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TEMPERATURE AND ELECTRIC FIELD STRENGTH DEPENDENCE OF ELECTRON DRIFT VELOCITY IN LIQUID ARGON

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Abstract

The drift velocity of electrons (*e*) in liquid argon (LAr) has been measured at the LAr temperature range of (86.8 - 97.6) K and electric field strength from 0.5 to 7.5 kV/cm.An empirical function of drift velocity dependence on temperature (T) and electrical field strength (E) has been used for describes data:

V(T,E)=(p1(T-T0)+1)(p3*E*ln(1+p4/E)+p5*E^p6)+p2(T-T0)

with 6 parameters: p1 -p6,adjasted on the data. This function satisfies the the measured data within r.m.s. of 0.45%.

Introduction

The measurements were carried out in the framework to prepare experiment NA-48[1].The technique of signal readout from the calorimeter is based on short-time integraition of the initial electric current caused by LKr ionization of impact particles. The signal amplitude is proportional to the drift velocity of e in LKr. To achieve a rather small parameter of the constant term, less than 0.5%, the drift velocity should be stable enough, or,at least,well controlled.

Due to the large volume of cryostat containing Lkr, the electrode structure, preamplifiers of readout electronics, power supply, HV and signal cables, etc., the temperature distribution over the calorimeter volume is not well defined. The problem is to determine and take into account this temperature distribution for signal corrections using the e drift velocity.The same problem is actual for ATLAS LAr calorimeters.

Thee drift velocity dependence on the temperature in noble liquids has been studied in some previous works were the temperature shift of e drift velocity obtained for LXe [5] is about -0.5%/K ,for LAr about -1.5%/K in [3] and [4]. These measurements for LKr are in contradiction. The temperature shifts obtained for LKr are as follows: -5%/K in [6], changing with the electrical field strength from -0.3%/K at 0.3 kv/cm to -1.4%/K at 4 kv/cm in [7], -0.87%/K in [2,8] and -0.8%/K in [10]. Probably, this shift depends on concentration of non-electro-negative impurities in LKr, different in various commercial gases as well as methods of their extra purification [3,7].

In our previous papers presents the results of precise measurements of the e drift velocity in the wide interval of temperature electrical field strength and e -life time for the Kr to be used in the full scale calorimeter [2,9].An empirical function has been obtained (see Data Analysis).This function satisfies experimental data for LKr measurements within r.m.s. of 0.39%.Temperature shift about -1% /K for drift velocity was found,it is in good agreement with the resalts of measurements in paper [8] ,were carry out for the same Kr,and the rezalts in paper [10].In our measurements there is no dependence of the e-drift velocity and temperature shift on the e-life time,it is also in agreement with [10].

Here we present the resalts of measurements for LAr was produsedon the same experimental technique.

Experimental set-up

The apparatus used for the measurements is shown in fig.1.A simple parallel plates ionization chamber is installed inside a stainless steel conteiner in which the Kr or Ar are liquified.This container wrapped with superinsulation is inserted into a vacuum vessel providing thermal insulation.The electrodes are two flat disks made of stainless steel, 80 mm in diameter, separated by 10 mm MACOR ceramic spacers with an accuracy of 0.01 mm.A quartz fiber brings the UV light pulse (266 nm) from a YAG laser throught a 1.1 mm diameter hole at the centre of the anode.The light crosses the gap and produces electrons by photoelectric effect on the cathode surface.

The temperature was measured by PT-100 termoresistor installed in the middle plane between the electrodes and 2 cm outside the cell with an accuracy of 0.1 C. The chamber container was filled (~0.5 litre LKr,LAr) and termostabilized using a liquid nitrogen cooling loop located in the gas volume of the chamber. The liquid nitrogen flow was controiied (on/off) throught a valve which received its signal from an absolute pressure gauge controller measuring the vapour pressure.The lower and upper limits on the pressure were set according to the wanted liquids temperature.

A positive high voltage from a Novelec supplied was applied to the anode through HV filter (fig.2). All HV elements and the preamplifier were installed inside the vacuum vessel to avoid noise induced by the laser pulsed power supply. The cathode was connected to the preamplifier. The charge sensitive preamplifier from V.Radeka was modified to obtain a short integration time of ~100 ns. With this mode of operation we measure the quasi-current pulse indused by electrons drifting between the electrodes. The signal from the preamplifier was fed into linear amplifier (ORTEC 501 timing filter amplifier no integration or differentiation) for amplification and degitized by a LeCroy wave form analyzer connected to a Macintosh. Data were taken using the minimum 50 ns sampling time of the analyzer.The digitization was triggered by the signal indused on a photo diode by the laser pulse.

Measurements

Fig.3 shows the pulse induced by the fast electrons when the chamber is under vacuum. The rise time and slope of the pulse are practically the same and equal to ~140 ns. A typical pulse induced by drifting electrons in LKr is shown in fig.4. To reduce a stochastic noise, about 100 pulses were averaged for each measurement .

Before liquifying Ar,the chamber and the transfer line were pumped for 3 days at a temperature of 100 C,we achieved a vacuum of ~8*10-7 mbar.To obtain hight purity samples the argon gas (from Air Liquid firm) was purified using HIDROSORB and OXISORB filters [11].The measurements for the e- life time value ~120 μs in LAr were done from 1 to 3 bar of the Ar vapor pressure (11 values), it corresponds to the (86.8-97.6) K temperature interval and the (0.5 - 7.5) kv HV interval with 0.25 kv step from 0.5 kv to 3.0 kv and 0.5 kv step from 3.0 kv to 7.5 kv (20 points). In totall we have 220 points for the drift time. After 1 hour of termostabilization the temperature variation was less than 0.1 C while measuring.

