PROPOSAL FOR DETERMINING THE RELATIVE ALIGNMENT OF THE E614 DETECTOR AND THE MAGNETIC FIELD ON AN EVENT-BY-EVENT BASIS

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Figure 1 shows three views of a typical E614 event. The lines indicate the actual track, and the dots indicate the hits in the PDC wire planes. The starting parameters for this track are: $x_0 = 1.0$ cm, $y_0 = 1.0$ cm, $x = 0.5$, $\theta = 45°$, and $\phi = 135°$. The magnetic field is $B_z = 2$ Tesla, $B_x = B_y = 0$. The equations for the track can be written as:

$$x = a\sin(bz - c) + x_c \quad (1)$$

and

$$y = a\cos(bz - c) + y_c \quad (2)$$

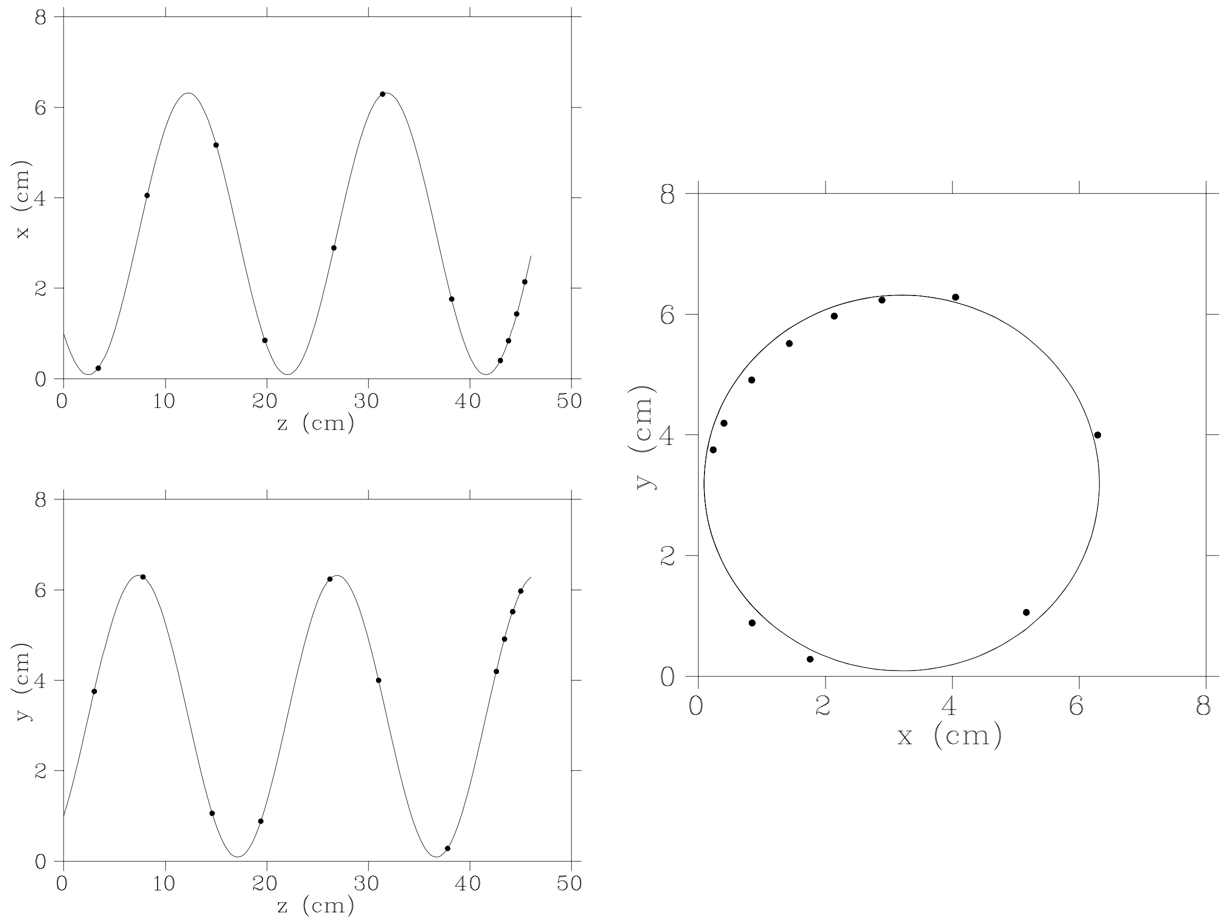

Figure 1: Typical track with magnetic field aligned with detector.

