Chapter 5

Systematic errors

Systematic errors may arise from uncertainties in the the event selection, in the reconstruction method and in the background. The uncertainties due to the selections are estimated by varying the cut values within reasonable values. The maximum deviation of the measurement obtained within this range is taken as the contribution to the total systematic error of the measurement due to this cut.

Furthermore, there arises an uncertainty due to the reconstruction method used for the B meson. Therefore, the analysis is repeated with the rapidity method to reconstruct the B-meson properties. The difference of these results with the those from the weighted-average method is taken as a measure of the uncertainty due the the B-meson reconstruction.

Finally, there is a contribution to the systematic error due to the uncertainty in the background shape. To estimate the uncertainty, two factors are considered. First, instead of using the MC background distribution as an estimate of the background, a threshold function is used. The results obtained this way are compared with those where the MC background was used. Secondly, the fragmentation parameter in the MC is varied within its estimated errors. The MC background distribution thus obtained is used to determine the signal. The results obtained this way are compared with those of the original MC background distribution where the default MC parameters were used.

5.1 Charged-pion channel

In the charged-pion case, the cut on the pion energy, the b-purity cut, the $L/\sigma(L)$ cut and the cut on the probability that the particle comes from the PV were varied. The influence on the Bπ mass, width and branching ratio are plotted in figure 5.1, 5.2 and 5.3, respectively. The contributions to the total systematic error are listed in table 5.1.

When the analysis is redone with the rapidity algorithm to reconstruct the B meson, a $\mathrm{B}^{**}_{\mathrm{u,d}}$ mass of 5.698 ± 0.008 GeV, a width of 0.076 ± 0.006 GeV and a number of signal events of 2970 ± 218 is obtained. This uncertainty mainly affects the mass of the signal. The contribution to the systematic error due to the reconstruction method of the B properties is listed in line 5 of table 5.1.

In order to get an idea of the systematic error due to the uncertainty in the background, one can try to fit the background. An attempt is made with a threshold function, $F(x) = (x - p_1)^{p_2} e^{(p_3(x-p_1)+p_4(x-p_1)^2+p_5(x-p_1)^3+p_6(x-p_1)^4)}$, where x is the Bπ mass and the

