Recent ARGUS results on tau and charm physics

Elena Gershtein
Institute of Theoretical and Experimental Physics,
117259 Moscow, Russia

Abstract

We have improved upper limits for two-body τ-decays into a lepton and an unobservable particle. Michel parameter δ and sign of ξ in $\tau^{\mp} \to l^{\mp}\nu\bar{\nu}$ decays were determined for the first time through study of spin correlations using semihadronic τ-decay as analyser of the τ-spin: $\xi = 1.26^{+0.30}_{-0.26} \pm 0.09$ and $\delta\xi = 0.77^{+0.18}_{-0.16} \pm 0.05$. The decay $D^{*+}_{s2} \to D^0 K^+$ was measured. Using partial reconstruction of D^{*+} decays we have measured the semileptonic decay fractions of D^0 meson to be $Br(D^0 \to e^+\nu_e X) = 6.8 \pm 0.3 \pm 0.5\%$, $Br(D^0 \to \mu^+\nu_\mu X) = 6.0 \pm 0.7 \pm 1.2\%$ and the semileptonic decay fraction of charm mixture from e^+e^- annihilation around 10 GeV to be $Br(c \to e^+\nu_e X) = 9.6 \pm 0.4 \pm 1.0\%$.

1 A search for the decays $\tau \rightarrow e\alpha, \tau \rightarrow \mu\alpha$.

Previously, upper limits for $\tau \rightarrow e\alpha$ ($\tau \rightarrow \mu\alpha$) decays have been obtained for α masses $m_\alpha <$ 0.5 GeV/c^2 from a fit of the lepton spectra in the laboratory frame [1],[2]. The expected momentum spectra of leptons resulting from $\tau \rightarrow \ell\nu\overline{\nu}$ and $\tau \rightarrow \ell\alpha$ are shown in Fig. 1a.

It is best to search for $\tau \rightarrow \ell\alpha$ decays in the τ rest frame. Here the lepton momentum distribution is shaped as a peak with a position depending on the α mass. To perform the Lorentz boost to this frame one needs to know the τ flight direction which is not directly measured at ARGUS. However, for events where the second τ lepton decays into $(3h)^\pm\nu_\tau$ or $(3h)^\pm\pi^0\nu_\tau$, this direction can be well approximated by the momentum vector of the heavy 3-prong system [3]. The τ energy coincides with the beam energy up to initial state radiative corrections. Therefore, a transformation to the τ pseudo rest frame becomes possible (see Fig. 1b). We selected $\tau^+\tau^-$ pairs with one τ decaying into $l\nu\overline{\nu}$ or $l\alpha$ and the other τ decaying into $(3h)^\pm\nu_\tau$ or $(3h)^\pm\pi^0\nu_\tau$requiring the events to satisfy 1-3 topology cuts [4].

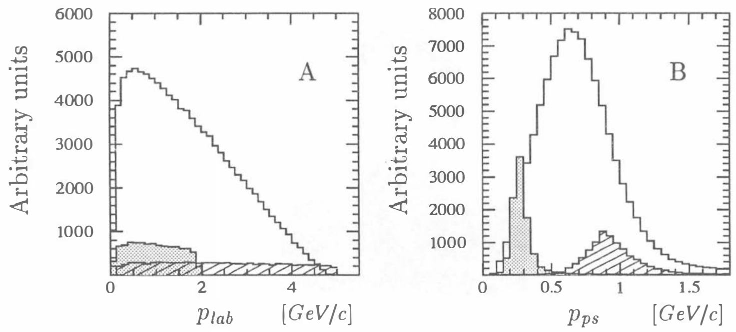

Figure 1: Prediction for spectra of leptons from the decays $\tau \rightarrow \ell\nu\overline{\nu}$ (hist.), $\tau \rightarrow \ell\alpha$ with $m_\alpha = 0$ (hatched hist.), and $m_\alpha = 1.4$ GeV/c^2 (shadowed hist.).

