly stage in preparation for colliding beams in 1992. At its core is a compact (r <72 cm), non-magnetic tracking system consisting of the vertex, central and forward drift chambers and a transition radiation detector [2]. The requirements placed on the vertex chamber (VTX) include good spatial resolution, good track pair resolving power, and large η coverage.

During July and August of the 1990 fixed target run at FNAL, the completed VTX was exposed to pion and electron beams under various operating conditions. The goals of this run were to optimize the VTX performance through the study of its operational parameters and to accumulate calibration data in a well controlled environment. Results presented here include measurements of the distance–time relation, efficiency, spatial resolution and pulse-pair resolution.

2. Vertex chamber design

The DØ VTX is a jet-cell based drift chamber, consisting of three mechanically independent, nested layers. Each layer has its wires supported by thin (3.3 mm) G-10 bulkheads mounted on a carbon fiber tube defining its inner radius. Titanium tie rods connecting each wire bulkhead to an aluminum collar on the inner tube balance the wire tension. A fourth tube defines the outer boundary. In addition to providing mechanical support and defining the gas volumes, each tube surface facing an active volume has 1 mil thick aluminum traces on a multi-layer epoxy/Kapton laminate (carbon fiber tube at ground) which provides coarse field shaping for the jet-cell sectors. A coat of resistive epoxy ($\approx 10^{12}\Omega/\Box$) covering this artwork prevents charge build-up. Table 1 lists the design parameters for each layer.

Figure 1 shows a quadrant of the VTX illustrating the wire placement and the sector staggering between layers. The sense wires are staggered ±100 μm relative to the sector centerline to resolve left-right ambiguities. The field shaping wires, which define the inner and outer radius of each cell and line up with the coarse field shaping traces mentioned above, together with the cathode wires, which define radial planes separating the cells, produce a uniform drift field region. Two planes of grid wires at ground potential surrounding the sense wires separate the uniform drift region from the gas amplification region. Each sector has two high voltage feeds to supply the eight sense wires: one for the middle six and one for the outer two.

The sense wires (25 μm Nicotin [3] at 80 g tension, resistivity 1.8 kΩ/m) are read out at both ends, allowing axial coordinate determination through charge division. All other wires are 152 μm gold plated aluminum at 360 g.

The requirements of good spatial resolution and track pair resolving power demand a low diffusion, low drift velocity gas. A CO_2(95%)-ethane(5%) mixture at atmospheric pressure was chosen[1] to meet these requirements. A consequence of this gas choice is that the distribution of electron arrival times for a given track is broad. Electrons produced near the endpoints of a sampled track segment will drift to the sense wire in the same amount of time as electrons produced near the midpoint of a track segment which is 1.5 mm further away. Fluctuations in the the primary ionization along a track segment can appear as multiple hits (see Section 4.) Pre-mixed gas was supplied [5] for the test run with the ethane fraction maintained at $5.00 \pm 0.05\%$. Gas flowed through the VTX at 0.5–1.0 ℓ/min.

3. Testbeam setup

The Neutrino-West beamline at Fermilab supplied pions or electrons at selectable momenta ranging from 15–150 GeV/c. Triggers were formed from the coincidence of small scintillation counters upstream of the VTX, illuminating a 5×5 cm^2 area. Four proportional wire chamber (PWC) stations, each measuring beam particle positions in the horizontal and vertical directions, were positioned in the beamline. This system was found to have a 300 μm interpolated resolution at the position of the VTX.

A moveable table and VTX support fixture permitted control over the incident angle and position of the beam. The readout chain consisted of Fujitsu MB43458 [6] preamplifiers, shaping amplifiers [7] and digitizers based on the Sony CX20116 8-bit 106 MHz flash A/D converter (FADC) [8]. Zero-suppressed, digitized waveforms were read out and written to tape for offline analysis.

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[1] Originally dimethyl ether (DME) was chosen [4] for its lower drift velocity and higher specific ionization. However, its use was eventually abandoned due to purity and material compatibility problems.

During the first part of the run, the sense wire charge (gain) and bulk drift field were varied independently. Data were collected from exposures at several incident angles and positions along the VTX. The second part of the run was dedicated to a detailed mapping of the whole chamber.

