AB

DESY 95–087
May 1995

Tau Decays into K^* Mesons

The ARGUS Collaboration

ISSN 0418-9833

DESY 95-087
May 1995
ISSN 0418-9833

Tau Decays into K^* Mesons

The ARGUS Collaboration

H. Albrecht, T. Hamacher, R. P. Hofmann, T. Kirchhoff, R. Mankel[1], A. Nau, S. Nowak[1],
H. Schröder, H. D. Schulz, M. Walter[1], R. Wurth
DESY, Hamburg, Germany

C. Hast, H. Kapitza, H. Kolanoski, A. Kosche, A. Lange, A. Lindner, M. Schieber,
T. Siegmund, B. Spaan, H. Thurn, D. Töpfer, D. Wegener
Institut für Physik[2], *Universität Dortmund, Germany*

P. Eckstein, K. R. Schubert, R. Schwierz, R. Waldi
Institut für Kern- und Teilchenphysik[3], *Technische Universität Dresden, Germany*

K. Reim, H. Wegener
Physikalisches Institut[4], *Universität Erlangen-Nürnberg, Germany*

R. Eckmann, H. Kuipers, O. Mai, R. Mundt, T. Oest, R. Reiner, W. Schmidt-Parzefall
II. Institut für Experimentalphysik, Universität Hamburg, Germany

J. Stiewe, S. Werner
Institut für Hochenergiephysik[5], *Universität Heidelberg, Germany*

K. Ehret, W. Hofmann, A. Hüpper, K. T. Knöpfle, J. Spengler
Max-Planck-Institut für Kernphysik, Heidelberg, Germany

P. Krieger[6], D. B. MacFarlane[7], J. D. Prentice[6], P. R. B. Saull[7], K. Tzamariudaki[7],
R. G. Van de Water[6], T.-S. Yoon[6]
Institute of Particle Physics[8], *Canada*

C. Frankl, D. Reßing, M. Schmidtler, M. Schneider, S. Weseler
Institut für Experimentelle Kernphysik[9], *Universität Karlsruhe, Germany*

G. Kernel, P. Križan, E. Križnič, T. Podobnik, T. Živko
Institut J. Stefan and Oddelek za fiziko[10], *Univerza v Ljubljani, Ljubljana, Slovenia*

V. Balagura, I. Belyaev, S. Chechelnitsky, M. Danilov, A. Droutskoy, Yu. Gershtein,
A. Golutvin, I. Korolko, G. Kostina, D. Litvintsev, V. Lubimov, P. Pakhlov, S. Semenov,
A. Snizhko, I. Tichomirov, Yu. Zaitsev
Institute of Theoretical and Experimental Physics, Moscow, Russia

---

[1] DESY, IfH Zeuthen

[2] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 054DO51P.

[3] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 056DD11P.

[4] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 054ER12P.

[5] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 055HD21P.

[6] University of Toronto, Toronto, Ontario, Canada.

[7] McGill University, Montreal, Quebec, Canada.

[8] Supported by the Natural Sciences and Engineering Research Council, Canada.

[9] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 055KA11P.

[10] Supported by the Ministry of Science and Technology of the Republic of Slovenia and the Internationales Büro KfA, Jülich.

Abstract

Using the ARGUS detector at the storage ring DORIS II we have measured τ decays into three charged mesons containing K^* mesons. Exploiting the good particle identification capabilities of the detector we have determined the following branching ratios: $Br(\tau^- \to \overline{K^{*0}}\pi^-\nu_\tau) = (0.25 \pm 0.10 \pm 0.05)$ %, $Br(\tau^- \to K^{*0}K^-\nu_\tau) = (0.20 \pm 0.05 \pm 0.04)$ %, and $Br(\tau^- \to K^{*-}(X^0)\nu_\tau) = (1.19 \pm 0.15\,^{+0.13}_{-0.18})$ %.

1 Introduction

Decays of the τ lepton into hadrons offer a unique possibility to study the electro-weak hadronic charged current at the energy scale of the τ mass. The hadronic final state in τ decays is usually described by spectral functions for specific spin-parity and flavor quantum numbers of the hadronic current. The standard model predicts selection rules for these quantum numbers most of which have been confirmed with high precision. Best studied are the pionic final states. In general less well known are final states containing kaons which have a much smaller branching ratio than pionic channels.

In this paper we study final states in τ decays with three charged particles containing a K^*. Both Cabbibo allowed decays with two associated kaons and Cabbibo suppressed decays with single kaons are considered.

The data for these studies were collected with the ARGUS detector at the storage ring DORIS II of DESY. The center-of-mass energies ranged from 9.4 GeV to 10.6 GeV. The event sample corresponds to an integrated luminosity of 387 pb^{-1} which yields the number of τ pair events $N_{\tau\tau} = 373\,000 \pm 8\,000$.

The ARGUS detector is a 4π magnetic spectrometer described in detail elsewhere [1]. The momenta of charged particles and their mean specific energy loss were measured with the central drift chamber, the latter was used for particle identification. The reconstruction of decay vertices of K_S^0 mesons was improved by a vertex drift chamber.