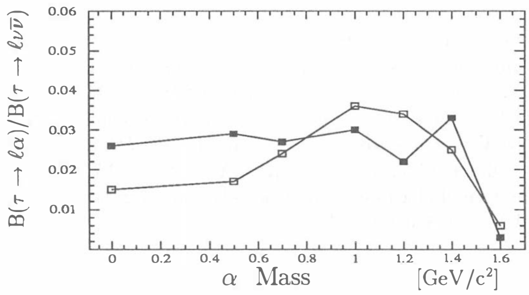

Figure 2: The upper limits @ 95% CL on $B(\tau \rightarrow \ell\alpha)/B(\tau \rightarrow \ell\nu\overline{\nu})$ for electrons (open squares) and muons (full squares)

Muons with momenta below about 1 GeV/c in the laboratory frame can not be used in analysis because of the background from pions from $\tau \rightarrow \pi^-\nu$ decay. However, they can partially be separated from pions in the τ pseudo rest frame. Pion momentum spectrum in the τ rest frame is a delta function.In the pseudo rest frame it transforms into a broad peak. But there is still a large region where pions and muons are separated kinematically. Therefore it is possible to use them in the analysis. The efficiency corrected experimental spectra were fit to a sum of the theoretical expectations for 3– and 2–body τ decays for different m_α. We have found no excess expected for $\tau \to \ell\alpha$ decays in the whole kinematically allowed region of m_α. In fig.2 the results are presented in terms of upper limits on $\mathcal{B}(\tau \to \ell\alpha)/\mathcal{B}(\tau \to \ell\nu\overline{\nu})$.

2 Michel parameters ξ and δ in leptonic τ decays.

We present the first measurement of sign of ξ and the first measurement of δ in $\tau^\mp \to l^\mp\nu\overline{\nu}$ decay combining the observations on electrons and muons. In the τ rest frame, neglecting radiative corrections and terms proportional to m_l^2/m_τ^2 the energy spectrum of the charged lepton $l^\mp$ in $\tau^\mp \to l^\mp\nu\overline{\nu}$ is given by

$$\frac{d\Gamma(\tau^\mp\to l^\mp\nu\overline{\nu})}{d\Omega dx} = \frac{G_F^2 m_\tau^5}{192\pi^4}x^2\Big[3(1-x)+\tfrac{2}{3}\rho(4x-3)+6\eta\frac{m_l}{m_\tau}\frac{1-x}{x}$$

$$\mp\xi P_\tau\cos\theta((1-x)+\tfrac{2}{3}\delta(4x-3))\Big],$$

where $x = E_l/m_\tau$ is the scaled lepton energy, P_τ the τ polarization, and θ the angle between τ-spin and lepton momentum. With unpolarized τ we obtain no information on the parity-violating Michel parameter ξ and δ. Though the τ-leptons at ARGUS are unpolarized, there are spin-spin correlations between the two τ-leptons in $e^+e^- \to \tau^+\tau^-$. In our analysis, where one τ decays leptonically and the other one into $\pi^\mp\pi^+\pi^-\nu$, the potential information about τ-spin from all available kinematical information (the three pion momenta, kinematical constraints on the τ directions with respect to the decay products from hadronic τ decays and measured momentum of the decay lepton) were used. A likelihood function of one event was defined by forming a weighted sum over all possible kinematical configurations taking into account initial state radiation, radiative corrections to $\tau^\mp \to l^\mp\overline{\nu}\nu$, external bremsstrahlung, and uncertainties of the measured momenta. The integration over the unmeasured quantities was done numerically using Monte Carlo methods [5]. The Michel parameters are included in the set of parameters that is determined in the fit.

The events were required to have 1-3 topology [5]. The set of selection criteria was aimed to obtain a very pure lepton sample. After all cuts [5] non-$\tau\tau$ contribution was suppressed to an insignificant level and a data sample of 3622 events was obtained comprising 2110 candidates for $(e^\pm\nu\overline{\nu})(\pi^\mp\pi^+\pi^-\nu)$ and 1512 candidates for $(\mu^\pm\nu\overline{\nu})(\pi^\mp\pi^+\pi^-\nu)$. The only considerable background contribution (about 9% to the total number of events) comes from 3-prong side and it was taken into account in the likelihood function. For hadronic current the data driven description was used [5]. The parameter η was fixed to the value 0.03 ± 0.22 [3]. Fit gives $\rho = 0.72 \pm 0.04 \pm 0.02$, $h_{\nu_\tau} = -0.85^{+0.15}_{-0.17} \pm 0.05$, $h_{\nu_\tau}\xi = -1.07 \pm 0.17 \pm 0.08$, $h_{\nu_\tau}\xi\delta = -0.66 \pm 0.10 \pm 0.03$, $\xi = 1.26^{+0.30}_{-0.26} \pm 0.09$ and $\xi\delta = 0.77^{+0.18}_{-0.16} \pm 0.05$. The results obtained agree with the Standard Model prediction and with previous measurements.

