Chapter 4

Results

4.1 Signal extraction

Using the method described in the previous chapter, the $M_{B\pi}$ distribution is obtained for $\pi^{\pm}$ and π^0 and plotted in figures 4.1 and 4.2, respectively. Also plotted in both figures is the expected background determined from the MC as described in section 3.5. An enhancement above the MC background estimation is seen in both plots. A binned likelihood fit is used to extract the signal properties. The likelihood function is given by:

$$\mathcal{L} = \prod_i \frac{(b_i + s_i)^{d_i} \cdot e^{-(b_i+s_i)}}{d_i!}, \tag{4.1}$$

where b_i is the number of background combinations (from MC) in bin i, d_i the number of data combinations in bin i and s_i the number of signal combinations in that bin obtained with a single Gaussian function given by: $s_i = N_\mathrm{s} \frac{1}{\sqrt{2\pi}\sigma} \int_{\mathrm{bin}\,i} \exp\left[-\frac{(m_{\mathrm{B}^{**}_{\mathrm{u,d}}} - m_{\mathrm{B}\pi})}{2\sigma}\right] \mathrm{d}m_{\mathrm{B}\pi}$, where the total number of $\mathrm{B}^{**}_{\mathrm{u,d}}$, N_s, the $\mathrm{B}^{**}_{\mathrm{u,d}}$ mass, $m_{\mathrm{B}^{**}_{\mathrm{u,d}}}$ and the width of the Gaussian σ are fitted.

4.1.1 $\mathrm{B}^{**}_{\mathrm{u,d}}$ signal from the charged-pion channel

The $M_{B\pi}$ distribution for $\mathrm{B}\pi^{\pm}$ combinations is plotted in figure 4.1 for the data and the smoothed MC background. The performed fit is shown as a solid line. The χ^2 of the fit is 119 for 77 degrees of freedom. The structure in the $M_{B\pi}$ distribution is observed at

$$M_{\mathrm{B}^{**}_{\mathrm{u,d}}} = (5.712 \pm 0.010)\ \mathrm{GeV}. \tag{4.2}$$

with a width of

$$\sigma = (0.079 \pm 0.006)\ \mathrm{GeV}. \tag{4.3}$$

The number of $\mathrm{B}^{**}_{\mathrm{u,d}}$ decays to $\mathrm{B}^{(*)}\pi^{\pm}$ is

