COSMIC RAY TEST OF THE JLC−CDC baby CHAMBER

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1. Introduction

One of the most important goals of experiments at a future linear e^+e^- collider such as the JLC is to discover the Higgs boson and to determine its properties. In particular, the question as to the nature of that observed Higgs boson − whether it is of the Standard Model type or not − is among the most significant for JLC to answer. It is thus of vital importance to confirm the narrowness of the Higgs boson by measuring the recoil mass distribution opposite to the *Z* boson decaying into a lepton pair in the process: $e^+e^- \rightarrow HZ$ with $Z \rightarrow l^+l^-$. This measurement demands that the width of the recoil mass peak be determined by the beam energy spread alone and not by the performance of the central tracker; and this is among the most stringent requirement in the central tracker design so far.

In order to fulfill the physics requirements, we need to achieve a high resolution central tracker with a momentum resolution $\left(\frac{\sigma_{P_T}}{P_T}\right) \simeq 10^{-4} \cdot P_T(\mathrm{GeV})$, $\left(\frac{\sigma_{P_{l^\pm}}}{P_{l^\pm}}\right) \simeq 0.4\ \%$ at $P_{l^\pm} = 50\,\mathrm{GeV}$, which requires the following performance goals to our central tracker: $\sigma_{r\phi} \approx 85\,\mu m$, $\sigma_{rz} \approx 1\,mm$, and a two−track separation better than 2 mm. The second and the third of the above goals are to ensure good track−cluster matching in a jetty environment which would ensure e.g. the clear separation of *W* and *Z* through jet invariant mass measurements. [1, 2]

2. The Baby Chamber

In order to test the overall performance of the central drift chamber including two−track separation capability, the baby chamber is constructed with the same cell structure as the 4.6 m−long CDC test chamber [2]. The cross−sectional size of the baby chamber is 26 cm x 27 cm and the wire length is 40 cm. This chamber has three identical jet cells, each being 7 cm x 10 cm in size and having 5 sense wires and a maximum drift length of 5 cm. The sense wire spacing is 1 cm. These sense wires are made of Au−plated W and have a diameter of 30 μm. Other wires are made of Au−plated Al and are 125 μm thick. The chamber gas mixture is 90% CO_2 and 10% isobutane.[3] Figure 2.1 shows a picture of the baby chamber, Figure 2.2 shows its cell structure, Figure 2.3 shows the high voltage applied on each wire and equipotential lines in the cell, and plotted in Figure 2.4 are the drift lines and iso−chrons calculated with the drift chamber simulation program GARFIELD.