3 Measurement of the decay $D_{s2}^{*+}(2575) \to D^0K^+$.

ARGUS has recently measured narrow P-wave charmed strange meson $D_{s2}^{*+}(2575)$ decaying into D^0K^+. The spin-parity quantum number assigned to this state is 2^+. The D_{s2}^{*+} was reconstructed using the decay channel $D_{s2}^{*+} \to D^0K^+$ with a subsequent decay $D^0 \to K^-\pi^+$ or $D^0 \to K^-\pi^-\pi^+\pi^+$ requiring $x_p = p(D^0K^+)/p_{max}(D^0K^+) > 0.6$. Fig.3 shows the D^0K^+ invariant mass spectrum after subtraction of feed-down from $D_2^{*+}(2470)$ and $D_1^+(2430)$ decays.

The fit of mass spectrum yields 93 ± 37 events at a mass of $(2574.5 \pm 3.3 \pm 1.6)$ MeV/c^2

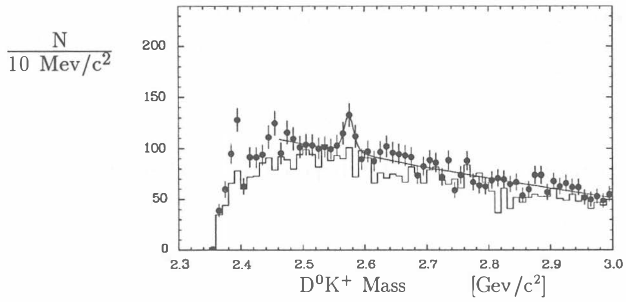

Figure 3: D^0K^+ invariant mass distribution after feed-down subtraction. The solid histogram corresponds to the D^0 sidebands. The curve corresponds to the fit described in the text.

and a natural width of $(10.4 \pm 8.3 \pm 3.0)$ MeV/c^2. Fitting corrected for efficiency D_{s2}^{*+} momentum spectrum to the Peterson fragmentation model we obtained $\epsilon = 0.027^{+0.043}_{-0.015}$ and $\sigma(e^+e^- \to D_{s2}^{*+}X)Br(D_{s2}^{*+} \to D^0K^+) = (10.6 \pm 4.2^{+2.3}_{-1.2})$ pb. The results are in agreement with the previous CLEO measurement [6]. After $D_{s2}^{*+} \to D^0K^+$ decay measurement all predicted narrow P-wave charmed strange mesons are experimentally observed.

4 The semileptonic D^0 branching fractions.

The difference in D^0 and D^+ lifetimes is not quantitatively understood but is expected to be due to a difference in hadronic decays. To prove this conjecture an accurate measurement of the semileptonic branching ratio of the D^0 meson is required. The known exclusive semileptonic D^0 decay modes do not saturate the inclusive lepton rate [7]. One possible reason for this discrepancy could be an overestimation of the inclusive semileptonic branching ratio based on a single precise measurement by MARK III [8].

The number of D^0 mesons produced in the $D^{*+} \to D^0\pi^+$ decay was determined using a partial reconstruction technique similar to [9] using the excess over background of low momentum pions correlated with the thrust direction. The determination of the number of $D^{*+} \to D^0\pi^+$, $D^0 \to l\nu X$ decays requires in addition the presence of a lepton of appropriate charge and direction with respect to the pion in the event. Given the ratio of this numbers the semileptonic branching ratio of D^0 meson can be calculated.

