MEASUREMENTS OF ELECTRON DRIFT VELOCITIES AND LORENTZ ANGLES IN FAST GAS MIXTURES

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Charged particle tracking in experiments at high energy hadron colliders should satisfy some special requirements. In particular high space and time resolutions should be achieved operating in magnetic fields at extremely high particles rates. Cathode strip chambers (CSC) [1], where the track position is determined by the charges induced on precision cathode strips, are good candidates for application in muon systems of the collider detectors.

Although the electron transport parameters of the wire chamber gases have been studied intensively during the last several years, most of the existing experimental data have been obtained without magnetic field. In order to find the optimal gas for the CSC we have designed and constructed an experimental set-up to measure the electron drift velocity in crossed electric and magnetic fields.

The measurements of the electron drift velocities and Lorentz angles were carried out using a new method based on detection of α-decay recoils in coincidence with α-particles [2].

The main idea of the method is that the recoils emitted into the chamber gas volume have a short range (≤ 50 μm at normal pressure), so they produce ionization electrons localized very close to the surface of the α-source. The detection of α-particles with a Si-detector defines the moment of the recoil release.

The direction of the magnetic field was perpendicular to the electric field so that drifting electrons were bent by Lorentz force along the anode wire. The two-side configuration (Fig.1) of the drift chamber allows to take into account the drift time and the deflection of the electron swarm in the gap between the grid and the anode wire where electric field is not uniform. The signals from Si-detectors D1 and D2 served as "start" signals for the time measurements. The pulses from the anode wire were used as "stop" signals.

The position of the electron avalanche along the anode wire was determined by center of gravity of the charge induced on the cathode 2 strips. This was done by measuring the difference of arrival times of the signals from the delay line.

In the magnetic field the electrons drifting from cathodes C1 and C2 were deflected along the anode wire in the opposite directions by ΔS_{GS}.

The displacement in the main drift cell was found as: $\Delta S_D = \Delta S - \Delta S_{GS}$. Including systematic uncertainties, we evaluated the accuracy of the absolute measurements of the drift velocity to be about $\pm 1\%$ and the accuracy of the Lorentz angle about $\pm 0.5°$. It should be mentioned that the precision in the relative drift velocity measurements is 0.1%.

To check our method for possible systematic errors, we have performed measurements in the best known gas mixtures: $Ar + 10\% CH_4$ and $Ar + 50\% C_2H_6$ (Fig.2), for which the most precise data on electron drift velocities and Lorentz angles are available from experiments with laser beams [3, 4]. The results of our measurements are in good agreement with these data.

We have also measured the electron drift velocities and Lorentz angles in various fast gas mixtures: $Ar - CH_4$, $Ar - C_2H_6$, $CO_2 - CF_4$, $Ar - CO_2 - CF_4$, as well as in pure CH_4, C_2H_6, CF_4 and CO_2.

