TRIUMF Experiment E614
Technical Note #65.3

GARFIELD optimization of TEC

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The existing today TEC geometry presented in Fig.1. The TEC has efficiency about 50% for surface muons. The efficiency, according to Jingliang data, depends on a drift distance essentially. This is result of low gain value at usual registration threshold ($140mV$) and diffusion in the low pressure gas. An original compact group of drift electrons spread in space and time (see Figs.2-7). Result is a small amplitude of a total signal. Fig.10 shows event when a total signal amplitude only slightly higher a threshold of $140mV$. Registration efficiency is about 80% for surface muon in DME at $p = 60Torr$, gain $G = 15000$, and threshold $thr = -140mV(1.6e)$. The efficiency value does not depend from a drift distance according to Garfield simulation. An efficiency of 50% corresponds to $G \simeq 7000$ (or $thr = -280mV(2.8e)$ at $G = 15000$) according to my simulation results. The efficiency depends sharply from drift distance. It is about 50% at $d = 1mm$, and about 15% at $d = 58mm$.
The existing TEC is not so accuracy tool for muon beam measurement. It impossible, according to Grant, increase HV of sense wires and gain because sparks. We will name the TEC as DC2.

Original TEC has been designed as PC with pitch of $1mm$. A possible cross talk between nearest wires force us to change the TEC geometry. First solution was to put a thick (nonsense) wires between sense ones to eliminate the cross talk. Disadvantage of the solution is decreasing of registration length from $2mm$ to $1mm$, decreasing of original electron number and loss of registration efficiency. Second solution was to put a field wire instead of the thick (nonsense) wire. Result of that is described above.

Several methods are suggested below to improve an accuracy of the TEC tool.

1. Original fear of a big cross talk between sense wires is not so important because a TEC with (or without) a passive wire has $\geq 5\%$ cross talk because a drift electron diffusion. One can see in Figs. 2-7 more than 5% electrons leakage to nearest wire because the diffusion. One hundred electrons has been simulated in each Fig. First suggested design is to join two nearest wires with pitch of $1mm$ between them to one preampf input. The solution requests more HV value on the joint wires than existing one. My guess we can do it because we have $4mm$ to $HV = 0$ instead of $1mm$ in the existing design. Probability to have an electrical cross talk can be high because the small pitch of $1mm$ between wires. Advantage of the PC(1+1) is small time spread of $30ns$ (Fig.13) instead of $120ns$ for DC2 (Fig. 12). We will name the above TEC as PC(1+1). An electrical cross talk between channels can be tested using ^{56}Fe source with $E_\gamma = 5keV$. Muon losses only $0.5keV$ per $2mm$.

2. Second suggested design is to put sense wires with pitch of $2mm$ between them without field wires (TEC PC2). The PC2 has larger leakage than for DC2 and PC(1+1). The leakage will worse a space and time resolution only. Advantage of the PC2 is less time spread ($70ns$, Fig.14) than for DC2 ($120ns$). The PC2 will request a slightly higher HV on sense wires. An electrical cross talk between channels can be tested using ^{56}Fe source with $E_\gamma = 5keV$. Muon losses only $0.5keV$ per $2mm$. Let me remind that we have a cross talk about 2% in existing PCs2 with sense wire length of $300mm$, with about $32e$ per a $4mm$ cell from a muon decay positron, and with a threshold of $1.6e$ (ratio $k = 32/1.6 = 20$). We have in TEC PC2 sense wire of $80mm$ length, about $11e$ per $2mm$ cell

(see Fig.8,9) from a surface muon, and can reach threshold of $1.6e$ (ratio $k = 11/1.6 = 8$). We could estimate a cross talk in TEC PC2 because the cross talk is proportional to a sense wire length and ratio k. Therefore one can estimate a cross talk in TEC PC2 as $2\% \cdot (80mm/300mm) \cdot (8/20) \simeq 0.2\%$.

3. Next suggested design is to use ISO gas instead of DME in the existing design. One can see in Fig. 8 a number N_e of original electron distribution per $2mm$ for DME($\bar{N}_e = 11$) and ISO($\bar{N}_e = 24$) gas at $p = 60Torr$ for a surface muon. Twice more electrons for ISO gas can increase the efficiency. Disadvantage of the ISO gas is more sensitivity to a magnetic field because ISO gas has more Lorentz angle (Fig.21) compare with DME gas (Fig.20). TEC with ISO has space shift of $1mm$ at $B_z = 500G$ even (Fig.19).

4. Last design has been suggested by Grant. Idea is to change gap from $4mm$ to $3mm$. That increases gain according to GARFIELD estimation. Time spread does not change from $120ns$ ($4mm$ gap). Cathode HV $V_c \leq -1000V$ is good to minimize a space shift in a magnetic field (Figs.15-18).

Conclusion

TEC PC2 seems the best variant. The TEC PC2 has a time spread of $70ns$ compare with $120ns$ for the TEC DC2. Proposed TEC PC2 presented in Fig. 22. Space resolution of the TEC PC2 changes from $200\mu m$ to $600\mu m$ (Fig23). The removing of field wires will request slightly higher value of V_s. Now we have $V_s = 1500V$. It corresponds to $\simeq 62V \cdot cm^{-1} \cdot torr^{-1}$ average electric field between sense and grid plane. Low pressure chamber studies have a long time story and a huge number of publications. Let me quote only one: A. Breskin "Progress in low-pressure gaseous detectors", Nucl. Instr. Meth. 196(1982)11-21 (see Fig.13). A proportional chamber is presented and investigated. It is chamber with $10\mu m$ sense wires with $20mm$ length and pitch of $1mm$. Gap between sense and cathode plane (mylar) was $3.2mm$. ISO gas has been used at $p = 2.9torr$ with $V_s = 580V$ on the chamber. It corresponds to $E = 625 \cdot cm^{-1} \cdot torr^{-1}$. This E value is 10 times more than E in our TEC. No report about a cross talk between wires with pitch of $1mm$! No report about sparks at gas pressure of $p = 2.9torr$! Some admixture of water in DME gas or air leak in TEC volume could explain the sparks in TEC DC2. Second reason of the sparks could be an electron collection near TEC edge (Figs.24, 25). One can see that guard wire at $Y = 1.05cm$ collects 7 times more electrons compare with any different wire. The guard wire can be a source of ultraviolet and sparks therefore in TEC multiplication area. A guard wire with $d \simeq 500\mu m$ or 2-3 wires with $d \simeq 250\mu m$ at $Y = 1.05cm$ could remove the problem.