Figure 2.1: The baby chamber

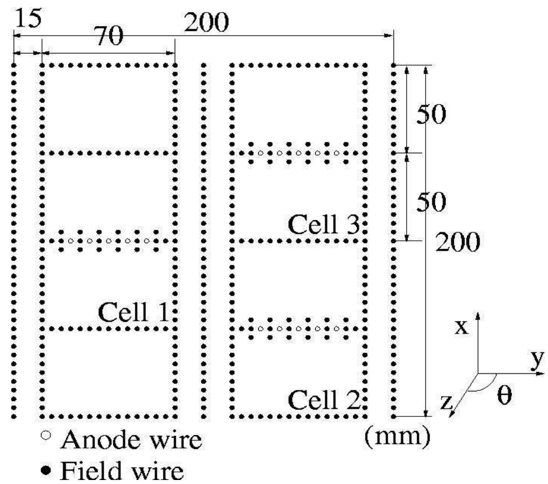

Figure 2.2: cell structure of the baby chamber

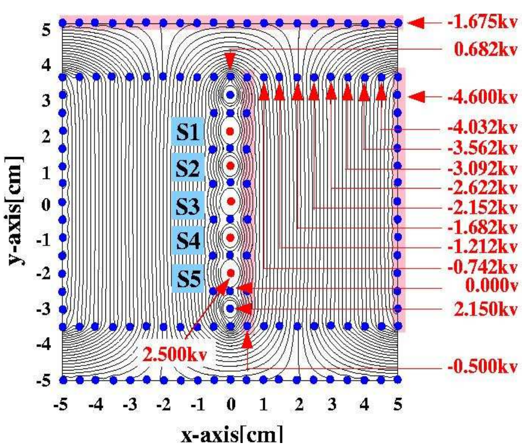

Figure 2.3: H. V. on each wire and the equipotential lines in the cell

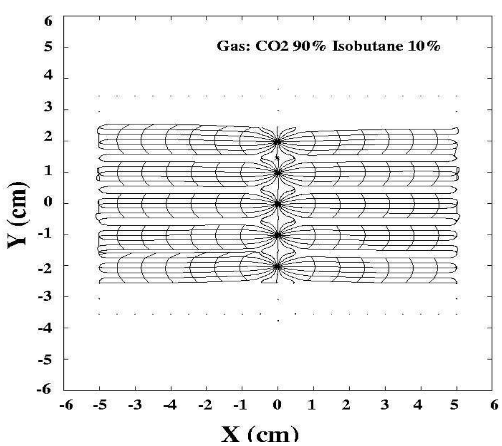

Figure 2.4: drift lines and iso−chrons in the cell

3. Methodology

3.1 The Experiment

The CDC baby chamber was shipped to Hiroshima University in September 24, 2000. A beam test was made using electron–positron pairs produced by bremsstrahlung photons from the internal target of Hiroshima's University's Relativistic Electron Facility for Education and Researches (REFER) [4]. Analyses of the beam test data are currently undergoing. However, in this report only cosmic ray runs are being scrutinized. The data used in this report were run numbers 801 for pedestal run, 802 and 803 for cosmic ray test for the two jet cells. The cosmic ray runs are done at normal incidence, each having 2000 events. The experimental setup is shown in Figure 3.1.

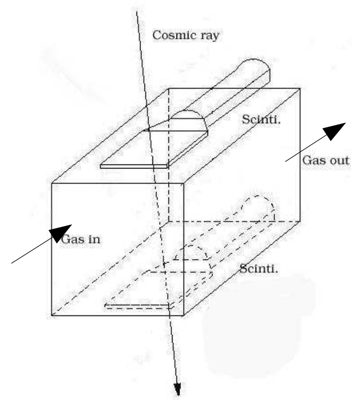

Figure 3.1: Experimental Setup

3.2 The Data Acquisition System

Current amplifiers are mounted on the endplate of the test chamber. The signals from the preamplifiers go into flash ADCs after passing through post amplifiers. The flash ADCs have 8–bit and a 500 Mhz sampling frequency over a 1.6 μs time window. The time bin width of one channel is 2 ns. We used these flash ADCs to analyze the pulse shape, to separate close tracks and make clear distinction between the signal and the noise. The details of the data acquisition system is given in Ref. 5.

3.3 The Software

A software, CDC Analysis program, is developed to analyze cosmic ray and beam data taken with the data acquisition system described above. This software uses the JSF (JLC Study framework) which is based on ROOT[6]. The program first unpacks the raw data consisting of trains of digits from the flash ADCs and convert them into a ROOT file.The unpacked data are then read from the ROOT file and scanned to find flash ADC clusters, each of which comprises a possible chamber signal. Any cluster containing two or more clearly separated peaks is further split into subclusters. Each of these subclusters is a hit point candidate and is given a hit coordinate, according to X–t relations. The program then loops over possible combinations of so obtained hit points to find tracks. Making use of the hit point and reference track information, the package creates histograms to know the efficiency of each wire and other characteristics of the test chamber. The package is also equipped with an event display where we can see clusters of flash ADCs, hitpoints and tracks made in every event.

4. Analysis, Results and Discussions

4.1 Pulse Shape for a Typical Cosmic Ray Track

Typical signal shapes for a single track are shown in Figure 4.1 as displayed by the event display of the CDC analysis package. The horizontal axis is the drift time (nsec) and the vertical axis is pulse height (flashADC counts). The distance between sense wires and the cell boundary is 5 cm.

