A search for the pseudoscalar meson $\eta_b$ was performed at LEP II energies with an integrated luminosity of $700 \text{pb}^{-1}$. The search, done for the decay modes into 4 and 6 charged particles yielded 0 and 1 candidates, respectively. Upper limits on $\Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}$ for both modes of 57 eV and 128 eV were obtained with corresponding limits of 17% and 38% on branching ratios $\text{BR}(\eta_b \rightarrow 4 \text{ charged particles})$ and $\text{BR}(\eta_b \rightarrow 6 \text{ charged particles})$ at a confidence level of 95%. The candidate has a mass of $9.30 \pm 0.04 \text{ GeV}$.

1 Introduction and Motivation

The $b\bar{b}$ ground state, the $\eta_b$ meson has not been observed yet. Because of their initial state two-photon collisions are well suited for the study of pseudoscalar mesons $J^{PC} = 0^{+-}$, in which they can be produced exclusively. The high $\gamma\gamma$ cross section, the high LEP luminosity and energy as well as the low background from other processes make LEP II events a good sample to search for this meson.

The ALEPH experiment has started a search for the still undiscovered $\eta_b$ pseudoscalar meson. The meson has been searched for in two-photon events in its exclusive decays to 4 and 6 charged particles.

The analysis is motivated by various predictions for the mass of the $\eta_b$, e.g., from potential models, pQCD, NRQCD, and lattice calculations, which are tested or constrained by a measurement of the $\eta_b$ mass. See the contributions by G. Bali and by S. Collins at this conference and the contributed paper. The allowed mass $m(\eta_b)$ of these estimates ranges from $9.32 \text{ GeV}/c^2$ to $9.45 \text{ GeV}/c^2$.

2 Potential for the Measurement

The production cross sections has been estimated as follows. In two-photon collisions the cross section for $\eta_b$ is calculated with the equivalent photon approximation using the estimated $\eta_b$ mass in the form factor (a mass of 9.4 GeV is used). The partial width $\Gamma_{\gamma\gamma}$ is calculated from the ratio $\Gamma_{\gamma\gamma}(\eta_b)/\Gamma_{\gamma\gamma}(\eta_c)$ using the Coulomb potential approach.

Using the measured partial width $\Gamma_{\gamma\gamma}(\eta_c) = 7.4 \pm 1.4 \text{ keV}$ a value of $\Gamma_{\gamma\gamma}(\eta_b) = 416 \text{ eV}$ is obtained. (See, however, the contribution by N. Fabi-
ano at this conference indicating a larger \( \Gamma_{\gamma\gamma}(\eta_b) \). This translates into a production cross section of 0.222 pb at \( \sqrt{s} = 197 \) GeV (luminosity weighted for the 700 pb\(^{-1}\) at LEP II above \( W^+W^- \) threshold). This would correspond to 156 \( \eta_b \) mesons produced in ALEPH during LEP II data taking.

The branching ratios of the \( \eta_b \) decay can only be estimated. Here, a new (different to the ALEPH conference note) approach is used, where for the production probability of \( n_{\text{pair}} \) pion (or kaon) pairs a Poisson distribution is assumed. The number \( n_{\text{pair}} \) can be obtained, because the energy evolution of the mean charged multiplicity \( \langle n \rangle \) is predicted in modified leading log approximation (MLLA) with the assumption of local parton-hadron duality (LPHD) and is fitted to \( e^+e^- \) data. With the choice \( n_{\text{pair}} = \langle n \rangle / 2 \) for charged and \( n_{\text{pair}} = \langle n \rangle / 4 \) for neutral pairs, the branching ratios can be estimated. Evaluation for the \( \eta_b \) a branching ratio to (0 neutral and) 4 charged particles of \( P_0P_2 = 9.9\% \) is estimated, while the measured decays add up to \( 9.3 \pm 1.8\% \). For the \( \eta_b \) decay to 4 and 6 charged particles \( P_0P_2 = 2.7\% \) and \( P_0P_3 = 3.3\% \) are obtained, respectively.