Data Analysis

The drift time is measured from the crossing of the base line and front edge of the pulse and the crossing of the plateau and the back edge of the pulse as shown on fig. 4 and 5. The exponential form of the plateau is due to the capture of the drifting electrons by impurities and defines the e-life time in liquids.Two points on this plateau with a time difference t and amplitudes A1 and A2 define the electron life time T following the equation :

$$T=-t/\ln(A2/A1)$$

The accuracy of the measurements is estimated to be ~1% for the electron life time and ~10 ns for electron drift time. The drift velocity is equal to the distance between the electrodes divided to the drift time [mm/μs]. We used an empirical function [9] for data discription:

$$V(T,E) = (p1*(T-T0)+1)*(p3*E*\ln(1+p4/E)+p5*E^{p6})+p2*(T-T0)$$

where E is the electrical field strength [kv/cm], and T0=92.91 K is the avereged temperature. The best adjastment to all the data is obtained for the following values of the parameters p1-p6:

-0.016863, -0.0083412, 0.18088, 8.9751, 1.4614, 0.32891

Fig.6 shows the deviation of all the 220 experimental points from our fit, the r.m.s. deviation is 0.45%. It is in agreement with the accuracy of our measurements and there is no regular devlation for any points (fig.7,8). An example of the fit for the drift velocity vs HV data at the 86.8 K temperature are shown in fig. 9.The relative temperature shift for the drift velocity at certain velue E can be obtain by the following way:

$$(dV/dT)/V=-1.69\%-0.83\%/V(T0,E)$$

Conclusion

We have measured the electric dependence and temperature dependence of the electron drift velocity in liquid krypton and argon. A variation of about -1%/K for Lkr and about -2%/K for LAr was found.No dependence of the drift velocity on the electron life time was observed.All data for both liquids can be parametrized by the same formula.

Acknowledgements

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[11] OXISORB, Messer Griesheim GmbH production.