4. Results

Figure 2 shows turn-on behavior of the VTX as a function of the sense wire's linear charge density (data points are separated by 20 V). The two curves result from different hit-finding parameters[2]. The price paid for using higher efficiency hit-finding parameters at a given voltage is an increased incidence of multiple hits of small time separation (see Figure 3.) Most of these extra hits are believed to result from primary ionization fluctuations where relatively large depositions occur near the endpoints of the sampled track segments. The remaining extra hits are due to nearby tracks. The probabilities shown in Figure 3 and all subsequent data presented here were obtained using a linear charge density of 0.72 esu/cm, corresponding to a gas gain of about 4×10^4.

Figure 4 shows the correlation of drift distance, as measured by the PWC system and drift time as measured by the VTX for a single wire and bulk drift field of 1 kV/cm. The point scatter is dominated by the 300 μm PWC resolution. Straight line fits to data in the interval 4 mm $< x <$ 14 mm, collected at $\langle \mathrm{E} \rangle = 0.966$, 1.357 and 1.642 kV/cm yield $7.27 \pm .03$, $10.69 \pm .04$ and $13.13 \pm .04$ μm/nsec respectively, where the errors are statistical only. A linear fit of these points yields a drift velocity, $v_d = v_0 + \alpha(|\mathrm{E}| - \langle|\mathrm{E}|\rangle)$, where $v_0 = 9.74 \pm 0.02$ μm/nsec, $\alpha = 8.68 \pm 0.07$ μm/nsec/kV/cm, $\langle|\mathrm{E}|\rangle = 1.25$ kV/cm and $|\mathrm{E}|$ is in kV/cm. The systematic error is estimated to be 3%, due primarily to uncertainties in the high voltage measurement. All subsequent data presented here were obtained using the 1 kV/cm drift field setting.

The intrinsic spatial resolution of the VTX was determined from a study of hits on groups of three adjacent wires. The triplet time difference, defined for a single track as $t - \frac{1}{2}(t_+ + t_-)$, is the difference between the drift time measured by one wire and the

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[2] Hit-finding is performed on the array of 1^{st} differences obtained from the FADC profiles, $D_i = F_{i+1} - F_i$: Three consecutive D_i greater than a first threshold or two consecutive D_i greater than this threshold with their sum greater than a second threshold define a hit's leading edge.

average drift time measured by its neighbors. The width of this distribution, multiplied by $\sqrt{2/3}$, approximates the intrinsic timing resolution for a single wire. Multiplying this by the drift velocity gives the intrinsic spatial resolution, σ_0, which is shown in Figure 5 as a function of the drift distance. The degraded resolution at small drift distances is due to the high and rapidly varying electric field strength near the sense wires.

An estimate of the track pair resolving power was made by application of the hit-finding algorithm to FADC profiles of single hits superimposed in software. Figure 6 shows the efficiency for finding both hits as a function of the separation in time of their leading edges. The high efficiency hit-finding parameters mentioned above were used in this study. For a 1 kV/cm drift field, a 90% efficiency is reached for tracks separated by 0.63 mm.

5. Conclusions

We have constructed and tested a vertex drift chamber for the DØ experiment at FNAL. Using CO_2(95%)-ethane(5%) at atmospheric pressure, low electron drift velocity and diffusion were achieved. A spatial resolution of 60 μm or better for drift distances larger than 2 mm and a track pair efficiency of 90% for 0.63 mm separation were achieved for 1 kV/cm drift field.

We would like to thank the LBL and Fermilab staffs for their contributions to the success of this project. This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics, of the U.S. Department of Energy under contract No. DE-AC03-76SF00098.

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[3] Nicotin is an alloy consisting of Co, Cr, Ni, Fe, Mo in the percentages 38.8, 19.3, 15.6, 13.3, 11.4 respectively. It is manufactured by Microfil Industries SA, Switzerland.

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Tables

Table 1 : Detector specifications

Figures

Figure 1 : End view of VTX quadrant showing wire placement.

Figure 2 : Sense voltage plateau curves for low-threshold (diamonds) and high-threshold (crosses) hit-finding algorithms.

Figure 3 : Probability of detecting a second hit later than a time *t* for low-threshold (solid) and high-threshold (dashed) hit-finding algorithms

Figure 4 : Distance-time correlation for 1 kV/cm field setting

Figure 5 : Intrinsic single-wire spatial resolution for 1 kV/cm field setting.

Figure 6 : Efficiency for resolving two hits as a function of their time separation.

