A Study of Vertex Resolution in GlueX

GlueX-doc-388

Curtis A. Meyer
Carnegie Mellon University

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Abstract

This document reports on a study of vertex resolution in the GlueX detector using the HDFast package. The study examines both the effect of the location of the stereo layers in the straw-tube chamber on the vertex resolution, and the effects of putting g straw tubes at smaller radius in the detector. Such changes can significantly improve the vertex resolution of the GlueX detector.

1 Introduction

During the GlueX detector review, the placement of the stereo layers in the CDC was questioned. In particular, it was pointed out that the GlueX vertex resolution would likely suffer due to the fact that the first stereo layer does not occur until a radius of about $22\,cm$ has been reached. The goal of this study is to try and address the effects on detector vertex resolution due to various configurations of straight and stereo layers in the CDC.

This study has been carried out using the HDFast Monte Carlo program, and examining the reconstructed vertex from the reaction

$$\gamma p \rightarrow \eta_1(1800) p \rightarrow \pi^+\pi^-\pi^+\pi^- p. \tag{1}$$

As far as I can tell, MCFast does not actually have a constrained vertex fit option. Rather, for each track it returns the (x, y, z) coordinate of the point of closest approach to the z axis. For physics events in which there is only one track, this measure is as good as one is going to be able to do. For events with more than one track, a combined fit to both tracks simultaneously will be able to sharpen the vertex resolution.

Throughout this document, we will refer to the two sets of vertex coordinates. The generated vertex will be written as: (x_0, y_0, z_0), while the *fit* vertex will be written as $(x_{fit}, y_{fit}, z_{fit})$.

Events from the reaction $\gamma p \to \eta_1(1800)p$ with $\eta_1 \to \pi^+\pi^-\pi^+\pi^-$ were generated and tracked through several different geometrical configurations of the the GlueX straw-tube chamber, CDC using the HDFast package. Figure 1 shows the primary vertex distribution distribution in x, y and z. Note that HDFast throws Gaussian distribution sin all of these variables. As a caveat, HDFast does not actually fit a vertex to the event, but rather returns the point of *closest approach*, (DCA), to the z–axis for each track. It is this DCA, or some average of several DCAs that we use throughout this work.

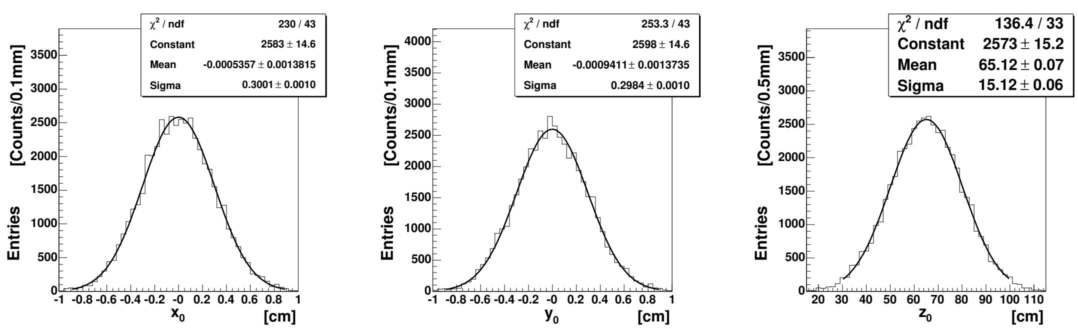

Figure 1: The vertex distribution of the generated events from this study. Note that the scale on z is different from that on x and y.y

2 Vertex Resolution

As discussed above, the returned vertex coordinate from the HDFast program does not necessarily have a lot to do with the primary vertex. unless the interaction took place on the z–axis, a distribution that examines either $x_{fit} - x_0$ or $y_{fit} - y_0$ will be skewed and broadened. Similarly, $z_{fit} - z_0$ will also be somewhat broadened as well. To lowest order, this broadening will be proportional to the actual vertex distribution. It is possible to perform a very crude vertex fit by averaging the vertex coordinates of each of the five charged tracks in an event. This is certainly not as good as a true vertex fit, but will reduce some of the uncertainties.

In Table 1 we summarize the various geometries we have used in addressing the vertex question. We started out with the nominal CDC configuration as geometry A1. This has stereo blocks at radius $21--28\,cm$, and a second block at $39--46\,cm$ cm. In geometry A2, we just moved these blocks inward to $14--21\,cm$ and $35--41\,cm$. The next step in the geometrical changes was to add 4 additional layers on the inside of the CDC. Geometry B1 has the stereo at the same place as A2, while geometry B2 has moved them inward by about $7\,cm$. Lastly, we extend in even closer to the vertex, but have three sets of stereo layers rather that just 2. These are shown as geometry C1 and C2. The only difference between the latter two is that the innermost layer of stereo wires in C2 is at 3° rather than 6°.

Geometry	Geometry File	r_{min}	Layers	r_{stereo}	n_{stereo}
A1	HDFast_v30.db	$14.77\,cm$	23	$21.91\,cm$	2
A2	HDFast_v34.db	$14.77\,cm$	23	$14.77\,cm$	2
B1	HDFast_v31.db	$7.91\,cm$	27	$15.03\,cm$	2
B2	HDFast_v35.db	$7.91\,cm$	26	$7.91\,cm$	2
C1	HDFast_v32.db	$5.37\,cm$	27	$5.37\,cm$	3
C2	HDFast_v33.db	$5.37\,cm$	27	$5.37\,cm$	3

Table 1: The geometries looked at for studying vertex resolution in GlueX. The radius of the first wire is r_{min}, the total number of layers is given and Layers. The radius of the first stereo layer is $r + stereo$ and the number of blocks of stereo layers is given as n_{stereo}. The difference between geometries 32 and 33 is that 32 has 6° stereo blocks every where, but 33 has 3° stereo in the innermost block and 6° in the outer two blocks.

Table 2 summarizes the results for the z vertex resolution over all of the above geometries. The four columns give different estimates of the true vertex resolution. The *All* column is based on an entry for each of the five charged tracks in each of the events. The *Average* column is is based on a single vertex that is the average of each of the file individual points. We then look at the vertex calculated only for the two π^+s in the events and that calculated only for the protons in the events. The protons tend to be slow, and thrown out with relatively large polar angles. One of the two π^+ is the lead decaying π in the η_1 decay, and tends to be fast and forward. The data from which this table is generated is given in Figures 2, 3, 4, 5, 6 and 7 for the *Average* and *All* columns. Figures 8, 9, 10, 11, 12 and 13 are for the π^+ and proton plots.

Geometry	$\sigma_z(All)$	$\sigma_z(Average)$	$\sigma_z(p)$	$\sigma_z(\pi)$
A1	$0.78\,cm$	$0.57\,cm$	$0.50\,cm$	$0.82\,cm$
A2	$0.63\,cm$	$0.43\,cm$	$0.38\,cm$	$0.68\,cm$
B1	$0.50\,cm$	$0.44\,cm$	$0.31\,cm$	$0.54\,cm$
B2	$0.36\,cm$	$0.38\,cm$	$0.24\,cm$	$0.39\,cm$
C1	$0.29\,cm$	$0.30\,cm$	$0.20\,cm$	$0.30\,cm$
C2	$0.37\,cm$	$0.32\,cm$	$0.30\,cm$	$0.40\,cm$

Table 2: The z vertex resolution for each of the geometries described in Table 1. All and Average are described in the text. The column for p is for the proton alone, while the column for π is for the two π^+s in the final state.