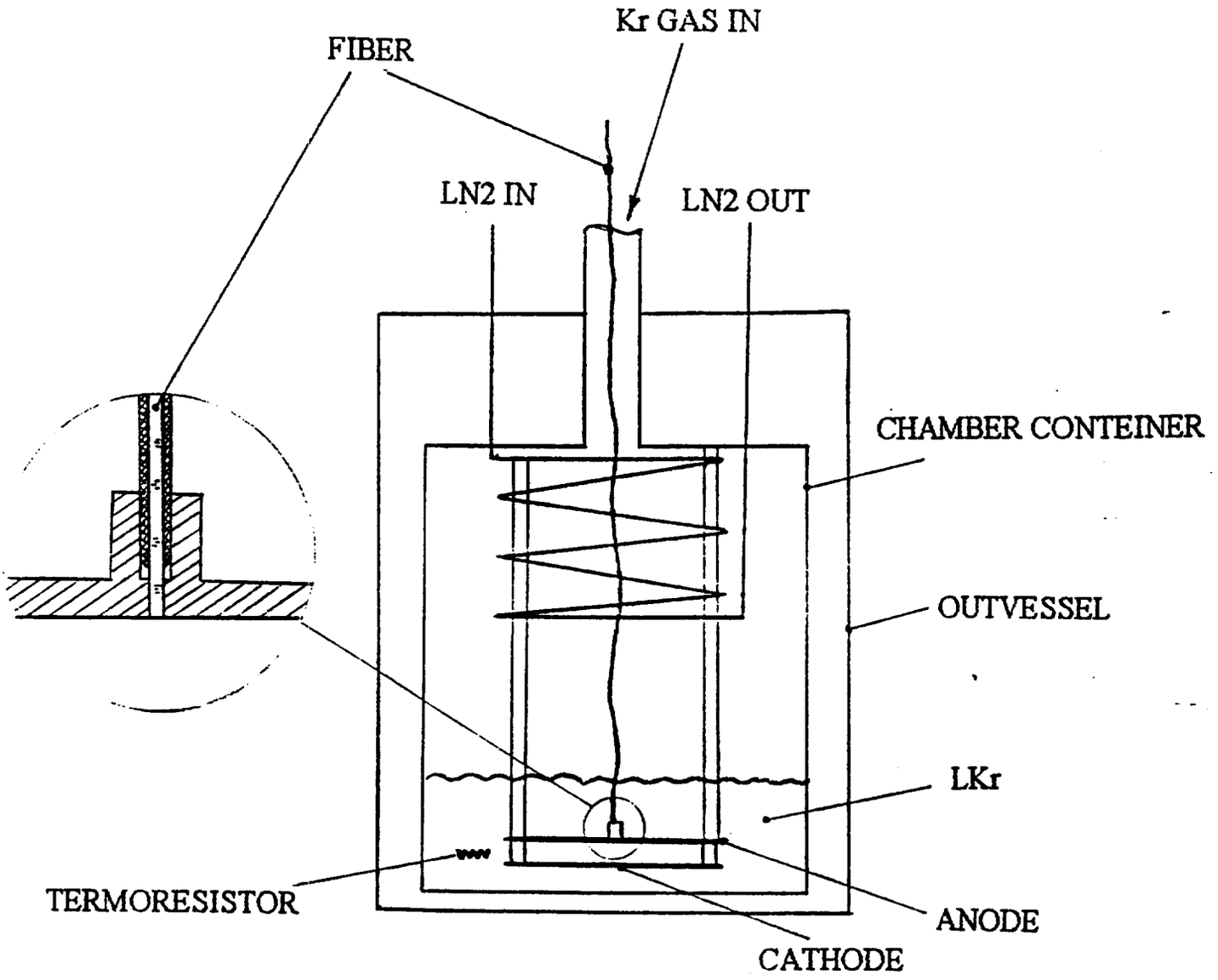

Figure 1 Apparatus

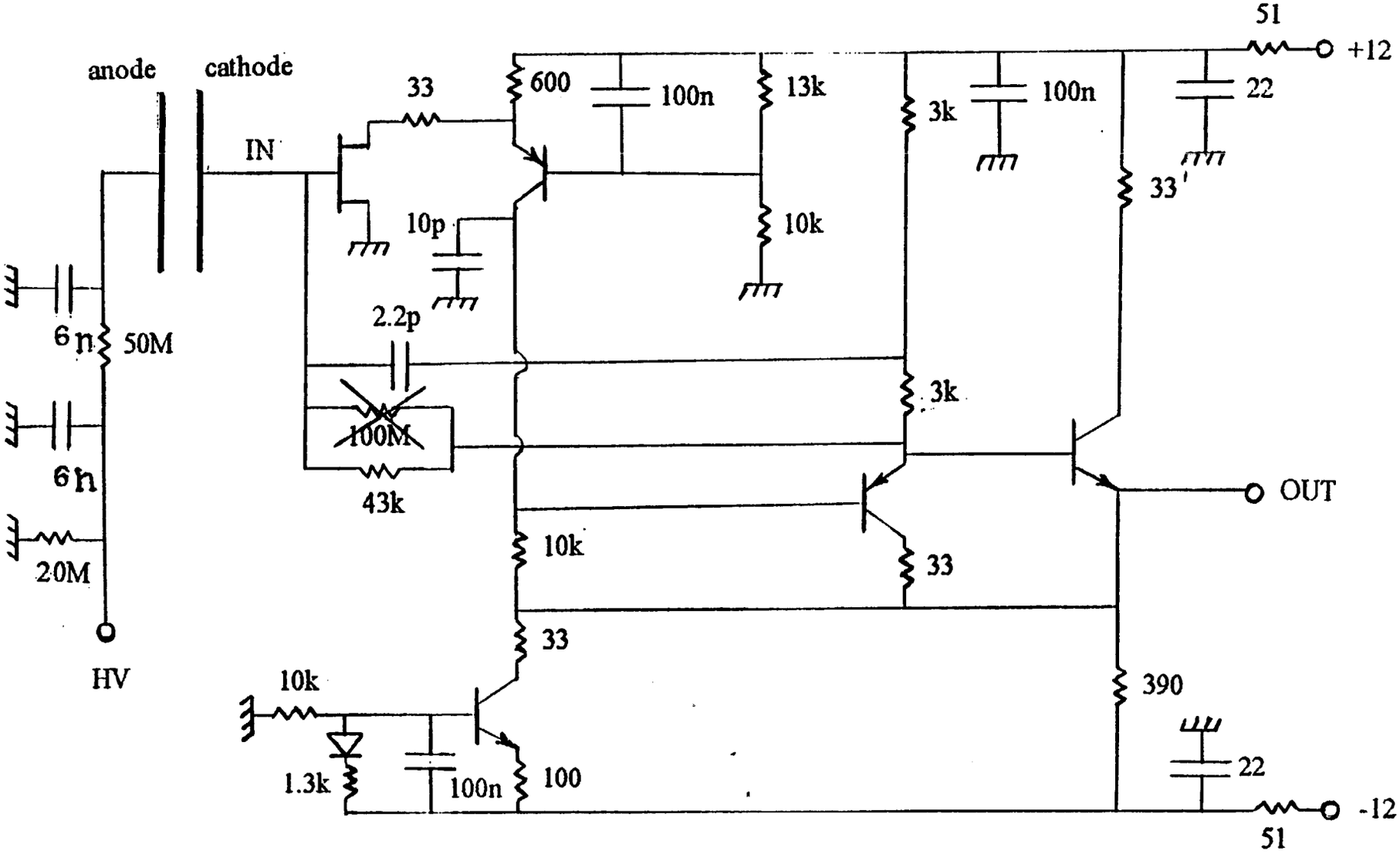

