TRIUMF Experiment E614
Technical Note #86

GARFIELD Simulation of STR and Resolution for DC4 at B=2T

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26 November 2003

STR and time resolution of DC4 of E614 were calculated at $B = 2T$ using SIGNAL Section of the GARFIELD 7.08. HEED package been used for simulation of positron interactions with DME gas. Gas file has been calculated using MONTE-CARLO-INTEGRATION procedure with $ncoll = 600$. All drift parameters, as result of so big $ncoll$ number, were calculated at very small values of electric field $E > 5V/cm$. It means the program works correctly on DC4 square excluding a circle with $r = 3\mu m$ with center in center between nearest sense wires where $E < 5V/cm$. MONTE-CARLO integration procedure with MONTE-CARLO-DISTANCE-INTERVAL=$5\mu m$ been used for more accurate calculations. SIGNAL Section has used for STR and time resolution calculations. Full description of the procedure has been done in TN-81. The program is in home/selivano/garf_7/STR_B2/dc4_signal.input.

Fig.1 shows the geometry used for calculations. Particle track (straight line) is orthogonal to vector of shortest distance $\overrightarrow{d}$. φ-angle is defined in Fig.1. The selected geometry (d, θ, φ) is natural system for STR calculations. One can see below transformation formulas from the above system to Dekart orthogonal right handed coordinate system. 200 events been generated at each given (d, θ, φ). Accumulated spectrum is fitted by a gaussian:

$$N(t) = N_0 exp[-(t - t_0)^2/2\sigma_t^2]$$

Results of the fit are files in home/selivano/garf_7/STR_B2/ , for example, file STR_DME_e-30MeV_theta45_phi60_thr-140_V-1950_T-300_p-760_B2_HEED_1e-90mV_space5.out corresponds to $\theta = 45°, \varphi = 60°$. The file consists of the gaussian parameters for $d \in [0, d_{max}]$ with step of $\Delta d = 0.1mm$. $t0 \equiv t_0$, st0≡stat.error of t_0, s≡ σ_t, ss≡stat. error of σ_t, chi$\hat{2}$≡ χ^2 at $NDF = 30$. Calculations done for $\theta \in [0, 90°]$ with step of $\Delta\theta = 5°$, and for $\varphi = 0, 15, 30, 40°$, and $\varphi \in [45°, 75°]$ with step of $\Delta\varphi = 5°$.

Additional calculations are done near a sense wire because a changing of STR and time resolution more sensitive in this area to φ value. The calculations done at $\theta = 0$, $d \in [0, 0.54mm]$ with step of $\Delta d = 0.02mm$, and at $\varphi = 0, 15, 30, 40°$, and $\varphi \in [45°, 75°]$ with step of $\Delta\varphi = 5°$. An example of the file at $\varphi = 40°$ is STR_DME_e-30MeV_theta00_phi40_thr-140_V-1950_T-300_p-760_B2_HEED_1e-90mV_space5_0-05mm.out.

Table 1: File STR_DME_e-30MeV_theta45_phi60_thr-140_V-1950_T-300_p-760_B2_HEED_1e-90mV_space5.out.

