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DØ NOTE 1397

PULSE SHAPE SIMULATION FOR THE VERTEX DRIFT CHAMBER OF D0.

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1. Introduction.

The real value of any Monte Carlo simulation significantly depends on how accurate detector response is reproduced. This is especially true for detectors with analog output.

Pulse shape simulaton for central detectors of D0 was based on experimental results for drift chambers with gas mixtures characterized by high saturated electron drift velocity. Vertex Drift Chamber (VTX) uses "cool" gas with low diffusion and low non-saturated drift velocity. This fact can result in significant variations of pulse shapes for the detector. This can be seen in fig.1, where pulse shapes from test beam data and from D0GEANT are shown. Differences are obvious. To make pulses more "realistic" some attempts of more careful simulation of processes inside the chamber have been carried out. They are described in this paper.

2. Algorithm.

The most obvious and reasonable method of pulse shape simulation seems to create a library of pulses from experimental data (for example, test beam data). But this library should include results (preferably of high quality) for particles with different ionizations, incident angles and drift distances. If such data are not available one can try to simulate them.

Simulation program is based on the algorithm more or less standard for this kind of programs [1-3]. It produces ionization electrons along the track of the primary particle, follows them to electrodes and generates signals from anode wires.

Simulation of ionization is based on the method implemented in D0GEANT for drift chambers. It uses experimental data on mean number of primary collisions per unit length and on mean energy of the electron-ion pair production.

The program follows ionization electrons to wires taking into account direction and strength of electric field, drift velocity [4] and diffusion (figs.2,3) [3,5].

Electric field in any point of a drift cell is calculated as superposition of fields from electrodes of the cell:

$$\varphi = -2\sum_{i=1}^{N} q_i \cdot ln(\frac{r_i}{R_i}),$$

where φ is the potential in the point, q_i is the charge on the ith wire, r_i is the distance between point and the wire, R_i is its radius and N is the number of wires. Charges on wires is determined from initial conditions, namely, from their potentials:

$$U_i = -2\sum_{\substack{j=1 \\ j\neq i}}^{N} q_j \cdot ln(\frac{r_{ij}}{R_j}),\ i = 1, N,$$

where U_i is the potential on the ith wire and r_{ij} is the distance between ith and jth wires.

Signal produced by a single electron arriving at an anode wire is given by the expression [6]:

$$I(t) \approx \frac{I_0}{1 + t/t_0}.$$

Here I_0 is the amlitude determined by the gas gain, t_0 is the time constant [6]:

$$t_0 = \frac{pr_a}{2\mu E_a},$$

where p is the pressure, r_a is the wire radius, μ is the ion mobility and E_a is the field strength at anode surface.

Gas gain fluctuations are described by the Polya distribution [7]:

$$P(A) = \sqrt{A} \cdot exp(-1.5A),$$

where A is the ratio of the gas multiplication factor for a given electron to the mean gas gain.

Current generated by electrons is convoluted with electronic response, which has been found as the response of the electronic chain to step voltage (fig.4).

3. Including into D0GEANT.

The program described above is used as a preprocessing package for D0GEANT. It creates a library of pulses. The current version has sets of pulses for different drift distances and polar angles of tracks (i.e. for different numbers of primary clusters per unit length).

Modified version of D0GEANT works as follows. It passes information about particle coordinates and directions in vertex chamber to a digitization routine *SIMNEW*. This information is used to randomly pick up a signal from the corresponding set of the pulse library.

4. Results.

Electric field in a cell of the drift chamber calculated by the preprocessing package is presented in fig.5. Distance - time correlation functions obtained from the program and from test beam data are shown in fig.6. One can see that Monte Carlo data reproduce experimental results reasonably well.

In fig.7 FADC outputs are shown for test beam and for the simulation program. Main features (for example, double peaks in pulse shapes and afterpulses) can be seen in MC data. It is necessary to note, that MC pulses from the library have arbitrary normalization. Scaling coefficient can be found by comparing peak hight distributions for test beam and simulated data.

More detailed comparisons between MC and test beam data have been done. In fig.8 hit multiplicity data (number of pulses on anode wire) are presented. MC pulses have been produced by radial tracks with random azimuth angle. These distributions have been obtained using the same pulse finding algorithm for both MC and test beam data. Fig.9 gives information about distribution of time intervals between pulses. One can see that Monte Carlo and experimental results look quite similar. Some differences can be possibly explained by delta electrons, which can not be reliably simulated. It is necessary to emphasize also that the algorithm of the simulation of ionization used in the program is not adequate, especially for the VTX gas mixture. This fact could also affect results of the simulation.