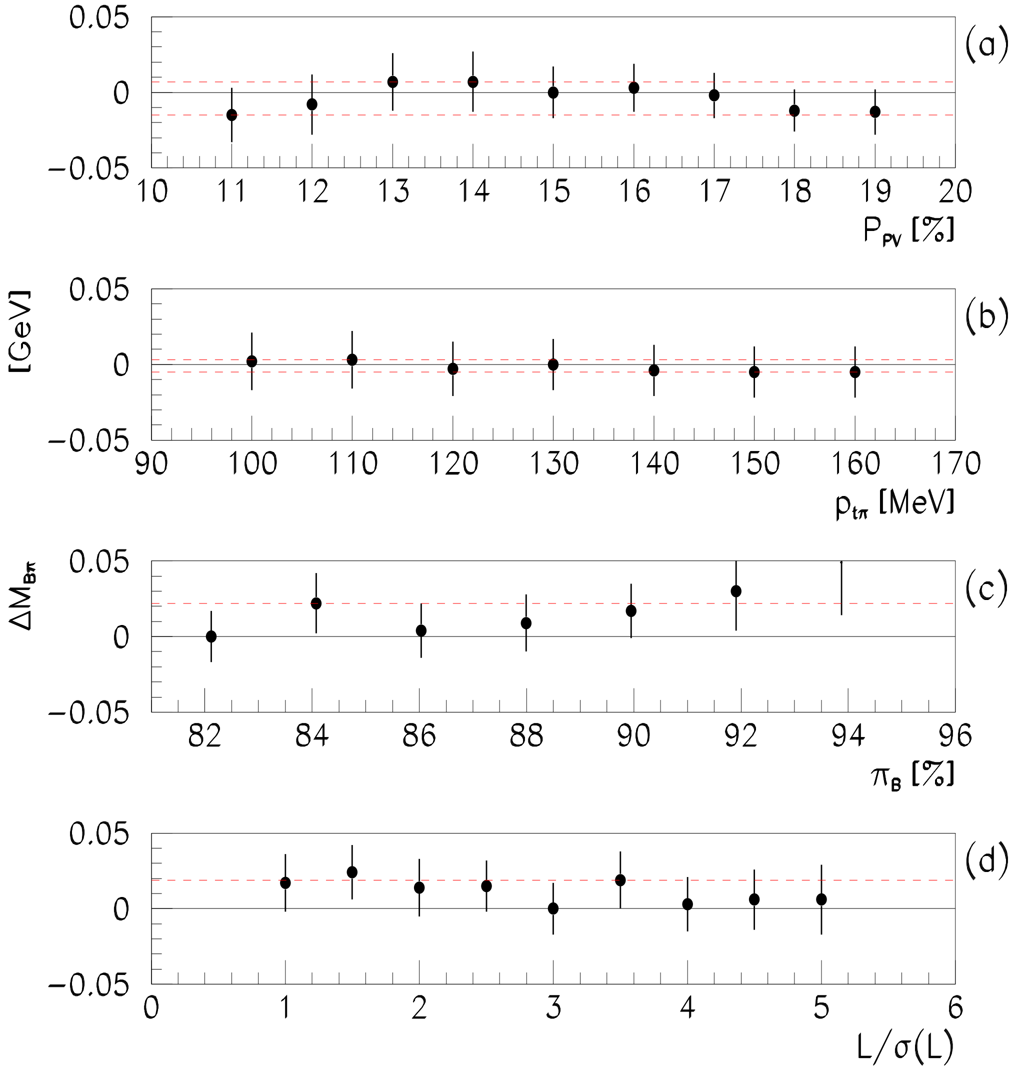

Figure 5.1: *Change in $B\pi^{\pm}$ mass as a function of: (a) the cut on the probability of a particle to come from the PV , (b) the cut on the pion energy E_{π}, (c) the btag cut (expressed in the corresponding purity values) and (d) the cut on $L/\sigma(L)$.*

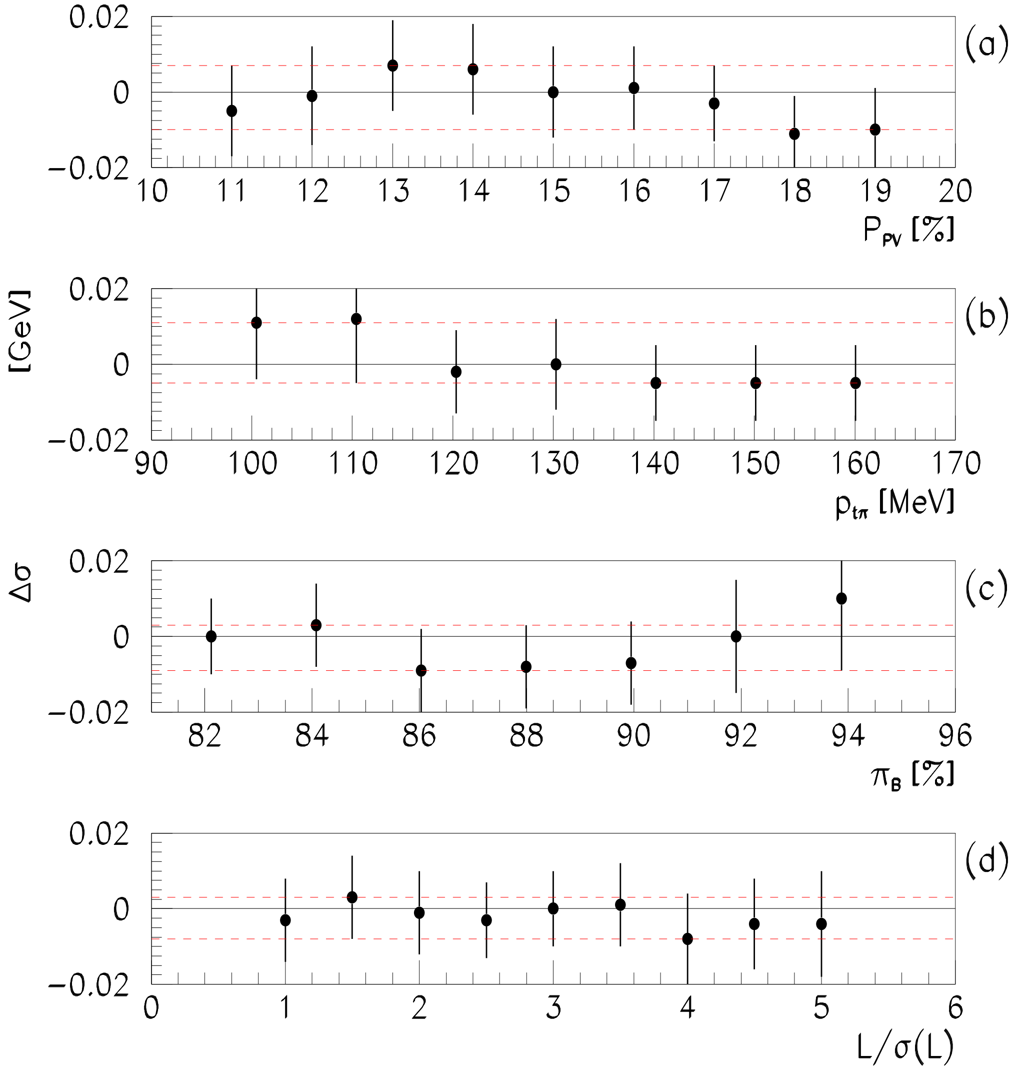

Figure 5.2: *Change in width of the signal of the charged-pion channel as a function of: (a) the cut on the probability of a particle to come from the PV , (b) the cut on the pion energy E_π, (c) the btag cut (expressed in the corresponding purity values) and (d) the cut on $L/\sigma(L)$.*

