CDC for Asian Joint Linear Collider

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Abstract

Past and current status of JLC-CDC activity is presented, which includes measurements of gravitational and electrostatic sags for a 4.6m test chamber, its cosmic ray tests, designing of stereo-wire geometry, and preliminary results of Lorentz angle and two-track separation measurements.

1 Introduction

In order to fulfill the physics requirements, we need to achieve the following performance goals: $\sigma_{r\phi} \simeq 100$ μm, $\sigma_{rz} \simeq 1$ mm and two track separation better than 2 mm in a magnetic field of 2 T for a wire length of 4.6 m. The second and the third of the above goals are to ensure good track-cluster matching in a jetty environment. One possible approach to realizing these design goals is to use a slow gas mixture with a small Lorentz angle and a mini-jet cell structure to allow stereo wires for z-coordinate measurements. A large cylindrical drift chamber with small jet cells is a candidate central tracking device to fulfill these requirements.

The paper is organized as follows. Measurements of gravitational and electrostatic sags for a 4.6m test chamber are described in Section 2 [1]. Section 3 is devoted to the performance of a 4.6 m-long drift chamber filled with a CO_2 iso-butane (90 : 10) mixture studied using cosmic ray data [2]. In Section 4 common problems in designing stereo-wire geometry for a long cylindrical drift chamber with small jet cells are described and possible ways to approach them are discussed in detail [3]. Section 5 is devoted to Lorentz angle measurement of the CO_2/Isobutane gas mixture [4]. Preliminary results of two track separation experiment by using a small test chamber (*Baby*) are presented in Section 5 [5]. Finally Section 6 summarizes our results and concludes this paper.

2 Gravitational and Electrostatic Wire Sags for a 4.6 Meter-Long Drift Chamber

We have been developing a software program to predict wire displacement, knowing the cell structure, wire tension, and high voltage on each wire. The validity of the prediction has to be proved experimentally. We have developed a wire tension and position measurement system and measured wire tensions, gravitational and electrostatic sags for a 4.6 m

long test chamber with a mini-jet cell (see Fig. 1). The results of the measurements were then compared with the predictions. We found reasonable ageements.

Figure 1: 4.6 m CDC test chamber with wire position measurement system.

3 Cosmic Ray Test

The next question is whether we can actually achieve the required spatial resolution over the full length of the 4.6 m-long chamber, armed with the quantitative knowledge on the wire sags. In order to confirm this, we studied the performance of the test chamber using cosmic rays. The pulse shapes for a typical cosmic-ray track is shown in Fig.2. The spatial resolution of the central sense wire as a function of drift length is shown in Fig. 3. The average resolution of $\sigma_{r\phi} \lesssim 100\mu$m is confirmed to be feasible.

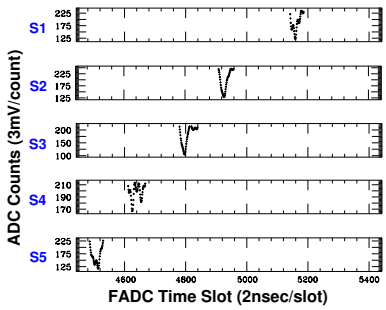

Figure 2: Pulse shapes for a typical cosmic-ray track.

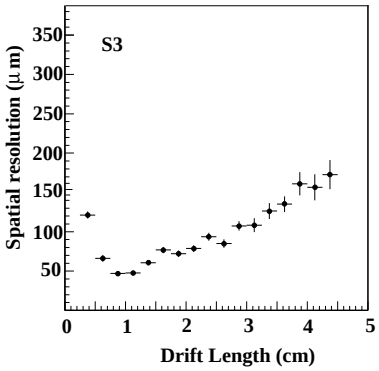

Figure 3: Spatial resolution of the central sense wire as a function of the drift distance.

4 Stereo-Wire Geometry for a Long Cylindrical Drift Chamber with Small Jet Cells

The spatial resolution per wire in the axial direction σ_z is given by

$$\sigma_z = \sigma_{r\phi} / \tan\alpha \tag{1}$$

in the case of stereo wires with a stereo angle α, where $\sigma_{r\phi}$ is spatial resolution in the r-ϕ plane per wire. Apparently the larger the stereo angle becomes the better the spatial resolution per wire in the axial direction. There are, however, various restrictions to the stereo angle which are the main topics of this Section.