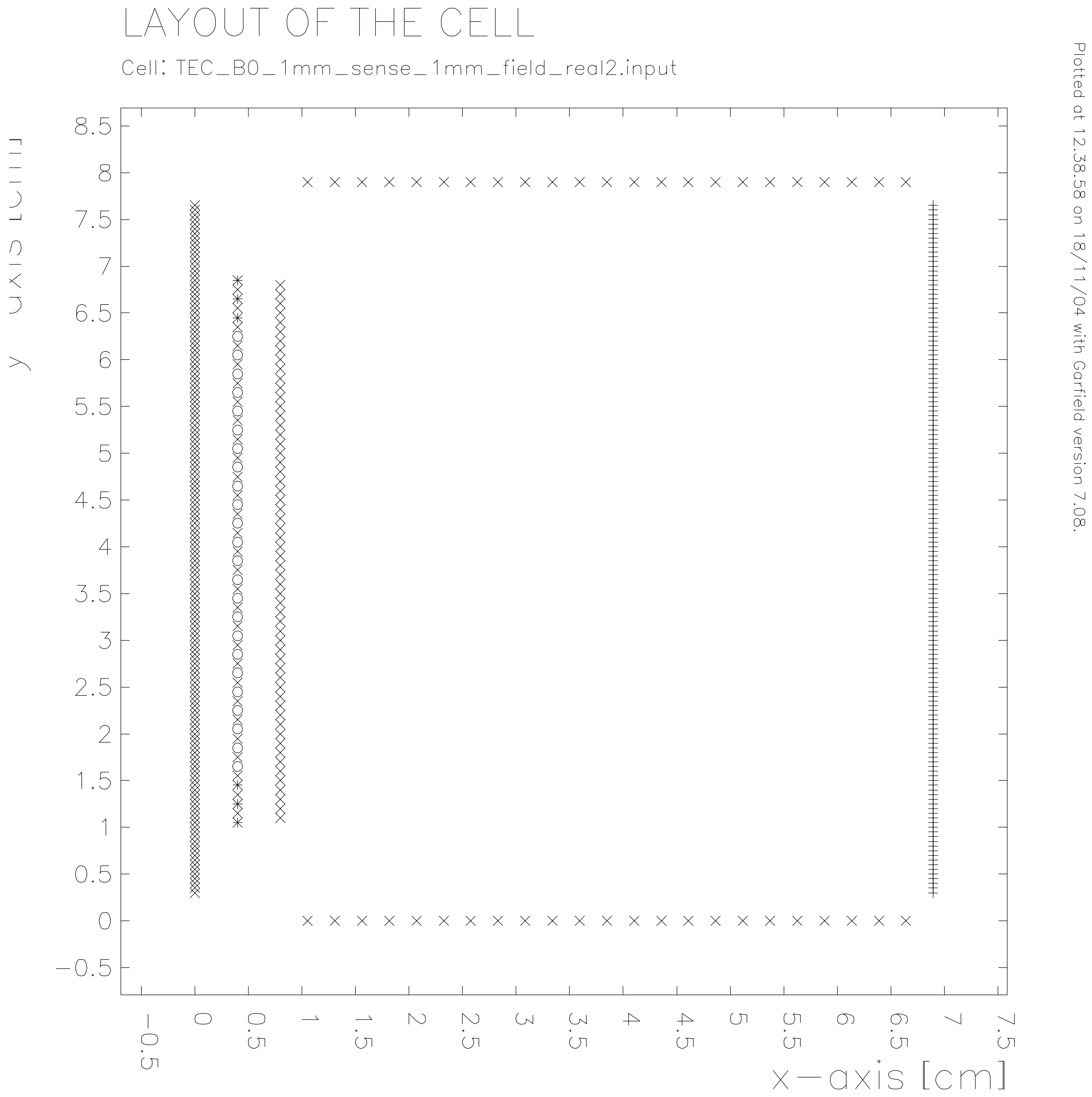

Figure 1: Existing TEC DC2 with field wires (view in XY-plane). Drift area of TEC lies from X=0.8cm to X=6.85cm. Multiplication area lies from X=0 to X=0.8cm. ($\circ$) are sense wires ($d = 25\mu m$) with $V_s = 1500V$, ($*$) are edge wires ($d = 125\mu m$) with $V_f = 750V$, ($\times$) at X=0.4cm are field wires ($d = 125\mu m$) with $V_f = 750V$, ($\times$) at X=0.8cm are grid wires ($d = 125\mu m$) with $V_g = 0V$.

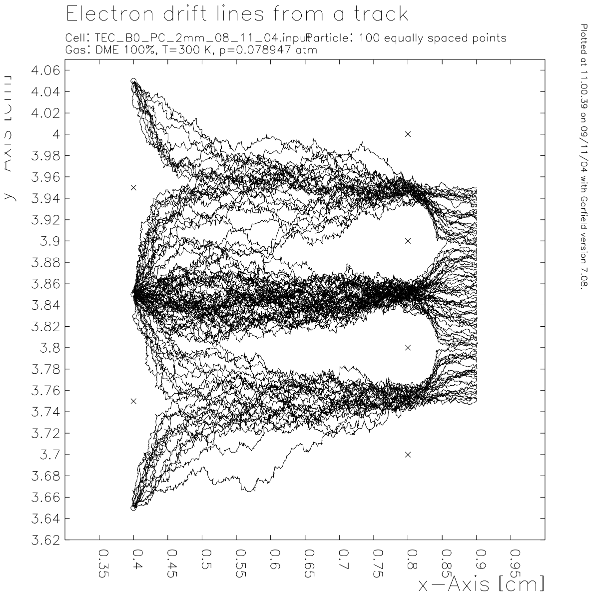

Figure 2: Drift lines of electrons in existing TEC DC2. Original track with length of $2mm$ along Y axis goes at $X = 0.9cm$ and covers one cell with signal wire at $Y = 3.85cm$. One can see an electron leakage outside the cell. 100 primary electrons have been simulate in Figs.2-7.

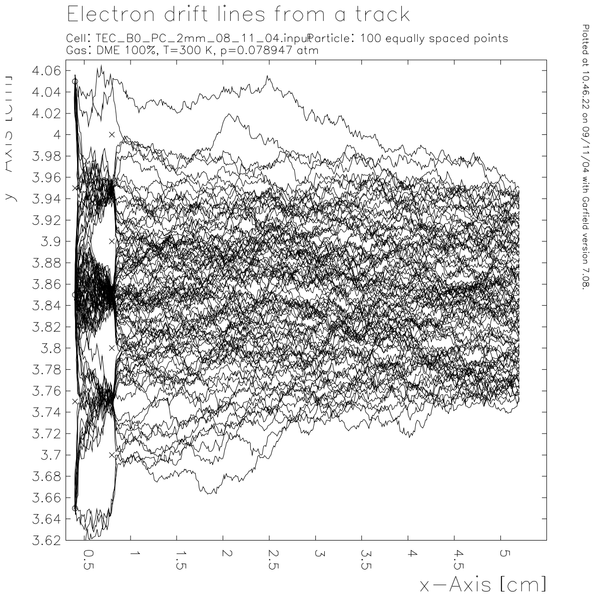

Figure 3: Drift lines of electrons in existing TEC DC2. Original track with length of $2mm$ along Y axis goes at $X = 5.2cm$ and covers one cell with signal wire at $Y = 3.85cm$. One can see an electron leakage outside the cell.