4.2 x−t Relation

Any pulse which continues longer than 120 ns above the threshold (pedestal + five counts) was regarded as a signal pulse. Also the peak of the flashADCs must be greater than 30 counts. The parameter settings for signal pulse determination is shown in Table 4.1. The drift time is the arrival time measured from T_0 (the signal arrival time for zero drift length). The conversion of drift time to drift length is plotted on Figure 4.2 using the x−t relation for each wire.

4.3 Reference Track Selection

When more than four out of five sense wires have the above−defined signal pulses, we regard the event as a track candidate. Sometimes, there are events with no tracks. In order to study the chamber performance including the efficiencies of individual sense wires, we need to use events with well defined reference tracks consisting of four hits on the wires excluding the wire to study. Such a track was selected by demanding the following conditions:

(1) χ^2 of the linear fitting to the four hits had to be less than 15.
(2) There had to be no left−right ambiguity.
(3) The expected hit position for the wire in question had to be well within the fiducial volume of the cell.
(4) The four signal pulses that define the track candidate had to be within 500 μm from the fitted track.

The parameter settings for track fitting is shown in Table 4.2.

Parameter Settings for Signal Pulse Determination	
WidthCut	12
PeakCut	30
PhSumCut	200
SoftThresh	16
SplitThresh	20
SigmaMS	0.01

Table 4.1 Parameter Settings for Signal Determination

Parameter Settings for Track Fitting	
NsigCut	3
Chi2Cut	15
KCNsigCut	3
DXpivotCut	0.05