2 Event Selection and Particle Identification for the Decays $\tau^- \to \overline{K^{*0}}\pi^-\nu_\tau$ and $\tau^- \to K^{*0}K^-\nu_\tau$

The K^{*0} mesons are reconstructed in their decay mode $K^{*0} \to K^+\pi^-$ *. We therefore performed a preselection by searching for events of the one-versus-three topology:

$$\begin{array}{l}
e^+e^- \longrightarrow \tau^+\tau^- \\
\qquad\qquad \hookrightarrow h_2^- h_3^+ h_4^- \nu_\tau \\
\qquad\qquad \hookrightarrow (e^+,\ \mu^+,\ \pi^+ n\,\pi^0,\ K^+ n\,\pi^0,\ K^{*+})\,\overline{\nu}_\tau\,; \quad n \geq 0 \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \hookrightarrow K_S^0\pi^+ \to \pi^0\pi^0\pi^+ \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \hookrightarrow \mathrm{K}_{\mathrm{L}}^0\pi^+
\end{array}$$

where $h^\pm$ stands for the hadrons $\pi^\pm$ and $K^\pm$.

Exactly four charged tracks with zero charge sum were required. Each track had to point to the main vertex and had to have a transverse momentum of $p_T > 0.06\ GeV/c$. Photons were identified as energy deposits in the calorimeter with energies larger then 0.08 GeV not associated to a charged track. The characteristic one-versus-three topology was selected by

---

*References to a specific charged state are meant to imply the charge conjugate state as well.

requiring:

$$cos(\vec{p}_1, \vec{p}_i) < 0 \quad (i = 2, 3, 4) \quad \text{and} \quad cos(\vec{p}_1, \sum_{i=2}^{4} \vec{p}_i) < -0.5 \ ,$$

where $\vec{p}_1$ denotes the momentum of the charged particle on the one-prong side and $\vec{p}_i$ $(i = 2, 3, 4)$ the particle momenta on the three-prong side. Photons were only accepted in the one-prong hemisphere with $cos(\vec{p}_1, \vec{p}_{\gamma_i}) > 0$ $(i = 1, 2)$. Their number was restricted to $n_\gamma \leq 2$ to suppress background from $e^+e^- \rightarrow q\overline{q}$ events. To ensure a high trigger efficiency we required the one-prong to point into the barrel region of the detector: $|\cos\theta_1| < 0.75$. Good particle identification was ensured by demanding the three-prong tracks to fulfill the condition $|\cos\theta_i| < 0.92$ (i = 2, 3, 4). With this cut at least eight drift layers could be used for measurements of the specific ionisation.

In order to suppress background from QED processes, two-photon reactions, and hadronic events the following cut was applied:

$$\left|\sum_i^n \vec{p}_{T_i}\right| > \left(\kappa \cdot \left(\sum_i^n |\vec{p}_i| \cdot \frac{c}{\sqrt{s}} - 0.60\right)^2 + 0.20\right) \ GeV/c$$

where the parameter κ was chosen as $\kappa = 10$ for events with $\sum_i^n |\vec{p}_i| \cdot \frac{c}{\sqrt{s}} < 0.60$ and $\kappa = 6$ for the rest. $\vec{p}_i$ and $\vec{p}_{T_i}$ denote the momentum and transverse momentum vectors of all charged and neutral particles in the event. To further suppress radiative QED events the invariant mass of oppositely charged particles on the three-prong side, assuming them to be electrons, had to exceed 0.10 GeV/c^2. By this converted photons were suppressed. Events containing secondary vertices consistent with a signature of converted photons were rejected, too. After this preselection 11 741 events remained.

Background from two-photon reactions was found to be negligible from Monte Carlo studies. Details can be found in [2]. The same holds for background from radiative QED events which was studied using the data. The amount of background events of the reactions $e^+e^- \rightarrow \Upsilon(4S) \rightarrow b\overline{b}$ and $e^+e^- \rightarrow \Upsilon(1S/2S) \rightarrow ggg\,(gg\gamma)$ was found to be negligible. This decays typically result in a larger number of charged tracks than demanded in this analysis [3]. Another background contribution arises from the continuum process $e^+e^- \rightarrow q\overline{q}$. We used the Monte Carlo program JETSET 6.2/6.3 [4] to simulate 711 553 events including initial state radiation effects. After the preselection 309 events remained. To scale these to the number of expected $e^+e^- \rightarrow q\overline{q}$ events in our data we compared the mass spectra $m_{\pi^-\pi^+\pi^-}$ of our data and the simulation in the region above m_τ [2]. This procedure yields a scaling factor of 1.2 ± 0.2, altogether resulting in a background contribution to the data of 3.2 %.

Final states containing kaons are distinguished from those with three pions by particle identification through the measured specific ionisation (dE/dx). It turned out that the standard particle identification method of the ARGUS Collaboration [1] does not reach the requirements needed to suppress the huge amount of background from a_1^- decays to three charged pions. Therefore a different method was developed which neither depends on the measured error $\sigma_{dE/dx}$ nor on the theoretically expected energy loss which are needed in the standard method to calculate the χ^2 values for different particle hypotheses. It is based on measured momentum and angle dependent dE/dx distribution functions for kaons and pions which are used in both, data and Monte Carlo, therefore allowing stringent particle identification with simple determination of its efficiency. This method is described in detail in ref. [5].

