Internal Report

Study of Gas Properties for the PANDA Straw Tube Tracker.

O.N. Hartmann, INFN-LNF

January 5, 2007

Introduction and Contents

The behaviour of counting gas mixtures for the PANDA [1] straw tube tracker [2, 3] is studied using the simulation program GARFIELD and the built-in program MAGBOLTZ [4].
A single straw tube is investigated. The basic parameters as input to the simulation are:

- magnetic field: $\vec{B} = (0, 0, 2\text{T})$
- tube diameter: 1 cm
- wire diameter: 20 μm
- wire voltage: +2 kV

The following parameters are variable:

- temperature (room temperature 300 K; 250 K)
- pressure (1 atm; overpressure 2 atm)
- gas mixture compenents (Ar, CO_2, C_2H_6), mixture ratio
- skew angle (0, 3°, 20°)

The studied quantities, shown in the following plots, are:

- drift velocity $[\frac{\text{cm}}{\mu\text{s}}]$
- Lorentz angle [radians]
- longitudinal and tranverse diffusion coefficients $[\sqrt{\text{cm}}]$
- Townsend coefficient $[\frac{1}{\text{cm}}]$
- space-time-relation
- diffusion along the fastest driftline [μs]

Temperature Variation

The quantities are calculated for two temperature values, T=300 K (room temperature) and T=250 K. The gas mixture is always Ar:CO$_2$ with a ratio of 9:1, the pressure is 1 atm, and no skew angle is applied.

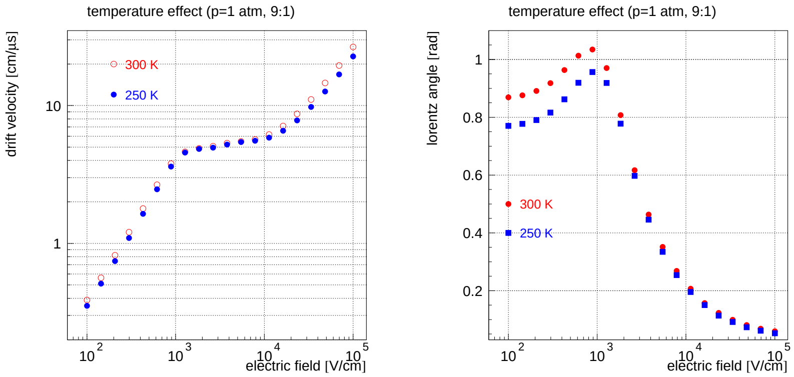

Figure 1: Left: drift velocity; right: Lorentz angle

The drift velocity changes marginally when lowering the temperature by 50 K. In case of the Lorentz angle, the effect is more prominent for the lower values of the electric field, where the Lorentz angle goes down.

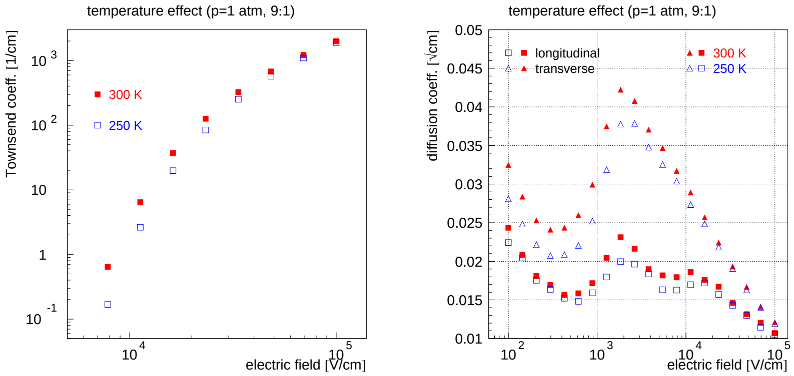

Figure 2: Left: Townsend coefficient; right: longitudinal and transverse diffusion coefficients

For the lower temperature, Townsend and diffusion coefficients are reduced.