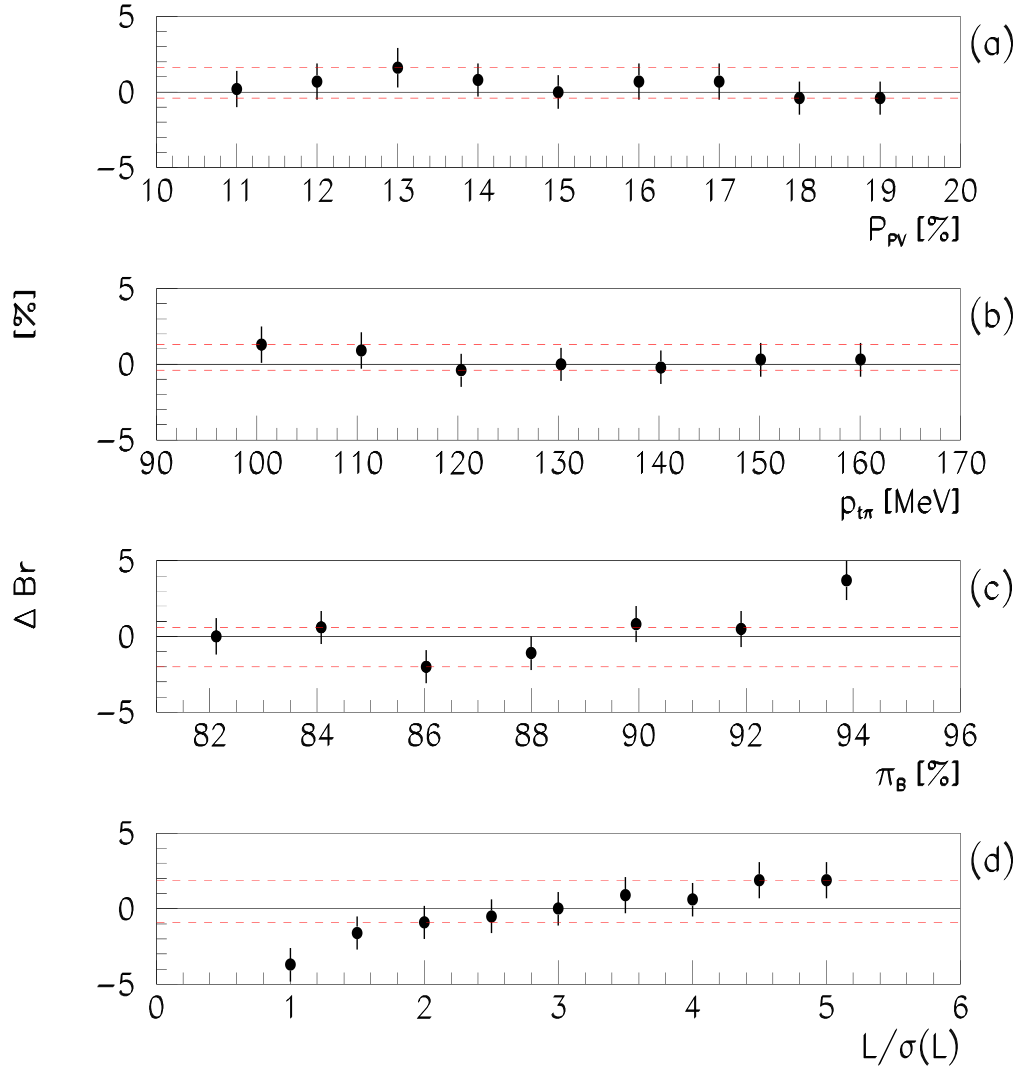

Figure 5.3: *Change in branching ratio of the charged-pion channel as a function of: (a) the cut on the probability of a particle to come from the PV , (b) the cut on the pion energy E_π, (c) the btag cut (expressed in the corresponding purity values) and (d) the cut on $L/\sigma(L)$.*