5. Conclusions.

Presented results show that the described program can be used to reproduce VTX response with reasonable accuracy.

6. References.

[1]. F.Ranjard, A.Rothenberg, "EFIELD: a program to compute the electric field in a drift chamber", CERN DD/EE/80-4 (1980).

[2]. J.Fehlmann et al., "WIRCHA: program package to simulate drift chambers", ETH Zurich (1983).

[3]. "GARFIELD: a drift chamber simulation program", HELIOS note 154 (1986).

[4]. E.Oltman, Private communication (1990).

[5]. SLD Design Report, SLAC Report 273 (1984).

[6]. J.Va'vra, "Measurement and simulation of the drift pulses and resolution in the micro-jet chamber", Nucl. Instr. and Meth., 217 (1983) 322.

[7]. F.Lapique, F.Piuz, "Simulation of the measurement by primary cluster counting of the energy lost by a relativistic ionizing particle in argon", Nucl. Instr. and Meth., 175 (1980) 297.

[8]. A.Clark et al., "D0 vertex drift chamber construction and test results", D0 note 1169

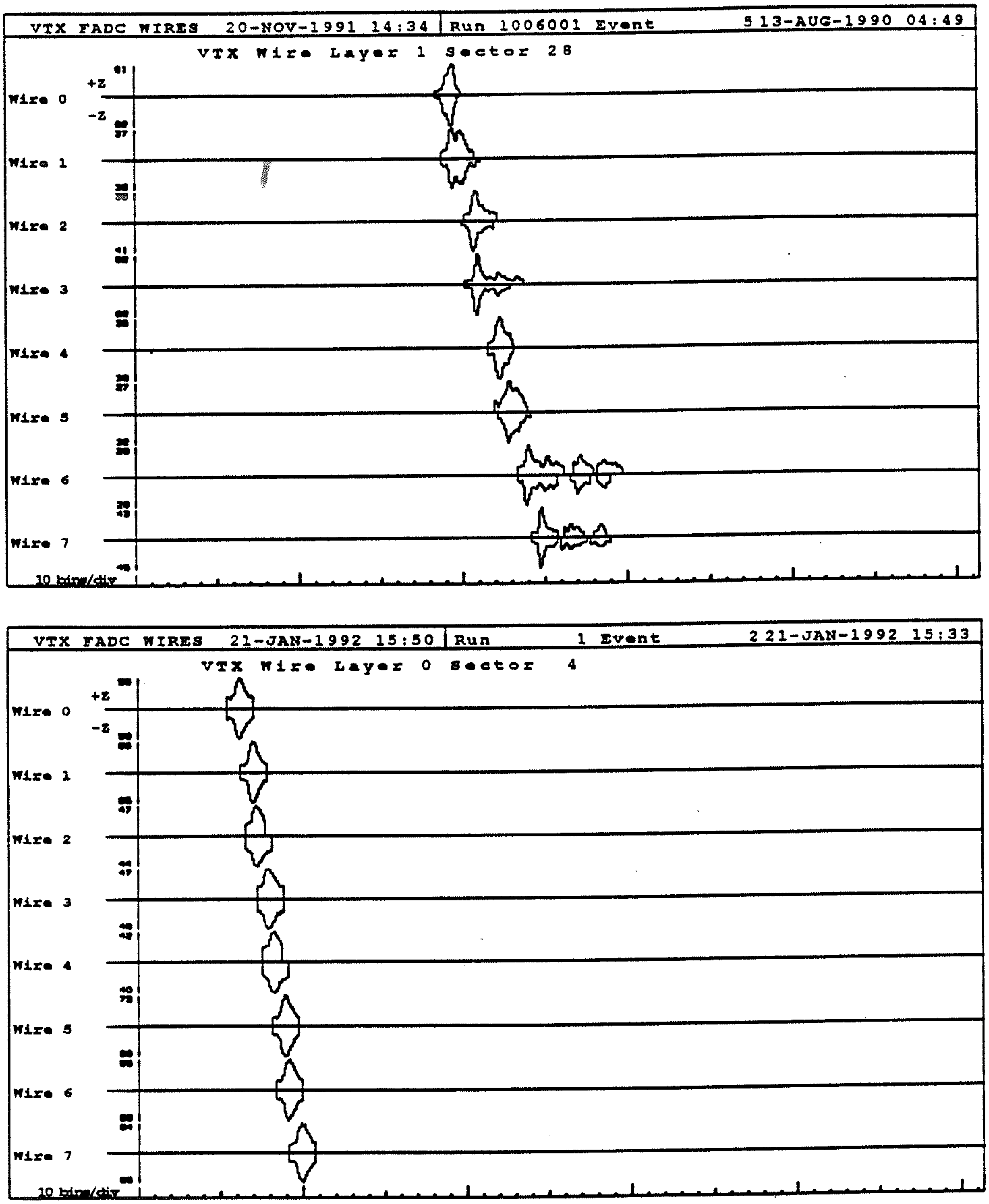

Fig.1. Pulse shapes from one sector of the VTX (FADC outputs): above - test beam data, below - D0GEANT simulation.

