RECENT ARGUS RESULTS ON B PHYSICS

Pavel N. Pakhlov
Institute of Theoretical and Experimental Physics
117259, Moscow, Russia

Abstract

Using the ARGUS detector at the e^+e^- storage ring DORIS II at DESY, we have analized for the first time the inclusive primary lepton spectrum in the whole momentum interval. We have measured the decay $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ with partial reconstruction of the D^{*+} meson. This method allowes also to measure the $BR(\overline{B^0} \to X\ell^-\overline{\nu})$ and $BR(D^0 \to K^-\pi^+)$. Finally, we have measured the $BR(B \to baryons)$ using baryon-antibaryon, baryon-lepton and baryon-antibaryon-lepton correlations.

1. Study of the inclusive spectrum of the primary leptons

The spectator model [1] predicts the semileptonic branching ratio for B mesons to be (12–14)%. Experimentally a smaller value was obtained using only the hard region of momentum spectrum. The low momenta part is dominated by the secondary leptons and in fact excluded from the analysis. Therefore a model-dependent extrapolation to the low momentum interval was required. The branching ratio obtained from different model extrapolations varies from 9.5 to 11.2% [2]. To suppress theoretical uncertainties a measurement of the primary lepton spectrum in the whole momentum region was performed.

In the ARGUS detector electrons are well identified practically in the whole momentum interval. The primary electron spectrum can be extracted by subtracting the secondary electron contribution. In order to suppress the secondary electrons and then to determine their residual contribution from the data, we tagged the flavour of one B meson by the sign of the fast lepton ($tag^{+1} = e^+$ or μ^+, with $p_{tag^-} > 1.4\ GeV/c$) and then studied the momentum spectrum of opposite-sign electrons. The secondary electrons from the untagged B meson have opposite sign to that of the primary ones (except those originating from D_s^-, ψ or τ^- decays). They contribute to the studied spectrum only in the case of B^0–$\overline{B^0}$ mixing and are therefore suppressed. The secondary electrons from the tagged B meson have a proper sign but they are correlated in angle with fast leptons used for tagging and can be significantly removed by the cut $cos\theta_{tag^+e^-} > 0$. Continuum, hadrons misidentified as leptons, as well as electrons from photons converted in matter, were subtracted using the data.

Most secondary electron contributions were extracted from the data. Using the like-sign fast lepton as tagging one allows one to determine the shape of the momentum spectrum of the secondary electrons from the untagged B meson tagging by the like-sign fast lepton. In this case the obtained spectrum contains practically only the secondary electrons from the untagged B meson with small primary electron contribution because of B^0–$\overline{B^0}$ mixing. After subtraction of the primary electron contribution using Monte Carlo simulation, the obtained spectrum was multiplied by the normalization factor (~ 0.1), calculated from the known mixing parameter.

To determine the contribution from the secondary electrons, produced in the decay of the tagged B meson, the angular correlation between the tagging fast lepton and the opposite-sign electron was studied. The contribution to the studied region

[1] References in this paper to a specific charged state are to be interpreted as implying the charged-conjugate state also.

of $cos(\theta_{tag^+e^-}) > 0$ was determined from a fit to the whole angular distribution. in each bin of the studied electron momentum (Figure 1). The shape of the angu-

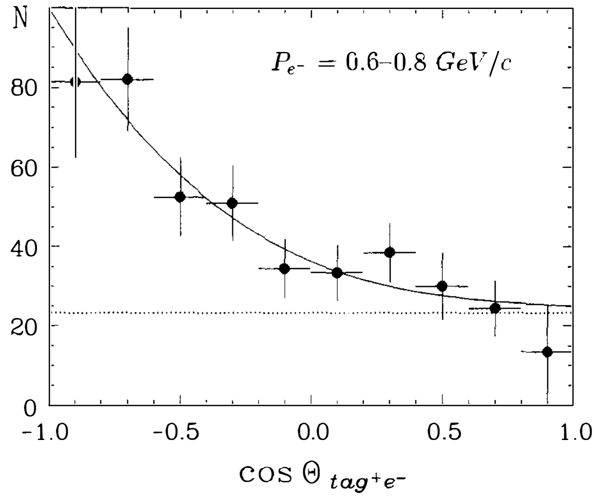

Figure 1: Angular distribution between tagging lepton and studied electron.