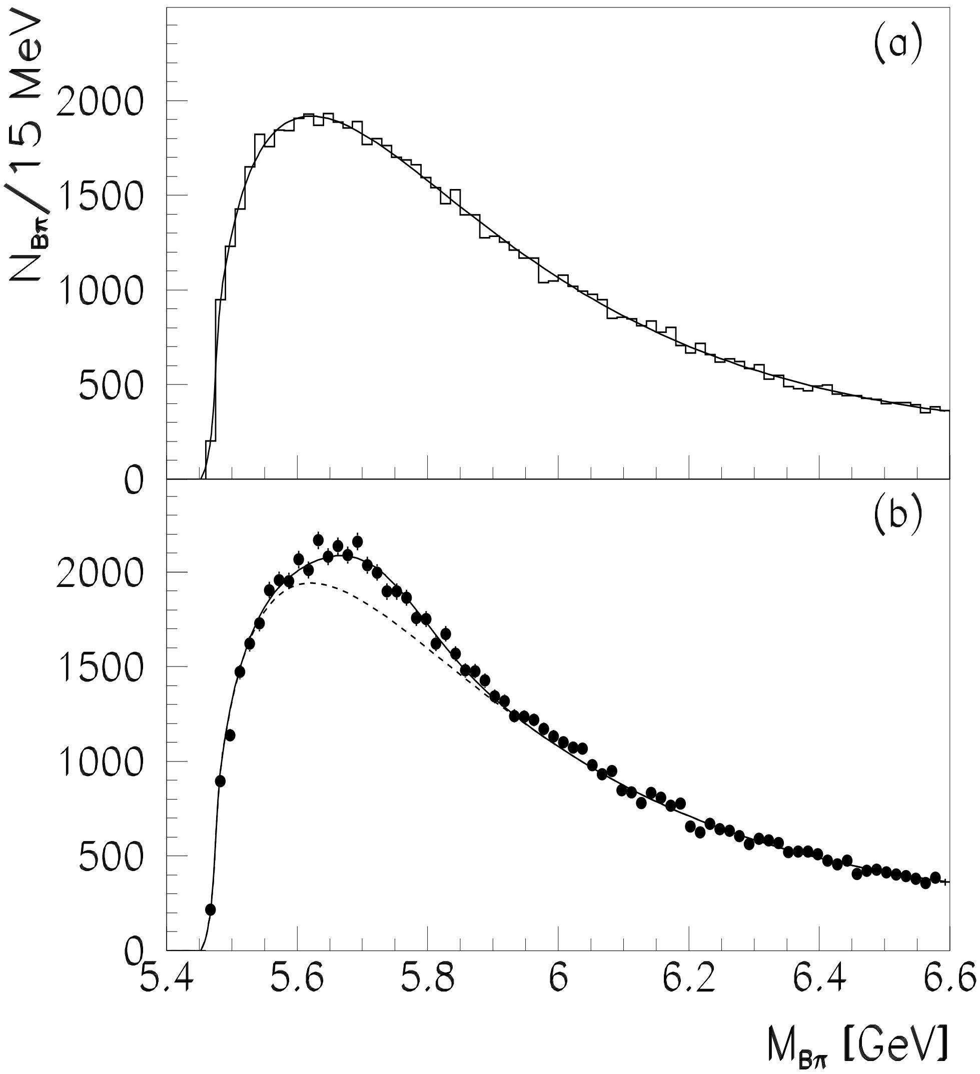

Figure 5.4: *(a) The MC $M_{\mathrm{B}\pi^\pm}$ background distribution fitted with the threshold function $F(x)$ and (b) The $M_{\mathrm{B}\pi^\pm}$ distribution. The dots are data and the dotted line is the threshold function fitted to the MC background. The signal is fitted with a simple Gaussian function. The solid line is the total fit.*

error source	$M_{B\pi}$ [GeV]	σ [GeV]	Br[%]
b purity (82-86)%	+0.022 -0.0	+0.003 -0.009	+0.6 -2.0
$L/\sigma(L)$ cut (2.0-5.0)	+0.019 -0.0	+ 0.003 -0.008	+1.9 -0.9
$p_{\perp}\pi$ cut (0.080-0.170) GeV	+0.003 - 0.005	+0.011 -0.005	+1.3 -0.4
P_{PV} cut (11-19) %	+0.007 -0.015	+0.007 -0.010	+1.6 -0.4
B reco method	$\pm$ 0.014	$\pm$ 0.003	$\pm$ 0.2
bg shape uncertainty 1	$\pm$ 0.005	$\pm$ 0.001	$\pm$ 0.3
bg shape uncertainty 2	+0.001 -0.008	+0.005 -0.001	$\pm$ 1.9
total	+0.034 -0.023	+0.015 -0.016	+3.5 -3.0

Table 5.1: *The systematic errors on the B$\pi\pm$ mass, width and branching ratio due to event selection and use of different methods for the signal fit.*

parameters p_1 through p_6 are determined by a fit to the MC background. As can be seen in figure 5.4(a), this function fits the MC background distribution well in the signal region. The fit to the data is shown in figure 5.4(b) . A simple Gaussian is used for the signal. In this case, a $B^{**}_{u,d}$ mass of 5.717 $\pm$ 0.008 GeV is obtained, with a width of 0.078 $\pm$ 0.005 GeV and a number of signal events of 2982 $\pm$ 208. The contribution to the systematic error due to the uncertainty in the background shape is listed in line 6 of table 5.1.