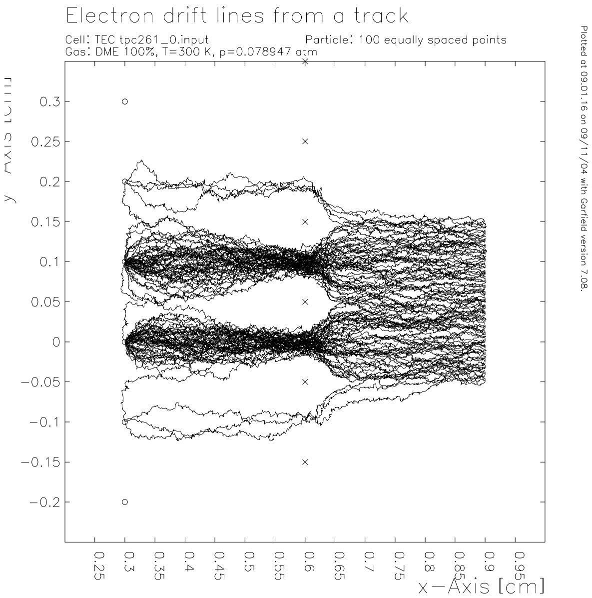

Figure 4: Drift lines of electrons in TEC PC(1+1). Original track with length of $2mm$ along Y axis goes at $X = 0.9cm$ and covers one cell with signal wires at $Y = 0$ and $Y = 0.1cm$. One can see an electron leakage outside the cell.

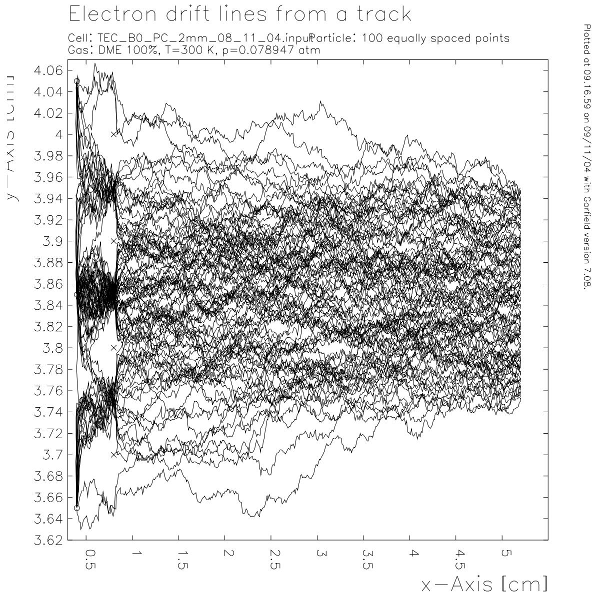

Figure 5: Drift lines of electrons in TEC PC(1+1). Original track with length of $2mm$ along Y axis goes at $X = 5.2cm$ and covers one cell with signal wire at $Y = 3.85cm$. One can see an electron leakage outside the cell.

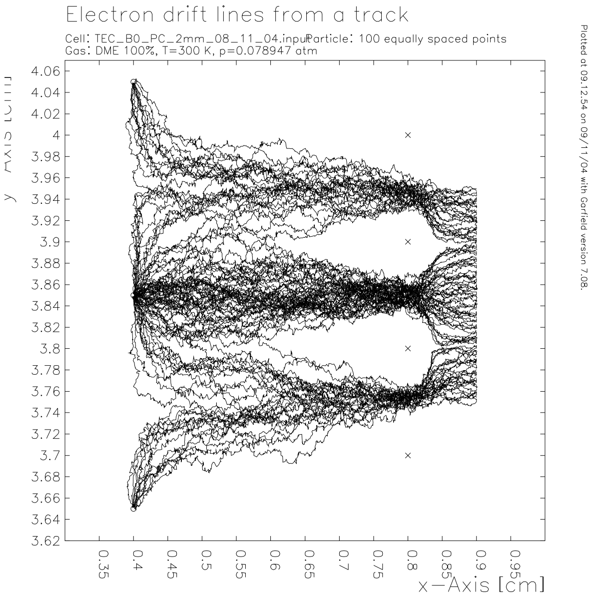

Figure 6: Drift lines of electrons in TEC PC2. Original track with length of $2mm$ along Y axis goes at $X = 0.9cm$ and covers one cell with signal wire at $Y = 3.85cm$. One can see an electron leakage outside the cell.

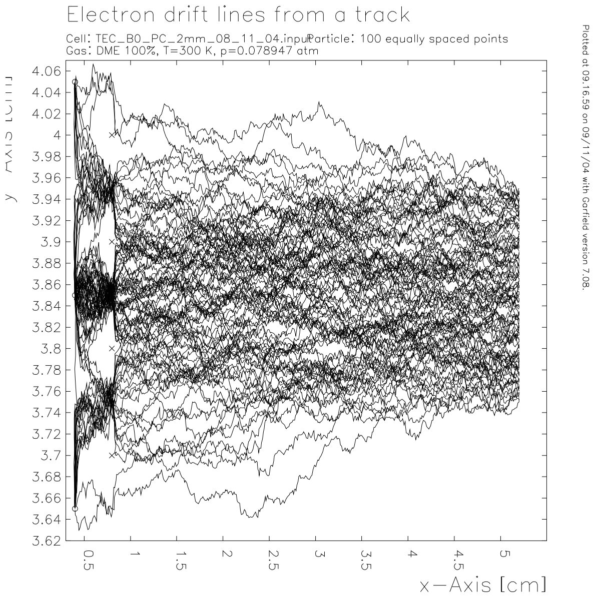

Figure 7: Drift lines of electrons in TEC PC2. Original track with length of $2mm$ along Y axis goes at $X = 5.2cm$ and covers one cell with signal wire at $Y = 3.85cm$. One can see an electron leakage outside the cell.