A stereo layer can be formed by rotating the end point of each wire belonging to this layer by a small angle ($\Delta\phi$) with the other end point fixed, as illustrated in Fig.4.

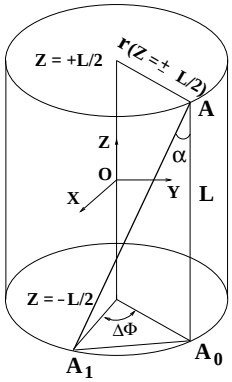

Figure 4: 3-dimensional view of a single stereo wire.

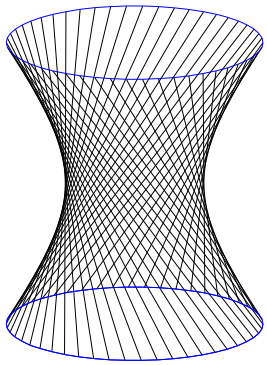

Figure 5: Formation of a hyperboloidal surface due to stereo wires.

The otherwise cylindrical surface of this wire layer turns into a hyperboloidal surface as shown in Fig.5. As a result, both the azimuthal angle and the radial position of the stereo wire becomes z-dependent. This inhomogeneity distorts the electric field to some extent and limits the maximum possible stereo angle, thereby restricting the z resolution σ_z. Fig.6 demonstrates how a single stereo cell structure deforms as one moves from one endplate to the other.

It is already clear that there is a definite geometrical limit to the maximum possible stereo angle: the stereo angle should be small enough to avoid mechanical contact of wires belonging to different layers. The decisive parameter is therefore the minimum distance between shielding wires and the stereo wires. This is more important for the A-to-V gaps, since an A super-layer stays as a cylinder, while the V super-layer surrounding it shrinks in the middle: it changes its shape to a hyperboloid. Fig.7 illustrates the $r\phi$ projection (A_0A_1) of a single stereo wire. We found the gain variation less than 8 % due to the cell deformation.

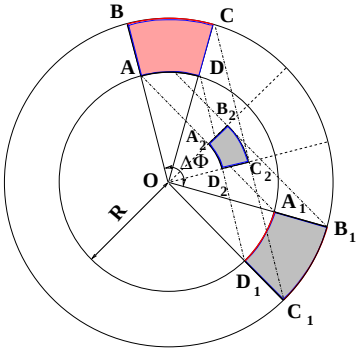

Figure 6: Exaggerated illustration of the stereo-cell formation through rotation by an angle $\Delta\phi$ and its deformation along the wires.

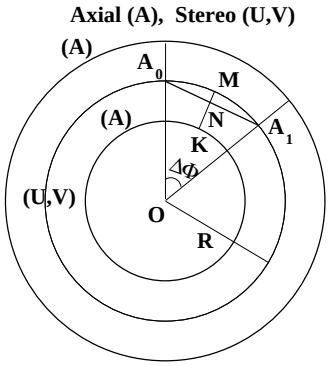

Figure 7: r-ϕ projection of a stereo wire (A_0A_1): MN is the maximum displacement of the stereo wire.

5 Lorentz Angle Measurements

We measured the Lorentz angle for CO_2-Isobutane mixtures, 90:10, 95:5, and 85:15, in the electric-field range between 0.2 and 2.0 kV/cm and under the magnetic-fields between 0 and 1.5 T.

The preliminary results of the Lorentz angle measurements are shown in Fig.8 as a function of electric field for different magnetic fields. The experimental results were compared with the prediction of the gaseous detector simulation program GARFIELD - 6.27 interfaced with MAGBOLTZ program. There are good agreements with the simulation.

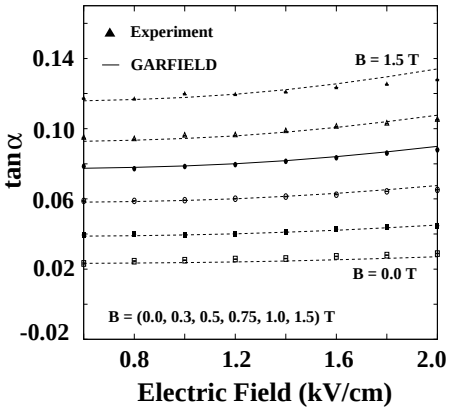

Figure 8: Comparison with GARFIELD simulations for the CO_2-isobutane (90:10).

