Temperature dependence of the drift velocity

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SB Meeting

Intro

- In the simulation we assume a constant temperature throughout the TPC volume
- Electron drift velocity is temperature dependent
- The dependence is not completely negligible $\Delta v_{\mathrm{d}}/v_{d}\Delta T\ \sim 2\%/\mathrm{K}$
- Would be particularly import for for long drifts if persistent gradient O(K) exists throughout the active volume
  - Could impact the studies of the space-charge effect

W. Walkowiak, NIM A 449 (2000) 288

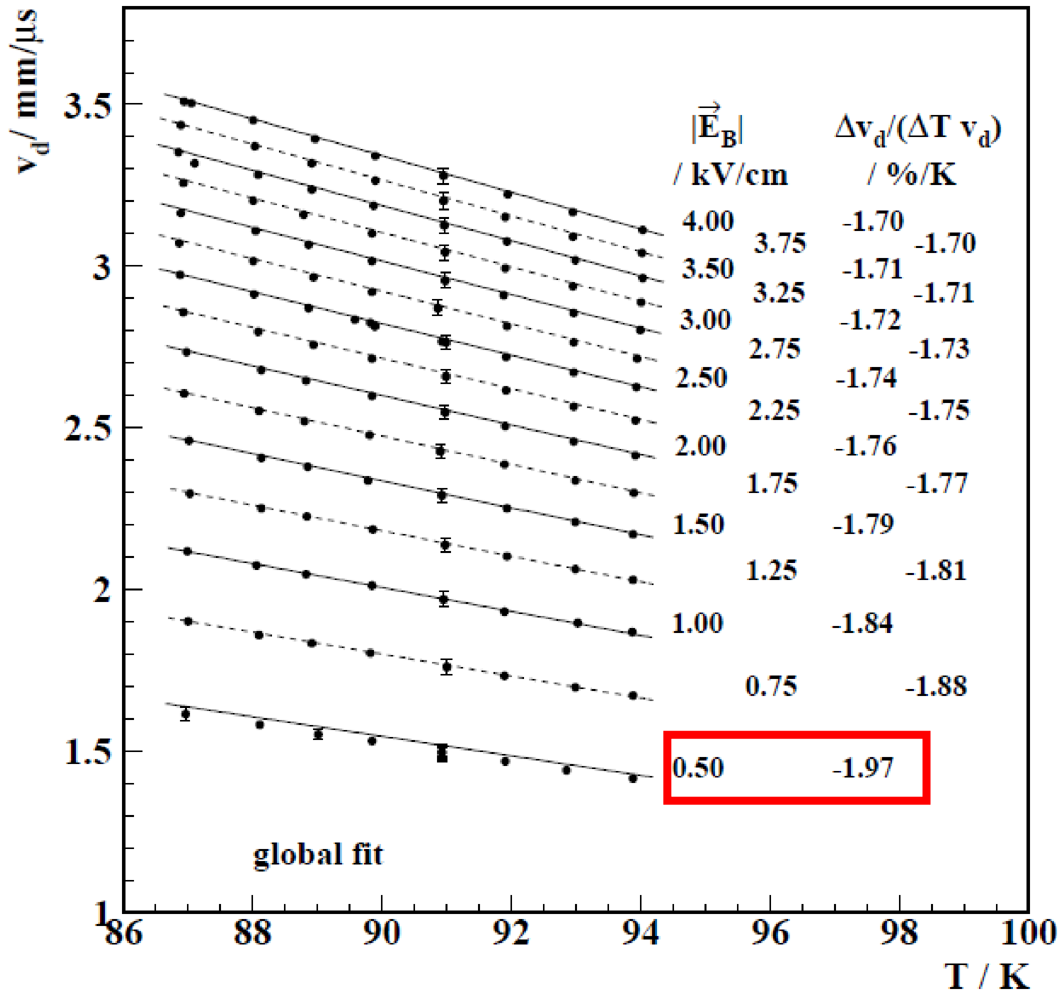

Fig. 5. *The electron drift velocity v_d (in the second drift section) as a function of the temperature T for different values of the electric field strength $|\vec{E}_B|$. The result of the global fit of (1) to the data points is superimposed. Except for the data points at $T = 91$ K, where the total error on the individual v_d value is shown, only statistical error bars are included.*

At 0.5 kV/cm E-field the drift velocity varies by ~2% / K

Effect on electron arrival time

- Assume some constant temperature gradient in LAr over the entire 6m drift
- Take:
  - T at CRP = 87 K
  - T at cathode = 87 – ΔT (colder == denser LAr at the bottom)
  - Gives linear temperature profile:

  T = 87 – ΔT x d [cm] / 600.0 [cm]
- Use the "Walkowiak" parametrization for drift velocity to look at temperature dependence (basically linear in T)

$$v_d(T,|\vec{E}|) = (P_1\,(T-T_0)+1)\left(P_3|\vec{E}|\ln\left(1+\frac{P_4}{|\vec{E}|}\right)+P_5|\vec{E}|^{P_6}\right) + P_2\,(T-T_0)\ .$$

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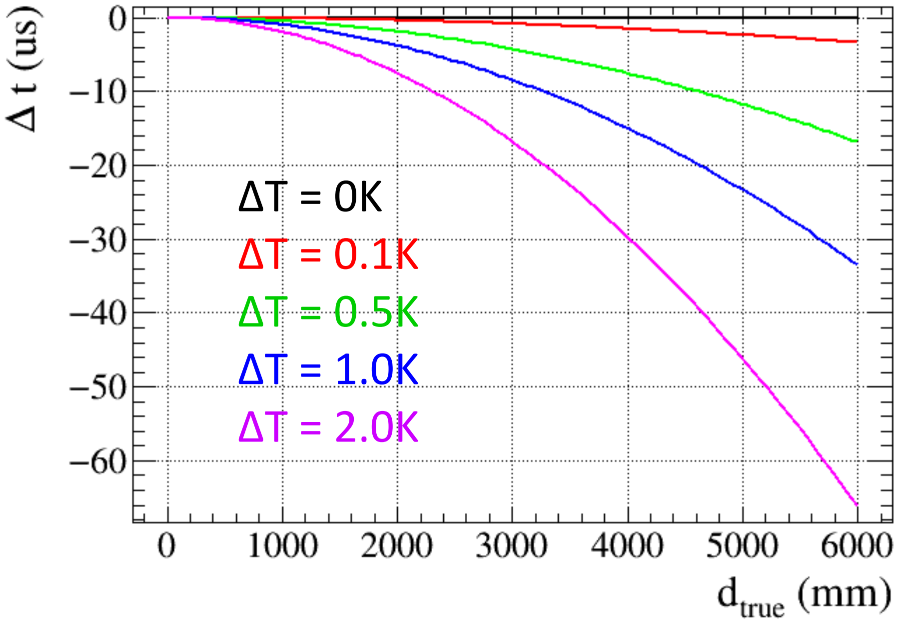
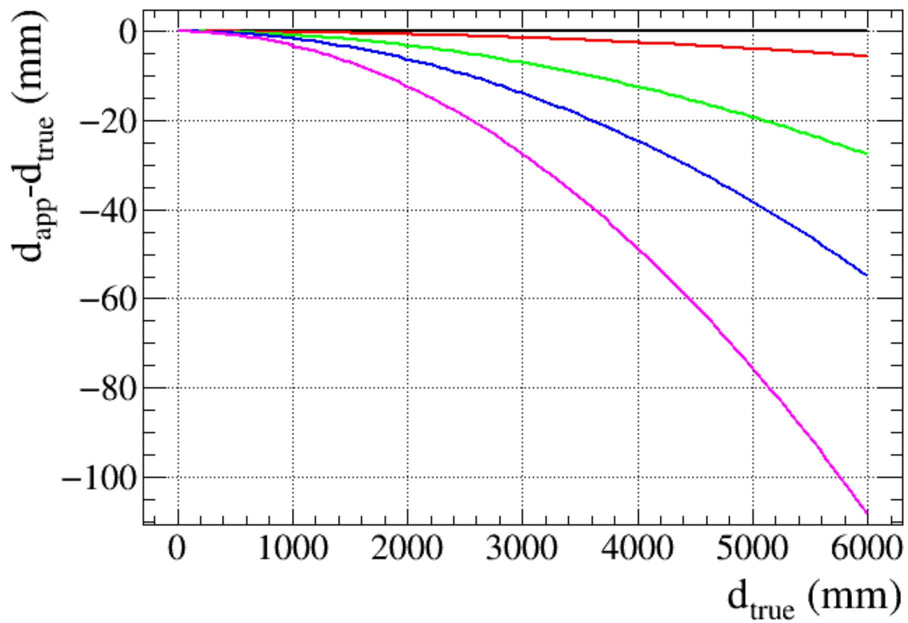
parameter	value			
P_1	-0.01481	$\pm$	0.00095	K^{-1}
P_2	-0.0075	$\pm$	0.0028	K^{-1}
P_3	0.141	$\pm$	0.023	$\left(\frac{\mathrm{kV}}{\mathrm{cm}}\right)^{-1}$
P_4	12.4	$\pm$	2.7	$\left(\frac{\mathrm{kV}}{\mathrm{cm}}\right)$
P_5	1.627	$\pm$	0.078	$\left(\frac{\mathrm{kV}}{\mathrm{cm}}\right)^{-P_6}$
P_6	0.317	$\pm$	0.021	
T_0	90.371		(fixed)	K