To separate the few expected events on the three-prong side containing kaons from those containing only pions we calculate the probabilities:

$W(\pi\pi\pi) = w(\pi_2^-)\cdot w(\pi_3^+)\cdot w(\pi_4^-)$,
$W(K\pi\pi) = w(K_2^-)\cdot w(\pi_3^+)\cdot w(\pi_4^-) + w(\pi_2^-)\cdot w(\pi_3^+)\cdot w(K_4^-)$, and
$W(KK\pi) = w(K_2^-)\cdot w(K_3^+)\cdot w(\pi_4^-) + w(\pi_2^-)\cdot w(K_3^+)\cdot w(K_4^-)$
assuming that the three-prong consists of either three charged pions, one kaon and two pions or two kaons and one pion, respectively. Other combinations, as for example $(\pi_2^-)(K_3^+)(\pi_4^-)$ are excluded by their quark content. Each of these event types was selected by requiring a minimal value in the ratios of the identification probabilities. We tested this procedure with decays of the kind $D^{*+} \rightarrow D^0\pi^+ \rightarrow K^-\pi^+\pi^+$ where similar identification probabilities can be defined, and compared our data with simulated events. From this independent check we deduced a systematic error of approximately 15 % on the number of the decays $\tau^- \rightarrow K^-\pi^+\pi^-\nu_\tau$ and $\tau^- \rightarrow K^-K^+\pi^-\nu_\tau$ which were selected with this particle identification procedure.

2.1 The Decay $\tau^- \longrightarrow \overline{K^{*0}}\pi^-\nu_\tau$

The following identification cuts were applied to the preselected 11 741 events:

$$W(K\pi\pi) > 10\cdot W(\pi\pi\pi) \quad \text{and} \quad W(K\pi\pi) > W(KK\pi)\ .$$

Whereas the first cut reduces the large background of $\tau^- \rightarrow a_1^-\nu_\tau \rightarrow \rho^0\pi^-\nu_\tau \rightarrow \pi^-\pi^+\pi^-\nu_\tau$ events, the second one guarantees that no event contributes to both the $K^-\pi^+\pi^-$ and $K^-K^+\pi^-$ sample. After these cuts 199 events remained. In a next step the two possible arrangements of the particles $K_2^-\pi_3^+\pi_4^-$ or $\pi_2^-\pi_3^+K_4^-$ are distinguished, and only the most probable combination, which was shown to be the correct one in 90 % of all cases by Monte Carlo means, is used for further analyses. For simplicity it will always be referred to as $K^-\pi^+\pi^-$. 185 events fulfill the condition $m_{K^-\pi^+\pi^-} < m_\tau$. Fig. 1 shows their invariant $K^-\pi^+$ mass distribution. The number of $\overline{K^{*0}}$ mesons was determined by fitting a relativistic P-wave Breit-Wigner function [6] to the

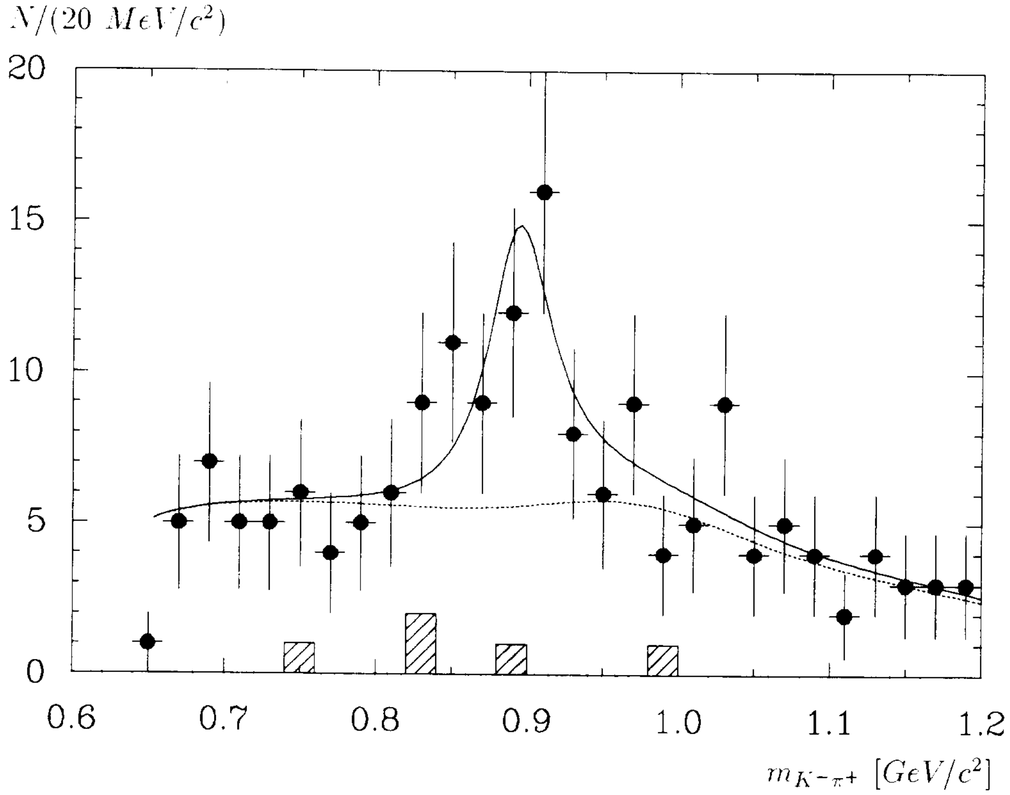

Figure 1: Invariant mass distribution of $m_{K^-\pi^+}$ of data, hatched the expected background contribution of $e^+e^- \rightarrow q\bar{q}$ events. The result of a fit to the data is shown as a full line, the background contribution is represented by the dotted line.

data. Mass and width of the $\overline{K^{*0}}$ meson were fixed to their table values [7]. The Breit-Wigner function was convoluted with a Gaussian function to take into account the detector mass resolution which was determined to be $\sigma_{res} = 6.2\ MeV/c^2$. To deduce the number of $\overline{K^{*0}}$ mesons these convoluted functions where integrated in the interval $\pm 3\,\Gamma_{\overline{K^{*0}}}$ around the nominal $\overline{K^{*0}}$ mass.