$$N(\mathrm{B}^{**}_{\mathrm{u,d}}) = 2926 \pm 213. \tag{4.4}$$

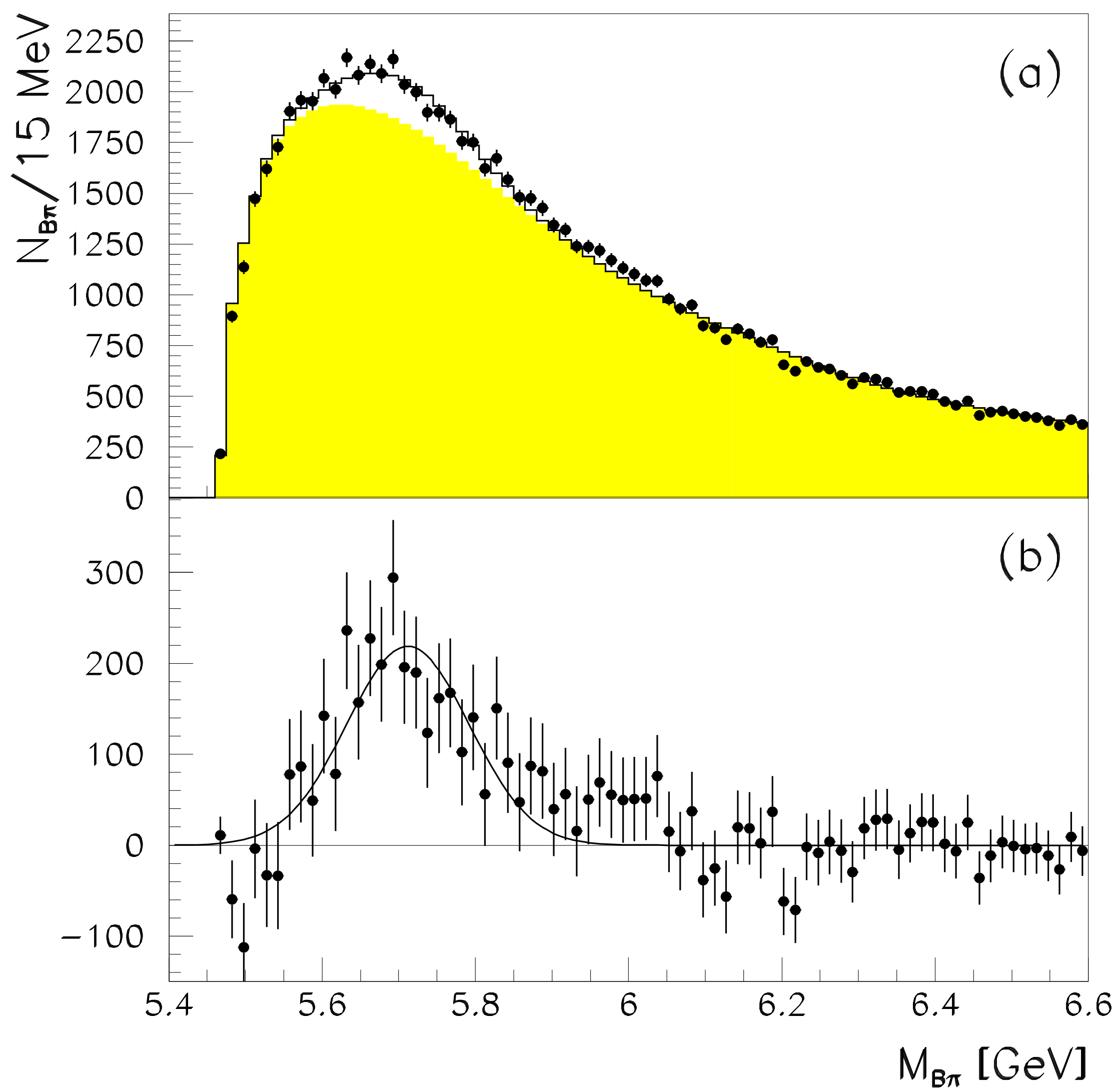

Figure 4.1: *(a) The $M_{B\pi^{\pm}}$ distribution. The dots are the data, the shaded histogram the MC background and the open histogram the total fit, when the signal is fitted with a single Gaussian; (b) the MC background is subtracted from the data and the signal fit is plotted.*

4.1.2 $B^{**}_{u,d}$ signal from the neutral-pion channel

In figure 4.2 the $M_{B\pi}$ distribution for $B\pi^0$ combinations is plotted for the data and the smoothed MC background. The fit is shown as a solid line. The χ^2 of the fit is 44.7 for 37 degrees of freedom. The structure is observed at

$$M_{B^{**}_{u,d}} = (5.604 \pm 0.019)\ \text{GeV}. \tag{4.5}$$

This value is lower than the $B^{**}_{u,d}$ mass obtained in the charged-pion channel of this analysis. The signal has a width of

$$\sigma = (0.082 \pm 0.026)\ \text{GeV}. \tag{4.6}$$

This value is consistent with the Gaussian width obtained in the charged-pion channel. The number of reconstructed $B^{**}_{u,d}$ decays to $B^{(*)}\pi^0$ is

$$N(B^{**}_{u,d}) = 527 \pm 156. \tag{4.7}$$

4.1.3 Resolution

The measured width found in the previous two sections is large compared to the predicted Breit-Wigner width of the narrow states and of about the same order of magnitude as the Breit-Wigner width of the broad states. This suggest that a large part of the measured width is due to the detector resolution. To get an idea of the contribution of the resolution to the measured width, each MC signal is fitted separately with a Breit-Wigner convoluted with a Gaussian. The Breit-Wigner width is fixed to the known MC value given in section 3.1. The resulting resolution is plotted in figure 4.3. In the case of the narrow resonances, a large part of the width is due to the resolution. The obtained resolution is not good enough to fit several signal shapes for the signal and to try to determine the parameters of the different resonances.