Specification		Layer 1	Layer 2	Layer 3
Number of sectors		16	32	32
Sense wire separation	(cm)	.457	.457	.457
Inner sense wire radius	(cm)	3.73	8.40	13.00
Outer sense wire radius	(cm)	6.93	11.60	16.23
Maximum drift distance	(cm)	1.37	1.14	1.60
Length of active volume	(cm)	96.6	106.6	116.8

Table 1

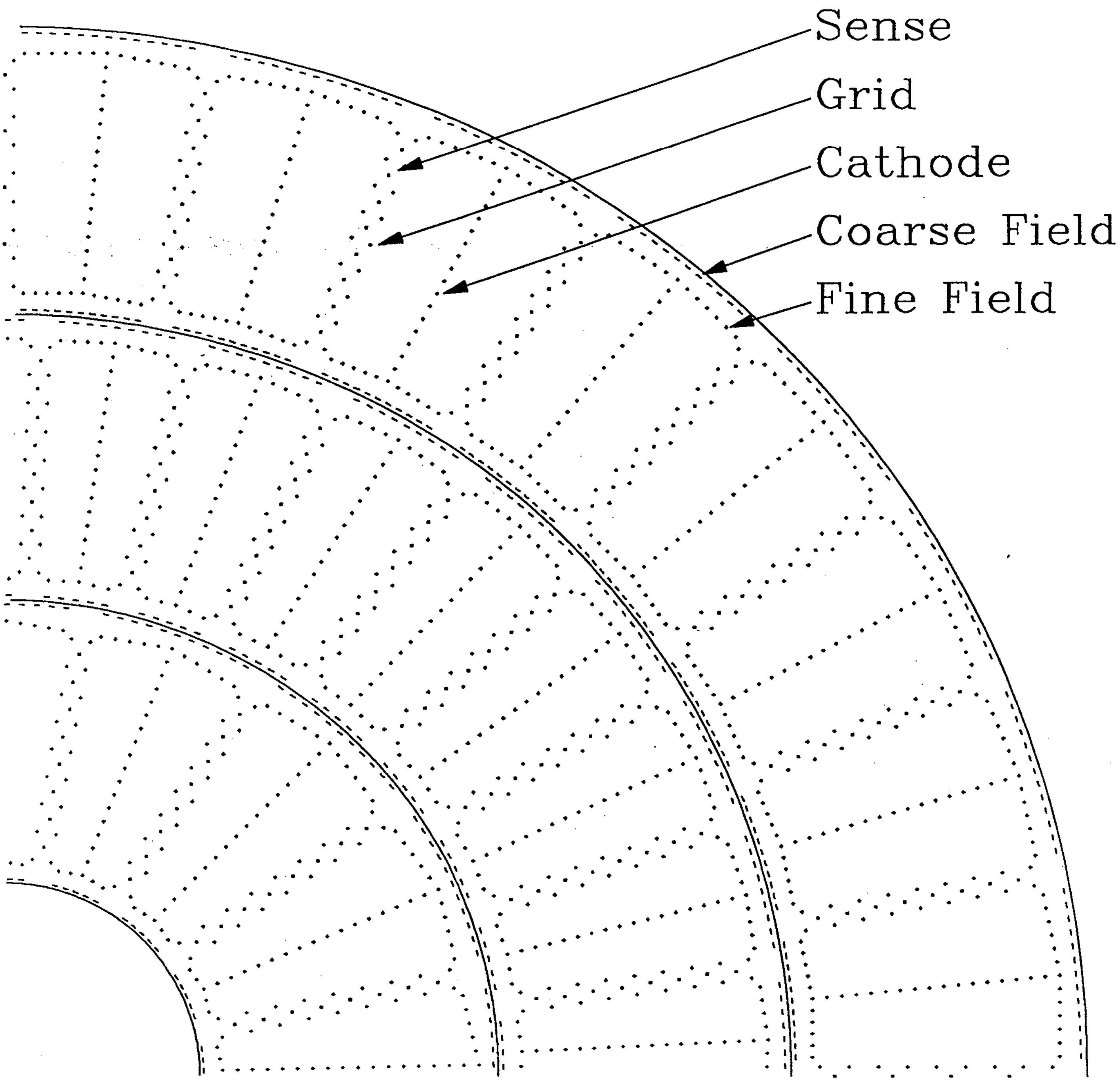
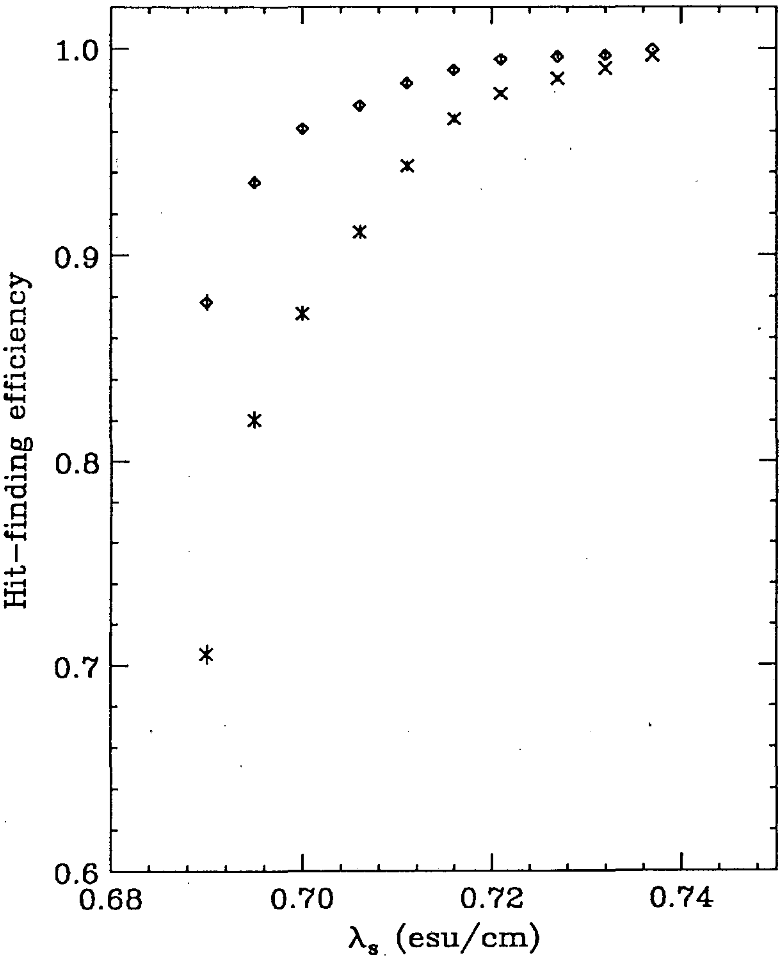