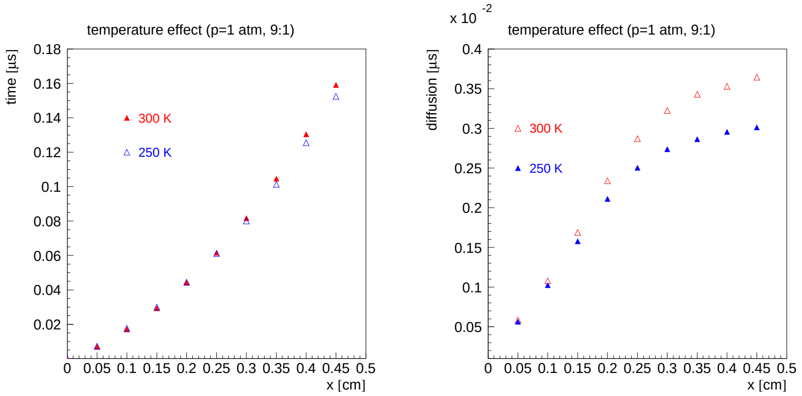

Figure 3: Left: space-time-relation; right: diffusion along the fastest driftline

Whereas the space-time-relation is not much affected, the diffusion drops by 30% close to the tube wall.

Pressure Variation

The gas pressure inside the tube is 1 atm and 2 atm. The temperature is 300 K, the gas mixture is always Ar:CO_2 with a ratio of 9:1, and no skew angle is used.

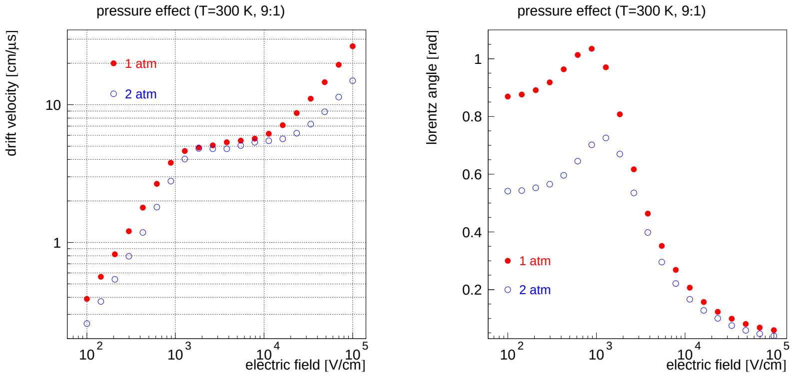

Figure 4: Left: drift velocity; right: Lorentz angle

For the higher pressure, the plateau region of the drift velocity curve gets prolongated, and the Lorentz angle for electric field values below ≈ 1 kV/cm is reduced significantly.

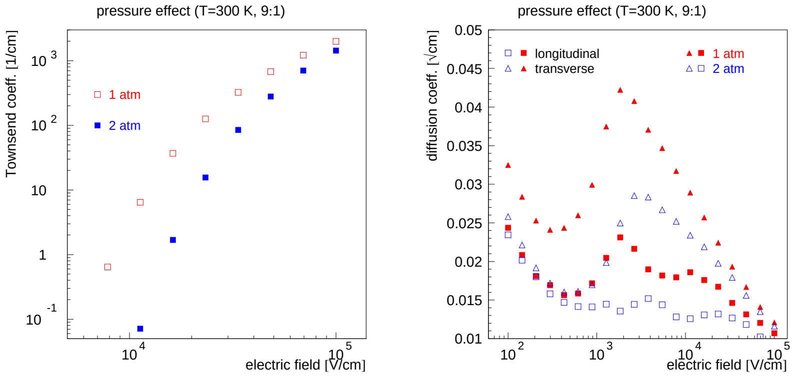

Figure 5: Left: Townsend coefficient; right: longitudinal and transverse diffusion coefficients

The Townsend and both the longitudinal and the transverse diffusion coefficients are reduced for the higher gas pressure.

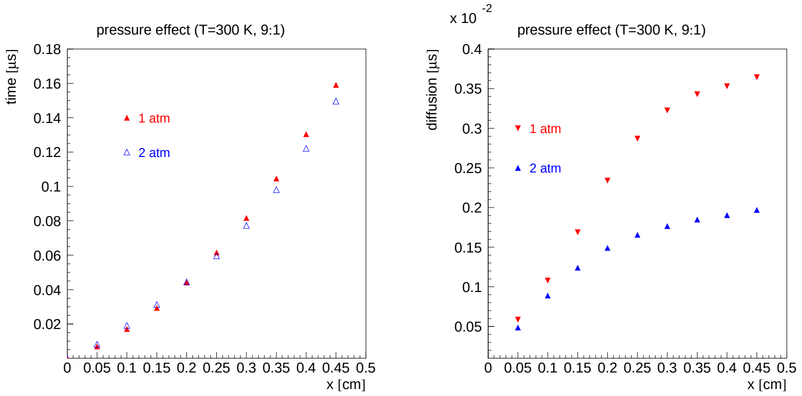

Figure 6: Left: space-time-relation; right: diffusion along the fastest driftline

While the space-time-relation is nearly kept, the diffusion for the higher gas pressure is much less, reduced by a factor of two close to the tube wall.