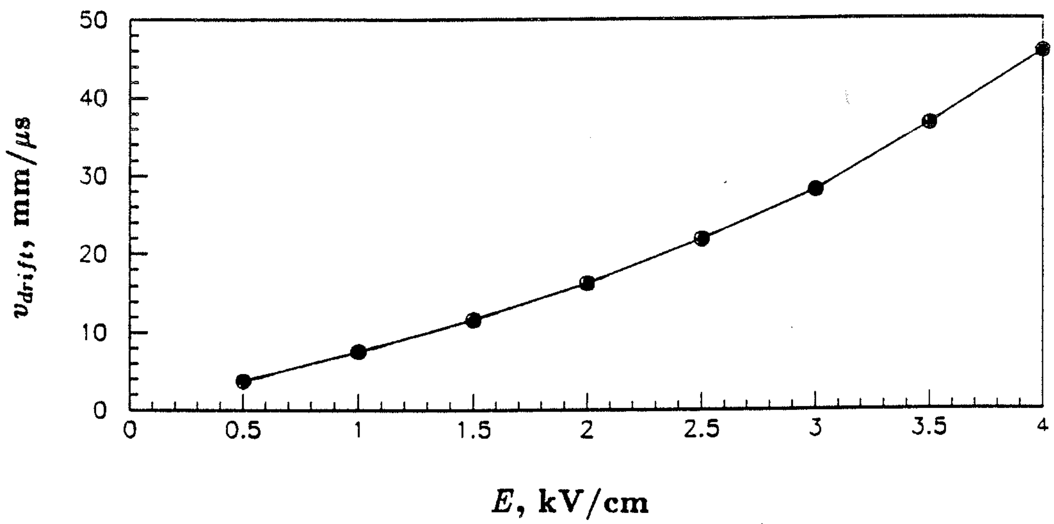

Fig.2. Electron drift velocity in VTX gas as a function of electric field.

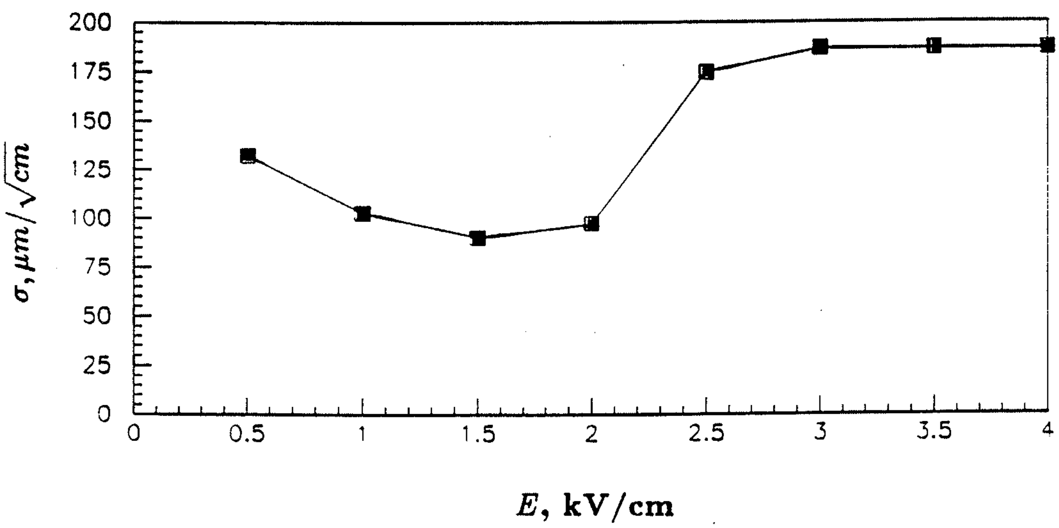

Fig.3. Diffusion as a function of electric field.