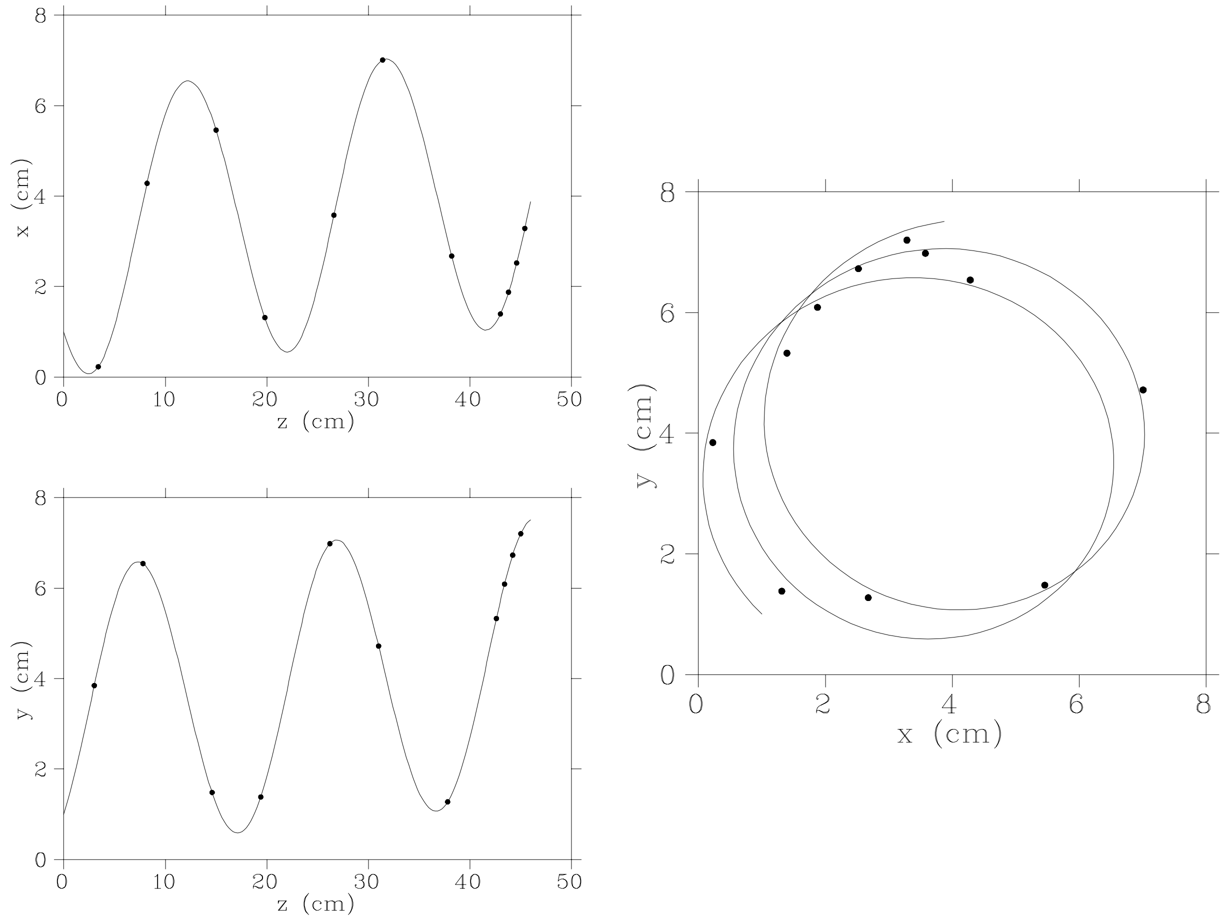

Figure 2: Same track as shown in Figure 1, but now with magnetic field misaligned by two degrees.