Figure 2 Preamplifier diagram

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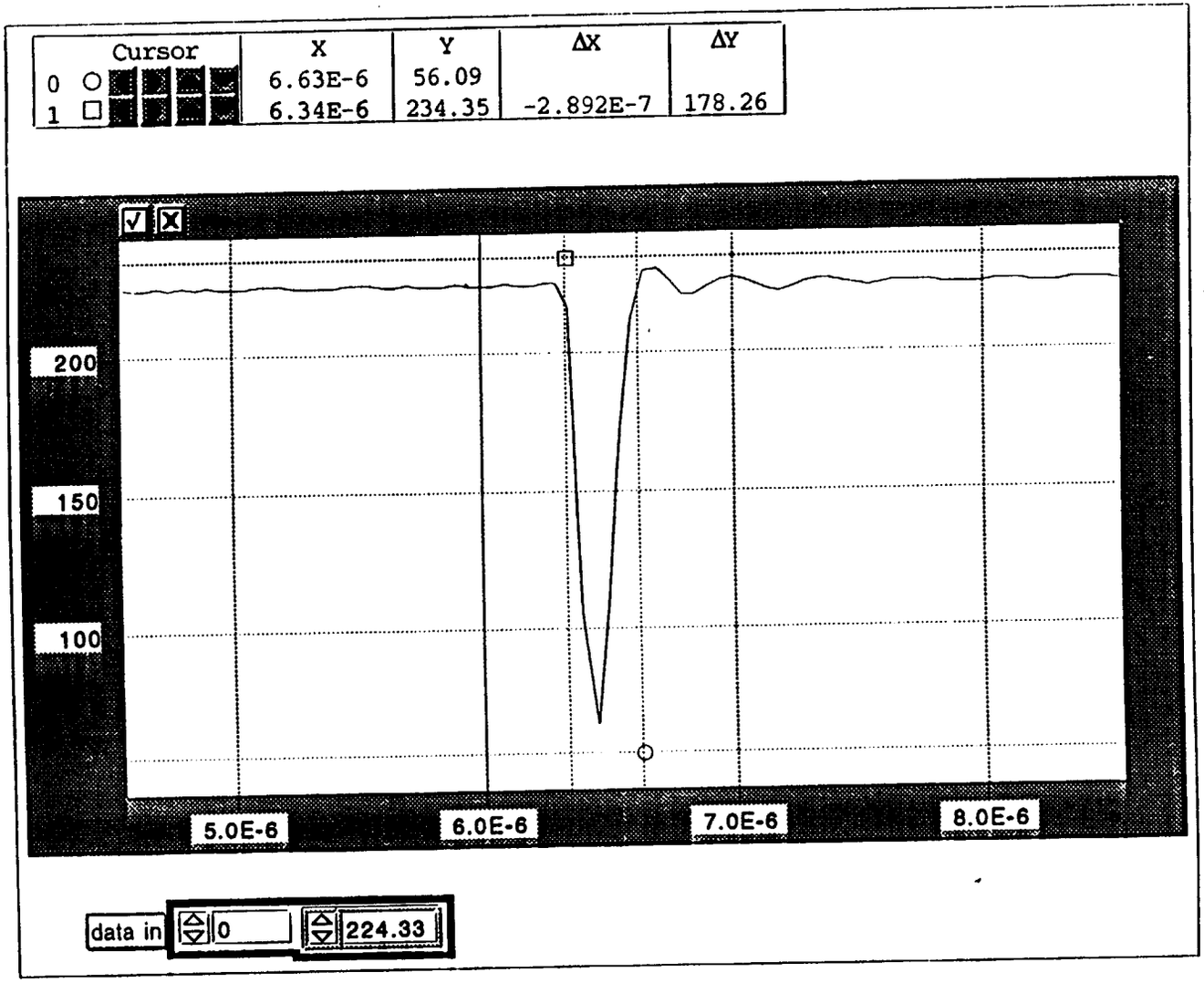

