TRIUMF Experiment E614
Technical Note #65.2

GARFIELD simulation of the manufactured TEC with field wires

V.I.Selivanov
14 April 2004

First design of the TEC has been analyzed in TN-65 and TN-65.1. The design consists of a proportional chamber with wire pitch of 1mm in amplification area of the TEC. The design has two disadvantages: possible big crosstalk between nearest wires and a small primary electron number per the 1mm pitch. Present design consists of sense and field wires with pitch of 1mm between them. As result we should have twice more primary electron number per the 2mm pitch between sense wires and have possibility to track relativistic positrons and pions. A field wire is a good screen between nearest sense wires.

1 TEC geometry

View of the manufactured TEC in XY-plane is presented in Fig.1. All dimensions are from TWIST "Internal" Pages, Chambers section, Grant Sheffer "TEC Module with dimension", 30-07-2003. One can see from Figs.3,4 a remarkable difference between drift time from edge and middle of the TEC. It is result of a penetration of electric field from the drift area ($X > 0.8cm$) into amplification area through holes between guard wires ($X = 0.8cm$) and field forming wires at ($Y = 0$) and ($Y = 8cm$). The six field wires placed on ends of the sense wire plane can not remove the drift time difference. Results of next design are presented in Figs.5-8. This design gives a less drift time difference for ISO gas (Fig.7) and practically the same difference for DME gas (Fig.8). The "third" TEC design presented in Fig.9 provides a good homogeneity of the drift time for the both gases (Figs.11,12). Description of the "third" TEC design done in Tabl.1.

TEC calculation has been done also for different V_f value of field wires placed at $X = 0.4cm$ to define a minimal possible value of $(V_s - V_f)$ when drift electrons do not captured by the field wires. Results presented in Figs.13-16. One can see from Fig.15 that a field wire begins to capture of primary electrons at $V_f = 1190V$. Figs.17-19 show a TEC gain distribution for different values of V_s and V_f. One can see in Fig.18 that the gain decreases about in 10^5 times at $V_f = 1000V$ compare with Fig.17 where $V_f = 0V$. Increasing of V_s to $2600V$ recovers the original gain value. The Figs.17-19 show some disadvantage of the V_f changing because a gain value drops sharply. GARFIELD calculates a gain value with a big errors, therefore the Figs.17-19 serve as an illustration of the gain worsening. The V_f changing does not worse the drift time homogeneity (Figs.11-12).

2 Registration of surface muons, positrons and pions by the TEC

GARFIELD calculations of the TEC has been described in detail in TNs 65 and 65.1. Monte Carlo method (as in TN65.1) with step of $100\mu m$ has been used for STR calculations. The step value is too big and it restricted by GARFIELD, therefore the below results have not good accuracy. Figs.20-23 show a distribution of number of primary electrons for surface muon and positron. One can see that the distributions far from a Gaussian form. The original files will be done by a request.

Average distance between primary electrons is shown in Tabl.2. Efficiency of a particle registration by a one sense wire is shown in Tabl.3. One can see from Tabl.2 that number of primary electrons twice more in ISO gas than in DME gas, therefore an efficiency of a particle registration is higher in ISO gas than in DME gas. ISO gas seems better for positron and pion registration. Results of the GARFIELD calculations are presented in Figs.24-39. "Travel distance" d equals to zero ($d = 0mm$) at $X = 0.8cm$. "Travel time" t_0 is an average drift time from a particle track to a sense wire. Fitting formulas and parameters are presented in the Figs. Monte Carlo drift lines are shown in Figs.40,41. Monte Carlo motion is bigest contribution to the TEC resolution at a low pressure of a gas.

Real values of V_c, V_s, V_f will be selected by an experimental studies. All the TEC parameters will be recalculated after that.

Table 1: Wires location, diameter and H.V. for the "third" TEC design. $V_s = 2000V$, $V_c = -2500V$ for ISO and for DME at $P = 60Torr$, $V_c = -4000V$ for DME at $P = 100Torr$.

Wire type	Number of wires, (N)	Diameter, (μm)	$X_i, i = 0, 1, ..N$, (cm)	$Y_i, i = 0, 1, ..N$ (cm)	H.V.
Sense	24	125	0.4	$1.65 + 0.2i$	Vs
Field	1	125	0 4	1.05	Vs
Field	1	125	0.4	1.25	Vs
Field	1	125	0.4	1.45	Vs
Field	1	125	0.4	6.45	Vs
Field	1	125	0.4	6.65	Vs
Field	1	125	0.4	6.85	Vs
Field	29	125	0.4	$1.15 + 0.2i$	Vf
Cathode	148	50	0.0	$0.3 + 0.05i$	Vg=0
Cathode	148	50	6.896	$0.3 + 0.05i$	Vc
Field	23	25	$1.054 + 0.254i$	0.0	$Vg + (Vc - Vg)(i + 1)/24$
Field	23	25	$1.054 + 0.254i$	7.9	$Vg + (Vc - Vg)(i + 1)/24$
Grid	58	125	0.8	$1.1 + 0.1i$	Vg=0

Table 2: Average distance between primary electrons from particles in the TEC at different pressures of ISO/DME gas.

Av.distance, mm	20Torr	40Torr	60Torr	80Torr	100Torr
$\mu^+, 4.12MeV$	0.28/0.55	0.13/0.27	0.084/0.18	0.063/0.12	0.050/0.10
$e^+, 30MeV$	2.3/4.8	1.1/2.17	0.78/1.48	0.55/1.32	0.45/0.87
$\pi^+, 120MeV/c$	1.3/2.9	0.65/1.16	0.43/0.91	0.32/0.67	0.26/0.53

Table 3: Efficiency of a particle registration by a one sense wire of the TEC at different pressures of ISO/DME gas.

Efficiency, %	20Torr	40Torr	60Torr	80Torr	100Torr
$\mu^+, 4.12MeV$	72/50.5	98/78.5	100/96.0	100/97.5	100/100
$e^+, 30MeV$	11/7	26.5/13.5	36/20	52.5/34	54.5/37
$\pi^+, 120MeV/c$	22/11	42/21	62/29.5	75/41	84/49

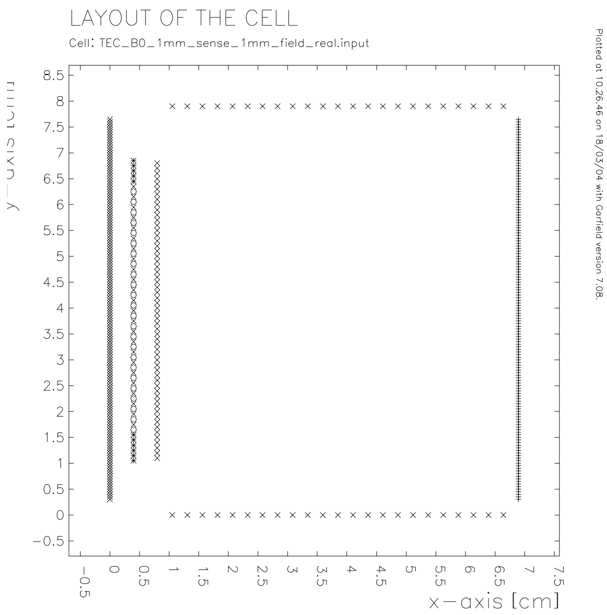

Figure 1: Existing TEC view in XY-plane. A particle moves along Y-axis. ($\circ$)-sense wire. First sense wire placed at ($Y = 1.65cm, X = 0.4cm$). ($\times$)-field wires placed between sense wires, ($*$)-6 field wires at both ends of sense wire plane.