d [mm]	t0 [ns]	st0 [ns]	s [ns]	ss [ns]	chi2 NDF=30
0.00	8.56	0.12	1.46	0.11	13.44
0.10	8.99	0.13	1.51	0.11	14.38
0.20	10.40	0.12	1.20	0.10	15.62
0.30	11.53	0.17	0.97	0.15	38.94
0.40	13.67	0.09	1.23	0.08	10.39
0.50	15.98	0.07	1.08	0.06	9.33
0.60	19.02	0.17	1.00	0.15	37.79
0.70	22.82	0.11	1.21	0.09	14.85
0.80	27.43	0.10	1.34	0.09	10.41
0.90	33.01	0.10	1.13	0.08	13.41
1.00	39.24	0.19	1.52	0.17	26.04
1.10	46.88	0.14	1.43	0.11	15.98
1.20	54.90	0.13	1.57	0.11	12.46
1.30	64.10	0.10	1.34	0.08	9.79
1.40	74.00	0.11	1.44	0.09	10.64
1.50	84.56	0.14	1.68	0.12	13.88
1.60	95.70	0.18	1.69	0.15	18.40
1.70	107.89	0.15	1.71	0.13	15.45
1.80	119.82	0.16	1.60	0.13	17.05
1.90	134.27	0.32	2.34	0.26	30.78
2.00	151.09	0.47	3.87	0.38	23.52
2.10	170.21	0.59	4.46	0.46	26.19
2.20	194.50	0.78	6.02	0.61	26.38
2.30	226.65	0.80	9.71	0.62	13.39
2.40	263.15	1.82	11.04	1.42	36.12
2.50	309.65	2.33	11.59	1.97	47.80
2.60	393.44	4.95	26.48	3.52	40.78
2.70	546.70	12.72	73.85	9.31	26.27
2.80	721.12	68.79	111.24	64.34	5.58

One can see below a translation of above coordinate system to 3D Dekart system. Track straight line is defined by two points (X_1, Y_1, Z_1) and (X_2, Y_2, Z_2).

Y plane: wire is directed along X-axis. Wire center is at $Y = Z = 0$.

$$\theta \leq 44.957^\circ$$

$$X_1 = (-1.997/\cos\theta + d\tan\theta)\tan\varphi, X_2 = (1.997/\cos\theta + d\tan\theta)\tan\varphi.$$
$$Y_1 = -1.997\tan\theta + d/\cos\theta, Y_2 = 1.997\tan\theta + d/\cos\theta.$$
$$Z_1 = -1.997, Z_2 = 1.997.$$

$$\theta > 44.957^\circ$$

$$X_1 = (2.0/\sin\theta + d/\tan\theta)\tan\varphi, X_2 = (2.0/\sin\theta - d/\tan\theta)\tan\varphi.$$
$$Y_1 = -2.0, Y_2 = 2.0.$$
$$Z_1 = -d/\sin\theta - 2.0/\tan\theta, Z_2 = -d/\sin\theta + 2.0/\tan\theta.$$

X plane: wire is directed along Y-axis. Wire center is at $X = Z = 0$.

$$\theta \leq 44.957^\circ$$

$$X_1 = -1.997\tan\theta + d/\cos\theta, X_2 = 1.997\tan\theta + d/\cos\theta.$$
$$Y_1 = (-1.997/\cos\theta + d\tan\theta)\tan\varphi, Y_2 = (1.997/\cos\theta + d\tan\theta)\tan\varphi.$$
$$Z_1 = -1.997, Z_2 = 1.997.$$

$$\theta > 44.957^\circ$$

$$X_1 = -2.0, X_2 = 2.0.$$
$$Y_1 = (2.0/\sin\theta + d/\tan\theta)\tan\varphi, Y_2 = (2.0/\sin\theta - d/\tan\theta)\tan\varphi.$$
$$Z_1 = -d/\sin\theta - 2.0/\tan\theta, Z_2 = -d/\sin\theta + 2.0/\tan\theta.$$

$$0 \leq \theta \leq 90^\circ, 0 \leq \varphi \leq 75^\circ,$$
$$d_{max} = 2.8263\cos(44.957^\circ - \theta), \text{ at } \theta \leq 44.957^\circ,$$
$$d_{max} = 1.997 sin\theta, \text{ at } \theta > 44.957^\circ,$$

d_{max} is a maximum distance at given θ between wire center and track which hits the cell.