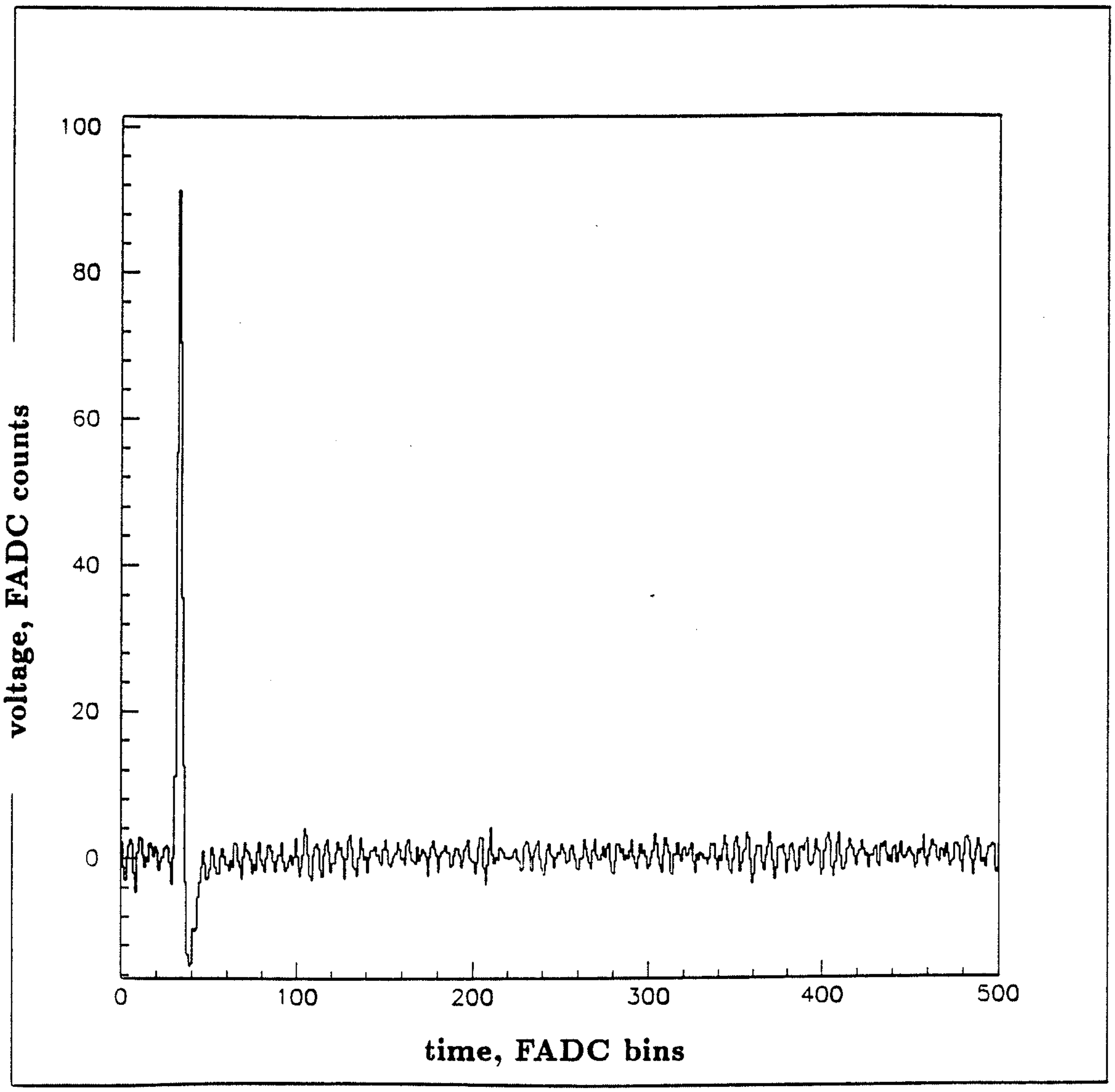

Fig.4. Response of standard VTX electronics to step voltage.

