Title
Measurement of the Branching Fraction for the Cabibbo-Suppressed Decay $\tau^- \to K^{*-}(892)\nu_\tau$

Journal
Physical Review Letters, 46(4)

ISSN
0031-9007

Authors
Dorfan, JM
Blocker, CA
Abrams, GS
et al.

Publication Date
1981-01-26

DOI
10.1103/physrevlett.46.215

Measurement of the Branching Fraction for the Cabibbo-Suppressed Decay $\tau^- \to K^{*-}(892)\nu_\tau$

J. M. Dorfan, C. A. Blocker, G. S. Abrams, M. S. Alam,[a] A. M. Boyarski, M. Breidenbach, D. L. Burke, W. C. Carithers, W. Chinowsky, M. W. Coles, S. Cooper, W. E. Dieterle, J. B. Dillon, J. Dorenbosch, M. W. Eaton, G. J. Feldman, M. E. B. Franklin, G. Gidal, G. Goldhaber, G. Hanson, K. G. Hayes, T. Himel,[b] D. G. Hitlin,[c] R. J. Hollebeek, W. R. Innes, J. A. Jaros, P. Jenni,[b] A. D. Johnson, J. A. Kadyk, A. J. Lankford, R. R. Larsen, V. Lüth, R. E. Millikan, M. E. Nelson, C. Y. Pang, J. E. Patrick, M. L. Perl, B. Richter, A. Roussaire, D. L. Scharre, R. H. Schindler,[b] R. F. Schwitters,[d] J. L. Siegrist, J. Strait, H. Taureg,[b] M. Tonutti,[e] G. H. Trilling, E. N. Vella, R. A. Vidal, I. Videau, J. M. Weiss, and H. Zaccone[f]

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305, and Lawrence Berkeley Laboratory, Berkeley, California 94720, and Department of Physics, University of California, Berkeley, California 94720

(Received 25 August 1980)

This Letter presents a measurement of the branching fraction for the Cabibbo-suppressed decay $\tau^- \to K^{*-}(892)\nu_\tau$ with use of data obtained with the Mark-II detector at SPEAR. Eleven events containing a $K^{*\pm}(892)$ in coincidence with a muon or an electron of opposite charge were found in data which span the center-of-mass energy region $4.2 < E_{\text{c.m.}} < 6.7$ GeV. It was determined that $B[\tau^- \to K^{*-}(892)\nu_\tau] = (1.7 \pm 0.7)\%$. The absence of events at the $K^{*\pm}(1430)$ yields a 2-standard-deviation upper limit $B[\tau^- \to K^{*-}(1430)\nu_\tau] < 0.9\%$.

PACS numbers: 13.10.+q, 14.60.-z

We present herein a measurement of the branching fraction for the decay[1] $\tau^- \to K^{*-}(892)\nu_\tau$, which constitutes the first measurement of a Cabibbo-suppressed decay of the τ. Recently[2] we published a measurement of the branching fraction for the Cabibbo-favored decay $\tau^- \to \rho^-\nu_\tau$ which is in good agreement with the theoretical expectation based on a weak vector hadronic coupling. The presence of the Cabibbo-suppressed decay $\tau^- \to K^{*-}\nu_\tau$ and its measured rate adds further support to the notion that the standard weak vector hadronic current mediates the decays of the τ. We also present a 2-standard-deviation upper limit for the decay $\tau^- \to K^{*-}(1430)\nu_\tau$.

The measurement is based on all Mark-II SPEAR data with $4.2 < E_{\text{c.m.}} < 6.7$ GeV. The energy threshold of 4.2 GeV is chosen to avoid those regions where production of D mesons could constitute a significant background. The data represent a total of 14 600 nb^{-1} with most of the running occurring between 4.2 and 5.2 GeV. This luminosity, when converted with use of the theoretical cross section, corresponds to 40 200 produced $\tau^+\tau^-$ pairs.