Another contribution to the uncertainty in the background shape is the uncertainty in the MC parameters. The so-called fragmentation parameter ε_b is considered to be the most important cause for the uncertainty in this analysis. The value used in the simulation is -0.0035 [77]. However, ε_b itself is not a measurable quantity. Usually $x_E = E_{hadron}/E_{beam}$ is used, where E_{hadron} is the generated b-hadron energy and E_{beam} is the beam energy. The choice of ε_b results in a mean normalised hadron energy $<x_E>$ of (0.70 ± 0.02) [78]. The variation of x_E within its errors corresponds to a variation of ε_b from -0.0018 to -0.0065. The correspondingly varied x_E distributions are compared on the generator level with the original one. The ratio of the new and the original distribution is used to reweight the MC at the detector level. The reweighted MC background distribution thus obtained is used to determine the new $B^{**}_{u,d}$ signal. The difference with the results obtained with the original MC background is taken as an estimate of the uncertainty due to the background shape. It is listed in line 7 of table 5.1. This mainly affects the branching ratio.

5.2 Neutral-pion channel

For the neutral-pion channel, the cut on the pion energy, the b-purity cut, the $L/\sigma(L)$ cut, the π^0 mass cut and the cut on the probability that the particle comes from the PV were varied. These variations for the Bπ mass, width and number of signal events are plotted in figure 5.5, 5.6 and 5.7, respectively. In table 5.2 the contributions to the total systematic error are listed for the π^0 channel.

When the analysis is redone with the rapidity algorithm to reconstruct the B meson, a $B^{**}_{u,d}$ mass of 5.603 $\pm$ 0.026 GeV, a width of 0.083 $\pm$ 0.030 GeV and a number of signal events of 535 $\pm$ 158 is obtained. The contribution to the systematic error due to the reconstruction

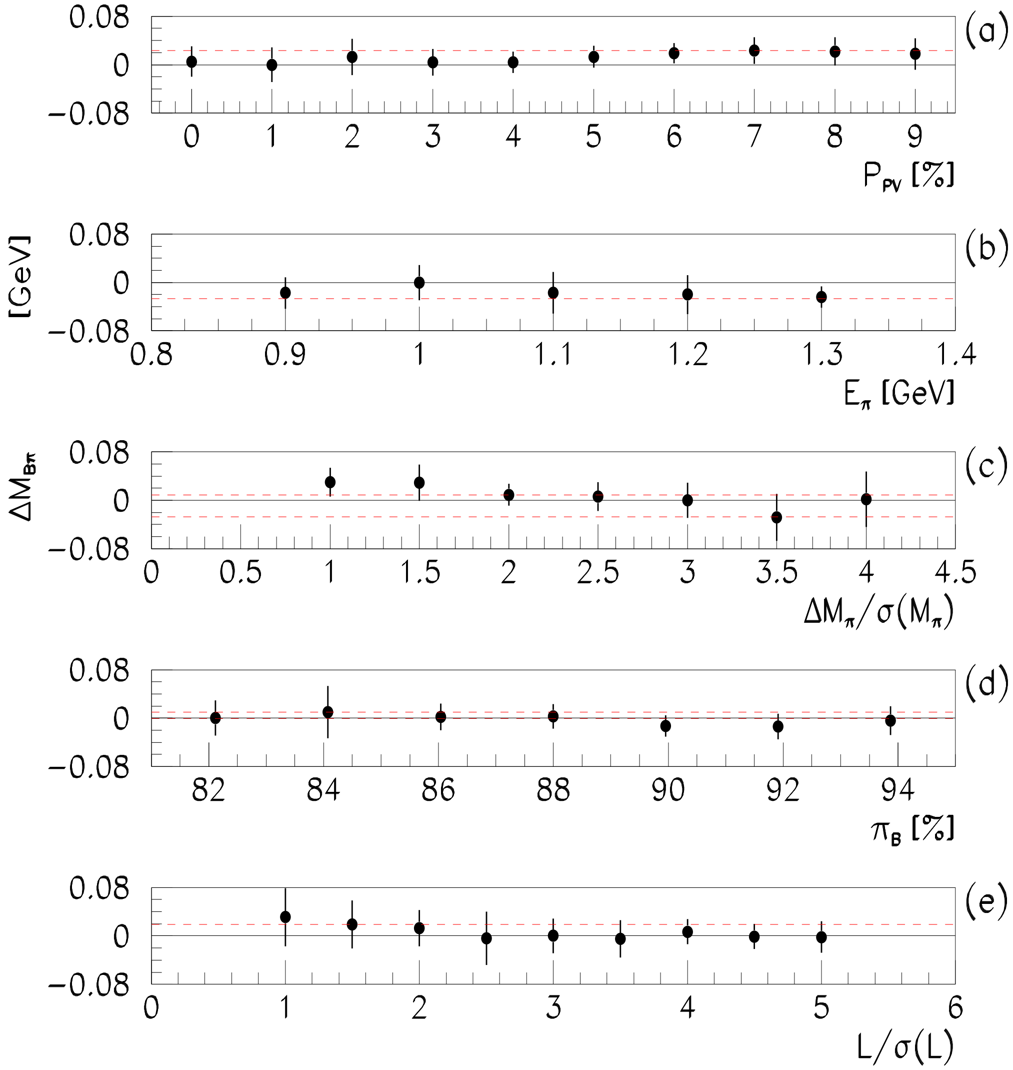

Figure 5.5: *Change in $B\pi^0$ mass as a function of: (a) the cut on the probability of a particle to come from the PV , (b) the cut on the pion energy E_π, (c) the cut on the reconstructed π^0 mass, (d) the btag cut (expressed in the corresponding purity values) and (e) the cut on $L/\sigma(L)$.*