The selection and reconstruction efficiencies are studied using event generated with PHOT02. For the decays it is assumed that the momentum distributions are given by phase space. The efficiencies are found to be 15.7\% and 10.1\%, respectively.

| mean cms energy | = 196.6 GeV |
| total luminosity | = 700 pb\(^{-1}\) |
| \( \alpha_s(m(\eta_b/2)) \), \( \alpha_s(m(\eta_c/2)) \) | = 0.22, 0.36 |
| \( \Lambda_{5,4} \) | = 220 MeV, 306 MeV |
| cross section | = 0.222 pb (lumi.weighted) |
| \# produced \( \eta_b \) | = 156 |
| efficiency (4 charged) | = 15.7\% |
| efficiency (6 charged) | = 10.1\% |
| \# \( \eta_b \) (BR(4 charged) = 2.7\%) | = 0.65 events |
| \# \( \eta_b \) (BR(6 charged) = 3.3\%) | = 0.52 events |

### 2.1 Data Analysis

In order to keep the efficiency high, loose selection cuts are chosen for event and track selection. So, no attempt is made to reconstruct the \( K_S \) at this stage. The mass resolution of the accepted events is around 0.14 GeV, mainly due to \( \pi-K \) misidentification and mass assignment, with an average reconstructed
mass of 9.4 GeV. A signal region 9.0 GeV to 9.8 GeV is chosen. The background, which is dominated by $\gamma\gamma$ continuum production, is therefore estimated from the number of data events: a) the number of events in the signal region before the final cuts, which is 78 (139) events for 4 (6) charged particles, and b) by a fit to the ratio of the mass spectra after all cuts are applied and before the final cuts on $\sum p_{t,i}$, thrust, $\theta$ (thrust axis), and hemisphere mass are applied. The background is estimated to be $0.3 \pm 0.3$ (0.8 $\pm$ 0.4) events.

3 Results

The invariant mass spectra of the selected events from 700 pb$^{-1}$ at LEP II with 4 (and 6) charged particles are shown in Figure 1. In the signal region 0 (and 1) events are found.

From the knowledge of the background, the efficiency and its uncertainty (±25%) the observed number of events are converted into upper limits.

For a confidence limit of $\alpha = 95\%$ upper limits for $\Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}$ of 57 eV (and 128 eV) are obtained. Including the evaluated two photon width of 416 eV and its uncertainty (±25%) the upper limits on the branching ratio
of the $\eta_b$ meson at 95% C.L. are $\text{BR}(\eta_b \rightarrow 4 \text{ charged particles}) < 17\%$ and $\text{BR}(\eta_b \rightarrow 6 \text{ charged particles}) < 38\%$.

The selected event, shown in Figure 2, has a $V^0$ particle compatible with a $K_S$. One daughter of the $V^0$ has the kaon mass assigned. Compatible in $dE/dx$ with a pion ($\chi^2_\pi = 0.86$ rather than $\chi^2_K = 0.18$) we recalculate the mass of the event. A mass estimate of $9.30 \pm 0.04 \text{ GeV}$ is obtained, where the error is a conservative estimate of the total error.

4 Conclusion

In an integrated luminosity of 700 pb$^{-1}$ at LEP II energies the pseudoscalar meson $\eta_b$ has been searched for by the ALEPH collaboration in its decays to 4 and 6 charged particles. One candidate is retained in the decay mode into 6 charged particles, while the expected signal is 0.65 and 0.52 events for the two decay modes and a background of $0.3 \pm 0.3 \ (0.8 \pm 0.4)$ events is expected. The candidate has a mass of $9.30 \pm 0.04 \text{ GeV}$. The event is compatible with background.

Upper limits on $\Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}$ of 57 eV and 128 eV corresponding to limits of the branching ratios, $\text{BR}(\eta_b \rightarrow 4 \text{ charged particles})$ and $\text{BR}(\eta_b \rightarrow 6 \text{ charged particles})$, of 17% and 38% are obtained with a confidence level of 95%. A discovery would need the effort of all 4 LEP experiments.

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