The background contribution was parameterized in the following way: Since the main background arises from the decay $\tau^- \rightarrow a_1^- \nu_\tau \rightarrow \rho^0 \pi^- \nu_\tau \rightarrow \pi^- \pi^+ \pi^- \nu_\tau$, where the ρ^0 resonance reflects into the $\overline{K^{*0}}$ signal. the shape of this background was determined by Monte Carlo. Only the strength of this contribution and in addition a second order polynomial describing background from the decay $\tau^- \rightarrow \pi^- \pi^+ \pi^- \pi^0 (\pi^0) \overline{\nu}_\tau$ and $\tau^- \rightarrow K^- K^+ \pi^- \nu_\tau$ were fitted to the data. The result of the fit is shown in fig. 1 as a full line. the background contribution is shown dotted. The number of $\overline{K^{*0}}$ mesons was determined to be $N_{\overline{K^{*0}}} = 27.4\,^{+11.1}_{-10.3} \pm 1.0$ where the small systematic error covers the uncertainties in the determination of the shape of the mass spectrum of the decays $\tau^- \rightarrow a_1^- \nu_\tau \rightarrow \rho^0 \pi^- \nu_\tau \rightarrow \pi^- \pi^+ \pi^- \nu_\tau$.
In fig. 1 the expected contribution of $e^+e^- \rightarrow q\overline{q}$ events is shown as a hatched histogram. The contribution to the $\overline{K^{*0}}$ signal was determined to be less than 2 events (90 % Cl) in the signal region. This number contributes to the negative systematic error of the branching ratio. $\tau^- \rightarrow K^{*0} K^- \nu_\tau$ decays can only contribute to the signal via self reflection of the K^{*0} mesons and are suppressed by the particle identification requirements to a negligible quantity.

The acceptance for the decay $\tau^- \rightarrow \overline{K^{*0}} \pi^- \nu_\tau$ was determined by a Monte Carlo simulation of the detector [8] using the MOPEK event generator [9]. We assumed this decay to proceed via the two resonances $K_1^-(1270)$ and $K_1^-(1400)$ [10] which decay among others via $\overline{K^{*0}} \pi^-$ to $K^- \pi^+ \pi^-$ [7]. The total efficiency ϵ is factorized:

$$\epsilon = \epsilon_{selection} \cdot \epsilon_{trigger} \cdot \epsilon_\gamma \ ,$$

where $\epsilon_{selection}$ comprises the efficiency for the event reconstruction, the selection criteria and the particle identification. It was determined to be $\epsilon_{selection} = 0.028 \pm 0.003 \pm 0.005$. The trigger simulation results in a trigger efficiency of $\epsilon_{trigger} = 0.961 \pm 0.008$ (statistical error only). The efficiency $\epsilon_\gamma = 0.964 \pm 0.005$ (systematical error) describes the influence from the requirement that no photons are allowed on the three-prong side due to electronic noise or misidentified clusters in the electro magnetic calorimeter. The limitation of the number of photons on the one-prong side requires only a negligible small correction. The probability to find faked photons in an event was determined with a new method described in ref. [11]. Within the statistical accuracy of the Monte Carlo simulation no dependence of the acceptance on $m_{K^-\pi^+}$ or $m_{K^-\pi^+\pi^-}$ was found. The branching ratio was calculated following the formula

$$Br(\tau^- \rightarrow \overline{K^{*0}} \pi^- \nu_\tau) = \frac{N_{\overline{K^{*0}}} \cdot \frac{3}{2}}{2 \cdot N_{\tau\tau} \cdot \epsilon \cdot Br_1} \ . \qquad (1)$$

Here the factor $\frac{3}{2}$ comprises the fact that only 2/3 of all $\overline{K^{*0}}$ decays lead to the final state $K^- \pi^+$. With a topological one-prong branching ratio of $Br_1 = (85.49 \pm 0.24)$ % [7] the branching ratio of the decay $\tau^- \rightarrow \overline{K^{*0}} \pi^- \nu_\tau$ becomes

$$Br(\tau^- \rightarrow \overline{K^{*0}} \pi^- \nu_\tau) = (0.25 \pm 0.10 \pm 0.05)\ \%$$

where the first error is due to the statistical uncertainty on the number of events. The second error is due to the above mentioned systematic uncertainties in the Monte Carlo simulation including the trigger Monte Carlo. the luminosity measurement. the error on the particle identification. the branching ratio Br_1. on ϵ_γ. and background from $e^+e^- \rightarrow q\overline{q}$ events.

