A Beam Position Measurement from $\gamma\gamma$ Events

J. Putz and S. Wasserbaech
University of Washington

Abstract

We perform a measurement of the beam position with $\gamma\gamma$ events from one fill in the 1993 data. We use a chunk-by-chunk method to measure the beam position. We find an average beam position uncertainty of 52 $\mu$m in $x$ and 46 $\mu$m in $y$ for chunks of 7.48 nb$^{-1}$. We conclude that chunks of roughly 5 nb$^{-1}$ will yield adequate measurements at LEP II.

1 Introduction

Recent Aleph notes [1, 2] have considered the possibility of using two-photon events and wide-angle Bhabhas to measure the beam position at LEP II. The Monte Carlo study described in [2] shows that a beam position uncertainty of $\Delta x_{\text{beam}} = 42 \mu$m and $\Delta y_{\text{beam}} = 32 \mu$m (or better) can be achieved for a chunk of 3.6 nb$^{-1}$ at $\sqrt{s} = 175$ GeV. For comparison, the official julia algorithm at LEP 1 averages over chunks corresponding to 75 $Z^0$ events and achieves $\Delta x_{\text{beam}} = 20 \mu$m and $\Delta y_{\text{beam}} = 10 \mu$m.

In this note, we present an analysis of real two-photon events collected with the Aleph detector in 1993 at $\sqrt{s} = 89.4$ GeV. Our objectives are to determine what cuts are needed to reduce the contamination from beam-gas interactions and cosmic rays to a reasonable level and to measure the precision of beam position measurements made with $\gamma\gamma$ events.
2 \( \gamma\gamma \) Event Selection

We use fill 1703 (runs 21706 – 21711), with an integrated luminosity of 419nb\(^{-1}\), to
determine the precision of the beam position measured from \( \gamma\gamma \) events. We choose a fill
at \( \sqrt{s} = 89.4 \text{ GeV} \) to take advantage of the lower \( Z^0 \) cross section. Cuts are chosen using
Monte Carlo simulations of wide-angle Bhabha events, hadronic and leptonic \( Z^0 \) decays,
and two-photon events. Although wide-angle Bhabha events will be present at LEP II,
we try to exclude them here in order to analyze only the two-photon events. We begin
with class 5 events (one to seven good tracks). We exclude events satisfying any of the
following:

- \( \geq 1 \) charged track with \( p > 35 \text{ GeV} \)
- total energy of energy flow objects \( > 30 \text{ GeV} \)
- accepted by the \( \tau^+\tau^- \) event selection algorithm TSLT02.

We accept events with only one charged track, whereas the current program requires two.
In the official julia production, VDET data are not reconstructed in one-track events.
We therefore reprocess our selected events, beginning with the raw data, using a VREC
card in julia in order to force the VDET reconstruction.

Our Monte Carlo sample corresponds to five times the integrated luminosity of the
real data. Two-photon events are generated with PHOT02 and GGMJ01. A single charged
electromagnetic, single muon, or total energy trigger is required. The table below lists
the predicted signal (\( \gamma\gamma \)) and background contributions to our event sample.

<table>
<thead>
<tr>
<th>Channel</th>
<th>events</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma\gamma \to ff \ (W &gt; 2 \text{ GeV}/c^2) )</td>
<td>2744</td>
</tr>
<tr>
<td>( e^+e^- \to e^+e^- \ (</td>
<td>\cos \theta^*</td>
</tr>
<tr>
<td>( Z^0 \to \mu^+\mu^- )</td>
<td>&lt;1</td>
</tr>
<tr>
<td>( Z^0 \to \tau^+\tau^- )</td>
<td>4</td>
</tr>
<tr>
<td>( Z^0 \to q\bar{q} )</td>
<td>0</td>
</tr>
<tr>
<td>total</td>
<td>2781</td>
</tr>
</tbody>
</table>

The number of selected events in the data is 4340. The \( \cos \theta \) and momentum distributions
for tracks in the selected events from data and Monte Carlo are compared in figure 1. We
expect some discrepancies between data and Monte Carlo because

- a cutoff on the final state invariant mass, \( W > 2 \text{ GeV}/c^2 \), was used in the generation
  of two-photon events with PHOT02. The \( \gamma\gamma \) cross section increases rapidly with
decreasing \( W \).
- a cutoff on \( \theta^* \) is imposed in the UBAB01 (Bhabha) generator. Since one-track events
  are accepted in this analysis, radiative events with \( |\cos \theta^*| > 0.95 \) may be selected
  in the real data, but such events are not present in the Monte Carlo sample.
- the SiCAL is not active in our simulation. This has a large effect on the selection
  efficiency for two-photon events and Bhabhas, due to the cut on total energy.
Figure 1: $\cos \theta$ and momentum distributions for good tracks from selected events in data (points with error bars), $\gamma\gamma$ Monte Carlo (solid line), and background (Bhabha and $Z^0$ decay) Monte Carlo (shaded region). We drop the VDET hit requirement in these plots in order to show the gain in statistics that VDET95 will yield. (The $|\cos \theta|$ limits of VDET91 and VDET95 are 0.85 and 0.95, respectively.)

We estimate the number of Bhabha events that pass the cuts by measuring the number of tracks that are asymmetric in $\cos \theta$ and charge in the way one would expect for Bhabhas. An excess of positively charged tracks at $\cos \theta \simeq -1$ or negatively charged tracks at $\cos \theta \simeq +1$ is interpreted as being due to Bhabha events. The number of such events is estimated to be 251, of which 52 contain at least one selected track for the beam position determination. The observed charge asymmetry is much larger than that expected from any of the simulated processes. We suppose that the cutoffs in $\theta^*$ and acollinearity¹ in UBABO1 might explain the discrepancy. The peaked $z_0$ distribution rules out beam-gas events as the origin of the asymmetry. In any case, the events in question do not contain particularly high momentum tracks, so our calculation of the beam position uncertainty will not be biased by more than a few percent.