4.2 The $B^{**}_{u,d}$ production rate

4.2.1 The production rate in the charged-pion channel

The measured number of $B^{**}_{u,d}$ mesons, $N(B^{**}_{u,d})$, is related to the relative production rate of $B^{**}_{u,d}$ mesons in Z decays by the following expression:

$$N(B^{**}_{u,d}) = N_{tag}\eta_B\varepsilon_{\pi^{**}}\frac{N_{B^{**}_{u,d}}}{N_B}, \tag{4.8}$$

were N_{tag} is the number of tagged events, η_B the b purity of the sample, $\varepsilon_{\pi^{**}}$ the efficiency to select charged decay pions from $B^{**}_{u,d}$ and N_B the total number of B mesons and baryons. The pion efficiency and b purity obtained from MC are (12.6 $\pm$ 0.2) % and (85.52 $\pm$ 0.37) % , respectively, and N_{tag} = 183 068. Using these numbers, the following relative $B^{**}_{u,d}$ production rate is found to be

$$B_c = \frac{BR(Z \to b \to B^{**}_{u,d} \to B^{(*)}_{u,d}\pi^{\pm})}{BR(Z \to b)} = (14.8 \pm 1.2)\%. \tag{4.9}$$

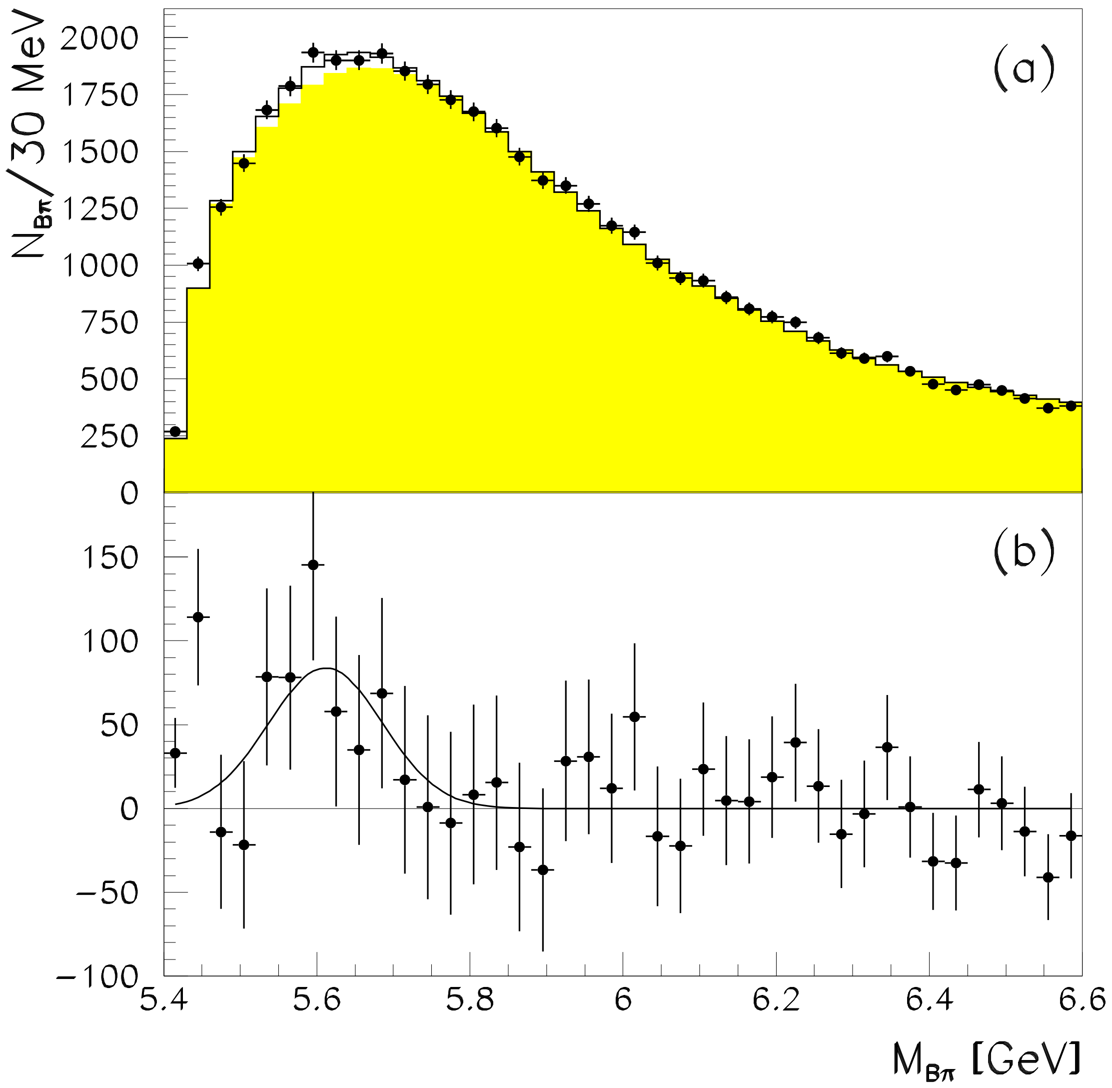