Variation of the Ratio Ar:CO$_2$ in the Gas Mixture

The quantities are calculated for two mixture ratios of Ar to CO$_2$ – the standard 9:1, and the 7:3 case. Temperature and pressure are 300 K and 1 atm, respectively. Also here, no skew angle is used.

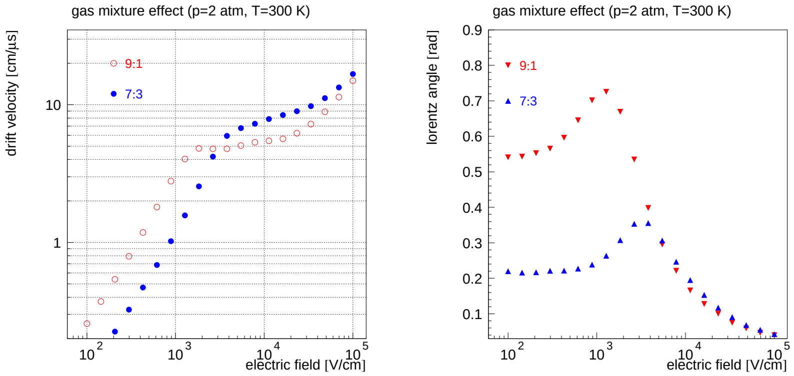

Figure 7: Left: drift velocity; right: Lorentz angle

As one sees in the left panel, the qualitative behaviour of the drift velocity changes evidently for a larger amount of CO_2. For the Lorentz angle, the difference is dramatic and becomes important also for electric field values up to $\approx$ 3 kV/cm.

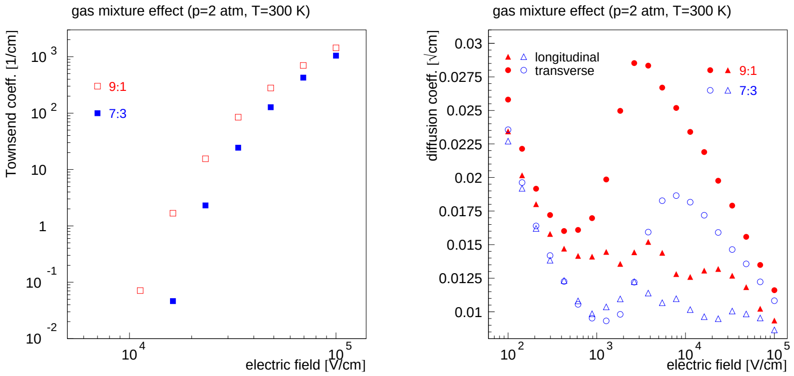

Figure 8: Left: Townsend coefficient; right: longitudinal and transverse diffusion coefficients

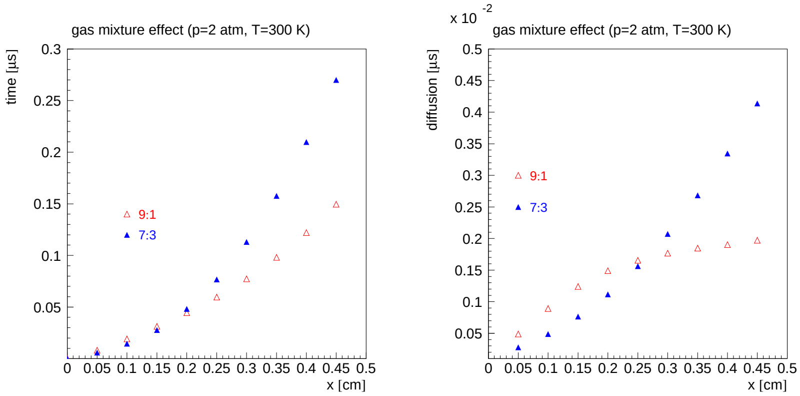

Figure 9: Left: space-time-relation; right: diffusion along the fastest driftline

For the larger amount of CO_2, the space-time-relation comes closer to a parabola. Consequently, the diffusion times become much bigger.