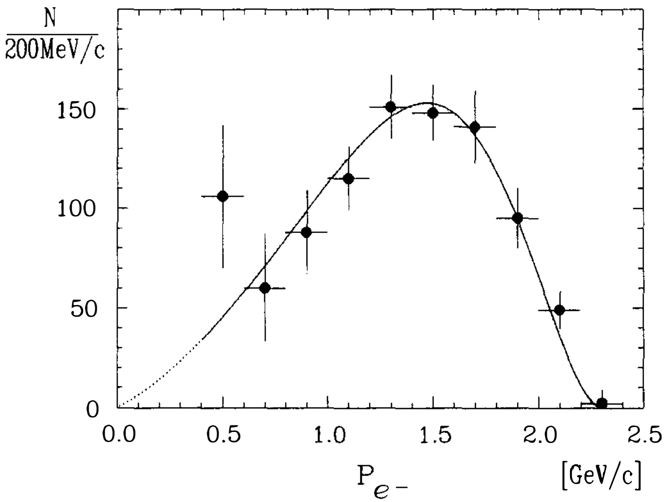

Figure 2: Momentum spectrum of primary electrons.

lar distribution for the background under consideration was fixed by Monte Carlo simulation, while other sources producing uncorrelated unlike-sign dileptons (except continuum and misidentified hadrons. which were subtracted before fitting) have a flat angular distribution. The result only slightly depends on the models, used to describe the shape of the angular distribution. In any case the contribution from this background source was already suppressed by a factor of 7.

Backgrounds from the secondary electrons originating from the decays of D_s^-, ψ and τ^- were estimated by Monte Carlo simulation.

The spectrum obtained after all backgrounds subtraction is in good agreement with the ACM model [3] using the parameters found in our previous analysis [4], where only the hard part of the lepton spectrum was studied (Figure 2).

2.1 Measurement of the decay $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ with partial reconstruction of D^{*+} meson

The decay $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ was measured by ARGUS [5] and CLEO [6] with full reconstruction of the D^{*+} in the decay chain $D^{*+} \to D^0\pi^+$, followed by $D^0 \to K^-\pi^+$. The information about the unobserved neutrino was obtained using the recoil mass technique, where M^2_{recoil} is defined by :

$$M^2_{recoil} = (E_{beam} - E_{D^{*+}} - E_{\ell^-})^2 - (\vec{p}_{D^{*+}} + \vec{p}_{\ell^-})^2. \quad (1)$$

In this expression the B meson energy was substituted by the beam energy and the small momentum of the B meson was ignored.

Since the energy released in the decay $D^{*+} \to D^0\pi^+$ is very small, the direction of the pion from this decay is close to that of the D^{*+} while the magnitudes of their momenta are strongly correlated. Using information only about the soft pion, it is possible to calculate the momentum of the D^{*+} without reconstruction of the D^0. The kinematical limit for the the pions in the studied process is around 200 MeV/c, therefore only pions with momentum below this limit were used in this analysis. Assuming that the direction of the D^{*+} meson coincides with that of the pion, the momentum of the D^{*+} was calculated using the formula $p_{D^{*+}} = \alpha p_{\pi^+} + \beta$, with parameters α and β fixed by Monte Carlo simulation. The resolution of the D^{*+} momentum using this method is sufficiently good for the standard technique of the recoil mass to be applied. As shown by Monte Carlo studies the recoil mass resolution allows us to distinguish between the decay under consideration and the contribution from the $B \to D^{**}\ell^-\overline{\nu}$ decay.