Figure 4.2: *(a) The $M_{B\pi^0}$ distribution. The dots are the data, the shaded histogram is the MC background and the open histogram the total fit when the signal is fitted with one Gaussian; (b) the background is subtracted from the data and the signal fit is plotted.*

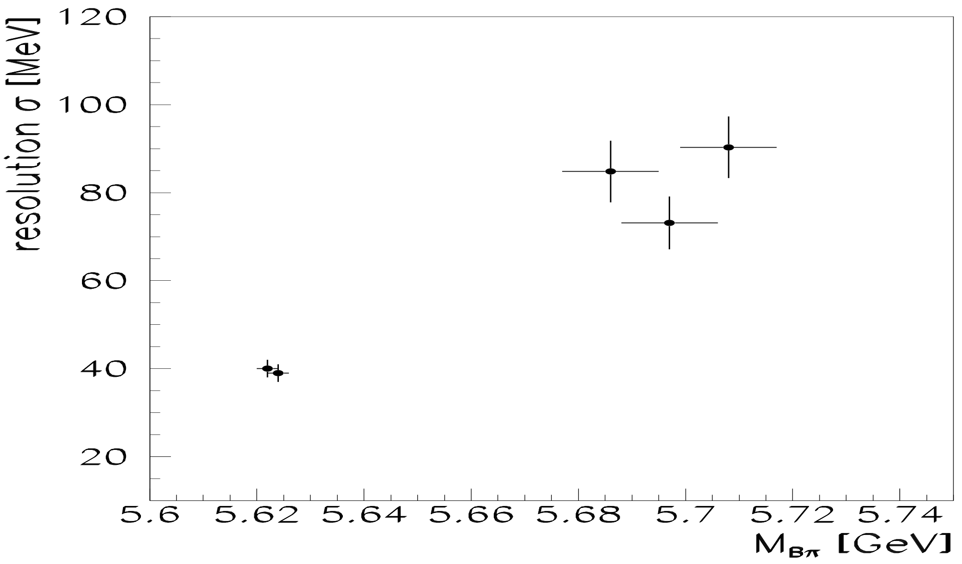

Figure 4.3: *The resolution obtained from a Breit-Wigner convoluted with a Gaussian as a function of the measured Bπ mass.*

4.2.2 Production rate in the neutral-pion channel

For the neutral pion channel an expression similar to 4.8 can be written down with $\varepsilon_{\pi^{**}}$ replaced by ε_{π^0} and $N(\mathrm{B}^{**}_{\mathrm{u,d}})$ obtained from the neutral-pion fit. The pion efficiency obtained from MC is $(3.8 \pm 0.1)\%$. With these numbers the following relative $\mathrm{B}^{**}_{\mathrm{u,d}}$ production rate is found to be

$$B_{\mathrm{n}} = \frac{\mathrm{BR}(\mathrm{Z}{\rightarrow}\mathrm{b}{\rightarrow}\mathrm{B}^{**}_{\mathrm{u,d}}{\rightarrow}\mathrm{B}^{(*)}_{\mathrm{u,d}}\pi^0)}{\mathrm{BR}(\mathrm{Z}{\rightarrow}\mathrm{b})} = (8.9 \pm 2.5)\%. \tag{4.10}$$

