Path Length Correction for dE/dx

Olushakin Olojo
Department of Mechanical Engineering
Wayne State University, Detroit, MI, 48205

Abstract

Specific ionization (dE/dx) is one method of particle identification used in CLEO. Due to the recent use of Helium Propane gas in the drift chamber, it is now possible to investigate simplifying one correction needed to optimize resolution.

Introduction

The change from the use of 50-50% Argon-Ethane to 60-40% Helium-Propane in the CLEO drift chamber has reduced effects caused by the magnetic field in the drift chamber cells.

With the new cell behavior, a more geometric approach can be applied to corrections for the $r - \phi$ behavior of the cell. Such corrections were formerly determined empirically from the data.

Specific Ionization

Specific ionization, also known as dE/dx, is the energy lost by a particle in a substance per unit path length it travels. Particles measured in the CLEO drift chamber can be identified using this principle.

The CLEO drift chamber is where specific ionization is measured [1]. Charged particle tracks go through this region of the detector and ionize the Helium and Propane, liberating electrons. Electrons are attracted to a wire in the center of a cell due to an electric field. A typical cell consists of a sense wire in the middle surrounded by eight field wires in the form of a trapezoid.

Newly freed electrons accelerate toward the sense wire. As the electron gets closer to the center of the cell it begins to pick up speed, moving so fast that it ionizes other molecules. Electrons liberated from secondary collisions free other electrons. The process continues until there is an avalanche of electrons at the sense wire. Due to the avalanche the original charge is multiplied by a large factor, perhaps 10^4.The charge collected by the sense wire is proportional to specific ionization of the particle. It is modified by several effects that must be calibrated away.

Particle Identification in dE/dx

Different particles can be be identified in the drift chamber because of the special relationship between dE/dx and $\beta\gamma$ (the relativistic generalization of velocity). dE/dx varies rapidly at low $\beta\gamma$ until it reaches a minimum ionization point. It then rises again due to relativistic effects. All particles of the same speed loose the same energy because dE/dx depends only on $\beta\gamma$.

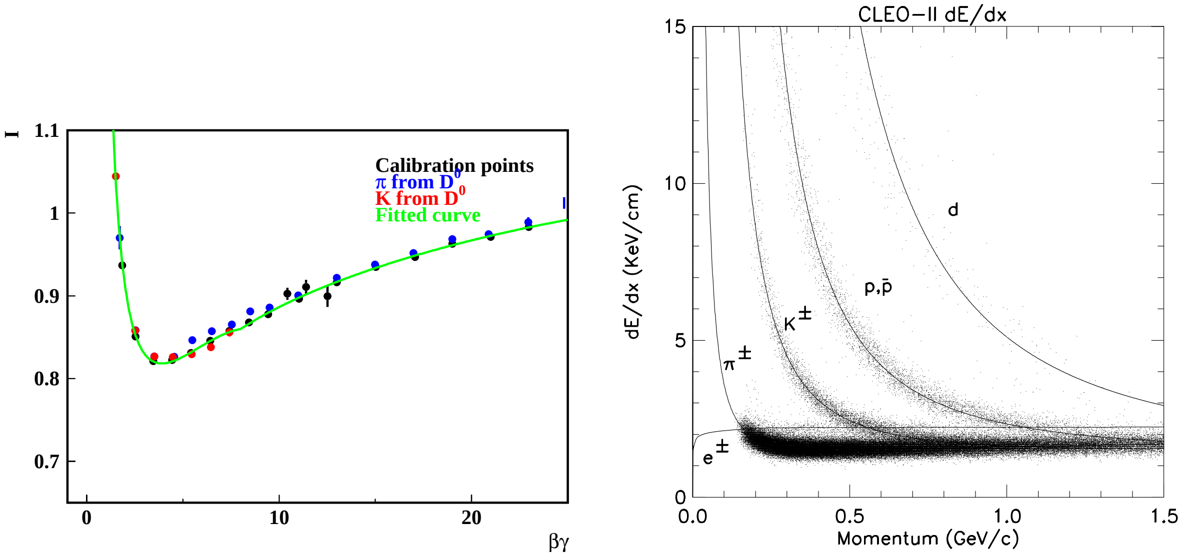


FIGURE 1. (Left) Plot of dE/dx vs. $\beta\gamma$. Shows universal behavior for all particles. (Right) dE/dx vs. momentum. The difference in mass distinguishes the particles in the momentum plot.