Table 4.2 Parameter Settings for Track Fitting

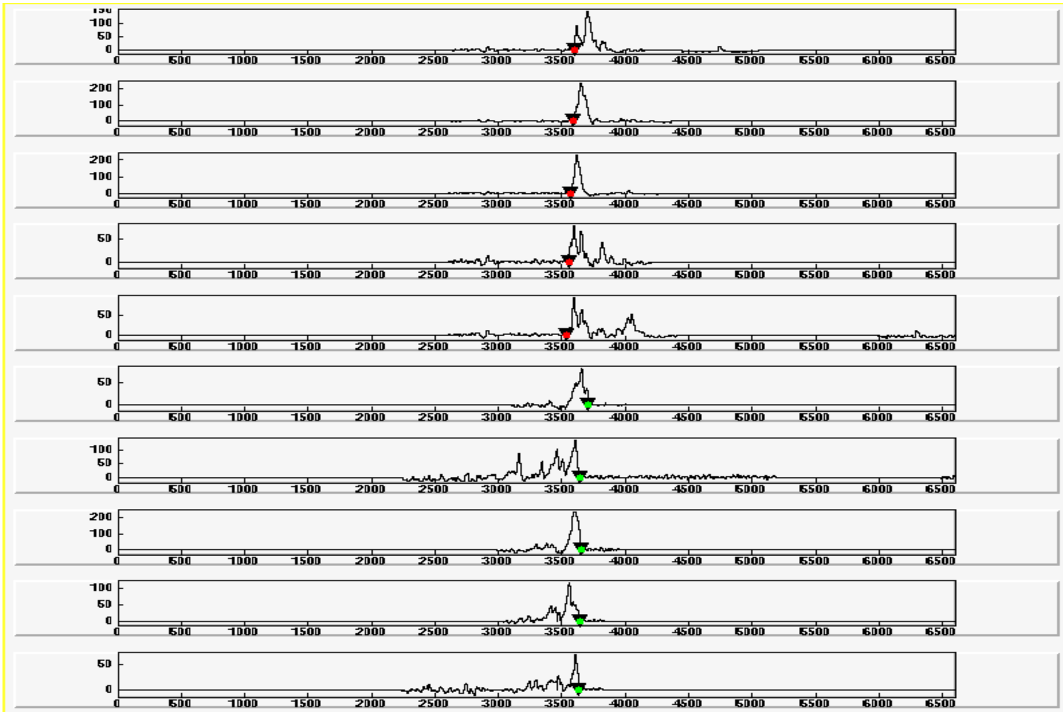

Figure 4.1: A typical pulse shape of a cosmic ray track

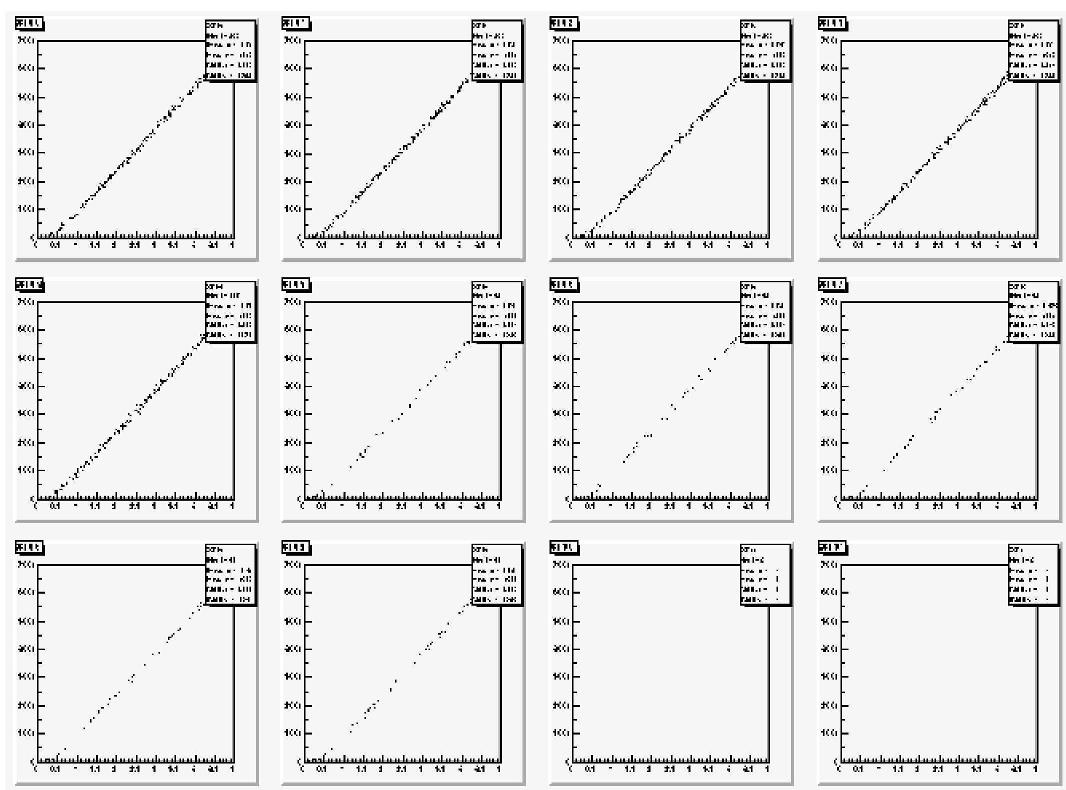

Figure 4.2: x−t relation wire each sense wire (run number 802)