All aspects of the Mark-II solenoidal detector pertinent to this measurement have been fully discussed elsewhere.[3] The $\tau^- \to K^{*-}\nu_\tau$ decay is identified by the following topology:

$$\begin{aligned} e^-e^+ \to\ & \tau^-\tau^+ \\ & \tau^+ \to l^+\bar{\nu}_\tau\nu_l \\ & \tau^- \to K^{*-}(892)\nu_\tau \\ & \quad K^{*-} \to \pi^- K_S{}^0 \\ & \qquad K_S{}^0 \to \pi^+\pi^-, \end{aligned} \tag{1}$$

which results in four charged particles in the detector. The symbol l^- represents either an electron or a muon. The selection criteria for the leptons are identical to those used in the analysis of $\tau^- \to \rho^-\nu_\tau$ and are discussed by Abrams *et al.*[2] Events are required to have four charged particles, two positive and two negative, and no photons with $E_\gamma > 100$ MeV. Two of the charged particles are required to be consistent with the decay $K_S{}^0 \to \pi^+\pi^-$. The reconstruction techniques used for the $K_S{}^0$ are fully covered by Schindler.[4] Briefly, secondary vertices are formed at the point of closest approach between particles of opposite sign. This crossing point is evaluated in the plane transverse to the beam direction; the distance between the primary and secondary vertices is required to lie between 1 and 30 cm. The directions of the particles are corrected to the radial crossing point and the momenta are corrected for dE/dx losses. A final candidate cut requires that the $K_S{}^0$ direction, as measured by its momentum, agree within measurement errors with the direction calculated from the position of the beam interaction point and the secondary vertex position. Figure 1 shows the $\pi^+\pi^-$ invariant-mass spectrum for secondary vertices found in the event topology described above. A ± 30-MeV mass cut is made for these $K_S{}^0$ candidates and a one-constraint fit to the $K_S{}^0$ mass is performed. A χ^2 cut of 10 is made for this analysis. The resulting detection efficiency, including the branching ratio $B(K_S{}^0 \to \pi^+\pi^-)$, is approximately 20%, independent of the $K_S{}^0$ momentum. The position of the primary vertex formed by the two particles which do not come from the $K_S{}^0$ decay is required to be consistent with the known position of the beam interaction point. Cuts of ± 10 cm along the beam direction and 2 cm radially are applied.

79 events survive the selection criteria described above. If we label both the particles at the primary vertex as π's, then we can form two $K_S{}^0\pi^\pm$ invariant-mass combinations. These mass combinations are shown in Fig. 2. A signal at the $K^*(892)$ mass is seen above background. The background in Fig. 2 arises from double counting (~ 65%), feeddown from multihadronic events (~ 15%) and hadronic four-prong events in which two of the tracks pass the $K_S{}^0$ requirements because of measurement errors. In order to remove the background due to double counting and substantially reduce the hadronic backgrounds, we require that one of the tracks at the primary vertex be a lepton. This requirement also strongly enhances the probability that the K^* arises from τ decay. Figure 3 is the invariant-mass spectrum of the $K_S{}^0$ and the $\pi^\pm$ for events containing a lepton. A clear excess of events is present at the $K^*(892)$ mass. We attribute these K^*-lepton coincidences to the decay topology outlined in (1). From the 11 events in the five bins 825–950 MeV/c^2 we have subtracted a background of 2.0 events as obtained from the ten surrounding bins. This leaves a signal of 9.0 ± 3.6 events. Of the 11 events, 7 have an electron tag and 4 a muon tag which is consistent with the relative electron-muon tagging efficiency of ~ 1.6. The momentum spectrum for the lepton tags and for the K^*'s is well reproduced by the Monte Carlo program which assumed a $\tau^+\tau^-$ production process. In particular, the lepton momentum spectrum is "hard": 9 of the 11 leptons have momenta above 700 MeV/c and all the muons have momenta above 1.0 GeV/c.