Geometry	$\sigma_x(All)$	$\sigma_x(Average)$	$\sigma_x(p)$	$\sigma_x(\pi)$
A1	$0.077\,cm$	$0.059\,cm$	$0.085\,cm$	$0.075\,cm$
A2	$0.077\,cm$	$0.062\,cm$	$0.087\,cm$	$0.077\,cm$
B1	$0.035\,cm$	$0.048\,cm$	$0.050\,cm$	$0.047\,cm$
B2	$0.037\,cm$	$0.050\,cm$	$0.053\,cm$	$0.049\,cm$
C1	$0.028\,cm$	$0.036\,cm$	$0.037\,cm$	$0.036\,cm$
C2	$0.027\,cm$	$0.035\,cm$	$0.037\,cm$	$0.035\,cm$

Table 3: The x vertex resolution for each of the geometries described in Table 1. All and Average are described in the text. The column for p is for the proton alone, while the column for π is for the two π^+s in the final state.

3 Summary

After having looked at several possible geometries for the GlueX straw tube chambers, we see some clear trends as far as vertex resolution is concerned. Simply moving the stereo blocks to smaller radius (geometry A1 to A1) improves the z resolution by about 25%, without having a noticible effect on the x and y resolution. A significant improvement in the overall vertex resolution can be obtained by extending the straw-tube chamber to smaller radius. Moving in from about $15\,cm$ to $8\,cm$ provides roughly a 40% improvement in

Geometry	$\sigma_y(All)$	$\sigma_y(Average)$	$\sigma_y(p)$	$\sigma_y(\pi)$
A1	$0.078\,cm$	$0.057\,cm$	$0.086\,cm$	$0.075\,cm$
A2	$0.078\,cm$	$0.062\,cm$	$0.087\,cm$	$0.078\,cm$
B1	$0.035\,cm$	$0.048\,cm$	$0.051\,cm$	$0.046\,cm$
B2	$0.037\,cm$	$0.050\,cm$	$0.052\,cm$	$0.049\,cm$
C1	$0.028\,cm$	$0.035\,cm$	$0.036\,cm$	$0.035\,cm$
C2	$0.028\,cm$	$0.035\,cm$	$0.035\,cm$	$0.036\,cm$

Table 4: The y vertex resolution for each of the geometries described in Table 1. All and Average are described in the text. The column for p is for the proton alone, while the column for π is for the two π^+s in the final state.

the x, y and z resolutions. Moving in even further to about $5\,cm$ can yield even better results.

Assuming that we do not have a start-counter in the GlueX experiment, the inner radius of the straw-tube chamber should be moved inward and the layout of the stereo layers changed to provide z information at a smaller radius. If it is possible to come in in radius as small as $6\,cm$, then we should consider three blocks of stereo layers rather than two.

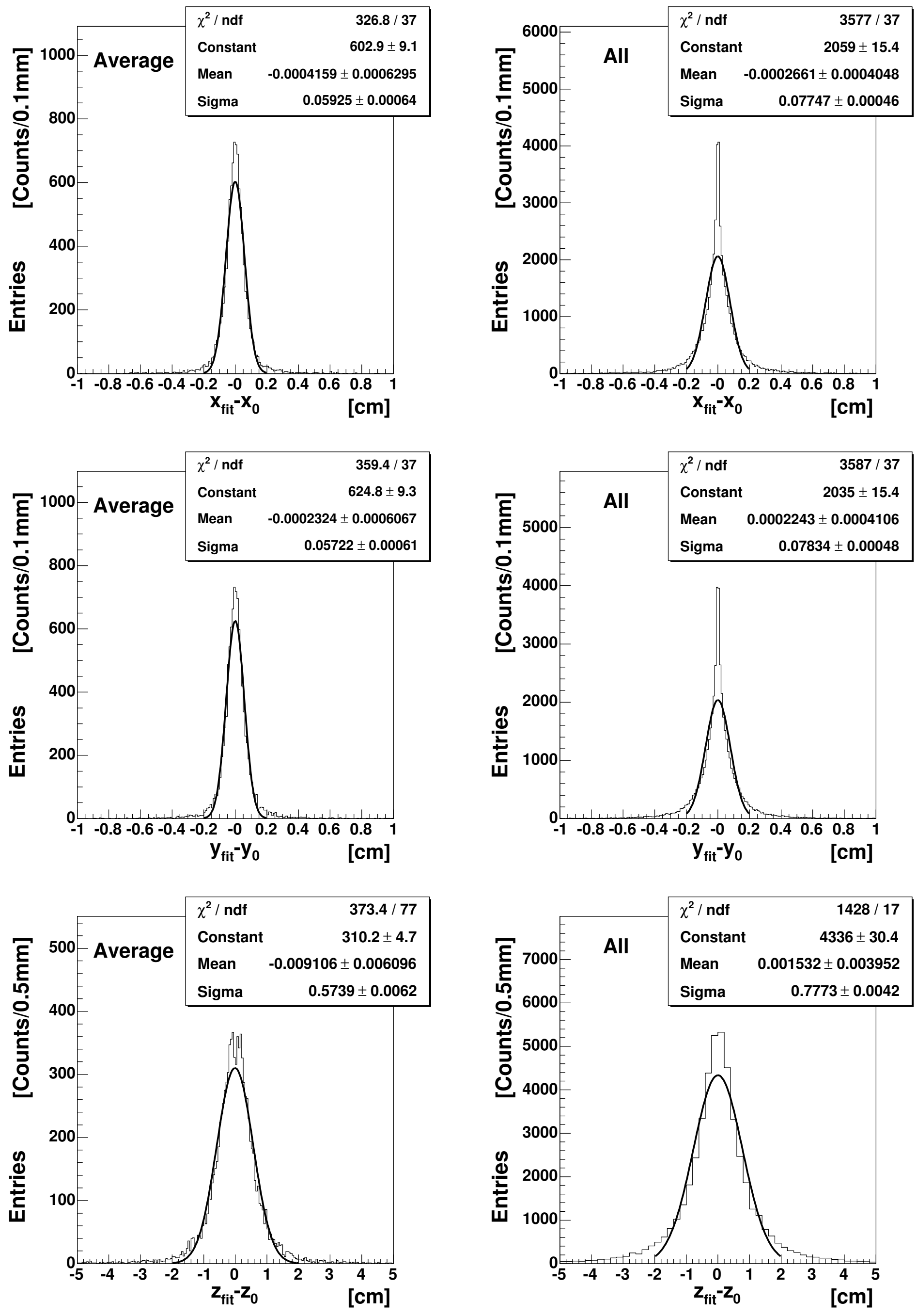

Figure 2: Vertex Resolution for geometry A1. The left-hand plots labeled *Average* are made by averaging the DCA of all five tracks in the events. The right-hand plots labeled *All* have one entry for each of the DCAs.