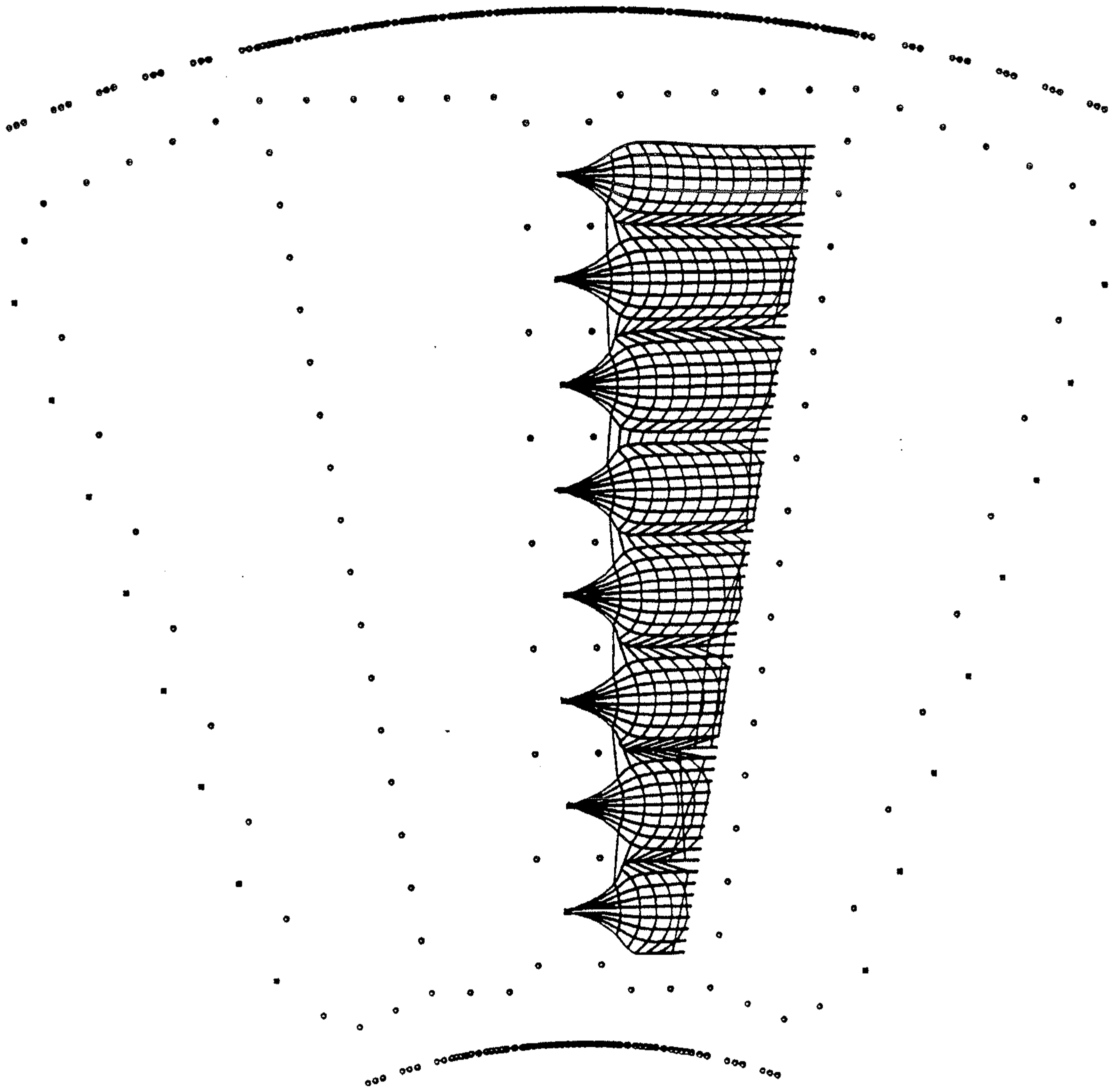

Fig.5. Configuration of electric field in a sector of the chamber. Lines of electron drift and isochrones are shown.