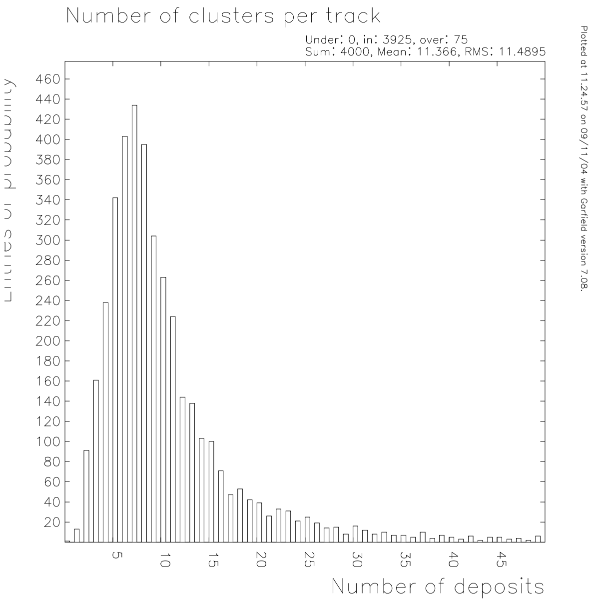

Figure 8: Number of primary electrons per $2mm$ in DME gas at $p = 60Torr$ for surface muons.

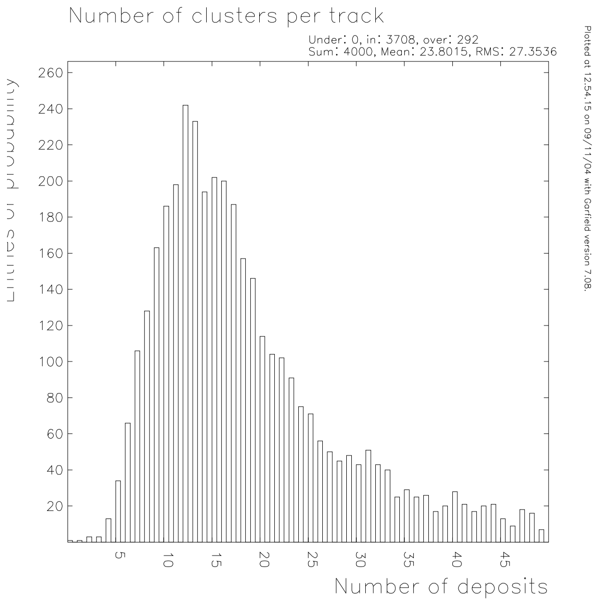

Figure 9: Number of primary electrons per $2mm$ in ISO gas at $p = 60Torr$ for surface muons.

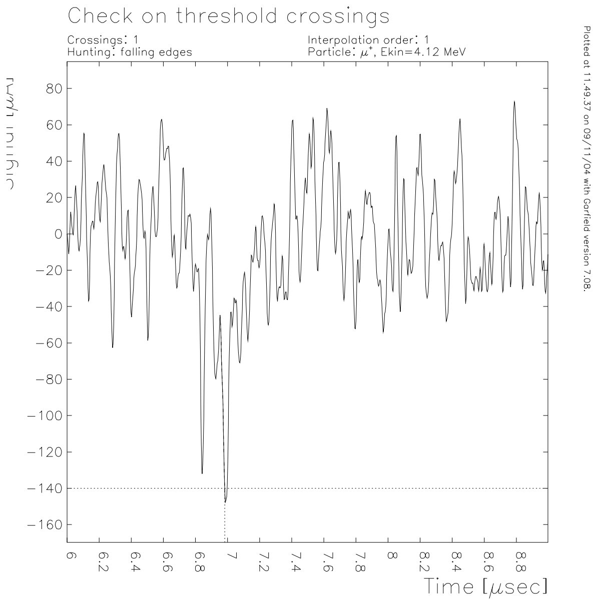

Figure 10: Total gained signal on a wire of TEC DC2 from surface muon goes at $X = 6cm$ along Y-axis. The track covers several sells. The total signal hits a discriminator with threshold of $140mV$ (about in 30% events). Response function of electronics and noise are introduced.

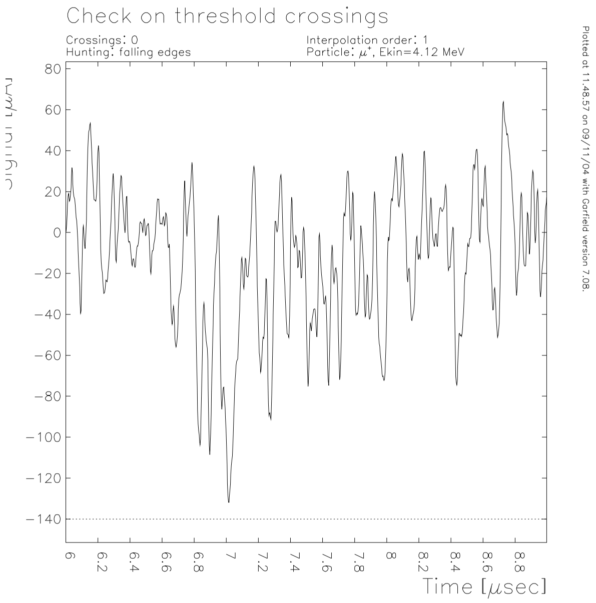

Figure 11: Total gained signal on a wire of TEC DC2 from surface muon goes at $X = 6cm$. The track covers several sells. The total signal does not hit a discriminator with threshold of $140mV$ (about in 70% events) because a diffusion and leakage.

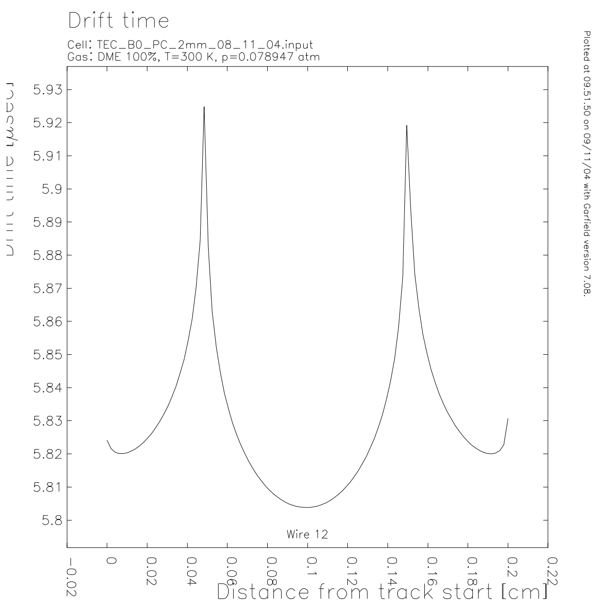

Figure 12: Time spread of electrons in TEC DC2. Track with length of $2mm$ covers one cell with wire 12. Maximal spread riches $\sim 120ns$.