Figure 3 Pulse in vacuum

Front Panel

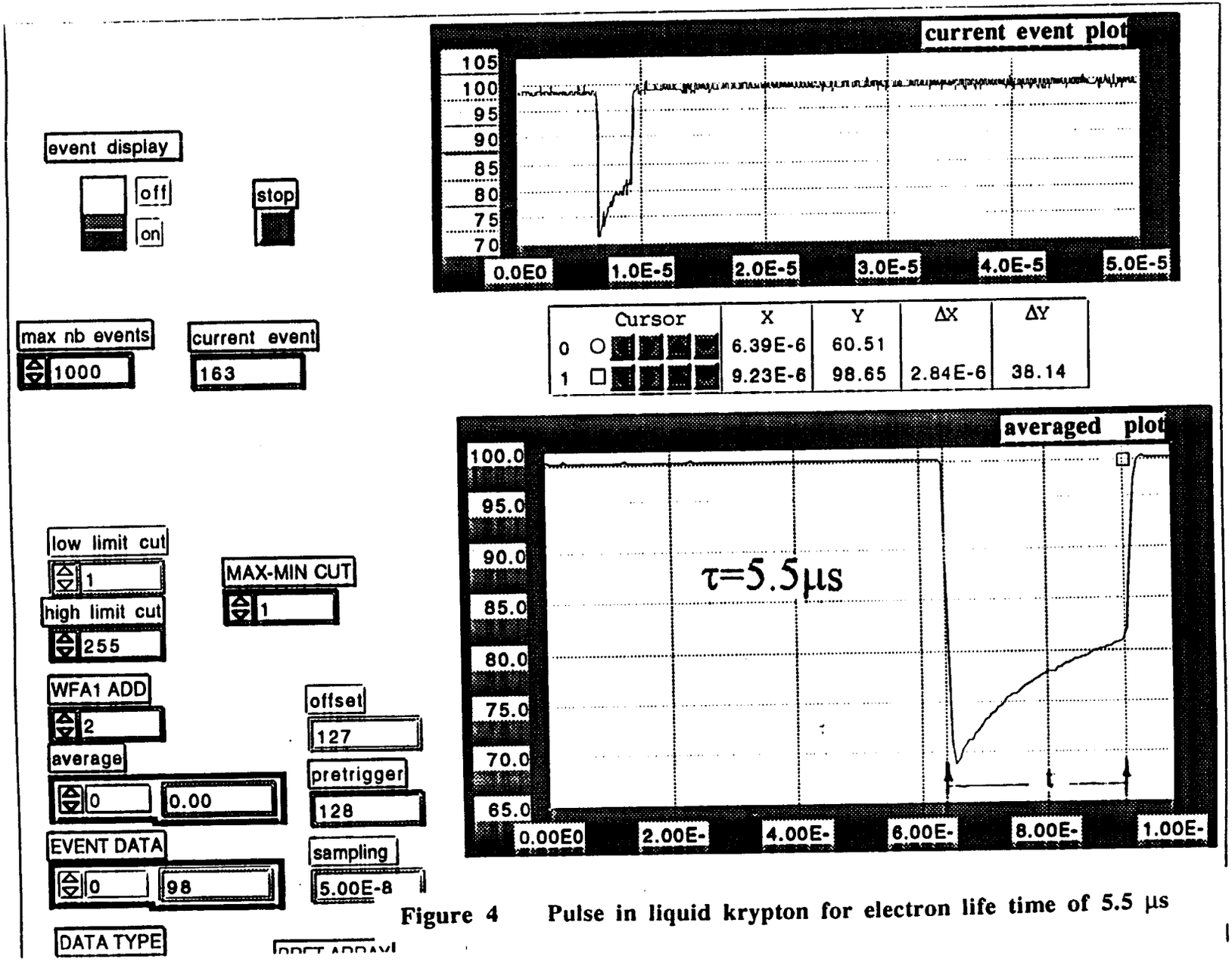

Figure 4 Pulse in liquid krypton for electron life time of 5.5 μs