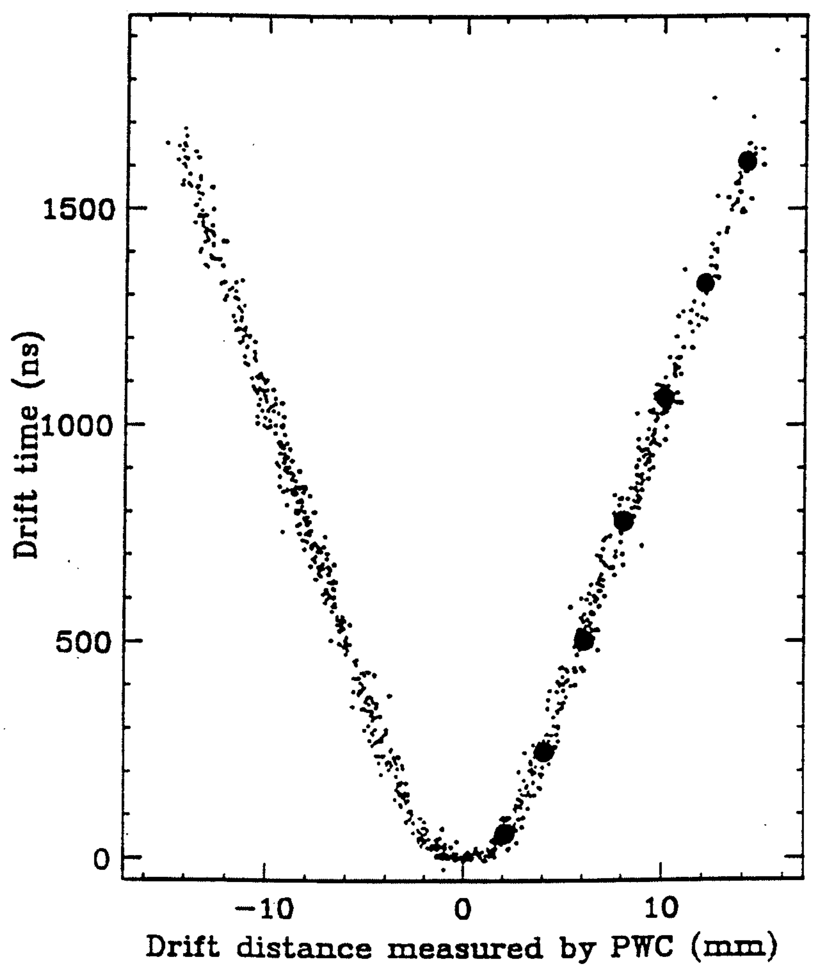

Fig.6. Distance - time correlation function: points - test beam data [8], circles - program calculation.