Figure 1



Hit-finding efficiency
1.0
0.9
0.8
0.7
0.6
0.68
0.70
0.72
0.74
λ_s (esu/cm)

Figure 2

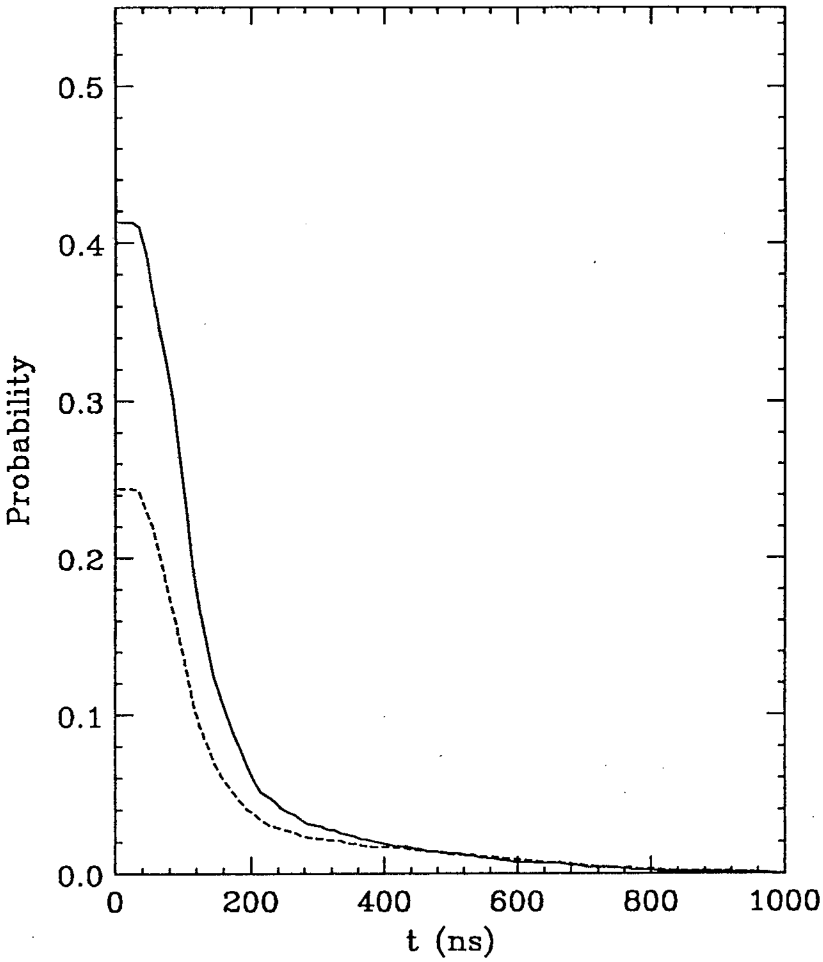


Figure 3

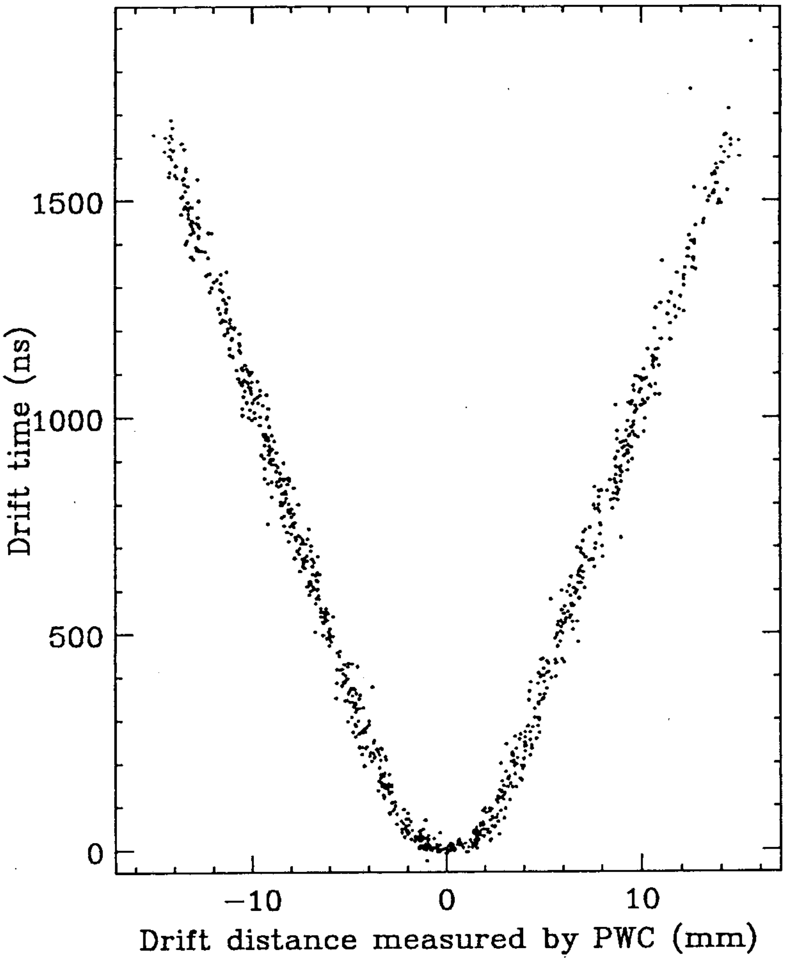

1500
1000
500
0
Drift time (ns)
−10
0
10
Drift distance measured by PWC (mm)