4.2.3 Total $\mathrm{B}^{**}_{\mathrm{u,d}}$ production rate

Isospin symmetry predicts that, for two-body decays to pions, 2/3 of the $\mathrm{B}^{**}_{\mathrm{u,d}}$ decays are into $\pi^{\pm}$ with the remaining 1/3 decaying to π^0. In this analysis, for the first time, both the charged- and neutral-pion channels were measured. Their relative production ratio can be combined by minimising the following χ^2, which imposes the 1:2 decay ratio:

$$\chi^2(x) = \frac{(2/3x - B_{\mathrm{c}})^2}{\sigma(B_{\mathrm{c}})^2} + \frac{(1/3x - B_{\mathrm{n}})^2}{\sigma(B_{\mathrm{n}})^2} \tag{4.11}$$

where, x is the total production ratio, B_{c} and B_{n} are the production ratio into the charged and neutral channel, respectively, and $\sigma(B_{\mathrm{c}})$ and $\sigma(B_{\mathrm{n}})$ are the errors on the production ratio into the charged and neutral channel, respectively. This results in a value of $\mathrm{BR}(\mathrm{b} \rightarrow \mathrm{B}^{**}_{\mathrm{u,d}}) = (22.4 \pm 1.8)$ % for the total production ratio. The value of the χ^2 is 0.2 for 1 dof. So, the data are in good agreement with the isospin-symmetry hypotheses.

The total $B^{**}_{u,d}$ production rate of BR(b $\rightarrow B^{**}_{u,d}$)= (23.7 ± 2.8)% , obtained by simply adding the results of the charged- and neutral pion- channels, compares well with the result obtained by imposing isospin symmetry.

In order to compare the results with other experiments, one should actually calculate the ratio of the number of $B^{**}_{u,d}$ events to the number of $B_{u,d}$ events. Taking into account that about 10% of the b events are baryons and about 12 % are B_s, a production ratio of $\frac{BR(b\rightarrow B^{**}_{u,d})}{BR(b\rightarrow B_{u,d})}$ = (29.9 ± 3.5)% is obtained. This value is consistent with the other LEP experiments [37–40].

4.3 Results on $B^* \rightarrow B\gamma$

4.3.1 Signal fit of the B^*

The fit of the B^* signal is performed in the same way as that of the $B^{**}_{u,d}$. In figure 4.4 data, MC background and fit results are plotted. The χ^2 of the fit is 170 for 77 degrees of freedom. The structure is observed at:

$$M_{B\gamma} = (5.3254 \pm 0.0007)\ \text{GeV}, \tag{4.12}$$

This gives a mass splitting $(M_{B^*} - M_B)$ of (46.5 ± 0.7) MeV. This value is in agreement with experimental results obtained by other experiments including L3. The Gaussian has a width of:

$$\sigma = (15.7 \pm 0.4)\ \text{MeV}. \tag{4.13}$$

The number of reconstructed B^* decays to $B\gamma$ is:

$$N(B^*) = 5712 \pm 137. \tag{4.14}$$

4.3.2 The $B^* \rightarrow B\gamma$ production rate

The measured number of B^* mesons, $N(B^*)$, is related to the relative production rate of B^* mesons in Z decays by the following expression:

$$N(B^*) = N_{tag}\eta_B\varepsilon_\gamma\frac{N_{B^*}}{N_{B^*} + N_B}, \tag{4.15}$$

with ε_γ the efficiency to select B^* decay photons, N_{tag} the number of tagged events and η_B the b purity of the sample. The photon efficiency and b purity, both obtained from MC, are ε_γ = (5.0 ± 0.2)% and η_B = (85.52 ± 0.37)%, respectively and N_{tag} = 183 068. With these numbers the following relative B^* production rate is found to be

$$\frac{BR(Z\rightarrow b\rightarrow B^*\rightarrow B\gamma)}{BR(Z\rightarrow b)} = (72.7 \pm 3.3)\%. \tag{4.16}$$

This value is consistent with the other experimental results [43–49].