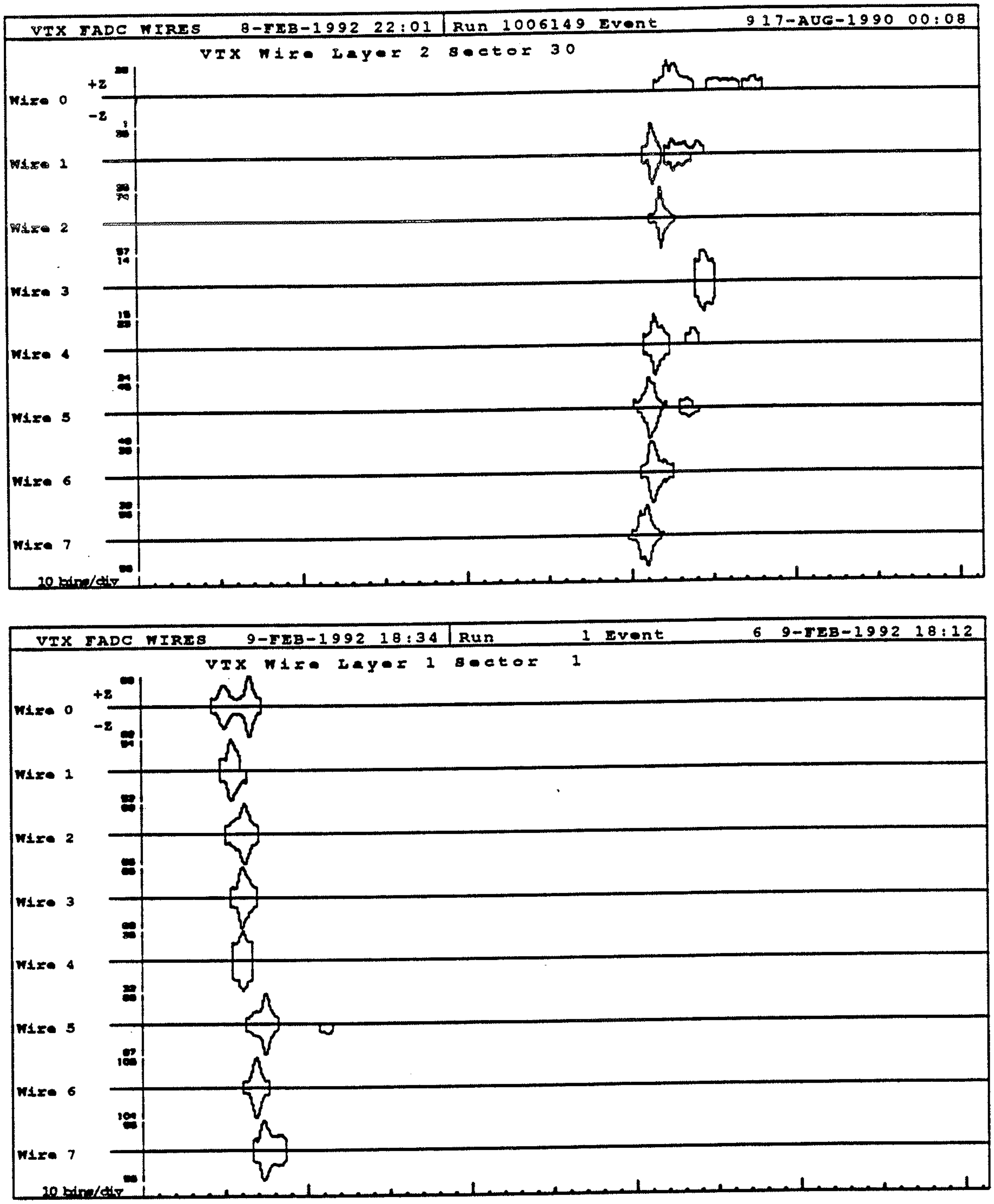

Fig.7. Pulse shapes from the VTX (FADC outputs): above - test beam data, below - Monte Carlo simulation.

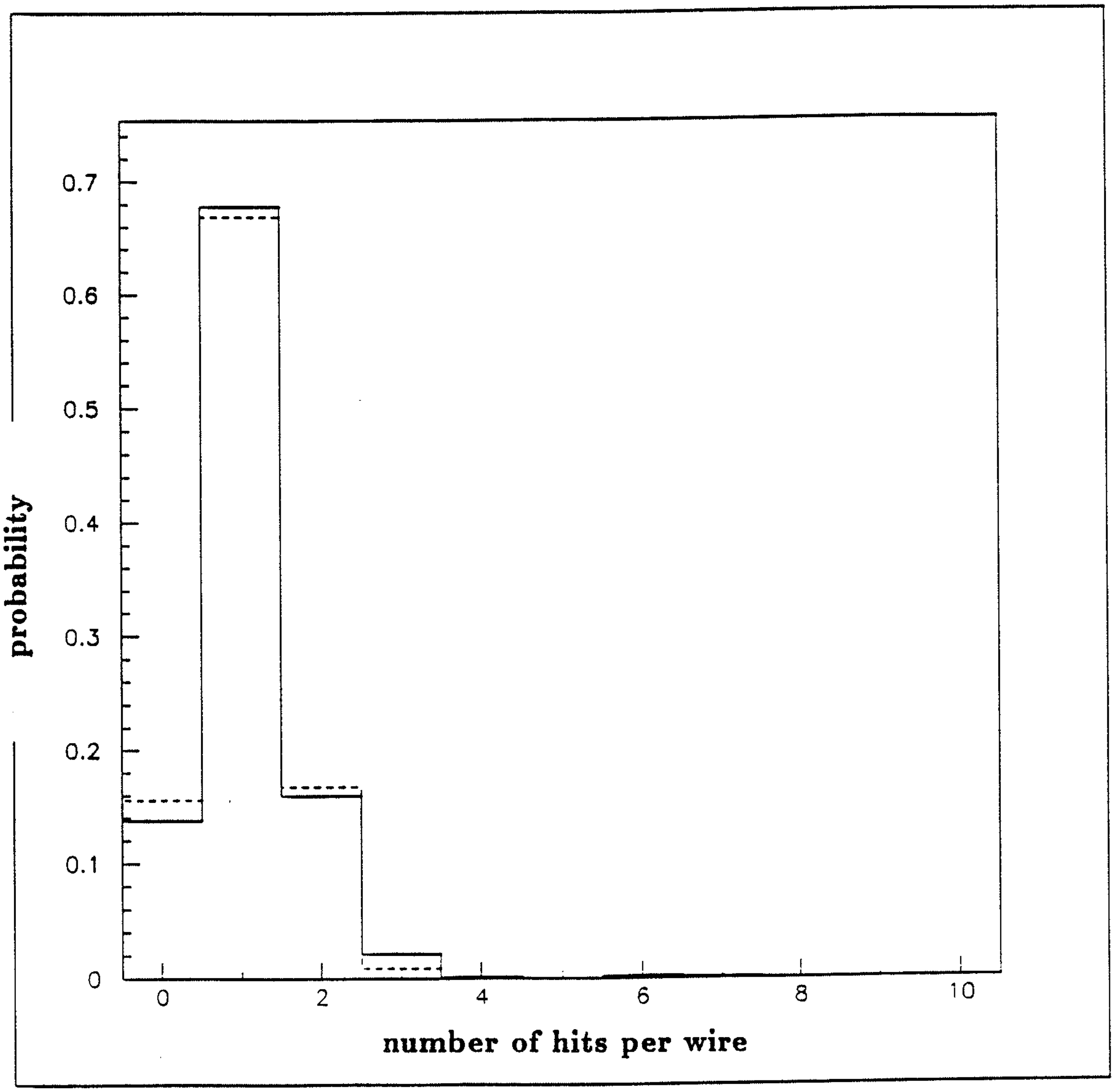

Fig.8. Distribution of the number of found pulses on anode wire: solid line - test beam data, dashed line - MC.