2.2 The Decay $\tau^- \longrightarrow K^{*0}K^-\nu_\tau$

The analysis of the decay $\tau^- \longrightarrow K^{*0}K^-\nu_\tau$ follows closely the preceding one. The identification cuts on the preselected 11 741 events were changed to

$$W(KK\pi) > 10 \cdot W(\pi\pi\pi) \quad \text{and} \quad W(KK\pi) > W(K\pi\pi) \, .$$

After these cuts 183 events remain. Only the most probable combination of the two arrangements $K_2^- K_3^+ \pi_4^-$ or $\pi_2^- K_3^+ K_4^-$ is used in the further analyses; it will always be referred to as $K^-K^+\pi^-$. The condition $m_{K^-K^+\pi^-} < m_\tau$ is fulfilled by 140 events. Fig. 2 shows a clear K^{*0} signal in the $K^+\pi^-$ channel. The fitting procedure to the data was already described in sec. 2.1.

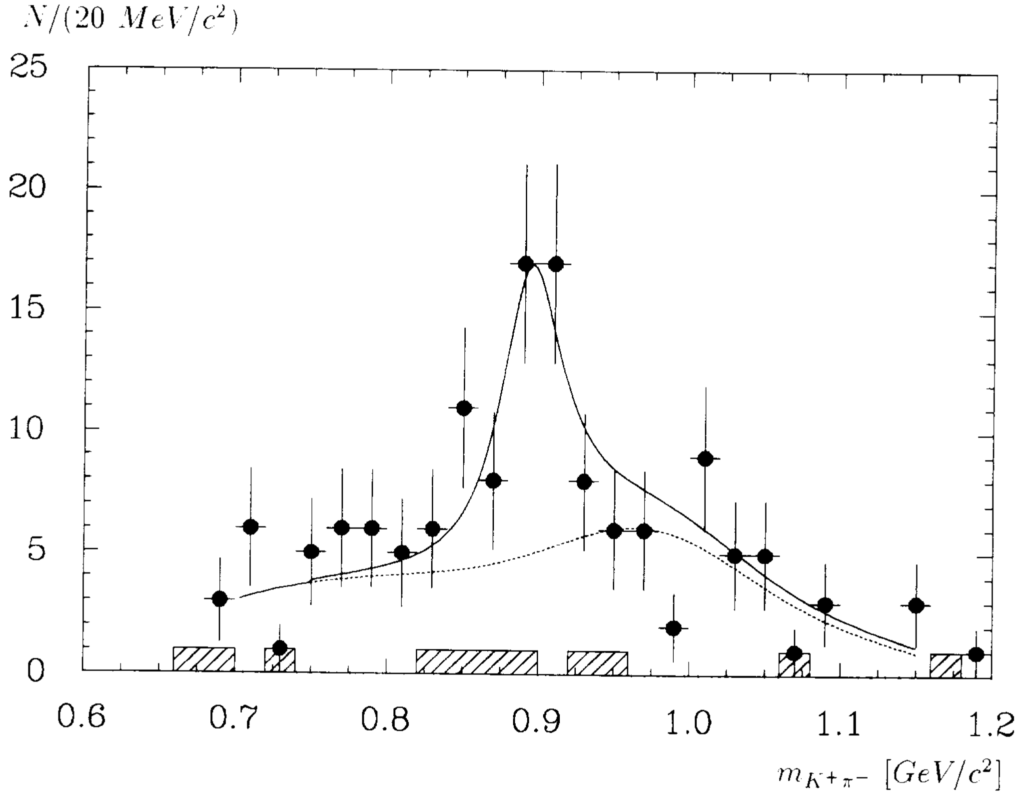

Figure 2: Invariant mass distribution $m_{K^+\pi^-}$ of data, hatched the expected background contribution of $e^+e^- \rightarrow q\bar{q}$ events. The result of a fit to the data is shown as a full line, the background contribution is represented by the dotted line.

The result is shown as full line, the background contribution as dotted line in fig. 2. The number of K^{*0} mesons found is $N_{K^{*0}} = 47.1^{+10.9}_{-10.1} \pm 1.5$. The expected contribution of $e^+e^- \rightarrow q\bar{q}$ events is shown hatched and was determined to be less than 4 events (90 % Cl) which is added to the negative systematic error of the branching ratio.
Determining the selection efficiency we assumed this decay to proceed via either a_1^- or $\rho^-(1700)$ mesons. No mass dependence neither on $m_{K^+\pi^-}$ nor on $m_{K^-K^+\pi^-}$ of the acceptance was found. The branching ratio was calculated following formula 1. With a selection efficiency of $\epsilon_{selection} = 0.061 \pm 0.001 \pm 0.011$ and the other factors unchanged the branching ratio of the decay $\tau^- \rightarrow K^{*0}K^-\nu_\tau$ amounts to:

$$Br(\tau^- \rightarrow K^{*0}K^-\nu_\tau) = (0.20 \pm 0.05 \pm 0.04)\ \%$$

where the first error is statistical and the second systematical.

In a recent paper the CLEO Collaboration quoted an upper limit on the branching ratio $Br(\tau^- \to \phi\pi^-\nu_\tau) < 0.026$ % (90 % Cl) [12]. This decay mode may shed light on a possible four-quark state with a mass of 1480 MeV/c^2 and $J^{PC} = 1^{--}$ which decays into $\phi\pi$. The expectation for the branching ratio of this decay is $Br(\tau^- \to \phi\pi^-\nu_\tau) < 0.02$ % [13].
We have estimated the acceptance for this decay to be $\epsilon = 0.015 \pm 0.002 \pm 0.003$ using the same event selection criteria as for the $\tau^- \to K^{*0}K^-\nu_\tau$ decays. This number includes the branching ratio of the decay $\phi \to K^+K^-$. From a fit to the invariant K^+K^- mass spectrum of our 140 selected events we estimated the number of ϕ candidates to be less than 3.2 (90 % Cl). From this we derive an upper limit of

$$Br(\tau^- \to \phi\pi^-\nu_\tau) < 0.035\ \%\ (90\ \%\ Cl)$$

which is consistent with the CLEO measurement.