Effect on electron arrival time

Difference in transit time between
ΔT = 0K and uniform gradient

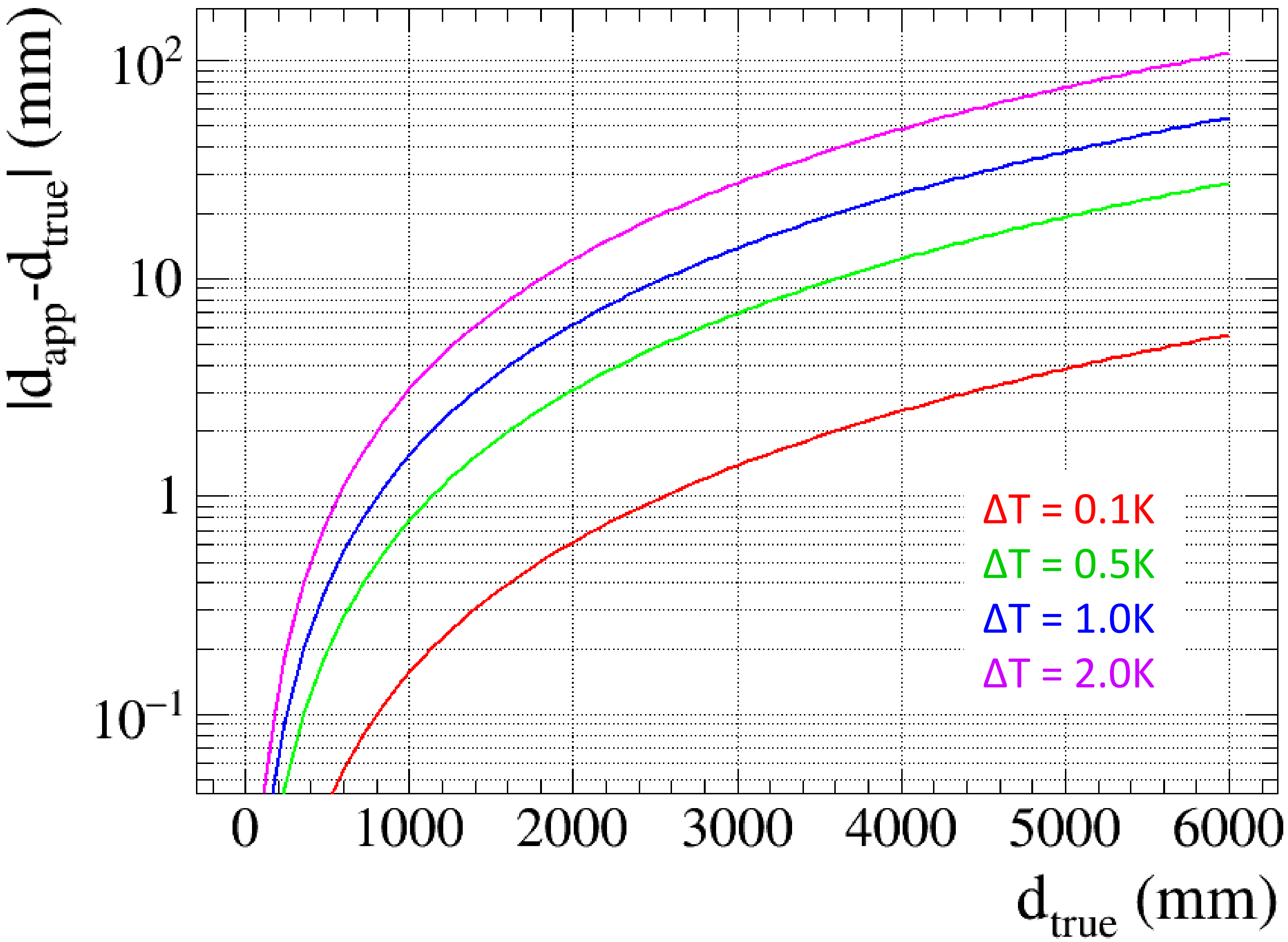


Apparent position t_{drift}/v_{drift}
calculated assuming nominal drift velocity



E.g., the requirement for MicroBooNE was <0.1 K temperature gradient throughout the volume for drift velocity uniformity
[MicroBooNE TDR (2/3/2012-DocDB 1821-v12): Cryostat (WBS 1.3)]

Effect on electron arrival time



Conclusions

- The dependence of the drift velocity on temperature is not negligible in particular in the case of long drifts
- Need to minimize formation of a temperature gradient inside the active volume of the TPC
  - Re-inject warmer liquid at the bottom after recirculation loop to generate convective flows inside the cryostat
  - Could help with space-charge as well if the liquid movement is such that the ion density is dispersed towards the field cage
- Would be nice to revisit thermodynamic simulation of the liquid movement inside the cryostat