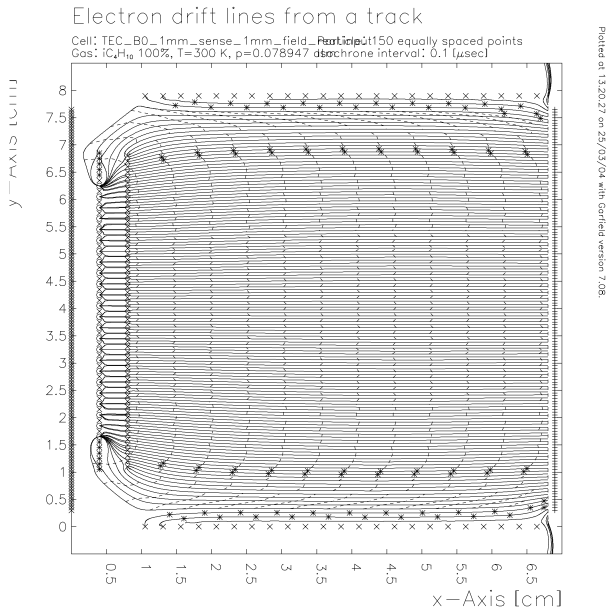

Figure 2: Drift lines for TEC (Fig.1). A particle moves at $X = 6.8cm$ from $Y = 0$ to $Y = 8cm$ and produces 150 equally spaced primary electrons. Isochronous intervals of $0.1\mu s$ are marked.

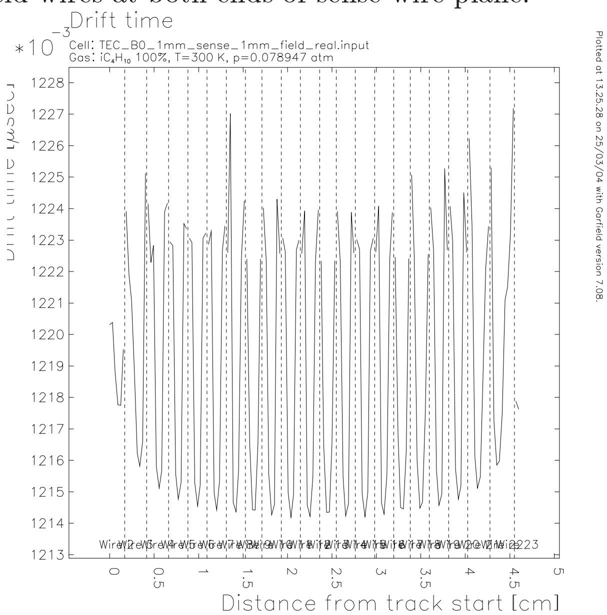

Figure 3: Drift times of primary electrons from the track of Fig.2. First sense wire position corresponds to 0.1cm on the horizontal axis. Drift gas is the ISO. Difference between the drift time from the 1st and 12th wire is defined by a path length difference mainly because the ISO gas is saturated at used $E \simeq 420V/cm$ and $p = 60Torr$.

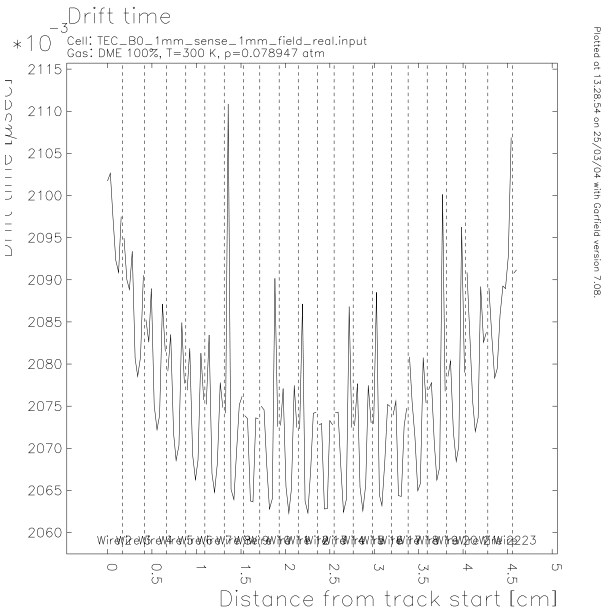

Figure 4: Drift times of primary electrons from the track of Fig.2. First sense wire position corresponds to 0.1cm on the horizontal axis. Drift gas is the DME. Difference between the drift time from the 1st and 12th wire is defined by a path length difference and a drift velocity dependence $v_d = f(E)$ because the DME gas is not saturated at used $E \simeq 420V/cm$ and $p = 60Torr$.

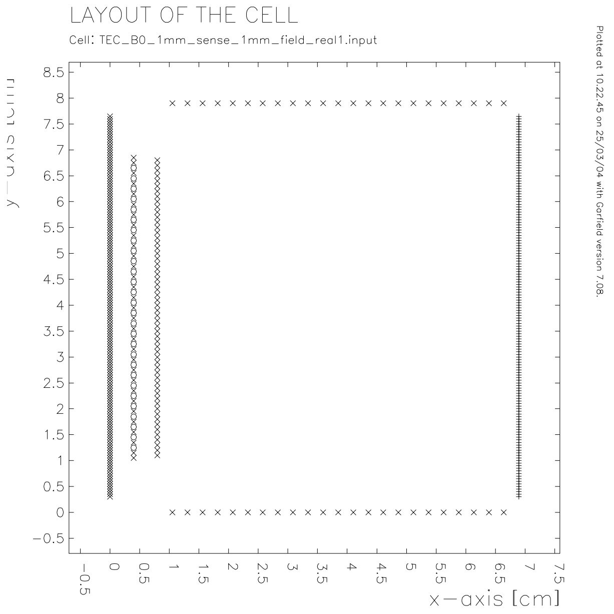

Figure 5: Second design of the TEC to decrease a drift time difference between the end and middle of the TEC. (○)-"sense" wire with $d = 25\mu m$. First real sense wire placed at ($Y = 1.65cm, X = 0.4cm$). (×)-field wires with $d = 125\mu m$ placed between sense wires and 2 field wires placed at both ends of sense wire plane.

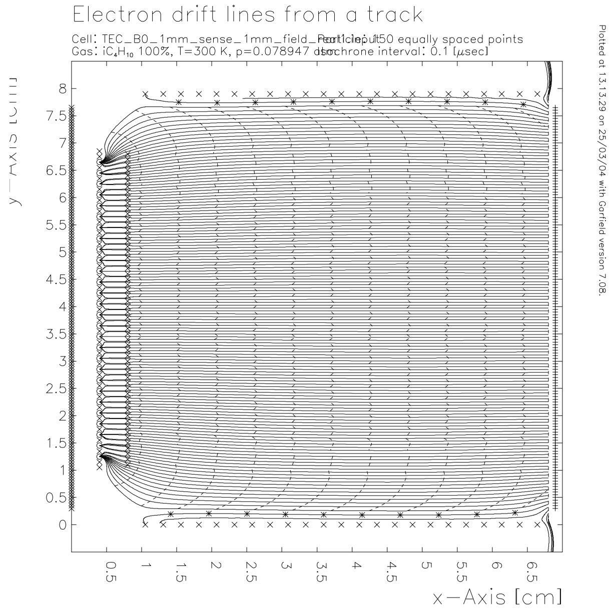

Figure 6: Drift lines for TEC (Fig.5). A particle moves at $X = 6.8cm$ from $Y = 0$ to $Y = 8cm$ and produces 150 equally spaced primary electrons. Isochronous intervals of $0.1\mu s$ are marked.

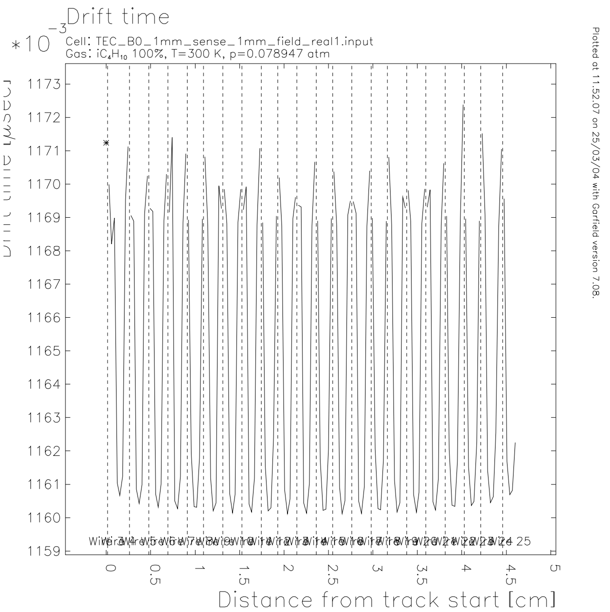

Figure 7: Drift times of primary electrons from the track of Fig.6. First sense wire position corresponds to 0.1cm on the horizontal axis. Drift gas is the ISO. Difference between the drift time from the 1st and 12th wire is defined by a path length difference mainly because the ISO gas is saturated at used $E \simeq 420V/cm$ and $p = 60Torr$. The difference is less compare with the existing design (Fig.1).

