# JLC Central Tracker R&D

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**Abstract.** The current status of the JLC central tracker R&D is reviewed, stressing progress made since the Sitges meeting. R&D's future direction is also discussed, taking into account possible changes in basic chamber parameters.

## INTRODUCTION

Let me now begin my talk with reminding you of physics requirements on the central tracker performance [1]. The most stringent requirement comes from the recoil mass measurement for $e^+e^- \to Zh$ followed by $Z \to l^+l^-$. In order to confirm the narrowness of the Higgs boson, the recoil mass against the lepton pair from the $Z$ decay should be measured to an accuracy only limited by the natural beam energy spread. This sets the following performance goal for the momentum measurement: $\sigma_{p_{l^\pm}}/p_{l^\pm} \lesssim 0.4$ % at $p_{l^\pm} = 50$ GeV. Separation of $W$ and $Z$ through jet invariant mass measurements demands a resolution comparable with the gauge boson natural widths. This necessitates good track-cluster matching: $\sigma_Z \simeq 1$ mm and 2-track separation better than 2 mm. Time stamping of tracks from different bunches will be very important to suppress otherwise overlapping mini-jet backgrounds, which requires $\sigma_{T_0} \lesssim$ bunch spacing (1.4/2.8 ns).

These physics requirements should be translated into chamber parameters and, consequently, R&D items. The current set of CDC parameters: $\sigma_{xy} = 85$ $\mu$m, a lever arm length of 185 cm (= 230(outer cylinder) − 45(support tube)), the number of sampling points $n = 80$, $B = 2$ T, and a wire length of 460 cm (full lever arm above 45°), satisfies the requirement from the recoil mass measurement.

The spatial resolution of 85 $\mu$m indicates use of a cool gas mixture and a mini-jet cell structure. The required $z$ resolution of 1 mm also suggests use of the mini-jet cell structure with a stereo angle of $\tan\alpha_{stereo} \simeq 0.1$ through $\sigma_z = \sigma_{xy}/\tan\alpha_{stereo}$. The remaining physics demand on the time stamping capability can then be translated into the limit on the drift velocity through $\sigma_{T_0} \simeq \sigma_{xy}/(v_{drift}\sqrt{n}) \lesssim 1.4$ ns. A drift velocity of 10 $\mu$m/ns satisfies the requirement. If we assume a jet cell with 5 sense wires and a maximum drift length of 5 cm, there will be about 14k jet cells and, correspondingly, about 100k wires total.

The chamber parameters described above lead us to the following list of questions: (1) Can we control gravitational and electrostatic sags for 4.6m-long wires? (2) Can we achieve a spatial resolution of 85 $\mu$m everywhere in this big chamber? (3) Can we achieve 2-track separation better than 2 mm? (4) Can we stably operate 4.6m-long stereo cells? (5) Is Lorentz angle small enough to allow straight cells? (6) Is gas gain saturation observed for cool gas mixtures no problem? (7) Is tension drop controllable for $Al$ wires? (8) Is neutron background ($\sim$3k hits/train for $B = 2$ T [2]) no problem? How big is the signal charge for a single neutron hit? Is there any dead time expected? These questions naturally comprise our R&D items.

## WHAT WE HAVE DONE SINCE SITGES MEETING

Corresponding to these R&D items, we set the following publication plan: (1) gravitational and electrostatic sags [3], (2) cosmic ray tests of a 4.6m chamber [4], (3) 2-track separation (in preparation), (4) designing of stereo-wire geometry [5], (5) Lorentz angle measurement [6], (6) gas gain measurement [7], (7) wire tension measurement, (8) background studies, and (9) general gas properties. By the time of the Sitges meeting, (1), (2), and (4) had been published. Since then, (5) and (6) have been completed, while (3) being intensively studied. In what follows, I will thus quickly go through these three topics.

### Gas Gain Measurements

The gas gains for $CO_2$/iso-$C_4H_{10}$ mixtures have been measured with a single wire proportional tube, primarily for supplementing the stereo-wire geometry study [5]. The measurement revealed the easily saturating nature of the mixtures: already at a gas gain $\lesssim 10^5$, a significant broadening of the pulse height peak started and further high voltage increase led us to the apparent onset of a new gas multiplication mode as observed as a separate peak that eventually dominated the spectrum. This quick gas gain saturation can be attributed to the small diffusion of the gas mixtures, resulting in concentration of avalanche charge on a small spot on the wire. Further studies are necessary to clarify the implications of this observation in terms of local dead regions, 2-track separation, and $dE/dx$ measurements.

### Lorentz Angle Measurements

The Lorentz angle, being one of the key parameters to constrain the cell design, have been measured for our chamber gas at different magnetic fields up to 1.5 T with a newly developed precision measurement system using 2 laser beams to produce primary electrons and FADC's to read their signals simultaneously [6]. Final results from the measurement are plotted in Fig.1-(a), showing good agreements with GARFIELD/MAGBOLTZ [8] simulations. Notice that for our gas mixture the magnetic deflection coefficient ($\Psi$), as defined by $\tan\alpha = \Psi(B/E)v_D^0$, is close to unity, justifying the extrapolation of our measurement to higher magnetic fields.