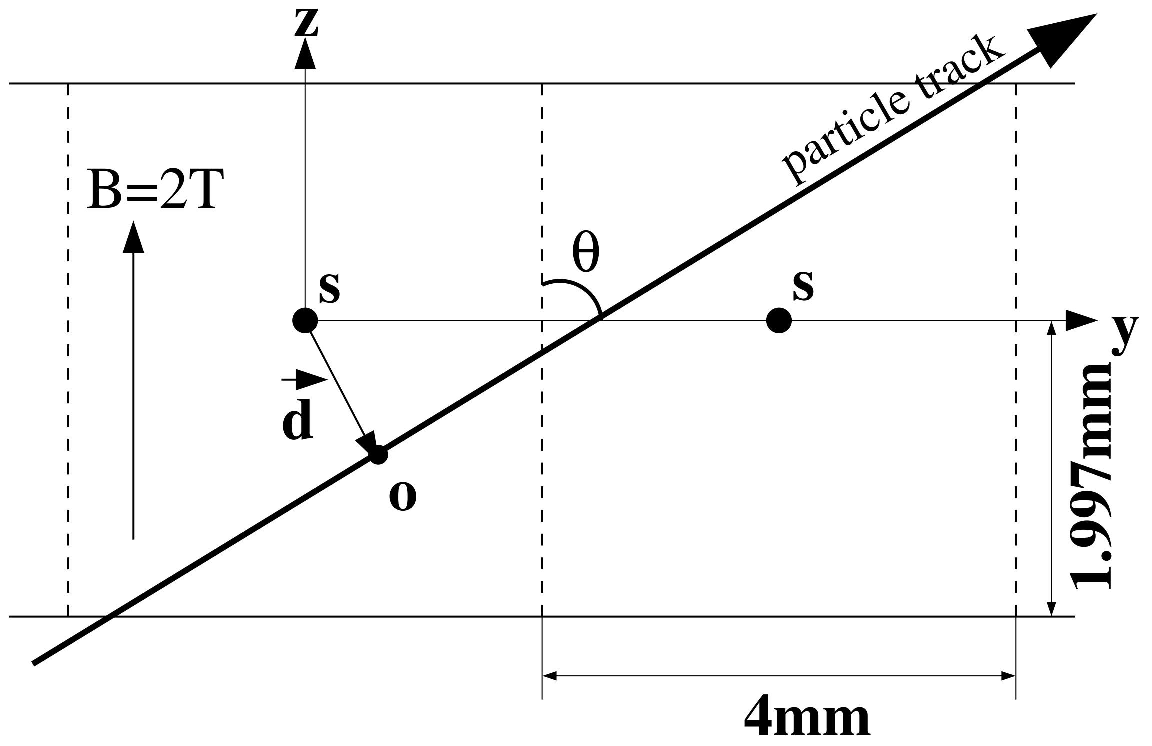
Figs.2, 3 demonstrate drift electron distribution from a track taking to account all processes in drift gas. More detailed description of the processes has been done in TN-81. Figs.4, 5 practically imitate drift electron distribution as that done now in GEANT clusterization. Let me hope to see the same distributions from GEANT.

Figs.6-17 show some results of the calculations. Space resolution has been calculated as

$$\sigma_d = \sigma_t / f'(d).$$

In conclusion:

- All results are in home/selivano/garf_7/STR_B2.
- File
STR_DME_e-30MeV_theta45_phi60_thr-140_V-1950_T-300_p-760_B2_HEED_1e-90mV_space5.out corresponds to $\theta = 45°, \varphi = 60°, d \in [0, d_{max}]$ with step of $\Delta d = 0.1mm$.
- File
STR_DME_e-30MeV_theta00_phi40_thr-140_V-1950_T-300_p-760_B2_HEED_1e-90mV_space5_0-05mm.out corresponds to $\theta = 0°, \varphi = 40°, d \in [0, 0.54mm]$ with step of $\Delta d = 0.02mm$.



Sense wires are directed along X−axis (orthogonal to paper plane). Right handed 3D Dekart system.

Particle track is described by shortest distance "d", θ and φ angles. Vector $\vec{d}$ lies in ZY−plane. θ is an angle in ZY−plane between particle track projection on ZY−plane and Z axis. φ angle is result of rotation of track from ZY−plane on the φ angle around point "o" in plane orthogonal to $\vec{d}$ vector.