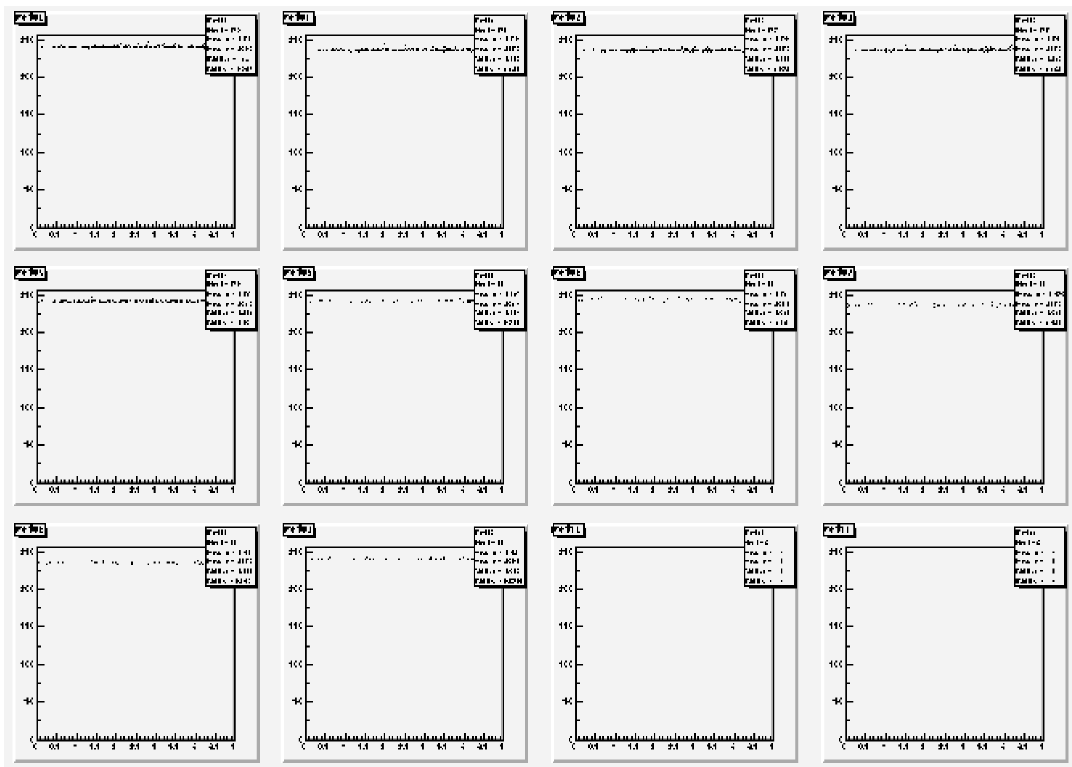

Figure 4.3: Pedestal plots

4.4 Chamber Performance

Sometimes, there is no signal pulse in an event. Therefore, only signals of pulse height less than the peak cut can be seen in the event display. Figure 4.6 shows an event display where there is no defined signal pulse. We can see that wire number 2 of cell number 2 produces unnecessary signals. This wire should be further fine tuned. Its effect to the chamber performance is to lessen the number of tracks it can find. Figure 4.7 shows a track in cell number 2 which does not pass the track selection criteria although it could define a track. As a result, only few tracks can pass the track selection criteria. The number of tracks per event are shown in Figure 4.5 and Figure 4.6 for run numbers 802 and 803 respectively. Then, these events having well defined tracks were used to determine the chamber performance such as wire efficiency.