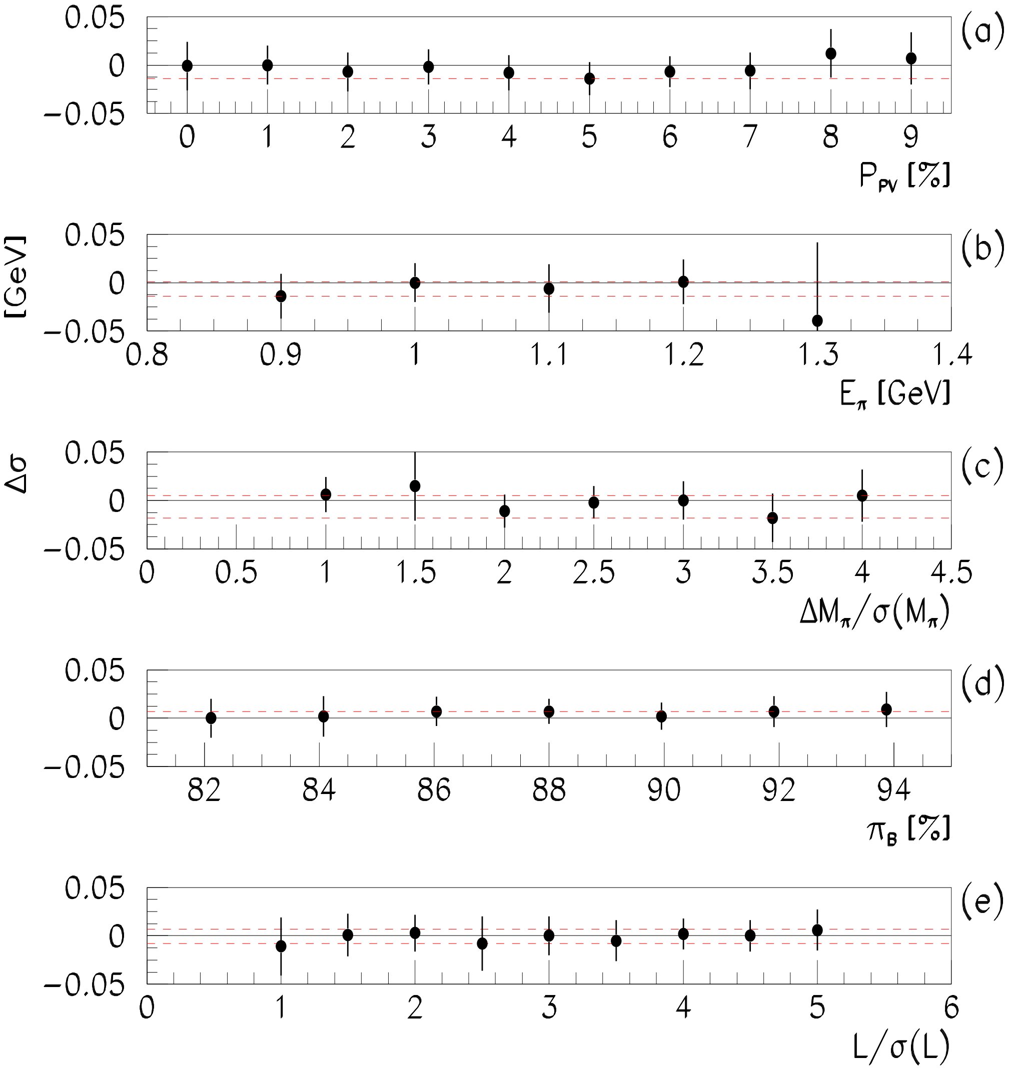

Figure 5.6: *Change in width of the signal of the neutral-pion channel as a function of: (a) the cut on the probability of a particle to come from the PV , (b) the cut on the pion energy E_π, (c) the cut on the reconstructed π^0 mass, (d) the btag cut (expressed in the corresponding purity values) and (e) the cut on $L/\sigma(L)$.*