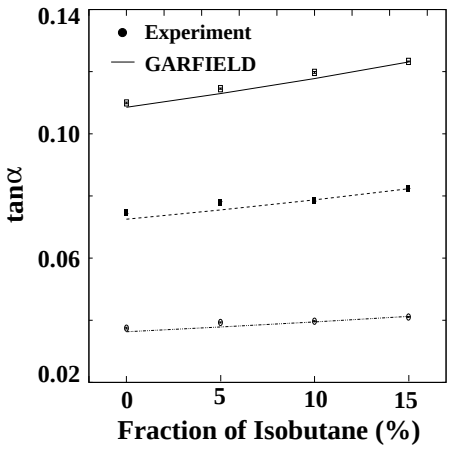

Figure 9: Dependence of the Lorentz angle as a function of Isobutane concentration

In order to get gas-mixture-dependence of the Lorentz angle we measured it for the different gas mixtures of CO2 and Isobutane. The results are shown in Fig.9. The Lorentz angle increases with the concentration of Isobutane.

6 Two-Track Separation Experiment

We have built a test chamber with a candidate cell structure filled with a possible gas mixture CO_2/Isobutane(90:10) and made a beam test with special emphasis put on two-track separation study. The beam test was carried out at the $\gamma 2$ beam line of the 1.3-GeV KEK-Tanashi Electron Synchrotron (ES), using an extracted electron beam for studying single track performance, or using a bremsstrahlung photon beam converted to e^+e^- pairs for studying two-track separation capability.

Fig. 10 shows a picture of the test chamber. The cross-sectional size of the test chamber is 26cm $\times$ 27cm and the wire length is 40cm. This chamber has three identical jet cells with the same cell structure as our previous 4.6m-long test chamber.

Preliminary results of spatial resolution as a function of drift length is shown in Fig. 11. As we can see the spatial resolution is less than 100 μm per wire over the full drift length.

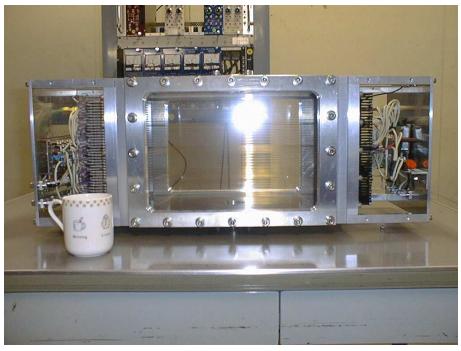

Figure 10: *Baby* chamber.

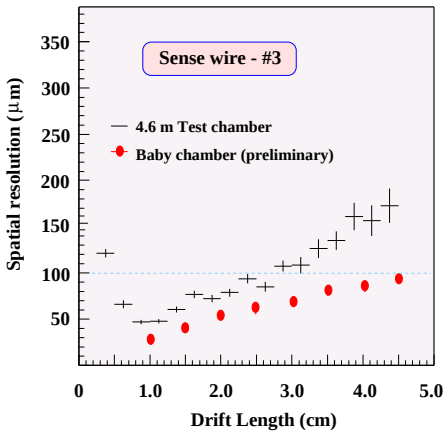

Figure 11: Spatial resolution as a function of drift distance

7 Conclusions

We have constructed a 4.6 m-long test drift chamber in the course of JLC detector R&D's. The test chamber has the same wire length, cell structure, and chamber gas (CO_2 isobutane(90 : 10)) as a current design of the JLC central drift chamber.

We have also developed a software program to calculate wire displacements in electrostatic fields, knowing the cell structure, wire tension, and high voltage on each wire.

The performance of the 4.6 m-long test drift chamber was studied by using cosmic ray events. It is confirmed that the test chamber satisfies the required spatial resolution of 100 μm per wire in the r-ϕ plane over the full length of the chamber.

We have outlined a general design procedure for a long cylindrical drift chamber with small jet cells with an emphasis put on the decision process for stereo wires geometry. The procedure was illustrated, taking a concrete example of a possible central tracker for JLC.

We have established a Lorentz angle measurement system. Using this we measured the Lorentz angle of the CO_2-isobutane gas mixture for different proportions. The results of the measurements of Lorentz angle are compared with the GARFIELD program.

We have fabricated a small test chamber with the same jet cell structure as our previous 4.6m-long test chamber, in order to carry out beam tests on basic chamber performance.

Acknowledgments

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References

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[5] JLC CDC group, a paper on two-track separation paper, in preparation.