Now consider what happens if the magnetic field is not perfectly aligned with the detector wire planes. Let's keep the coordinate system fixed with the detector, and assume that the field misalignment is given by the polar and azimuthal angles θ_B and ϕ_B, so that $B_z = B\cos\theta_B$, $B_x = B\sin\theta_B\cos\phi_B$, and $B_y = B\sin\theta_B\sin\phi_B$, and θ_B is small. Figure 2 shows a track with the same parameters as the one illustrated in Figure 1, but for the case of $\theta_B = 2°$ and $\phi_B = 45°$. Clearly, even a relatively small misalignment of the field has a fairly large impact on the trajectory through the detector. Empirically, it turns out that to a good approximation the equations for the track can now be written as:

$$x \simeq a'\sin(b'z - c') + x'_c + d_x z \tag{3}$$

$$\text{and} \quad y \simeq a'\cos(b'z - c') + y'_c + d_y z \tag{4}$$

where

$$d_x = \sin(\theta_B)\cos(\phi_B)$$

$$\text{and} \quad d_y = \sin(\theta_B)\sin(\phi_B)$$

So that if we can determine d_x and d_y for each track, we should be able to find θ_B and ϕ_B from

$$\theta_B = \arcsin\sqrt{d_x^2 + d_y^2} \tag{5}$$

$$\text{and} \quad \phi_B = \arctan(d_y/d_x) \tag{6}$$

In order to test this idea, I employed the following procedure: I generated 10,000 events, tracing each one from the stopping target through the E614 detector using a Runge-Kutta method, ignoring energy loss and multiple scattering effects. For each track, the initial location on the target was chosen at random from a uniform circular distribution centered at the origin, with a radius of 2. cm. The track angles were chosen randomly from an isotropic distribution with $5° < \theta < 85°$ and $0° < \phi < 360°$. The track momentum was chosen randomly from a uniform distribution with $0.3 < x < 1.0$. The only restriction was that I did not consider tracks with $p_z < 6.5$ MeV/c, i.e. with wavelengths shorter than 6.8 cm. For each track, I made a 'first guess' at the five standard track parameters using the algorithm discussed in my posting of March 10. This algorithm uses only the positions of the hit wires. Using these five 'first guess' parameters as the starting point, I made a seven parameter fit to the exact hit coordinates, using the functional form given in equations (3) and (4) for each track, and calculated θ_B and ϕ_B from equations (5) and (6). The fitting routine was a modified version of Bevington's 'CURFIT' routine.

Typical results for the case of $\theta_B = 2°$ and $\phi_B = 45°$ are shown in Figure 3. These results do not depend on the starting point of the fit. I have checked this by repeating the procedure using the actual generated track parameters (i.e. a, b, c, x_c, and y_c in equations (1) and (2)) as the 'first guess' for the fit, and obtained essentially the same answer. The results also do not depend on the spatial resolution assumed for the hit coordinates, at least for resolutions $\leq$ 100 microns. The main limitation on the accuracy one can obtain comes from the fact that the functional form assumed in equations (3) and (4) is only approximate. We could do better if we had the exact (x,y,z) coordinates of every hit, rather than only the (x,z) or (y,z) coordinates. Equations (3) and (4) become a better approximation as θ_B gets smaller. This can be seen in Figure 4, which shows results for the case of $\theta_B = 1°$ and $\phi_B = 45°$. It is evident that the $\Delta\theta_B$ distribution in Figure 4 is narrower, with smaller tails, than the corresponding distribution in Figure 3. I have not done a careful error analysis, but it seems reasonable to assume that we should be able to determine the centroid of the $\Delta\theta_B$ distribution very well, especially if we restrict the analysis to small values of $a \propto p_{xy}$. For reference, the bin width for $\Delta\theta_B$ plotted in Figures 3 and 4 is 0.04°.

Of course, the task of aligning the detector with the magnetic field will be one of the first things we will do, and it is quite probable that we will not have a very good knowledge of the chamber xt relations at that point. So, it is probably interesting to ask whether this event by event technique can be applied without knowing the hit coordinates very well. I have tested this by using the same procedure as described above, except that in the last step, instead of making a seven parameter fit to the hit coordinates, I made a seven parameter fit to just the hit wire positions. The results for this case, for $\theta_B = 2°$ and $\phi_B = 45°$ (as in Figure 3), are shown in Figure 5. While the resolution is obviously much worse, it does appear that it should be possible to use this technique to get the alignment to much better than one degree.