The momentum of the lepton was required to be more than 1.4 GeV/c to suppress the cascade charm decays as well as the decays of $B \to D^{**}\ell^-\overline{\nu}$, where the lepton momentum is expected to be softer.

The recoil mass distribution after subtraction of the continuum and misidentified hadrons is shown in Figure 3. A prominent peak near zero recoil mass in the right-

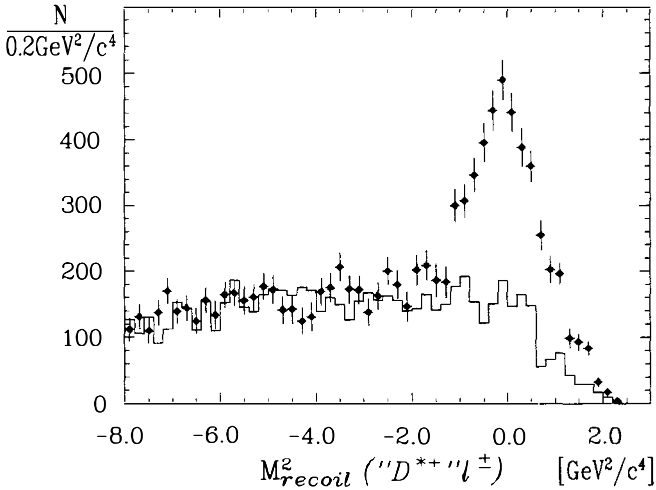

Figure 3: Recoil mass distribution for right- and wrong-sign π–ℓ combinations.

sign combinations (points with errors) corresponds to the studied decay, while the wrong-sign combinations distribution behaves smoothly in this region (histogram).

Monte Carlo simulation predicts similar shapes for the wrong- and right-sign background distributions, therefore the wrong-sign combinations were used to describe the background under the signal. We checked that there are no pairs of correlated leptons and soft pions except the process under consideration. For this reason the recoil mass distributions for pions and leptons from different events and from the same event were compared. No significant difference was observed between mixed and real events.

After wrong-sign combination subtraction, the recoil mass distribution was fitted by two functions corresponding to the decays $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ and $B \to D^{**}\ell^-\overline{\nu}$ (Figure 4). The fit found the number of the events from the studied decay to be equal to $N(\overline{B^0} \to D^{*+}\ell^-\overline{\nu}) = 2333 \pm 140 \pm 75$, which corresponds to

$$BR(\overline{B^0} \to D^{*+}\ell^-\overline{\nu}) = (4.4 \pm 0.3 \pm 0.5)\%.$$

This result is in good agreement with the previous measurements [2] and independent on the exclusive branching ratios for D^0 meson.

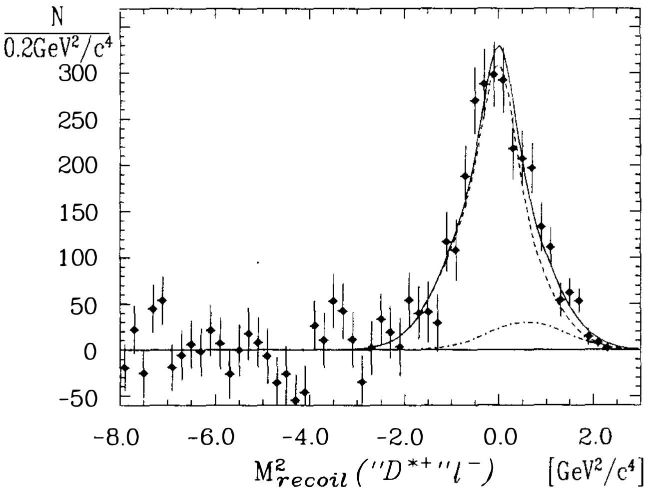

Figure 4: Recoil mass distribution for π^+-ℓ^- combinations.

