Chapter 5

CP Asymmetry

As stated, if the isospin breaking contribution is significant, there could be an observable direct CP asymmetry in $B^{\mp} \to \rho^{\mp}\rho^0$ decays. We define the CP asymmetry in this decay as

$$\mathcal{A}_{CP}(B^{\mp} \to \rho^{\mp}\rho^0) = \frac{N_{(\rho^-\rho^0)} - N_{(\rho^+\rho^0)}}{N_{(\rho^-\rho^0)} + N_{(\rho^+\rho^0)}}. \tag{5.1}$$

In the following sections, we describe a search for CP asymmetry.

5.1 Fitting Results

Figure 5.1 shows the fits to the ΔE distributions separately for B^- and B^+ mode. As described (see section 3.9.2), the ΔE fits include four components: signal, mis-reconstructed signal, continuum, and $B\bar{B}$ component. Here, the $B\bar{B}$ component is fixed to one half of the $B\bar{B}$ yield of the $B^{\pm}$ fit results (i.e. 84.5 events), since the generic $B\bar{B}$ should have the same contributions to $\rho^+\rho^0$ and $\rho^-\rho^0$. In addition, we shift the mean values from signal-MC for $\rho^-\rho^0$ and $\rho^+\rho^0$ differently according to the calibration results described in the following section.

The fits give

$$N_{(\rho^-\rho^0)} = 29.30 \pm 9.47,$$

$$N_{(\rho^+\rho^0)} = 29.25 \pm 9.09.$$

5.2 Statistical Errors

Since the measurements are independent, there are no correlation between the B^- signal yield and the B^+ signal yield. The error of $\mathcal{A}_{CP}$ is

$$(\Delta\mathcal{A}_{CP})^2 = (\frac{\partial\mathcal{A}_{CP}}{\partial N_{\rho^-\rho^0}})^2(\Delta N_{\rho^-\rho^0})^2 + (\frac{\partial\mathcal{A}_{CP}}{\partial N_{\rho^+\rho^0}})^2(\Delta N_{\rho^+\rho^0})^2,$$

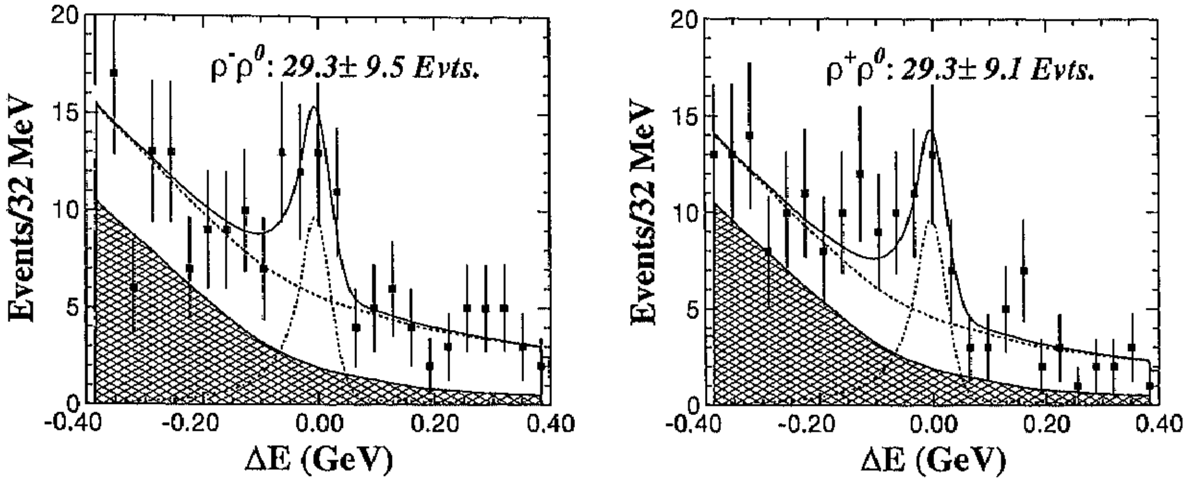

Figure 5.1: The ΔE fit to the $B^- \to \rho^-\rho^0$ (left) and the $B^+ \to \rho^+\rho^0$ (right) candidate events. The sum of the $B\bar{B}$ and continuum components is shown as a dashed line. The cross-hatched histogram represents the $B\bar{B}$ background.

so that

$$\Delta\mathcal{A}_{CP} = \frac{2}{(N_{\rho^-\rho^0} + N_{\rho^+\rho^0})^2}\sqrt{(N_{\rho^+\rho^0}\Delta N_{\rho^-\rho^0})^2 + (N_{\rho^-\rho^0}\Delta N_{\rho^+\rho^0})^2}.$$

Substituting the numbers given in section 5.1, we obtain the statistical error $\Delta\mathcal{A}_{CP}(B^\mp \to \rho^\mp\rho^0) = 22.4\%$.