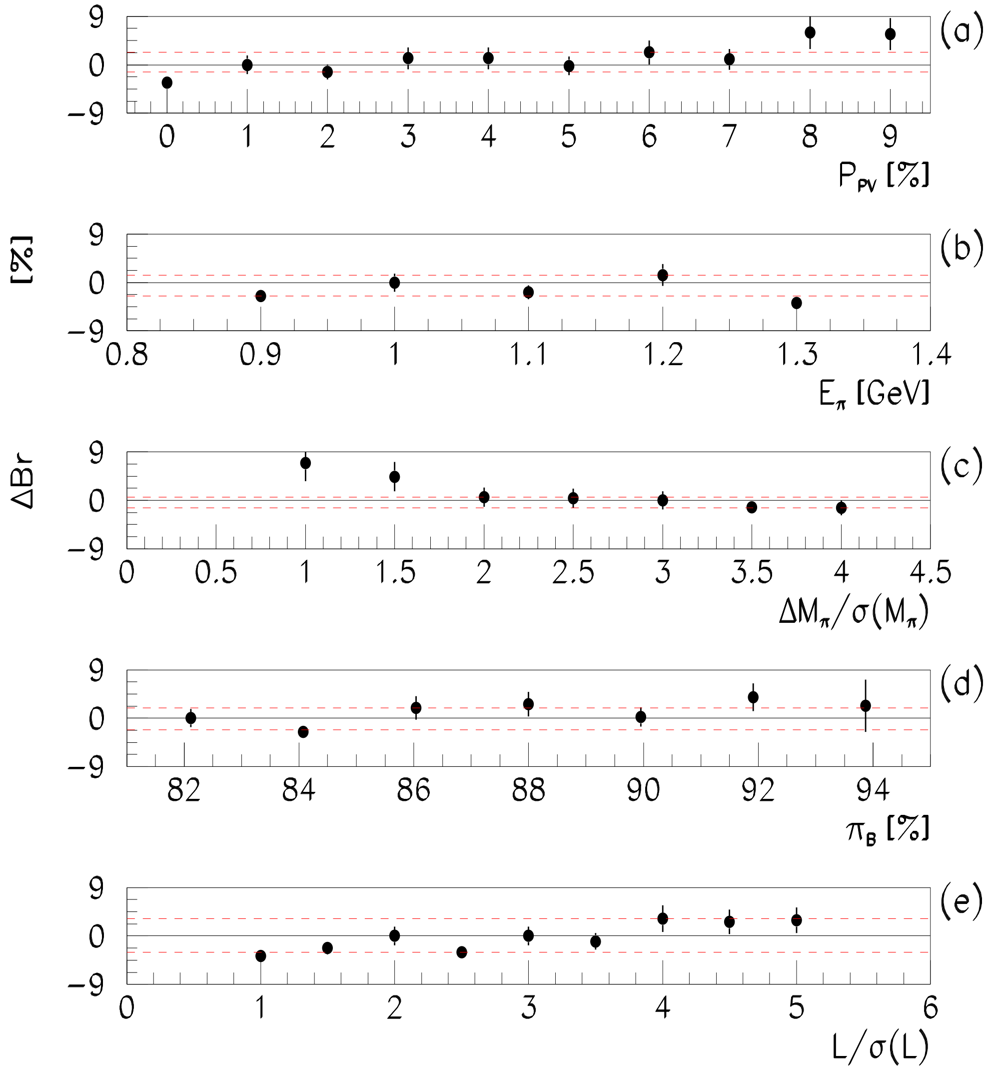

Figure 5.7: *Change in branching ratio of the neutral-pion channel as a function of: (a) the cut on the probability of a particle to come from the PV , (b) the cut on the pion energy E_π, (c) the btag cut (expressed in the corresponding purity values) and (d) the cut on $L/\sigma(L)$.*

error source	$M_{B\pi}$ [GeV]	σ [GeV]	Br[%]
b purity (82-86) %	+0.010 -0.001	+0.007 -0.0	+1.9 -2.2
$L/\sigma(L)$ cut (1.5-5.0)	+0.019 -0.005	+ 0.007 -0.008	+3.2 -3.0
E_π cut (0.9-1.2) GeV	+0.00 - 0.027	+0.001 -0.014	+1.4 -2.5
P_{PV} cut (1-7) %	+0.023 -0.0	+0.0 -0.014	+2.3 -1.3
π^0 mass cut (2.0-4.0)	+0.009 -0.027	+0.005 -0.018	+0.6 -1.4
B reco method	$\pm$ 0.001	$\pm$ 0.001	$\pm$ 0.1
bg shape uncertainty 1	$\pm$ 0.007	$\pm$ 0.014	$\pm$ 1.0
bg shape uncertainty 2	+0.027 -0.010	$\pm$ 0.041	$\pm$ 2.8
total	+0.041 -0.048	+0.045 -0.051	+5.5 -5.7

Table 5.2: *The systematic errors on the $B\pi^0$ mass, width and branching ratio due to event selection and use of different methods for the B reconstruction and uncertainty in the background shape.*

method of the B properties is listed in line 6 of table 5.2.