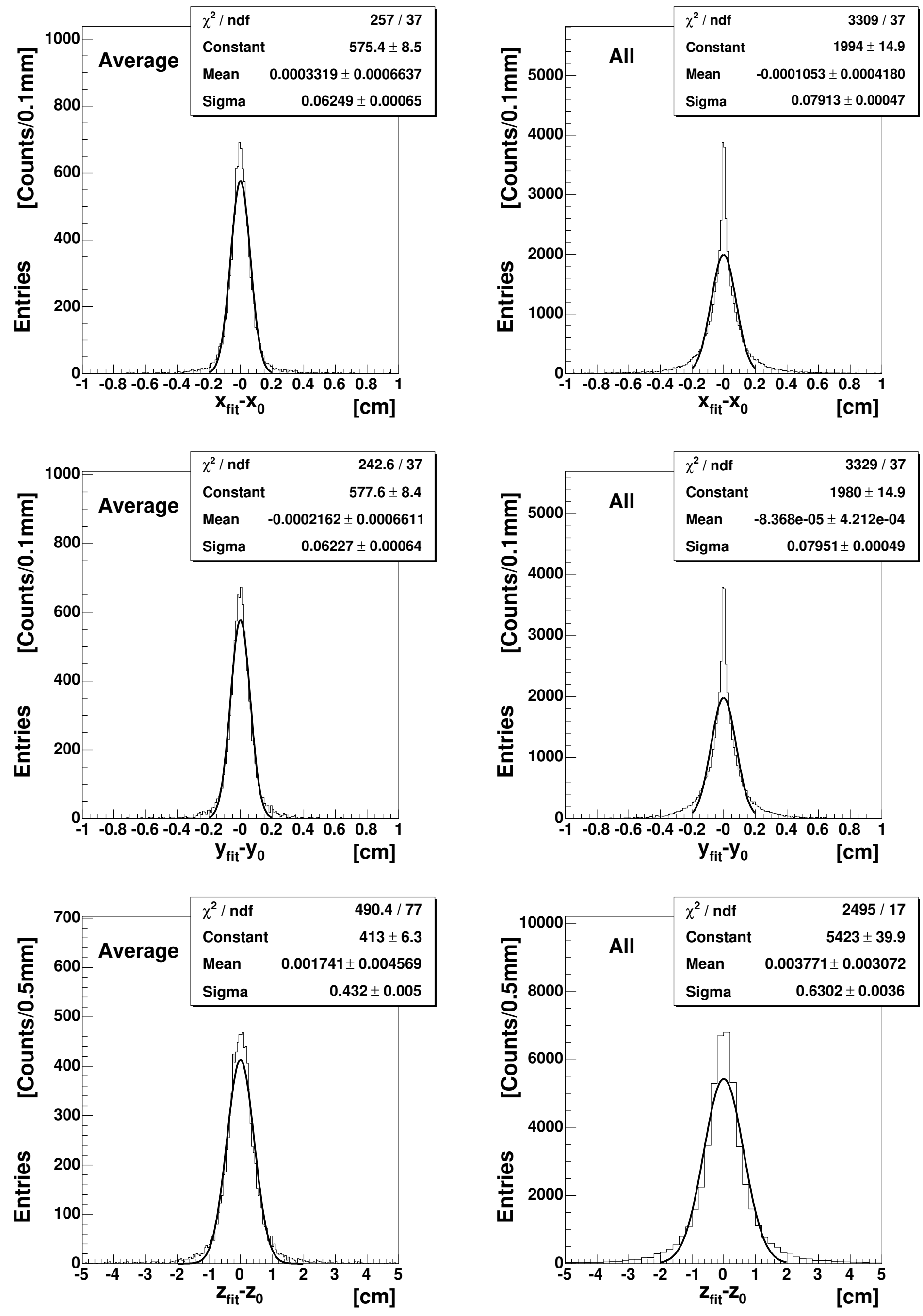

Figure 3: Vertex Resolution for geometry A2. The left-hand plots labeled *Average* are made by averaging the DCA of all five tracks in the events. The right-hand plots labeled *All* have one entry for each of the DCAs.

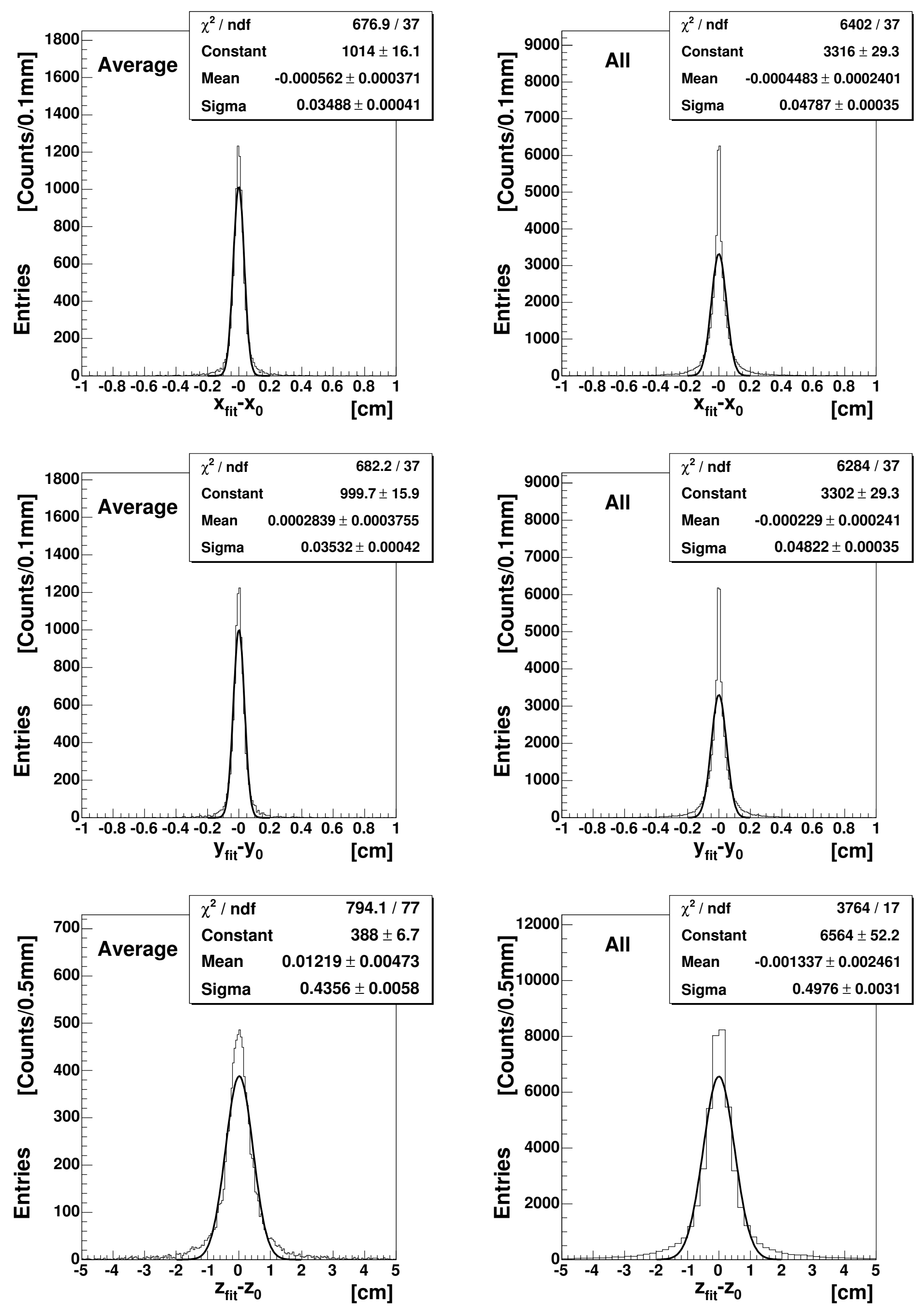

Figure 4: Vertex Resolution for geometry B1. The left-hand plots labeled *Average* are made by averaging the DCA of all five tracks in the events. The right-hand plots labeled *All* have one entry for each of the DCAs.