The CLEO drift chamber directly measures momentum, which is $\beta\gamma$ times the rest mass of a particle. Now because all particle have different masses they will also have different dE/dx at the same momentum. With this method individual particles can be identified. The drift chamber primarily measures the specific ionization for e, μ, π, K and p. These are the only common charged particles that traverse the drift chamber.

dE/dx Measurements

The CLEO drift chamber consists of 51 layers of wire. Only 49 are used in measurement because layers 1 and 51 give biased results due to a modified cell structure.

At most one pulse per layer is used to calculate the ionization of the particle. The data collected in the drift chamber is distributed in the form of a Talman curve. This curve has a long tail, causing large fluctuations in the data. Because of this the highest 30% of the data is truncated, to ensure the average calculated is a better approximation of the peak. The mean of the truncated data is then taken and used for particle identification.

Calibrating dE/dx

There are a many effects encountered in the CLEO drift chamber which must be taken into account prior to the use of data.

The path length of a track through a cell has the greatest impact on the dE/dx measured. A track that goes directly through the cell will have a larger ionization than a track that barely clipped the corner. Both the path length in the $r-\phi$ plane and the dip angle in the $r-z$ projection affect the measured energy loss.

Another correction that must be made in the drift chamber is a function of the angle (as seen in the $r-z$ plane), θ to a given wire in the chamber. This effect is known as "dip angle saturation", it is greatest when θ is at 90 degrees to the wire. All charge from the track deposits itself near one point on the wire. This causes a concentrated build up of electrons in one area on the sense wire, which screens the electric field. Electrons that come near the wire don't accelerate as quickly there by ionizing less molecules.

A third calibration problem encountered in the drift chamber is the collection efficiency of electrons. To get a good dE/dx measurement we try to collect all the charge a track gives off. Unfortunately the cells in the drift chamber have trouble collecting electrons at great distances from the sense wire. As a result electrons far away from the wire may not be collected at all.

Energy lost in the drift chamber is a function of the $\beta\gamma$ of a particle, but this intrinsic dependence is modified by many of the calibration difficulties stated. In order to get the best measurement possible these effects must be removed.

New $r-\phi$ Path Length Corrections for dE/dx

Many of the calibration details encountered in the drift chamber affect the energy collected by the CLEO electronics. In essence these difficulties distort the (dE) read in the drift chamber. Our new correction involves the path length (dx) of the track.

The new $r-\phi$ path length correction is now possible because CLEO recently change the gas used for ionization the drift chamber [2]. In 1995 a combination 60-40% Helium Propane replaced the 50-50% Argon Ethane mixture.

The use of the Helium Propane combination has substantially reduced the size of the Lorentz angle. Thereby reducing the effect caused by the magnetic field and improving the behavior of cells in drift chamber. The effect is shown graphically in Figure 2.

Now that cells in the chamber have a simpler behavior, a geometric approach can be taken to find the path length of a given cell. The correction approximates the behavior of the cell with pure geometry, ignoring magnetic field effects. The cell is illustrated in Figure 4.

The correction is made by calculating the path length of the particle and dividing the energy loss by this length. Formerly, the correction was an empirically determined function of drift distance and entrance angle.

Results

Correcting for $r-\phi$ effects improve dE/dx resolution by 10%. Results of our studies show that the new $r-\phi$ path length correction gives a resolution approximately equal to the old $r-\phi$ correction. This is illustrated in Figure 3.

Conclusions

The $r-\phi$ path length correction is a simple very effective way to improve resolution by approximately 10%. This correction is less cumbersome than corrections made in past CLEO data sets. Most importantly the correction can be installed in the software prior to taking data and can be tested on CLEO II.V data.