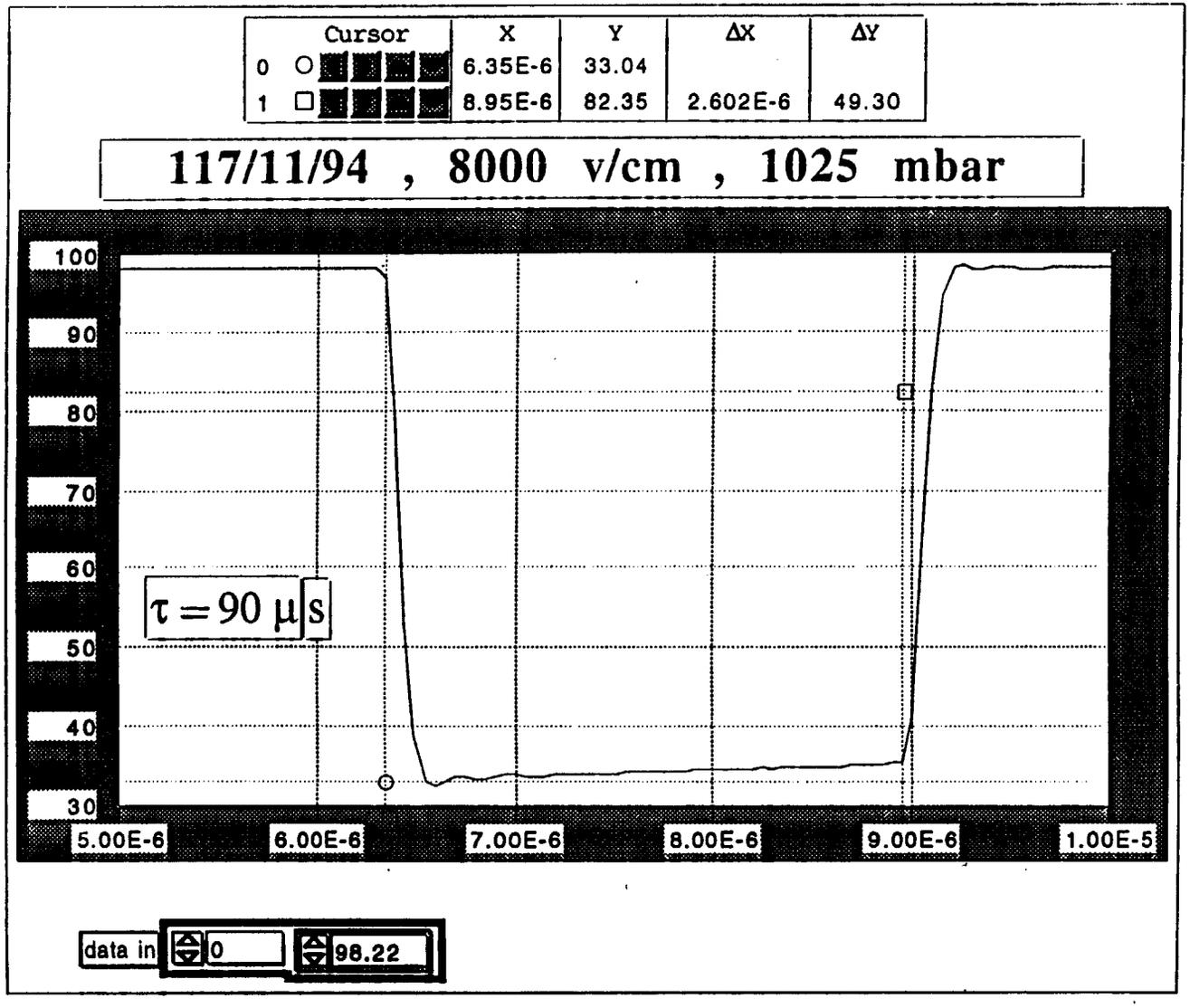

Figure 5 **Pulse in liquid krypton for electron life time of 90 μs**

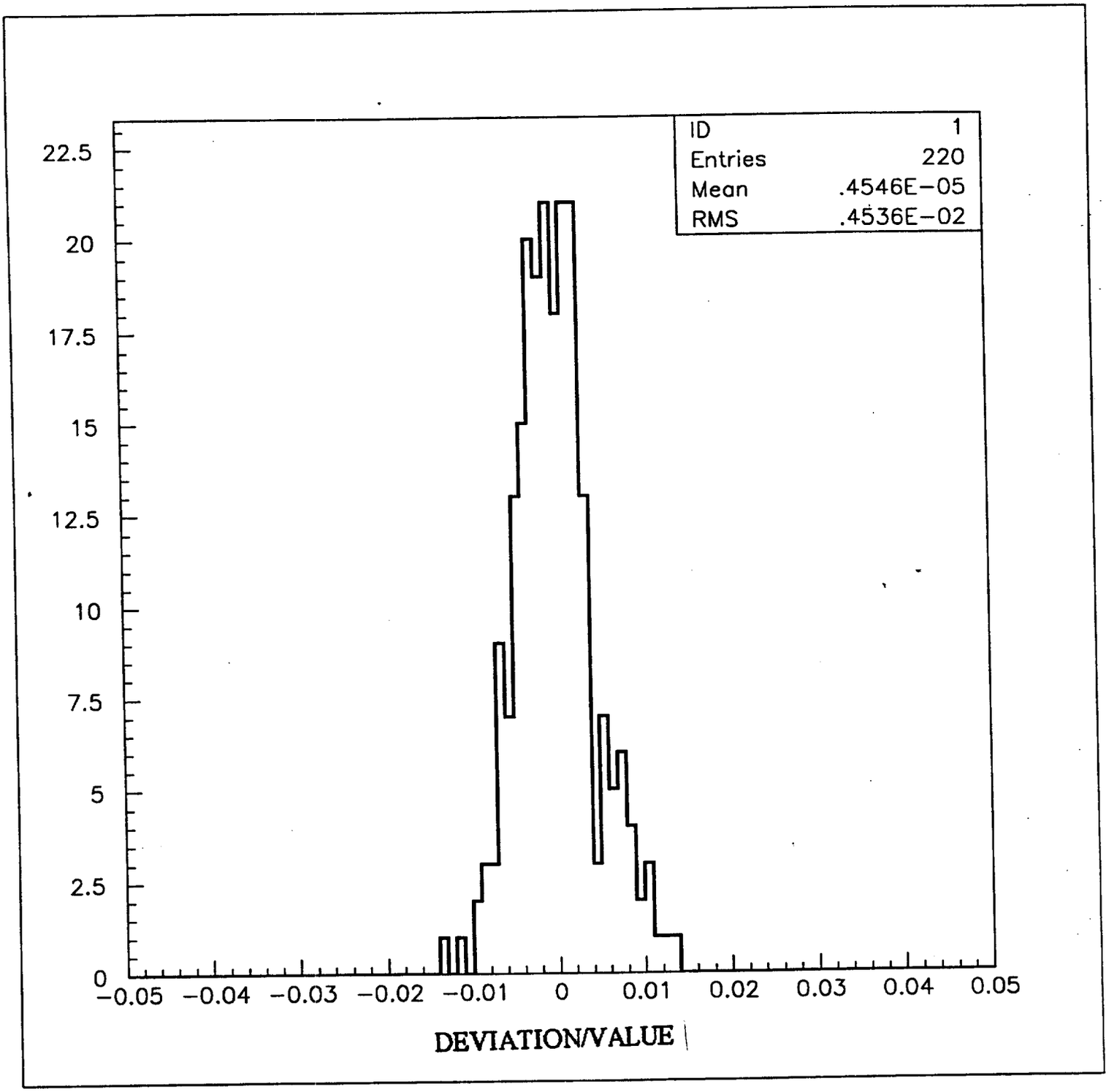

Figure 6 **Deviation of all