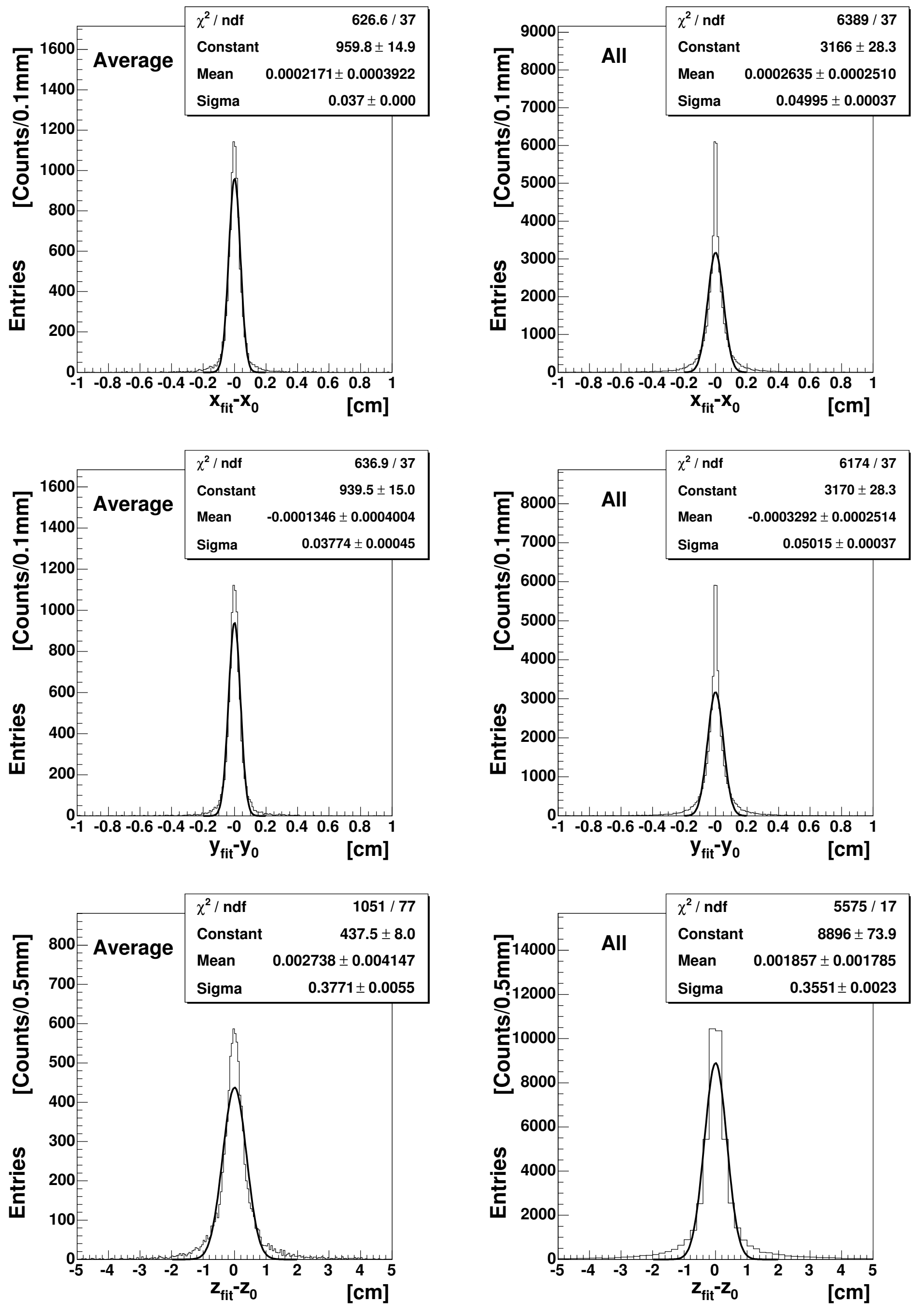

Figure 5: Vertex Resolution for geometry B2. The left-hand plots labeled *Average* are made by averaging the DCA of all five tracks in the events. The right-hand plots labeled *All* have one entry for each of the DCAs.

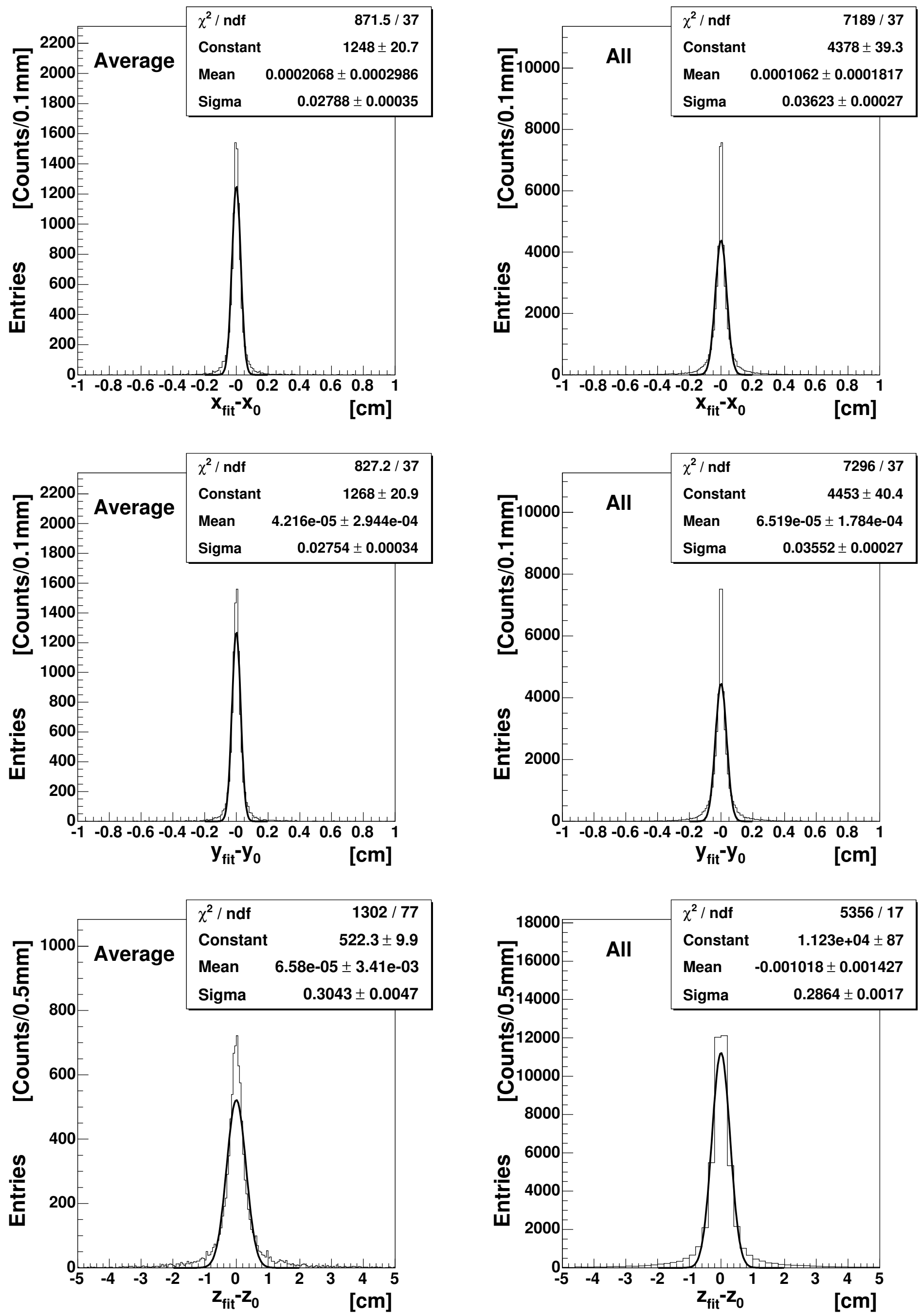

Figure 6: Vertex Resolution for geometry C1. The left-hand plots labeled *Average* are made by averaging the DCA of all five tracks in the events. The right-hand plots labeled *All* have one entry for each of the DCAs.