We check for contamination due to cosmic rays by looking for evidence of a single track crossing the detector. We look for events in which the two highest momentum oppositely-charged tracks with at least four TPC hits are back to back (within 5 mrad in $\theta$ and 20 mrad in $\phi$) and have equal momenta ($|p_+ - p_-|/(p_+ + p_-) < 0.15$) and small impact parameter sum ($|d_+ + d_-| < 1$ cm). In addition, we require that one track in the event meet the track selection requirements (except for the $d_0$ cut). We find two such events and predict a contamination of 0.4 events in our sample.

The beam-gas event content of our sample is difficult to determine precisely. The clearest signature of beam-gas events, their even distribution along the beam axis, is of limited use in measuring the contamination because the level 2 trigger is fully efficient only for tracks that originate within $\sim$10 cm of the interaction point. Because we require $|z_0| < 5$ cm, there is no region with clear background events to extrapolate into our

¹In our sample, Bhabhas are generated with acollinearity between 0 and 135°.
acceptance window. If we are conservative and imagine the region of $|z_0|$ between 5 and 10 cm to contain only tracks from beam-gas events, we find that 0.4% of our accepted tracks originate in these events.

3 Beam Position Measurements

Beam positions are calculated using the chunk-by-chunk procedure described in [2]. The procedure is modified to force the chunk boundaries to be the same as those used by the current julia beam position calculation for this fill. This is done so that the beam positions calculated with the $\gamma\gamma$ events may be compared with the beam positions previously calculated with the julia algorithm. 56 chunks are used in this fill, corresponding to an average of 7.48 nb$^{-1}$ per chunk.

The track selection criteria for the beam position determination are relaxed with respect to the julia algorithm, as in [2]. The criteria include the requirement of at least one VDET $r$-$\phi$ hit. Plots of beam position measurements in the $x$ and $y$ directions using the current $Z^0$ events and the $\gamma\gamma$ events are shown in figure 2.

The beam position uncertainty is evaluated from the differences of the $\gamma\gamma$ and julia measurements. The uncertainties from the $\gamma\gamma$ measurement must be multiplied by fudge factors of 1.16 in $x$ and 1.38 in $y$ to explain the observed differences. The mean difference ($\gamma\gamma$ minus julia) is $-1 \pm 8 \mu$m in $x$ and $-3 \pm 7 \mu$m in $y$. In this calculation we assume the $\gamma\gamma$ and julia measurements to be completely independent. In reality 4% of the tracks in the new sample are also selected by the julia algorithm, but this correlation is negligible for our present purposes. After application of the fudge factors, the average beam position uncertainty for a chunk of 7.48 nb$^{-1}$ is 52 $\mu$m in $x$ and 46 $\mu$m in $y$. The $\gamma\gamma$ Monte Carlo predicts resolutions of 50 $\mu$m and 37 $\mu$m, respectively, under these conditions.
4 Conclusions

A beam position uncertainty of 52 $\mu$m in $x$ and 46 $\mu$m in $y$ is measured for 7.48 nb$^{-1}$ chunks. For comparison, we consider the results of the Monte Carlo study at $\sqrt{s} = 175$ GeV in [2]. The Bhabha events are removed from that study and the predicted uncertainties are scaled to the present chunk size. The predicted uncertainties are then $\Delta x_{\text{beam}} = 29 \mu$m and $\Delta y_{\text{beam}} = 28 \mu$m. Our results are summarized in the table below. The two-photon cross section at $\sqrt{s} = 89.4$ GeV is a factor of $\sim 1.5$ smaller than at 175 GeV, and there is presumably an additional quality factor associated with the higher momenta of the tracks produced at 175 GeV. Considering also the cutoffs in the Monte Carlos and the improvements that VDET95 will bring, we cannot make a precise prediction of the beam position uncertainty that will be achieved at LEP II. However, our studies suggest that chunks of roughly 5 nb$^{-1}$ will be feasible. We find that no special cuts against cosmic rays or beam-gas events are needed for the beam position determination.

<table>
<thead>
<tr>
<th>Uncertainty in beam position for chunks of 7.48 nb$^{-1}$.</th>
<th>$\Delta x (\mu$m)</th>
<th>$\Delta y (\mu$m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z^0$ data at $\sqrt{s} = 89.4$ GeV</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>$\gamma\gamma$ data at $\sqrt{s} = 89.4$ GeV</td>
<td>52</td>
<td>46</td>
</tr>
<tr>
<td>$\gamma\gamma$ Monte Carlo at $\sqrt{s} = 89.4$ GeV</td>
<td>50</td>
<td>37</td>
</tr>
<tr>
<td>$\gamma\gamma$ Monte Carlo at $\sqrt{s} = 175$ GeV</td>
<td>29</td>
<td>28</td>
</tr>
</tbody>
</table>

Acknowledgements

We thank our ALEPH colleagues at Florida State University for the use of their computing facilities. We also wish to thank Joe Rothberg for his suggestions.

References


\footnotesize The cutoff $W > 2$ GeV/$c^2$ is used at both energies in this calculation. As the cross sections for the various two-photon final states have different dependences on $\sqrt{s}$, the relative contributions of the final states to the beam position measurement are taken into account.