D^{*+} mesons from the fragmentation of charmed quarks in the continuum process $e^+e^- \to c\bar{c}$ have a hard momentum spectrum and therefore their direction is close to the jet axis. The available energy in the $D^{*+} \to D^0\pi^+$ decay is only 6 MeV. Therefore the angle between the D^* flight direction, or jet axis, and pion momentum vector is small. The jet axis was approximated by the thrust axis of the event. The distribution of the angle Θ_π between the thrust axis and the pion momentum vector was then studied. Fig.4 shows $|\cos\Theta_\pi|$ distributions from events having a lepton in the pion hemisphere for $l^+\pi^+$ and $l^-\pi^+$ combinations after bin by bin subtraction of fake leptons and electrons from photon conversion. There are peaks at $|\cos\Theta_\pi| = 1$ in case of $l^+\pi^+$ combinations due to semileptonic D^0 decays while distributions are flat for $l^+\pi^+$ combinations. According to the Monte Carlo simulation the distribution shapes for $l^+\pi^-$ combinations describe well the background shapes for for $l^+\pi^+$ combinations. To extract the number of semileptonic D^0 decays the distributions for $l^+\pi^+$ combinations were fit with a background shape fixed from distributions for $l^+\pi^-$ combinations and a signal term from [9]. The fit yielded $1670 \pm 76 \pm 36(310 \pm 35 \pm 51)$ events for the electron (muon) samples.

Combining the numbers of $D^{*+} \to D^0\pi^-$ decays of $48500 \pm 640 \pm 374$, and $D^{*+} \to$

$D^0\pi^+$,$D^0 \to l^+\nu_l X$ decay chains, and taking into account efficiencies of lepton reconstruction and identification we obtained $Br(D^0 \to e^+\nu_e X) = 6.9 \pm 0.3 \pm 0.5\%$, $Br(D^0 \to \mu^+\nu_\mu X) = 6.0 \pm 0.7 \pm 1.2\%$.

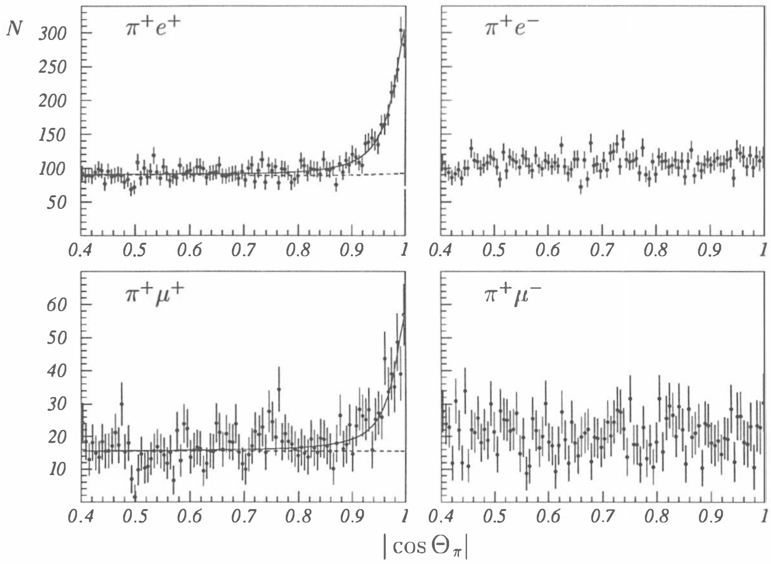

Figure 4: The $|\cos\Theta_\pi|$ distribution for events with a lepton in the pion hemisphere after background subtraction. Solid lines show the results of the fits described in the text. Dashed lines represent the background parametrization.

A similar method can be used to determine the number of semileptonic decays of the second $\bar{c}$ quark in the hemisphere opposite to the pion from D^{*+}. We investigated the $|\cos\Theta_\pi|$ distribution from events having an electron in the hemisphere opposite to the pion. The fit yielded $2207 \pm 93 \pm 155$ $\bar{c} \to e^-\overline{\nu_e}X$ decays that leads to an average semileptonic branching ratio over charm mixture produced in e^+e^- annihilation around 10 *GeV* of $9.6 \pm 0.4 \pm 1.1\%$.

References

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