Since D meson decays give rise to both leptons and strange particles, it is important to establish that the $K^{*\pm}l^\mp$ events do not arise from charm production. Since we see no events of the type $K^{*\pm}l^\pm$, we can assume that in most of the $K^{*\pm}l^\mp$ events there are no missing (undetected) charged particles. Charm events have relatively high charged- and neutral-particle multiplicities. This fact, coupled with the good solid-angle coverage of the Mark-II detector, makes it very difficult for charm events to populate the low-multiplicity $(K^{*\pm}l^\mp)$–no-photon topology. The decay $D^\pm \to K^{*\pm}$

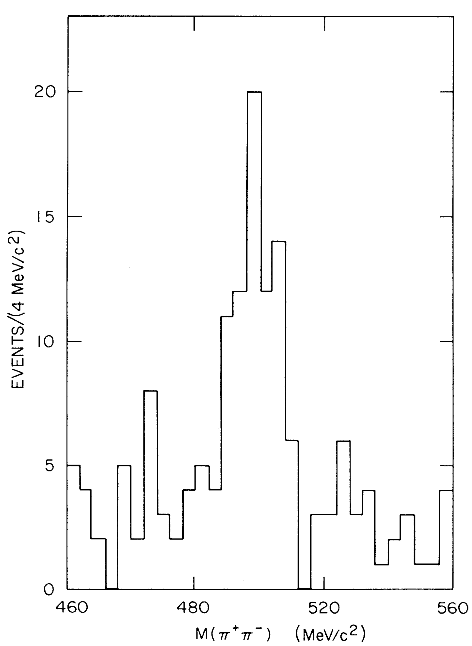

FIG. 1. $\pi^+\pi^-$ invariant-mass spectrum for events containing four charged particles and no photons.

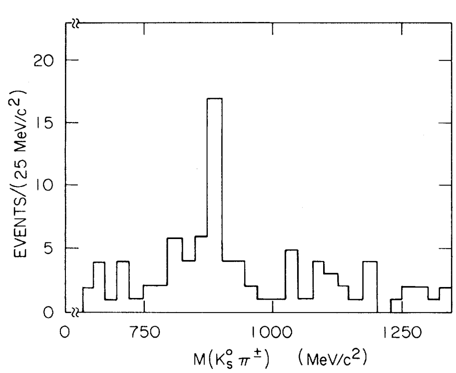

FIG. 2. $K_s{}^0\pi^\pm$ invariant-mass spectrum with use of both tracks at the primary vertex.

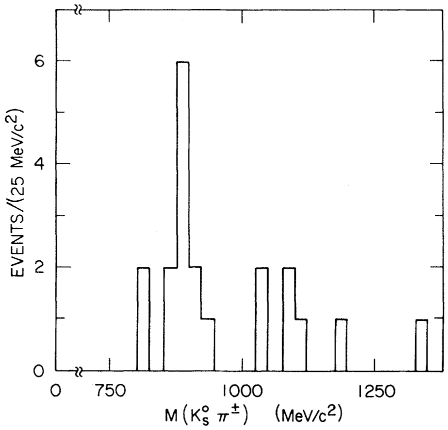

FIG. 3. $K_S{}^0\pi^\pm$ invariant-mass spectrum for events which have a lepton at the primary vertex.

+neutrals is forbidden by the $\Delta S = \Delta C$ selection rule, and thus does not represent a background problem. An example of a possible source of background is $e^+e^- \to D^0\bar{D}^0$ where $D^0 \to l^\pm K^{*\mp}$ +neutrals and $\bar{D}^0 \to$ all neutrals. The data rule out this possibility because 7 of 11 events have the K^*l invariant mass $[M(K^*l)]$ above the D mass and two of the remaining events have $M(K^*l) > 1.6$ GeV/c^2. D's, which result from $D\bar{D}$ and $D^*\bar{D}^*$ production and which are the most probable source of the K^* and lepton, are accompanied by pions and photons and therefore do not populate the low-multiplicity (K^*l)-no-photon event category. A Monte Carlo simulation program has been used to estimate that charmed-particle production contributes at most 0.1 events to the $K^{*\pm}l^\mp$ sample. The leptons which come from the semileptonic D decays, as simulated by the Monte Carlo programs, have a momentum spectrum which is much "softer" than that observed in the K^*l events. Almost all these leptons would have momenta below 700 MeV/c, in strong contrast to the data.