Figure 1: Geometry in ZY-plane of the calculations.

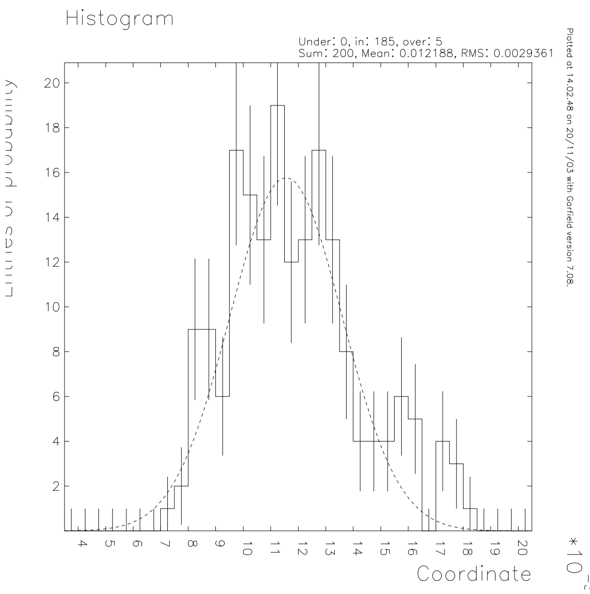


Figure 2: Time distribution of drift electrons from e^+ track with $d = 0mm, \theta = 0°, \varphi = 0°$ and gaussian fit of the distribution. SIGNAL Section of Garfield. Registration threshold is $1.5e$. All processes are on.

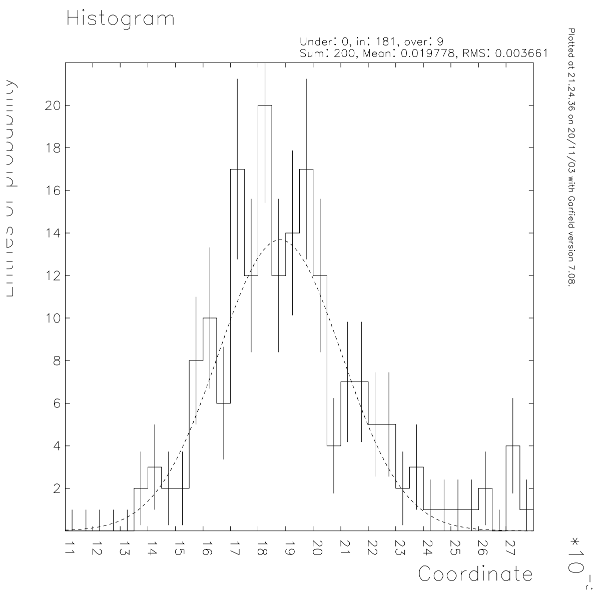


Figure 3: Time distribution of drift electrons from e^+ track with $d = 0.5mm, \theta = 0°, \varphi = 0°$ and gaussian fit of the distribution. SIGNAL Section of Garfield. Registration threshold is $1.5e$. All processes are on.