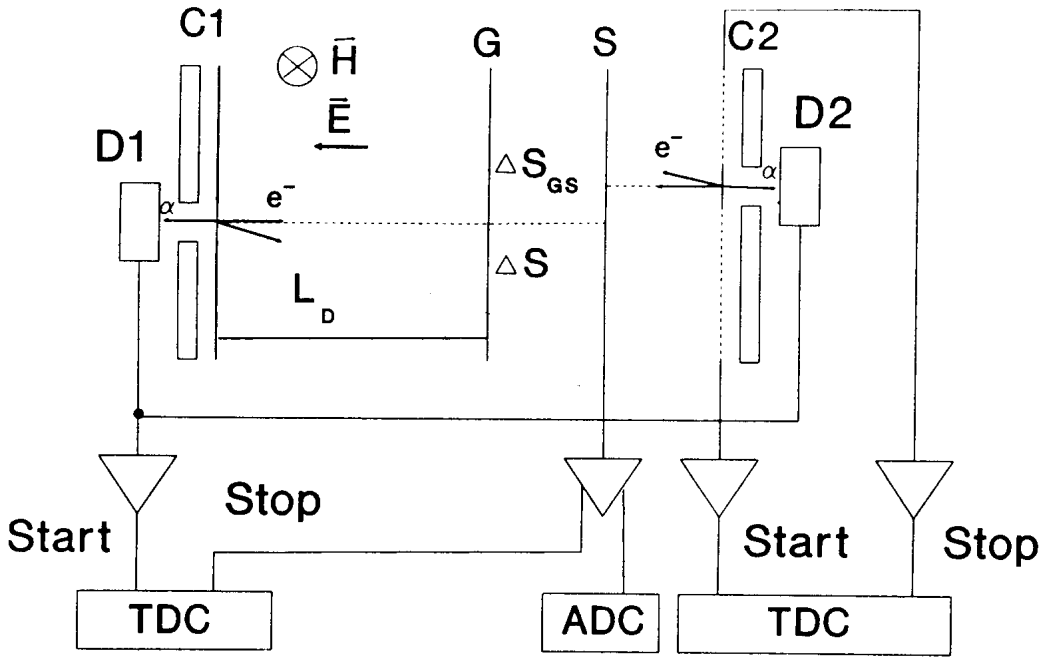

Fig.1. Schematic view of experimental set-up.
C1,C2 — cathodes, S — anode plane, G — grid, D1,D2 — Si-detectors. Dashed lines show drift path of electrons without magnetic field, doted lines — with magnetic field. ΔS and ΔS_{GS} are displacements of the peaks corresponding to the C1 and C2 recoils when magnetic field is changed from $B = 0$ to B

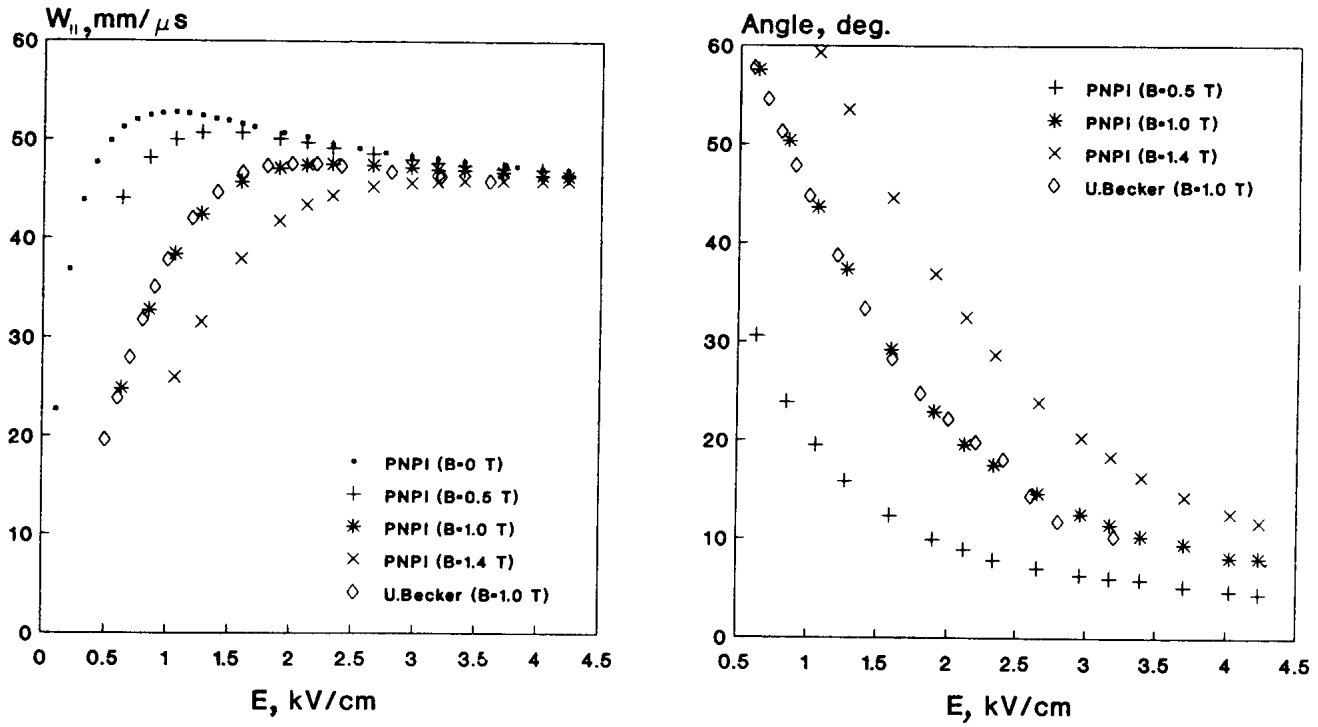

Fig.2. Measurements of parallel electron drift velocity and Lorentz angle in 50% $Ar + 50\%C_2H_6$ for $B = 0$, $B = 0.5$, $B = 1.0$ and $B = 1.4T$. For $B = 1.0T$ our data are compared to data of U.Becker [3]