Replacing CO_2 by Ethane (C_2H_6)

In this section, the standard gas mixture Ar:CO_2 with the ratio 9:1 is compared to a mixture Ar:C_2H_6, first also in a ratio 9:1, and second with only a small amount of ethane, 98:2. Temperature, pressure and skew angle are the same like in the section before.

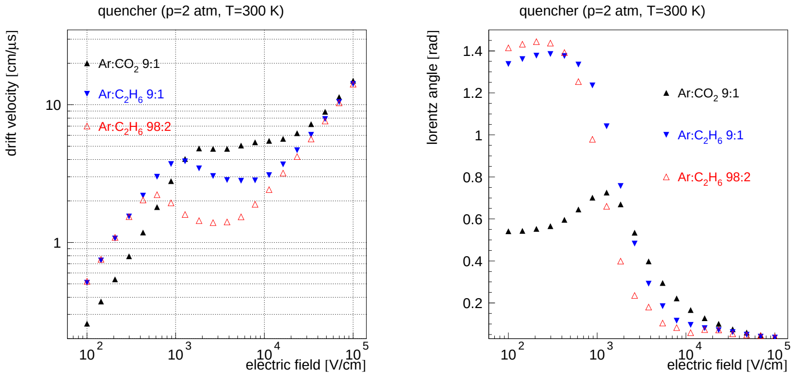

Figure 10: Left: drift velocity; right: Lorentz angle

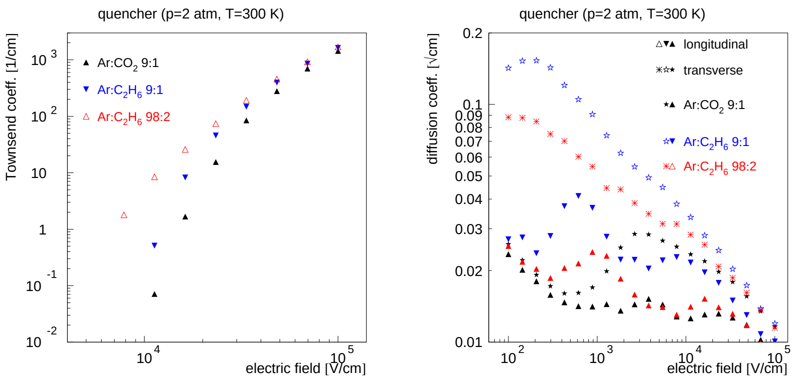

Figure 11: Left: Townsend coefficient; right: longitudinal and transverse diffusion coefficients

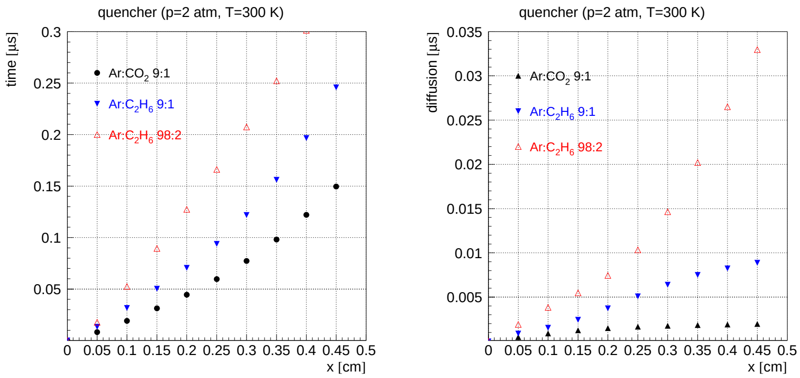

Figure 12: Left: space-time-relation; right: diffusion along the fastest driftline

Going to ethane instead of CO_2, nearly all quantities change dramatically. In particular Lorentz angle, diffusion coefficients and the diffusion along the fastest drift line give much larger values.

Influence of a Skew Angle

Finally, the influence of a skew angle on the single straw tube is investigated. In practice, the magnetic field vector is rotated by the skew angle relative to the direction of the tube. The quantities are evaluated for angles of 0 and 3°. To make the effect visible, in addition an angle of 20° is used. The temperature is 300 K, pressure 1 atm, standard gas mixture.