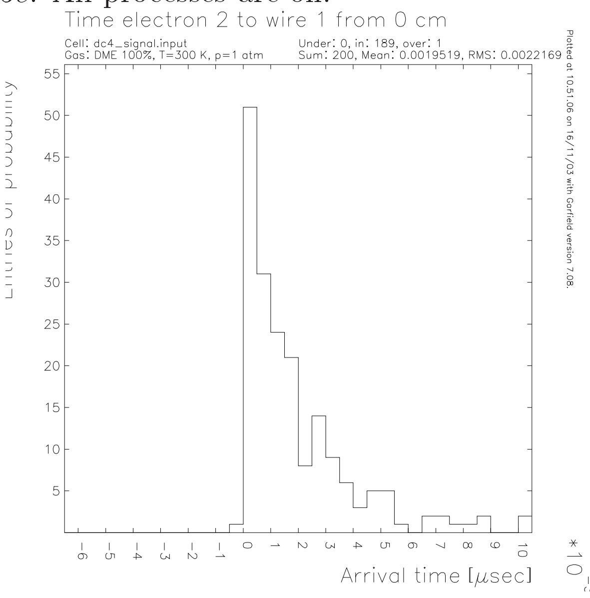


Figure 4: Time distribution of drift electrons from e^+ track with $d = 0mm, \theta = 0°, \varphi = 0°$. DRIFT Section of Garfield. No diffusion, no gain and its fluctuations, no noise, no attachment, no δ-electrons. Rising time of a signal equals to zero. Registration threshold is $1.5e$. Scattering of e^+ is on only.

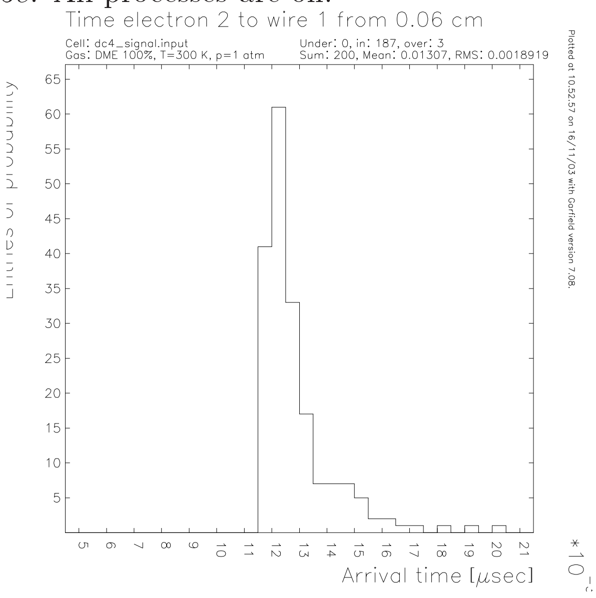


Figure 5: Time distribution of drift electrons from e^+ track with $d = 0.6mm, \theta = 0°, \varphi = 0°$. DRIFT Section of Garfield. No diffusion, no gain and its fluctuations, no noise, no attachment, no δ-electrons. Rising time of a signal equals to zero. Registration threshold is $1.5e$. Scattering of e^+ is on only.

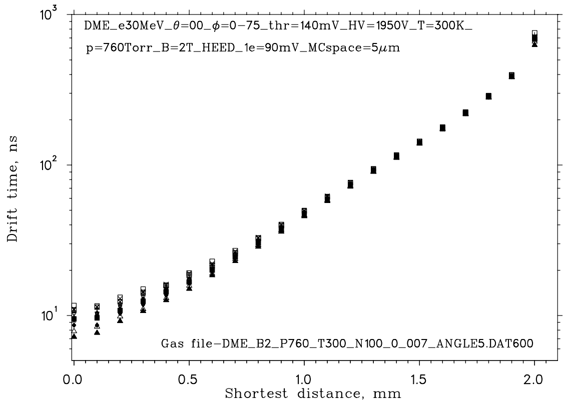


Figure 6: $t_0 = f(d)$ at $d = 0 - 2.0mm, \theta = 0°, \varphi = 0 - 75°$. Lowest values of t_0 correspond to $\varphi = 75°$.

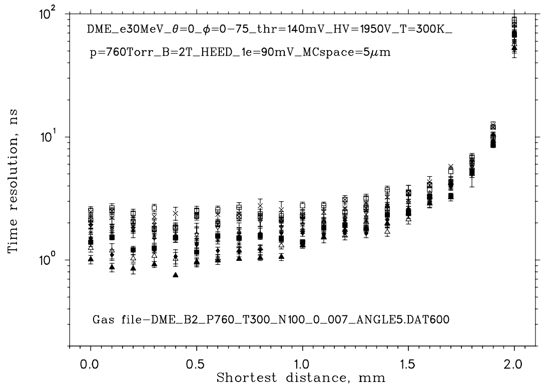


Figure 7: Time resolution $\sigma_t = F(d)$ at $d = 0 - 2.0mm, \theta = 0°, \varphi = 0 - 75°$. Lowest values of σ_t correspond to $\varphi = 75°$.