2.2 Measurement of the decay $BR(\overline{B^0} \to X\ell^-\overline{\nu})$

The sample of events with $|M^2_{recoil}| < 1\ GeV^2/c^4$ is enriched with tagged B^0 mesons (Figure 3). Using this sample we measured the semileptonic branching ratio for B^0 mesons only. Background in this sample is due to the mixture of charged and neutral B mesons. Equal fractions of B^0 and B^- contributions to the background and equal semileptonic branching ratios for charged and neutral B mesons were assumed. Since the background is small, the error made by these assumptions contributes only slightly to the value obtained. With these assumptions the semileptonic branching ratio of the neutral B^0 is equal to

$$BR(B^0 \to X\ell^-\overline{\nu}) = \frac{N_2}{N_1\eta_{\ell^-}} \cdot (1.00 \pm 0.06), \qquad (2)$$

where N_1 is the number of events in the sample, N_2 is the number of events in the sample with an additional fast lepton ($p_{\ell^-} > 1.4\ GeV/c$) and η_{ℓ^-} is the efficiency of the lepton reconstruction. The factor (1.00 ± 0.06) arises because of the errors of the above assumptions.

The semileptonic branching ratio obtained is equal to

$$BR(B^0 \to X\ell^-\overline{\nu}) = (9.4 \pm 1.0 \pm 0.8)\%.$$

2.3 Measurement of the decay $BR(D^0 \to K^-\pi^+)$

The same sample of tagged $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ decays was used for a measurement of the exclusive branching ratios of D^0. We compared numbers of decays $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ with fully reconstructed D^{*+} and with partially reconstructed D^{*+} by the method described in section 2.1. The branching ratios for the decays $D^0 \to K^-\pi^+(\pi^+\pi^-)$ are equal to

$$BR(D^0 \to K^-\pi^+(\pi^+\pi^-)) = \frac{N_{full} \cdot \eta_{D^0 \to K^-\pi^+(\pi^+\pi^-)}}{N_{partial}}, \tag{3}$$

where N_{full} is the number of the fully reconstructed D^{*+} in the decay chain $D^{*+} \to D^0\pi^+$ followed by $D^0 \to K^-\pi^+(\pi^+\pi^-)$, $N_{partial}$ is the number of the partially reconstructed $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ decays and $\eta_{D^0 \to K^-\pi^+(\pi^+\pi^-)}$ is the reconstruction efficiency of the D^0 meson in these decay modes.

After all background subtraction the numbers of fully reconstructed $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$ decays equal to 70 ± 10 and 104 ± 21 for the $K^-\pi^+$ and $K^-\pi^+\pi^+\pi^-$ decay modes of D^0 respectively. These values allow one to calculate $BR(D^0 \to K^-\pi^+) = (3.82 \pm 0.49 \pm 0.36)\%$ and $BR(D^0 \to K^-\pi^+\pi^+\pi^-) = (9.6 \pm 1.5 \pm 1.8)\%$, which are in good agreement with the PDG values [7].

3. Measurement of the $BR(B^0 \to baryons)$

Baryon production from B mesons was previously measured by both ARGUS [8] and CLEO [9], using proton and lambda yields from $\Upsilon(4S)$ decays. The slow baryons (with $p < 0.4\ GeV/c$) cannot be measured because of their scattering in the beam-wall, while for fast protons the identification fails to separate them from other charged particles. Some assumptions about neutron production were also required because they are not observed in both experiments.

In this analysis information about the unmeasured part of the baryon spectrum and about neutron production was obtained by comparing the number of events with one baryon and with baryon-antibaryon pairs, using the fact that baryons should be accompanied by antibaryons. The baryons are produced by at least two mechanisms: they originate from the charmed baryon decay and from the fragmentation. The separation of these two mechanisms is possible if the flavour of B is tagged by the sign of the fast lepton.

We derived twelve equations with five unknown variables, which can be found in ref. [10]. From the overall least-squared fit the branching ratio of B mesons into baryons was found to be equal to:

$$BR(B \to baryons) = (6.8 \pm 0.5 \pm 0.3)\%.$$

This result is not dependent on the model used to describe the baryon spectrum, and is in good agreement with previous measurements.

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