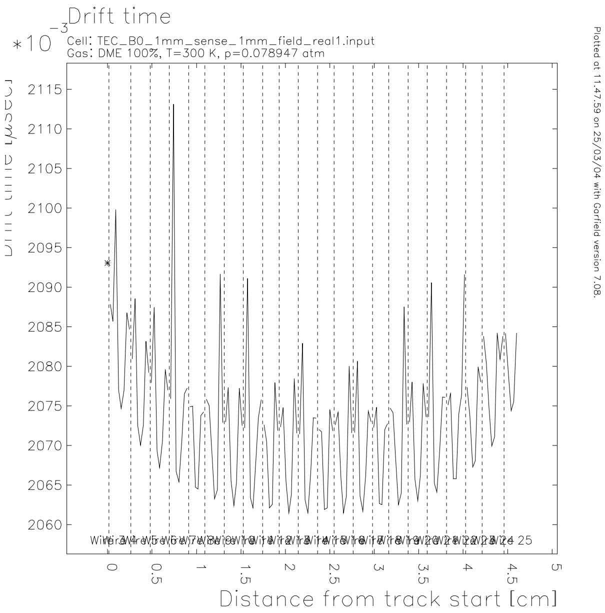

Figure 8: Drift times of primary electrons from the track of Fig.6. First sense wire position corresponds to 0.1cm on the horizontal axis. Drift gas is the DME. Difference between the drift time from the 1st and 12th wire is defined by a path length difference and a drift velocity dependence $v_d = f(E)$ because the DME gas is not saturated at used $E \simeq 420V/cm$ and $p = 60Torr$. The difference is less compare with the existing design (Fig.1).

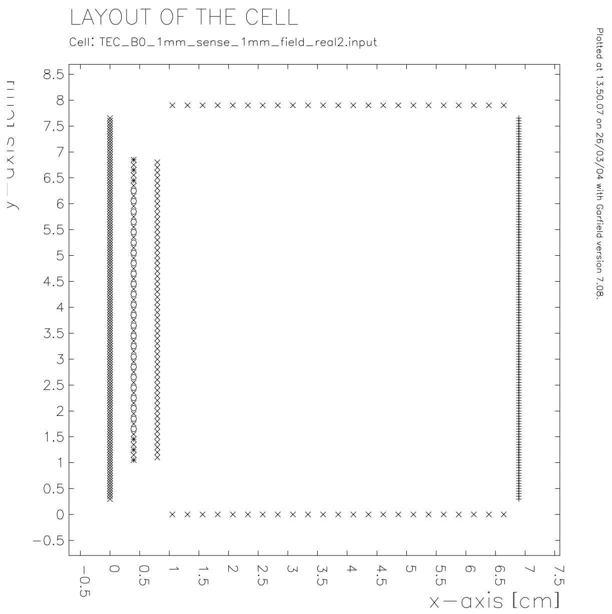

Figure 9: Third design of the TEC to decrease a drift time difference between the end and middle of the TEC. ($\circ$)-sense wire with $d = 25\mu m$. First sense wire placed at ($Y = 1.65cm, X = 0.4cm$). ($\times$)-field wires ($d = 125\mu m$) placed between sense wires and 3 "sense" wires ($*$) ($d = 125\mu m$) placed at both ends of sense wire plane.

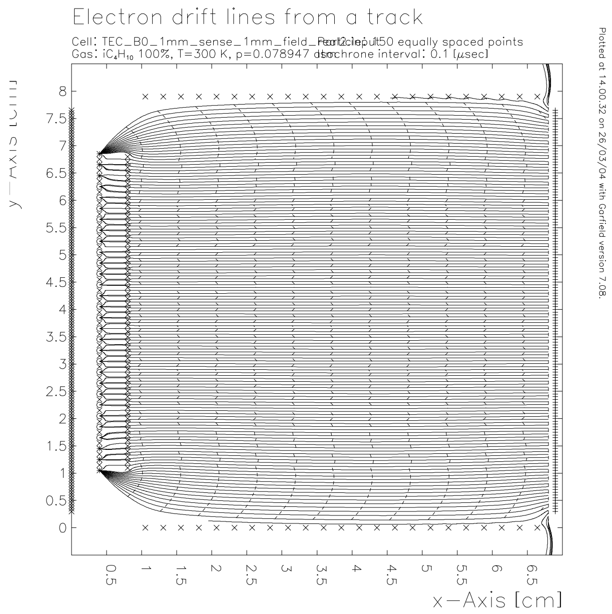

Figure 10: Drift lines for TEC (Fig.9). A particle moves at $X = 6.8cm$ from $Y = 0$ to $Y = 8cm$ and produces 150 equally spaced primary electrons. Isochronous intervals of $0.1\mu s$ are marked.

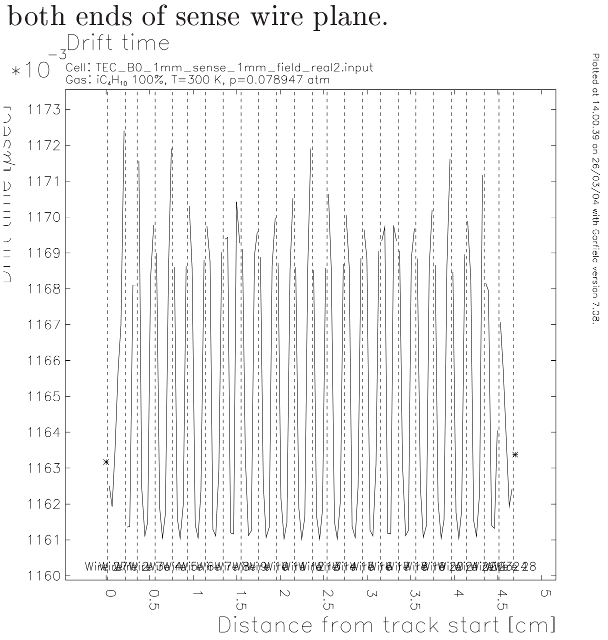

Figure 11: Drift times of primary electrons from the track of Fig.10. First sense wire position corresponds to 0.1cm on the horizontal axis. Drift gas is the ISO. Practically no difference between the drift time from the 1st and 12th wire.

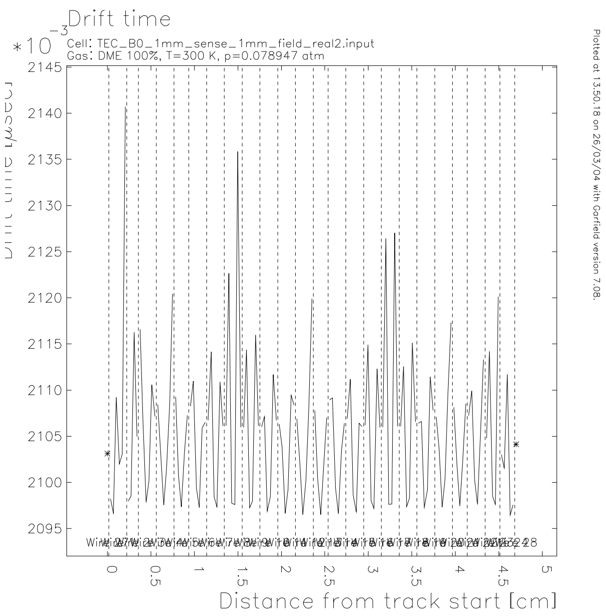

Figure 12: Drift times of primary electrons from the track of Fig.10. First sense wire position corresponds to 0.1cm on the horizontal axis. Drift gas is the DME. Practically no difference between the drift time from the 1st and 12th wire.