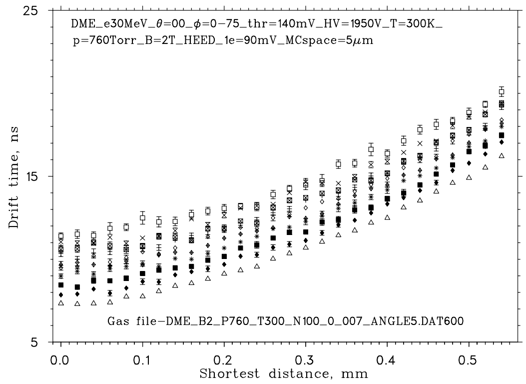


Figure 8: $t_0 = f(d)$ at $d = 0 - 0.54mm, \theta = 0°, \varphi = 0 - 75°$. Lowest values of t_0 correspond to $\varphi = 75°$.

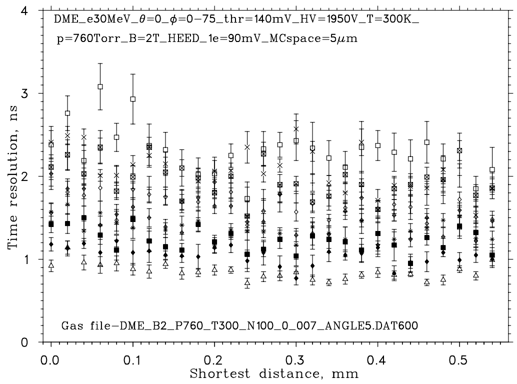


Figure 9: Time resolution $\sigma_t = F(d)$ at $d = 0 - 0.54mm, \theta = 0°, \varphi = 0 - 75°$. Lowest values of σ_t correspond to $\varphi = 75°$.

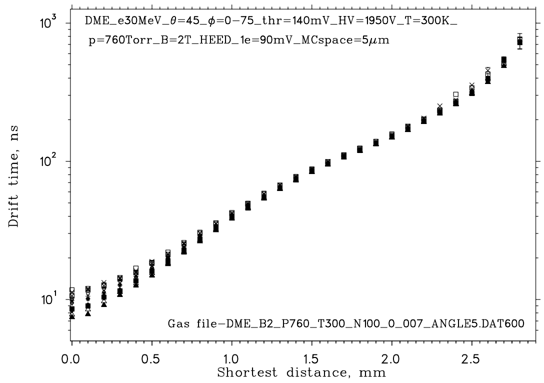


Figure 10: $t_0 = f(d)$ at $d = 0 - 2.8mm, \theta = 45°, \varphi = 0 - 75°$. Lowest values of t_0 correspond to $\varphi = 75°$.

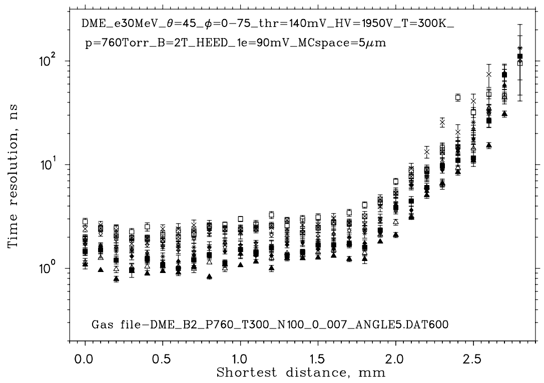


Figure 11: Time resolution $\sigma_t = F(d)$ at $d = 0 - 2.8mm, \theta = 45°, \varphi = 0 - 75°$. Lowest values of σ_t correspond to $\varphi = 75°$.