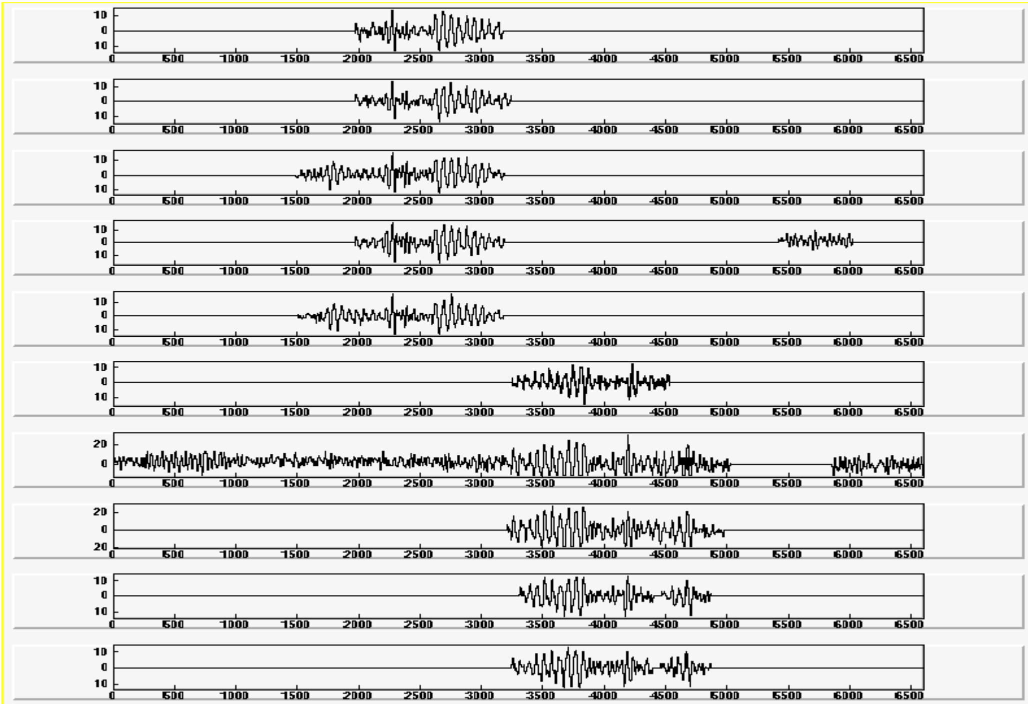

Figure 4.6: Event display where there is no signal pulse.

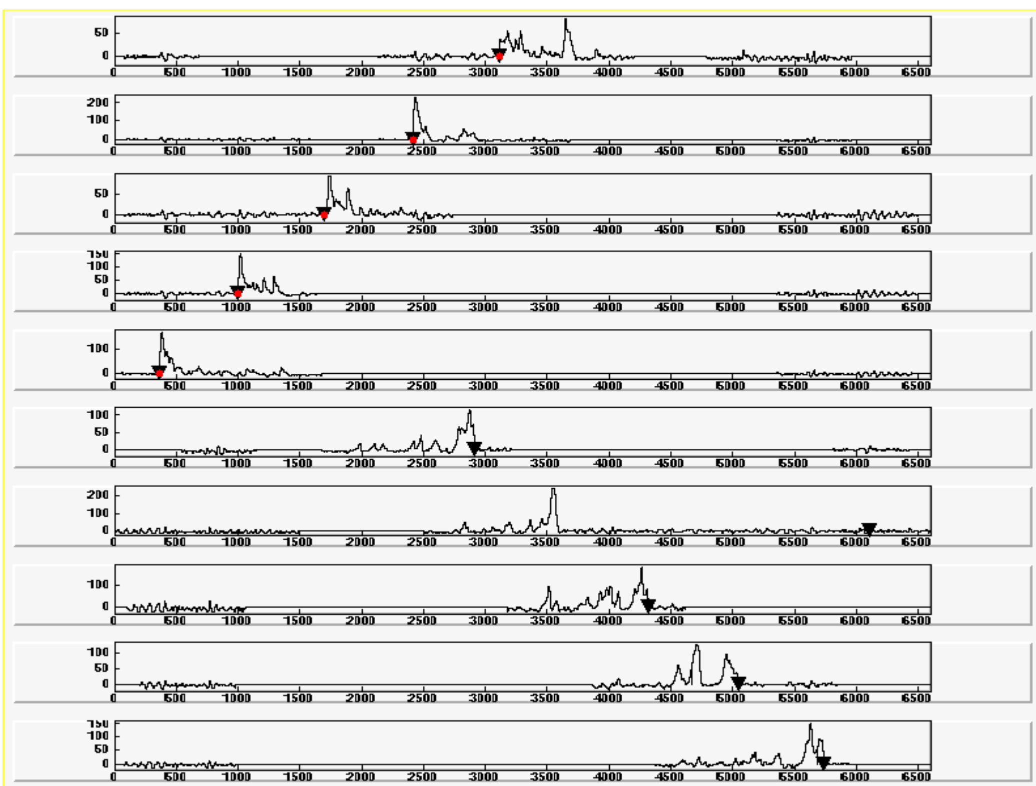

Figure 4.7: Wire number 2 of cell two is not fine tuned.