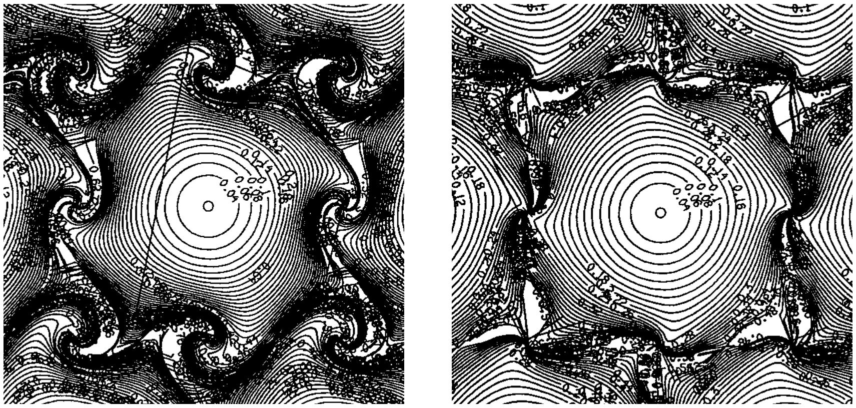


FIGURE 2. (Left) 50-50% Argon-Ethane gas. (Right) 60-40 Helium- Propane gas. The peculiar distortions are caused by magnetic field. The lines shown are isochrones, which are lines of equal drift time. As stated, the Helium-Propane mixture has an improved behavior. Isochrones near the cell boundary are almost square.

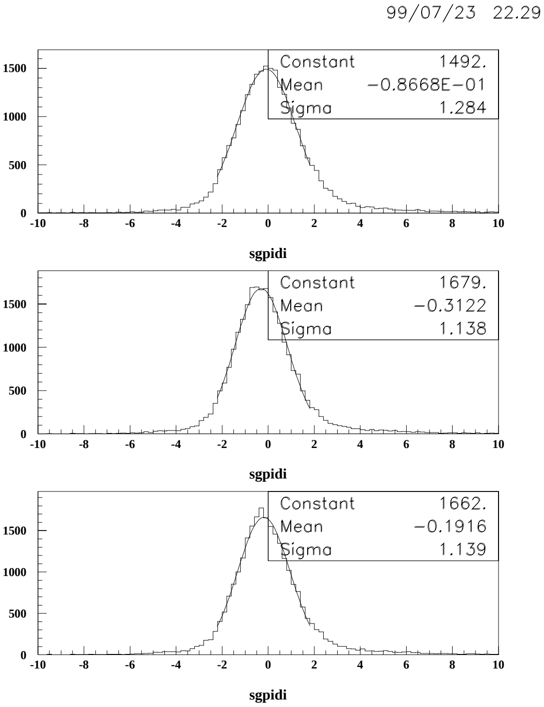
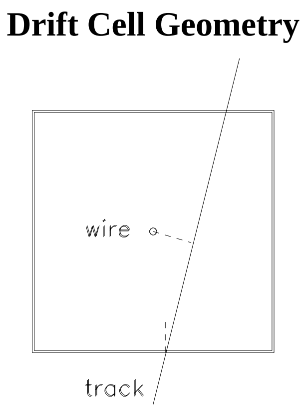

99/07/23 22.29

FIGURE 3. (Top) Shows resolution with all corrections except the old $r-\phi$ correction. (Middle) Resolution with all dE/dx corrections used in CLEO II.V including old $r-\phi$ correction. (Bottom.) Resolution with all corrections, but with new $r-\phi$ path length correction replacing the old one. All data is fit to Gaussians, only the relative widths (sigma) are relevant.



Drift Cell Geometry

FIGURE 4. The square box is an illustration of a typical cell in the drift chamber. Dotted line from wire to track show distance of closest approach (drift distance). The other dotted line from cell and track show entrance angle of particle into the cell. The drift distance and entrance angle are used to calculate path length of track through the cell.

Acknowledgments

I am pleased to acknowledge Prof. Roy Briere of Carnegie-Mellon University and Prof. Ahren Sadoff of Ithaca College, who proposed this summer project and guided my effort. Special thanks are also in order to Profs. Giovanni Bonvicini and David Cinarbro of Wayne State University for choosing me to be a part of this Research Experience for Undergraduates. This work was supported by the National Science Foundation REU grant PHY-9820306 and research grant PHY-9809799.

Footnotes and References

1. Y. Kubota, et. al; Nucl. Instrum. Methods Phys. Res., A320 Rev. **66**(1992).
2. Roy A. Briere (for the CLEO Collaboration), “Tracking in Helium-Based Gases: Presents and Future B Factories”; to appear in the Proceedings of the Seventh International Symposium on Heavy Flavor Physics, Santa Barbara, CA July, 1997.