PROCEEDINGS OF SCIENCE

Excited b-Hadrons and Search for η_b in Two-Photon Collisions at DELPHI

Markus Moch[*†]

INFN Roma1, Italy

E-mail: Markus.Moch@roma1.infn.it

For the DELPHI collaboration

New analyses from DELPHI concerning the spectroscopy of excited b-hadron states from data collected during the years 1992-98 are reported. Both the total $B^{**}_{u,d}$-production rate and the production rate of the narrow $B^{**}_{u,d}$-states have been measured. The masses of both narrow states B^*_2 and B_1 have been determined to be $m(B^*_2) = 5738 \pm 14$ MeV/c^2 and $m(B_1) = 5732 \pm 20$ MeV/c^2. The splitting between these two states has been measured to be $m(B^*_2) - m(B_1) = 6 \pm 14$ MeV/c^2 and an upper limit on the intrinsic width of a narrow $B^{**}_{u,d}$-state has been set to be 40 MeV/c^2 @ 95% C.L.

For B^{**}_s-mesons, only one narrow peak has been observed which has been interpreted as originating from the decay of the B^*_{s2}-state to BK. The production rate of that meson has been measured and its mass has been determined to be 5852 ± 5 MeV/c^2. An upper limit on the intrinsic width of the narrow B^*_{s2}-state has been set at 13 MeV/c^2 @ 95% C.L.

For $\Sigma_b^{(*)}$-baryons, no narrow signal is observed. An upper limit for the production rate of a narrow resonance decaying into $\Lambda_b\pi$ has been extracted.

The pseudoscalar meson η_b has been searched for in two-photon interactions at LEP II. The data sample corresponds to a total integrated luminosity of 617 pb^{-1} at centre-of-mass energies ranging from 161 to 209 GeV. Upper limits at a confidence level of 95% on the product $\Gamma_{\gamma\gamma}(\eta_b) \times BR(\eta b)$ are 150, 450 and 660 eV/c^2 for the η_b decaying into 4, 6 and 8 charged particles, respectively.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

[*] Speaker.

[†] This work was partially financed by the Research Training Network of the EU *The 3rd Generation as a Probe for New Physics*, contract RTN-HPRN-CT-2002-00292.

PoS(HEP2005)232

1. $\mathbf{B^{**}_{u,d}}$-Mesons

DELPHI data from 1992-1998 have been re-analysed for excited b-hadrons. The reasons for that are manyfold. First, B-factories do not have access at their energies to excited b-hadrons. Second, up to now there is only one published result for B_s^{**}-mesons from OPAL [1] and there are no published results for $\Sigma_b^{(*)}$. Additionally, the contributions of narrow and broad states to the signal is unknown in the published analyses [1, 2]. The recent results in the charm sector [3] allow together with the predictions of HQET [4] a consistent extractions of the masses of the narrow $B^{**}_{u,d}$-states.

Two different approaches have been used for this analysis. The first is cut-based and works at high efficiency, the second uses neural networks and works at high purity. Both approaches have in common that the B^{**}-candidate is inclusively reconstructed. The weakly decaying B-meson (B^+ and B^0 respectively) is inclusively reconstructed, identified and combined with a pion candidate with the appropriate charge by using charge correlation variables. These variables take advantage of the fact that a B_u^{+**}-meson, containing an anti-b-quark, decays into a B^0 and a π^+ and a B_d^{0**}-meson, also containing an anti-b-quark, decays into a B^+ and a π^-. Such variables allow right and wrong sign samples to be defined. Q-value spectra[1] have been determined for right and wrong sign samples. One expects three contributions from the decays of the narrow states. The rates of the broad states and the mass differences within the broad doublet and between the broad and narrow doublet have been fixed according to both spin and state counting, the predictions of HQET and the results from the charm sector [3]. The fit results from both approaches and are well compatible with each other and have been combined leading to the following results for the total and narrow rate:

$$\left(\frac{\sigma(B^{**}_{u,d})\cdot BR(B^{**}_{u,d}\to B^{(*)}\pi)}{\sigma_b}\right)_{\text{total}} = 0.156\pm 0.011(\text{stat.})^{+0.022}_{-0.014}(\text{syst.})\pm 0.019(\text{model})$$

$$\left(\frac{\sigma(B^{**}_{u,d})\cdot BR(B^{**}_{u,d}\to B^{(*)}\pi)}{\sigma_b}\right)_{\text{narrow}} = 0.091\pm 0.007(\text{stat.})^{+0.013}_{-0.008}(\text{syst.})\pm 0.011(\text{model})$$