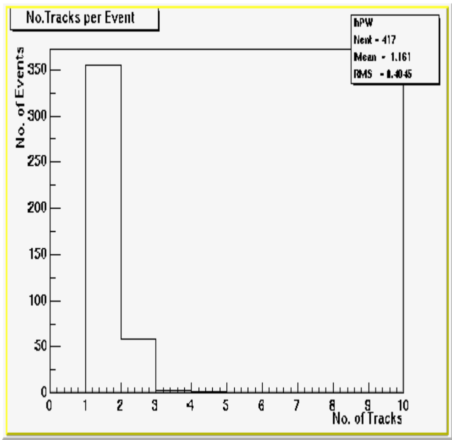

Figure 4.4: Number of Tracks per event (Run number 802)

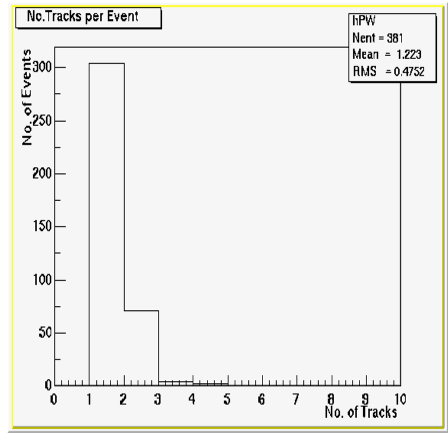

Figure 4.5: Number of Tracks per event (Run number 803)

4.5 Wire Efficiency

To study the efficiency of each wire, we need to exclude the wire to study from track finding in order to carry out bias−free determination of wire efficiency. The efficiency of wire 3 of cell 1 is plotted as a function of drift distance in Figure 4.9 for run number 802. The efficiency of wire 3 of cell 1 seems significantly lower than 100%. It should be noted, however, that this result is very preliminary in the sense that various cuts for hit point selection including those on pulse heights are not yet optimized. In addition, there is some room for improvements in hit coordinate calculation in a noisy environment, as mentioned in Section 4.4.

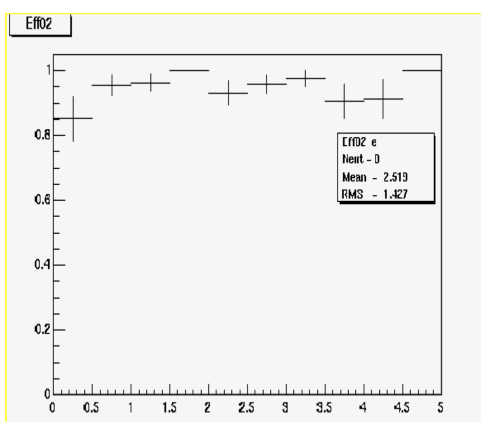

Figure 4.9: Wire efficiency as a function of drift length for wire 3 of cell 1 (*very preliminary*).