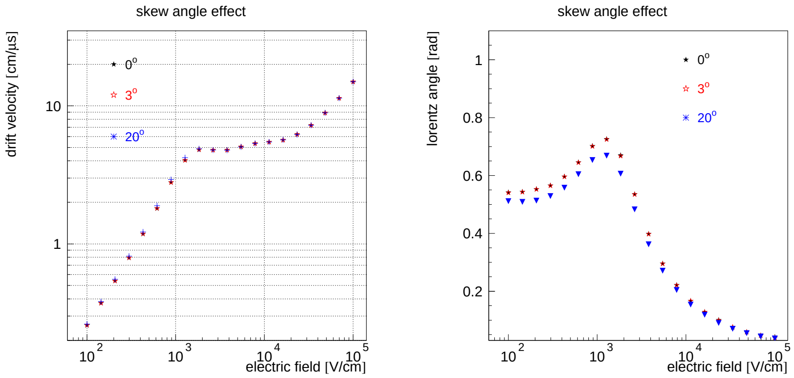

Figure 13: Left: drift velocity; right: Lorentz angle

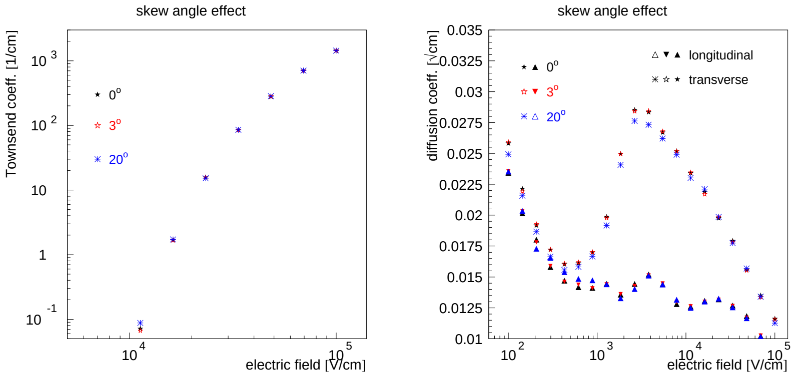

Figure 14: Left: Townsend coefficient; right: longitudinal and transverse diffusion coefficients

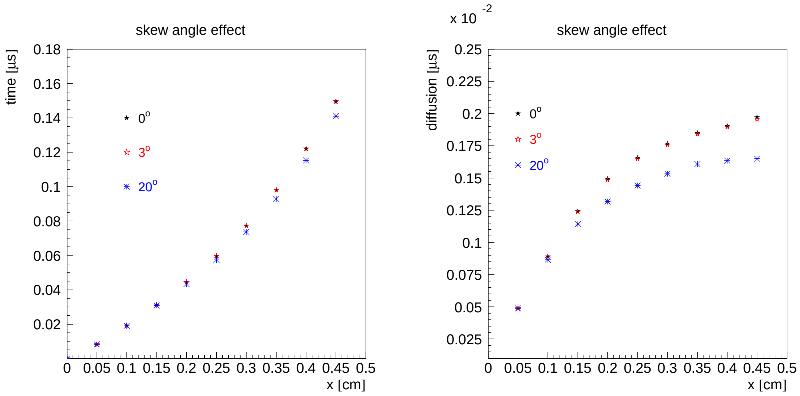

Figure 15: Left: space-time-relation; right: diffusion along the fastest driftline

The difference between 0 and 3° of skew angles is hardly visible in the representations here, the data points lie practically always on top of each other. Only in the (artificial) case of a 20° skew angle an effect becomes visible, however it is still relatively small.

Final Comment

As the presented plots for the gas properties indicate, the most severe effects come from the change of the gas mixture components and/or their mixing ratio. Lower temperature and higher pressure improve in principle the properties regarding the detector performance. No significant influence of a skew angle of the envisaged value is found.

References

[1] http://www-panda.gsi.de/

[2] Technical Progress Report for PANDA, GSI, Darmstadt, Germany, 2005

[3] O.N. Hartmann and the PANDA Collaboration, Nucl.Instr.Meth. A 566 (2006) 66

[4] http://consult.cern.ch/writeup/garfield/