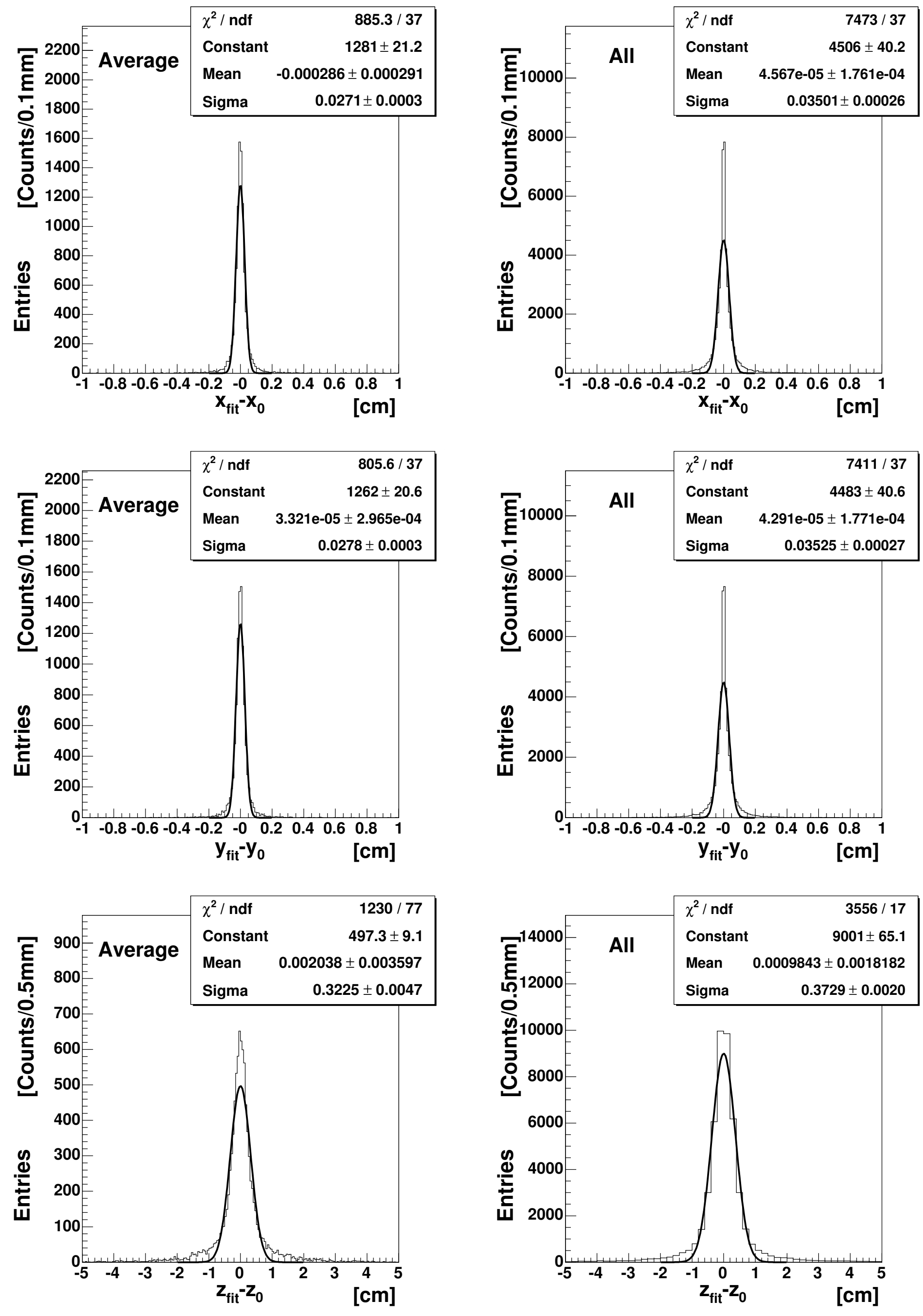

Figure 7: Vertex Resolution for geometry C2. The left-hand plots labeled *Average* are made by averaging the DCA of all five tracks in the events. The right-hand plots labeled *All* have one entry for each of the DCAs.