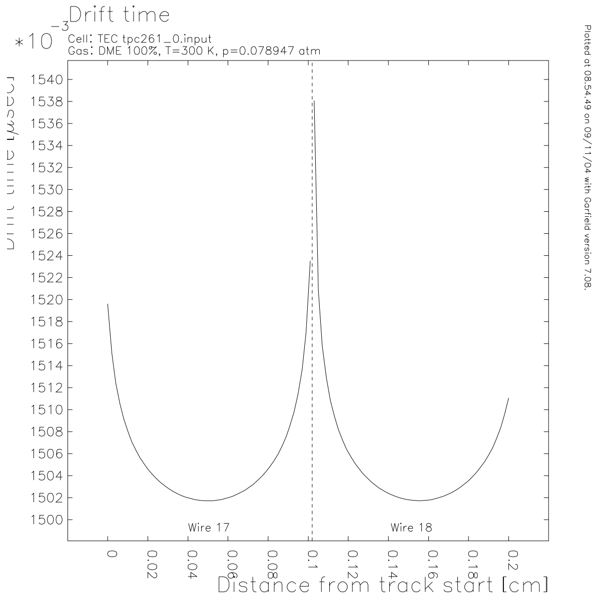

Figure 13: Time spread of electrons in TEC PC(1+1). Track with length of $2mm$ covers one cell with joint wire 17 and 18. Maximal spread riches $\sim 30ns$.

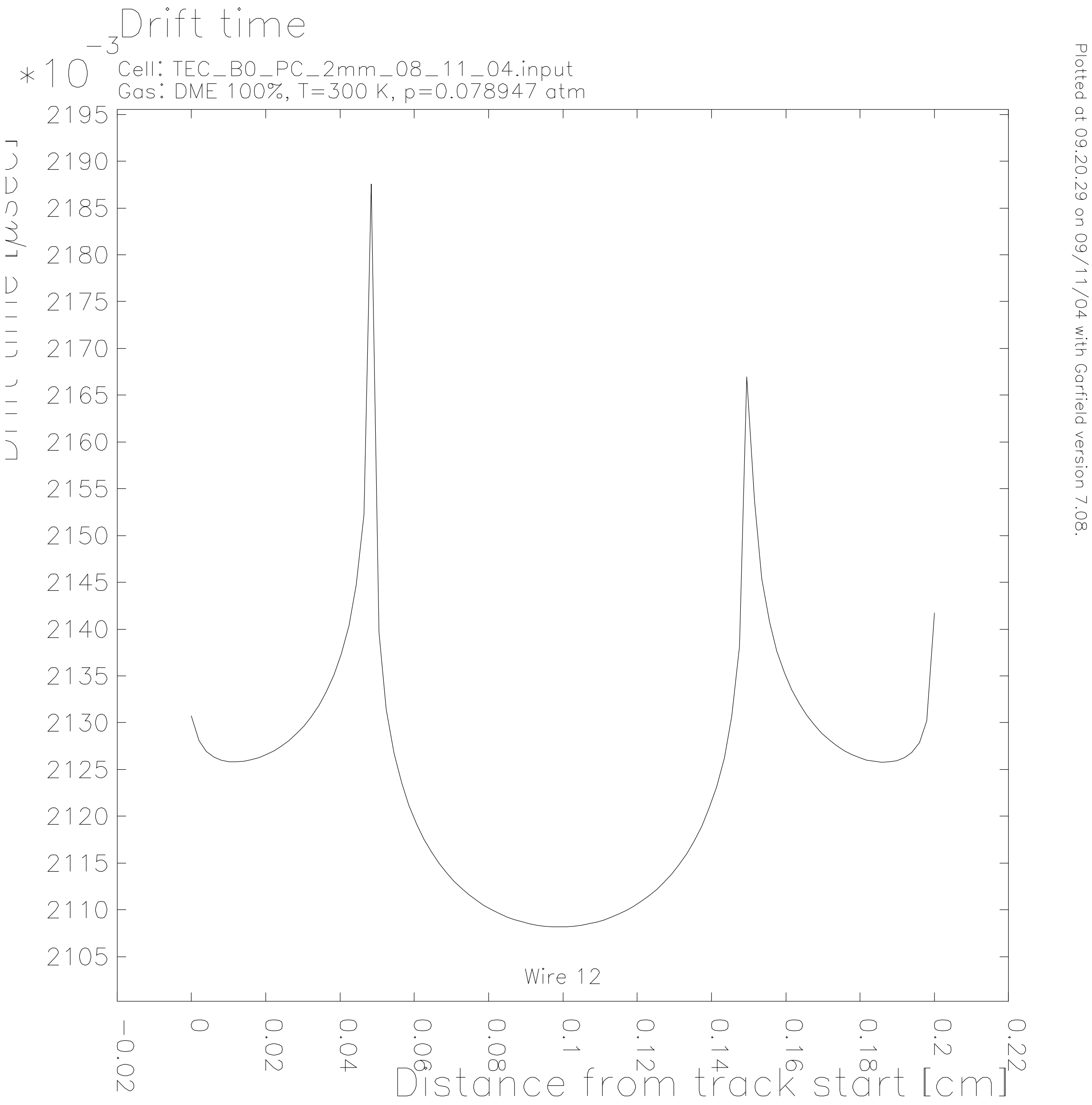

Figure 14: Time spread of electrons in TEC PC2. Track with length of $2mm$ covers one cell with wire 12. Maximal spread riches $\sim 70ns$.

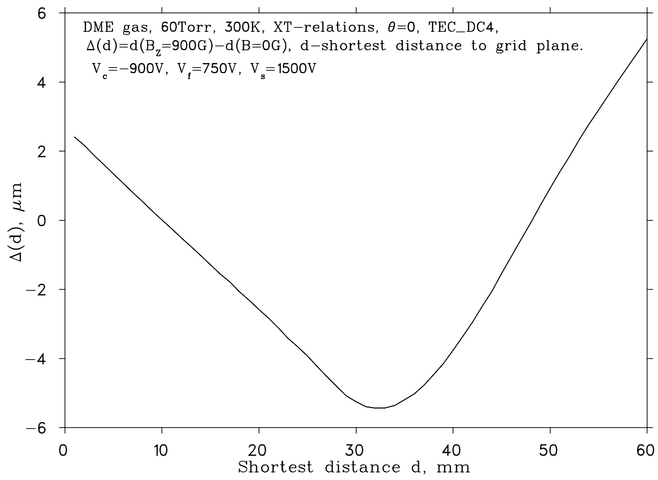

Figure 15: Space shift of TEC STR with DME at $p = 60Torr$ and $B_z = 900G$. $V_c = -900V$. V_c, V_f, V_s are cathode, field and sense wires HV respectively. Grid wires have $HV = 0$.