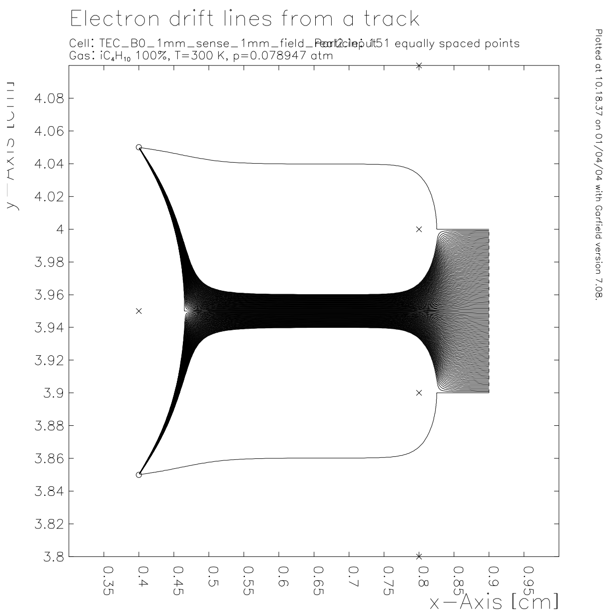

Figure 13: Drift lines from a particle moves at $X = 0.9cm$ from $Y = 3.9$ to $Y = 4.0cm$ and produces 150 equally spaced primary electrons. ($\circ$)-sense wire. ($\times$)-field wires between sense wires (f) and guard wires (g) between drift and multiplication volume of the TEC. Drift gas is ISO at $p = 60Torr$. $V_c = -2500V, V_s = 2000V, V_g = V_f = 0V$.

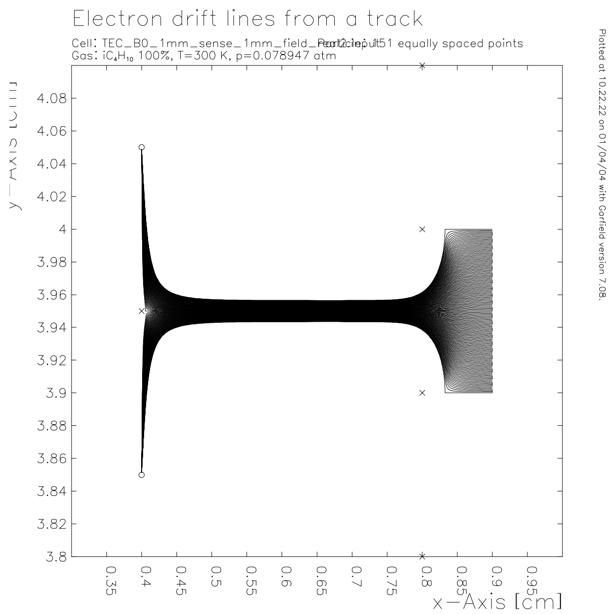

Figure 14: Drift lines from a particle moves at $X = 0.9cm$ from $Y = 3.9$ to $Y = 4.0cm$ and produces 150 equally spaced primary electrons. ($\circ$)-sense wire. ($\times$)-field wires between sense wires (f) and guard wires (g) between drift and multiplication volume of the TEC. Drift gas is ISO at $p = 60Torr$. $V_c = -2500V, V_s = 2000V, V_g = 0V, V_f = 1180V$.

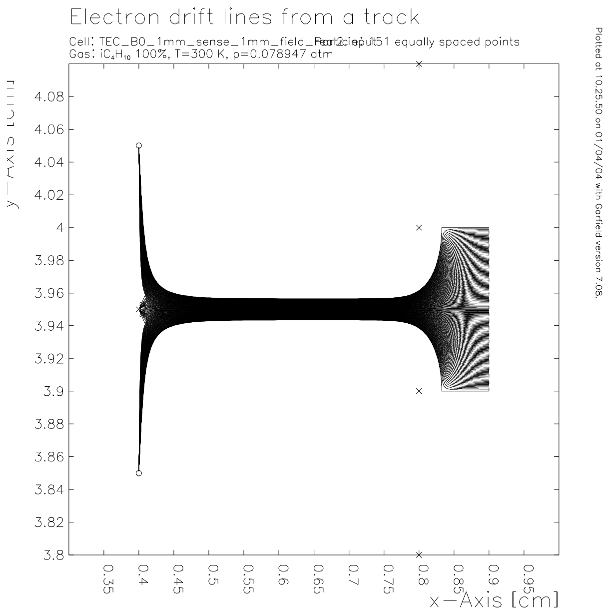

Figure 15: Drift lines from a particle moves at $X = 0.9cm$ from $Y = 3.9$ to $Y = 4.0cm$ and produces 150 equally spaced primary electrons. ($\circ$)-sense wire. ($\times$)-field wires between sense wires (f) and guard wires (g) between drift and multiplication volume of the TEC. Drift gas is ISO at $p = 60Torr$. $V_c = -2500V, V_s = 2000V, V_g = 0V, V_f = 1190V$.

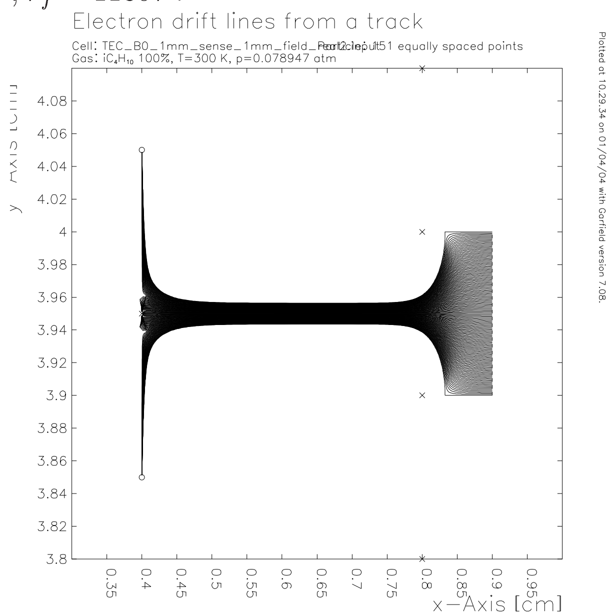

Figure 16: Drift lines from a particle moves at $X = 0.9cm$ from $Y = 3.9$ to $Y = 4.0cm$ and produces 150 equally spaced primary electrons. ($\circ$)-sense wire. ($\times$)-field wires between sense wires (f) and guard wires (g) between drift and multiplication volume of the TEC. Drift gas is ISO at $p = 60Torr$. $V_c = -2500V, V_s = 2000V, V_g = 0V, V_f = 1230V$.

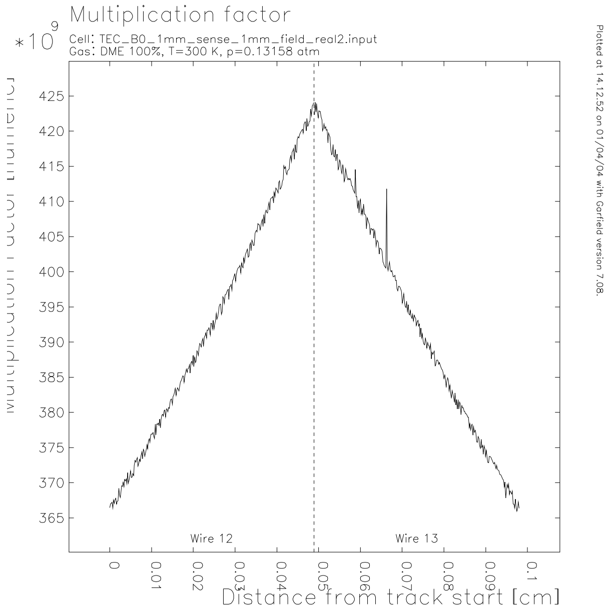

Figure 17: Gain distribution from a particle moves at $X = 0.9cm$ from $Y = 3.9$ to $Y = 4.0cm$ (see Figs.13-16) and produces 500 equally spaced primary electrons. Drift gas is DME at $p = 100Torr$. $V_c = -4000V, V_s = 2000V, V_g = V_f = 0V$.