The systematic uncertainty is dominated by the modeling of the background in the fit. The mass splitting within the narrow doublet has been left as a free parameter and has been determined to be $m(B_2^*) - m(B_1) = 6\pm 11(\text{stat.})\pm 7(\text{syst.})\pm 6(\text{model})\ \text{MeV}/c^2$. The main systematic uncertainty is due to the reconstructed B energy. The model uncertainty has been evaluated by changing the parameters fixed in the fit within their uncertainties and by combining the results from spin and state counting. The masses of the narrow states have been measured to be $m(B_2^*) = 5738\pm 14\ \text{MeV}/c^2$ and $m(B_1) = 5732\pm 20\ \text{MeV}/c^2$ respectively. An upper limit for the intrinsic width of a narrow resonance has been measured to be 40 MeV/c^2 @ 95% C.L.

2. $\mathbf{B_s^{**}}$-Mesons

Within the neural network approach a search for B_s^{**}-mesons have been performed by replacing the decay pion by a kaon. The background has been parametrised by an analytical function, the

[1]The Q-value is defined as $Q = m(B\pi) - m(B) - m(\pi)$.

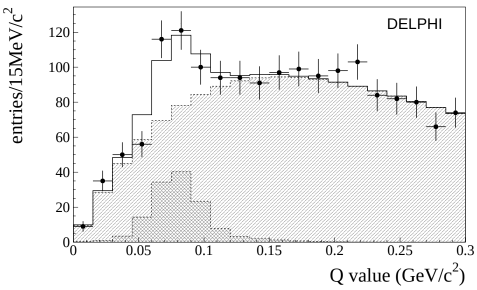

Figure 1: B_s^{**} fit result. The hatched area is the fitted background, the cross-hatched is the fitted signal.

resolution has been fixed to the expected one from simulation. The fit result to the reconstructed Q-spectrum is shown in figure 1. The extracted production rate is:

$$\frac{\sigma(B_s^{**}) \cdot BR(B_s^{**} \to BK)}{\sigma_b} = 0.0093 \pm 0.0020(\text{stat}) \pm 0.0013(\text{syst}).$$

In contrast to the case of $B_{u,d}^{**}$-mesons, it is expected that at least two peaks from the three narrow state decays can be resolved due to improved resolution close to the threshold. However, only one is observed. A likely interpretation of the observed peak is that it derives from the decay $B_{s2}^* \to BK$. The second peak, from the decay $B_{s1} \to B^*K$ and expected approximately 60 MeV/c^2 below the observed signal, could be suppressed due to an enhancement of the isospin forbidden decay into $B_s^*\pi^0$ near threshold. Thus, the mass of the B_{s2}^* has been determined from the fit result to be 5852 ± 5 MeV/c^2. An upper limit on the intrinsic width have been extracted to be 13 MeV/c^2 @ 95% C.L.

3. Search for $\Sigma_b^{(*)}$-Baryons

A search for $\Sigma_b^{(*)}$-baryons decaying into $\Lambda_b\pi$ has been performed within the neural network approach. No signal could be observed. An upper limit on the rate of a narrow resonance has been extracted by scanning for a Gaussian signal over the Q-spectrum:

$$\frac{\sigma(\Sigma_b^{(*)}) \cdot BR(\Sigma_b^{(*)} \to \Lambda_b\pi)}{\sigma_b} < 0.012 \text{ @ 95\%C.L.}$$

4. Search for η_b-Mesons

The pseudoscalar bottomonium state has not yet been discovered. Models estimate its mass to be 10 to 130 MeV/c^2 below the Υ. ALEPH determined the following limits: $\Gamma_{\gamma\gamma}(\eta_b)\times BR(\eta_b) \to$ 4 charged particles < 48 eV/c^2 and $\Gamma_{\gamma\gamma}(\eta_b)\times BR(\eta_b) \to$ 6 charged particles < 132 eV/c^2 respectively, L3 extracted the following limit by combining decay modes with 2, 4, 6 charged particles only or associated with a π^0: 200 eV/c^2 at 95% C.L [5].