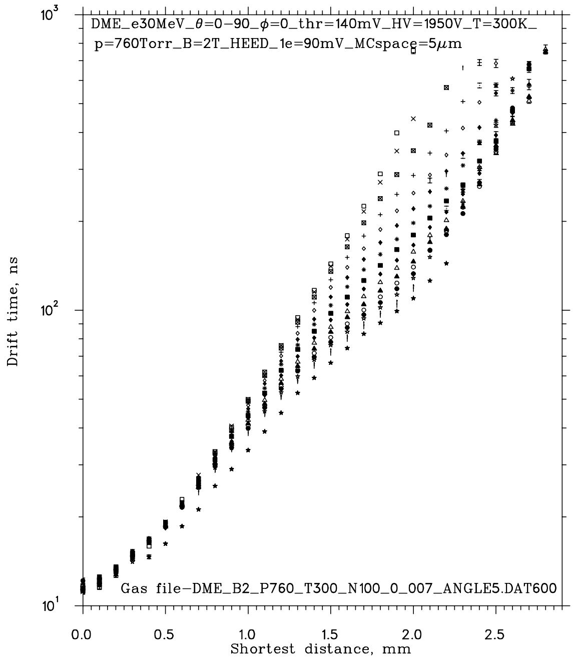


Figure 12: $t_0 = f(d)$ at $\theta = 0 - 90°, \varphi = 0°$.

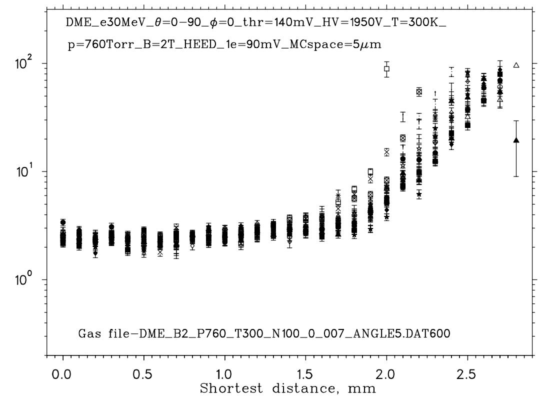


Figure 13: Time resolution $\sigma_t = F(d)$ at $\theta = 0 - 90°, \varphi = 0°$.

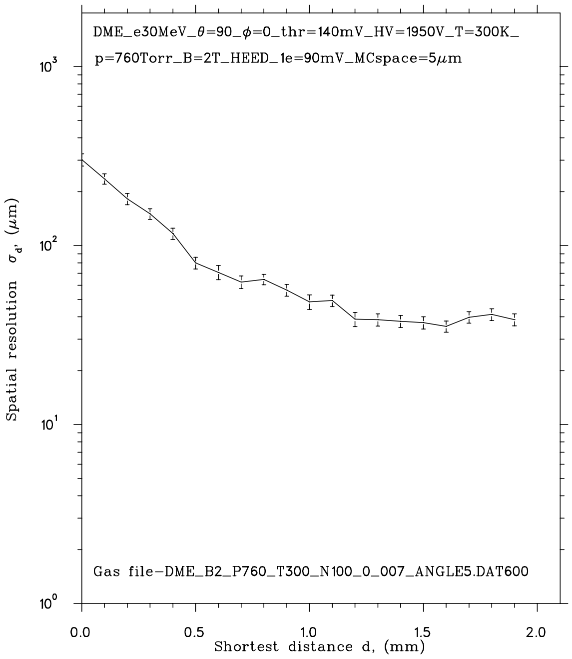


Figure 14: Space resolution $\sigma_d = F_d(d)$ at $\theta = 90°, \varphi = 0°, d = 0 - 2.0mm$.