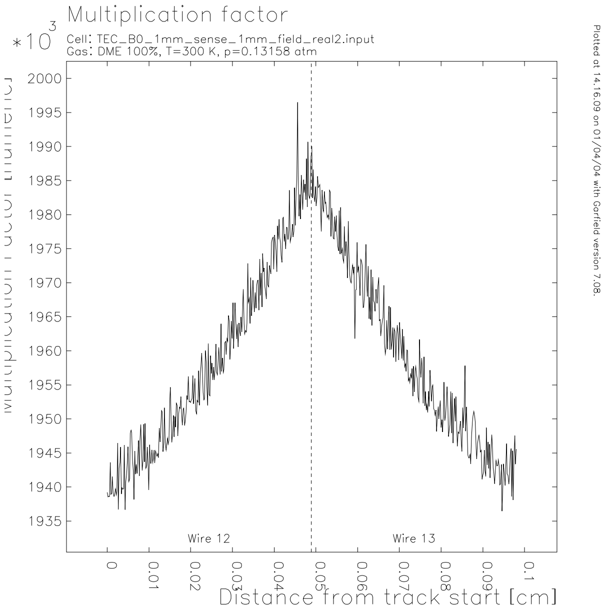

Figure 18: Gain distribution from a particle moves at $X = 0.9cm$ from $Y = 3.9$ to $Y = 4.0cm$ (see Figs.13-16) and produces 500 equally spaced primary electrons. Drift gas is DME at $p = 100Torr$. $V_c = -4000V, V_s = 2000V, V_g = 0V, V_f = 1000V$.

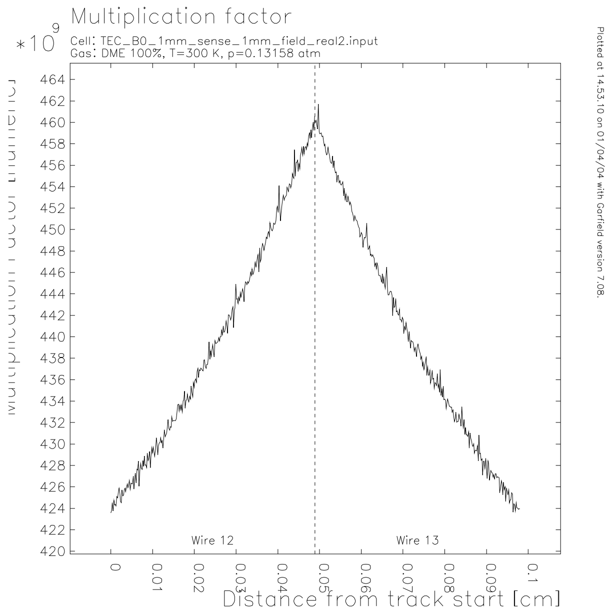

Figure 19: Gain distribution from a particle moves at $X = 0.9cm$ from $Y = 3.9$ to $Y = 4.0cm$ (see Figs.13-16) and produces 500 equally spaced primary electrons. Drift gas is DME at $p = 100Torr$. $V_c = -4000V, V_s = 2600V, V_g = 0V, V_f = 1000V$.

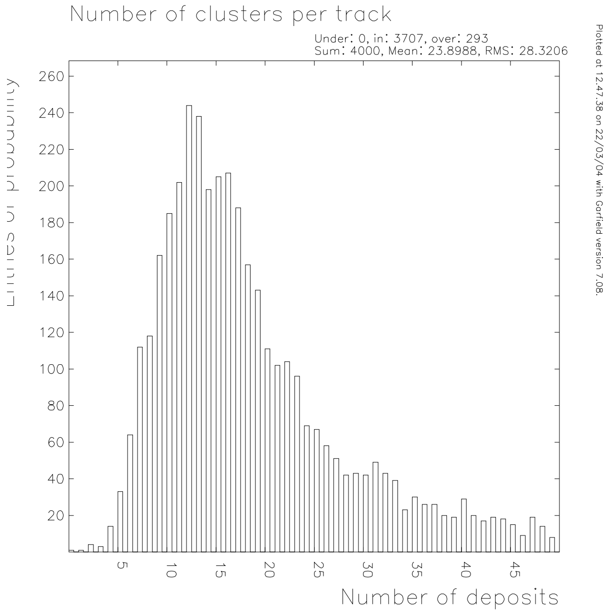

Figure 20: Distribution of primary electron number per 2mm in ISO gas at $P = 60Torr$ from μ^+ with $p = 29.8MeV/c$.

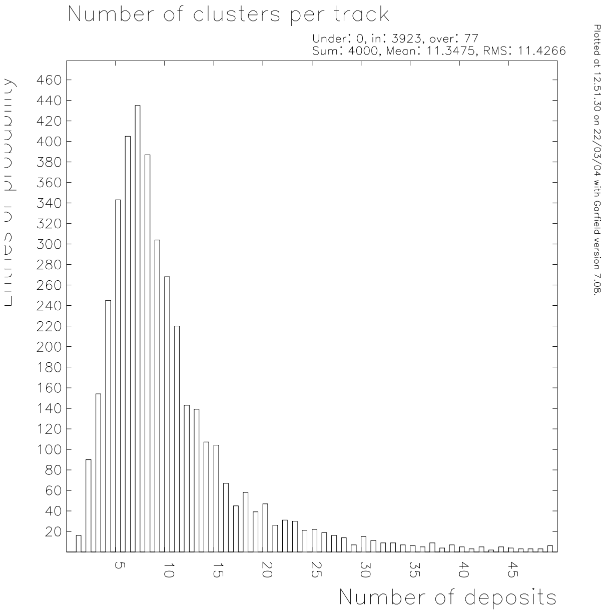

Figure 21: Distribution of primary electron number per 2mm in DME gas at $P = 60Torr$ from μ^+ with $p = 29.8MeV/c$.

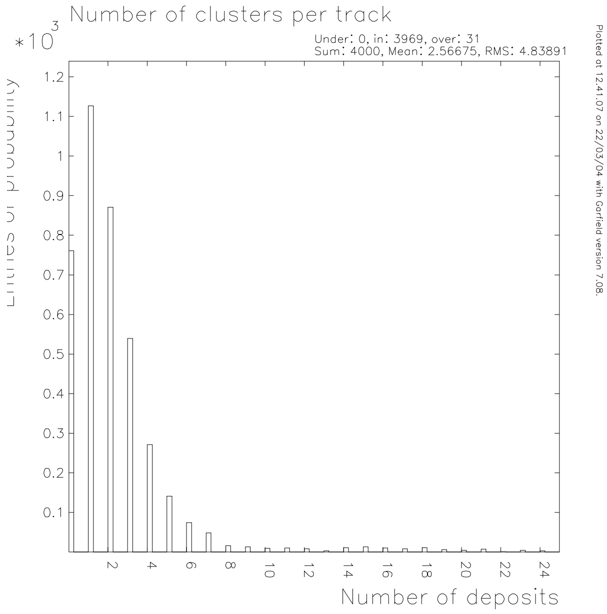

Figure 22: Distribution of primary electron number per 2mm in ISO gas at $P = 60Torr$ from e^+ with $p = 29.8MeV/c$.

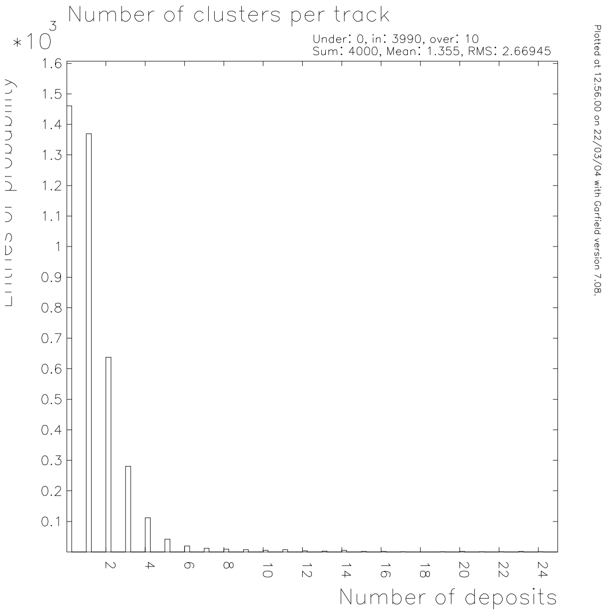

Figure 23: Distribution of primary electron number per 2mm in DME gas at $P = 60Torr$ from e^+ with $p = 29.8MeV/c$.