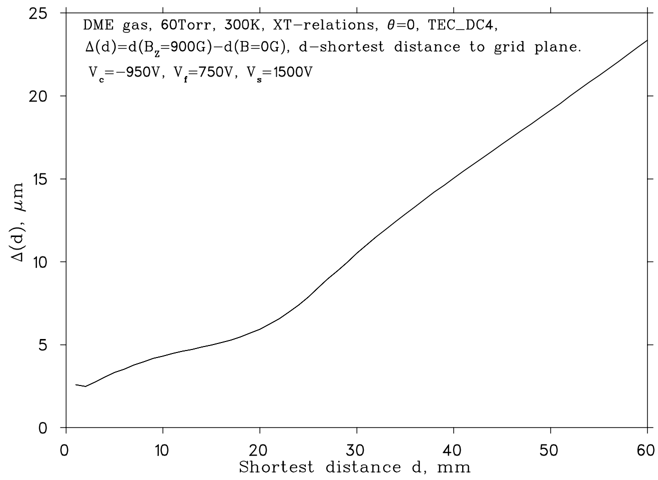

Figure 16: Space shift of TEC STR with DME at $p = 60Torr$ and $B_z = 900G$. $V_c = -950V$. V_c, V_f, V_s are cathode, field and sense wires HV respectively. Grid wires have $HV = 0$.

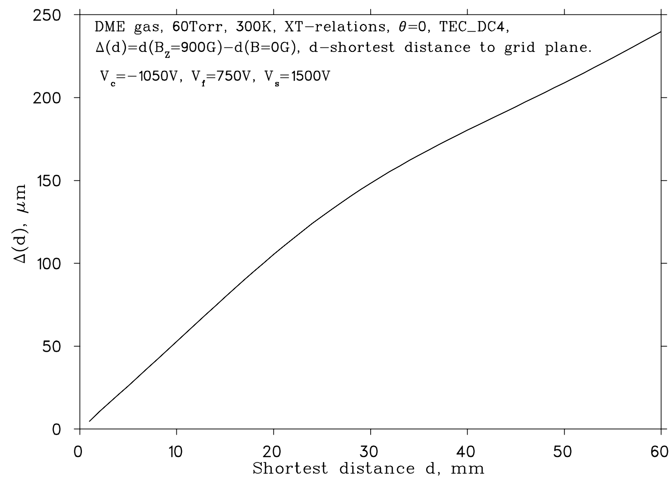

Figure 17: Space shift of TEC STR with DME at $p = 60Torr$ and $B_z = 900G$. $V_c = -1050V$. V_c, V_f, V_s are cathode, field and sense wires HV respectively. Grid wires have $HV = 0$.

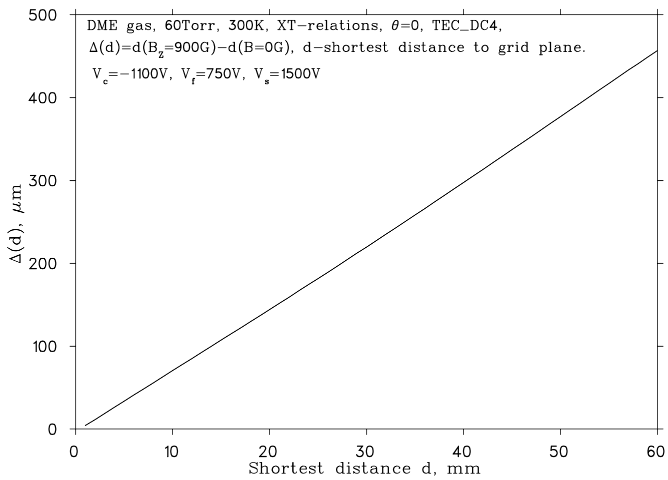

Figure 18: Space shift of TEC STR with DME at $p = 60Torr$ and $B_z = 900G$. $V_c = -1100V$. V_c, V_f, V_s are cathode, field and sense wires HV respectively. Grid wires have $HV = 0$.

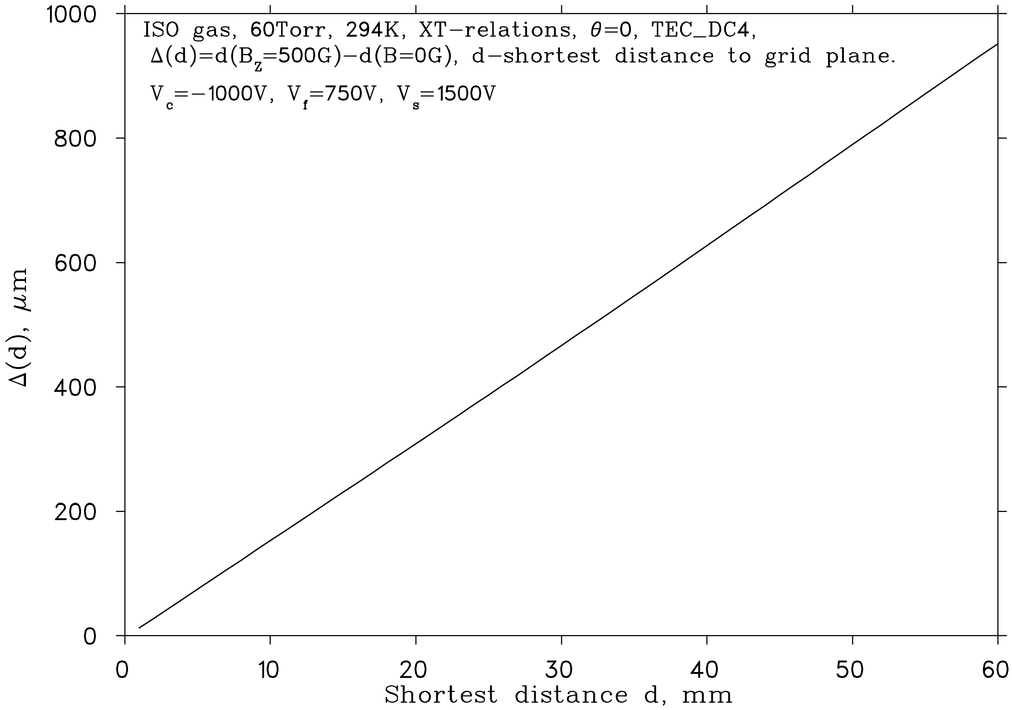

Figure 19: Space shift of TEC STR with ISO at $p = 60Torr$ and $B_z = 500G$. $V_c = -1000V$. V_c, V_f, V_s are cathode, field and sense wires HV respectively. Grid wires have $HV = 0$.