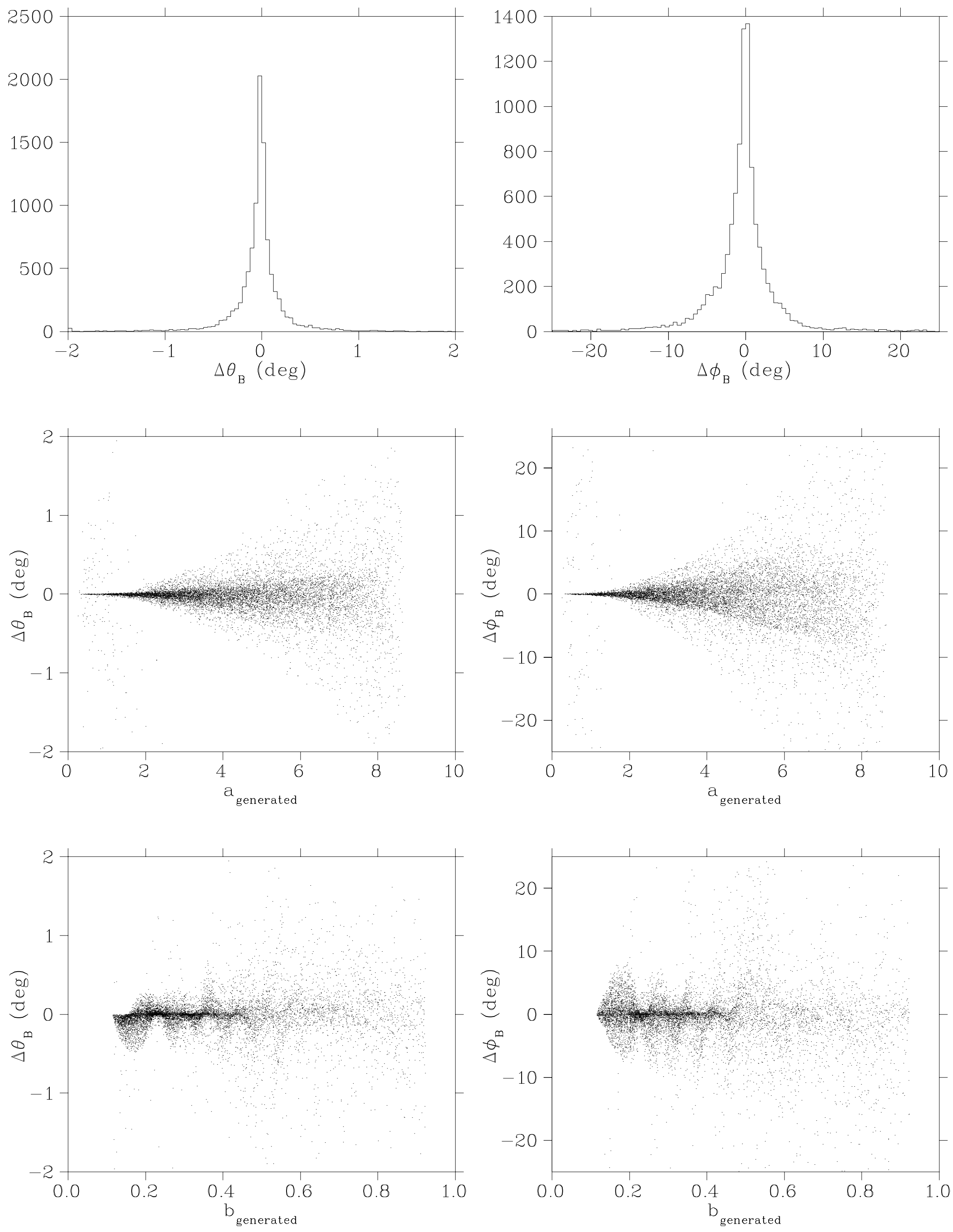

Figure 3: Illustration of how well we can expect to be able to determine the direction of the magnetic field using a fit to the exact hit coordinates. The reconstructed events were generated with $\theta_B = 2°$ and $\phi_B = 45°$.