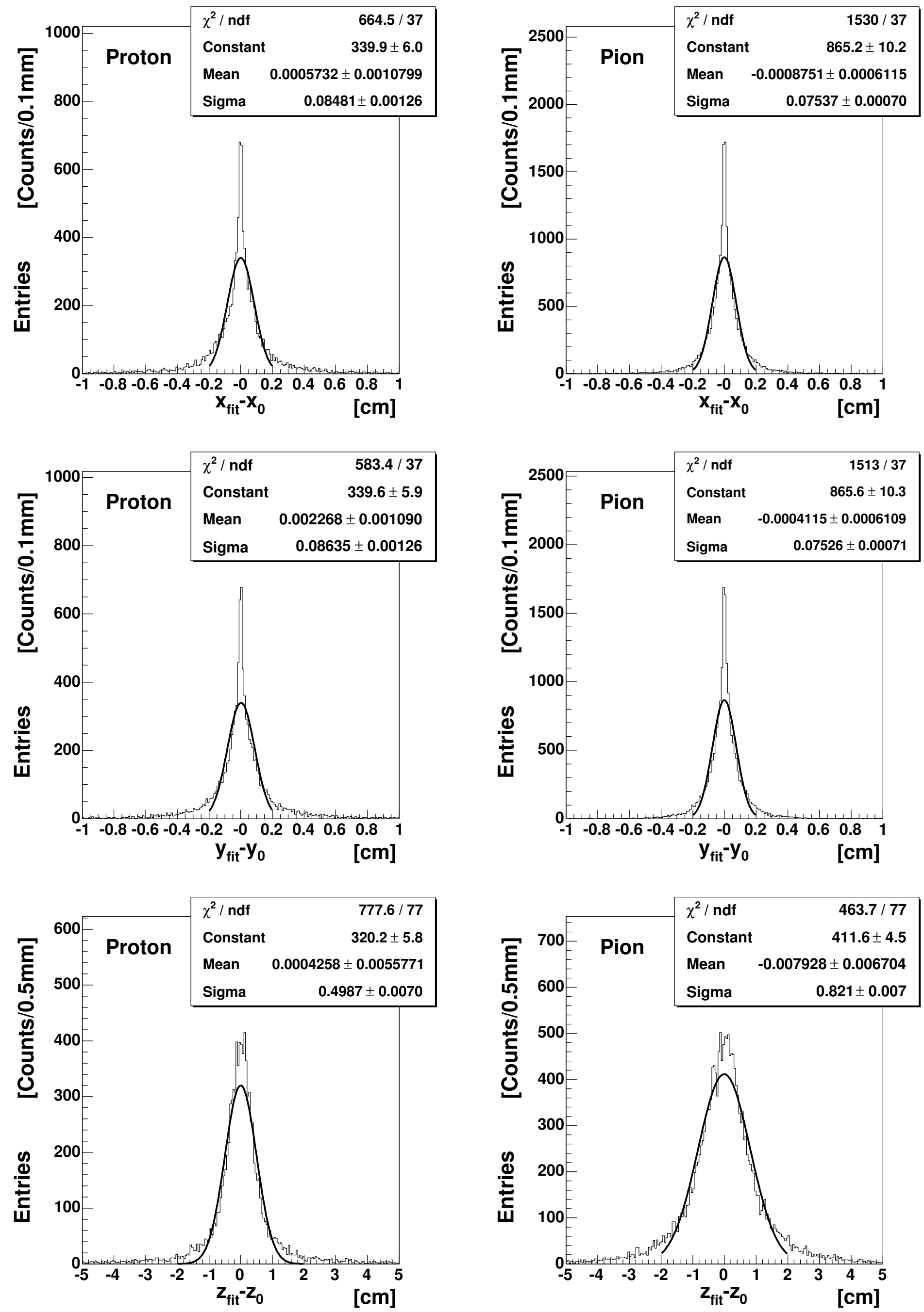

Figure 8: Vertex Resolution for geometry A1. The left-hand plots labeled *Proton* are made by using the DCA of proton in the event. The right-hand plots labeled *Pion* are made using the DCAs from the two π^+s in the event.

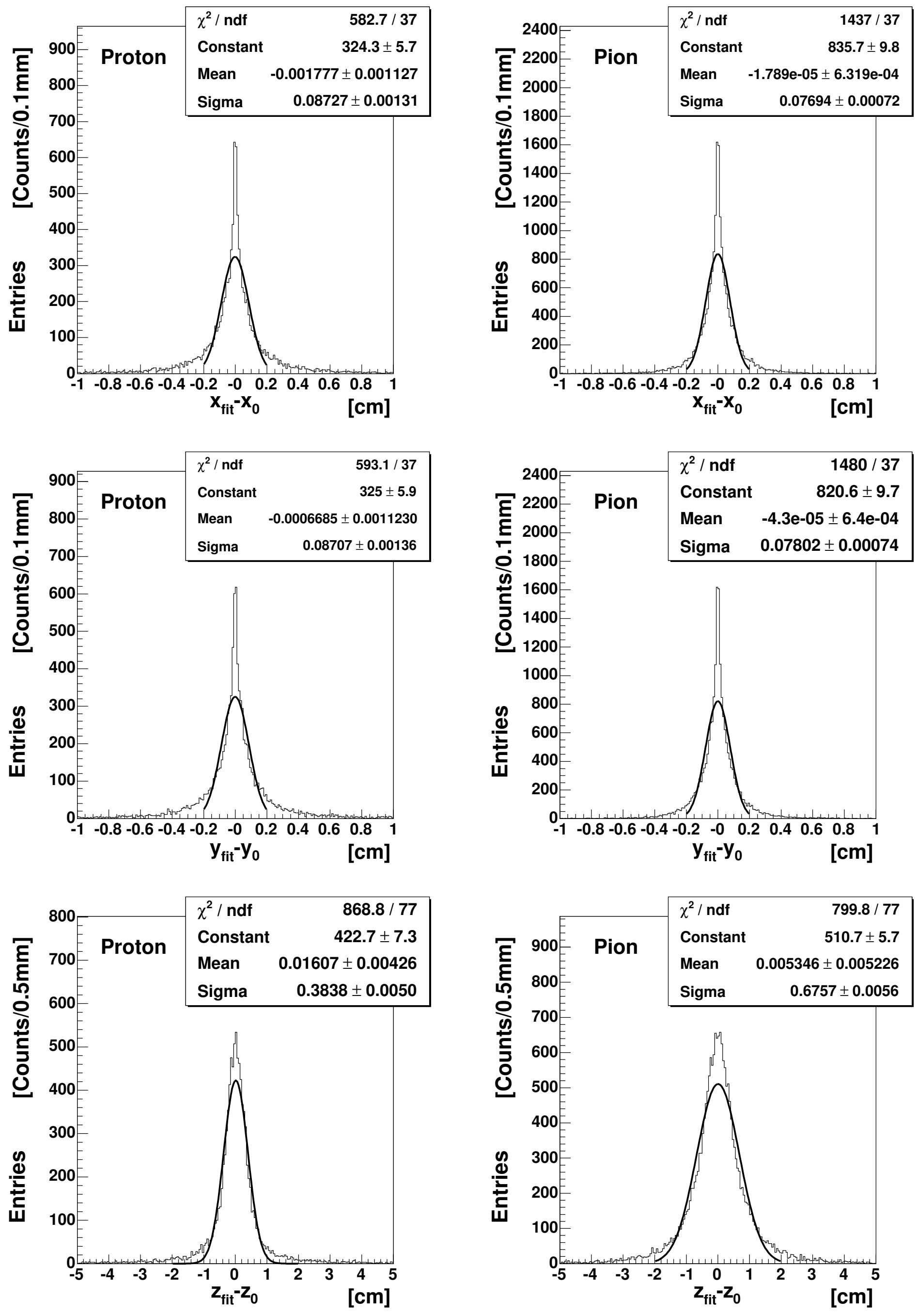

Figure 9: Vertex Resolution for geometry A2. The left-hand plots labeled *Proton* are made by using the DCA of proton in the event. The right-hand plots labeled *Pion* are made using the DCAs from the two π^+s in the event.