5.3 Systematic Errors

The $\mathcal{A}_{CP}$ systematic errors may be caused by the asymmetric detector performance, reconstruction and the fitting procedure.

The possible charge asymmetry of the detector performance and the reconstruction procedure is checked by using the decays of $B^+ \to \bar{D}^0\pi^+$, $\bar{D}^0 \to K^+\pi^-\pi^0$ and its charge conjugate mode. The analysis procedure is the same as that for $B^+ \to \rho^+\rho^0$ except that we select one kaon and two pions instead of three pions, and require the invariant mass of $M(K\pi\pi^0)$ to be within $0.05\,\mathrm{GeV/c^2}$ of the nominal D^0 mass. The results of the fits to $B^- \to D^0(K^-\pi^+\pi^0)\pi^-$ and $B^+ \to \bar{D}^0(K^+\pi^-\pi^0)\pi^+$ are shown in Fig. 5.2, and listed in Table 5.1, which indicate $\mathcal{A}_{CP}(B^\mp \to D^0\pi^-(\bar{D}^0\pi^+)) = (-2.1 \pm 2.5)\%$, consistent with 0 within errors. We take the 2.5% as the systematic error for the detection and reconstruction based asymmetry.

Removing the $\mathcal{LR}$ cut, again we examine the asymmetry of $B \to D^0(K\pi\pi^0)\pi$ decays, $\mathcal{A}_{CP}(B^\mp \to D^0\pi^-(\bar{D}^0\pi^+)) = 0.16 \pm 2.11\%$, also consistent with 0.

In addition, we see a 2.9 MeV shift in the mean value between $B^- \to D^0\pi^-$ and