In the DELPHI analysis presented here, decays in 4, 6 and 8 charged pions and/or kaons with zero net strangeness have been considered. The integrated luminosity is 617 pb^{-1} at centre-of-mass energies of 161 to 209 GeV. The pion and kaon identification is based on dE/dx and RICH

	η_b decay modes		
	4 ch.tracks (N_{bkg})	6 ch.tracks (N_{bkg})	8 ch.tracks (N_{bkg})
N_{obs} (9.2 $<$ W_{vis} $<$9.4 GeV/c^2)	0 (0.6)	2 (0.7)	0 (0.5)
N_{obs} (9.4 $<$ W_{vis} $<$9.6 GeV/c^2)	0 (0.6)	0 (0.4)	1 (1.0)
Signal events (95% C.L. upper limit)	3.9	5.7	4.1
overall efficiency	5.9%	3.5%	1.8%
$\Gamma_{\gamma\gamma}(\eta_b)\times$BR$(\eta_b)$, eV/$c^2$ (95% C.L. upper limit)	190	470	660

Table 1: Overview over the number of observed and expected background events in the invariant mass W_{vis} intervals considered and the extracted limits for the different η_b decay modes.

measurements both separately and combined by a neural network. The considered backgrounds are $\gamma\gamma \rightarrow q\bar{q}$ which is the main background and $e^+e^- \rightarrow e^+e^-\tau^+\tau^-$. The main systematic uncertainties come from the statistical uncertainty of the background, the generator used for simulating the signal and the uncertainities of the η_b parameters. The extracted limits for the different decay modes are given in table 1. The combined upper limit for the sum of the three branching ratios assuming that the branching ratio is the same for each channel is 360 eV/c^2 @ 95% C.L.

5. Summary

New analyses of excited b-hadrons have been presented. Both the narrow and total production rate have been measured for $B^{**}_{u,d}$-mesons, with more control over the background than previous inclusive measurements, as well as the masses of both narrow states. and the mass splitting between them. For B^{**}_s-mesons only one narrow state has been observed, its production rate and mass have been measured. No signal for both $\Sigma_b^{(*)}$ (in Z decays) and η_b (in two-photon interactions) has been observed, limits on their production have been set.

References

[1] OPAL Collab., R. Akers et al., Z. Phys. **C66** (1995) 19.

[2] DELPHI Collab., P. Abreu et al., Phys. Lett. **B345** (1995) 598; ALEPH Collab., D. Buskulic et al., Z. Phys. **C 69** (1996) 393; ALEPH Collab., R. Barate et al., Phys. Lett. **B 425** (1998) 215; L3 Collab., M. Acciarri et al., Phys. Lett. **B465** (1999) 323; OPAL Collab., G. Abbiendi et al., Euro Phys. J. **C23** (2002) 437; CDF Collab., T. Affolder et al., Phys. Rev. **D 64** (2001) 072002.

[3] PDG, K. Hagiwara et al, Phys. Rev. **D 66** (2002) 010001; CLEO Collab., S. Anderson et al., Nucl. Phys. **A 663** (2000) 647; BELLE Collab., K. Abe et al., BELLE-CONF-0235, submitted to ICHEP02, [hep-ex/0307021]; BABAR Collab., B. Aubert et al., Phys. Rev. Lett. **90** (2003) 242001; CLEO Collab., D. Besson et al., CLEO CONF 03-01 (2003); CLEO Collab., T. Bergfeld et al., Phys. Lett. **B340**(1994) 194; Y. Kubota et al., Phys. Rev. Lett. **72** (1994) 1972.

[4] N. Isgur, M. B. Wise, Phys. Lett. **B232** (1989) 113; N. Isgur, M. B. Wise, Phys. Lett. **B237** (1990) 527.

[5] ALEPH Collab., A. Heister et al., Phys. Lett., **B 130** (2002) 56; L3 Collab., M. Levtchenko et al., Nucl. Phys. B Proc. Suppl. **126** (2004) 260.