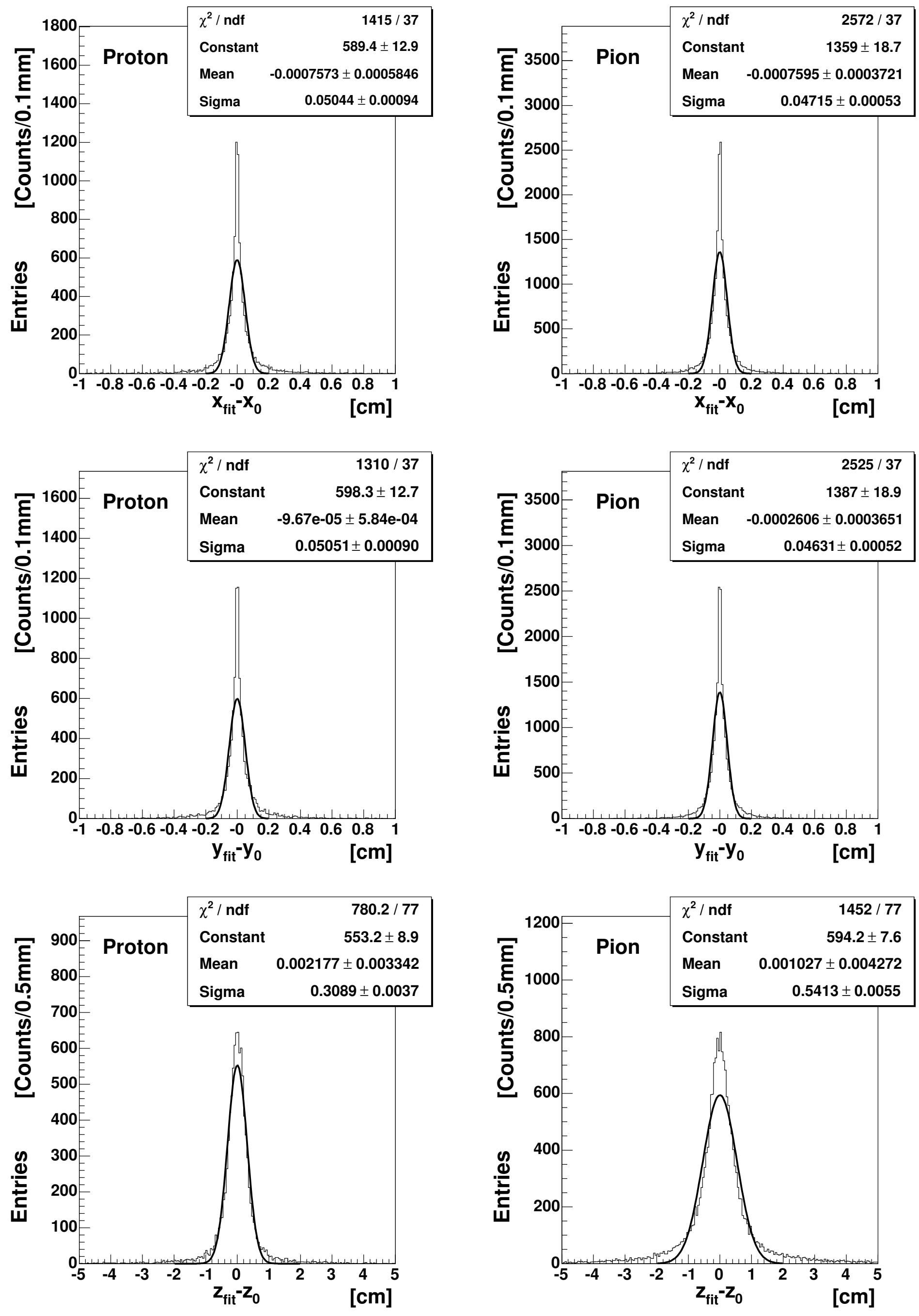

Figure 10: Vertex Resolution for geometry B1. The left-hand plots labeled *Proton* are made by using the DCA of proton in the event. The right-hand plots labeled *Pion* are made using the DCAs from the two π^+s in the event.

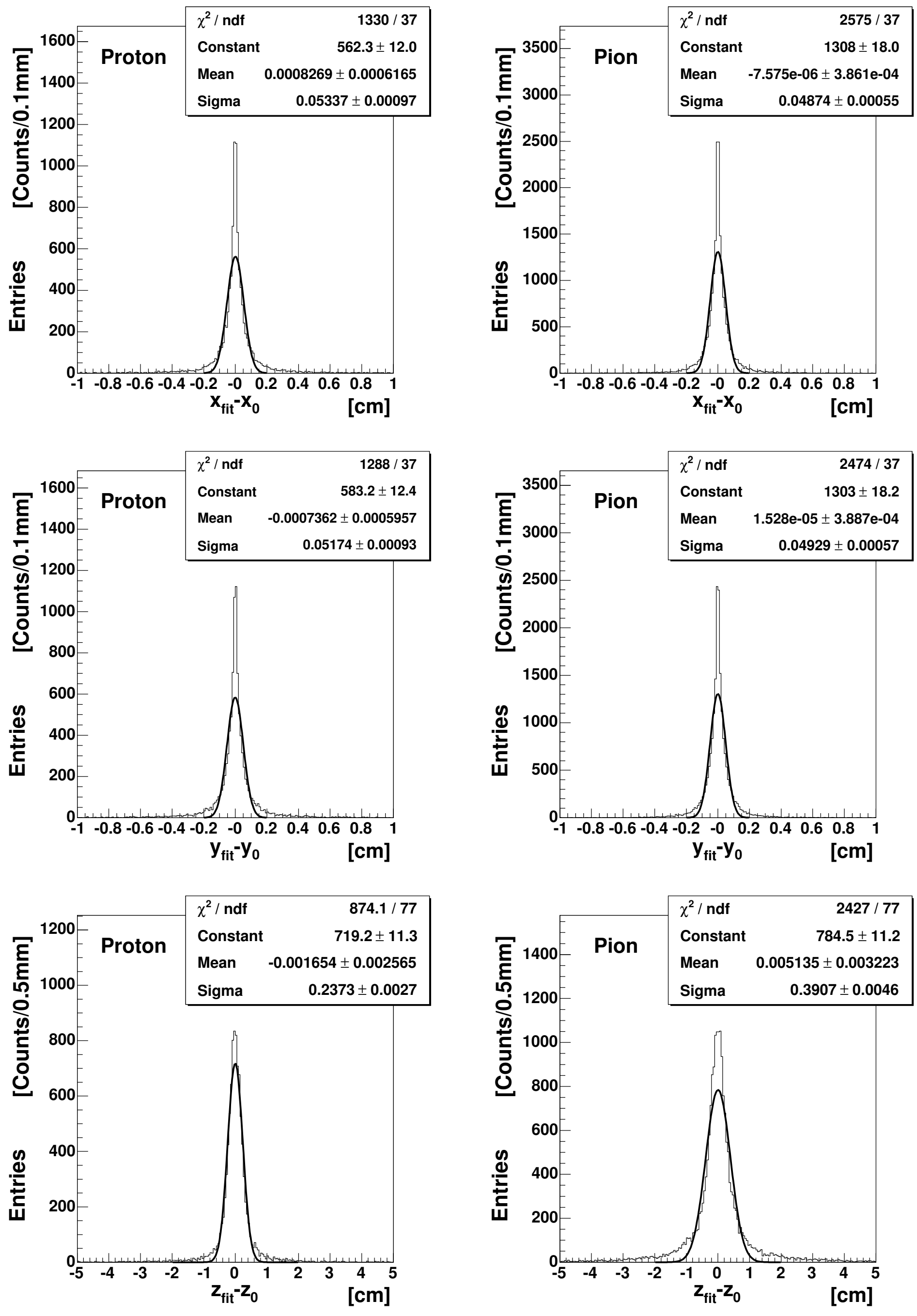

Figure 11: Vertex Resolution for geometry B2. The left-hand plots labeled *Proton* are made by using the DCA of proton in the event. The right-hand plots labeled *Pion* are made using the DCAs from the two π^+s in the event.