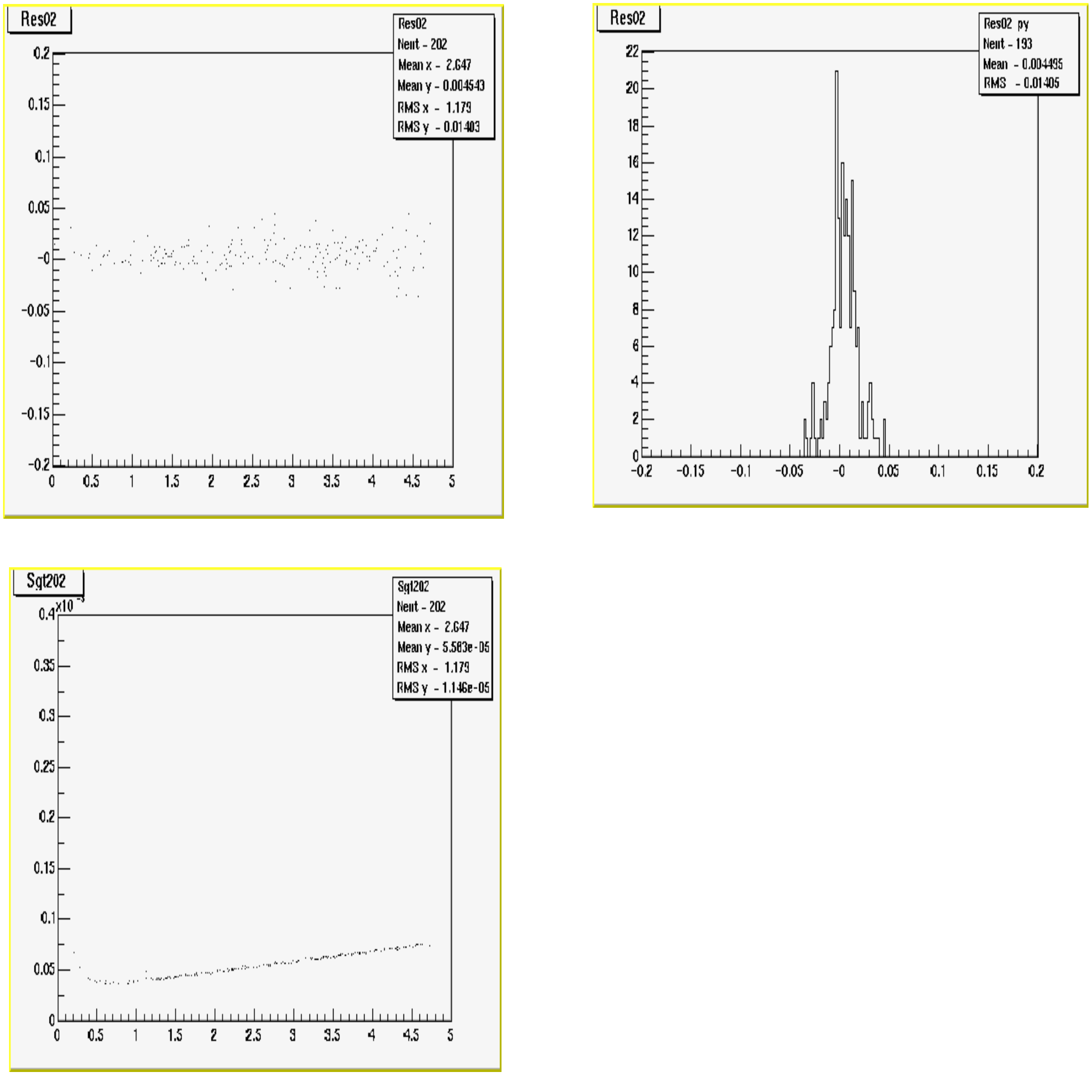

Figure 4.8: (a) Residual as a function of drift length, (b) its projection along the y−axis, and (c) track error plots of central sense wire of cell 1.

4.6 Spatial Resolution

The next target in this study is to study the spatial resolution of each sense wire. The spatial resolution of each wire is calculated by taking off the track error from the sigma of the residual distribution on a bin by bin basis. Figure 4.8 shows the residual distribution as a function of drift length, its projection along the y−axis and the track error plots of wire 3 of cell 1.

5. Conclusion

The performance of the baby chamber was studied using cosmic ray test run numbers 802 and 803 done at Hiroshima University, Japan and by using the CDC analysis program. From the event display of an event where only pedestal signals are present, sense wire number 2 of cell 2 needs to be fine tuned.

Further studies and program debugging are on−going to study the intrinsic spatial resolution and other characteristics of the baby chamber. Also, to test some functions of the CDC analysis program especially the splitting function of multipeak signals since these functions are not yet fully tested. This splitting function is very useful in studying two−track separation capability of the test chamber.

7. Acknowledgments

We would like to thank Prof. A. Miyamoto for his invaluable contribution to the research works being done by the Mindanao group. His constant help, encouragement and close supervision make it possible for JLC related studies to be established in Mindanao, Philippines. We would also like to thank Y. Kato of Kinki University for sending to Mindanao the cosmic ray and beam tests data of the CDC baby chamber. Finally we would like to thank all the members of the JLC−CDC group for their significant contribution to this study.

6. References

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