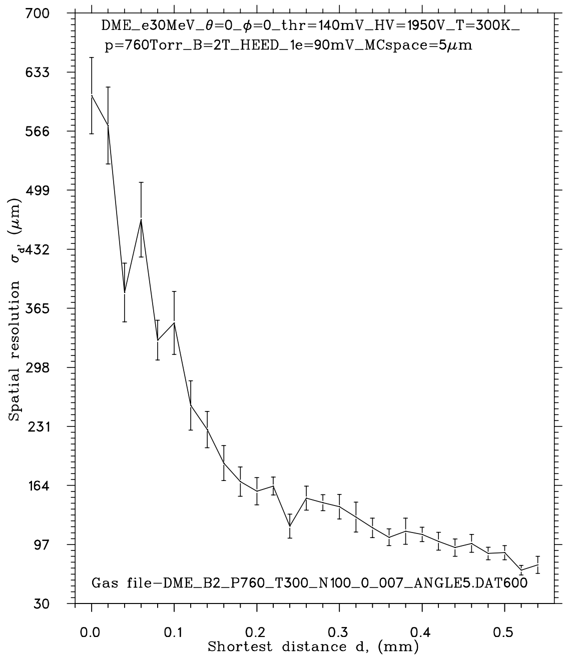


Figure 15: Space resolution $\sigma_d = F_d(d)$ at $\theta = 0°, \varphi = 0°, d = 0 - 0.54mm$.

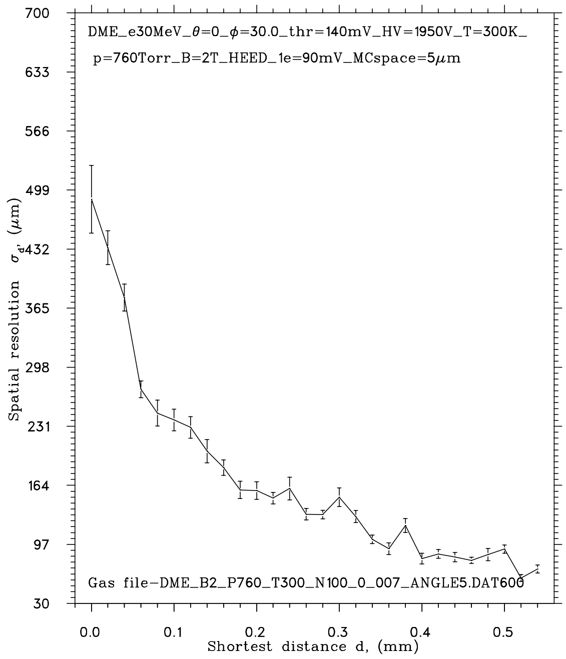


Figure 16: Space resolution $\sigma_d = F_d(d)$ at $\theta = 0°, \varphi = 30°, d = 0 - 0.54mm$.

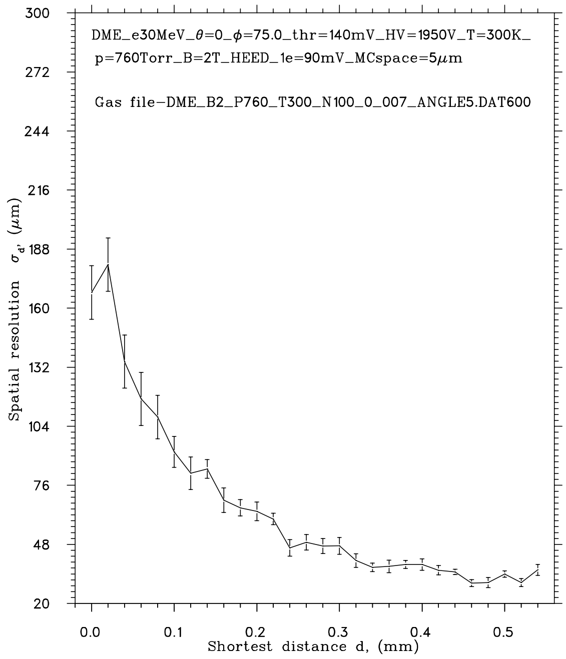


Figure 17: Space resolution $\sigma_d = F_d(d)$ at $\theta = 0°, \varphi = 75°, d = 0 - 0.54mm$.