3 The Decay $\tau^- \to K^{*-}(X^0)\,\nu_\tau$

The K^{*-} mesons are reconstructed via their decay $K^{*-} \to K^0_S\pi^- \to \pi^+\pi^-\pi^-$ where the decay vertex of the K^0_S meson can be reconstructed with high efficiency. In this inclusive measurement the symbol (X^0) denotes neutral particles as $n\,\pi^0$ or $n\,K^0_L$ mesons ($n \geq 0$) which were not reconstructed.

Since this decay results in a final state of three charged pions the event selection criteria are very similar to those described in sec. 2. In addition we required two oppositely charged tracks, considered as pions, to form a K^0_S candidate. Candidates were accepted in the mass interval $0.488\,GeV/c^2 \leq m_{\pi^+\pi^-} \leq 0.510\,GeV/c^2$. A mass constraint fit to the K^0_S mass was performed. The distance between the reconstructed K^0_S vertex and the main vertex has to be larger than 1 cm. All topological cuts and cuts against background remained unchanged. To suppress Bhabha events with converted photons, no particle on the three-prong side was allowed to be consistent with the electron hypothesis. These conditions are fulfilled by 305 events. The number of photons was not limited on the three-prong side but limited to less than three on the one-prong side to suppress possible background from $e^+e^- \to q\bar{q}$ events. These conditions were fulfilled by 230 events.
Combining the K^0_S candidates with the third track on the three-prong side, assuming this to be a pion, yields the spectrum of the mass $m_{K^0_S\pi^-}$ shown in fig. 3.

Due to the cut against electrons radiative Bhabha events are suppressed to a negligible amount. From our Monte Carlo studies of two-photon events $e^+e^- \to e^+e^-K^{*+}K^{*-}$ we found this background contribution negligible, too. The same holds for events of the types $e^+e^- \to \Upsilon(4S) \to b\bar{b}$ and $e^+e^- \to \Upsilon \to ggg\,(gg\gamma)$ since these typically result in a larger number of charged tracks than demanded in this analysis. A background contribution to the number of K^{*-} mesons can occur from events $e^+e^- \to q\bar{q}$. This was determined to be smaller than 10 events (90 % Cl) (see fig. 3) and checked as described below. This number is included in the negative systematic error of the branching ratio. Contrary to the previous investigations the decays $\tau^- \to a_1^-\nu_\tau \to \rho^0\pi^-\nu_\tau \to \pi^-\pi^+\pi^-\nu_\tau$ and $\tau^- \to \pi^-\pi^+\pi^-\pi^0(\pi^0)\,\bar{\nu}_\tau$ do not contribute to the background since the selection requirements for K^0_S mesons suppress these decays completely.

To determine the number of K^{*-} mesons we have fitted a relativistic P-wave Breit-Wigner function convoluted with a Gaussian function to account for the detector resolution to the $K^0_S\pi^-$ mass distribution. Mass and width of the Breit-Wigner function were fixed to the K^{*-} table values [7]. The mass resolution was determined to be $\sigma_{res} = 5.2\ MeV/c^2$. The number