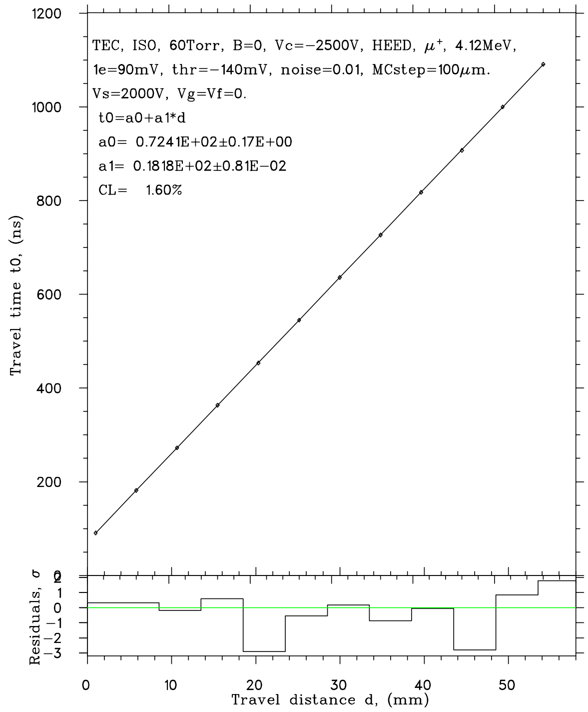

Figure 24: STR for μ^+ with $p = 29.8MeV/c$ in ISO gas at $P = 60Torr$. Travel distance $d = 0$ corresponds to $X = 0.8cm$ (boundary between drift and multiplication area of the TEC).

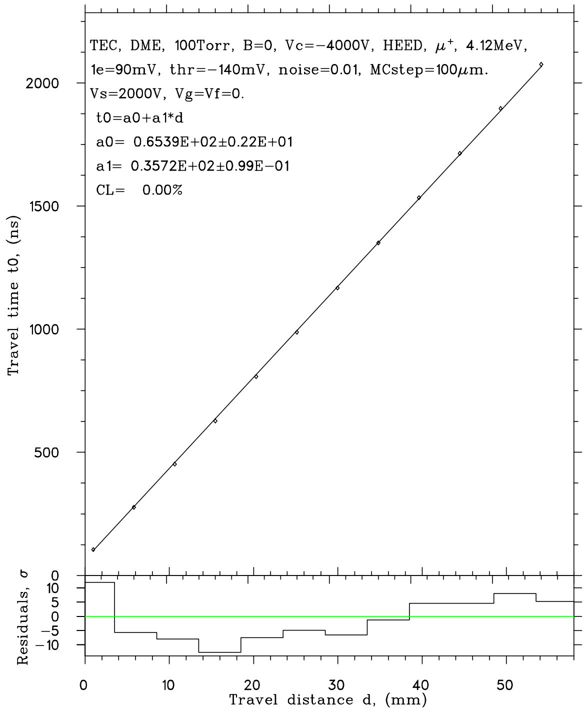

Figure 25: STR for μ^+ with $p = 29.8MeV/c$ in DME gas at $P = 60Torr$. Travel distance $d = 0$ corresponds to $X = 0.8cm$ (boundary between drift and multiplication area of the TEC).

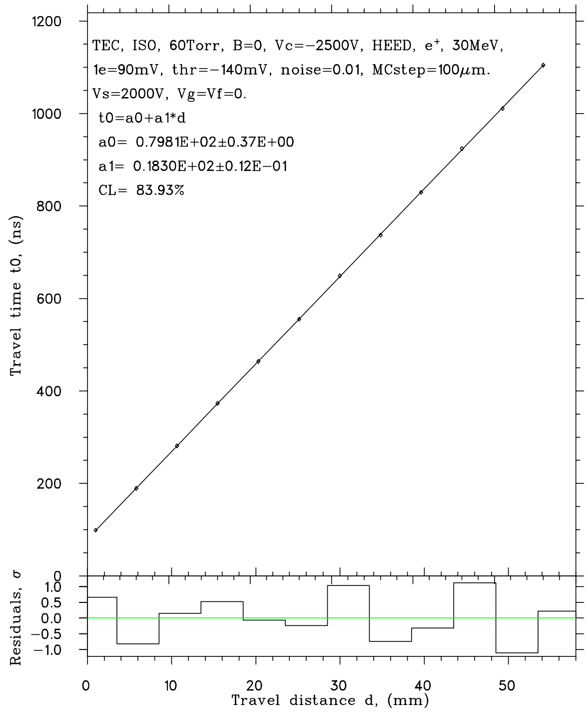

Figure 26: STR for e^+ with $p = 30MeV/c$ in ISO gas at $P = 60Torr$. Travel distance $d = 0$ corresponds to $X = 0.8cm$ (boundary between drift and multiplication area of the TEC).

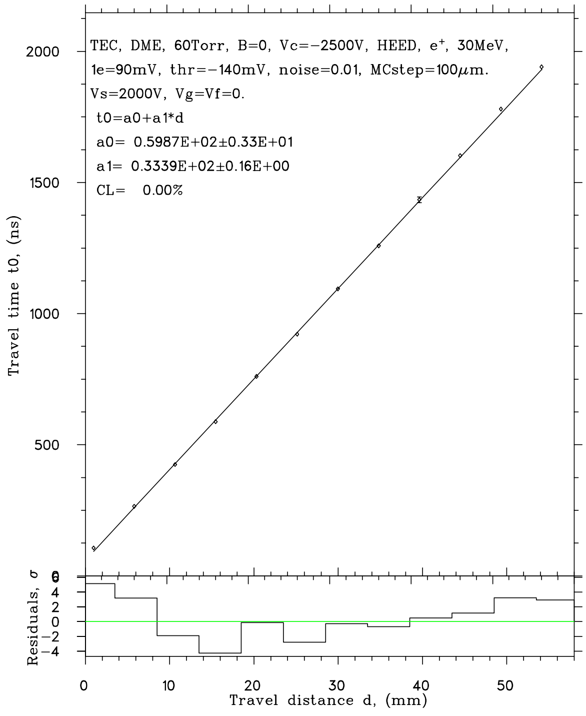

Figure 27: STR for e^+ with $p = 30MeV/c$ in DME gas at $P = 60Torr$. Travel distance $d = 0$ corresponds to $X = 0.8cm$ (boundary between drift and multiplication area of the TEC).

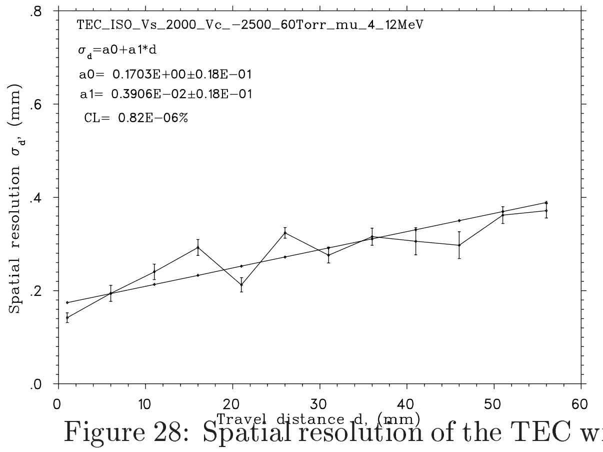

Figure 28: Spatial resolution of the TEC with ISO gas at $P = 60Torr$ for μ^+ with $p = 29.8MeV/c$.

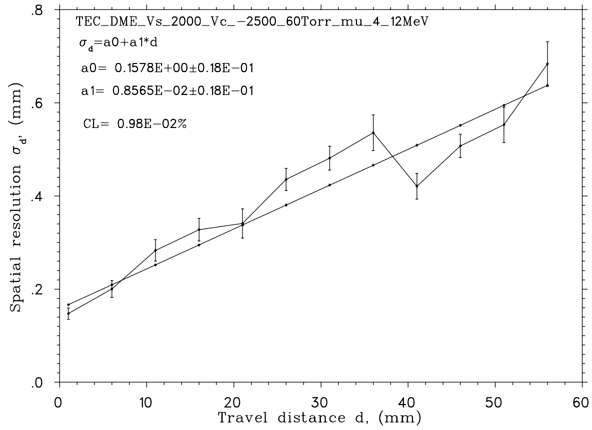

Figure 29: Spatial resolution of the TEC with DME gas at $P = 60Torr$ for μ^+ with $p = 29.8MeV/c$.