data from the empirical function**

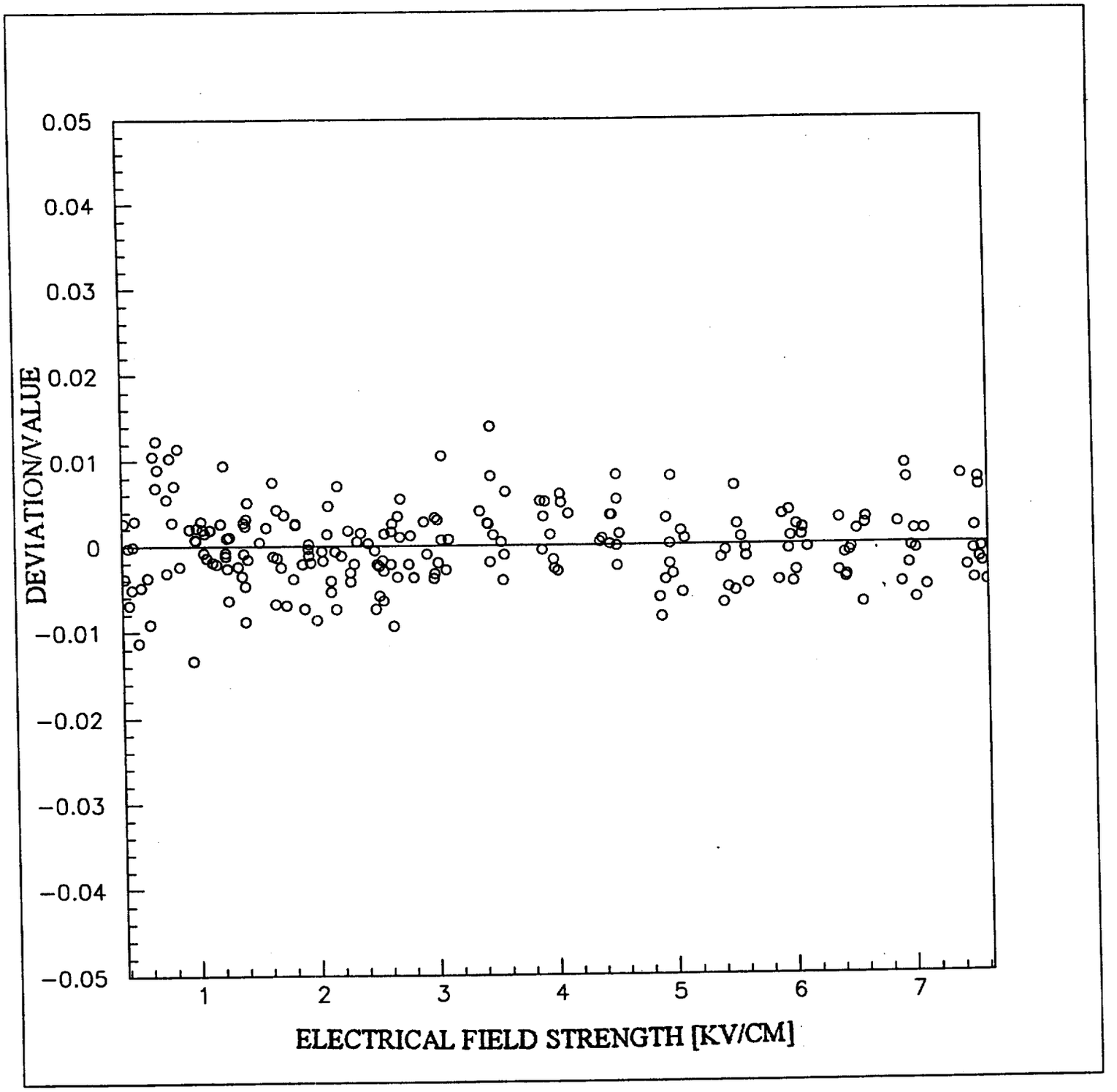

Figure 7 Deviation versus electric field

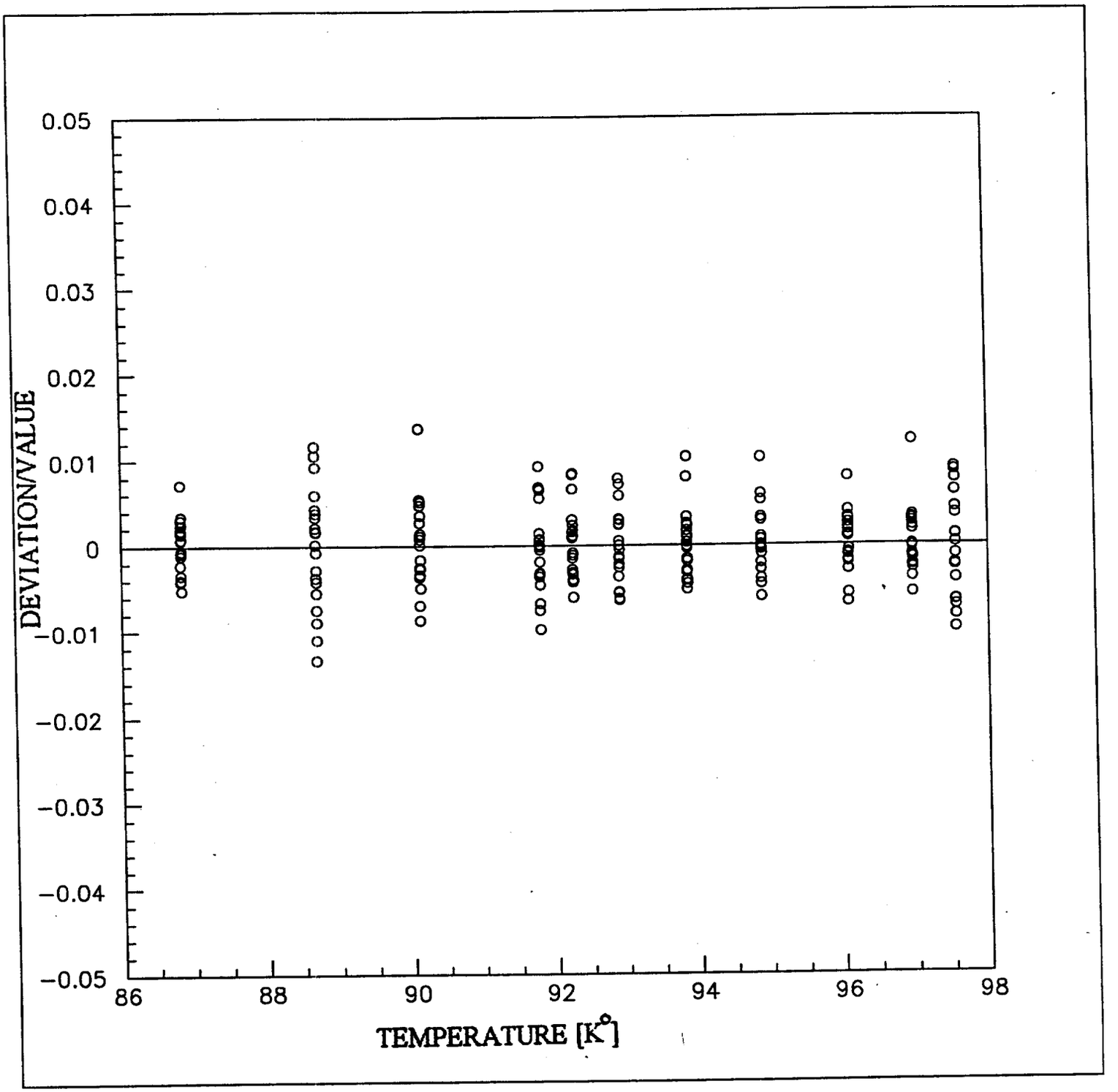