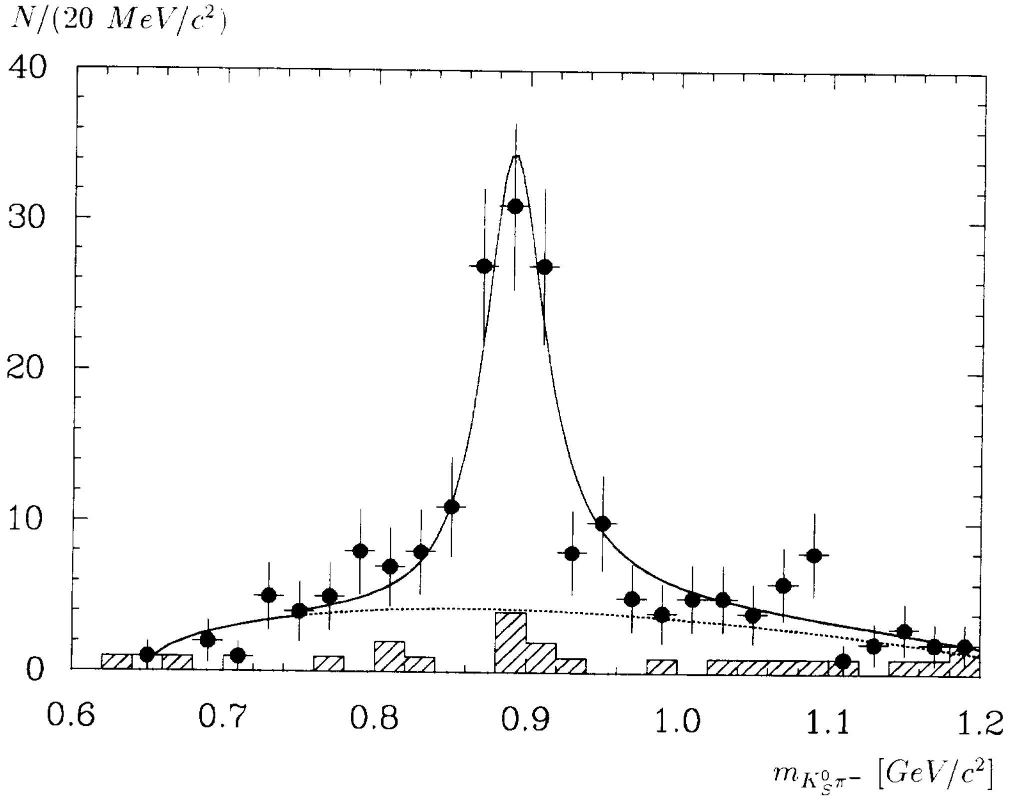

Figure 3: Invariant mass distribution of the $K^0_S\pi^-$ candidates for the decay $\tau^- \rightarrow K^{*-}(X^0)\,\nu_\tau$. The full line shows the result of a fit to the data. The expected background contribution of other τ decays is shown as a dotted line. The expected background from $e^+e^- \rightarrow q\bar{q}$ events is represented by the hatched histogram.

of K^{*-} mesons was derived by integrating this function in the interval $\pm 3\,\Gamma_{K^{*-}}$ around the nominal K^{*-} mass. The non-resonant contribution from other τ decays was parameterized by the function $\sqrt{(m_{K^0_S\pi^-} - a)}\cdot(b + c\cdot m_{K^0_S\pi^-})$ with a, b and c as free parameters. The result of this fit is shown in fig. 3 as full line, as well as the background function, shown dotted. The number of K^{*-} mesons amounts to $104 \pm 13\,^{+\,2}_{-\,10}$ on a background of 62 events. Possible background from $e^+e^- \rightarrow q\bar{q}$ events leads to the asymmetric systematic error. A systematic uncertainty of ± 2 events due to the background parameterization was added in quadrature.

To determine the acceptance for the decay $\tau^- \rightarrow K^{*-}(X^0)\,\nu_\tau$ we parameterized the selection efficiency depending on the momentum of the K^{*-} meson which yielded a mean of $\epsilon_{selection} = 0.0143 \pm 0.0006 \pm 0.0014$. No dependence on the invariant mass of the subsystem $K^0_S\pi^-$ has been found. The trigger efficiency was determined to be $\epsilon_{trig} = 0.960 \pm 0.008$. In these decays ϵ_γ is equal to one since the number of photons on the three-prong side is not limited. From the numbers given above we calculated the branching ratio to be

$$Br(\tau^- \rightarrow K^{*-}(X^0)\,\nu_\tau) = (1.19 \pm 0.15\,^{+0.13}_{-0.18})\ \% \ .$$

The systematic error includes contribution from the background parameterization, the error on the parameterization of the selection efficiency, the error on the Monte Carlo simulation, and the small errors on the number of τ pair events, the branching ratio Br_1, and background from $e^+e^- \rightarrow q\bar{q}$ events.

To check this result, namely the background determination from $e^+e^- \rightarrow q\bar{q}$ events, we demanded as an additional selection criterion for the particle on the one-prong to be either a well identified electron or muon. By this cut possible background of $e^+e^- \rightarrow q\bar{q}$ events is strongly suppressed. Unfortunately the number of K^{*-} mesons found is reduced drastically, too. From a number of $40 \pm 7 \pm 2$ K^{*-} mesons and a selection efficiency of $\epsilon_{selection} = 0.0047 \pm 0.0003 \pm 0.0005$, the branching ratio $Br(\tau^- \rightarrow K^{*-}(X^0)\,\nu_\tau) = (1.39 \pm 0.24 \pm 0.17)\,\%$ agrees well with the one given above. This observation gives confidence to the treatment of the background contributions.

4 Discussion of the Results and Summary

We have measured branching ratios of τ decays into charged and neutral K^* mesons. Comparing our measured branching ratio of the Cabbibo suppressed decay $Br(\tau^- \rightarrow \overline{K^{*0}}\pi^-\nu_\tau) = (0.25 \pm 0.10 \pm 0.05)\,\%$ to the results of the DELCO [14] ($Br(\tau^- \rightarrow K^-\pi^+\pi^-\nu_\tau) = (0.22^{+0.16}_{-0.13})\,\%$), CLEO [15] ($Br(\tau^- \rightarrow \overline{K^{*0}}\pi^- \geq 0\,\text{neutrals}\ \nu_\tau) = (0.38 \pm 0.17)\,\%$), and TPC/Two-Gamma Collaborations [10] ($Br(\tau^- \rightarrow K^-\pi^+\pi^-\nu_\tau) = (0.58^{+0.15}_{-0.13})\,\%$) shows agreement within the errors. The theoretical prediction based on DMO sum rules [16] yield a branching fraction of the decay $\tau^- \rightarrow K^-\pi^+\pi^-\nu_\tau$ in the order of $0.2\,\%$ [17] which coincides with the measurements.