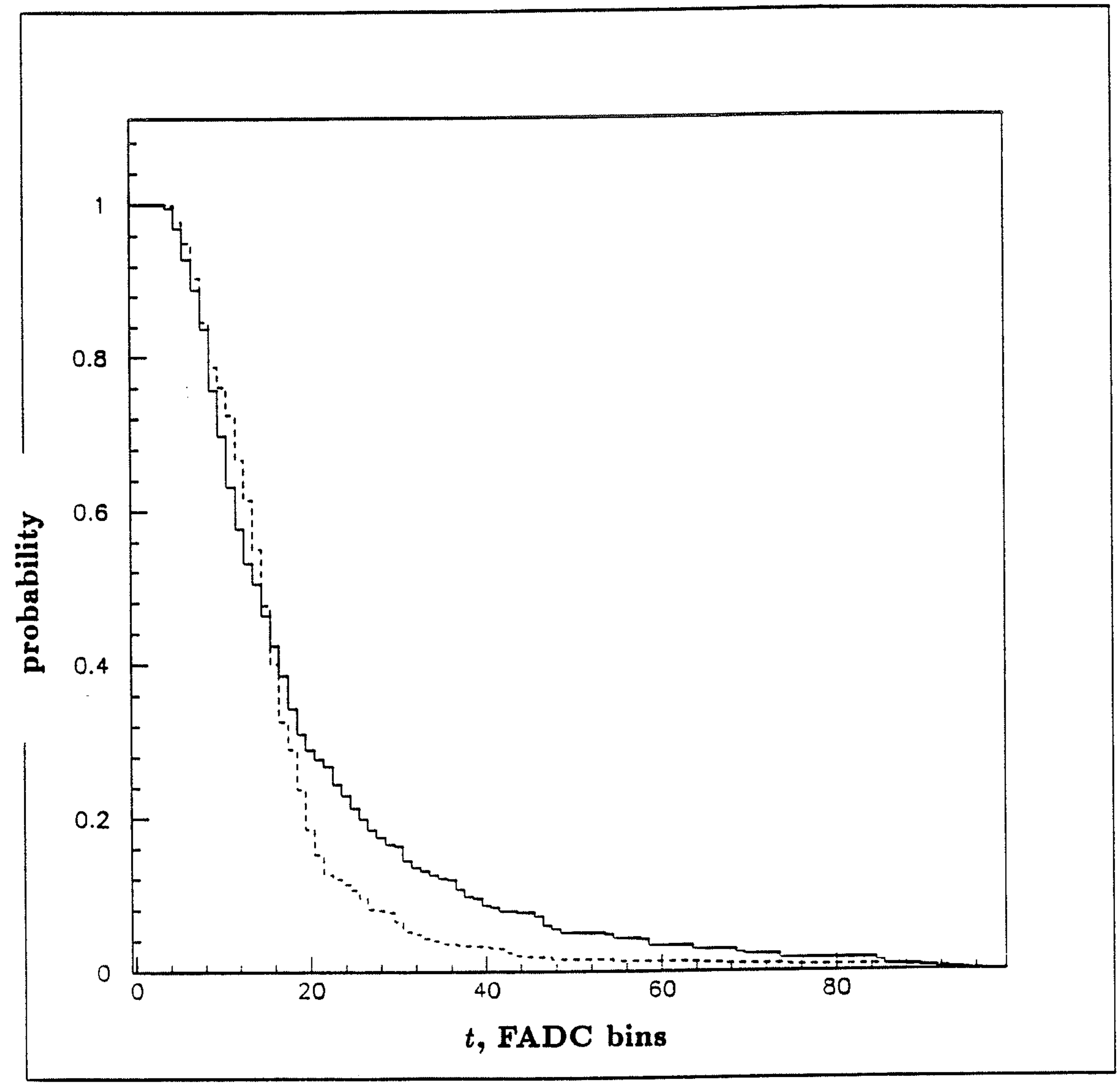

Fig.9. Probability of detecting a second hit later than a time t: solid line - test beam data, dashed - MC.