Figure 8 Deviation versus temperature

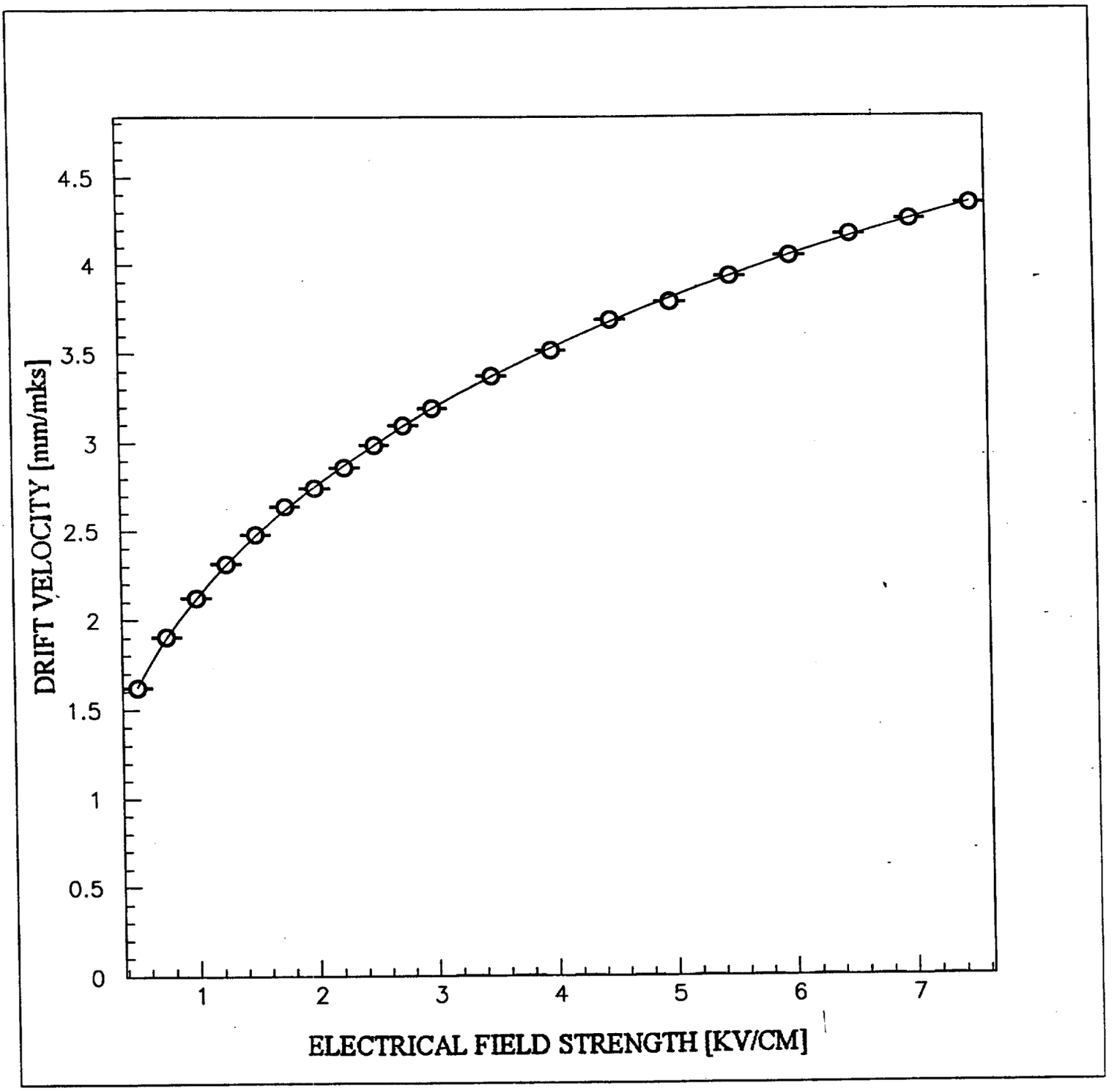

Figure 9 Drift velocity versus electric field, calculated from the empirical function