Likewise is the situation in the decay $\tau^- \rightarrow K^-K^+\pi^-\nu_\tau$. Our result $Br(\tau^- \rightarrow K^{*0}K^-\nu_\tau) = (0.20 \pm 0.05 \pm 0.04)\,\%$ agrees with the measurements of the DELCO [14] ($Br(\tau^- \rightarrow K^-K^+\pi^-\nu_\tau) = (0.22^{+0.17}_{-0.11})\,\%$), CLEO [15] ($Br(\tau^- \rightarrow K^{*0}K^- \geq 0\,\text{neutrals}\ \nu_\tau) = (0.32 \pm 0.14)\,\%$), and TPC/Two-Gamma [10] Collaborations ($Br(\tau^- \rightarrow K^-K^+\pi^-\nu_\tau) = (0.15^{+0.09}_{-0.07})\,\%$), and the DMO sum rule prediction [16] of $Br(\tau^- \rightarrow K^-K^+\pi^-\nu_\tau) \approx 0.2\,\%$ [17].
These numbers show that both decays $\tau^- \rightarrow K^-\pi^+\pi^-\nu_\tau$ and $\tau^- \rightarrow K^-K^+\pi^-\nu_\tau$ are dominated by K^{*0} mesons.

Comparing our result $Br(\tau^- \rightarrow K^{*-}(X^0)\,\nu_\tau) = (1.19 \pm 0.15\,^{+0.13}_{-0.18})\,\%$ to the measurements of the TPC/Two-Gamma [18] $Br(\tau^- \rightarrow K^{*-}(X^0)\,\nu_\tau) = (1.4 \pm 0.9)\,\%$ and CLEO [15] Collaborations $Br(\tau^- \rightarrow K^{*-}(X^0)\,\nu_\tau) = (1.43 \pm 0.17)\,\%$ shows good agreement. The agreement of our result with the exclusive ARGUS measurement [19] $Br(\tau^- \rightarrow K^{*-}\nu_\tau) = (1.23 \pm 0.30)\,\%$ shows that most of the K^{*-} mesons are not accompanied by additional neutral particles. Here the DMO prediction [16] of $Br(\tau^- \rightarrow K^{*-}\nu_\tau) = 1.1\,\%$ [17] again corresponds nicely to the measurements.

In general the results agree within the errors with previous measurements and standard model predictions. All experimental analyses of this suppressed decay channels, especially questions about resonance structures, suffer from lack of statistics. Here high statistic experiments with improved particle identification capabilities are needed to reduce the errors further.

Acknowledgments

It is a pleasure to thank U.Djuanda-Guindo, E.Konrad, E.Michel, and W.Reinsch for their competent technical help in running the experiment and processing the data. We thank Dr.H.Nesemann, B.Sarau, and the DORIS group for the excellent operation of the storage ring DORIS II. The visiting groups wish to thank the DESY directorate for the support and the kind hospitality extend to them.

References

[1] H.Albrecht et al. (ARGUS), Nucl. Instr. Meth. **A275** (1989) 1

[2] H.Albrecht et al. (ARGUS), Z. Phys. **C58** (1993) 61

[3] H.Albrecht et al. (ARGUS), Z. Phys. **C54** (1992) 13

[4] B.Andersson et al., Phys. Rep. **97** (1983) 31

[5] C.Hast, Doctoral Thesis, University of Dortmund (1993), unpublished

[6] J.D.Jackson, Il Nuovo Cimento **34** (1964) 1644

[7] Particle Data Group, Phys. Rev. **D50** (1994) 1173

[8] H.Gennow, "SIMARG: A Program to simulate the ARGUS Detector", DESY internal report, DESY **F15–85–02** (1985)

[9] R.Waldi, "Using the Event Generator Program MOPEK for ARGUS", ARGUS software note **28** (1984), unpublished

[10] D.A.Bauer et al. (TPC/Two-Gamma) Phys. Rev. **D50** (1994) R13

[11] M.Schieber, Doctoral Thesis, University of Dortmund (1994), unpublished
M.Schieber, "Noisy Shower Counters: Detection and Removing",
ARGUS software note **48** (1992), unpublished

[12] J.P.Alexander et al. (CLEO), Contributed paper to the International Europhysics Conference
on High Energy Physics, Marseille, France (July, 22.–28. 1993)

[13] S.I.Bityukov et al., Phys.Lett. **188B** (1987) 383;
F.E. Close and H.J.Lipkin, Phys. Rev. Lett. **41** (1978) 1263
S.I.Eidelman and V.N.Ivanchenko, Proceedings of the Workshop on τ Lepton Physics, Paris, France, M.Davier and B.Jean–Marie (Ed.) Editions Frontiers (1990) 161
N.N.Achasov and A.A.Kozhevnikov, Phys.Lett. **207B** (1988) 199
B.Delcourt et al., Phys.Lett. **113B** (1982) 93

[14] G.B.Mills et al. (DELCO), Phys. Rev. Lett. **54** (1985) 624

[15] M.Goldberg et al. (CLEO), Phys. Lett. **251B** (1990) 223

[16] T.Das, V.S.Mathur and S.Okubo, Phys. Rev. Lett. **18** (1967) 761
S.Matsuda and S.Oneda, Phys. Rev. **171** (1968) 1743

[17] A.J.Weinstein and R.Stroynowski, Ann. Rev. Nucl. Part. Phys. **43** (1993) 457

[18] H.Aihara et al. (TPC/Two-Gamma), Phys. Rev. Lett. **59** (1987) 751

[19] H.Albrecht et al. (ARGUS), Z. Phys. **C41** (1988) 1