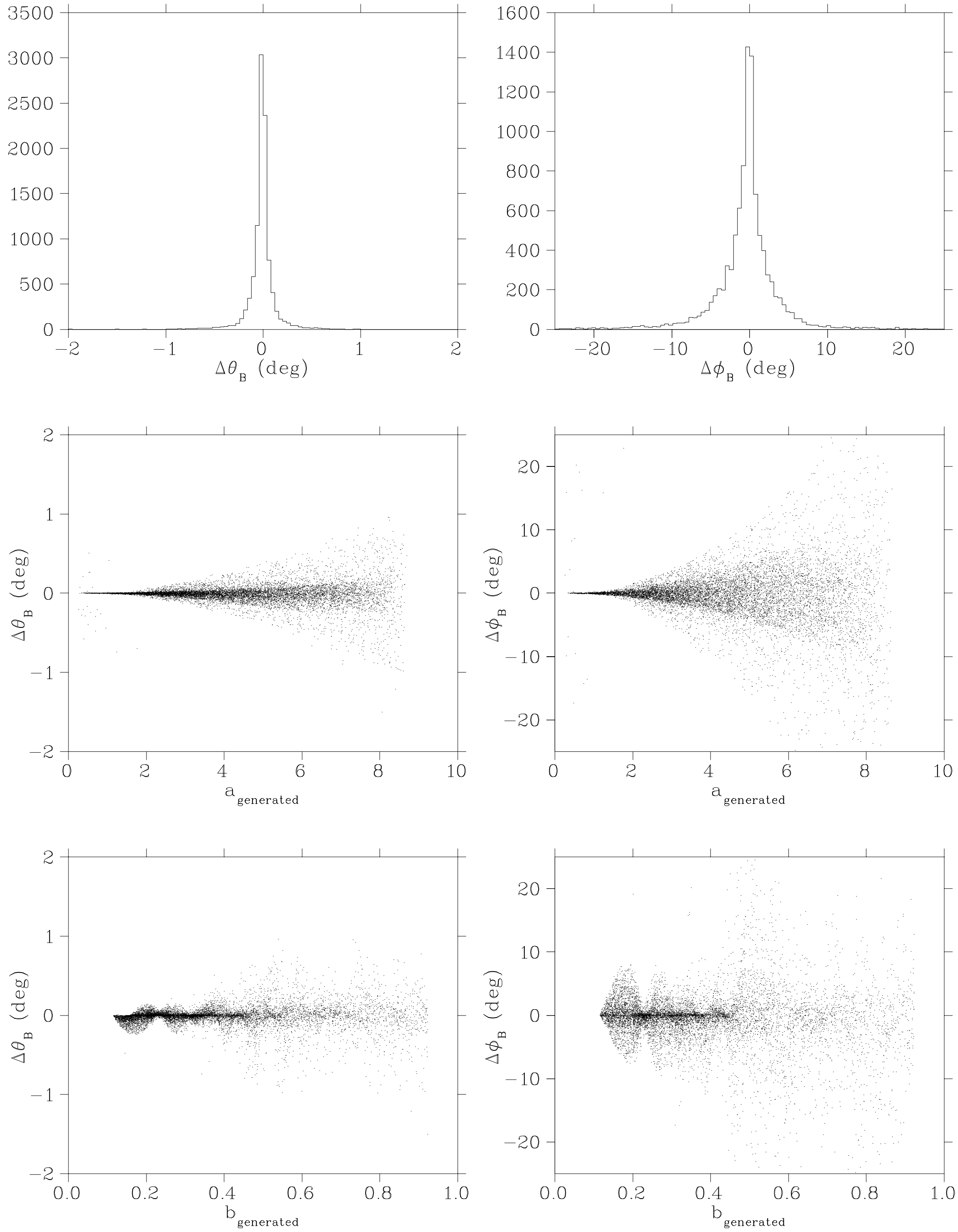

Figure 4: Illustration of how well we can expect to be able to determine the direction of the magnetic field using a fit to the exact hit coordinates. The reconstructed events were generated with $\theta_B = 1°$ and $\phi_B = 45°$.