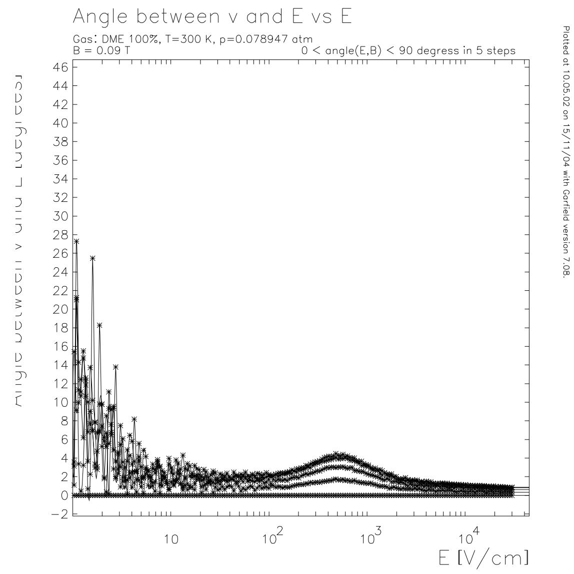

Figure 20: Lorentz drift angle in DME at $p = 60Torr$ and $B_z = 900G$. Z-axis is the solenoid field direction. $V_c = -1000V$ corresponds to $E = 170V/cm$. Lorentz angle has been calculated at differnt angles θ between $\vec{E}$ and $\vec{B}_z$ with step of $\Delta\theta = 15^\circ$ with $\theta = 0 - 90^\circ$.

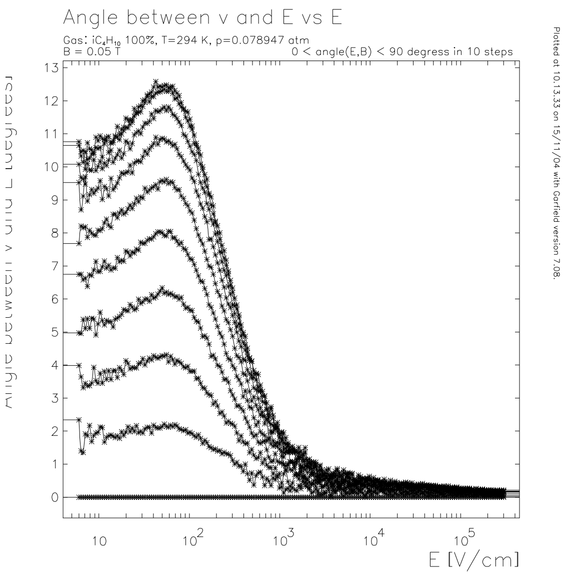

Figure 21: Lorentz drift angle in ISO at $p = 60Torr$ and $B_z = 500G$. Z-axis is the solenoid field direction $V_c = -1000V$ corresponds to $E = 170V/cm$. Lorentz angle has been calculated at differnt angles θ between $\vec{E}$ and $\vec{B}_z$ with step of $\Delta\theta = 15^\circ$ with $\theta = 0 - 90^\circ$.