The detection efficiency for the K^*l events was obtained from a Monte Carlo program which produced raw data for decays of the type described in (1). These events were then passed through the identical reconstruction programs as the data and in particular the same $K_S{}^0$ selection criteria were applied to the Monte Carlo events. The efficiencies for the K^*-electron and K^*-muon events are 2.1% and 1.3%, respectively. In contrast to electrons which are identified at all momenta, muons cannot be identified below 700 MeV/c. Combining these efficiencies, the number of produced $\tau^+\tau^-$ pairs and the number of signal events, we obtain

$$B(\tau^- \to K^{*-}\nu_\tau)B(\tau^- \to l^-\bar{\nu}_l\nu_\tau) = 0.0031 \pm 0.0013.$$

Using the Mark-II measurement[2] of

$$B(\tau^- \to l^-\bar{\nu}_l\nu_\tau) = (18.5 \pm 1.5)\%$$

and assuming electron-muon universality in τ decays,[5] we obtain

$$B(\tau^- \to K^{*-}\nu_\tau) = (1.7 \pm 0.7)\%.$$

The quoted error contains the statistical uncertainty and systematic uncertainties of 5% for lepton misidentification, 6% for luminosity, and 10% for the Monte Carlo efficiency. The data are corrected for initial-state radiation effects, which amount to 2.2%. There are no $K^{*\pm}l^\mp$ events in the mass region of the $K^*(1430)$ which allows us to set a 2-standard-deviation upper limit

$$B[\tau^- \to K^{*-}(1430)\nu_\tau] < 0.9\%.$$

Since the $K^*(1430)$ is a spin-2 particle, this decay is forbidden in any $V-A$ theory.

It is worth noting that the excess of $K^*(892)$ mass combinations in Fig. 2 (no lepton tag) can be accounted for by the decay $\tau \to K^*\nu_\tau$. Using $B(\tau \to K^*\nu_\tau)$ obtained above, we would expect a contribution of 23 ± 9 K^*-mass combinations in Fig. 2, which is in good agreement with the background corrected signal of 23.5.

As a check on the above data we searched for events in which the $K^{*\pm}$ was identified via the decay mode $K^{*\pm} \to K^\pm\pi^0$, with a lepton tag required. The $K^\pm$ were identified with the time-of-flight system[3] and the π^0's were reconstructed from photons in the liquid-argon barrel modules.[2] Because of the low π^0 efficiency coupled with $K^\pm$ losses due to decays in flight, this mode of detection has an efficiency of 25% relative to the $K_S{}^0\pi^\pm$ mode. Hence, based on the number of $K_S{}^0\pi^\pm l^\mp$ events we would expect to see 2.3 ± 0.9 $K^\pm\pi^0 l^\mp$ events. There are three events in the mass region of 825–975 MeV/c^2 and virtually no background. These data constitute a statistically weak signal. However, they offer confirmation of the signal found with the decay $K^{*\pm} \to K_S{}^0\pi^\pm$.

The most naive theoretical expectation for the $\tau \to K^*\nu_\tau$ branching fraction is

$$B(\tau \to K^*\nu_\tau) = (\tan^2\theta_C)B(\tau \to \rho\nu_\tau),$$

where θ_C is the Cabibbo angle. A more detailed calculation of Tsai[6] yields

$$B(\tau \to K^*\nu_\tau) = (\tan^2\theta_C)B(\tau \to \rho\nu_\tau)F_{K^*}/F_\rho, \qquad (2)$$

where

$$F_j = [1-(M_j/M_\tau)^2]^2[1+2(M_j/M_\tau)^2].$$

We can use two independent measures for $B(\tau \to \rho\nu_\tau)$ to evaluate (2). Tsai[7] has calculated $B(\tau \to \rho\nu_\tau) = (21.5 \pm 1.8)\%$ assuming the conserved-vector-current hypothesis and the measurement[8] $\Gamma(e^+e^- \to \rho^0) = 5.8 \pm 0.5$ keV, where the error in $B(\tau \to \rho\nu_\tau)$ reflects the uncertainty in $\Gamma(e^+e^- \to \rho^0)$. For $\tan^2\theta_C = 0.05$ and $M_\tau = 1.782$ GeV/c^2, one obtains[9] $B(\tau \to K^*\nu_\tau) = (1.0 \pm 0.1)\%$. Alternatively we can use the Mark-II measurement[2] $B(\tau \to \rho\nu_\tau) = (20.5 \pm 4.1)\%$ to obtain $B(\tau \to K^*\nu_\tau) = (0.95 \pm 0.19)\%$. The experimental measurement presented in this Letter agrees well with both these predictions.