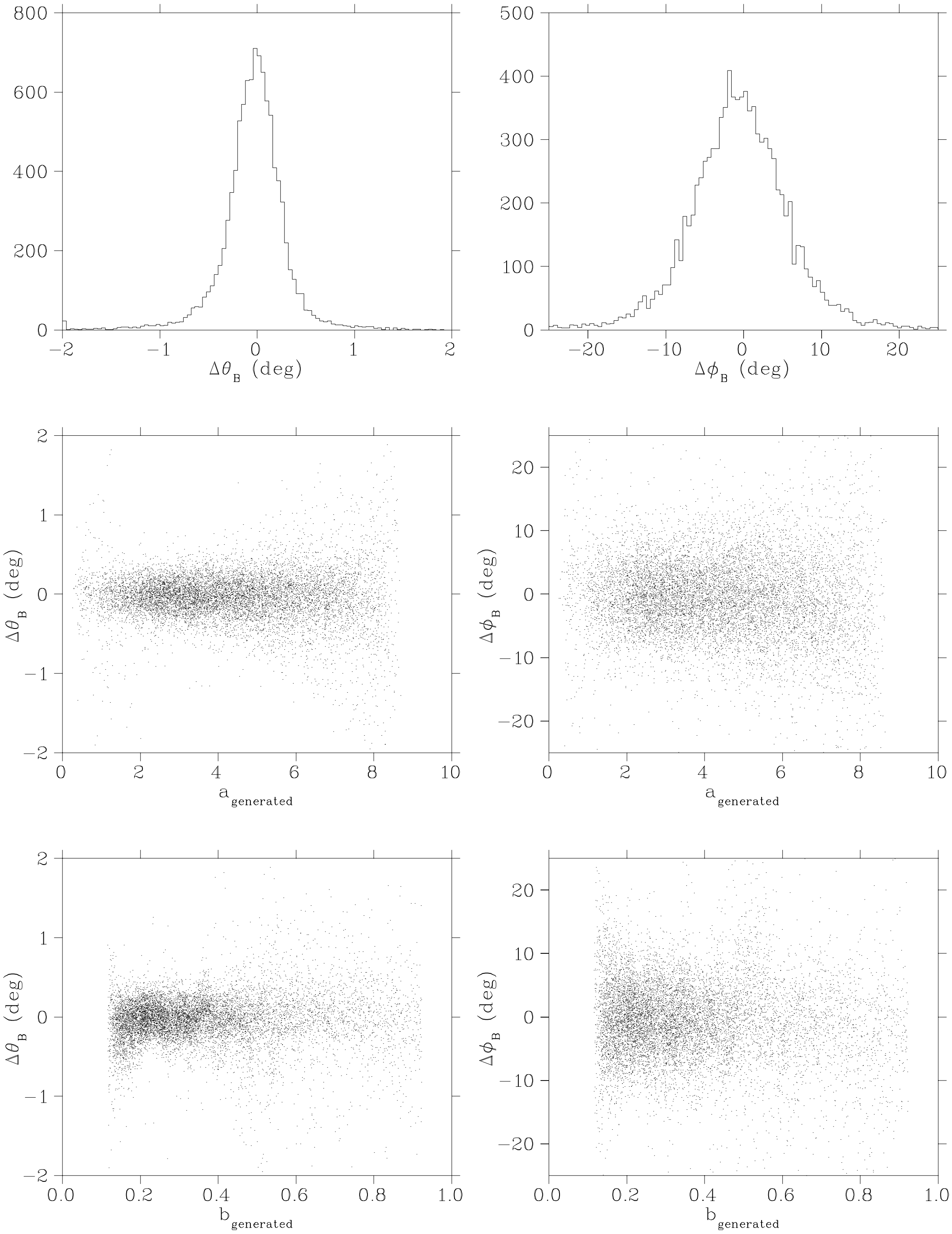

Figure 5: Illustration of how well we can expect to be able to determine the direction of the magnetic field using a fit only to the hit wire positions. The reconstructed events were generated with $\theta_B = 2°$ and $\phi_B = 45°$, as in Figure 3.