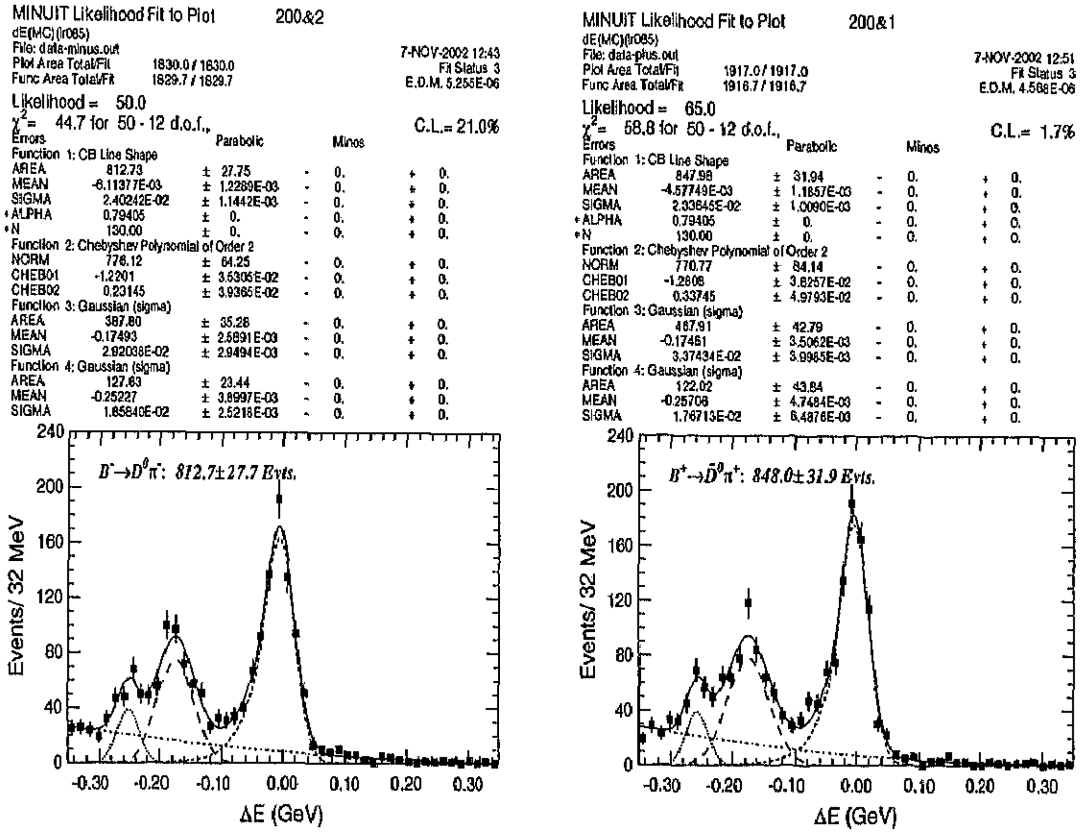

Figure 5.2: The ΔE fits to the $B^- \to D^0\pi^-$ candidate events (left) and $B^+ \to \bar{D}^0\pi^+$ candidate events (right). A shift of 2.9 MeV in the mean value is found.

	$B^- \to D^0\pi^-$	$B^+ \to \bar{D}^0\pi^+$	$\mathcal{A}_{CP}(\%)$
$\mathcal{LR} > 0.85$	812.7 ± 27.7	848.0 ± 31.9	-2.1 ± 2.5
no $\mathcal{LR}$ cut	2128.0 ± 64.1	2121.3 ± 63.1	0.16 ± 2.1

Table 5.1: Bias check by using the decay of $B^+ \to \bar{D}^0\pi^+$, $\bar{D}^0 \to K^+\pi^-\pi^0$ and its charge conjugate mode.

$B^+ \to \bar{D}^0\pi^+$, which may be explained by the difference in tracking between positive and negative particles. This is taken into account when fitting the ΔE distributions for $B^- \to \rho^-\rho^0$ and $B^+ \to \rho^+\rho^0$.

We estimate the $\mathcal{A}_{CP}$ systematic error due to the ΔE fit by shifting each parameter of the fitting functions by $\pm 1\sigma$, including the constrained $B\bar{B}$ yield. The quadrature sum of the percentage change in $\mathcal{A}_{CP}$ for each parameter is taken as the fitting systematic error. A $+0.8\%/-1.2\%$ systematic error is assigned for the fitting procedure.

Parameter	B^-	B^+	$\mathcal{A}_{CP}(\%)$	$\Delta\mathcal{A}_{CP}(\%)$
normal fit	29.3 ± 9.5	29.3 ± 9.1	0.1 ± 22.4	
mean-1σ	29.28	29.52	-0.41	-0.49
$+1\sigma$	29.25	28.97	0.48	0.41
sigma-1σ	28.59	28.64	-0.09	-0.17
$+1\sigma$	29.91	29.82	0.15	0.07
alpha-1σ	30.27	30.69	-0.70	-0.77
$+1\sigma$	28.39	28.04	0.63	0.55
N -1σ	30.32	30.68	-0.58	-0.66
$+1\sigma$	28.69	28.43	0.45	0.37
Gau/CB-1σ	28.92	28.85	0.13	0.05
$+1\sigma$	29.63	29.66	-0.06	-0.14
sigma1-1σ	29.12	29.17	-0.09	-0.17
$+1\sigma$	29.41	29.33	0.14	0.06
Cheby slope -1σ	28.53	28.45	0.13	0.06
$+1\sigma$	30.14	30.16	-0.04	-0.11
N_{BB} yield -1σ	28.66	28.67	-0.01	-0.08
$+1\sigma$	29.64	29.58	0.09	0.02
Total $\Delta\mathcal{A}_{CP}(\%)$	+0.79 / -1.17			

Table 5.2: The percentage change in $\mathcal{A}_{CP}$ by varying each parameter of the fitting functions by $\pm 1\sigma$.

The quadrature sum of these errors is taken as the total $\mathcal{A}_{CP}$ systematic error, listed in Table 5.3.

	$\Delta\mathcal{A}_{CP}(\%)$
Fitting	$0.8/-1.2$
Bias	2.5
Total	$2.6/-2.8$

Table 5.3: The $\mathcal{A}_{CP}$ systematic errors

In summary, we obtain the CP asymmetry

$$\mathcal{A}_{\mathrm{CP}}(\mathrm{B}^{\mp} \to \rho^{\mp}\rho^{0}) = (\mathbf{0.1} \pm \mathbf{22.4}(\mathbf{stat.})^{+\mathbf{2.6}}_{-\mathbf{2.8}}(\mathbf{sys.}))\%.$$

This result of $\mathcal{A}_{CP}$ is consistent with zero, within quite large errors. To reduce the errors, we need more data, or more powerful separation to reduce the backgrounds.