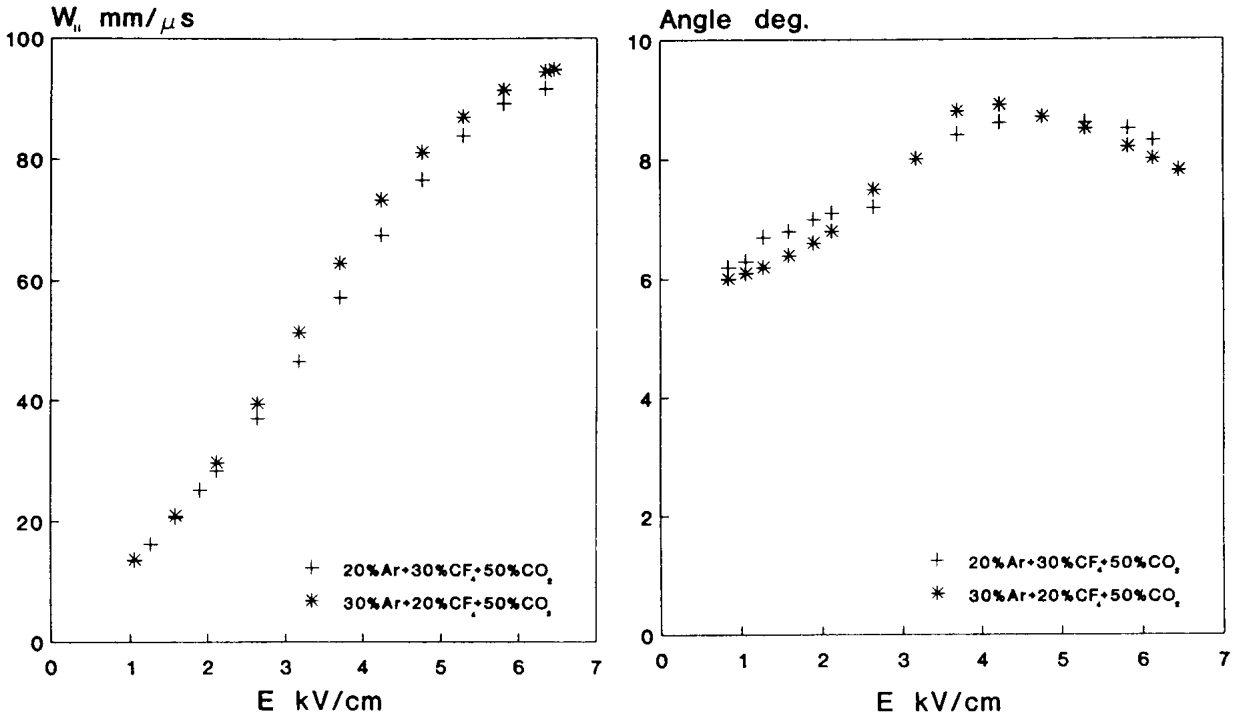

Fig.3. Our measurements of parallel electron drift velocity and Lorentz angle in 50% $CO_2 + 30\%CF_4 + 20\%Ar$ and $50\%CO_2 + 20\%CF_4 + 30\%Ar$ for $B = 0.8T$

The drawback of the $CO_2 - CF_4$ mixtures is due to the fact that sufficient gas gain is achieved only at relatively high voltage in the chamber. This could introduce a problem of electrostatic instability of anode wires in large CSC chambers. The addition of a noble gas in CO_2/CF_4 mixtures allows to decrease the operating high voltage in the chamber. As shown in Fig.3, the Lorentz angle for triple $Ar/CO_2/CF_4$ gas mixture is about 8°–9° and it is practically insensitive to the drift field. The drift velocity at 5 kV/cm (operation electric field) is about 80 mm/μs. The presence of CF_4 in the gas mixture should also provide a long life time of the chambers. These properties of the $Ar/CO_2/CF_4$ mixture satisfy most of the requirements for the gas filling of the CSCs. All these arguments allowed us to recommend the $CO_2/Ar/CF_4$ mixture for the CSC-based tracking systems.

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