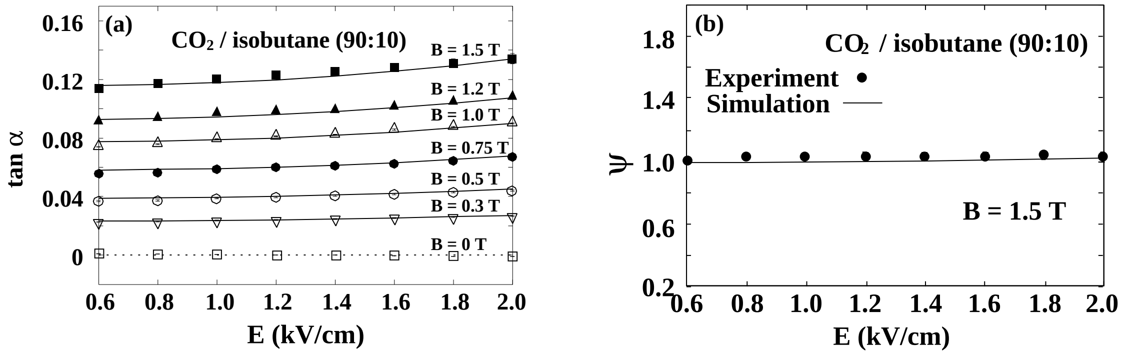


**FIGURE 1.** (a) Lorentz angle as a function of electric field at different magnetic fields, (b) magnetic deflection coefficient at $B = 1.5$ T as a function of the electric field for $CO_2(90)$/iso-$C_4H_{10}(10)$. Solid lines are GARFIELD/MAGBOLTZ simulations.

## 2-Track Separation

We have carried out 2-track separation experiments for our small test chamber, using $e^+e^-$ pairs produced by gamma conversions at an $Al$ converter (see Fig. 2-(a) for typical FADC signals for a single event). Figure 2-(b) shows a preliminary result of 2-hit separation efficiency for a single sense wire as a function of 2-track distance, in the case of normal incidence. Although the preliminary result looks

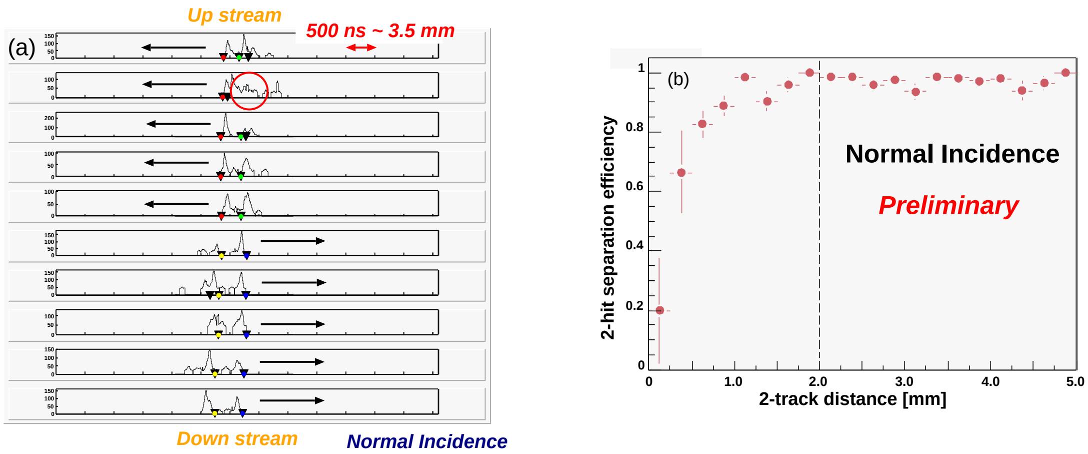


**FIGURE 2.** (a) FADC signals as a function of time (500 ns/division) for a typical 2-track event. (b) 2-hit separation efficiency as a function of 2-track distance.

promising, more studies are needed to investigate possible space charge effects due to the small diffusion nature of our gas mixture.

## SUMMARY AND FUTURE PLAN

We have given affirmative answers to most of the basic R&D questions we raised in the introduction: in particular, we have demonstrated the possibility to achieve an average spatial resolution of $\sigma_{xy} \simeq 85$ $\mu$m. Still remaining are those related to the gas gain saturation and space charge effects inherent in the gas mixtures having small diffusion coefficients, and the tension drop problem for $Al$ wires. The space charge effects are being studied using laser beams as well as charged particles, while wire material studies are in progress.

As discussed in this meeting by T. Tauchi and Y. Sugimoto [9,2], there is a demand for a higher magnetic field from beam-related background reduction point of view. We are thus investigating possibilities to increase the magnetic field from 2 T to 3 T. If we could scale all the chamber parameters that have the dimension of length by a factor of 2/3, the chamber performance would stay unchanged. This is, however, impracticable since wire spacing, spatial resolution, and inner radius are difficult to scale, if not impossible. The expected performance of a 3 T design, where these three parameters are kept unchanged, is discussed by A. Miyamoto [10] in this meeting. In any case, any design change should be made consistently to the whole detector system, and should be justified by physics simulation studies. For this purpose, we started developing a full detector simulator with GEANT4, while brushing up the one based on GEANT3.

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