The work was supported in part by the Department of Energy under Contract No. DE-AC03-76SF00515 and No. W-7405-ENG-48. Support for individuals came from the listed institutions in addition to Deutsche Akademische Austauschdienst, Bonn, Germany, and Ecolê Polytechnique, Paris, France.

[a]Present address: Vanderbilt University, Nashville, Tenn. 37235.

[b]Present address: EP Division, CERN, CH-1211 Geneva 23, Switzerland.

[c]Present address: California Institute of Technology, Pasadena, Cal. 91125.

[d]Present address: Harvard University, Cambridge, Mass. 02138.

[e]Present address: Universität Bonn, D-5300 Bonn, Federal Republic of Germany.

[f]Present address: Centre d'Etudes Nucléaires de Saclay, F-91190 Gif-sur-Yvette, France.

[1]The notation $\tau^- \to \rho^-\nu_\tau$ and $\tau^- \to K^{*-}\nu_\tau$, used throughout the text, imply also the charge-conjugate reactions $\tau^+ \to \rho^+\bar{\nu}_\tau$ and $\tau^+ \to K^{*+}\bar{\nu}_\tau$.

[2]G. S. Abrams *et al.*, Phys. Rev. Lett. 43, 1555 (1979).

[3]G. S. Abrams *et al.*, Phys. Rev. Lett. 43, 477 (1979).

[4]R. H. Schindler, Ph.D. dissertation, 1979 (unpublished), SLAC Report No. SLAC-219, 1979.

[5]Because the lepton tagging criteria are identical for both this analysis and that of Abrams *et al.* (Ref. 2), systematic effects in lepton identification tend to cancel. For this reason, we use $B(\tau^- \to l^-\bar{\nu}_l\nu_\tau)$ from Ref. 2 rather than a world average.

[6]Y.-S. Tsai, Phys. Rev. D 4, 2821 (1971).

[7]Y.-S. Tsai, SLAC Report No. SLAC-PUB-2450 (to be published).

[8]D. Benaksas *et al.*, Phys. Lett. 39B, 289 (1972).

[9]The calculation $B(\tau^- \to K^{*-}\nu_\tau) = 1.46\%$ in Ref. 7 differs from that quoted herein because the author uses $\tan^2\theta_C = 0.073$.

Investigation of the (d,p) Stripping Reaction around 700 MeV

A. Boudard, Y. Terrien, R. Beurtey, L. Bimbot,[a] G. Bruge, A. Chaumeaux, P. Couvert, J. M. Fontaine, M. Garçon, Y. Le Bornec,[a] D. Legrand, L. Schecter,[b] and J. P. Tabet

Département de Physique Nucléaire/Moyenne Energie, Centre d'Etudes Nucléaires de Saclay, F-91190 Gif-sur-Yvette, France

and

M. Dillig

Institute for Theoretical Physics, University of Erlangen–Nüremberg, D-8520 Erlangen, Germany

(Received 14 January 1980)

First results for the (d,p) reaction on ^{6}Li, ^{9}Be, and ^{16}O are presented for a scattering energy $T_d = 698$ MeV at momentum transfers 2 fm$^{-1} \leq q \leq 5$ fm^{-1}. Simple distorted-wave Born-approximation and rescattering calculations stress the need for a more comprehensive analysis by explicitly including both the stripping amplitude and mesonic degrees of freedom.

PACS numbers: 25.40.Gr, 24.10.-i

In recent years there has been constantly increasing interest in one-nucleon-transfer reactions at intermediate energies and at momentum transfers q of typically $q \geq 2$ fm^{-1} as they might provide information on high-momentum components in wave functions of bound nucleons[1] and on virtual or real isobar degrees of freedom in nuclei.[2] Presently, however, such processes are only understood qualitatively on a microscopic level.[1-5] To remedy this unsatisfactory situation—which dominantly reflects the lack of detailed experimental information—we present