Figure 4

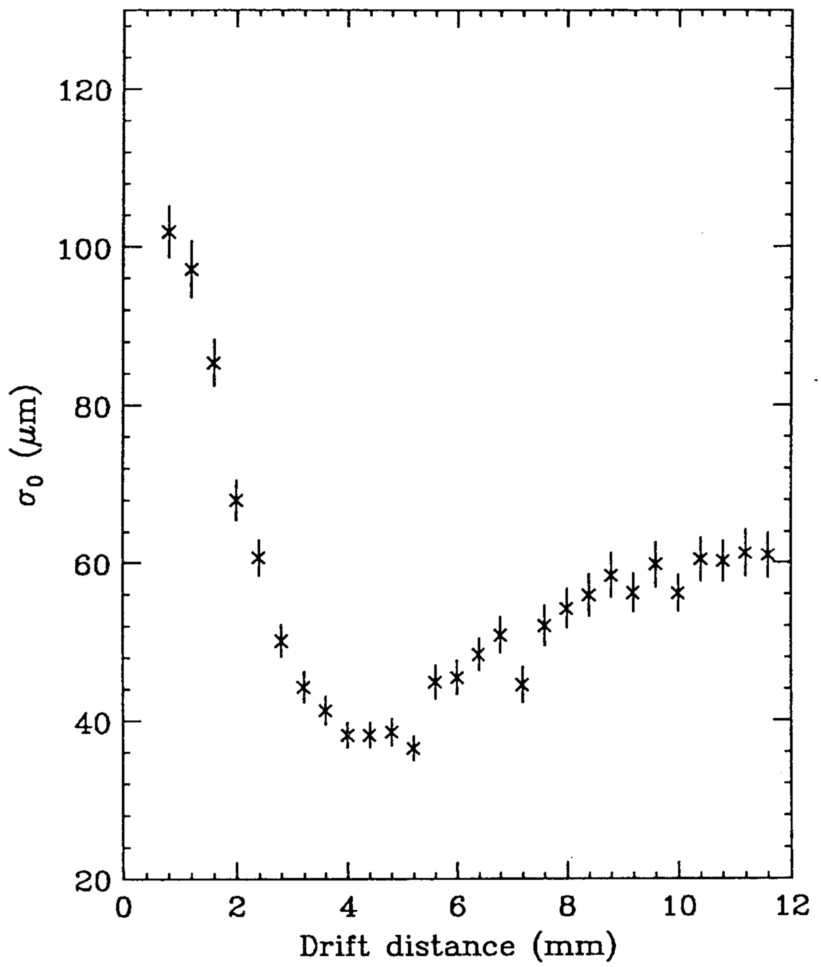
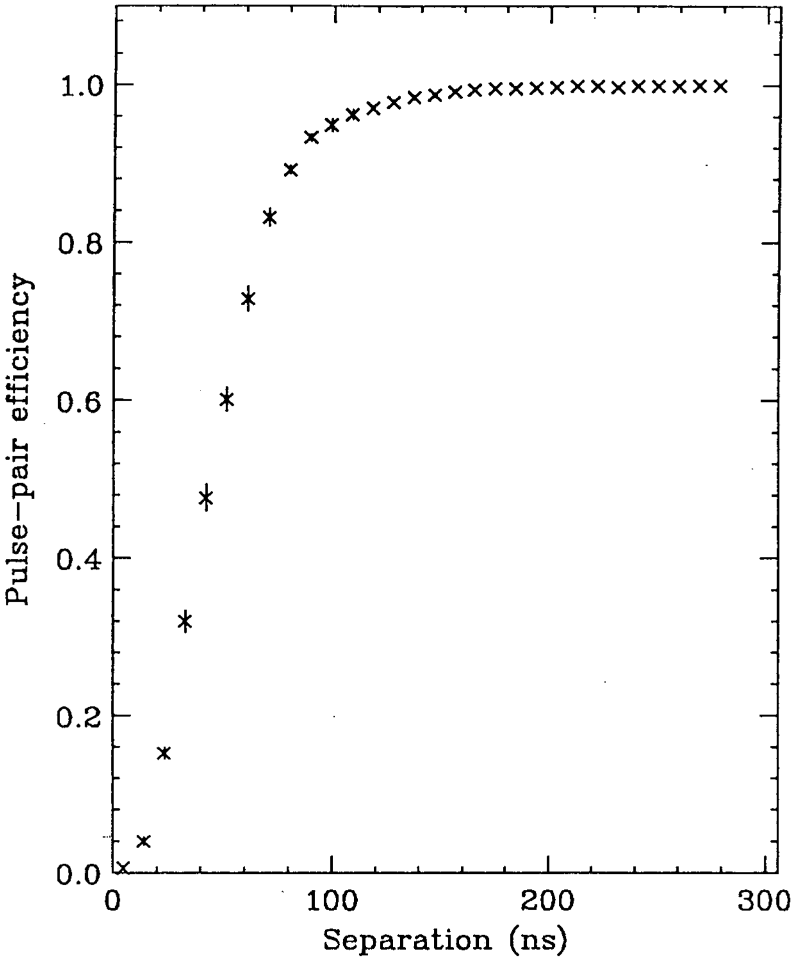


Figure 5



1.0
0.8
0.6
0.4
0.2
0.0
Pulse-pair efficiency
0
100
200
300
Separation (ns)

Figure 6

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