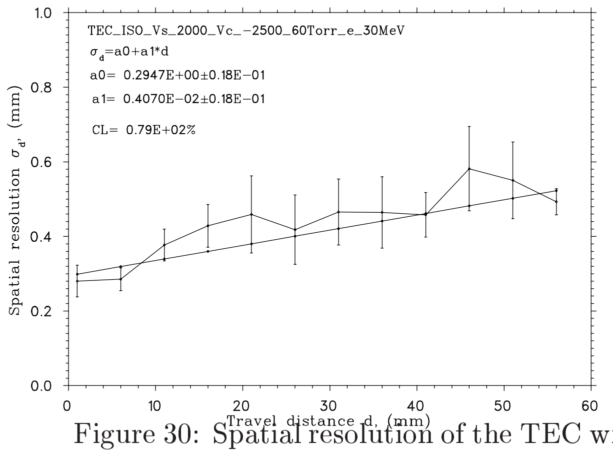

Figure 30: Spatial resolution of the TEC with ISO gas at $P = 60Torr$ for e^+ with $p = 30MeV$.

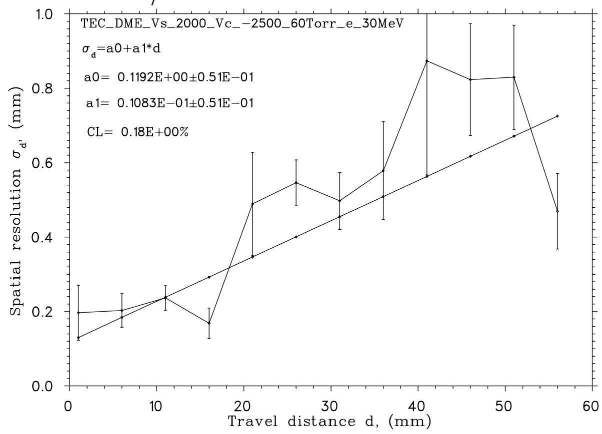

Figure 31: Spatial resolution of the TEC with DME gas at $P = 60Torr$ for e^+ with $p = 30MeV$.

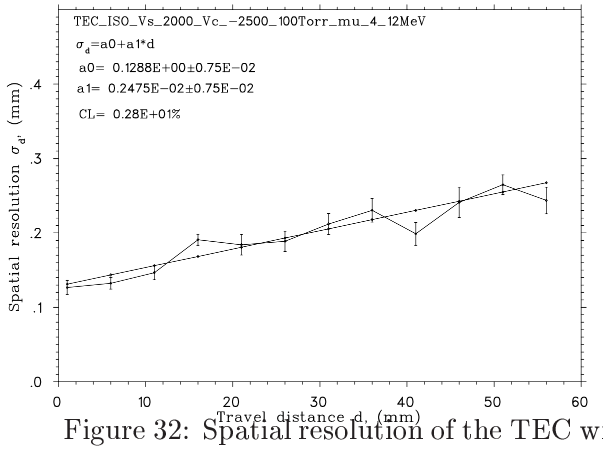

Figure 32: Spatial resolution of the TEC with ISO gas at $P = 100Torr$ for μ^+ with $p = 29.8MeV/c$.

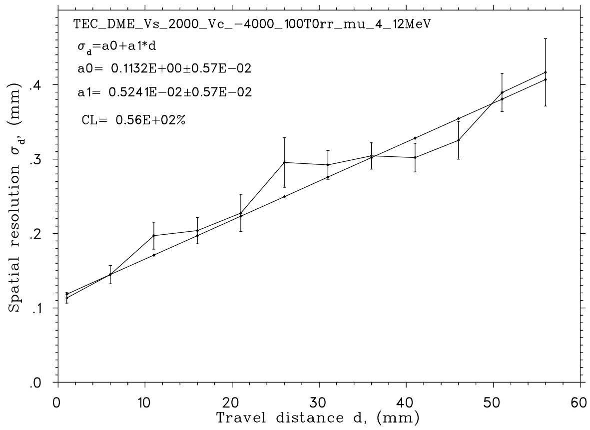

Figure 33: Spatial resolution of the TEC with DME gas at $P = 100Torr$ for μ^+ with $p = 29.8MeV/c$.

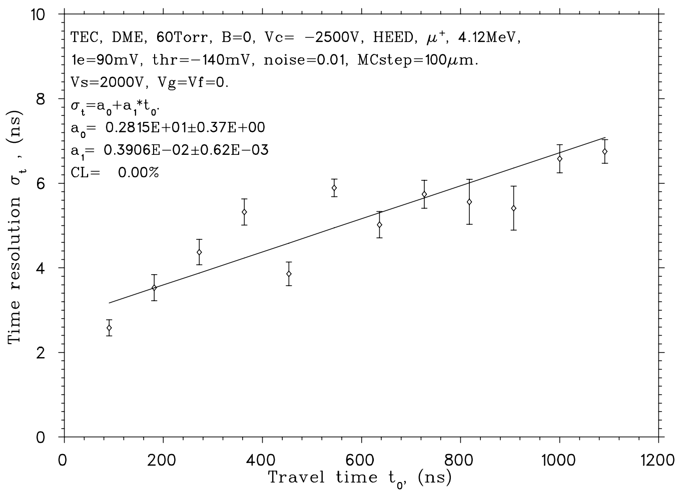

Figure 34: Time resolution of the TEC with ISO gas at $P = 60Torr$ for μ^+ with $p = 29.8MeV/c$.

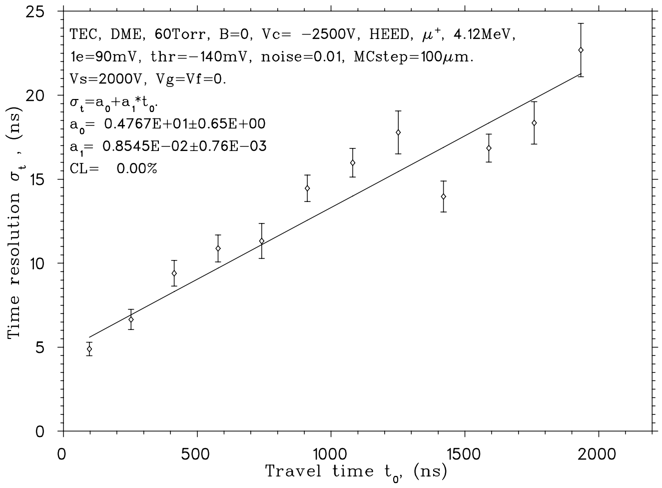

Figure 35: Time resolution of the TEC with DME gas at $P = 60Torr$ for μ^+ with $p = 29.8MeV/c$.

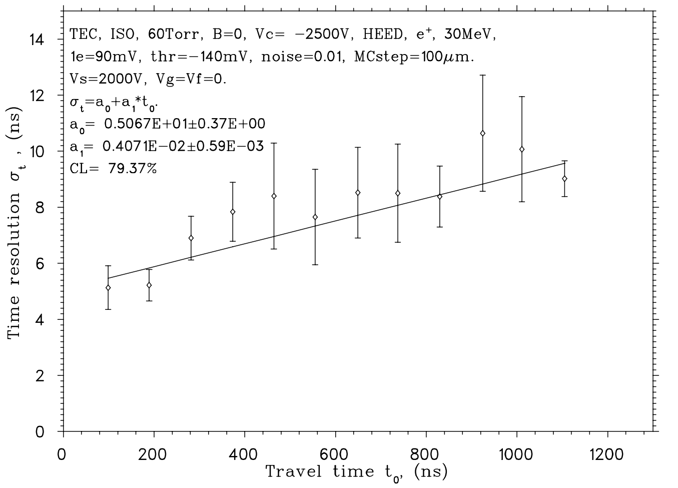

Figure 36: Time resolution of the TEC with ISO gas at $P = 60Torr$ for e^+ with $p = 30MeV$.