The background is fitted with the same threshold function as was used for the charged-pion channel (see previous section). The background fit is plotted in figure 5.8(a). The fit to the data is shown in figure 5.8(b). A simple Gaussian is used for the signal fit. In this case, a $B^{**}_{u,d}$ mass of 5.597 $\pm$ 0.026 GeV is obtained, with a width of 0.068 $\pm$ 0.031 GeV and a number of signal events of 469 $\pm$ 160. This uncertainty mainly affects the width of the signal. The contribution to the systematic error due to the uncertainty in the background shape is listed in line 7 of table 5.2.

Another contribution in the background shape is the uncertainty in the MC parameters. The fragmentation parameter ε_b is varied as described in the previous section. The contributions to the systematic error is listed in line 8 of table 5.2.

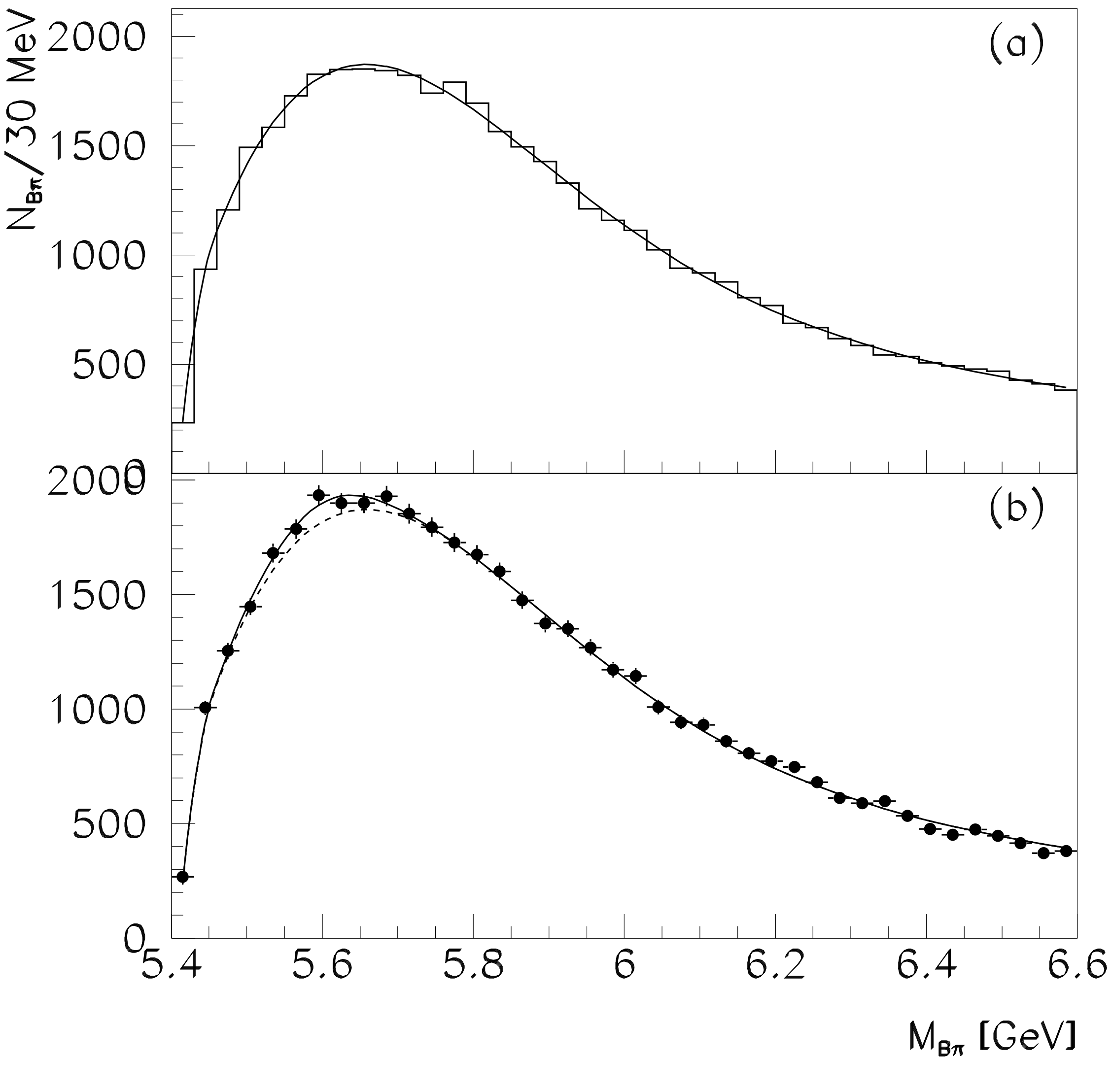

Figure 5.8: *(a) The MC $M_{B\pi^0}$ background distribution fitted with the threshold function $F(x)$ and (b) the $M_{B\pi^0}$ distribution.The dots are data and the dotted line is the threshold function fitted to the MC background. The signal is fitted with a simple Gaussian function. The solid line is the total fit.*