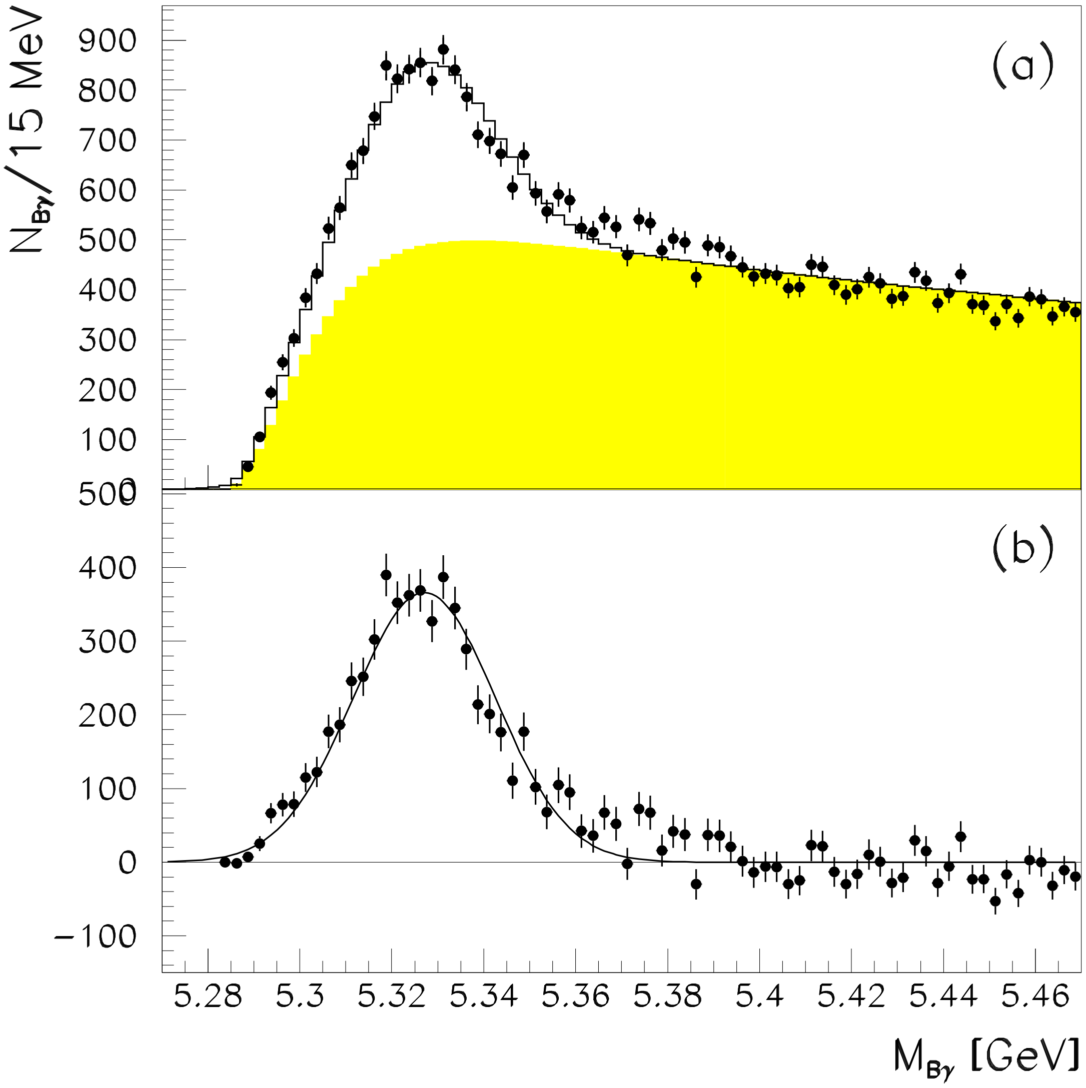

Figure 4.4: *(a) The $M_{B\gamma}$ distribution. The dots are the data. The shaded histogram the MC background and the open histogram the total fit when the signal is fitted with one Gaussian; (b) the background is subtracted from the data and the signal fit is plotted.*