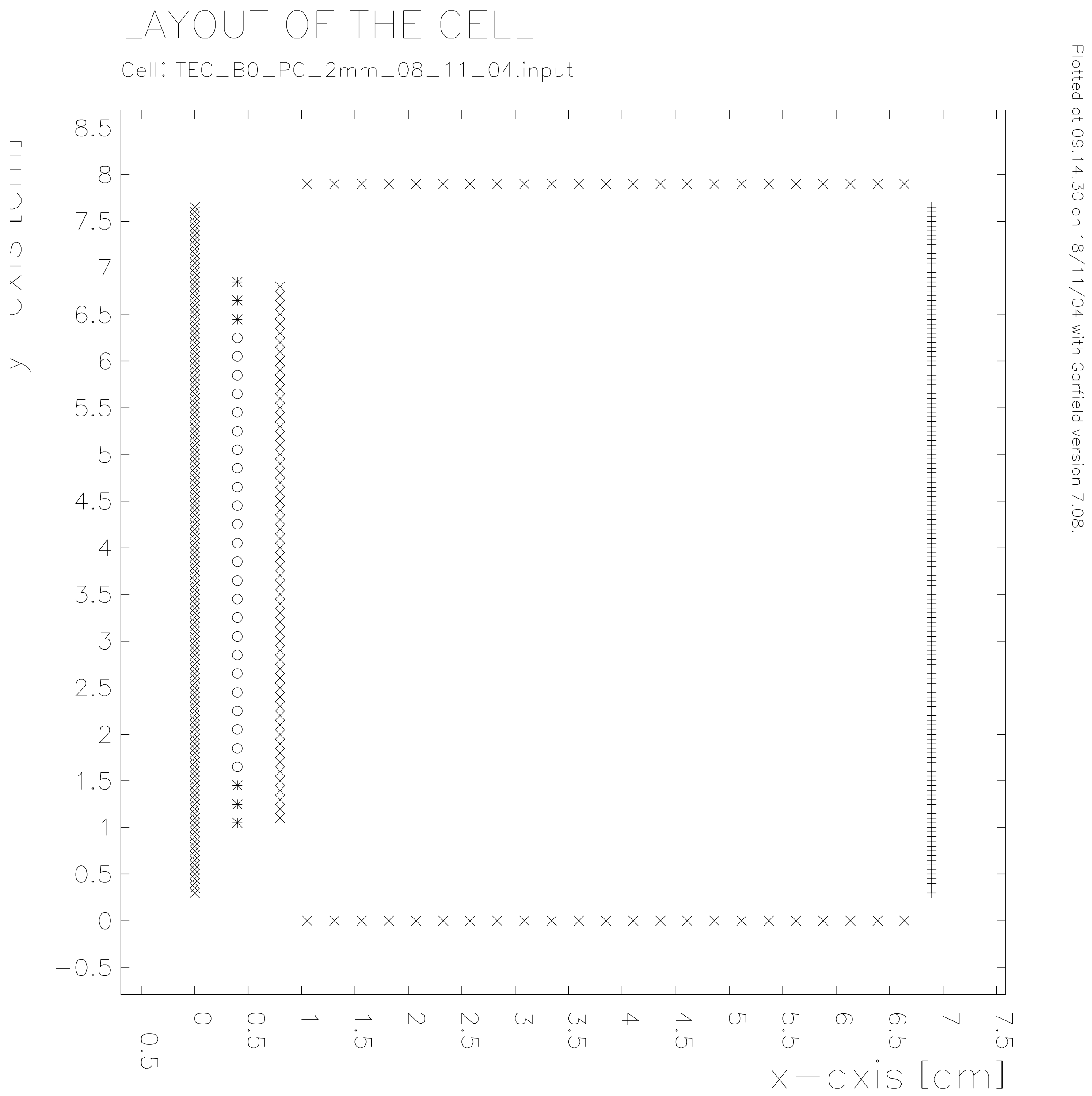

Figure 22: View in XY-plane of TEC without field wires. Drift area of TEC lies from X=0.8cm to X=6.85cm. Multiplication area lies from X=0 to X=0.8cm. ($\circ$) are sense wires ($d = 25\mu m$) with $V_s = 2000V$, ($*$) are edge wires ($d = 125\mu m$) with $V_f = 2000V$, ($\times$) at X=0.8cm are grid wires ($d = 125\mu m$) with $V_g = 0V$.

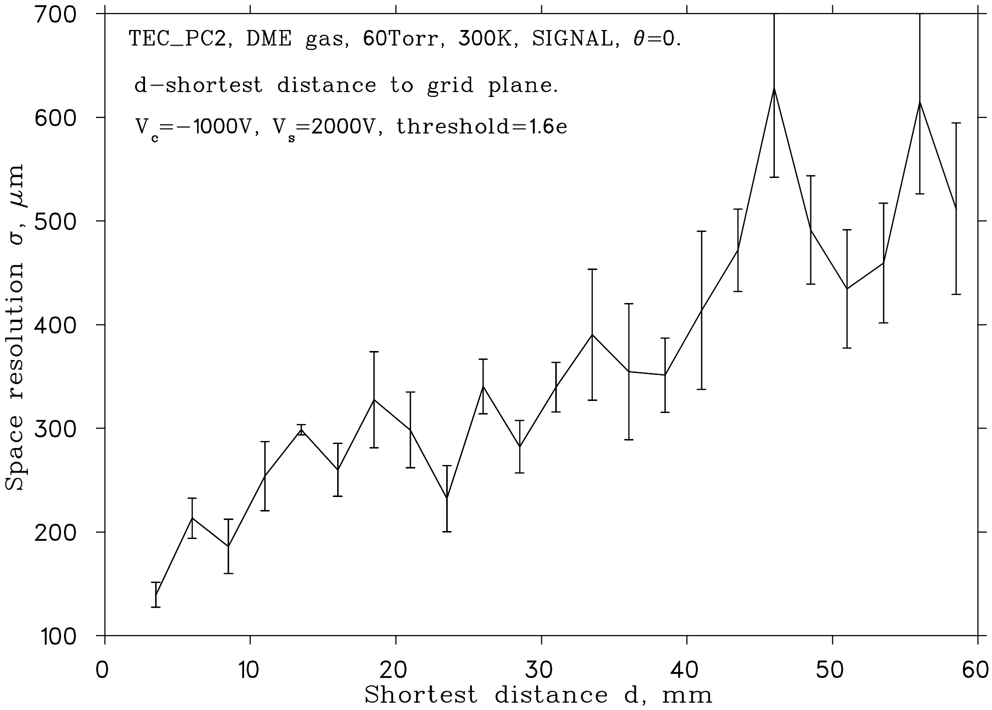

Figure 23: Space resolution of TEC PC2 with DME at $p = 60 Torr$. $V_s = 2000V$, $V_c = -1000V$. One can see that a time spread (Fig.14) gives a resolution of $200 \mu m$ at $d < 10mm$. A space resolution growth with d increasing because a diffusion and a leakage of drift electrons (Figs.6, 7).

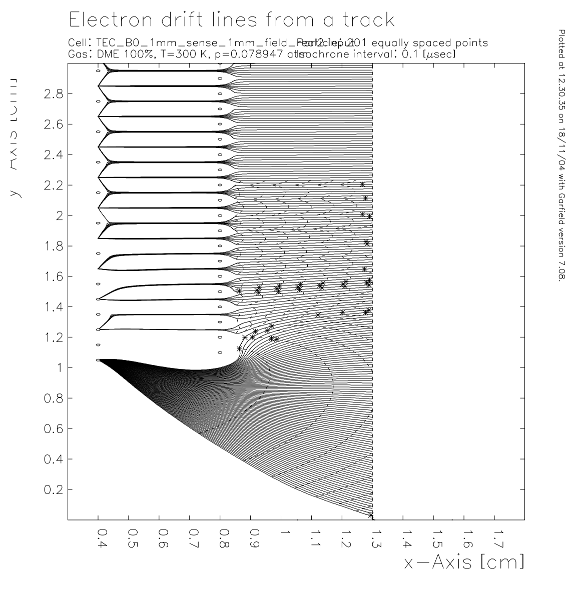

Figure 24: Electron drift lines near TEC edge in DC2. Original track goes at $X = 1.3cm$ along Y axis. First signal wire placed at $Y = 1.85cm$. One can see that the edge wire at $Y = 1.05cm$ accumulates 7 times electrons more than a sense wire. The wire at $Y = 1.05cm$ can be a source of a spark in the first place.

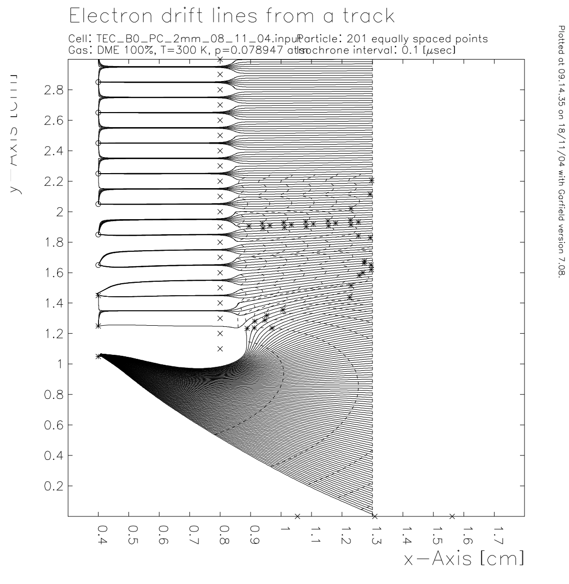

Figure 25: Electron drift lines near TEC edge in PC2. Original track goes at $X = 1.3cm$ along Y axis. First signal wire placed at $Y = 1.85cm$. One can see that the edge wire at $Y = 1.05cm$ accumulates 7 times electrons more than a sense wire. The wire at $Y = 1.05cm$ can be a source of a spark in the first place.