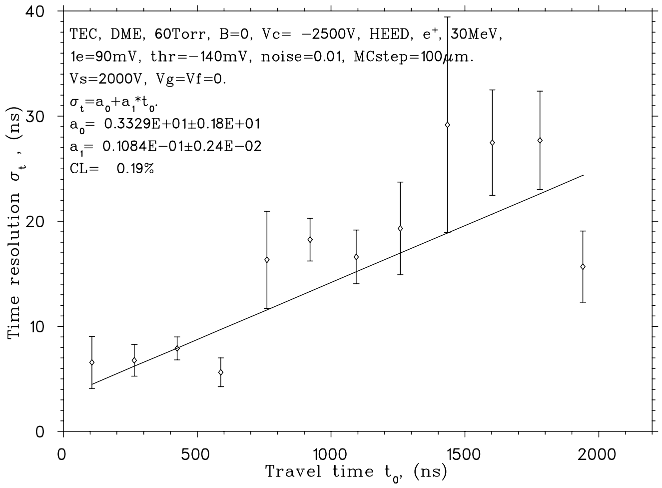

Figure 37: Time resolution of the TEC with DME gas at $P = 60Torr$ for e^+ with $p = 30MeV$.

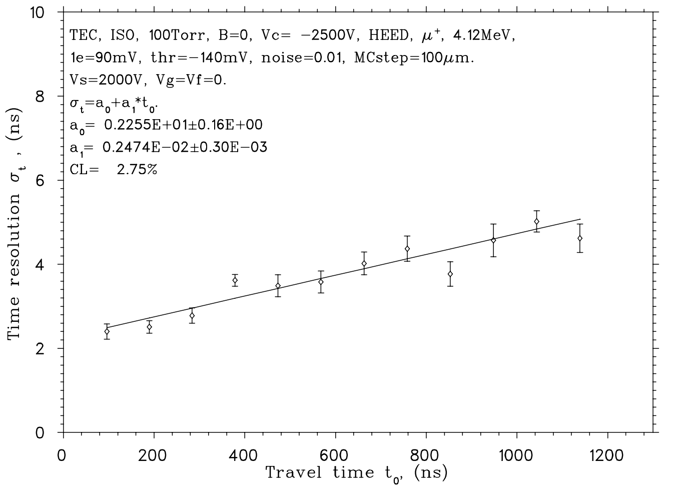

Figure 38: Time resolution of the TEC with ISO gas at $P = 100Torr$ for μ^+ with $p = 29.8MeV/c$.

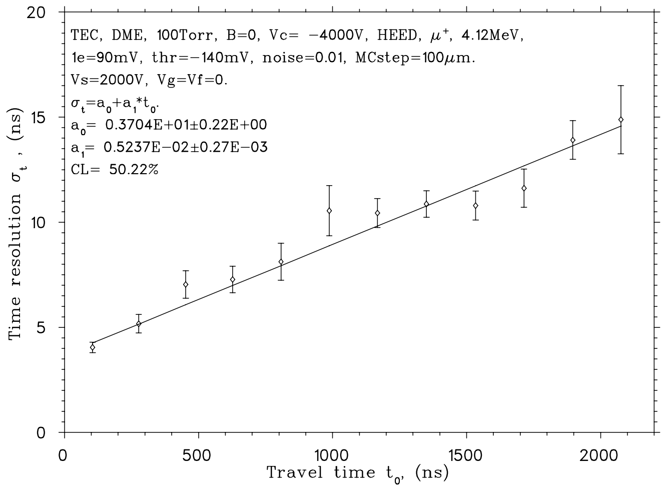

Figure 39: Time resolution of the TEC with DME gas at $P = 100Torr$ for μ^+ with $p = 29.8MeV/c$.

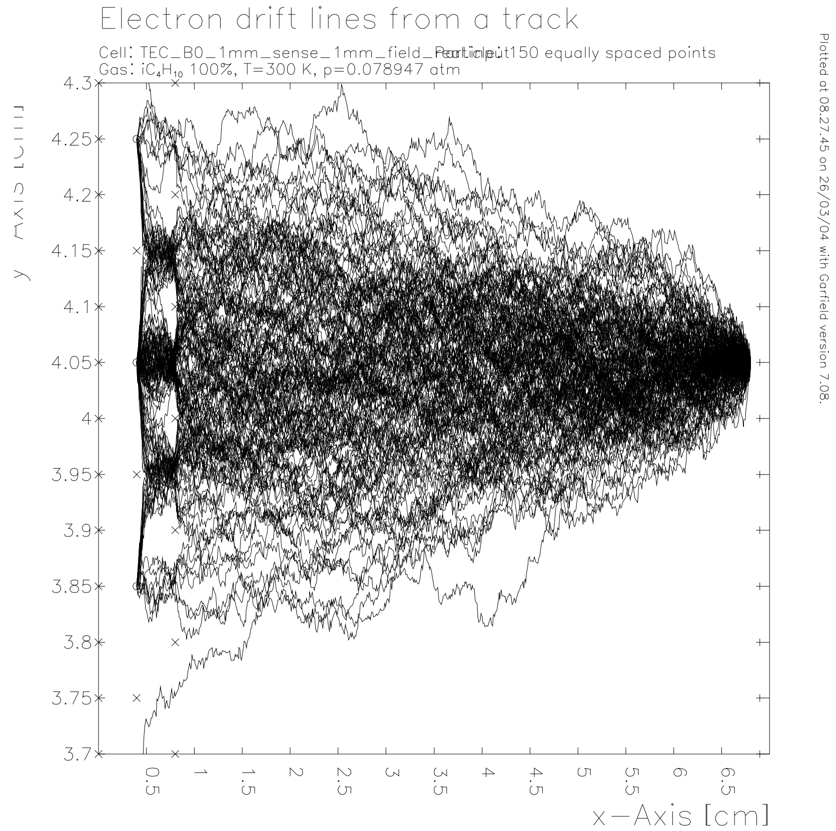

Figure 40: Monte Carlo drift lines of electrons in ISO gas at $P = 60Torr$. Original track goes at $X = 6.8cm$ from $Y = 4.045cm$ to $Y = 4.055cm$. The track has length of $100\mu m$ and covers a small part of cell with width of $2mm$ with sense wire at $(X = 0.4cm, Y = 4.05cm)$.

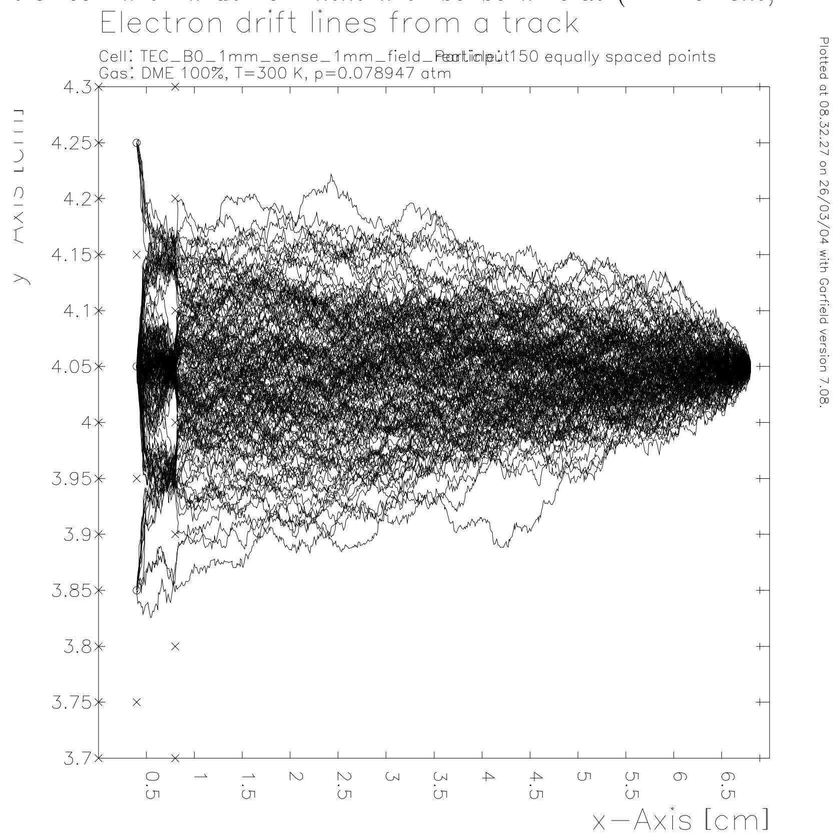

Figure 41: Monte Carlo drift lines of electrons in DME gas at $P = 60Torr$. Original track goes at $X = 6.8cm$ from $Y = 4.045cm$ to $Y = 4.055cm$. The track has length of $100\mu m$ and covers a small part of cell with width of $2mm$ with sense wire at $(X = 0.4cm, Y = 4.05cm)$.