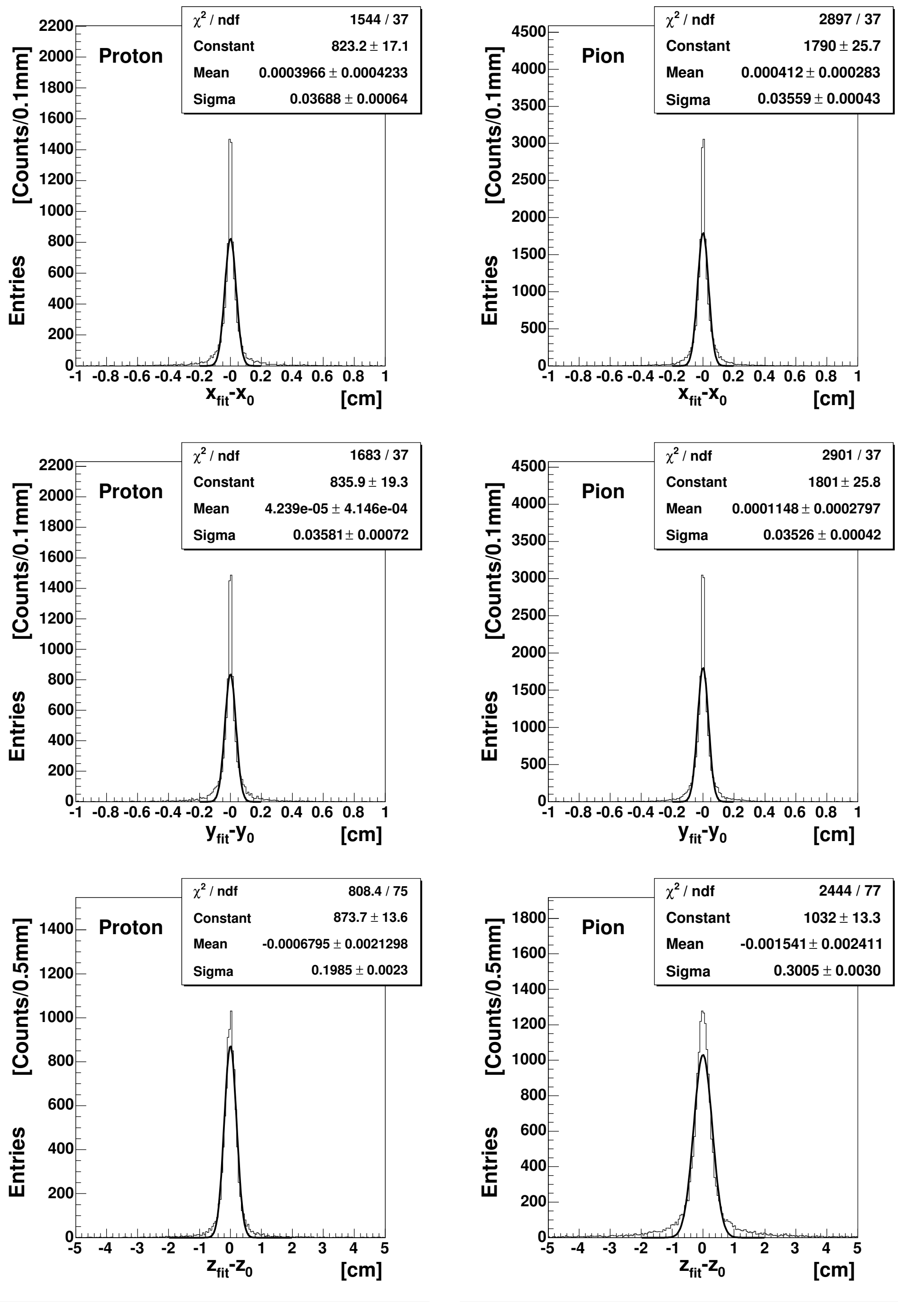

Figure 12: Vertex Resolution for geometry C1. The left-hand plots labeled *Proton* are made by using the DCA of proton in the event. The right-hand plots labeled *Pion* are made using the DCAs from the two π^+s in the event.

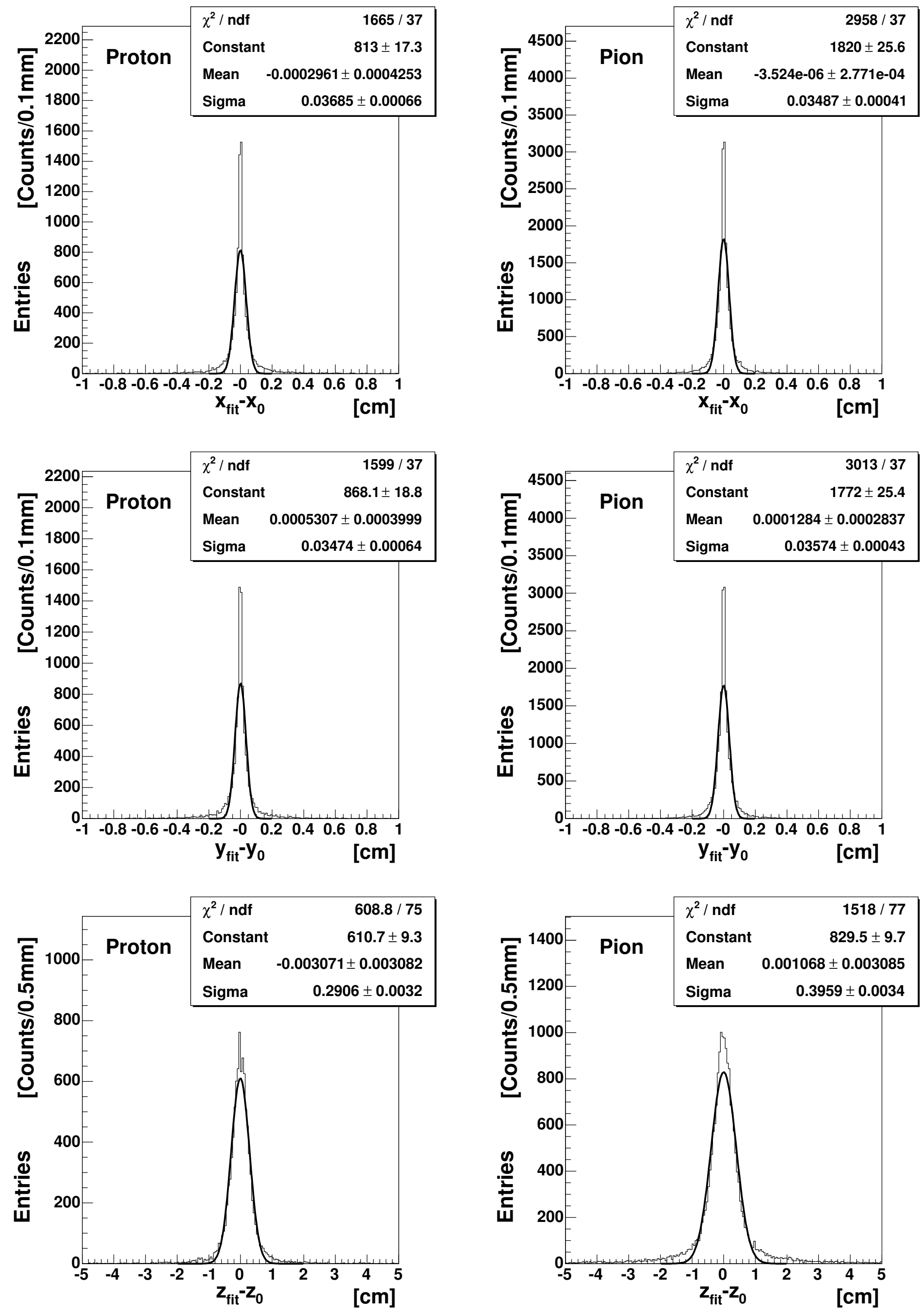

Figure 13: Vertex Resolution for geometry C2. The left-hand plots labeled *Proton* are made by using the DCA of proton in the event. The right-hand plots labeled *Pion* are made using the DCAs from the two π^+s in the event.